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ASTRONOMY

Chapter 6 ASTRONOMICAL INSTRUMENTS

PowerPoint Image Slideshow

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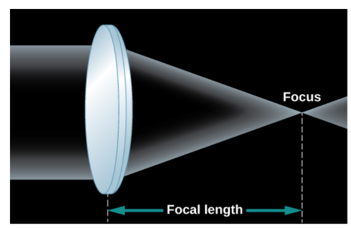
6.1-6.4 Telescopes

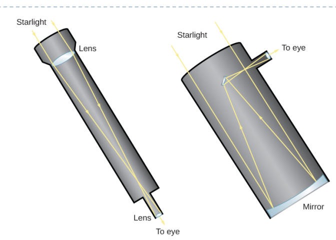
(a)

(b)

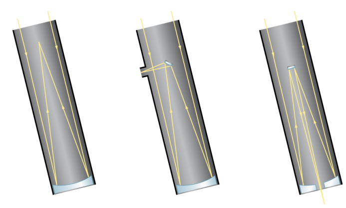
- **Two Pre-Telescopic Observatories (Fig 6.3).**
  (a) Machu Picchu is a fifteenth century Incan site located in Peru.
  (b) Stonehenge, a prehistoric site (3000–2000 BCE), is located in England.



- **Formation of an Image by a Simple Lens (Fig 6.4)** . Parallel rays from a distant source are bent by the convex lens so that they all come together in a single place (the focus) to form an image.



- **Refracting and Reflecting Telescopes (Fig 6.5).** Light enters a refracting telescope through a lens at the upper end, which focuses the light near the bottom of the telescope. An eyepiece then magnifies the image so that it can be viewed by the eye, or a detector like a photographic plate can be placed at the focus.



- **Focus Arrangements for Reflecting Telescopes.** Reflecting telescopes have different options for where the light is brought to a focus. With prime focus, light is detected where it comes to a focus after reflecting from the primary mirror. With Newtonian focus, light is reflected by a small secondary mirror off to one side, where it can be detected (see also Figure 6.5). Most large professional telescopes have a Cassegrain focus in which light is reflected by the secondary mirror down through a hole in the primary mirror to an observing station below the telescope.

How do telescopes help us learn about the universe?

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

Figure 6.7

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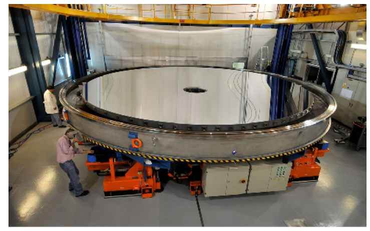

- **Large Telescope Mirror.** This image shows one of the primary mirrors of the European Southern Observatory's Very Large Telescope, named Yepun, just after it was recoated with aluminum. The mirror is a little over 8 meters in diameter.

Figure 6.8

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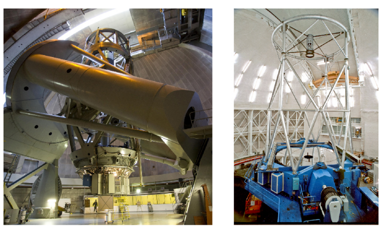

(a) (b)

- **Modern Reflecting Telescopes.**

(a) The Palomar 5-meter reflector: The Hale telescope on Palomar Mountain has a complex mounting structure that enables the telescope (in the open "tube" pointing upward in this photo) to swing easily into any position.

(b) The Gemini North 8-meter telescope: The Gemini North mirror has a larger area than the Palomar mirror, but note how much less massive the whole instrument seems.

Figure 6.11

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- **World's Largest Refractor.** The Yerkes 40-inch (1-meter) telescope.

Figure 6.9

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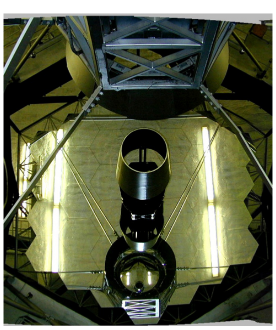

- **Thirty-Six Eyes Are Better Than One.** The mirror of the 10-meter Keck telescope is composed of 36 hexagonal sections. (credit: NASA)

Figure 6.12

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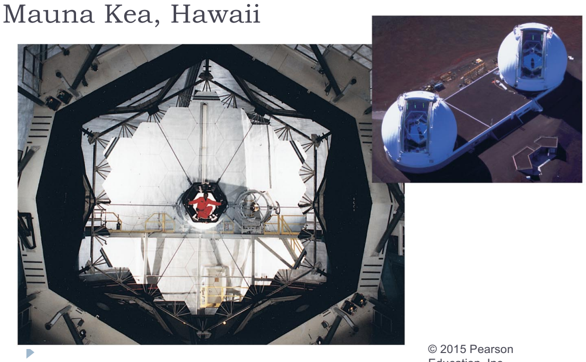
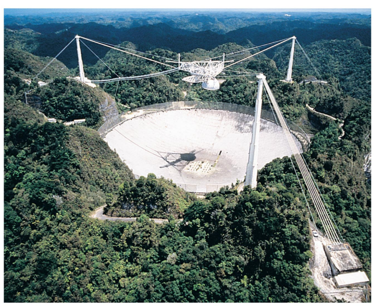
- **High and Dry Site.** Cerro Paranal, a mountain summit 2.7 kilometers above sea level in Chile's Atacama Desert, is the site of the European Southern Observatory's Very Large Telescope. This photograph shows the four 8-meter telescope buildings on the site and vividly illustrates that astronomers prefer high, dry sites for their instruments. The 4.1-meter Visible and Infrared Survey Telescope for Astronomy (VISTA) can be seen in the distance on the next mountain peak. (credit: ESO)

Keck I and Keck II
Mauna Kea, Hawaii



Mauna Kea, Hawaii

Different designs for different wavelengths of light



Radio telescope (Arecibo, Puerto Rico)

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Figure 6.10

- **George Ellery Hale (1868–1938).** Hale's work led to the construction of several major telescopes, including the 40-inch refracting telescope at Yerkes Observatory, and three reflecting telescopes: the 60-inch Hale and 100-inch Hooker telescopes at Mount Wilson Observatory, and the 200-inch Hale Telescope at Palomar Observatory.

Figure 6.2

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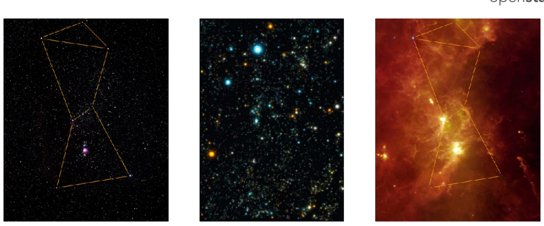

(a) (b) (c)

- **Orion Region at Different Wavelengths.** The same part of the sky looks different when observed with instruments that are sensitive to different bands of the spectrum.

(a) Visible light:.

(b) X-rays:

(c) Infrared:

Figure 6.15

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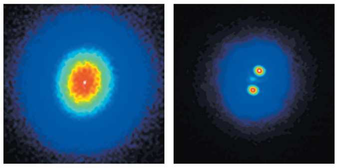
- **Infrared Eyes.** Infrared waves can penetrate places in the universe from which light is blocked, as shown in this infrared image where the plastic bag blocks visible light but not infrared. (credit: NASA/JPL-Caltech/R. Hurt (SSC))

Improvements for ground-based telescopes

Adaptive optics

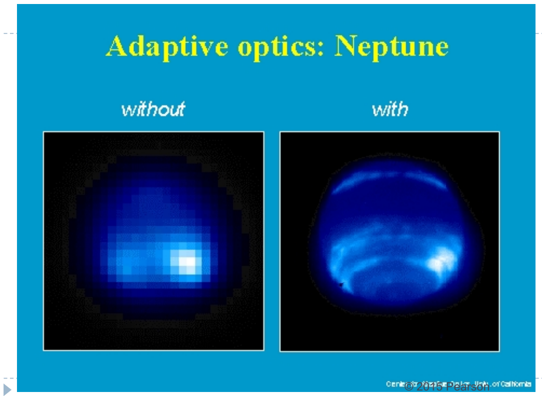
- Rapid changes in mirror shape compensate for atmospheric turbulence.



a Atmospheric distortion makes this ground-based image of a double star look like a single star.

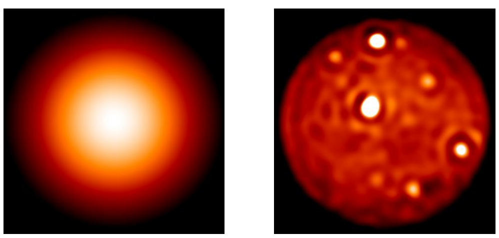
b When the same telescope is used with adaptive optics, the two stars are clearly distinguished. The angular separation between the two stars is 0.28 arcsecond.

Without adaptive optics | With adaptive optics



Adaptive Optics

- Jupiter's moon Io observed with the Keck telescope



without adaptive optics | with adaptive optics

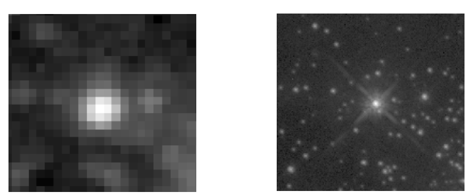
Why do we put telescopes into space?

It is NOT because they are closer to the stars!

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

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

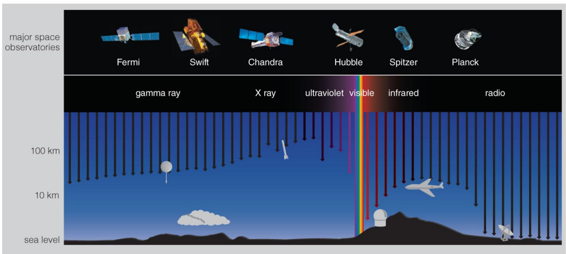
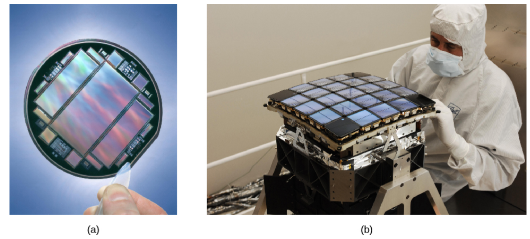
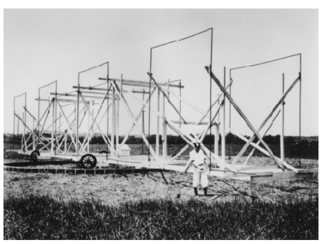


Figure 6.14



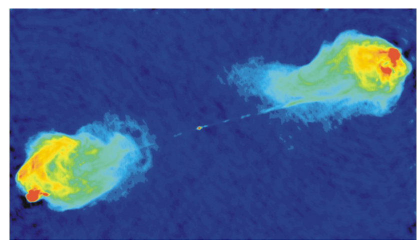
- **Charge-Coupled Devices (CCDs).**
  - (a) This CCD is a mere 300-micrometers thick (thinner than a human hair) yet holds more than 21 million pixels.
  - (b) This matrix of 42 CCDs serves the Kepler telescope.

Figure 6.17



- **First Radio Telescope.** This rotating radio antenna was used by Jansky in his serendipitous discovery of radio radiation from the Milky Way.

Figure 6.18



- **Radio Image.** This image has been constructed of radio observations at the Very Large Array of a galaxy called Cygnus A. Colors have been added to help the eye sort out regions of different radio intensities. Red regions are the most intense, blue the least. The visible galaxy would be a small dot in the center of the image. The radio image reveals jets of expelled material (more than 160,000 light-years long) on either side of the galaxy. (credit: NRAO/AUI)

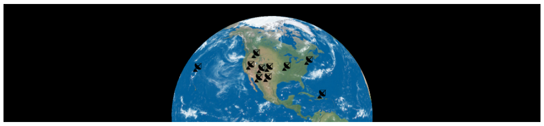
Figure 6.19

- **Robert C. Byrd Green Bank Telescope.** This fully steerable radio telescope in West Virginia went into operation in August 2000. Its dish is about 100 meters across. (credit: modification of work by "b3nscott"/Flickr)

Figure 6.20

- **Atacama Large Millimeter/Submillimeter Array (ALMA).** Located in the Atacama Desert of Northern Chile, ALMA currently provides the highest resolution for radio observations. (credit: ESO/S. Guisard)

Figure 6.21



- **Very Long Baseline Array.** This map shows the distribution of 10 antennas that constitute an array of radio telescopes stretching across the United States and its territories.

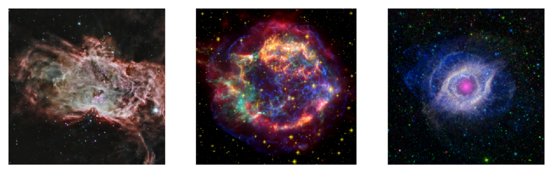
Figure 6.22

- **Largest Radio and Radar Dish.** The Arecibo Observatory, with its 1000-foot radio dish-filling valley in Puerto Rico, is part of the National Astronomy and Ionosphere Center, operated by SRI International, USRA, and UMET under a cooperative agreement with the National Science Foundation. (credit: National Astronomy and Ionosphere Center, Cornell U., NSF)

Figure 6.23

- **Stratospheric Observatory for Infrared Astronomy (SOFIA).** SOFIA allows observations to be made above most of Earth's atmospheric water vapor. (credit: NASA)

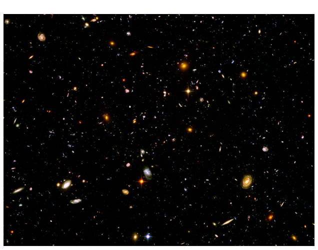
Figure 6.24



Flame nebula | Cassiopeia A | Helix nebula

- **Observations from the Spitzer Space Telescope (SST).** These infrared images—a region of star formation, the remnant of an exploded star, and a region where an old star is losing its outer shell—show just a few of the observations made and transmitted back to Earth from the SST. Since our eyes are not sensitive to infrared rays, we don't perceive colors from them. The colors in these images have been selected by astronomers to highlight details like the composition or temperature in these regions.

Figure 6.25

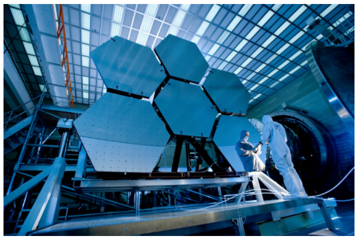


- **Hubble Ultra-Deep Field (HUDF).** The Hubble Space Telescope has provided an image of a specific region of space built from data collected between September 24, 2003, and January 16, 2004. These data allow us to search for galaxies that existed approximately 13 billion years ago.

Figure 6.26

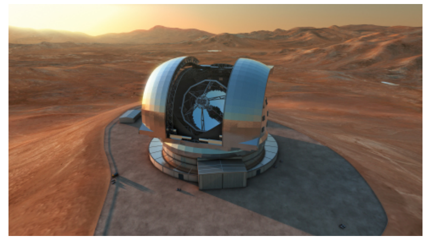
- **Chandra X-Ray Satellite.** Chandra, the world's most powerful X-ray telescope, was developed by NASA and launched in July 1999. (credit: modification of work by NASA)

Figure 6.27



- **James Webb Space Telescope (JWST).** This image shows some of the mirrors of the JWST as they underwent cryogenic testing. The mirrors were exposed to extreme temperatures in order to gather accurate measurements on changes in their shape as they heated and cooled.

Figure 6.28



- **Artist's Conception of the European Extremely Large Telescope.** The primary mirror in this telescope is 39.3 meters across. The telescope is under construction in the Atacama Desert in Northern Chile. (credit: ESO/L. Calçada)

Links

- Telescope spectrum 6 min
- hubble 3 min
- hubble images 6 min

Reading

- 6.1-6.4 (optional)