Donald P. Shiley School of Engineering
EGR 491 Telescope Design, Fall 2019
Assignment 6 – How Big and How Bright?

The main purpose of this assignment is to help you become familiar with "size" and "brightness" of astronomical observations.

First, we need to define a few things.

Extended object: optically, these are objects that "have size", and if we increase magnification, they will appear larger. Jupiter appears to be a point of light to most unaided eyes, but it appears to be a disk even with low magnification.

Point: mathematically, points have no size. Points are not real, but at times, things may behave as points. Stars are so far away that they are nearly points, and optically are considered to be "points." They do not appear larger with greater magnification. Only telescopes with *extremely* high resolution are capable of "seeing" a star as an extended object, not a point.

Actual Size: the actual size of an object as a length, such as meters, inches or light years. Your height is a measure of your size. The size of stars is usually expressed in terms of relative size to the Sun or compared to our solar system. The size of most other astronomical targets, such as galaxies or nebulae, are measured in terms of light years (ly).

Apparent Size: a measure of "how big" the object appears. This is measured in terms of **angular size** (degrees, arcminutes, arcseconds). 3600 arcseconds = 3600" = 60 arcminutes = 60' = 1 degree = 1°. Objects appear bigger if they are 1) closer and/or 2) have greater actual size…that's not too shocking.

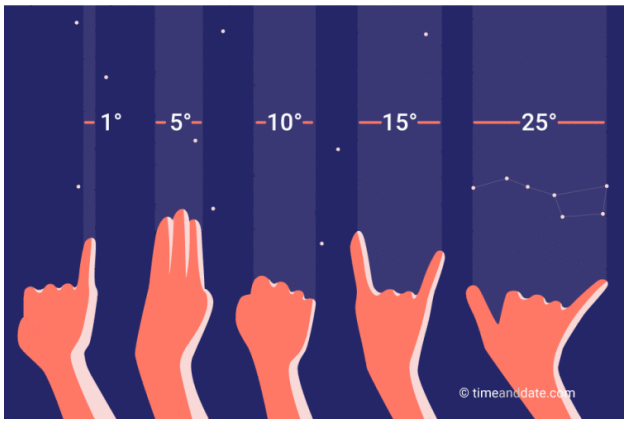
Resolution of the eye: the human eye has an angular resolution of about 1' (1 arcminute = 60 arcseconds); although this varies substantially from person-to-person.

For any of the following problems, if you want to create a spreadsheet or use Matlab to calculate these values, you may do so. Submit a printout of your code or spreadsheet to show your work, and include at least one hand calculation to show the methodology. In other words, in 2 years when you have forgotten what you did today, you can easily replicate your work based only on what you submit for the homework.

Assigned questions:

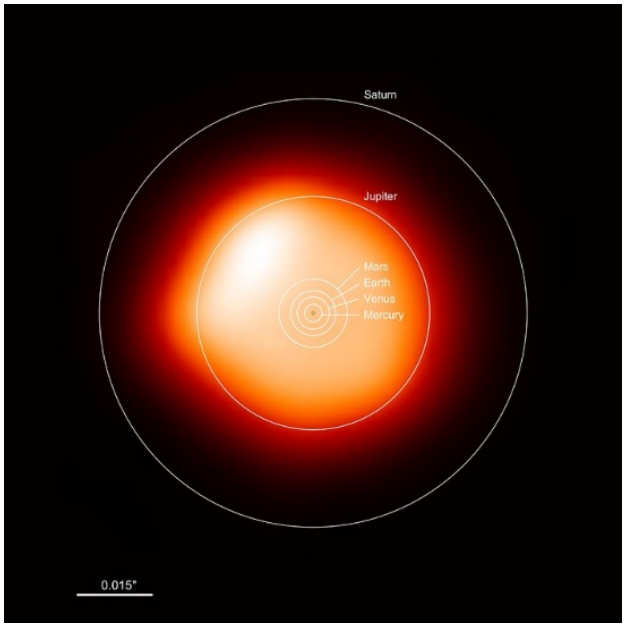
1) How many kilometers are in 1 ly (1 light year)?
2) What is parallax (see video posted at: http://earthsky.org/space/what-is-a-parsec)
3) Parsec is an astronomical measure of distance. Describe/define a parsec. And also, how many light years is a parsec?

Since apparent size is measured in degrees, it would be "handy" for you to carry a degree-ruler with you….oh wait, you do….(see next questions)



https://www.timeanddate.com/astronomy/measuring-the-sky-by-hand.html

4) Calculate the apparent size (arcminutes) of your pinky extended at your arms-length. Compare with the "rule of thumb" in the above image.
5) Calculate the apparent size (arcminutes) of your fist extended at your arms-length. Compare with the "rule of thumb" in the above image.
6) Calculate the apparent size (arcminutes) of your open hand (from pinky-tip to thumb-tip) extended at your arms-length. Compare with the "rule of thumb" in the above image.
7) Calculate the apparent size of the moon from Earth when it is at its closest and furthest from Earth (its orbit is elliptical). Your answers should be about 0.5 degrees. During the next full moon, calibrate your pinky.
~~8)~~ Skip: ~~What is the apparent size of the sun from earth, from Jupiter and from Neptune?~~
9) The average distance from the Sun to Earth is called 1 astronomical unit (1 AU). Calculate the apparent size of the Sun at 1 AU (the average apparent size from Earth).
10) Calculate the average apparent size of the Sun from Saturn.
11) When the outer planets are at their closest to Earth in their orbit, they are said to be "at opposition" and appear on the meridian at local mid-night. Jupiter is at opposition about every 13 months. On average, its distance from the sun is 780 million kilometers. Calculate Jupiter's apparent size from Earth during opposition for "average distances". Assuming the resolution of your eye is 1' (1 arcminute) approximately what magnification is required to resolve Jupiter as an extended object (a disk)?
12) Betelgeuse (α-Orionis) has one of the largest apparent sized stars in the sky (obviously, the Sun appears larger, so does *R Doradus*, and perhaps others – we haven't measure all of them). It has a diameter of approximately 821 million km, and lies about 640ly from us, calculate its angular size. Calculate the magnification required to make its apparent size 10 arcminutes.



Betelgeuse compared to our solar system. Betelgeuse image was resolved with the Atacama Large Millimeter/submillimeter Array (ALMA).

13) The apparent size of the Andromeda Galaxy (M31) is 2.6°X1.1° and lies about 2.6 Mly (million light years) away. Calculate its actual size. How does its apparent size compare to the apparent size of a full moon?

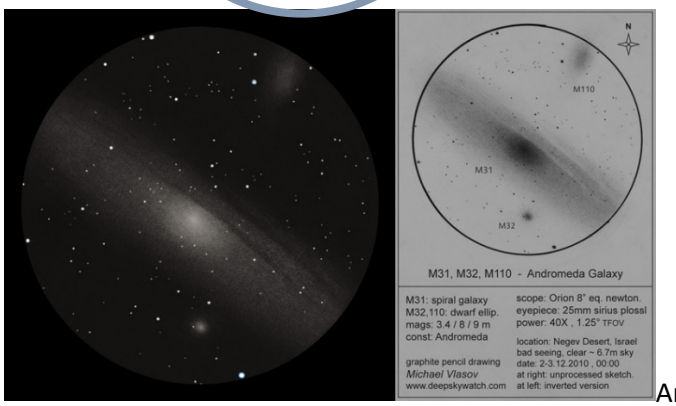
Enough of "size", what about "brightness"? We need to understand what is meant by "how bright" is the object. Brightness is measured in terms of magnitude, but "how bright" is ambiguous – it could mean apparent magnitude or absolute magnitude (inherent luminosity).

Read https://en.wikipedia.org/wiki/Magnitude_(astronomy) and/or: https://www.e-education.psu.edu/astro801/content/l4_p4.html and/or something similar...and answer the following questions.

14) Which appears brighter, a star with magnitude of -1 or 1? How many times brighter (or dimmer) is a magnitude 7 star than magnitude 5 star?
15) What is the apparent magnitude of the Sun from Earth? What is its inherent luminosity?
16) What is the apparent magnitude of the Sun from Neptune?
17) What is the apparent magnitude of the brightest star? What is that star? How far away is it, and what is its inherent luminosity? Cite your sources, as always.
18) "*Surface brightness*" is often used to describe apparent brightness of extended objects, such as nebulae and galaxies. If we consider the Andromeda Galaxy, it has an apparent magnitude of 4.3, but that light is spread out over a larger area, so it does not look nearly as bright as a 4.3 magnitude star. *Surface brightness* (SBr) is usually reported in *magnitude per square arcsecond* (mag/arcsec^2). For a source with a total or integrated magnitude **m** extending over a visual area of **A** square arcseconds, the surface brightness, **SBr,** is given by: **$SBr = m + 2.5 \log_{10} A$**. Calculate the surface brightness (SBr) of the Andromeda Galaxy if it has an apparent magnitude (m) of 4.3 and is 2.6°X1.1° ellipse. Your answer should be close to 22.8mag/arcsec^2. This is the average surface

brightness. Most objects do not have homogeneous surface brightness – galaxies usually have bright cores.


Andromeda Galaxy (M 31), photograph



Andromeda Galaxy, Hand sketch (M. Vlasov)

19) *Limiting magnitude* is the faintest apparent magnitude of a celestial body that is detectable or detected by a given instrument; including "naked" eye. It is affected by ambient light (light pollution, moon light, etc.) and atmospheric transparency (how clear the atmosphere is) – and varies from person to person (some people have more sensitive eyes than others). If transparency is good, the limiting magnitude with different amounts of light pollution is <u>approximately</u>:

Condition (light pollution)	**Limiting magnitude, naked eye**
Far from city (no light pollution)	About 6.5 to 7
Country (Some light pollution)	About 6
Suburban	About 4.5
Urban	About 3 to 3.5

Since the actual limiting magnitude is affected by many factors, it is nice to be able to estimate limiting magnitude on any given observing night. The "Little Dipper" (Ursa Minor) provides an effective way of determining the naked eye limiting magnitude. The North Star (Polaris) is about magnitude 2. To two significant figures, what are the limiting magnitudes of the other six stars? Look this up and cite your source.