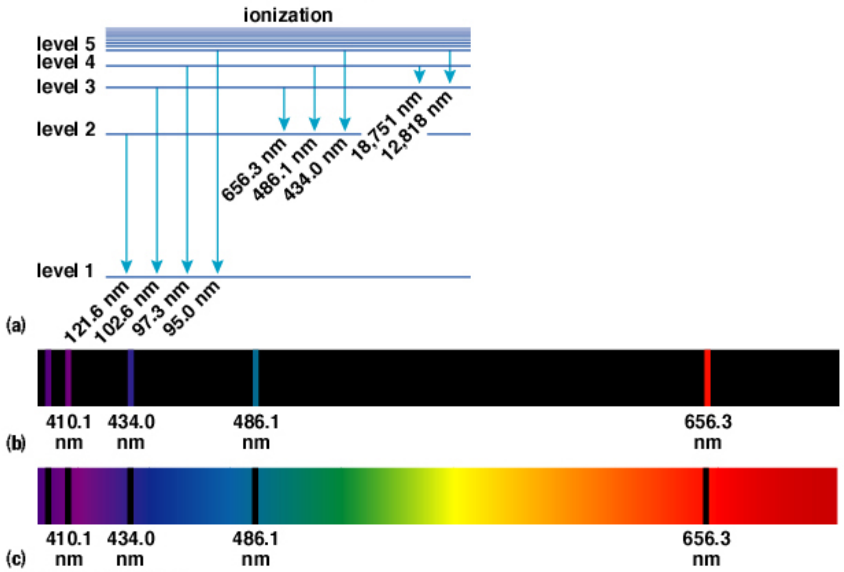
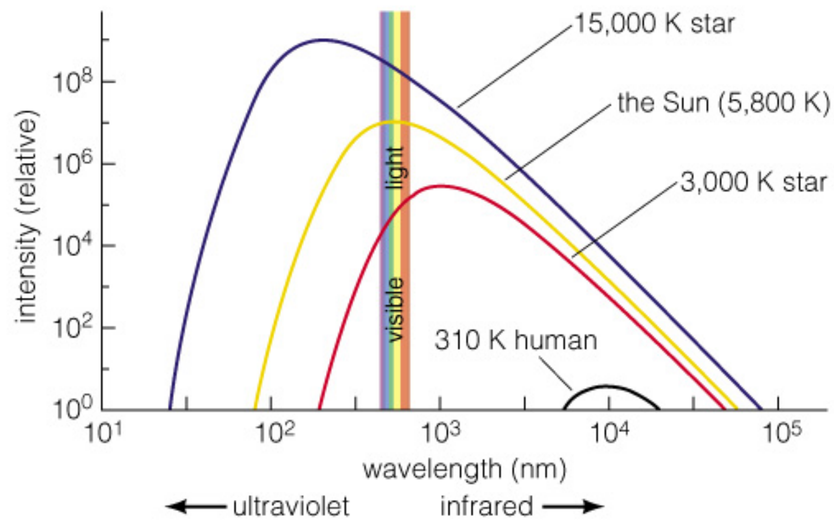
Collecting Light with Telescopes

Two Fundamentally Different Spectral Mechanisms





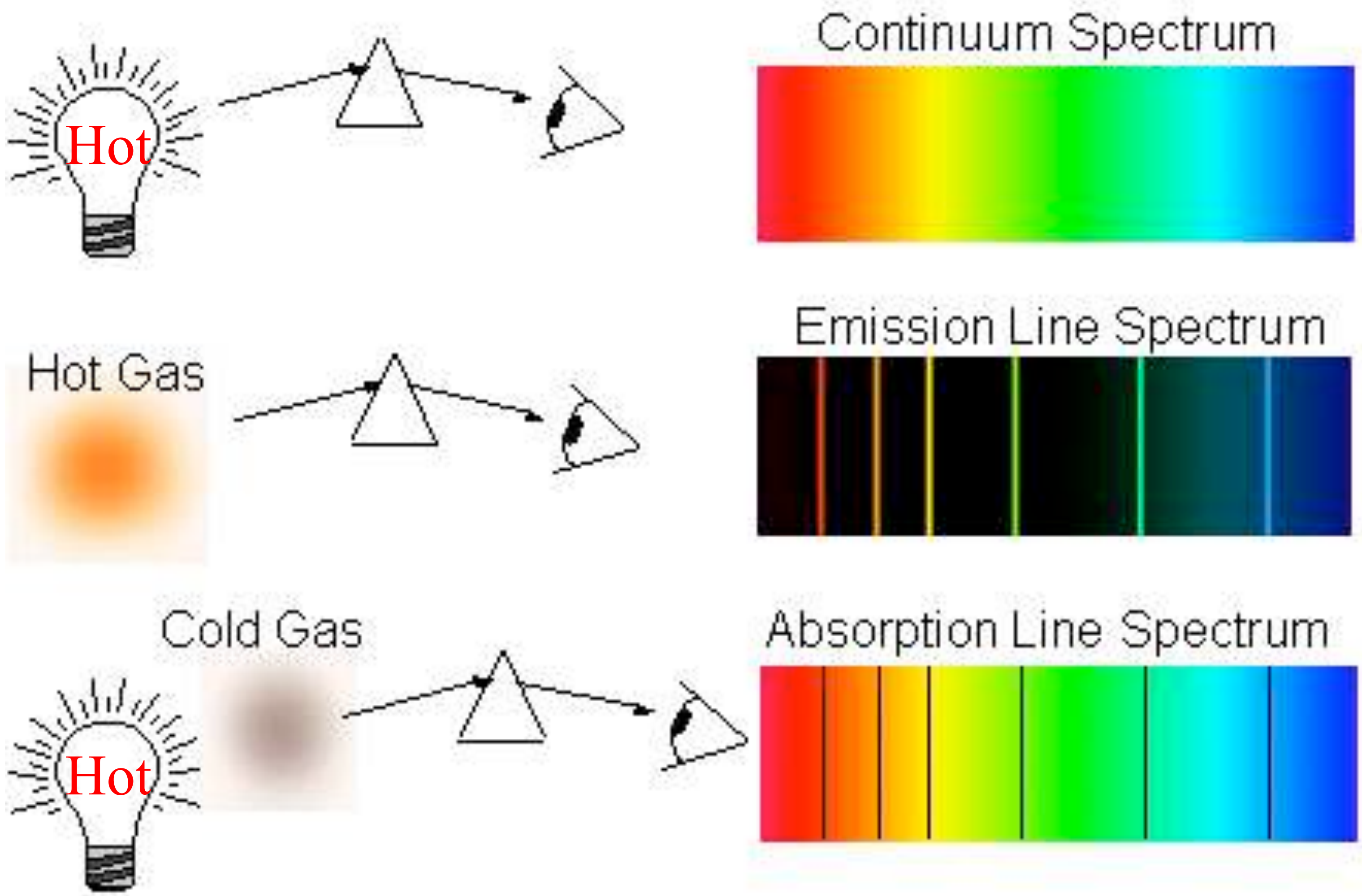
Spectral lines:

- narrow, sharp features
- pattern unique to each element
- gives chemical composition
- emission (hot, diffuse gas)
- absorption (cool, diffuse gas)

Thermal radiation:

- broad, smooth continuum
- peak emission gives temperature
- higher temp, shorter wavelength
- no information on composition
- everything emits thermally

RULE: To have absorption spectrum, you must have **cold** stuff in front **hot**

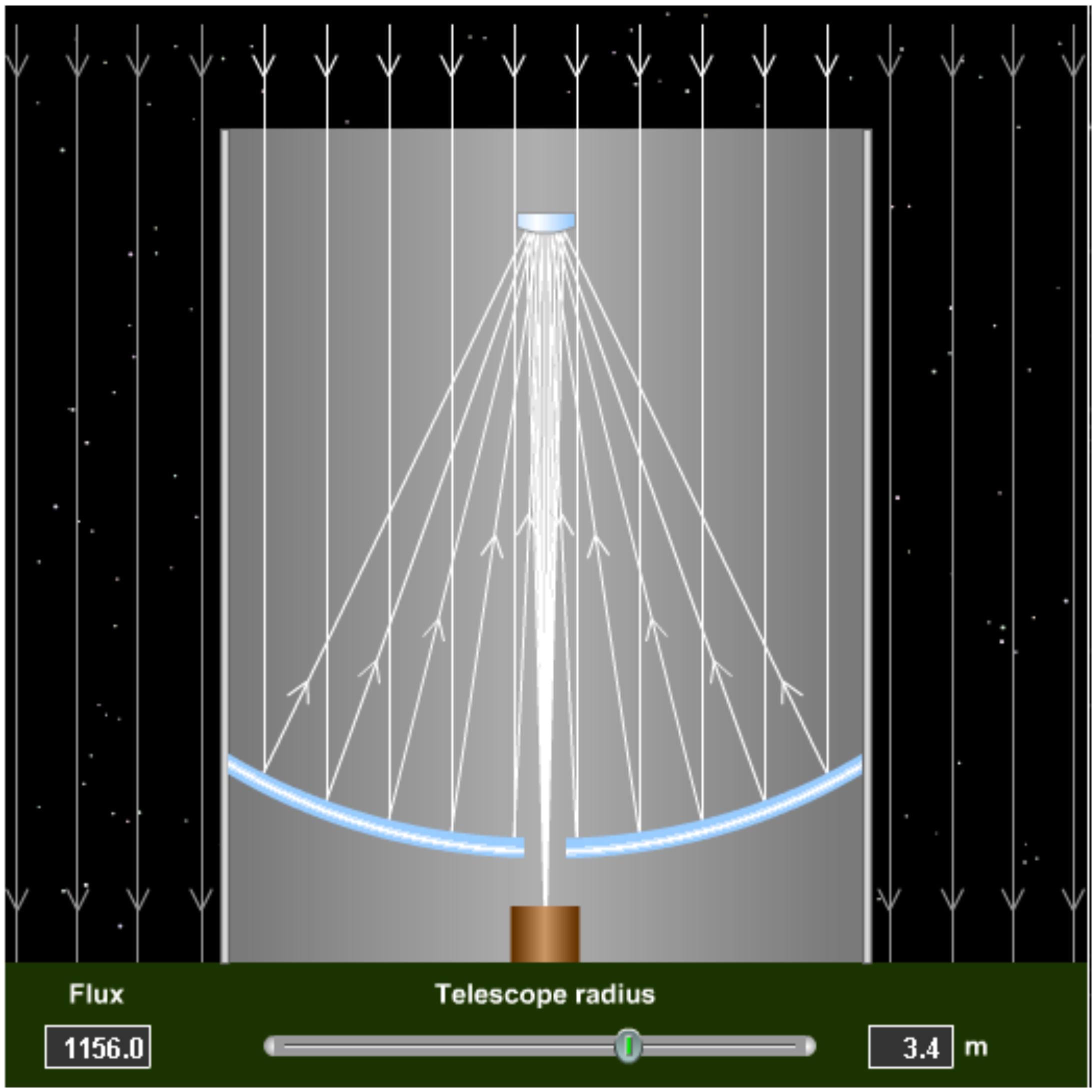


How do telescopes help us learn about the universe?

- Telescopes collect more light than our eyes ⇒ **light-collecting area**
- Telescopes can see more detail than our eyes ⇒ **angular resolution**
- Telescopes/instruments can detect light that is invisible to our eyes (e.g., infrared, ultraviolet)
- Bigger is better! More light collected and the images are sharper with larger telescopes

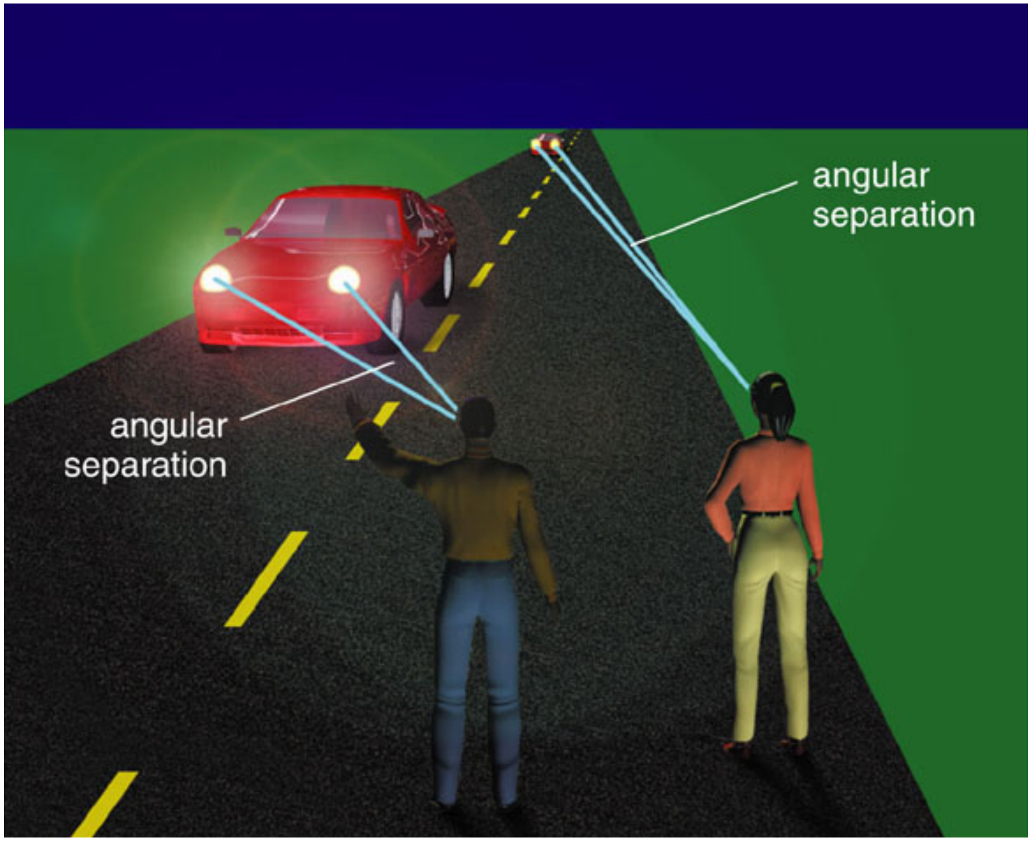
Bigger is better

Shape of mirror is a parabola to bring light to a focus



Angular Resolution

- The *minimum* angular separation that the telescope can distinguish.



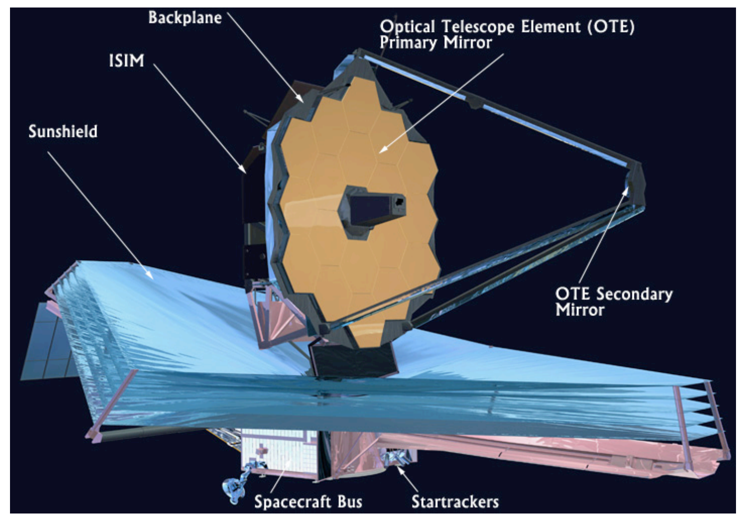
Angular Resolution of a Telescope

- The angular resolution in ***inversely*** proportional to the diameter of the telescope for a given wavelength

$$\theta \sim 1/D$$

Webb Space telescope will have 3x better angular resolution!

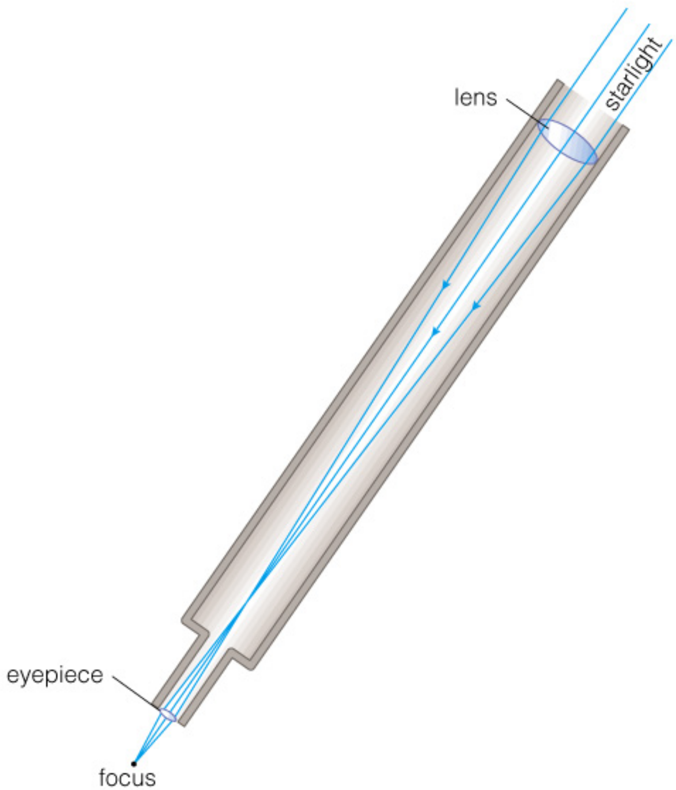
Hubble Space Telescope D ~ 2m



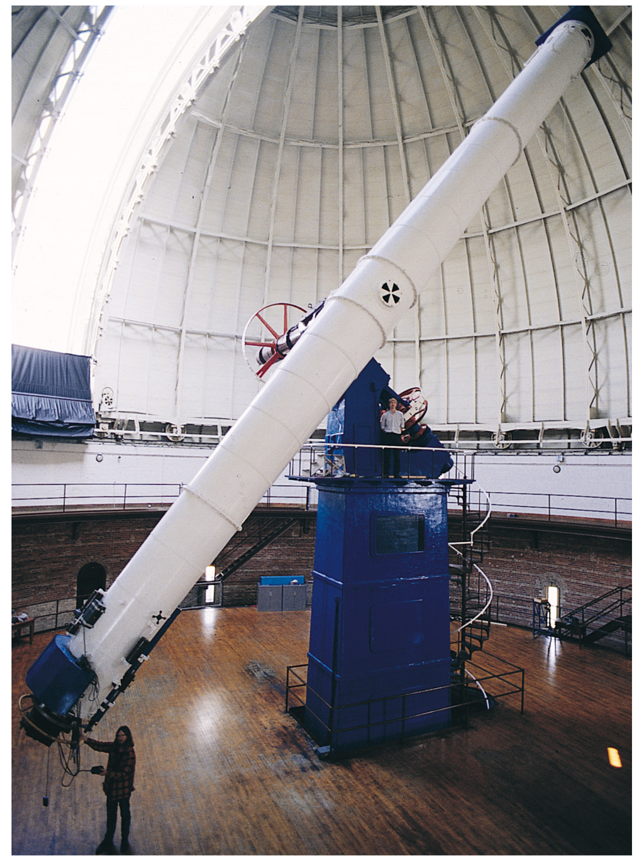
Webb Space Telescope D ~ 6m

Basic Telescope Design

- **Refracting**: lenses



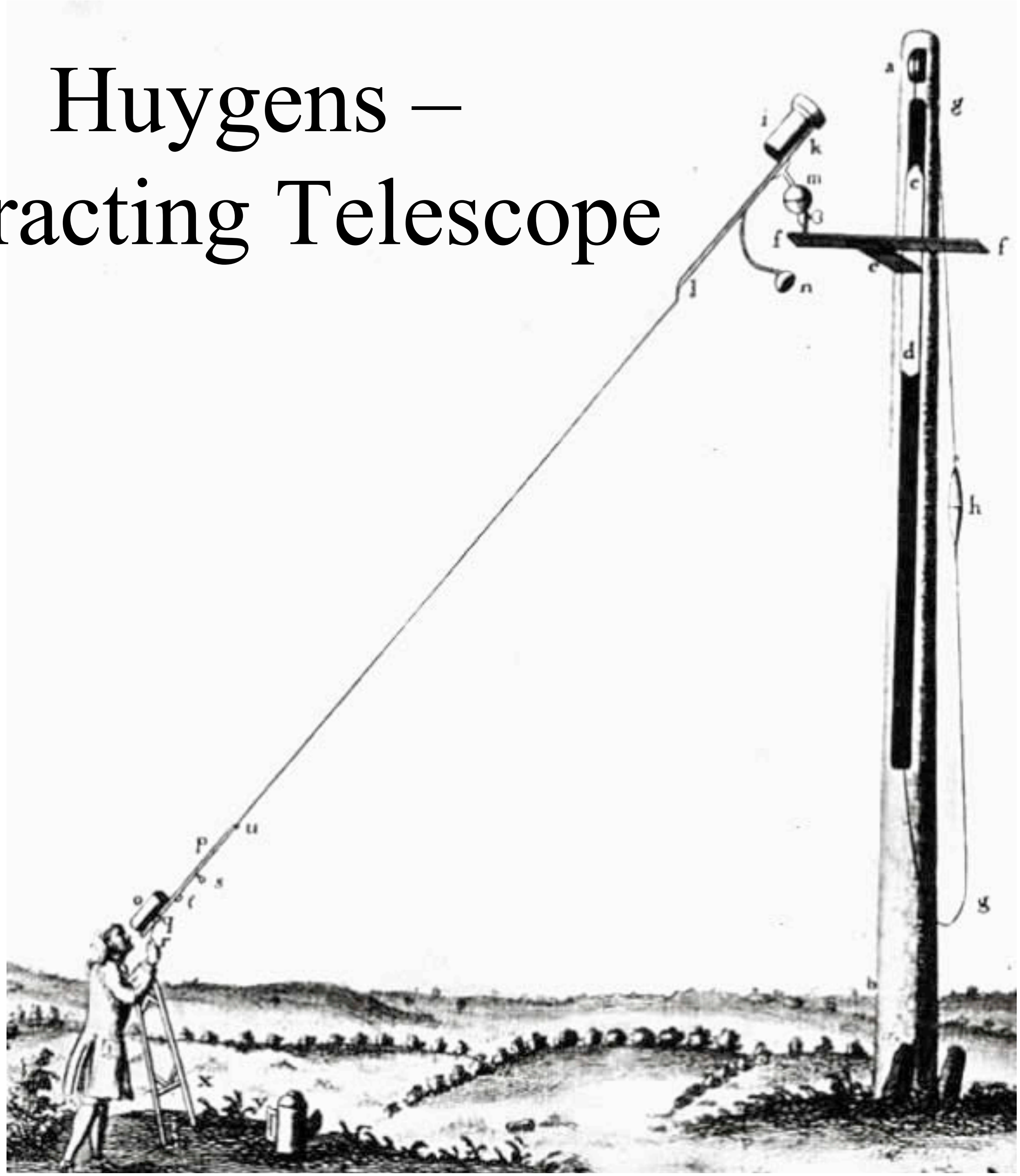
Refracting telescope



Yerkes 1-m refractor

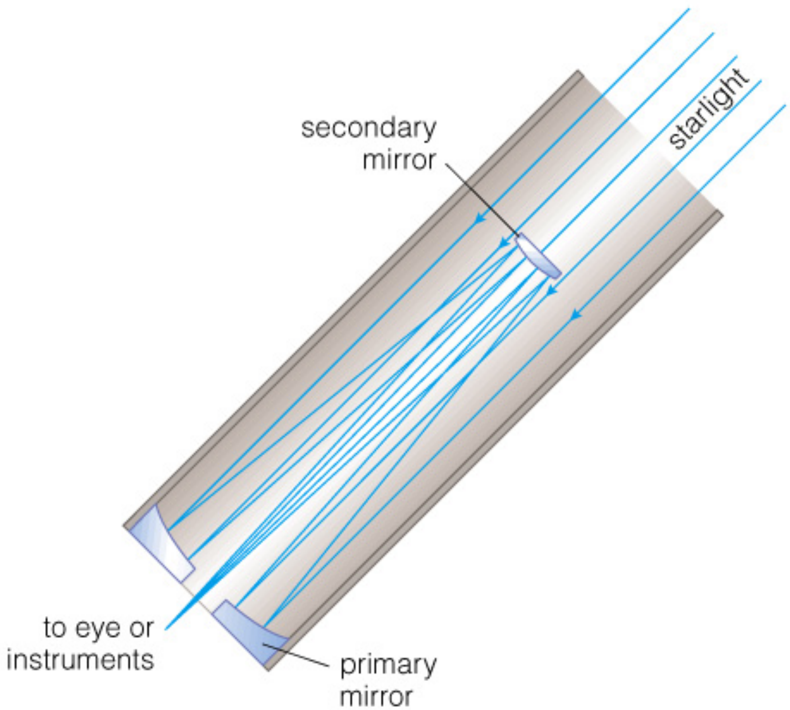
Galileo – Refracting Telescope

Huygens – Refracting Telescope



Basic Telescope Design

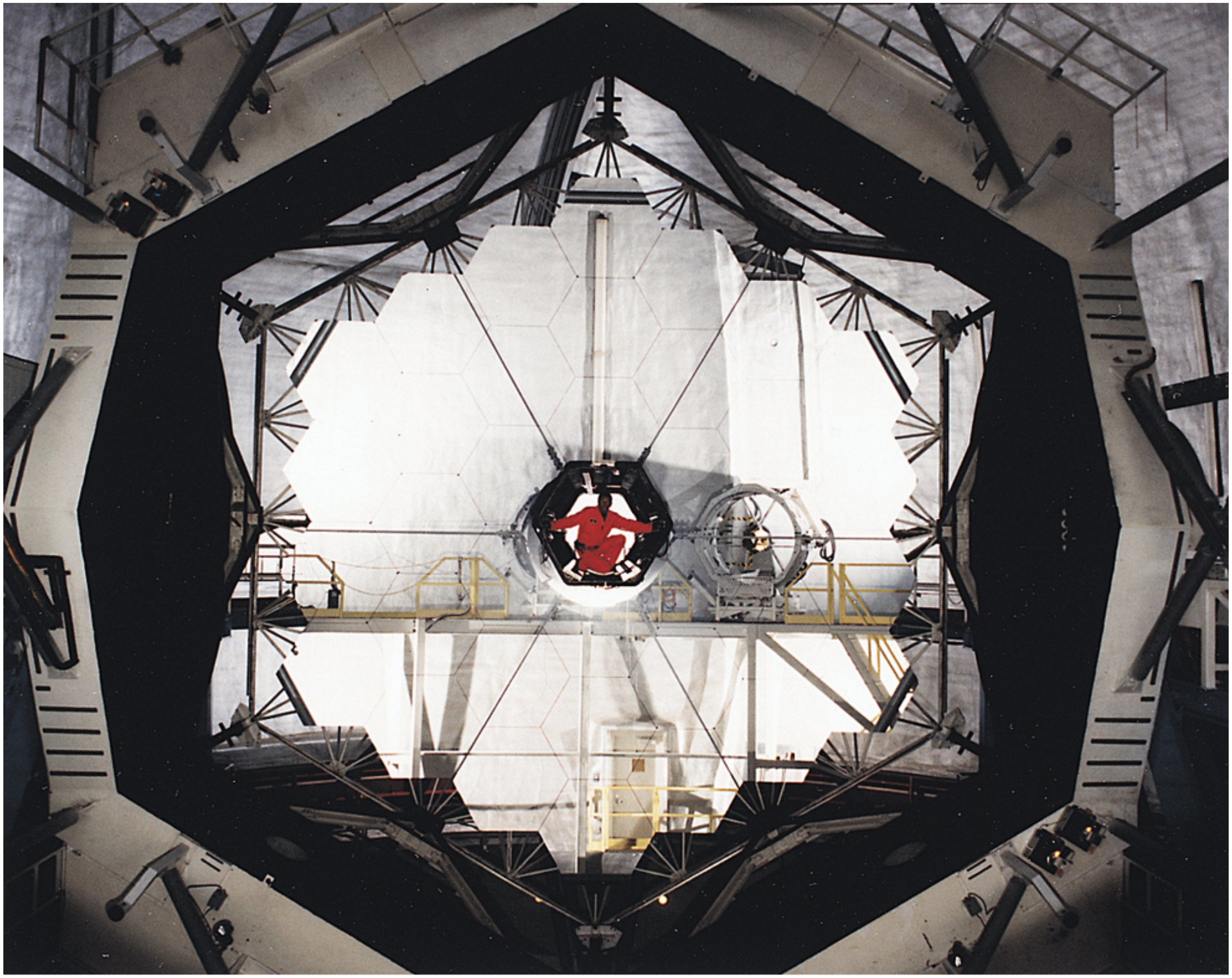
- **Reflecting**: mirrors
- Most research telescopes today are reflecting



Reflecting telescope

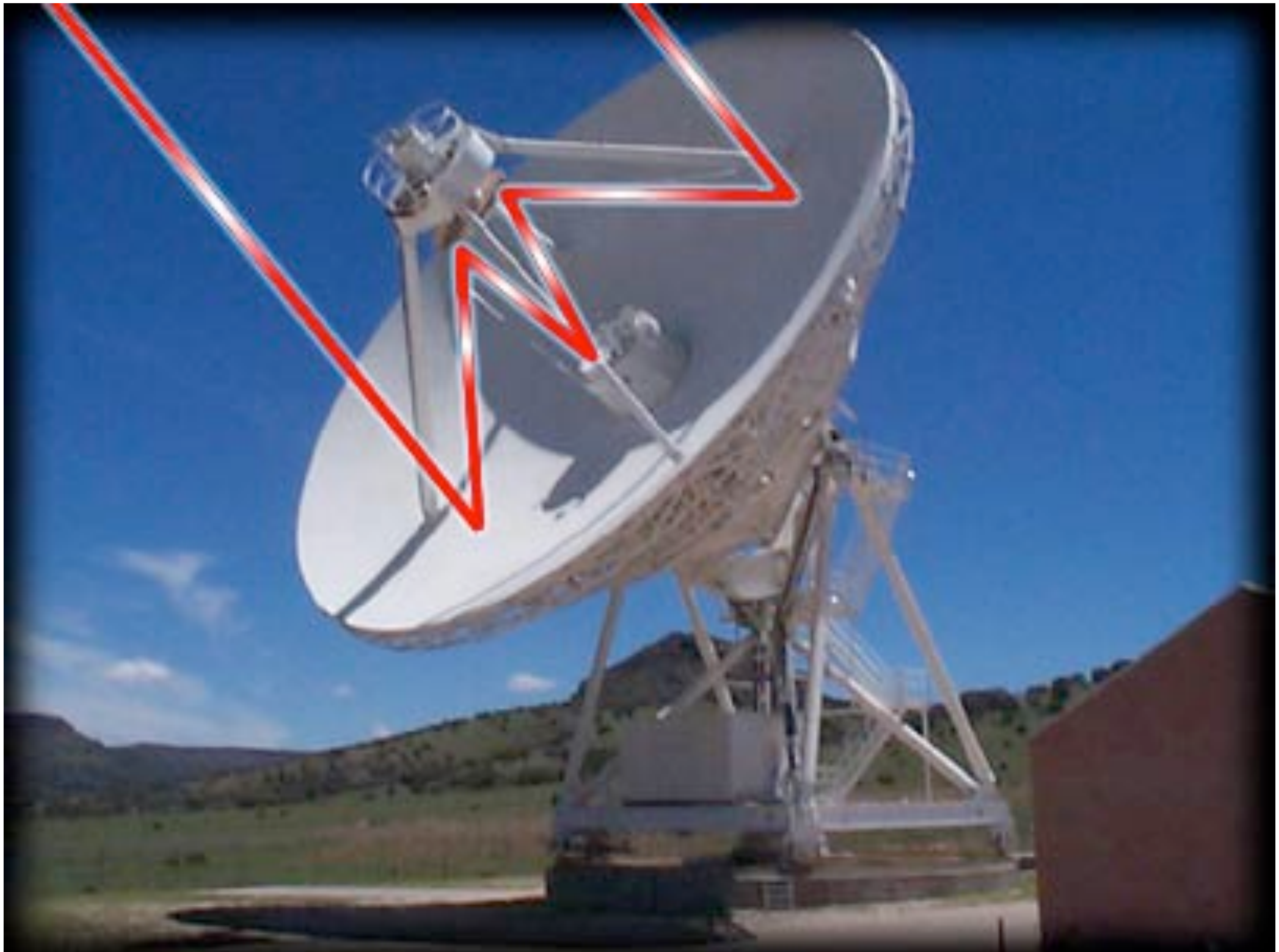
Gemini North 8-m

Keck I and Keck II, Mauna Kea, Hawaii



Different designs for different wavelengths of light

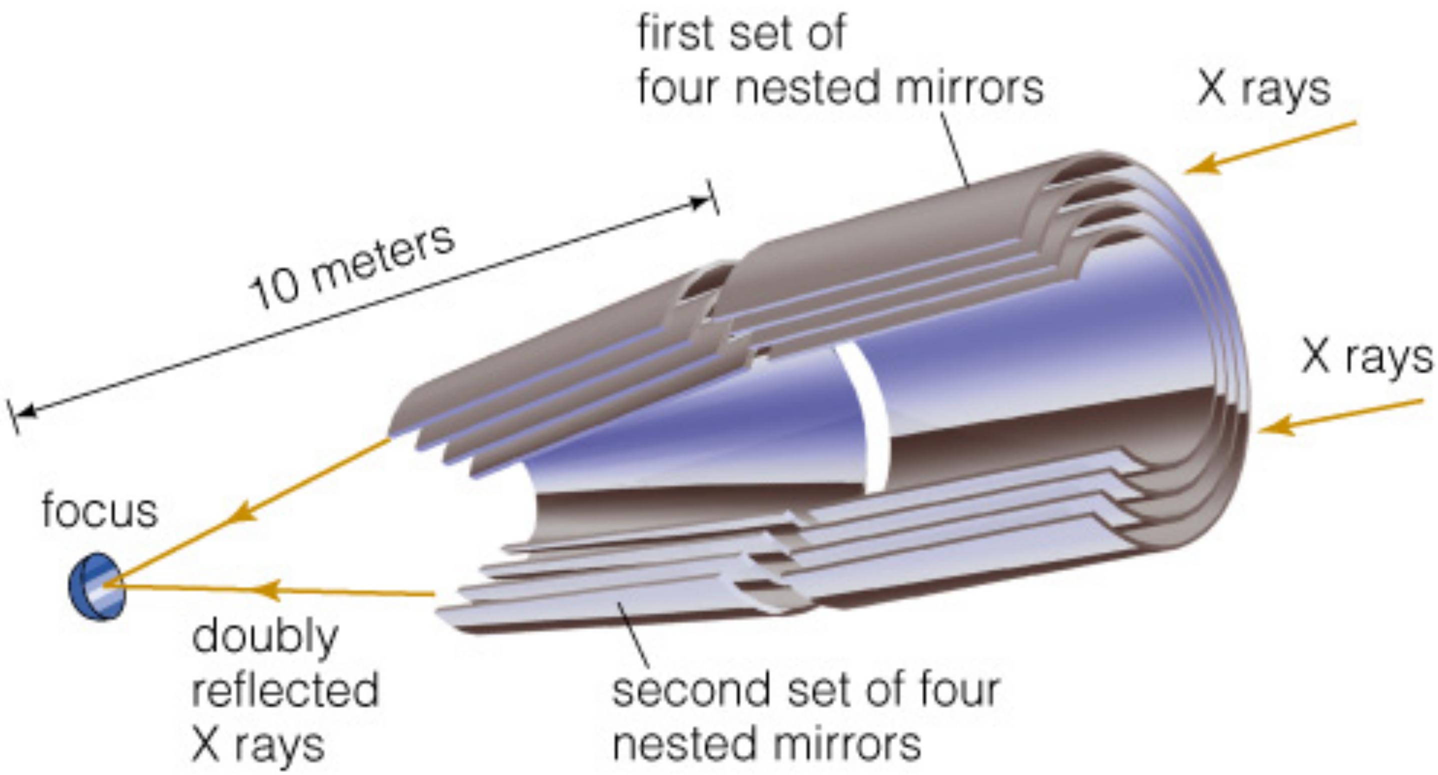
Radio telescope (Arecibo, Puerto Rico)



VLBA Antenna located at Fort Davis, TX

The colored beam illustrates how the radio signal from the source is reflected from the dish to the subreflector and into the feed horn of the receiver.

X-ray telescope: “grazing incidence” optics



Mirror elements are 0.8 m long and from 0.6 m to 1.2 m in diameter.

Why do we put telescopes into space?

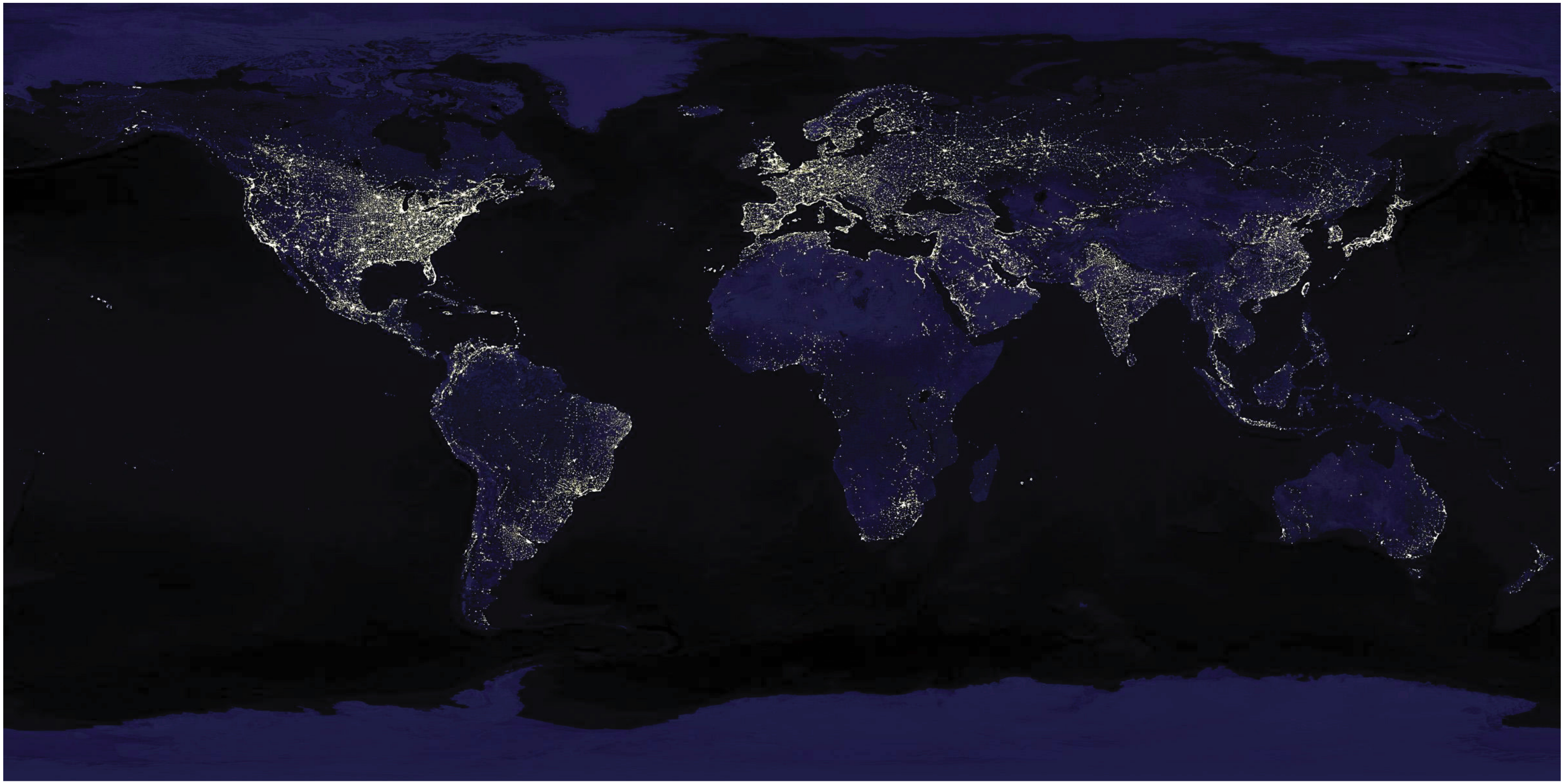
It is NOT because they are closer to the stars!

On a 1-to-10 million scale:

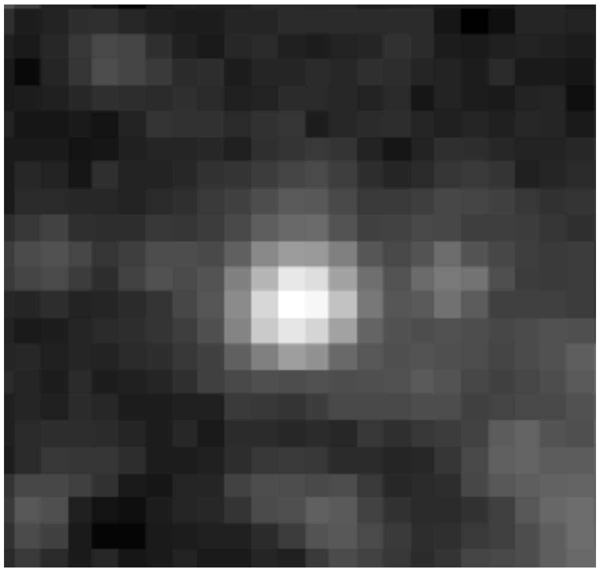
- Sun height of grapefruit
- Earth size of 6cm ball, length of UofA mall from Sun
- Nearest * few 100,000 miles
- Hubble orbit microscopically above 6cm size Earth

Observing problems due to Earth's atmosphere

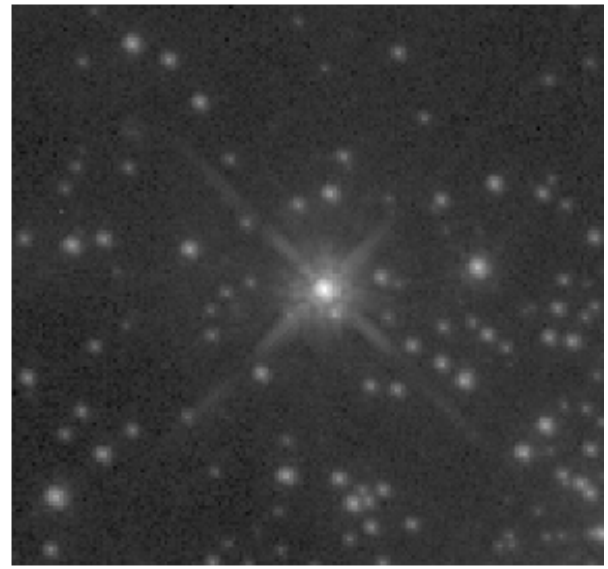
1. Light Pollution



2. Turbulence causes *twinkling* ⇒ blurs images.

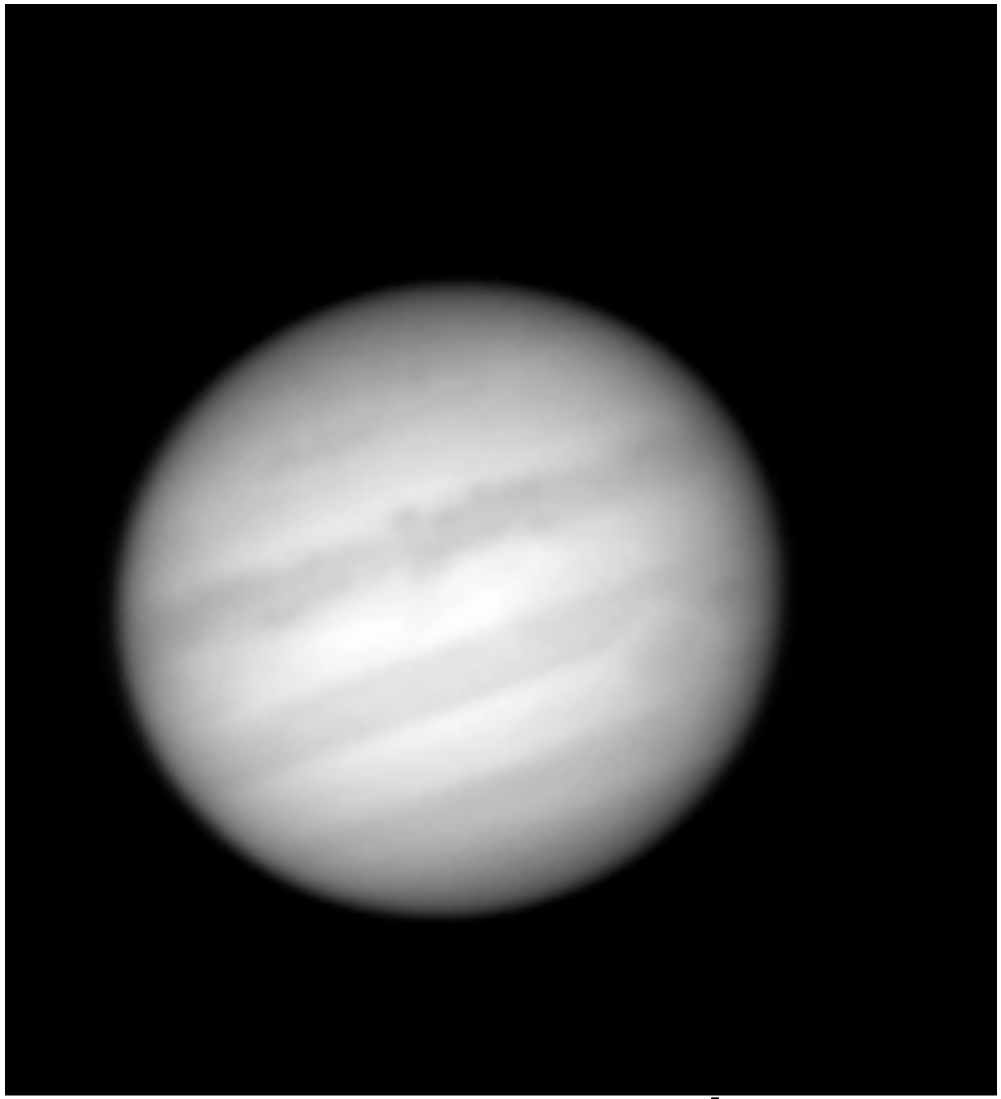


Star viewed with
ground-based telescope



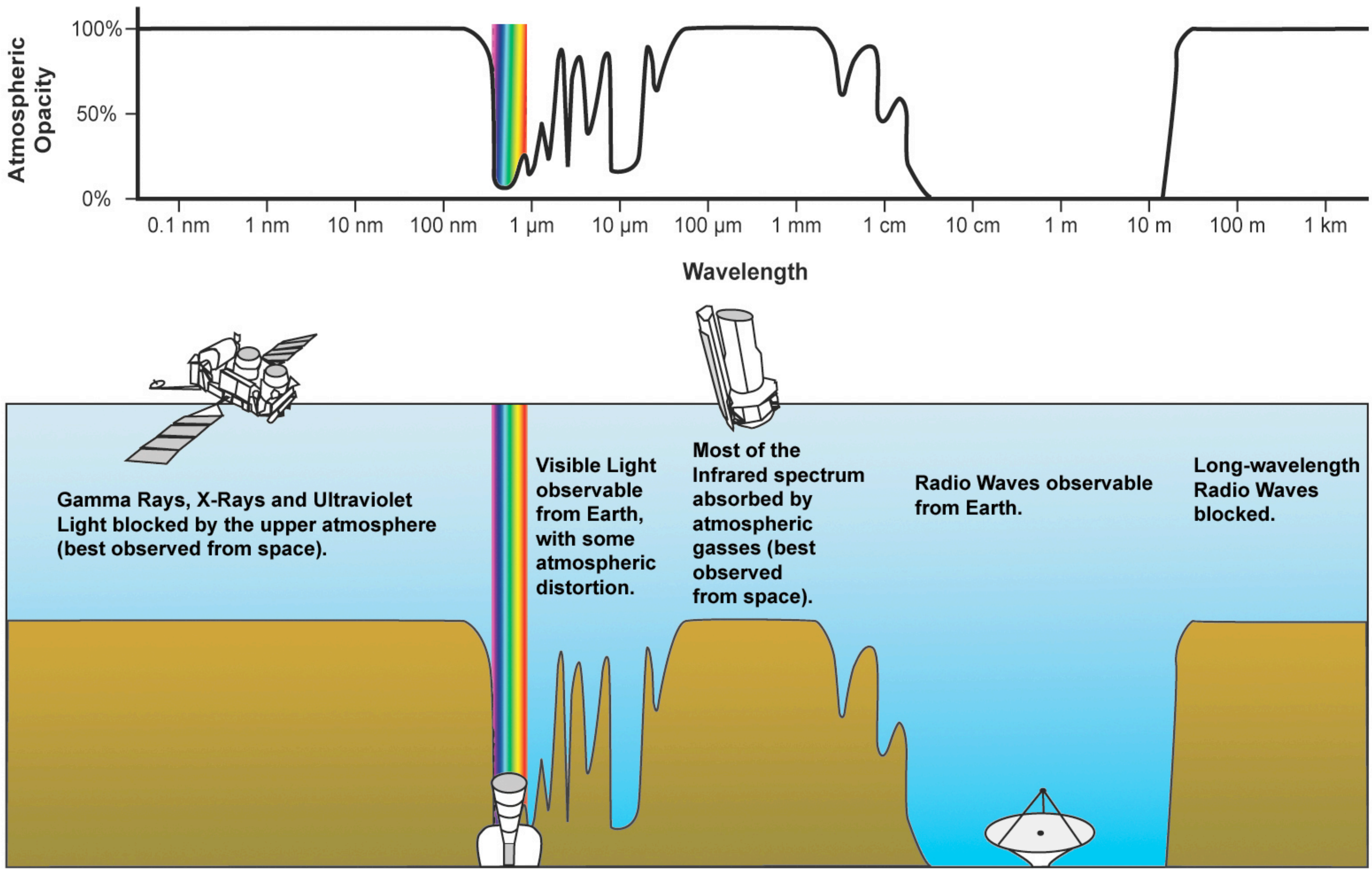
View from Hubble
Space Telescope

2. Turbulence causes *twinkling* $\Rightarrow$ blurs images.



Jupiter viewed through Earth's atmosphere

3. Atmosphere absorbs most of EM spectrum, including all UV and X-ray, most infrared

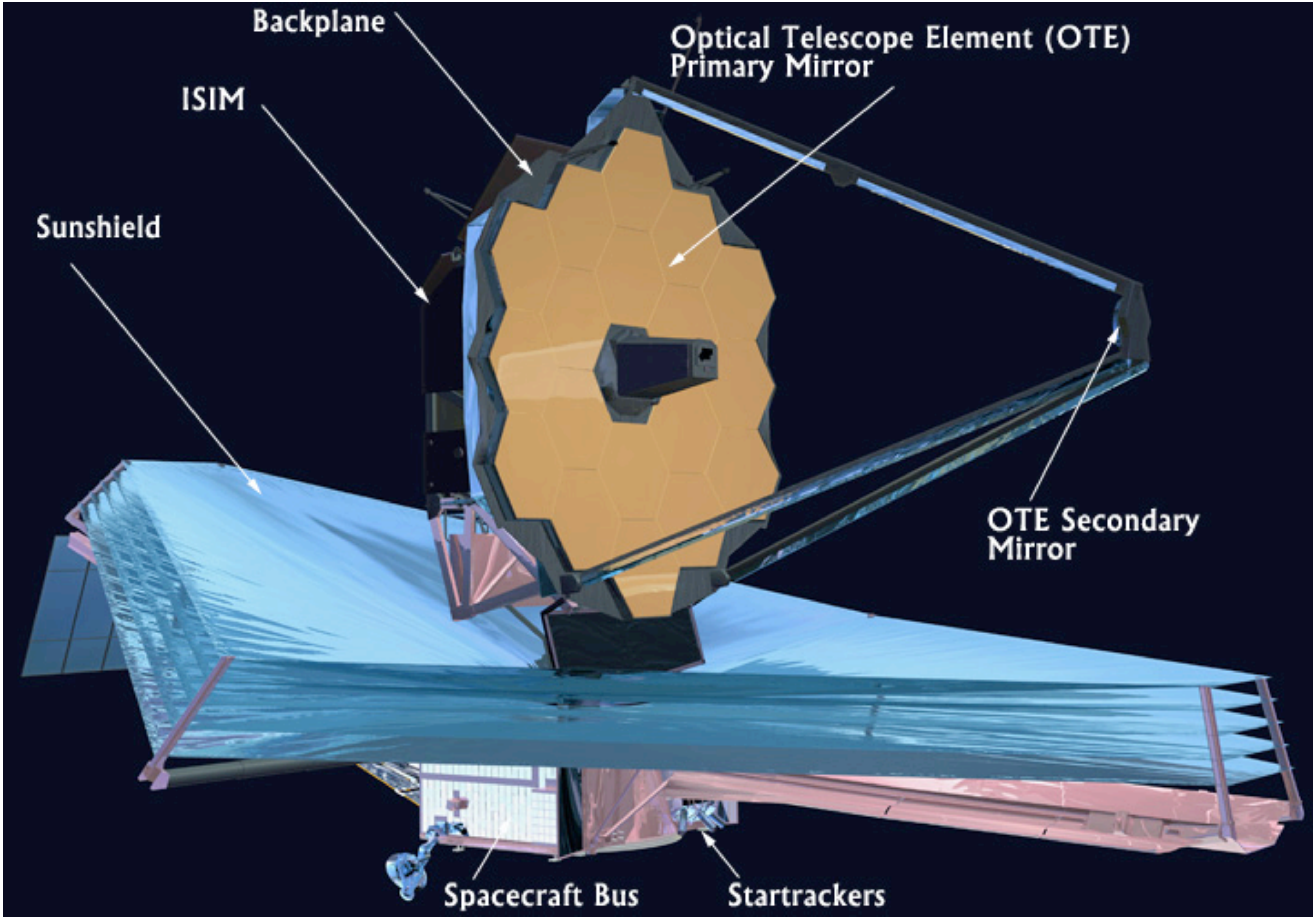


Telescopes in space solve all 3 problems.

- Location/technology can help overcome light pollution and turbulence.
- Nothing short of going to space can solve problem of atmospheric absorption of light.

Chandra X-ray Observatory

James Webb Space Telescope – 6m in Space ~ 2018



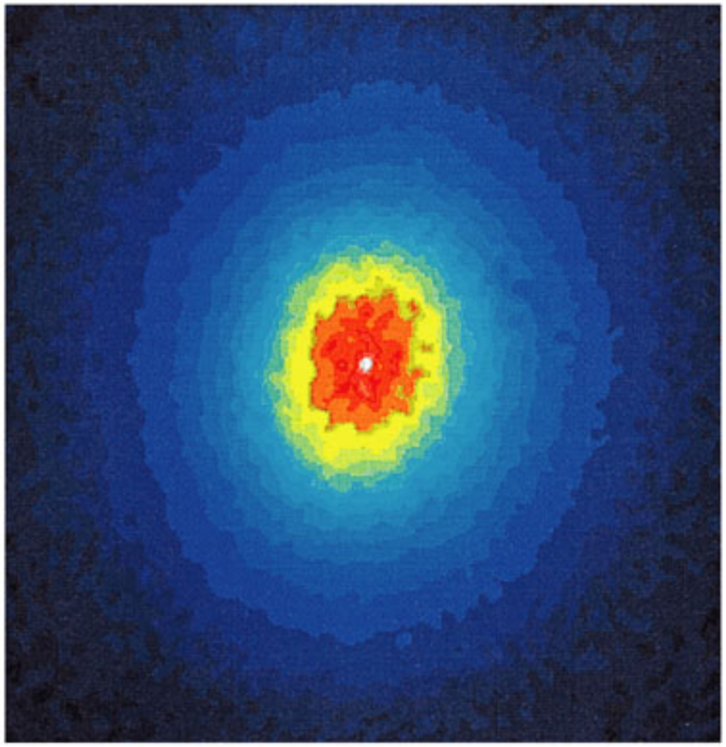
Can't goto space? .. Try an infrared telescope in an airplane!

Flies at 40,000 ft. !

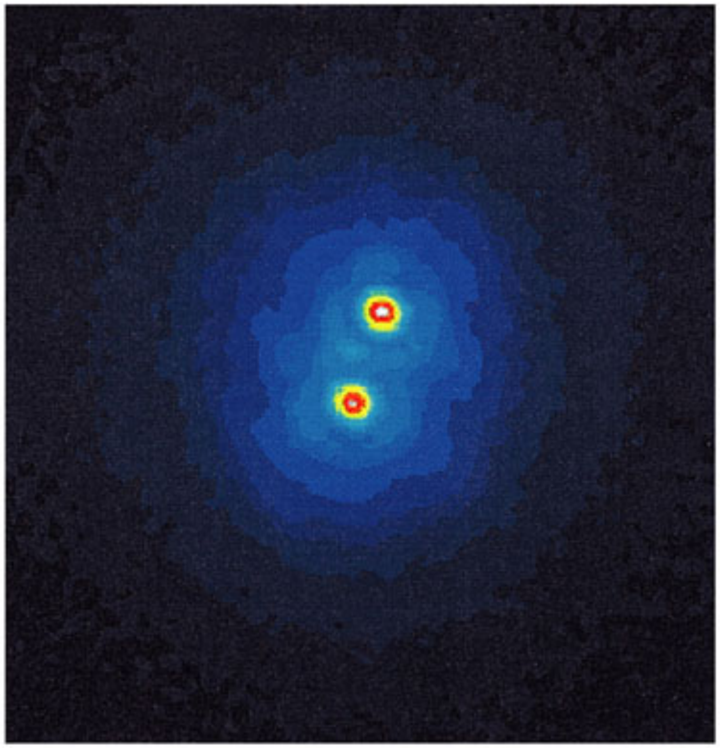
How is technology revolutionizing astronomy?

adaptive optics

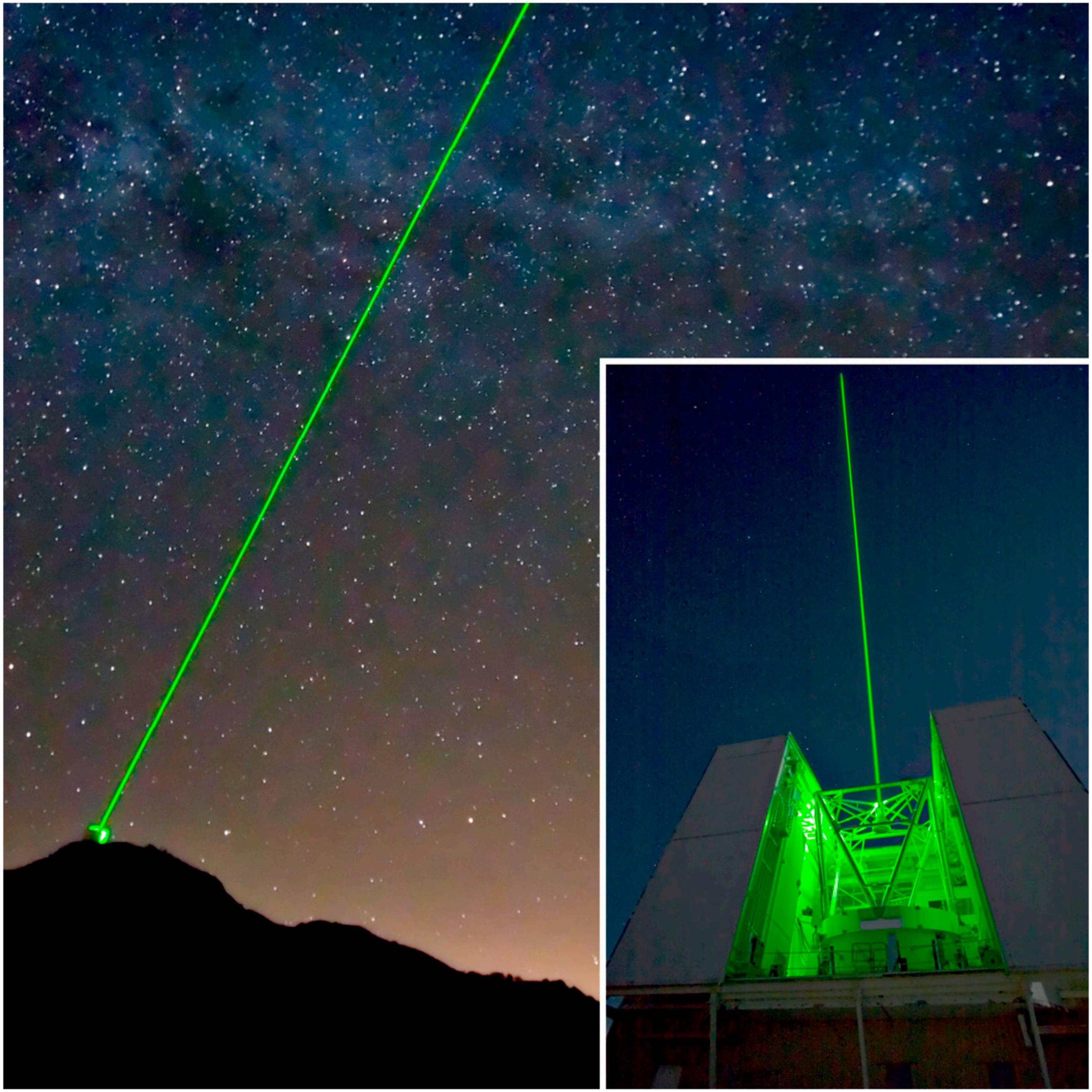
• Rapid changes in mirror shape compensate for atmospheric turbulence.



Without adaptive optics



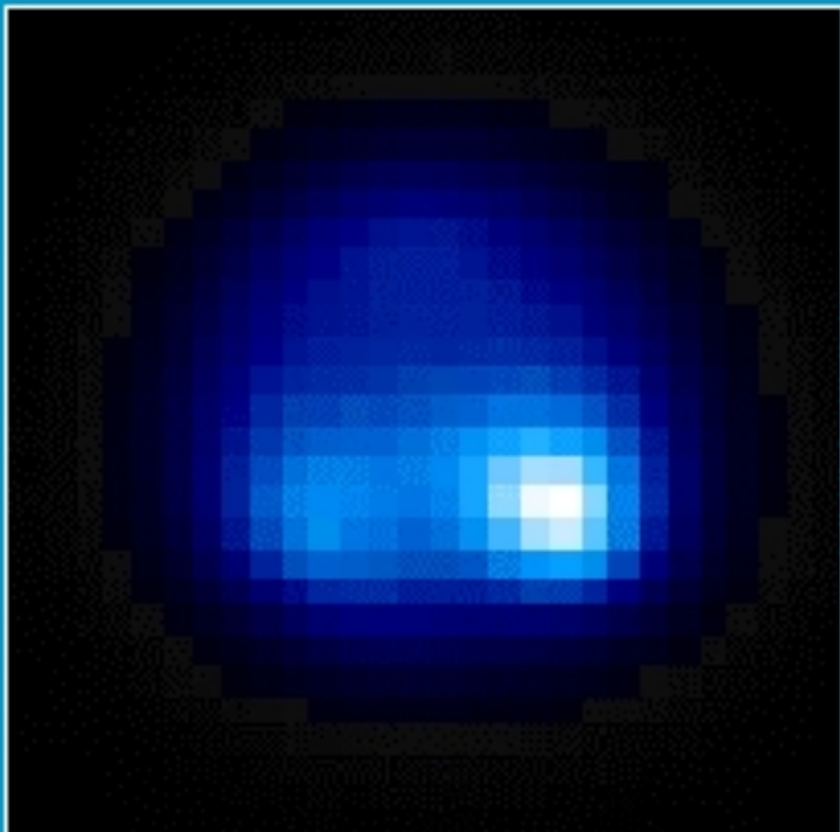
With adaptive optics



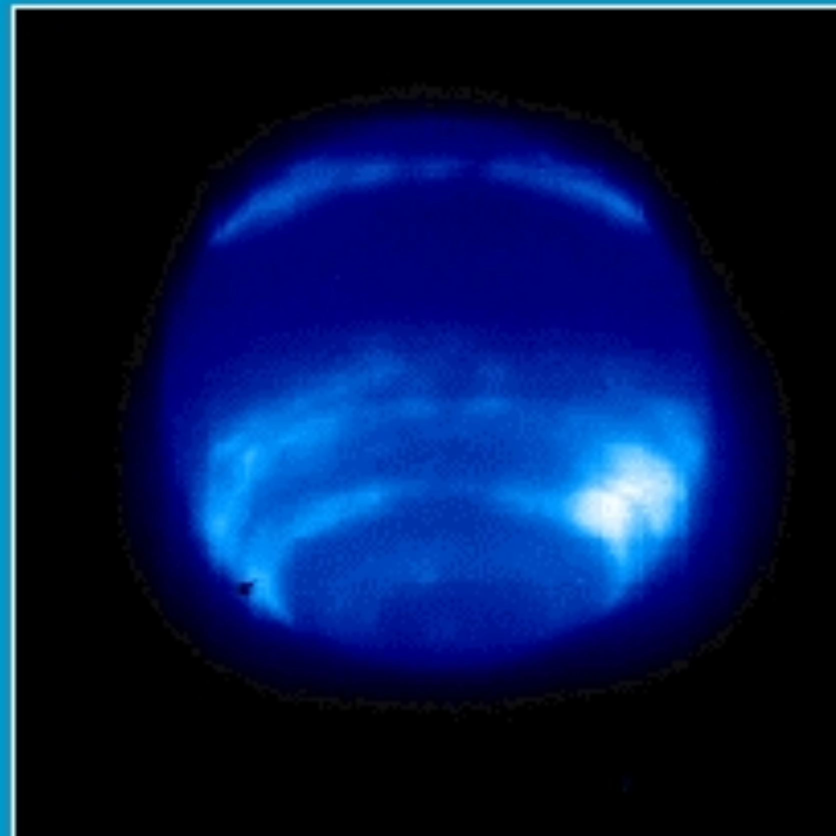
Large Binocular Telescope – Mnt Graham

Adaptive optics: Neptune

without



with



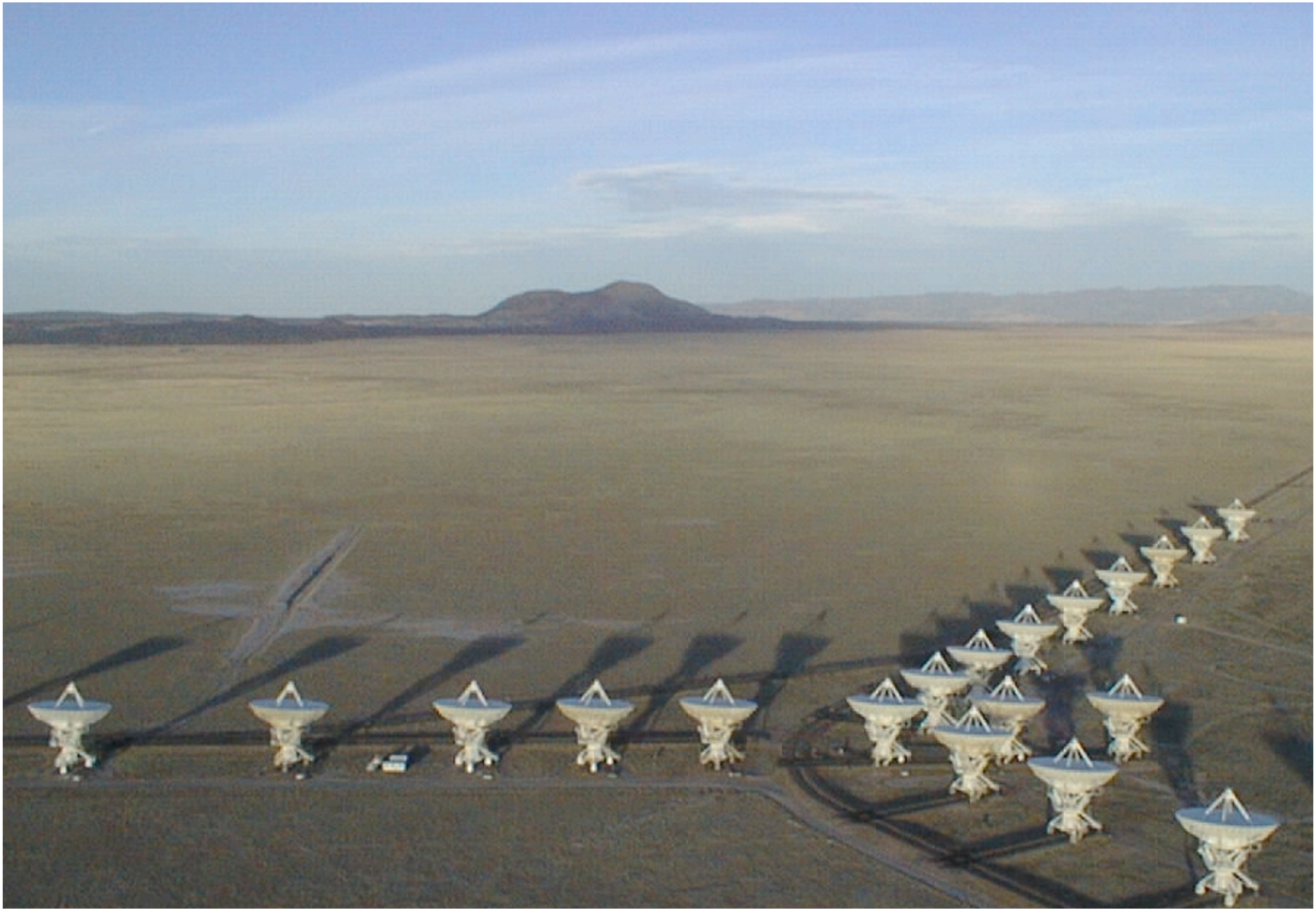
Center for Adaptive Optics, Univ. of Californ

Interferometry

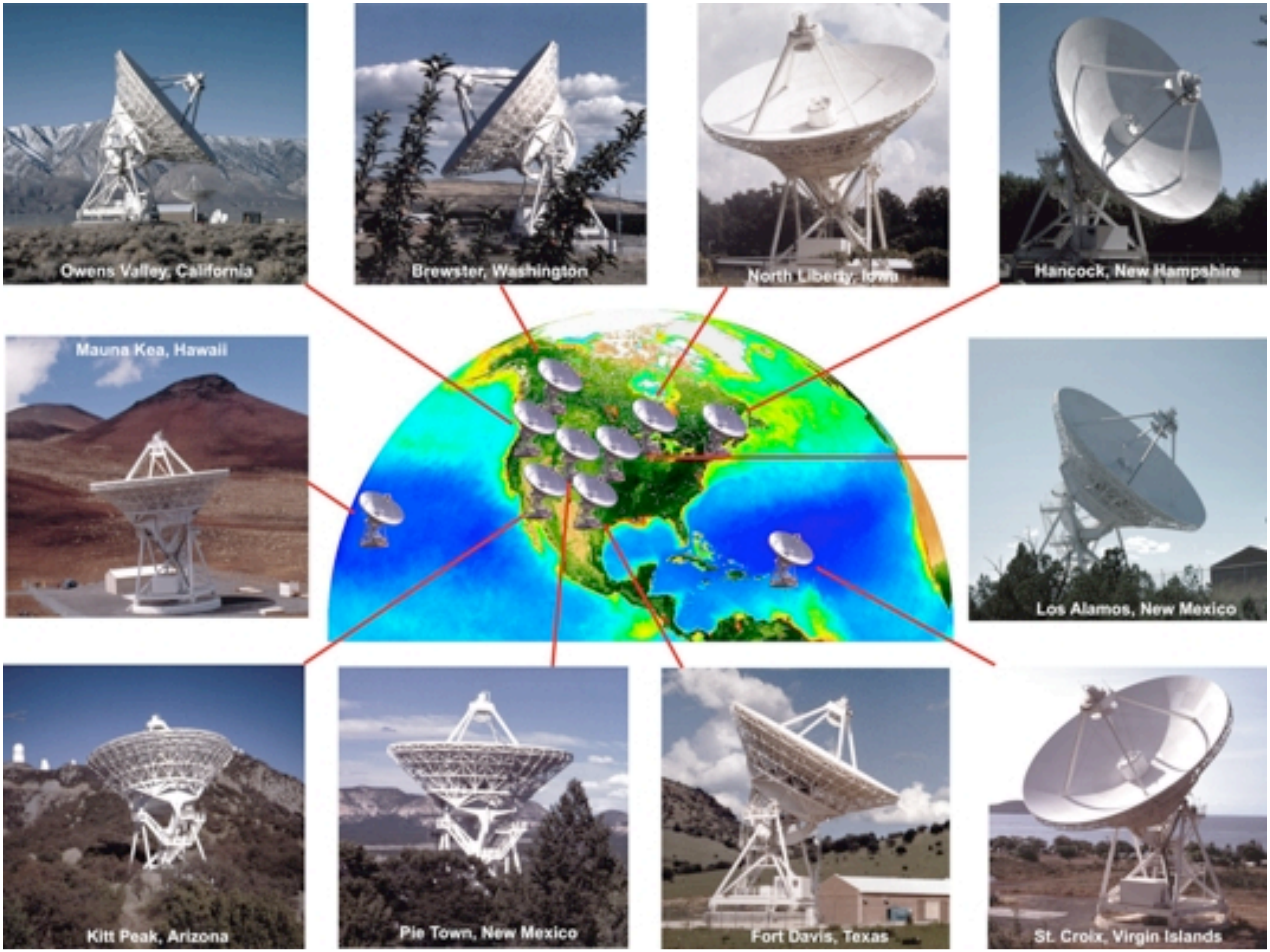
• Allows two or more small telescopes to work together to obtain the *angular resolution* of a larger telescope.

Very Large Array (VLA), New Mexico

Very Large Array (VLA), New Mexico

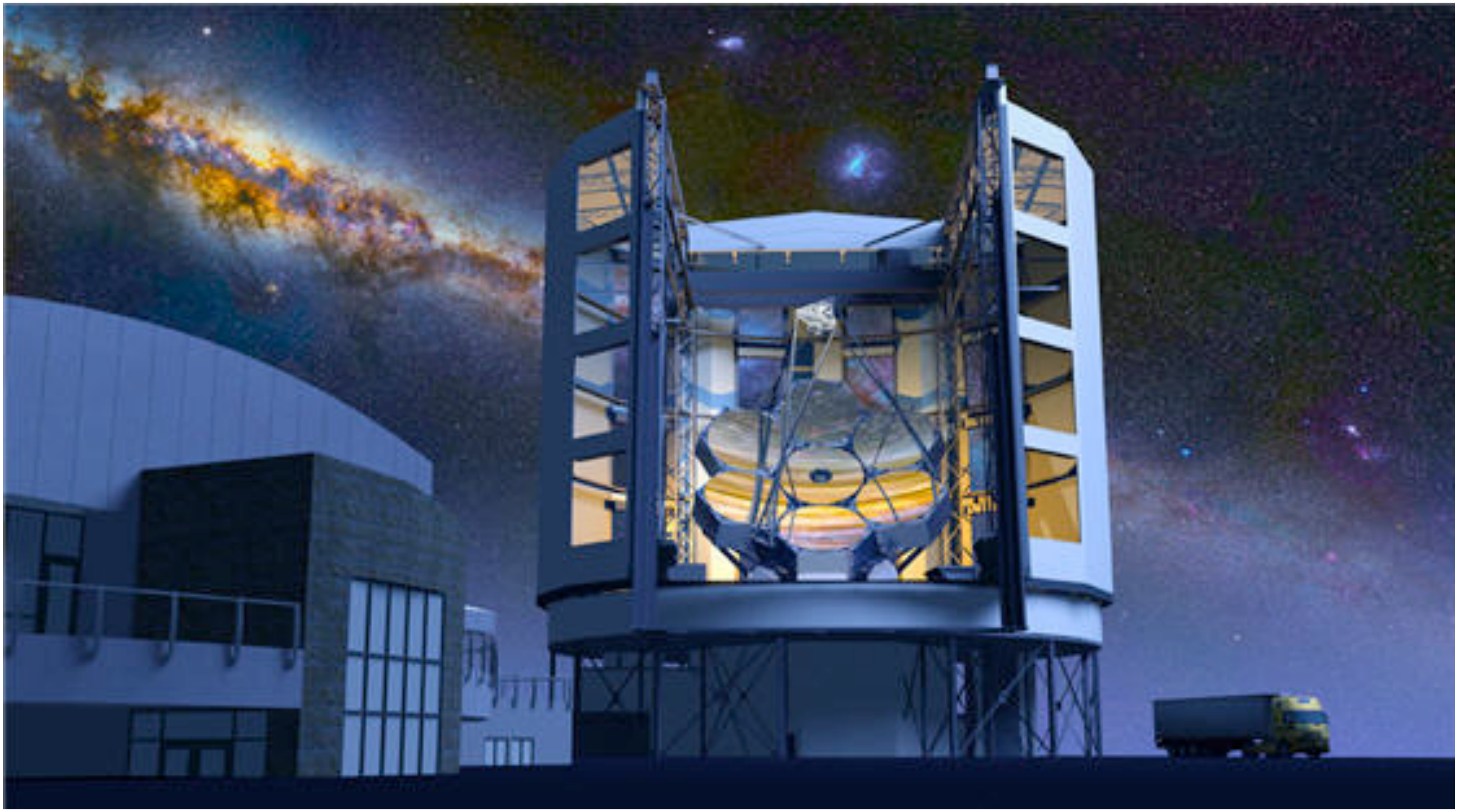


Very Long Baseline Array (VLBA)



Large Binocular Telescope – Optical/Near-IR interferometry

What’s Next? 2020: A 25m Optical/Infrared Telescopes!



Giant Magellan Telescope
UofA is a partner

We are making the mirrors for this telescope on campus!

A Giant Magellan Telescope Mirror

Want to buy your own telescope?

- Buy binoculars first (e.g. 7x35) - you get much more for the same money.
- *Ignore magnification (sales pitch!)*
- Notice: aperture size, optical quality, portability.
- Consumer research: Astronomy, Sky & Tel, Mercury. Astronomy clubs.