

LUCY: SURVEYING THE DIVERSITY OF TROJANS

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Abstract

The *Lucy* mission, selected as part of NASA's Discovery Program, is the first reconnaissance of the Jupiter Trojans, objects that hold vital clues to deciphering the history of the Solar System. Due to an unusual and fortuitous orbital configuration, *Lucy*, will perform a comprehensive investigation that visits six of these primitive bodies, covering both the L4 and L5 swarms, all the known taxonomic types, the largest remnant of a catastrophic collision, and a nearly equal mass binary. It will use a suite of high-heritage remote sensing instruments to map geologic, surface color and composition, thermal and other physical properties of its targets at close range. *Lucy*, like the human fossil for which it is named, will revolutionize the understanding of our origins.

1. *Lucy's* Comprehensive Tour

Lucy will perform flybys of six Trojans (Tab. 1, Fig. 1) that span the diversity of the Trojan population: (3548) Eurybates, (15094) Polymele, (11351) Leucus, (21900) Orus and the (617) Patroclus-Menoetius binary. *Lucy* will also encounter the Main Belt asteroid (52246) Donaldjohanson. It will launch in 2021 and will have encounters from 2027-2033 (Tab. 2). *Lucy* leverages multiple successful missions: 1. The scientific payload traces heritage to instruments flown on New Horizons, OSIRIS-REx, and Mars Global Surveyor /Mars Expedition Rover, 2. The spacecraft has high heritage from multiple previous missions, 3. The *Lucy* team includes experienced spacecraft (Lockheed Martin), mission (GSFC), and science (SwRI) Operations Teams.

Through its unique tour, *Lucy* will provide crucial input to four of the ten Priority Questions for Planetary Science as expressed by the 2013-2022 Decadal Survey [1] (DS13):

- What were the initial stages, conditions and processes of Solar System formation?
- How did the giant planets accrete, and is there evidence that they migrated to new orbital positions?
- What governed the accretion, and what roles did

bombardment by large projectiles play?
• What were the sources of primordial organic matter?

The Trojan swarms contain a wide variety of small bodies, C-, D-, and P-spectral types. Giant planet migration models indicate that they formed throughout the outer Solar System and were captured in the aftermath of migration [2]. Therefore, it is only by sampling their diversity, as *Lucy* does, that their true scientific potential can be realized.

Lucy's primary science objectives are:

1. Surface composition. *Lucy* will map the color, composition and regolith properties of the surface and determine the distribution of minerals, ices and organic species,
2. Surface geology. *Lucy* will map albedo, shape, crater spatial and size distributions, determine the nature of crustal structure and layering, and determine the relative ages of surface units,
3. Interior and bulk properties. *Lucy* will determine the masses and densities, and study subsurface composition via crater windows, fractures, ejecta blankets, and exposed bedding,
4. Satellite and ring search. *Lucy* will determine the number, size-frequency distribution and location of km-scale satellites and dense rings.

2. Figures

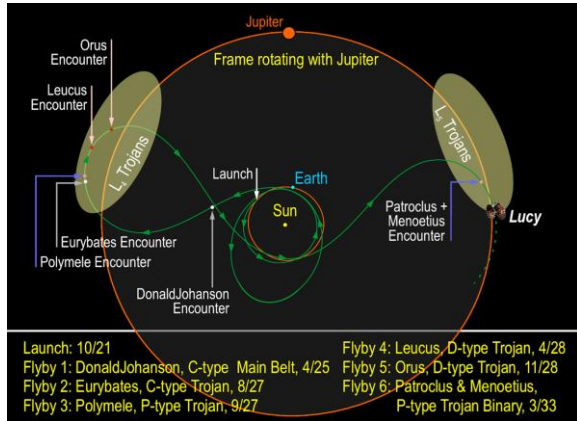


Figure 1: The trajectory of the *Lucy* mission (green) is shown in a frame fixed relative to Jupiter. Dates (month/year) for launch and encounters are noted.

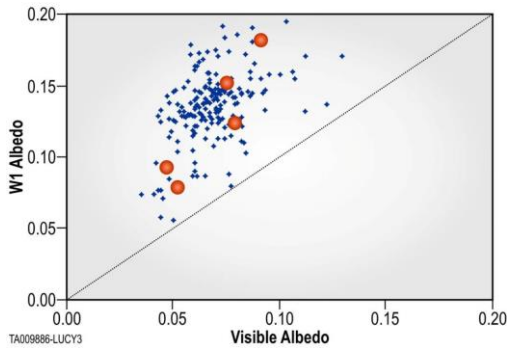


Figure 2: 540 nm and 3.4 μm albedos of the *Lucy* targets (red) are shown with all other Trojans (blue). *Lucy* targets sample the full space of Trojan albedos.

3. Tables

Table 1: Targets

Target	Diameter (km, <i>est.</i>)	Spectral Class	P_{rot} (hr)
Donaldjohanson	3.9	C	-
Eurybates	64.	C	8.7
Polymele	21.	P	6.1
Leucus	34.	D	440
Orus	51.	D	13.5
Menoetius	104.	P	103
Patroclus	113.	P	103

Table 2: Encounter circumstances.

Target	Encounter Date	Velocity (km/s)	Phase Angle*
Donaldjohanson	04/20/25	13.4	15°
Eurybates	08/12/27	5.8	81°
Polymele	09/15/27	6.0	82°
Leucus	08/18/28	5.9	104°
Orus	11/11/28	7.1	126°
Menoetius	03/02/33	8.8	56°
Patroclus	03/02/33	8.8	56°

*Approach

4. Summary

Because of their unique location near Jupiter and the critical role they play in revealing and constraining models of the formation and evolution of the Solar System, Trojans have been a high priority for space missions for over a decade. This is evidenced by calls for their reconnaissance by spacecraft in DS13 and the 2014 NASA Science Plan. Both documents identify a survey of the diversity of Trojan asteroids as one of the highest priority missions to small bodies. *Lucy* will accomplish the related goals of DS13 and the NASA Science Plan with a high-heritage, low-risk spacecraft and science payload.

References

- [1] Visions and Voyages for Planetary Science in the Decade 2013-2022. National Research Council, National Academies Press (2011).
- [2] Levison, H. F., et al.: Origin of the structure of the Kuiper belt during a dynamical instability in the orbits of Uranus and Neptune, *Icarus*, Vol. 196, pp. 258-273, 2008.