Pre-lab 3: The Magnitude System

AST 105

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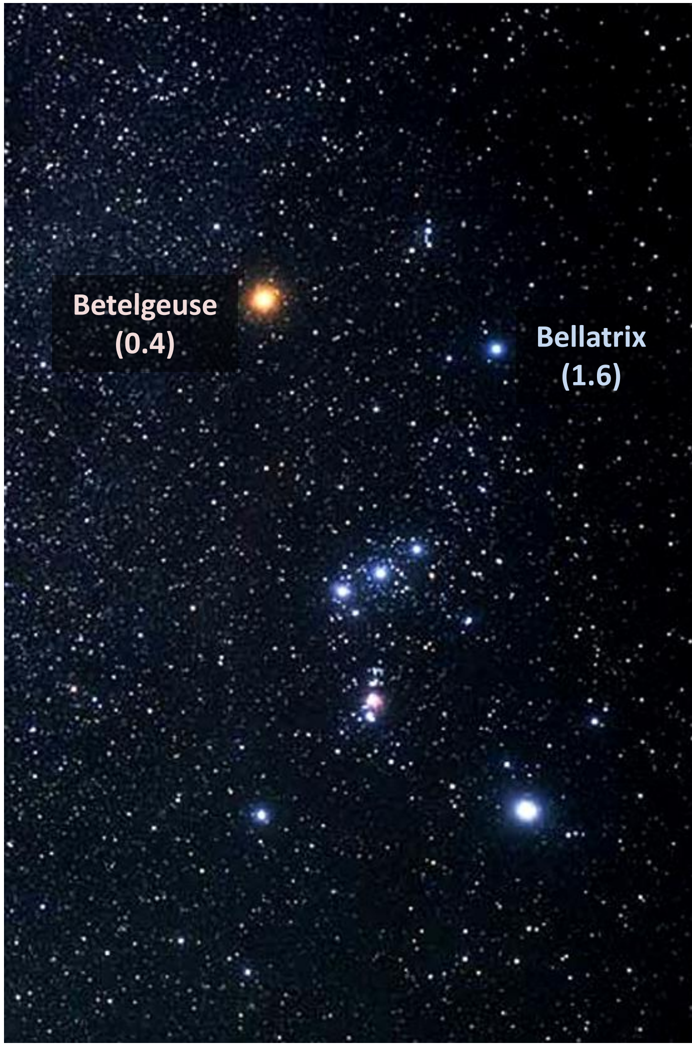
One of the most basic measurements regarding a star is how bright it is.

In astronomy, how bright a star looks in the sky is often given as an **apparent magnitude**. This is a number (without units), where lower numbers are brighter.

For example, the two stars that form the shoulders of Orion are Betelgeuse (usually around an apparent magnitude 0.4) and Bellatrix (apparent magnitude 1.6). Since 0.4 is smaller than 1.6, we know that Betelgeuse is (usually) the brighter star.

(If “smaller number” = “brighter” sounds counter-intuitive, try thinking of it more like a “rank” for the star. A #1 star is better than a #2 star.)

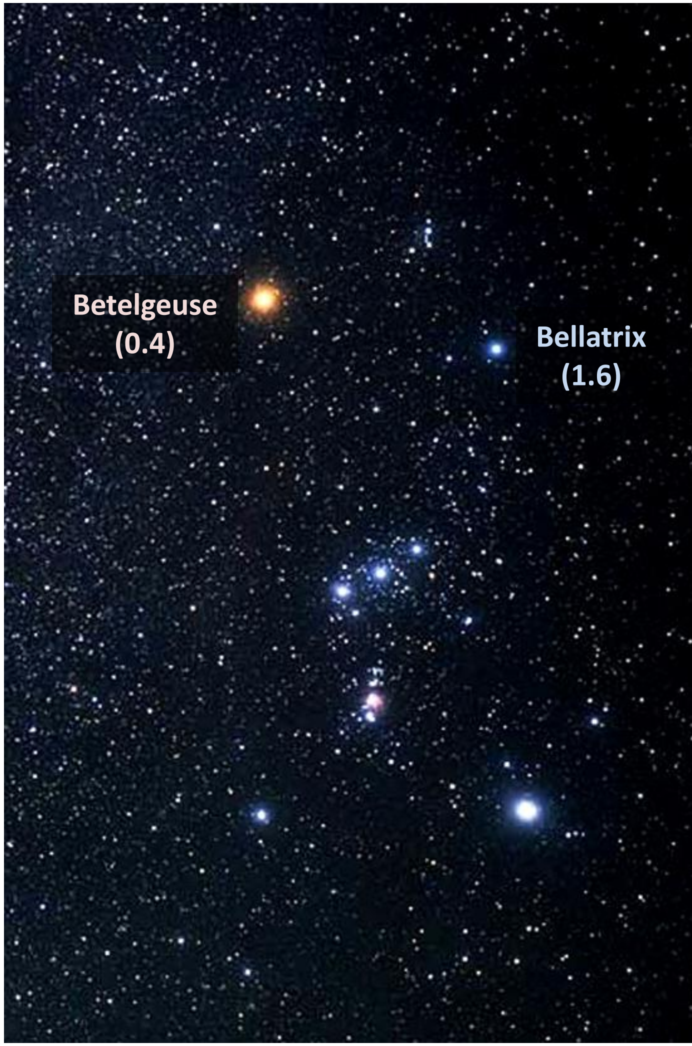


You know how the Richter scale, used to measure earthquakes, is not linear? In other words, a "magnitude 6" earthquake is not twice as strong as a "magnitude 3" earthquake. No, each full step along the scale means multiplying by 10 – so a "magnitude 6" earthquake is 10 times stronger than a "magnitude 5" quake, and 100 times stronger than a "magnitude 4" quake.

Stellar magnitudes use a similar working, but it's a little more complicated. If one star is *five magnitudes* lower than another, then it is 100 times brighter. So Bellatrix (magnitude 1.6) would be 100 times brighter than a star with apparent magnitude 6.6. If two stars differ in magnitude by exactly 1, then one is about 2.51 times brighter than the other.

Do some complicated math, and we can say that Betelgeuse (magnitude 0.4) is typically about 3 times the brightness of Bellatrix (magnitude 1.6).

Yes, that system is rather awkward, but it's been in place since ancient Greece.



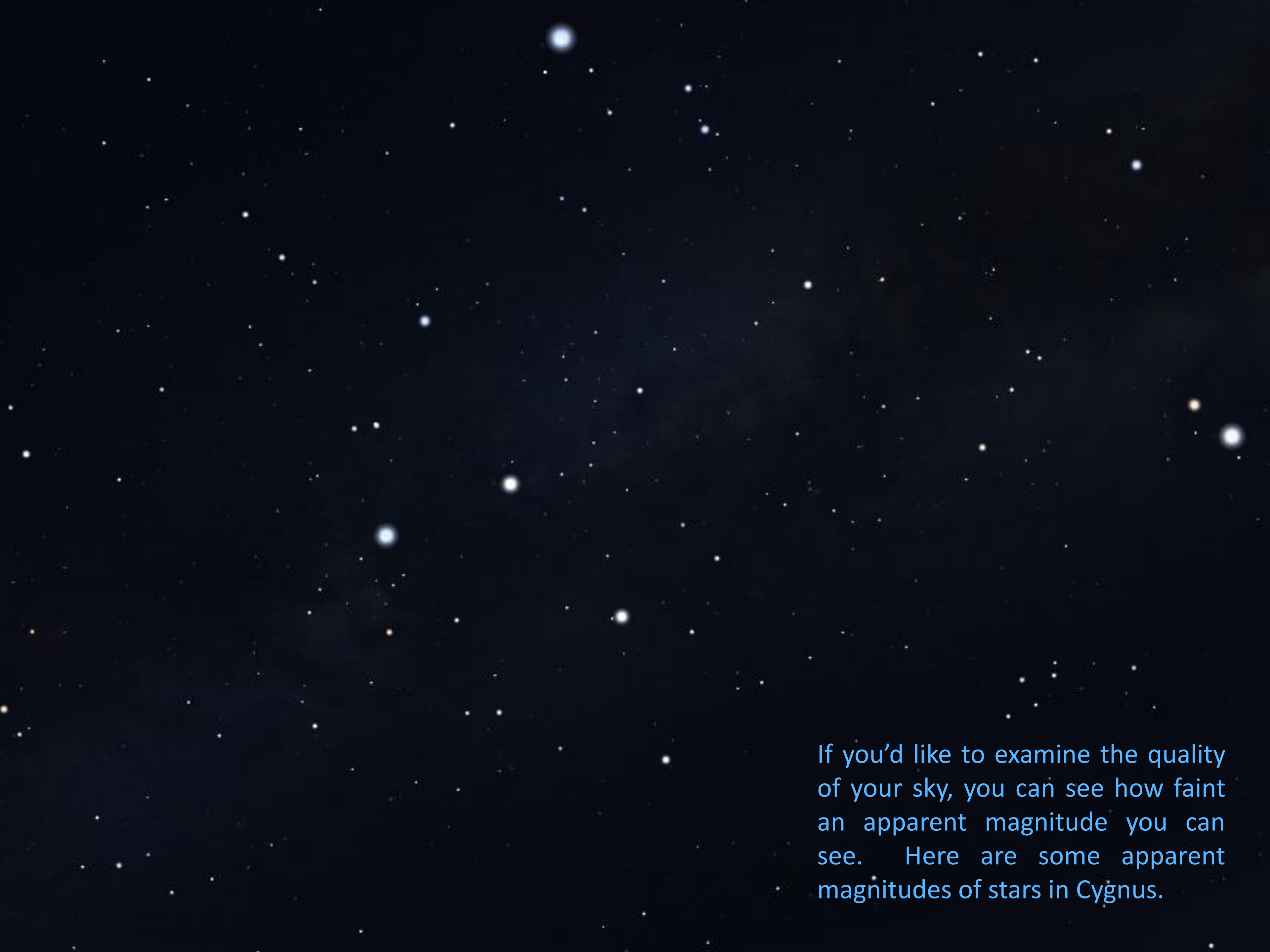
The magnitude system we use today is based upon the star **Vega**, a star of type A0.

Vega is the 5th brightest star in the night sky – or if you're only counting stars that can be seen in most of the US, the 3rd brightest. Vega also has the advantage of being in a part of the sky that makes it often visible to viewers in the northern hemisphere.

When the magnitude system was set up, Vega was given magnitude 0, and other stars were assigned their magnitudes based on how bright they were compared to Vega – a "magnitude 5" star would have been a star about 100 times fainter than Vega. (Nowadays we are a little more exact about it.)

Here are some convenient apparent magnitudes:

-26.7	The Sun
-12.7	the full moon
-4.9	Venus, at its brightest
-2.9	Jupiter, at its brightest
-1.5	Sirius, the brightest star in the night sky
0.03	Vega (slightly corrected to a more modernized system)
0.4	Betelgeuse, the bright red star that marks one of Orion's shoulders
1.25	Deneb
2.2	Alpha Cassiopeiae, the brightest star in Cassiopeia (though Beta Cas and Gamma Cas are not far behind)
3.9	Eta Cygni, the brightest star on the line between Sadr (the middle of the Northern Cross) and Albireo (the foot of the Northern Cross)
about 6	the faintest star you can see with the unaided eye, on a clear dark night far from city lights
11	Proxima Centauri, the closest star to the Sun (way too faint to see without a telescope!)



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As far as traits go, an object’s apparent magnitude is an easy thing to figure out. You can simply take a picture of the object and see how bright it looks, without knowing anything else about the object.

Apparent magnitude is also useful in planning observations. Is your object bright enough to see with this particular telescope, or do you need something bigger? How long do you need to have the telescope “stare” at the object for the telescope’s imaging chip to get enough signal? How long before you get too much light for the imager to handle?

However, apparent magnitude is not very useful if you want to learn about the object itself. This is because an object’s apparent magnitude depends on how far away it is. If you’re walking around at night, a bright lantern held by a distant person could look as bright as a weak lantern held by someone closer. It works similarly with stars.

If you move a star farther away, it will appear fainter.

A way to avoid “closer objects look brighter” complications is to refer to the object’s **absolute magnitude**, which is a measure of what its apparent magnitude would be, if the object were moved to a distance of **10 parsecs away**.

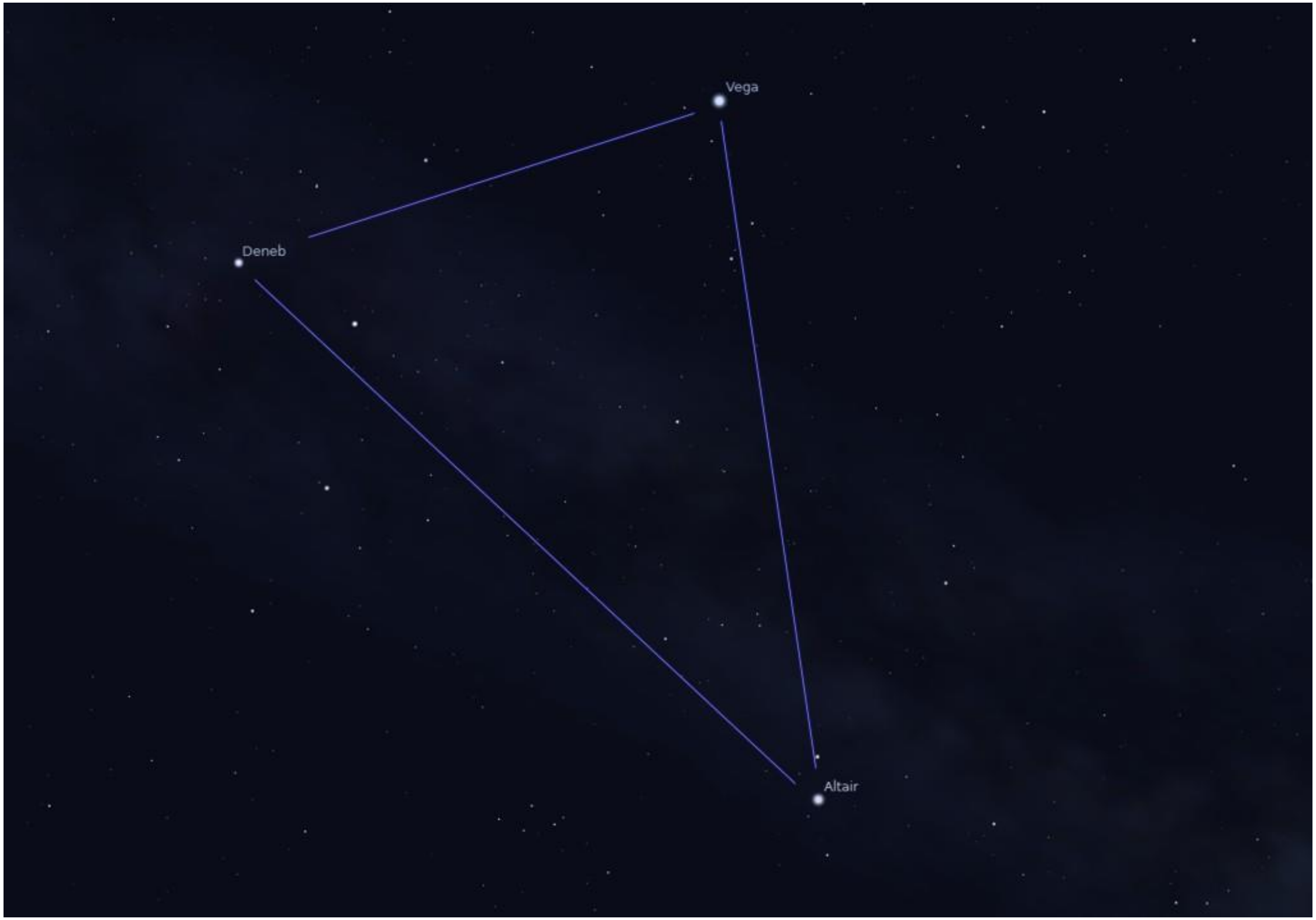
(One parsec is a distance of about 3.26 light years, so 10 parsecs would be a distance of 32.6 light years.)

Returning to our “two lanterns” scenario, this would be like imagining how bright they’d be if the two people moved so they were the same distance away from you.

If a star is closer than 10 parsecs away, moving it to 10 parsecs would make it fainter - so the star’s absolute magnitude would be larger (fainter) than its apparent magnitude. If a star were more than 10 parsecs away, the reverse would be true.

Though one of the problems is that you need to know how far away the star is in order to calculate its absolute magnitude.

So let’s take a look at the three stars of the Summer Triangle: Vega, Altair, and Deneb – the 5th, 12th, and 20th brightest stars in the night sky.



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	Apparent Magnitude	Distance	Absolute Magnitude
Vega	0.03	7.7 pc	0.6
Altair	0.77	5.1 pc	2.2
Deneb	1.25	800 pc	-8.38

This table lists each star’s apparent magnitude, distance (in parsecs), and absolute magnitude.

Looking at these numbers, which of these stars is the brightest as seen by someone on Earth, and which is the faintest?

Now let’s remove any “closer stars appear brighter” bias. Which star of the three gives off the most total light? Which gives off the least?

Take a moment to answer these questions. The answers are on the next page.

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Apparent magnitude tells us how bright things appear. Vega has the lowest apparent magnitude, so it is the brightest of these three stars in the night sky. Deneb is the faintest.

Absolute magnitude tells us the brightness of the object, if we get rid of any "closer stars are brighter" effects. Of these three stars, Deneb gives off the most total light, and Altair gives off the least.

If you're having trouble understanding what these two different brightnesses are, think about a birthday candle located a foot away from you, compared to a 120-watt light bulb located half a mile away. The light bulb gives off more light, but the candle would appear brighter to your eye. The candle would have a lower (brighter) apparent magnitude. If we placed them next to each other, you'd see the light bulb as brighter. The light bulb has a lower (brighter) absolute magnitude.

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Once we take it all in, we notice something: *one of these things is not like the others!* While Vega and Altair appear bright to us partly because they are in our neighborhood, Deneb appears bright because it is putting out a ridiculous amount of light.

If the star Deneb were only 10 parsecs away, on a moonless night on Earth, Deneb would be bright enough to produce shadows. If Deneb were 4 light years away – as close as the nearest star to the Sun – *you could read by its light.*