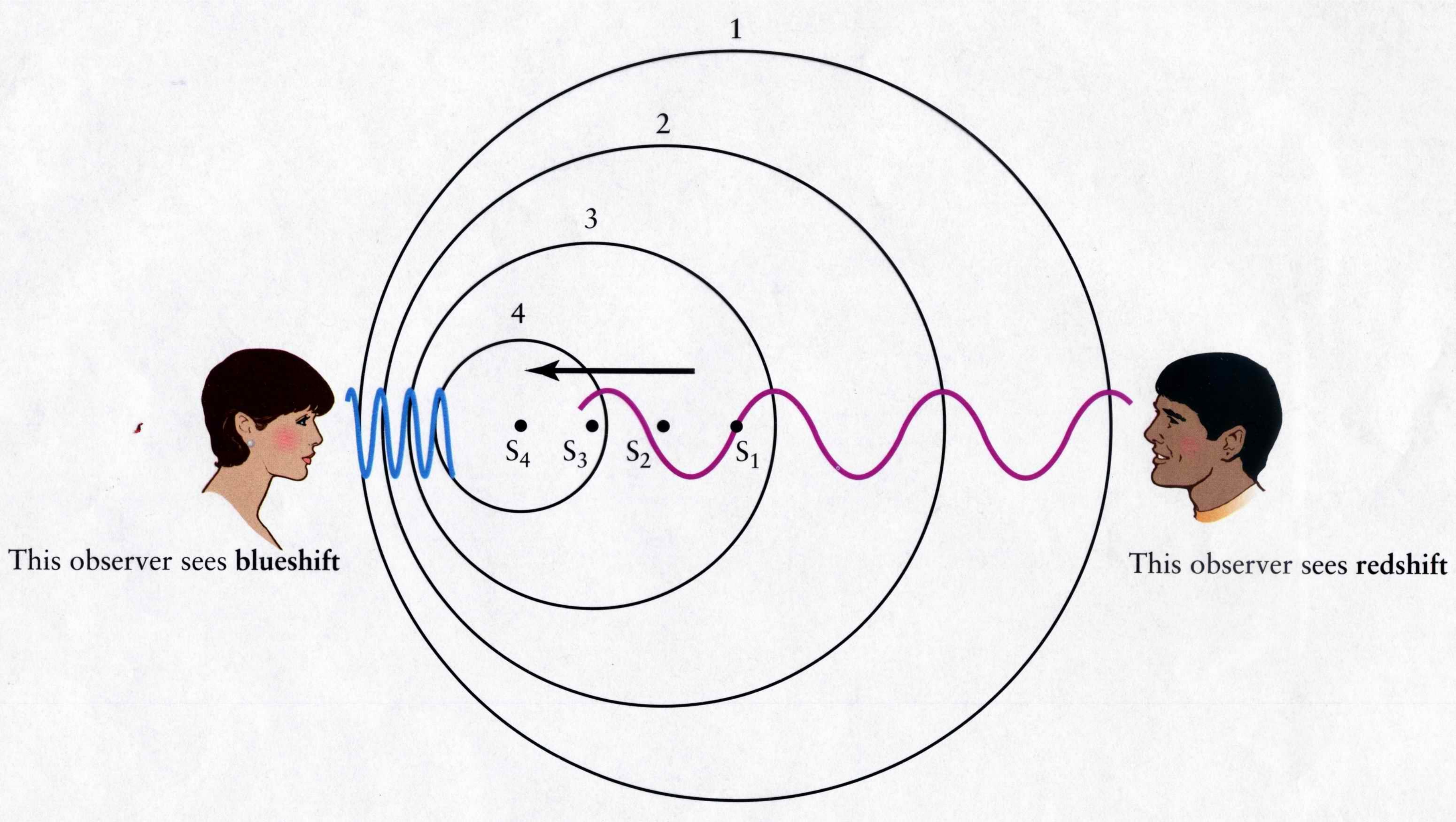
Announcements

- Hand in/email your planetarium assignment
- Stargazing all nights this week, 8:00-9:00 pm on 5th floor
- First midterm is Wed. October 1st in class (1 week from today)
  - Will cover Lectures 1-8 (through Sept 19th + a bit of today)
  - Textbook up to Chapter 2
  - Problems will be similar to those on quizzes
    - Problems on material through Chapter 2 – includes parts of quiz 4
  - No book, notes or calculator
    - Sheet of formulas will be given
    - Calculations will be doable without a calculator
  - Review in class on Monday Sept 29th (next Monday)

Light and Matter

Chapter 2 wrap-up

Doppler shift



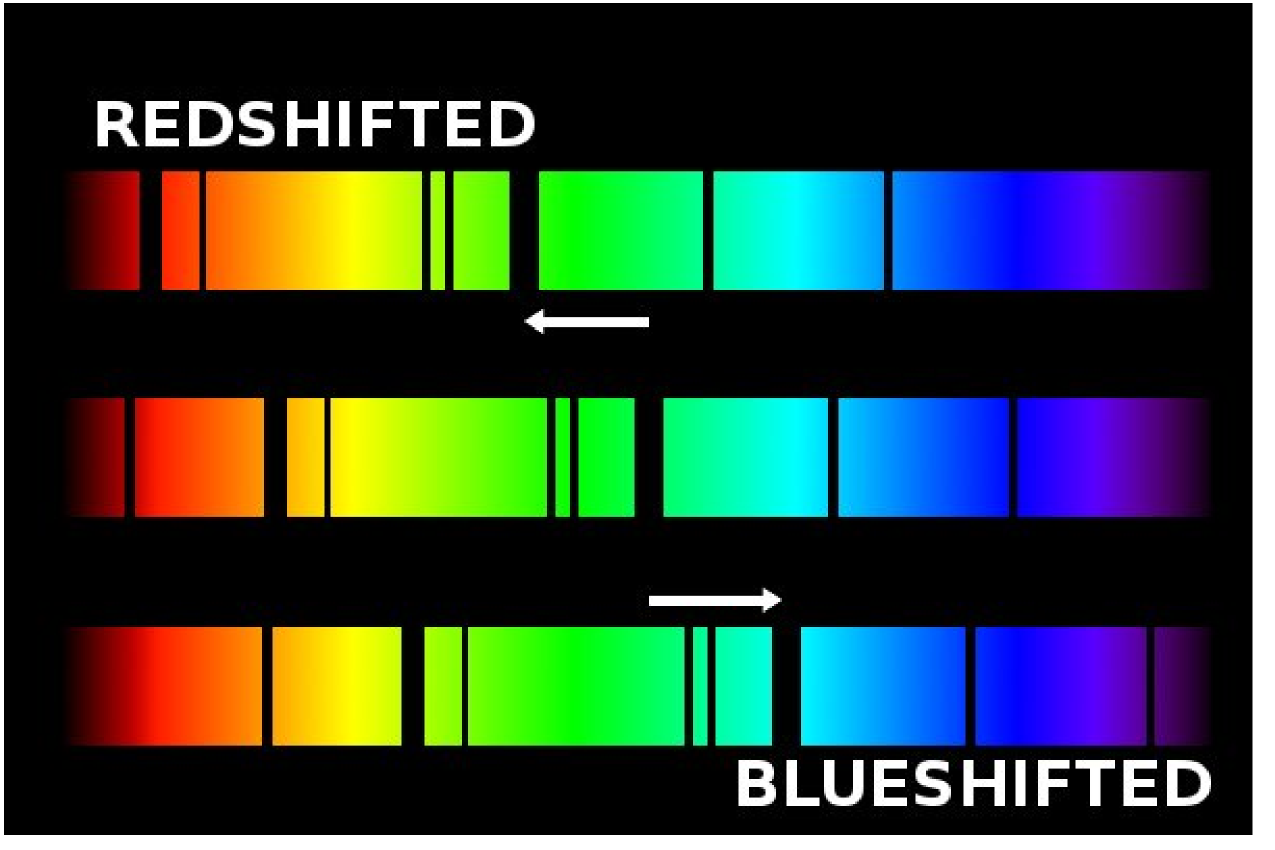
Source moves from position S_1 to position S_4

The Doppler Effect for sound waves

Source: youtube.com/watch?v=K2cNqaPSHv0

Doppler Shift

- When a source of light (or sound) is moving away from you, its wavelength, seen by you, is longer.
- When a source moves toward you, its wavelength, seen by you, is shorter.



Source: sciencequestionswithchris.wordpress.com

Recap: Light and Matter

- Light is electromagnetic radiation, carried by the electric field at the speed of light, c = 300,000 km/s
- Light is characterized by its wavelength and its frequency:

$$\lambda = \frac{c}{f}$$

- The electromagnetic spectrum ranges from radio waves with very long wavelengths to x-rays and gamma rays with very short wavelengths
- Visible light has wavelengths between 400 and 700 nm
- Astronomical objects emit light over the entire electromagnetic spectrum

Recap: Light and Matter

- All objects emit **continuous, thermal radiation** because of their **temperature**
  - Hot objects emit more radiation at all wavelengths, and emit their peak radiation at shorter wavelengths than cooler objects
- Atoms create **emission or absorption lines** by absorbing or emitting light
  - They emit light when an electron moves to a lower energy level, and absorb light when an electron moves to a higher energy level
- The **Doppler effect**: light or sound moving toward you is shortened in wavelength (blueshifted), and light or sound moving a way is longer in wavelength (redshifted)

Astronomy 103

Telescopes

Please read chapter 3

Why Telescopes?

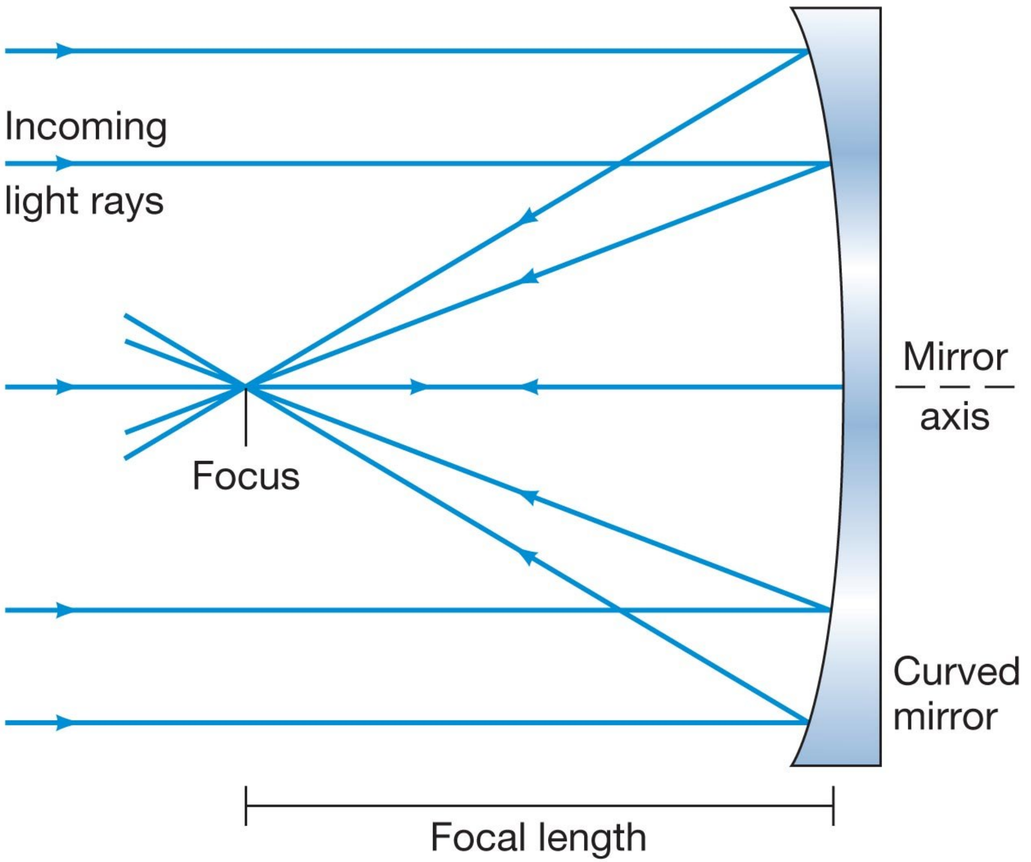
analogy

telescopes are light buckets

Optical Telescopes

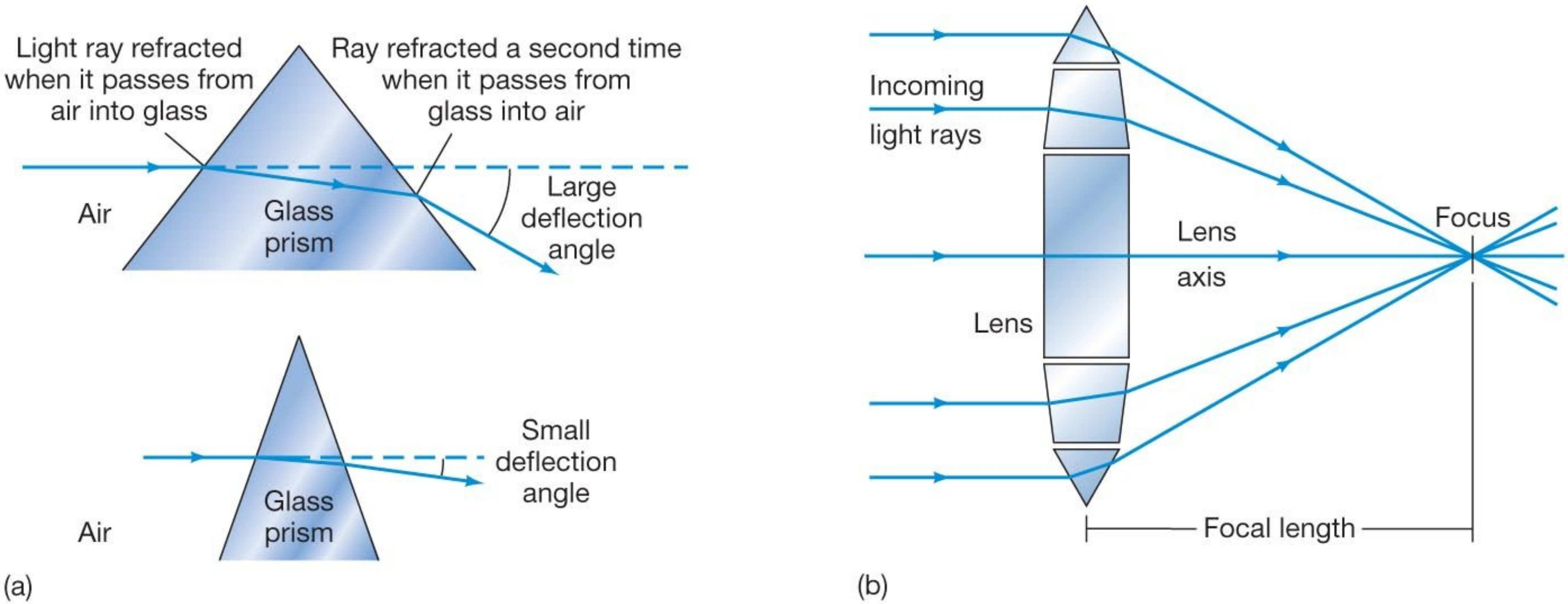
Images can be formed through **reflection or refraction**.

Reflecting mirror

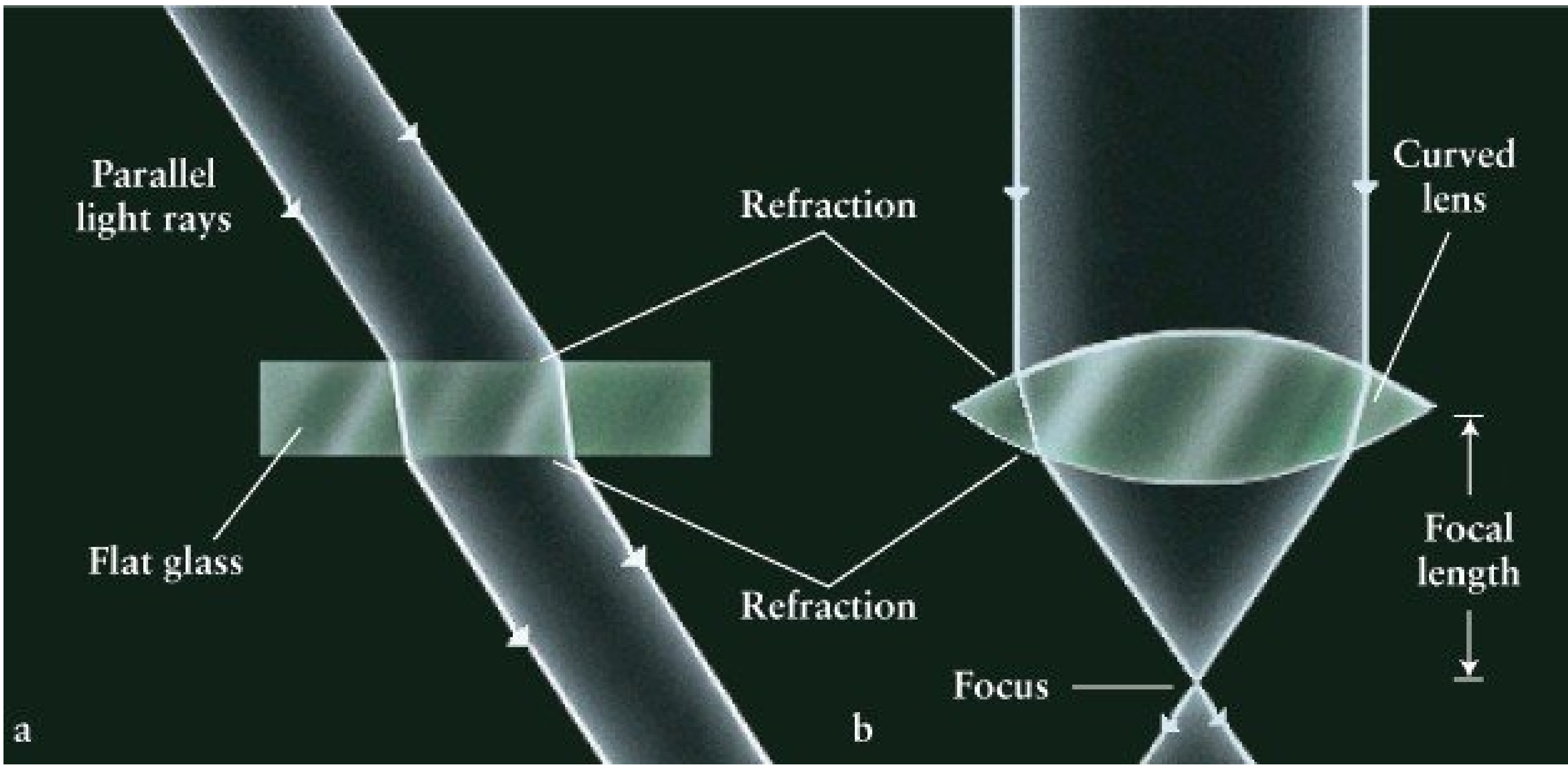


Note that the incoming light rays are parallel. This is because astronomical objects are so far away.

Refracting lens



Light travels fastest in space (in a vacuum), and slower in matter. The direction of light changes when it goes from one material to another in which its speed is different. This is how a lens focuses light.



By curving the sides of a piece of glass, one can make it into a lens -- something that takes the rays of light from a single point of an object and focuses them to a single image point at the focus. This is true of curved (reflecting) mirrors as well

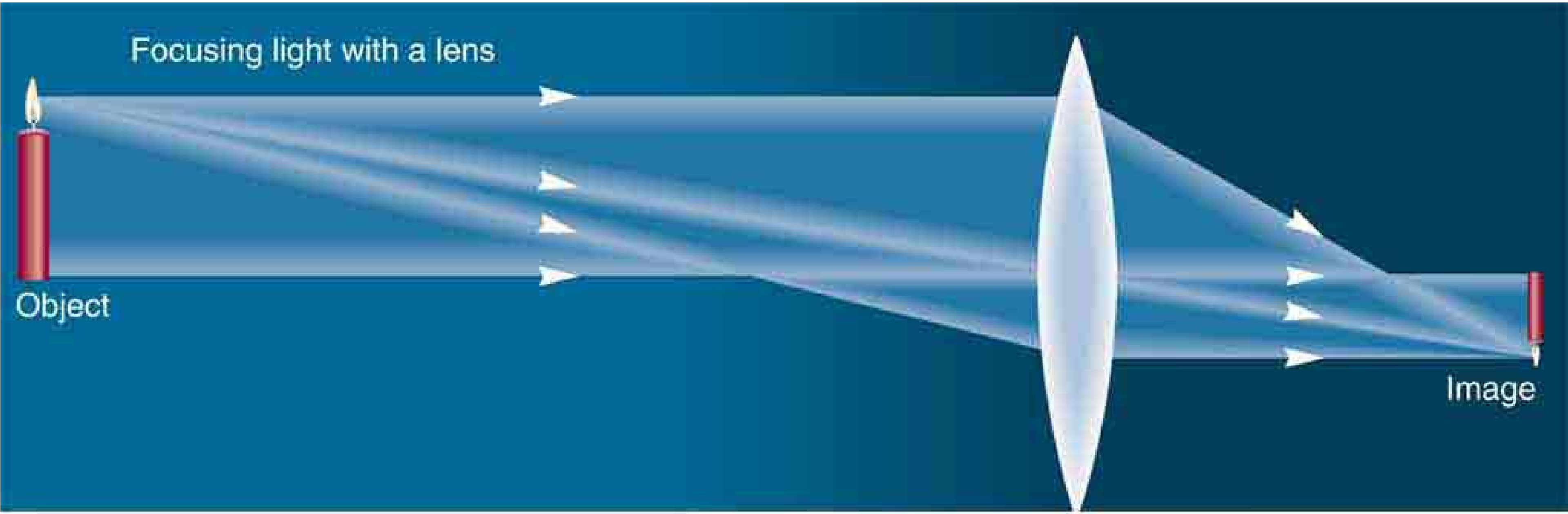


Image is inverted (upside down)

Image formation

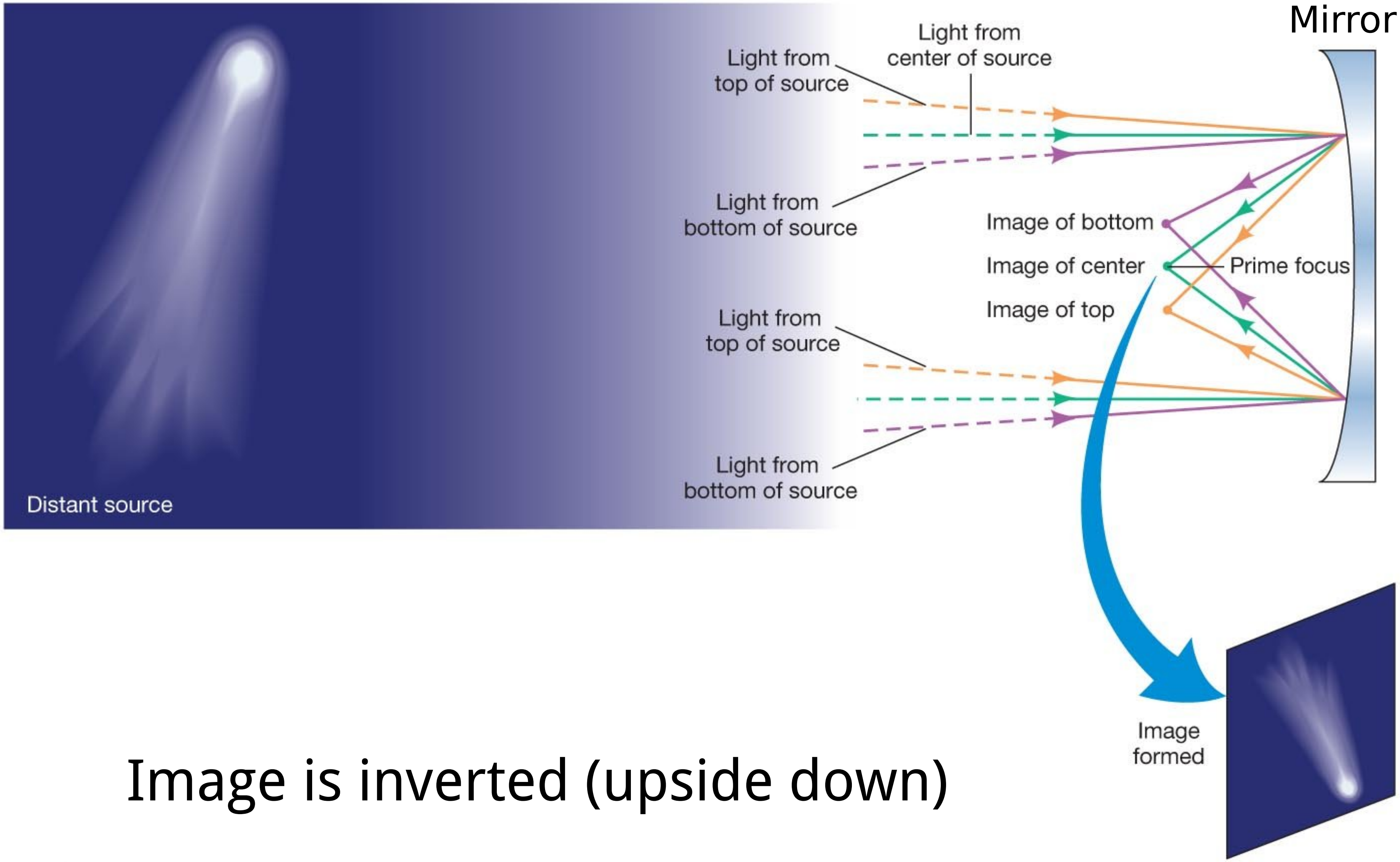
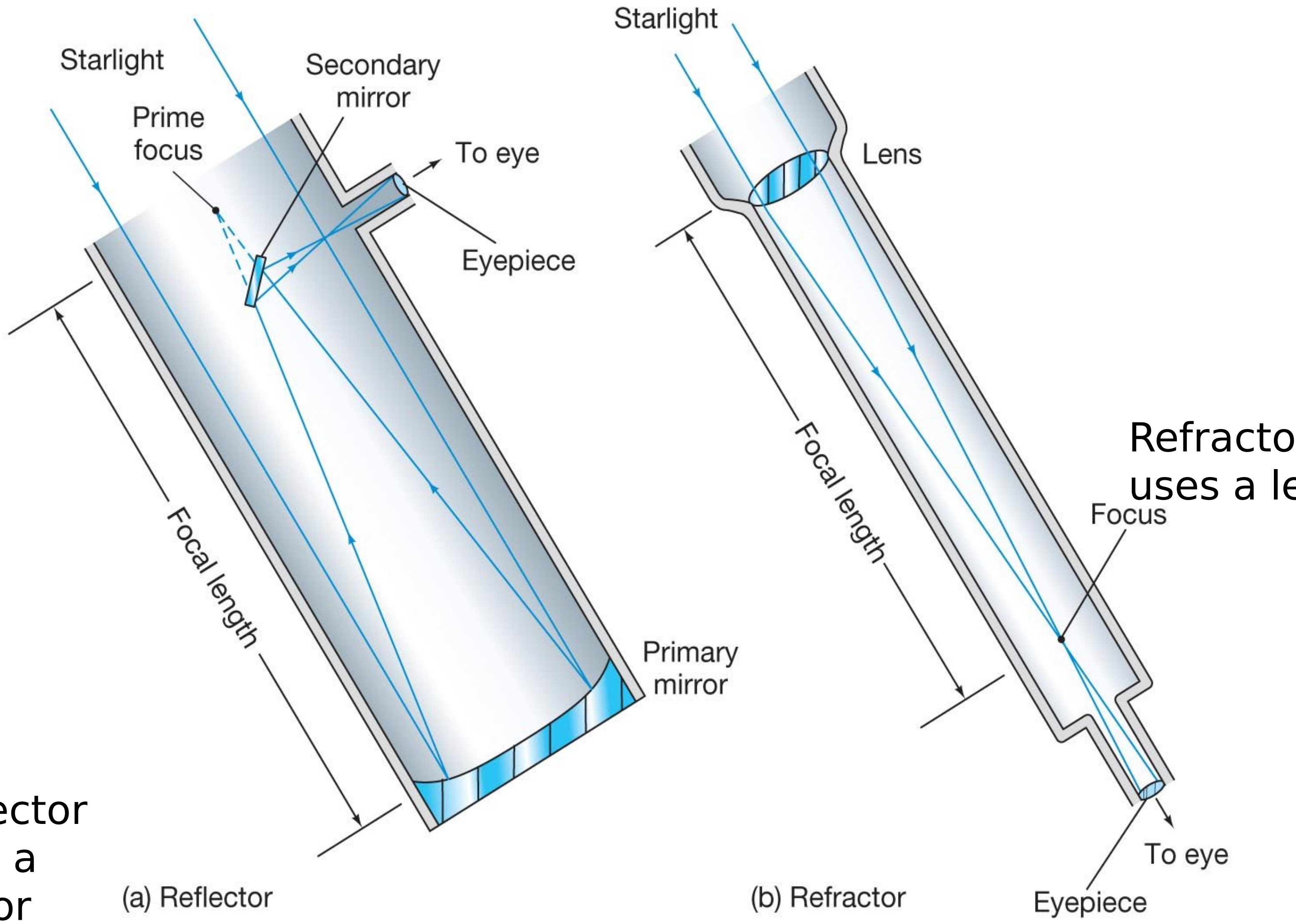


Image is inverted (upside down)

Two types of optical telescopes: Reflecting and refracting telescopes



Reflector uses a mirror

Refractor uses a lens

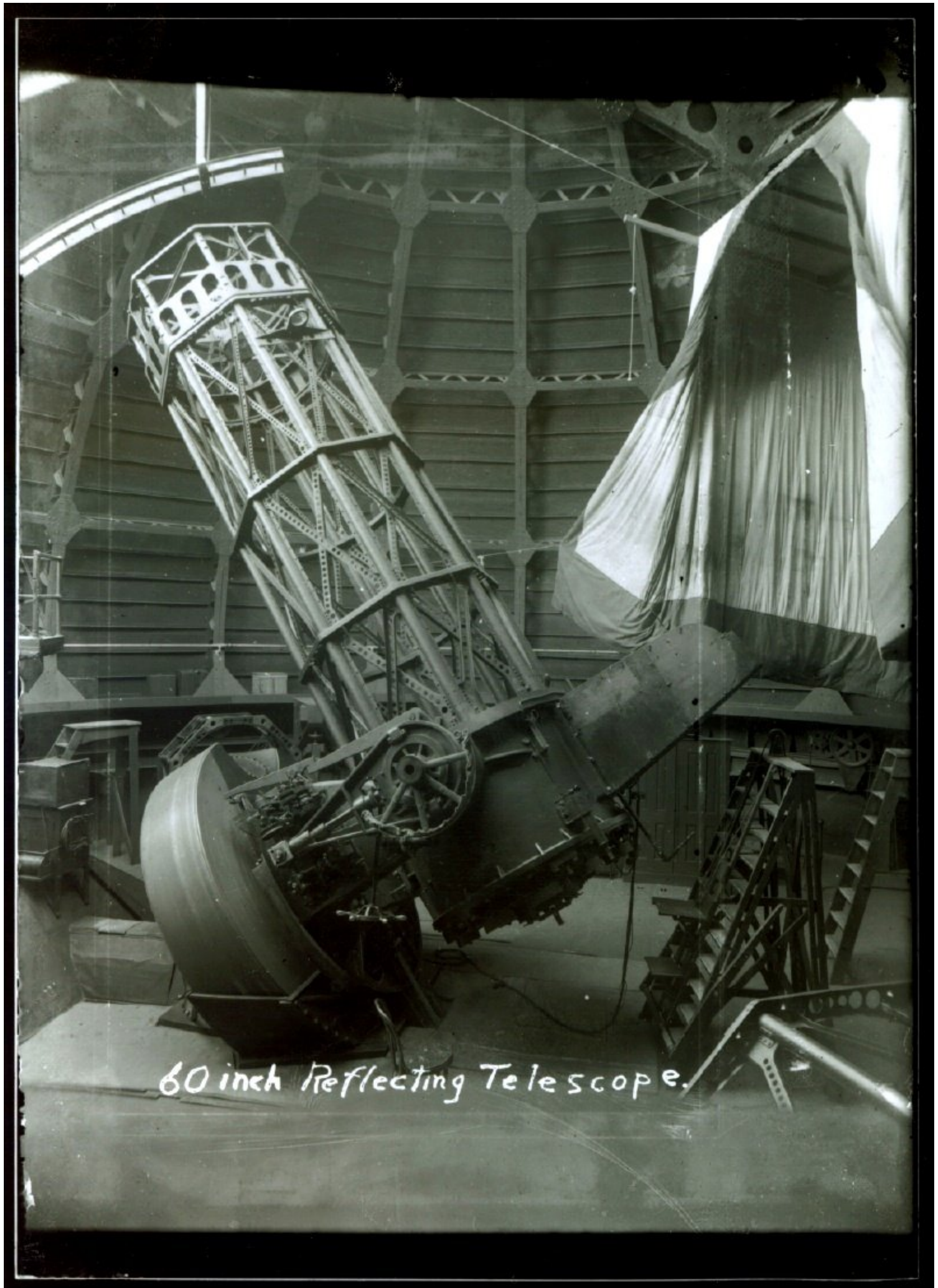
Modern telescopes are all reflectors

- Light traveling through a lens is refracted differently depending on wavelength (chromatic aberration). Mirrors don't suffer from this.
- Some light traveling through lens is absorbed (especially IR and UV light). Mirrors can be made to reflect this IR and UV.
- Large lens can be very heavy, and can only be supported at edge. Mirrors are supported at the back.
- Lens needs two optically acceptable surfaces, mirror only needs one, though mirror surfaces have to be more precise.

Yerkes Observatory, Williams Bay, WI -
40 inch telescope (1893), world's largest refractor

Built by George Ellery Hale - world's largest telescope when built

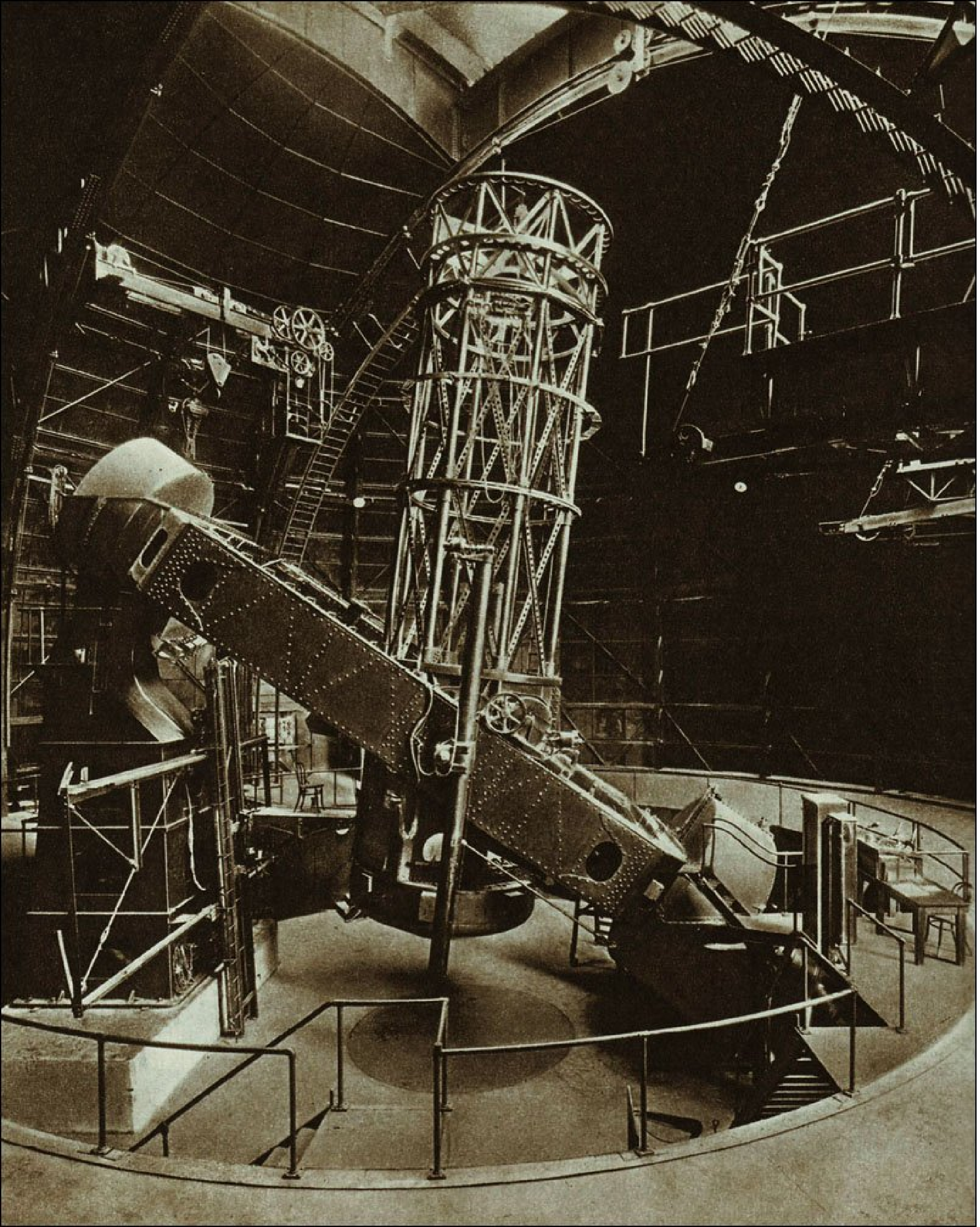
Yerkes Observatory



60 inch reflecting telescope, Mt Wilson, CA

Built by George Ellery Hale in 1908 – world’s largest telescope at the time

Because large lenses, held at the edges, sag from gravity, the largest telescopes are reflectors and have been for the last century.

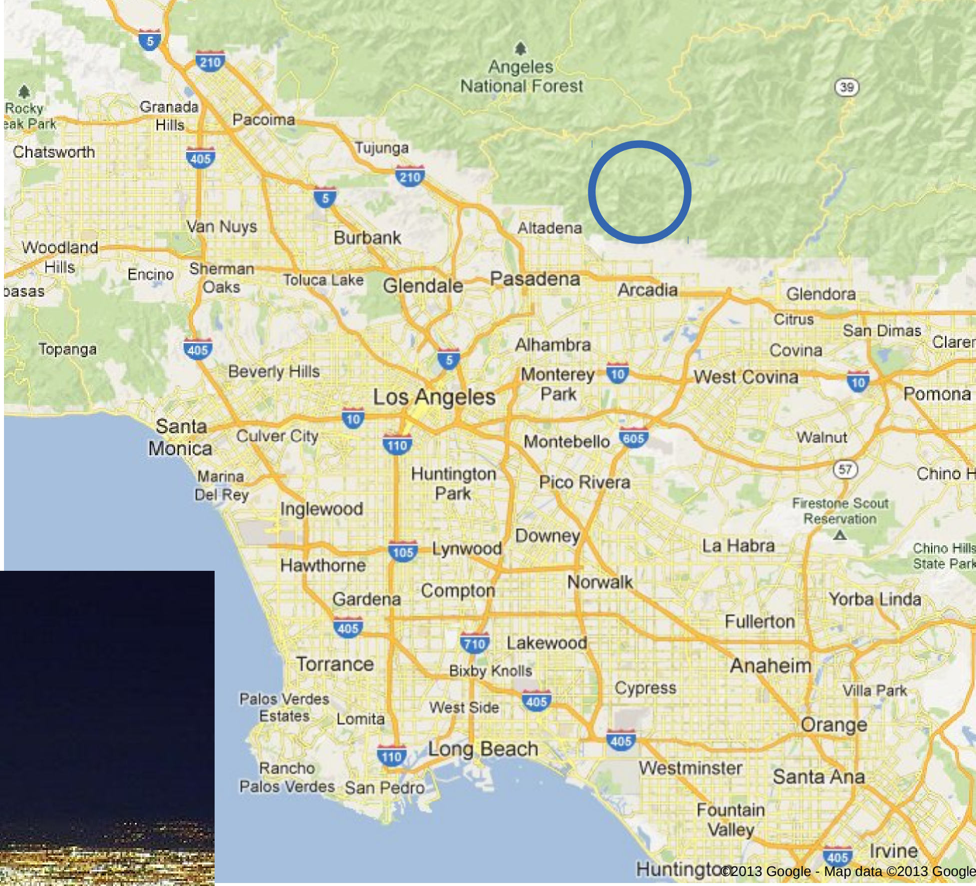


100 inch reflecting telescope, Mt Wilson, CA

Built by George Ellery Hale in 1917 – world's largest telescope until 1948

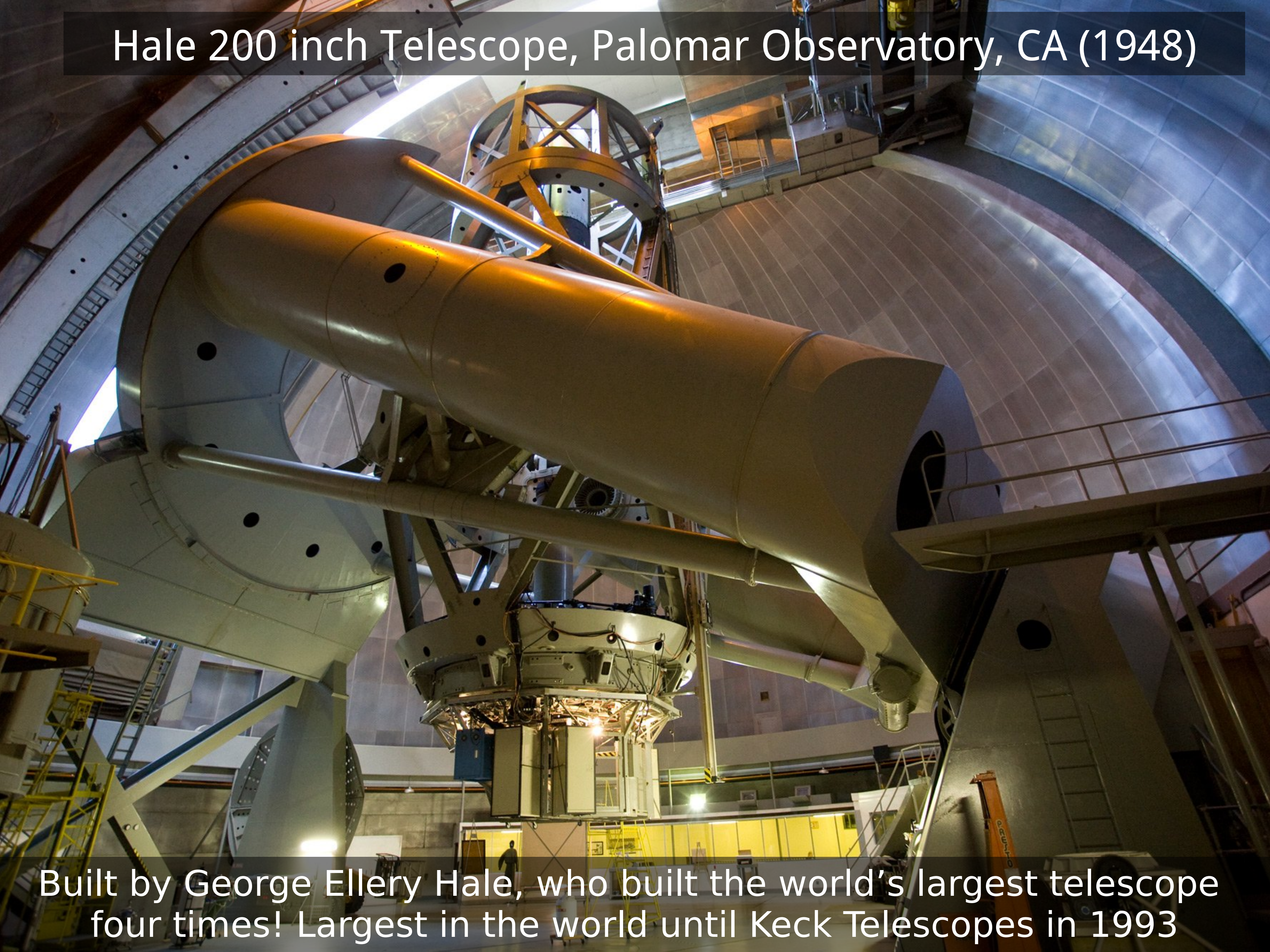
Used by Edwin Hubble to discover galaxies outside the Milky Way and the expanding universe

Astronomy from Mt Wilson became increasingly difficult as the population of Los Angeles grew



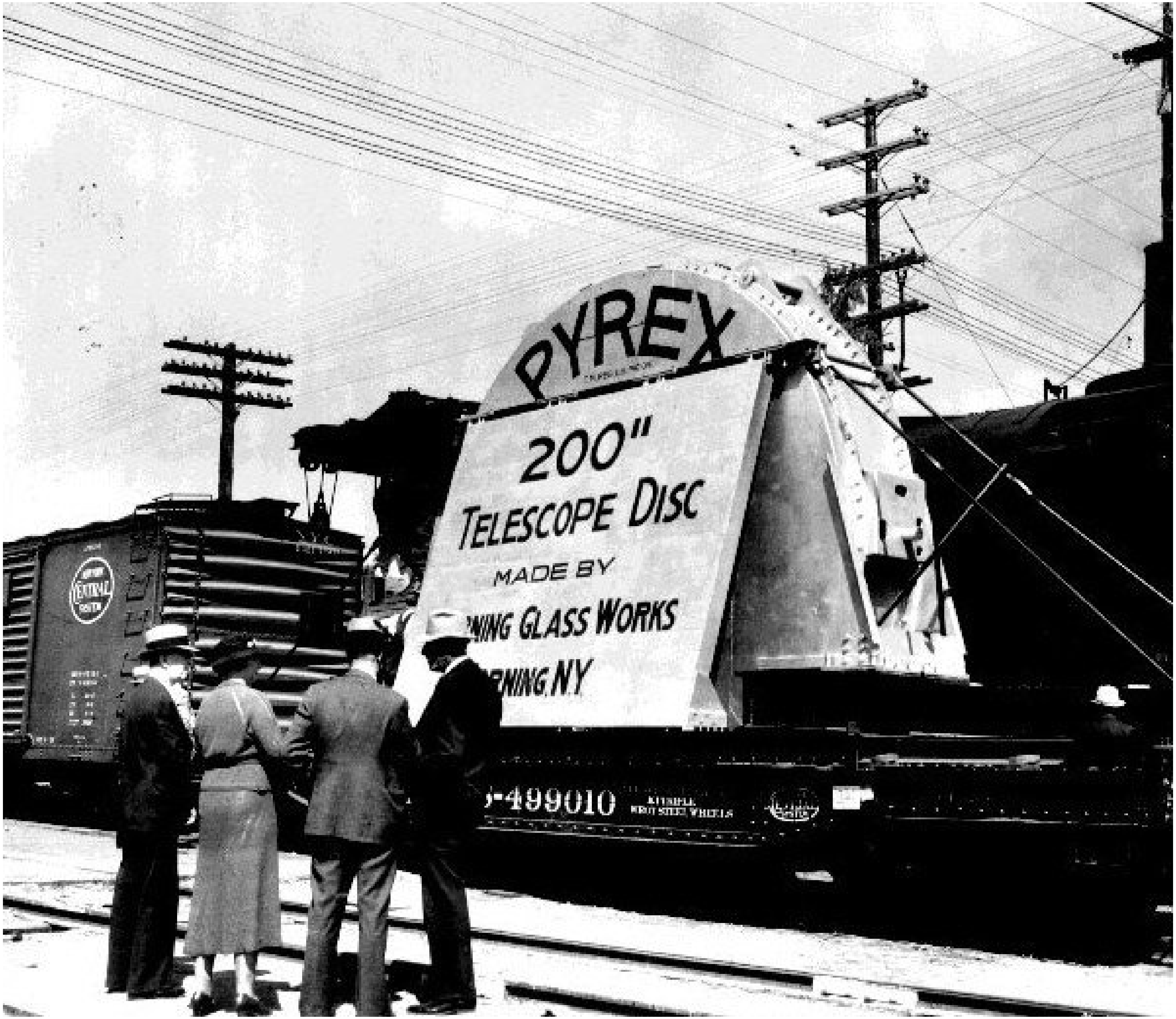
...though there was a productive period during the blackouts of World War II

Hale 200 inch Telescope, Palomar Observatory, CA (1948)

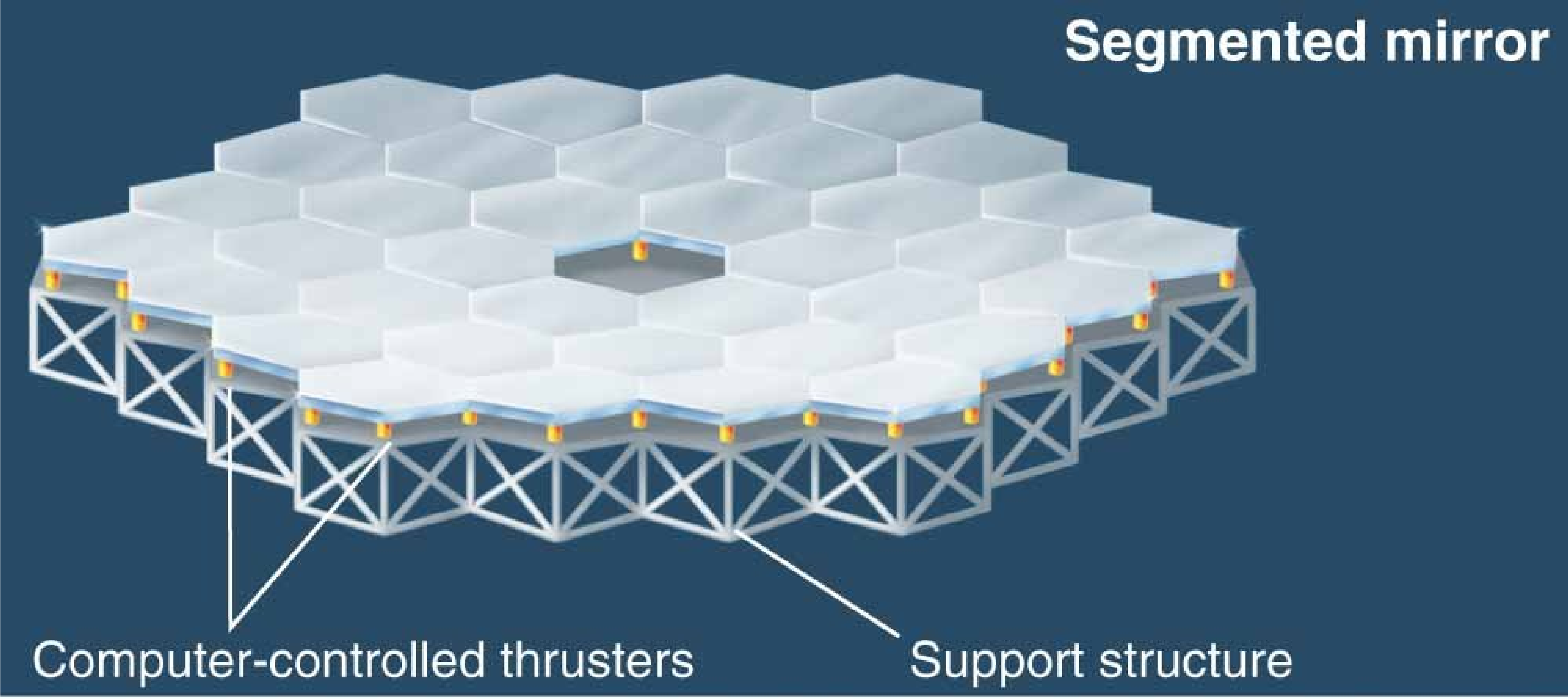


Built by George Ellery Hale, who built the world’s largest telescope four times! Largest in the world until Keck Telescopes in 1993

Hale Telescope Dome, Palomar Observatory, CA (1948)

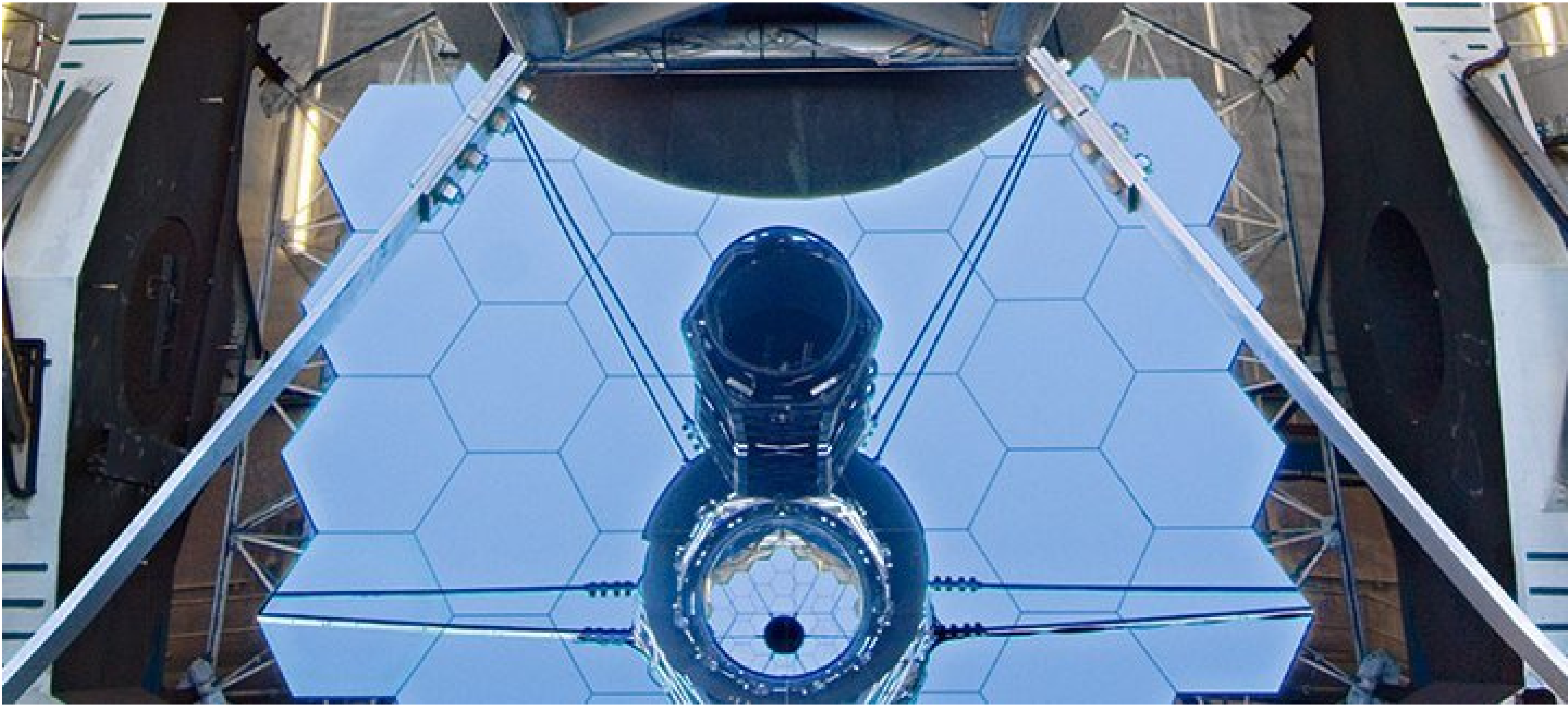


PYREX
200"
TELESCOPE DISC
MADE BY
NING GLASS WORKS
NING, N.Y.
-499010



The largest telescopes now (in the last 20 years or so) have segmented mirrors, each segment computer-controlled for proper alignment.

Segmented mirrors are lighter, allowing for less structural steel to support everything.

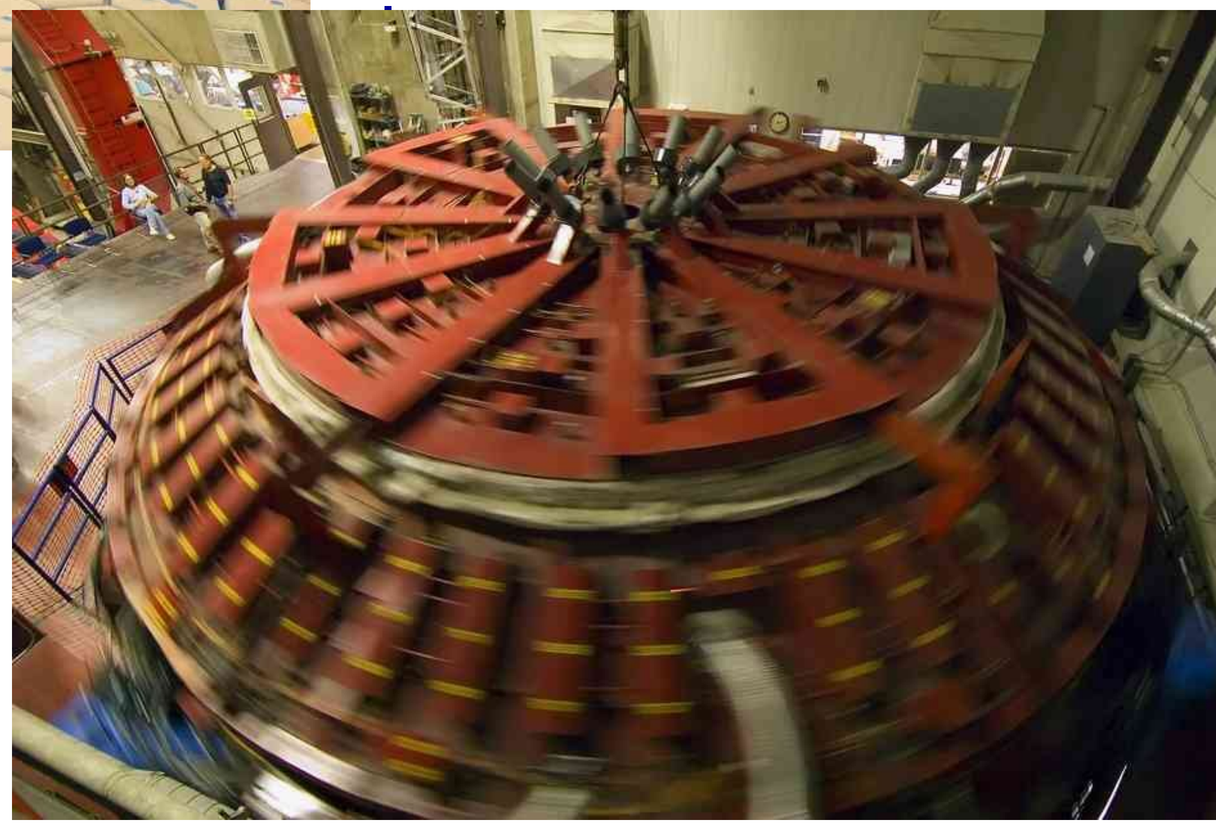


Keck Telescope Mirror, Mauna Kea, HI (1993)

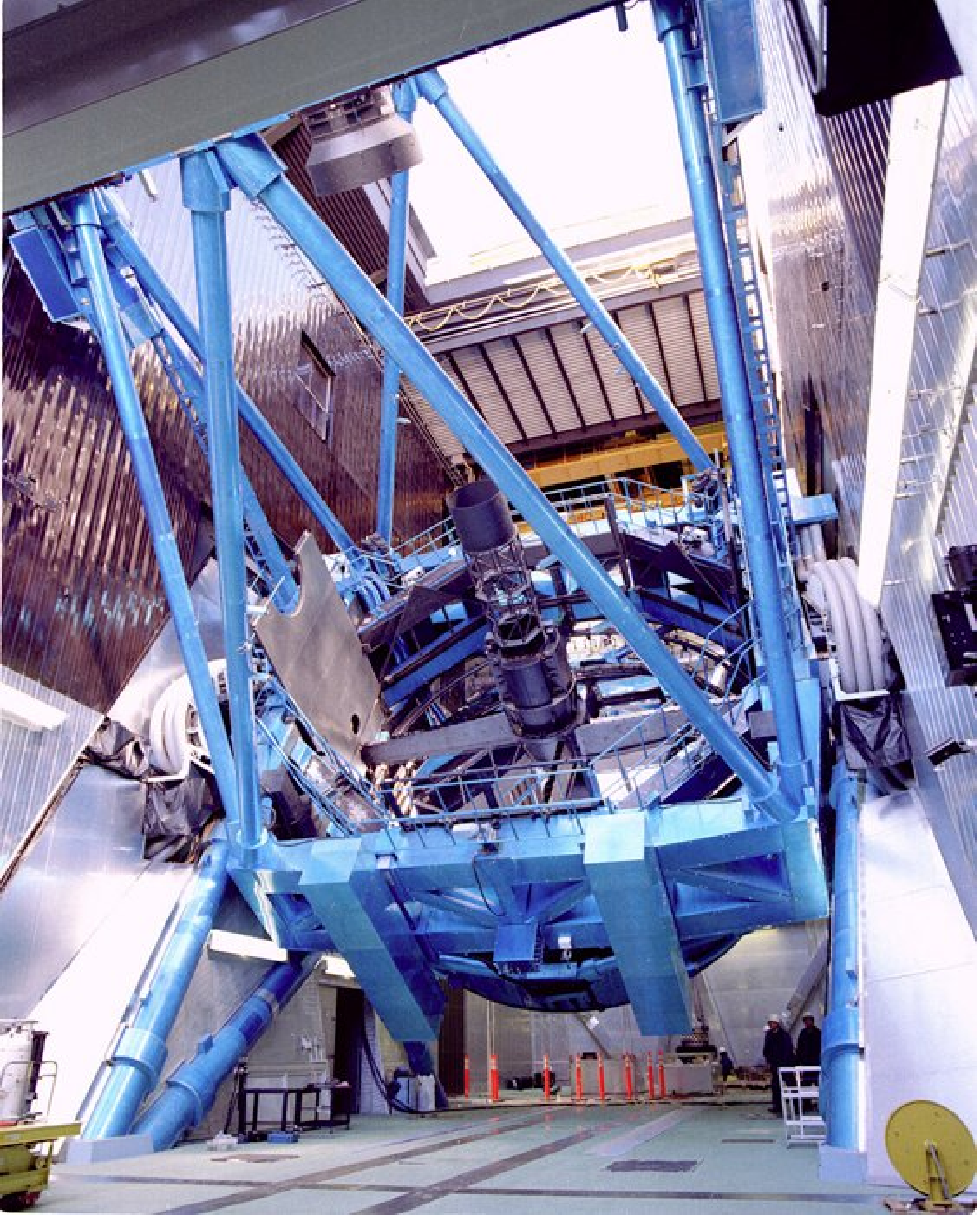
The largest optical telescopes on earth use segmented mirrors.

Keck Telescopes, Mauna Kea, HI (1993-1996)

Other large mirrors use honeycomb structure – to reduce weight – and are spun while cooling to create a curved shape that uses less



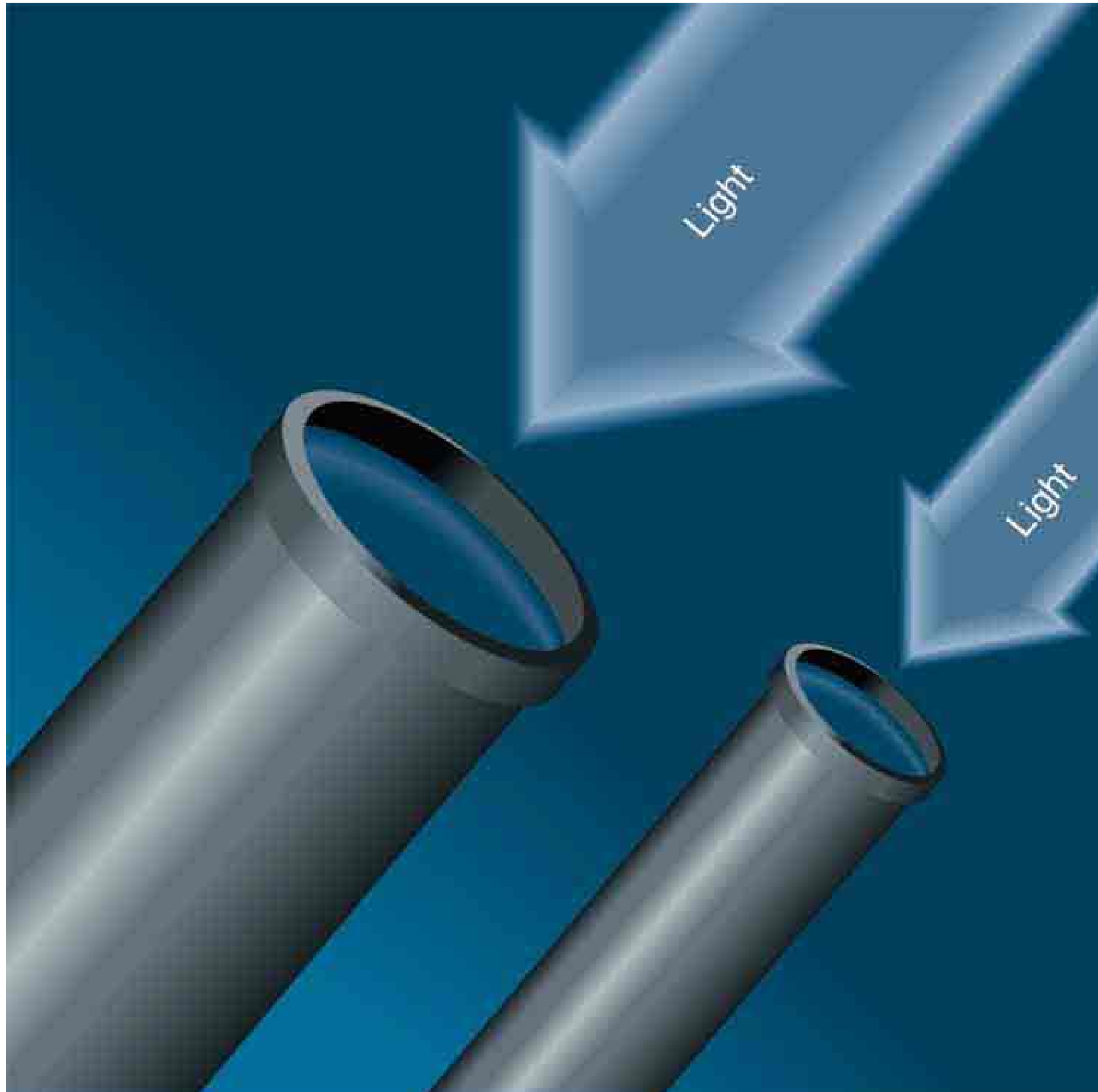
University of Arizona Mirror Lab



Here is an example of such lightweight mirrors: the Subaru Telescope, Japanese telescope on Mauna Kea, HI.

Bigger is Better in Astronomy

A larger telescope gathers more light and so can see dimmer objects.



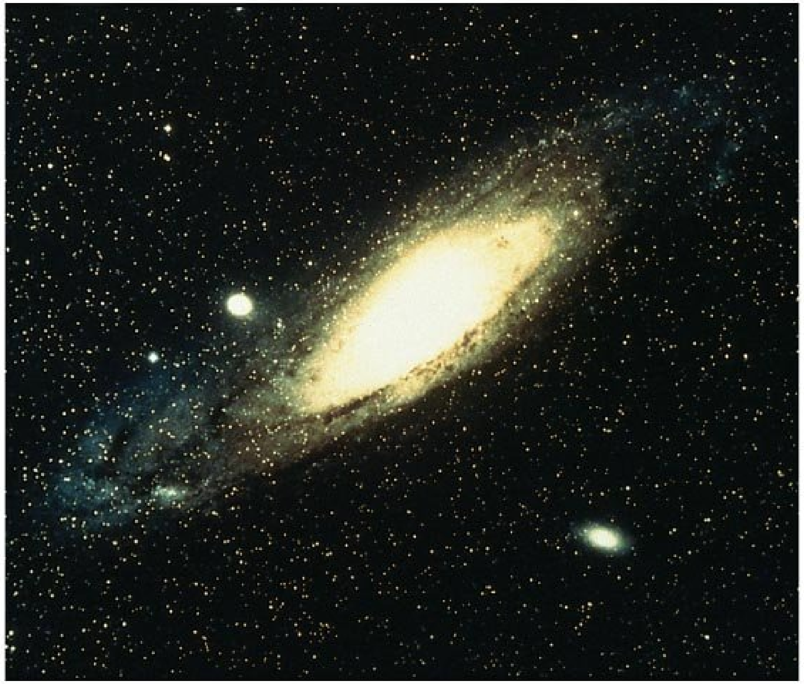
Light gathering power

Improves detail

The figure, part (b) was taken with a telescope twice the size of (a).

Twice the diameter means four times the light, since the area of the telescope is four times larger.

(a)



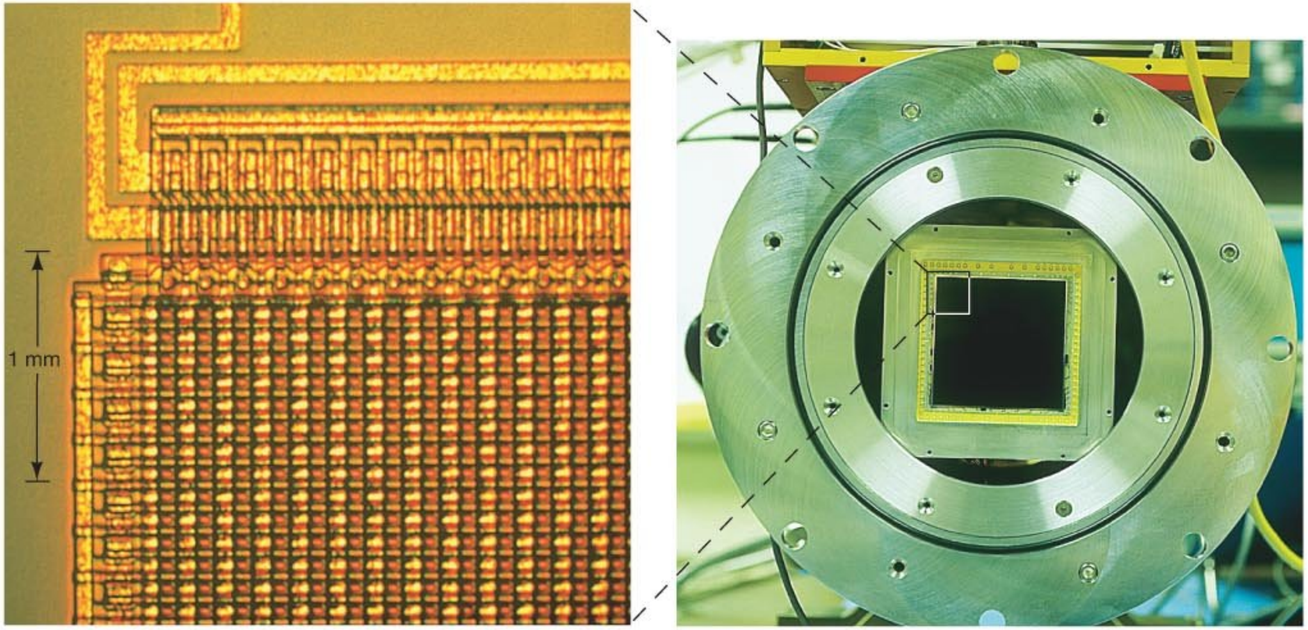
Why size matters

Because the stars and collections of stars (galaxies) that we look are at immense distances, they are very faint. To see them, what is crucial is to gather as much of their light as possible:

First by having a mirror (or a lens) that is **as large as possible**, and second by **adding up all the light** that comes to the telescope over a time of minutes or hours – long exposures, in other words.

You add up the light by using a camera – we used to use photographic plates that were exposed for minutes or hours, nowadays use a digital camera. Astronomers use CCDs (charge-coupled devices) to detect light – very similar to the detector in your digital camera.

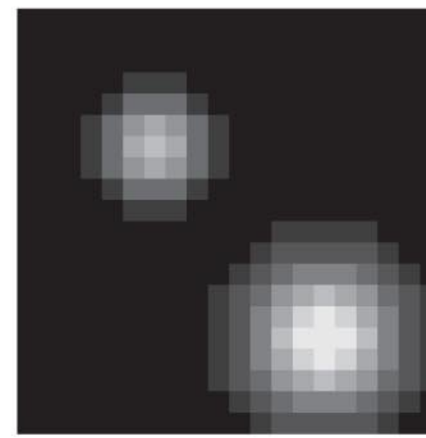
Image acquistion: CCDs



(a) (b)

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	3	3	3	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	3	5	6	5	3	1	0	0	0	0	0	0	0	0	0	0
0	0	0	1	3	6	7	6	3	1	0	0	0	0	0	0	0	0	0	0
0	0	0	1	3	5	6	5	3	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	3	3	3	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	1	0	0
0	0	0	0	0	0	0	0	0	0	1	2	3	4	4	4	3	2	1	0
0	0	0	0	0	0	0	0	0	1	2	3	5	6	7	6	5	3	2	1
0	0	0	0	0	0	0	0	0	1	2	4	6	8	9	8	6	4	2	1
0	0	0	0	0	0	0	0	0	1	2	4	7	9	9	9	7	4	2	1
0	0	0	0	0	0	0	0	0	1	2	4	6	8	9	8	6	4	2	1
0	0	0	0	0	0	0	0	0	1	2	3	5	6	7	6	5	3	2	1
0	0	0	0	0	0	0	0	0	0	1	2	3	4	4	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	1	0	0

(c)



(d)

Image acquisition: Charge-coupled devices (CCDs) are electronic devices that detect photons, can be quickly read out and reset.

Also CCDs can be made sensitive to different wavelengths of light.

The effect of improving angular resolution

(a) (b) (c) (d)

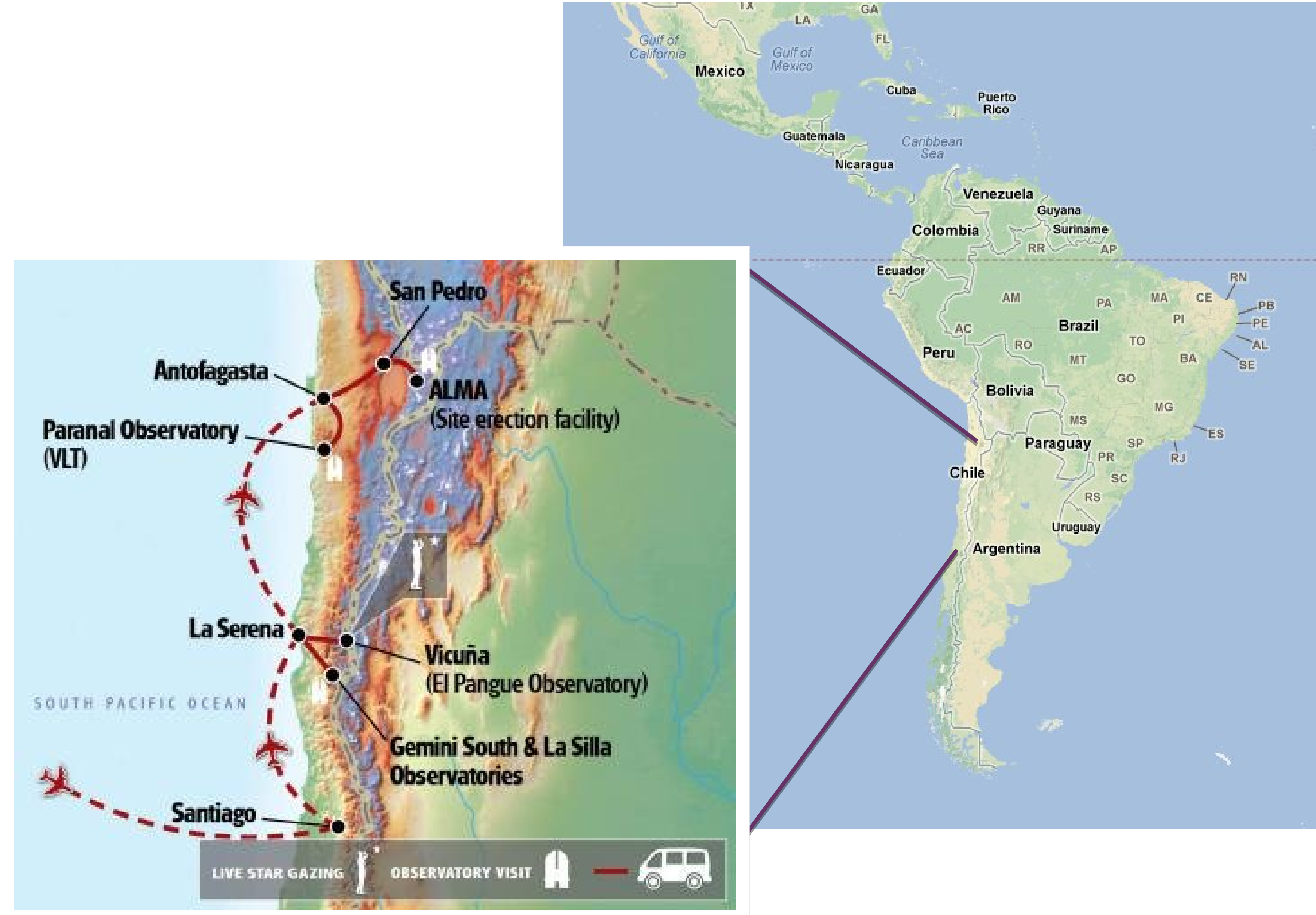
The resolving power of all ground-based optical telescopes is limited by the blurring effect of turbulence in the atmosphere.

Many of the world's best optical telescopes are on the summit of Mauna Kea on the Big Island of Hawaii, with elevation 14,000 feet.

More views of Mauna Kea

Most of the other premier optical observatories are in the mountains of Chile. These are the Very Large Telescopes (8.2 m each), operated by the European Southern Observatory.

Address


San Pedro
Antofagasta
ALMA
(Site erection facility)
Paranal Observatory
(VLT)
La Serena
Vicuña
(El Pangue Observatory)
SOUTH PACIFIC OCEAN
Gemini South & La Silla
Observatories
Santiago
LIVE STAR GAZING
OBSERVATORY VISIT
TX
LA
GA
FL
Gulf of
California
Gulf of
Mexico
Mexico
Cuba
Puerto
Rico
Guatemala
Caribbean
Sea
Nicaragua
Venezuela
Guyana
Suriname
Colombia
RR
AP
Ecuador
AM
PA
MA
CE
RN
PB
PE
AL
SE
PI
Brazil
AC
RO
TO
BA
Peru
MT
GO
Bolivia
MG
MS
ES
Paraguay
SP
RJ
PR
Chile
SC
RS
Uruguay
Argentina

Las Campanas Observatory, north of La Serena, Chile. Site of several telescopes now, and future site of the Giant Magellan Telescope.

It’s very important to have telescopes in both the northern and southern hemispheres in order to see the whole sky: both northern and southern stars!

Video: ESOcast 63

- view at home: http://www.eso.org/public/videos/esocast63a

Reminder:

- Stargazing all nights this week, 8:00-9:00 pm on 5th floor
- First midterm is Wed. October 1st in class (1 week from today)