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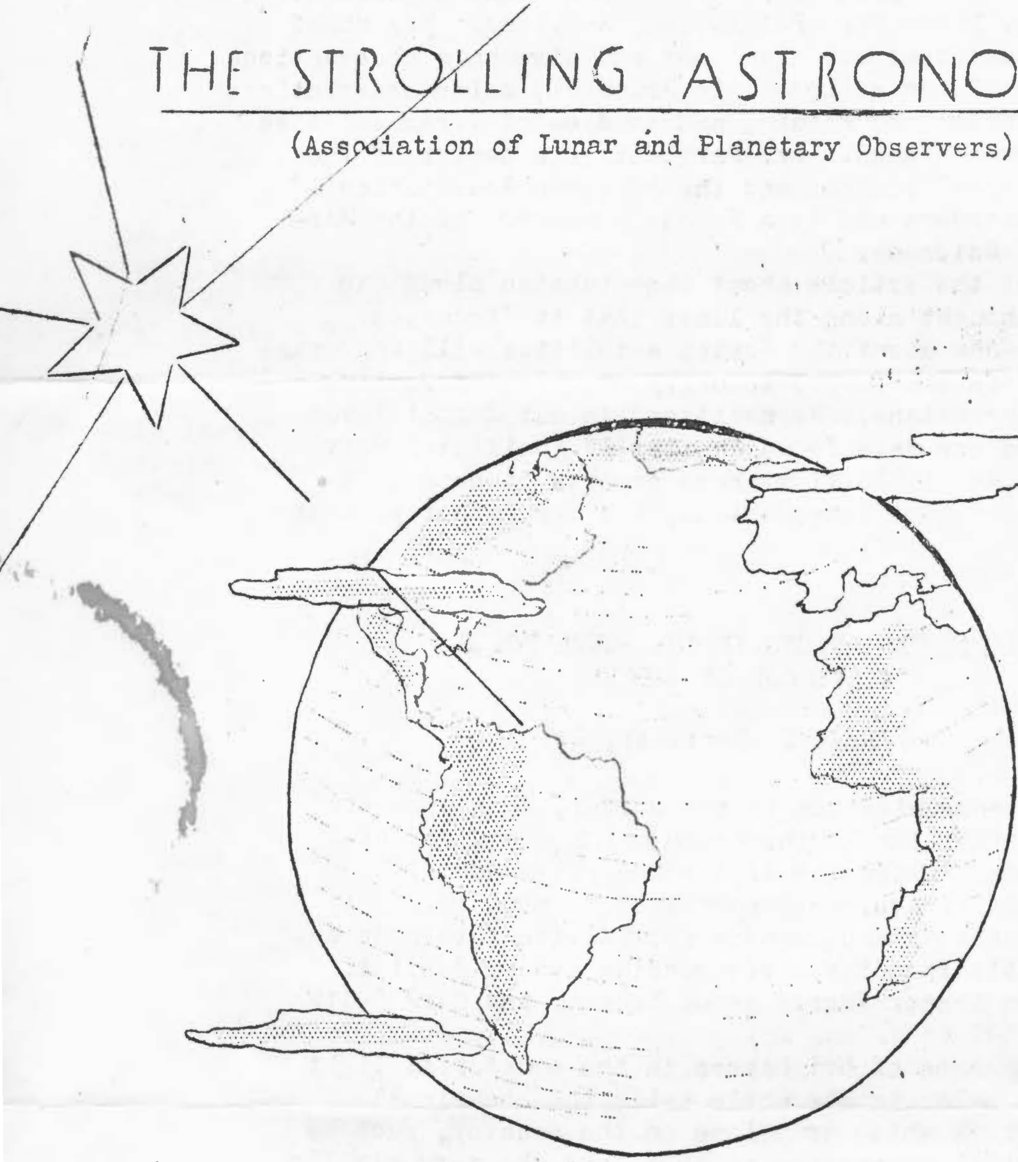

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Introducing a Double Feature

The name of James C. Bartlett, Jr., as an author is familiar to the readers of such magazines as Sky and Telescope, Popular Astronomy, and Science. It is characteristic of the prolific Dr. Bartlett that he has sent us two articles on planetary subjects, which we gladly present in this issue. Our contributor's address is 300 N. Eutaw St., Baltimore 1, Maryland. His chief interest is in sunspots; but his lunar and planetary observations include drawings of the walled-plain Grimaldi, color-observations of details on Jupiter and Saturn, and studies of irregularities on the terminator of Venus. Dr. Bartlett is a member of the American Astronomical Society and the American Association of Variable Star Observers and is a former Secretary of the Maryland Academy of Sciences.

We hope that the article about the Saturnian cloud cap will stimulate thought along the lines that it discusses. We hope that the one about the Jovian satellites will encourage possessors of small telescopes to carry on this interesting and easy sort of observations. We mentioned in our August issue how T. R. Cave on one date found Jupiter IV (Callisto) very hazily outlined, as Dr. Bartlett here reports it sometimes to be. But without more introduction, let the author present his theses:

RAPID VARIATIONS IN THE SOUTH POLAR CLOUD CAP OF SATURN

by James C. Bartlett, Jr.

In a recent communication to the writer, Haas commented on the marked variability in the south polar cloud cap of Saturn, a phenomenon which the writer has often noticed. Observations at Baltimore, with apertures varying from 3 to 5 inches, suggest that as a permanent marking the Saturnian cap is much less stable than the corresponding cap on Jupiter. The same thing in lesser degree seems true of the dark belts on Saturn.

Analagous changes of brightness in the equatorial light zone; changes of color in the whole ball; the occasional appearances of great white eruptions on the equator, such as during the classical apparition of 1876, and the very similar White Spot of 1933, all suggest that could we see Saturn as easily as we see Jupiter the rapidity of surface changes might be greater for the former than for the latter.

This is contradicted by some authorities who regard Saturn as the more quiescent of the two, basing this opinion on the greater distance of the planet from the sun; but such reasoning involves the assumption that the observed changes are due entirely to solar heating or other influences— which is unproven. However, granting that the sun may yet be the chief motivator of surface changes, certain factors are commonly overlooked, factors which would greatly increase the effectiveness of solar action even for the greater distance.

In the first place, the inclination of the equator of Saturn to the plane of the orbit is 27°. This factor alone would make for very marked seasons, especially in contrast to Jupiter whose inclination is only 3° 5'. On Saturn, therefore, one would expect to find a much steeper thermal gradient between equator and pole which would promote vigorous exchange between the respective regions. It is true, of course, that on Jupiter there must also be marked temperature differences between equator and pole; but the thermal gradient, as it relates to the sun, must be relatively constant due to the slight inclination. On Saturn, the thermal gradient is subject to slow but profound modification as the planet progresses in its orbit and the sun moves towards and away from the solstice. Therefore, on Saturn, we should expect to find intensification of the solar heating effect despite the greater distance of the planet from the sun. It is all a question of relative values.

In comparing the atmospheric system of Saturn with that of the earth we encounter a fundamental difficulty. Our atmosphere is essentially a gaseous solution in which an admixture of nitrogen and oxygen plays the part of solvent while water vapor plays the part of solute. As dissolved substances crystalize out from liquid solutions when the pressure or temperature is altered, so water vapor condenses out in the form of clouds or precipitates when the atmosphere becomes saturated for any given pressure-temperature level which is later altered. The analogy with a true liquid solution is not perfect, of course, but serves well as a graphic illustration.

However, in the case of Saturn, we deal with a planet whose atmosphere consists chiefly of hydrogen with methane and other light gases. The precipitants, moreover, are not condensations of water vapor but apparently of ammonia and other substances of very low boiling point. Also, they are not in the form of liquid droplets but of solid crystals. In this they are somewhat analogous to our high-level cirri, which are composed of ice crystals but with this important difference: Whereas terrestrial, high-level cirrus is usually a very thin and comparatively uncommon cloud, the ammonia clouds of Saturn appear to be very thick and to be the principal cloud substance. It is clear, therefore, that the dynamics of the Saturnian atmosphere must be very different.

Nevertheless there are fundamental points in common. There must, for instance, be a horizontal pressure distribution which will result in belts or zones of alternating high and low pressure between equator and poles. This should result in zones of comparatively clear atmosphere and belts of cloudiness, which corresponds well to observational appearances. Moreover, it must be remembered that even if the absolute temperature of the planet be very low, as recent measures suggest, there will nevertheless exist marked differences in temperature; and when one considers the low boiling point of the substances in the Saturnian atmosphere, it is clear that these temperature differences are capable of producing effects comparable to those in our own atmosphere. Again, it is merely a matter of relative values. To see graphically what is meant, throw a chunk of "dry ice" into a glass of ice-water--but keep well away from it! You will engender a commotion more violent than any boiling ever heard of.

Pressure distribution likewise must be fundamentally similar. On the earth, for instance, we find pressure at the poles consistently lower than for the equator, though at first it would seem that the reverse should be true—and so it would if the earth did not rotate. But the earth's rotation creates a polar whirl which materially reduces the pressure at the pole. Now the rotation period of Saturn, 10.2 hours, must produce a very marked polar whirl. We should, therefore, expect to find an extensive area of low pressure—and therefore of maximum cloudiness—around the pole. But since the clouds would not be clouds of water vapor or ice crystals, but rather of ammonia and other crystals, apparently contaminated by metallic oxides as Wildt suggests for Jupiter, reflection would be greatly modified. There would, for instance be selective absorption giving rise to color, as well as reflection of selected wave lengths—also giving rise to color. The polar cap, therefore, would appear dark and colored rather than brilliant and white, as is the case with the earth and Mars. Thus, on Jupiter and Saturn, both marked by extremely short rotations, we find characteristically dark and colored polar cloud caps. It is extremely probable that Uranus and Neptune would exhibit the same phenomenon, if they could be seen as well.

It is probable that this great polar mass of condensed, crystalline cloud has a marked tendency to settle out of the atmosphere at the pole of Saturn. This follows from the effects of the polar compression, nearly 10% and most marked for all the planets in Saturn. According to Young, this results in a variation of surface gravity of nearly 25% between equator and pole. The weight of a mass of cloud on the equator, assumed to be 10,000 tons, would become 12,000 tons if transported to the pole. At the pole, where the centrifugal force is zero, the greater weight would produce higher density in the cloud. We may therefore reasonably assume a constant settling and a constant renewal as equatorial currents join the polar whirl. This should result in more or less constant variations in area, darkness, and color of the cloud cap—and this is certainly more marked for Saturn than for Jupiter. Indeed the variability of the Saturnian cap may be said to be one of its most "constant" features.

JOVIAN SATELLITE PHENOMENA FOR SMALL TELESCOPES

by James C. Bartlett, Jr.

In the June, 1948, issue of The Strolling Astronomer, an article by Mr. Walter H. Haas invites observation of the surface markings of the four large satellites of Jupiter; but, as Mr. Haas points out, effective observations require excellent instruments and large apertures. However, for those of us who can command only modest apertures—say from 3 to 5 inches—there remain other phenomena equally as interesting and easily within range of the small glass.

I refer to the singular and non-periodic variations in the apparent magnitudes of all four of the Galilean satellites and to related changes in color, mostly affecting IV but seen in all the moons at one time or another. Both magnitude and color changes may be studied easily with any good 3-inch refractor or reflector, the latter being superior for color determinations.

Such observations, if continued regularly over a sufficient period of time, are important contributions to our knowledge of the probable surface conditions of these satellites and may also have some bearing on the question of their rotation periods. The latter is still an open question, though it is generally believed that the axial rotations are synchronized with the orbital revolutions so that the satellites always present the same face to Jupiter while presenting different faces to us. If this is true, surface areas of unequal reflectivity would account well for changes in apparent magnitude--but such changes should then always occur for any given satellite with definite positions in the orbit, and the same change should always occur at the same point in the orbit.

In 1926, Stebbins, using the photoelectric photometer of the Lick Observatory, established small variations in apparent magnitude which were definitely related to the orbital position. A year later, Antoniadi, using the 33-inch refractor at Meudon, made a comprehensive study of the surface markings of the four large satellites which indicated to him that they all kept the same face towards Jupiter.

Nevertheless, despite the admitted weight of these authorities, there are many observations on record which are not easy to reconcile with the theory that such variations depend upon the orbital position. Any close student of the satellites will, I think, agree that major light fluctuations and changes in color often occur in the same satellite quite independently of its orbital position--a fact very difficult to explain on the assumption that such changes are linked to an axial-orbital synchronization.

However, it is possible to reconcile such phenomena with this hypothesis if we concede atmospheres to these satellites. It is clear that if major light fluctuations, or changes in color, can be referred to atmospheric effects, i. e. to the formation or evaporation of cloud covers, then such changes would have no relation to orbital position whatever.

The atmospheric theory perhaps best explains the non-periodic character and especially the marked suddenness of many of these fluctuations. If to these fluctuations are added those which do depend entirely upon orbital position we would then have an explanation for the puzzling fact that sometimes the changes appear to depend upon orbital position while at other times they do not. It is all a question of which effect is dominant at any given time.

Perhaps it is well to remark at this point that, contrary to many textbook statements, there are really no sound a priori grounds for denying an atmosphere to any body merely because it may have a small mass. It is true that there is a critical velocity of escape for all gases, and that the value of this critical velocity becomes markedly smaller for small masses; but, as Russell pointed out, there is much more involved than kinetic energy of molecules and the critical velocity of excape (Russell, Henry Norris, "The Atmospheres of the Planets"; Science, January 4th, 1935).

For instance, the kinetic energy of any given gas molecule will depend partly upon the mass of the molecule and thus will vary with the chemical composition of the gas. It will also depend partly upon the temperature of the gas, the kinetic energy becoming much lower with lowered temperatures until a point may be reached at which the established kinetic energy of the molecule is insufficient to provide the velocity necessary to escape the planetary mass. Thus a small body at Jupiter's distance from the sun will have a much greater chance to retain an atmosphere than an even larger body at Mercury's distance. This fact, often overlooked, perhaps explains the demonstrated retention of an atmosphere by Titan, the largest satellite of Saturn.

At any rate there are good observational reasons for believing that the four large satellites of Jupiter possess appreciable atmospheres. Indeed it is difficult to explain sudden changes in apparent magnitude, in apparent size, and even in shape (III has sometimes been observed to have an elliptical shape while at other times appearing quite round) without recognizing the effects of atmospheric agencies. Moreover, some observers have glimpsed apparent polar caps on III while in 1890 Barnard concluded that I possessed a bright equatorial zone and dark poles like Jupiter itself. J. IV occasionally presents anomalous appearances, sometimes appearing "fuzzy" or nebulous with a bright, star-like central point—an appearance perhaps due to absorption at the limbs of the satellite. [W. H. Pickering sought to determine the rotation period of J. III from its changing ellipticity. An atmospheric explanation would be supported if the variations have <u>no</u> regular period, orbital or otherwise.-Editor]

Be that as it may, it is a fact that marked changes in color and in apparent magnitude were early recorded of these satellites. As early as 1707 Maraldi found IV sometimes brightest of all, though usually it is faintest. Bianchini, in 1711, once found IV so faint <u>for more than an hour</u> that it could scarcely be perceived, and other competent observers have noticed changes in the apparent diameter of the disc. I have myself often observed it to be apparently smaller when in its red phase than when in its blue. Newcomb remarked: "The light of these satellites varies to an extent which is difficult to account for, excepting by supposing very violent changes constantly going on on their surfaces." (Newcomb, Simon, <u>Popular Astronomy</u>, p. 345; Harper and Brothers, New York; 1878). To this writer it appears much more probable that the changes are not on the surfaces but in the atmospheres. It seems clear that the precipitation of an extensive cloud mass would result in an appreciable brightening of the satellite, and also perhaps in an apparent increase in diameter possibly through an effect of irradiation. [There is little hope of a direct observation of atmosphere-produced differences in level since a second of arc is never less than about 2,000 miles at the distance of Jupiter.-Ed.]

Color changes have been seen in all four satellites, perhaps explaining the widely varying color estimates given by different observers. In color IV is the most variable, III, I and II the least in that order; III, however, is generally very steady and IV is the most markedly variable of all, a fact also noticed by Newcomb. The color of IV is normally bluish, though often it appears to have a sort of grayish tinge and not infrequently is reddish, varying from an orange hue to deep red. J. III is usually some shade of orange-red, often appearing like a miniature of Mars; though the writer has sometimes seen it white and once unmistakeably bluish. J. I usually appears yellowish and II, white, though the colors are sometimes reversed; both occasionally appear reddish. Light fluctuations are more common to II than to I.

Very striking changes are frequent with IV. This satellite is commonly—though not invariably—brightest at its western, and faintest at its eastern, elongations. It is usually brightest and appears to have a larger disc when in its blue phase than when in its red, though here again the reverse has been noted. The writer's observations over a period of 8 years show that for 94 apparitions IV appeared bluish for 74% and reddish for 26% of them. It appeared bluish for 55% of its eastern elongations and reddish for only 29 of its western elongations. The writer has also seen the disc nebulous and indistinct and at other times very sharply defined.

These then are the phenomena easily available to the possessor of a small glass. If a careful, night-to-night record is kept, not only will these phenomena be observed but their non-periodic and unpredictable character will be fully established. Accurate records thus kept will help greatly in understanding the atmospheric phenomena of these satellites.

Color estimates and magnitude determinations should be made only against a dark sky and on clear nights. Proximity of the moon is fatal to accurate work. Moreover, the determinations should be made when Jupiter is on or very near to the meridian which is to say when it is at its greatest altitude. A light haze is not detrimental to determination of relative magnitudes but is fatal to accurate color work, either damping out the colors or giving a spurious red tint to all of the satellites depending upon the depth of the haze. Transits across Jupiter may be utilized to determine apparent changes in reflectivity of a satellite between two or more successive transits. This is done by noting whether the transit is light or dark. If light, the satellite will appear as a bright disc near the limbs of the planet commonly becoming difficult to invisible in the center of the disc. If dark, the satellite seems to darken as it approaches the center and in some instances—especially with IV—may appear as black as its shadow. Often the same satellite may exhibit a light and a dark transit in the course of one complete orbital revolution, thus indicating considerable change in reflectivity.

The writer may perhaps be pardoned for ending this paper with some observations of his own, which may be encouraging to those who would like to do useful work on the Jovian satellites with such means as may be available.

April 1, 1946, at 3h 35m., (U. T. here and later) II was so faint at the beginning of the observation as to be seen with difficulty but within an hour had become brighter than I.

April 22, 1946, at 5h 45m., within 30m. II again brightened until it surpassed I.

May 11, 1947, at 5h 21m., J. I was not only brightest of all but distinctly red. In fact I mistook it for J. III until I had consulted the satellite configurations in the <u>American Ephemeris and Nautical Almanac</u> after the observation. Incidentally, it is good practice for the observer <u>never</u> to consult the Ephemeris <u>before</u> observation but to sketch in the positions of the satellites assigning them estimated values as he sees them, later making identifications. This procedure helps eliminate the factor of suggestion.

May 12, 1947, at 5h 50m., III brightest, was distinctly bluish—a color checked carefully by filter.

July 9, 1948, at 3h 35 m., IV second in brightness, bluish.

July 9, 1948, at 5h 31 m., IV much fainter and now very red; apparent disc noticeably smaller.

These observations, excepting the last two which were made with a 3.5 in. reflector, were all made with 3-in. and 5-in. refractors. A 3-inch, with sufficient power, will raise definite discs on all of the satellites though little or nothing can be done with markings. A good 5-inch will sometimes show at least the existence of markings, while even a 2-inch will enable one to follow the apparent magnitude variations.

Saturnian Rotation Rates and Belt Latitudes

by Walter H. Haas

We have recently received from Mr. E. J. Reese a summary of two important phases of his studies of Saturn during its 1947-8 apparition. This material is undoubtedly important enough to deserve publication in a more significant astronomical periodical than this one. But since Mr. Reese is extremely modest about the worth of his excellent observations, we venture to give his summary here. His work was carried out with a 6-inch reflector, of his own construction and used at 240X, in Uniontown, Penna. His views of Saturn were good enough that he frequently saw Cassini's Division all around the visible part of the rings and Encke's Division for some dozens of degrees near the ansae.

From September 12, 1947, to June 3, 1948, Reese recorded fully 55 central meridian transits. The marks observed were almost all dark objects on the north edge of the South Equatorial Belt. From a careful study of a graph in which the longitude of a mark is plotted against time he deduced the following five (linear) drifts. All five objects are dark features on the north edge of the north component of the South Equatorial Belt, and hence near Saturnigraphic latitude -12°. The "terminal dates" are those of the first and last observations. The third column gives the longitude on February 9, 1948, the drift being extrapolated if necessary. Reese's longitudes are by A. F. Alexander's System B, which employs an arbitrary zero meridian and an assumed rotation-period of 10h 15m.9.

No.	Terminal dates	Long. at opposition	No. transits	Change in long. in 30 days.	Rotation period
1	Dec.30-Feb.7	87°	5	$+16.1^{\circ}$	
2	Dec.10-Feb.16	118	4	+5.3	
3	Dec.13-Feb.17	154	5	+3.2	
4	Jan.15-Feb.17	171	4	+5.5	
5	Dec.13-Feb.11	193	4	+7.0	
	Mean..			+7.4	10h 16m 4s
	Mean without no. 1............................			+5.25	10h 16m 1s

Perhaps the fact most favoring Reese's interpretation of his data, as above, is the very close agreement between four of his drift-rates. Indeed, one often gets much more scatter when dealing with Jovian drifts. Otherwise, one must admit that the individual drifts rest on scantay data; and an experienced Jovian transit-observer would not ordinarily base a rotation-period on four or five transits scattered over an interval of two months. It is interesting that Reese's mean period is near the 10h 15m 54s that A. F. Alexander obtained for the same latitudinal current in 1946-7. It is thus again slower than the "normal" equatorial current of 10h 14m.

Reese obtained belt-latitudes by measuring the originals of his 38 drawings, the first on September 12, 1947, and the last on June 6, 1948. He determined Saturnigraphic latitudes, which take account of the oblateness of the planet through suitable formulas. As usual, negative signs denote southern latitudes. We summarize his results as follows:

Position	No. drawings measured	Average latitude
center North Temperate Belt	23	44°.1
center Equatorial Band	21	-3.9
north edge South Equatorial Belt North	38	-11.7
south Edge South Equatorial Belt South	38	-27.0
south edge South Temperate Belt	20	-35.9
south edge South South Temperate Belt	11	-44.7
center narrow bright zone	11	-47.7
north edge South Polar Band	37	-64.1
south edge South Polar Band	23	-71.7

During the period of observations the quantity B, the Saturnicentric latitude of the earth, ranged from -12°.9 to -16°.0.

The reader might like to compare Reese's values with those published in The Strolling Astronomer, Volume 1, No. 4, pg. 6, 1947. There is little evidence for changes in latitude between 1946-7 and 1947-8. The most likely change is for the south edge of the South Equatorial Belt South, which three observers put at -30° or -31° in 1946-7.

Speaking now only of Reese's 1947-8 latitudes, the mathematical reader will wonder about their accuracy. Wishing to measure random errors only, we first assure ourselves by studying his original data that there is no evidence of systematic changes in the latitude of the north edge of the South Equatorial Belt North, or in that of the center of the Equatorial Band so that we may use these two positions as samples. We then compute that the probable error of a single measured latitude of the S. E. B. $_N$ is 1°.2 and that the probable error of the adopted mean of -11°.7 is hence 0°.2. Perhaps it is more pictorial to say that the average numerical error of a single measured latitude, paying no attention to the sign, is 1°.4 and that there are only three errors exceeding 3°.0 in the set of 38 measures (all other measures fall within 3°.0 of -11°.7). For the E. B. one gets that the probable error of a single measure is 1°.3 and that the probable error of the mean of -3°.9 is hence 0°.3. The average numerical error is here 1.°5. The degree of accuracy achieved by Reese on his drawings appears to us truly remarkable. Bear in mind that even at opposition and in the center of the disc a degree of saturian latitude is only one-sixth of a second of arc.

It is natural to ask whether Reese's measures give any evidence of changes in belt-latitudes during the course of the 1947-8 apparation. The North Temperate Belt was placed at +33° to +39° in February and March and thus farther south than usual; it was very faint in those months and was recorded on only three drawings. There is evident a southward trend of the South Polar Band during the apparition. In the summary below of its Saturnigraphic latitudes, the numbers in parentheses show on how many measures each value rests.

Month	North Edge S. P. B.	South Edge S. P. B.
1947, September	-56.°2 (2)	
October	-59.2 (5)	
November	-61.2 (3)	-69.°1 (2)
December	-66.2 (8)	-70.5 (4)
1948, January	-66.2 (5)	-72.2 (3)
February	-64.4 (4)	-71.0 (3)
March	-63.0 (3)	-69.3 (3)
April	-65.9 (2)	-73.0 (2)
May-June	-68.2 (5)	-75.0 (5)

It may be worthwhile to record a few other facts for the student of Saturnian latitudes--an almost untouched field. On December 1 Reese measured a North North Temperate Belt to lie at +53.°0. On December 7 he placed the north edge of a white South Polar Cap at -85.°2. Seven measures of the south edge of the South Equatorial Belt North give an average latitude of -18.°1, and seven measures of the north edge of the South Equatorial Belt South give -23.°5. Occasional measures of the north edges of the South Temperate Belt and of the South South Temperate Belt give each of these belts a width of three degrees.

It is possible that the changing value of the tilt B of the axis of Saturn introduces systematic errors into measured latitudes. Our A. L. P. O. studies to date do not allow judging this matter.

We are indebted to Mr. Reese for an excellent bases on which to build future studies of Saturnian latitudes. We hope that some of our readers will help do the building. Carefully made drawings on a large enough scale are all that is required. It would, however, be excellent if those members having the use of a filar micrometer would employ it to determine these latitudes independently.

Lunar Tidbits

It is well known that Schroeter often observed a prolongation of the cusps of the crescentic moon into the dark hemisphere and imputed the appearance to a rare lunar atmosphere. A drawing of the prolongations is given in Volume I of T. W. Webb's still very readable Celestial Objects for Common Telescopes. The extensions have also been recorded by Gruithuisen, the Messrs. Henry, and W. H. Pickering. In more recent years they have been noted by F. R. Vaughn, H. M. Johnson, and W. H. Haas and have been suspected by D. P. Barcroft. It is proper to state that some observations of their absence have also been made by members of our A. L. P. O. The prolongations are extremely faint, scarcely more than a slightly greater brightness of the rim of the earthlit moon near each cusp. We now read on pg. 172 of The Journal of the British Astronomical Association for June, 1948, that H. P. Wilkins on the evening of April 14, 1948, found the star-like points of the lofty Leibnitz peaks near the south cusp "connected by exceedingly fine filaments brighter than the earthshine." He was using a 12-inch reflector at 150X in a very clear sky.

On pg. 171 of the same J. B. A. A. we find: "A. W. Vince saw 1948, April 15, 22h 23m, with power 50 on a 6 3/8 inch O. G. [refractor], a bright flash on the earthlit east limb, 30° to the north of Grimaldi, and estimated it as equal to a third magnitude star." One is reminded of the very similar flashes remarked by A. W. Mount and F. H. Thornton; refer to The Strolling Astronomer, Volume 1, no. 8, pp. 2-5, 1947. Are all three objects meteoritic impact-flashes?

Error in August issue. The sentence near the middle of page 8 should read; "The polar radius of Jupiter was 22" in June, and it follows that a cloud projecting only 0".1 must rise nearly 200 miles [not 400] above the reflecting surface of the planet." This changed number does not change the editor's opinion of the theoretical unlikelihood of actual Jovian cloud-projections.

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