

Extreme Astrophotography

How Amateurs compete with the Pro's



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Professional Observatories

Apertures of 8-10 m in operation

Huge CCD cameras

Limited field of view

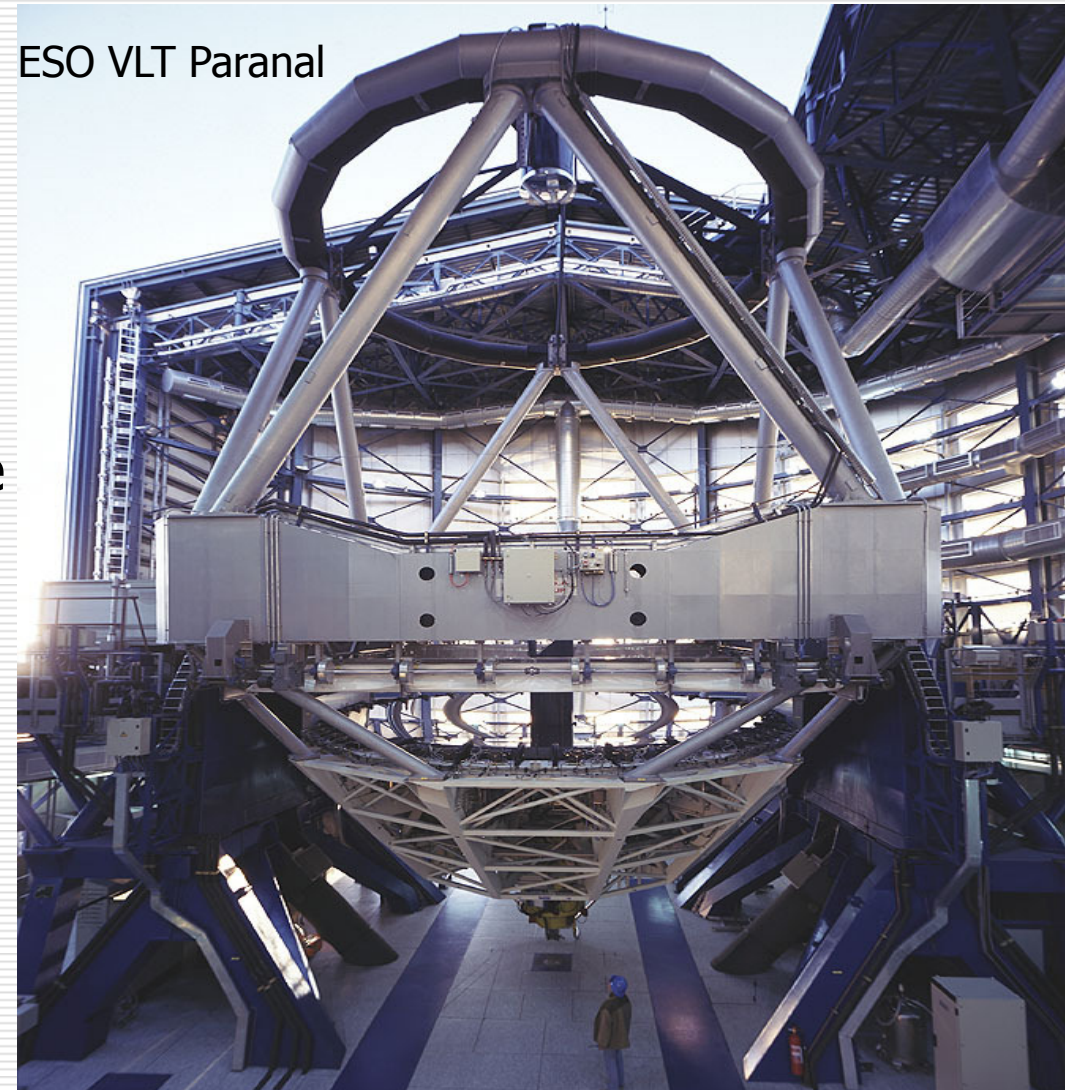
Adaptive Optics (partly)

Observing time extremely expensive
⇒ short exposures

Typical goals: spectroscopy
far infrared

Amateurs goal: pretty imaging

ESO VLT Paranal



Aperture rules!

Observatory	Mirror (m)	Mag in 10 sec*	Resolution (arcsec th.)
Keck, KeckII (Hawaii)	10	25,2	0,014
Large Binocular Telescope (USA)	2x 8,4	24,7	0,016
SALT (South Africa)	10	25,2	0,014
ESO Paranal (Chile)	4x 8,2	24,6	0,017
Gemini North (Hawaii)	8,1	24,2	0,017
Gemini South (Chile)	8,1		
Hubble Space Telescope (UDF: mag 30)	2,4	22	0,055
Panther-Observatory (Cassegrain 16")	0,4	18	0,34

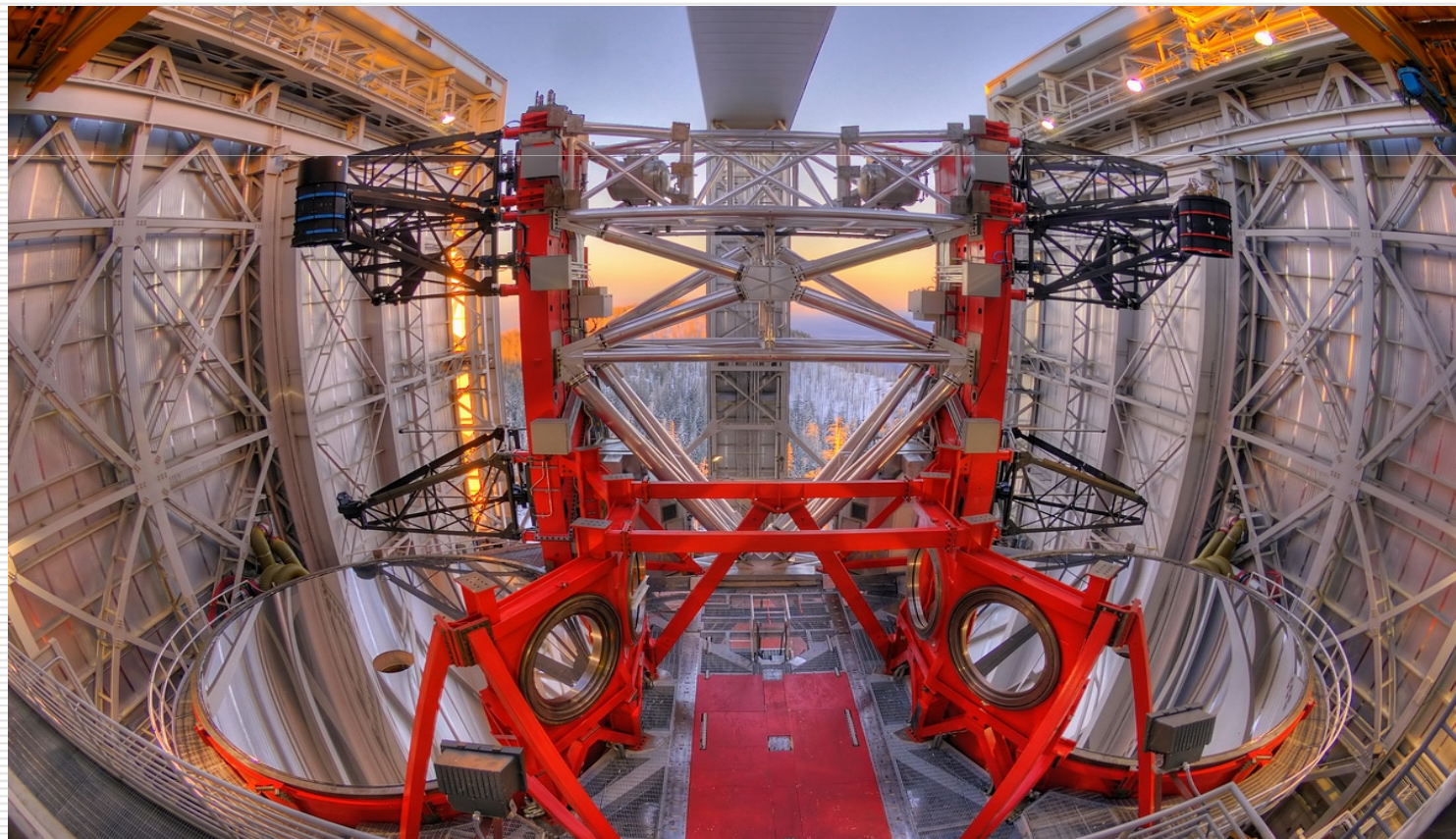
* for S/N=3 KAF-16803

Large Binocular Telescope (LBT Arizona /USA)

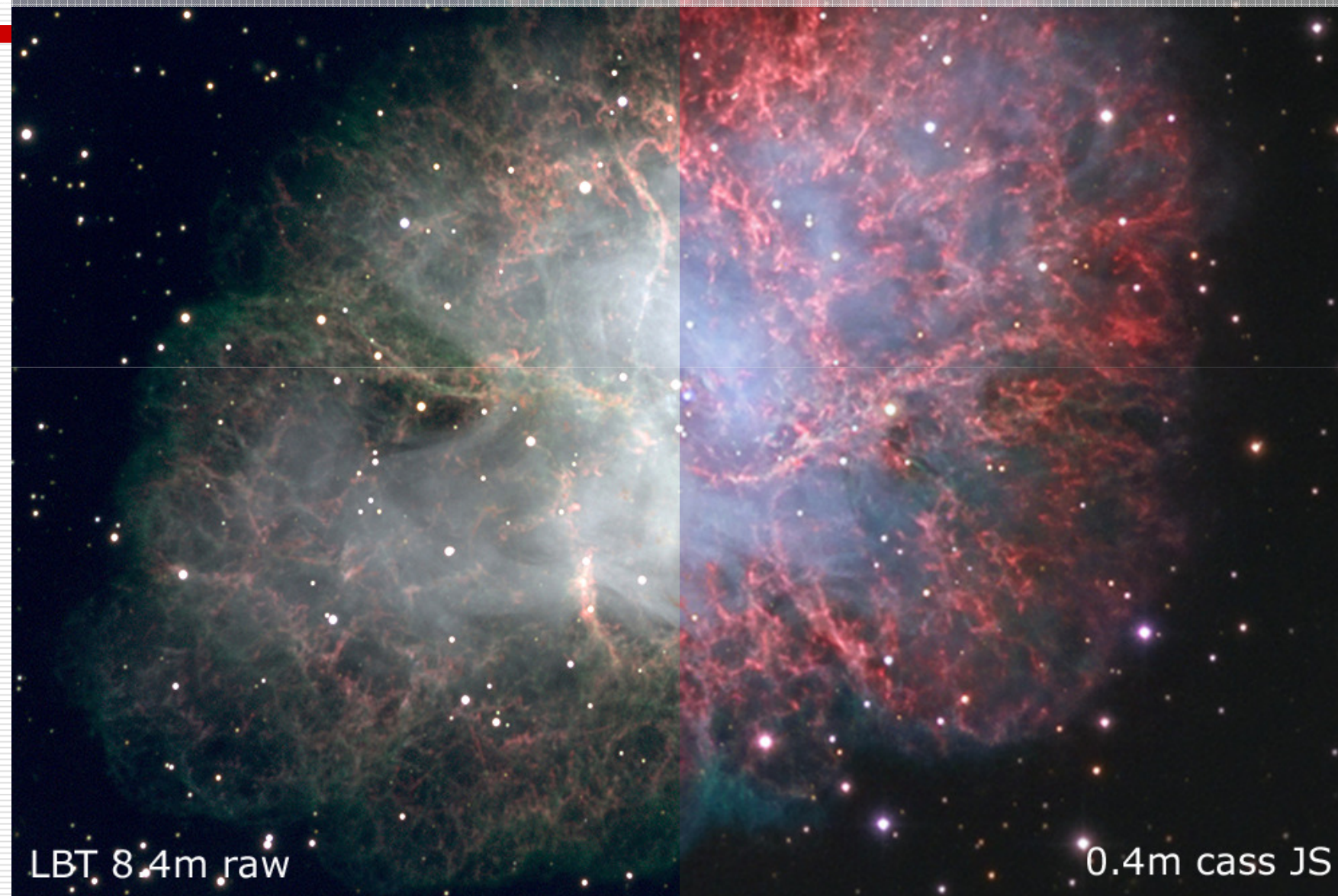
Link: http://medusa.as.arizona.edu/lbto/astronomical_images.htm

LBT Commissioning:

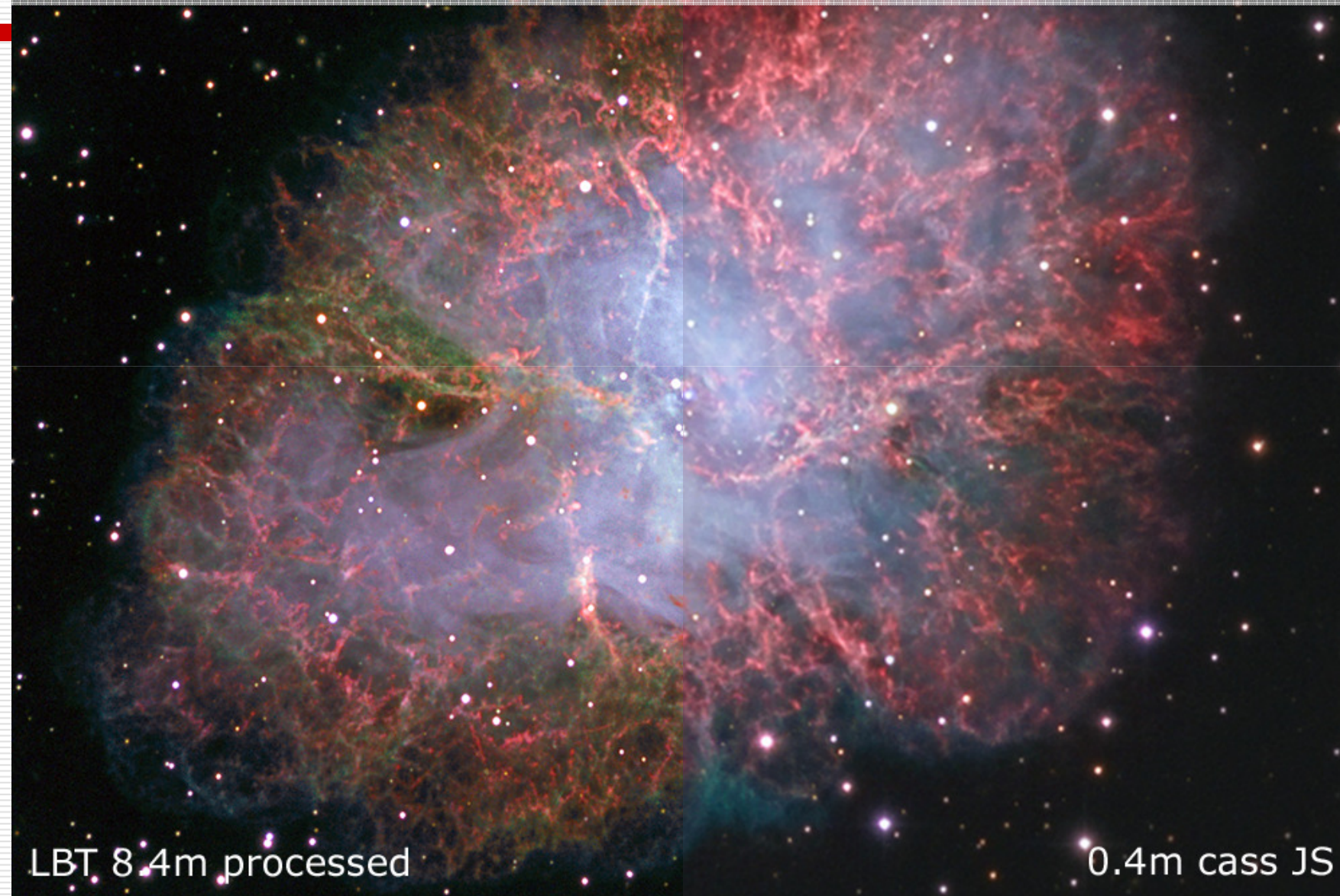
M1 image on following page was referred to my own image by LBT research stuff in Arizona



Comparison with LBT 8.4m on M 1



Comparison with LBT 8.4m on M 1



How to compete?

Invest in exposure time....
(very expensive for professionals!)

Aperture / Exposure time	Mag at S/N=3	Resolution (arcsec eff.)
ESO 8,5 m 10 sec	24,6	0,5
IAS 0,5 m 10 sec	18,4	1,5
IAS 0,5 m 10 min	22,5	1,5
IAS 0,5 m 100 min	23,8	1,5
IAS 0,5 m 1000 min	25,0	1,5

How to compete?

Concentrate the light!

- use a high quality and well collimated telescope
- use very good tracking/guiding ($< 10\%$ of FWHM)
- use long focal length to benefit from good seeing conditions



speckle

FWHM for stars	Airy disk spreaded on x Pixels at f/9 and 9um pixels	Mag at 10 min (L)
4"	290	21,5
3"	164	21,8
2"	73	22,3
1,5"	42	22,5
1"	19	23
0,5"	5,5	23,6

Eagle Nebula (M 16) 0,5 m at IAS



Pillars of Creation in M 16

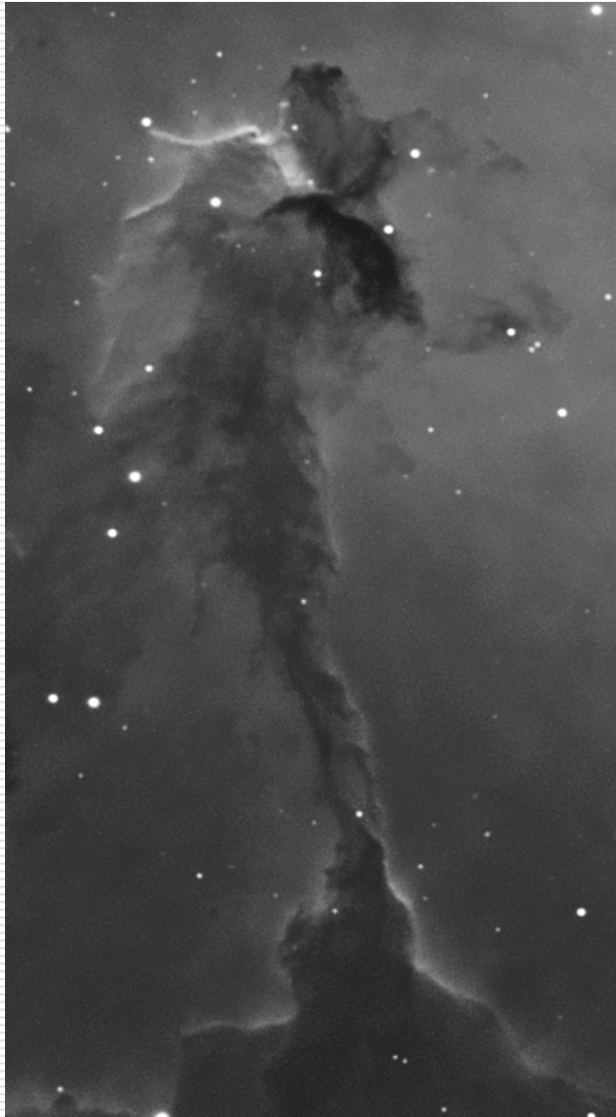


H-alpha 0,5 m



S-II/H-alpha/O-III 2,5 m HST

Rose in M 16



H-alpha 0,5m

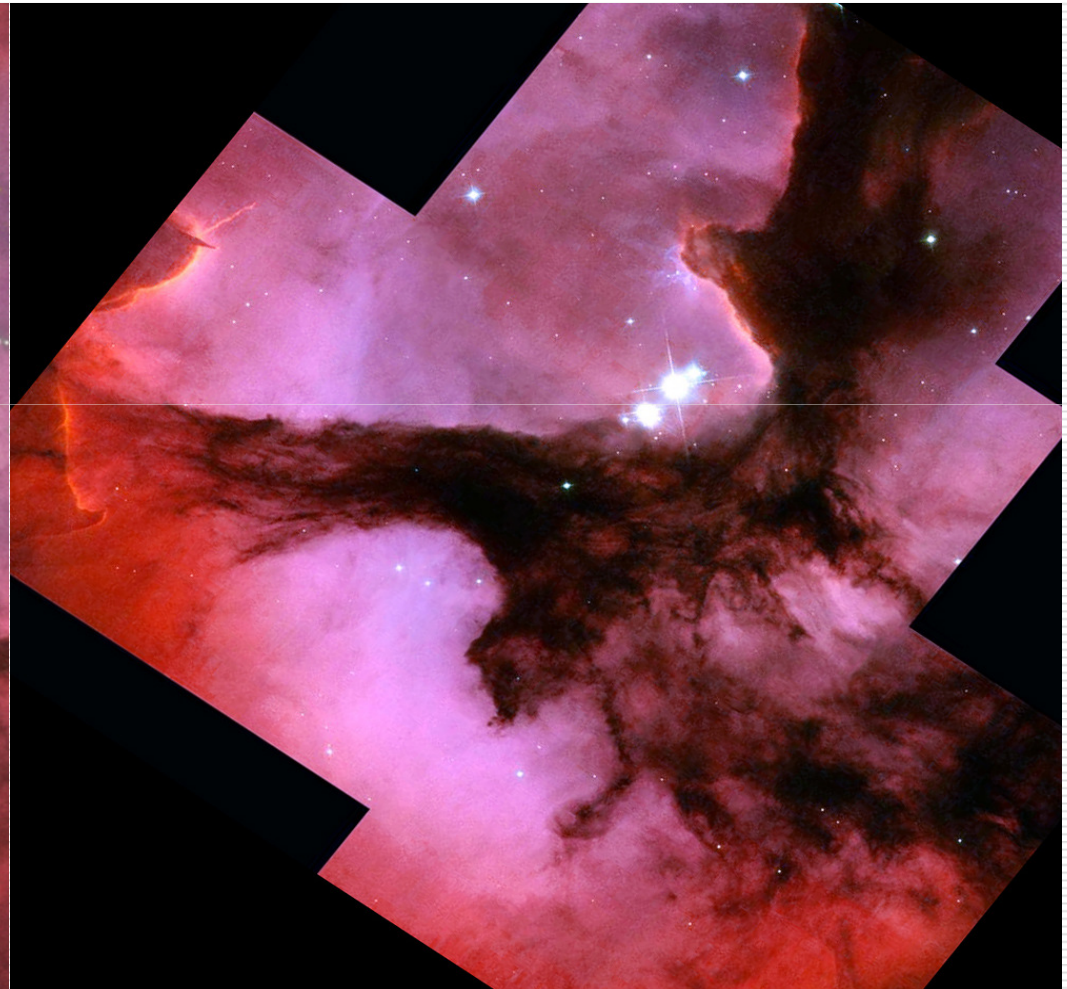


S-II/H-alpha/O-III
2,5m HST

Center of Trifid Nebula (M 20)



0,5 m JS



2,5 m HST

Airy Disk

$$d = 2.44 \times \lambda \times f \text{ (Rayleigh Criterion)}$$

d = Diameter airy disk (mm)

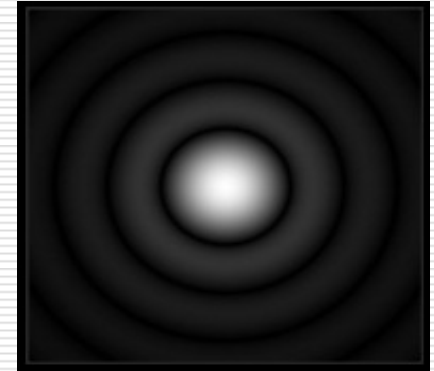
λ = Wavelength (mm)

f = Focal ratio (FL/D)

FL= Focal length (mm)

D = Aperture telescope (mm)

θ = angular resolution



Linear diameter of airy disk (1st minimum) valid for all FL

Focal Ratio	650 nm	400 nm
f/2.8	0.00444 mm	0.00273 mm
f/5.6	0.00888 mm	0.00546 mm
f/11	0.01745 mm	0.01342 mm

Epsilon Lyrae at f/20

Angular Resolution

$$A = 208700 * (\text{ArcTan}(1.2197 * \lambda / D))$$

A = Angular Diameter Airy Disk (Arc Seconds)

λ = Wavelength (mm)

D = Aperture telescope (mm)

θ = Angular resolution acc. Rayleigh = A (arc-sec)

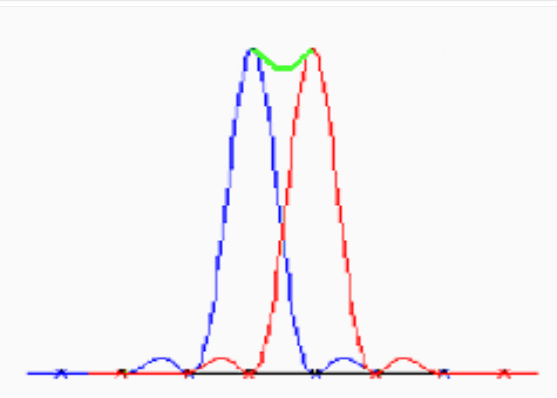
$$\theta = 140/D \text{ (550 nm)}$$

(Rayleigh)

$$\theta = 116/D \text{ (550 nm)}$$

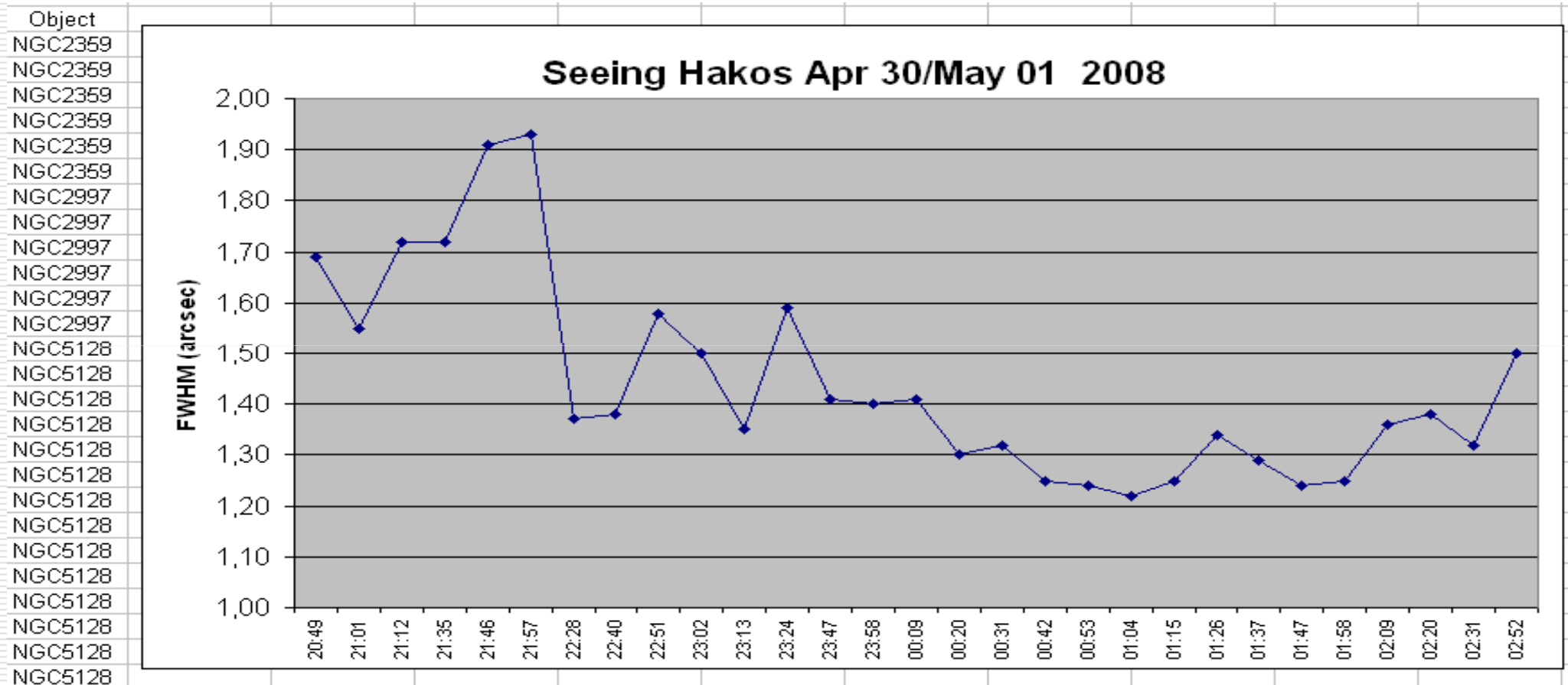
(Dawes)

Aperture	Rayleigh res. at 650 nm	Rayleigh res. At 400 nm
140 mm	1,182"	0,727"
400 mm	0,414"	0,255"
800 mm	0,207"	0,127"

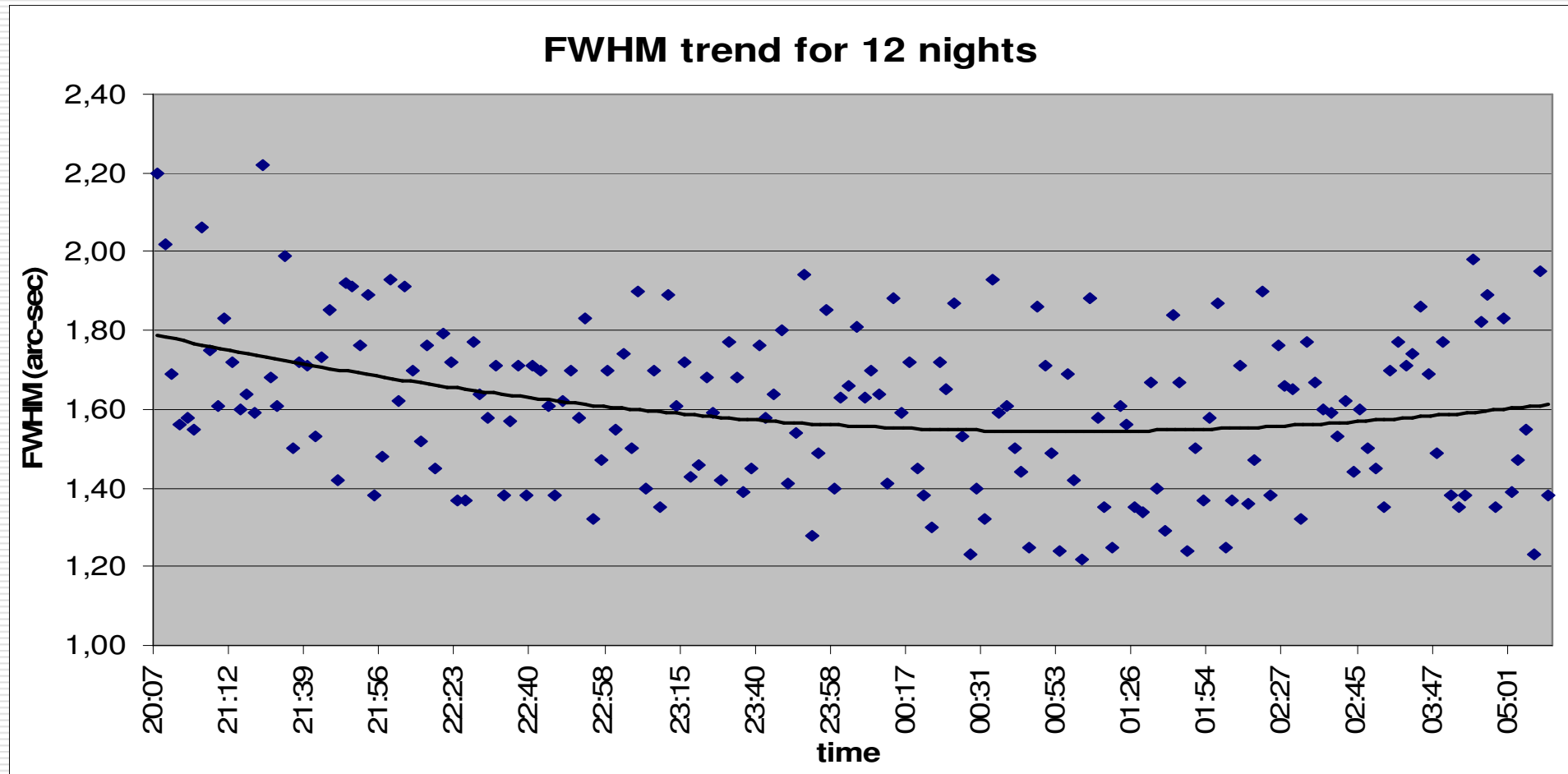


**2 PSF separated
by 1 radius**

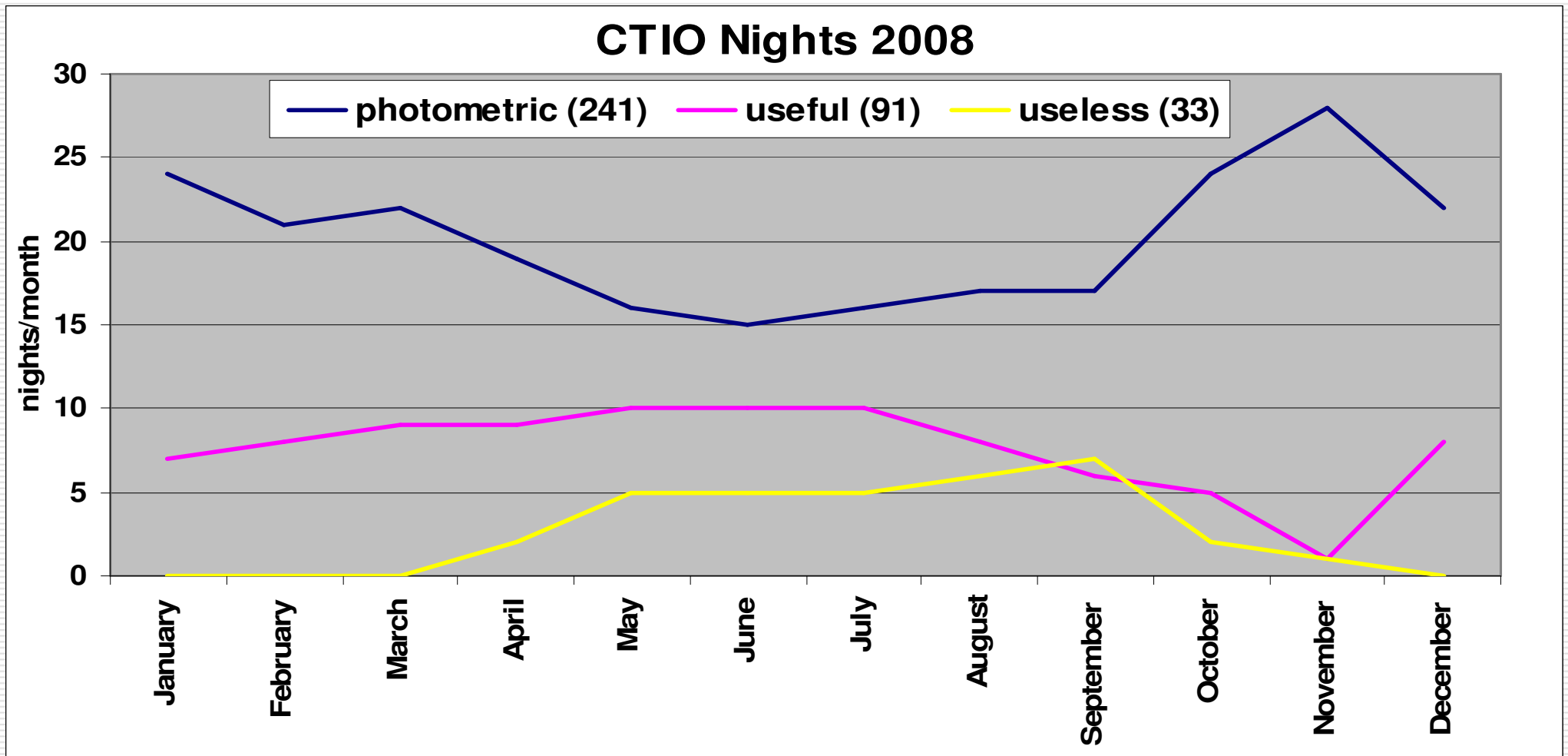
Seeing at Hakos



Seeing at Hakos



Weather at CTIO (Chile)



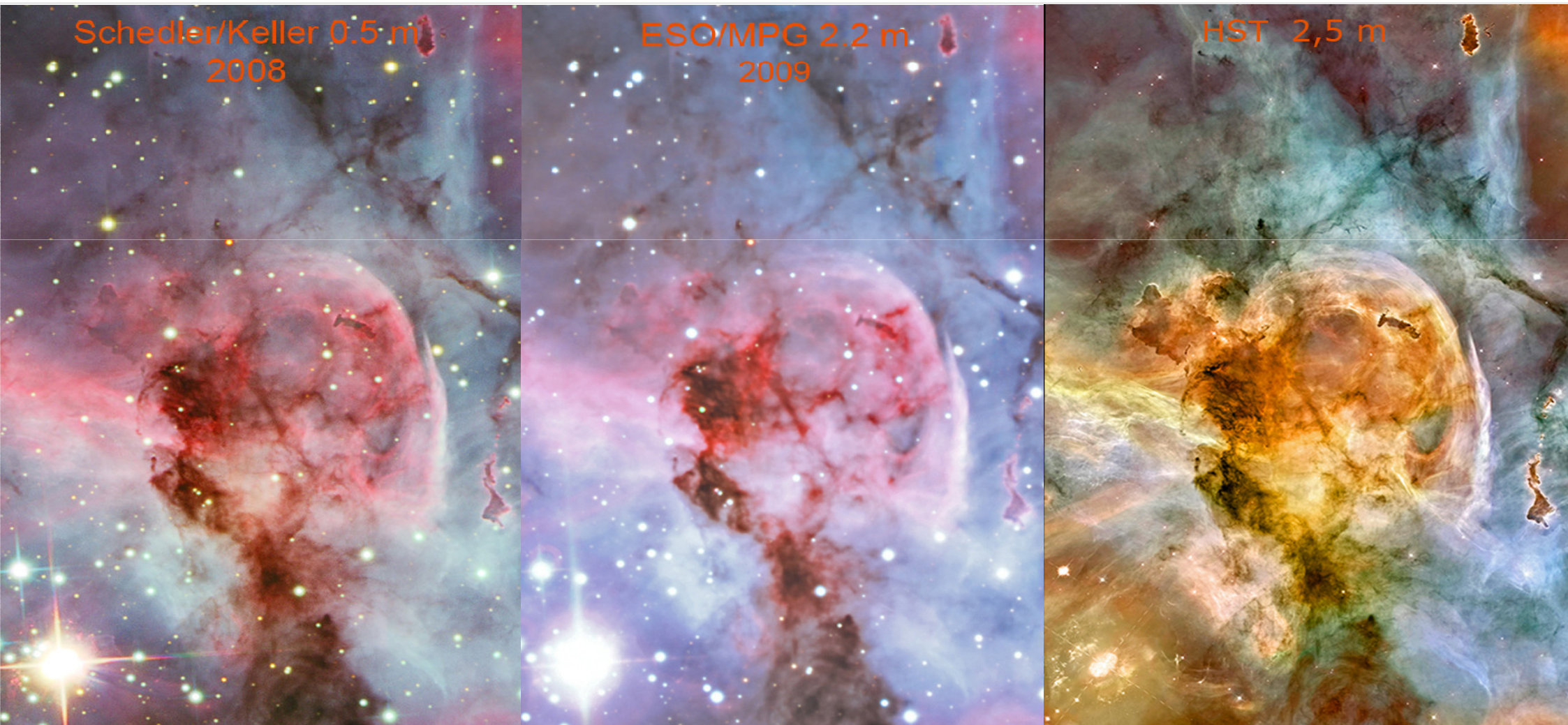
How to compete?

- Search for dark rural skies, laminar winds
- Make mosaics
- Use narrowband filters
- Use good calibration files (master bias, dark, flat)
- Exercise in postprocessing

Eta-Carina Nebula (NGC 3372)



Keyhole in Eta-Carina (NGC 3372)



Cosmic Finger in Eta Carina (45'' wide image)



0,5 m
JS



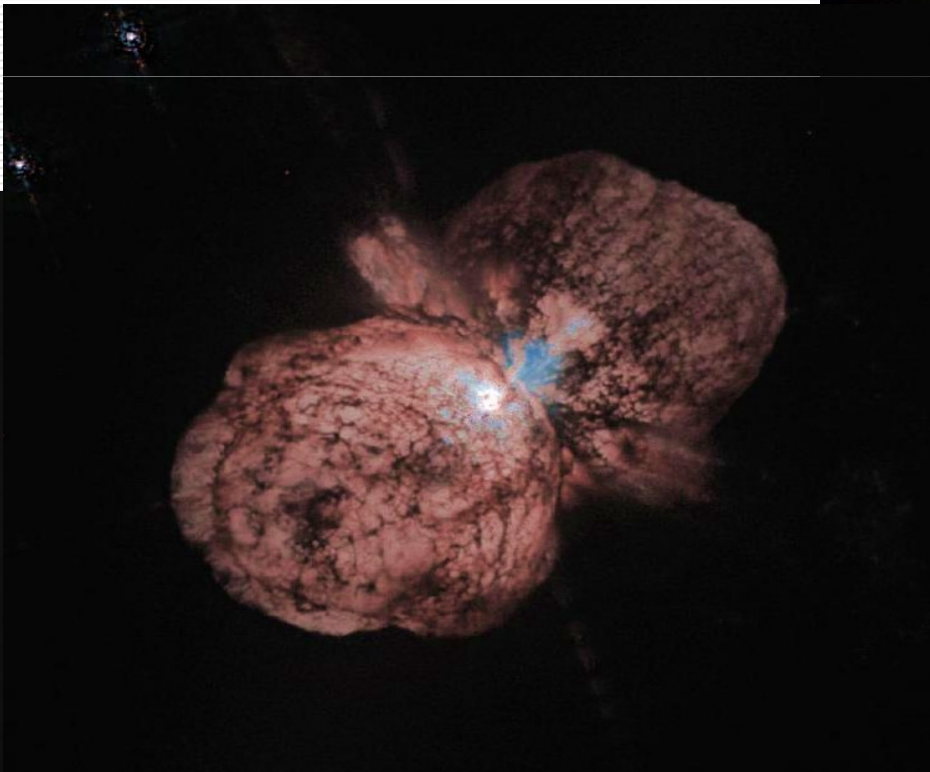
2,5 m
HST

Eta Carina - Homunculus (20'' diameter)

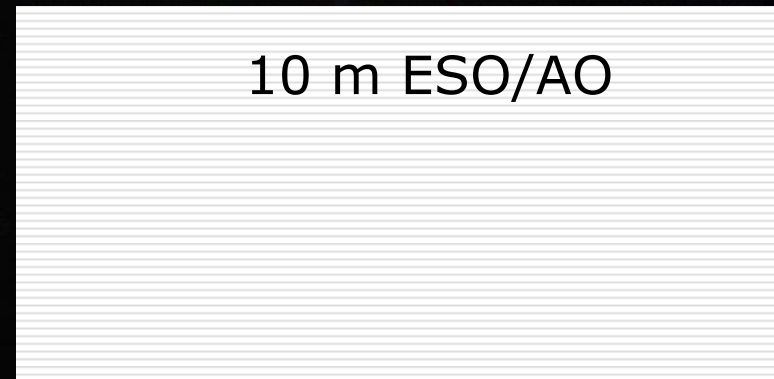
2,5 m HST



0,5 m JS



10 m ESO/AO



Further Goals of Ambitious Amateurs

- New Minor Planets/comets
- Variable stars
- Exo-Planets
- Planetary Imaging (example: Damian Peach)

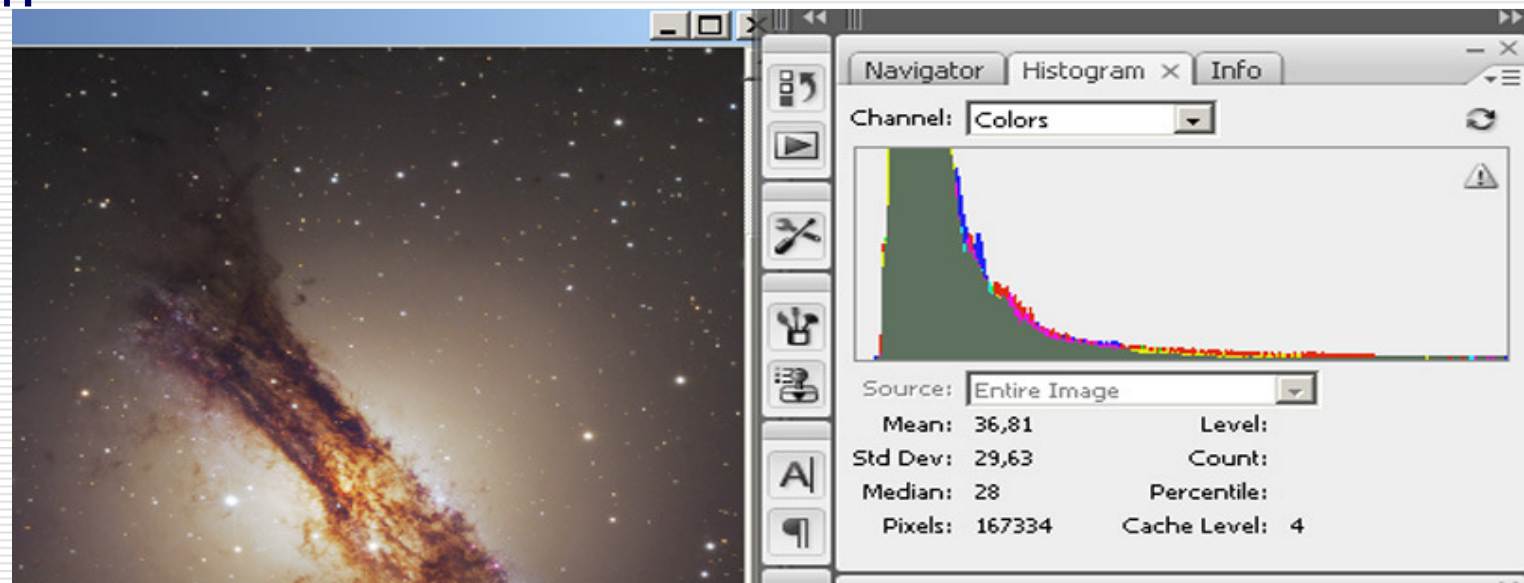
Postprocessing I

Import:

Fits Format imported by Fitsliberator (Freeware) into Photoshop converting to 16 bit tiff

Histogramm:

Clipped (black and white) areas are generating an irreversible loss of information!



Postprocessing II

Colors:

- Take colors in 1x1 binning
- Use 1:1:1 color weighted RGB filters
- Use flats (gradients!)
- Do RGB acquisition in RGB-RGB-RGB sequence
- Increase saturation in early stage
- Create synthetic luminance in no L available

Postprocessing III

Sharpening:

Less is superior!

Excessive sharpening produces artefacts and may destroy the image

Sharpening only should be applied to bright areas!

Noise Reduction:

Noise reduction means low pass filtering, loss of details is the consequence

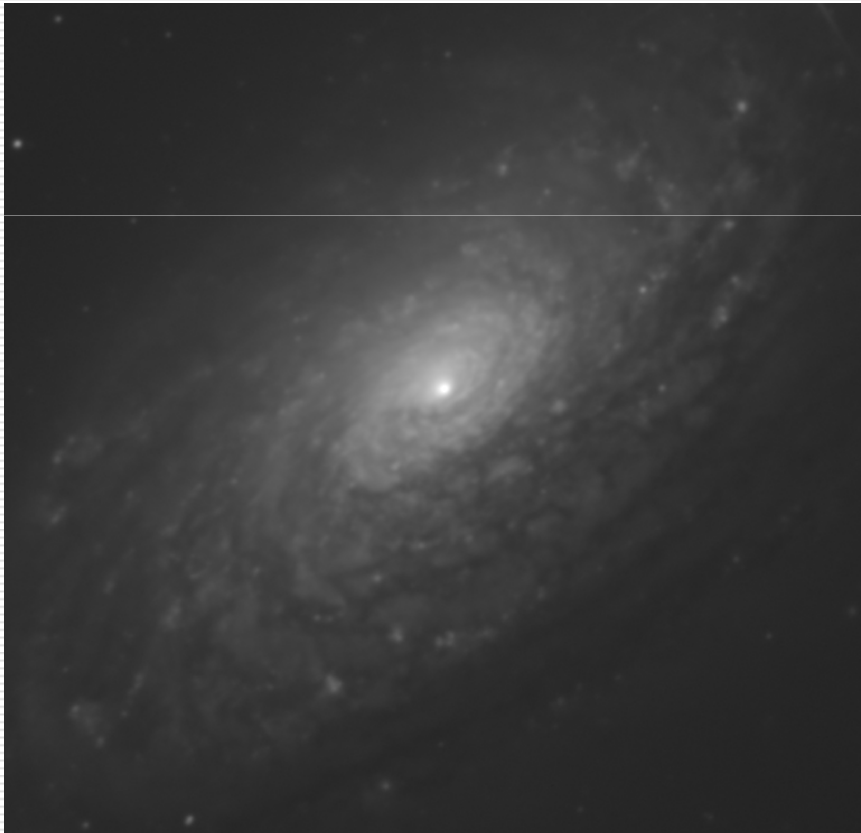
NR only should be used for darker areas

Bright areas are showing a high S/N ratio and contain details that are sacrificed by applying noise reduction

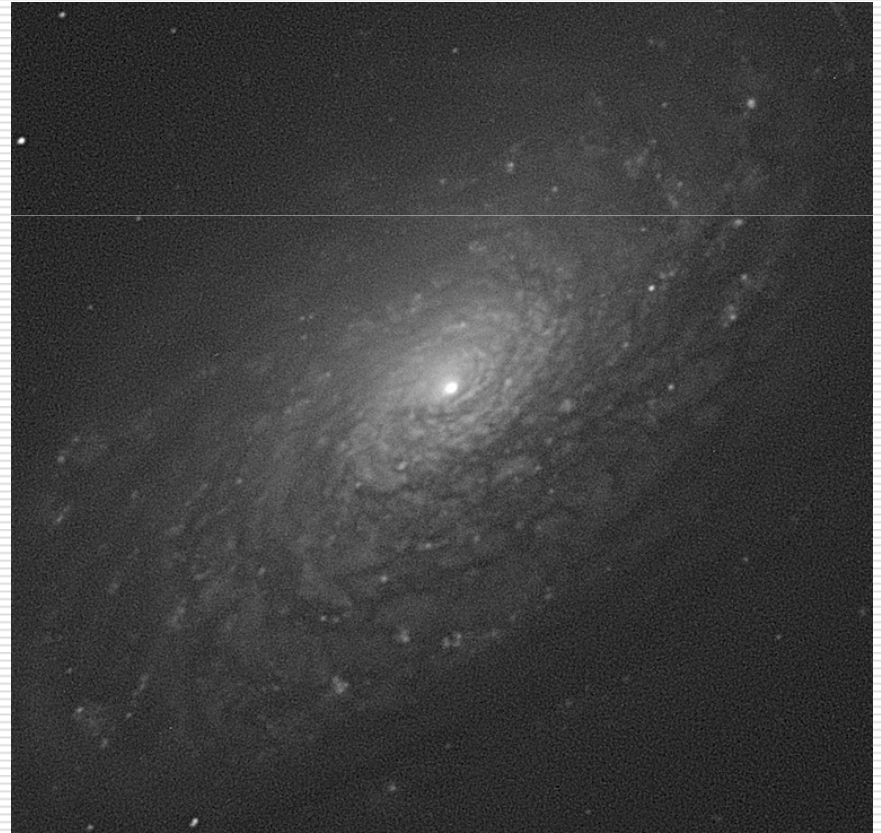
Postprocessing IV: revealing details

Exposure 30 min

M 63 straight luminance



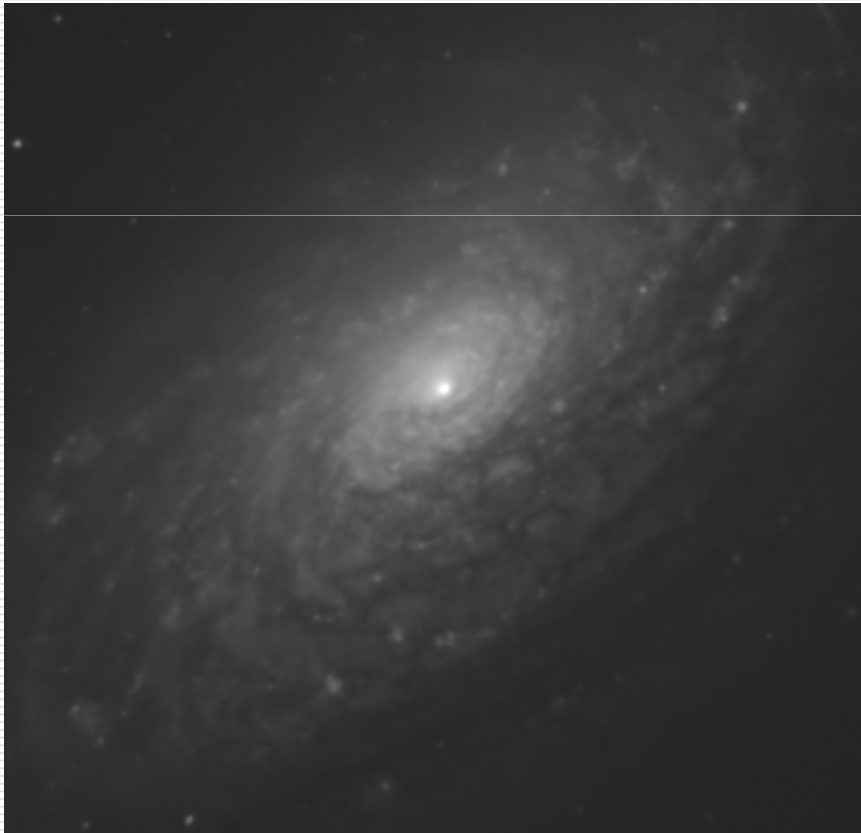
M 63 luminance with wavelets filter



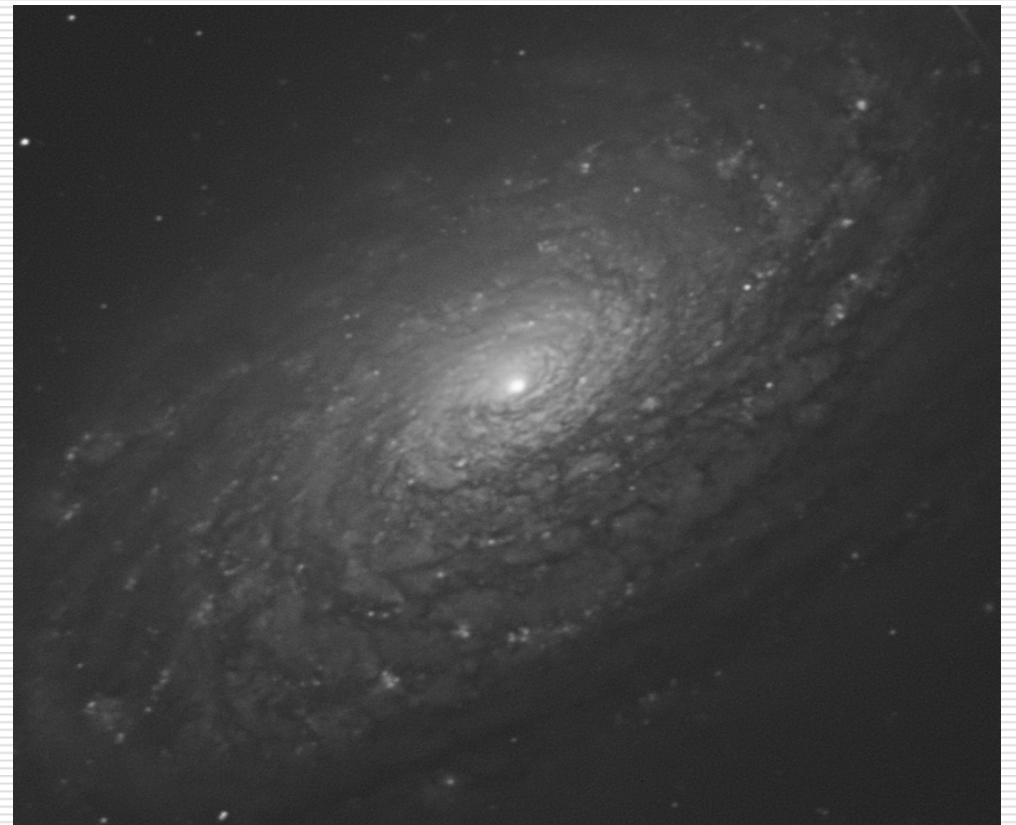
Postprocessing IV: revealing details

Exposure 8 h

M 63 straight luminance



M 63 luminance with wavelets filter



HST

NGC 6357 (0,5 m)

Gemini



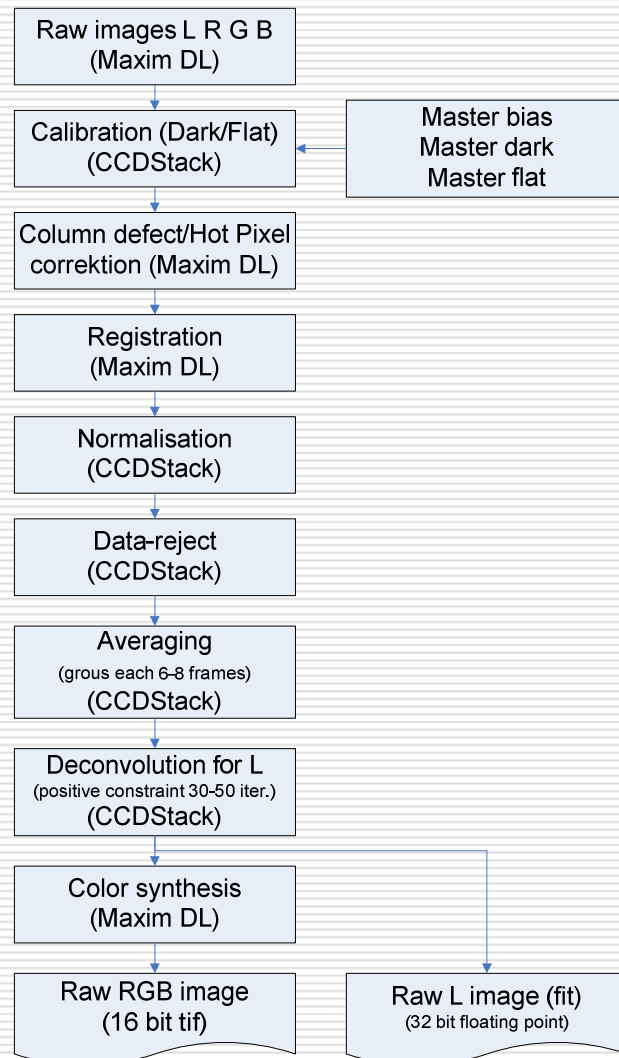
Center of M 8 (hourglass area)



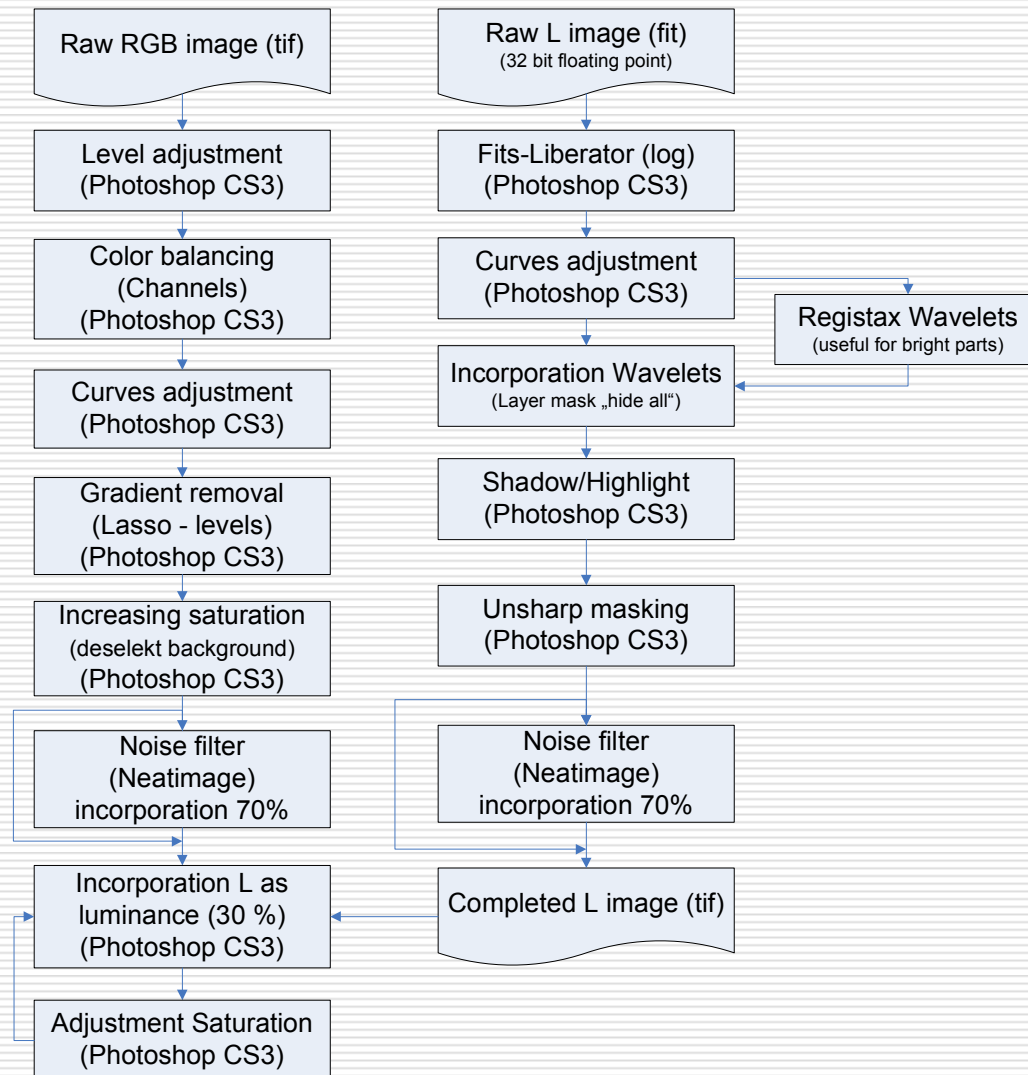
Center of M 8 (hourglass area)



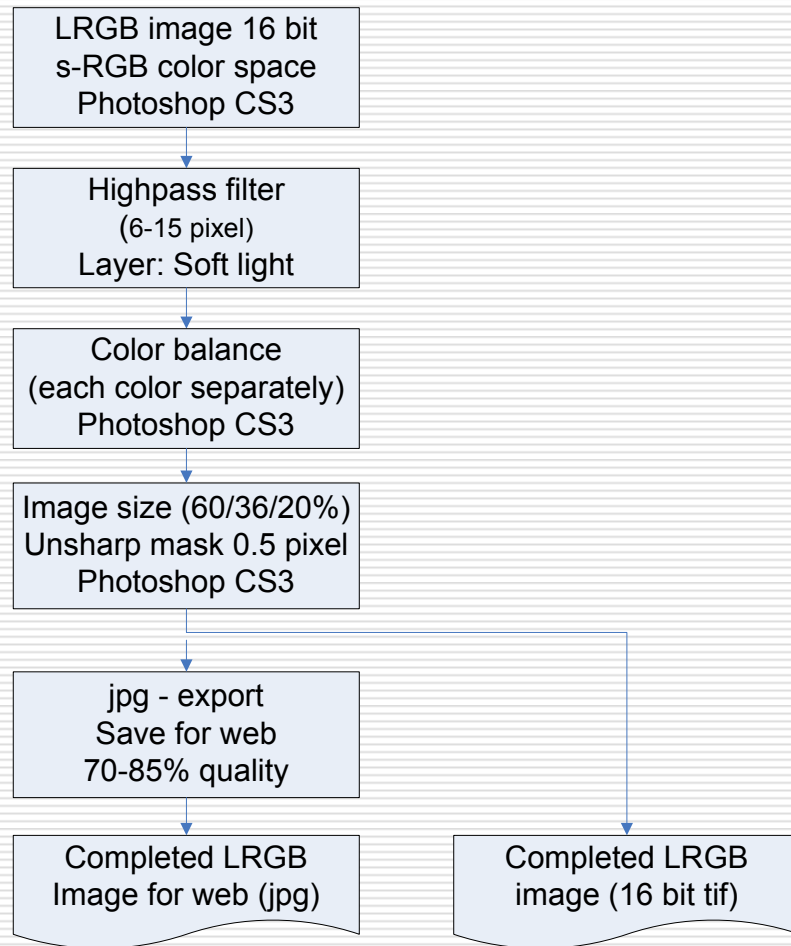
Workflow 1



Workflow 2



Workflow 3

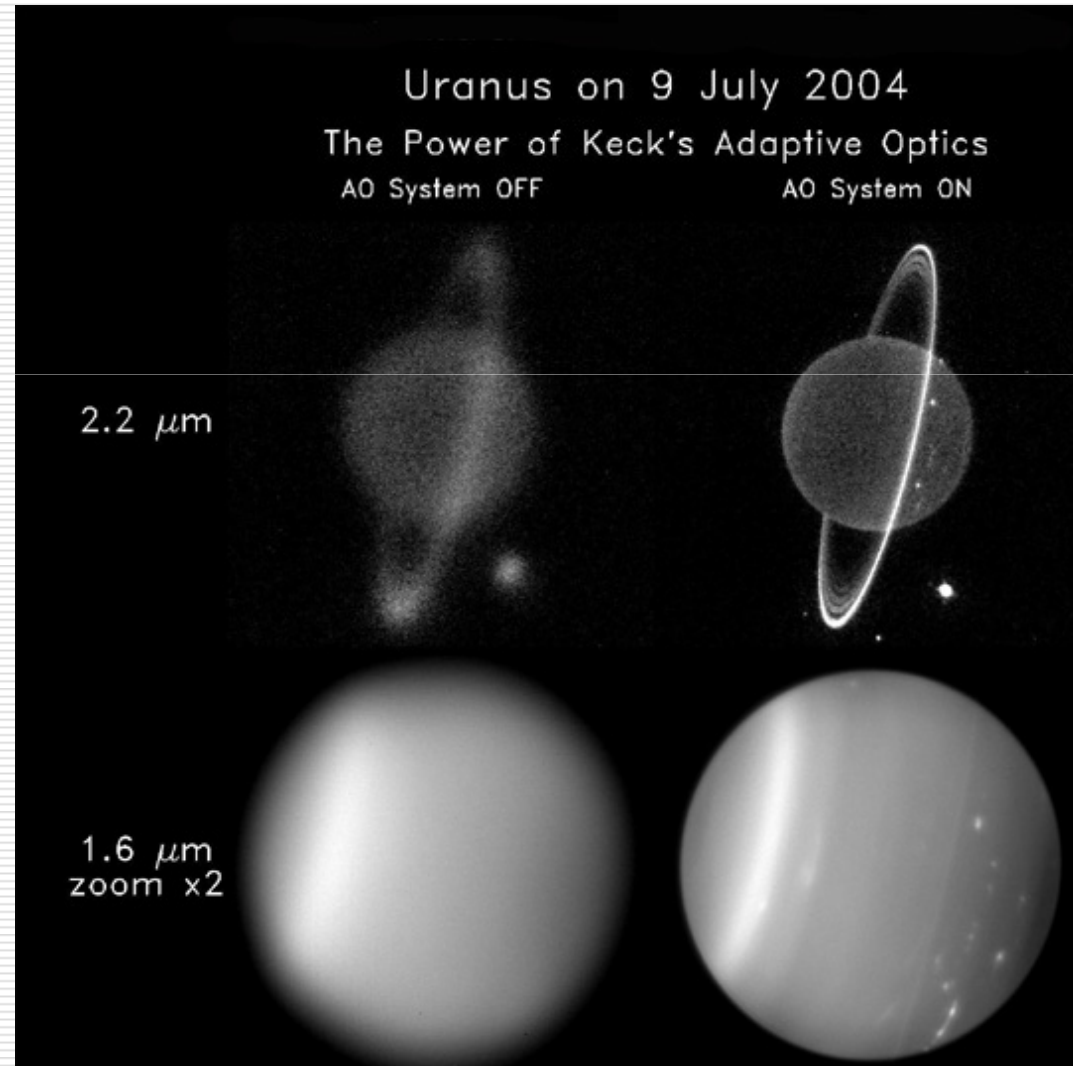


Future

Remote imaging from dark sites

Single photon CCDs

Adaptive Optics for amateurs



Links

Panther-Observatory:

<http://panther-observatory.com/>

Bernd Wallner's Homepage:

<http://www.colour-universe.de/>

Philipp Keller Telescope Manufacturer:

<http://www.astrooptik.com/>

IAS Observatory (Hakos):

<http://www.ias-observatory.org/>

Baader Filters:

<http://www.baader-planetarium.de/sektion/s43c/s43c.htm>