Laboratory simulations of asteroidal regoliths by polarization measurements

E. Hadamcik, A.C. Levasseur-Regourd

edith.hadamcik@latmos.ipsl.fr

Outline

Introduction

Instruments PROGRA^2-surf and PROGRA^2-vis

Samples

Packing density influence on deposited samples

Orgueil and C-type asteroids

Aubrite from Antarctic and E-type asteroids

Summary

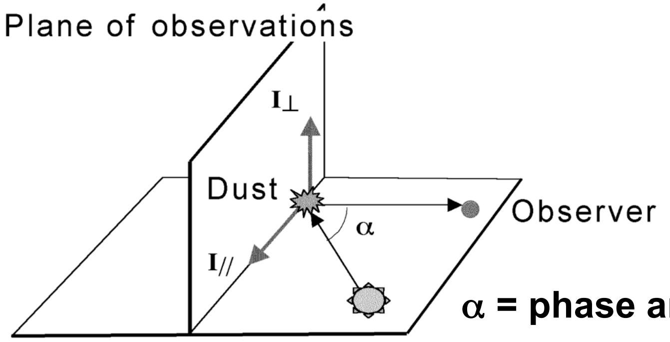
References

Introduction

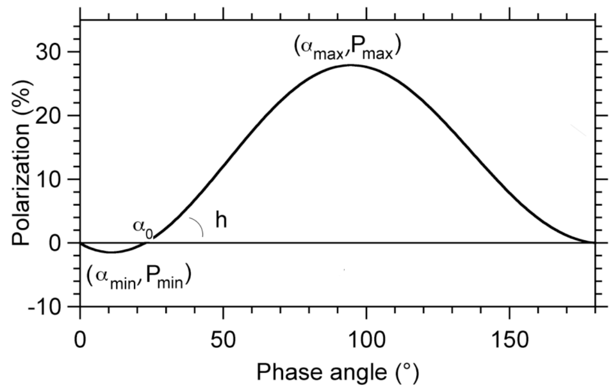
Polarization depends on:
sizes, size distributions
(constituent grains and aggregates)
Complex refractive index
Structure (porosity), surface properties
Albedo

Wavelength of observations
(size parameter, refractive index)

Geometry of observations



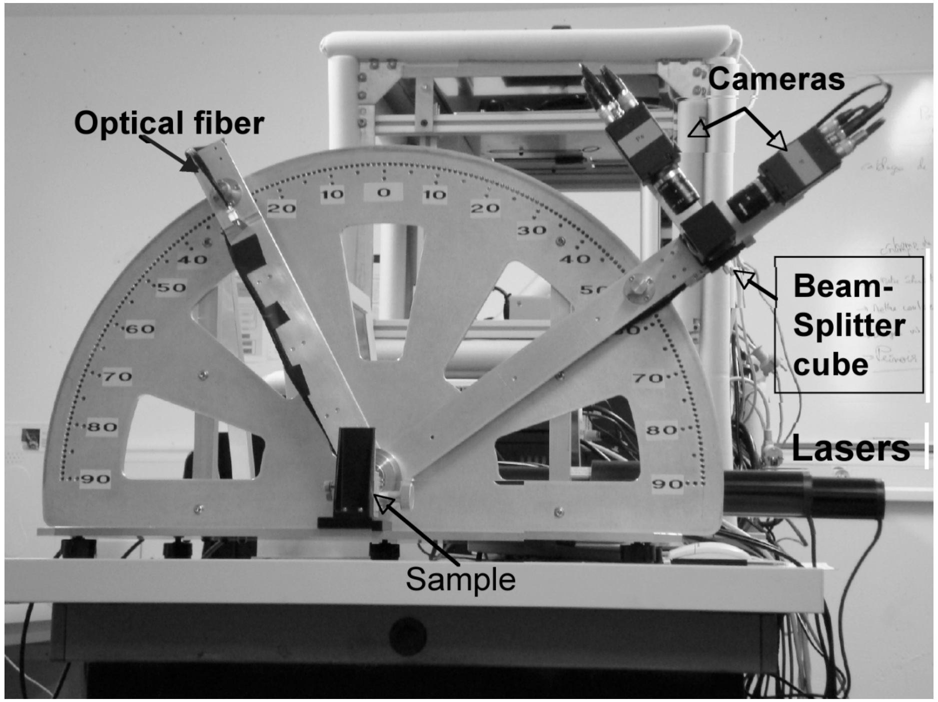
Polarimetric phase curves for solar system small bodies are smooth and typical of irregular particles



Levasseur-Regourd et al., 2003

Experimental simulations

(1) PROGRA^2-surf instrument



Sample in a cup
Rotation and translation to cover an about 1 cm surface

2 randomly polarized lasers:
543.5 nm and 632.8 nm

A beam-splitter cube:
I_{perp} and I_{par}

2 CCD-cameras

Phase angle range: 6°-160°

$$I = I_{perp} + I_{par}$$

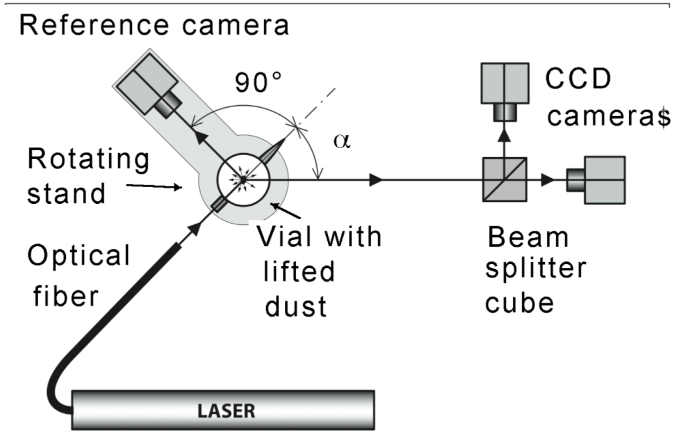
$$P = \frac{I_{perp} - I_{par}}{I_{perp} + I_{par}}$$

Generally: Incidence angle = emergence angle = phase angle / 2

More details on the experimental set-ups *Hadamcik et al., 2009a*

Experimental simulations

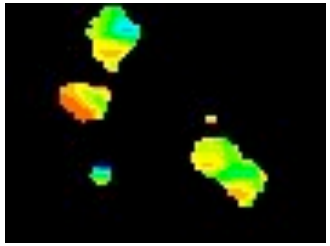
(2) PROGRA^2-vis instrument and size effect



PROGRA2-vis instrument diagram

Interest of measurements on lifted single grains

Images allow to study P vs particles size



2 mm

A polarization map for agglomerates

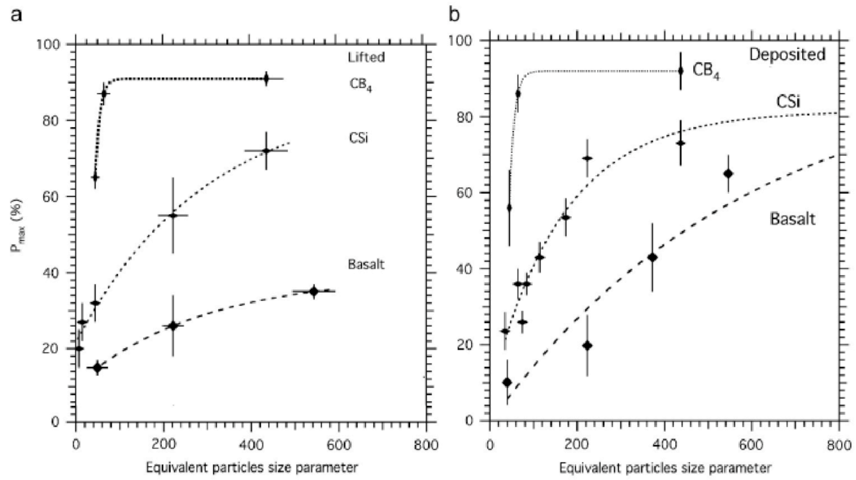


Fig. 13. P_{max} vs particle sizes for compact irregular particles made of different absorbing materials ($\lambda = 632.8$ nm): (a) lifted particles; (b) deposited particles.

Amplitude of the positive branch vs grains'size for absorbing samples:

Similar trend for layers and Lifted particles

Hadamcik et al., 2009a

Hadamcik et al., 2009b

Experimental simulations

(3a) Samples

As analogs for different solar system dust or to study the influence of different physical properties in particles (difficult to model)
Spheres are used to try to understand the different light scattering process

-Spheres and aggregates of spheres
-Irregular grains and aggregates

Hadamcik et al., 2007a
Lasue et al., 2007

Clouds of particles lifted in reduced gravity conditions or by a nitrogen-draught

cometary dust analogs, solid aerosols in atmospheres…

Hadamcik et al., 2007b *Renard et al., 2005; 2010* *Hadamcik et al., 2009c*

single scattering and internal interactions between monomers

Layers deposited on a plane surface

asteroidal or cometary nuclei surfaces, planetary surfaces,

multiple scattering, surface rugosities, packing density..

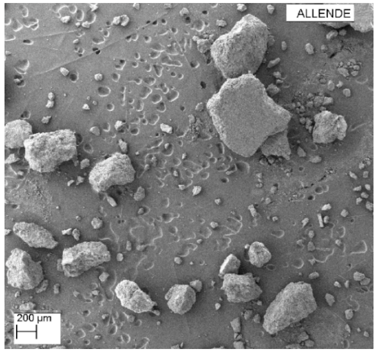
Worms et al., 2000

Experimental simulations

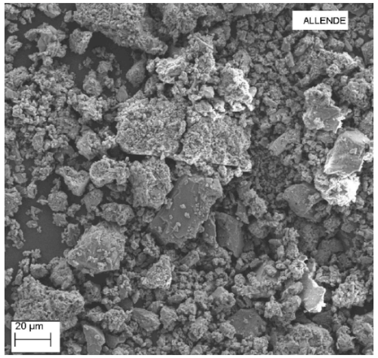
(3b) Samples: powdered meteorites

different size distributions: maximum mass 2g/size for layers and 0.3g for lifted

CV3 (Allende) grey

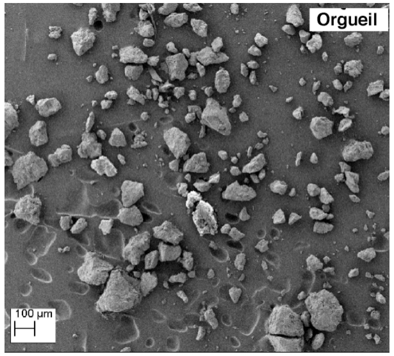


s < 500 μm

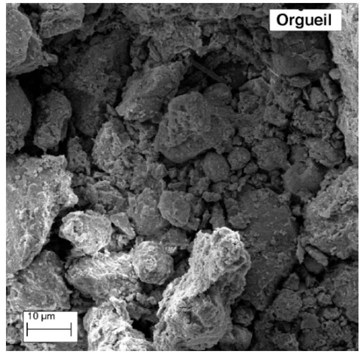


s < 50 μm

CI1 (Orgueil) dark brown

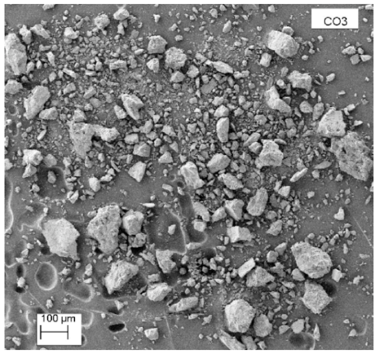


s < 400 μm



s < 50 μm

CO3 (NWA 4868) brown



s < 200 μm

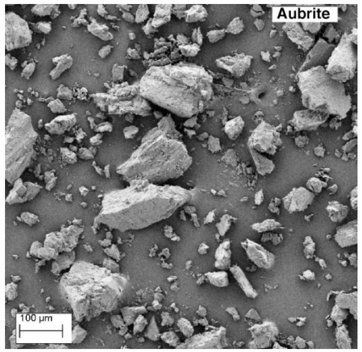
s < 50 μm

Aubrite (ALH78113,82)

clear greenish

250 μm< s <125 μm

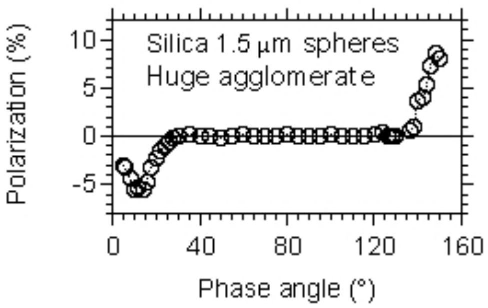
s <125 μm

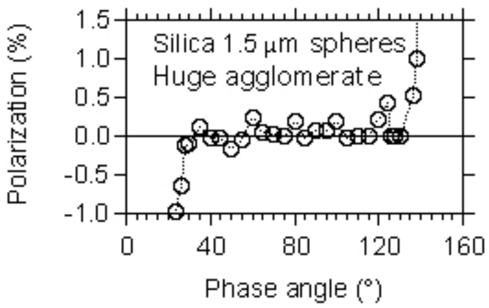


SEM images, LISE/UPMC, Paris

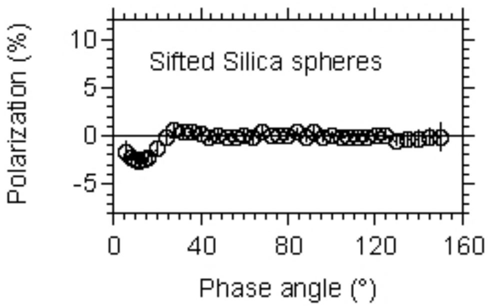
Experimental simulations

(3c) Packing density influence for layers

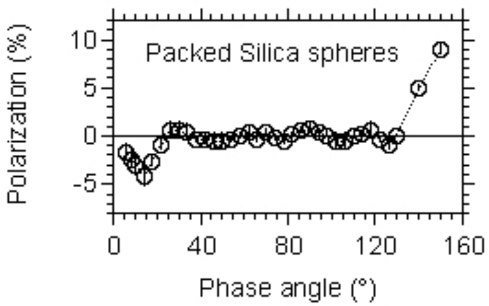




Huge agglomerates (cm)
by random deposition
Volume filling factor (VFF)
0.12-0.20 *(Blum et al., 2004)*
At a microscopic scale irregular surface
Hadamcik et al., 2006; 2007a



Sifted sample
- deagglomerate the aggregates
- macroscopic rough surface
- VFF 0.4 ± 0.1



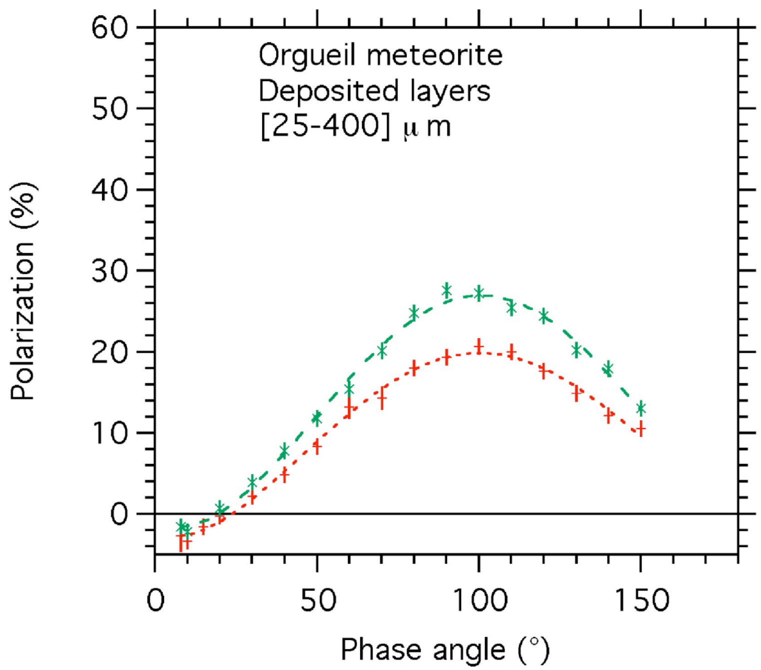
Packed samples
VFF 0.6 (0.7)
Less rugosities than in the previous case

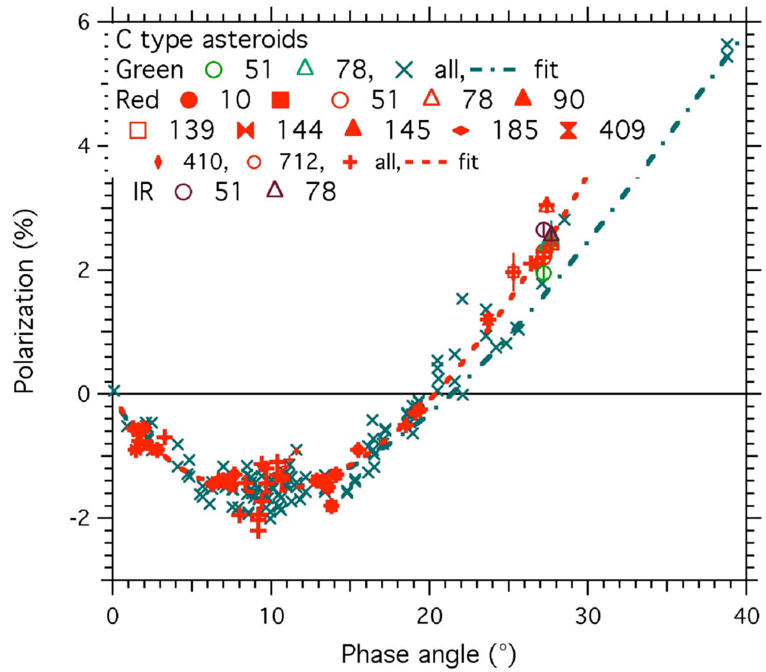
●For deposited spheres when VFF ↗, typical oscillations ↗

●For irregular particles when VFF ↗ Amplitude of positive branch ↗
Worms et al., 1999

Experimental simulations

Phase curves for a CI1 meteorite (Orgueil) compared to C type asteroids (1)





Absorbing carbonaceous material

Dark C-type asteroids

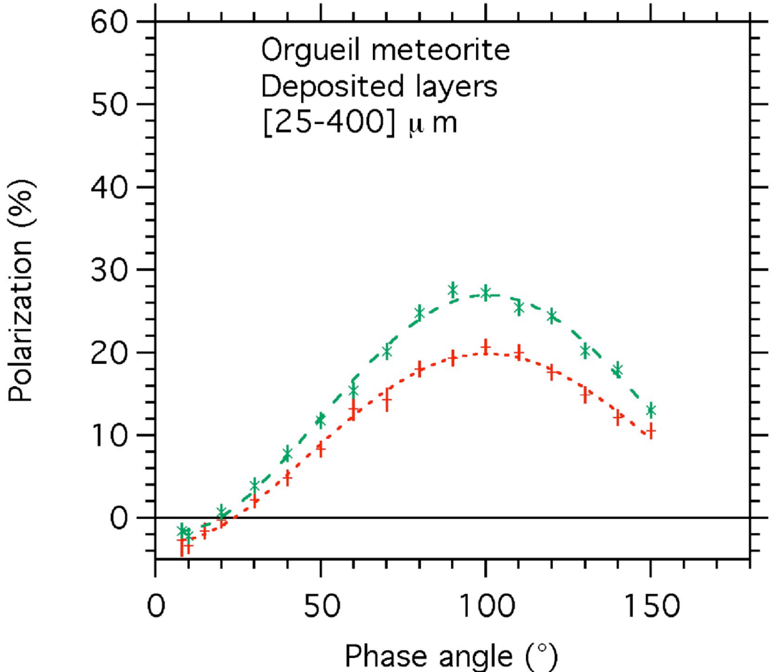
- Inverse color effect in polarization

Fig adapted from *Worms et al., 1999*
Hadamcik et al., in preparation

Hadamcik et al., submitted

Experimental simulations

(7) Phase curves for a CI1 meteorite (Orgueil) compared to C type asteroids (2)



Hadamcik et al., in preparation

Orgueil grinded meteorite

Wavelength	α_{min} °	**P_{min} %**	α_0 °	**h %/°**
543.5 nm	8	**-1.6**	19.5	**0.24**
632.8 nm	9	**-1.7**	24	**0.26**

Filters	α_{min} °	**P_{min} %**	α_0 °	**h %/°**
Green	9	**-1.6**	21.5	**0.23**
Red	9	**-1.6**	20.3	**0.28**

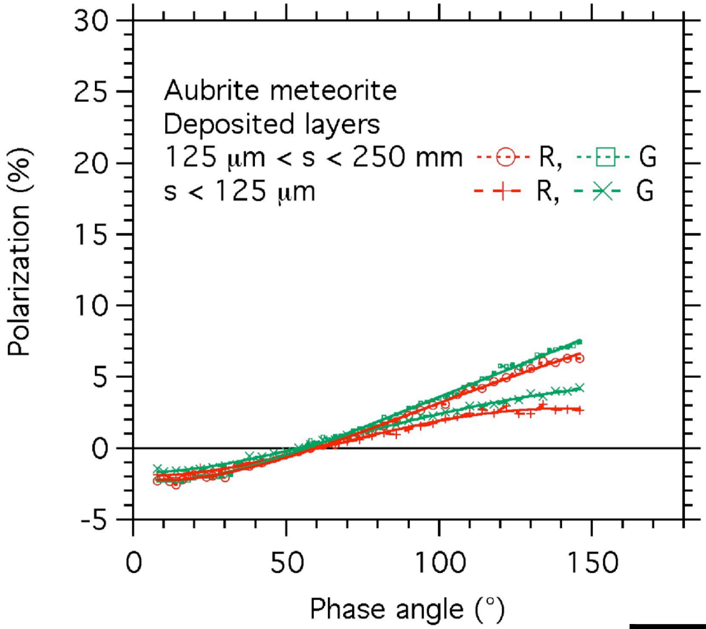
C-type asteroids

- Slope at inversion: in agreement with C-type asteroids observations
- P_{min}: in agreement with C-type asteroids observations
- **But inverse color effect in polarization (in the visible domain)**

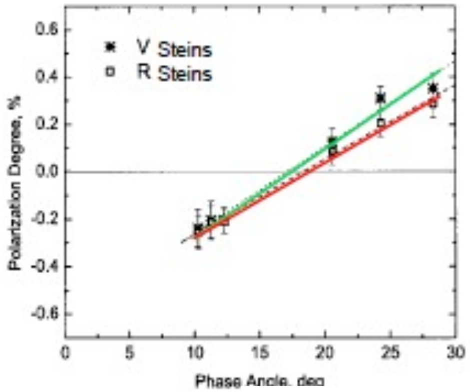
➔ Orgueil is not a good analog for C-type asteroids

Experimental simulations

Phase curves for aubrite (ALH78113,82) as compare to E-type asteroids (1)



Hadamcik et al. In preparation



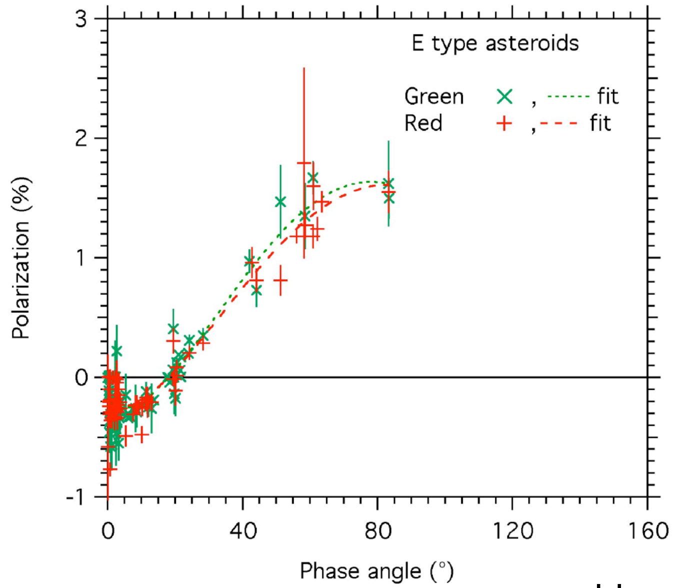
Fornasier et al., 2006

Filters	α_0°	**h %/°**
Green	17.3	**0.04**
Red	18.4	**0.03**

2867 Steins

Filters	α_0°	h %/°
Green	18	0.033
Red	18	0.028

E-type asteroids



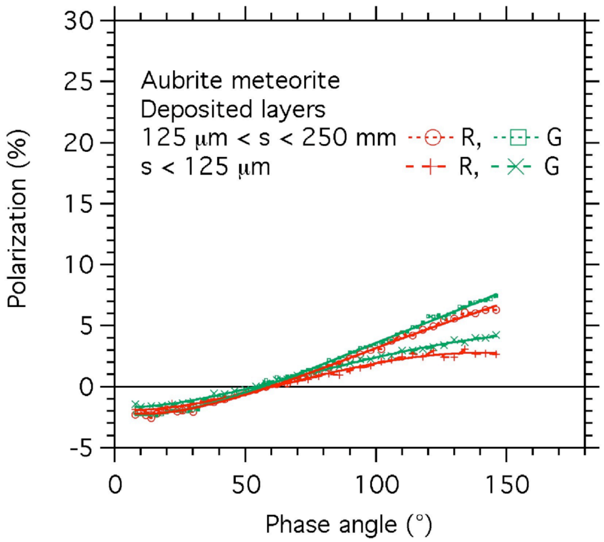
Hadamcik et al., in preparation

Transparent material
High albedo asteroid

Hadamcik E.
Meudon-2010 Dec 1-3

Experimental simulations

Phase curves for aubrite (ALH78113,82) as compare to E-type asteroids (2)



Wavelength	α_{min} °	**P_{min} %**	α_0 °	h%/°	P_{max} %
543.5 nm L	7	**-2.1**	55	0.08	7.5
S	7.5	**-1.4**	57	0.05	4.1
632.8 nm L	8	**-2.3**	55	0.07	6.4
S	9	**-1.8**	55	0.04	2.8

Filters	α_{min} °	P_{min} %	α_0 °	h %/°	P_{max} %
Green	6	-0.25	18	0.033	1.65
Red	6	-0.25	18	0.028	1.6

E-type asteroids

- Inversion angle very different

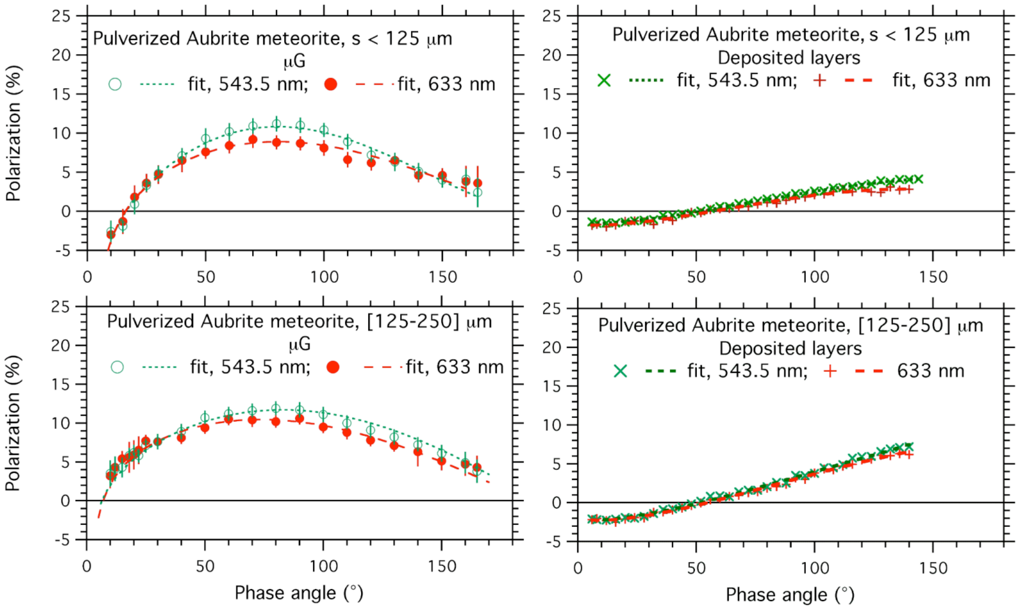
For smaller sizes:

- Slope at inversion: may be in agreement with E-type asteroids observations
- P_{min} may be in agreement with E-type asteroids observations

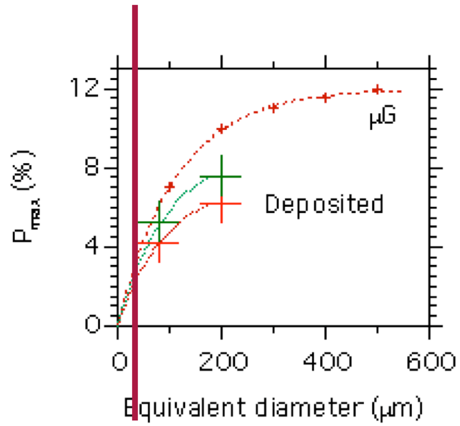
- Color effect in polarization in agreement (P ↘ when λ ↗)

Experimental simulations

Phase curves for aubrite (ALH78113,82) as compare to E-type asteroids (3)



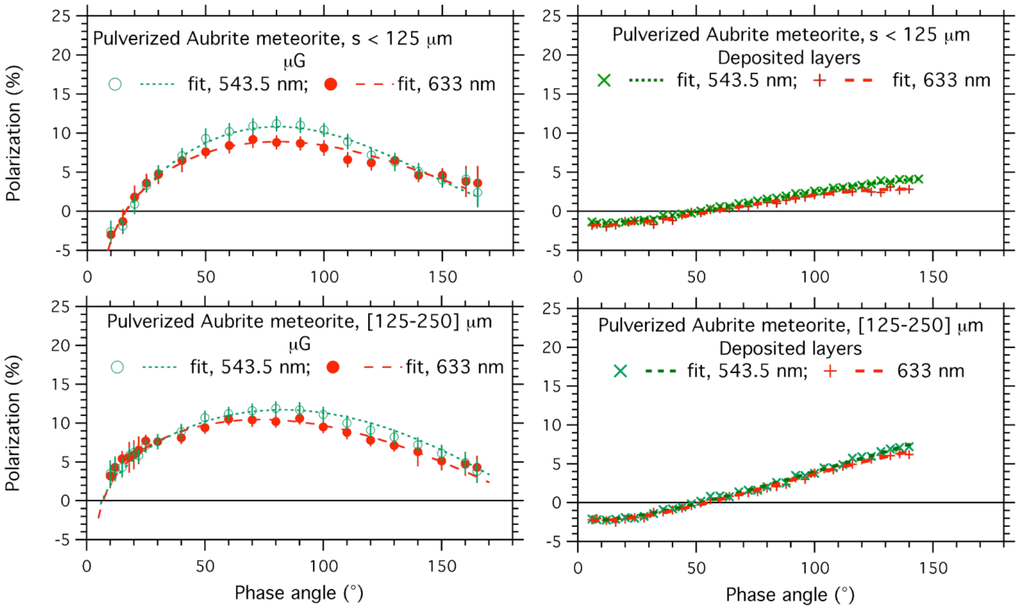
McFadden et al., 2009
Levasseur-Regourd et al., in preparation

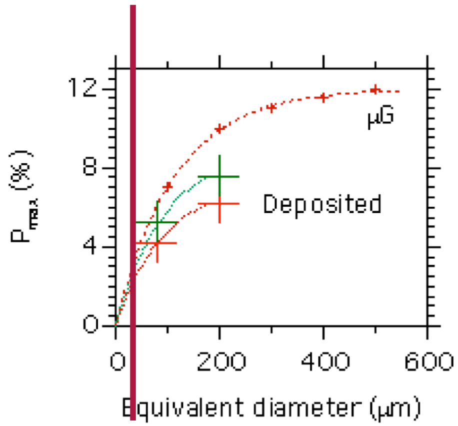


Hadamcik et al., in preparation

The average size seems to be smaller than 20 μm

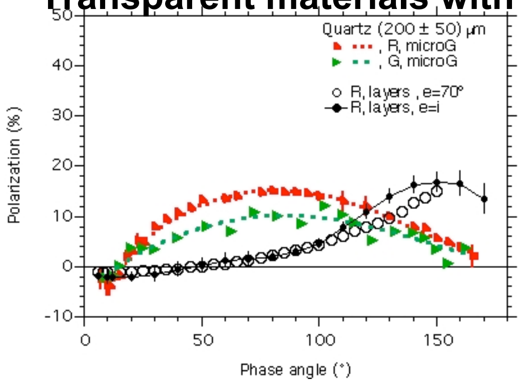
Experimental simulations
Phase curves for aubrite (ALH78113,82) as compare to E-type asteroids (3)





Hadamcik et al., in preparation

Transparent materials with large grains



Hadamcik et al., 2009a

The average size seems to be smaller than 20 μm

Aubrite from Antarctic seems to be a good analog as polarization is concerned for E-type asteroids

200 μm Quartz, similar trends than Aubrite

Summary

Linear polarization phase curves and their parameters (slope, depth of the negative branch and amplitude of the positive branch when available) as a function of the size distribution of the measured grains allow a rough estimation of the average size distribution of the grains on the asteroidal surface (but it is difficult to compare one small fragment of meteorite with an integrated observation on the whole surface of on asteroid which is not homogeneous).

●P ➚ when λ ➚ for C-type asteroids (Orgueil not a good analog)

●P ➘ when λ ➚ for E-type asteroids and 2867 Steins

Aubrite from antarctic seems to be a good analog for 2867 Steins with an average size of the grains smaller than 20μm (as also suggested by other methods)

●P ➚ when λ ➚ for Lutetia

NWA4868 from Sahara: inverse color effect (weathering?)

CV3 (Allende) seems to be a good analog for 21 Lutetia with an average size of the grains smaller than 50μm

see Levasseur-Regourd and Hadamcik presentation and Hadamcik et al., submitted

References

Fornasier et al., 2006, A&A 449, L9-L12
Hadamcik et al., 2006, Adv Space Res 38, 2006
Hadamcik et al., 2007a, JQSRT 106, 74-89
Hadamcik et al., 2007b , Icarus 190, 660
Hadamcik et al., 2009a, In: Light scattering Rev 4, Single light scattering and radiative transfer, Springer-Praxis, Berlin, A. Kokhanovsky Ed, pp. 31-70
Hadamcik et al., 2009b, JQSRT 110, 1755
Hadamcik et al., 2009c, PSS 59, 1631
Hadamcik et al., submitted
Levassseur-Regourd et al., 2003, JQSRT 79-80, 903
Levasseur-Regourd and Hadamcik, 2010, BAAS, DPS meeting 42, 1033
Lasue et al., 2007, JQSRT 106, 212
McFadden et al., 2009, LPI abstract 40, 2287
Renard et al., 2005, Appl Opt 44, 591
Renard et al., 2010, Appl Opt 49, 3552
Worms et al., 1999, Icarus 142, 281
Worms et al., 2000, PSS 48, 493