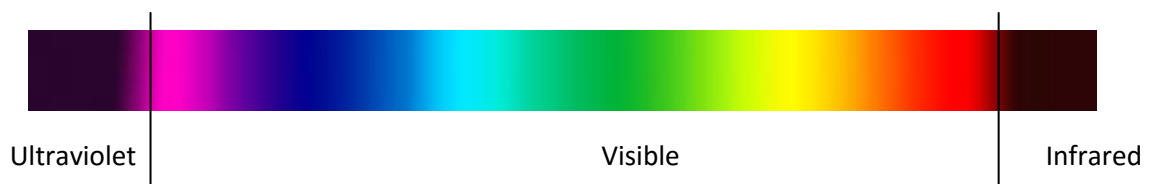


## Hubble's Law and the Big Bang Theory Problems

1. There was a gradual shift from the steady state theory to the big bang theory because of new observations made in the middle of the 20th century.
  - a. List the main features of the universe as viewed using a steady state theory cosmological model.
  - b. What was the first observational evidence that led to the steady state theory being refuted? Briefly describe the observation and how it disagrees with the assumptions in the steady state theory.
  - c. Which features of the steady state theory are also evident in the big bang theory?
2. The spectrum shown below shows the visible region but also extends to both the infrared and ultraviolet regions as well.



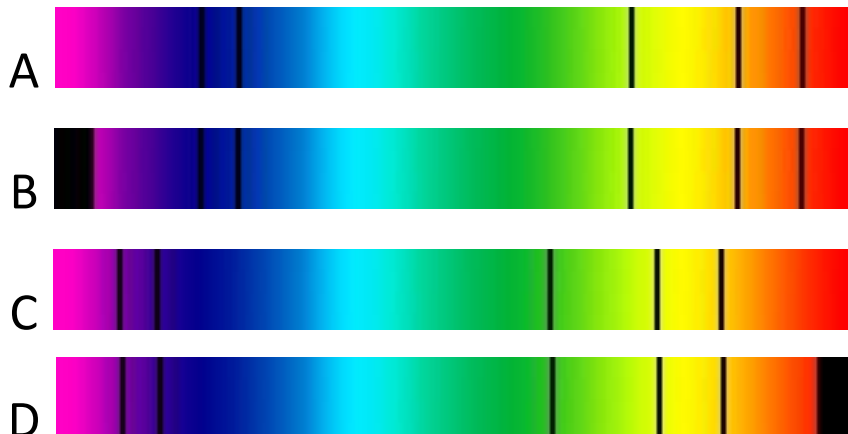
Can electromagnetic radiation in the infrared portion of the spectrum be red shifted? Justify your choice.

3. State three observations that support the Big Bang theory.
  
  
  
  
  
  
  
  
  
  
4. Edwin Hubble used measurements of both distance and velocity of galaxies when forming his law.
  - a. Briefly describe the usefulness of Cepheid variable stars in relation to the measurements Hubble required.
  
  
  
  
  
  
  
  
  
  
  - b. Briefly describe the what red shifted light is.
  
  
  
  
  
  
  
  
  
  
  - c. Explain why red shifted light is useful for the formation of Hubble's law.

5. Observing spectra is one tool astronomers have to help determine the nature of distant astronomical objects. While all types of electromagnetic waves are useful for learning about astronomical objects, ground based observatories are limited because the Earth's atmosphere blocks a wide range of frequencies.
- State two properties of a star that could be determined from observing it's spectrum. Describe how this information is obtained from the spectra.
  - The visible spectrum shown below is observed when at rest relative to the star producing it. You may consider the star produces a continuous spectrum in all non-visible electromagnetic frequencies.

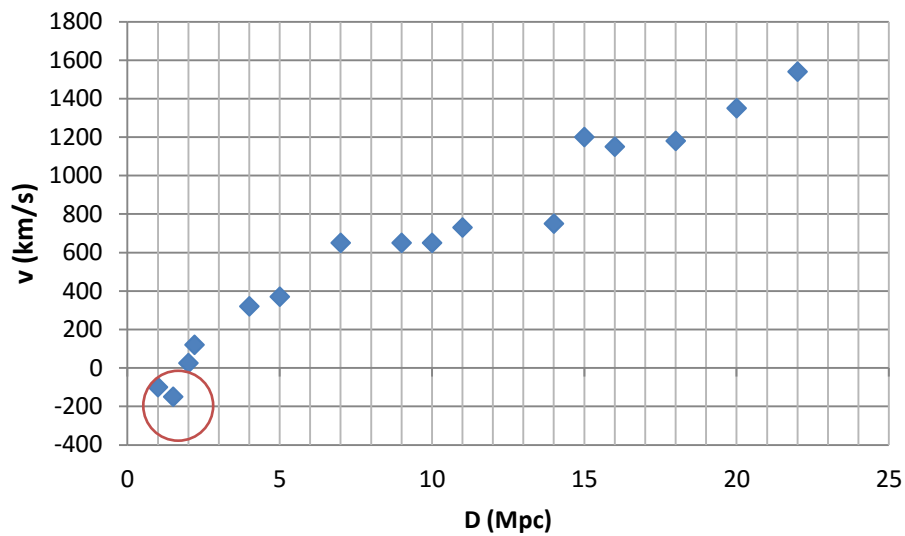


A ground based observatory is only capable of making observations within the visible spectrum. Which of the spectra below (A,B,C or D) would best represent the observation for the spectrum of the star that is moving toward Earth at a significant velocity?



- Justify your answer to part (b) by explaining how you can eliminate all of the wrong choices.

6. Edwin Hubble is famous for his contribution to developing the modern cosmological view of the universe. He is most noted for "Hubble's Law". The image below shows the graphical representation of Hubble's law.



- What are the two physical quantities of the graph's axes? Be specific in your answer.
- The circled data has negative values for the vertical axis. Describe what this means in the context of the measurements taken to produce this graph.
- The largest  $D$  measured values tend to have the largest  $v$  measurements as well. What is the most significant physical concept that can be attributed to this trend?
- Suggest a reason why the circled data does not follow this trend.

- e. Calculate the gradient of this graph. Include units.
- f. Using the conversion that  $1 \text{ Mpc} = 3.086 \times 10^{19} \text{ km}$ , use the gradient to calculate the age of the universe.
7. The cosmic microwave background (CMB) is detected in all directions. It has the same spectrum as a black body at approximately 2.7 K or  $-270^\circ\text{C}$ .
- Describe where this microwave radiation has originated from.
  - Why does the CMB have a much longer wavelength compared to when it was first produced?
  - "The low black body temperature of the cosmic microwave background helps show space is cold and empty". Do you agree or disagree with this statement? Justify your response.*

- d. The CMB is from the furthest regions of the universe and we will never see any further. Explain why this is so.
  
  
  
  
  
  
  
  
  
  
- e. In the far future, it is expected that the cosmic microwave background would appear different to what it is today. What is the main reason for the expected change?
  
  
  
  
  
  
  
  
  
  
- 8. The expansion of space has caused sources of electromagnetic radiation to be red shifted.
  - a. Describe the difference between red shift due to the expansion of space and red shift due to the Doppler effect.
  
  
  
  
  
  
  
  
  
  
  - b. The measurements taken on Earth suggest that the light observed from distant galaxies has been red shifted. Describe why the assumption is made that it is the expansion of space rather than the Doppler effect that causes the red shift.

9. According to Hubble's law the recessional velocity of a galaxy is proportional to the distance of that galaxy from an observer. Einstein's theory of special relativity limits any massive object from reaching the speed of light. Hubble's' law would suggest at a large enough distance, a galaxy would be moving faster than the speed of light.
- a. Explain why it is not contradictory that Hubble's' law predicts that a galaxy can recede from Earth at a rate greater than the speed of light.
  - b. Describe the issue with trying to validate these predictions using current astronomical measurement techniques.