TEACHER NOTES – ASTRONOMY IN THE NEWS #23

MOON FRAGMENT ASTEROID

Slide 2 – Background Science: Near Earth Objects

The Moon, everyone knows this as the only natural satellite of the Earth. To be defined as a natural satellite, an object has to be in a stable orbit around another, larger planet, dwarf planet, or even satellite.

However, along with the Moon, there are a number of other objects which are claimed to be satellites of Earth. There are 27,000 known Near Earth Objects (NEOs), objects that come within 1.3 AU (astronomical units) of the Sun but there are a few objects that are quasi-satellites. These are objects that appear to be in orbit around the planet, but actually aren't. They are usually in a resonance orbit, i.e. they orbit the Sun over the same time frame (1 year) but do not follow the orbit of Earth.

A lot of objects that fall into these orbits are not stable, and are too far away from the planet to remain. This leads to them either entering the orbit of Earth (or other planets) temporarily as natural satellites, before moving out again, or entering a different resonance orbit which is much further out than the planet.

IMAGES:

1. (Left) GIF of the orbit of the quasi-stable satellite, Cruithne. This object takes 364 days to orbit the Sun, but doesn't orbit the Earth.
2. (Right) GIF of the NEOs around the Earth. From the animation, it's obvious the objects are in orbit around the Sun as opposed to Earth.

Slide 3: Characterising Near Earth Objects

One quasi-stable satellite is the NEO 469219 Kamo'oalewa, named as such as it was discovered in Hawaiian and in Hawaiian, that translates to oscillating celestial object. Kamo'oalewa orbits the Sun with a period of 366 days at a distance of 0.9-1.1 AU. This orbital period and distance confirms its existence as a quasi-stable satellite.

Kamo'oalewa, and it's origin, are of importance to identify the origin of NEOs. By measuring the reflectance spectrum, which is the proportion of light reflected at particular wavelengths, and its rotational period, you can start to identify it. The reflectance spectrum does not match any known populations of asteroids around Earth, implying that it does not come from those populations. However, the reflectance spectrum does match that of Moon rock that was returned from the Apollo 14 mission, implying that the asteroid is made of Lunar material, namely the silicates present on the surface of the Moon. This could be due to an impact on the surface of the Moon, which ejected the object. Another piece of evidence supporting this is the relative velocity of Kamo'oalewa, which is 10 times lower than the usual velocities of other NEOs.

Other possibilities for the origin of Kamo'oalewa are a population of as yet undiscovered Trojans, objects that follow, or trail the orbit of Earth, or another NEO dragged into the orbit of Earth.

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

https://www.theguardian.com/science/2021/nov/11/near-earth-asteroid-is-a-fragment-from-the-moon-say-scientists

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

https://arxiv.org/abs/2111.06372

IMAGES:

1. (Left) Image of the Moon taken from onboard Apollo 17. Any images of the Moon show the obvious crater marks.
2. (Top right) Two animations showing the orbit of Kamo'oalewa, the left panel shows the orbit in around Earth (shown in blue), whilst the right panel shows the orbit around the Sun (yellow), with the Earth's orbit shown in blue. These two animations show how the two orbits are clearly linked, but that Kamo'oaelewa is not orbiting around the Earth in the same manner as the Earth-Moon, or Earth-Sun systems. These two animations cover the 300-year period of 2000 to 2300.
3. (Bottom right) The reflectance spectrum as a function of wavelength. The y-axis shows the reflectance, which is the percentage of light that is reflected at the relevant wavelength. The dark blue and grey-blue lines are from other asteroids, whilst the blue line is the reflectance from some Moon rock brought back from a previous mission. The black and red points are the reflectance as measured from Kamo'oaelewa. The spectrum was normalised to be 1 at 0.70 µm.

Slide 4 – Activity: How unusual is Kamo'oaelewa?

The activity this week is one to gauge an understanding of statistics. On the slide is a Figure from the research paper which presents the gradients of the reflectance spectrum for a population of asteroids. On the same plot is a shaded region which gives the range of values for Kamo'oaelewa. A Gaussian fit to the population gives a mean of 12 %/µm and a standard deviation of 11 %/µm. The most likely value for Kamo'oalewa is given as 90.5 %/µm.

I am asking the students to first calculate how many standard deviations this value falls from the mean, in this case it is 7.13 and what this says about the statistical significance of the result. A 3-standard deviation gap between observations implies an unusual result and would indicate that it is not from this population, so a 7 standard deviation gap gives even more evidence to the fact it is from a different population.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	2.3, 6.1, 7.6, 8.3, 11.9, 11.10

Pearson Edexcel Physics	7.5
AQA Physics	4.8.1.1, 4.8.1.3