Sec.2.4.5-End of Sec. 2

McLean seminar
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Sec.2.4.5 Laser guide star systems

- To correct atmospheric turbulence: star light is necessary
- Shack-Hartmann wavefront sensor: divide light among several sub-apertures
  - Requirement: ~150,000 stars / steradian brighter than m=12 at visible wavelength
  -> In reality, it is a very difficult condition

Solution 1)
To select the guide star and perform scientific observation in that neighborhood
- Good for galaxies at high-z
- Reason: can find faint objects

Solution 2)
Use curvature-sensing method
- Allow for much fainter guide stars by using all of the light collected by telescope.
- Problem of solution 2: no suitable reference star within isoplanatic path -> adaptive optics system cannot work
  -> To solve this problem: to create an 'artificial star' using laser beam

Sec.2.4.5 Laser guide star systems

- How to make artificial star?
  pulsed laser beam with sodium D is projected through a telescope in upper atmosphere
  -> artificial star glow
  -> to update the shape of the deformable mirror

- Main challenge: not easy to construct narrow-line source

- Kind of transmitter
- Bistatic: laser transmitter is displaced from telescope
  -> Positional offset causes laser guide star to be elongated
  -> decrease sensitivity of wavefront correction
- Monostatic: telescope itself transmits the laser beam
  -> Most new telescopes

Sec.2.5 Optical and IR interferometers

- Single telescope: have diffraction limit
  -> solution: combining light collected by widely placed telescope

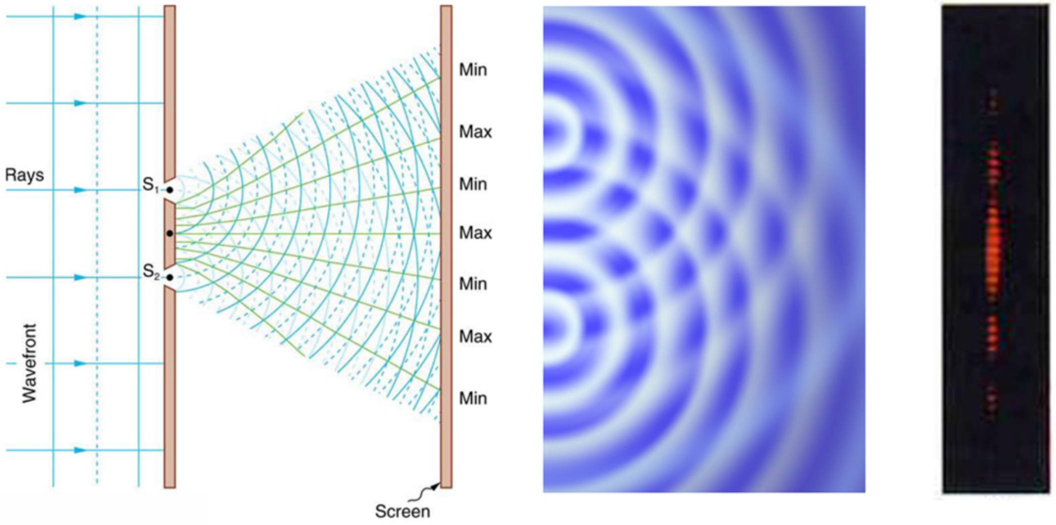
- Multi-aperture interference technique in radio astronomy: have been using for decades
- Interferometers in optical and infrared much difficult
  - Teason: wavelengths are about 100,000 times smaller
  - Current optical & IR instrument can achieve 0.001 seconds of arc
  - More detail: Monnier (2003)

- Albert Michelson: two separate mirrors combine beams -> measure diameters of red supergiant stars

Bright fringes: $h = n\lambda(L/d)$

Dark fringes: $h = (n + \frac{1}{2})\lambda(L/d)$

d: separation of two slits
L: distance between screen and slits
h: height



Young's double slit experiment

Sec.2.5 Optical and IR interferometers

- For propagation along the x-axis and with electric filed only in the x-y plane,
  - Magnitude of wave at time t and position x :

$$E_y = E_0 \sin(\omega t + kx + \varphi)$$

  - Intensity of combined light on distant screen:

$$I = 4E_0^2 \cos^2(\delta/2)$$

Square of the combined electric field

Intensity is maximum when the phase difference is an integer multiple of 2π

- Application of interferometer to astronomy:
  - Measure binary star separation
  - Angular diameters of stars

- Angualr separation of two point sources (Rayleigh's criterion): $\alpha = 1.22\lambda/D$

  D: diameter of mirror

- Interference fringes are observed at following condition: $d \sim D/1.22$

Sec.2.5 Optical and IR interferometers

- Spatial interferometer
  - Keck telescope: interferometric pair with baseline of 85m
  - ESO VLT: four 8 meter and many smaller telescope as an interferometer array (VLTI)
  - CHARA: array of six 1meter telescopes

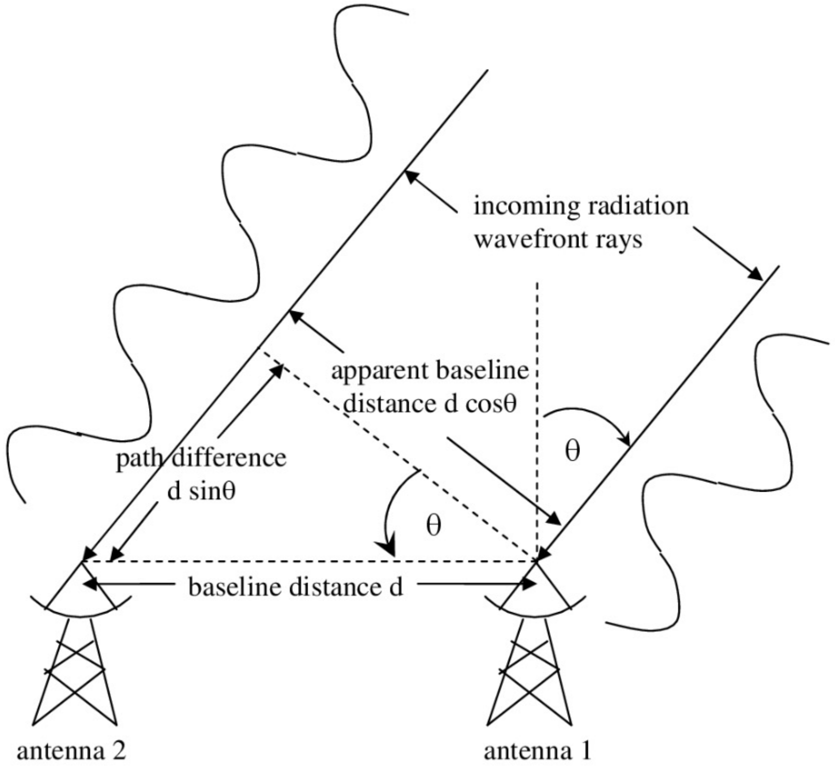
- Very few 'images' have been made by current optical/IR interferometers
  - Reason: difficulty of obtaining enough baselines to cover all spatial frequencies

- Earth’s rotation: causes apparent position of astronomical objects always change
  - To solve this problem:
    to compensate delay line between wavefronts reaching two telescopes
  - Current situation:
    precision at nanometer levels moving at high speed -> this a very challenge in optical interferometry

Sec.2.5.1 Phase closure

- Multiple telescopes collect light from same object at different times and spaces
  -> light collected by each telescope have a different phase.
  -> Images are created by taking into account the phase difference of light collected by multiple telescopes.

This process is called ‘phase closure’.
-> improving image accuracy and resolution.



Sec.2.6 Space telescope

- Reduce poor transmission by Earth's atmosphere
- Observation wavelength in space: much of infrared and sub-millimeter, all of UV, X-ray, gamma-ray

- Instrument in HST
- Wide Field/Planetary Camera (WF/PC)
- Faint Object Camera (FOC)
- Faint Object Spectrograph (FOS)
- Goddard High Resolution Spectrometer (GHRS)
- High Speed Photometer (HSP)
- Fine Guidance Sensors (FGSs)

- Diameter of HST: 2.5m
- Diffraction limit (λ/D)
- 0.025″ at 300 nm in UV
- 0.1″ at 1.2 μm in near-infrared
- 0.2″ at 2.4 μm

Sec.2.7 Summary

- To achieve angular resolution improvement as well as the light gathering boost
  - Telescope in space
  - Develop technology to remove the effect of atmospheric turbulence
    - Development of laser guide star adaptive optics
  - Multiple telescope in optical/infrared interferometer array