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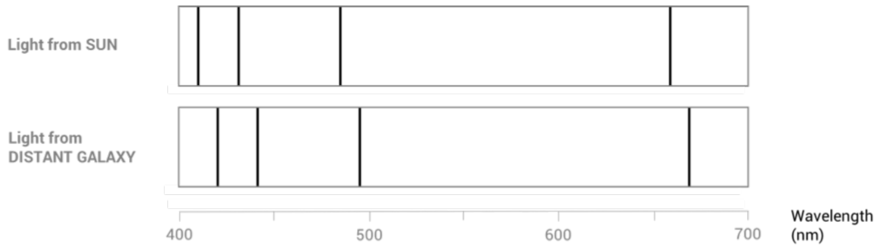
Astrophysicists are very interested in the spectra of stars. The spectrum of a star can tell us, among other things, the types of elements which it contains. The below diagram shows four of the **absorption lines** in the spectrum of the Sun, and the corresponding lines which are observed in the light we receive from a distant galaxy.



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Describe the way in which the absorption lines which we observe in the light we receive from a distant galaxy differ from those of the Sun.

The absorption lines in the light we receive from a distant galaxy are red-shifted / longer in wavelength [1].

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Explain the reason for this difference.

The distant galaxy is moving away from us [1]. This causes the light we receive from it to be red-shifted.

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The absorption line at 656 nm in the light from the Sun is observed at a wavelength of 668 nm in the light from the distant galaxy. Calculate the difference in **frequency** between these two wavelengths.

The speed of light in vacuum is $v = 3 \times 10^8$ m/s.
One nanometer (1 nm) = 10^{-9} m.

656 nm: $f = v \div \lambda = (3 \times 10^8) \div (656 \times 10^{-9}) = 4.57 \times 10^{14}$ Hz
668 nm: $f = v \div \lambda = (3 \times 10^8) \div (668 \times 10^{-9}) = 4.49 \times 10^{14}$ Hz

Difference in frequency = 0.08×10^{14} Hz = **8×10^{12} Hz**

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Edwin Hubble was the first person to investigate how the red-shift of a galaxy depended on its distance from us.

The overall trend which he saw in his data is summarised by the below graph.

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Describe the trend which is shown in the above graph.

As the distance to a galaxy increases, the amount of red-shift in the light we receive from it increases / red-shift is proportional to distance [1].

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Explain the significance of this trend in relation to the development of the Universe.

This tells us that galaxies which are further from us are moving away from us more quickly [1], which means that the Universe is expanding and that there must have been a point at which this expansion began (which we call the Big Bang) [1].

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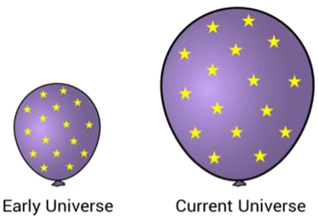
A teacher uses a starry balloon to explain the expansion of the Universe. She tells the class that the motion of the stars printed on the surface of the balloon as it is inflated as like the motion of the stars in the Universe as it expands.



Write down one strength and one weakness of this model for the expansion of the Universe.

Strength As time increases, the stars on the surface of the balloon move away from one another (just as stars in the Universe are moving away from one another).

Weakness Any ONE of: the surface of the balloon is two-dimensional, unlike the Universe ('there are no stars inside the balloon'); the balloon can only expand so much (but the Universe may be infinite); (if the rate at which the balloon is inflated is constant) the rate at which stars on the surface of the balloon move away from one another will decrease with time (we believe that the rate at which our Universe is expanding may be increasing with time due to *dark energy*).

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