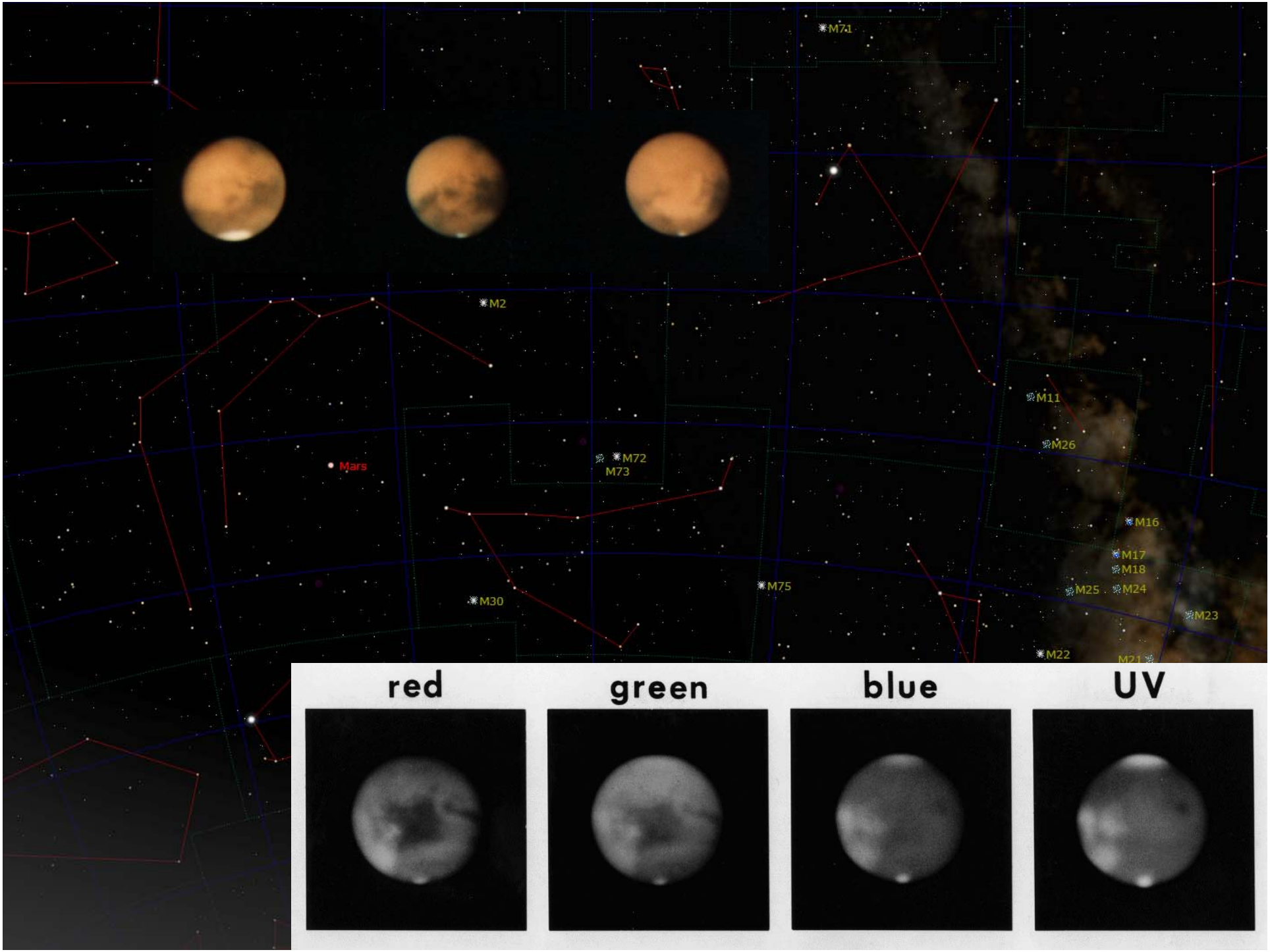

# Planetary Imaging Workshop

*Larry Owens*


M71
M2
M11
M26
Mars
M72
M73
M16
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M24
M75
M30
M23
M22
M21
red
green
blue
UV

# *Lowell Observatory, 1971-1973*

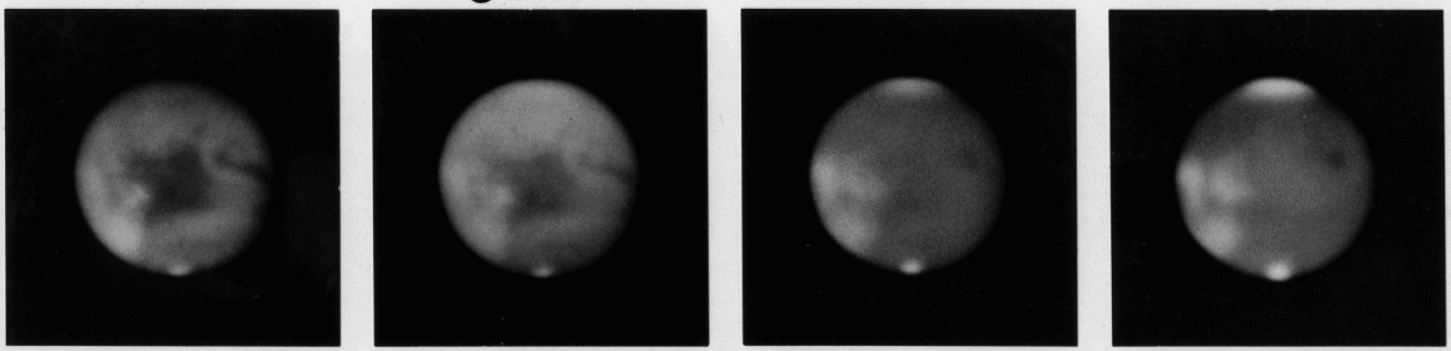

CHANGES IN MARTIAN ALBEDO FEATURES AND THE EFFECT OF A DUST STORM IN 1973 ARE SHOWN WITH COLOR RESTORED IMAGES.


DIFFERING COLORS OF MARTIAN STORM CLOUDS

OCT. 16, 1973 – 0900 UT

4th STORM DAY – 14.5 hrs. AST at 0°

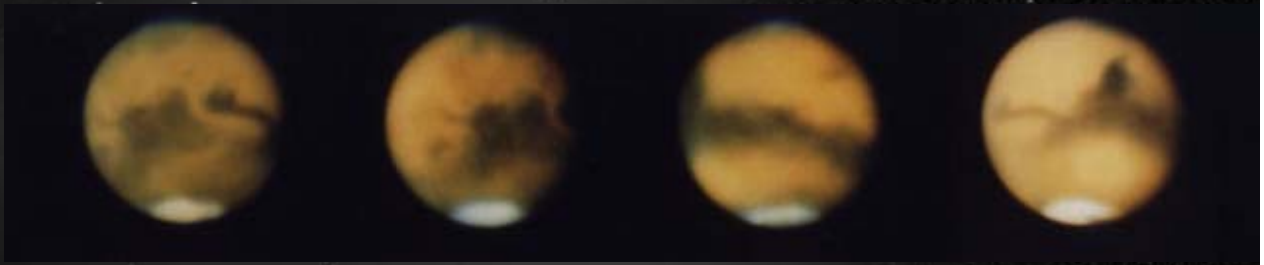
red green blue UV

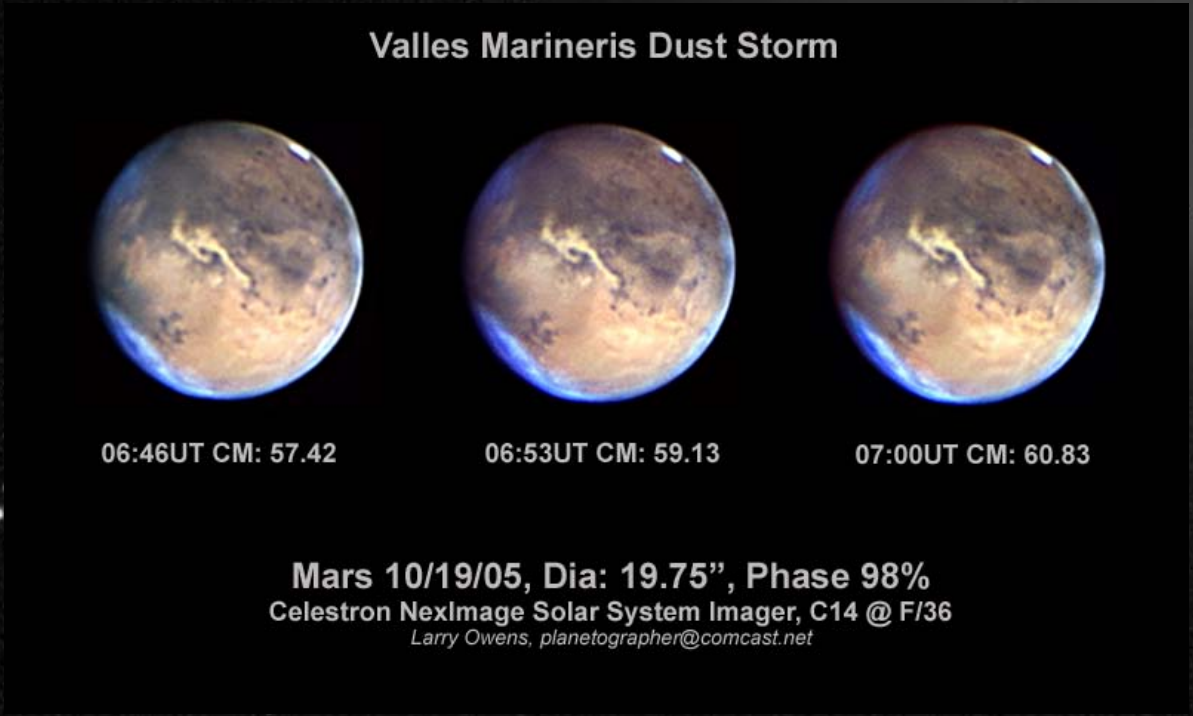


# *Backyard Telescope, 2005*

# *How is it Possible?*
# *How is it done?*

Lowell Observatory Sequence,1971





# *The Secret…*

- Use the right tool for the job!
- Get the “sampling” right
- Use slower frame rates, longer exposures

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  - For the best images,  11” – 16” aperture
    - C9.5, high end refractors - exception
  - Long inherent focal length
    - Schmidt-Cassegrain, Maksutov, Refractor (would be nice)
  - Sturdy low PE equatorial mount
  - Motorized focuser
  - Monochrome CCD camera with filter wheel
    - Best images, best for analysis

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- Get the “sampling” right
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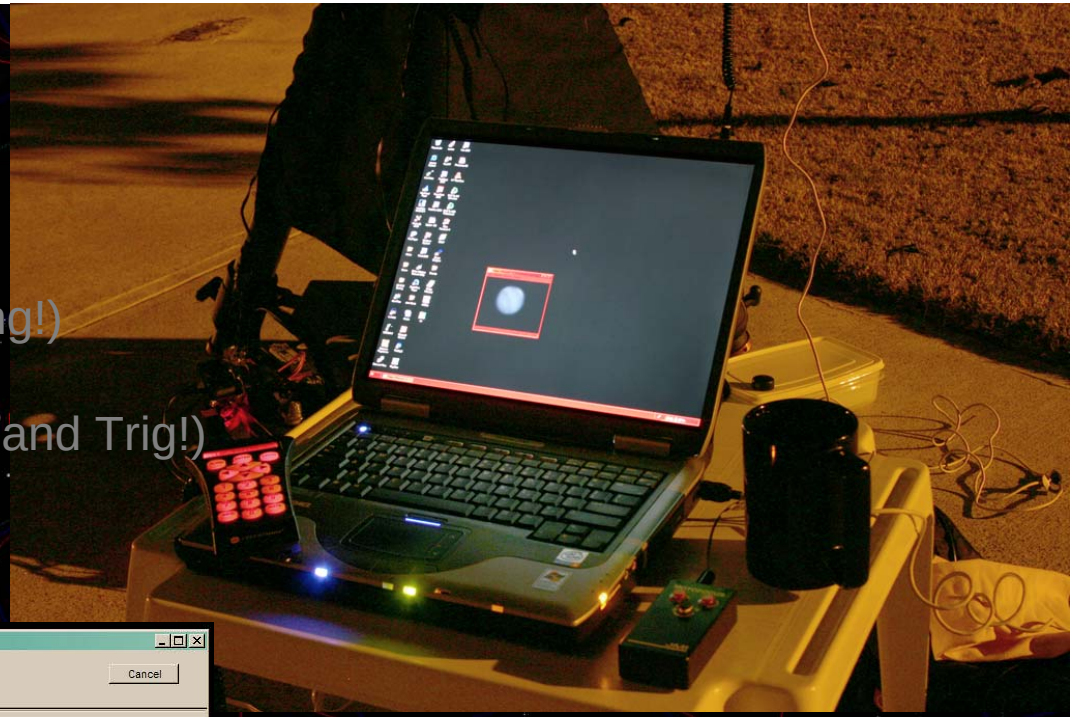
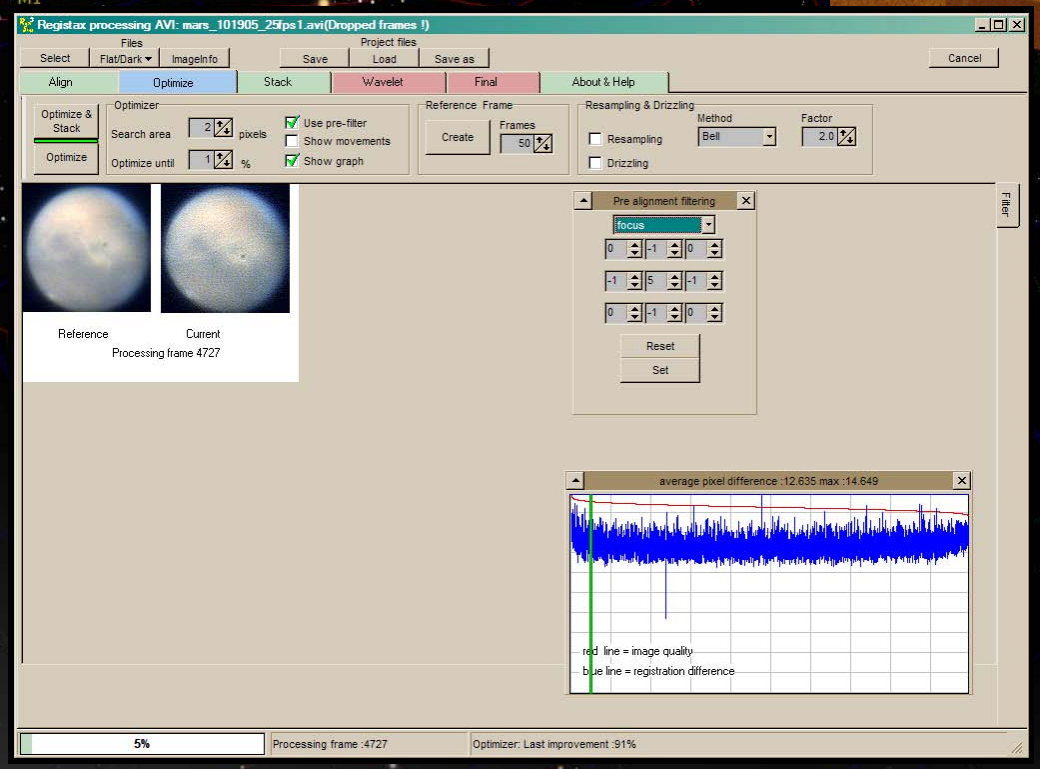
- Use slower frame rates, longer exposures
  - 60-140ms, 5-15fps
- F-O-C-U-S!
- C-O-L-L-I-M-A-T-I-O-N!
- E-X-P-E-R-I-M-E-N-T-A-T-I-O-N!

# Acquisition

Using monochrome cameras & filters
Color cameras and resolution
Format: 640x480 or 320x240 (Sampling!)
Frame rates, compression & noise
How long to capture (fun with Algebra and Trig!)
Exposure, Gain and White Balance






# Processing

Reference frame selection
Alignment box size (feature or planet)
Quality settings, Pre-filter usage
To resample or not to resample
Selecting frames with stack graph
Selecting frames with frame list
Final adjustments and PhotoShop
Data to present with your image

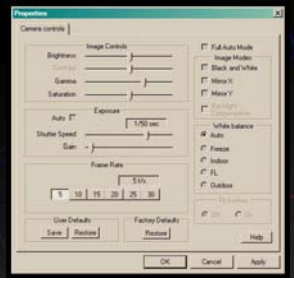
# *Acquisition*

# Acquisition Strategies

- Acquisition Software
  - VRecord, AMcap
  - AstroVideo, IC Capture, K3CCD Tools
  - StreamPix, MaximDL


- Things to consider
  - Raw image feature resolution
  - Frame resolution
  - Monochrome cameras and filters

  - Experiment with Exposure and Gain



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    - If very soft, acquire frames according to rotation maximum
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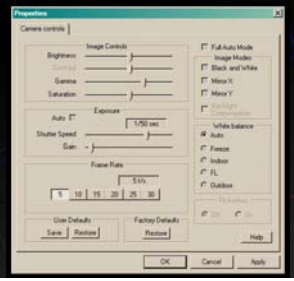

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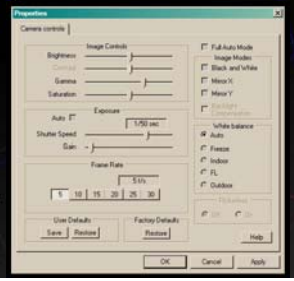
  - Frame resolution
    - 640x480, sub-frame, 320x240
    - Planet angular diameter, sampling, chip area
  - Monochrome cameras and filters



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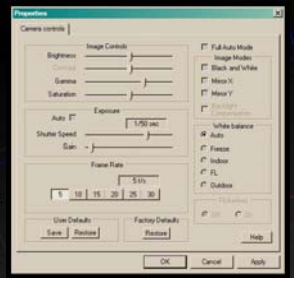
  - Monochrome cameras and filters
    - Consider time it takes to acquire full RGB sets (color shift tolerance)
    - Plan for LRGB (if desired): color set – luminance set – color set
    - Consider filter to use for Luminance – UV/IR block, IR, Red, Green
    - Watch filter distance from chip in optical train
  - Experiment with Exposure and Gain



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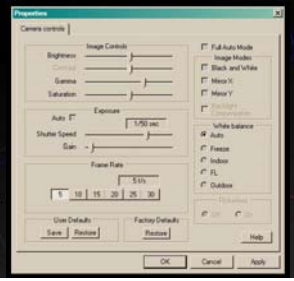
    - Watch filter distance from chip in optical train
  - Experiment with Exposure and Gain
    - Longer exposures, lower gain, fewer frames
    - Shorter exposures, higher gain, higher frame counts



# *Monochrome Cameras*

- Lumenera
- Atik
- Modified Philips Cams (mono chip + raw mode)
- CCD Cameras
- Filter wheel or slider
- Filters

- Full Chip Resolution
- Color Combine in MaximDL


Schuler Standard Bandpass

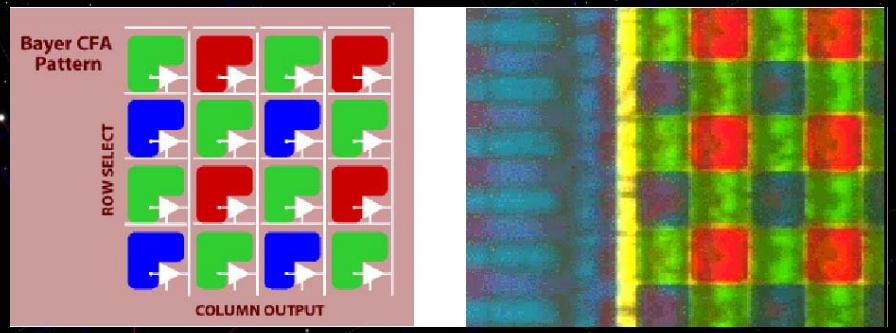
| | | |
|---|---|---|
| UV | 345-385nm | 70% |
| Bu | 375-475nm | 75% |
| V | 488-688nm | 86% |
| Rs | 570-725nm | 78% |
| Is | 700-980nm | 77% |

Custom Scientific (RGB)

| | | |
|---|---|---|
| R | 612-670nm | 97% |
| G | 488-574nm | 96% |
| B | 392-508nm | 95% |

# Color Cameras

- Actual Resolution of 640x480 Color Chips:
  - RED=320x240
  - GREEN=320x480
  - BLUE=320x240



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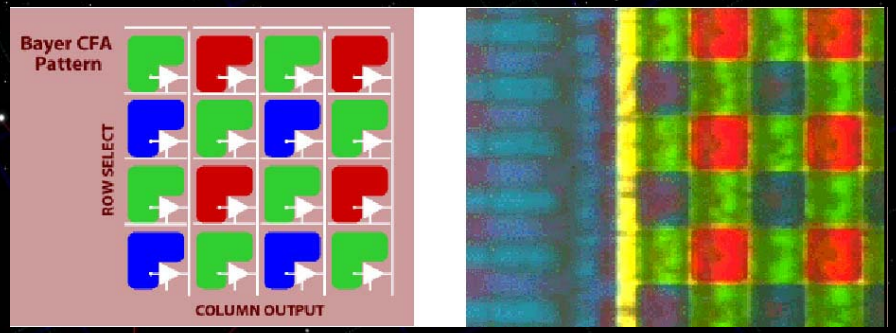
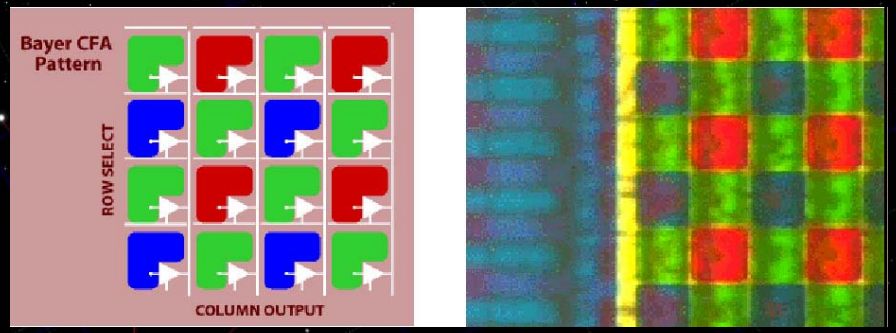



  - At 320x240, Full color resolution (use RAW mod to be sure, see link) http://www.astrosurf.com/astrobond/ebrawe.htm

# Color Cameras




- Actual Resolution of 640x480 Color Chips:
  - RED=320x240
  - GREEN=320x480
  - BLUE=320x240

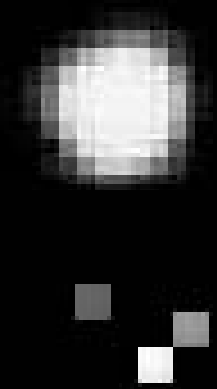
  - At 320x240, Full color resolution (use RAW mod to be sure, see link) http://www.astrosurf.com/astrobond/ebrawe.htm

  - At 640x480, Something less than full resolution
    - Bayer pattern interpolation
    - Twice the resource usage without twice the resolution
    - Longer stacking and processing times
    - High resource usage can cause processing problems
  - 640x480 usage
    - If you can't get the sampling right (more on this later)
    - Short focal length Newtonians

- Philippe Bernascolle has performed some interesting resolution tests with ToUcams
- http://www.astrosurf.com/astrobond/Using-RAW-Mode.pdf

# *Sampling*

- Resolution is **not** the important setting
- Sampling is really what matters
- Oversampling (too many pixels)
- Undersampling  (not enough pixels)
- Correct Sampling



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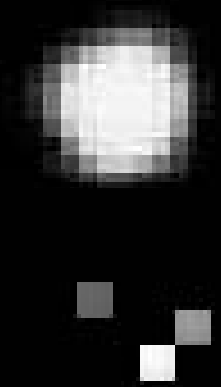
- Resolution is **not** the important setting

- Sampling is really what matters
  - Nyquist sampling rule:  2-3 pixels over the highest possible resolution
  - Use the Dawes limit of your scope
  - Raise the focal length so that 1 pixel covers half of the Dawes limit
  - Somewhat dependent on seeing though - Experimentation

- Oversampling (too many pixels)



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- Oversampling (too many pixels)
  - Power is too high, brightness too low
  - Requires longer exposure times
  - Very long exposures can cause loss of detail

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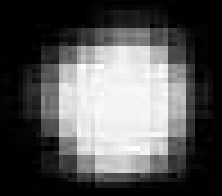
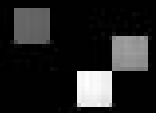
  - Resolution of optics is wasted
  - Not enough pixels to represent finest details

- Correct Sampling





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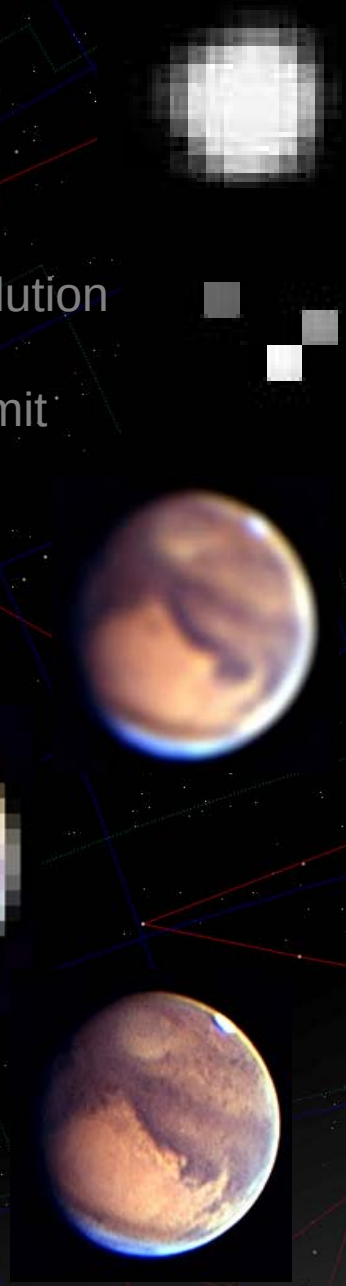
- Correct Sampling
  - Records all that is possible from optics and seeing conditions
  - Reasonable exposure times and gain settings
  - May need to undersample a bit – seeing, camera sensitivity



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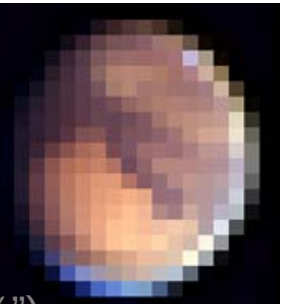
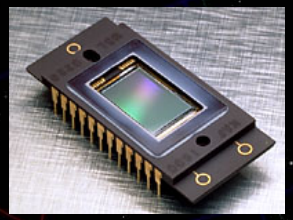


- Dawes Limits: (116/aperture in mm)

| | |
|---|---|
| 4” - 1.14” | 11” - .41” |
| 8” - .57” | 14” - .33” |
| 10” - .46” | 16” - .29” |

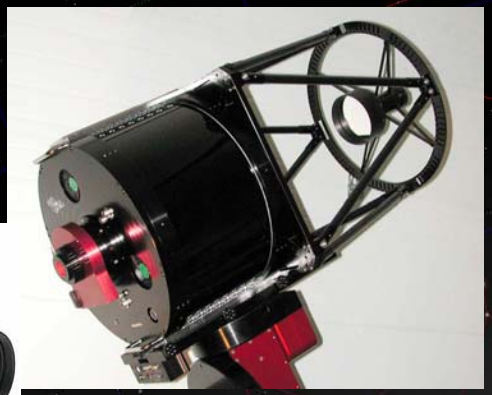
Pixel Sizes:

ICX098BL – 5.6µ (Toucam, ATIK ¼”)
KAF402 – 9µ (ST-402ME, ST-7E)
TC-237 – 7.4µ (ST-237)
ICX424 – 7.4µ (Lumenera & other 1/3” Cams)



- Two ways to find arc seconds per pixel:
  - Arcseconds per pixel = $\frac{\text{(Pixel Size in microns)}206}{\text{Focal length in mm}}$ ***(Must know exact FL)***
  - Arcseconds per pixel = $\frac{\text{Size in arcseconds of known object}}{\text{Number of pixels across known object}}$ ***(Must know angular size of Planet)***

- Now you can find your exact focal length:
  - Focal length = $\frac{\text{(Pixel Size in microns)}206}{\text{Arcseconds per pixel}}$

# *How Long to Capture Frames*

- Planetary rotation can affect the image in as little as 5 minutes

- ***Theoretically***, capture time should not exceed the time it takes the planet to rotate through one pixel
    - In reality, longer times are fine – seeing, arcsec/pixel vary – Experimentation!
    - Times can be extended if you align by feature (more later)
    - *Two ways to calculate:*

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When you know
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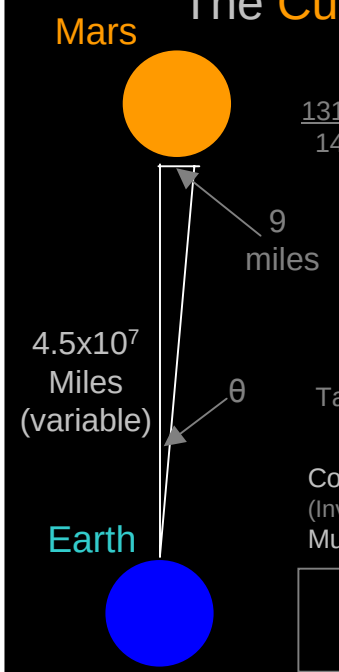


$\frac{13195\text{mi}}{1479^m} = 9\text{mi/min}$

A feature on the surface travels 9mi/min

How many arcseconds per minute is that?

$\text{Tan}\theta = \frac{\text{opposite}}{\text{adjacent}}$

Convert Tanθ to °
(Inv, tan=angle in °)
Multiply by 3600 (for arcsec)

$\boxed{am = \theta}$

Diameter=4,200mi
Circumference=13,195mi (πD)
Period of Rotation=$24^h\ 39^m$ ($1479^m$)
Apparent Diameter=19.45”
Distance from Earth=44,701,711mi

$\text{Cap Limit} = \frac{\text{arcsec per pixel}}{am}$

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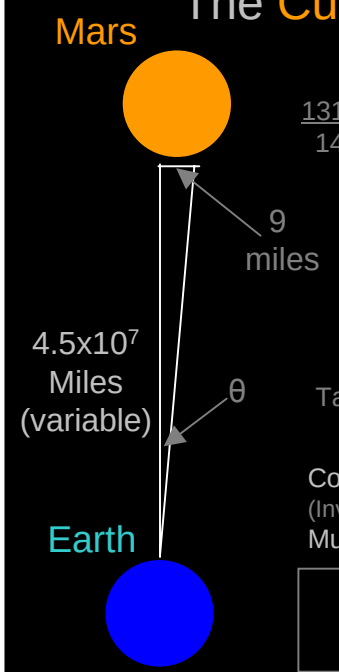
## When you know The Current Distance

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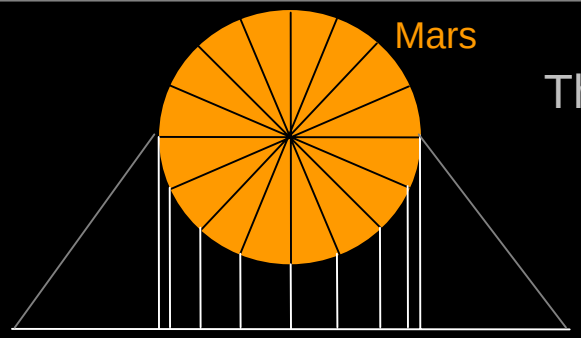
## When you know The Apparent Diameter

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Period of Rotation=$24^{h}$ $39^{m}$ ($1479^{m}$)
Apparent Diameter=19.45"
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d = diameter (4200mi)
d' = apparent diameter (arcsec)(var)
hc= half circumference (6598mi)
hc'= apparent length of hc (arcsec)
hd = half day (740min for Mars)
am = apparent motion (arcsec/min)
T = Time (minutes)

1) Find the "apparent" half circumference

$$\frac{hc}{hc'} = \frac{d}{d'}$$

$$d(hc') = hc(d')$$

$$hc' = \frac{hc(d')}{d}$$

2) Now find "apparent" motion

$$\frac{hc'}{hd} = \frac{am}{T}$$

$$hd(am) = hc'(T)$$

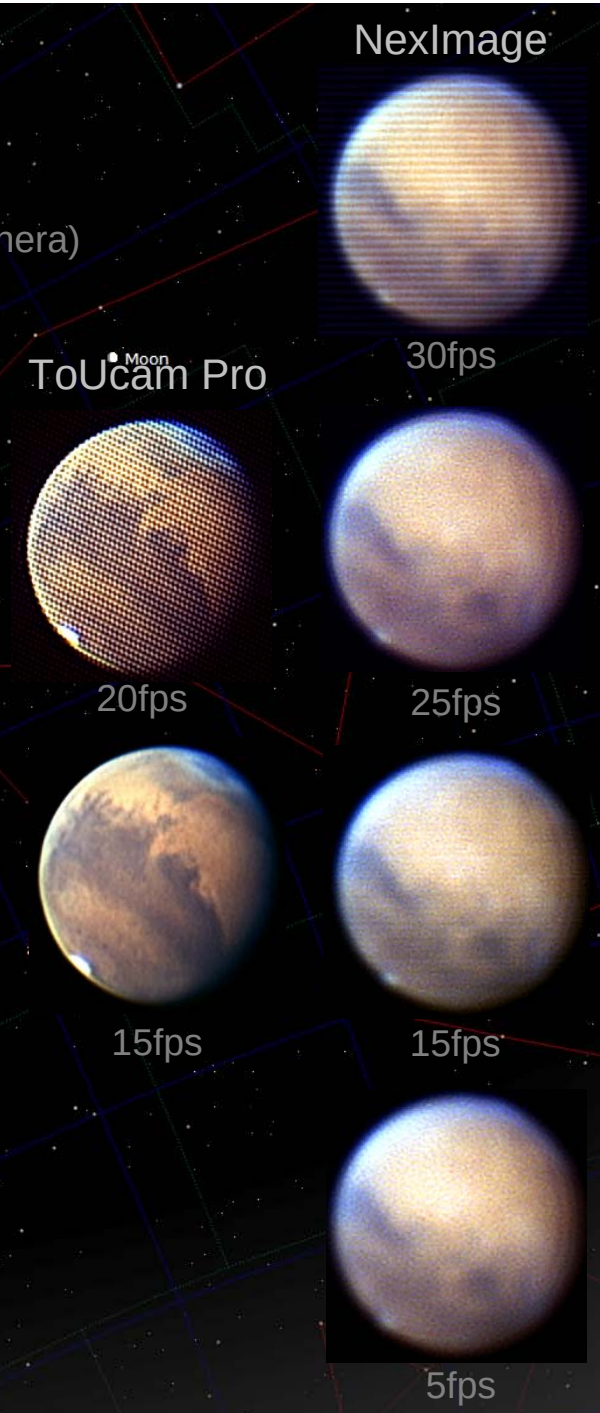
$$am = \frac{hc'(T)}{hd}$$

$$\text{Cap Limit} = \frac{\text{arcsec per pixel}}{am}$$

# *Frame Rates*

- Compression issue (Not a problem with CCD Cameras, SBIG, Lumenera)

- Noise issue



# *Frame Rates*

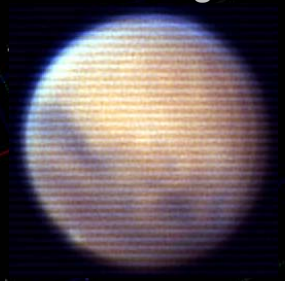
- Compression issue (Not a problem with CCD Cameras, SBIG, Lumenera)
  - Above a certain frame rate the camera performs compression
  - Effects of compression *not visible on video*
  - Causes ***severe*** processing artifacts

  - ToUcam Pro
    - Starts compression at 20fps and above
    - 5, 10 and 15 fps are fine

  - Celestron NexImage
    - Starts compression at 30fps
    - Rates from 5-25 fps are OK, 5 and 25 seem best

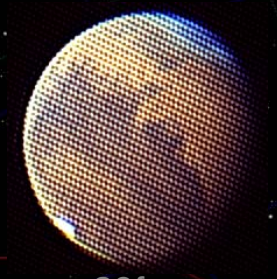
- Noise issue

NexImage

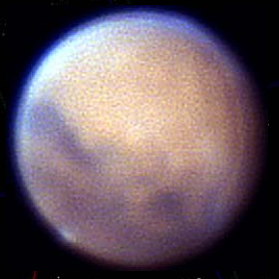


30fps

ToUcam Pro

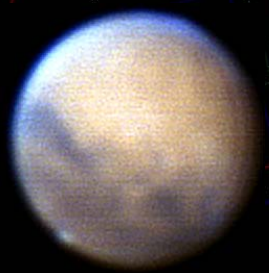


20fps

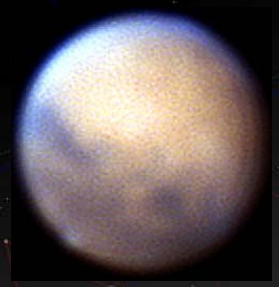


25fps

15fps



15fps



5fps

# *Frame Rates*

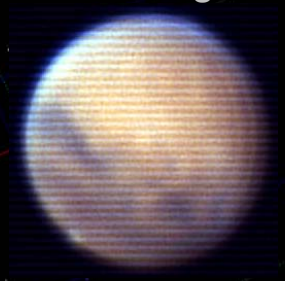
- Compression issue (Not a problem with CCD Cameras, SBIG, Lumenera)
  - Above a certain frame rate the camera performs compression
  - Effects of compression *not visible on video*
  - Causes ***severe*** processing artifacts

  - ToUcam Pro
    - Starts compression at 20fps and above
    - 5, 10 and 15 fps are fine

  - Celestron NexImage
    - Starts compression at 30fps
    - Rates from 5-25 fps are OK, 5 and 25 seem best

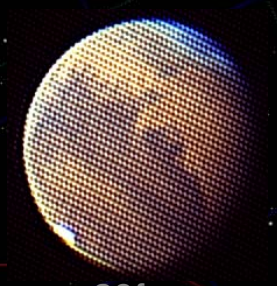
- Noise issue
  - Some cameras have different levels of noise at different fps (even at slower rates)
  - Take several test shots with your camera, pick the best exposure and frame rate after processing.

NexImage

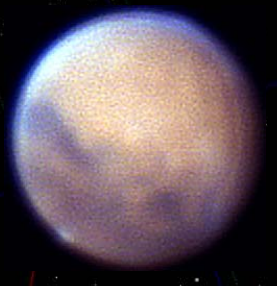


30fps

ToUcam Pro

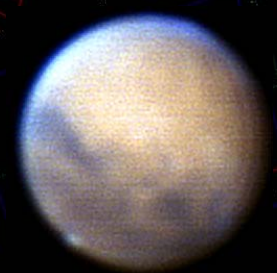


20fps

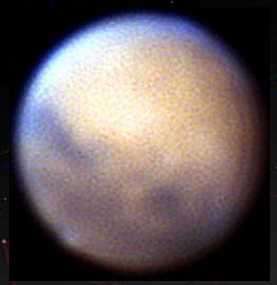


25fps

15fps

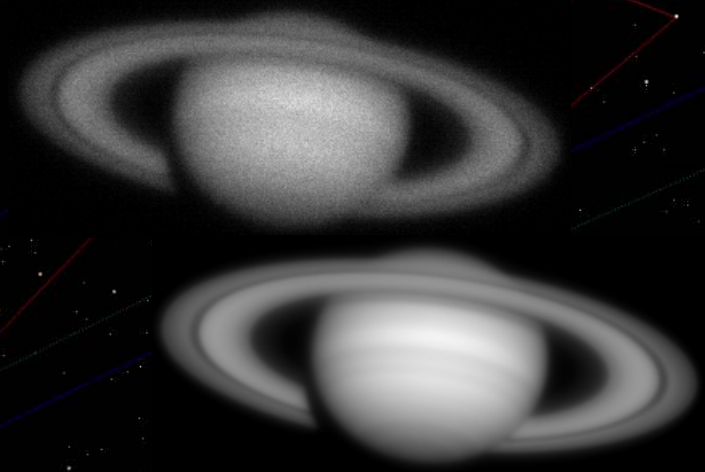


15fps



5fps

# *How Many Frames to Capture*



- Why capture large numbers of frames to begin with?
- The number of frames to capture is dependent on:
- CCD cameras can get excellent images with only 100 or 200 frames
- Web cams require 1000 or 2000 frames to reduce noise to the same level
- Best of both worlds (Lumenera, USB-2 CCD Cams – ST-402ME):

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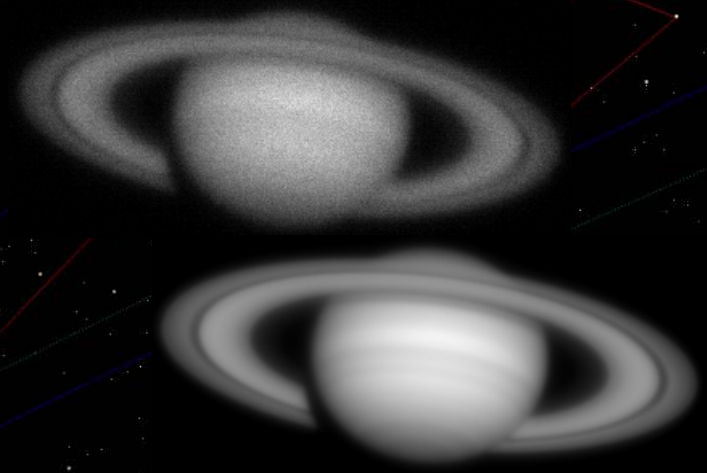

- Why capture large numbers of frames to begin with?
  - Defeat atmospheric turbulence (lucky imaging)
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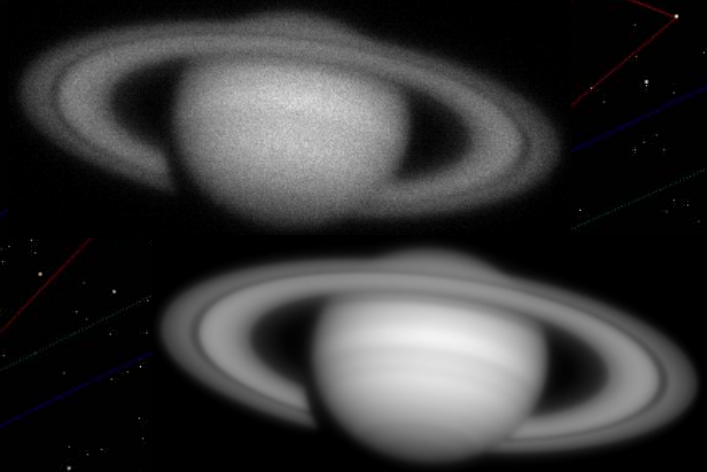

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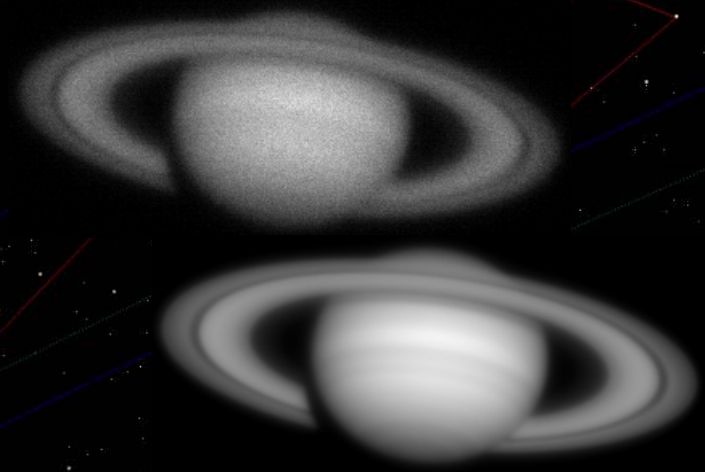

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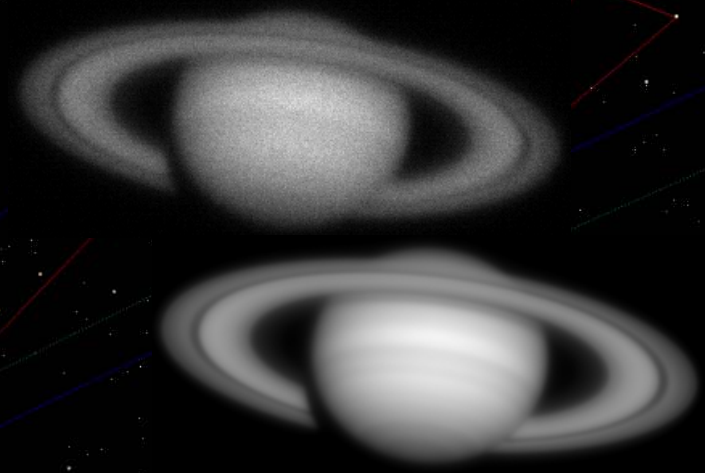

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  - Low noise camera
  - High sensitivity
  - High frame rates

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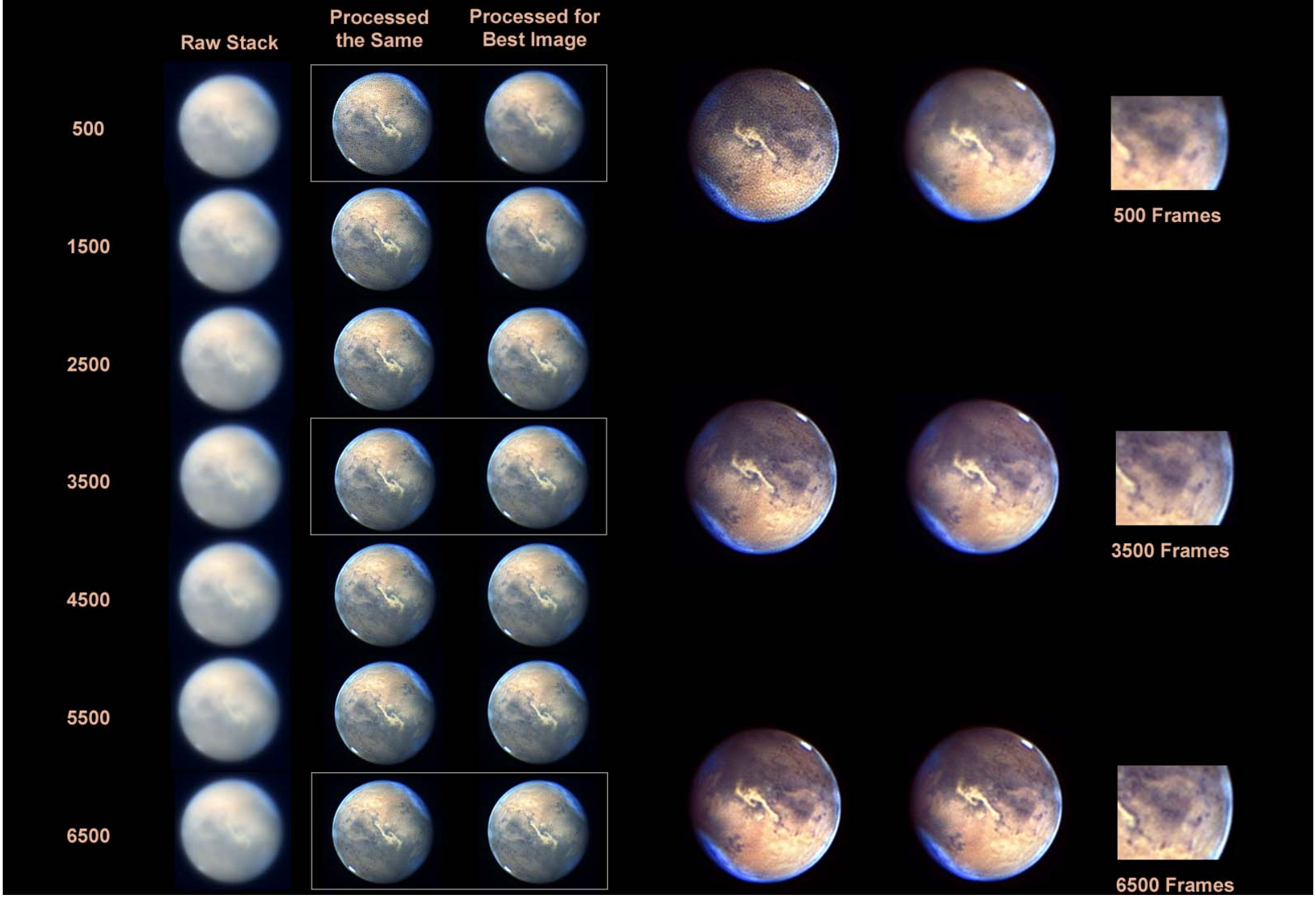
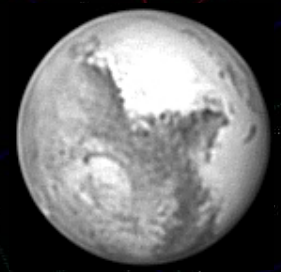
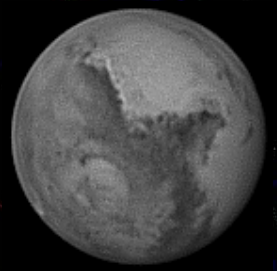
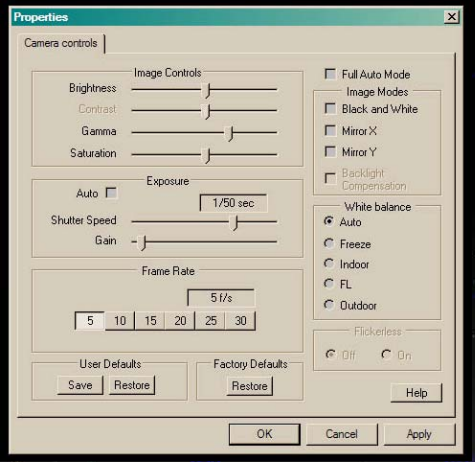


# *Exposure, Gain & White Balance*

- It's not a good idea to use the camera's auto exposure setting
  - Use manual camera settings for better control
- Exposure and gain settings go hand in hand
- White balance seems to work best in "automatic" mode







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  - Set the gain just below the point where saturation occurs

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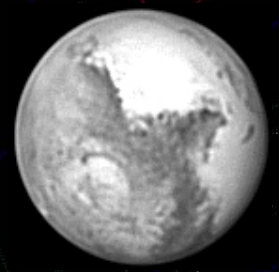

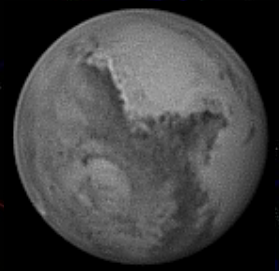

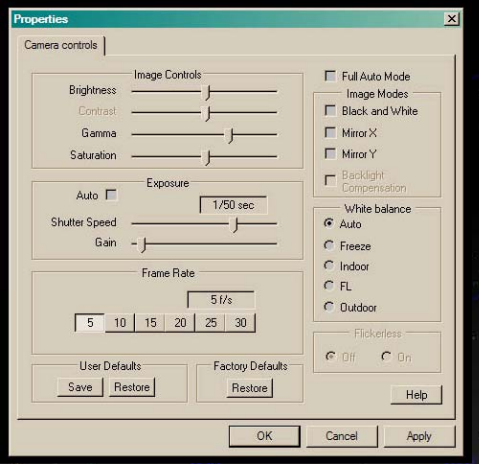

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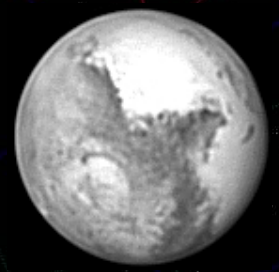
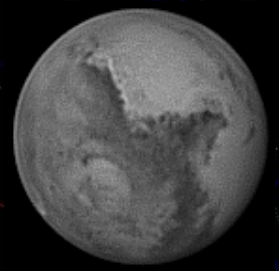
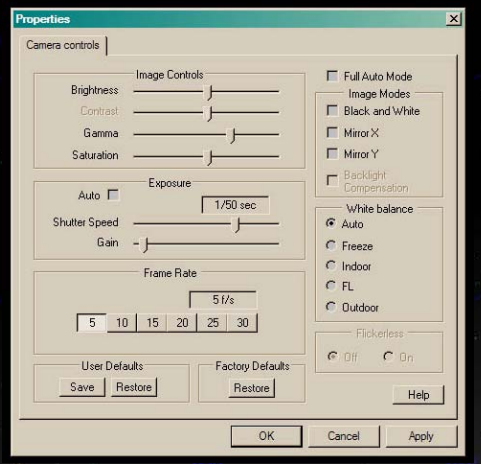
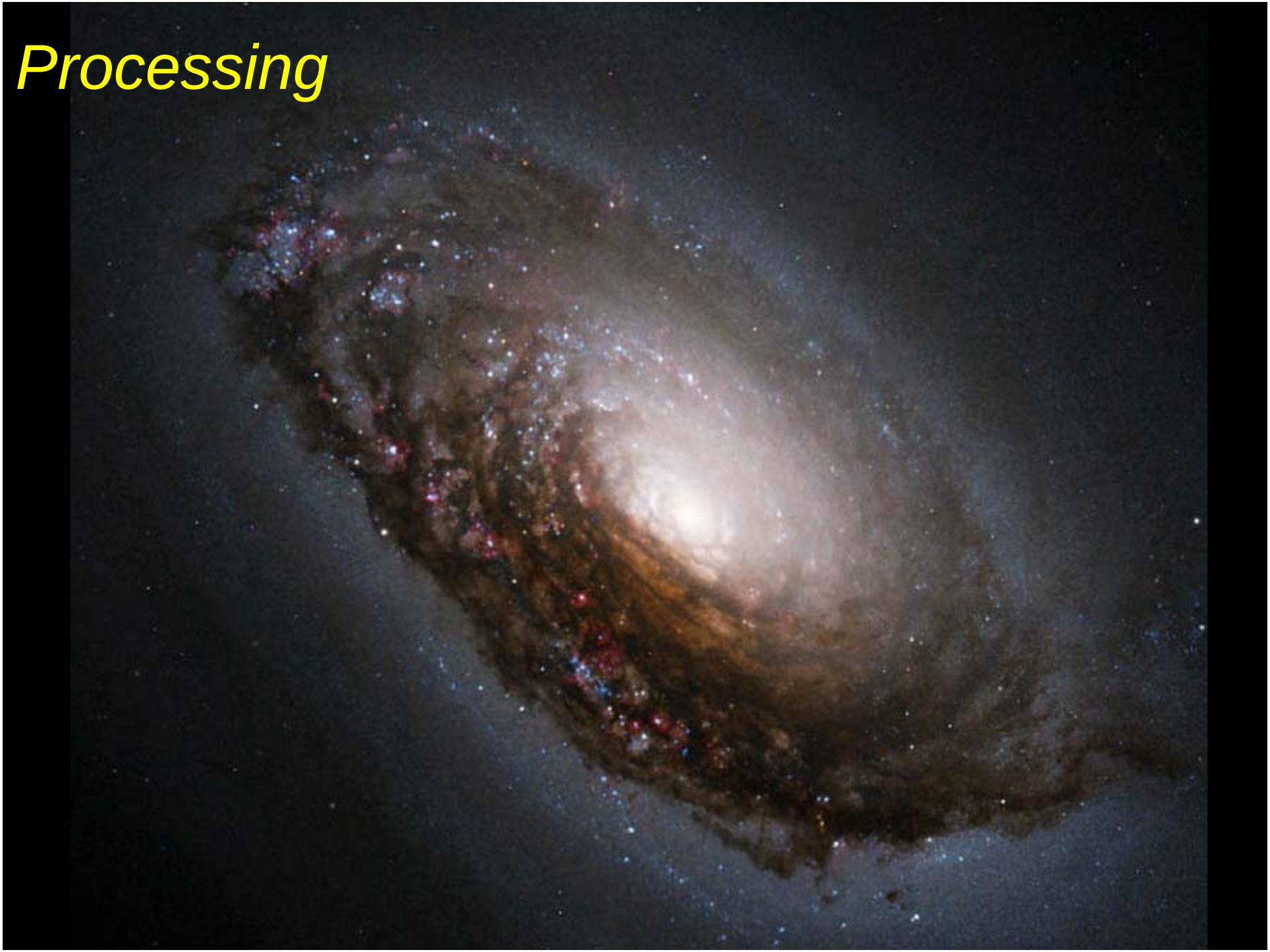
- White balance seems to work best in "automatic" mode
  - Experiment with color settings
  - A pale under colored video image can easily be enhanced later
  - Images saturated with color tend to be difficult or impossible to correct





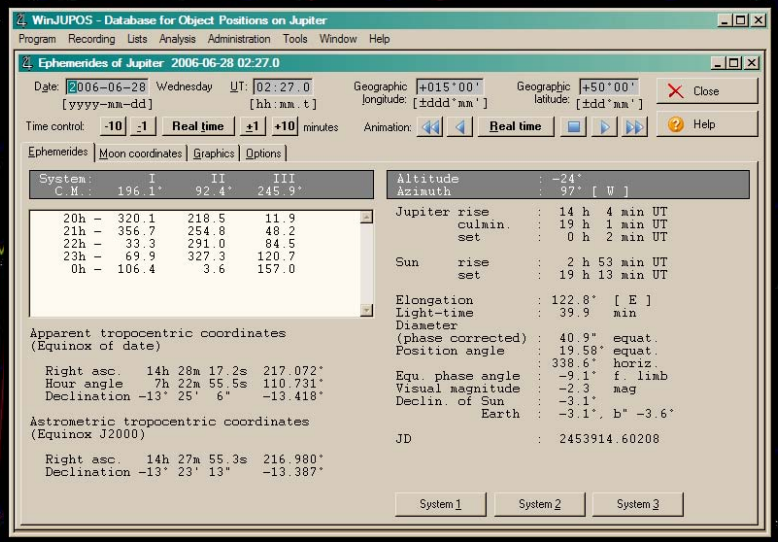


# *Processing*



# Processing Strategies

- Prcessing Software
  - RegiStax V3 (aligning, stacking, initial proc)
  - MaximDL (color combining)
  - WinJupos (planetary ephemeris)
  - Photoshop CS (luminance stacking, final proc)




- Things to consider
  - Acquisition strategy
  - Raw image quality
  - Reference frame selection
  - Frame rejection strategy
  - Monochrome cameras

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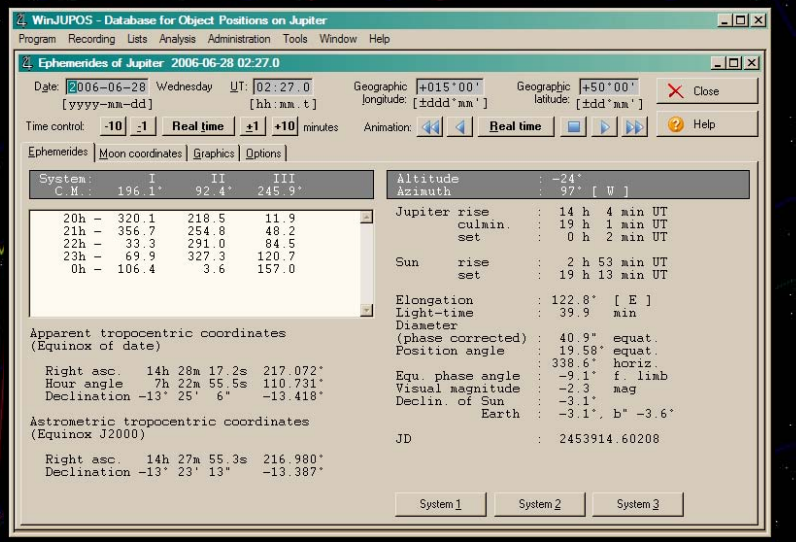


- Things to consider
  - Acquisition strategy
    - Somewhat determines the processing strategy
    - Longer sets taken? (may need to feature align)
    - Luminance filter sequences taken?
  - Raw image quality

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  - Frame rejection strategy

  - Monochrome cameras

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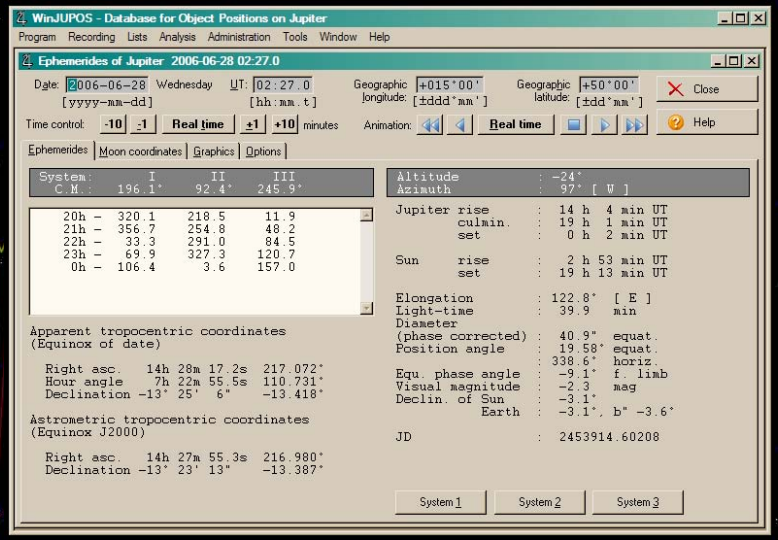


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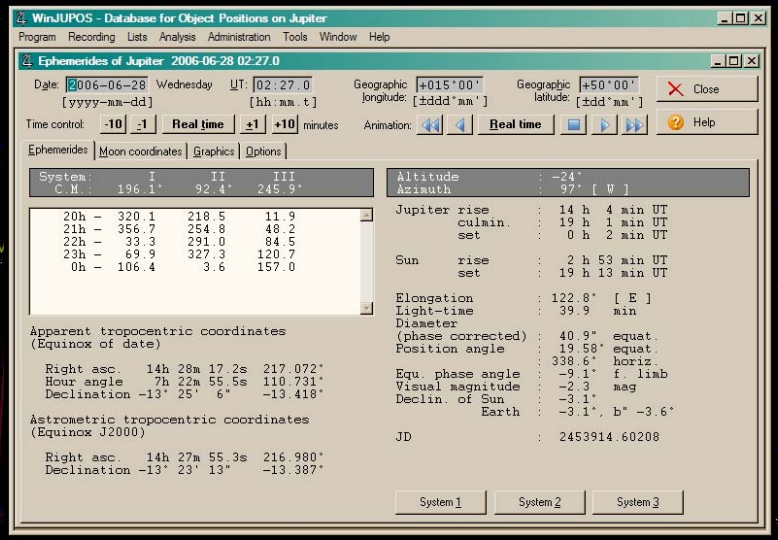


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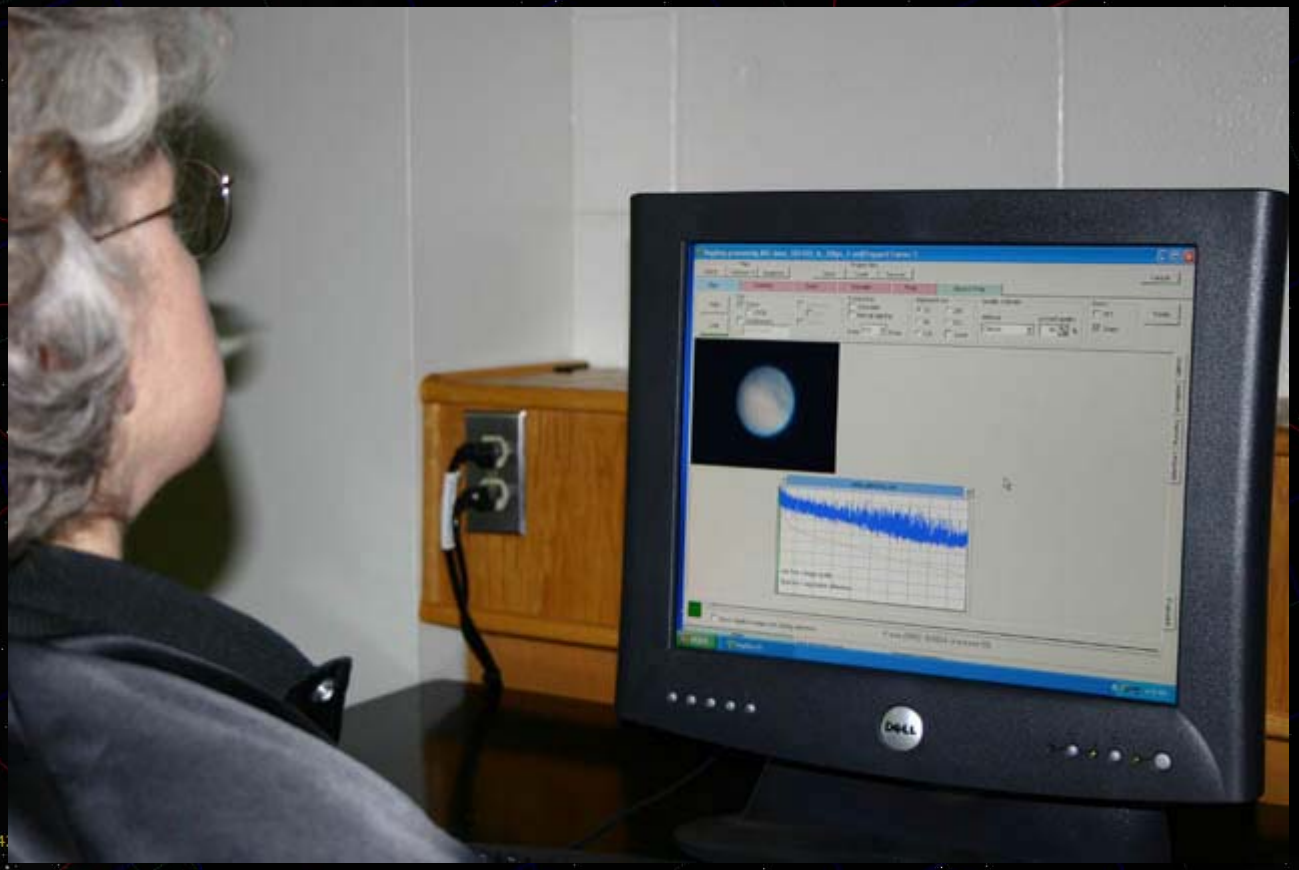
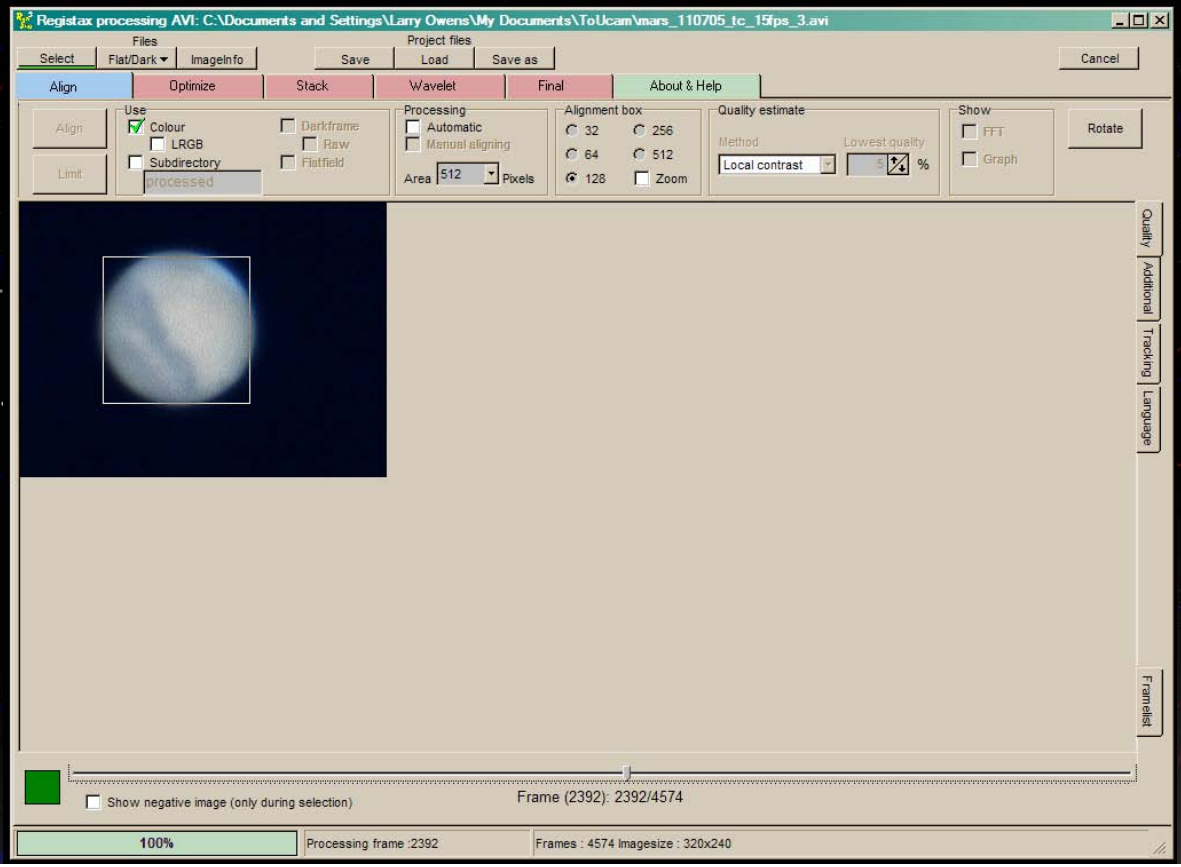
  - Reference frame selection
  - Frame rejection strategy
    - Quality only
    - Quality and alignment accuracy
  - Monochrome cameras
    - LRGB, process color sets before and after luminance set

# *Processing Workshop*



# Reference Frame Selection

- Reference frame becomes the model for Alignment and Alignment Optimization
  - Selecting an “average” frame seems to work best
    - An average frame produces a flatter alignment curve (important later)
    - A frame from the middle of the AVI reduces planetary rotation artifacts (unless aligning by planetary feature)



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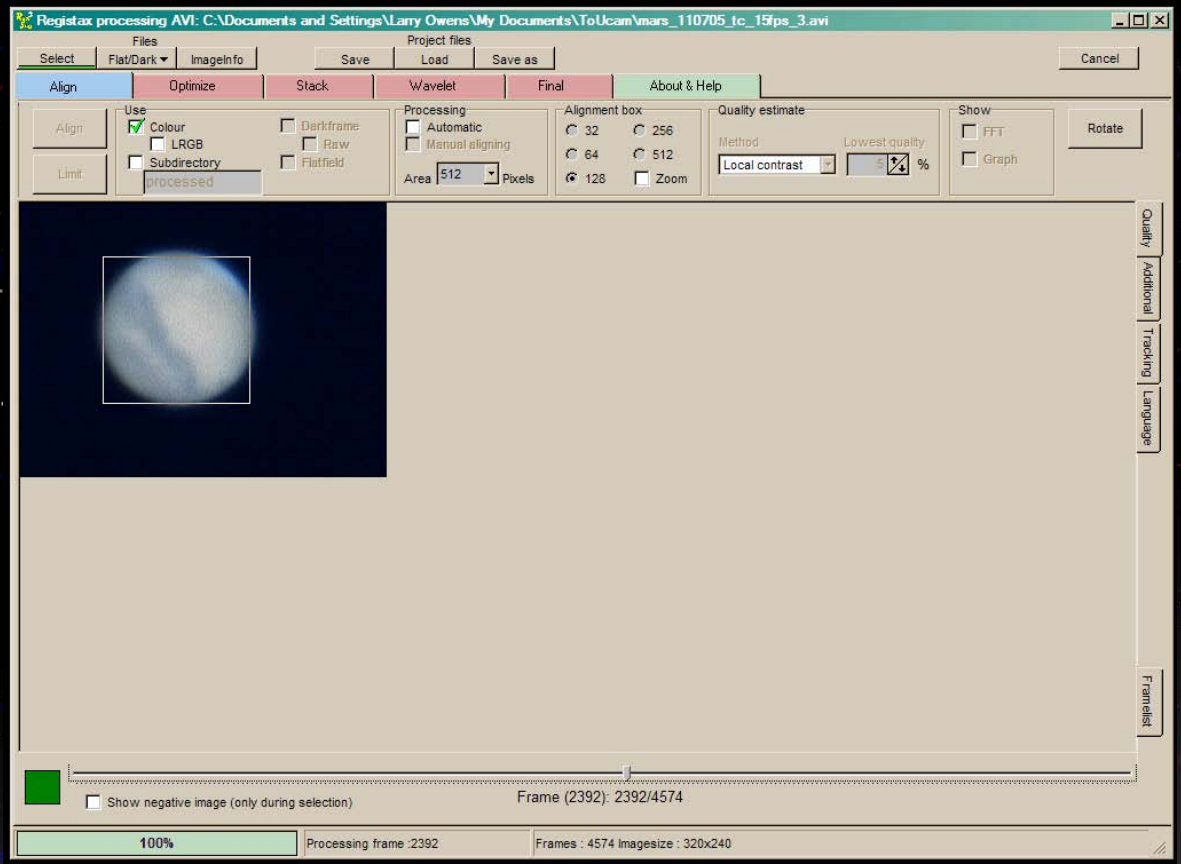
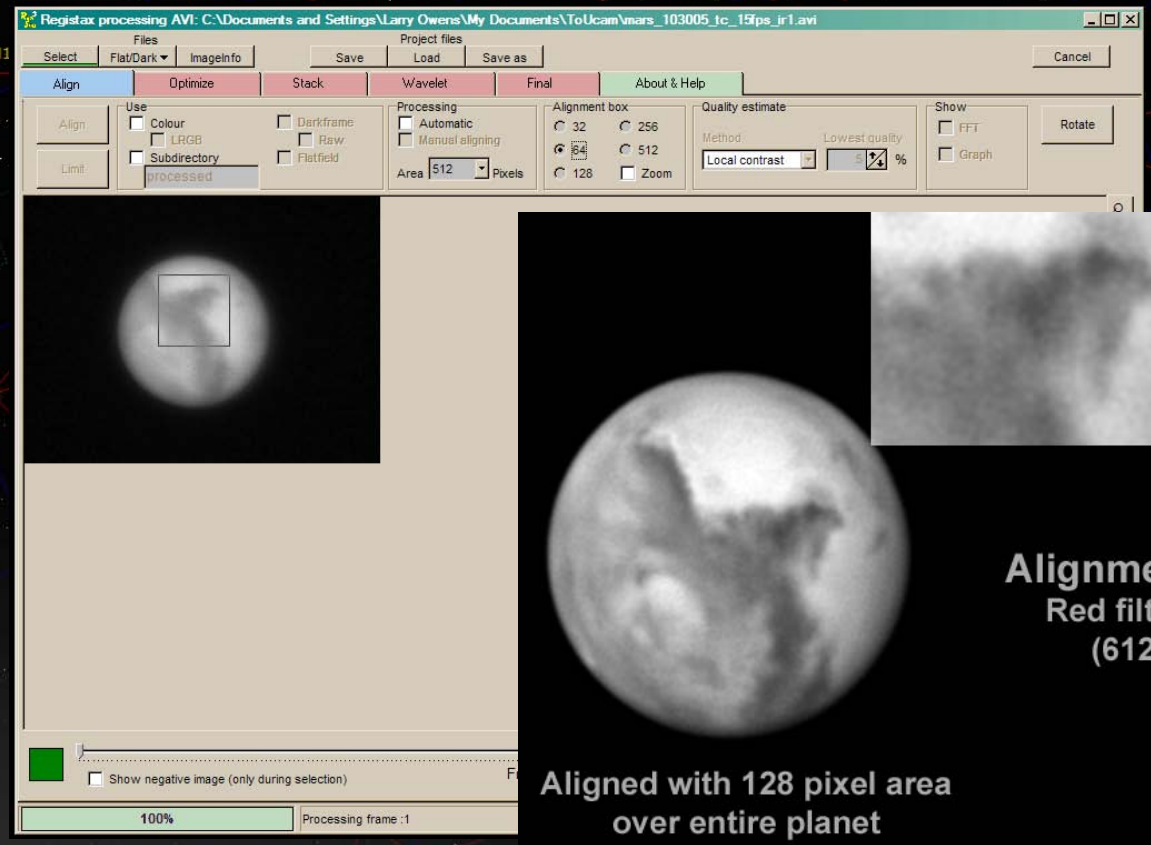
Select Reference Frame

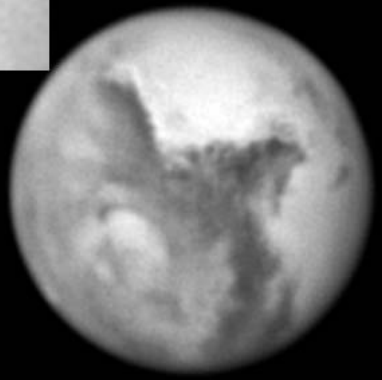


# *Alignment Box Size*

- There are 2 options with planets
  - Align the entire planet
    - Planetary rotation affects central detail
  - Align on a feature of the planet
    - Use if there are high contrast features (best with Jupiter)
      - Better central detail, less limb detail





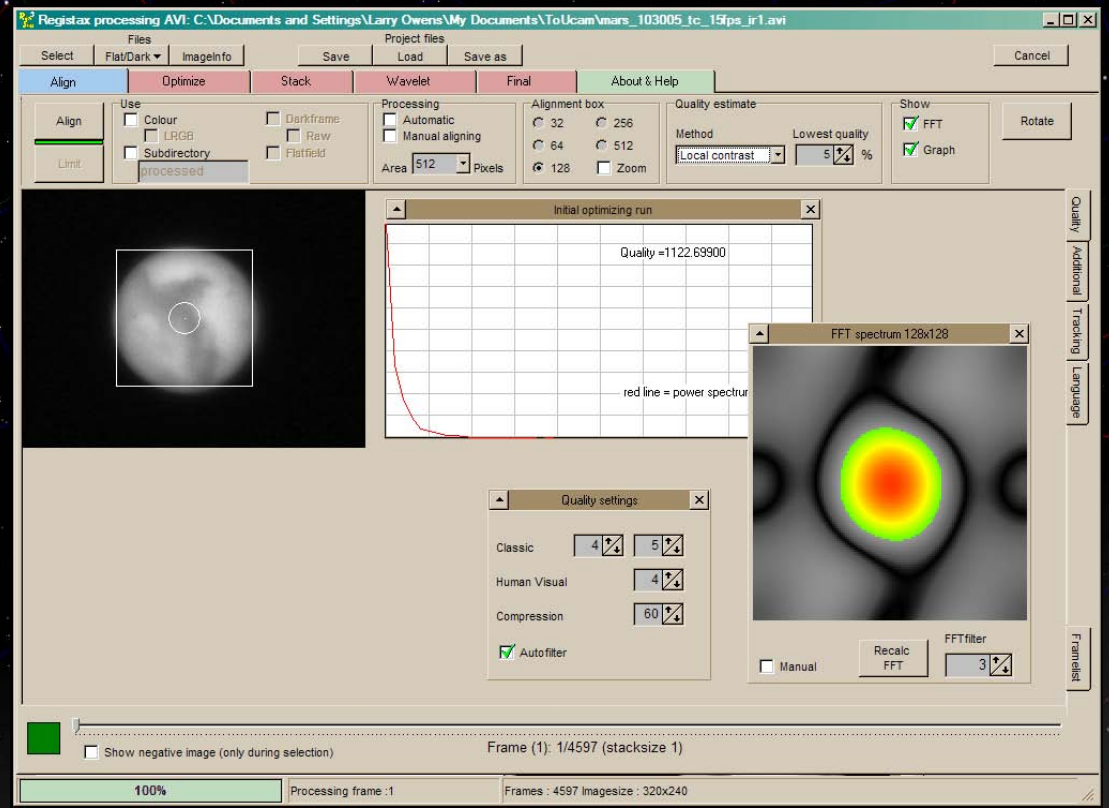
**Alignment Options**
**Red filtered image**
**(612-670nm)**

**Aligned with 128 pixel area over entire planet**

**Aligned with 64 pixel area over Syrits Major**

# *Quality Setting, Alignment Optimization*

- Better results are obtained when you take some manual control
  - Pick a low “Lowest Quality” number or even 0
    - Quality setting limits frames for you, but there are 2 other ways to do that
  - Use “Local Contrast” quality estimate method – others work well also
  - The FFT Spectrum value estimates are usually OK
    - Adjust filter until you see a single sizable red area in center



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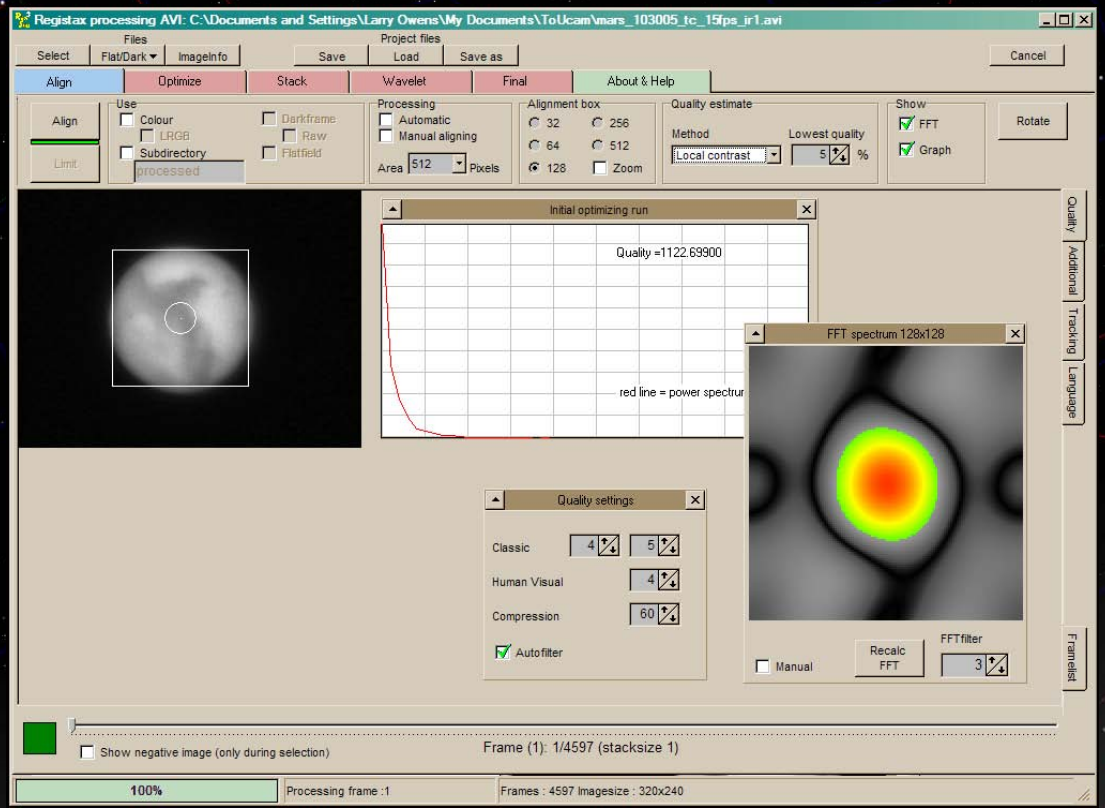
Select Alignment Box Size

Select “Local Contrast”

Select “0” Lowest Quality

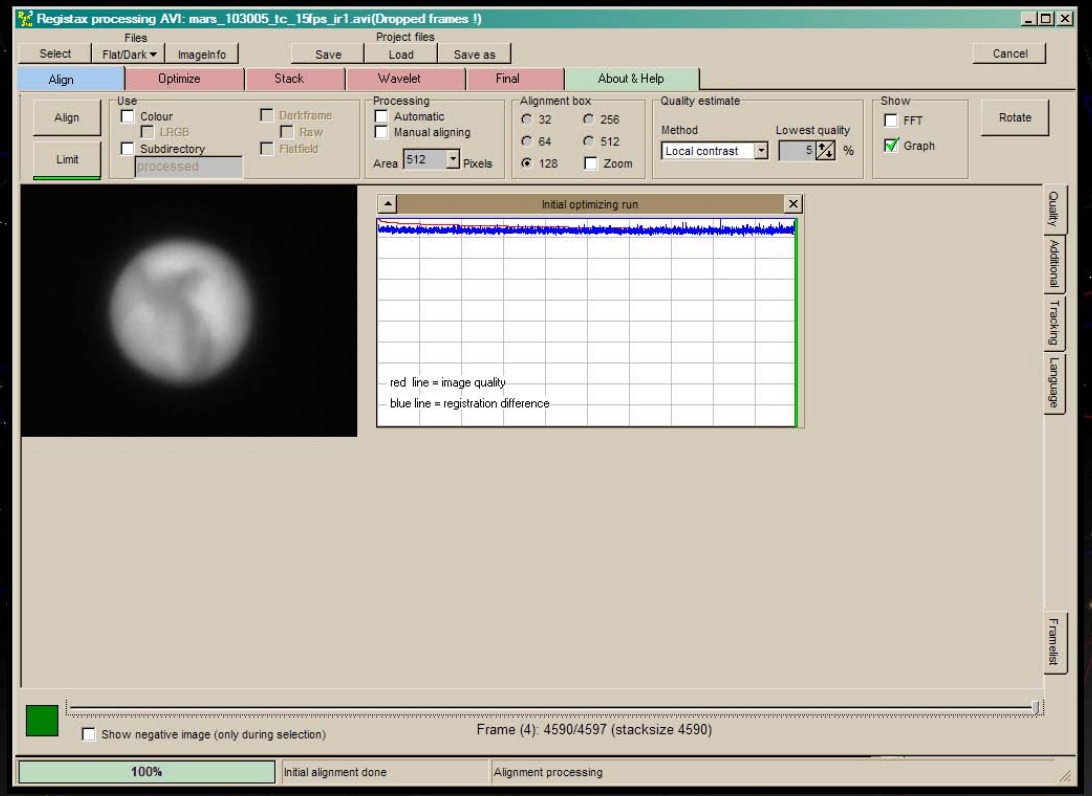
Adjust FFT Filter

Press “Align”



# *Quality Setting, Alignment Optimization*

- Evaluate initial alignment curve (blue curve)
  - If not relatively flat, select a different reference frame
  - We are looking for the “average” alignment of most frames
  - This will enable us to select a larger number of similarly aligned frames
- The “Limit” button is just a time saver
  - Allows exclusion of very low quality frames before alignment optimization
  - Use frame slider to exclude frames



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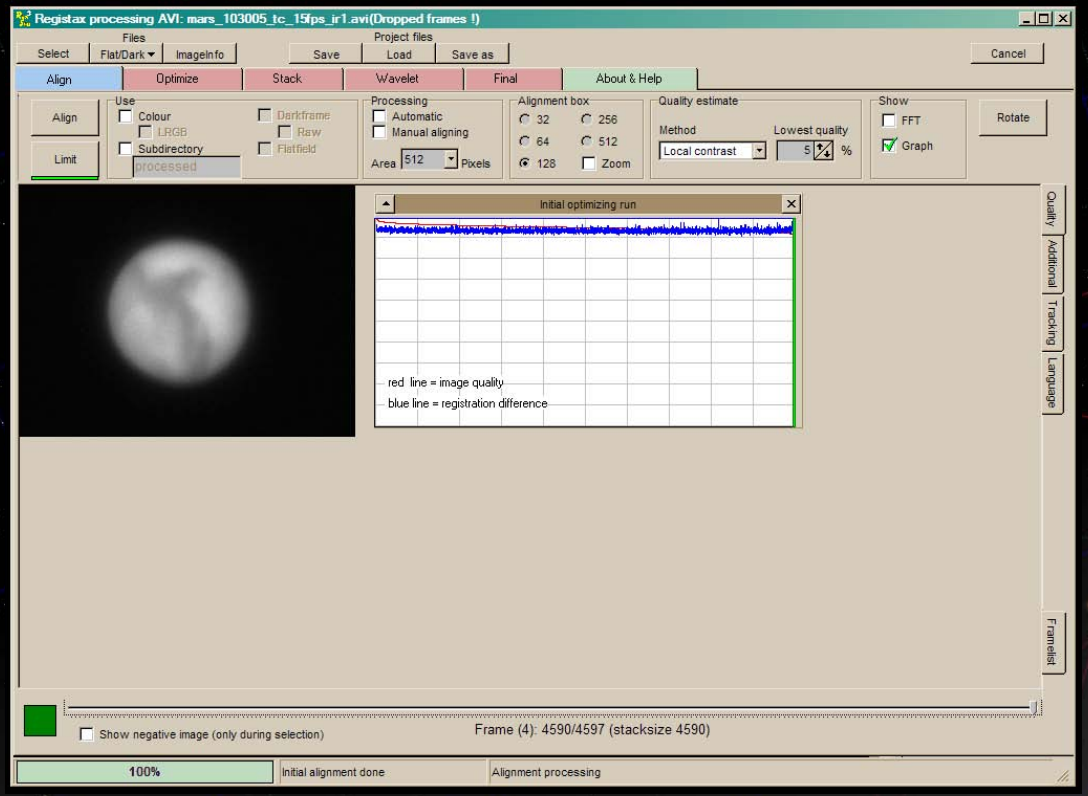
If “alignment curve” is OK

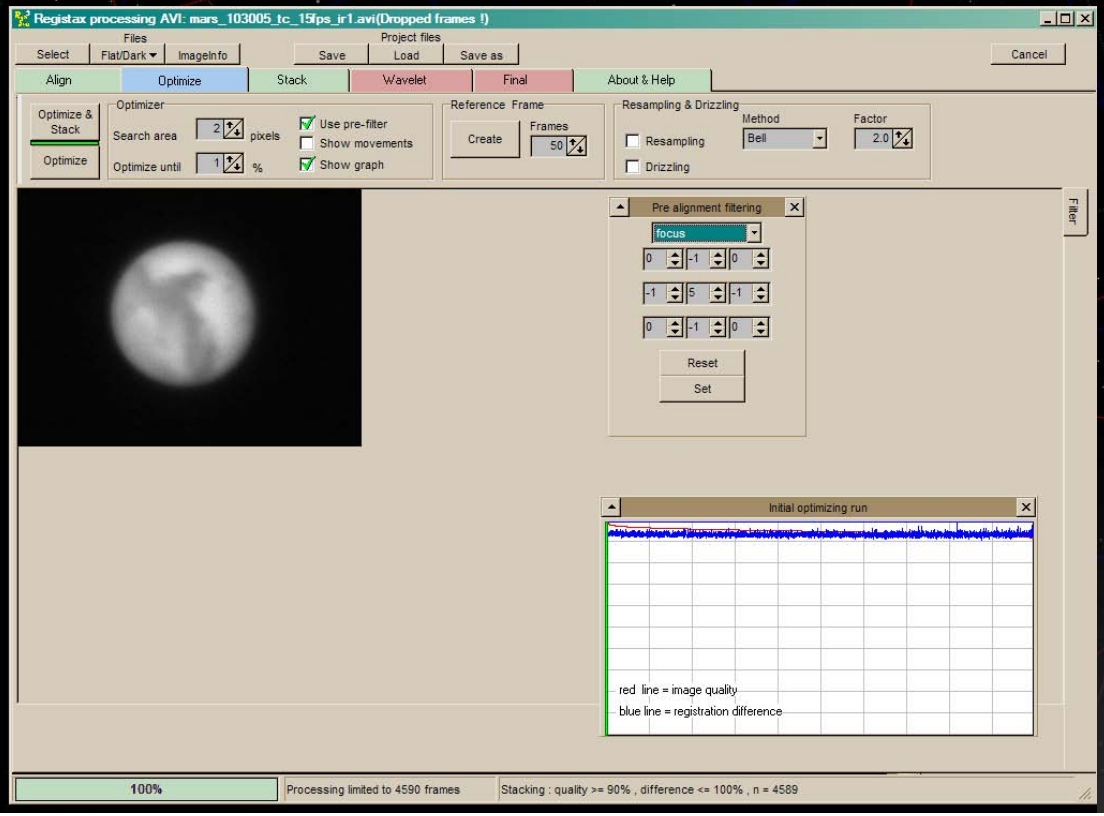
Press “Limit”

WAIT - DO NOT PRESS
Optimize and Stack!



# Alignment Optimization

- After pressing "Limit" you have more options
  - Don't use "Optimize and Stack" - more selecting to do
  - Optimize until - sets optimization limits
  - Reference frame – gives you the option to create a perfect frame for alignment optimization (not recommended)
  - Resampling and Drizzeling – allows each frame to be "enlarged" before alignment optimization and stacking (not recommended)
  - Use Pre-filter – enhances each frame before optimization (NexImage)



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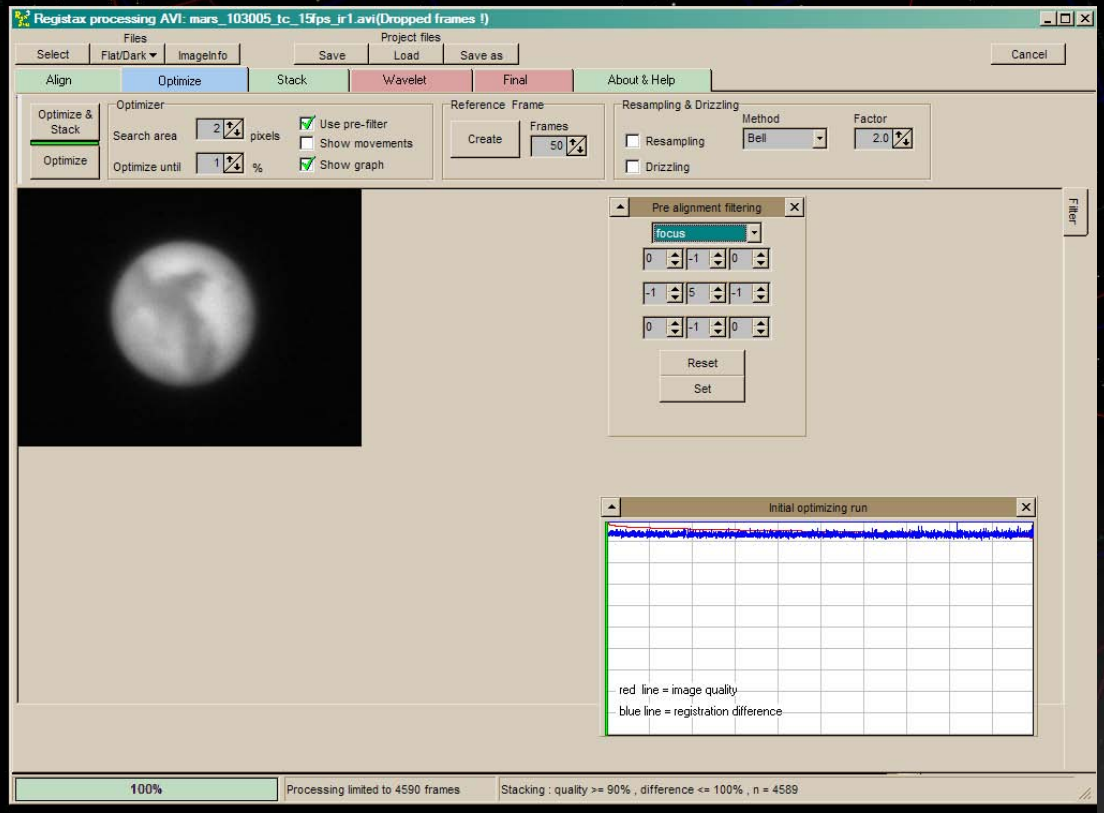
Select Optimize until 1%

Press “Optimize”

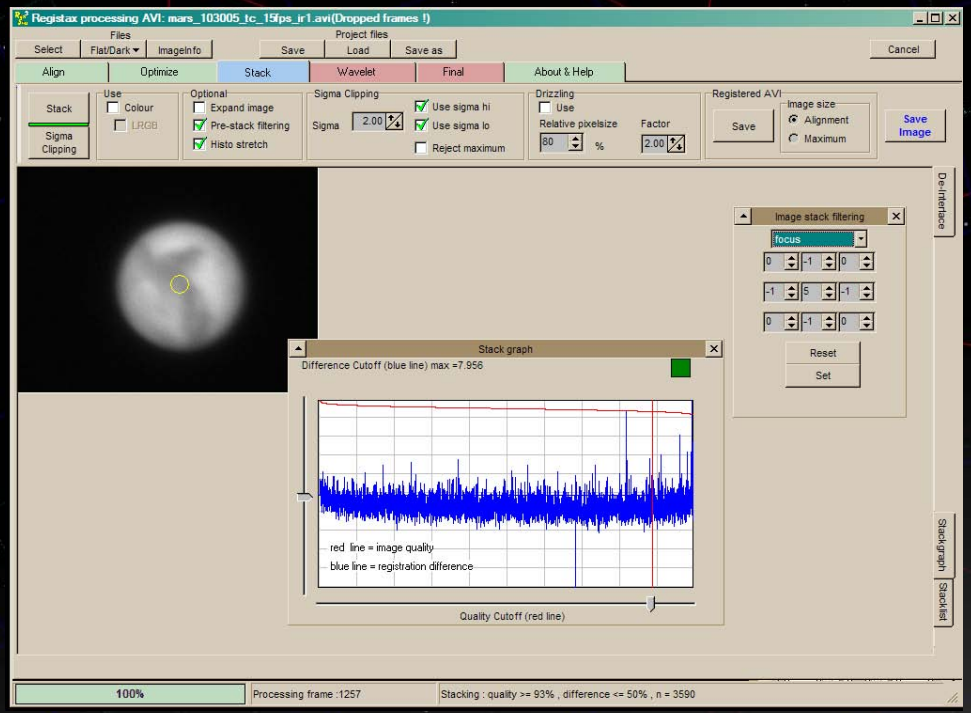
Wait for completion…

Press the Green “Stack” tab (top)



# *Final Frame Selection, Stacking*

- When alignment optimization is complete
  - The “Stack graph” (tab on the lower right) is key to fine tuning stacking
    - Vertical axis is used to select frames based on alignment (relative to ref frame)
    - Flat curve allows more “alike” frames to be stacked (exclude 10-30%)
    - Horizontal axis is used to select frames based on quality (exclude 10-20%)
    - Exclude more frames with bad seeing – Experiment!
  - Some cameras benefit from using the “Focus” pre-stack Filter (NexImage)
  - “Histo stretch” expands the number of colors or levels of gray to 32bits



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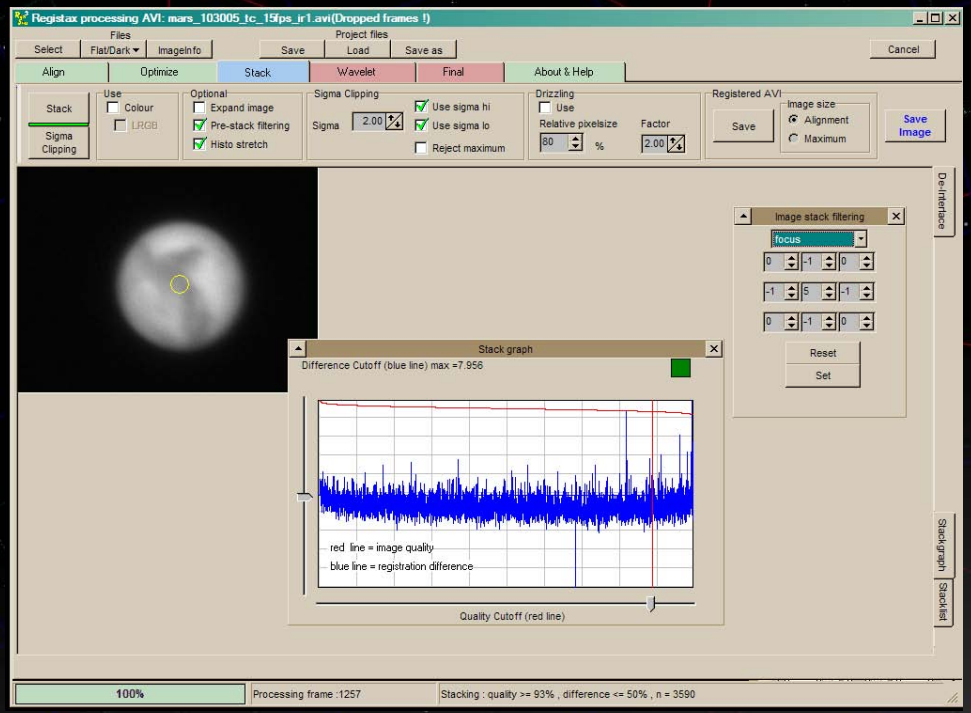
Select “Stack Graph” tab

Exclude 10-30% of frames by alignment deviation (vertical bar)

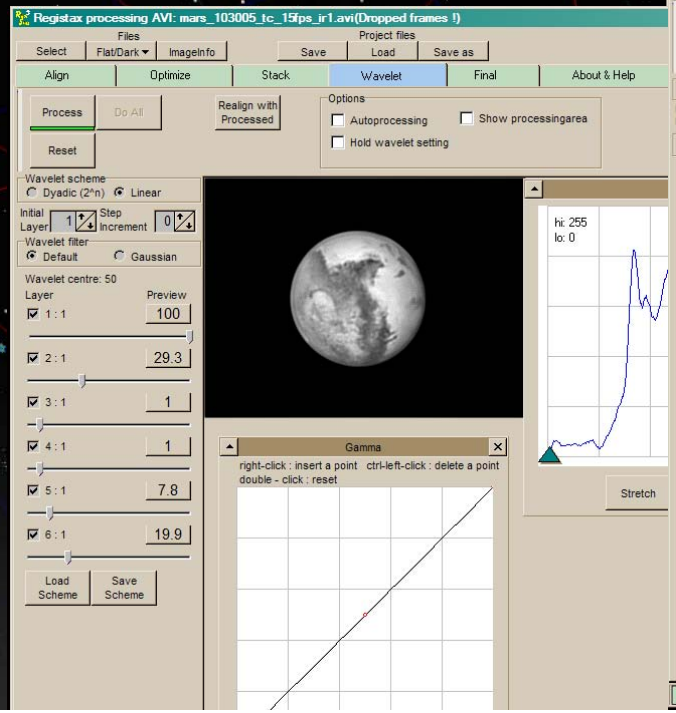
Exclude 10-30% lowest quality frames (horizontal bar)

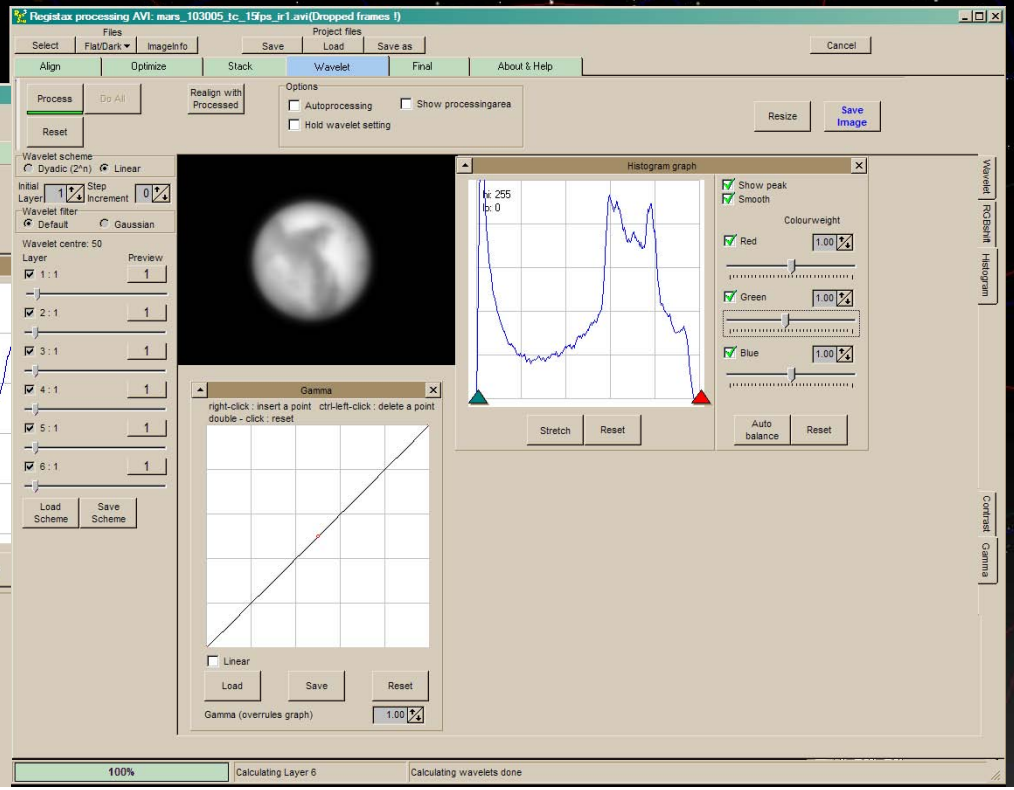
Select “Histo Stretch”
Select “Brightness equalization”
Press “Stack”



# *Wavelet Processing*

- Press the “Wavelet” tab
  - Open “Histogram” and “Gamma”
    - Use histogram to prevent clipping and adjust color
    - Use gamma to enhance contrast
  - Wavelet enhancement
    - 1:1 slider – fine details
    - 6:1 slider – large details
  - Save images in a 16-bit format for further processing in PhotoShop
    - PNG or TIFF

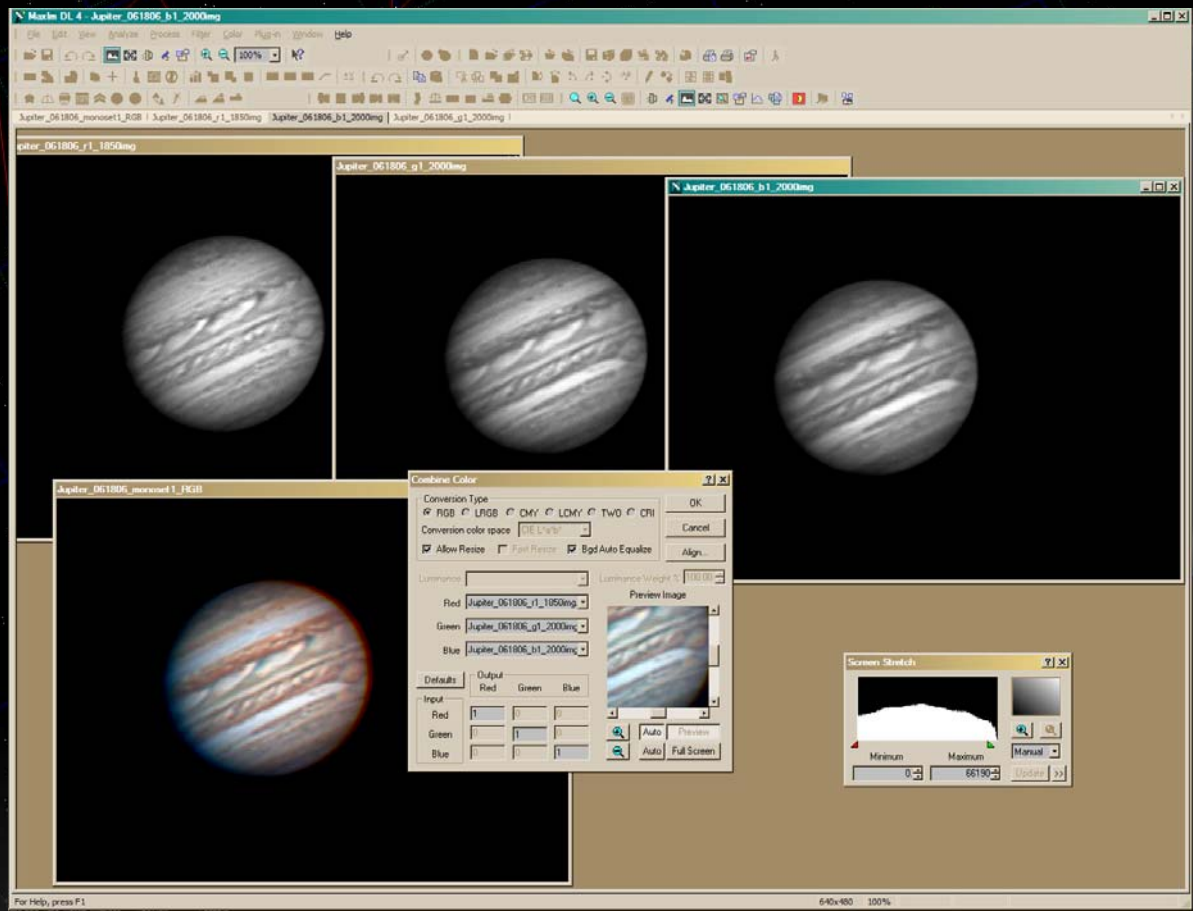


# Color Combining (MaximDL)

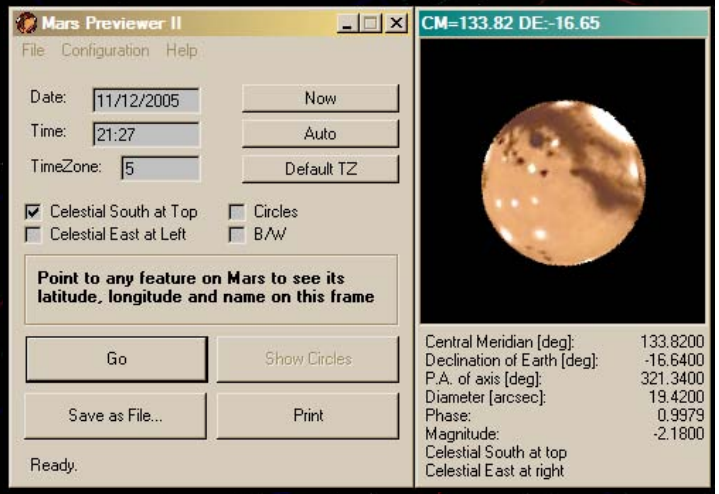
- Open RED, GREEN and BLUE filtered images
  - Move “Screen Stretch” to maximum for each image
  - Convert to monochrome
  - Color Combine
    - Select RGB process
    - Select Red, Green and Blue files
    - Align
    - Color Combine
  - Save color RGB image
    - 16 bit format – TIFF

  - Next stop: PhotoShop



# *PhotoShop and Final Image Prep*

- PhotoShop CS or PhotoShop Elements
  - Frequently used Features
    - Levels
    - Unsharp Mask
    - Gaussian Blur
    - Noise
    - Polygon Tool
    - Selection Feathering
    - Brightness/Contrast
    - Hue/Saturation
    - Color Balance
    - Selective Color
    - Mode
    - Image Size
    - Rotate Canvas
    - Layers – Lum Layering
    - Text Tool
- Planetary Data
  - WinJupos
  - Mars Previewer II



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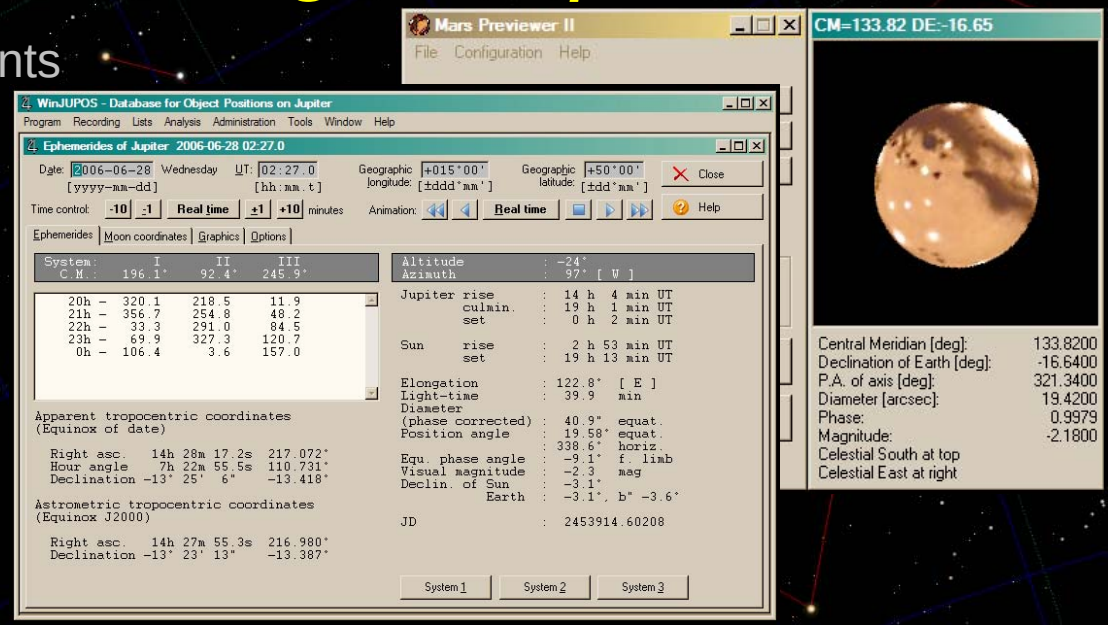

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# *More Practice… PhotoShop, RegiStax, MaximDL*

*Questions*

*Suggestions*

*Comments*