AST 222 Problem Set 1

Due on Fri. Jan 22 at 11:59pm

Please submit via Quercus

Student name: *Student number:*

Problem 1: (2 points)
For the following problem, draw a sketch for each part, labeling your drawing.
(a) Calculate the best angular resolution that can be achieved with the human eye. Indicate what pupil diameter and wavelength you assumed for your calculation. Express your answer in arcminutes.
(b) Calculate the angular resolution of the Hubble Space telescope at a wavelength of 0.5 um (the primary mirror of Hubble is 2.4 m).
The very first "image" of a black hole, at the centre of galaxy M87, was recently taken by the Event Horizon Telescope (EHT). More accurately, EHT imaged radio emission from the disc of gas that orbits the black hole with a lack of emission from the centre being attributed to the black hole. This image was only possible because EHT is not a single radio telescope, but is in fact of network of telescopes from around the world that take advantage of something known as interferometry. Interferometry is a method for combining the light from multiple telescopes to create images with an angular resolution equal to the distance between the telescopes—referred to as the "baseline"—rather than the size of each individual telescope. EHT in particular combines observations from several *Very Long Baseline Interferometry* (VLBI) stations in order to achieve a high angular resolution.
(c) Given that the "baseline" of EHT is effectively the diameter of the Earth, compute its angular resolution when observed the 21 cm line of hydrogen.
(d) If one could install a radio telescope on the Moon, by what factor could EHT's resolution be increased.

Problem 2: (2 points)
The `gaia` telescope is currently measuring the positions and velocities of billions of stars in the Milky Way. It is able to view stars down to a limiting magnitude of 21. If a star orbiting in the plane of the Milky Way's disc has an apparent magnitude of 21 and has had its distance measured via parallax to be 3 kpc. What would you conclude the star's absolute magnitude and stellar type to be if reddening is ignored?
What if reddening (extinction) were not ignored? Discuss the process of extinction.

Problem 3: (2 points)
Discuss the observational evidence we have for the structure of our Milky Way given that we cannot observe its structure from outside the Galaxy. Include a sketch or image of the Milky way, both edge and face on and label the structure and discuss the evidence for each structure.

Problem 4: (2 points)
In order to view the most distant galaxies possible the Hubble Space Telescope was pur-

posefully pointed at a patch of sky that is very empty and has have low extinction. After completing several long exposures, the images were combined to reveal over 10,000 galaxies within an area of 5.76 square arcminutes. Some of the galaxies visible in the image are nearly 13 billion light years away. Ignoring extragalactic sources, discuss whether each of the following pointings would be more or less favourable for viewing distant galaxies than the coordinates of the Hubble Deep Field (Ra = 3h32m39.0s, Dec = -27^{o}47'29.1").
(1)$(l, b) = (35°, 80°)$
(2)$(l, b) = (45°, 2°)$
(3) $(l, b) = (165°, 0°)$
(4) $(l, b) = (3°, -60°)$

Problem 5: (2 points)
A galaxy's rotation curve is a measure of the orbital speed of stars as a function of distance from the galaxy's centre. The fact that rotation curves are primarily flat at large galactocentric distances ($v_{rot}(r) \sim$ constant) is the most common example of why astronomer's believe dark matter exists. Lets work out why!

Assuming that each star in a given galaxy has a circular orbit, we know that the acceleration due to gravity felt by each star is due to the mass enclosed within its orbital radius r and equal to v_c^2/r. Here, v_c is the circular orbit velocity of the star. (a) Show that the expected relationship between v and r due to the stellar halo ($\rho(r) \propto r^{-3.5}$) does not produce a flat rotation curve. (b) Show that a $\rho(r) \propto r^{-2}$ density profile successfully produces a flat rotation curve and must therefore be the general profile that dark matter follows in our galaxy.

Problem 6: (2 points)
Galaxy Zoo (https://www.zooniverse.org/projects/zookeeper/galaxy-zoo) uses citizen science to help classify the large number of galaxies that have been observed by astronomers. Algorithms and machine learning are still no match for the human eye (for now.....). For this question "classify" three galaxies. For each galaxy, Galaxy Zoo will ask you a series of questions. For submission, take a snapshot of each galaxy you are classifying and record the answers you gave to Galaxy Zoo. Annotate the images to show why you gave them that particular classification. Estimate the Hubble type of each galaxy. (Note: Your submissions to Galaxy Zoo are being used for actual science!)

How many hours did you spend on this assignment?