TEACHER NOTES – ASTRONOMY IN THE NEWS #49

JWST HIGHLIGHTS 2

The format of this week's bulletin is different to previous ones as it will contain 3 slides of science, all showing off some results from the JWST that we haven't discussed either in these bulletins or in the Lite postings.

Slide 2: Wolf-Rayet Binary System

The paths taken through the lifecycles of stars is very different depending on their initial mass. Low-mass stars, like our Sun, live a relatively sedate life. They are formed, burn through their hydrogen core and eventually end with a planetary nebula and a white dwarf. However, high-mass stars have a much more violent and energetic lifetime which spans a fraction of the time. A star like the Sun will burn for billions of years, whilst a massive star will form, live and die within half a million.

The most massive stars, as alluded to above, die a violent death in the form of a supernova. However, the path they take is also dependent on initial mass. Stars above 8 solar masses will end in supernova and will follow the basic evolutionary sequence of main sequence-supergiant-supernova. However, those above 20 solar masses will go through the Wolf-Rayet phase. WR stars are evolved massive stars that have lost their outer hydrogen and are fusing helium or heavier elements in the core. They have strong stellar winds, and this combination causes them to be both luminous and dusty.

This mass loss has caused this fascinating image captured by JWST. In this image, there is a central binary system comprised of a WR star along with a blue supergiant. When these two objects orbit each other, the stellar winds interact and at their closest approach every 7.93 years, the gas ejected from the stars is compressed, causing dust formation to occur and producing these rings. 17 rings are observed in total, spanning approximately 135 years.

The results discussed on this slide were presented in the following articles:

https://www.bbc.co.uk/news/science-environment-63234027

https://www.theguardian.com/science/2022/oct/12/james-webb-space-telescope-cosmic-fingerprint-dust-rings-wolf-rayet-140

IMAGES:

1. (Left) JWST image of the ring system surrounding this WR system.
2. (Right) Simulation of a WR star (left) with an HST image of a WR star. These show the clumpy nature of the stellar wind.

Slide 3: Star-Forming Cloud

Stars form in the densest parts of molecular clouds. Under the force of gravity, the gas and dust collapses until the densities are high enough for fusion of hydrogen atoms to occur. As this is occurring, more and more material infalls into the young protostar. This happens via a circumstellar disc. This disc is either torus, pancake or ring-shaped. The material is accreted onto this central disc which continues to feed the central protostar as it forms. This process, for low-mass stars is very slow, lasting a few million years at a rate of between 10^{-7} and 10^{-9} solar masses per year.

The appearance of a structure like this is what is shown in the JWST image on the slide. The protostar is hidden in the darkness in the neck of the hourglass like structure. Light is emitted from the top and bottom of the disc, which lights up the material in the clouds that was ejected from the star.

The result discussed on this slide were presented in the following article:

https://www.theguardian.com/science/2022/nov/16/nasa-space-telescope-james-webb-hourglass-star

IMAGE:

1. HST image of the L1527 star-forming system, found in Taurus molecular cloud.

Slide 4: Highest Redshift Galaxies

The baton is officially passed from the Hubble Space Telescope to the JWST in regard to discovering the most distant galaxy in the Universe. The galaxy discovered is at a redshift of z=13.2, or 13.8 billion years old.

A previous claim to this record was made but that only had photometric redshifts calculated as opposed to the more accurate spectroscopic redshifts, however this redshift was confirmed using the Lyman-alpha break. Observations of individual galaxies (i.e. the output of the stars in the galaxy) can be converted to redshifts by observing two sets of hydrogen lines, the Lyman series and the Balmer series. These lines are prevalent in stellar objects due to the high abundance of hydrogen in the Universe. They are caused by the transition of an electron from a higher energy level to either the first (Lyman) or second (Balmer). There is a break in the spectrum which is caused once an electron completely leaves the hydrogen atom, thus causing a hydrogen ion and these breaks occur at the wavelengths quoted below. The observed wavelengths can be converted to redshifts using the standard redshift formula:

$$z = \frac{\lambda_{obs} - \lambda_{emit}}{\lambda_{emit}}$$

Where z is the measured redshift, λ_{obs} is the observed wavelength and λ_{emit} is the emitted wavelength (i.e. the theoretical wavelength).

The article discussed here can be read at this link:

https://www.bbc.co.uk/news/science-environment-63919257

IMAGE:

1. Observations of the wide-field images with the four studied galaxies highlighted. They are hard to see since they are just small blobs! These galaxies all had their redshifts confirmed spectroscopically, with redshifts ranging from 10.3 to 13.2.