Today: Chapter. 12-Stars

Midterm Exam: Oct 17
Review Sheet handed out

First Extra Credit due Oct. 17
(Media report or sky observation)

Office Hours Monday, Tuesday 3-4 PM
Measuring Stars: Magnitudes

Another way to measure the brightness of a star is its “Magnitude”

Ancient people put stars into 5 classes, from

“First Magnitude” (brightest) to “Fifth Magnitude” (dimmest)

This system is still in use today
Magnitudes of stars in Orion

- Betelgeuse: +0.45
- Bellatrix: +1.62
- 51 Orionis: +4.87
- Saiph: +2.06
- Sirius: -1.44
- Rigel: +0.15
Magnitudes

- *Lower* magnitudes = *brighter* stars

- So a 1st magnitude star is *brighter* than a 2nd mag. star

- We use the symbol: \( m \) to mean magnitude.

- Originally there were only magnitudes 1-5

- However a very *bright* object can even have a negative magnitude.
Magnitude Examples

• The planet Venus’ magnitude is $m = -4.0$

• A very faint object can have a magnitude above 5.

• E.g.: A distant galaxy has a magnitude: $m = 20$.

• Q: What object in the sky has the lowest magnitude?
Magnitude

- Sun (-26.7)
- Full moon (-12.6)
- Venus (at brightest) (-4.4)
- Sirius (brightest star) (-1.44)
- Naked eye limit (+6.0)
- Binocular limit (+10.0)
- Pluto (+15.1)
- Hubble Space Telescope and large Earth-based telescopes (+30.0)
Some stars are a million times brighter than others. But, their magnitude difference is just 15.

<table>
<thead>
<tr>
<th>Magnitude Difference</th>
<th>Intensity Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>6.3</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
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<td>6</td>
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<td>7</td>
<td>630</td>
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<td>8</td>
<td>1600</td>
</tr>
<tr>
<td>9</td>
<td>4000</td>
</tr>
<tr>
<td>10</td>
<td>10,000</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>15</td>
<td>1,000,000</td>
</tr>
<tr>
<td>20</td>
<td>100,000,000</td>
</tr>
<tr>
<td>25</td>
<td>10,000,000,000</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Calculating Magnitude Differences

- Each magnitude is a factor of 2.5
- So a difference of 3 magnitudes = $2.5 \times 2.5 \times 2.5 = 15.6$ times brighter!
- 5 magnitudes difference corresponds to a star which is 100 times brighter.

Example:

- Star A’s magnitude is 1.0, Star B’s magnitude is 6.0
- The difference in magnitudes is $6.0 - 1.0 = 5$ Mags.
- So, Star B is 100 times fainter than Star A.
Inverse Square Law

As the light from a star goes into space, it fills a larger and larger sphere.
If “r” is the radius of the sphere, then the area of a sphere is given by: \( A = 4 \pi r^2 \)

The intensity of light decreases with the square of our distance from the star:

Brightness of a star \( \sim 1 / r^2 \)
Distance & Brightness

- If we view the same star from double the distance, it will appear four times fainter.
- Its apparent magnitude will be higher.
- So, nearby stars can trick us into thinking they are truly bright.
- To compare stars fairly, we need to place them all at the same distance...

- We need a way to measure the intrinsic (true) brightness of stars.

- The Absolute Magnitude does not depend on how far away it is.
- It is a measure of the star’s true energy output, not just its brightness as viewed from Earth.
Absolute & Apparent Magnitude

**Apparent** magnitude (m): the magnitude we see from Earth.

**Absolute** magnitude (M): the Intrinsic Magnitude (regardless of distance)

Absolute Mag. is defined as the magnitude that a star would have if we viewed it at a distance of 10 parsecs.

The Sun’s Apparent magnitude is: \( m = -27 \)

The Sun’s Absolute magnitude is: \( M = 4.8 \)

If the Sun were moved to a distance of 10 parsecs away, it would just barely be visible (Apparent Magnitude 4.8)
Example:

<table>
<thead>
<tr>
<th></th>
<th>Betelgeuse</th>
<th>Rigel</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m$</td>
<td>0.45</td>
<td>0.15</td>
</tr>
<tr>
<td>$M$</td>
<td>-5.5</td>
<td>-6.8</td>
</tr>
<tr>
<td>$d$</td>
<td>152 pc</td>
<td>244 pc</td>
</tr>
</tbody>
</table>

Betelgeuse
$m = 0.45$ mag

Rigel
$m = 0.15$ mag
Different Types of Star
(How many are there?)

- To understand the diversity of stars, we first classify them.
- We can use the star’s **spectrum** to do this.
- This was first done in the early 1900’s at Harvard Univ. by Annie Jump Cannon

- She was assigned the job of classifying stellar spectra into types (A,B,C ....)
- In her life she classified over 200,000 spectra!!!
Different Types of Star

- Cannon found that most stars fell into 7 different categories.
- A star’s spectral lines depend on what its temperature is.
- Cannon re-organized the spectral types to form a temperature sequence:

  O, B, A, F, G, K, M
These absorption lines are used to distinguish the different spectral types.
How Do We Classify Stars?

- **O** type stars are the hottest
- **M** type stars are the coolest.

“**Oh, Be A Fine Guy/Girl Kiss Me.**”
OBAFGKM shows spectral types in order of decreasing temperature

- Oh Boy, An F Grade Kills Me!
- Octavius became Augustus, fighting gallantly, killing many.
- Only Boys Accepting Feminism Get Kissed Meaningfully.
- Oops! Bacon Appetizers for generally Kosher man.
- On Break After Finals: Good, Key Moment
A star’s **spectral type** can be specified more precisely using a **subtype** ranging from 0 to 9.

Example: spectral type A is divided into A0, A1, A2, ..., A9

A0 is the hottest, and A9 is the coldest.

F0 is cooler than A9.

If you know a star’s spectral type, then you know its temperature.

The Sun is a type G2 star, corresponding to a temperature of 5800 K.