Observations and laboratory measurements, as tool to reveal primitive asteroids and extinct comets amongst NEA

A. Chantal Levasseur-Regourd

UPMC Univ Paris 6 / IPSL-CNRS, France
Motivation

Marco Polo to lead to a better knowledge of initial conditions, early evolution and origin of life in the solar system

Best target 1999 JU3
Yet, hope for quite a few new targets in a near future

Need to recognize rapidly and accurately primitive objects, i.e. C- or D-types and dormant or extinct cometary nuclei

Approach
   Spectral data
   Albedo (expected to be very low)
   More generally polarimetric observations
Scattered light and polarization

Solar light scattered by dust partially linearly polarised, as used by:
- arthropods (honeybees) to navigate
- Arago to establish the presence of dust in comets

Linear polarisation $P$, dimensionless ratio, allowing comparisons

$P$ varying only with:
- phase angle $\alpha$ (or scattering angle $\theta = \pi - \alpha$)
- wavelength $\lambda$
- properties of the scattering medium

For numerous solar system objects, “smooth” polarization phase curves, typical of scattering by irregular particles with sizes greater than the wavelength

$$P = \frac{(I_\perp - I_{||})}{(I_\perp + I_{||})} = -\frac{Q}{I}$$

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Observations of asteroids
\( \alpha \) dependence

Mostly observations of S-type and C-type

Observations small \( \alpha \), but for NEA

Slope at inversion increasing when the albedo decreases, with ‘empirical law’ between \( h \) and albedo

Trend of the positive branch providing information about the taxonomic type, as illustrated by a principal component analysis

Trends in \( P_\lambda(\alpha) \) [e.g. \( \alpha_{\text{min}}, P_{\text{min}}, \alpha_0, h, \alpha_{\text{max}} \)] to be interpreted in terms of physical properties, i.e. albedo, porosity, size distribution of the dust particles

Levasseur-Regourd & Hadamcik, JQSRT2003

Pentillä et al., A&A 2005

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Well documented on the positive branch for a few NEA, e.g. 4179 Toutatis and 25143 Itokawa

Negative branch also well documented for MBA

Above $\approx 25^\circ$, polarisation significantly decreasing with increasing $\lambda$
(as opposed to cometary dust)

See also poster by I. Beskaya

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**Asteroids $\lambda$ dependence, S type objects**

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Levasseur-Regourd et al., JQSRT 2003

Belskaya et al., Icarus 2009

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Marco Polo, Paris, 2009
From ongoing observations at Haute-Provence Observatory, trend to a slight increase of polarisation with increasing $\lambda$. 

Asteroids $\lambda$ dependence, C type objects
Interpretation through simulations

Need to interpret the changes in $P_\lambda(\alpha)$ and in $P_\alpha(\lambda)$ in terms of physical properties through experimental and numerical simulations, as successfully done for cometary dust.

Excellent match with porous aggregates of subµm ($\text{MgSiO} + \text{FeSiO} + \text{C}$) grains and compact Mg-silicates

Experimental setup and results

Hadamcik et al., Icarus 2007

Numerical models and results

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Levasseur-Regourd & Zolensky., PSS 2008
New laboratory measurements on dust agglomerates

Huge agglomerates
U. of Braunschweig

Experimental setup
Hadamcik et al., JQSRT 2009

h and $P_{\text{max}}$ decreasing when albedo increases higher (less absorbing)
$P_{\text{max}}$ smaller for deposited transparent particles (multiple scattering)

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In fine…

Polarization is a powerful tool to derive physical properties (e.g. different coma regions and comets, as far as their dust is concerned)

It has been known for long that the slope of polarization phase curves at inversion provides a value of the bulk albedo of the surface of asteroids

Besides, wavelength dependence is now beginning to be monitored

Such results provide constraints for experimental (and numerical) simulations of the properties of surface layers on low gravity bodies

Assuming numerous small NEO are to be discovered in a near future…

- Systematic polarimetric observations would provide indications on the type
- Systematic observations on a couple of wavelengths could provide indications on the surface layer porosity

However…
Such observations require rather large axially symmetric telescopes, operating on quite a regular basis (to monitor different phase angles)