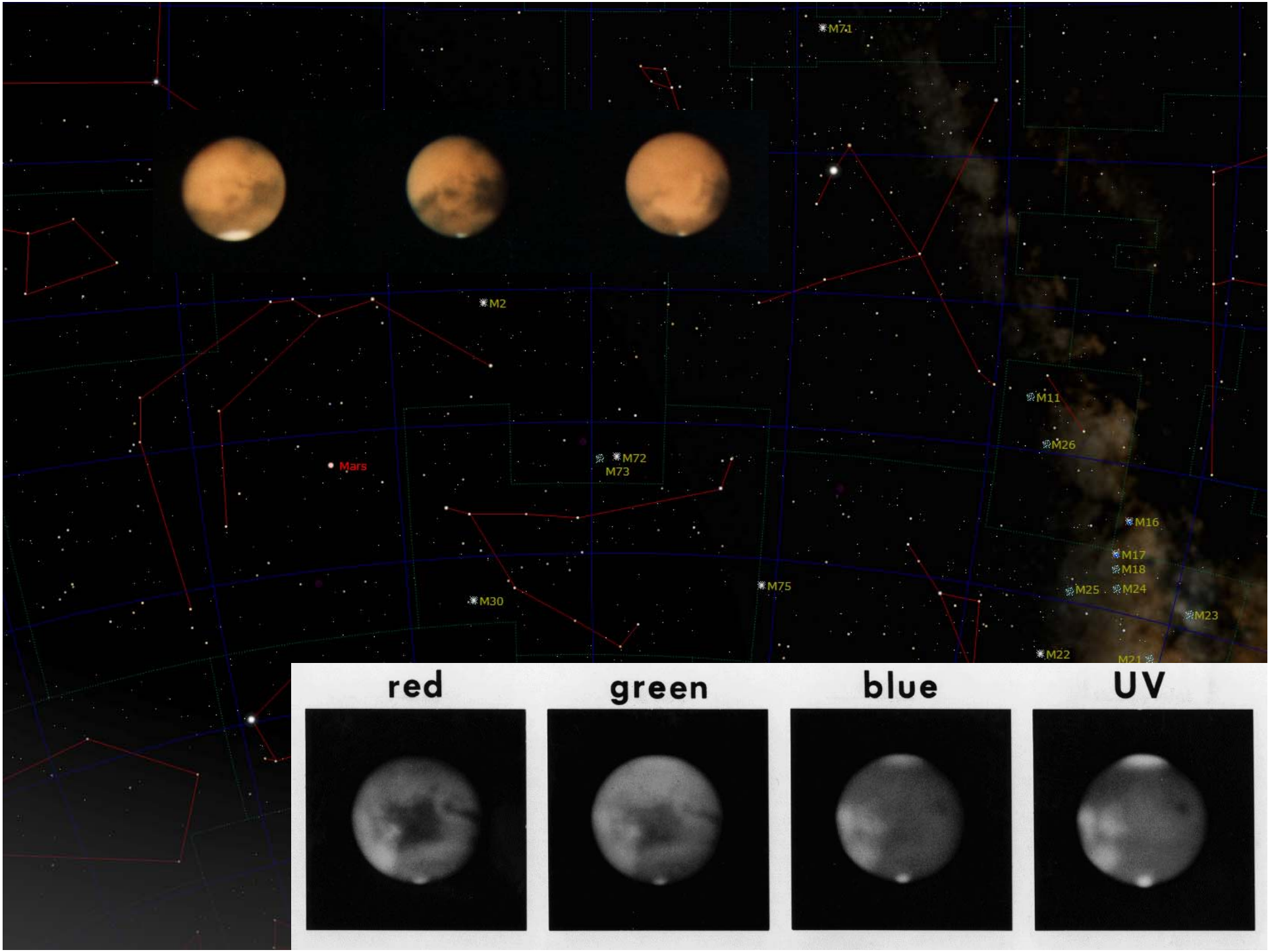
Planetary Imaging Workshop

Larry Owens


M71
M2
M11
M26
Mars
M72
M73
M16
M17
M18
M25
M24
M75
M30
M23
M22
M21
red
green
blue
UV

Lowell Observatory, 1971-1973

1971 1973 1973

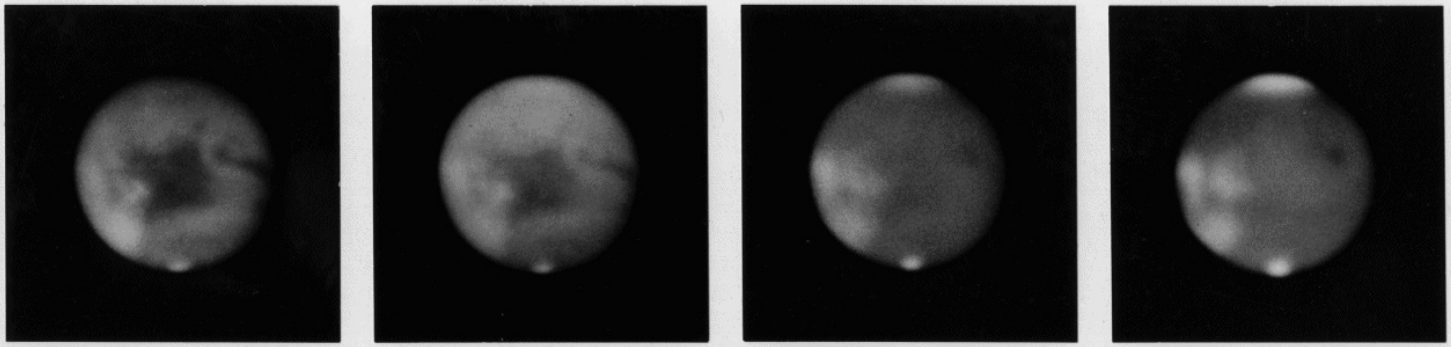
CHANGES IN MARTIAN ALBEDO FEATURES AND THE EFFECT OF A DUST STORM IN 1973 ARE SHOWN WITH COLOR RESTORED IMAGES.

DIFFERING COLORS OF MARTIAN STORM CLOUDS

OCT. 16, 1973 – 0900 UT

4th STORM DAY – 14.5 hrs. AST at 0°

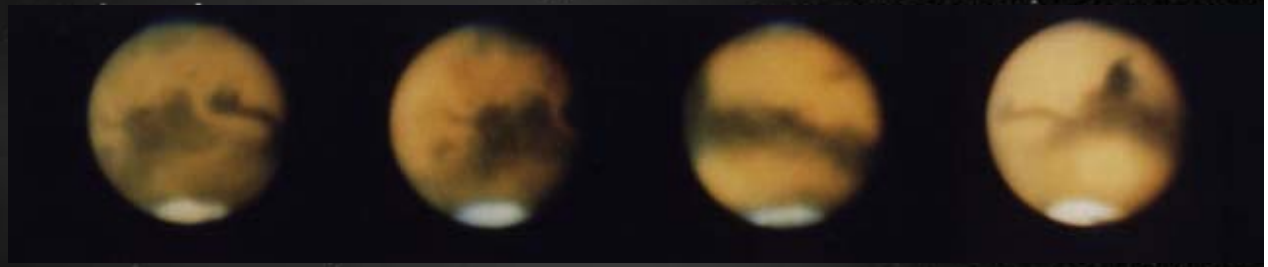
red green blue UV

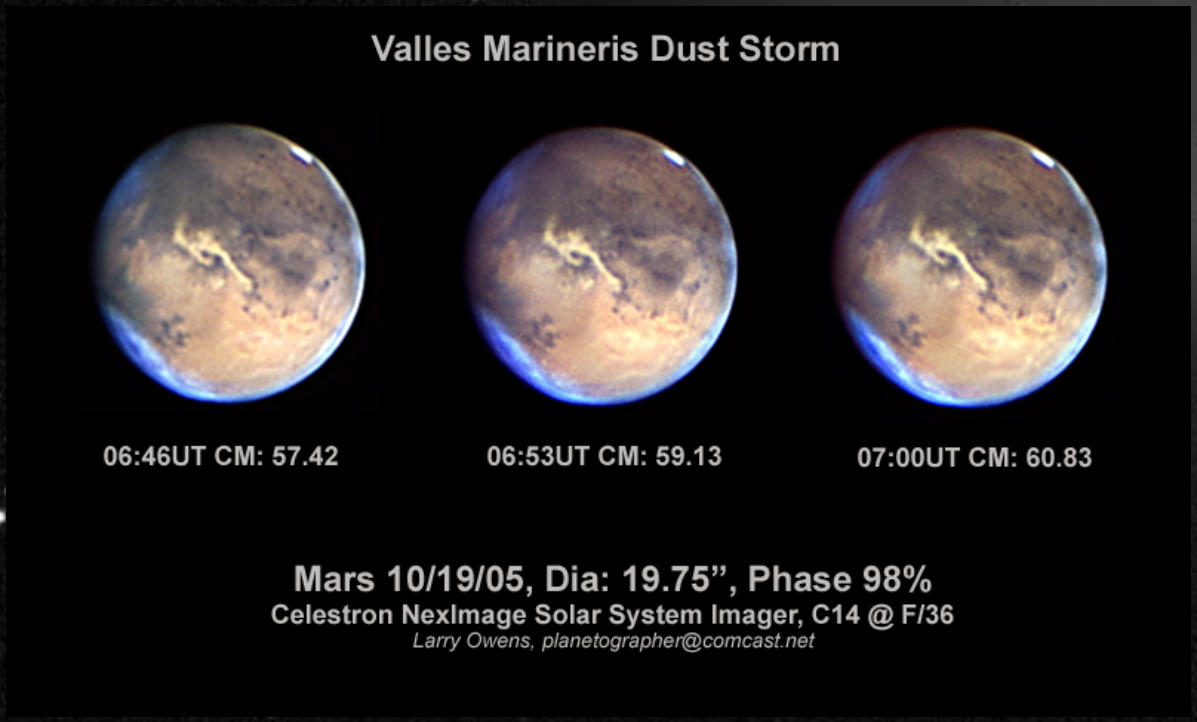


Backyard Telescope, 2005

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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- Use the right tool for the job!
  - 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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  - Ideal – half the Dawes Limit per pixel
  - Reduce, depending on atmospheric stability

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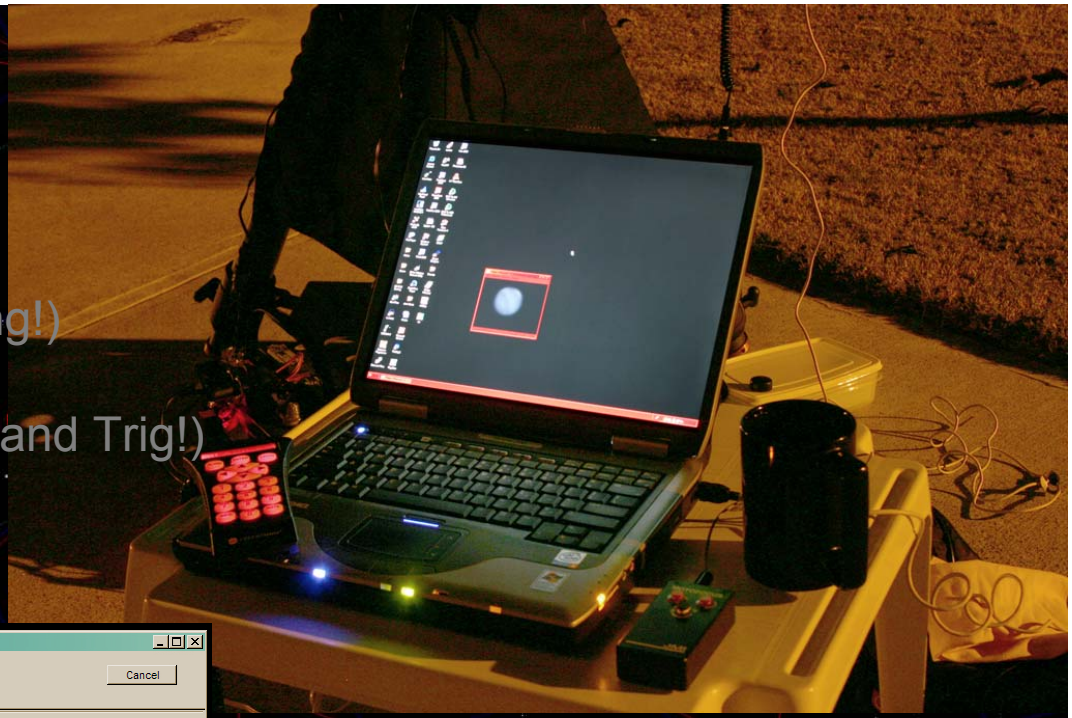
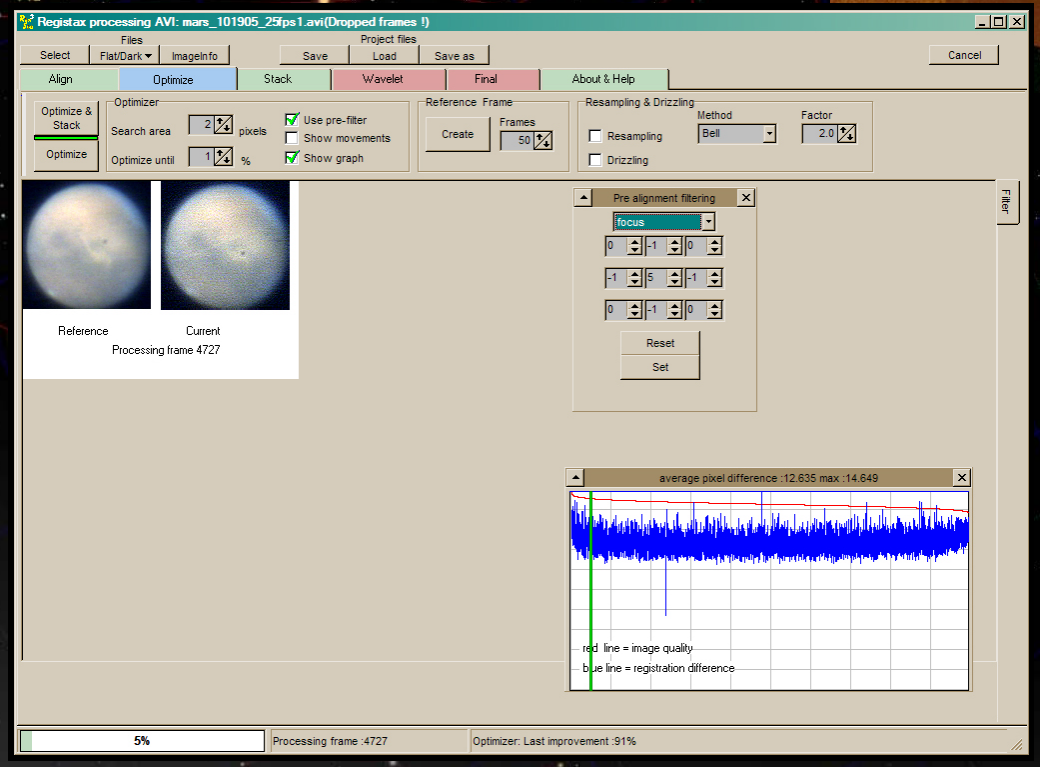
- Get the “sampling” right
  - Ideal – half the Dawes Limit per pixel
  - Reduce, depending on atmospheric stability
- Use slower frame rates, longer exposures
  - 60-140ms, 5-15fps
- F-O-C-U-S!
- C-O-L-L-I-M-A-T-I-O-N!
- E-X-P-E-R-I-M-E-N-T-A-T-I-O-N!

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

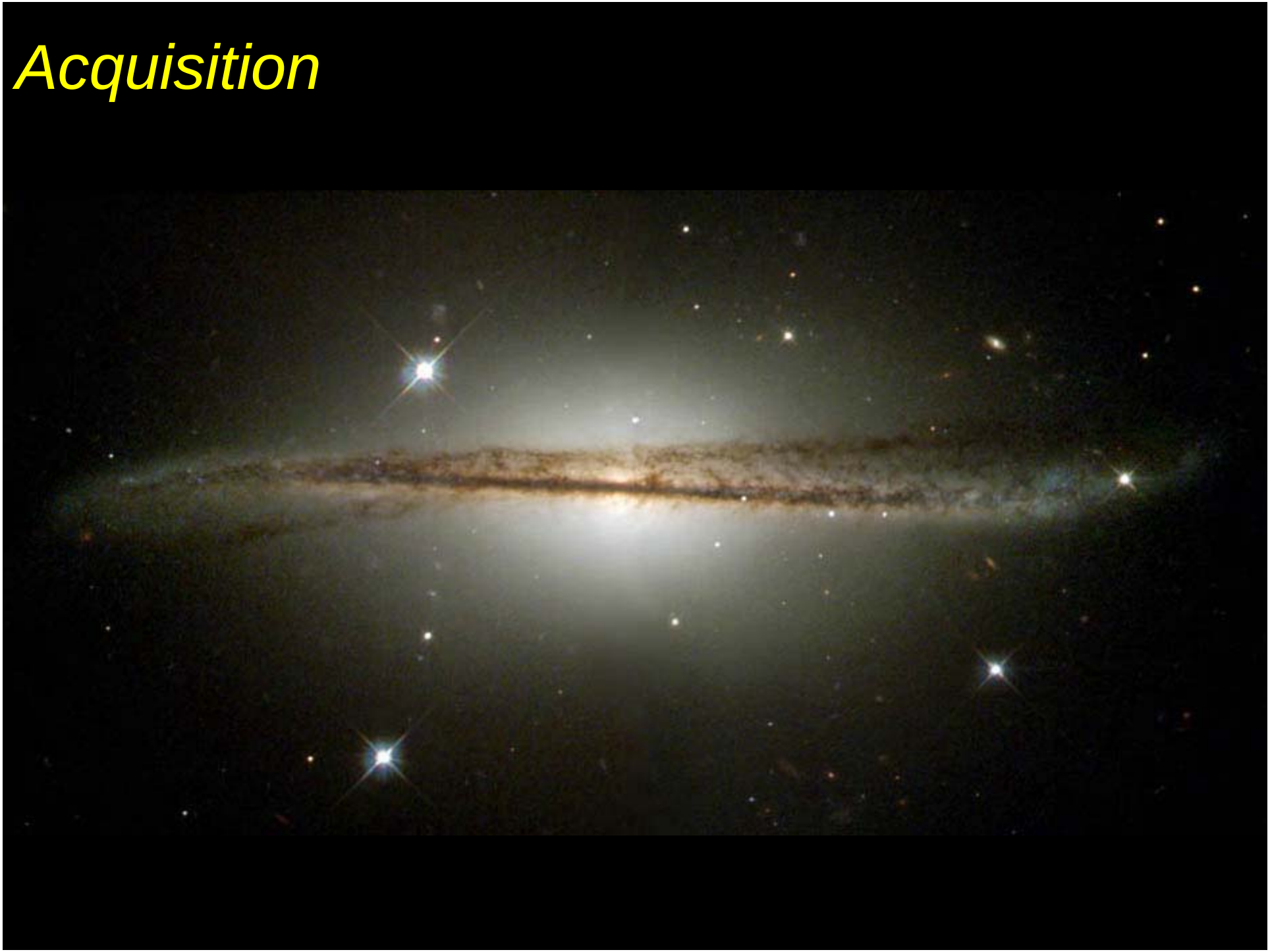




Processing

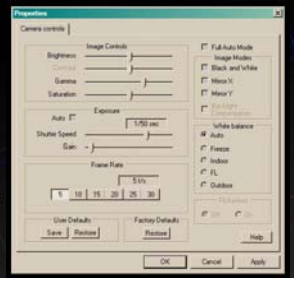
Reference frame selection
Alignment box size (feature or planet)
Quality settings, Pre-filter usage
To resample or not to resample
Selecting frames with stack graph
Selecting frames with frame list
Final adjustments and PhotoShop
Data to present with your image

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 good, acquire frames for longer period – for Feature based alignment
    - If very soft, acquire frames according to rotation maximum
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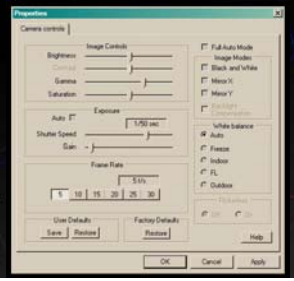

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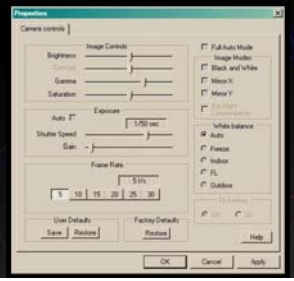
  - Frame resolution
    - 640x480, sub-frame, 320x240
    - Planet angular diameter, sampling, chip area
  - Monochrome cameras and filters



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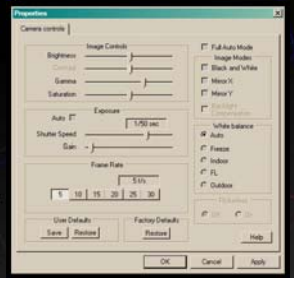
  - Monochrome cameras and filters
    - Consider time it takes to acquire full RGB sets (color shift tolerance)
    - Plan for LRGB (if desired): color set – luminance set – color set
    - Consider filter to use for Luminance – UV/IR block, IR, Red, Green
    - Watch filter distance from chip in optical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



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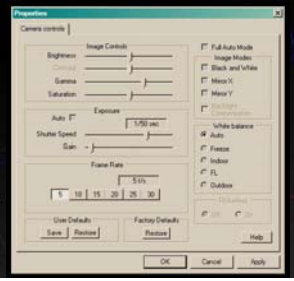
    - Watch filter distance from chip in optical train
  - Experiment with Exposure and Gain
    - Longer exposures, lower gain, fewer frames
    - Shorter exposures, higher gain, higher frame counts



Monochrome Cameras

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

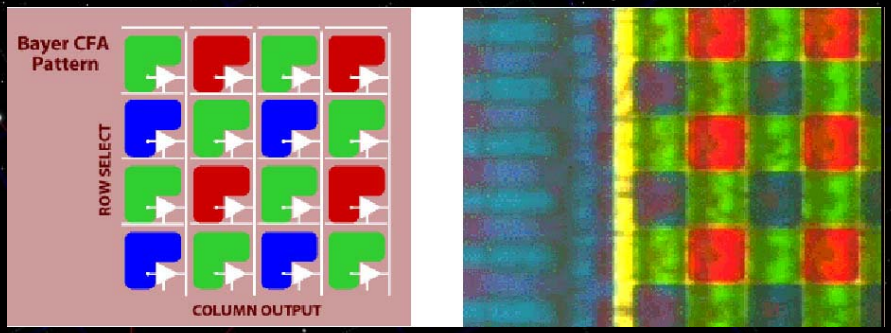
- Full Chip Resolution
- Color Combine in MaximDL

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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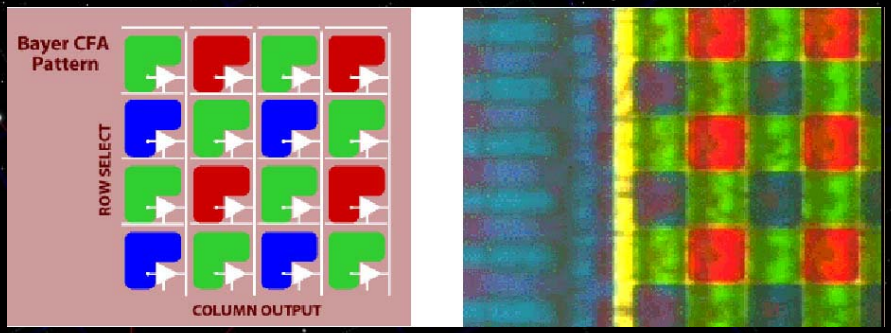
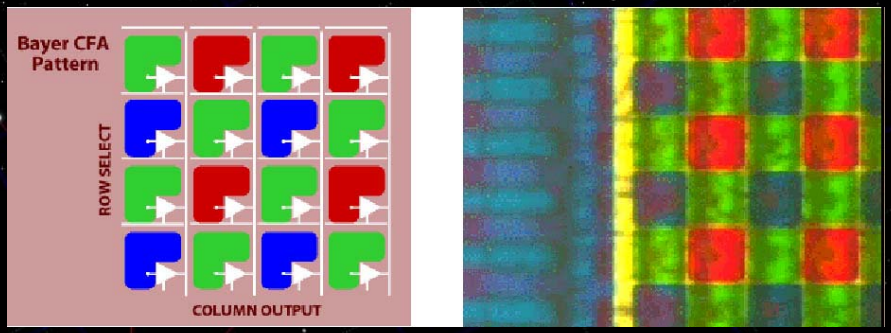


- At 320x240, Full color resolution (use RAW mod to be sure, see link)
  http://www.astrosurf.com/astrobond/ebrawe.htm

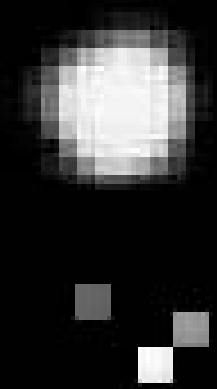
Color Cameras



- 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

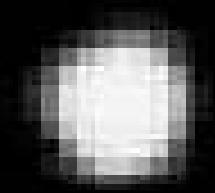


- Oversampling (too many pixels)
- Undersampling (not enough pixels)
- Correct Sampling

Sampling

- 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



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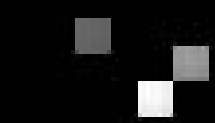

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- Oversampling (too many pixels)
  - Power is too high; brightness too low
  - Requires longer exposure times
  - Very long exposures can cause loss of detail

- Undersampling (not enough pixels)

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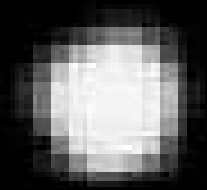

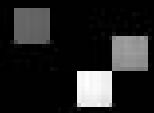

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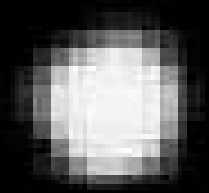
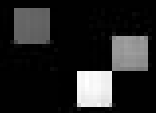
  - Resolution of optics is wasted
  - Not enough pixels to represent finest details

- Correct Sampling

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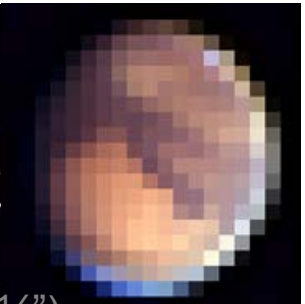
- Correct Sampling
  - Records all that is possible from optics and seeing conditions
  - Reasonable exposure times and gain settings
  - May need to undersample a bit – seeing, camera sensitivity

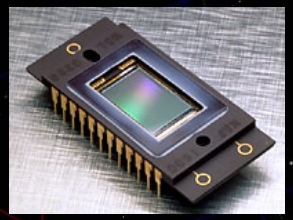
Sampling



- Dawes Limits: (116/aperture in mm)

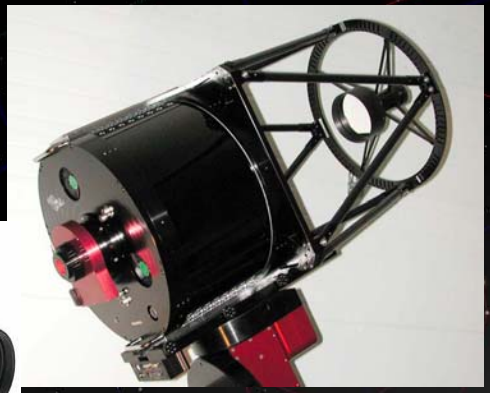
4” - 1.14”	11” - .41”
8” - .57”	14” - .33”
10” - .46”	16” - .29”

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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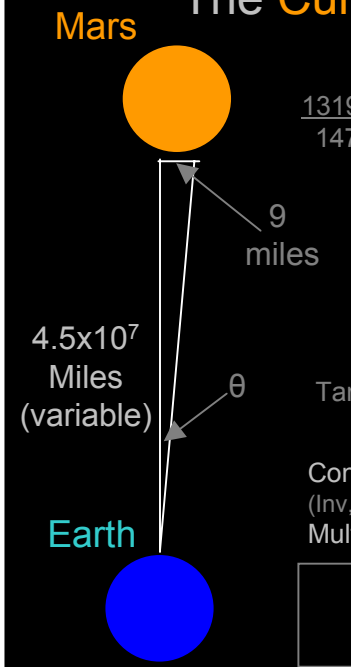
When you know The Current Distance



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

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)

am = θ

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

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

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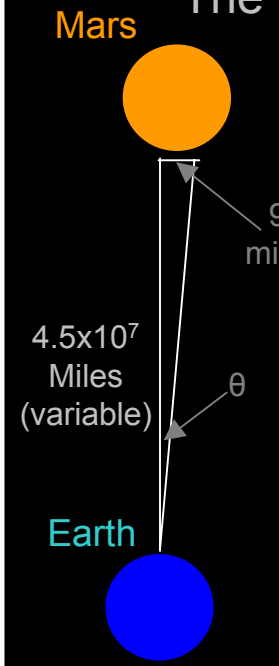

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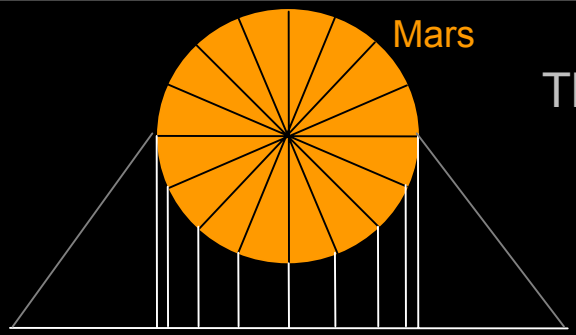

When you know The Apparent Diameter

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

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

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

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

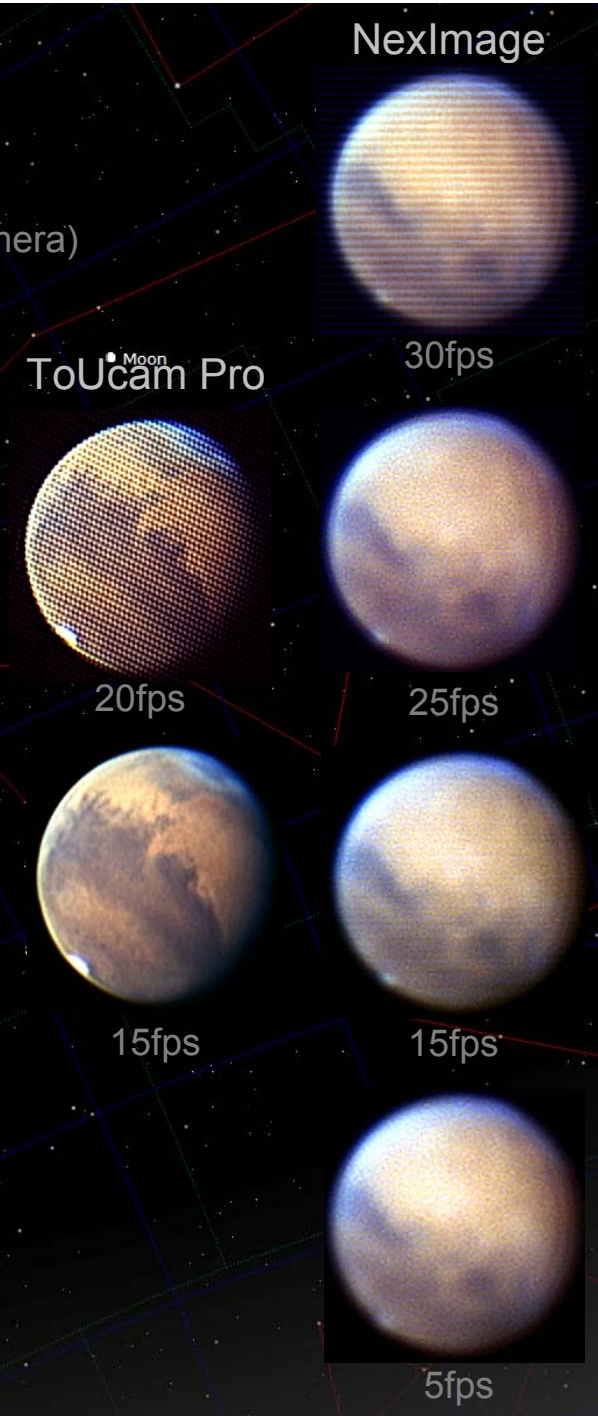
$am = \frac{hc'(T)}{hd}$

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

Frame Rates

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

- Noise issue



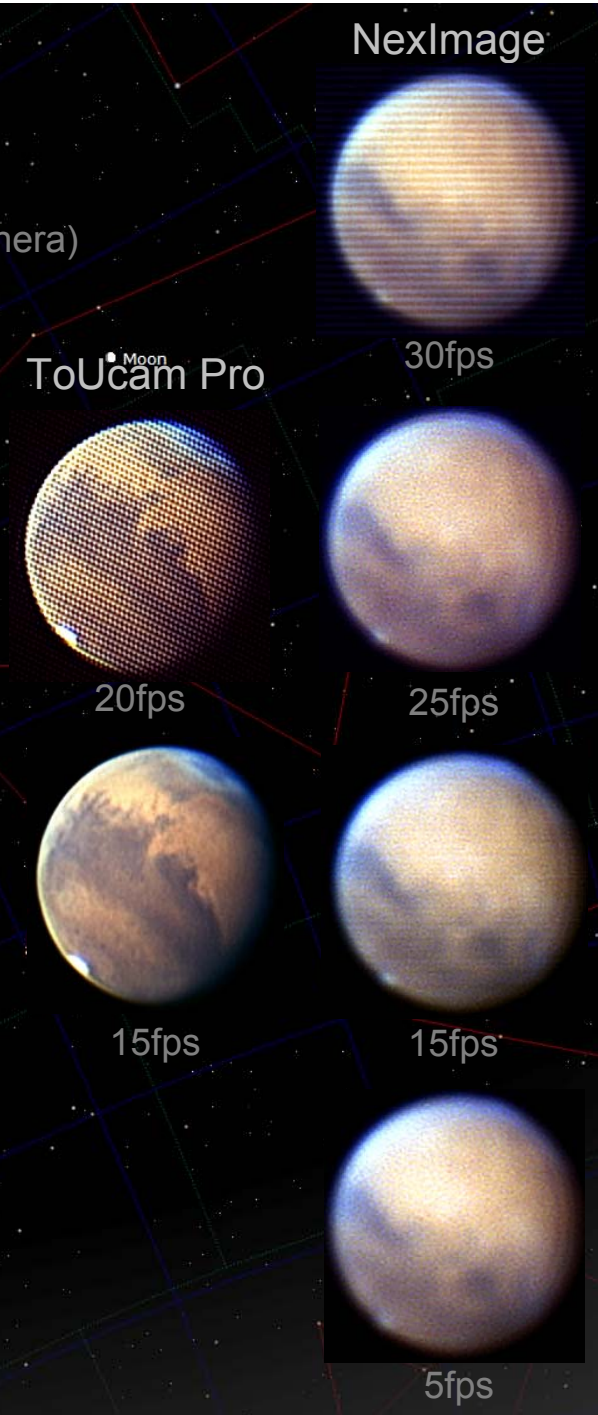
Frame Rates

- 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



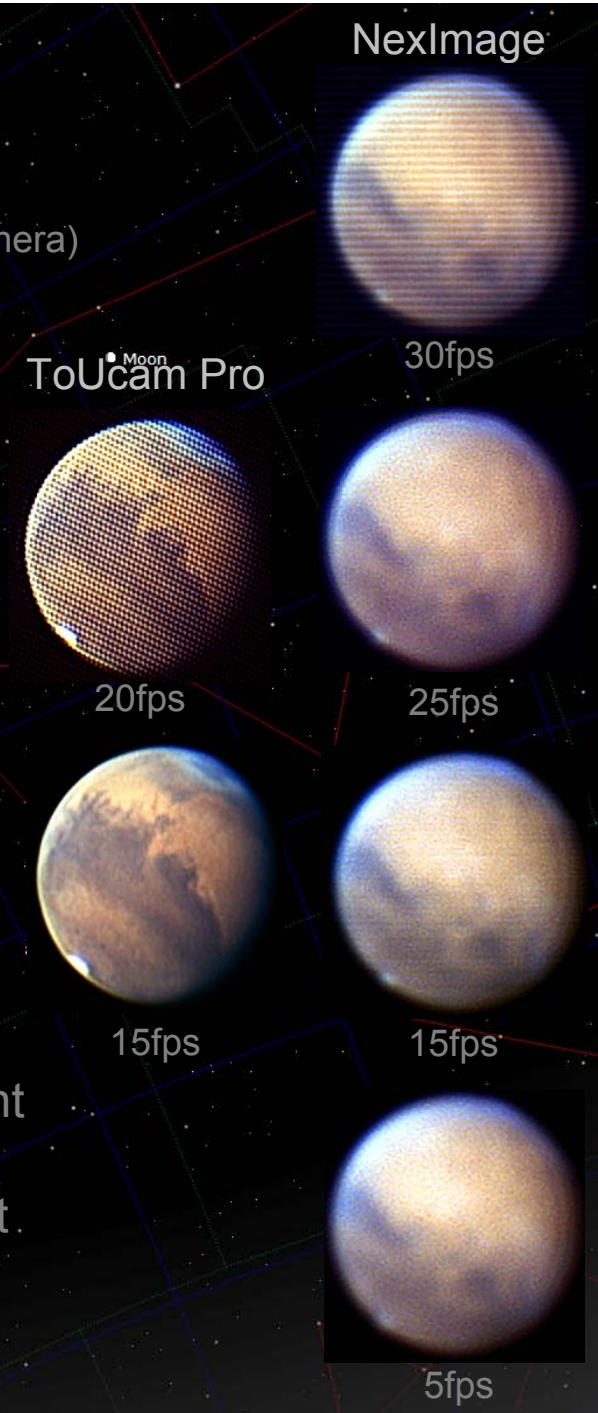
Frame Rates

- 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

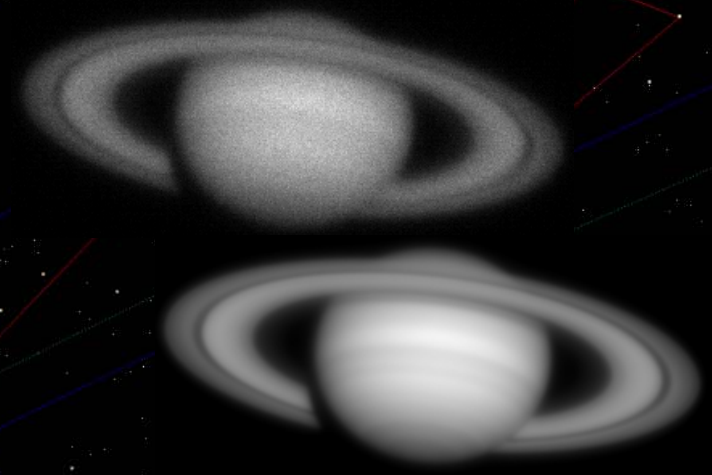
  - Celestron NexImage
    - Starts compression at 30fps
    - Rates from 5-25 fps are OK, 5 and 25 seem best

- 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.



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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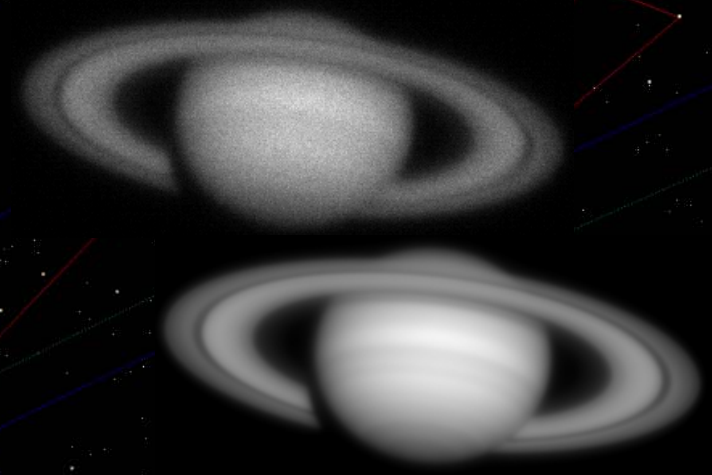

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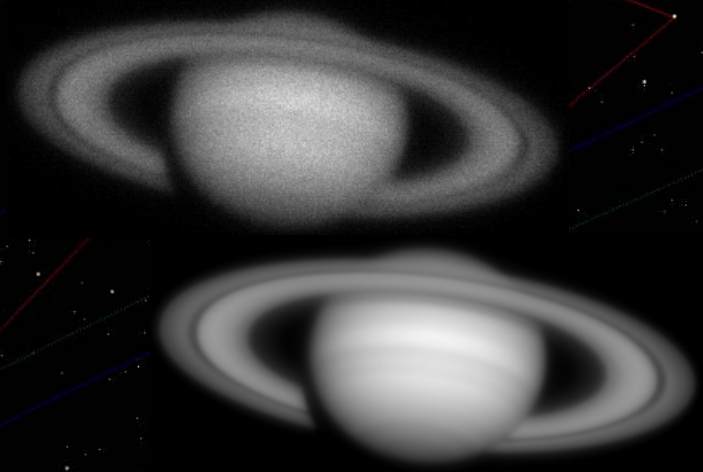

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  - High sensitivity
  - High frame rates

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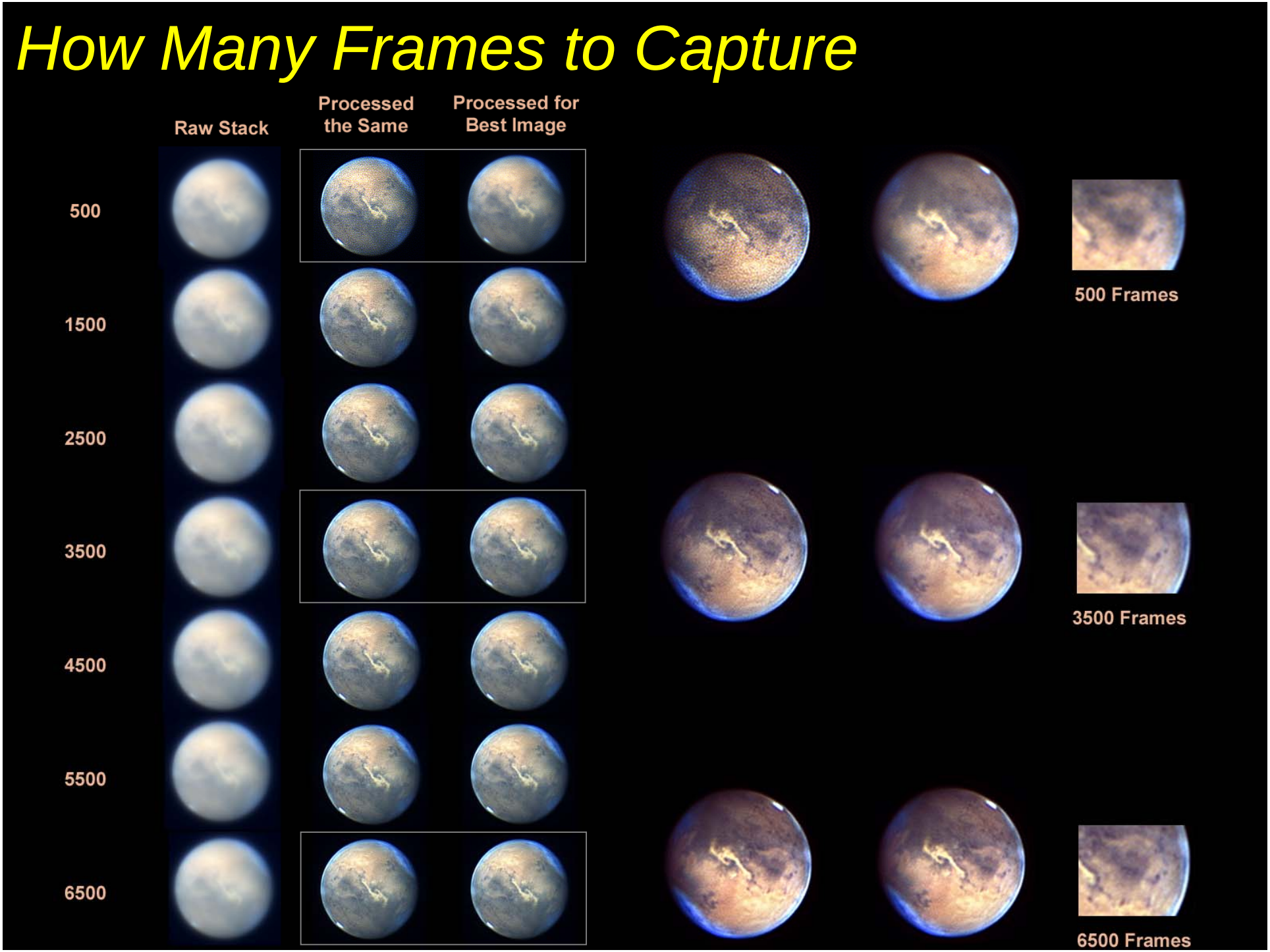
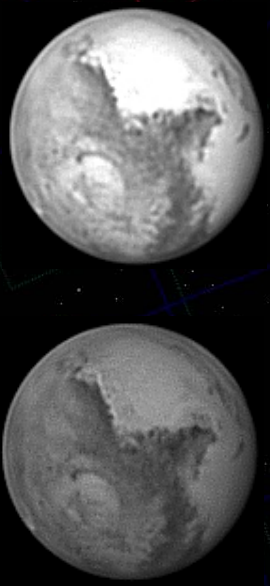
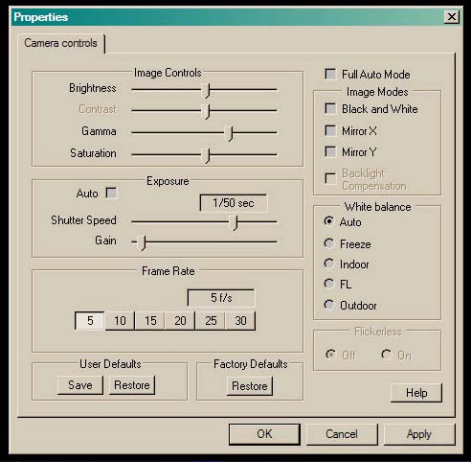


Exposure, Gain & White Balance

- 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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    - Longer exposures require slower frame rates
  - Set the gain just below the point where saturation occurs

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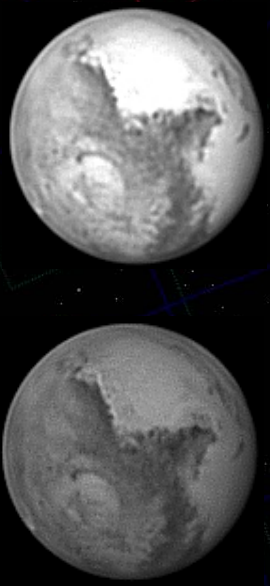

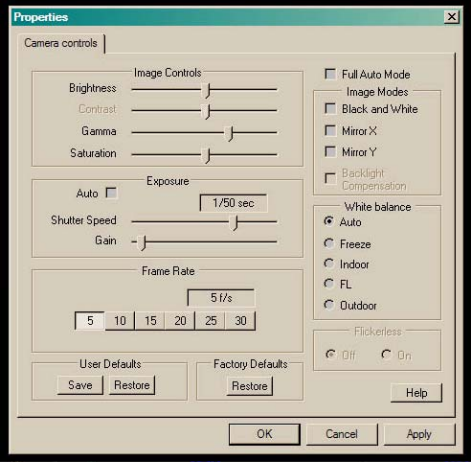

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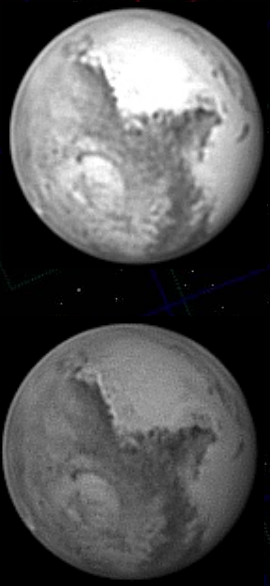
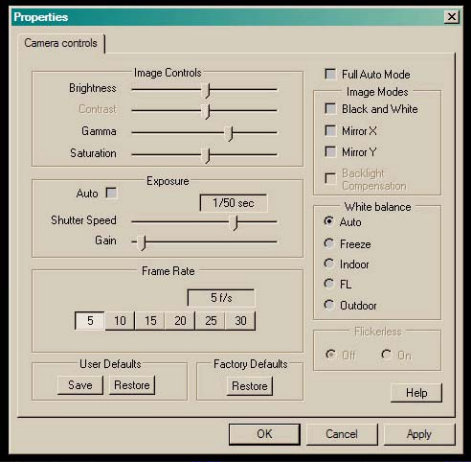
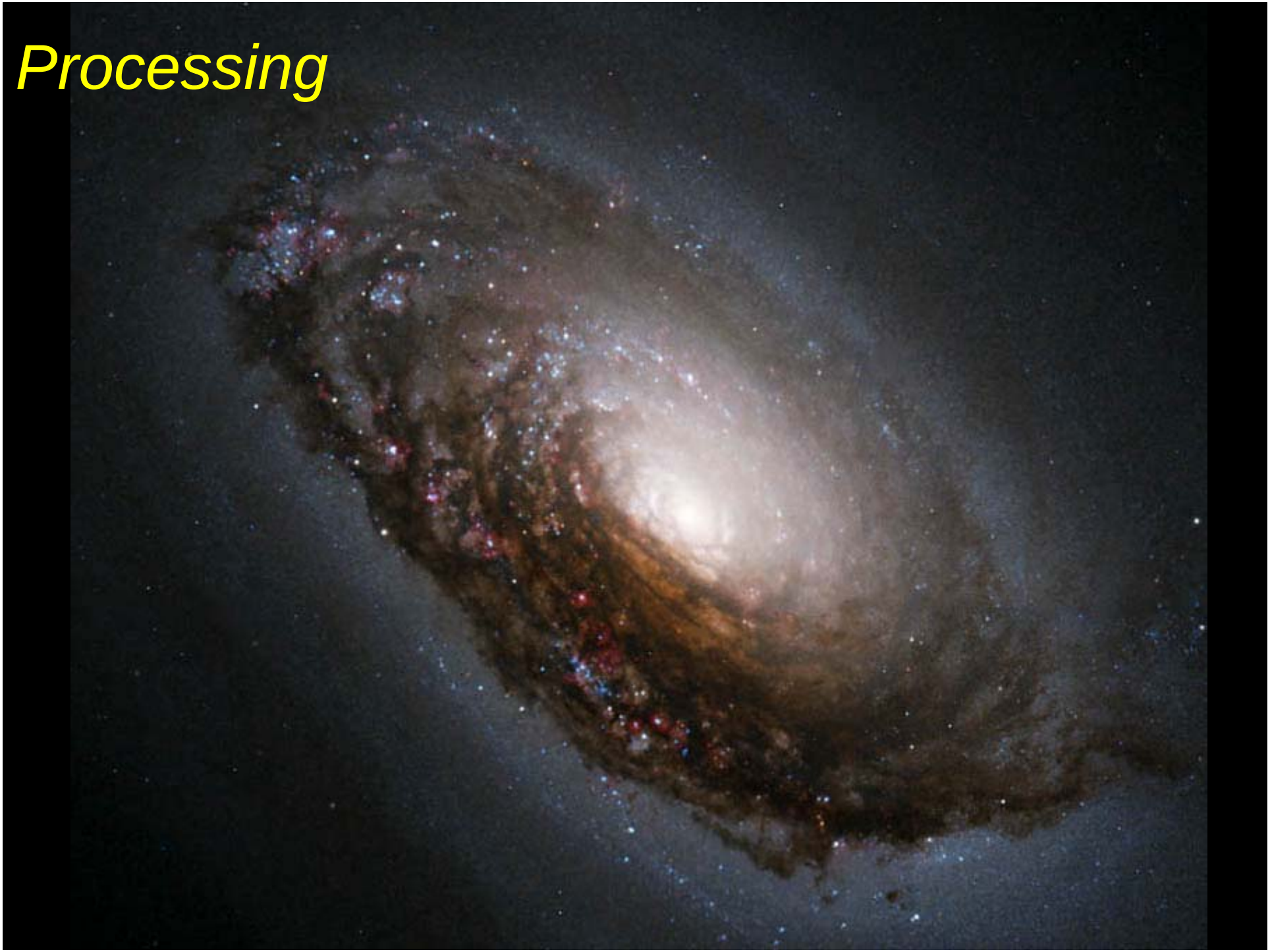
- White balance seems to work best in "automatic" mode
  - Experiment with color settings
  - A pale under colored video image can easily be enhanced later
  - Images saturated with color tend to be difficult or impossible to correct





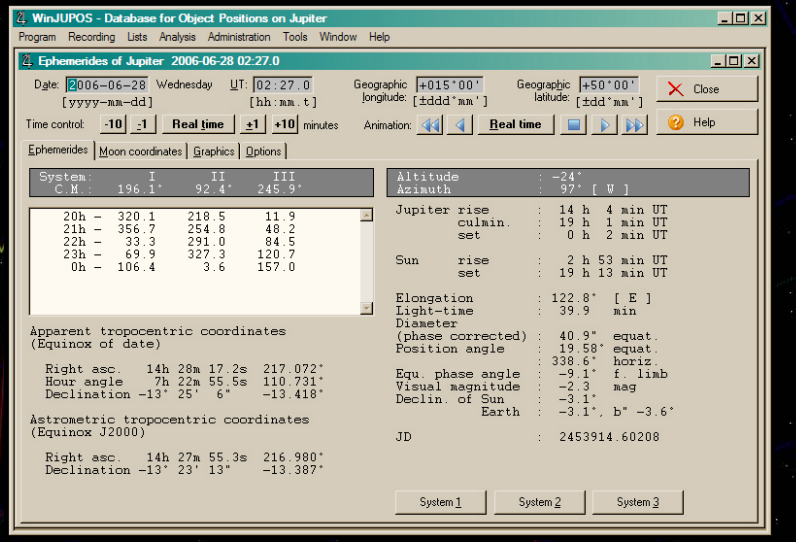
Processing

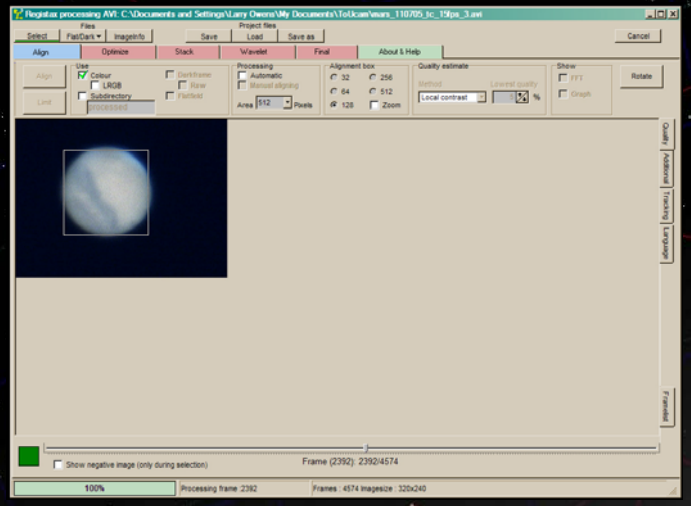


Processing Strategies

- 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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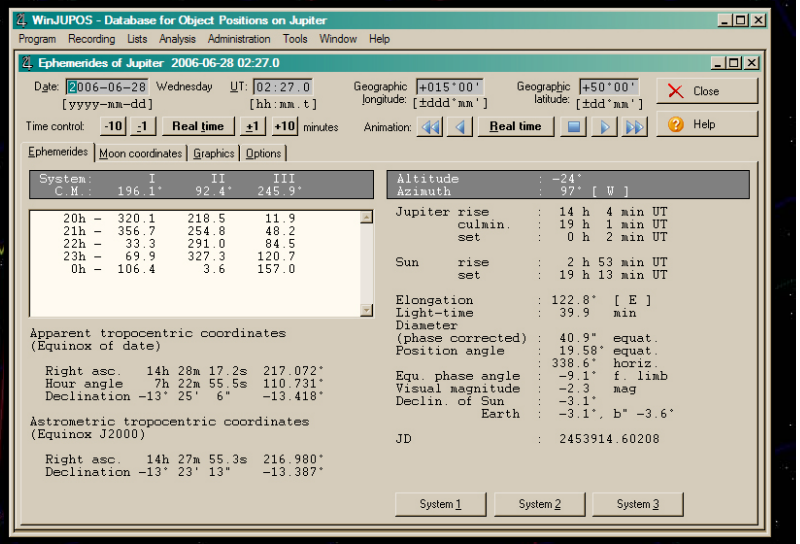

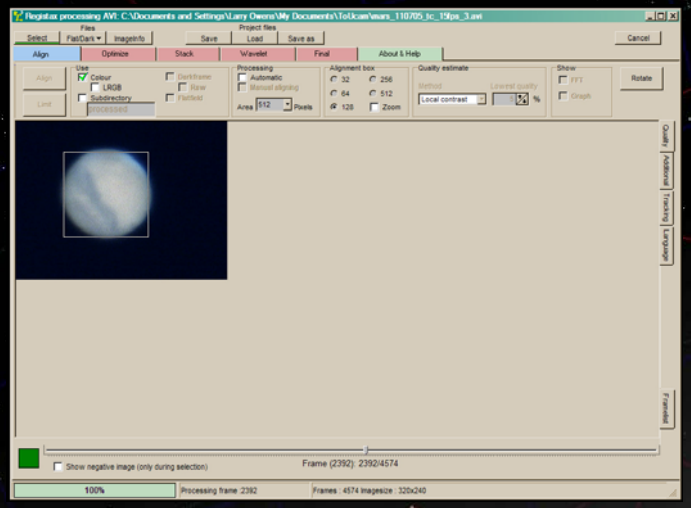

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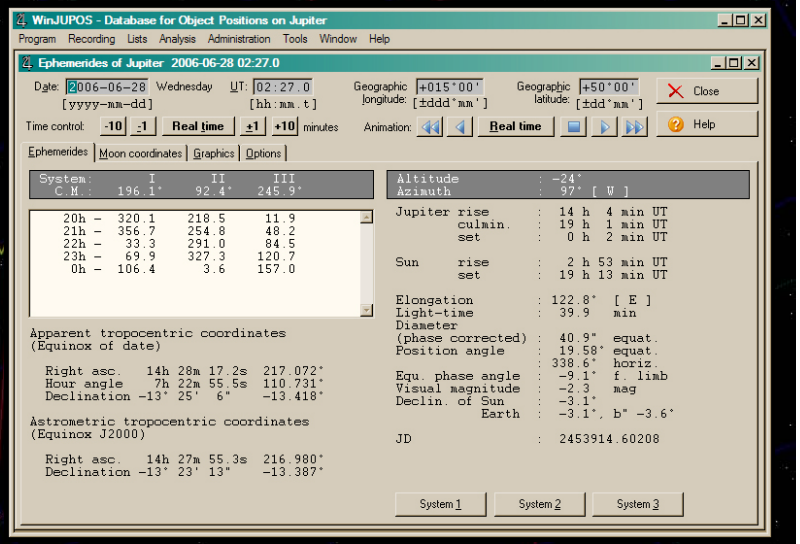

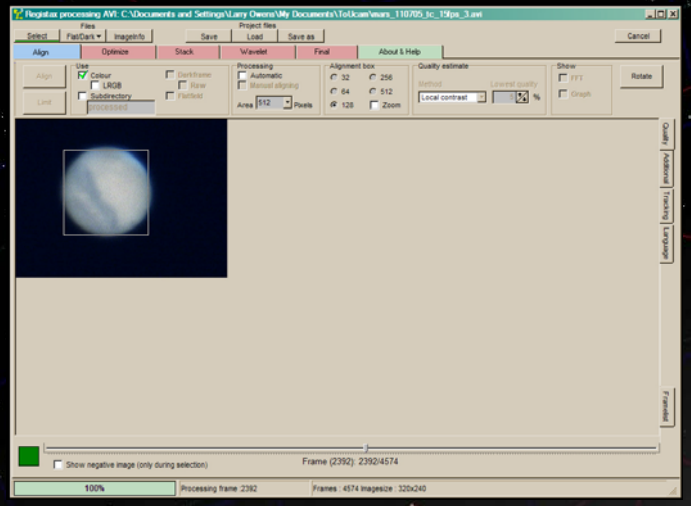

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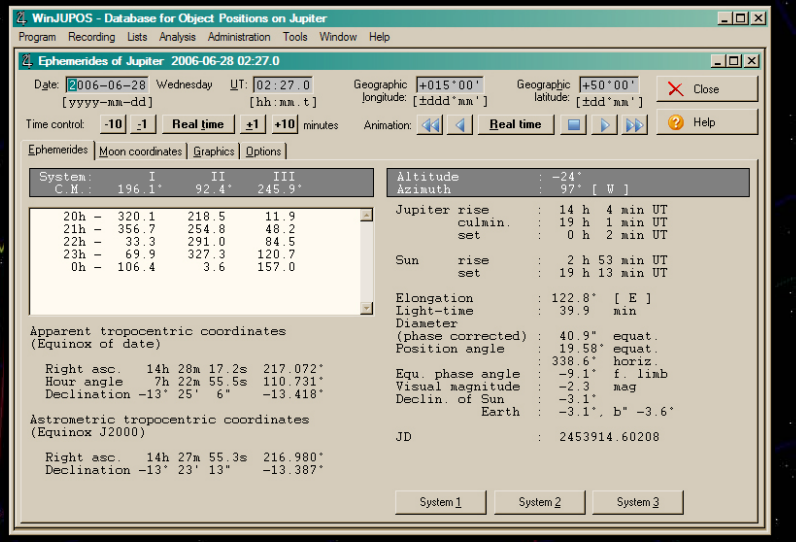
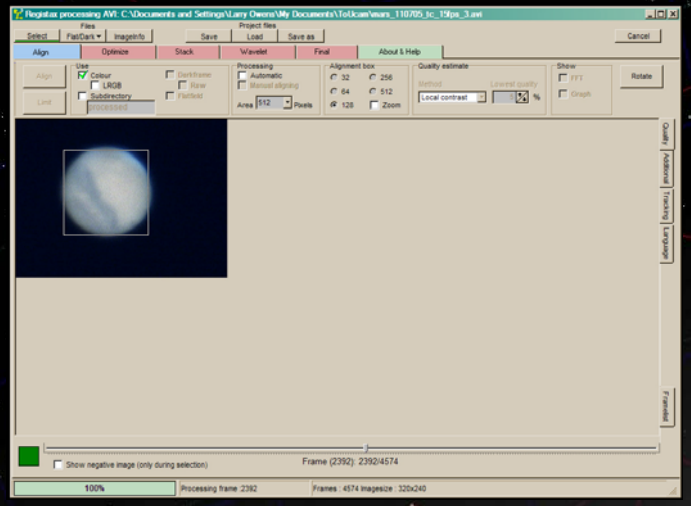
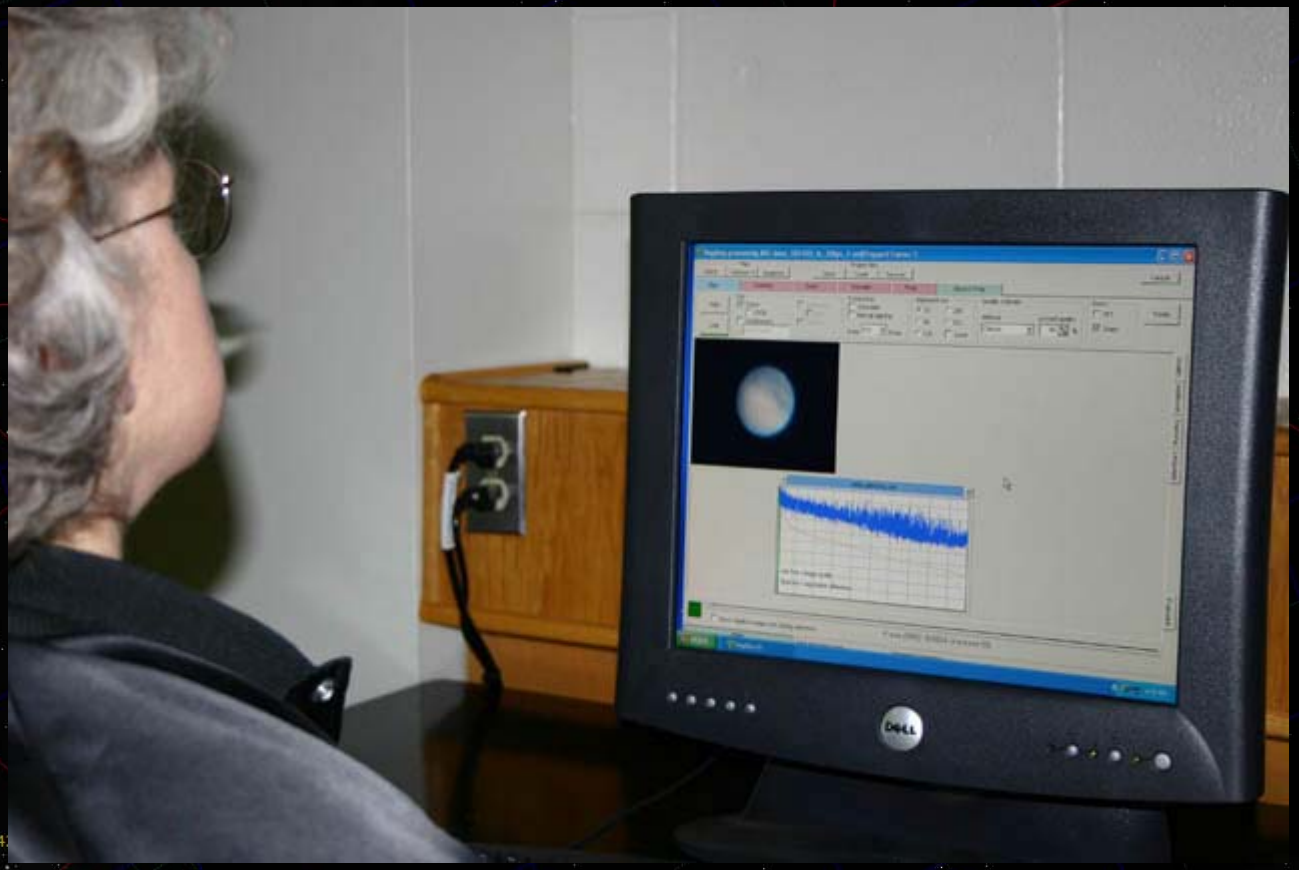
    - Quality only
    - Quality and alignment accuracy
  - Monochrome cameras
    - LRGB, process color sets before and after luminance set



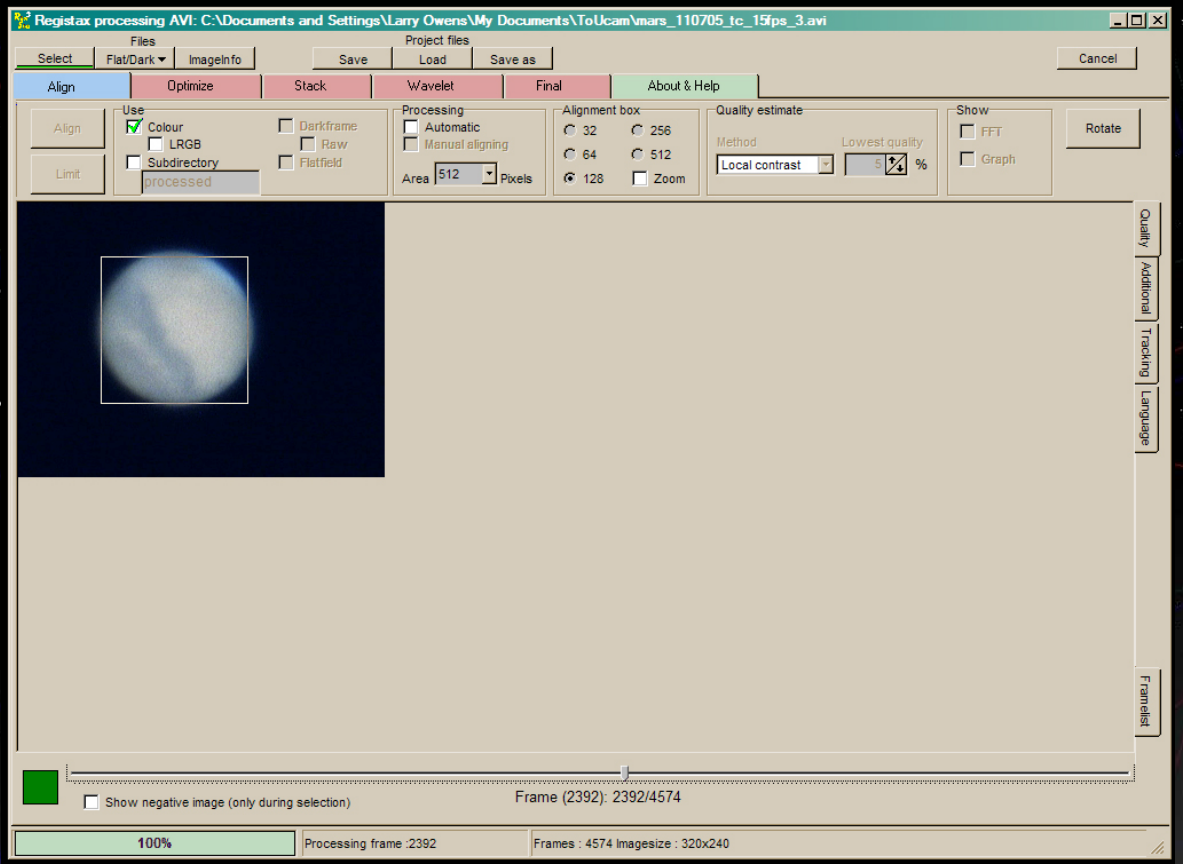


Processing Workshop



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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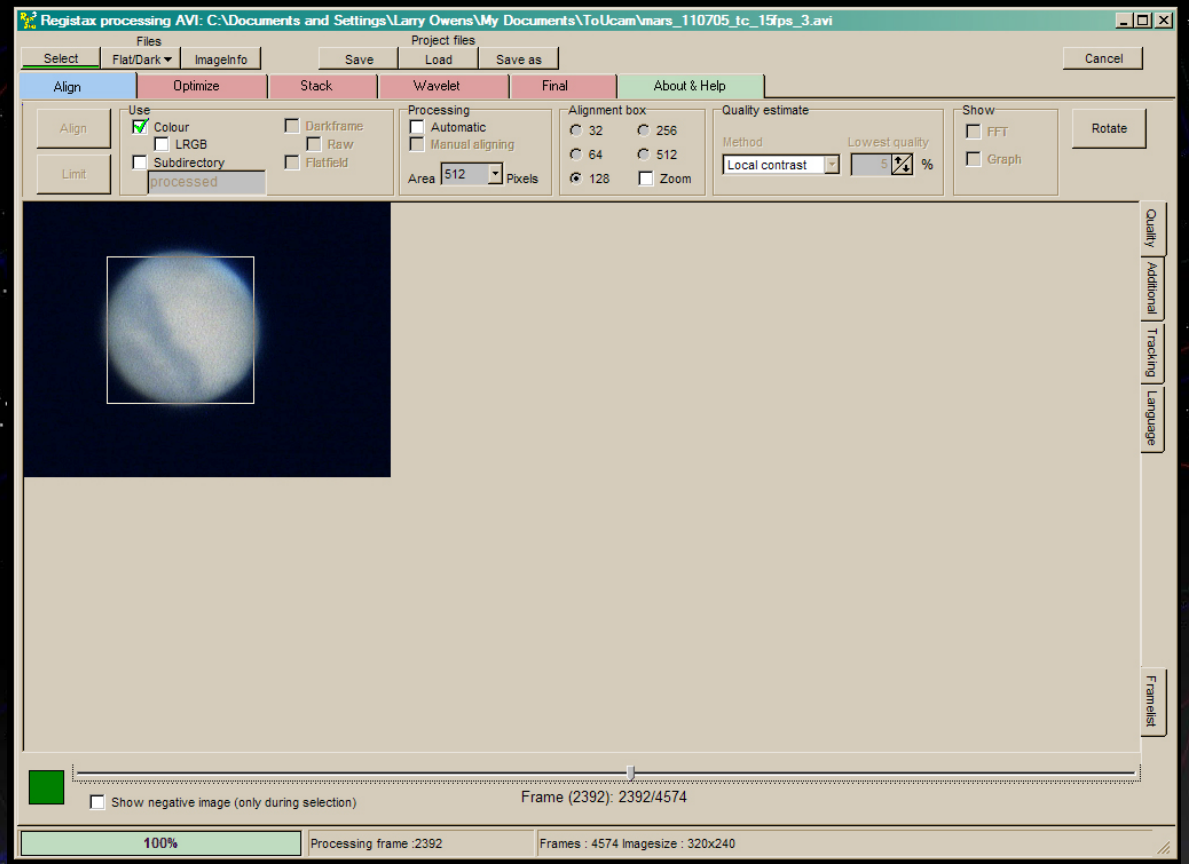
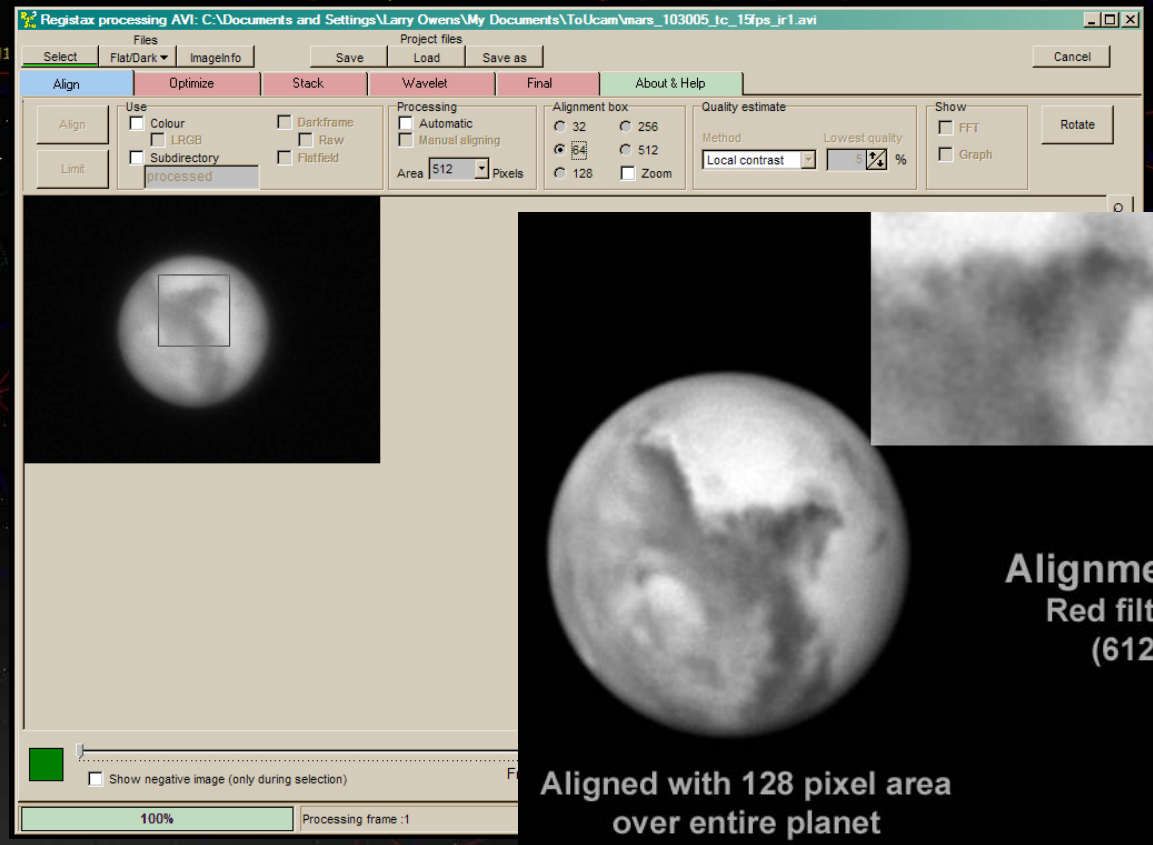
Select Reference Frame



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



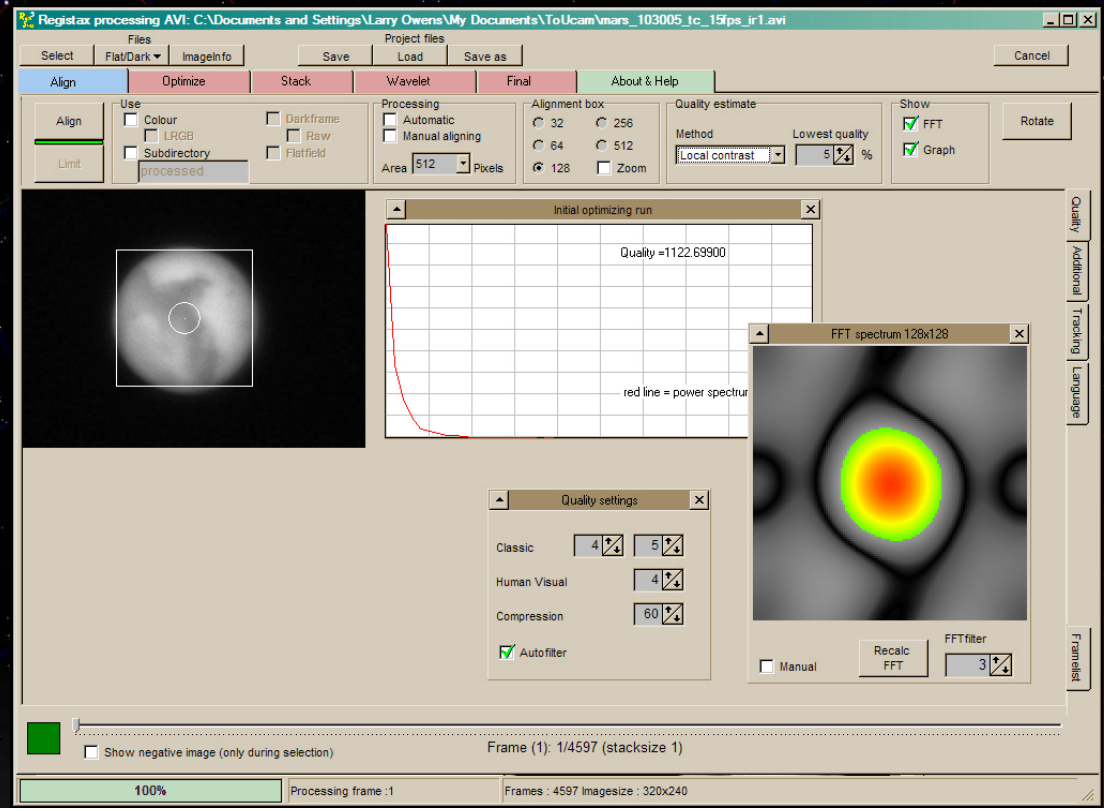
Alignment Options
Red filtered image
(612-670nm)

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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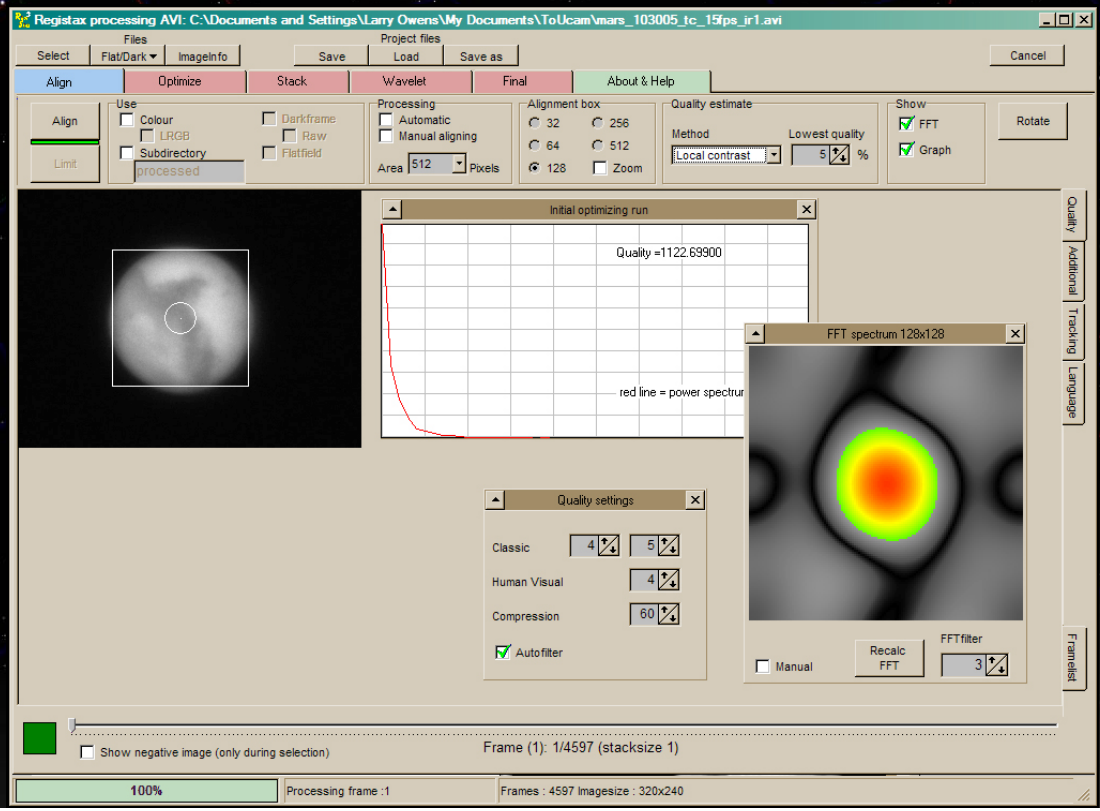
Select Alignment Box Size

Select “Local Contrast”

Select “0” Lowest Quality

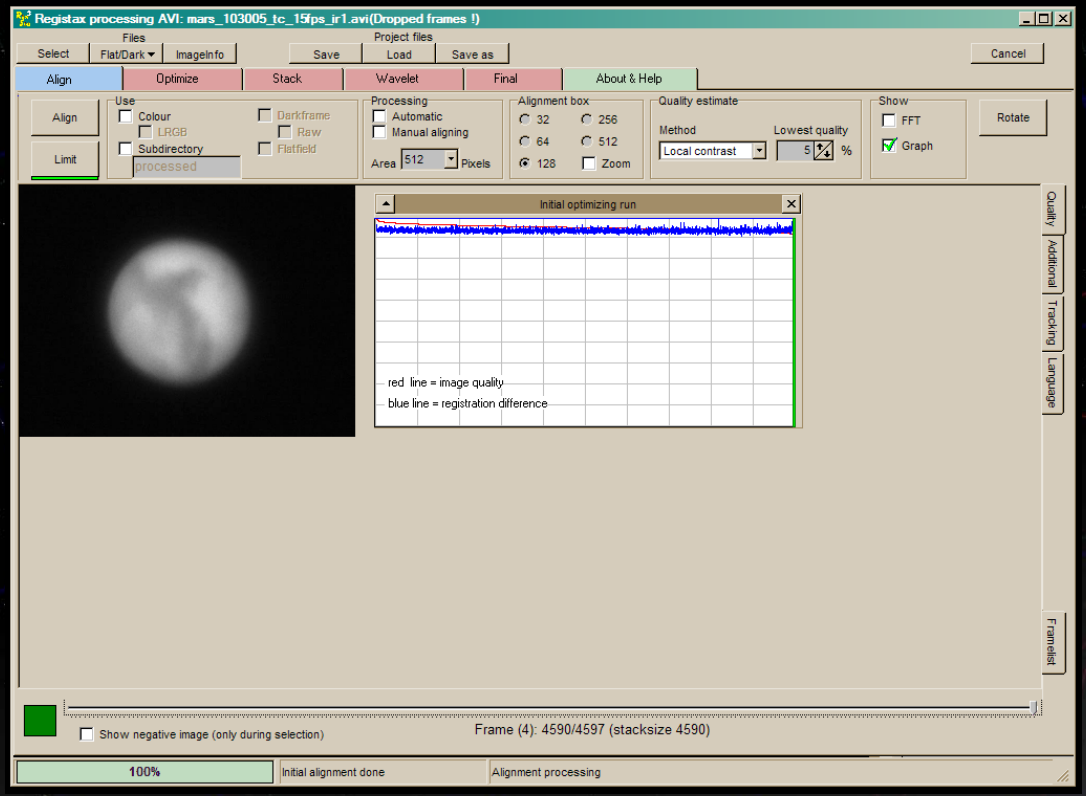
Adjust FFT Filter

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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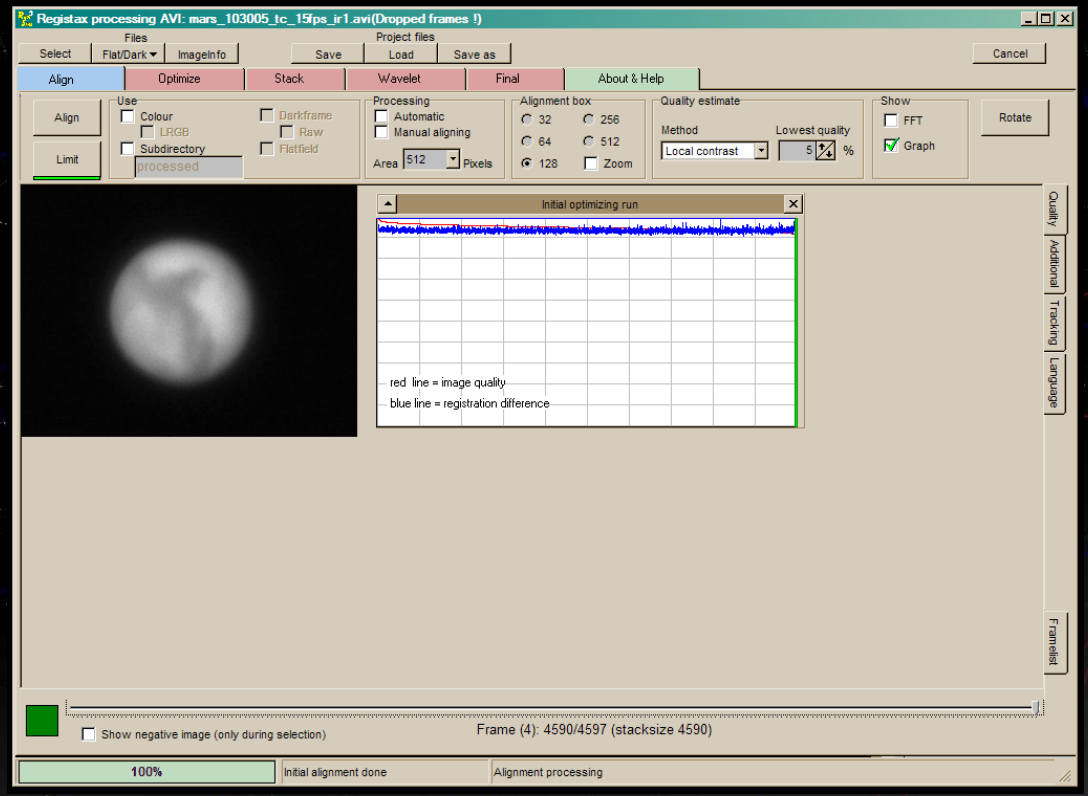
If “alignment curve” is OK

Press “Limit”

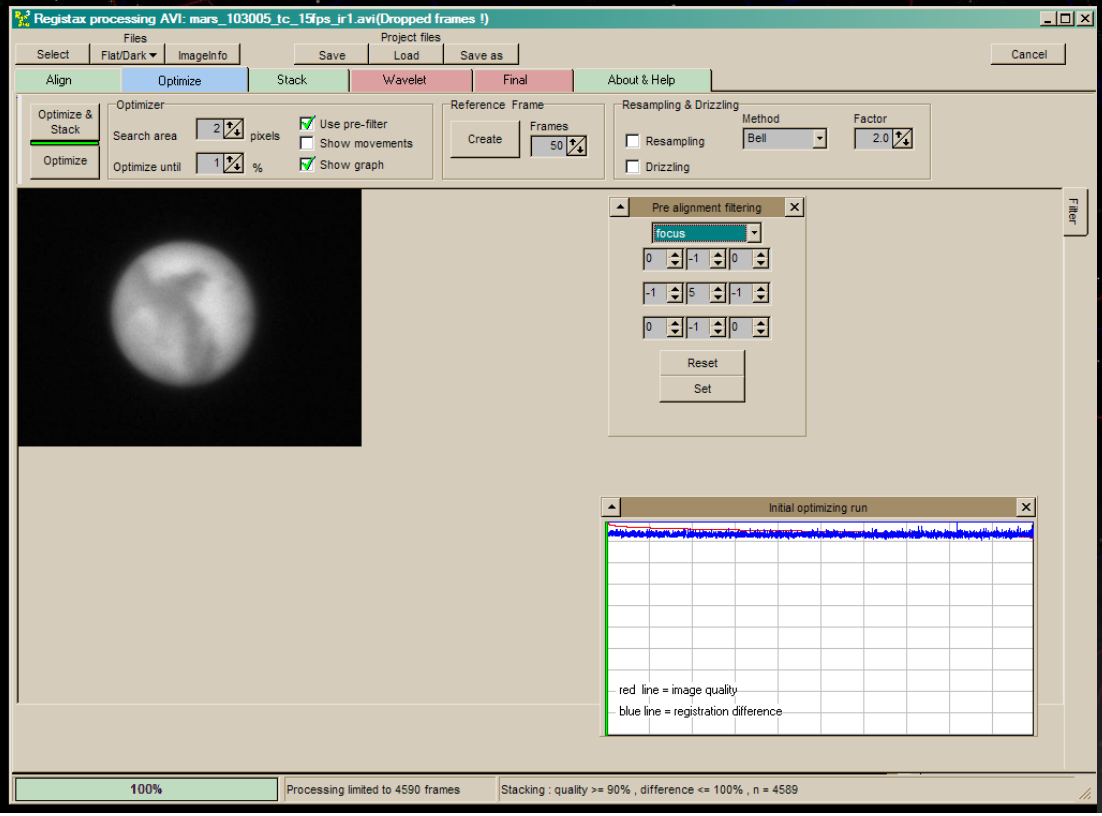
WAIT - DO NOT PRESS

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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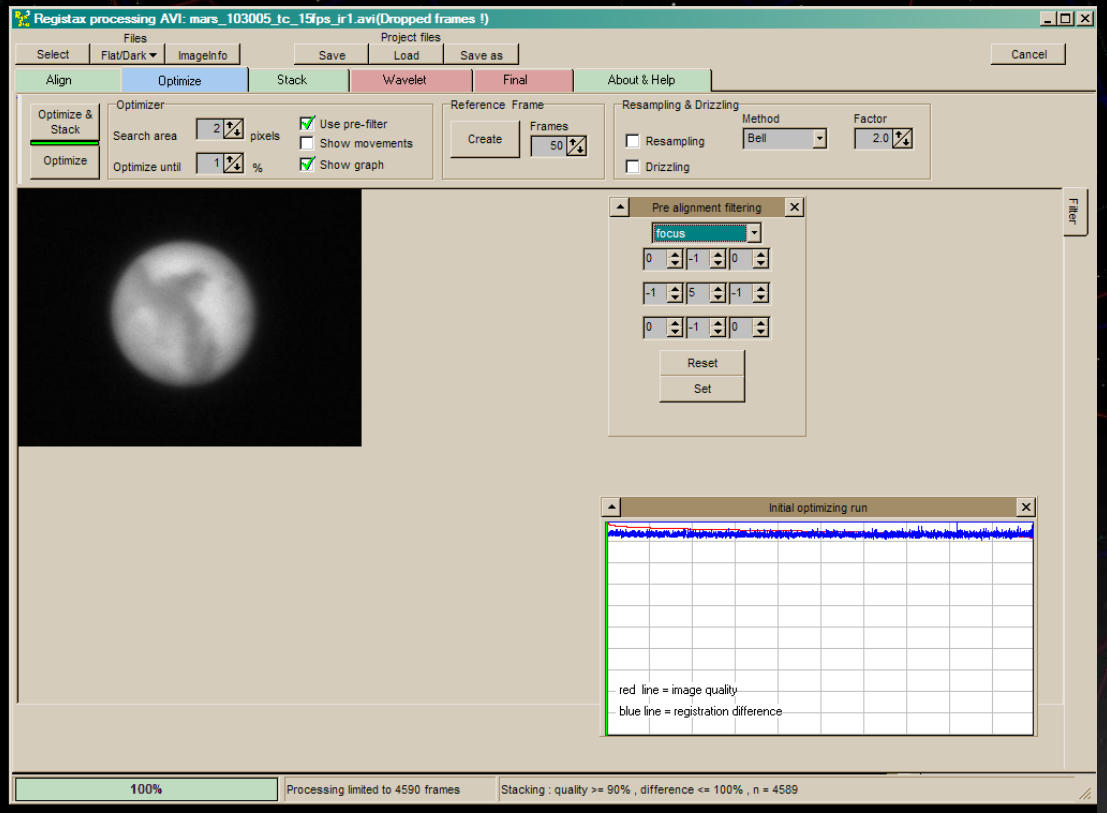
Select Optimize until 1%

Press “Optimize”

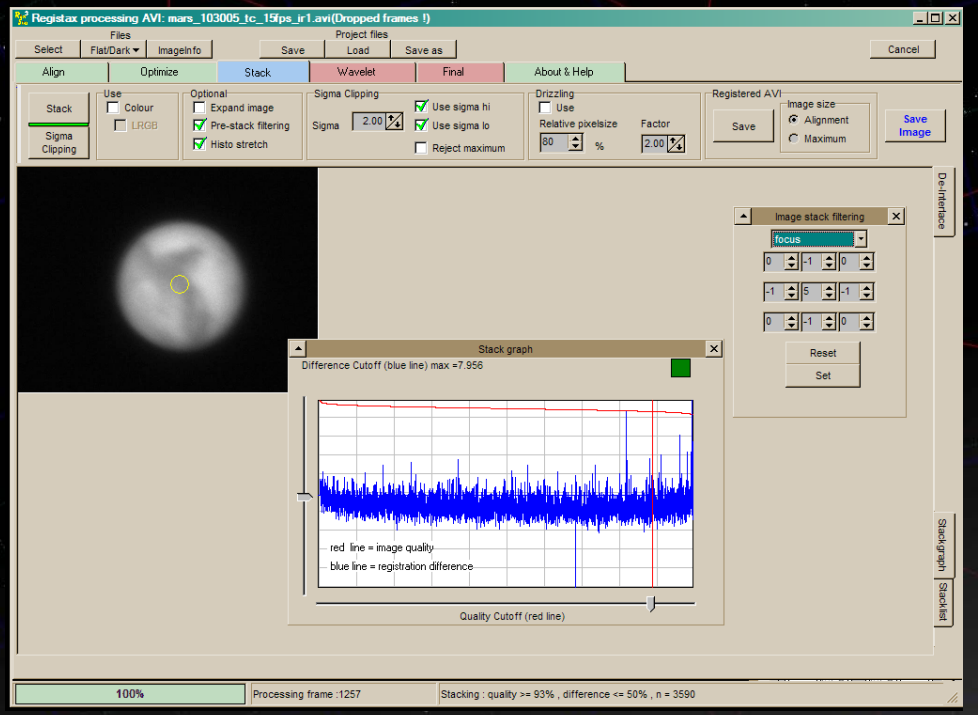
Wait for completion…

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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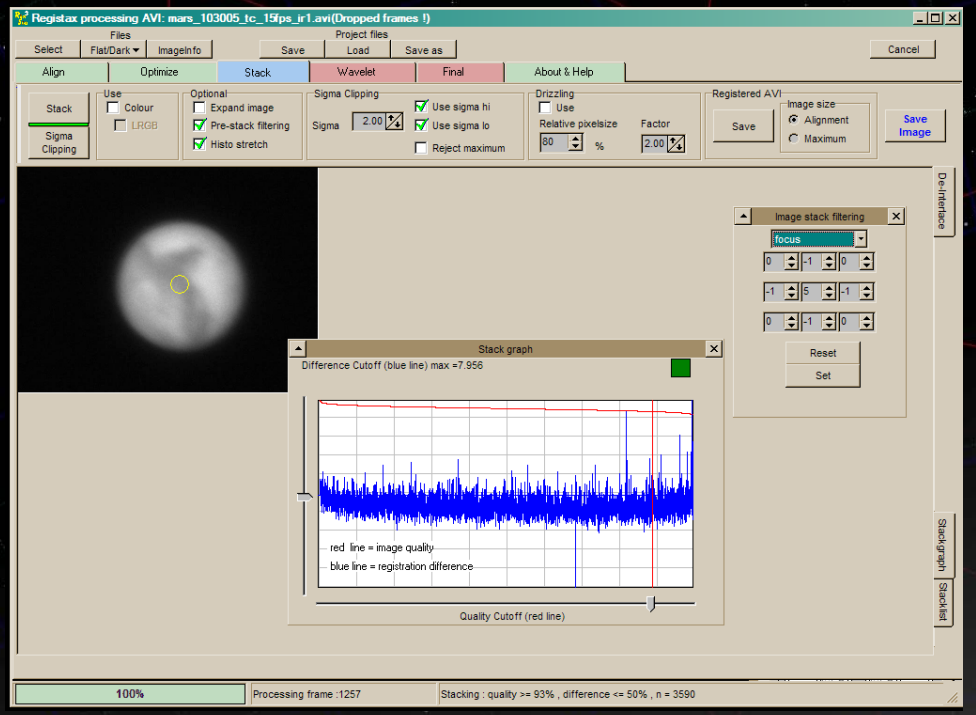
Select “Stack Graph” tab

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

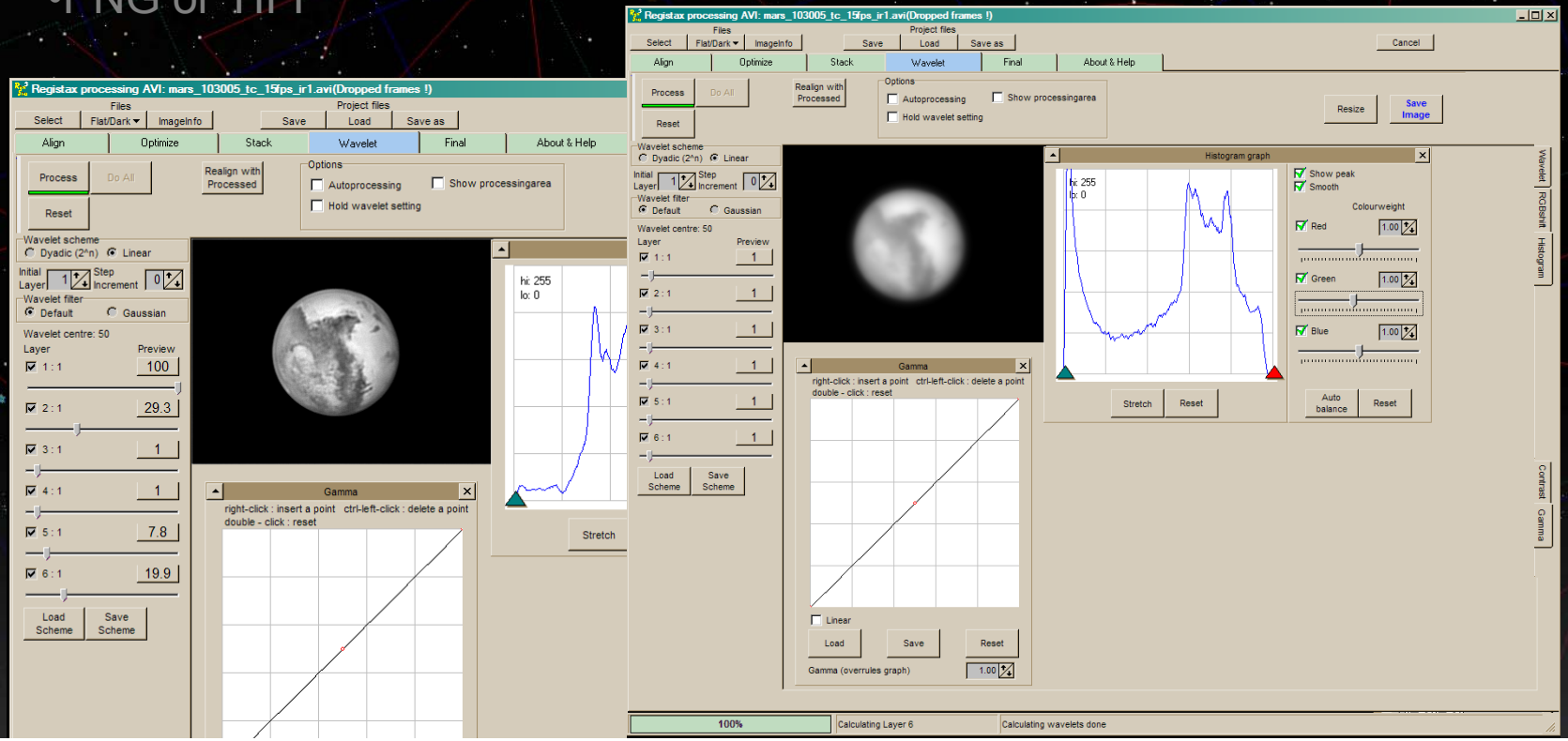
Exclude 10-30% lowest quality frames (horizontal bar)

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



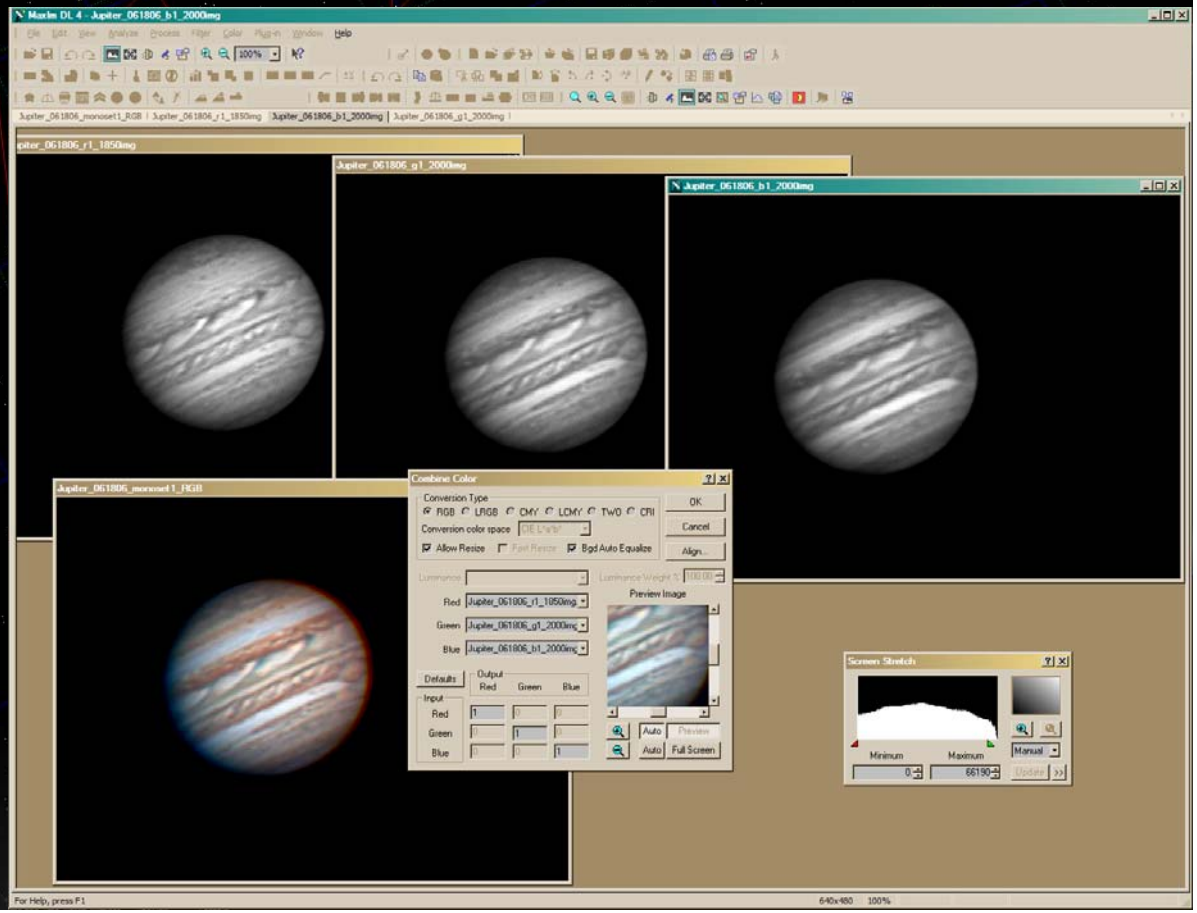
Wavelet Processing

- 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



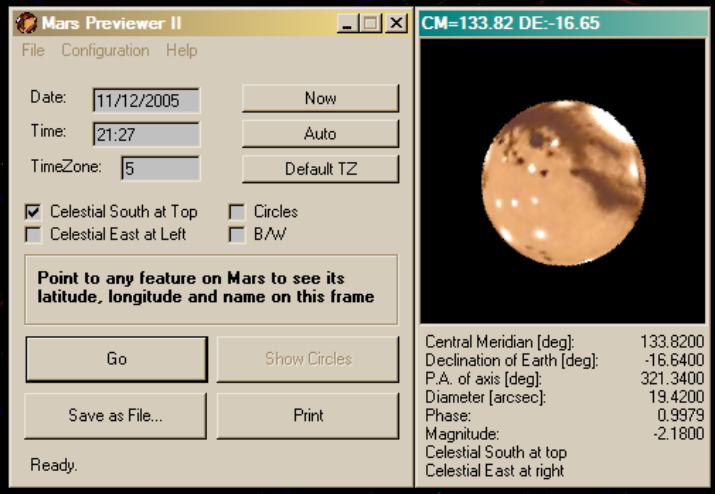
Color Combining (MaximDL)

- 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



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
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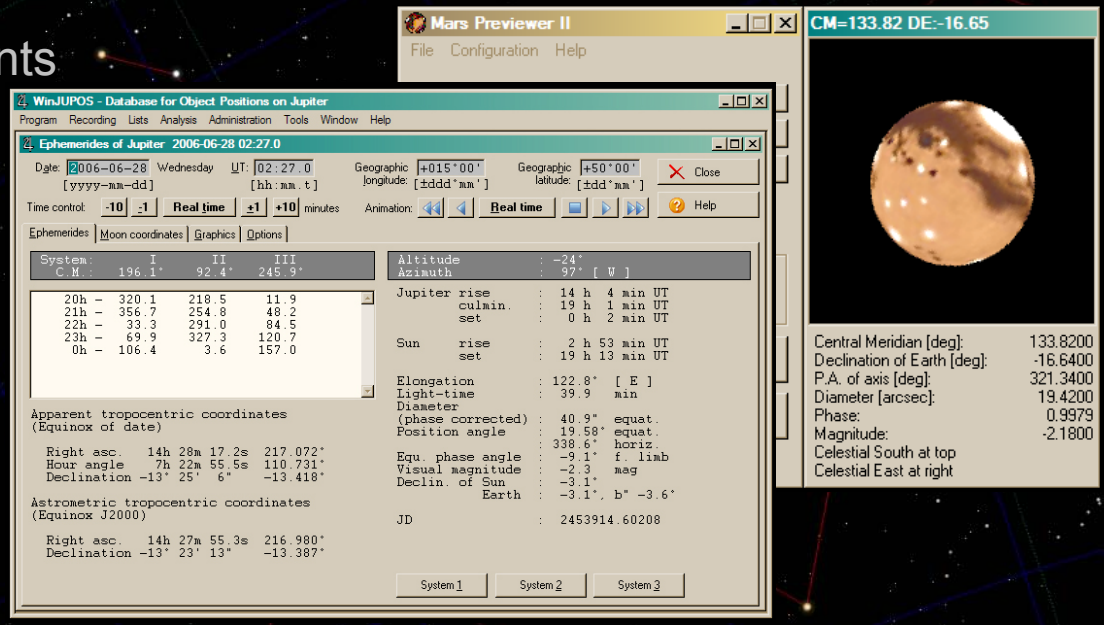

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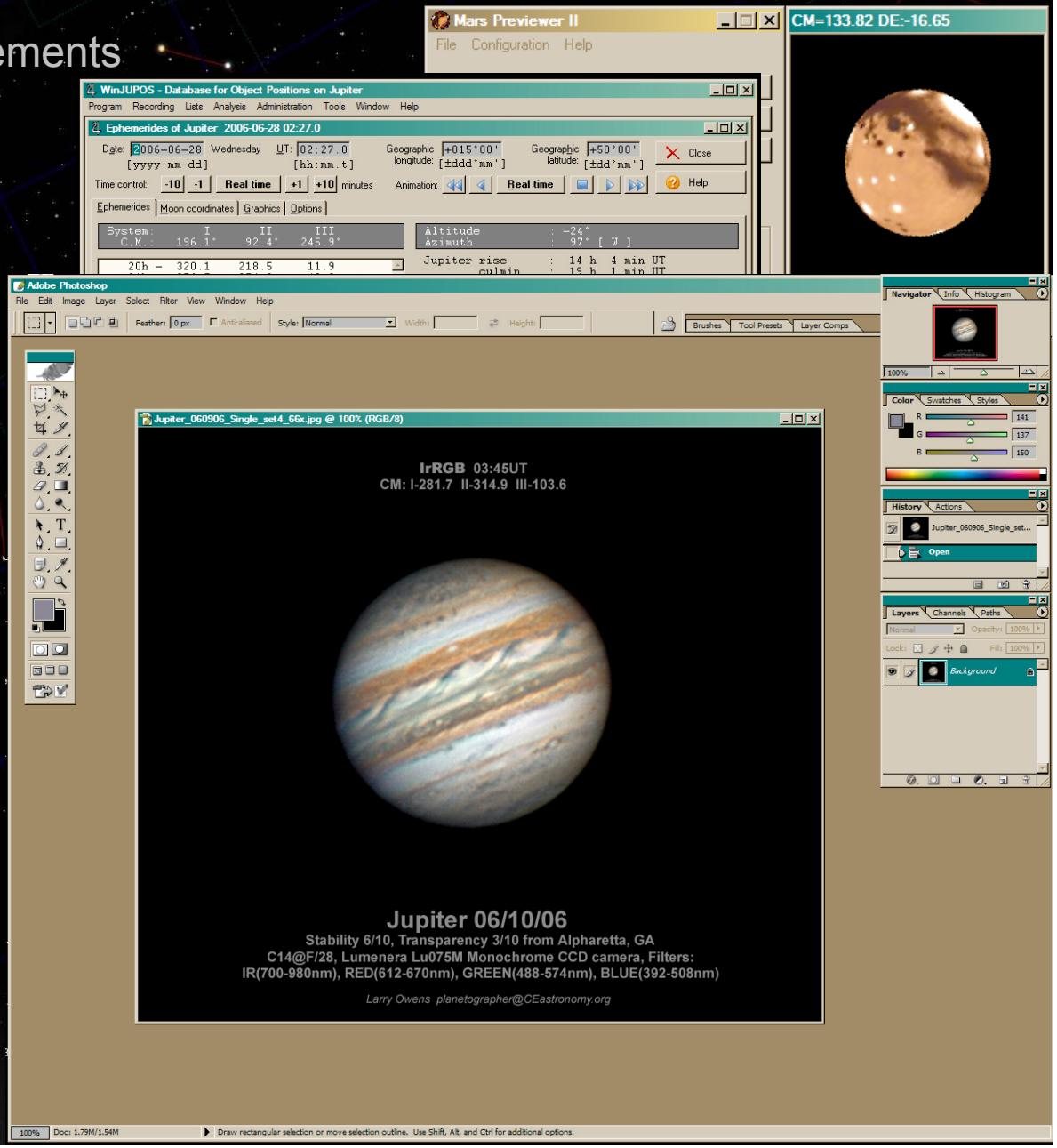

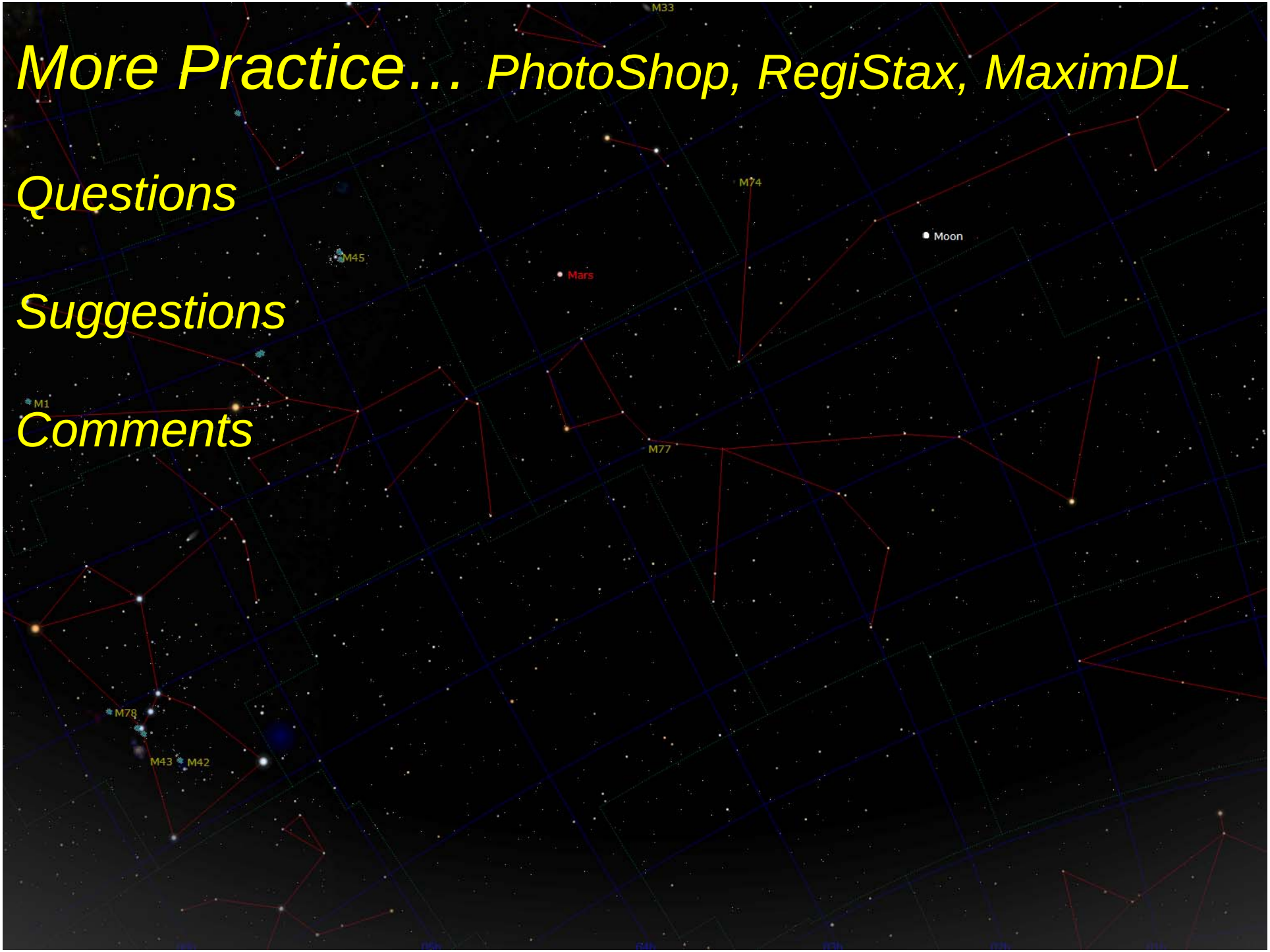

More Practice… PhotoShop, RegiStax, MaximDL

Questions

Suggestions

Comments