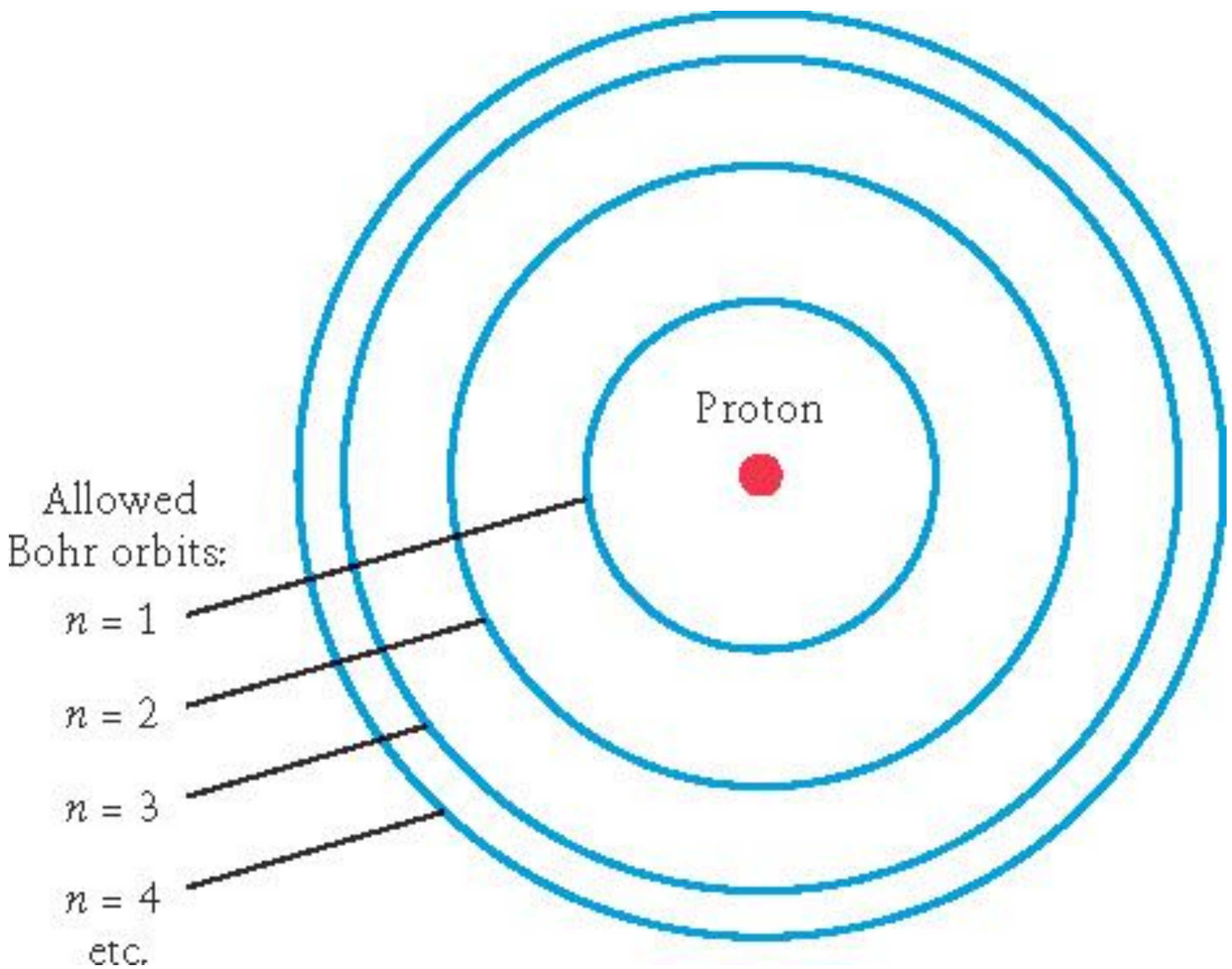
Today

- Emission & Absorption lines
  measuring elemental abundances
- Doppler Effect
  measuring motion
- Telescopes
  technology to measure with
- Solar System Overview
  what's out there?

Next time

- Homework 3 Due

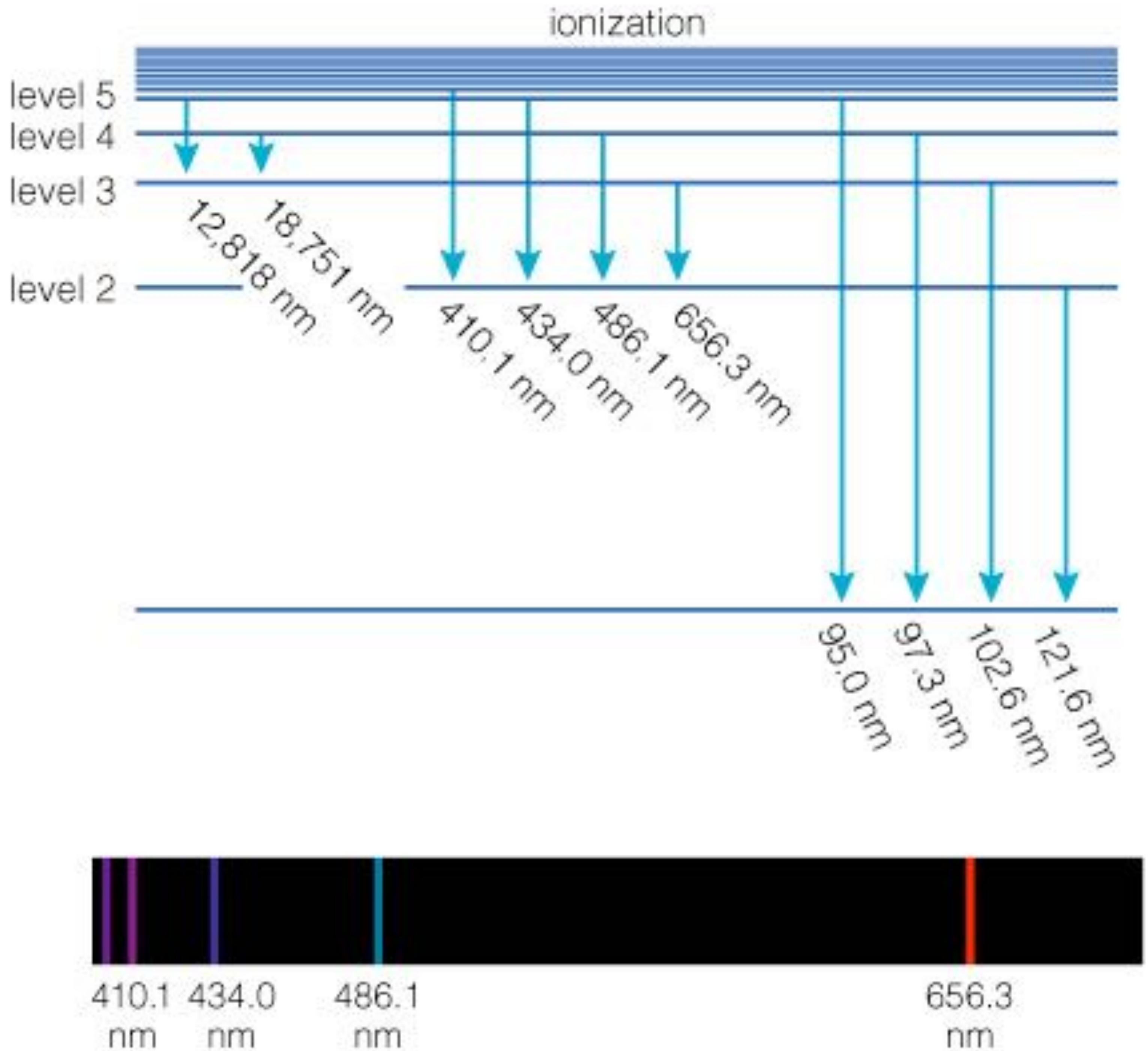
Chemical Fingerprints



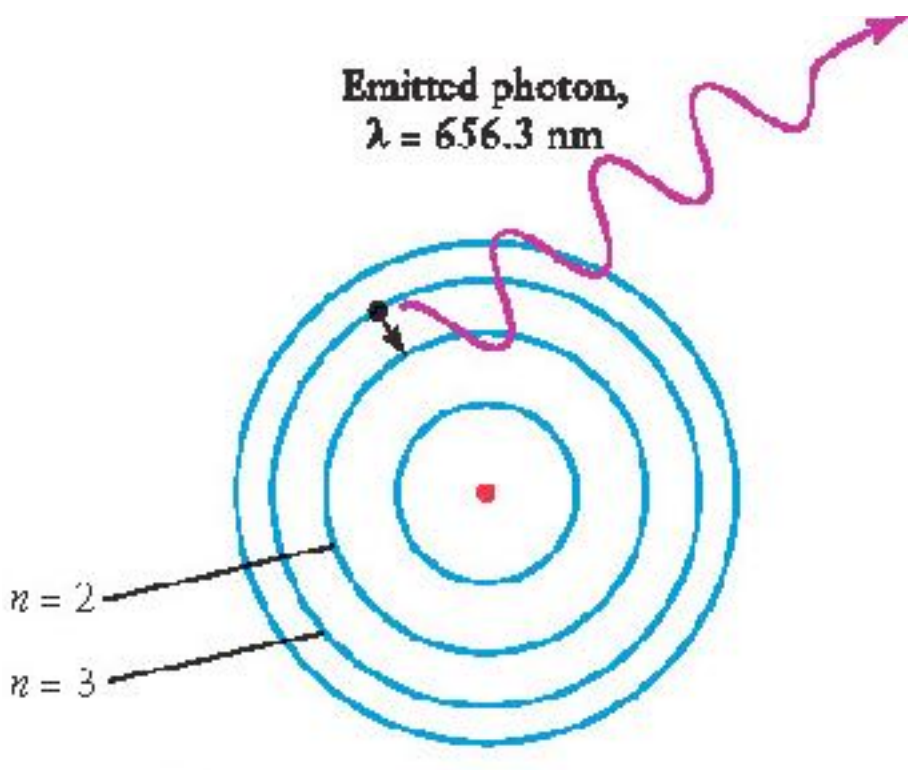
Energy levels of hydrogen

- Each type of atom has a unique set of energy levels.
- Each transition corresponds to a unique photon energy, frequency, and wavelength.

Chemical Fingerprints

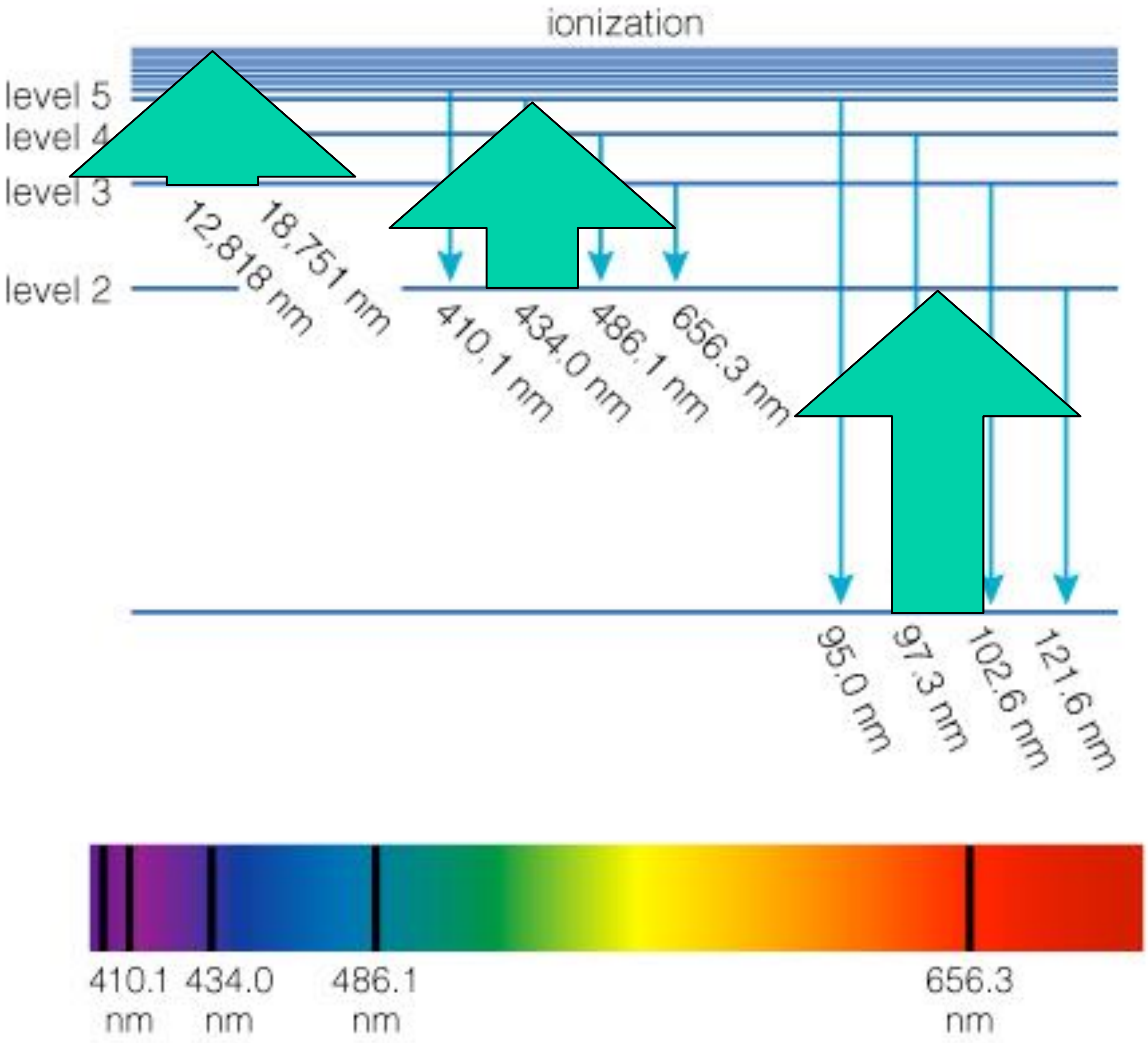


- Downward transitions produce a unique pattern of emission lines.

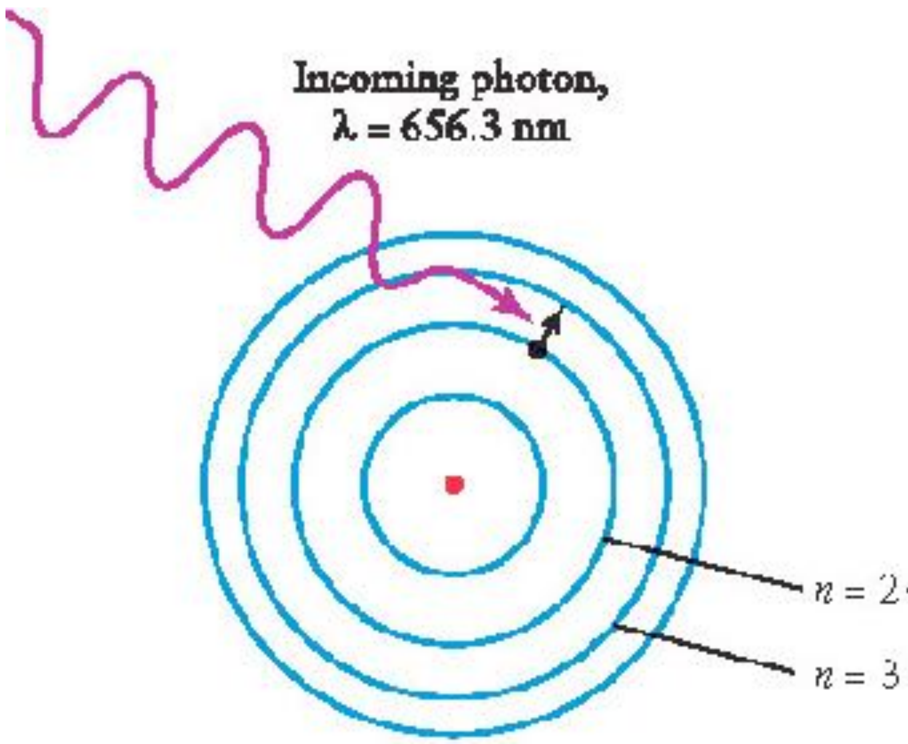


(b) Electron falls from the n = 3 orbit to the n = 2 orbit; energy lost by atom goes into emitting a 656.3-nm photon

Chemical Fingerprints



- Atoms can absorb photons with those same energies, so upward transitions produce absorption lines.

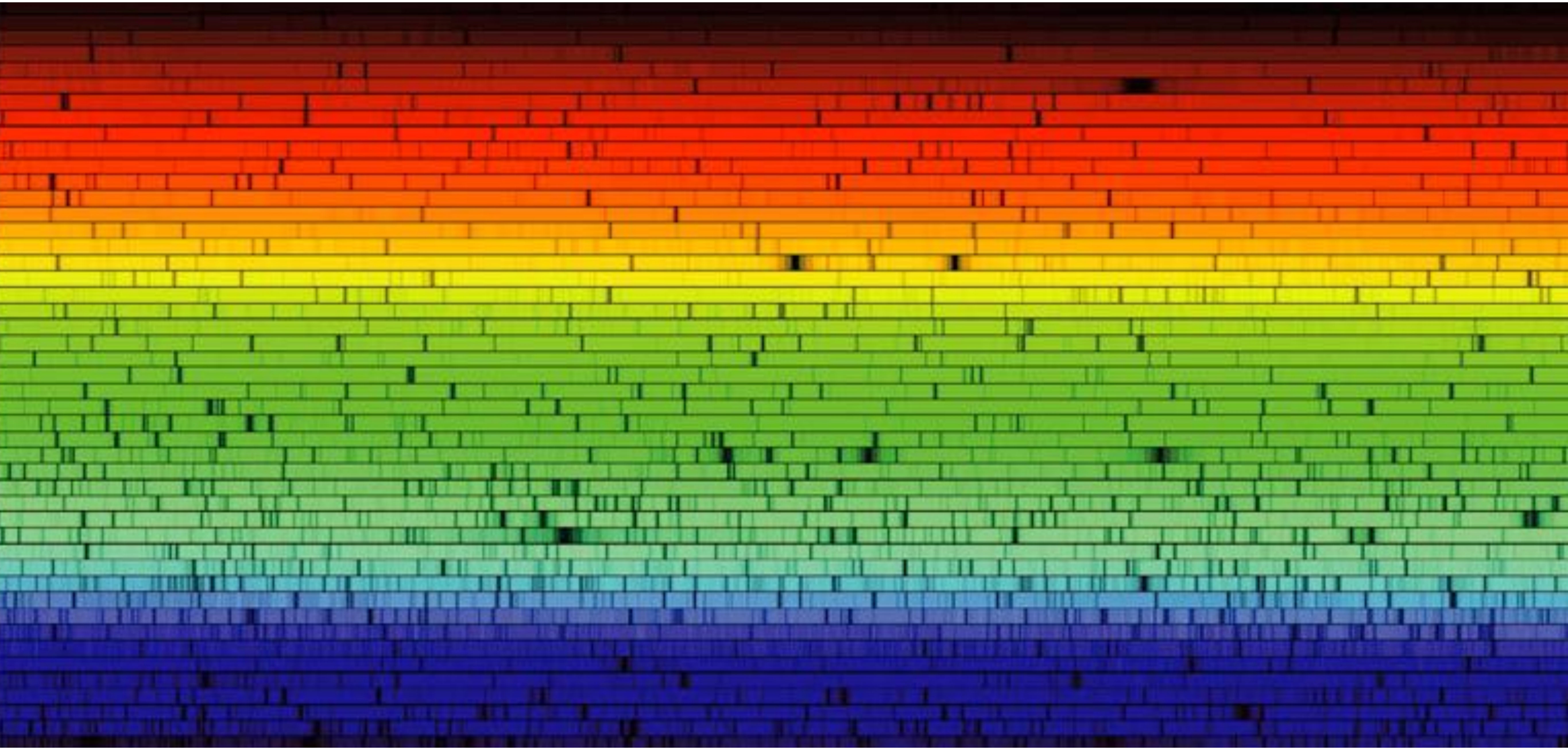


(a) Atom absorbs a 656.3-nm photon; absorbed energy causes electron to jump from the n = 2 orbit up the n = 3 orbit

Chemical Fingerprints

- Each type of atom has a unique spectral fingerprint.

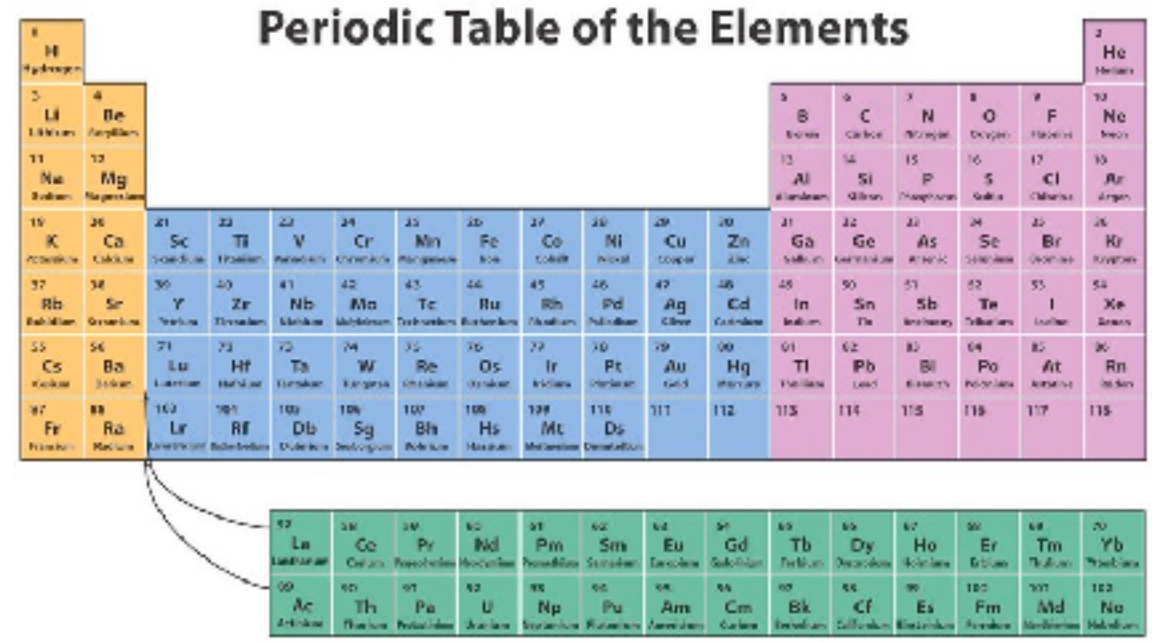
Example: Solar Spectrum



All the dark regions are absorption lines due to all the elements in the sun's atmosphere. The strengths of the lines tell us about the sun's composition and other physical properties like temperature and surface gravity.

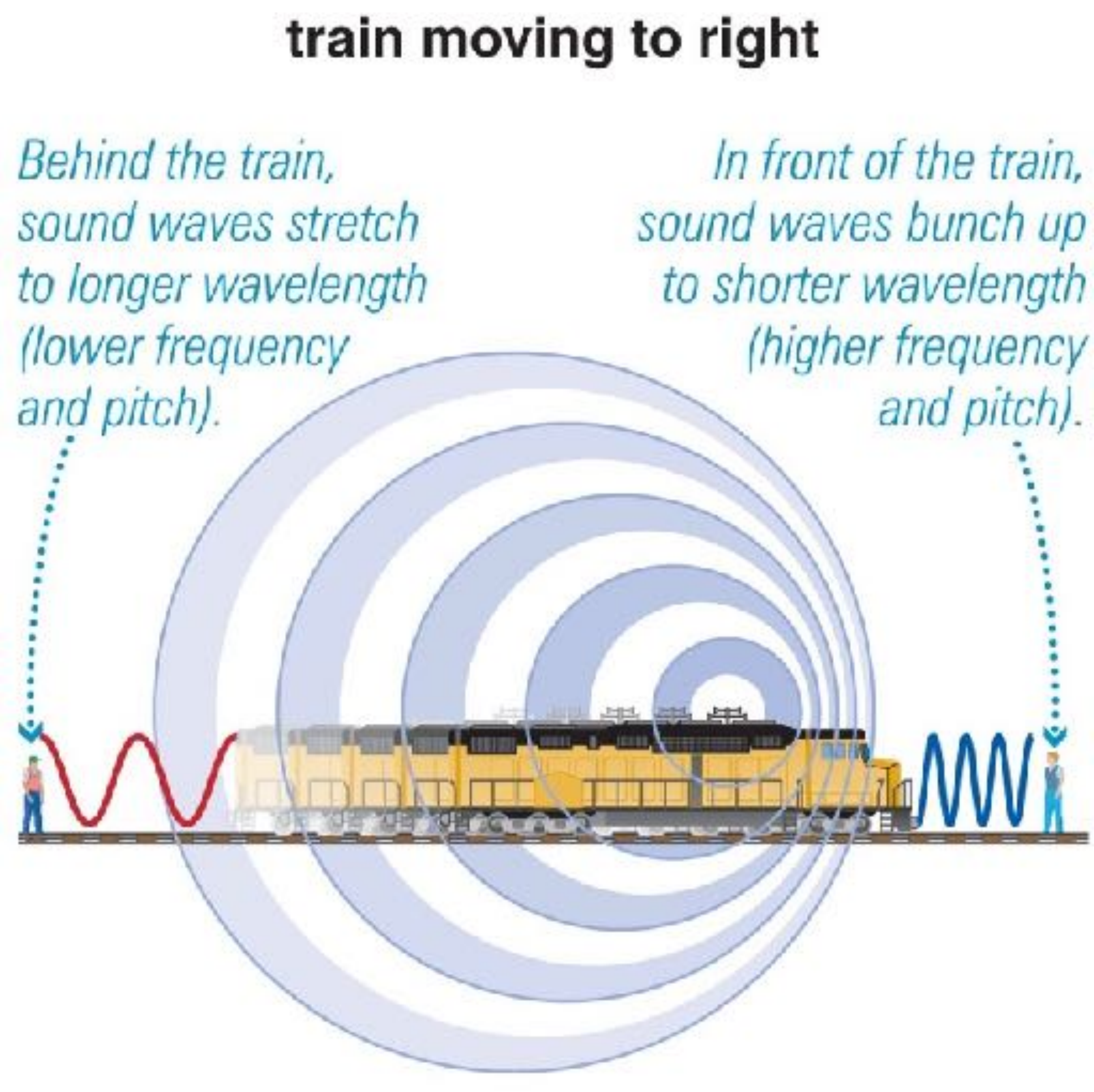
Solar composition

- 73% Hydrogen
- 25% Helium
- 2% everything else
  - "metals"



- Other stars similar
  - H & He most common stuff in the universe
  - Helium was *discovered* in the spectrum of the sun
  - nearly everything other element made by stars

The Doppler Effect



b For a moving train, the sound you hear depends on whether the train is moving toward you or away from you.

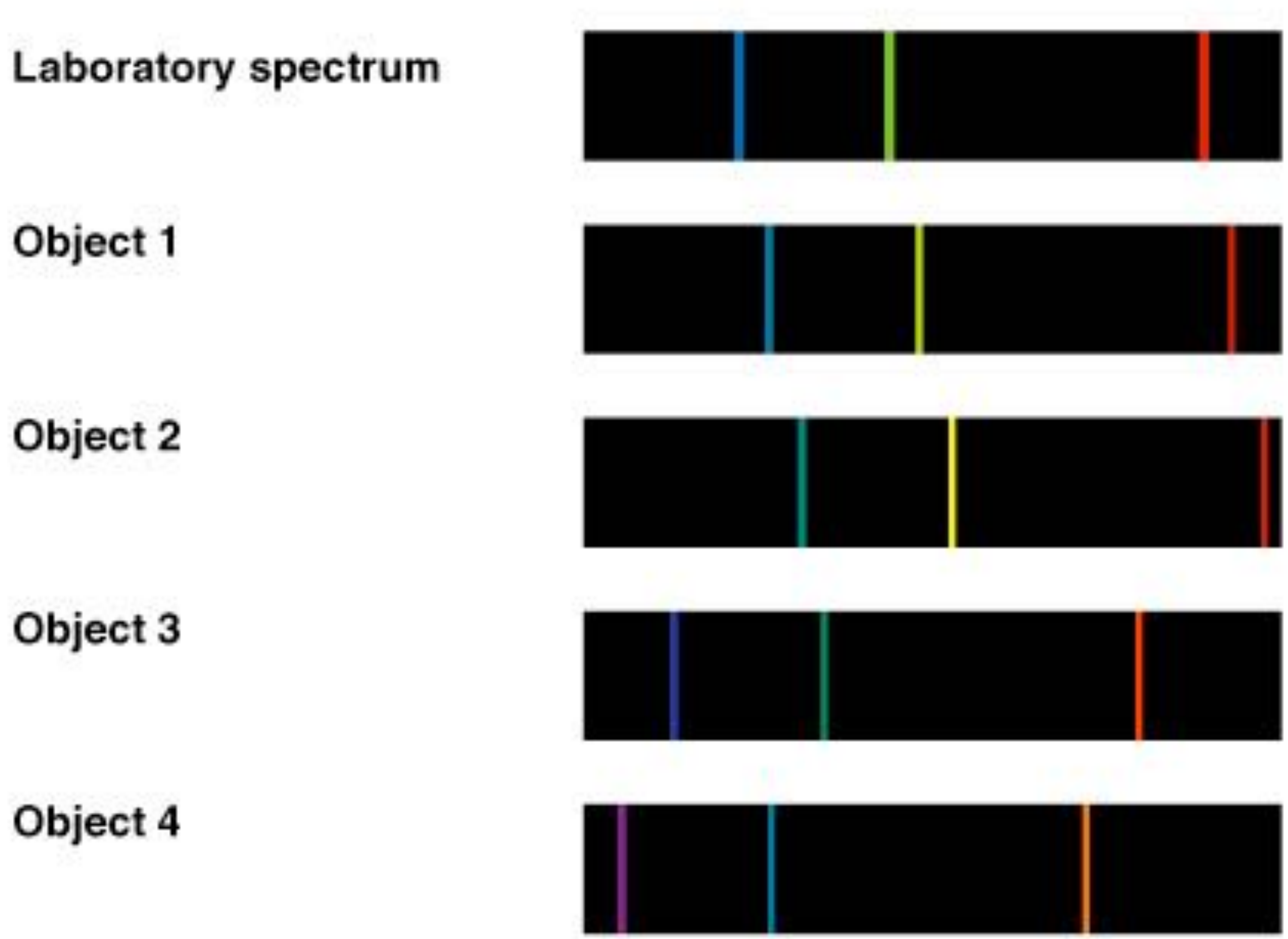
Doppler ball

Doppler Effect for Light

- Motion away -> redshift
- Motion towards -> blueshift

$$\frac{\text{wavelength shift}}{\text{wavelength}} \quad \frac{\Delta\lambda}{\lambda} = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{v}{c} \quad \frac{\text{speed}}{\text{speed of light}}$$

Measuring the Shift



Stationary

Moving Away

Away Faster

redshift

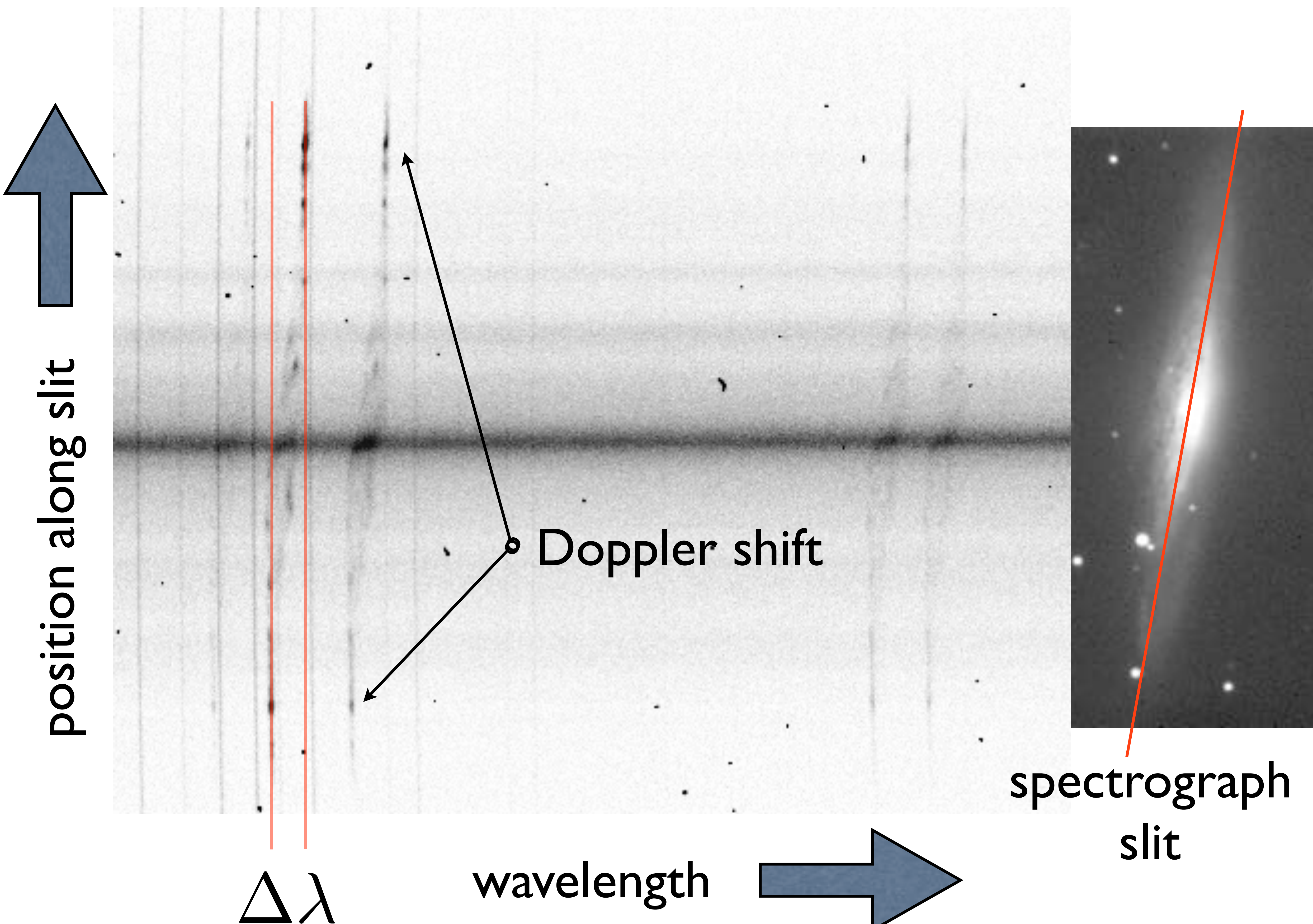
Moving Toward

Toward Faster

blueshift

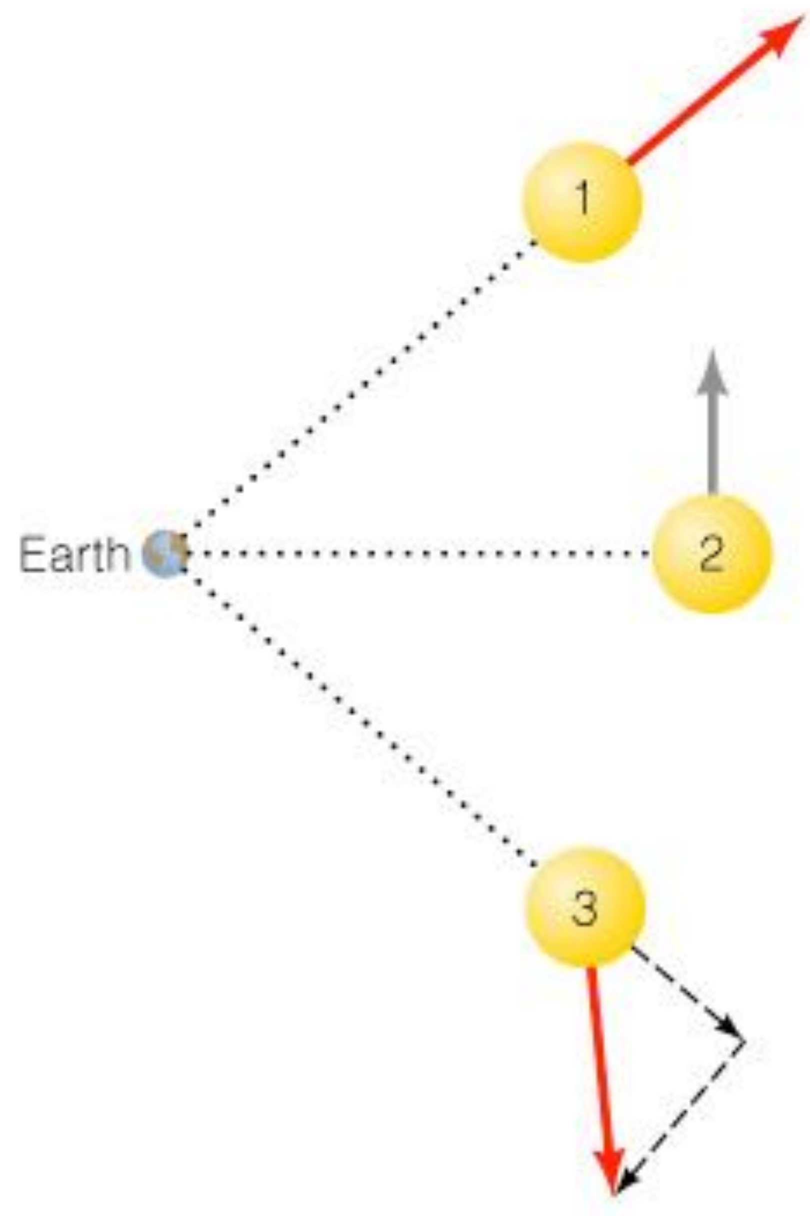
- We generally measure the Doppler effect from shifts in the wavelengths of spectral lines.

Spectrum



position along slit
Doppler shift
$\Delta\lambda$
wavelength
spectrograph
slit

Doppler shift tells us ONLY about the part of an object's motion toward or away from us (along our line of sight).



maximum doppler effect

no doppler effect

intermediate case

Telescopes

- Telescopes collect more light than our eyes ⇒ **light-collecting area**
- Telescopes can see more detail than our eyes ⇒ **angular resolution** (magnification)
- Telescopes/instruments can record light more sensitively than our eyes, and detect electromagnetic radiation that is invisible to our eyes (e.g., infrared, ultraviolet)

Bigger is better

1. Larger light-collecting area

   can see fainter things

2. Better angular resolution

   can see smaller things

Bigger is better

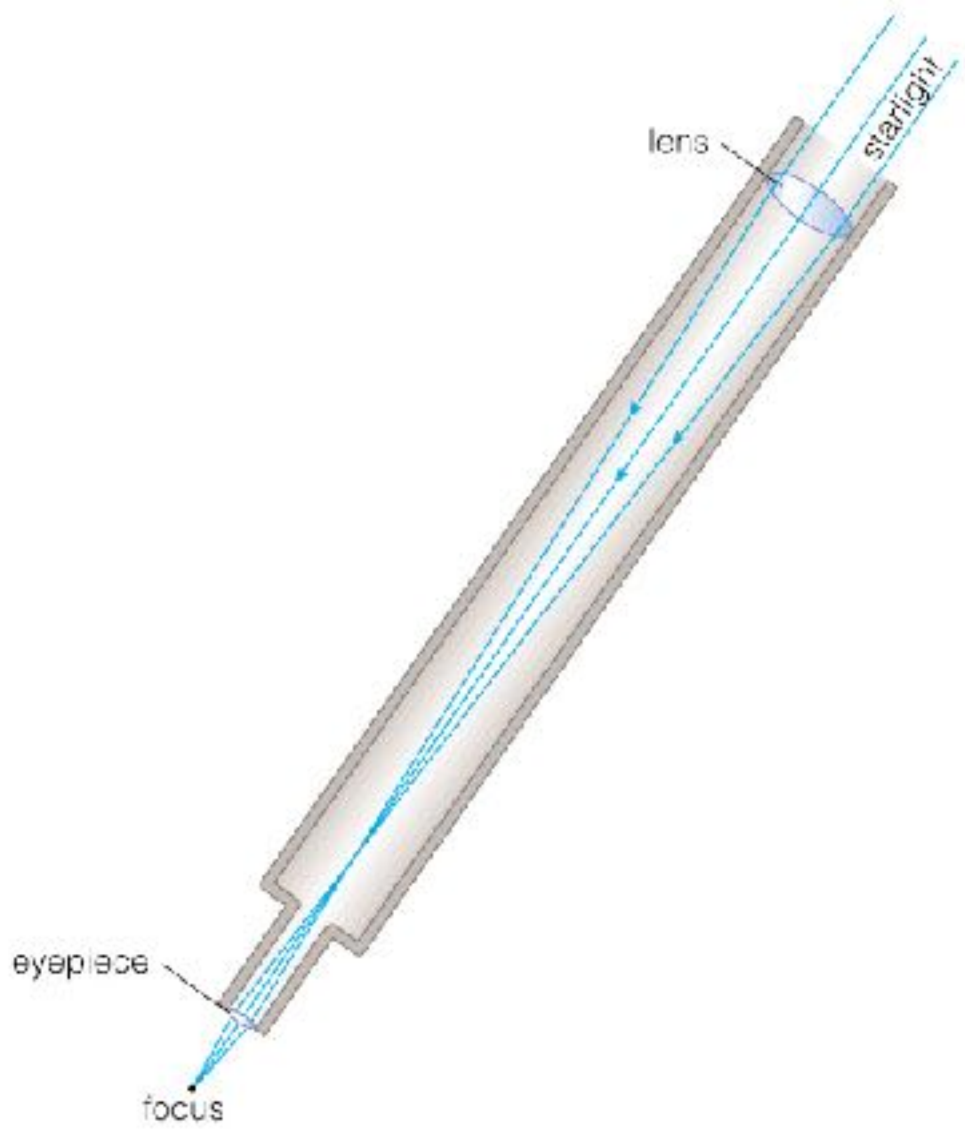
For a telescope with mirror of diameter D,

can see fainter: $$b^{-1} \propto D^2$$

with higher resolution: $$\theta \propto \frac{\lambda}{D}$$

Basic Telescope Design

- Refracting: lenses

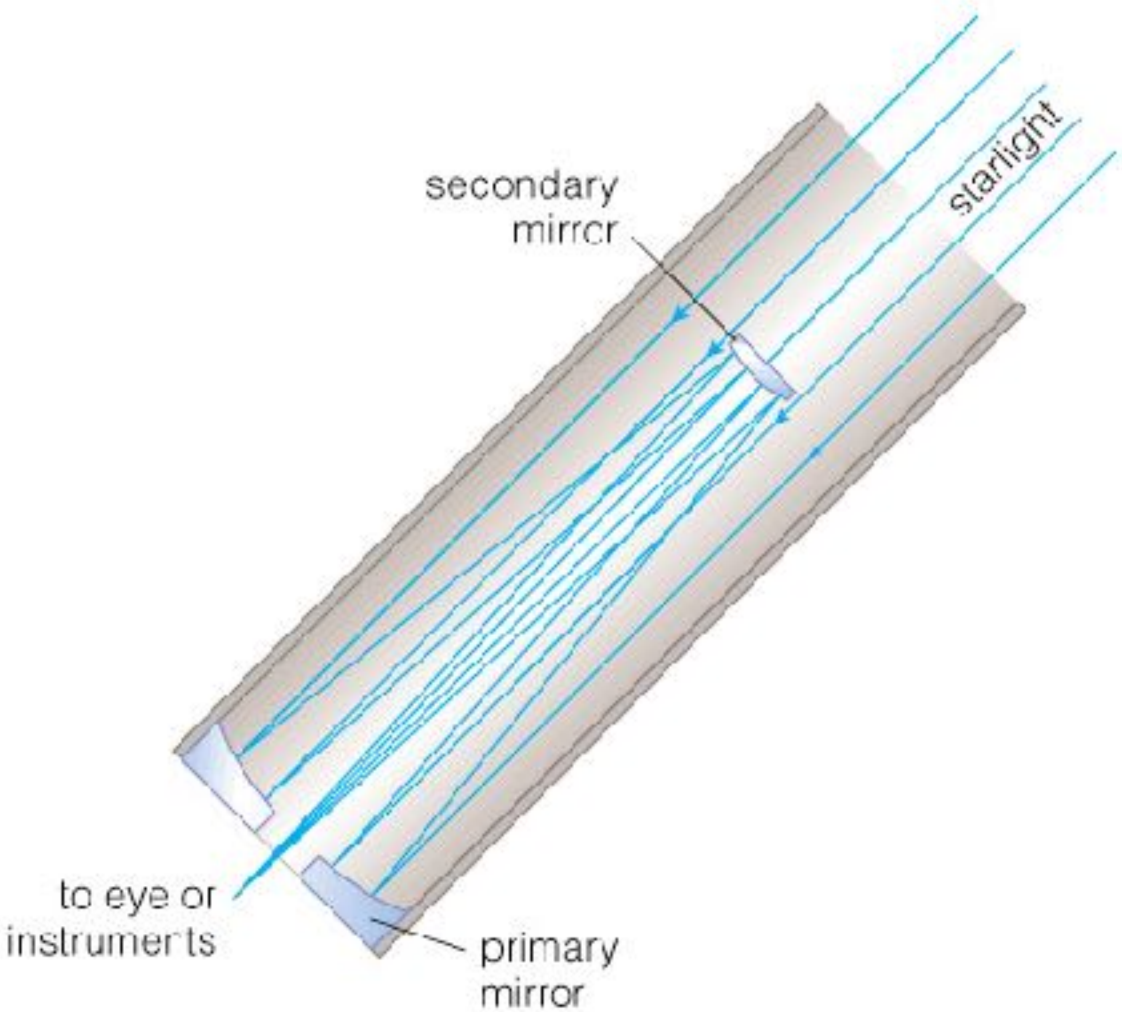


Refracting telescope

Yerkes 1-m refractor

Basic Telescope Design

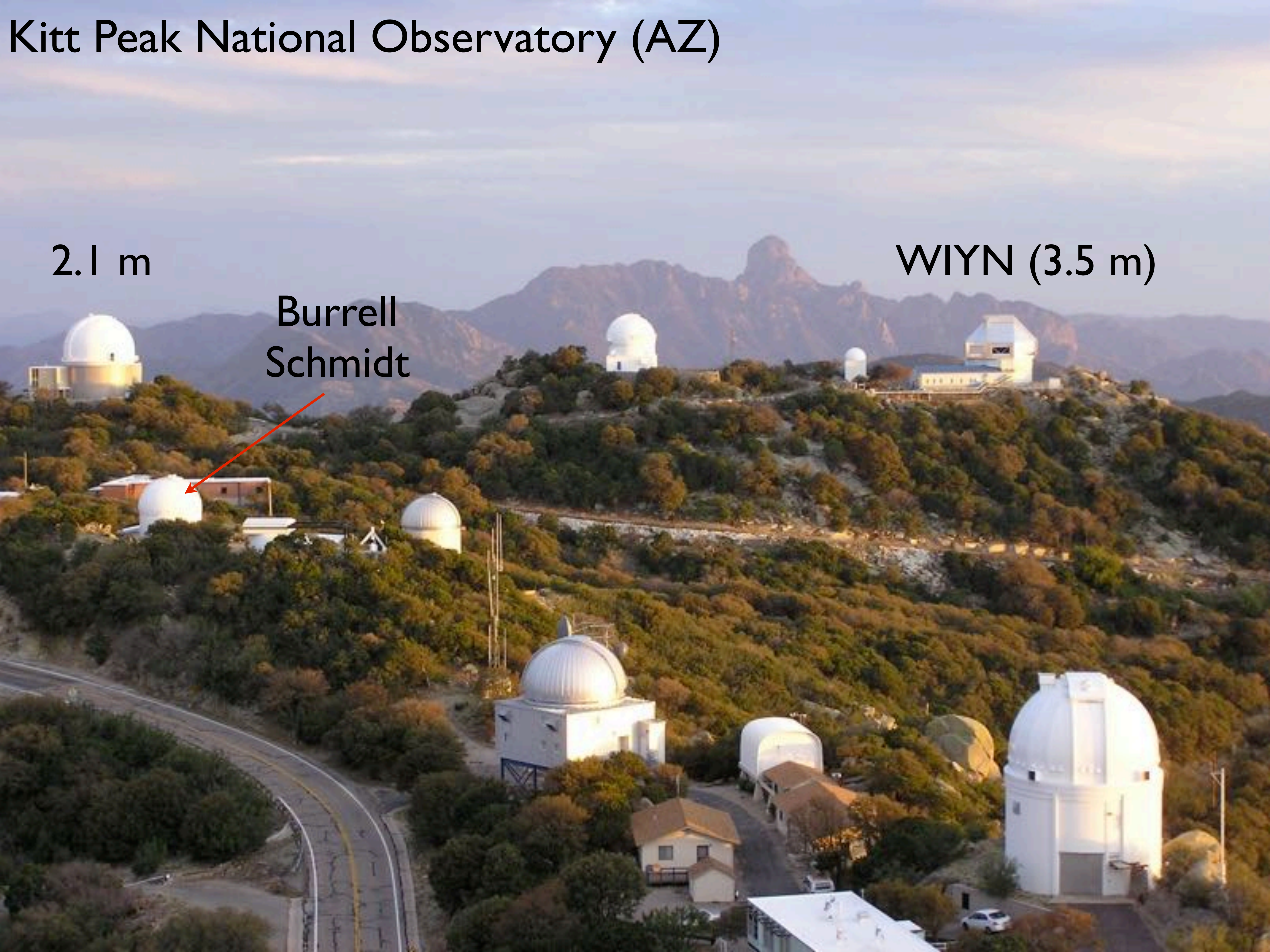
- Reflecting: mirrors
- Most research telescopes today are reflectors



Reflecting telescope

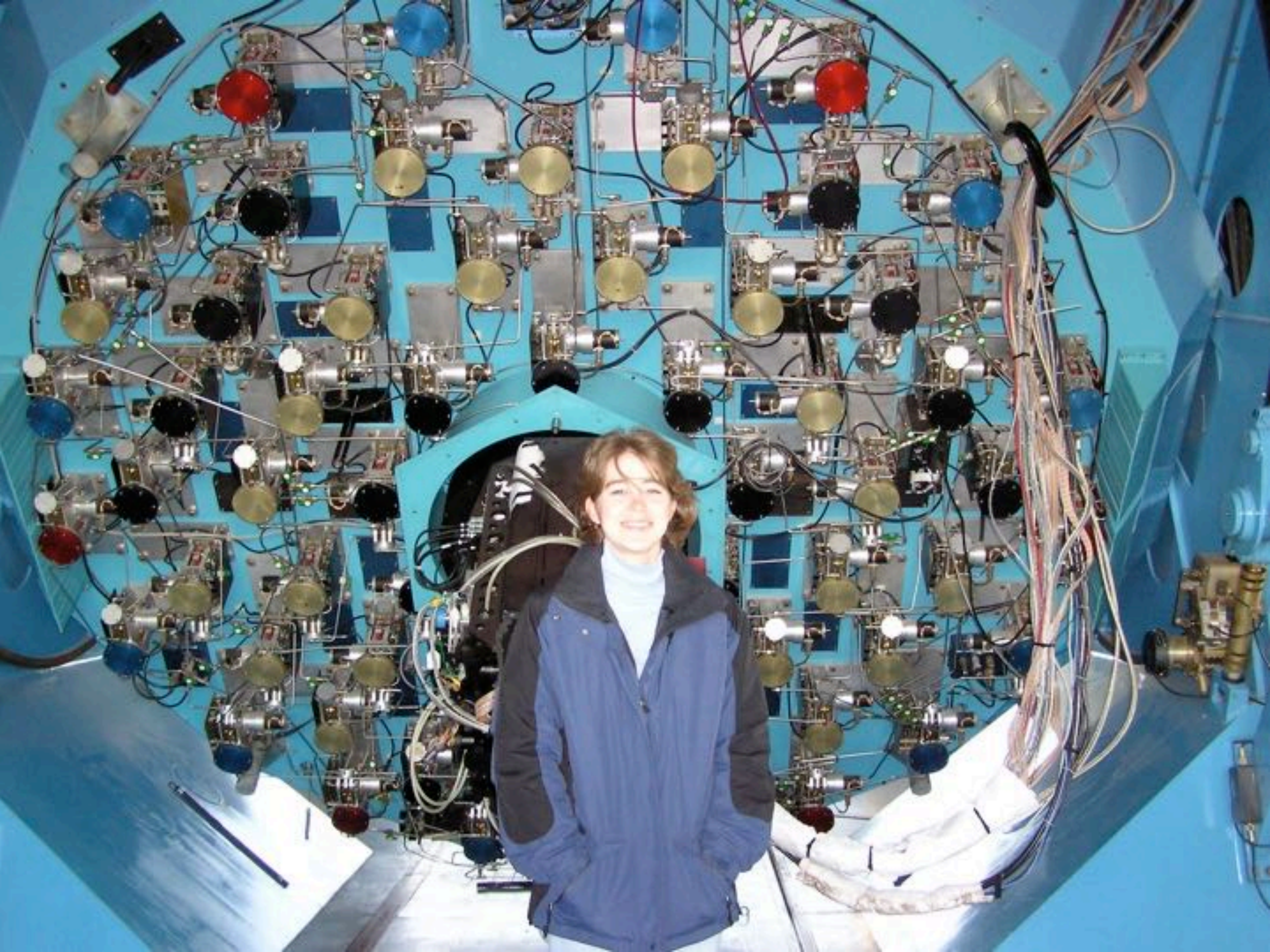
Gemini North 8-m

Kitt Peak National Observatory (AZ)



Burrell Schmidt

WIYN 3.5 m



Advantages of telescopes in space

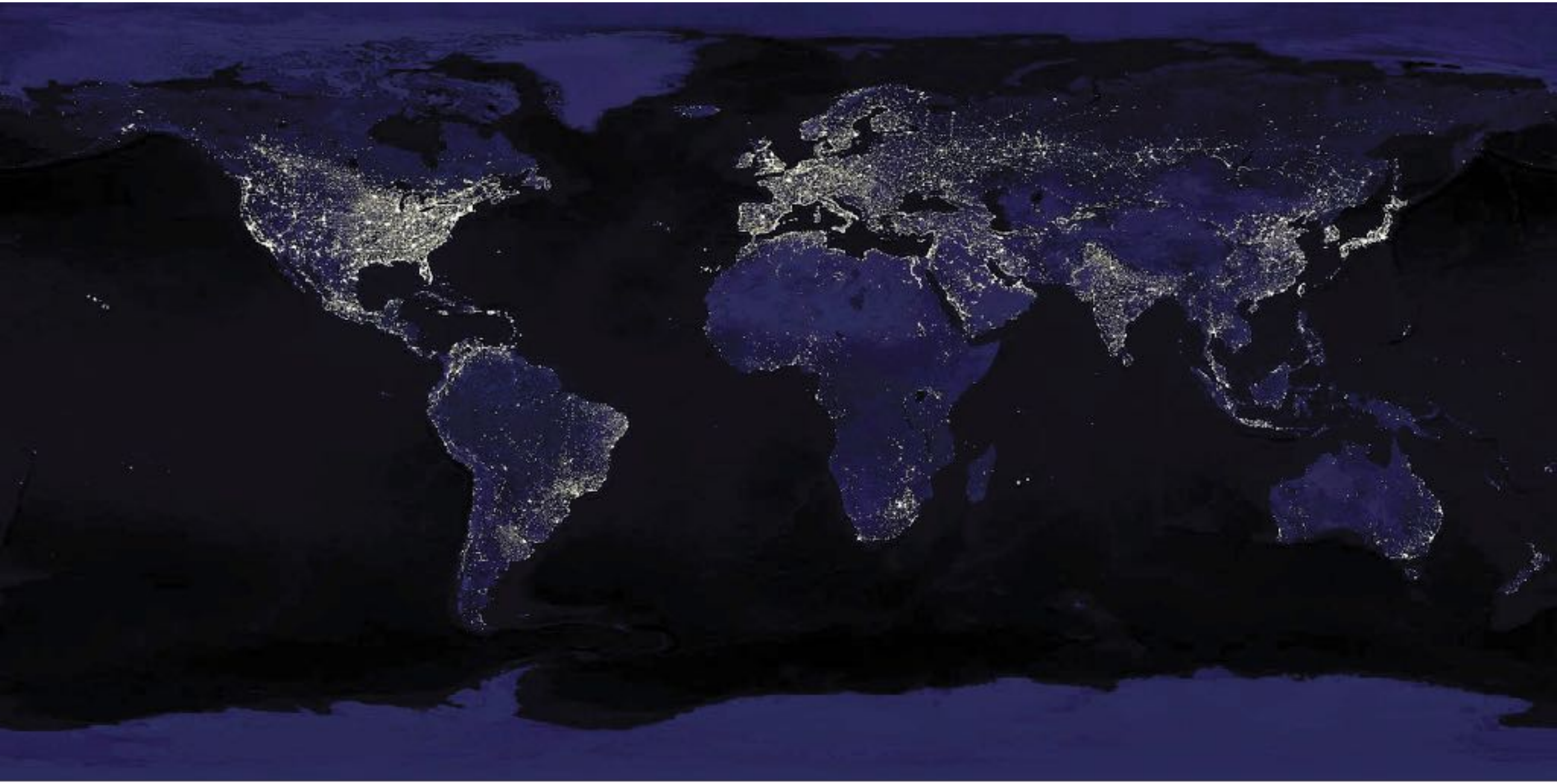
Hubble

Chandra

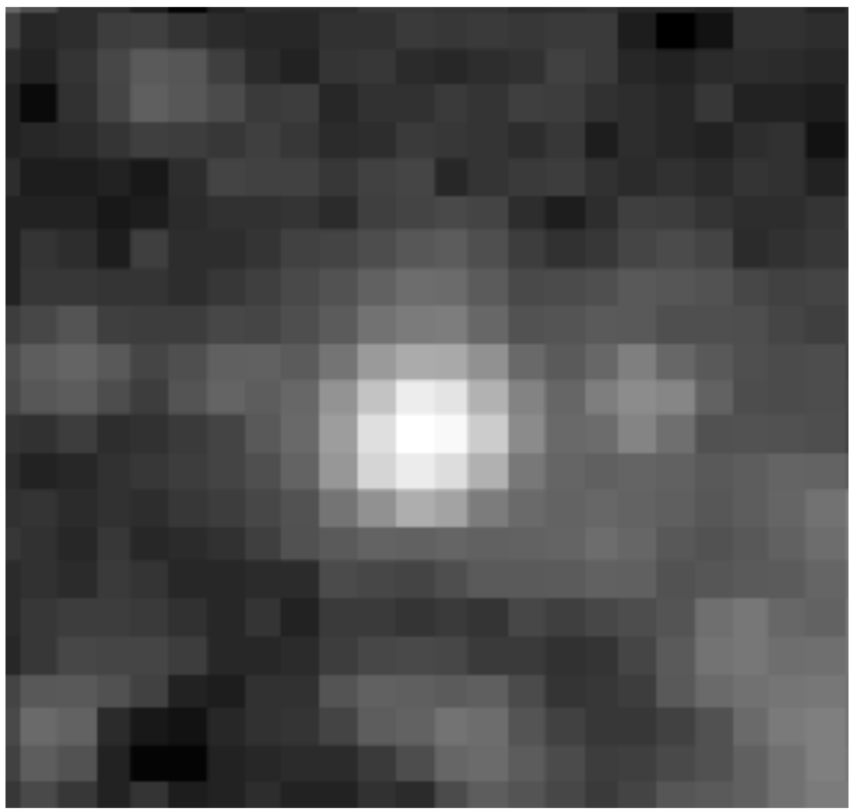
Fun fact: one of these pictures is real; the other is fake. Can you tell the difference?

Observing problems due to Earth's atmosphere

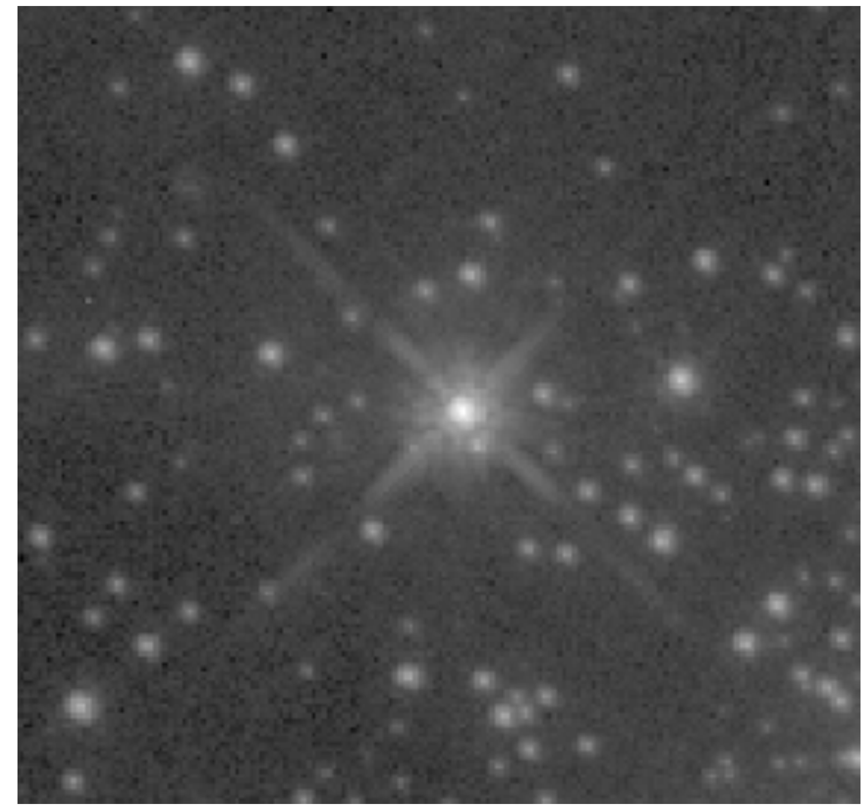
1. Light Pollution



2. Atmospheric Turbulence causes *twinkling* ⇒ blurs images (called “seeing” by astronomers).



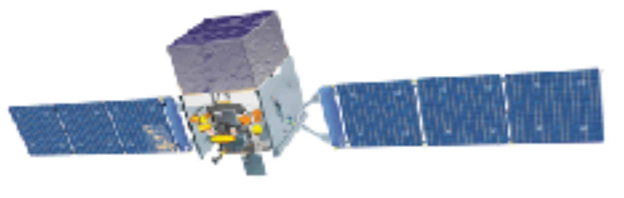
Star viewed with ground-based telescope

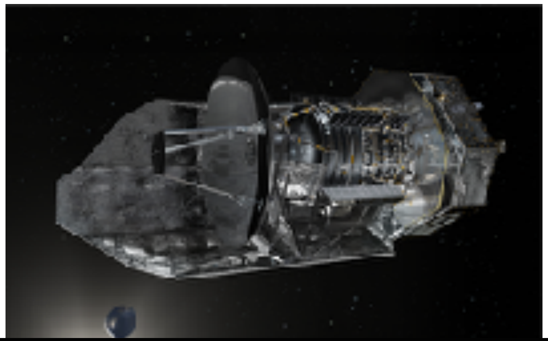


View from Hubble Space Telescope

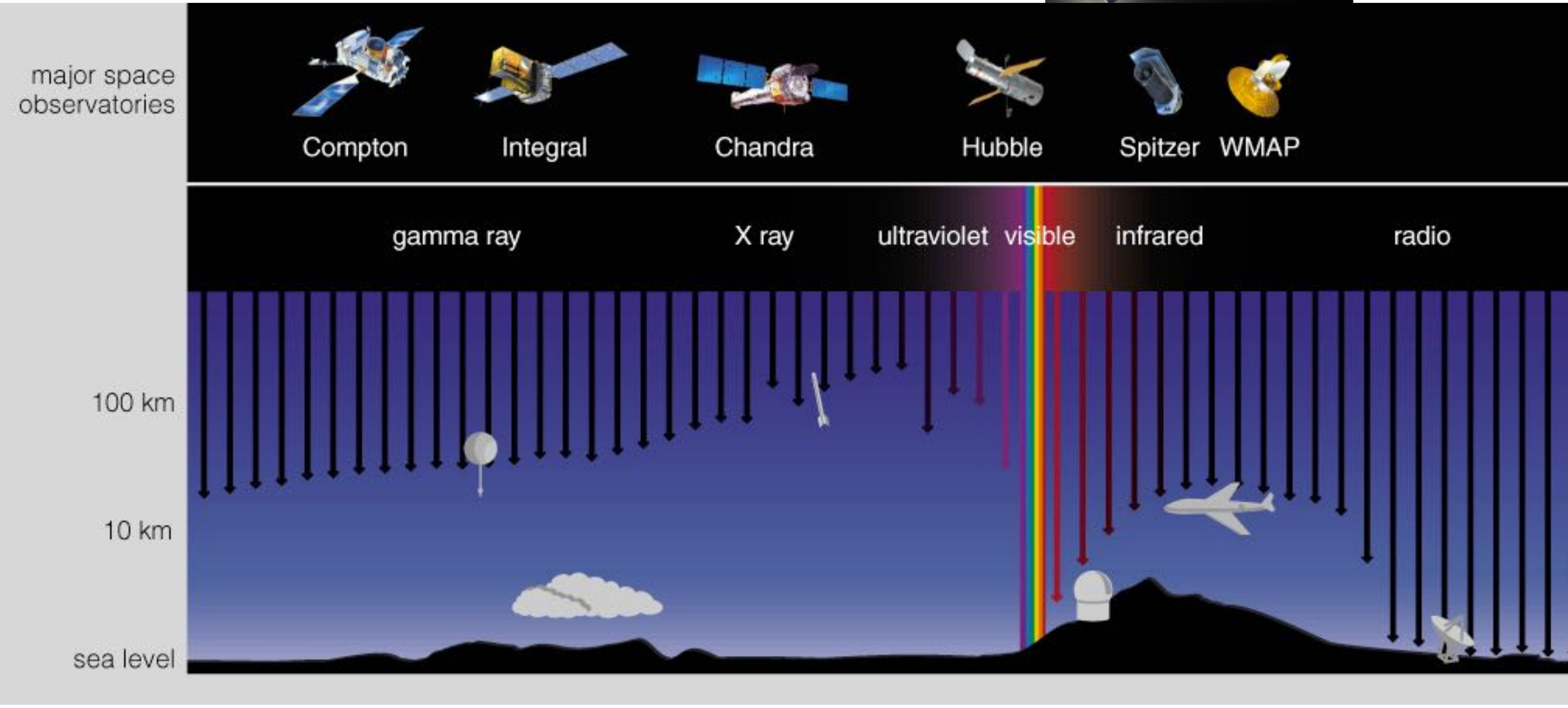
3. Atmosphere absorbs most of EM spectrum, including all UV and X ray and most infrared.

Fermi



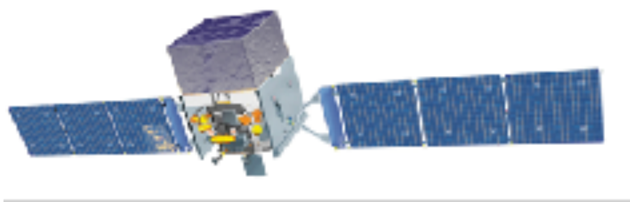


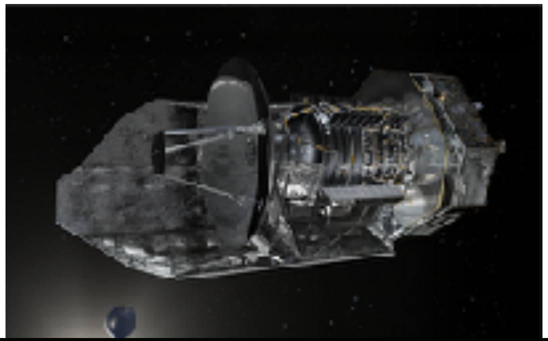
Herschel



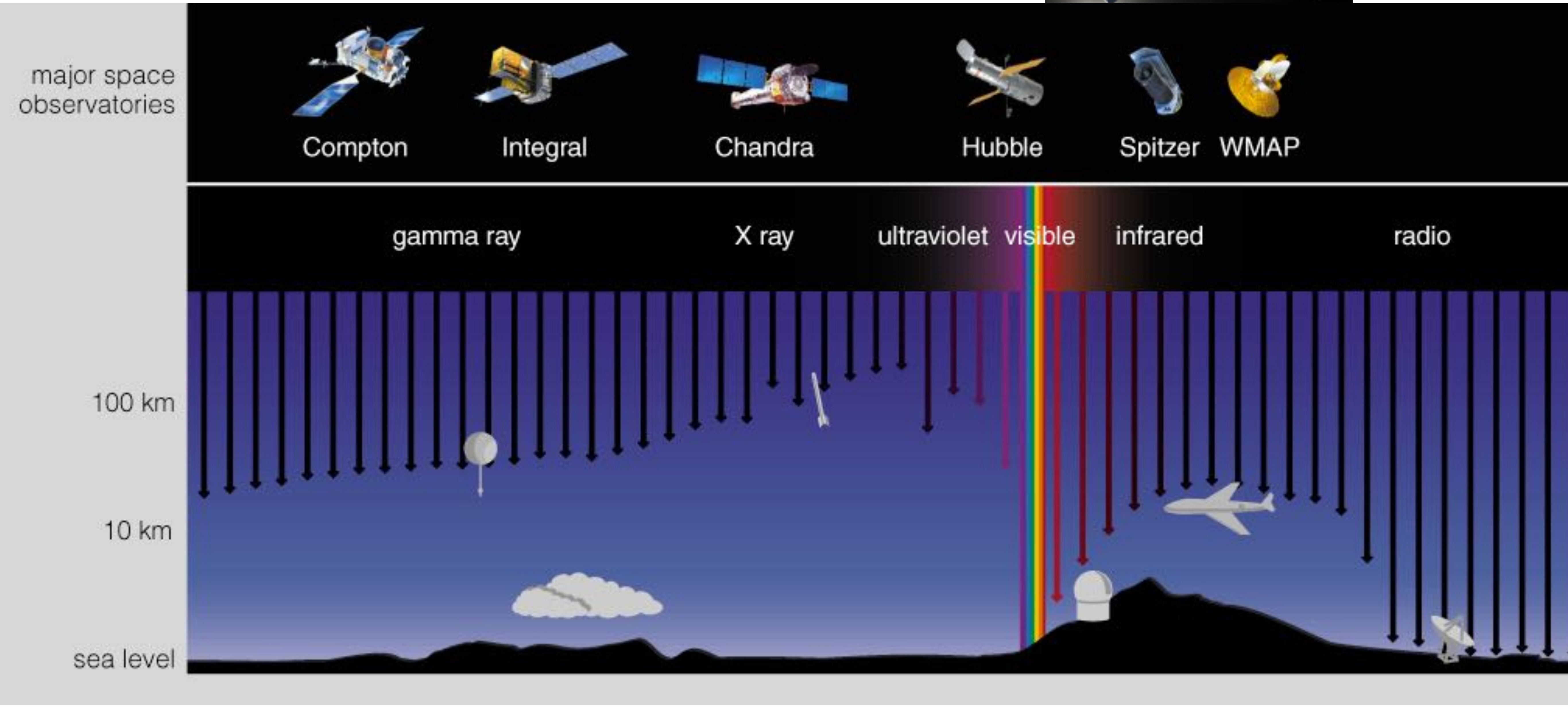
Telescopes in space solve all 3 problems.

Fermi



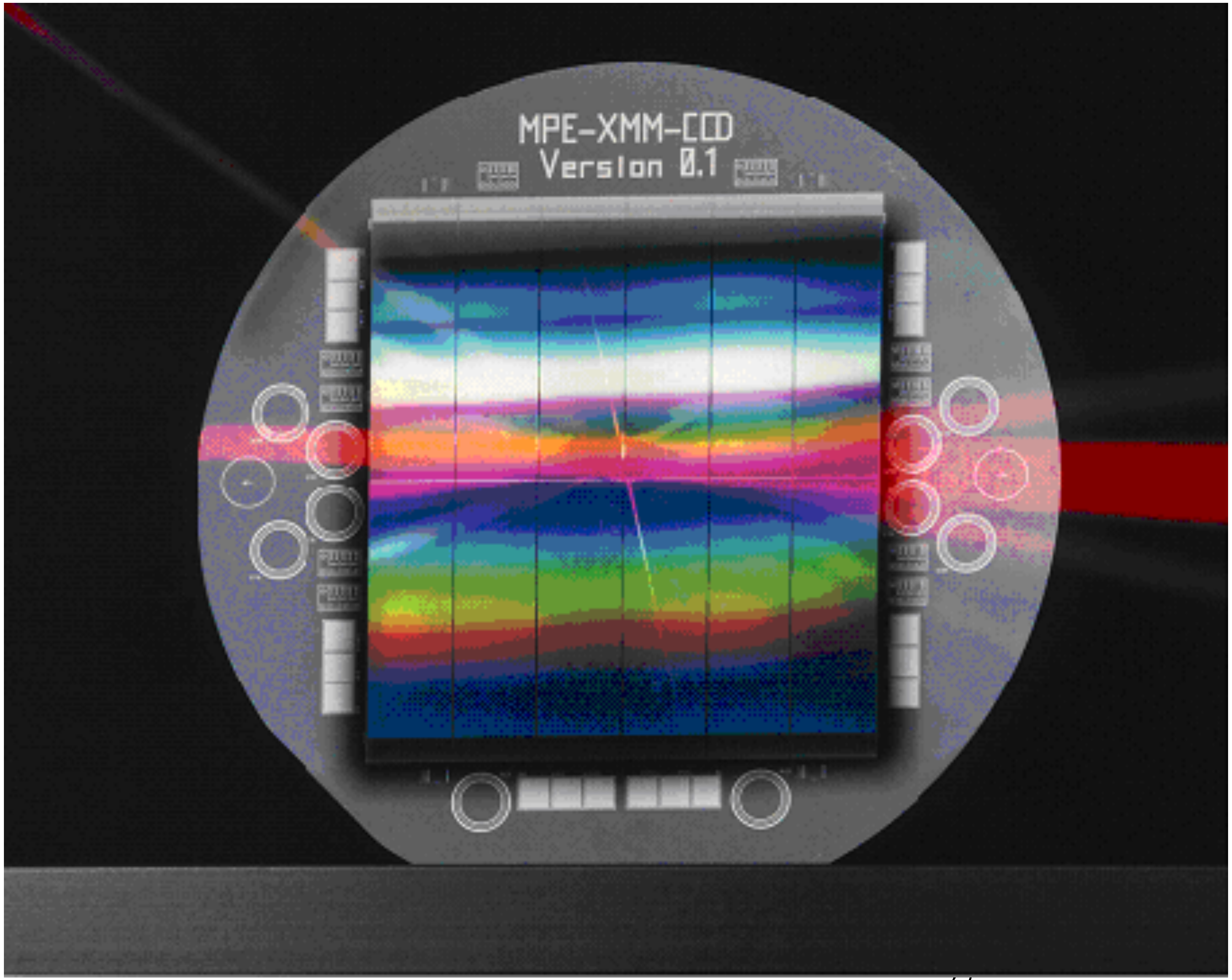


Herschel

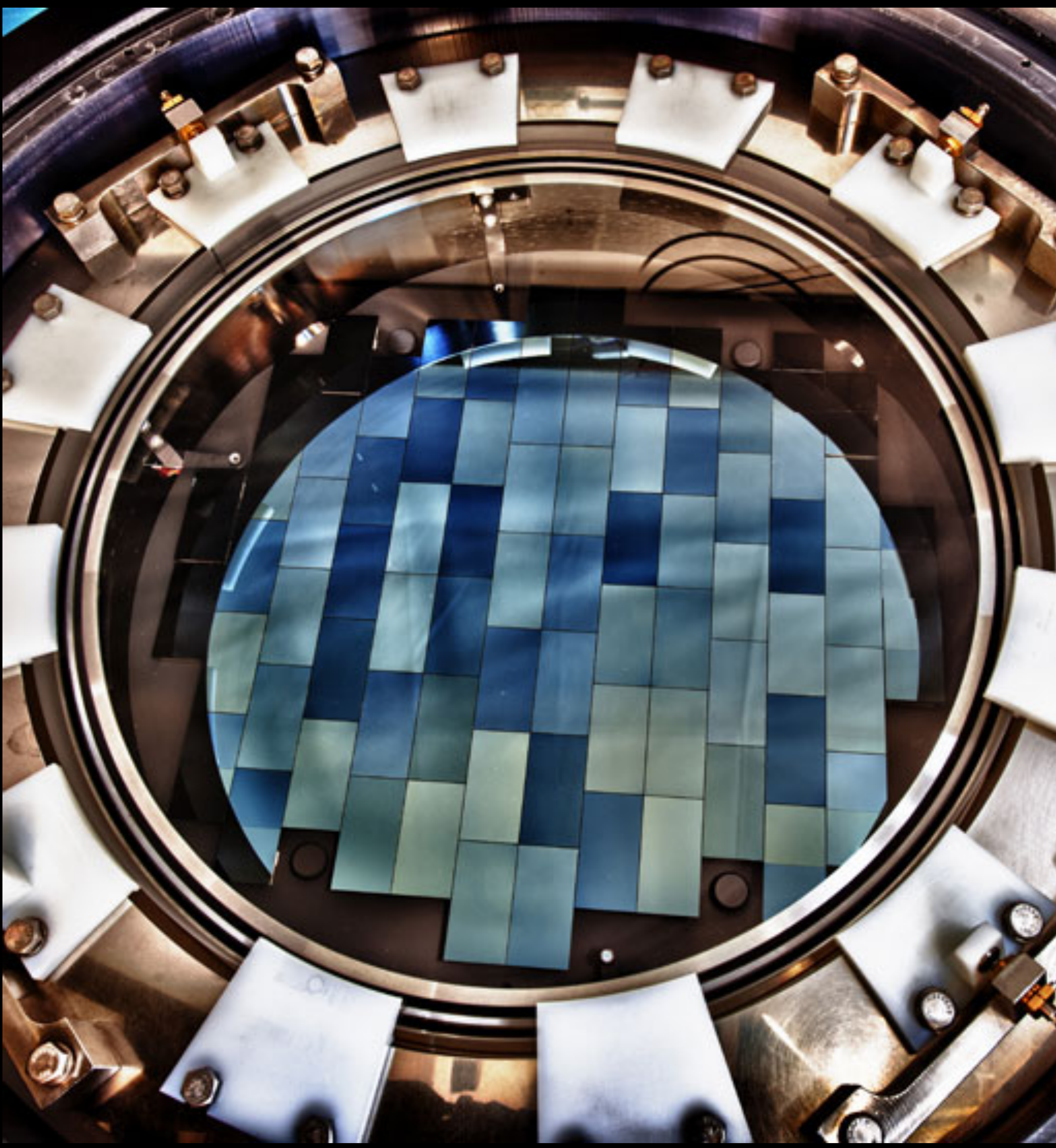


Instruments

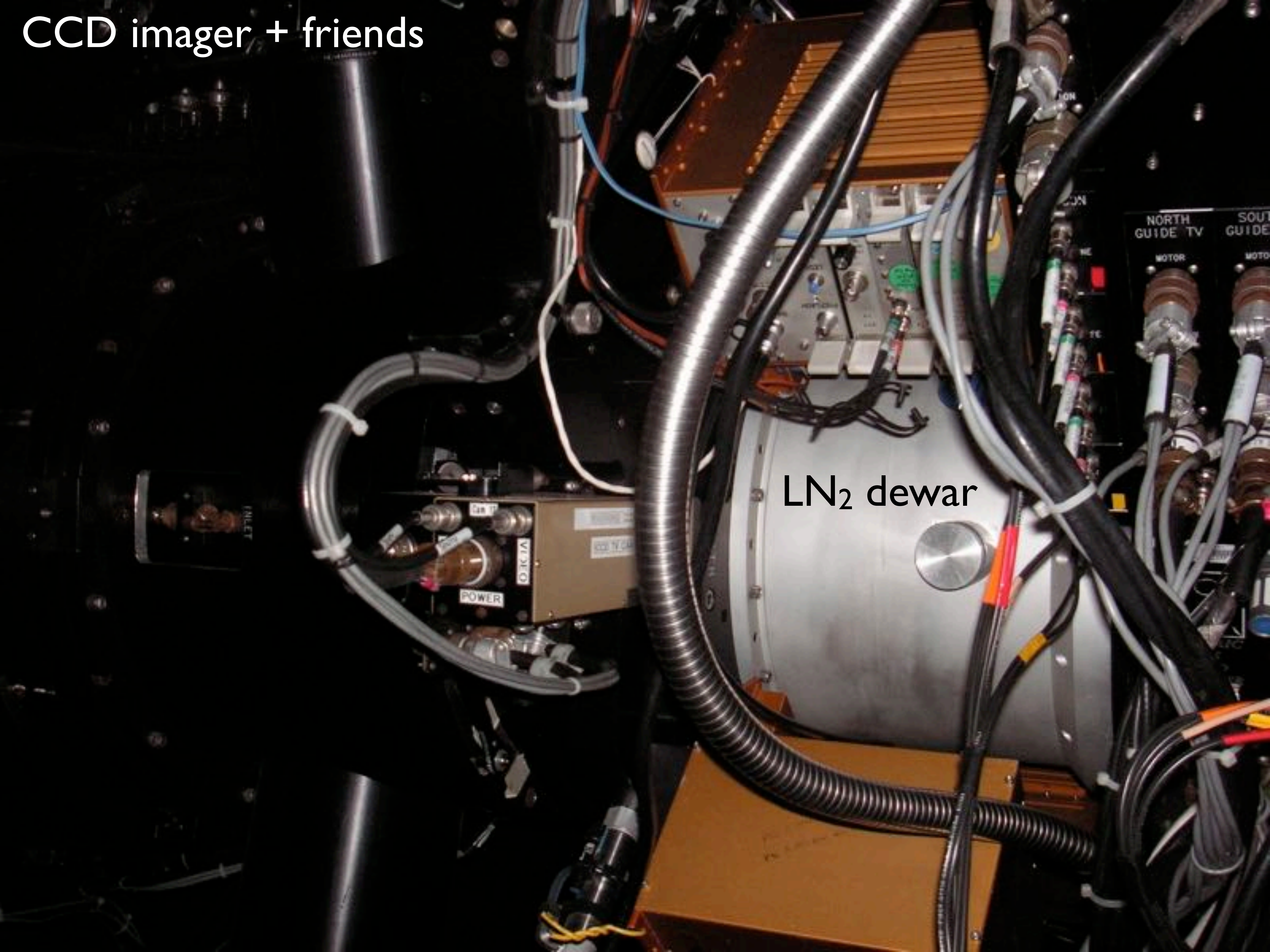
- Cameras



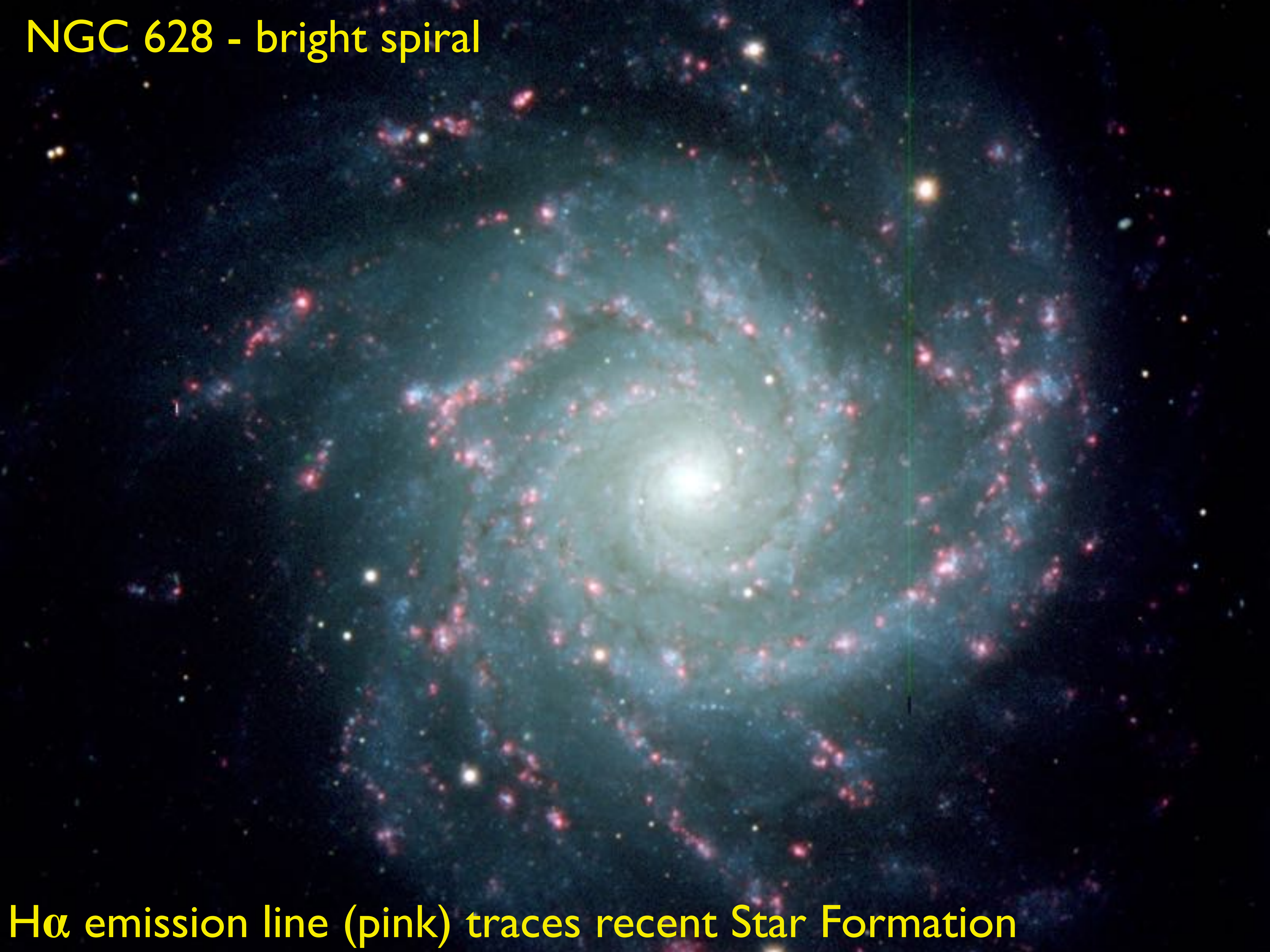
Dark Energy Camera
570 Megapixel



CCD imager + friends



NGC 628 - bright spiral

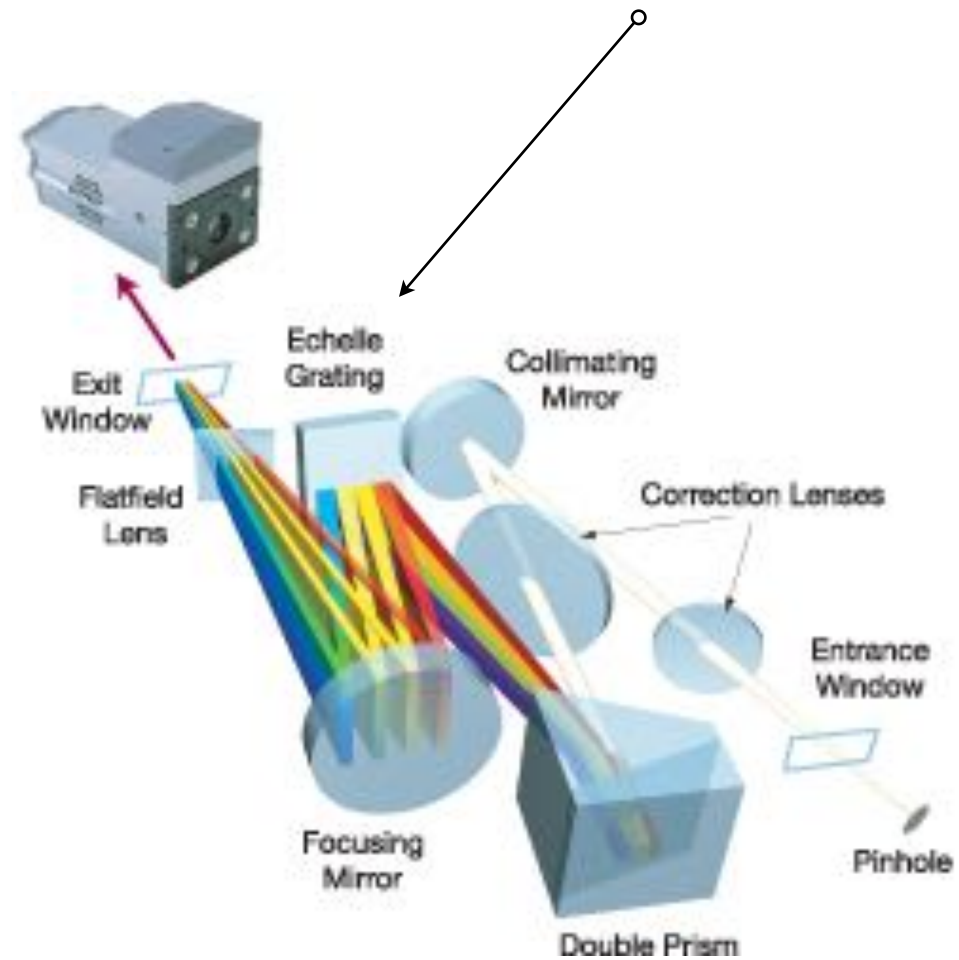


Hα emission line (pink) traces recent Star Formation

Instruments

grating

- Spectrographs




spectrograph


grating

Contents of the Solar System

- The Sun
- Major Planets
  - Terrestrial: Mercury, Venus, Earth, Mars
  - Jovian planets: Jupiter, Saturn } Gas Giants
  - Ice Giants: Uranus, Neptune } Gas Giants
- Moons
- Dwarf Planets
  - KBOs/TNOs: Pluto, Quaoar, Eris, Sedna...

  KBO: Kuiper Belt Object } same thing
  TNO: Trans-Neptunian Object } same thing
- Asteroids
- Comets
  - misc. dust, meteoroids, solar wind particles...