TEACHER NOTES – ASTRONOMY IN THE NEWS #37

PRIORITISE URANUS FOR A NEW SPACE MISSION

Slide 2 – Background Science: Uranus

Uranus, the seventh planet from the Sun, and the fourth most massive has some very unusual traits. The three most cited when discussing Neptune are that: 1. It is on its side; 2. It is rotating in the opposite direction to the other planets (apart from Venus); 3. It is the colder planet in the Solar System despite the fact it is not the furthest from the Sun.

The cause of these unusual features is thought to be the same thing, a large collision during the formation of the planet. This large collision, or collisions, caused the planet to be now on its side (the tilt is 98 degrees, compared to the 23 degrees for Earth), and the spin to be retrograde. This tilt also causes the temperature to be so low. When the core produces heat, this is forced out into space, rather than be retained on the planet due to the fact it is on the side.

Another feature of Uranus is that it has rings. These rings were discovered in 1977 when astronomers were trying to observe a star which was in the same region of the sky as Uranus. When Uranus was passing in front, the star was flickering. This flickering was determined to be caused by the rings. Since that time, the Voyager 2 probe and the Hubble Space Telescope have discovered at least 13 rings.

IMAGES:

1. (Left) Hubble Space Telescope images of Uranus side on, showing the rings observed in 2003, 2005 and 2007. Over the period of the observations the rings became more side on.
2. (Right) HST images of Uranus, again showing the rings of the system, along with the clouds in the upper atmosphere, indicating the complex climate and weather on the planet.

Slide 3: A mission to Uranus

Uranus is a relatively unchartered body in the Solar System. Uranus and Neptune have never had a dedicated satellite visit them. The decadal study of Planetary Science and Astrobiology has determined that the highest priority large strategic mission should be to visit the ice giants. However, due to the orbits of the ice giants (Uranus and Neptune), along with the other planets that would give gravitational assistance, in this decade (2023-2032), Uranus should be the priority.

The goals of this mission would be wide ranging, and a fraction of these questions are listed below, with an explanation of the problem shown in red:

- How do the layers of the atmospheres of an ice giant interact with each other, and what is the structure of the atmosphere? Observations have shown that there are clouds high in the atmosphere of Uranus. We can determine how deep these clouds go, the 3D structure, and whether this differs in an ice giant from a gas giant.
- How did Uranus, and other ice giants, form? Scientists have determined that ice giants are the planets most likely to form in the outer extremes of a Solar System. Observations of other planetary systems have found that rocky planets or "hot Jupiters" exist in close orbits to their host stars, but Uranus-sized planets are mostly found where they are in the Solar System. However, unlike for Jupiter-sized planets, and Earth-like planets, the formation mechanism is unclear.
- How are the winds produced, and how deep into the atmosphere are they found? Massive storms are observed on Uranus, what causes these to occur, and how close to the surface are they.
- How did Uranus gain its tilt and retrograde orbit? The details of this issue are discussed on the previous slide.
- What causes the complex magnetic field? The magnetic field of Uranus has many unusual traits. The first is that it is not aligned to the polar axis, offset by 59 degrees from the rotation axis. It is also displaced from the rotation axis, 31 percent of the planet radius from the centre. There are also large, small-scale features of the field, which implies that it is generated at shallow depths, much shallower than seen in the gas giants of Jupiter and Saturn, and of Earth.
- What are the compositions of the major moons of Uranus? Uranus has a large number of orbiting bodies, including moons and rings. A number of these moons are thought to have subterranean oceans.

As can be seen, these questions cover the origin, interior and atmosphere of both Uranus and potentially other ice giants. They also aim to determine the history of the satellites and ring system.

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

https://www.bbc.co.uk/news/science-environment-61155725

A free, downloadable version of the decadal strategy can be found here:

https://nap.nationalacademies.org/catalog/26522/origins-worlds-and-life-a-decadal-strategy-for-planetary-science

This decadal study is very detailed about the direction that NASA should take over the next ten years in the areas of Planetary Science and Astrobiology. The relevant section regarding this mission begins on Page 22-26 (Page 639 of the PDF).

IMAGES:

1. (Left) Plot showing observed exoplanets, with the orbital period vs. planet radius. This shows that the majority of planets discovered fall in the radius range of approximately 2-5 times that of Earth, which is the radius of Uranus and Neptune. As a result, this is the most common size of planet discovered!

2. (Top right) Depiction of the magnetic field around Uranus showing a twisted magnetic field, and a much complex field than on Earth.
3. (Bottom right) The number of moons, and their relative orbits, of Uranus. Uranus has 13 inner moons, 5 major moons and a further 9 irregular moons. This is in addition to the, at least, 13 rings.

Slide 4 – Activity: Investigating Uranus-like planets

This week's activity is to use the following website:

https://exoplanetarchive.ipac.caltech.edu/cgi-bin/IcePlotter/nph-icePlotInit?mode=demo&set=confirmed

to investigate the properties of exoplanets discovered around other stars. In particular, the students should be observing the planets that we talked about here, those that are similar to Uranus. The properties of discovered planets are given in Jupiter radii and Jupiter masses, with the conversion to Uranus given on the slide.

Some plots that could be produced would be histograms of the masses and radii, which will allow the students to see that most exoplanets discovered have similar radii to Uranus and Neptune. In terms of scatter plots, the orbital period vs. planet mass/radius should show that a lot of Uranus-like planets are not found near the host star, but further away.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	7.5, 11.1, 11.6, 11.7, 11.26, 11.27, 12.3, 12.5
Pearson Edexcel Physics	7.2, 7.3
OCR Physics B	6.5.1
AQA Physics	4.8.1.1, 4.8.1.3

A-Level Physics Specifications:

Specification	Knowledge Point
OCR Physics A	1.1.3(d), 5.5.1(a)
OCR Physics B	1.1.3(d)