

A Pilot Rapid-Response Project to Characterize Small Near Earth Objects

Remington Cantelas (1), David Trilling (1), Joey Chatelain (2), Nicolas Erasmus (3), Tim Lister (2), Andy Lopez-Oquendo (4), Nick Moskovitz (5), Cristina Thomas (1)

(1) Northern Arizona University, (2) Las Cumbres Observatory, (3) South African Astronomical Observatory, (4) NASA Goddard Space Flight Center, (5) Lowell Observatory



RESEARCH SUMMARY

This pilot project is designed as a demonstration for a larger survey to characterize ~1000 very small Near Earth Objects over the course of three years using the Las Cumbres Observatory's **MuSCAT 3/4** simultaneous four-channel imagers on the 2-meter telescopes at Haleakalā, Hawaii and Sliding Springs, Australia. This observing campaign aims to answer the following questions:

- How much discrepancy is there between the compositions of the smallest NEOs and the meteorite collection?
- Does the measured compositional distribution of small NEOs match the predicted distribution based on the Granvik dynamical model?

BACKGROUND

Meteorite Discrepancy:

Most meteorites are ordinary chondrites, a rocky composition that has been linked to S-type asteroids [1]. However, the ratio of primitive (C-, D-, and X-types) to S-type NEOs appears to be close to unity [2], different from the 80% chondrite fraction found in the meteorite collection.

NEO Source Regions:

The Granvik dynamical model [3] calculated the source regions of the debiased NEO population as a function of size. They argued that NEOs of different sizes have different source regions elsewhere in the Solar System. Different source regions, in turn, imply different compositions.

The characterization of small NEOs lags behind discovery; due to their size, they appear very faint and sometimes are only visible during close approaches with Earth.

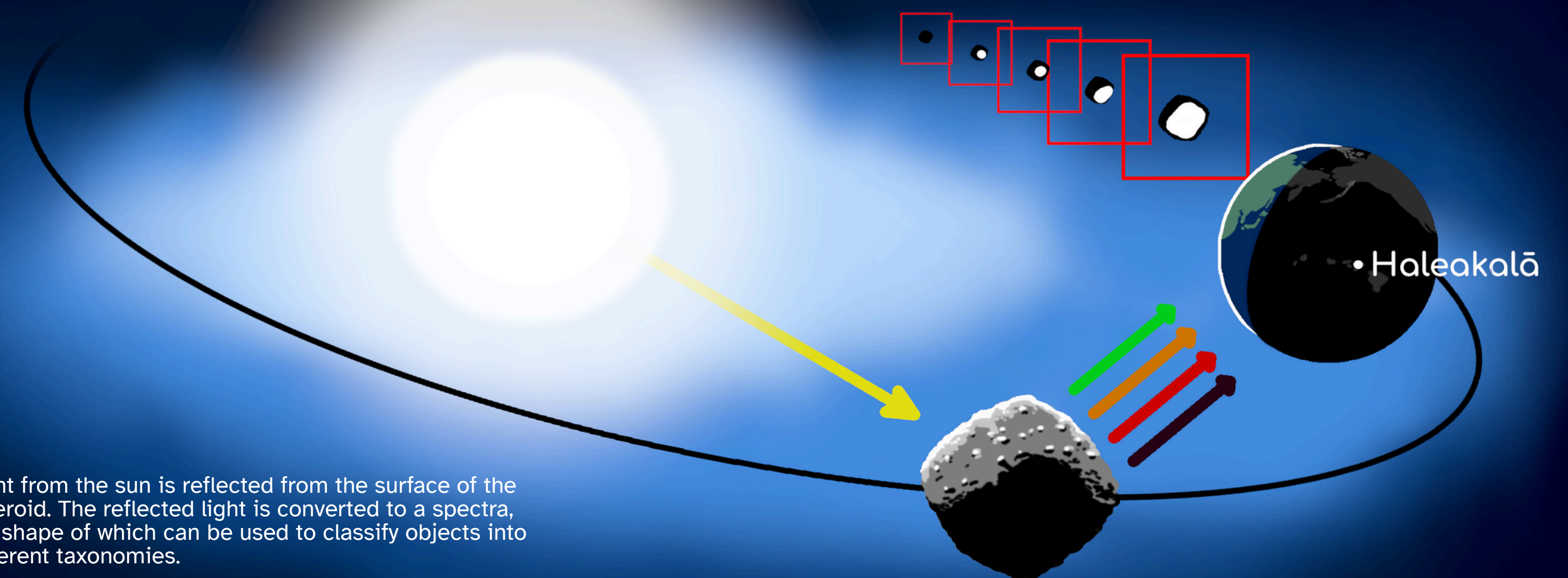
- Spectroscopy is not often possible as it's expensive and struggles with fainter targets.
- **Spectrophotometry** is less informative but more efficient.

The MuSCAT 3/4 cameras can **observe in four filters simultaneously, observing one object in ¼ of the time it would take a traditional filter-wheel camera system.**

- Didymos data taken with MuSCAT 3 from the LCO archive matches known spectra from the literature.

METHODS

As the asteroid approaches, it becomes bright enough to be visible to Earth-based telescopes. Once discovered, the object is reported to the Minor Planet Center. From there, objects are grabbed by our target selection tool and submitted to the LCO's observing queue.



Light from the sun is reflected from the surface of the asteroid. The reflected light is converted to a spectra, the shape of which can be used to classify objects into different taxonomies.

Target Selection:

Newly discovered Near Earth Asteroids are taken from the MPC database and submitted to LCO's observing queue.

Targets are selected with the following criteria:

- Absolute Magnitude (H) > 25 (**< 30m diameter**)
- Apparent Magnitude (V) < 21
- Rate < 1000 arcsec/hour

Observations:

Observations were made between October 2024 and March 2025. Targets are moving very quickly during their close encounter, therefore targets must be tracked, and trailing is unavoidable. A trailed background makes calibration difficult. To address this, we used the following observing technique:

- 1 - 10 second exposure (calibration, no trailing)
- 7 - 60 seconds exposures (science, trailed)
- 1 - 10 second exposure (calibration, no trailing)

Reduction:

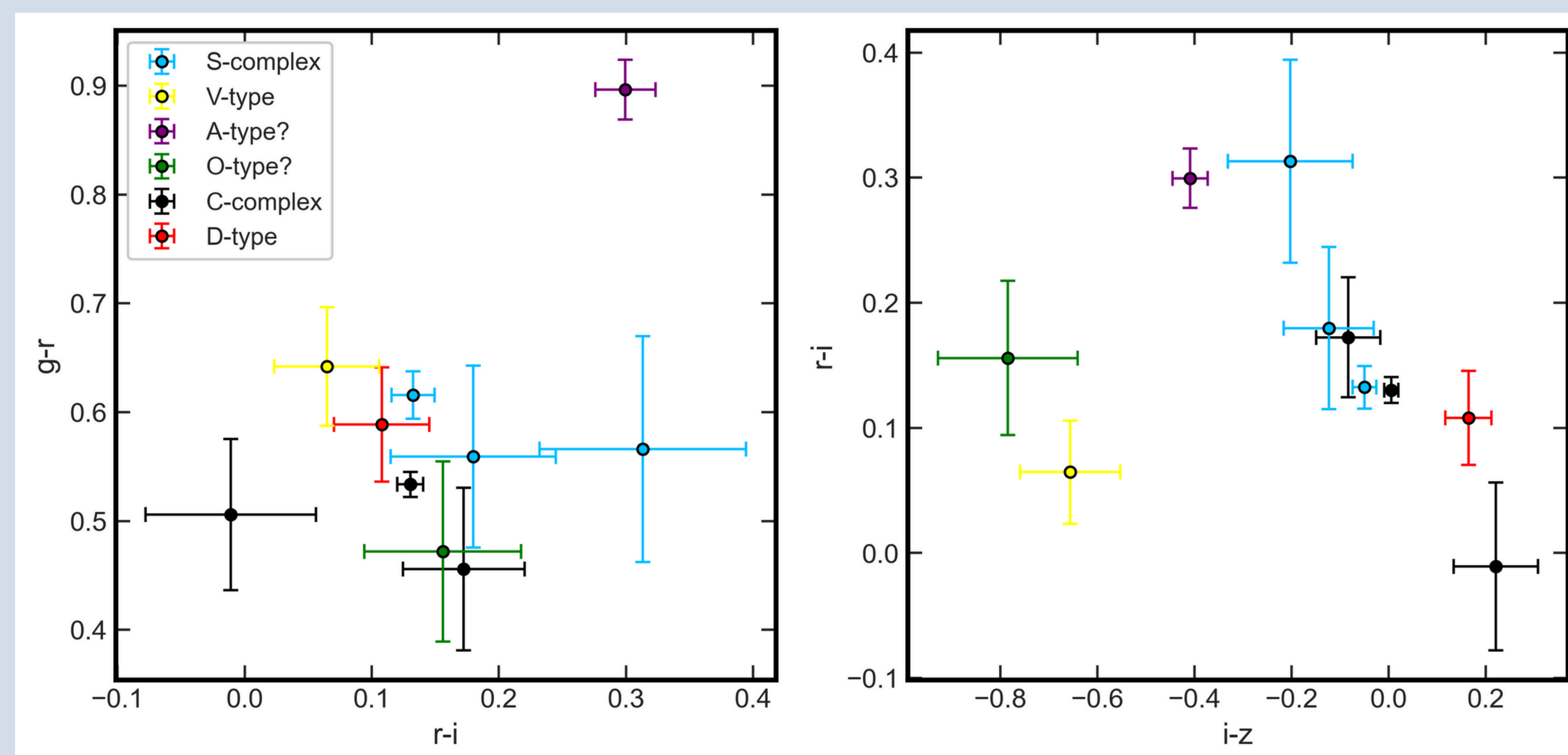
LCO provides data in both raw and reduced forms. Reduction, calibration, and photometry are done using LCO's in-house BANZAI software. Due to some of our targets being faint, additional photometry was done using the Python photutils package.

PRELIMINARY RESULTS

Object	UT Date	H	SDSS r	Type
2024 UC5	11/21/2024	26.25	20.13 ± 0.02	D
2024 VC	11/09/2024	27.41	18.48 ± 0.01	A
2024 XB16	12/13/2024	26.85	19.88 ± 0.03	C-complex
2024 YX5	01/08/2025	25.77	20.06 ± 0.04	C-complex
2024 YZ12	01/08/2025	26.28	19.17 ± 0.01	S-complex
2024 AD2	01/08/2025	26.73	20.77 ± 0.04	S-complex
2025 AF	01/07/2025	25.10	20.46 ± 0.03	O
2025 BB2	02/05/2025	25.62	18.20 ± 0.01	C-complex
2025 CK	02/05/2025	28.22	19.74 ± 0.02	V
2025 DX	02/22/2025	26.30	20.98 ± 0.05	S-complex

10 asteroids were observed using MuSCAT3 installed on the 2-meter Faulkes North Telescope in Haleakala with SDSS g, r, i, and z filters. Colors were compared to mean Bus-DeMeo spectra [4] to assign tentative taxonomic classifications.

Preliminary results indicate that 6 out of the 10 sampled objects exhibit colors consistent with S- and C-type classifications, evenly divided between the two. The remaining four resembled less common types, including V-, A-, O-, and D-types.



DISCUSSION

Notable is that **4 of 10 objects match best with rare taxonomic classes.**

A and O types in particular are rare amongst all asteroids:

- 17 known A-types (mostly Inner Main Belt asteroids and Mars-crossers) [5]
- 7 known O-types (all NEOs with one exception in the main belt) [6]

The high fraction of uncommon taxonomic classes found within our target sample could be indicative of higher diversity within the small NEO population. Further observations will confirm or deny these preliminary results.

These findings demonstrate that the MuSCAT3 and 4 instruments, along with our analysis tools, are sufficient to derive coarse taxonomies for small NEOs.

FUTURE WORK

Our survey began in May and will continue into 2028:

Year 1 (2025)	67 hrs	336 targets
Year 2 (2026)	67 hrs	336 targets
Year 3 (2027)	66 hrs	331 targets

Total 200 hrs ~ 1000 targets

As part of the goals for this pilot project, we developed a pipeline to automate observations and analysis. Each step — from selecting targets from the Minor Planet Center database, submitting targets to the LCO queue, acquiring reduced, calibrated data and photometry — was carried out using this pipeline. Future work will incorporate a machine learning-based tool to assign objects to a probabilistic taxonomic classification.

ACKNOWLEDGEMENTS

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REFERENCES

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CONTACT

Remington Cantelas
rcantelas@nau.edu

David Trilling
david.trilling@nau.edu