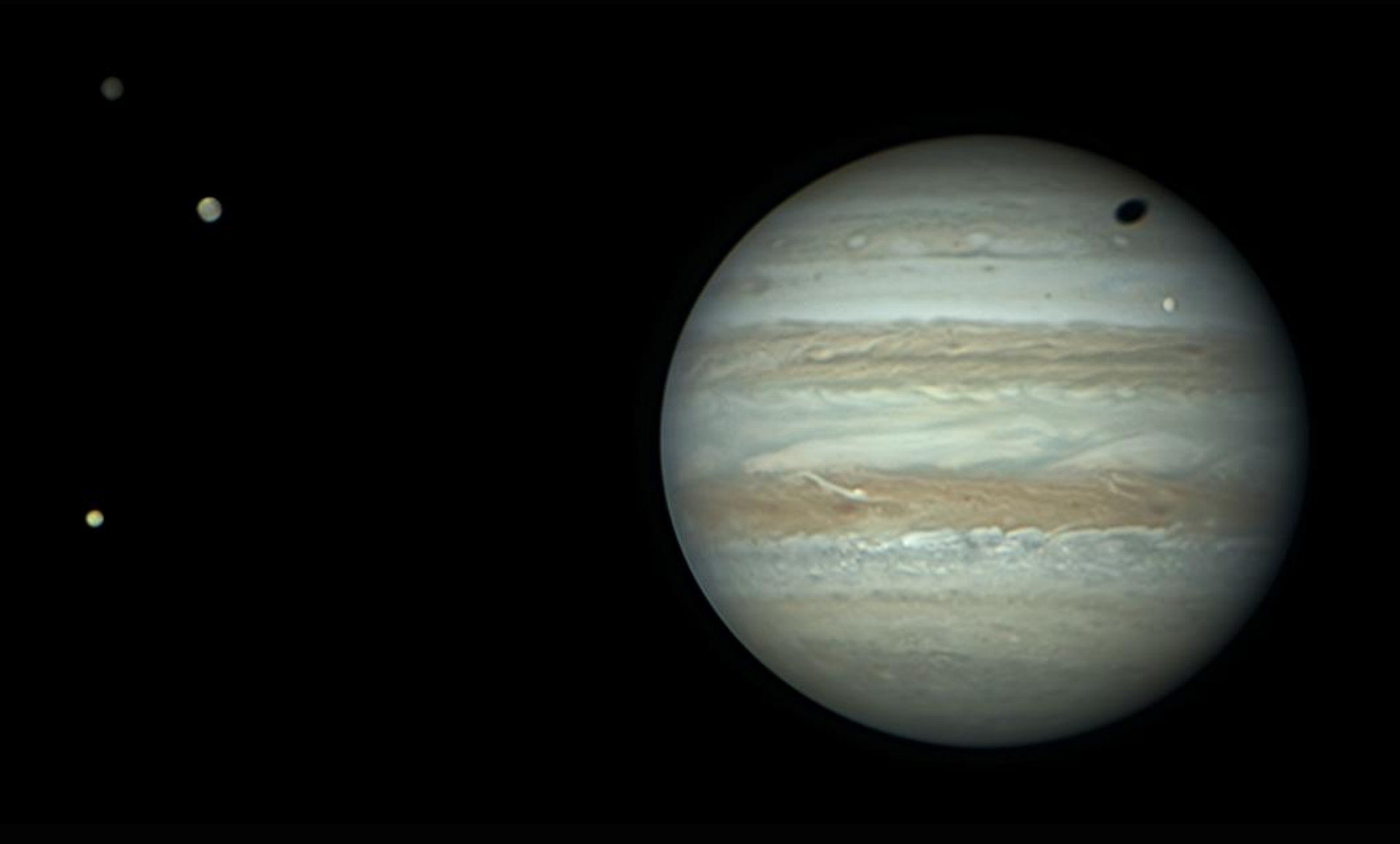
High-resolution Imaging of Jupiter

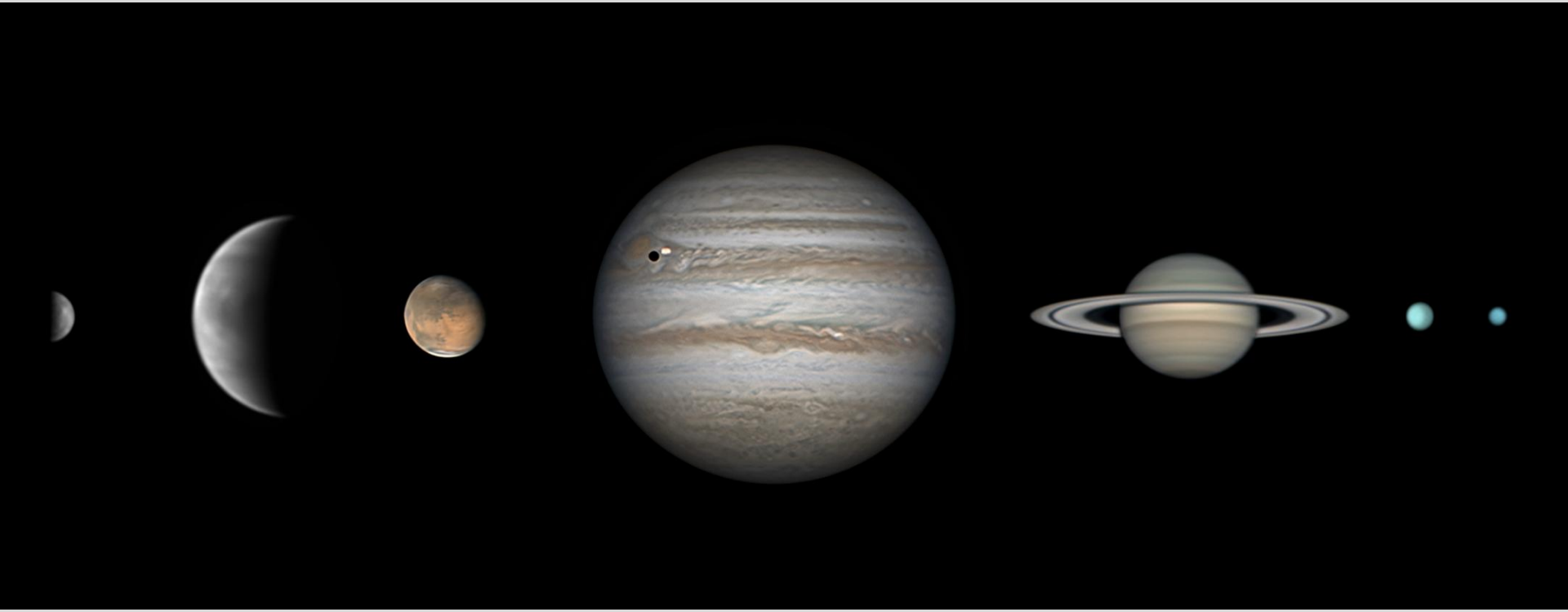


BAA Winchester Weekend, April 12th 2025
www.SkyInspector.co.uk

Martin Lewis

High-resolution imaging of Jupiter- Overview

- *Principles of digital video Imaging of the Planets*
- *Tips for best imaging of Jupiter*

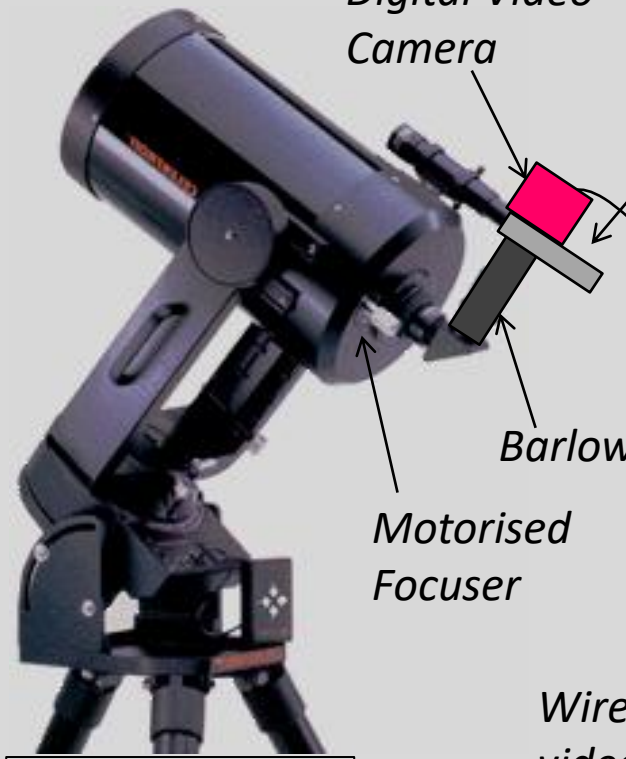


What's the big deal with imaging the Planets anyway?

Principles of Digital Video Imaging of the Planets

Principles of Digital Video Imaging of the Planets

Principles of Digital Video Imaging of the Planets



Hi-speed Digital Video Camera

Filter wheel (for mono camera)

GBs!

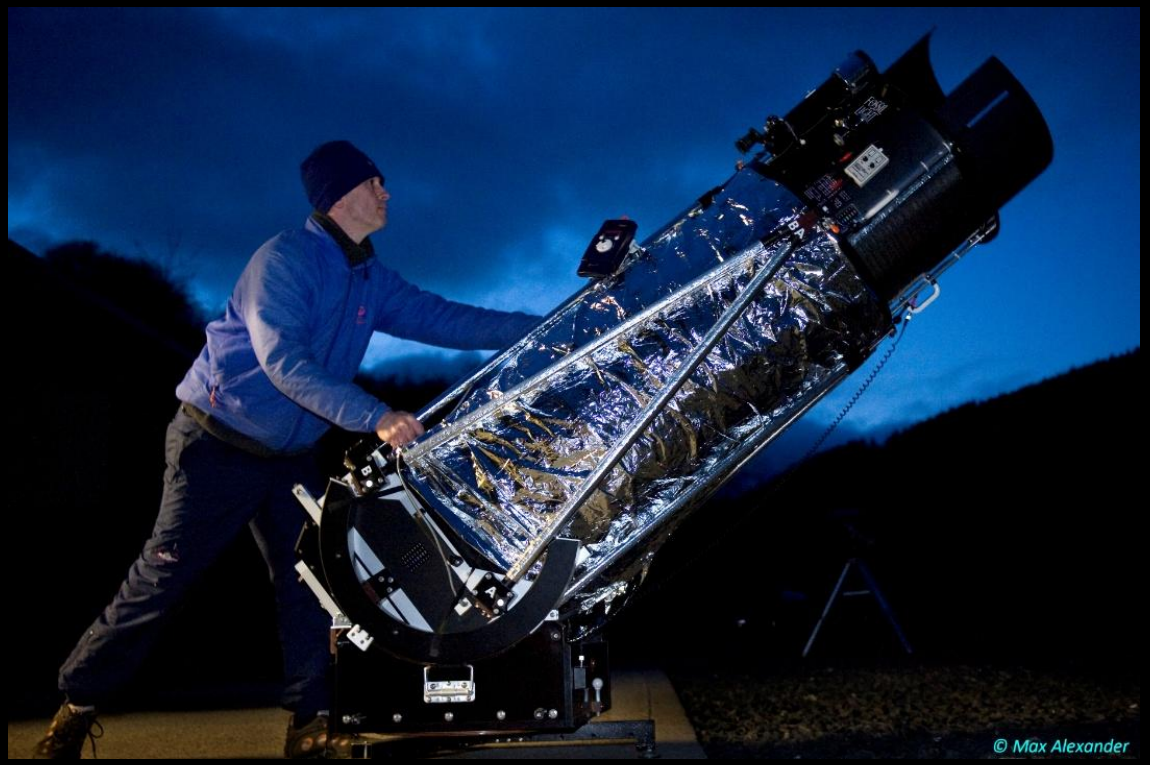
Barlow

Motorised Focuser

Wired connection for high video data transfer rate

Equatorial tracking mount

Principles of Digital Video Imaging of the Planets



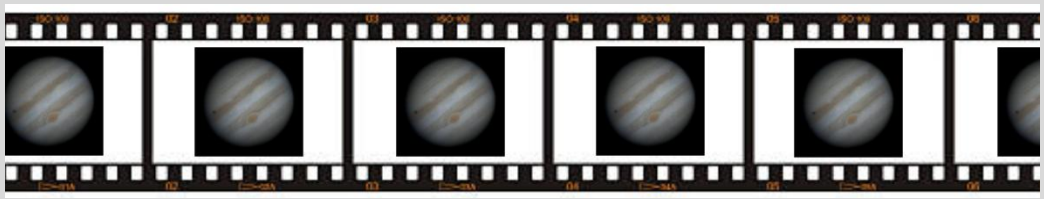
Principles of Digital Video Imaging of the Planets

- *With the set-up on the previous page –*
  - *you record a **Video** of the planet onto a computer at the telescope*

- *Later process your Video*

  - *Use software to auto sort through the video and place in quality order*
  - *Combine the best frames, where the air was steadiest, into an averaged **Single Image***
  - *This is then processed to boost the contrast of the fine detail*

4GB Video



100kB Single Image

The resulting single image can be stretched to bring out the detail as it is now very low noise. This is because it is ……

A LONG exposure image made up of many SHORT exposures

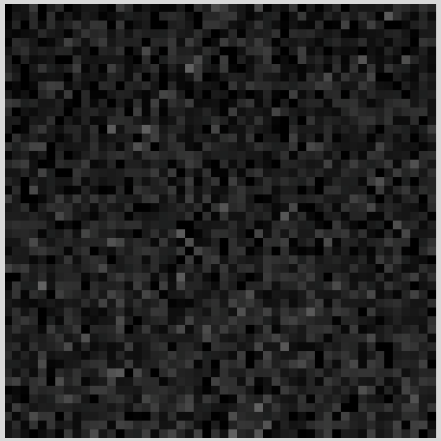
-Long exposure means less noise

-Short exposures mean it is less blurred by the constant movement of the atmosphere

Long exposure means less noise

Why?

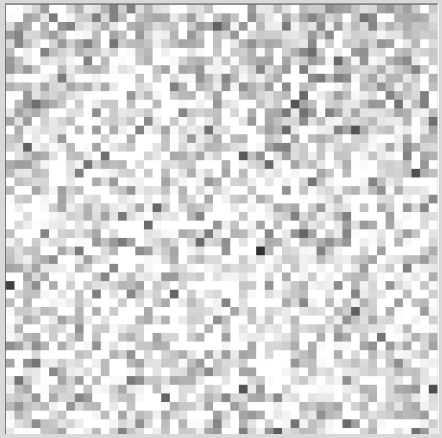
- *In low light conditions light is considered to behave like particles arriving in discrete packets of energy –* ***Photons***
- *Photons arrive at Random intervals – variation in number collected at one pixel in one frame is simply the square-root of the number collected*



Average of 100 photons/pixel

Variation (noise) =10 photons
SNR 10

100x100 pixel sensor



Average of 10,000 photons/pixel

Variation (noise) =100 photons
SNR 100

Principles of Digital Video Imaging of the Planets

1 frame = 2.5msec total ***10 frames stacked = 25msec total*** ***100 frames stacked = 250msec total***

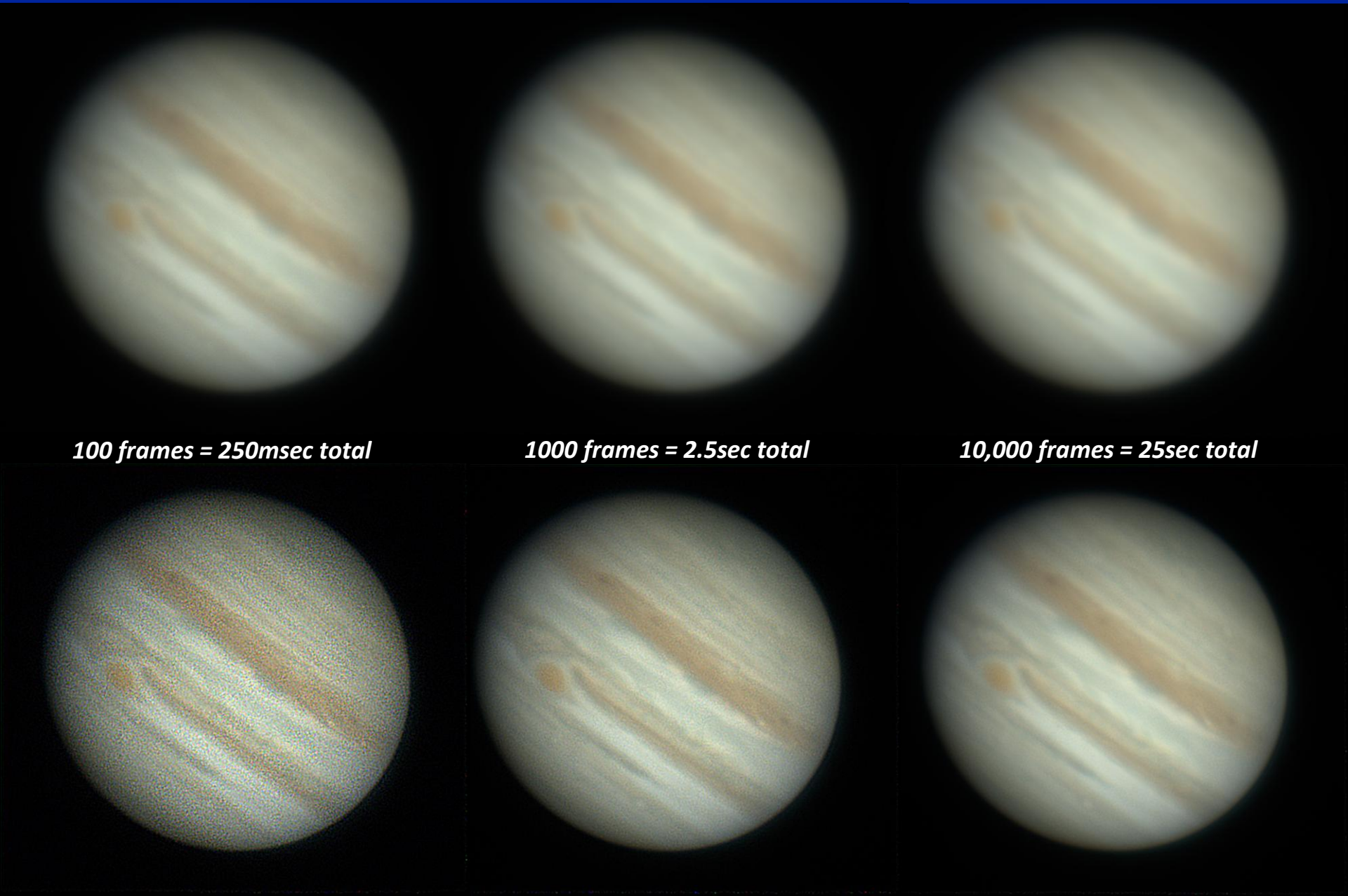
- *Stacking increases the accumulated exposure time & Improves SNR*
- *100 frames is 100x the photons but is not 100x brighter*
- *Stacked image is divided by the number of frames*
- *Hence, stacking is essentially an **averaging** process*
- *For Jupiter need accumulated exposure times in 10's of seconds in the stack*

Principles of Digital Video Imaging of the Planets

100 frames = 250msec total ***1000 frames = 2.5sec total*** ***10,000 frames = 25sec total***

- *But doesn't 250msec look smooth enough!?*

Principles of Digital Video Imaging of the Planets



100 frames = 250msec total

1000 frames = 2.5sec total

10,000 frames = 25sec total

Modern planetary imaging uses…

A LONG exposure image made up of many SHORT exposures

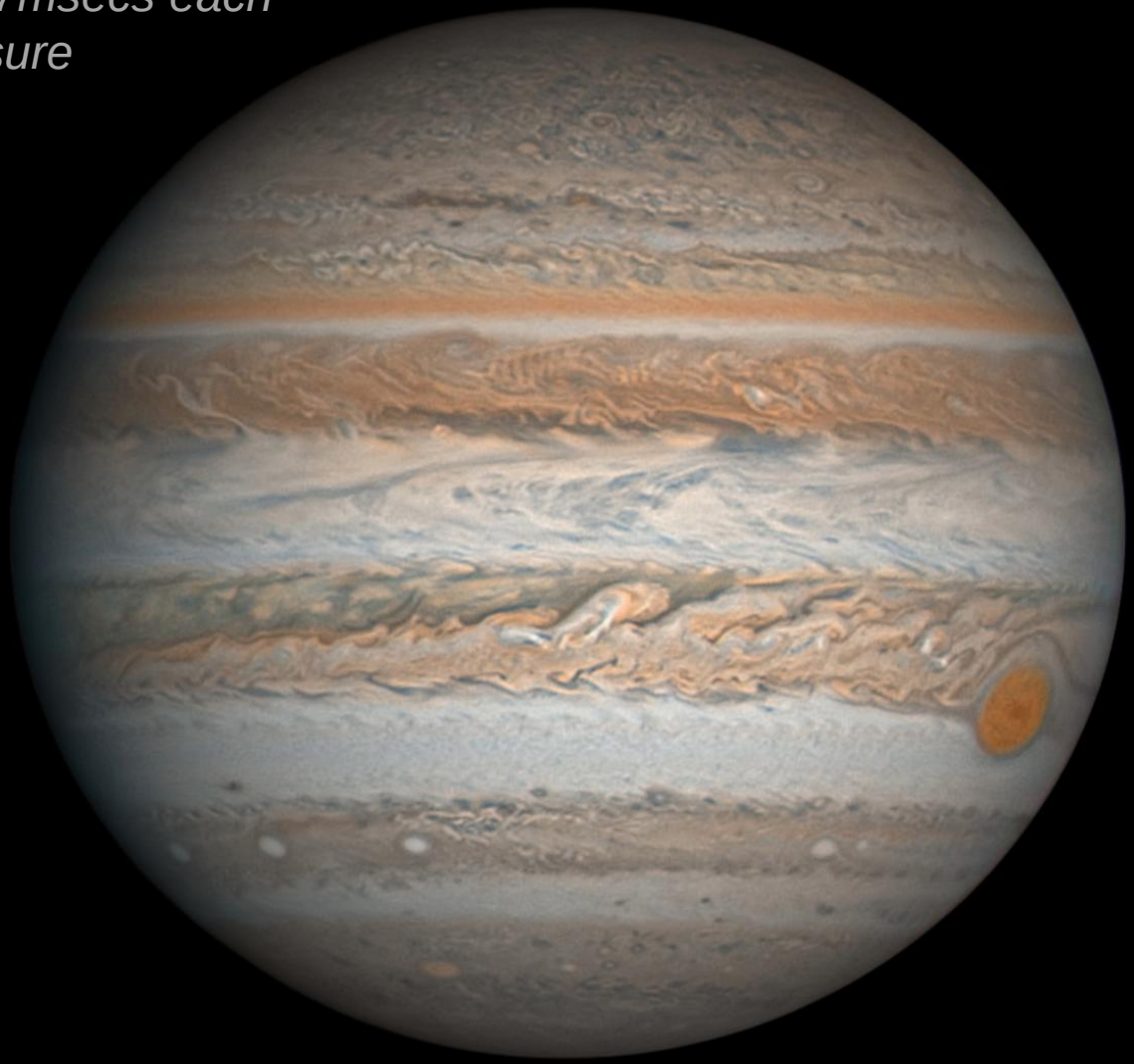
How about a Single longish exposure??

Pic du Midi 1.06m scope 1988 – Single Shot Method

Single ~1.5secs exposure

Pic du Midi 1.06m scope 2017 – Digital Video Imaging

2,500 frames of 17msecs each
43 sec total exposure



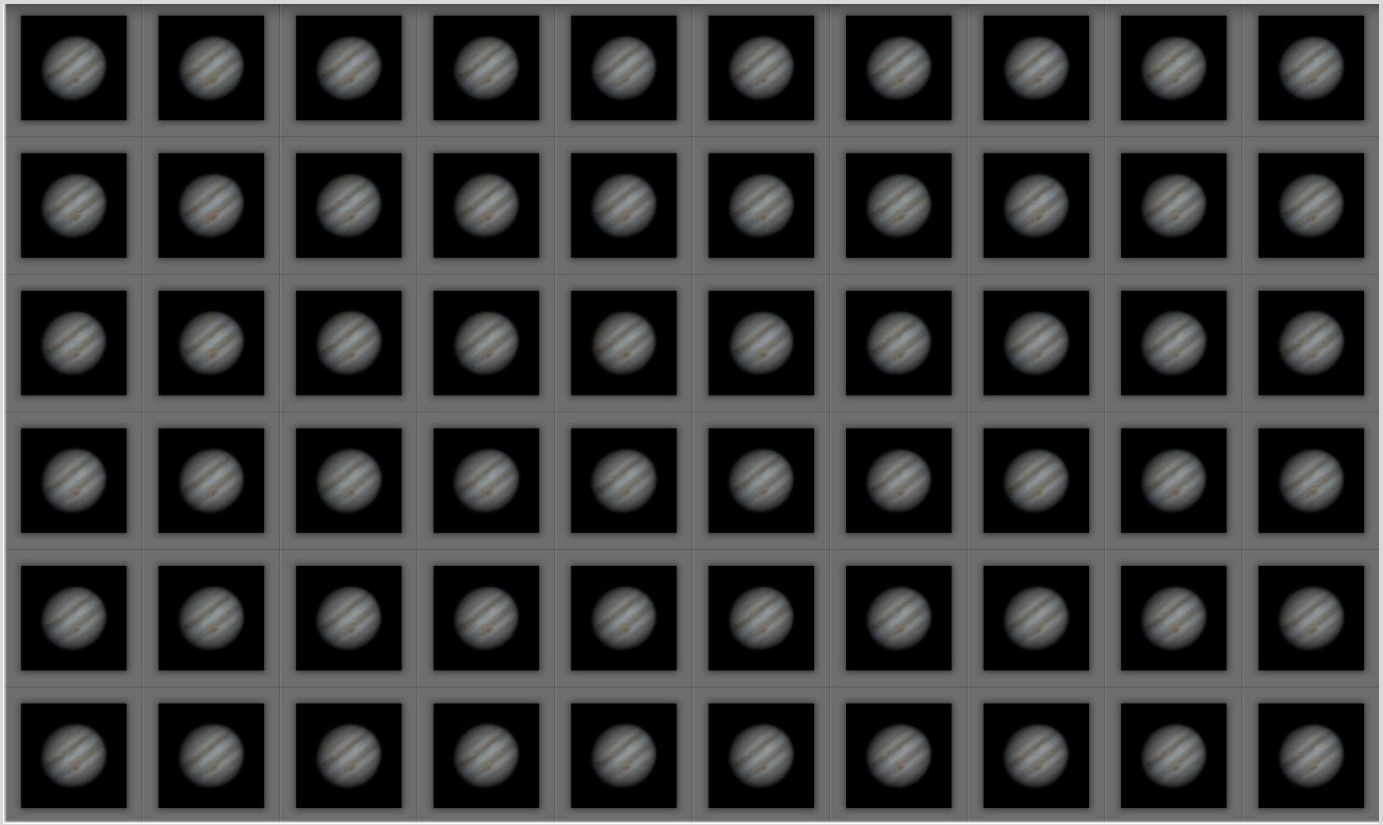
T1M Pic du Midi / pic-net.org - D. Peach/E. Kraaikamp/F. Colas/M. Delcroix/R. Hueso/C. Sprianu/G. Therin
Pic du Midi observatory (OMP-IRAP), Paris Observatory (IMCCE/LESIA), CNRS (PNP), Europlanet, S2P
105cm F17 Cassegrain with ASI290MM

Imaging Workflow

Jupiter 3rd May 2016

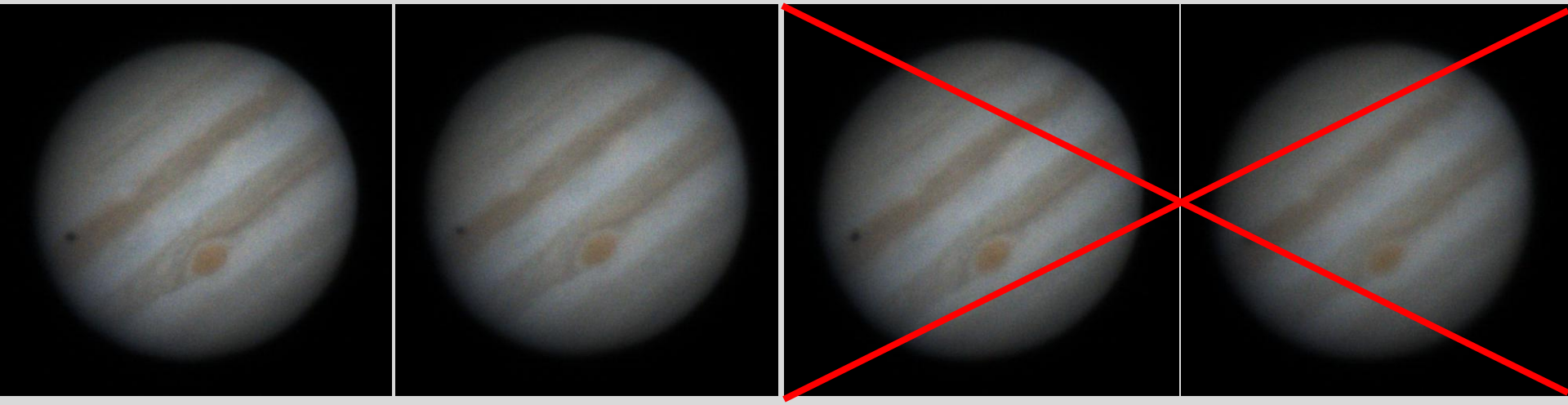
Digital Video Imaging of Planets – Frames

Use dedicated software (AutoStakkert!) to break the video into 1760 individual frames



Then automatically Sort them in order of Quality – best first

Digital Video Imaging of Planets – Quality Sort



Best frame | *264th Best Frame* | *265st Best Frame* | *Worst of 1760 frames*

*KEEP best **15**%*

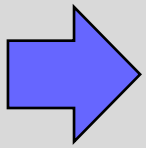
REJECT Rest

Digital Video Imaging of Planets - Stack

Auto-Align and Stack best 264 frames

Best frame

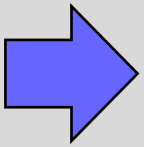
264th Best Frame

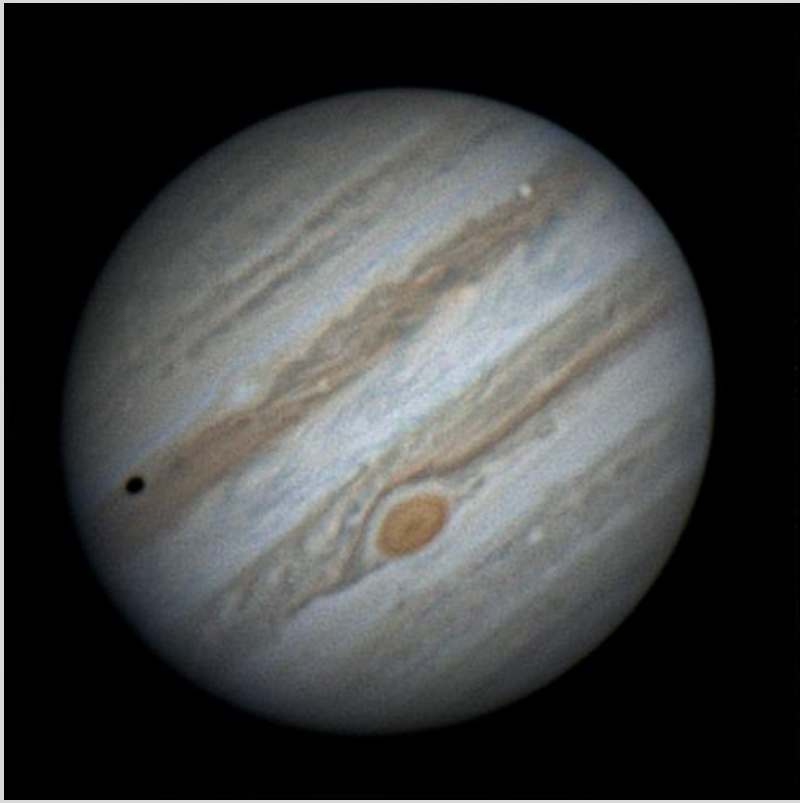


-Noise reduced
-Atmospheric turbulence averaged

Digital Video Imaging of Planets – Wavelets on Stack

8 sec exposure in 264 chunks of 30msec





Aligned Stack of 264 best frames

-Noise reduced

-Atmospheric turbulence averaged

-Worst frames for seeing ignored

Wavelet Processing of Stacked image in Registax brings out the details

Tips for better Imaging of Jupiter

Assuming you have a high-quality, well-collimated scope of decent aperture that has cooled close to ambient temperature and the Seeing is at least reasonable! Plus a correctly set ADC-

- *Match your Telescope Resolution to the Camera Pixel size*
- *Pick a good frame Exposure time*
- *Pick the best Stack % size*
- *Combine the best videos in Winjupos to increase the accumulated exposure time*
- *Pick the right video duration*
- *Pick the best videos to combine*

Match the Scope Resolution to the Camera

- *Use an Image Scale that matches your camera Pixel Size* ***to your telescope max. resolution***
- *Resolution dictated by diffraction effects which turns every point of detail into a tiny disc*

- *Ideally need 3 or 4 pixels to span smallest detail scope can produce*
- *For* ***mono*** *camera choose f-ratio 5x pixel size in microns =* ***3 pixel span at 5x***
  - *2.9um camera use f15*
- *For a one-shot colour camera choose an f-ratio of 7x pixel size =* ***4 pixel span at 7x***
  - *2.9um camera use f20*
- *Best measure of smallest detail →* ***Dawes limit***

Match the Scope Resolution to the Camera

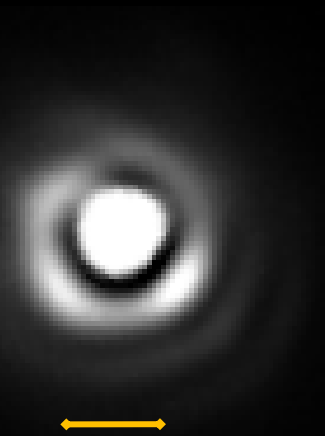
Expected?

Reality

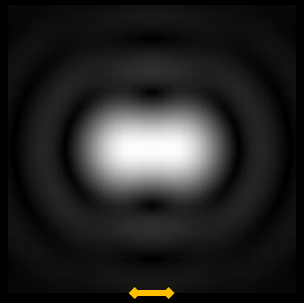
Airy Disc with surrounding concentric light rings and dark spaces

Match the Scope Resolution to the Camera

Aldebaran
444mm Newt

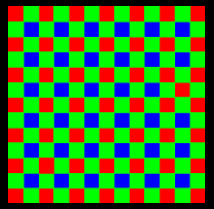


Airy Disc 0.6”

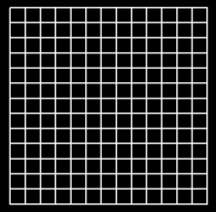


Dawes limit for double star
0.26” (41% of Airy disc)

Colour camera
*Dawes = 4 pixels in XY at f20= **7x***
pixel size (0.065”/pix)



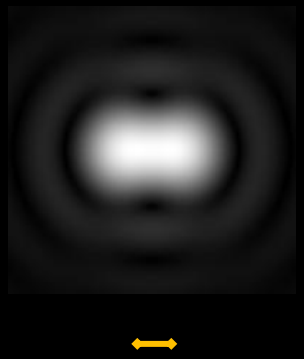
2.9um Pixel Bayer grid



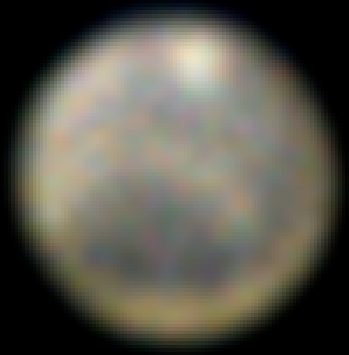
2.9um Pixel grid

Mono Camera
*Dawes = 3 pixels in XY at **f15** =*
***5x** pixel size (0.09”/pix)*

Match the Scope Resolution to the Camera



Dawes 0.26”
(41% of Airy disc)



Ganymede 1.8”
444mm scope
26-10-2023

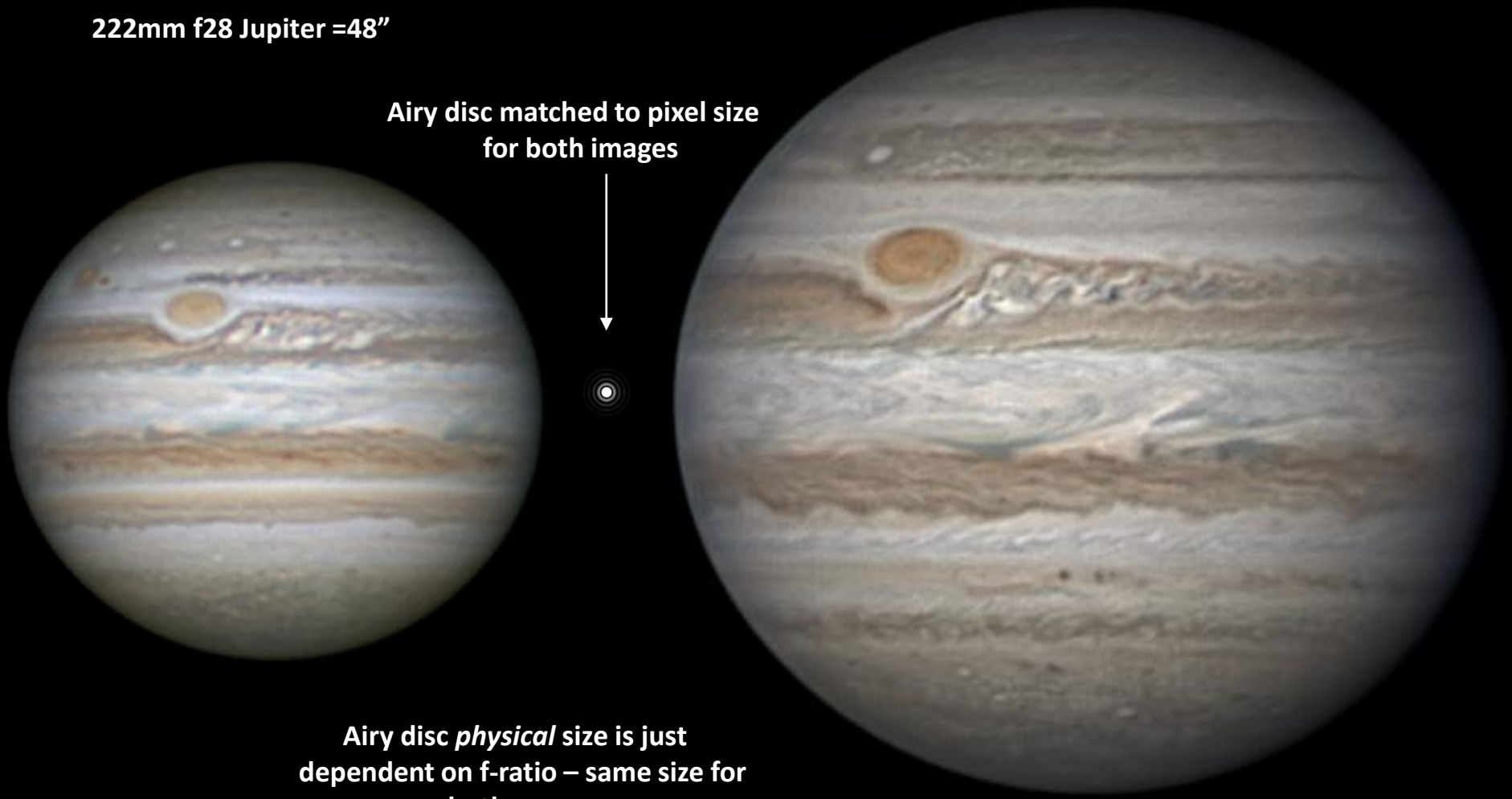
Winjupos simulation

Match the Scope Resolution to the Camera

444mm f27 Jupiter =38”

222mm f28 Jupiter =48”

Airy disc matched to pixel size for both images



Airy disc *physical* size is just dependent on f-ratio – same size for both scopes

Bigger scope has larger image scale

Match the Scope Resolution to the Camera

Both 10msec expose
best 15% of 60secs

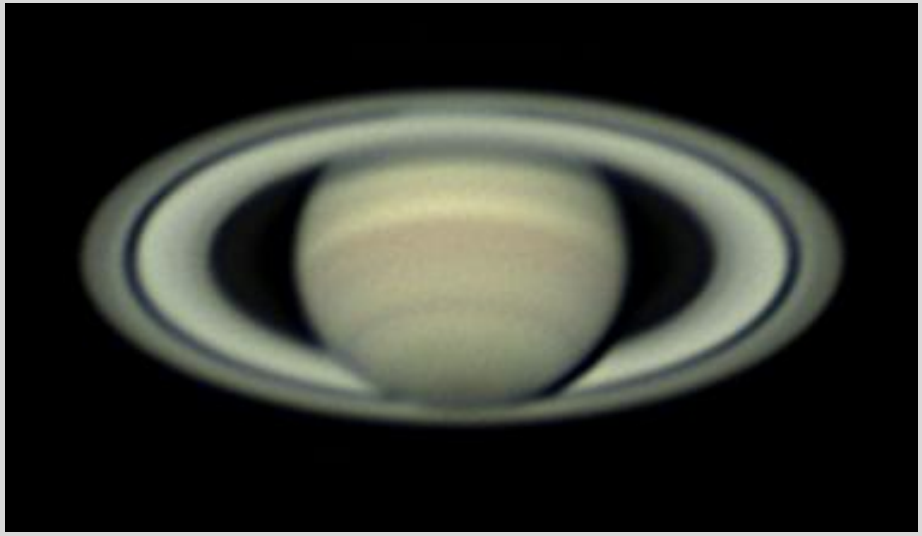
Correctly sampled
444mm f20 = 7x pixel size

Under-sampled
444mm f12.7 = 4.3x pixel size

Picking the frame Exposure time – Exposure too Long

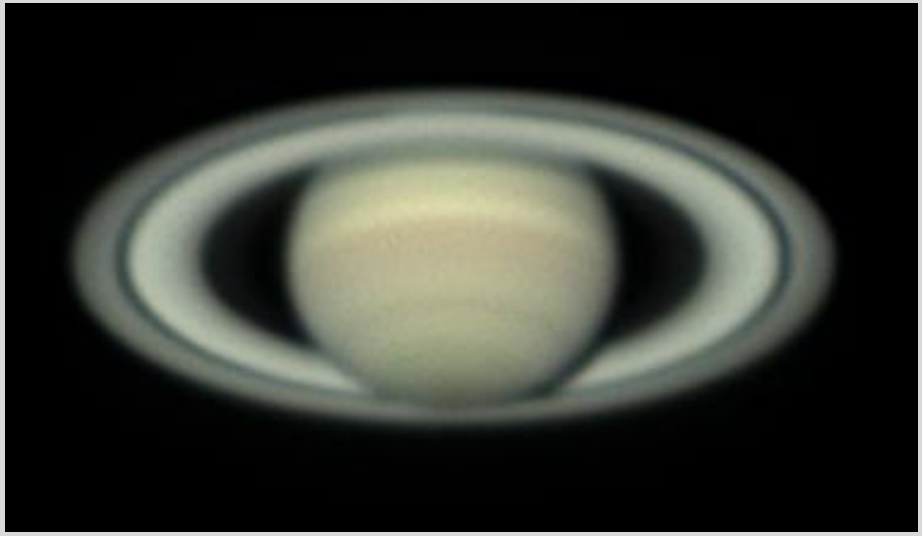
4x the exposure ¼ the gain and ¼ the number of frames

***15msec** exposure & Gain 56x*



*Processed STACK of best 30% of **8000** frames*

***60msec** exposure & Gain 14x*



*Processed STACK- Best 30% of **2000** frames*

- *Same shot noise as **both 36secs** accumulated exposure time*
- *Details are better with the shorter exposure- due to less movement smearing*

Picking the frame Exposure time – Exposure too Short

- *Too short an exposure can lead to other issues though*
  - *Data Choking - reduced accumulated exposure time.*
  - *Example for Jupiter with ROI 700x640:*
    - *40msec frame exposure time. Speed 24fps = 58 secs per 1min video*
    - *10msec frame exposure time. Speed 95fps = 57 secs per 1min video*
    - *2.5msec frame exposure time. Speed 237fps = Only 36 secs per 1min video*
  - *Dropped frames*
    - *Even if camera doesn't choke the SSD might not be able to save the data fast enough and data will be lost*
  - *Short frame exposure times can lead to a poorer ability to stack in Autostakkert! as frames will be noisier and Autostakkert! can't 'see' the detail as easily to locally align*

Picking the frame Exposure time – Exposure too Short

Both best 15% of total frames

10msec 5820 frames
57 sec accumulated

2.5msec 14,220 frames
36 secs accumulated

Selecting the optimum stack size

100% 60 secs total accumulated time

Best 80% = 48 secs total

Best 40% =24 secs total

Best 20% =12 secs total

Best 10% =6 secs total

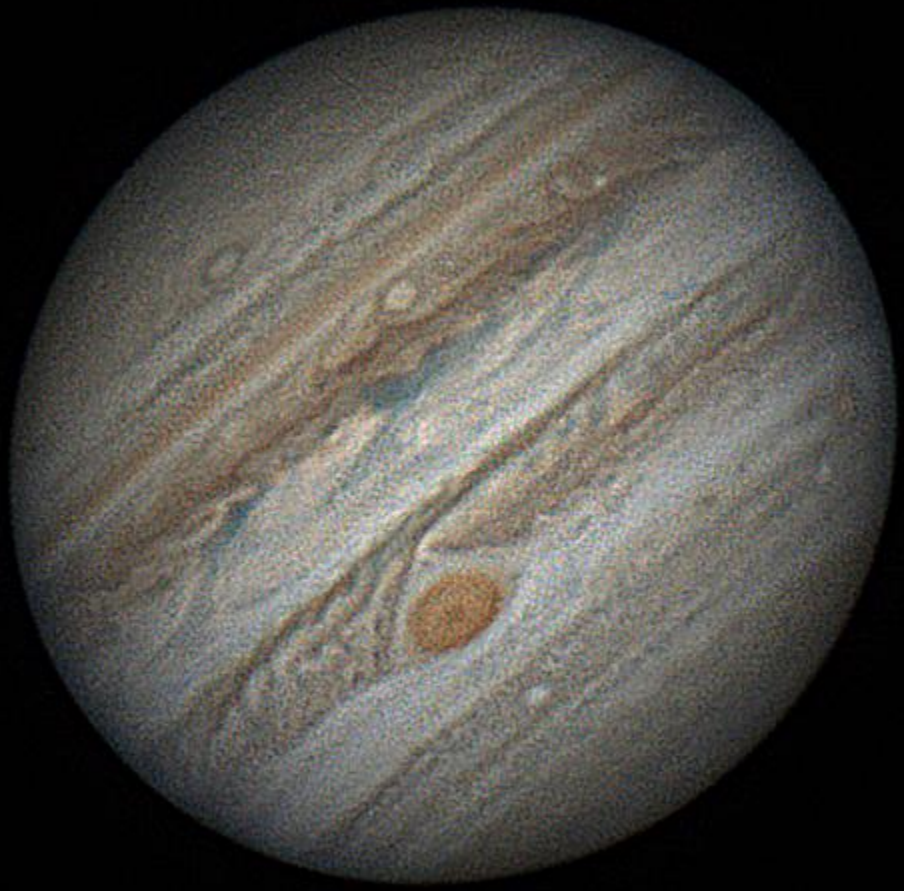
Best 5% =3 secs total

- Accumulated time versus Noise and Image Quality
- 11msec exposure & 1min videos

Selecting the optimum stack size

Best 80%. Low noise but soft – details blurred

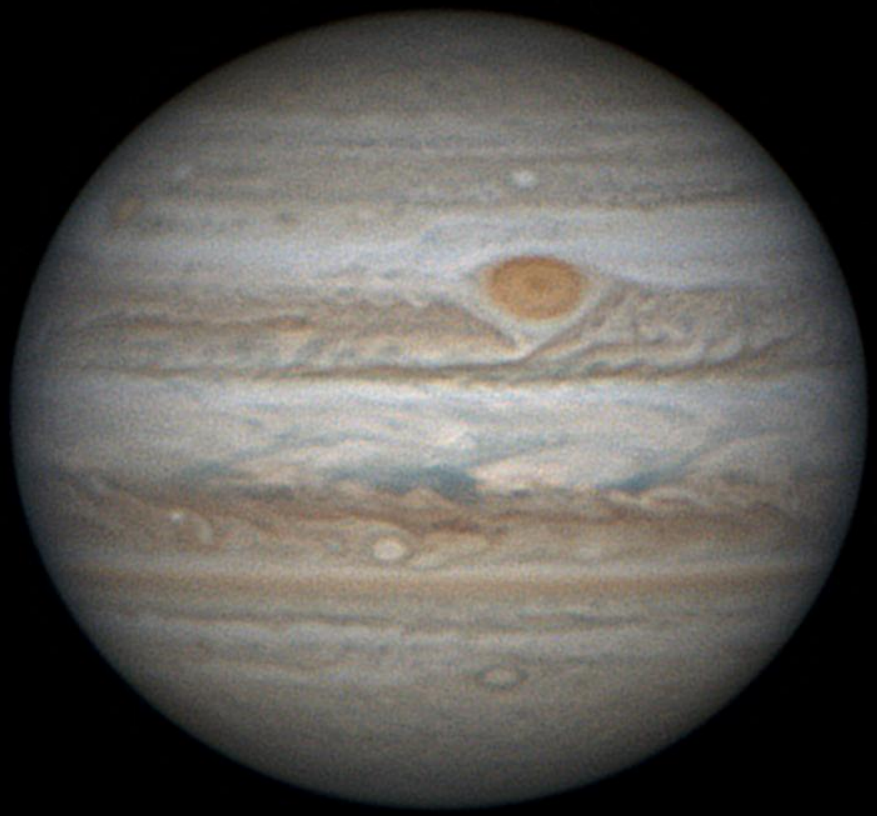
Best 5%. Detail lost in the shot noise



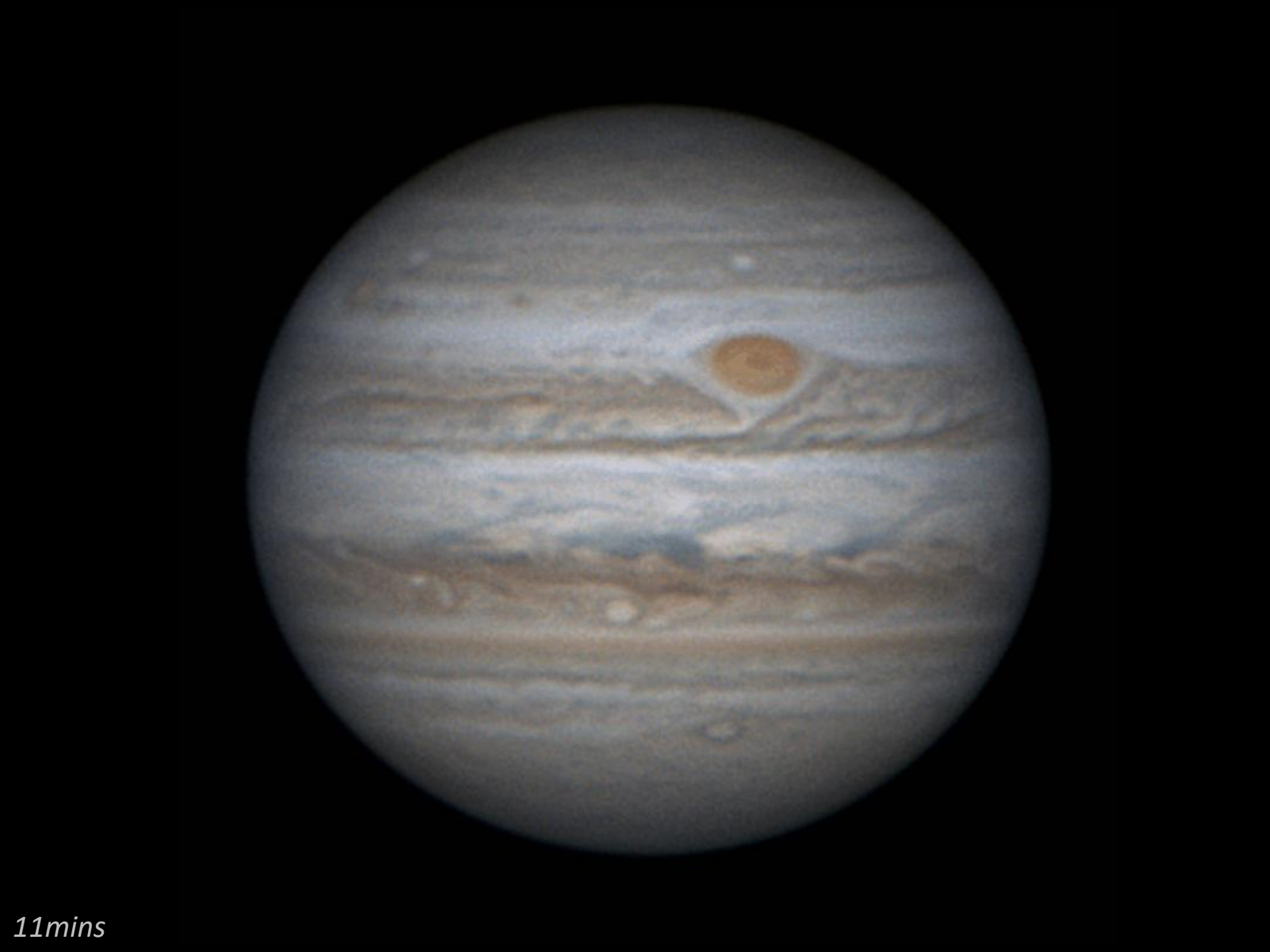
Selecting the optimum stack size

Best 20%. A good compromise?

Use Winjupos Derotate to combine images and reduce noise



Best 20% from 1 video
*=**12 secs accumulated***



11mins

Use Winjupos Derotate to combine images and reduce noise

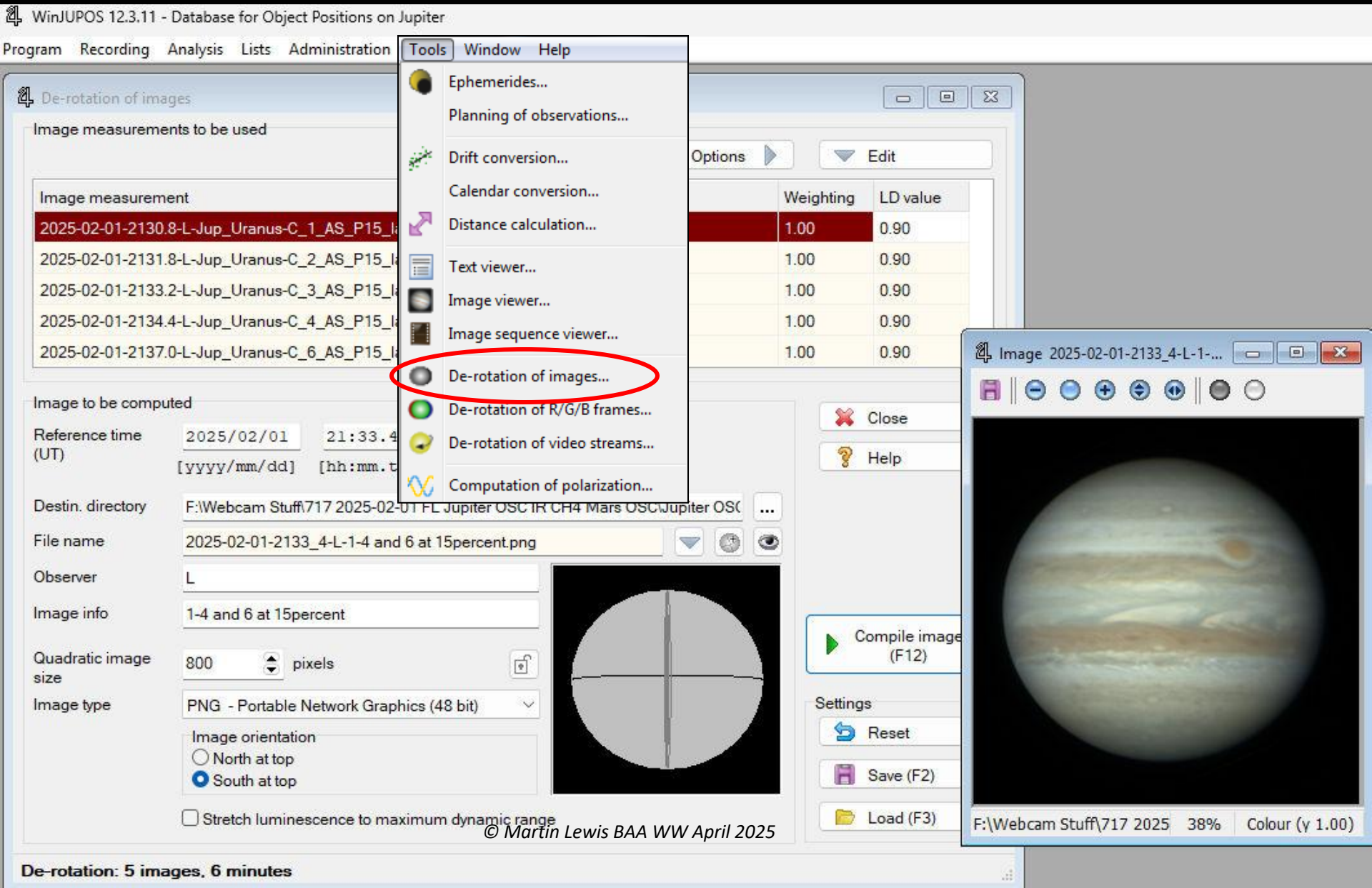
22.28UT *22.32UT* *22.34UT*

Before Derotate

22.32UT *22.32UT* *22.32UT*

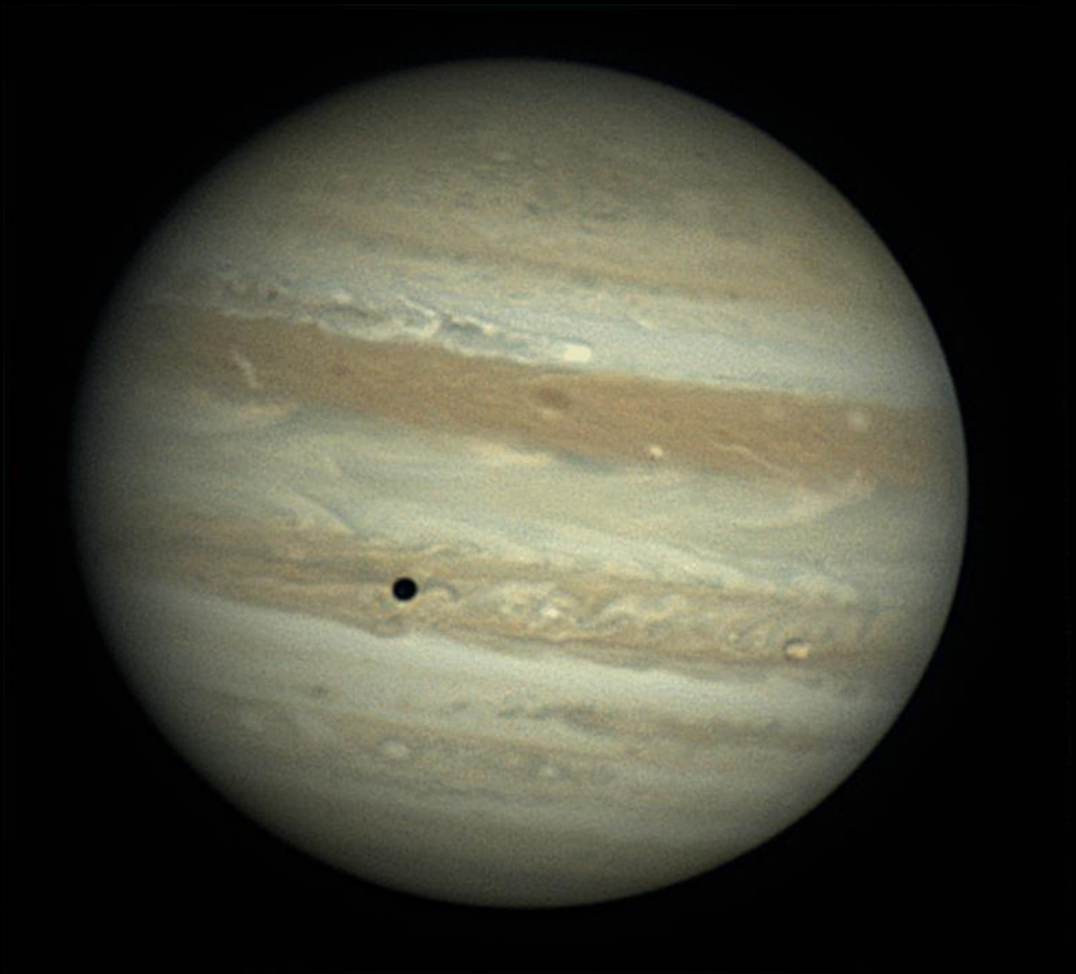
After Derotate

Use Winjupos Derotate to combine images and reduce noise



Best 20% from each of 3 videos
Combined in Winjupos
=36 ***secs accumulated***

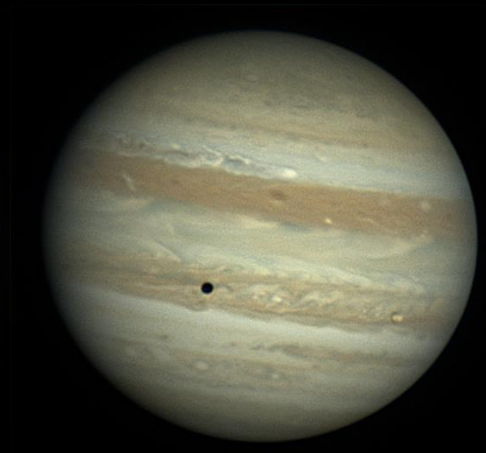
Pick just the best videos to combine in Winjupos



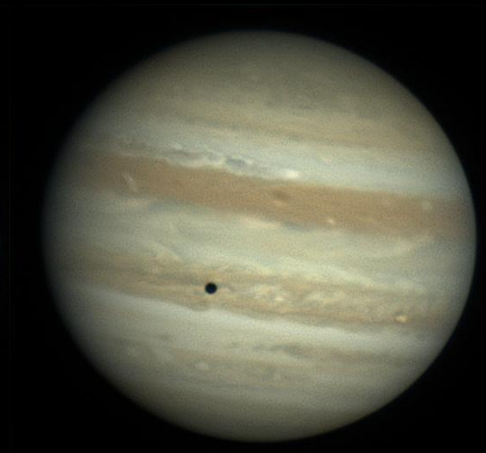
Animation of 20 stacked 60 sec videos
20.00 to 20.20UT 3rd Feb. 2025

Pick just the best videos to combine in Winjupos

✓ *20.00UT V.Good*



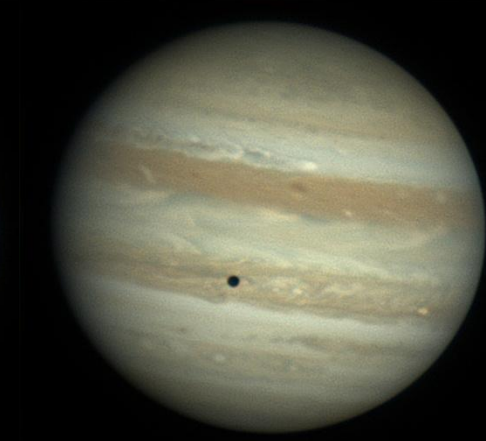
✓ *20.01UT V.Good*



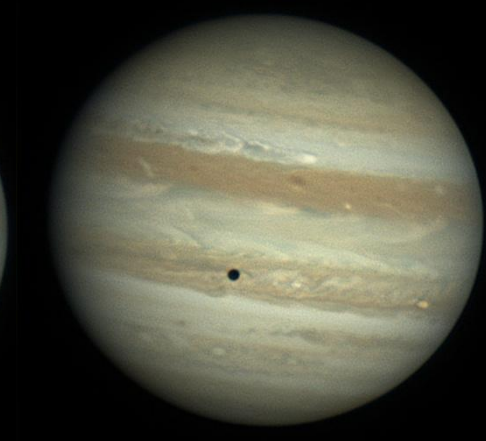
X 20.03UT Fair

X 20.05UT Fair

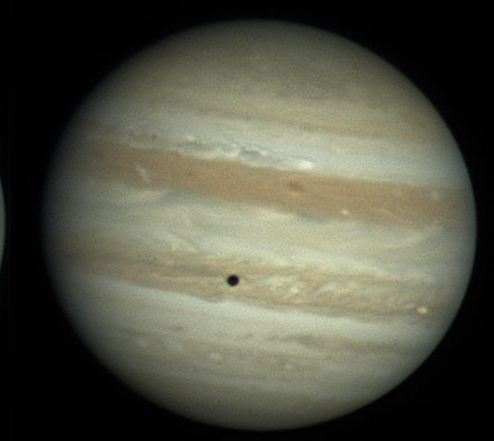
✓*? 20.06UT Good*



✓*? 20.07UT Good*

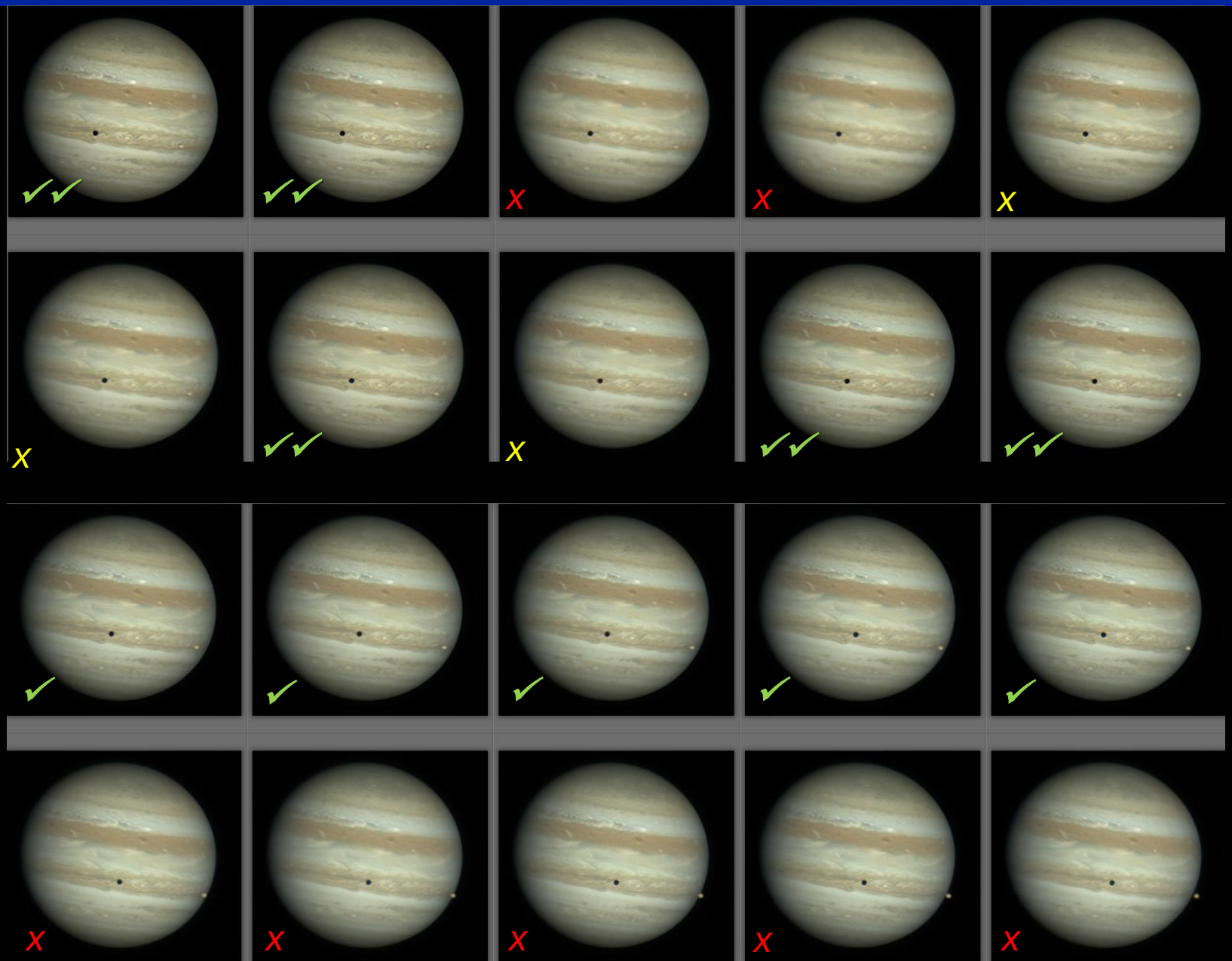


✓*20.08UT V.Good*



✓*? 20.09UT Good*

Pick just the best videos to combine in Winjupos

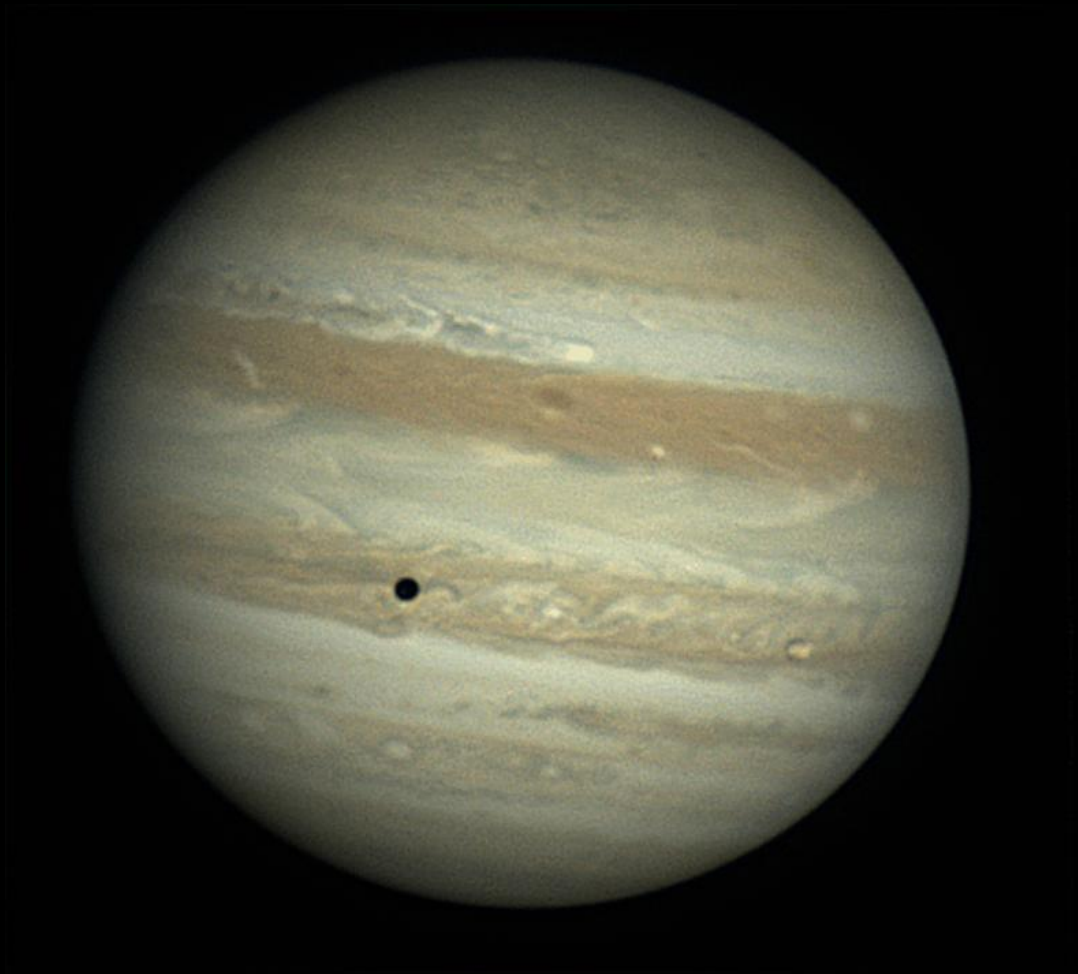


Pick just the best videos to combine in Winjupos

Best 8% of 10 x 1min videos
=48 secs accumulated exposure time in 10msec frames (4800 frames stacked)

Jupiter & Io 3rd Feb. 2025 20.11UT *MLewis St Albans UK 444mm Dob with PO Uranus-C + L filter + PA ADC @0.065"/pix WJ derot. 17min CM I=44° II=289° III=89° Dia. 42.7" Alt. 59° Resize 80% S. top*

Pick the right video duration



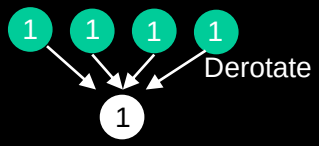
Animation of 20 stacked 60 sec videos
20.00 to 20.20UT 3rd Feb. 2025

Pick the right video duration

All images are best 16% of 23,200 frames

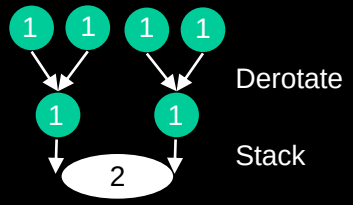
4x1min videos

4x1min videos all derotated in Winjupos



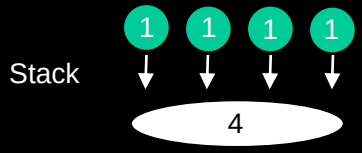
2x2min videos

2x1min + 2x1min vids. Derotated within each pair



1x4min video

4x1min videos 4 pile stack no derotation



Pick the right video duration

4 sequential 1min videos stacked

4x1min videos in a 4 pile stack – no derotation

Single 4min video in Autostakkert Multipoint align

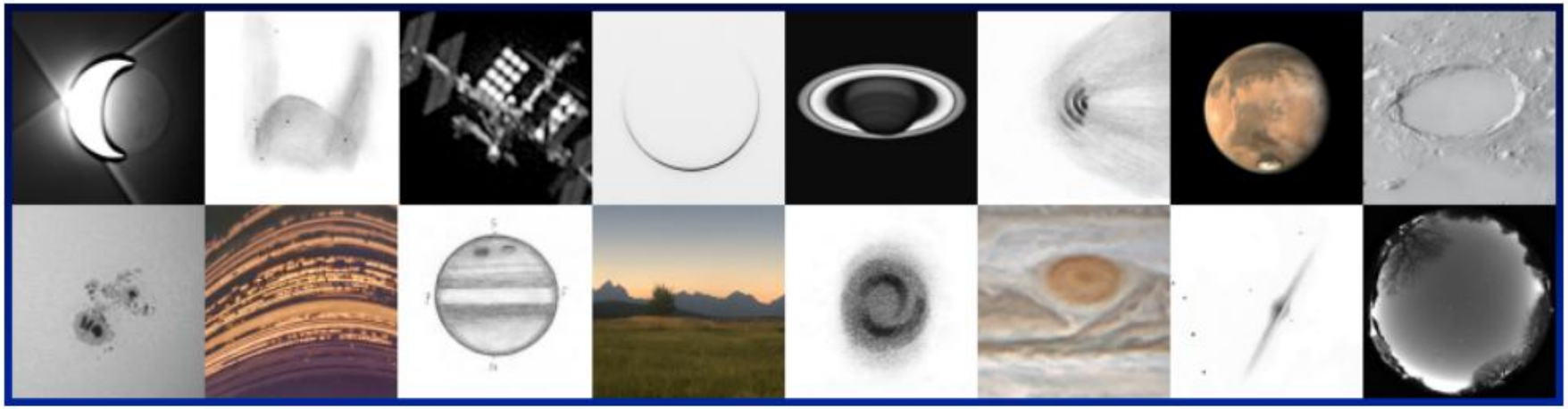
4x1min joined in PIPP

All images are best 16% of 23,200 frames

- *10th April 2025 @ 35” dia.*
- *@ f20 colour camera 2.9um pixels (=6.9x pixel size)*
- *10msec exp*
- *Best 15% of*
- *60sec videos*
- *6 best vids of 14 total*
- *Combined in WJ*
- *54 sec accumulated*

Sky Inspector.co.uk

Astronomy and Sky website of Martin Lewis



Hi,

A warm welcome to my personal website which allows me to promote my life-long interest in Astronomy and the Sky. I do hope you enjoy browsing the images, videos, sketches and other related information that you see on here, which I have generated over the years.

Do feel free to contact me with your comments and suggestions about my website or anything on it, at martin@skyinspector.co.uk