Calern Asteroid Polarimetric Survey 2.0

(CAPS 2.0)

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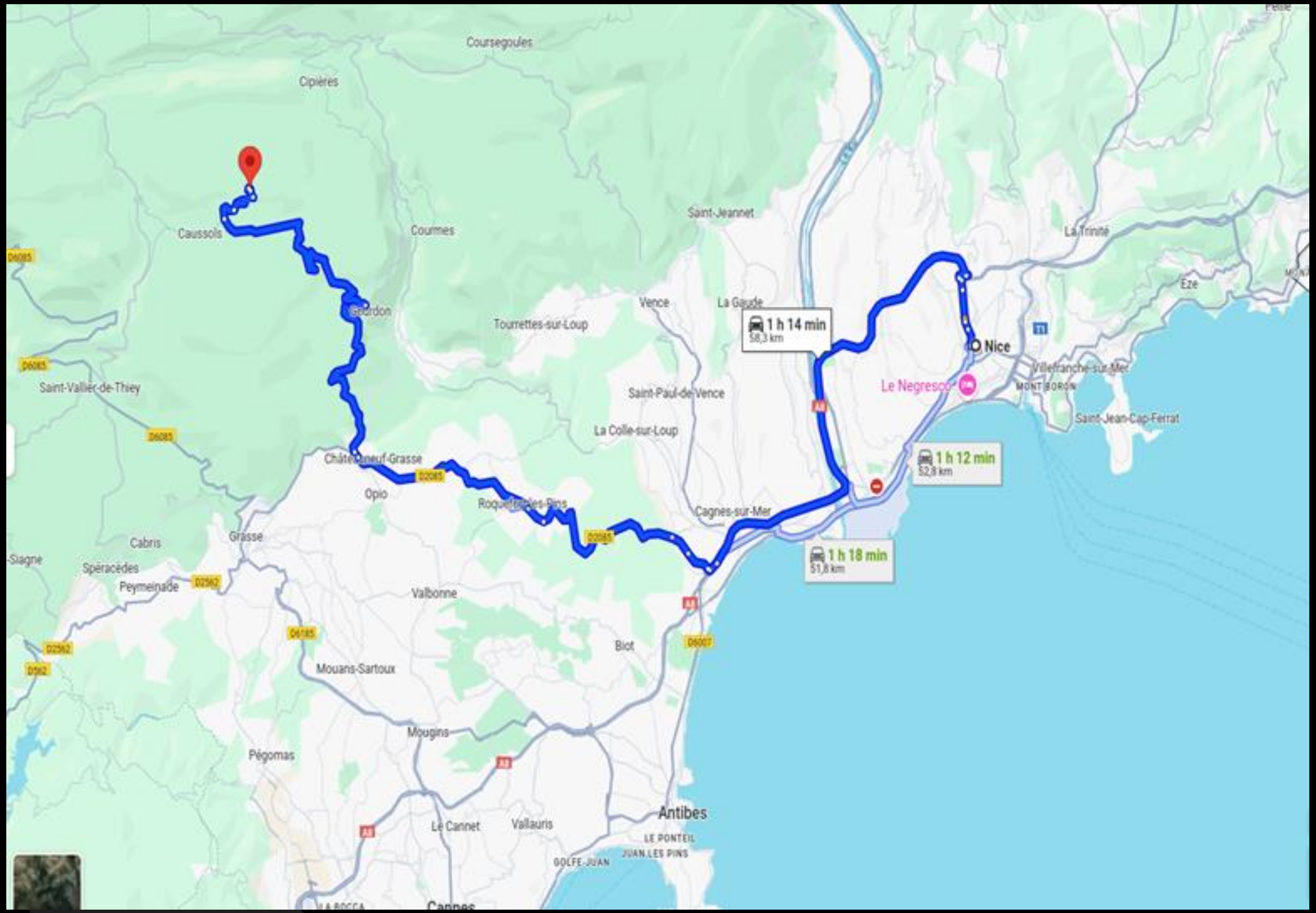
Calern Asteroid Polarimetric Survey 2.0



Calern Observatory in Caussols (France), part of the Observatoire de la Côte d'Azur

50 km from Nice

Latitude:	43° 45' 13.2" N	(43.75367° N)
Longitude:	06° 55' 22.7" E	(6.92297° E)
Altitude:	1270 m	

Code UAI: 010

About 180 observable nights/year (Bonneau 1997)

From June to October 80% night seeing better than 1.25" , 20% better thant 1"

The extinction coefficient in V 0.1412 ± 0:0009 magnitude per airmass unit (Devogèle et al., 2017)

Calern Asteroid Polarimetric Survey 2.0

Two twin telescopes 1.04 m in diameter
Left one dedicated to photometry and polarimetry

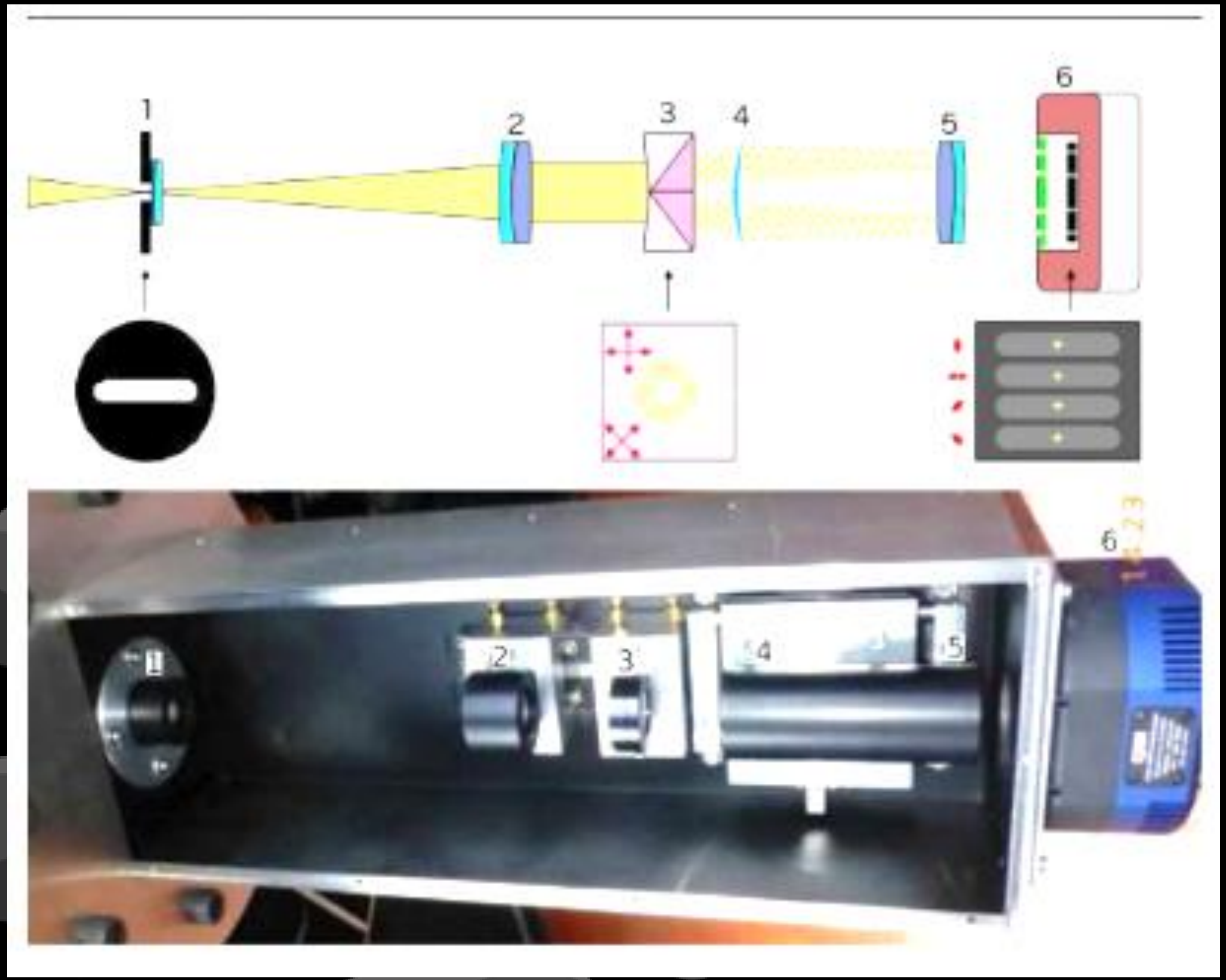
Diameter 1.04m
2 focal configurations
  Primary F/D = 3.14 (wide field)
  Secondary F/D 12.5 ==> polarimetry
Yoke mount ==> no observation above declination=+60°

Calern Asteroid Polarimetric Survey 2.0

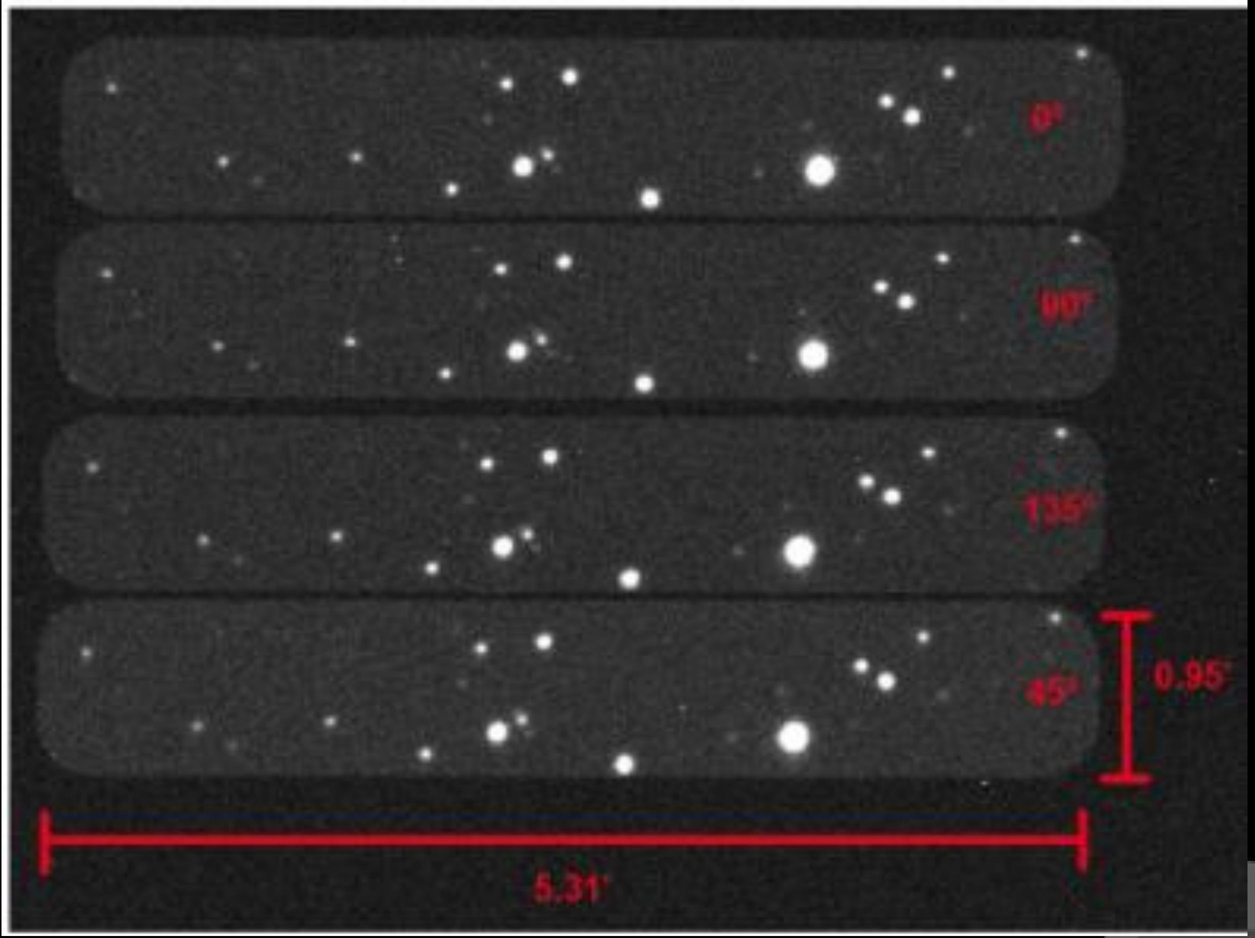
2.0 means necessarly 1.0

CAPS 1.0

Collaboration Osservatorio di Torino + Observatoire de la Côte d'Azur
2015
Wedged double Wolaston



Devogele et al 2016 MNRAS



Pros :

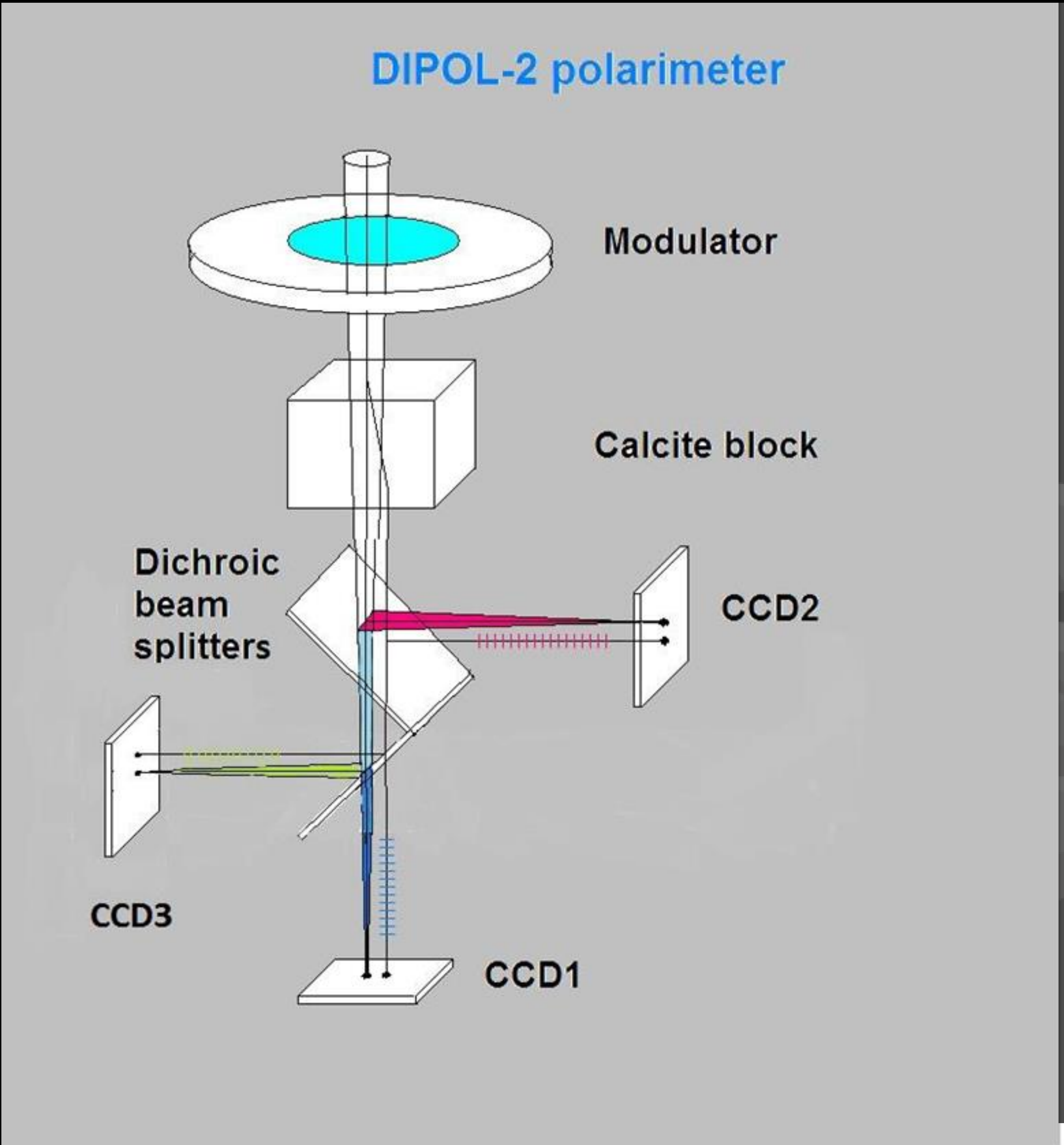
- Simultaneous calculation of the 3 Stokes parameters

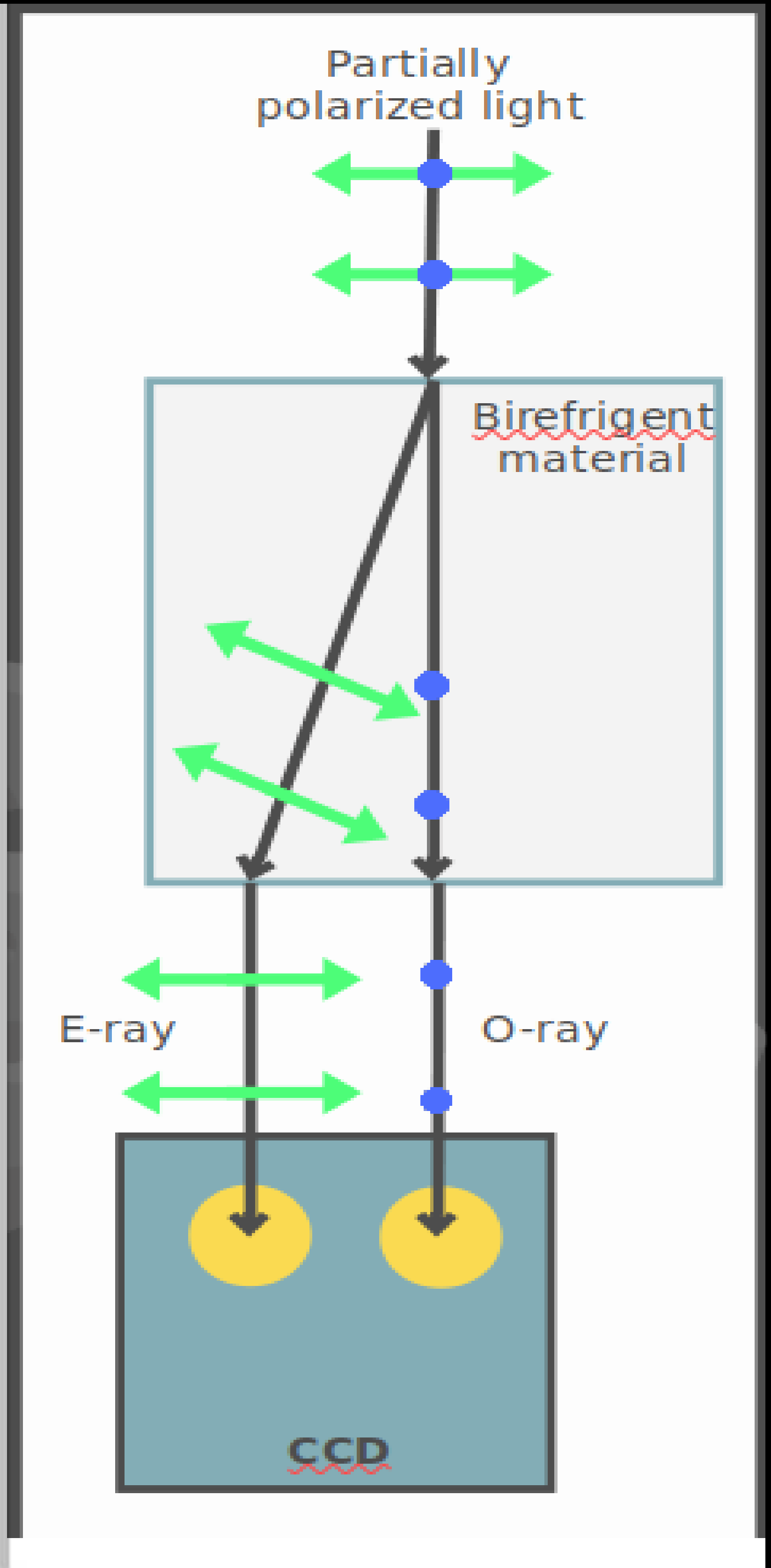
Cons :

- Lower limit on apparent magnitude of 14 with goood SNR
- One filter (UBVRI) at a time
- Camera QSI poor QE in Blue

Calern Asteroid Polarimetric Survey 2.0

FRANCE, FINLAND, UK, GERMANY, ITALY





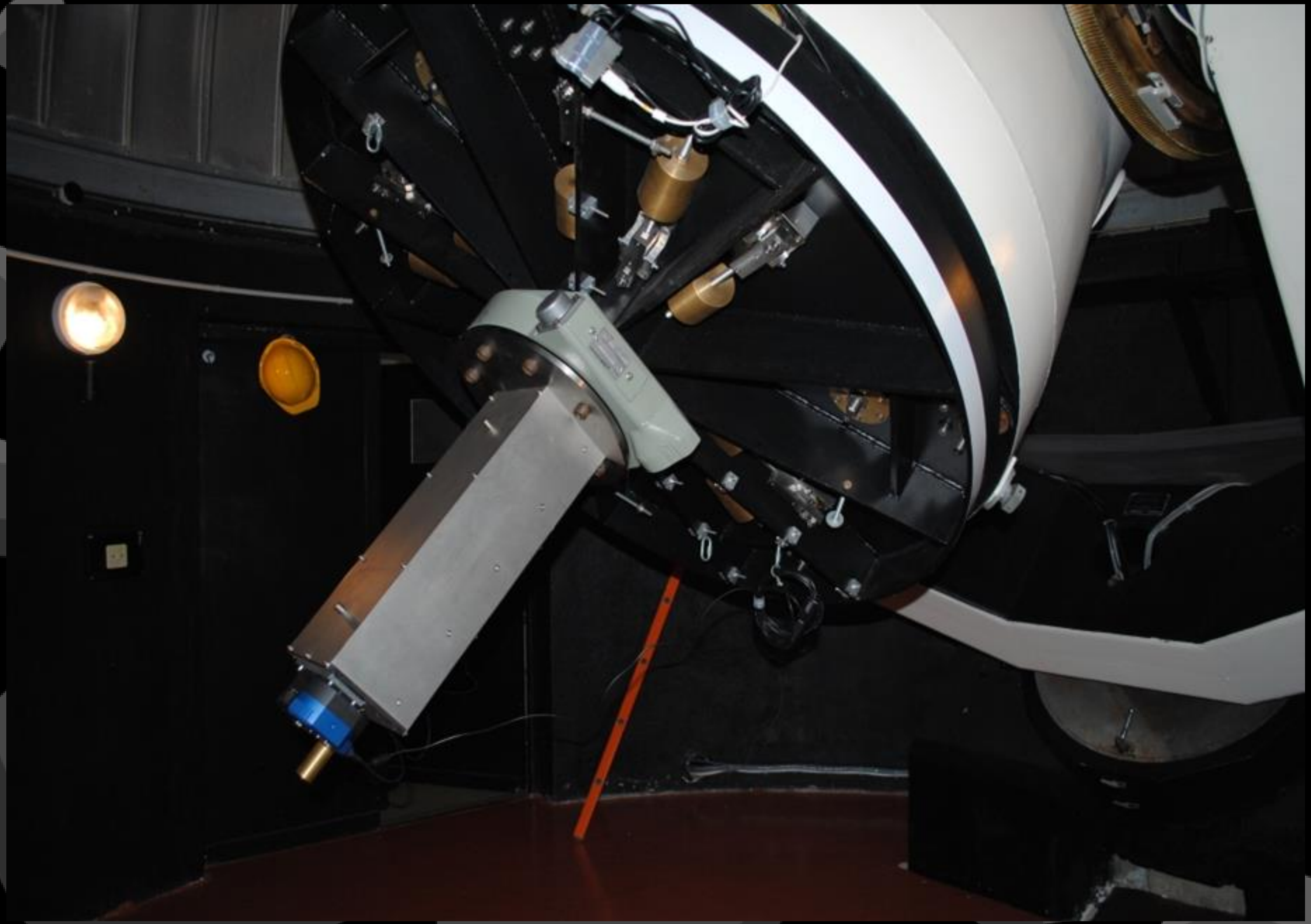
Pros:

- Lower limit on apparent magnitude of 16 (number of targets x 100)
- Can look with 3 different filters at the same time (BVR)
- 3 high performance cameras
  - CCD1 and CCD2 are Emccd Andor iXon Cameras
  - CCD3 Andor ASPEN
- 120 night/year dedicated to CAPS (possibly more)

Cons

- no more simultaneity (different polarization states recorded in sequence)

Calern Asteroid Polarimetric Survey 2.0

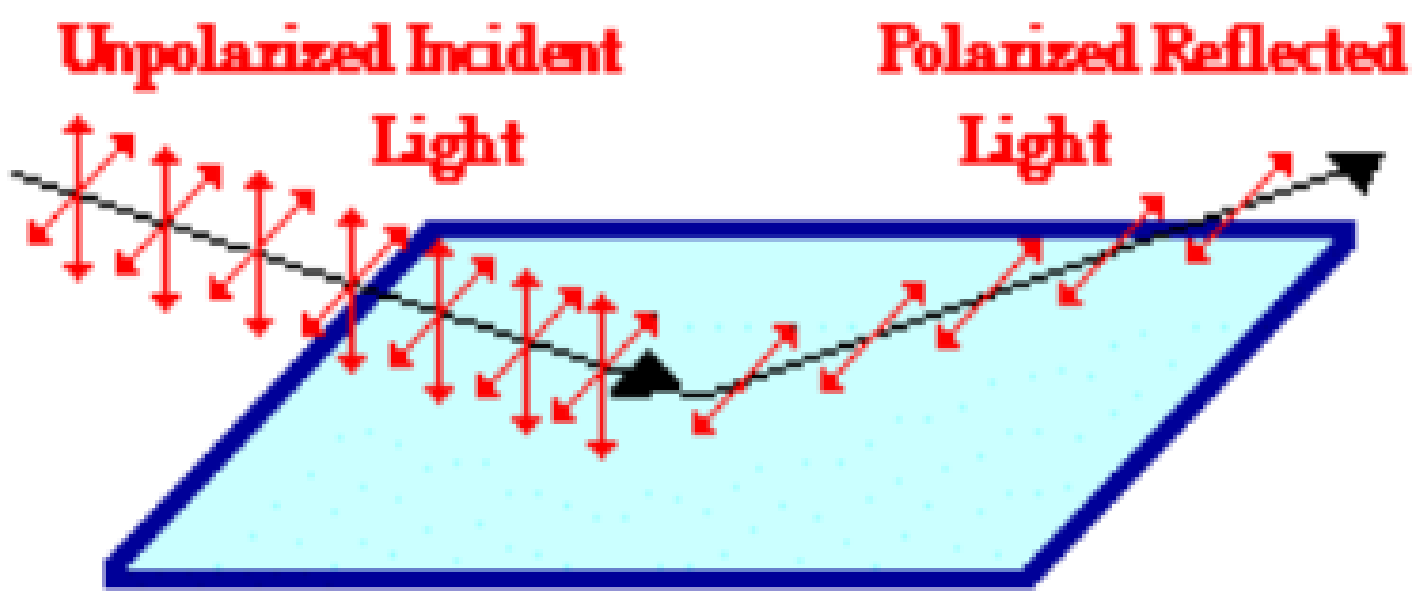


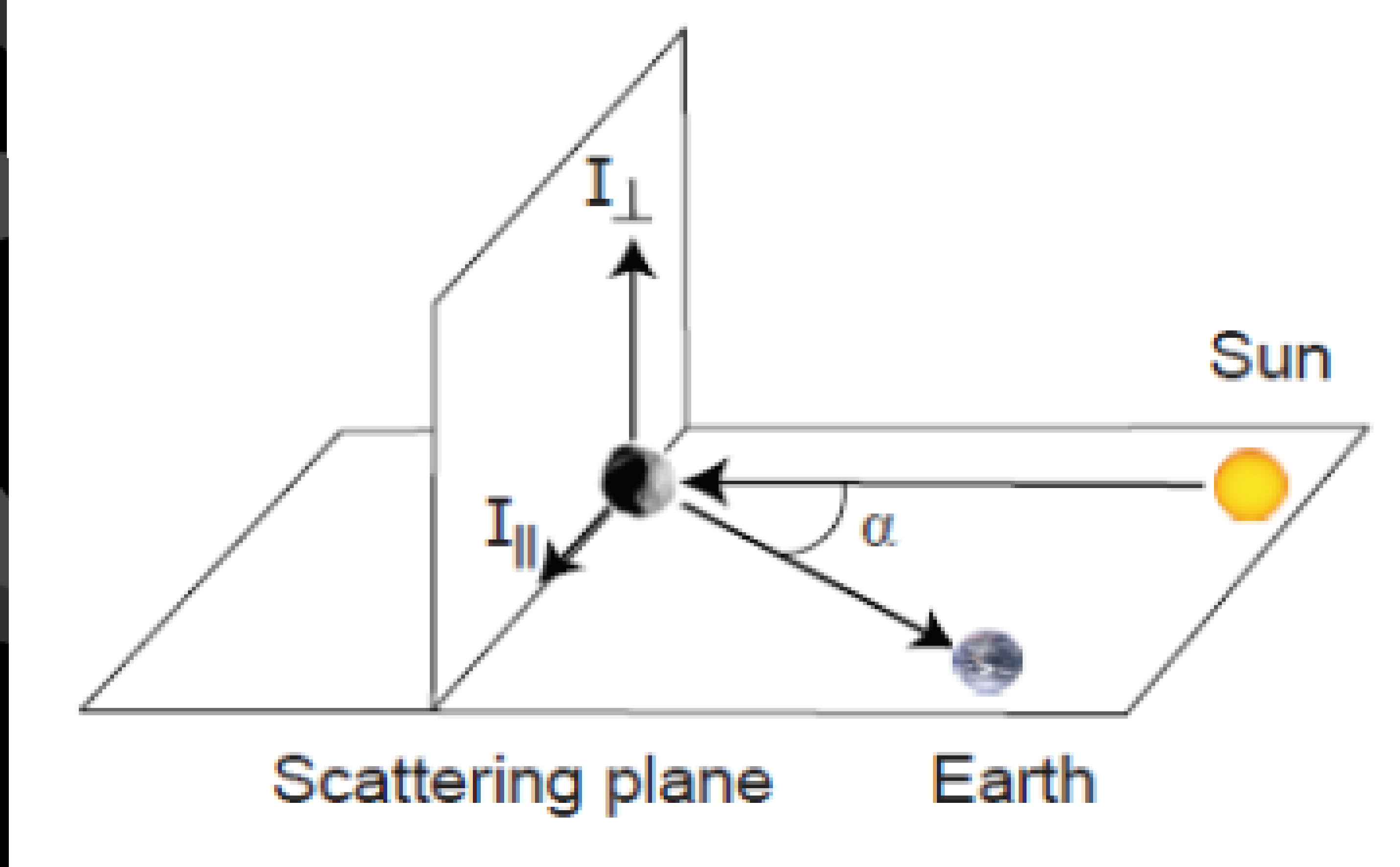
From 2013 to 2023

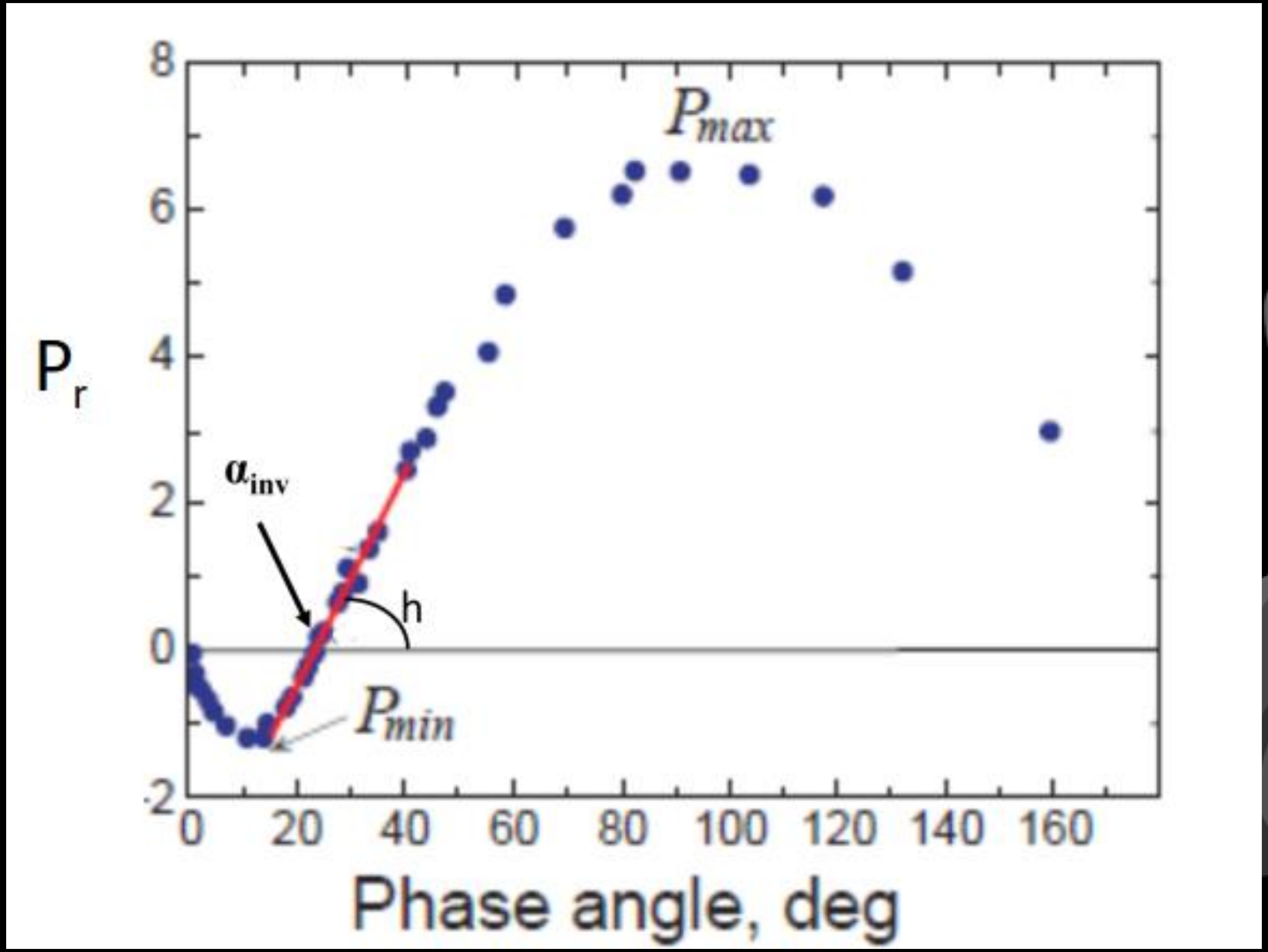
Since 2023

Calern Asteroid Polarimetric Survey 2.0

Diffusion and reflection produce (partial or total) linear polarization







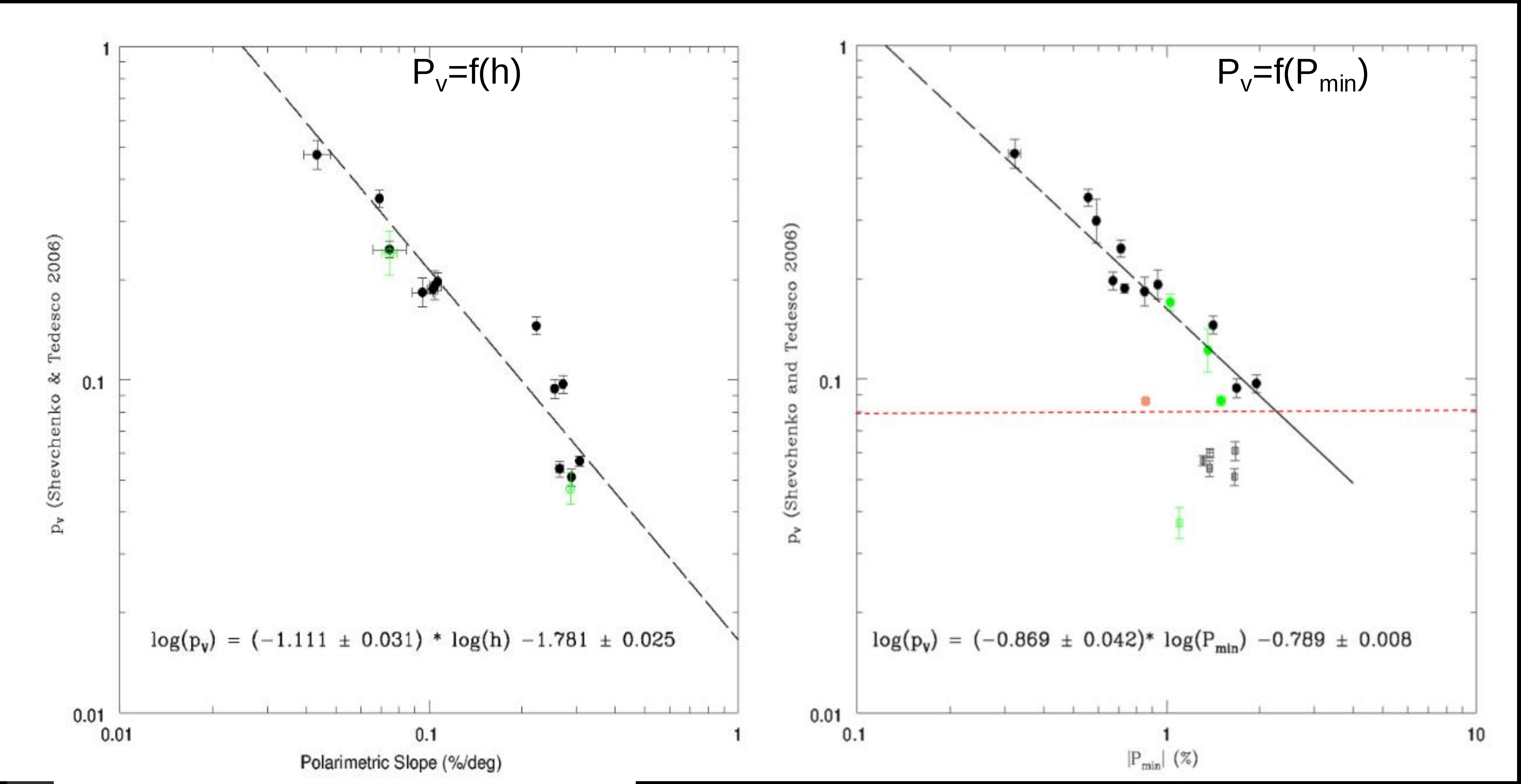
$$P_r = \frac{(I_\perp - I_\parallel)}{(I_\perp + I_\parallel)}$$

- P_{min}
- α_{inv}
- Polarimetric slope h
- α_{min}
- α_{max}
- P_{max}

Why Asteroid Polarimetry is important and Usefull ?

- Determination of the geometric albedo
- Determination of some surface regolith properties
- For taxonomic classification purposes
- Because it is useful to identify special classes of objects having anomalous compositions
- Because it is useful to identify objects exhibiting cometary properties
- Because it can be useful for the physical characterization of newly discovered near-Earth objects
- Because it provides data to constrain the theories of light scattering from asteroid surfaces

And of course Albedo and Diameter Determination



The more data the better fits

Geometric Albedo

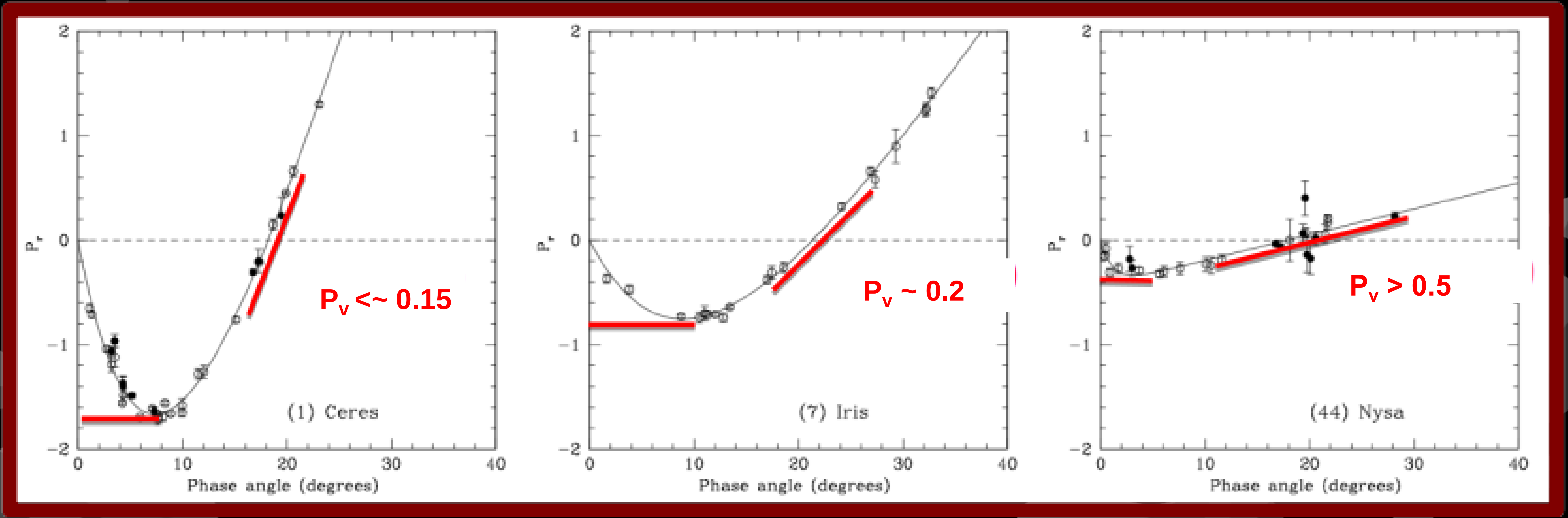
$$log(p_V) = C_1 log(h) + C_2$$

$C_1 = -1.016 \pm 0.010$

$C_2 = -1.719 \pm 0.012$

lupishko+2017

$$\log(D) = 3.1236 - 0.2H - 0.5\log(p_V)$$



Credit Bagnulo

Linear exponential Relation

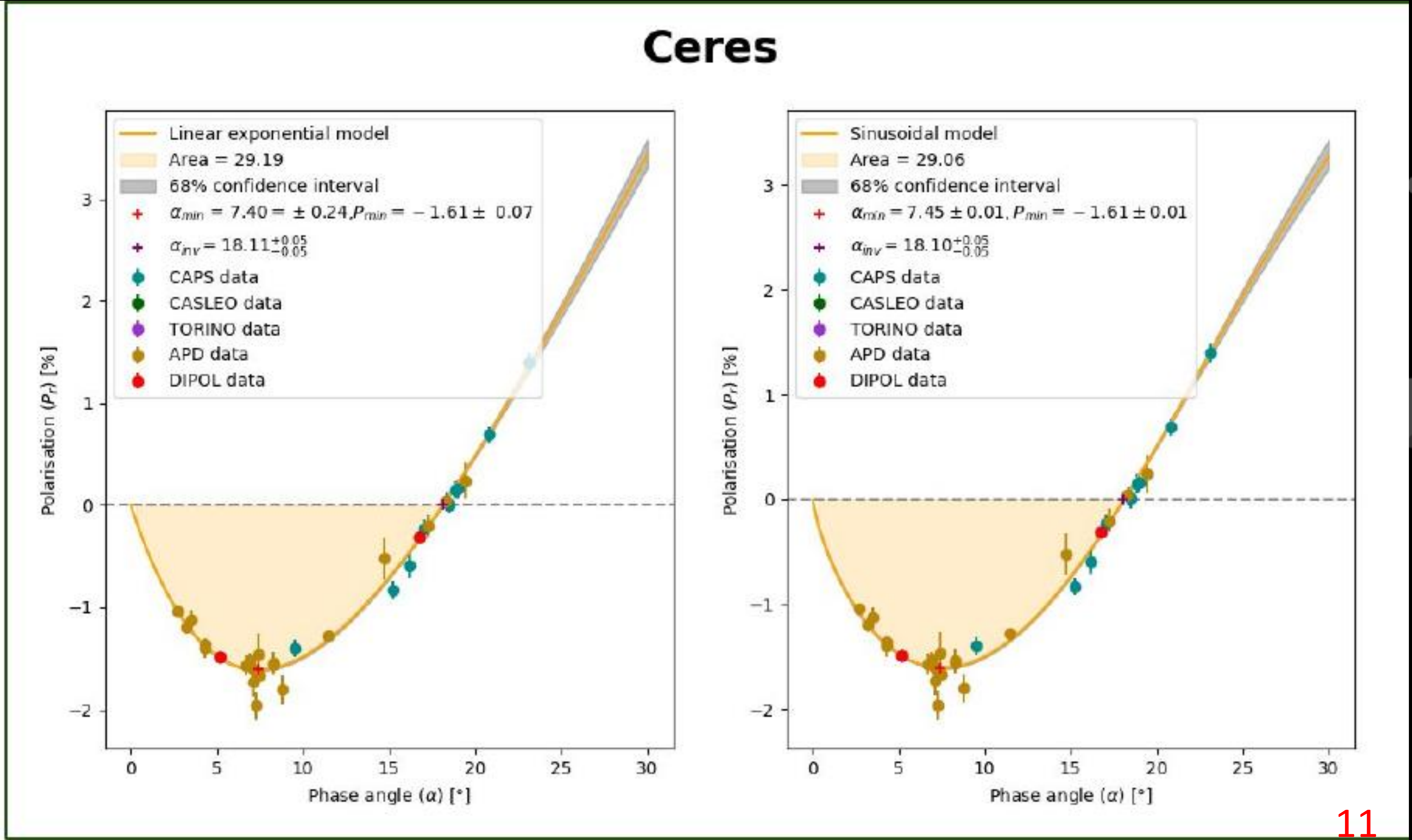
$$P_r(\alpha)=A(\exp(-\alpha /B)-1) + C\alpha$$

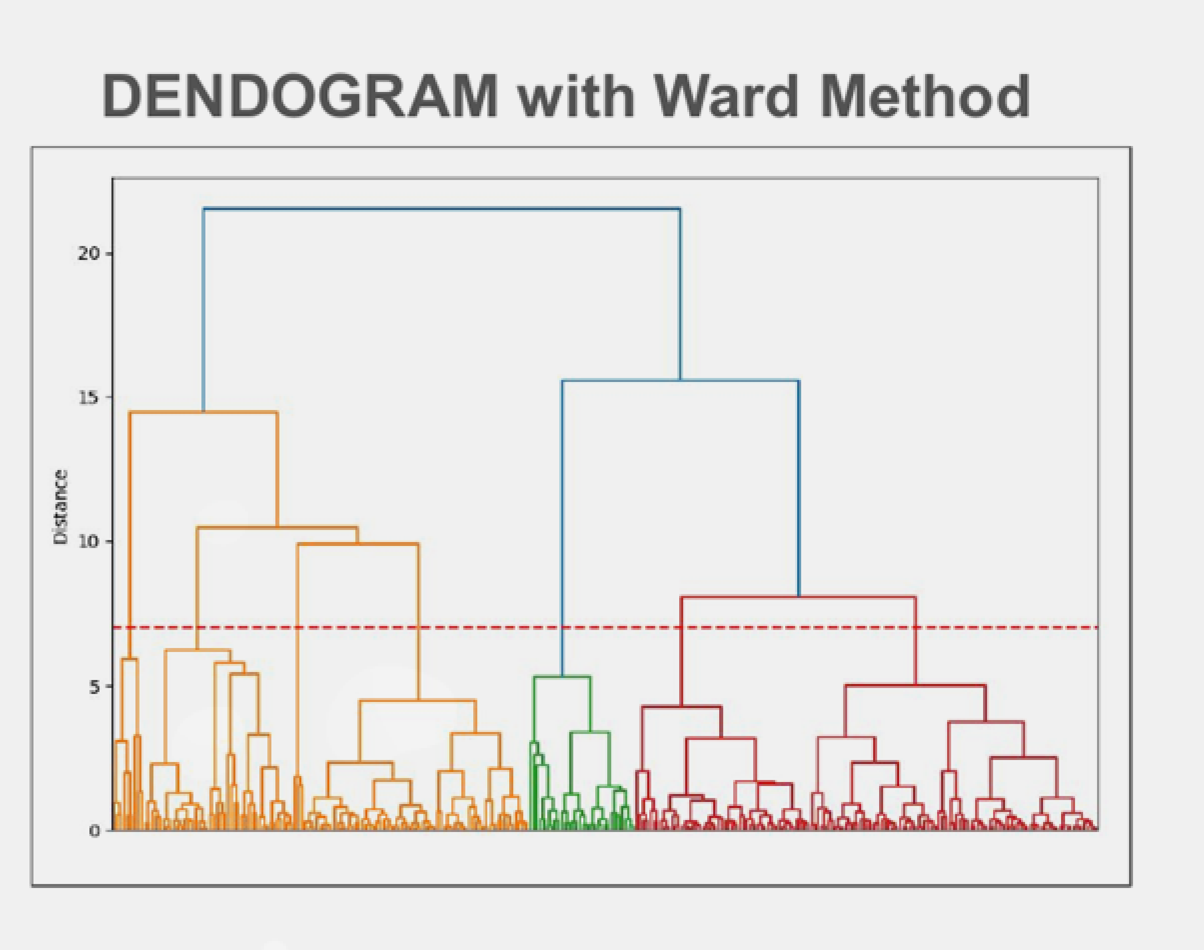
Sinusoidal Relation

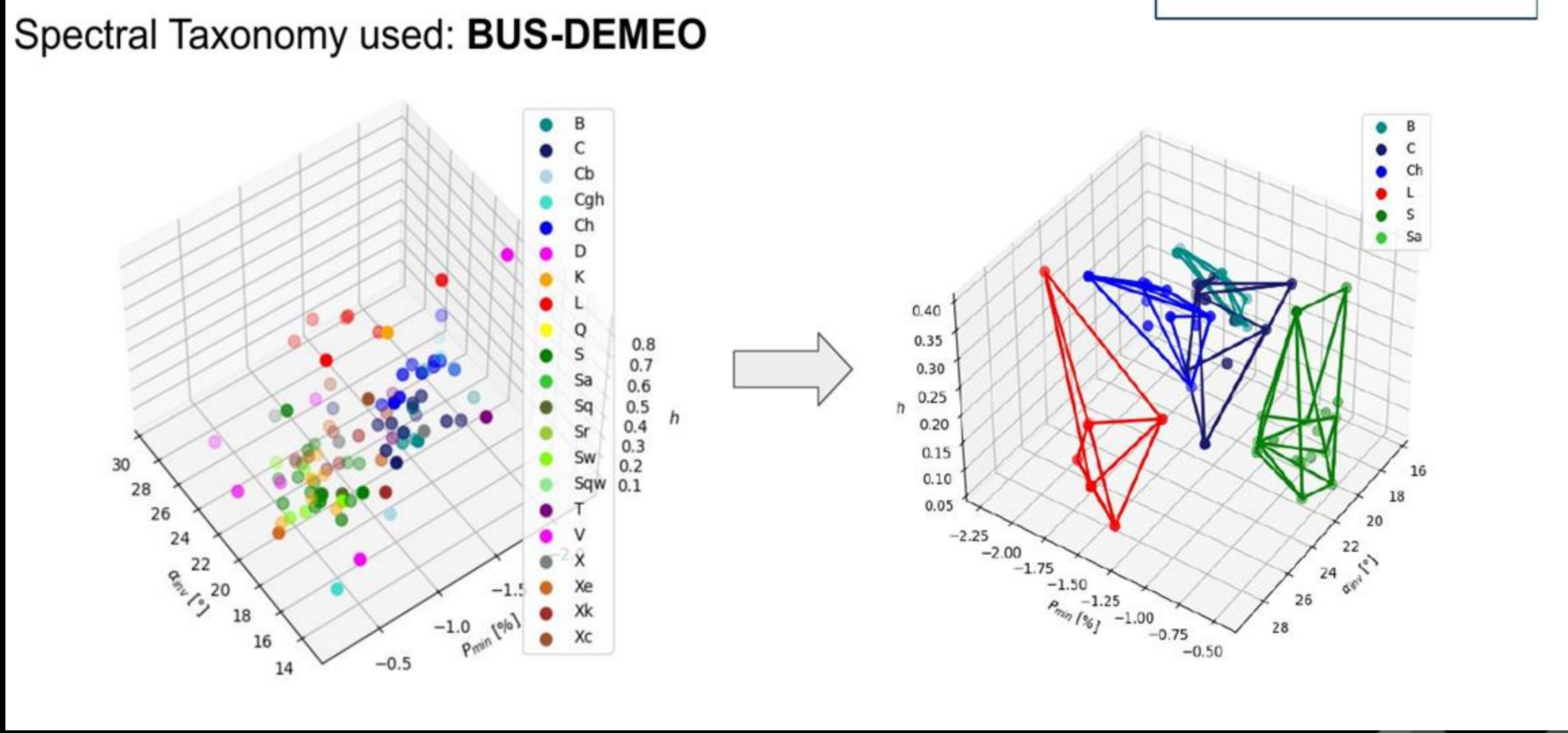
$$P_r(\alpha)=A\sin(\alpha)^{c1}\cos(\alpha/2)^{c2}\sin(\alpha-\alpha_0)$$

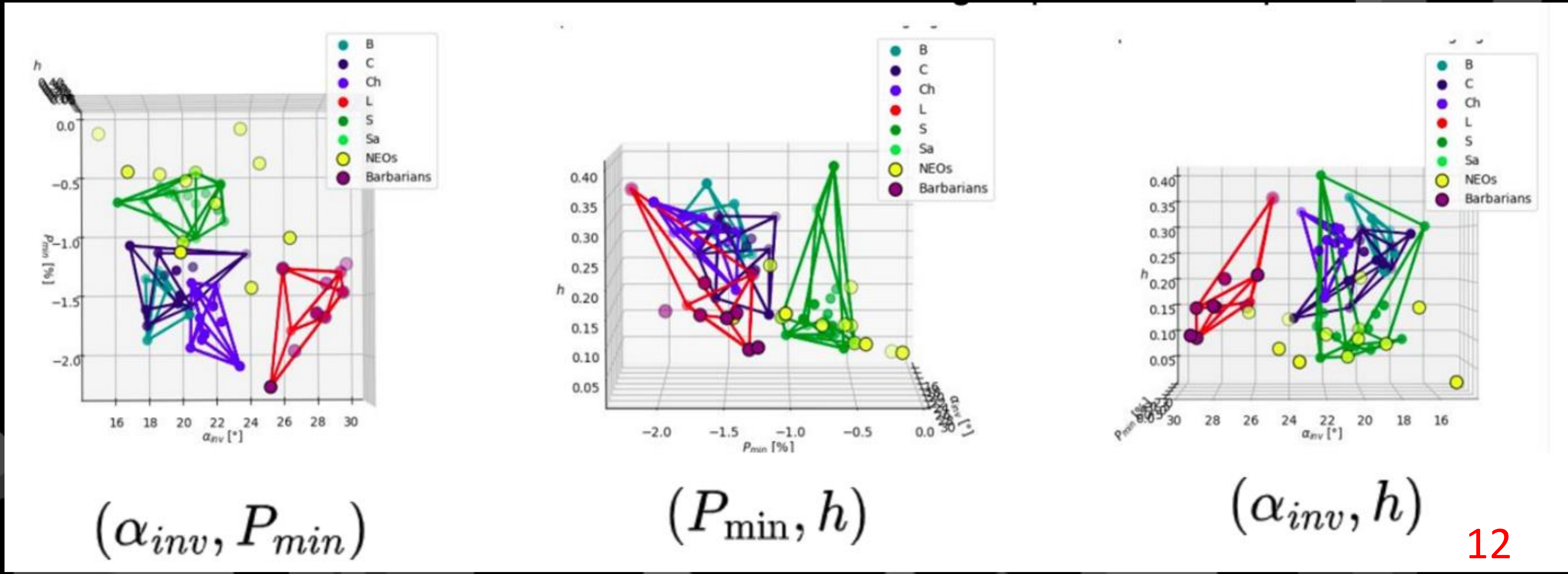
MCMC approach

- P_{min}
- α_{inv}
- Polarimetric slope h
- α_{min}
- α_{max}
- P_{max}




DENDOGRAM with Ward Method
Distance
0
5
10
15
20


Spectral Taxonomy used: BUS-DEMEO
B
C
Cb
Cgh
Ch
D
K
L
Q
S
Sa
Sq
Sr
Sw
Sqw
T
V
X
Xe
Xk
Xc
h
α_{inv} [°]
P_{min} [%]


B
C
Ch
L
S
Sa
NEOs
Barbarians
(α_{inv}, P_{min})
$(P_{\min}, h)$
(α_{inv}, h)

CAPS 1.0

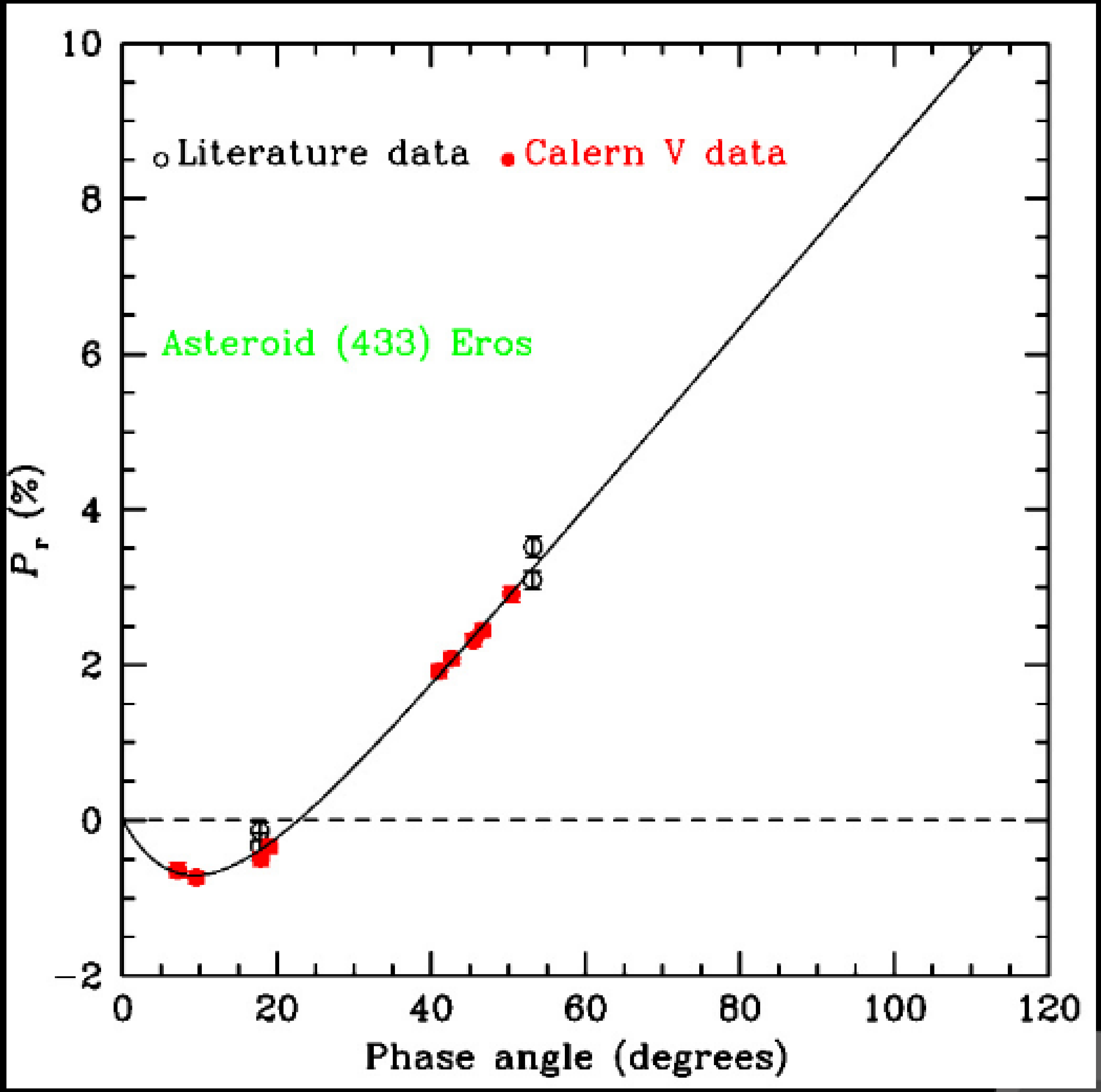
- Data base of 2025 measurements in V band on line (Bendjoya et al. 2022)

- 285 asteroids fitted parameters **$P_{min,}$ α_{min} , α_{inv} h** (MCMC , 2 models)

Finally CAPS vs NEO !!

CAPS 1.0

Peculiar focus on NEO started in 2020 but because of COVID-19 Pandemia 2021 is the real start for NEO as CAPS priority



since CAPS 2.0 started in 2023 :

- test phase
- V camera problem (fixed)
- More to come

Although 433 ER0S has been intensively observed in the past, having been visited by the NEAR Shoemaker probe, its phase- polarisation curve was poorly covered before the CAPS observation

Finally CAPS vs NEO !!

NEO observed with CAPS 1.0

Object	Number of measurements	Covered interval of phase angle
(1036) Ganymed	1	14
(1627) Ivar	7 (+2)	From 4 to 7 (+26, +29)
(1862) Apollo	2	51, 62
(2100) Ra-Shalom	2	18, 23
(2212) Hephaistos	3	35, 37, 38
(4660) Nereus	15	From 12 to 106
(5143) Heracles	3	92, 94, 97
(5189) 1990 UQ	6	28, 32, 34, 36, 70, 94
(5693) 1993 EA	1	44
(7335) 1989 JA	2	26, 27
(7358) Oze	1	15
(25916) 2001 CP44	1(+1)	25 (+19)
(35107) 1991 VH	2	8,9
(40267) 1999 GJ4	4	44, 48, 50, 51
(52768) 1998 OR2	14	From 30 to 78
(68063) 2000 YJ66	8	From 6 to 24
(143649) 2003 QQ47	4	22, 24 29, 32
(153591) 2001 SN 263	23	From 25 to 65
(159857) 2004 LJ1	4	55, 60, 61, 63
(162149) 1998 YQ11	1	6
(163899) 2003 SD220	8	From 85 to 101
(215188) 2000 NM	2	38, 40
(285571) 2000 PQ9	4	25, 30, 32, 49
(326732) 2003 HB6	1	28

Available data

Object	Diameter (km)	Geometric albedo	Taxonomic classification(s)
(1036) Ganymed	37.68 ± 0.40	0.238 ± 0.041	Tholen class: S SMASS class: S
(1627) Ivar	9.12	0.15	Tholen class: S SMASSII class: S
(1862) Apollo	1.5 km	0.25	Tholen class: Q SMASSII class: Q
(2100) Ra-Shalom	2.3 ± 0.2	0.13 ± 0.03	Tholen class: C SMASSII class: Xc
(2212) Hephaistos	5.7	0.163 ± 0.027	Tholen Class: SG
(4660) Nereus	0.33 ± 0.05	0.55 ± 0.17	SMASSII class: Xe
(5143) Heracles	4.843 ± 0.378	0.227 ± 0.054	SMASSII class: O
(5189) 1990 UQ	--	--	--
(5693) 1993 EA	--	--	--
(7335) 1989 JA	1.8	0.448 ± 0.043	--
(7358) Oze	--	--	SMASSII class: Sq
(25916) 2001 CP44	5.683 ± 0.030	0.177 ± 0.029	--
(35107) 1991 VH	0.929 ± 0.035	0.408 ± 0.048	SMASSII class: Sk
(40267) 1999 GJ4	1.641 ± 0.053	0.214 ± 0.03	SMASSII class: Sq
(52768) 1998 OR2	1.75 ± 0.3	--	--
(68063) 2000 YJ66	2.301 ± 0.071	0.211 ± 0.037	--
(143649) 2003 QQ47	--	--	--
(153591) 2001 SN 263	2 km	--	--
(159857) 2004 LJ1	3.070 ±1.324	0.130 ± 0.158	--
(162149) 1998 YQ11	--	--	--
(163899) 2003 SD220	0.791 ± 0.025	0.340 ± 0.042	--
(215188) 2000 NM	--	--	SMASSII class: Sr
(285571) 2000 PQ9	--	--	--
(326732) 2003 HB6	--	--	--

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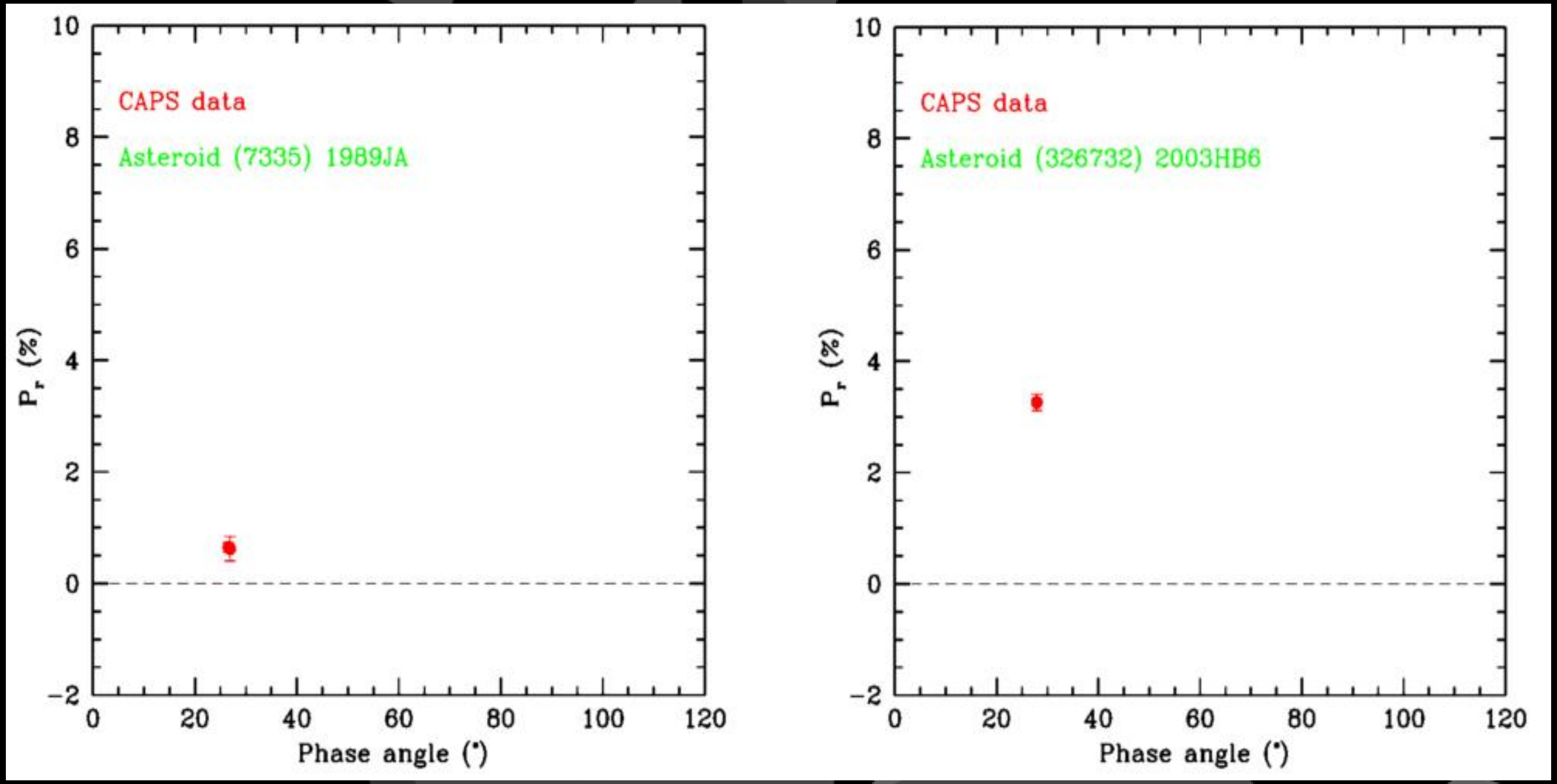
the size, albedo and taxonomic classification(s) taken from the literature are listed. This information comes from a variety of different techniques, including asteroid spectroscopy, multi-band photometry, and thermal IR fluxes. Source: JPL Small Bodies Database (https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/

One shot may often be enough !!

Same phase angle around 30 deg
Big difference in Pr => low and intermediate Albedo

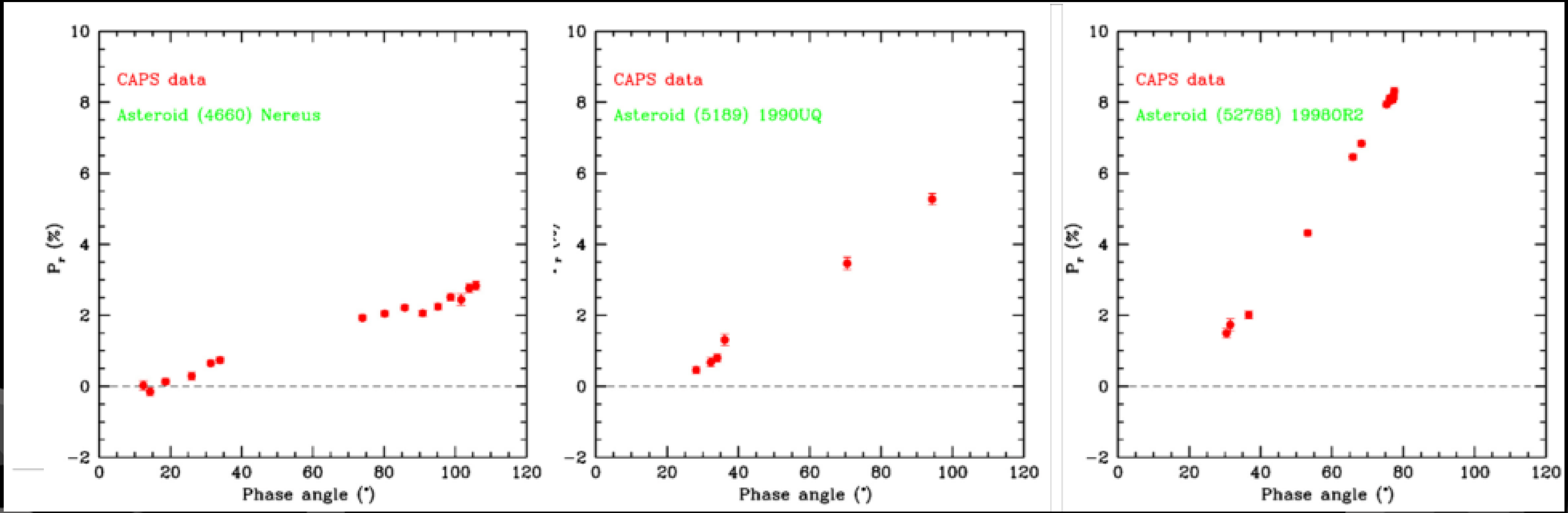
the differences in polarimetric slope between objects of different albedo produce in the positive polarisation branch, (phase >= 30 degrees) sharp differences in linear polarisation.



No albedo in littérature for 326732 (2003 HB6) asteroid and 0.44 for 7335 (1989 JA)

Even with no h slope derived we can estimate we can expect an albedo twice fainter for 326732 than 7335's one

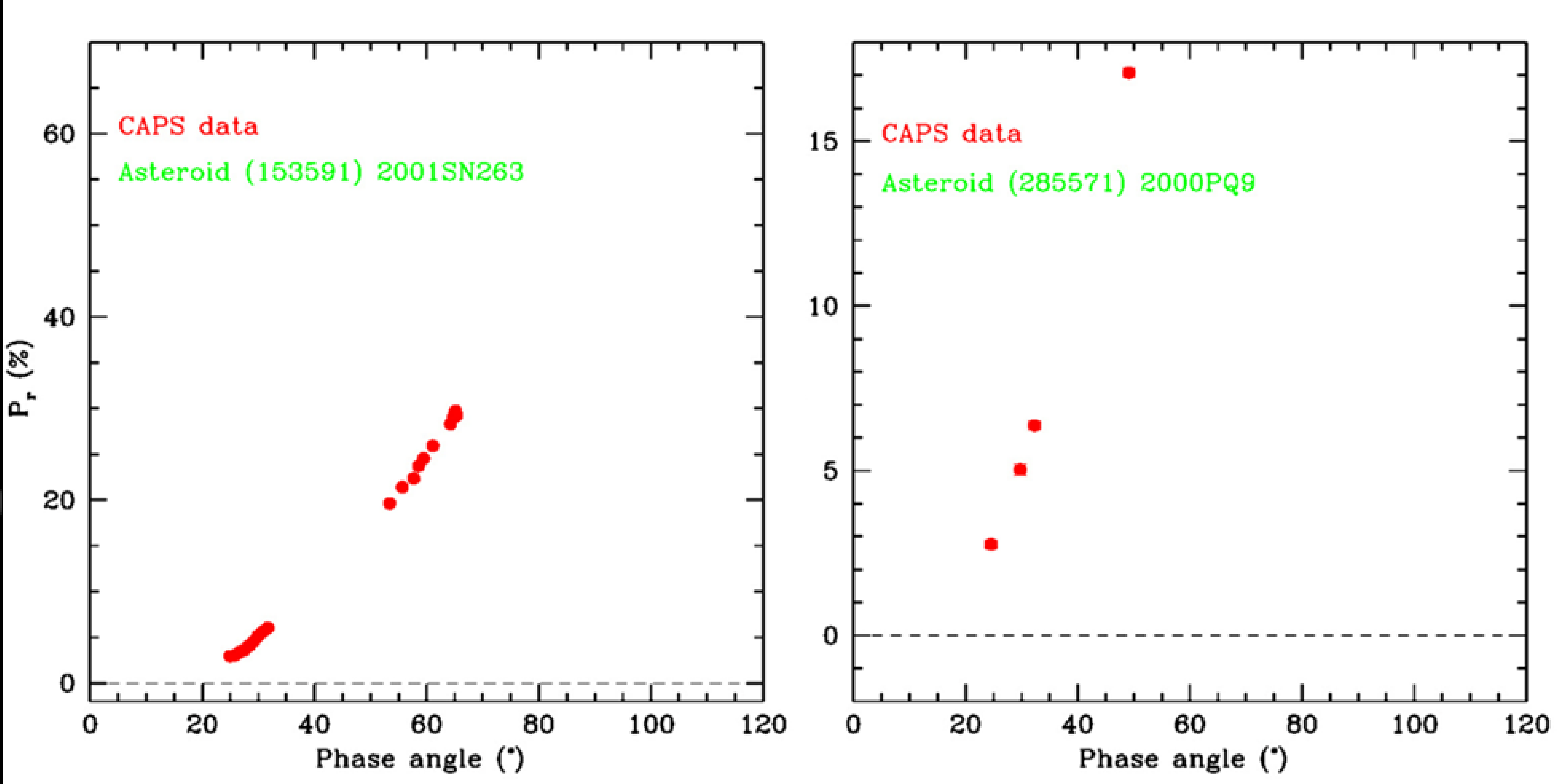
Variety of curves for NEO !!



Not surprising NEO belong to quite different taxonomic classes, and are characterised by different albedos.

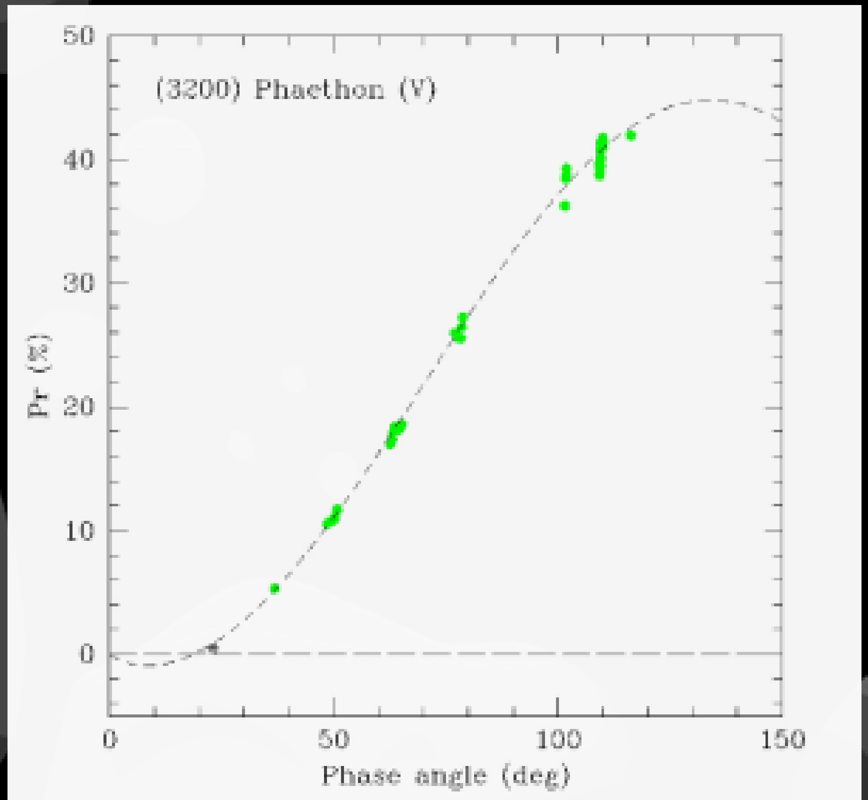
The heterogeneity of the NEO population is due to the fact that different dynamical paths connect the inner Solar System region with different regions in the asteroid Main Belt

Some interesting cases (1)



((153951) 2002 AC3

(285571) 2000 PQ9

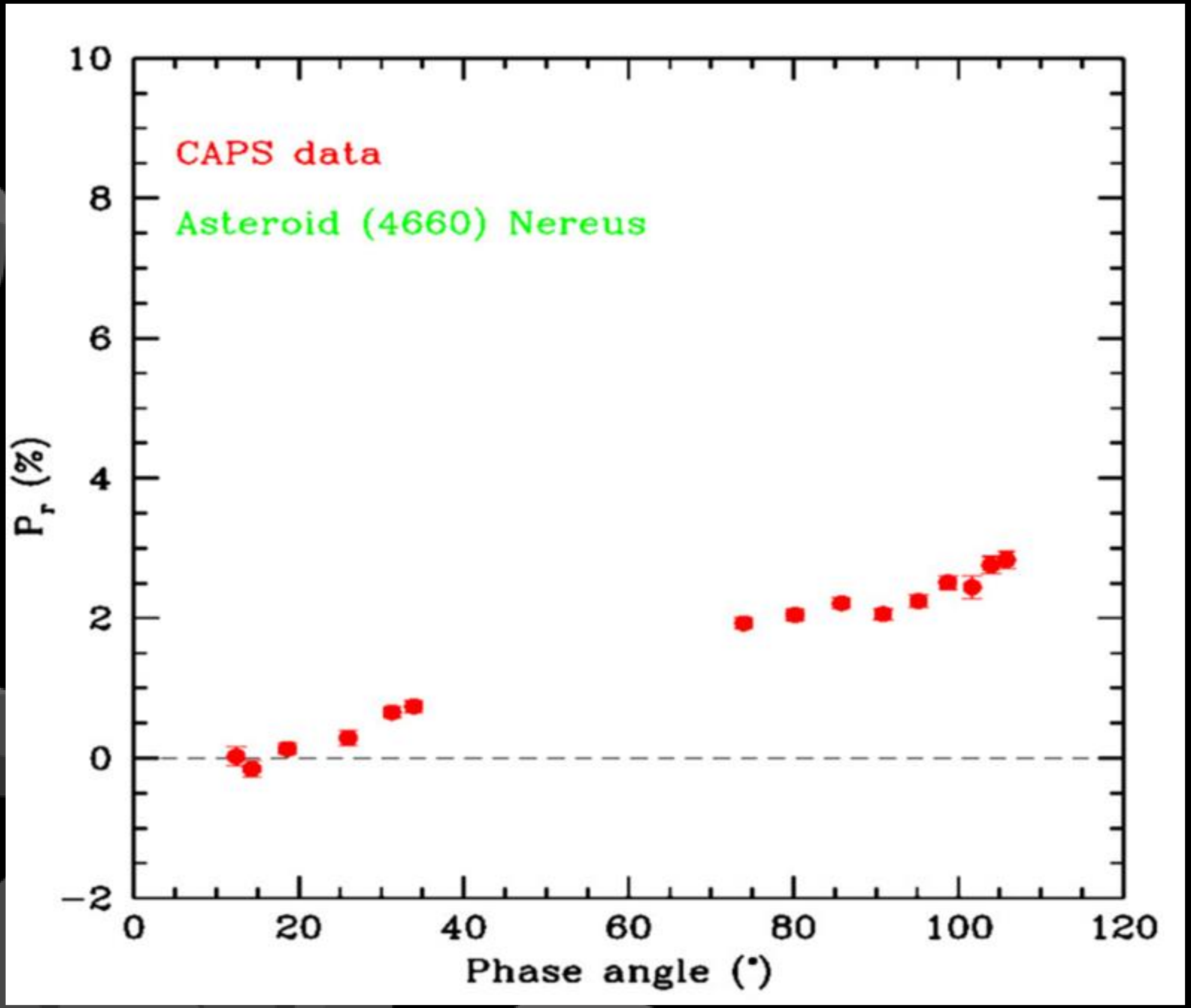


(3200) Phaeton

Devogele et al 2018

- No physical parameter currently known, but steepness of polarimetric slopes is strongly diagnostic of low albedo.
- Remark high measured value of positive polarisation for these new objects.
- (285571), the rapid increase of linear polarisation seems to be similar or even steeper than that of (3200) Phaethon (Ito et al., 2018, Devogèle et al., 2018b).
- By assuming that the phase – polarisation curve of this object keeps raising in a way similar to (3200) Phaethon, the geometric albedo should be tentatively around 0.09 (Ito et al., 2018).
- In the case of (153591),seems to be even steeper. Assuming that the increase of polarisation continues up to large phase angles, a very low albedo, of just a few times 0.01, can be hypothesised.

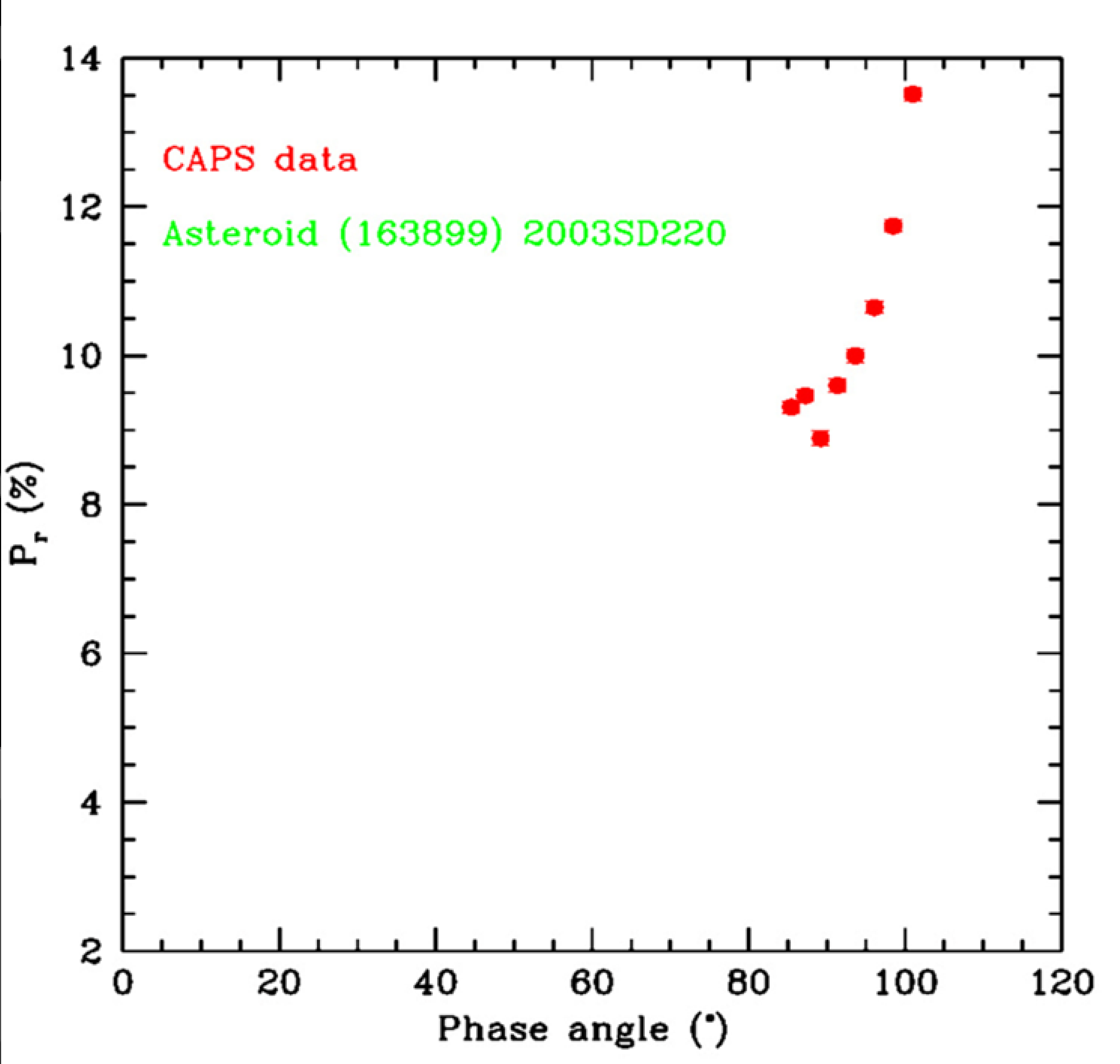
Some interesting cases (2)



(4660) Nereus

- An opposite behaviour is shown by (4660) Nereus, whose very shallow phase – polarisation curve
- This behaviour nicely fits the expectations based on the Xe SMASSII taxonomic class and very high geometric albedo of 0.55 ± 0.17 for this very small object (0.33 km),

Some interesting cases (3)

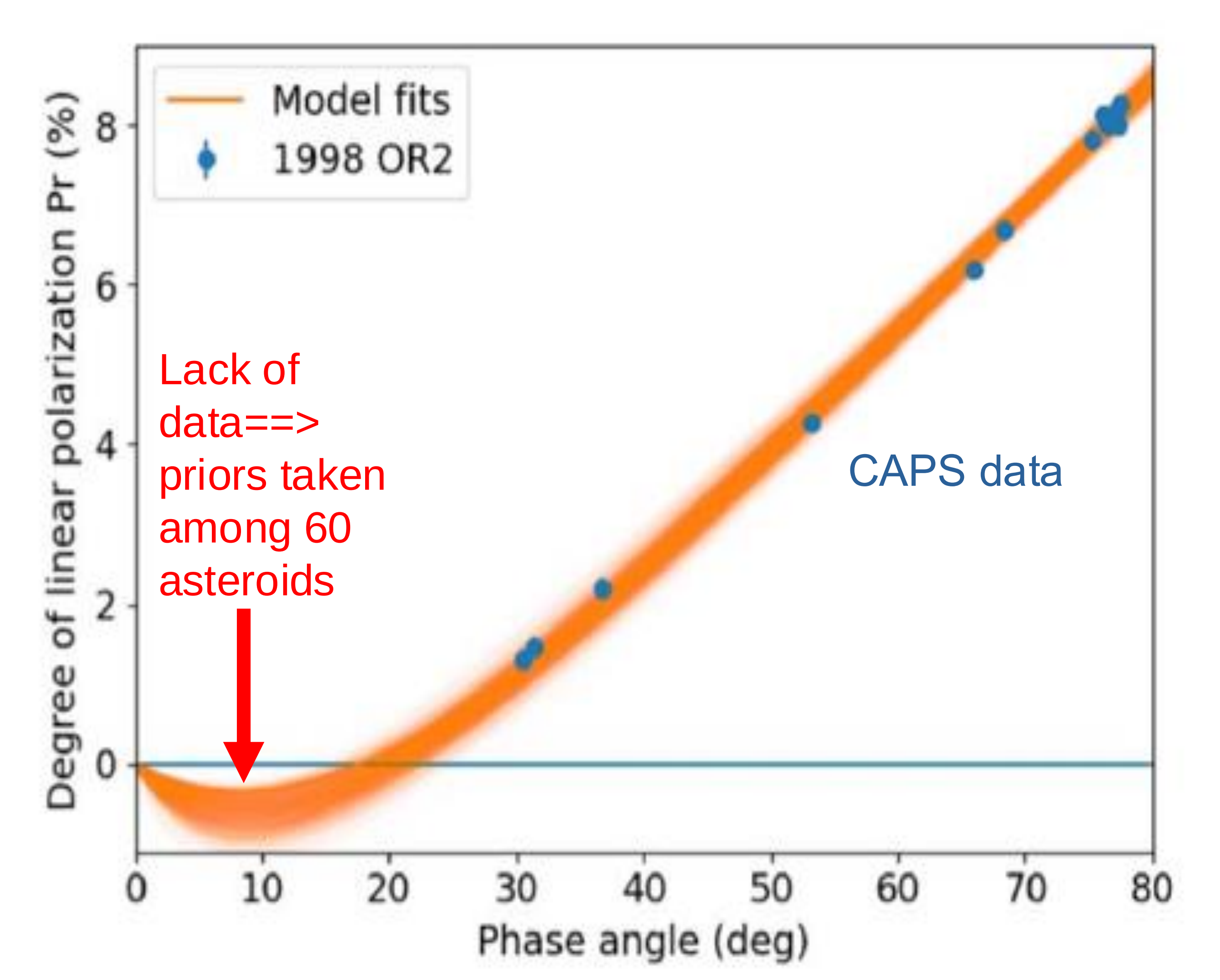


(163899) 2003 SD220

- The phase – polarisation curve , at high phase angles between 80º and 100º,
- exhibits an overall fast increase of linear polarisation,
- but with a complicated behaviour at the lowest covered phase angles which has currently no explanation.
- No decrease of polarisation is seen at phase angles around 100º, prevents us from estimating a reliable value of P_{max} for this object.
- However, according to the relation published by Ito et al. (2018), and assuming a lower limit of 14% for the value of P_{Max}, (163899) turns out to have a low albedo, lower than an upper limit of about 0.09.

Some interesting cases (4)

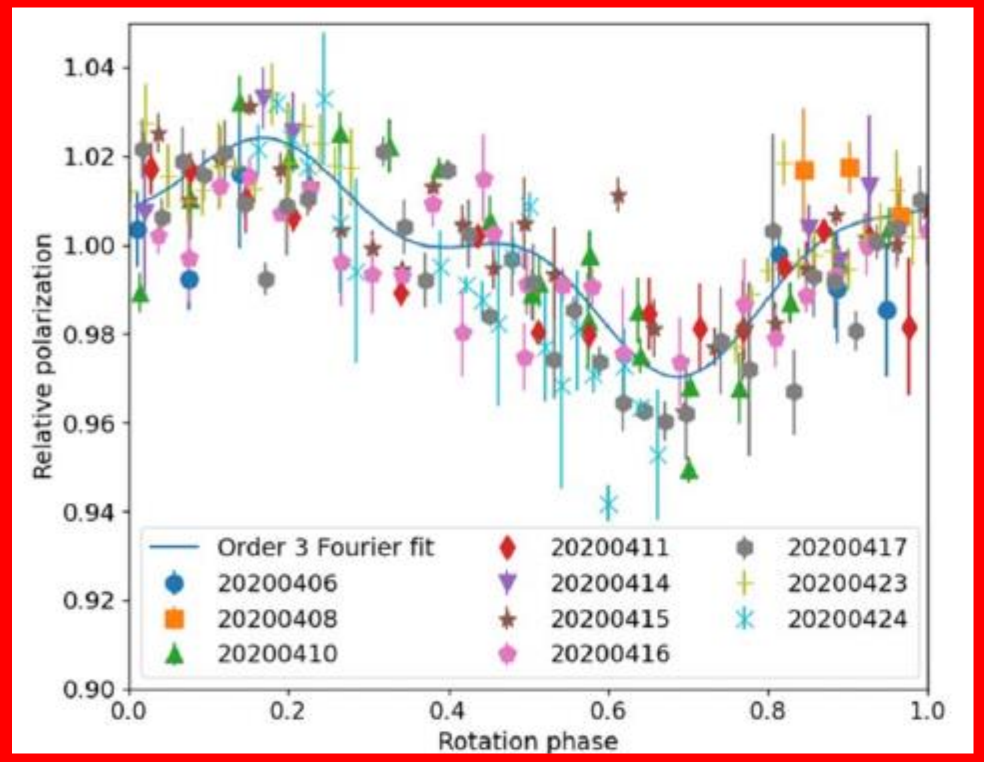
(52768) 1998 OR2



Devogèle et al. 2024

P_V=0.215 +/- 0.05

- On 2020 April 29, close approach to Earth at a distance of 16.4 lunar distances (LD). Can currently come as close to Earth as 3.4 LD
- absolute magnitude H = 16.04
- observations in polarimetry, photometry, and radar.
- variation of the polarimetric behaviour as a function of the rotation suggests that the surface of 1998 OR2 may be heterogeneous
- From radar, and two epochs from the NEOWISE satellite observations,
- D = 1.80 ± 0.1 km and a **visual albedo P_v = 0.21 ± 0.02**



April 6 and April 24 1998 OR2 was continuously observed at Calern Observatory 4–5 hr per night to measure its linear degree of polarization as a function of time. One full rotation every night.

Summary of the first Phase of NEO Survey with CAPS 1.0

Object	Albedo class	Criterion
(1036) Ganymed	Intermediate	Polarimetric slope
(1627) Ivar	Uncertain, but certainly not high	Discrepancies with literature data
(1862) Apollo	Intermediate	Polarimetric slope
(2100) Ra-Shalom	Low	Polarimetric slope
(2212) Hephaistos	Intermediate	Polarimetric slope
(4660) Nereus	High	Polarimetric slope
(5143) Heracles	Low-Intermediate	Pmax
(5189) 1990 UQ	Intermediate	Polarimetric slope
(5693) 1993 EA	Intermediate	Uncertain, only one measurements
(7335) 1989 JA	Intermediate	Uncertain due to poor coverage of phase angle
(7358) Oze	Uncertain	Only one measurement in the negative branch
(25916) 2001 CP44	Intermediate-low	Polarimetric slope
(35107) 1991 VH	uncertain	Unrealistically steep slope at low phase angles
(40267) 1999 GJ4	Intermediate	Polarimetric slope
(52768) 1998 OR2	Intermediate-low	Polarimetric slope
(68063) 2000 YJ66	Intermediate	Polarimetric slope, Pmin
(143649) 2003 QQ47	Intermediate-low	Polarimetric slope
(153591) 2001 SN 263	Low	Steep polarimetric slope
(159857) 2004 LJ1	Intermediate	Polarimetric slope
(162149) 1998 YQ11	Low albedo	Depth of negative branch
(163899) 2003 SD220	Low	Based on lower limit for PMax
(215188) 2000 NM	Intermediate	Polarimetric slope
(285571) 2000 PQ9	Low	Steep polarimetric slope
(326732) 2003 HB6	Low	Uncertain, only one measure

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Conclusion

CAPS 2.0

- "Formula one" Polarimeter
- Three performing CCD Cameras (2 EMCCD + 1 CCD)
- V=16 reached with SNR about 70 in 1 min exposure time
- Fainter magnitude to be tested
- Good observing Site (Calern)
- New faster reduction pipeline (in development)
- At least 120 nights/yr dedicated to CAPS

↓

MANY INFOS AND SURPRISES....

....To be continued......


THANKS.