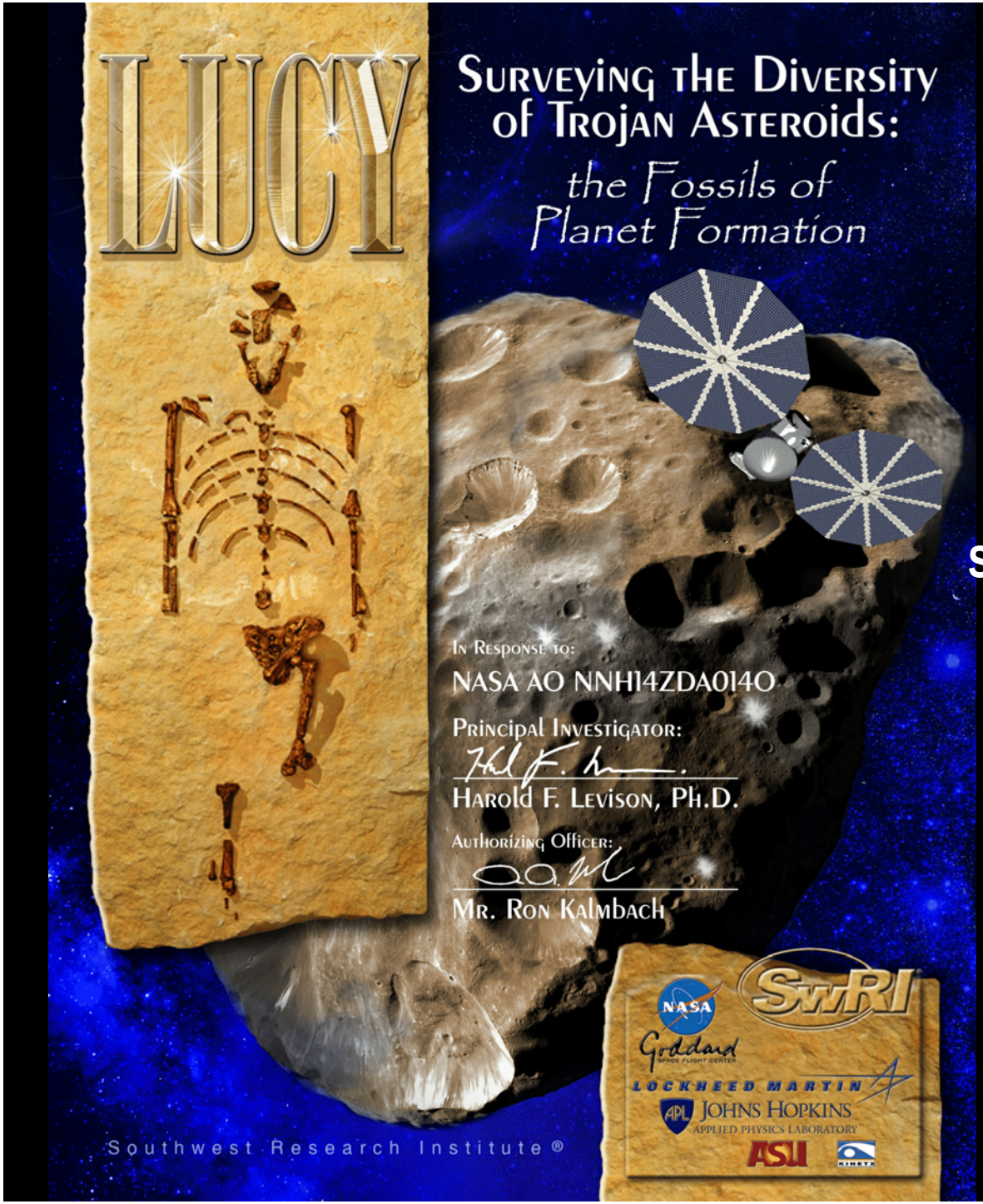


PI: Hal Levison

DPI: Cathy Olkin (SwRI)
SwRI Manager: John Andrews

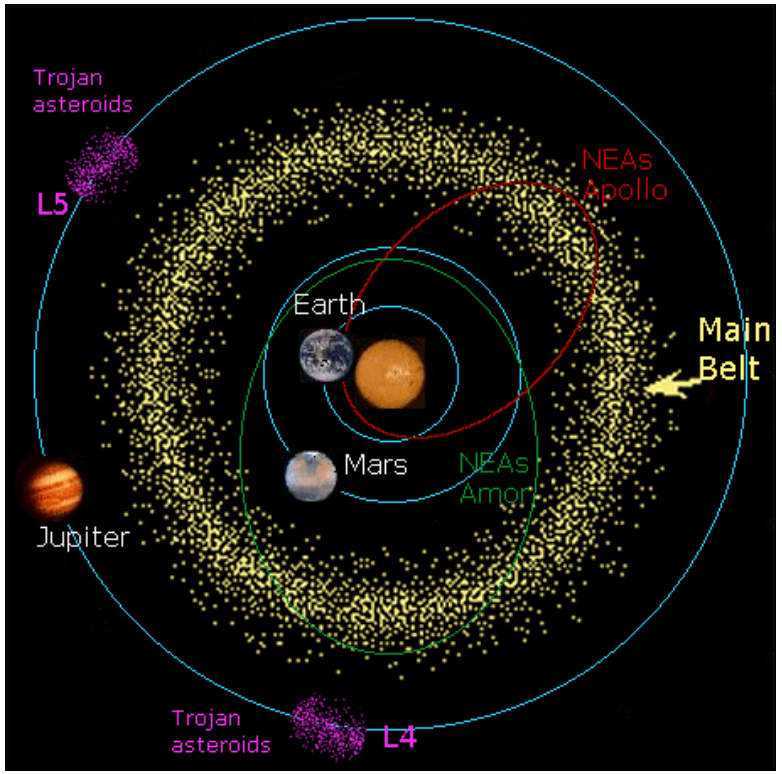
PM: Mike Donnelly (GSFC]
DPM: John Loiacono [GSFC]

S/C Provider: LM

LUCY

Surveying the Diversity of Trojans

- Lucy is a Trojan asteroid tour
  - Called for in Decadal Survey
  - It will perform flybys of 6 Trojans.
- Its strengths are:
  - High science return from never before encountered objects.
  - Low risk mission – high heritage.
  - Low cost mission – costs fit comfortably within AO constraints.
  - Timely – unique opportunity in launch window gets multiple high-value Trojans.



- 2021 launch, encounters from 2025-2033.

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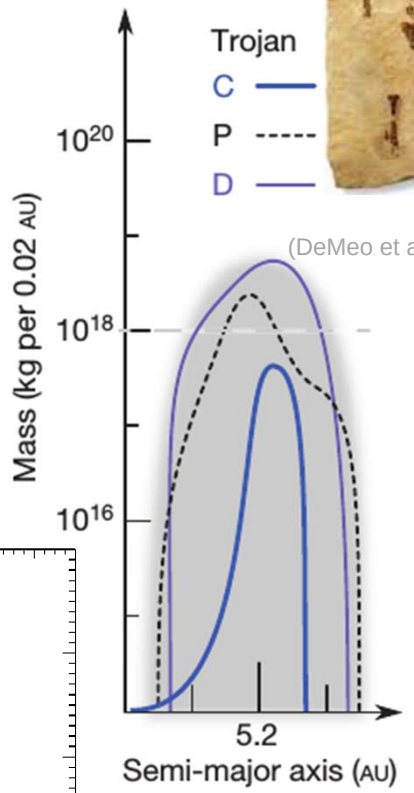
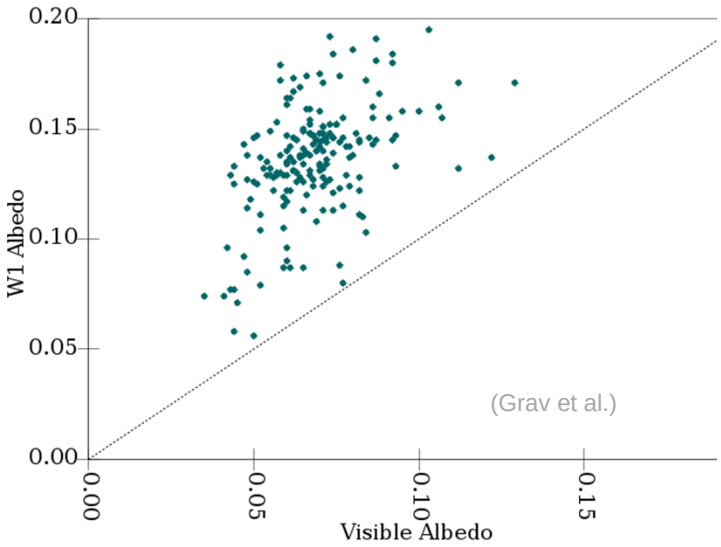
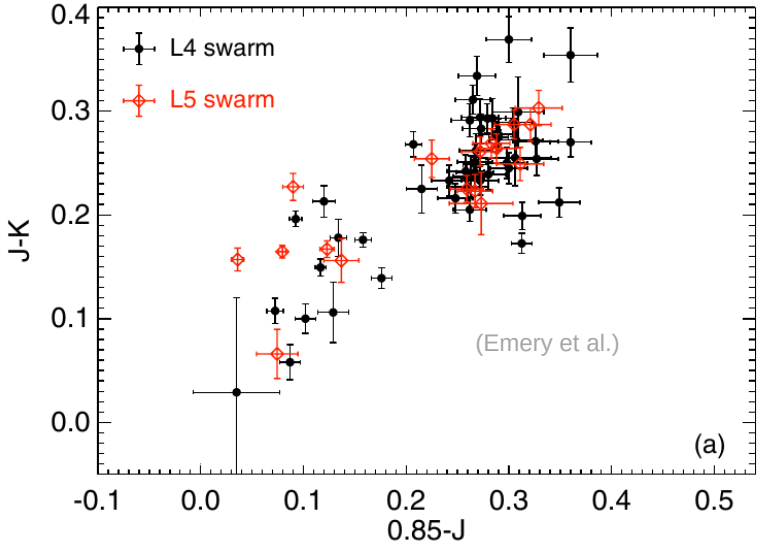
Science Motivation

- To boldly go where no one has gone before.
  - We have never seen one close up.
- Trojans are remnants of giant planet formation.
- They are not a monolithic population, however.
  - Contain C-, D-, and P-type spectral types.
  - Have albedos from ~4 - ~15%
  - Wide range of colors – also bimodal.

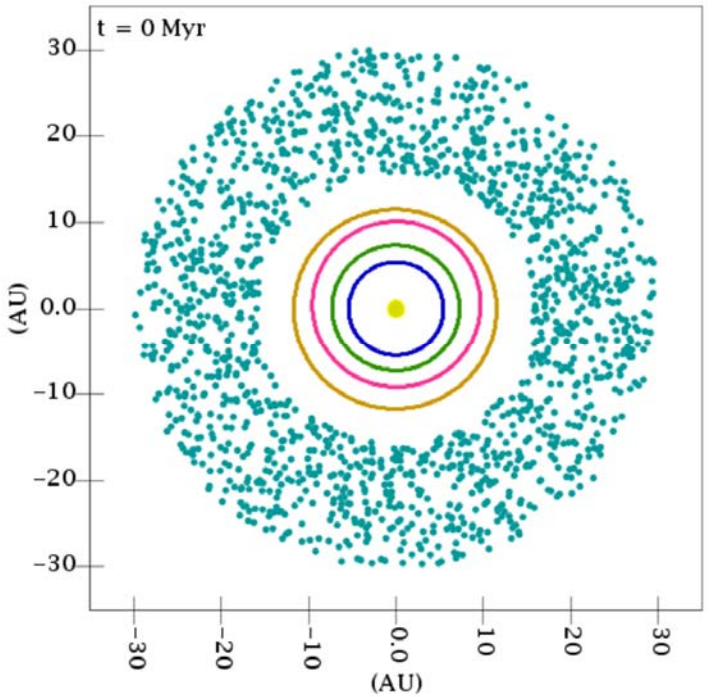


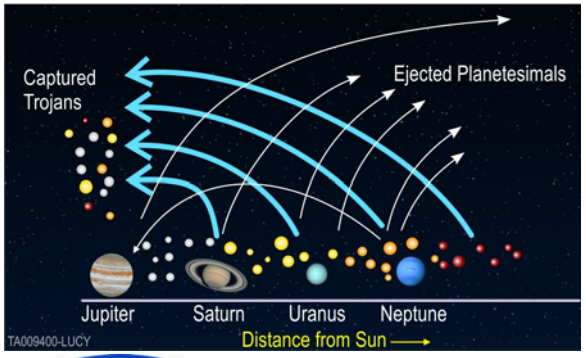




Science Motivation (cont)

- Trojans present us with a UNIQUE opportunity to constrain planet formation and evolution models
  - ➢ Constrain planet migration models
    - ❖ Ds and Ps are more primitive then Cs
    - ❖ They likely formed at different locations
    - ❖ Were mixed together by planet formation and migration





Trojans likely harbor objects that formed throughout the outer Solar System. **It is only by sampling their diversity that their true scientific potential can be realized.**

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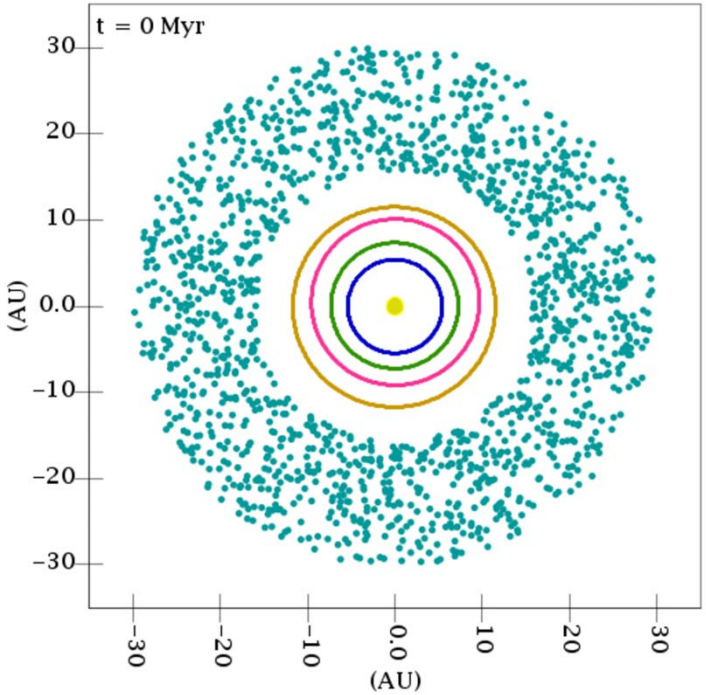

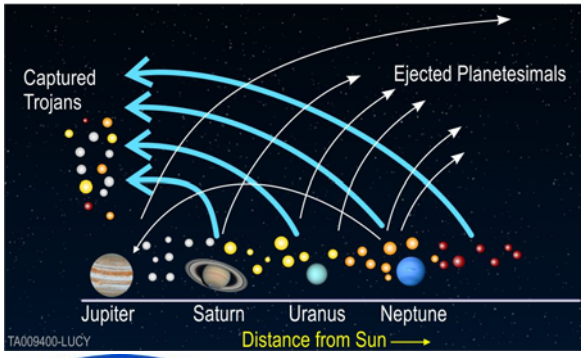

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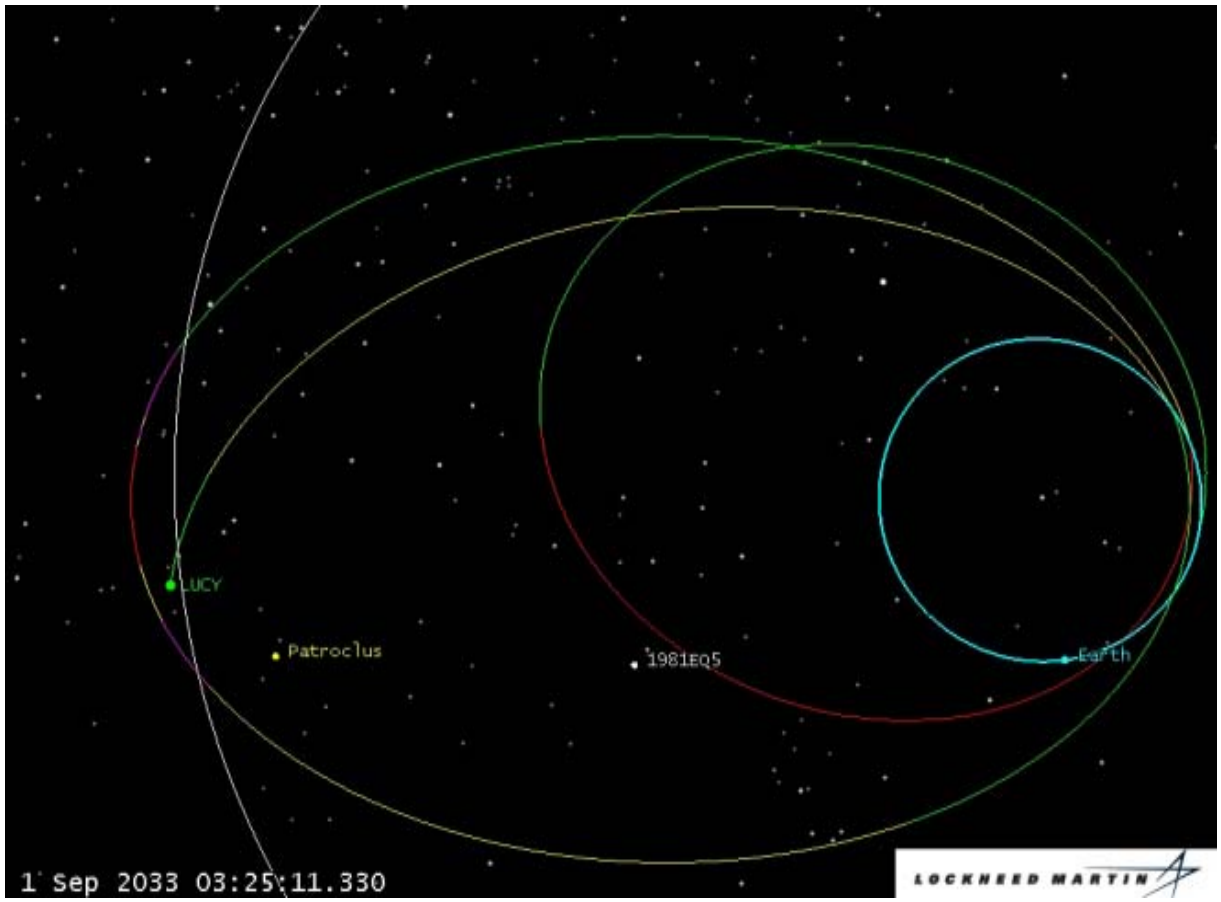
Lucy's Orbit

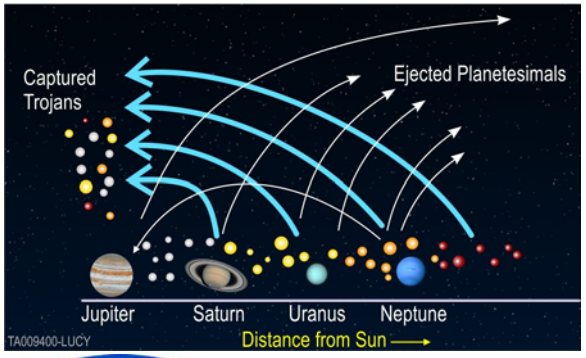
With q~1AU and Q~6AU, Lucy will pass through the 2 swarms on back-to-back orbits



Science Motivation (cont)

- To boldly go where no one has gone before.
- Compare **all** Trojans types.
  - Contain C-, D-, and P-type spectral types.
- Trojans present us with a UNIQUE opportunity
  - To study Cs, Ds, and Ps in the same environment
  - Constrain planet migration models
    - Ds and Ps are more primitive then Cs
    - They likely formed at different locations
    - Were mixed together by planet formation and migration

(DeMeo et al.)



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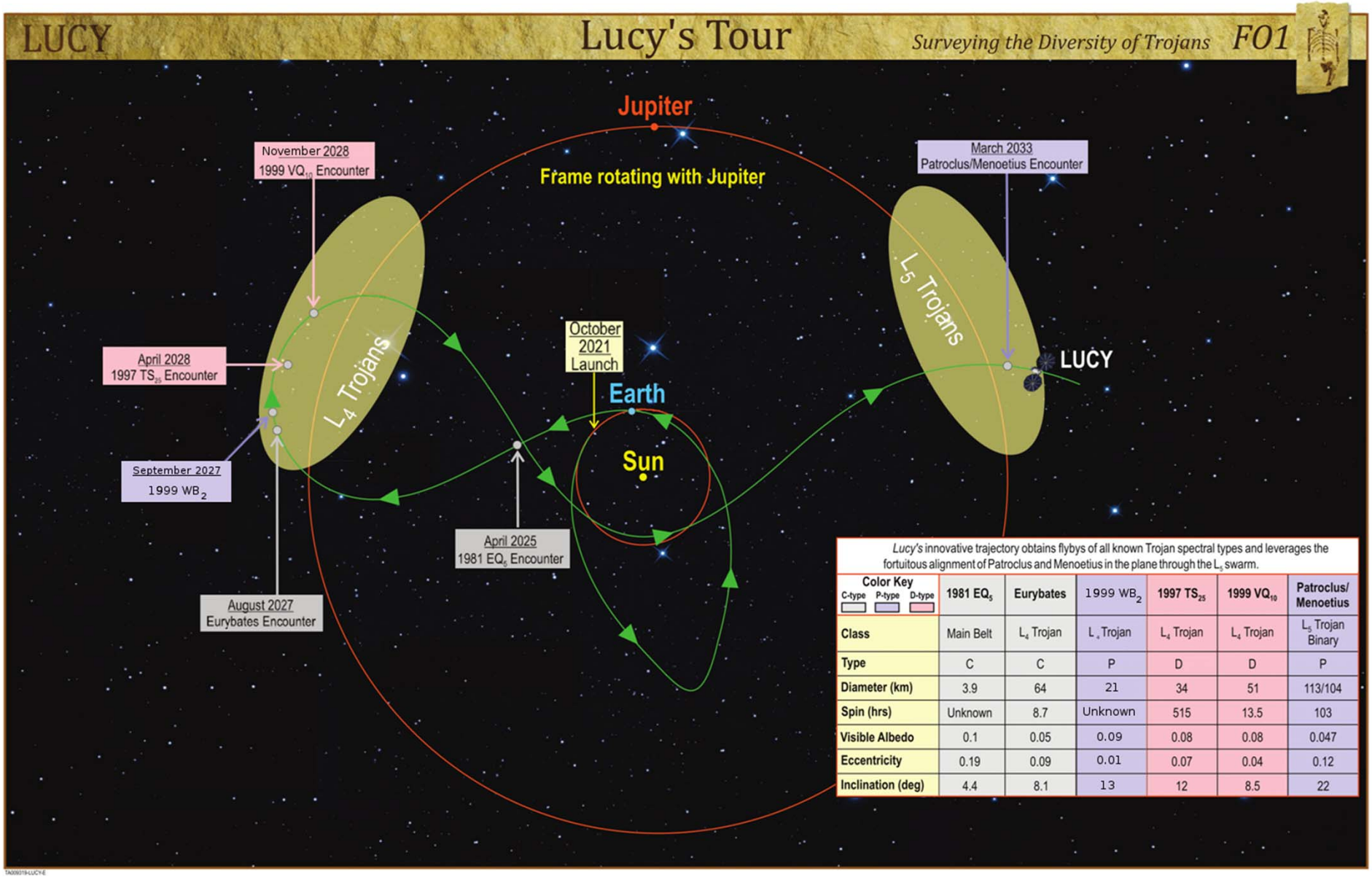
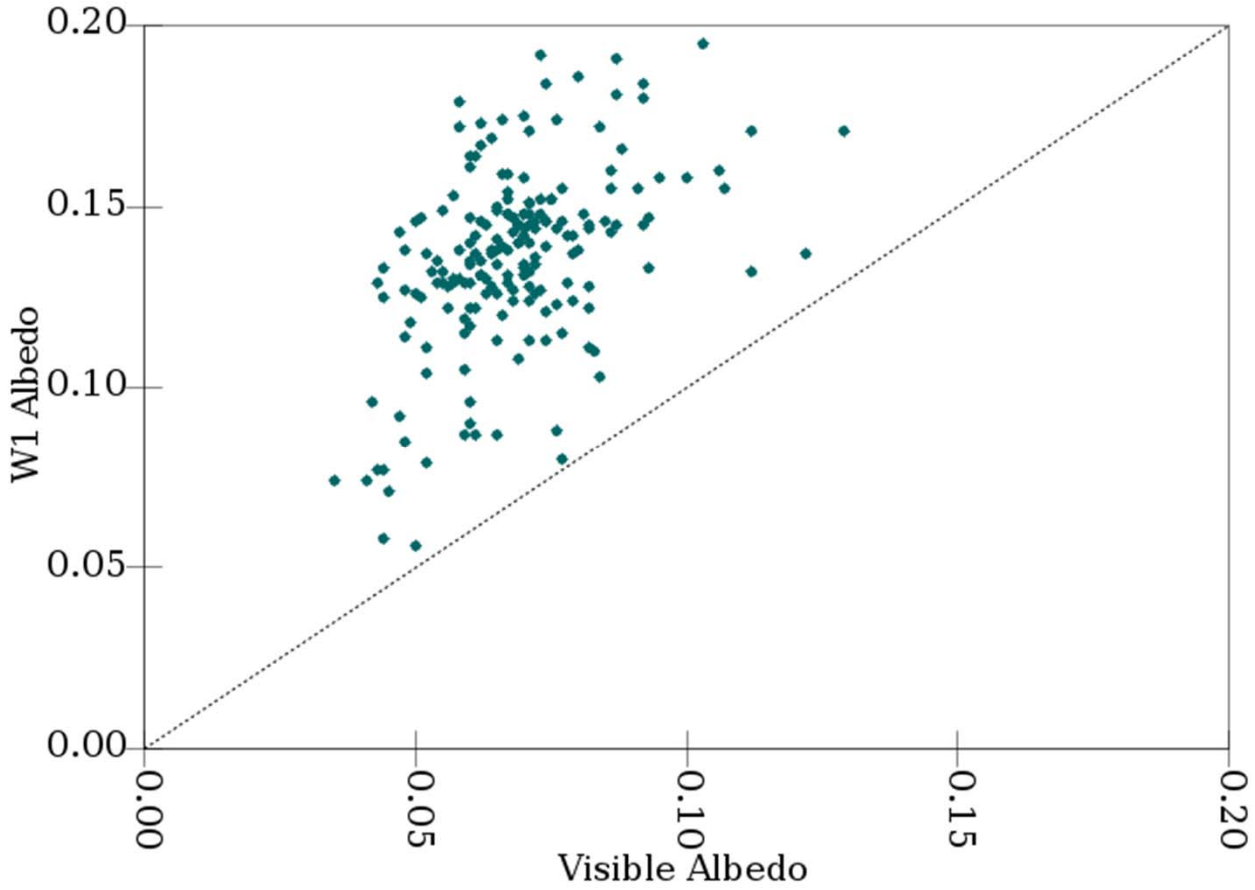


Lucy's innovative trajectory obtains flybys of all known Trojan spectral types and leverages the fortuitous alignment of Patroclus and Menoetius in the plane through the L_5 swarm.

Color Key (C-type, P-type, D-type)	1981 EQ_5	Eurybates	1999 WB_2	1997 TS_{25}	1999 VQ_{10}	Patroclus/ Menoetius
Class	Main Belt	L_4 Trojan	L_4 Trojan	L_4 Trojan	L_4 Trojan	L_5 Trojan Binary
Type	C	C	P	D	D	P
Diameter (km)	3.9	64	21	34	51	113/104
Spin (hrs)	Unknown	8.7	Unknown	515	13.5	103
Visible Albedo	0.1	0.05	0.09	0.08	0.08	0.047
Eccentricity	0.19	0.09	0.01	0.07	0.04	0.12
Inclination (deg)	4.4	8.1	13	12	8.5	22

- All known spectral types - Both the L_4 and L_5 swarms

Lucy's Coverage



(Grav et al.)

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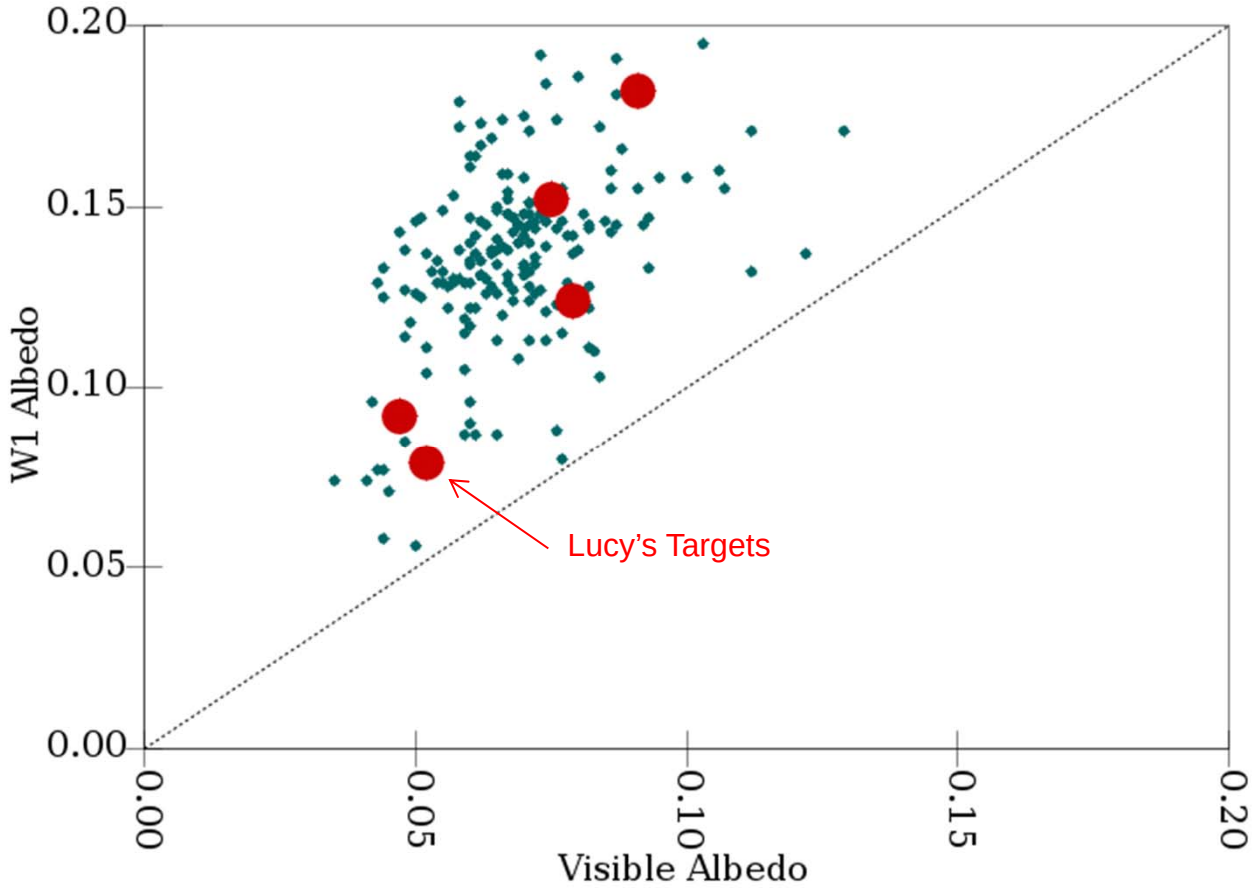
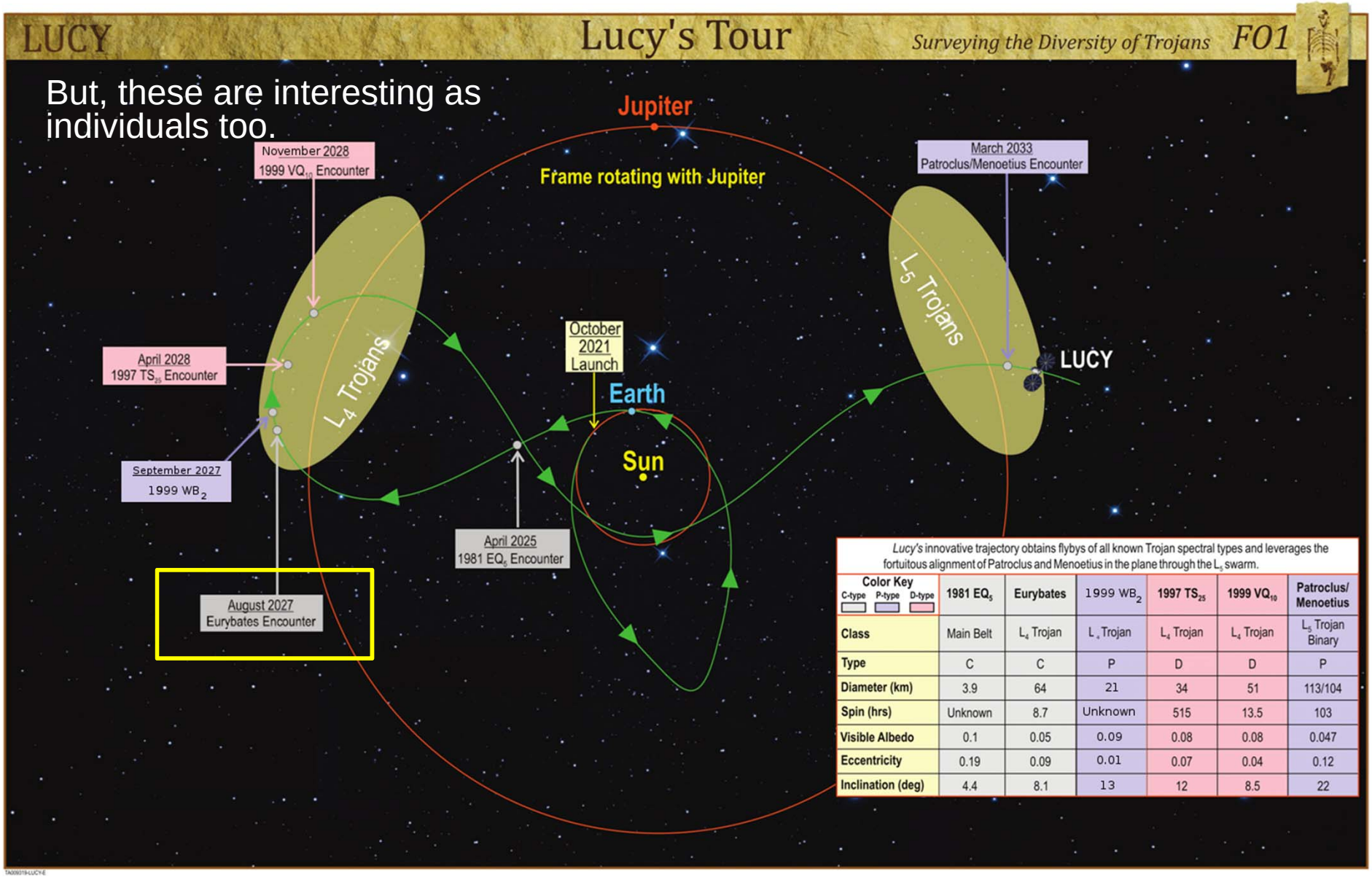
Lucy's Coverage



(Grav et al.)

But, these are interesting as individuals too.



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Inclination (deg)	4.4	8.1	13	12	8.5	22

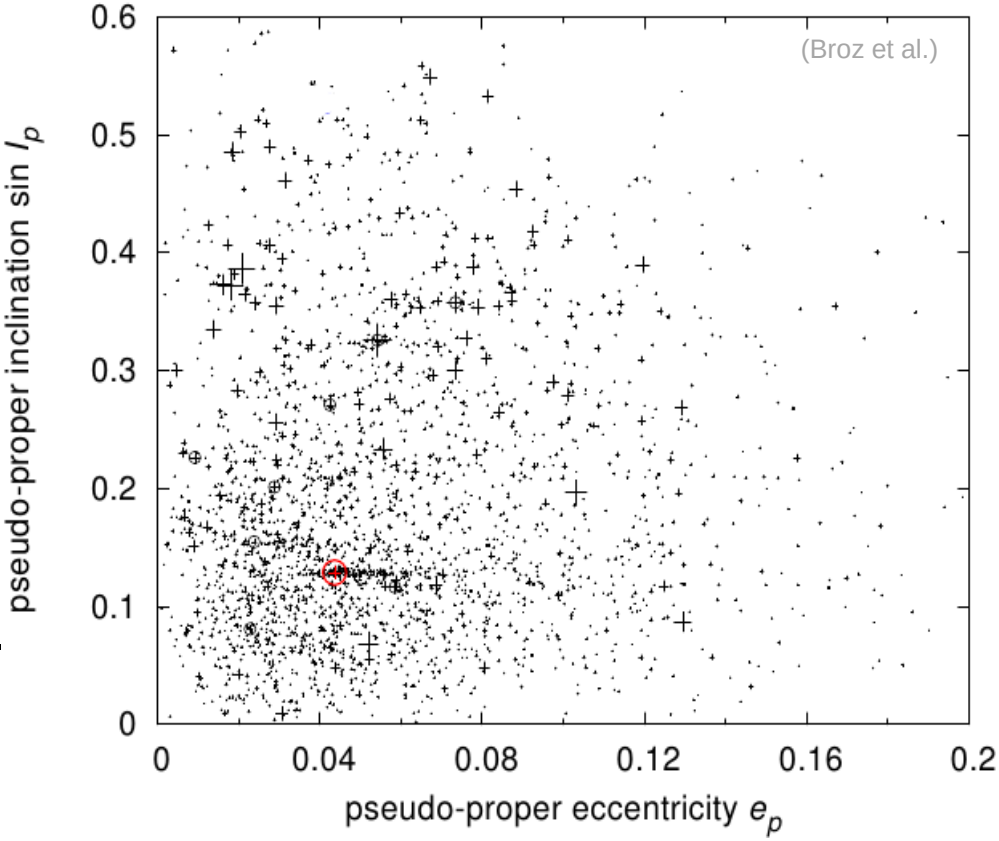
- All known spectral types - Both the L_4 and L_5 swarms

The Mystery of Asteroid Families

(3548) Eurybates is the largest member of the only major disruptive collisional family.

- We have never visited such an object before.
- Will give unique insight into collisional processes

•Eurybates is a C-type?!?
- Rare in the Trojans.
- No D-type families in asteroid belt.
- Perhaps D's disintegrate when hit.
- Perhaps D's become C's when hit.
- Lucy will help understand this.



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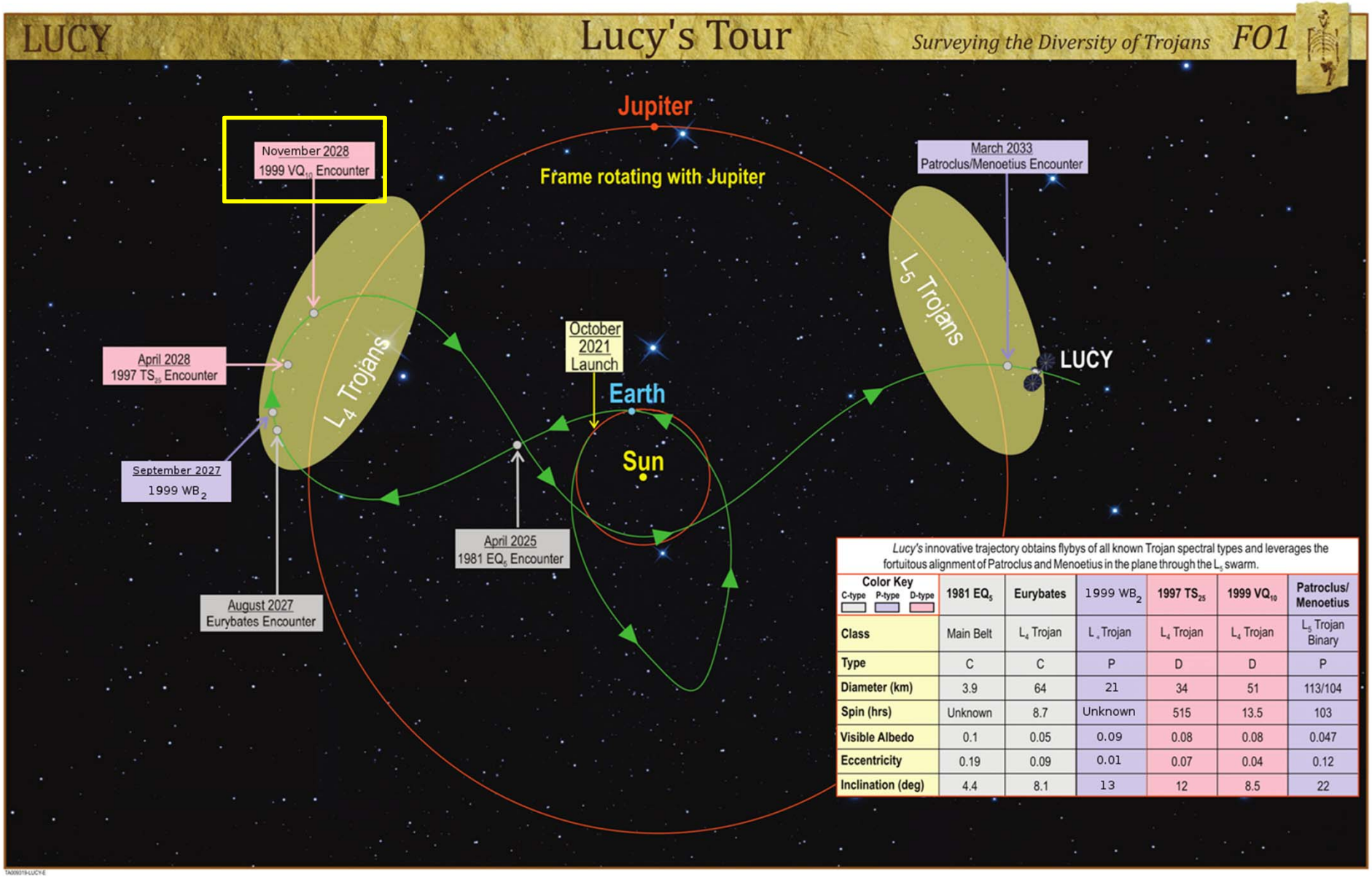

- All known spectral types - Both the L_4 and L_5 swarms
- Disruptive collision remnant

The Perfect Couple

	(3548) Eurybates	(21900) 1999 VQ_{10}
H	9.8	9.9
D	64 km	51 km
P rot	8.7 hr	13.5 hr
e	0.09	0.04
i	8.1 deg	8.5 deg
type	C	D (color)
p_v	0.05	0.08
Color	gray	red

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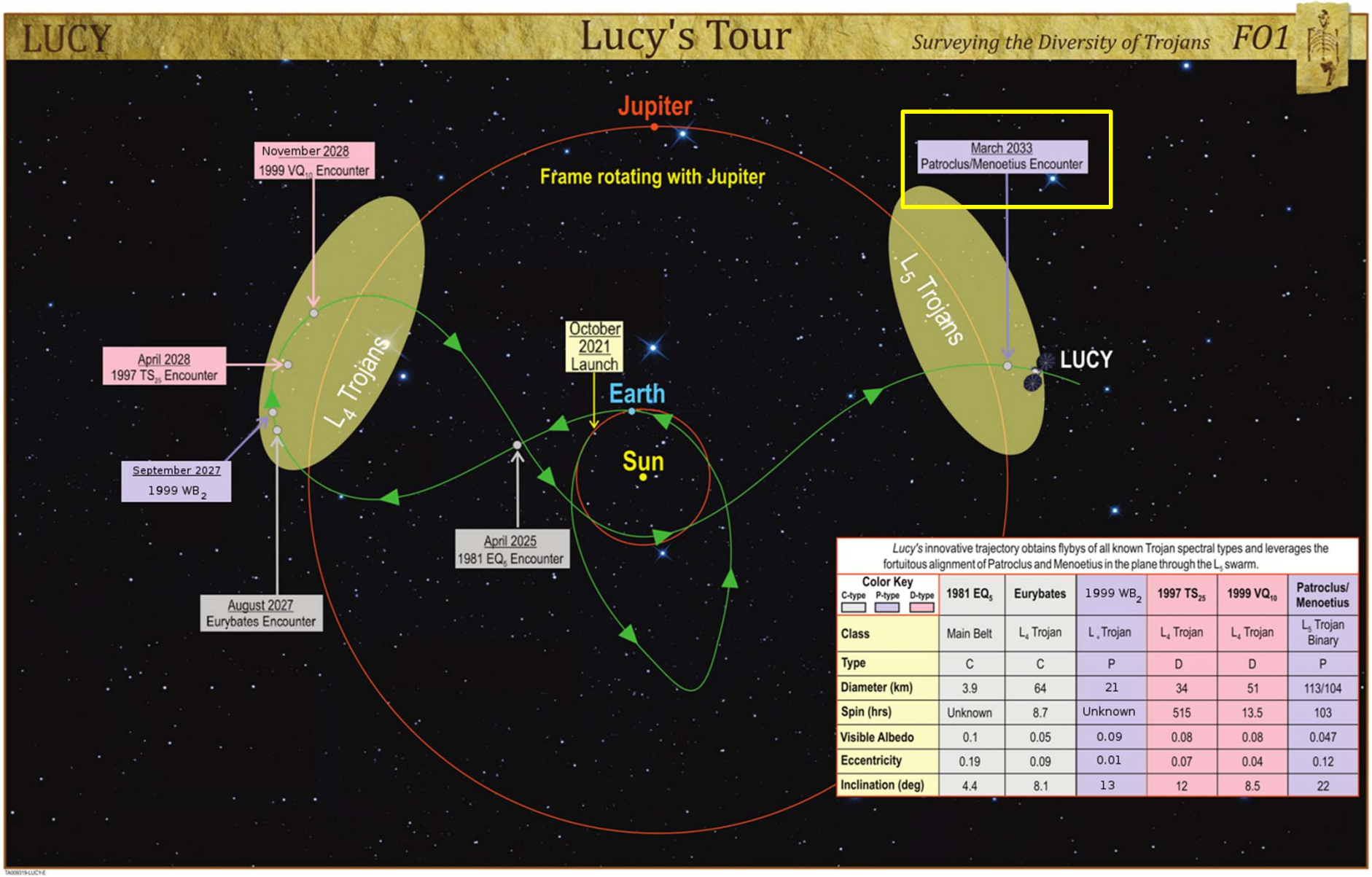
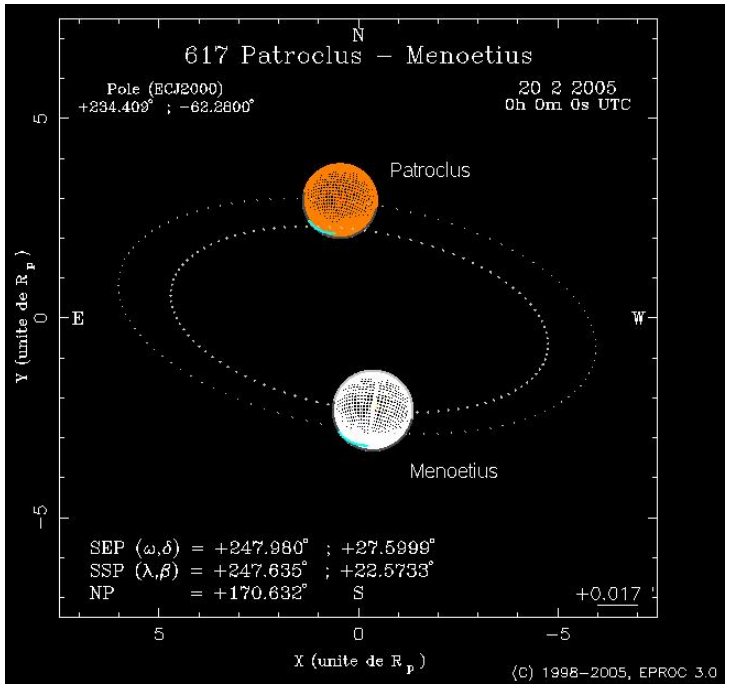


- All known spectral types - Both the L_4 and L_5 swarms
- Disruptive collision remnant

Pièce de Résistance

We have been amazingly lucky and found multiple other targets that make this a much richer mission!

	(617) Patroclus and Menoetius
H	8.2
Dia	141 km & 112 km
P rot	4.3 days
e	0.14
i	22 deg
type	P

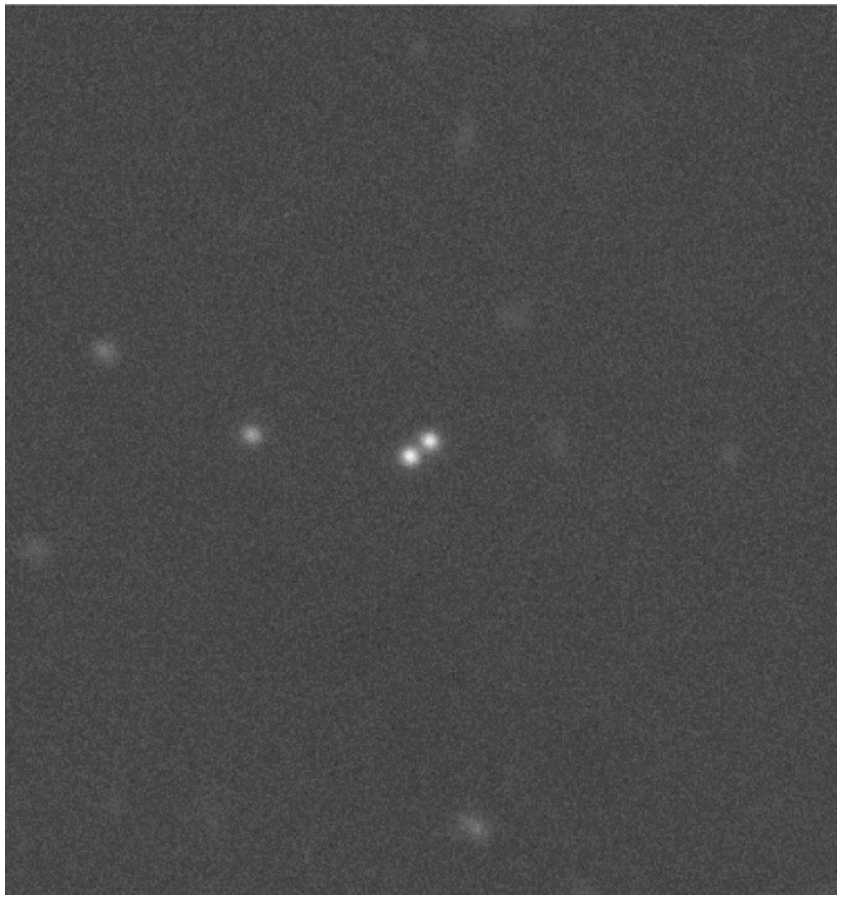


The Mystery of Equal Mass Binaries

Many Cold Classical KBOs are equal mass binaries

- Most undisturbed population in the Solar System.
  - Most objects formed this way?
- Their formation is a mystery.
  - Classical ideas don't work.
  - Most successful idea relies on pebble accretion.

- (617) Patroclus is very similar.
  - It will give insight into how these things came to be.



We will also be able to go to these Trojans.

	(15094) 1999 WB_2	(11351) 1997 TS_{25}
	L_4 Trojan	L_4 Trojan
H	11.6	10.7
Dia	21 km	34 km
a	5.2 AU	5.2 AU
e	0.10	0.07
i	13.0 deg	11.6 deg
type	P (color)	D (color)
p_v	0.09	0.08

We cover diversity in the L_4 swarm alone.

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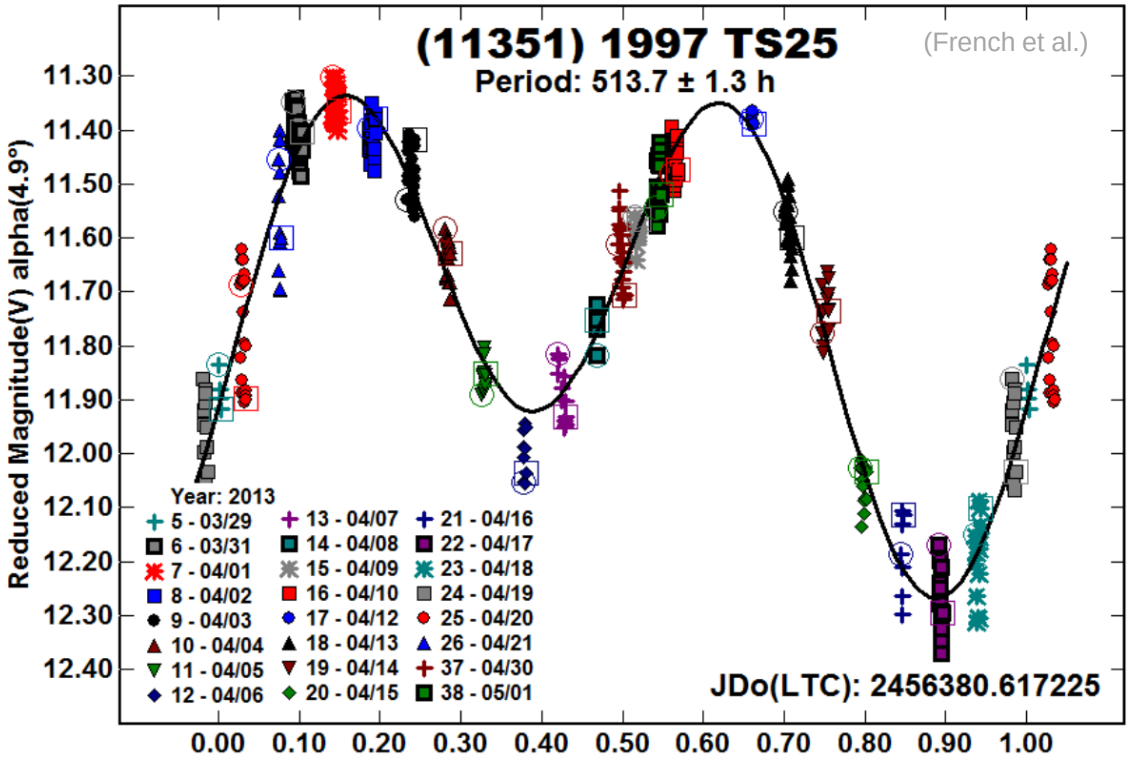
TS_{25} is a strange bird



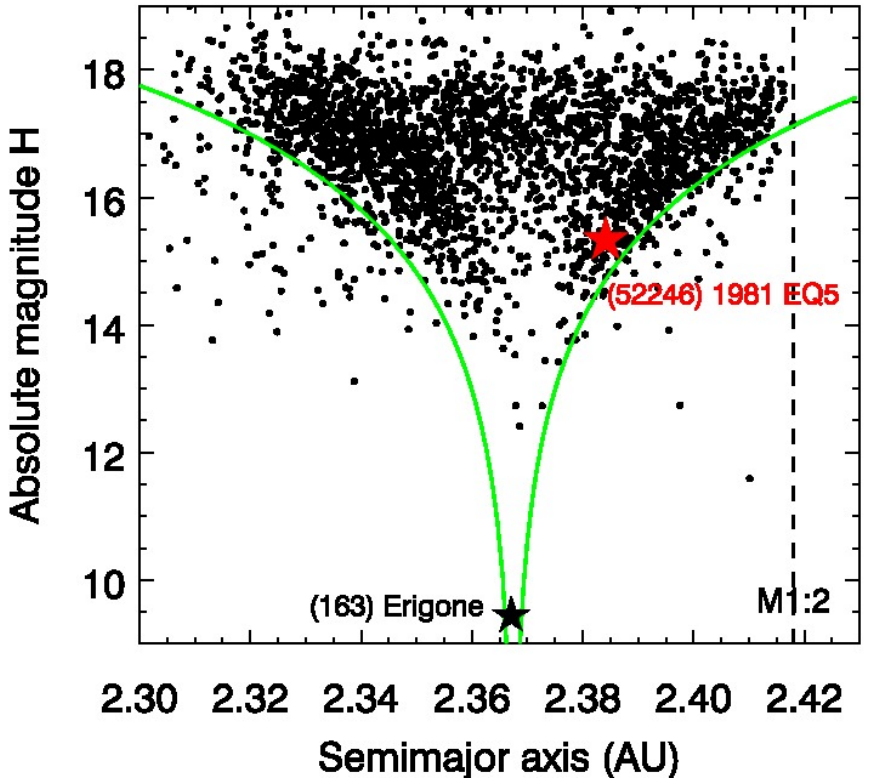
- Extremely long period (514 hr).
- Huge amplitude (1 mag)! Also it is asymmetric (?).
  - Remember this object is 34 km.
- Potential second 53 hr period → Satellite?

1981 EQ_5 - Not Just Another Pretty Face

We will also visit a main belt asteroid, 1981 EQ_5

- Intended simply to test our procedures.
- However, it is a member of the ~100Myr Erigone family

- We will get to see a young surface.
  - Fresh craters will help us understand collisional evolution of asteroid belt.
  - It will constrain space weathering.
  - Will help us understand the Yarkovsky forces.



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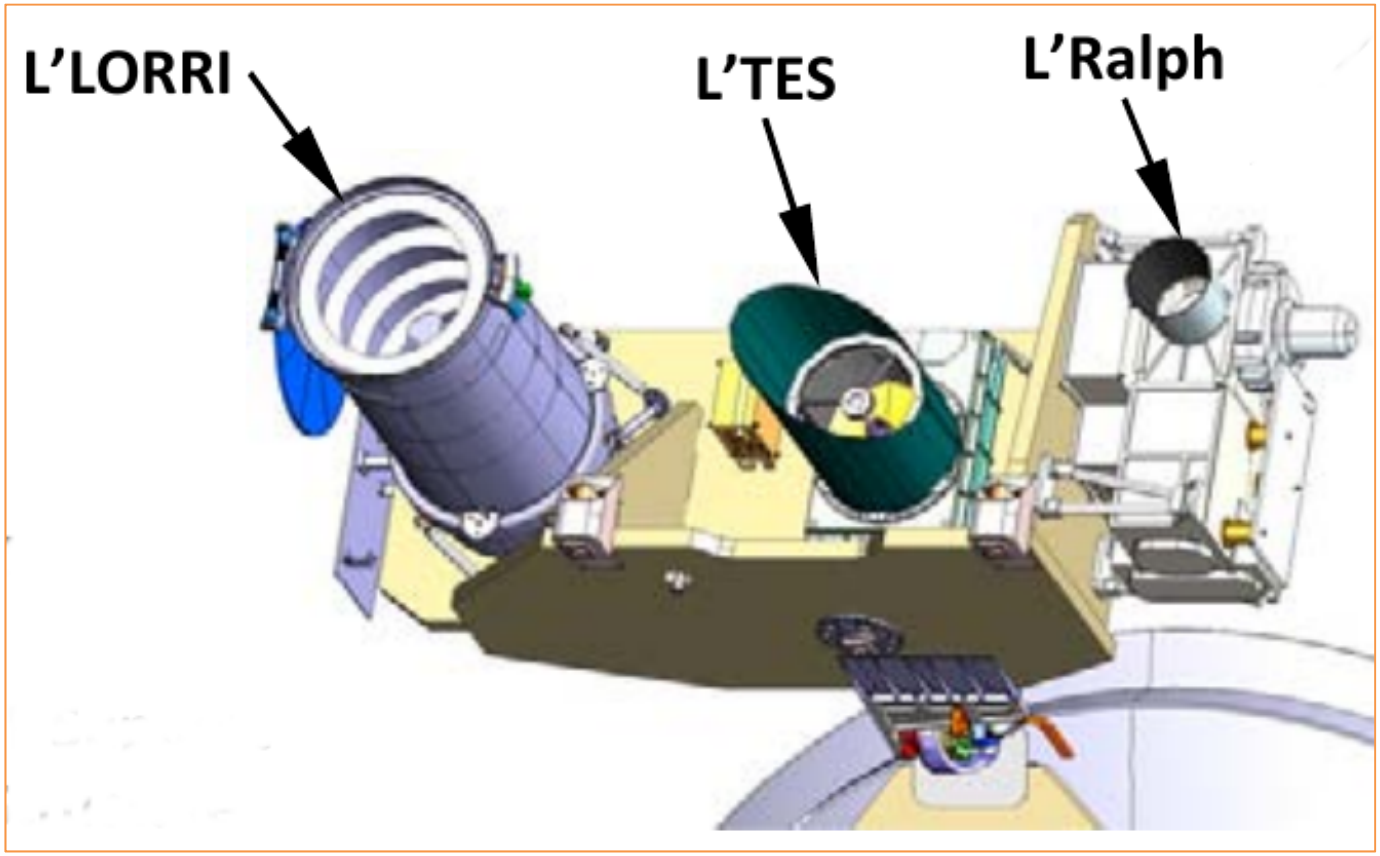
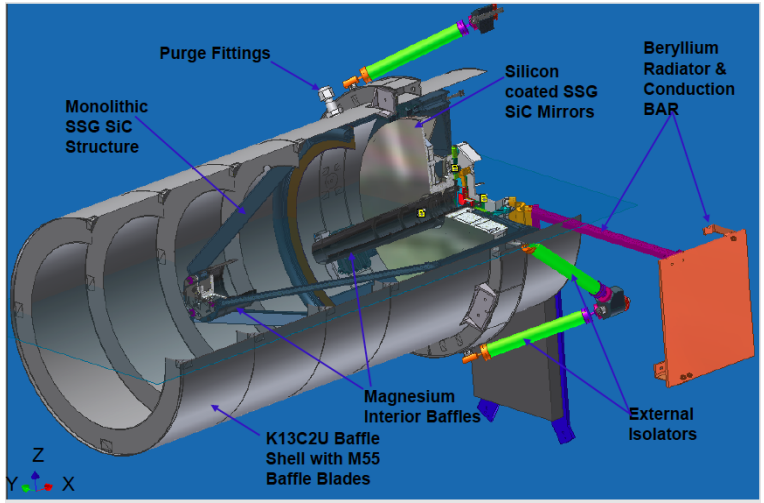
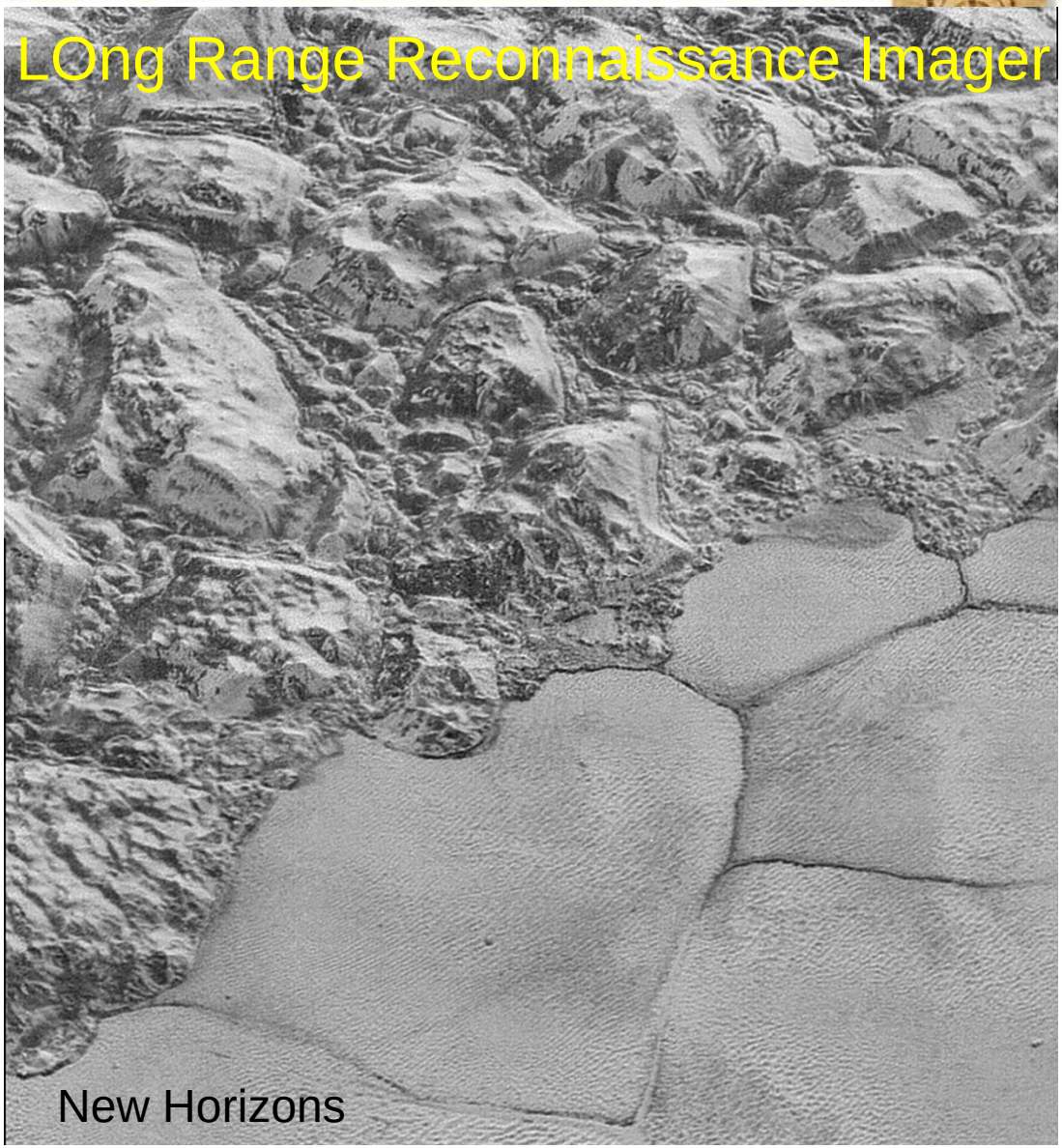
Payload



L'LORRI

- Heritage: New Horizons
- Provider: APL
- Average Power: 4.7 W
- Mass: 9 kg
- Volume: 65.0 x 42.2 x 42.5 cm
- IFOV: 5 µrad
- FOV: .29 x .29 deg
- Panchromatic 0.35 – 0.85µm





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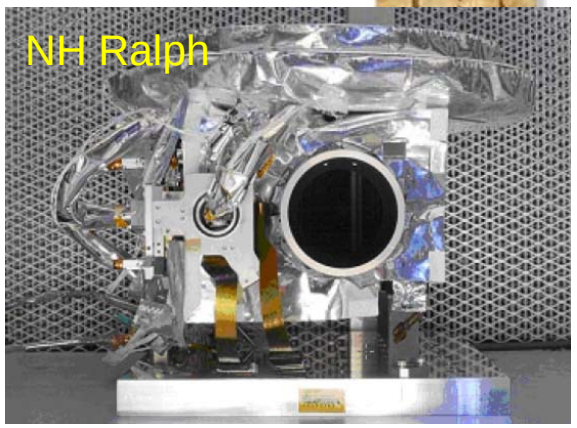
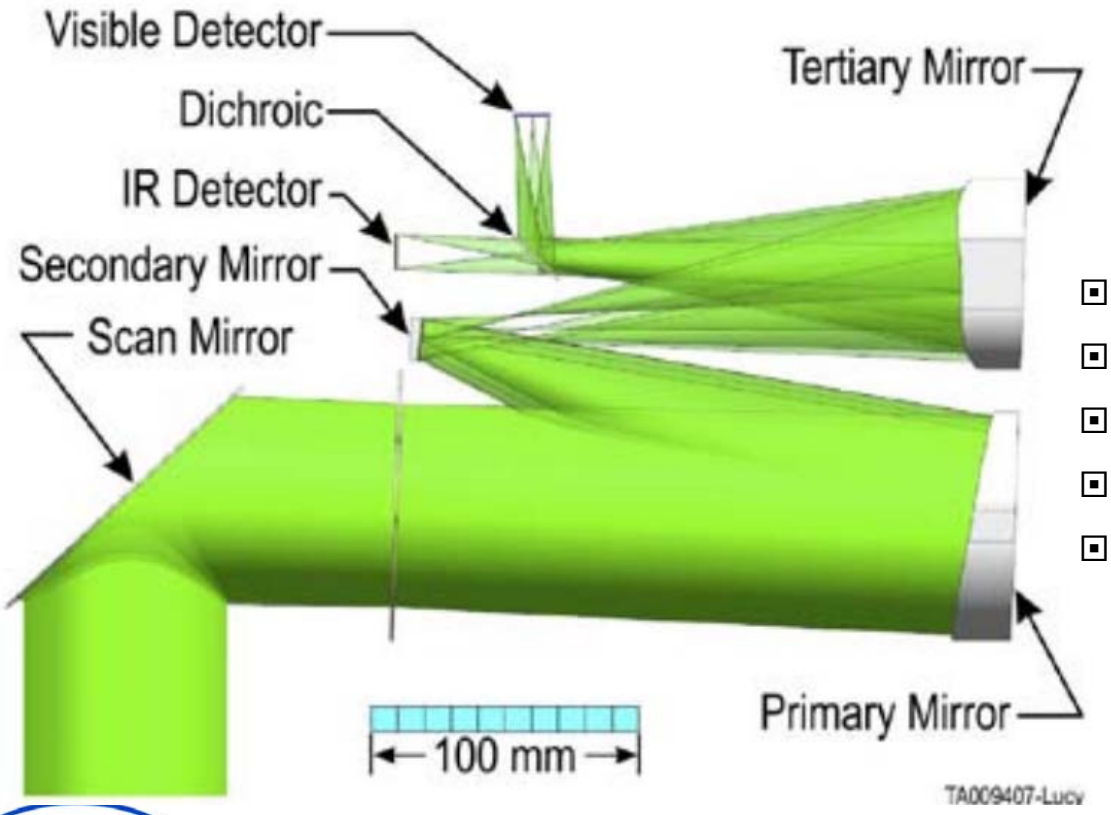
L'Ralph

- Visible: Multi-spectral Visible Imagining Camera (MVIC)
- NIR: Linear Etalon Imaging Spectral Array (LEISA)





- Provider: GSFC
- Heritage: NH, O'REX
- Average power: 8.1 W
- Mass: 15.6 kg
- Volume: 37.3 x 48.5 x 30.5 cm

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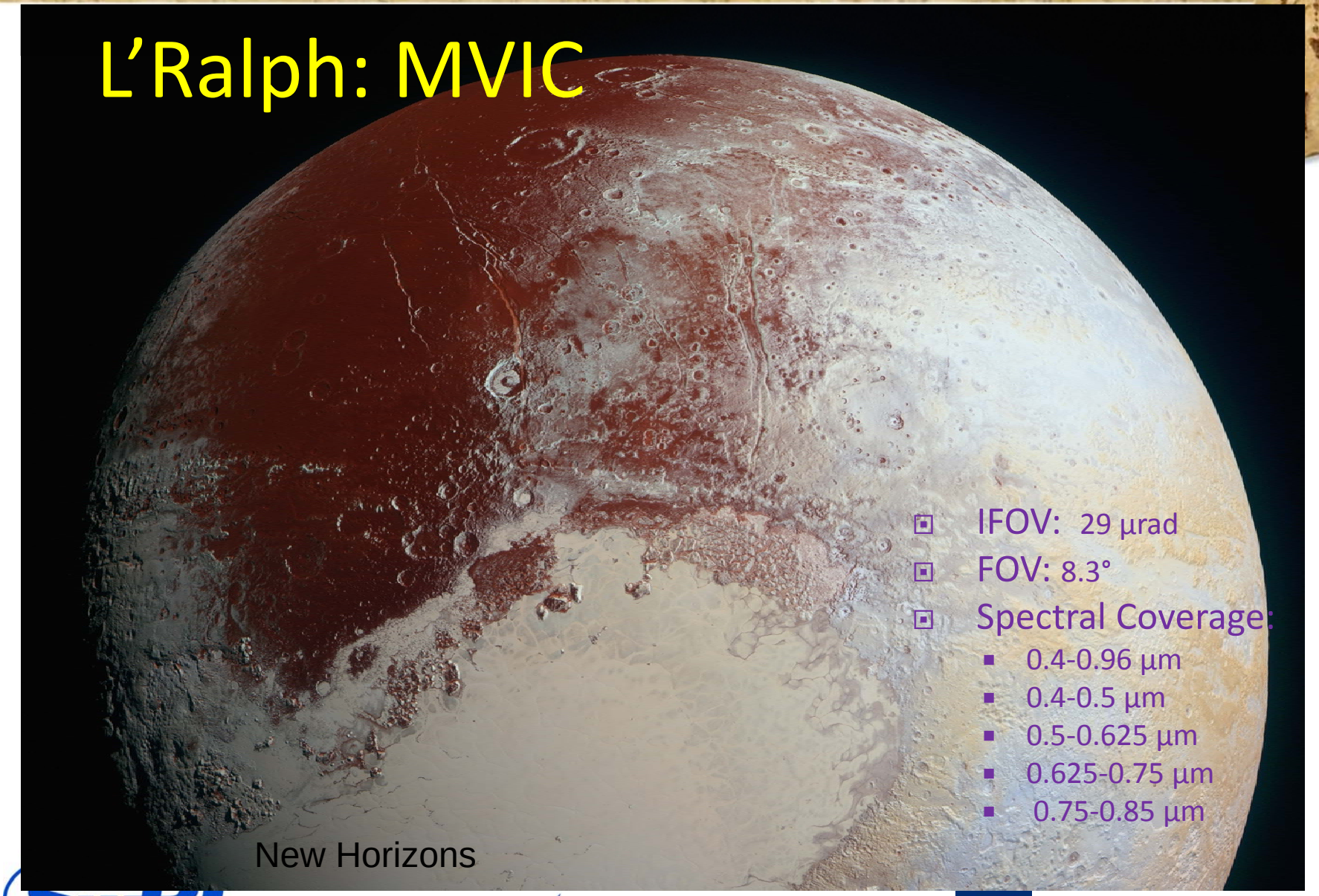
L'Ralph: MVIC



- IFOV: 29 µrad
- FOV: 8.3°
- Spectral Coverage:
  - 0.4-0.96 µm
  - 0.4-0.5 µm
  - 0.5-0.625 µm
  - 0.625-0.75 µm
  - 0.75-0.85 µm

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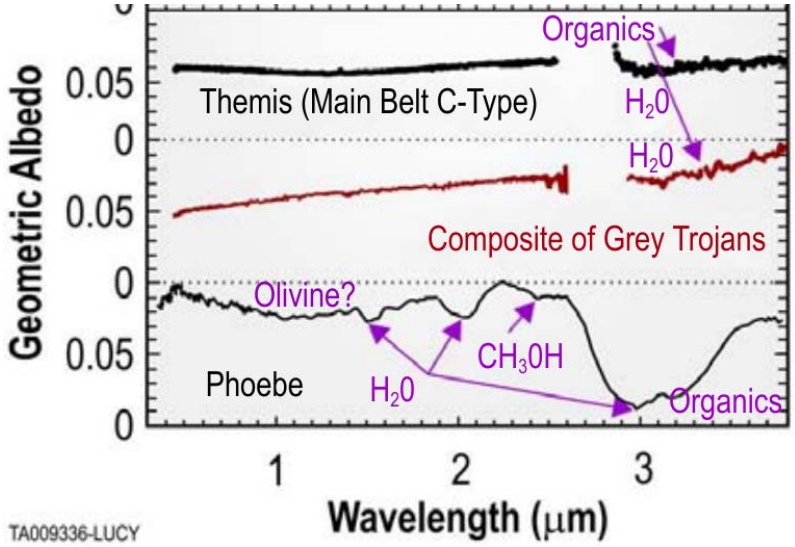
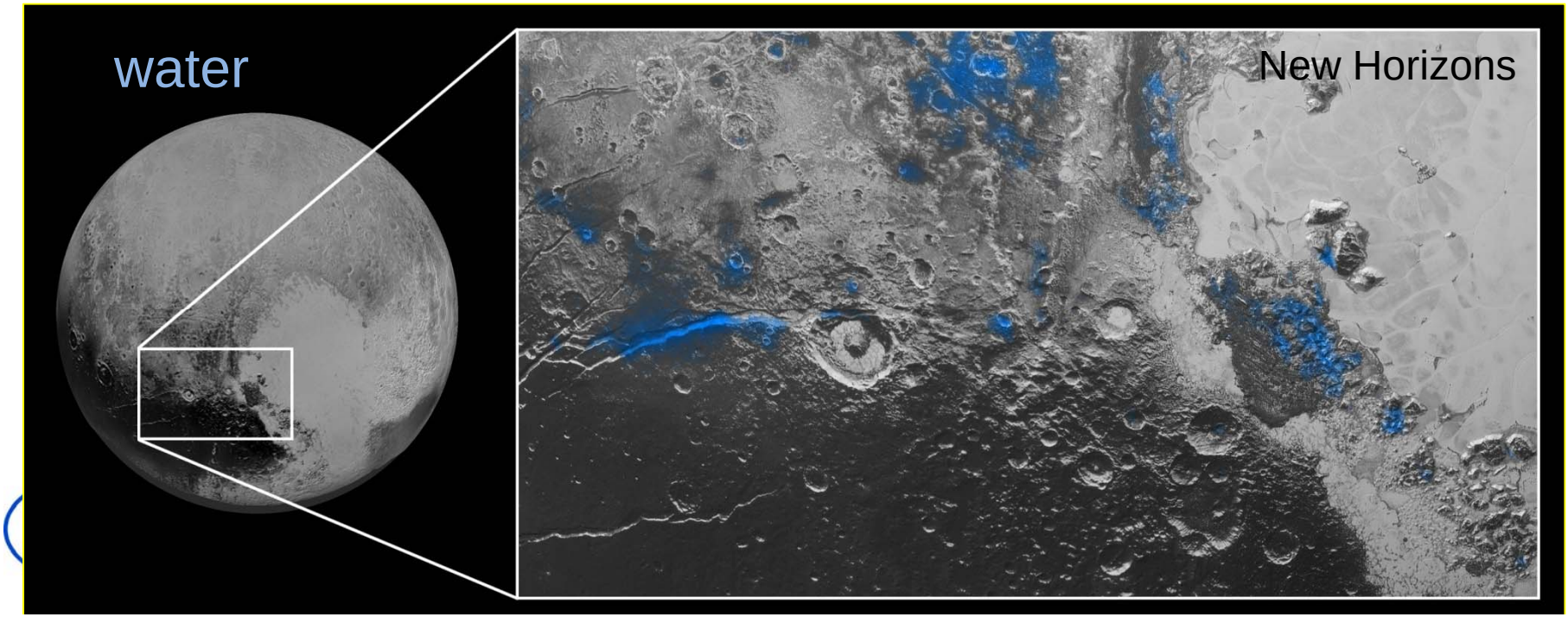
L'Ralph: LEISA

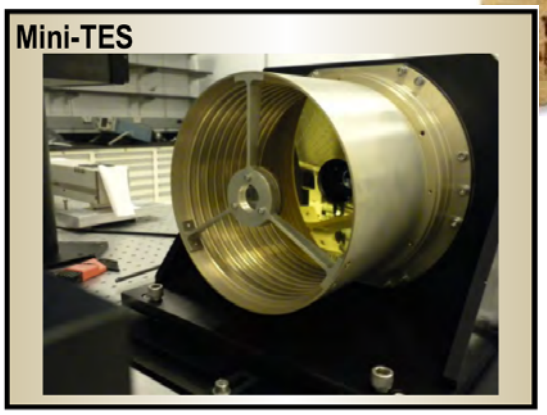
- IFOV: 80 µrad
- FOV: LEISA 4.6°x3.2°
- Spectral Coverage: 1.0-3.6 µm

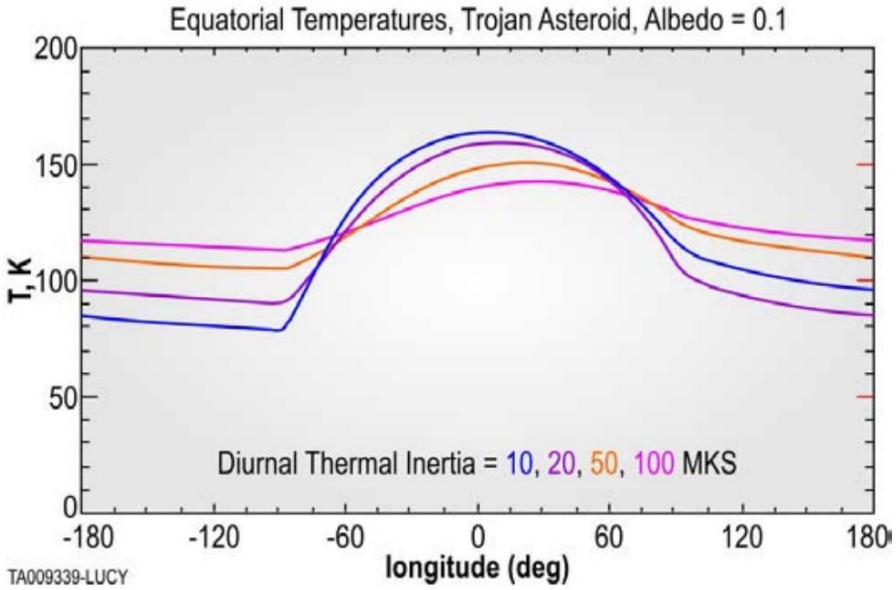


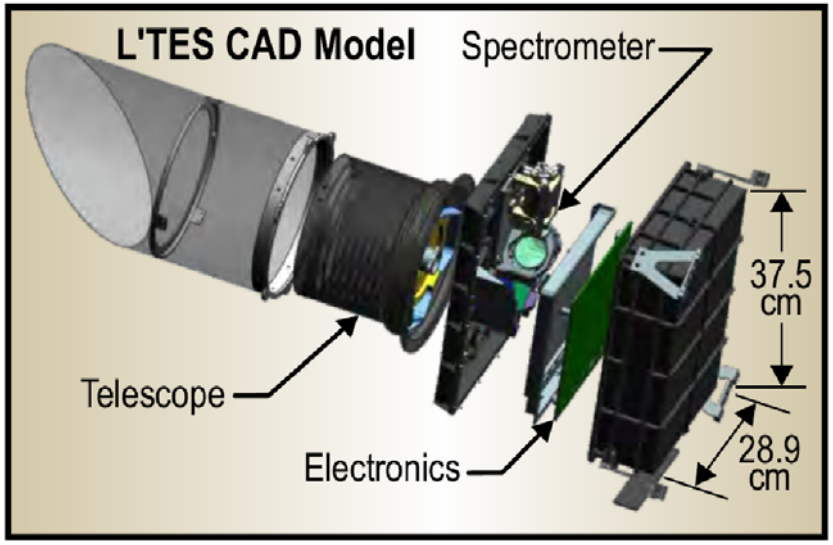


L'TES

- Thermal Emission Spectrometer
  - Provider: ASU
  - Heritage: O'REX, MGS
  - Average Power: 11.9 W
  - Mass: 6.2 kg
  - Volume: 28.9 x 37.5 x 51.2 cm
  - Spectral Range: 6 – 100 um
  - FOV: 8 mrad (single channel)







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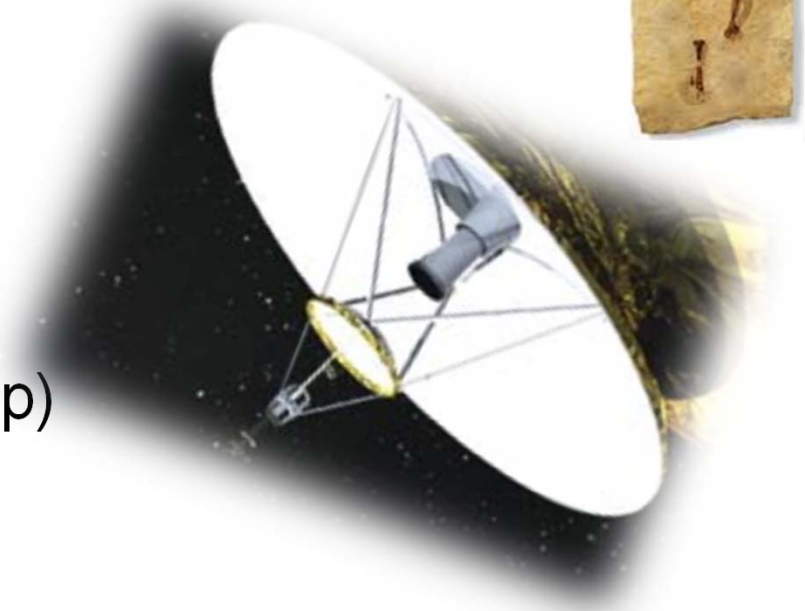
Radio Science

- Radioscience EXperiment



- Measures target masses
- 2-way measurement (i.e. round trip)
- Onboard telecom system
- Ground antenna network

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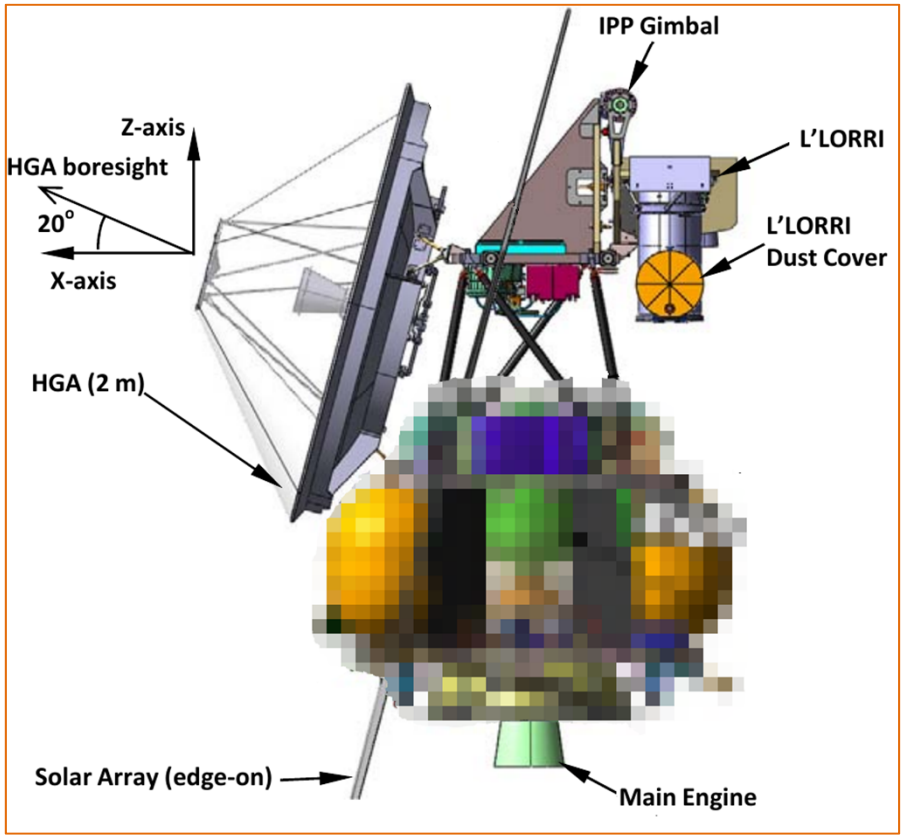
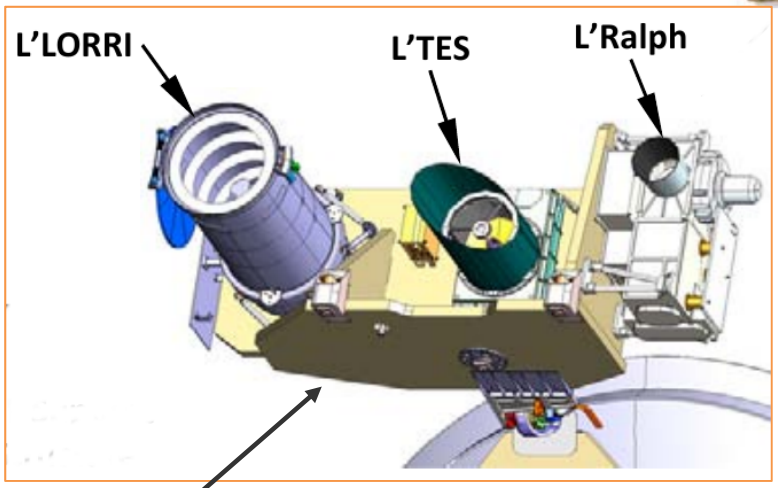
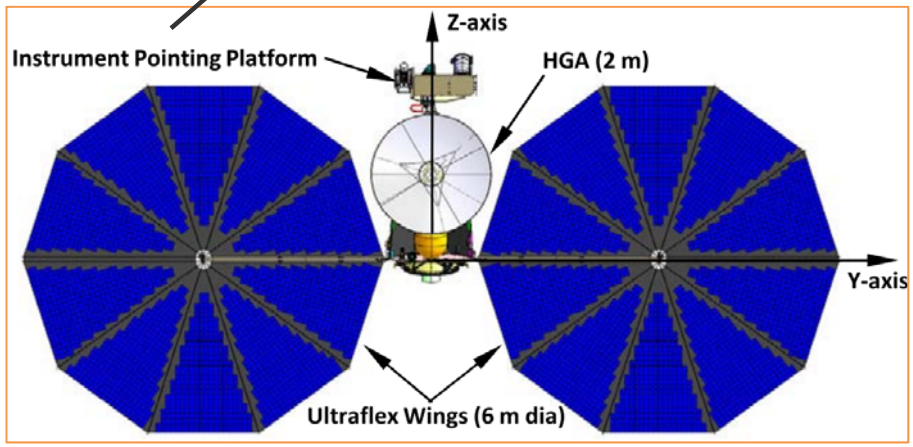
Spacecraft







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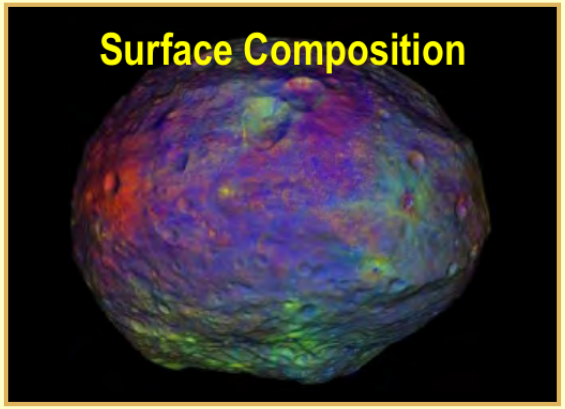
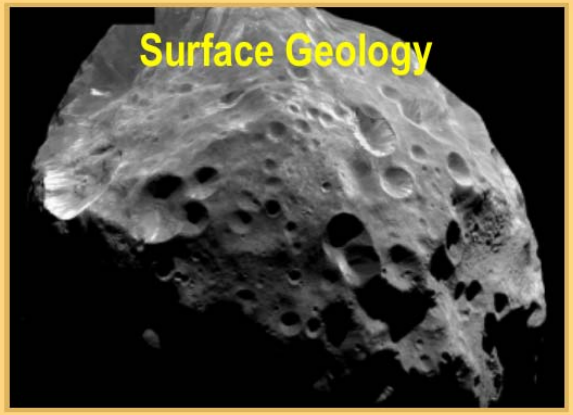
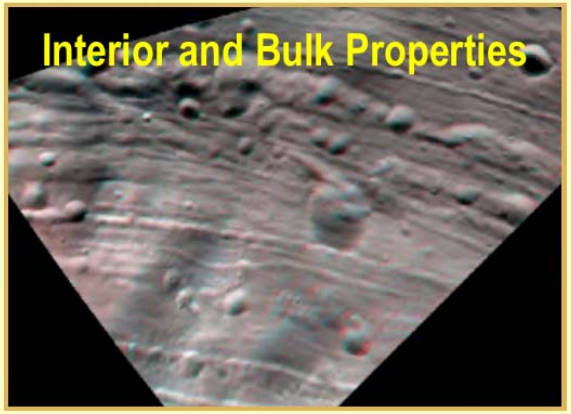
Science Objectives



Lucy will map the color, composition and regolith properties of the surface and determine the distribution of minerals, ices and organics species.



Lucy will map albedo, shape, crater spatial and size-frequency distributions, determine the nature of crustal structure and layering, and determine the relative ages of surface units.



Lucy will determine the masses and densities, and study sub-surface composition via crater windows, fractures, ejecta blankets, and exposed bedding.

We will also look for rings and satellites

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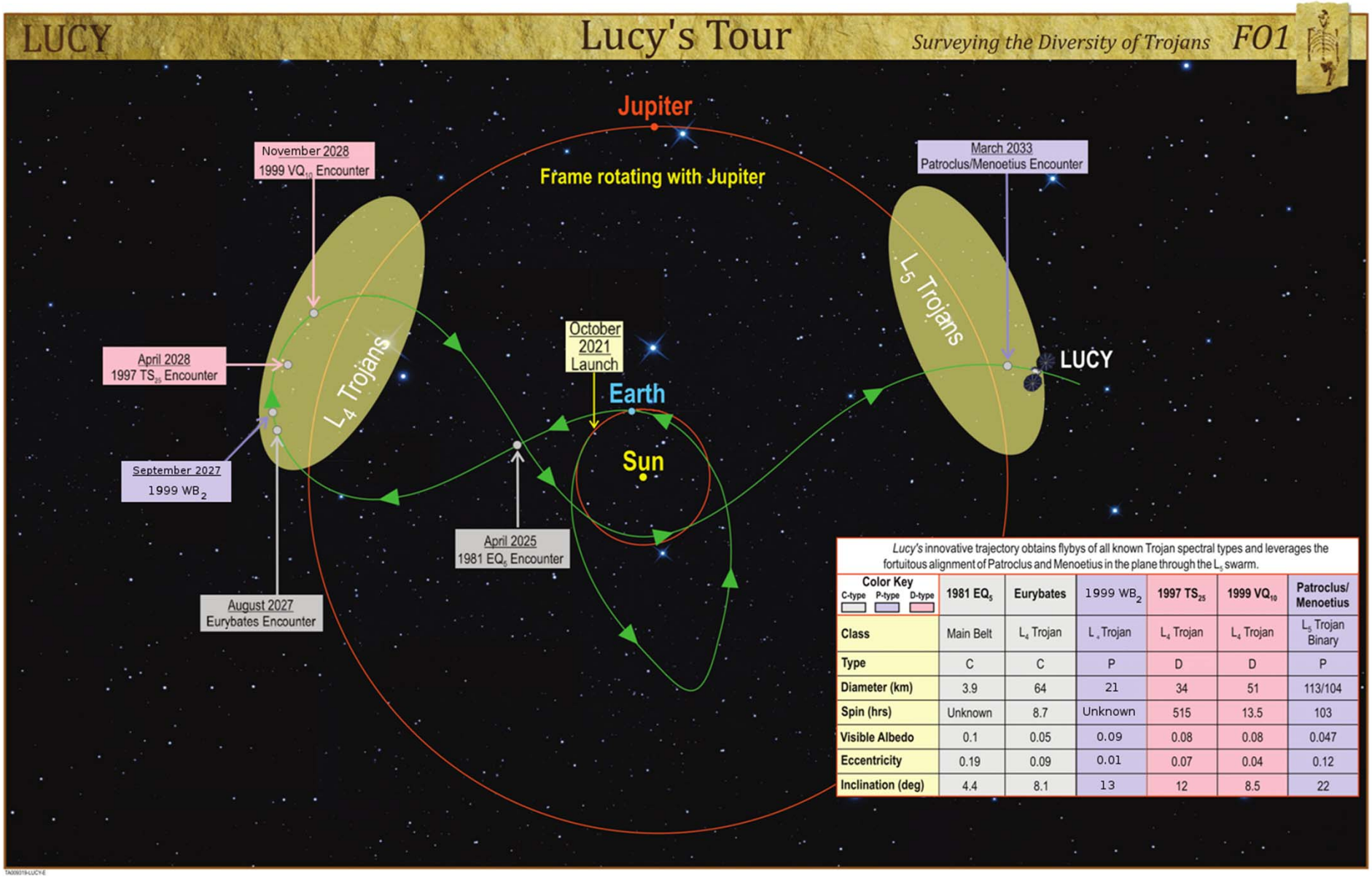

Lucy's innovative trajectory obtains flybys of all known Trojan spectral types and leverages the fortuitous alignment of Patroclus and Menoetius in the plane through the L_5 swarm.

Color Key (C-type, P-type, D-type)	1981 EQ_5	Eurybates	1999 WB_2	1997 TS_{25}	1999 VQ_{10}	Patroclus/ Menoetius
Class	Main Belt	L_4 Trojan	L_4 Trojan	L_4 Trojan	L_4 Trojan	L_5 Trojan Binary
Type	C	C	P	D	D	P
Diameter (km)	3.9	64	21	34	51	113/104
Spin (hrs)	Unknown	8.7	Unknown	515	13.5	103
Visible Albedo	0.1	0.05	0.09	0.08	0.08	0.047
Eccentricity	0.19	0.09	0.01	0.07	0.04	0.12
Inclination (deg)	4.4	8.1	13	12	8.5	22

- All known spectral types - Both the L_4 and L_5 swarms
- Near-equal mass binary - Disruptive collision remnant
- Very young MBA.

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We have found a trajectory that visits 6 Trojans and 1 MBA