Similarity in the negative polarization produced by comets and dark asteroids

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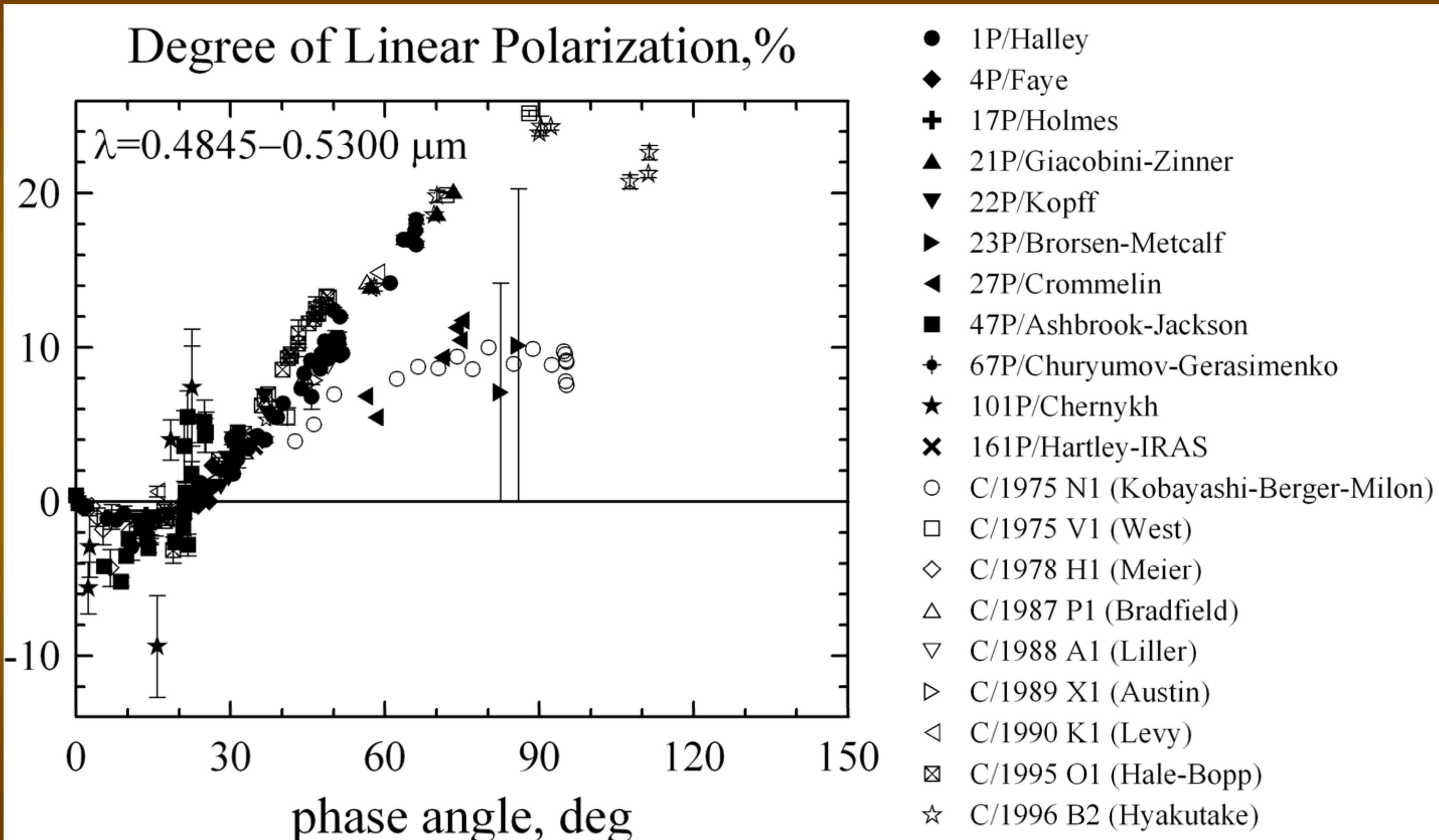
Aperture-averaged polarimetry of comets

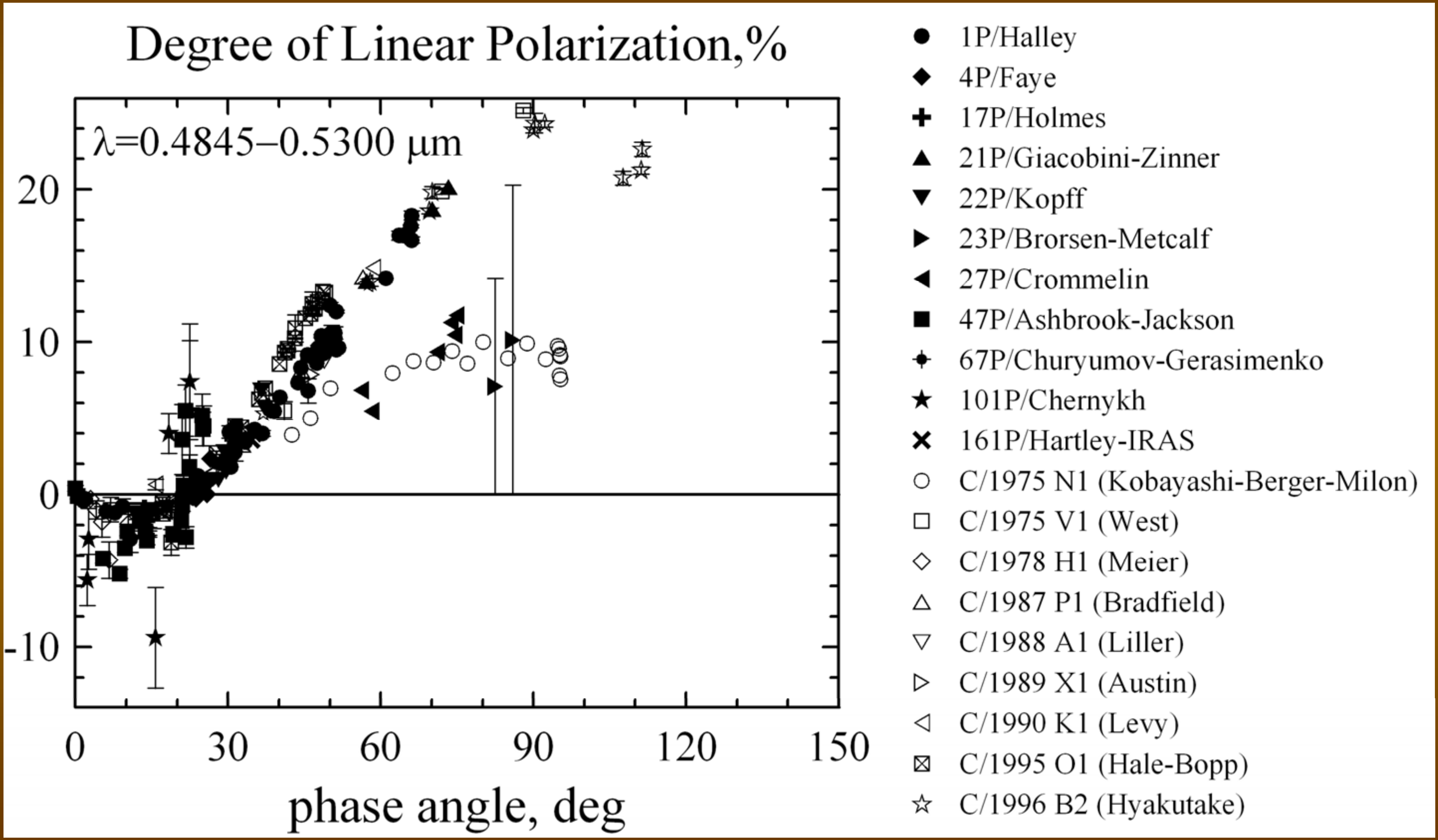


Aperture-averaged polarimetry of comets

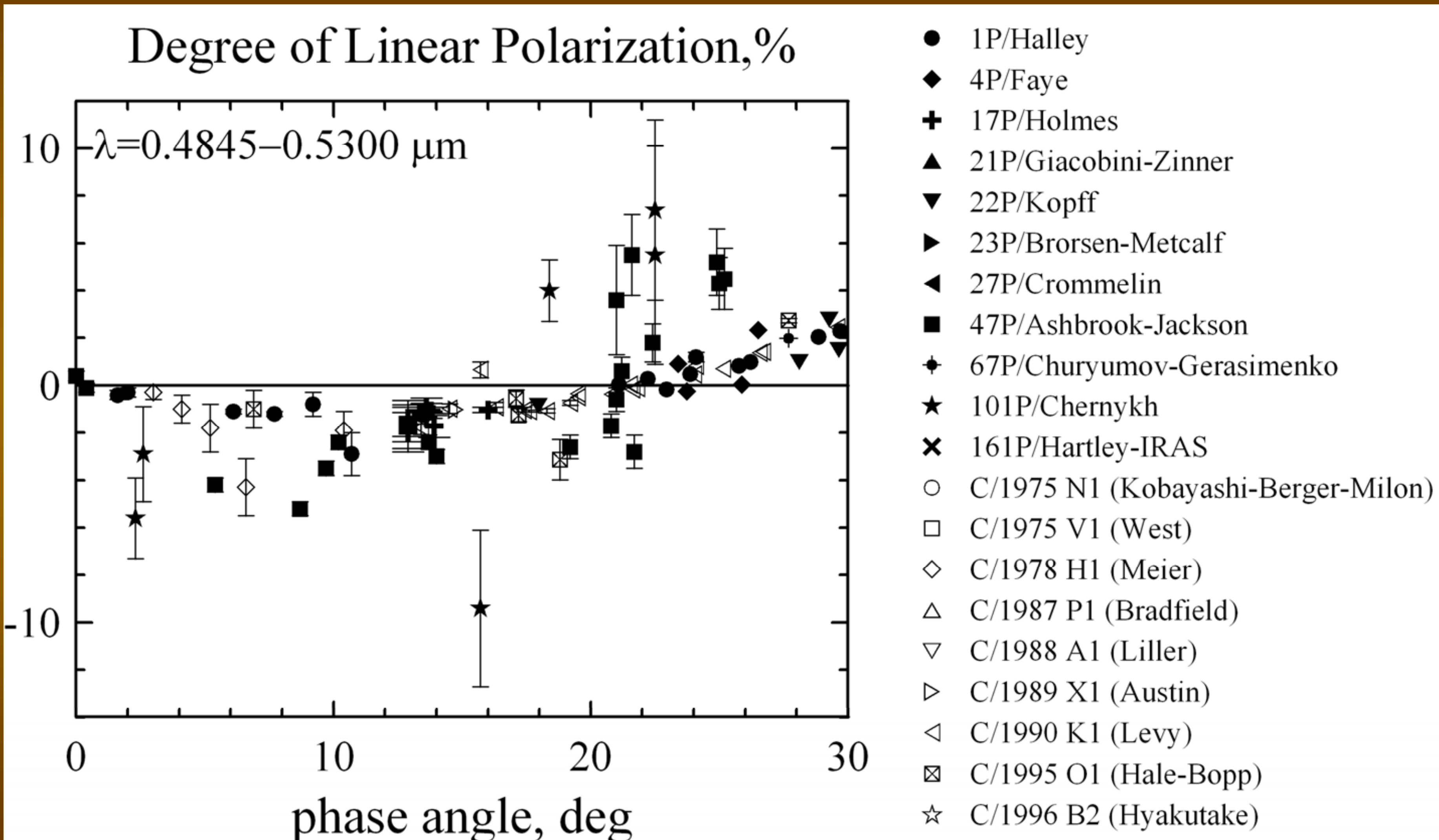
Data adapted from:

- Kiselev and Chernova, 1981
- Michalsky, 1981
- Kikuchi et al., 1987
- Sen et al., 1991
- Chernova et al., 1993
- Rosenbush et al., 1994; 2009
- Kiselev and Velichko, 1997; 1998
- Joshi et al., 1998; 2010
- Ganesh et al., 1998
- Hadamcik and Levasseur-Regourd, 2003

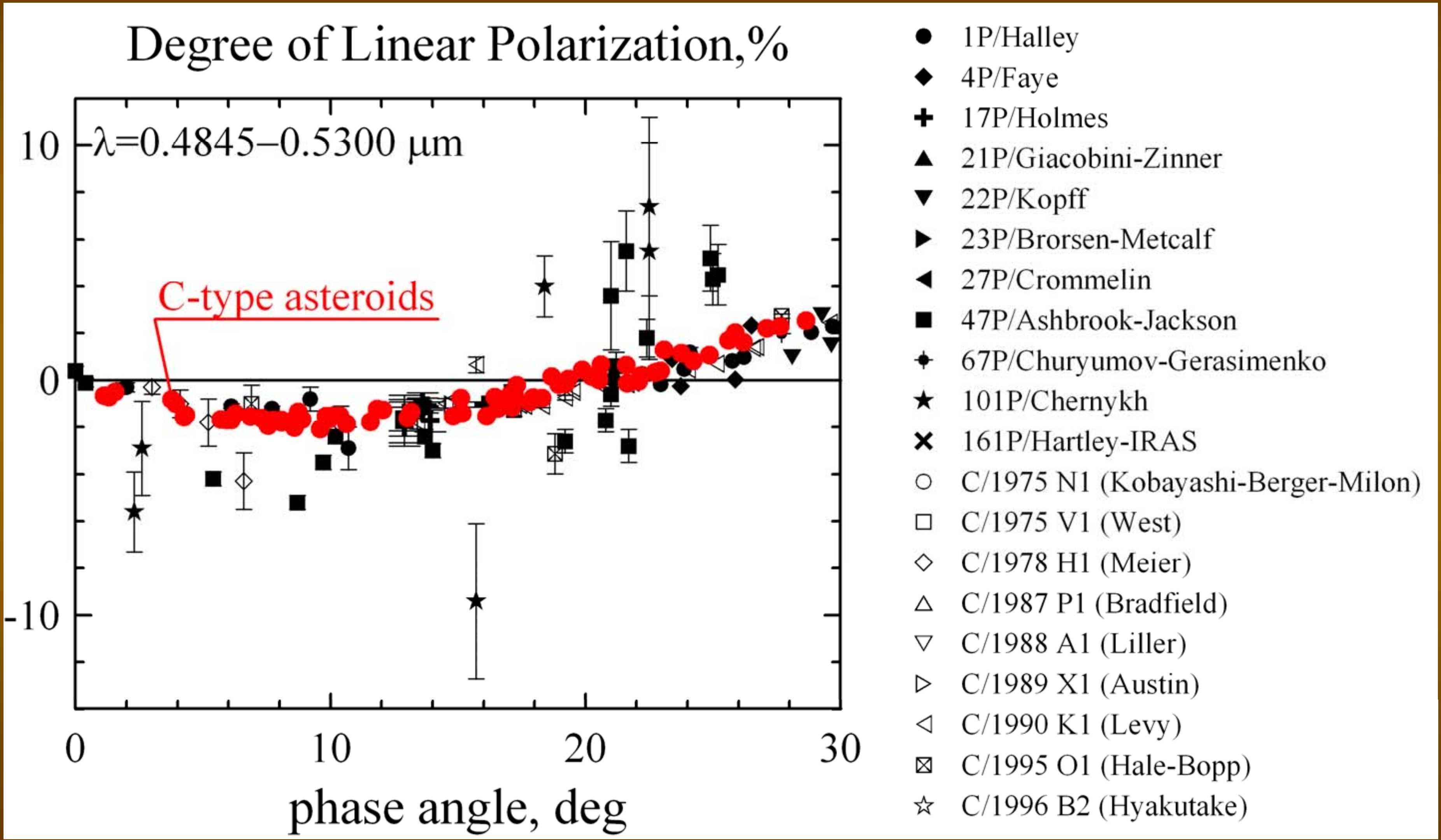
Aperture-averaged polarimetry of comets



Aperture-averaged polarimetry of comets



Comparison of comets and asteroids



data for 13 C-type asteroids are adopted from Zellner and Gradie, 1976

Does the coincidence in angular profiles of the linear polarization for comets and C-type asteroids really mean that their dust particles are similar?

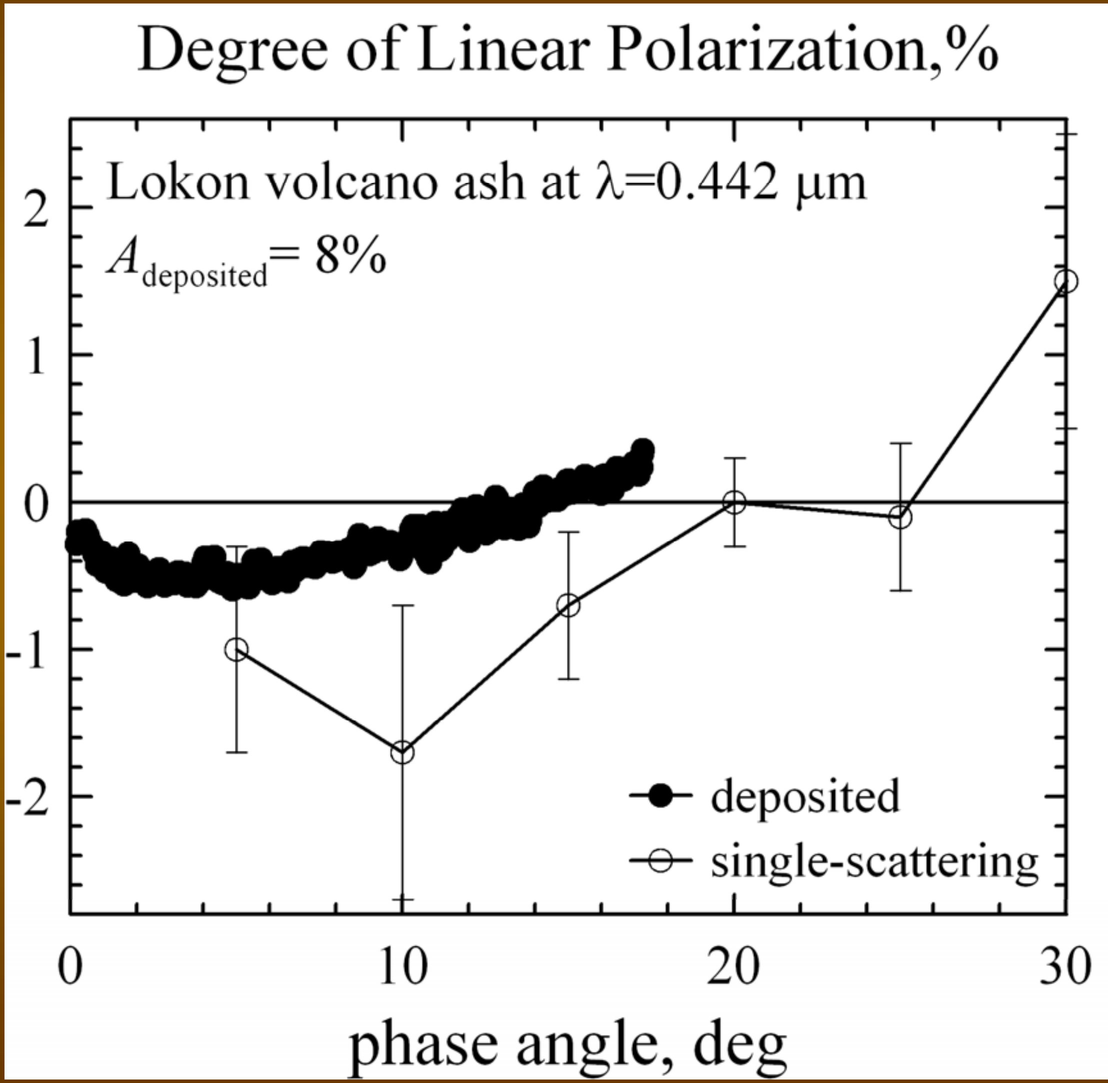
Answer to this question can be found in comparative study of light scattering by single and deposited dust particles (Shkuratov et al., 2004; 2006).

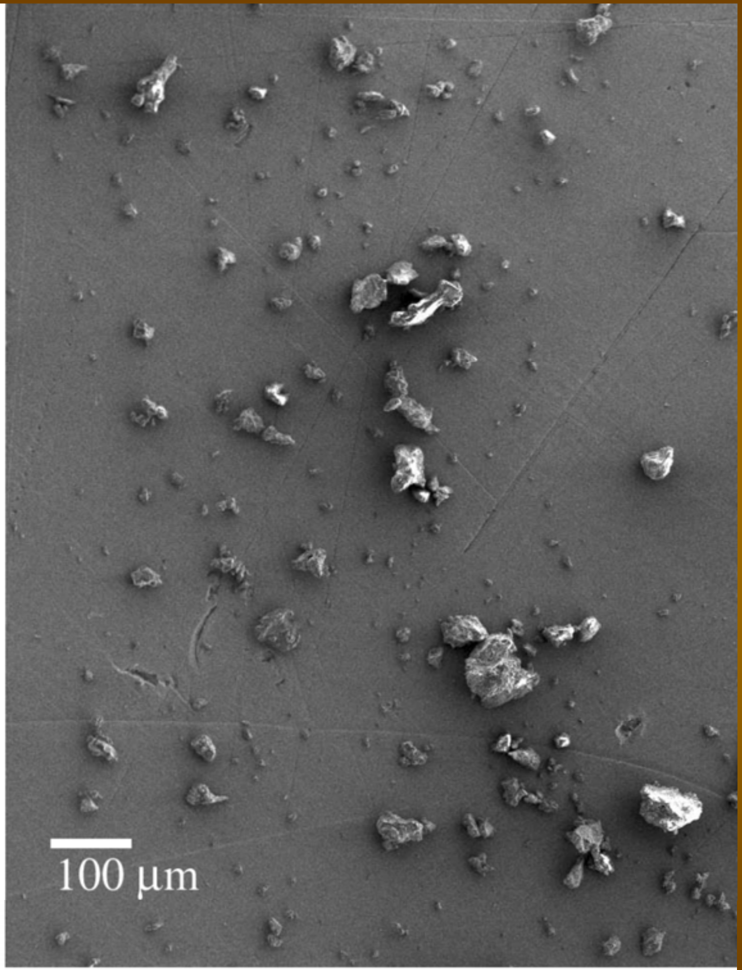
There were studied 10 different sorts of dust.

Single-scattering was measured using the experimental setup at University of Amsterdam (the Netherlands).

Light scattering by regoliths was studied with the setup at Kharkov National University (Ukraine).

Comparison of single dust particles and regolith





data adopted from Shkuratov et al., 2004; 2006

Answering on the question

Does the coincidence in angular profiles of the linear polarization for comets and C-type asteroids mean that their dust particles are similar?

we have to admit that the similarity in the negative polarization of comets and C-type asteroids must indicate a dramatic difference in the physical properties of particles.

However, it is very hard to believe this conclusion...

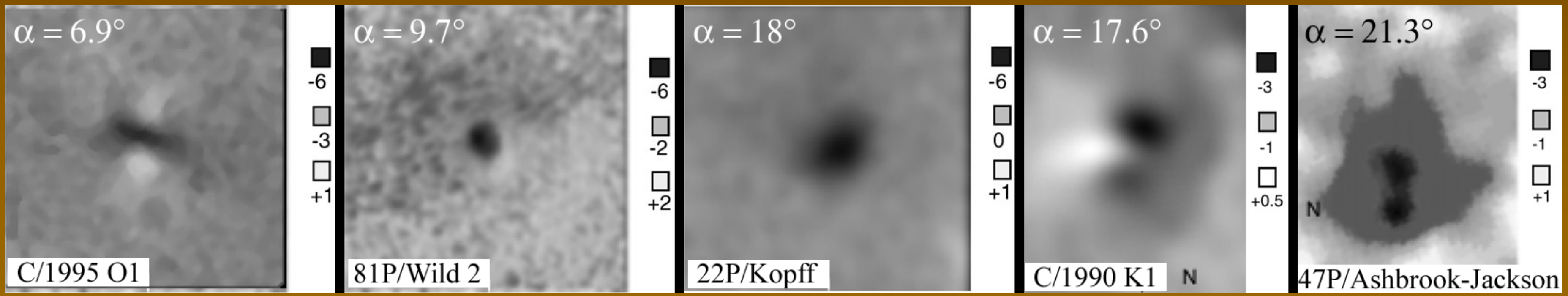
Indeed:

1. interplanetary dust particles (IDPs) originated from comets are quite similar to those originated from asteroids (e.g., Brownlee et al., 1993; Brownlee and Joswiak, 1995);
2. featureless visible spectra, color, low albedo, and surface morphology of cometary nuclei are typically similar to C-type and D-type asteroids (Weissman et al., 2001; also, compare images in Veverka et al., 1997 and A'Hearn, 2006).

Therefore, it has to be another explanation...

Variations of the linear polarization within a coma

R=4.2 AU | R=1.8 AU | R=1.6 AU | R=1.5 AU | R=2.3 AU



38000 km | 9000 km | 4400 km | 4000 km | 9000 km

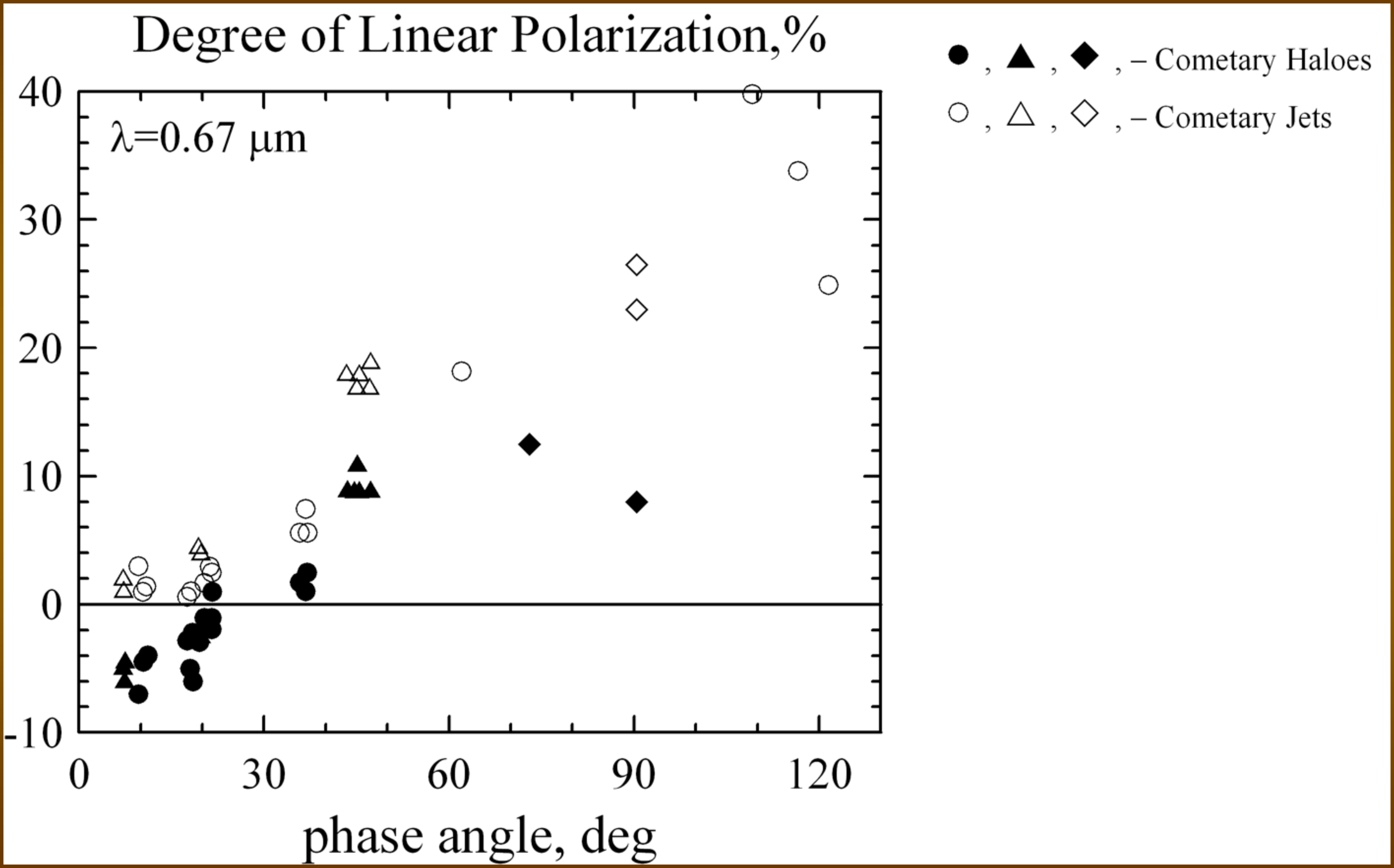
Two noticeable features have been found in the coma:

Circumnuclear Halo (high negative and low positive polarization)

Jets (only positive polarization)

data adapted from Hadamcik and Levasseur-Regourd, 2003

Profiles of the linear polarization in haloes and jets



data adapted from Hadamcik and Levasseur-Regourd, 2003

Note that the existence of two features in coma with distinctive behavior of polarization is well consistent with findings of space probes: cometary particles consist of so-called ROCK and CHON components.

e.g., Jessberger, Space Science Rev., **90**, 91–97

However, taking into account findings of laboratory study of light scattering by single and deposited particles, the difference in the negative polarization in haloes ($P_{min} \approx -6\%$, $\alpha_{min} \approx 15^\circ$) and C-type asteroids ($P_{min} \approx -1.8\%$, $\alpha_{min} \approx 10–11^\circ$) can be interpreted in terms of similar properties of dust particles.

If the linear polarization is dramatically varied through the coma, isn’t it more convenient to interpret polarimetric properties of haloes and jets separately from each other?

Indeed, the separated interpretation gives two following benefits:

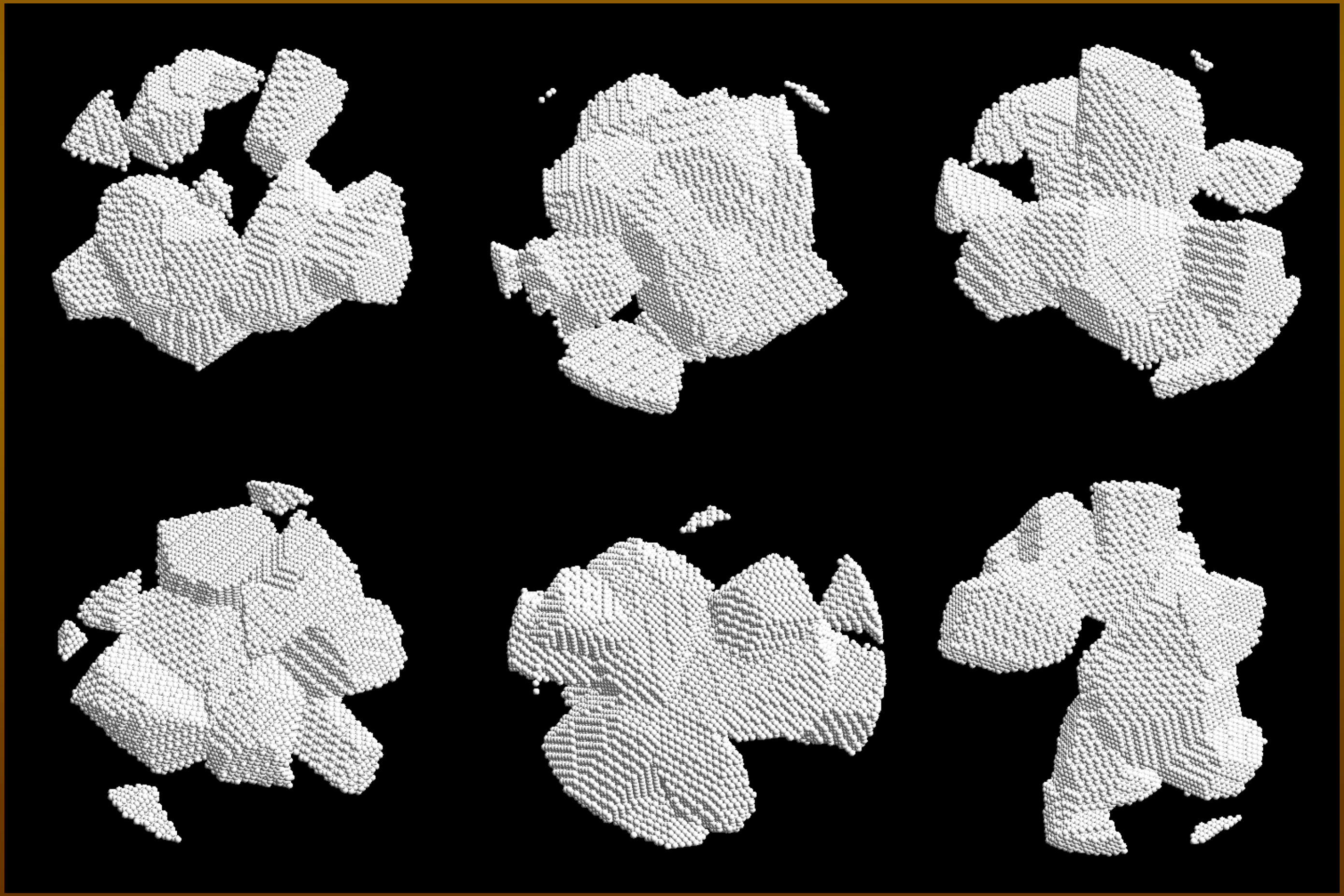
(1) one can exclude a parameter from consideration (i.e., ratio between contributions of jets and halo);

(2) high negative polarization in the haloes is much easier to interpret.

In what follows, we will discuss what does the deep negative polarization.

We simulate light scattering by irregularly shaped particles using the Discrete Dipole Approximation (DDA)

Our model of cometary dust is so-called agglomerated debris particles (packing density $\rho = 0.236$)



Important feature of light scattering by small particles

Light scattering by particles comparable to wavelength depends not on size of particles, but on the ratio of that size to wavelength. The ratio is quantified with the size parameter:

$$x = 2\pi r/\lambda$$

where, r – radius of circumscribing sphere around the irregularly shaped particle, λ – wavelength.

For instance, at λ = 0.5 μm and x = 10, r = 0.8 μm.

Set of parameters for agglomerated debris:

$m = 1.6+0.0005i$: $x = 2 – 26$

$m = 1.6+0.02i$: $x = 2 – 28$

$m = 1.6+0.1i$: $x = 2 – 32$

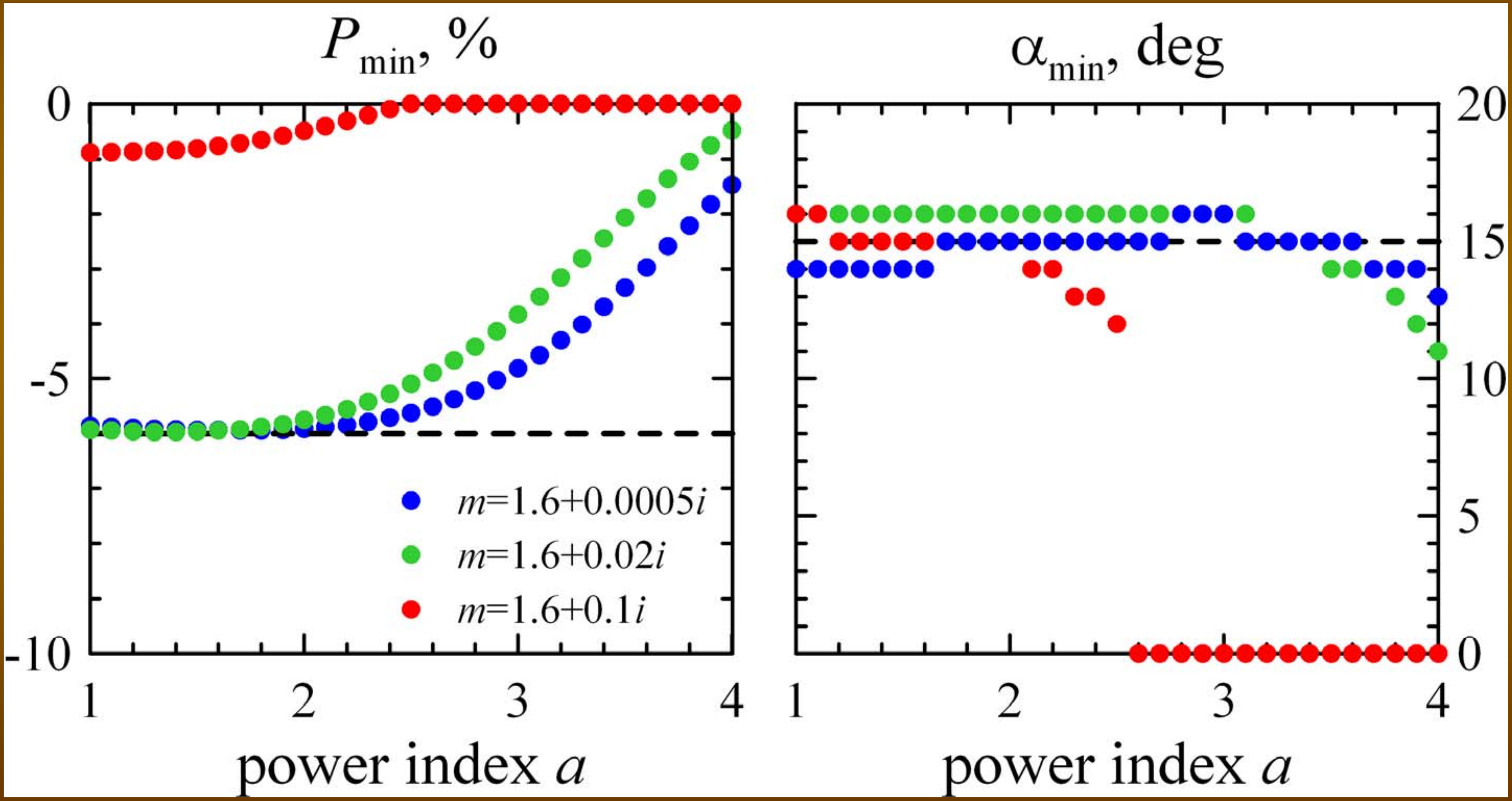
However, the cometary dust particles follow the power law size distribution:

$$r^{-a}$$

where r is radius of particles and the index a is varied from 1.5 to 3.4.

Mazets et al., Nature, **321**, 276–278

P_{min} and α_{min} versus the power index a



One can immediately conclude that there is no highly absorbing materials (i.e., Im(m) > 0.02) in the circumnuclear haloes in considerable amount.

Zubko et al., 2009, JQSRT, **110**, 1741–1749

The refractive index with Re(m) = 1.6 and Im(m) = 0 – 0.02 could be associated with Mg-rich silicates

Dorschner et al., 1995, Astron. Astrophys., **300**, 503–520

as well as with some organic materials, like, for instance, kerogen type II

Khare et al., 1990, Proc. LPSC 21, 627–628

or ice tholin

Khare et al., 1993, Icarus, **103**, 290–300

Imaging polarimetry of comets reveals dramatic variations of the linear polarization through coma. There are two features with distinctive behavior of the linear polarization: circumnuclear haloes and jets.

High negative polarization found in the circumnuclear haloes suggests similar properties of dust particles forming those haloes and regolith in C-type asteroids.

High negative polarization in the haloes is a signature of weakly absorbing materials ($\mathrm{Im}(m) \leq 0.02$).