

TODAY

- DOPPLER EFFECT & MOTION
- TELESCOPES

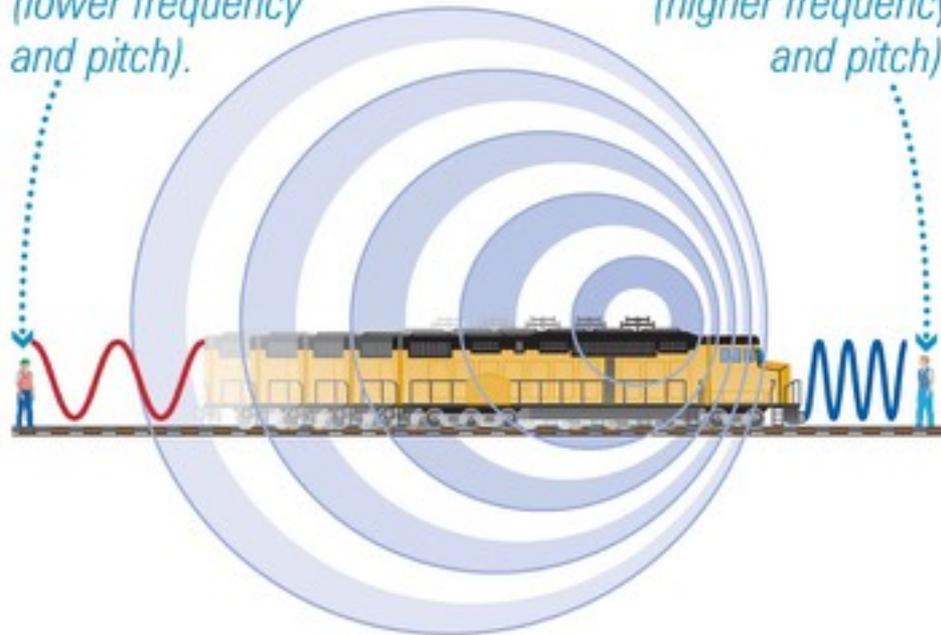


The Doppler Effect

train moving to right

*Behind the train,
sound waves stretch
to longer wavelength
(lower frequency
and pitch).*

*In front of the train,
sound waves bunch up
to shorter wavelength
(higher frequency
and pitch).*



Doppler
ball

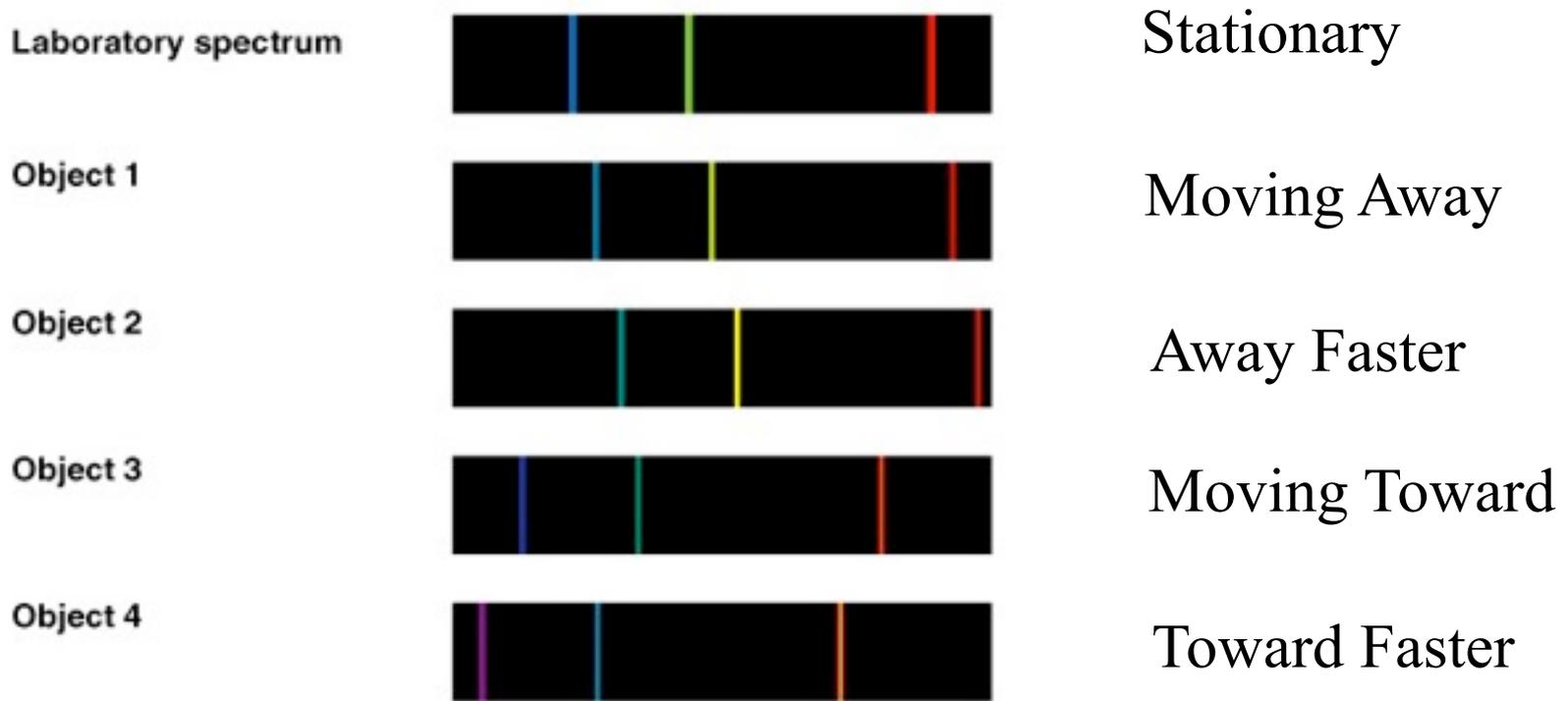
b For a moving train, the sound you hear depends on whether the train is moving toward you or away from you.

Doppler Effect for Light

- Motion away \rightarrow redshift
- Motion towards \rightarrow blueshift

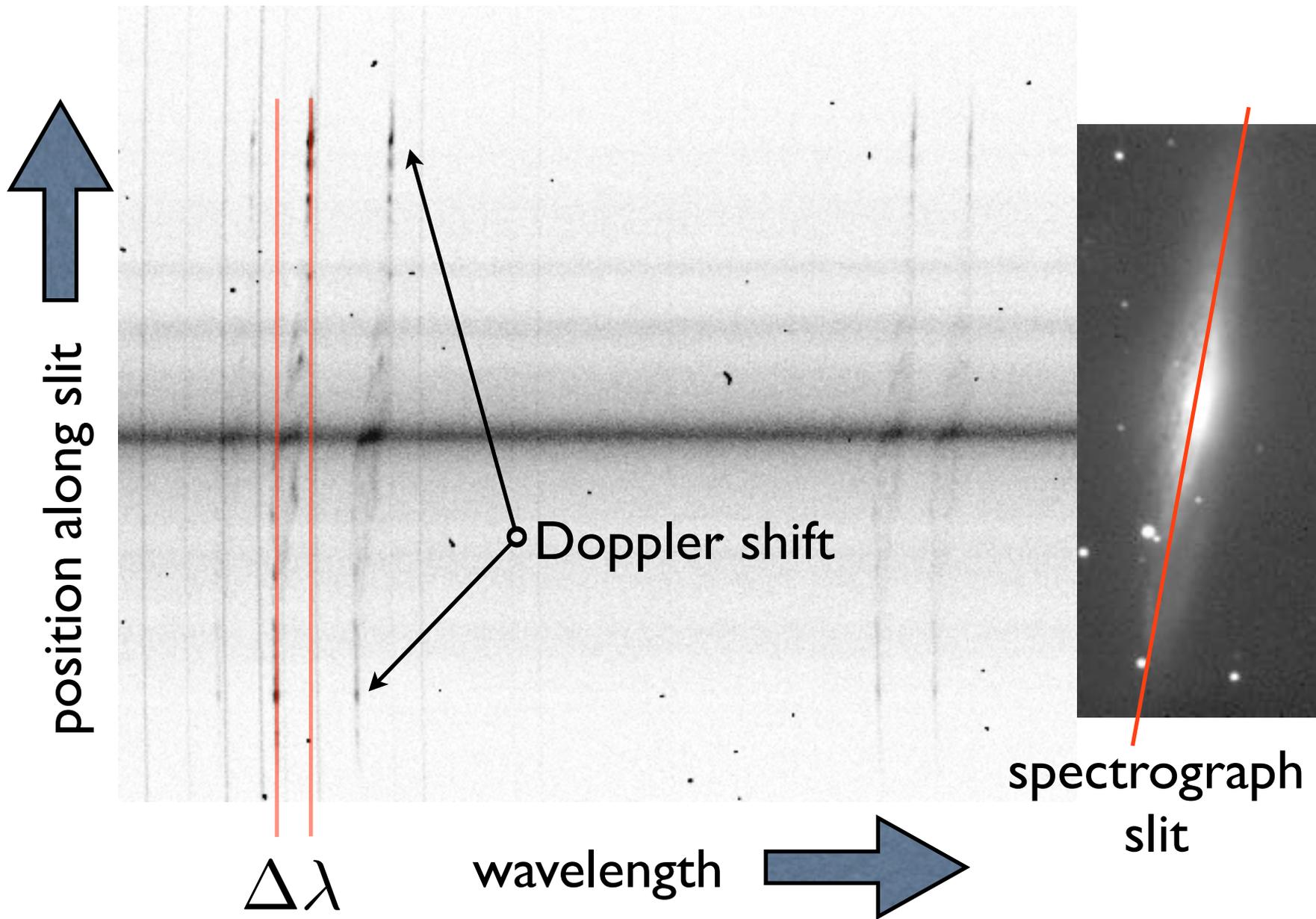
$$\frac{\Delta\lambda}{\lambda} = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{v}{c}$$

Measuring the Shift

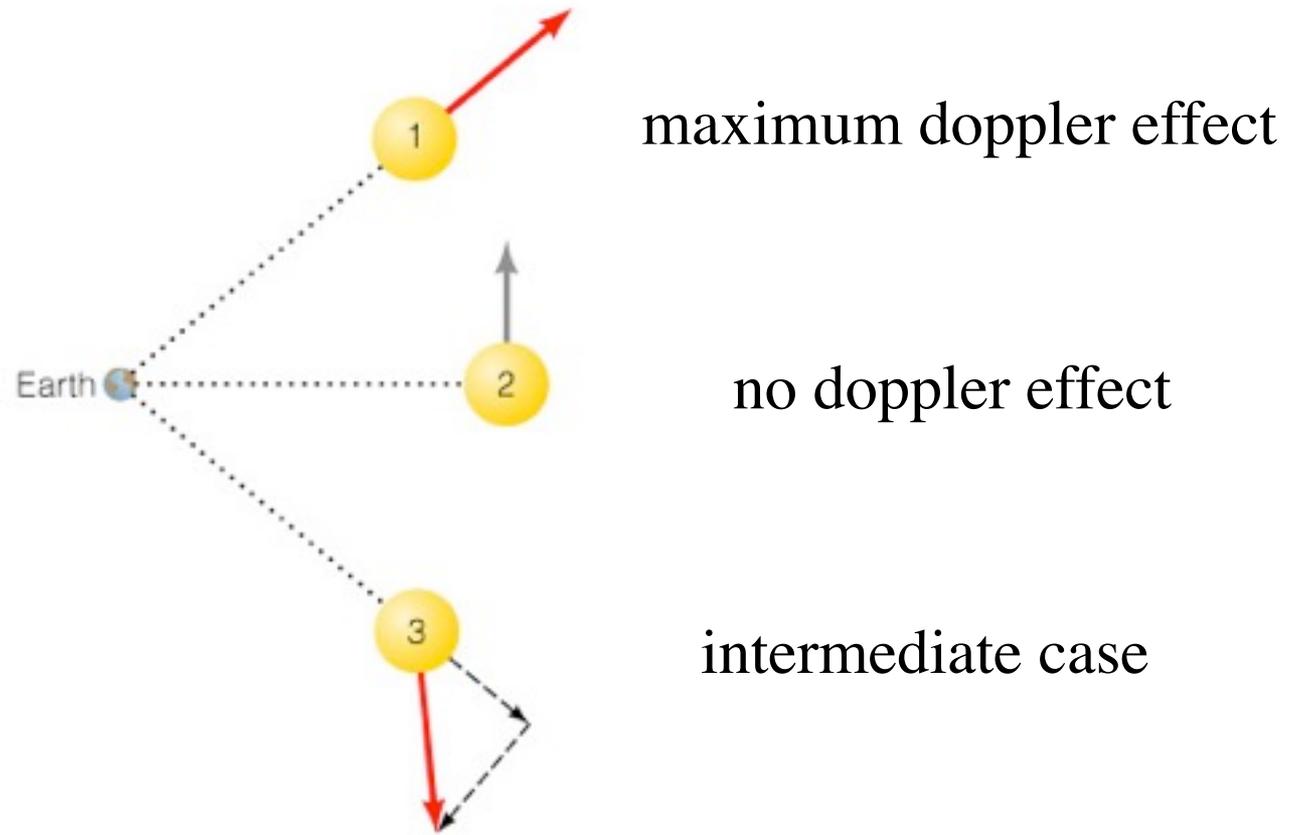


- We generally measure the Doppler effect from shifts in the wavelengths of spectral lines.

Spectrum



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



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

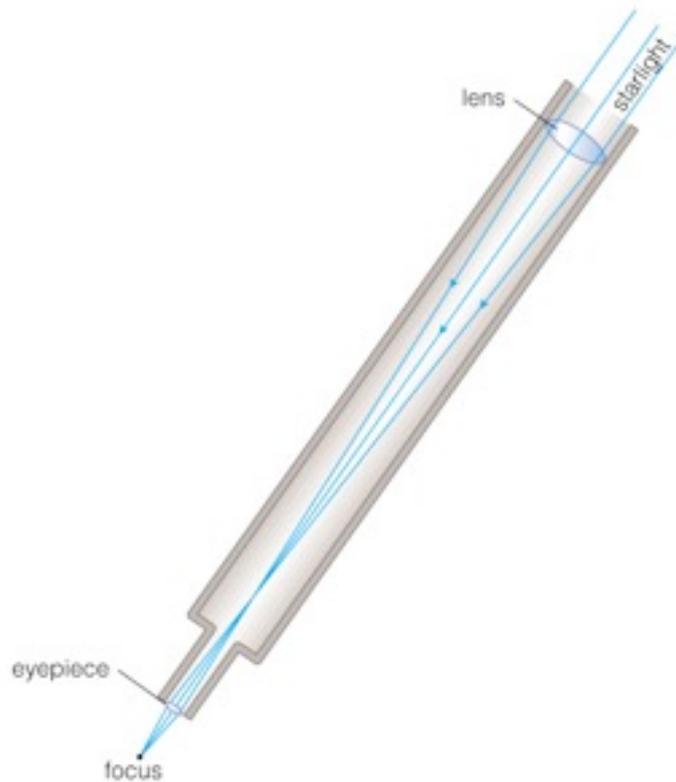
For a telescope with mirror of diameter D ,

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

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

Basic Telescope Design

- Refracting: lenses



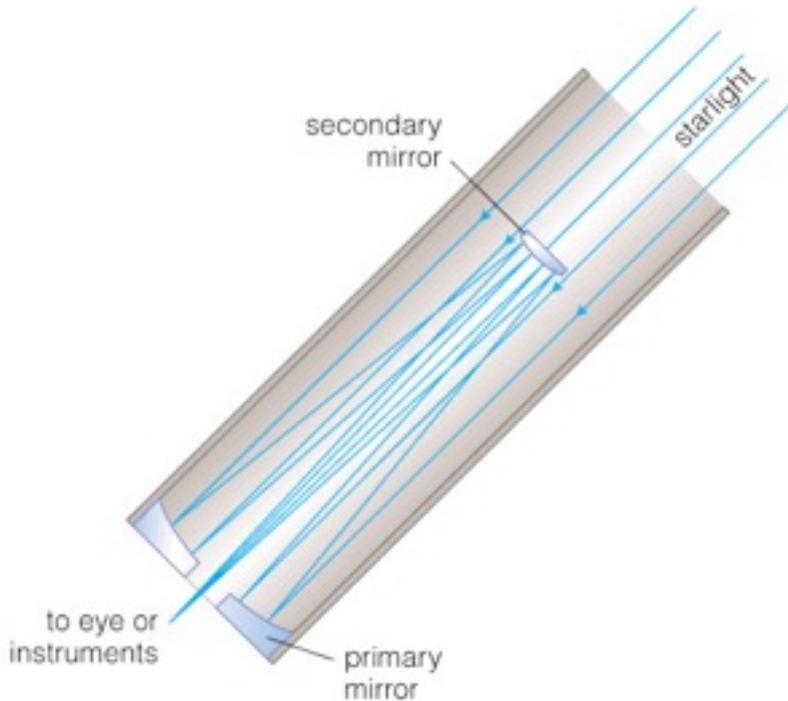
Refracting telescope



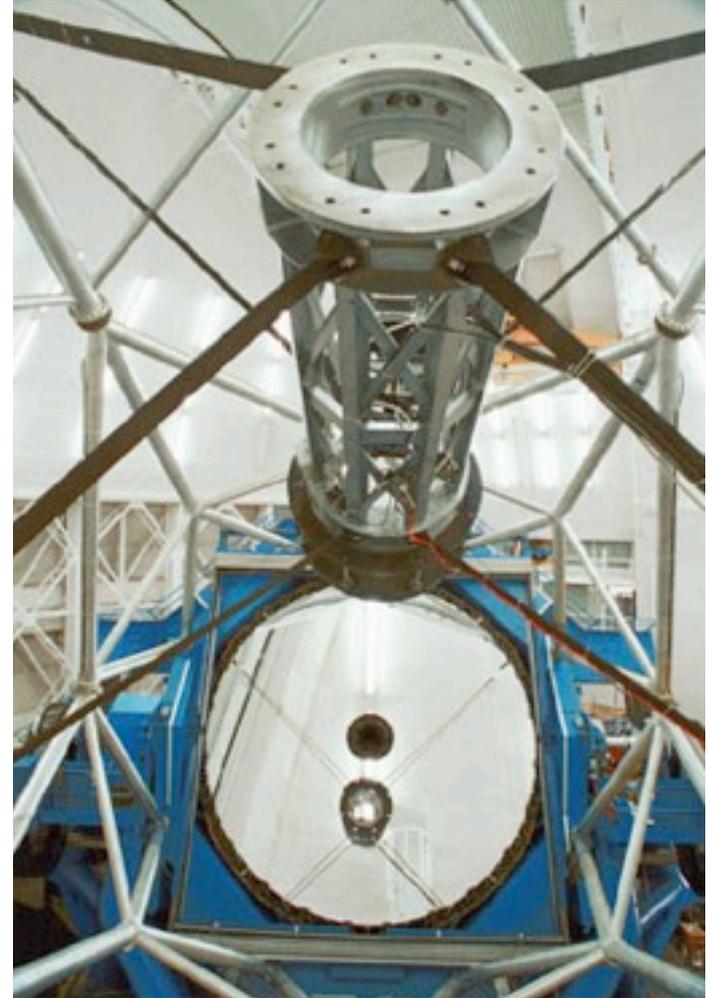
Yerkes 1-m refractor

Basic Telescope Design

- Reflecting: mirrors
- Most research telescopes today are reflectors



Reflecting telescope



Gemini North 8-m

Kitt Peak National Observatory (AZ)

4 m



2.1 m

WIYN (3.5 m)

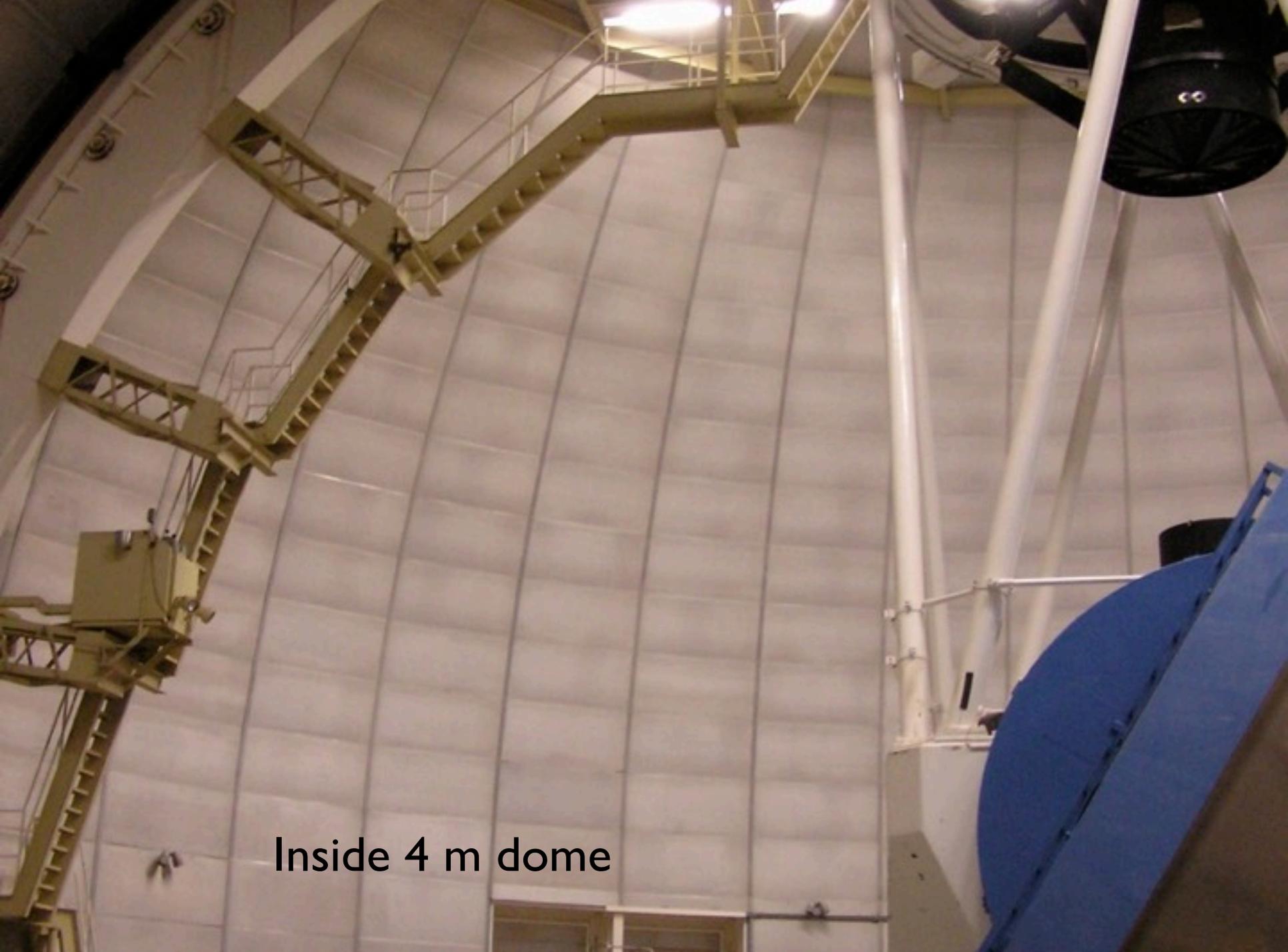
Burrell
Schmidt





2.1 m





Inside 4 m dome

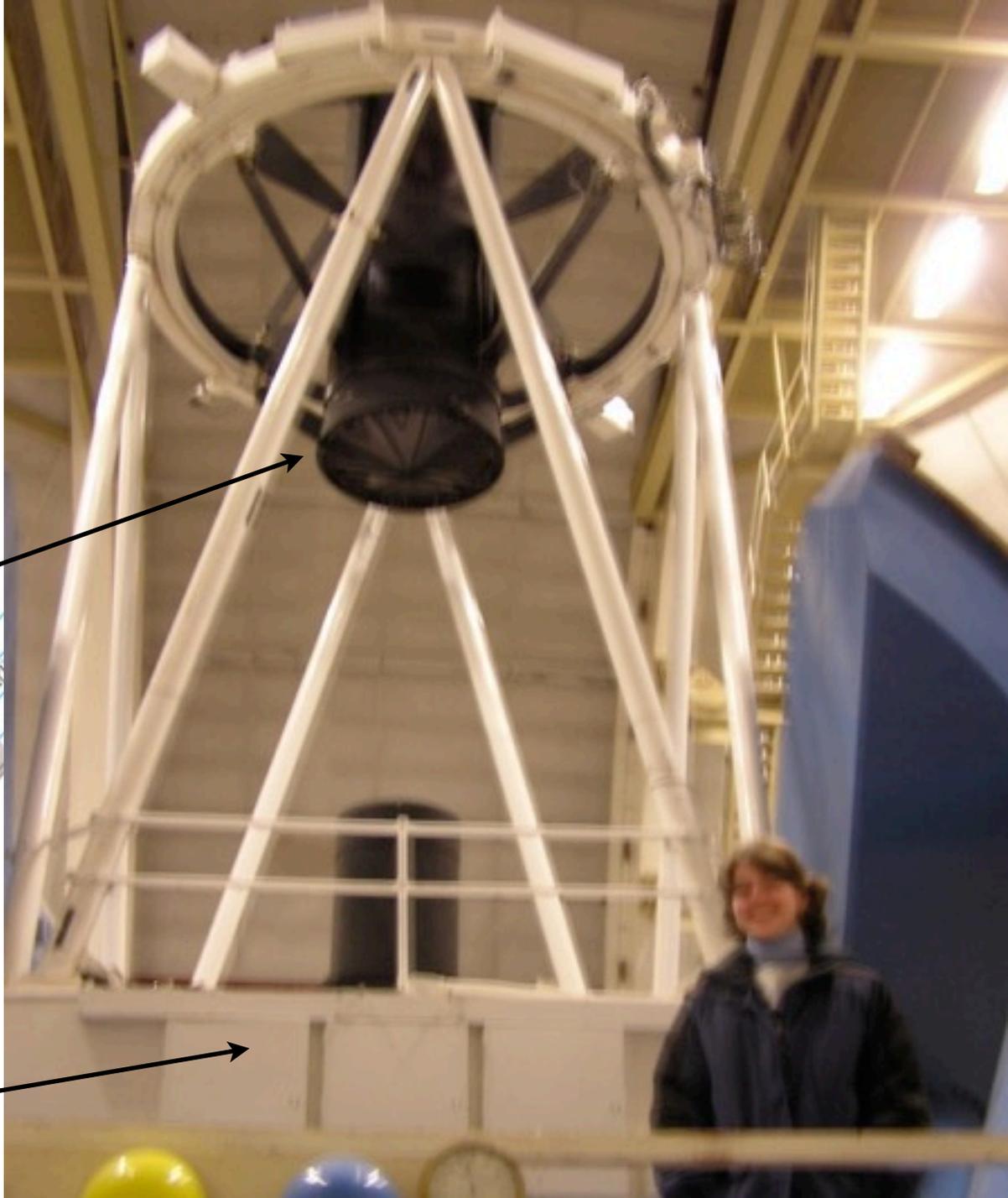
4 m

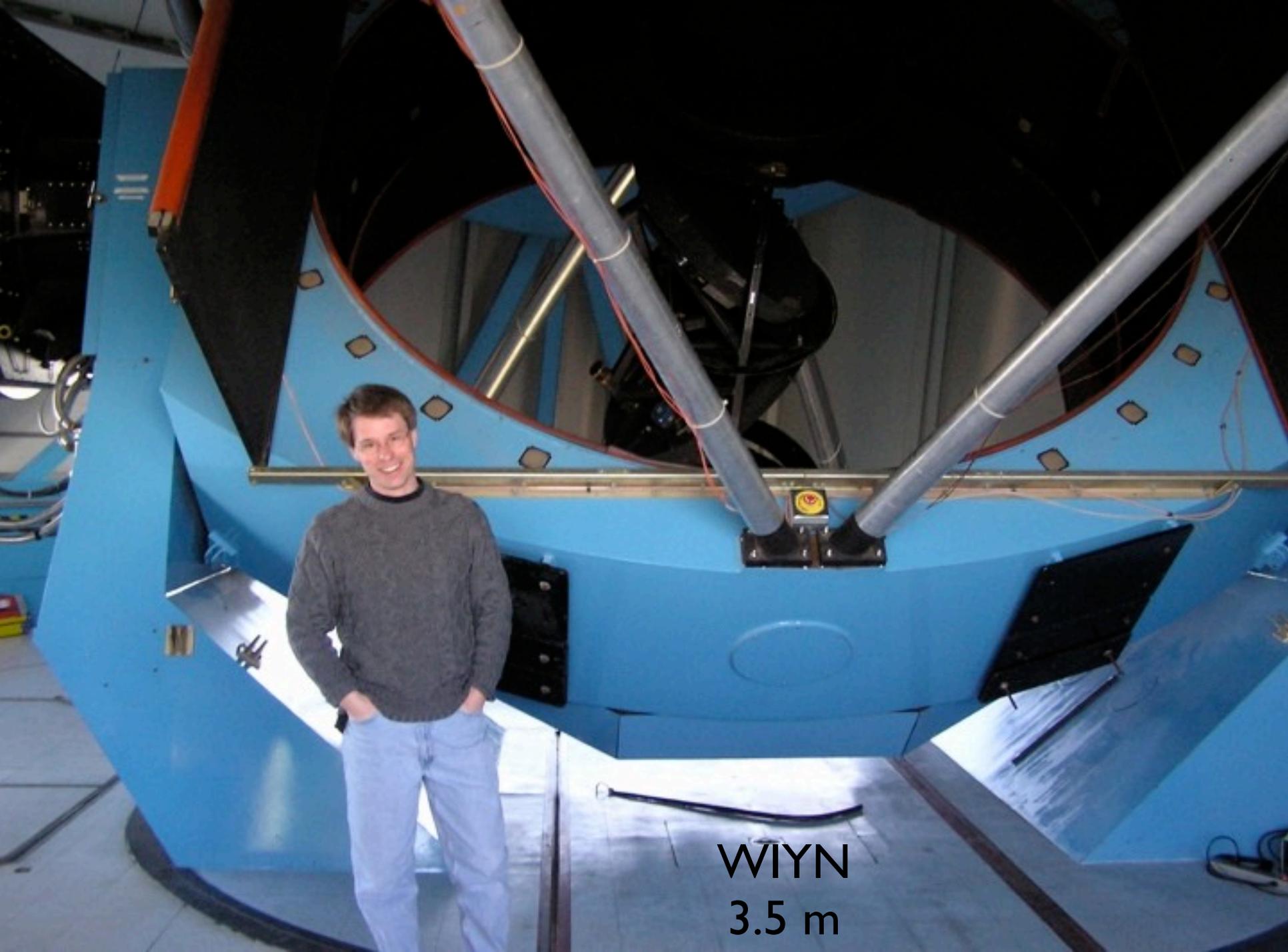
secondary mirror

star

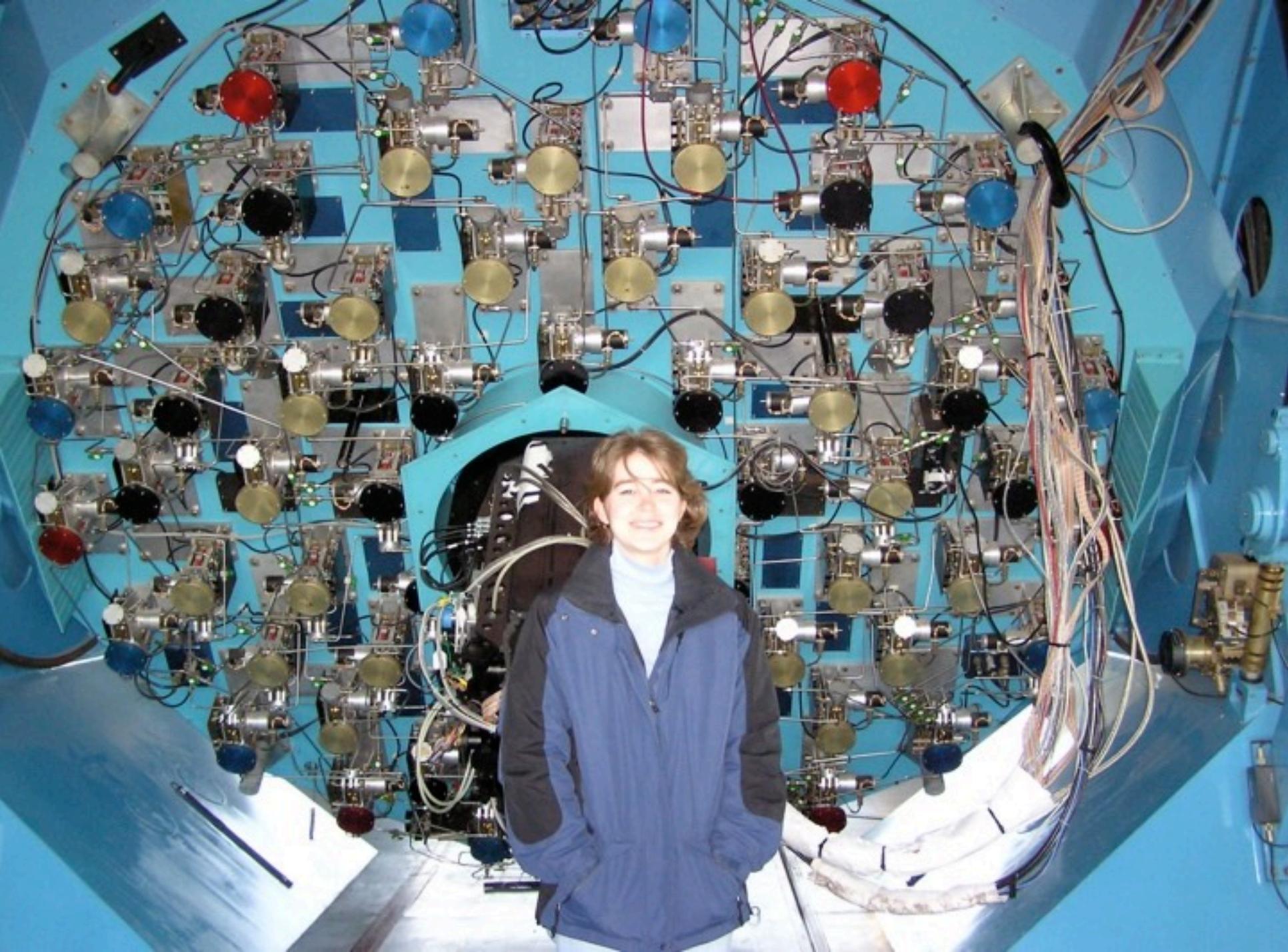
to eye or instruments

primary mirror





WIYN
3.5 m



Different designs for different wavelengths of light

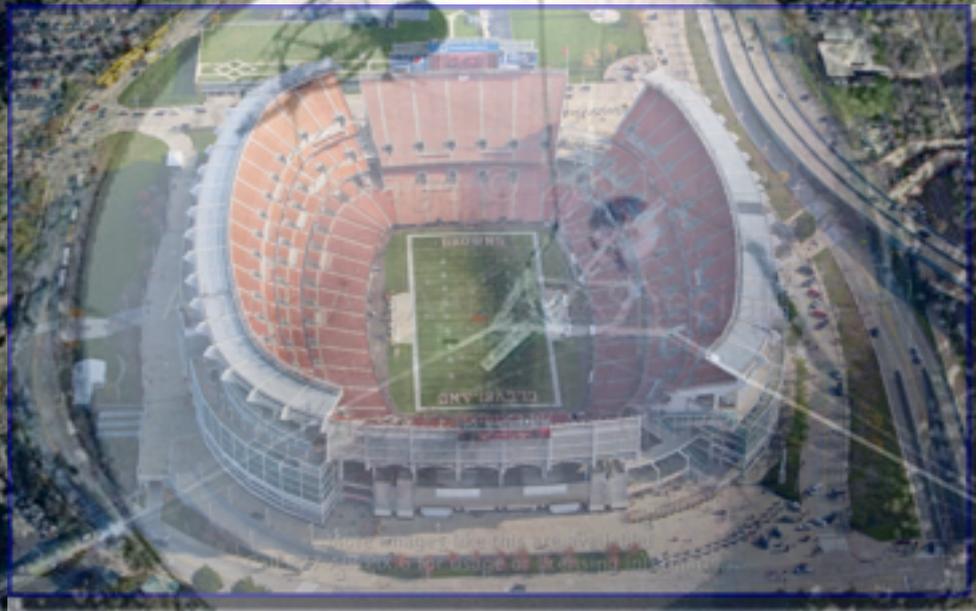


Radio telescope (Arecibo, Puerto Rico)
Longer wavelengths need larger “mirrors”

Aricebo 305 m



Aricebo 305 m



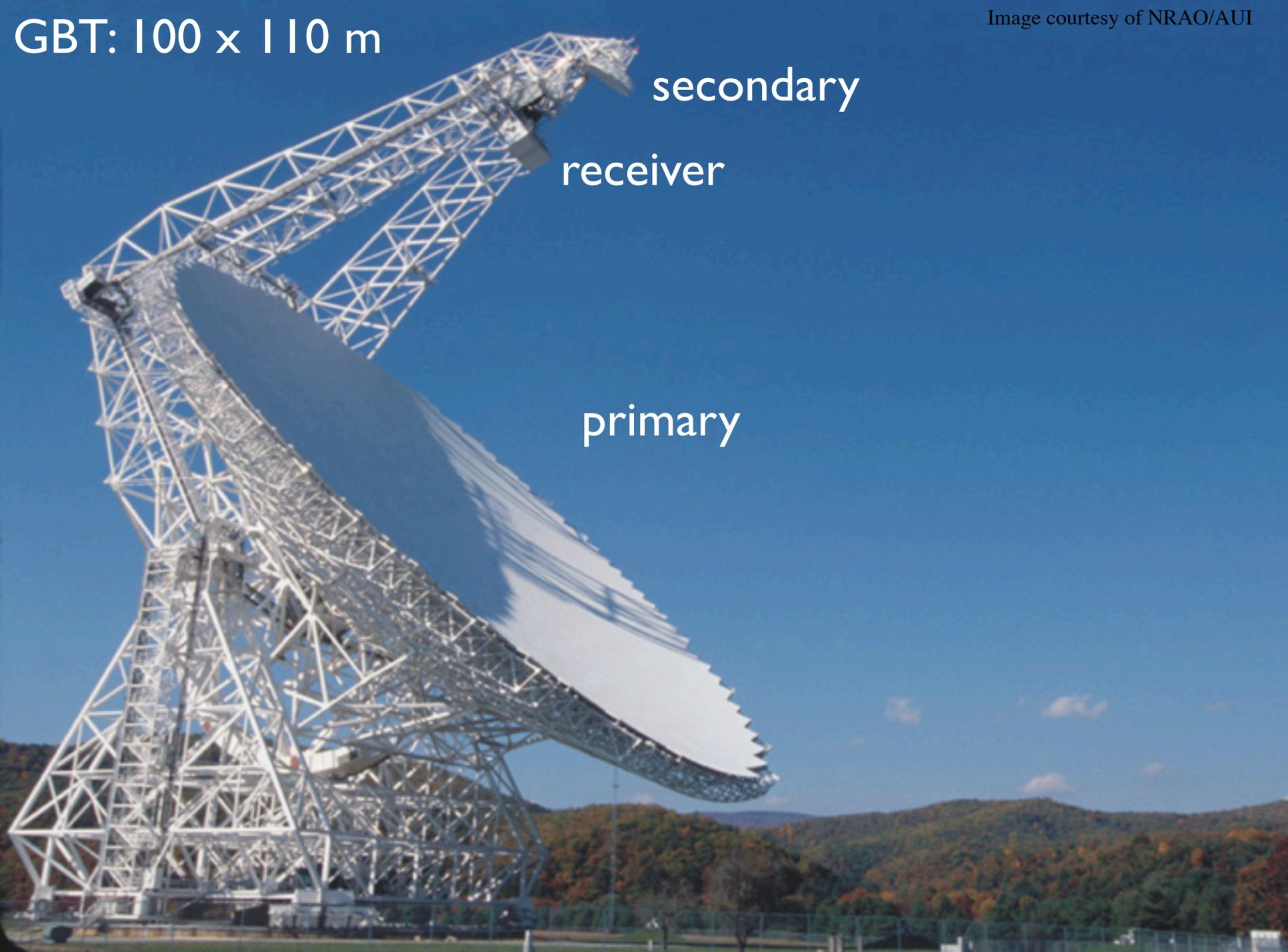
Aricebo 305 m



GBT: 100 x 110 m

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



28 x 25 m



EVLA (HI @ 21 cm)



CARMA (CO @ 2.6 mm)



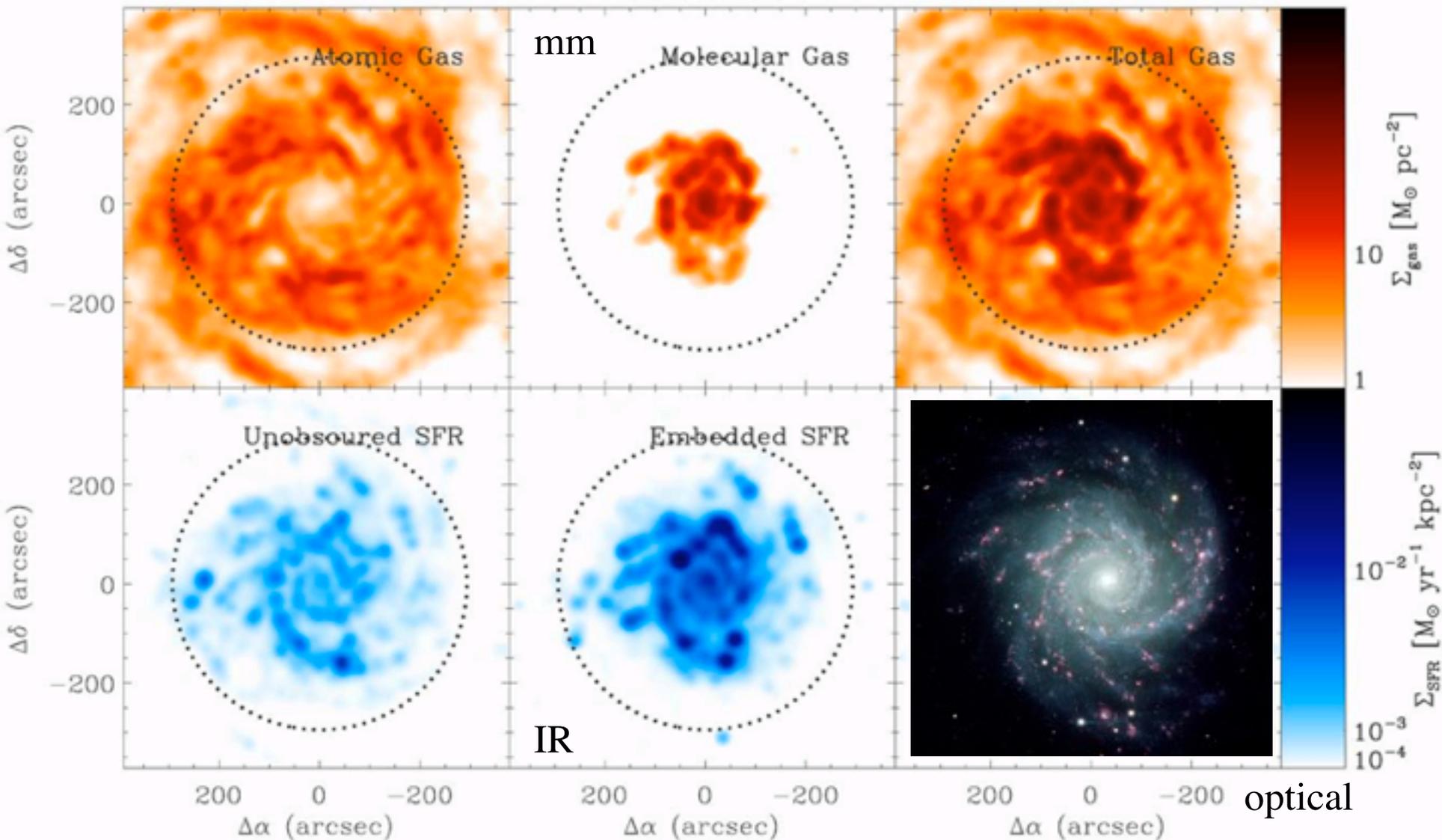
10.4 m

6.1 m

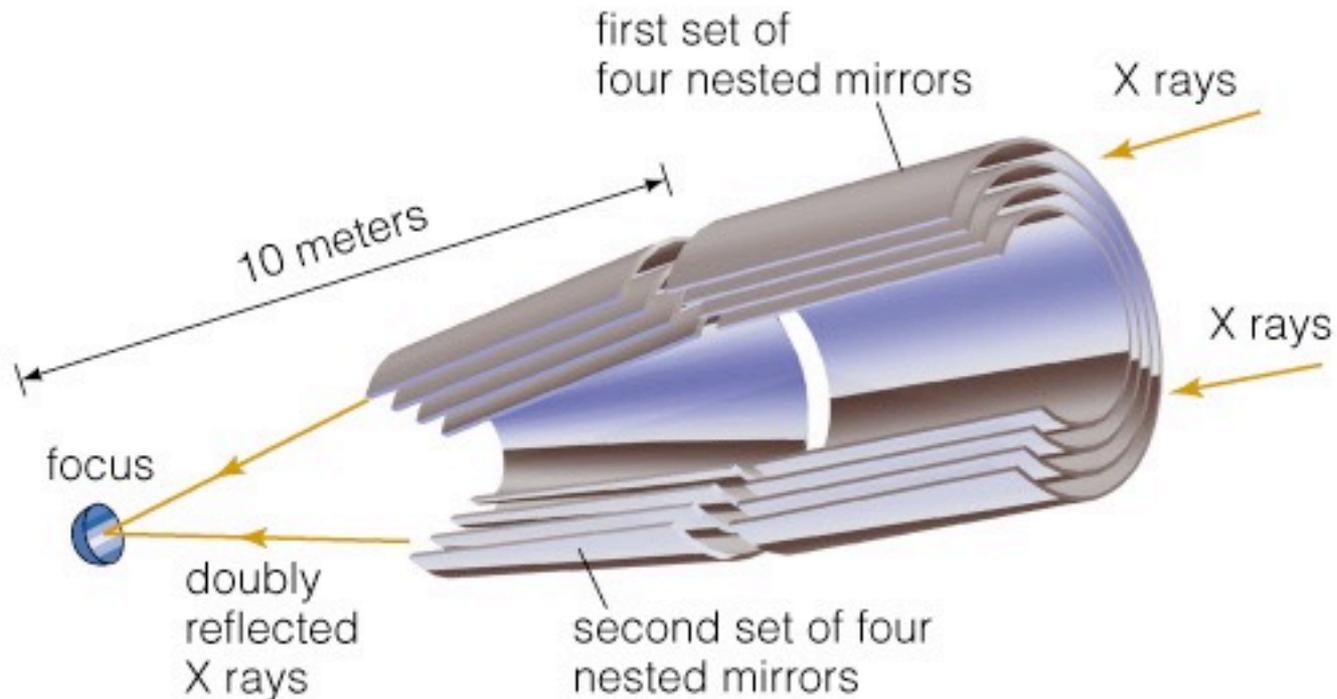
3.5 m

RADIO

NGC 0628



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



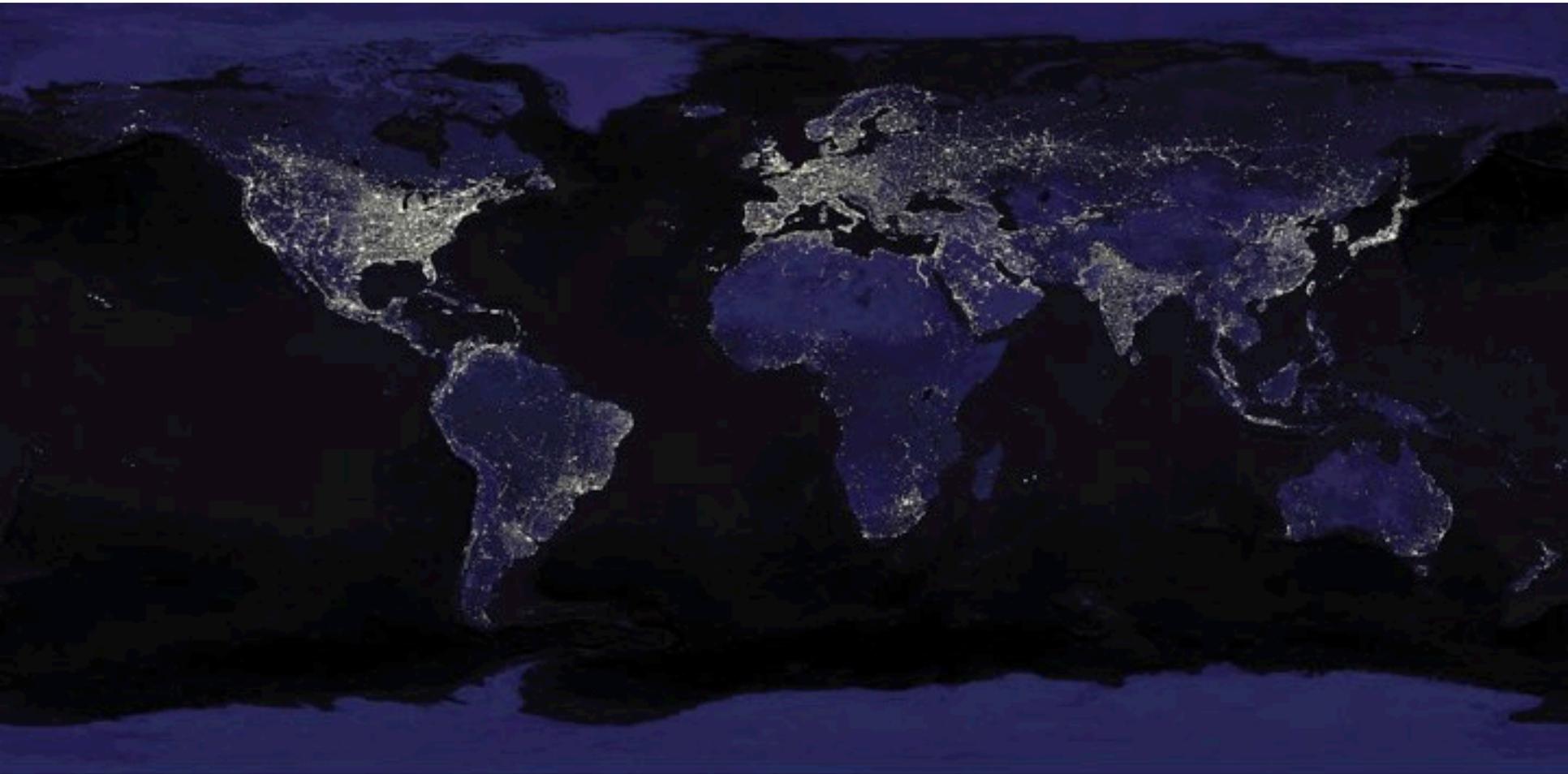
Hubble



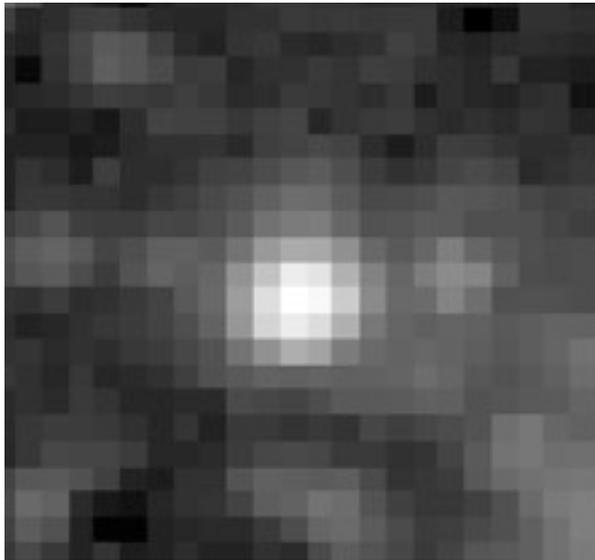
Chandra

Observing problems due to Earth's atmosphere

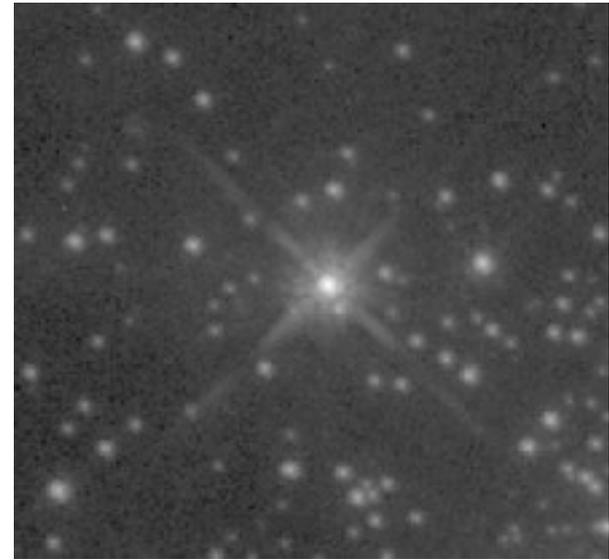
1. Light Pollution



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



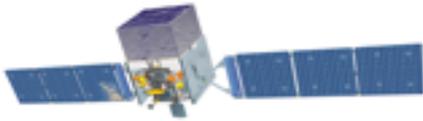
Star viewed with
ground-based telescope



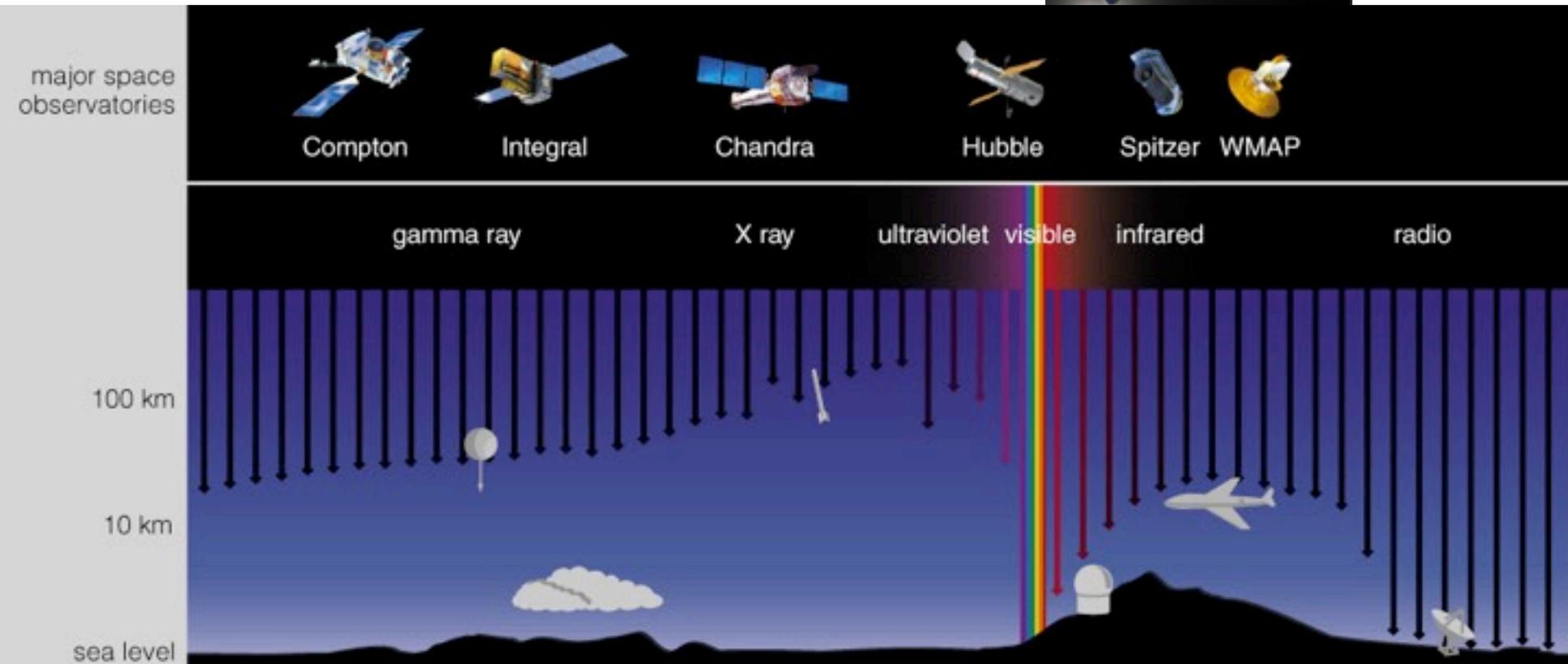
View from Hubble
Space Telescope

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

Fermi



Herschel



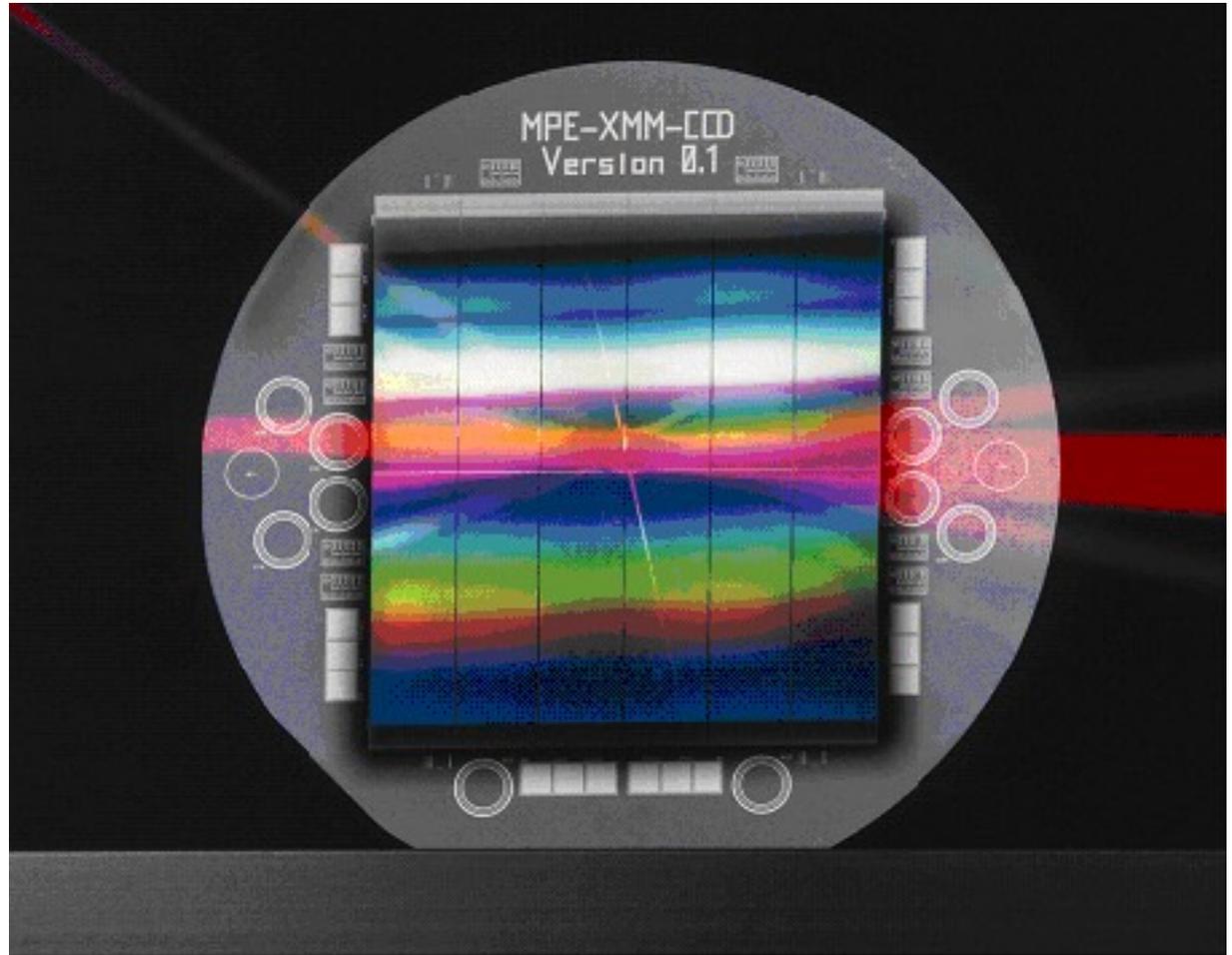
Telescopes in space solve all 3 problems.

Chandra X-ray
Observatory

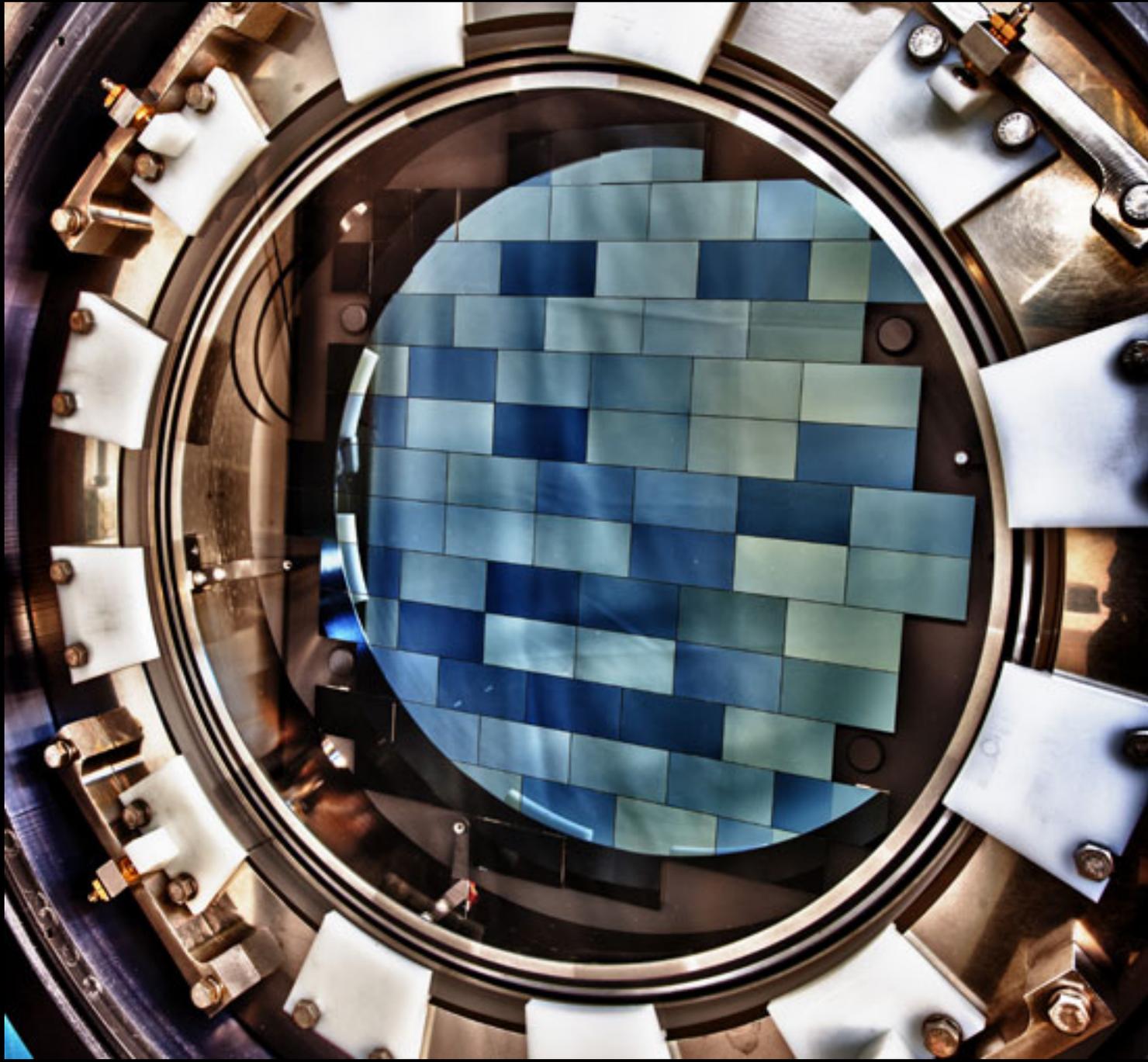


Instruments

- Cameras

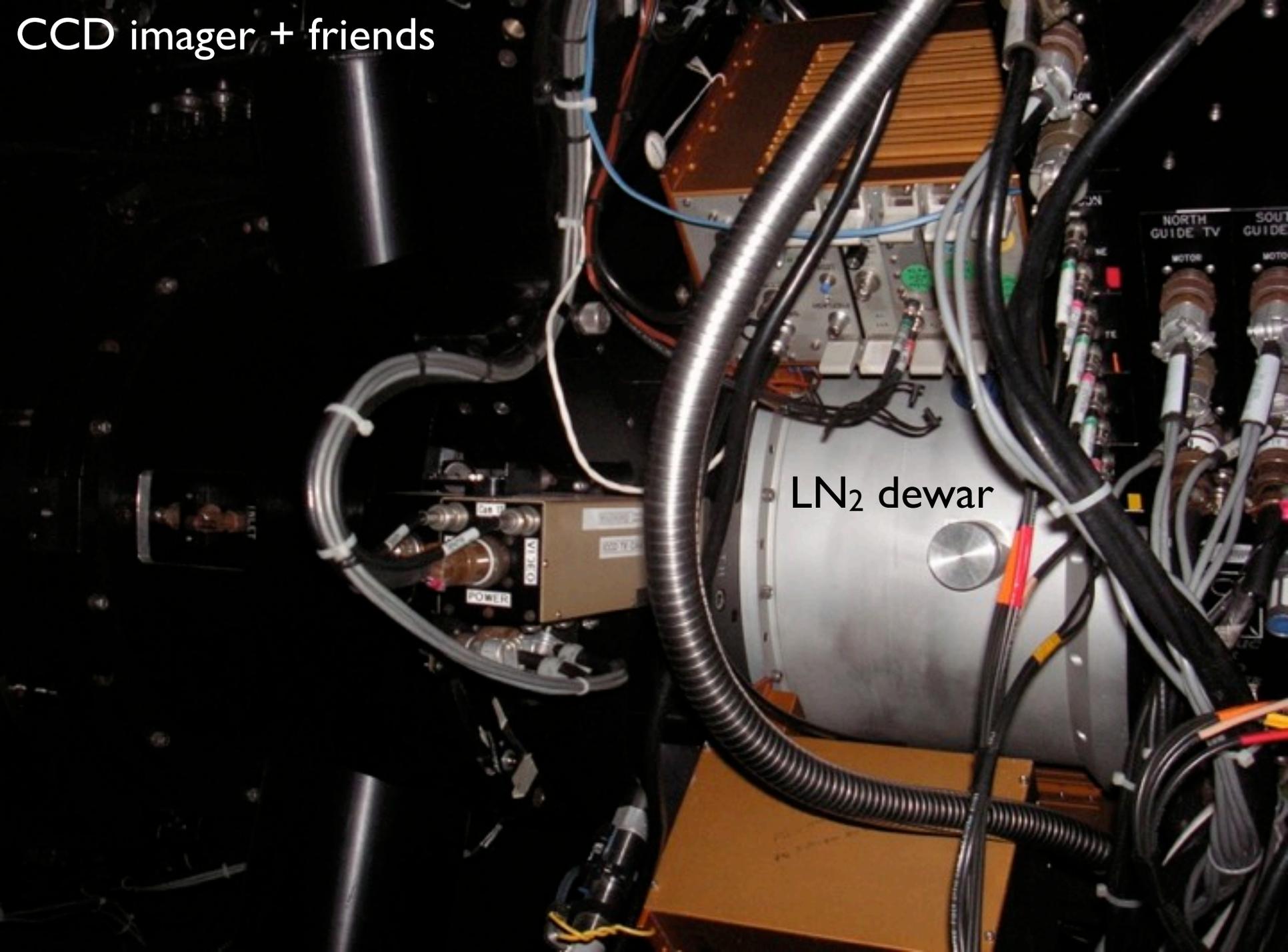


Dark Energy Camera
570 Megapixel

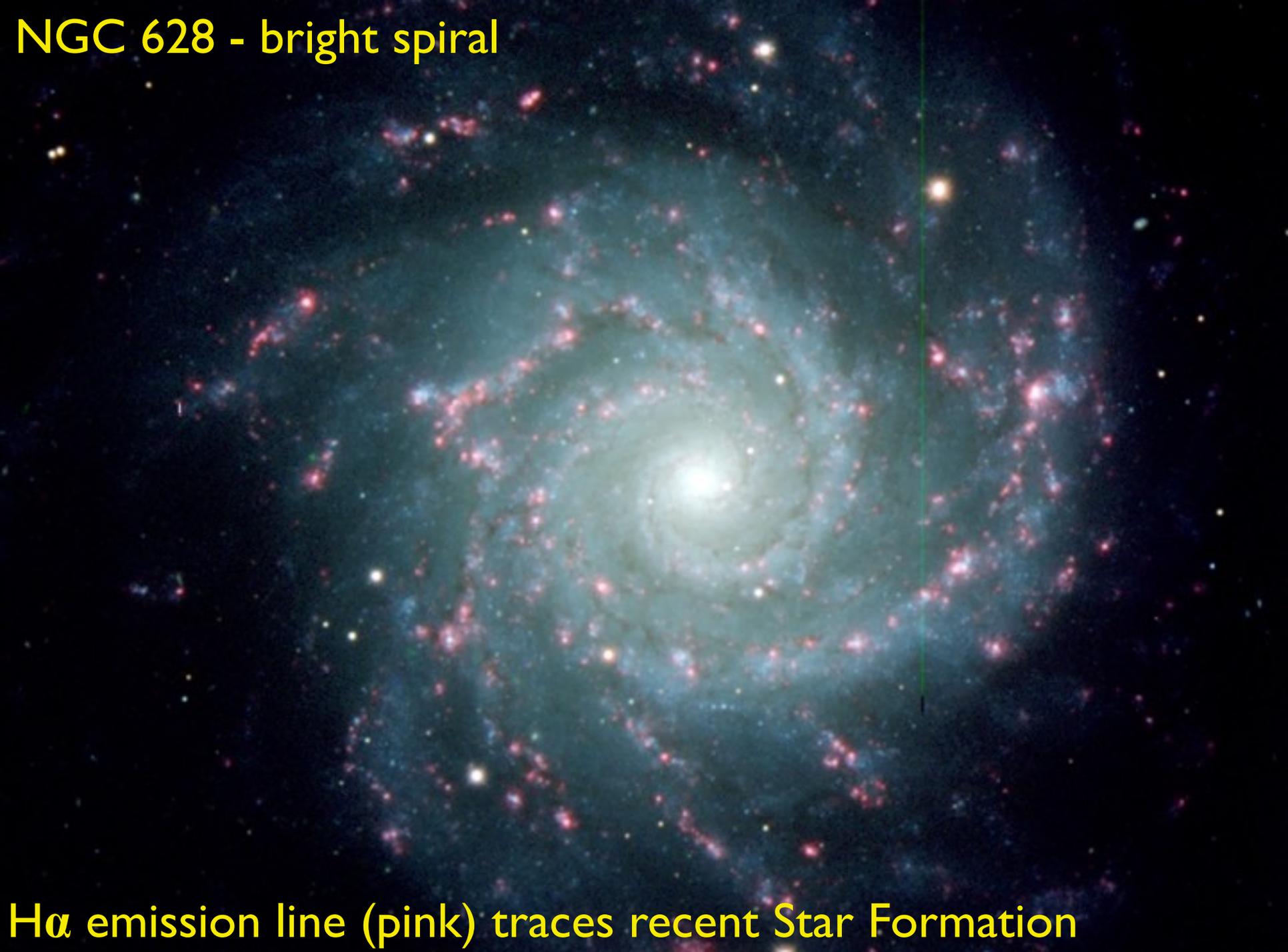


CCD imager + friends

LN₂ dewar

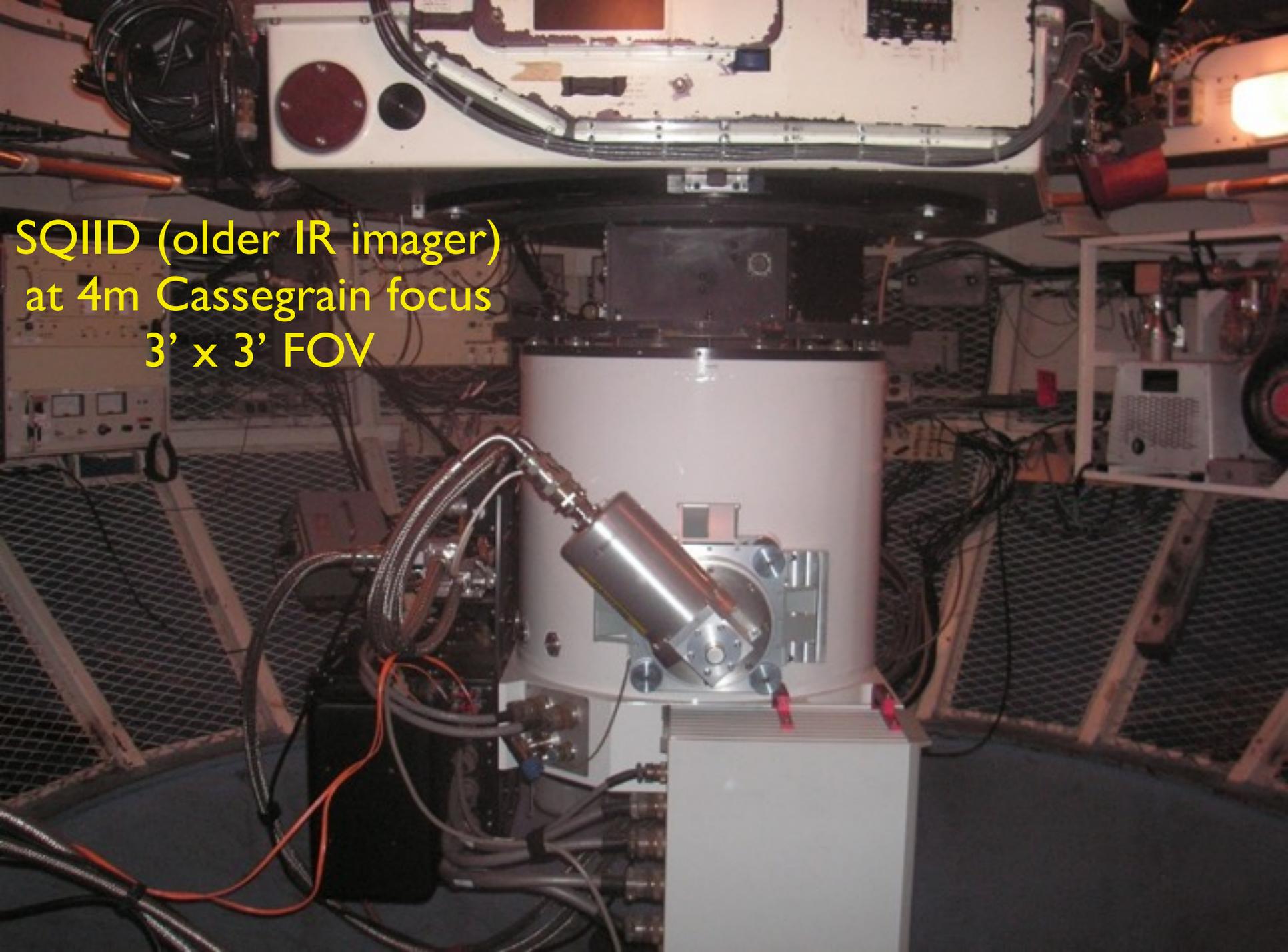


NGC 628 - bright spiral



H α emission line (pink) traces recent Star Formation

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



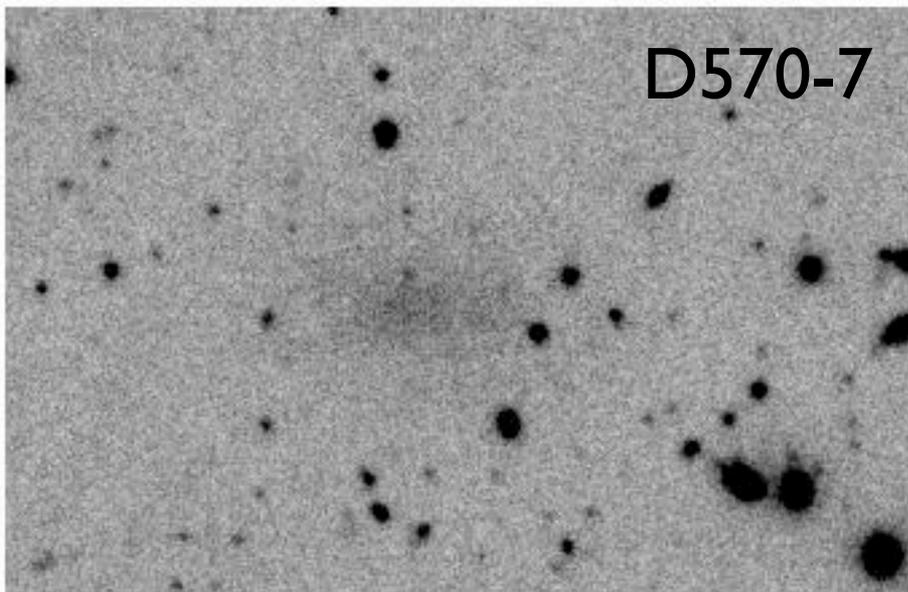
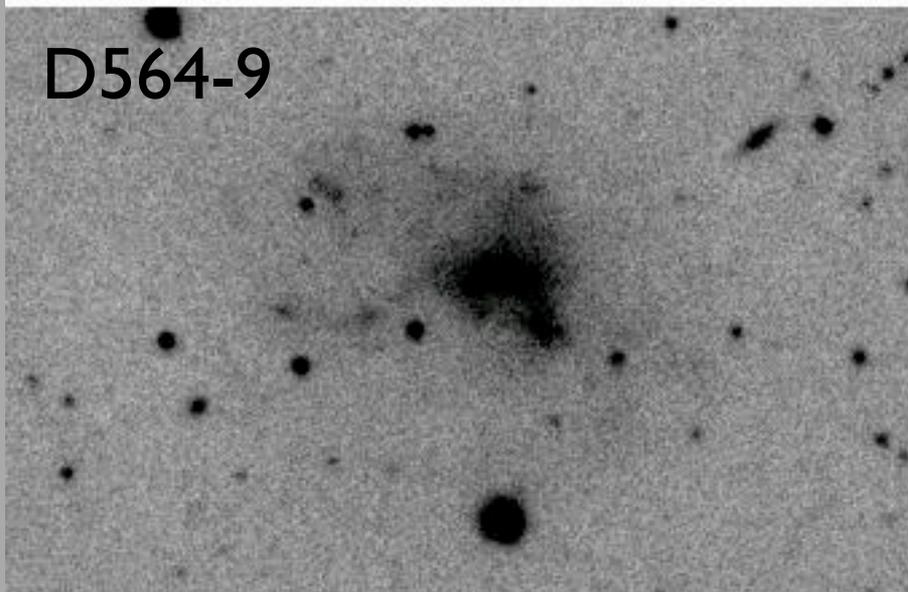
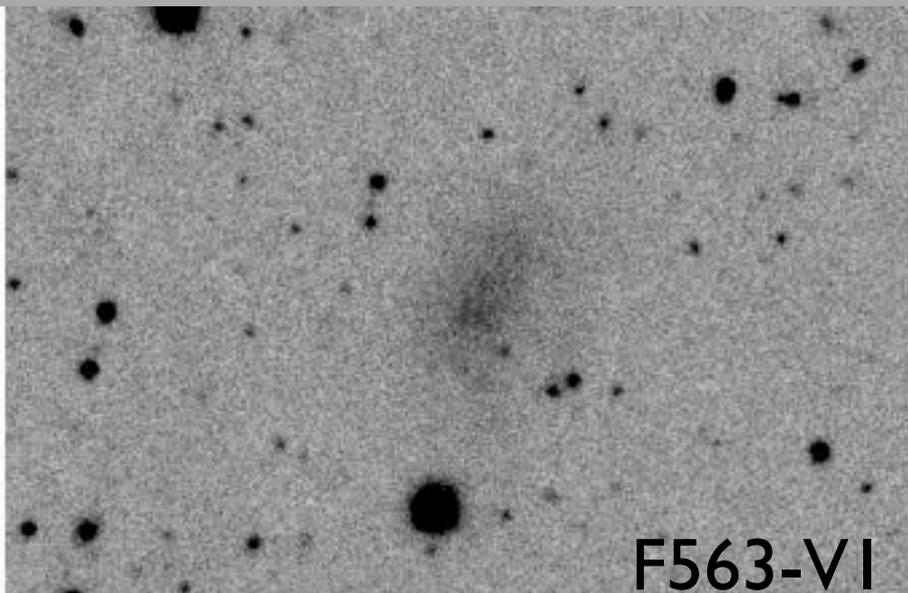
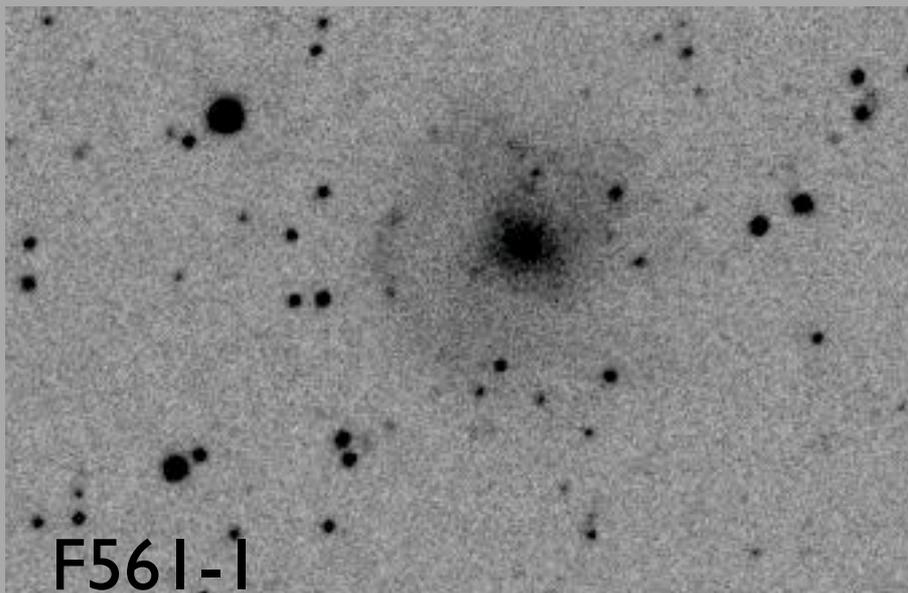
SQUID



NEWFIRM near-IR imager
28' x 28' FOV



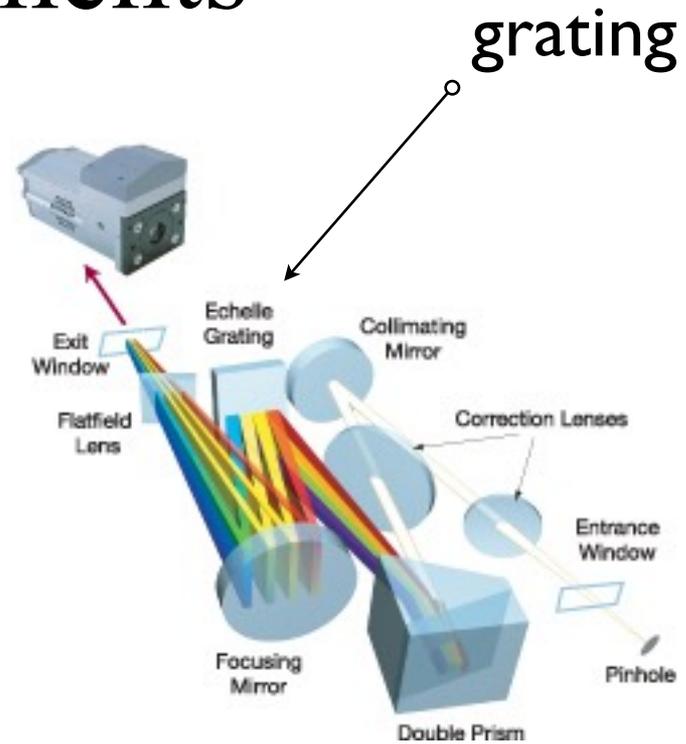
STELLAR MASS MAPS FROM NEAR-IR DATA (2.2 OR 3.6 MICRONS)



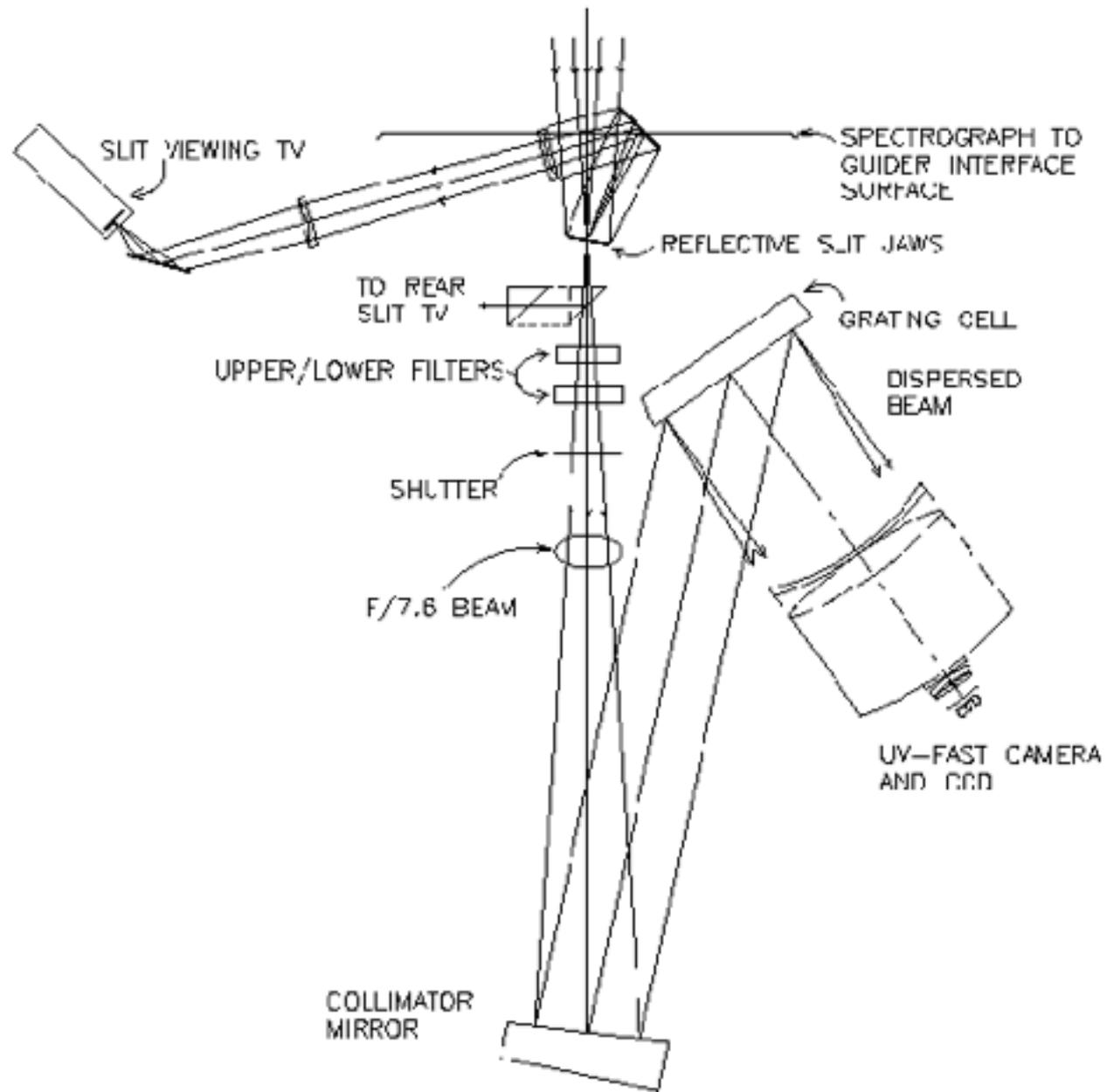
Kitt Peak 4m + NEWFIRM K'-band (2.2 micron)

Instruments

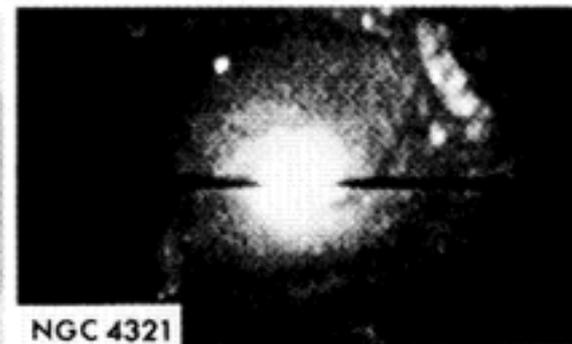
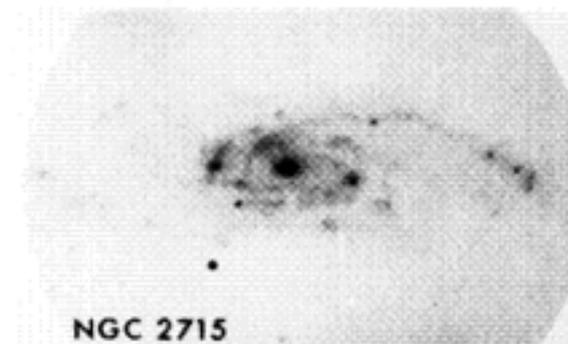
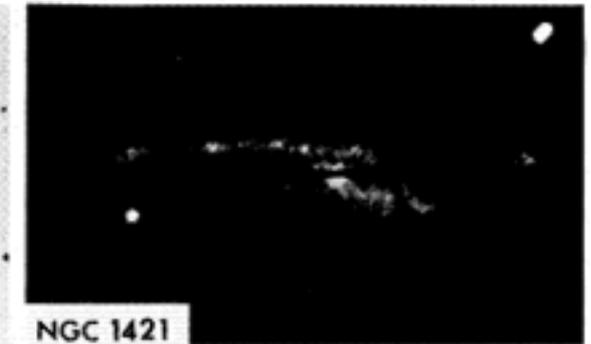
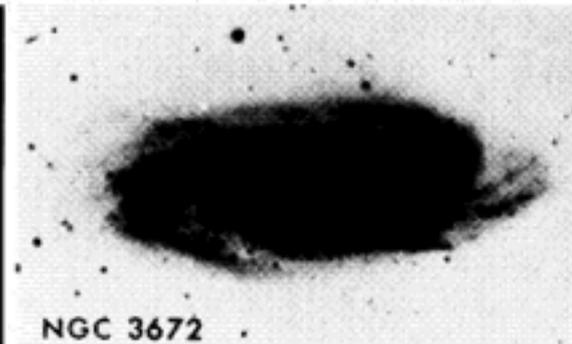
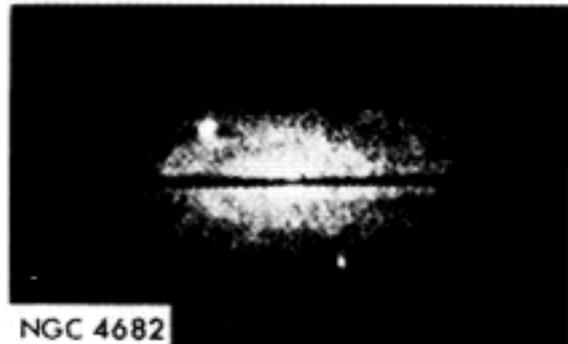
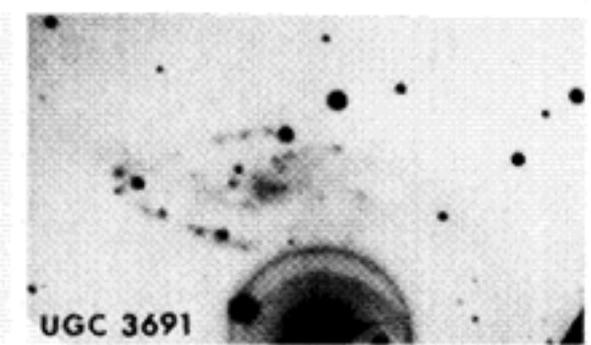
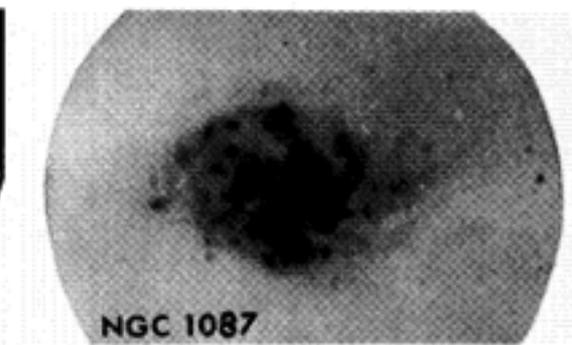
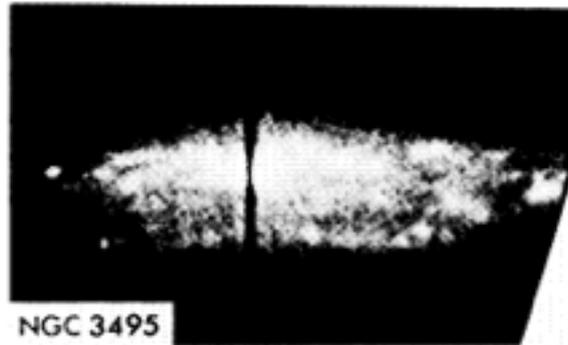
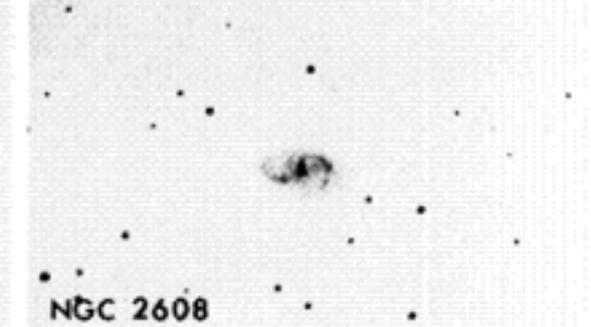
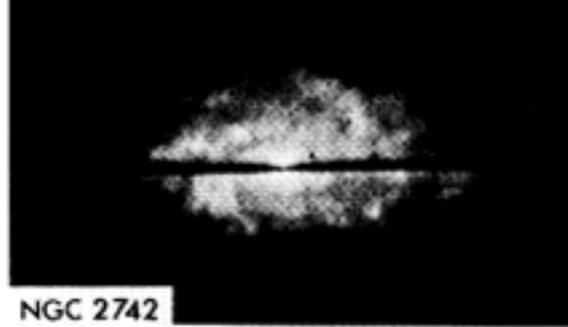
- Spectrographs



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



slit view





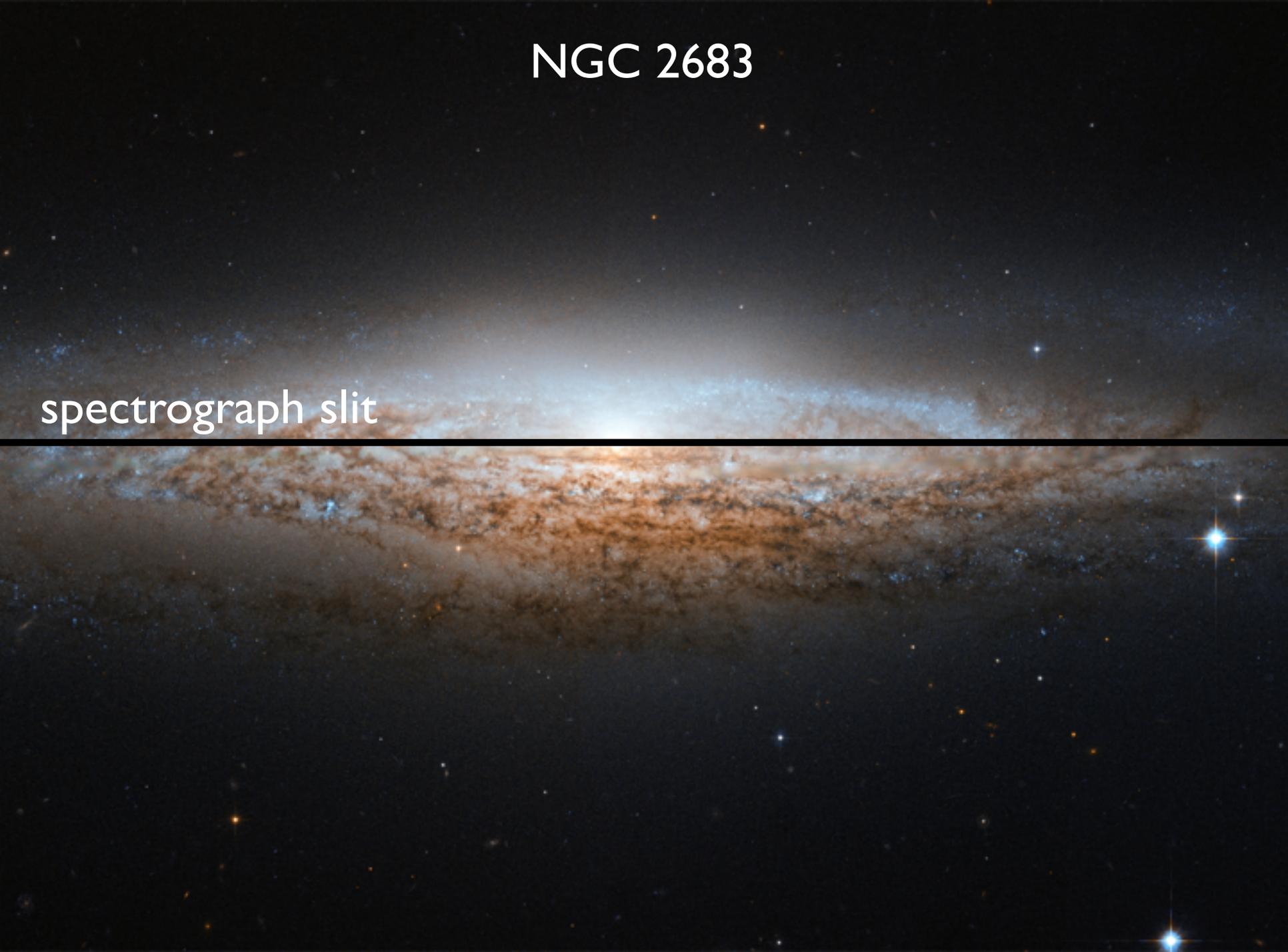
spectrograph



grating

NGC 2683

spectrograph slit



Spectrum

