Astro 1: Introductory Astronomy

David Cohen

Class 20: Thursday, April 3

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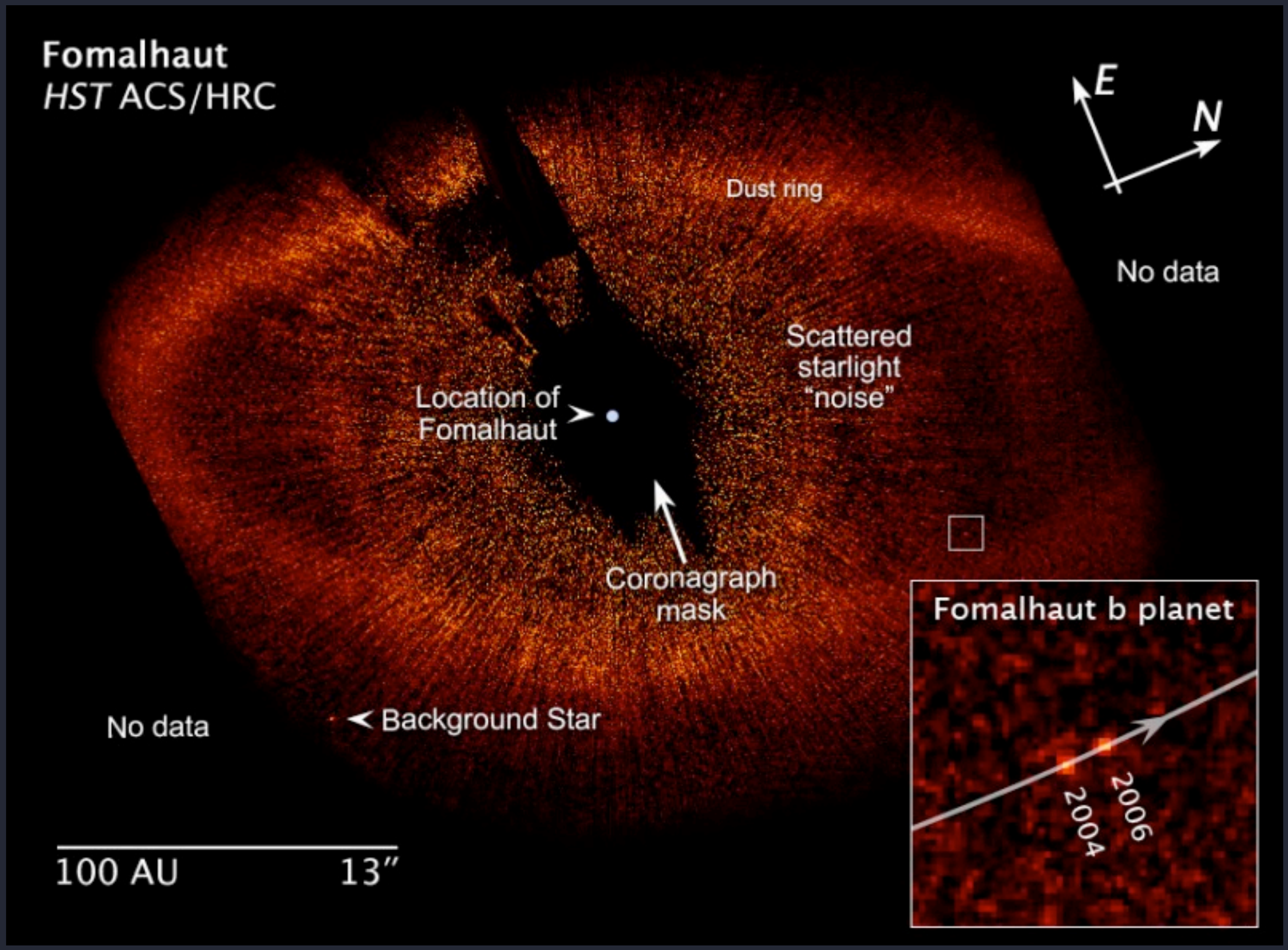
Direct imaging of exoplanets will be common someday (probably)

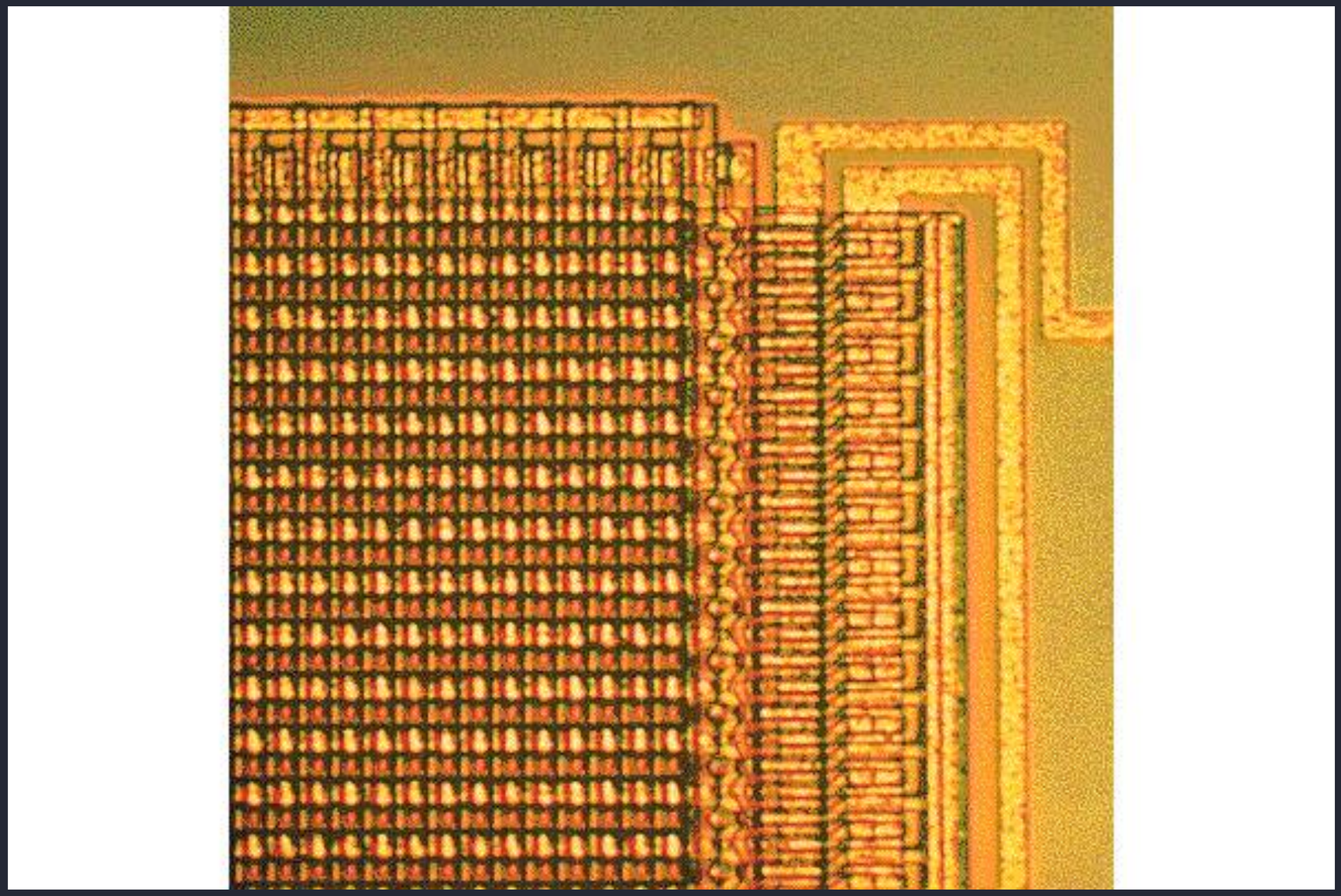


Telescopes: form images enabling us to see fine detail (resolution) and they collect a lot of light, allowing us to see faint objects

The Hubble Space Telescope – 200 km above the Earth, but it makes all the difference: above the distorting effects of the atmosphere

Also able to observe infrared (IR) and ultraviolet (UV) light, which is absorbed by the atmosphere.

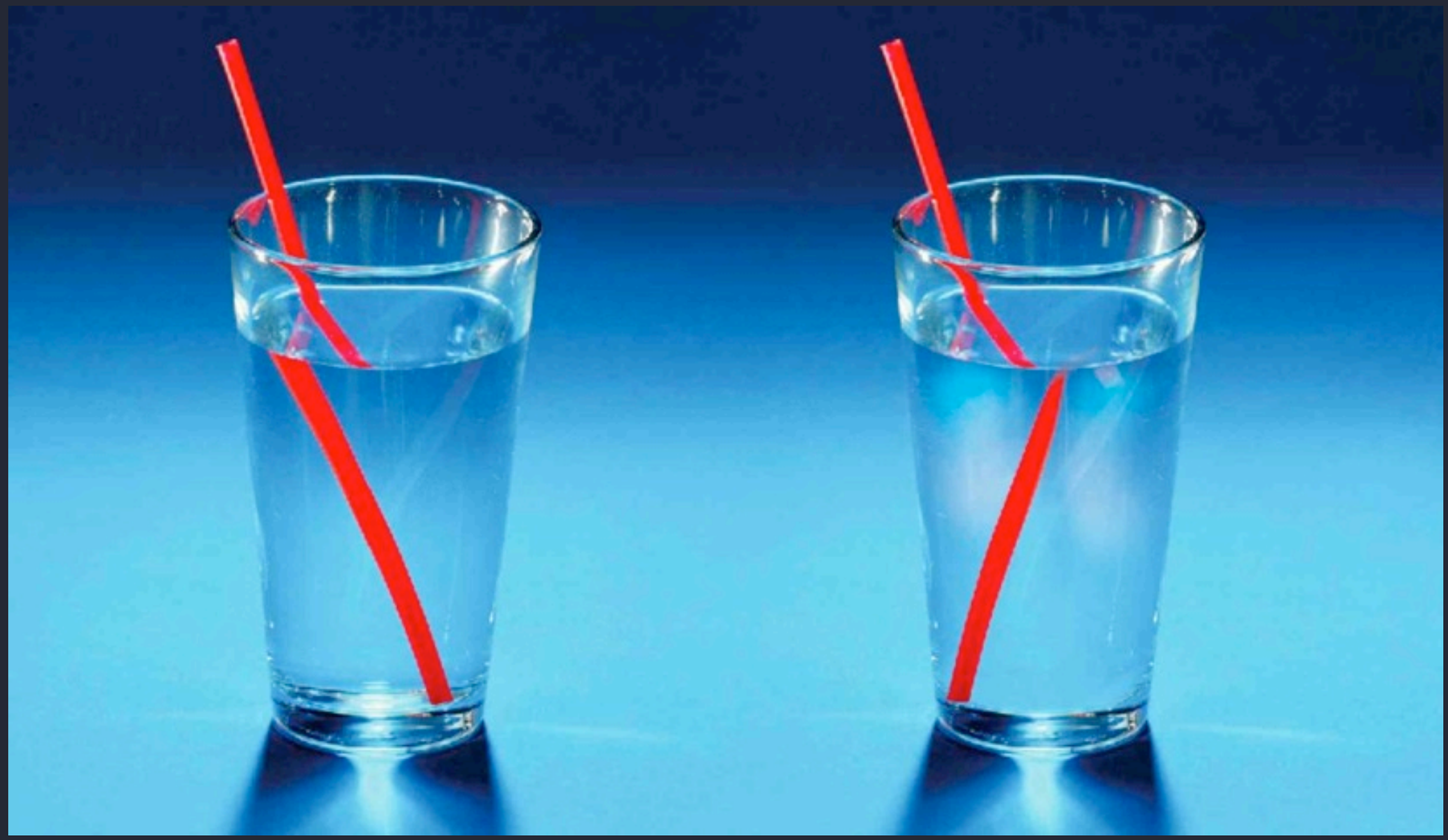
No astronomers put their eye up to a research telescope these days… Collect data on electronic detectors, such as this charge-couple device (CCD) (same type of detector as those in commercial digital cameras).

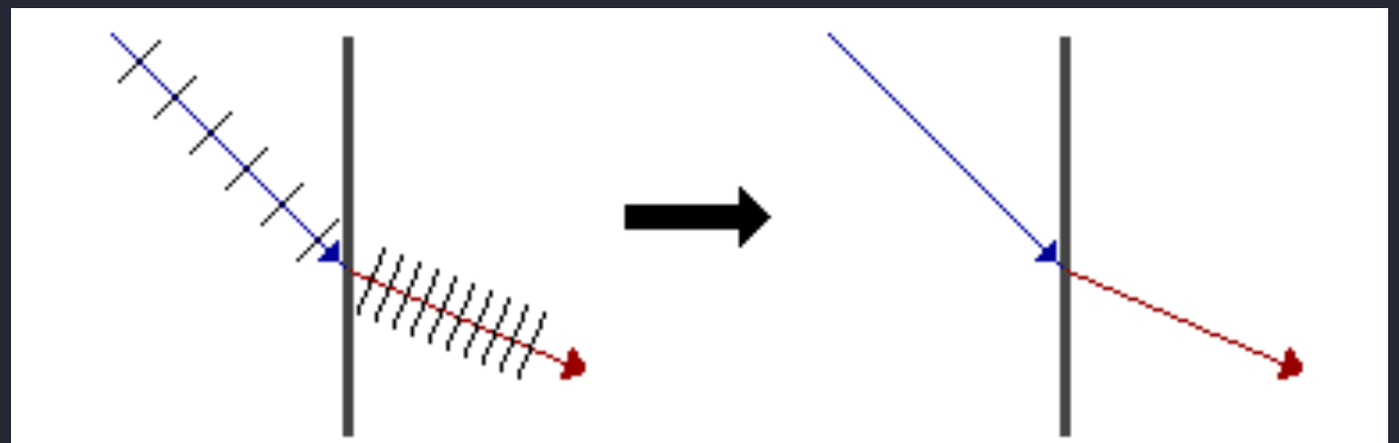


Magnified image of a CCD. Each little square is a pixel, in which photons get converted to electrons, which can be counted, or "read out"

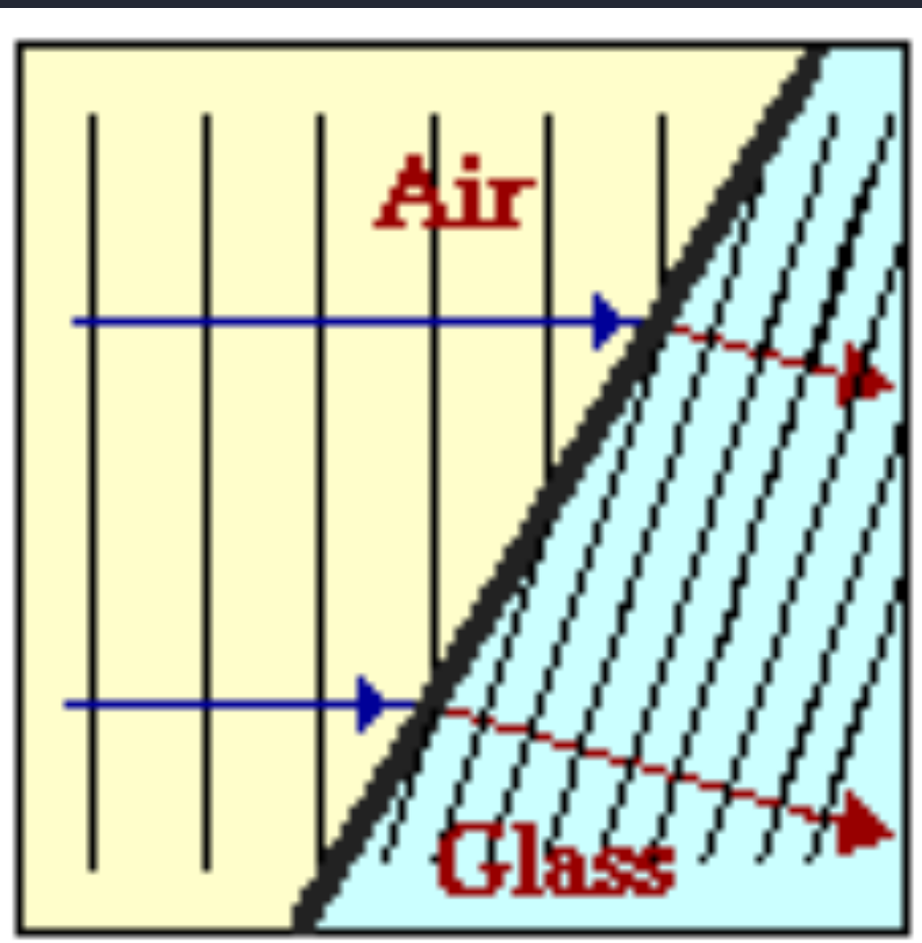
Now for some slides on **refraction** which is the basis for how lenses and telescopes work

the path a light ray takes changes direction at the interface between two substances



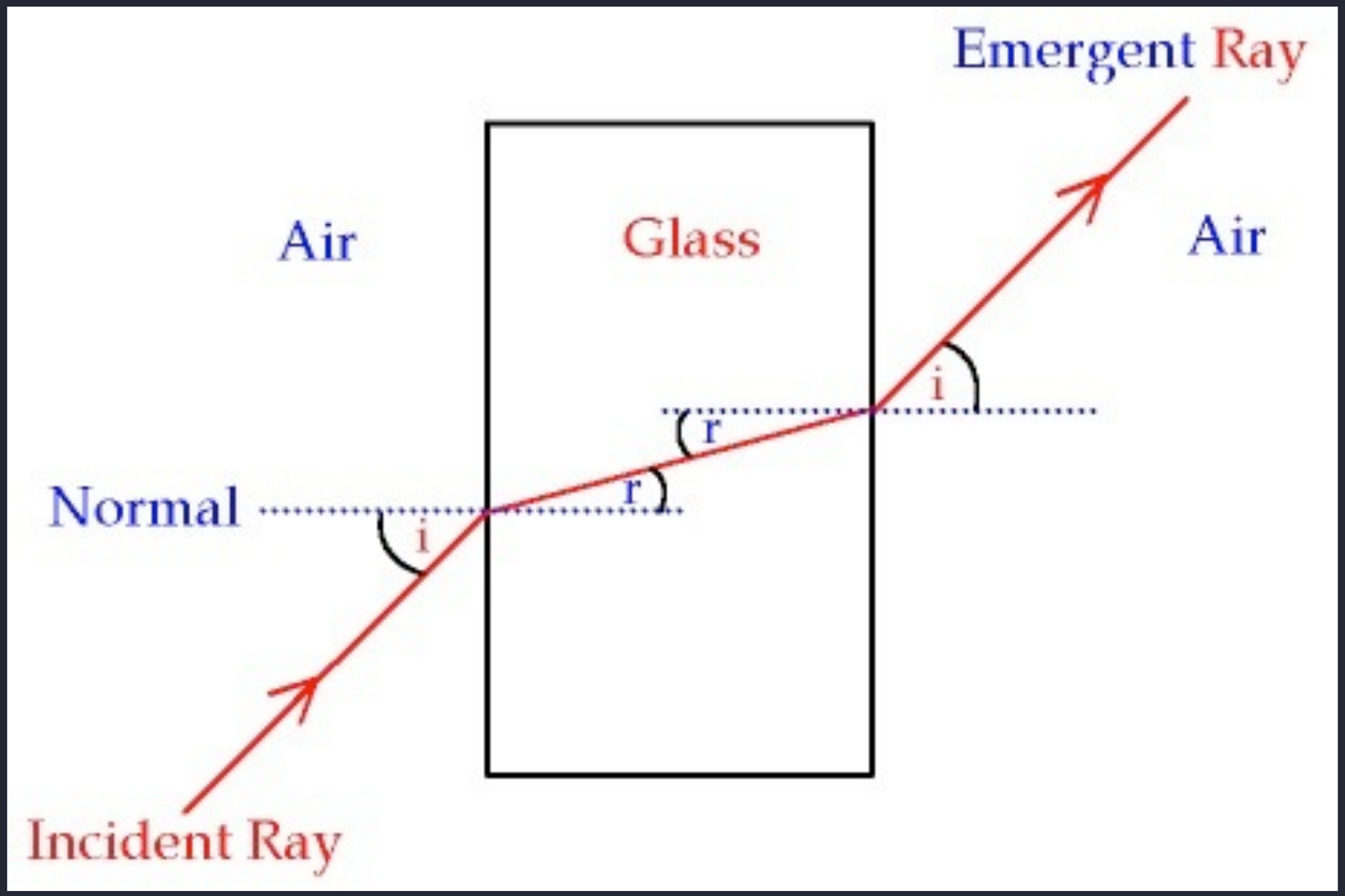


A ray will be used to depict the direction which a wavefront travels.

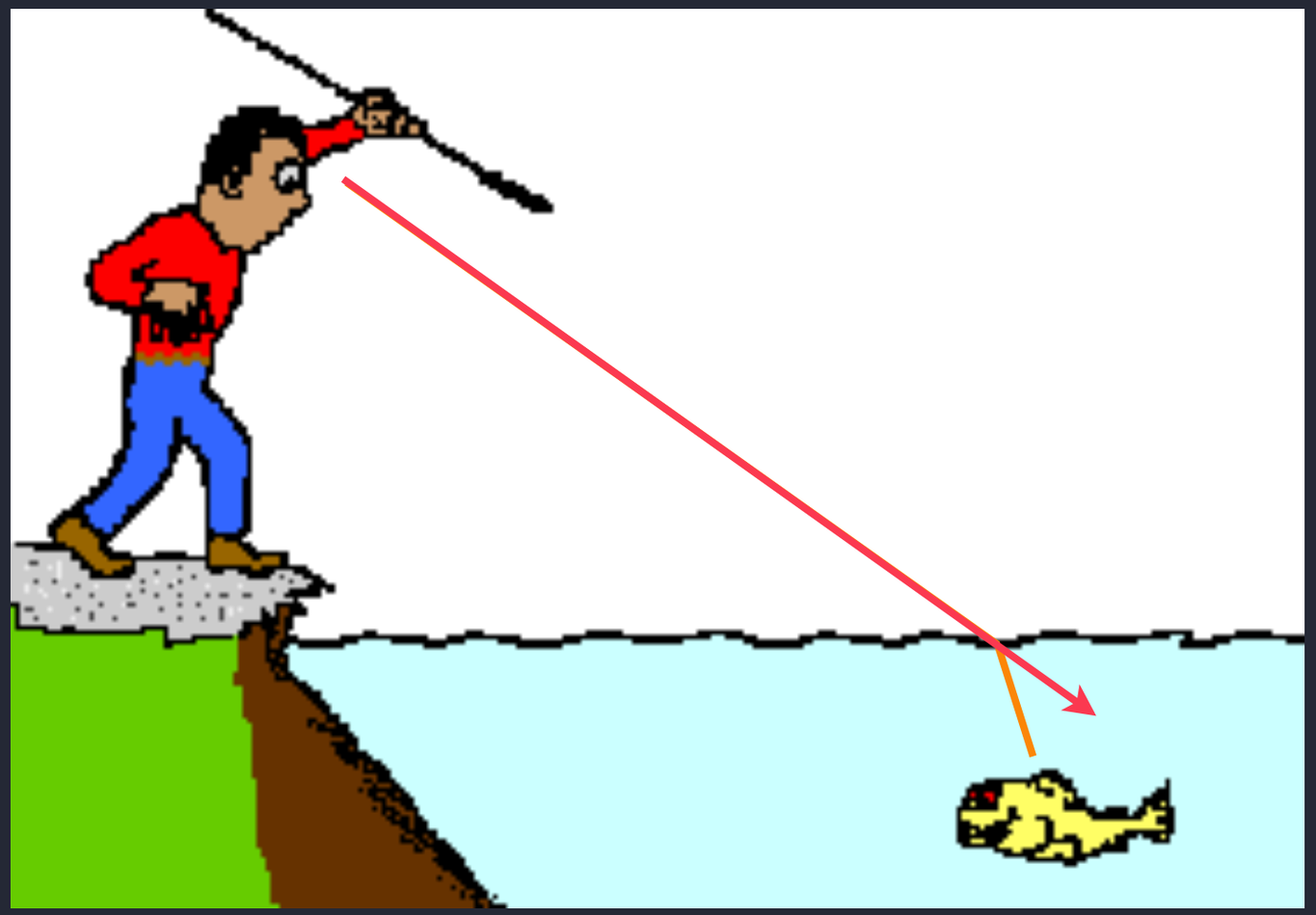


Refraction of light occurs at the air-glass boundary.

the path a light ray takes changes direction at the interface between two substances



Where will the fisherman see the image of the fish?



The human eye is like a telescope or camera

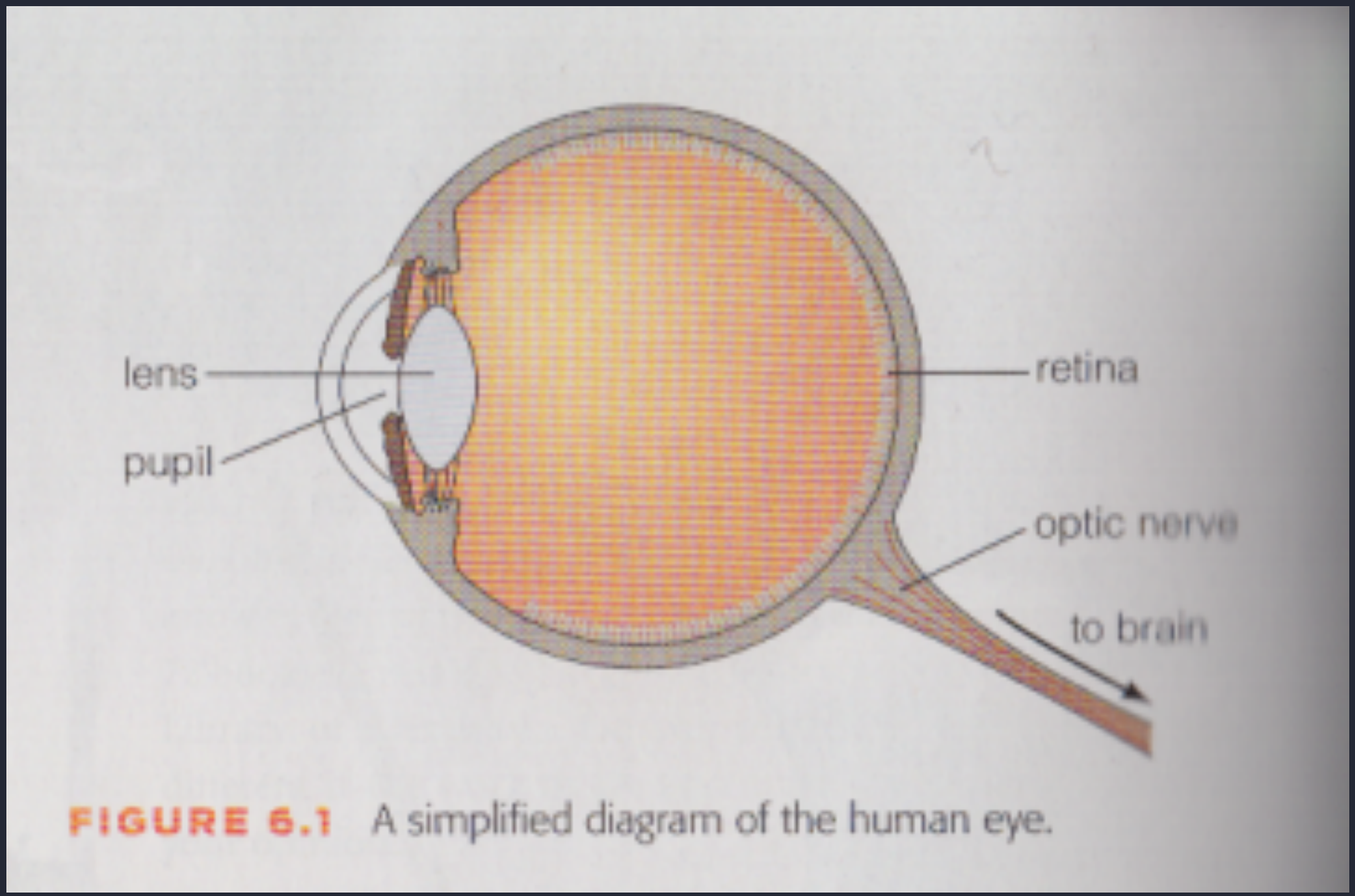


FIGURE 6.1 A simplified diagram of the human eye.

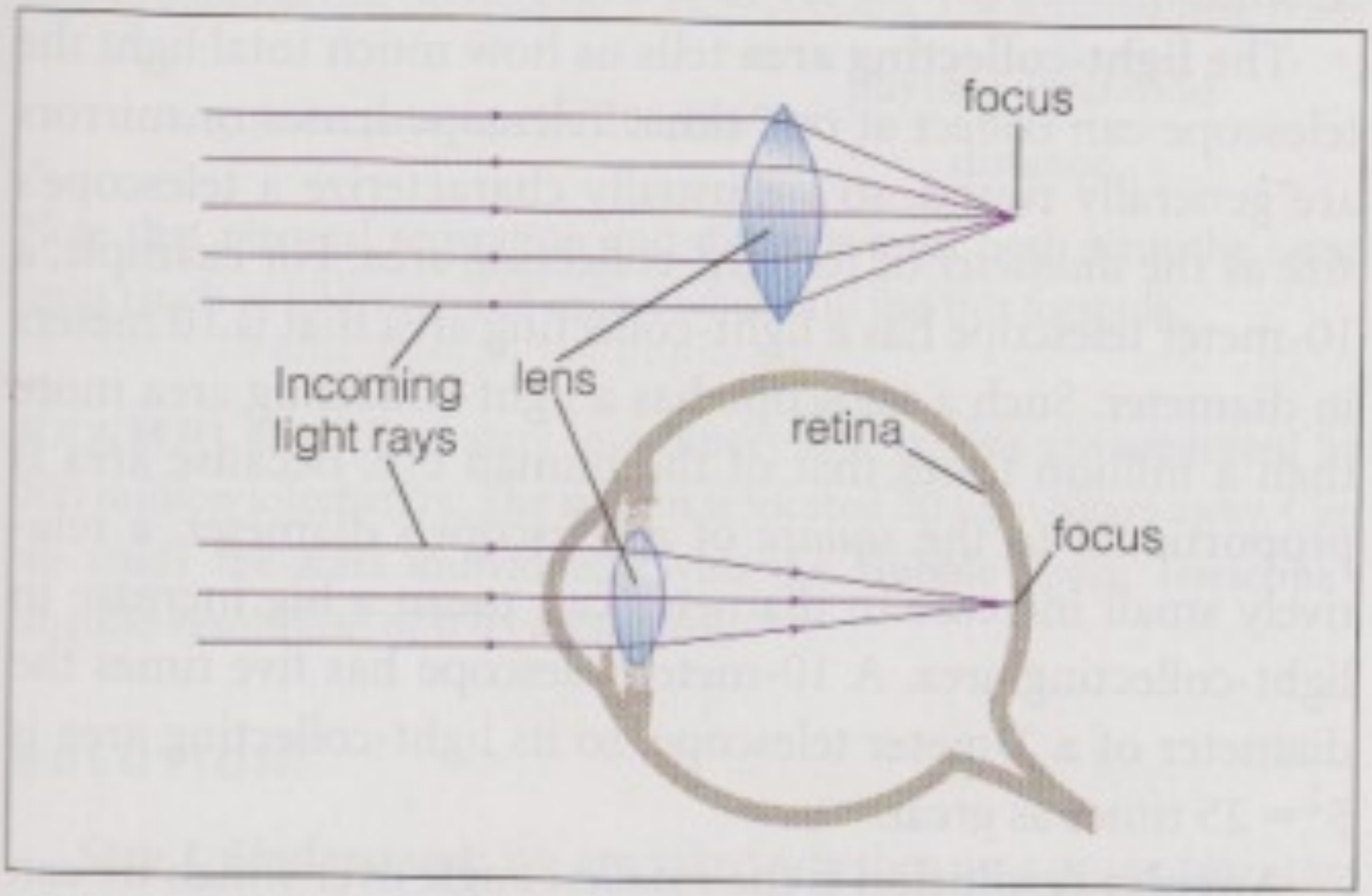


FIGURE 6.3 A glass lens bends parallel rays of light to a point called the *focus* of the lens. In an eye with perfect vision, rays of light are bent to a focus on the retina.

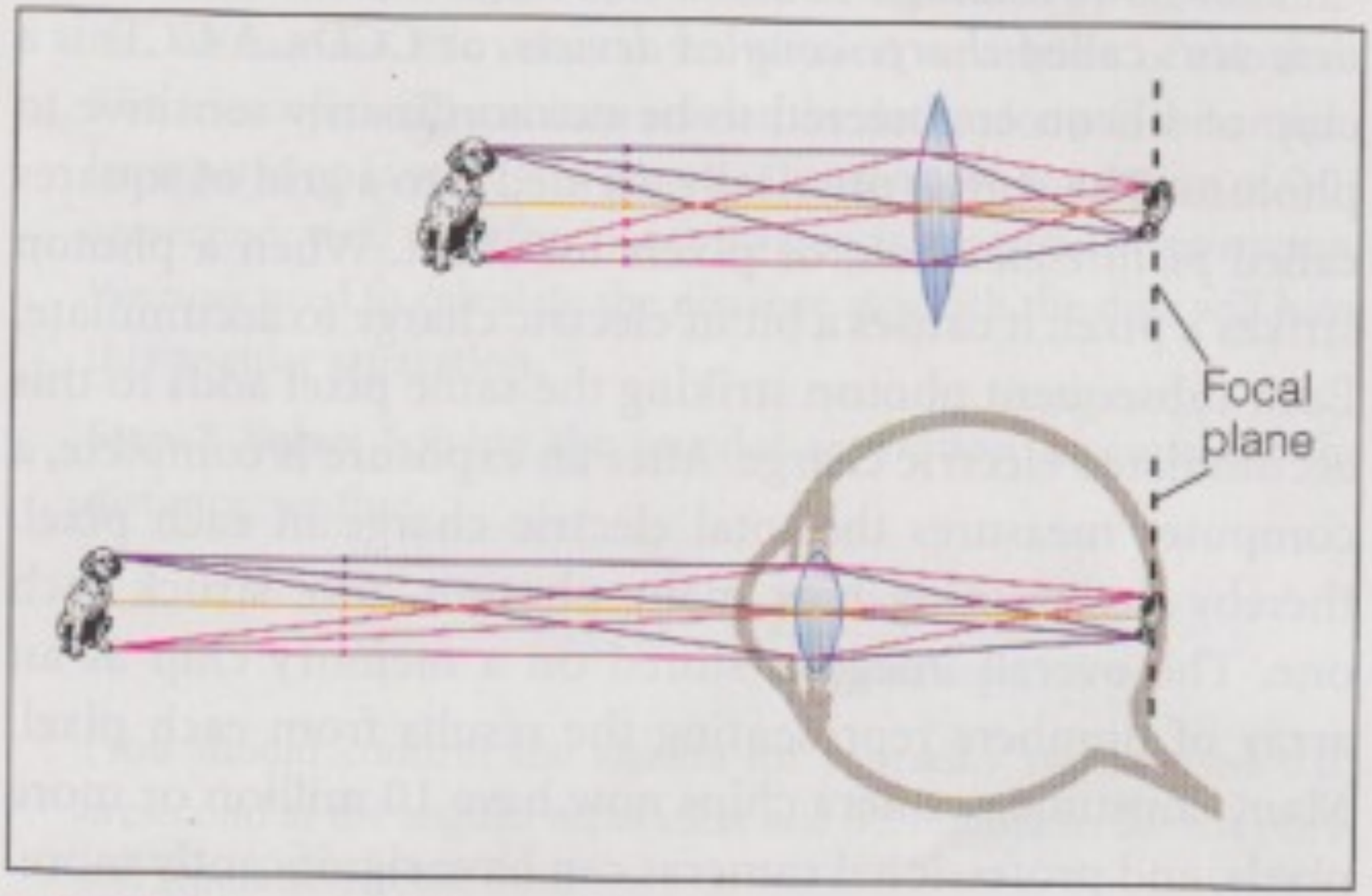


FIGURE 6.4 Light from different parts of an object focuses at different points to make an (upside-down) image of the object.

The concept of *resolution*

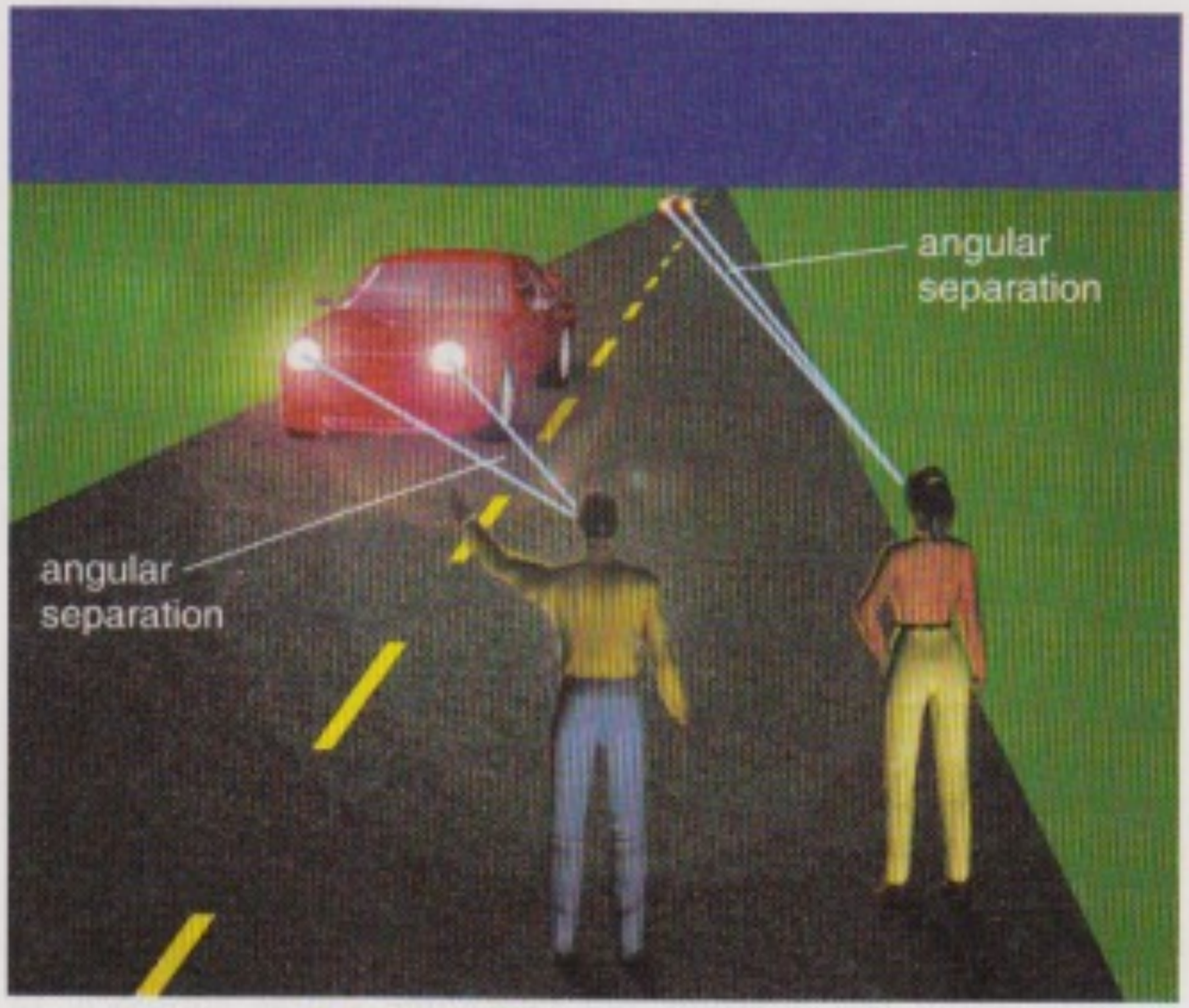
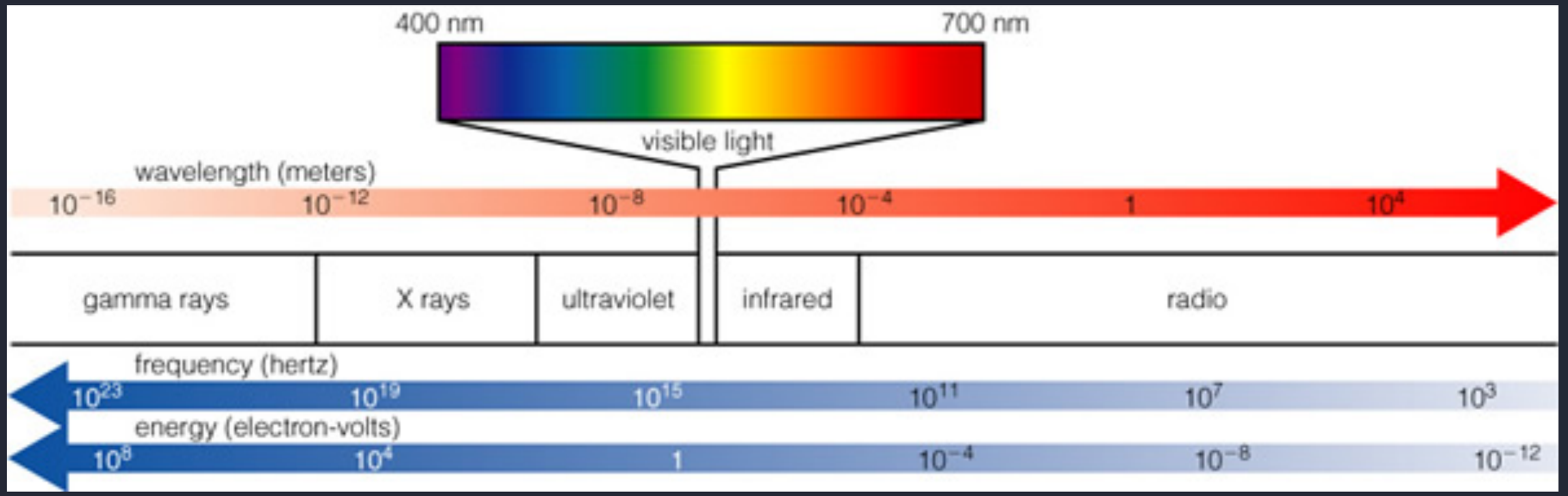
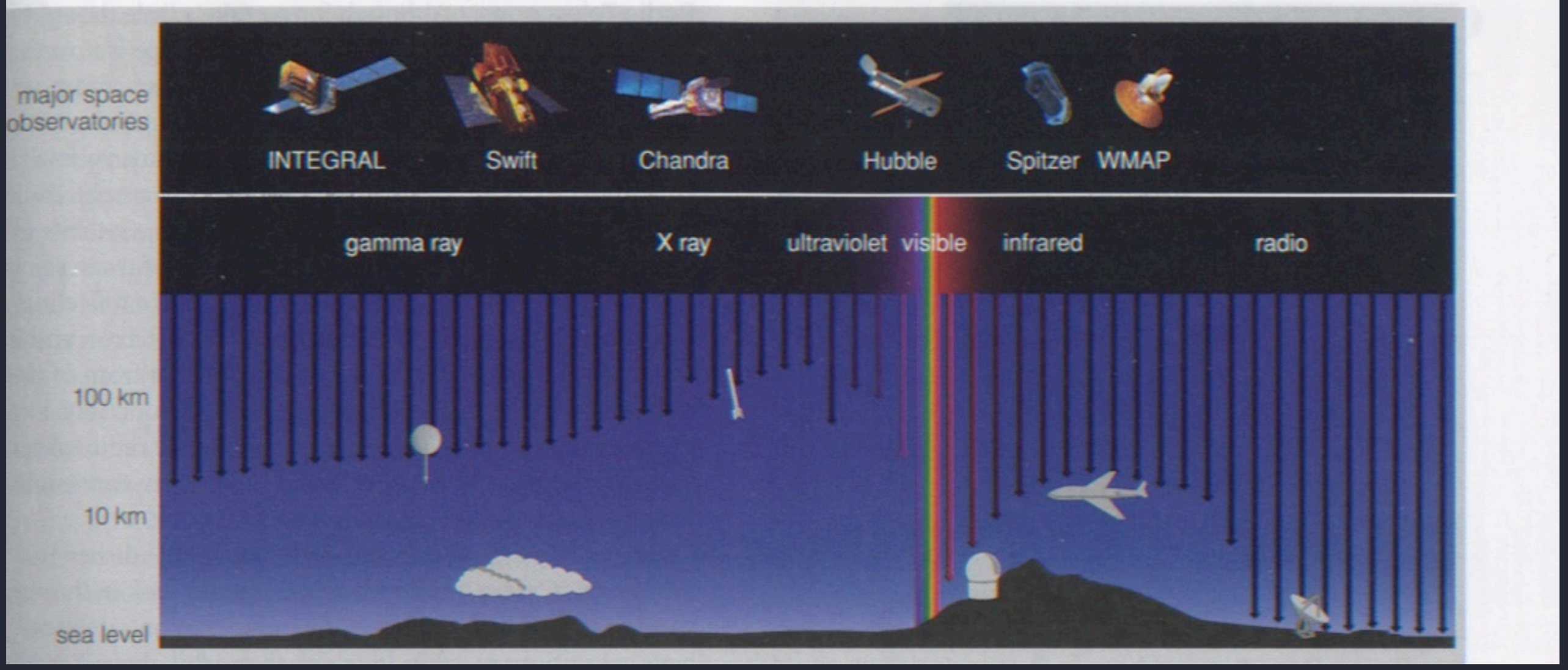
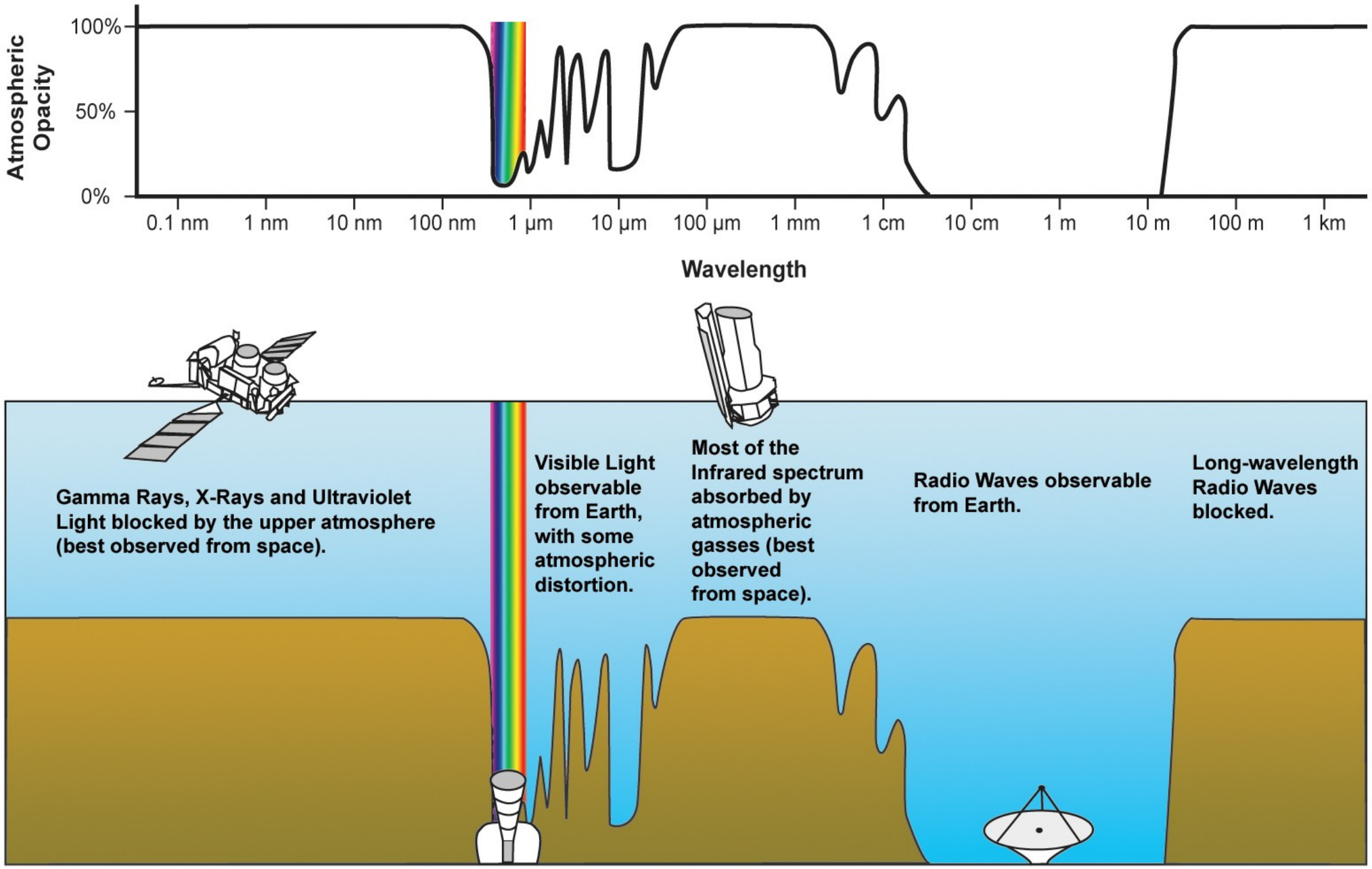


FIGURE 6.6 Interactive Figure This diagram shows how angular separation depends on distance. The headlights on the car have the same physical separation in both cases, but their angular separation is larger when the car is closer. Similarly, two stars separated by a particular distance will have a larger angular separation if they are nearby than if they are farther away.

able to observe infrared (IR) and ultraviolet (UV) light, which is absorbed by the atmosphere


400 nm
700 nm
visible light
wavelength (meters)
10^{-16}
10^{-12}
10^{-8}
10^{-4}
1
10^{4}
gamma rays
X rays
ultraviolet
infrared
radio
frequency (hertz)
10^{23}
10^{19}
10^{15}
10^{11}
10^{7}
10^{3}
energy (electron-volts)
10^{8}
10^{4}
1
10^{-4}
10^{-8}
10^{-12}


major space observatories
INTEGRAL
Swift
Chandra
Hubble
Spitzer
WMAP
gamma ray
X ray
ultraviolet
visible
infrared
radio
100 km
10 km
sea level


Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.

Radio waves can make it through the atmosphere…but they don't show up on film or CCDs… need different kinds of detectors (that rely on the wave-nature of light).

Radio telescopes are often coupled in arrays…which act like one big telescope. The Very Large Array (VLA) in New Mexico.

Question: Why do radio telescopes need to be so **big** in order to achieve **good resolution**?

The Sombrero Galaxy

Photograph in visible light

The Sombrero Galaxy

Photograph in *infrared* light

Telescopes allow us to see faint objects (light gathering power) in great detail (theoretical resolution – diffraction limit)

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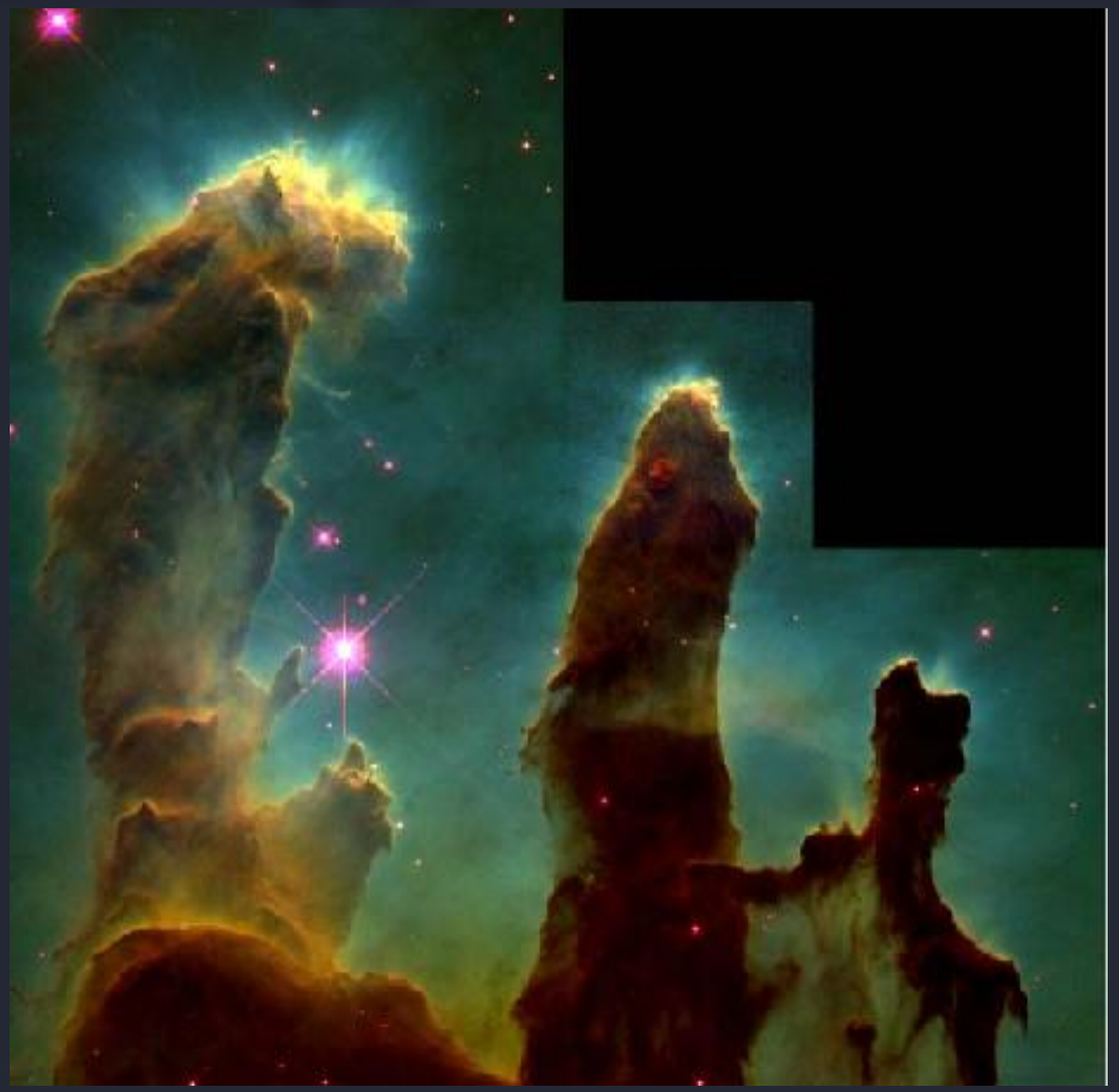
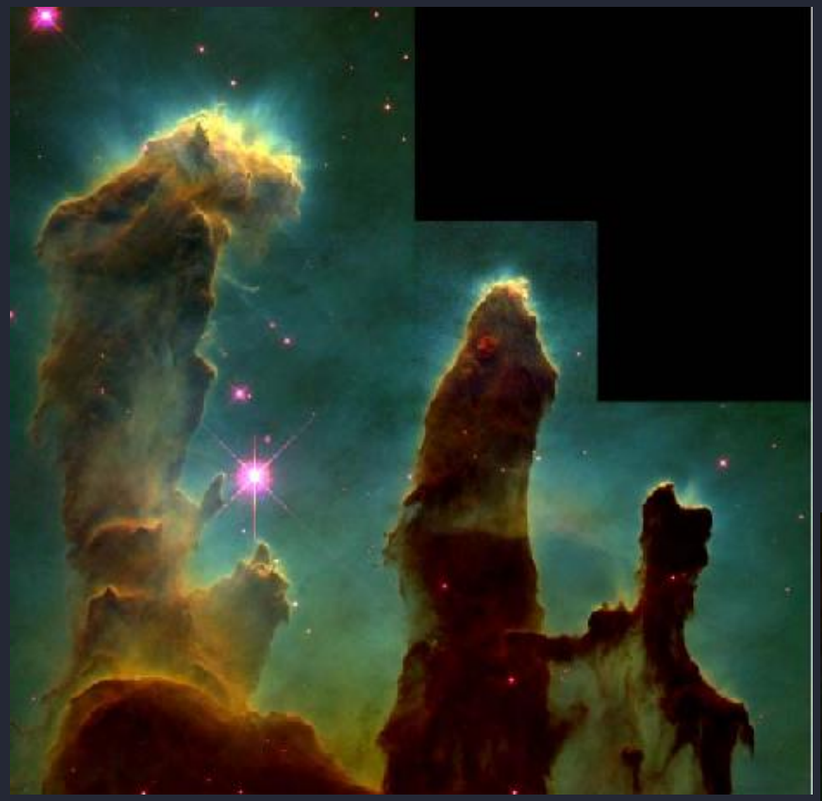
And the Hubble Space Telescope image (below) shows incredible detail (why? Its theoretical resolution is worse than the telescope that made the IR image?)





Telescope + camera = ability to observe faint objects

If the dimmest star you can see with your naked eye has $B = 10^{-9}\ W/m^2$, then what's the the brightness B of the dimmest star you can see with an 8 hour exposure on a 10 meter telescope?

And if the naked-eye visible star has the same luminosity as the Sun, how far away is it? (How many AU? How many parsecs?)

Telescope + camera = ability to observe faint objects

Now, how far away can the 10 meter telescope see?
(assuming that the star it sees also has $L = L_{sun}$)