AY 4: The Stars

- Instructor: Jean Brodie ISB 345
- Lectures: T/Th 10:00 - 11:45 am
  in 152 Baskin Engineering
- Sections: optional although labs will be administered through the sections and people who attend the sections do better in the class!
- Book: There isn't one!
- Note: Everything related to the class can be found at http://www.astro.ucsc.edu/~neil/ay4_s08/index.html

Grades

- Grades: best four of five quizzes plus two labs (done in sections).
- Homework questions will be assigned and some of the quiz questions will taken from the homeworks.
- Optional final.

Philosophy

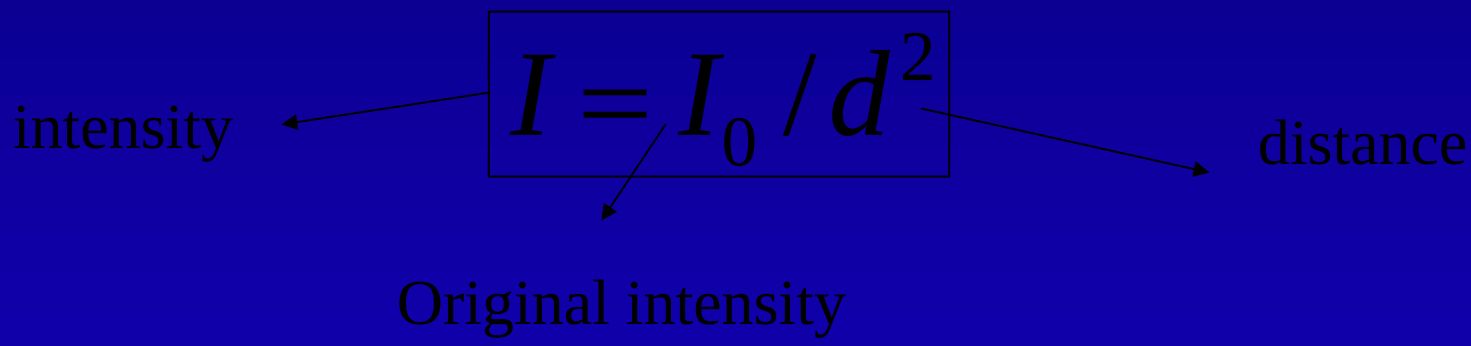
- Understand the process of scientific investigation.
- Learn some astronomy. The details are not so important, the fact that we have been able to learn so much about the Universe is a more important point.

Quantitative - the `Q' thing

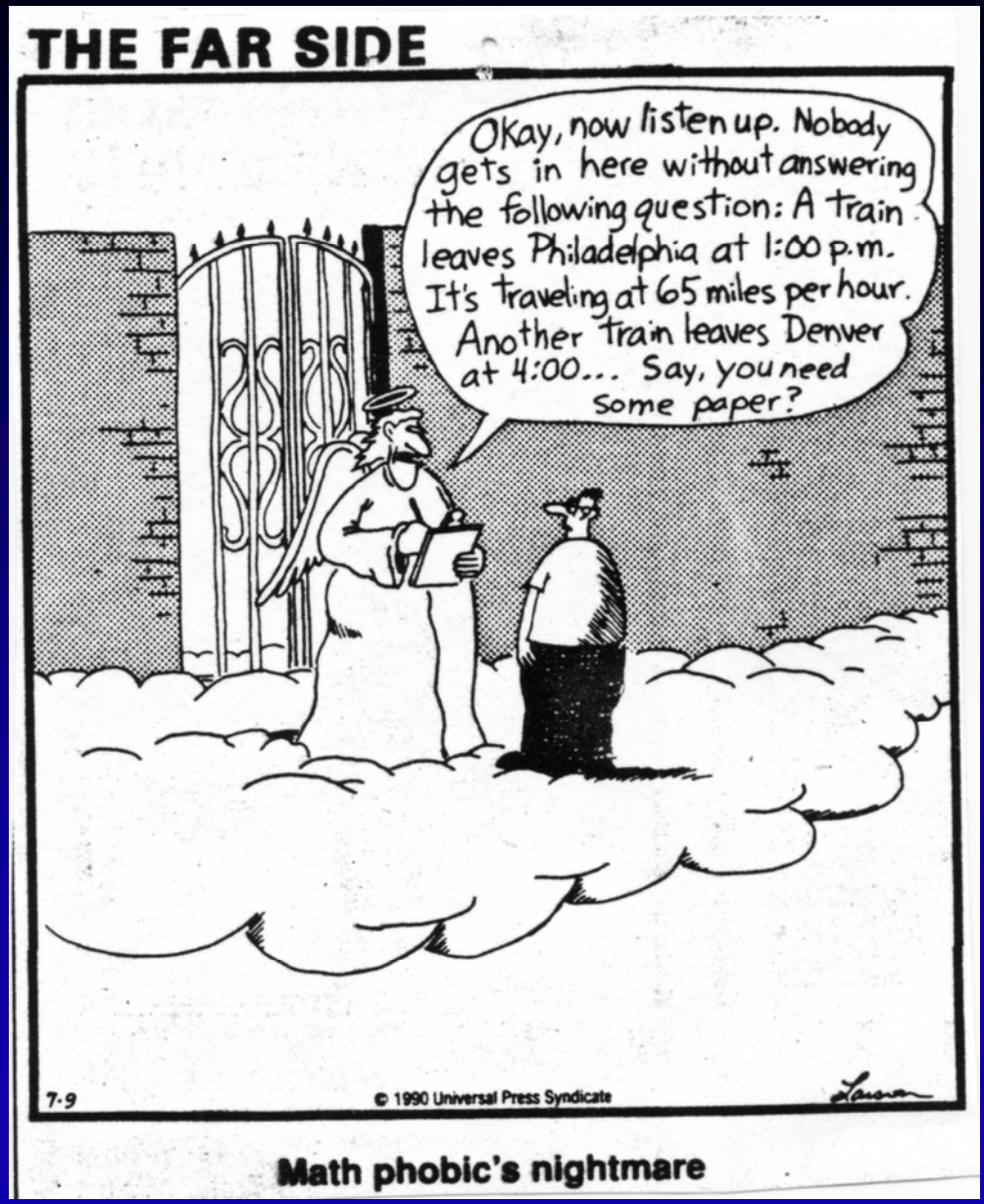
- How would the appearance of the Sun change if it were moved to twice its current distance?

  Qualitative answer: *It would get fainter*.

  Quantitative answer:



<u>It would be 1/(2x2)=1/4 as bright</u>



Math phobic's nightmare

The Plan

- Telescopes
- Earth Motions
- Physics background
- Properties of Stars (mass, size, energy output, temperature)
- How stars work
- The lifecycle of stars
- Stellar death - white dwarfs, neutron stars, black holes and the formation of the elements

Note! This class is NOT about

- Planets (AY 3)
- The Big Bang (AY 5)
- The Accelerating Universe (AY 5)
- Dinosaur-Murdering Killer Asteroids (AY 8)

Q. Astronomy is most closely related to:

a)Cosmetology

b) The Human Genome Project

c) Astrology

d) Physics

Q. While `at' the telescope, most astronomers wear:

a) Down Jackets

b) Trendy Patagonia Synchilla Jackets

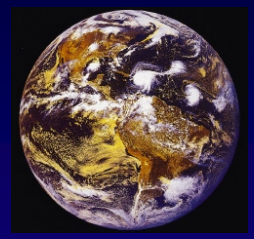
c) Politically incorrect animal furs

d) Bermuda shorts and Hawaiian shirts

Astronomy as a Career

- Typical path to astro-career
  - Undergraduate degree in Physics
  - 5 to 7 years in graduate school in A&A leading to PhD
  - 3 to 6 years as a research postdoc
  - Faculty position at some University
- Around 50% head in other directions
  - Aerospace, software, financial markets

Our Place in Size Scales



10^{-15} 10^{-10} 10^{-5} 1 10^{5} 10^{10} 10^{15} 10^{20} 10^{25}

Atomic nuclei

Atoms

virus

human

Diameter of Earth

1 AU

Distance to the nearest star

Diameter of the Galaxy

Size of the observable universe

Scale of the Universe

Earth
X 5

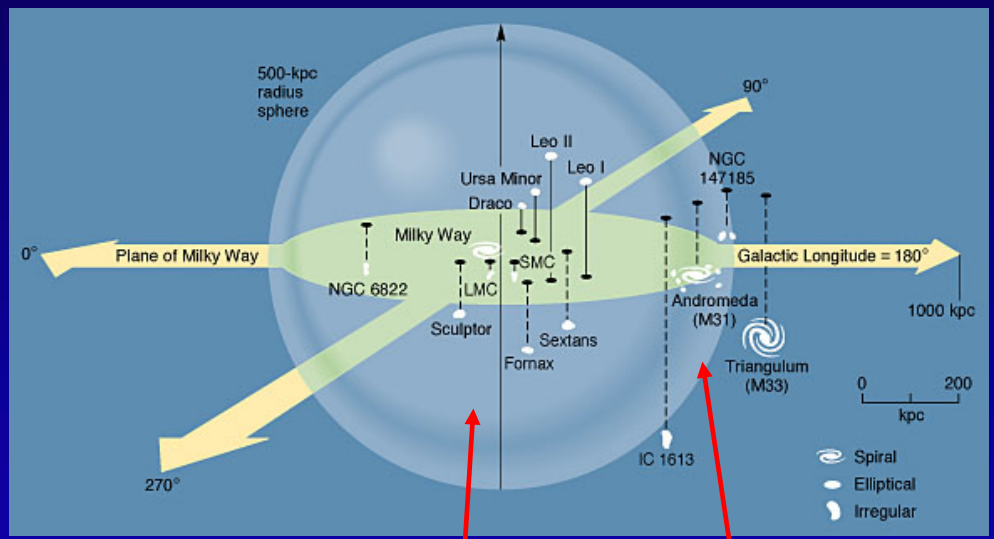
- It is hard to get the scale of the Solar System in our heads, impossible to really comprehend the size of the Universe.
- Scale the Sun to the size of a human.
  - Earth will be 300 yards from the Sun
  - Pluto will be 4 miles from the Sun
  - Nearest star would be 30000 miles away…

Scale: Galaxies

- A large spiral galaxy like the Milky Way Galaxy contains around *100 billion* stars.
- We live in the suburbs of the Milky Way Galaxy

Groups of Galaxies

6 million light years



The Milky Way Galaxy is a member of a small group of galaxies.

Andromeda

Milky Way

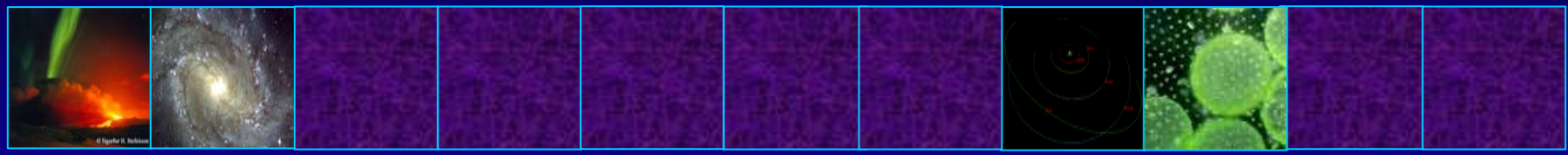
The Local Group is falling into the Virgo Cluster

There are many clusters of galaxies in the nearby Universe

Hubble
UltraDeep
Field

Our Place in Time

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov



14 billion years

The Big Bang

13 billion years

The formation of the Milky Way Galaxy

Dec

4.5 billion years

Formation of the Sun and Solar System

Life on Earth

December of the Cosmic Year

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

First vertebrates

First land plants

First amphibians

First reptiles

First Dinosaurs

First Mammals

First birds

First primate, Asteroid wipes out Dinos

9:24pm - First human ancestor to walk upright

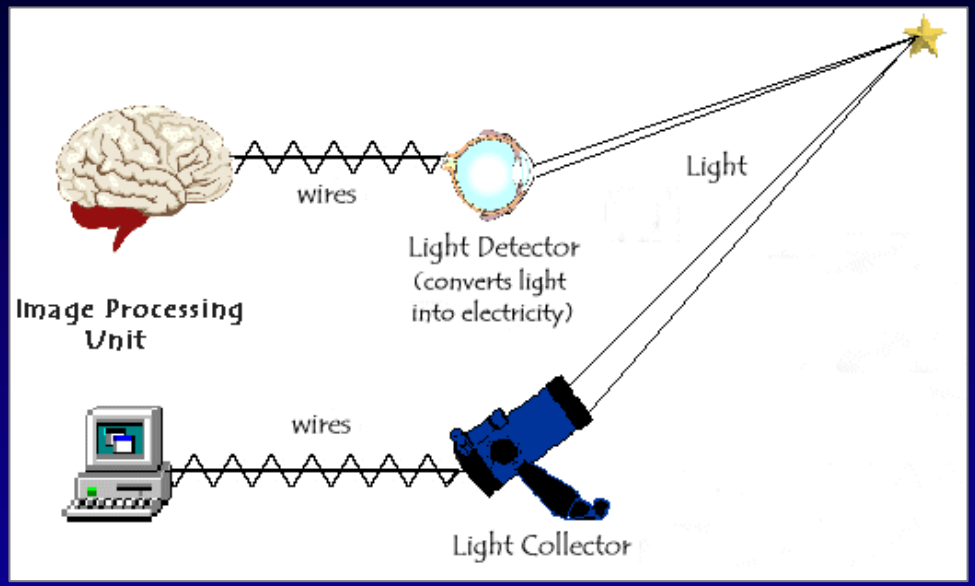
11:30pm - Fire becomes human tool

11:54pm - Homo Sapiens appears

11:59:50pm - The pyramids are build

11:59:59pm - Columbus sails to the New World

Telescopes

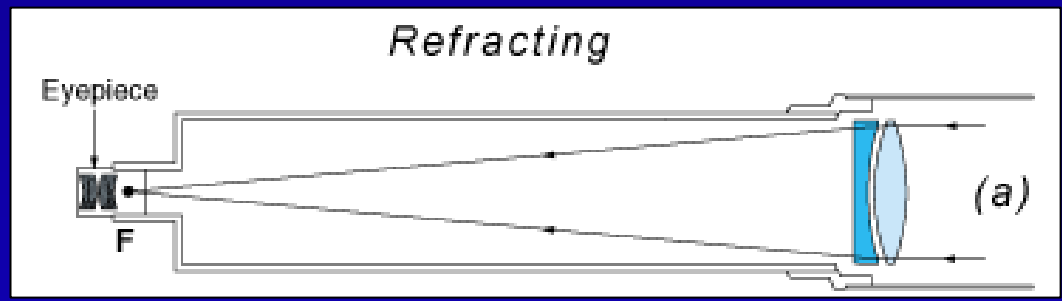


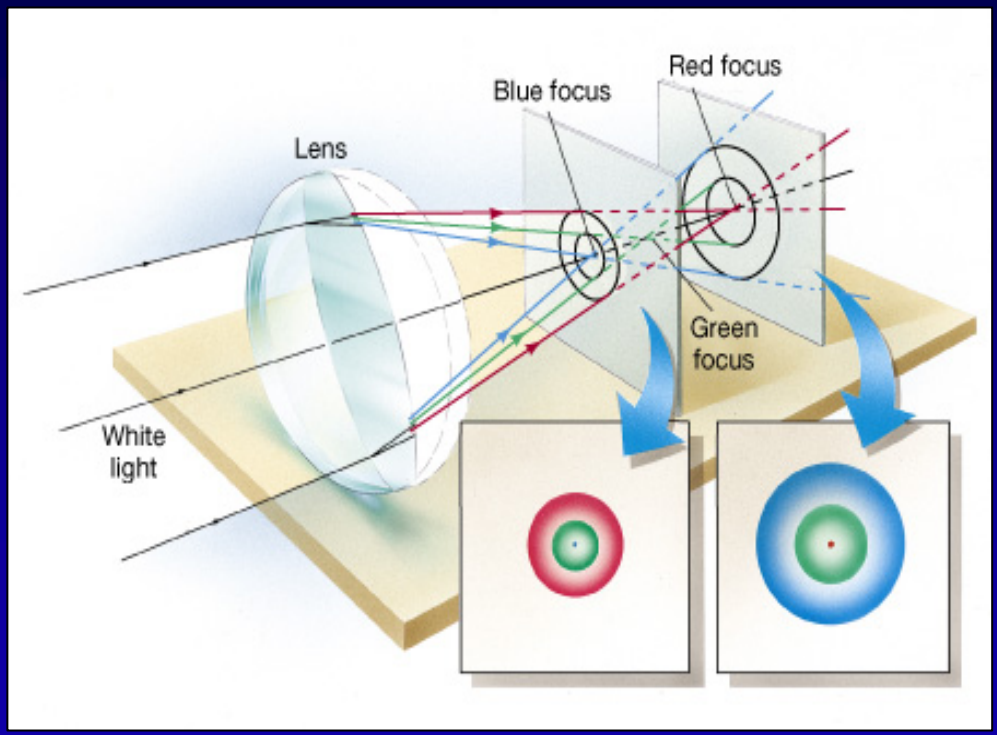
Telescopes only have a few jobs:

1) Point to a particular point on the sky
2) Collect lots of light and focus it onto a detector
3) Follow the apparent motion of the object

Refractor

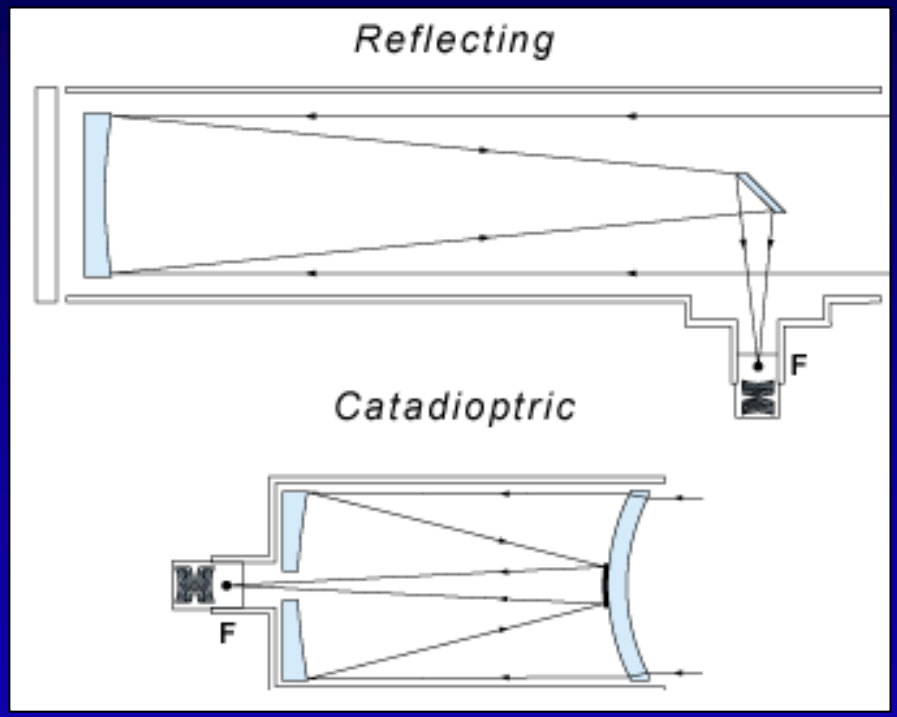
- Up to the early part of the 20th century the largest telescopes were `refractor' telescopes -- they used a lens and refraction to focus the gathered light





- Among the problems of using lenses, the most serious is chromatic aberration.
- Light of different wavelengths (colors) gets focused at different distances from the lens.

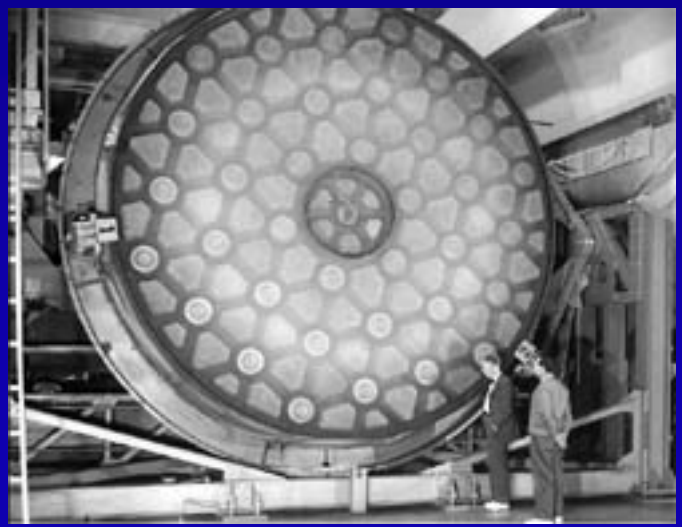
Reflecting Telescopes



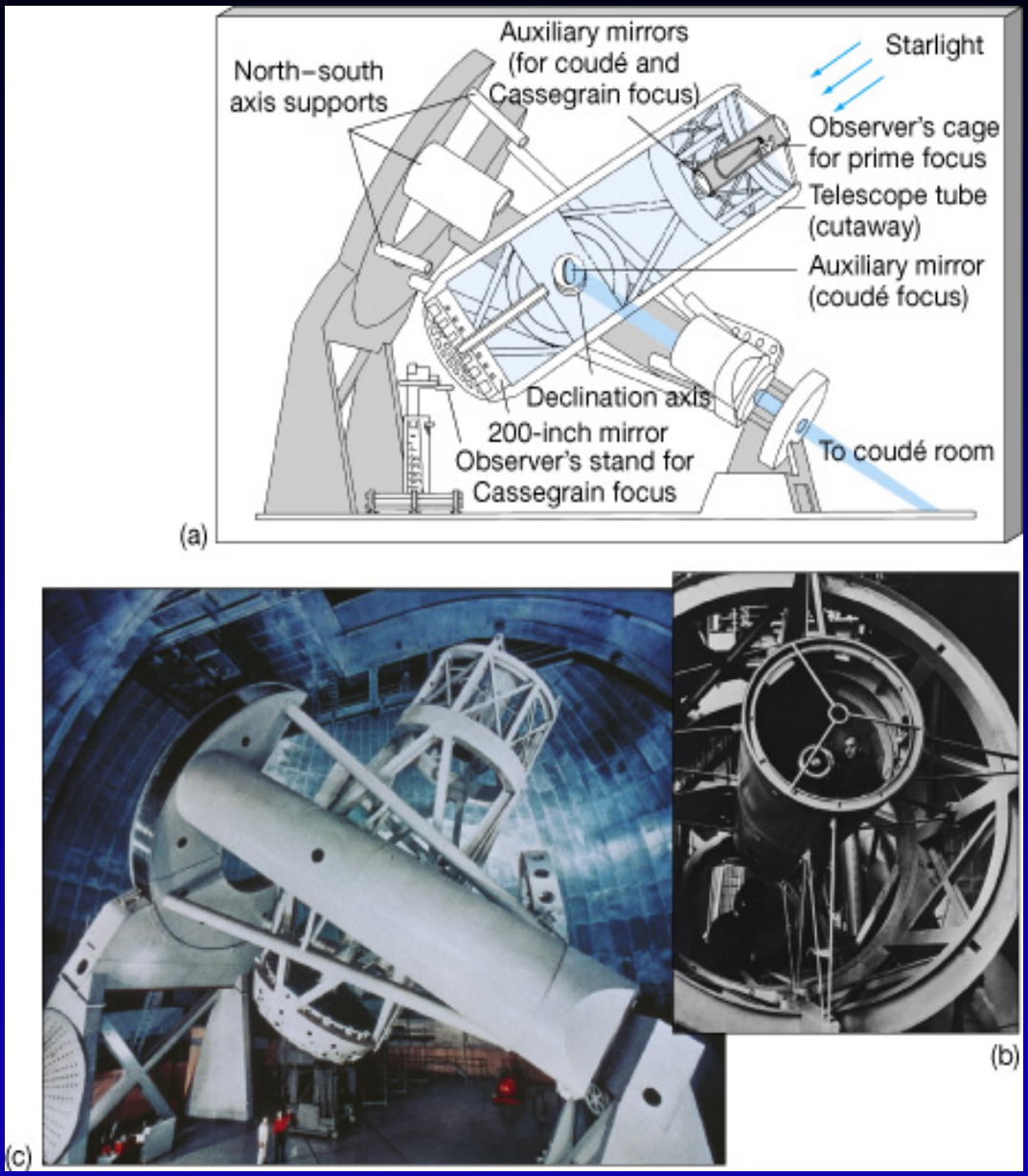
- Most large telescopes for the last 80 years use mirrors. Most common are a two-mirror designs.
- Instead of the secondary mirror, sometimes an instrument is installed at the `prime' focus.

Telescopes

- The size of a telescope is characterized by the diameter of its primary mirror.
- 1918 - 100” (2.5m) Mt Wilson Telescope
- 1958 - 200” (5m) Mt Palomar Telescope
- 1968 - Soviet 6m (doesn’t work very well)

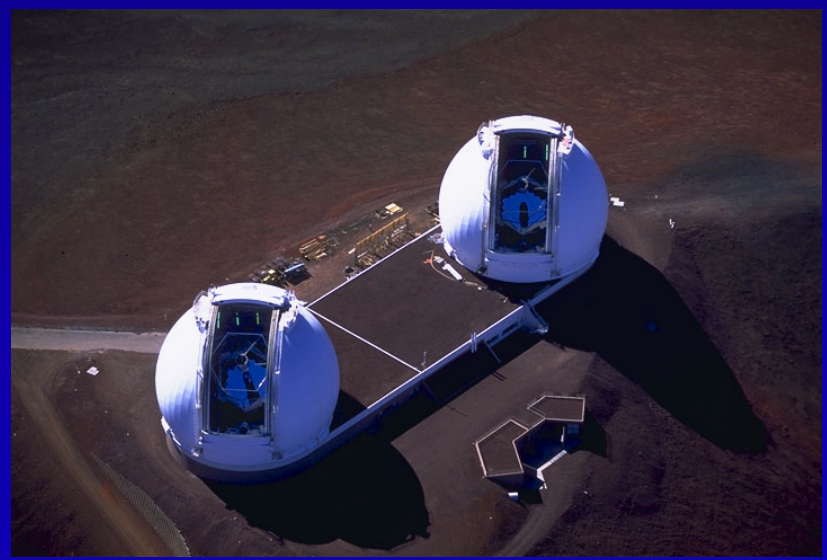


Palomar 200” (5m) mirror


Auxiliary mirrors
(for coudé and
Cassegrain focus)
Starlight
North–south
axis supports
Observer's cage
for prime focus
Telescope tube
(cutaway)
Auxiliary mirror
(coudé focus)
Declination axis
200-inch mirror
Observer's stand for
Cassegrain focus
To coudé room
(a)
(b)
(c)

Keck Telescopes

- In 1993, the first real breakthrough in telescope size occurred with the Keck I 10m segmented-mirror telescope. UCSC professor Jerry Nelson was the person who had the idea and made it happen.



Telescopes

- The US operates optical national facilities in Chile, near Tucson, on Mauna Kea (Hawaii) and near Sunspot, NM.

CTIO

KPNO

Kitt Peak National Observatory
near Tucson

KPNO 4m + Steward 90”

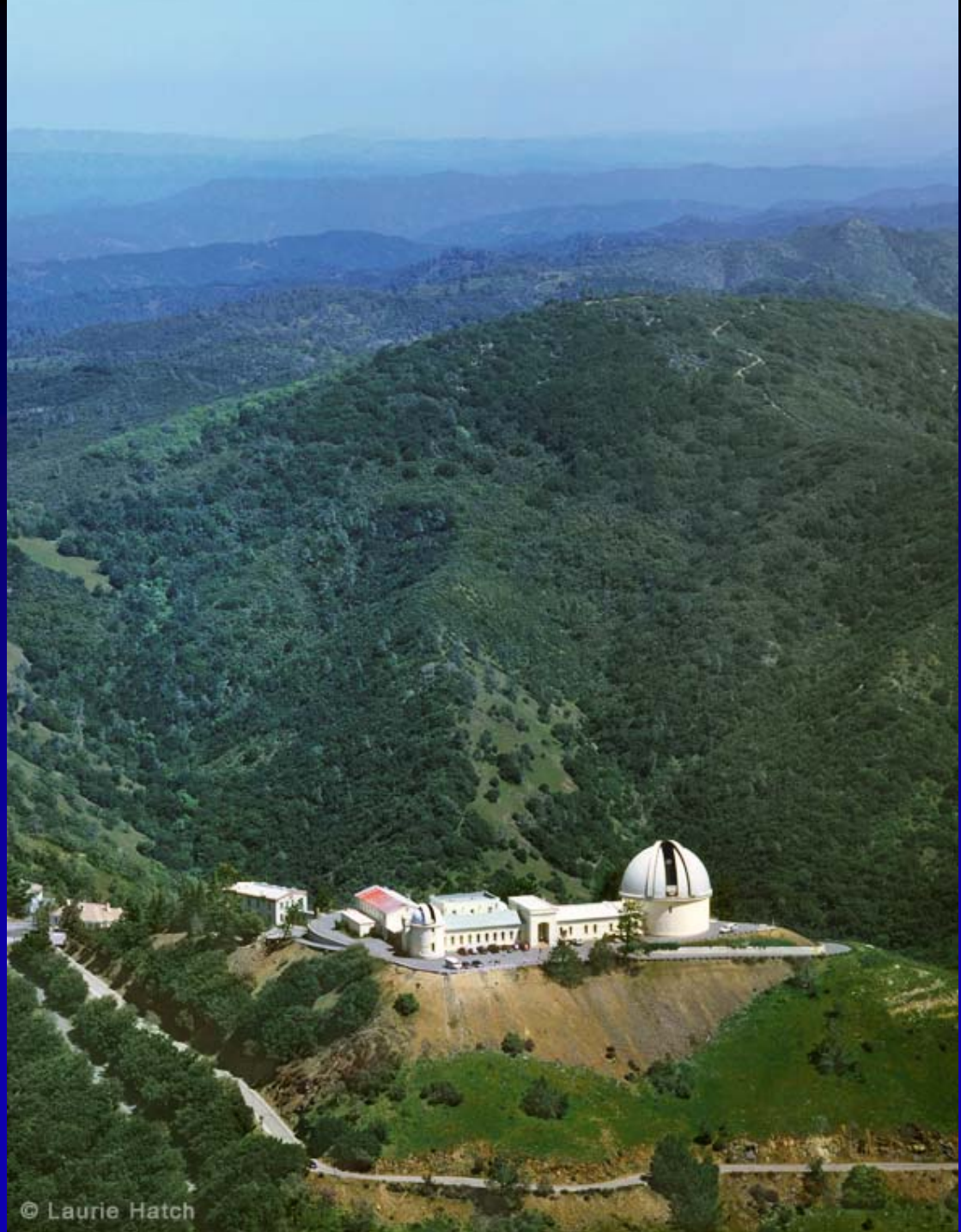
Cerro Tololo Interamerican Observatory, Chile

European Southern Obs

European Southern Observatory

ESO Very Large Telescope Array

Lick Observatory on Mt Hamilton near San Jose

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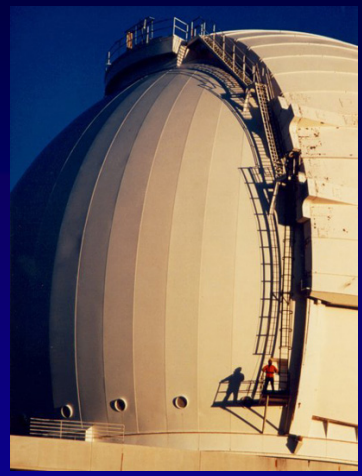
UH 2.2m
CFHT
Keck 10m telescopes
IRTF
Gemini North
UKIRT
Subaru
JCMT
Mauna Kea, HI


QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Keck Telescopes



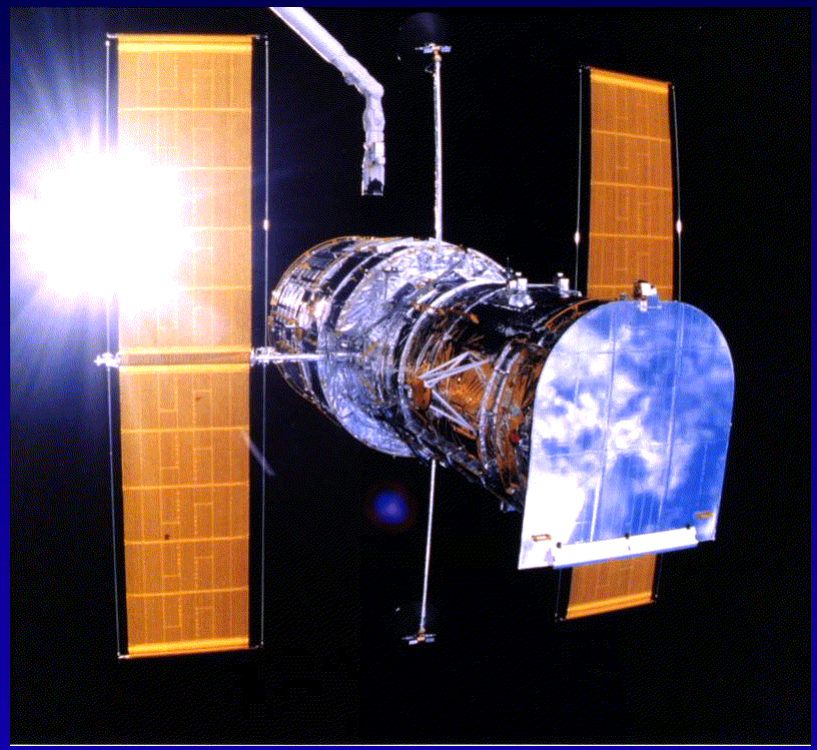
- Completed in 1993 and 1996, the twin Keck 10m telescopes on top of Mauna Kea, HI were a huge jump in light collecting area. The facility is run by the University of California and Cal Tech.

Keck Observatory

- The telescopes weight 300 tons each and are 8 stories tall
- The big increase in mirror size was made possible by a new technology- segmented mirrors. The Kecks have 36 segments each.

The Keck are connected by a light tunnel and can be used as an optical interferometer with the resolution of an 85m telescope.

Space Telescopes



- No distortion from the atmosphere
- No absorption or emission background from the atmosphere. Xray telescopes, far infrared telescopes, gamma-ray telescopes have to be in orbit.

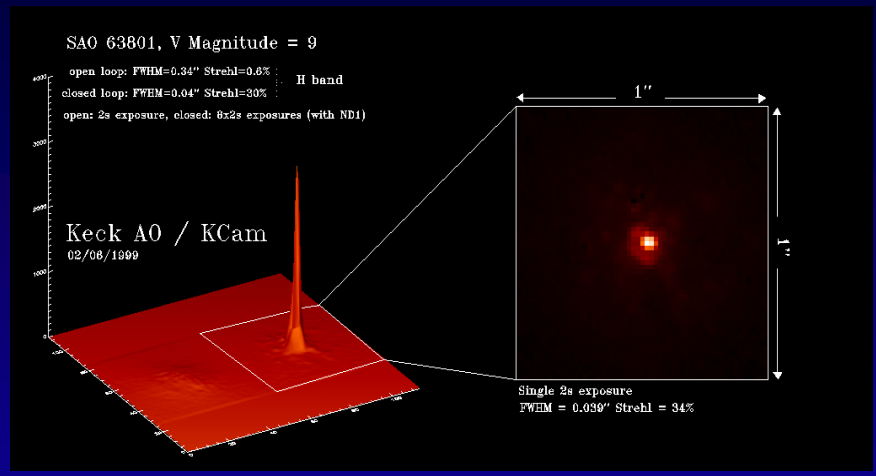
Radio Telescopes

- As we will talk about later, there are many different types of signals from the Universe.
- Radio telescopes are sensitive to long wavelength electro-magnetic radiation

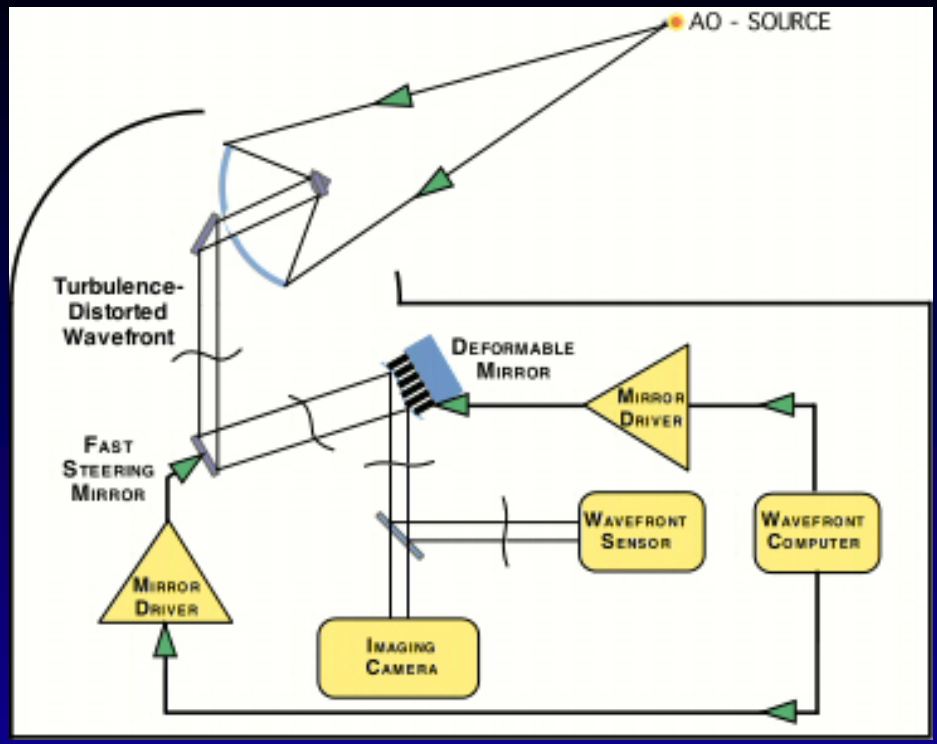
Light pollution

- Increasingly, ground-based sites are plagued by increases in the optical sky background.

The Future: Adaptive Optics



- High-spatial-resolution imaging is about to return to ground-based telescopes.
- `Adaptive optics' (AO) uses a deformable mirror and sophisticated sensing and allows for correction of the atmospheric distortions.
- Lick & Keck Observatories are leading the way here.

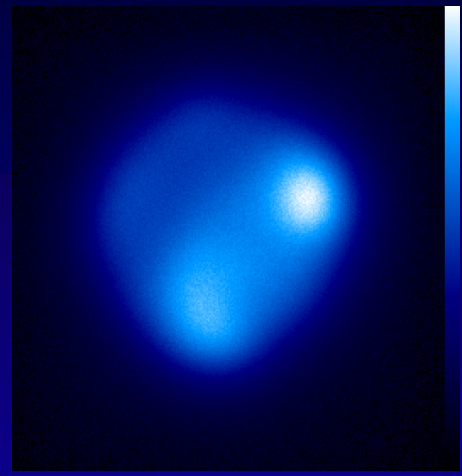


- AO is tricky, difficult stuff. It is amazing that it works.
- One problem is that you need a bright star to do the corrections

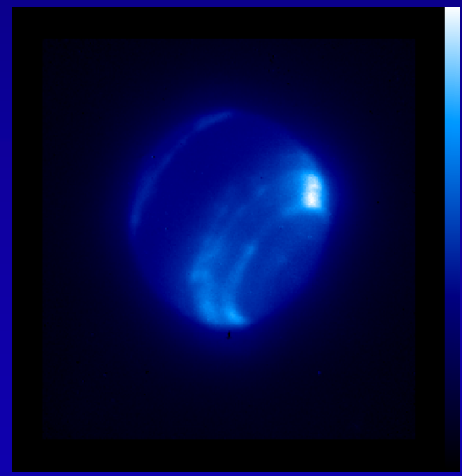

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

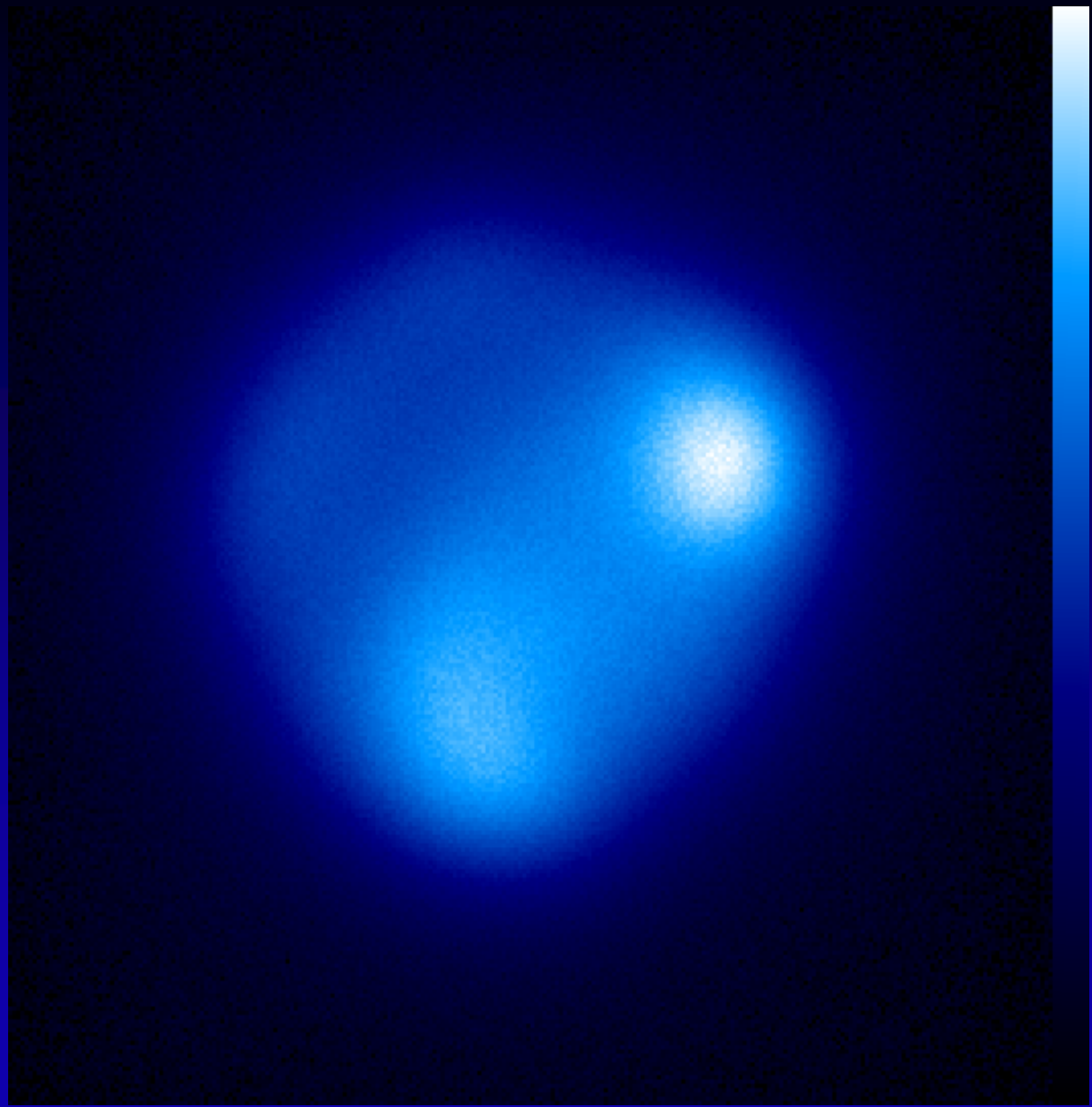
AO works

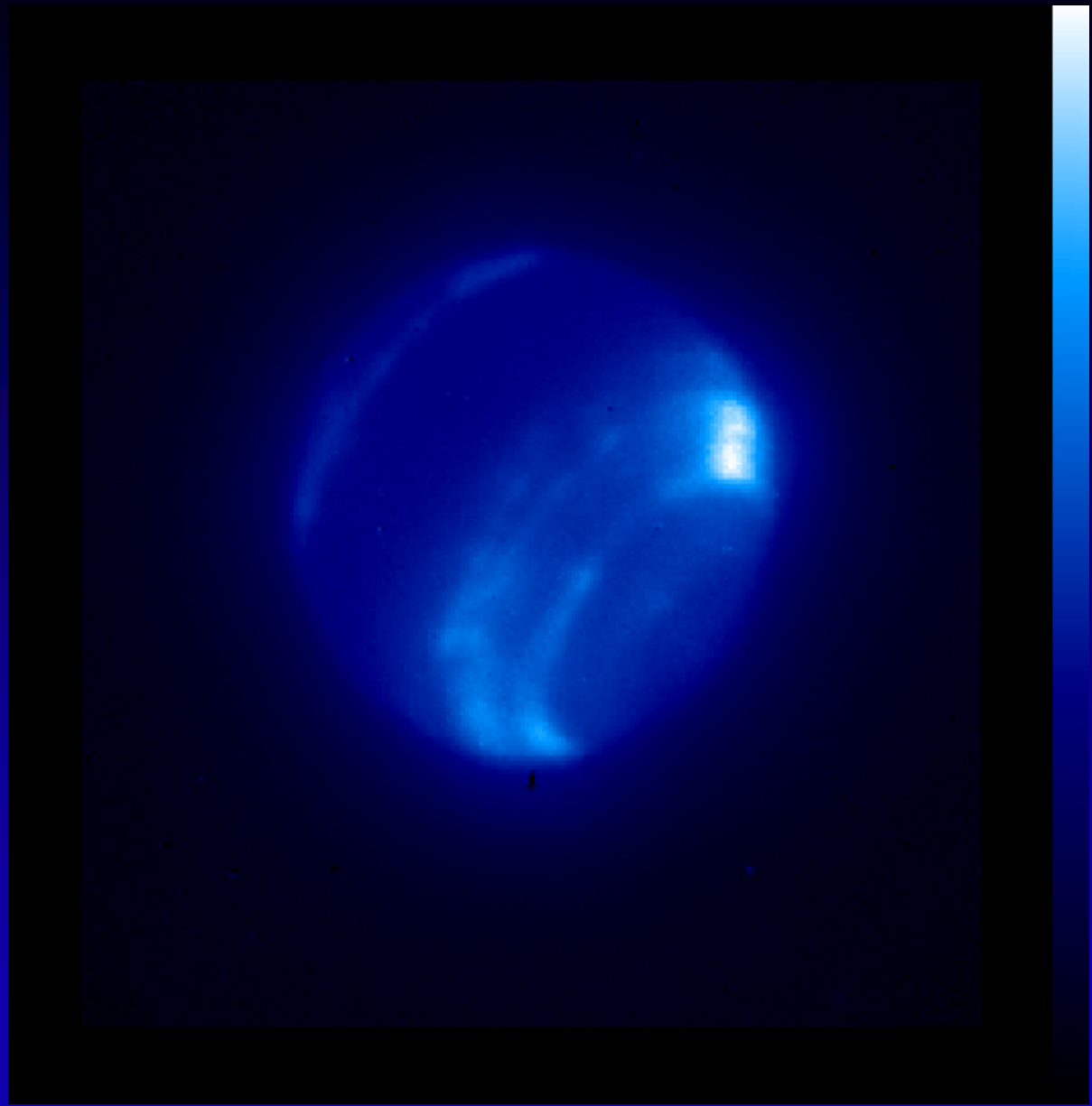
- AO loop off

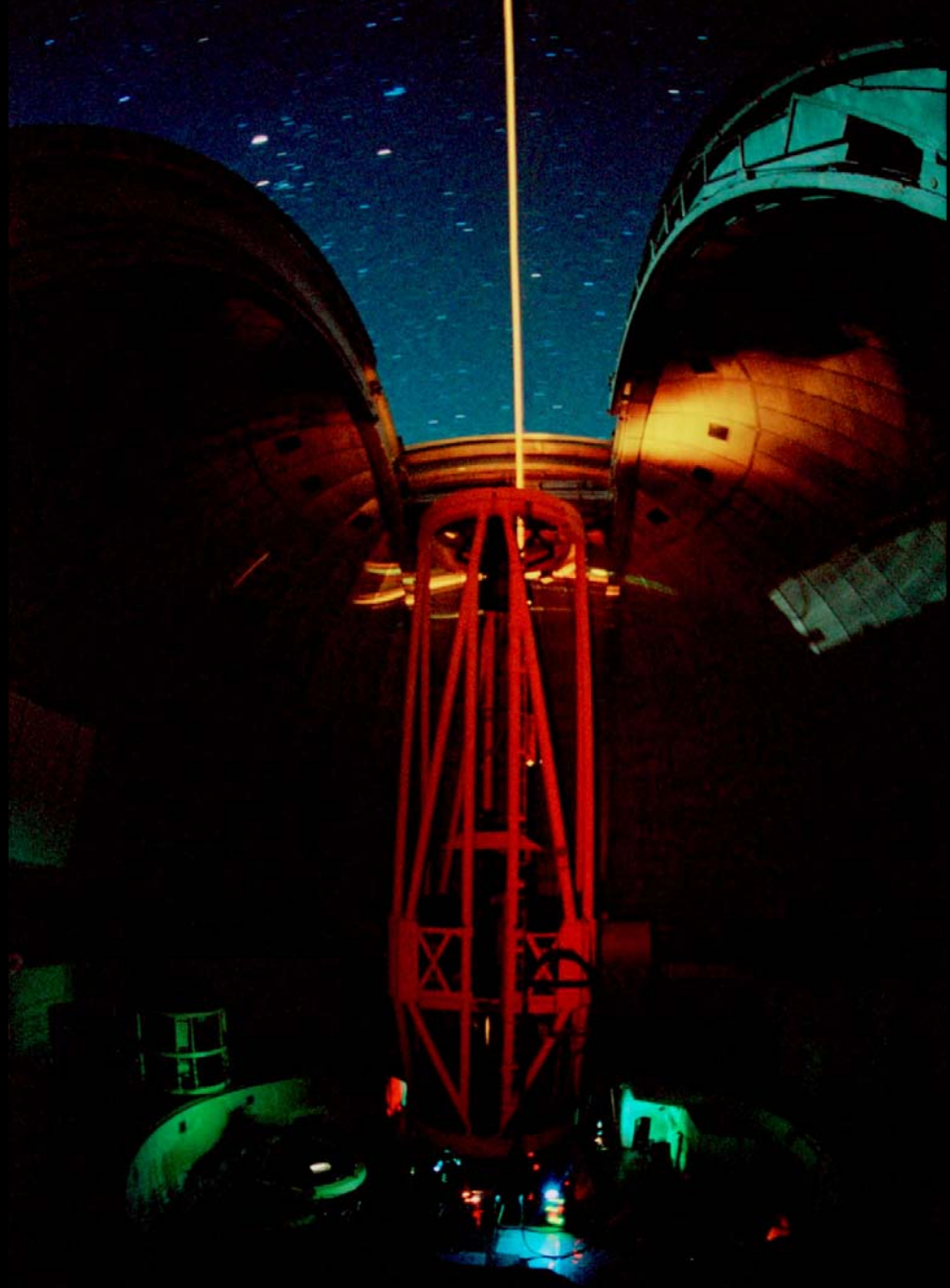


- AO loop on…









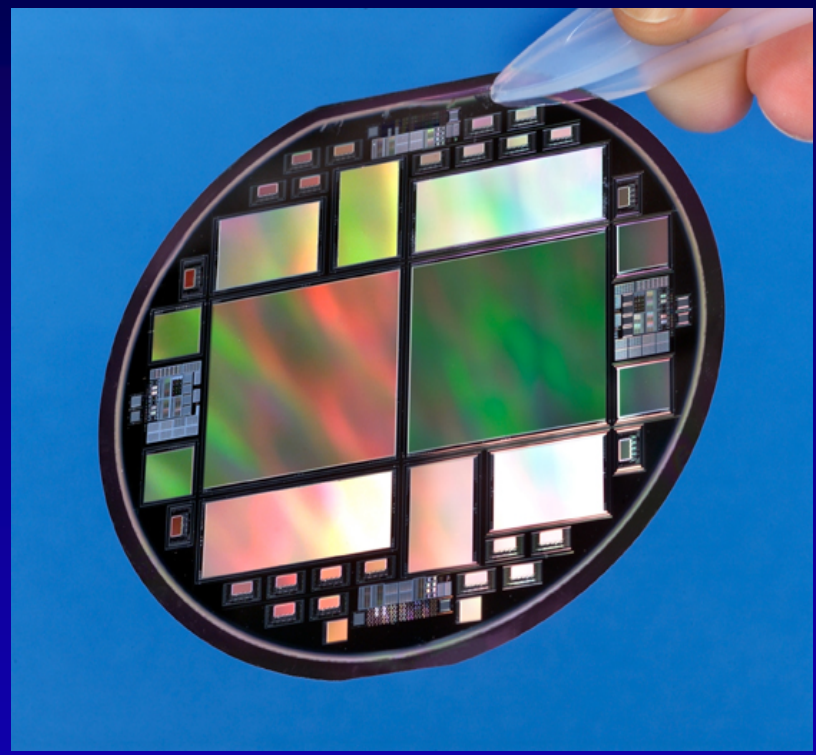
Lick 3m laser


© Laurie Hatch

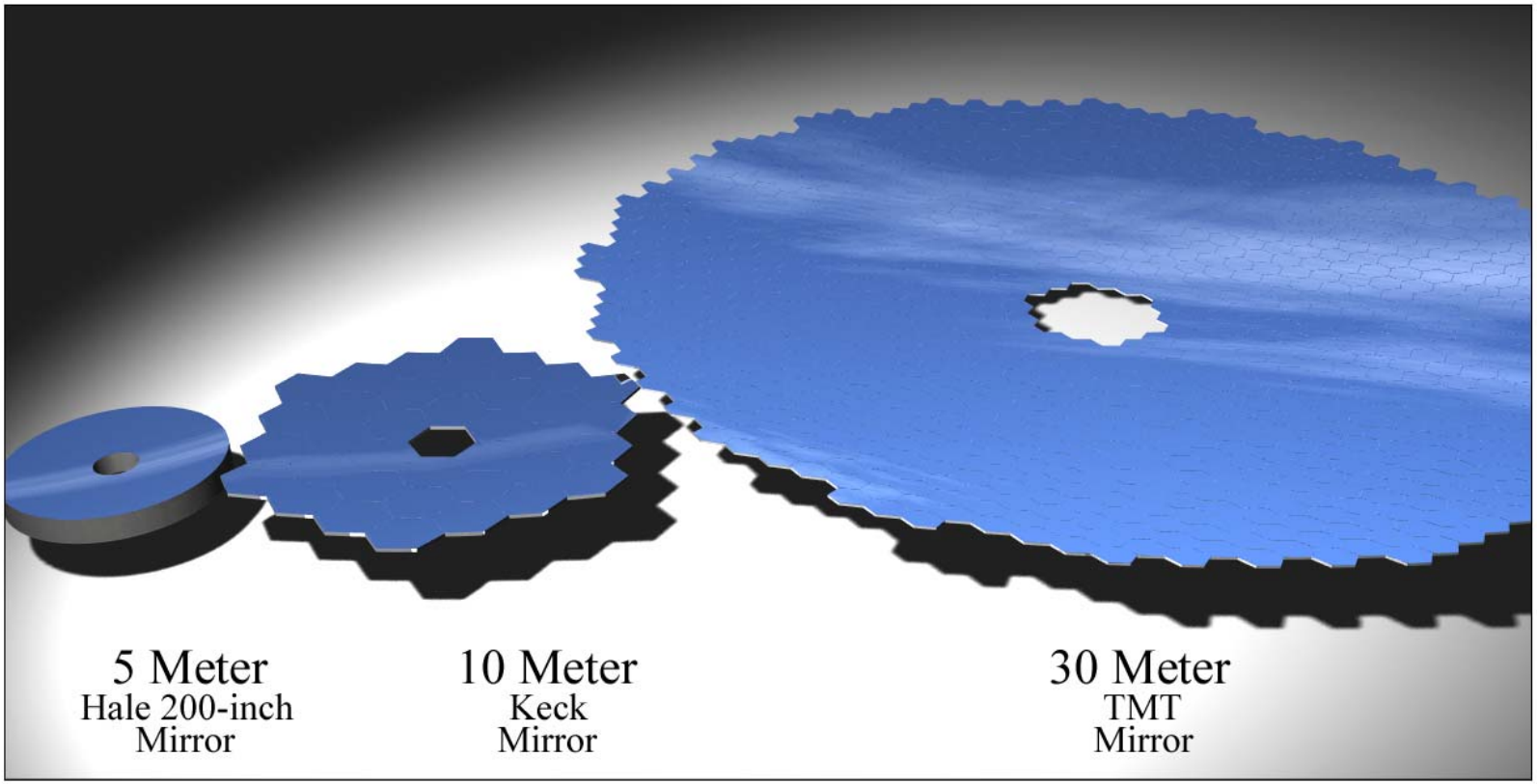
Keck Laser

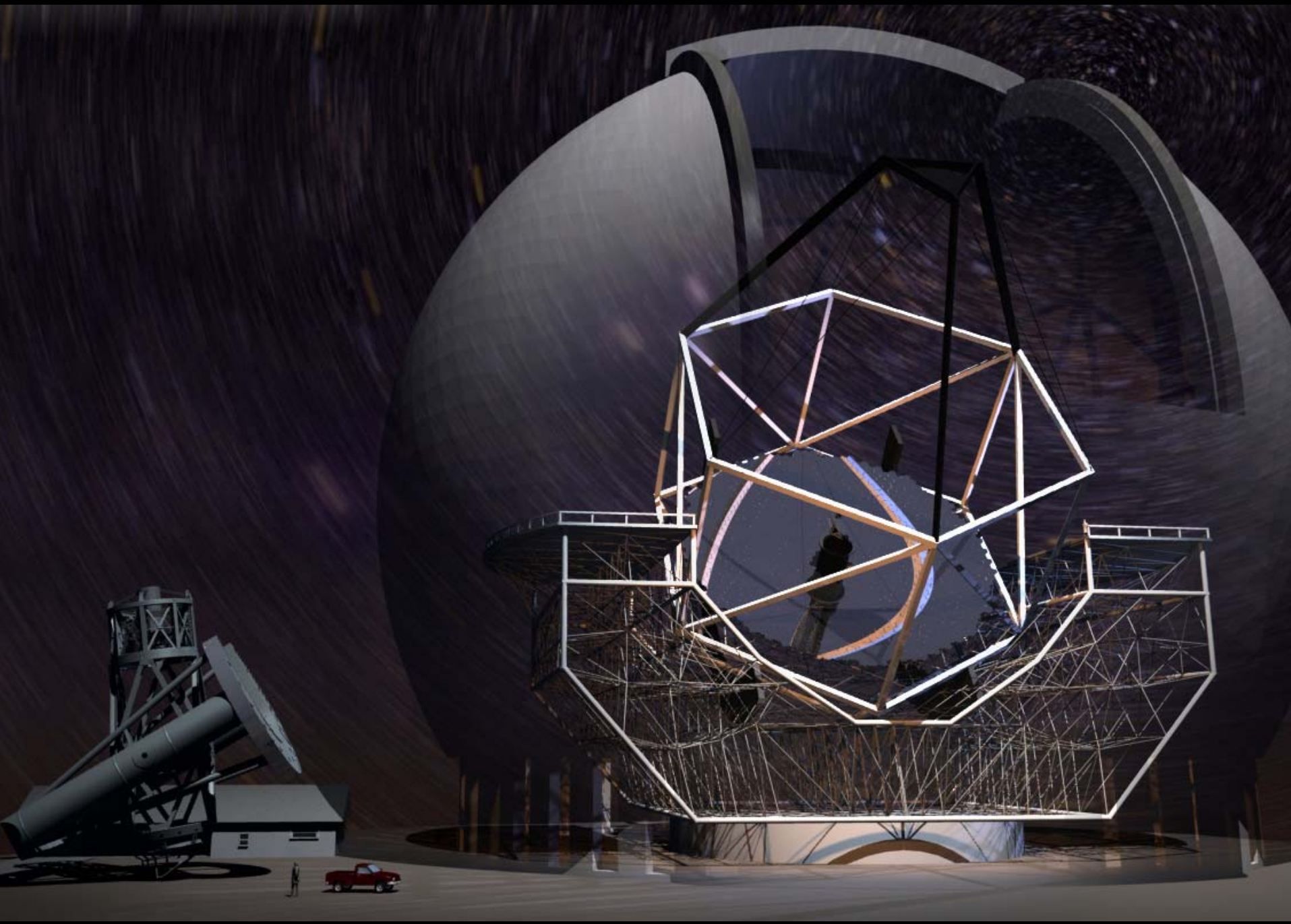
Detectors have come a long way

- In the late 1980's a new kind of detector replaced photographic plates.
- `Charge-coupled' detectors are a factor of more than 100 better in efficiency.



The Future II - ELTs

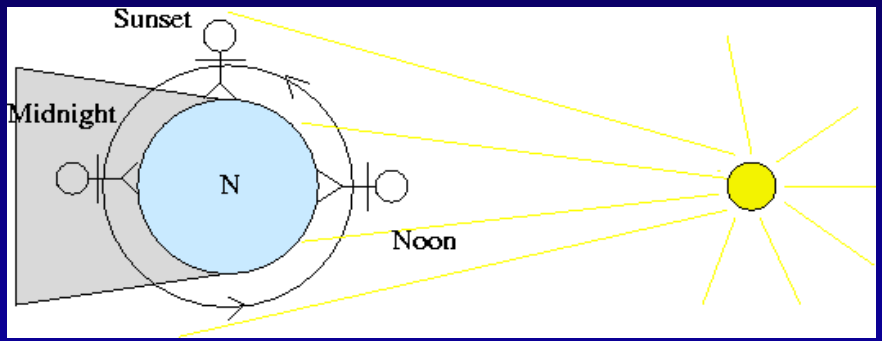




Motions of the Earth

- Stuff everyone should know

Earth Motions



- Why is there day and night?
  OR
- Why do the Sun and stars appear to move through the sky?

Because the Earth rotates around its N-S axis once every 24 hrs

- How fast is a gaucho napping at the equator traveling due to the Earth's rotation?

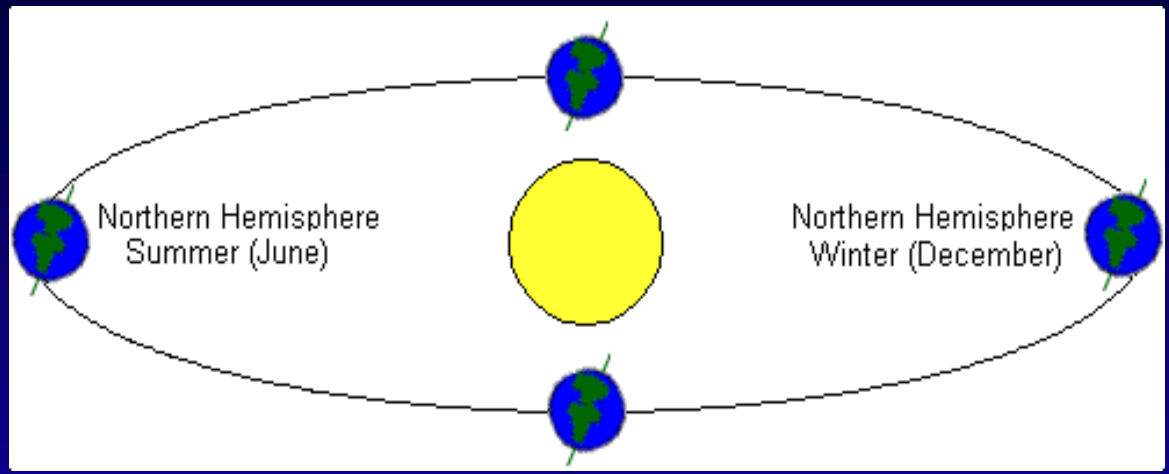
  Travels 24,000 miles in a day:

$$\text{Speed} = \text{Distance/time}$$

$$S = 24000\text{miles}/24\text{hours}$$

$$S = 1000 \text{ miles/hour}$$

The Reason for Seasons

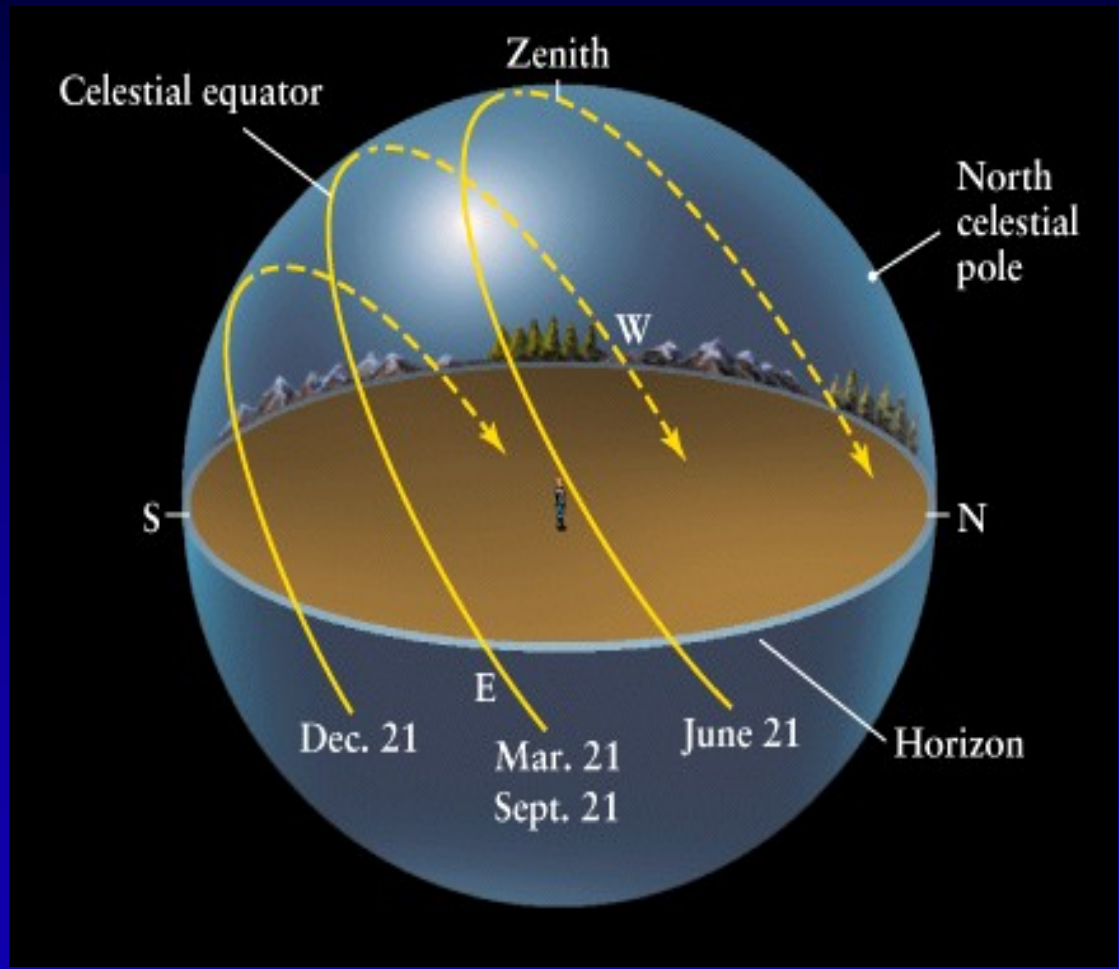


- The Earth is in a slightly elliptical orbit around the Sun - we are ***furthest*** from the Sun during the Northern Hemisphere summer.
- It is the ***tilt*** of the Earth's axis with respect to orbit plane that is the cause of the seasons.

Dec 21 Southern hemisphere summer, Sun is directly above the Tropic of Capricorn

June 21 Northern hemisphere summer, Sun is directly above the Tropic of Cancer

Sun's Path Through the Year

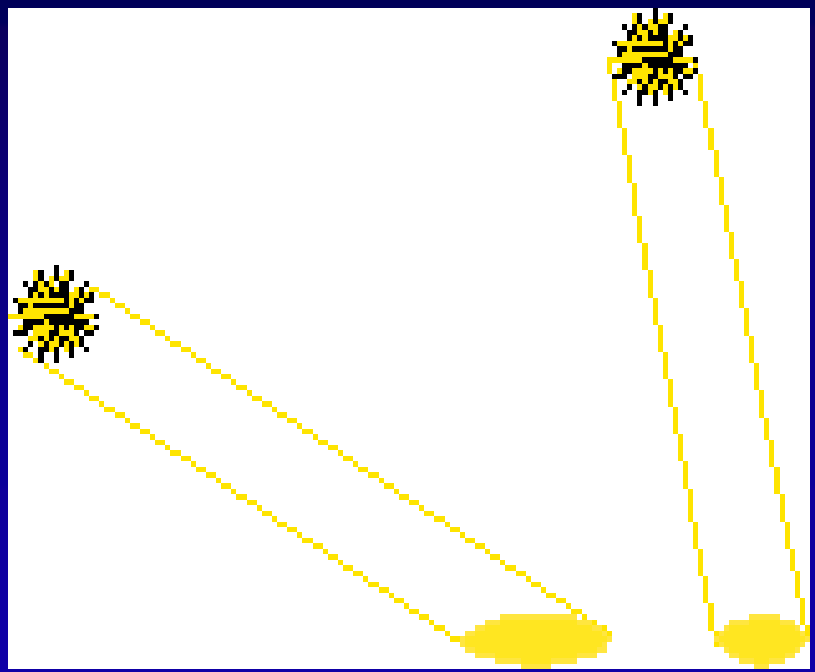


Reason for Seasons cont.

The tilt has two main effects.

1) The path the Sun takes through the sky changes during the year (look to the South to see the Sun in the winter, over head in the summer). Fewer daylight hours in the Winter.
2) The intensity of sunlight decreases in the winter (the Sun is at a larger angle from the zenith).

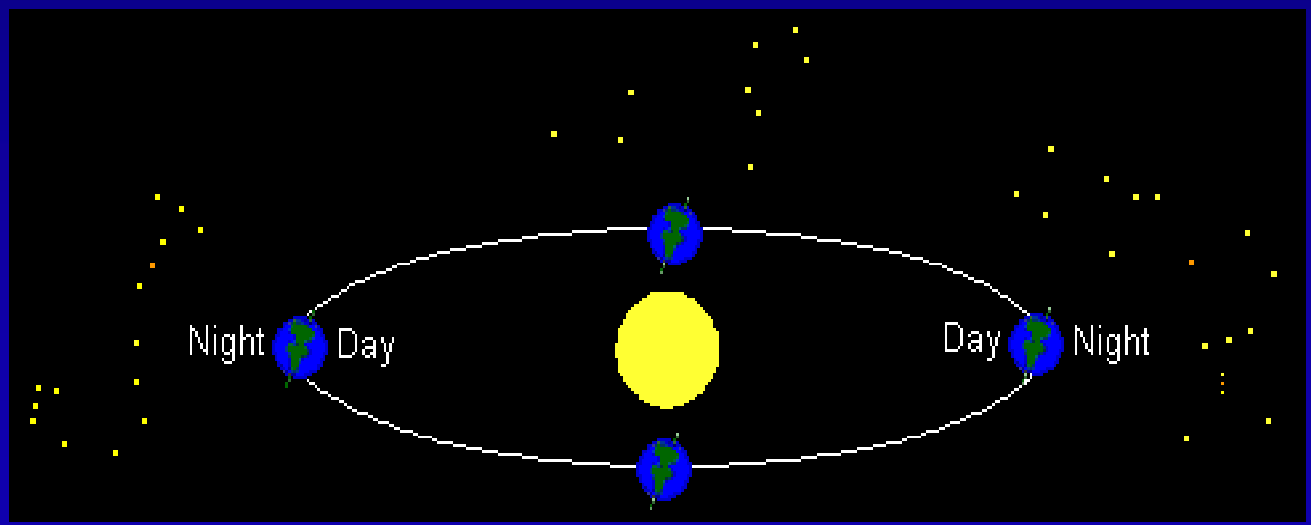
- So, it is cold in the winter.



- The solar energy per unit area decreases as the Sun moves lower in the sky. This is the reason it is cooler in the winter and in the morning.afternoon.

The Night Sky at Different Seasons

- We see different stars at different times of the year. The stars are always there, but can only be seen against the dark night sky.



- How fast is the Earth moving in its orbit around the Sun?

$$S = D/t$$

$$D = 2\pi R \Rightarrow R = 94 \times 10^{6} miles$$

$$t = 1 year$$

$$S = 5.85 \times 10^{8} \frac{miles}{year} \times \frac{1 year}{365 days} \times \frac{1 day}{24 hr} = 66{,}800 \frac{miles}{hour}$$

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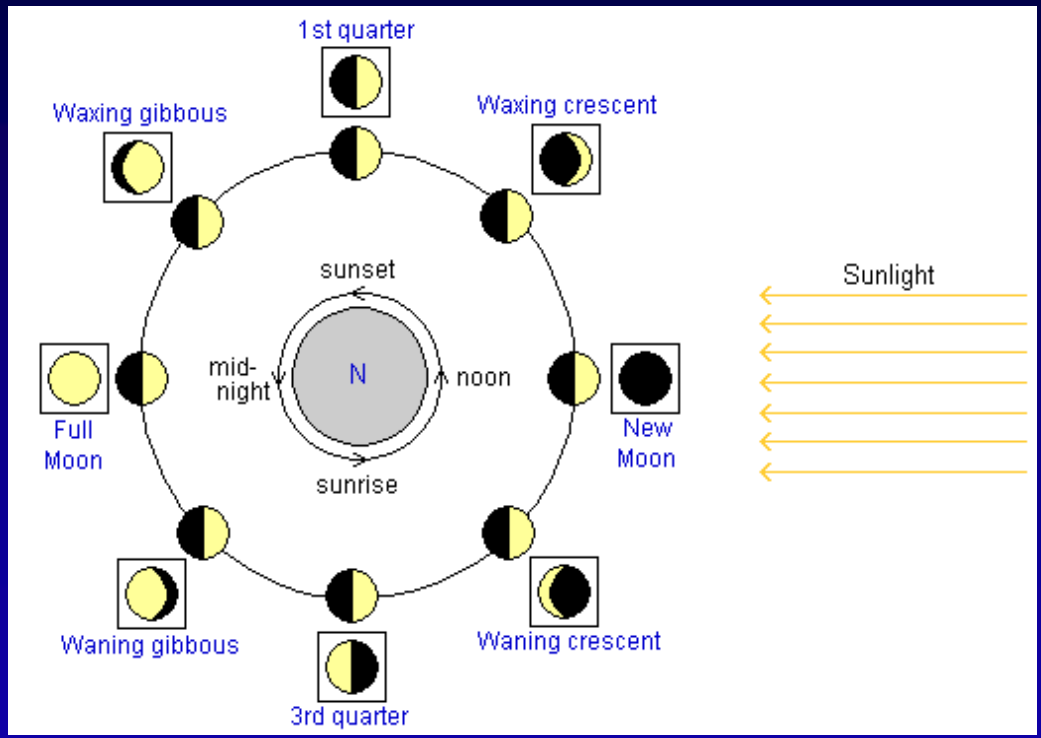
Funny way to write 1

Moon phases



- The moon phases are due to the relative positions of the Sun and moon. One half of the moon is always illuminated, it is only a question of what fraction of the illuminated face we can see from the Earth.

Q. What time does the full moon rise?

a) At midnight

b) At sunrise

c) At sunset

d) Any old time, this is a trick question.

Q. What time does the full moon rise?

a) At midnight

b) At sunrise

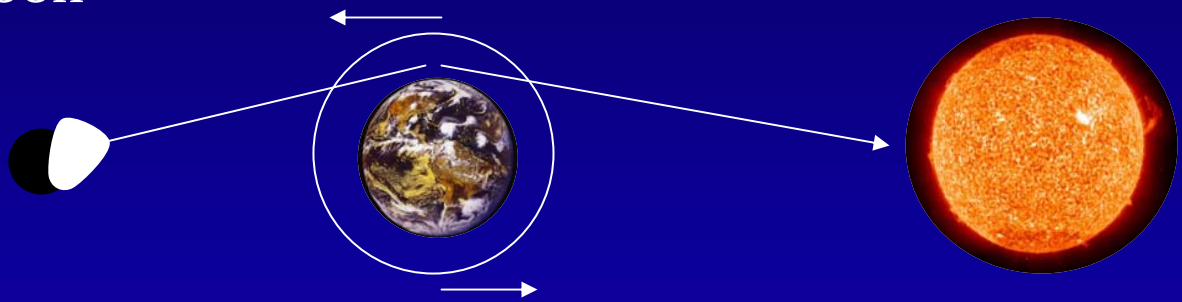
c) At sunset <<<

d) Any old time, this is a trick question.

Full moon rise (`top view')

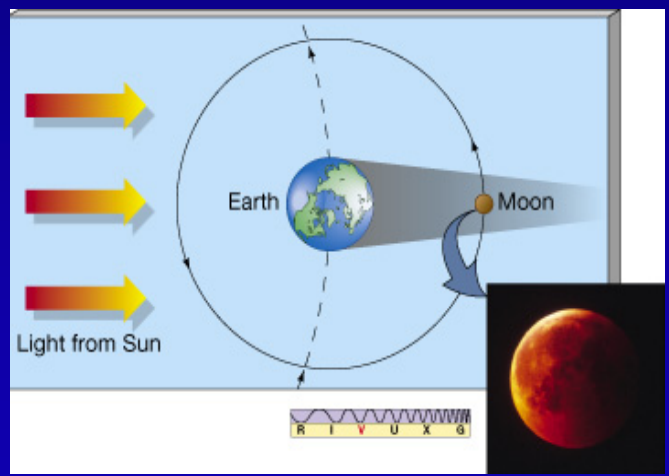
Look east to rising full moon

Look west to setting Sun

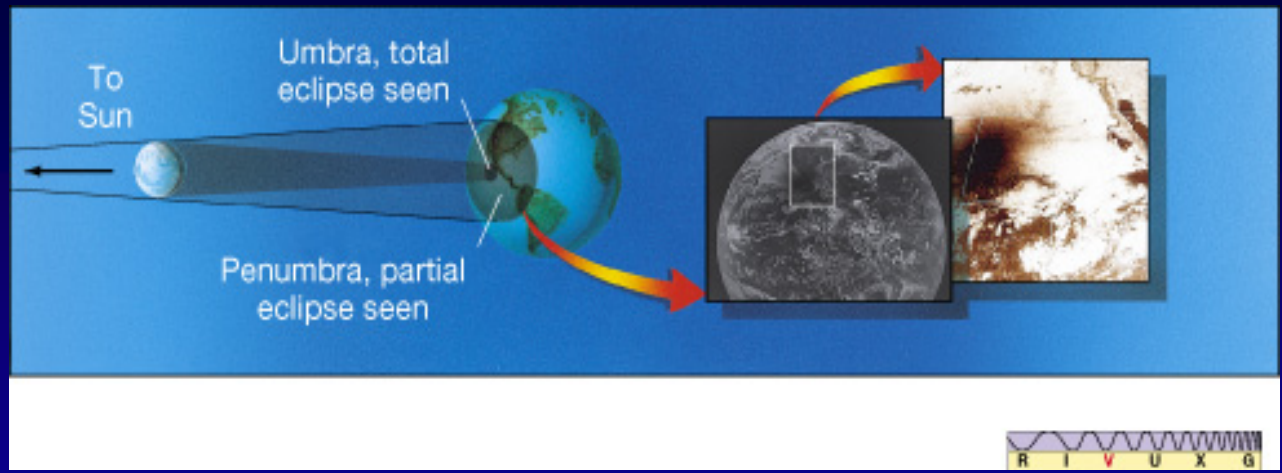


Lunar Eclipse

- For a full moon, the Sun, Earth and Moon are all aligned. The Moon can fall into the shadow of the Earth. This is called a lunar eclipse.



Solar Eclipse



- A similar thing can happen during the new moon. The Moon can cast a shadow on the Earth when it passes in front of the Sun.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Why don’t we have an eclipse every month?