Small body science with occultations

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2019 Jan 29

Current active mission-level investments in small bodies

- OSIRIS-REX
- Hayabusa 2
- New Horizons
- Psyche Mission
- Lucy Mission
- Recently completed: Rosetta and Dawn

Gaia: A Door is Opened

- DR2 improvements over past catalogs are profound
  - 100-200 micro-arcsecond precision and tied to the same ICRF as used for mission navigation
  - Raw precision needed but getting accurate proper motions is even more important
- Excellent tool for predicting stellar occultations but the catalog not good forever
  - After end of mission (end of 2020, maybe 2022) the positions will begin to degrade due to proper motion uncertainties

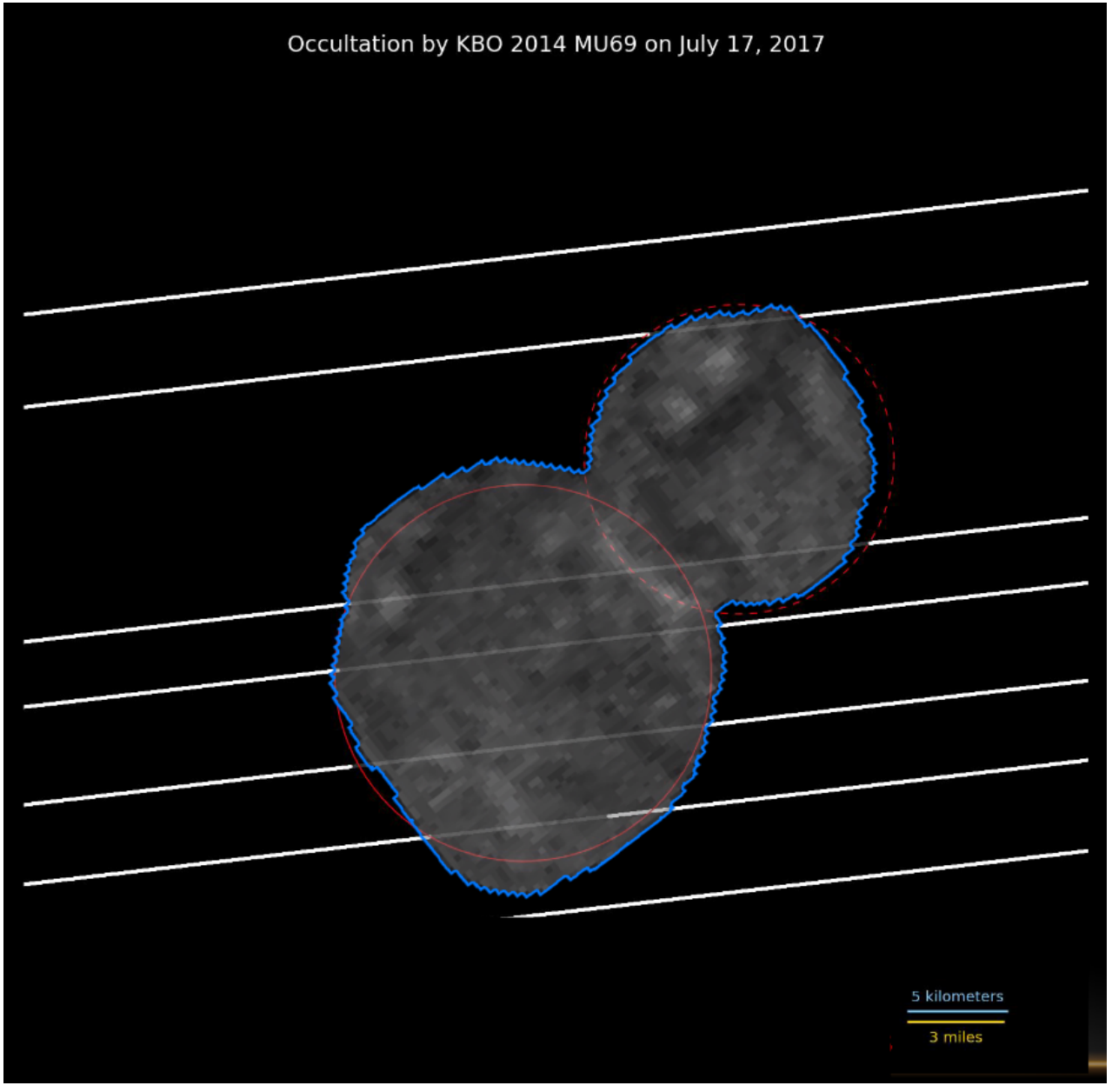
2014MU69 occultations for New Horizons

- 2017 June 3 – 24 stations, Argentina & South Africa
- 2017 July 10 – SOFIA
- 2017 July 17 – 24 stations, Argentina
- 2018 Aug 4 – 24 stations, Colombia & Senegal
- Total cost of deployment = $1.25M
  - < 10% of cost was buying equipment
- Heavy use of volunteers

Value of 2014MU69 occultations

- Albedo (sequence planning)
- Targeting
  - Double or single? What to expect during encounter
- Navigation
  - HST data & occultation astrometry provided necessary a priori information required for optical navigation
  - Important validation of using Gaia's implementation of the ICRF against radio tracking ICRF of spacecraft
- Paves the way to use occultations to enhance science return from small-body missions

Occultation result compared to imaging data from New Horizons



Pre-launch opportunities for Lucy

Target	Date	G	G*	Goal	Event Type	Details
Leucus	2018-11-14	15.8	15.6	A	Regional	Tucson (success!, but faint)
Leucus	2018-11-18	14.0	13.9	A	Regional	San Antonio (success!)
*Orus	2019-11-04	13.1	11.9	A	Foreign	Australia
Leucus	2019-12-29	10.9	11.0	B	Regional	Arizona, New Mexico
Donaldjohanson	2020-09-11	11.0	12.9	A	Regional	Arizona, New Mexico
*Eurybates	2020-09-16	15.5	14.4	A	Local	Wyoming
Donaldjohanson	2020-10-09	14.1	14.9	A	Regional	Texas
Orus	2020-10-21	17.0	15.8	A	Regional	Texas, southeast US
*Polymele	2020-11-16	14.6	14.6	A	Foreign	Angola, Zambia, Mozambique
Donaldjohanson	2020-12-29	13.3	13.9	A,B	Regional	Florida, Mexico
Patroclus	2021-03-26	14.8	12.4	A	Foreign	Peru, Colombia
*Polymele	2021-10-01	15.6	14.5	A	Foreign	Spain, north Africa
*Eurybates	2021-10-20	13.5	12.2	A	Regional	Arizona, New Mexico

Events in FY19 are shown with a lavender background, FY20 with a blue background, FY21 with a green background, and FY22 with a red background.

http://lucy.swri.edu/occultations.html

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Cost estimate: $2.8M

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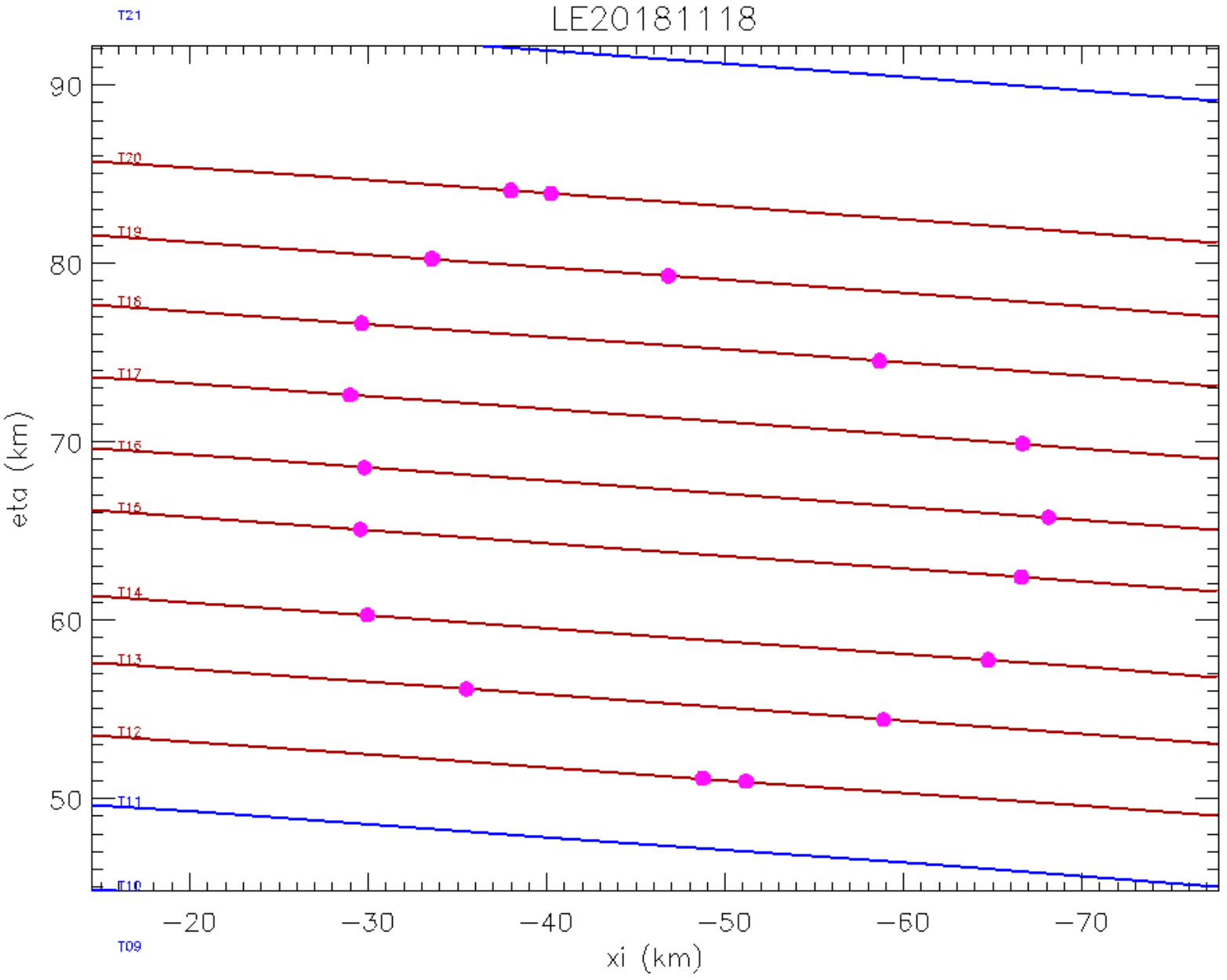
Lucy target: (11351) Leucus

- Long 440-hr rotation period with high amplitude lightcurve
- 2017 August – successful 2-chord result MIT/IOTA
  - Enabled high-density shape mapping deployment
- 2018 Nov 14 – 23 stations near Tucson/Phoenix
  - low SNR but chords detected, 4 km spacing
- 2018 Nov 18 – 23 stations near San Antonio
  - 9 successful chords, 4 km spacing
- 2018 Dec 13 – Europe, 2-chords
  - Reaching to collaborators and observers

Leucus is not a “simple” ellipsoid



RECON

- Research and Education Collaborative Occultation Network
- Fix locations, 11-in telescope, video cameras, sited at school, operated by teachers and students
- Nominal 50-km spacing
- Targeting H<9 (D~100 km or larger)
- Search for duplicity
- Preference for cold-classical but event rate is low enough that we take what we can get
- Attempt 6-8 events per year, prior to Gaia release event rate was low, picking up now
- Funded by NSF, $1M over 5 years, very difficult level of funding to get and results are limited as a result

The Opportunity

- Stellar occultations provide a means to probe small bodies
  - Size, shape, duplicity, high-precision astrometry
- All populations within reach: eg., MBO, Jupiter Trojans, and on out into the Kuiper Belt
- Provide greater context to mission results with properties that sample the populations
- Probe many objects, faster and with much less cost than a mission
- Example: sample 10 CCKBOs, how many look like 2014MU69 and what would that tell us about solar system formation processes?
- Can reach down almost to the size of the serendipitious occultation survey objects

The Challenge

- Occultation results don’t come for free
  - Initial observation to pin down orbit
  - Second event with high-density measurements for shape
  - Current efforts so far just funded by missions for mission targets for D<100 km
- Traditional R&A programs are very limited in what they can support for this type of observation
- Need to find a way to leverage mission investments (New Horizons, Psyche, Gaia, etc.) during the present window of opportunity

Recommendation

- Suggest that NASA investigate ways to provide support for occultation-based investigations of small bodies commensurate with their ability to leverage the PSD investment in small-bodies missions.
- This is a near-term problem that needs a solution faster than can be addressed with the next Decadal survey. Note that this type of science addressing small-body populations is consistent with the last Decadal even if the method wasn’t foretold.