Mars

Jupiter

Saturn

Uranus

Neptune

Triton

Capture a Planet

The simplest way in a nutshell

2020-09-11	2020-10-01	2020-10-06	2020-10-13	2020-11-01	2020-11-26
15:07 UTC	15:30 UTC	14:47 UTC	12:37 UTC	11:20 UTC	11:40 UTC
-2.07 mag	-2.50 mag	-2.57 mag	-2.62 mag	-2.13 mag	-1.28 mag
size: 20.5″	size: 22.47″	size: 22.57″	size: 22.37″	size: 19.99″	size: 15.37″
phase: 94.5%	phase: 99.0%	phase: 99.6%	phase: 100%	phase 98.1%	phase: 93.2%
dist: 0.457 AU	dist: 0.417 AU	dist: 0.415 AU	dist: 0.419 AU	dist: 0.469 AU	dist: 0.609 AU
CM: 326.5°	CM: 153.1°	CM: 98.5°	CM: 5.2°	CM' 178.6°	CM: 314.8°

closest

opposition

2020-09-15	2020-10-04	2020-10-10	2020-10-26	2020-11-16
15:26 UTC	13:30 UTC	15:00 UTC	12:03 UTC	11:47 UTC
-2.16 mag	-2.54 mag	-2.61 mag	-2.32 mag	-1.62 mag
size: 21.02″	size: 22.56″	size: 22.50″	size: 20.96″	size: 17.19″
phase: 95.6%	phase: 99.4%	phase: 99.9%	phase: 99.1%	phase: 95.1%
dist: 0.446 AU	dist: 0.415 AU	dist: 0.416 AU	dist: 0.447 AU	dist: 0.545 AU
CM: 294.9°	CM: 97.3°	CM: 66.4°	CM: 242.1°	CM: 48.9°

6" Newtonian 750mm F-5, 3x barlow, ASI462MC, IR-Cut filter,1.5x drizzled
capture: SharpCap 3.2, stacking: Autostakkert!3, wavelet: Registax6, fine tuning: Photoshop CS2
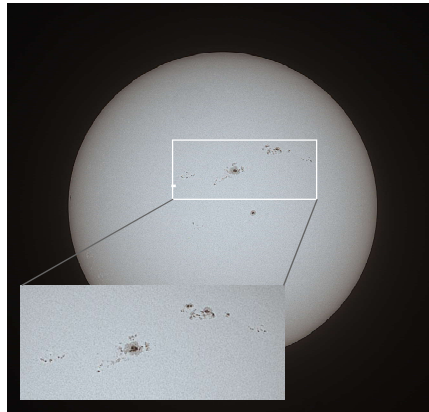Robert Brenner, Okinawa, Japan

A bad weather publication.

Contents

⬆ Solar imaging is made easy with simply a light reducing foil (1 / 100,000) over the objective lens or mirror (NEVER DO WITHOUT!) and either an UV/IR-Cut or infrared pass filter depending on the purpose. However, serious imaging of say, solar activity, involves specialized optics and filters which are not affordable for everyone. Solar imaging requires experience and thorough safety measures. The image above is taken with a Baader AstroSolar filter foil over a Ø71/ 450mm APO and a Uranus-C (IMX585) camera with UV/IR Cut filter on May 9, 2023 at 03:30 UTC.
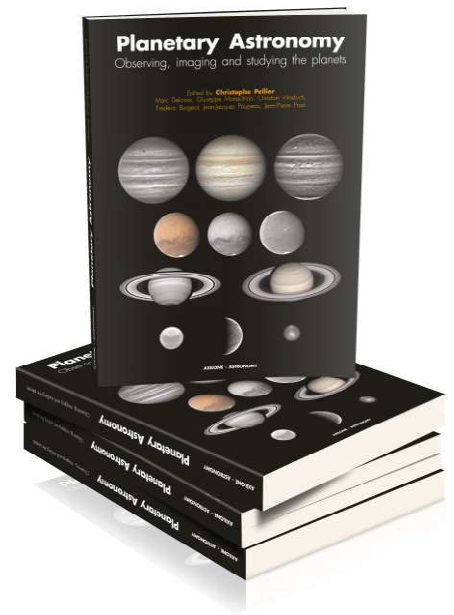
This e-booklet is not for imaging buddies aiming at professionality. For nerds the way better choice is for example Christophe Pellier's book Planetary Astronomy available French and English. Further reading:

https://www.planetary-astronomy-and-imaging.com/en/planetary-astronomy-the-book/

⬇Venus is a tough object to image not only because the planet is always near to the sun. Its clouds appear to be featureless in small scopes and without filters, such as an UV pass, or a CH4 methane filter.

The Planet Venus

Celestron 8, Uranus-C (IMX585)
ROI 800 x 600 pixels

Autostakkert!3 and Registax 6

1.5x drizzled

2023-05-12 10:39 UTC
Exposure: 4ms, gain 200,
247fps, 2500 frames (10%),
Baader UV/IR-Cut filter,
Altitude: 35°

Ephemerides
at 10:45 UTC
Diameter: 18.7"
Elongation: 43.9°
Phase: 62%
Light time: 7.4 min
Magnitude: -4.2 vis
CM II: 262°

2023-05-12 10:49 UTC
Exposure: 7ms, gain 300,
142fps, 2500 frames (10%),
ZWO IR850nm filter,
Altitude: 33°

1.5x drizzled

Credit: NASA's Goddard Space Flight Center

Please appreciate that this booklet cannot substitute hardware and software manuals. The author is not affiliated with any manufacturer. No liability assumed whatsoever for product specifications.

Foreword

This e-booklet introduces gear and software for planetary imaging which is owned by the author who cannot attest suitability or quality of other instruments although there are plenty of choices by which same or better results can be obtained.

Experience comes alongside practical use, the more you fail the more you learn. Giving up is no option since you would be missing a lot.

A dark site and favorable meteorological conditions make half the success. The fidelity of images (details, colors, sharpness, contrast), too strongly depends on size and quality of an objective lens or mirror. The larger the aperture the more details are resolved and the faster light can be gathered. At the end of the day it is a matter of budget.

▲ This is 16-years old "Ken", the author's shadow, best friend and guardian (when not sleeping).

This e-booklet is not a in-depth tutorial and not going deeply into technical details. The purpose is for giving starters the first motivation kick towards planetary imaging. The methods described herein are merely the steps the author is using.

Unlike deepsky imaging by which an object needs to be exposed (integrated) for several hours or days, planetary imaging is faster, involving short videos in the order of one or a few minutes that can be taken also between clouds, absence of haze provided.

While deepsky imaging demands a clear, moon-less sky (else filters are indispensible), imaging of bright planets can be managed under city lights.

Any object is best resolved when it is nearest to the photographer. "**Opposition**" occurs when the Earth passes between an outer planet and the sun, placing the planet opposite the sun. Opposition of *Mars* occurs every 2.135 years in that we have to wait quite a while for favorable imaging opportunities. The intervals for Jupiter, Saturn, Uranus and Neptune are 1.092 years, 1.035 years, 1.012 years and 1.006 years respectively.

The illustration (bottom) shows *Jupiter* close to opposition. As Earth is orbiting faster it will soon cross the line of opposition. Then, for this year, *Earth* and *Jupiter* near on each other. Since planetary orbits are of elliptical shape opposition distance varies with every event.

The inner planets *Mercury* and *Venus* are difficult targets as most of the time too near to the Sun and too low above horizon. *Venus* offers welcome imaging opportunities at great **elongation** (angular distance) from the sun, either as "evening star" or "morning star".

▲ *Uranus and Neptune on September 19, 2021 with C8-XLT, 2x barlow, ASI462MC camera.*

Imaging of *Uranus* and *Neptune* requires a telescope with large aperture, else they will appear like tiny pale bluish disks.

▼ *Approaching Jupiter opposition in 2023 (JupiterSIM app).*

Telescope

You may wish to look for similarly sized Schmidt-Cassegrain telescopes from Meade, or Maktsutov Cassegrain telescopes from Sky-Watcher and others.

With the unaided eye, the planets in the sky are merely dots of light, even the largest and nearest appear just like bright stars. Consequently, high magnification is essential for enlarging their disks.

You definitely need a telescope with large aperture starting at 5 inches minimum and long focal length, in other words a telescope with a focal ratio of f/10 to f/15 which will provide the right magnification within ability to resolve details.

Did you know that if Jupiter's vast magnetosphere would be visible it would take the space of the full moon?

One of many candidates is the Celestron 8 XLT, an 8-inch, Ø203mm aperture f/10 Schmidt-Cassegrain telescope with a focal length of 2030mm which is long enough for stunning lunar images but still not for the planets.

Another fine instrument is Sky-Watcher's Skymax 180 with Ø180mm aperture f/15 Maksutov-Cassegrain telescope with a focal length of 1800mm. The Maktsutov optical design is popular for its crisp images.

Telescope Accessory

In most cases the native focal length of a telescope does not provide sufficient magnification for close-up images. For imaging planets with reasonably large disks a barlow lens comes in handy. Since the resolving power of a telescope is limited the magnification of the barlow lens should be around 2x, any more would not resolve any further details. Also a good choice is a 2.5x Powermate lens.

For fine adjustment tubeless barlows provide lower magnification depending on the distance to the focal plane.

▲ *Tubeless barlows, 1.6x (left) and 2x. When directly threaded to the nose piece adapter of a camera, the effective magnifications are 1.25x and 1.42x, respectively.*

Not crucial, but a truly useful focusing assistant is a dual-speed 10:1 and 100mm long Crayford focuser with 25mm focus travel which threads to the visual back of an SCT, such as the C8. It accepts 1.25" and 2" imaging gear including a Ø48mm filter thread. It allows way finer focusing than the standard focuser knob.

Mating Scope and Camera

Telescope and camera should be matched for best possible image scale, which is the tiny angle of sky every pixel is seeing and measured in arc seconds per pixel ("/px).

As a rule of thumb the optimal focal ratio at which a telescope can best resolve details with a given camera is approximated by **pixel size x 5**. For instance, a camera with 2.9μm pixels is best matched with a telescope working at f/15. In case of a C8 with a native f/10 a 1.5x barlow would boost it to f/15 and a focal length of a bit over 3000mm which is nice for the gas planets.

On the other hand, when seeing is transparent and the air quiet then it is worth trying with a longer focal length. The disk of a planet is a linear area in that sampling is as critical as for resolving stars.

Camera

Basically, any color CMOS planetary camera is suitable. Since planets are small the sensor size can be small as well. Most modern planetary cameras sport HD-class 1920 x 1080 pixels sensors which are mainly supplied by Sony Inc.

A color camera is the best choice as monochrome cameras would need to be triple-filtered for composing a color image which is time, material and budget consuming.

The major Chinese camera providers are ZWO, QHY, Player One, Svbony and a few more, in that for reasons of fairness the author refers to the part numbers of the Sony sensors.
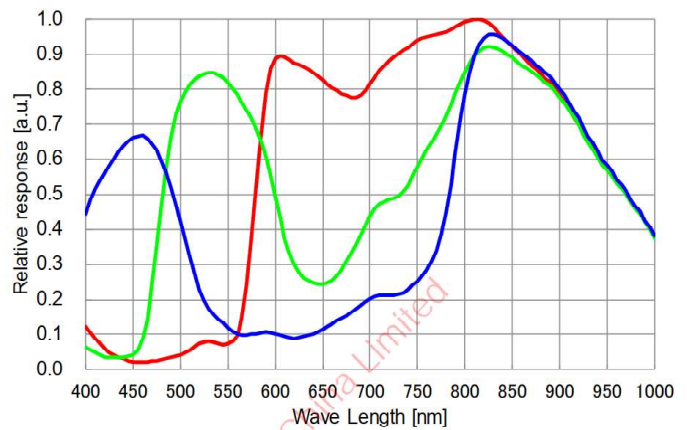
⬆ Response curve of the IMX462 color sensor. Meanwhile the IMX462 is replaced by IMX662 but still a fine choice. Source: Sony Corporation.

Some Planetary Camera Sensors

Part Number	Pixel Size	Resolution [px]	Sensor Size	QE	Full-well	ADC
Sony IMX174	5.86μm	1936 x 1216	11.3 x 7.1mm	~77%	24.8k e-	12-bit
Sony IMX178	2.40μm	3096 x 2080	7.4 x 5mm	~81%	15k e-	14-bit
Sony IMX224	3.75μm	1304 x 976	4.8 x 3.6mm	~75%	19.2k e-	12-bit
Sony IMX290	2.90μm	1936 x 1096	5.6 x 3.2mm	~80%	14.6k e-	12-bit
Sony IMX385	3.75μm	1936 x 1096	7.4 x 4.1mm	~80%	18.7k e-	12-bit
Sony IMX462	2.90μm	1936 x 1096	5.6 x 3.2mm	~80%	14.6k e-	12-bit
Sony IMX464	2.90μm	2712 x 1538	7.9 x 4.5mm	~90%	12k e-	12-bit
Sony IMX482	5.80μm	1920 x 1080	11.1 x 6.2mm	~85%	51.5k e-	12-bit
Sony IMX568	2.74μm	2472 x 2046	6.7 x 5.6mm	?	8.8k e-	12 bit
Sony IMX585	2.90μm	3840 x 2160	11.2 x 6.3mm	~91%	38.8k e-	12-bit
Sony IMX662	2.90μm	1936 x 1100	5.6 x 3.2mm	~91%	37.8k e-	12-bit
Sony IMX664	2.90μm	2704 x 1540	7.4 x 4.5mm	~91%	37.8k e-	12-bit
Sony IMX678	2.00μm	3840 x 2160	7.7 x 4.3mm	~91%	38.5k e-	12-bit
Sony IMX715	1.45μm	3840 x 2160	5.6 x 3.2mm	~80%	5.7k e-	12-bit

Although HD-class sensors are well sized for planetary work, recent cameras come with 4K-class sensors which provide a wide field of view which is not required for planets, however, the field (ROI, region of interest) can be reduced by means of software control. The latest sensors come with increased sensitivity, also in infrared, and dynamic range while smaller ROIs make them deliver images faster.

The author's cameras are housing IMX462 (ZWO ASI462MC) and IMX585 sensors (Player One Uranus-C), an 2K-class and an 4K-class sensor, respectively, both with 2.9μm pixels. Note the high near-infrared response of both sensors.

The IMX462 has been replaced by IMX662 with improved characteristics, such as dynamic range and lower noise, however, with less infrared sensitivity. The IMX462 is still one of the finest choices for planetary work.
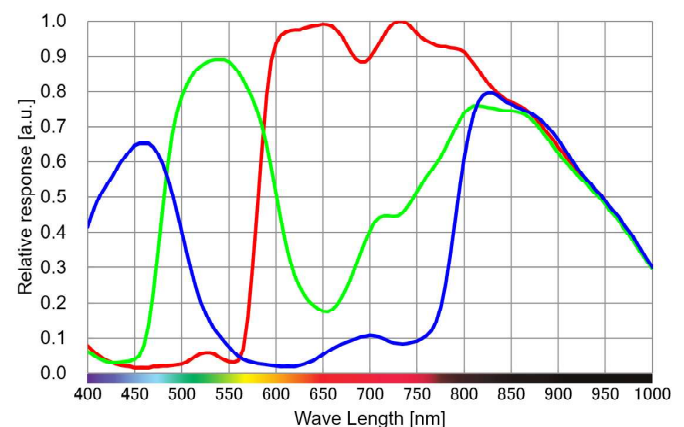
⬆ Response curve of the IMX585 color sensor (source: Sony Corporation). The 11.2 x 6.2mm dimensioned, 12.85 mm diagonal IMX585 is an 8.3 megapixels 4K color sensor with 3840 x 2160 pixels 2.9μm each sporting four times the chip area of the IMX462 resulting in twice the field of view. In 2x2 binning mode the pixel size doubles to 5.8μm while still providing HD resolution, but a planet would be too small on a binned view. The IMX585 peaks a quantum efficiency (QE) of ~91% with a full-well capacity of 47k -e.

Useful Formulae

image scale = 206.265 * pixel[μm] / focal length[mm] (in arc seconds per pixel)
field of view = 2 * Atan(sensor size[mm] / 2 * focal length[mm]) * 57.3 (in degrees)

Camera Accessory

A filter is required for imaging in visual color, namely an UV/IR-Cut filter which blocks ultra-violet and infrared light. The filter is essential because an unfiltered image would appear washed out as visual and infrared do not focus on the same plane.

The author's filter is a CMOS-optimized filter from Baader Planetarium. Similar filters are available from all major Chinese camera suppliers plus other sources.

In order to connect a planetary camera with a telescope a 1.25" nose piece will be sufficient given the small camera sensor. It is threaded to the camera (M42 x 0.75) and directly plugged into the 1.25" focuser of a telescope. A nose piece is threaded for a filter such as the required UV/IR-Cut filter.

Computer

The faster the better, especially for capturing and stacking speed. There is no specific recommendation, but the CPU should be an i5 ~ i9 or a Ryzen counterpart definitely with a fast SSD disk. Recent planetary cameras include a buffer memory to help reduce frame dropping by slow PCs and disks.

The author's computer is a Fujitsu AH with an AMD Ryzen 7 5700U CPU running @1.80 GHz, 8C/16T, 16GB Memory, 512GB SSD which works smoothly and fast, however the choice of computers in the market is vast.

Mount

Actually, the arguably most important gear is an electronic equatorial mount capable of accurate tracking. The heavier the telescope the sturdier a mount is required. High magnifications typically required for planetary imaging call for accurate tracking. The mount should be specified for a payload of, say, 1.5 times the weight of the complete imaging gear. The mount should support computer control via USB or WiFi and is most likely the most budget-consuming component of gear. A sturdy alt/azimuth mount is also suitable as capture times are typically short.

Software

Capture

ZWO's **ASIStudio** software suite for Windows supports planetary imaging. We appreciate that ASIStudio does not connect with cameras other than ZWO's fine range of planetary CMOS cameras.

SharpCap 4.x Pro by AstroSharp Limited is a fully fledged Windows application for most aspects of astronomical imaging and is compatible with cameras from major manufacturers. SharpCap 4.x provides a number of tools to assist improve imaging quality and comfort, including plate solving and polar alignment.

An intuitive user interface contributes to a flat learning curve. SharpCap is accompanied by a detailed user manual, online or PDF, while numerous experienced users have posted videos on YouTube with tipps and tricks, odds and evens, success and failure stories.

SharpCap 4.x is free, SharpCap 4.x Pro is available for 18 USD per year (as of Nov 2024), while its value for serious imaging way exceeds the fee. The manual alone contains over 300 pages.

Another fine piece of capture software with many useful functions for planetary imaging is **FireCapture**, however, the author has no experience in using it.

Stacking

Autostakkert!4 is most popular among planetary imagers for accurate stacking of video files. It loads a video, aligns (registers) all frames, sorts them by quality and averages the final image to a single stack file for the next step which is sharpening.

Sharpening

Registax 6.x for 32-bit Windows is a strong partner for wavelet sharpening. It loads Autostakkert's stack file and facilitates sharpening using sliders, so adjusted as to unveil most of the surface details of a planet.

Recently, the second prototype of a wavelet processing software named **waveSharp** for 64-bit Windows and other platforms has been released to recreate the RegiStax6 wavelet sharpening module (as of Oct 2023).

Please also try **AstroSurface** which provides powerful wavelet/deconvolution processing.

Fine Tuning

For the last touches **Photoshop** or **GIMP** can be used or any other image processor of your liking.

> Did you know that Jupiter's mass, thus gravitational pull varies a little depending on the region?

Camera Settings

► Image
2023-01-07
11:12.5 UTC
CM II: 64.1°
Altitude: 69°
2x standard barlow
333fps, 4000 frames
Exp: 3ms, gain 360
Sensor temp: 26.1°C

1.5x drizzled

Best single frame by AS!3

▲ *Often a planet looks noisy and blurred in the capture preview, however, no reason for giving up as the result can be satisfactory after stacking and further processing.*

*Imaging of planets is implemented with a method referred to as "lucky imaging". Unlike when imaging deepsky by means of EAA or separate files for each image, we are recording in uncompressed video preferably in *.ser file format which is optimized for astronomical imaging.*

The capture software controls image acquisition and sets properties, such as ROI, exposure time and gain.

Earlier, we have briefly discussed the mating of a camera with a telescope (sampling) and found that a focal ratio of pixel size x 5 is a good approach, however, nobody likes the idea of purchasing several cameras each with different pixel sizes for various imaging situations.

"Binning" is a method by which means four sensor pixels are arranged in a 2 x 2 and treated as one pixel. This is accomplished by the capture software controlling the camera. Larger pixels gather more light with the advantage of shorter exposure times, less noise and faster frame rates but at the expense of resolution. A camera with 2.9µm pixels will act like a camera with 5.8µm pixels. Mathematically this results in an optimal focal ratio of nearly f/30, or over 6000mm focal length in case of our C8 telescope, but now we are having a situation as the image scale would result to 0.2"/px while the resolving power of the C8 is 0.57"/pixel, meaning there isn't much to gain in terms of detail.

Anyway, please experiment yourself or consult experienced fellow imagers. The better the seeing condition the more merciless you can push your gear. The author does not hesitate to shamelessly use a 2.5x barlow (Powermate) with the C8 and an IMX462 or IMX585 based camera and is not disappointed, but seeing must at least be acceptable, such as 3/5.

Short exposure times help freeze turbulences over the planet when the atmosphere is turmoil. Also, the shorter the exposure time the faster the frame rate, but if too short the noise portion will grow (signal-to-noise ratio) which can be compensated for by stacking a large number of frames, say, several thousands. Also, the dynamic range lowers with too fast exposures.

Depending on the visual brightness of a planet, the author starts as low as 5ms and adjusts gain until the histogram extends to about 70-80%. When gain appears too noisy then there is no choice but to increase exposure time until both parameters agree with the histogram. Yet, there is no need to be too much concerned about a gain higher than usual, provided you stack a large number of frames which will cancel out noise. For instance, with 10,000 frames in the stack the noise ratio is mathematically improved by the factor of 100 (Sqrt(#frames)). Every camera has a specified gain at which it performs the best dynamic range and noise characteristics (unity gain), however, for planetary imaging the gain will be too low for most imaging situations.

Other imaging properties include framing (region of interest, ROI) and color space.

The image frame can be drawn to any ROI which encompasses the planet with sufficient margin in case mount tracking is inaccurate and the planet drifting out of view in a worst case.

Color space refers to the images consisting of 8-bit or 16-bit data, while the author considers 8-bit with 256 colors sufficient for planets, also considering the advantage of faster frame rates and smaller data files with 8-bit data. Consequently, for color imaging, "raw8" is the recommended choice for the time being.

Did you know that Jupiter's vast magnetosphere extends almost 1 billion kilometers, as far out as to Saturn's orbit?

Caution Items

This is a list of important points which are often neglected or forgotten when rushing into an imaging session.

Collimation

Both, Newtonian and Cassegrain reflecting telescopes need to be "collimated", meaning their optical axis must be aligned for best possible results. This is facilitated by adjustment of both primary and secondary mirrors in Newtonians and secondary mirror only in Cassegrains usually by slightly turning forth and back three screws holding each mirror while watching a defocused star until it looks uniform on both sides outside focus. Even when imaging objects as small as planets a reflector should be collimated in regular intervals, even better, before every imaging session.

Acclimation

The temperature inside an optimal tube must be brought to or near ambient temperature (equilibrium). While Newtonians are open designs quickly acclimating, closed Cassegrain designs need an hour or so for equilibrium, often more as depending on the tube's mass and volume. If not acclimated, heat plumes and air currents inside the tube will definitely affect or ruin your image. For acclimation it helps to tip the scope with the visual back sticking straight up. Then replace the camera with a vacuum cleaner filter to allow the warmer air inside the OTA to escape out the top. In nights when the temperture drops quickly it might not be possible to reach equilibrium.

Seeing

Planetary imaging is best done in a clear night with favorable "seeing". Since we are typically operating with a long focal length and an extremely narrow field of view any disturbance or turmoil in the atmosphere or thin veils of haze high up in the sky can render any attempt fruitless. The best advice then is go to sleep to spare yourself a disappointment. In fact, the larger the scope aperture and the longer the focal length the more prone to poor seeing in spite of the ability of big scope to resolve details from which you can benefit only when seeing is favorable. Seeing is rated on a scale from 1 to 10 where 5 is mediocre.

Did you know that Jupiter's "fuzzy" core, contrary to earlier assumptions, consists of stone mixed with liquid hydrogen?
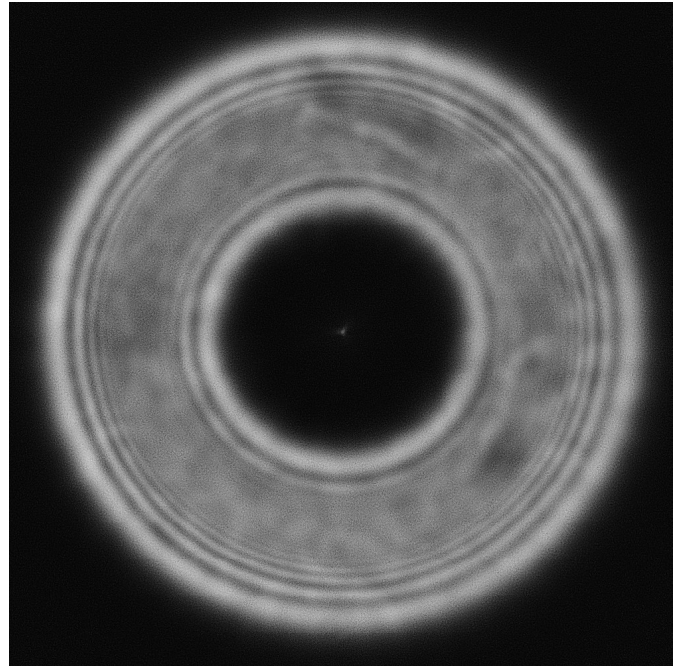
⏶ *The defocused star Bellatrix in a roughly collimated SCT. The rings are largely concentric but the blotch that runs from about 12 to 4 o'clock can be caused by a tube current or dew on the corrector plate. Accurate collimation with the airy disk of a focused star makes sense only when seeing is excellent which was not the case when this collimation was made.*

Focusing

If you do not own an electronic focuser it is safest to point the telescope at a star, focus on it if possible with a Bahtinov mask and then return to the planet. When imaging Jupiter focusing on its moons is quicker, even better, focusing on a moon's shadow on Jupiter's clouds when fortunate. Since alteration in ambient temperature can affect focusing it is a good idea to check focus in regular intervals. Also, when a planet has crossed the meridian, "mirror shift", if any, in Cassegrains may occur, hence requiring refocusing. When focusing take your time, it will pay off.

The author captures three videos of the same planet with the same settings, refocusing the second and third, in that it is for almost sure that one of the videos has best focus.

Sampling

In digital photography every image is made of an array of pixels. It requires several pixels, at least a square array of three, to resolve a feature such as a star, in other words, a pixel must be smaller than a feature. A single pixel cannot contain information.

Without going into details the optimum pixel size depends on the focal ratio. When seeing is good divide it by 5 to obtain the optimal size. The native focal ratio of a Cassegrain is typically f10 which would require 2µm pixels and with a 2.5x barlow 5µm pixels. We want to make high resolution images but don't want to split hairs, simply because this is purely theoretical as the seeing condition is the most influential factor.

Acquisition

▼ *Essential settings in SharpCap (enlarged).*

This is a single frame of Jupiter as seen in SharpCap's preview while recording a video on September 25, 2023. Seeing was "acceptable".

This example was exposed with the Uranus-C (IMX585) camera with 8ms at gain 430 and a frame rate of 124fps. The video in 8-bit *.ser file format contains 11,190 frames of which 2,000 (22%) will be stacked later in Autostakkert!3.
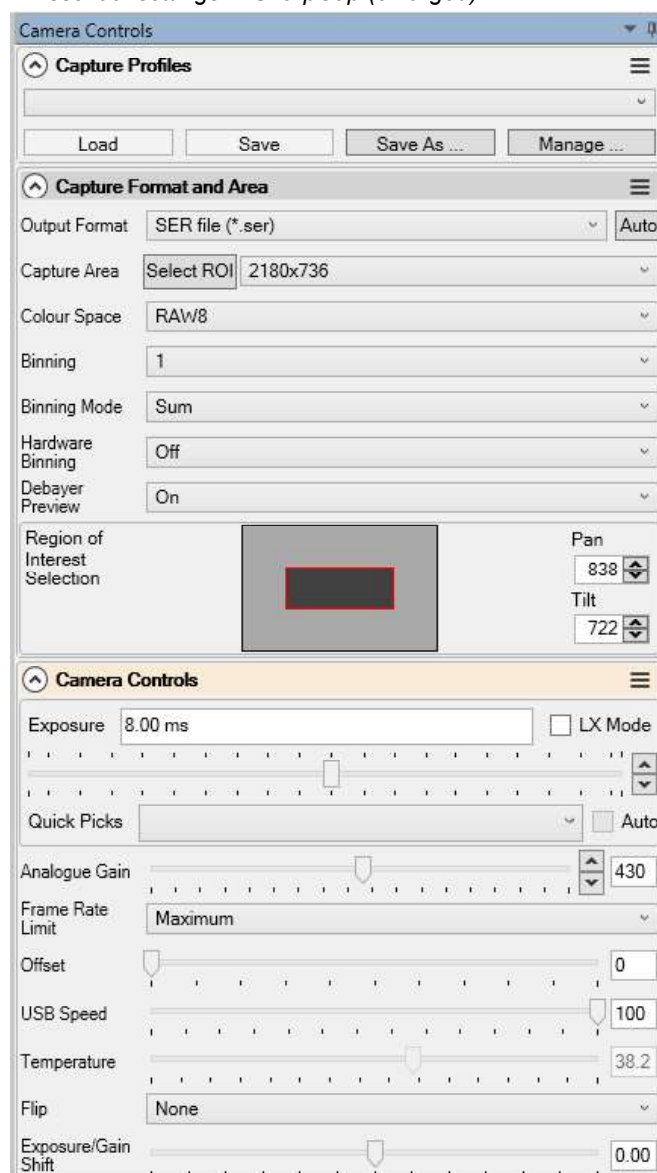
Given Jupiter's fast axial rotation the duration of the video capture was limited to 90 seconds to avoid smearing of cloud details. The maximum allowable capture time is a function of aperture, planet size and planet rotation velocity. The larger the apparent size of Jupiter's disk and the larger the scope aperture, the shorter the time after which the image rotates and smears.

Usually the 256 steps of color which 8-bit data provides is sufficient range for planetary imaging. The advantages versus 16-bit files are faster frame rate and smaller video files, hence also faster stacking.

The field of view (ROI) has been reduced to just embrace Jupiter and all four of its moons, also in the interest of a faster frame rate and smaller file size. When imaging the planet only, then, we can reduce the field down to a square of some 480 x 480 pixels given the focal length at which Jupiter was captured. As we have only about 90 seconds for recording we need to obtain as many frames as possible for optimal noise reduction by stacking and a wide dynamic range for aggressive sharpening without overdoing things.

> Did you know that NASA's spacecraft Juno which flew to Jupiter is one of the fastest ever at 260,000 km / hour?
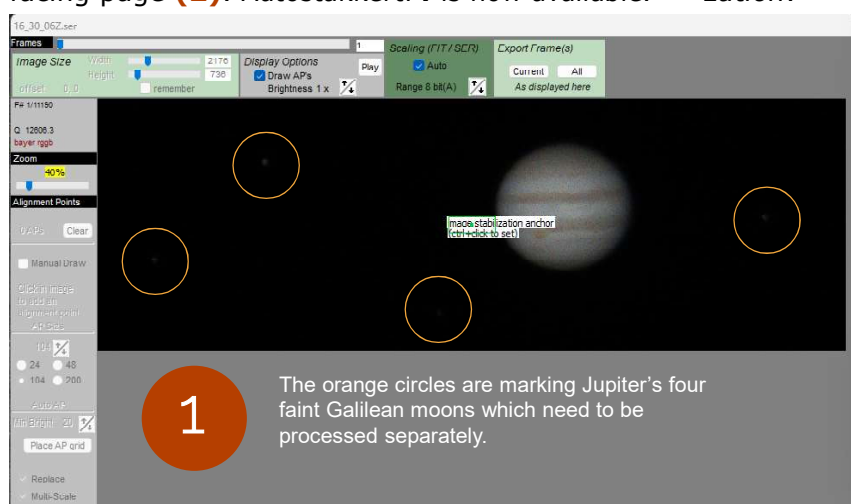
Stacking

not drizzled

1.5x drizzled

3x drizzled

This is the first single frame of Jupiter as seen in Autostakkert!3 after loading the video file **(1)**. The settings are shown enlarged on the facing page **(2)**. Autostakkert!**4** is now available.

1

The orange circles are marking Jupiter's four faint Galilean moons which need to be processed separately.

▲ Autostakkert screen after loading a video.

Since this pamphlet cannot replace the software manual, here a few notes in a nutshell.

The capture encompasses Jupiter with its four major moons in that we need to select **Surface**, else the planet would be centered and a few moons cropped out.

The analysis and stacking process can be accelerated by reducing the image size to encompass only the view of your interest, such as isolating the planet disk.

Improved Tracking is best for the moon and slows down but can improve shaky videos.

The choice of **Expand** makes sure that nothing will be cropped in the final image.

Anything below *Quality Estimator* is left on default, including selected Local (AP).

Under *Stack Options* we enter the number of frames we want to stack, here 2000 out of a total of 10,000. Check RGB Align and whether you want to drizzle or not. Then click on the [2) Analyse] button.

The result is shown on the facing page. The red background under the image shows how much the planet drifted while capturing as a

result of inaccurate mount tracking. The red frame shows the area that would have been left if we had selected Planet under *Surface Stabilization*.

Autostakkert can save multiple stacks in units of frames or percentage in TIF, PNG or FIT file formats. This is helpful when you have doubts about how many frames would make sense to stack. More when seeing condition was good, less if it wasn't. With this choice you won't need to repeat the entire process should a result disappoint.

The quality graph **(3)** sorts the frames by quality, best to the left. By this you can judge how many frames to stack would be appropriate. Basically any below 50% can be ignored.

The next step on following pages involves setting the Alignment Points, AP **(4)**. For Jupiter the number of APs should be between 40 and 60, more could confuse alignment and stacking. In this example the size is 104 pixels and the minimum brightness 20% resulting in an auto-placement of 40 APs. Select *Multi Scale* for best results. Since for planets APs should be set close to the edge of a planet disk set minimum brightness to a low percentage. Next click on 3) Stack.

Screen snap **(5)** shows Autostakkert!3 when its job is done. The stack file can now be wavelet sharpened in Registax6. Please also refer to Sky & Telescope issue Sep 2016, page 68.

*▼ Reducing image size to 480 x 480 for faster processing.*

▲ *Analysis result*
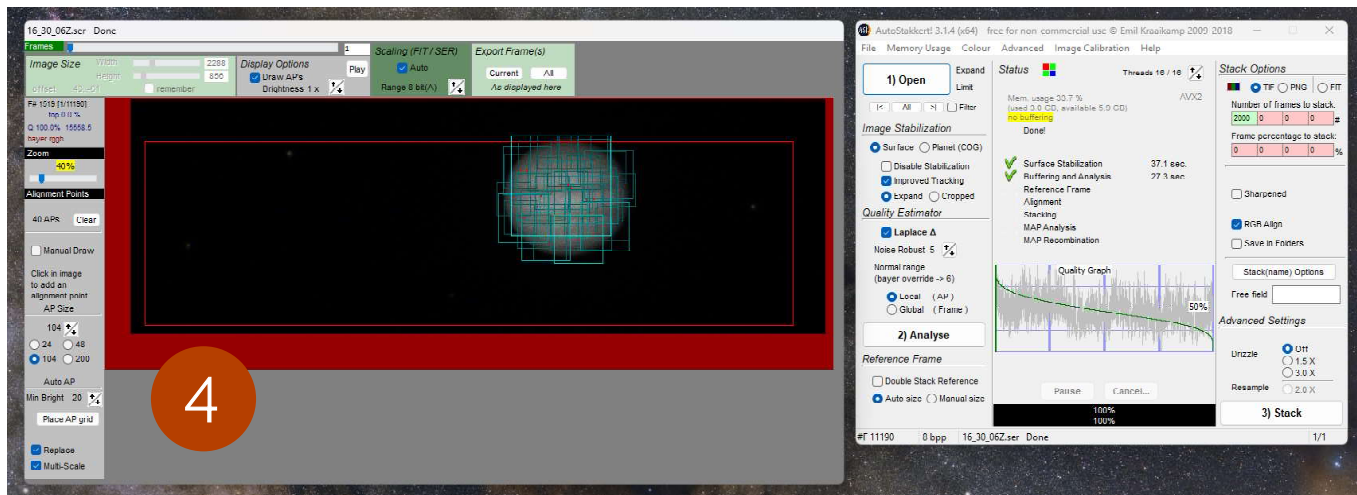
UPDATE:
Autostakkert!4 has been rolled out in November 2023.
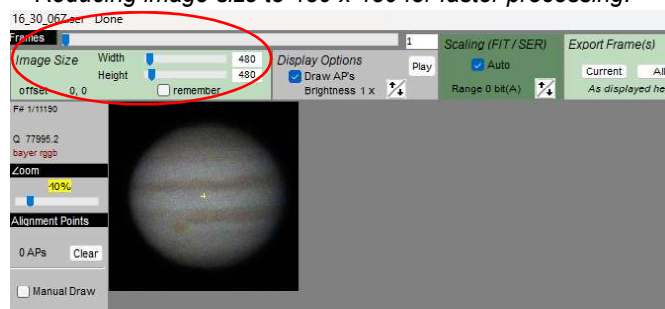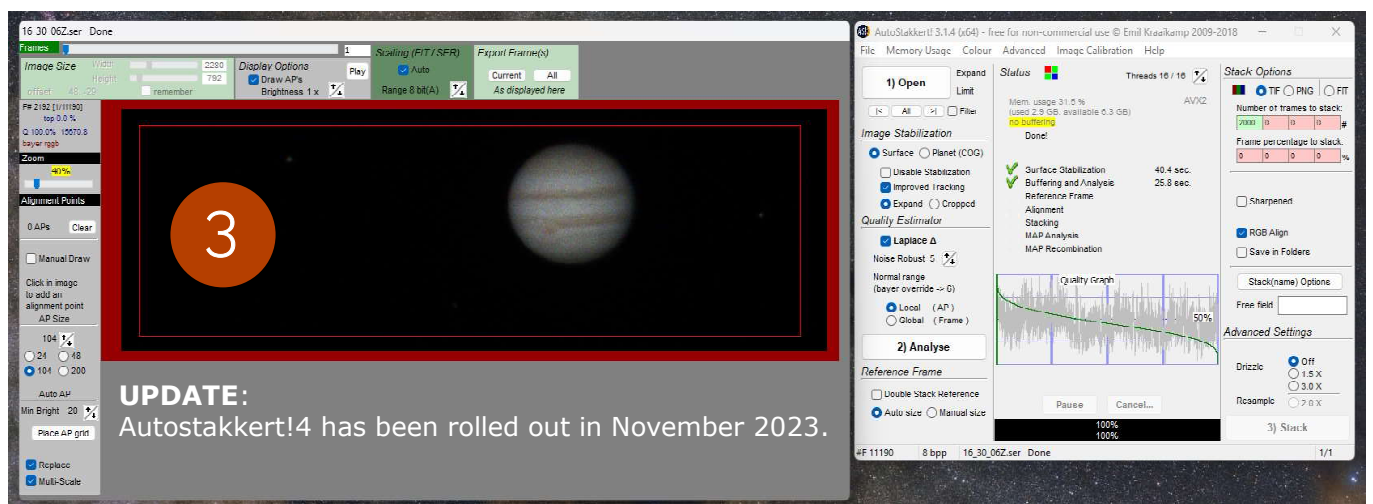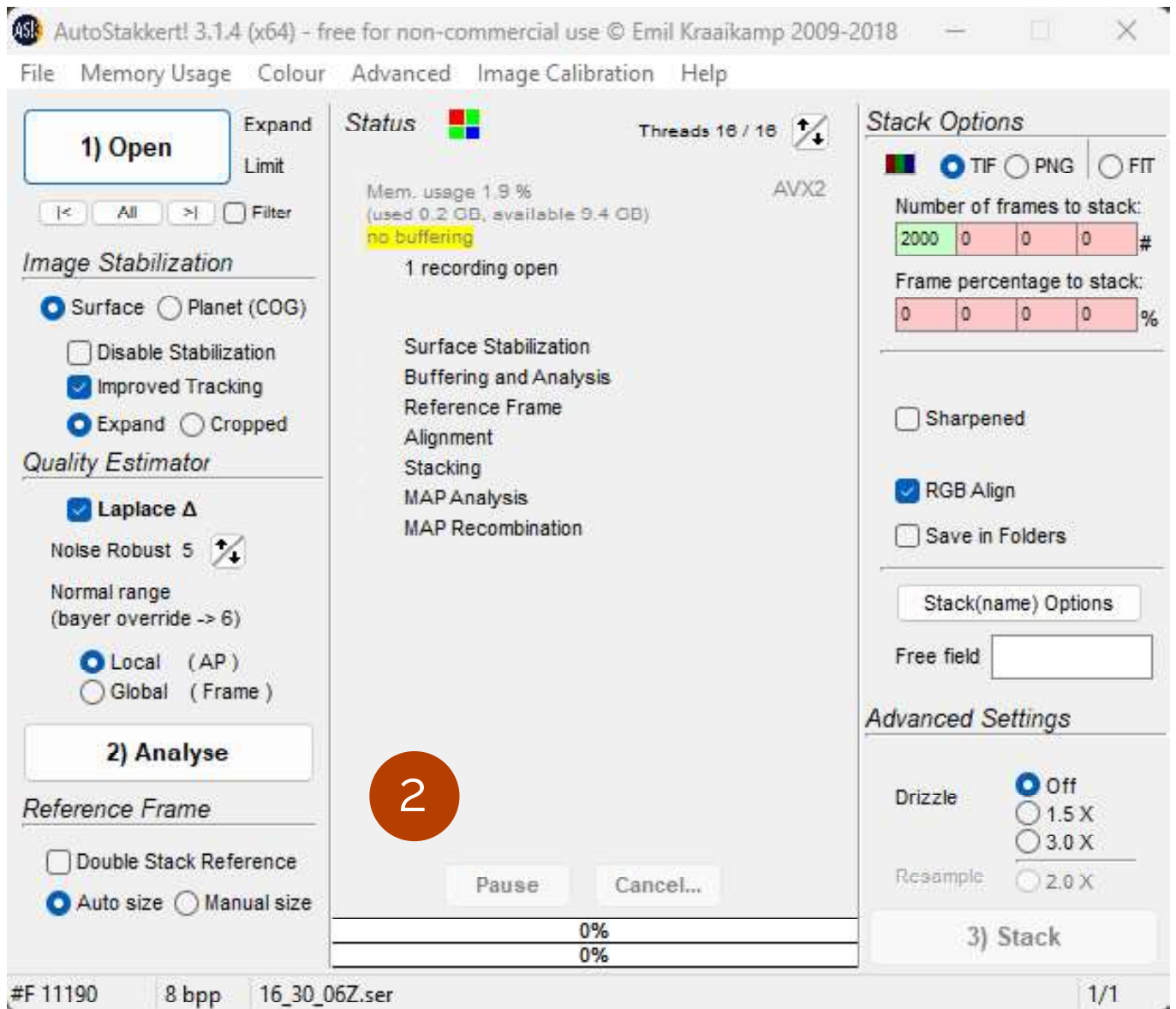
Upscaling Images

Under *Advanced Settings* the image can be resampled or drizzled for upscaling. Drizzle is the preferable choice as it improves resolution by filling missing information between pixels across movement of frames while resampling is merely an interpolation algorithm.
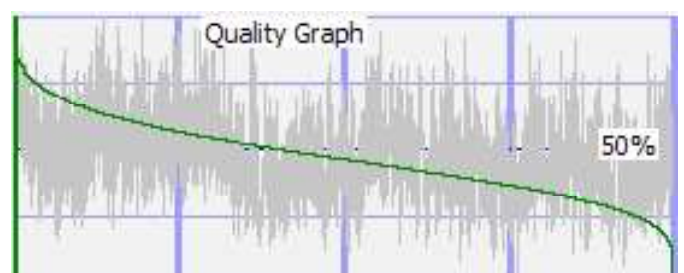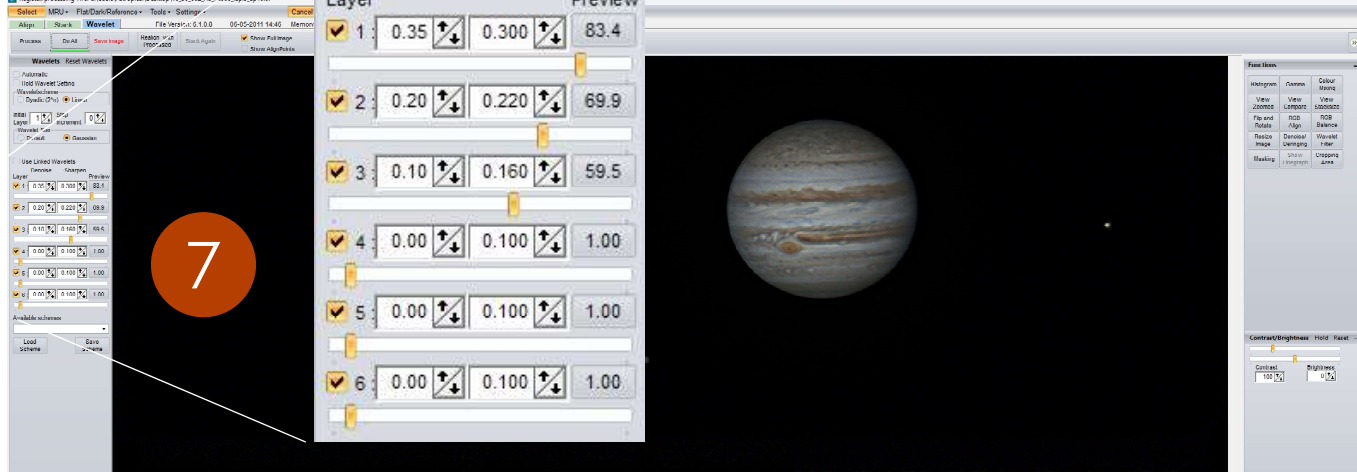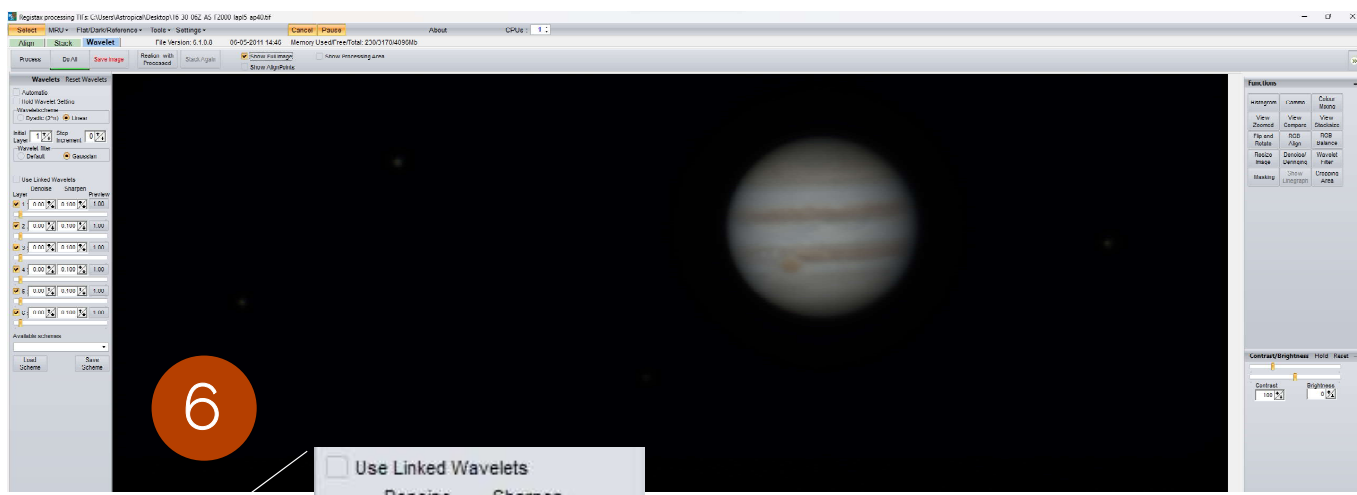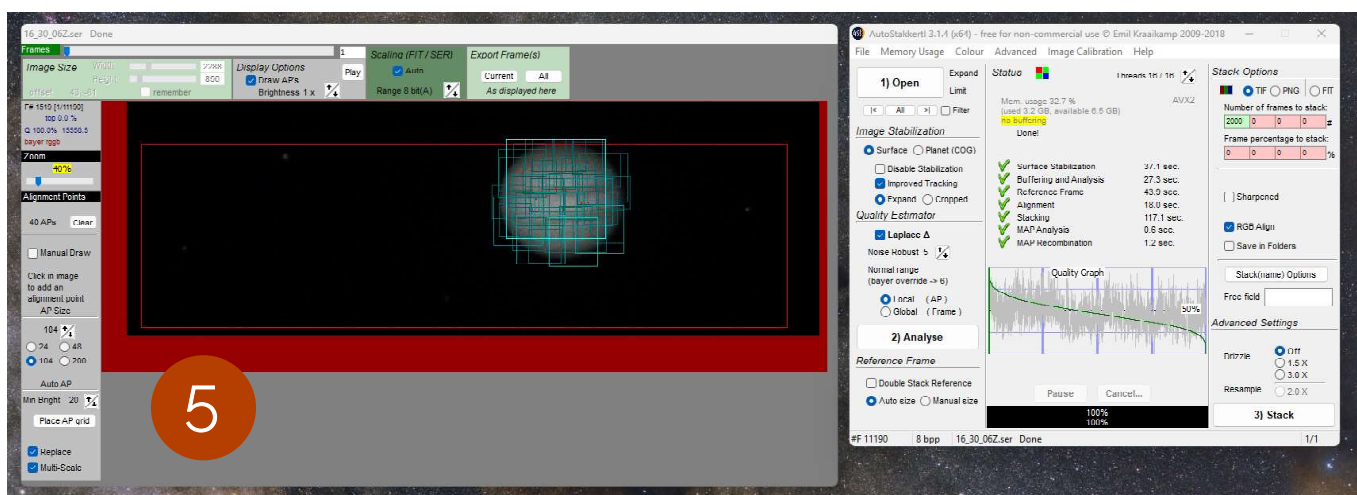
In **Registax** click on [Select] to pick the stack file which looks blurry **(6)**. Leave *Linear* and *Gaussian* by default. Then move the sliders for *Denoise* and *Sharpen* until the planet shows details **(7)**. The optimal values vary a lot with the quality and frame count of the stack file.

▲ *Before deringing*
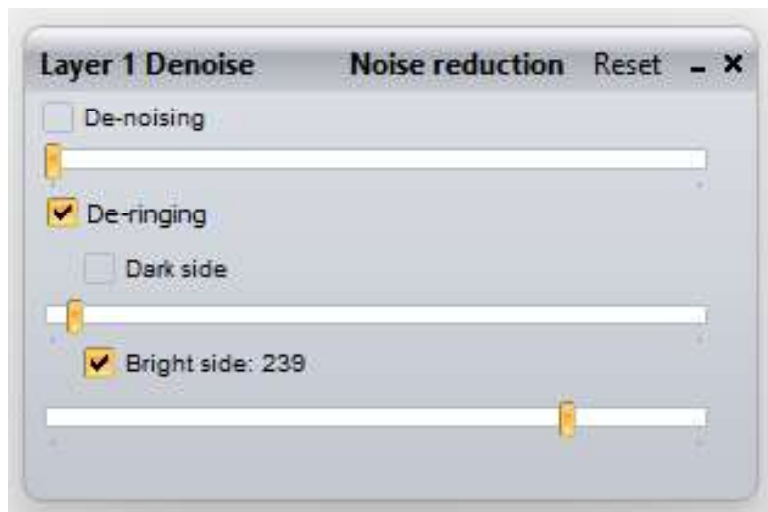
Registax has a useful function for 'deringing' a planet's disk in case of present edge ringing. However, when like in this example the moons are in the view then deringing will eat them up. In such a case, save a deringed and a not deringed file seperately and layer them in Photoshop or GIMP as you would do when imaging planet and moons separately. The compromise is loss of details at the edges of the disk which renders its look somewhat 3-dimensional. With Saturn deringing is difficult as also the rings will be, well, deringed.

▲ *After deringing*

▲ *Final presentation of the example image.*

Imaging Examples

Saturn

Like Jupiter, Saturn, too, is quickly spinning around its axis in that the duration of a video needs to be considered. However, unlike Jupiter, Saturn's disk is apparently smaller and the cloud structures more uniform in that a video over 3 minutes is possible when the planet is at or near opposition.

This is a composite of two captures, one exposed for the planet another over-exposed for the moons and overlayed in Photoshop.

Equipment
Celestron C8 XLT
Crayford Focuser
2x Barlow lens
ASI462MC (IMX462)
Baader UV/IR-Cut filter

2021-09-21 10:48 UTC
C8-XLT, ASI462MC, 2x barlow, UV/IR-Cut,
15ms, gain 350, 600 frames, 66fps.

Planet Video

OTA Aperture [mm] 203

Planet Size ["] 18

Planet Saturn

3.23
minutes

Resolving power: 0.57"
Rotation period: 10.656 hours
Rotation rate: 0.563 deg / min
Angle moved at center: 0.09" / min
Time to move resolution: 387 sec

Titan

Tethys

Saturn

Dione

Rhea

Mars

The axial rotation of Mars is similar to that of the Earth, in that video capture duration is not a critical issue and we can record up to eight minutes with 200mm telescope aperture. Mars is 22% the size of Jupiter or half the size of Earth. Consequently, even at closest possible approach its apparent size won't exceed 25.7". During the 2003 opposition its size was a historical 25.11" at a distance of 55,758,006 kilometers and a magnitude of -2.9 outshining Jupiter.

The example images centered on 49.3° martian longitude (Vallis Marineris) were taken three days after Mars' closest approach in December 2022 in Taurus. It was merely 17.2" wide at magnitude -1.9, in fact not a breathtaking event, but good enough for resolving and recognizing a few surface details.

1.5x drizzled   not drizzled

Above another image of December 13, 2022 taken at 13:24 UTC. Size 16.7" centered on 310° longitude. Exposure 2ms at gain 250, 498fps, 6000 frames. Past opposition the size is shrinking notably after nine days, so let's hurry also as clouds are merciless.

Steady air, clear, humid.
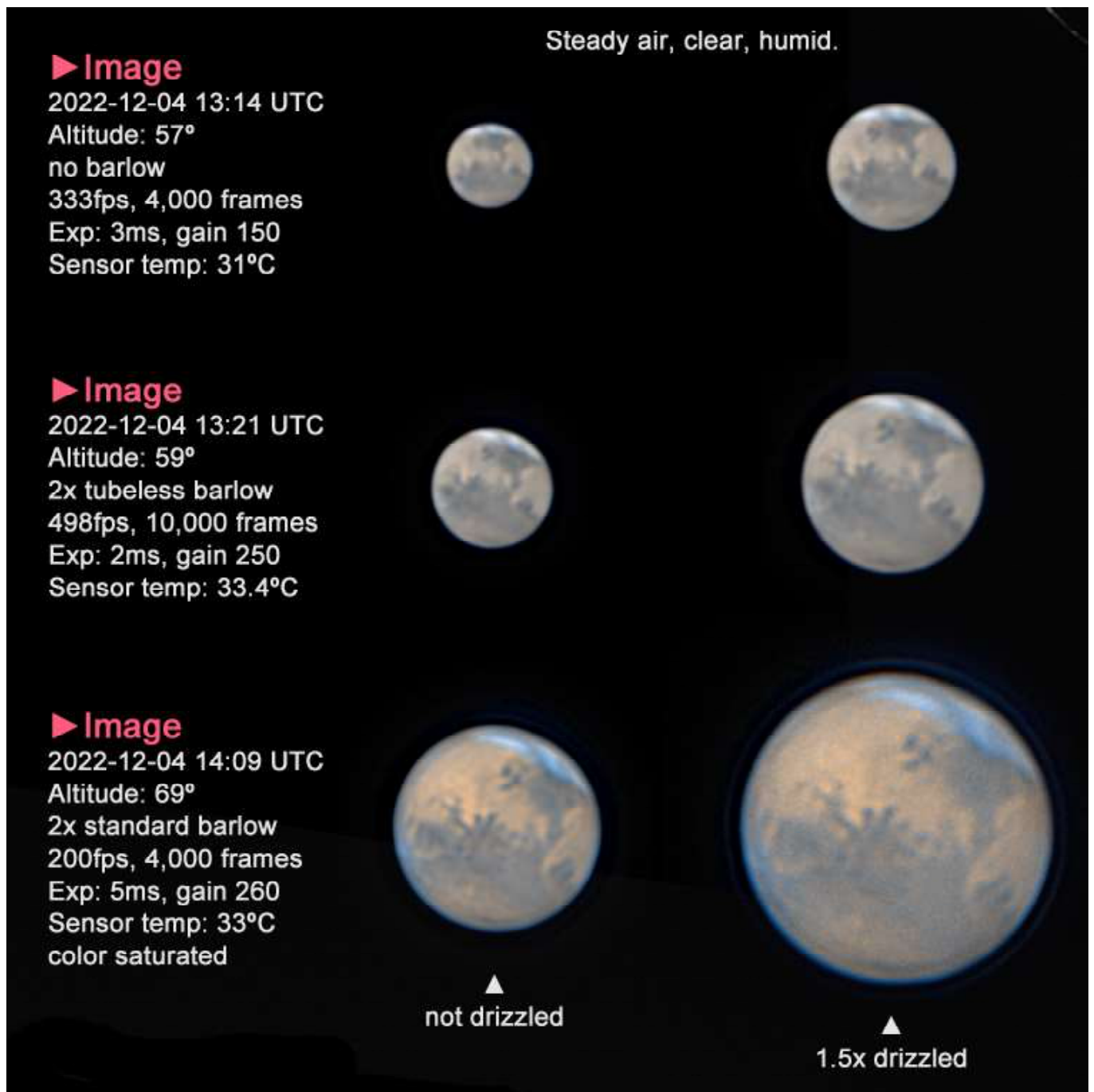
▶ Image
2022-12-04 13:14 UTC
Altitude: 57°
no barlow
333fps, 4,000 frames
Exp: 3ms, gain 150
Sensor temp: 31°C

▶ Image
2022-12-04 13:21 UTC
Altitude: 59°
2x tubeless barlow
498fps, 10,000 frames
Exp: 2ms, gain 250
Sensor temp: 33.4°C

▶ Image
2022-12-04 14:09 UTC
Altitude: 69°
2x standard barlow
200fps, 4,000 frames
Exp: 5ms, gain 260
Sensor temp: 33°C
color saturated

not drizzled   1.5x drizzled

Jupiter

Equipment
Celestron C8 XLT
Crayford Focuser
2.5x Powermate
Uranus-C (IMX585)
Baader UV/IR-Cut filter

Ø 49.5'

1.5x drizzled

2023-11-03 14:36 UTC Ganymede Transit

Transparent but turbulent air required short exposure time in an attempt to freeze frames and to obtain a large frame count in the interest of noise reduction. Given the telescope's aperture of 203mm and Jupiter's size of nearly 50 arcmin the maximum allowable recording time per video is 1 minute before surface details smear out due to the gas planet's fast axial rotation.
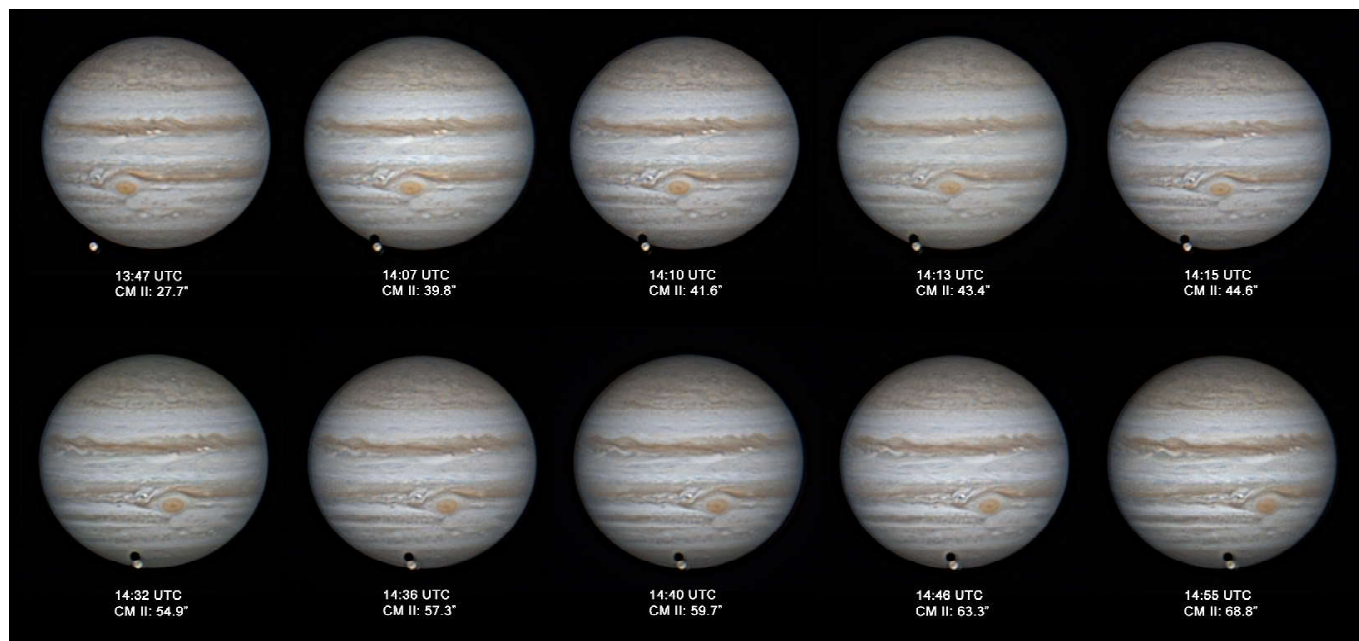

Simulation

Ganymede at 14:36 UTC

Magnitude:	4.61 mv
Distance to J:	1,073,700 km
Jupiter size:	7.62º
Jupiter phase:	178.9º
Jupiter CM:	58º
Orbit velocity:	10.87 km/s

Central meridian II: 41.6°, altitude 70º, exposure: 4ms, gain: 440, 3000 frames, 246fps, recording time: 1 minute, sensor temp: 32ºC.

▲ *Sequence of the transit of Ganymede.*

▲ *Single frame from the SER video.*

▲ *Best frame from Autostakkert!3.*

2023-10-29 13:54 UTC

Ø 49.5'

⌃Central meridian II: 359.9°, altitude 63°, exposure: 4ms, gain: 450, 2000 frames, 117fps, recording time: 1 minute, sensor temp: 32ºC.

⌄Central meridian II: 62.7°, altitude 78º, exposure: 4ms, gain: 450, 1500 frames, 117fps, recording time: 1 minute, sensor temp: 32ºC.

2023-10-29 15:38 UTC

Ø 49.5'

1.5x drizzled

1.5x drizzled

2023-11-02 13:47 UTC

Ø 49.5'
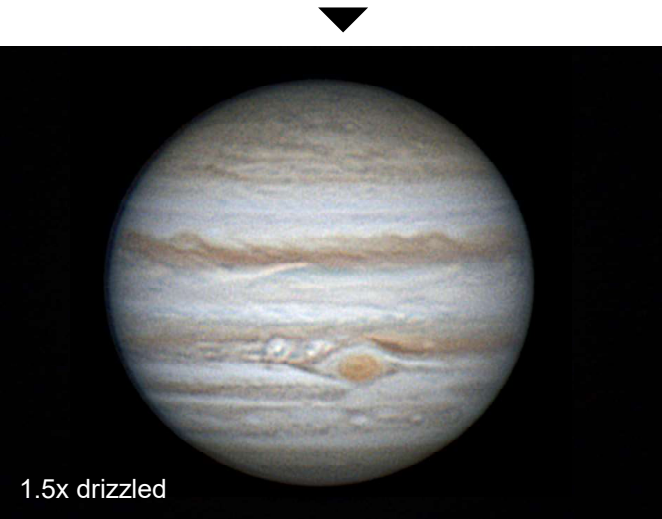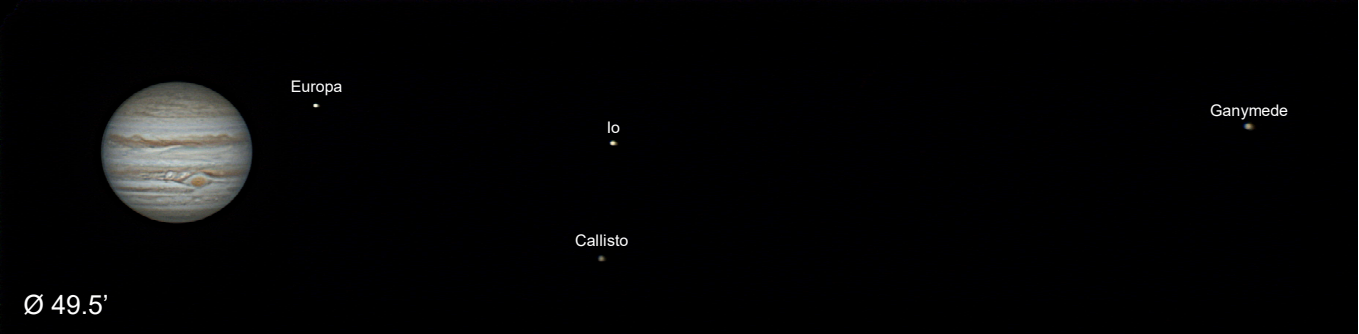
⌃Central meridian II: 237°, altitude 65º, exposure: 3ms, gain: 470, 2000 frames, 146fps, recording time: 1 minute, sensor temp: 31ºC.

Closest approach to Earth (perigee) occured on Nov 2nd at 21:00 UTC while the planet assumed opposition on Nov 3rd at 04:55 UTC.

When seeing is exceptional, you can take pictures of the planets with good resolution.

This sample was captured under seeing 4/5 is from **2023-11-23 11:36** UTC with Jupiter's central merdian II at 76°.

The mons from left to right are: Callisto, Europa and Io.

Image Data

Celestron 8, Uranus-C camera (IMX585), 2.5x Powermate, UV/IR-Cut filter.

Exposure: 5ms
Gain: 450
Rate: 156 fps
1 min recording
Frames: 3000
Sensor temperature: 29°C

▲ *Best frame from Autostakkert!3.*

▲ *1.5x drizzled*

The Planet Jupiter

► Ephemerides
2023-09-25 16:31 UTC
Central Meridian II: 21°
Diameter: 47"
Magnitude: -2.8 vis
Light time: 34.8 min
Altitude: 65°

► Imaging
Exp: 8ms, gain 430
124fps, 2000 frames
Sensor temp: 32.6°C

Five days apart

Simulation

◄ Ephemerides
2023-09-30 15:19 UTC
Central Meridian II: 9.5°
Diameter: 47.5"
Magnitude: -2.8 vis
Light time: 34.4 min
Altitude: 55°

◄ Imaging
Exp: 4ms, gain 450
247fps, 5000 frames
Sensor temp: 35.2°C

Ganymede
Europa Io
Callisto

Ganymede
Europa Io I
Callisto

E G C

Equipment
Celestron C8 XLT, Crayford Focuser, 2.5x Powermate, Uranus-C (IMX585), Baader UV/IR-Cut filter

2023-11-28 12:24
Exposure: 3ms, gain 450,
3000 frames, 220fps
Recording time: 1 min
Sensor temperature: 27ºC

The mons from left to right are: Europa, Ganymede and Io.

◄ to image scale

Ephemeris
Central Meridian II: 137º
Altitude: 71º
Diameter: 48.1"
Magnitude: -2.8 vis
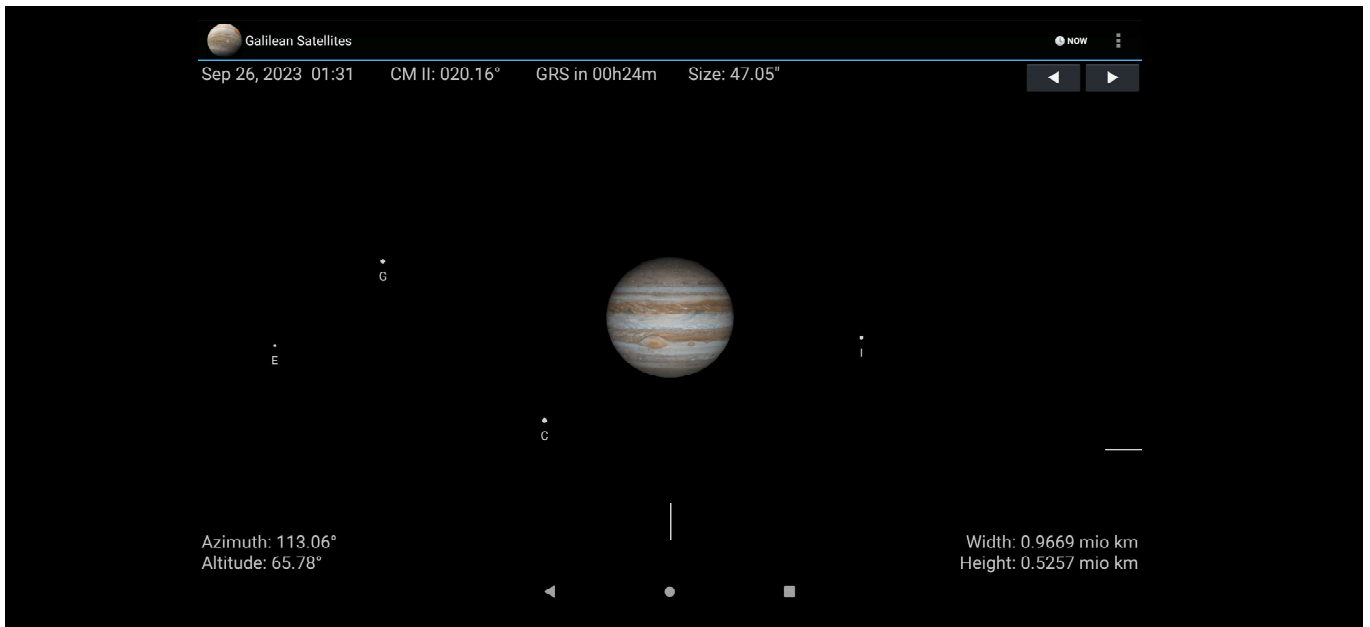Light time: 34 min
Distance: 4.088 AU
Constellation: Aries

Cleomedes

Exposure time was short in order to freeze the frames because of unsteady air and wind gusts and in the interest of a high frame count. This Jupiter images was wavelet-sharpened in 'Astrosurface'.

to be continued...

Simulation App

"JupiterSIM" is the author's home-brewed Android application for the purpose of simulating the planet and its four Galilean Satellites for present time or selected dates. The screen snap above shows Jupiter at the time the sample image was captured.

The field of view can be reduced or enlarged. Overlays include the moon orbits and a time scale plot. Provided for data nerds, such as the author, are physical and ephemeris information about all five bodies.

It is useful for checking the next transit of the GRS or for the moon positions plus their shadows casted on Jupiter's surface. It is also helpful for documentation of Jupiter images.
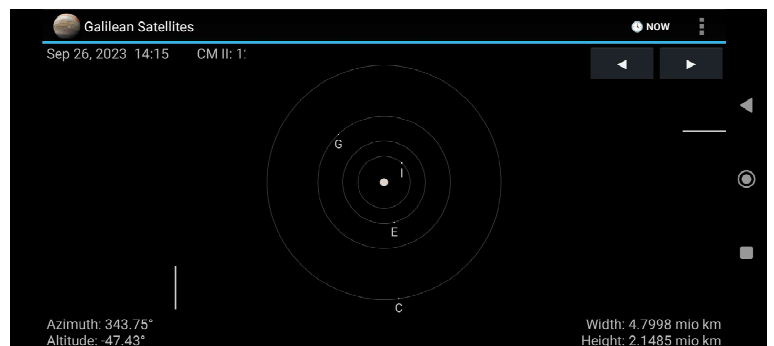
Orbit overlay
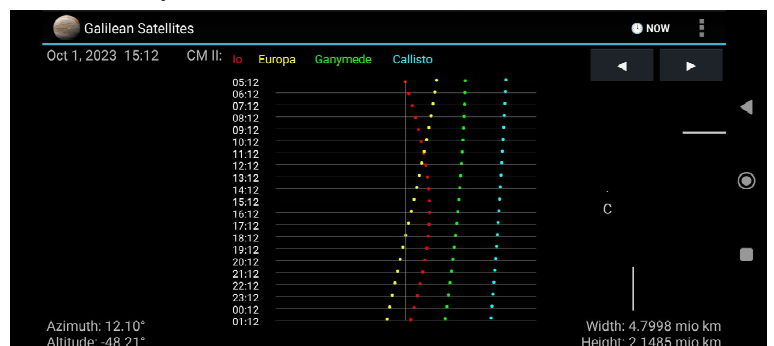
Moon plot

Planet and moon data

The Aristarchus Plateau with Vallis Schröteri.
The planets are inserted to image scale.

Celestron 8 XLT, ASI290MM, 1.6x tubeless barlow,
focal length 2540mm, IR640nm filter, ROI 1920 x 1080 pixels, 12ms, gain 200, 82fps, mono16, 12-bit ADC.
Image scale: 0.236"/pixel, image FOV: 7.83 x 4.35 arc min, linear resolution: 440 meters/pixel.

Image Award

This image has won an USD 450.00 award in the "60th Anniversary Sightron Japan Astrophotography Contest 2021", and is featured in the largest Japanese monthly astronomy magazine TENMON GUIDE, issue December 2021, page 39 bottom.

This image has also been selected by the jury for Sightron Japan's 2022 calendar.

Alongside great images of 11 other winners this image has been exhibited at the Sightron Japan booth at the world premiere show for cameras and images "CP+2023" in Yokohama.

Though it is hardly a realistic event, the author likes to decorate his lunar images with planet images all taken in the same night and superimposed to image scale. Such a composite compares the apparent sizes of all bodies as viewed from Earth.

Quiz question for experts: In 2011, NASA launched Juno to Jupiter. What is the destination of the spacecraft?

Imaging Application

For Android 8+

    Compatible with Android 8 and higher smartphones and tablets **Lunar Imaging** is a companion for visual Moon observers and imagers alike. It provides abundant lunar information for current and selectable dates, including positional, physical and ephemeris as well as libration data. The phase of the moon is represented by a 3D globe in 8K resolution which can be swiped to change dates by one day back or forth. Its orientation can be toggled between upright and diurnal angles, while the phase shadow can be toggled on and off.

    Further menu items include a **Lunar Calendar** and **Lunar Atlas**. The **Camera Simulator** is for imagers, the **Scope Simulator** for visual observers while its **Polar Finder** should please both. **Annual Libration** data is provided in form of a table. An **Observatory Clock** is a time keeper for your observatory. **More information** is made available via online links.

▲ *Lunar information at a glance.*

▲ *A few gorgeous gauges for the Moon.*

▼ *The Lunar Atlas contains a rotatable lunar globe and a database of over 550 major lunar features (craters, dorsa, lacus, mare, montes, mons, oceanus, palus, planitia, sinus, rima, rupes, vallis and Apollo sites) half of them with image thumbnails.*

Sony IMX178

Focal Length [mm]
2030

Field of View	Image Scale
0.21 x 0.14°	0.244"/px

Linear Resolution: 0.432 km/px

Sensor Data

Current lunar angular size is 32.66

FOV: 0.73°

PARAMETERS
Aperture	203 mm
Focal length	2030 mm
Obstruction	35%
Eyepiece focal length	18 mm
Eyepiece apparent FOV	82°
Barlow/Reducer	1x
Performance Plot	

Optical Performance

...ar angular size is 32.66' (0.544°).

Sony IMX585

Sony IMX585

Pixel size: 2.9µm
Sensor size: 11.14 x 6.26 mm
Diagonal: 12.8 mm
Total pixels: 8.29 Mp
Effective pixels: 3840 x 2160
Diagonal: 4406 pixels
Aspect ratio (H/W): 0.563

Quantum efficiency: ~91%
Full-well capacity: 38.8k e
A/D converter: 12-bit

NOTE:
Succeeds IMX485

Player One: Uranus-C
ZWO: ASI585MC
QHY: QHY5III585C
Svbony: SV705C

Close

Sensor Data

☁ *The simulator does does not take into account atmospheric seeing. Ideally, the image scale should be a third of the seeing but is often unrealistic.*

The **Camera Simulator** helps choose a suitable camera for a given focal length and vice-versa. Pick an image sensor from a dropdown and enter the effectve focal length of your optical system to compute the resulting field of view, FOV, image scale and, for the moon only, the linear resolution. The apparent size of the moon changes with its distance to the Earth and is calculated for real-time for best accuracy. The simulator also has a few deepsky images against which to check the FOV. The data of a selected sensor is also available.

☁ *The aperture of a reflecting telescope is obstructed by its secondary mirror which is accounted for in Optical Performance data.*

The **Telescope Simulator** is for visual observers. Against provision of aperture and focal length as well as focal length and apparent field of view, AFOV, of the eyepiece (ocular) the simulator will provide the true field of view, TFOV, value and the simulated view through the speci-fied eyepiece. Sine the apparent size of the moon changes with its distance to the Earth it is calculated for real-time for best accuracy. The TFOV can also be checked against an image of the southern region of Orion. The overall optical perfor-mance data is also available.

From ChatGPT (just for fun)

This photo is the author's, not AI generated.

The solar system is a collection of celestial bodies that orbit around the Sun. It consists of the Sun, eight planets, moons, asteroids, comets, and other smaller objects. The eight planets in the solar system, in order of their distance from the Sun, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The solar system formed about 4.6 billion years ago from a giant molecular cloud of gas and dust. The Sun, which is at the center of the solar system, provides light, heat, and gravitational pull that keeps the planets in their orbits. The solar system is vast, with the distances between planets measured in astronomical units (AU) or the average distance between the Earth and the Sun (about 93 million miles or 150 million kilometers). It is an intriguing and fascinating subject of study in astronomy.

1. **Mercury**: It is the closest planet to the Sun and the smallest planet in the solar system. It has a rocky surface and no atmosphere.

2. **Venus**: Known as Earth's "sister planet" due to its similar size and composition. Venus has a thick atmosphere that traps heat, making it the hottest planet in the solar system.

3. **Earth**: Our home planet, Earth is the only known planet to support life. It has a diverse environment and is covered mostly by water.

4. **Mars**: Often called the "Red Planet" due to its reddish appearance, Mars has a thin atmosphere and is known for its polar ice caps and surface features like canyons and volcanoes.

5. **Jupiter**: The largest planet in the solar system, Jupiter is a gas giant with a strong magnetic field. It has a distinctive striped appearance and is known for its Great Red Spot, a giant storm.

6. **Saturn**: Known for its beautiful ring system, Saturn is also a gas giant. It has numerous moons and is less dense than water, meaning it could float in a large enough body of water.

7. **Uranus**: Uranus is an ice giant with a blue-green color due to the presence of methane in its atmosphere. It rotates on its side, making it unique among the planets.

8. **Neptune**: The farthest planet from the Sun, Neptune is also an ice giant. It has a deep blue color and strong winds, including the fastest recorded winds in the solar system.

About the author

Born in July 1955, the author is a German national living in Japan since late 1996. Formerly a marketing communications manager for a Tokyo-based semiconductor company, he moved to Okinawa as a freelance web developer, now retired and stranded on the island with two wonderful dogs. A life long interested in astronomy, he started with astrophotography in late 2018 initially with a Vixen A80Mf and a DSLR on an old but working Orion Atlas EQ-G mount. His current workhorse is a Celestron C8 XLT telescope. He began with lunar and planetary imaging because persistent cloudy weather does not permit serious deepsky work.