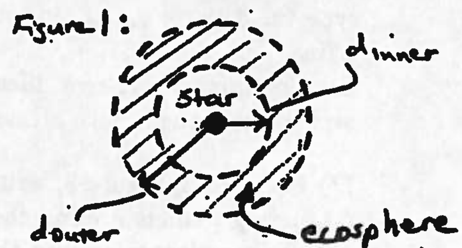
Astr 202 Laboratory on the

The Ecospheres of Stars

1 Background Information

One of the key conditions for life to originate and sustain itself ought to be the temperature of the planet in which life could form. A star's **ecosphere** – the zone in which planets must lie to have a temperature range suitable for life *as we know it* – depends primarily on the luminosity of the star. Living cells have been found in hot springs almost at the boiling point of water. Though individual cells are destroyed when the water in them freezes, organisms that provide their own heat can survive at much lower temperatures. Let's take the range of temperatures from 200 to 373 K (-73°C to 100°C) as the range suitable for life. The thickness of the ecosphere around a star depends on its luminosity. A very luminous (hot) star will have its ecosphere farther out than a low luminosity (cool) star. A planet at a distance d from a star with a luminosity L has a temperature



$$T(Kelvins) = 279(\frac{L}{d^2})^{1/4}$$

Turning this equation around we have,

$$d(inAU) = (279)^2\frac{L^{1/2}}{T^2}$$

At the inner edge of the ecosphere, T = 373 K; at the outer edge, 200 K. For the solar system (L = 1),

$$d_{inner} = \frac{(279)^2(1)^{1/2}}{(373)^2} = 0.6\ AU$$

$$d_{outer} = \frac{(279)^2(1)^{1/2}}{(200)^2} = 1.9\ AU$$

and the thickness of the ecosphere is 1.3 AU. Planets should be contained within the ecosphere to have a chance to harbor life as we know it (see Figure 1).

It turns out that more luminous stars are more massive (heavier) and tend to burn up their nuclear fuel faster. So their lifetime is shorter. Our Sun (a G2 star) has a projected lifetime of 10 billion years and is close to 4.5 billion years old (it's starting to think about having a mid-life crisis). On the other hand Sirius A which is an A1 star has a projected lifetime of only one billion years. Life on the Earth is at least 3.5 billion years old. For life as we know it, intelligent life needed 3.5 billion years to evolve. That would tend to rule out shortlived stars like Sirius A as a likely candidate for finding intelligent life. Given the mass of a star M, the lifetime of the star in solar lifetimes is

$$t_{life} = 1/M^{2.5}$$

where M is in solar masses and t_{life} is in solar lifetimes (10 billion years).

Way back in 1924, Arthur Eddington found that the luminosity and mass of a star are related in the following way:

$$M \sim L^{1/3}$$

where M is in solar masses and L is in solar luminosities. Combining the equations for t_{life} and M, we find

$$t_{life} \sim 1/L^{0.833}$$

2 Questions

A) An H-R (Hertzsprung-Russell) diagram is a plot relating the temperature and spectral class of stars to their luminosity. An H-R diagram of a number of nearby stars is shown in Figure 2. Note that most stars are clustered along an imaginary line which runs from the top left of the diagram to the bottom right. This imaginary line is referred to as the main sequence. Stars that fall on the main sequence get their energy by fusing hydrogen into helium. Stars spend most of their lives on the main sequence, that's why you see so many stars located there. Using the attached H-R diagram, estimate the luminosity of each filled-in star. List the star number, spectral type, and luminosity in Table 1.

B) Now, using the equations discussed above, complete Table 1 for the 8 filled-in stars.

C) On Figure 3, "The Diagram Showing Ecosphere Size or Lifetime vs Spectral Type", (i) plot spectral type vs. $d_{outer} - d_{inner}$ (in units of AU) for all 8 stars. Use circles to plot points and connect them with a line.
(ii) plot spectral type vs. lifetime of the star (in units of yrs) for all ten stars. Use squares to plot points and connect them with a line.

D) Examining Figure 3, write a few sentences describing which spectral type(s) are optimal for
(i) finding planets around the star with life
(ii) finding planets around the star with *intelligent* life.

Life in the Universe Lab
Ecospheres of Stars Lab

Name(s):____________________________________

Table 1

Star Name	Spectral Type	Luminosity (Sun = 1)	Mass (Sun = 1)	d_{inner} (AU)	d_{outer} (AU)	$d_{outer} - d_{inner}$ (AU)	Lifetime (10 billion yrs)	Lifetime (yrs)
1	B0	8x10^5	93	500.	1744	1244	1.2x10^-5	1.2x10^5
2								
3								
4								
5								
6								
7								
8								

Life in the Universe Lab
Ecospheres of Stars Lab

Name(s):______________________________

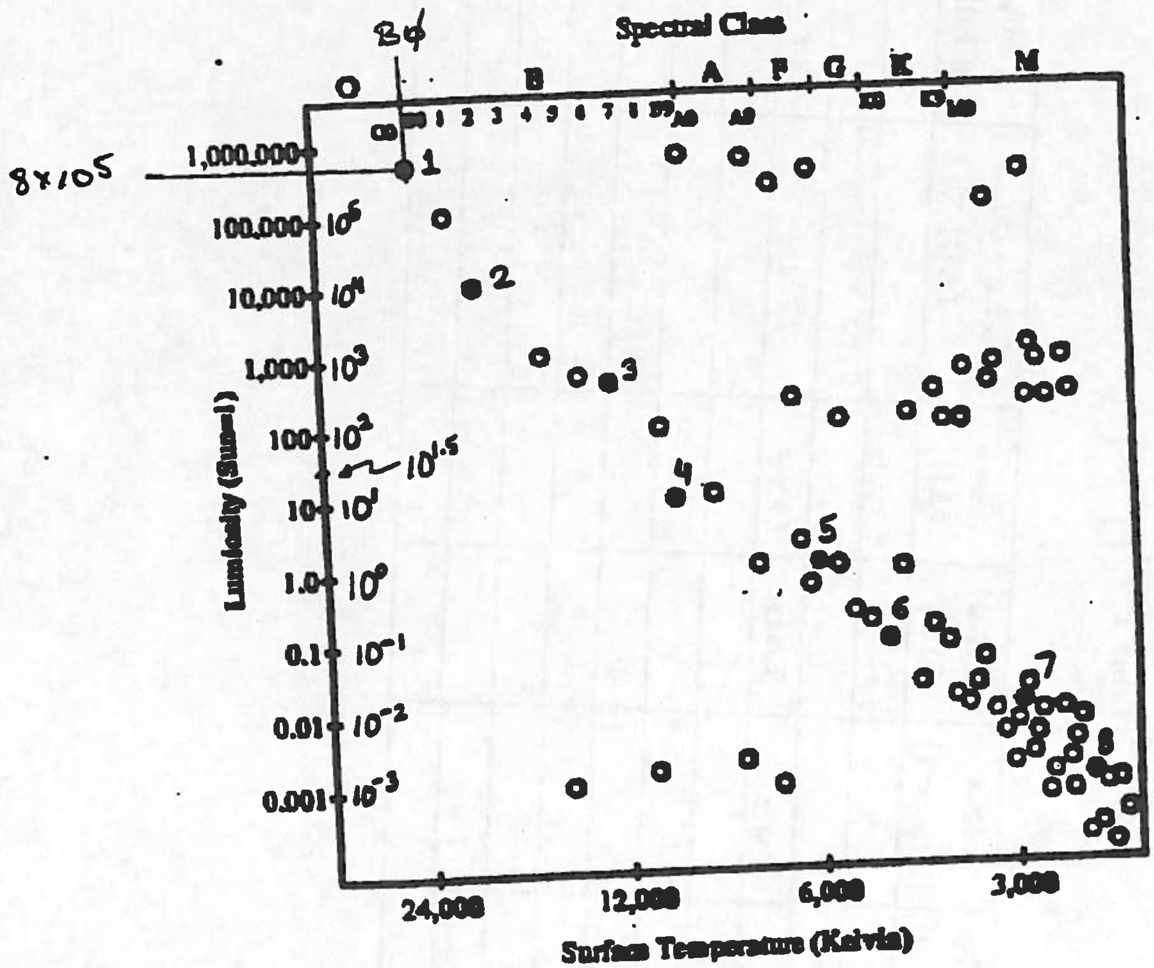


Figure 2: The H-R Diagram

Life in the Universe Lab

Ecospheres of Stars Lab

Name(s):____

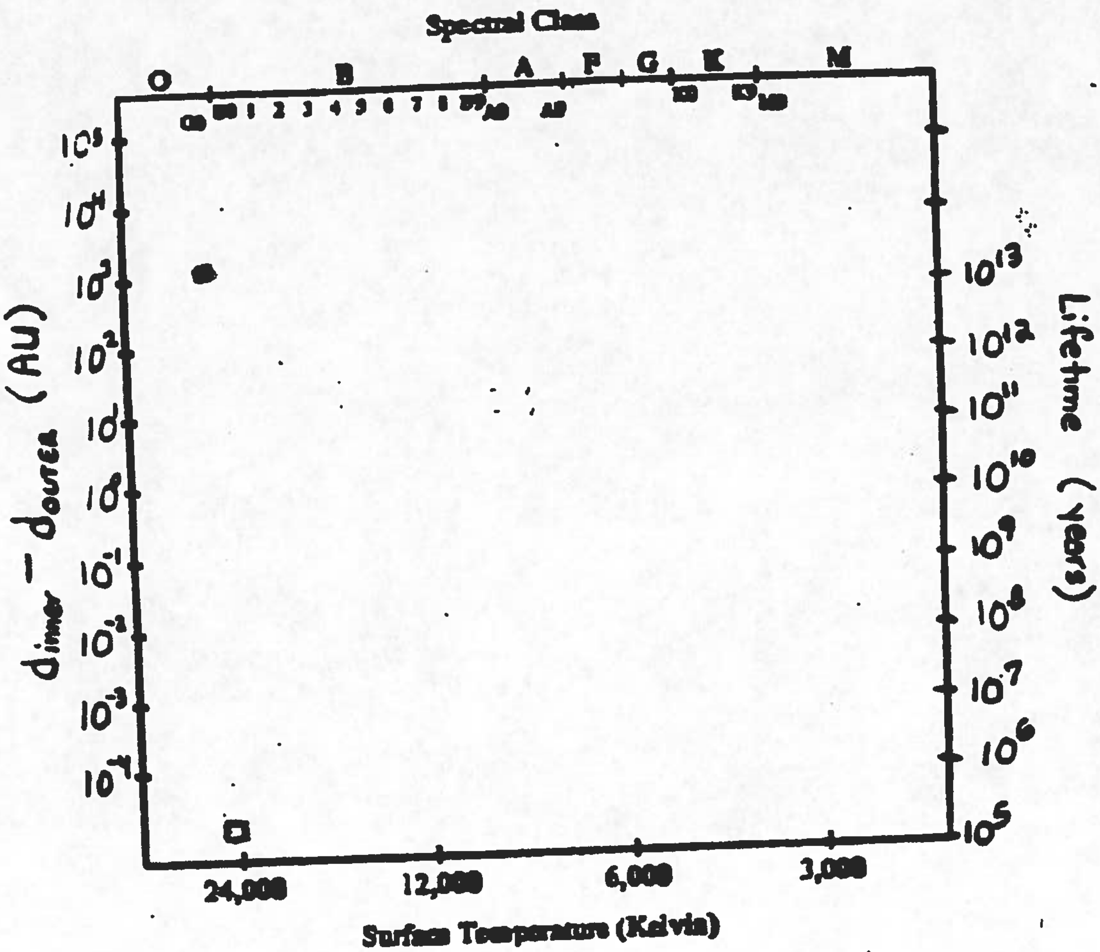


Figure 3: The Ecosphere Size or Lifetime vs. Spectral Type Diagram