Asteroid Adventures
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On Sunday evening, a small spacecraft called *Lucy* flew past a moderate sized asteroid named DonaldJohanson. A denizen of the inner part of the main asteroid belt between Mars and Jupiter, until that passage it had never been seen as anything other than a point of light. With Lucy now receding into the distance, it may be many centuries before humanity gets another look at this previously unknown world, now revealed as a place with a complex history to share with us.

With recent missions to near Earth asteroids Ryugu and Bennu returning samples to Earth, and lab investigations into both bearing intriguing fruit, this week therefore seemed like a good time to take stock of what we're finding about the Solar System's smaller bodies. With results still being returned from *Lucy*, rather than a full transcript I've provided brief notes and pointers for further reading for each of the places we'll visit on the tour.

1. Donaldjohanson

The *Lucy* spacecraft was named after the famous hominid fossil found in Ethiopia in 1974, which belongs to a female *Australopithecus afarensis*, herself named after the team's favourite Beatles song. Scientists studying *Lucy*, who when found was the oldest known hominid specimen, hope to find evidence of the origins of our species, while the scientists and engineers behind the NASA mission are undertaking a tour of 11 asteroids to investigate the origins of our Solar System. Donald Johnason was the paleoanthropologist who made the discovery of the fossil.

Studying Donaldjohanson from a distance had suggested it was about 3-5km across, with a common ('c type') composition. It belongs to a family of asteroids who seem to owe their origins to a catastrophic event 150 million years ago; either a parent body must have disintegrated, or a collision scattered material out into the main belt. (On average, an asteroid the size of this one should survive about a billion years before undergoing another collision, so we should see a surface last affected by this dramatic event.) The asteroid seems to rotate once every 252 hours – surprisingly slowly – and in doing so changes brightness dramatically. This suggested – pre-flyby – that it might be elongated (like Arrokoth, an inhabitant of the distant Kuiper belt visited by the *New Horizons* spacecraft after its encounter with Pluto), or even host an unresolved satellite.

Sunday's flyby sent *Lucy* within 900 km of Donaldjohanson, swinging by at a relative velocity of 13.4 km/s. A need not to point the sensitive cameras too close to the Sun means that we won't see images from closest approach, but features as small as 10m should be visible.

For a good summary of our pre-encounter knowledge of Donaldjohanson, please see "A Pre-flyby View on the Origin of Asteroid Donaldjohanson, a Target of the NASA Lucy Mission", Marchi et al, 2025, Planetary Science Journal https://arxiv.org/abs/2503.14148

2. Dinikesh

This is *Lucy*'s second encounter with an asteroid. The first was much smaller Dinkinesh[1], added to the tour

[1] Translated as 'you are wonderful' in Amharic, this is the local name for the Lucy fossil.

itinerary only after launch. Another member of the main belt, at just 790m in diameter this is the smallest such asteroid we've been to – though it surprised the team with the presence of a small moon named Selam[2]. Selam itself proved to be a compact binary, with two two-hundred meter lobes touching each other.

How Selam formed is a mystery. One possibility is the brilliantly named YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack) effect, caused by the changes in momentum caused by interaction with sunlight integrated over many millions of years, may have increased the rate with which the asteroid spins to the point where it shattered, leaving Selam as the rubble.

We're still waiting for peer reviewed papers on the Dinkinesh encounter (the Lucy team have been busy) but there's a good conference summary here:

https://meetingorganizer.copernicus.org/EPSC2024/EPSC2024-561.html

3. Dimorphos and Didymos

Understanding how asteroids change their properties over time is essential in helping us prepare for the possibility that one might hit us. Ever since the father and son team of physicist Luis and palaeontologist Walter Alvarez found evidence that a large impact coincided with the mass extinction that killed the dinosaurs, the idea that an impact might cause catastrophic change on Earth has not been far from the public consciousness[3].

We are getting better at defending ourselves from this cosmic threat. Partly this means getting better at spotted objects moving through the sky, a task accomplished through surveys such as that undertaken by the NeoWISE mission and the upcoming Vera Rubin Observatory's LSST survey. The upcoming NEOSurveyor mission[4] will find 200,000-300,000 Earth-crossing asteroids down to 10m in size, hugely increasing the chance of finding a potential impactor before it can do any damage.

Partly it also means getting better at doing something about it. The recent DART mission deliberately collided with the asteroid Dimorphos in the Didymos binary system in order to measure our ability to deflect a small near Earth object. The result was rather more spectacular than expected, and the European Space Agency's Hera spacecraft is now on the way to inspect the damage.

For NeoWISE see Mainzer et al 2017, 'NEOWISE Reactivation Mission Year Three: Asteroid Diameters and Albedos', Astronomical Journal, 154, 4, 168 https://arxiv.org/abs/1708.09504

For LSST asteroids see Lynne Jones et al, 2017, 'The Large Synoptic Survey Telescope as a Near-Earth Object Discovery Machine', Icarus, 303, 181 https://arxiv.org/abs/1711.10621

For NEOSurveyor, see Mainzer et al 2023, 'The Near-Earth Object Surveyor Mission', Planetary Science Journal, 4, 12 https://arxiv.org/abs/2310.12918

Preliminary DART results are given in Cheng et al 2023, 'Momentum transfer from the DART mission kinetic impact on asteroid Dimorphos', Nature, 616, 457

Hubble images were given by Jewitt et al, 2023, 'The Dimorphos Boulder Swarm' https://arxiv.org/abs/2307.12506

4. Bennu

Larger rocks than Dimorphos threaten the Earth. Near the top of the table of potentially hazardous objects (updated here, if you want to check the asteroid forecast for yourself: https://cneos.jpl.nasa.gov/sentry/) is 101955 Bennu, a 250m rubble pile discovered in 1999. Bennu was recently visited by the OSIRIS-REx spacecraft, which returned samples to Earth for study.

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[2] Another fossil

[3] See films *Deep Impact*, *Armageddon*, and more recently *Don't Look Up* for examples.

[4] Subject to the threats to NASA's budget currently being discussed in the US.

Excitingly, these samples do not look like any meteorite that has been recovered, though this might partly be because of their relative freshness. Early results reported by the team focused on the unexpected presence of phosphates, and features which suggest that it may have once been part of a much larger body. Results released in the last few weeks suggest that such a world may have had briny water features, perhaps suggesting an icy origin in something rather like Saturn's moon Enceladus.

For a great review of the OSIRIS-REx mission at a popular level, see 'Asteroid Hunter' by Dante Lauretta, 2024 Grand Central Publishing.

Early results are given by Lauretta et al 2024, 'Asteroid (101955) Bennu in the laboratory: Properties of the sample collected by OSIRIS-REx', Meteoritics and Planetary Science

Recent papers on Bennu's chemistry:

https://ui.adsabs.harvard.edu/abs/2025NatAs...9..199G/abstract

https://ui.adsabs.harvard.edu/abs/2025Natur.637.1072M/abstract

5. Donaldjohanson revisited

On Monday, we got our first images back from the Lucy flyby. They show, as expected, a complicated world, consisting of two lobes joined together in what seems to be a contact binary. To my eye, it's somewhat reminiscent of asteroid Toutatis, which was visited by the Chang'e 2 craft as it flew past Earth in 2012.

One of the lobes seems heavily cratered, while the smaller of the two does not, though I suspect that might be a trick of the light. Early speculation is that this sort of shape might be the natural consequence of gravity acting on a rubble pile, producing lobes of this sort of size which can then gently merge together early in their history. Much more will be learnt as data is returned to Earth over the course of the next week or so.

The most up to date source for Lucy is the mission website: https://science.nasa.gov/mission/lucy/