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Ground Observation of asteroids at mission ETA through JPL Horizons and SPICE

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Abstract

This work presents an integrated approach for enhancing science return of targeted asteroids at spacecraft mission estimated time of arrival (ETA) through JPL Horizons and SPICE to inform ground-based and/or space-based telescope observations.

1. Introduction

NASA funding for ground-based support of spacecraft missions to small bodies has increased to enhance data science return. Thus emphasis for targeted asteroids (i.e. Lucy) data collected during observations carried out at ground-based observatories at mission estimated time of arrival (ETA), would provide to, and be recognized by, NASA as a valuable asset. Lucy, a SwRI mission proposal to study primitive asteroids among the Jupiter's Trojans, is one of five science investigations under the NASA Discovery Program [1]. Lucy's science payload/instrumentation is mirroring the New Horizons payload with: L'Ralph, Panchromatic and color visible imager and Infrared spectroscopic mapper (400nm -2.5µm); L'LORRI, high-resolution visible imager (350-850 nm); L'TES, thermal infrared spectrometer is similar to OTES on the OSIRIS-REx mission spectral range 5.71–100 µm (1750–100 cm^{-1}); and radio science investigation will determine the mass of the Trojans by using the spacecraft radio telecommunications hardware to measure Doppler shifts [2].

2. Approach

Observations through the Large Binacular Telescope (LBT) Multi-Object Double Spectrographs (MODS 1) - Imager and spectrograph covering 0.32-1.1 microns with a 6'x6' FOV - has been targeted for this assessment [3]. The importance of some Eurybates members spectra show a drop off in reflectance shortward of 0.52µm - similar features are seen in main belt C-type asteroids and commonly attributed to the intervalence charge transfer transition in oxidized iron [4,5]. Jupiter Trojan Asteroids targeted by Lucy are listed in Table 1.

Table 1. Lucy's Jupiter Trojan Asteroids albedo [4,5].

Mission	Number	Target	Vmag	Size (mas)	Albedo (µm)
Lucy	3548	Eurybates	16.8 to 17.7	13 to 20	0.052
	15094	Polymele	18.9 to 19.8	5 to 7	0.091
	11351	Leucus	17.8 to 18.8	7 to 11	0.079
	21900	Orus	16.9 to 17.9	11 to 16	0.075
	617	Patroclus	15.9 to 16.5	33 to 39	0.047
	52246	Donaldjohanson	18.3 to 20.1	2 to 4	

To derive Lucy targeted asteroids information for best ground-based observation at mission estimated time of arrival (ETA) we used data from JPL Horizons [6]. ETA of Lucy at Jupiter Trojan Asteroids are listed in Table 2.

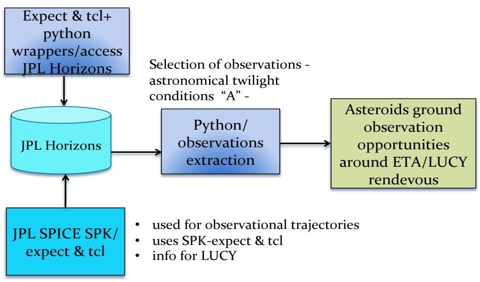
Table 2. Lucy's Jupiter Trojan Asteroids ETA [1,2].

Lucy Mission	Encounter date	Location	Dia-meter (km)	Spectral type	**ETA targets**
Launch	Oct. 2021				
DonaldJohanson	April 2025	Main belt	3.9	C	
Eurybates	Aug. 2027	Greeks	64	C	12 Aug 2027
Polymele	Sept. 2027	Greeks	21	P	15 Sep 2027
Leucus	April 2028	Greeks	34	D	18 Apr 2028
Orus	Nov. 2028	Greeks	51	D	11 Nov 2028
Patroclus/Menoetius	March 2033	Trojans	113/ 104	P	02 Mar 2033

The workflow, shown in Figure 1, used *expect & tcl*, plus a *python* wrapper to access the JPL Horizons [6] database and extract observations of targeted asteroids at twilight conditions. The derived data provide the best suitable opportunities to observe the asteroids using LBT ground observations.

The SPICE implementation [7] has allowed to obtain details on observational parameters at ETA that could be utilized to optimize ground observations for added value on science return. Observational trajectories used Spacecraft and Natural Bodies Trajectories Kernels (SPK) and Tcl to derive parameters/info for Lucy at the various considered targets to establish optimal geometry of observation that is then used as input for ground observation planning through JPL Horizons. The SPICE implementation is an addition to previous work, which mainly focused on the JPL Horizons implementation [8].

Figure 1. Workflow/pipeline for data extraction. (need to update)



3. Results

The extracted observations for all targeted asteroids outlined several opportunities for suitable LBT ground observations. However, only one was found to be suitable during close approach of Lucy ETA to asteroid Leucus, as shown in Table 3.

Table 3. LBT ground observations.

Leucus

Date___UT___HR:MM:SS	Date____JDUT	A/	R.A.___(ICRF/J2000.0)___DEC		dRA*cosD	d(DEC)/dt	APmag	S-brt	Azi_(a-appr)_Elev	
2028-Apr-01 12:00:01	2461863.000011574	A	16 48 05.3186	-23 52 34.935	-2.03708	1.967876	18.61	8.16	188.7451	32.8560
2028-Apr-02 12:00:01	2461864.000011574	A	16 48 02.0368	-23 51 47.257	-2.47764	2.039883	18.60	8.16	189.8220	32.7334
2028-Apr-03 12:00:01	2461865.000011574	A	16 47 57.9864	-23 50 57.883	-2.91644	2.112077	18.59	8.15	190.8982	32.5952
2028-Apr-04 12:00:01	2461866.000011574	A	16 47 53.1706	-23 50 06.809	-3.35331	2.184463	18.58	8.15	191.9734	32.4413
2028-Apr-05 12:00:01	2461867.000011574	A	16 47 47.5929	-23 49 14.030	-3.78812	2.257043	18.57	8.15	193.0469	32.2716
2028-Apr-06 12:00:01	2461868.000011574	A	16 47 41.2569	-23 48 19.543	-4.22079	2.329823	18.56	8.14	194.1184	32.0863
2028-Apr-07 12:00:01	2461869.000011574	A	16 47 34.1662	-23 47 23.343	-4.65131	2.402808	18.55	8.14	195.1872	31.8853
2028-Apr-11 03:00:01	2461872.625011574	A	16 47 02.3258	-23 43 44.342	-5.64235	2.480793	18.51	8.12	97.9176	-34.7549
2028-Apr-12 03:00:01	2461873.625011574	A	16 46 51.7975	-23 42 40.171	-6.06957	2.550339	18.50	8.12	98.3705	-33.8900
2028-Apr-13 03:00:01	2461874.625011574	A	16 46 40.5368	-23 41 34.262	-6.49439	2.620069	18.49	8.11	98.8227	-33.0234
2028-Apr-14 03:00:01	2461875.625011574	A	16 46 28.5406	-23 40 26.614	-6.91652	2.689957	18.48	8.11	99.2744	-32.1550
2028-Apr-15 03:00:01	2461876.625011574	A	16 46 15.8382	-23 39 17.225	-7.33564	2.759975	18.47	8.10	99.7260	-31.2850
2028-Apr-16 03:00:01	2461877.625011574	A	16 46 02.4117	-23 38 06.092	-7.75140	2.830090	18.46	8.10	100.1776	-30.4134
2028-Apr-17 03:00:01	2461878.625011574	A	16 45 48.2757	-23 36 53.215	-8.16346	2.900269	18.44	8.09	100.6294	-29.5403
2028-Apr-18 03:00:01	2461879.625011574	A	16 45 33.4374	-23 35 38.595	-8.57145	2.970479	18.43	8.08	101.0817	-28.6658
2028-Apr-19 03:00:01	2461880.625011574	A	16 45 17.9047	-23 34 22.233	-8.97501	3.040684	18.42	8.08	101.5347	-27.7899
2028-Apr-20 03:00:01	2461881.625011574	A	16 45 01.6862	-23 33 04.131	-9.37380	3.110844	18.41	8.07	101.9885	-26.9129
2028-Apr-21 03:00:01	2461882.625011574	A	16 44 44.7908	-23 31 44.293	-9.76743	3.180921	18.40	8.07	102.4433	-26.0347
2028-Apr-22 03:00:01	2461883.625011574	A	16 44 27.2284	-23 30 22.723	-10.1555	3.250870	18.39	8.06	102.8995	-25.1554
2028-Apr-23 03:00:01	2461884.625011574	A	16 44 09.0094	-23 28 59.426	-10.5377	3.320647	18.38	8.05	103.3570	-24.2752
2028-Apr-24 03:00:01	2461885.625011574	A	16 43 50.1450	-23 27 34.408	-10.9136	3.390205	18.37	8.05	103.8162	-23.3941
2028-Apr-25 03:00:01	2461886.625011574	A	16 43 30.6468	-23 26 07.678	-11.2828	3.459496	18.35	8.04	104.2773	-22.5123

Observation days for Leucus are 22

4. Considerations

This effort could be enhanced by integrated spacecraft, space telescope, and ground observatory missions. A possible space telescope would be SOFIA, while candidate ground station to be considered in future work is the European Southern Observatory (ESO) in Chile. Also, the 23m Fizeau Imaging on LBT could fill the pre-ELT gap (~ 2018 to 2023) for resolved imaging of Lucy mission targets via appulse events, which are estimated to occur approximately once per week [9].

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