STUDY OF NEAR-EARTH ASTEROIDS BY POLARIMETRIC TECHNIQUE

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Asteroid polarimetry: main applications

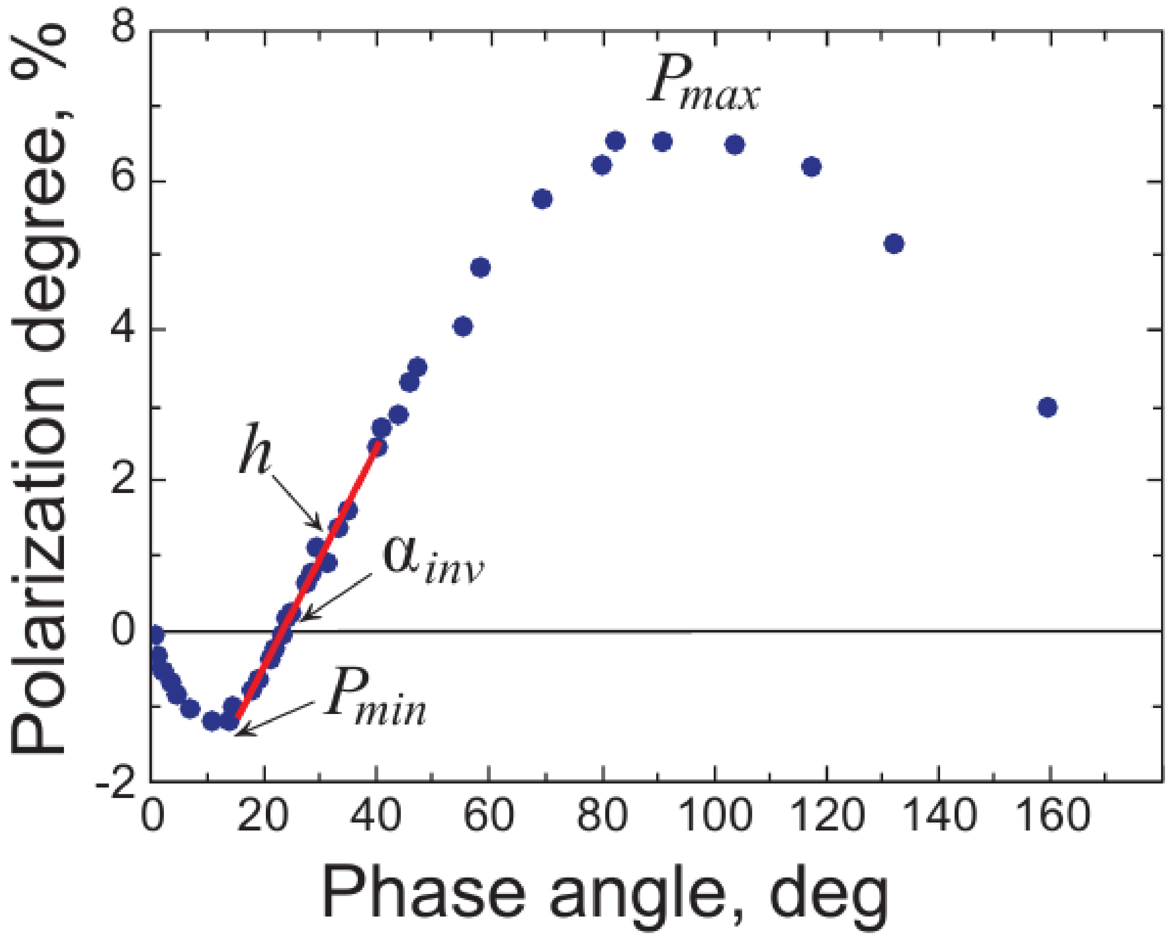
- Estimations of surface’s albedo
- Constrains on surface texture and composition

Polarimeric method of albedo determination: advantages

- Albedo can be derived directly from polarimetric measurements without any need of additional information.

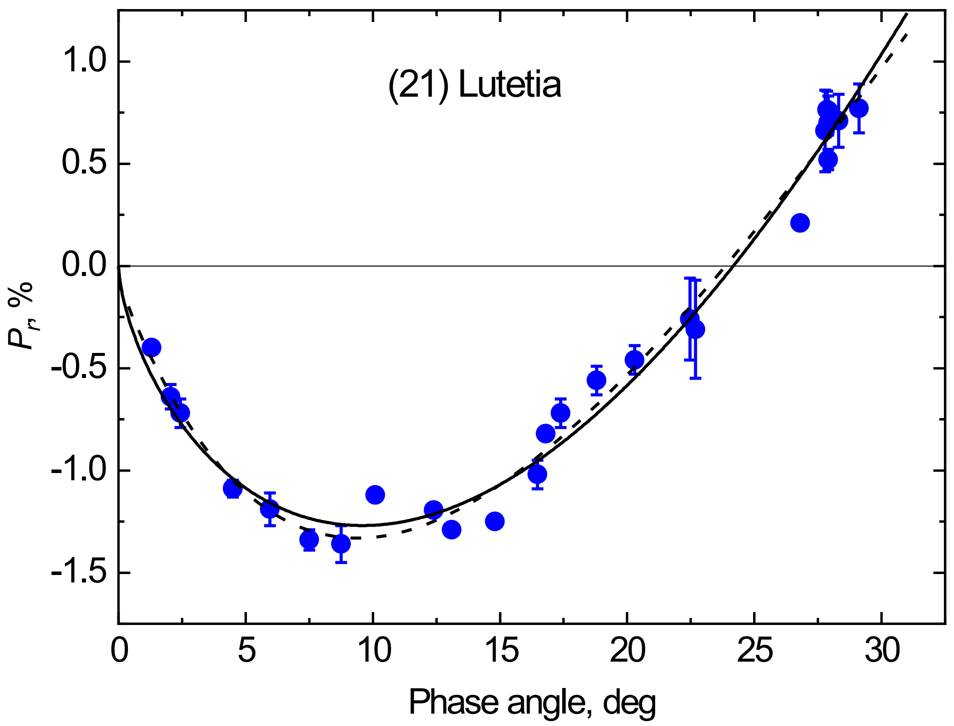
$$\log(p) = C_1 \log(P_{max}) + C_2$$
$$\log(p) = C_3 \log(h) + C_4$$
$$\log(p) = C_5 \log(P_{min}) + C_6$$

- Estimated accuracy of albedo is ~10-20%.

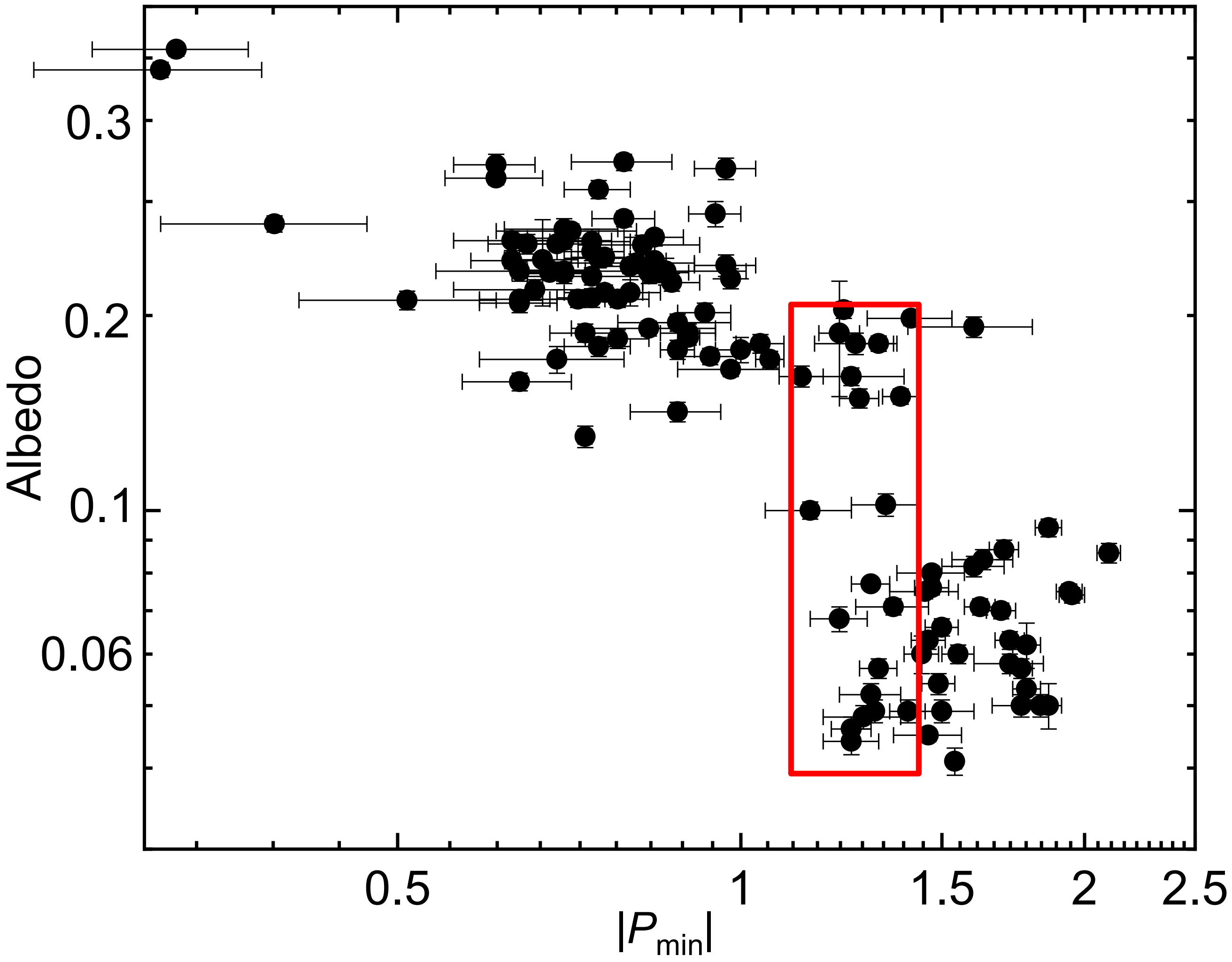


Albedo determination based on P_{min}

P_{min} ~ -1.2% – -1.4% inherent for asteroids with p_v from 0.04 to 0.2



p_v=0.08-0.09 (P_{min}=-1.3%)
p_v=0.19±0.01 (Sierks+ 2011)

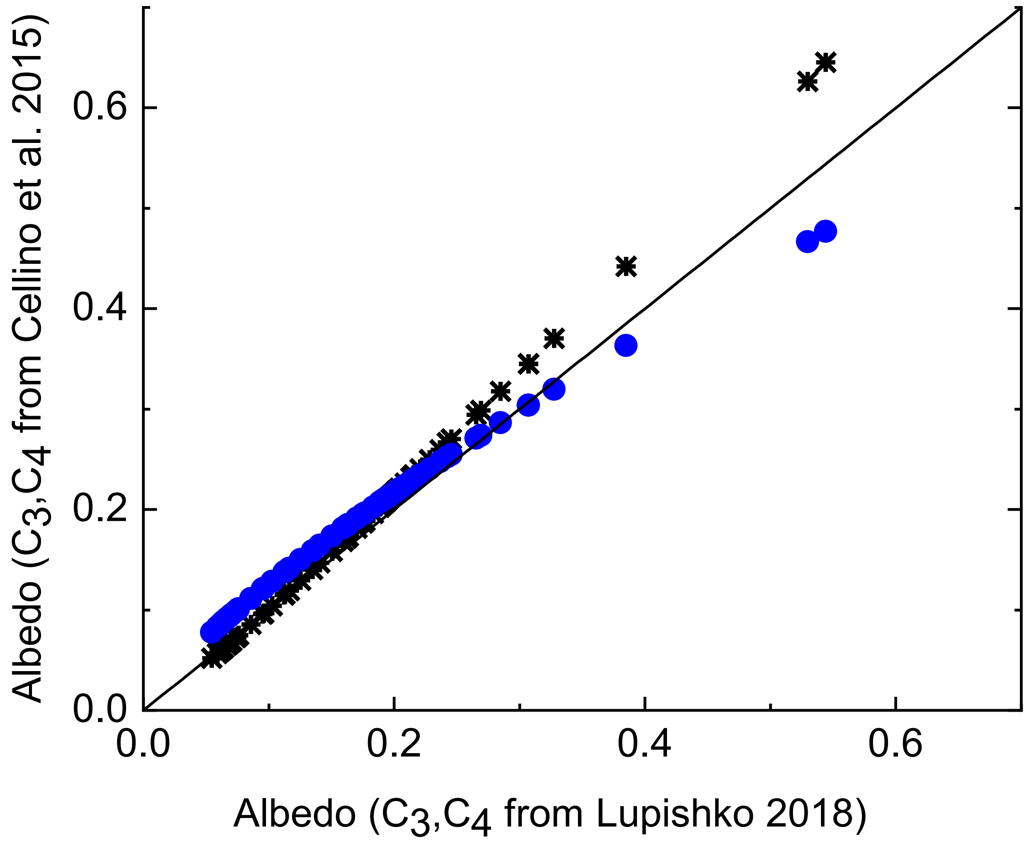


Albedo determination based on polarimetric slope

I. Calibration coefficients

$$\log(p) = C_3 \log(h) + C_4$$

Reference	Source of albedo data	C_3	C_4
Bowell&Zellner 1974	Meteorites	-1.00	-1.78
Zellner et al. 1977	Meteorites	-0.92	-1.72
Lupishko et al. 1996	IRAS/Occultations/ Space-based	-0.983	-1.731
Cellino et al. 1999	IRAS	-1.118	-1.779
Cellino et al. 2012	Occultations	-0.970	-1.667
Masiero et al. 2012	WISE	-1.207	-1.892
Cellino et al. 2015	Occultations	-1.124	-1.789
Lupishko et al. 2018	WISE/Akari/Occultations/Space-based	-1.016	-1.719



Albedo determination based on polarimetric slope

II. Validation

Bennu: p_r=0.059±0.003 (Cellino+ 2018) h=0.276 ± 0.012
p_v=0.046 ± 0.007 (Lee+ 2021)

Itokawa: p_v=0.24±0.01 (Cellino+ 2005) h=0.091 ± 0.003
p_v=0.23±0.02 (Lee&Ishiguro 2018)

Steins: p_v=0.45±0.10 (Fornasier+ 2006) h=0.037 ± 0.003
p_v=0.39±0.02 (Spjuth+ 2012)

Albedo determination based on polarimetric slope

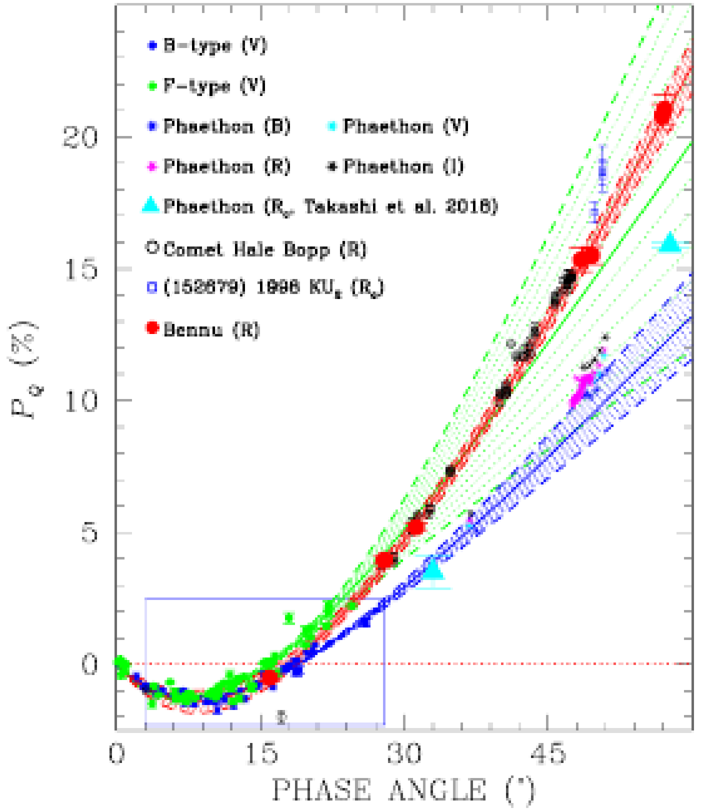
III. Comparison of different calibrations

$$\log(p) = C_3 \log(h) + C_4$$

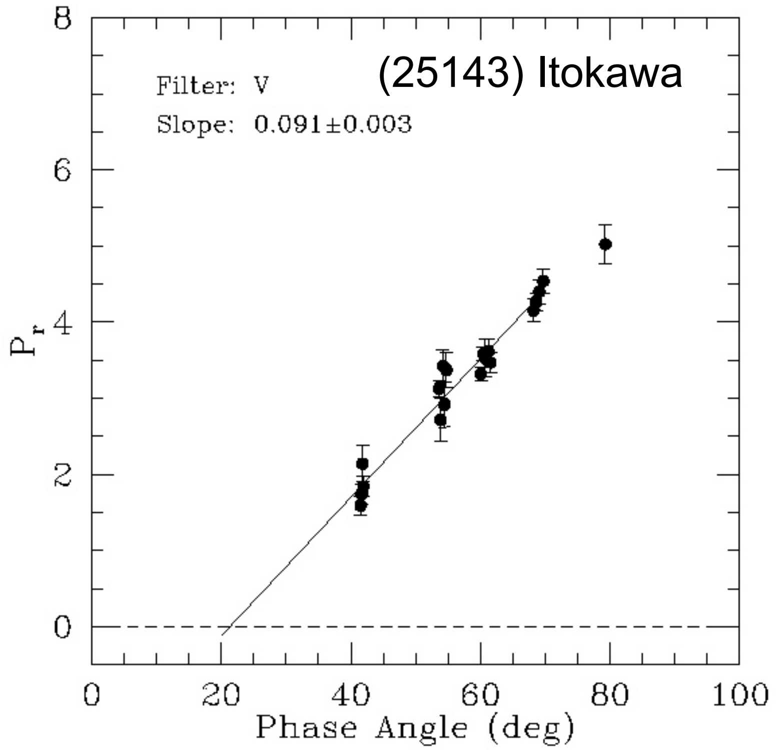
Reference	Source of albedo data	C_3	C_4	Bennu h=0.276	Itokawa h=0.091	Steins h=0.036
Bowell&Zellner 1974	Meteorites	-1.00	-1.78	0.060	0.18	0.46
Zellner et al. 1977	Meteorites	-0.92	-1.72	0.062	0.17	0.41
Lupishko et al. 1996	IRAS/Occultations/ Space-based	-0.983	-1.731	0.066	0.20	0.49
Cellino et al. 1999	IRAS	-1.118	-1.779	0.070	0.24	0.68
Cellino et al. 2012	Occultations	-0.970	-1.667	0.075	0.22	0.54
Masiero et al. 2012	WISE	-1.207	-1.892	0.061	0.23	0.71
Cellino et al. 2015	Occultations	-1.124	-1.789	0.069	0.24	0.68
Lupishko et al. 2018	WISE/Akari/Occultations/Space-based	-1.016	-1.719	0.071	0.22	0.56

Albedo determination based on polarimetric slope

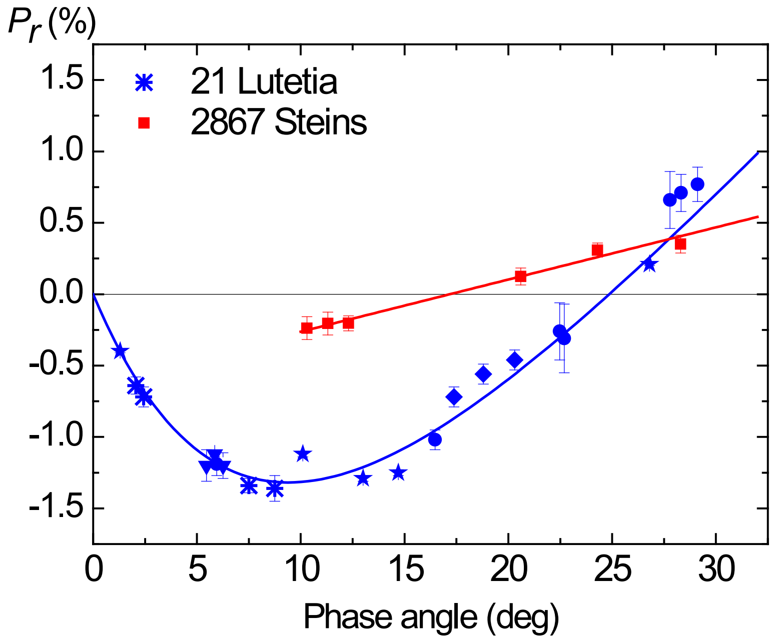
IV. Accuracy of polarimetric slope determination



Cellino et al. 2018



Cellino et al. 2005



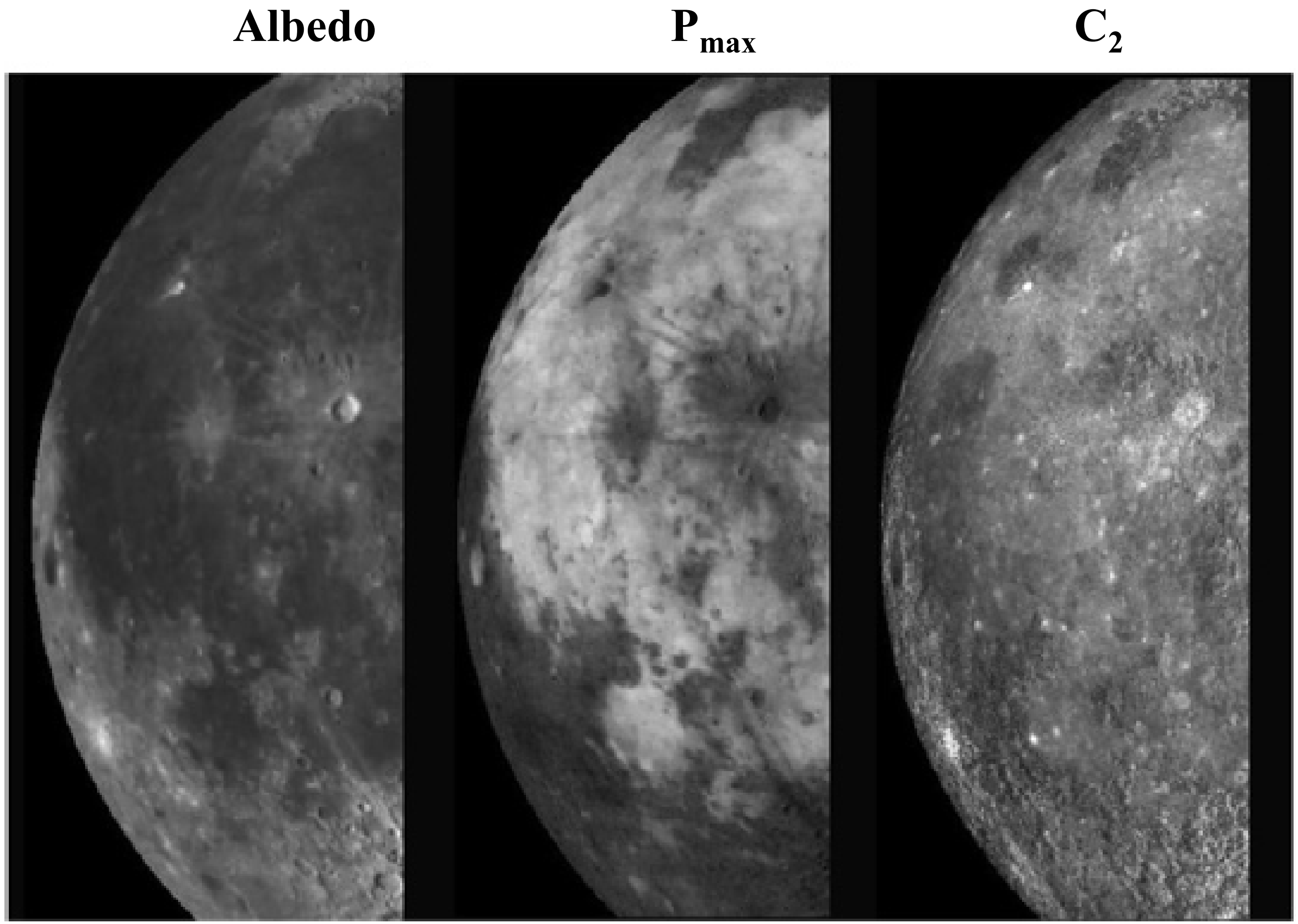
Fornasier et al. 2006
Belskaya et al. 2010

$\log(p) = -0.987 \log(\Psi) - 0.458$, $\Psi = P_r(30°) - P_r(10°)$ (Cellino et al. 2015)

Albedo determination based on P_{max}

I. Lunar surface

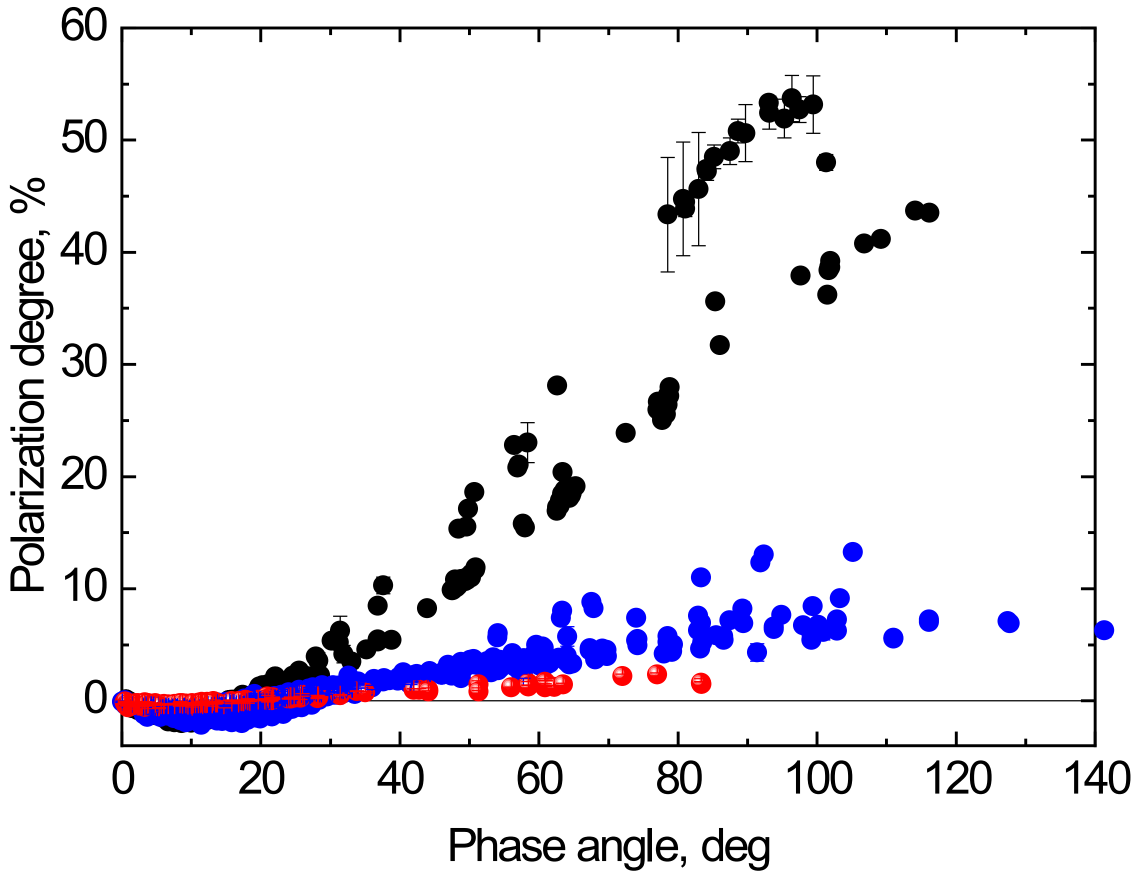
$$\log(p) = C_1 \log(P_{max}) + C_2$$



Shkuratov &Opanasenko 1992, Shkuratov et al. 2011

Albedo determination based on P_{max}

II. Near-Earth Asteroids



C-complex (p~0.07) P_{max} ~ 40-50%

S-complex (p~0.2) P_{max}~ 6-12%

E-type (p~0.4) P_{max}~ 2%

Asteroid	P_{max}	α_{max}	Reference
Ryugu	53±0.4%	102±2°	Kuroda+2021
Phaethon	50±1%	106±2°	Ito+2018
Phaethon	>42%	>114°	Shinnaka+2018
Phaethon	~45%	~130°	Devogele+2018
Phaethon	45±1%	124±1°	Kiselev+2022
1998 KU2	~49%		Kuroda+2018
2005 UD	~36%	~100	Ishiguro+2022

Sizes of potentially hazardous asteroids

Asteroid	H (MPC)	α, deg	*P*, %	Albedo range	*D*, km	D, km (radiometry, radar)
(4183) Cuno	14.4	80	6.3±0.1	0.2-0.25	3.5-3.9	3.6[1]
(66391) 1999 KW4	16.6	75	6.0±0.2	0.2-0.25	1.3-1.4	1.3[2]
(85989) 1999 JD6	17.1	96	12.3±0.3	0.1-0.15	1.3-1.6	1.5[1]
(143404) 2003 BD44	16.9	123	6.6±0.3	0.2-0.25	1.1-1.2	0.9-2.5
(215588) 2003 HF2	19.4	90	12.8±0.3	0.1-0.15	0.5-0.6	0.5[1]

[1]Mainzer et al. NEOWISE Diameters and Albedos (2019); [2]Ostro et al. (2006).

Observations at the 2-m telescope of the Bulgarian National Astronomical Observatory in Rozhen (*Krugly et al.* 2024).

Summary

- Polarimetry provides one of the best tools to determine asteroid albedos.
- The most accurate albedos can be obtained from the measurements of polarimetric slope. Uncertainties in calibration coefficients introduces additional errors for high-albedo asteroids.
- Even a single accurate measurement of polarization degree at α>40° can provide reliable estimate of albedo by simple comparison with the average polarization behavior of asteroids with known albedos.
- Polarimetric monitoring of potentially hazardous NEOs at the time of their close approach to the Earth can be of great importance for determining their reliable sizes.

Thanks to all people who helps Ukraine to stop russia’s aggression!