Gaia-FUN-SSO 3rd Workshop
Paris Observatory, PARIS, France
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Polarimetric observations of NEAs at RTT150. First results.

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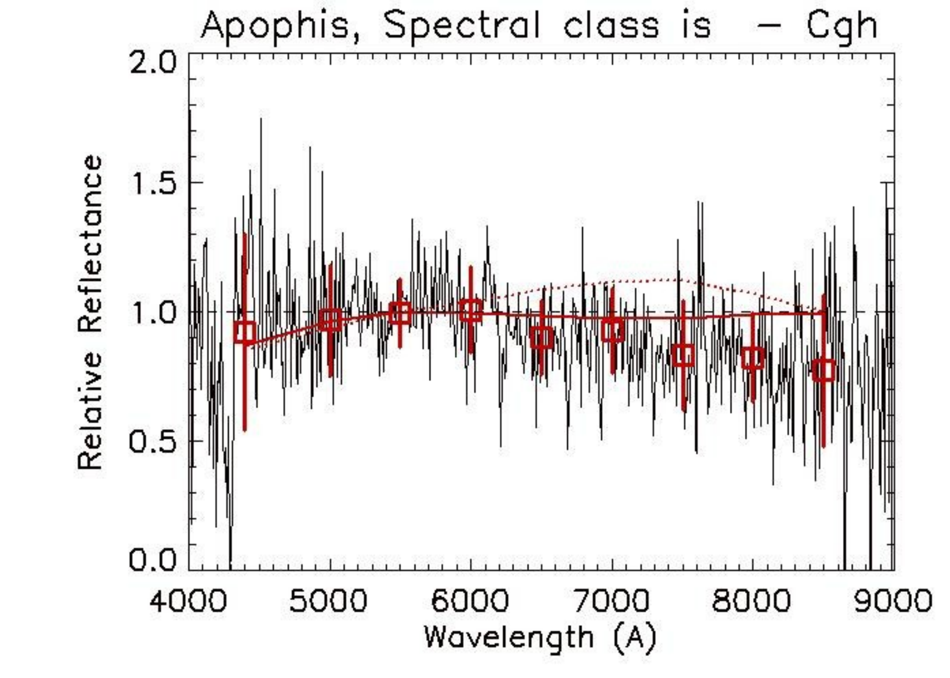


On the base of our estimations Apophis most likely belongs to C-complex, as compared with S-complex definition by Bensel et al. (2009).

...

At the next stage we are planning to make polarimeter

(I.Khamitov, talk at The 4th GAIA Science Alert workshop)

TÜBİTAK supports the design of TFOSC Compatible Polarimeter for Polarimetric Observations

Duration: **2 years**. *No*.: **113F263**

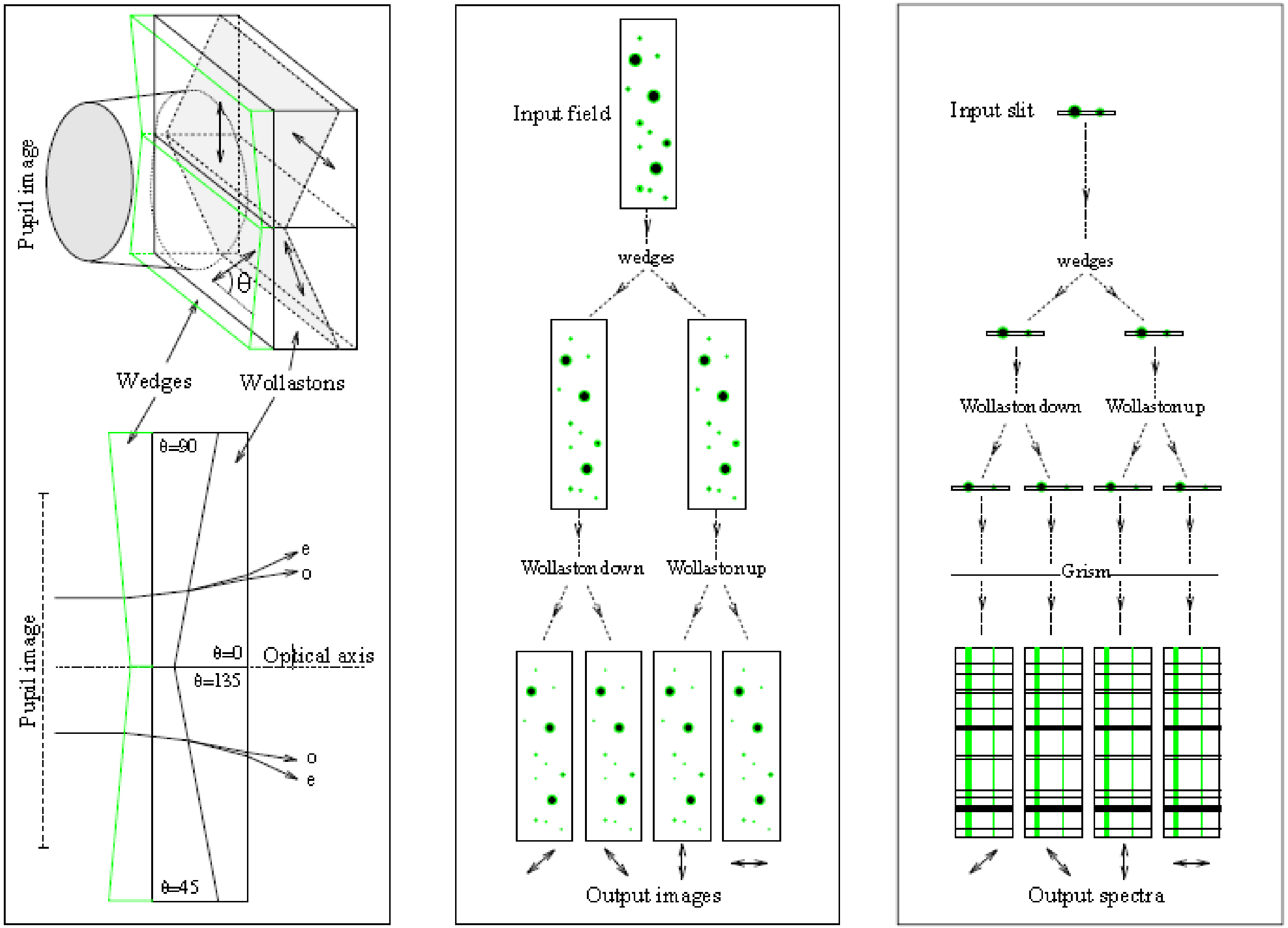
Principal Investigator: **Selcuk HELHEL**

Participants: **Gizem KAHYA, Cevdet BAYAR**

Consultant: **İrek KHAMİTOV**

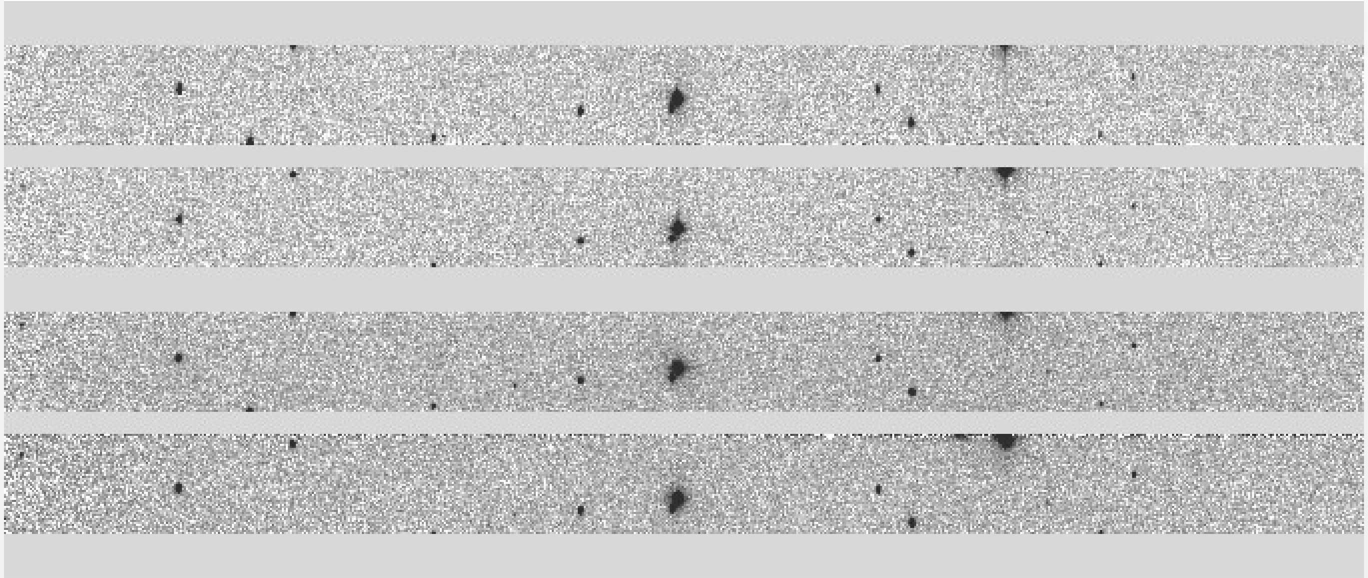
Project aims: The design a TFOSC compatible polarimeter and investigation the physical parameters of targeted asteroids (such as albedo, diameter, taxonomy of asteroids, porosity) based on the polarization properties of light by using this polarimeter.

Suleyman KAYNAR & **Rustem GUMEROV** had joined the team on observational stage.



WeDoWo (Wedged Double Wollaston) operation principle (OLIVA,1997)

The product was manufactured by ELAN Ltd.
http://www.elan-optics.com/



TFOSC-WP images of 4 polarized beam at 0°, 45°, 90° and 135° separated by 60 arcsec of strongly polarized star ***Hiltner 960.***
B-band, 23 August 2014.

Formulae and errors of measurements of degree of linear polarization ***P*** and position angle ***ϑ*** of polarization plane in the instrumental reference system using TFOSC-WP:

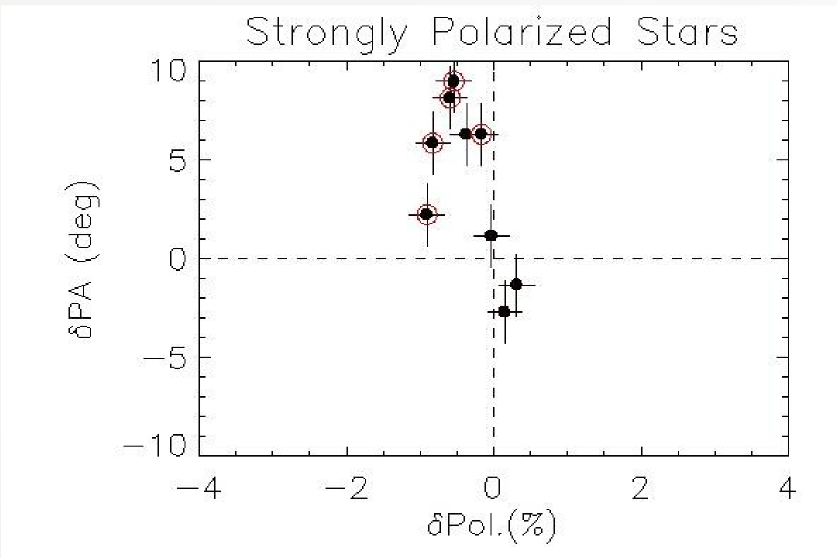
$$Q = \frac{I_0 - I_{90}}{I_0 + I_{90}}, \qquad U = \frac{I_{45} - I_{135}}{I_{45} + I_{135}}$$

$$P = \sqrt{Q^2 + U^2}, \qquad \theta = \frac{1}{2}\arctan\frac{U}{Q}$$

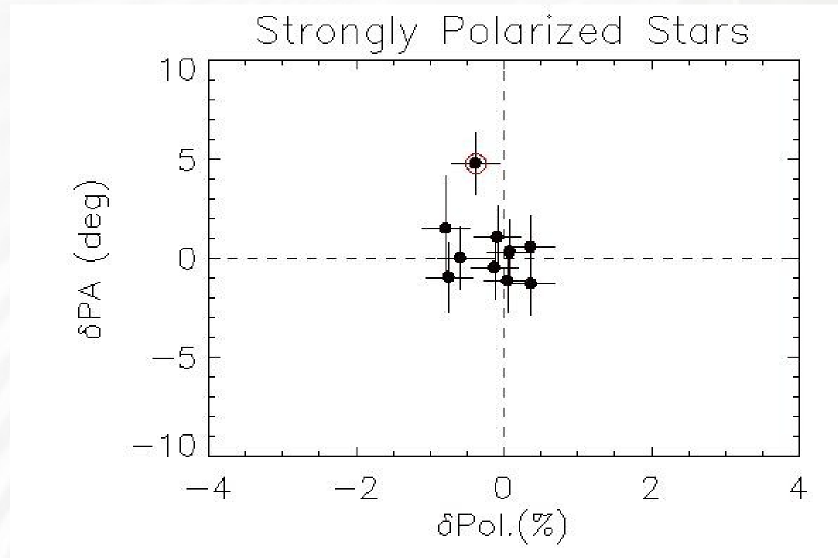
$$\sigma_P = \frac{|QdQ + UdU|}{P}, \qquad \sigma_\theta = \frac{28.65 * \sigma_P}{P}$$

Shakhovskoy & Efimov 1972; Fornasier et al., 2006

TFOSC-WP calibration



August 2014

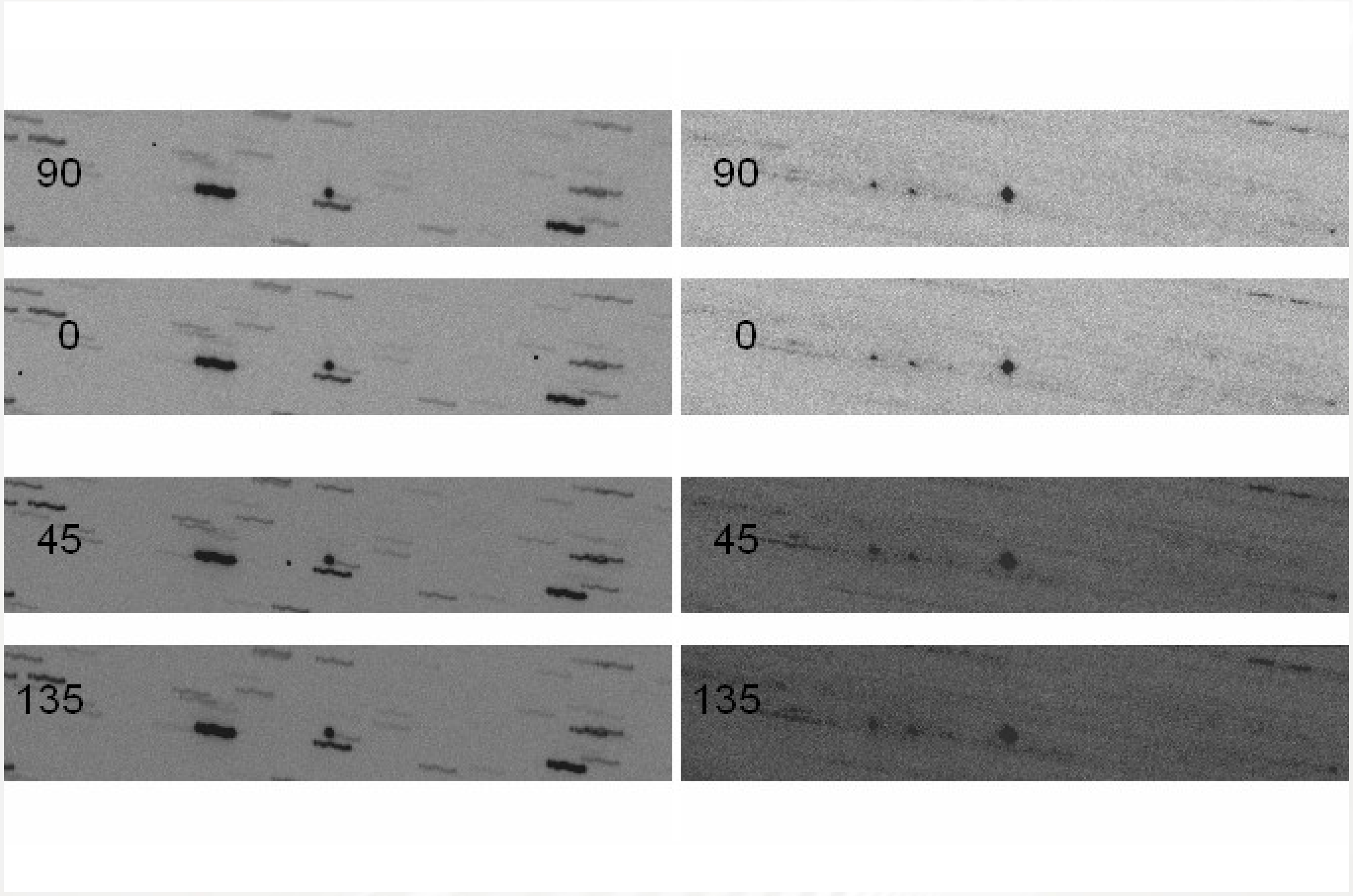


September 2014

Systematic errors: $\sigma_P \approx 0.4\%$ $\sigma_\theta \approx 1.^\circ5$

Polarimetric and photometric observations NEAs at RTT150

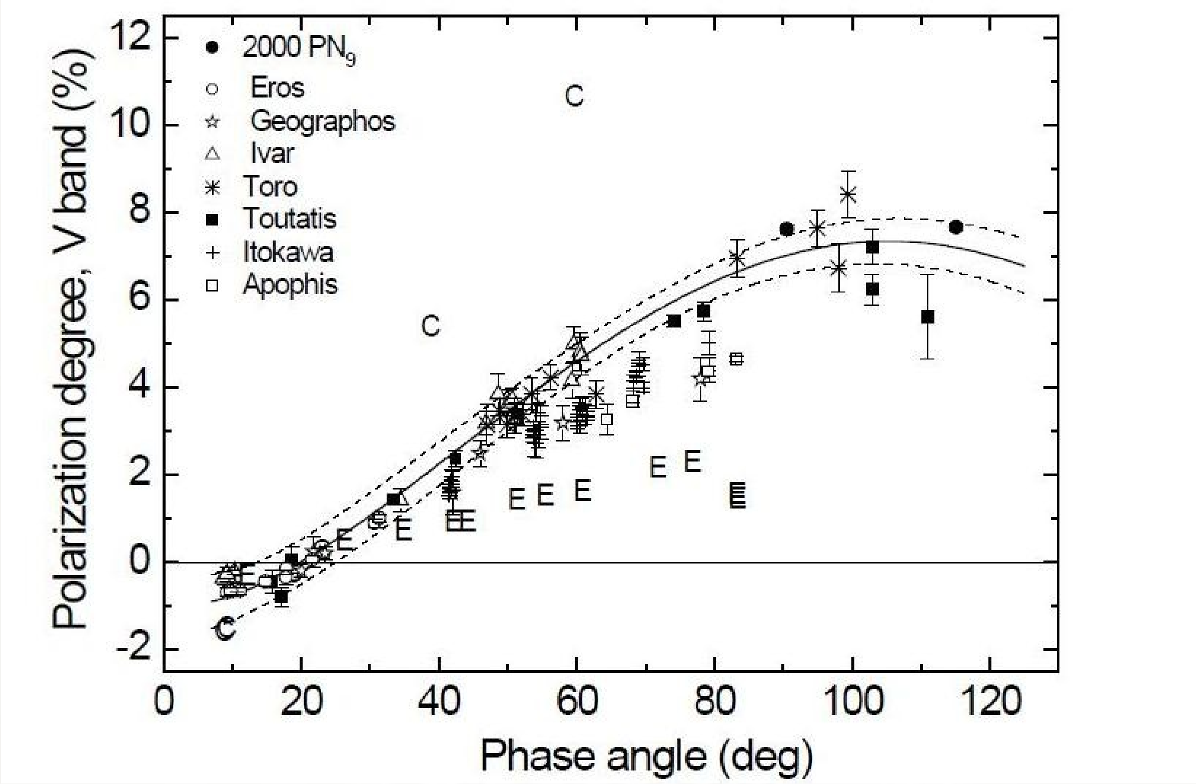
3 NEAs during theirs close approaches were selected and observed using TFOSC-WP: 163132, 276049, 333578



- Polarimetric and photometric observations NEAs at RTT150

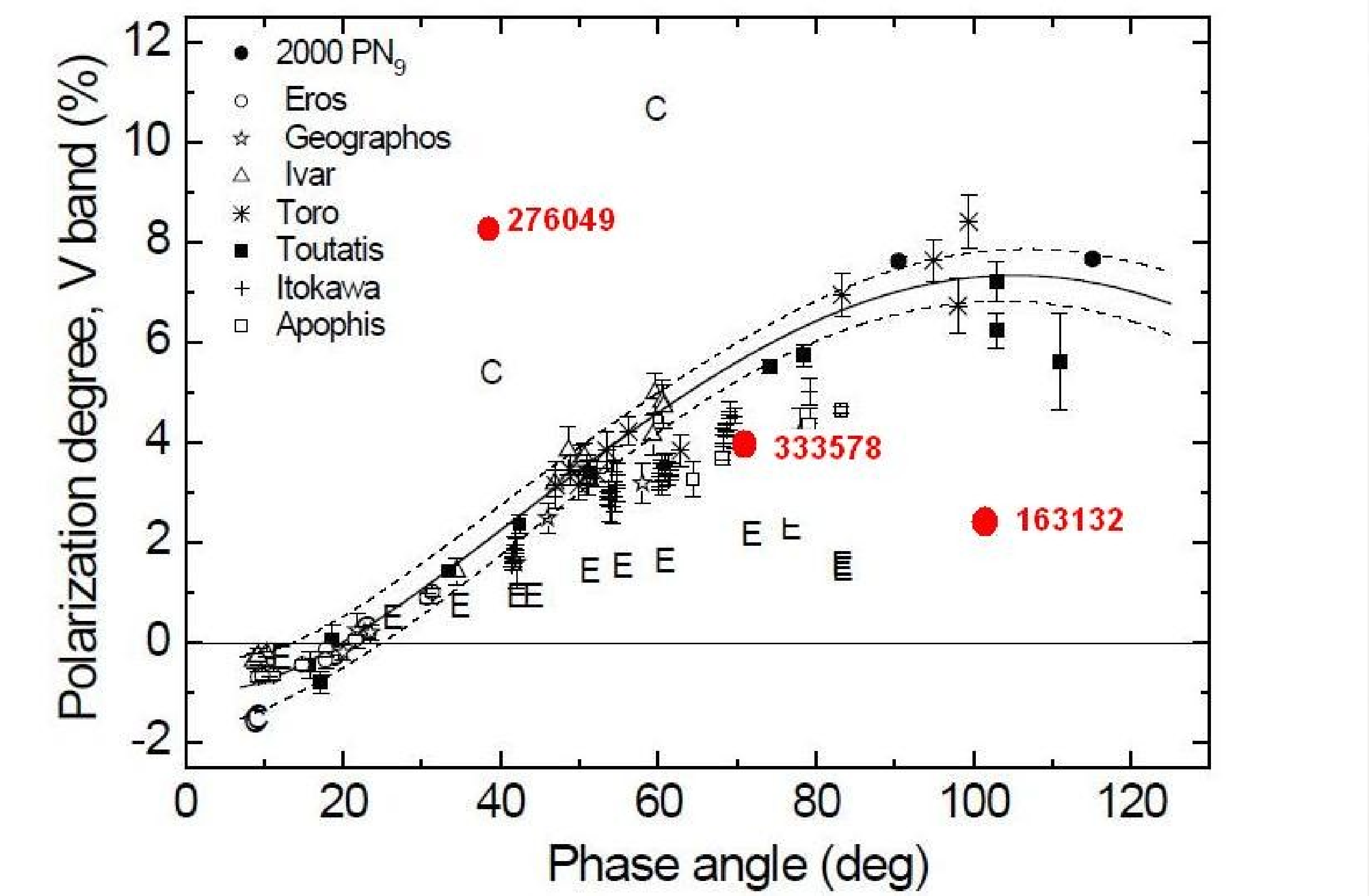
Asteroid	V (mag)	Proper α·cos(δ) (“/min)	motion δ (“/min)	Phase angle (˚)	P_V (%)	P_{rV} (%)
163132	16.80±0.01	-2.5	5.0	102.15	2.18 ±0.40	2.01±0.40
276049	15.91±0.01	-0.6	-2.8	38.55	8.51±0.25	8.03±0.25
333578	17.00±0.01	4.7	4.8	71.00	3.79 ±0.30	3.58±0.30

Polarization phase dependence of NEOs*



*Irina N.Belskaya, Sonia Fornasier , Yurij N.Krugly, Icarus, 201, p167-171, 2009

Determination of SType



Albedo estimation (p_v)

Formula and error

$$\log(p_v) = A + B * \log(h)$$

p_v – geometric albedo,
h – polarimetric slope around of inverse angle α_{inv}
A=-1.731, B=- 0.983

(Lupishko and Mohamed 1996)

$$\frac{\delta p_v}{p_v} = |B| * \frac{\delta h}{h}$$

Albedo estimation (p_v)
Polarimetric slope *(h)* estimation

Albedos and parameters of average polarization phase dependences of the main asteroid types in the V band *

Asteroid type	Average albedo	$\|P_{min}\|$ (%)	α_{min} (deg)	α_{inv} (deg)	h (%/deg)
F	0.05	1.15 ±0.10	7.0 ±1.7	15.5 ±1.5	0. 327±0.037
C	0.07	1.55 ±0.55	8.7 ±2.1	19.7 ±1.5	0. 369±0.039
M	0.15	1.08 ±0.25	8.4 ±1.3	22.0 ±2.0	0. 170±0.010
S	0.20	0.77 ±0.20	8.0 ±1.2	20.6 ±2.0	0. 107±0.005
A	0.42	0.40 ±0.10	<7	18.1 ±1.5	0. 044±0.008
E	0.51	0.31 ±0.05	4.7 ±1.3	18.0 ±1.5	0. 042±0.013

*) taken from the book:

Mishchenko M. I., Rosenbush V. K., Kiselev N. N., Lupishko D. F., Tishkovets V. P., Kaydash V. G., Belskaya I. N., Efimov Y. S., Shakhovskoy N. M. Polarimetric remote sensing of Solar System objects. – Kyiv: Akademperiodyka, 2010. 291 p., 24 p. il.

Albedo estimation (p_v)
Polarimetric slope (h) estimation

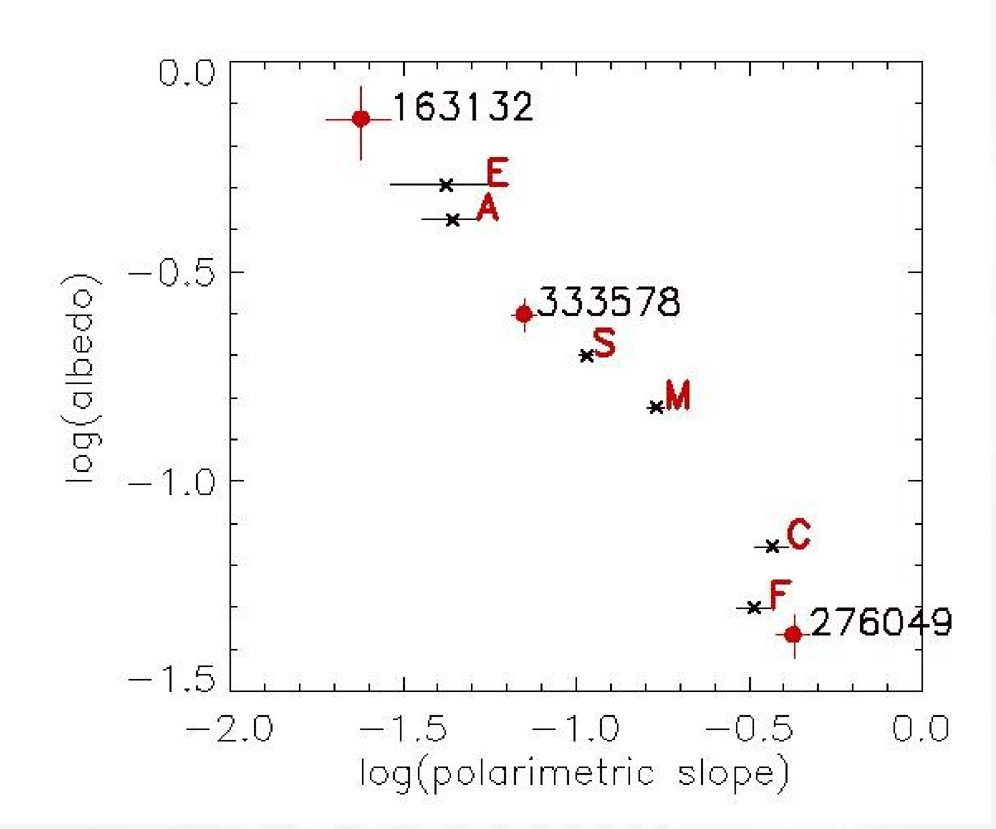
Formula and error

$$h = \frac{P_{rV}}{(PA_{obs} - \alpha_{inv})}$$

P_{rV} – polarization degree in asteroid reference system
PA_{obs} – phase angle of observation
α_{inv} – inverse angle

$$\frac{\delta h}{h} = \sqrt{\left(\frac{\delta P_{rV}}{P_{rV}}\right)^2 + \left(\frac{\delta \alpha_{inv}}{(PA_{obs} - \alpha_{inv})}\right)^2}$$

Albedo estimation (p_v)



Estimation of absolute magnitude of HG-system (H)

(Formulae)

$$H = m - 5*\log(d*r) + 2.5*\log((1-G)*\varphi_1 + G*\varphi_2)$$

$$\varphi_1 = \exp\left[-3.33*tg(0.5*PA_{obs})^{0.63}\right]$$

$$\varphi_2 = \exp\left[-1.87*tg(0.5*PA_{obs})^{1.22}\right]$$

H – absolute magnitude in V-band
d – geocentric distance in AU
r – heliocentric distance in AU
G – photometric slope
PA – phase angle

Bowell et al. (1989)

Estimation of absolute magnitude of HG-system (H) (error)

$$\delta H = \sqrt{(\delta m)^2 + (\delta G_H)^2}$$

$$\delta G_H = 1.09 * (\varphi - \varphi^2 G + \varphi^3 G^2) * \delta G, \qquad if\ \varphi G < 1$$

$$\delta G_H = \left(\frac{2.5}{G} + 1.09 * \frac{1 - \varphi G}{\varphi^2 G^3} \right) * \delta G, \qquad if\ \varphi G > 1$$

$$\varphi = \frac{\varphi_2 - \varphi_1}{\varphi_1}$$

δm – magnitude error
δG – photometric slope error

Estimation of absolute magnitude of HG-system (H)

TABLE 2. *Mean G-values.*

Taxonomic type	$<G>$	$\sqrt{\sum^{N} \frac{(G-<G>)^2}{N-1}}$	N
S	0.23 ± 0.02	0.11	26
M	0.22 ± 0.02	0.05	11
C	0.04 ± 0.02	0.06	7
G	0.09 ± 0.02	0.03	3
P	0.08 ± 0.01	0.02	3
E	0.45 ± 0.03	0.04	2
T	0.25	—	1
R	0.40	—	1
B	0.10	—	1
V	0.33	—	1
F	-0.03	—	1
C,G,B,F,P,T (low albedo)	0.09 ± 0.01	0.07	28
S,M (intermediate albedo)	0.22 ± 0.02	0.10	37
E,V,R (high albedo)	0.41 ± 0.03	0.06	4
All objects	0.19 ± 0.02	0.12	69

*mean values of phase slope parameter <G> were adopted from Lagerkvist & Magnusson (1990) for low, moderate and high albedo asteroid classes.

Diameter estimation (Deff)

Formula and errors

$$Deff = \frac{1329.}{\sqrt{p_v}} 10^{(-0.2H)}, (km)$$

$$\frac{\delta D_{eff}}{D_{eff}} = 0.5 * \sqrt{\left(\frac{\delta p_v}{p_v}\right)^2 + (\delta H)^2}$$

Fowler, J.W., Chillemi, J.R., 1992.

Results

Asteroid	SType	p_v (albedo)	<G>	V (mag)	H (mag)	D(km)
163132	E (high p_V)	0.730±0.146 (10%)	0.41±0.06	16.80±0.01	18.94±0.34	0.254±0.05 (20%)
276049	C (low p_V)	0.043±0.005 (6%)	0.09±0.07	15.91±0.01	16.54±0.15	3.141±0.30 (10%)
333578	S (mod p_V)	0.250±0.023 (5%)	0.22±0.10	17.00±0.01	20.33±0.36	0.228±0.03 (13%)

Conclusion

RTT150 is owner of new facility – polarimeter. Together with photometry and spectroscopy it gives promising results of NEOs physical parameters investigation

Suggestion to GAIA-FUN-SSO

After series of astrometric images (R-band) to get at least 5 images in V-band and Landolt standard star at the same airmass. Or only Landolt standard star in R-band for photometric calibration.

THANK YOU!