Earth 101
Introduction to Astronomy

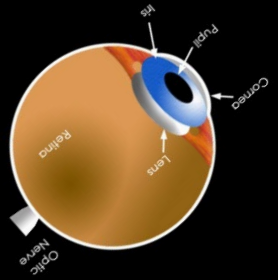
Telescopes

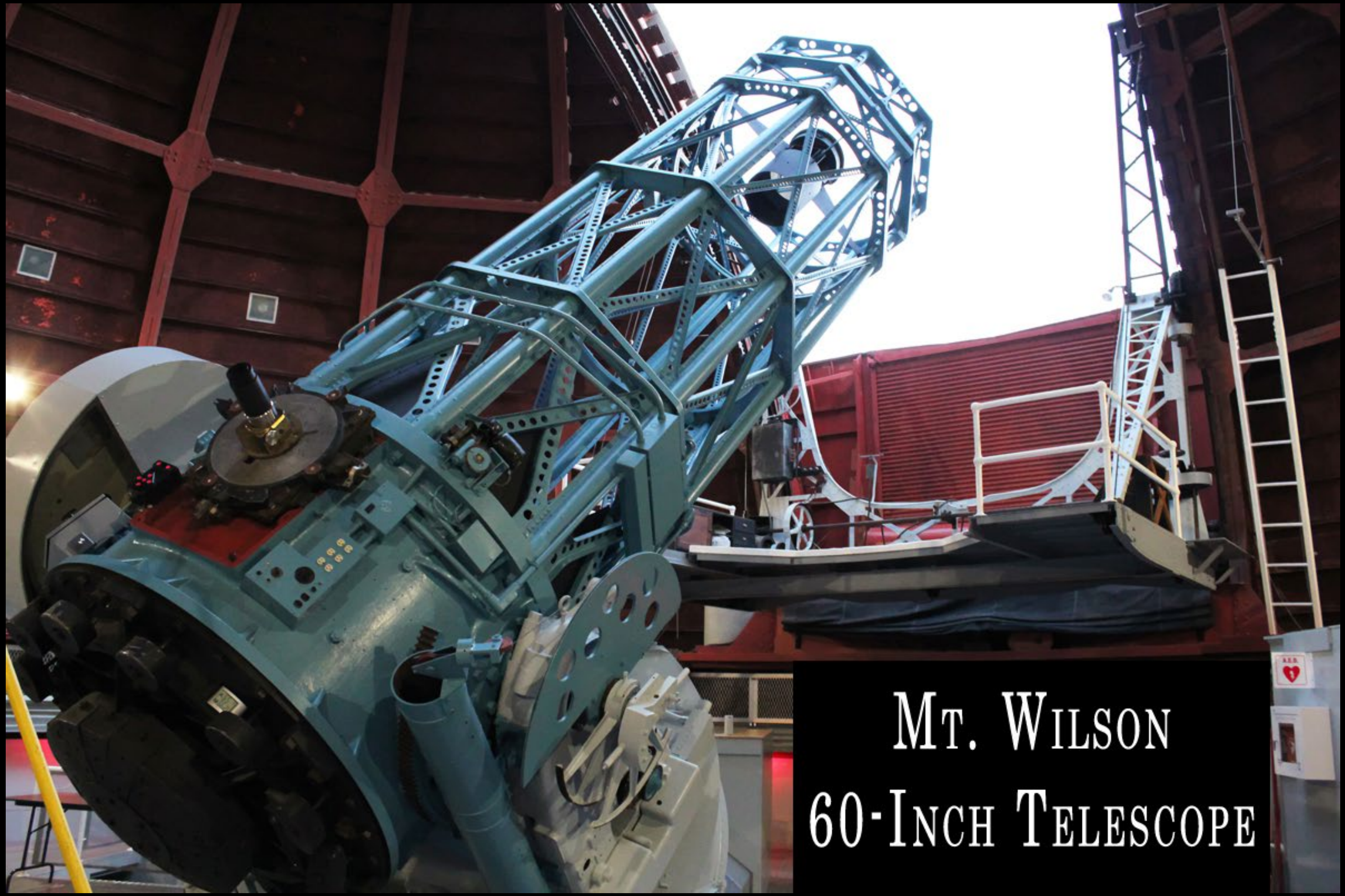
Instructor:
Erin O'Connor

OpenStax Ch 6
Telescopes (principles)
Modern Telescopes

Photo/Material Credit:
- Fred Marschak
- Dr. Jatila van der Veen
- Erin O'Connor + others

TELESCOPES: EXTENSIONS OF OUR EYES









Types of Telescopes

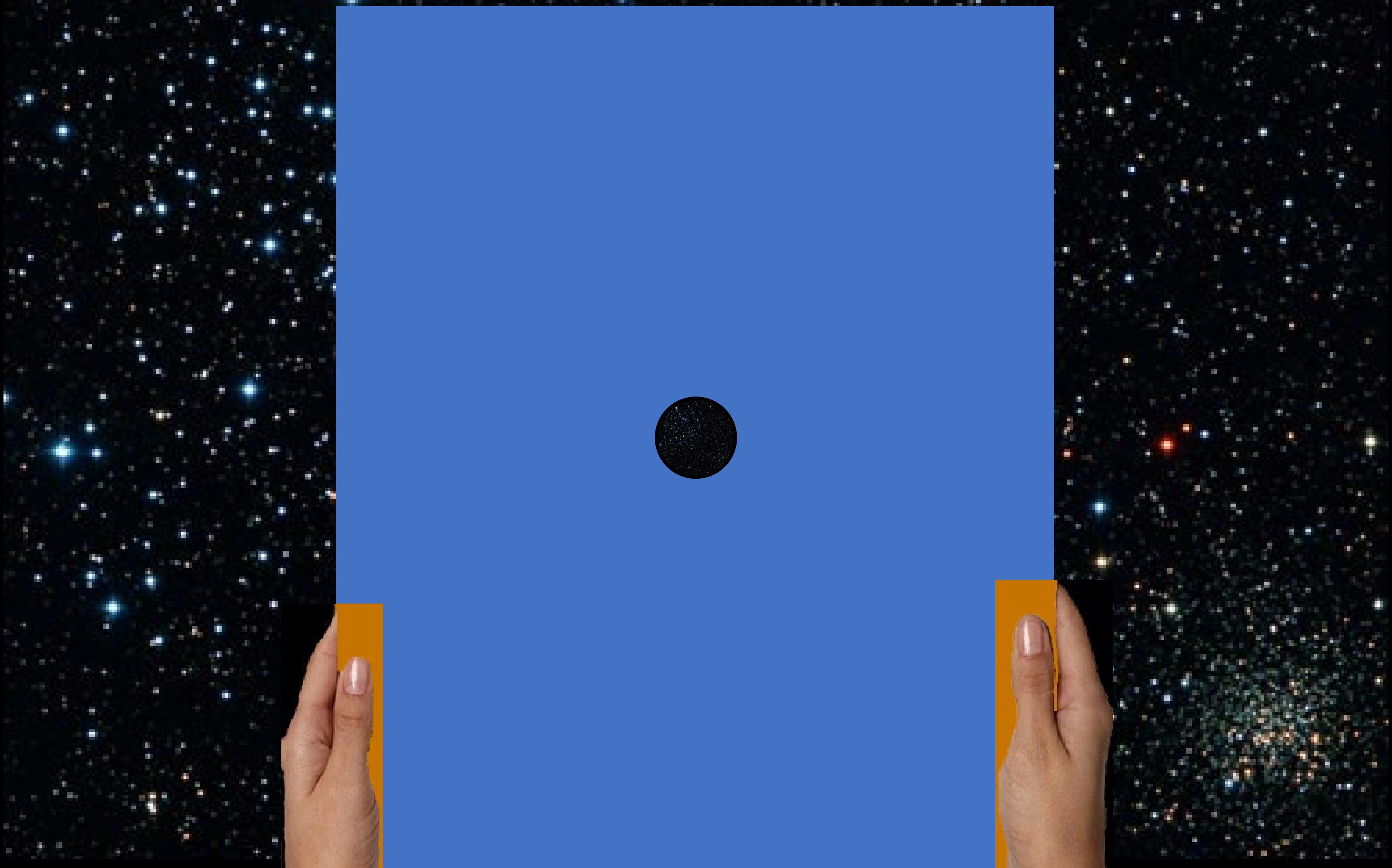
Refractor - the light is bent (refracted)

Reflector - the light is bounced (reflected)

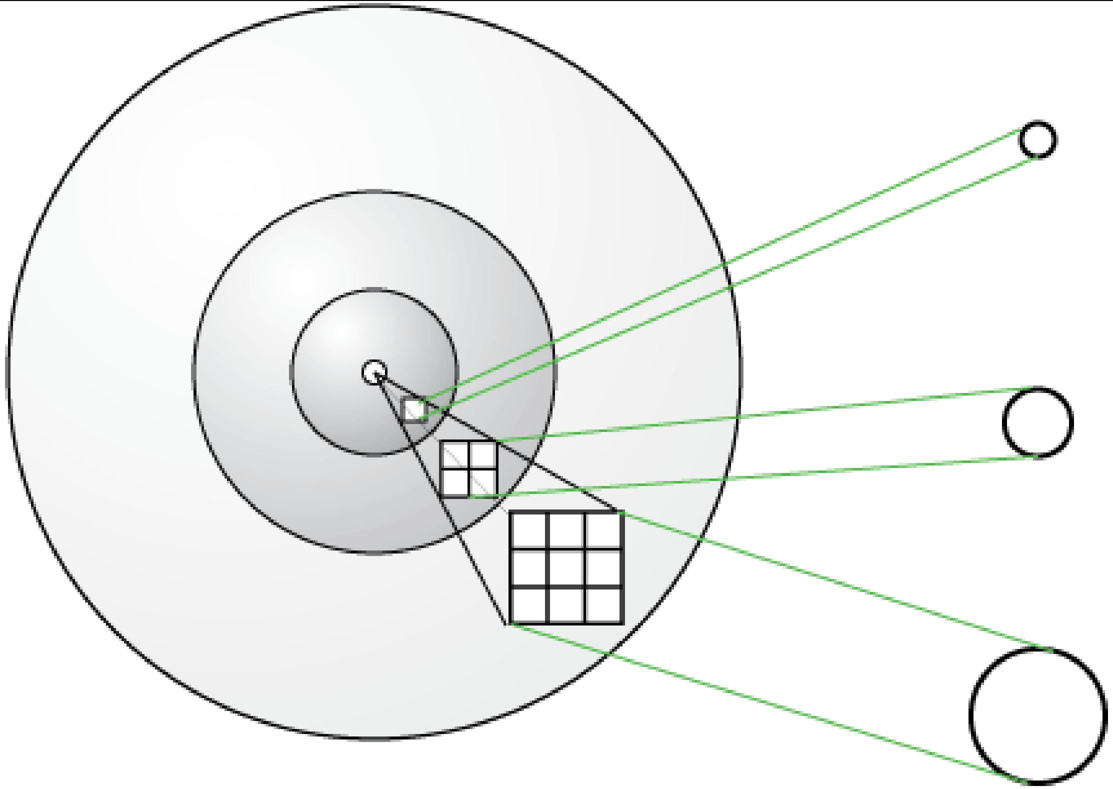
Newton's Reflector

Cassegrain Reflector

What is meant when someone says the telescope 'gathers light'?



Light-gathering power depends on diameter of primary mirror.



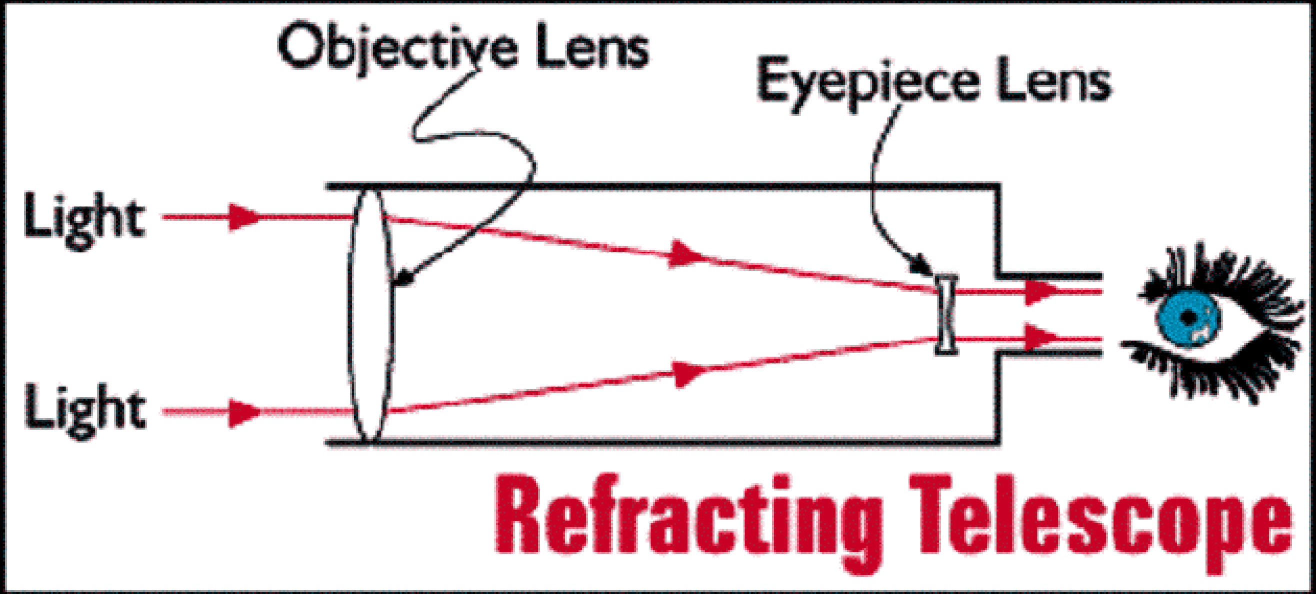
If 1-meter telescope has area = 1 and if it can see an object at 1 AU

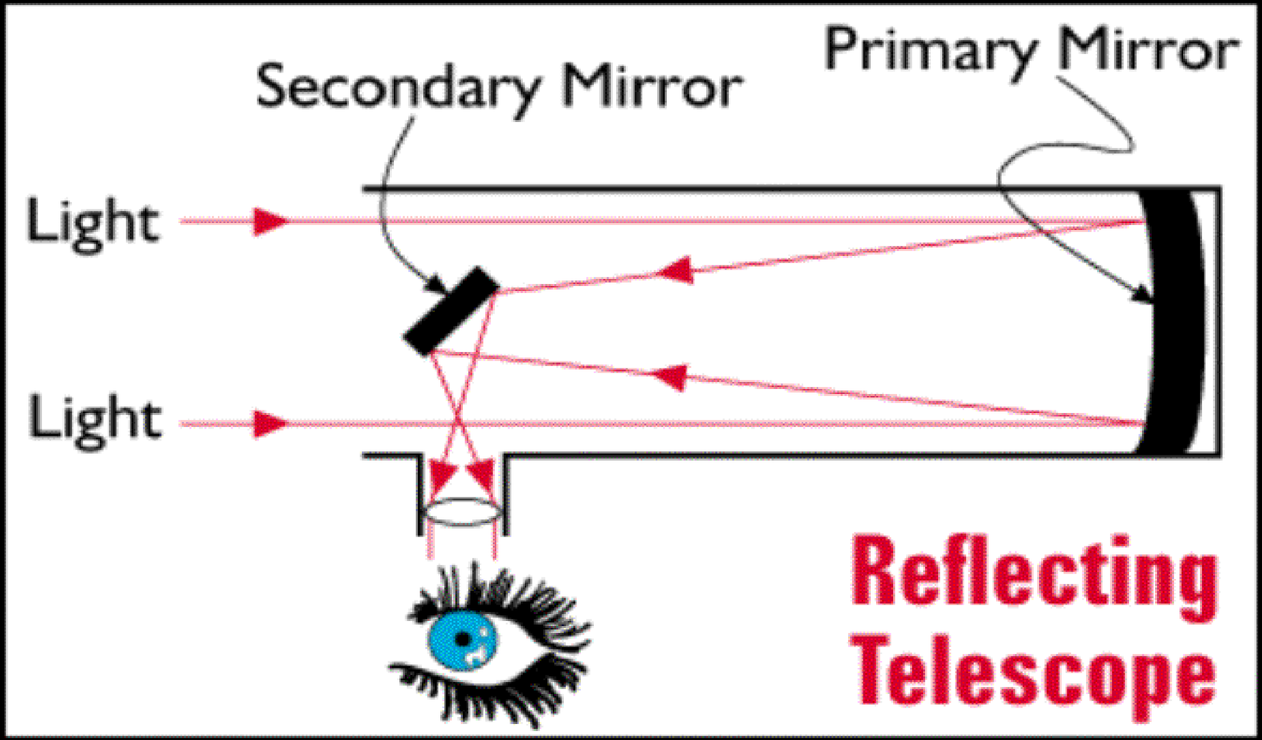
THEN:
2-meter telescope has area = 4; can see same object at 2 AU

3-meter telescope has area = 9; can see same object at 3 AU

Light spreads out with the **square** of the distance. Through a sphere twice as large, the energy covers an area **four** times larger. Through a sphere three times as large, the energy covers an area **nine** times larger.

2 basic types of telescopes:

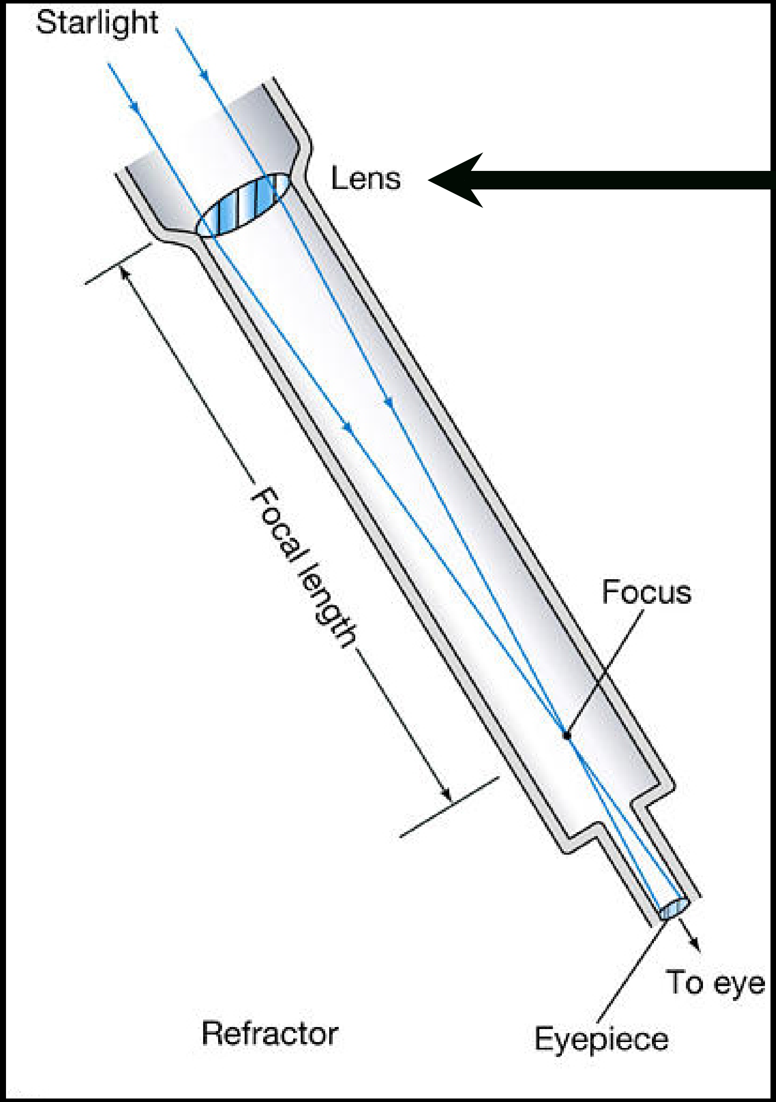




demos: lenses and mirrors

Refracting Telescope

Refracting Telescope

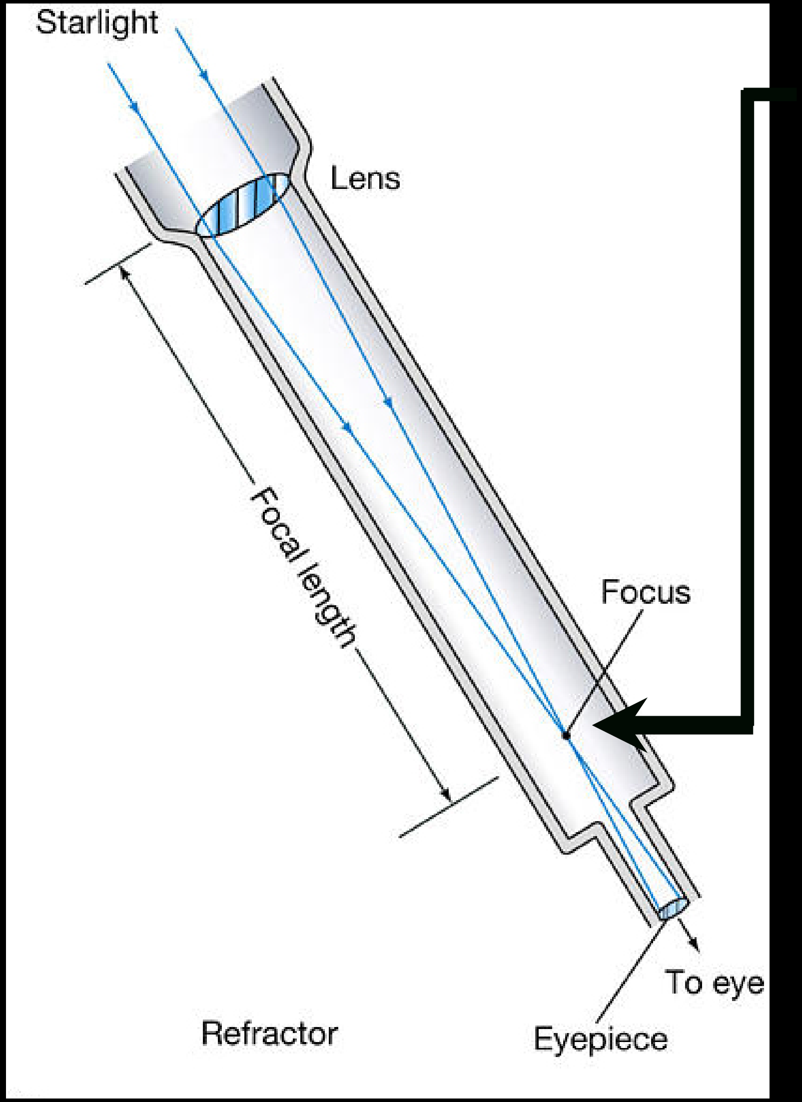


The Primary Lens (the part that gathers the light sometimes called the Objective) is curved so that ALL the light gathered is properly focused.

Binoculars are two refracting telescopes parallel to each other.

Inexpensive to make smaller lenses, but larger ones cost much more than mirrors to manufacture.

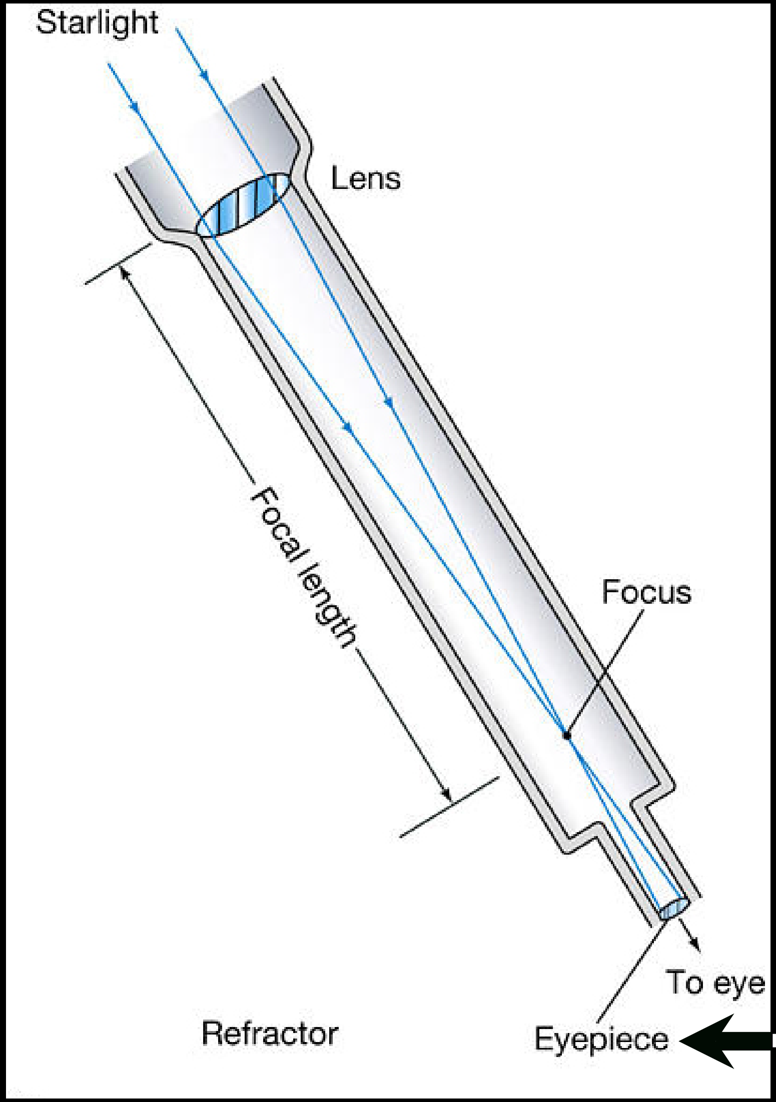
Refracting Telescope



The focus is where the telescope makes ONE image that is a combination of ALL the images collected.

Therefore, every object in this one focused image will be brighter depending upon how large the Primary Lens is in diameter (i.e. how many images were collected).

Refracting Telescope

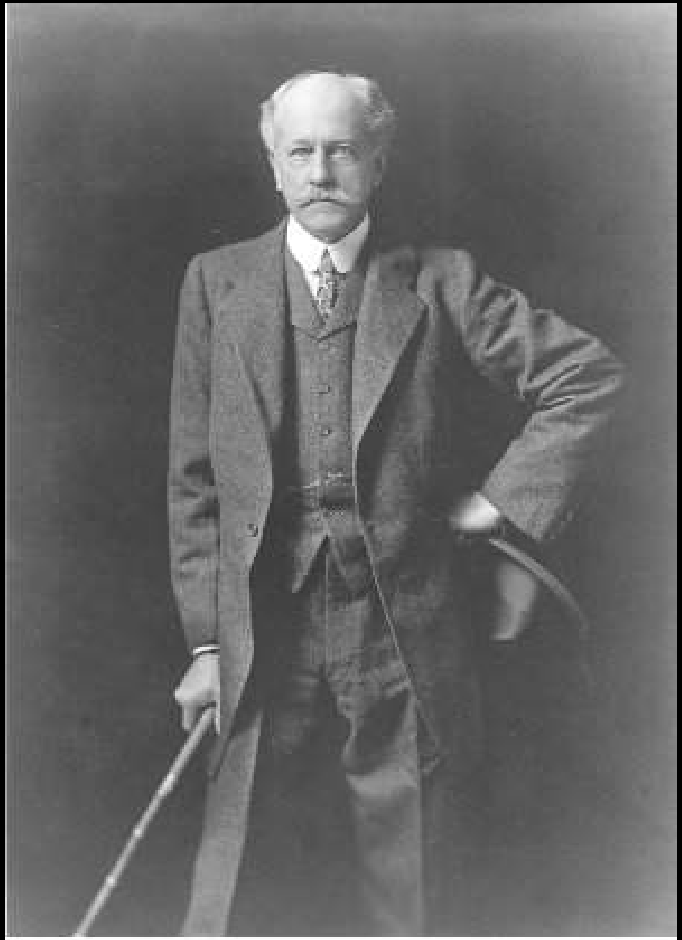


The eyepiece magnifies that ONE image at the focus.

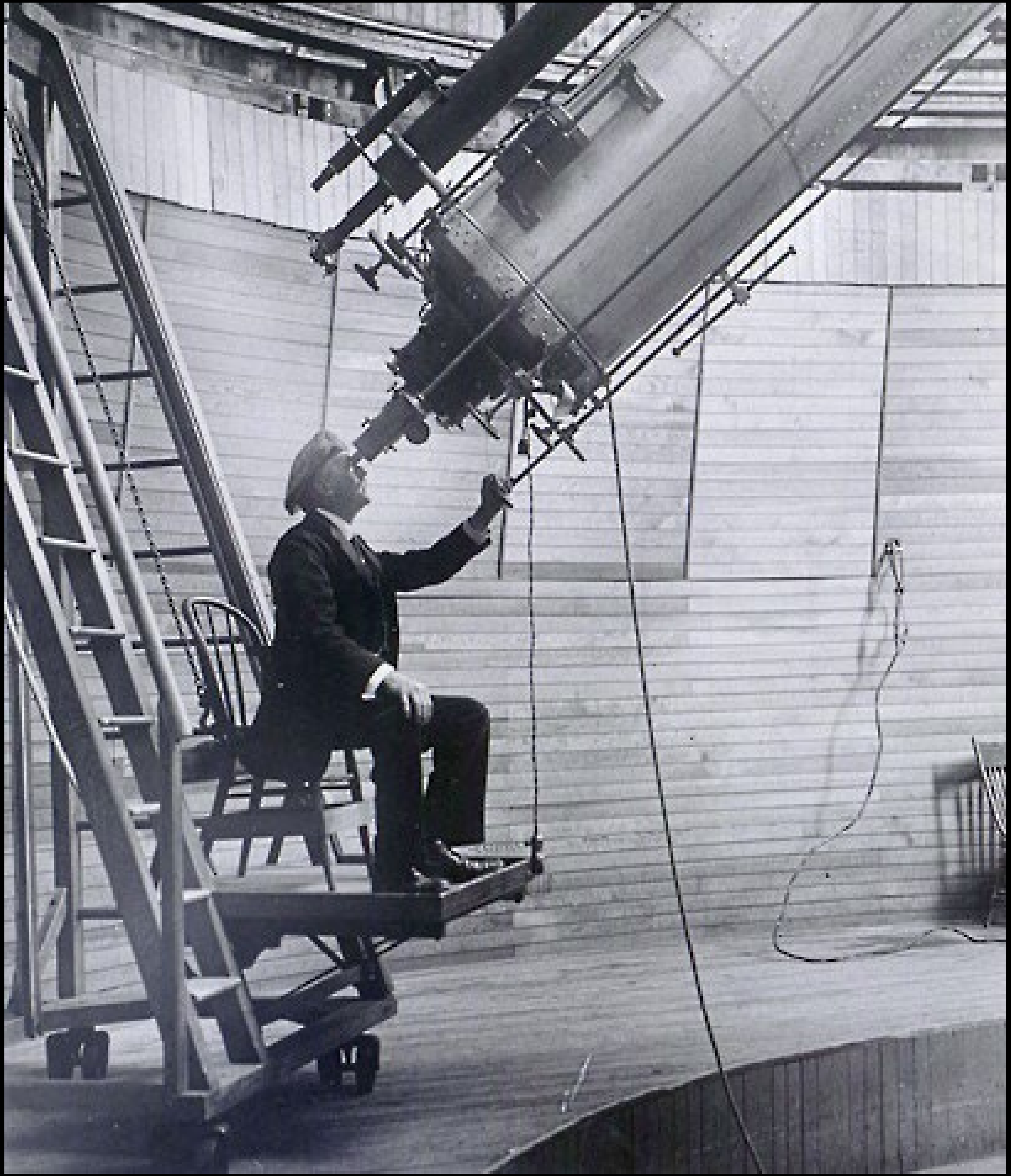
An observer changes the eyepiece to change the magnification.

Galileo’s telescope was a refractor, using a series of lenses to gather and focus light.

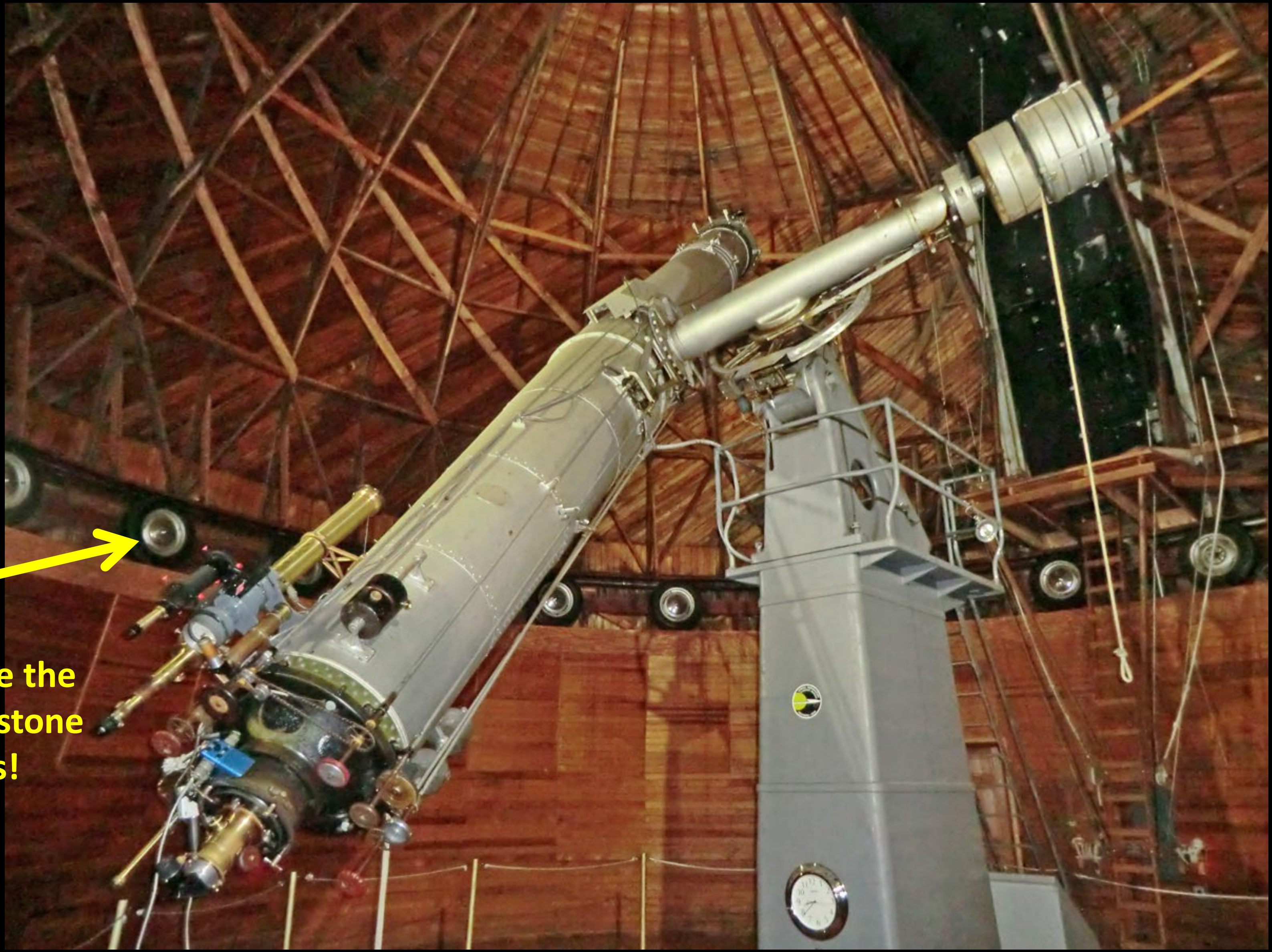
The Lowell Telescope in Flagstaff, AZ, built by Percival Lowell in 1894 is one of the largest refractors in the world.



Percival Lowell

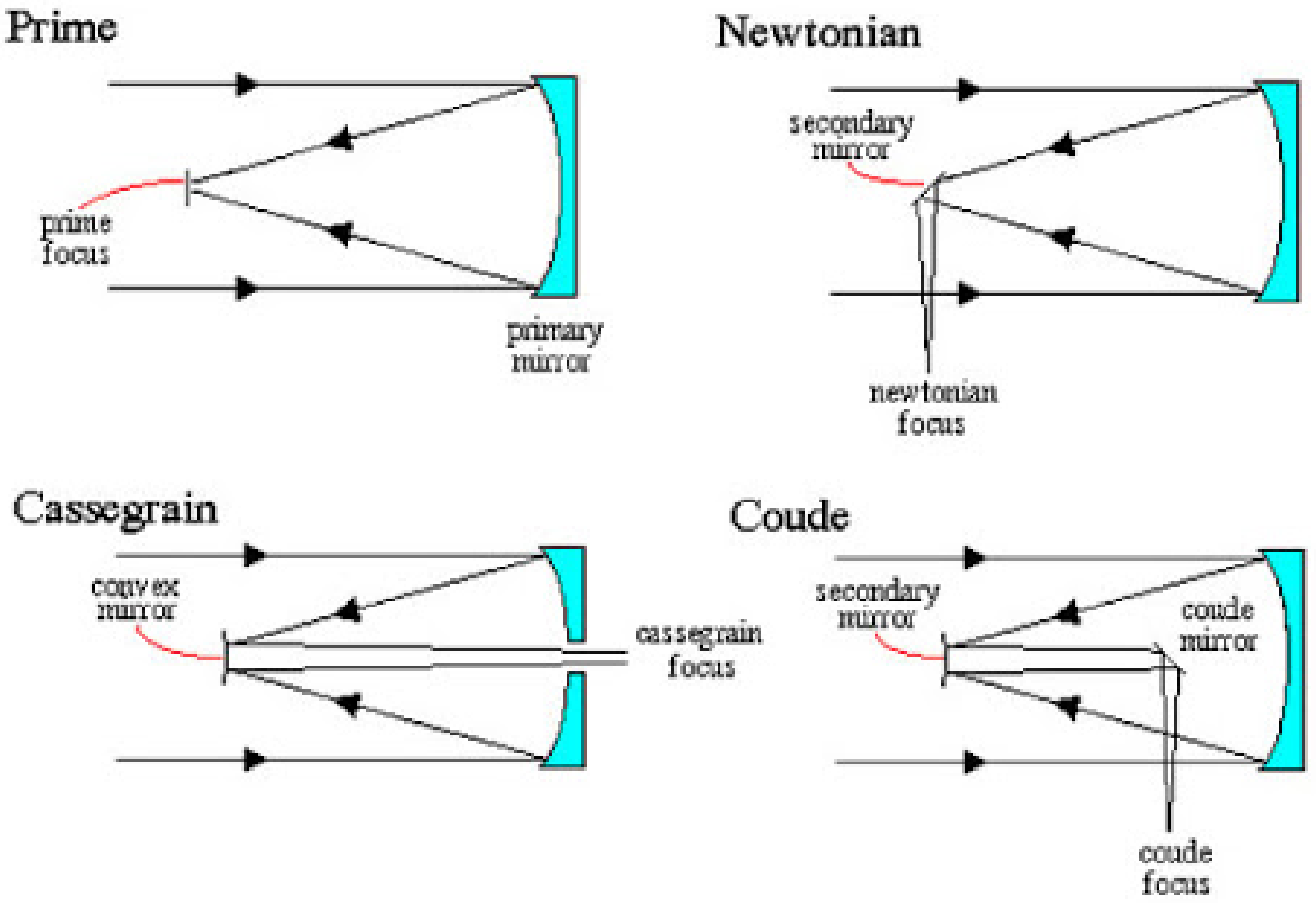


24” refractor at Lowell Observatory, Flagstaff, AZ

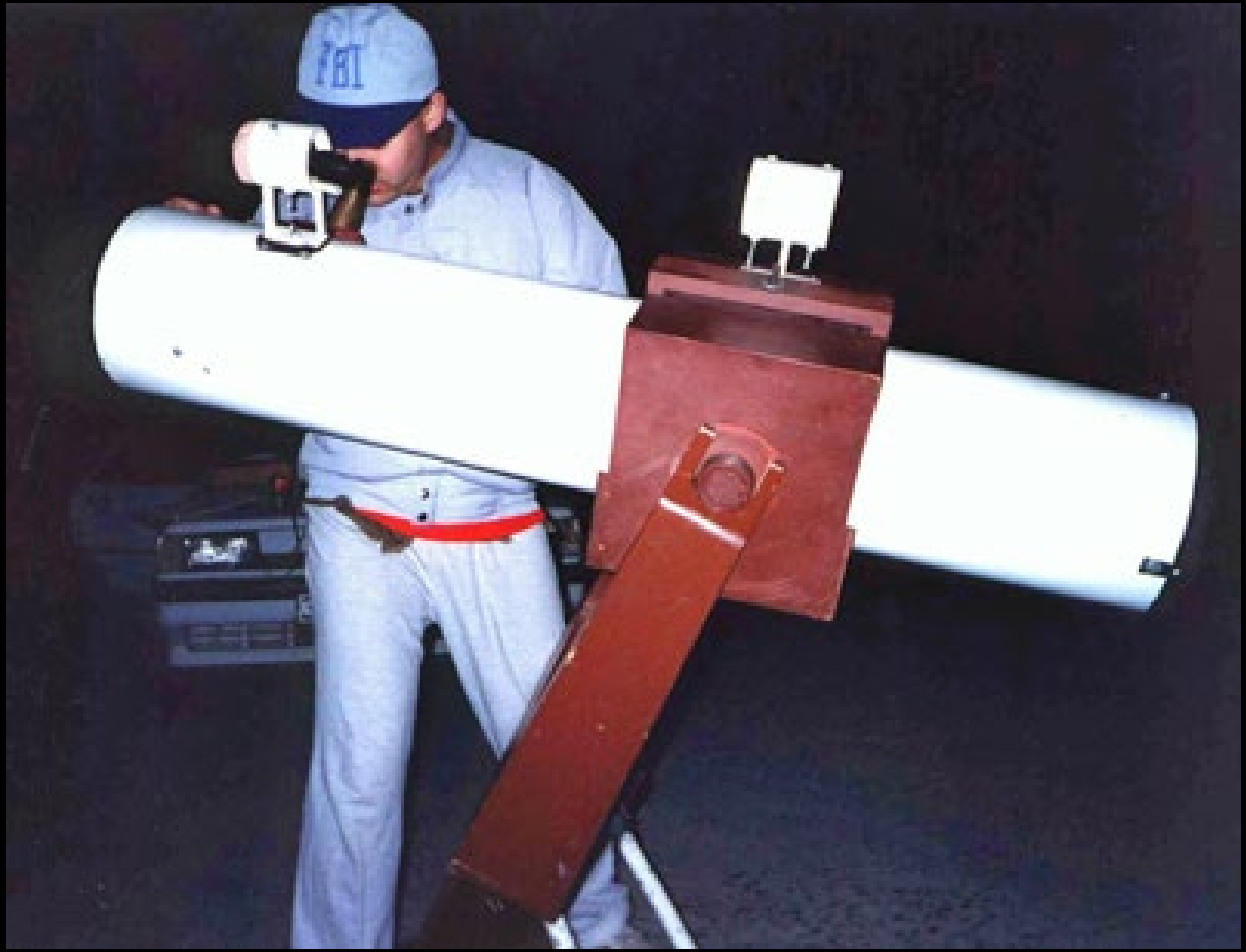


Note the Firestone tires!

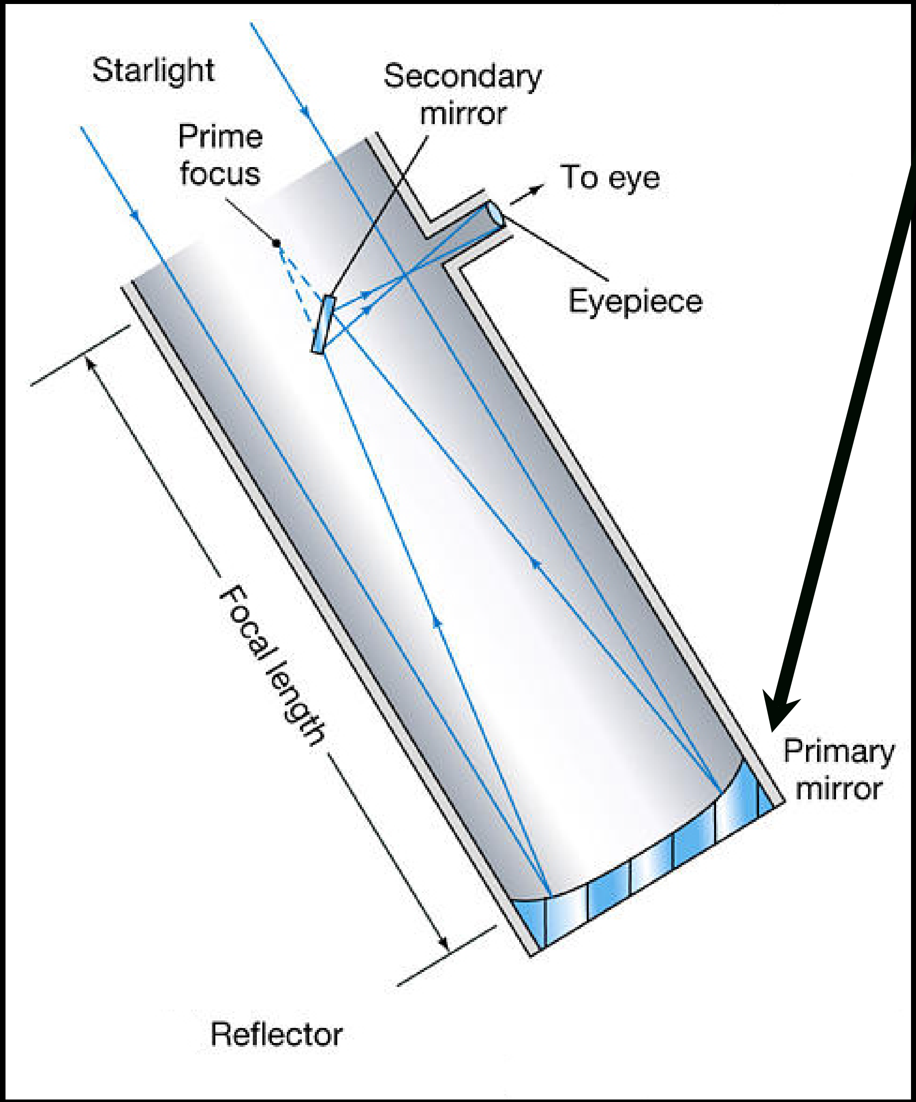
Reflecting Telescopes



Newtonian Reflector



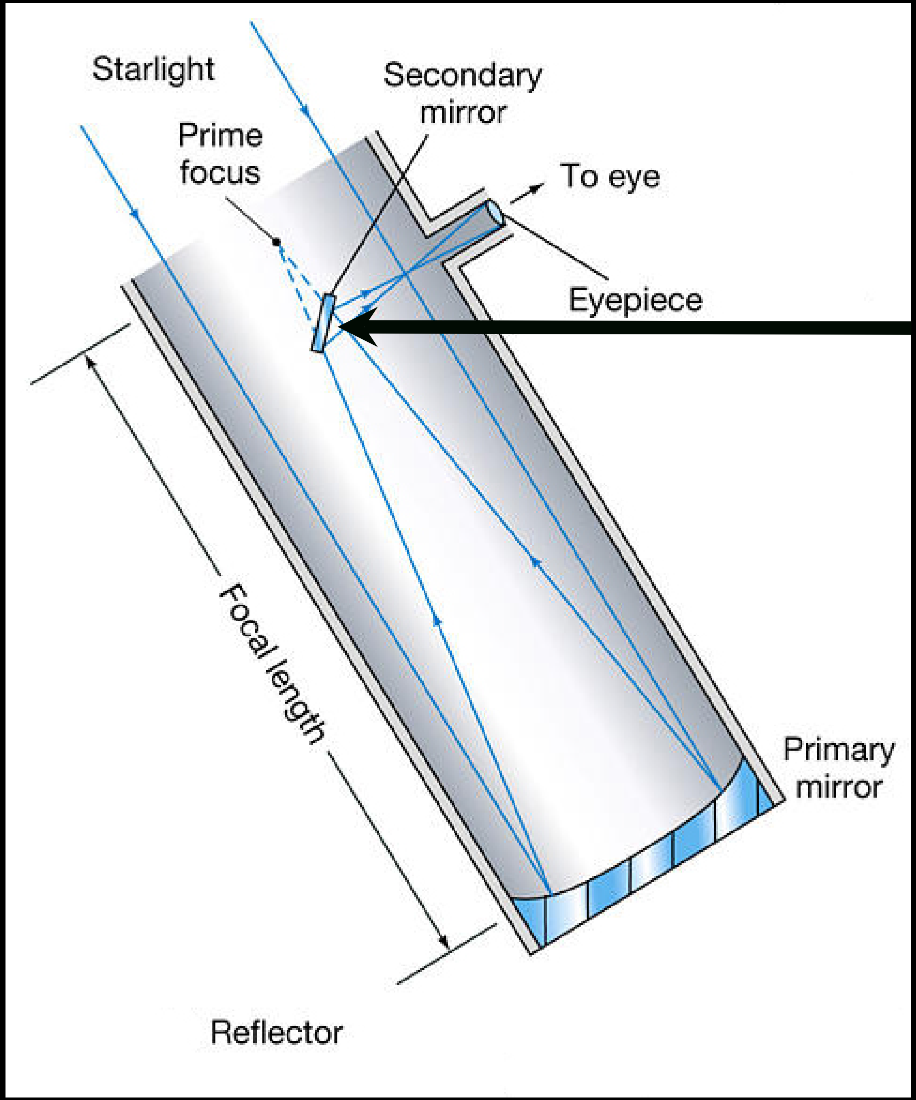
Newtonian Reflecting Telescope



The PRIMARY MIRROR (the part that gathers the light) is not a lens but a curved mirror.

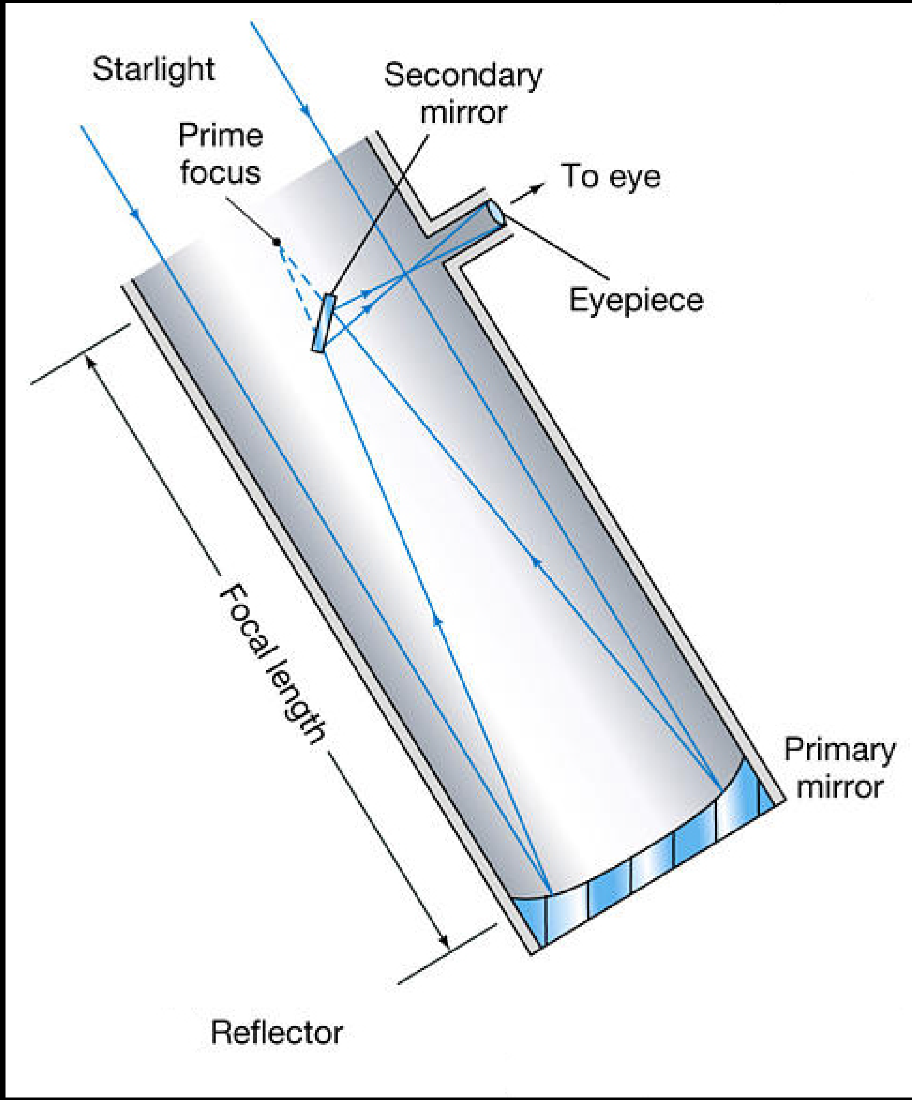
Notice that the mirror can be supported from the back instead of just at the edges like a lens is in a refracting telescopes.

Newtonian Reflecting Telescope



This type of reflecting telescope has a SECONDARY MIRROR to reflect the light to an eyepiece just before it comes to a focus.

Newtonian Reflecting Telescope



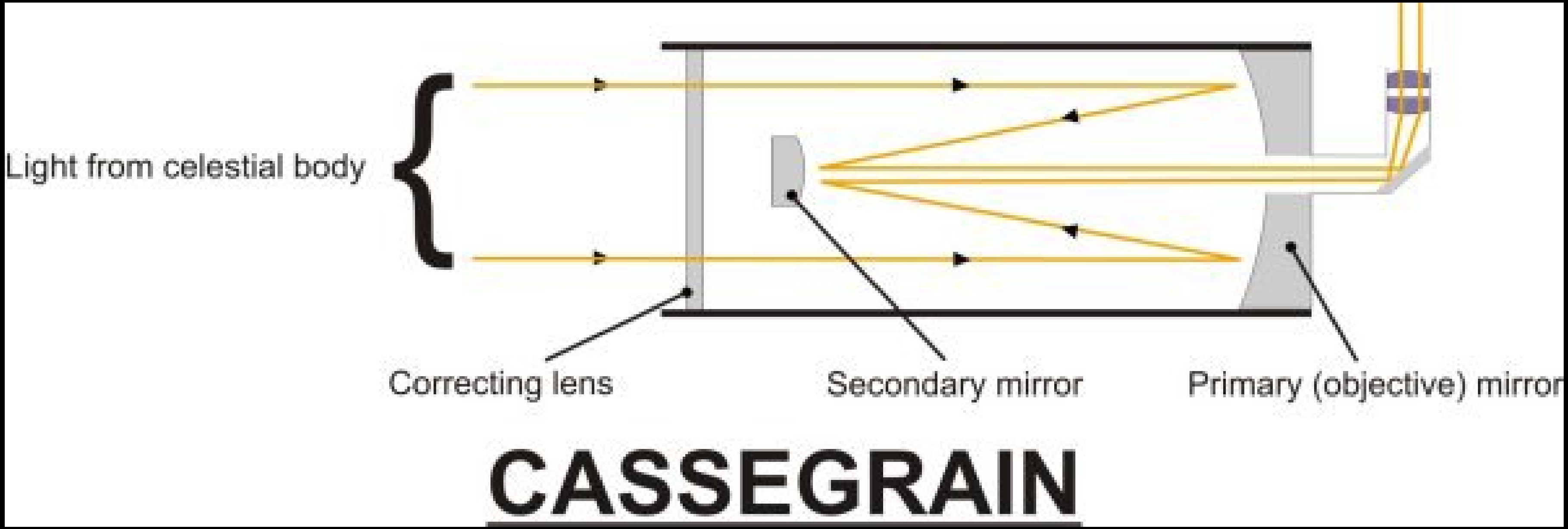
As in the refractor, the eyepiece magnifies that ONE image at the focus.

An observer changes the eyepiece to change the magnification.

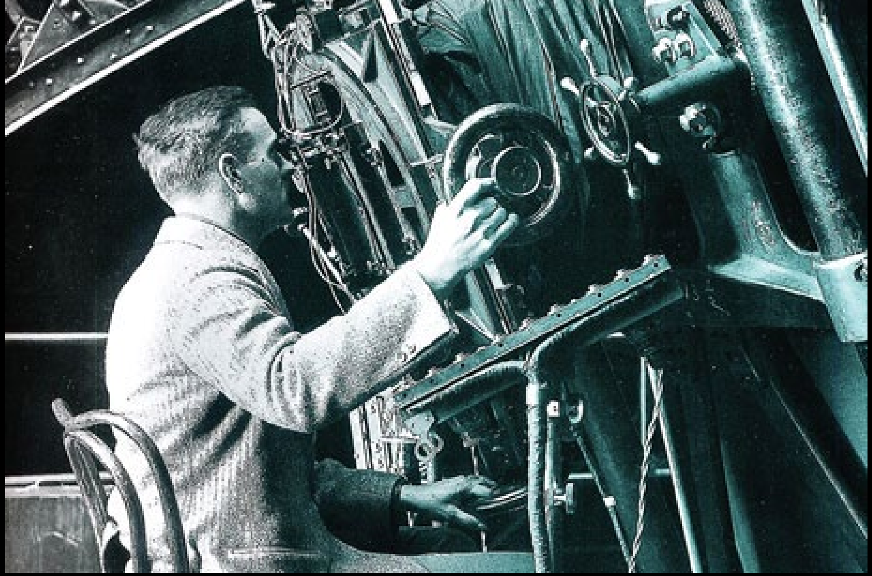
Cassegrain Telescope

The Cassegrains we use at SBCC have a piece of glass in the front, called a 'correcting lens', in order to have a higher quality image at the eyepiece. Officially, ours would be a Schmidt-Cassegrain

These telescopes are very desirable for amateurs because they have such a short tube and, therefore, easier for one person to carry and take up much less space.



Most professional astronomers do NOT look through telescopes anymore.



Since the images are digitized, they can look at them on their computer. Modern telescopes have NO direct viewing through an eyepiece.

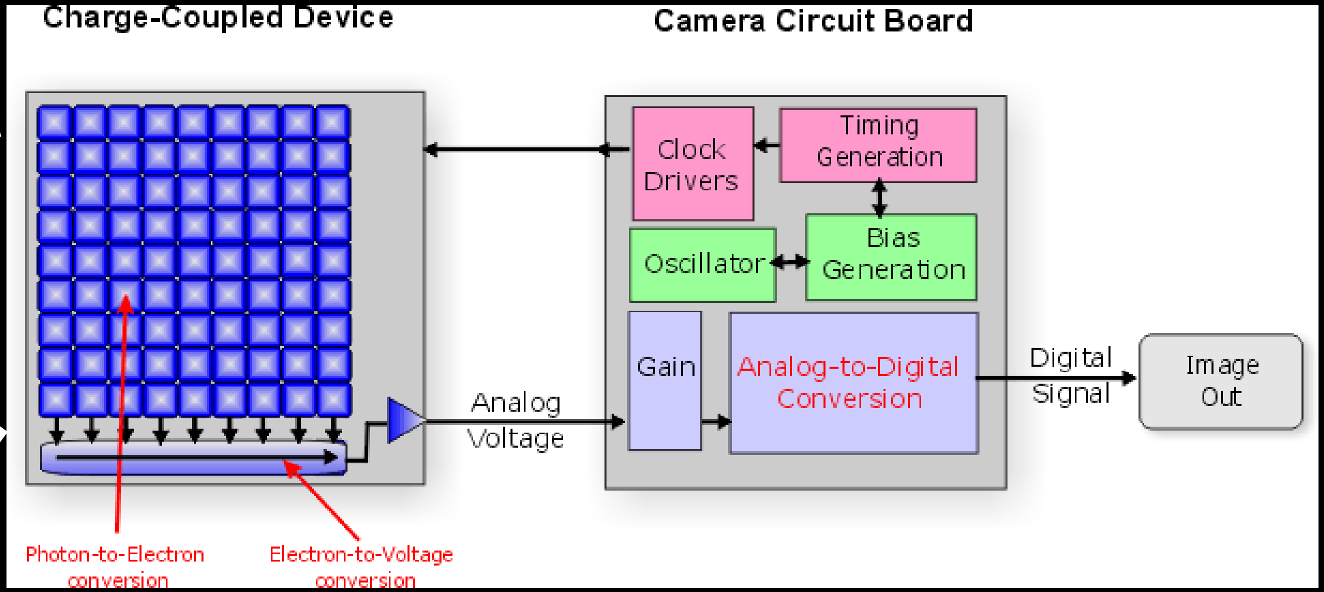
Information from a telescope today is digitized.
Just like digital cameras or cell phone cameras, the image is in an electronic form.

The capturing and converting part is called a CCD or Charged Couple Device

Three examples of a CCD chips

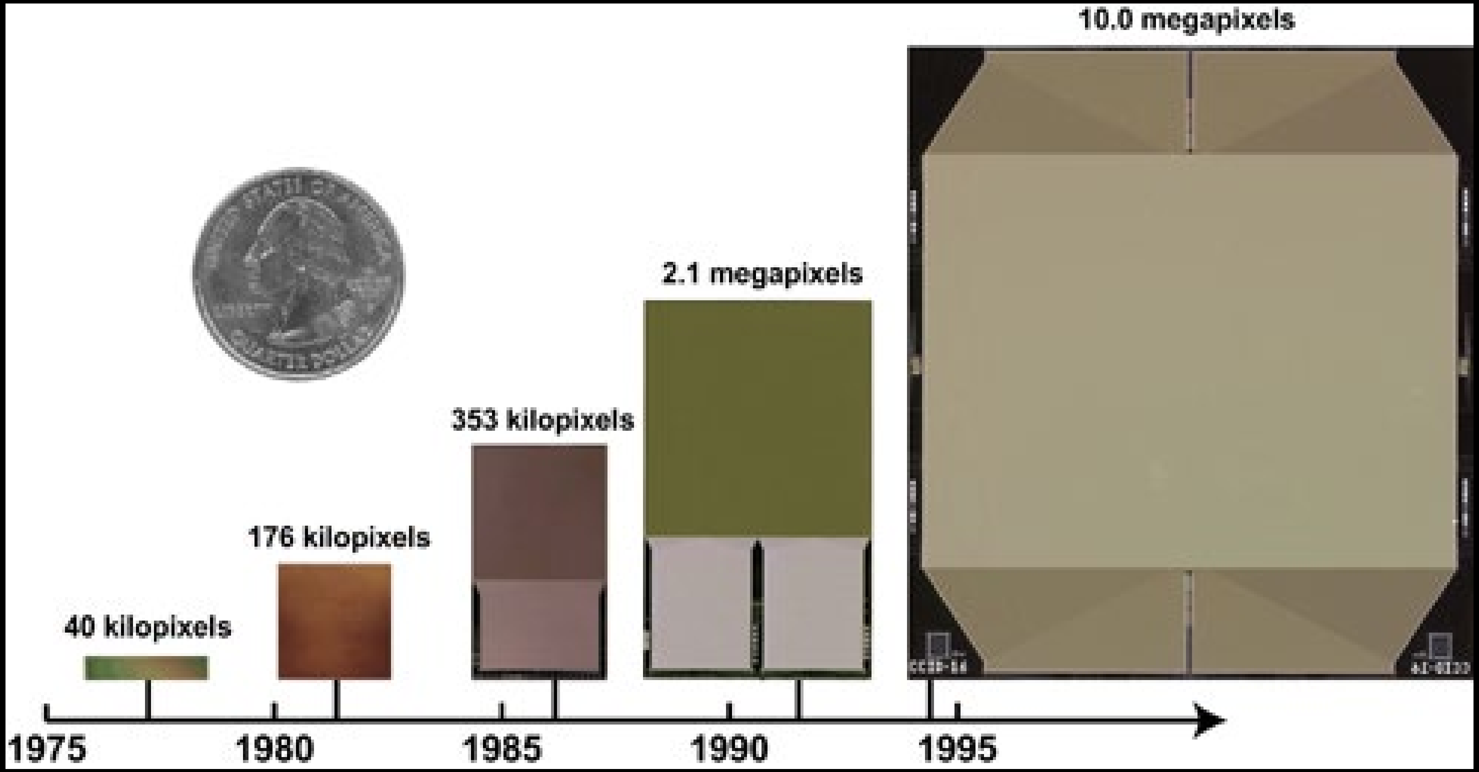
The CCD chip is an array of small photon receptors called pixels (Picture Elements)

CCD chip



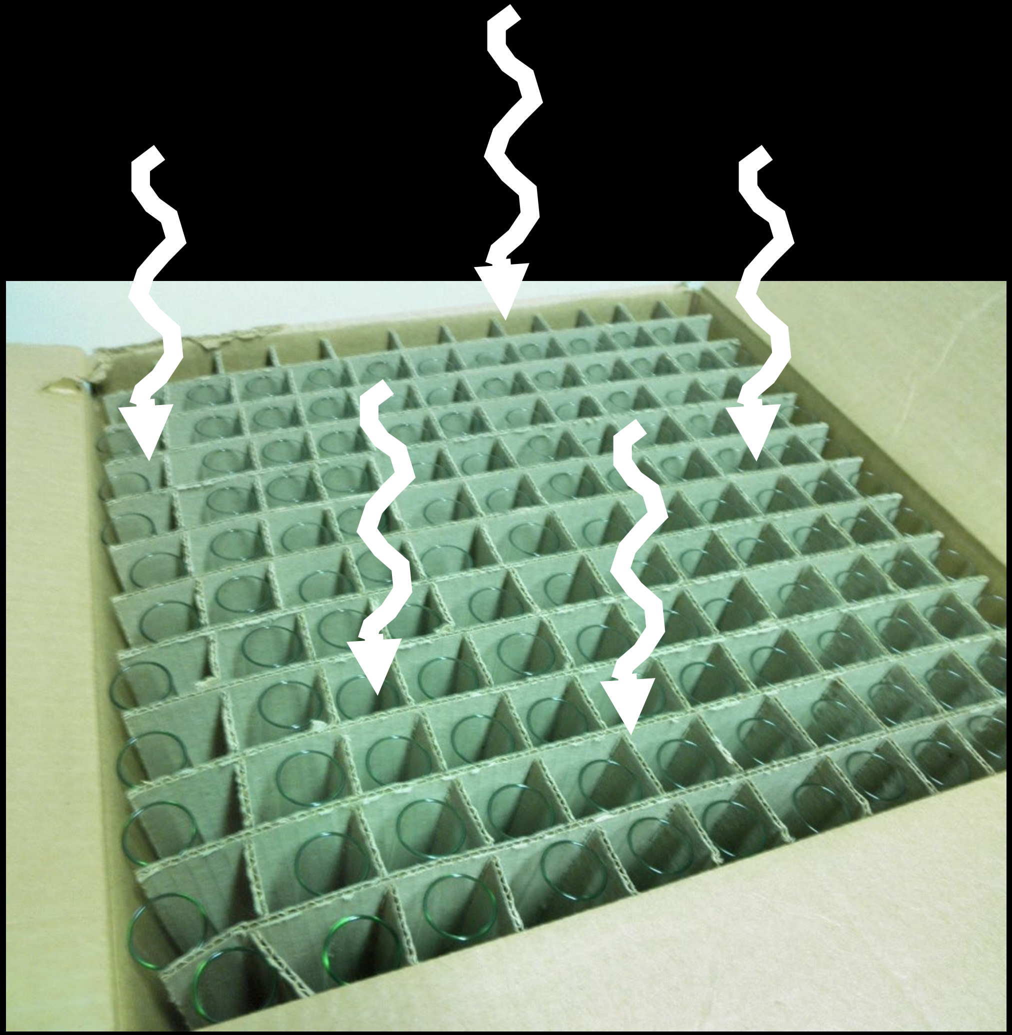
Zooming in on a digital image will show the pixels

The more pixels you have per inch, the more detail you can see.



Now we are making CCD's that are over 100 megapixels (100 million pixels)

Think of a CCD chip as a box of test tubes that catch photons (bundles of energy - light)



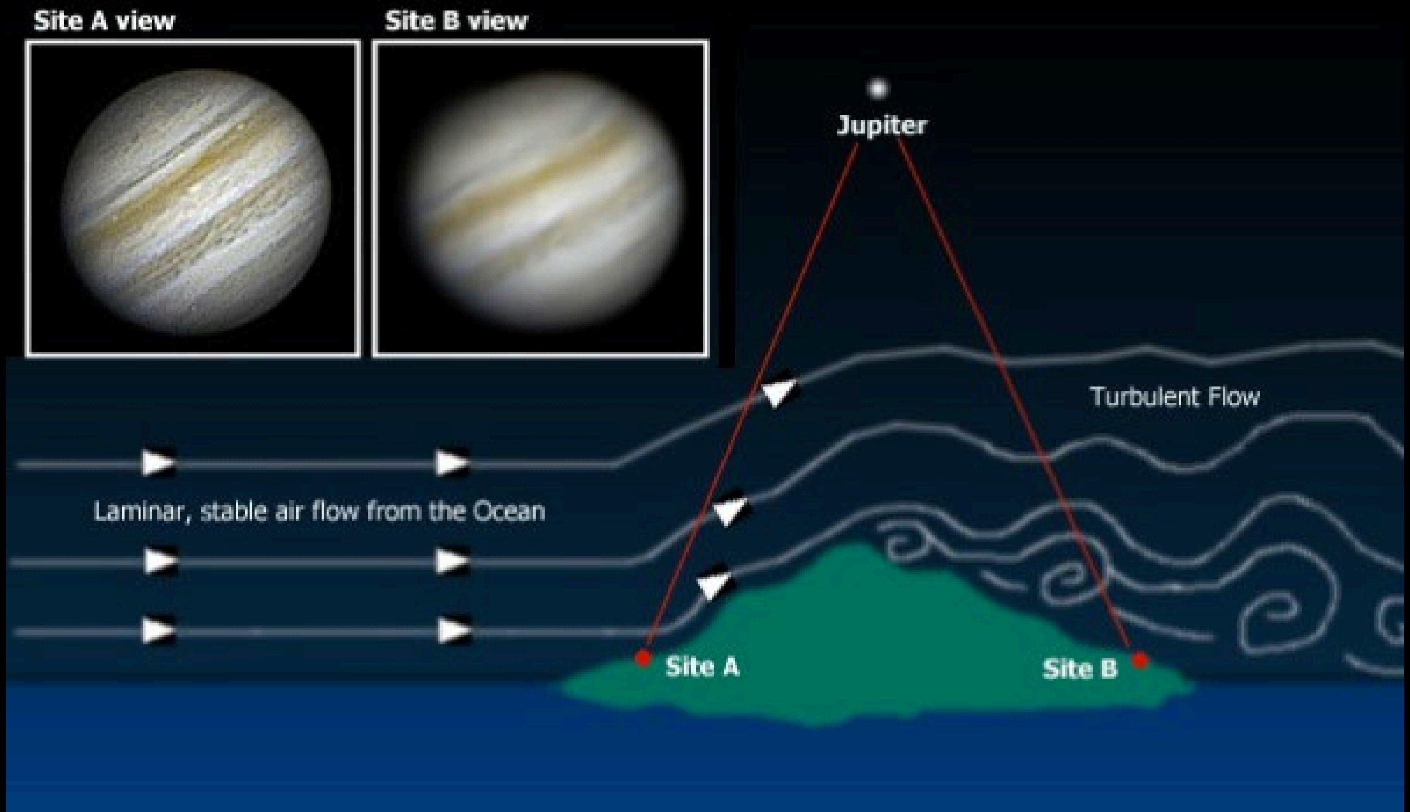
If you take a picture of something white and bright or over too long a time, the 'test tubes' fill up and overflow like this pic.

If you take a picture of something dark or over too short a time, the 'test tubes' have very few photons in the bottom and look like this pic.

Since the individual pixels can be changed (edited), the astronomer can take the overexposed and take some photons out. Also, photons can added to the underexposed resulting in a great image WITH DETAIL.

No matter how high the resolution of the CCD is, from the Earth's surface we must look through that moving ocean of air, our atmosphere.

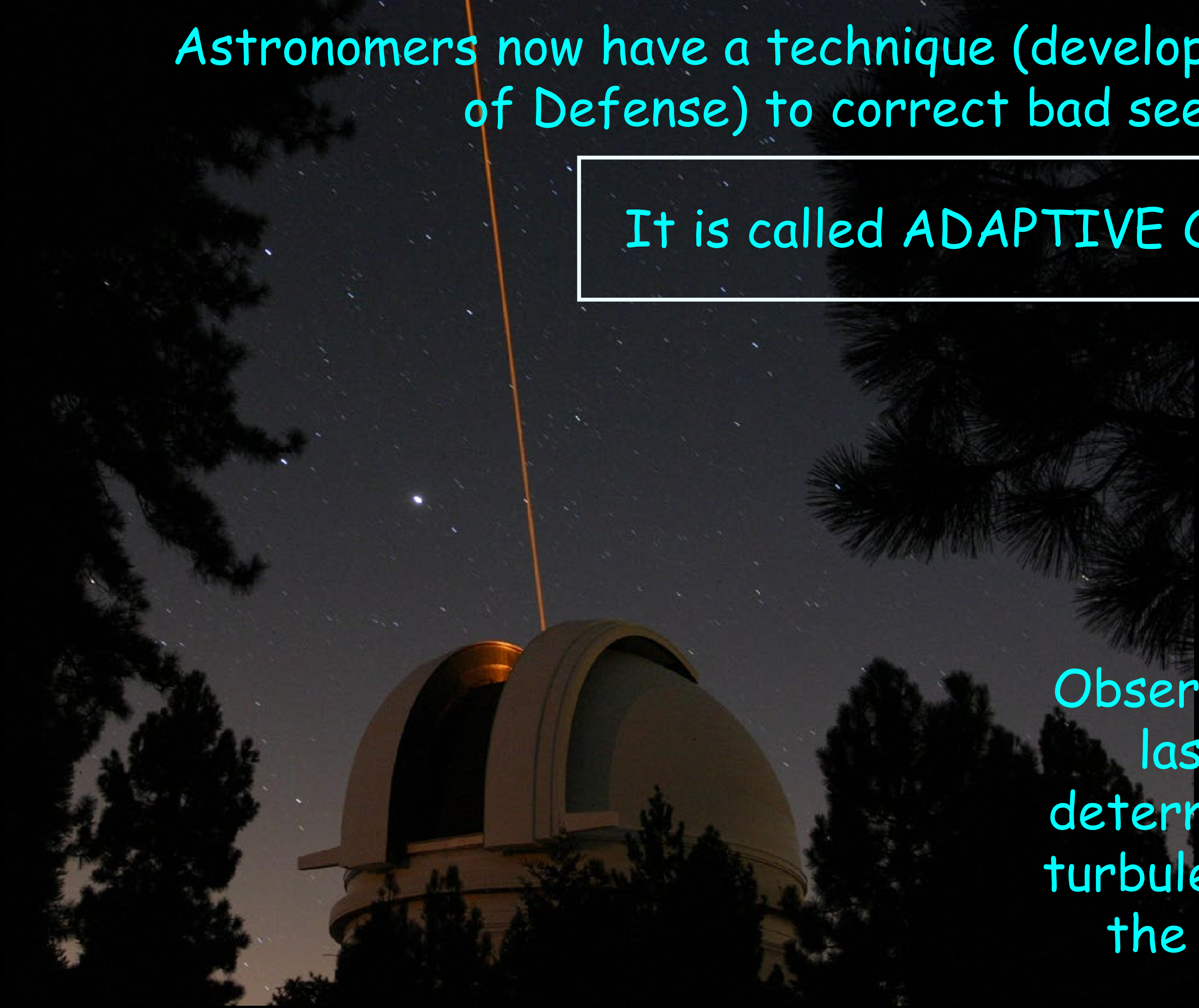
We call that motion TURBULENCE. Lots of turbulence is called 'BAD SEEING' by astronomers.



Santa Barbara is like Site B

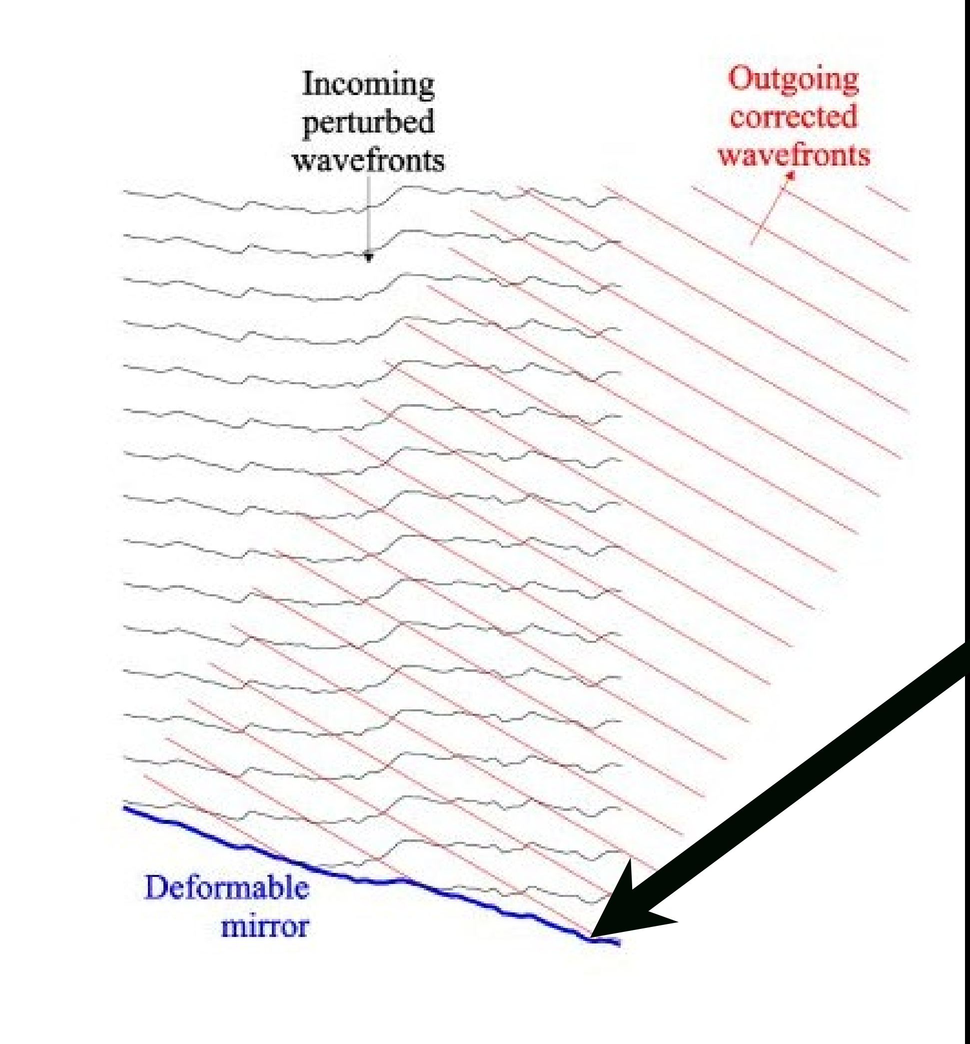
Astronomers now have a technique (developed by the Dept. of Defense) to correct bad seeing.

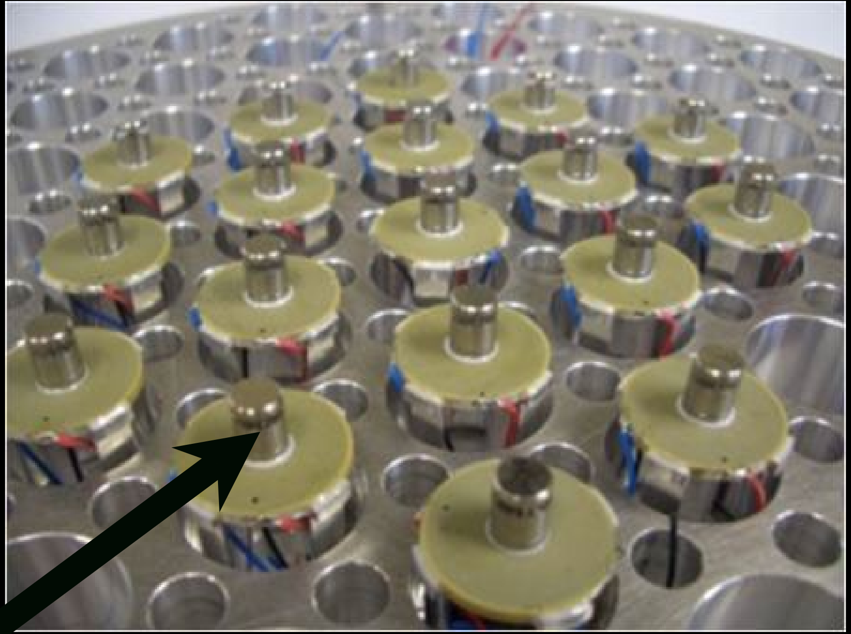
It is called ADAPTIVE OPTICS



Observatories use a laser beam to determine how much turbulence there is in the atmosphere.

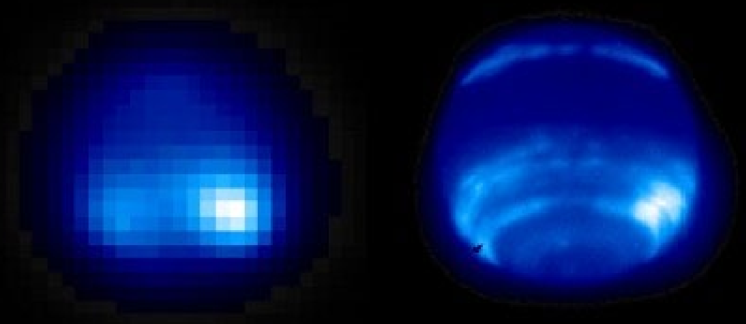
In a VERY short period of time, the primary mirror is distorted to account for the turbulence. Results...



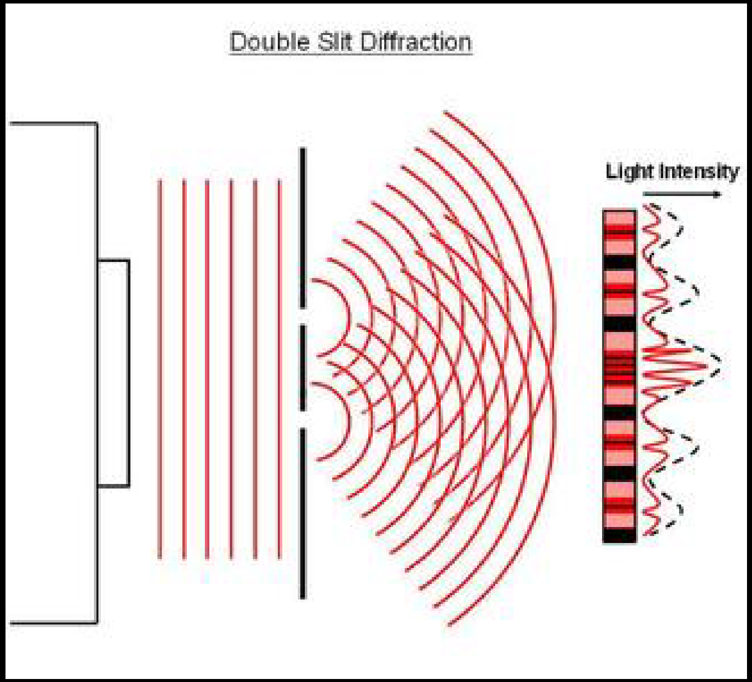


By deforming the mirror slightly with these mirror supports, the image will become MUCH better like...

Adaptive Optics



Diffraction fringe – due to wave nature of light.



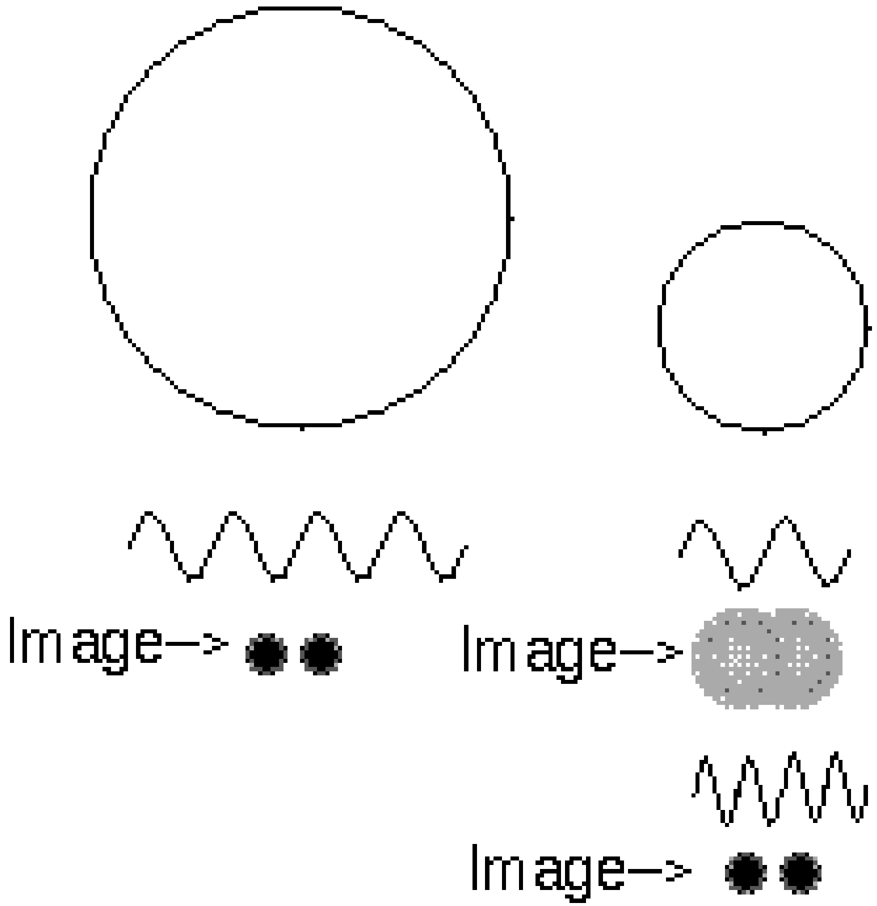
Resolving power: How close two objects can be in the sky and be seen as separate by a telescope.

$$\theta_R = \frac{\lambda}{D}$$

The smallest angular separation of two stars on the sky that can be observed as separate objects is equal to the wavelength of light divided by the diameter of the mirror.

Resolving power depends on both the diameter of the primary mirror and the wavelength you want to observe.

$$\theta_R = \frac{\lambda}{D}$$



Bigger objective samples more of the light: sharper images! Depends on **diameter** of objective and **wavelength**: $\theta_R \sim (\lambda/D)$.

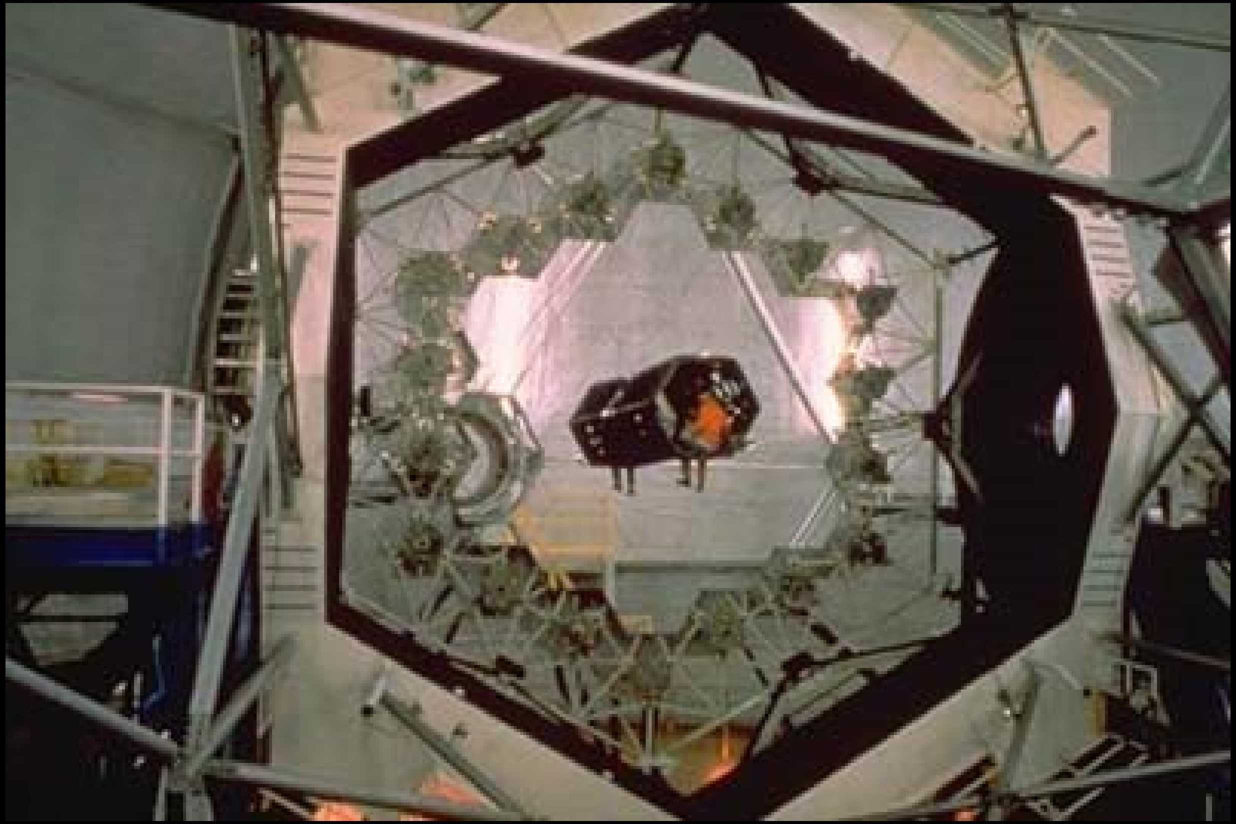
Make **diameter** *bigger* or **wavelength** *smaller* for sharper images.

Images for same two stars are shown.

$$\theta_R = \frac{\lambda}{D}$$

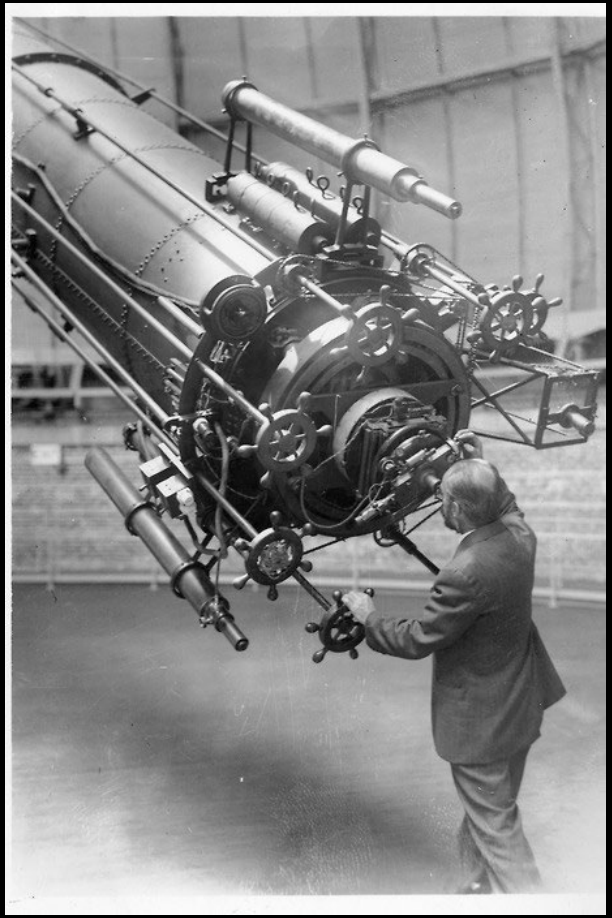
For Keck Telescope, for λ = 550 nm, and D = 10 m. θ is measured in radians. This comes out to around 0.013” .

1 arc second = 1/3600 of a degree.
For reference, your little finger covers an angular width of around 1 degree.

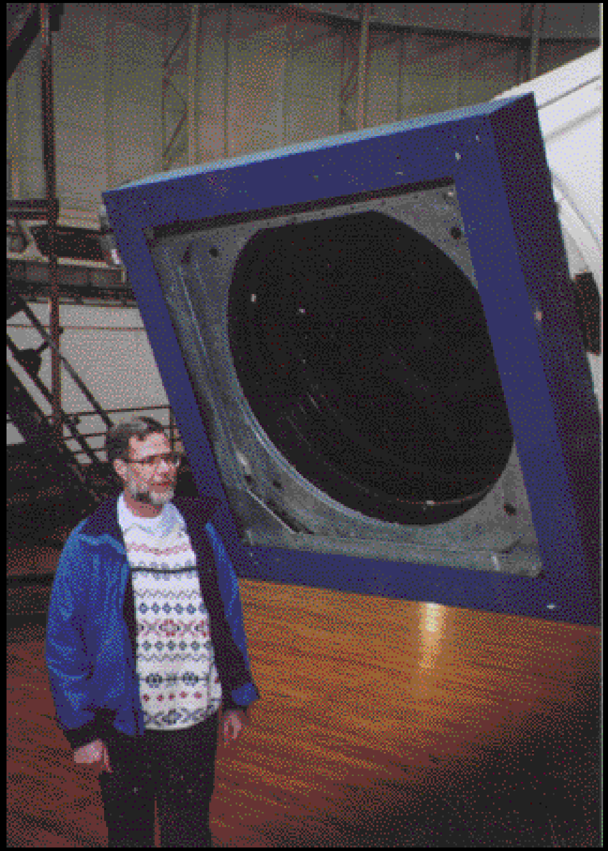


Famous Telescopes

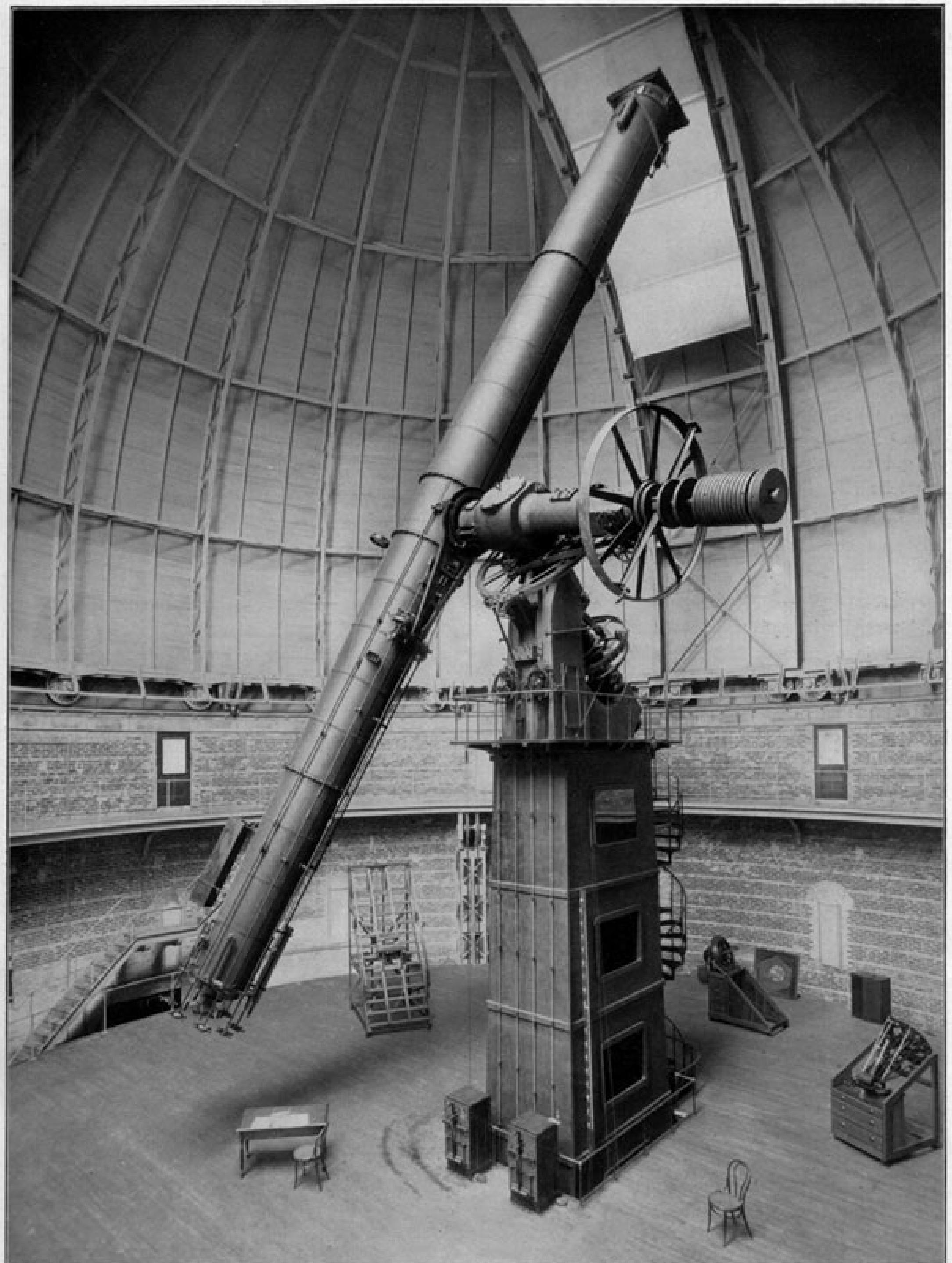
Largest Refractor has a 1m or 40″ lens in the front.
It is located at Yerkes Observatory in
Williams Bay, WI.



Getting ready to look through the 40″ refracting telescope



Standing in front of the 40″ lens



The 60' long
telescope is very
large.
The observatory
floor raises and
lowers so that the
observer can see
through the
eyepiece no matter
where the
telescope is
pointing.

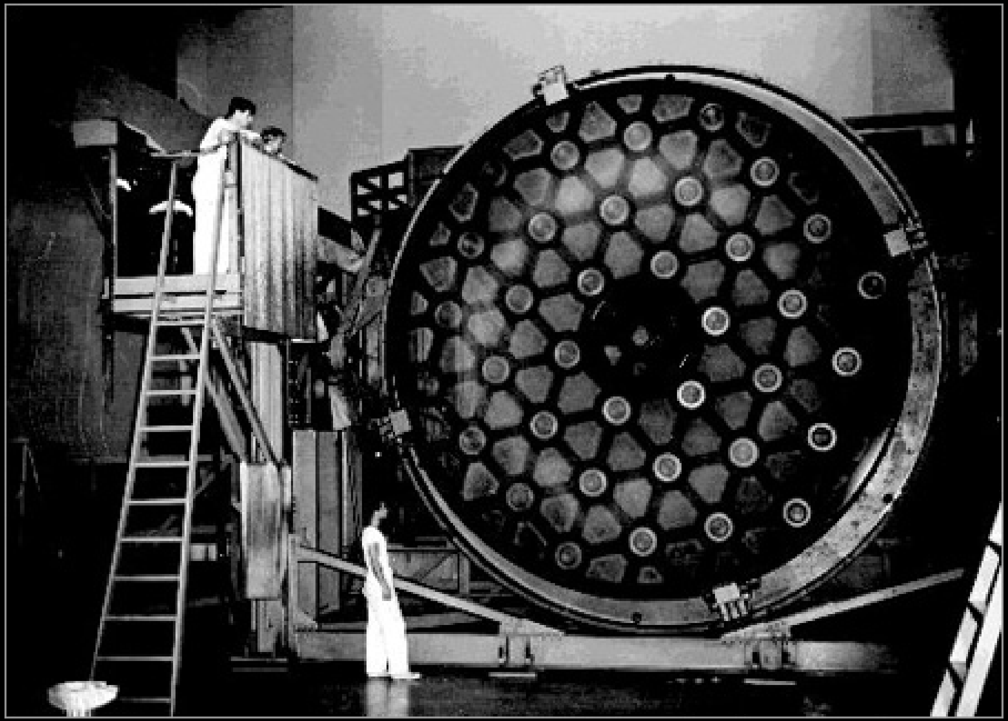
Famous Telescopes

The Mount Wilson Telescopes will be discussed later in the semester. This site is located just north of the LA basin.

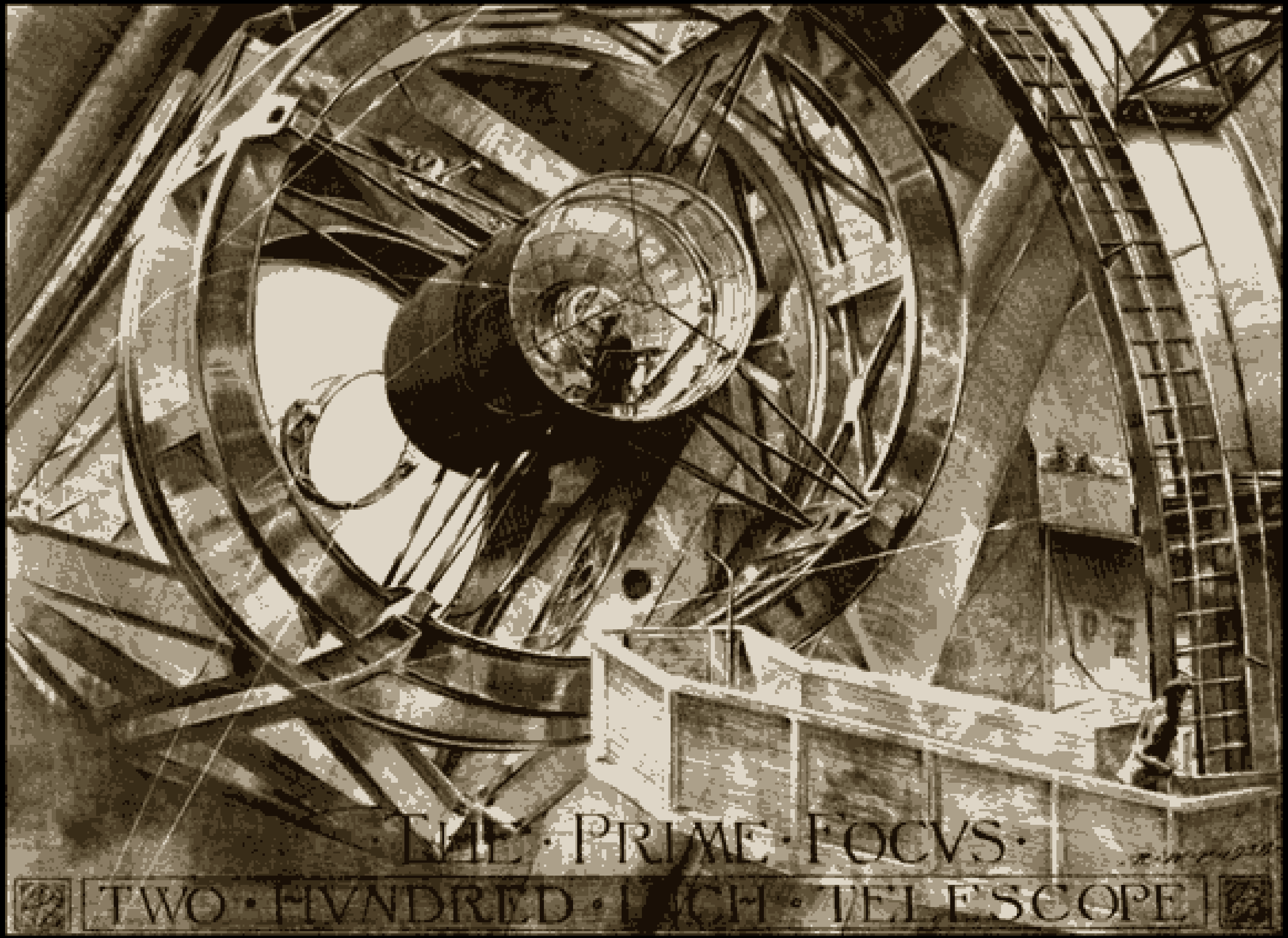
Famous Telescopes

Mt Palomar Observatory is north of San Diego.

For many years this 5m or 200" telescope was the largest single mirror in the world.

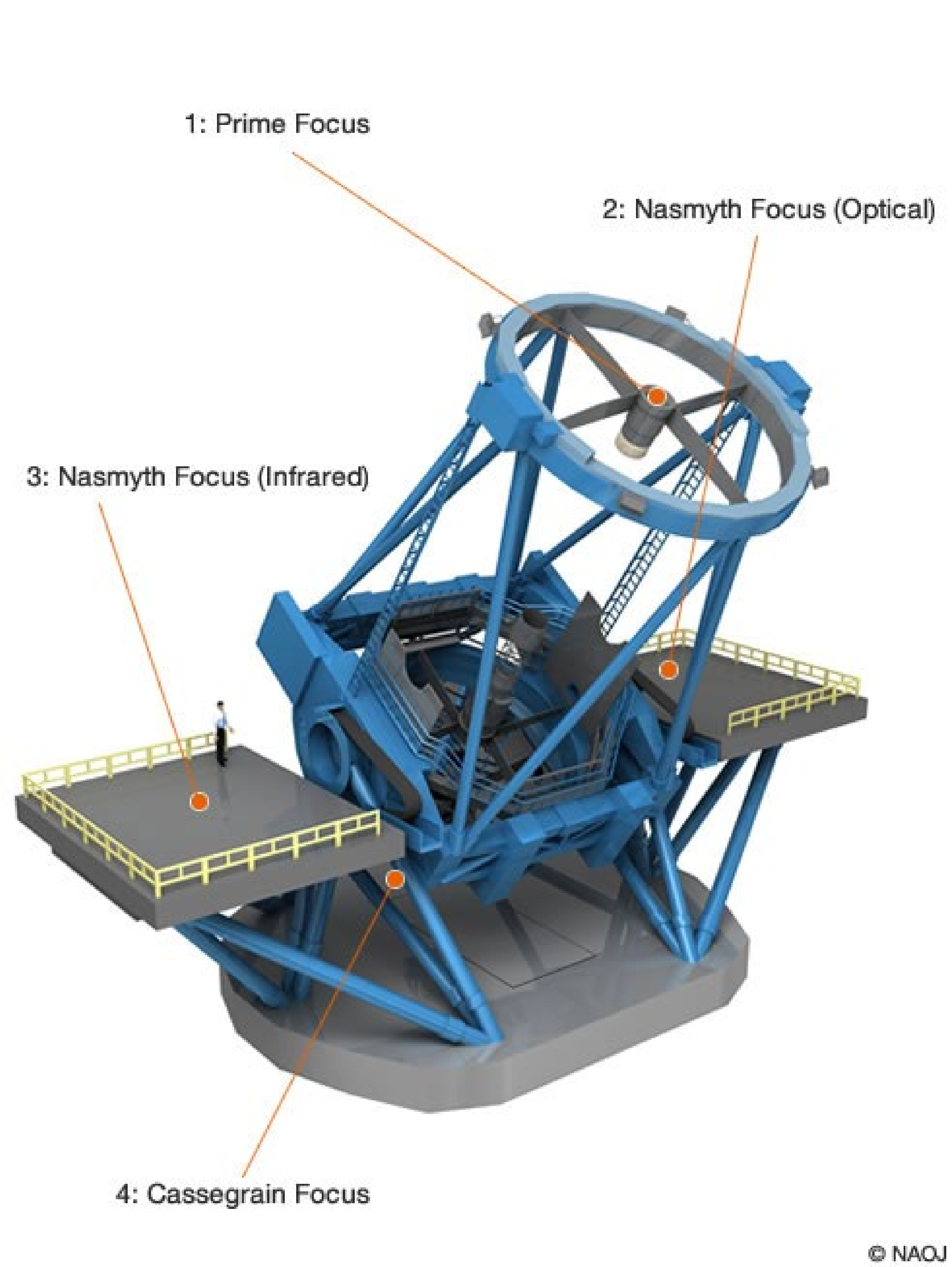


Palomar Observatory is impressive.



200-inch Hale Telescope at Mt. Palomar, California. Notice the astronomer sitting in the Prime Focus cage *inside* the telescope tube.

The Subaru Telescope on Maunakea has four foci (mentioned in chapter 4).



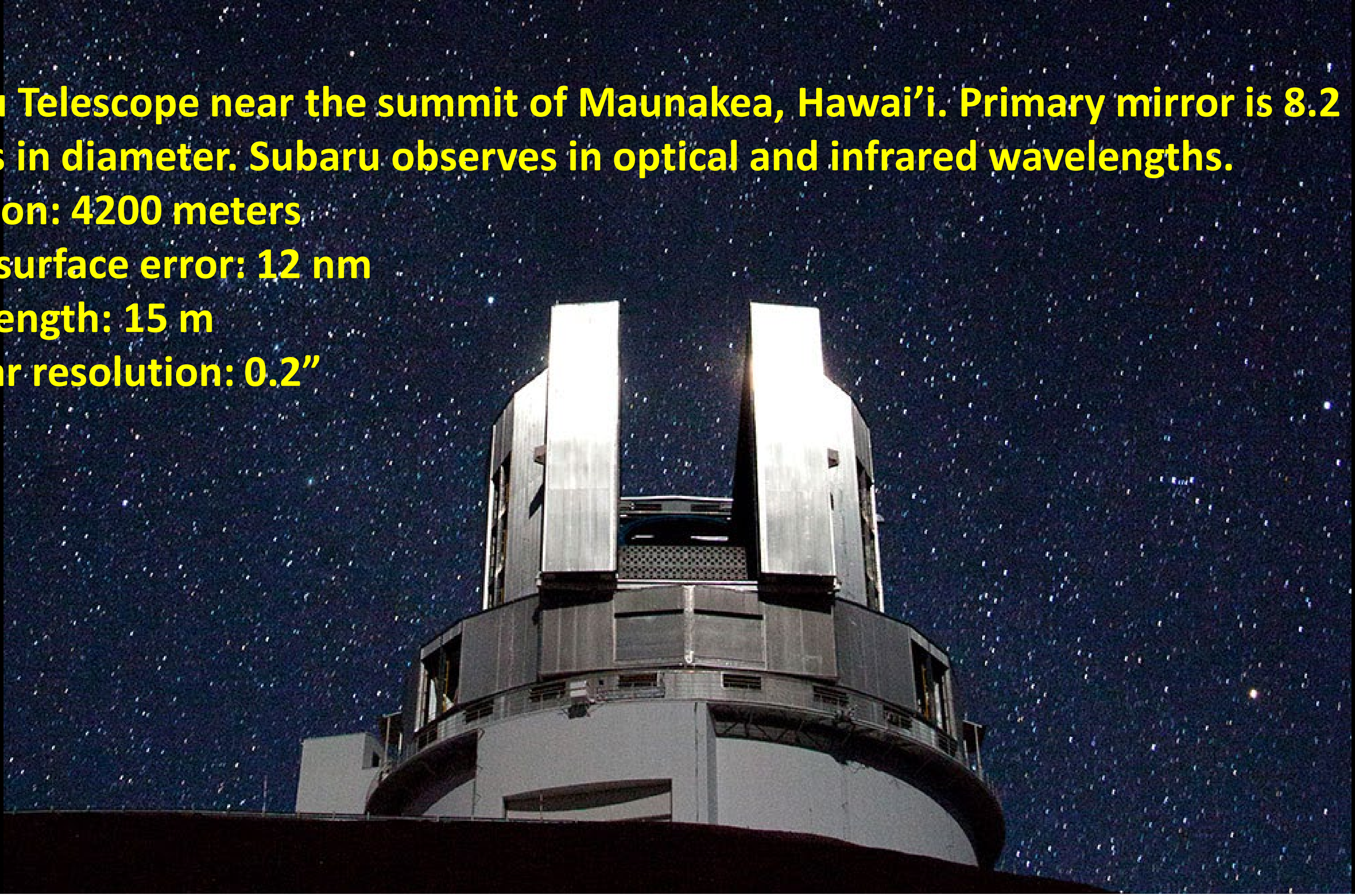
Subaru Telescope near the summit of Maunakea, Hawai'i. Primary mirror is 8.2 meters in diameter. Subaru observes in optical and infrared wavelengths.

Elevation: 4200 meters

Mean surface error: 12 nm

Focal length: 15 m

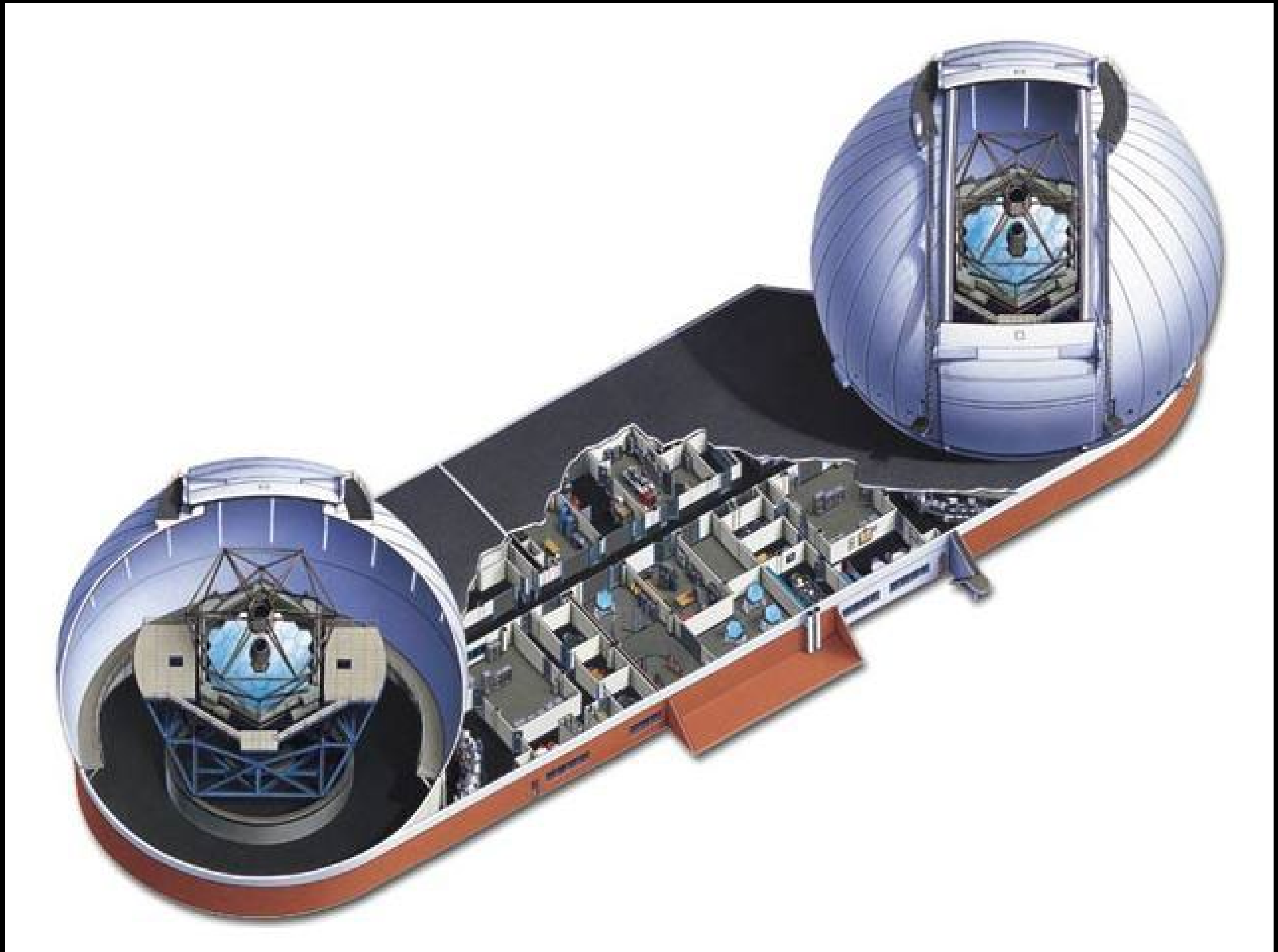
Angular resolution: 0.2"



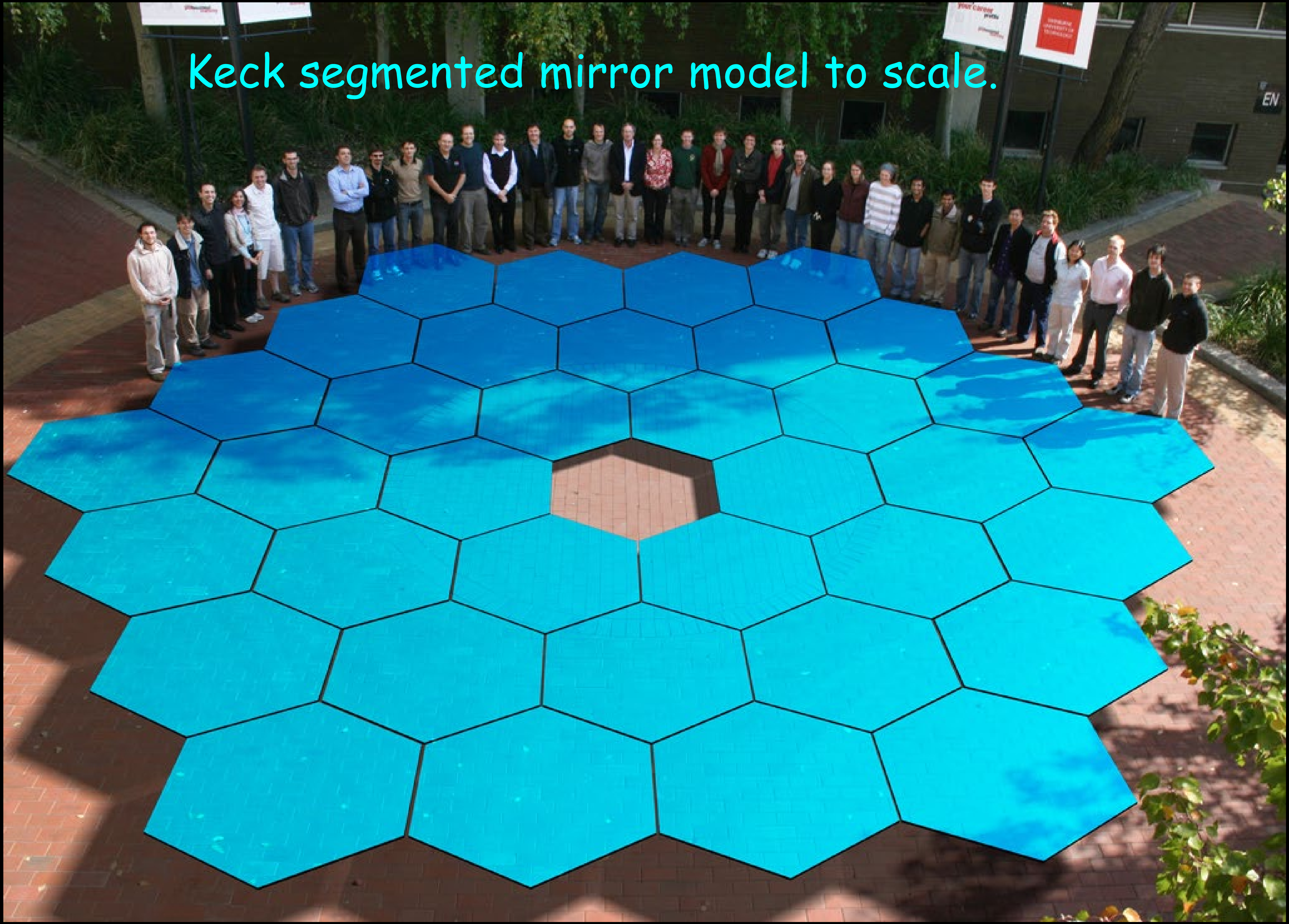
How do big telescopes do it? See https://www.youtube.com/watch?v=Muk4F_LvbYs

Credit:NAOJ

Keck Telescopes are the largest in the world.
There are 2 twin Observatories
each with a 10m or 400′ mirror in Hawaii
on Mauna Kea



Keck segmented mirror model to scale.



Looking at the 36 hexagonal segments.
EACH 6 feet wide and weighing 800 pounds.

Research telescopes are placed in locations that are as high as possible, and as dry as possible, or in orbit.

Twin Keck 10-meter telescopes and Subaru Telescope on Mauna Kea, Hawai'i

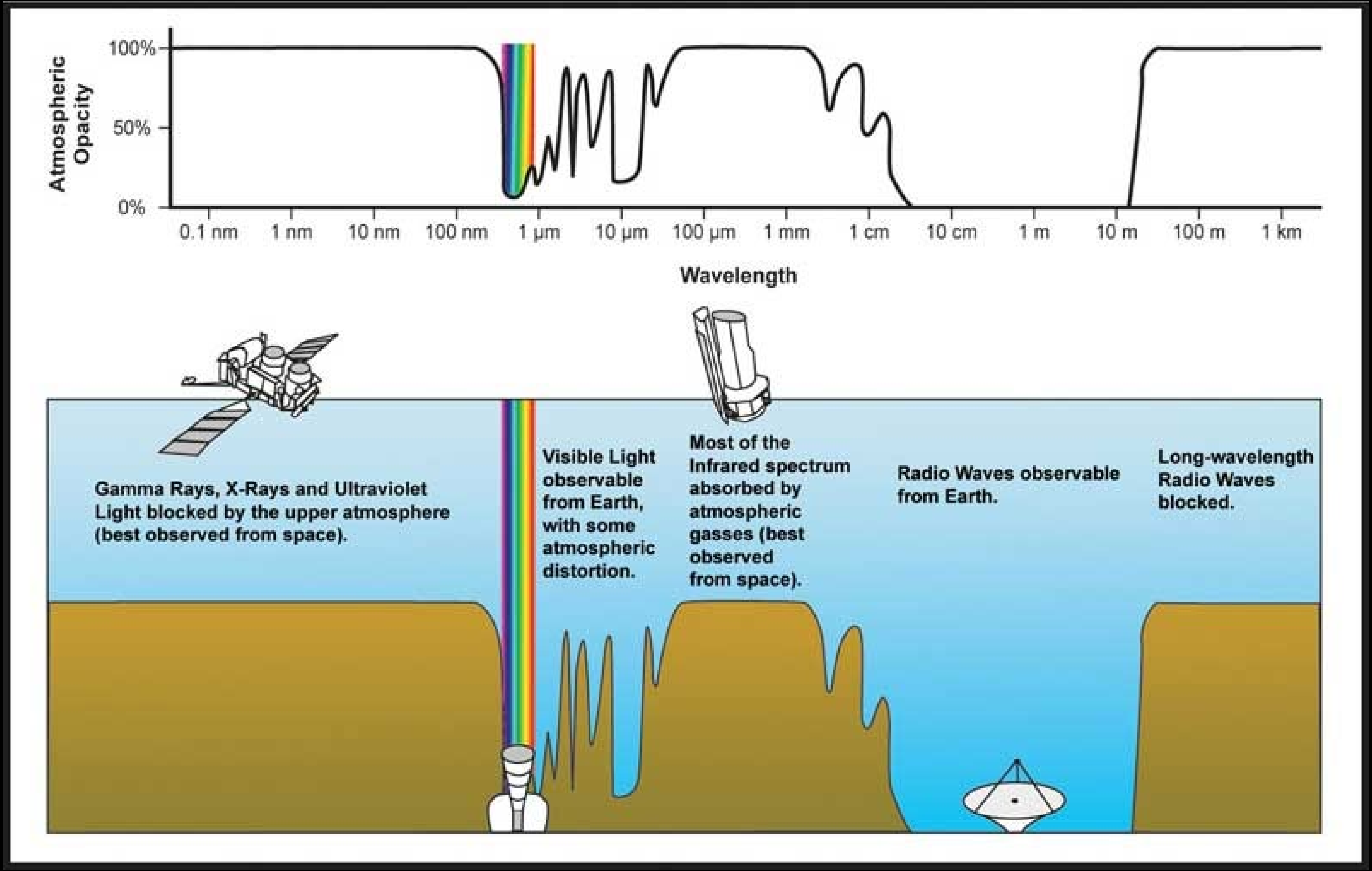
Hubble Space Telescope

Space Telescopes

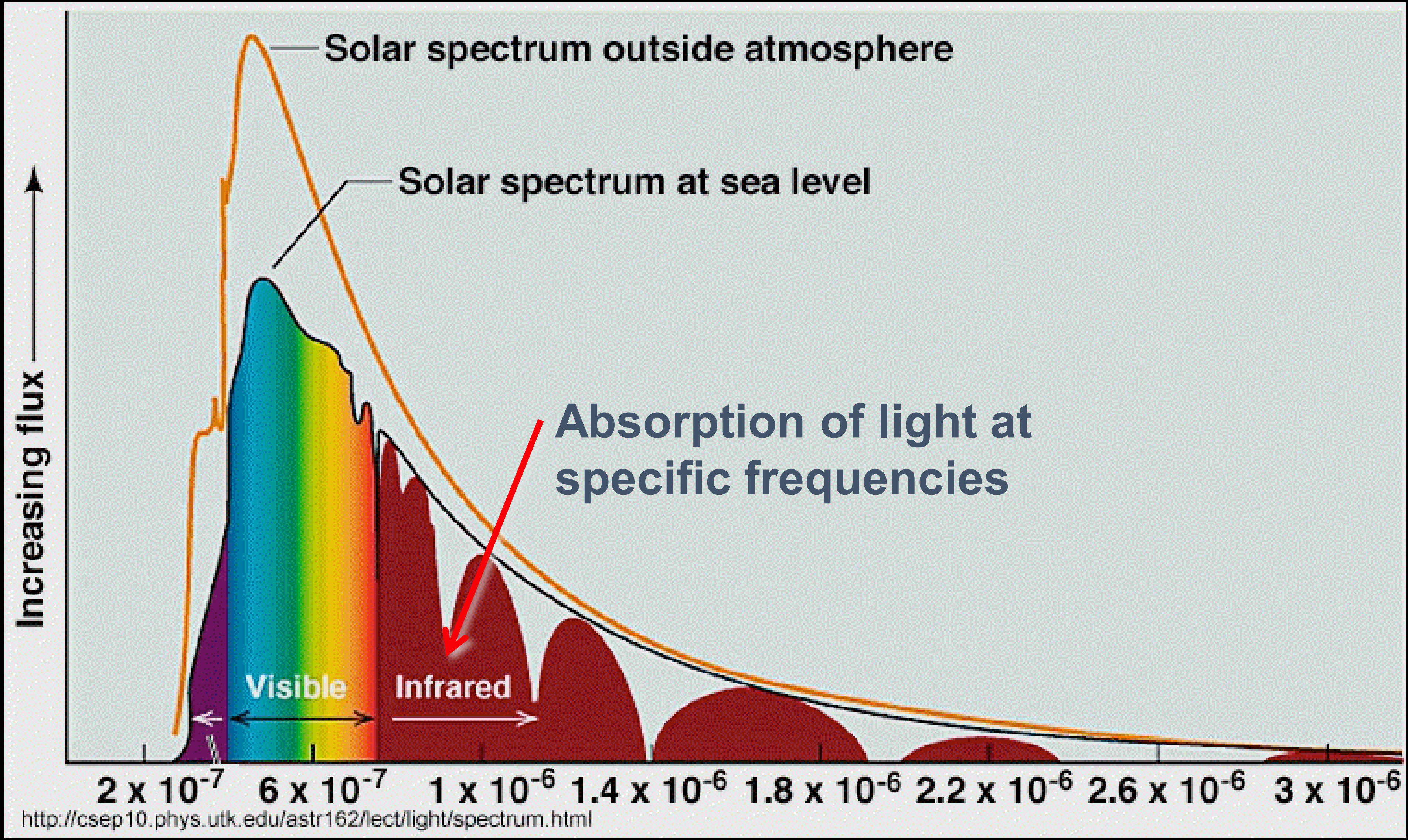
Hubble Space Telescope - HST

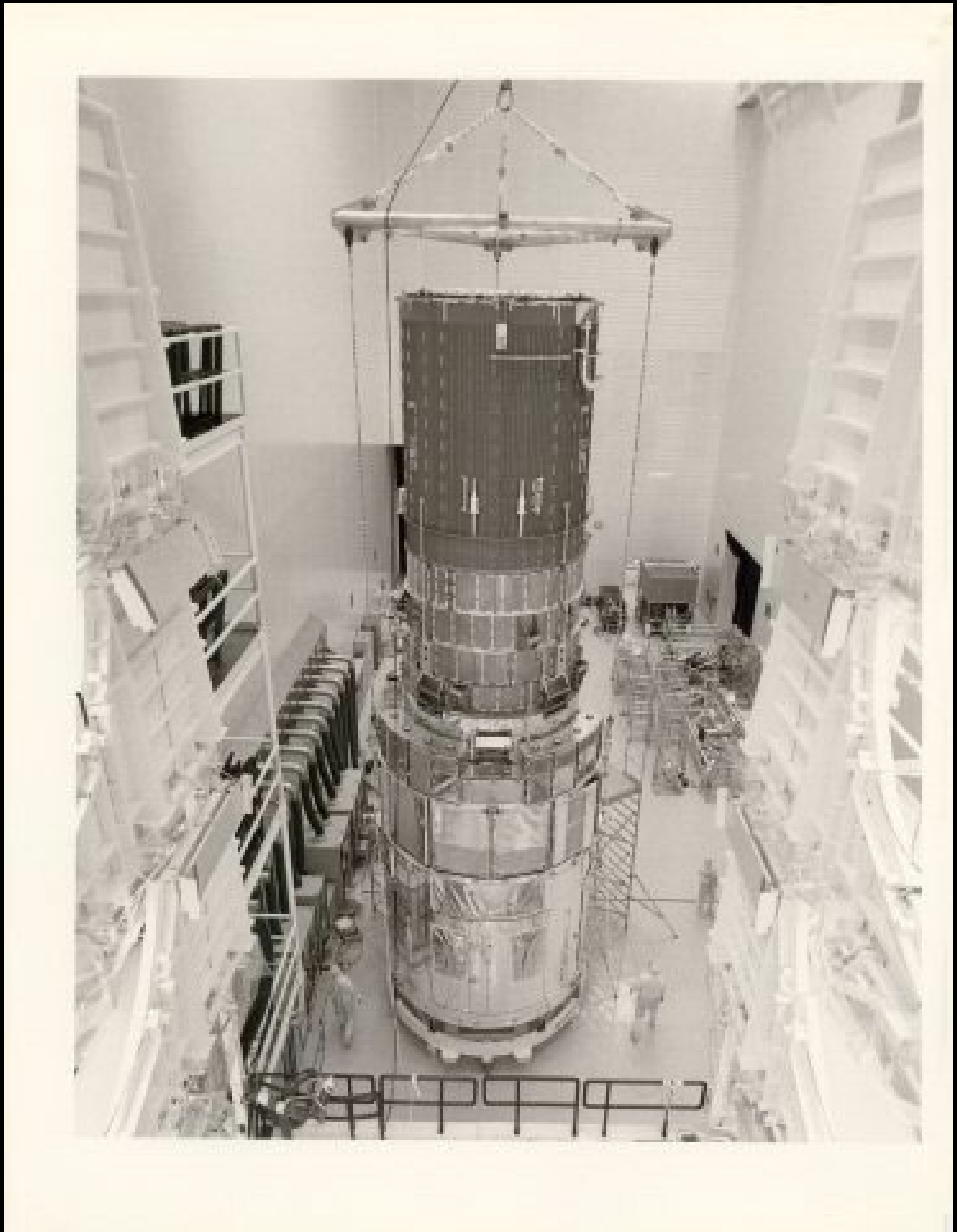
Hubble is a reflecting type telescope with a mirror of 2.4m or 94” in diameter.

Light from space that we can see from the ground depends on the absorption / transmission of the atmosphere.



Real solar spectrum…



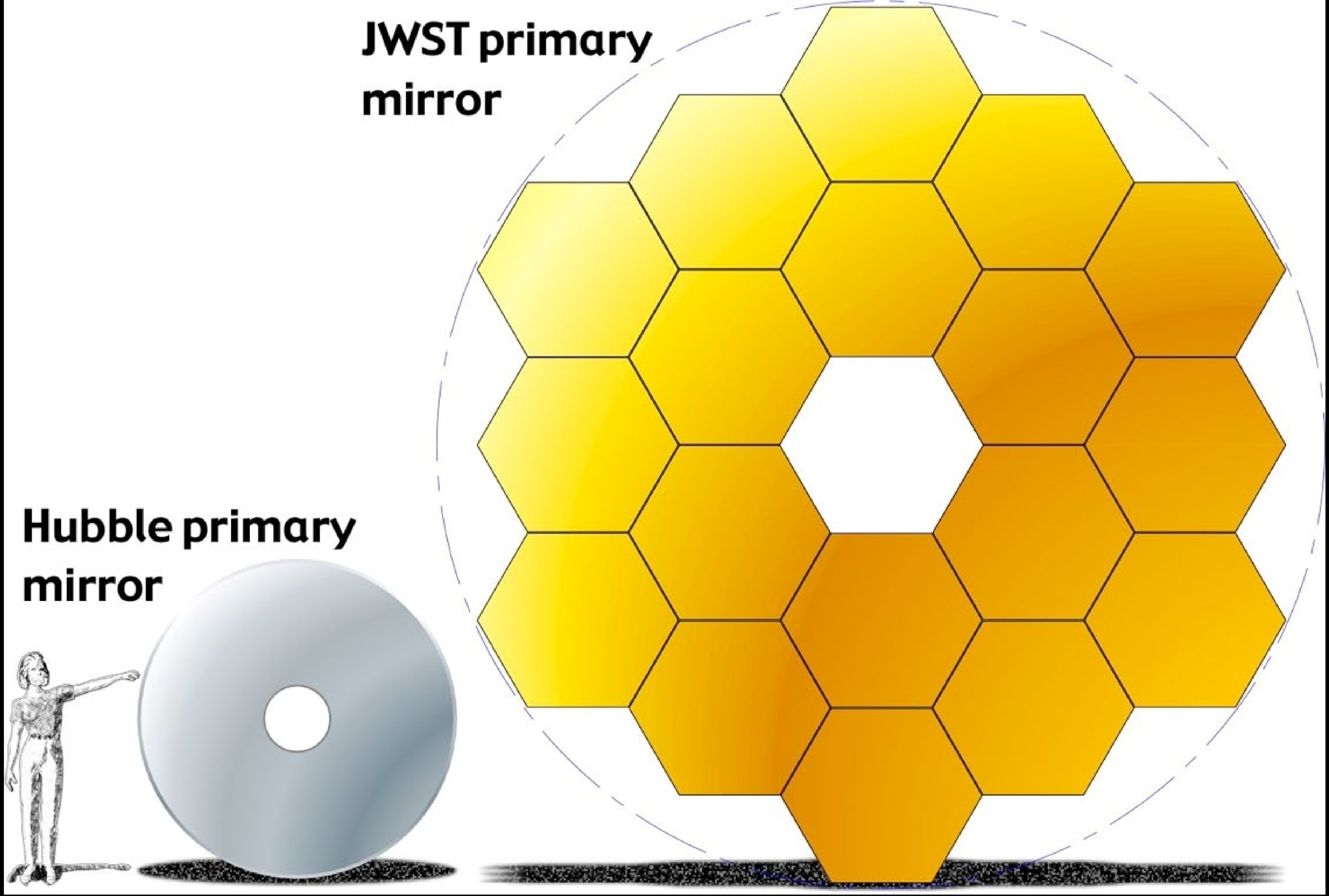


Hubble being prepped for Launch

Think school bus size!

Hubble Launch on April 25, 1990 by Shuttle Discovery

Next Generation Space Telescope is the James Webb Space Telescope (JWST)

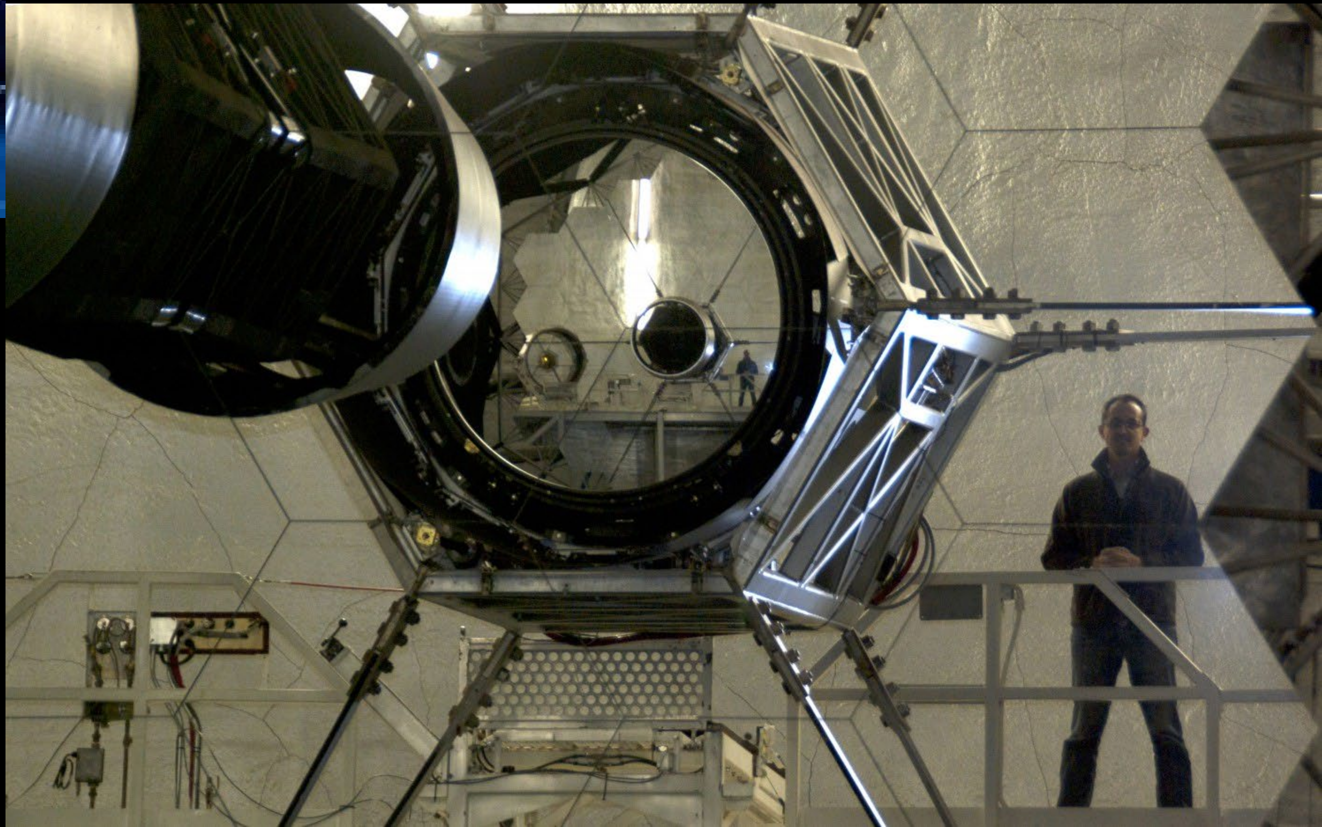


JWST has a 6.5m or 21′ mirror (18 segments)

JWST to scale - it is VERY large!!

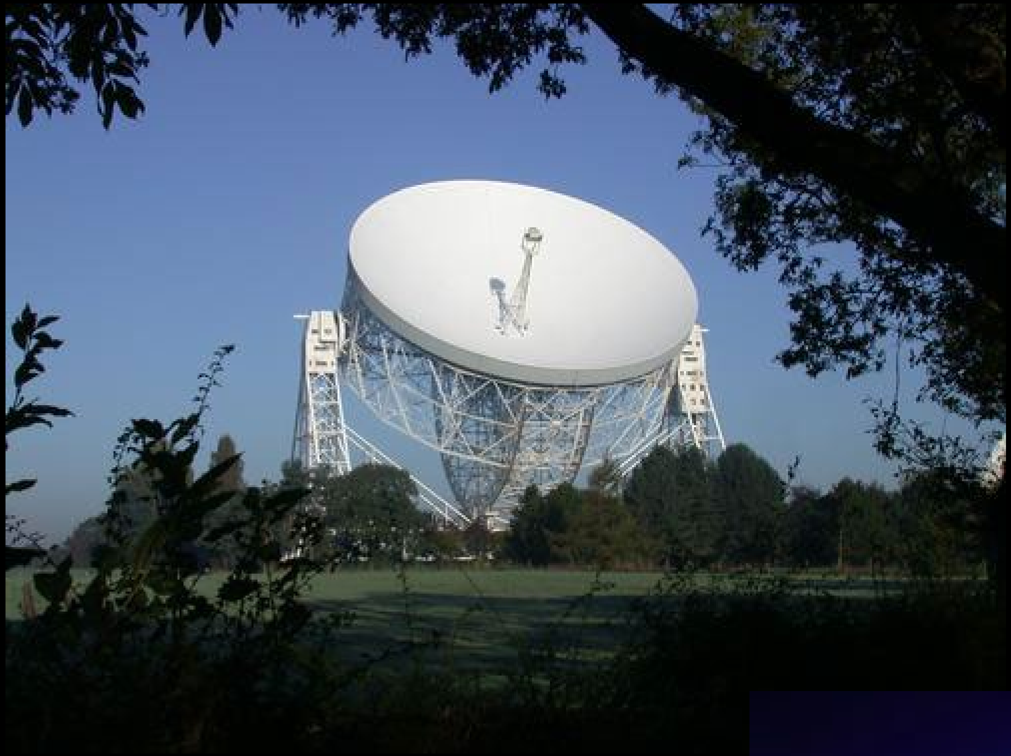
The 18 mirror segments being manufactured

Big telescopes are made in precise segments that are fit together. They can be individually focused to great precision.



Reflecting telescopes are the only ones being built for research purposes today, because mirrors can be made much larger than lenses, and their deformation can be controlled mechanically.

Radio telescopes have largest-diameter dishes



Interferometer: Increases diameter by linking telescopes together