Assignment #11 – Red Giants

As we discussed in class, the brightest stars in the sky are not the same as the nearest stars in the sky. Those two groups are not the same! The nearby stars in the sky are mostly dim Type-M stars. The bright stars in the sky, on the other hand, tend to be Type O, B or A stars, with a few Type-M stars tossed in for good measure. Today we’ll be focusing on those few Type-M stars that are amongst the brightest stars in the sky. Why are these stars so bright? What is going on with them?

These unusually bright red stars are called “Red Giants.” Giant stars, and especially Red Giants, are stars that are near the ends of their lives. They have run out of protons (also known as Hydrogen nuclei) to fuse in their cores, and have therefore begun a complex process of expansion of their outer layers, and compression of their inner layers. As the outer layers of the dying star expand, they cool off (in much the same way as air expanding out of a tank causes your refrigerator to cool down!). Cooler gases are, of course, redder, as described by Wien's Law, so the star gets redder. You would also think it would get dimmer, since cooler gases are also dimmer, according to the Stefan-Boltzmann Law. But the expanding gases at the same time make the star very large, which keeps it bright. Hence the name “Red Giants.”

To give you a sense of how big some Red Giant stars are, here's a picture of the Red Giant star Betelgeuse, with a scale marked on the bottom:

Betelgeuse is larger than the orbit of Jupiter! Clearly Red Giants are no ordinary stars!

Let's use Stellarium to take a look at some stars in the sky, and see how many of them are Giants of one sort or another, and see if that can help us understand these bizarre, aging stars.
PART A
First let's see how many Red Giant stars there are among the bright stars in our average night sky. Start Stellarium. Turn off the Atmosphere and Ground if they are on. Table 1 is a familiar list of the 25 brightest stars in the sky (and the Sun). For each star, find the star's Absolute Magnitude and Spectral Type as you did in the previous exercise. Enter them in the Table for each star. The Sun's Spectral Type is entered for you. After you've filled in the table, plot the stars on the blank H-R Diagram on page 3.

Table 1
Brightest Stars in the Sky

<table>
<thead>
<tr>
<th>#</th>
<th>Star</th>
<th>Absolute Magnitude</th>
<th>Spectral Type</th>
<th>Luminosity Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Sun</td>
<td>4.7</td>
<td>G2</td>
<td>V</td>
</tr>
<tr>
<td>2</td>
<td>Sirius</td>
<td></td>
<td>V</td>
<td></td>
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<tr>
<td>3</td>
<td>Canopus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rigil Kent</td>
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<tr>
<td>5</td>
<td>Arcturus</td>
<td></td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Vega</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Capella</td>
<td></td>
<td>III</td>
<td></td>
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<tr>
<td>8</td>
<td>Rigel</td>
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<tr>
<td>9</td>
<td>Procyon</td>
<td></td>
<td>IV</td>
<td></td>
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<tr>
<td>10</td>
<td>Achernar</td>
<td></td>
<td>V</td>
<td></td>
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<tr>
<td>11</td>
<td>Betelgeuse</td>
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<tr>
<td>12</td>
<td>Hadar</td>
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<tr>
<td>13</td>
<td>Acrux</td>
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<tr>
<td>14</td>
<td>Altair</td>
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<td>IV</td>
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<tr>
<td>15</td>
<td>Aldebaran</td>
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<tr>
<td>16</td>
<td>Antares</td>
<td></td>
<td>Ia</td>
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<td>17</td>
<td>Spica</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Pollux</td>
<td></td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Fomalhaut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Beta Crucis (Mimosa)</td>
<td></td>
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<tr>
<td>21</td>
<td>Deneb</td>
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<tr>
<td>22</td>
<td>Regulus</td>
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<td></td>
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<tr>
<td>23</td>
<td>Adhara</td>
<td></td>
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<tr>
<td>24</td>
<td>Castor</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Gacrux</td>
<td></td>
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<td></td>
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<tr>
<td>26</td>
<td>Shaula</td>
<td></td>
<td>IV</td>
<td></td>
</tr>
</tbody>
</table>
Some of these stars are Main Sequence stars, and some are not. It's not easy to tell which are which. Most blue stars are Main Sequence stars. But whereas some red stars in the list are simply tiny, cool Main Sequence stars, other red stars of the exact same color are huge Red Giants! Telling the difference between the Main Sequence red stars and the Red Giant stars involves some complex measurements of the properties of the absorption lines in a star's spectrum. Thankfully, many astronomers have already done these careful measurements for us, and have developed a classification system to distinguish between Main Sequence stars and Giants. This system is called the Luminosity Class system. Every star is assigned to a Luminosity Class – either I, II, III, IV or V, with subdivisions within several of the classes (e.g., Ia or Ib, or IIIa or IIIb).

Stars of Luminosity Classes I, II, III, and IV are different kinds of Giants, while Luminosity Class V stars are Main Sequence stars. Stars of Luminosity Class I are the Super Giants, Luminosity Class II are the Bright Giants, Luminosity Class III are the Giants, and Luminosity Class IV are the Sub-Giants.

Go back and look at Table 1 above. See the column that says Luminosity Class? For each star in Table I that does not have its Luminosity Class listed, search for that star in Stellarium and find its
Luminosity Class, which is the Roman Numeral listed just AFTER the star's Spectral Class. Fill in the blanks in the Table 1.

- Draw a circle around the Main Sequence on your H-R Diagram (remember, all stars with **Luminosity Class V** are Main Sequence stars).
- How many of the 26 stars in the table are *off* the Main Sequence? ________________
- List them ____________________________________________________________________
- If we assume that all the non-Main Sequence stars are Giants, what fraction of the total stars in the table are Giants? ____________________________________________________________________
- Which stars in the Table are **Luminosity Class I** or “Super Giants”? ______________
  ____________________________________________________________________
- On your H-R Diagram, circle and label the area that is occupied by these **Class I Super Giant** stars.
- How many stars in the table are **Luminosity Class II “Bright Giants”**? _____________
- Name the stars in the table that are **Luminosity Class III “Red Giants”**? ___________
  ____________________________________________________________________
- On your H-R Diagram, circle and label the area that is occupied by the **Class III Giant** stars.

**PART B**

Now let's try to understand how stars evolve from one part of the H-R diagram to another as they get older. First, let's assume that the larger and bluer a star is to begin with, the larger a Red Giant it will eventually become. These largest of Giants are the **Type I Super Giants**. Notice that not all of these Giant stars are *red* – some are so hot to begin with that even when they enlarge and cool down, they're still blue!

- If that's the case, which stars in our table were once bright, hot, blue Main Sequence stars?
  ____________________________________________________________________
- Which stars in our table will some day *become* Type I Super Giants? ______________
  ____________________________________________________________________

Let's also assume that the bigger the Red Giant is, the faster it will die (just as the bigger a Main Sequence star is, the faster it will consume its fuel and *become* a Red Giant).
• If this is the case, which star in our table is closest to its death? ________________________

So large, Type-O or Type-B stars become Type I Blue Giants, and Type A and F stars might become Type II Red Super Giants or Type III Red Giants. Now let's think about our Sun. It's a Type-G star. Where do you think it might end up when it runs out of nuclear fuel?

• Which star in our table do you think the Sun will be most like when it gets older? ____________

• What property of a star is the only important factor that determines what its fate will be – whether it becomes a Type I Super Giant, a Type II Bright Giant, a Type III Red Giant? ______________

• In a Red Giant star the core is hotter than it was when the star was on the Main Sequence, while its surface is cooler! How can this be?

_______________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

• In your own words, explain how and why a star becomes a Giant.

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Write a brief conclusion describing what you learned in this exercise
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