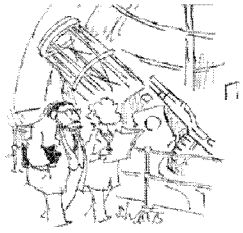
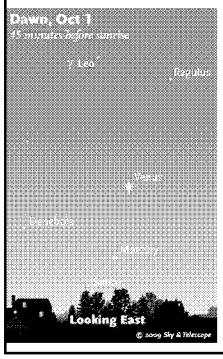
# Tools of Modern Cosmology




## Friday, October 2

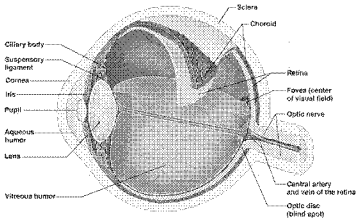
Next Planetarium Shows: Mon, Tue, Wed 7 pm

We learn about the universe by gathering light from distant objects.



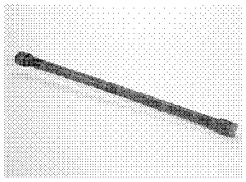

Some objects emit light (stars, Sun);
others reflect light (planets, Moon).

Our eyes are good, but not perfect, at detecting light.




Blurry vision on small scales.
Can't see faint sources.
Can't see ultraviolet, infrared, etc.

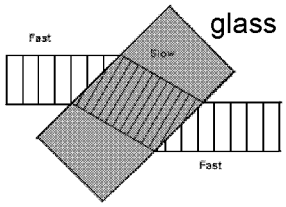
**Telescopes** ("far lookers") remedy some of our eyes' problems.



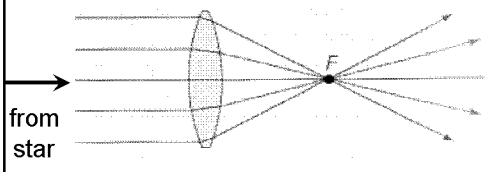
Galileo's telescope (early 17th century) revolutionized astronomy.

A **refracting** telescope uses a **lens** to gather light.

Light is bent (or "refracted") when going from air to glass (or vice versa).

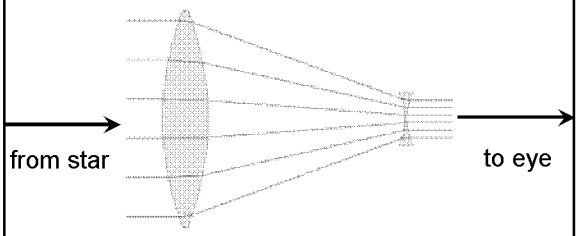



A **convex** lens (thick in the middle) focuses light to a point:

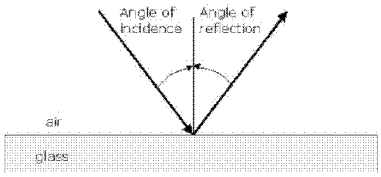



Light from a large area is funneled into a small area.

Galileo made a refracting telescope, with an added lens to act as an eyepiece.

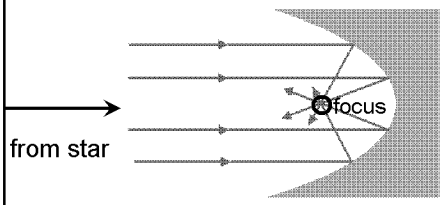



A **reflecting** telescope uses a **mirror** to gather light.

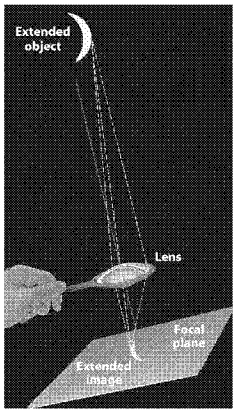



When light reflects from a mirror, **angle of incidence** equals **angle of reflection**.

A mirror shaped like a **parabola** focuses light to a point:

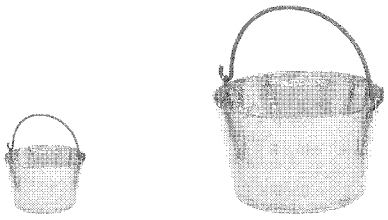



Light from a large area is funneled into a small area.



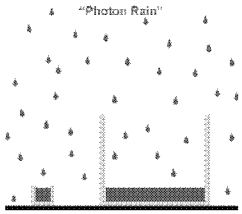

Lenses and mirrors, if shaped correctly, produce an accurate image of an object.

The main purposes of a telescope are to **gather light** and **resolve detail**.



Telescope = "light bucket".
Bigger bucket = more light.

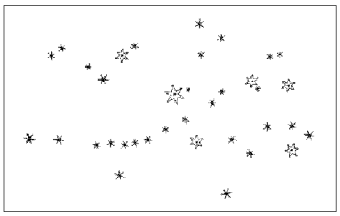
Amount of light collected per second is proportional to **area** of the lens or mirror.




$$\text{Area} = \frac{\pi}{4} D^2$$

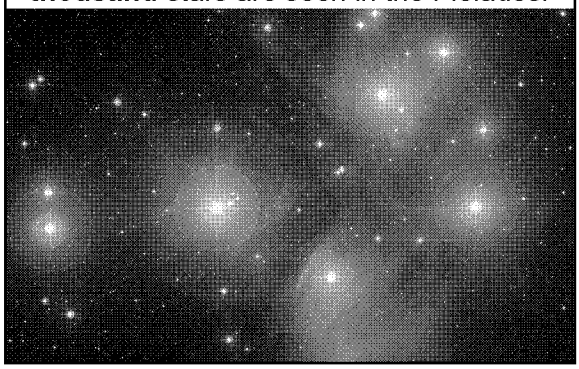
D = diameter of lens/mirror

Without a telescope, most people can see **six** stars in the Pleiades.

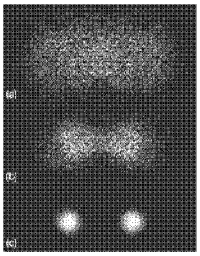


With his small telescope, Galileo saw more than **thirty**.

With large modern telescopes, about a **thousand** stars are seen in the Pleiades.



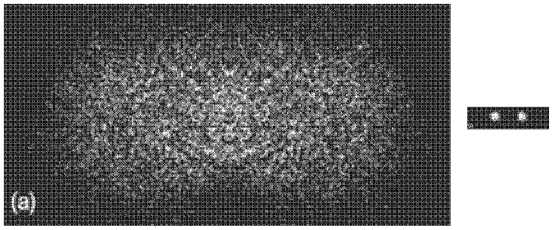
A bigger lens or mirror is able to **resolve finer detail**.



low resolution

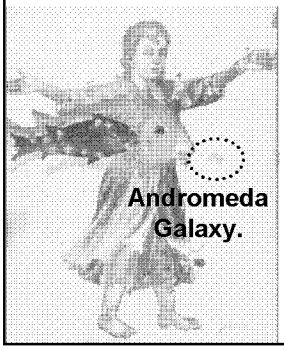
high resolution

Two stars are **resolved** if they are seen as separate points.




**Magnification** is not as important: Big, blurry image is less useful than small, sharp image.

The **Andromeda Galaxy**, as seen by unaided eyes, is a faint oval smudge.




Star atlas of Al Sufi, AD 964.

With large modern telescopes, the Andromeda Galaxy looks like this….

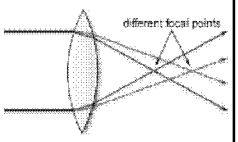
# BIGGER IS BETTER!

Larger lens or mirror means more light, higher resolution.

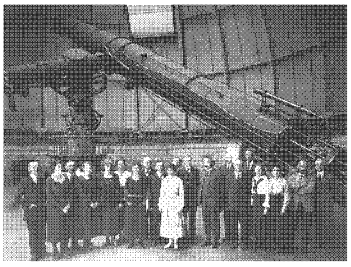
The world's biggest telescopes are **reflectors**, not **refractors**.

What's wrong with lenses?

- Lenses absorb light.
- Lenses sag.
- Lenses have **chromatic aberration**: colors don't focus at the same point.

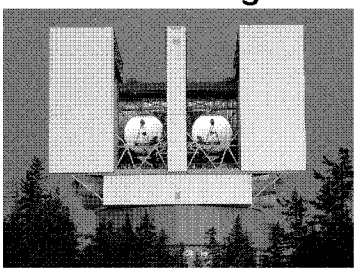



World's largest refracting telescope:



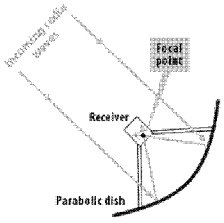
Yerkes Observatory, D = 1 meter, completed **1897**.

A modern **reflecting** telescope:



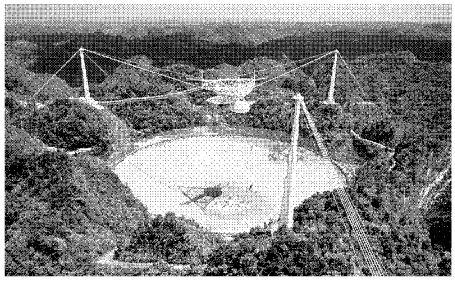
Large Binocular Telescope: **two** mirrors, each with D = 8.4 meters.

**Radio telescopes** can detect radio waves invisible to your eyes.



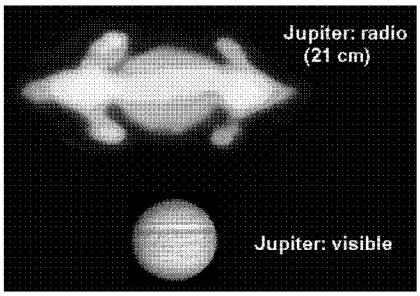

Parabolic "dish" of a radio telescope acts as a mirror, reflecting radio waves to the focus.

Radio telescopes can be huge, because they don't have to be fantastically smooth.



Arecibo Telescope, Puerto Rico

Why bother with radio observations?
They give a different view of the universe.

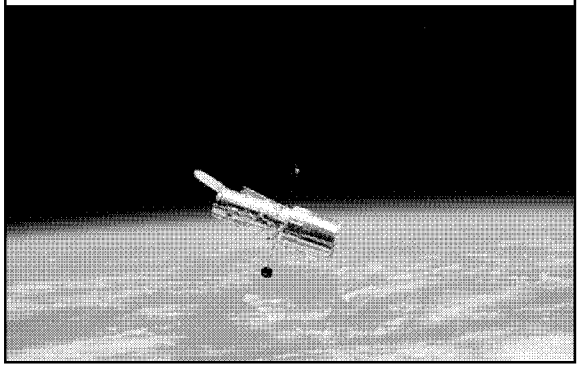



Turbulence in air makes stars "twinkle" and limits resolution.

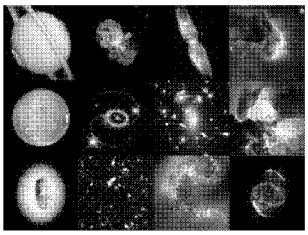
City lights drown out faint stars.

Good idea: Put a telescope in orbit!

The ***Hubble Space Telescope*** is 600 kilometers above the Earth's surface.



Hubble Space Telescope has great angular resolution; it's above the turbulent atmosphere.



Light-gathering ability? Not as great; it's only D = 2.4 meters in diameter.

## Monday's Lecture:

Light

## Reminders:

Please read chapter 3 by **Monday**.
Problem Set 1 is due **Wednesday**.
Planetarium shows **Mon, Tue, Wed**.