TEACHER NOTES – ASTRONOMY IN THE NEWS #32

JWST IS FULLY FOCUSED!

Slide 2 – Background Science: Fully Focused JWST

The James Webb Space Telescope was launched on Christmas Day, and since that time has gone through a painstakingly tense deployment sequence as it travels to its orbit position at the second Lagrangian (L2) on the other side of the moon. Part of this deployment was to align the 18 segments of the primary mirror, which involved using small motors attached to each segment, called actuators, to produce the perfect curvature. This was often movements many times smaller than the width of a human hair.

Each of these mirrors has had an image taken of a nearby star taken to ensure they were all set correctly, and this first image of all 18 working in synergy was released by NASA this week. The star observed is 2MASS J17554042+6551277, a star that is located 1987 light years away, with a V-band magnitude of 10.95, or K-band magnitude of 8.549 (the wavelength of the image). This image has diffraction spikes, typical of stellar observations. However, the background galaxies demonstrate the power that JWST will have in determining the physics that shaped our Universe!

IMAGES:

1. (Left) A cartoon of the fully deployed JWST, and as it will look as it makes observations. The segmented primary mirror is visible, with the fully extended sunshield.
2. (Right) Fully focused image of the star 2MASS J17554042+6551277 at the infrared wavelength of 2μm, with a red filter used for contrast. The star, which was chosen just because it had the brightness required, displays the diffraction spikes commonly seen in stellar observations. Background galaxies are also visible.

Slide 3: Discovering Other Worlds

This slide presents some of the potential science that JWST will perform. The last time we spoke about the JWST, I discussed observing the earliest galaxies in the Universe (AITN #26), but this time I will discuss observing exoplanets, as well as the Solar System.

JWST will be a powerful instrument to investigate “Other Worlds”, both outside and within our Solar System. Exoplanets will be detected using the transit method, where the planet will dim the light of the star as it passes in front of it.

Along with detecting exoplanets, the JWST will also detect the atmospheres of these planets, allowing the composition of the atmospheres to be determined. The spectrum of the star, when added to that of the planet, will show an absorption line where those elements/molecules are present. The infrared wavelengths contain molecules that would both be signatures of life, and allow a spectrum of an atmosphere similar to Earth to be found.

Within the Solar System, one of the projects of the JWST will be to investigate Mars, mainly the history of water and methane on the planet. Water escapes from Mars as ultraviolet radiation from the Sun breaks apart the water molecules. This occurs due to the thinner atmosphere on the planet. However, water is still found on the planet, and in two forms, water and heavy water. Water is made up of two hydrogen atoms and one oxygen, to make H_2O. Heavy water contains one atom of deuterium, the isotope of hydrogen which contains one proton and one neutron, along with one hydrogen atom and one oxygen atom. This has the chemical formula HDO. The ultraviolet light preferentially breaks apart water molecules, therefore by measuring the ratio of H_2O and HDO, it can be determined how much water has escaped from Mars.

The Martian atmosphere is made up of almost entirely carbon dioxide. However, there is a small amount of methane. This methane is seasonal, and is released periodically, especially in the Northern hemisphere in the summer. However, the source of this methane is not understood since on Earth, methane is released from either biological or geological processes, neither of which we have evidence for on Mars.

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

https://www.bbc.co.uk/news/science-environment-60771210

https://www.theguardian.com/science/2022/mar/16/nasa-telescope-star-photo-ancient-galaxies

There is also an accompanying article about the involvement of the Armagh Observatory and Planetarium in both the development and the ongoing use of the JWST:

https://armaghplanet.com/james-webb-space-telescope-latest-news.html

IMAGES:

1. (Top left) Cartoon of detecting the transit method. The top is an image showing the orientation of the planet and stars, whilst the lower panel is the light curve of the light reaching Earth. As the planet is not in front of the star, the brightness of the star is at 100%, whereas when the planet is in front of the star, a dimming occurs. This will occur periodically, with the period length the same as the orbit period of the planet.
2. (Bottom left) Methanol concentrations in the atmosphere of Mars during the Northern summer. The yellow and red show the highest concentrations, while blue and purple are the lowest.
3. (Right) Example absorption lines from an exoplanet atmosphere in part of the wavelength regime visible with JWST. These lines show the absorption of water, carbon monoxide, carbon dioxide, methane and ammonia.

Slide 4 – Activity: What produces methane?

This week's activity is to discuss the causes of methane on Earth. They can be separated into two categories of processes, biological or geological. Can the students come up with lists of processes that fall into these categories? Biological comes from the break down of organic material, or from food digestion. Geologically, it is produced from the break down of hydrocarbons or fossils in things such as volcanoes, geothermal heating and mud volcanoes.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	12.4, 13.21, 13.32, 13.34
Pearson Edexcel Chemistry	9.10
AQA Chemistry	4.7.1.1
AQA Combined Science: Trilogy	5.7.1.1

A-Level Physics Specifications:

Specification	Knowledge Point
OCR Physics A	5.5.2(e,f)
AQA Physics	3.9.3.4