ASTR 300 Stars and Stellar Systems Spring 2011

Homework Set No. 4 **Solutions**

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1. Why don't astronomers know the inclination of a spectroscopic binary ? How do they know the inclination of an eclipsing binary ? (Chapter 9, p 190, Review Question 11)

   In a spectroscopic binary the stars are so close together that they look like a single point of light, and the orbit can't be seen directly. The Doppler effect tells us the stars are orbiting but we don't know the tilt of the orbit.

   In an eclipsing binary, the stars pass in front of one another so we know that we are seeing the orbit edge-on.

2. If you look only at the brightest stars in the night sky, what kind of stars are you likely to be observing ? Why ? (Chapter 9, Review Question 15)

   See your text, in the box on page 187: "The brightest stars in the sky tend to be highly luminous stars – upper-main-sequence stars, giants, or supergiants. They look bright because they are luminous, not because they are nearby."

3. Why are interstellar lines so narrow ? Why do some spectral lines forbidden in spectra on Earth appear in spectra of interstellar clouds and nebulae ? What does that tell you ? (Chapter 10, p 208, Review Question 6)

   "The interstellar gas is cold and has a very low density, and this makes interstellar absorption lines (p 197) much narrower than the spectral lines produced in stars." (p 208 of your text).

   "The gas in nebulae has a low density, and the atoms collide so rarely that an electron caught in a metastable level (p 196) can remain there long enough to finally fall to a lower level and emit a photon. This produces so-called forbidden lines (p 196) that are not seen on Earth where the atoms in the gas collide too often." (p 207 of your text). So it tells you that the gas density is very low.

4. How can the HI clouds and the intercloud medium have similar pressures when their temperatures are so different ? (Chapter 10, Review Question 8)

   Pressure depends on both the number of particles and their temperature. The regions of higher temperature have lower density, so the larger number of particles in the cooler clouds compensates for their lower temperatures.

5. The density of air in a child's balloon 20 cm in diameter is roughly the same as the density of air at sea level, 10^{19} particles/cm^3. To how large a diameter would you have to expand the balloon to make the gas inside the same density as the interstellar medium, about 1 particle/cm^3? Give your answer in km. (Hint: The volume of a sphere is $\frac{4}{3}\pi R^3$.) (Chapter 10, Problem 5)

   The number of particles in the balloon is the number/cm^3 times the volume of the balloon. The diameter of the balloon is $d = 20$ cm, so the radius of the balloon is $R = d/2$ and the total number of particles is $N = 10^{19} \times \frac{4}{3}\pi(20/2)^3$. After expansion, the total number is again the number/cm^3, which is now 1, times the volume, $\frac{4}{3}\pi(d/2)^3$. But expansion does not change the total number, so we have the equality $10^{19} \times \frac{4}{3}\pi(20/2)^3 = \frac{4}{3}\pi(d/2)^3$. Canceling gives $10^{19} \times 20^3 = d^3$, or, taking the cube root, $d = 20 \times \sqrt[3]{10^{19}}$. Thus $d = 20 \times 2.15 \times 10^6 = 4.31 \times 10^7$ cm. One km=10^5cm, so the expanded diameter is 431 km!

6. If a giant molecular cloud has a diameter of 30 pc and drifts relative to neighboring clouds at 20 km/s, how long will it take to travel its own diameter ? (Chapter 10, Problem 6)

   The time is just the distance traveled divided by the velocity, but we must make sure the units of distance and velocity are compatible. Since the velocity is in km/s, we need to express the distance in km. From Table A-6 (p 422), we see that 1 pc = 3.09×10^{16} m = 3.09×10^{13} km, since there are 10^3 km in a meter. Thus we have 30 pc = $30 \times 3.09 \times 10^{13} = 9.27 \times 10^{14}$ km as the distance traveled. At a velocity of 20 km/s, the time is thus $(9.27 \times 10^{14})/20 = 4.635 \times 10^{13}$ seconds. In years this is $4.635 \times 10^{13}/(365.24 \times 24 \times 60 \times 60) = 1.47 \times 10^6$ years.

7. How does the geometry of bipolar flows and Herbig-Haro objects support the hypothesis that protostars are surrounded by rotating disks ? (Chapter 11, p 230, Review Question 5)

   See your text, p 223. Herbig-Haro objects are found along the same axis as jets that form the bipolar flows. In particular, 4b, which states "Observations of these bipolar flows is evidence that protostars are surrounded by disks because only disks could focus the flows into jets."

8. If a giant molecular cloud has a mass of 10^{35} kg and it converts 1 percent of its mass into stars during a single encounter with a shock wave, how many stars can it make ? Assume the stars each contain 1 solar mass. (Chapter 11, Problem 3)

   One percent of the cloud is 10^{33} kg. The mass of the Sun is 2×10^{30} kg (Table A5, p 422). Thus the cloud can make $10^{33}/(2 \times 10^{30}) = 500$ stars.

9. The gas in a bipolar flow can travel as fast as 100 km/s. If the length of the jet is 1 ly, how long does it take for a blob of gas to travel from the protostar to the end of the jet ? (Chapter 11, Problem 6)

   This is very much like question No. 6 above, except here the distance traveled is in light-years. So again from Table A-6 we find that 1 ly = 9.46×10^{15} m = 9.46×10^{12} km. Thus we see that the time is $(9.46 \times 10^{12})/100 = 9.46 \times 10^{10}$ seconds. In years this is $9.46 \times 10^{10}/(365.24 \times 24 \times 60 \times 60) = 3000$ yr.

10. The CNO cycle is very sensitive to temperature; the temperature dependence of the CNO energy generation rate is approximately T^{16} for the relevant temperatures ($\sim$20 million K). By what factor would the energy generation increase if the temperature were to increase from 20 million to 21 million K?

    The increase is a factor of $21/20 = 1.05$, so the energy generation would increase by a factor of $(1.05)^{16} = 2.18$ – the energy generation more than doubles.