TEACHER NOTES – ASTRONOMY IN THE NEWS #39

JWST MIRROR IS DAMAGED

Slide 2 – Background Science: JWST Mirror Damaged

The James Webb Space Telescope launched on Christmas Day and has gone through a number of significant stages in its preparations to becoming the most powerful space telescope ever made. These stages include reaching the orbit point of the second Lagrangian (L2), completely unfolding the mirror and aligning the mirror.

However, one of the many risks with the JWST is the orbiting position. The L2 is on the opposite side of the moon, meaning that it cannot be visited and repaired, unlike the Hubble Space Telescope. One of the results of this was seen recently when a micrometeoroid struck the mirror. The micrometeoroid was tiny, dust sized, but has left a noticeable impact on the images from the telescope. The mirror segment affected was realigned and this has mitigated some of the issue. The good news is that JWST was performing above expectations prior to the impact, and this is still the case!

NASA did foresee this issue and tested the mirror on the ground for these impacts, however, the micrometeoroid that hit the mirror on this occasion was larger than those modelled.

IMAGES:

1. Schematic showing the damaged mirror segment, known as C3. This is just one of the 18 mirrors that make up the 6.5m primary mirror.

Slide 3: Star Lifecycle

This is the fourth Astronomy in the News bulletin to discuss the JWST, following on from AITN #26, #32, and #36. In each of these bulletins, I used this slide to introduce some of the expected science from the facility. There are four broad areas of science and we have discussed two of them (Early Universe, Other Worlds, and Galaxies Over Time), and this week I will discuss Star Lifecycle.

Some of the key questions that this area of science are: how do clouds of gas and dust collapse to form stars; why do most stars form in groups; exactly how do planetary systems form; and how do stars evolve and release the heavy elements they produce back into space for recycling into new generations of stars and planets?

I will focus on two of those questions here, how do clouds of gas and dust collapse to form stars and how do planetary systems form? The formation of stars is fairly well understood, at least in low-mass stars. A turbulent cloud of gas and dust begins to collapse under gravity, especially in local dense region called eddies. Within these eddies, they begin to collapse under their own gravity, and material begins to fall onto the central point until the material is dense enough to begin hydrogen burning through fusion. Once this fusion begins, you have a star, with the radiative pressure caused by this fusion balancing the gravitational collapse of the star, and as long as this fusion continues, this balance will remain in place.

However, there are some unanswered questions regarding this process. How does this get scaled up to larger stars, those that we know exist, such as 40-50 times the mass of the Sun as current theories do not allow these stars to form so easily? What physically regulates the efficiency of this process as large variations in star-formation efficiency are seen from cloud to cloud, but it is unclear what causes this.

Infrared telescopes, like the JWST, are uniquely placed to answer these questions of star formation since they are able to look into the dense molecular clouds and detect the forming stars.

Planetary systems form from the "leftover" material from the star-formation process. A circumstellar disk, or protoplanetary disk, forms around the star in the formation process. It is this disk that accretes material onto the star. However, within this disk, material collects together causing planets to form. These planets "carve" out gaps in the disk, implying their presence, and eventually the disk dissipates leaving a solar system.

Planetary formation theories constantly change as new systems are found. By detecting and observing more stars with protoplanetary disks, a greater understanding of the process can be obtained.

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

https://www.bbc.co.uk/news/science-environment-61744257

More information on this branch of JWST science can be found here:

https://webb.nasa.gov/content/science/birth.html

IMAGES:

1. (Top left) Histogram of star-formation efficiencies for a sample of molecular clouds in the Milky Way. The star-formation efficiency was calculated by calculating the ratio of the luminosity of the forming stars (which is related to their mass) and the mass of the molecular cloud from which it formed. The red histogram is a distance-limited sample attempting to remove bias, whilst the blue line is a Gaussian fit to the sample.
2. (Top right) ALMA image of the protoplanetary disk around the young stellar object HL Tau. There are obvious gaps in the disk, which are thought to have been carved out by planets forming.
3. (Bottom) A 3-colour (70 µm [blue], 250 µm [green], 350 µm [red]) image of the star-forming complex W3/W4/W5. These wavelengths show the power of infrared wavelengths in observing star-forming regions by "looking through" the dense material.

Slide 4 – Activity: Momentum of a micrometeoroid

This week's activity is to calculate the momentum of a micrometeoroid. The typical mass of one of these objects is less than a gram, but for the sake of this calculation, we'll use 1g. The velocity is usually, with respect to the satellite, 10 km/s. Therefore, the momentum can be calculated as 10 kg m/s.

To put this number into context, I then ask the students to calculate the velocity required for a pool/snooker ball to reach this value. The typical mass of these is 160g, giving a velocity of 62.5 m/s. In miles per hour, this is approximately 140 mph. No wonder the micrometeoroid left a dent!

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	13.30, 13.31, 13.32, 14.3, 14.9, 14.10
Pearson Edexcel Physics	2.24, 7.16, 7.17
Pearson Edexcel Combined Science	P2.24
OCR Physics B	4.3.4, 6.5.4, 6.5.6
OCR Combined Sciences B	P4.3.4
AQA Physics	4.5.7.1, 4.8.1.1, 4.8.1.2
AQA Combined Science: Trilogy	6.5.5.1

A-Level Physics Specifications:

Specification	Knowledge Point
Pearson Edexcel Physics	21
OCR Physics A	3.5.1(b), 5.5.1(b)
OCR Physics B	4.2(b)
AQA Physics	3.4.1.6