Astronomy 1144 Quiz 2 Review

Prof. Pradhan

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Light

1. What is light?
   - Light is electromagnetic radiation.
   - It is composed of perpendicular electric and magnetic fields, and interacts with charged particles.
   - Electromagnetic radiation can have many different wavelengths/frequencies, most of which we are not able to see. The visible spectrum runs from 4000-7000 Angstroms in wavelength.
2. How does the electromagnetic spectrum run?
   - From longest wavelength to shortest, it is radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.
3. How large is an angstrom? What is it often used for?
   - An angstrom (Å) is 10^{-10} m.
   - It is often used to specify the wavelength of visible or ultraviolet light.
4. What is the relationship between an electromagnetic wave's wavelength and frequency? How about between the energy of a photon and its frequency/wavelength?
   - $c = \lambda f$, where c is the speed of light, f is the frequency, and λ is the wavelength.
   - $E = hf$, or $E = hc/\lambda$, where h is Planck's constant.
5. What is the Doppler Effect, and how does it apply to light?
   - The Doppler Effect is a feature of all waves. When an object is moving towards you, any waves it emits "pile up" and their frequency increases. When an object is moving away from you, any waves it emits towards you are more spread out and their frequency decreases.
   - The faster the wave source is moving with respect to you, the larger the effect.
   - With light, this manifests as blueshifts (moving towards) and redshifts (moving away) - i.e., an object moving towards you looks bluer, while an object moving away from you looks redder.
6. What is a spectrum?
   - It is the light from an object arranged according to wavelength or frequency; i.e., light from an object spread out into its constituent colors.
7. What subatomic particles make up atoms?
   - Protons and neutrons in the nucleus, electrons in the orbits around them.

8. How many protons, electrons and neutrons does a hydrogen atom have?
    - One proton and one electron, no neutrons. A neutral atom (an atom without any net charge) always has equal numbers of protons and electrons.
9. What is special about an electron orbiting an atomic nucleus? What are some consequences of this?
    - Electrons *must* be in specific orbits around the nucleus with a specific amount of energy. They cannot be in arbitrary orbits!
    - Since atoms absorb and emit light through their electrons, they may only emit or absorb certain wavelengths which correspond to the gaps between energy levels/orbits.
    - The energy level pattern for each atom is unique; hydrogen has different levels from helium or iron, for example. This makes each atom have a different pattern of spectral lines.
10. What are spectral lines?
    - Spectral lines come in two flavors: emission and absorption.
    - Emission lines are from electrons in atoms jumping down to a lower energy level and emitting light, and are bright lines of color.
    - Absorption lines come from electrons absorbing light and jumping to a higher energy level, and are dark. E.g., the dark lines in the solar spectrum are absorption lines.
    - As long as the change in energy level is the same (e.g., from 2nd to 3rd or 3rd to 2nd), the wavelength of emission and absorption lines are identical.
11. What are the most well-known emission and absorption series of lines of hydrogen, and what part of the electromagnetic spectrum are they in?
    - The Balmer series: the electron transitions from higher-energy levels to the second lowest-energy level, seen in visible light.

Introduction to Cosmology

1. What is Hubble's Law?
    - Hubble's Law is a relationship between a galaxy's distance from us and its redshift or recessional velocity (i.e., how quickly it is moving away from us).
    - Mathematically, $v = H_0 d$. v is the recessional velocity of the galaxy, H_0 is Hubble's constant, and d is the galaxy's distance from us.
    - Therefore, using the galaxy's redshift, we can determine its distance from us.
2. What does Hubble's Law imply?
    - The universe is expanding!
    - The universe had a beginning, what we call the Big Bang.
3. What is the approximate age of the universe?
    - Roughly $1/H_0$. Numerically, this is 13-14 billion years.
4. What is the cosmic Microwave Background (CMB)? What are some of its properties?
    - The CMB is extremely uniform relic radiation from the Big Bang.
    - It is a blackbody to very high precision; in fact it has the purest blackbody spectrum we know of.

- It is very cold: only 2.73 K (3 degrees above absolute zero).
- It is almost totally isotropic; i.e., it looks virtually the same in all directions.
- However, it has some extremely slight deviations generated by matter immediately following the Big Bang.

5. What are the most abundant elements in the universe?

   - Hydrogen and helium.

Relativity

1. What are the two postulates of special relativity?

   - The laws of physics are the same everywhere in the universe.
   - The speed of light, c, is the same in all inertial (non-accelerating) reference frames. No matter how fast you are going, you will always measure the speed of light to be c ($\sim$ 300,000 km/s).

2. What are some consequences of these postulates (i.e., what are some results from special relativity)?

   - It takes an infinite amount of energy for a massive object to travel at c, therefore the speed of light is the maximum speed anything in the universe can travel.
   - For fast-moving objects, time moves slower, and distances contract in the direction of motion (to an outside observer, a fast-moving spacecraft would appear shorter).
   - The notion of simultaneity changes; two events which are simultaneous according to one observer may not appear to be simultaneous to a different observer.
   - $E = mc^2$. Matter and energy are two forms of the same thing, and can be converted into one another.

3. What is the basic statement of general relativity?

   - Matter and energy curve space. Motion through this curved space generates the feeling of gravity, i.e., gravity is not actually a force - it is simply a manifestation of curved spacetime.

4. What are some additional predictions general relativity makes over special relativity?

   - Being in freefall is indistinguishable from being in an inertial (non-accelerating) reference frame. Thus astronauts feel weightless.
   - Similarly, an observer standing in a small box cannot tell the difference between them being on the surface of the Earth and being accelerated by a rocket with the same strength as Earth's gravity.
   - Light bends in the gravitational field of a massive object such as the Sun.

Stars and Stellar Classification

1. What is a star's energy source, or how do stars shine?

   - Stars shine by fusing light elements into heavier ones.
   - During fusion, some mass is converted into energy. For example, a Helium-4 nucleus (two protons, two neutrons) is lighter than the four protons that went into making it.
   - This energy is radiated as light/heat, causing a star to shine.

2. Nuclear fusion, as happens in stars, require extremely high temperatures. Why?

    - Atomic nuclei are partially made of charged particles (protons).
    - In order to fuse, two nuclei must be able to overcome the electrical repulsion from their protons.
    - High temperatures = higher particle speeds = more likely to fuse.

3. What is the layer of a star that we are actually able to see? How is it defined?

    - This layer is called the photosphere.
    - The depth of the photosphere is the depth from which the average photon can escape the Sun without hitting a particle before doing so.

4. Why does the Sun appear darker towards its edge?

    - This is called limb-darkening.
    - Photons from the edge of the Sun's disk are reaching us after being emitted by higher, cooler layers of the Sun. A photon from the center of the disk and the limb both travel about the same distance in the photosphere before exiting the Sun.

5. What is the solar corona, and what are some of its characteristics?

    - The corona is a hot plasma atmosphere which surrounds the Sun.
    - It is very tenuous, and heavily affected by the Sun's magnetic field.
    - Sometimes, solar flares or coronal mass ejections can send large amounts of charged particles zooming off into space.

6. How are stars classified?

    - Mainly by temperature/color and spectral line strengths.
    - The spectral classes (OBAFGKML) are defined by the ratios of spectral line strengths.
    - The spectral class sequence is also a temperature sequence, with O & B stars being the hottest, and M & L stars being the coolest.

7. What is the Hertzsprung-Russell (HR) diagram? What are some of its main features?

    - A plot of luminosity vs. temperature for stars.
    - Stars only fall into certain places on the diagram - they may not have arbitrary properties.
    - Most stars lie on the main sequence, where they burn hydrogen into helium.