

Polarimetric Observations of the Near-Earth Asteroid 2024 MK

During Its close approach within the Lunar Distance

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1. Introduction

【Planetary Defense】

Near-Earth Asteroids (NEAs), Potential-Hazardous Asteroids (PHAs, size > 140 m)

- Avoiding collisions
- Predicting impact hazards
- **Deriving physical properties in advance** (size, composition, grain size, porosity, etc.)

【Upcoming events】

- Apophis: closest approach in 2029
~0.08 Lunar Distance (LD), RAMSES targets
- 2024 YR4: closest approach in 2032
~0.004 % probability of impact to Earth remains

【PHA: 2024 MK】

- Discovered on 16 June 2024 by the ATLAS, closest approach to Earth at ~0.76 LD on 29 June
- **5th closest Earth approach among PHAs, a once in several decades event!**
- Minimum V-mag. over the next ~200 years: 17.8 mag., so that **only opportunity for ground-based observations (mid-size telescope)!**

【Other Observations】

- NASA's Goldstone radar derived shape and size ~140 m (Naidu et al., 2024)

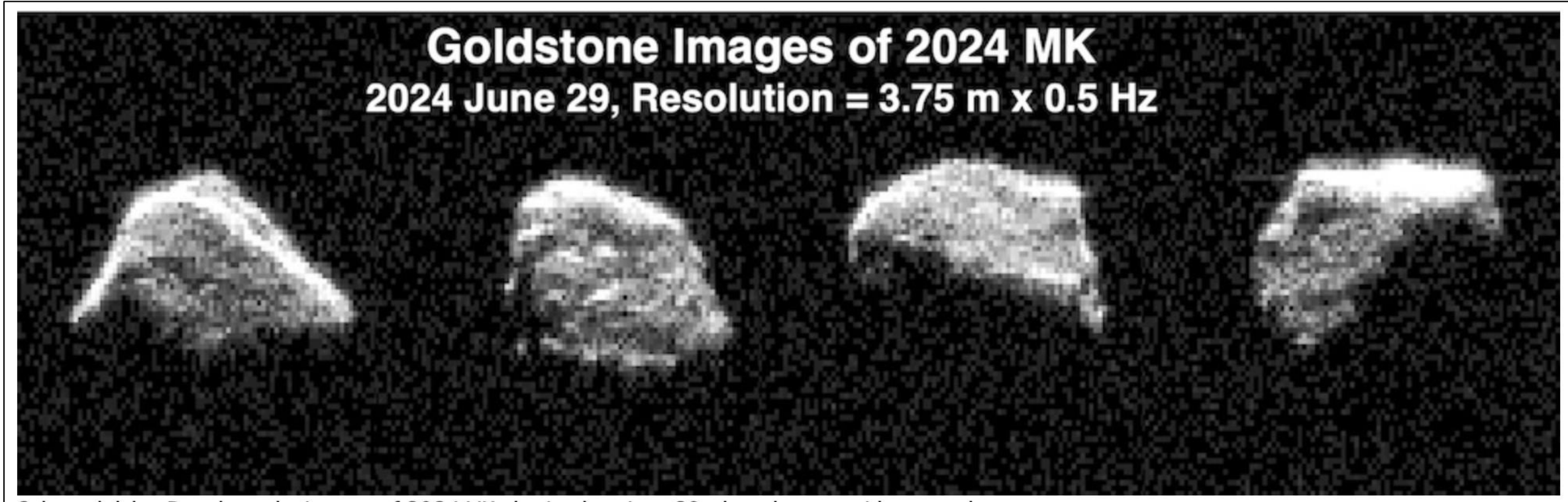


Fig. 2. Goldstone radar images of 2024 MK

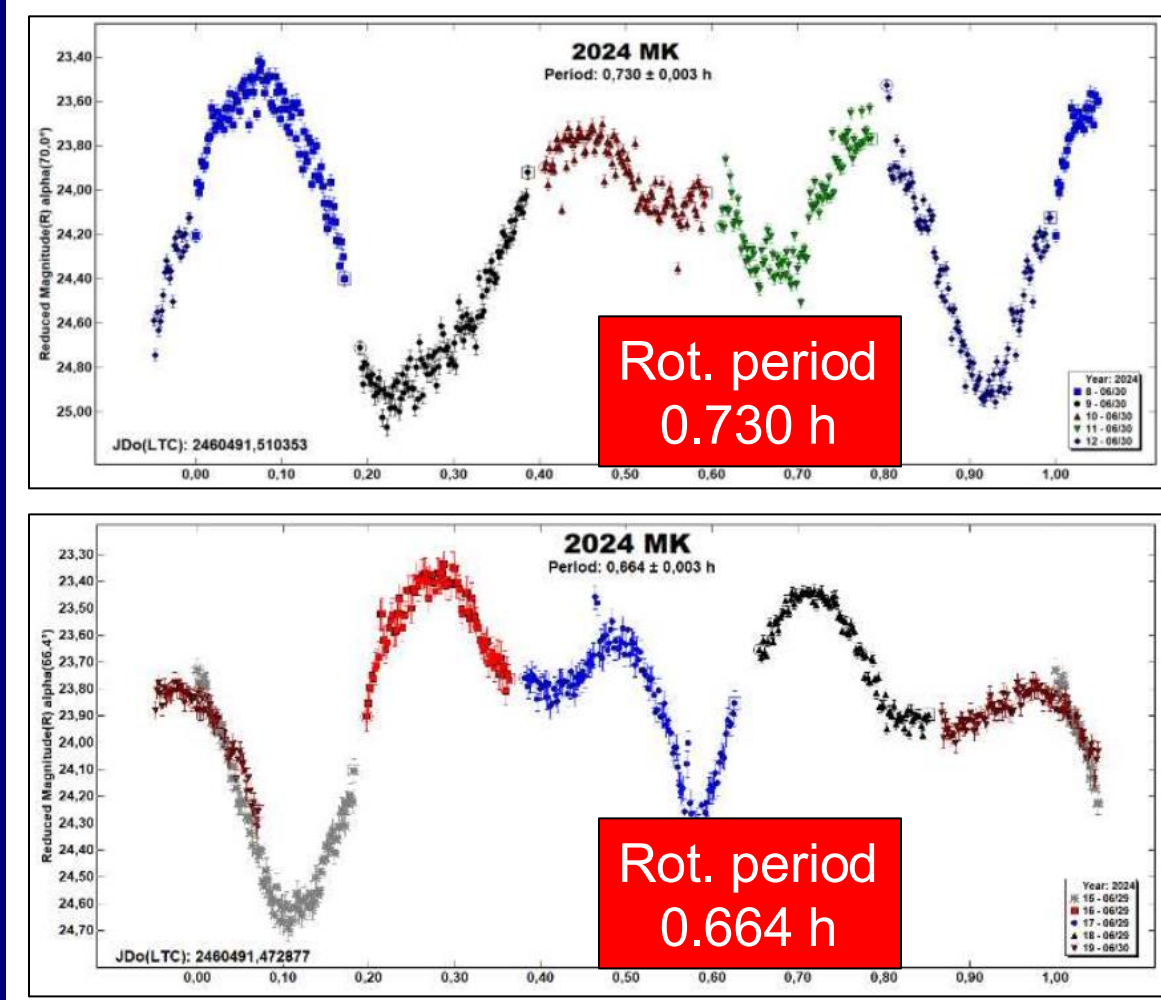


Fig. 3. Light-curve and rotation period of 2024 MK (Sioulas, 2024).

- Reflectance spectral is most likely **S-type**
- Older surface (spectral reddening) by experienced space weathering (Fig. 4)
- Older asteroids tend to possess finer-grained regolith by space weathering
- Spectral slope is influenced by regolith grain size

【Motivations】

- Is 2024 MK an old asteroid and/or possess finer-grained regolith?
- World-First Polarimetric Observations study of PHA within the LD!

2. Observations

【1.6-m Pirka telescope at Hokkaido University, Nayoro】



Fig. 5. Hokkaido University's Nayoro Observatory in Hokkaido and 1.6-m Pirka telescope.

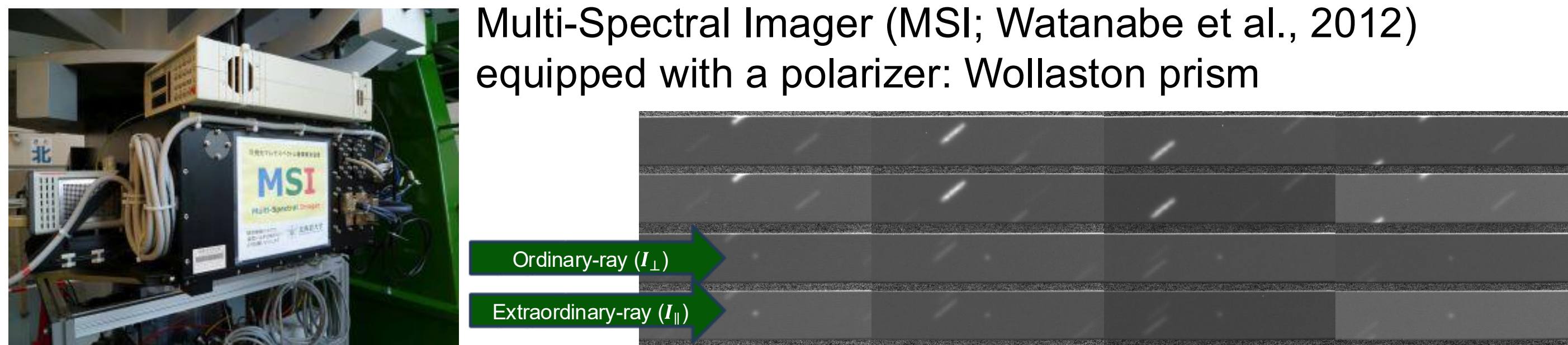


Fig. 6. MSI and four images were taken on July 2, from left to right, the half-wave plate was rotated to 0°, 45°, 22.5°, and 67.5°.

【Polarimetric Observations】

- **Phase Angle: α (°)**
Sun - Target - Observer (S-T-O) angle
- **Polarization Degree: P_r (%)**
~ scattering property: composition/albedo, grain size, porosity
- Observed 2 nights and each image was a only single shot:
Jun. 29 was closest approach night (V, Rc)
Jul. 2 was largest phase angle night (V)

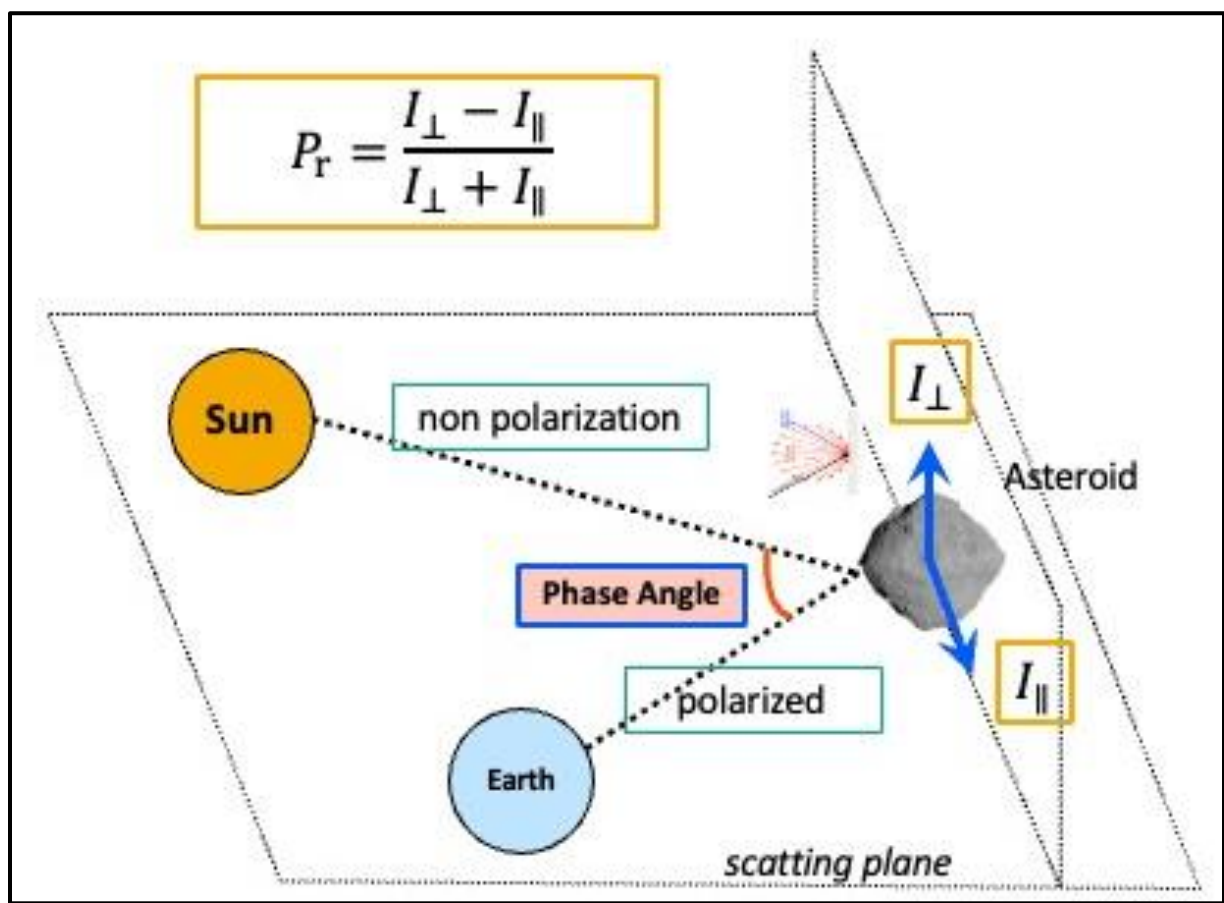


Fig. 7. Asteroid Polarimetry.

Tab. 2. Polarimetric observational conditions and measurement results of 2024 MK

Date	UT	Filter	Exp. [s]	V mag.	r [au]	Δ [au]	α [°]	$P_r \pm \sigma P_r$ [%]	Notes
Jun. 29, 2024	14:46:23-14:48:51	V	30	9.71	1.01840	0.00196	26.351	2.03 ± 0.19	Closest approach night
Jun. 29, 2024	14:50:18-14:52:47	V	30	9.73	1.01840	0.00196	26.765	1.80 ± 0.23	
Jun. 29, 2024	14:55:36-14:58:05	V	30	9.74	1.01839	0.00196	27.386	2.22 ± 0.22	
Jun. 29, 2024	14:58:36-15:01:05	V	30	9.76	1.01839	0.00196	27.696	2.37 ± 0.22	S/N ~1500
Jun. 29, 2024	15:06:06-15:08:35	Rc	30	9.78	1.01838	0.00197	28.418	2.02 ± 0.22	
Jun. 29, 2024	15:08:50-15:11:20	Rc	30	9.79	1.01837	0.00197	28.727	1.95 ± 0.18	
Jul. 2, 2024	16:56:48-17:17:19	V	300	16.85	1.01337	0.01683	100.984	35.28 ± 5.72	S/N ~50

3. Analysis

【Polarization Degree: P_r 】

- $P_r = \frac{I_{\perp} - I_{\parallel}}{I_{\perp} + I_{\parallel}}$ (%), depends on phase angle: α
reached ~35 % at $\alpha \sim 101^\circ$
near P_{\max} (typically at 90-100 °)

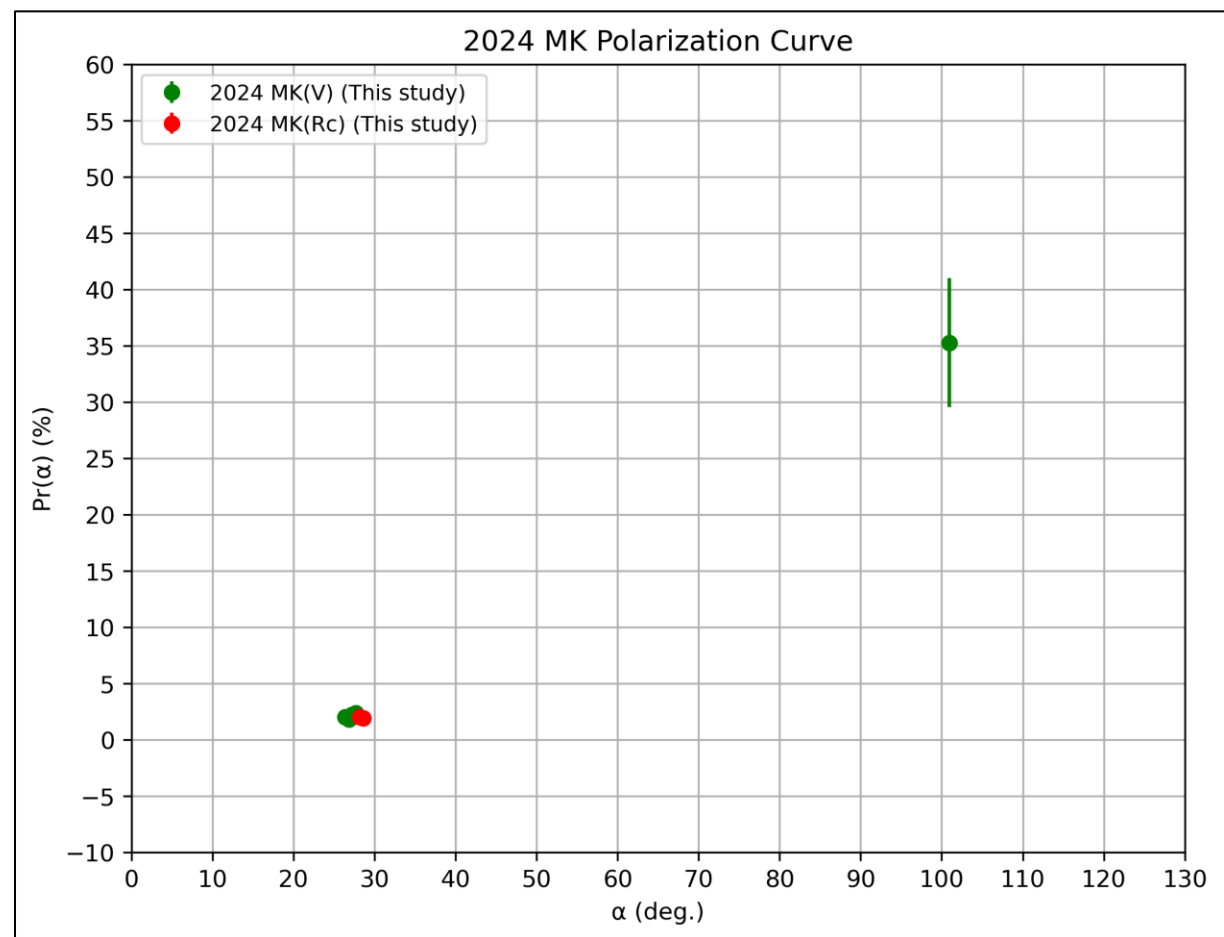
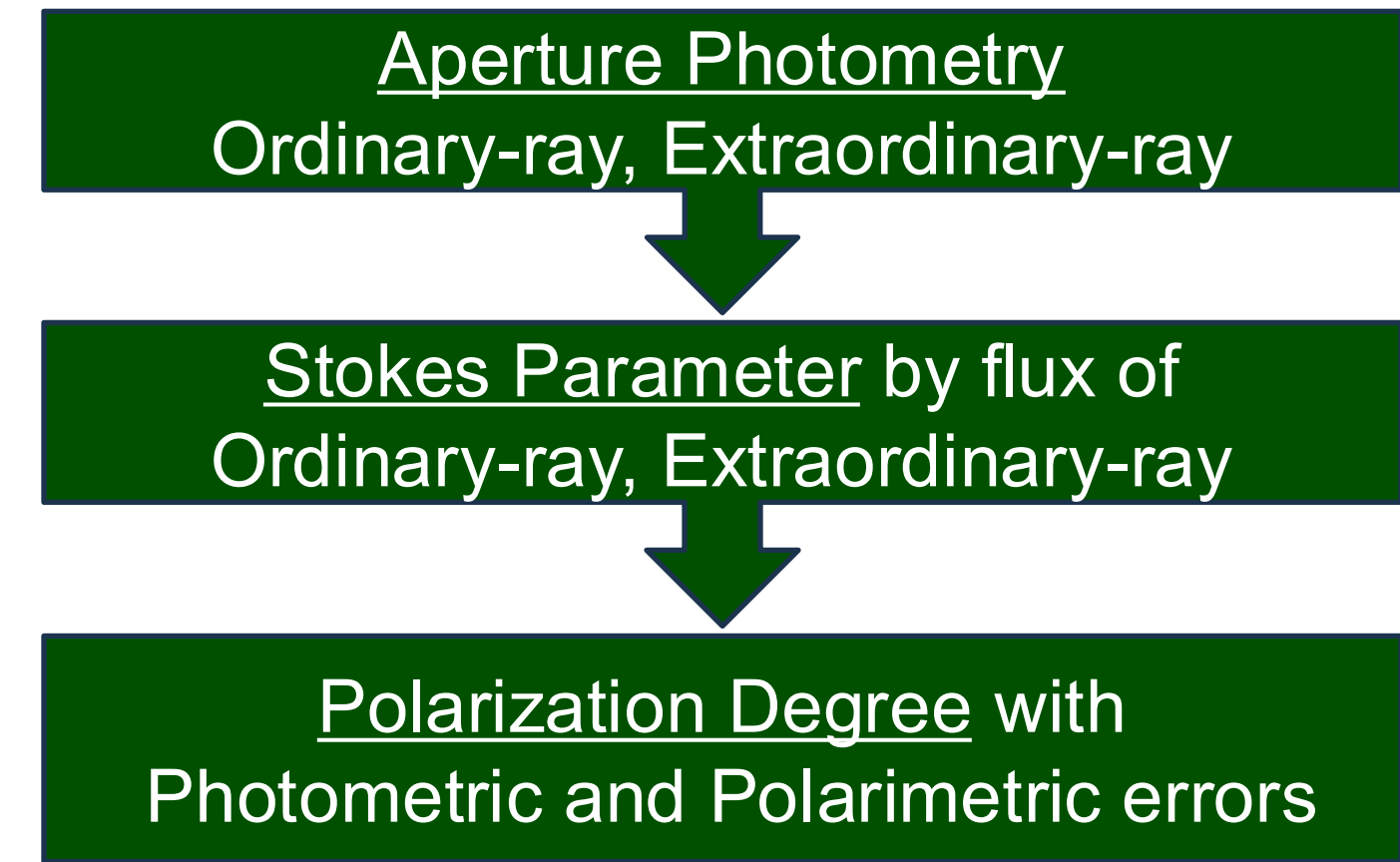


Fig. 8. Polarization degree of 2024 MK as a function of the phase angle. Red circles represent the R-band filter data and green circles represent the V-band filter data.

4. Discussion

【Comparison with Polarization degree of NEAs】

- Derived Polarization characteristics of typical **C-type**

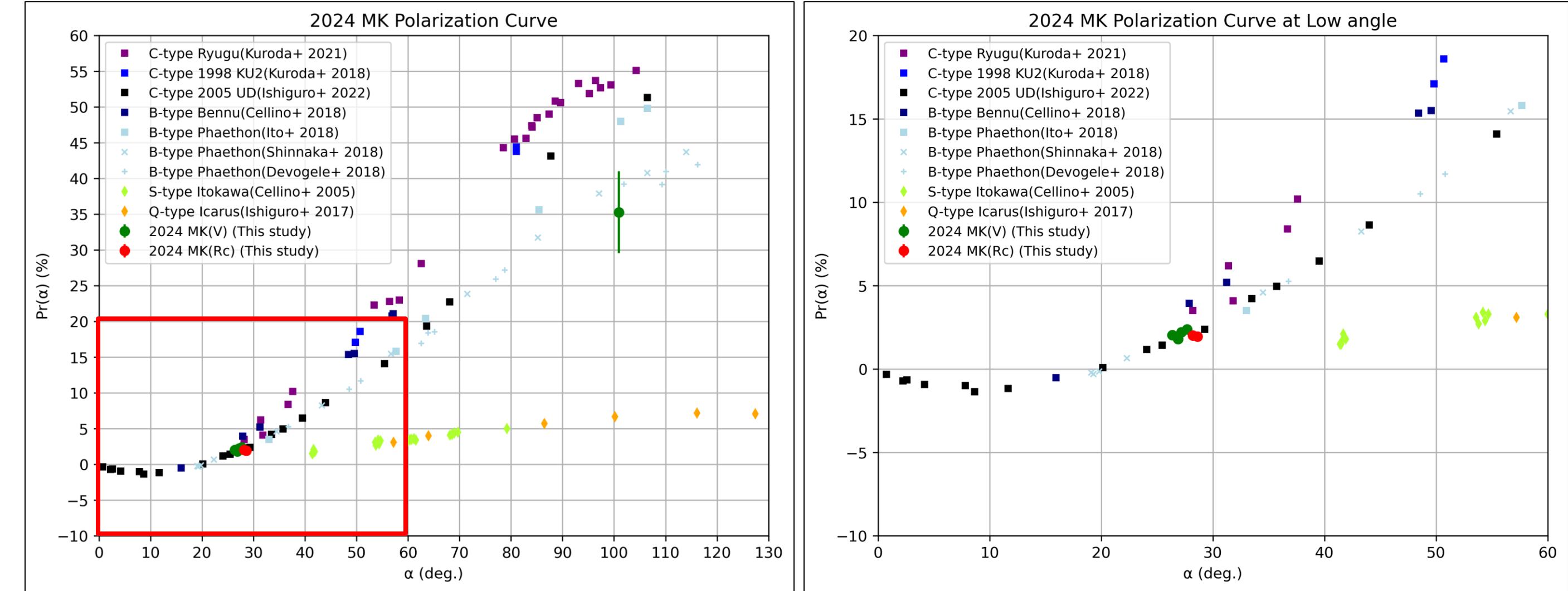


Fig. 9. Polarization degree of several type NEAs, Ryugu (purple squares; Kuroda et al., 2021), 1998 KU2 (blue squares; Kuroda et al., 2018), 2005 UD (black squares; Ishiguro et al., 2022), Bennu (navy squares; Cellino et al., 2018), Phaethon (light blue squares; Ito et al., 2018, crosses; Shinnaka et al., 2018, pluses; Devogele et al., 2018), Itokawa (green yellow diamonds; Cellino et al., 2005), Icarus (orange diamonds; Ishiguro et al., 2017) and 2024 MK (This study).

【Discrepancy with previous study suggesting **S-type**】

A. Rotation Phase

- Differences in the observed surface (front-back) based on Rotation period (0.730 or 0.664 h; Fig. 3) and observation timing
- We and McGraw et al. observed the same surface, so **compositional heterogeneity could not be detected**

B. Regolith Grain size

- May be more space-weathered and/or possess finer regolith grains than typical S-type (Fig. 4)
- Presence of **fluffy aggregates** on the surface increases the Polarization Degree (Fig. 10) e. g., NEA 1998 KU2 (Kuroda et al., 2018)

$$\text{Grain size parameter: } X = \frac{\pi d}{\lambda}$$

d : Grain diameter [μm]
 λ : Wavelength of observational light [μm]

- Assuming $P_{\max} \sim 35.28 \pm 5.72$ %, estimated grain size: 0.2 – 1.2 μm (sub-micron – micron)
- On the other hand, 2024 MK is likely a **monolith** and lacks surface grains (Fig. 11)

C. Porosity

- **High porosity** increases the Polarization Degree, regardless of grain size e. g., NEA Phaethon (Ito et al., 2018)

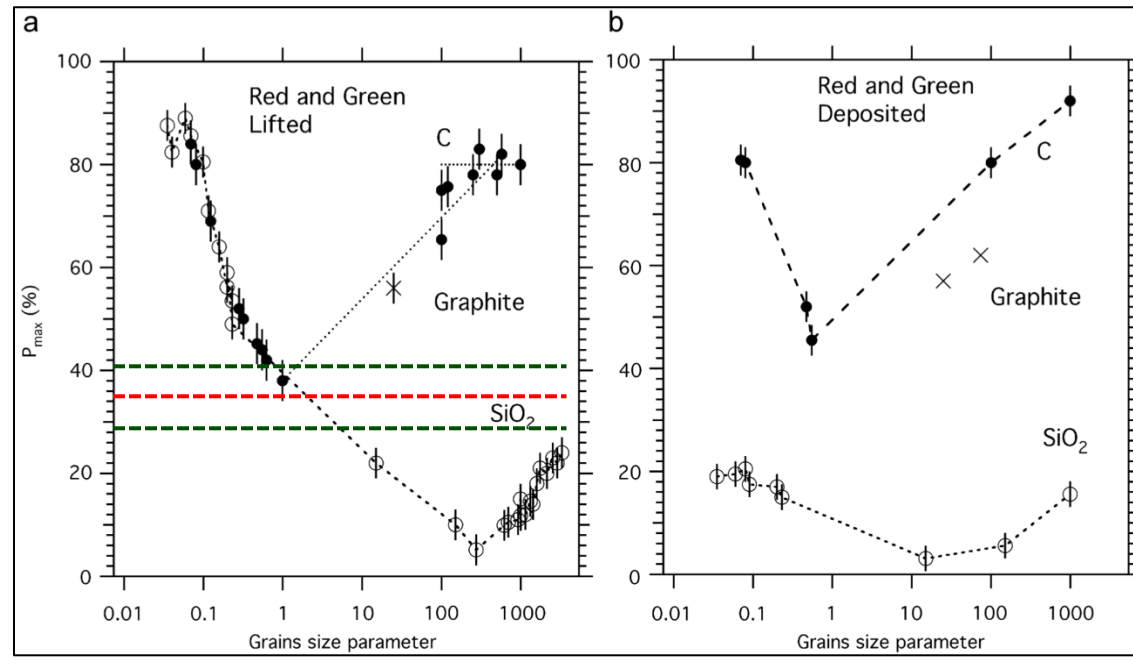


Fig. 10. Pmax vs Grains size parameter (small grains in agglomerates, large grains as individual particles for silica & carbon). Red is 632.8 nm; green is 543.5 nm: (a) lifted particles, (b) deposited particles (Hadamcik et al., 2009).

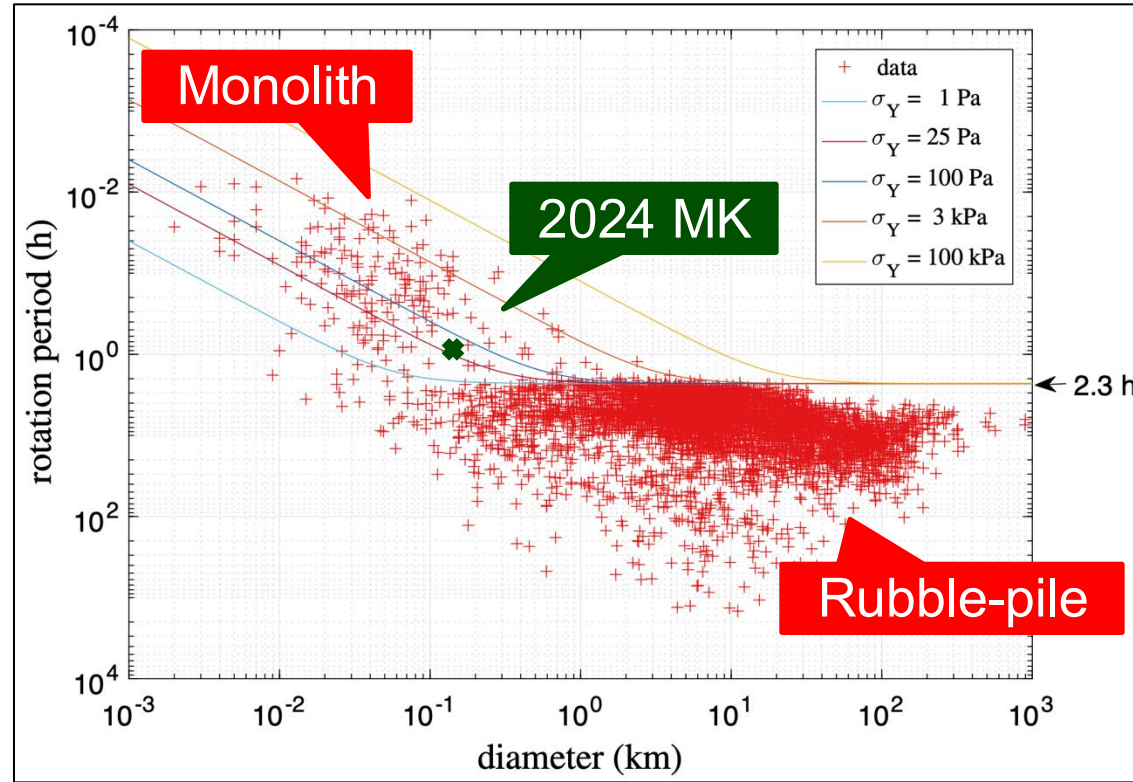


Fig. 11. Spin barrier of asteroids. Almost larger than 300 m are rubble-piles and rotate with a period longer than 2.3 hours (Persson and Biele, 2022).

5. Summary

- We conducted Polarimetric Observations of PHA within the LD approach (World-First!) 2024 MK using the Pirka telescope
- We derived Polarization characteristic of typical **C-type**
- Although 2024 MK is classified **S-type**, we conjectured that its C-type like polarization characteristics may be attributed to the **grain size** and/or **porosity** of its surface regolith