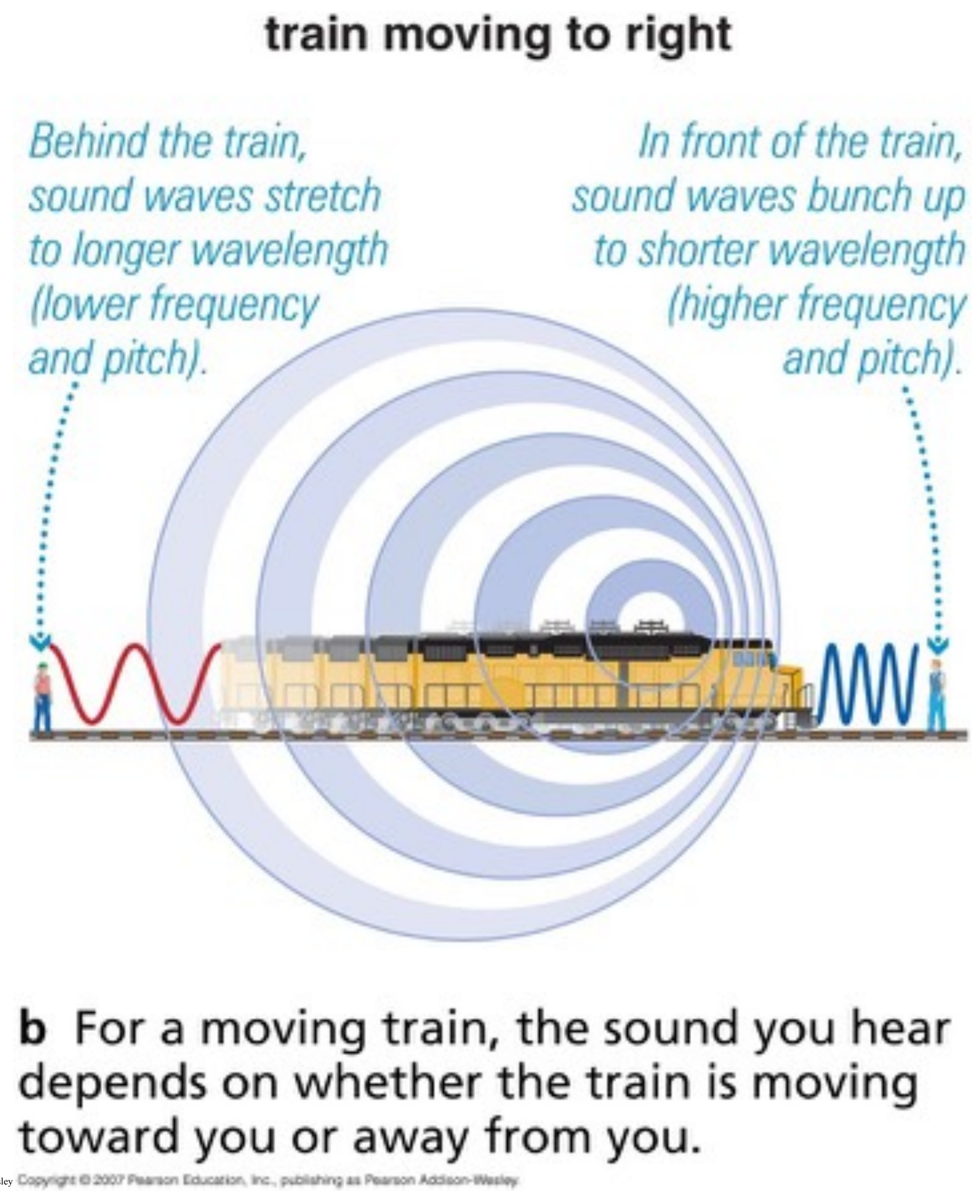
Today

- Doppler Effect & Motion
- Telescopes

Events

- Exam I on Feb. 17
  - next time

The Doppler Effect



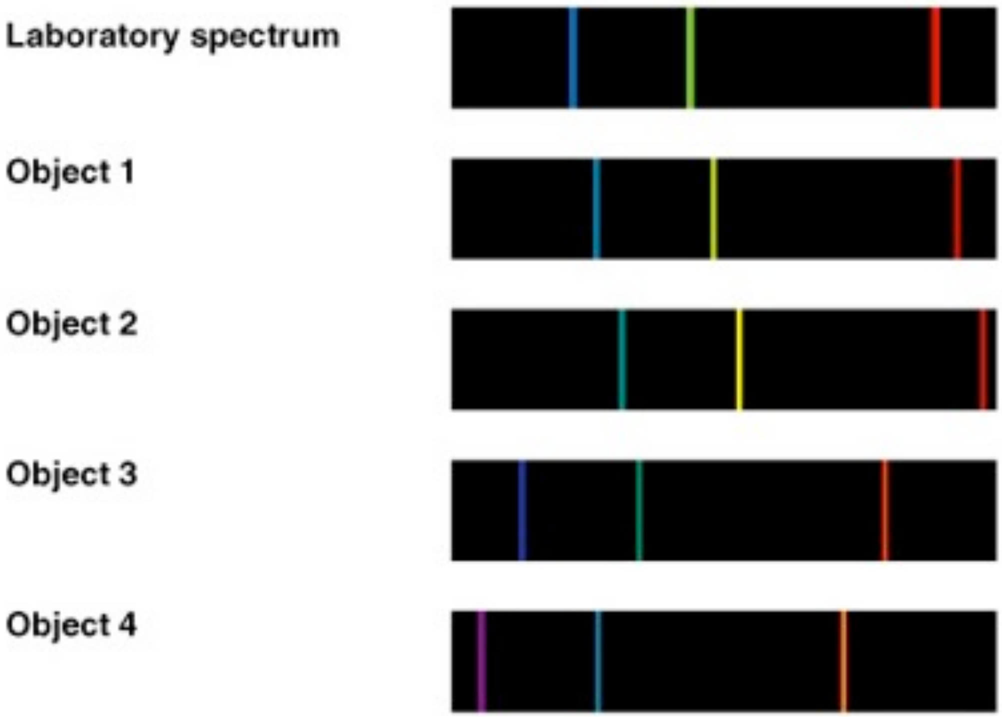
Doppler ball

Doppler Effect for Light

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

$$\frac{\Delta\lambda}{\lambda} = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{v}{c}$$

Measuring the Shift



Stationary

Moving Away

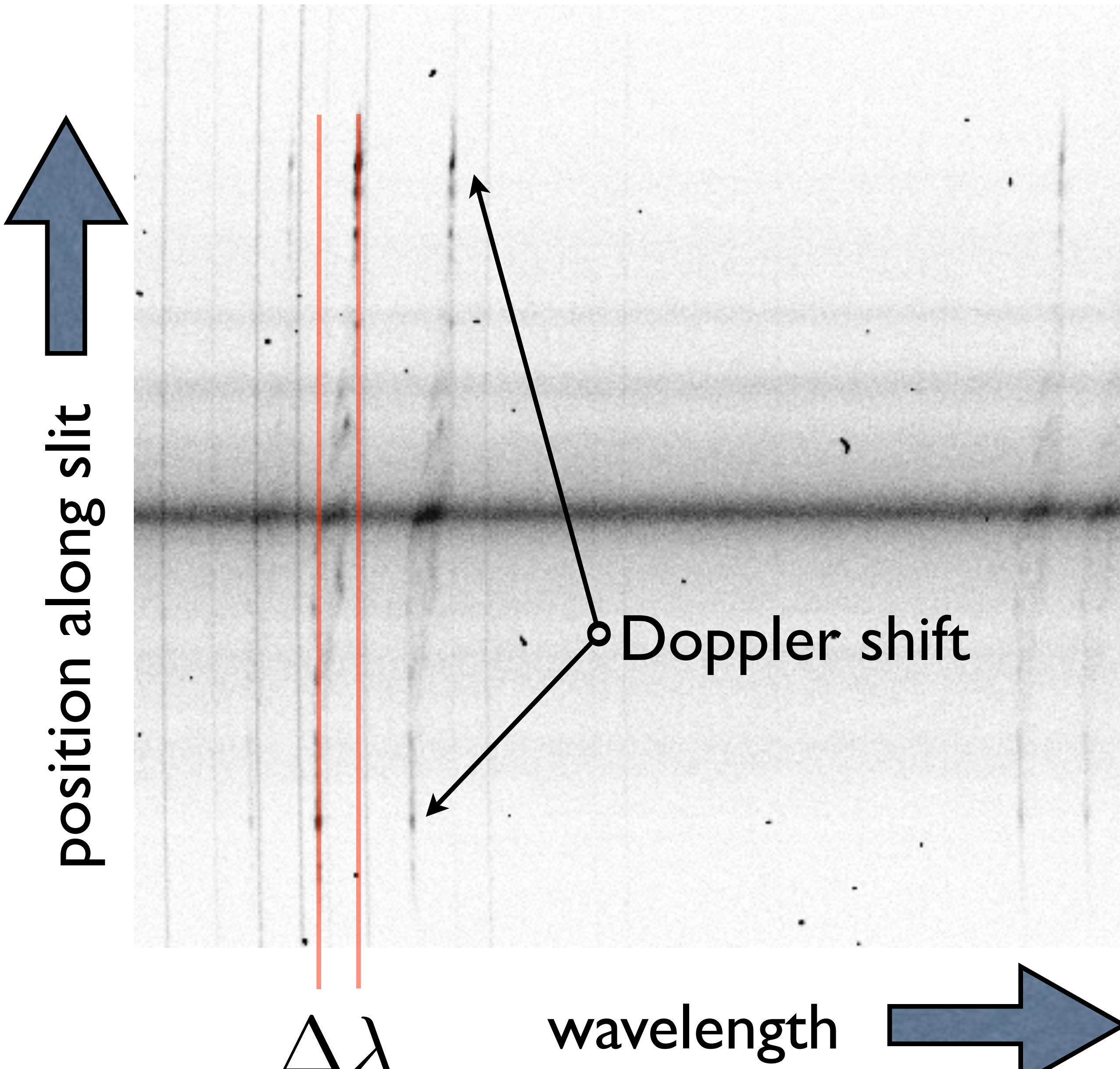
Away Faster

Moving Toward

Toward Faster

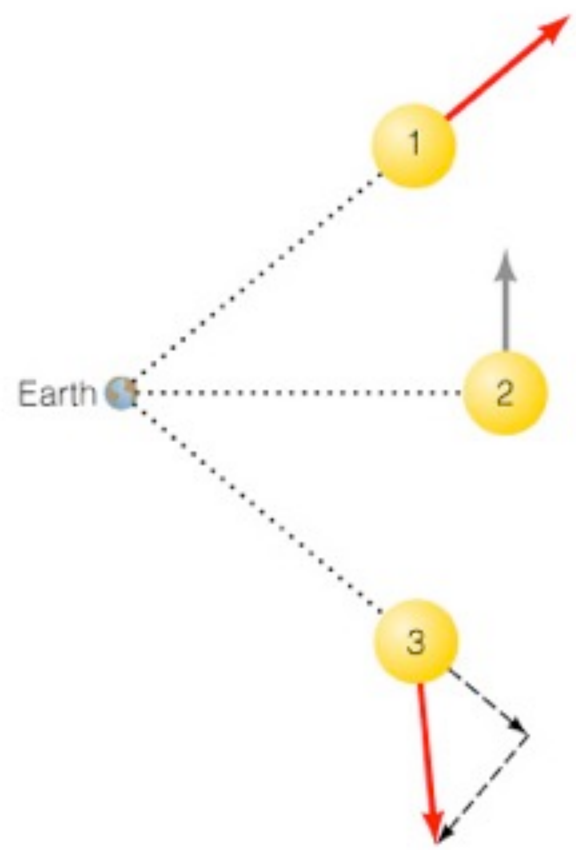
- We generally measure the Doppler effect from shifts in the wavelengths of spectral lines.

Spectrum



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

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 $\Rightarrow$ **light-collecting area**
- Telescopes can see more detail than our eyes $\Rightarrow$ **angular resolution** (magnification)
- Telescopes/instruments can detect light 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

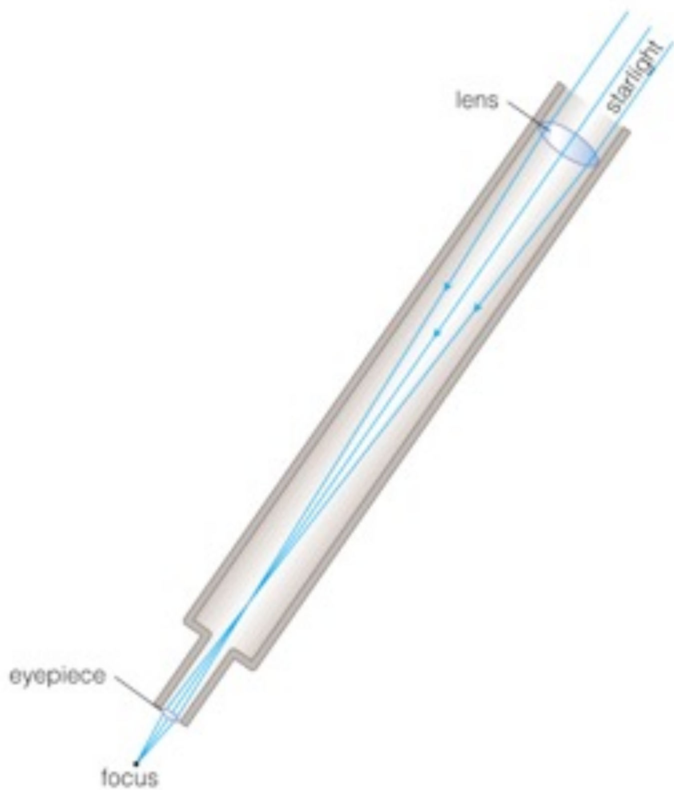
For a telescope with mirror of diameter D,

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

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

Basic Telescope Design

- Refracting: lenses

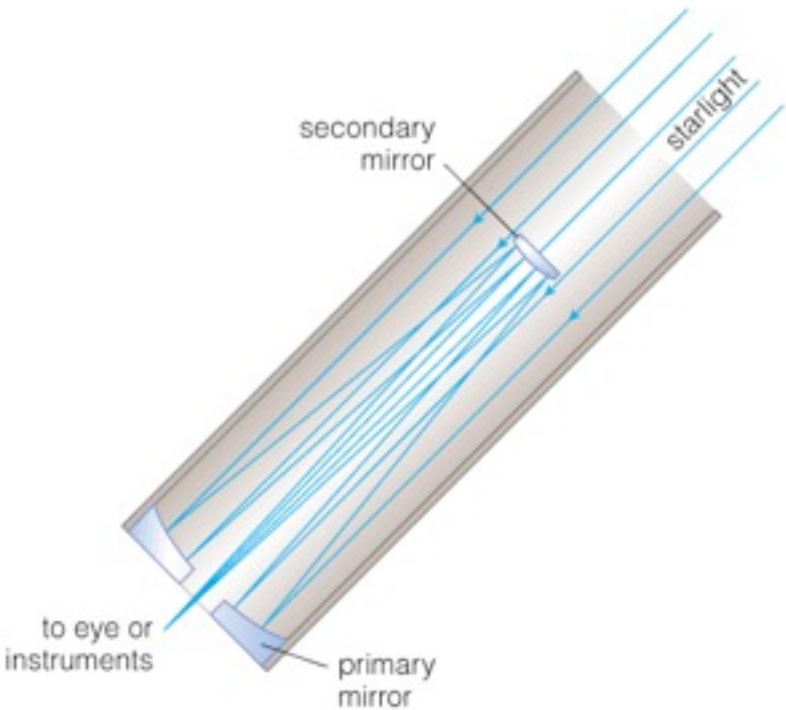


Refracting telescope

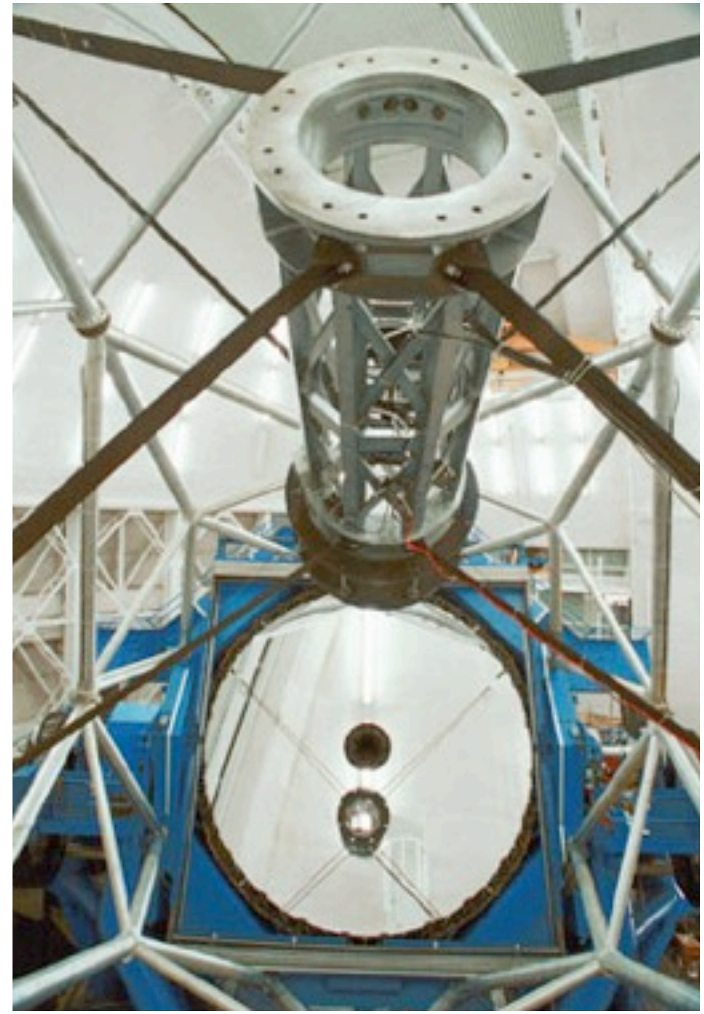
Yerkes 1-m refractor

Basic Telescope Design

- Reflecting: mirrors
- Most research telescopes today are reflecting



Reflecting telescope



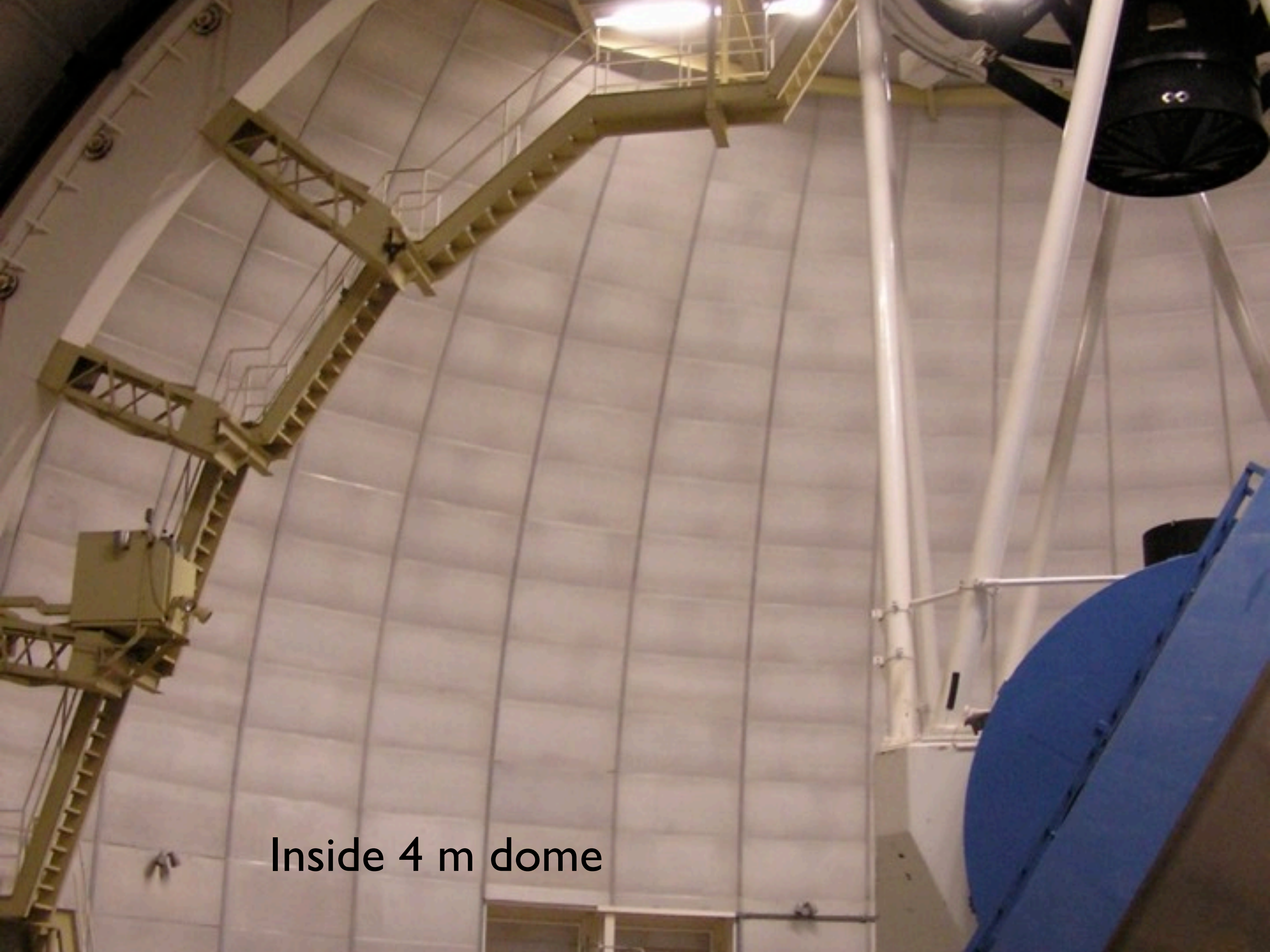
Gemini North 8-m

Kitt Peak National Observatory (AZ)

4 m

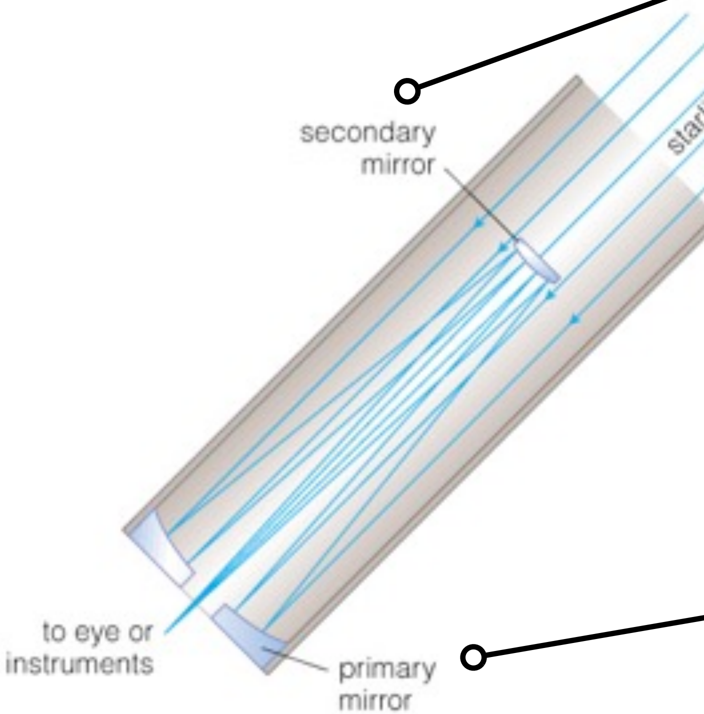

2.1 m
WIYN (3.5 m)

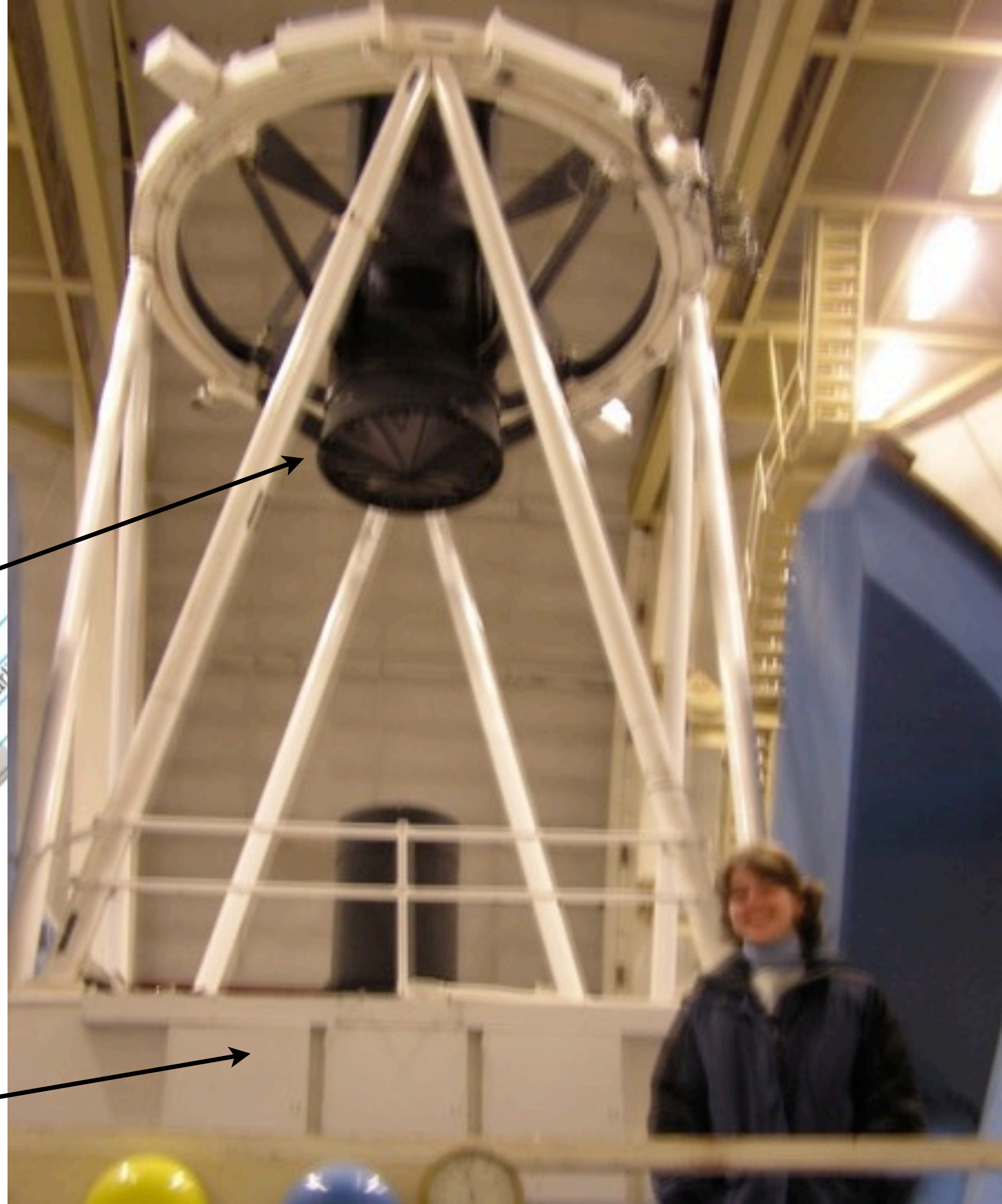
2.1 m

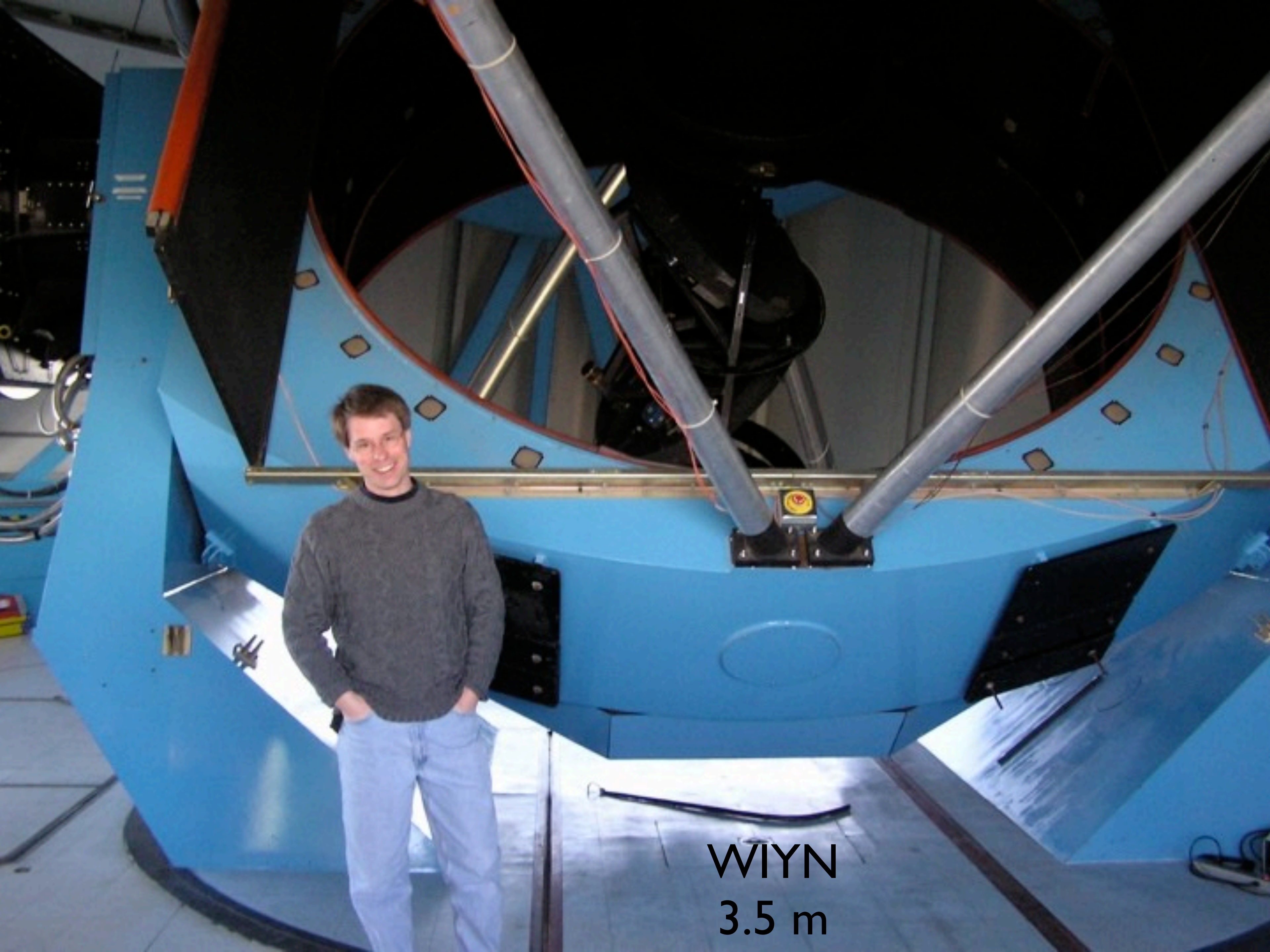


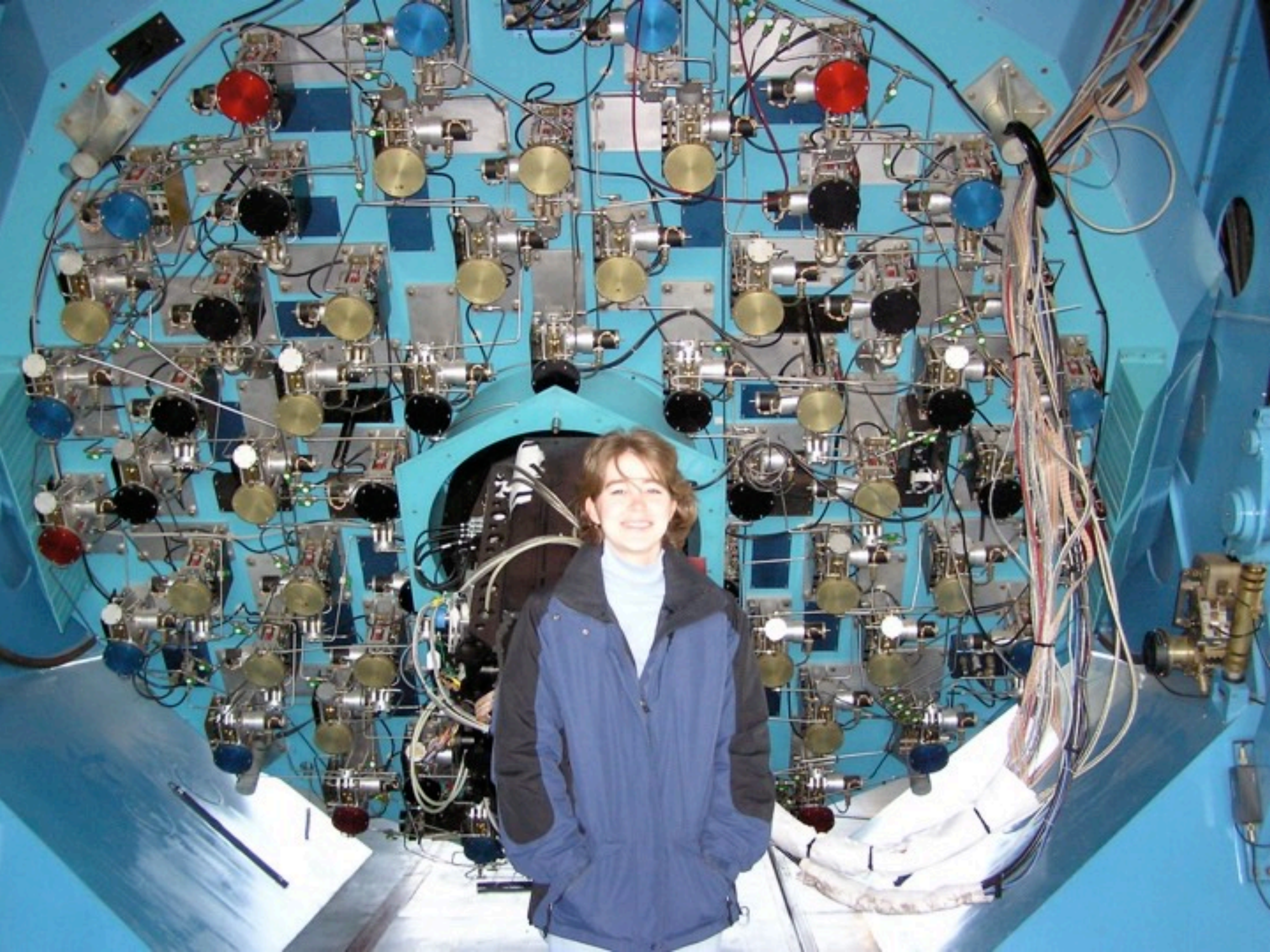
Inside 4 m dome

4 m






WIYN
3.5 m



Different designs for different wavelengths of light

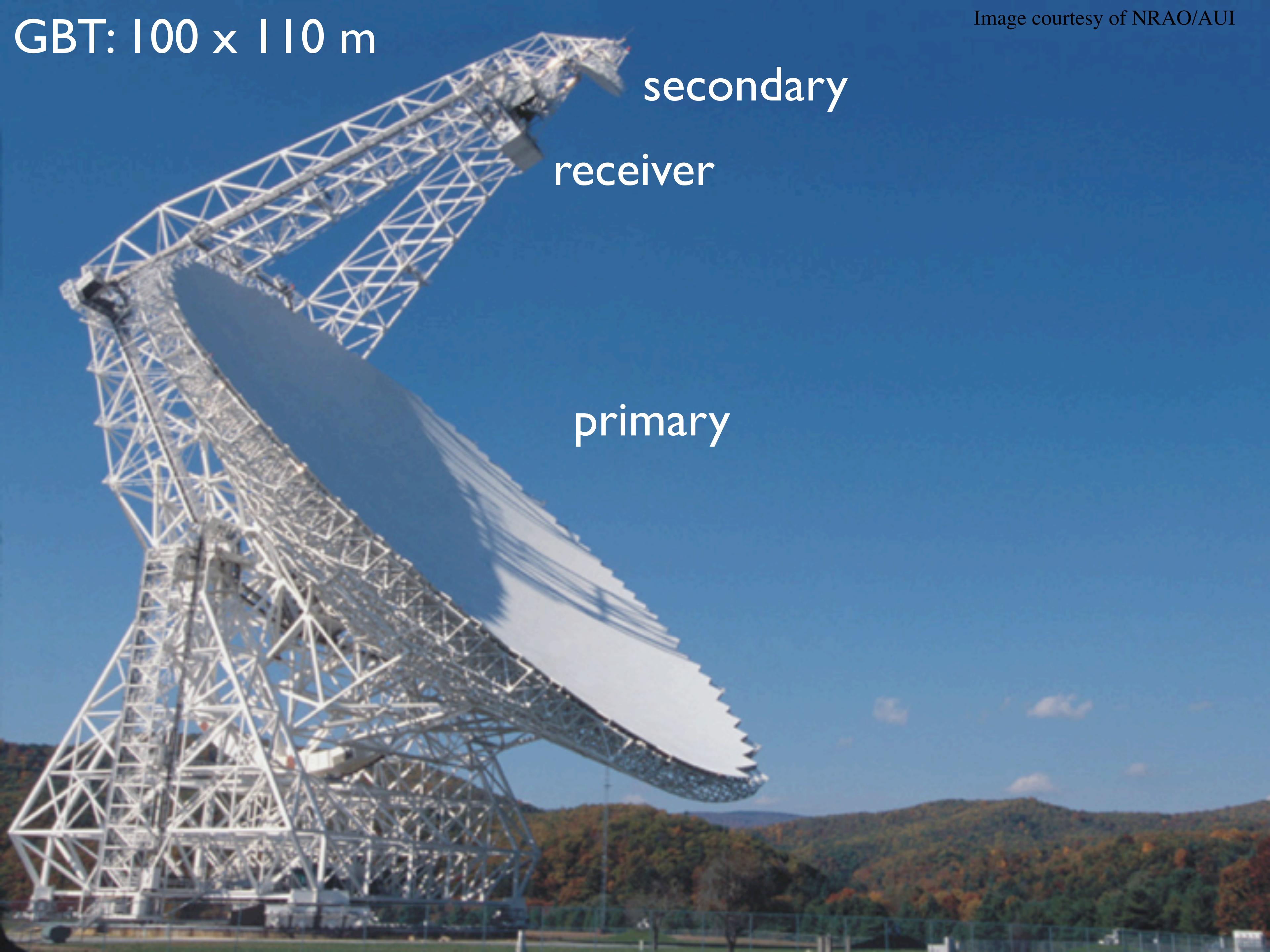
Radio telescope (Arecibo, Puerto Rico)

Longer wavelengths need larger "mirrors"

Aricebo 305 m

Aricebo 305 m


Aricebo 305 m


GBT: 100 x 110 m
Image courtesy of NRAO/AUI
secondary
receiver
primary

Interferometry

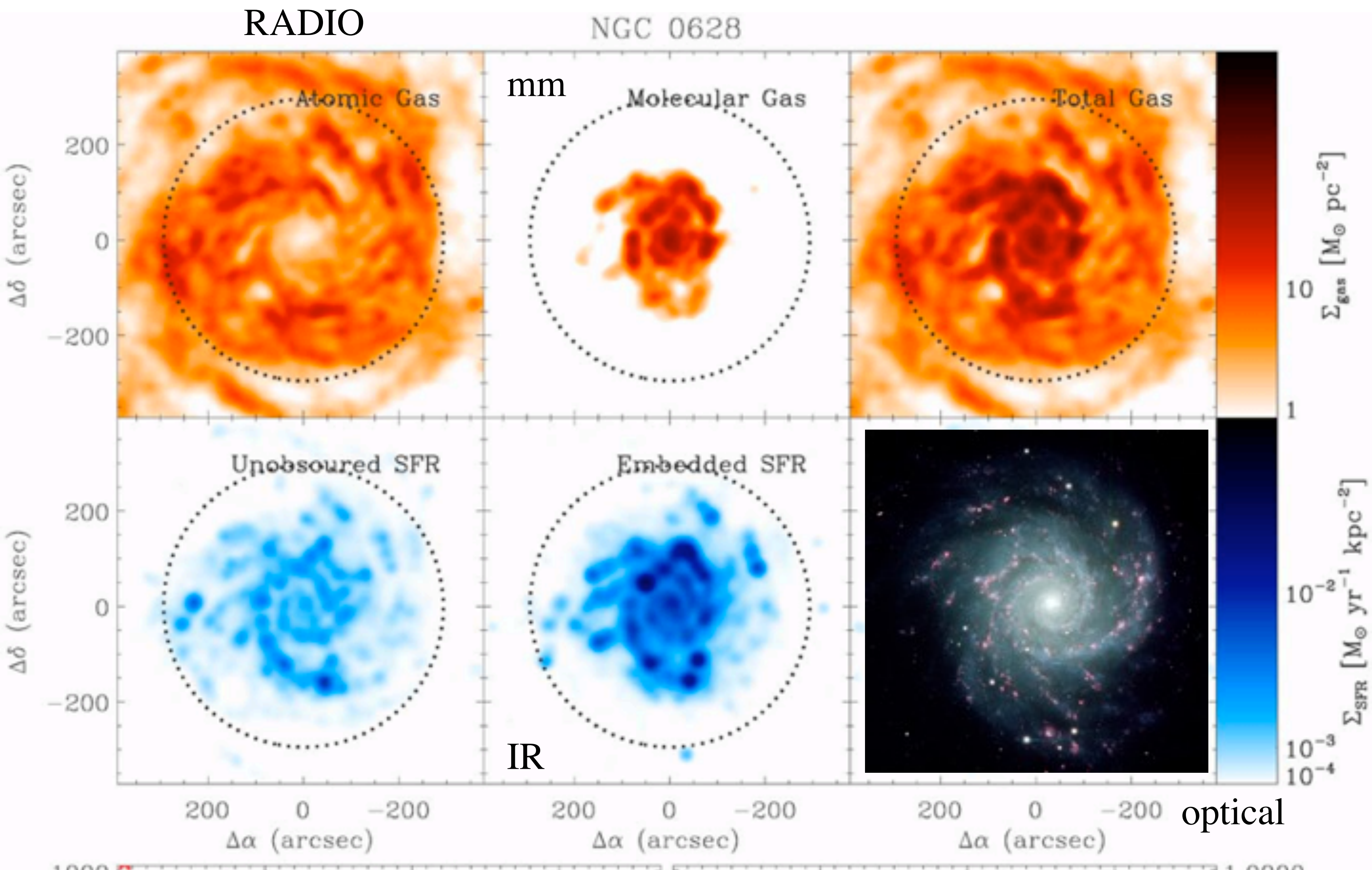
- This technique allows two or more small telescopes to work together to obtain the *angular resolution* of a larger telescope.

Very Large Array (VLA), New Mexico

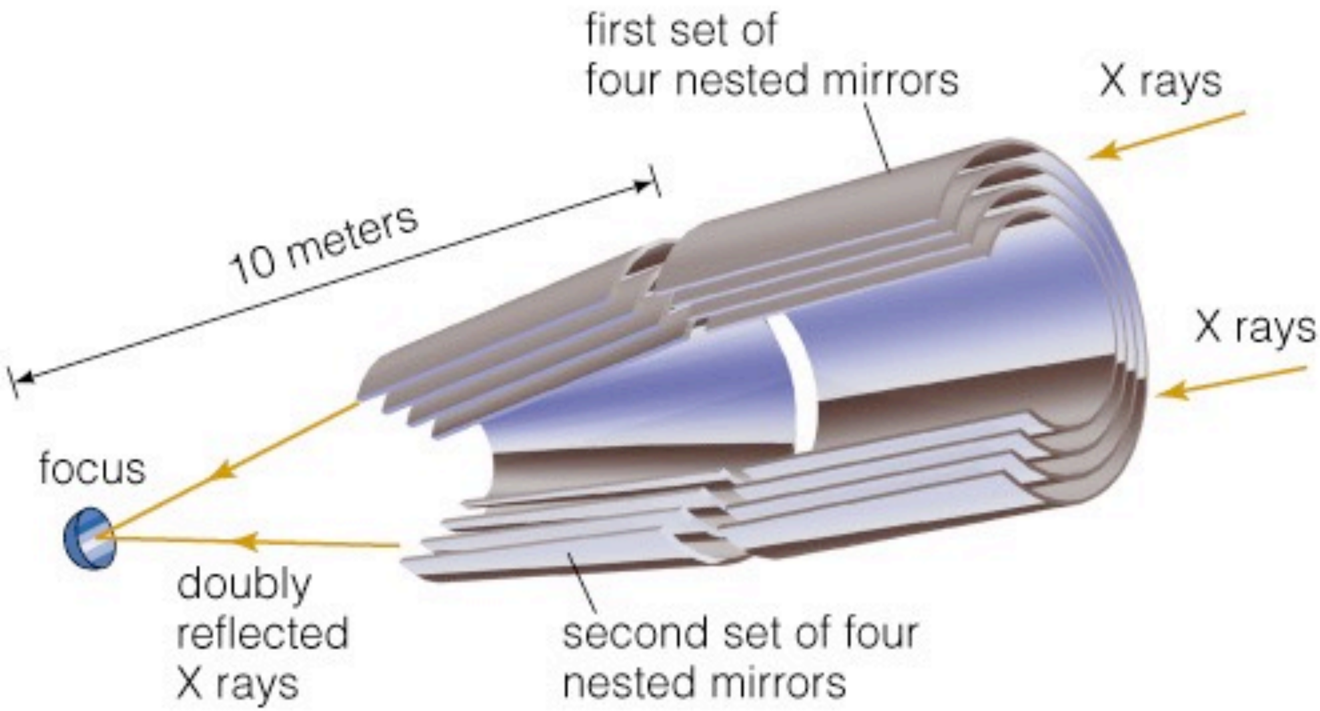
Very Large Array (VLA), New Mexico

angular resolution of a telescope this size

EVLA (HI @ 21 cm) CARMA (CO @ 2.6 mm)


RADIO
NGC 0628
mm
Atomic Gas
Molecular Gas
Total Gas
Unobscured SFR
Embedded SFR
IR
optical
Δδ (arcsec)
Δα (arcsec)
200
0
−200
Σ_{gas} [$M_\odot$ pc^{-2}]
10
1
Σ_{SFR} [$M_\odot$ yr^{-1} kpc^{-2}]
10^{-2}
10^{-3}
10^{-4}

X-ray telescope: “grazing incidence” optics



Mirror elements are 0.8 m long and from 0.6 m to 1.2 m in diameter.

b

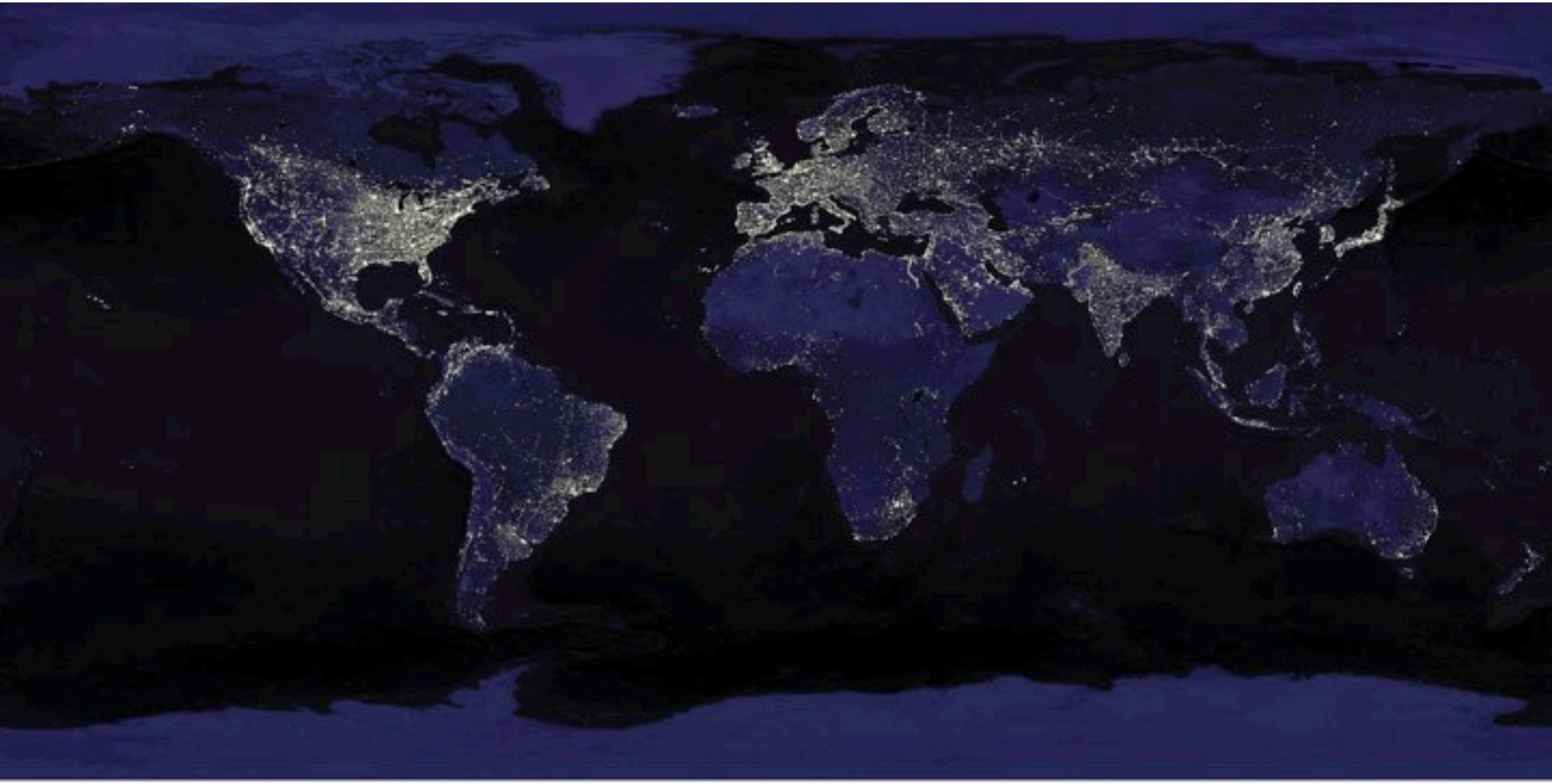
Advantages of telescopes in space

Hubble

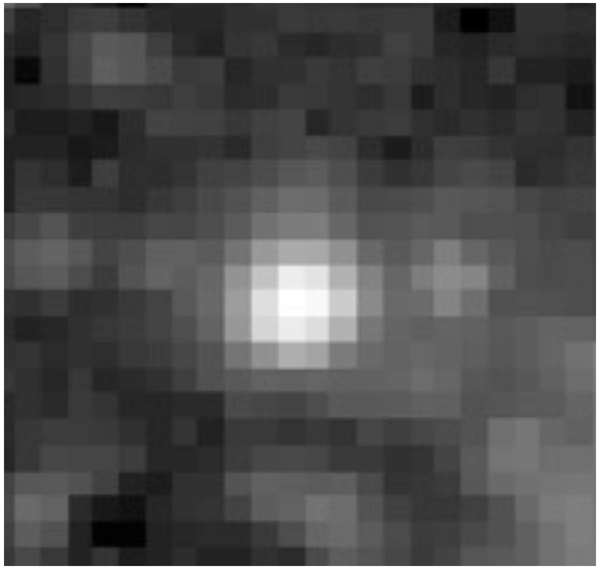
Chandra

Observing problems due to Earth’s atmosphere

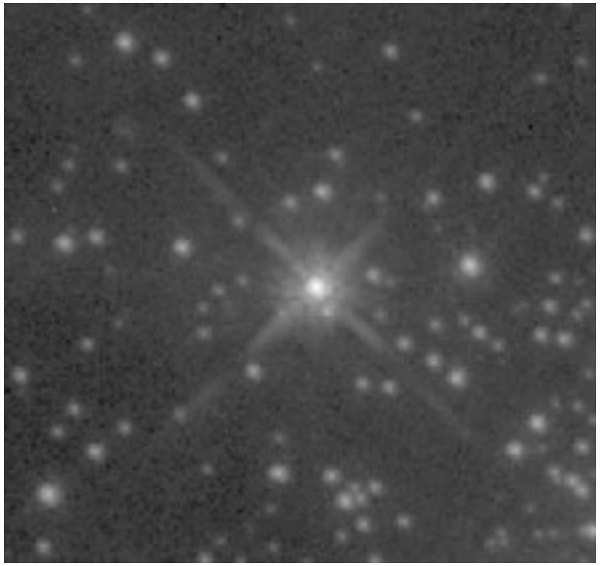
1. Light Pollution



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

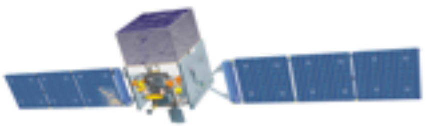


Star viewed with ground-based telescope

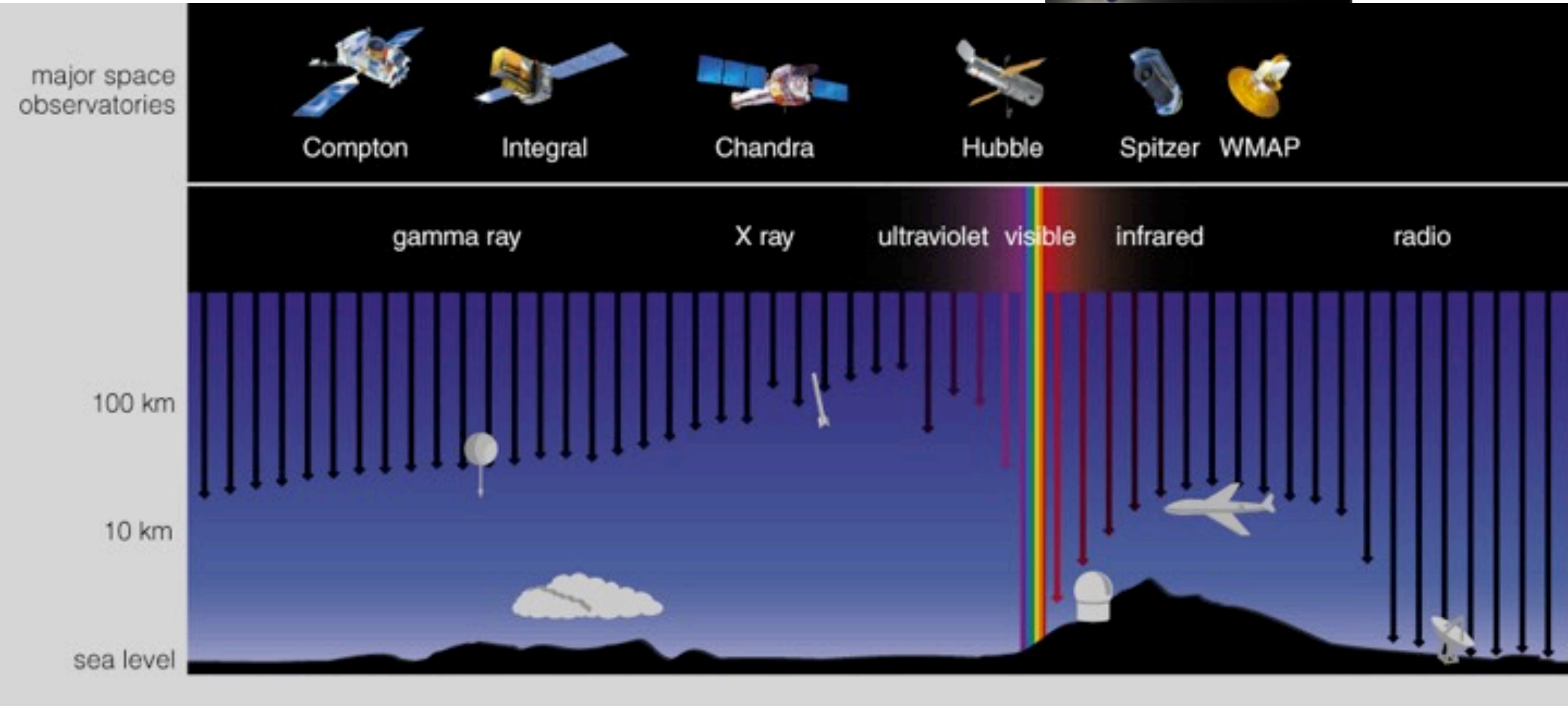


View from Hubble Space Telescope

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

Fermi 

 Herschel

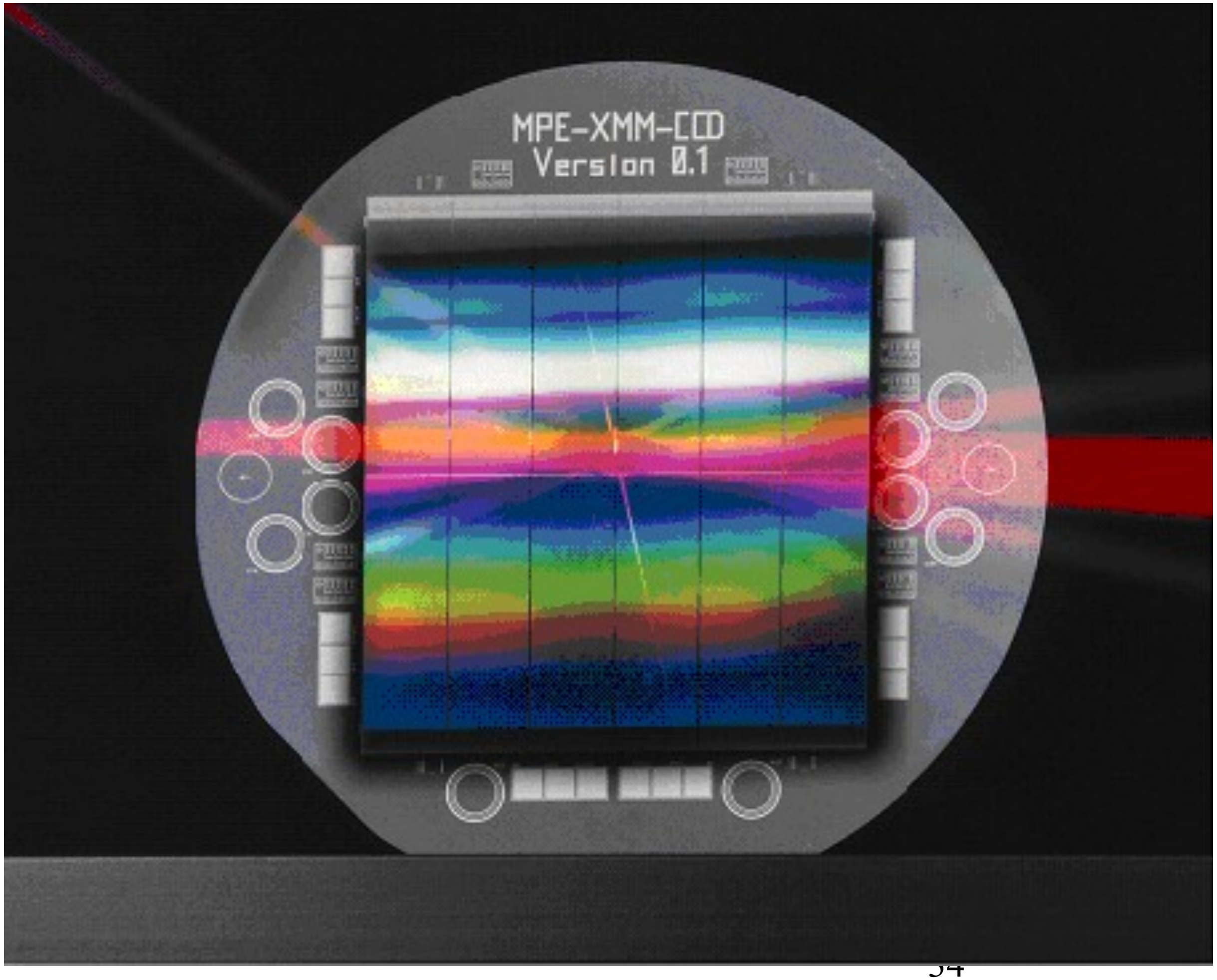


Telescopes in space solve all 3 problems.

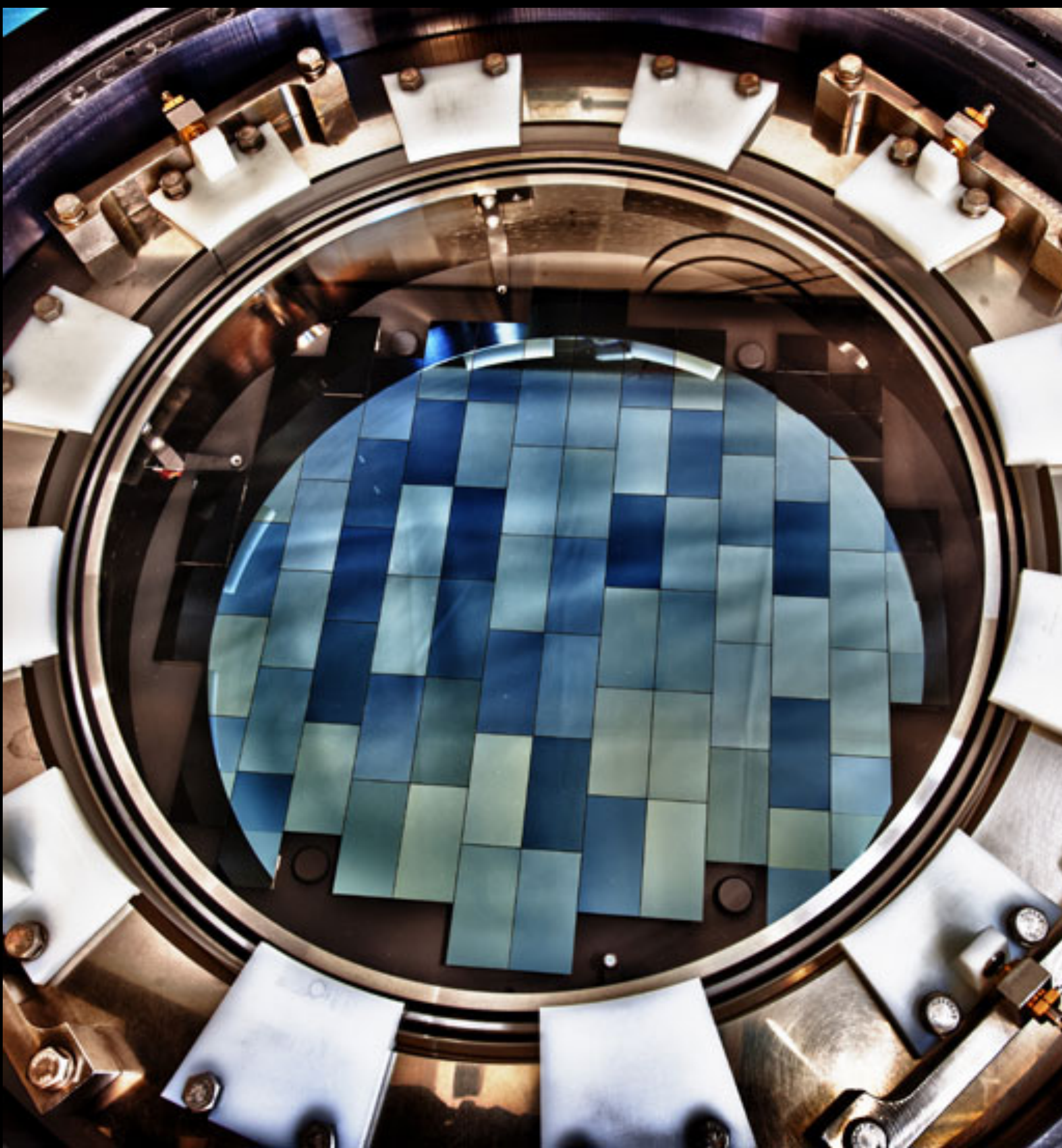
Chandra X-ray Observatory

Instruments

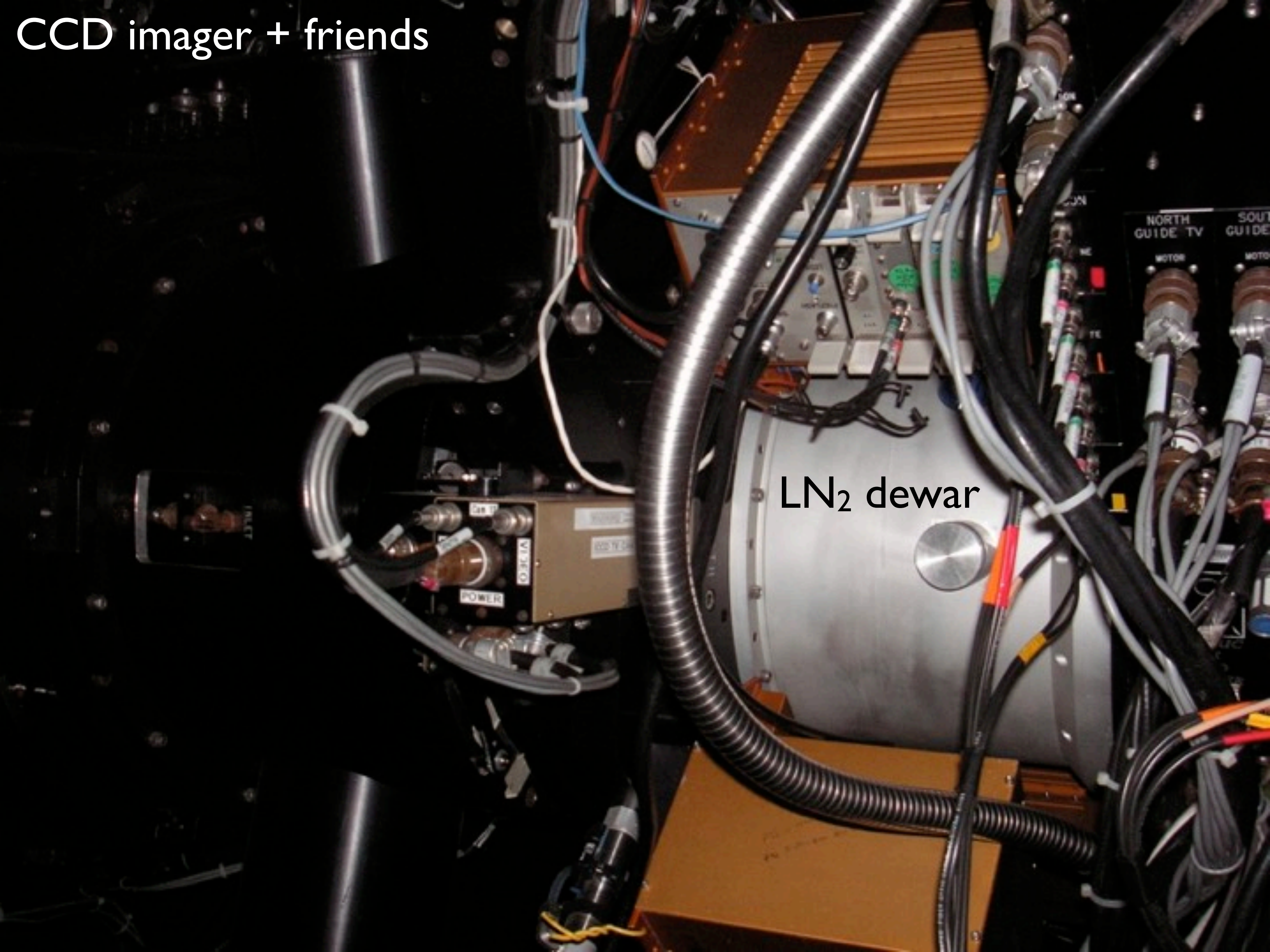
- Cameras



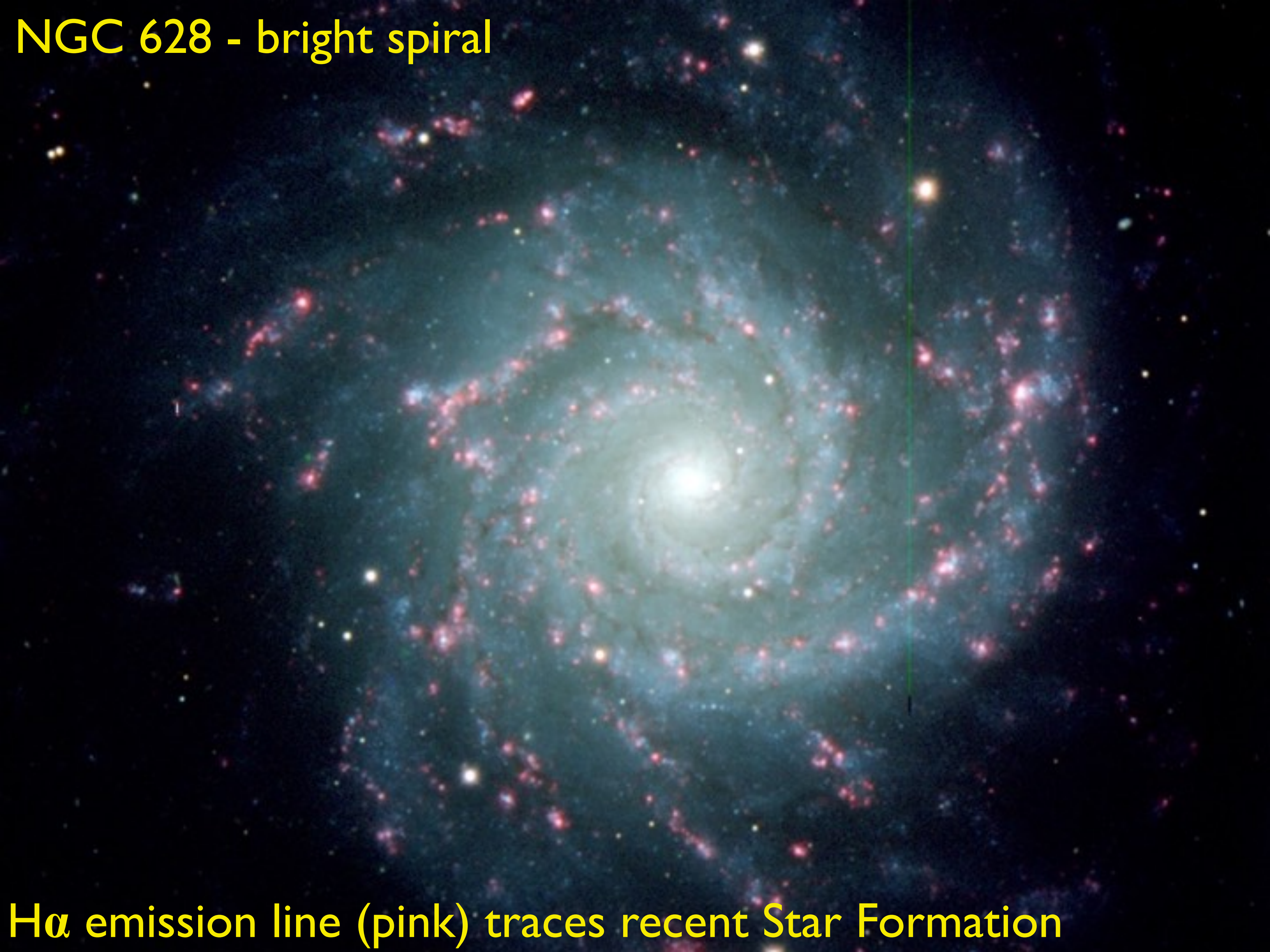
Dark Energy Camera
570 Megapixel



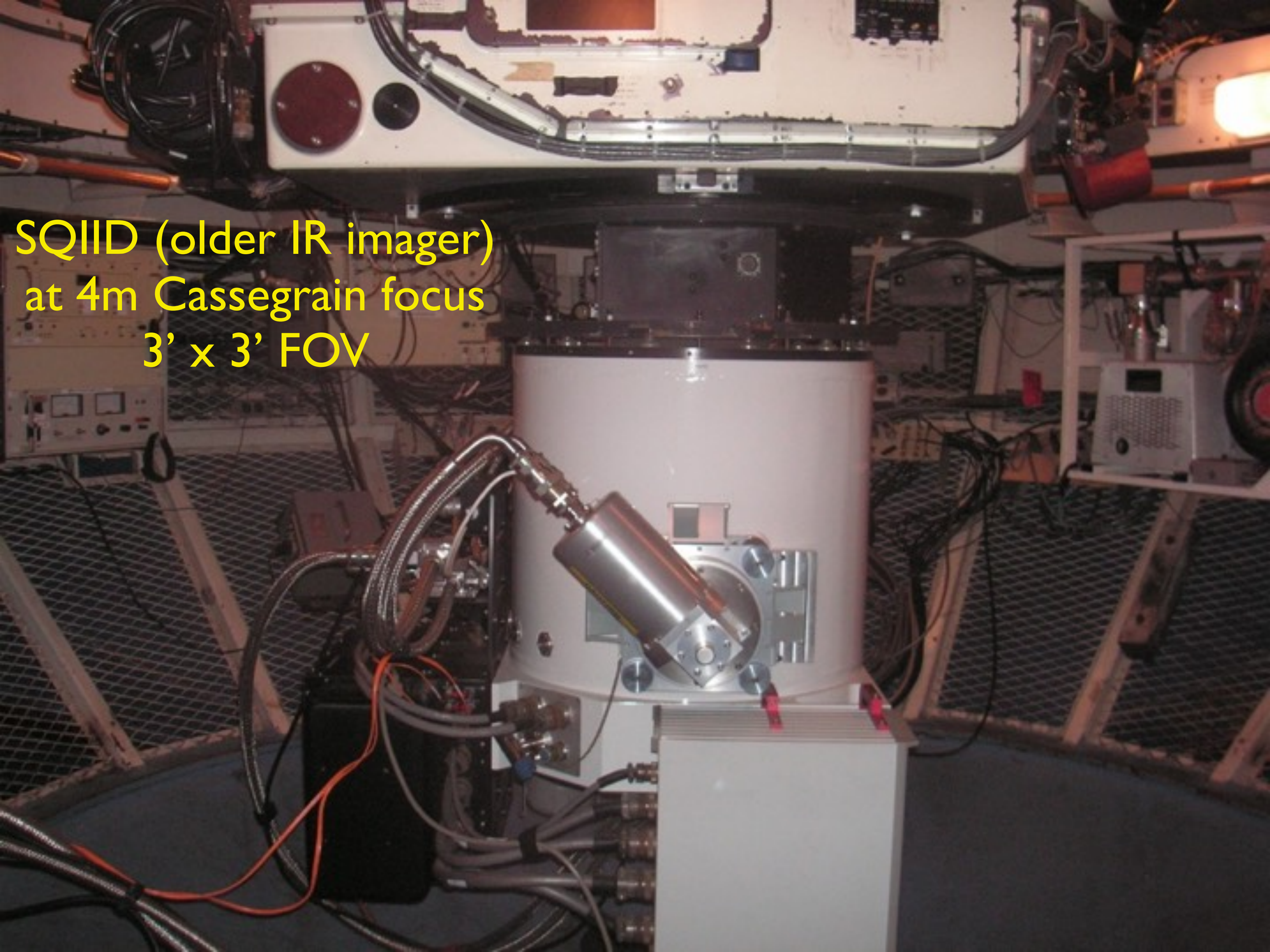
CCD imager + friends



NGC 628 - bright spiral



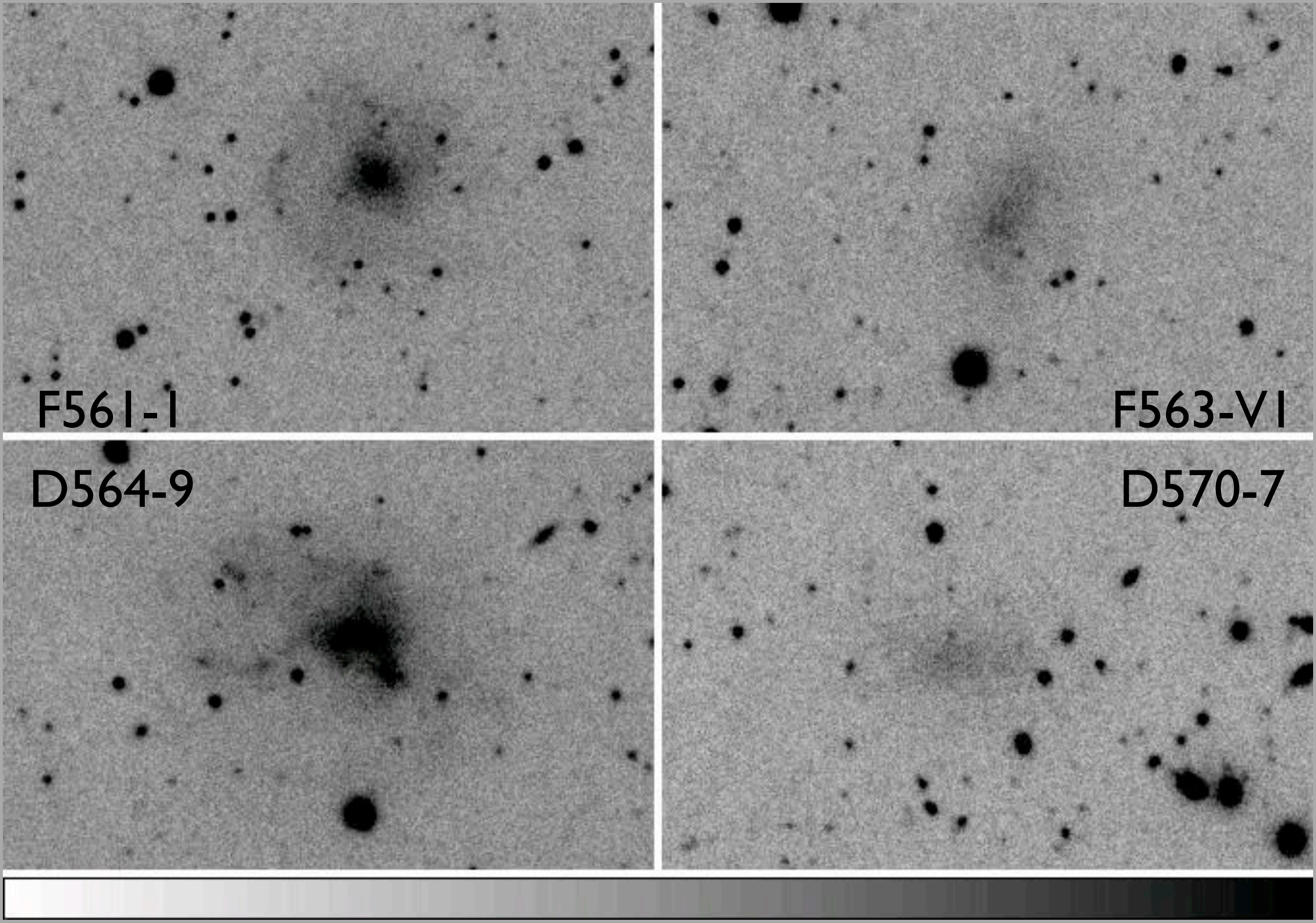
Hα emission line (pink) traces recent Star Formation


SQIID (older IR imager)
at 4m Cassegrain focus
3' x 3' FOV


SQIID
CAUTION


NEWFIRM near-IR imager
28' x 28' FOV

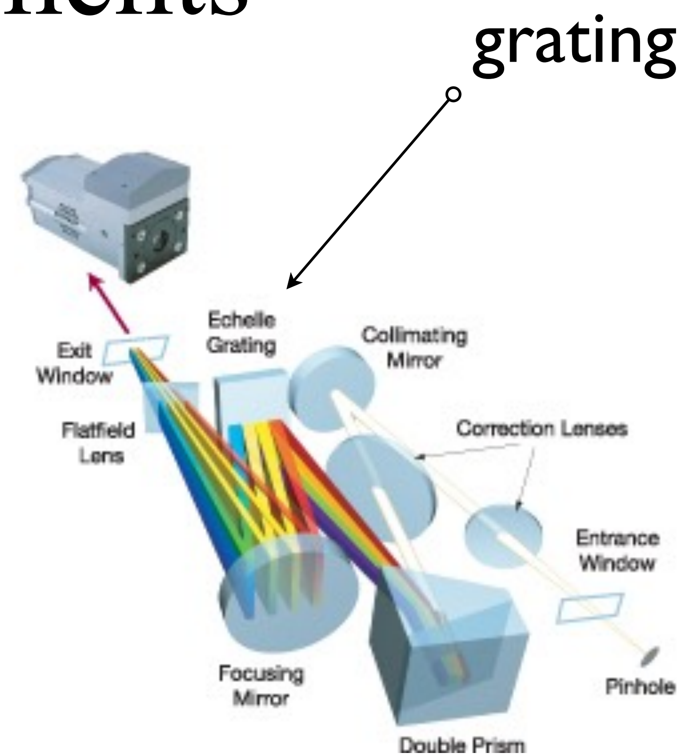
Stellar mass maps from near-IR data (2.2 or 3.6 microns)



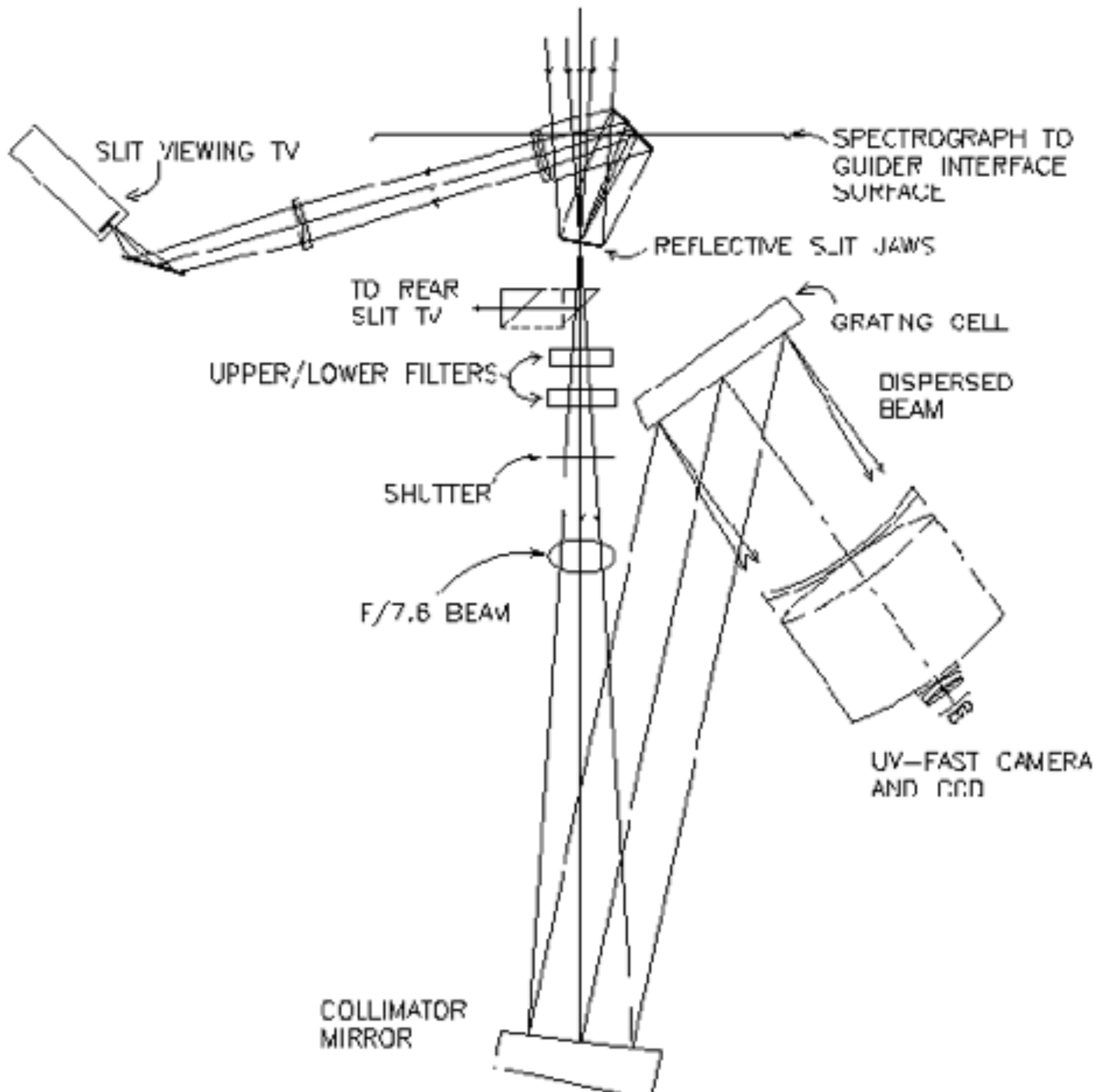
Kitt Peak 4m + NEWFIRM K'-band (2.2 micron)

Instruments

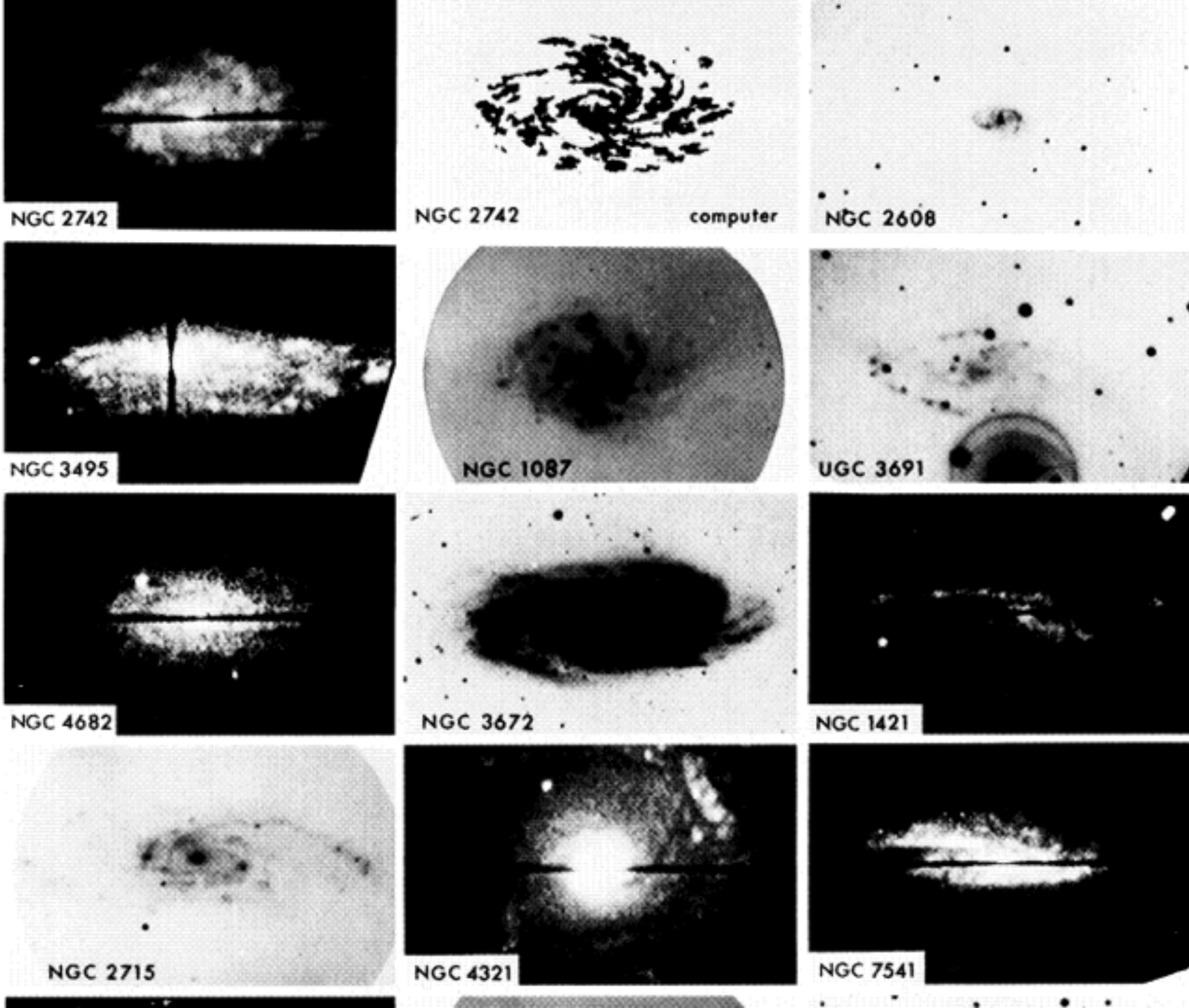
- Spectrographs



4-METER TELESCOPE – R.C. SPECTROGRAPH
– – OPTICAL DIAGRAM – –

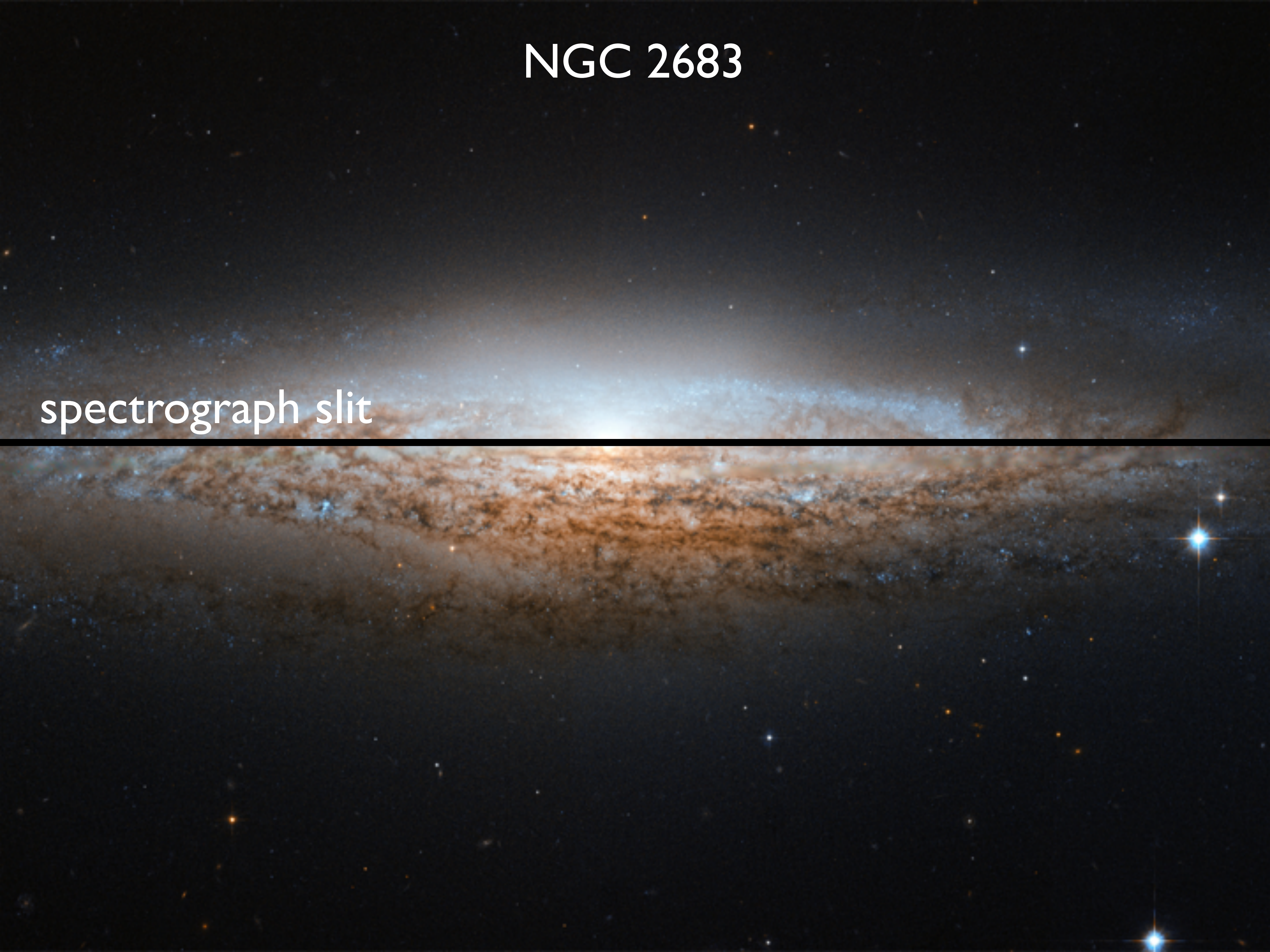


slit view

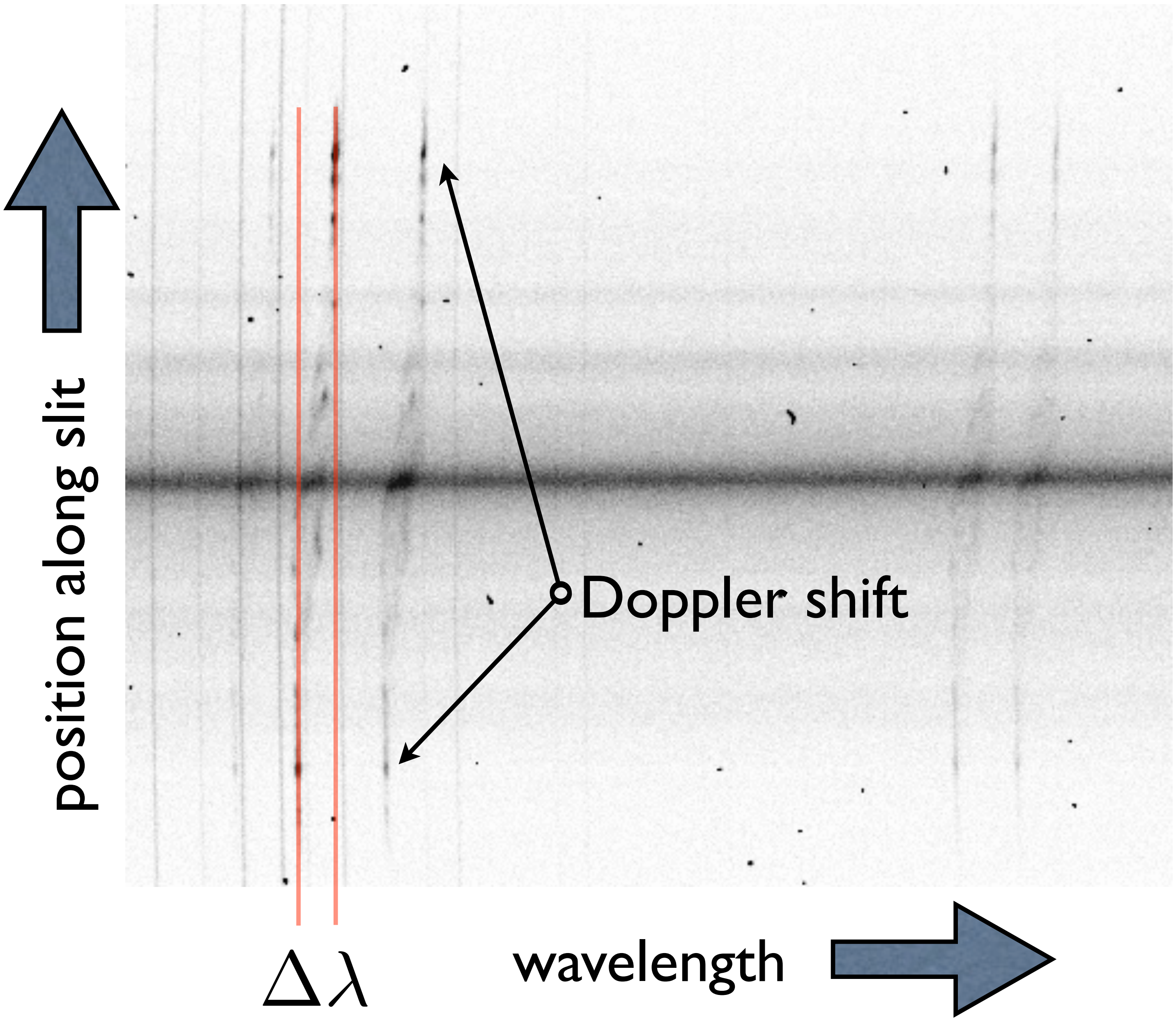

NGC 2742
NGC 2742
computer
NGC 2608
NGC 3495
NGC 1087
UGC 3691
NGC 4682
NGC 3672
NGC 1421
NGC 2715
NGC 4321
NGC 7541


spectrograph


grating


NGC 2683
spectrograph slit

Spectrum



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