ISSN-0039-2502

Journal of the Association of Lunar & Planetary Observers

The Strolling Astronomer

Volume 61, Number 2, Spring 2019
Now in Portable Document Format (PDF) for
Macintosh and PC-compatible computers
Online and in COLOR at http://www.alpo-astronomy.org

ASSOCIATION OF LUNAR & PLANETARY OBSERVERS
ALPO
Founded in 1947

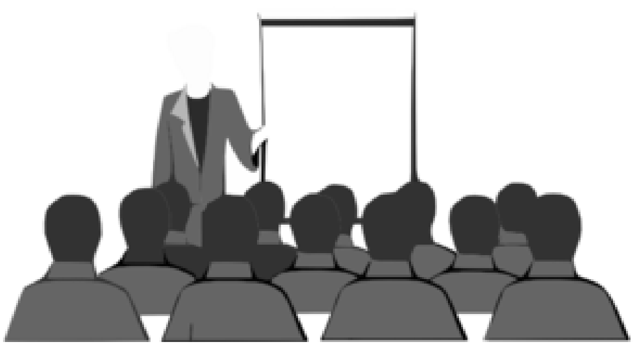
A "red-eye express"
(See page 3 for details)

https://youtu.be/mOyFzaw7FxM?t=2

ALPO '19

July 12-13, 2019

A joint conference of the
Assn of Lunar & Planetary Observers and the
Southeast Region of the Astronomical League



Venue: Gordon State College, in picturesque
Barnesville, Georgia (near Atlanta)

Look for conference details via regular and e-mail soon!

Journal of the Association of Lunar & Planetary Observers

The Strolling Astronomer

Volume 61, No.2, Spring 2019
This issue published in March 2019 for distribution in both portable document format (pdf) and hardcopy format.

This publication is the official journal of the Association of Lunar & Planetary Observers (ALPO).

The purpose of this journal is to share observation reports, opinions, and other news from ALPO members with other members and the professional astronomical community.

For membership or general information about the ALPO, contact:

Matthew Will
ALPO Membership Secretary/Treasurer
P.O. Box 13456
Springfield, Illinois 62791-3456

E-mail to: matt.will@alpo-astronomy.org

Visit the ALPO online at:
http://www.alpo-astronomy.org

Founded in 1947

Inside the ALPO

Papers & Presentations

ALPO Resources

Inside the ALPO
Member, section and activity news

Point of View

Are ALPO Annual Meetings Obsolete?

By Matthew L. Will, ALPO secretary & treasurer

I want to extend to every ALPO member an invitation to attend this year's annual meeting to be held in Barnesville, Georgia, from July 12th through July 13th of this year. This event will be a joint meeting between the ALPO and the Southeastern Region of the Astronomical League. I encourage our staff members to inform attendees about the latest developments in your observing sections and programs by way of a presentation. This invitation is also extended to regular dues-paying members, as well, to participate in giving a presentation about a favorite topic of yours in Solar System astronomy. The deadline to submit an abstract for your presentation is fast approaching, so please consider giving a presentation and being the "life of the party" for 15 or 20 minutes on stage. Either way - attending and/ or presenting - we would love to have you!

Aside from this invitation, I would like to share some personal observations from our past few meetings, particularly our joint meeting with the Society for Astronomical Sciences (SAS) in Ontario, California, this past June. The SAS had a great turnout of their membership at an event that was basically a paper presentation-type meeting, a format that the ALPO is accustomed to in past meetings. The ALPO was treated kindly and well by the SAS. So the ALPO members that did attend had a great time at this meeting. However, there weren't many ALPO members at this annual gathering, probably no more than 10. We were expecting a larger turnout of ALPO members, especially since we hadn't met on the West Coast since 2004. We had hoped on seeing many members from the western portion of the U.S. that hadn't been to an annual meeting in many years due to most annual meetings being far removed from the West Coast. The western U.S. is well-represented in the ALPO, so the low attendance for the ALPO was a bit disheartening.

This writer is wondering if the purpose of an annual meeting for the ALPO, as we hold them now, is an obsolete concept.

(Continued on page 22)

Inside the ALPO
Member, section and activity news

News of General Interest

Our Cover: A "Dark-Hearted" Lunar Eclipse

A first for *The Strolling Astronomer*, appears on the front cover of this issue, that is, a video image sequence of the lunar eclipse as observed and imaged by Howard Eskildsen on the evening of January 20 - 21, 2019, Eastern Standard Time in the USA, in Ocala, Florida, USA.

Just click on the hyperlink on the front cover to get things started.

The image on the cover was taken by Howard using a 6-inch, f/8 refractor equipped with an Explore Scientific objective lens, a 1,200mm focal length Meade telescope tube, and a MoonLite focuser. The camera was a Canon EOS 60D set at prime focus exposed at 1/25 second and ASA 6,400. He manually adjusted the exposure prior to eclipse and settled on 1/8,000 second, ASA640 for the penumbral and umbral ingress portions.

Says Howard: "Just before totality, I set the exposure at 1/25 second, ASA 6,400 and used that setting for the duration of totality. For egress, I changed to 1/1,000 second and ASA 1,000 since I could barely see it at the 1/8,000 second settings I had used for ingress. The first five egress images were exposed at the 1/1,000 and ASA 1,000 exposure. It became too bright so the next image was set at 1/2,000 and ASA 1,000. The final two egress images were set at 1/8,000 second and ASA 1,000.

"For the individual eclipse images, no processing other than rotation, cropping, and labeling was done with Photoshop. The mount was an Orion Sirius EQ-G, which has proven to be an inexpensive, but reliable workhorse for that telescope."

(Text by Howard Eskildsen) The white-tubed 6" f/8 refractor in this image (described in the text to the left of this photo) originally belonged to Jose Olivarez; he sold it to me around 2005. It was originally a Meade LXD 55, but a few years later, the objective glazed over and Meade's only solution was to buy a new refractor. I ran into Scott Roberts, now with Explore Scientific, at the Winter Star Party a few years ago and he got me a new Explore Scientific lens, had it installed and collimated for much less than the cost of a new OTA from Meade. He even threw in an Explore Scientific 2" diagonal. The lens is perfect, near as I can tell. The Meade focuser was marginal so I replaced it with a MoonLite focuser and replaced the finder with an Orion 9X50 right angle finder that attaches to the MoonLite focuser and rotates with it. It really works well. The LXD mount was not the best and finally the hand controller gave up the ghost, so I mounted the refractor on a Sirius EQ-G. It works very well for my needs, but would be marginal for deep sky imaging with the moment arm of the refractor. For planetary imaging it is no problem at all and I love the whole set up that I have now. Curiously, the only remaining original part of the Meade that I purchased is the metal tube and internal baffling. At the time I met Scott, I was willing to just buy an Explore Scientific 6" f/8 achromat, but he was more than willing to get me a new lens at a substantial savings.

The Maksutov-Cassegrain scope to the right is my Meade ETX-125 (125 mm, f/15, 1,900mm focal length) that my wife bought me in 2001. The original mount wore out at the plug-in of the hand controller; the contact wires broke after repeated use. Again, Meade had no replacement mount. No problem, I attached it to a dovetail and shimmed the front of it to minimize vibration and have used it on a variety of mounts. Currently, I have it on an Orion StarSeeker IV mount, and it works great for my situation. It was used for crater eclipse timings with a Meade Super Possl 32 mm eyepiece.

I can only see about 40 percent of the sky from any one location in my yard, so the ETX/StarSeeker is a great combination. It weighs about 12 lbs, so I can carry it in one hand and my observing stool in the other, and go wherever I want to observe. Since it is an alt/az set-up, I don't need to worry about aligning with the celestial pole. It is very easy to set up, align with two stars, and start observing as I did the night of the eclipse. The hand controller is much easier than the three other go-to controllers I have tried in the past and works very well. Also for a quick look at Venus or Jupiter in the morning, I don't bother with alignment, I just start from home position with a rough guess as to north, set time and date and instruct go to Venus, Jupiter, or whatever, and they are always in the finder, and sometimes in the eyepiece. *(Photo by Howard Eskildsen.)*

Inside the ALPO
Member, section and activity news

Next Month, Spotlight on the ALPO Lunar Section

By Ken Poshedly
Editor, *The Strolling Astronomer*

With the 50th anniversary of the Apollo 11 Moon landing only a few short months away, this editor plans to feature our ALPO Lunar Section in JALPO61-3 (for release in June), similar to what we did for the ALPO Solar Section in JALPO58-1, Winter 2016.

Note that I personally reviewed the three *Strolling Astronomer* journals released at the time of the Apollo 11 landing in July 1969 and those immediately afterwards and found no recognition of this feat in any of them: this includes Volume 21, Nos. 9-10, released in July 1969; Volume 21, Nos. 11-12, released in October 1969; and Volume 22, Nos. 1-2 released in January 1970.

While I realize there's a difference between viewing the Moon with a 6-inch reflector in one's back yard and actually setting foot on that dusty surface pert near 240,000 mile away, it just seems sad to this editor that the ALPO — whose perhaps biggest celestial enjoyment comes from keeping track of the Moon — didn't even bother to acknowledge what is still today considered mankind's greatest achievement.

Therefore, I'm inviting _all_ ALPO members to submit a short write-up about your remembrances of that July 1969 event for inclusion in this Journal stating if and how it influenced your lunar observing activities.

Please send all submissions by May 1, 2019 to (email address) Ken.Poshedly@ALPO-Astronomy.org or (regular mail address)

1741 Bruckner Ct.
Snellville, Georgia 30078

ALPO Staff Update

By Richard Schmude,
ALPO executive director

I believe that John Westfall was in charge of the Mercury and Venus transit section. (With his passing several months ago,) I would like to appoint Mike Reynolds as the acting coordinator of the Mercury and Venus transit section. At this time I believe it would be better to keep the transit section separate from the eclipse section.

A Final Paper by John Westfall

Those who knew our late, great friend John Westfall very well remember him as a prolific writer who was concerned about every detail in what he produced. His reports detailing observations of Jupiter's Galilean satellite eclipses are certainly proof of that. And while the "main course" of this Journal is ordinarily reports from our many observers of solar system phenomena, we include in this issue a very special paper written by John with collaboration from two others (William Sheehan and Alberto Gomez Gomez).

Titled "Reconstructing Aristarchos' 'Sizes and Distances'", it deals with the method devised by the brilliant Greek geometer, Aristarchos of Samos, in the 3rd century BCE to determine the distance from the Earth to the Sun. Unfortunately, John passed away while his paper was in the hands of his co-authors, both of whom are satisfied that there was little they could do to improve on what was already one of John's most impressive papers.

As editor & publisher of this Journal, I am most honored to present that paper in this Journal and I hopeyou find it most enlightening.

Asteroid "417955 Mallama"

Asteroid 417955 Mallama has been named for ALPO member Anthony Mallama. The name was proposed by the discoverer of the asteroid, D.R. Skillman, and made official by the International Astronomical Union. The dedication reads, "Anthony Mallama (b. 1949) is known for his research on the brightness and variability of all eight planets in our solar system. These investigations revealed important characteristics of their atmospheres, surfaces and interiors."

The various details about "417955 Mallama" can be found at *https://ssd.jpl.nasa.gov/sbdb.cgi#top*

ALPO 2019 Conference News

Interested parties are hereby invited to submit papers and research posters on the astronomy-related topics of their choice for presentation at the next ALPO conference to be held jointly with the Southeastern Region of the Astronomical League (SERAL) at Gordon College, in Barnesville, Georgia, Friday and Saturday, July 12 and 13, 2019.

Barnesville is located just southwest of Atlanta and is accessible by air via Atlanta's Hartsfield Airport and by freeway via I-75 and I-20.

Paper presentations will take place from 9 a.m. to 5 p.m., Friday, with additional papers being presented on Saturday as-needed. The annual ALPO board meeting will be held on Friday evening and the SERAL meeting will be held following the last presentation on Saturday.

Registration deadline is June 18, 2019.

As is traditional, there will be an awards dinner on Saturday evening.

There will be 30-minute blocks of time allotted for each presentation to accommodate the presentation itself plus time for questions from the audience.

Inside the ALPO
Member, section and activity news

The preferred format is Microsoft PowerPoint.

Research posters, commonly done at other academic and professional conferences everywhere, also requested.

Participants are encouraged to submit research papers, presentations, and experience reports concerning various aspects of Earth-based observational astronomy. Suggested topics for papers and presentations include the following:

- New or ongoing observing programs and studies, specifically, how those programs were designed, implemented and continue to function.
- Results of personal or group studies of solar system or extra-solar system bodies.
- New or ongoing activities involving astronomical instrumentation, construction or improvement.
- Challenges faced by Earth-based observers such as changing interest levels, deteriorating observing conditions brought about by possible global warming, etc.

A hard-copy version of your paper should be made available for future web site publication.

A special, more detailed announcement, including registration and lodging information, will be released to all ALPO members in the near future, well in time for lodging and travel arrangements to be made.

Out of Sight, Man!

Below are links to news of solar system accomplishments not directly observable by Earth-based telescopes:

- New Horizons at MU69

https://www.nasa.gov/mission_pages/newhorizons/main/index.html

- Craft at Asteroid Benu

https://www.nasa.gov/feature/goddard/2019/osiris-rex-mission-status-update

- Insight at Mars

https://mars.nasa.gov/insight/

Inside the ALPO
Member, section and activity news

ALPO Interest Section Reports

ALPO Online Section

Larry Owens, section coordinator
Larry.Owens@alpo-astronomy.org

Follow us on Twitter, "friend" us on FaceBook or join us on MySpace.

To all section coordinators: If you need an ID for your section's blog, contact Larry Owens at *larry.owens@alpo-astronomy.org*

For details on all of the above, visit the ALPO home page online at *www.alpo-astronomy.org*

Computing Section

Larry Owens, section coordinator
Larry.Owens@alpo-astronomy.org

Important links:

- To subscribe to the ALPOCS yahoo e-mail list, *http://groups.yahoo.com/group/alpocs/*
- To post messages (either on the site or via your e-mail program), *alpocs@yahoogroups.com*
- To unsubscribe to the ALPOCS yahoo e-mail list, *alpocs-unsubscribe@yahoogroups.com*
- Visit the ALPO Computing Section online at *www.alpo-astronomy.org/computing*

Lunar & Planetary Training Program & 'Observers Notebook' Podcasts

Tim Robertson, program coordinator
cometman@cometman.net

ALPO Lunar & Planetary Training Program

The ALPO Lunar & Planetary Training Program currently has three active students at various stages of the program.

The ALPO Training Program currently has 3 active students at various stages of the program.

The ALPO training program is a two-step program, and there is no time requirement for completing the steps. But I have seen that those students who are motivated usually complete the program in a short amount of time. That motivation comes from the desire to improve their observing skills and contribute to the pages of the Journal of the ALPO.

The ALPO Lunar & Planetary Training Program is open to all members of the ALPO, beginner as well as the expert observer. The goal is to help make members proficient observers. The ALPO revolves around the submission of astronomical observations of members for the purposes of scientific research. Therefore, it is the responsibility of our organization to guide prospective contributors toward a productive and meaningful scientific observation.

The course of instruction for our program is two-tiered.

- The first tier is the "Basic Level" and includes reading the ALPO's *Novice Observers Handbook* and mastering the fundamentals of observing. These fundamentals include performing simple calculations and understanding observing techniques.
- When the student has successfully demonstrated these skills, he or she can then advance to the "Novice Level" for further training where one can specialize in one or more areas of study. This includes obtaining and reading handbooks for specific lunar and planetary subjects. The novice then continues to learn and refine upon observing techniques specific to his or her area of study and is assigned to a tutor to monitor the novice's progress in the Novice Level of the program.

When the novice has mastered this final phase of the program, that person can then be certified to "Observer Status" for that particular field.

'Observers Notebook' Podcasts

The ALPO's *Observers Notebook* series of podcasts is now two years old. I have recorded over 67 podcasts with various members of the ALPO, mostly section coordinators, to highlight the programs within each section.

A new *Observers Notebook* podcast is released every about every two weeks,

Inside the ALPO
Member, section and activity news

and if you subscribe to it via iTunes, it will automatically be downloaded to your device.

The length of the podcast averages around 30 minutes in length. The longest podcast thus far is over 1 hour and 30 minutes. But we can record longer, there is no time limit – the hosting service that I am using has unlimited space available for podcasts.

It takes a great amount of time and money to make and produce the podcast. Thus far, it has been done with the help of a service called "Patreon", and we currently have five supporters – two of whom are NOT members of the ALPO!

You can support the podcast by giving as little as $1 a month; for $5 per month, you receive early access to the podcast before it goes public; for a monthly donation of $10, you receive a copy of the *Novice Observers Handbook*; and for a $35 monthly donation, you receive producer credits on the podcast and a year's membership to the ALPO. You can help us out by going to the link below:

https://www.patreon.com/ObserversNotebook

The most recent podcasts now online include:

- A fun conversation with Carl Hergenrother on the upcoming comets for 2019.
- Lunar expert and founder of the *Lunar Photo of The Day* website, Chuck Wood who came on to chat about everything lunar.
- Astronomical League Master Observer couple of David and Valorie Whalen who chatted with me about the process they went through to get that prestigious award.
- Gary Tomlinson, who came on to discuss National Astronomy Day.
- Mike Reynolds, who talked about his life and career in astronomy.

If you have an idea for a podcast, please drop me a note. I would like to have a discussion on the use of color filters for planetary observing and how you plan your own evening observing sessions. If any of you would be interested in discussing those subjects, please let me know.

I am also looking for member profile pieces where we get to know the members of the ALPO. Please contact me if any of you would be interested in discussing those subjects.

Our podcasts are also used to announce any breaking astronomy news or events happening in the night sky. So let me know if you have any breaking news that you want announced.

Here are a few interesting statistics you might be interested in as well:

- Number of downloads as of January 14, 2019: 15,000+
- Number of subscribers (all formats): 200+
- Average of number daily downloads (last 3 months): 53
- iTunes rating: 5 Stars!
- Locations of most downloads: USA, UK, Canada, Australia, Sweden, France, and Germany.
- The number one most downloaded podcast so far is with Mars Geologist Caitlin Ahrens, a graduate of West Virginia University with Bachelor of Science degrees in Geology and Physics with an emphasis in Astrophysics. Episode 53.

You can hear the podcast on iTunes, Stitcher, iHeart Radio, Amazon Echo, and Google Play just search for *Observers Notebook*. You can also listen to it at the link below:

https://soundcloud.com/observersnotebook

The *Observers Notebook* is also on Facebook – just search for "Observers Notebook" in the search field on top.

Thanks for listening!

For more information about the ALPO Lunar & Planetary Training Program or the *Observers Notebook*" podcasts, contact Tim Robertson at:

- (e-mail) cometman@cometman.net
- (regular mail) Tim Robertson
195 Tierra Rejada Rd #148
Simi Valley CA, 93065

Publications Section

Ken Poshedly, section coordinator
ken.poshedly@alpo-astronomy.org

The ALPO Publications Section Gallery has now been updated to include ALPO Journals from1953 thru 2018. We will post the remaining volumes (1947 thru 1952) as soon as they are made available.

Available indexes are as follows:

- Volumes 1 through 8.
- Volumes 16 through 29.
- Volumes 34 thru 56.

As with the ALPO Journals, we will post the remaining indexes as soon as they are made available.

All Journals and indexes are freely available with no password required.

Journals for calendar year 2019 will be available only to ALPO members as a benefit of their paid membership.

Besides the ALPO journals and indexes, the Publications Section Gallery also includes various observing forms and monographs, all of which will be upgraded as new versions are made available.

Inside the ALPO
Member, section and activity news

To begin your own exploration of the Publications Gallery:

1. Go to the ALPO home page at http://www.alpo-astronomy.org/, then click on the "ALPO Section Galleries" link at the top-right of the screen.
2. Click on the icon for the "Publications Section".
3. Click on the icon for the "ALPO Journals".
4. Click on the icon for any of the various years.
5. Click on the icon for any of the Journals in the chosen year.
6. Click on the link near the top of the screen to access that publication.

Accessing the monographs and observing forms is similar.

Then either save the document to your own computer or just read it online without saving it. Saving the document to your own terminal allows you to access it at any time, even if online access is not available.

Call for JALPO Papers

The ALPO appreciates articles for publication and encourages its membership to submit written works (with images, if possible).

As with other peer-reviewed publications, all papers will be forwarded to the appropriate observing section or interest section coordinator.

Thus, the best method is to send them directly to the coordinator of the ALPO section which handles your topic.

A complete list of ALPO section coordinators and their contact information can be found in the *ALPO Resources* section of this Journal.

ALPO Observing Section Reports

Eclipse Section

Mike Reynolds, section coordinator
m.d.reynolds@fscj.edu

A preliminary report on the January 2019 lunar eclipse appears later in this issue of your ALPO Journal.

E-mail -- star.man13@hotmail.com

Visit the ALPO Eclipse Section online at www.alpo-astronomy.org/eclipseblog

Mercury / Venus Transit Section

Mike Reynolds, acting section coordinator
m.d.reynolds@fscj.edu

Visit the ALPO Mercury/Venus Transit Section online at www.alpo-astronomy.org/transit

Meteors Section

Robert Lunsford, section coordinator
lunro.imo.usa@cox.net

A reminder here that your section recorder has taken advantage of podcasts to verbally spread the news of upcoming major meteoric events. Tim Robertson does a great job asking interesting questions while I try my best not to bore the listener! Give these podcasts a try at:

https://soundcloud.com/observersnotebook

Be sure to also check out the other interesting podcasts offered by the many sections of ALPO!

Visit the ALPO Meteors Section online at www.alpo-astronomy.org/meteorblog/ Be sure to click on the link to viewing meteors, meteor shower calendar and references.

Meteorites Section

Report by Dolores H. Hill, section coordinator
dhill@lpl.arizona.edu

Section News

This report includes meteorite highlights and new meteorite approvals from November 1, 2018 to January 31, 2019 from the Meteoritical Society's Nomenclature Committee.

Randy Tatum provided a report on impact crater sites in the U.S. midwest he visited in November 2018, including Kentland, Des Plaines, Glover Bluff, Rock Elm and Decorah. Mitch Noda investigated interesting regmaglypts in two Sikhote Alin iron-nickel specimens.

We received several inquiries about suspected meteorites, most of which are terrestrial and do not require further analysis. As always, ALPO members who collect meteorites are encouraged to report unusual features in their own meteorite samples that might be of interest to researchers for specialized analysis.

Meteorite News

Noteworthy meteorites approved or updated during this period include the Los Vientos 263 ungrouped pallasite from Chile and 8 witnessed chondrite falls: Homestead (L5), Ablaketka (H5), Karimati (L5), Renchen (L5-6), Andila (L6), Parauapebas (H4-5), Gueltat, Zemmour (L4), Mahbas Arraid (LL6).

The *Meteoritical Bulletin Database* (https://www.lpi.usra.edu/meteor/) records officially recognized, classified meteorites of the world's inventory. As of January 31, 2019, it contains a total of 60,155 meteorites. There were 349 new

Inside the ALPO
Member, section and activity news

meteorites approved, most from desert regions. Newly approved meteorites include 234 ordinary chondrites; 27 carbonaceous chondrites, 3 enstatite chondrites; 3 irons; 1 acapulcoite; 3 pallasites, 1 mesosiderite, 9 ureilites; 35 HEDs; 6 lunar (1 basaltic breccia; 5 feldspathic breccias); 7 Martian Shergottites; 16 Martian polymict breccias; 3 ungrouped achondrites; and 1 angrite.

For more information and official details on particular meteorites, go to https://www.lpi.usra.edu/meteor/metbull.php

Northwest Africa 12,222 and Northwest Africa 8,114 were the smallest meteorites reported this period with a mass of only 1.9 grams each. The largest meteorite reported (updated) was the 230 kg Homestead L5 chondrite that fell in 1875.

Visit the ALPO Meteorites Section online at www.alpo-astronomy.org/meteorite/

Comets Section

Report by Carl Hergenrother, section coordinator
carl.hergenrother @ alpo-astronomy.org

The year 2018 turned out to be an exciting one for comet watchers. Last year saw the first visual comet discovery since 2010 [C/2018 Y1 (Machholz-Fujikawa-Iwamoto), a historic close approach of a naked-eye short-period comet (46P/Wirtanen), and a disintegrating long-period comet [C/2017 S3 (PANSTARRS)]. Comet Section

Short-period comet 46P/Wirtanen moving between the Hyades and Pleiades on 2018 December 15. Image taken by Chris Schur with aÂ Canon 17-40mm f/4 at 28mm lens and Canon XTi DSLR camera.

Inside the ALPO
Member, section and activity news

contributors submitted 1,510 images and sketches of past and current comets resulting in a nearly 50% increase in the size of the Comet Section Image Gallery. A total of 888 magnitude observations of 27 different comets were also reported in 2018. This pushed the number of magnitude estimates in the archive over the 9000 mark. For both magnitude estimates and images/sketches, the best observed comet of 2018 was 46P/ Wirtanen which peaked at 3rd magnitude during its close Earth flyby in December.

The new year (2019) is predicted to be a quiet year for comets. A new amateur discovery, C/2018 Y1 (Iwamoto), was predicted to reach 7th magnitude in February but will already be rapidly fading as you read this. The April-June 2019 quarter should see no comets brighter than magnitude 12.The relatively bright comet drought will end this fall, however, as two long-period comets, C/2017 T2 (PANSTARRS) and C/2018 W2 (Africano), reach 9th magnitude.Â

As always, the Comet Section is happy to receive all comet observations, whether images, drawings, magnitude estimates, and even spectra. Please send your observations via email to carl.hergenrother @ alpo-astronomy.org

Drawings and images of current and past comets are being archived in the ALPO Comets Section image gallery at http://www.alpo-astronomy.org/gallery/main.php?g2_itemId=4491

Visit the ALPO Comets Section online at www.alpo-astronomy.org/comet

Solar Section

Report by Rik Hill, section coordinator & scientific advisor
rhill@lpl.arizona.edu
Theo Ramakers, assistant section coordinator
theo@ceastronomy.org

> Appearing later in this Journal are the following:
>
> - A report on Carrington Rotations 2206 through 2209.
> - A paper addressing amateur and scientific data associated with the transition from Solar Cycle 24 to Solar Cycle 25.

Solar activity is very low now and expected to drop even more. The ALPO Solar Section staffing and operations are very stable and while growth in members is poor during solar minimum, we still have a good core of active observers as the activity report shows. Assistant Coordinator Theo Ramakers sums up things as follows and I can add little to his remarks:

As of January 1, 2019, the ALPO Solar Section archive at www.alpo-astronomy.org contained 39,482 solar images and observations. This is an increase of 2,810 images/observations over 2018 — a great job which could only be obtained with the tremendous dedication of all our observers. They all deserve a great THANK YOU.

And while we are awaiting completion of the revised book "Observe and Understanding the Sun" which was authored by a group of our own solar observers in the second half of 2015, a group of Europeans under the coordination of Christian Viladrich (whose excellent images can be seen in our reports) have published a new book about solar observing in French: "Astronomie Solaire" (Solar Astronomy). This book is now available from Springer Verlag. It was co-written with a group of his fellow solar observers much like the above-mentioned book was written in 2015. So if you speak French, you might want to check this out! The previous ALPO Journal (61-1) showed one of Christian's magnificent images on the front cover.

For more information go to:

http://www.astronomiesolaire.com/index.php

And now, some solar cycle transition statistics: I've now documented seven images of reverse polarized areas from the ALPOSS archive (Cycle 25). In addition, the last cycle transition from Cycle 23 to 24 had two spotless streaks of over 50 days (51 and 52), whereas for the current transition, the two maximum spotless streaks were 24 and 25 spotless days so far (SWPC daily EOEG reports).

To join the Yahoo Solar ALPO e-mail list, please go to https://groups.yahoo.com/neo/groups/Solar-Alpo/info

For information on solar observing – including the various observing forms and information on completing them – go to www.alpo-astronomy.org/solar

Mercury Section

Report by Frank J. Melillo, section coordinator
frankj12@aol.com

Mercury went through inferior conjunction with the Sun on November 27, but there was a special treat for most of us in the northern hemisphere in December. Mercury displayed a favorable morning apparition where we could see it a lot easier than any time of the year. Additionally, Venus was shinning brightly nearby and added a nice view with Mercury by naked eye during the morning twilight.

As the twilight progressed into daylight hours, Mercury could still be easily found using Venus as a guide. I took advantage of observing and imaging Mercury under the best condition as possible in daylight. Unfortunately, December is the worst time of the year for planetary observations, with many cold fronts

Inside the ALPO
Member, section and activity news

passing through, which create turbulences. This author observed Mercury many times during the third week of December while the seeing was poor. It was so bad that Mercury's phase wasn't unrecognizable!

There were two days out of the whole month when the seeing conditions were pretty good. On December 12, Mercury displayed nearly a half-phase just before the greatest elongation on December 15. I imaged it successfully with two rayed craters possibly seen along the southeast limb. The second time was on Christmas Day when the seeing was above average. Mercury showed a gibbous phase and some features might have been seen. The two rayed craters that were visible on the limb on December 12 rotated into the disk and just past the central meridian.

As you read this, Mercury perhaps just ended the evening apparition and will appear in the morning sky again by mid-March. But within the next two months prior, until May 21, it will be not be favorable to view Mercury.

Mercury as imaged by Frank Melillo on December 12, 2018 at 15:09 UT. CM = 279°. No other details provided.

Please be sure to send in your observations to the Mercury section so we can have nice coverage of its favorable morning apparition of the year.

Visit the ALPO Mercury Section online at *www.alpo-astronomy.org/mercury*

Venus Section

Report by Julius Benton, section coordinator
jlbaina@msn.com

Venus entered Inferior Conjunction with the Sun back last October 26, 2018 marking the end of the 2018 Eastern (Evening) Apparition. Venus continues to rise a few hours ahead of the Sun this spring, and the planet attained greatest elongation West on January 6, 2019 roughly a day after appearing at theoretical dichotomy (predicated half phase) on January 5th. During the current 2018-19 Western (Morning) Apparition Venus is passing through its waxing phases as it shrinks in angular diameter, as it slowly changes from a thin crescent to a gibbous and ultimately a fully illuminated disk as it reaches Superior Conjunction on August, 14, 2019.

The accompanying table of Geocentric Phenomena in Universal Time (UT) are presented for the convenience of observers for the 2018-19 Western (Morning) Apparition:

As of the date of this report (early January), a considerable number of excellent visual drawings in integrated

Paul Maxson of Surprise, AZ, USA, submitted an excellent UV and IR image of Venus taken at 14:03 UT on December 27, 2018, employing his 25.4cm (10.0 in.) Mewlon (Dall Kirkham) telescope under good seeing conditions. The UV image shows a shaded and slightly irregular terminator and banded dusky markings across the disk as well as the bright limb band running along the limb of Venus between the northern and southern cusps. The apparent diameter of Venus is 28.1 arc-seconds, crescent phase k=0.446 (44.6% illuminated) and visual magnitude -4.6. South is at the upper left hand top of image.

light and with color filters, as well as digital images at UV and near IR wavelengths have been received from several ALPO Venus Section observers for the ongoing 2018-19 western (morning) apparition.

Readers of this Journal should be familiar with our on-going collaboration with professional astronomers as exemplified by our sharing of visual observations and digital images at various wavelengths during ESA's previous *Venus Express*

Geocentric Phenomena of the 2018-19 Western (Morning) Apparition of Venus in Universal Time (UT)

Inferior Conjunction	2018 Oct 26 14^h (angular diameter = 61.8°)
Predicted Dichotomy	2019 Jan 05.81^d (Venus is predicted to be exactly half-phase)
Greatest Elongation West	2019 Jan 06 05^h (46°)
Superior Conjunction	2019 Aug 14 06^h (angular diameter = 61.8")

Inside the ALPO
Member, section and activity news

Lunar Calendar for April through June 2019 (All times in Universal Time)

Date	Time	Event
Apr 01	00:14	Moon Apogee: 405600 km
02	04:17	Moon-Venus: 3° N
02	23:01	Moon-Mercury: 4° N
05	08:50	New Moon
09	06:40	Moon-Mars: 5° N
11	23:59	Moon North Dec.: 22° N
12	18:08	Moon Ascending Node
12	19:06	First Quarter
16	22:02	Moon Perigee: 364200 km
19	11:12	Full Moon
23	11:36	Moon-Jupiter: 1.8° S
24	21:22	Moon South Dec.: 22.1° S
25	14:38	Moon-Saturn: 0.4° N
25	15:02	Moon Descending Node
26	22:18	Last Quarter
28	18:20	Moon Apogee: 404600 km
May 02	11:39	Moon-Venus: 3.9° N
04	22:45	New Moon
07	23:36	Moon-Mars: 3.3° N
09	05:46	Moon North Dec.: 22.2° N
09	18:50	Moon Ascending Node
12	01:12	First Quarter
13	21:53	Moon Perigee: 369000 km
18	21:11	Full Moon
20	16:54	Moon-Jupiter: 1.8° S
22	06:41	Moon South Dec.: 22.3° S
22	21:12	Moon Descending Node
22	22:25	Moon-Saturn: 0.6° N
26	13:27	Moon Apogee: 404100 km
26	16:33	Last Quarter
Jun 01	18:15	Moon-Venus: 3.4° N
03	10:02	New Moon
05	12:58	Moon North Dec.: 22.4° N
05	15:05	Moon-Mars: 1.6° N
05	22:46	Moon Ascending Node
07	23:21	Moon Perigee: 368500 km
10	05:59	First Quarter
16	18:50	Moon-Jupiter: 2.1° S
17	08:31	Full Moon
19	15:33	Moon South Dec.: 22.4° S
18	05:49	Moon Descending Node
19	03:58	Moon-Saturn: 0.5° N
24	07:50	Moon Apogee: 404500 km
25	09:46	Last Quarter

Table courtesy of William Dembowski and NASA's SkyCalc Sky Events Calendar

(VEX) mission that ran for about nine years from 2006 until the mission ended in 2015. It remains as one of the most successful Pro-Am efforts to date involving ALPO Venus observers around the globe. Such observations will remain important for further study and will continue to be analyzed for several years to come as a result of this endeavor.

For reference, the VEX website is

http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=38833&fbodylongid=1856.

A follow-on collaborative Pro-Am effort continues in in 2019 in support of Japan's (JAXA) *Akatsuki* mission that began full-scale observations starting back in April of 2016. The website for the *Akatsuki* mission has is currently active so interested and adequately equipped ALPO observers can still register and start submitting images if they have not already done so. More information will continue to be provided on the progress of the mission in forthcoming reports in this Journal.

It is extremely important that all observers participating in the programs of the ALPO Venus Section always first contribute their observations to the ALPO Venus Section at the same time submittals are sent to the Akatsuki mission.

This will enable full coordination and teamwork between the ALPO Venus Section and the Akatsuki team in collection and analysis of all observations whether they are submitted to the Akatsuki team or not. If there are any questions, please do not hesitate to contact the ALPO Venus Section for guidance and assistance.

Those still wishing to register to participate in the coordinated observing effort between the ALPO and Japan's (JAXA) *Akatsuki* mission should utilize the following link:

Inside the ALPO
Member, section and activity news

https://akatsuki.matsue-ct.jp/

The observation programs of the ALPO Venus Section are listed on the Venus page of the ALPO website at http://www.alpo-astronomy.org/venus as well as in considerable detail in the author's *ALPO Venus Handbook* available from the ALPO Venus Section as a pdf file.

Observers are urged to attempt to make simultaneous observations by performing digital imaging of Venus at the same time and date that others are imaging or making visual drawings of the planet. Regular imaging of Venus in both UV, IR and other wavelengths is important, as are visual numerical relative intensity estimates and reports of features seen or suspected in the atmosphere of the planet (for example, dusky atmospheric markings, visibility of cusp caps and cusp bands, measurement of cusp extensions, monitoring the Schröter phase effect near the date of predicted dichotomy, and looking for terminator irregularities).

Routine use of the standard ALPO Venus observing form will help observers know what should be reported in addition to supporting information such as telescope aperture and type, UT date and time, magnifications and filters used, seeing and transparency conditions, etc. The ALPO Venus observing form is located online at:

http://www.alpo-astronomy.org/gallery/main.php?g2_view=core.DownloadItem&g2_itemId=8564[illegible]

Venus observers should monitor the dark side of Venus visually for the Ashen Light and use digital imagers to capture any illumination that may be present on the plane as a cooperative simultaneous observing endeavor with visual observers. Also, observers should undertake imaging of the planet at near-IR wavelengths (for example, 1,000 nm), whereby the hot surface of the planet becomes apparent and occasionally mottling shows up in such images attributable to cooler dark higher-elevation terrain and warmer bright lower surface areas in the near-IR.

The ALPO Venus Section encourages readers worldwide to join us in our projects and challenges ahead.

Individuals interested in participating in the programs of the ALPO Venus Section are encouraged to visit the ALPO Venus Section online http://www.alpo-astronomy.org/venusblog/

Lunar Section

Lunar Topographical Studies / Selected Areas Program

Report by Wayne Bailey, program coordinator
wayne.bailey@alpo-astronomy.org

The ALPO Lunar Topographical Studies Section (ALPO LTSS) received a total of 140 observations from 18 observers during the October-December quarter.

Twenty three contributed articles were published in addition to numerous commentaries on images submitted.

The *Focus-On* series continued under Jerry Hubbell with articles on the Apollo 16 and 15 Regions.

The next *Focus-On* subjects will continue the series on each of the Apollo landing sites.

Electronic submissions can now be submitted through the ALPO website, (lunar@alpo-astronomy.org). (The former method of sending them to both myself and Jerry Hubbell will still work, but please don't submit both through the website and directly). See the most recent issue of *The Lunar Observer* (moon.scopesandscapes.com/tlo) for instructions on its use. Hard copy submissions should continue to be mailed to me at the address listed in the ALPO resources section of the Journal.

The lunar image gallery/archive is also now active. By the end of the year all images submitted in 2018 should be

available. Images will continue to be inserted, working back through the years

Thanks to Theo Ramakers and Larry Owens for setting up the gallery.

Visit the following online web site for more info moon.scopesandscapes.com (including current and archived issues of *The Lunar Observer*).

Lunar Meteoritic Impacts

Brian Cudnik, program coordinator
cudnik@sbcglobal.net

We've received several reports of meteor impacts on the Moon over the last months:

- The Remote Observatory of Campos dos Goytazes (ROCG) group in Brazil reports five lunar meteor impact candidates associated with the annual Geminid meteor shower. Times in these images are given in UT. The observations were made by Tiago Augusto, Torres Moreira and Carlos Henrique Barreto.
- In addition, we received reports of a lunar impact event that happened near the onset of totality. An impact flash was observed at 4:41:38 UT (MIDAS-reported time; event originally reported as 4:41:43) 21 January by a significant number of webcast entities and individuals, to include the MIDAS survey in Europe, operated by Jose Madiedo. One example from Spaceweather.com is an image taken by Christian Fröschlin of the Netherlands, which shows the meteor nicely against the

Inside the ALPO
Member, section and activity news

ruddy backdrop of the Moon's eclipsed face.

We seek confirming observations for the Geminid impact candidates; we would also like to know how many people actually saw the eclipse lunar meteor. The ALPO Lunar Meteoritic Impact Section will continue the ongoing work of coordinating observations for this and other meteor showers throughout 2019 and beyond. Check the ALPO website and/or join the Lunarimpacts listserve for more information.

Please visit the ALPO Lunar Meteoritic Impact Search site online at http://alpo-astronomy.org/lunarupload/lunimpacts.htm

Lunar Transient Phenomena

Report by Dr. Anthony Cook, program coordinator
tony.cook@alpo-astronomy.org

We welcome new participants in our program, whether they are experienced visual observers, or high-resolution lunar imagers. This helps us to solve some past historical lunar observational puzzles.

A list of dates and UTs to observe repeat illumination events can be found on: http://users.aber.ac.uk/atc/lunar_schedule.htm, and LTP observational alerts are given on this Twitter page: https://twitter.com/lunarnaut

Finally, please visit the ALPO Lunar Transient Phenomena site online at http://users.aber.ac.uk/atc/alpo/ltp.htm

Lunar Domes

Report by Raffaello Lena, acting program coordinator
raffaello.lena@alpo-astronomy.org

A report on a lunar dome in the Milichius-Tobias Mayer Region appears later in this issue of your ALPO Journal.

We have received many images including some by Richard Hill, K.C. Pau, Guy Leinen, Frank Schenck and Jim Phillips for a total of 24 images. Some images display the well-known domes in Arago, Milichius, Gruithuisen, Piccolomini dome, Birt domes, Lansberg domes, Laplace domes, Wollaston domes and a putative intrusive dome in Plato. Many images are shared in our Facebook group Lunar Dome Atlas Project ((https://www.facebook.com/groups/814815478531774/).

The identification of further domes and lunar cones in the wide Marius shield is ongoing and future updates will be done, including morphometric and spectral properties of further 22 volcanic constructs. Frank Schenck has imaged the dome Kepler1 (Ke1) and the dome Encke1, which was described in a previous our article published in the spring 2018 issue of this Journal (JALPO60-2), two previously reported domes near Laplace and the three domes near Wollaston. Some previous lunar domes images are now included in the ALPO Section Galleries in the specific lunar domes folder. Interested observers

(Left) Image by Christian Fröschlin of the Netherlands of the meteoroid impact. See second bulleted text on text on page 13 for more details.

(Right) Meteoroid impact during the January lunar eclipse as imaged by Brett Ashton (bashton@bex.net) on 20 January 2019 at 11:41:11 EST from northwestern Ohio, USA; latitude N41 36 37, longitude W 83 31 44, altitude 534 feet, using a Celestron 8SE on an EQ wedge with a Canon T6. Camera settings were ISO 800 and exposure 0.8 second, with all other automatic options turned off.

Inside the ALPO
Member, section and activity news

can publish their future images using the email lunar-domes@alpo-astronomy.org .

Phillips has imaged two Birt domes under strongly oblique solar illumination angle. Hill has imaged three highland domes (Gruithuisen Gamma, Delta, NW) and the Piccolomini dome. Pau has imaged an effusive dome located near Cavalerius A and Hevelius A in a complex region known as Hevelius Formation, showing evidence of ancient (pre-Orientale) mare volcanism and cryptomare deposits. It has a base diameter of 27x25 km, its height amounts to 188 m and the average slope angle corresponds to 0.83°. Cav 1 lies to coordinates 70.28° W and 3.59° N. It displays similar general morphometric, rheologic and feeder dike characteristics of the ancient cryptomare dome Mee 1, situated near the craters Mee R and Drebbel F, previously recognized by Phillips and described in our work. Based on the examined data, the examined dome Cav 1 is the second exemplar detected in criptomare regions during our long survey (conducted since 1998). According to the classification scheme of lunar domes, Cav 1, like Mee 1, belongs to class C1 and to rheologic group R1, the latter indicating an origin of the dome-forming magma from well-below the lunar crust. We have observed similar general morphometric, rheologic and feeder dike characteristics of the ancient cryptomare dome Mee 1 and Cav 1. More data about cryptomare domes in ancient volcanic regions are needed to establish more firmly possible differences between them and the younger classical mare domes of Imbrian and Eratosthenian age.

Contacts have been made with Dr. James W. Rice (Senior Scientist Mars Exploration Rover Project: Geology Team Leader, Planetary Science Institute Tucson, AZ) and Dr. Kacper Wierzchos (Graduate Research Assistant, Department of Physics, University of South Florida) about specific topics still needed to be addressed in lunar domes studies. Of course future contacts are welcome because the ALPO really does favor professional-amateur collaborations. Wierzchos has noticed the presence of a possible lunar cone located at 35.34° W and 14.88° N. I made some preliminary measurements and the feature is 100 m high with a diameter of 1.8 km, yielding an average slope of 6.3°. Based on its morphology and derived morphometric data, it matches the lunar cones class.

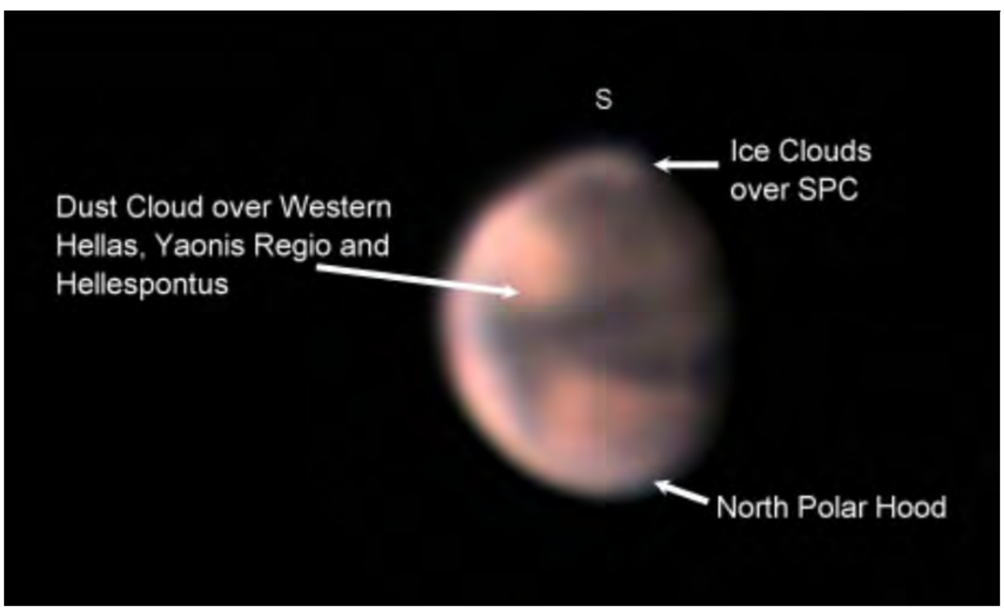
Interested observers can participate in the lunar domes program by contacting and sending their observations to both Raffaello Lena (coordinator email raffaello.lena@alpo-astronomy.org) and Jim Phillips (assistant coordinator (thefamily90@gmail.com).

Mars Section

Report by Roger Venable, section coordinator
rjvmd@hughes.net

Clyde Foster and Jim Melka observed a peculiar, streak-like cloud extending westward from the western flank of Arsia Mons in September. A trace of its shadow on the ground can be seen in some of the images. Spacecraft images also documented it and its shadow.

The shadow will enable its height to be computed. Its appearance was very different from that of the broad orographic clouds frequently seen in that area, and the season of the Martian year was far from that of orographic clouds. We know of no previous clouds like it, so we consider it to have been a rare occurrence. Jim proposes that it may have been due to seasonal sublimation of water ice in caves and depressions that are known to exist on the western flank of that volcano, when vapor then



Mars as imaged by Jim Melka on 2019 January 6 at 00:37 UT with CM=331° and Ls=319°. Seeing 3 (ALPO scale), transparency 4/6. Equipment: Newtonian telescope of 45 cm (18 in.) aperture and DBK21AU618.AS color camera with UV and IR block.

Inside the ALPO
Member, section and activity news

condensed to form a cloud high in the atmosphere.

Mars passed the traditional end of its 2017-2019 observing season upon shrinking to a subtended diameter of 6.0 arc seconds on February 4, 2019. However, its small apparent size has been balanced for observers in Earth's Northern Hemisphere by its transition to a northern declination. Committed observers have continued to observe it and occasionally to document some interesting phenomena. In early January, Japanese observers documented a regional dust storm affecting Chryse and Xanthe, Margaritifer and Aurorae Sinuses, and parts of Solis Lacus. This storm remitted before North American observers had a chance to see it. Jim Melka, who is our assistant coordinator, imaged a bright dust cloud in Hellas that spread westward, obscuring Yaontis Fretum and Hellespontus on January 6. This short-lived storm is documented in the accompanying figure by Jim.

The South Polar Cap is now tiny. On March 23, 2019, spring will have begun in Mars's Northern Hemisphere. At about that time, the North Polar Hood (NPH) began to thin and dissipate, and the North Polar Cap (NPC) might still be glimpsed in early April. However, Earth's southerly declination in the Martian sky will conspire with the small apparent size of Mars to render the observation of the NPC very difficult. Nevertheless, observers are encouraged to document the changes in the NPH and the visibility of the NPC. (It is an unusual coincidence that in 2019, northern spring will begin on Mars and on Earth at about the same time.) The red planet will continue to become more distant, and will subtend to fewer than 4 arc seconds diameter beginning on May 16, when it will still have an evening sky elongation of 35 degrees from the Sun.

This coordinator expresses special thanks to Theo Ramakers and Jim Melka for their work in upgrading our online image gallery during the last several months. Images sent to Theo at mars@alpo-astronomy.org will be included into the gallery and copied to me for inclusion into the archive of the world's ground-based images of Mars that I maintain. If anyone is shy about including his or her images in the online gallery, please at least send your work directly to me at rjvmd@hughes.net .

Those who are considering committing themselves to observing Mars in the next apparition are encouraged to check out the Mars Observing Program of the Astronomical League at https://www.astroleague.org/content/mars-observing-program. The best information on observing Mars is to be found in the online in *The New Internet Mars Observer's Handbook*, written by Jeff Beish and recently updated. To find it, visit www.alpo-astronomy.org, click on "Mars Section" in the left side-bar; and on the resulting Mars page, scroll down to find "Mars Observer's Cafe" in the list on the right. Also, you can participate in conversations about Mars and upload your images, drawings and descriptions on the Yahoo Mars observers list at https://groups.yahoo.com/neo/groups/marsobservers/info .

Minor Planets Section

Frederick Pilcher,
section coordinator
pilcher35@gmail.com

Some of the highlights published in *The Minor Planet Bulletin*, Volume 46, No. 1, January-March 2019, are hereby presented. These represent the recent achievements of the ALPO Minor Planets Section.

Andrew Salthouse publishes a summary of more than 50 years of observing faint objects that revolve around the Sun. These objects include 2894 minor planets, 58 comets, and the two dwarf planets Ceres and Pluto, a total of 28696 observations. We congratulate Andrew on this magnificent accomplishment.

The Minor Planet Bulletin announces a position opening for Associate Producer that will probably promote in two years into Producer. Required skills are Proficiency with Microsoft Word 2013/2010, pdf computer documents, and email. Production status is tracked using Microsoft Excel. The applicant should also have sufficient expertise with asteroid astronomy to do some error checking, recommending editorial corrections, and strong skills with written English. Any ALPO member who would like to apply please send an application to Richard Binzel, publisher of *The Minor Planet Bulletin*, email address rpb@mit.edu.

Most of the contributions to *The Minor Planet Bulletin* in recent years have had topics in asteroid CCD photometry and lightcurve analysis. Two papers in the current issue deal with multicolor photometry and determination of taxonomic class. Hanjie Tan and Xing Gao found for 4730 Xingmingzhou, in addition to the rotation period, the color indices B-V, V-R, amd R-I, from which they classify (4730) as a C-type asteroid. A large consortium led by Jessica Forelli performed broadband BVRI photometry on the near-Earth asteroid (276049) 2002 CE26 and found the colors most consistent with C-type taxonomy and, to a lesser extent, X-type taxonomy.

A satellite of an asteroid may be detected photometrically if a brief dip is observed in the rotational lightcurve as the secondary either transits or is occulted by the primary. Their combined light is reduced during these satellite events. Dual-period software can separate the

Inside the ALPO
Member, section and activity news

two lightcurves with separate periods from the observed combined lightcurve. Two asteroids with this behavior were reported, as in the accompanying table.

If the satellite's orbital plane is not close to the line of sight, satellite events are not observed. It may be possible to detect the presence of the satellite if the primary and secondary have different rotation periods and amplitudes and their combined lightcurve can be separated with dual-period software. Asteroids reported to have different primary and secondary rotation periods, but no observed transit/occultation events, are also listed in the accompanying table.

Finally, two other very small Earth-approachers were found to have very short rotation periods, faster than the centrifugal limit and therefore indicative of their being solid rocks (monoliths) rather than rubble piles. They, likewise, are also listed in the accompanying table.

In addition to the asteroids specifically identified above, lightcurves with derived rotation periods are published for 148 other asteroids as listed below:

131, 156, 232, 374, 433, 445, 660, 676, 719, 734, 831, 852, 929, 983, 1006, 1007, 1026, 1117, 1149, 1229, 1277, 1334, 1409, 1513, 1523, 1539, 1549, 1583, 1599, 1603, 1774, 1865, 1903, 1939, 1991, 2017, 2119, 2304, 2326, 2406, 2498, 2661, 2699, 2746, 2764, 2920, 3146, 3230, 3287, 3552, 3617, 3677, 3709, 3744, 3793, 3890, 3893, 3894, 4019, 4060, 4181, 4183, 4262, 4483, 5110, 5175, 5182, 5351, 5405, 5998, 6124, 6456, 7230, 7736, 8419, 8505, 8550, 9856, 11099, 11200, 11650, 11830, 12237, 13679, 14510, 15231, 15376, 15633, 15638, 16024, 16834, 17274, 17408, 17938, 18109, 19911, 23174, 25059, 26578, 27135, 27395, 28281, 31098, 34459, 37378, 42701, 44588, 46304, 47606, 51258, 56213, 73418, 76978, 82298, 86324. 86878, 115052, 141527, 144332, 186035, 282505, 283729, 333889, 337248, 418929, 438429, 441987, 457260, 481394, 1999 RB32, 1999 VQ11, 2001 QA143, 2005 RB, 2007 RX19, 2011 GA62, 2012 OD1, 2013 EP41, 2015 AX16, 2015 FP118, 2015 RJ83, 2016 NF23, 2018 GA5, 2018 MM8, 2018 NB, 2018 PJ10, 2018 QU1, 2018 QV1, 2018 RQ2.

Secure periods have been found for some of these asteroids, but for others only tentative or ambiguous periods. Some are of asteroids with no previous lightcurve photometry, others are of asteroids with previously published periods that may or may not be consistent with the newly determined values. Newly found periods that are consistent with periods previously reported are of more value than the uninitiated may realize. Observations of asteroids at multiple oppositions widely spaced around the sky are necessary to find axes of rotation and highly accurate sidereal periods.

Table 1. Asteroids Detailed in This Report

Minor Planet	Type	Author(s)	Primary Rotation Period (h)	Orbital Revolution Period (h	Status
Asteroids with Occulting Satellites					
7002 Bronshten	Mars Crosser	B. Warner, D. Stephens	2.67025	13.323	secure
31345 1998 PG	Near-Earth	B. Warner et al.	2.5139	16.014	tentative
Asteroids with Non-Occulting Satellites					
3563 Ignatius	Main Belt	R. Stephens	2.832	16.00	tentative
2018 KE3	Near-Earth	B. Warner	4.168	47.1	tentative
Probable Solid Rock Asteroids (Very Fast Rotation Periods)					
2011 UA	Near-Earth	B. Warner	0.31639		
2018 LQ2	Near-Earth	B. Warner	0.47185		

The *Minor Planet Bulletin* is a refereed publication and that it is available online at:

http://www.MinorPlanet.info/MPB/mpb.php

Annual voluntary contributions of $5 or more in support of the publication are welcome.

Please visit the ALPO Minor Planets Section online at http://www.alpo-astronomy.org/minor

Jupiter Section

Report by section staff members Schmude, MacDougal and McAnally

Jupiter will be visible for most of the morning hours in April. It will reach opposition around June 10 and will then transition to becoming an evening object.

Craig MacDougal reports there are 511 members in the ALPO_Jupiter Yahoo Group as of January 31, 2019. He also reports that members discuss and share observing techniques and, hence, this would be a good group to join. He reports that a few people have already posted early images of Jupiter (made before February 2) on the Jupiter Yahoo site. Craig reminds everyone that Yahoo does not allow file attachments. Observers should instead provide a link to their own images.

Coordinator Schmude recorded a set of near-infrared brightness measurements of Jupiter on January 11. He plans to

Inside the ALPO
Member, section and activity news

continue making these measurements to determine if Jupiter undergoes long-term changes in brightness. He is also planning to work on the 2015-16 Jupiter apparition report this spring.

John McAnally feels we should incorporate Jupiter transit timings into our training program. Therefore people who want to learn how to observe Jupiter and make scientific contributions to our study of Jupiter should consider learning how to make transit timings of Jupiter's features.

This is a reminder that this coordinator has decided to retire the Galilean Satellite Eclipse Timings Program. I did this because the orbital models of the satellites are accurate to about a second, whereas visual timings are accurate to about a minute or so.

Visit the ALPO Jupiter Section online at *http://www.alpo-astronomy.org/jupiter*

Galilean Satellite Eclipse Timing Program

This Journal will publish the remaining Eclipse Timing Program reports completed by the late John Westfall before his passing.

A summary of Galilean satellite eclipse timing observations covering 2007-2011 appears later in this issue of your ALPO Journal.

Finally, a paper explaining the discontinuance of this program can also be found later in this Journal.

As stated above, this program is being discontinued.

For those who remain interested, an Excel catalog of this program's observations from the 1975/76 through the 2000/01 Jupiter apparitions is available. This read-only, two-megabyte file contains the results of 10,308 visual timings, with 20 entries for each timing.

The data are more detailed than given in the reports published in this Journal over the years, and include observed UT, delta-t, the predicted event time based on the Lieske E-2 ephemeris, as well as the observer name, instrument aperture, and observing conditions.

Saturn Section

Report by Julius Benton, section coordinator
jlbaina@msn.com

Saturn entered conjunction with the Sun on January 2, 2019, marking the end of the 2018-19 apparition. Saturn's westward elongation increases during mid-April 2019, becoming visible for more than half the night, reaching opposition on July 9, 2019 affording an excellent opportunity for observers to view and image the planet most of the night.

The accompanying Table of Geocentric Phenomena for the 2018-19 Apparition in Universal Time (UT) is included here for the convenience of observers.

As of this writing (January 2019), the ALPO Saturn Section has accumulated hundreds of excellent digital images of the planet at visual and infrared wavelengths during the previous 2018-19 apparition, when observers reported discrete atmospheric phenomena in Saturn's northern hemisphere, including an interesting recurring white spot in the EZn (northern half of the Equatorial Zone), as well as a small white spot in the EZs (southern half of the Equatorial Zone, as well as a persistent group of white spots in the NNNTeZ (North North North Tmperate Zone) with what appeared to be a closely associated white spot near the southern edge of the NPR.

Somewhat elongated white streaks were reported in the EB (Equatorial Belt). The aforementioned white spots have persisted and have shown up well in images captured with RGB, 685nmIR, and red filters. It will be extremely worthwhile to continue to monitor Saturn to determine if the longevity and changing morphology of these or similar features persist well into the 2019-20 apparition. Observers should be watchful for any new atmospheric phenomena that might suddenly appear. With the rings tilted by about +24o toward our line of sight from Earth in 2019-20,

Table of Geocentric Phenomena for the 2019-20 Apparition of Saturn in Universal Time (UT)

Conjunction	2019 Jan 02^d UT
Opposition	2019 July 09^d
Conjunction	2020 Jan 13^d
Opposition Data for July 09, 2019	
Equatorial Diameter Globe	18.08″
Polar Diameter Globe	16.68″
Major Axis of Rings	41.05″
Minor Axis of Rings	18.24″
Visual Magnitude (m_v)	+0.2
B = Declination Constellation	+26.18° -22.80° Sagittarius

Inside the ALPO
Member, section and activity news

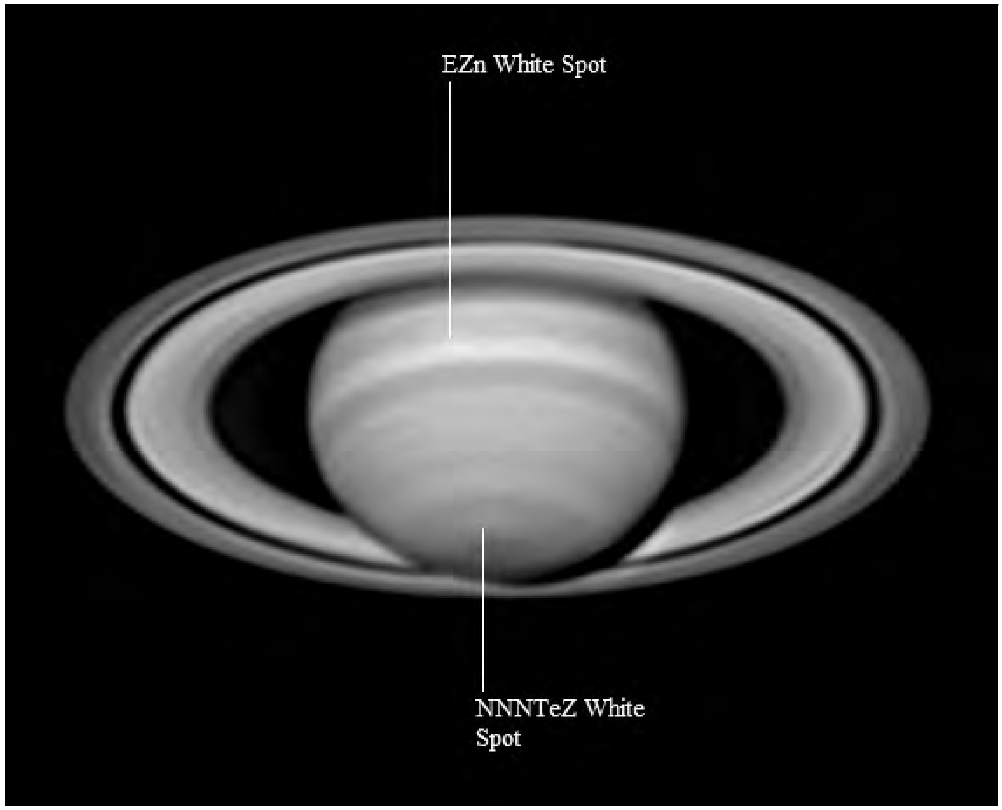
observers still have fairly good view of the northern hemisphere of the globe and north face of the rings during the apparition.

Pro-Am cooperation with the Cassini mission continued during the past 2016-17 apparition as NASA's remarkable close-range surveillance of the planet for nearly thirteen years that started back on April 1, 2004, and concluded its amazing odyssey on last year on September 15, 2017 when it plunged into Saturn's atmosphere.

For years to come, however, planetary scientists will be carefully studying the vast database of images and data gleaned from the Cassini mission, Pro-Am efforts did not cease in the immediately preceding 2018-19 apparition as we regularly monitored atmospheric phenomena on Saturn and actively shared our results and images with the professional community. Thus, anyone who wants to join us in our observational endeavors is highly encouraged to submit systematic observations and digital images of the planet at various wavelengths throughout the current 2019-20 apparition.

Observers are also reminded that visual numerical relative intensity estimates (also known as visual photometry) remain an extremely important part of our visual observing program and are badly needed to ascertain recurring brightness variations in the belts and zones on Saturn as well as the major ring components.

ALPO Saturn observing programs are listed on the Saturn page of the ALPO website at http://www.alpo-astronomy.org/saturn as well as in more detail in the author's book, *Saturn and How to Observe It*, available from Springer, Amazon.com, etc., or by writing to the ALPO Saturn Section for further information.



Excellent image of Saturn taken by Clyde Foster of Centurion, South Africa November 8, 2018, at 17:10 UT. His red channel image was captured in fair seeing using a 35.6cm (14.0 in.) DCT His image shows the recurring diffuse white spot within the EZn adjacent to the EB, plus a vague appearance of the long-lived white spots in Saturn's NNNTeZ (North North North Temperate Zone). Cassini's division (A0 or B10) is quite obvious running all the way around the circumference of the rings except where the globe blocks our view of the rings. The north polar hexagon is also barely visible. The apparent diameter of Saturn's globe was 15.5" with a ring tilt of +26.3º. CMI = 239.5º, CMII = 174.3º, CMIII = 83.0º. Visual magnitude +0.6. S is at the top of the image.

Observers are urged to pursue digital imaging of Saturn at the same time that others are imaging or visually monitoring the planet (i.e., simultaneous observations).

The ALPO Saturn Section thanks all observers for their dedication and perseverance in regularly submitting so many excellent reports and images in recent years. Cassini mission scientists, as well as other professional specialists, continue to request drawings, digital images, and supporting data from amateur observers around the globe in an active Pro-Am cooperative effort.

Information on ALPO Saturn programs, including observing forms and instructions, can be found on the Saturn pages on the official ALPO Website at www.alpo-astronomy.org/saturn

All are invited to also subscribe to the Saturn e-mail discussion group at Saturn-ALPO@yahoogroups.com

Inside the ALPO
Member, section and activity news

ALPO Book Authors

Besides this Journal, which includes detailed observation reports and similar data from various ALPO section coordinators, there are also a number of books written by ALPO members about various facets of solar system astronomy.

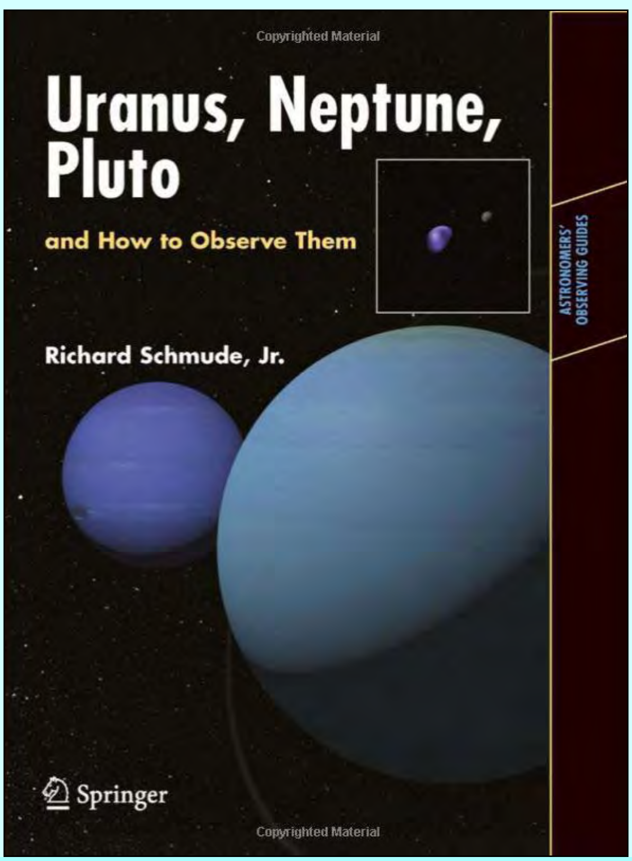
These books are published by Springer and are available at all the usual online and many brick-and-mortar outlets.

In this issue of your Journal, we present another of these books with hopes that you consider adding it to your own personal collection.

Uranus, Neptune, Pluto and How to Observe Them (authored by Richard Schmude, coordinator of the ALPO Remote Planets Section) can be found at booksellers such as *Amazon.com* and *Springer.com.*

“This book has a lot of interesting and detailed information on the outer planets and would be perfect for an advanced amateur astronomer who wants to do his own research and observations. An armchair astronomer or beginning enthusiast might have trouble understanding some of the technical information in this book and may decide to skip over some of the graphs and equations. Dr. Schmude has a very direct and no-nonsense style of writing that packs a lot of technical information and data into each chapter. A reader who wants a coffee table style book with basic information and large photographs should look elsewhere. I enjoyed the book because it was a challenge to understand all of the information and I actually learned how to do planetary research with basic equipment.” (One of the reviews at Amazon.com, July 2010)

"*Uranus, Neptune and Pluto and How to Observe Them* is truly an enthusiast’s book, aimed at the serious amateur astronomer. Schmude … reviews in detail the findings from Voyager as well as Earth-based telescopes such as the Hubble Space Telescope. He does this in a tone that is accessible to nonscientists, offering them the latest information as well as allowing them to tailor their observation … about these fascinating objects. … Summing Up: Highly recommended. All readership levels." (E. S. Perlman, Choice, Vol. 46 (7), March, 2009)



Remote Planets Section

Report by Richard W. Schmude, Jr., section coordinator
schmude@gordonstate.edu

Uranus and Neptune will be near the Sun by the first week of April; by June, however, both planets should be visible just before sunrise. Pluto will be in the southeastern sky before sunrise in April. Sunlight is now hitting the mid-latitudes of Uranus, which will reach its solstice in 2029.

If you have observations of Uranus, Neptune or Pluto please send them in to this coordinator for inclusion in the 2018-19 Remote Planets apparition report to be written in June.

Several people have been successful in imaging bright cloud features on both Uranus and Neptune using either red or near-infrared light. Please consider imaging these planets. This coordinator plans to continue monitoring the brightness of Uranus and Neptune using a photometer.

To find any of the remote planets for telescopic observations, I suggest that you first use a star chart which shows the position of the target, then use binoculars to find the target. [Note: *skyandtelescope.com* is a great source to find specific locations of sky objects.]

Next, locate the target in the finder scope of your telescope. Finally, use a low-power eyepiece and center it in the field-of-view.

Note that you may need a dark site to locate Neptune in binoculars and in the finder scope.

Finally, a reminder that the book *Uranus, Neptune and Pluto and How to Observe Them*, which was authored by this coordinator, is available from Springer at *www.springer.com/astronomy/popular+astronomy/book/978-0-387-76601-0* or elsewhere (such

Inside the ALPO
Member, section and activity news

as *www.amazon.ca/Uranus-Neptune-Pluto-Observe-Them/dp/0387766014*) to order a copy.

Visit the ALPO Remote Planets Section online at *www.alpoastronomy.org/remote*

Letters, Sometimes We Get Letters

To: Julius Benton, coordinator, ALPO Saturn Section

Julius, thanks for including my Saturn and Neptune images in the latest ALPO journal. It is always rewarding to have that little bit of recognition of the work I am doing!

It was also nice to be recognised and credited with contributing images to the recent article that has been published (Molter, de Pater, et al) in *Icarus* on last year's Neptune storms. It still amazes me what we can do in these times- Exciting!

Best regards, Clyde Foster
Centurion, South Africa
clyde@icon.co.za

****

Below is a series of e-mails between long-ago ALPO memberv Bob Danford and this editor regarding Bob's hopeful finding of a past issue of *The Strolling Astronomer* which included one of Bob's own contributions. Please note that YOUR own contributions published in this Journal all those years ago can likewise be found. So please remember this publication is not just an announcement of technical findings, but also a journal that communicates the enthusiasm of ALPO members of the past. Take some time to peruse our online library, find an article or paper of your liking and enjoy the way we _used_ to write (and even how we looked!).

By the way, our pdf files are searchable. That is, you can use the "Find" tool in Adobe Reader, Adode Acrobat or whatever pdf reader you use to locate words or phrases on an issue-by-issue basis.

Finally, if any of you wish to add to Bob's remembrances of the Astronomy Club of Tulsa and its 12-inch reflector, please tell us! (We note that Professor Balfour S. Whitney who was referenced in this account passed away on September 18, 1992. His full obituary can be found at *https://aas.org/obituaries/balfour-s-whitney-1903-1992* .)

And now, "the rest of the story . . ."

****

On October 2, 2018, Bob Danford wrote:

During the years of (probably) 1960 or 1961, when I was in high school, I made numerous observations of Jupiter using the Astronomy Club of Tulsa's telescope (a 12-inch Newtonian, as I recall). I submitted at least some of my drawings (which is the way things were done back then) to the ALPO, and one of them was published in its Journal. I once had a copy of the publication, but it has long ago been lost, probably discarded by my parents during one of their relocations. I have no real reason except nostalgia, but I would love to have a copy of the publication, or at least a copy of my drawing that was published. I went on to major in astronomy at Oklahoma University under Professor Balfour S. Whitney, but got diverted by my fascination with computers and went on to a long career in aerospace.

Please let me know if what I am seeking is at all possible, and what the cost would be. Thank you very much.

-- Bob Danford

****

On October 3, 2018, Ken Poshedly replied:

Bob -- At this time, we are all out of hardcopy back issues of the Journal before 1962.

However, we are in the process of posting to our website pdf files of all back issues obtained from scans of our Journals from the private library of one of our members (John Westfall).

Go to alpo-astronomy.org, then click on the "ALPO Section Galleries" link near the top right of the screen.

Then click on the Publications Section icon, then the ALPO Journals icon.

I expect that in the coming months, you should see Journals from the time-frame you stated.

-- Ken

****

Also on October 3, 2018, Bob Danford wrote:

Ken,

Thank you for your reply and the information about posting the PDF files of past issues of the Journal. I will certainly check out the web site and look forward to watching the archives grow over time. A PDF of the journal I was published in would be quite interesting to me, though I'm not clear exactly what I should be looking for. To the best of my recollection, my drawing of Jupiter was one of many gathered from numerous amateur observers. I don't know if this was an annual (or semi-annual) compendium of observations strictly devoted to Jupiter. I do remember being quite surprised and pleased that my drawing had been selected for inclusion.

Again, thank you for taking the time to get back to me.

Cordially,

-- Bob Danford

****

Inside the ALPO
Member, section and activity news

On January 11, 2019, Ken Poshedly wrote:

Hey Bob,

Well, at least some good news. We've made lots of progress making our way-back issues available online.

Furthermore, I am pleased to include with this email the attached pdf file of *The Strolling Astronomer*, Volume 15, Nos. 3-4, which was the March-April 1961 issue. In it, you will find your name listed among the contributors on page 40 to the article "Some Highlights of the 1960 Jupiter Apparition" by Philip R. Glaser. Further, your own glorious sketch of Jupiter is Figure 24 and can be found on page 44.

Let's see . . . , you said you were in high school in about 1960-1961, making you then about age 16 or 17.

So whatever happened to that 12-inch club reflector and the club itself?

-- Ken

****

On January 15, 2019, Bob Danford wrote:

Greetings, Ken –

What a pleasant surprise to hear from you and to get a PDF of *The Strolling Astronomer* issue in which my Jupiter drawing was published. After the summer of 1960, I did no more observations using the club's 12-inch reflector. After completing high school, I went on to Oklahoma University, majoring in astronomy under professor Balfour S. Whitney. I did some work on variable stars there (professor Whitney's primary interest), but as a result of avoiding the tedium of repetitive computations to determine the period of binary variables, I discovered a new passion for computer programming. That path led me to a long and very interesting career in aerospace, from which I have now retired.

I have no idea what became of the 12-inch reflector I used. It was in the backyard of one of the club members, and I'd guess it was built entirely by him and a few other members (including grinding the mirror). I don't know if my memory is accurate here, but I seem to recall that the equatorial mount was fashioned from an automobile rear axle. I do remember that the instrument was sheltered by a plywood construction which tipped out of the way on the north side of the mount. There was a platform which allowed you to reach the eyepiece, which probably was 10 feet or so off the ground for objects near the zenith.

The club seems to be alive and thriving: see http://www.astrotulsa.com/. They now have a very nice, fully enclosed (with dome) observatory, housing a 14-inch Mead RCX telescope. Sweet instrument, I'd guess, and probably considerably easier to use than the 12-inch Newtonian I worked with. I'll never forget, though, those warm Oklahoma nights and the hours spent alone peering through the eyepiece to capture momentary passings of atmospheric stability. I'm grateful to have had the opportunity for such experiences.

Well, thank you so much for remembering me and sending the journal that triggered so many pleasant memories for me. (Hard to believe so much time has passed since then.)

All best,

-- Bob Danford

(Continued from page 2)

The ALPO has always had a format at these meetings of presentations in the daytime, nighttime events like an informal dinner and a field trip to an observatory or other interesting venues, and the more formal, concluding banquet. While there is a lot going on at these meetings to get attendees' attention, the underlining purpose of these annual meetings has been for ALPO members and non-members to socialize and network with others having a common interest in a facet of Solar System astronomy or perhaps acquire better knowledge of a topic, through the presentations, to get fresher insights from others. While this has been motivation enough for significant numbers of ALPO members to meet in person in the past, one wonders if that matters in most members minds anymore in light of current trends in attendance. Does the age of fast and easy communications electronically make in-person meetings somewhat less desirable? Are the costs and planning involved in traveling to annual meetings too much to prepare for? Is the traditional format of our annual meeting less accommodating in sustaining members' interests and needs?

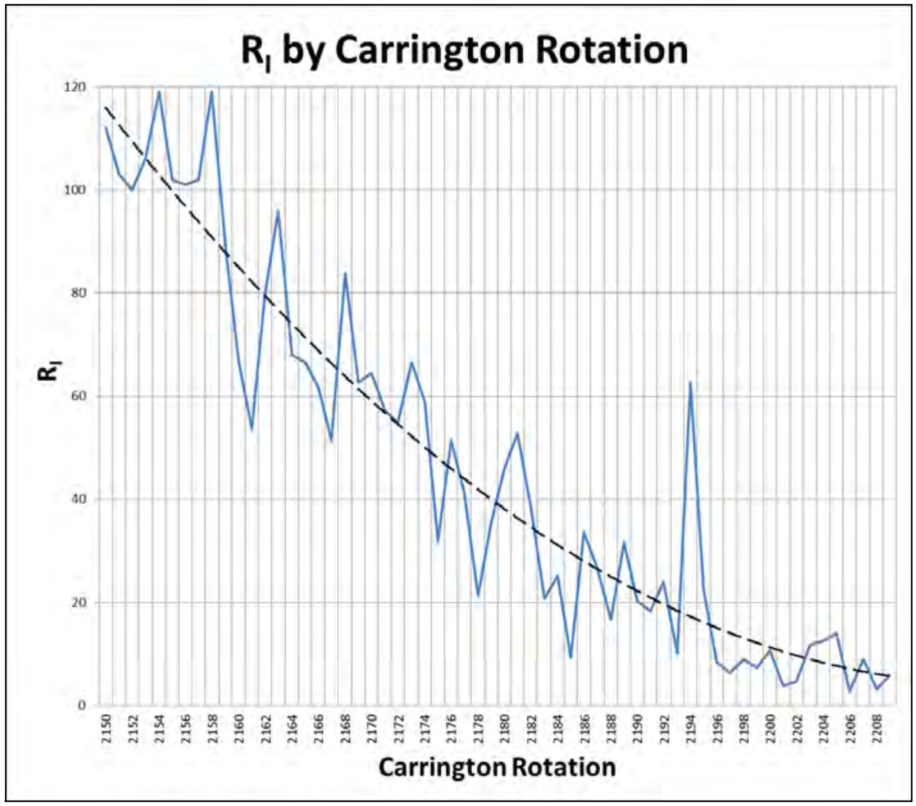
Generally, we have increasingly relied on more help from cohosts, like the SAS, that have taken more responsibility in organizing events. As a result, the ALPO has fewer opportunities to give papers at these events and fewer openings to present itself more fully than in the past. Would members prefer more independent meetings with more ALPO papers? Would members prefer a different format in these meetings, more options or things to do at these meetings, or should we just scuttle having these yearly get-togethers? Many personal opportunities still can happen with face-to-face contact, as they have for many of us at these annual meetings over the years, sometimes without anticipating what we may learn or who we might meet. Lifelong learning such as what we do in amateur astronomy often comes from personal interaction. Over the years, in just being a member, the personal relationships I have had with other ALPO members has been invaluable in motivating me to be a better observer. I am now at that age where I have known a lot of longtime ALPO staff and members that are no longer with us. Who among the next generation of ALPO members will be the productive observers and lead our organization? Please join me this July, at our annual meeting in Barnesville, Georgia, and get

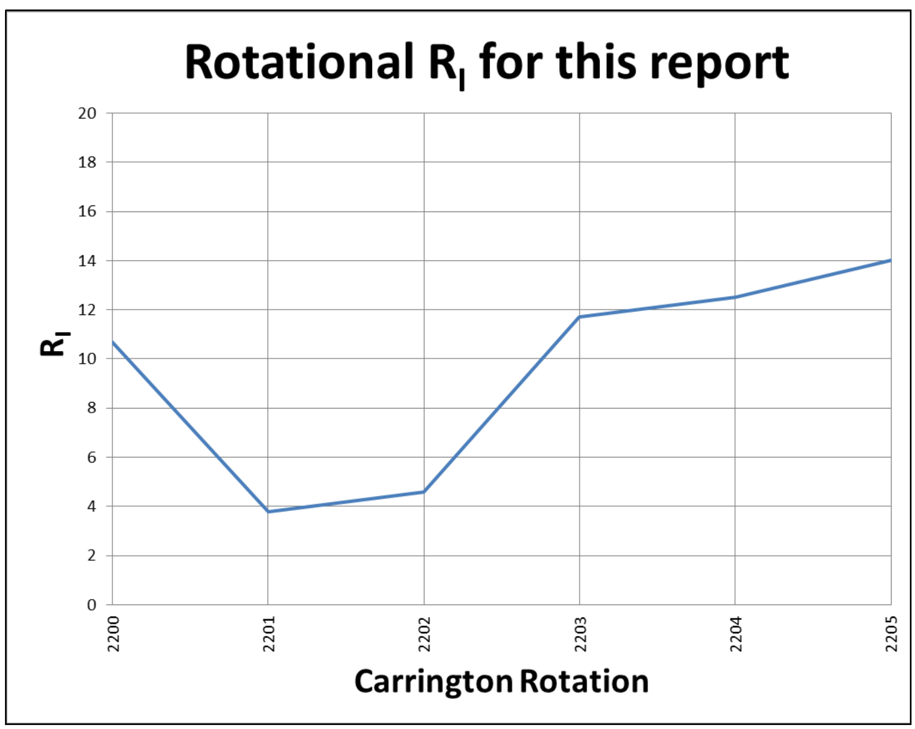
Papers & Presentations: ALPO Solar Section

A Report on Carrington Rotations 2206 through 2209 (2018 07 09.8597 to 2018 10 26.8687)

By Richard (Rik) Hill,
Coordinator &
Scientific Advisor,
ALPO Solar Section
rhill@lpl.arizona.edu

To our hard-copy readers: This paper can be viewed in full-color in the online (pdf) version of this Journal.





Overview

The activity during this report interval was characterized as very low. The average sunspot number was 5.2 which is less than half of the previous period (10.7). Of the 109 days in this report, 70 (64%) had no spots. There were a total of 10 active regions (ARs), but only one region (AR 2720 in Carrington Rotation 2207) got as large as 100 millionths — and that was for only one day. Everything else was smaller. None evolved beyond D-class or mag. class "beta". AR 2720 was also the source for over 90% of what few flares there were.

Terms and Abbreviations Used In This Report

While this brief section is similar to the same in earlier reports it should be at least reviewed. As in previous reports, the ALPO Solar Section will be referred to as "the Section" and Carrington Rotations will be called "CRs". Active Regions are designated by the National Oceanic and Atmospheric Administration (NOAA) and will refer to all activity in all wavelengths for that region and will be abbreviated "AR" with only the last four digits of the full number being used. The term "groups" refers to the visible light or "white light" sunspots associated with an Active Region. Statistics compiled by the author have their origin in the finalized daily

Table of Contributors to This Report

Observer	Location	Telescope	Camera	Mode	Format
Michael Borman	Evansville IN	102mm, RFR	Point Grey GS3	W-L	digital images
		90mm		H-a	
		102mm, RFR		CaK	
Richard Bosman	Enschede, Netherlands	110mm, RFR	Basler Ace 1280	H-a	digital images
		355mm, SCT		W-L	
Raffaello Braga	Milano, Italy	112mm,RFR	PGR Chameleon	H-a	digital images
Tony Broxton	Cornwall, UK	127mm, SCT	N/A	W-L	drawings
Jeffery Carels	Bruges, Belgium	100mm, RFR	ZWO-ASI 120MM	W-L	digital images
Jean-Francois (Jeff)	France	30mm, Projection	N/A	W-L	drawings
Gabriel Corban	Bucharest, Romania	120mm, RFL-N	Point Grey GS3-U3	H-a	digital images
				W-L	
Brennerad	Sao Palo, Brazil	90mm, MCT	ASI224MC	W-L	digital images
Franky Dubois	West-Vlaanderen,	125mm, RFR	N/A	visual sunspot	
Howard Eskildsen	Ocala, FL	80mm, RFR	DMK41AF02	W-L wedge	digital images
				CaK	
Joe Gianninoto	Tucson, AZ	85mm, RFR	N/A	W-L	drawings
		60mm, RFR		H-a	
Guilherme	Curitiba, Brazil	60mm, RFR	Lumenera Skynyx	H-a	digital images
Richard Hill	Tucson, AZ	90mm, MCT	Skyris 445m	W-L	digital images
		120mm, SCT		""	
Bill Hrudey	Grand Cayman	200mm, RFL-N	ASI174MM	W-L	digital images
		60mm, RFR		H-a	
David Jackson	Reynoldsburg, OH	124mm, SCT	N/A	W-L	drawings
Jamey Jenkins	Homer, IL	102mm, RFR	DMK41AF02	W-L	digital images
		125mm, RFR		CaK	
Pete Lawrence	Selsey, UK	102.5mm, RFR	ZWO ASI174MM	H-a	digital images
Monty Leventhal	Sydney, Australia	250mm, SCT	N/A	W-L/H-a	drawings
			Canon-Rebel	H-a	digital images
Tom Mangelsdorf	Wasilla, AK	120mm, RFR	N/A	W-L	drawings
Frank Mellilo	Holtsville, NY	200mm, SCT	DMK21AU03AS	H-a	digital images
Efrain Morales	Aguadilla, Puerto Rico	50mm, RFR	Point Grey Flea 3	H-a	digital images
German Morales C.	Bolivia	200mm, SCT	N/A	visual sunspot	
John O'Neal	NC			Na-D	digital images
Theo Ramakers	Oxford GA	80mm, RFR	ZWO ASI174MM	H-a	digital images
		11in. SCT	DMK41AU02AS	W-L	
		40mm, H-a PST	DMK21AU03AS	H-a	
		40mm, CaK PST		CaK	
Ryc Rienks	Baker City OR	203mm, SCT	N/A	W-L	drawings
		40mm, H-a PST		H-a	
Laura Schreiber	Wuertzburg, Germany	280mm, SCT	Basler IMX174	W-L	
Chris Schur	Payson, AZ	152mm, RFR	DMK51	CaK	digital images
				W-L (CaK-	
		100mm, RFR		H-a	
Randy Shivak	Prescott, AZ	152mm, RFR	ZWO-ASI174	H-a	digital images
Avani Soares	Canoas, Brazil	120mm, RFR	ZWO-ASI 224	W-L	digital images
Randy Tatum	Bon Air, VA	180mm, RFR	DFK31AU	W-L-	digital images
David Teske	Louisville MS	60mm, RFR	N/A	W-L/H-a	drawings
		100mm, RFR	ZWO-ASI 120MM	H-a	digital images
Vince Tramazzo	Tucson, AZ	94mm, RFR	N/A	W-L	drawings
		50mm, RFR		H-a	
James Kevin Ty	Manila, Philippines	TV101-RFR	ZWO-ASI 120MM	H-a	digital images

International Sunspot Number data published by the WDC-SILSO (World Data Center - Solar Index and Long Term Solar Observations) at the Royal Observatory of Belgium. All times used here are Coordinated Universal Time and dates are reckoned from that. Dates will be expressed numerically, with month/day such as "9/6" or "10/23". Carrington Rotation commencement dates are from the table listed on the Section webpage on the ALPO website *http://alpo-astronomy.org/solarblog/wp-content/uploads/ephems/CNSun_2159_2306_A.pdf*

The terms "leader" and "follower" are used instead of "east" or "west" on the Sun to avoid misunderstandings. This follows the "right-hand rule" where, using your right hand, your thumb pointing up is the north pole and the rotation follows the curl of your fingers. Orientation of images shown here will be north up and celestial west to the right (northern hemisphere chauvinism). The cardinal directions (north, south, east, west) if used at all, will be abbreviated as N, S, E and W and Central Meridian of the visible disk will be CM.

The abbreviation to indicate white-light observations is "w-l", while hydrogen-alpha is "H-a" and calcium K-line is "CaK". "Naked-eye sunspots" means the ability to see these spots on the Sun without amplification but through proper and safe solar filtration. As a reminder, you should never look at the Sun, however briefly, without such filtration even at sunrise/set.

Areas of regions and groups are expressed in the standard units of millionths of the solar disk, with a naked-eye spot generally being about 900-1,000 millionths for the average observer. The McIntosh Sunspot Classification used here is the one defined by Patrick McIntosh of NOAA (McIntosh 1981, 1989) and detailed in an article in the JALPO Volume 33 (Hill 1989). This classification system is also detailed by the author on the Section website at *http://www.alpo-astronomy.org/solar/W-Lft.html* in an article on white-light flare observation.

Table of Contributors to This Report (Continued)

Observer	Location	Telescope	Camera	Mode	Format
David Tyler	Buckinghamshire, UK	178mm, RFR	ZWO	W-L	digital images
		90mm, RFR		H-a	
Christian Viladrich	Nattages, France	300mm, RFN	Basler 1920-155	W-L	digital images
Telescope Types: Refractor (RFR), Newtonian Reflector (RFN), Schmidt Cassegrain (SCT), Maksutov-Cassegrain (MCT), Cassegrain (Cass)					

This will be referred to as the McIntosh Class. The magnetic class of regions is assigned by NOAA and will be entered parenthetically after the McIntosh class or elsewhere referred to as "mag. class".

Lastly, due to the constraints of publishing, most of the images in this report have been cropped, reduced or otherwise edited. The reader is advised that all images in this report, and a hundred times more, can be viewed at full resolution in the ALPO Solar Archives. This can be accessed by going to the Solar Section webpage and following the Archives link at the top of the right sidebar. You can also go to the Archives through this link: *http://www.alpo-astronomy.org/gallery/main.php?g2_itemId=1699*

Section observers, their equipment and modes of observing are summarized in Table 1 on this page. While not all individuals necessarily contributed to this specific report, they have contributed to recent reports and are ALPO Solar Section members. This should be used as a reference throughout this report.

References

Hill, R.E., (1989) "A Three-Dimensional Sunspot Classification System" Journal of the Assn of Lunar & Planetary Observers, Vol. 33, p. 10. *http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1989JALPO..33...10H&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf*

Livingston, W., Penn, M.; (2008) "Sunspots may vanish by 2015." *https://wattsupwiththat.files.wordpress.com/2008/06/livingston-penn_sunspots2.pdf*

McIntosh, Patrick S., (1989) "The Classification of Sunspot Groups" Solar Physics, Vol. 125, Feb. 1990, pp. 251-267. *http://adsabs.harvard.edu/abs/1990SoPh..125..251M*

McIntosh, Patrick S., (1981) "The Physics Of Sunspots". Sacramento Peak National Observatory, Sunspot, NM; L.E. Cram and J.H.Thomas (eds.), p.7. *https://sourcelibraries.com/browse/the-physics-of-sunspots/*

Additional references used in the preparation of this report:

Solar Map of Active Regions
https://www.raben.com/maps/date

SILSO World Data Center
http://sidc.be/silso/home

SILSO Sunspot Number
http://www.sidc.be/silso/datafiles

The Mass Time-of-Flight spectrometer (MTOF) and the solar wind Proton Monitor (PM) Data by Carrington Rotation
http://umtof.umd.edu/pm/crn/

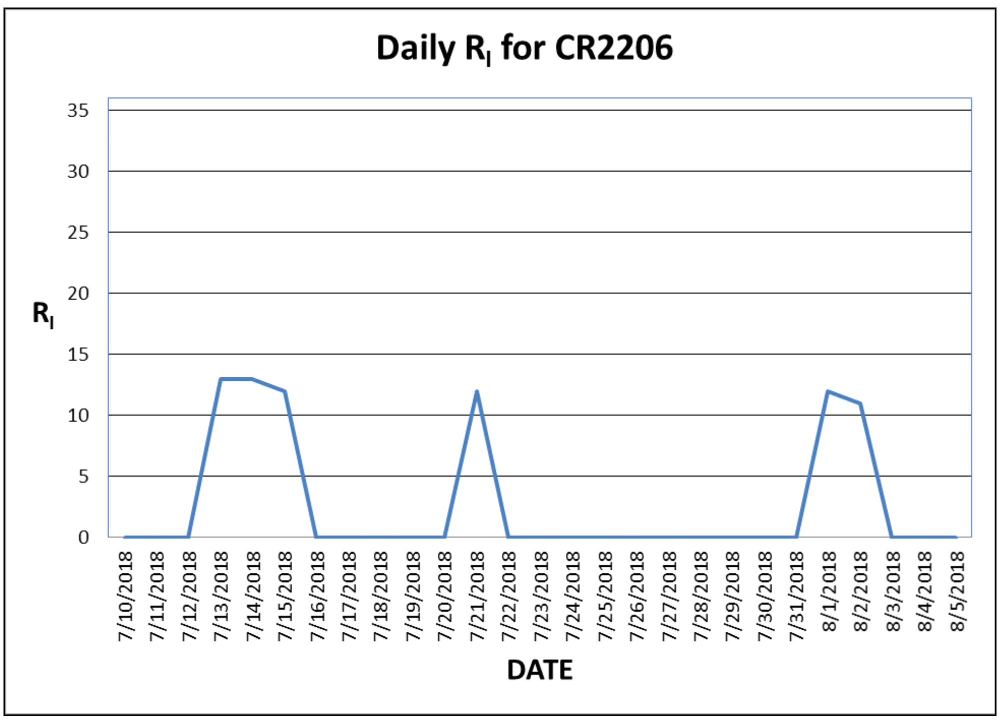
Carrington Rotation 2206

Dates: 2018 07 09.8597 to 2018 08 06.0715

Avg. R_I = 2.7
High R_I = 13 (7/13 & 7/14)
Low R_I = 0 (21 days)

There were only two active regions in this rotation (AR 2716 and AR 2717), neither of which evolved beyond Axx nor attained an area greater than 10 millionths.

The first region (AR 2716) appeared on the disk near the CM as Axx of 10 millionths late on 7/21 and was gone in w-l 24 hours later. But in its place was a large filament that was observed on 7/24 and 7/25 in H-a by Grassmann (Figure 1). Four days later, when it was on the limb, Ramakers got an excellent view of it as a limb prominence, also in H-a (Figure 2).



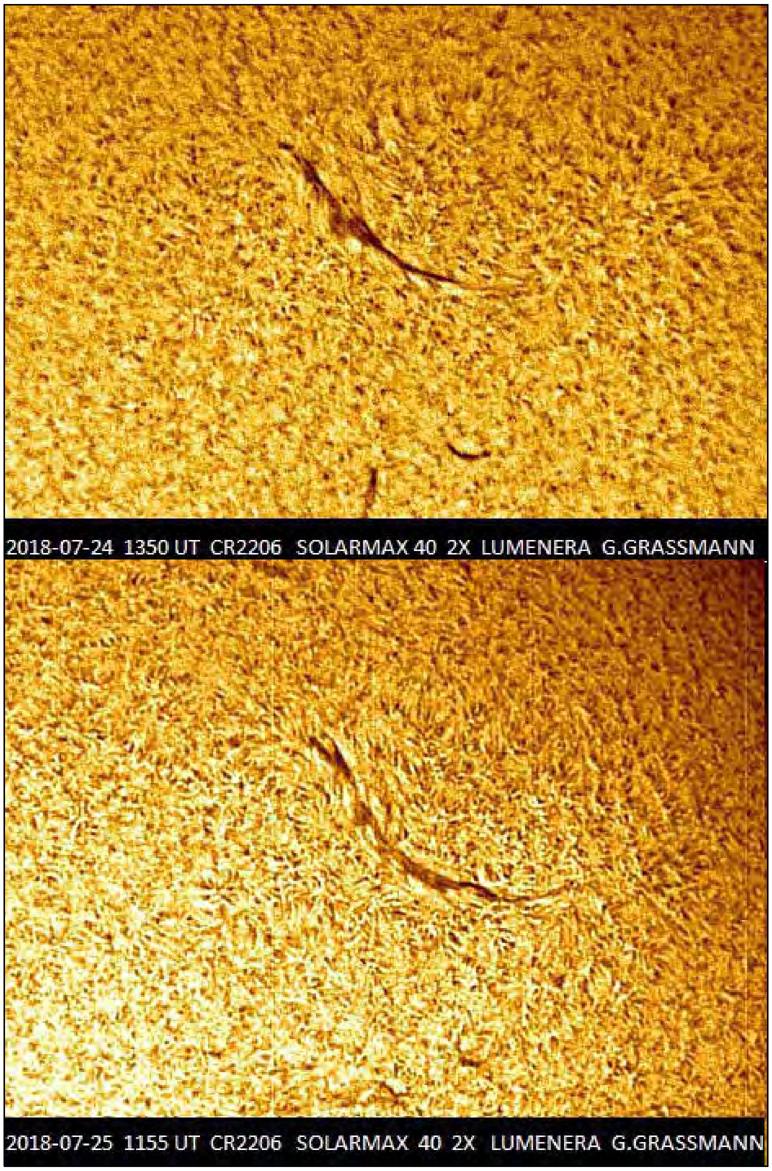


Figure 1. Large filament on two consecutive days, 7/24 and 7/25 in H-a by Grassmann.

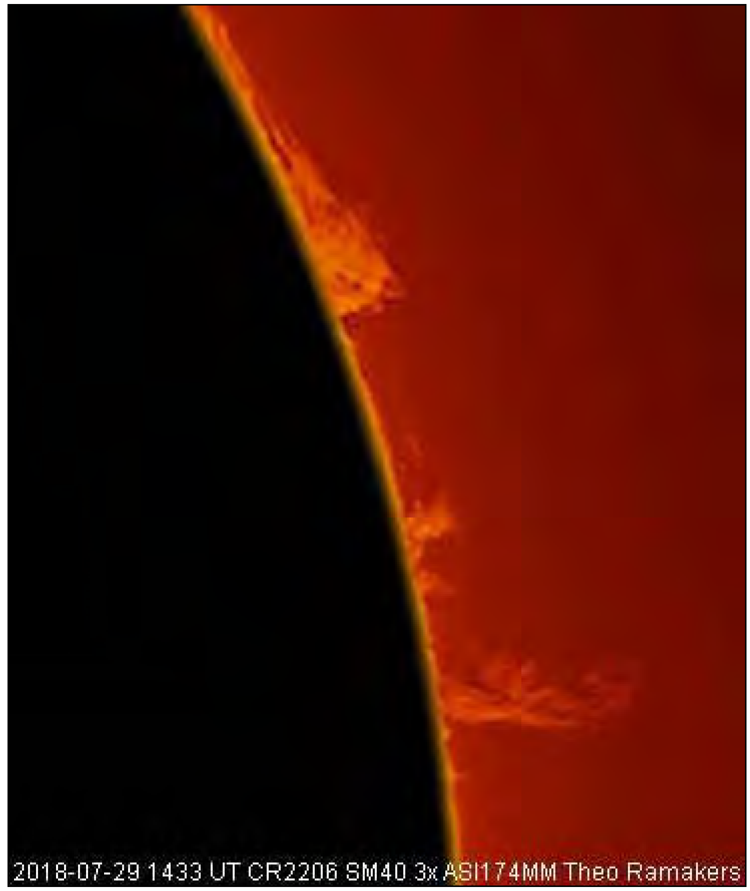


Figure 2. Prominences observed by Ramakers on 7/29 at 14:33 UT on the NW limb.

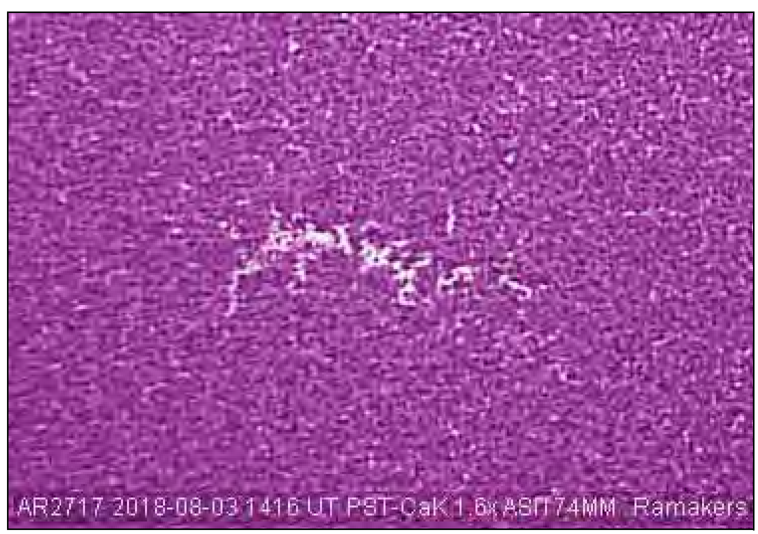


Figure 3. CaK image of AR 2717 by Ramakers on 8/3 at 14:16 UT.

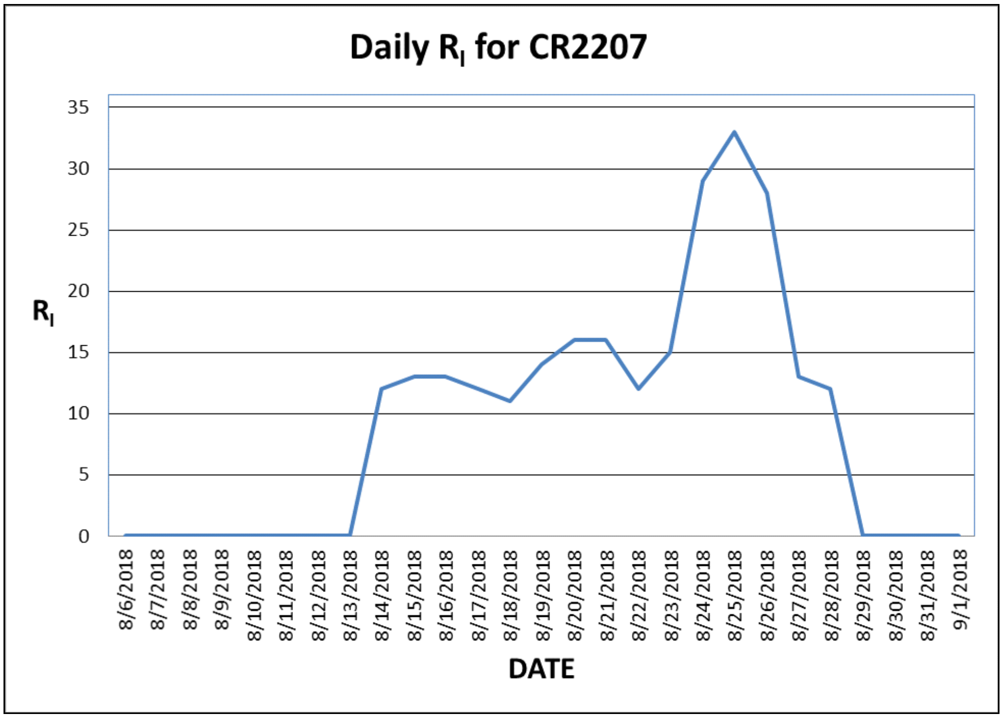
AR 2717 formed about 30 degrees east of the CM on 8/1 and as its predecessor, was Axx of 10 millionths. It lasted a bit longer, reducing to a plage on 8/3 and leaving the disk on 8/9. Gianninoto first observed the plage that would become AR 2717 on 8/1 at 14:16 UT and actually noted two tiny umbral spots in one of his combined w-l/ H-a drawings.

Ramakers shows us a good CaK image of the region on 8/3 at 14:29 UT (Figure 3). Then on 8/4 at 09:36 UT, we get a spectacularly detailed view in CaK by Viladrich (Figure 4). In this image, individual granules that make up the plage can be clearly seen. Then Ramakers gives us one last CaK look at this region as it's nearing the limb on 8/7 at 12:40 UT, getting smaller and dimmer (Figure 5). Gianninoto observed it two hours later as a plage at 14:20 UT.

Carrington Rotation 2207

Dates: 2018 08 06.0715 to 2018 09 02.3118

Avg. R_I = 9.0
High R_I = 33 (8/24)
Low R_I = 0 (12 days)



The average R_I was 9.0, more than three times higher than the previous rotation. This was the high activity point for this reporting period but an increase of only one active region to three (AR 2718, AR 2719 and AR 2720).

The most active of the three regions was AR 2720, and possibly the most hyped region of 2018! It was separately touted as a rapidly growing sunspot, a "monster" spot and that it "exploded into view". The facts are that it was designated late on 8/24 north of AR 2719 as a Dro group (beta) of 30 millionths area. In the next 24 hours, it grew to 100 millionths, classed as Dao. Teske was the first in the Section to catch it in a w-l on 8/23 at 14:20 UT. Gianninoto observed it at 15:00 UT the same day as a Bxo group.

This is all very normal growth. But it stopped there! Late on 8/26, it was Cso (beta) with an area of 60 millionths. Two days later it was Hsx (alpha), a single spot and heading for the limb. The first image we have of the region was on 8/24 by Viladrich at 10:16 UT, a nice sub-arc-second w-l image showing a main leader spot with rudimentary penumbra followed by half a dozen umbral spots (Figure 6).

Maximum development is shown in an Eskildsen w-l image on 8/25 at 13:11 UT (Figure 7), a beautiful CaK view of the same at 13:21 UT (Figure 8) and an H-a image showing the nice bi-polar magnetic field of the region (Figure 9).

The dissolution of the region can be seen in a Ramakers w-l image as it approached the limb on 8/28 at 13:35 UT (Figure 10). The class at that time was Axx (alpha) with an area of 10 millionths, so it was just a tiny spot trailing a filigree of faculae that roughly outlined the plage.

Carrington Rotation 2208

Dates: 2018 09 02.3118 to 2018 09 29.5799

Avg. R_I = 3.11
High R_I = 16 (9/11)
Low R_I = 0 (22 days)

Activity dropped back down in this rotation with the highest number of zero days (22) for the reporting period. There were only two active regions (AR 2721 and AR 2722), neither of which exceeded 10 millionths in area or a McIntosh class of "B".

Most observers resorted to prominence observations during such an inactive rotation. Grassmann captured a nice set of prominences on 9/13 on the NW limb displaying a few different morphologies in one image (Figure 11). Two days later, on 9/15, Ramakers shows all the prominences on all the limbs in an interesting presentation technique preserving the cardinal limb positions with north up and east left (Figure 12). Then on 9/22, Braga imaged a pair of delicate tornadic prominences (Figure 13).

Carrington Rotation 2209

Dates: 2018 09 29.5799 to 2018 10 26.8687

Avg. R_I = 5.85
High R_I = 26 (10/13)
Low R_I = 0 (15 days)

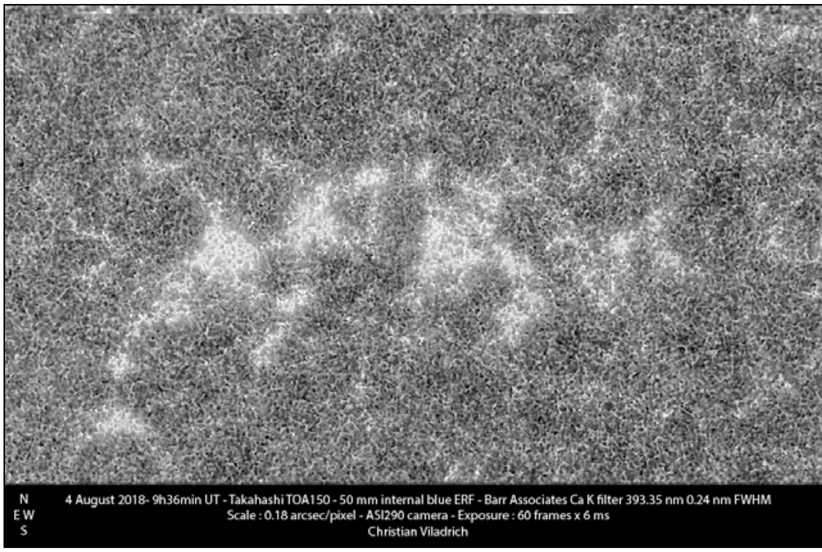


Figure 4. Spectacular CaK image of AR 2717 by Viladrich on 8/4 at 09:36 UT.

Figure 5. CaK image of AR 2717 nearing the limb by Ramakers on 8/7 at 12:40 UT.

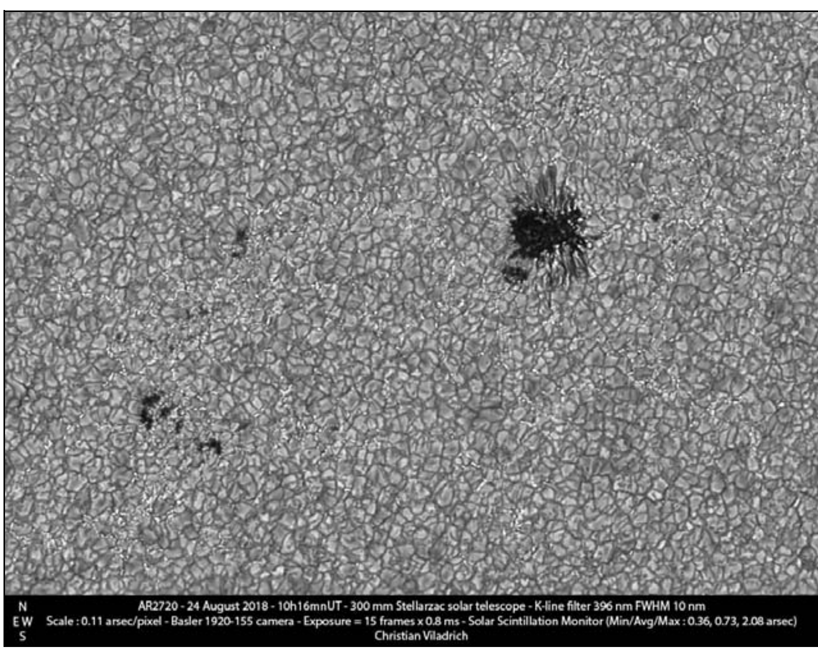


Figure 6. Sub-arc-second w-l image by Viladrich of AR 2720 08/24 at 10:16 UT.

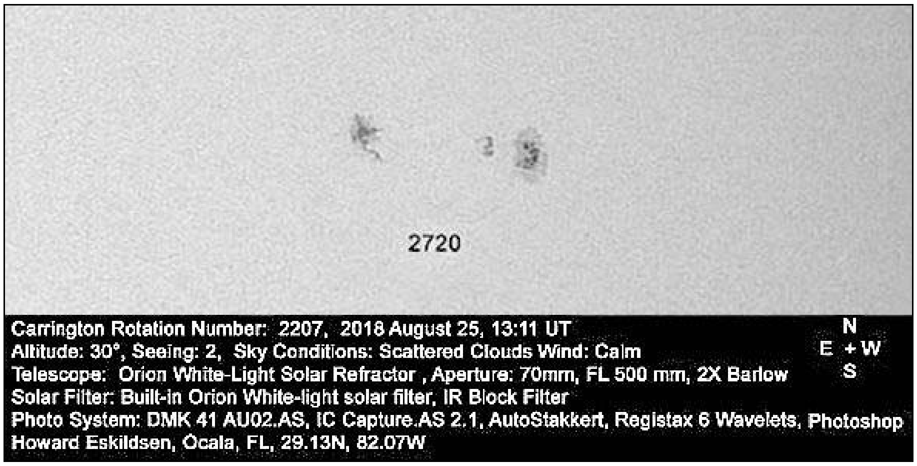


Figure 7. A w-l image of AR 2720 by Eskildsen on 8/25 at 13:11 UT.

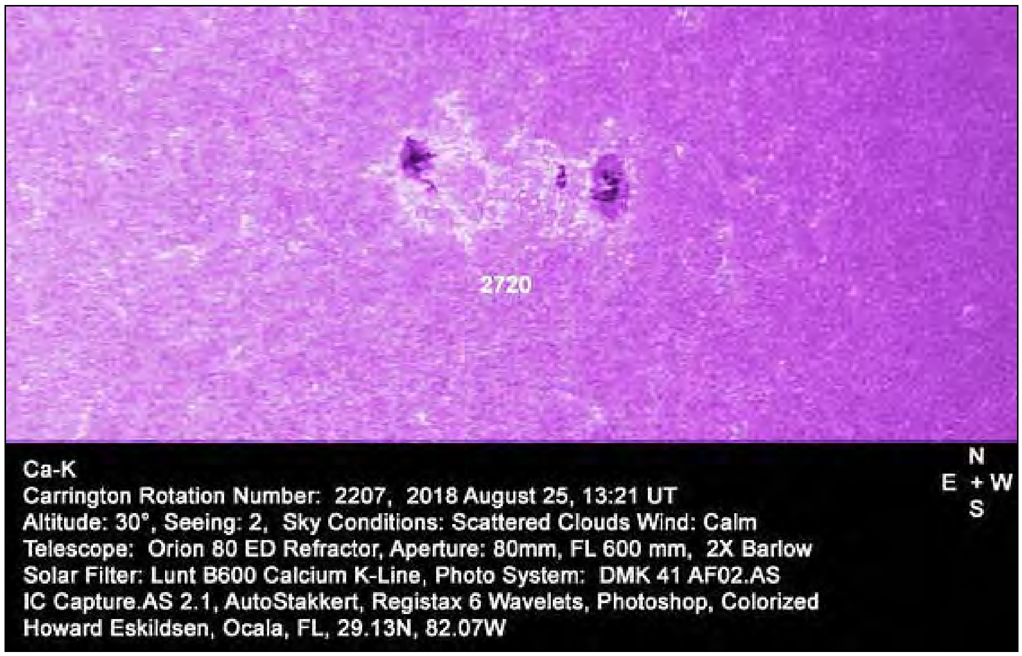


Figure 8. A CaK image of AR 2720 by Eskildsen on 8/25 at 13:21 UT.

Figure 9. A H-a image of AR 2720 by Eskildsen on 8/25 at 13:14 UT.

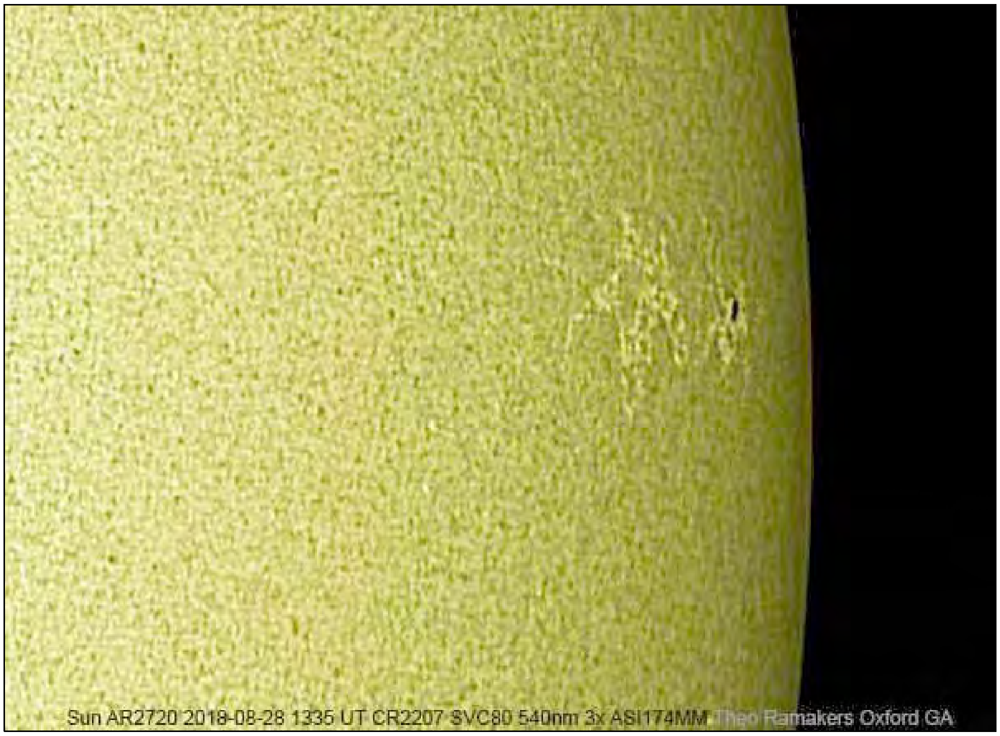


Figure 10. A Ramakers w-l image of AR 2720onthelimbon8/28at13:35UT.

Figure 11. An H-a limb prominence image by Grassmann on 09/13 at 11:48 UT.

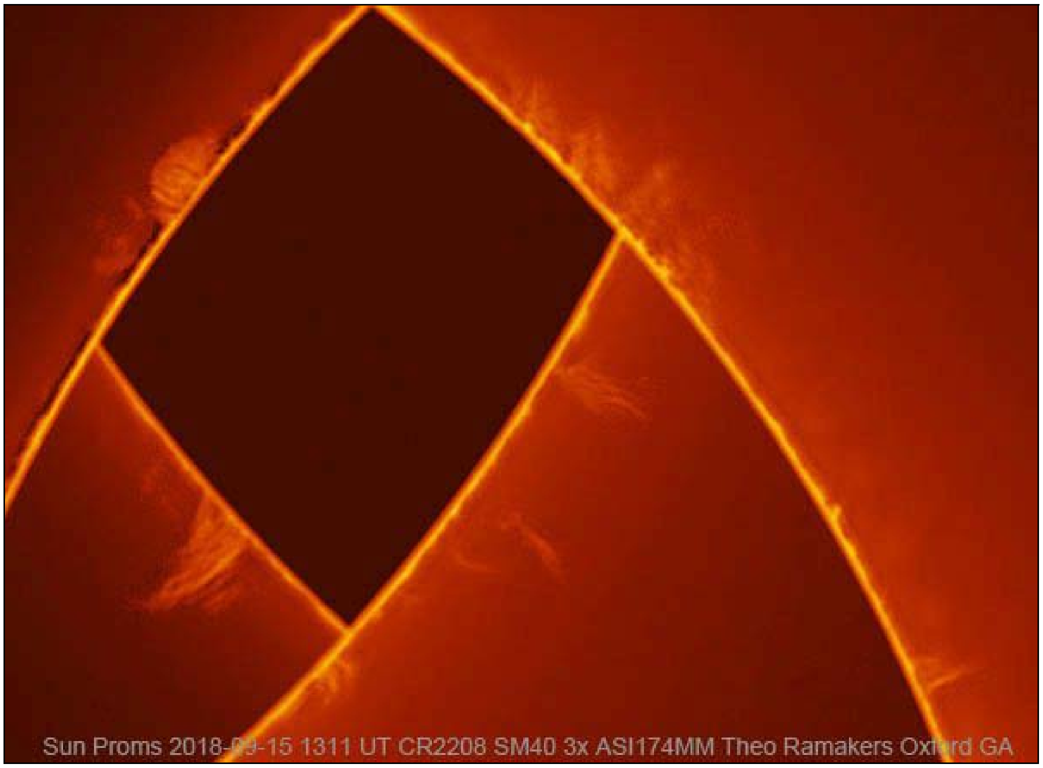


Figure 12. An unusual H-a limb prominence montage by Ramakers on 09/15 at 13:11 UT.

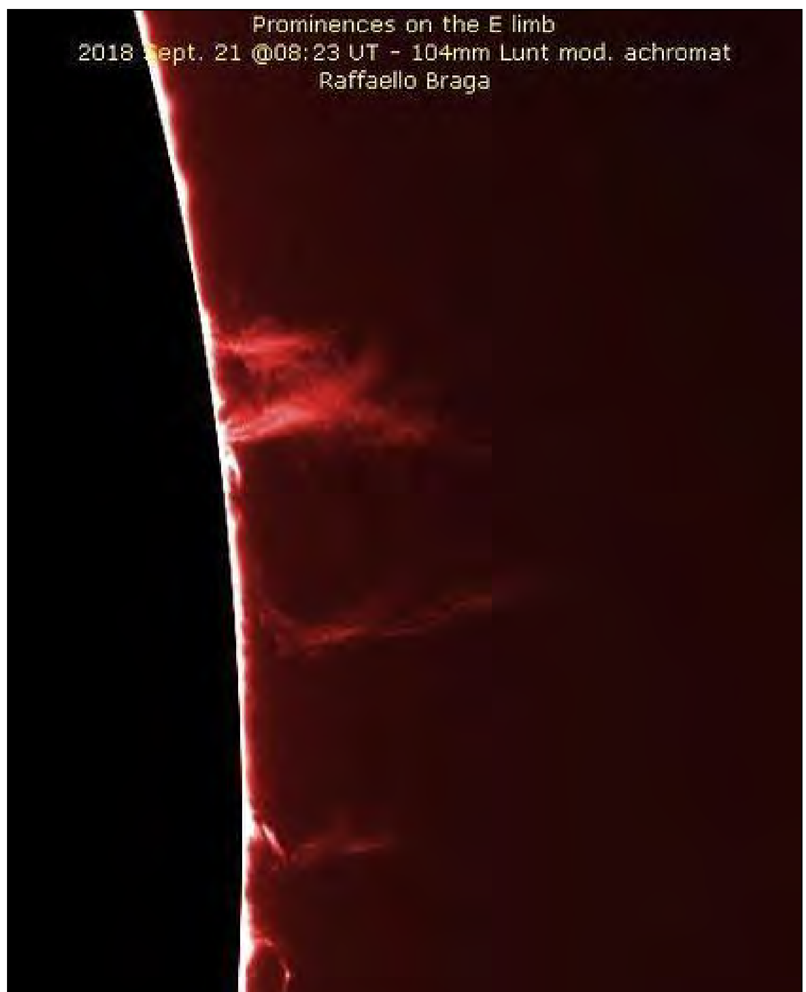
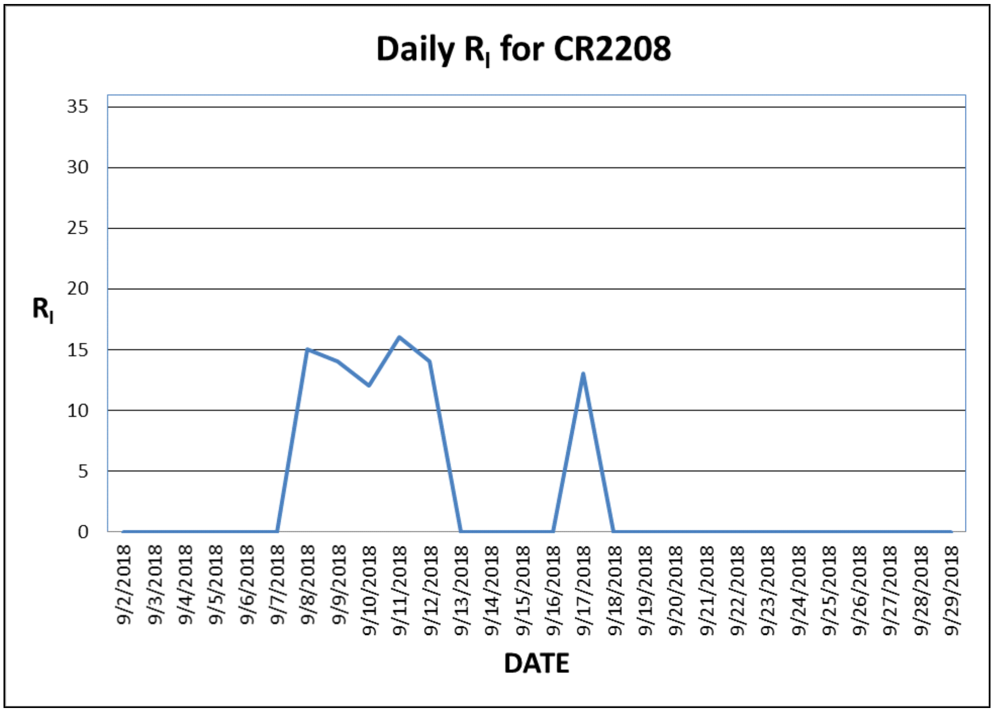


Figure 13. A Braga H-a limb prominence image on 9/21 at 6:23 UT.



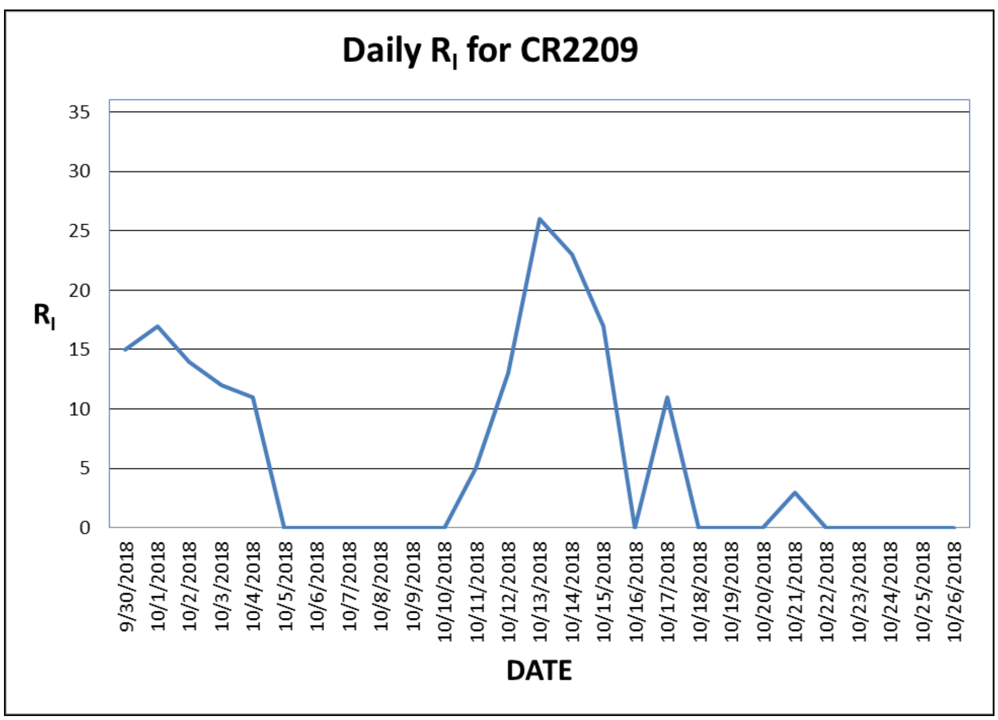
Of the three regions for this rotation (AR 2723 through AR 2725), only AR 2723 exceeded 10 millionths. It started as a Bxo region of 10 millionths area on 9/30, rapidly growing to Dro (beta) with an area of 30 millionths later that same day. Carels got a good high resolution w-l image of it on this date at 08:43 UT and Melillo got an H-a at 15:45 UT, showing hot spots along the neutral line between the leader and follower spots (figures 14 and 15).

Maximum development was on 10/1 as a Dso region with an area of 30 millionths and then back to a Bxo group of 10 millionths on 10/4. On 10/2, Gianninoto noted only four spots in the group in an Ha/w-l composite drawing at 14:46 UT, which was confirmed in another H-a/w-l drawing by Teske at 15:27 UT.

On 10/9 at 13:08 UT, Tyler got a spectacular image of a large prominence complex over the position where AR 2723 had passed around the limb (Figure 16). Gianninoto noted a "double arch" prominence at this location at 15:10 UT that day and Teske noted the complex at 18:18 UT. This constituted the bulk what activity there was for this rotation.

Conclusion

This report shows how diligent observing, even during periods of very low activity, can lead to some interesting results where prominences, filaments and spots can be related. It serves to get observers in the habit of noting this when things get more active.



All observers should review the Table of Contributors to This Report earlier in this report and make sure that all notations pertaining to equipment, modes of observing and observing locations are correct. We have no way of knowing when these things change unless you tell us. Send all such changes to the author for prompt updating.

We are still not at the nadir of the transition between Cycle 24 and Cycle 25. There will be entire rotations with an average R_I of zero before we see a significant rise. Watching for Cycle 25 regions and groups is important at this time as is discussed by Ramakers in his article. So keep looking for and reporting what activity you can find!

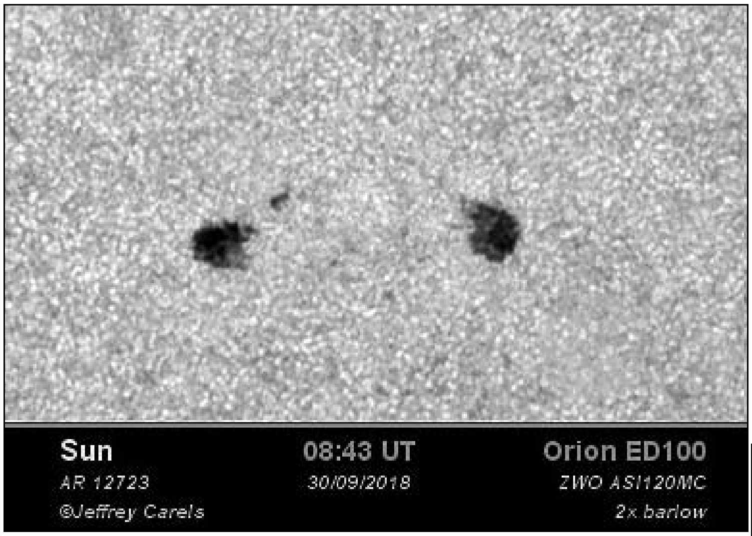


Figure 14. An excellent w-l image by Carels showing AR 2723 on 09/30 at 8:43 UT.

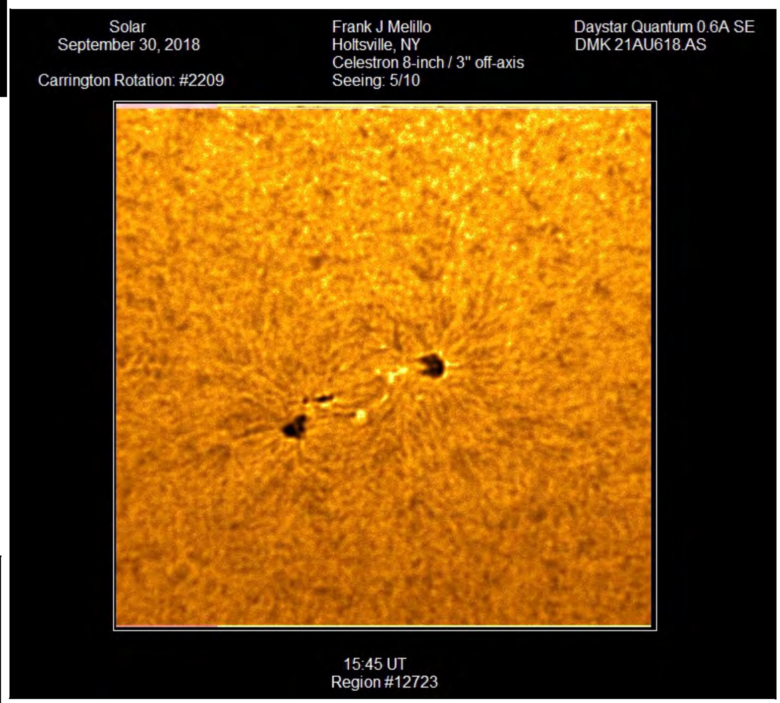


Figure 15. An H-a image of AR 2723 by Melillo on 9/30 at 15:45 UT.

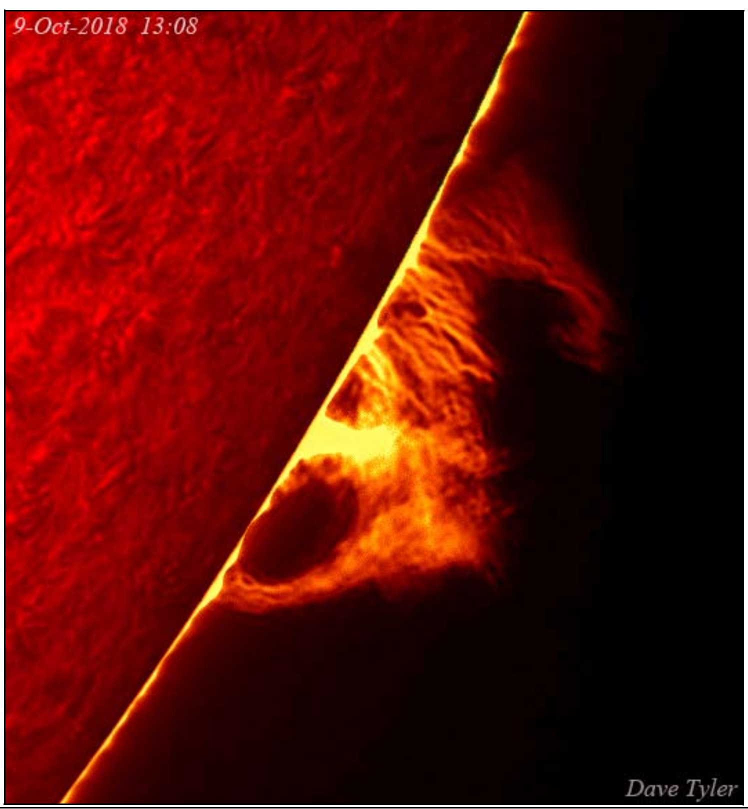


Figure 16. A wonderful Tyler H-a image of AR 2723 by Tyler on 10/9 at 13:08 UT.

ALPO Solar Section

OBSERVER____

ADDRESS____

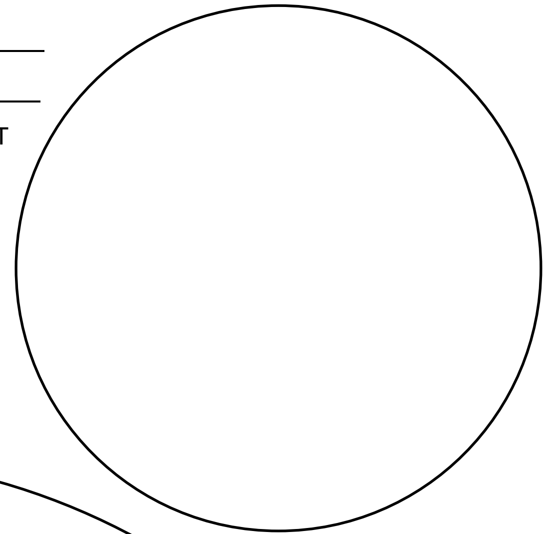
DATE/TIME____UT

SEEING____________ CLOUDS____________ WIND____________

APERTURE__________mm FOCAL LENGTH__________mm TYPE______

EYEPIECE_______mm FILTRATION__________________________

OBSERVATION: *DIRECT* OR *PROJECTED*? (CIRCLE ONE)



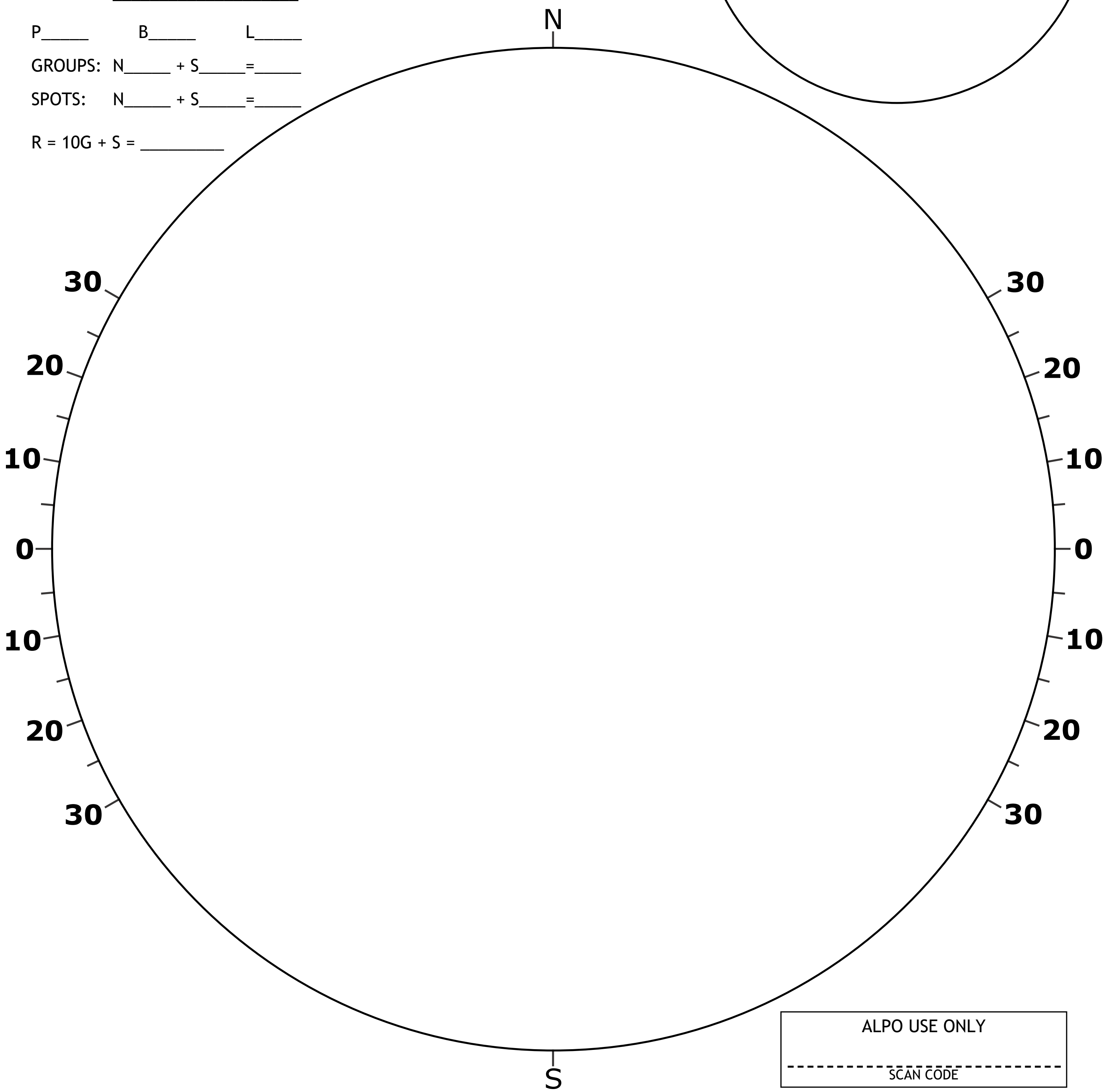
ROTATION______________

P____ B____ L____

GROUPS: N____ + S____=____

SPOTS: N____ + S____=____

R = 10G + S = _______



ALPO USE ONLY

SCAN CODE

ALPO SOLAR SECTION

ACTIVE REGION DRAWING REPORT FORM

SKY/SITE

Date/Time(UT) ____

Rotat.No. _______ A.R. __________ Cen.Meridian _________ Altitude _________

Sky cond. _____________ Seeing __________ Clouds _____________ Wind ________

Observatory type (circle one): roll off roof, roll off bldg., dome, none

TELESCOPE:

Inst. type ________________________ Mounting type ___________________________

Clock drive? ______ Type of drive ____

Full aperture ___________________________ Focal length ____________ f/________

Aperture stop/type ___________________________ Final f/_______________________

Address: Phone No. ( )area code_______________________

Papers & Presentations:

Are We There Yet? When Will Solar Cycle 25 Arrive?

By Theo Ramakers,
Assistant Coordinator,
ALPO Solar Section
theo@ceastronomy.org

To our hard-copy readers: This paper can be viewed in full-color in the online (pdf) version of this Journal.

Abstract

Questions arise about where we are in the current solar cycle and what is happening in the transition to the new Cycle on a day to day basis. This paper is a limited review of the amateur and scientific data associated with the transition from Solar Cycle 24 to Solar Cycle 25.

Discussion

We know that we are somewhere between solar maximum and solar minimum but we also wonder exactly when we will be at solar minimum? We know that all of the nice spots and flares of a few years ago are gone. The last real activity was in the beginning of September 2017, when out of nowhere, AR2673 popped up and then increased in size to over a whopping 1,000 millionths of the solar hemisphere. While AR2673 was growing rapidly on September 6, it produced an X9.3 flare, the largest X flare of Cycle 24. But that was not all. A few days following that event on September 10, a new short-lived and unnamed active region became visible in the northern solar hemisphere (North 36°). However, the odd thing about this area was that the magnetogram showed that the polarity of this region did not line up with the other Cycle 24 areas. Its poles were reversed, suggesting that some Cycle 25 activity below the surface might have been

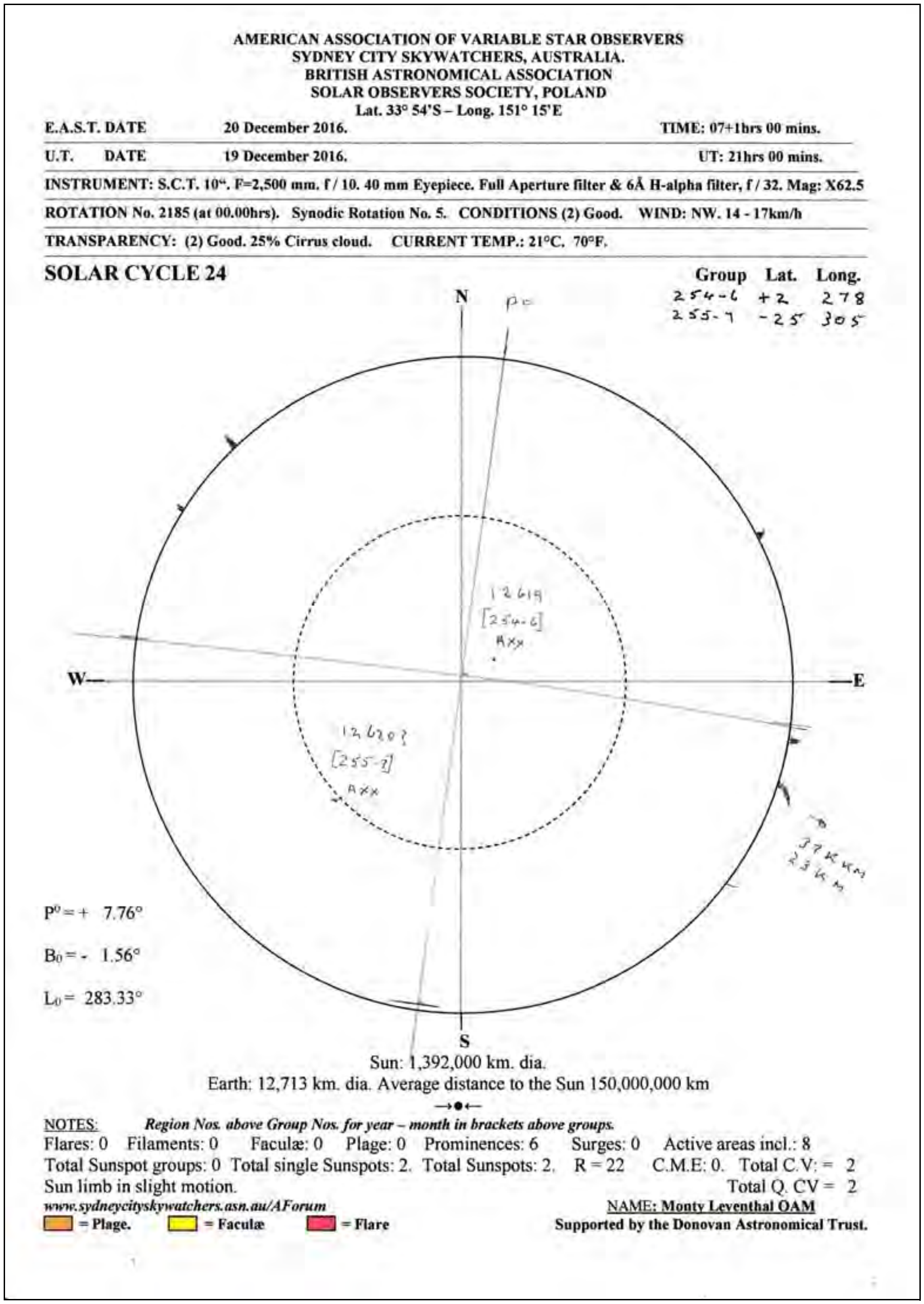


Figure 1. AR2620, a reversed polarized area on 2016-12-19 by Leventhal, South 25°.

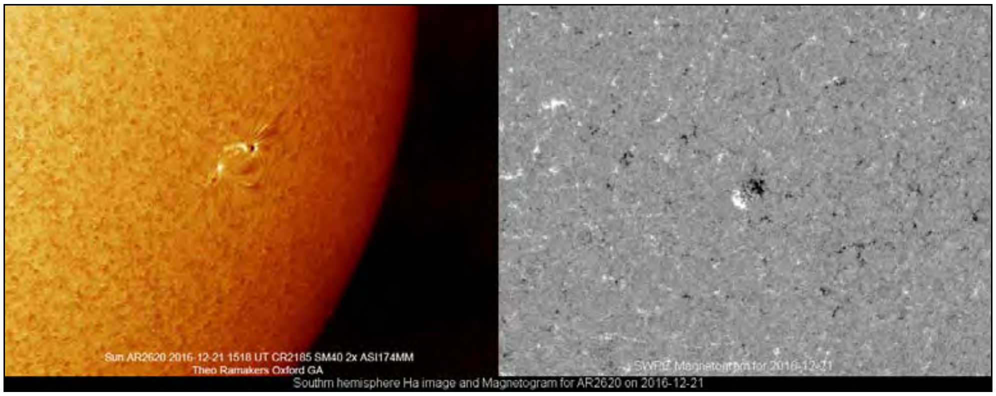


Figure 2. AR2620, a reversed polarized area on 2016-12-21 by Ramakers, South 23°.

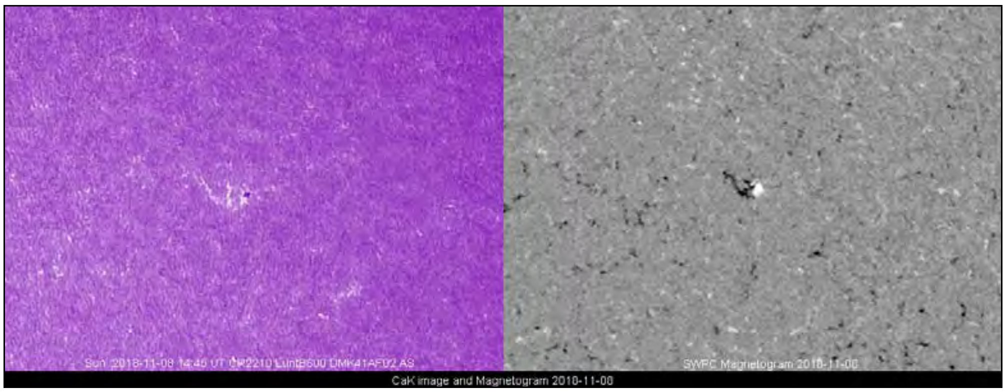


Figure 3. Small Cycle 25 polarized area on 2018-11-08 by Eskildsen, North 26°.

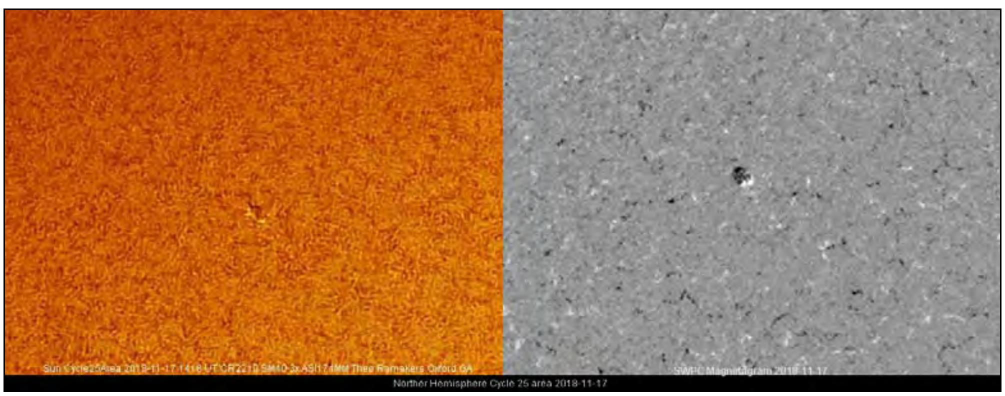


Figure 4. A small Cycle 25 polarized area on 2018-11-17 by Ramakers, North 27°.

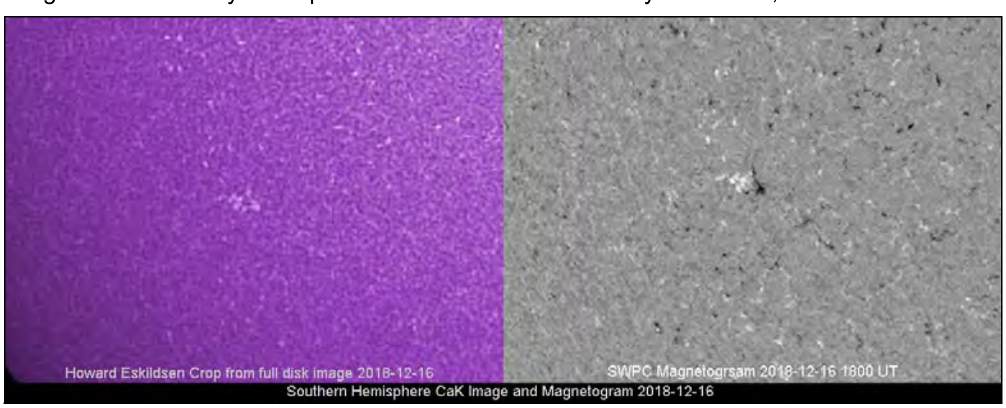


Figure 5. Small Cycle 25 polarized area on 2018-12-16 by Eskildsen, South 20°.

NOTE: The magnetogram images shown with figures 2 through 7 were extracted from the magnetogram images provided by NASA's SDO HMIB archive.

struggling with the prevailing Cycle 24 activities. The appearance of this region might support claims that this disruption might have contributed to the immense X9.6 solar flare of September 6.

We have known for a long time that the Sun's activities go through cycles. Approximately every 11 years or so, the Sun goes through a period of high solar activity and then low activity. In addition, the magnetic fields of the Sun reverse every 11 years; so after approximately 22 years (two solar cycles), the magnetic field is restored to what as it was at the beginning. This can be seen by observing the polarity of the dipoles associated with active regions which are shown in magnetograms. Dark and light areas depict the difference in polarity indicating which way the plasma moves that follows the magnetic field. In addition, it should be noted that the normal polarity of the regions in the northern and southern hemispheres of the Sun, regardless of the cycle, are reversed from each other.

The appearance of the reversed polarized region described in the event above, showed that Cycle 25 was already on its way in the fall of 2017. However, this was not the first time we had seen Cycle 25 areas. To our knowledge, the first Cycle 25 polarized area in our archive is AR2620, which appeared at the solar latitude South 23°, and whose observation was submitted in a drawing by Leventhal on December 19, 2016 (Figure 1), as well as an image captured on December 21, 2016 by Ramakers (Figure 2). On these days, the magnetogram showed again a polarization of the region conforming with Cycle 25. Occurrences of the Cycle 25 polarized areas have been long and far, but between October and December 2018, their frequency has increased. Two small Cycle 25 areas were observed on October 9, both in the southern solar

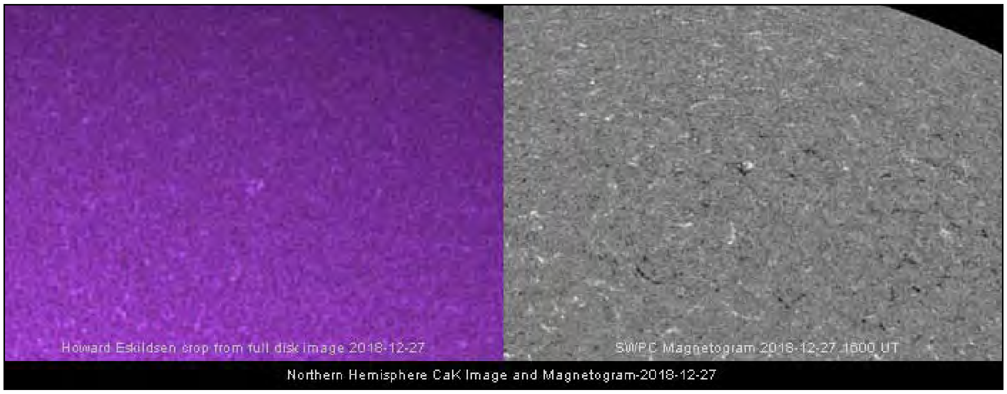


Figure 6. Cycle 25 polarized area on 2018-12-27 by Eskildsen, North 48°.

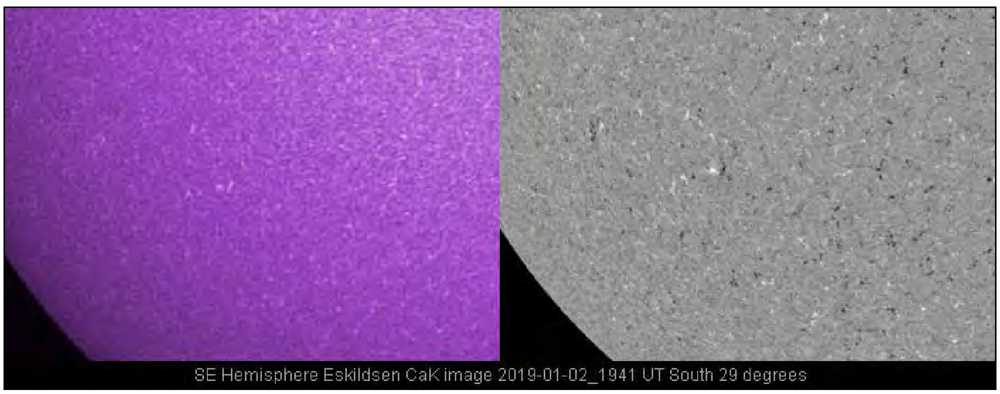


Figure 7. SE hemisphere Cycle 25 polarized area on 2019-01-02 by Eskildsen South 29°.

hemisphere (South 29° and 49°). A small Cycle 25 area started developing in the northern solar hemisphere on November 8 (North 26°), and was imaged the same day by Eskildsen (Figure 3), but it disappeared after a few days. Nine days later on November 17, another Cycle 25 polarized area was imaged by Ramakers (Figure 4), this time, in Ha in the solar northern hemisphere, at a latitude of approximately North 27°. The last two Cycle 25 polarized areas of 2018 can be seen in two full-disk CaK images captured by Eskildsen — the first one on December 16 at a latitude North South 18° (Figure 5), and the second one on December 27 (Figure 6) at a latitude of North 48°. And finally the first occurrence of a reversed polarized area in the new year happened on January 2, 2019 which can be seen in Eskildsen's image (Figure7) from the same date.In addition to the areas mentioned here, reports show a number of additional Cycle 25 polarized areas (or "pores"). And even though we might not see sunspots, we notice plages in CaK and Ha in higher latitudes as well as many associated filaments and prominences. These are all indications of the solar activity in areas where we expect the next Cycle 25 sunspots to start to occur.

The observation of areas on the Sun and determining when an area is a spot or pore can be very subjective, and reports of the observed sunspot number, or "Wolf number", varies widely and depends on the observer, their eyesight and equipment, as well as seeing conditions. There is also the question of when does a pore become a spot. Many observers ask why the region they saw did not get assigned an Active Region number by the SWPC (Space Weather Prediction Center) in Boulder, which is the authority to assign these numbers.

It is, therefore, important to know the guidelines SWPC follows in assigning Active Region numbers which can be found in "Region Summary" on page 6 of its *Users Guide to The Preliminary Report and Forecast of Solar Geophysical Data*. Regions are assigned SWPC region, or "AR numbers", if any of the following conditions exist:

(1) The region has a sunspot group with a first digit spot class of C, D, E, F or H,

(2) Two or more reports confirm the presence of class A or B spot group,

(3) The region produces a solar flare, or

(4) The region is "bright" in Ha and exceeds 5 heliographic degrees in either latitude or longitude."

In this context, one should also review the observing sites which submit reports to the SWPC which can be found on page 11 of the guide.

So we can see many areas with polarities that are consistent with Cycle 25, but if they do not meet the Active Region naming requirements, they might be recorded but not named by SWPC. In addition, new cycles' activities start at higher latitude locations on the Sun and move to the lower latitudes (equator) in a butterfly pattern as the cycle progresses (see Figure 8).

So it should not be a surprise if active regions with new polarity are not deemed members of the new cycle if their location is not consistent with this but appear at the lower latitudes. Lastly, don't despair if your sunspot number is different from the official sunspot number. Different organizations report different results for the sunspot number simply because the observing sites for the organizations are different and observers might use different interpretations.

For the record, we want to point out that the organization responsible for assigning the AR (active region) numbers is NOAA and its SWPC, while the organization responsible for the International Sunspot Number (Ri) is the World Data Center for the production, preservation and dissemination of the International Sunspot Number of SILSO (Sunspot Index and Long-Term Solar Observations), which is associated with the Royal Observatory of Belgium.

Conclusion

So to come back to the question we started with: Are we there yet? The answer is: We don't know. And with it, the questions raised by predictions of different scientists predicting "the most active cycle" or the "Maunder Minimum" will not be answered until we have proof of being on the way to solar maximum again, and we have not seen any proof of that yet.

The Sun not only goes through the 11-year solar cycle, but other cycles are also at work, which cause subsequent cycles to go up or down in solar activity. One might refer to *The Gleissberg Cycle of Solar Activity* by Frederick Colbourn (see References at the end of this paper). The solar minimum happens when the smoothened Ri is lowest, and we won't know until it starts rising again.

To refresh our memory, one might remember that we had two peaks in Cycle 24 of which the second produced the solar maximum; also, the longest spotless streak of the last solar minimum was 52 days and so far, we have seen a streak of only 25 days. But in addition to the lowest Ri, we should also see an increase in Cycle 25 areas at higher latitudes, indicating that we have left Cycle 24 and have entered Cycle 25.

References

Colbourn, Frederick S. (2015). "The Gleissberg Cycle of Solar Activity." https://geoscienceenvironment.wordpress.com/2015/10/23/the-gleissberg-cycle-of-solar-activity/

Hathaway, Dr. David. (revised, 2017), "The Sunspot Cycle." https://solarscience.msfc.nasa.gov/SunspotCycle.shtml including butterfly diagram shown in this paper https://solarscience.msfc.nasa.gov/images/bfly.gif

Livingston, W., Penn, M. (2008) "Sunspots may vanish by 2015."https://wattsupwiththat.files.wordpress.com/2008/06/livingston-penn_sunspots2.pdf

Space Weather Prediction Center. "Users Guide to The Preliminary Report and Forecast of Solar Geophysical Data." https://www.swpc.noaa.gov/sites/default/files/images/u2/Usr_guide.pdf

For information on solar observing – including the various observing forms and information on completing them – go to www.alpo-astronomy.org/solar

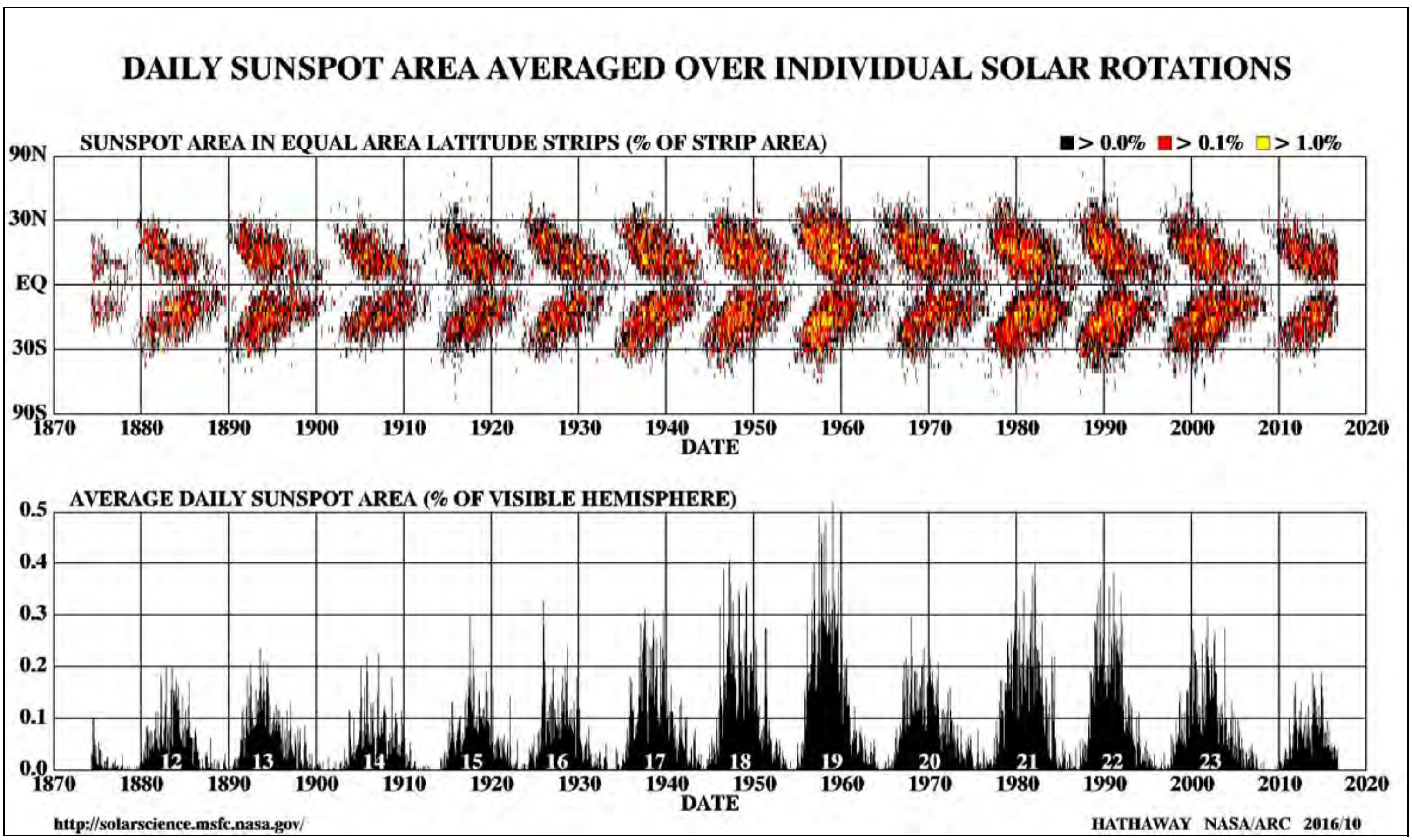


Figure 8. Sunspot location butterfly diagram. Source: Dr. David Hathaway, *NASA SolarScience*.

Papers & Presentations

Reconstructing Aristarchos' 'Sizes and Distances'

By John Westfall, principal author, with Alberto Gomez Gomez and William Sheehan, co-authors
sheehanw987@gmail.com

Online Readers

Your comments and questions about this report are appreciated. Please send them to co-author Sheehan by left-clicking your mouse on his e-mail address under the byline on this page in blue text.

Also left-click on any hyperlinks in blue text in the References section for additional information.

How This Paper Came to Exist

John Westfall and William Sheehan shared a mutual interest in transits, eclipses and occultations, and collaborated together on two rather massive book projects, "Transits of Venus" (published in 2004) and "Celestial Shadows" (2015). These celestial events have been historically important because they have allowed accurate measures of the scale of the Solar System, which is the fundamental basis, in turn, for measures to the stars and more distant objects in the universe.

Necessarily mentioned in both books — though not in very much detail — is the method devised by the brilliant Greek geometer, Aristarchos of Samos, in the 3rd century BCE to determine the distance from the Earth to the Sun. That determination, in turn, is a foundational datum to what may be regarded as the most remarkable achievement of ancient astronomy — the heliocentric system. Aristarchos' method which, as John writes, was "simple, elegant, and impractical," depends on noticing when the Moon appears exactly at half-phase and then measuring the apparent elongation of the Moon from the Sun. The Sun being at a finite distance, the elongation should be somewhat less than 90 degrees, and Aristarchos famously gave 87 degrees. Exactly how Aristarchos came to adopt this figure has, however, been shrouded in mystery; many authors seem to assume he simply pulled it out of thin air.

In 2012, after numerous e-mails were exchanged between Westfall, Sheehan, and Alberto Gomez Gomez, a Spanish student of mathematics who had also become very interested in Aristarchos and had published a preliminary monograph on him, the authors decided to investigate the Aristarchos problem further. Though nothing certain is known of the way Aristarchos might have attempted to measure the angle, or even if he did, we brainstormed various instruments that could have been constructed by the ancients in the 3rd century BCE. These were all very simple, and far less sophisticated than, say, the Antikythera mechanism of the following century. With these instruments, all three of us made systematic attempts to observe lunar dichotomies and to determine the elongation by such means. (Westfall even enlisted his wife Beth into trying to determine the time of dichotomy while on walks with their dogs, and she did find her results improved with practice.) By a considerable margin, Westfall and Gomez made the most observations, and Westfall himself did most of the analysis. Though obviously the results are necessarily somewhat speculative, we succeeded beyond what might have been expected at the outset; above all, we showed that the 87 degree value — far from being pulled out of a hat — is fully believable, and that Aristarchos probably actually did make some observations.

The draft that is being published here was completed by the early summer of 2017, when John was already seriously ill; he sent it out and awaited comments from the co-authors. While Sheehan and Gomez were reviewing the manuscript, John died. There was little that his collaborators could do to improve the draft, which appears here as far as possible according to John's last indications. It is certainly one of the most impressive papers John ever wrote; it makes an important contribution to a celebrated and yet poorly understood episode of the history of astronomy. It seems a fitting coda to John's remarkably productive career. -- W.S.

Introduction

Aristarchos of Samos is best known as being the first philosopher to conjecture that the Earth circles the Sun. (Heath 1913). As with many ancient writers we do not have his actual words but rather a reference to them elsewhere: Archimedes' *Sand Reckoner*, "… the fixed stars and the sun remain unmoved, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit …" (Archimedes 1897: 520).

If Aristarchos gave any evidence to support his heliocentric hypothesis it has not survived. On the other hand, another work by him has: *On the sizes and distances of the Sun and Moon* (reprinted and translated in Heath 1913:

352-411). There may be some relationship between the conclusions of this extant work and Aristarchos' heliocentric hypothesis.

A Ladder to the Heavens

His surviving work places Aristarchos as a member of a series of philosophers fascinated by the problem of determining the distances and sizes of the objects in the observable universe; a chain of thinkers that stretches from before his time to (no doubt) past our own. The sequence of measurement of distances (and thus sizes) has generally been from the near to the far; a sequence often called the “cosmological distance ladder”. The ladder analogy often assigns the lowest rung to the Earth itself (i.e., its size which is identical to our distance from its center); next up is the Moon, followed by the Sun, then further up and up to the limit of mankind's ability to make meaningful measurements. In antiquity only the first three rungs were reachable except through guesswork.

The ladder analogy is rarely carried to the question of what the ladder rests on; perhaps nothing if all the distances and sizes are simply relative to each other. We are not satisfied, though, unless all the dimensions can ultimately be stated in some absolute unit – standardized and of a size that we can visualize. Nowadays the meter serves this purpose and, if it is needed, can be converted accurately to many other units – feet, astronomical units, parsecs, and so forth.

We might be deceived into thinking that the ancients had a standard length unit. After all, the majority of terrestrial and celestial distance measurements that survive refer to the “stade” (plural, “stades”; often spelled “stadion”/ ”stadia”; Greek: σταδιον). Unfortunately the stade was not standardized so it is not certain whether different sources, even in what we might call “technical literature”, used the same value for their stades. This means that the varying values cited by different authorities may in part differ due to different lengths of their stades. The ancient authorities did not state what type of stade they used, giving rise to the optimistic interpretation that they didn't need to because its was understood that they were using a standard stade (Pothecary 1995: 49-50). Even were this the case, any conversion of ancient units to modern (e.g., from stades to meters) remains uncertain. The cosmological distance ladder rests on shaky ground.

Ultimately the problem of the stades' lengths may remain insoluble. When necessary, we will be forced to assume a constant length, and for conversion to modern units, we will use one equivalent to 185 meters. (A summary of the stade-length question is provided in “Appendix: The Elastic Stade”.)

Be warned that we shall be unashamedly anachronistic from here on. We will refer to “degrees” although this angular measure did not come into Western use until Hipparchus, about a century after Aristarchos, who would have described such an angle, for example, as 1/360 of a circle or 1/30 of a zodiacal sign. We shall also use trigonometry and algebra as simpler and shorter substitutes for geometrical proofs.

The First Rung: The Size of the Earth

There is no evidence that Aristarchos measured the Earth's size himself; he didn't need to because others had done it before him. The sphericity of the Earth having been recognized long before, by Pythagoras of Samos (c. 570-495 BCE) or perhaps one of his followers, possibly Parmenides of Elea (born c. 515 BCE) or Empedocles of Akrogas (c. 490-430 BCE), it was natural to want to know its size, particularly its circumference. (For a comprehensive survey of pre-modern attempts to find the Earth's circumference see Nicastro 2008.)

The earliest specific reference, made before Aristarchos' time and thus probably available to him, was in *De Coelo* by Aristotle (383-322 BCE) (Aristotle 1922, II, Part 14): “Also, the mathematicians who try to calculate the size of the earth's circumference arrive at the figure of four hundred thousand stades.” The reference is as vague as they come; who are “the mathematicians”? Archytas of Tarentum (428-347 BCE) and Eudoxus of Cridus (c. 390-337 BCE) have been suggested, in which case Aristarchos may have had direct access to their results.

We don't know how Aristotle's “mathematicians” made their measurements either. It is logical to assume that they used the terrestrial-arc method employed by Eratosthenes and other, later, measurers of the Earth. However, it is conceivable that they used quite different methods, either by measuring the horizon dip or the horizon distance, as described in “Appendix: Near Horizons”. Whatever method they used, 400,000 stades is obviously too large, given any reasonable value for the stade.

The terrestrial-arc method was used by several Hellenistic geodesists and its principle is diagrammed in Figure 1; three such arcs are mapped in Figure 2. (“Geodesy” is the science of measuring the Earth's size and shape, which is a modern term; the investigators themselves could have described themselves as philosophers, mathematicians, astronomers or geographers.)

At its simplest, determining the circumference of the Earth by the terrestrial-arc method involved five steps;

- Find two places on the same meridian (i.e., north and south of each other).

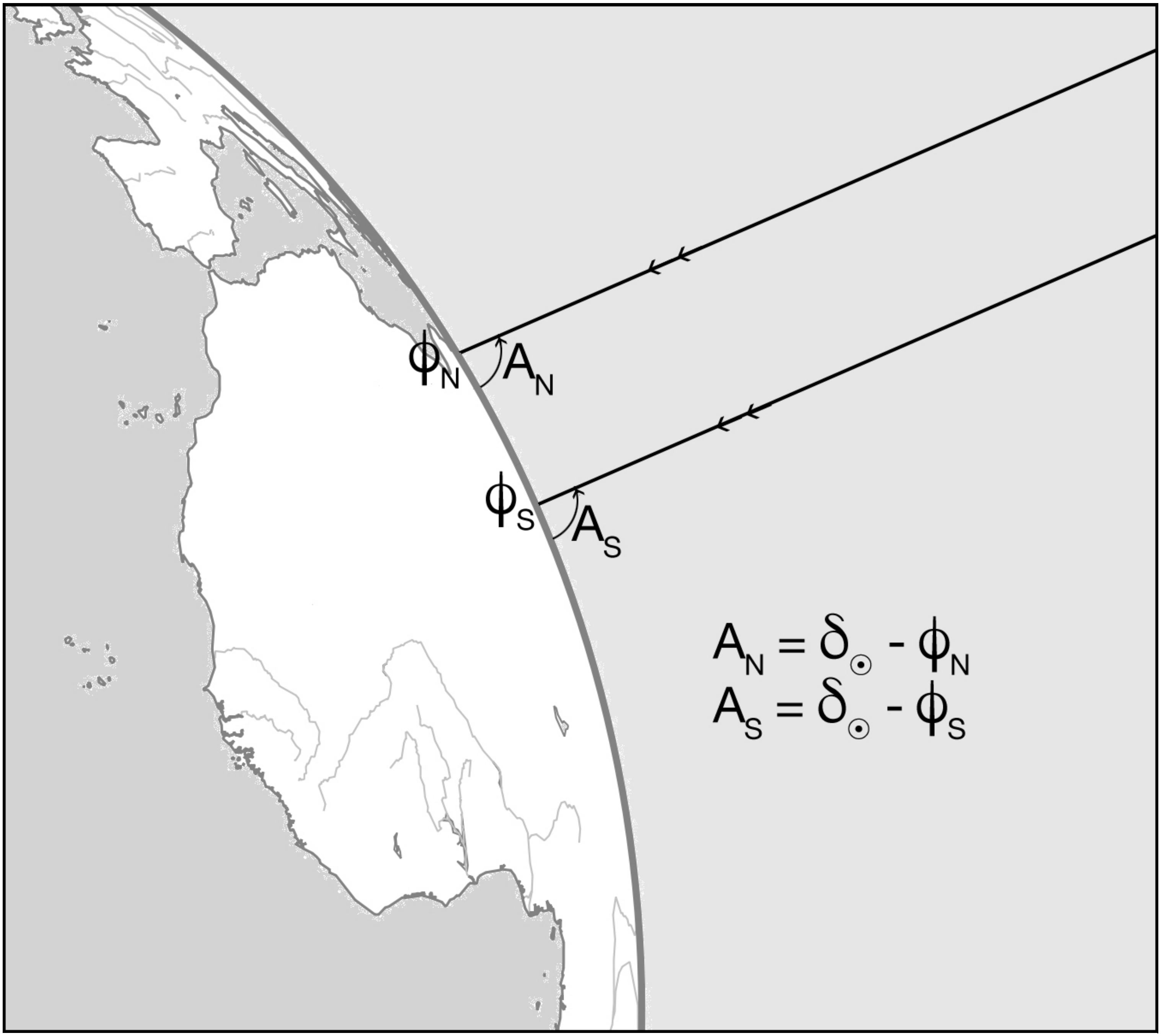


Figure 1. Two light rays from the Sun, here assumed to be parallel, strike two terrestrial locations, both on the same meridian and at latitudes ϕN and ϕS. AN and AS are the solar altitudes at each place, while $\delta\odot$ is the declination of the Sun. The terrestrial arc between the two points equals the solar altitude difference between them.

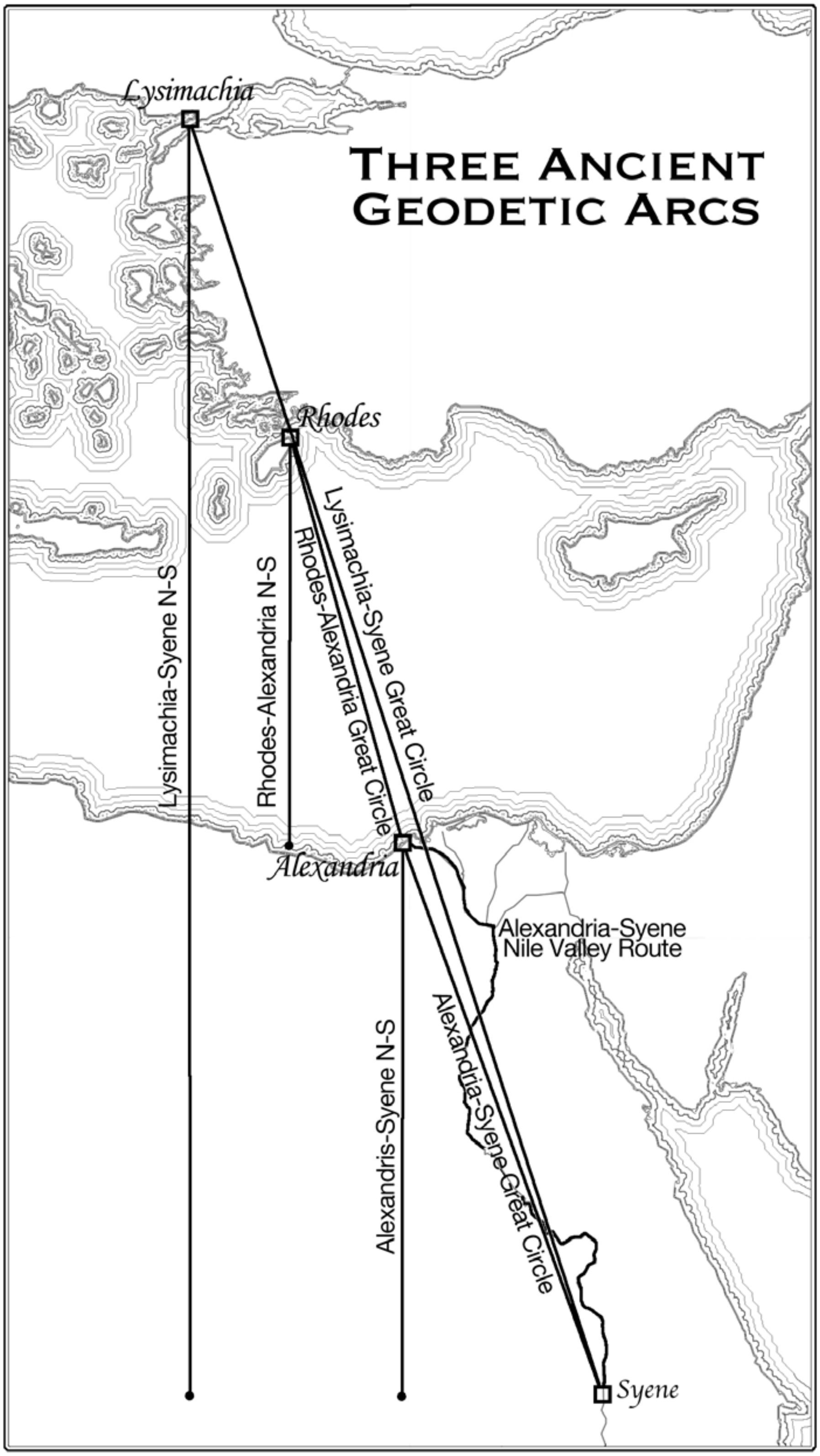


Figure 2. Three sample ancient geodetic arcs: Lysimachia-Syene, Rhodes-Alexandria and Alexandria-Syene. All four endpoints were believed to lie on the same meridian; clearly not the case here. The great-circle distances between each pair of endpoints are all greater than the north-south distances between the endpoints were they assumed to lie on the same meridian.

- Determine their latitudes, ϕ_N and ϕ_S.
- Find their latitude difference, $\Delta\phi = \phi_N - \phi_S$.
- Measure the over-land, over-sea or over-both distance between the two places, D.
- The Earth's circumference, $C = D \times 360°/\Delta\phi$.

The earliest definite application of the terrestrial-arc approach that we know of was by Dicaerchos of Messana (c. 350 - c. 285 BCE), taking the distance between Lysimachia in Thrace and Syene in southern Egypt. Since Dicaerchos was a student of Aristotle and Lysimachia was founded in 309 BCE, we may take the date of his measure as somewhere near 300 BCE, again making his result potentially available to Aristarchos.

Dicaerchos assumed that Syene lay on the Tropic of Cancer, in 300 BCE at latitude 23.73° north. Lysimachia's ruins are at latitude 40.58° north. This would make the latitude difference 16.85°. Dicaerchos, however, took the latitude difference to be 24° and the terrestrial distance to Syene as 20,000 stades. Since 24° is 1/15 of a full circle, this yielded a circumference of 300,000 stades; a result still larger than the truth but closer than the earlier 400,000 stades. (Sarton 1959: 56; Thomson 1965: 154) The exaggerated latitude difference was compensated somewhat by an exaggerated terrestrial distance (regarding the latter, note from Figure JW02 that much of the arc would involve estimating sea distances).

Figure 2 shows the Lysimachia-Syene arc, along with the later Alexandria-Syene and Rhodes-Alexandria arcs. It is clear that the four places involved do not fall on the same meridian. Curiously, they do fall near a straight line, but one inclined about 19° east of south. This creates a systematic error in the assumed arc distances between the places, their great-circle spacing from 3.5 to 6.8 percent more than their latitudinal spacing.

Circumference results continued to improve, at least from our modern perspective. Using the Alexandria-Syene arc, Eratosthenes of Cyrene (c. 285-196 BCE) published a result of 252,000 stades, so it is definitely possible that Aristarchos (c. 310 - c. 230 BCE) would have had access to the former's result.

Eratosthenes' project has been described in a number of places (e.g., Nicastro 2008: 25-28, Sarton 1959: 158-164, Thomson 1965: 103-105). (It would, of course, have been described in Eratosthenes' own *On the Measurement of the Earth*, a missing book from antiquity we would especially like to have.) Syene is described by Eratosthenes as being placed on the Tropic of Cancer (at 23.75° north in Eratosthenes' time) because, on the summer solstice, the Sun shone vertically down a local well; Sarton (p. 104) and Nievergelt (p. 79) think he might have used a gnomon instead. At any rate, Eratosthenes found an Alexandria-Syene latitude different of 7.2°, a convenient 1/50th of a full circle. He took 5,000 stades as the equivalent terrestrial distance between them, resulting in a tidy 250,000 stades circumference for the Earth.

There are several minor and major questions about Eratosthenes' methodology. First, his result is usually given as 252,000 stades. Apparently he added 2,000 stades to his result to make the value more easily divisible (e.g., 252,000/60 = 4,200; 700 stades/degree, etc.)(Diller 1949: 7). We don't know explicitly Eratosthenes' value for the latitude of Alexandria. (We would like to think it was accurate; Eratosthenes was the Chief Librarian at Alexandria for about 40 years.) Syene, however, is at latitude 24.08°, not 23.73°; taking Alexandria at 31.20° would make the latitude difference 7.12° rather than 7.2°. Actually, this disagreement is relatively minor, just slightly over one percent. The fact that the two places are not on the same meridian (their longitudes differ by 2.99°) would have no effect on their latitude difference.

More serious questions are raised by his 5,000-stades terrestrial distance. There is the obvious question as to what length of stade he used, which we'll leave for the time being. There remains the question as to what line or route he chose between the two places. It appears that there was a common belief in antiquity that the Nile followed a straight north-south line through Egypt; "the Nile flows from the Aethiopian boundaries towards the north in a straight line to the district called 'Delta' …" (Strabo, I, Cpt. 1). This gives rise to three possible routes for his 5,000-stades distance: (1) a truly north-south course between the two latitudes (788.1 km or 157.6 m/stade; the distances given here in kilometers are based on the WGS84 ellipsoid, which has an equatorial circumference of 40,075.014 km and a polar circumference of 40,007.860 km); (2) a great-circle course between the two places (841.3 km or 168.3 m/stade). Either alternative supposes precise distance measurement (by pacing?) across the Libyan (Western) and Arabian (Eastern) Deserts; the great-circle route actually crossing the Nile several times. Another possibility is alternative (3): Follow the course of the Nile, apparently believed to be straight and to flow north-south. Indeed, the Nile flood plain was already repeatedly surveyed; given access to cadastral records, Eratosthenes could base his distance on documents rather than field work. We have approximated the distance along the Nile by adding distances on the Alexandria-Aswan highway, totaling 1,097 km (Macmillan, Map 194). This gives a ratio of 219.4 m/stade, an exceptionally high value. It also appears unlikely that adding together the distances from a series of surveys would result in such an even value as 5,000 stades. Taking Eratosthenes's assumption that the distance constituted 1/50th of the Earth's circumference, the three alternatives give circumferences, in order, of 39,405, 42,065 and 54,850 km (i.e., 1.5 percent too small, 5.1 percent too large and 37.1 percent too large).

Eratosthenes' measurement was the latest terrestrial circumference that Aristarchos would have had the possibility of knowing; we will use it later when we need to calibrate his lunar and solar sizes and distances.

Although it was conducted two centuries after Eratosthenes, we should mention the circumference measurement of Posidonius of Apamea (135-51 BCE) because its result was close to Eratosthenes'. Posidonius took the sea distance between Rhodes and Alexandria as 5,000 stades, along with a latitude difference of 1/48th of a circle (i.e., 7.5°). Thus 48 x 5,000 = 240,000 stades. (Sarton 1959: 204) To find his latitude difference, Posidonius assumed that the star Canopus culminated on the horizon at Rhodes and at elevation +7.5° at Alexandria (Nicastro 2008: 149-151; Heath 1913: 344-345); actually in, say, 90 BCE, taking refraction into account, it would have culminated at +1.28° at Rhodes and +6.29° at Alexandria, making a latitude difference of 5.01°, only 2/3 of the value he used. Apparently his over-seas distance was similarly exaggerated, the errors in the angular and linear distances almost cancelling out. (Strabo stated that Posidonius later corrected his latitude-difference error and reduced the Earth's circumference to 180,000 stades (Strabo II, 2, 2). The 180,000-stades value is notorious for being used by Columbus in his argument that it was feasible to sail westward from Europe to reach the Far East.)

Earth's Nearest Neighbor

As our ladder's rungs are arranged by distance, it is clear that the second rung should be the distance to the Moon. The Moon moves more rapidly in our sky than any other celestial body and when it overtakes another body the Moon occults it, be it a planet, a star, or even the Sun itself in the case of a solar eclipse.

Aristarchos did not actually compute the distance to the Moon; ancient authorities, once they had worked out an elegant geometric solution to a problem, often did not descend to dirtying their model by applying actual numbers to it.

Nowadays we routinely find the Moon's distance by bouncing laser beams from retroreflectors emplaced by the American Apollo and Soviet Lunokhod missions, with the resulting distance approaching 1-millimeter accuracy. Before this, the lunar distance was found by measuring the Moon's parallax, a method pioneered by Ptolemy (Claudius Ptolemaeus, f.c. 130 CE), with reasonable results (at least for New Moon and Full Moon; see Van Helden 1985: 16-17). Before that, the size of the Earth's shadow during a lunar eclipse was brought into play, with a method apparently first devised by Aristarchos.

Fortunately Aristarchos gives us the tools we need to quantify his model:

- A diagram showing the Sun, Earth, Moon and Earth's umbral shadow during a lunar eclipse. Figure 3 is a simplified version of his eclipse diagram, definitely not to scale.

- The apparent diameters of the Sun and Moon. Aristarchos states that they were equal and also that the Moon's apparent diameter was 2°. (He gave an angular diameter value that was obviously far too large in order to demonstrate that, although such a large Sun would illuminate more than a lunar hemisphere, the difference from a hemisphere would be imperceptible to the eye. Archimedes tells us that Aristarchos later adopted ½° as the apparent diameter for the Sun and Moon (Van Helden 1985: 8).)

- The apparent diameter of the Earth's umbral shadow on the Moon, which

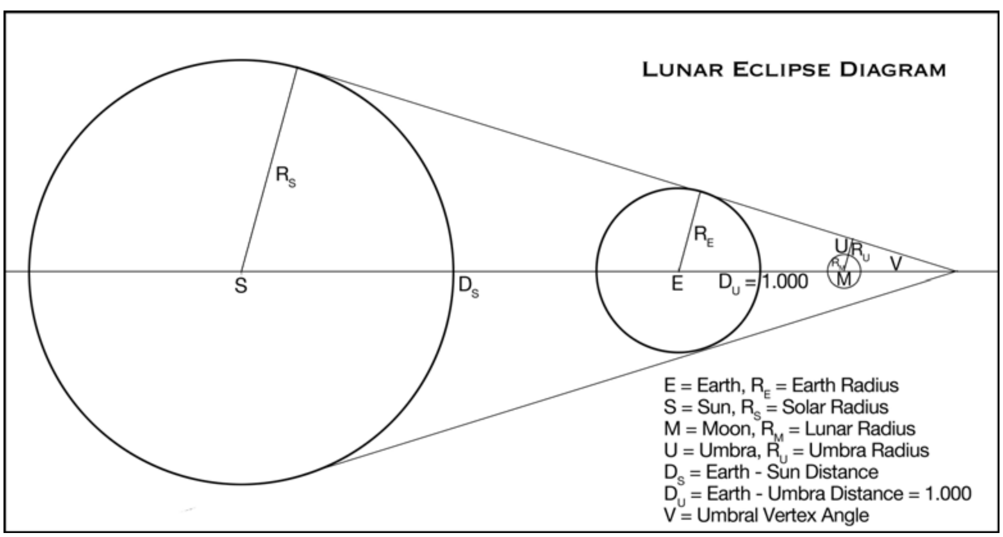


Figure 3. The alignment of the three bodies involved in an eclipse of the Moon: Sun, Earth and Moon; the Moon being located in the Earth's umbra, U. Sizes and distances are not to scale.

Aristarchos considered to be twice the Moon's size. This was clearly a naked-eye estimate and is definitely significantly too small; the mean umbra:Moon ratio for the 23 umbral lunar eclipses from 2011-2020 is 2.695±0.011, which includes a 2-percent enlargement to allow for the effect of the earth's atmosphere.

- The Earth-Sun distance in terms of the Earth-Moon distance. Here we have a problem with our ladder as we have to climb one rung higher in order to obtain this quantity, What we shall do here is to set up the lunar-distance formulae so that we can easily insert this quantity later to achieve a solution.

Figure 3 defines the quantities we shall use in our solution. Because they are too small to plot accurately, it does not show three angles; the angular semidiameters of the Sun, Moon and umbral shadow (as seen from Earth), the first two taken to be 0.25° and the umbral semidiameter as 0.5°.

Then:

(1) $R_U = \tan 0.5°$

(2) $R_S = D_S \tan 0.25°$

(3) $\tan V = (R_S - R_U)/(D_S + 1) = R_E - R_U$

(4) $R_E = (R_S - R_U)/(D_S + 1) + R_U$

Since we set the Earth-umbra (and thus the Earth-Moon) distance equal to 1.000, the Earth-Moon distance, expressed in terrestrial radii, will be the reciprocal of RE.

Note that the quantity D_S, the Earth-Sun distance, appears in several steps in our solution, so our final answer will have to wait until we determine that quantity. James Evans, in his *The History and Practice of Ancient Astronomy* (1998: 68-71) uses a somewhat different mathematical approach to solve for the lunar distance. However, his solution requires using the value of the solar parallax, which is itself dependent on the solar distance. It appears, ironically, that we cannot escape the need to first find the Sun's distance in order to find the Moon's distance.

Reaching Out to the Sun

Aristarchos's approach to finding the distance to the Sun is simple, elegant and, it turns out, impractical. One notes the moment when the Moon appears exactly at half-phase ("dichotomy") and then measures the apparent elongation of the Moon from the Sun. Because the Sun is at a finite distance, the elongation should be somewhat less than 90°. (As Aristarchos put it in his Proposition 6, "The moon moves [in an orbit] lower than [that of] the sun, and, when it is halved, is distant less than a quadrant from the sun." (Heath 1913: 371.) We will call the difference between the elongation and 90° (i.e., 90° - elongation) the "deficiency". Figure 4 illustrates the concept, where D_M = the Earth-Moon distance, D_S = the Earth-Sun distance, E = the elongation and D = the deficiency. The mathematics is quite simple when expressed in modern notation: $D_S = D_M/\sin D$.

Observationally, it all sounds very simple - outside of the need to note when the Moon appears to be exactly at half-phase, the only quantitative measurement is the elongation of the Moon from the Sun. (Alternatively, with a suitable instrument, one can measure the deficiency directly.) Aristotle describes the observation: "[Hypothesis] 4. That, when the moon appears to us halved, its distance from the sun is then less than a quadrant by one-thirtieth of a quadrant." (Heath 1913: 353) A quadrant being 90°, 1/30 of a quadrant equals 3° (i.e. the deficiency), making the elongation 87°.

Using the above observation, Aristarchos found the ratio of the solar distance to the lunar distance by using a fairly complex geometric solution, concluding that the distance ratio was between 18 and 20. If we use the formula $D_S = D_M/\sin D$, the ratio would be 19.11.

Actually, on the average, the Sun lies 389 times further than the Moon (making the mean deficiency 0.147°).

Well, we said the method was impractical. First, and most seriously, the human eye cannot judge the moment of dichotomy to the accuracy required. In this writer's opinion, it is difficult to judge the time of half phase to at best two

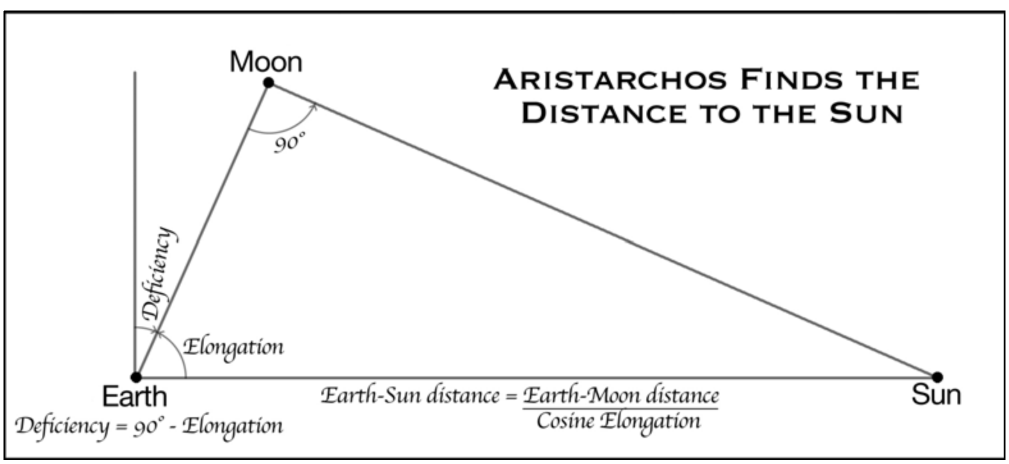


Figure 4. The Sun-Moon-Earth triangle at the moment of a lunar dichotomy observation; the principle behind Aristarchos' solar-distance measurement.

hours, during which time the Moon moves about 1°. Second, as small an angle as 0.147° (about 9 arc minutes) is very difficult to measure without a telescope to an accuracy of 1 arc minute. Since the factor Sine D is in the denominator in the formula, a small uncertainty in D causes a large uncertainty in the solar distance (e.g., D = 10 arc minutes, D_S/D_M = 344; D = 8 arc minutes, D_S/D_M = 430).

Nonetheless, off by a factor of 20 is pretty bad. Also, one would expect Aristarchos to have been able to judge an angle to better than an almost 3° error. He gave us no details for his observation, not even whether dichotomy occurred with a waxing or waning Moon. Perhaps it was all a thought experiment, with Aristarchos simply picking a 3° deficiency as a reasonable value in order to demonstrate his method.

We do not have enough information in order to decide whether or not Aristarchos actually made his described lunar-dichotomy observation. What we propose instead is to make similar observations ourselves to demonstrate whether or not he *could have made* the observation.

The Aristarchos Experiment

Assuming that Aristarchos actually made a lunar-dichotomy observation, the first challenge would have been to measure the lunar elongation, or perhaps the deficiency directly. If measuring the elongation, he would have had to use an instrument capable of subtending a 90° angle. A "dioptra" would have done this, if only because the term is used so broadly as to cover versions that ranged from ones measuring a full circle (used in both astronomy and surveying) to ones for gauging small angles such as the diameters of the Sun and Moon. (Price 1957: 591)

For this experiment, the writer (Westfall) constructed what he calls a "dichotometer," a specialized dioptra designed specifically to measure deviations of a few degrees from a right angle. Figure J shows the dichotometer with its parts labeled; Figure 6 shows the instrument in use, mounted on a triaxial tripod so as to lie in the Earth-Sun-Moon plane. Except for the modern tripod, every effort was made in constructing the instrument in using only materials and techniques available in Aristarchos' time.

The instrument was tested at the waning-Moon dichotomy of 2016 March 31.

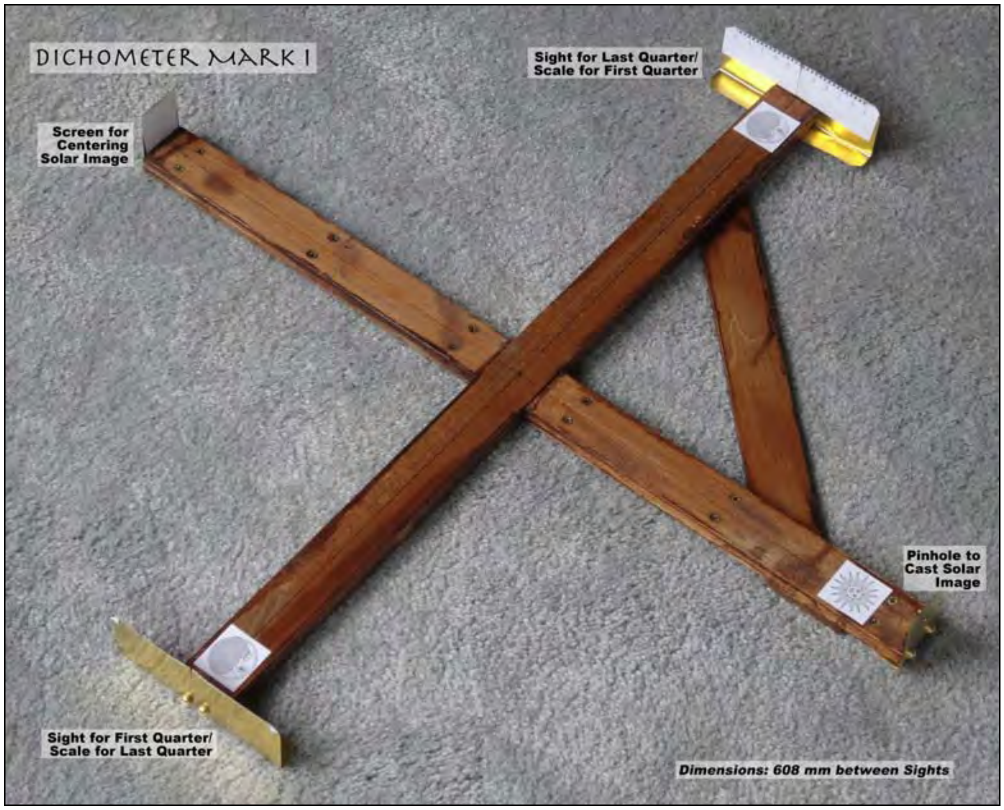


Figure 5. The "dichotometer", used to measure the Sun-Moon elongation when near 90°.

Figure 6. The dichotometer, mounted on a triaxial tripod to measure the elongation of a waning quarter-Moon.

Fourteen readings over the corrected elongation range 90.25°-89.00° gave a mean (observed-actual) elongation of +0.031°, with a RMS uncertainty of ±0.133°. (The actual elongations were found from JPL's HORIZONS website.) The small mean difference of observations from actual elongations suggests that the instrument's readings are unbiased. The ±0.133°-scatter of the individual readings is bothersome, but was reduced by taking the mean of multiple observations; unfortunately we have no evidence that the ancients knew how to do this.

The second challenge in the lunar-dichotomy method is judging the moment of dichotomy. Indeed, “moment” is far too optimistic - to be correct within an hour would be fortunate. Remember that Aristarchos had to make his observation in full sunlight, with poor Moon-sky contrast, because he also needed to measure the Sun-Moon elongation. There are two approaches to identifying dichotomy, the estimation of 50 percent illumination or the straightness of the lunar terminator. The writer found it much easier to adopt the criterion of terminator straightness, using it for all 31 timings, 17 with a waxing Moon and 14 with a waning Moon; they are individually listed in the “Appendix: Lunar Dichotomies”, whose results are summarized in Table 1.

A glance at Table 1 raises several questions. The first is the difference between “apparent” and “corrected” elongations. Both types were obtained from the JPL HORIZONS website for the times and place of observation, but apparent elongations are affected by refraction and corrected elongations have the refraction effect removed. (We shall encounter this annoying phenomenon again in the “Appendix: Near Horizons”.) Our atmosphere acts as a weak negative lens, squeezing 181° of sky into the apparent 180° of the celestial hemisphere. Were the atmosphere removed, the Moon-Sun elongations would each be a little larger, having a marked effect on the Sun:Moon distance ratios (compare the last two columns).

Table 1. Means of Lunar Dichotomy Observations

Lunar Dichotomy Observations Subset	Mean Apparent Elongation (°)	Mean Corrected Elongation (°)	Mean Apparent D_S/D_M	Mean Corrected D_S/D_M
All (N = 31)	89.483	89.584	110.8	137.7
Waxing Phase (N = 17)	88.638	88.754	42.1	46.0
Waning Phase (N = 14)	90.508	90.593	-	-
Waxing and Waning Phases Weighted Equally (N = 2)	89.573	89.674	134.2	175.8

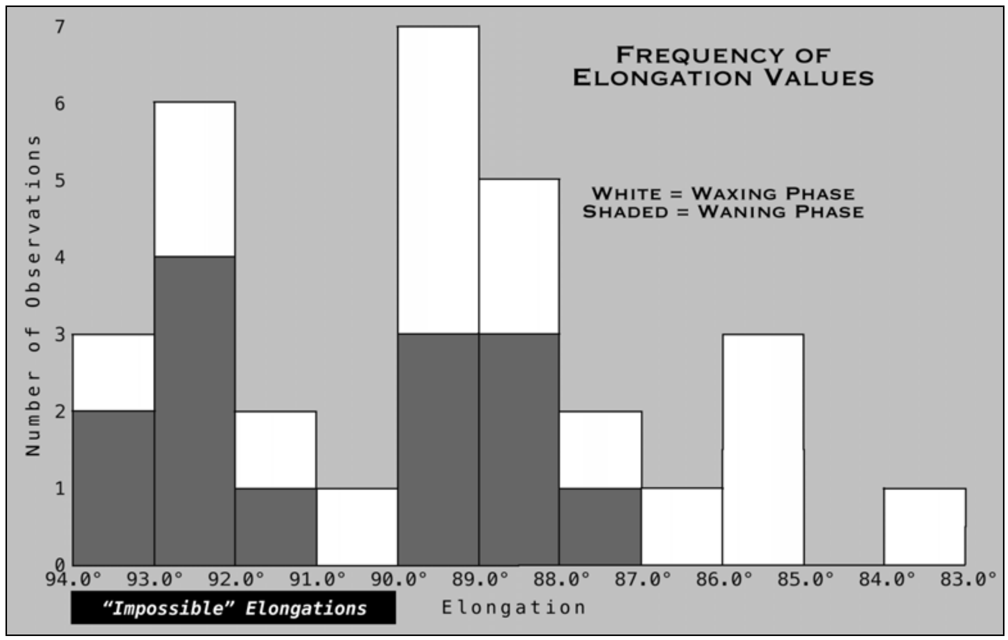


Figure 7. Frequency diagram of Sun-Moon elongations, corrected for refraction, for the 31 estimates of the moment of dichotomy. Elongations exceeding 90° are geometrically impossible and due to observational error.

Figure 7 is a frequency diagram of the individual corrected elongations. Twelve of the 31 corrected elongations plotted exceed 90° - a geometrical impossibility. Such paradoxes happen when one is measuring a small quantity whose magnitude is near that of its uncertainty range, for example a frequent result with stellar parallaxes (even the 2018 *Gaia Data Release 2* includes many negative parallaxes). Perhaps it's counterintuitive, but when analyzing a group of observations, one should not discard the “impossible” ones. Doing so would eliminate one tail of the frequency distribution and, among other problems, would bias the mean.

Both Table 1 and Figure 7 show a systematic difference between the observations made at waxing phase (first quarter) and waning phase (last quarter). Fully half of the latter have elongations over 90°, while that is the case with only 5 of the 17 waxing-phase elongations. Statistical tests of the differences between the means of the waxing- and waning-phase elongations showed that the likelihood of the differences occurring by chance were 4.58 percent for apparent elongations and 5.18 percent for corrected elongations. Thus the first quarter-last quarter differences appear to be real, but are difficult to explain. One suggestion is that at first quarter the sunlit lunar surface near the terminator is mainly fairly bright highlands, while at last quarter the sunlit terrain near the terminator is largely darker mare.

To select a “best” unbiased mean solar distance from the several in the above table, we need to try to be impartial and thus to weigh equally the means of the 17 first-quarter observations and the 14 last-quarter observations. We also need to remove the bias caused by refraction, the result being that the Sun lies a mean 175.8 lunar distances from the Earth (lower right cell of table). This less than one-half the actual mean of 389, but a decided improvement on Aristarchos's 19.1 lunar distances.

Nonetheless, the standard deviation of all 31 of our apparent elongations was ±2.62°, making Aristarchos's 87-degree elongation fully believable - it is indeed possible that he actually made his observation.

Others than this writer have applied Aristarchos' lunar-dichotomy method more recently than Aristarchos himself, particularly after the introduction of the telescope in the Seventeenth Century. (Hoag 1990: 17) (However, the telescope was more successful in revealing the irregularity of the terminator than in better judging the moment of dichotomy.) We should mention, for example, such figures as Thomas Harriot, E (elongation) = 89.1°, 1611; Johannes Kepler, E = 88.1°, 1615); Godfrey Wendelin, E = 89.75°, 1625. (Hoag 1990: 17; see also Gomez 2014). Arthur Hoag in the 1980s made a series of estimates for each of five dichotomies, with a final result of E = 89.9°±0.6° (i.e., mean D_S/D_M = 573, range = 82 - ∞) (Hoag 1990).

(We need now to admit what the reader may already know: the distances to the Moon and Sun are actually variable (the Moon's distance varies by ±3.5 percent, that of the Sun by ±1.7 percent). Yet we have treated them as constants. Given the large uncertainties of the distance means, combined with the fact that the distance variations had not been measured in Aristarchos' time, justifies us in restricting ourselves to mean distances.)

Synthesis

Using Aristarchos' numerical values we were able to compute the Sun's distance as 19.11 times that of the Moon. We now can return to formulae (1) - (4) and insert the quantity D_S/D_M = 19.11, with the result that R_E = 0.01931 D_M or D_M = 51.79 Earth radii. We now have enough information to characterize the sizes and distances of the three bodies of interest.

The numbers in the Table 2 depend on a handful of inputs and several assumptions, as shown in the notes in the table's last row. The assumptions make a difference. Were Eratosthenes's result not yet available to Aristarchus, the most recent source for him would have been Dicaerchos' 300,000-stade terrestrial circumference, raising all the values in columns 3, 4 and 6 by 20 percent! Adopting a stade length other than 185 meters would proportionally affect all the values in columns 4 and 6.

Looking at the tabulated values as they are, the 15-percent excess for the Earth's radius is a disappointment - apparently no better than from the simpler methods using horizon measurement. It appears that, however Eratosthenes measured the Alexandria-Syene terrestrial distance, it was too great, or perhaps his stade length was closer to 160 meters than 185.

On the other hand, the relatively accurate lunar parameters indicate a happy near-cancellation of errors - a three-way compensation with too small an umbra compensated for by too small a solar distance and too large a terrestrial radius.

It is with the Sun's size and distance that we have gross disagreement with modern values - by a factor of 20! The reasons are obvious; the true deficiency of 0.15°

Table 2. Terrestrial, Solar and Lunar Dimensions

Quantity	Ancient Value			Modern Value	Ancient Value – Modern Value
	Earth radii	Stades[b]	km[c]	km[d]	%
Earth radius	1.000	39,790	7,361	6,378	+15.4
Moon radius[a]	0.2260	8,991	1,663	1,737	-4.3
Moon distance	51.79	2,061,000	381,300	384,400	-0.8
Sun radius[a]	4.318	171,800	31,780	696,000	-95.4
Sun distance[e]	989.7	39,380,000	7,285,000	149,600,000	-95.1

[a] Based on 0.5° angular diameter. [b] Based on Eratosthenes' circumference of 250,000 stades. [c] Based on 1 stade = 0.185 km. [d] *Astronomical Almanac for the Year 2019*, pp. K6-K7. [e] Based on Aristarchos' stated deficiency of 3°.

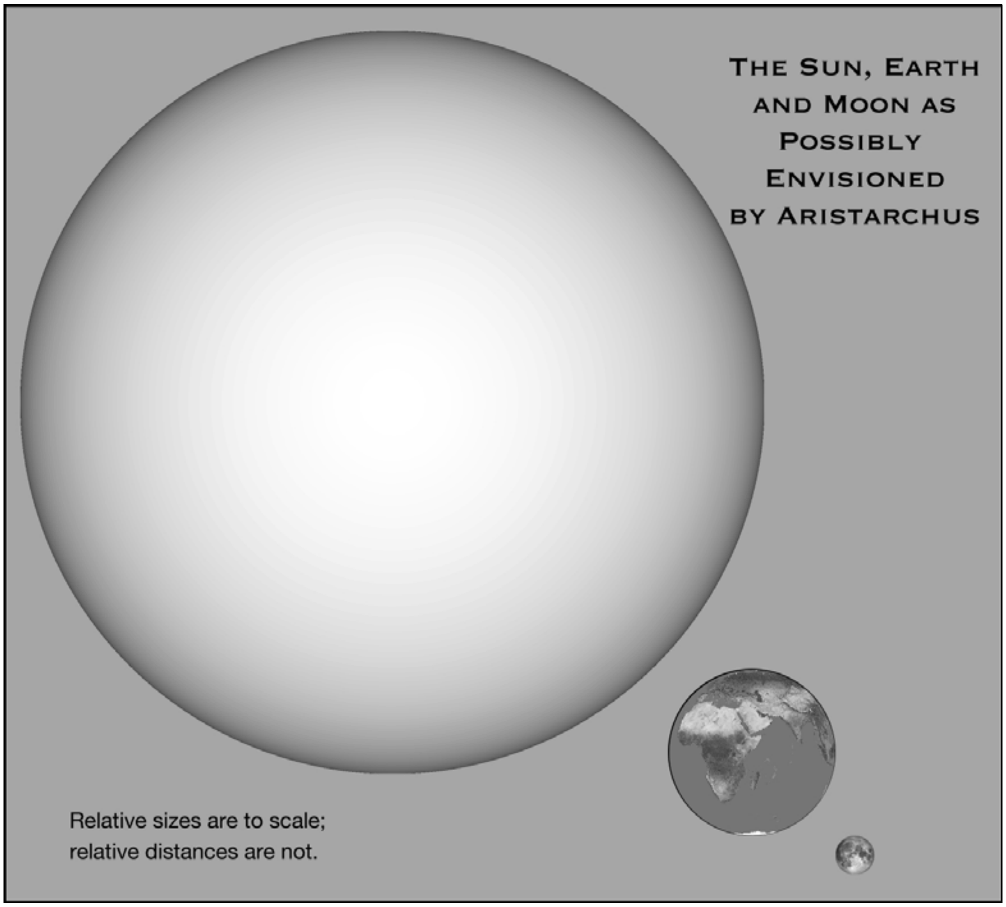


Figure 8. The relative sizes of the Sun, Earth and Moon as possibly envisioned by Aristarchos, including the result of his solar-distance measurement. Relative sizes are to scale but distances are not.

was just too small to estimate accurately with ancient measurements and, particularly, with naked-eye judgment of the moment of lunar dichotomy.

In the most basic sense, though, the *ranking* of the sizes of the three bodies, the size values in Table 2 are accurate: Sun>>Earth>>Moon, as shown in Figure 8. When converted to volumes, the differences among the three bodies are yet more striking: 80 Earths could fit into the Sun while 89 Moons could be fitted into the Earth.

The relative motions of these three bodies raise at least two questions. First, why do we almost instantly accept that the Moon circles the Earth rather than *vice versa*? Perhaps this is partly geocentric bias, but it does seem intuitive that the little Moon should circle the 80-times larger Earth. There is also the point that the Earth has forced the Moon to have a hemisphere always directed toward the Earth, while the Moon has caused the Earth no such indignity.

The second question is: Why, if it is logical that the smaller Moon circle the larger Earth is it not equally logical that the smaller Earth circle the larger Sun? The opposite would appear to be unequivocally a result of geocentric bias. The astronomical measurements, both those made by others but available to Aristarchos, combined with those originating with himself, either under the skies or as thought experiments, compelled him to see the logic of the heliocentric system that he proposed.

The cosmological distance ladder ended with the Sun in pre-telescopic times, with estimates of the sizes and distances of the three bodies that can be seen as disks - Earth, Sun and Moon. Beyond these, all the ancients could do was to (correctly) rank the distances of the five remaining planets by ranking their synodic periods. Relative distances would have to wait for Kepler, nineteen centuries after Aristarchos. And the stars still lay beyond.

Appendix: The Elastic Stade

The stade originated as the length of the running track (dromon) in a Greek stadium; the first being constructed at Olympia c. 700 BCE with a 192-meter dromon. There was, however, no panhellenic sports commission to enforce standardization, so this writer easily was able to construct a list of 61 Hellenic and Hellenistic stadiums, the length of whose running tracks ranged from 148 to 225 meters (mean 153.77 m). (We note the analogy between the use of an ancient sports measurement to quantify scientific results and NASA's frequent reference to football fields to express sizes in its press releases.)

Sometimes the stade was defined in terms of other ancient units, as in Table 3. Six hundred Greek feet to the stade was a common conversion; the difficulty here being that there were three recognized foot sizes and we are not sure how closely those were adhered to. There is a similar problem with any stade:Roman mile conversion, particularly as in Aristarchos' time Roman rule had not reached east of the Adriatic.

There is another approach - select the stade:meter conversion such that the ancient stade corresponds most closely to the modern SI (*Système international*) equivalent. For example, take the Earth's 40,007,860-m polar circumference and

Table 3. Relation of Stades to Other Ancient Units

Unit	Unit SI Equivalent	Stades per Unit	Stade SI Equivalent
Greek Foot: Attic	0.2941 m	1/600	176.5 m
Doric	0.3269 m	“	196.1 m
Ionic	0.3487 m	“	209.2 m
Roman Mile: Italian conversion	1481.5 m	8	185.2 m
Polybian conversion	“	8-1/3	177.8 m
Pythian conversion	“	10	148.2 m
Egyptian *skhoinos*	6288 m	40	157.2 m
Sources: Diller 1949: 8-9; Gulbekian 1987: 359-360; Pothecary 1995; Walkup 2018			

divide into it Eratosthenes's 250,000-stade circumference, obtaining a result of 160.03 meters. By coincidence, that's close to the 157.5-m “Eratosthenian” stade (Sarton 1959:105), a difference of only 1.6 percent! Of course this is a classic example of circular reasoning. Given the large uncertainties in ancient angular and distance measurement, this procedure would simply sweep their problems under the rug.

So we are faced with a variety of stades. In 1929, Carl Ferdinand Friedrich Lehmann-Hupt (1861-1938) listed stades ranging from 149 to 298 m (Lehmann-Hupt 1929). The Russian classicist Lev Vasilevich Firsov (1926-1981; Firsov 1972; cited by Nicastro 2008:126) compared 87 stade distances cited by Eratosthenes and Strabo with modern measurements, finding a mean stade:meter conversion of 157.95. We hesitate, however, to equate Eratosthenes' stade with the mean of a sample of variable-length stades as there is no reason that Eratosthenes would have known the concept of reducing uncertainty through sampling; or if he did, whether he would have sampled from the same populations as have modern scholars.

In Table 3, all the SI distances and sizes depend on the SI equivalent of Eratosthenes' stade; if other geodesists used different stades, that affects only comparisons of his results with those of other ancient authorities. Thus it is not surprising that a large body of literature has been focused on identifying the SI equivalent of his stade. An early influential paper was published posthumously by Jean Antoine Letronne (1787-1848) in 1851 (Letronne 1851: 93-95). Equating the stade with the Egyptian “skhoinos”, he advocated a stade of 157.2 m. The quest for the stade had begun. Unfortunately, although Pliny described the skhoinos as 40 stades, he also noted that others defined the skhoinos as 32 stades; worse, Herodotus made it 60 stades, Heron of Alexandria 30 stades, while Strabo made the conversion 30-40 stades to the skhoinos. (All cited by Gulbekian 1987: 360).

The argument swung away from Letronne's157-m stade in 1985, when historian Donald W. Engels published a paper advocating a 185-m stade (Engels 1985). Engels argued that the ancient authorities used a standard stade. He also argued that the stade used was the “Attic stade” of 184.98 m (600 “Attic feet” of 308.3 mm, used at the stadium in Athens, and differing somewhat from the 294.1 mm in Table 3). Engels also commented that this was the stade length used by Alexander the Great in Asia. In addition, Pliny (II. xx. 85) wrote “A stade is equivalent to 125 Roman paces, that is 625 feet.” Taking the units cited as Roman feet (296 mm), the stade's SI equivalent would again be 185 m. Thus in compiling columns 4 and 6 of Table 3, we have chosen a 185-meter stade; we freely admit that this remains uncertain, but more likely than values much larger or much smaller.

Appendix: Near Horizons

It's possible to measure the radius of the Earth without having to travel to distant parts, using either of two methods that involve observation of the apparent horizon. (One restriction: The horizon should be on water - the ocean or a sufficiently large lake - although the observer may be on dry land.)

The situation is shown in Figure 9, where: D = horizon dip (the angle below the horizontal that the apparent horizon falls), h = height of the observer above water level, r = the radius of the Earth, s = surface distance to horizon, and t = tangential distance to horizon (h, r, s and t are in the same units)

The first method is to measure the distance to the horizon (on a map, by triangulation, etc.). Then, measuring the tangential distance, t:

$t^2 = (r + h)\ 2 - r^2 = r^2 + 2rh + h^2 - r^2 = 2rh + h^2$

since $r >> h$, $t^2 \sim 2rh$ and

(1) $r \sim t^2/2h$

If the over-surface distance, s, is measured, convert to t and use formula (1):

(2) $t \sim (s^2 + h^2)0.5$

And, if the horizon dip, D, is measured in radians:

(3) $r = 2h/D^2$ (Rawlins 1980: 299)

As a hypothetical example, assume that a member of the Museum of Alexandria takes a stroll (or more likely a litter-ride) to the Pharos lighthouse. He (almost certainly a he) ascends to the top, say 110 meters above sea level (an altitude within the range of estimates of the structure's height; note that we will be using modern units).

His first estimate is the distance to the horizon. Looking east, past the city of Canopus and the Canoptic Mouth of the Nile, the lake, Kanopike Limne, appears to be at the limits of visibility. Knowing from surveys that the lake is about 40 km east of the Pharos, we estimate the Earth's radius as 7,273 km (formula (2), although formula (1) would give essentially the same result).

Then using a level (probably a long water-filled trough), the sea horizon dip appears to be about 0.312 degree. This converts to 5.45 X 10-3 radians and formula (3) gives an Earth radius of 7,407 km.

The two results are well above the modern value of 6,378 km (equatorial radius, WGS84); by 14 and 16 percent respectively. However, the values supplied were deliberately chosen to provide a correct radius. What went wrong? The diagram and formulae assume that light travels in straight lines; i.e., in a vacuum. Actually of course we would be sighting through the Earth's atmosphere, and through air layers of differing density at different altitudes. The light paths would be curved, making the visible horizon slightly farther and the horizon dip slightly smaller. (Newcomb 1906: 198-203)

It is unfortunate that nobody in Aristarchos' time had the meteorological or optical knowledge needed to model and correct for refraction. Still, errors of 14-16 percent, when compared with the modern earth radius, are not unknown for the more-often cited ancient applications of the terrestrial-arc method. For all we know, Aristotle's "mathematicians" may have used one of the horizon-based methods.

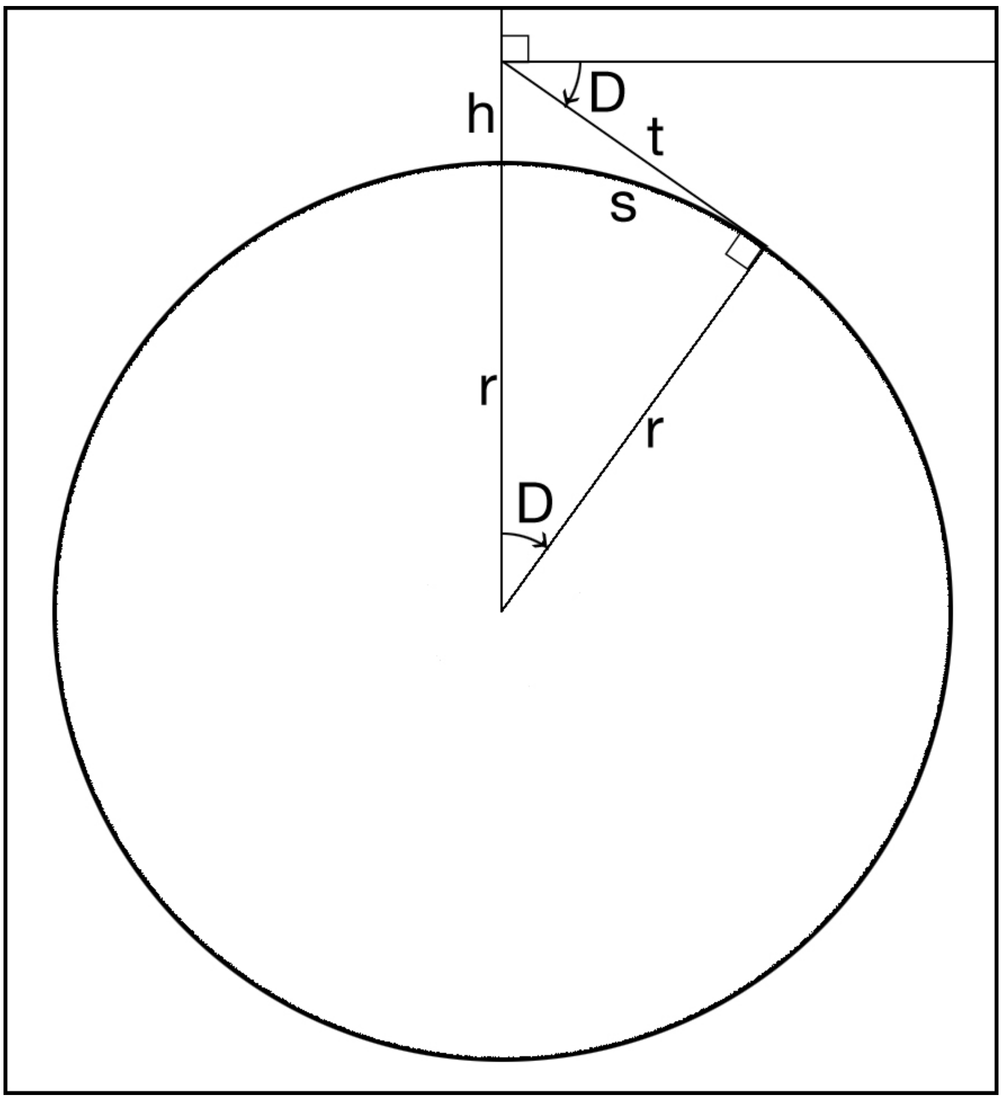


Figure 9. The geometric relations among the Earth's radius (r), angular horizon dip (D), height above water level (h), straight-line distance to horizon (t) and surface distance to horizon (s).

Appendix: Lunar Dichotomies

On 31 occasions during 2012-2018, the writer (Westfall) estimated the moment when the Moon appeared to be exactly at half-phase (dichotomy). In all cases, he observed with the naked eye, from Antioch, California, USA (37.960°N/ 121.812°W/81 m MSL) using the criterion of straightness of the terminator.

The first two columns of Table 4 give the UT date and time of perceived dichotomy. For that time and the observer's location, JPL's HORIZONS website was used to compute: "True Phase", Terminator Longitude ("Term. Long."), and the True Elongation of the Moon from the Sun ("True Elong."; eliminating the effect of atmospheric refraction). From HORIZONS output, the writer derived "Apparent Elong." (Apparent elongation; including the effect of atmospheric refraction), "Apparent Sun/Moon Distance" (based on Apparent elongation), "Corr. Sun/Moon Distance" (Corrected Sun/Moon Distance; based on True elongation) and "True Sun/ Moon Distance" (the distance of the Sun in lunar distances).

Beside the individual observations, when appropriate we have given the median, mean, standard deviation and standard error of the following sets of observations: "Waxing Phase" (N = 17), "Waning Phase" (N =14), "All Observations" (N = 31) and "Waxing and Waning Medians and Means Weighted Equally" (N = 2).

References

Archimedes (1897). *The Sand-Reckoner of Archimedes*. Translated by Thomas L. Heath, Sir Thomas Little. Cambridge, UK: Cambridge University Press. http://www.sacred-texts.com/cla/archim/sand/sandreck.htm

Aristotle (1922). *On the Heavens*. Translated by John Leofric Stocks. Oxford: Clarendon

Table 4. Dichotomy Phase Estimates

UT Date	UT	True Phase	Term. Long. (°)	Apparent Elong. (°)	True Elong. (°)	Apparent Sun/Moon Distance	Corr. Sun/ Moon Distance	True Sun/Moon Distance
Waxing Phase (N = 17)								
2012 Mar 31	01:04	.526	-9.7	92.80	92.86	-	-	385.2
2012 Apr 29	02:29	.469	-4.2	86.14	86.31	14.8	15.5	393.5
2012 Jun 26	23:43	.489	-3.5	88.59	88.61	40.6	41.2	409.9
2012 Jun 27	01:27	.495	-4.4	89.21	89.25	72.5	76.4	411.1
2012 Aug 24	01:48	.445	+6.7	83.45	83.50	8.8	8.8	412.7
2012 Dec 19	23:39	.479	+10.2	87.33	87.39	21.5	22.0	382.1
2013 Feb 18	01:41	.522	-0.4	92.00	92.38	-	-	372.0
2013 Jul 16	01:47	.497	-6.4	89.46	89.50	106.1	114.6	404.3
2013 Jul 16	03:22	.502	-7.2	89.82	90.03	318.3	-	403.5
2013 Aug 13	19:08	.461	+2.6	85.37	85.43	12.4	12.6	407.3
2013 Oct 12	01:26	.513	-0.6	91.14	91.34	-	-	407.3
2014 Jan 08	00:20	.487	+9.2	88.31	88.41	33.9	36.0	389.2
2014 Ju1 05	02:29	.463	-2.0	85.55	85.61	12.9	13.1	383.3
2014 Sep 02	02:26	.462	-2.8	85.28	85.47	12.2	12.7	399.4
2014 Dec 29	00:41	.531	+1.0	93.13	93.37	-	-	399.0
2016 Jul 11	23:14	.501	+2.7	89.90	89.93	573.0	818.5	380.3
2017 Jun 30	21:57	.496	+1.2	89.37	89.42	90.9	98.8	390.2
Median	-	.4970	-0.60	89.210	89.250	(72.5)	(76.4)	399.00
Mean	-	.4905	-0.45	88.638	88.754	(42.1)	(46.0)	395.90
S	-	±.0248	±5.56	±2.807	±2.846	-	-	±12.45
SE	-	±.0060	±1.35	±0.681	±0.690	-	-	±3.02
Waning Phase (N = 14)								
2012 Jun 11	14:19	.488	+4.9	88.46	88.52	37.2	38.7	389.4
2012 Aug 09	15:19	.519	+3.3	91.96	92.01	-	-	380.8
2012 Nov 06	18:35	.531	-3.9	93.37	93.43	-	-	379.6
2013 Mar 04	16:59	.529	+1.8	93.09	93.13	-	-	402.8
2013 Aug 29	14:00	.484	-9.9	87.84	88.02	26.5	28.9	382.2
2013 Nov 25	15:04	.519	-3.9	91.69	92.08	-	-	374.8
2014 May 21	15:07	.495	+1.8	89.20	89.24	71.6	75.4	413.1
2014 Jun 19	14:05	.525	+8.0	92.47	92.65	-	-	412.7
2015 Mar 13	16:36	.510	-6.9	90.99	91.02	-	-	391.1
2016 Mar 31	16:13	.501	-7.8	89.93	89.96	818.5	1432.4	386.9
2017 Apr 19	15:22	.482	-8.7	87.74	87.78	25.4	25.8	383.4
2017 Jul 16	15:48	.523	-4.0	92.41	92.42	-	-	409.4
2017 Oct 12	16:02	.487	+1.6	88.30	88.35	33.7	34.7	408.0
2018 Feb 07	17:18	.499	+5.5	89.66	89.69	168.5	184.8	374.0
Median	-	.5055	-1.15	90.450	90.490	-	-	388.15
Mean	-	.5066	-1.30	90.508	90.593	-	-	392.01
S	-	±.0177	±5.84	±2.013	±2.026	-	-	±14.28
SE	-	±.0047	±1.56	±0.538	±0.541	-	-	±3.82
All Observations (N = 31)								
Median	-	.4970	-0.60	89.460	89.500	(106.1)	(114.6)	391.10
Mean	-	.4977	-0.83	89.483	89.584	(110.8)	(137.7)	394.14
S	-	±.0230	±5.61	±2.618	±2.639	-	-	±13.27
SE	-	±.0041	±1.01	±0.470	±0.474	-	-	±2.38
Waxing and Waning Medians and Means Weighted Equally (N = 2)								
Median	-	.5012	-0.88	89.830	89.870	(337.0)	(440.7)	393.58
Mean	-	.4941	-0.88	89.573	89.674	(134.2)	(175.8)	393.96
S	-	±.0051	±0.60	±1.322	±1.300	-	-	±2.75
SE	-	±.0036	±0.42	±0.935	±0.920	-	-	±1.94

Press.
https://ebooks.adelaide.edu.au/a/aristotle/heavens/

Brezinski, Claude and Wuytack, Luc (2001). *Numerical Analysis: Historical Developments in the 20th Century*. Amsterdam, etc.: Elsevier.
http://math.univ-lille1.fr/~bbecker/ano/pub/2001/ano428.pdf

Diller, Aubrey (1949). "The Ancient Measurements of the Earth." *Isis* 40 (1): 6-9.
https://www.journals.uchicago.edu/doi/10.1086/348986

Engels, Donald W. (1985). "The Length of Eratosthenes' Stade." *The American Journal of Philology*, 106 (3): 298-311.
https://www.jstor.org/stable/pdf/295030.pdf

Evans, James (1998). *The History and Practice of Ancient Astronomy*. New York, etc.: Oxford University Press.
https://global.oup.com/academic/product/the-history-and-practice-of-ancient-astronomy-9780195095395?cc=us&lang=en&

Gomez, Alberto G. (2014). *Aristarchos of Samos the Polymath*. Bloomington, IN: AuthorHouse UK.
https://www.amazon.com/Aristarchos-Samos-Polymath-Collection-Interrelated/dp/148178949X

Gulbekian, Edward (1987). "The Origin and Value of the Stadion Unit Used by Eratosthenes in the Third Century B.C." *Archive for History of Exact Sciences*, 37 (4 Dec.): 359-363.
https://link.springer.com/journal/407

Heath, Sir Thomas Little (1913/2004). *Aristarchus of Samos, the Ancient Copernicus*. Mineola, NY: Dover Pub.
https://archive.org/details/aristarchusofsam00heatuoft/page/n5

Hoag, Arthur A. (1990). "Aristarchos revisited." *Griffith Observer*, 54 (8; August): 10-18.
http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1989PASP..101R.885H&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf

Lehmann- Haupt, Carl Ferdinand Friedrich (1929). "Stadion." In *Paulys Real-Encyclopädie de classischen Altertumswinnsenschaft*. 2nd Ser. Vol. IIIA. Stuttgart.
http://ancientworldonline.blogspot.com/2010/09/emerging-open-access-paulys.html

Letronne, Jean Antoine (1851). *Recherches critiques, historiques et géographiques sur les fragments d'Heron d'Alexandrie, ou du système métrique Égyptien*. Paris: A l'Imprimerie Nationale.
https://ia800504.us.archive.org/4/items/recherchescritiq00letr/recherchescritiq00letr.pdf

Macmillan Library Reference USA (1999). *Macmillan Atlas of the World*. 2nd U.S. ed. New York: Macmillan Library Reference.

Newcomb, Simon (1906). *A Compendium of Spherical Astronomy With Its Application to the Determination and Reduction of Position of the Fixed Stars*. New York: The Macmillan Company. Reprinted 1960 by Dover Publications.
https://archive.org/details/acompendiumsphe00newcgoog/page/n8

Nicastro, Nicholas (2008). *Circumference: Eratosthenes and the Ancient Quest to Measure the Globe*. New York: St. Martin's Press.
https://us.macmillan.com/books/9781250068446

Nievergelt, Yves (2001). "A Tutorial History of Least Squares With Applications in Astronomy and Geodesy." pp. 77-112 in Brezinski & Wuytack 2001.
https://www.sciencedirect.com/science/article/pii/S0377042700003435

Pliny the Elder (Gaius Plinius Secundus) (1949). *Natural History. Preface and Books 1-2*. Translated by H. Rackham. Loeb Classical Library. Cambridge, MA: Harvard University Press.
https://mafiadoc.com/queue/l330-pliny-natural-history-i-books-1-2_59ddb3441723dd46f58e76b6.html

Pothecary, Sarah (1995). "Strabo, Polybios, and the Stade." *Phoenix* 49 (1): 49-67.
https://www.jstor.org/stable/1088361

Price, Derek J. (1957). "Precision Instruments: to 1500." Cpt. 22, pp. 582-619, in: Singer, Charles; Holmyard, E. J.; Hall, A. R. and Williams, Trevor I., eds. (1957) *A history of technology. Volume III. From the Renaissance to the Industrial Revolution c 1500-1750*. New York and London: Oxford University Press.
https://quod.lib.umich.edu/cgi/t/text/pageviewer-idx?c=acls;cc=acls;rgn=full%20text;idno=heb02191.0003.001;didno=heb02191.0003.001;view=image;seq=00000622;node=heb02191.0003.001%3A34

Rawlins, Dennis (1980). "On Measuring the Earth With a Hose." *Journal of the Royal Astronomical Society of Canada*, 74 (5): 299-301.
http://adsabs.harvard.edu/full/1980JRASC..74..299R

Sarton, George (1959). *Hellenistic Science and Culture in the Last Three Centuries B.C.* Cambridge, MA: Harvard University Press. Reprinted by Dover Publications, 1993.
http://store.doverpublications.com/0486277402.html

Strabo (1917-32). *The Loeb Classical Library: The Geography of Strabo in Eight Volumes*. Translated by John Robert Sitlington Sterrett. Cambridge, MA: Harvard University Press.
https://archive.org/details/Strabo08Geography17AndIndex

Thomson, James Oliver (1965). *History of Ancient Geography*. New York: Biblo and Tannen.
https://books.google.com/books/about/History_of_Ancient_Geography_Illustr.html?id=qheAAAAAMAAJ

Van Helden, Albert (1985). *Measuring the Universe. Cosmic Dimensions from Aristarchus to Halley*. Chicago: University of Chicago Press.
https://www.press.uchicago.edu/ucp/books/book/chicago/M/bo3622291.html

Westfall, John and Sheehan, William (2015). *Celestial Shadows: Eclipses, Transits, and Occultations*. New York: Springer.
https://www.springer.com/us/book/9781493915347

Papers & Presentations

Preliminary Report: The 20-21 January 2019 Total Lunar Eclipse

By Michael J. Reynolds, coordinator, ALPO Eclipse Section
m.d.reynolds@fscj.edu

The 20-21 January 2019 total lunar eclipse was well-placed for observers in western Europe, western Africa, and especially the Americas (see Figure 1). Even though the moon's passage through earth's umbral shadow was not as deep as the 27 July 2018 total lunar eclipse, the event promised observers 62 minutes of totality versus 103 minutes of totality for the 27 July 2018 total lunar eclipse.

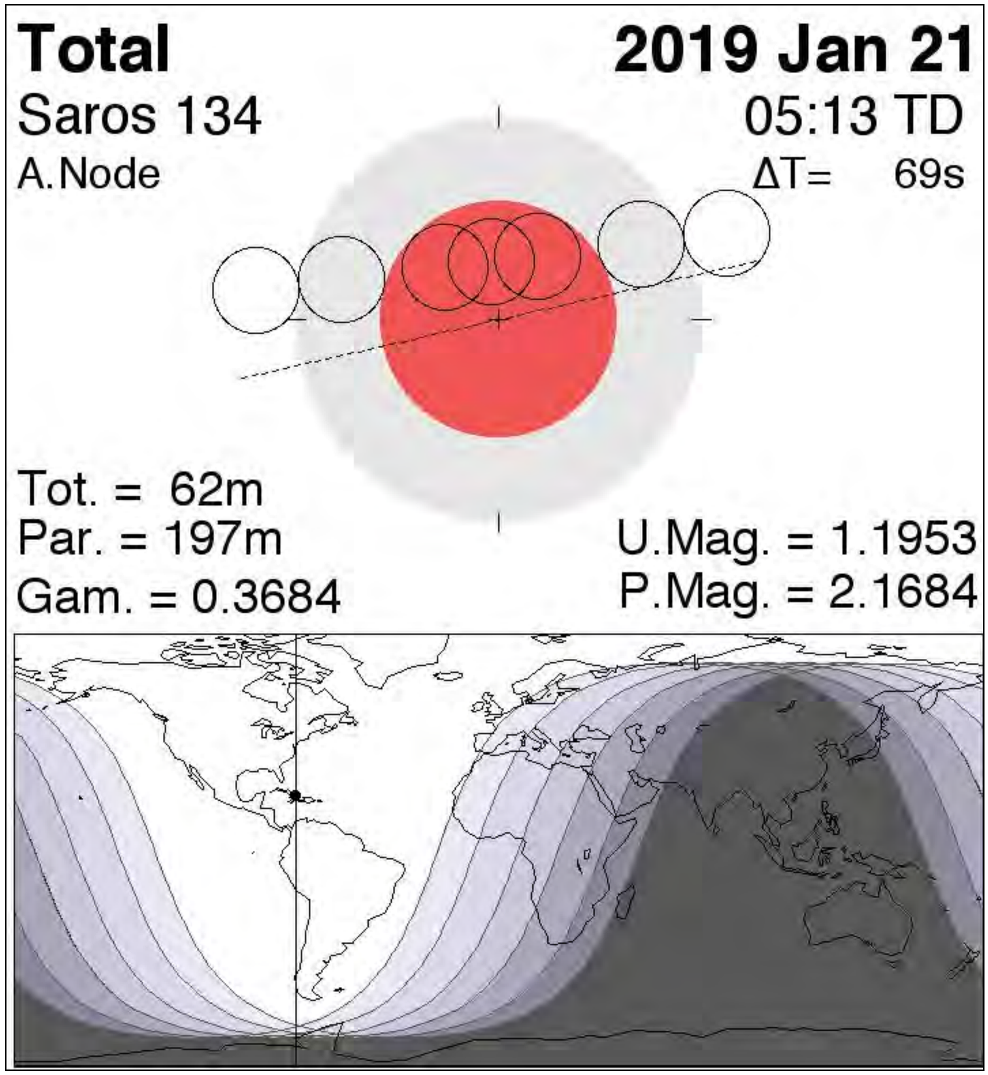


Figure 1. The Moon's path through Earth's penumbral (grey) and umbral (red shadows, as well as eclipse visibility. Courtesy of Fred Espenak. (Source: *Thousand Year Canon of Lunar Eclipses*, copyright 2014 by Fred Espenak.)

This report is a preliminary look at the data and images received by the ALPO Eclipse Section. Very clear skies prevailed in some regions in the United States, other regions were not as fortunate with either partial or total overcast.

A number of excellent eclipse images were submitted by observers (see Table 1). Examples here include works by Dan Llewellyn (see Figure 2) and Robert H. Hays, Jr. (see Figure 3).

In 1921 André-Louis Danjon proposed a five point scale (the “L” value), for estimating the brightness and visual appearance of the Moon during a total lunar eclipse (see Table 2). At the time, Danjon believed that a total lunar eclipse's brightness was in some way related to the solar cycle. Danjon was also interested in other lunar observations, such as earthshine measurements.

Submitted Danjon luminosity estimates and brightness estimates for this eclipse were fairly consistent. Additional ALPO member Danjon luminosity estimates and brightness estimates would be helpful in establishing a better and more-consistent overall estimate of this eclipse's brightness.

Perhaps one of the more-interesting observations from this eclipse was meteoroid impact images taken during totality by Brett Ashton, Kent Blackwell, and Christian Fröschlin.

In preparing our final ALPO report on the 20-21 January 2019 Total Lunar Eclipse, we would welcome additional reports - including those who did not see the eclipse due to weather. Please send your total lunar eclipse reports to either of the addresses or emails listed here.

Mike Reynolds
Section Coordinator,
m.d.reynolds@fscj.edu
12740 Shellcracker Road
Jacksonville, FL 32226 USA

or

Keith Spring
Acting Assistant Section Coordinator
star.man13@hotmail.com

Figure 2. Image taken by Dan Llewellyn, Deerlick Astronomy Village (east central Georgia, coordinates 33.561420, -82.763140, +N33° 33' 41.11", -W82° 45' 47.30", Elevation: 550 - 600 ft). Esprit 120 APO F7, Sony A7r2 unmodified, ISO 5000, 0.5 second exposure.

Table 1. Reports Received & Logged

Name	Observation(s) Conducted
Amato, Michael	Danjon luminosity estimates, general observations
Cudnik, Brian	Crater contact timings, Danjon luminosity estimates
Eskildsen, Howard	Contact timings, crater contact timings, imaging
Hays, Jr., Robert H.	Contact timings, crater contact timings, Danjon luminosity estimates, drawings/ sketches, occultation timing
Legrand, Michel	Drawings/sketches
Llewellyn, Dan	Imaging
Melillo, Frank J.	Imaging, totality magnitude estimates
Poshedly, Ken	General observations
Reynolds, Mike	Danjon luminosity estimates, imaging, totality magnitude estimates, sky brightness estimates
Schmude, Richard	Photometric brightness measurements
Spring, Keith	Imaging
Teske, David	Imaging, other observations
Will, Matt	General observations

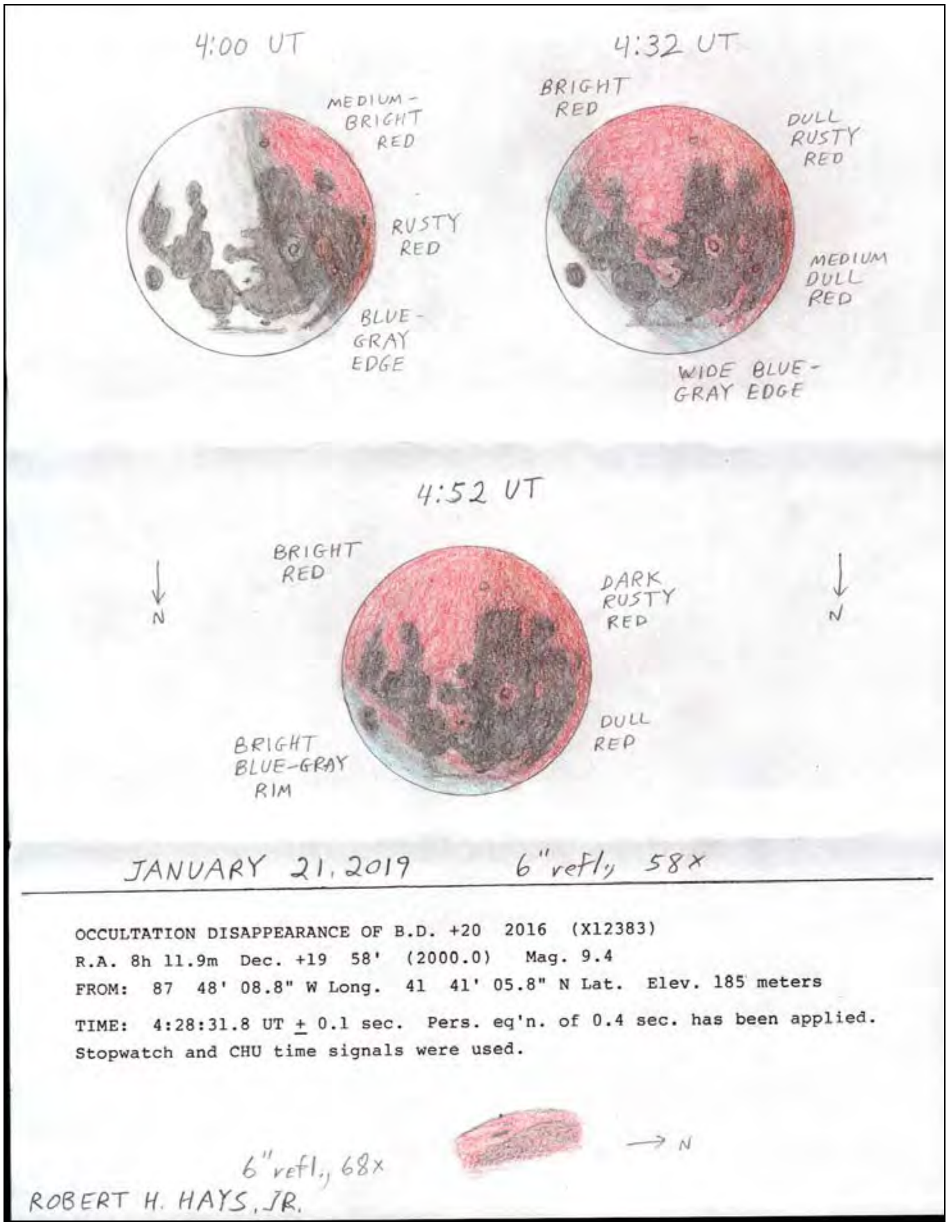


Figure 3. Drawings made by Robert H. Hays, Jr. 150 mm (6-inch) Newtonian reflector at 58x. Location Worth, Illinois, USA, coordinates as stated on the drawing.

Table 2. Danjon Luminosity Estimates

L value	Totality Characteristics
L = 0	Very dark eclipse Moon almost invisible, especially at mid-totality
L = 1	Dark Eclipse, gray or brownish in coloration Details distinguishable only with difficulty
L = 2	Deep red or rust-colored eclipse Very dark central shadow, while outer edge of umbra is relatively bright
L = 3	Brick-red eclipse Umbral shadow usually has a bright or yellow rim
L = 4	Very bright copper-red or orange eclipse Umbral shadow has a bluish, very bright rim

Papers & Presentations

A Lunar Dome in the Milichius-Tobias Mayer Region

By Raffaello Lena,
Acting Coordinator,
ALPO Lunar Domes Program,
raffaello.lena@alpo-astronomy.org
Jim Phillips, Acting Assistant Coordinator, ALPO Lunar Domes Program,
thefamily90@gmail.com

Abstract

In this article, we examine the morphometric and spectral characteristics of a dome, specifically dome M21, which was identified using CCD terrestrial images, LROC WAC imagery and LROC WAC-based GLD100 dataset. It lies at coordinates 13.78° N and 29.24° W and has a base diameter of 5.75 ± 0.3 km. This area of the Moon, from Hortensius to Tobias Mayer, contains large numbers of domes.

We have updated the catalogue and the domes maps, including dome M21, which are online at the link: http://hortdomes.blogspot.com/

Introduction

The region west of Copernicus extending from Hortensius to Milichius and to Tobias Mayer contains large numbers of lunar domes and cones [1-2]. The basalts of Oceanus Procellarum exhibit a wide range of spectral characteristics and ages. Spectrally, large parts of Mare Insularum are influenced by basalt lavas of low to moderate TiO_2 content on which ejecta of the craters Copernicus, Kepler, and Eratosthenes are superimposed [1]. In this wide volcanic region, domes of moderate to steep slope are located. During our "long" survey (14 years since 2004) we have identified and characterized a total of 20 domes (M1-M20) in the Milichius -Tobias Mayer region and 11 domes (H1-H11) in the Hortensius region, for a total of 31 domes. We have derived information about the physical parameters of their formation providing a geological interpretation as published in previous papers: for M1-M15 and H1-H7 [1-3], for M16-M18 [4], for M19-M20 [5] and for H8-H11 [6-7]. A comprehensive map of the area under description was recently produced by the authors and is published on-line in the lunar domes atlas quadrant http://hortdomes.blogspot.com/

In the Appendix portion of this paper are reported the morphometric properties of all lunar domes that we have previously characterized. In the current study, we examine the morphometric and spectral characteristics of another dome, which is termed M21, identified using CCD terrestrial images, LROC WAC imagery and LROC WAC-based GLD100 dataset. The dome lies at coordinates 13.78° N and 29.24° W and has a base diameter of 5.75 ± 0.3 km.

Ground-Based Observations

Telescopic CCD images of the examined lunar region are shown in Figures 1 through 4. Notably, the detailed study of lunar domes is possible based on images of the lunar surface acquired under oblique illumination conditions for their measurements and for maximum detail. In this study we show the appearance of some domes imaged under higher solar angle. As shown in the *proposed* images, the recording of finer details on the *domes summit* is related to telescopes optically of high quality, large diameters and favorable seeing reducing the negative effect of atmospheric turbulence.

The image shown in Figure 1 was taken by Zannelli on May 25, 2018 at 21:36 UT using a Celestron C14 (355 mm) Starbright SCT, a 2x Baader-Zeiss Abbe barlow and a Baader R filter. In this image, dome M21, which is located southeast of the small domes M8-M9 (Figures 1 and 2), is partly covered by the shadow of the nearby mountain and displays a crater on the summit. The image shown in Figure 3 was made by Barzacchi on March 19, 2016 at 22:18 UT using a Canopus 18-in. (477 mm) and a 2x Baader barlow. Note the well-resolved Rima Tobias Mayer and the appearance of M21 and other lunar

Online Readers

Your comments, questions, submitting observing reports of your own, etc., about this report are appreciated. Please send them to the authors by left-clicking your mouse on either of the e-mail addresses under the bylines on this page in blue text.

Also left-click on any hyperlinks in blue text within the text of this paper for additional information.

Observing Scales

Standard ALPO Scale of Intensity:
0.0 = Completely black
10.0 = Very brightest features
Intermediate values are assigned along the scale to account for observed intensity of features

ALPO Scale of Seeing Conditions:
0 = Worst
10 = Perfect

IAU directions are used in all instances.

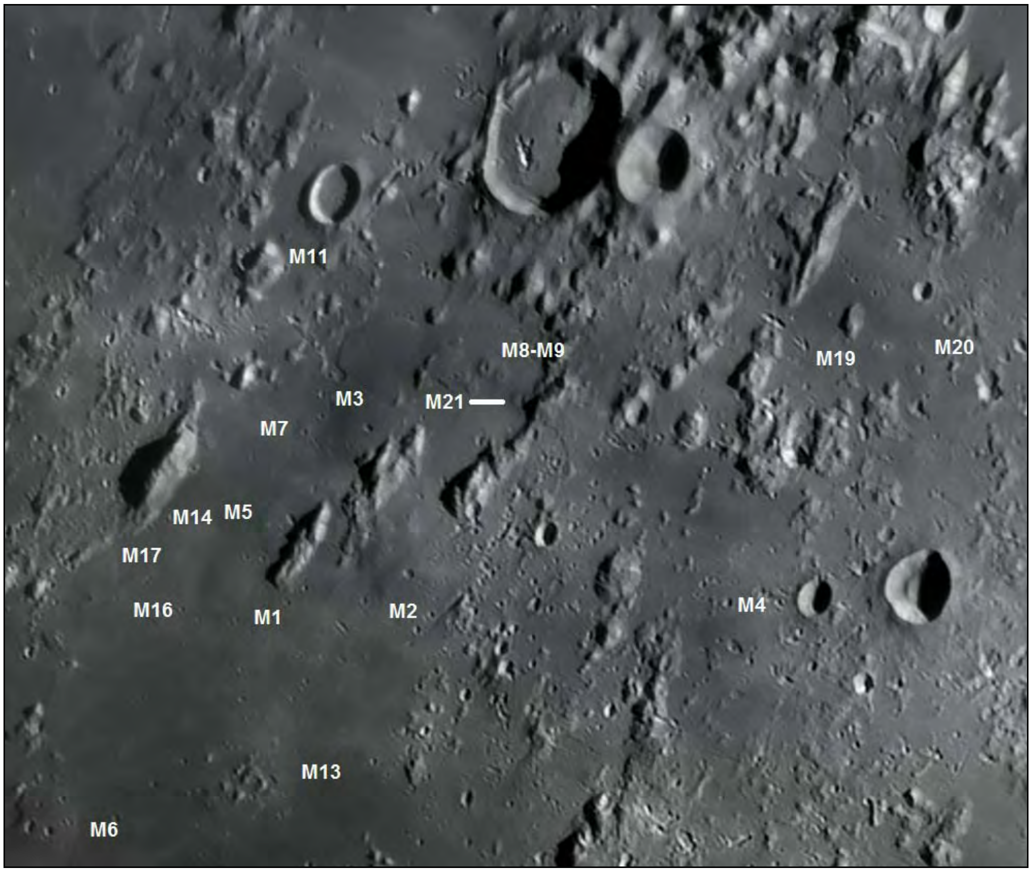


Figure 1. Image by Carmelo Zannelli (Italy) showing the dome M21, marked by white line, and the domes termed M1, M2, M3, M4, M5, M6, M7, M8-M9, M11, M13, M14, M16-M17 and M19-M20.

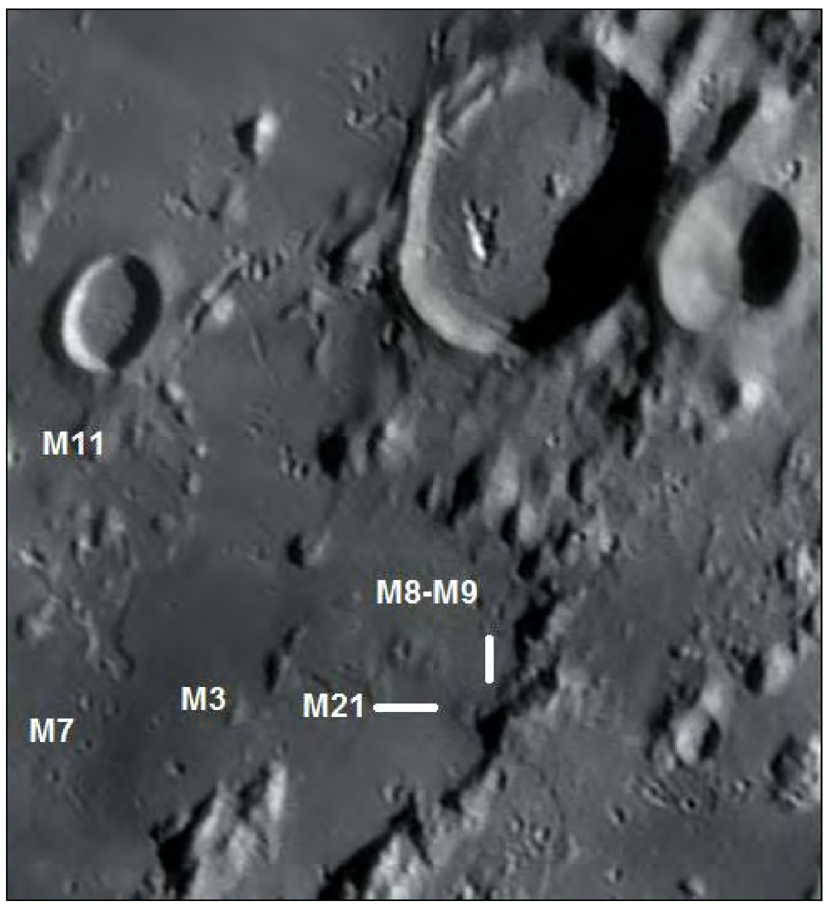


Figure 2. Crop of the previous image, including the examined dome M21 and the nearby domes M3, M7, M8-M9 and M11.

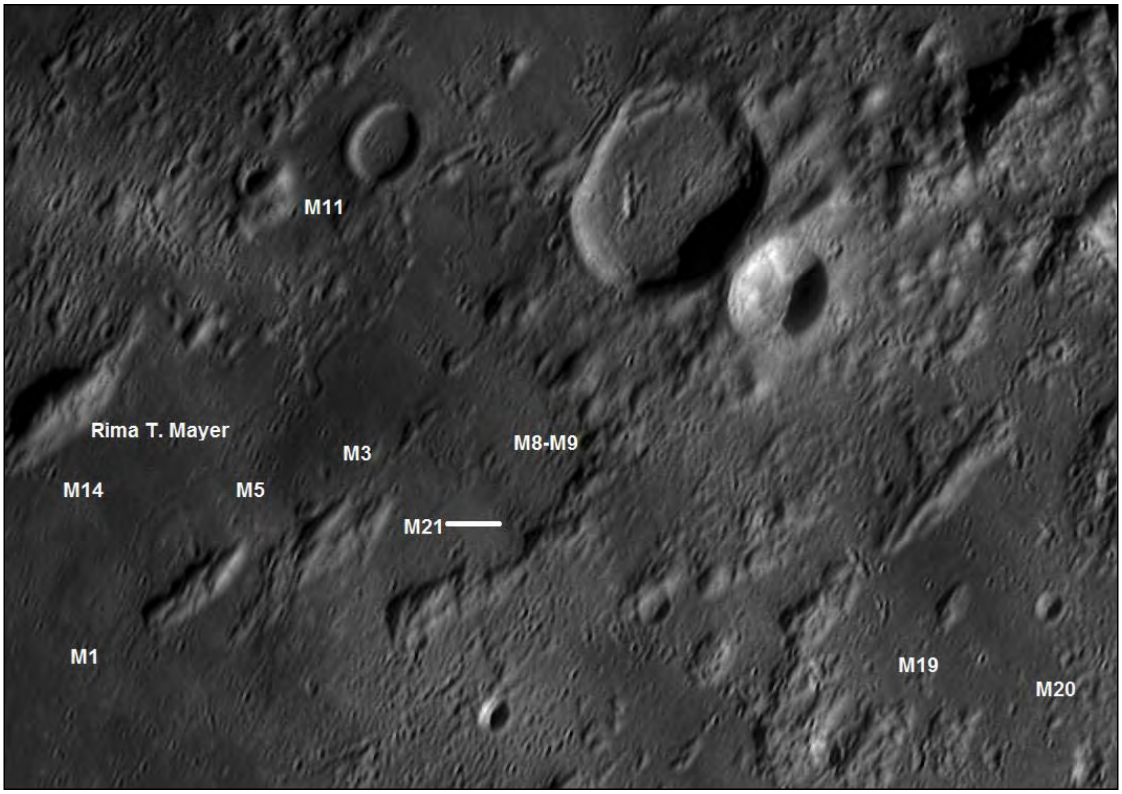
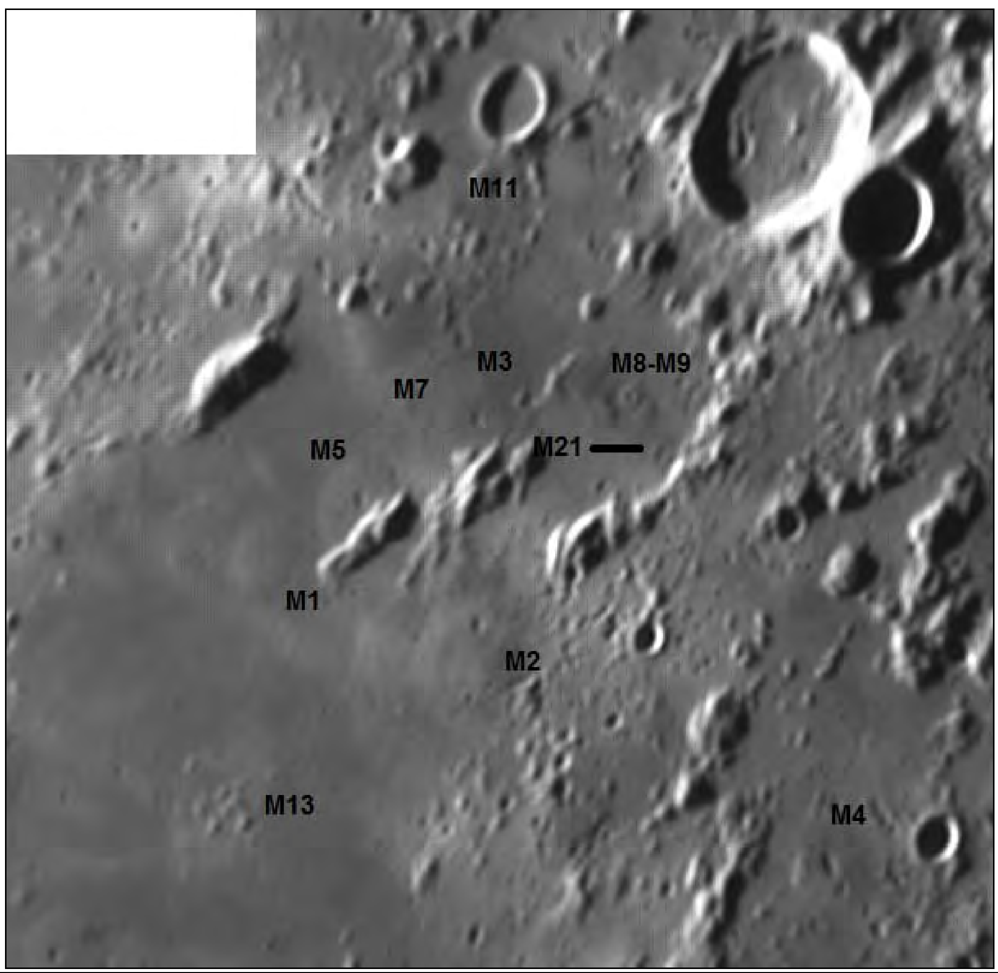


Figure 3. Image by Raffaele Barzacchi showing the dome M21 marked by white line, the Rima T. Mayer and the domes M1, M3, M5, M8-M9,M11, M14, M19 and M20.

Figure 4. Image by Jim Phillips showing under higher solar illumination angle the dome M21 marked by black line and the domes M1, M2, M3, M4, M5, M7, M8-M9, M11 and M13.



domes, which have already been measured in previous studies [1-7], under higher solar angle. The image in Figure 4 was taken by Phillips using a TMB 10-in. (254 mm) refractor on September 25, 2016 and shows M21 and several lunar domes.

Morphometric Properties

The new global topographic map of the Moon obtained by the Lunar Reconnaissance Orbiter (LRO) is the principal source of topographic information used in this study. Associated topographic profile of the examined dome was extracted from the GLD100 database using the Quickmap LRO global basemap (*http://target.lroc.asu.edu/da/qmap.html*). The 3D reconstruction using WAC mosaic draped on top of the global WAC-derived elevation model (GLD100) is shown in Figures 5a and 5b. The dome height, determined using the cross-sectional profile in E-W direction (Figure 6), amounts to 85 ± 10 m, while the average slope angle corresponds to 1.7° ± 0.1°.

The summit crater of M21 has a diameter Dc of 2.0 ± 0.3 km, while its depth corresponds to 80 m (Figure 6). Note that the depth is significantly different from the D/5 ratio typical for

Lunar Dome Classification System

Effusive Domes

Class A domes are small and shallow and formed by high-TiO_2 lavas of low viscosity, erupting at high effusion rates over very short periods of time, resulting in edifices of low volume.

Class B domes consist of lavas of intermediate to high viscosity and moderate TiO_2 content, erupting at low to intermediate effusion rates. If the effusion process continues over a long period of time, steep flank slopes and high volumes may occur (class B_1), while short periods of effusion result in shallower edifices of lower volume (class B_2).

Class C domes are formed out of low-TiO_2 (class C_1) or high-TiO_2 (class C_2) lavas building up edifices of large diameter but shallow flank slope. These at shapes are due to low lava viscosities and high effusion rates.

Class E domes represent the smallest volcanic edifices formed by effusive mechanisms (diameter < 6 km). In analogy to class B, the class E domes are subdivided into subclasses E_1 and E_2, denoting the steep-sided flank slope larger than 2° and the shallow edifices of this class, respectively.

Class D comprises the very complex, shallow but large and voluminous edifices Arago α and ß, which were most probably formed during several subsequent effusion stages, while classes A-E describe simple, likely monogenetic effusive domes.

Class G comprises the highland domes, which have highland-like spectral signatures and high flank slopes of 5°–15°, represented by Gruithuisen and Mairan highland domes.

Class H is represented by the non-monogenetic Marius domes, subdivided into three different classes. Small domes of less than 5 km diameter belong to subclass H_1. The irregular shapes of domes of subclass H_2 with more than 5 km diameter and flank slopes below 5° indicate a formation during several effusive episodes. Domes of subclass H_3 have diameters comparable to those of monogenetic class B_1 domes, but their flank slopes are all steeper than 5° and reach values of up to 9°.

Putative Intrusive Domes

Lunar domes with very low flank slopes differ considerably from the more typical lunar effusive domes. Some of these domes are exceptionally large, and many of them are associated with faults or linear rilles of presumably tensional origin, while they do not show summit pits. A reliable discriminative criterion is the circularity of the dome outline: these domes are elongated and with low slopes (< 0.9°). The putative intrusive domes have circularity values below 0.8, while the circularity is always higher than 0.9 for the effusive domes having flank slopes below 0.9° and displaying effusive vents.

Class In1 comprises large domes with diameters above 25 km and flank slopes of 0.2°–0.6° and have linear o curvilinear rilles traversing the summit.

Class In2 is made up by smaller and slightly steeper domes with diameters of 10-15 km and flank slopes between 0.4° and 0.9°.

Class In3 comprises low domes with diameters of 13-20 km and flank slopes below 0.3°.

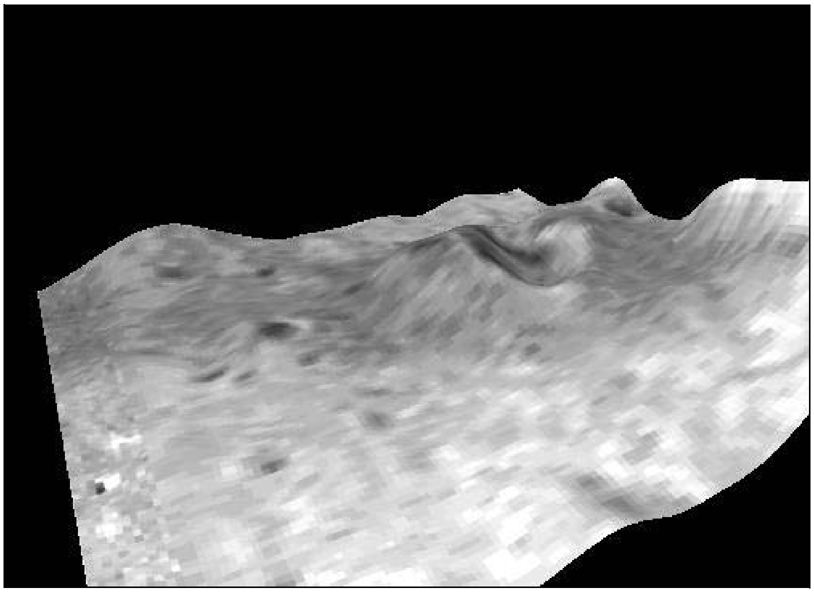
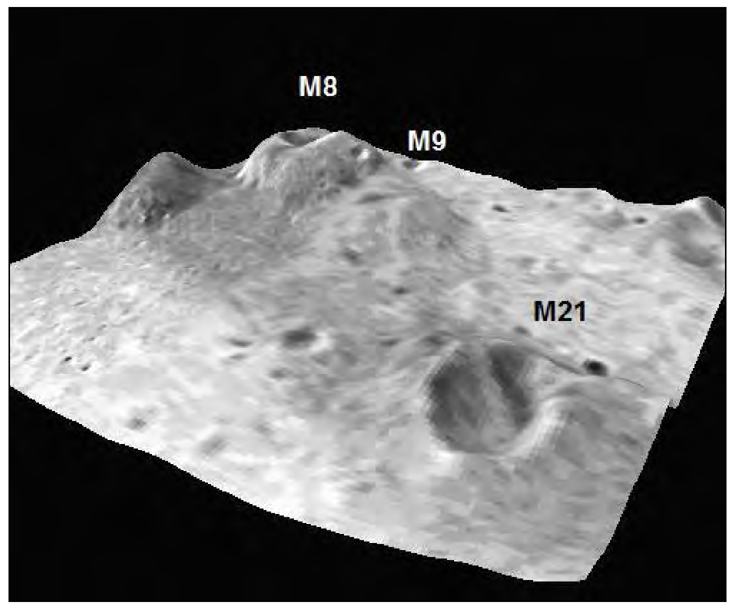


Figure 5a. 3D reconstruction. The elevation of the dome M21 corresponds to 85 ± 10 m. The vertical axis is 10 times exaggerated.

Figure 5b. 3D reconstruction of M8-M9 and M21. The vertical axis is 10 times exaggerated.



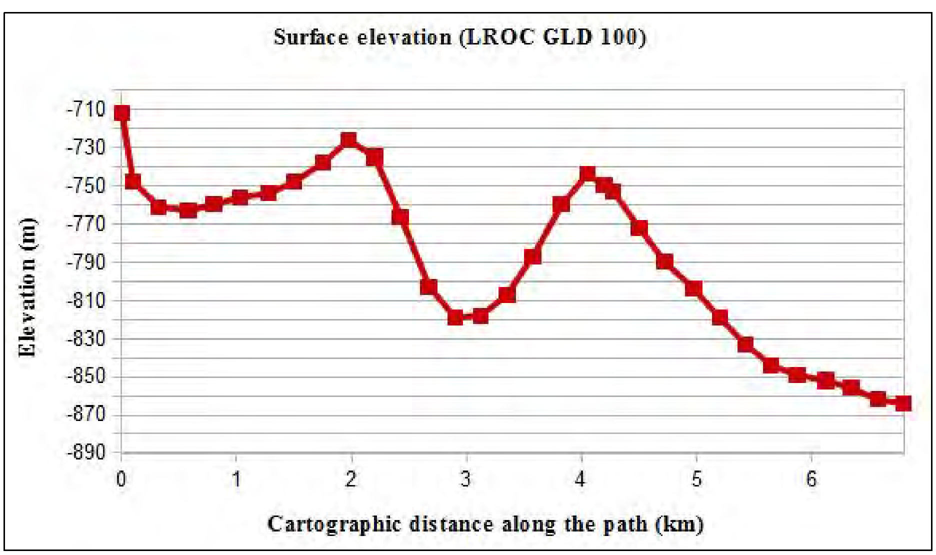


Figure 6. Cross-sectional profile in E-W direction of the dome M21.

small fresh impact craters of similar diameter [9]. The location of the shallow pit crater on a typical domical relief is furthermore suggestive of a volcanic origin. According to the empirical relation between vent diameter and dome base diameter for effusive mare domes [2], $D_c = 0.12D + 1.17$ (D and Dc in kilometers and with a correlation coefficient of 0.74), the expected value for the pit crater diameter corresponds to 1.9 km, given the dome diameter of D = 5.75 km, which is in good agreement with our measured values of Dc (2.0 km). To determine the morphometric properties of the dome, we also make use of an image-based 3D reconstruction approach which relies on a combination of photoclinometry and shape from shading techniques [1, 8]. This method takes into account the geometric configuration of camera, light source, and the surface normal, as well as the reflectance properties of the surface to be reconstructed, as described in our previous article in this journal [10]. The height h of M21 was thus obtained by measuring the altitude difference in the reconstructed 3D profile between the dome summit and the surrounding surface, taking into account the curvature of the lunar surface. The average flank slope ζ is determined according to: $\zeta = \arctan 2h/D$. We have obtained the 3D reconstruction shown in Figure 7.

Note that dome M21 is not reported in the USGS map I-515 [11]. In the revised catalogue of lunar domes by Kapral and Garfinkle [12], a dome is reported at coordinates 29.35° W and 13.77° N (termed Tobias Mayer 18) with a diameter of only 3 km and with a height of 200 m. Our measurements, computed from our CCD images and probes data, indicate a different base diameter of 5.75 km and a different height of 85 m as described above. Thus, the last published ALPO catalogue probably contains errors and incomplete data. When ALPO and the BAA first began their dome catalogue in the 1960s, observers were using different maps. This led to the fact that some of the domes in the catalogue are actually multiple observations of the same dome, and different and wrong coordinates and heights values are given.

Spectral Properties

For spectral analysis, we utilize the Clementine UVVIS dataset. For all spectral data extracted in this study, the size of the sample area on the lunar surface was set to 1.5 x 1.5 km^2. Variations in soil composition, maturity, particle size and viewing geometry are indicated by the reflectance R_{750} at 750 nm wavelength. Another important spectral parameter is the R_{415}/R_{750} ratio, which is correlated with the variations in TiO_2 content of mare soils. The third regarded spectral parameter, the R_{950}/R_{750} ratio, is related to the strength of the mafic absorption band, representing a measure for the FeO content of the soil and being also sensitive to the optical maturity of mare and highland materials [13].The Clementine UVVIS data reveal that M21 appears spectrally red. It has a 750 nm reflectance of $R_{750} = 0.1222$, a moderate value for the UVVIS color ratio of $R_{415}/R_{750} = 0.5746$, indicating a low TiO_2 content, and a weak mafic absorption with $R_{950}/R_{750} = 1.0024$.

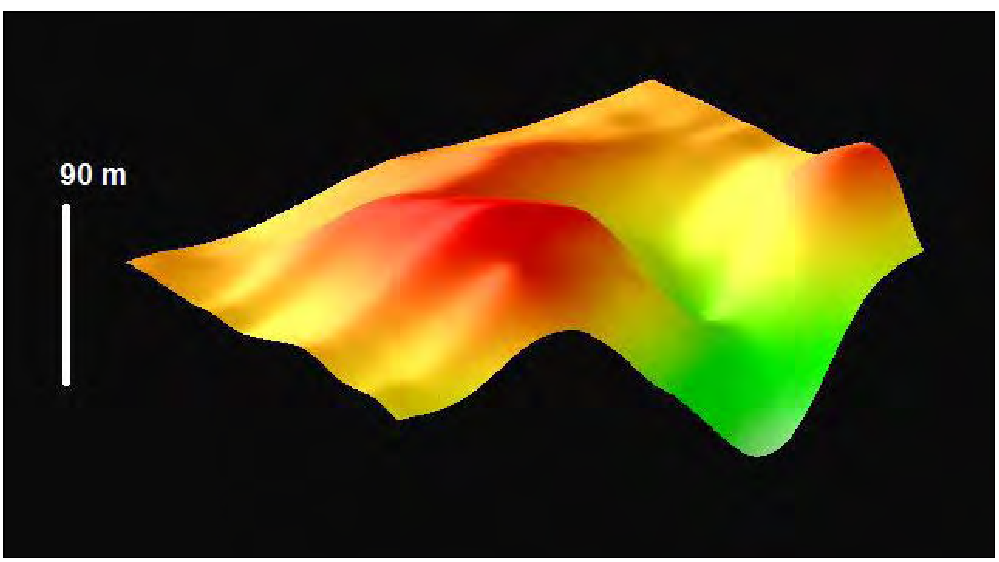


Figure 7. 3D reconstruction derived for the dome M21 based on shape from shading (SfS) approach using the CCD image taken by Zannelli on May 25, 2018 at 21:36 UT (Fig. 1). The vertical axis is 10 times exaggerated.

The Christiansen Feature (CF) from gridded data record (GDR) level 3 data product of Diviner Lunar Radiometer Experiment/Lunar Reconnaissance Orbiter (DLRE/LRO) data were used for further analysis. The Lunar Reconnaissance Orbiter's (LRO) Diviner Lunar Radiometer Experiment has a spatial resolution of 950 m/pixel. Diviner produces thermal emissivity data, and can provide compositional information from three wavelengths centered on 8 µm which can be used to characterize the Christiansen Feature (CF), which is directly sensitive to silicate mineralogy and the bulk SiO_2 content [14]. Silicic minerals and lithologies exhibit shorter wavelength positions at the 8 µm channel. For the study area, CF values of 8 µm are towards longer wavelength (CF~8.30 µm) indicating less a silicic composition and a basaltic composition [14]. Average CF value of 8.16 µm are consistent with a mixture of plagioclase and some pyroxene, while the average CF values of maria basalts range from 8.3-8.4 µm.

Results and Discussion

We have used the basic classification and mapping introduced in previous studies by the Geological Lunar Research (GLR) group, including the distinction between effusive domes and putative intrusive domes, based on physical modeling [1]. These models have been routinely used for estimating the rheologic properties and dike geometries in previous studies by some of us and reported in the book *Lunar Domes: Properties and Formation Processes* published by Springer [1], where more detailed explanations can be found. Wilson and Head provide a quantitative treatment of such dome-forming eruptions [15]. This model estimates the yield strength, i.e., the pressure or stress that must be exceeded for the lava to flow, the plastic viscosity yielding a measure for the fluidity of the erupted lava, the effusion rate E, i.e., the lava volume erupted per second, and the duration T = V/E of the effusion process. This model relies on the morphometric dome properties and several physical constants such as the lava density, the acceleration due to gravity, and the thermal diffusivity of the lava. In the computation, we assume a magma density of 2,800 kg m^{-3}. Based on the morphometric properties of M21 we obtain a moderate lava viscosity of 2.2 x 10^5 Pa s, an effusion rate of E = 100 m^3 s^{-1}, and a duration of the effusion process of T = 0.35 years. The magma rise speed amounts to U = 4.3 x 10^{-5} m s^{-1} and the dike width and length to 22 m and 100 km, respectively. Three rheologic groups of effusive lunar mare domes [1-3] differ from each other by their rheologic properties and associated dike dimensions, where the basic discriminative parameter is the lava viscosity. The first group R_1, is characterized by lava viscosities of 10^4 - 10^6 Pa s, magma rise speeds of 10^{-5} - 10^{-3} m s^{-1}, dike widths around 10-30 m, and dike lengths between about 30 and 200 km.

Rheologic group R_2 is characterized by low lava viscosities between 10^2 and 10^4 Pa s, fast magma ascent (U > 10^{-3} m s^{-1}), narrow (W = 1-4 m) and short (L = 7-20 km) feeder dikes.

The third group, R_3, is made up of domes which formed from highly viscous lavas of 10^6-10^8 Pa s, ascending at very low speeds of 10^{-6} - 10^{-5} m s^{-1} through broad dikes of several tens to 200 m width and 100-200 km length. With its moderate lava viscosity of 2.2 x 10^5 Pa s and fairly broad (W = 22 m) and long (L = 100 km) feeder dike, dome M21 clearly belongs to rheologic group R_1. If it is assumed that the vertical extension of a lunar dike is comparable to its length L [16], the magma which formed M21 originated in the upper lunar mantle, well below the crust. Based on the spectral and morphometric data obtained in this study, dome M21 belongs to class E1 with a tendency to class E_2 in the classification scheme of lunar mare domes [1].

A short summary of the classification scheme appears earlier in this paper [10]. Nearby domes M8 and M9 are spectrally red but steeper than M21 and with their higher slopes, corresponding to 3.2°- 3.5° and small diameters < 6 km, belong to class E_1.

Class E domes represent the smallest volcanic edifices formed by effusive mechanisms (diameter < 6 km). The class E domes are subdivided into subclasses E_1 and E_2, denoting the steep-sided flank slope larger than 2° and the shallow edifices of this class, respectively [1].

In this work, data from the M^3 instrument were used to derive spectral data that highlight mineralogical characteristics of lunar volcanic materials. Chandrayaan-1's *Moon Mineralogy Mapper* (M^3) is an imaging reflectance spectrometer that can detect 85 channels between 460 to 3,000 nm, and has a spatial resolution of 140 and 280 meters per pixel [17]. Data have been obtained through the M^3 calibration pipeline to produce reflectance with photometric and geometric corrections using an image set taken during the optical period OP1B. For deriving the spectral parameters, the photometrically corrected Level 2 data of the PDS imaging node have been used [17]. In order to characterize the 1,000 nm band, we use a continuum removal method that enhances the characteristic of the 1,000 nm absorption band and more accurately shows the position of the band center.

Pyroxenes are characterized by distinct absorption bands around 1,000 and 2,000 nm, with low-calcium pyroxenes displaying bands shifted to slightly shorter wavelengths, and high-calcium pyroxenes exhibiting bands at slightly longer wavelengths with increasing Ca and Fe [18]. Olivine has a complex absorption centered near 1,000 nm, with no absorption at 2,000 nm. Therefore, olivine-rich lunar deposits are characterized by a broad 1,000 nm absorption band which is enhanced relative to the 2,000 nm band. The 1,000 nm band center of lunar glass is generally shifted to longer wavelengths when compared to pyroxene, and the 2,000 nm band center to shorter wavelengths. Thus, two 1,000 and 2,000 nm band center positions of lunar glasses will typically appear close together than those of pyroxenes [18].

The examined volcanic dome displays a spectrum (Figure 8) with a 1,000 nm absorption centered at 990 nm and 2,000 nm absorption centered at 2,130 nm. Thus, the spectrum indicates a classic basaltic signature without evidence of volcanic glasses signature. The excellent images taken by Zannelli and Barzacchi demonstrate as high resolution CCD imagery of the elusive lunar domes is useful for the recognition of non-

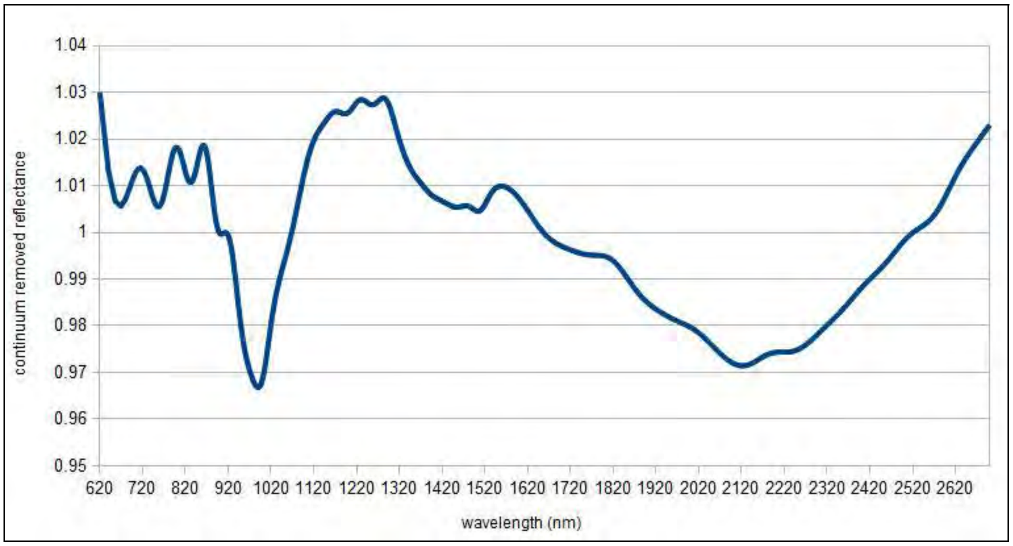


Figure 8. Spectral analysis of dome M21.

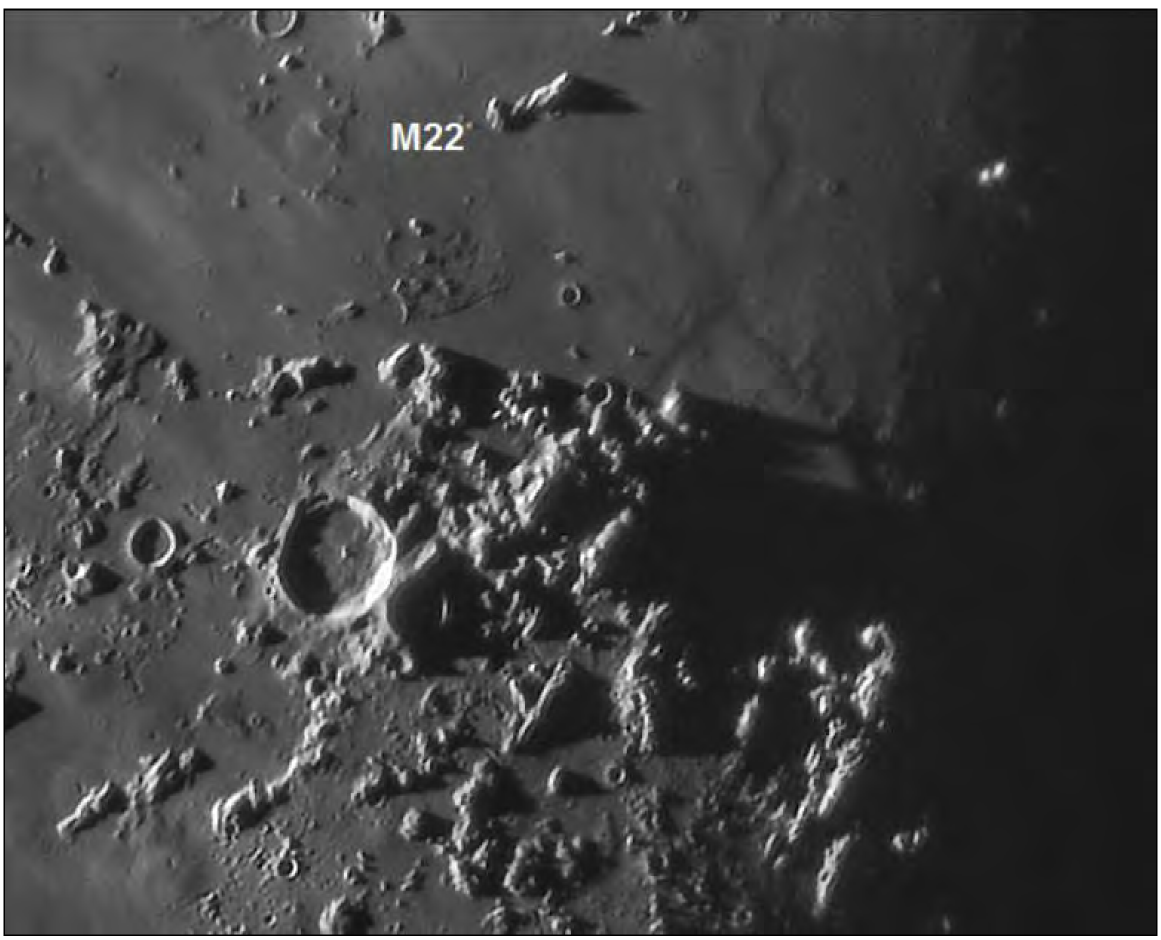


Figure 9. Another possible suspected dome (M22) under investigation. Image taken by Guy Heinen on May 25, 2018 at 21:36 UT using a Celestron C14 (355 mm) Starbright SCT.

cataloged or non-characterized/classified domes. This area of the Moon, from Hortensius to Tobias Mayer, contains large numbers of domes (see the Appendix). This area has been searched extensively many times in the past and it is exciting to report that in spite of this, another dome has been characterized right in the center of this area. We have updated the catalog and the domes maps which are online at the link: *http://hortdomes.blogspot.com/*.

Appendix

According to the classification scheme [1], the domes termed as M1, M2, M3, M5, M6, M10 and M15 belong to class C1. Their low slopes suggest high effusion rates of the erupted lavas. M1, M3, and M5 have volumes smaller than 12 km^3, while M2, M6, M10 and M15 have volumes larger than 20 km^3. With their smaller diameters and steeper slopes, domes M4, M11, and M12 (Milichius π) belong to class B_1. M11 and M12 (Milichius π) are characterized by steep slopes > 2.5°.

Dome M7 is morphometrically similar to the small, shallow, low-volume Class A domes of the Cauchy and Arago dome fields, but consists of spectrally red material, belonging to class E_2. Domes M8 and M9 with slopes corresponding to 3.2°- 3.5° and small diameters < 6km belong to class E_1. Dome M13, with its large diameter and low slope of only 0.41° is considered a putative intrusive dome and belong to class In1. The inferred rheologic properties of M16 are comparable to those of the dome M7 in the Milichius region for small diameter, low-volume and spectrally red material, belonging to class E_2, while the domes M17 and M18 belong to class C_1. Dome M20, like M17 and M18, is a typical mare dome and for their rheologic properties is similar to most domes found in Milichius-Tobias Mayer region belonging to class C_1, while dome M19 belongs to class C_1 with a tendency

Table of Morphometric Properties of the Domes in Milichius (M1-M21) and Hortensius (H1-H11)

Dome	longitude [°]	latitude [°]	slope [°]	D [km]	h [m]
Milichius 1	-31.58	12.76	0.86± 0.1	13.4± 0.5	100± 10
Milichius 2	-30.05	12.79	1.80± 0.1	20.1± 0.5	320± 30
Milichius 3	-30.43	13.78	1.40± 0.1	15.6± 0.5	190± 20
Milichius 4	-27.39	12.04	1.27± 0.1	15.3± 0.5	170± 15
Milichius 5	-31.01	13.24	0.60± 0.1	15.3± 0.5	80± 10
Milichius 6	-32.74	11.48	1.34± 0.1	19.7± 0.5	230± 20
Milichius 7	-30.96	13.75	0.99± 0.1	5.2± 0.5	45± 5
Milichius 8	-29.50	14.06	3.46± 0.3	4.3± 0.5	130± 10
Milichius 9	-29.40	13.98	3.15± 0.3	4.0± 0.5	110± 10
Milichius 10	-31.70	14.06	0.84± 0.1	19.0± 0.5	140± 15
Milichius 11	-31.08	14.77	2.80± 0.3	6.0± 0.5	150± 15
Milichius 12	-31.20	10.08	2.72± 0.2	9.7± 0.5	230± 20
Milichius 13	-31.53	11.68	0.41± 0.1	27.8± 0.5	100± 10
Milichius 14	-32.13	12.76	0.27± 0.1	14.8± 0.5	35± 5
Milichius 15	-25.40	10.10	0.60± 0.1	210.± 0.5	110± 10
Milichius 16	-32.41	12.85	1.14± 0.1	5.0± 0.5	50± 5
Milichius 17	-32.58	13.02	0.93± 0.1	11.0± 0.5	90± 10
Milichius 18	-32.02	10.60	0.84± 0.1	12.3± 0.5	90± 10
Milichius 19	-26.11	13.64	1.03± 0.1	10.0± 0.5	90± 10
Milichius 20	-26.95	13.62	0.60± 0.1	9.5± 0.5	50± 5
Milichius 21	-29.24	13.78	1.70± 0.1	5.75±0.3	85±10
Hortensius 1	-28.41	7.18	1.89± 0.1	8.5 ± 0.5	140±15
Hortensius 2	-28.01	7.12	3.45± 0.3	7.6 ± 0.5	230±20
Hortensius 3	-27.78	7.59	2.05± 0.2	12.3 ± 0.5	220±20
Hortensius 4	-27.51	7.47	3.21± 0.3	6.8 ± 0.5	190±10
Hortensius 5	-27.54	7.87	5.39± 0.5	8.5 ± 0.5	400±40
Hortensius 6	-27.34	7.82	3.57± 0.3	12.5 ± 0.5	390±40
Hortensius 7	-25.17	6.07	1.12± 0.1	7.8 ± 0.3	80±10
Hortensius 8	-27.86	5.38	1.18± 0.1	6.0± 0.5	65±10
Hortensius 9	-27.88	5.62	3.33± 0.3	3.3± 0.5	97±10
Hortensius 10	-27.74	5.00	1.98± 0.2	8.2± 0.5	142±10
Hortensius 11	-26.87°	6.88	0.83± 0.1	8.3± 0.5	60±10

towards class C_2. Dome M21, examined in the current study, belongs to class E_2.

In the Hortensius domes field, we have characterized 11 volcanic edifices. The dome Hortensius 7 (H7) is located near the crater Hortensius E, with a height of 80 ± 10 m, and belongs to class B_2. Dome H1, like H7, with its shallower slope and lower volume belongs to class B_2. Domes H2 through H6 belong to class B_1 according to their steep slopes (comprised from 2.1° and 5.4°). Domes H8 and H9, with slopes corresponding to 1.18° and 3.33°, belong to class E_2 and E_1 respectively, while the dome H10 belongs to class C_2. Dome H11 belongs to class C_1 with a tendency to class C_2 due to smaller diameter and edifice volume.

Another possible dome has been recently imaged by Guy Heinen (from Linger, Luxembourg) on May 25, 2018 at 21:36 UT using a Celestron C14 (355 mm) Starbright (355 mm) SCT, a 2x Baader-Zeiss Abbe barlow and a Baader R filter. It lies at coordinates 18.94° N and 30.36° W (Figure 9). Based on available data, it displays an elongated shape and a base diameter of about 20x25 km (preliminary analysis) with a height of about 140 m. At the present, we await further images of this feature in order to characterize it with more consolidated measures; we have termed the feature M22.

References

[1] Lena, R., Wöhler, C., Phillips, J., Chiocchetta, M.T., 2013. "Lunar domes: Properties and Formation Processes," Springer Praxis Books. http://www.springer.com/gp/book/9788847026360

[2] Wöhler, C., Lena, R., Lazzarotti, P., Phillips, J., Wirths, M., & Pujic, Z., 2006. "A combined spectrophotometric and morphometric study of the lunar mare dome fields near Cauchy, Arago, Hortensius, and Milichius.", *Icarus*, 183, 237-264. https://www.sciencedirect.com/science/article/pii/S0019103506000960?via%3Dihub

[3] Wöhler, C., Lena, R., & Phillips, J., 2007. "Formation of lunar mare domes along crustal fractures: Rheologic conditions, dimensions of feeder dikes, and the role of magma evolution." *Icarus*, 189 (2), 279-307. http://adsabs.harvard.edu/abs/2007Icar..189..279W

[4] Phillips, J. and Lena, R. 2016. "Domes in Mare Insularum: Morphometry and Mode of Emplacement." Lunar and Planetary Science Conference 2016 http://www.hou.usra.edu/meetings/lpsc2016/pdf/1006.pdf

[5] Lena, R., 2017. Lunar domes (Part IX): domes in Mare Insularum, the Milichius domes field, BAA LS circular March 2017.

[6] Lena, R., Wirths, M., Mallama, A. 2016. "Lunar domes to the south of Hortensius: Morphometry and mode of formation". Lunar and Planetary Science Conference 2016 https://www.hou.usra.edu/meetings/lpsc2016/pdf/1004.pdf

[7] Wirths, M., Lena, R., Mallama, A, 2016. "A study about a lunar dome near Hortensius: Morphometry and mode of formation". Lunar and Planetary Science Conference 2016 https://www.hou.usra.edu/meetings/lpsc2016/pdf/1005.pdf

[8] Horn, B. K. P., "Height and Gradient from Shading", MIT technical report, AI memo no. 1105A, 1989. http://people.csail.mit.edu/people/bkph/AIM/AIM-1105A-TEX.pdf

[9] Wood, C., Andersson, L., 1978. "New morphometric data for fresh lunar craters", Proceeding of the 9th Lunar and Planetary Science Conference, pp. 3669-3689. http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1978LPSC....9.3669W&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf

[10] Lena, R., Philips, J., 2018. Lunar Domes -The Marius Shield. *Journal of the Assn. of Lunar & Planetary Observers*, 60 (4), pp. 52-67.

[11] Schmitt, H. H, Trask, N. J., Shoemaker, E. M.: "Geologic Map of the Copernicus Quadrangle of the Moon". USGS map I-515 (1967). https://www.lpi.usra.edu/resources/mapcatalog/usgs/I515/72dpi.jpg

[12] Kapral, C., Garfinkle, R., 2005: "GLR Catalog of Lunar Domes". https://digilander.libero.it/glrgroup/kapralcatalog.pdf

[13] Lucey, P.G., Blewett, D.T., Hawke, B.R., 1998. "Mapping the FeO and TiO2 content of the lunar surface with multispectral imagery". *Journal of Geophysical Research*. 103 (E2), 3679-3699. http://adsabs.harvard.edu/abs/1998JGR...103.3679L

[14] Greenhagen, B.T., Lucey, P.G., Wyatt, M.B., Glotch, T.D., Allen, C.C., Arnold, J.A., Bandfield, J.L., Bowles, N.E., Donaldson Hanna, K.L., Hayne, P.O., Song, E., Thomas, I.R., Paige, D.A., 2010. "Global silicate mineralogy of the Moon from the Diviner Lunar Radiometer". *Science.* 329, 1507-1509 http://science.sciencemag.org/content/329/5998/1507

[15] Wilson, L., & Head, J. W., 2003. "Lunar Gruithuisen and Mairan domes: Rheology and mode of emplacement". *Journal of Geophysical Research* Atmospheres, 108 (E2), 5012, doi:10.1029/2002JE001909. https://www.researchgate.net/journal/0148-0227_Journal_of_Geophysical_Research_Atmospheres

[16] Jackson, P.A., Wilson, L., Head, J.W., 1997. "The use of magnetic signatures in identifying shallow intrusions on the Moon". Conference Paper, 28th Annual Lunar and Planetary Science Conference, abstract #1429. https://www.lpi.usra.edu/meetings/lpsc97/pdf/1429.PDF

[17] Isaacson, P., Besse, S., Petro, N., Nettles, J., and the M3 Team: "M3 Overview and Working with M3 Data". November 2011". http://pds-imaging.jpl.nasa.gov/documentation/Isaacson_M3_Workshop_Final.pdf.

[18] Besse, S., Sunshine, J.M. and L. R. Gaddis, 2014. "Volcanic glass signatures in spectroscopic survey of newly proposed lunar pyroclastic deposits". *Journal of Geophysical Research: Planets.* 119, doi:10.1002/2013JE004537. http://planetary.brown.edu/pdfs/Besse-Lunar%20Pyroclastic%20Glasses-jgre20209-1.pdf

ALPO Lunar Dome Observation Form

Submit electronically (attach images and scanned drawings to e-mail) to:
Raffaello.Lena@alpo-astronomy.org
or via regular mail to:
Raffaello Lena
Cartesio 144 D
00137 Rome, Italy

Observers Name:	**Last:**					**First:**				
Date: (UD)	**Month:**			**Day:**				**Year:**		
Time: (UT)	**(UT) Hours:**					**(UT) Minutes:**				
Colongitude:										
Region Observed:										
Telescope:	**Size (Inches or Cm.):**					**Type:**				
Eyepieces Used:									**Filters:**	
Seeing (Circle)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Transparency:										
Type of Observation (list details):	**Visual:**					**Photographic:**				

Domes Observed (Positions)

Xi	Eta	OR	Lunar Long.	Lunar Lat.

Notes: (**Include observer location here (City, State, and Country):** Use back if necessary):

____

____

____

____

____

Papers & Presentations

Galilean Satellite Eclipse Timings: 2007/09-2010/11 Summary

By: John E. Westfall,
Program Coordinator,
Galilean Satellite Eclipses
johnwestfall@comcast.net

Abstract

The 2007/09, 2009/10 and 2010/11 Apparitions have been reported on individually. This report compares the three apparitions with each other and provides overall statistics of all three as well as summarizes our results for the 2001/02-2010/11 period.

Introduction

The three apparitions summarized here comprise the 31st - 33rd observed by our program, whose methodology has been described earlier (Westfall 2009:40, 42, 48; 2012, 2015, 2016a and 2016b). Besides including the ongoing eclipses of Io, Europa and Ganymede, the 2007/09-2010/11 apparitions included one full series of eclipses of Callisto.

Observations and Observers

The 206 timings received for 2007/09-2010/11 brought our 33-apparition total to 10,944 observations, and reflect a welcome increase from the 155 received for the three 2004/05-2006/07 apparitions. Table 1 gives descriptive statistics for the observations made during the three apparitions covered in this report.

Also gratifying is the more even balance between the number of observations made following opposition and of those made before. Still, a bias remains, as well as for more reappearance timings than disappearance timings, which has held throughout the history of our program. This time inequality is understandable, given the inconvenience of observing after midnight, but the statistical significance of our results would be improved were the observations more evenly distributed.

Table 2 lists the participants in our program during 2007/09-2010/11, with their nationalities, instrument apertures and number of timings, both short-term and long-term.

It is pleasing to see that five of our six observers have continued with our program for eleven or more apparitions, and four have also contributed well over one hundred timings each. The international basis of our program continues, with half the observers residing outside the United States.

The contributors all used moderate-size telescopes in the aperture range 6.3-35.6 cm. The mean aperture, weighted by number of observations, was 22.6 cm, while the median aperture was 14.0 cm. Half of the observers used more than one telescope during the observing period.

Table 1. Number of Eclipse Timings, 2007/09-2010/11 Apparitions

Quantity	Apparition			
	2007/09	2009/10	2010/11	2007-11
Number of Timings	53	73	80	206
Timings before Opposition	24 (45%)	24 (33%)	40 (50%)	88 [43%]
Timings after Opposition	29 (55%)	49 (67%)	40 (50%)	118 [57%]
Disappearance Timings	23 (43%)	27 (37%)	41 (51%)	91 [44%]
Reappearance Timings	30 (57%)	46 (63%)	39 (49%)	115 [56%]

All Readers

Your comments, questions, etc., about this report are appreciated. Please send them to: *ken.poshedly@alpo-astronomy.org* for publication in the next Journal.

Online Features

Left-click your mouse on:

The author's e-mail address in blue text to contact the author of this article.

The references in blue text to jump to source material or information about that source material (Internet connection must be ON).

Observing Scales

Standard ALPO Scale of Intensity:
0.0 = Completely black
10.0 = Very brightest features
Intermediate values are assigned along the scale to account for observed intensity of features

ALPO Scale of Seeing Conditions:
0 = Worst
10 = Perfect

Indeed, one contributor, Dietmar Büttner, made double timings of eight events, timing each event with 10-cm and 6.3-cm refractors.

Timings Analysis: Satellite Positions

Table 3 gives the three-apparition mean results for the means, standard errors of the means, and medians of the differences ("residuals") between our timings and the IMCCE E-5 ephemeris. All the residuals were corrected for oblique contact with Jupiter's shadow at disappearance and reappearance, using the formula R' = R cos ', where R' is the corrected residual, R the original residual,

Table 2. Participating Observers, 2007/09-2010/11 Apparitions

Observer and Telescope				Apparition				ALPO Timing Program Total	
I.D. No.	Name	Nationality	Tel. Aper. (cm)	2007 -09	2009 -10	2010 -11	2007-2011 (Total)	No. of Appar.	No. of Timings
1	Abbott, A.P.	Canada	15	-	3	-	3	11	34
2a	Büttner, D	Germany	6.3	-	5	8	13	16	119
2b			10	-	5	4	9 (22)		
3	Haas, W.H.	USA (NM)	31	4	-	-	4	20	152
4a	Hays, R.H., Jr.	USA (IL)	13	2	4	5	11	21	327
4b			15	16	20	24	60 (71)		
5	Talbot, J.*	New Zealand	25	-	-	7	7	1	7
6a	Westfall, J.	USA (CA)	12.7	-	1	18	19	30	556
6b			35.6	31	35	14	80 (99)		
Timings per Observer				17.7	18.2	20.0	34.3		
* Video timings, KT&C 350BH camera at f/4									

Table 3. Mean Timing Residual Statistics, 2007/09-2010/11 Apparitions Combined

Satellite and Event	Quantity	Satellite and Event	Quantity
Io		**Ganymede**	
1D: No. of Timings	37 (32)	3D: No. of Timings	20 (18)
1D: Mean	+92.8±1.2s	3D: Mean	+280.4±9.1s
1D: Median	+92.7±2.6s	3D: Median	+284.7±7.9s
1R: No. of Timings	51 (41)	3R: No. of Timings	22 (20)
1R: Mean	-97.6±0.9s	3R: Mean	-219.6±7.7s
1R: Median	-98.5±1.0s	3R: Median	-221.8±15.2s
(1D+1R)/2: Means	-2.4±0.2s**	(3D+3R)/2: Means	+30.7±6.1s*
(1D+1R)/2: Medians	-2.9±1.1s	(3D+3R)/2: Medians	+35.6±4.9s**
Europa		**Callisto**	
2D: No. of Timings	25 (19)	4D: No. of Timings	9 (8)
2D: Mean	+93.2±10.4s	4D: Mean	+337.6±12.2s
2D: Median	+92.3±12.1s	4D: Median	+342.2±11.0s
2R: No. of Timings	30 (29)	4R: No. of Timings	12
2R: Mean	-122.4±5.2s	4R: Mean	-341.7±6.0s
2R: Median	-124.8±3.7s	4R: Median	-341.7±2.3s
(2D+2R)/2: Means	-14.5±7.9s	(4D+4R)/2: Means	-2.0±6.8s
(2D+2R)/2: Medians	-16.3±7.8s	(4D+4R)/2: Medians	+0.6±4.9s

Events are designated: 1 = Io, 2 = Europa, 3 = Ganymede and 4 = Callisto; D = disappearance, R = reappearance. Numbers of timings in parentheses are the numbers used in the analysis after those with unusually large residuals (most often due to poor observing conditions) were omitted. In the right-hand column, values are the means of means or medians of the three apparitions weighted equally; * shows a mean observed-predicted difference that is significantly different from 0 at the 5-percent level, while ** indicates a difference significant at the 1-percent level.

and ' the zenographic latitude of the satellite relative to Jupiter's shadow. This correction made a difference of at most a few seconds for Io and Europa, but could reach over a minute for Ganymede and several minutes for Callisto.

In the analysis and in order to reduce the effect of any remaining unusually late or early timings, we also calculated and averaged the medians of the residuals. The results for the medians never differed significantly from those for the means, confirming the normal distributions within the sets of timings. Summarizing the three-apparition period, comparing with the E-5 ephemeris, we find that Io events tended to occur 2.4 seconds early, while Ganymede events were about a half-minute late.

Since we are combining the results of three different apparitions, we need also to investigate whether the timings of the three apparitions differ significantly from each other. A nonparametric ANOVA (analysis of variance) was used to test for any such differences, with the results shown in Table 4, where "ns" indicates no significant difference, "*" a difference significant at the 5-percent level and "**" a difference significant at the 1-percent level.

A significant difference occurred in only one of the 22 comparisons, involving the disappearances of Europa. (The entries marked "n.a." could not be tested because only a single timing was made of Callisto disappearances during the 2007/09 Apparition.) All the datasets passed the Kolmogorov-Smirnov test for normality, excepting those seven comparisons where there were too few observations to perform the test (Ganymede disappearances in 2007/09 and 2009/10, Callisto disappearances in 2007/09, 2009/10 and 2010/11 and Callisto reappearances in 2007/09 and 2009/10).

Timings Analysis: Aperture Effect

In the majority of types of satellite events, for most of the previous apparitions analyzed that had a sufficient number of observations, telescope aperture had a statistically significant effect on our observers' timings. Larger instruments have tended to show disappearances later, and reappearances earlier, than smaller telescopes. Unfortunately the current data set does not permit a reliable analysis of any aperture effect; with over 80 percent of the timings for the three apparitions being made by only two observers, it is impossible to disentangle personal equation from aperture effects.

However, we can gain some idea of the magnitude of the aperture effect from experiments conducted by one observer during the 2009/10 and 2010/11 Apparitions. Dietmar Büttner of Chemnitz, Germany, timed eight events using two telescopes, 6.3-cm and 10-cm refractors, recording consistent differences between disappearance and reappearance timings, shown in Table 5. The difference between the two same-event timings was particularly large for the Callisto events on 2010 Sep 06, a result of the extremely oblique entrance and exit of the satellite from Jupiter's shadow (at zenographic latitudes of +73° and +72° respectively).

Long-Term Results

Correcting the timing residuals for oblique entry in or exit from Jupiter's shadow was found to make a significant difference in the observed positions of the satellites, while also reducing their standard errors. Thus we have gone back over the timings for the 2001/02-2006/07 Apparitions, correcting for oblique shadow contact and at the same time referring the observed times to the IMCCE E-5 ephemeris, making them comparable with our 2007/09-2010/11 results, as given in Table 6.

Table 4. Analysis of Variance Test for Inter-Apparition Timing Differences, 2007/09-2010/11 Apparitions

Event Type	Apparitions Compared		
	2007/09 vs. 2009/10	2007/09 vs. 2010/11	2009/10 vs. 2010/11
Io disappearances	ns	ns	ns
Io reappearances	ns	ns	ns
Europa disappearances	ns	ns	**
Europa reappearances	ns	ns	ns
Ganymede disappearances	ns	ns	ns
Ganymede reappearances	ns	ns	ns
Callisto disappearances	(n.a.)	(n.a.)	ns
Callisto reappearances	ns	ns	ns

Table 5. Two-Aperture Eclipse Timings by Dietmar Büttner, 2009/10 and 2010/11 Apparitions

Apparition	Event Type	Date	Recorded UT, 10-cm	Recorded UT, 6.3-cm	10-cm – 6.3-cm Results
2009/10	1R	2009 Aug 28	23:01:37	23:02:01	-24
	2R	2009 Aug 28	23:52:59	23:53:24	-25
	4D	2009 Sep 19	22:06:36	22:05:36	+60
	2R	2009 Sep 22	21:06:10	21:06:52	-42
	3D	2009 Oct 19	20:50:31	20:49:34	+57
2010/11	4D	2010 Sep 06	22:02:37	21:57:17	+320
	4R	2010 Sep 06	22:55:44	22:59:42	-238
	3D	2011 Jan 28	18:38:40	18:37:25	+75

Event types: 1 = Io, 2 = Europa, 3 = Ganymede, 4 = Callisto; D = disappearance, R = reappearance.

Io's observed position disagreed with the E-5 ephemeris in only two of the nine apparitions, in 2003/04 and 2004/05, and its nine-apparition mean position was only 1.46 seconds late relative to the ephemeris. Europa was more aberrant, significantly early in five apparitions and for the overall mean. Ganymede's results fluctuated, significantly early once and significantly late for three apparitions, but not significantly different from the ephemeris for the overall mean. Callisto underwent eclipses during only six of the nine apparitions, and its position could be analyzed for only four of those. In no case was the fourth satellite's position found to significantly disagree with the E-5 ephemeris.

Figure 1 graphs the values given in Table 6 in order to display any consistent trends over time. [Figure 1]

Figure 1 shows one-sigma uncertainty ranges centered on each mean, but we should remember that statistically significant differences need to exceed two sigma or more. Thus we cannot identify any consistent trend for Io, except that it tended to be late during 2003/04-2005/06. Europa, on the other hand, continued to be erratic as characterized the satellite throughout the 1975/76-2000/01 period. The second satellite's graph suggests a periodic error, being latest in 2004/05 and earliest in 2009/10 (a long-term periodicity of Europa's residuals relative to E-5 is also suggested by Figure 9 in Mallama et al. 2010). Ganymede's performance relative to the E-5 ephemeris was also erratic, particularly given its significant tardiness in 2007/09-2010/11; again a possible periodicity is hinted at. Finally, we can say little about Callisto's long-term orbital trend, chiefly because of the large uncertainties in the residual means, combined with the three-apparition gap in eclipse occurrences and the five-apparition gap in statistical analyses.

Conclusion

The analysis of our program's timings made during the three Jupiter apparitions, 2007/09-2010/11, showed that the times of eclipses by Jupiter of Io consistently did not differ significantly from the IMCCE E-5 ephemeris during each individual apparition, although its three-apparition mean indicated that Io averaged 2.4 seconds early in its orbit. Europa's observed timings, however, disagreed significantly from the ephemeris during two of the three apparitions (2007/09 and 2009/10),

Table 6. Timing Residual Statistics, 2001/02-2010/11 Apparitions

Apparition	Io	Europa	Ganymede	Callisto
2001/02	-0.04±1.74- (14,26)	-17.90±5.27** (5,16)	0.00±10.38- (10,13)	+24.24±14.54- (5,7)
2002/03	+0.86±2.37- (18,23)	-7.74±2.32** (5,16)	-9.11±10.58- (6,9)	+28.75±17.56- (2,6)
2003/04	+6.18±1.87** (7,14)	-2.06±3.06- (7,10)	-7.25±8.45- (7,8)	+49.00 (4,1)
2004/05	+10.44±2.80** (4,9)	+7.57±9.72- (2,7)	-12.16±11.81- (3,3)	-
2005/06	+5.50±2.75- (8,10)	-11.20±3.05** (5,2)	-13.06±6.72** (7,5)	-
2006/07	-2.58±1.58- (18,20)	-6.66±3.25- (5,12)	+3.85±7.36- (10,8)	-
2007/09	-2.26±1.71- (9,10)	-15.77±4.81** (5,7)	+37.20±8.88** (3,5)	-8.84 (1,3)
2009/10	-2.88±1.54- (9,19)	-27.44±4.00** (6,11)	+35.62±9.25** (4,8)	-8.84±12.18- (3,4)
2010/11	-2.06±2.17- (14,12)	-0.58±3.59- (8,11)	+18.42±8.47* (11,7)	+11.55±25.40- (4,5)
MEAN	+1.46-±1.60-	-9.09±3.48*	+5.99±6.64-	+15.98±9.26-

Data given are: (i) Satellite's mean timing residual relative to the IMCCE E-5 ephemeris, (ii) 1-sigma standard error of mean residual, (iii) Statistical significance of the mean residual's difference from 0 (- = not significant, * = significant at 5-percent level, ** = significant at 1-percent level), (iv) Number of (disappearance,reappearance) timings used to determine mean and standard error. Because only one timing was made for Callisto's reappearances in 2003/04 and for its disappearances in 2007/09, the standard error of the mean for those entries could not be computed.

although its three-apparition mean was not significantly different from the ephemeris. With Ganymede, there were significant differences for all three apparitions and for the three apparitions overall, with the satellite being consistently late in its orbit. Finally, Callisto did not differ significantly from the IMCCE E-5 ephemeris for any of the three apparitions or overall.

We thank the observers who contributed timings during 2007/09-2010/11, and hope that they continue with our program. We also invite others who are interested in this visual observing program, which requires only modest-sized telescopes, to contact the program coordinator (John Westfall at johnwestfall@comcast.net, 5061 Carbondale Way, Antioch, CA 94531 USA). He will be happy to furnish interested observers with a copy of observing instructions, a timing report form, and a table of Galilean satellite eclipse predictions for the coming apparition.

References

United States Naval Observatory (2006). *The Astronomical Almanac for the Year 2008*. Washington: U.S. Government Printing Office. *https://www.amazon.com/Astronomical-Almanac-Year-Companion-Online/dp/0160773962*

________ (2007). *The Astronomical Almanac for the Year 2009*. Washington: U.S. Government Printing Office. *https://bookstore.gpo.gov/products/astronomical-almanac-year-2009-and-its-companion-astronomical-almanac-online-data-astronomy*

________ (2008). *The Astronomical Almanac for the Year 2010*. Washington: U.S. Gvernment Printing Office. *https://www.amazon.com/Astronomical-Almanac-Year-Companion-Online/dp/0160820081/ref=sr_1_1?ie=UTF8&qid=1545332321&sr=8-1&keywords=the+astronomical+almanac+2010*

________ (2010). *The Astronomical Almanac for the Year 2011*. Washington: U.S. Government Printing Office. *https://www.amazon.com/Astronomical-Almanac-Year-2011-Applications/dp/0707741033*

Westfall, John E. (2009). "Galilean Satellite Eclipse Timings During the 1998/99 Apparition." *Journal of the Assn of Lunar & Planetary Observers*, 51 (3): 38-48. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2009/DJALPO51-3-Summer2009*

________. (2012). "Galilean Satellite Eclipse Timings During the 1999/2000 Apparition." *Journal of the Assn of Lunar & Planetary Observers*, 54 (4): 45-54. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2012/DJALPO54-4-Autumn2012*

http://alpo-astronomy.org/gallery3/var/albums/Publications-Section/ALPO-Journals/DJALPO-2012/DJALPO54-4-Autumn2012.pdf?m=1521160591

________. (2015). "Galilean Satellite Eclipse Timings: The 2000/01 Apparition." *Journal of the Assn. of Lunar & Planetary Observers*, 57 (4): 37-47. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2015/JALPO57-4-Autumn2015*

________ (2016a). "Galilean Satellite Eclipse Timings: The 2001-2004 Apparitions." *Journal of the Assn. of Lunar & Planetary Observers*, 58 (2): 50-60. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2016/DJALPO58-2-Spring2016*

________ (2016b). "Galilean Satellite Eclipse Timings: The 2004-05, 2005-06 and 2006-07 Apparitions." *Journal of the Assn. of Lunar & Planetary Observers*, 58 (4): 44-52 *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2016/DJALPO58-4-Autumn2016*

________ (2017). "Galilean Satellite Eclipse Timings: The 2007-09 Apparition." *Journal of the Assn. of Lunar & Planetary Observers*, 59 (4): 57-60. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2017/JALPO59-4-Autumn-2017*

________ (2018a). "Galilean Satellite Eclipse Timings: The 2009-10 Apparition." *Journal of the Assn. of Lunar & Planetary Observers*, 60 (2): 57-60. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2018/JALPO60-2-Spring-2018*

________ (2018b). "Galilean Satellite Eclipse Timings: The 2010-11 Apparition." *Journal of the Assn. of Lunar & Planetary Observers*, 60 (3): 75-78. *http://alpo-astronomy.org/gallery3/index.php/Publications-Section/ALPO-Journals/DJALPO-2018/JALPO60-3-Summer-2018*

Papers & Presentations:

How Accurate Are the Galilean Satellite Ephemerides?

By: Anthony Mallama
anthony.mallama@gmail.com

Abstract

The predictions of several Galilean satellite ephemerides are compared to precision eclipse timings obtained with CCD cameras over a period of 20 years. Statistical analysis indicates that the best ephemeris is the JUP-series currently being produced by NASA/JPL which predicts eclipse times that are accurate to about one second of time. The least accurate ephemeris is the obsolete E5 ephemeris where errors of 20 seconds or more are not uncommon.

Introduction

The accuracy of Galilean satellite ephemerides has improved greatly in recent years for two reasons. The first is that highly precise spacecraft astrometry of the satellites has augmented ground-based observations. The data have been collected by the Galileo spacecraft which orbited Jupiter for eight years and by other space missions. The second reason is that computer models have become more powerful. Early models assumed elliptical (Kepler) orbits and then added gravitational perturbations. Current models use Newton's gravitational law directly, which leads to more accurate results.

The old type of ephemeris is exemplified by the E-series, including E5, which was produced by NASA/JPL during the last century (Lieske, 1998). Beginning about 20 years ago, JPL introduced the JUP-series ephemerides which include spacecraft astrometry and which use Newton's law (Jacobson et al., 1999).

Ground-based CCD eclipse timings were begun in 1990 in order to assess the accuracy of the E-series ephemerides. Some of the observers belonged to the ALPO. The precision of the timings easily illustrated the shortcomings of the E-series (Mallama, 1992 and Mallama et al. 2000). The predicted eclipse times often differed from the observed times by tens of seconds of time. However, when JPL introduced the JUP-series, those predicted times agreed very closely with observations (Mallama et al., 2010).

Ephemeris Assessment

Three ephemerides were selected for evaluation in this study. E5 was chosen to represent the old type, while JUP230 represents the new type. Additionally, the L1 ephemeris was selected as an intermediate type. L1 (Lainey et al., 2004a and 2004b) uses modern computer models but lacks spacecraft astrometry.

Figures 1 through 4 illustrate the differences (residuals) in seconds of time (left axis) and kilometers of orbital motion (right axis) between ephemeris predictions and CCD timings for Io, Europa, Ganymede and Callisto, respectively. In each case, the top panel corresponds to JUP230, the middle to L1 and the bottom to E5.

- For Io, the residuals reveal that the E5 ephemeris has a periodic error of about 1.3 years, while the differences for the L1 ephemeris begin to grow around year 2000. The JUP230 ephemeris shows no periodic or long-term-increasing errors.

- For Europa, the E5 differences exceed 30 seconds in some years. Both the E5 and L1 ephemerides exhibit the 1.3 year periodic error, while the JUP230 ephemeris is extremely accurate.

Online Features

Left-click your mouse on:

• The author's e-mail address in blue text to contact the author of this paper.

• The references in blue text to jump to source material or information about that source material (Internet connection must be ON).

- For Ganymede, the E5 ephemeris again shows the 1.3 year error and long-term errors appear to be growing in size after 2005. The L1 and JUP230 do not show any obvious long-term or period errors.

- For Callisto, the three ephemerides give somewhat more similar results, although the difference for E5 may be increasing towards the end of the time span.

Overall, we were unable to detect any significant errors at all in the JUP-230 ephemeris, except for a 1.3-year periodic error in Europa with amplitude of only about one second. The observing program was reduced in scope after 2010 for reasons given in the next section of this paper.

Discussion

The Galilean satellite CCD eclipse timing effort was the most accurate Earth-based program spanning the period from 1990 through 2010. Given the extreme accuracy of the JUP-series ephemeris, the program was de-scoped after 2010 and further timings have only been collected occasionally.

In fact, no significant errors are expected from the JUP-series ephemeris now or in the foreseeable future because the

Galilean satellites' motions are locked into resonance and, therefore, the orbits are not changing. The periods of Io, Europa and Ganymede are in the proportion 1 : 2 : 4, while Ganymede and Callisto are locked in a 3 : 7 resonance. Hence, our group of observers felt that the time had come to reduce our efforts in this area and pursue more fruitful topics of astronomical research.

The ALPO program of visual eclipse timings has detected residuals to Galilean satellite ephemerides. Most recently, Westfall (2018) reported a significant difference between timings of Ganymede recorded in 2010-2011 and predictions of the E-5 ephemeris. This difference can also be seen in the lowest panel for Figure 3 of this paper.

As noted above, though, the E-5 ephemeris is known to be quite inaccurate and it is widely considered obsolete. Given the extreme accuracy of the JUP-series ephemeris, it is very unlikely that visual eclipse timings could establish significant residuals to that model.

References

Jacobson, R., Haw, R., McElrath, T., and Antreasian, P. 1999 "A Comprehensive Orbit Reconstruction for the Galileo Prime Mission in the J2000 System". Presented at AAS/AIAA astrodynamics meeting, Girdwood, Alaska, USA. August 16,1999. Publication number AAS 99-330. *http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/17924/1/99-1374.pdf.*

Lainey, V., Arlot, J.E., Vienne, A. 2004a. "New Accurate Ephemerides for the Galilean Satellites of Jupiter, II. Fitting the Observations". *Astronomy & Astrophysics*. 427, 371-376. doi: 10.1051/0004-6361:20041271. *https://www.aanda.org/articles/aa/pdf/2004/43/aa1271.pdf*

Lainey, V., Duriez, L., Vienne, A. 2004b. "New Accurate Ephemerides for the Galilean Satellites of Jupiter, I. Numerical Integration of Elaborated Equations of Motion". *Astronomy & Astrophysics Supplement*. 420, 1171-1183. doi: 10.1051/0004-6361:20034565. *https://www.aanda.org/articles/aa/pdf/2004/24/aa0565.pdf*

Lieske, J.H. 1998. "Galilean Satellite Ephemerides E5". *Astronomy & Astrophysics Supplement* 129, 205-217. *https://www.researchgate.net/publication/45678966_Galilean_satellite_ephemerides_E5*

Mallama, A., 1992. "CCD Photometry for Jovian Eclipses of the Galilean Satellites". *Icarus*, 97, 298-302. *http://adsabs.harvard.edu/abs/1992Icar...97..298M*

Mallama, A., Collins. D.F., Nelson, P., Park, J. and Krobusek, B., 2000. "Precise Timings of Galilean Satellite Eclipses and Assessment of the E5 Ephemeris". *Icarus*, 147, 348-352, doi:10.1006/icar.2000.6455. *https://www.sciencedirect.com/science/article/abs/pii/S0019103500964558*

Mallama, A., Stockdale, C., Krobusek, B.A. and Nelson, P., 2010. "Assessment of Resonant Perturbation Errors in Galilean Satellite Ephemerides Using Precisely Measured Eclipse Times". *Icarus*, 210, 346-357, doi:10.1016/j.icarus.2010.06.007. *https://www.sciencedirect.com/science/article/abs/pii/S0019103510002290*

Westfall, J., 2018. "Galilean satellite eclipse timings: The 2010-2011Apparition". *Journal of the Assn of Lunar & Planetary Observers*, 60-3, pp. 77-80.

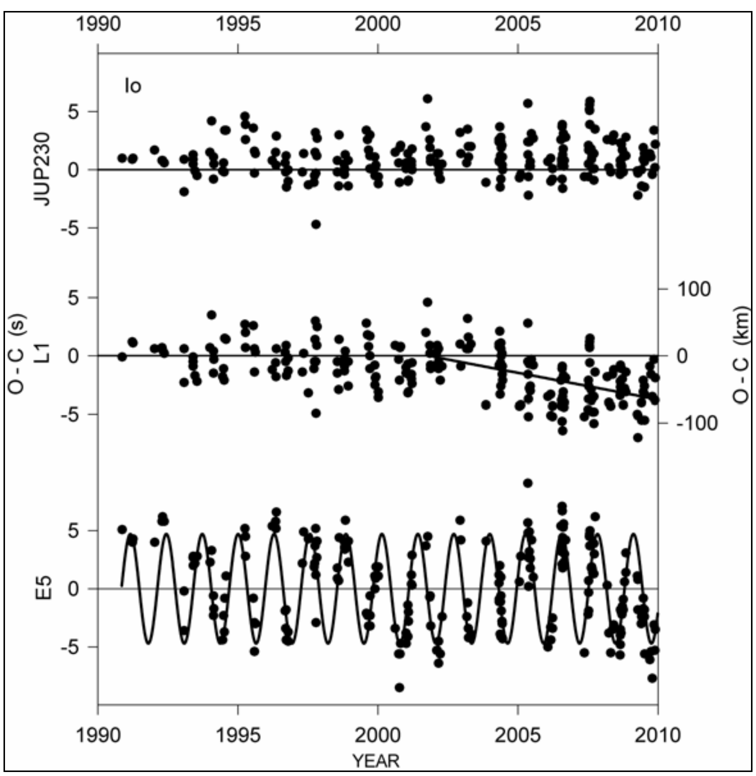


Figure 1. Residuals of Io to the JUP-230 ephemeris (top), L1 ephemeris (middle) and E-5 ephemeris (bottom). The vertical scales are seconds of time and kilometers of along-track orbital motion.

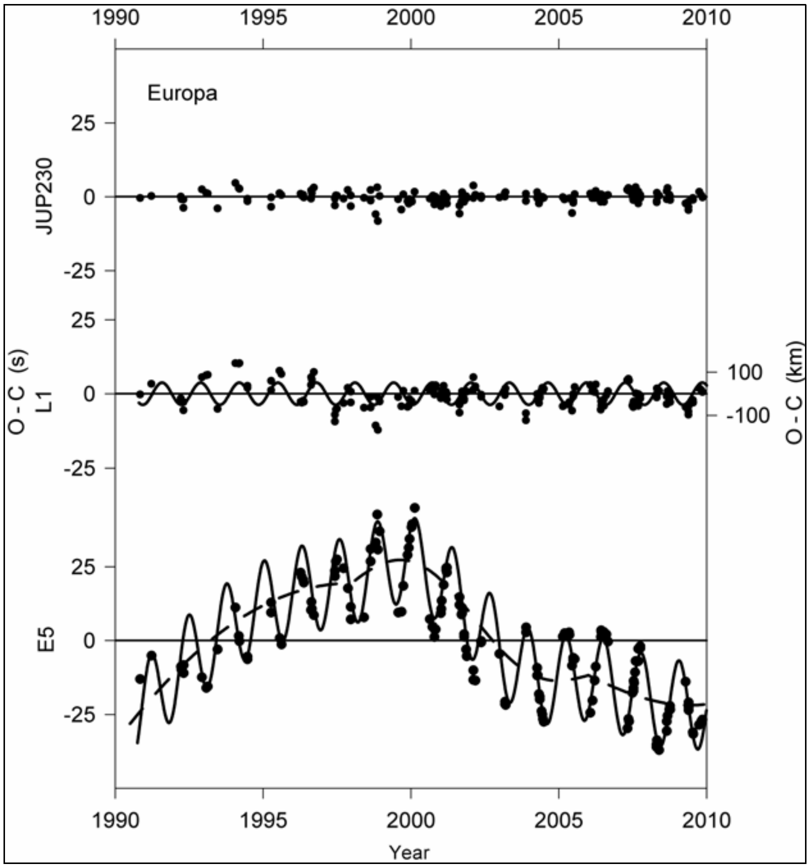
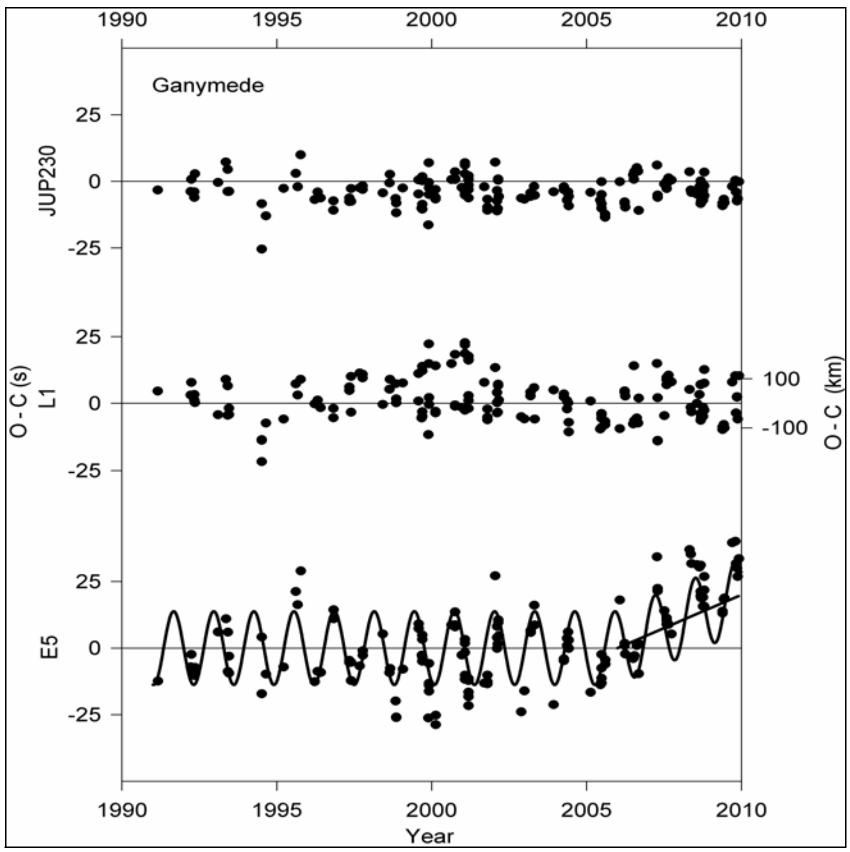


Figure 2. Same as Figure 1 but for Europa.

Figure 3. Same as Figure 1 but for Ganymede.



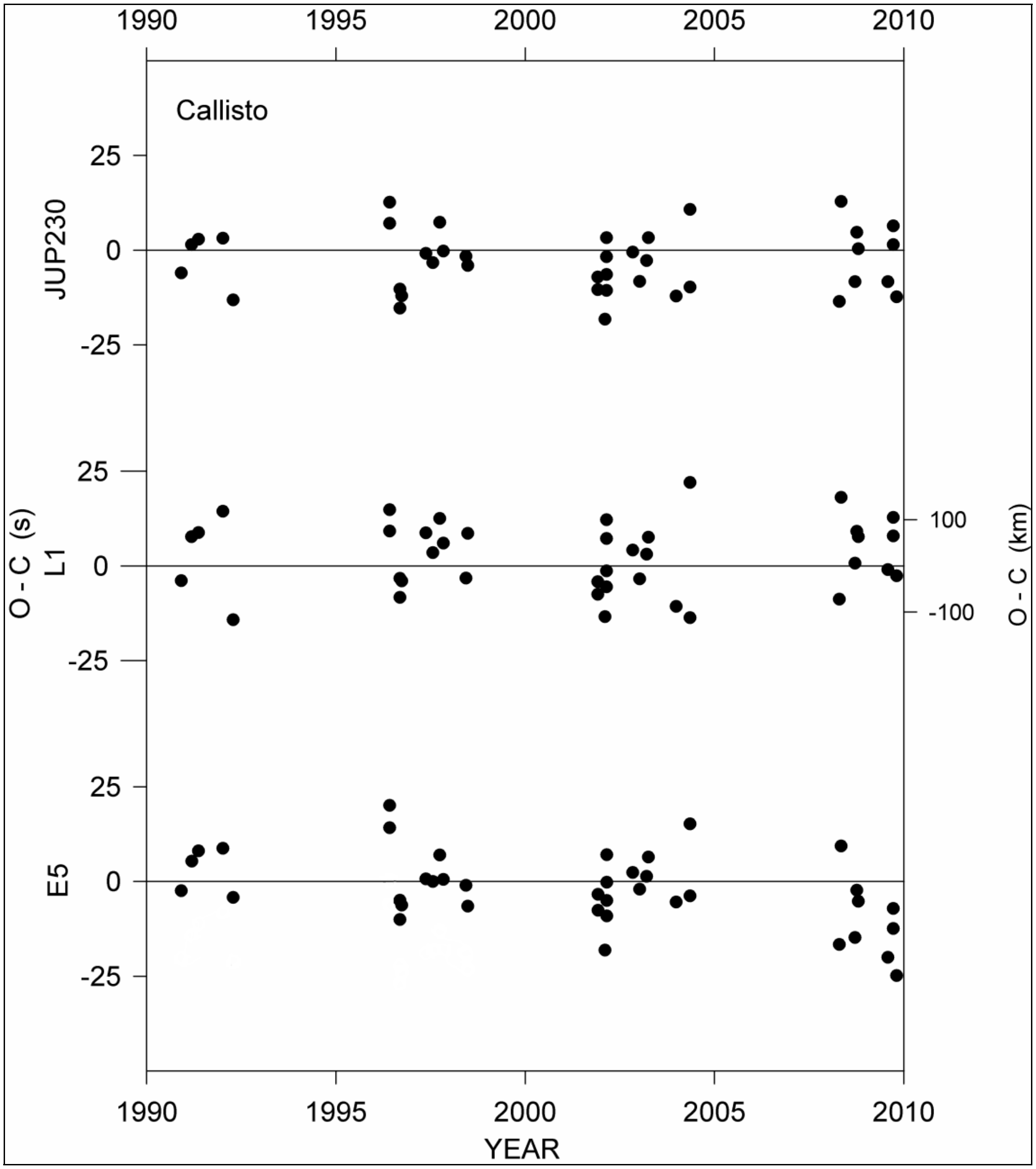


Figure 4. Same as Figure 1 but for Callisto.

ALPO Resources

People, publications, etc., to help our members

Board of Directors

http://www.alpo-astronomy.org/main/board.html

- Member of the Board (currently Associate Executive Director); Julius L. Benton, Jr., Associates in Astronomy, P.O. Box 30545, Wilmington Island, Savannah, GA 31410; *jlbaina@msn.com* (preferred) and *jbenton55@comcast.net*
- Member of the Board; Carl Hergenrother, 4101 North Sunnywood Place, Tuscon, AZ 85749; *chergen@lpl.arizona.edu*
- Member of the Board; Sanjay Limaye, University of Wisconsin, Space Science and Engineering Center, Atmospheric Oceanic and Space Science Bldg. 1017, 1225 W. Dayton St., Madison, WI 53706; *sanjayl@ssec.wisc.edu*
- Member of the Board; Ken Poshedly, 1741 Bruckner Ct., Snellville, GA 30078-2784; *ken.poshedly@alpo-astronomy.org*
- Member of the Board; Mike D. Reynolds, Dean of Liberal Arts & Sciences, Florida State College at Jacksonville, 3939 Roosevelt Blvd, F-112b, Jacksonville, FL 32205; *m.d.reynolds@fscj.edu*
- Member of the Board (currently Executive Director); Richard W. Schmude, Jr., Gordon State College, 419 College Dr., Barnesville, GA 30204; *schmude@gordonstate.edu*
- Member of the Board, Secretary/Treasurer; Matthew Will, P.O. Box 13456, Springfield, IL 62791-3456; *matt.will@alpo-astronomy.org*
- Founder/Director Emeritus; the late Walter H. Haas

Publications Section

- Coordinator (Editor & Publisher for *The Strolling Astronomer*; Ken Poshedly (all papers, submissions, etc, ALPO-Member-Discussion e-mail group moderator); 1741 Bruckner Ct, Snellville, GA 30078-2784; *ken.poshedly@alpo-astronomy.org*
- Book Review Editor; Robert A. Garfinkle, FRAS, 32924 Monrovia St., Union City, CA 94587-5433; *ragarf@earthlink.net*

Interest Sections

Computing Section

http://www.alpo-astronomy.org/computing

- Coordinator; Larry Owens, 4225 Park Brooke Trace, Alpharetta, GA 30022; *larry.owens@alpo-astronomy.org*
- Assistant Coordinator; Theo Ramakers, 130 Bluegrass Ct, Oxford, GA 30054; *theo@ceastronomy.org*

Lunar & Planetary Training Program

http://www.alpo-astronomy/training

- Coordinator; Timothy J. Robertson, 195 Tierra Rejada Rd., #148, Simi Valley, CA 93065; *cometman@cometman.net*

Online Section

http://www.alpo-astronomy.org/

- Coordinator (ALPO website); Larry Owens, 4225 Park Brooke Trace, Alpharetta, GA 30022; *larry@ceastronomy.org*
- Assistant Coordinator (ALPO social media); Steven Siedentop, 59 Mission Oak Dr., Grayson, GA 30017; *sdsiedentop@gmail.com*
- Assistant Coordinator; Theo Ramakers, 130 Bluegrass Ct, Oxford, GA 30054; *theo@ceastronomy.org*

Youth Section

http://www.cometman.net/youth

- Coordinator; Timothy J. Robertson,195 Tierra Rejada Rd., #148, Simi Valley, CA 93065; *cometman@cometman.net*

Observing Sections

Eclipse Section

http://www.alpo-astronomy.org/eclipseblog

- Coordinator; Mike D. Reynolds, Dean of Liberal Arts & Sciences, Florida State College at Jacksonville, 3939 Roosevelt Blvd, F-112b, Jacksonville, FL 32205; *m.d.reynolds@fscj.edu*
- Acting Assistant Coordinator; Keith Spring, 2173 John Hart Circle, Orange Park, FL 32073; *star.man13@hotmail.com*

Mercury/Venus Transit Section

http://www.alpo-astronomy.org/transit

- Acting Coordinator; Mike D. Reynolds, Dean of Liberal Arts & Sciences, Florida State College at Jacksonville, 3939 Roosevelt Blvd, F-112b, Jacksonville, FL 32205; *m.d.reynolds@fscj.edu*
- Acting Assistant Coordinator; Keith Spring, 2173 John Hart Circle, Orange Park, FL 32073; *star.man13@hotmail.com*

Meteors Section

http://www.alpo-astronomy.org/meteor

- Coordinator; Robert D. Lunsford, 14884 Quail Valley Way, El Cajon, CA 92021-2227; *lunro.imo.usa@cox.net*
- Assistant Coordinator; Robin Gray, P.O. Box 547, Winnemuca, NV 89446; *sevenvalleysent@yahoo.com*

Meteorites Section

http://www.alpo-astronomy.org/meteorite

- Coordinator; Dolores Hill, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; *dhill@lpl.arizona.edu*

Comets Section

http://www.alpo-astronomy.org/comet

- Coordinator; Carl Hergenrother, 4101 North Sunnywood Place, Tuscon, AZ 85749; *chergen@lpl.arizona.edu*
- Assistant Coordinator; Gary Kronk, 153 Samarra Estates Dr, Fenton, MO 63026; *gkronk@gmail.com*

Solar Section

http://www.alpo-astronomy.org/solar

- Coordinator & Scientific Advisor; Richard Hill, 10130 E. King Manor Dr., Tucson, AZ 85730; *rhill@lpl.arizona.edu*
- Assistant Coordinator (new observers and ALPO Solar Section Online Image Archive contact); Theo Ramakers, 130 Bluegrass Ct, Oxford, GA 30054; *theo@ceastronomy.org*
- Assistant Coordinator (primary moderator, ALPO Solar Section Yahoo email list); Rick Gossett, 20251 Lakeworth St., Roseville, MI. 48066; *rick2d2@sbcglobal.net*
- Assistant Coordinator; Pam Shivak, 4225 NW 32nd St., Cape Coral, FL 33993*; pamelashivak@yahoo.com*

ALPO Resources

People, publications, etc., to help our members

Mercury Section

http://www.alpo-astronomy.org/Mercury

- Coordinator; Frank J. Melillo, 14 Glen-Hollow Dr., E-#16, Holtsville, NY 11742; frankj12@aol.com

Venus Section

http://www.alpo-astronomy.org/venus

- Coordinator; Julius L. Benton, Jr., Associates in Astronomy, P.O. Box 30545, Wilmington Island, Savannah, GA 31410; jlbaina@msn.com (preferred) and jbenton55@comcast.net

Lunar Section

- Coordinator; Wayne Bailey, 17 Autumn Lane, Sewell, NJ 08080; wayne.bailey@alpo-astronomy.org
- Assistant Coordinator; William Dembowski, 219 Old Bedford Pike, Windber, PA 15963; dembowski@zone-vx.com
- Assistant Coordinator; Jerry Hubbell, 406 Yorktown Blvd, Locust Grove, VA 22508; jerry.hubbell@comcast.net

Lunar Topographical Studies Program

http://moon.scopesandscapes.com/ALPO_Lunar_Program.htm

Lunar Selected Areas Program

http://moon.scopesandscapes.com/alpo-sap.html

Lunar Banded Craters Program

http://moon.scopesandscapes.com/alpo-bcp.htm

Lunar Domes Program

- Acting Coordinator; Raffaello Lena, Cartesio 144 D, 00137 Rome, Italy; raffaello.lena@alpo-astronomy.org
- Acting Assistant Coordinator; Jim Phillips, 101 Bull St., Charleston, SC 29401-1712; thefamily90@gmail.com

Lunar Meteoritic Impacts Search Program

http://www.alpo-astronomy.org/lunar/lunimpacts.htm

- Coordinator; Brian Cudnik, 11851 Leaf Oak Drive, Houston, TX 77065; cudnik@sbcglobal.net

Lunar Transient Phenomena

http://www.alpo-astronomy.org/lunar/LTP.html; also http://www.LTPresearch.org

- Coordinator; Dr. Anthony Charles Cook, Institute of Mathematical and Physical Sciences, University of Aberystwyth, Penglais, Aberystwyth, Ceredigion. SY23 3BZ, United Kingdom; tony.cook@alpo-astronomy.org
- Assistant Coordinator; David O. Darling, 416 West Wilson St., Sun Prairie, WI 53590-2114; DOD121252@aol.com

Mars Section

http://www.alpo-astronomy.org/Mars

- Coordinator; Roger J. Venable, MD, P.O. Box 117, Chester, GA 31012; rjvmd@hughes.net
- Assistant Coordinator (photometry and polarimetry); Richard W. Schmude, Jr., 109 Tyus St., Barnesville, GA 30204; schmude@gordonstate.edu
- Assistant Coordinator; Jim Melka, 14176 Trailtop Dr., Chesterfield, MO 63017; jtmelka@yahoo.com

Minor Planets Section

http://www.alpo-astronomy.org/minor

- Coordinator; Frederick Pilcher, 4438 Organ Mesa Loop, Las Cruces, NM 88011; fpilcher35@gmail.com
- Scientific Advisor: Alan W. Harris, 4750 Walnut St, Suite 205, Boulder, CO 80301; harrisaw@att.net
- Scientific Advisor; Dr. Petr Pravec, Ondrejov Observatory, Astronomical Institute, Academy of Sciences, Cz-25 165 Ondrejov, Czech Republic; ppravec@asu.cas.cz
- Asteroid Photometry Coordinator; Brian D. Warner, Center For Solar System Studies, 446 Sycamore Ave, Eaton, CO 80615; brian@MinorPlanetObserver.com

Jupiter Section

http://www.alpo-astronomy.org/jupiter

- Section Coordinator, Apparition Reports; Richard W. Schmude Jr., 109 Tyus St., Barnesville, GA 30204; schmude@gordonstate.edu
- Assistant Coordinator, Transit Timings; John McAnally, 2124 Wooded Acres, Waco, TX 76710; CPAJohnM@aol.com
- Assistant Coordinator, Jupiter Section Yahoo email list; Craig MacDougal, 821 Settlers Road, Tampa, FL 33613; macdouc@verizon.net

Saturn Section

http://www.alpo-astronomy.org/saturn

- Coordinator; Julius L. Benton, Jr., Associates in Astronomy, P.O. Box 30545, Wilmington Island, Savannah, GA 31410; ; jlbaina@msn.com (preferred) and jbenton55@comcast.net

Remote Planets Section

http://www.alpo-astronomy.org/remote

- Coordinator; Richard W. Schmude, Jr., 109 Tyus St., Barnesville, GA 30204; schmude@gordonstate.edu

****

ALPO Publications

The Monograph Series

http://www.alpo-astronomy.org/publications/Monographs page.html

Publications too lengthy for publication in *The Strolling Astronome*r. All are available online as a pdf files. NONE are available any longer in hard copy format. There is NO CHARGE for any of the ALPO monographs.

- **Monograph No. 1.** *Proceedings of the 43rd Convention of the Association of Lunar and Planetary Observers. Las Cruces, New Mexico, August 4-7, 1993. 77* pages. File size approx. 5.2 mb.
- **Monograph No. 2**. *Proceedings of the 44th Convention of the Association of Lunar and Planetary Observers. Greenville, South Carolina, June 15-18, 1994. 52* pages. File size approx. 6.0 mb.
- **Monograph No. 3**. *H.P. Wilkins 300-inch Moon Map.* 3rd Edition (1951). Available as one comprehensive file (approx. 48 megabytes) or five section files (Part 1, 11.6 megabytes; Part 2, 11.7 megabytes; Part 3, 10.2 megabytes; Part 4, 7.8 megabytes; Part 5, 6.5 mb)
- **Monograph No. 4.** *Proceedings of the 45th Convention of the Association of Lunar and Planetary Observers.*

ALPO Resources

People, publications, etc., to help our members

Wichita, Kansas, August 1-5, 1995.127 pages. Hard copy $17 for the United States, Canada, and Mexico; $26 elsewhere. File size approx. 2.6 mb.

- **Monograph No. *5.*** *Astronomical and Physical Observations of the Axis of Rotation and the Topography of the Planet Mars. First Memoir; 1877-1878.* By Giovanni Virginio Schiaparelli, translated by William Sheehan. 59 pages. Hard copy $10 for the United States, Canada, and Mexico; $15 elsewhere. File size approx. 2.6 mb.
- **Monograph No. *6.*** *Proceedings of the 47th Convention of the Association of Lunar and Planetary Observers, Tucson, Arizona, October 19-21, 1996.20* pages. Hard copy $3 for the United States, Canada, and Mexico; $4 elsewhere.File size approx. 2.6 mb.
- **Monograph No. 7.** *Proceedings of the 48th Convention of the Association of Lunar and Planetary Observers. Las Cruces, New Mexico, June 25-29, 1997.76* pages. Hard copy $12 for the United States, Canada, and Mexico; $16 elsewhere.File size approx. 2.6 mb.
- **Monograph No. 8**. *Proceedings of the 49th Convention of the Association of Lunar and Planetary Observers. Atlanta, Georgia, July 9-11,1998.122* pages. Hard copy $17 for the United States, Canada, and Mexico; $26 elsewhere.File size approx. 2.6 mb.
- **Monograph Number 9**. *Does Anything Ever Happen on the Moon?* By Walter H. Haas. Reprint of 1942 article. 54 pages.Hard copy $6 for the United States, Canada, and Mexico; $8 elsewhere.File size approx. 2.6 mb.
- **Monograph Number 10.** *Observing and Understanding Uranus, Neptune and Pluto*. By Richard W. Schmude, Jr. 31 pages. File size approx. 2.6 mb.
- **Monograph No. 11**. *The Charte des Gebirge des Mondes* (Chart of the Mountains of the Moon) by J. F. Julius Schmidt, this monograph edited by John Westfall. Nine files including an accompanying guidebook in German. Note files sizes:
  Schmidt0001.pdf, approx. 20.1 mb;
  Schmidt0204.pdf, approx. 32.6 mb;
  Schmidt0507.pdf, approx. 32.1 mb;
  Schmidt0810.pdf, approx. 31.1 mb;
  Schmidt1113.pdf, approx. 22.7 mb;
  Schmidt1416.pdf, approx. 28.2 mb;
  Schmidt1719.pdf, approx. 22.2 mb;
  Schmidt2022.pdf, approx. 21.1 mb;
  Schmidt2325.pdf, approx. 22.9 mb;
  SchmidtGuide.pdf,approx. 10.2 mb

ALPO Observing Section Publications

Order the following directly from the appropriate ALPO section recorders; use the address in the listings pages which appeared earlier in this booklet unless another address is given.

- **Solar:** *Guidelines for the Observation of White Light Solar Phenomena*, *Guidelines for the Observing Monochromatic Solar Phenomena* plus various drawing and report forms available for free as pdf file downloads at http://www.alpo-astronomy.org solarblog.
- **Lunar & Planetary Training Section:** *The Novice Observers Handbook* $15. An introductory text to the training program. Includes directions for recording lunar and planetary observations, useful exercises for determining observational parameters, and observing forms. Available as pdf file via e-mail or send check or money order payable to Timothy J. Robertson, 195 Tierra Rejada Rd., #148, Simi Valley, CA 93065; e-mail cometman@cometman.net.
- **Lunar:** (1) *The ALPO Lunar Selected Areas Program Handbook* (hardcopy, $17.50). Includes full set of observing forms. (2) *Observing forms*: Send a SASE for a hardcopy of forms. Both the Handbook and individual observing forms are available for download (as pdf files) at moon.scopesandscapes.com/alpo-sap.html. Use of observing forms will ensure that all requested information is included with observations, but are not required. Various lists and forms related to other Lunar section programs are also available at moon.scopesandscapes.com. NOTE: Observers who wish to make copies of the observing forms may instead send a SASE for a copy of forms available for each program. Authorization to duplicate forms is given only for the purpose of recording and submitting observations to the ALPO lunar SAP section. Observers should make copies using high-quality paper.
- **Lunar**: *The Lunar Observer*, official newsletter of the ALPO Lunar Section, published monthly. Free at http://moon.scopesandscapes.com/tlo.pdf or send SASE to: Wayne Bailey, 17 Autumn Lane, Sewell, NJ 08080.
- **Venus (Benton):** Introductory information for observing Venus, the comprehensive *ALPO Venus Handbook*, as well as all observing forms and ephemerides, can be conveniently downloaded as pdf files at no cost to ALPO members and individuals interested in observing Venus as part of our regular programs at http://www.alpo-astronomy.org/venus.
- **Mars:** Free resources are on the ALPO website at www.alpo-astronomy.org . Click on "Mars Section" in the left column; then on the resulting webpage, look for links to resources in the right column including “Mars Observing Form”, and "Mars Links". Under “Mars Links”, click on "Mars Observers Cafe", and follow those links to The New “Internet Mars Observer's Handbook.”
- **Minor Planets (Derald D. Nye):** *The Minor Planet Bulletin*. Published quarterly; free at http://www.minorplanetobserver.com/mpb/default.htm. Paper copies available only to libraries and special institutions at $24 per year via regular mail in the U.S., Mexico and Canada, and $34 per year elsewhere (airmail only). Send check or money order payable to “Minor Planet Bulletin”, c/o Derald D. Nye, 10385 East Observatory Dr., Corona de Tucson, AZ 8564l-2309.
- **Jupiter:** *(1) Jupiter Observer’s Handbook*, from the Astronomical League Sales, temporarily out of stock. (*2*) *ALPO_Jupiter*, the ALPO Jupiter Section e-mail network; to join, send a blank e-mail to *ALPO_Jupiter-subscribe@yahoogroups.com* (3) *Jupiter Observer’s Startup Ki*t, $3 from Richard Schmude, Jupiter Section Coordinator.

ALPO Resources

People, publications, etc., to help our members

- **Saturn (Benton):** Introductory information for observing Saturn, including all observing forms and ephemerides, can be conveniently downloaded as pdf files at no cost to ALPO members and individuals interested in observing Saturn as part of our regular programs at http://www.alpo-astronomy.org/saturn. The former *ALPO Saturn Handbook* was replaced in 2006 by *Saturn and How to Observe It* (authored by Julius L. Benton) and it can be obtained from book sellers such as Amazon.com.

- **Meteors:** (1) *The ALPO Guide to Watching Meteors* (pamphlet). $3 per copy (includes postage & handling); send check or money order to Astronomical League Sales, 9201 Ward Parkway, Suite 100, Kansas City, MO 64114; phone 816-DEEP-SKY (816-333-7759); e-mail leaguesales@astroleague.org. (2) *The ALPO Meteors Section Newsletter*, free (except postage), published quarterly (March, June, September and December). Send stamps, check or money order for first class postage to cover desired number of issues to Robert D. Lunsford, 14884 Quail Valley Way, El Cajon, CA 92021-2227.

Back Issues of *The Strolling Astronomer*

Online Issues

Nearly all issues of this Journal are available for downloading via the ALPO website. As of January 2019:

• All indexes posted except for volumes 9 thru 15, volumes 30 thru 33, then volumes 57 and later.

• All ALPO Journals posted except for volumes 1 thru 6, and volume 61.

The missing ones will be posted as soon as they have been processed into pdf files.

1. Go to alpo-astronomy.org, then click on the "ALPO Section Galleries" link near the top of the right side-bar.

2. Next click on the Publications Section icon, then click on the ALPO Journals icon.

3. Choose either the folder of indexes or the desired volume of Journals according to year.

4. Finally, click on the desired Journal to view or download it.

Note that the newest four issues are available for downloading only by ALPO members.

Hard-Copy Issues

Some hard-copy back issues listed below may be out of stock with no guarantee of availability. Issues are sold on a first-come, first-served basis. Back issues are $4 each, and $5 for the current issue. Discounts available on orders over $30. Contact Secretary/Treasurer Matthew Will for downloading instructions or to order hard copies (see address under "Board of Directors,"):

$4 each:
Vol. 16 (1962) Nos. 3-4
Vol. 17 (1963) Nos. 1-2
Vol. 19 (1965) Nos. 3-4
Vol. 29 (1981-83) Nos. 1-2 and 11-12
Vol. 30 (1983-84) Nos. 1-2, 7-8, 9-10
Vol. 32 (1987-88) Nos. 3-4, 10-12
Vol. 33 (1989) Nos. 10-12
Vol. 34 (1990) Nos. 1 and 3
Vol. 35 (1991) Nos. 1, 2, and 4
Vol. 36 (1992-93) Nos. 1, 2, 3, and 4
Vol. 37 (1993-94) Nos. 1, 2, 3, and 4
Vol. 38 (1994-96) Nos. 1, 2, 3, and 4
Vol. 39 (1996-97) Nos. 1, 2, 3, and 4
Vol. 40 (1998) Nos. 2 and 3
Vol. 41 (1999) Nos. 1, 2, and 3
Vol. 42 (2000) Nos. 1 and 4
Vol. 43 (2001) Nos. 1, 2, 3, and 4
Vol. 44 (2002) Nos. 1, 2, 3, and 4
Vol. 45 (2003) Nos. 1, 2, and 3 (no issue 4)
Vol. 46 (2004) Nos. 1, 2, 3, and 4
Vol. 47 (2005) Nos. 1, 2, 3, and 4
Vol. 48 (2006) Nos. 1, 2, 3, and 4
Vol. 49 (2007) Nos. 1, 2, 3, and 4
Vol. 50 (2008) Nos. 1, 2, 3, and 4
Vol. 51 (2009) Nos. 1, 2, 3, and 4
Vol. 52 (2010) Nos. 1, 2, 3, and 4
Vol. 53 (2011) Nos. 1, 2, 3, and 4
Vol. 54 (2012) Nos. 1, 2, 3, and 4
Vol. 55 (2013) Nos. 1, 2, 3 and 4
Vol. 56 (2014) Nos. 1, 2, 3 and 4
Vol. 57 (2015) Nos. 1, 2, 3 and 4
Vol. 58 (2016) Nos. 1, 2, 3 and 4
Vol. 59 (2017) Nos. 1, 2, 3 and 4
Vol. 60 (2018) Nos. 1, 2, 3 and 4
Vol. 61 (2019) No. 1

$5: Vol. 61 (2019) No. 2 (current issue)

ALCon 2019

Kennedy Space Center and Southern Skies Cruise to the Bahamas

July 25 - 29, 2019

Join the **Astronomical League** to commemorate the

50th anniversary of the first manned moon landing!

First, on Thursday July 25, tour the **Kennedy Space Center**, the site of the Apollo 11 launch. Then, enjoy a three-day cruise – leaving July 26 and returning July 29 – to the Bahamas on a ship by **Royal Caribbean** and see the southern Milky Way of Sagittarius and Scorpius!

(The Astronomical League Council meeting will be on Wed. July 24 in Titusville, FL.)

- IMPORTANT...Cabin space for the cruise portion is limited at the AL discounted price. To reserve your cabin and for additional cruise details, please contact Marsha at Lin-Mar Travel, (631) 736-1049, or marsha@travelwithlin-mar.com.
- You must be a member of the Astronomical League.
- Your passport must be valid through January 2020.

For ALCon 2019 registration... https://alcon2019.astroleague.org

Life Is Short

Join a SKY & TELESCOPE Tour This Year!

From 37,000 feet above the Pacific Ocean, you'll be high above any clouds, seeing up to 3¼ minutes of totality in a dark sky that makes the Sun's corona look incredibly dramatic. Our flight will depart from and return to Santiago, Chile.

Total Eclipse Flight: Chile

July 2, 2019

skyandtelescope.com/2019eclipseflight

African Stargazing Safari

July 29–August 4, 2019

Join astronomer Stephen James O'Meara in wildlife-rich Botswana for evening stargazing and daytime safari drives at three luxury field camps. Only 16 spaces available! Optional extension to Victoria Falls.

skyandtelescope.com/botswana2019

Iceland Aurorae

September 26–October 2, 2019

This is our 6th year running this popular tour of Iceland. Visit historic sites, geysers, and towering waterfalls with a guide; at night, seek the fabled northern lights. Fine restaurants and hotels await you.

skyandtelescope.com/iceland2019

Australian Observatories

October 1–9, 2019

Travel Down Under to tour top observatories, including Siding Spring and "The Dish" at Parkes. Go wine-tasting, hike in nature reserves, and explore eclectic Sydney and Australia's capital, Canberra. Plus: Stargaze under Southern skies. Options to Great Barrier Reef and Uluru, or Ayers Rock.

skyandtelescope.com/australia2019

Uluru & Sydney Opera House: Tourism Australia; observatory: Winton Gibson

See all *S&T* tours at skyandtelescope.com/astronomy-travel