Observing the lunar crescent through electronic cameras

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Outline

- Introduction to electronic imaging
- Contrast as the central issue
- Crescent telescope details
- Benefits, advantages & results
- Conclusion & outlook

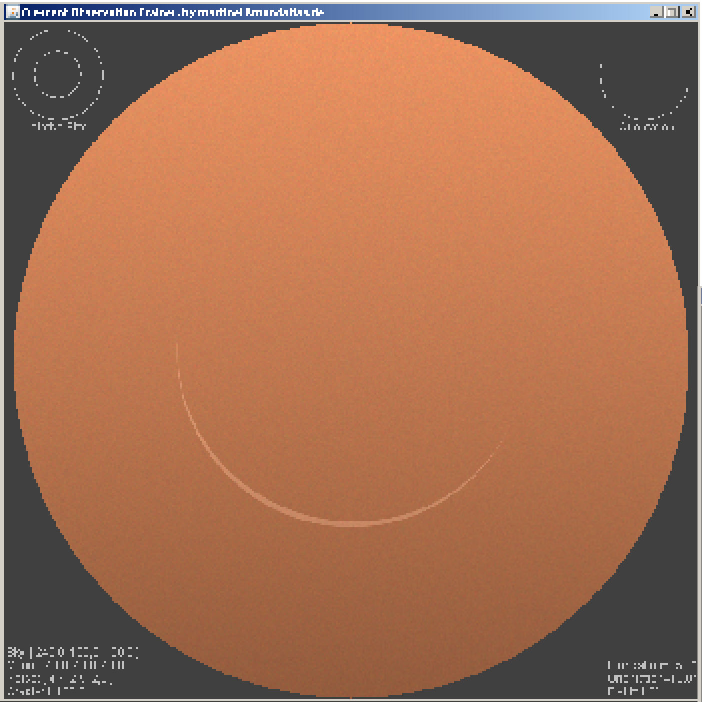
Introduction to electronic imaging

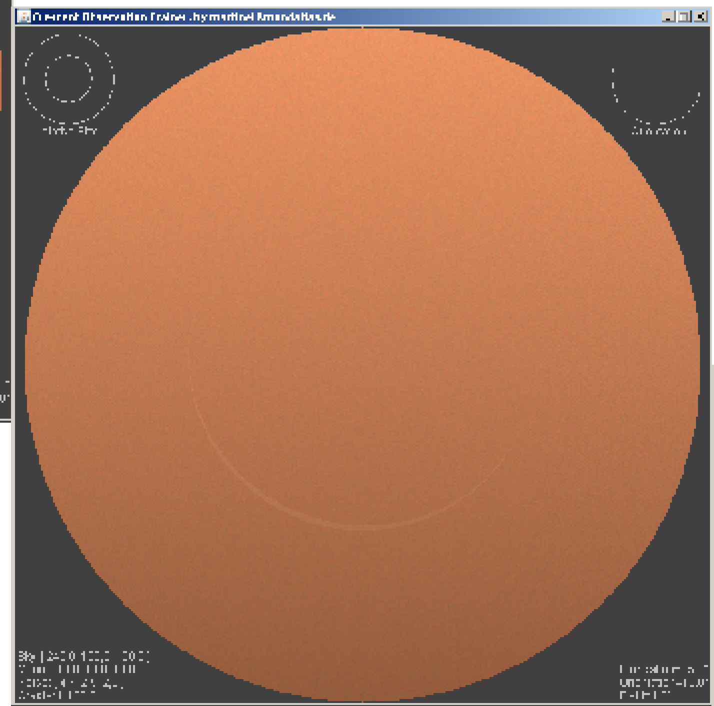
General notes on crescent imaging

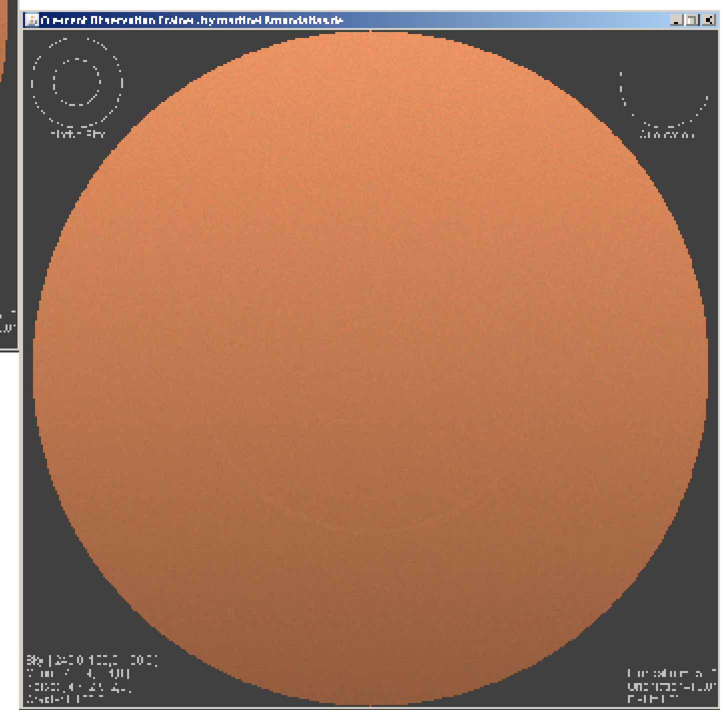
- Preparation: when and where to look for what
- Choose a safe location with clear view of the horizon
- Use a good quality camera
- Use a tripod
- Take series of images to capture changes and movement
- Take both wide field and zoomed images
- Foreground objects are useful for comparison and aesthetics

Visual contrast

- Contrast is the difference in brightness or color between an object and the background
- Difficult crescents hardly differ in brightness from the background sky
- The human eye has known limitations when searching for low contrast structures







Simulated views of a crescent with decreasing contrast

Reasons for low contrast

- The moon reflects all colors of sunlight
- The light from the moon must pass through the earths atmosphere, which adds unwanted light and thus reduces contrast

- Cause #1: Unfavorable weather
- Cause #2: Difficult geometry: small elongation from the sun or crescent low on the horizon

Crescent telescope details

A *high performance* crescent imaging telescope consists of:

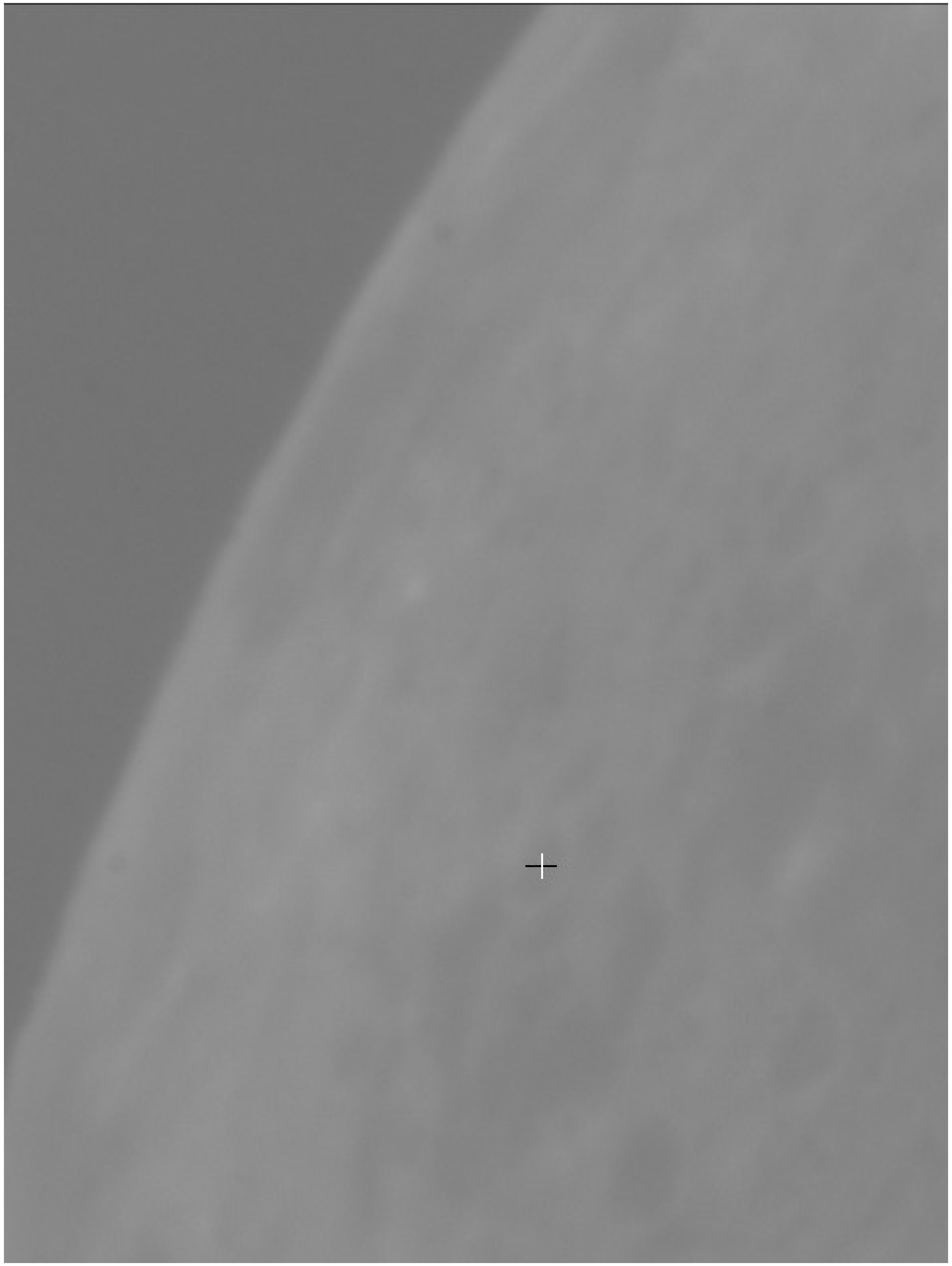
- Camera
- Optical filters
- Telescope optics
- Telescope mount
- Baffles
- Specialized software

Camera

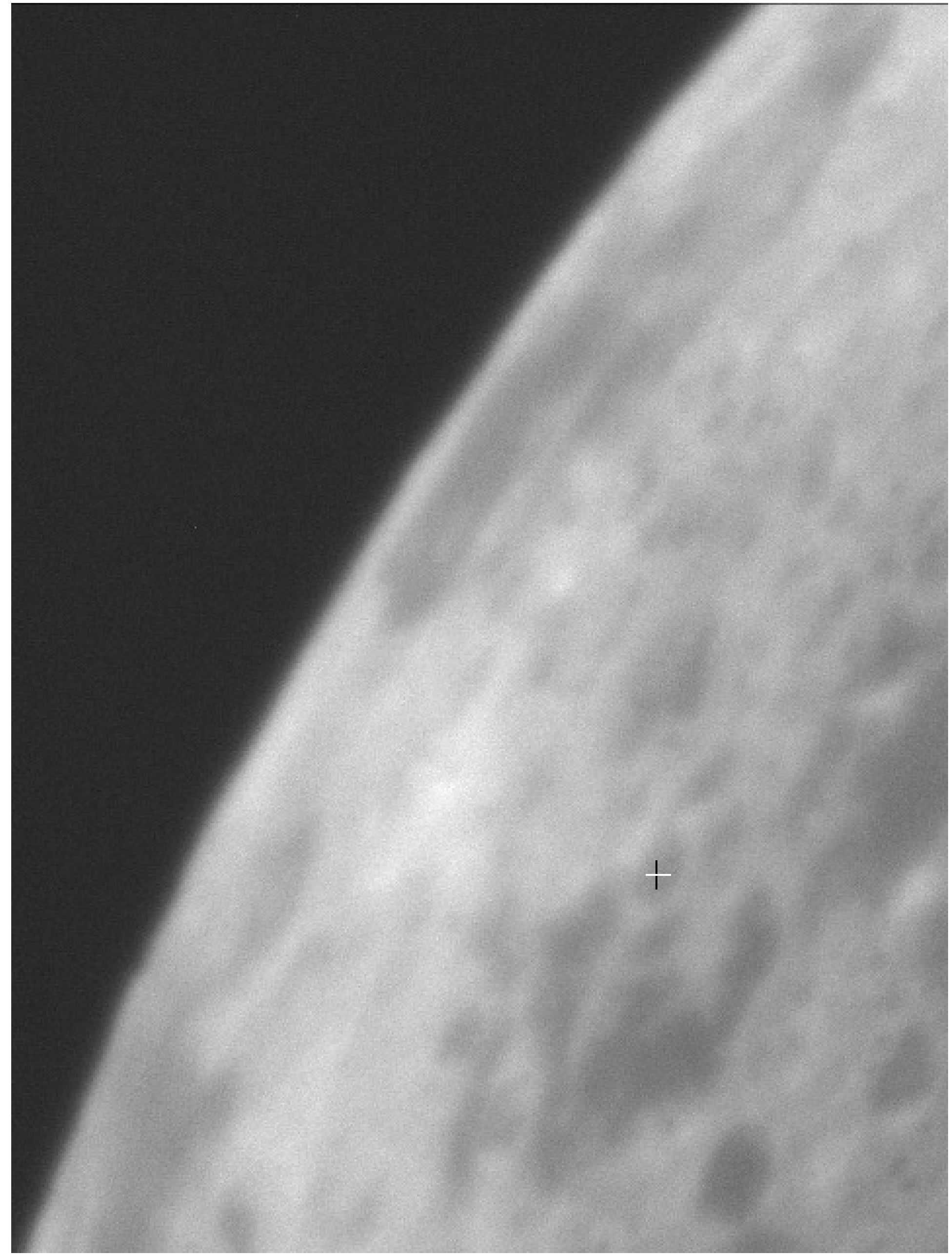
- Industrial video-camera, providing a digital, non compressed data-stream
- Monochrome camera for full sensitivity and flexibility of filter use
- Fast frame-rate to provide live-view and allow image-stacking
- Typical properties: CCD Chip,1280x960 pixels, 15fps, USB2 connection

Optical Filters

- Filters can selectively reject colors where contrast is low => this makes faint crescents more easily visible
- To strong filters can increase exposure times and impede fast frame-rates
- A dark red filter is a good choice for imaging when the sky is still blue



Daytime image, white light



Red filtered view

Telescope optics

- Good contrast and color correction
- Focal length should fit the camera sensor, so that the full width of the crescent is captured
- Lens diameter not to small, to resolve thin crescents at longer wavelengths
- Large diameters are more difficult to shield from the sun
- 80mm -110mm apochromatic lenses used so far, several options in the market place

Telescope mount

- Used to point and track the optics/camera on the calculated position of the crescent in the sky
- “Goto” capability does not require the target to be visible to the naked eye
- Required strength is determined by combined weight & length of optics and baffles
- Several suitable products are available in the market place

Baffles

- Vital for observation of difficult crescents where observation starts or happens in daytime
- Baffles improve contrast by blocking unwanted stray light from the optics
- SAFETY: prevent bright light of the sun from hitting the lens
- Baffles can be a serious load on the telescope mount

Full mechanical setup of a dedicated crescent telescope, while observing the crescent quite close to the sun

Camera software

Software is the *central* component, where the captured images are handled and displayed

- Controls all camera settings: exposure, resolution, frame-rate...
- Displays the stream of images
- Stores images and meta-data
- Can share the image with any number of displays, screens, broadcast systems...

Real-time processing and display

- Specialized software allows to process the captured images in real-time, displaying the enhanced images as live-view
- This drastically improves the visibility of low contrast structures
- A large part of the overall performance is created here

Raw camera image

Contrast enhanced image, displayed in real-time

Benefits & Advantages of imaging

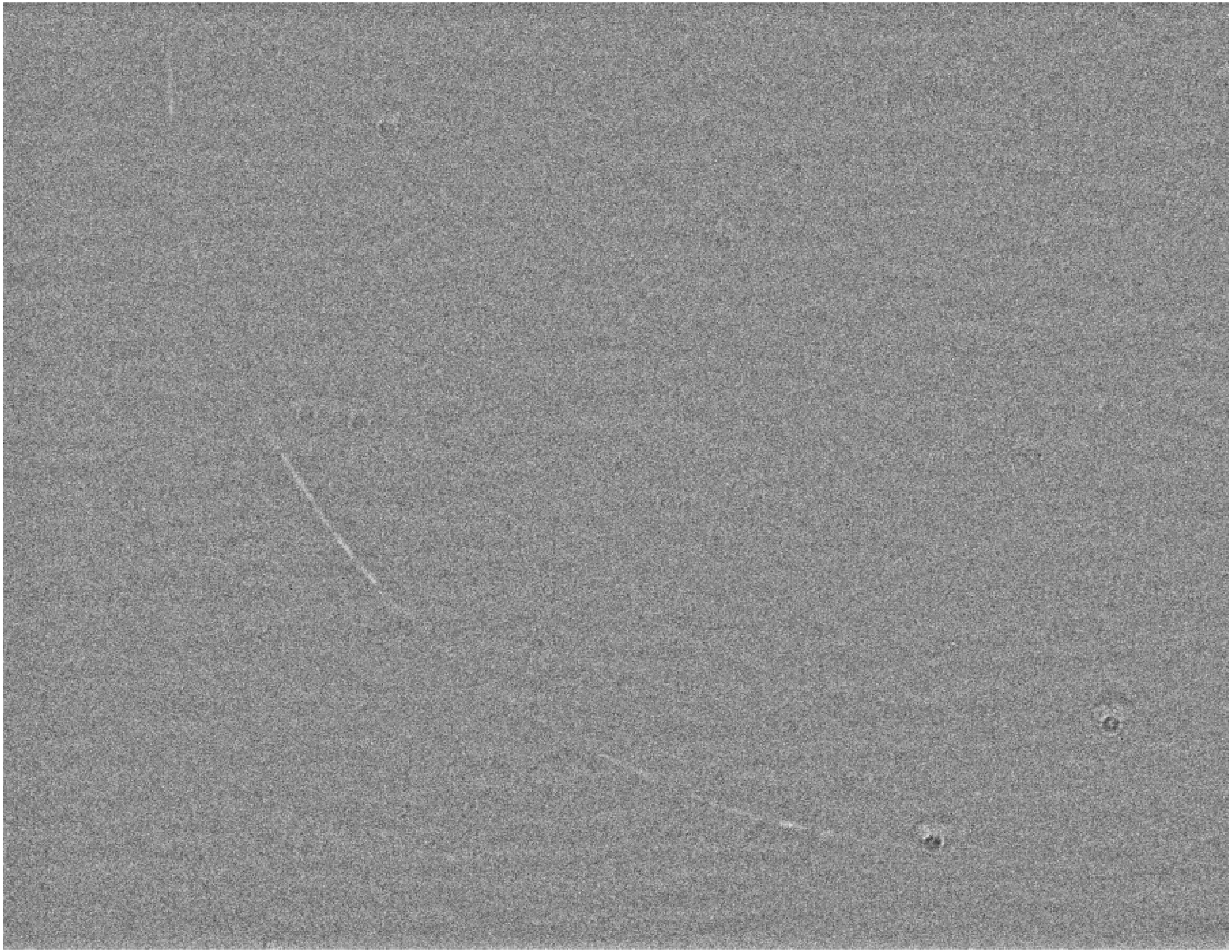
- Images and meta-data are a valuable documentation of the observation
- Credibility and usefulness of the observation is improved, compared to a seen/not-seen result
- Imaging depends less on personal eyesight and experience with telescopic viewing
- Imaging easily scales to any number of participants through broadcasting the live-images

More benefits & advantages

- Imaging can compensate for less than optimal weather conditions
- Successful imaging demonstrates the correctness and precision of astronomical calculations and observations methods

Results

- The imaging technique has proven to be *reliable* for the observation of low-contrast crescents in daytime and twilight, beyond what the human eye can do.
- The lunar crescent has been imagined at less than 4.6° elongation (in daytime) and about 6.5° elongation after sunset.
- The lunar crescent has been imaged at the very moment of conjunction.



Lunar crescent at 4.7° elongation, imaged in day-time with the specialized crescent telescope: a 90° arc of light

Conclusions

- Conjunction is not a magical moment: a lunar crescent has been imaged just before, during and after the conjunction by several groups.
- The Danjon "limit" is no hard limit at all, only a rule of thumb for when visual observation gets really difficult. “Limits” of imaging still to be found.
- The imaging approach can probably show the moon at almost any day of the year

Outlook

- Visual observation and imaging can be done in parallel: this simplifies the task of the visual observer, by using a parallel imaging scope to pinpoint the exact location of the crescent

- Crescent imaging techniques are spreading and will hopefully play a useful role, just as photography greatly advanced the science of astronomy

Questions?