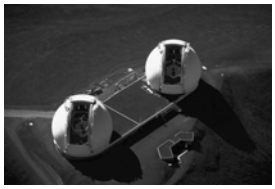
Telescopes

- *characteristics of telescopes*
  - refracting vs. reflecting telescopes
  - collecting area
  - resolution or 'sharpness'
- *space-based observatories and other telescopes*

Radio Telescope



Optical Telescope

1

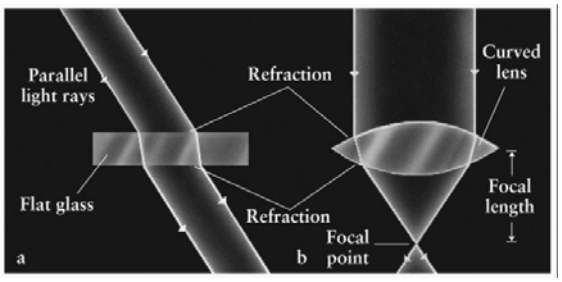
Two major types of telescopes:

Refracting Telescope

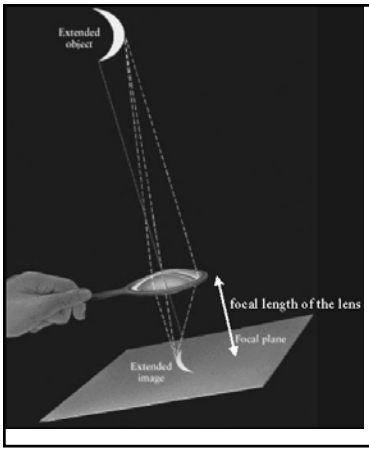
Reflecting Telescope

2

A refracting telescope uses a lens to concentrate incoming light at a focus.



3

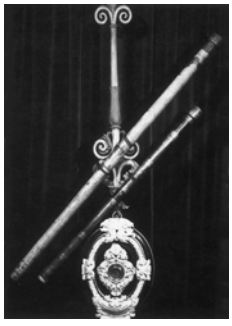


A lens creates an extended image of an extended object.

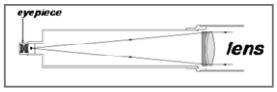
4

Refracting Telescopes

→ use lenses to BEND and FOCUS light



- the first telescopes were refractors
- bigger lenses collect more light, but need a LONGER focal length!
- Lenses eventually became too heavy for their size – began to sag under their weight!



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- famous refracting telescope
- tube is 64 feet long!
- lens diameter = 40 inches or ~ 1 m

a

Yerkes Observatory near Chicago

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Refracting Telescopes:

Advantages:

- **nice images after correction for aberration**
- **lenses do not deteriorate since the tube is sealed**
- **very rugged, so ideal for amateur work**
- **inexpensive**

Disadvantages:

- **most glass absorbs UV radiation! only good for redder objects**
- **suffers from *chromatic aberration* (focus different for all colors)**
- **difficult to make large, flawless lenses (bubbles in the glass)**
- **very heavy and must be suspended by its edge (can sag)**

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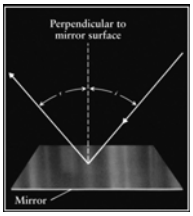
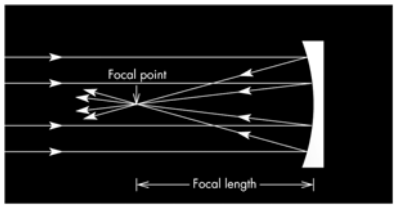
Reflecting Telescopes:

another way to collect light: use mirrors





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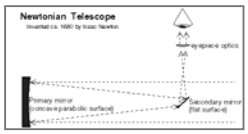
Reflecting Telescopes:

All modern research telescopes are reflectors.

Advantages:

- **only the front surface of the mirror must be flawless**
- **mirrors are lighter and can be supported from behind**
- **no chromatic aberration**
- **no UV absorption**
- **shorter tube**



Disadvantages:

- **spherical aberration, if mirror is imperfect**
- **reflective coating may need to be replaced often**
- **can be knocked out of alignment easily; not very rugged**

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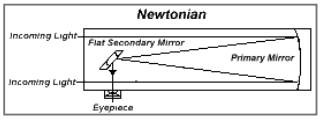
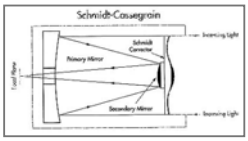
Different types of Reflecting Telescopes

- **Newtonian**
- **Cassegrain**
- **others**





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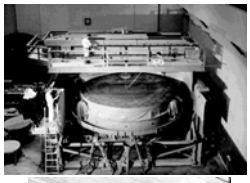
Palomar 200-inch Telescope

largest telescope in the world for almost 50 years



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Keck Telescope

10 m mirror-- made of 36 smaller parts

Each mirror computer controlled!

note size of person!

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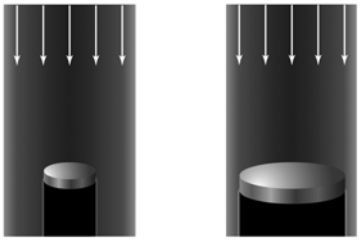
Common features of all telescopes:

1. Size
- *The bigger the telescope mirror or lens, the more light it collects*
- *not to be confused with magnification*



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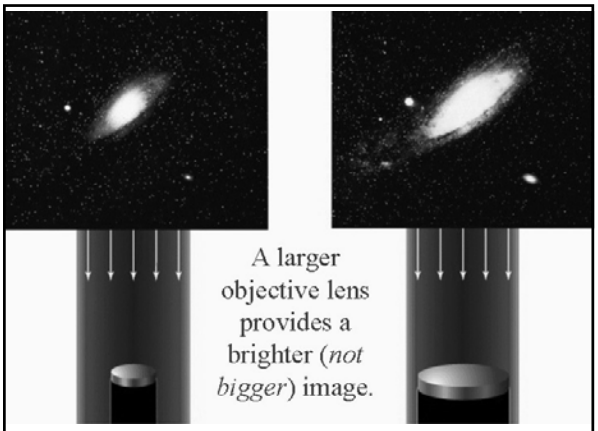
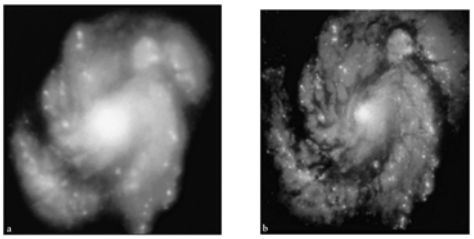


2. Sharpness/Detail – also known as "resolution"
→*depends on wavelength & diameter of telescope*
→ *resolution ~ λ/D*



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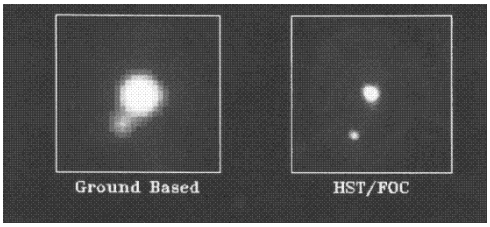
3. Magnification – not the most important factor for a telescope, but useful
-don't buy a telescope based on magnification!!

$mag_{telescope} = (focal\ length)_{obj} / (focal\ length)_{eye}$



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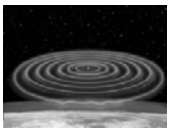
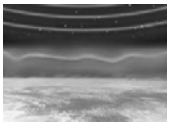
Earth's atmosphere: observing from the bottom of a swimming pool

Earth's atmosphere distorts images, making them blurry And "twinkle"



How do astronomers get around this?



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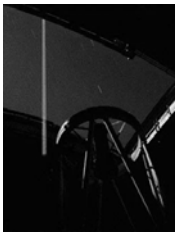
Two modern ways to "beat the atmosphere"

Put your telescope in space



Adaptive optics – bend the mirror to correct for the atmosphere

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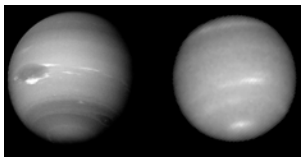
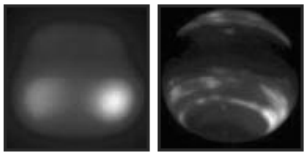
Neptune with Hubble and Adaptive Optics

Hubble image



Ground-based normal and ground-based with adaptive optics



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Space Observatories:

Hubble Space Telescope

- optical telescope
- 2.4-m mirror
- in "low-earth" orbit: 368 miles above Earth
- orbits every 90 minutes

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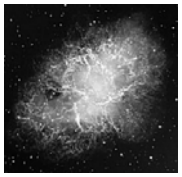
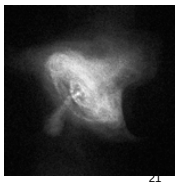
X-rays: Chandra X-ray Observatory

Crab Nebula:

Optical



X-Ray



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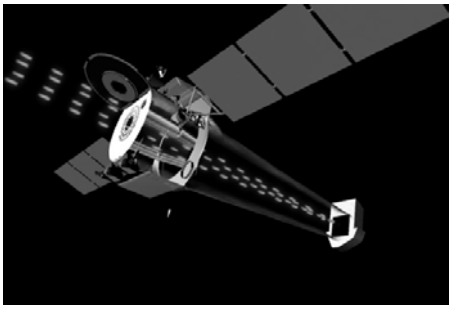
X-rays will pass through normal mirrors to focus X-rays, use "grazing incidence"



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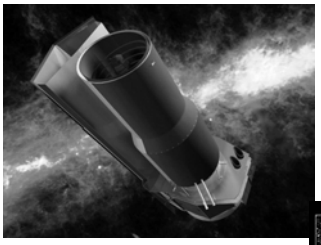
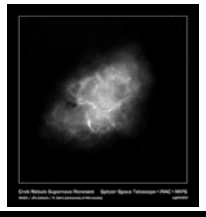
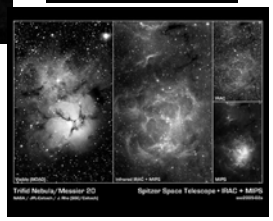
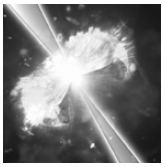


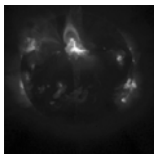




Spitzer Space Telescope (in earth orbit: an "infrared Hubble")

GLAST (Gamma-ray Large Area Space Telescope)

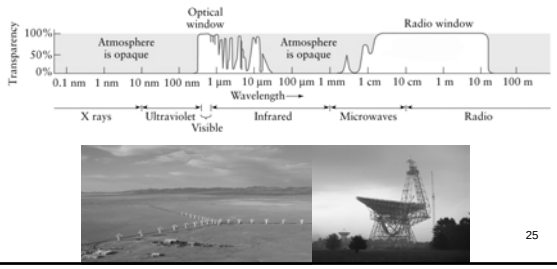




To be launched in 2007

Other wavelengths from Earth: Radio Telescopes

They are reflecting telescopes that work in the radio region of the electromagnetic spectrum



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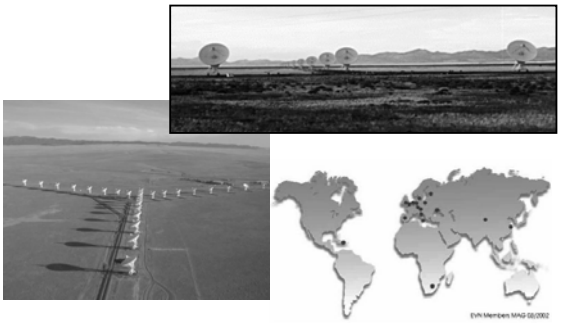
Radio Telescopes

Can have much larger collecting areas than optical telescopes

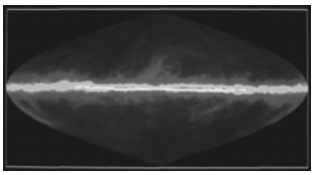
Radio wavelengths are much longer, so you can have "holes" in your telescope →

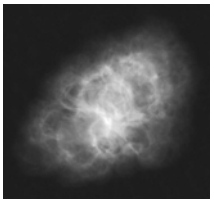
Radio telescopes can be linked together to form networks that act as a much larger telescope ("interferometry")



Radio "images" look different

Saturn





Crab Nebula

← Milky Way

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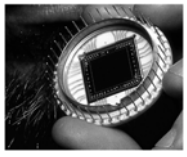
Instruments and Detectors

- The current detector of choice is the CCD
  - CCD = Charge Coupled Device
  - Array of silicon diodes which are light sensitive
  - Same device as used in digital cameras and video cameras.



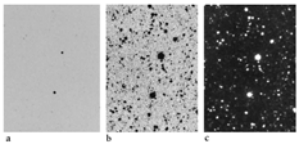


Photo CCD Composite

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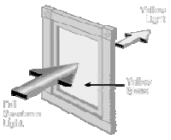
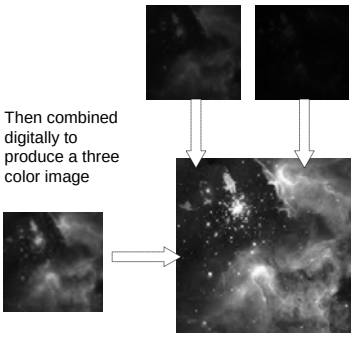
Three color imaging in Astronomy

CCDs only produce black-and-white images – so how do you get color?

Three or more images of each object are taken, one in each color

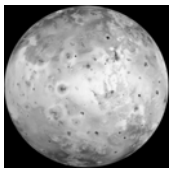


Then combined digitally to produce a three color image



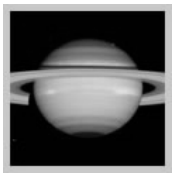
Examples of color images in astronomy

True color



False color

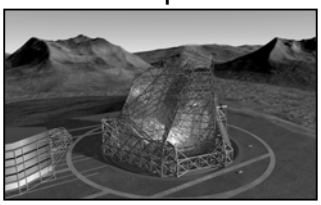
Enhanced color

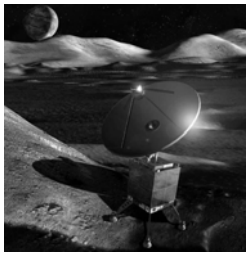


The Future of Telescopes

Bigger telescopes:

OWL – 100 m adaptive-optics





More telescopes in space

Maybe even on the Moon!