

### Homework 3, due Monday, April 27 at 3:00pm

**Instructions:** Please write your answers clearly and submit the assignment, **hand-written**, at the beginning of class on Monday, April 27.

**Write your ID number and your name in Chinese and in pinyin.** Some questions may not be covered in class. Show all work and explain your answers. No late homework will be accepted. The online textbook may be helpful: <https://openstax.org/details/books/astronomy>

**1. Stellar lifetimes (20 pts):** In the core of the sun, the temperature and density are hot enough that 4 H atoms fuse into one He atom. Four H atoms are 0.7% heavier than one He atom; the missing mass is turned into energy by  
Energy = mass  $\times$  (speed of light)<sup>2</sup>  
The luminosity of the sun is  $3.8 \times 10^{33}$  erg s<sup>-1</sup>.

- (a) The Main Sequence is defined by the star burning H in the core. The sun will stop burning H after 10% of the total H in the sun has burned. How long will the Sun be on the Main Sequence?
- (b) The luminosity  $L$  of a star on the Main Sequence scales as roughly as  $L \propto M_*^4$ , where  $M_*$  is the mass of the star. How long would a  $10 M_\odot$  star live for on the Main Sequence? ( $M_\odot$  is the mass of the sun).
- (c) How long would a  $0.3 M_\odot$  star stay on the Main Sequence? Compare this to the age of the universe. What does this comparison mean?
- (d) A brown dwarf is not massive enough to burn H, since the core never gets hot enough. What happens to a brown dwarf as it gets older?

### 2. Searching for Extrasolar Planets (17 pts)

- (a) Describe five techniques to search for planets outside of our solar system.
- (b) What does *bias* mean, in a scientific context?
- (c) What biases does each method from (a) have?
- (d) Has an Earth twin been detected yet? Explain why or why not and the implications for how common they are.

### 3. The Big Bang (13 pts)

- (a) Describe the Big Bang Theory. Where did the Big Bang happen?
- (b) Describe the three strongest pieces of evidence that supports the Big Bang.
- (c) What will happen in the future? How do we know?

**4. The Expanding Universe (20 pts):** In 1929, Hubble calculated his famous law (now called the Hubble-Lemaître Law) that the galaxies are traveling away from us at a velocity proportional to their distance,  $v = H_0d$ , where  $v$  is the velocity (redshift),  $H_0$  is Hubble's constant, and  $d$  is the distance. I will send you this paper by wechat.

- (a) Describe the importance of Hubble's Law.
- (b) Calculate Hubble's Constant from Table 1 in Hubble (1929). Plot the relevant parameters (preferably electronic, staple the printout to your homework). What value do you get for Hubble's Constant?
- (c) Compare your value in (b) to the current value. Plot what the current value would look like in (b).
- (d) Why was this initial measurement by Hubble, one of the most famous and classic papers, so incorrect?

**5. Galaxies Types (24 pts)**

- (a) What kind of galaxy is the Milky Way? How do we know?
- (b) Why do galaxies appear in different shapes? With what you may (or may not have) learned about stars and stellar evolution, why are some galaxies red and others blue?
- (c) What are globular clusters? How many stars do they typically have? Compare this to the number of stars in the Milky Way
- (d) List at least two ways that we know that supermassive black holes are located at the center of galaxies?
- (e) List at least two ways that we know that dark matter exists?
- (f) In the JWST deep field image, label the following:
  - (i) an elliptical galaxy
  - (ii) a spiral galaxy
  - (iii) at least two examples of gravitational lensing
  - (iv) a galaxy that we are seeing from the early universe
  - (v) a quasar that we are seeing from the early universe

**6. Science in your life (6 pts)?**

- (a) Describe the steps in the scientific method (hint: see Chapter 2).
- (b) Provide an example in your everyday life where you apply the scientific method. If more than four other people provide a very similar answer, you will automatically get -20 on the assignment.