Lunar & Planetary Imaging with Webcams

Walter Lickteig

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July 2004

Lunar & Planetary Imaging with Webcams

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Overview of Webcam Presentation

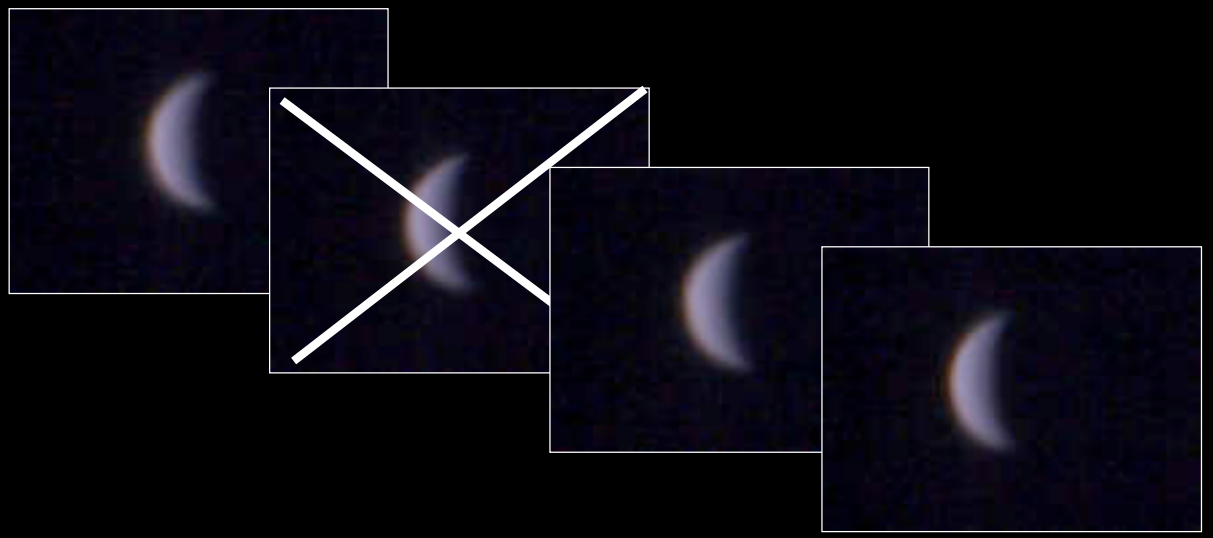
- Why Webcams for Lunar & Planetary Imaging?
- Choosing a Webcam
- Considerations in Choosing a Computer
- Telescopes, Mounts, and *f*-Ratios
- Set-up Factors
- Image Stream Pre-Capture
- Image Stream Capture
- Processing Image Streams
- Stacked Image Processing
- Final Touch-Up Processing
- Final Thoughts
- Imaging Examples

Why Webcams for Imaging?

- Webcams produce a stream of images -- as many as 30 a second -- that capture the subject as the “seeing” varies from great to poor.

Why Webcams for Imaging?

- The trick is to select the good frames, delete the poor ones, and then digitally “stack” the good frames to create a single image that is the averaged total of all the good frames



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Like Post-Facto Adaptive Optics

- The combination of selection, stacking and processing allows an amateur to enjoy the benefits of adaptive optics at a tiny fraction of the cost

Jupiter • Single Frame

Jupiter • Stacked/Processed

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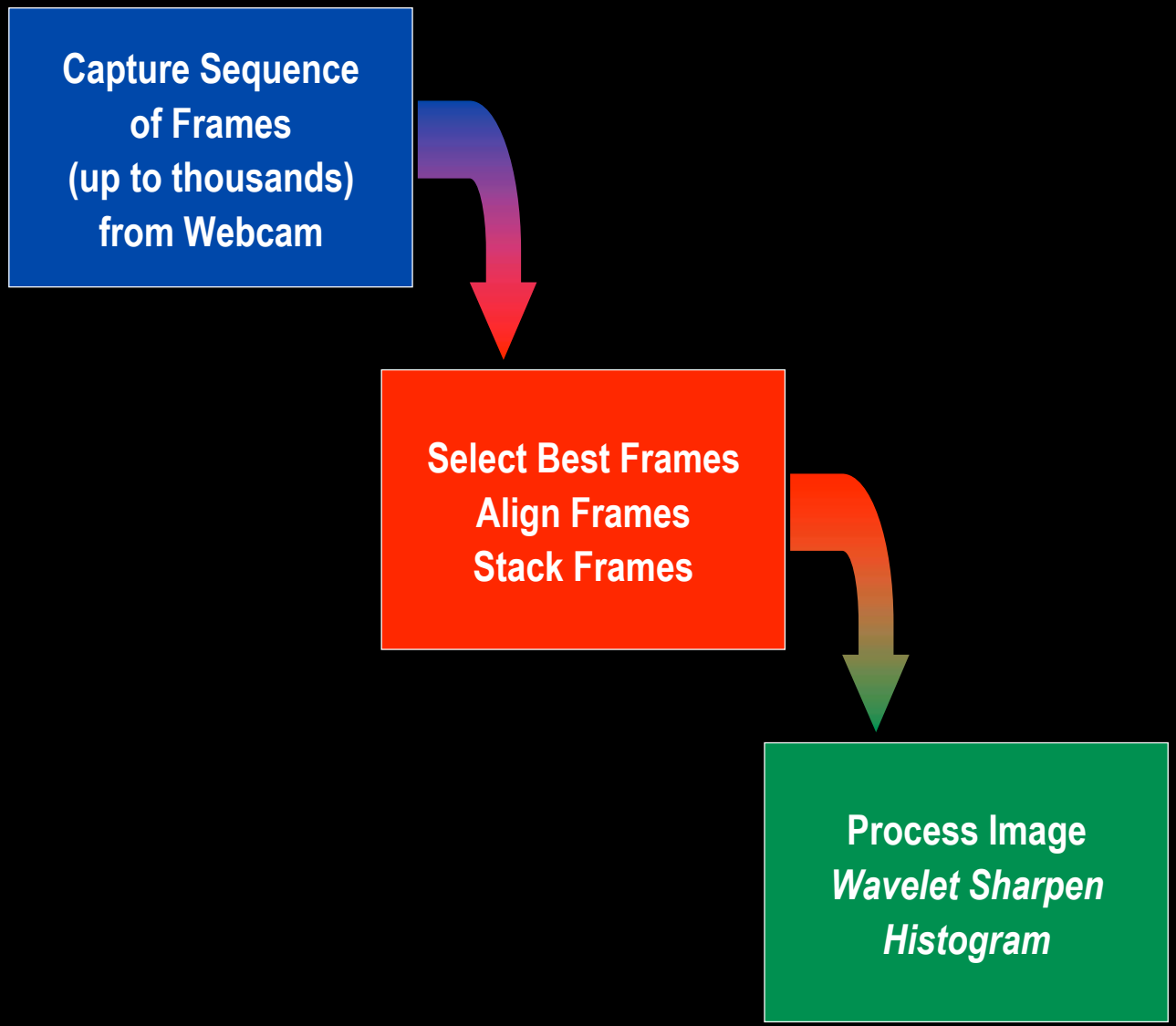
Webcam Imaging Workflow



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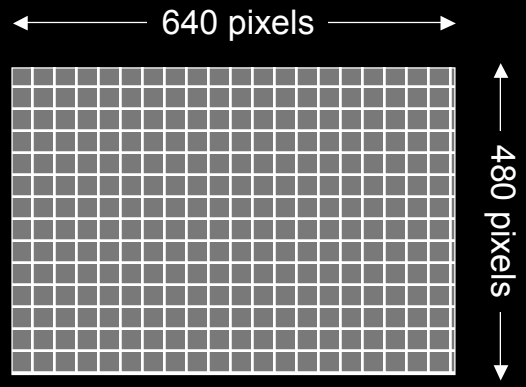
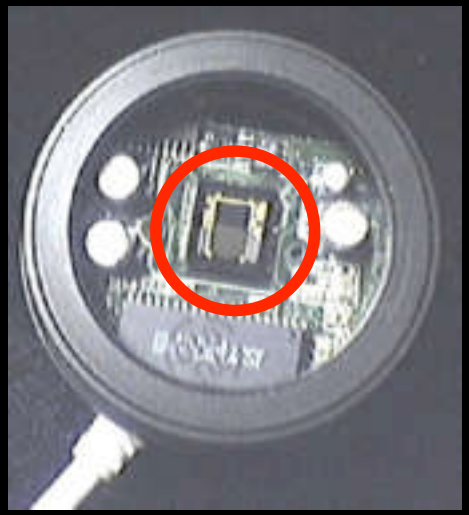
Basic Webcam Technology

- Most webcams use CCD chips with an array that is 640 pixels wide by 480 high



- Typical pixel size is 5.6 microns -- well-suited for planetary imaging

- Some webcams use CMOS rather CCD chips -- less sensitive



CCD chip is often less than 1/4-inch wide!

Choosing a Webcam

- USB vs. Firewire (IEEE 1394) Connector
  - USB
    - Common & generally low cost
    - USB 1 is slow & may lead to image compression
    - Philips ToUcam is most popular USB webcam for astrophotography
  - Firewire
    - Fast interface allows transfer of uncompressed image stream to computer
    - Harder to find, often more expensive
    - ADS, IREZ, Orange Micro, Unibrain make Firewire webcams

Choosing a Webcam (continued)

- Color versus Black & White
  - Color Webcams…
    - Produce one-shot color images
    - Have lower light sensitivity
    - Offer somewhat lower effective resolution
  - B&W Webcams…
    - Are generally more light sensitive
    - Provide higher effective resolution
    - Require tri-color filter wheel (RGB) for color
- Most imagers use color webcams, but high resolution work argues for B&W with filters

Attaching Webcam to Telescope

- Most webcams can be easily attached to a telescope by removing their lens assembly and replacing it with an 1.25-inch adapter

Webcam with lens attached

Webcam lens removed

Webcam with adapter attached

All images courtesy of Nite I's

- Adapters available from $10-$25

IR Filters for Webcams

- Most webcams are very sensitive to infrared (IR) light
  - Too much IR lowers contrast, details
  - For normal use, the lens that comes with the webcam typically has an IR filter built in
  - Best approach is to use a 1.25-inch screw-in IR filter in the webcam adapter

  - Good IR filters are available from Baader, Sirius, others for $35-$70

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Using Filters With B&W Webcam

- For greatest resolution and contrast, it is best to mimic traditional CCD imaging and use a B&W webcam equipped with a three color (RGB) filter wheel
- Rapidly shoot frames in each color, stack and process them, and then combine the channels in Photoshop

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What About the Meade LPI?

- Meade has recently introduced a CMOS device for “lunar-planetary imaging”
- Comes with capture, processing and planetarium software for $149
- Viable way to get into webcams, but requires powerful field computer to use some features

Choosing a Field Computer

- The ideal field system:
  - Laptop (duh)
  - 1 gigahertz or faster processor
  - 512+ megs of RAM
  - 80+ gigs of hard drive space
  - 1024 pixel screen is minimum; 1280+ better
  - USB 1.1, USB 2.0 and FireWire (400/800)
- OS: Either Windows XP or Mac OS-X
  - Earlier versions of Windows not highly USB or Firewire aware; avoid Linux

Telescope

- Basically, you can do webcam imaging with any kind of telescope
- Since primary targets for webcams are planets and the moon, focal length matters
  - For decent image scale, focal length should be at least 1000 mm
  - Effective focal length can be increased with either a Barlow or TeleVue Powermate
  - Take care not exceed *f*/30 unless you are using a very large (14+ inch) scope

Detail is Image Scale Dependent

- 10-inch SCT @ *f*/20 with ToUcam
  - 240 pixels across

- 10-inch SCT @ f/10 with ToUcam
  - 120 pixels across

- 5.25-inch MCT @ *f*/10 with ToUcam
  - 65 pixels across

Calculating Image Scale

- S=(205 x P)/FL
  - S=pixel scale in arc seconds
  - P=pixel size in microns
  - FL=focal length in millimeters
- My standard set-up:
  - 10-inch *ƒ*/10 SCT with 2x Barlow (5080 FL)
  - ToUcam with 5.6 micron pixels
  - 0.22 arc second per pixel =(205x5.6)/5080
  - Field is 141 seconds across (2.3 minutes)
  - Jupiter (40± arc sec) is 182 pixels across

Imaging Rules of Thumb

- You need at least 100 pixels across the primary target object to have an image with meaningful resolvable/printable detail
- For a color webcam, you want the arc second resolution per pixel to be at least 2X the scope's theoretical resolving power
  - R = 120/D
    - R=resolution in arc seconds, D=diameter in mm
  - 10-inch scope = .47 arc seconds
  - RM's standard set-up = .22 arc secs/pixel

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Altazimuth vs. Equatorial mounting

- Altazimuth allows quick set-up but target object rotates in the field of view over time

- Equatorial takes longer to set-up and typically requires a heavier equipment, but target maintains its orientation in the field of view

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Set-up Factors: God is in the Details

- Polar alignment
  - Not as critical as in long-exposure imaging
  - Mostly reduces workload
- Collimation
  - Incredibly important for high resolution
  - On SCTs, go beyond “the donut”
    - Tweak to center diffraction rings
- Scope cool-down
  - On SCTs, thermal “chimney” will seriously degrade images

Set-up Factors: More Details

- Seeing conditions
  - Most critical issue is lack of air turbulence that distorts light on its way to the telescope
  - Use Clear Sky Clock to check ahead of time for predicted sky steadiness
  - Watch for “twinkling” during evening
    - A little haze is a good thing; indicates “dead” air
  - If sky is unsteady, your options are:
    - Go to shorter exposures
    - Shoot only when the target is overhead
    - Pack up & go process previously captured videos

Set-up Factors: Just a few more…

- Clean optics
  - Corrector plates and mirrors should be clean, but aren't the most important optical elements
  - Glass surfaces closest to the camera & the focal plane are most critical
    - Make sure that barlow lens and filters are clean and free of dust
  - Finally, make sure CCD detector is as free of dust as possible
    - Store webcam in sealed plastic bag
    - Use compressed air to blow clean before use

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You're just about set up…
now it is time for the
final "Pre-Capture" adjustments

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Image Stream Pre-Capture

- Need image (Video) capture software
  - Popular PC applications are AstroVideo, K3CCD Tools, Astro-Snap, AstroArt
  - Mac apps include BTV, EquinoX, AstroIIDC

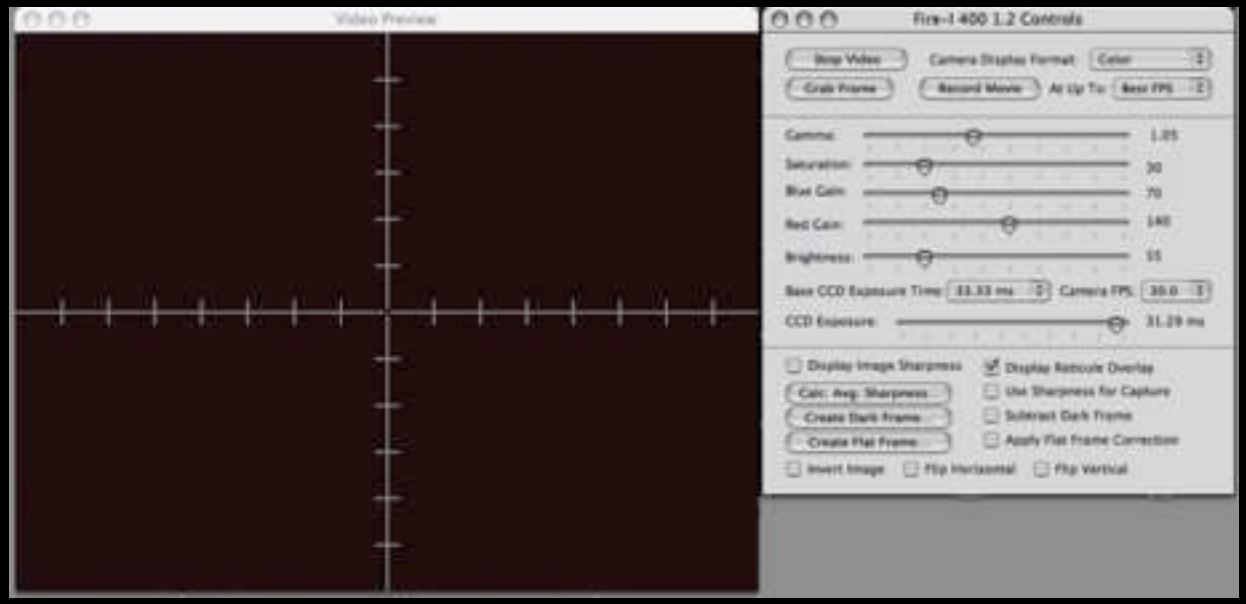

Image Stream Pre-Capture (continued)

- Key set-up variables
  - Shutter speed & frames per second (FPS)
    - Faster shutter speed freezes image movement
  - Gain
    - Too much introduces (lots of) noise
  - Gamma & color balance
    - Key to contrast enhancement
    - Color can be adjusted later, but important to strive to match visual appearance
      - Moon can be used to set neutral gray

Image Stream Pre-Capture: (continued)

- Flat-Fielding
  - Webcam's CCD sensitivity to light varies from pixel-to-pixel.
    - Used to correct the non-uniformities in image illumination.
    - It's the best [only easy] way to remove dust bunny shadows, dust donuts or dust spots.

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Image Stream Pre-Capture: (continued)

- Flat-Fielding or Flat-Field Division

Image Stream Pre-Capture: (continued)

- Finding and Centering the target
  - If it's bright…
  - If it's dim…
- Focusing

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Ok, now you are set up… it is time to capture some Image Streams

Image Stream Capture

- Besides "clicking" the "go" button…
  - Keep in mind:
    - Planetary Rotation, i.e. Jupiter
    - Field Rotation (if you're not polar aligned)
    - Hard-drive Space
    - Stay "in tune" with the conditions
      - Seeing
      - Wind
    - Image drift

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Now you are ready to do the hard part…

Image Processing

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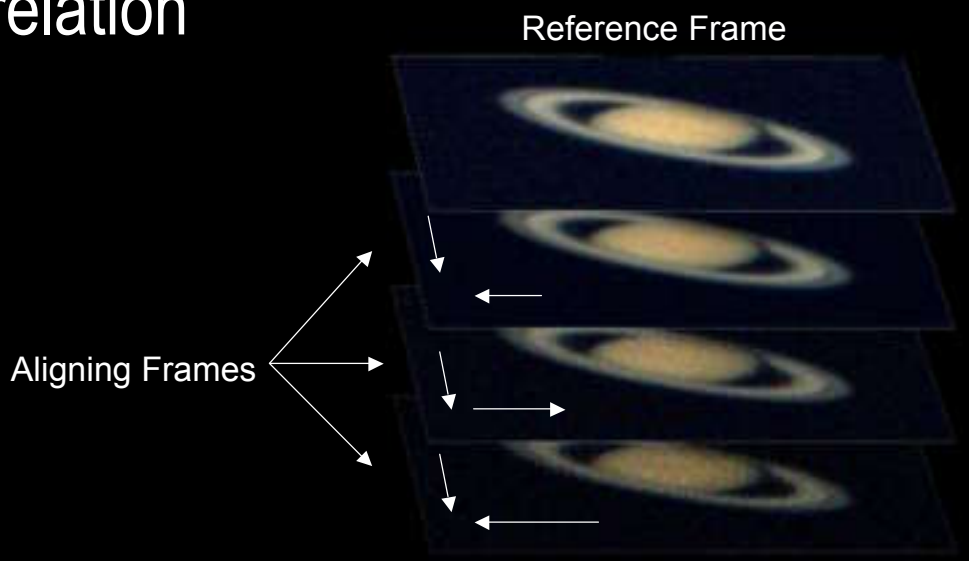
Image Processing Software

- Applications for PC Windows
  - Registrax
  - AstroStacker
  - AIP for Windows
- Applications for Macintosh
  - Keith's Image Stacker
  - AstroYacker
- Photoshop for both platforms

Processing Image Streams (continued)

- Aligning
  - Centroidal Area Comparison
  - Differential Alignment
    - Combined RGB Channels
    - Individual R, G, & B Channels
  - Cross-Correlation



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Processing Image Streams (continued)

- Select Best Frames: Sorting
  - Rarely advantageous to stack all the of frames
  - What it means for a frame to be very good to "just okay" can be a little difficult to specify.
  - Most Common Sorting Approaches:
    - Simplest method is "Manual Frame Selection"
    - Difference from Reference Frame
    - Degree of Saturation from Reference Frame
    - Degree of Brightness from Reference Frame
    - Value Range (between single darkest & brightest)
    - Various Fourier Transforms
  - Real-Time Accumulate (active sorting during capture!!!!!)

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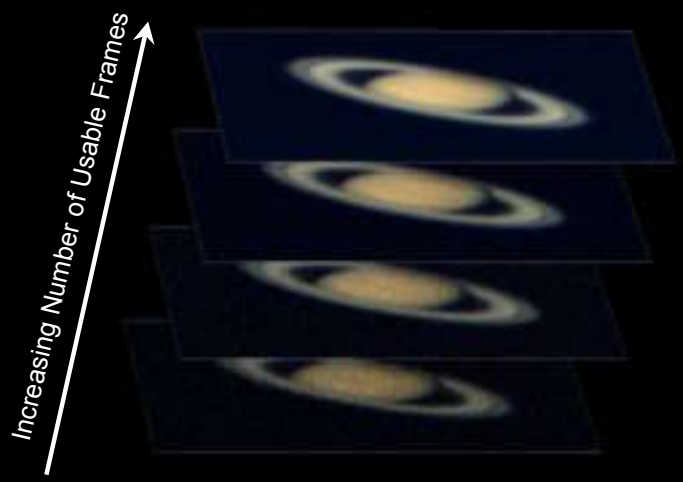
Processing Image Streams (continued)

- Stacking
  - Increases the Signal-to-Noise Ratio (S/N)
    - By a factor equal to the square root of the number of images stacked, i.e., 9 images 3 times, 100 images 10 times, etc.
  - And It Increases the Dynamic Range
    - Provides a greater difference between the maximum and minimum brightness



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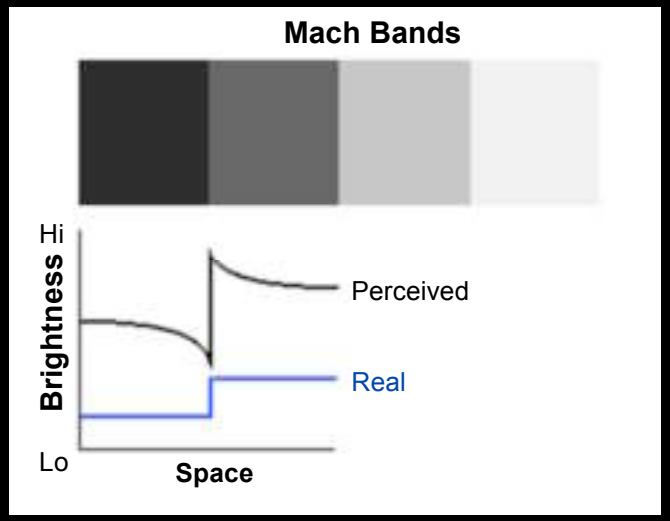
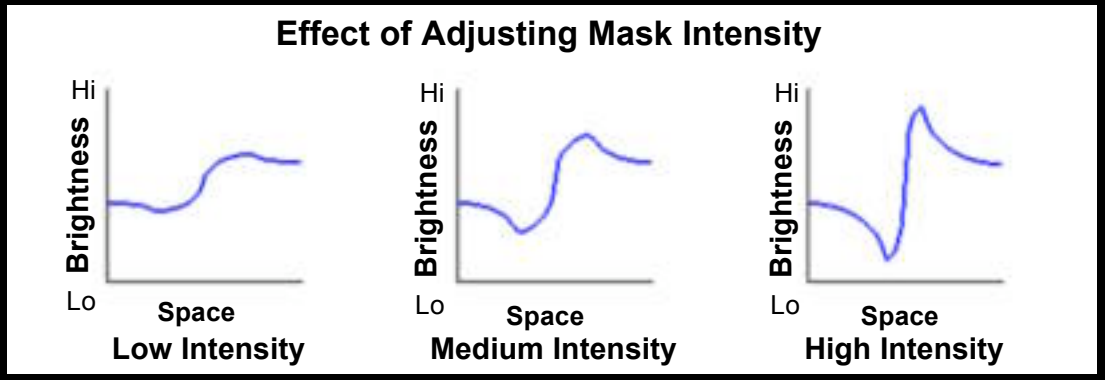
Stacked Image Processing

- UnSharp Masking (Convolution)
  - Underlying Principle Is Contrast Exaggeration
    - Accomplished Digitally by:
      - » Blurring the Original (Source Image)
      - » Subtracting Blurred Image from Original
      - » Add the New Image to Original
    - New Image Appears “Sharper” - Why???



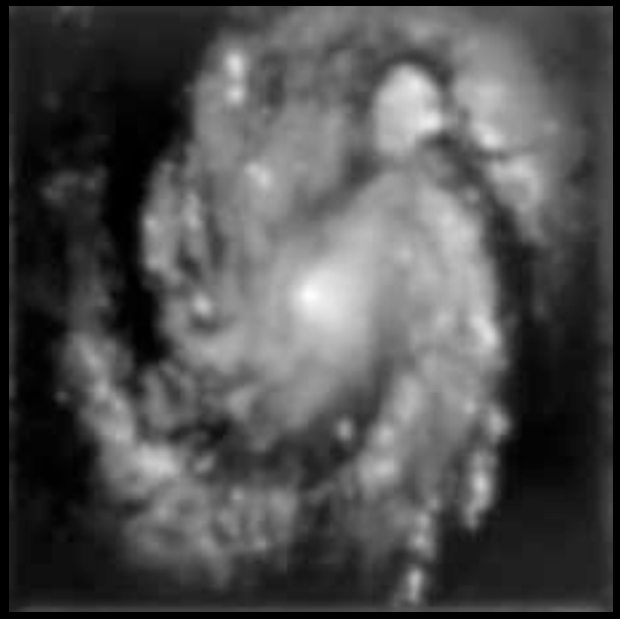
Stacked Image Processing (continued)

- Wavelet Sharpening
  - Advantage of Wavelet Sharpening over Unsharp Masking: individual control over Mach band edge generation at different scales in the same image.
  - Experimentation and practice are key



Stacked Image Processing (continued)

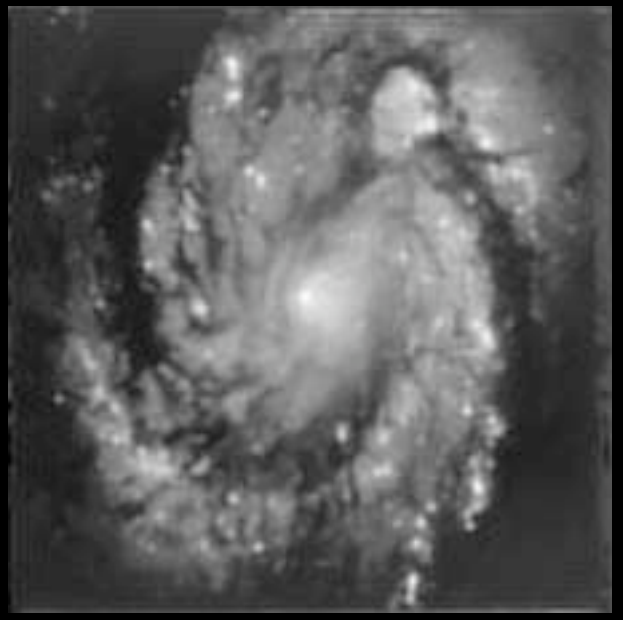
- Deconvolution Techniques
  - Or "What saved Hubble's initial optical SNAFU…"



Hubble Image **Before**

=

Point Spread Function, PSF



Hubble Image **After**

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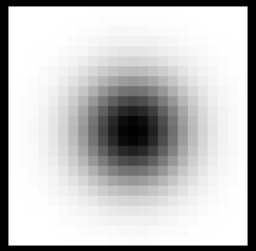
Stacked Image Processing (continued)

- Deconvolution Techniques
  - Richardson-Lucy
  - Van Cittert
  - Maximum Entropy



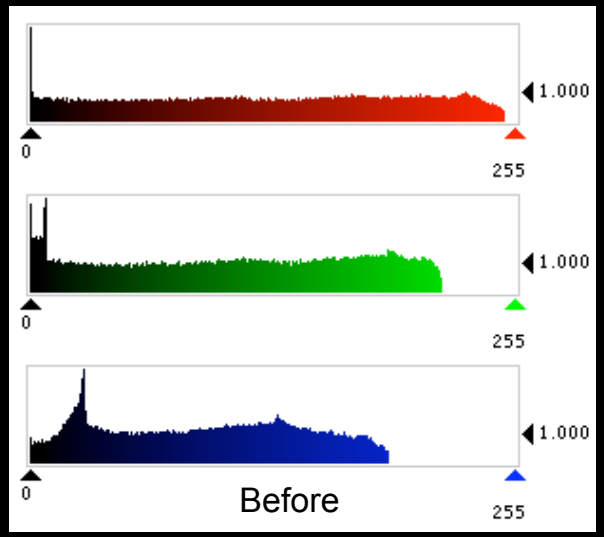
Point Spread Function, PSF

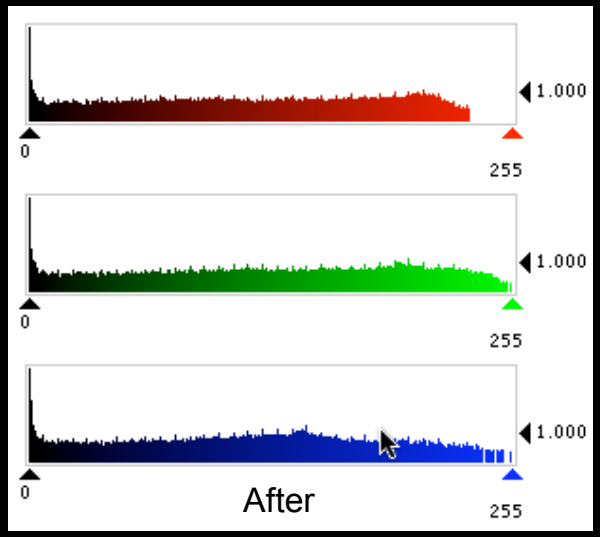
Spatial Domain Stacked Image

Frequency Domain Stacked Image

Stacked Image Processing (continued)

- Histogram Stretching
  - Sometimes called Histogram Re-mapping…
    - Reduces the range of an images histogram that doesn't contain much information
      - Which in turns makes the existing details within those ranges more visible





Final Touch-Up Processing

- The "Twiddle" Factors
  - I use Photoshop to tweak:
    - Contrast
    - Brightness
    - Saturation
    - Hue

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Final Thoughts…

- Words to the wise, "Don't Over Process"
  - If the detail isn't there, over processing is going to make it be there…
  - Your images can become very "ghoulish"…

- In this game, get the fastest computer you can buy
  - Processing Giga-Bytes of data definitely takes time…

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Imaging Examples

- Saturn
  - RTMC Nightfall
    - 9-28-03 @ 12:36 UTC
  - Processing: 309 Frames Manually Selected from 1,215

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Imaging Examples

- Jupiter with Io
  - RAS GMARS
    - 1-18-04 @ 13:47 UTC
  - Processing: 125 Frames Utilizing a Fourier Sort Selected from 450

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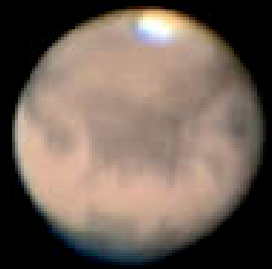
Imaging Examples

- Create Animations:
  - Last Year's Great Mars Rush:
    - 5 Image Streams
      - August 21 - Sept 7



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Imaging Examples

- Create Lunar Mosiacs:
  - October 12, 2003
    - 32 Images
    - 396 Frames per Image
    - Total of 12,672 Frames
  - Time-Lapse Mosiacs…

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Ralph's Images

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Jupiter on Drugs

Effects of Overprocessing

Venus

February March April May June

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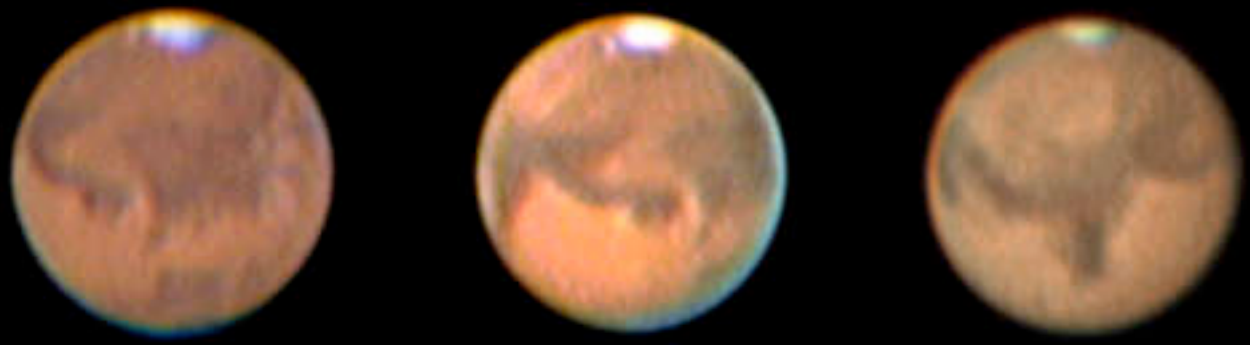
Mars 2003



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Jupiter

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Jovian Triple Transit

March 2004

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Jupiter • 28 March 2004 - 06:31 UT • Ralph Megna • 10" SCT @ *f*/20

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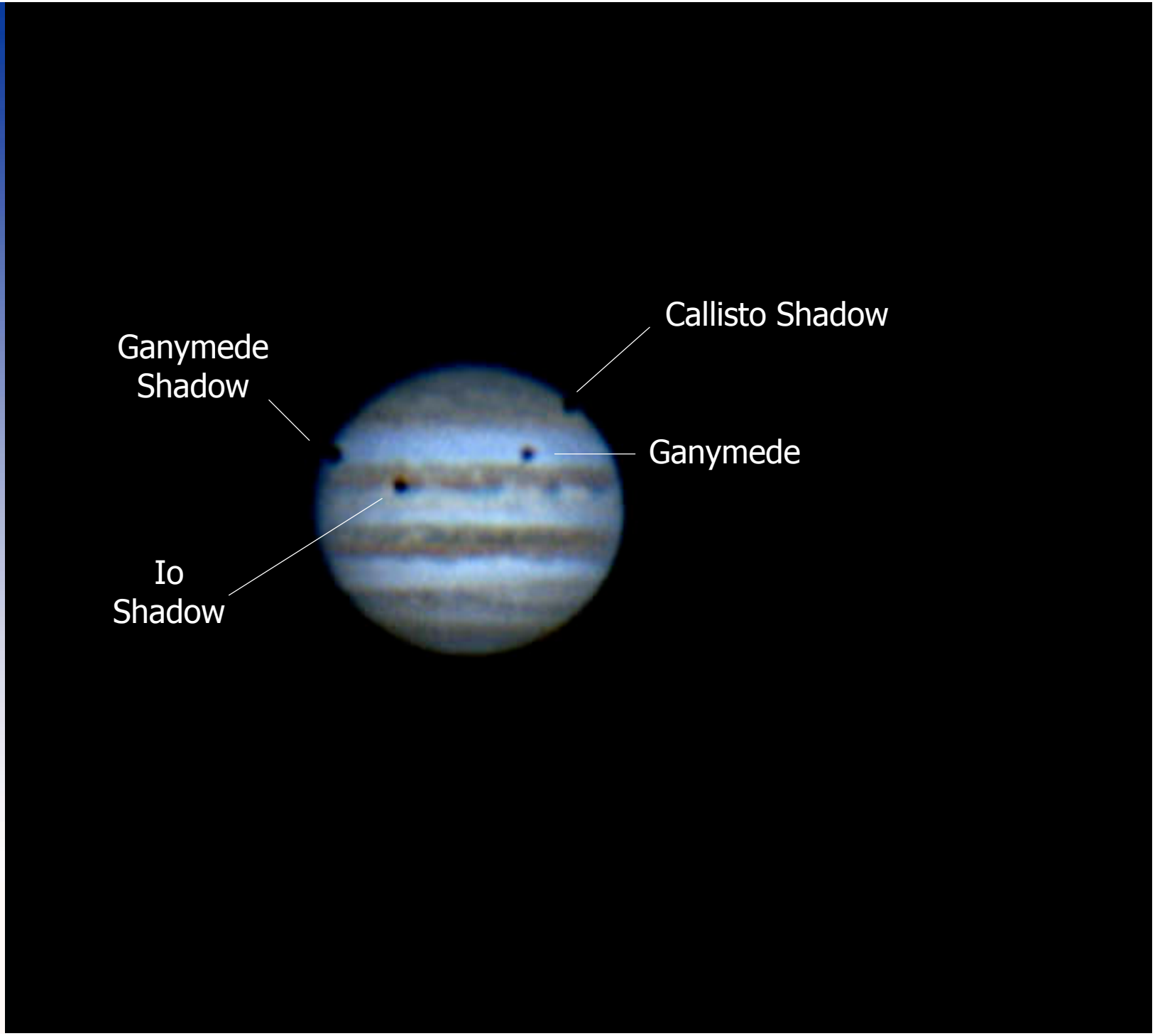

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"First Light" with CrystalCam

Images from prototype CrystalCam -- Firewire-based modified webcam with the capability of recording exposures of up to one hour using proprietary AstroIIDC control software. These images were captured with 10-inch SCT at *ƒ*/6.3 (focal reducer). M13 photo is stack of five 75-second exposures; M57 is single three-minute exposure.

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