TEACHER NOTES – ASTRONOMY IN THE NEWS #09

HUBBLE SPACE TELESCOPE IS…REVIVED

This bulletin is a bit different to previous editions of Astronomy in the News. The news story that this is built upon is the recent news that the Hubble Space Telescope (HST) was in trouble, with malfunctions in the computing system, and science operations ceased in June. The articles describing this are here:

https://www.bbc.co.uk/news/science-environment-57844454

https://www.theguardian.com/science/2021/jul/09/spacewatch-nasa-seeks-cure-for-hubble-troubles

However, in the time since these articles were written, operations have resumed, which is excellent news for the astronomical community:

https://www.bbc.co.uk/news/science-environment-57885865

As a result of this news, this week's bulletin will be a small tribute to the HST. The two slides that are usually dedicated to background science and the science of the news article will instead highlight two of the many key results that the HST has given us in 31 years of operation.

Slide 2: Hubble Deep Field

One of the most recognisable results from the early operation of the HST was the Hubble Deep Field (HDF). The HDF was an image collected over multiple HST orbits of a very small patch of the night sky (one 24-millionth in fact) and accounted for between 30-43 hours (depending on the wavelength) of observations over 342 images.

This area of sky was considered blank. However, after the 342 images were co-added, 3,000 galaxies were revealed. These galaxies were found to be at many different redshifts, and was the first major sample of galaxies found with a redshift above $z = 1$. In fact, when looking at longer wavelengths (such as infrared and radio), there are lots more galaxies in this patch of sky. These galaxies have redshifted out of the visible and ultraviolet wavelengths, with more information on this affect described in Bulletin #06 – First Stars in the Universe. These HDF observations were taken with an ultraviolet filter, two visible filters and one in the near-infrared.

The scientific impact of this image was that it detected a large number of disturbed and irregular galaxies, indicating that collisions and mergers between galaxies were much more common in the young Universe. Collisions between spiral galaxies and irregular galaxies are thought to form the largest elliptical galaxies that are evident in the early Universe.

Another significant result was the lack of foreground stars and other Galactic objects in the image. One theory for the makeup of dark matter, and what was causing the flattening of galactic rotation curves at the outer edges of galaxies was the existence of MACHOs (Massive Astrophysical Compact Halo Objects). These MACHOs would have been made up of red dwarfs, low luminosity stars which also the most common. However, as so few were detected at the outer edges of our Galaxy, they were ruled out as a significant contributor to dark matter.

The final result from this image that I'll highlight here was an estimate of the star-formation rate over the lifetime of the Universe. It was predicted that it was at a maximum 8-10 billion years ago (at redshifts of z = 1-2), and has since decreased by a factor of 10.

IMAGES:

1. (Left) The original HDF image. This image accounts for 1/24,000,000 of the sky, yet totalled over 3,000 galaxies in the wavelengths visible from the HST, with an even larger number found when observed at longer wavelengths. This field was chosen in the Northern sky. A follow-up experiment in the South revealed an almost exact result, which also confirmed cosmological principles that the Universe is homogeneous at the largest scales.
2. (Right) The evolution of the star-formation rate (in units of mass of stars formed per year per cubic megaparsec) as a function of redshift as derived from the HDF image. The distribution, and the resultant fits to the data, peak between redshifts of z = 1 and z = 2, or 6-8 billion years ago.

Slide 3: Star-formation revealed via proplyds

The formation of stars is a multi-stage process. One of these stages is the formation of a disk around the forming star called a protoplanetary disk. These are an accretion disk where material flows onto the forming star from the structure. Once the star has formed, it starts to photoevaporate this disk, at which point the star will be left to go onto the main sequence. It is also from these disks where planets or planetesimal objects may form.

However, the existence of such disks around forming stars was only postulated. Radio observations detected an extended structure around newly forming stars that were molecular in nature, but it was not clear whether it was these disks or ionised globules. Further observations pointed towards disks. However, HST observations in 1993 resolved ionised protoplanetary disks, or a proplyd using the filters in the visible wavelength regime.

IMAGES:

1. (Left) HST images of proplyds in the Orion molecular cloud, the only cloud close enough to Earth to resolve a large sample. These structures are photoevaporating which is when radiation is energetic enough to ionise gas and force it away from the ionising source, in this case the massive star forming at the centre of the structure.

2. (Right) A recent ALMA submillimetre image of a protoplanetary disk before photoevaporation. This image shows the disk surrounding a star that is forming with gaps where planets and planetesimal objects will condense and form.

Slide 4 – Activity: The Hubble mirror flaw

One of the most famous stories about the HST at launch was the mirror flaw. Images had a blurry nature (as seen by the image of a star on the slide), and this was caused by spherical aberrations from the mirror. The mirror was too flat at the edges by 2200 nm. This caused the light to be focused at different points from the edge compared to the centre of the mirror (the diagram on the slide also explains this).

This issue was fixed in the first service mission, but how was this fixed? The mirror could not be replaced in space, and it was too costly to bring HST back to Earth, replace the mirror, and put HST back into orbit. The students should discuss this, and the correct answer was to produce “glasses” for the mirror, by putting in a lens that was the exact opposite, thus refocusing the light. When new instruments were added to the HST in the future, this element wasn’t required as the new instruments accounted for this themselves.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	11.16, 13.22, 13.29, 13.31, 13.32, 13.34, 15.9, 15.14, 16.1, 16.8, 16.10
Pearson Edexcel Physics	5.3, 5.5, 5.10, 7.12, 7.16, 7.19
Pearson Edexcel Combined Sciences	5.10
OCR Physics B	1.1.1, 1.4.1, 1.4.3, 6.5.7
OCR Combined Science B	1.1.1
AQA Physics	4.6.1.3, 4.6.2.1, 4.6.2.5, 4.8.2
AQA Combined Science: Trilogy	4.6.2.1

A-Level Physics Specifications:

Specification	Knowledge Point
Pearson Edexcel Physics	76, 163
OCR Physics A	4.4.2, 4.4.3, 5.5.3(f,h,k)
OCR Physics B	3.1.1(b)
AQA Physics	3.9.1.2, 3.9.3.2