מבוא לאסטרופיזיקה - תרגיל 1

1. a. Calculate the best angular resolution that can, in principle, be achieved with the human eye. Assume a pupil diameter of 0.5 cm and the wavelength of green light, $\sim 0.5\ \mu$m. Express your answer in arcminutes, where an arcminute is 1/60 of a degree. (In practice, the human eye does not achieve diffraction limited performance, because of imperfections in the eye's optics and the coarse sampling of the retina by the light-sensitive "rod" and "cone" cells that line it.)

b. What is the angular resolution, in arcseconds (1/3600 of a degree), of the Hubble Space Telescope (with an aperture diameter of 2.4 m) at a wavelength of 0.5 μm?

c. What is the angular resolution, expressed as a fraction of an arcsecond, of the Very Long Baseline Interferometer (VLBI)? VLBI is an network of radio telescopes (wavelengths $\sim 1 - 100$ cm), spread over the globe, that combine their signals to form one large interferometer.

d. From the Table of Constants and Units, find the distances and physical sizes of the Sun, [redacted], and a Sun-like star 10 light years away. Calculate their angular sizes, and compare to the angular resolutions you found above.

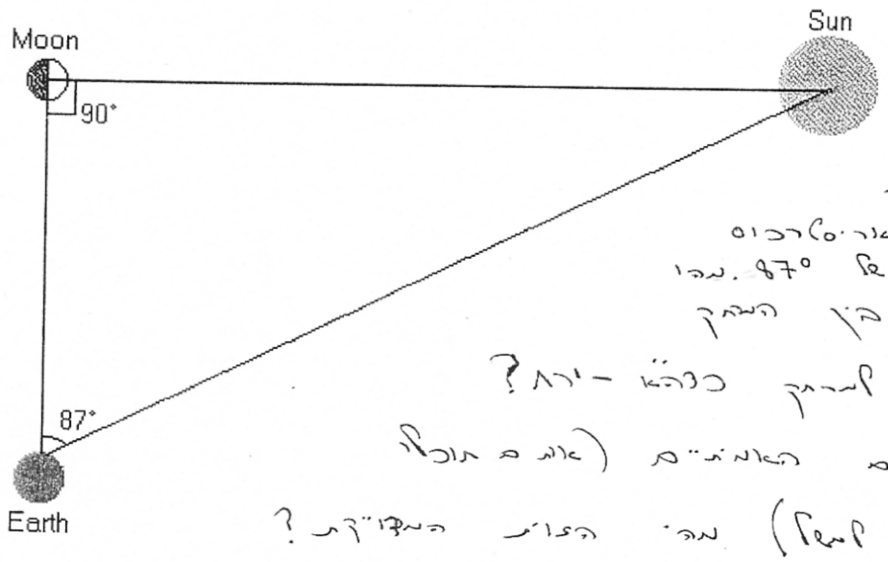
2. A CCD detector at the focal plane of a 1-meter-diameter telescope records the image of a certain star. Due to the blurring effect of the atmosphere (this is called "seeing" by astronomers) the light from the star is spread over a circular area of radius R pixels. The total number of photoelectrons over this area, accumulated during the exposure, and due to the light of the star, is $N_{\rm star}$. Light from the sky produces $n_{\rm sky}$ photoelectrons per pixel in the same exposure.

a. Calculate the signal-to-noise ratio (S/N) of the photometric measurement of the star, i.e., the ratio of the counts from the star to the uncertainty in this measurement. Assume Poisson statistics, i.e., that the "noise" is the square root of the total counts, from all sources.

b. The same star is observed with the same exposure time, but with a 10-meter-diameter telescope. This larger telescope naturally has a larger light gathering area, but also is at a site with a more stable atmosphere, and therefore has 3 times better "seeing" (i.e., the light from the stars is spread over an area of radius $R/3$). Find the S/N in this case.

c. Assuming that the star and the sky are not variable (i.e., photons arrive from them at a constant rate), find the functional dependence of S/N on exposure time, t, in two limiting cases: the counts from the star are much greater than the counts from the sky in the "seeing disk"; and vice versa.
Answer: S/N $\propto t^{1/2}$ in both cases.

d. Based on the results of (c), by what factor does the exposure time with the 1 m telescope need to be increased, in order to reach the S/N obtained with the 10 m telescope, for each of the two limiting cases?
Answer: By a factor 100 in the first case, and 1000 in the second case.



3. בקונפיגורציה
המשורטטת אריסטרכוס
מצא זווית של 87°. מהו
מכאן היחס בין המרחק
כדוה"א שמש למרחק כדוה"א - ירח?
מתוך המרחקים האמיתיים (אותם תוכל
למצוא בדף קבועים) מהי הזוית המדויקת?

המשך תרגיל 1

4. הניחו שמסת שמש אחת של מימן מפוזרת באופן אחיד בנפח שמוגדר ע"י ת. 3. המרחק בין השמש לכוכב הקרוב ביותר אלפא-קנטאורי: $d_{\alpha Cen}=1.33pc$. מהי צפיפות החלקיקים שמתקבלת? זוהי הערכה פשוטה לצפיפות התווך הבין כוכבי.