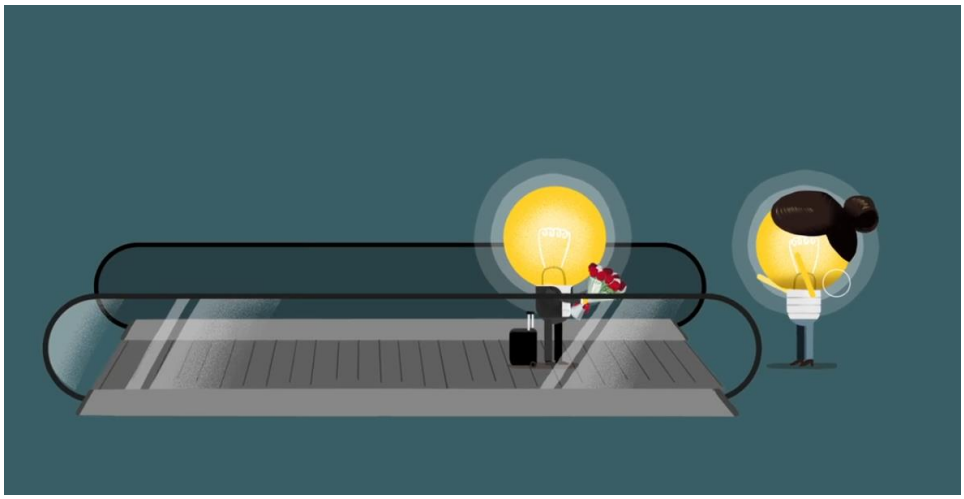
ROYAL OBSERVATORY GREENWICH

Cosmological redshift

Post-16

Topics covered: Doppler effect, velocity, distance, expansion of Universe

Watch the video "How big is the Universe?"
https://vimeo.com/88899162



The most distant galaxy discovered so far is z8_GND_5296. It was discovered in 2013 using the Hubble Space Telescope and confirmed by the Keck Observatory in Hawaii. Light took 13.1 billion years to reach us from this ancient galaxy however this distance has since increased and continues to increase as the Universe continues to expand. z8_GND_5296 has a very high redshift, z:

$$z = \frac{v}{c} = \frac{\lambda - \lambda_0}{\lambda_0} \qquad (1)$$

where v is the recessional velocity of the galaxy, c is the speed of light = 3×10^5 km s^{-1}, λ is the observed wavelength of a hydrogen emission line from the galaxy and λ_0 is the rest wavelength of the same hydrogen emission line in the laboratory.

The fractional size of the Universe when light first left the galaxy can be determined from its redshift:

$$1 + z = \frac{a_{now}}{a_{then}} \qquad (2)$$

where a_{now} is the scale factor of the Universe now and a_{then} is the scale factor of the Universe when light first left the galaxy 13.1 billion years ago.

ROYAL
OBSERVATORY
GREENWICH

1. Find the redshift of the galaxy, z using equation (1). The observed wavelength of the hydrogen alpha emission line from the galaxy is 5578.6 nanometres (nm) and the rest wavelength of the same emission line is 656.3 nm.

2. Use equation (2) to find out the fractional size of the Universe, a_{now}/a_{then} and work out how small the Universe was 13.1 billion years ago as a percentage of its current size.

ROYAL OBSERVATORY GREENWICH

Cosmological redshift: ANSWERS

Post-16

1. z = 7.5
2. Universe was 0.12 or 12% of current size or 8.5 times smaller.