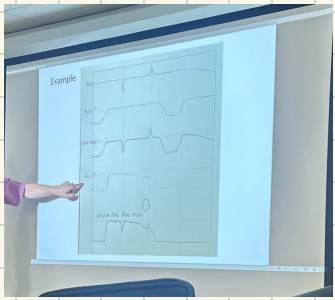
8/22 Class Notes



recall from last class:

→ we want to recover $S(t_0, \lambda, \vec{r})$ from $O(t_1, \lambda, \vec{r})$

- $O(\lambda) = S(\lambda) \times M(\lambda)$ } element-wise multiplication.
  $= S(\lambda) \times IGM(\lambda) \times ISM(\lambda) \times A(\lambda) \times T(\lambda) \times I(\lambda)$

some astronomers (albeit technically incorrectly) refer to this as convolution.

→ our atmosphere blocks many wavelength regions — only certain λs can get through:
- visible light spectrum
- some radio λs

↳ atmospheric composition has changed over time enabling different λs through, but of course the VLS was always present.
- radio λs were the first to be identified using instrumentation.
- infrared identified around the world wars. ⟶ important for protostellar observations! ☺
- x-ray has medical benefits, so naturally it has been developed. ⟶ also useful for super-massive black holes.
- UV has been ignored due to its availability. ⟶ blocked by atmosphere, so a UV space telescope is expensive and not worth the investment. Usually observed with all-sky surveys (first done ~10 years ago).

→ radio continuum reveals building blocks of stars; hydrogen.

→ infrared regions begin to reveal young stars and dust.

→ even shorter wavelengths show other phenomena (stars, noise, etc.)

→ diameters of observational telescopes have increased by about 5× over the past 100 yrs.
- largest optical telescope: Keck I and II in the past, & now GTC (grand telescope canary)
- others, incl. Radio: Very Large Telescope, European Extremely Large Telescope, Gemini, Subaru

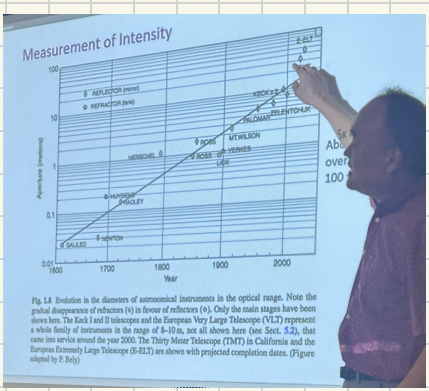
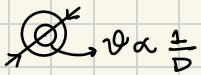


Fig. 1.8 Evolution in the diameters of astronomical instruments in the optical range. Note the gradual disappearance of refractors (●) in favour of reflectors (●). Only the main stages have been shown here. The Keck I and II telescopes and the European Very Large Telescope (VLT) represent a whole family of instruments in the range of 8–10 m, not all shown here (see Sect. 3.2), that came into service around the year 2000. The Thirty Meter Telescope (TMT) in California and the European Extremely Large Telescope (E-ELT) are shown with projected completion dates. (Figure adapted by P. Bely)

→ why do we keep building bigger telescopes?
- larger telescope aperture collects more light (LGP) exponentially.
  ↳ current big telescopes have 1E8 LGP to Galileo!
- we can resolve finer details:
  ↳ diffraction effects imaging after a certain degree.
  → 2D diffraction patterns:  } airy diffraction ring structure.

- point spread functions describe diffraction patterns as follows:



→ so, for example, if we were looking a distant protoplanetary system, with a smaller telescope, the airy rings would inhibit viewing the exoplanets when viewing the star.
  - why larger telescopes help!

astro.nineplanets.org/bigeyes.html → telescope infographic.
Palomar Observatory Sky Survey → one of the oldest sky surveys (POSS) { include later.

Space Telescopes!
- JWST — launched 12/25/21, post HST, 6.5m primary mirror, mid-IR telescope.
- GMT — another one funded by international association.
- these are very expensive (we're talking billions)
- why was Hubble optical?

↳ not just VLS: also UV & NIR
→ having visible capacity enables observation outside of atmosphere.

↓ has a heat shield to prevent obfuscation of observations:
→ cooling to < 10°K.

- how do we keep our telescopes cold?

↳ cryogenics run out!
→ JWST recycles the liquid helium instead — non-consumable.

Upcoming Telescopes:
- GMT (Magellan telescope)
- LSST
- TMT → being build on sacred ground ∴
- ELT

Sky Surveys:
→ ROSAT (x-ray), eROSAT (enhanced), IRAS, WISE, Gemini, VLT, ...

→ breakthrough in 1900s led our optical sensitivity to increase 10^6 ×
  - photographic plates / storing photons!
  - expensive.

Some history:
↳ in the past, observations using fancy scopes was limited to elite institutions.
→ universities formed coalitions to improve access a little.
→ national observatories formed to slowly enable astronomers to submit proposals.
→ introduction of sky surveys caused a huge flood of data.
  - inspired tools like virtual observatory, data mining.

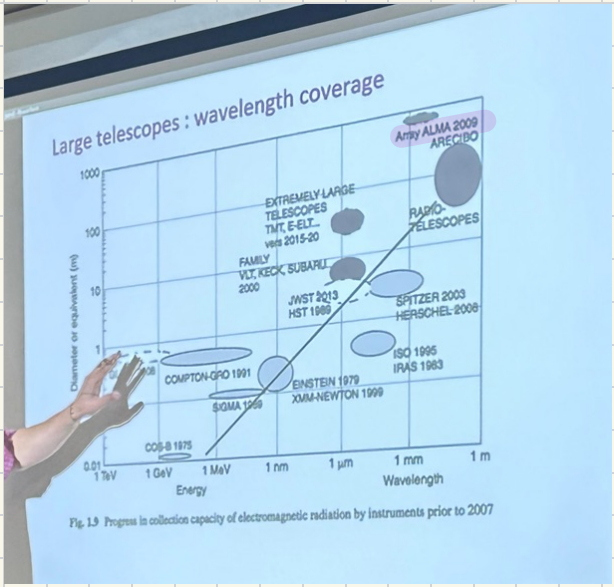


Fig. 1.9 Progress in collection capacity of electromagnetic radiation by instruments prior to 2007

→ we've also made great progress in spectral resolution:

- now finally we can observe distribution of wavelengths.

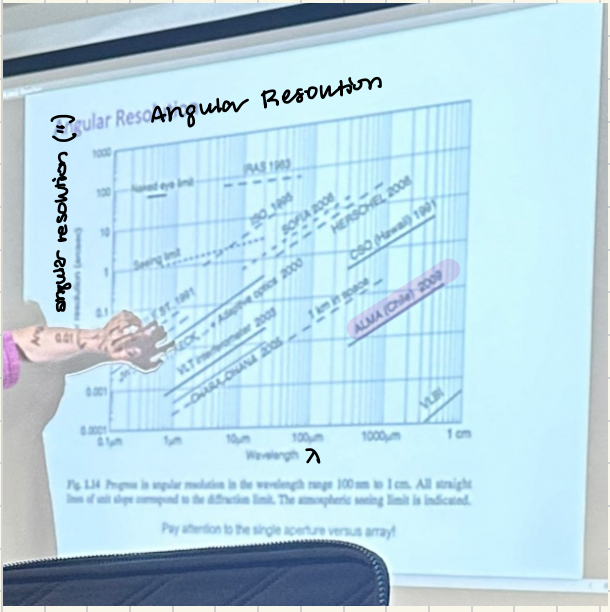


Fig. 1.14 Progress in angular resolution in the wavelength range 100 nm to 1 cm. All straight lines of unit slope correspond to the diffraction limit. The atmospheric seeing limit is indicated.

Pay attention to the single aperture versus array!

remember:

$$\vartheta \propto \frac{1}{D}$$