Project format

- Option 1: term paper
  - ~10 page report
  - scientific format (title, authors, abstract, main paper, references)
- Option 2: web page
  - ~10 pages/frame sets
  - pictures, animations, movies, descriptions
- Option 3: creative project
  - any idea for a term project you find more interesting ? Discuss it with me.

Project topics (a few examples)

- modern cosmology and creation myths
  - discuss concepts that are used or that have been abandoned in modern cosmology and whether and how they have been used in creation tales.
- history of cosmology
  - pick one particular epoch, discovery or person
- cosmology in the arts
- cosmology in the literature
- cosmology and politics

Project topics, a few more

- challenges in modern cosmology
  - The cosmic microwave background
  - galaxy formation
  - formation of large scale structure in the universe
- geometry of space and time
  - solutions to Einstein's equation and their geometrical interpretations
- Do you have better idea ?
  - discuss it with me

Project: procedures and deadlines

- Individual project or group project (up to 3 authors)
- Deadline 1, February 9
  - Title
  - Authors (for group proposal)
  - outline what you intend to do
- Deadline 2, April 6: first draft due
- Deadline 3, April 30: project due
- Grading: 25/25/50

Tutoring

- Location: Steward room 208
- Tutors:
  - Ariane Lee:
    - Mon, Wed, Fri 10:15-11:15
    - Thu 1:30-3:30
  - Andrea Urban
    - Mon, Wed 3:00-4:00
    - Tue 11:30-1:30
  - Shanna Shaked
    - Mon, Wed 4:00-5:00
    - Tue 2:00-5:00

Lecture 8
Distance Measurements

What we have done so far:

- Creation tales, philosophical concepts about the age, size and origin of the universe
- Scientific method
- Discovery of the layout of the solar system
  - Greek astronomers
  - Copernican revolution
- Development of modern physics
  - Newton's laws of motion
  - Newton's law of gravity

Newton's triumph: discovery of Neptune

- 1781: W. Herschel discovers Uranus
- Measurements of Uranus' orbit around the Sun: slight deviations from perfect ellipse. These cannot be accounted for by the perturbing influence of the known planets $\Rightarrow$ another planet ?
- Leverrier and Adams calculated the position of a hypothetical planet that could be responsible for the observed deviations
- Galle (1846) pointed a telescope to the predicted position and found the new planet (Neptune) within 1° of the predicted position

Next step: apply Newton's laws to cosmology

- Problem: ~1750 "universe" identical with solar system. Stars far away, but how far ?
- we need empirical data regarding the size and age of the universe, so we can compare model predictions against data

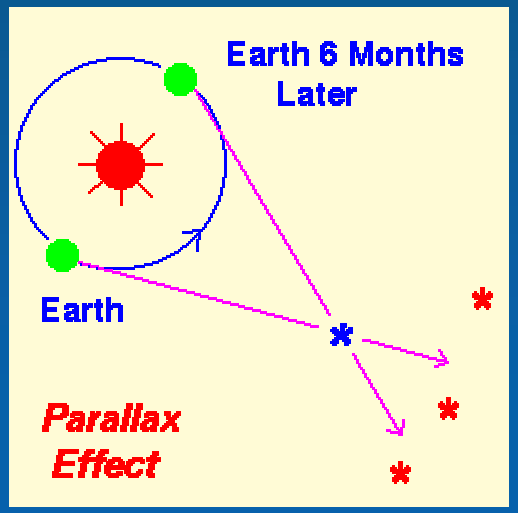
How do we measure distances in daily life ?

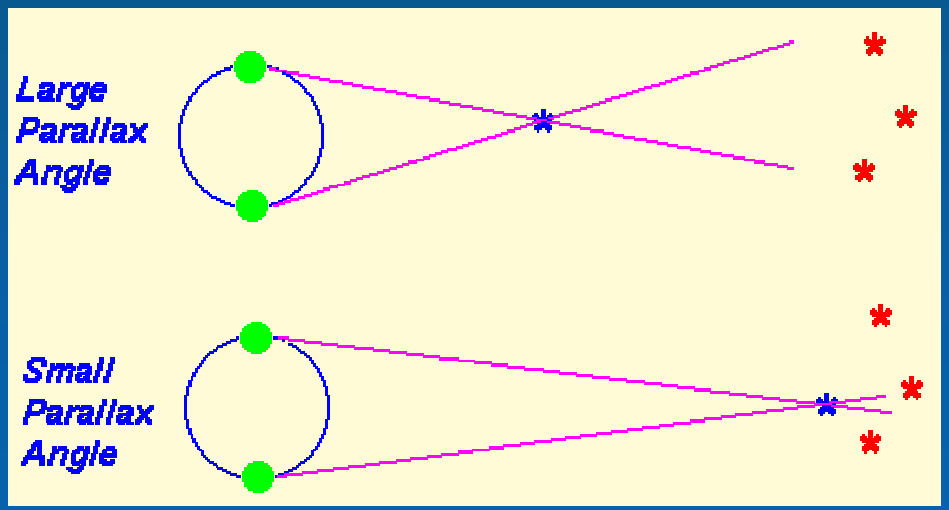
- parallaxes
- travel time
- via size of objects: comparison with standard yard stick
- via brightness of objects: comparison with standard candle

Parallaxes

- Measure the position of an object with respect to its background
- nearby objects show a larger “motion” than objects far away do
- The parallax angle θ, the distance of the object D and the diameter of the Earth’s orbit d are connected by simple geometrical relations. For small angles, it is

$$d = D \times \theta$$ [units !!!! θ measured in rad !]





Travel time

- If you know the speed v you're traveling with and the travel time Δt, the distance D can be obtained by simple multiplication:

$$D = v\,\Delta t$$

- Example 1: How far is it from Tucson to Phoenix?
  - It takes about 2 hours to get there by car traveling at 60 mph on I10 $\Rightarrow$ ca. 120 miles
- Example 2: How far is it from Los Angeles, CA to Honolulu, HI ?
  - It takes about 5 hours to get there on an airplane traveling at 500 mph $\Rightarrow$ ca. 2500 miles
- Astronomy: Use light travel times,

  i.e. v = 300 000 km/sec

Comparison with a standard ruler

- An object nearby spans a larger angle than an object of identical physical size far away
- The physical size l of the object, its distance D and the angle θ under which it appears are connected by simple geometrical relations. For small angles, it is

$$l = D \times \theta$$ [units !!!! θ measured in rad !]

- If the physical size l of an object is known ($\Rightarrow$ standard ruler), its distance D can be determined by measuring the angle θ under which the object appears

Comparison with a standard candle

- A nearby object appears brighter than an object of same luminosity far away
- The absolute luminosity $L_{absolute}$ of an object, its distance D and its apparent luminosity $L_{apparent}$ are connected by simple geometrical relations. It is

$$L_{apparent} = L_{absolute} / D^2$$

- If the absolute luminosity $L_{absolute}$ of an object is known ($\Rightarrow$ standard candle), its distance D can be determined by measuring its apparent luminosity $L_{apparent}$