Chapter 6: Telescopes

Our goals for learning

- How do telescopes help us learn about the universe?
- Why do we put telescopes into space?
- How is technology revolutionizing astronomy?

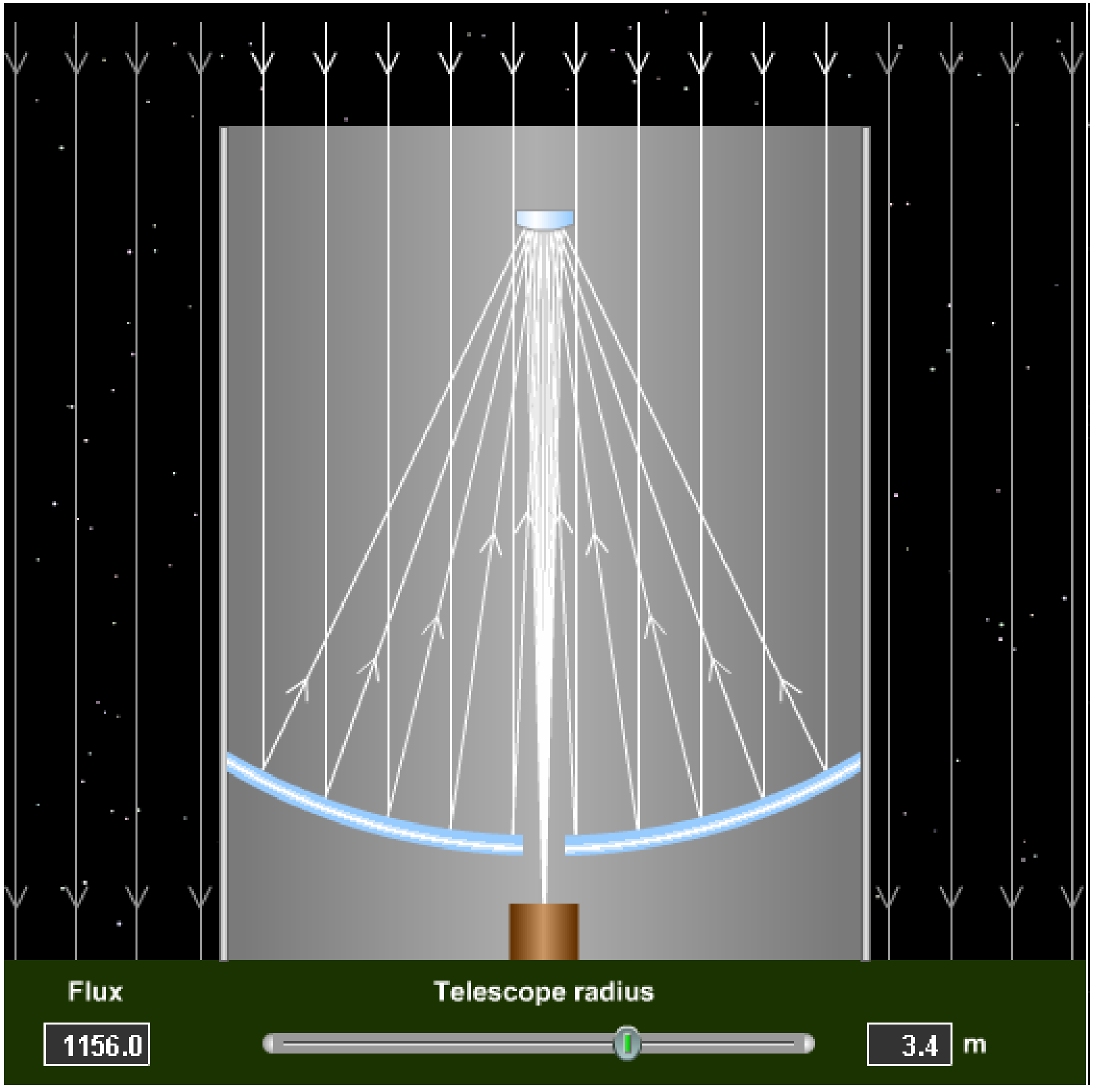
How do telescopes help us learn about the universe?

- Telescopes collect more light than our eyes $\Rightarrow$ **light-collecting area**
- Telescopes can see more detail than our eyes $\Rightarrow$ **angular resolution**
- Telescopes/instruments can detect light that is invisible to our eyes (e.g., infrared, ultraviolet)

Bigger is better

1. Larger light-collecting area
2. Better angular resolution

Bigger is better



Angular Resolution

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

Angular resolution: smaller is better

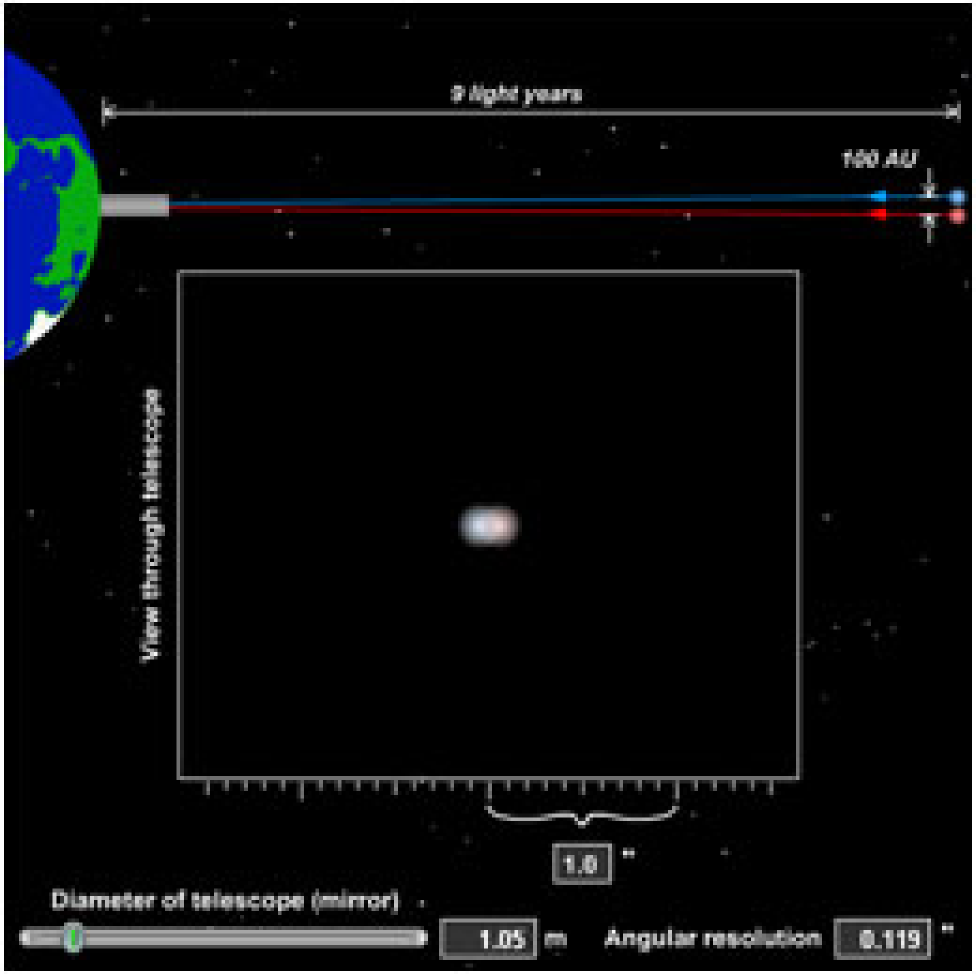
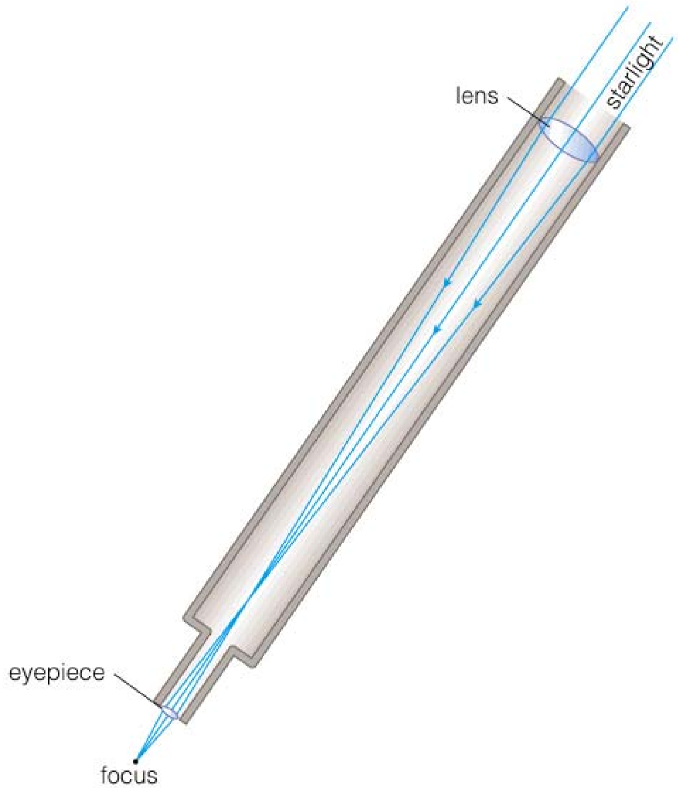


TABLE 5.1 *Largest Optical (Visible-Light) Telescopes*

Size	*Name*	*Sponsor*	*Location*	*Opened*	*Special Features*
10.4 m	Gran Telescopio Canarias	Spain, Mexico, U. Florida	Canary Islands	2005	Segmented primary mirror based on mirrors for Keck telescopes
10 m	Keck I and Keck II	Cal Tech, U. California, NASA	Mauna Kea, HI	1993/1996	Two identical 10-m telescopes, each with a primary mirror consisting of 36 1.8-m hexagonal segments
9.2 m	Hobby-Eberly	U. Texas, Penn State, Stanford, Germany	Mt. Locke, TX	1997	Consists of 91 1-m segments, for a total diameter of 11 m, but only 9.2 m can be used at a time; designed primarily for spectroscopy
9.2 m	South African Large Telescope	South Africa, Rutgers, UW–Madison, UNC–Chapel Hill, Dartmouth, Carnegie-Mellon, 5 others	South Africa	2004	Based on design of Hobby-Eberly telescope
2 * 8.4 m	Large Binocular Telescope	U. Arizona, Ohio State U., Italy, Germany	Mt. Graham, AZ	2004	Two 8.4-m mirrors on a common mount, giving light-collecting area of 11.8-m telescope
4 * 8.2 m	Very Large Telescope	European Southern Observatory	Cerro Paranal, Chile	2000	Four separate 8-m telescopes designed to work individually or together as the equivalent of a 16-m telescope
8.3 m	Subaru	Japan	Mauna Kea, HI	1999	Japan's first large telescope project
8 m	Gemini North and South	U.S., U.K., Canada, Chile, Brazil, Argentina	Mauna Kea, HI (North); Cerro Pachon, Chile (South)	1999	Twin telescopes, one in each hemisphere
6.5 m	Magellan I and II	Carnegie Institute, U. Arizona, Harvard, U. Michigan, MIT	Las Campanas, Chile	2000/2002	Twin 6.5-m telescopes, known respectively as the Walter Baade and Landon Clay telescopes
6.5 m	MMT	Smithsonian Institution, U. Arizona	Mt. Hopkins, AZ	2000	Replaced an older telescope in the same observatory

Basic Telescope Design

- Refracting: lenses

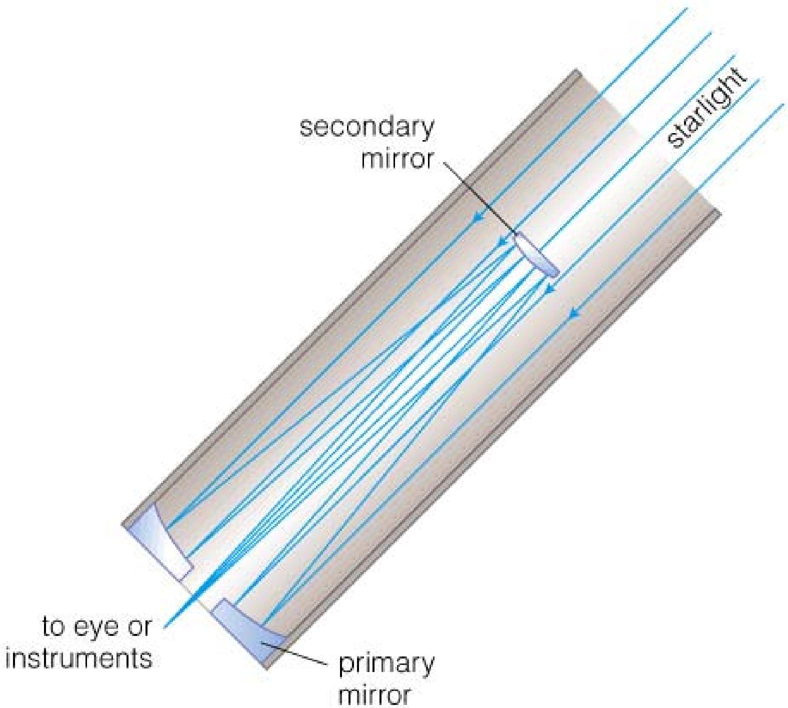


Refracting telescope

Yerkes 1-m refractor

Basic Telescope Design

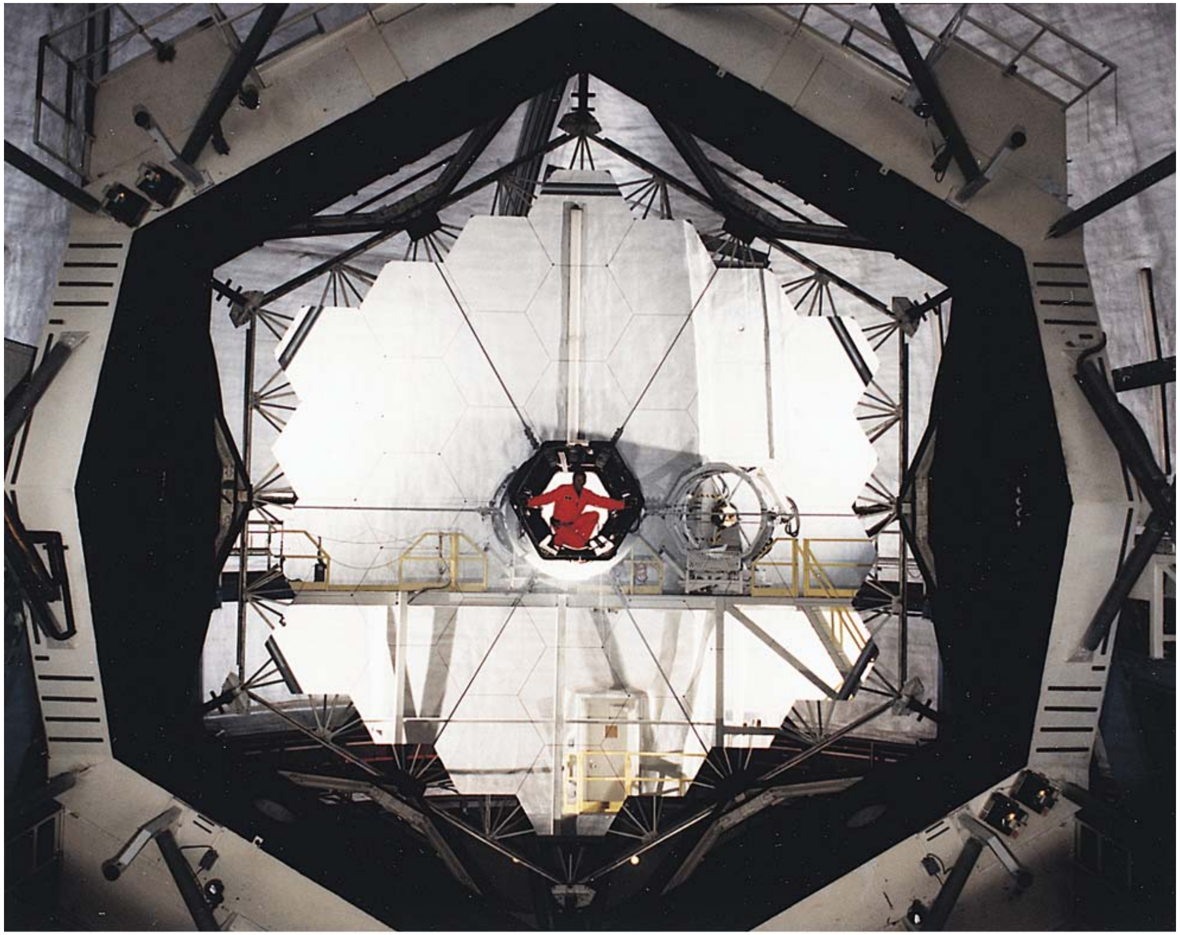
- Reflecting: mirrors
- Most research telescopes today are



Reflecting telescope

Gemini North 8-m

Keck I and Keck II
Mauna Kea, HI

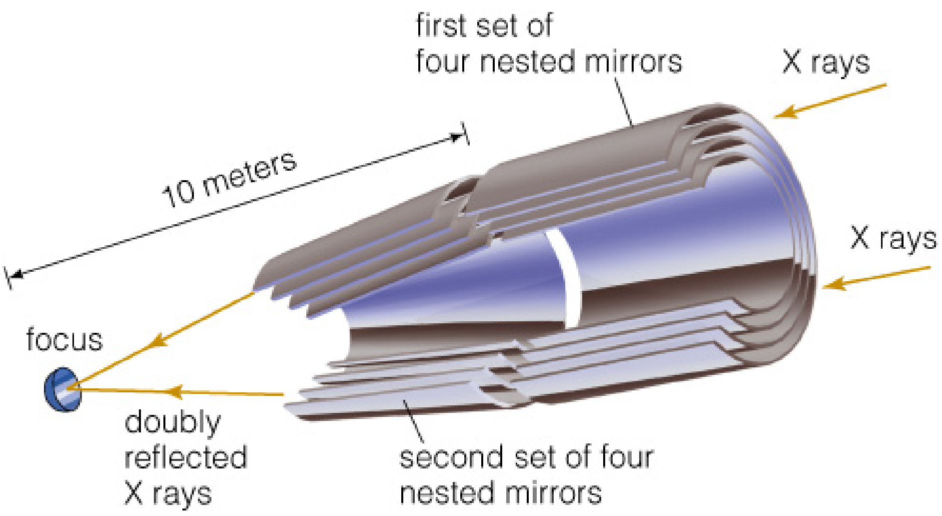


Mauna Kea, Hawaii

Different designs for different wavelengths of light

Radio telescope (Arecibo, Puerto Rico)

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!

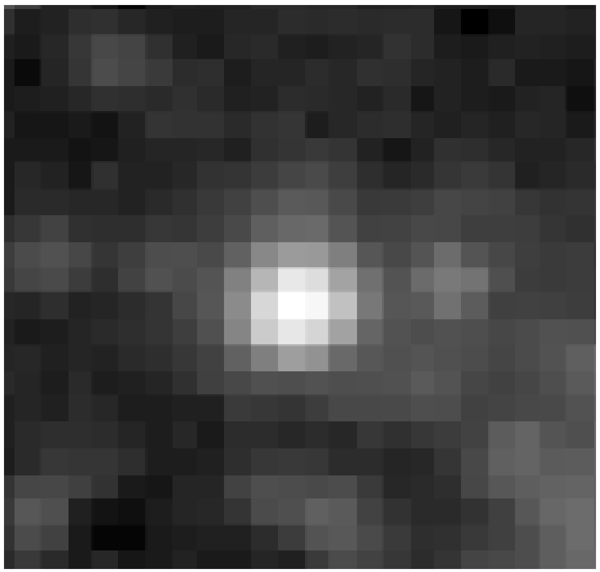
Recall our 1-to-10 billion scale:

- Sun size of grapefruit
- Earth size of ball point, 15 m from Sun
- Nearest stars 4,000 km away
- Hubble orbit microscopically above ball- point size Earth

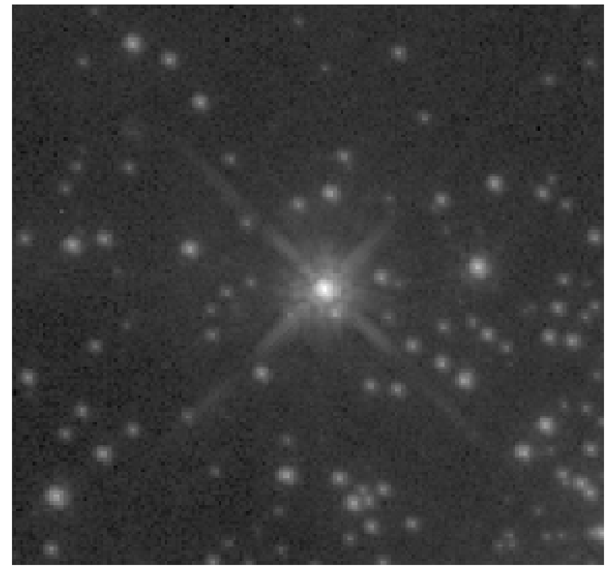
Observing problems due to Earth's atmosphere

1. Light Pollution

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

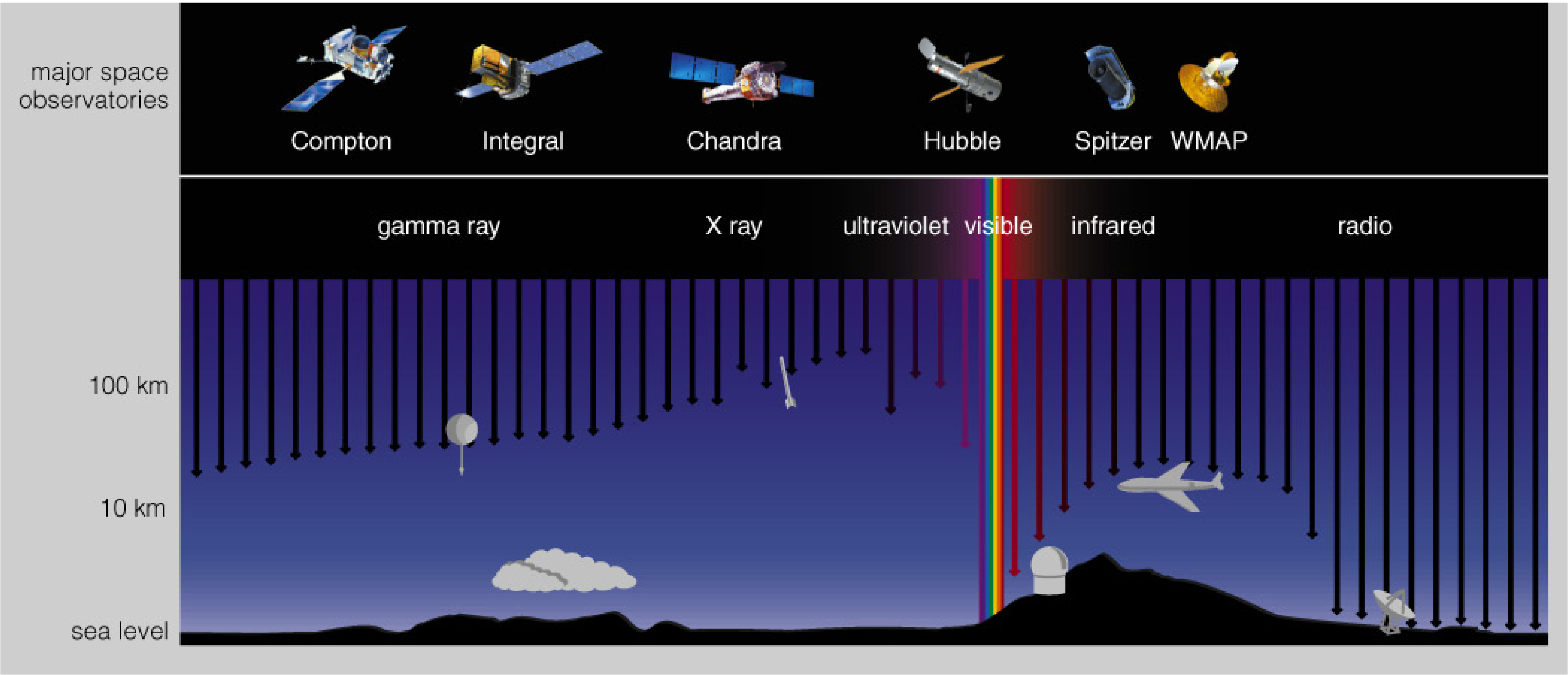


Star viewed with ground-based telescope



View from Hubble Space Telescope

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



Telescopes in space solve all 3 problems.

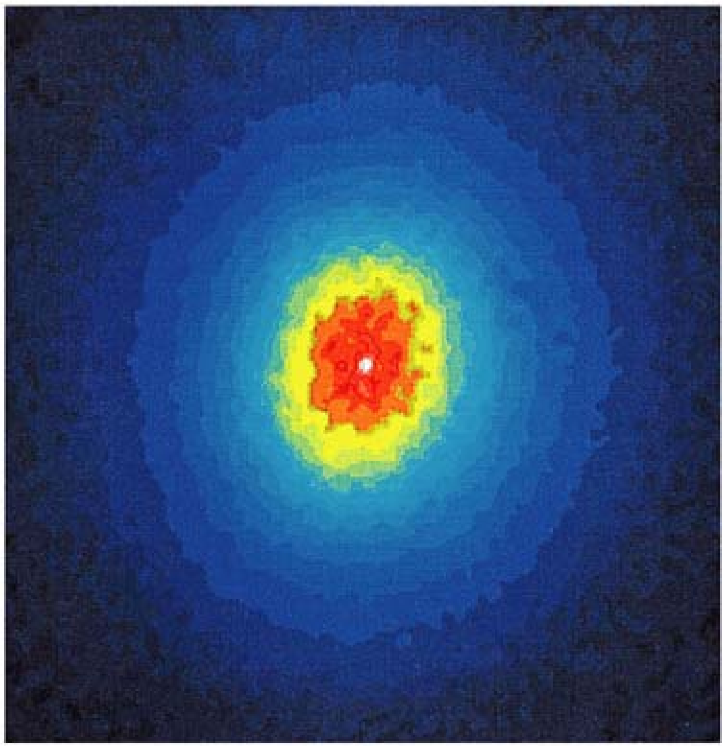
- Location/technology can help overcome light pollution and turbulence.
- Nothing short of going to space can solve problem of atmospheric absorption of light.

Chandra X-ray Observatory

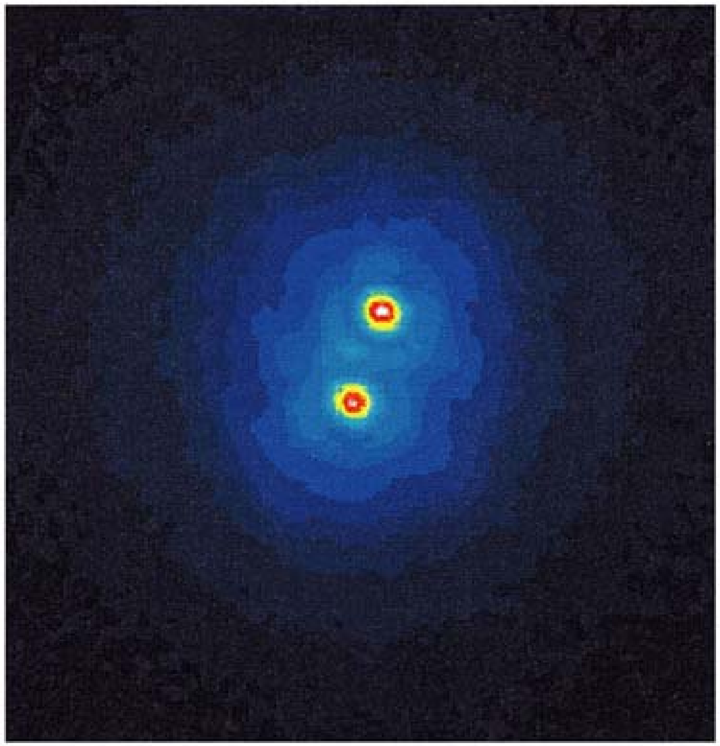
How is technology revolutionizing astronomy?

adaptive optics

- Rapid changes in mirror shape compensate for atmospheric turbulence.



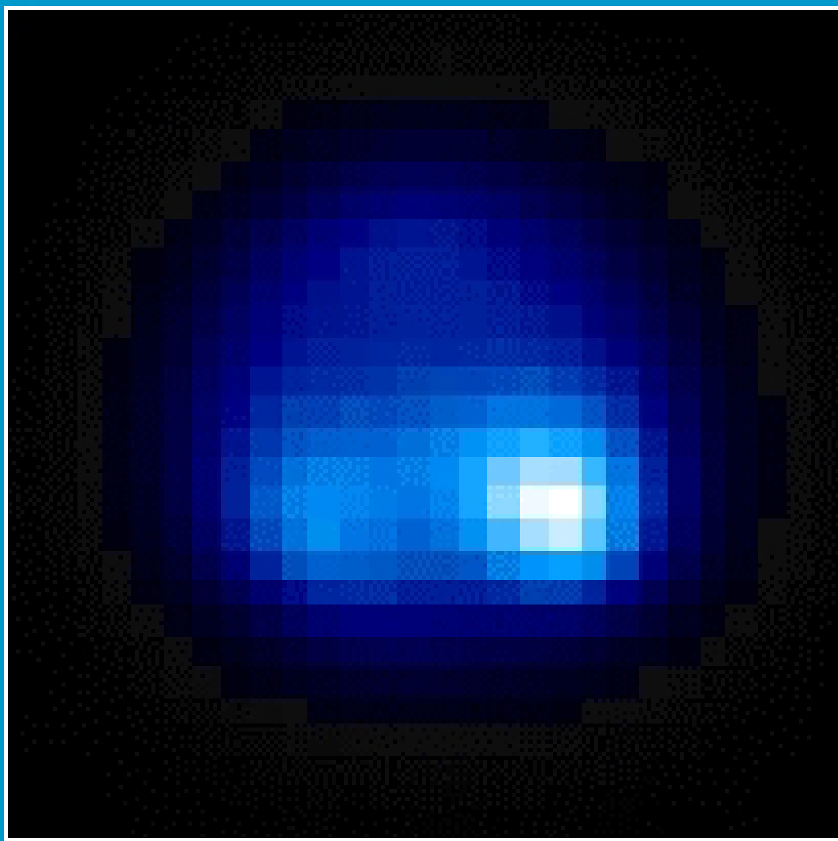
Without adaptive optics



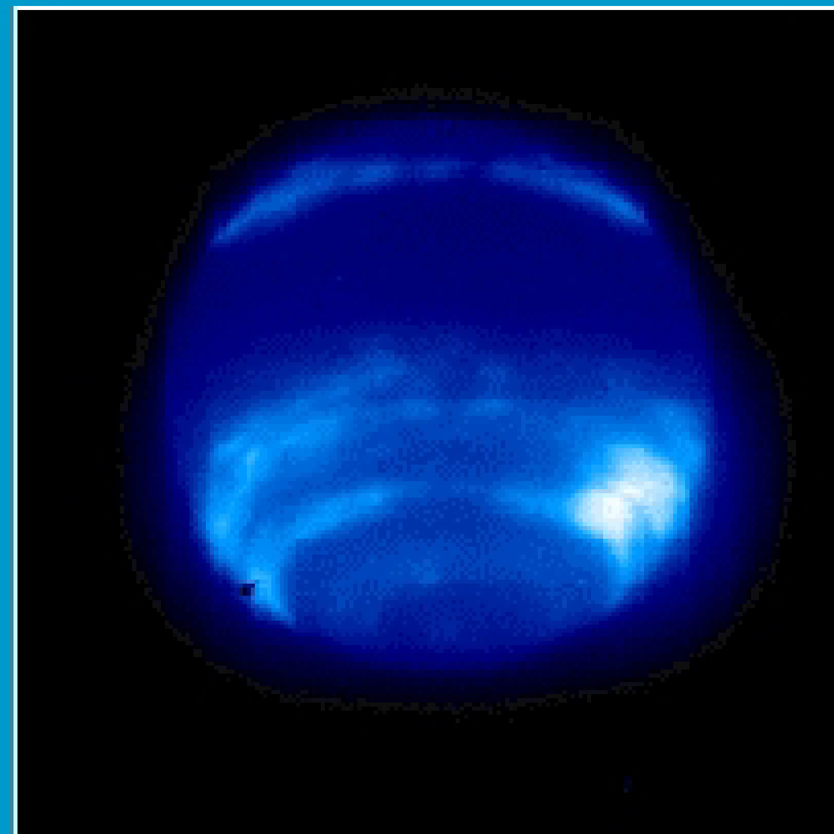
With adaptive optics

Adaptive optics: Neptune

without



with

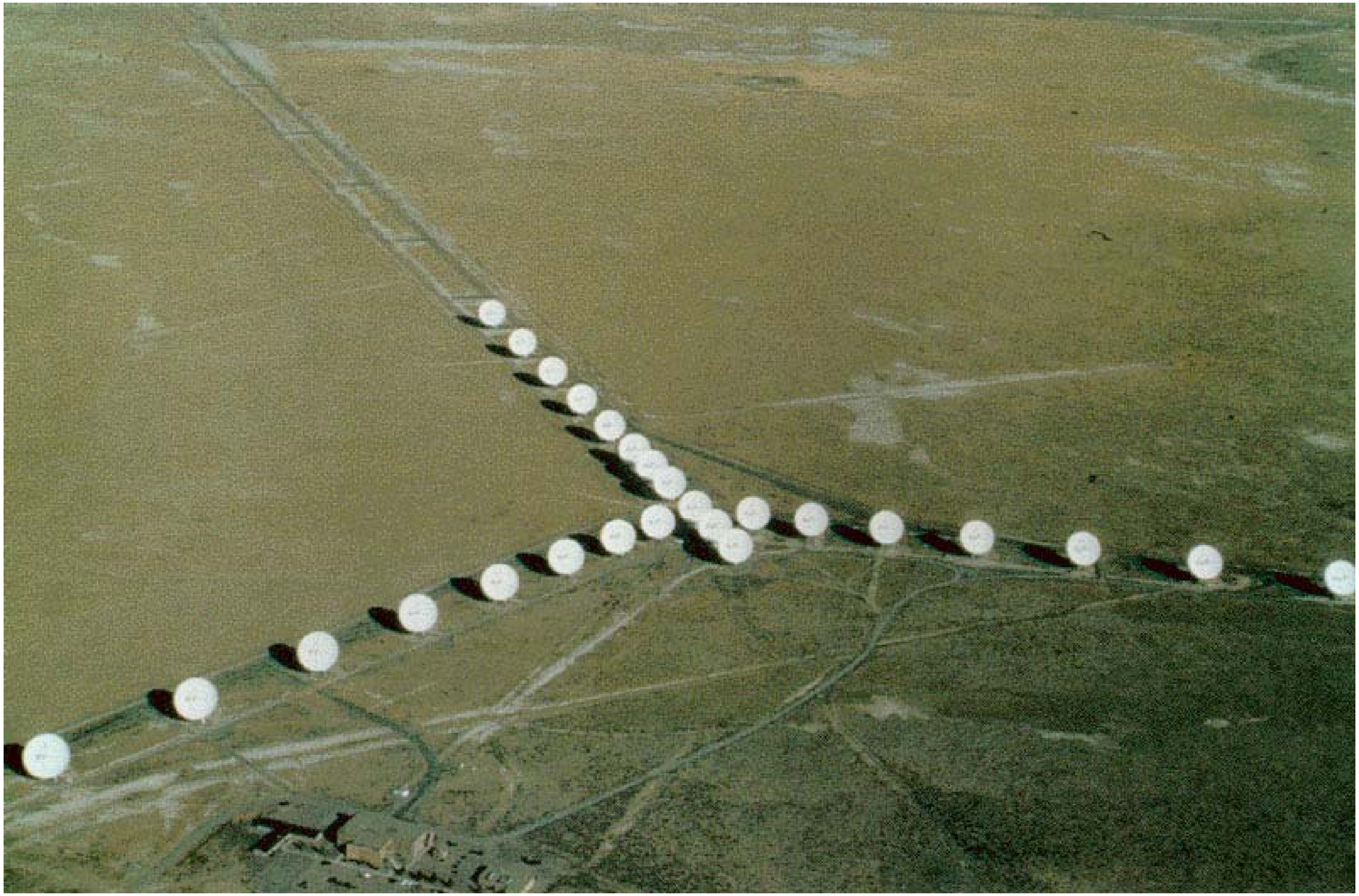


Center for Adaptive Optics, Univ. of Californ

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



The Moon would be a great spot for an observatory (but at what price?)

What have we learned?

- How do telescopes help us learn about the universe?
- We can see fainter objects and more detail than we can see by eye. Specialized telescopes allow us to learn more than we could from visible light alone.
- Why do we put telescopes in space?
- They are above earth's atmosphere and therefore not subject to light pollution, atmospheric distortion, or atmospheric absorption of light.

What have we learned?

- How is technology revolutionizing astronomy?

It makes possible more powerful and more capable telescopes

- Adaptive optics
- Interferometry