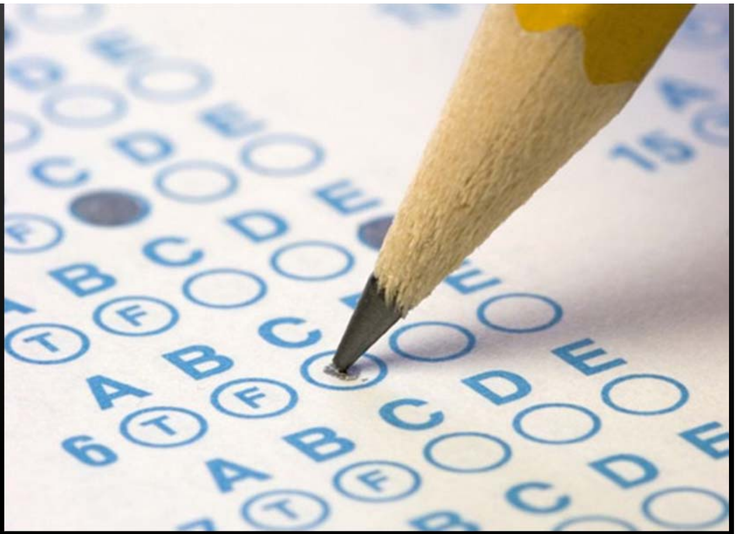
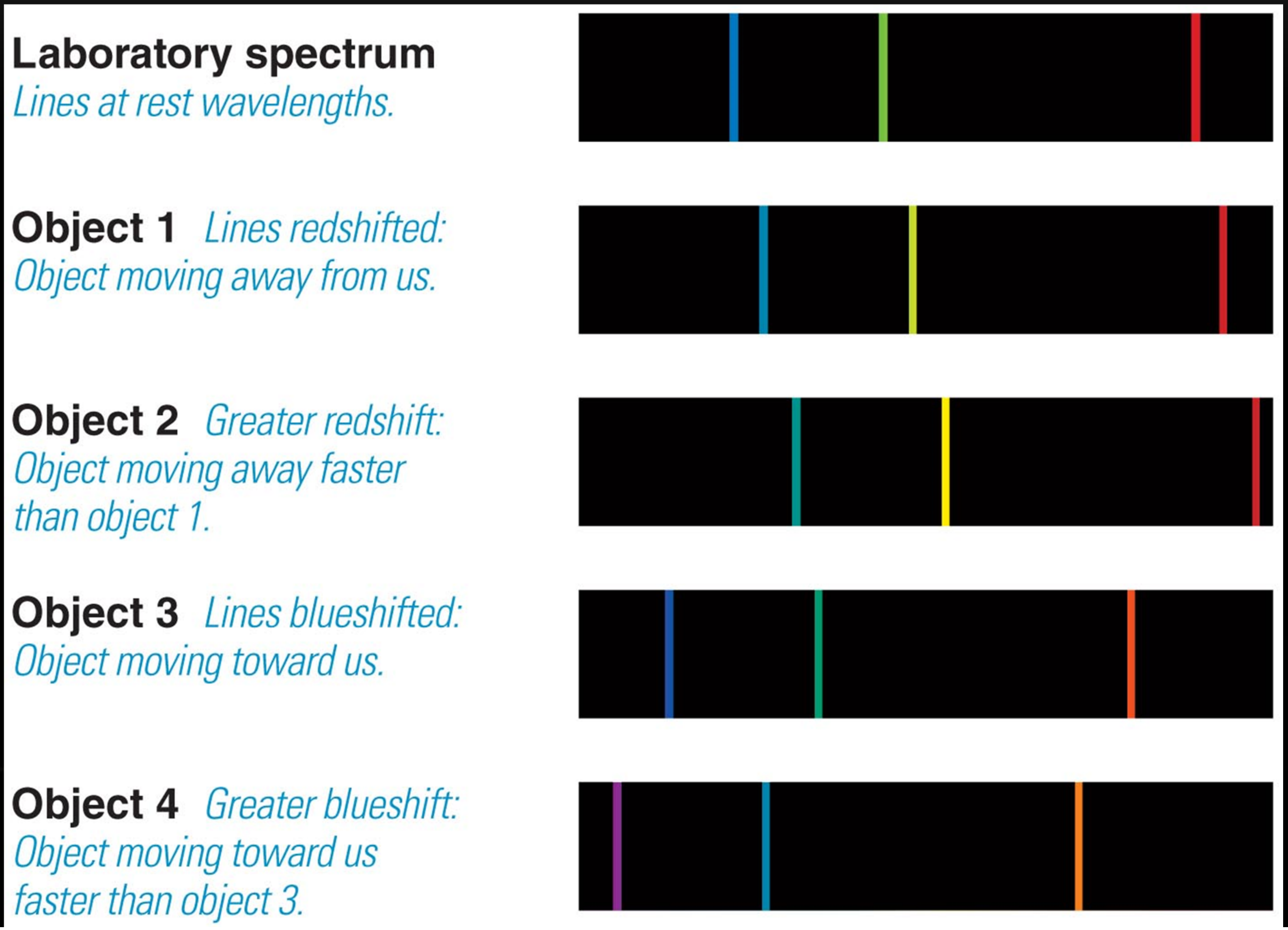
TEST IS COMING



- Test on Friday, 9/22
  - Ch.1 through Ch.5
  - Multiple choice, bring #2 pencil, eraser, & your ACT testing skills
  - No need for calculator
  - No phones
- Work through the practice test posted on the class webpage, end of chapter stuff in Mastering

DOPPLER SHIFT APPLIED

Fig.5.14



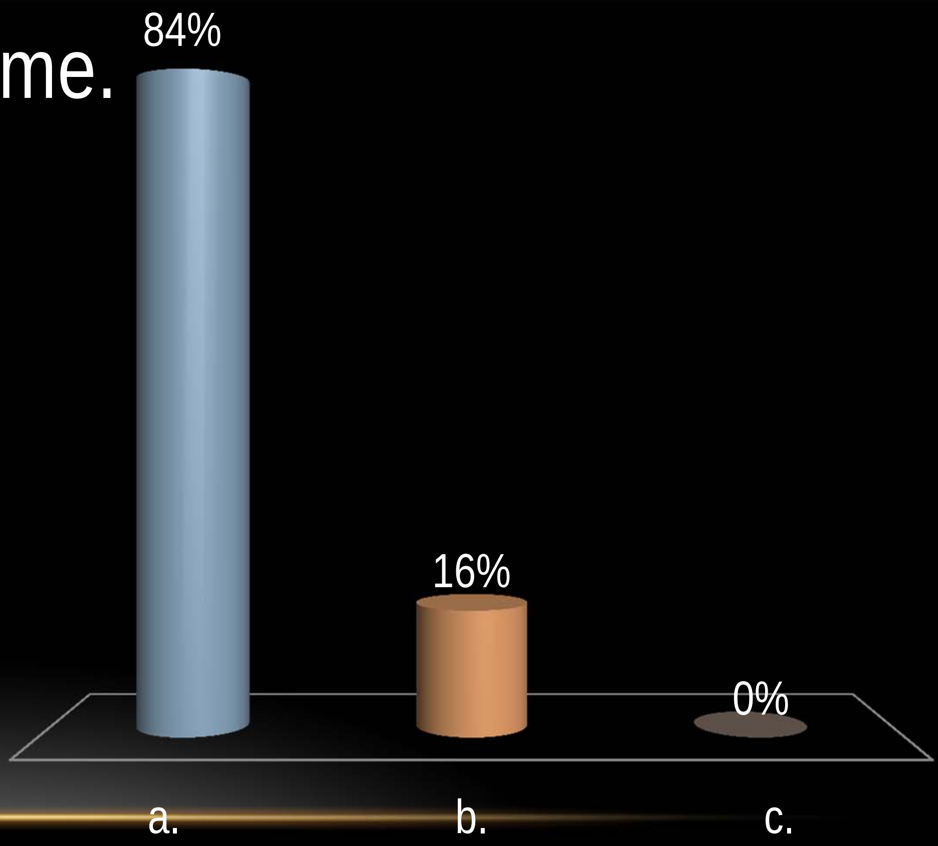
PLAY

I MEASURE A LINE IN THE LAB AT 500.7 NM. THE SAME LINE IN A STAR HAS WAVELENGTH 502.8 NM. WHAT CAN I SAY ABOUT THIS STAR?

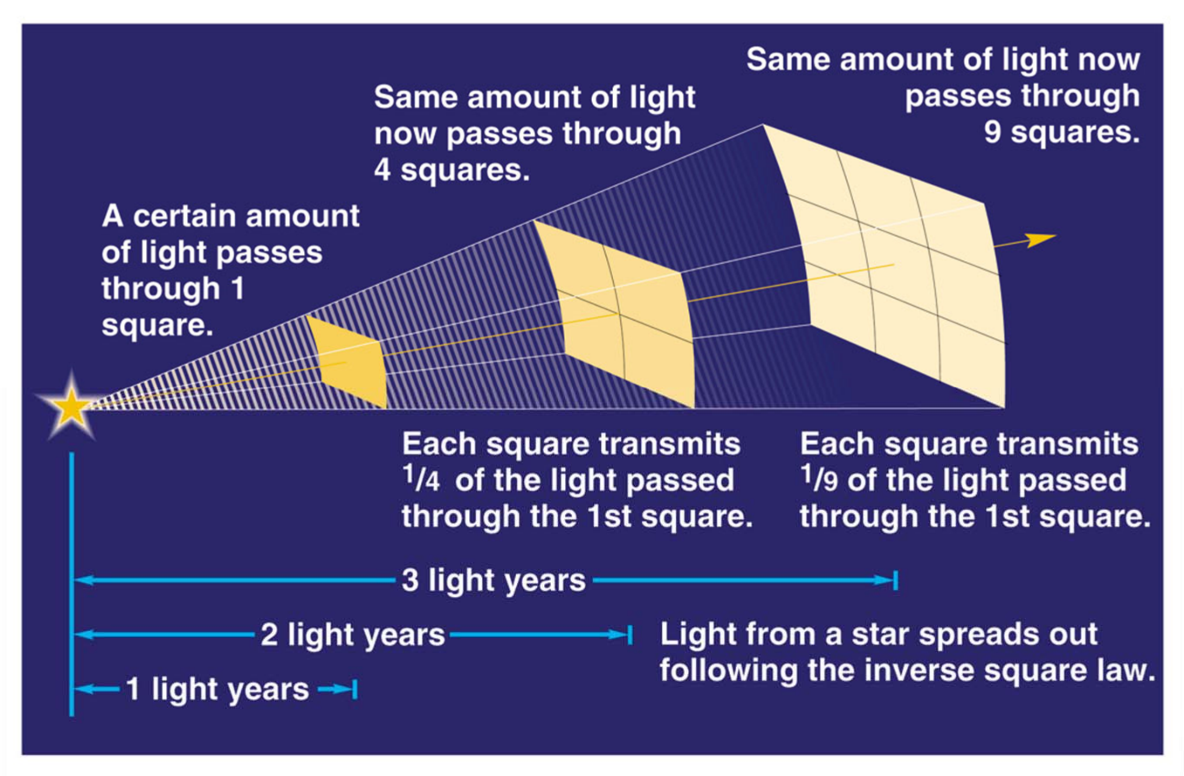
a. It is moving away from me. ✓

b. It is moving toward me.

c. It has unusually long spectral lines.



INVERSE SQUARE LAW



- How bright something is can also be measured
- Intensity, like gravity, falls off as $1/r^2$ where r is distance
- So, further things are fainter than they would be if closer

LIGHT & SPECTRA

- Light (and other EM waves) is the only thing we have to work with in Astronomy
- We can measure:
  - Direction
  - Wavelength (spectra)
  - Intensity

DIRECTION

- Where does the light appear to be coming from?
  - This star, some other star, our galaxy, another galaxy?

WAVELENGTH

- A spectrum is what you get when you take all the light coming from something and split it up by wavelength (color) λ
- Used to tell:
  - Chemical composition
  - Temperature
  - Velocity towards and away from us

INTENSITY

- How bright something is
- Follows inverse square law
- If we know how bright something is at a known distance, and we see something similar at an unknown distance, how bright it is will tell us how far away it is
  - “Standard Candle”

LOTS OF INFORMATION!

- EM waves are packed with the information which allow us to decode what is happening out there
- We will use these tools for the rest of the semester to understand our solar system, galaxy, and universe

PRACTICE QUIZ

- Three “Main Sequence” stars are:
  - Proxima Centauri, which is red
  - Sirius, which is white
  - Our Sun, which is yellow
- Write down the stars in order from coolest to hottest
- Which one puts out the least energy?
- Which one emits the most Ultraviolet light?

Without clickers on this one: write answers in your notes instead.
(couldn’t figure out how to get a more complicated
series of questions like this to work with clickers)

ANSWERS:

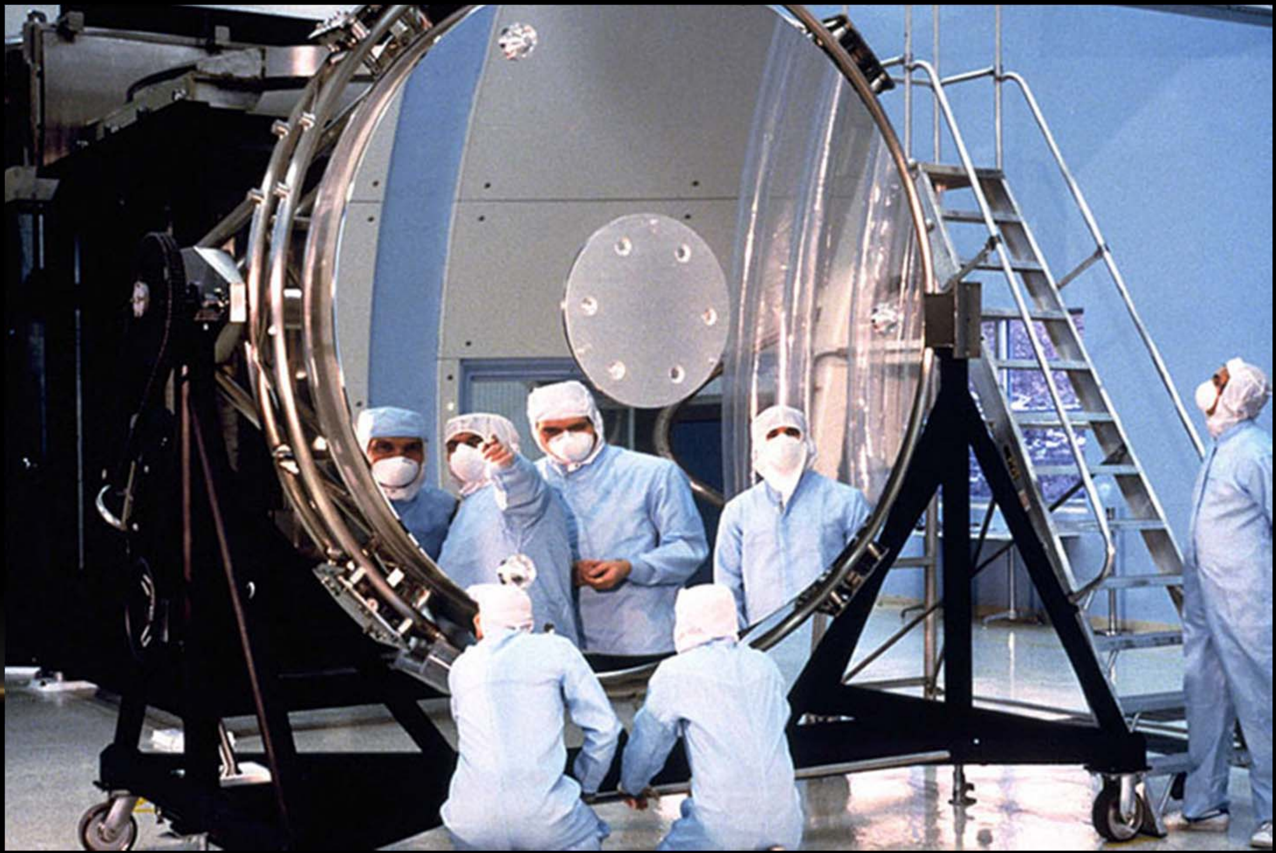
- Proxima Centauri, the Sun, Sirius
- Proxima Centauri puts out the least amount of energy
- Sirius emits the most UV
- Note that Betelgeuse, a Red Supergiant, puts out more energy than any of these – why?
  - Size matters! The temperature determines how much energy per square meter, but Betelgeuse is as big across as the orbit of Mars, so it has a Lot of Square Meters

TELESCOPES

- Let us see fainter things by collecting more light
- Let us see smaller details by improving angular resolution
- Let us see all the electromagnetic waves which aren’t visible light

LIGHT BUCKETS

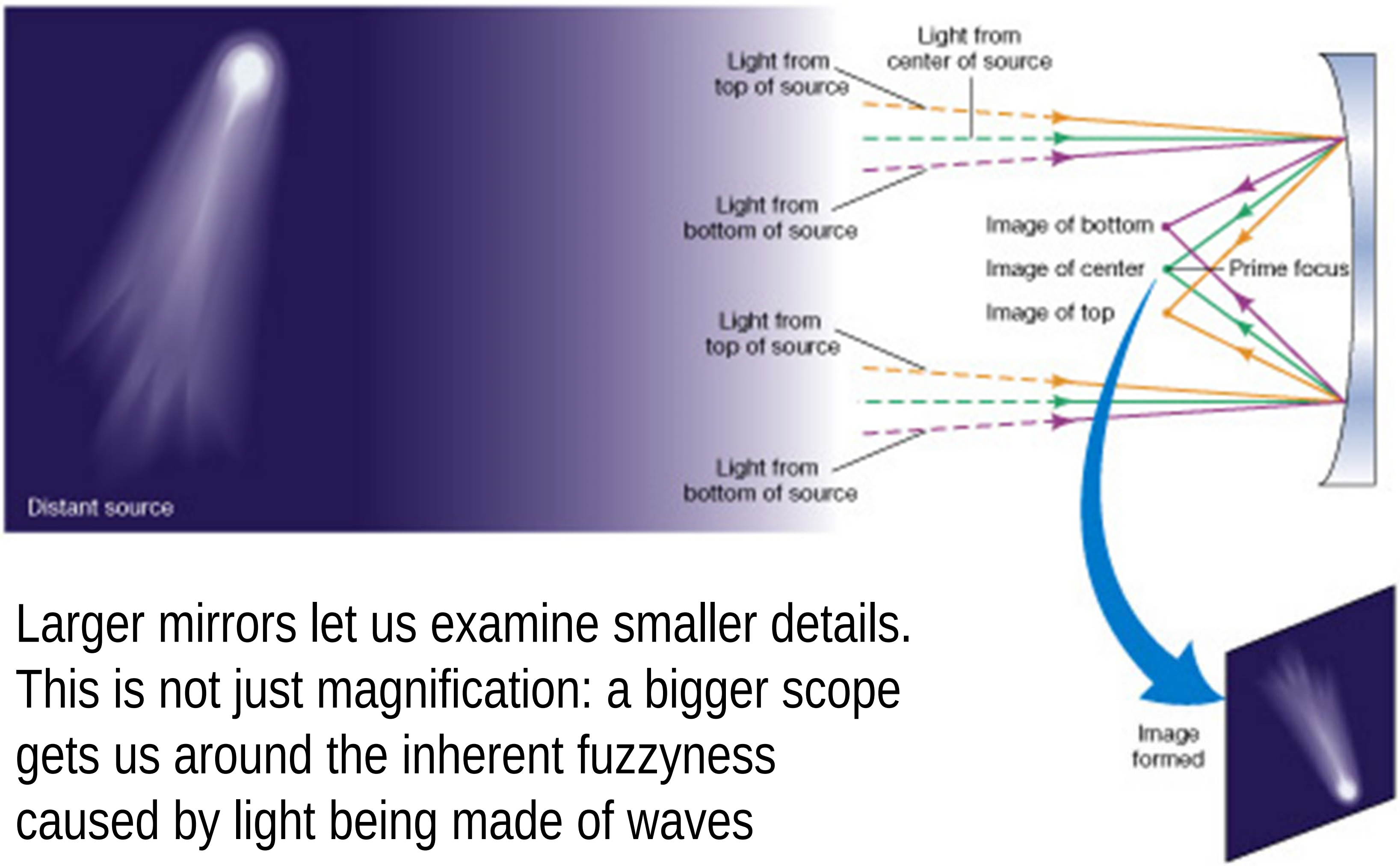
- Main job: collect more light by simply being bigger than our own pupils
  - See dimmer things



Workers inspect the Hubble's 8ft (2.4m) mirror before it was launched

PLAY

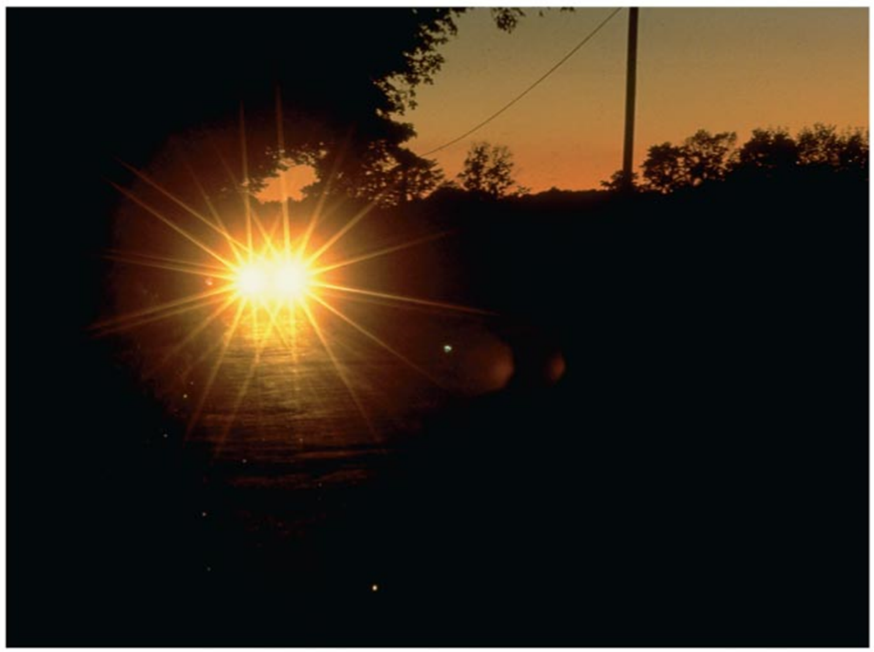
IMAGE FORMATION

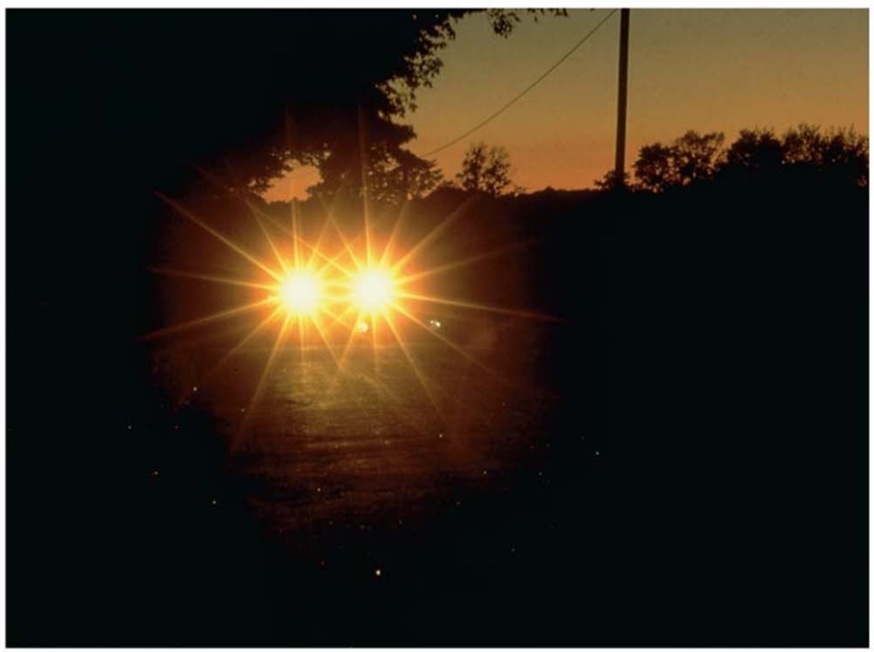


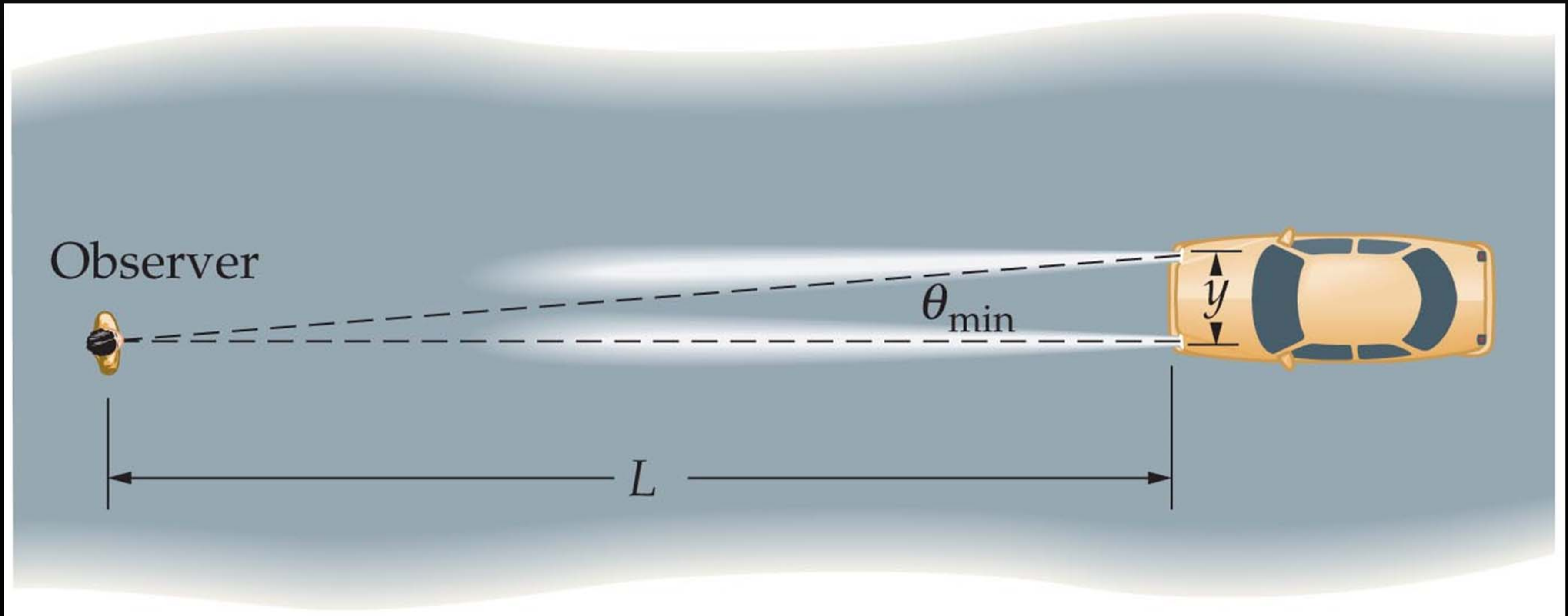
Larger mirrors let us examine smaller details. This is not just magnification: a bigger scope gets us around the inherent fuzzyness caused by light being made of waves

ANGULAR RESOLUTION

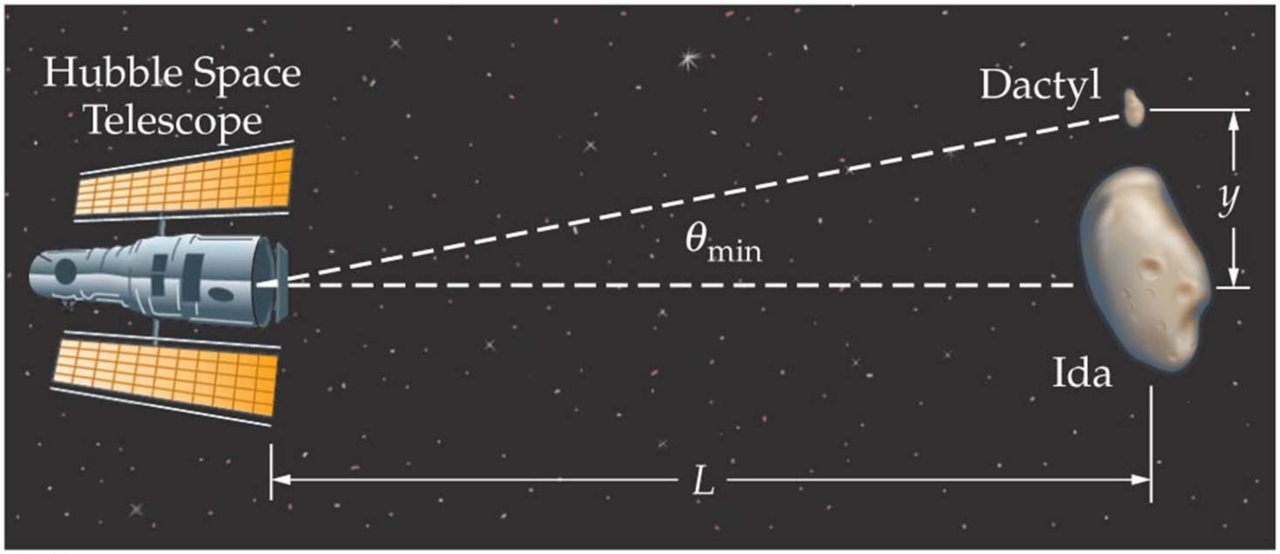
- How close together (in angle) can things get before you can't tell them apart?





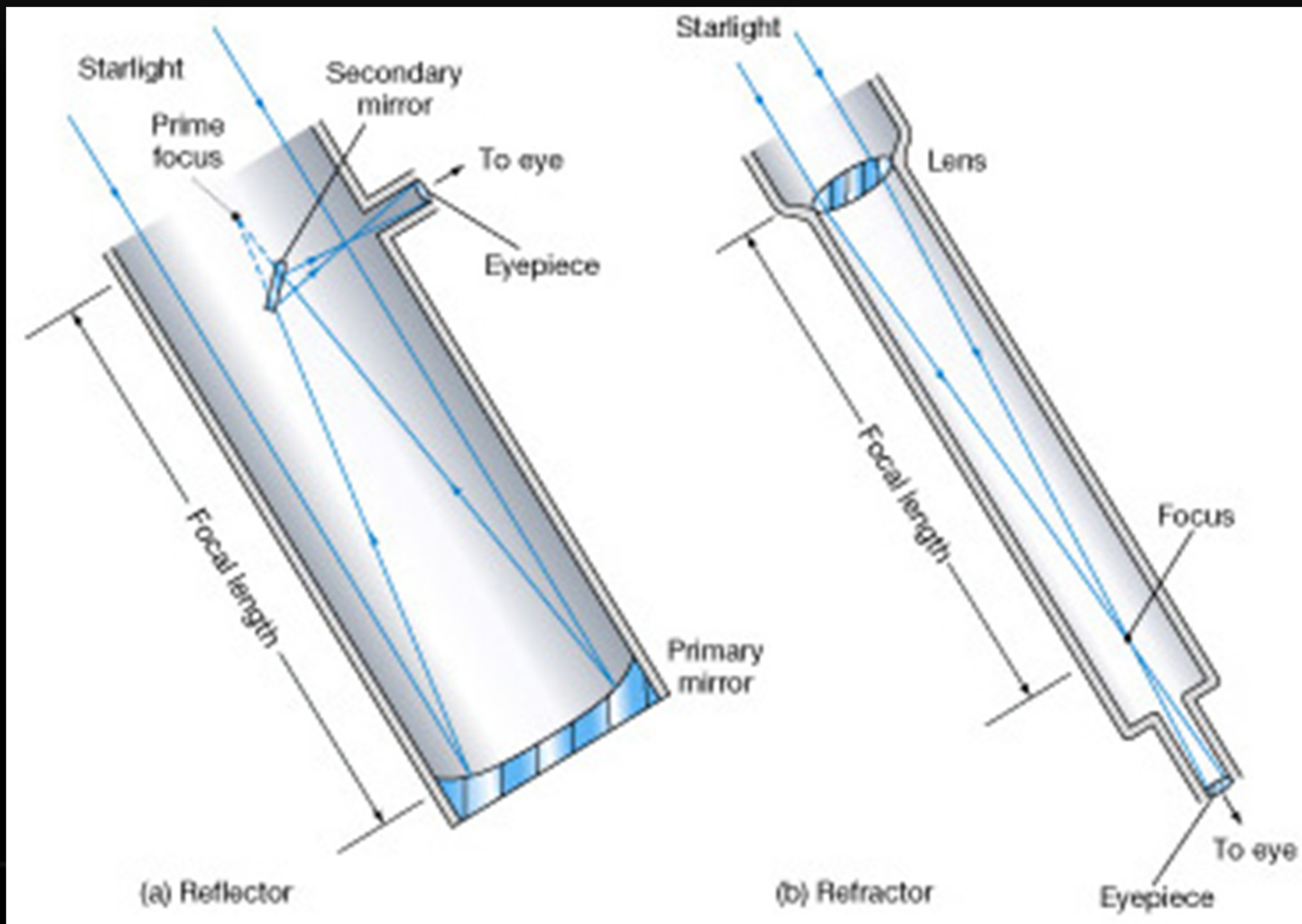


PLAY



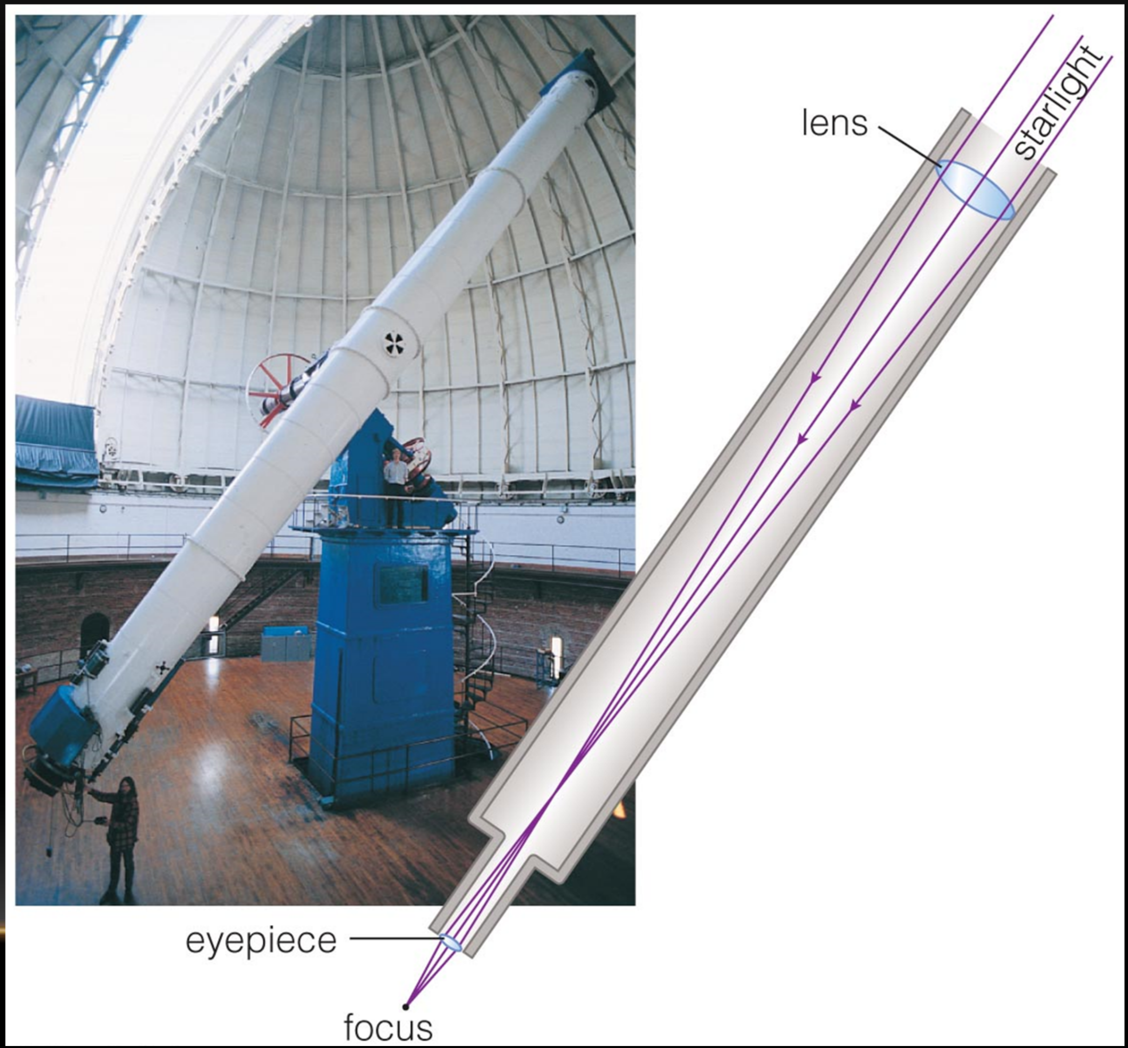
PLAY

REFRACTOR VS. REFLECTOR



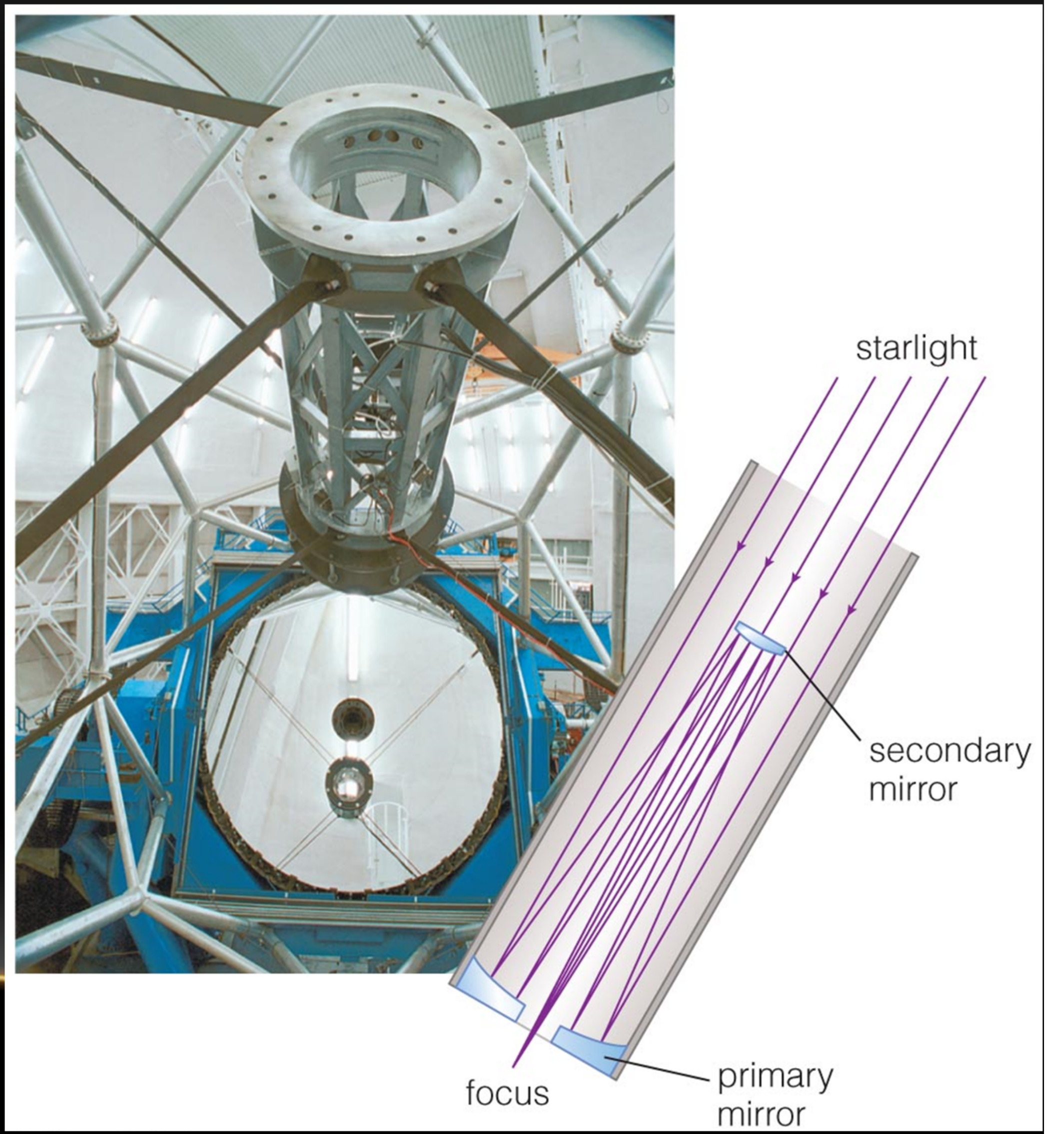
REFRACTORS

- Use lenses
- Mechanically hard to make these very large: this 1-m in Yerkes, WI is the largest

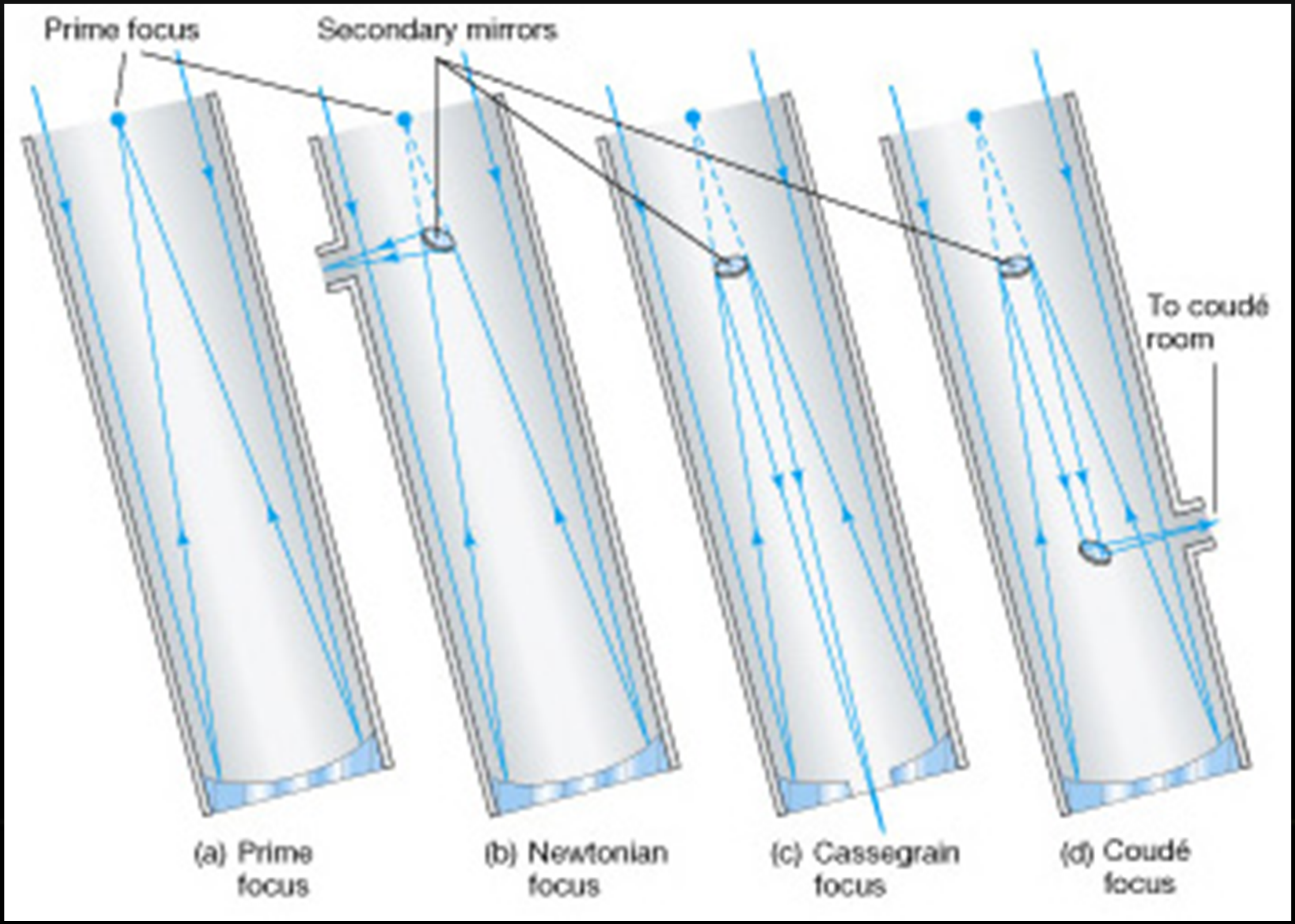


REFLECTORS

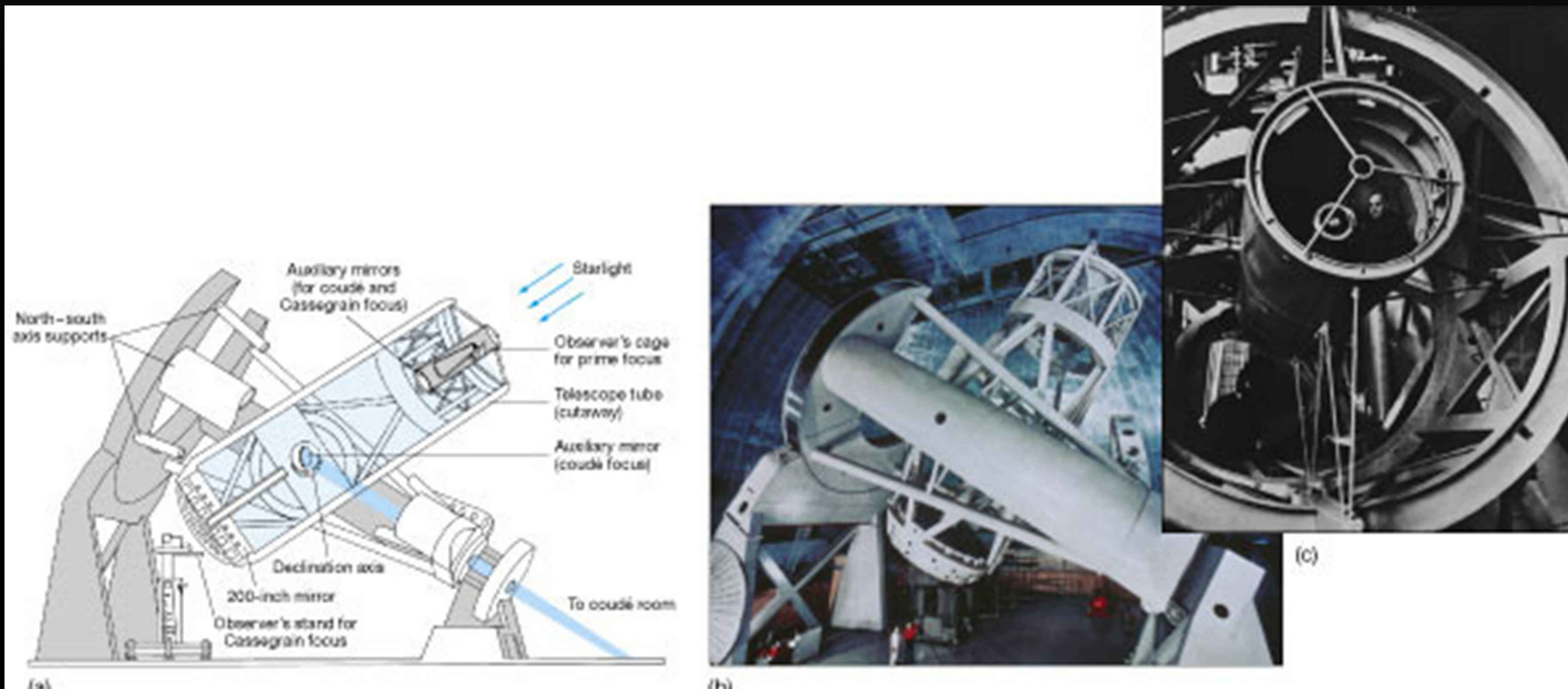
- Use mirrors
- Much easier to build huge mirrors
- All research-grade scopes are reflectors
    - This one is the 8m Gemini North



REFLECTORS


Prime focus
Secondary mirrors
To coudé room
(a) Prime focus
(b) Newtonian focus
(c) Cassegrain focus
(d) Coudé focus

PALOMAR 200 INCH

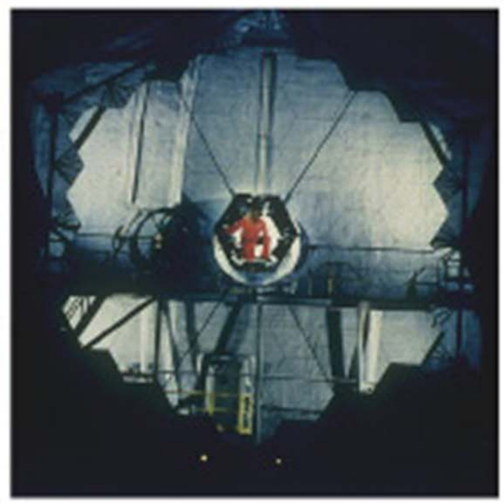


KECK


Robert Van Geen


Gemini-north telescope
United Kingdom infrared telescope
Canada-France-Hawaii telescope
NASA infrared telescope
Keck 2
Keck 1
Subaru telescope

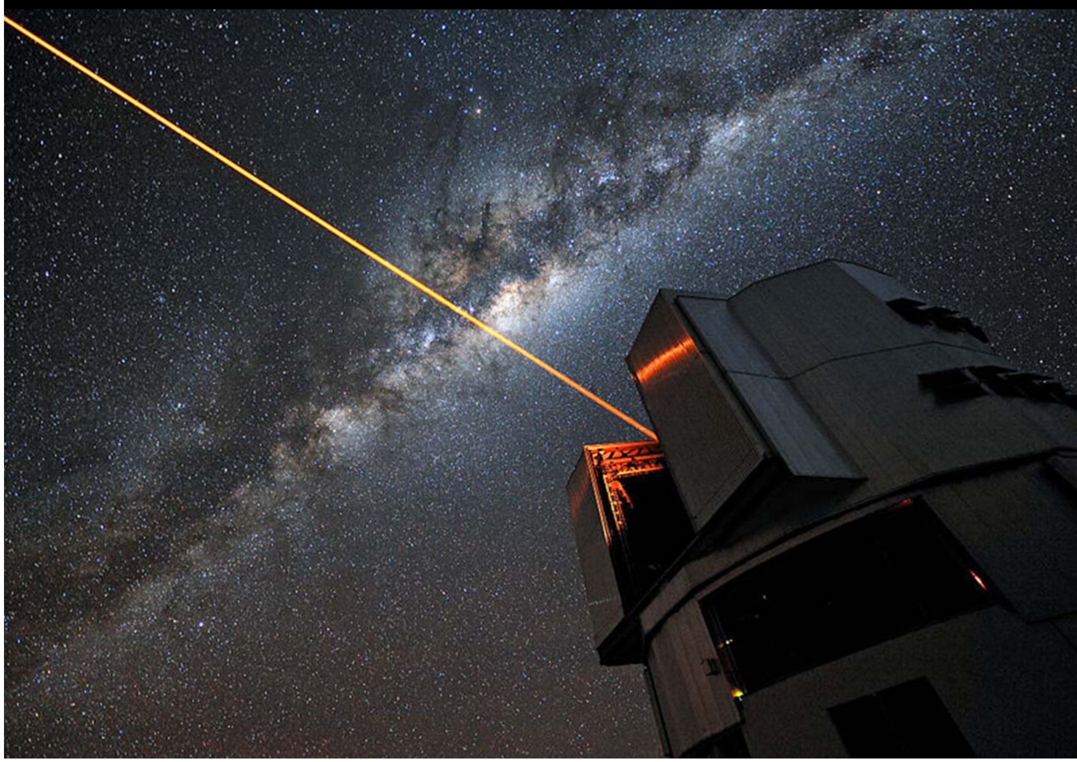
(a)

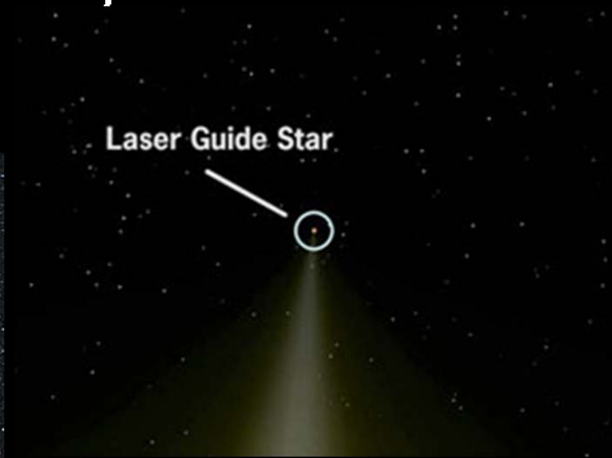


(b)

LASERS AND ADAPTIVE OPTICS

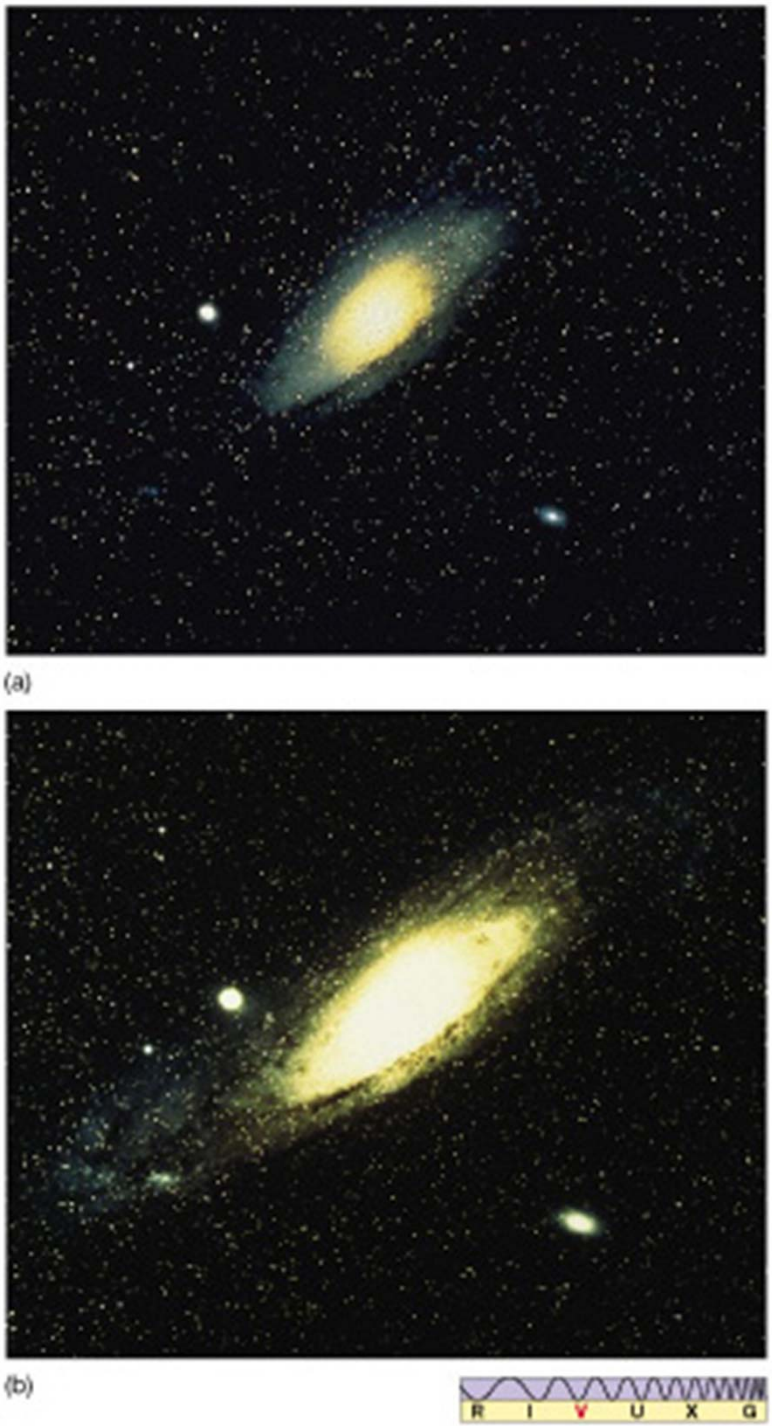
- Scopes like Keck can use an artificial star to see what the air is doing, then warp their mirrors to “de-twinkle” their images





The laser excites sodium atoms high in the atmosphere, causing them to emit light

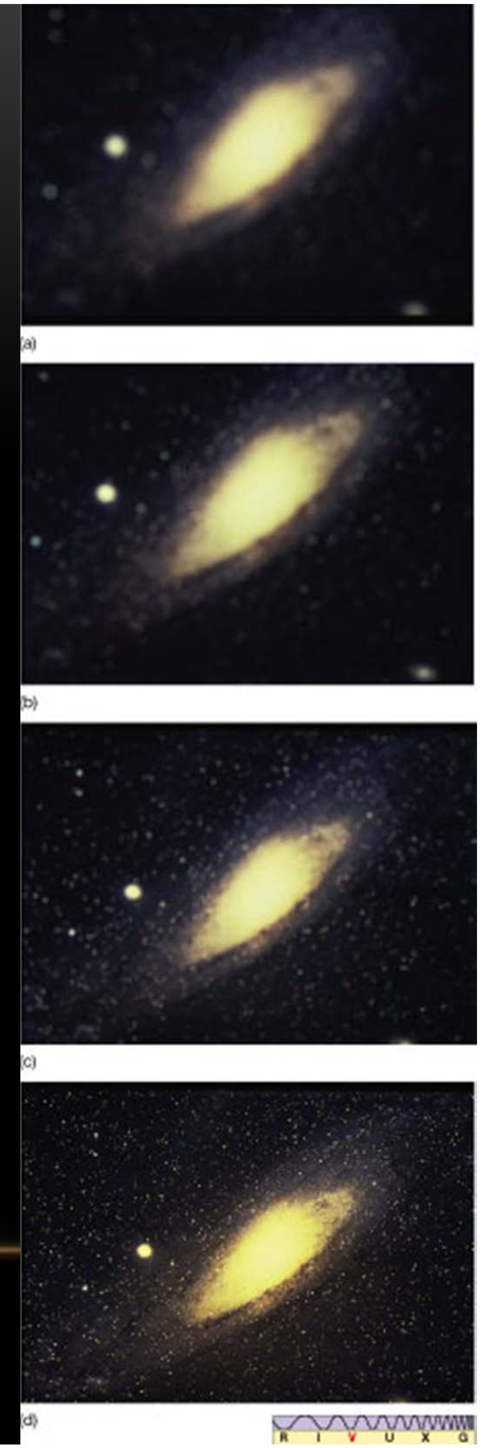
ESO’s VLT (Chile)



BIGGER IS BETTER

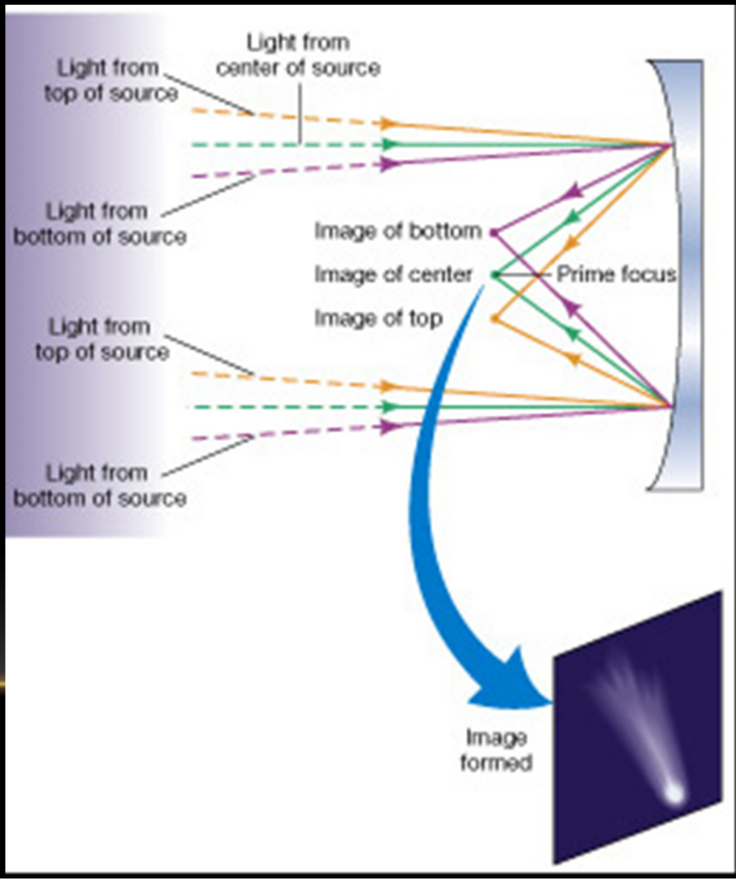
More light

Better Resolution

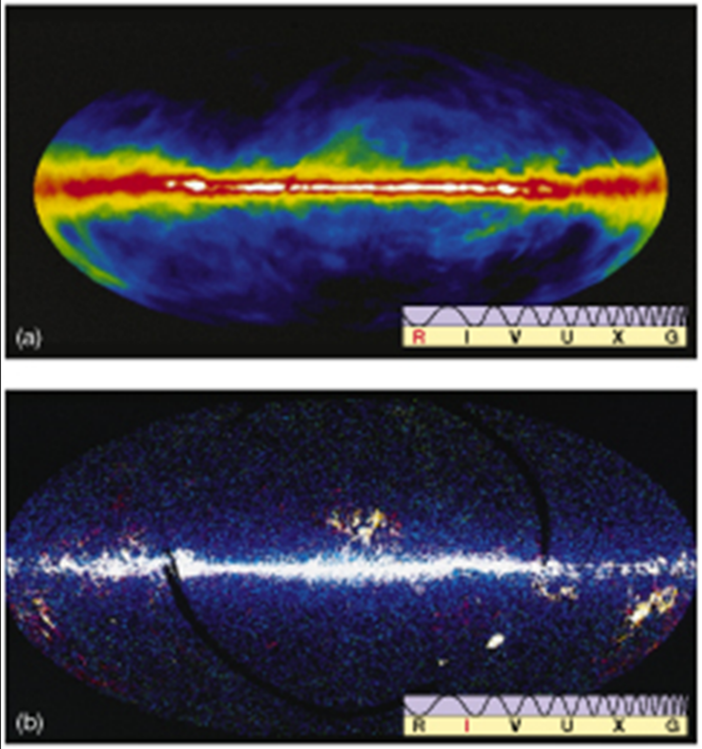


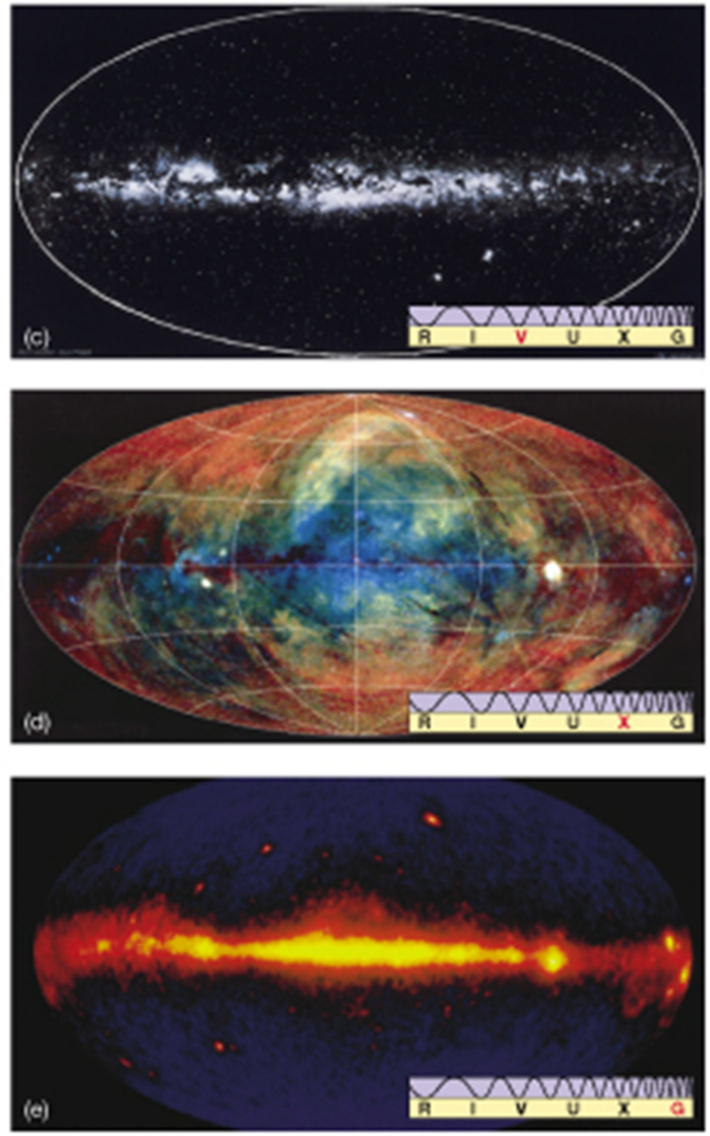
MAGNIFICATION?

- Not so important. Change the last little eyepiece lens. That last lens just is inspecting the image produced by the main lens or mirror, like a magnifying glass



OTHER E-M WAVES

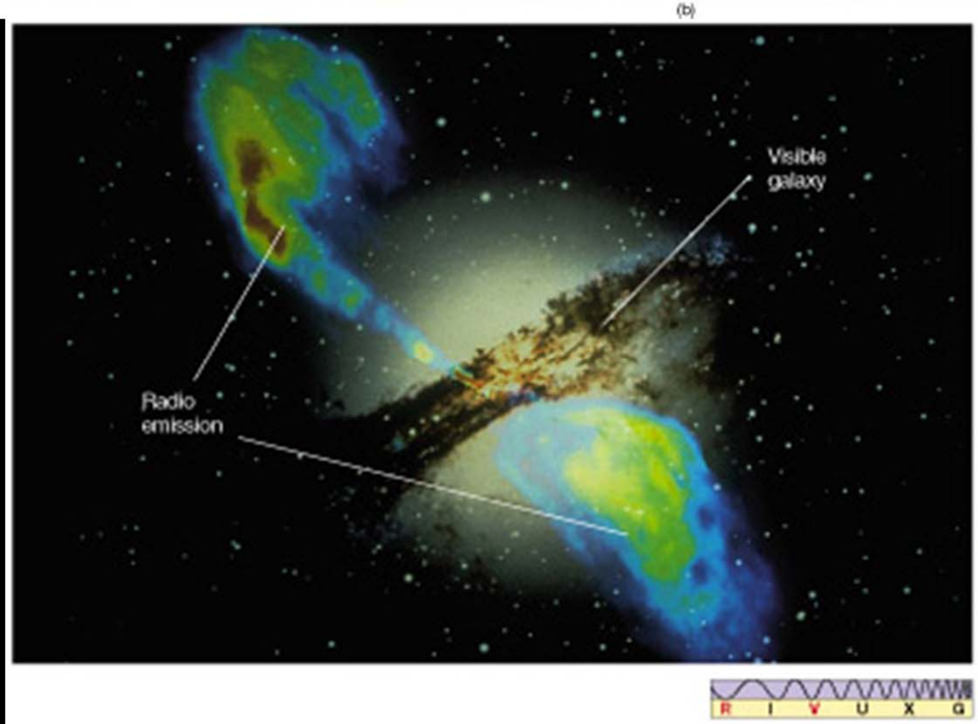


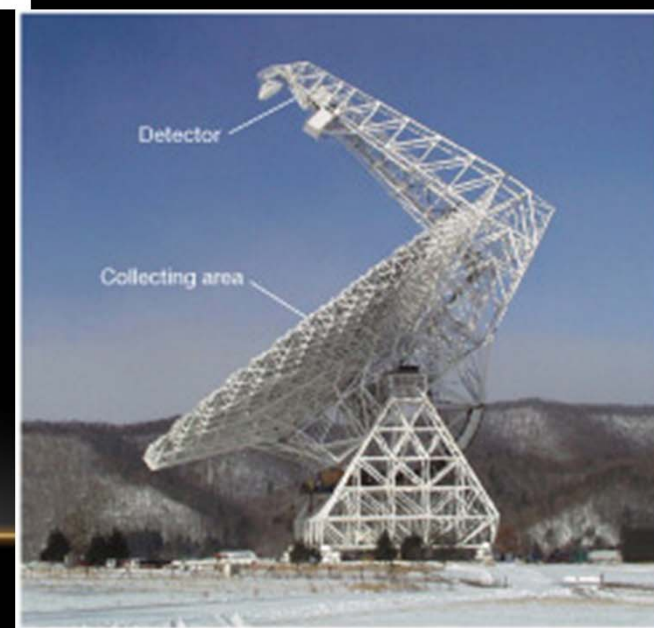


The Milky Way seen in many wavelengths

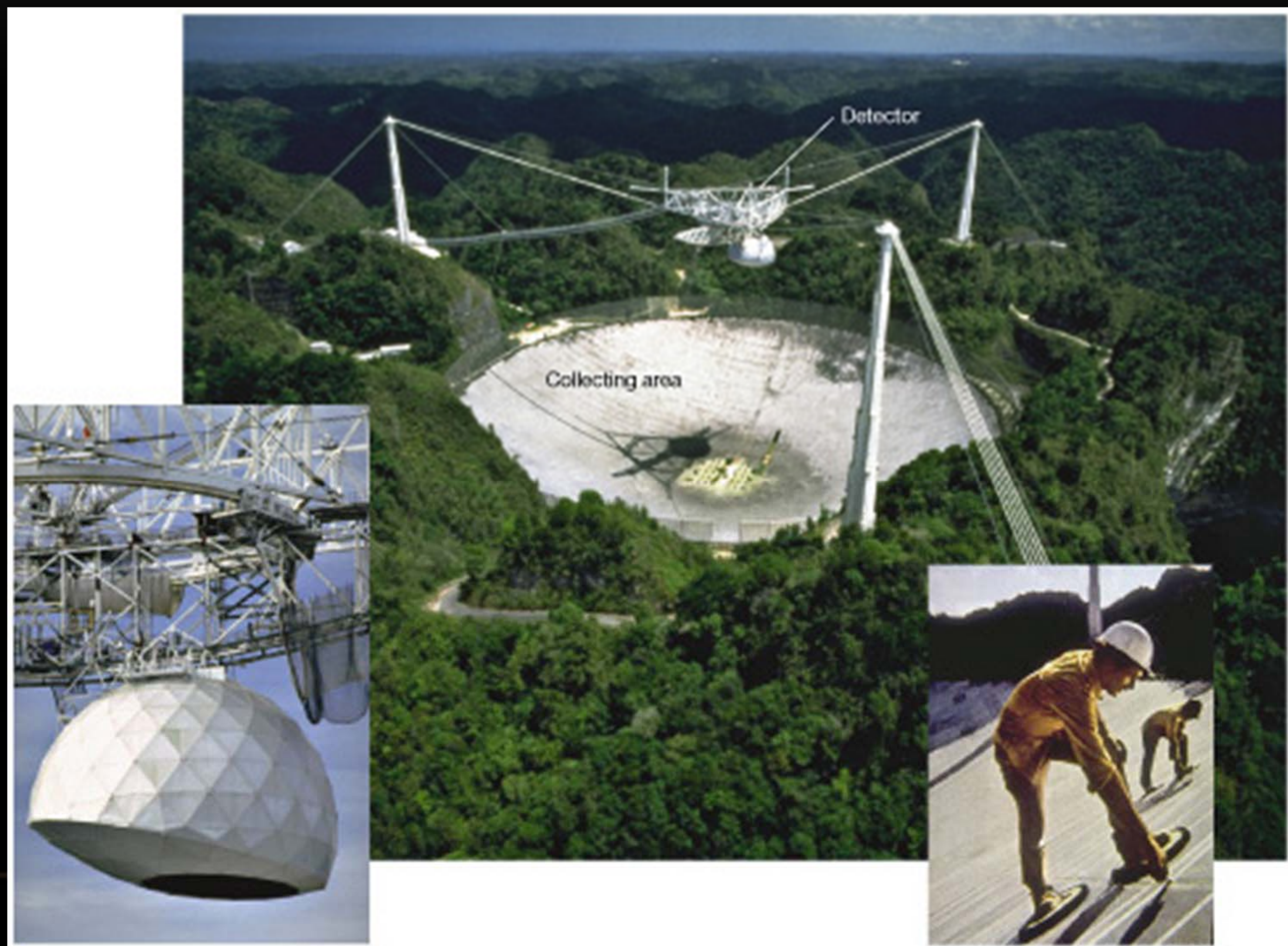
RADIO TELESCOPES

a) (b)





RADIO TELESCOPES



INTERFEROMETRY

- Use an array of smaller scopes to get the angular resolution of a larger one

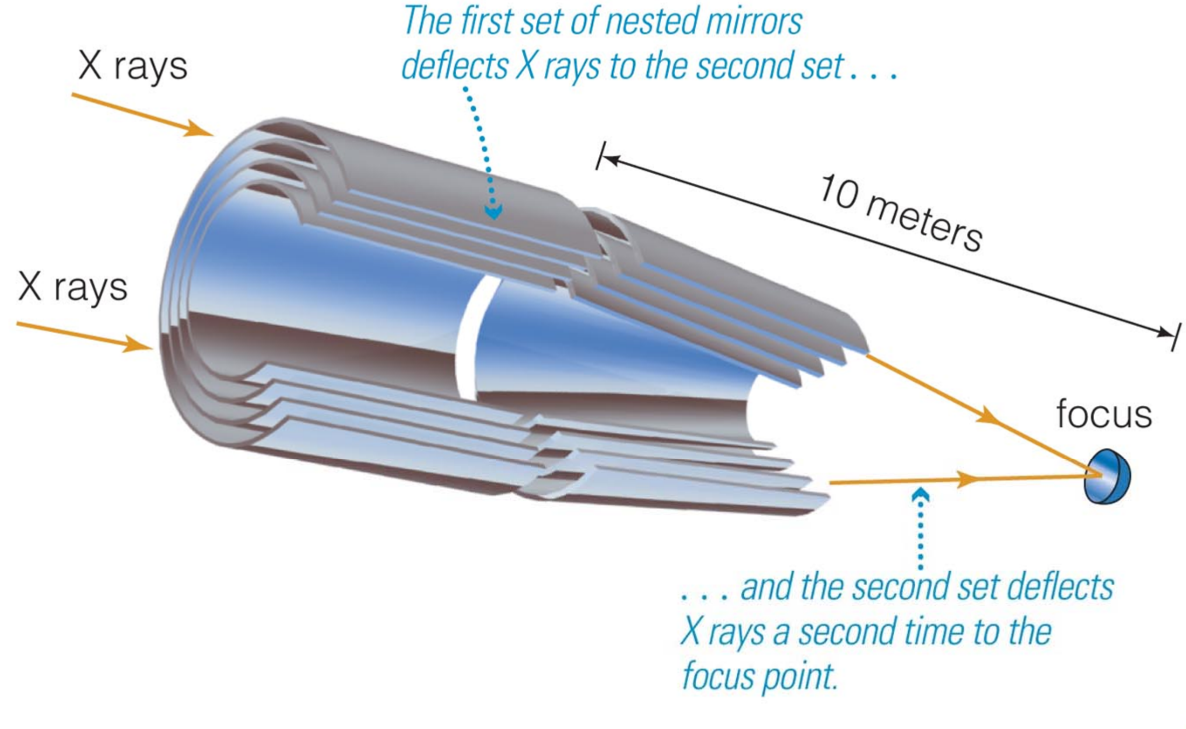
Fig.5.22

The Atacama Large Millimeter/submillimeter Array (ALMA) in Chile

X-RAY

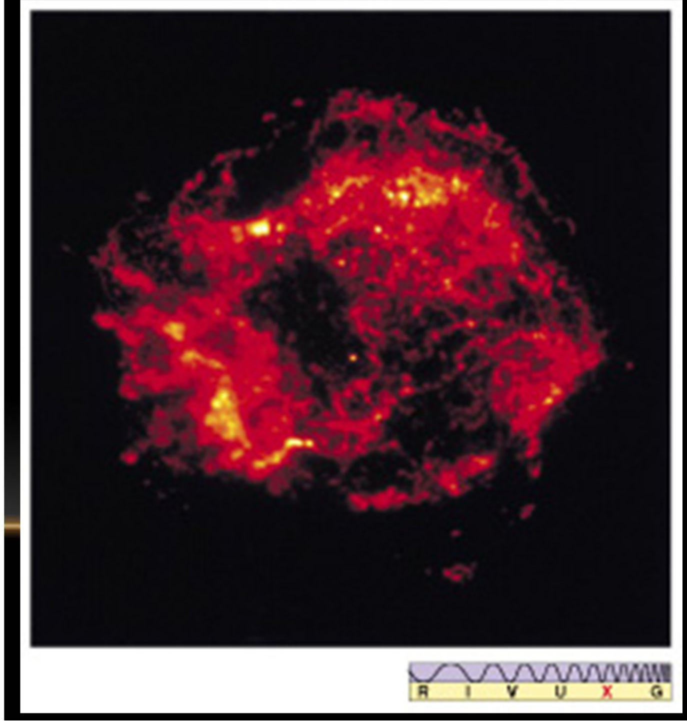
a Artist's illustration of the Chandra X-Ray Observatory, which orbits Earth.

Fig.5.23



b This diagram shows the arrangement of Chandra's nested, cylindrical X-ray mirrors. Each mirror is 0.8 meter long and between 0.6 and 1.2 meters in diameter.

A supernova remnant seen by Chandra in X-rays: click on this link for how it works



WHERE TO PUT TELESCOPES?

- Problems caused by where you put a scope include light pollution
  - So location needs to be remote

Fig.5.24

THE ATMOSPHERE…

- is not transparent to many wavelengths

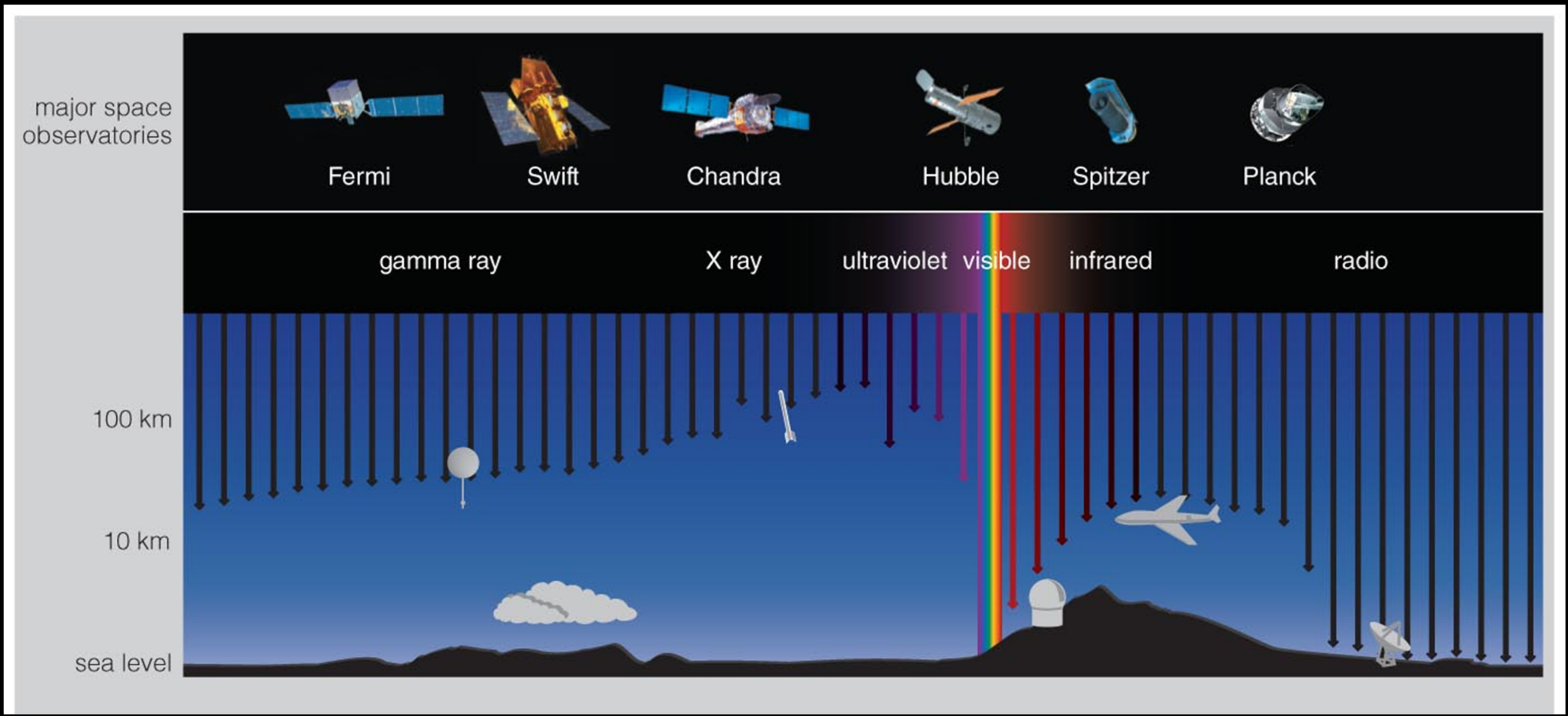
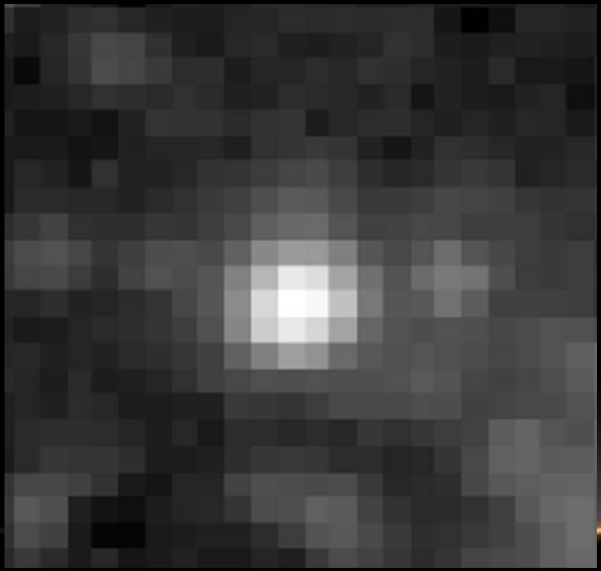


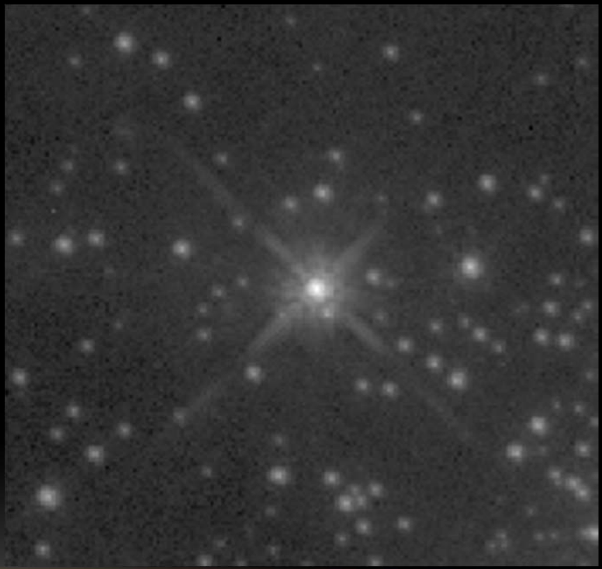
Fig.5.27

EVEN IF TRANSPARENT…

- The air still smears out what you see
  - Same thing happening as when you see the wavyness in the air above a hot grill
  - Makes stars "twinkle"



Star viewed with ground-based telescope



View from Hubble Space Telescope

SO, AVOID AS MUCH AIR AS POSSIBLE (*AND WEATHER!*)

- Go up a mountain to get above most of it
- Or in space to be above all of it

Fig.5.25
Mauna Kea
In Hawaii

Fig.5.26
Hubble Space Telescope
In low earth orbit