TUTORIAL 4

Class Assignment

1 Retrograde motion of planets using Stellarium

All planets in our solar system move in the same direction around the Sun. We have also previously learned that the inner planets (with smaller orbits) move faster around the Sun compared to the outer planets. When an inner planet passes the slower-moving outer planet, it appears that the outer planet moves backwards relative to its eastward motion with respect to the background stars. Such a motion is known as an apparent retrograde motion of the planet. It only happens during the time when an inner planet overtakes an outer planet. For an observer on an inner planet, this retrograde motion appears in the form of a loop. This is illustrated in Figure 1.

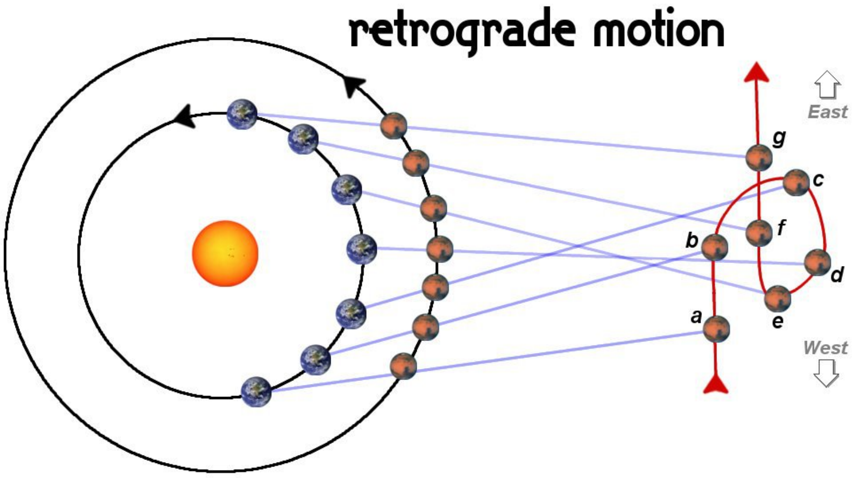


Figure 1

As an example, the TAs will demonstrate the retrograde motion of Jupiter in class. In a similar manner, observe the retrograde motions of Mars and Saturn, with the help of Stellarium. You can also follow the instructions given below. Based on your observations, answer the questions in the table given below.

1. Initialize Stellarium. Press **F11** for full screen mode. Remove the Ground and Atmosphere (press **g**, **a**). Enable the ecliptic line (press **,**)

2. Enable constellation markings and labels (press **c** and **v**).

3. Press **p** to view all planets. Select the planet you want to observe by clicking on it and press [**space**] to center it.

4. Now press **Shift + t** to view **Planet Trails**.

5. To observe the retrograde motion set the appropriate date at which the planet starts to move backwards. (Use **F5** to set the date).

6. Now, press = to advance 1 solar day. Keep advancing the days. You will observe the track of the planet making a loop. You can also press **o** to view its orbit and observe how it moves.

Mars	**Saturn**
Describe your observations.	
What is the time interval between one retrograde loop and the next one? Does it occur more than once in a year?	
In which constellation(s) does the retrograde motion occur? Does it occur in the same constellation again?	
Is the time taken for the retrograde motion to occur the same for both the planets?	

2 Magnitudes and Luminosities

In 120 B.C. Hipparchus, a Greek astronomer, ranked the brightness of stars he saw in the sky on a scale of one to six. He classified the brightest stars he could see as first magnitude and ranked the rest down to the faintest at sixth magnitude. This magnitude system was based on how bright a star appeared to the unaided eye. Astronomers still use this scale to measure the brightness of celestial objects, although it has since been modernized. There are two main magnitude scales used today:

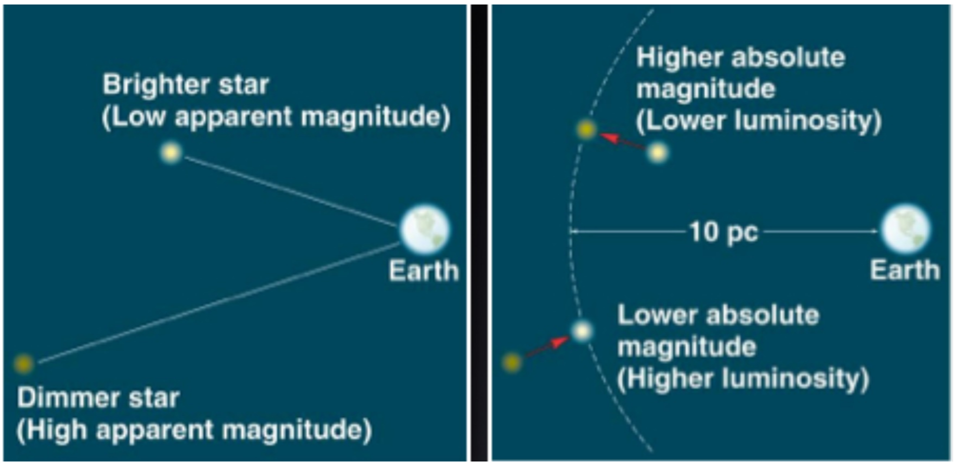


Figure 2

a)**Apparent Magnitude:**
It is a measure of how bright an object appears to an observer on Earth, or, in other words, the amount of photon flux from a star received by the observer. It is denoted by 'm'. The apparent magnitude of a star depends on its distance from the Earth, and its intrinsic luminosity.

b)**Luminosity and Absolute Magnitude:**
The luminosity of a star is a measure of the total amount of energy radiated by the star every second. Luminosity is related to a star's size and temperature. The larger a star is, the more energy it puts out and the more luminous it is.
With the assumption that a star is a black body, the luminosity is therefore given by

$$L = \sigma A T^4 \tag{1}$$

Where A is the surface area, T is the temperature and σ is a constant (known as the Stefan-Boltzmann constant, with $\sigma = 5.67 \times 10^{-8} W m^{-2} K^{-4}$).

The term 'absolute magnitude' (M) is closely related to the luminosity of a star. The absolute magnitude of a star is by definition, equal to the apparent magnitude the star would have, if it was placed at a standard reference distance of 10 parsecs from the Earth. By placing all stars at this distance, their relative luminosities can be compared on a magnitude scale. See Figure 2 where apparent and absolute magnitudes of two stars are being compared.

If you measure a star's apparent magnitude and know its absolute magnitude, you can find the star's distance by using the simple formula:

$$(m - M) = (5 \log_{10} d) - 5 \tag{2}$$

Where 'd' is the distance to the star in parsecs.

It may appear odd that the magnitude scales have been defined such that the brightest stars have magnitudes below 1, even negative numbers, while faint objects have larger values on the magnitude scale, owing to the fact that the magnitude scale is logarithmic in nature. This method was chosen to carry forward the traditional magnitude system set by Hipparchus.

To get a better understanding of these concepts, use the simulator at:
http://astro.unl.edu/classaction/animations/stellarprops/stellarmag.html

1. The simulator shows a star w.r.t the Earth on a distance scale that can be varied. You have three parameters to play with: The apparent magnitude (m), the Absolute magnitude (M) and the distance (d).
2. You can see the formula given above also displayed on the screen. You can lock any of the three parameters and observe how a change in one parameter changes the other.

Activity 1:
The table below provides partial magnitude and distance information for five known stars. Use the simulator to fill in the missing numbers.

Star Name	Apparent Magnitude	Absolute Magnitude	Distance from Earth (parsecs)
Aldebaran	0.9		20
Proxima Centauri	11.1	15.6	
Arcturus	-0.05	-0.3	
Sirius B		11.2	2.6
Alcyone	2.9	-2.6	

Activity 2:
An image of an open star cluster will be shown to you in class. These stars are at the same distance from the Earth. Some of the stars are labeled and their absolute magnitudes are given in the table below.

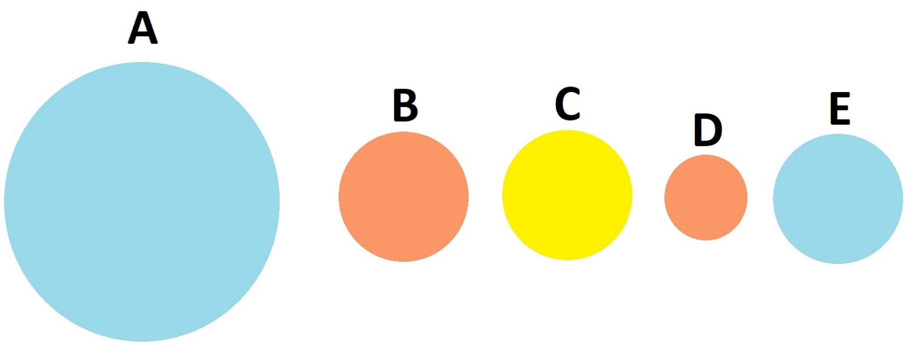
Star	Absolute Magnitude
C1	1.2
C2	-0.3
C3	2.3
C4	2.9

A. Ranking Instructions: Rank the apparent magnitude (from brightest to faintest) of each star (C1-C4) as it appears in the night sky.
Ranking Order: Brightest 1 _____2_____ 3_____ 4_____ Faintest
Carefully explain your reasoning for ranking this way:

B. Ranking Instructions: Rank the total amount of energy (from greatest to least) given off by each star (C1-C4).
Ranking Order: Greatest 1 _____ 2_____ 3_____ 4_____ Least
Carefully explain your reasoning for ranking this way:

C. In the image on the screen, the star labeled B is a background star. Compare this star to star C2 and comment on its apparent and absolute magnitudes.

Activity 3:



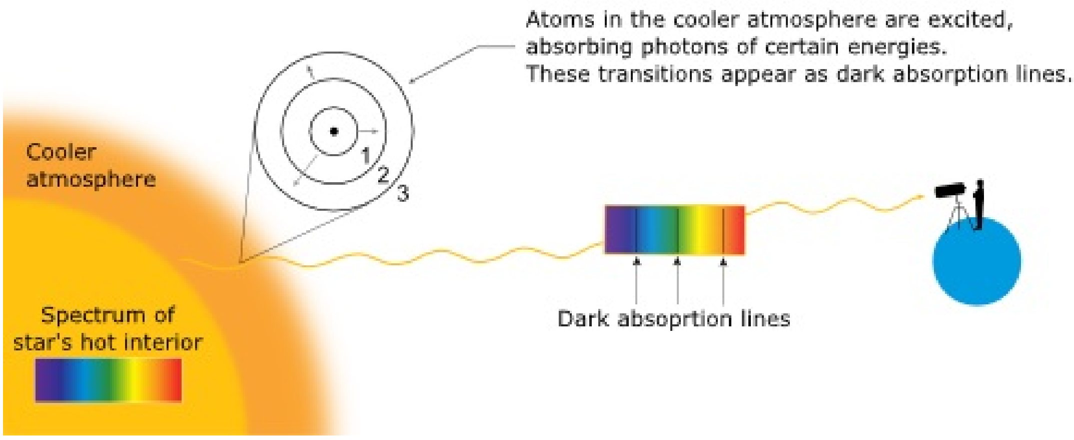
Imagine you are comparing five stars (A E) of different sizes and temperatures. The temperature of each star is indicated by different colors.
A. Ranking instructions: Rank the surface area (from largest to smallest) of the stars

Ranking Order: Largest 1_____ 2 _____ 3_____4_____ 5_____ Smallest

B. Ranking instructions: Rank the temperature (from highest to lowest) of the stars.
Ranking Order: Highest 1 _____ 2 _____ 3_____ 4 _____ 5_____ Lowest
Carefully explain your reasoning for ranking this way:

C. Ranking instructions: Rank the total energy output or luminosity (from greatest to least) of the stars.
Ranking Order: Greatest 1_____ 2_____ 3 _____ 4 _____ 5 _____ Least
Carefully explain your reasoning for ranking this way:

3 Absorption Spectrum of Stars



A star is a hot luminous body that is held together by its own gravity. The hot core of the star produces electromagnetic radiation at all wavelengths through nuclear fusion. Thus, one would expect to see a continuous spectrum from stars. However, it is observed that the spectrum from stars is not continuous, but has dark absorption lines over the continuum. Atoms of different elements and molecules that are present in a star's atmosphere absorb certain wavelengths corresponding to their electronic transition levels, thus giving rise to an absorption spectrum. Based on the absorption lines observed and their widths, stars are classified into spectral classes and luminosity classes. For more information, refer to the slides from lecture 9.
Use the simulator on: astro.unl.edu/classaction/animations/light/spectrum010.html
Follow the instructions below to use the simulator.

1. From the list of options, select 'Absorption'.
2. Change the spectral type to 'O0' using the slider.
3. Now select different elements (one at a time) and see how the spectrum changes for the selected spectral class. Observe which elements/molecules will create absorption lines and its intensity. Note this down. Use words like 'very dark' or dark' or 'faint' to describe the intensity of absorption lines.
4. Now repeat the steps 2. and 3. for different spectral classes given in the table below.

After you have noted your observations into the table, answer the questions below:

Q1. Choose any spectral class. Change the luminosity class and observe what happens to the absorption lines. What is the reason for this change?

Q2. As you change the spectral type, different absorption lines appear for different spectral classes. The intensity of each of these lines also varies with spectral class. Why does this happen?

Spectral Class	Lines Observed	Intensity of the observed lines
O0		
B0		
A0		
A4		
F0		
G0		
G2		
K0		
K5		
M0		
M1		