

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】

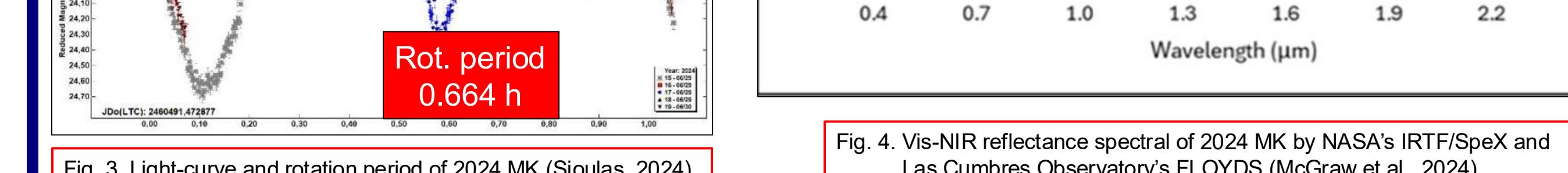
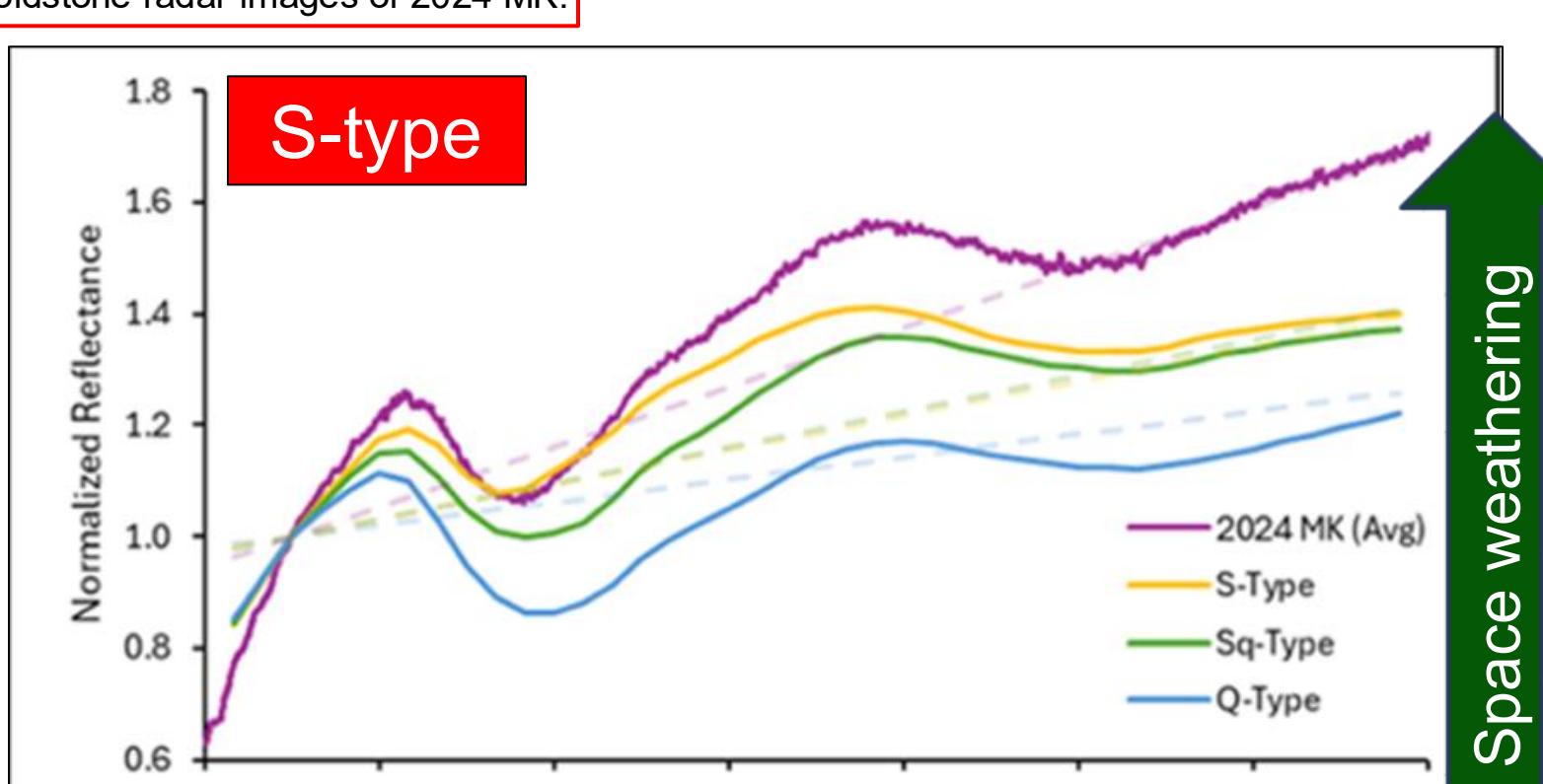
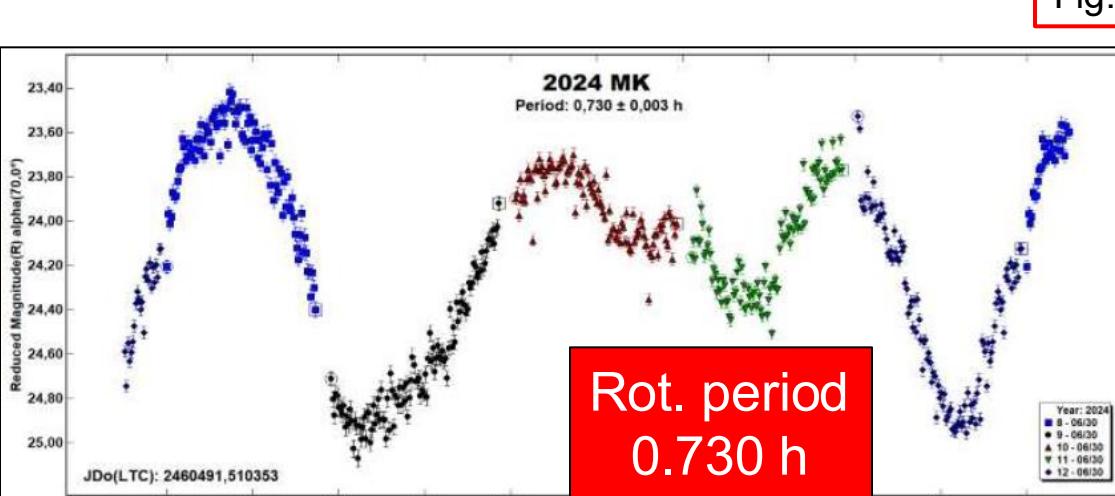
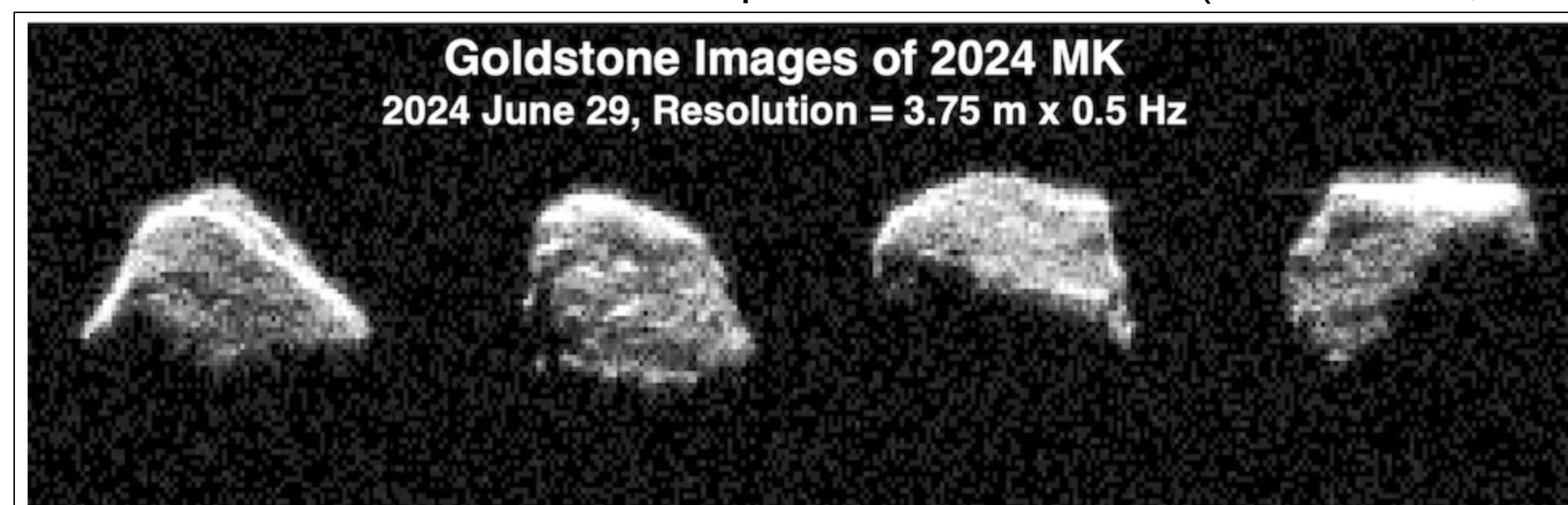
- Apophis: closest approach in 2029
~0.08 Lunar Distance (LD), RAMSES targets
- 2024 YR4: closest approach in 2032
~0.004 % probability of impact to Earth remains

【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)



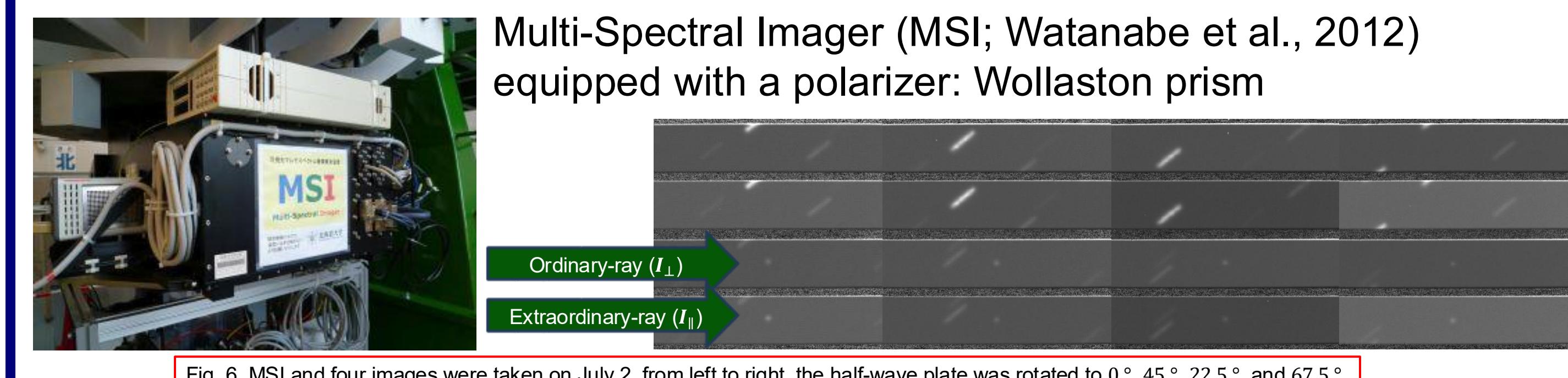
- Reflectance spectral is most likely **S-type**
- Older surface (spectral reddening) by experienced space weathering (Fig. 4)
- Older asteroids tend to possess finer-grained regolith by space weathering
- Spectral slope is influenced by regolith grain size

【Motivations】

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

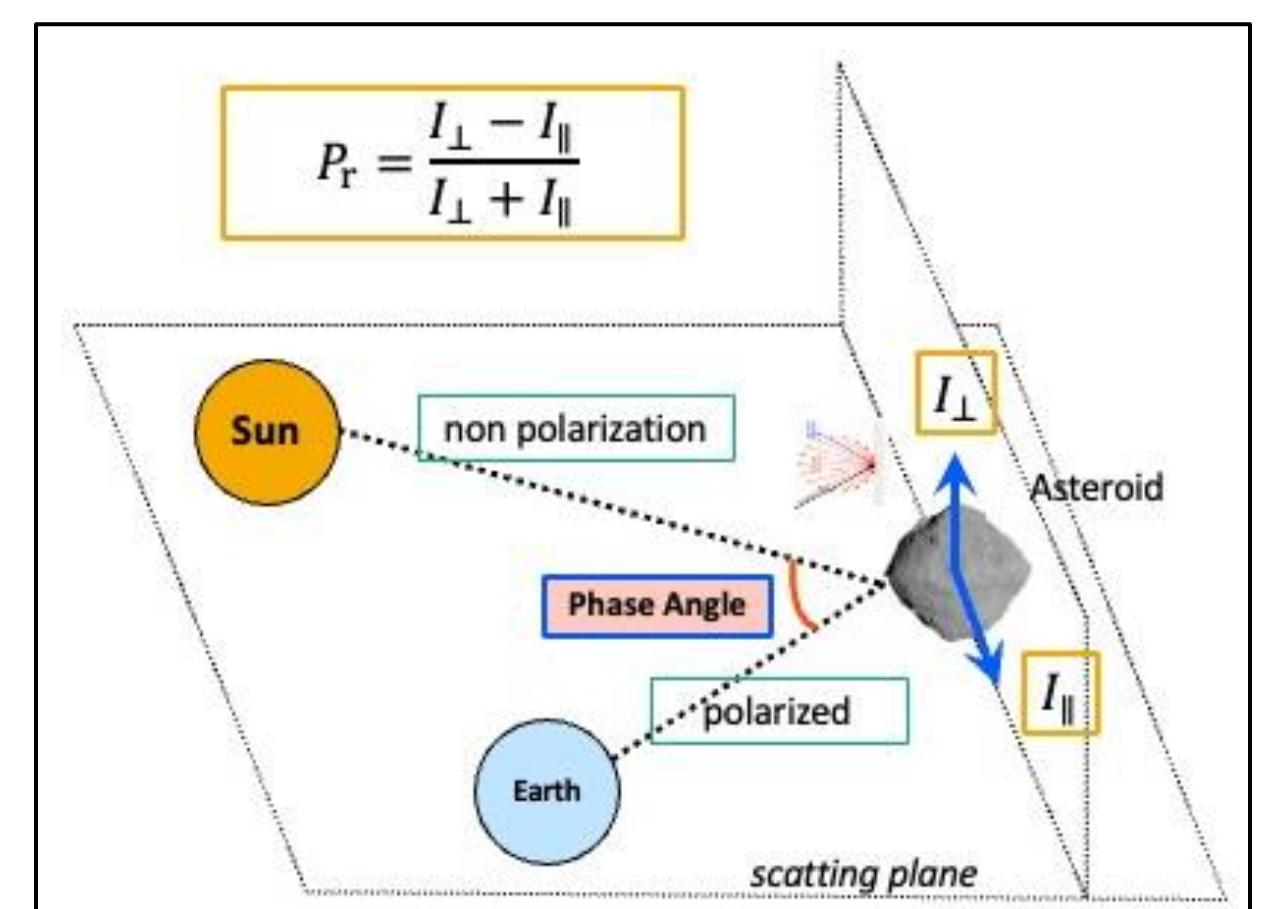
2. Observations

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



【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)

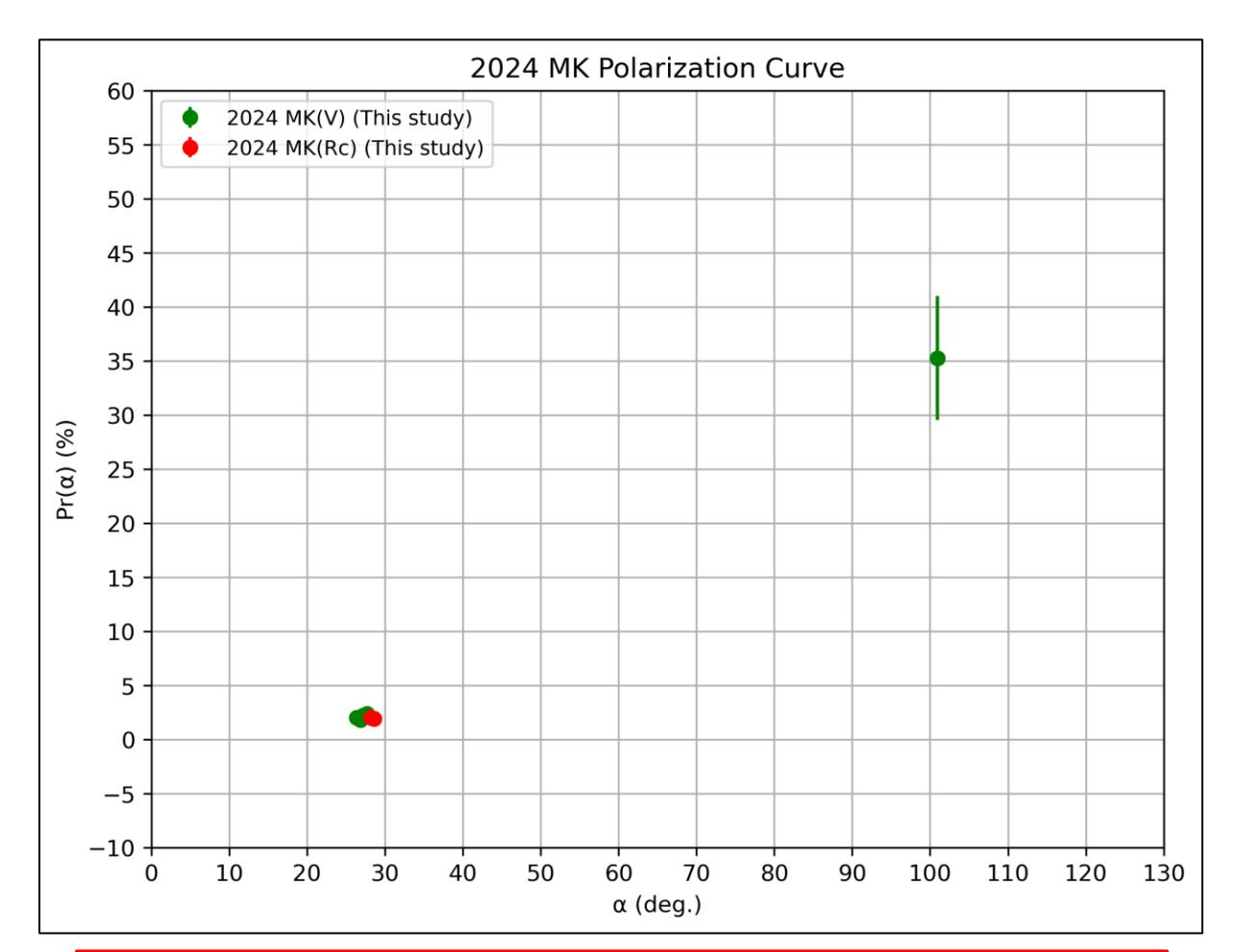
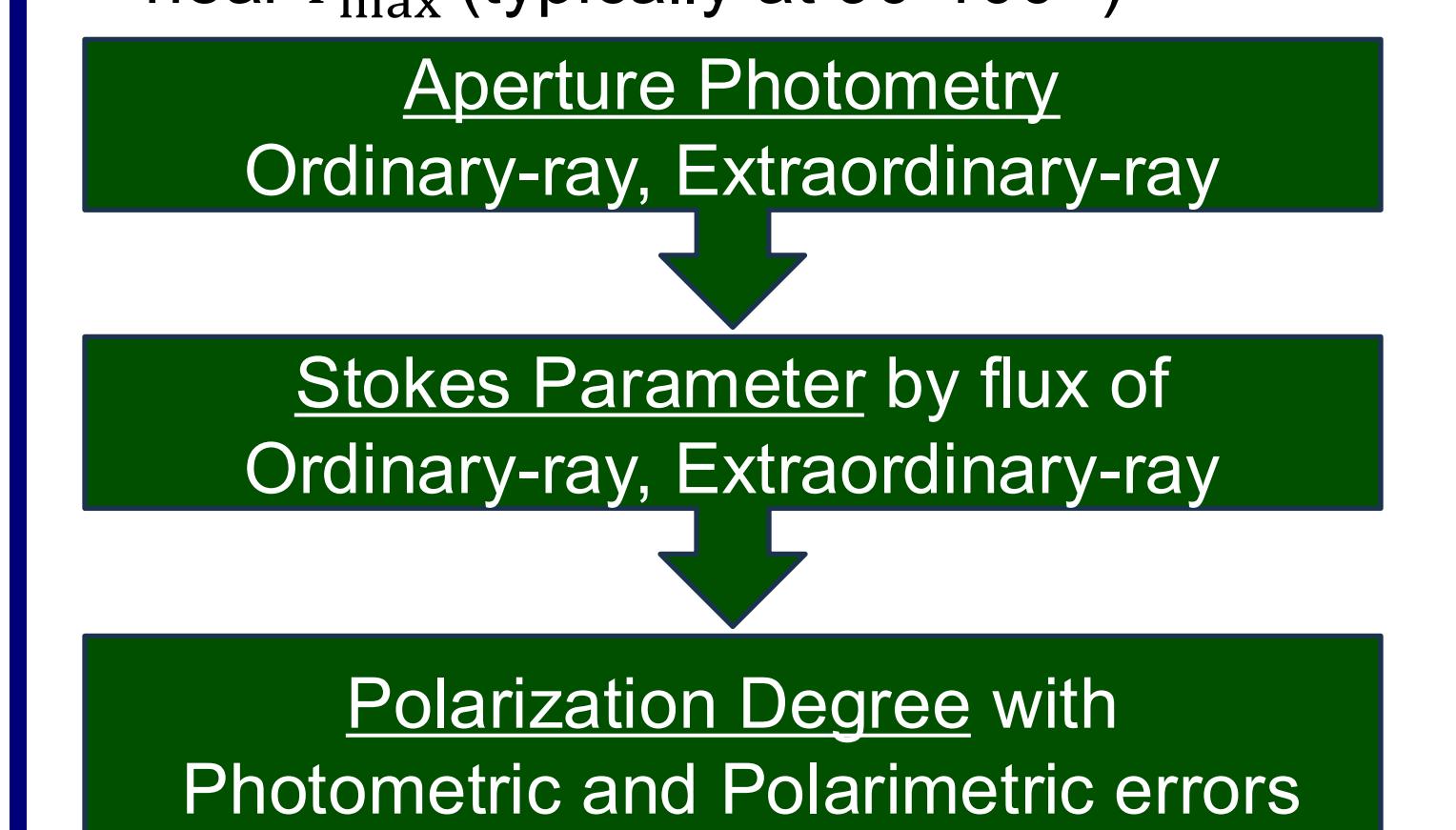


Date	UT	Filter	Exp. [s]	V mag.	r [au]	Δ [au]	α [°]	$P_r \pm \sigma P_r$ [%]	Notes
Jun. 29, 2024	14:46:23-14:48:51	V	30	9.71	1.01840	0.00196	26.351	2.03 ± 0.19	Closest approach night S/N ~1500
Jun. 29, 2024	14:50:18-14:52:47	V	30	9.73	1.01840	0.00196	26.765	1.80 ± 0.23	
Jun. 29, 2024	14:55:36-14:58:05	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	
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	1.01683	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 °)



4. Discussion

【Comparison with Polarization degree of NEAs】

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

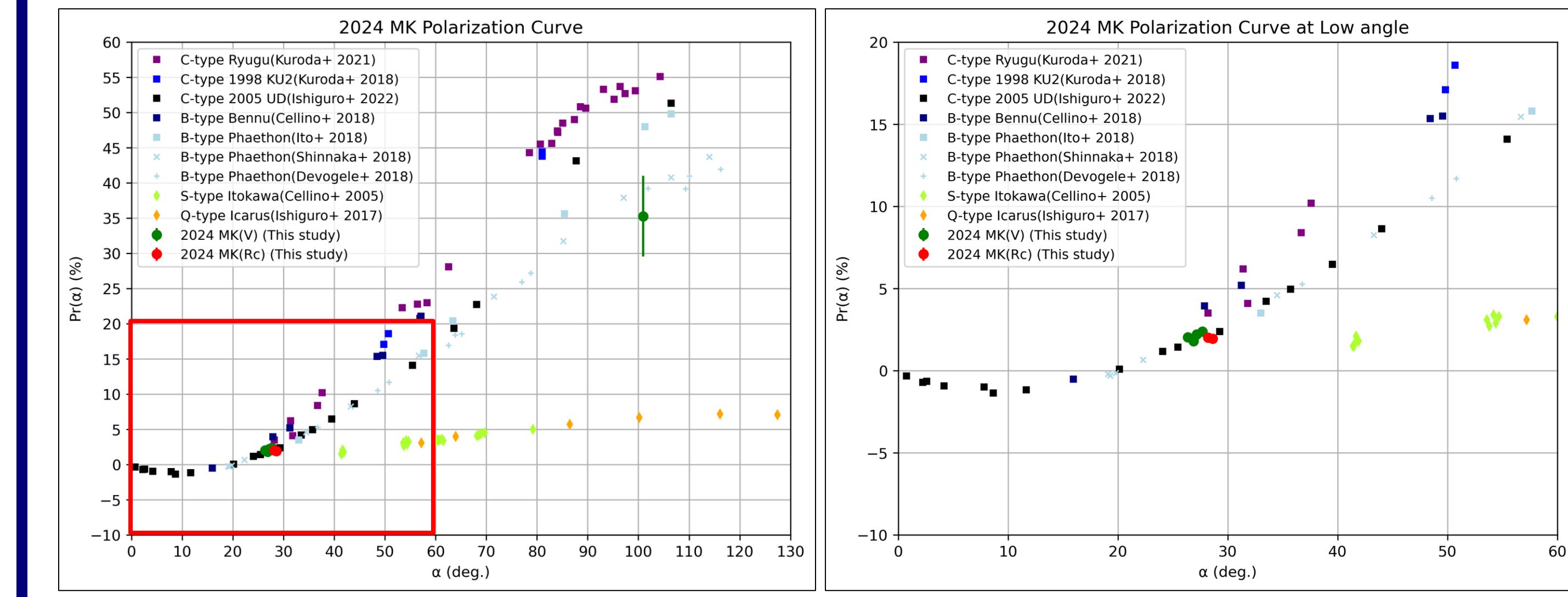


Fig. 9. Polarization degree of several type NEAs, Ryugu (purple squares; Kuroda et al., 2021), 1998 KU2 (blue squares; Kuroda et al., 2018), 2005 UD (black squares; Ishiguro et al., 2022), Bennu (navy squares; Celino et al., 2018), Phaethon (light blue squares; Ito et al., 2018, crosses; Shinnaka et al., 2018, pluses; Deogole et al., 2018), Itokawa (green yellow diamonds; Celino 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)

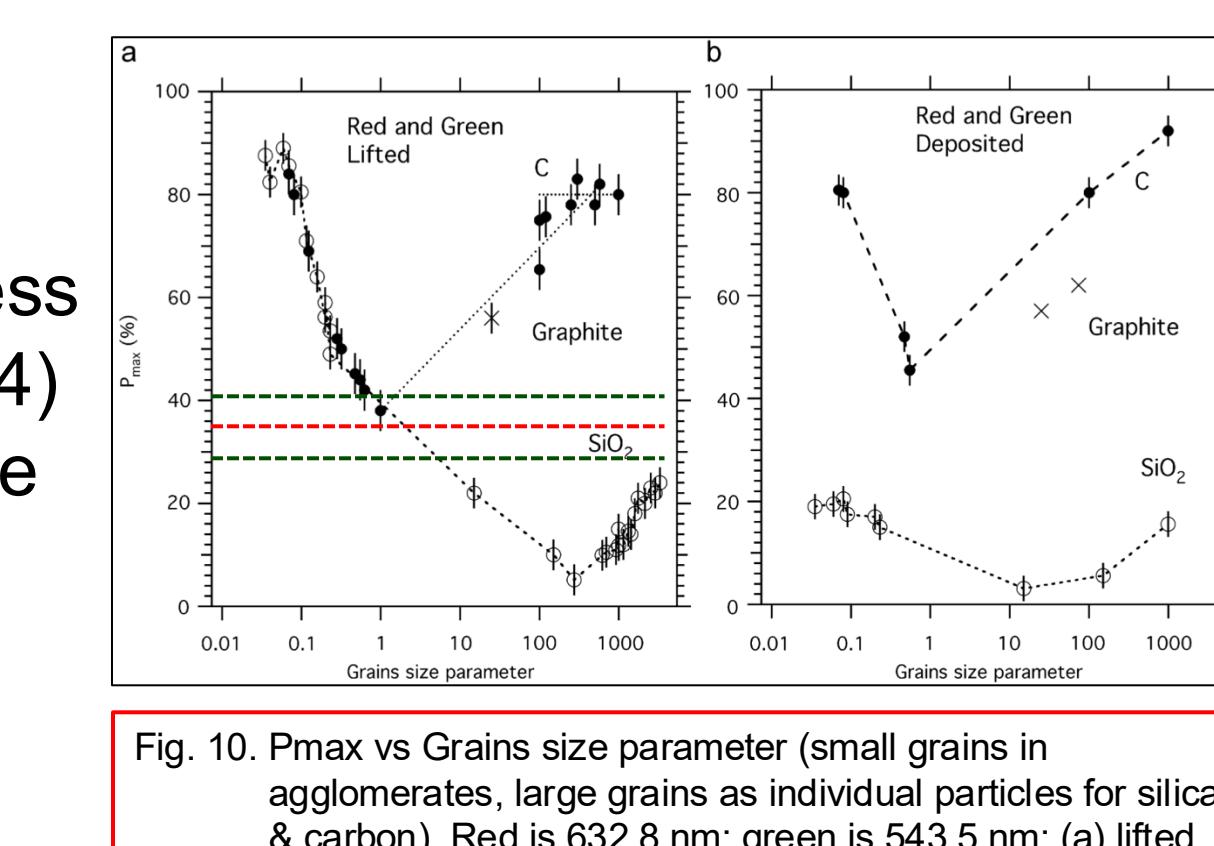


Fig. 10. P_{\max} vs Grains size parameter (small grains in agglomerates, large grains as individual particles for silica & carbon). Red is 532.8 nm; green is 543.5 nm; (a) lifted particles, (b) deposited particles (Hadamcik et al., 2009).

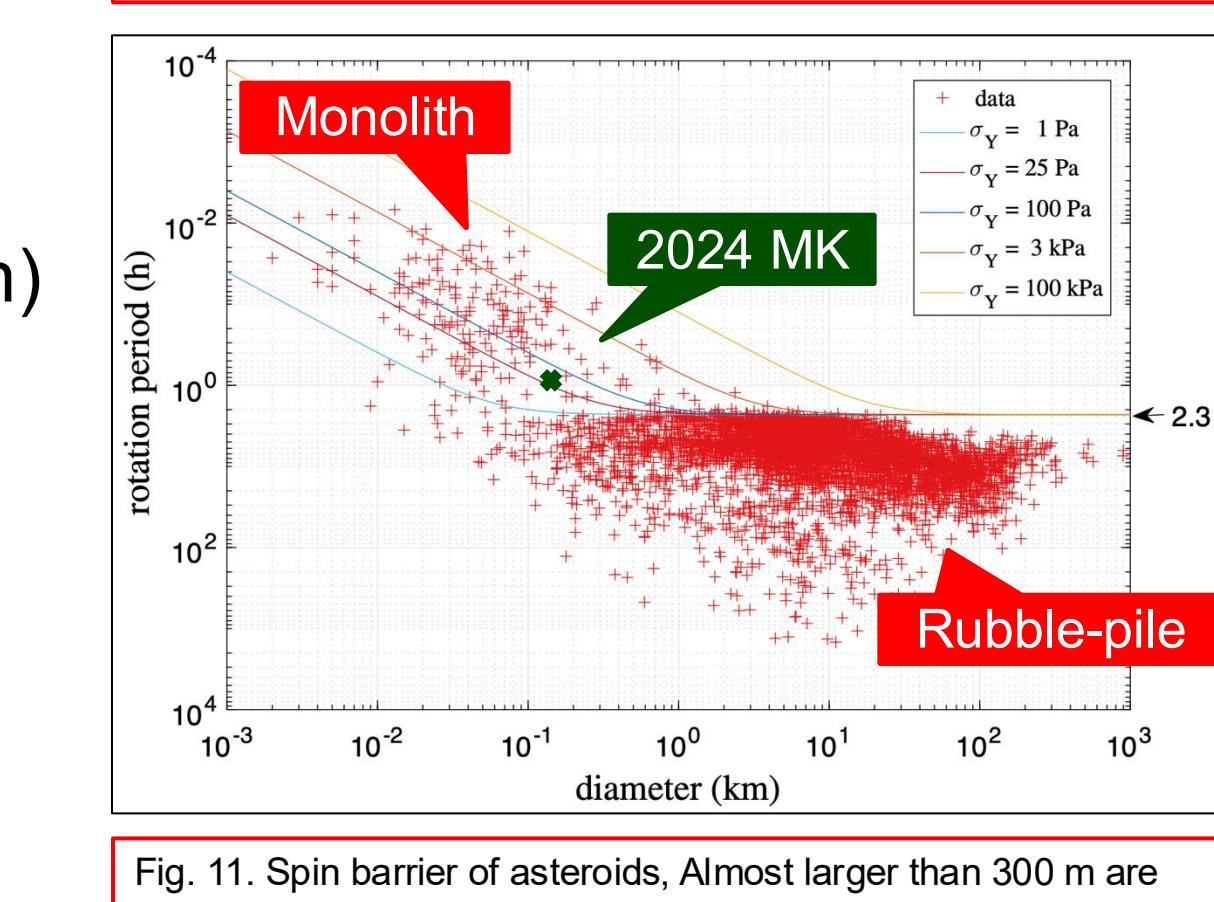


Fig. 11. Spin barrier of asteroids. Almost larger than 300 m are rubble-piles and rotate with a period longer than 2.3 hours (Persson and Biele, 2022).

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