Exam 1 March 4, 2019 Astro 132

Please answer the questions in your bluebooks. Answer each question as completely as you can. Partial credit will be given for partially correct answers. You must answer at least four questions in Section 1, and at least 2 in Section 2. If you answer more than the minimum number, then only your best answers in each section will be counted.

Section 1 (each question worth 20 points, and you must answer at least 4):

1) What phenomena in the Sun's photosphere and atmosphere are related to its magnetic field? Describe these phenomena in as much detail as you can.

*The phenomena related to the Sun's magnetic field are **sunspots**, **solar flares**, s**olar prominences**, and **coronal mass ejections**. Sunspots are regions on the Sun's photosphere where the temperature is lower than normal (about 4,500 K compared to 5,800 K). Because they aren't as hot, they appear dark in contrast to the surrounding hotter areas. These regions become cool because they are located where magnetic field lines pierce the photosphere. Theses field lines "freeze" the gas in place, so that when it becomes cool, it is unable to sink back down and be replace by hotter gas. The number of sunspots and their location varies according to the 11 year cycle of solar activity, which also governs the other phenomena. Solar prominences are regions of gas trapped between adjacent magnetic field lines in the solar atmosphere. The magnetic fields keep the gas in place, and it slowly, over days or weeks, radiates away its energy. Prominences are loop shaped, projecting upwards out of the Sun's surface. Solar flares are tremendous bursts of energy released when the looping magnetic field lines snap apart. Negatively charged particles like electrons stream out along the broken field lines to become part of the solar wind, while positively charged particles stream down and crash into the Sun's surface, releasing huge amounts of energy. Solar flares are usually brightest in x-rays and gamma rays, though they can be seen at other wavelengths of light sometimes. Coronal mass ejections (CMEs) occur when the solar activity becomes violent enough to blast gas out of the Sun off into space.*

2) You meet a strange woman at a party. After she learns you are taking an upper division astronomy course, she insists you help her out with a research project. She has discovered a star which is producing a consistent, repeating pattern of bright and dim light. She thinks this is a signal from an alien civilization trying to make contact with us, and has spent months trying to decipher the code. What is a more plausible astronomical explanation for this phenomenon, and what further observations might you make to prove it?

The most plausible answer is that she has found an eclipsing binary star system where the light from the two stars is periodically blocked by the eclipses. To verify this you could take a picture of the system with high magnification to see if you can see two stars moving around each other. This only works if the stars are pretty close to us. A better way would be to examine the spectra of the system to see if there are two sets of spectral lines – one from each of the stars. These lines should be alternating in redshift and blue shift as the two stars orbit around each other.

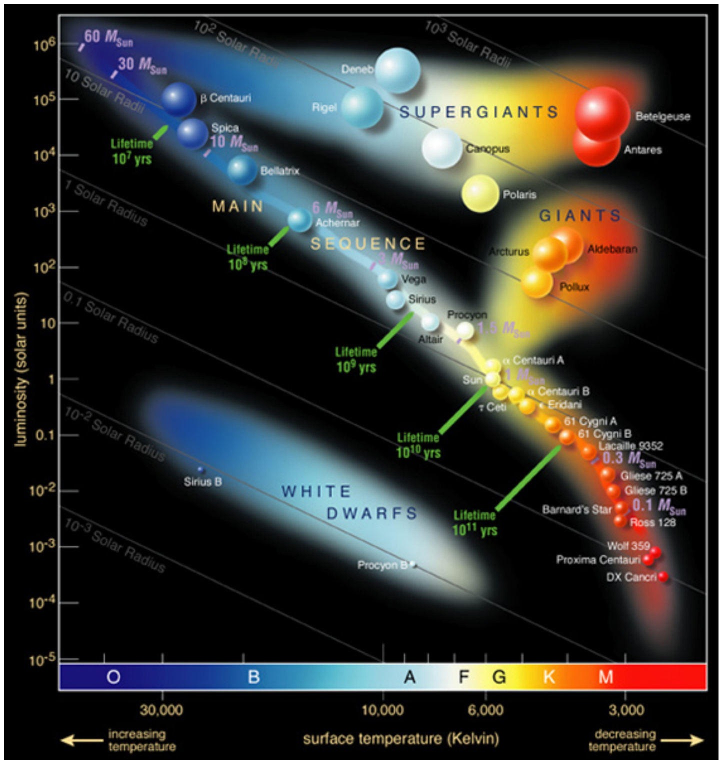
3) You work at a detector that is monitoring the level of solar neutrinos. After analyzing your last year's worth of data, you discover that the Sun's neutrino output has increased by a factor of 10! What would cause such an increase, and what other effects would this cause have on the Sun?

Solar neutrinos are created by nuclear fusion reactions like the proton-proton chain that occur in the Sun's core. If the Sun's neutrino output is increased by a factor of 10, that means an increase in the rate of such fusion reactions by a factor of 10. This will lead to an increase in the Sun's luminosity by a factor of 10, making the Sun hotter than it is now. This would increase the amount of solar energy reaching the Earth, having dramatic consequences for our climate. It would also cause the Sun to expand, as an increase in temperature would increase the Sun's internal pressure to become stronger than the inward pull of gravity. The other effects would take about 1,000,000 years to become noticeable.

4) According to the Doppler effect, the color of light from moving objects is shifted according to the speed and direction of motion. According to Wien's law, the wavelength of maximum brightness of a hot emitting objects becomes bluer for hotter and hotter objects. How can astronomers tell the difference between an object moving towards us in space and an objects which is being heated up?

To tell the difference between a blue shifted object from the Doppler effect and a very hot object emitting lots of blue light due to Wien's law, need to look at the spectrum of the object in question and compare the spectral lines observed to known spectral lines from chemical elements seen in laboratories on Earth. If spectral lines can be positively identified with specific elements, the velocity can be calculated using the Doppler effect. If the velocity is moving at low velocity towards us, or away from us, then the blue light must be due to the temperature of the object and not a Doppler blue shift.

5) Sketch an H-R diagram, with appropriate labels for the horizontal and vertical axes. Draw in the 4 major regions where stars appear in the H-R diagram, and label those too.



6) Describe the stellar spectral classification system (spectral types). Explain what determines why the spectra of the different types of stars have different absorption lines.

The spectral lines observed in the spectrum of a star depend strongly on the star's surface temperature. Stars are sorted into spectral types based on these spectral lines (OBAFGKM) O stars are much hotter than A stars (30,000 K vs. 10,0000 K). The spectral lines are created by the transitions between energy levels of electrons in atoms, specifically absorption lines are created when an electron in a lower energy level is able to absorb a photon of the right amount of energy to allow it to jump up to a higher energy level. For an electron in an atom, its starting point is determined by how hot the star is, so stars that are very hot don't have enough atoms with electrons in lower energy levels to make absorption features ***starting*** *at lower energy levels (say level 2 up to level 3). On the other hand, the hotter stars do have plenty of electrons starting in upper levels so that kind of absorption is possible (say level 7 up to level 9). Thus different temperatures give different spectral lines. The chemical composition of the stars also plays a role.*

7) Aliens have come to our solar system to wipe us out (they are very angry about all the bad TV programs we've been broadcasting into space for the past 50 years). They shoot a death-ray at the Sun which temporarily increases its core temperature from 15.6 million K to 25 million K. Use your knowledge of nuclear fusion and hydrostatic equilibrium to decide if we Earthlings are really doomed or not.

I would not be too worried. As long as the increase in core temperature is short lived, there will likely be no serious problems for us. An increase in temperature will lead to both an increase in fusion rate (due to a higher number of proton-proton collisions) and an expansion of the gas to a larger volume. But this expansion of the gas will reduce the density of the gas, thus reducing the number of collisions. Fewer collisions mean fewer fusion reactions, and less energy (heat) being produced. As the heat is reduced, the core will shrink back down again, until it reaches a balance between fusion powered heating and the inward pull of gravity. Since it takes light about 1,000,000 years to travel from the core to the surface of the Sun, our remote descendants will possibly notice the Sun getting brighter for a short period as a result of the alien's death ray attack.

Section 2 (each question worth 10 points, and you must answer 2):

9) The star Wolf 359 has an absolute magnitude of +16.7. If it is 2.4 parsecs away from us, then what is its apparent magnitude?

10) Our local public radio station, KXJZ, broadcasts on a frequency of 88.5 mega Hz (= 88.5 x 10^6 Hz). Calculate the wavelength of light at that frequency, and the energy of a single photon of that wavelength.

11) If you observe a galaxy moving towards us at a velocity of 1250 km/s, how big would the Doppler shift be for emitted light with a rest wavelength of 21 cm? Remember, 1 km = 1000 m, 1 cm = 0.1 m.

12) You observe a hot interstellar gas cloud, with a temperature of 10,000,000 K. At what wavelength does this cloud shine the brightest?