TEACHER NOTES – ASTRONOMY IN THE NEWS #41

BRIGHTEST QUASAR OF THE LAST 9 BILLION YEARS

Slide 2 – Background Science: Quasars

A quasar, or quasi-stellar object, is a subset of an active galactic nuclei (AGN). Quasars are extremely bright, often brighter than the host galaxies, and have masses of billions of solar masses.

The name quasi-stellar object comes from their discovery. Initially discovered as radio sources, the optical images displayed objects that appeared stellar in nature. Further spectroscopic observations allowed it to be determined that these objects were extragalactic in nature, and in fact, high redshift due to the Doppler shift demonstrated in the spectra.

The explanation that was finally accepted was that this was caused by gas and matter falling into a supermassive black hole, which heats up and releases energy. Among the evidence for this explanation is:

1) The relativistic jets of quasars and AGN require a mass too large to be a supermassive star.
2) The high-redshift nature of the spectra from these host objects.
3) Gravitational lensing of some quasars, which would further demonstrate the redshift of these objects.
4) That these objects become less common as the Universe ages since these are produced when a galaxy forms, and has more matter in its accretion disc. Once there is less matter, less energy is produced and then the galaxy becomes more regular. In the nearby Universe.

IMAGES:

1. (Left) A MUSE image from the Very Large Telescope of the accretion material surrounding the quasar, SDSS J102009.99+104002.7. The blue is Lyman-alpha, which is caused by the electron of a hydrogen atom dropping from the n=2 energy level to the ground state, whilst green and red are optical wavelengths at the respective wavelengths.
2. (Top right) Hydrogen spectrum of the quasar 3C273. This spectrum has, overlaid, the relevant spectral lines with their rest wavelength. This spectrum demonstrates the movement to longer wavelengths, indicating the high-redshift nature of the quasar.
3. (Bottom right) HST image of the jet emitted from the black hole at the centre of the galaxy, M87. This jet is 4,400 light years long.

Slide 3: Brightest Nearby Quasar

The quasar SMSS J114447.77-403859.3 was initially discovered by a blind survey on the South African Astronomical Observatory, and then designated as an AGN. The survey, SkyMapper Southern Survey was looking for binary stars. Further spectroscopic observations were then made using further facilities in Australia and Chile.

Analysis of the spectra determined that the AGN was indeed a quasar and was found at a redshift of 0.83. A z=0.83 corresponds to a look-back time of ~ 7 Gyr, which means that this quasar occurred around 6.5 Gyr after the Big Bang.

This quasar is very bright, with a luminosity larger than any quasar discovered with a look-back time less than 8.7 Gyr. The brightness cannot be currently explained, as it is an outlier compared to galaxies at a similar redshift but it may be due to a galactic merger which would put a lot of gas in the vicinity of the central supermassive black hole.

The discovery of this quasar, and its brightness is due to the location of the sky surveyed. Usually when making extragalactic observations, astronomers look away from the Galactic Plane. The Galactic Plane is the band of stars, gas and dust of the Milky Way which will contaminate any attempts to observe outside of our Galaxy. As a result, most studies only observe to latitudes of ± 25°, however, SMSS J114447.77-403859.3 was found at a Galactic longitude (i.e. the angular distance above the mid-plane of the Galaxy) of 18°.

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

https://www.theguardian.com/science/2022/jun/15/fastest-growing-black-hole-of-past-9bn-years-may-have-been-found-australian-led-astronomers-say

A free, permanent version of the research article can be found here:

https://arxiv.org/abs/2206.04204

IMAGES:

1. (Left) Optical image of the Milky Way with overlaid positions of cepheids. These stars are variable stars. However, the positions of them, along with the overlaid Galactic latitudes, show that the extent of the Galactic Plane does extend to significant heights above the Plane.
2. (Top Right) Plot of lookback time (i.e. how long ago, with redshift shown on the upper x-axis) vs. the bolometric luminosity (or brightness). The grey square is a particularly bright nearby quasar, whilst the blue star is the most luminous quasar known and the red circle is the one studied here. The green and black points are all known quasars from two quasar catalogues. This plot shows that there are no quasars brighter than this one in the last 9 Gyr, and it is only a factor of two dimmer than the brightest known quasar.
3. (Bottom Right) Colour image from the SkyMapper Southern Sky Survey of the quasar SMSS J114447.77-403859.3. The quasar is the blue object in the centre of the field.

Slide 4 – Activity: How far away is SMSS J114447.77-403859.3?

This week's activity is to use properties of the quasar SMSS J114447.77-403859.3 to calculate the distance to this object. There are many ways of calculating the distance to objects within cosmology, but this time we will use the comoving radial distance, as opposed to the angular size distance, luminosity distance or light travel time distance.

The comoving radial distance considers the expansion of the Universe since the light was emitted by the distant source. It is calculated using the formula:

$$D = \frac{c}{H_o}\ln(1+z)$$

Where c is the speed of light (3 x 10^5 km/s), H_o is 70 km/s/Mpc and *z* is 0.83. This gives then distance as 2590 Mpc.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	6.21, 7.6, 11.9, 15.1, 15.10, 15.11, 16.1, 16.2, 16.5, 16.8
Pearson Edexcel Physics	7.12, 7.13
OCR Physics B	6.5.7
AQA Physics	4.8.2

A-Level Physics Specifications:

Specification	Knowledge Point
Pearson Edexcel Physics	161
OCR Physics A	5.5.3(e,h,i)
OCR Physics B	5.1.3(a,c)
AQA Physics	3.9.3.1, 3.9.3.2, 3.9.3.3