Ground observation of asteroids at mission ETA. F. Paganelli[1] and A. Conrad[2], [1] SETI/NCCC (fpaganelli@nccc.edu), [2]LBTO/UHH (aconrad@lbto.org).

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].

Approach: Observations through the 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].

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	

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

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].

Lucy Mission	Encounter date	Location	Diameter (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

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

The workflow, shown in Figure 3, 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.

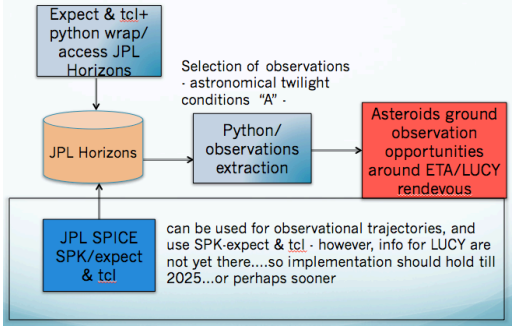
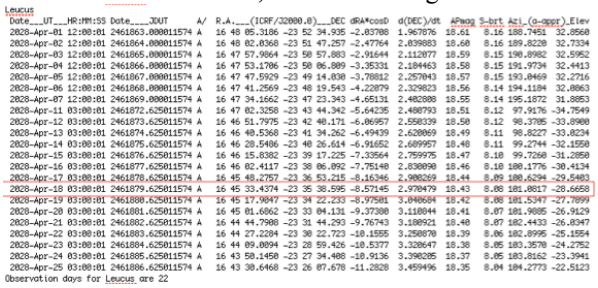


Figure 3. Workflow/pipeline for data extraction.

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 Figure 4.


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	-2.85788	1.967876	18.61	8.16	188.7451	32.0560
2028-Apr-02 12:00:01	2461864.000011574	A	16 48 02.4368 -23 51 47.257	-2.47764	2.039883	18.60	8.16	189.8238	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	2.498793	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	2.558339	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 28.5486 -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	-7.75148	2.830098	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	-8.97581	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	-9.37388	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 30.6460 -23 26 07.670	-11.2828	3.459496	18.35	8.04	104.2773	-22.5123

Observation days for Leucus are 22

Figure 4. LBT ground observations.

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 [7].

References: [1] Levison H.F. and the Lucy Science team (2016) *LPSC 47th,* Abstract #2061. [2] Weaver H.A. et al. (2008) *Space Sci. Rev. 140(1-4),* 75-91. [3] Rothberg B. et al. (2016) Astrophysics, arXiv:1608.00037 [astro-ph.IM]. [4] Fornasier et al. (2007) *Icarus, 190 (2),* 622-642. [5] Fernadez Y.R. et al. (2009) *The Astro. J.* 138, 240-250. J. H. (1996) *LPS XXVII,* 1344–1345. [6] JPL Horizons: ftp://ssd.jpl.nasa.gov/pub/ssd/Horizons_doc.pdf [7] Conrad A. et al. (2017) *AO4ELT5,* 1-8.