INAF --Osservatorio Astronomico di Torino

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Gaia-FUN-SSO Meeting

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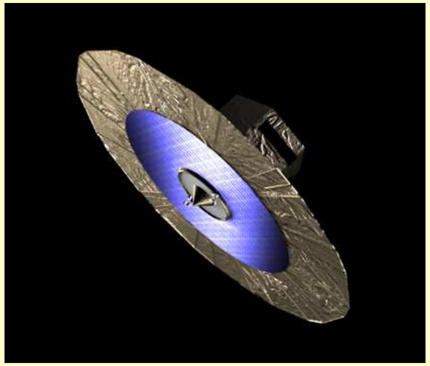
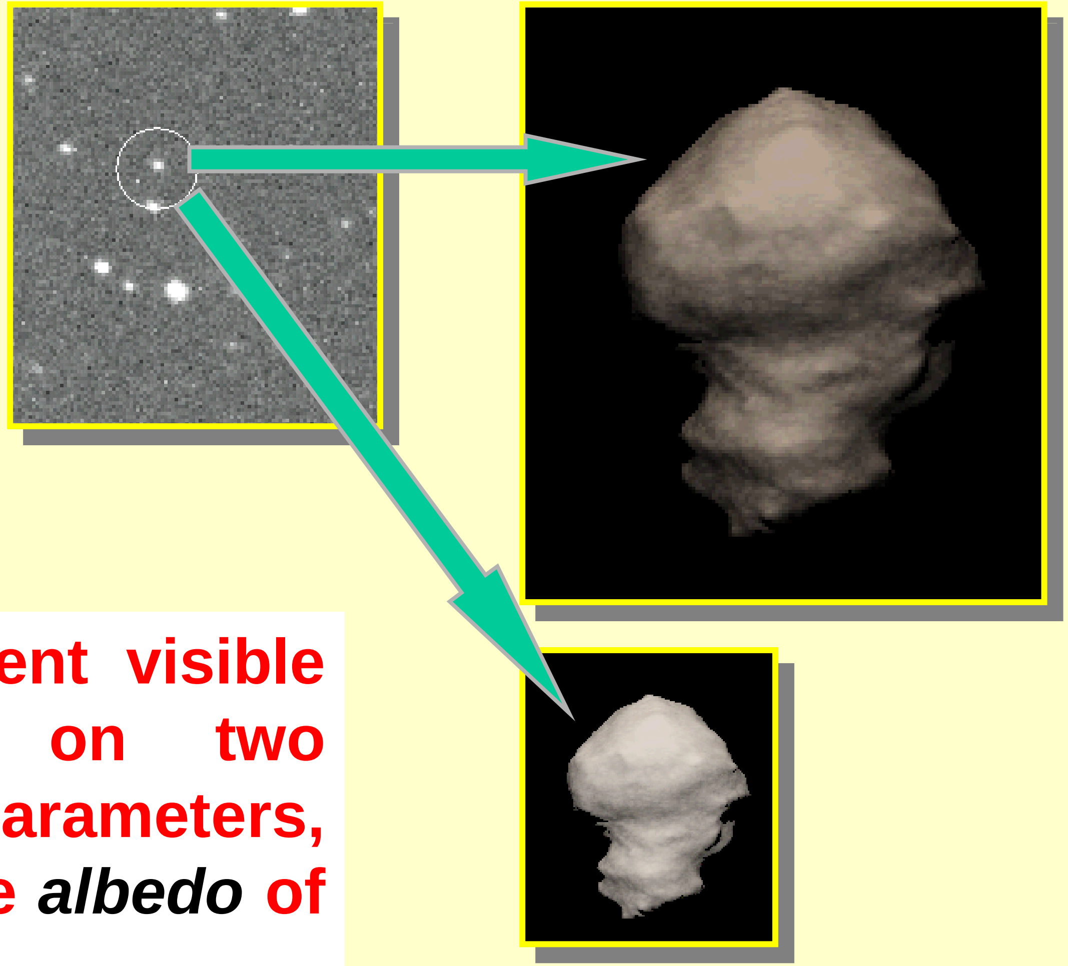
# GAIA SSO observations:

# The asteroid albedo problem

# And the possible role of ground-based support



The apparent brightness of an asteroid depends on many things. First, and trivially, it depends on its distance from both the observer and the Sun. Moreover, it depends in a more complicated way on the illumination conditions at the epoch of observation.



**In addition, the apparent visible magnitude depends on two fundamental physical parameters, namely the *size* and the *albedo* of the object.**

Note that, among asteroids, the albedo varies by a factor of 10.

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

In the above formula:

The 3.1236 constant is for V color (it depends on the wavelength)

***$p_V$* is the geometric albedo in V light ($p_V$).** *It is defined as the ratio between the actual brightness at zero phase angle to that of an idealized flat, fully reflective, diffusively scattering (Lambertian) disk with the same cross-section.*

***H* is the absolute magnitude, that is the magnitude in V light at unit distance from both the Sun and Earth, and at zero phase angle.**

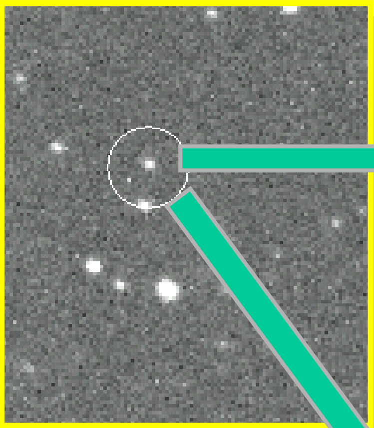
***D* is the diameter in km**, of the object (assuming it is spherical).

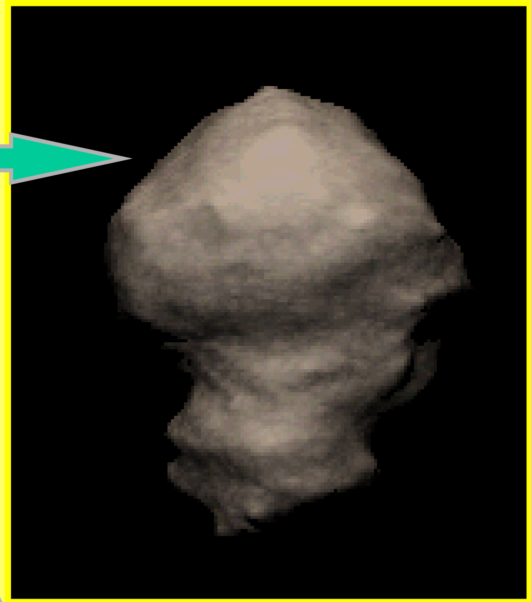
$$\log(D) = 3.1236 - 0.2H - 0.5\log(p_V)$$

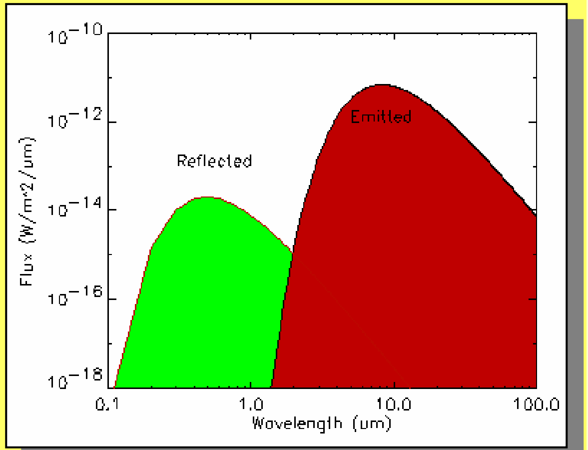
**The above formula is fundamental in many respects:**

1. **It is used to compute the albedo when one has H and D (from occultations or Thermal Radiometry)**
2. **It is used to compute D when one has H and $p_V$ (from Polarimetry)**
3. **A lot of asteroid science, including the evaluation of asteroid inventory and size distribution, and the evaluation of the composition and thermal histories of the objects, is based on size and albedo data.**
4. **The albedo is an important physical parameter *per se,* being related to composition and surface texture.**

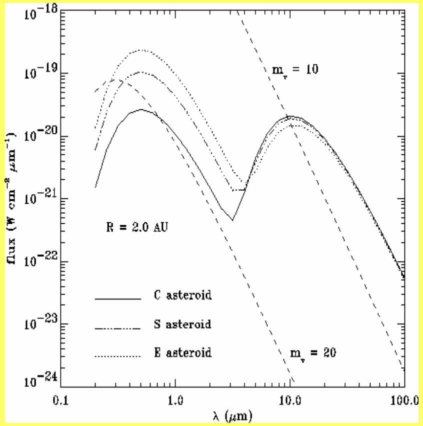
# How to derive the albedo?

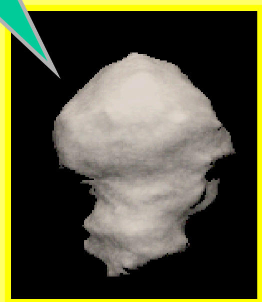


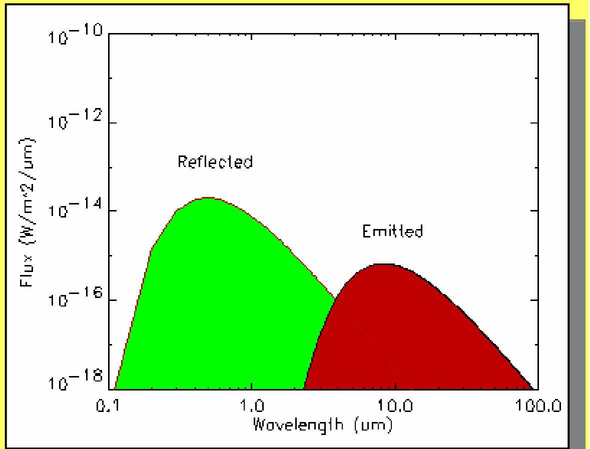





## Thermal Radiometry



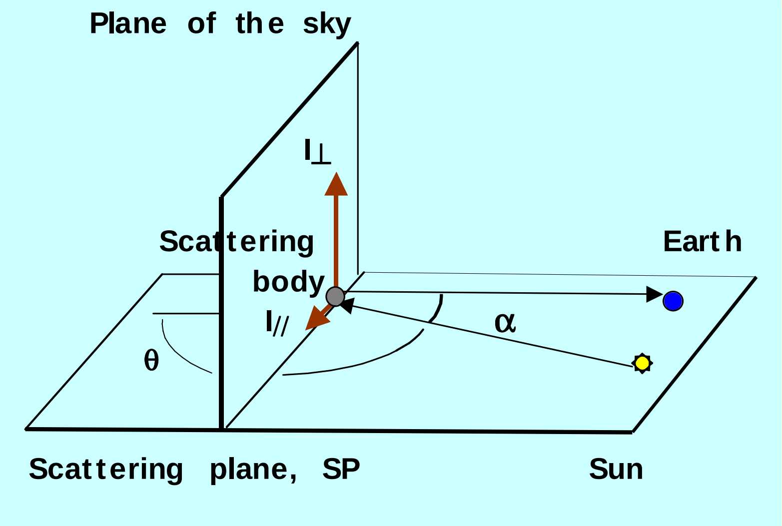



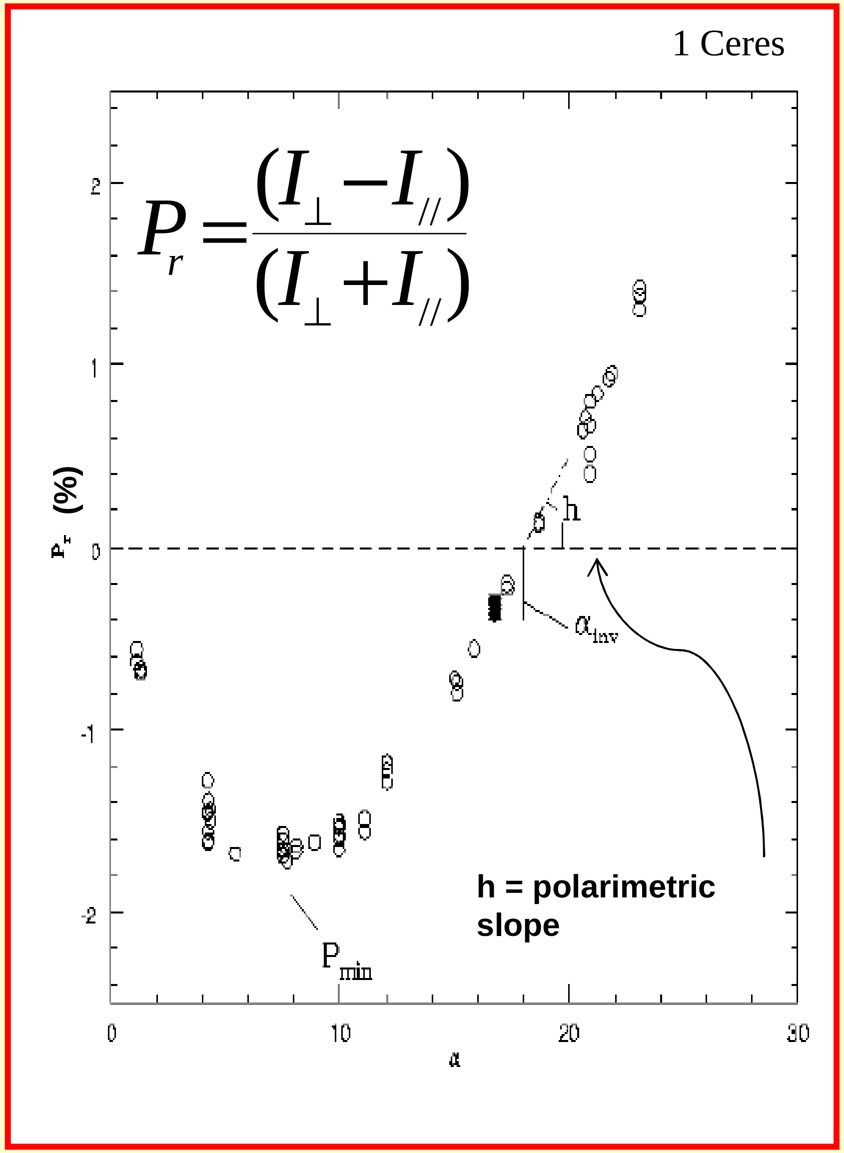


# Asteroid Polarimetry:

## What do we observe ?

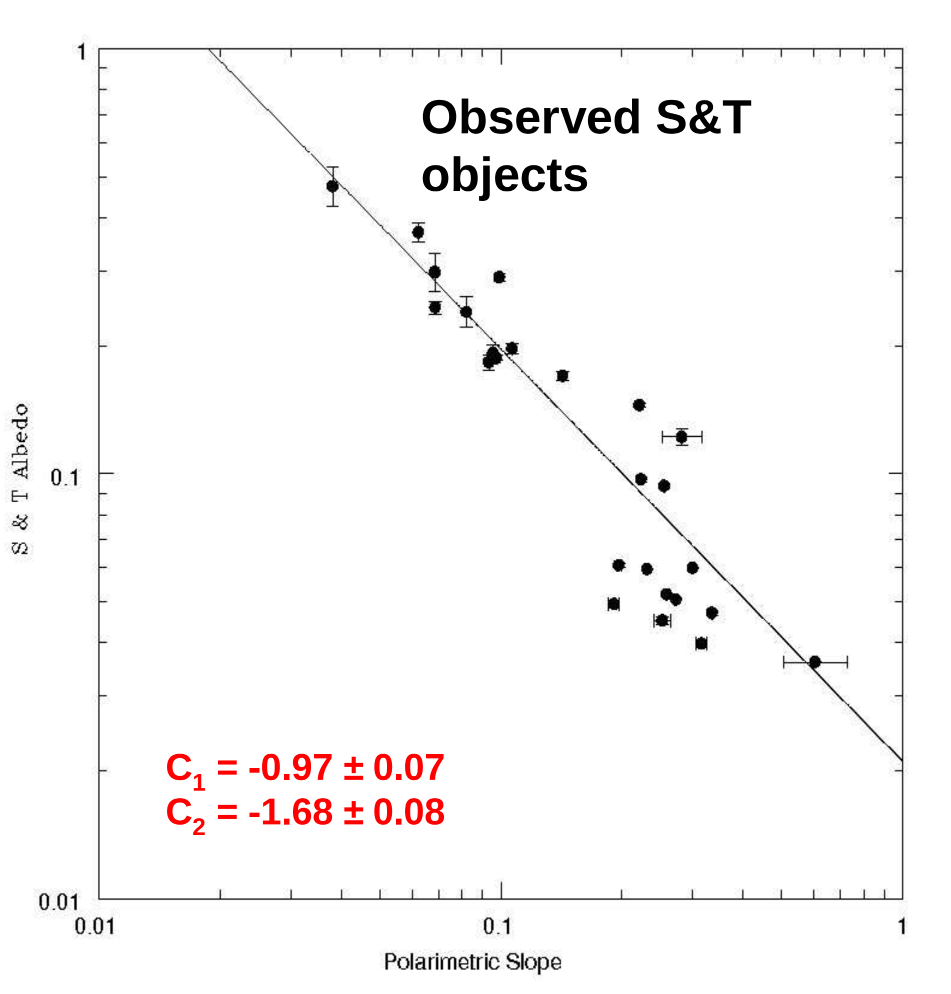
## Linear polarization and Phase – Polarization curves




- Presence of a Negative polarization branch
- Curve described by a few parameters

# Polarimetry: The slope –Albedo "law"




*Cellino et al. 2012*

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

**Polarimetry is in principle an excellent technique to derive asteroid albedoes.**

**Used in the past in asteroid taxonomy to distinguish between E, M, P classes (the big X complex). Some advantages over thermal radiometry, whose results <u>are model-dependent</u>, <u>require observations in different IR bands</u>, and generally <u>suffer from poor knowledge of H</u> (***and lightcurve effects, when measurements in different thermal IR bands are not simultaneous***). Radiometric albedoes for small asteroids observed in one single IR band have uncertainties of the order of 60%.**

# The role of Gaia: Some reminder...

Gaia will NOT measure the thermal IR flux.
Gaia will NOT make polarization measurements.
Gaia will never observe SSO at zero phase angle.

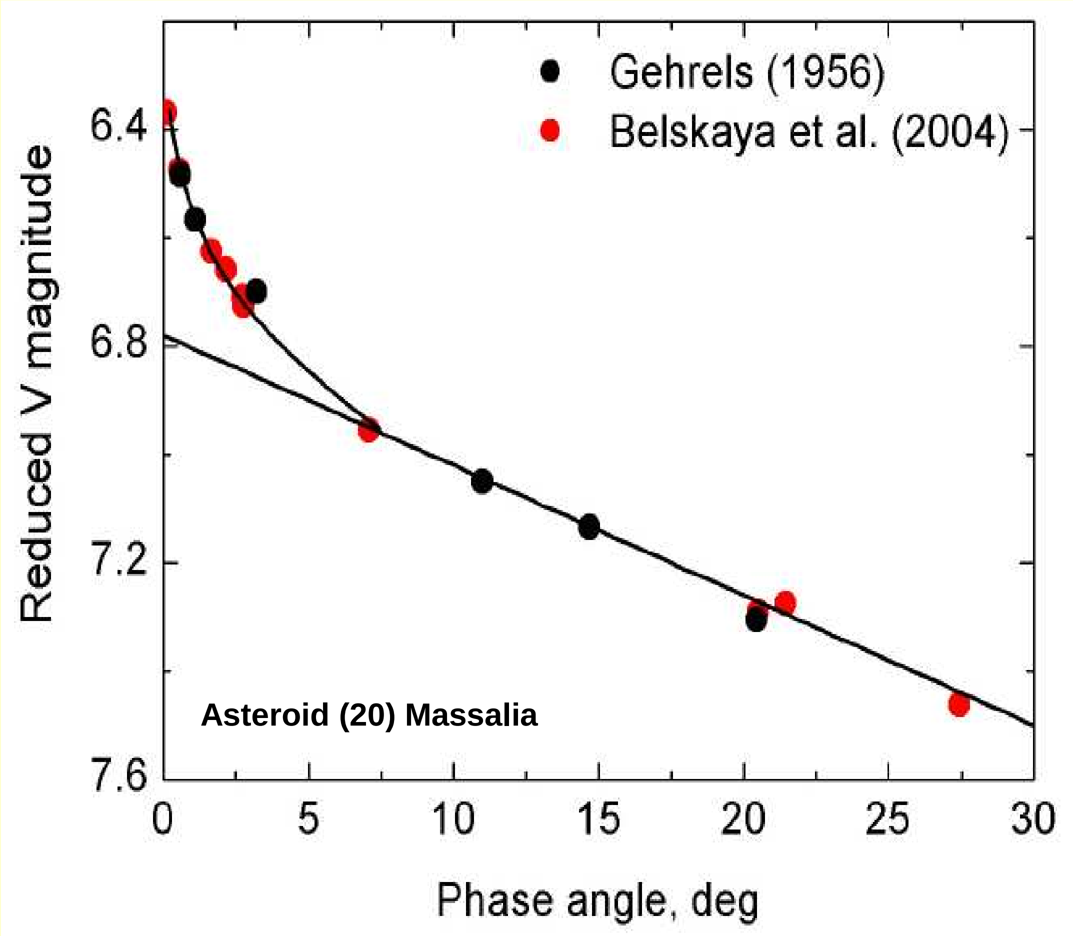
BUT

Gaia will directly measure the sizes of ~1000 objects.

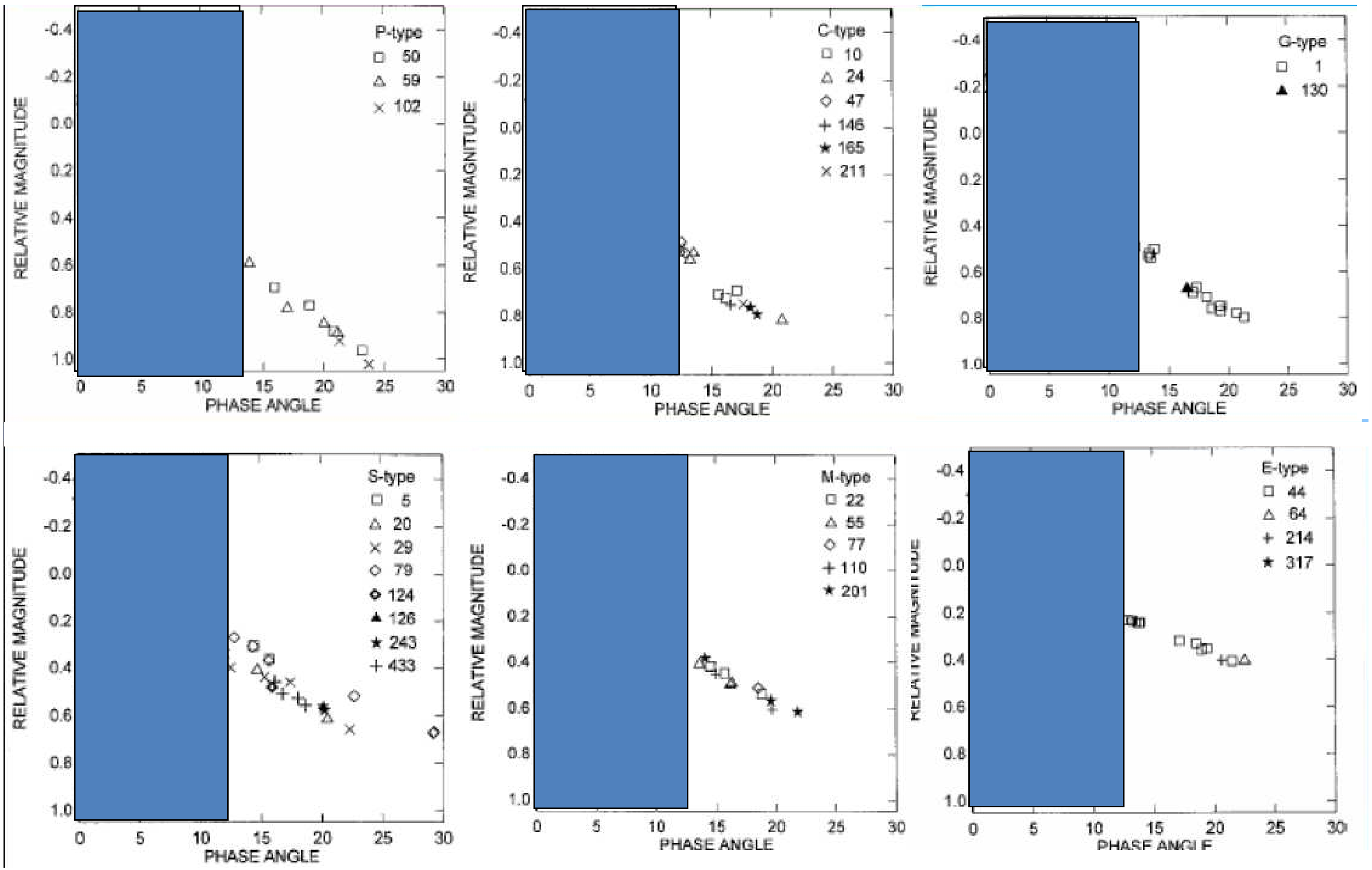
Gaia will make accurate photometric measurements in visual light. Each MB asteroid will be observed about 60 times during the mission lifetime. A Photometry inversion algorithm will be used to derive the rotational state and the overall shape, taking also into account a magnitude – phase relation.

It would be great to be able to derive also the albedo, but this requires knowledge of the absolute magnitude H.

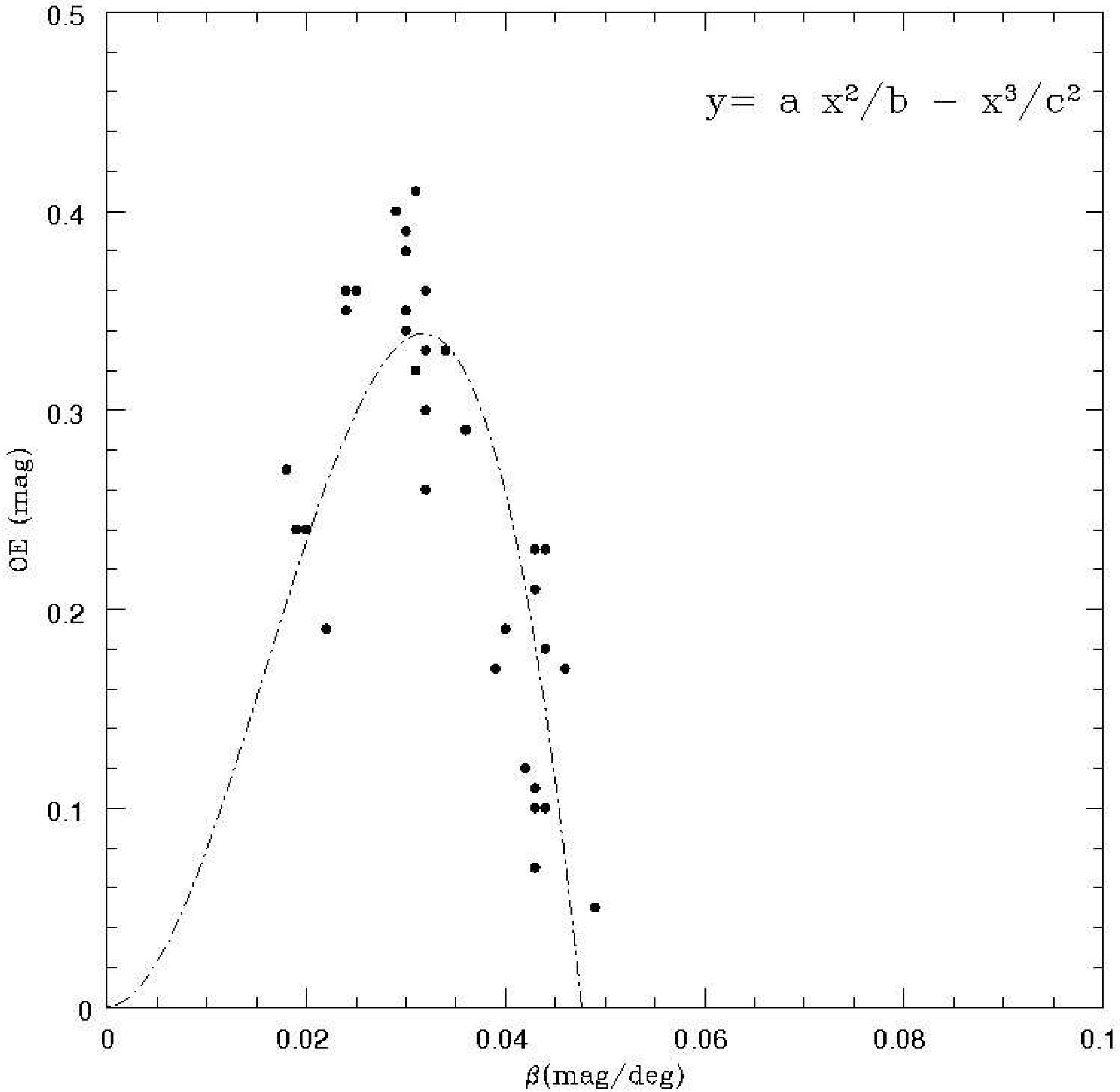
... and this is not so easy




**The variation of (normalized to unit distance) magnitude as a function of phase angle exhibits a linear dependence in a phase angle range between 7 and 80 deg. A non-linear surge takes place at phase angles less than about 5$^{o}$ (*brightness opposition effect*)**




The problem of the opposition effect for the determination of absolute mags and albedo by GAIA



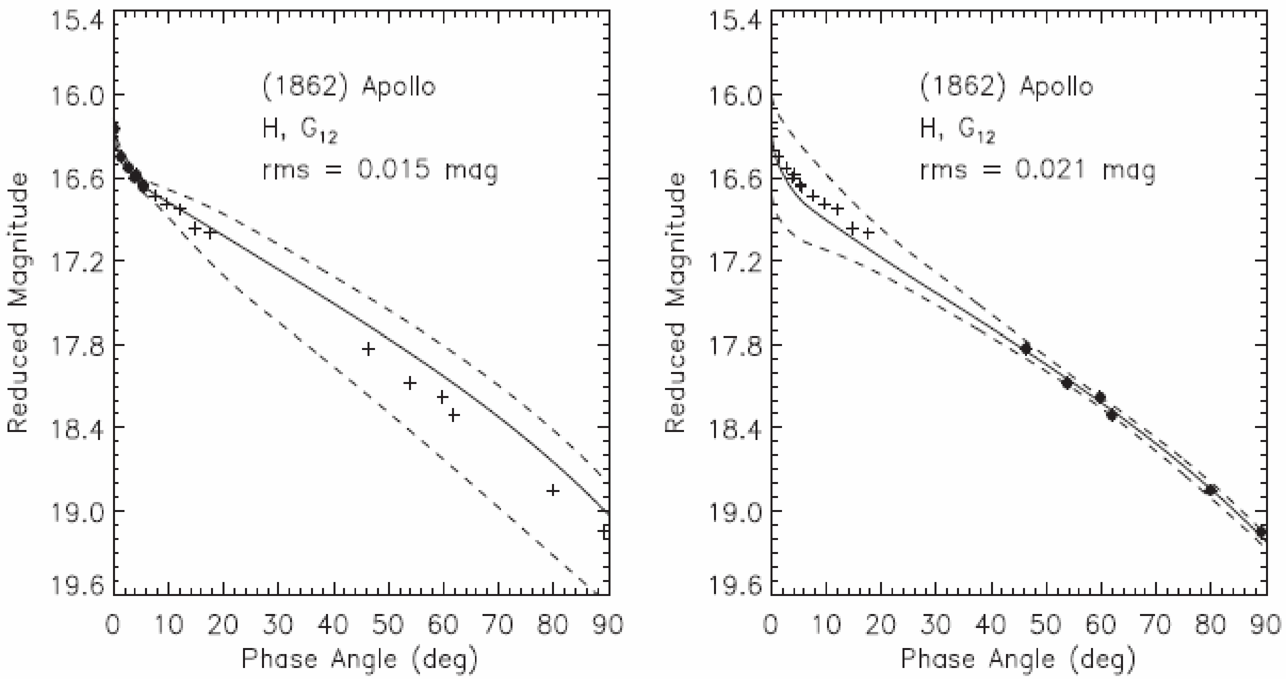

**The observed relation between photometric slope and opposition effect (the correction that should be applied to derive H from a simple, linear extrapolation of the phase-brightness relation)**

**Non-monotone relation**

**Large uncertainty !**

**Data from Belskaya and Shevchenko (2000)**

## A possible option: the new H, $G_1$, $G_2$ (or H, $G_{12}$) system

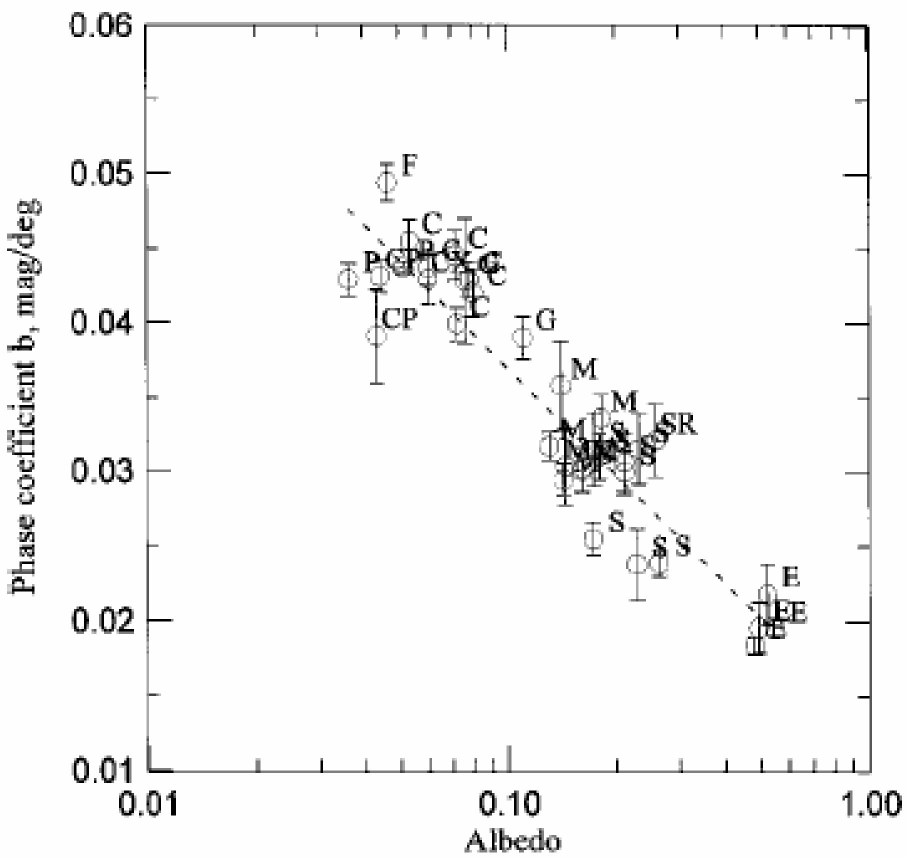



**The (H, G1 G2) photometric system has been accepted by IAU Div.III a few weeks ago during the 2012 IAU General Assembly in Beijing. It will replace the older (H,G) system.**

**Problem: can we put together data obtained at different aspect angles and hope that G12 remains constant?**

# Another possible approach: deriving the albedo from the slope of the linear portion of the phase – brightness relation without caring about H

$$b = 0.013\ (\pm 0.002) - 0.024\ (\pm 0.002)\ \lg\ p_V$$




If this or a similar relation is valid, we can derive the albedo of many thousands of asteroids from Gaia observations, even without knowing the absolute magnitude !

And this is based on a parameter which is given directly by photometric inversion for thousands of objects !

(Belskaya and Shevchenko, 2000, Icarus)

# The possible role of ground-based support

**We need:**

- **New, high quality phase-mag curves to improve H, G1, G2.**

- **New, high-quality phase-mag curves of objects already observed, to check that the slope of the linear part of the phase-mag curve does not change very much with the aspect angle.**

- **New polarimetric data of asteroids belonging to the Shevchenko & Tedesco (2006) list, to improve the calibration of the slope – albedo relation.**

- **New polarimetric albedos of objects for which the phase-mag relation is well determined, to improve the calibration of the relation between albedo and linear part of the phase-mag relation.**