TEACHER NOTES – ASTRONOMY IN THE NEWS #28

GIANT ATOMIC FILAMENTS

Slide 2 – Background Science: Filaments and Star Formation

Star formation is a multi-stage process with very broad stages. In a broad sense, atomic, neutral gas becomes denser, forming molecular gas, in the form of molecular clouds. These molecular clouds then get denser, causing clumps, from which individual cores and stars form in. This is a rather simplistic view of star formation, but does describe the "Russian doll" nature that is observed in star-forming regions.

A more detailed description of star formation starts with a molecular cloud. The molecular cloud, consisting of gas and dust, is disrupted, causing a turbulent environment. This turbulence causes regions within the cloud to become denser, and gravity takes over causing them to collapse. These regions become even denser and hotter, and begin to spin, forming a disc. Eventually, the protostar (the forming star) begins to burn hydrogen in the form of nuclear fusion. The stellar wind of the star will then, eventually, blow away the molecular gas from which it formed, leaving the star to burn. However, the condensation of the initial molecular cloud into denser clumps facilitates the formation of filaments, but the formation of these structures is one of two unanswered questions. The other is how large-scale molecular clouds form out of the more diffuse atomic gas.

IMAGES:

1. (Top left) Herschel Space Observatory 250-μm far-infrared image of the Taurus molecular cloud, showing the filamentary structure of a typical star-forming cloud.
2. (Top right) A cartoon demonstrating the hierarchical structure of the star-formation process. This cartoon starts at the molecular cloud stage. Within the clouds, clumps form where multiple stars form, which host filamentary structures. The densest regions of the filaments are called cores, where stars form, consisting of the envelopes of gas that they condense from into the discs and stars. What is missing from this cartoon is the atomic gas which surrounds the molecular gas, which gets denser to form the molecular gas.
3. (Bottom) Two images of the Galactic Plane showing the large-scale structure of the Milky Way. The top panel is the atomic gas (neutral hydrogen) whilst the bottom panel is the molecular gas, as illustrated by the 12CO emission. 12CO is the second-most abundant molecule in the Universe, behind molecular hydrogen, H_2. These illustrate the "Russian-doll" aspect of atomic gas versus the molecular gas.

Slide 3: Giant Atomic Filament

As mentioned above, one of the unanswered questions in the field of star formation is how molecular clouds form from the atomic gas. Within a survey of HI, atomic hydrogen, a large sample of atomic filaments were found. One of these filaments, "Maggie" was discovered to be very large, and coherent in position-position-velocity space. At a length of 4 degrees on the sky, and a distance of 17 kiloparsecs, “Maggie” has a length of 1.2 kiloparsecs. This is the largest, coherent molecular cloud discovered in the Milky Way.

The length of “Maggie” would, instinctively, imply it would be a feature of Galactic structure. However, it is found to lie between two spiral arms. This does not rule this out, as spur-like structures off the spiral arms are found in the Milky Way and other galaxies, but it is currently inconclusive.

No molecular emission is found on large-scales in “Maggie”, but it is found on smaller scales, in the densest regions of the atomic hydrogen. This shows that it is mostly atomic in nature, and is still forming the molecular component. As a result, this structure is a useful probe as to how the formation process of large-scale molecular gas proceeds.

This bulletin is slightly different to the usual bulletins in that it is not built upon a news article that was in the national media. Instead, it is built upon a press release from my host department at Liverpool John Moores University and I wanted to highlight some of the work done here. The article that this resource is built on can be found here:

https://www.ljmu.ac.uk/about-us/news/articles/2021/12/20/is-this-the-largest-thing-in-the-known-universe

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

https://arxiv.org/abs/2111.01057

IMAGES:

1. (Left) Cartoon of the Milky Way, derived from the distribution of star-forming regions detected in the GLIMPSE survey from the Spitzer Space Telescope. This image shows the major features of structure in the Milky Way, including the four spiral arms and the central bar. The position of the giant, atomic filament detected in this paper is depicted by the drawn-on red line.
2. (Top right) The giant atomic filament in HI (atomic hydrogen) emission. The position of it shows it below the mid-plane of the Galaxy. The length of it, at almost 4 degrees, responds to a length of over one kiloparsec at a distance of 17 kiloparsecs.
3. (Bottom right) The HI emission shown in position-velocity space. The velocity is a proxy for distance. On top of this emission are the two spiral arms, and the black line is the profile of the giant atomic filament. This structure is found between the two arms. The grey line is another structure found in these images.

Slide 4 – Activity: How do stars form?

The activity for this bulletin is to put the stages of star formation in to the correct order. The stages this refers to are the stages of how an individual star forms.

The correct order is:

1) A molecular cloud has no current star formation.

2) Regions within the cloud become denser and gravity starts to cause these regions to collapse.
3) Regions get denser and become hotter. The cloud starts to spin and produce a disc, with an outflow.
4) Star becomes hotter and begins to burn hydrogen via nuclear fusion.
5) The forming star blows away the remaining cloud material, leaving the star isolated.
6) A star remains and burns for lengths of time of 500,000 years to billions of years.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	7.6, 11.9, 14.10, 15.1, 15.2, 15.3, 15.8
Pearson Edexcel Physics	7.16, 7.18
OCR Physics B	6.5.4, 6.5.6
AQA Physics	4.8.1.1, 4.8.1.2

A-Level Physics Specifications:

Specification	Knowledge Point
OCR Physics A	5.5.1(b), 5.5.3(a)
AQA Physics	3.9.2.2