Problem set #1

Problem 1 *Parallax project*

Suppose you are designing a project for observational astronomy. You want to measure the distance to a near-Earth asteroid using parallax. You have two small telescopes you can use, one at Calar Alto Observatory (in Spain) and one at Wendelstein Observatory. The two telescopes are separated by 1662 km.

You take a simultaneous image of the asteroid from each telescope, and compare the position of the asteroid to background stars. This gives you the angular offset between the asteroid as seen from the two locations to a precision of $2''$.

Draw a picture that shows what you've done above. Indicate on this picture what measurement is 1662 km. Label with d the distance from the Earth to the asteroid.

(a) What is the largest distance an asteroid can have without being too far for your measurement given the precision of $2''$? (Hint: if you come up with an answer that is measured in parsecs or tenths of parsecs, you've done something very wrong. [Why?])

(b) How does your answer in (a) compare to the distance from the Earth to the Moon, and to 1 AU (the distance from the Earth to the Sun)?

(c) Where do you want the asteroid to be in the sky as seen from each observatory so as to make the best possible measurement? (E.g., near rising, near setting, directly overhead, a little east of overhead, or a little west of overhead?)

Problem 2 *Angular resolutions of radio and other telescopes*

Calculate, in arcseconds, the angular resolutions of some famous diffraction-limited telescopes:

(a) Caltech's 40 m single-dish radio telescope in Owens Valley, operating at 1.4 GHz frequency.

(b) Caltech's CARMA array of mm-wave telescopes, with longest baseline of 2 km, operating at 115 GHz frequency.

(c) The Arecibo single-dish radio telescope (1000-foot diameter) in Puerto Rico, operating at 1.4 GHz frequency.

(d) The national Very Large Array of radio telescopes in New Mexico, with longest baseline of 36 km, operating at 1.4 GHz frequency.

(e) The national Very Long Baseline Array, whose radio telescopes cover the continental US, with additional stations in Hawaii and the Virgin Islands, operating at 1.4 GHz frequency.

(f) The 2.4 m Hubble Space Telescope, observing at the shortest wavelength of its late lamented ACS camera, 380 nm.

(g) The 0.85 m Spitzer Space Telescope, operating at the shortest wavelength of its imaging photometer, 24 μm.

Problem 3 *RA, Dec, and angular sizes*

The most commonly used coordinate system is the equatorial system, where object coordinates are given in right ascension (RA) and declination (Dec). It is convention that right ascension coordinates are reported in hours, minutes, and seconds [why?] whereas declinations are reported in degrees, minutes, and seconds. It is useful to develop a feeling for these units.

(a) Work out the relation between a RA-second and a Dec-second.

(b) Suppose you observe two objects at the same declination but slightly different right ascension. How does the separation in right ascension translate to the angular separation on sky? How does this depend on the declination?

(c) What is the size of of the moon on the sky? What about Jupiter?

(d) Resolution of the human eye:
Take something with small structures that your eye can still resolve, e.g. pixels of an (old enough) cellphone or letters of a text. Move it to a distance where the individual pixels/letters start to fade into each other. From the size of the pixels/letters and the distance, you can work out the angular resolution of your eye. How does this compare to a typical spatial resolution of a telescope of one arcsecond?

(e) Now imagine a 2 Euro coin (diameter 2.5 cm). At what distance would a telescope not be able to resolve the coin any more?

Problem 4 *Key questions*

(a) In which two spectral regions are the dominant electromagnetic windows of the earth atmosphere?

(b) Which frequency regions are strongly absorbed by the earth atmosphere?