TEACHER NOTES – ASTRONOMY IN THE NEWS #34

MOST DISTANT STAR EVER DISCOVERED

Slide 2 – Background Science: Gravitational Lensing

Gravitational lensing is a prediction of Einstein's theory of General Relativity. Within General Relativity, it is postulated that space and time are linked by something called spacetime. Spacetime is a mathematical model which describes the four-dimensions of space and time (x, y, z, t). A body in spacetime produces a well, or curvature, in the spacetime. The more massive an object is, the greater the curvature is.

The theory of General Relativity explains a number of astronomical results such as gravitational lensing, where a dense, massive object in the foreground is able to bend the light from behind it around it. These objects can be black holes. The presence of this gravitational lensing is strong evidence supporting this theory.

This gravitational lensing produces a ring of mirror images, which, from our vantage point, surrounds the foreground image. One other effect that gravitational lensing has, is that it magnifies the background image, therefore allowing a background object to appear larger than it actually is.

IMAGES:

1. (Left) Einstein crosses, gravitationally lensed quasars (a very bright galactic nucleus) with four mirrors of the same object around foreground galaxies. Some objects have fewer than the four mirrors. These twelve examples come from the Gaia survey.
2. (Right) An example of a gravitational lens ring. The foreground red galaxy has deflected the light of a background, bluer galaxy, which is observed as a ring, with multiple mirrors, around the foreground object.

Slide 3: Most Distant Star

Strong gravitational lensing is the effect described on the previous slide and this is seen in the result from this week. Most astronomical objects that are lensed are galaxies, which are seen in arcs surrounding more foreground galaxies, or galaxy clusters. However, recent results have shown that the magnification from gravitational lensing can allow distant stars to be detected, usually in the red shift range of $z = 1 – 1.5$. However, recent observations from the Hubble Space Telescope have detected a magnified, background, high-red shift star in the lensing arc of a foreground galaxy cluster.

The star, given the name of Earendel, is thought to be at a redshift of $z = 6.2$, within a background galaxy. This red shift corresponds to 900 million years after the Big Bang. Earendel is thought to be a massive star, or at most a binary system, due to the compact nature of the lensed object. A cluster of stars would be more smeared, and look more galaxy-like in a lens, rather than an individual star.

Although this star is the most distant star ever observed, it is also possibly even more exciting than this! It could also be the first detection of a population III stars. Population I and II stars are the stars we observe today, with population I containing a lot of heavy metals, whilst population II are metal-poor in elements heavier than helium. Population I stars are, therefore, generally younger than population II stars due to the fact they required the Universe to be more enriched by heavy elements. However, population III stars are currently hypothetical stars which produced the first heavy elements in the Universe. They were formed from purely hydrogen and helium, with miniscule amounts of lithium and beryllium. As a result, they were thought to be much more massive than the stars that form today (i.e., several hundreds of solar masses). These stars would have been short lived, so to detect them, observations of the very early Universe are required. Studies have found they could have still existed at these red shifts, particularly in the outskirts of galaxies which are more metal poor. However, follow-up spectral observations with the James Webb Space Telescope will shed more light on its nature.

The articles that this resource is built on can be found here:

https://www.bbc.co.uk/news/science-environment-60931100

https://www.theguardian.com/science/2022/mar/30/hubble-space-telescope-captures-distant-star-earendel

A free version of the research article can be found here (although I do not know how long this will be free for):

https://www.nature.com/articles/s41586-022-04449-y

IMAGES:

1. (Top left) Hubble image of the lensed galaxy arc, at red shift, $z > 6$. The arc, on which the lensed objects are on contains two galaxies that appear three times, labelled in cyan and magenta. The red ring shows the best-fitting model of lensing that is used, connecting the objects in a lensing ring. The green star is the position of Earendel.
2. (Top right) The H-R diagram, showing evolutionary tracks, of a series of different stars at different masses with low metallicity. The green shaded region is the 1-sigma confidence interval for the Earendel, implying that the mass is greater than 40 solar masses.
3. (Bottom) An artist's impression of population III stars, the first stars to form after the Big Bang.

Slide 4 – Activity: How do heavier elements form?

This week's activity is to discuss the process of nucleosynthesis in the cores of stars, and more specifically, massive stars. The slide displays a periodic table, colour coded by how it is predicted that these elements were formed in the Universe. The question I ask for the students to think about is, although massive stars are responsible for a lot of elements, why is iron the heaviest element formed in the core of a star? The answer to that question is that fusing heavier elements than that requires energy to be put into the system, rather than producing energy. This answer forms the theory behind the next question as to how heavier elements are formed in a supernova. The energy produced by the supernova supplies the required energy to further fuse more elements.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	6.1, 13.7, 13.8, 14.10, 16.1, 16.2
Pearson Edexcel Physics	6.37, 6.43, 7.12, 7.18
OCR Physics B	5.3.4, 6.5.7
AQA Physics	4.4.4.2, 4.8.1.2, 4.8.2

A-Level Physics Specifications:

Specification	Knowledge Point
Pearson Edexcel Physics	159, 160, 162, 166, 167
OCR Physics A	5.5.1(b,e,g), 5.5.3(h), 6.4.4(d,e,j)
OCR Physics B	6.2.2(a,b)
AQA Physics	3.8.1.6, 3.9.2.5, 3.9.2.6, 3.9.3.2