TEACHER NOTES – ASTRONOMY IN THE NEWS #30

NOT A BLACK HOLE…JUST A BINARY

Slide 2 – Background Science: Binary Stars and Massive Stars

Stars are separated and classified by their spectral characteristics, namely their temperature. The most commonly used classification system is the Harvard system which is as follows:

O B A F G K M

Which goes in both decreasing temperature and mass. There are a few mnemonics to remember this order, with my favourite been "**O**nly **B**oring **A**stronomers **F**ind **G**ratification **K**nowing **M**nemonics".

The most massive stars, O and B, typically have masses of 2.1 solar masses and above. The boundary between O and B falls at around 16 solar masses, therefore every massive star falls into these two classes.

OB stars tend to form in binary or multiple order systems. In fact, the multiplicity frequencies of stars in these classifications are shown in the Table below:

Initial Stellar Mass (solar masses)	Multiplicity Frequency
1.5 – 5	> 50%
8 – 16	> 60%
> **16**	> 80%

These binary systems can either be two stars that only interact gravitationally yet evolve separately. There are then contact or semi-detached binaries where mass is transferred from one star to another, or where in a contact binary, the two stars share a common envelope.

IMAGES:

1. (Top left) Cartoon depicting the relative sizes, and colours, of the stellar classes. The O and B stars are much larger, and hotter, than the other classes. For comparison the Sun is a G-class star.
2. (Bottom left) Optical wavelength image of the Jewel Box open cluster taken by the Very Large Telescope in Chile. This young cluster contains about 100 stars, many of which are B class stars.
3. (Right) Hertzsprung-Russell diagram depicting the distribution of stars as a function of their temperature and absolute magnitude (or luminosity). These diagrams are very powerful in that they separate stars into different stages of their evolution. However, along the main sequence, the more massive the star, the more it moves to

the upper-left quadrant. The stellar classes that these represent are also given along the bottom x-axis.

Slide 3: HR 6819: Black Hole or Binary

The system HR 6819 was heralded as possible the nearest black hole to the Sun. However, this possibility was only one of two main scenarios proposed for this object. Both scenarios involved at least two stars. The first was that the object consisted of a binary black hole-B star system, with a wide orbiting Be star. The second scenario is that it is a classical binary system with a Be star and a stripped B star, a star that has lost its outermost layers to its companion. A Be star is a B-type star which also displays emission lines. These emission lines are Balmer lines, where an electron within the hydrogen atom drops from a higher energy level to the second energy level around the central proton.

Both of these scenarios are potentially interesting, either this system contains the nearest black hole to the Sun, or observations of a binary that has recently completed its mass transfer, possibly indicating that binaries are a formation mechanism for Be stars.

These two scenarios are easy to distinguish between observationally. The first requires a bright companion to be found at a radius of ~ 100 milliarcseconds (mas; 1/36,000 of a degree) from HR 6819, whilst the second requires a binary object to be found using high-resolution observations.

The observations found no companion at a wide angle, ruling out the black hole scenario. However, making high resolution interferometry observations, and then fitting the spectra with models, found that the best fitting models were that of a two-star system!

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

https://www.theguardian.com/science/2022/mar/02/black-hole-that-was-closest-yet-found-does-not-exist-say-scientists-in-u-turn

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

https://arxiv.org/abs/2203.01359

IMAGES:

1. (Left) MUSE optical observations of the system with a 120 mas ring shown on the image. This image clearly shows no companion at a wider radius.
2. (Right) High-resolution spectra of the system taken with GRAVITY on the Very Large Telescope Interferometer (VLTI) in Chile. These spectra, in the infrared, are compared to models (red) and these spectra are best matched by a two-body system of a B and Be star. As a result, this is the speculated make-up of HR 6819.

Slide 4 – Activity: Understanding Resolution

The observations that confirmed the make up of the system were made with very high-resolution telescopes and instruments. The resolution of a telescope is the angular difference between points that it can resolve. Therefore, when a telescope is said to have high resolution, it actually has a low-resolving distance since a smaller angle means better resolution.

The two factors that impact resolution are the wavelength of the object you are trying to detect, and the collecting area. I have put two examples on the slide, one is the eye and one is the VLT set up for MUSE in the Near Field Mode. Taking a collecting area of 4mm and 7m, you should find angular resolutions of 34 arcseconds (about half a minute; 1/120 of a degree) and 0.02 acrseconds.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	11.19, 11.20, 11.21, 11.22, 13.4, 13.7, 13.8, 13.10

A-Level Physics Specifications:

Specification	Knowledge Point
Pearson Edexcel Physics	103, 159, 160
OCR Physics A	5.2.1(a), 5.5.1(g)
OCR Physics B	2b(i)
AQA Physics	3.6.1.1, 3.9.1.4, 3.9.2.4, 3.9.2.5