



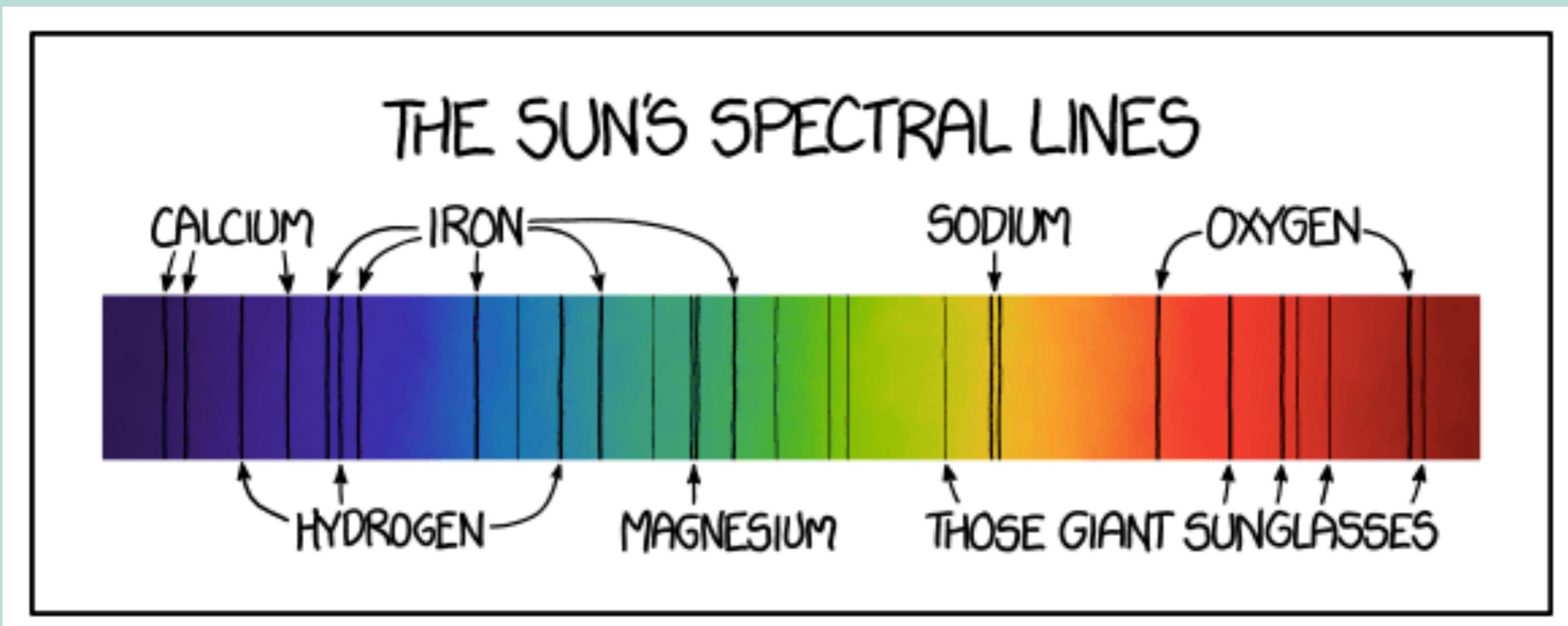
Lecture 5: Telescopes

with your host:

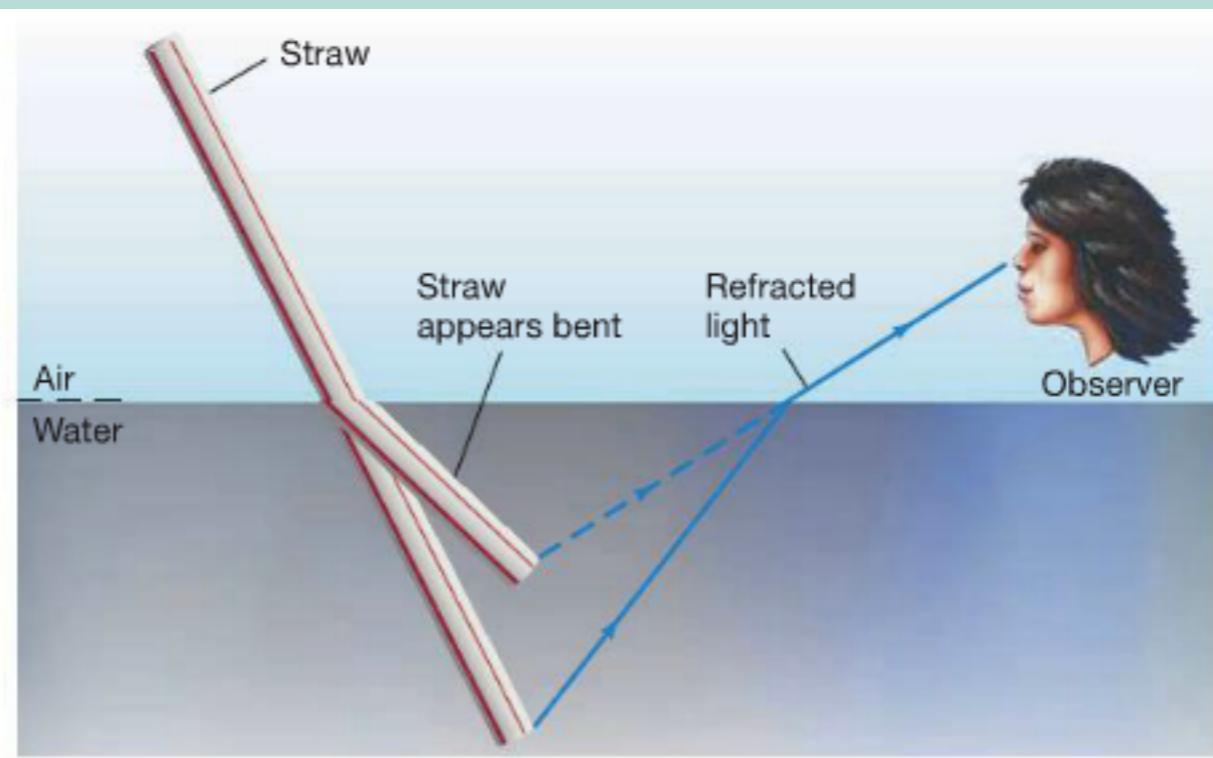


Coop

Telescopes: Ch 5

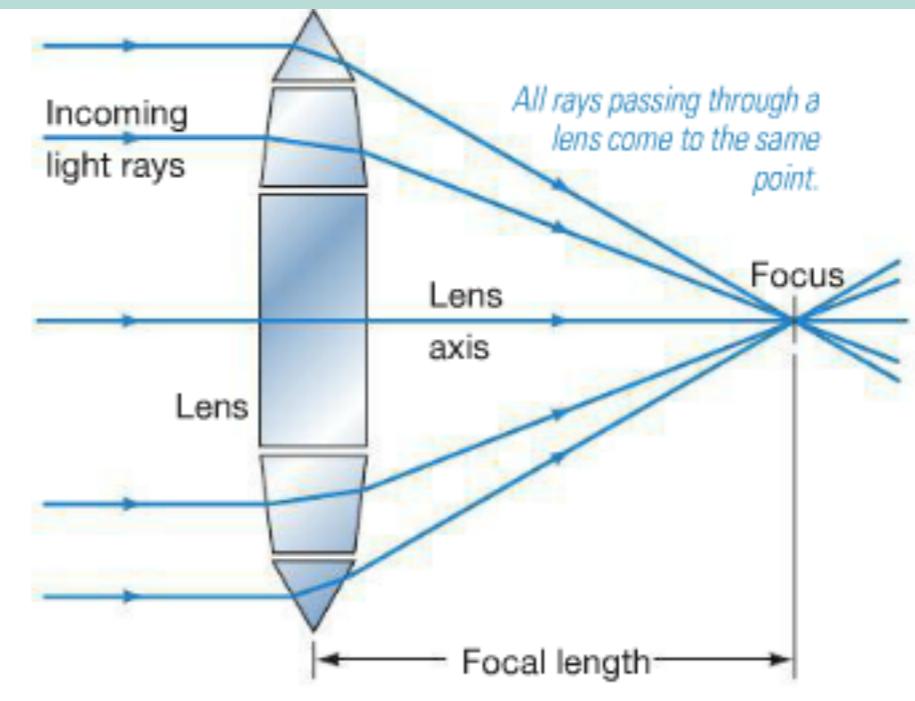
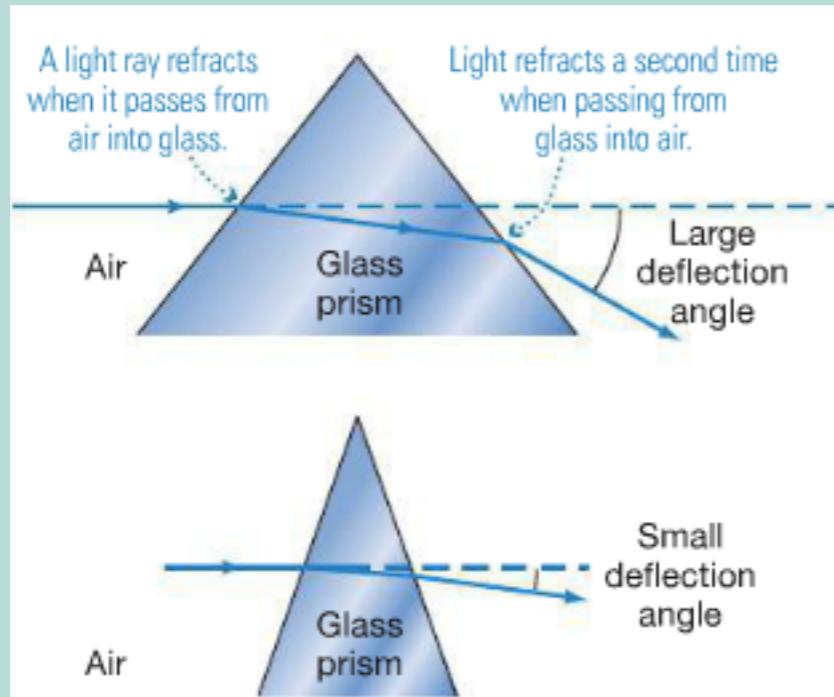


Refraction

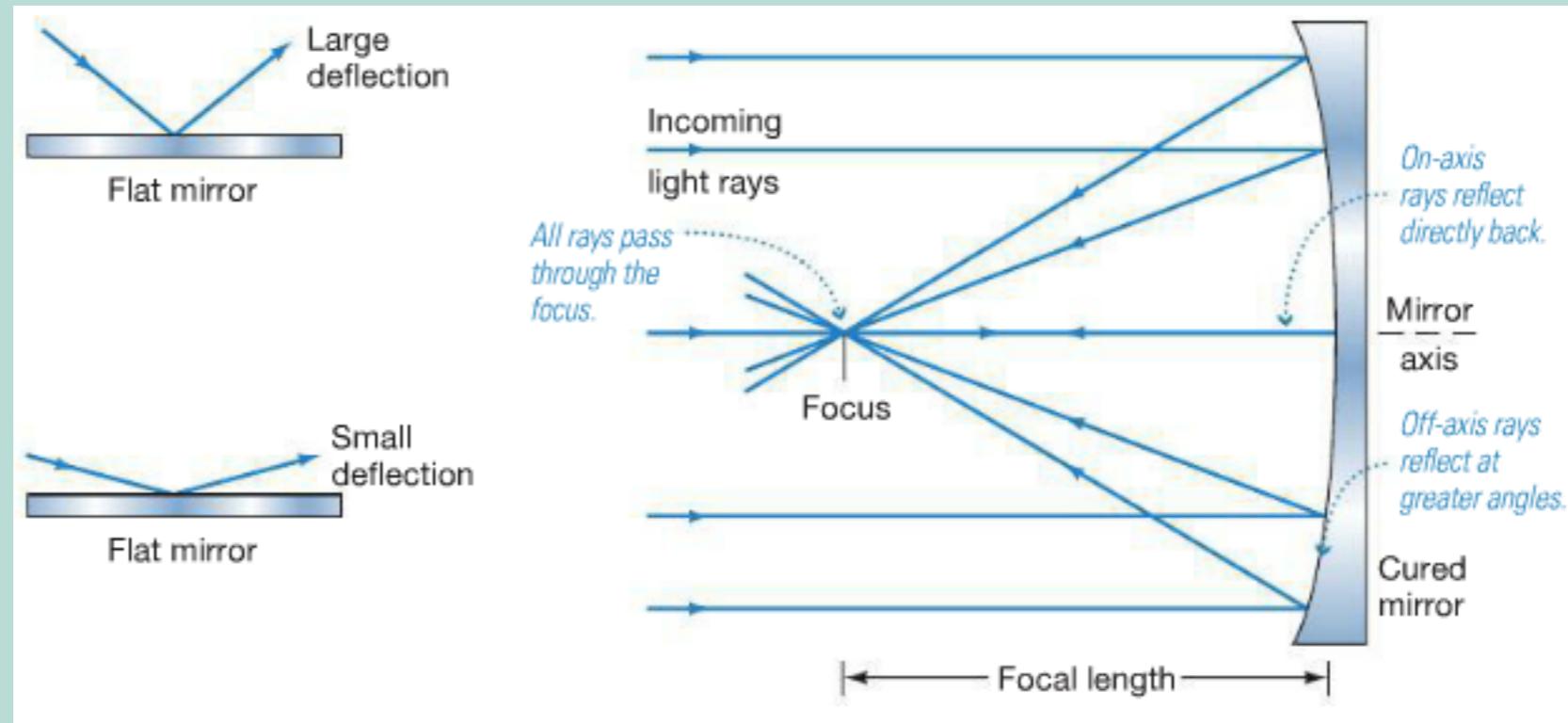


Telescopes: Ch 5

Lenses

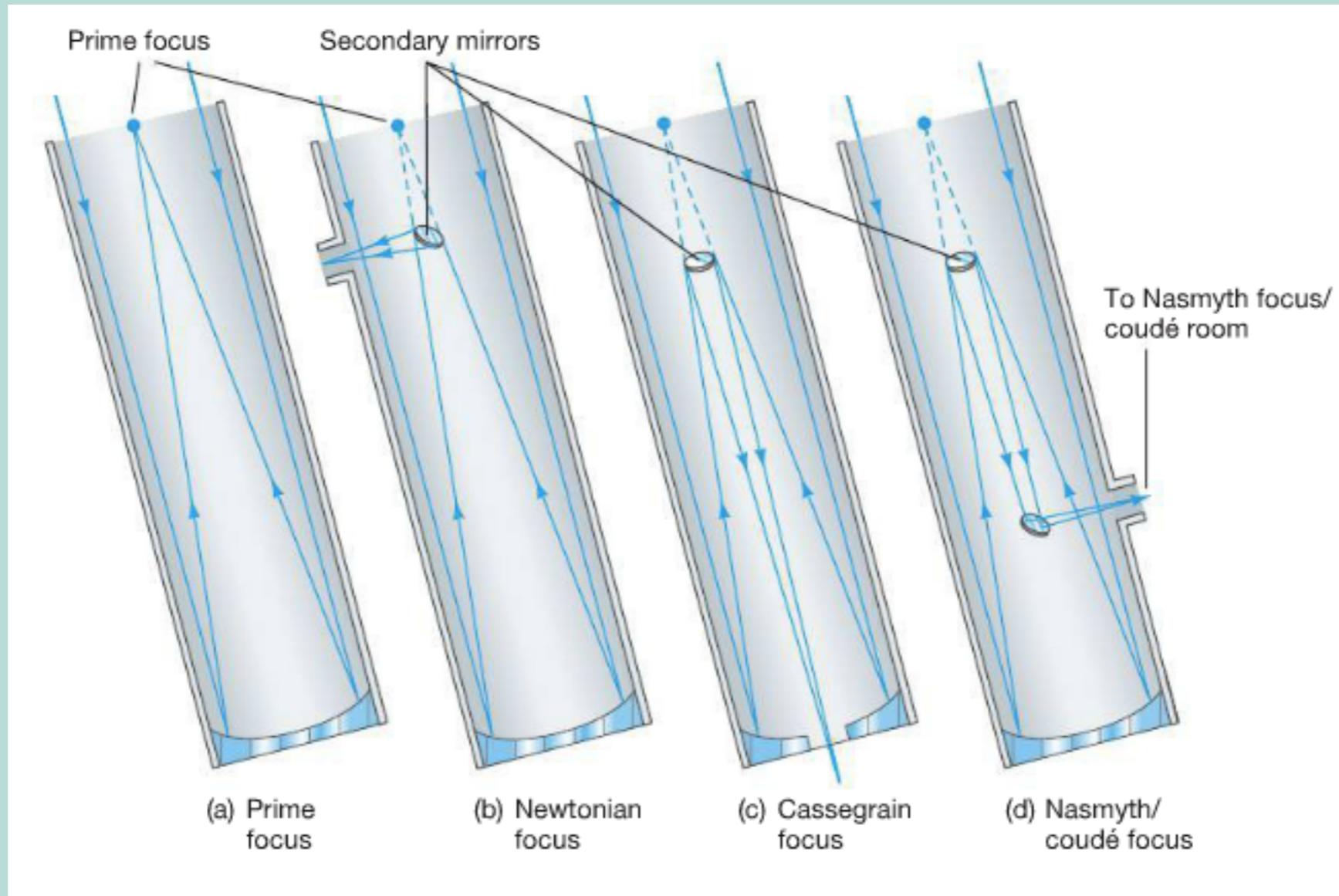


Reflection



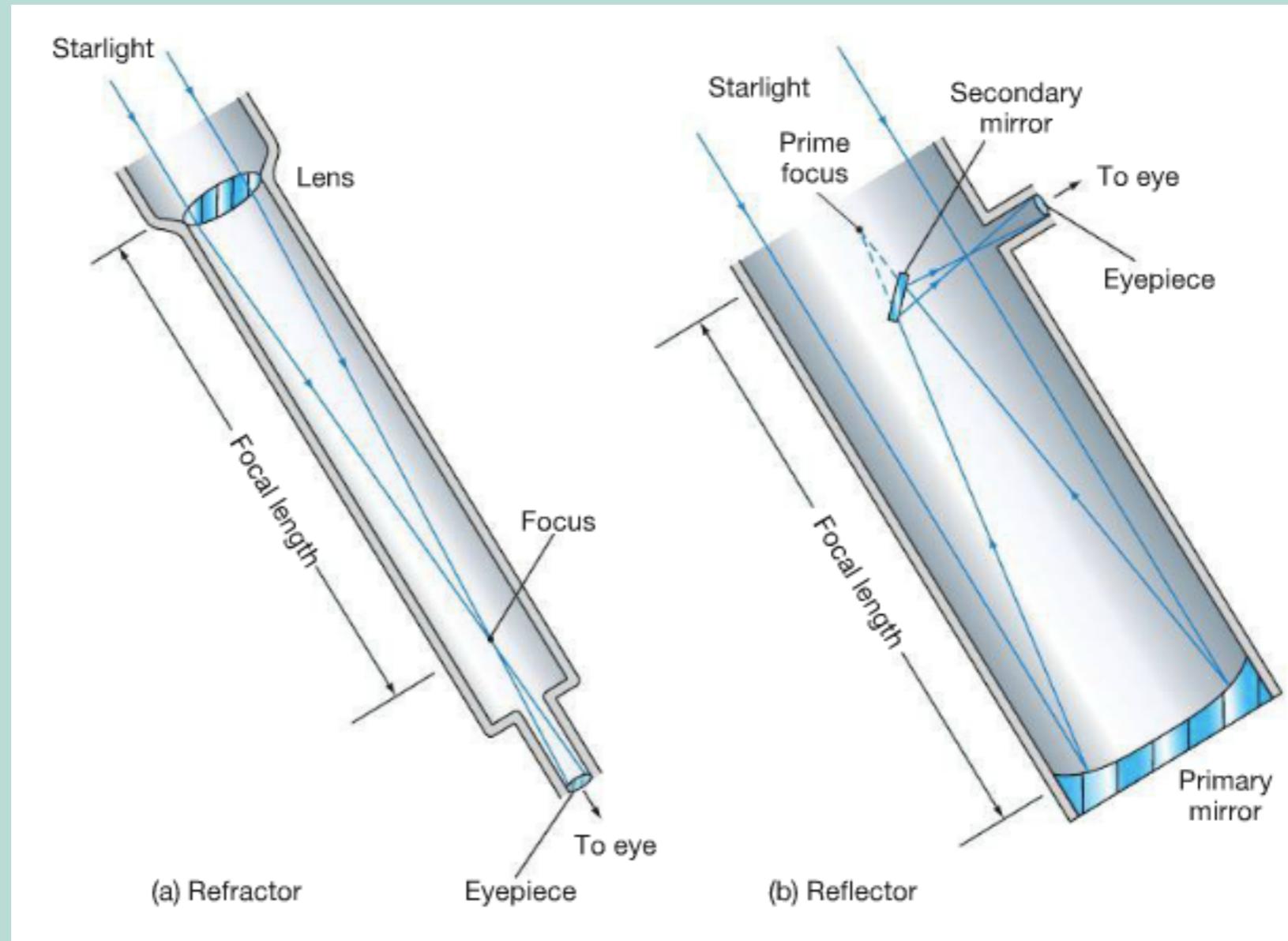
Telescopes: Ch 5

Different Reflecting Telescopes



Telescopes: Ch 5

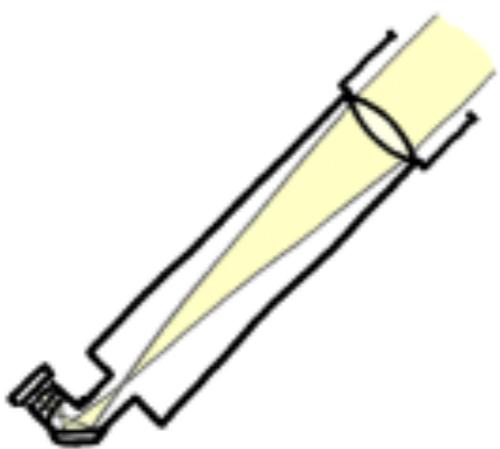
Refraction vs Reflection Telescopes



Refraction vs Reflection Telescopes

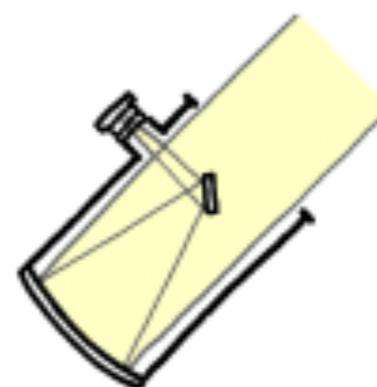
- Chromatic Aberration
- Absorption
- Support
- Double the Surfaces

REFRACTOR



- MORE EXPENSIVE
- LESS COMPACT
- CHROMATIC ABERRATION
- REDUCED LIGHT-GATHERING

REFLECTOR



- CAN'T SEE SPACE VAMPIRES

Telescopes: Ch 5

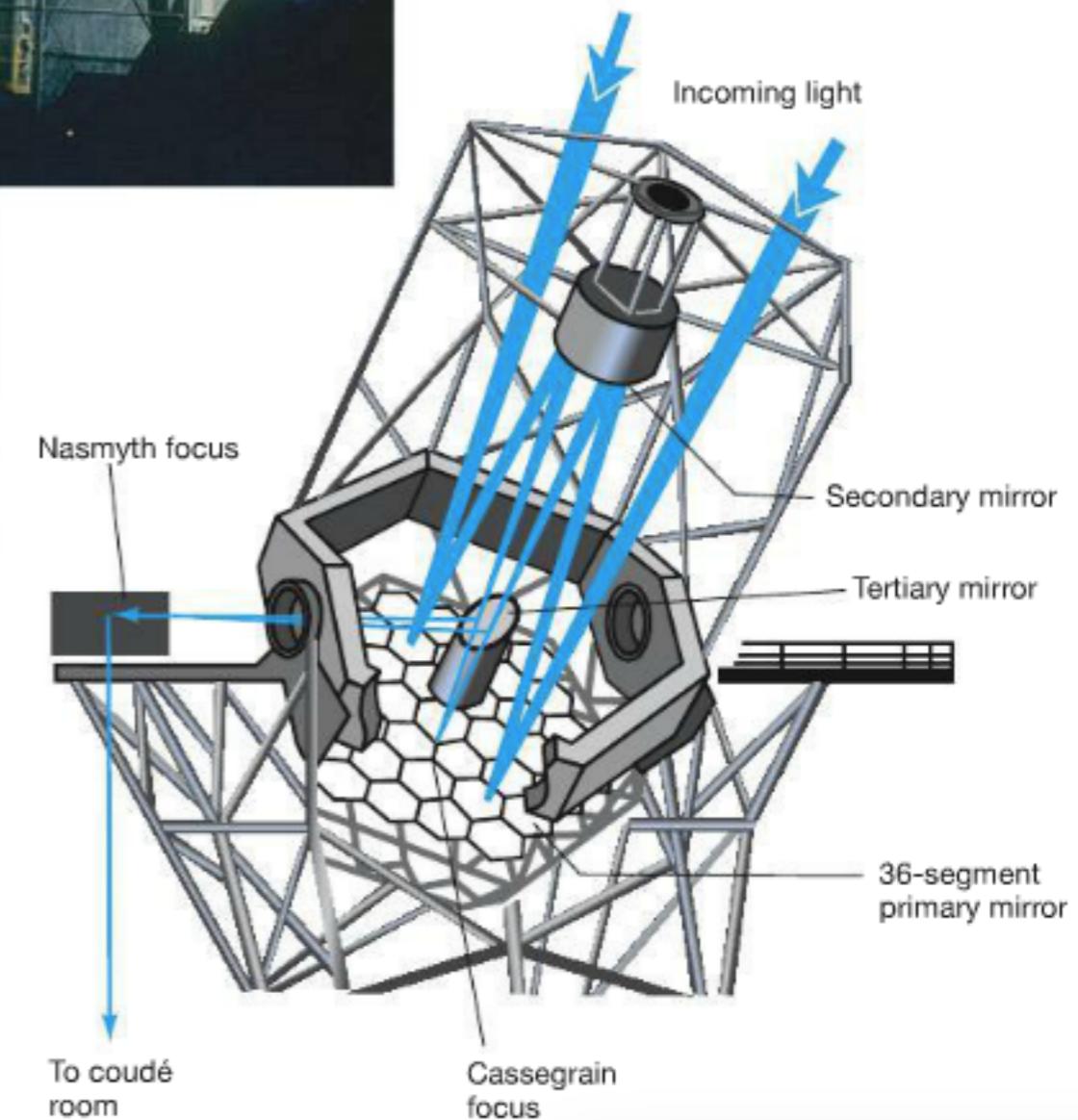
Telescopes are Light Buckets



- Gathering area goes like length squared

Telescopes: Ch 5

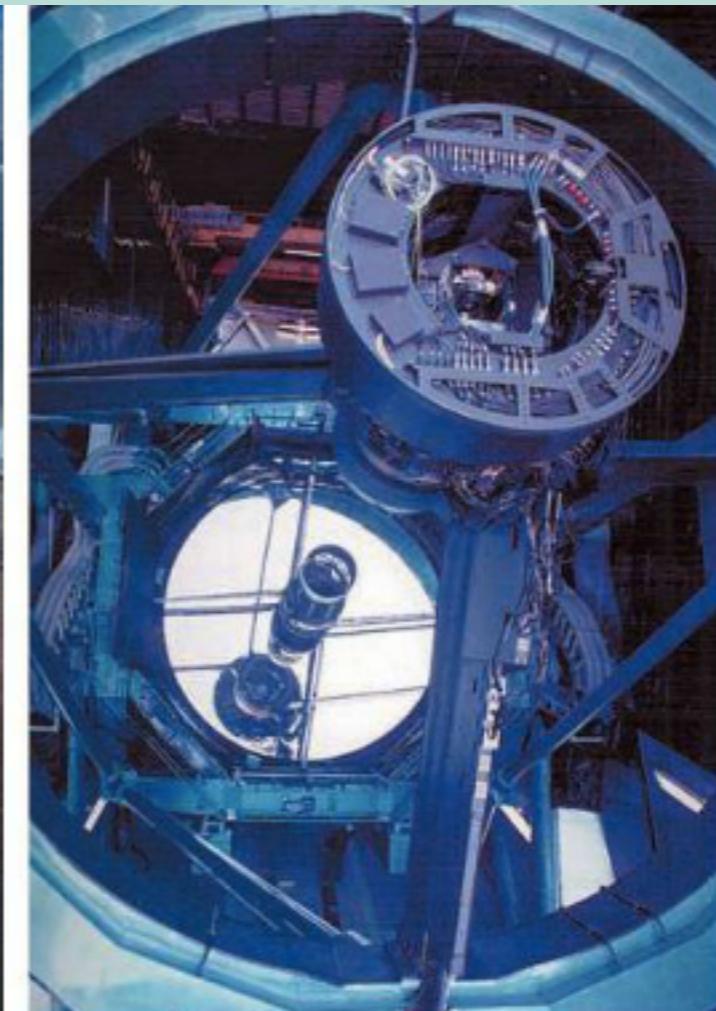
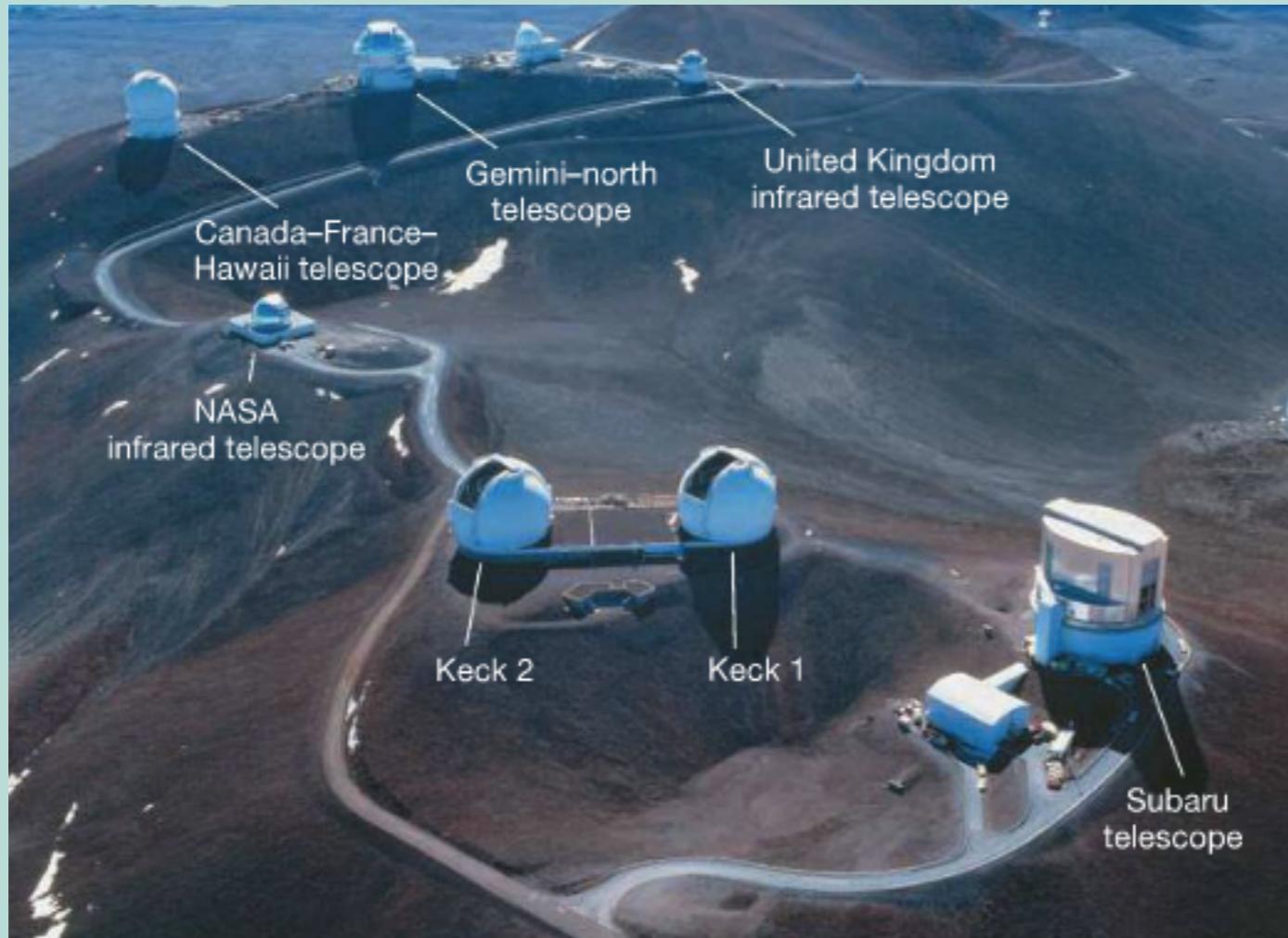
Keck I and II



36 hexagonal mirrors for a total of 10 meters

Telescopes: Ch 5

Mauna Kea



Telescopes: Ch 5



Telescopes: Ch 5

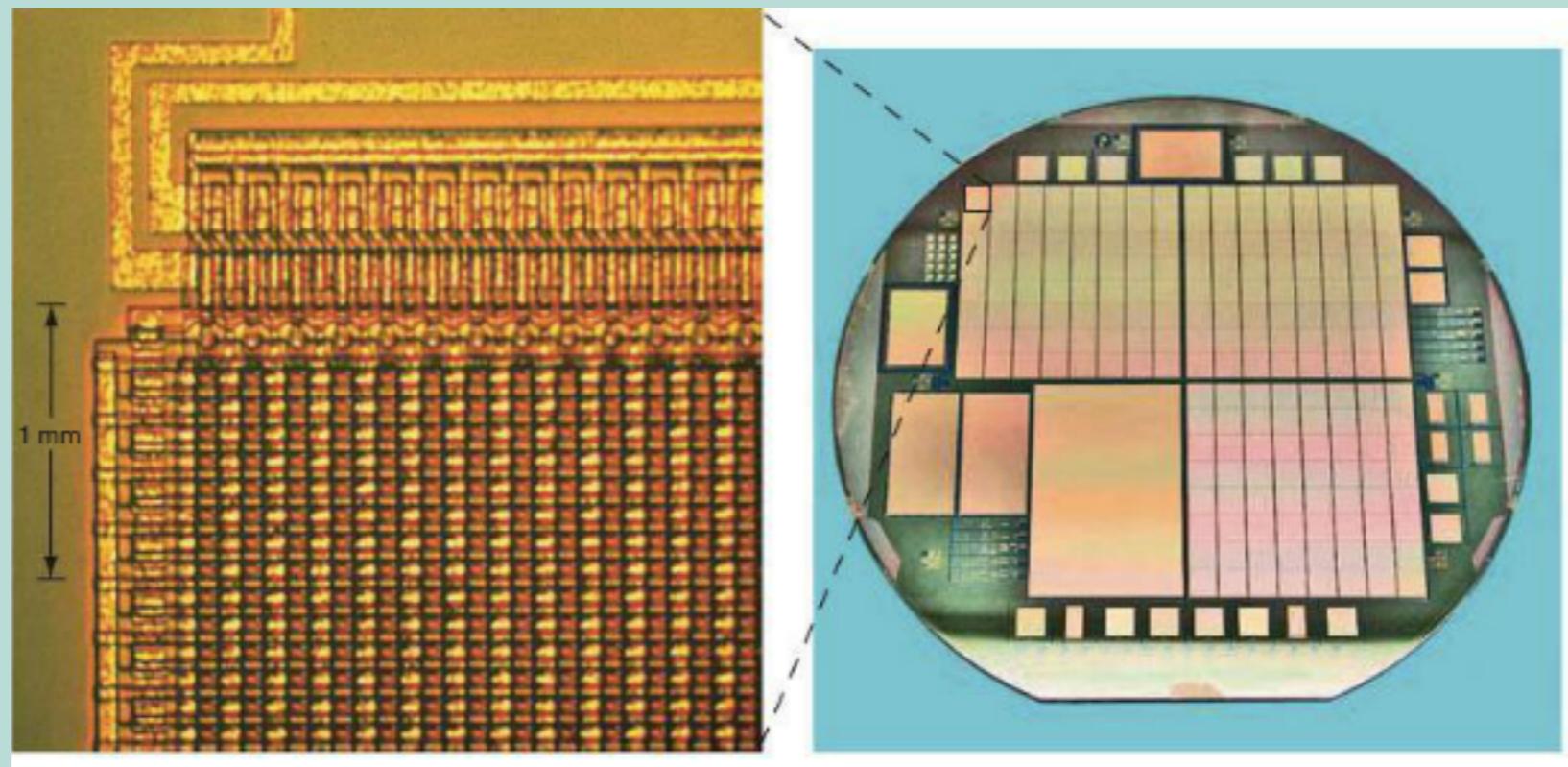
Atacama, VLT



- Atacama Desert (northern chile)
- 4, 8.2m mirrors (16m equivalent)
- can resolve .001" (2 meters on the moon)

Telescopes: Ch 5

CCD (Charge Coupled Device) Chip

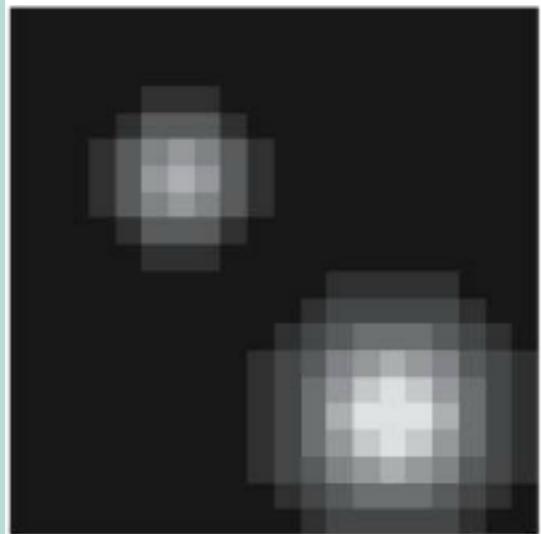


Telescopes: Ch 5

..I told you science was all a lie

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 3 | 5 | 6 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 3 | 6 | 7 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 3 | 5 | 6 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 3 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 4 | 4 | 4 | 3 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 5 | 6 | 7 | 6 | 5 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 6 | 8 | 9 | 8 | 6 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 7 | 9 | 9 | 7 | 4 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 6 | 8 | 9 | 8 | 6 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 5 | 6 | 7 | 6 | 5 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 4 | 4 | 4 | 3 | 2 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 |

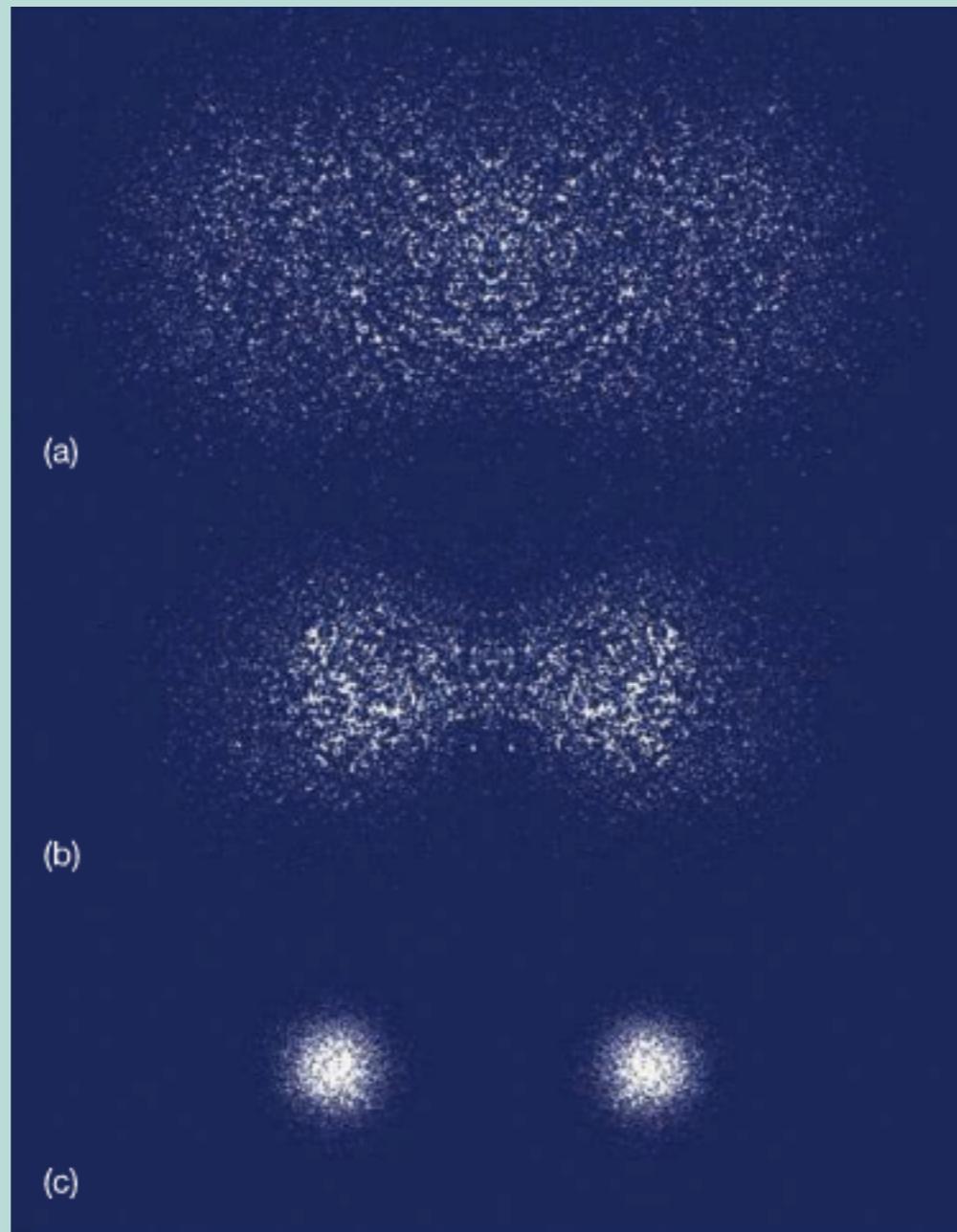
(c)



Diffraction Limitation

$$\text{angular resolution (arcsec)} = 0.25 \frac{\text{wavelength } (\mu\text{m})}{\text{diameter } (\text{m})}$$

Telescopes: Ch 5



Telescopes: Ch 5

Resolution



10'



1'



5''



1''

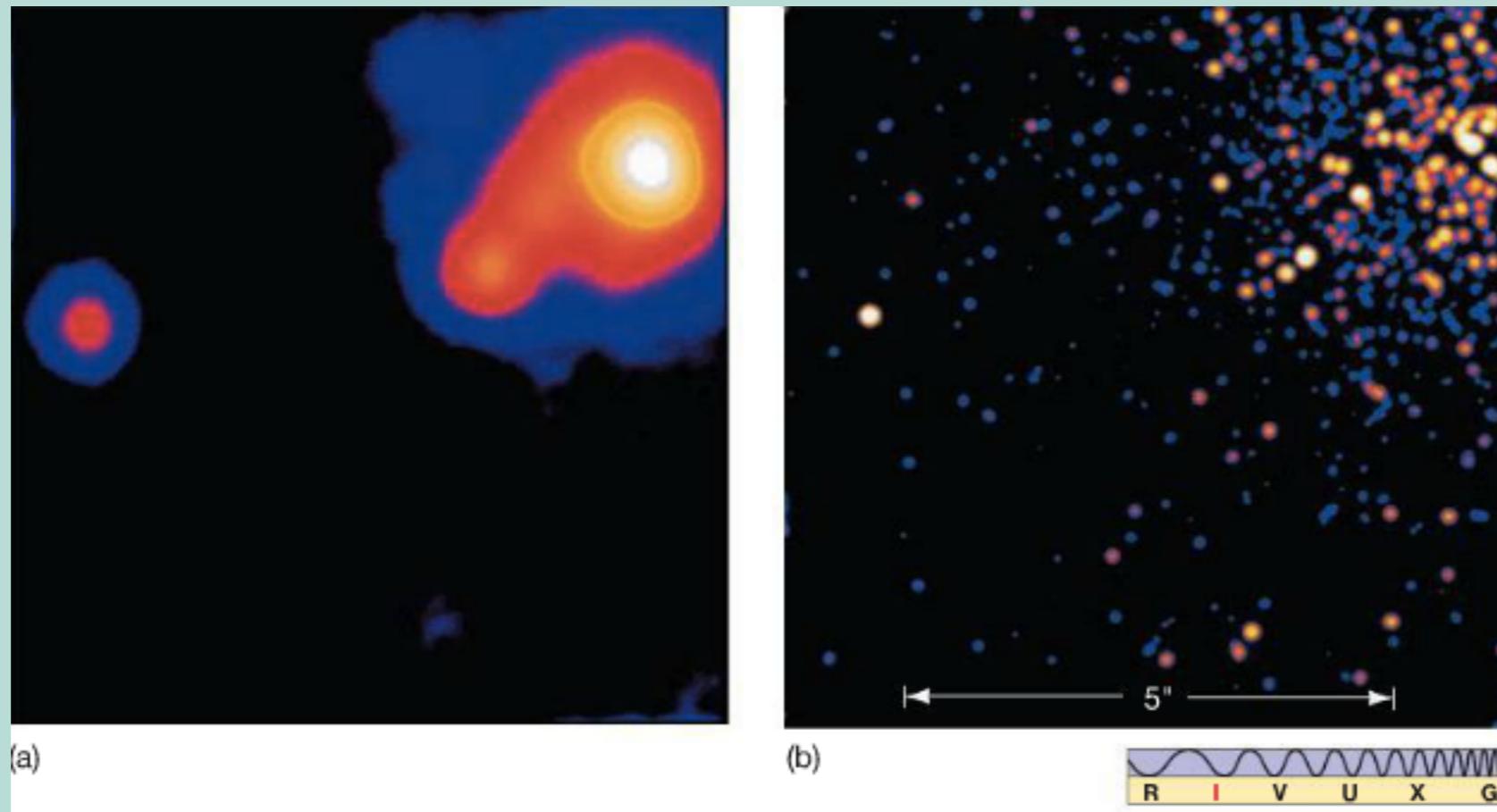
Telescopes: Ch 5



DISCUSSION

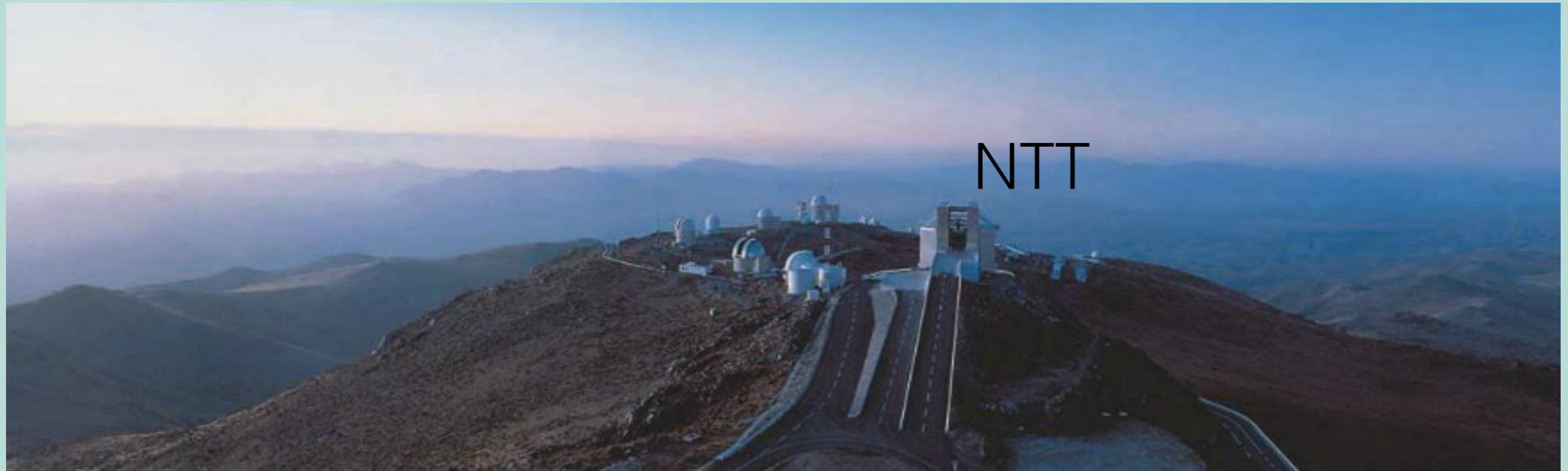
Telescopes: Ch 5

Active Optics



Telescopes: Ch 5

European Southern Observatory

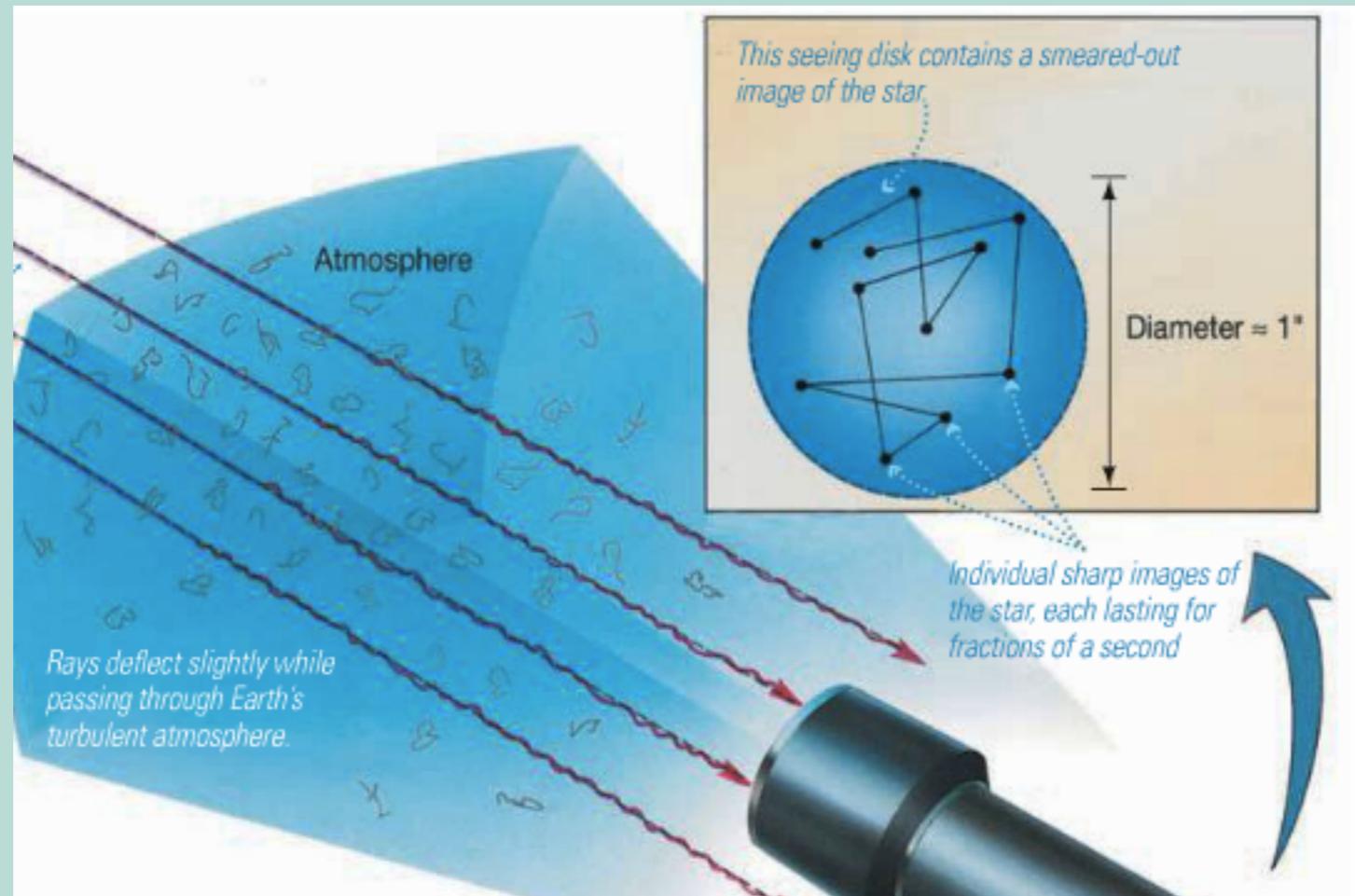


NTT

La Silla, Chile

Telescopes: Ch 5

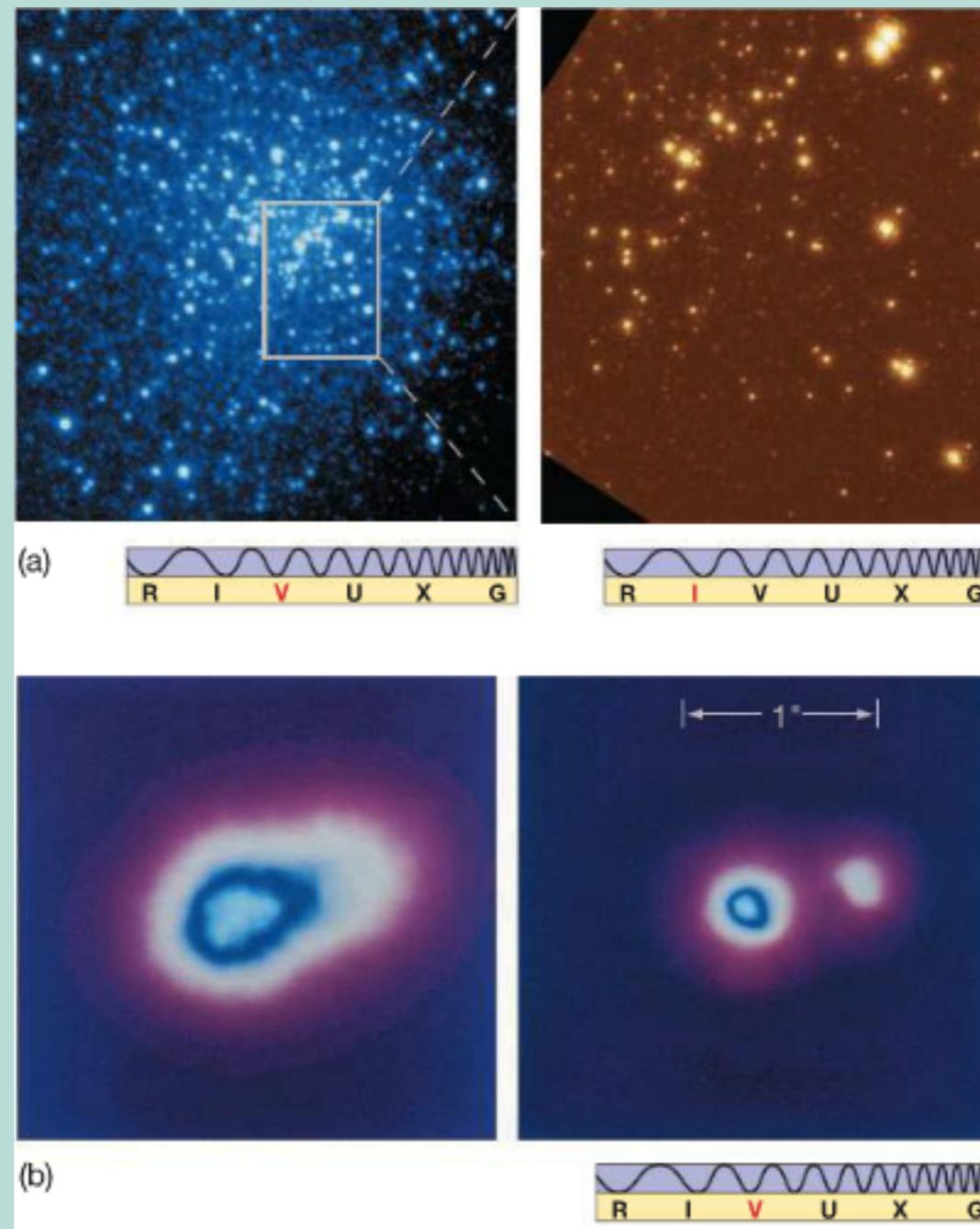
'seeing' stars



Adaptive Optics



Adaptive Optics



Telescopes: Ch 5

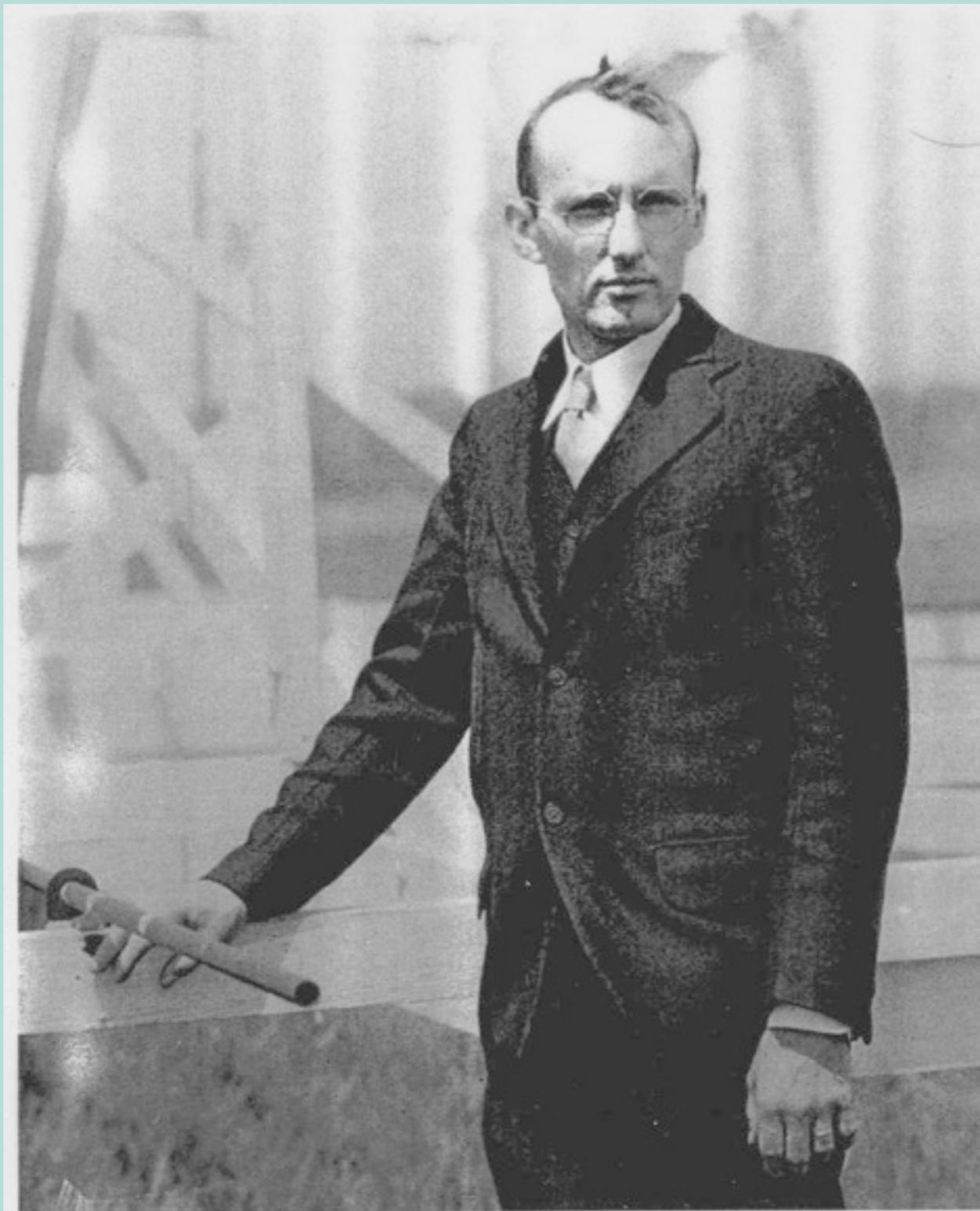


FIG. 1—Karl Guthe Jansky, about 1933.

Telescopes: Ch 5

National Radio Astronomy Observatory

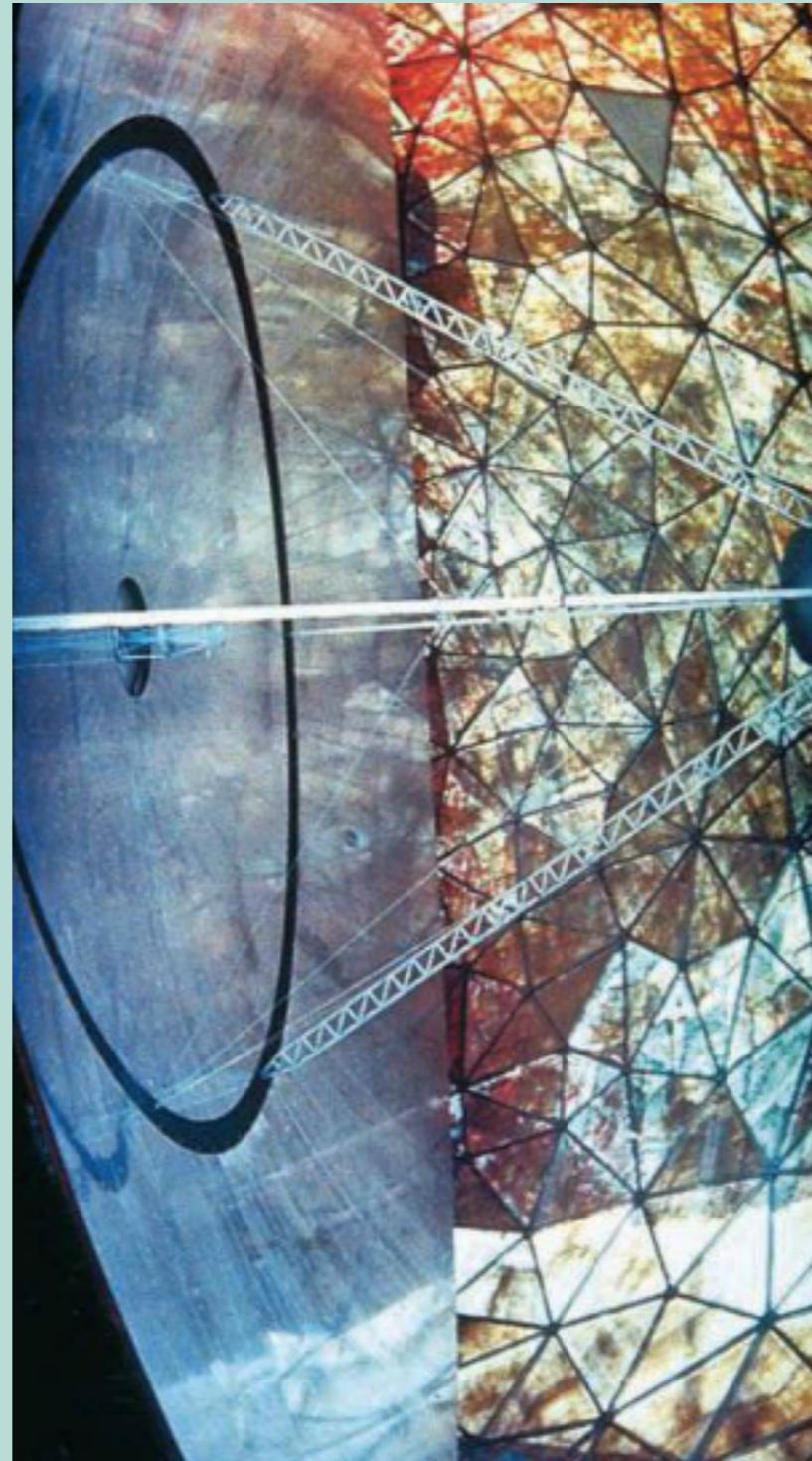


Greenback, WV

Steerable!

Telescopes: Ch 5

Haystack Observatory



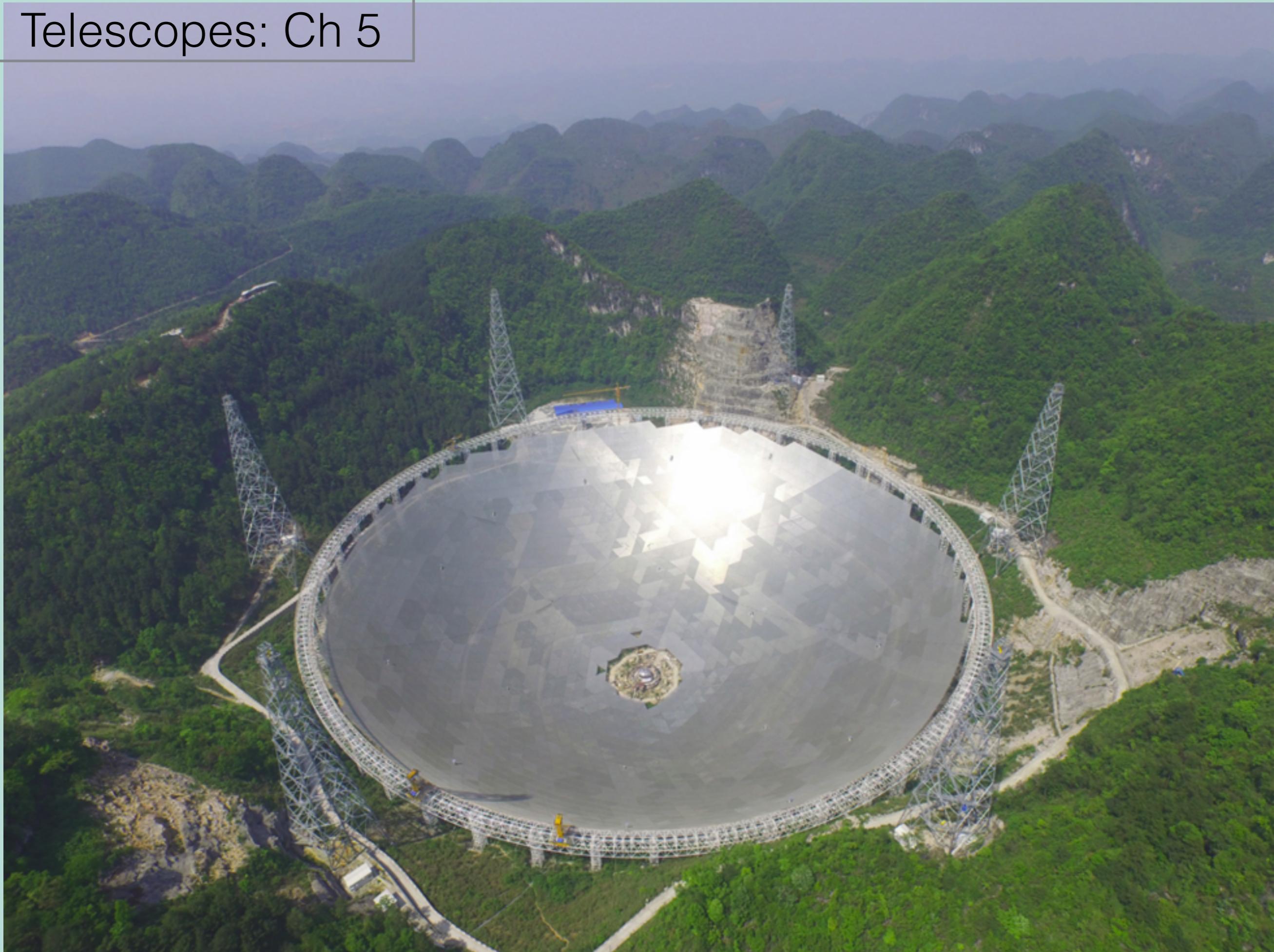
Telescopes: Ch 5



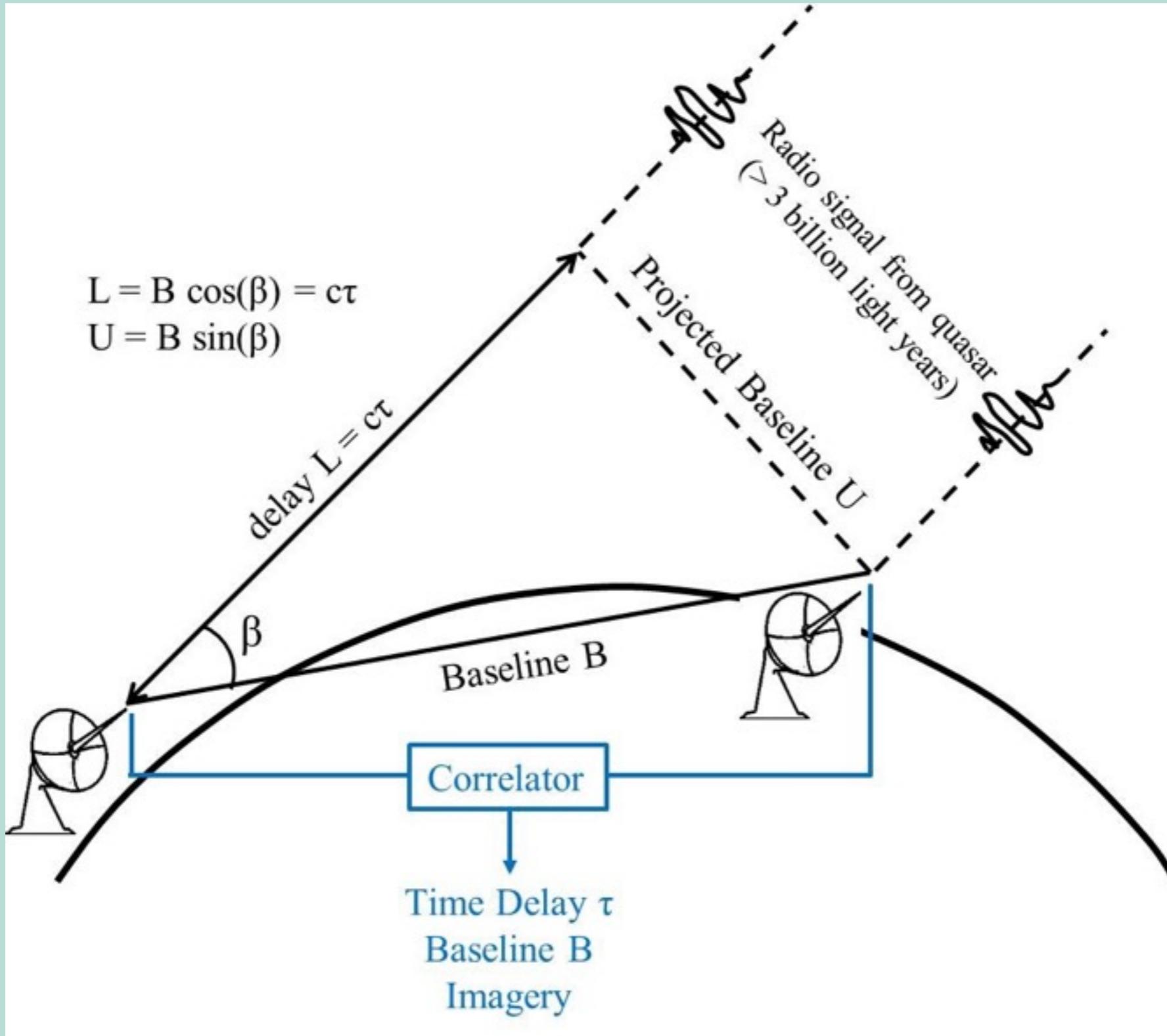
Telescopes: Ch 5



Telescopes: Ch 5



Telescopes: Ch 5



Telescopes: Ch 5

ALMA (Atacama Large Millimeter Array)



Telescopes: Ch 5

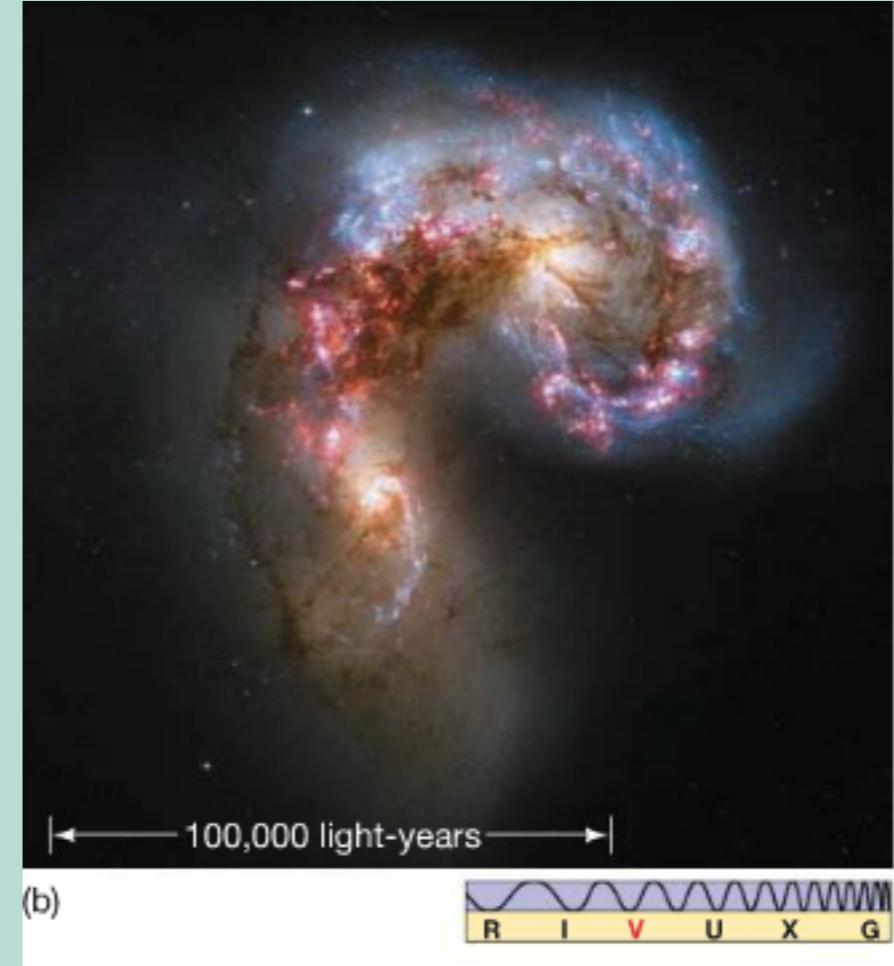
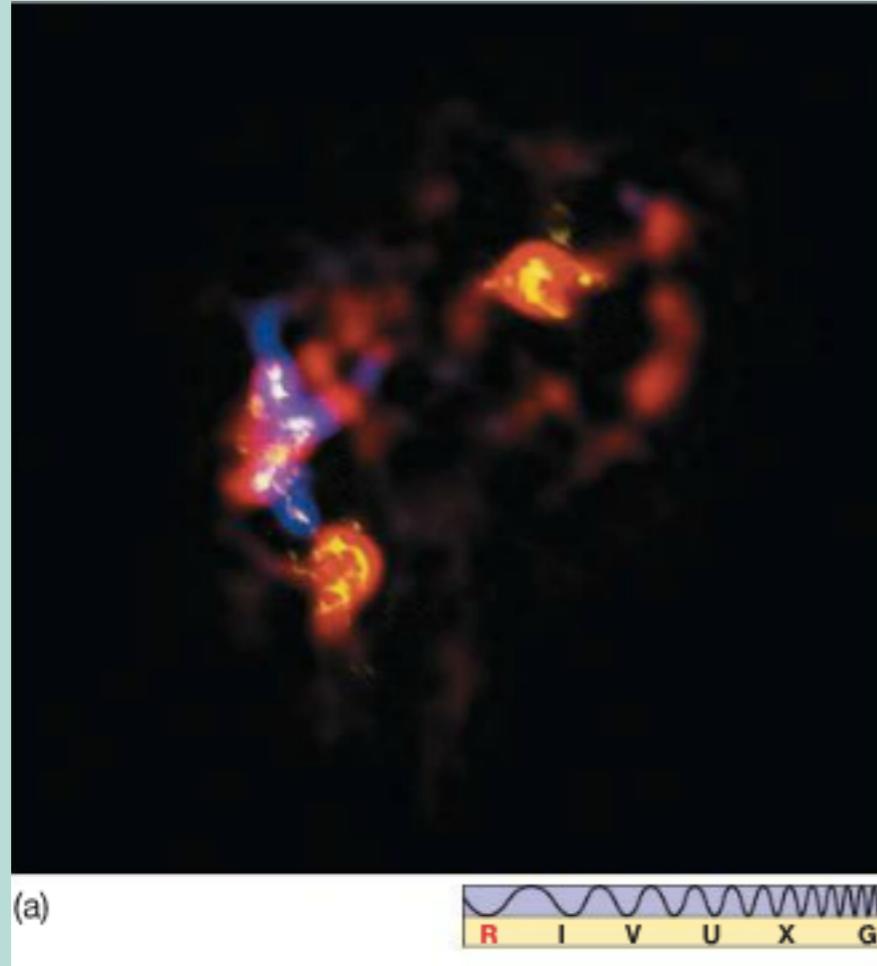
Very Large Array



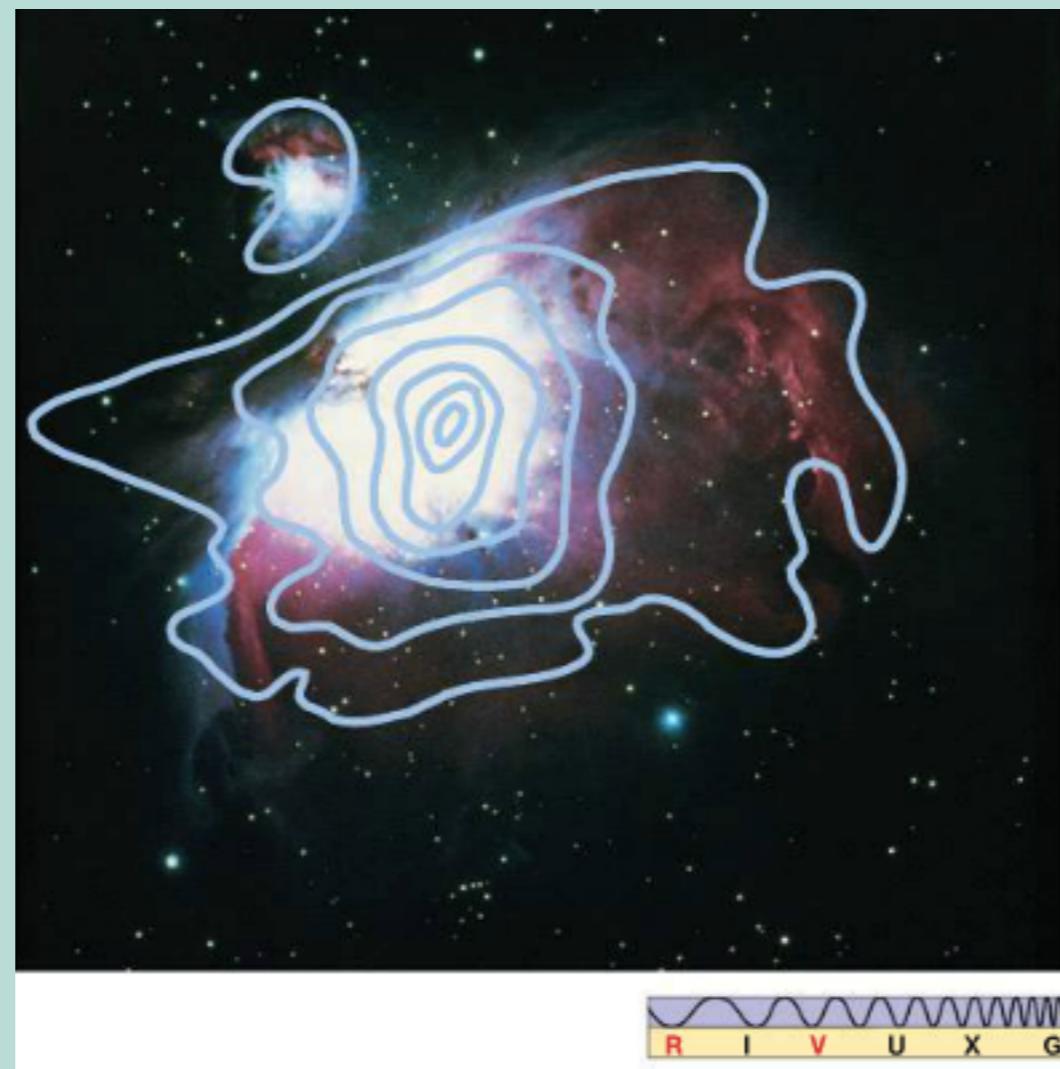
New Mexico

Telescopes: Ch 5

Galaxies Colliding (radio & visible)

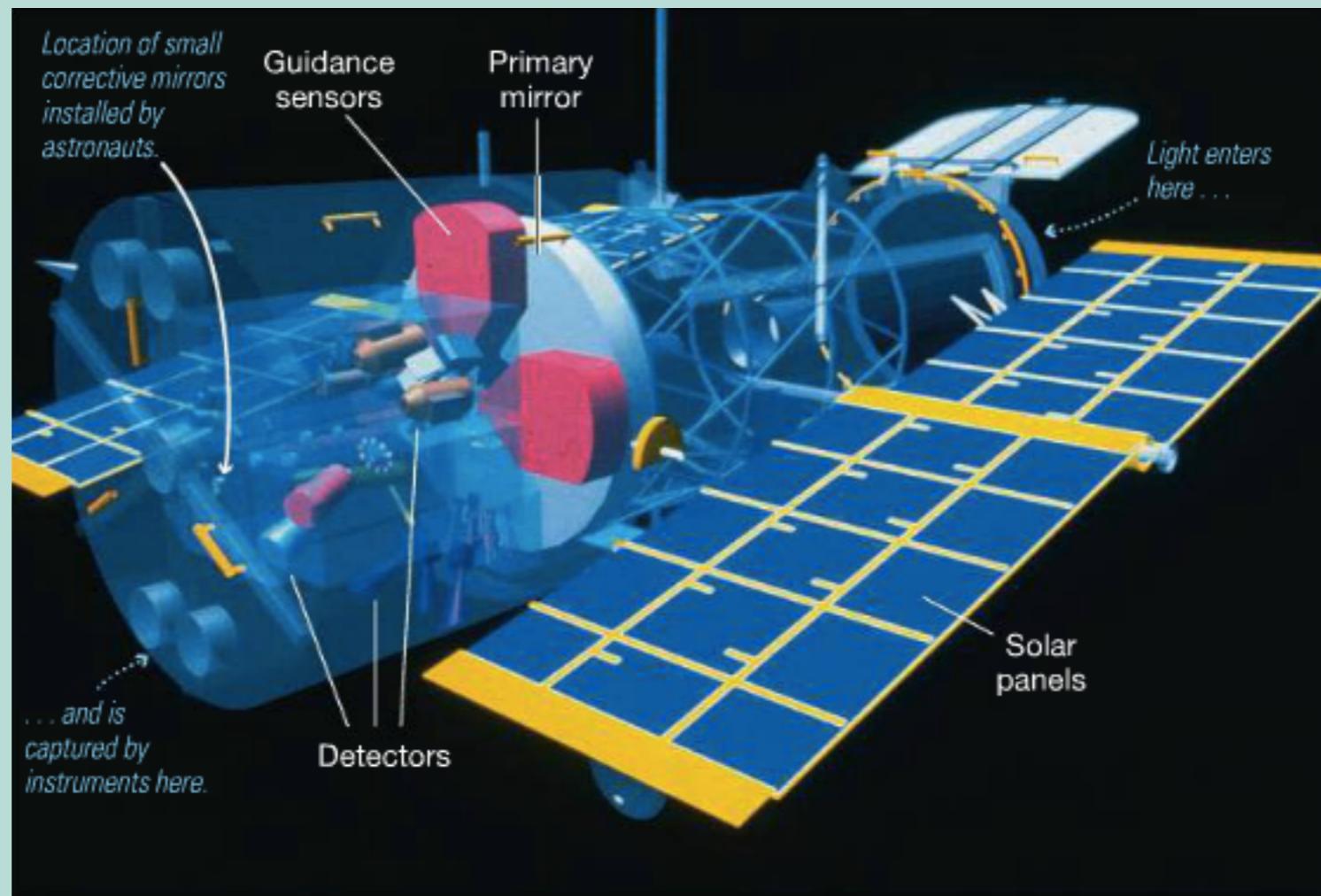


Radio Astronomy is Complementary!

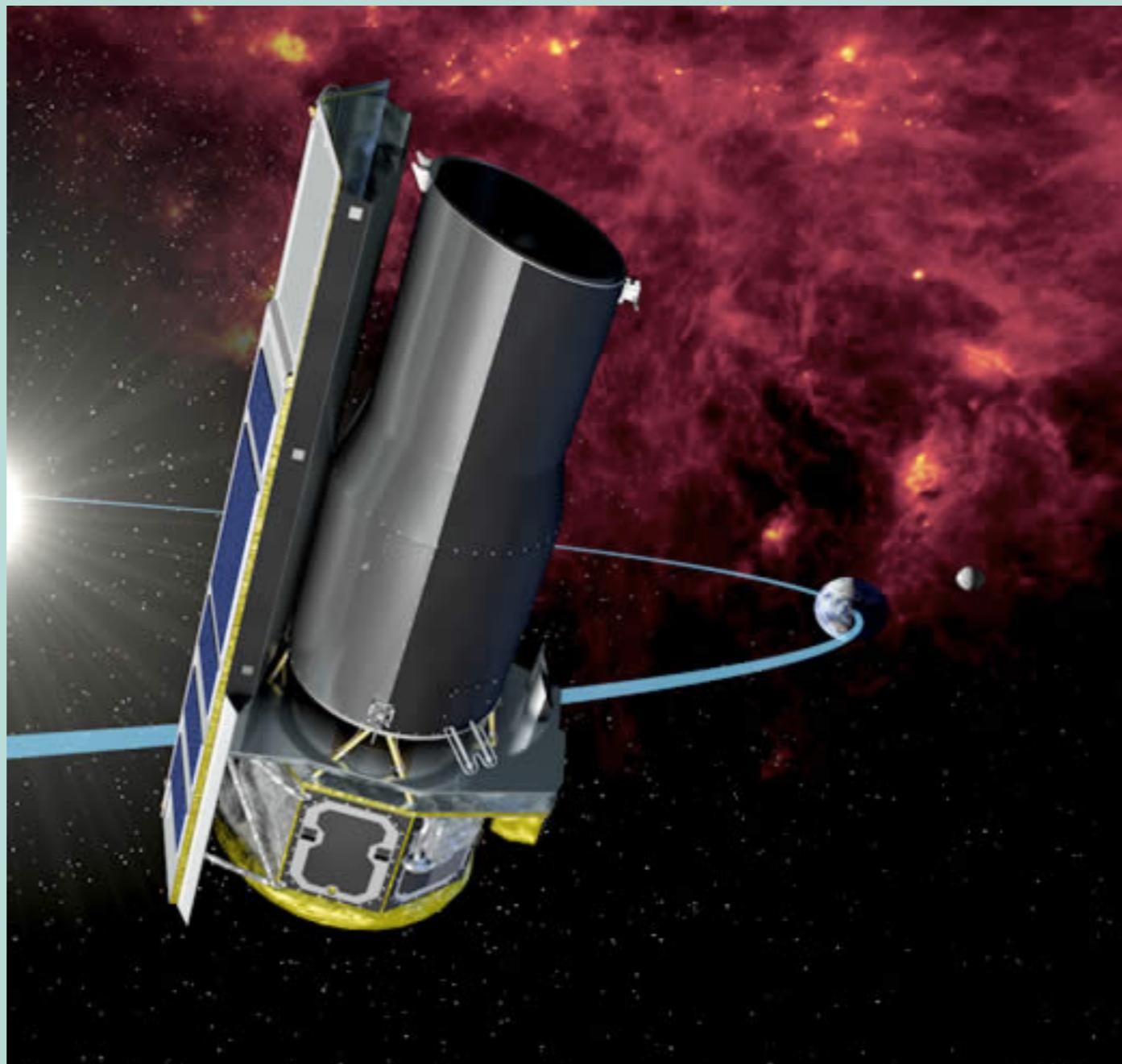


Good IR = Space!

Hubble Space Telescope



Spitzer Space Telescope

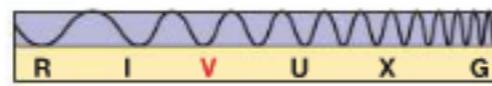


Telescopes: Ch 5

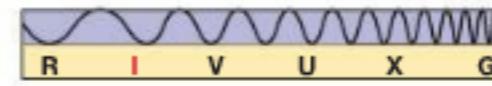
Infrared Reveals Structure



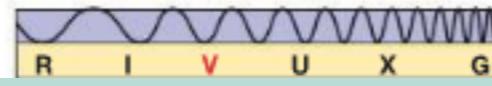
(a)



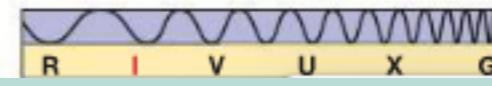
(b)



(c)

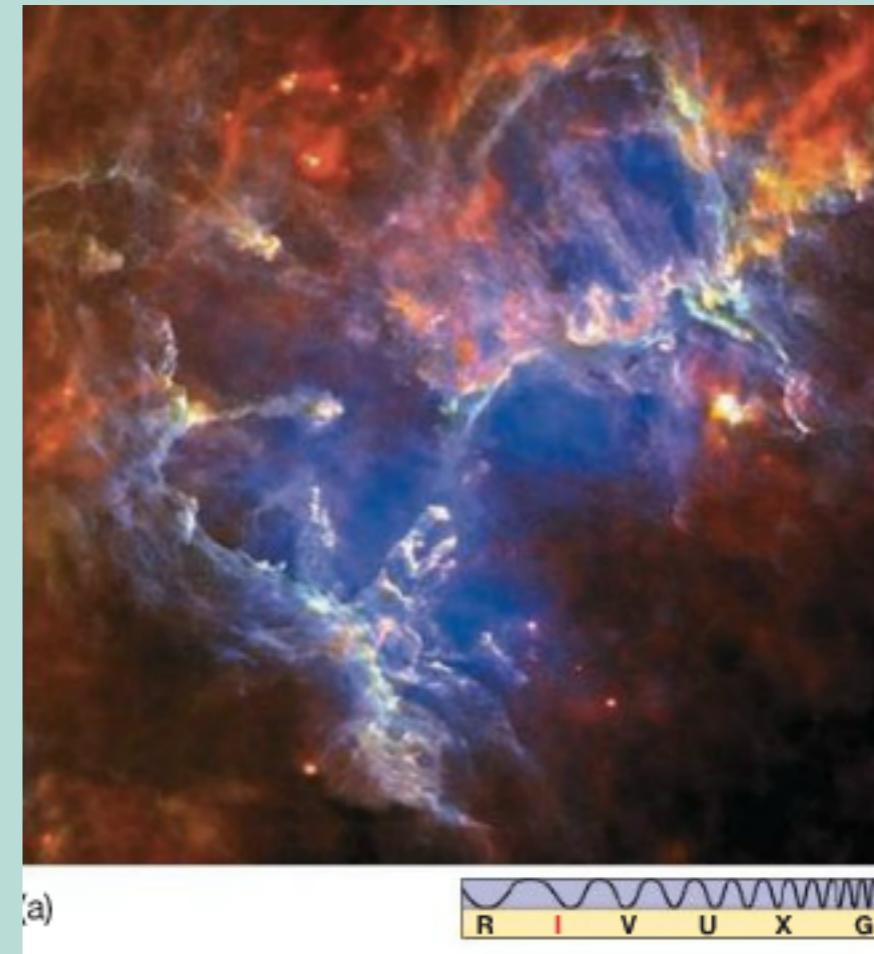
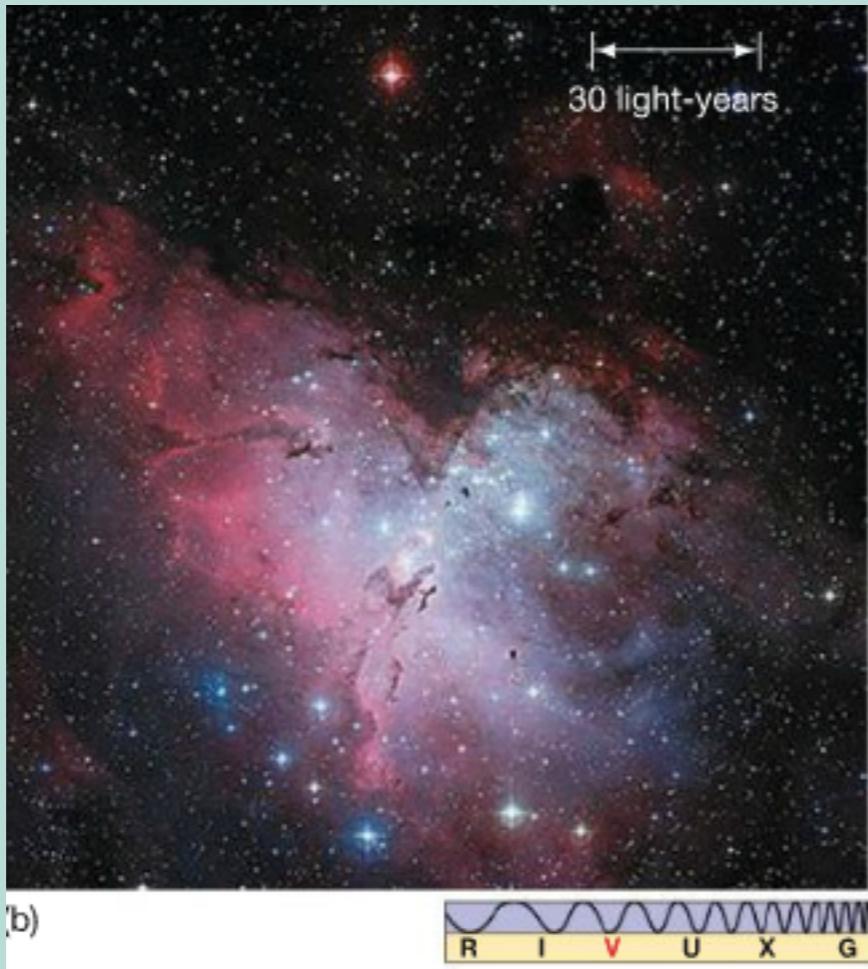


(d)



Telescopes: Ch 5

Infrared Reveals Structure



Spitzer in the IR

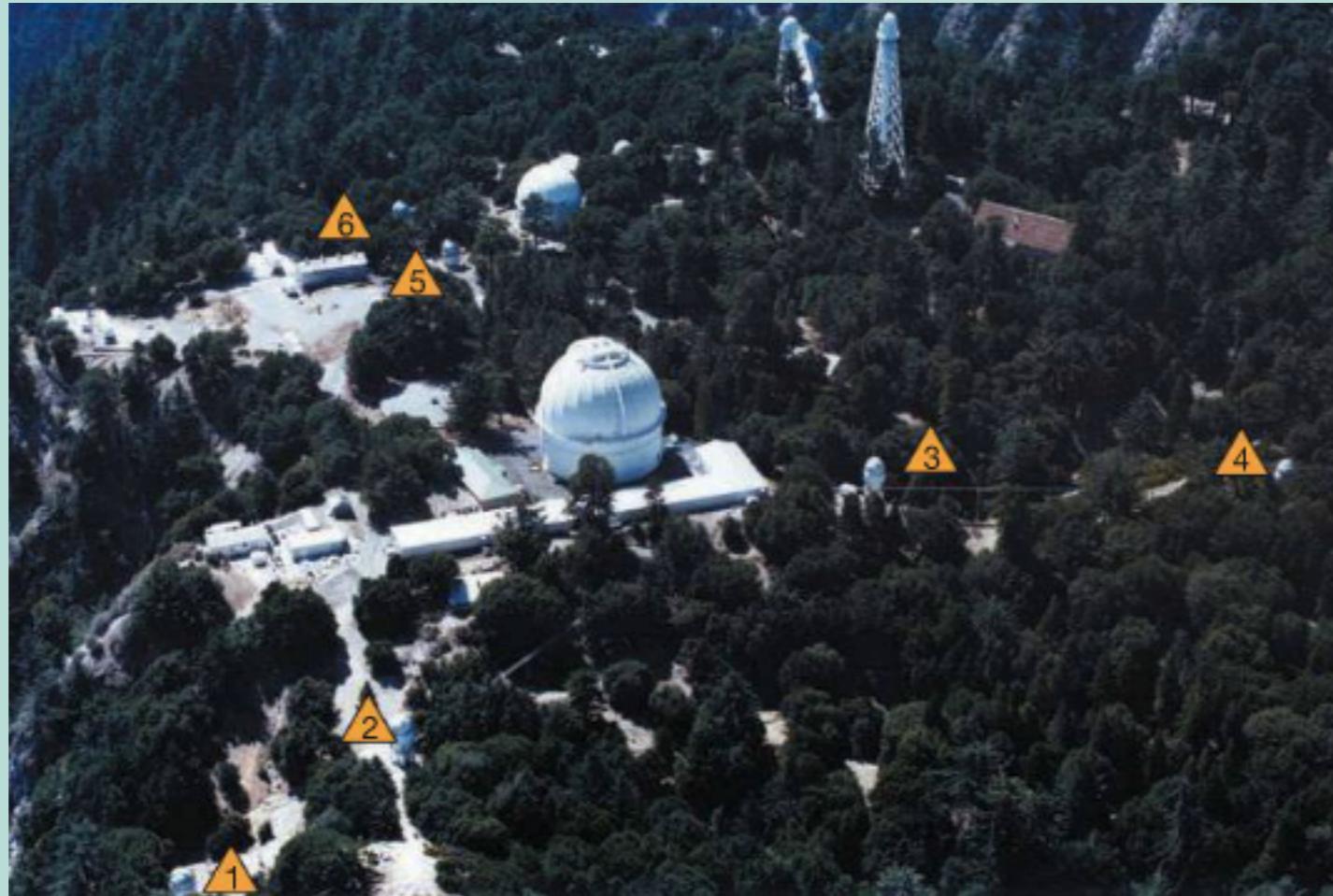


Spitzer in the IR



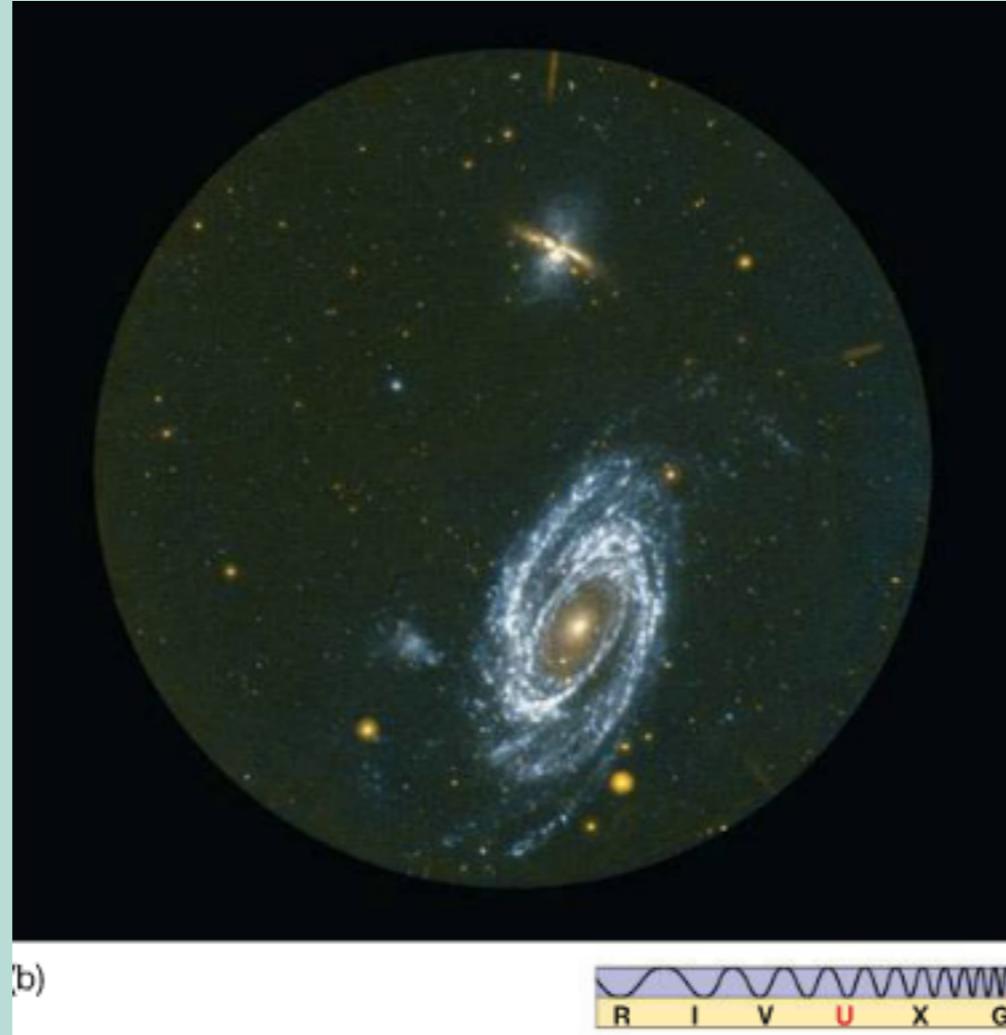
Telescopes: Ch 5

Chara



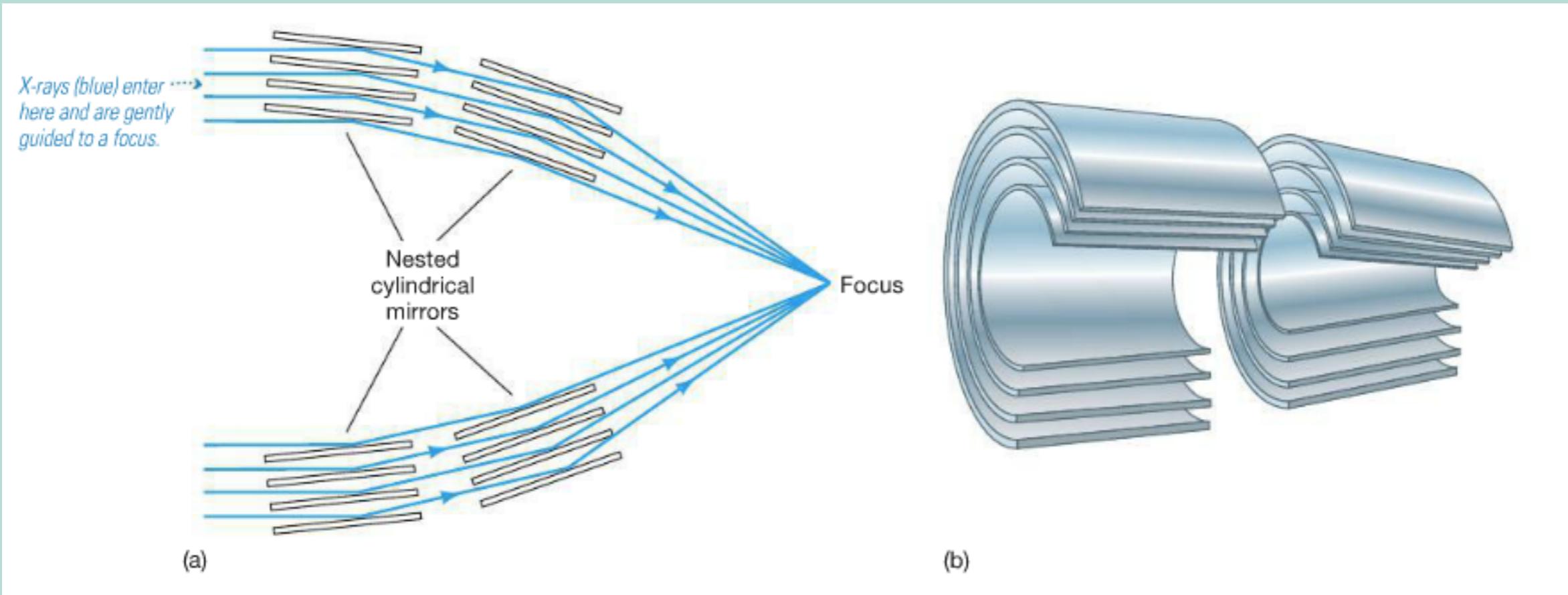
- Mt. Wilson CA

Ultraviolet



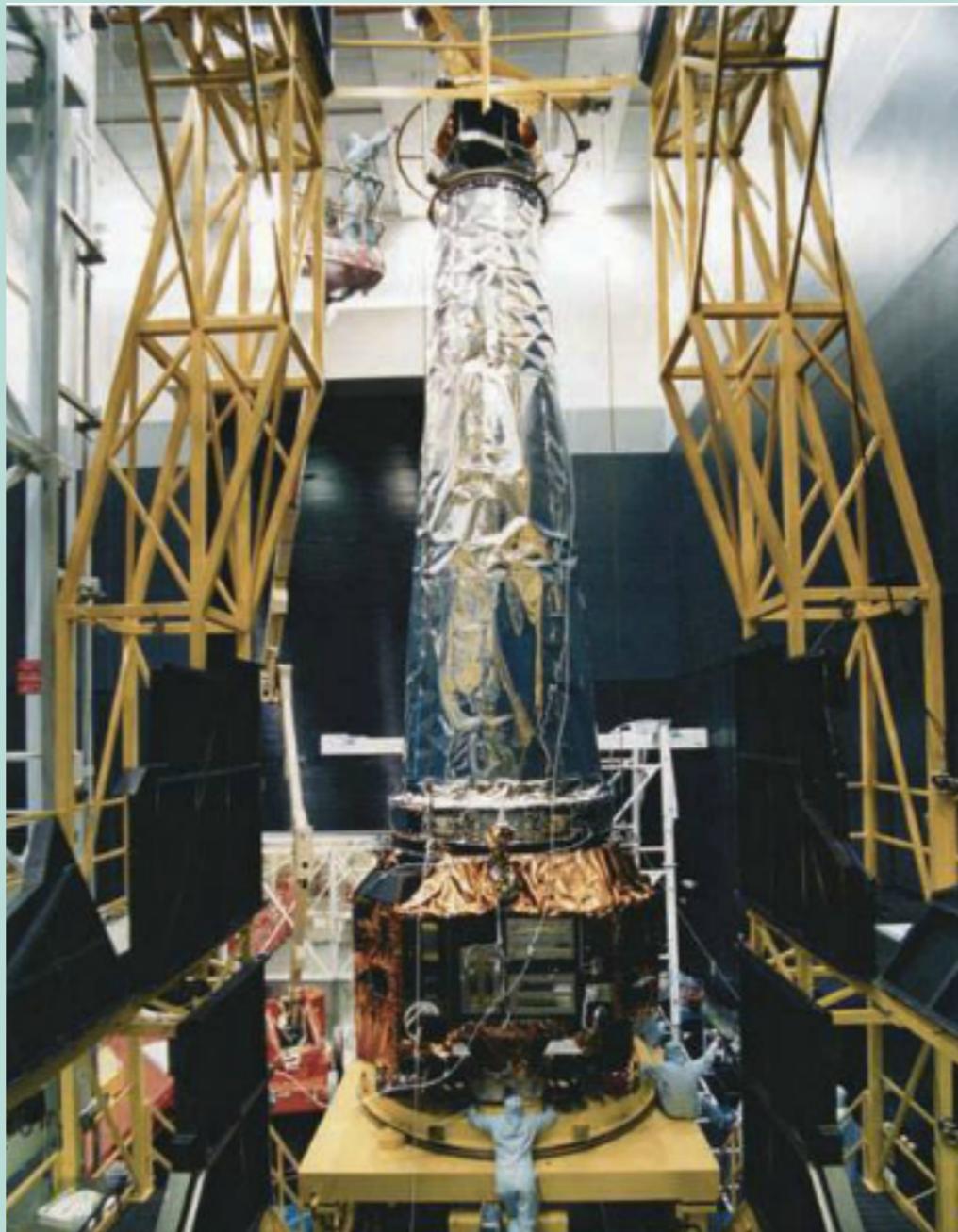
International Ultraviolet Explorer

X-Ray Mirrors



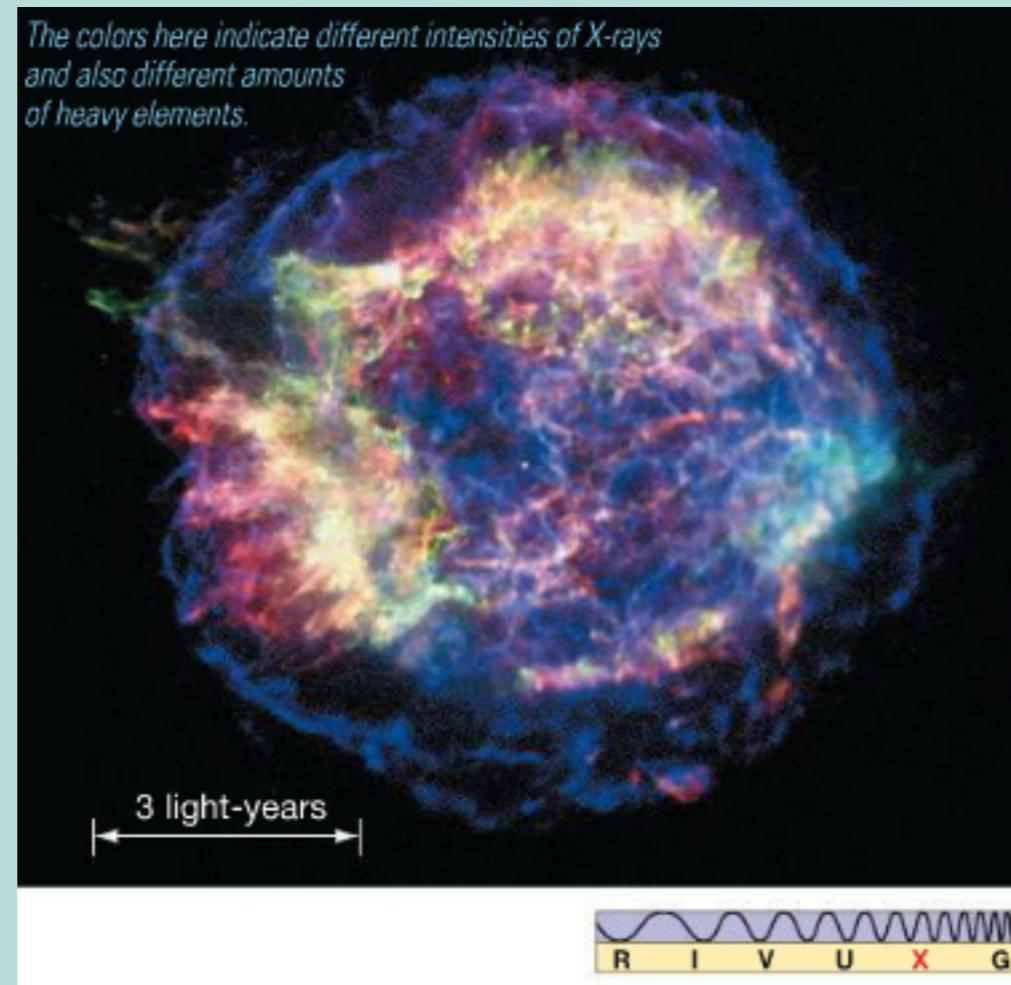
Telescopes: Ch 5

Chandra



Telescopes: Ch 5

False Color X-Ray image (supernova)



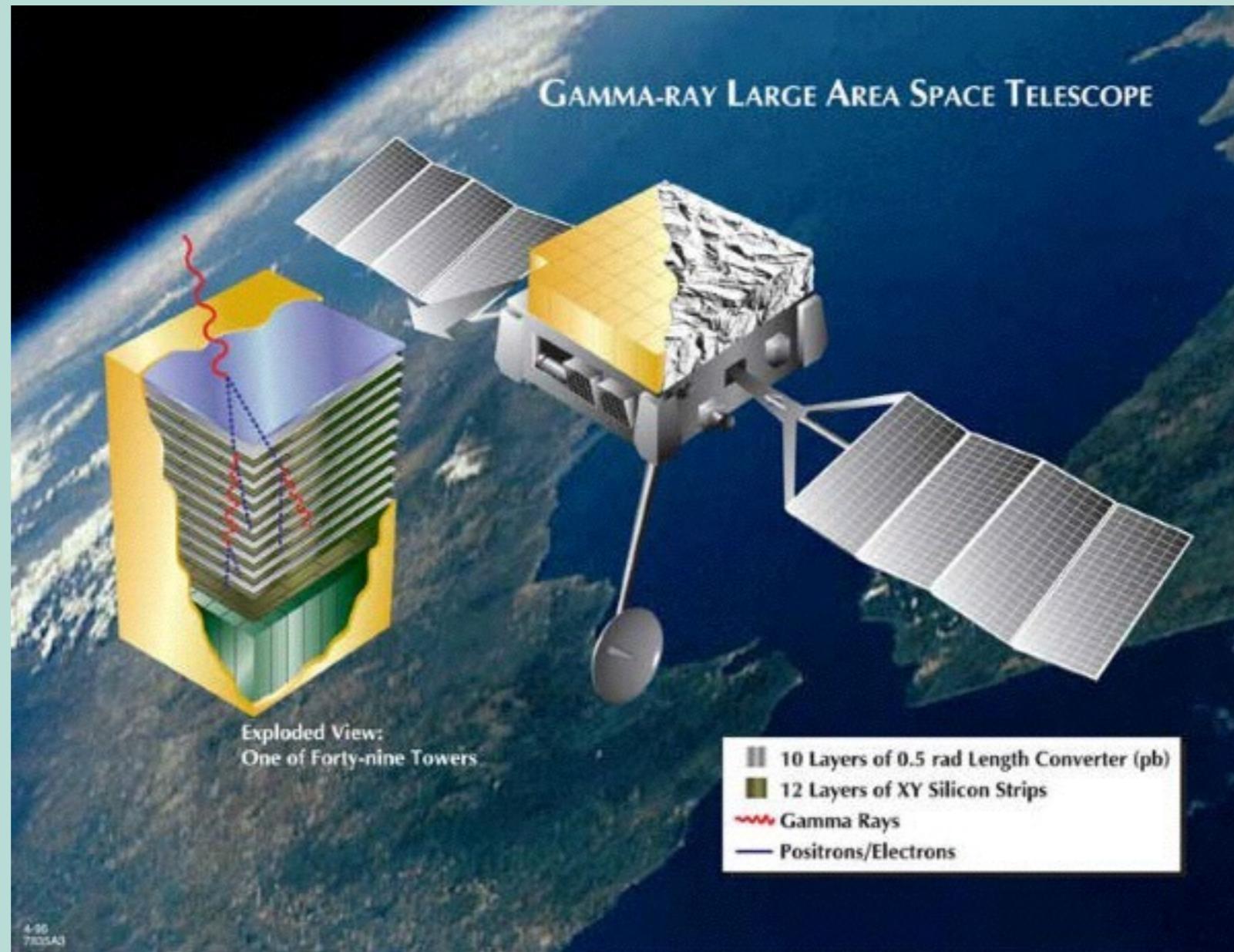
Telescopes: Ch 5

Hubble Spitzer Chandra: Crab Nebula



Telescopes: Ch 5

Fermi

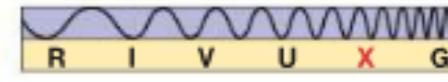
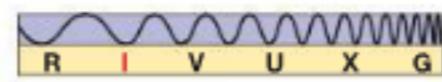
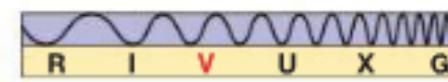
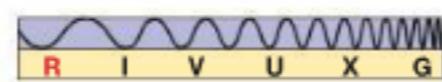
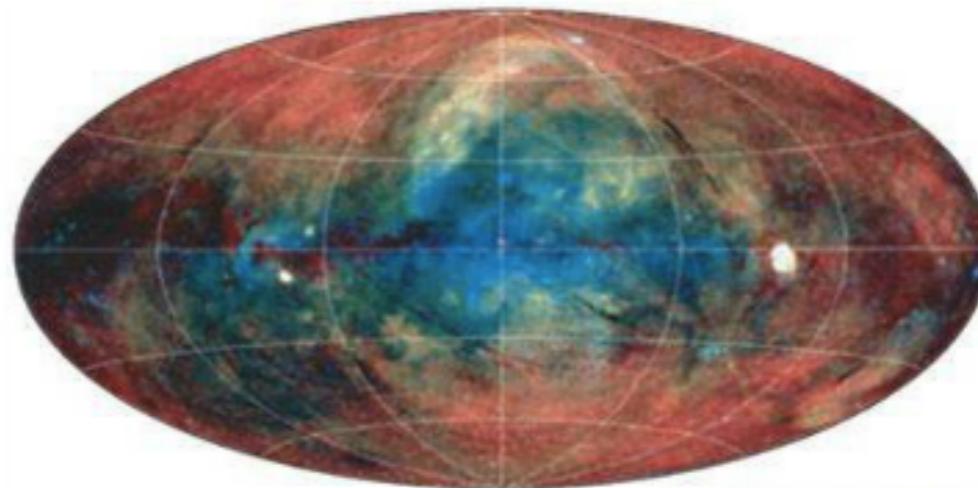
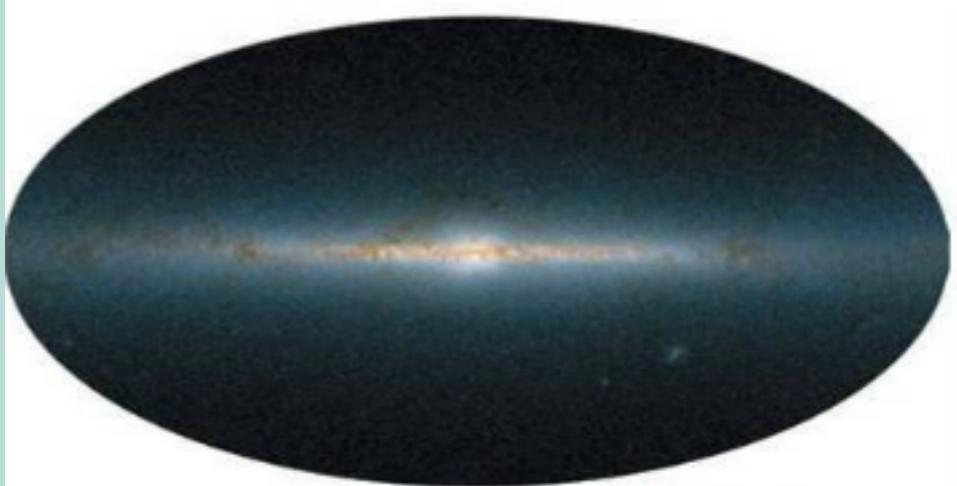
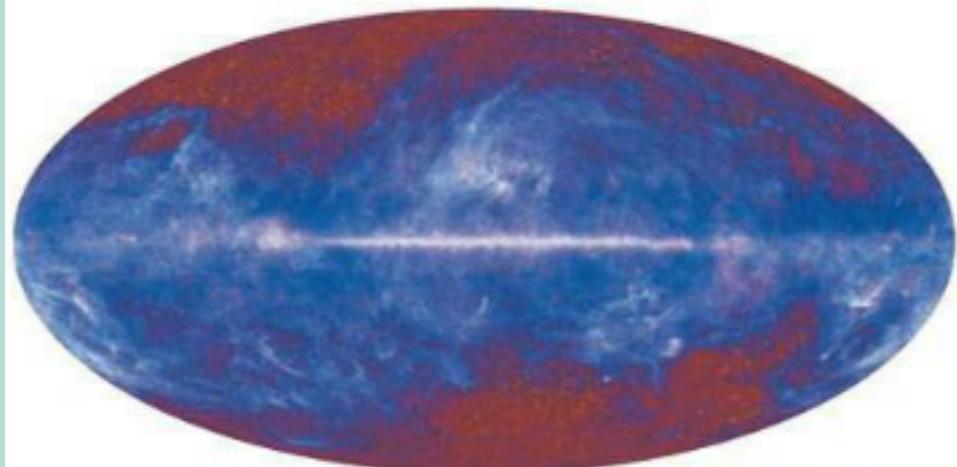


Telescopes: Ch 5

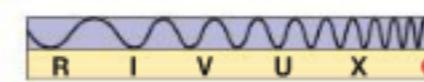
Gamma Ray Image



Telescopes: Ch 5



(e)

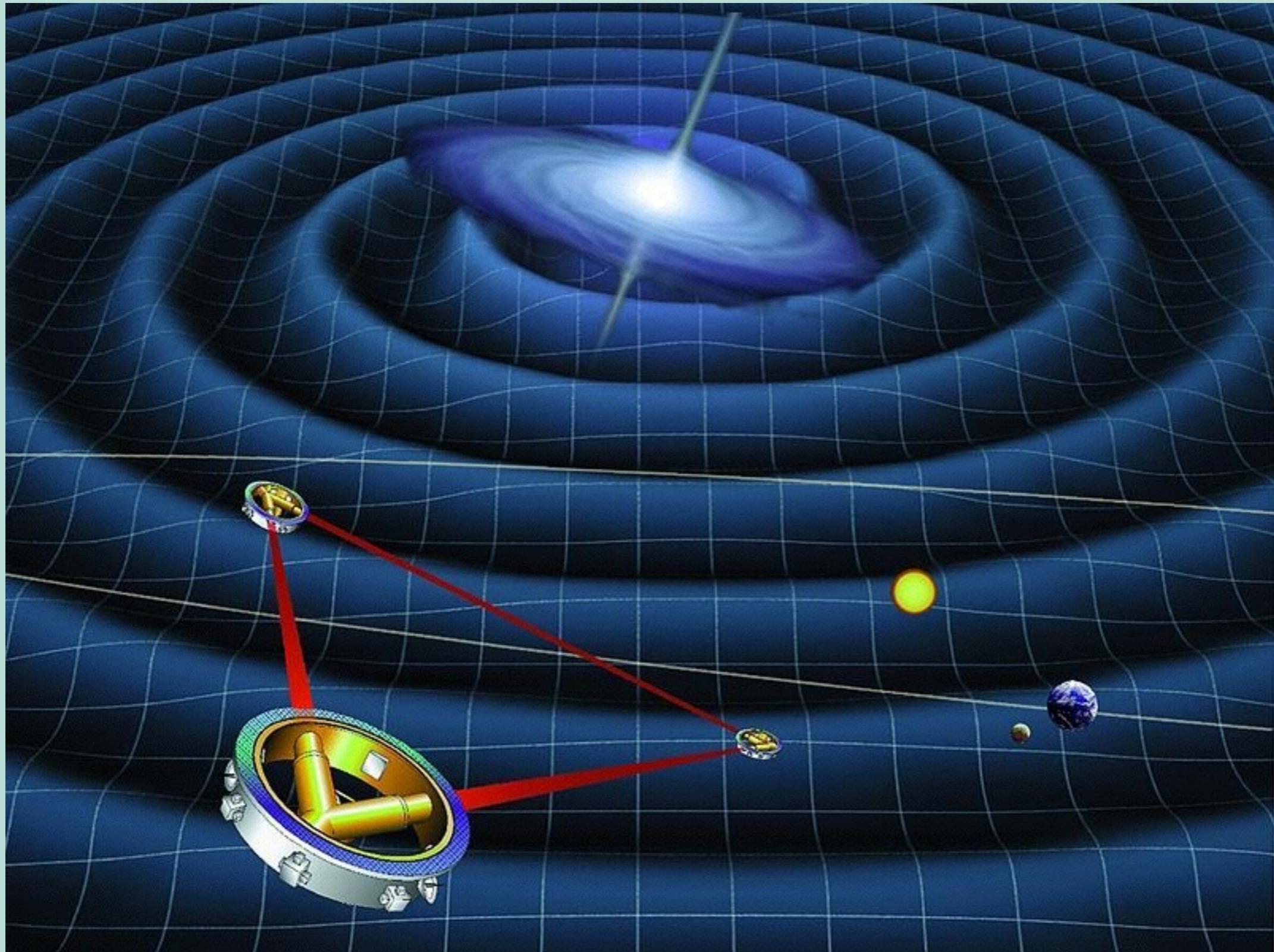


Telescopes: Ch 5



Telescopes: Ch 5

LISA (Laser Interferometer Space Antenna)



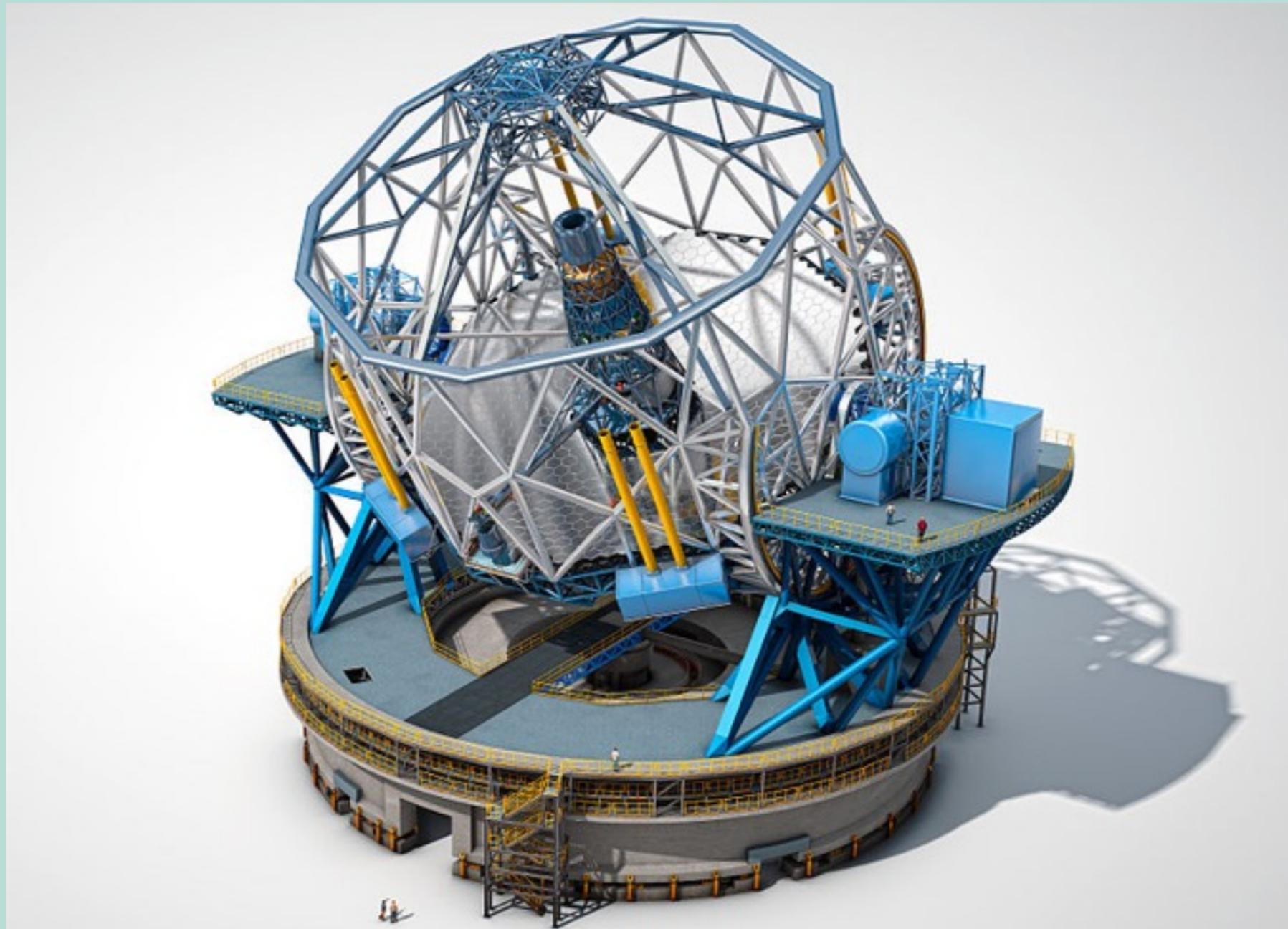
Telescopes: Ch 5

JWST (James Webb Space Telescope)



Telescopes: Ch 5

European Extremely Large Telescope



40 meter diameter, 6 laser adaptive optics