Telescope Innovations

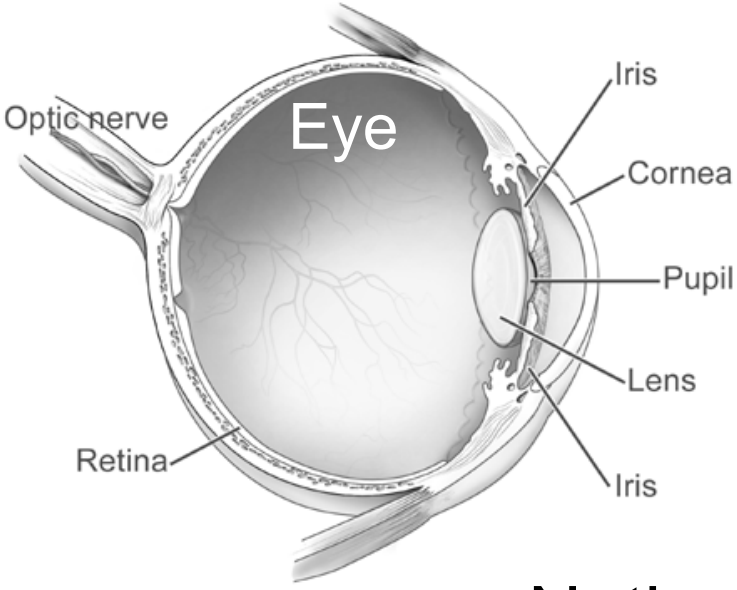
Modern Techniques

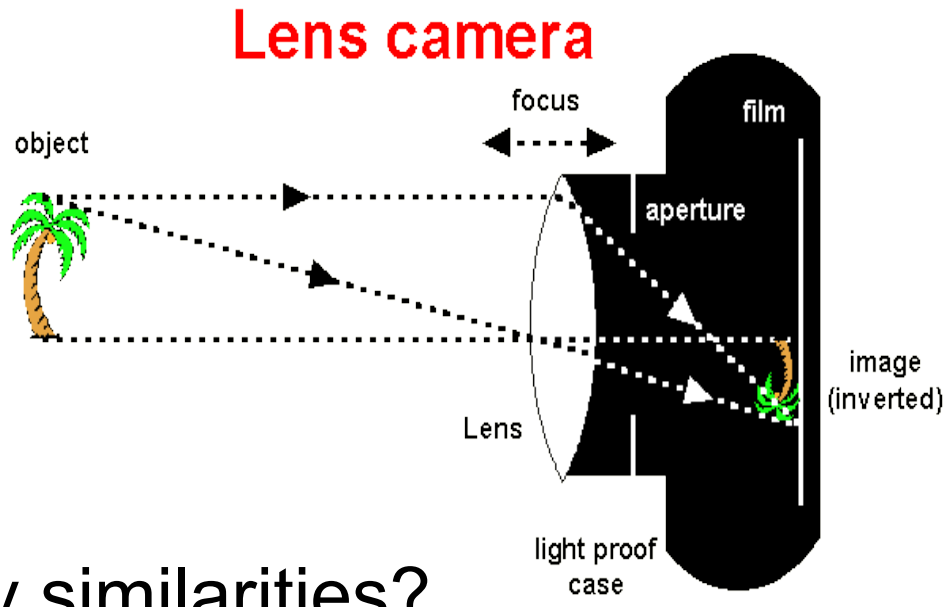
Modern Telescopic Techniques

- Imaging
- Interferometry
- Image Processing
- Adaptive Optics
- Spectrometer
- Photometer

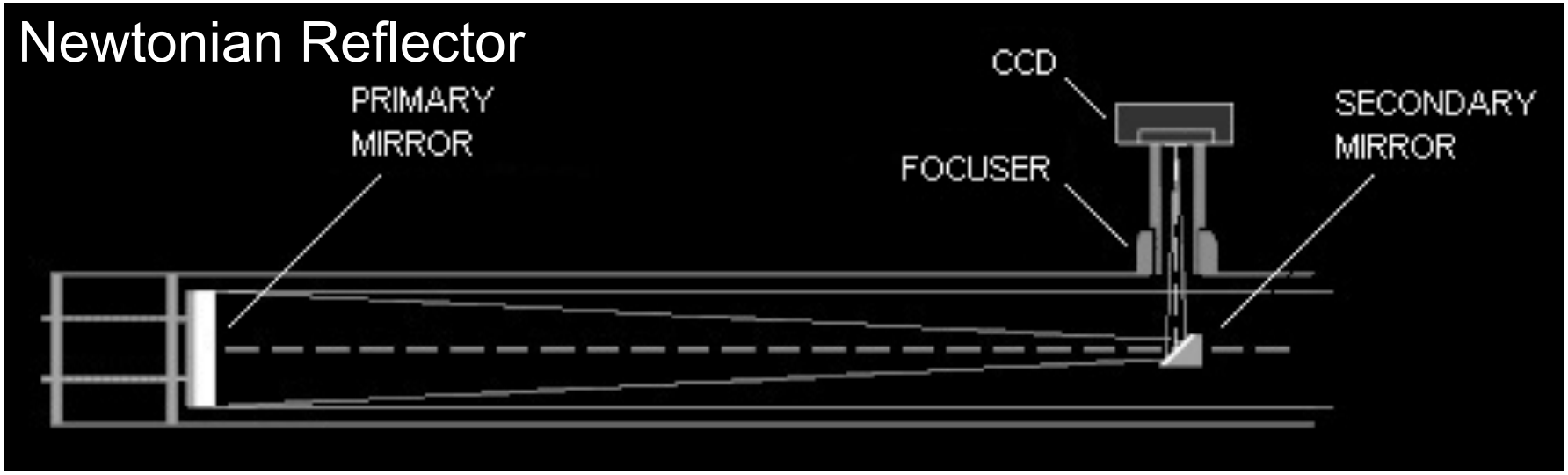
Imaging

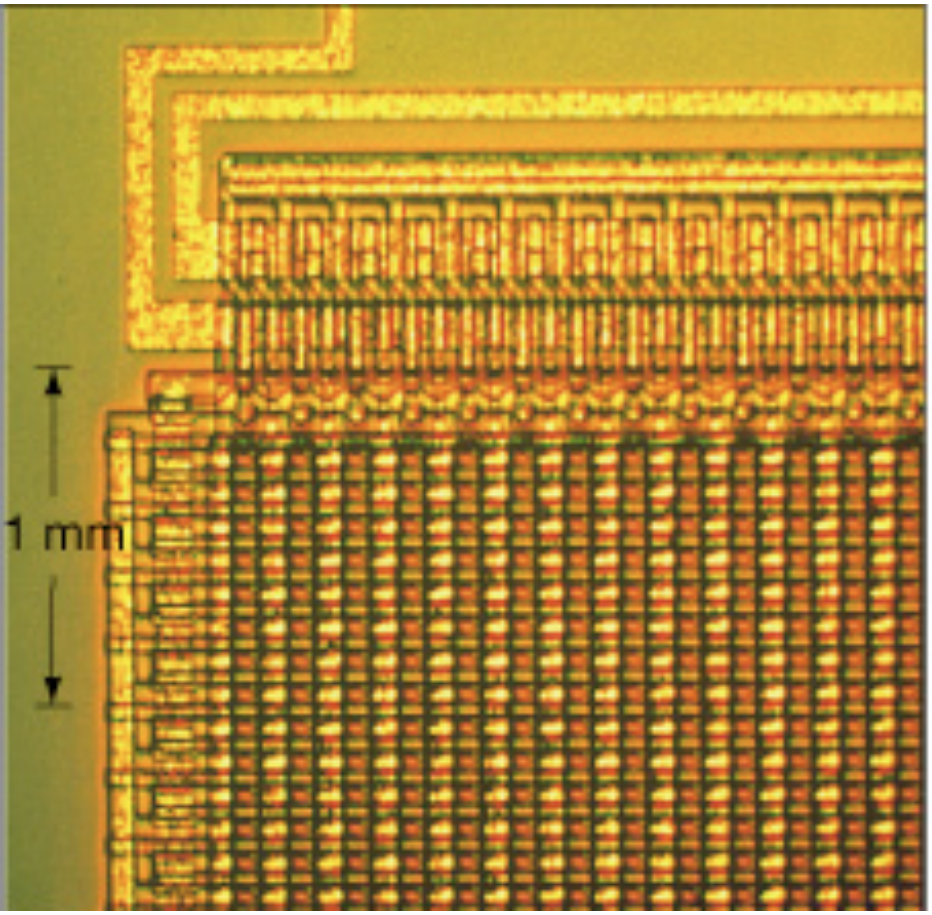
- A telescope is obviously useful for *looking* at distant objects, but also it can be used to *take pictures*! This is often the case.
- An imaging device is placed at the focus of the objective lens (or primary mirror).
- This device is usually a digital chip – a Charge-Coupled Device (CCD), same as found in digital camera or cell phone camera.
- Prior to digital technology, photosensitive film was used to capture images.

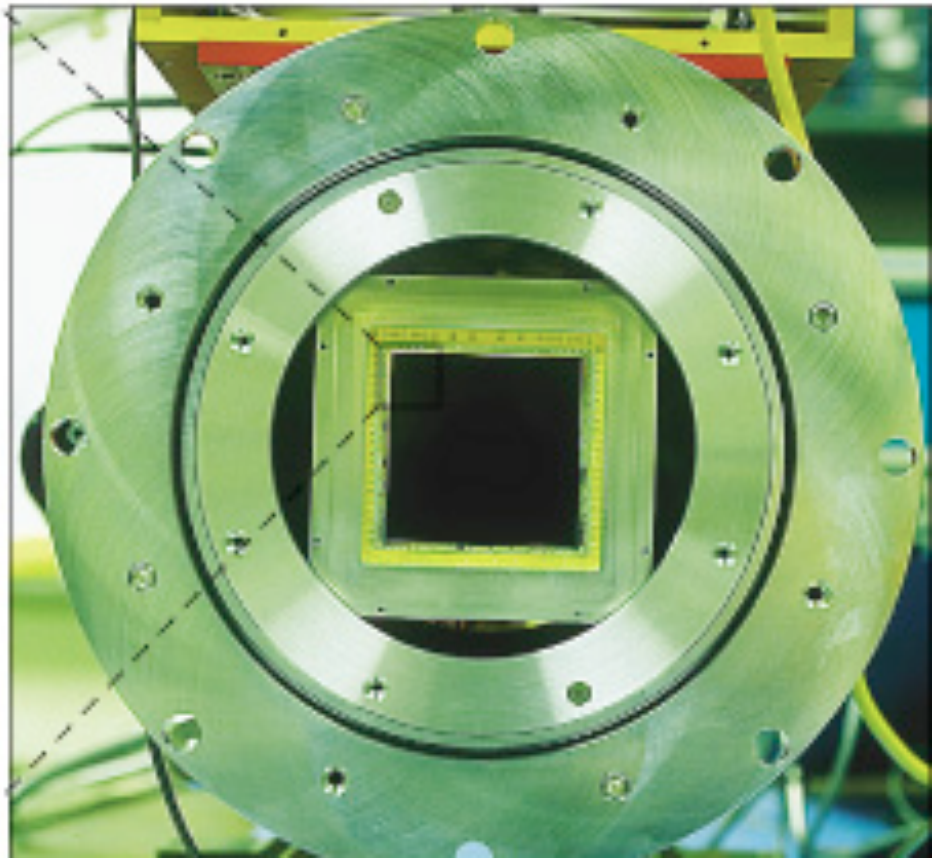




Notice any similarities?





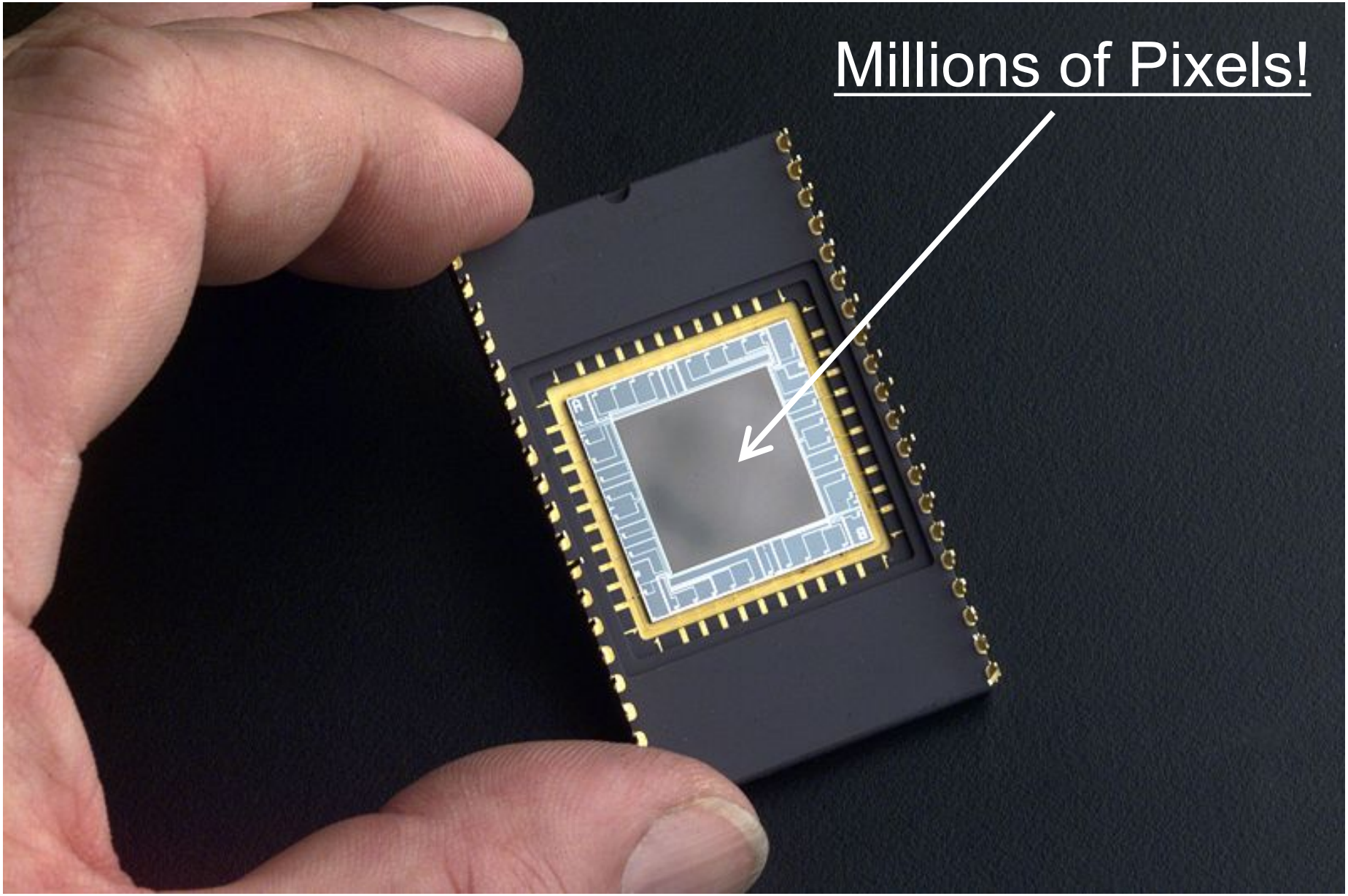


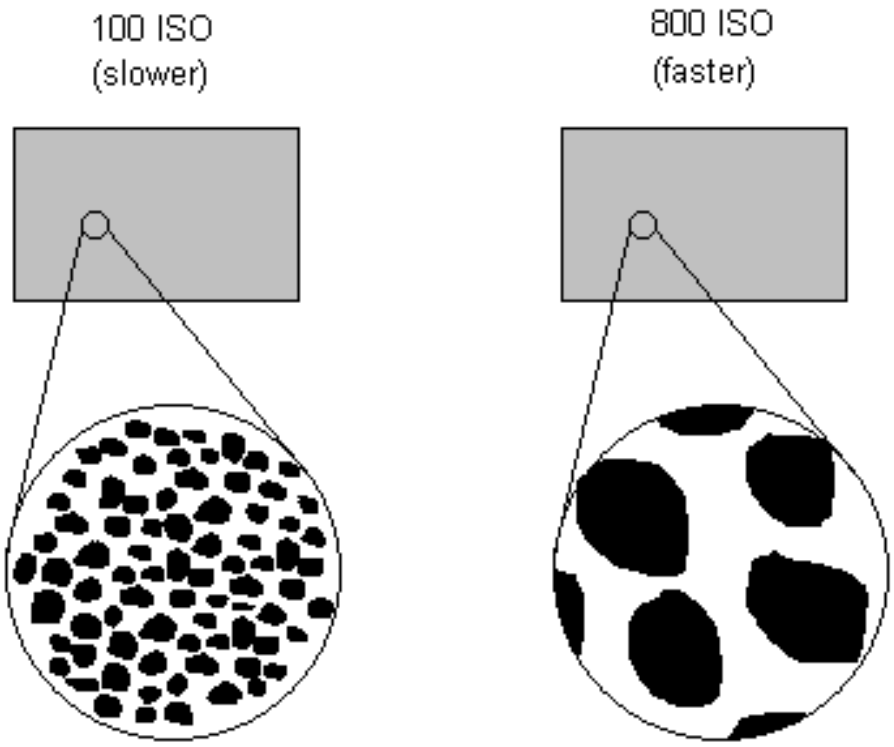
Consists of thousands of tiny electronic picture elements or "pixels"

CCD Imager – a digital "photographic plate"

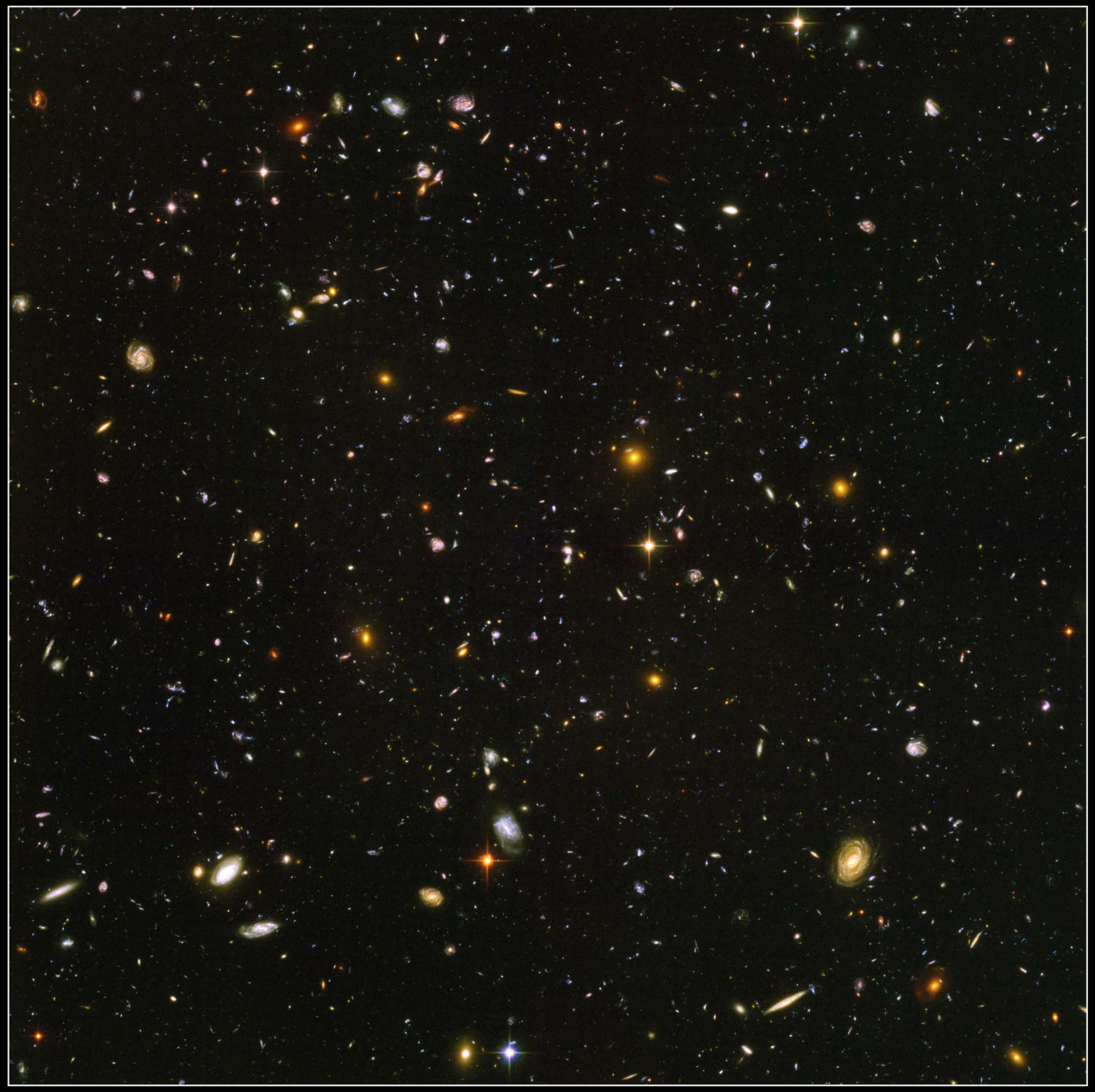
Resolution and Pixels

- The size and number of pixels affect the resolution of the resulting image.
- The smaller the pixels and/or greater the number, the greater the resolution.
- This is an issue separate from the resolving capabilities of the optics in a telescope.


Millions of Pixels!



A film's *grains* are similar to a CCD's *pixels*.



Hubble Ultra Deep Field
Hubble Space Telescope • Advanced Camera for Surveys

HST 2004

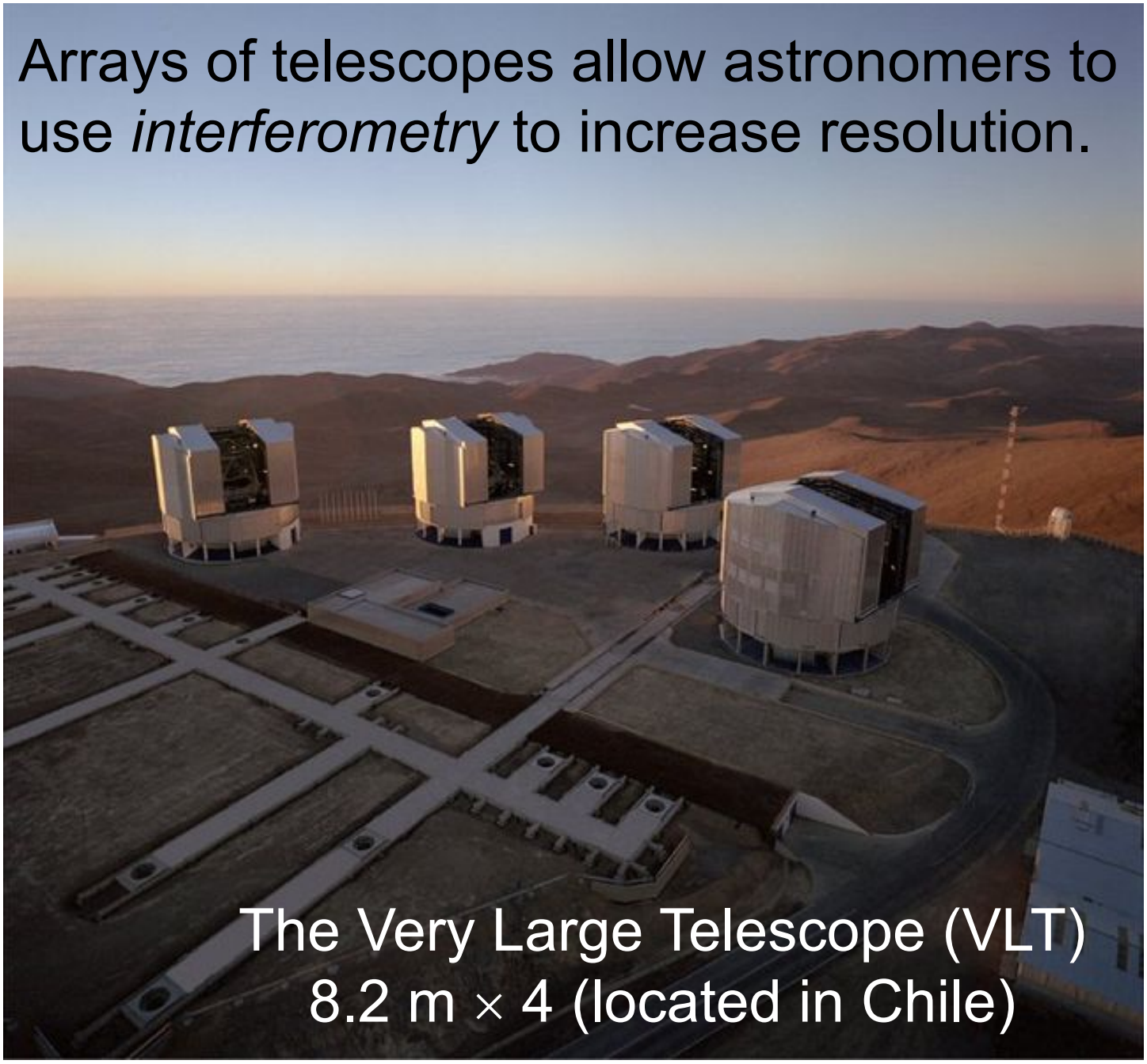
Look through the same telescope with an eyepiece and you would see nothing!

Exposure Time:
267 hours
(11 days)

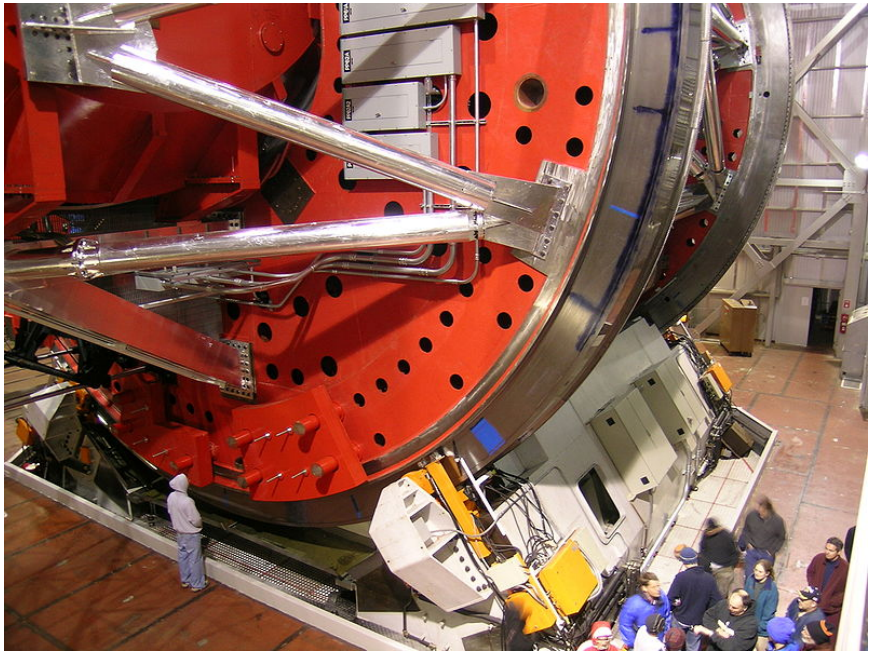
Imaging Summary

- Using film or CCD allows detection of features not visible to the naked eye.
- Light gathering can be increased by simply increasing exposure times.
- CCD's have become the standard because of greater sensitivity than film and pixel sizes comparable to grain sizes.

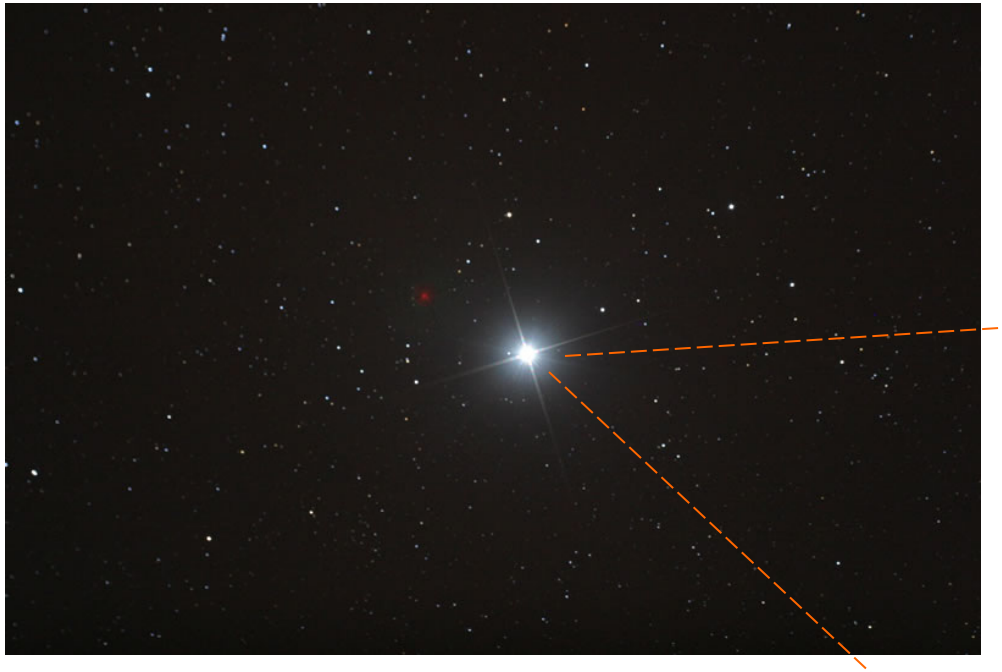
Arrays of telescopes allow astronomers to use *interferometry* to increase resolution.



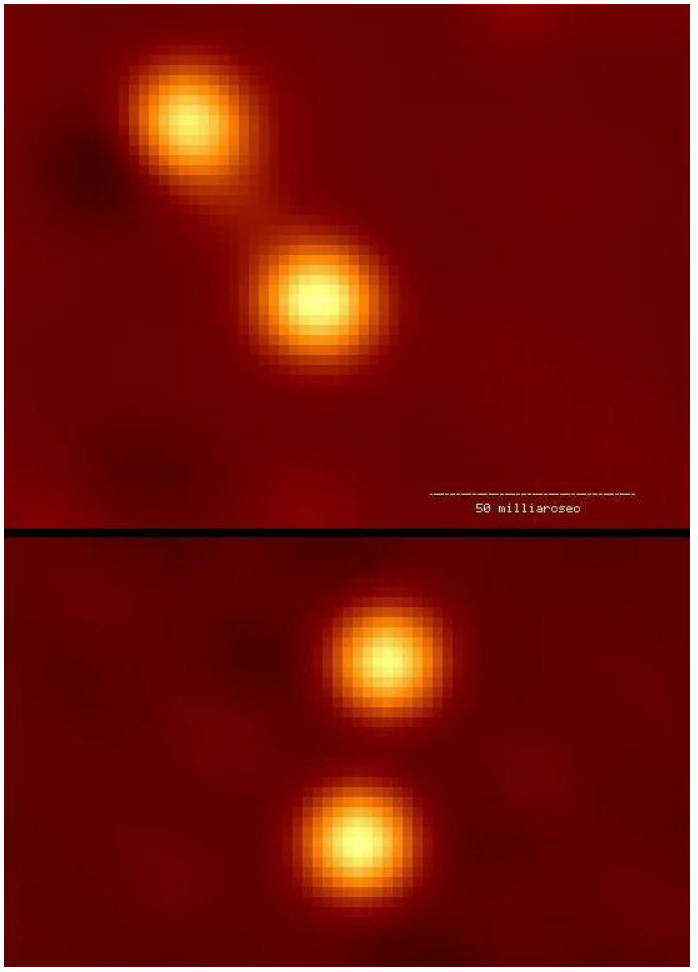
The Very Large Telescope (VLT)
8.2 m × 4 (located in Chile)



Large Binocular Telescope
8.4 m × 2

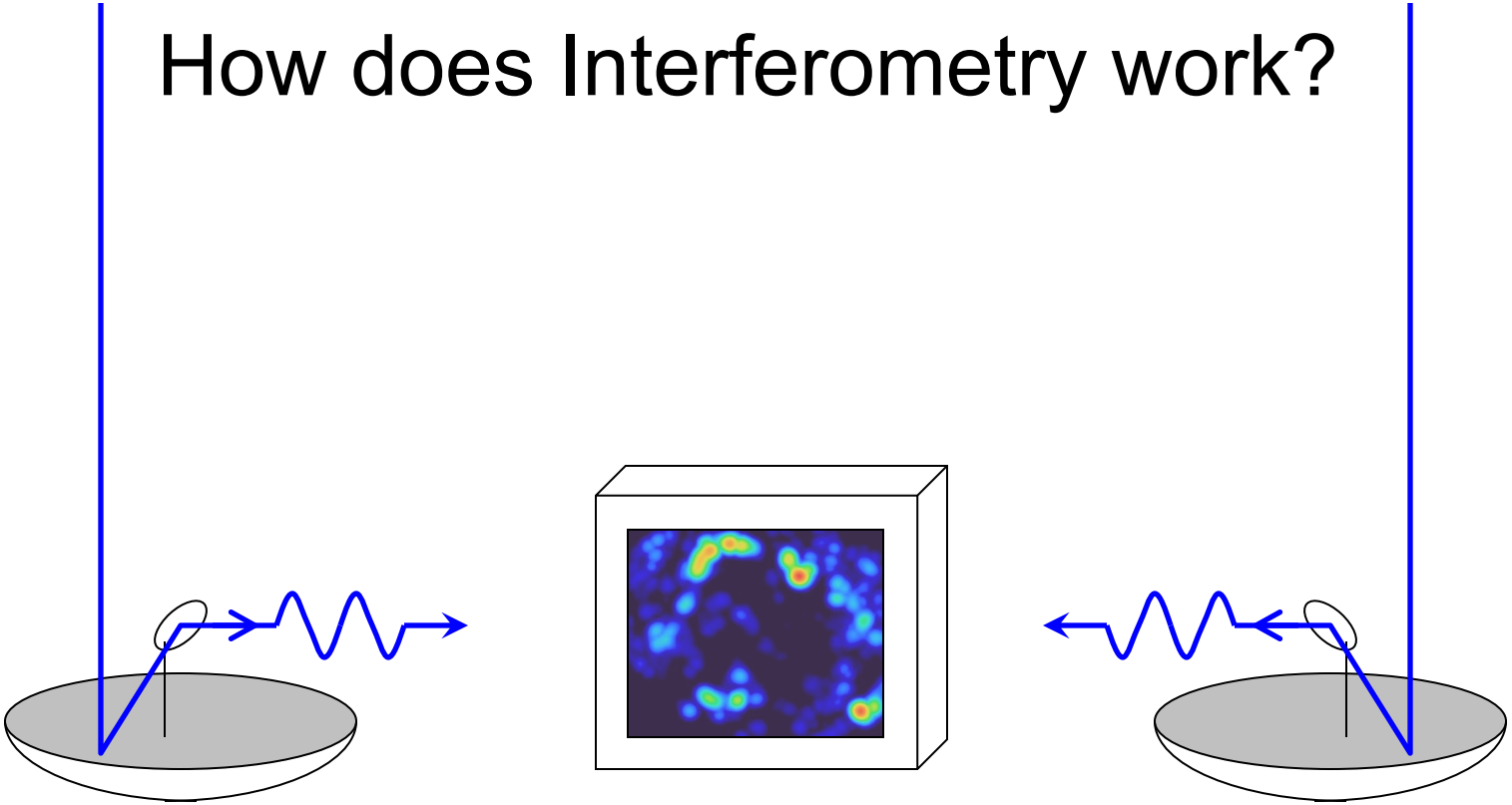


Capella is a bright star in Auriga…



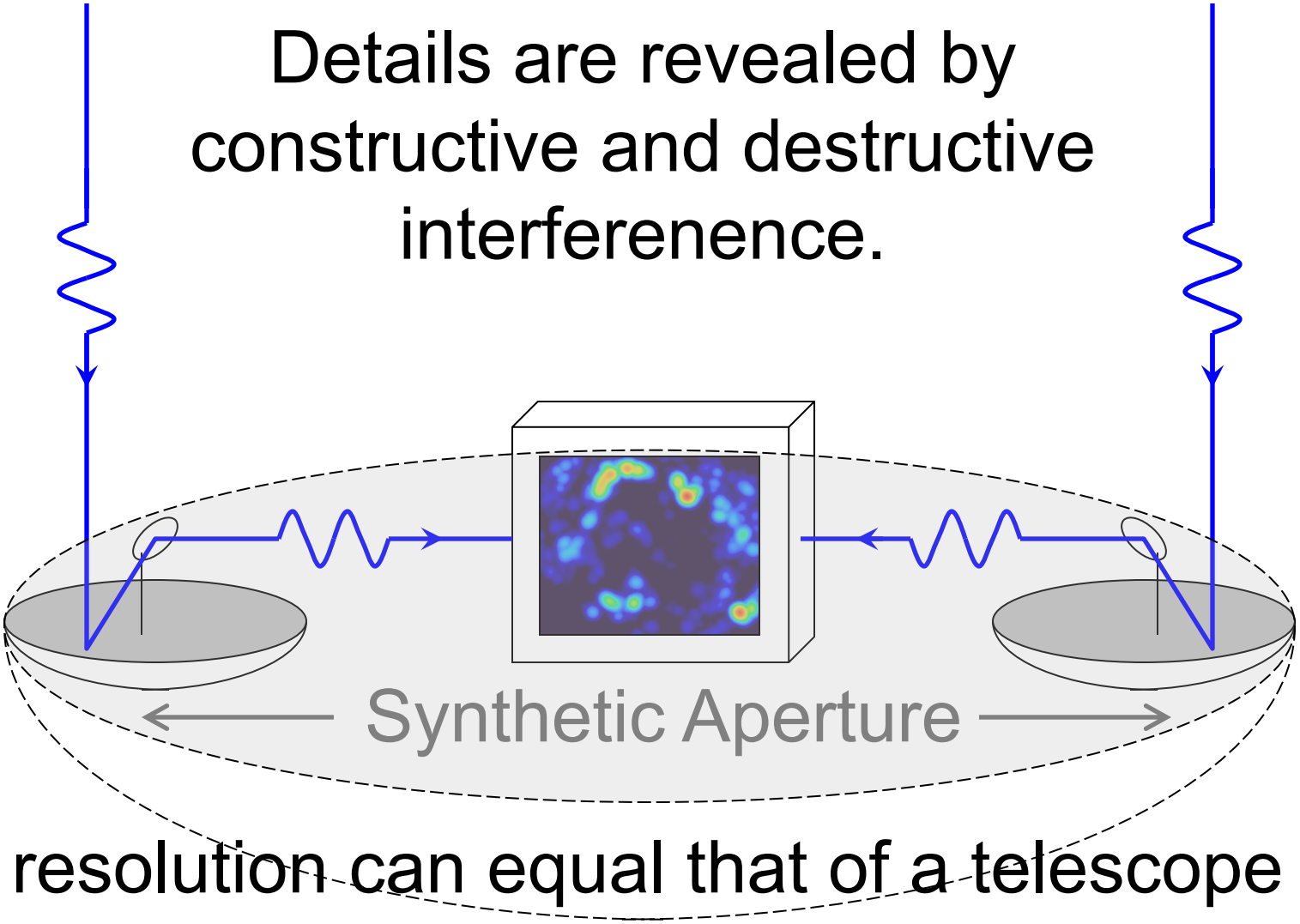
…but interferometry reveals it to be *two* stars orbiting one another – a binary star system.

How does Interferometry work?



Light (or other EMR) from two separate telescopes is combined to form an image.

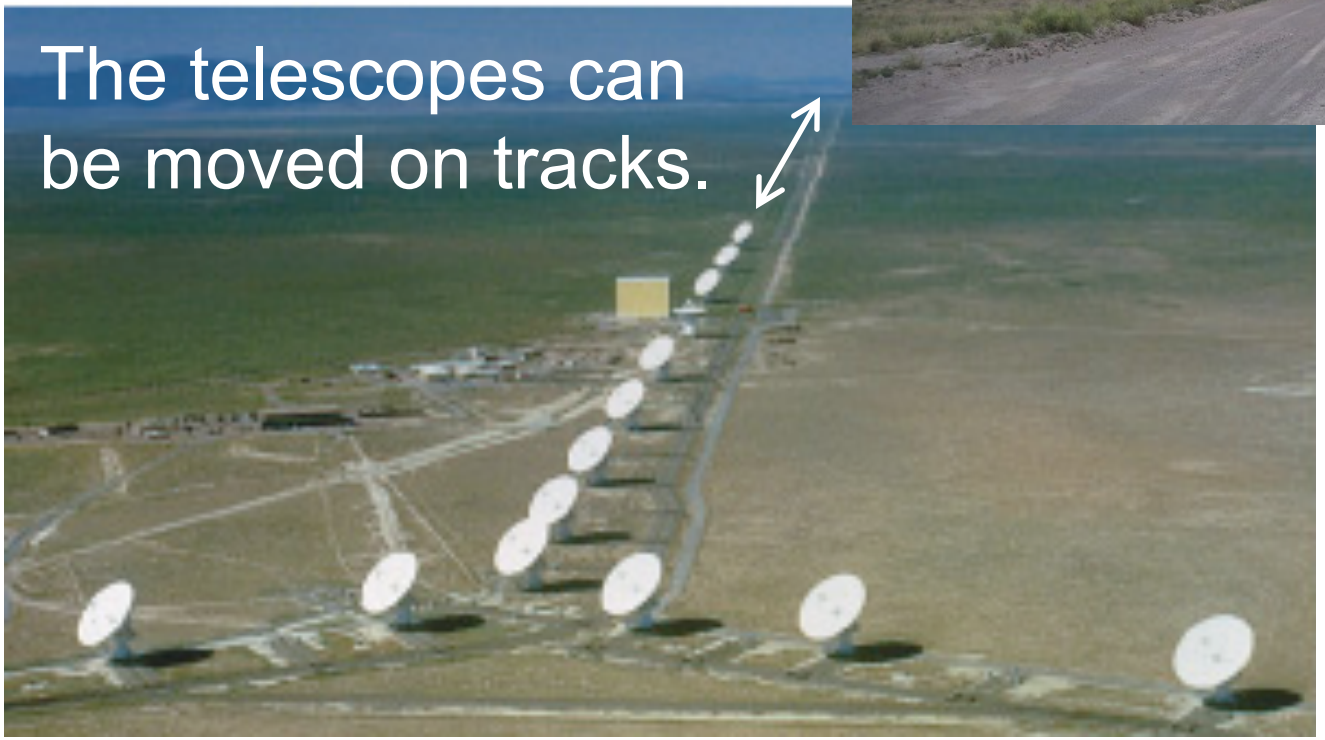
Details are revealed by constructive and destructive interferenence.



The resolution can equal that of a telescope with diameter equal to the maximum separation of the telescopes. This is called a *synthetic aperture*.

The Very Large Array

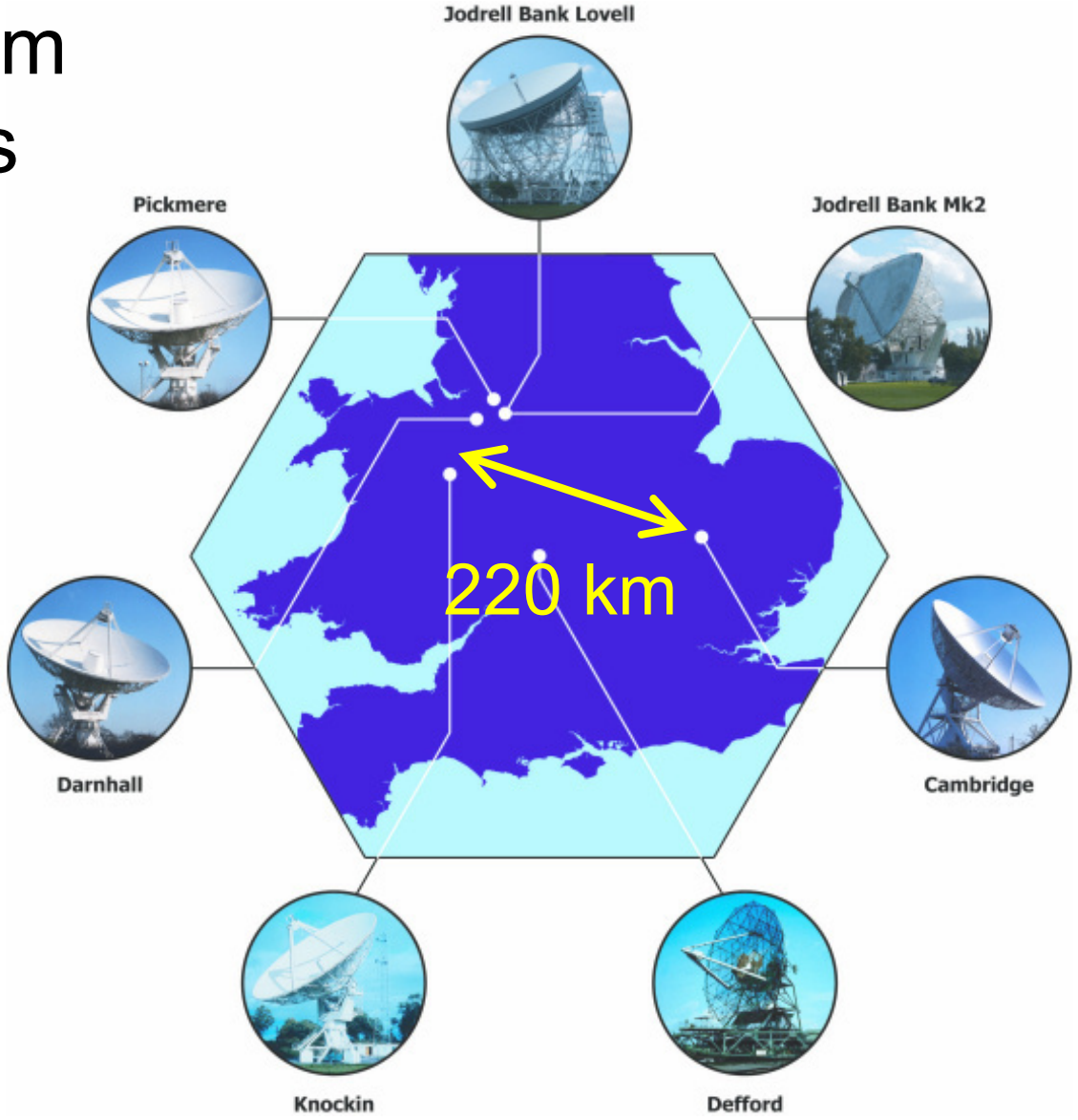
VLA consists of 27 radio telescopes, each with diameter 25 m.



Maximum synthetic aperture is 36 km.

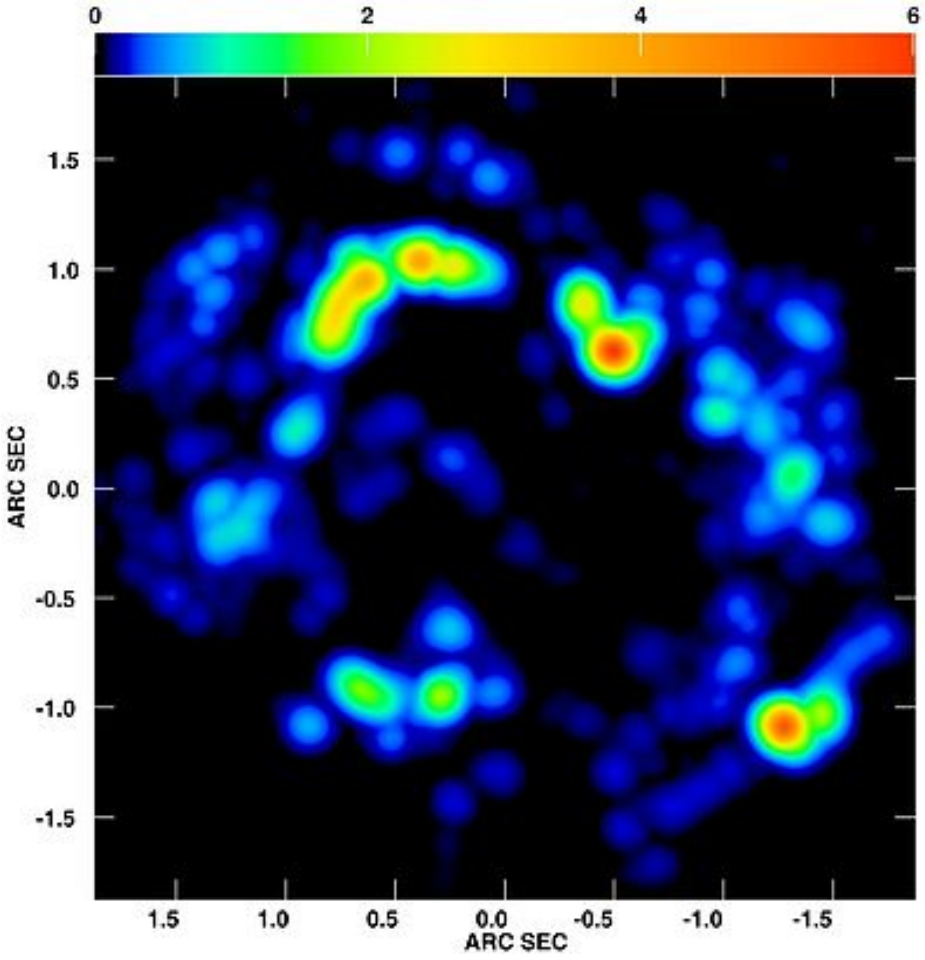
Working at 7 mm wavelength, its resolution is about 50 milliarcseconds.

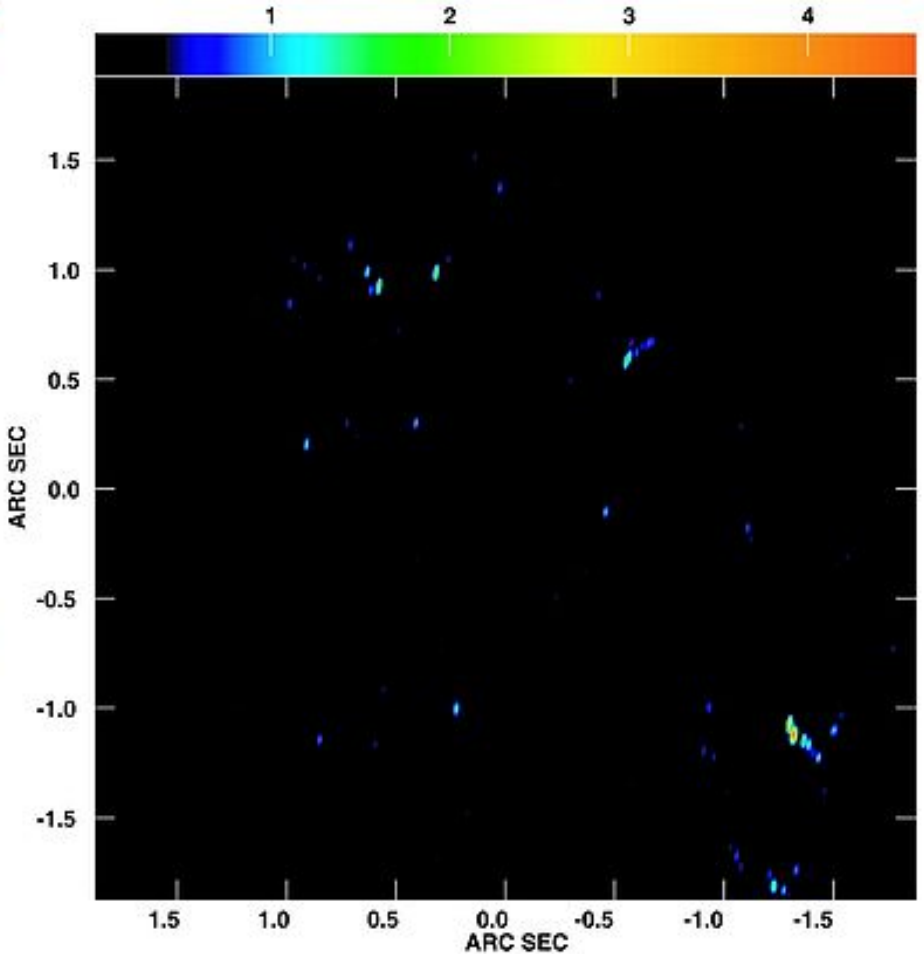
Working at 6 cm wavelength, its resolution is about 50 mas.



MERLIN

Multi-Element Radio Linked Interferometer Network





UK's MERLIN

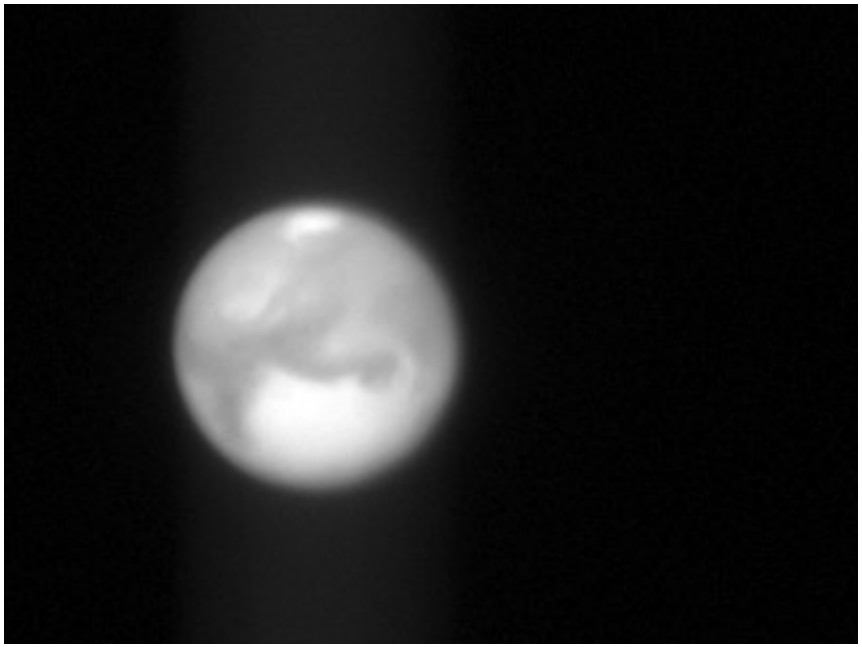
European VLBI Network

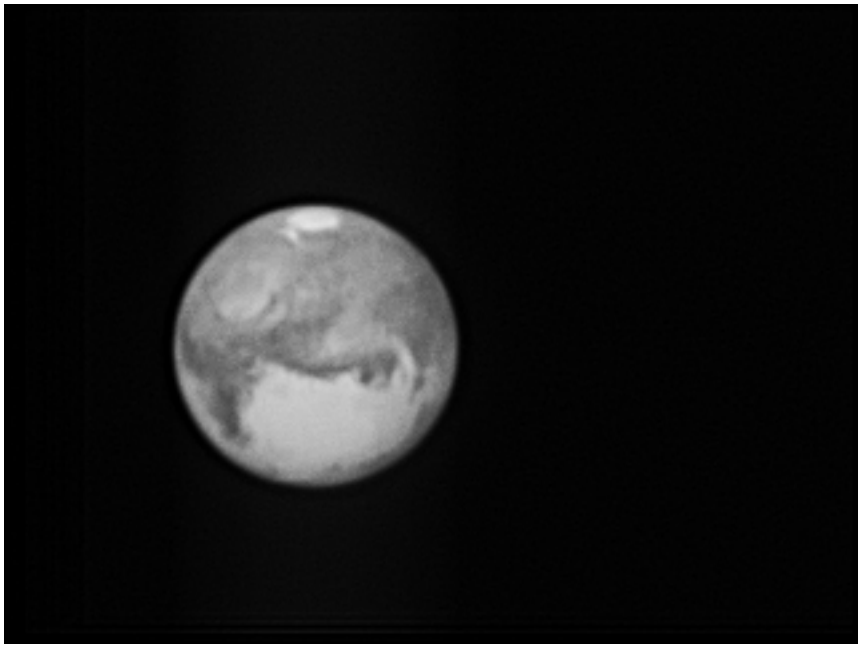
masers in a shell of gas from a supergiant star that exploded 900 years ago

Compensating for Atmospheric Blurring

Two ways to reduce blurring:
image processing (stacking)
and adaptive optics (AO).

Computerized Image Processing



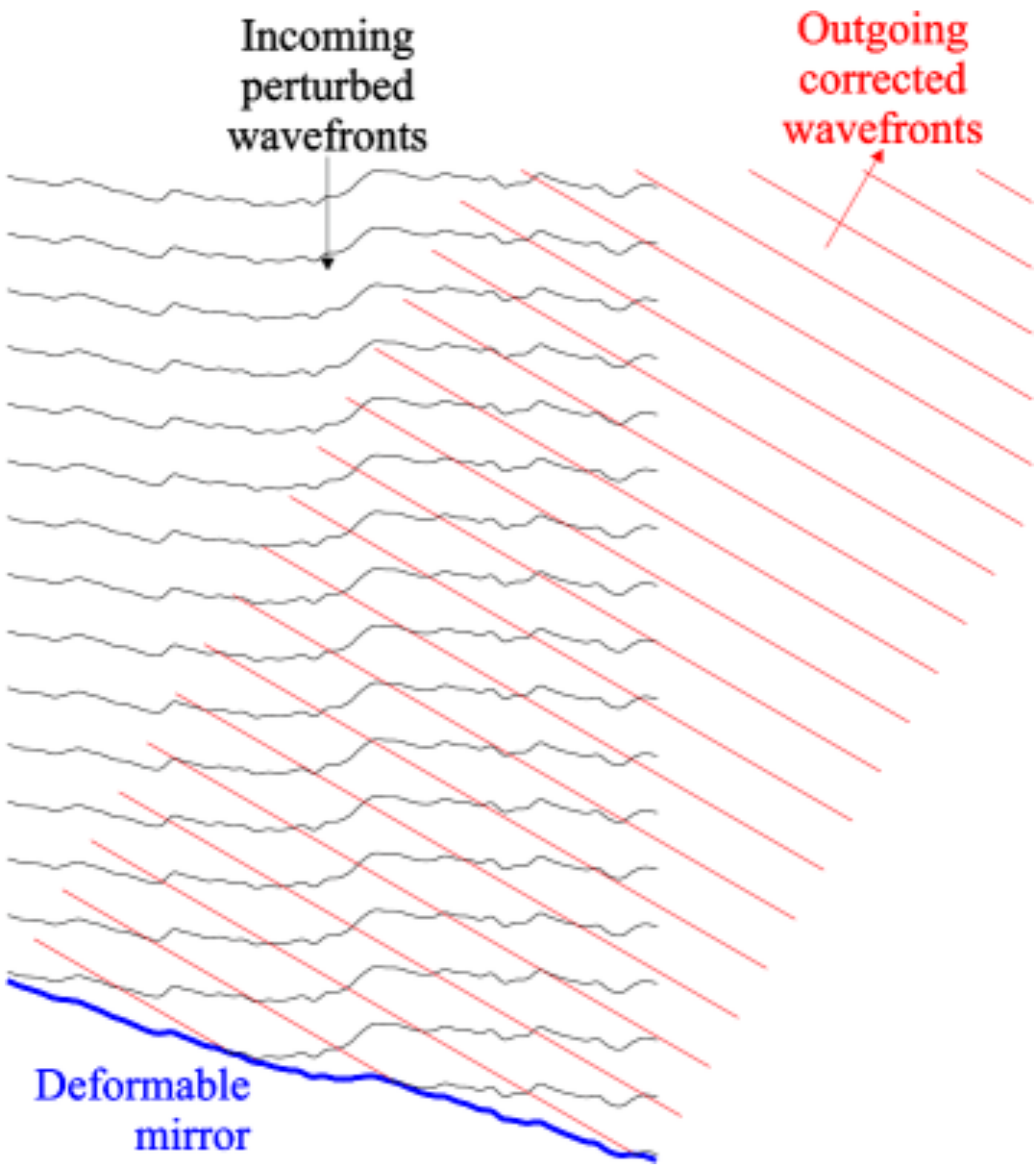


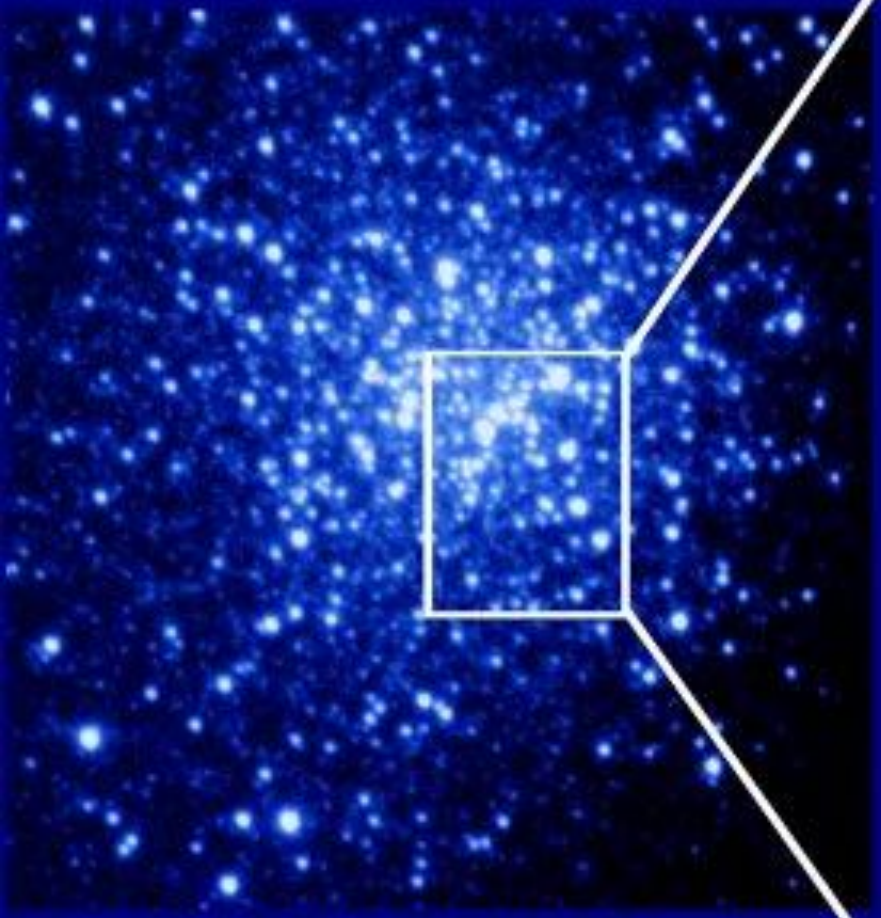
The image on the right is a computerized combination of 22 images like the one on the left. This is called "stacking" images. The effect is to "average out" distortions caused by atmospheric blurring.

Adaptive Optics

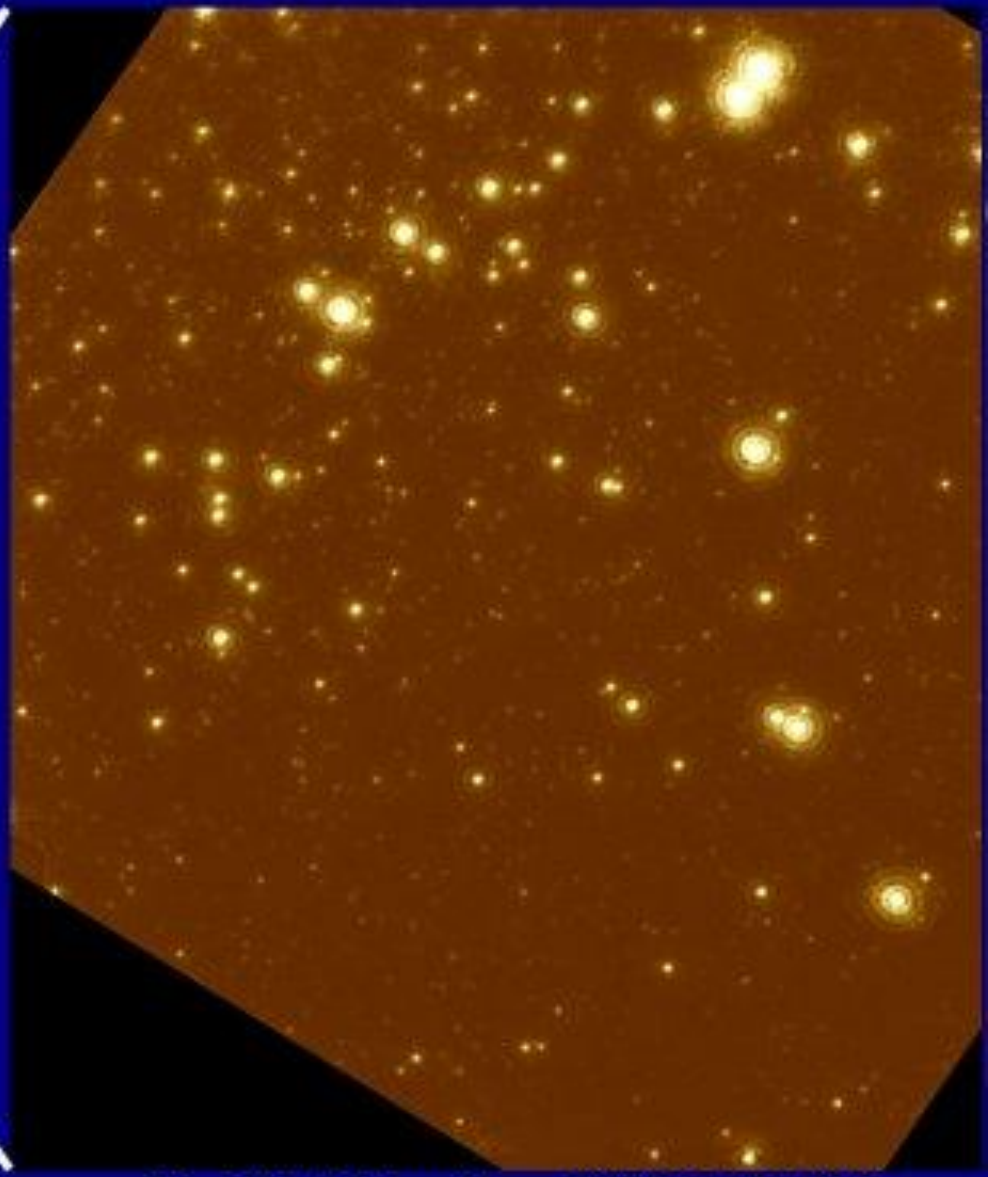
By adjusting the shape of the mirror, a telescope with AO can counteract atmospheric blurring.

These adjustments to the shape must be made repeatedly as the atmosphere changes!



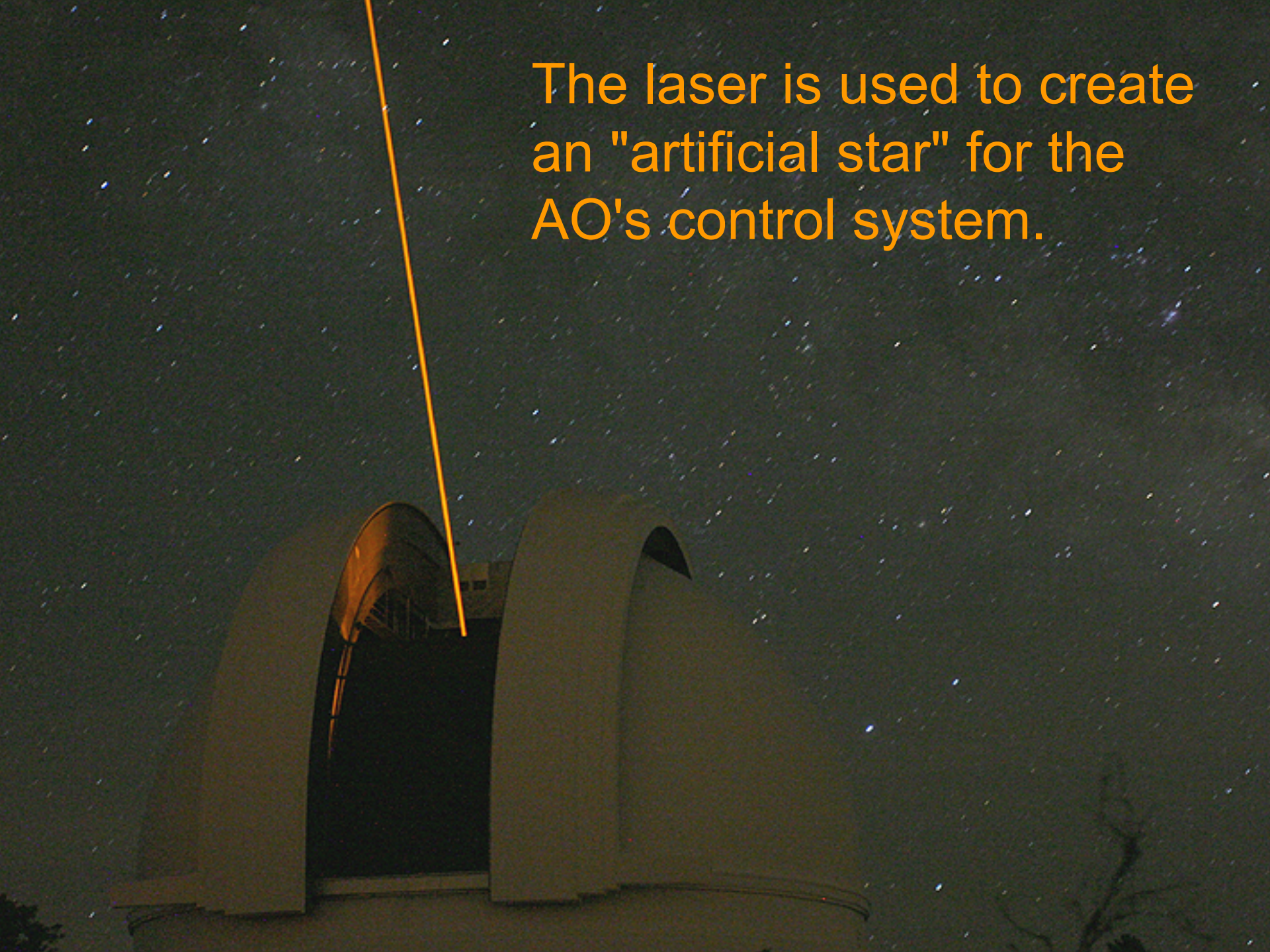


Gemini North Optical Image WITHOUT Adaptive Optics
(Resolution = 0.6 arcseconds FWHM)

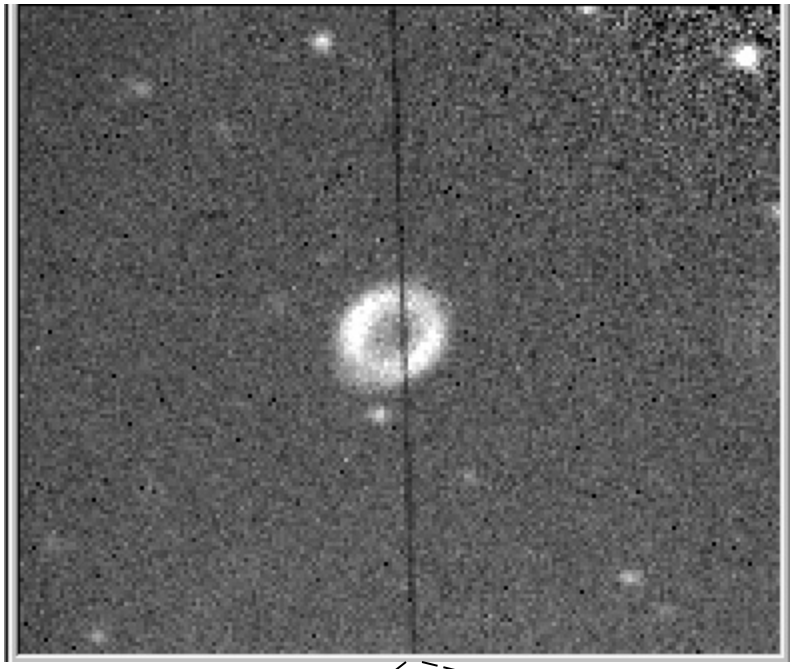


Gemini North Infrared Image WITH Adaptive Optics
(Resolution = 0.09 arcseconds FWHM)

Under control of computer, 150 actuators push or pull the mirror hundreds of times per second to counteract atmospheric distortions!

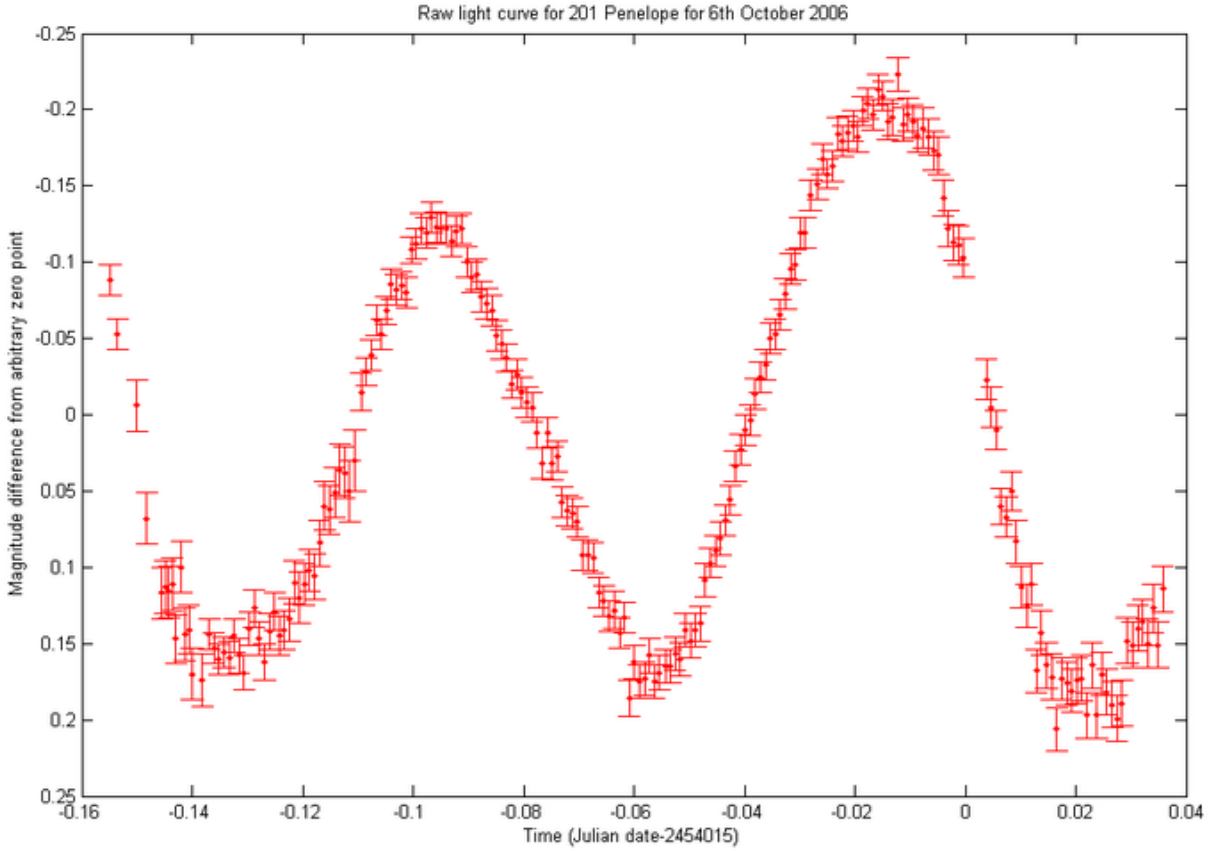

The laser is used to create an "artificial star" for the AO's control system.

ESO Paranal UT4 AO system



A telescope can be equipped with a **spectrometer** so that light from a particular part of the image may be analyzed.

Spectral Lines of the Ring Nebula



A **photometer** measures total light output very precisely and very rapidly.

Attaching a photometer to a telescope allows astronomers to monitor variability of a star's light.