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Astronomy 294 – Life in the Universe
Winter Quarter 2008 – Prof. Gaudi
Homework #3

Due Monday November 17 in class

Instructions

Answer the following six questions by circling the correct answer. Each question is worth the number of points given in parentheses (out of a total of 100). I may award partial credit if you show your work. In addition, there are two extra credit questions. These are a bit more challenging, but I encourage you to attempt them.

No late homework will be accepted.

These questions concern the concept of the *habitable zone*, including the habitable zone for our Sun today, how the habitable zone of the Sun changes as the Sun's luminosity changes, and the concept of a *continuously habitable zone*. The extra credit questions deal with habitable zones around other stars.

For these questions, we will adopt the *conservative* definition of the habitable zone, which for the Sun with its current luminosity has an inner edge of 0.95 AU and an outer edge of 1.4 AU.

Question 1 (10 points)

What is current width of the Sun's habitable zone?

- a) 1.40 AU
- b) 0.95 AU
- c) 0.86 AU
- d) 0.45 AU
- e) 1 AU

Question 2 (20 points)

When the solar system formed, the Sun’s luminosity was only 70% of its current luminosity. Assuming that the inner and outer edges of the habitable zone are dictated only by the equilibrium temperatures at those distances, what was the width of the habitable zone when the solar system was formed? (*Hint: Assume that the equilibrium temperature at the inner edge of the habitable zone is constant. Then, you can write a scaling relation between the distance of the current inner edge of the habitable zone to the inner edge of the habitable zone when the solar system formed in terms of only the ratio of the luminosity of the Sun then versus the luminosity of the Sun today to some power. You can write a similar relation for the outer edge of the habitable zone.*)

- a) 0.45AU
- b) 0.72 AU
- c) 0.38 AU
- d) 1.2 AU
- e) 0.86 AU

Question 3 (20 points)

What is the width of the continuously habitable zone, defined as the range of distances that have been in the habitable zone during the entire evolution of the solar system, from formation until the present? (*Hint: here it may help to draw a diagram*)

- a) 0.22 AU
- b) 0.45 AU
- c) 0.1 AU
- d) 0.01 AU
- e) 1 AU

Question 4 (20 points)

The future evolution of the Sun’s luminosity is approximately given the following expression:

$$\frac{L_{Sun, future}}{L_{Sun, now}} = \left(\frac{\text{Time}}{4.5 \text{ Gyr}} \right)^{1/2} .$$

Where “ $L_{Sun, future}$ ” is the luminosity of the Sun in the future, “ $L_{Sun, now}$ ” is the current luminosity of the Sun, and “Time” is the time since the

beginning of the solar system. For example, the current time since the beginning of the solar system is 4.5 Gyr, so by setting $\text{Time}=4.5$ Gyr in the above equation, we find from the formula that $L_{\text{Sun, future}} = L_{\text{Sun, now}}$, as we should. What will be the luminosity of the Sun 3.5 Gyr from now? (*Hint: Remember the Sun's luminosity is increasing with time!*)

- a) 88% of the current luminosity of the Sun
- b) 133% of the current luminosity of the Sun
- c) 515% of the current luminosity of the Sun
- d) 22% of the current luminosity of the Sun
- e) 149% of the current luminosity of the Sun

Question 5 (20 points)

What will be the width of the habitable zone 5.5 Gyr from now?

- a) 1.05 AU
- b) 0.01 AU
- c) 1.23 AU
- d) 3.51 AU
- e) 0.55 AU

Question 6 (10 points)

Will the Earth be in the habitable zone 5.5 Gyr from now?

- a) Yes
- b) No

Extra Credit Questions:

Question 7 (20 points)

An A-type main sequence star has a luminosity that is 20 times larger than the Sun's luminosity. What is the width of the habitable zone around such a star?

- a) 0.45 AU
- b) 0.01AU
- c) 2.01 AU
- d) 3.84 AU
- e) 450 AU

Question 8 (20 points)

An M-type main sequence star has a luminosity that is only 0.3% of the Sun's luminosity. What is the width of the habitable zone around such a star?

- a) 0.0014 AU
- b) 0.45 AU
- c) 0.25 AU
- d) 0.025 AU
- e) 821 AU