Martian Dust Analogs in Scattering Laboratory

INSTITUTO de ASTROFISICA de ANDALUCIA
CSIC
I·A·A

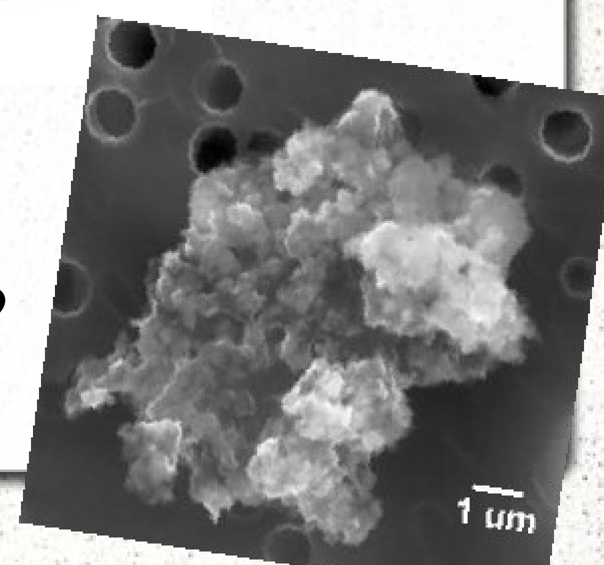
Laboratory ??

in Institute of Astrophysics???

Doesn´t it sound a bit strange?

What can be measured there?

How can it be applied in Astrophysics?



Overview:

- Introduction
    - Why to study dust?
    - Why to study dust? Mars case
    - Observation of dust, theoretical models
    - Martian Dust Analogs
        - Calcite, Basalt, Palagonite samples
- Theoretical basis, scattering matrix
- Laboratory measurements
    - Experimental Apparatus
    - Results
    - Comparisons with observations
    - Laboratory measurements vs simulations (examples)
- Summary & Conclusions

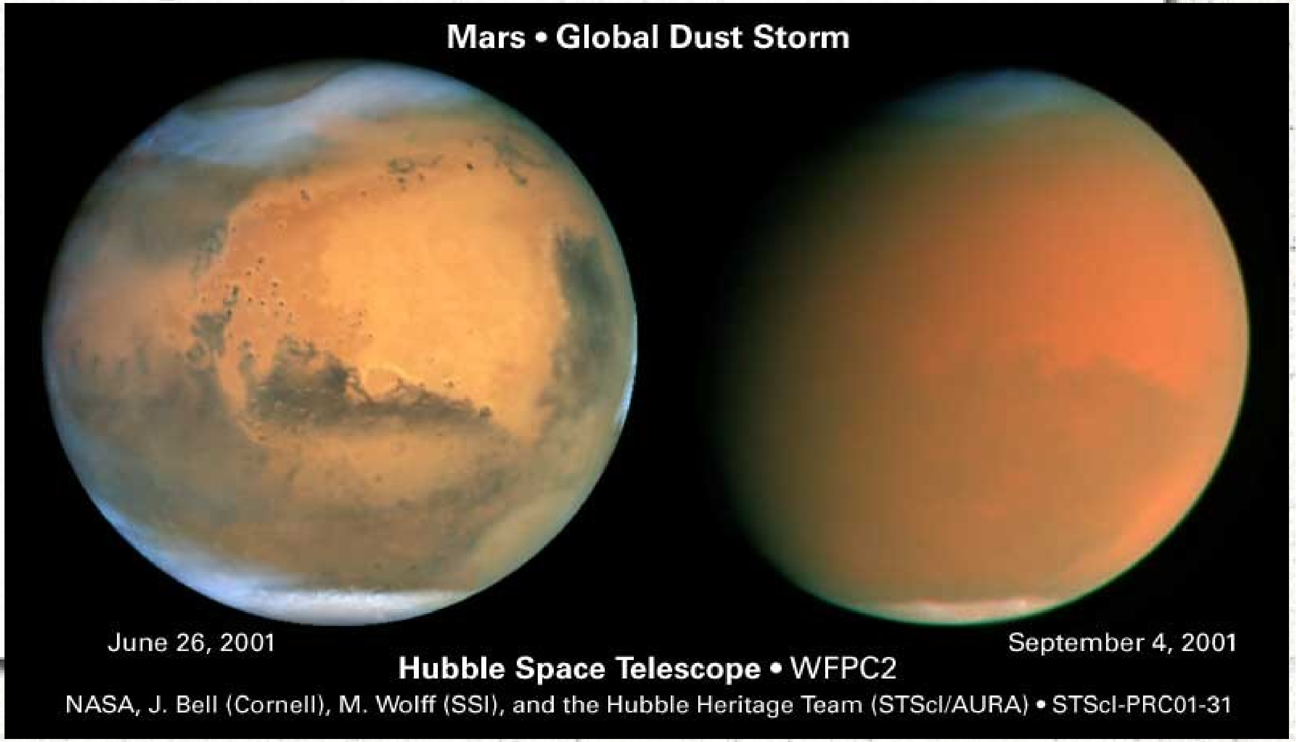
Introduction:

Introduction- dust on Mars

- Dust activity, local, regional, or sometimes even planet-wide dust storms
- The airborne dust particles scatter and absorb solar radiation very important for the thermal structure of the thin Martian atmosphere and for the temperature of the Martian surface
- Surface/dust

  composition
- Importance

  for future missions



Observation of dust

- Dust is observed by light it scatters
- We need scattering properties of dust to correctly interpret the observations (shape, refractive index, size distribution, …)

- Scattered flux(phase function) = F11(θ)
- Degree of linear polarization = 1-F12(θ)/F11(θ)
- Degree of linear depolarization = F22(θ)/F11(θ)

Teoretical Models (atmosphere)

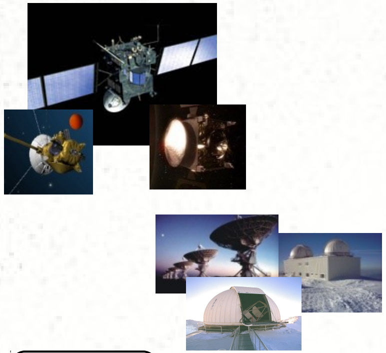
Investigation

VERTICAL STRUCTURE OF PARTICLES
AND DISTRIBUTION OF GAS
(scattering matrix, absorption and termic emission)

Inputs (experimental and teoric)

TRANSFER EQUATION

VARIFICATION
MODEL PARAMTERS



COMPARISON WITH
OBSERVATIONAL DATA

NO

YES

AGREE?

END

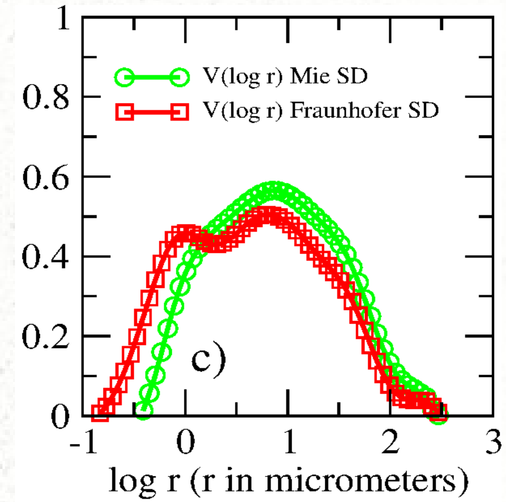
Martian Dust Analogs

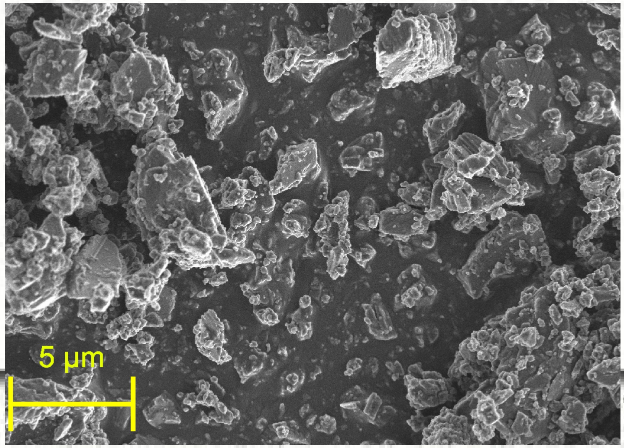
- Calcite
- Basalt
- JSC Palagonite samples

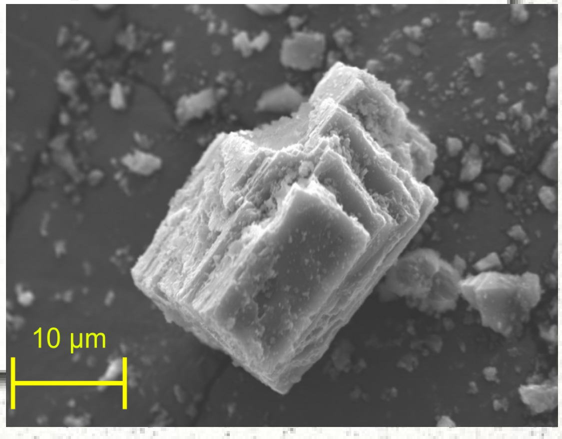
Calcite

- Carbonates up to few percents of the surface material
- Particularly important for its link with climate evolution and water resources on Mars
- Limestone (98% calcite), Lecce, Italy

	reff(μm)	veff
Mie*	3.3	4.9
Fraunhofer	1.7	7.6







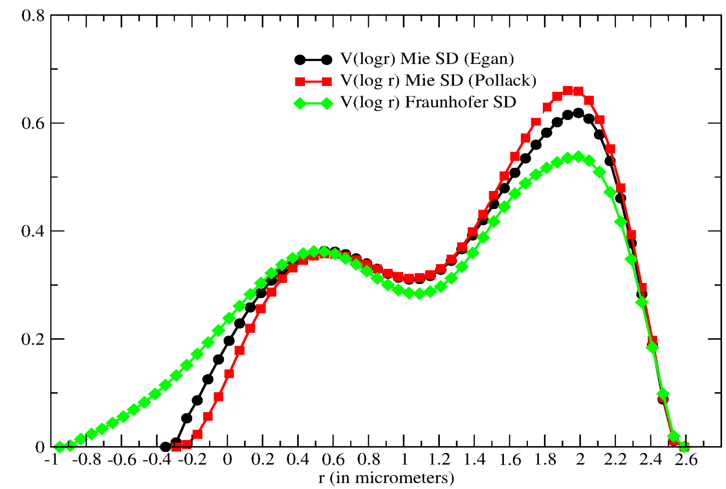
*RI=1.6+0i

Dabrowska et al 2012

Basalt

- Main component of Martian surface
- CAB

	reff(μm)	veff
Mie*	7.21	6.82
Mie**	5.86	8.18
Fraunhofer	3.01	15.03



* RI= 1.5+0.001i (Pollack et al 1973)
** RI= 1.62+0.000223i (Egan et al 1975)

JSC palagonite

- Spectral analog of Martian Dust (Visible)
- Hydrated (JSC0) and dehydrated samples (JSC200)
- collected from the Pu'u Nene, Hawaii

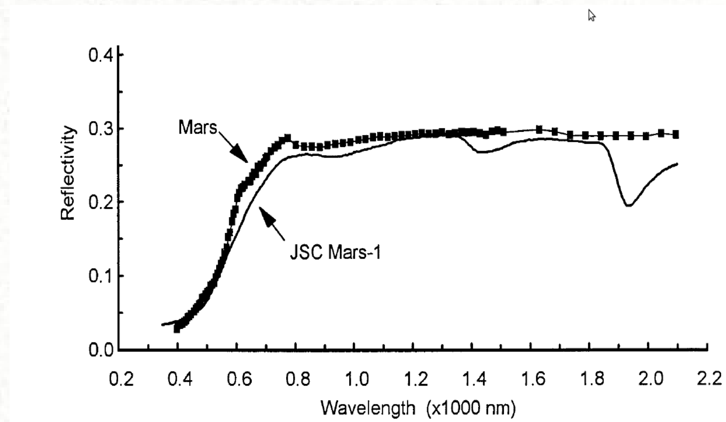
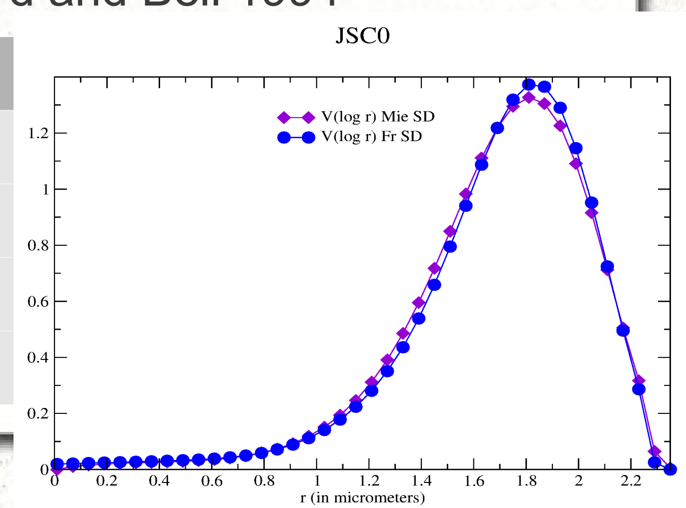


Figure 1. VIS/NIR reflectivity spectra of Mars Composite Bright Region [4] and JSC Mars-1

Mustard and Bell 1994

		reff(μm)	veff
JSC0	Fraunhoer	20.34	1.96
	Mie*	31.41	0.98
JSC200	Fraunhofer	18.15	2.40
	Mie*	29.36	1.16

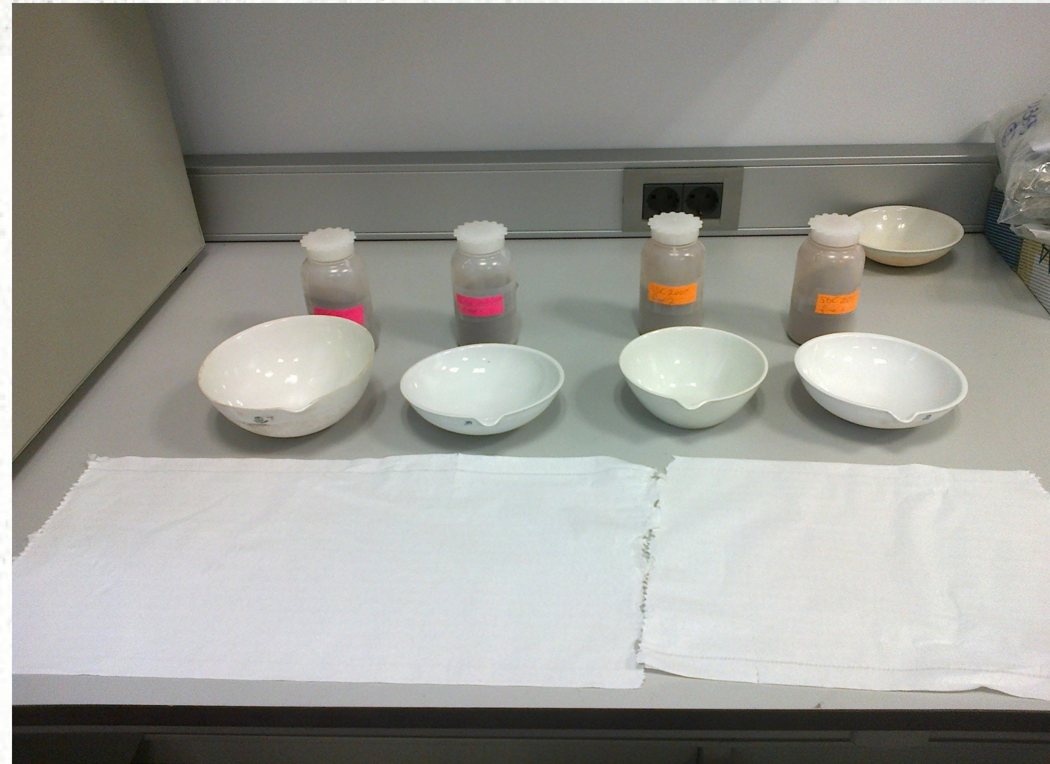


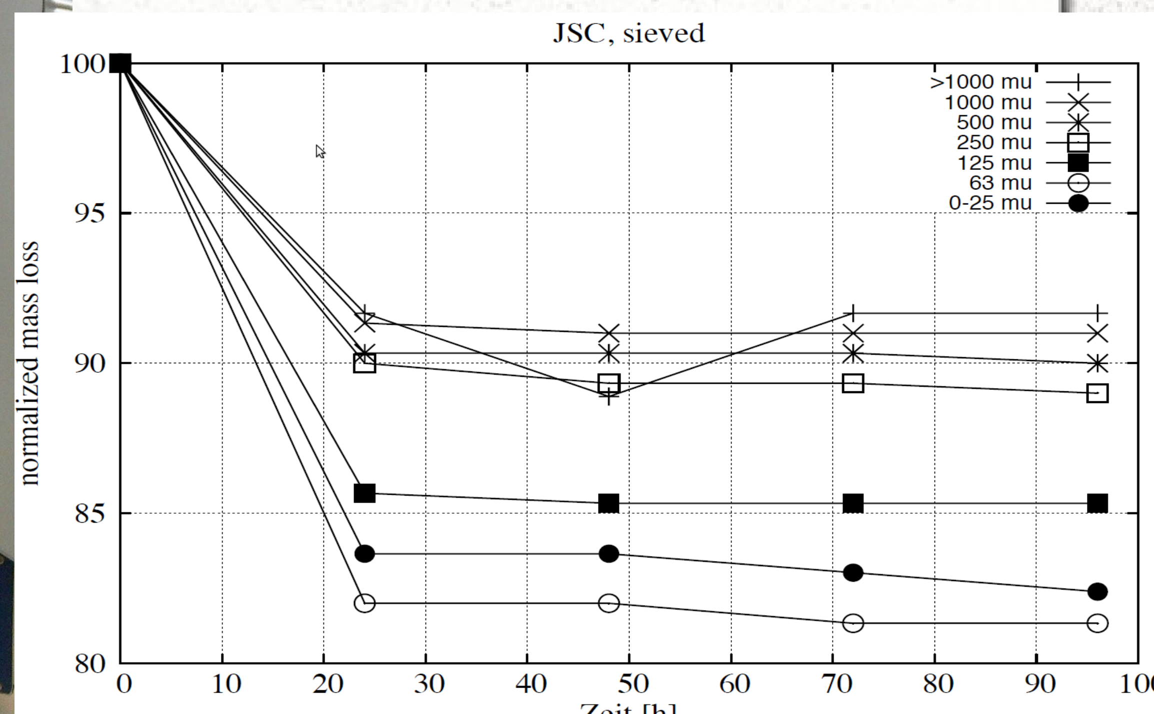
*1.5+0.001-0.0001i

JSC palagonite- sieving process

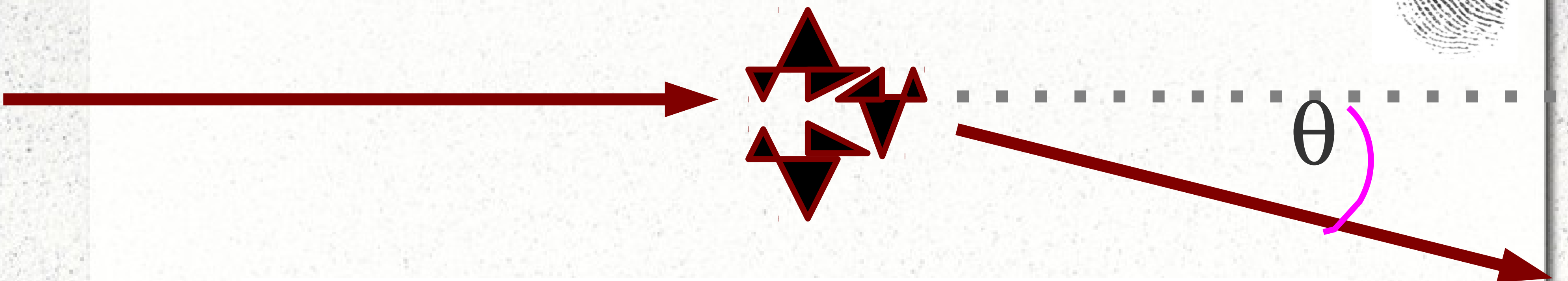
- Spectral analog of Martian Dust

JSC (re) dehydration process





Theory: scattering matrix



Intensity

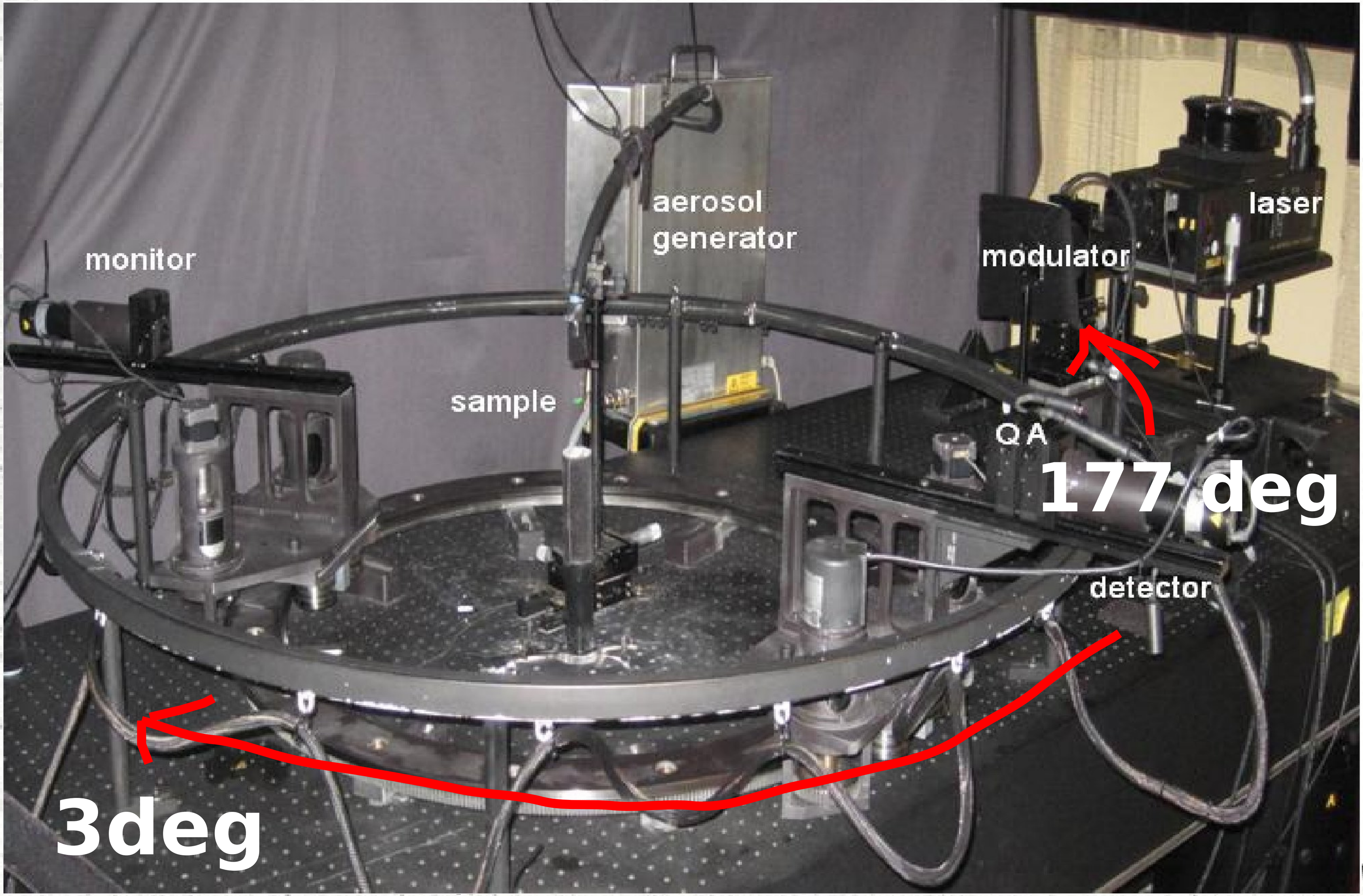
Lin. Polar.

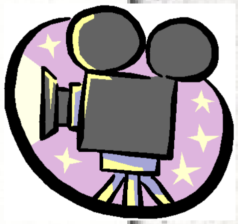
Circ. Polar.

$$\begin{pmatrix} I_{sc} \\ Q_{sc} \\ U_{sc} \\ V_{sc} \end{pmatrix} \propto \begin{pmatrix} F_{11} & F_{12} & 0 & 0 \\ F_{12} & F_{22} & 0 & 0 \\ 0 & 0 & F_{33} & F_{34} \\ 0 & 0 & -F_{34} & F_{44} \end{pmatrix} \begin{pmatrix} I_{in} \\ Q_{in} \\ U_{in} \\ V_{in} \end{pmatrix}$$

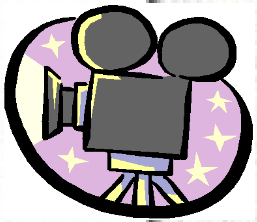
Stokes vector — Scattering Matrix — Stokes vector

Laboratory measurements: Exparimental Apparatus





MOVIE!!!



MOVIE!!!

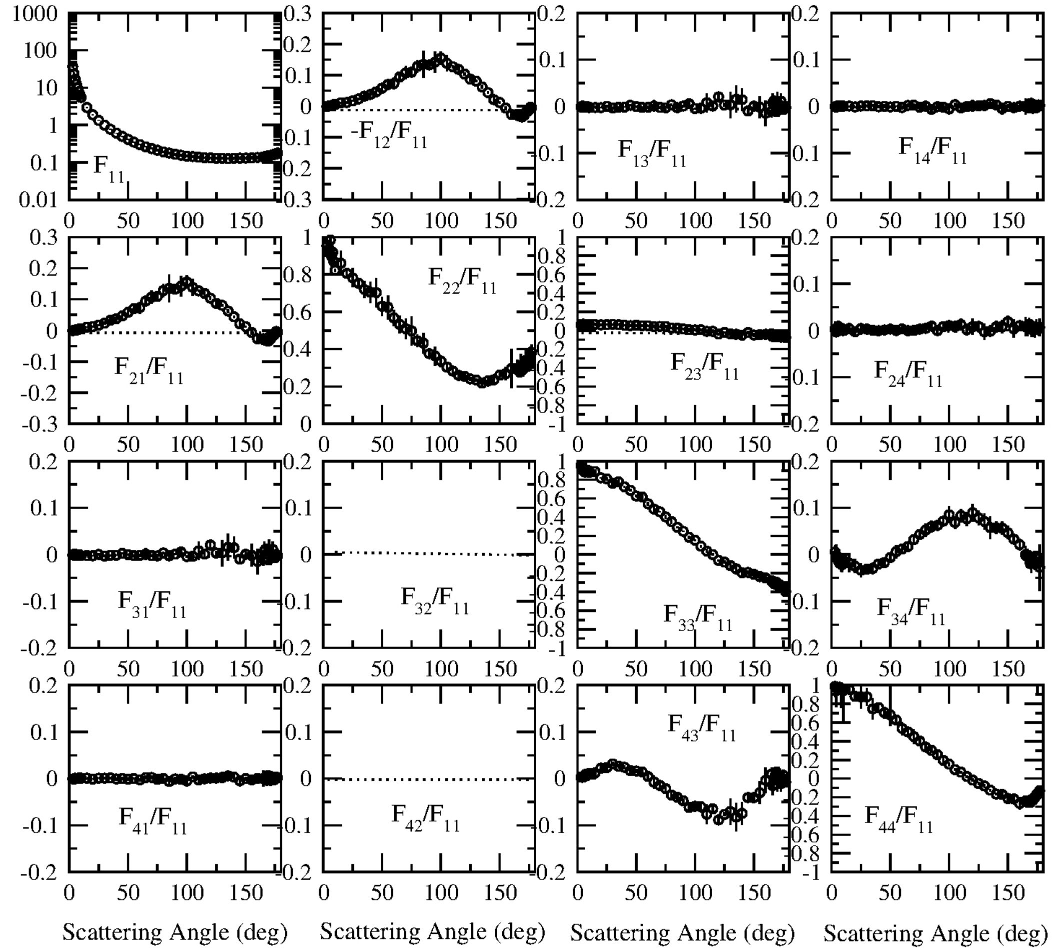
Laboratory measurements- results

- Calcite
- Basalt
- JSC0
- JSC200

http://www.iaa.es/scattering/

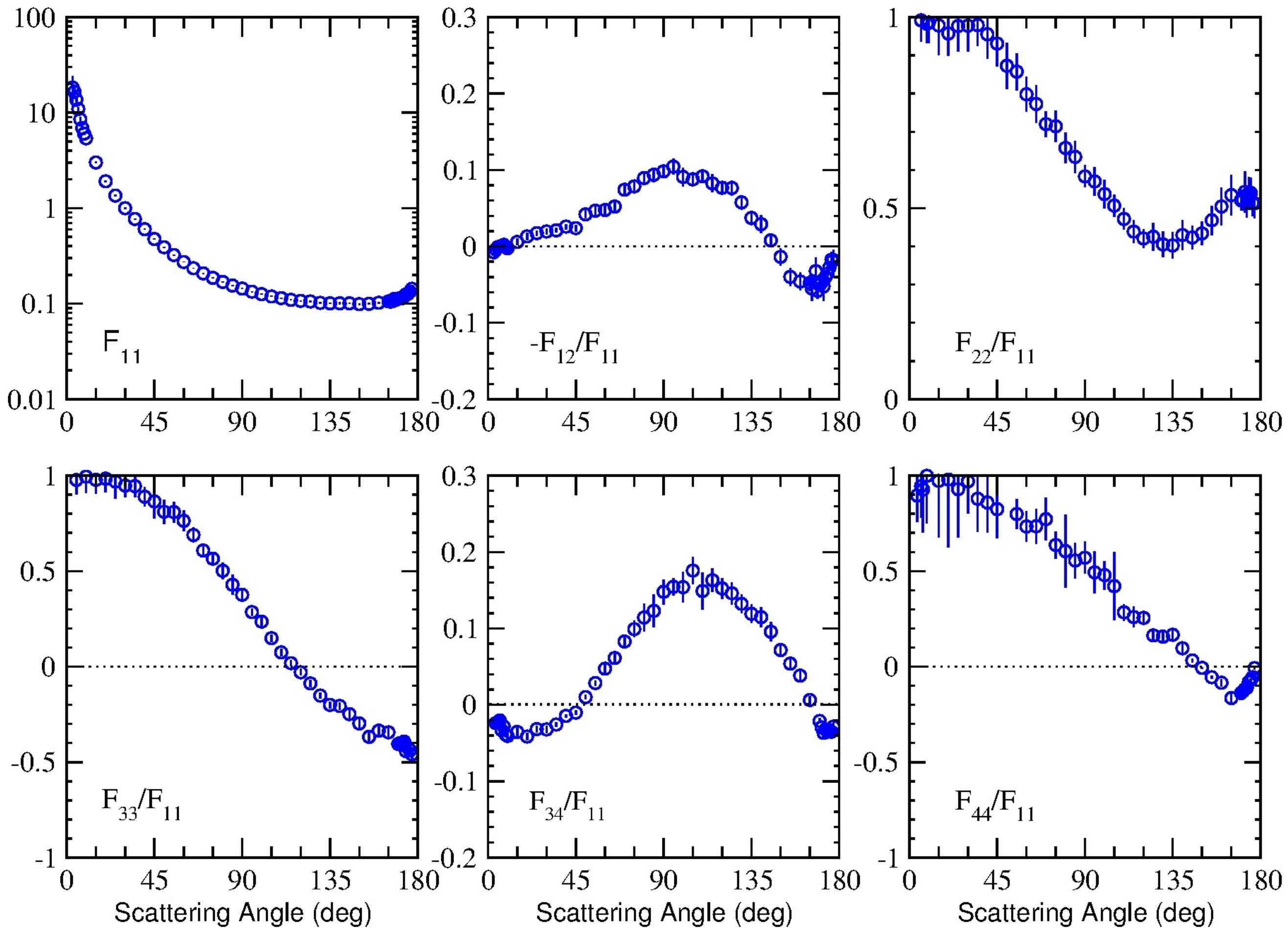
Laboratory measurements

- Calcite
- Basalt
- JSC0
- JSC200



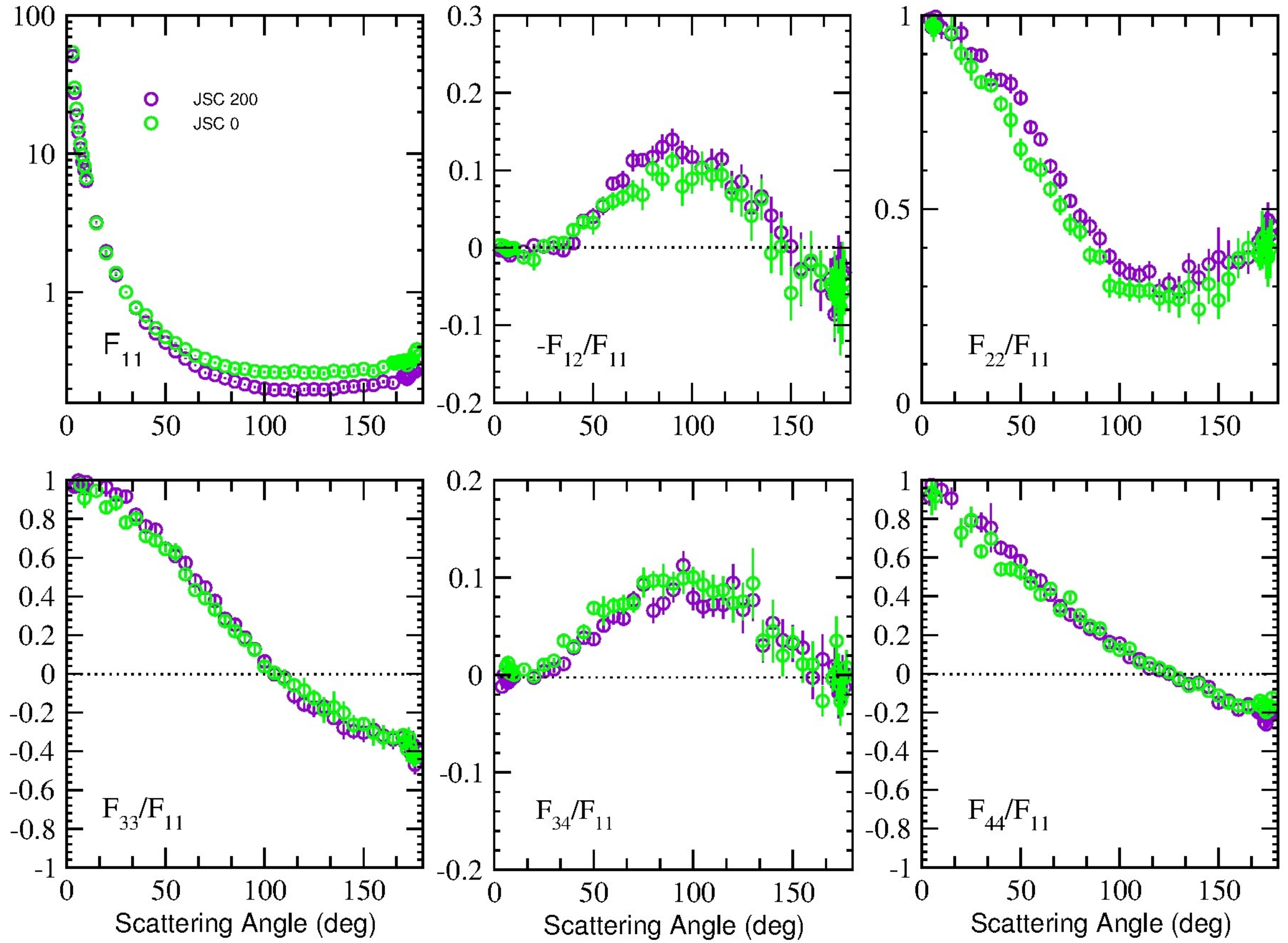
Laboratory measurements

- Calcite
- Basalt
- JSC0
- JSC200



Laboratory measurements

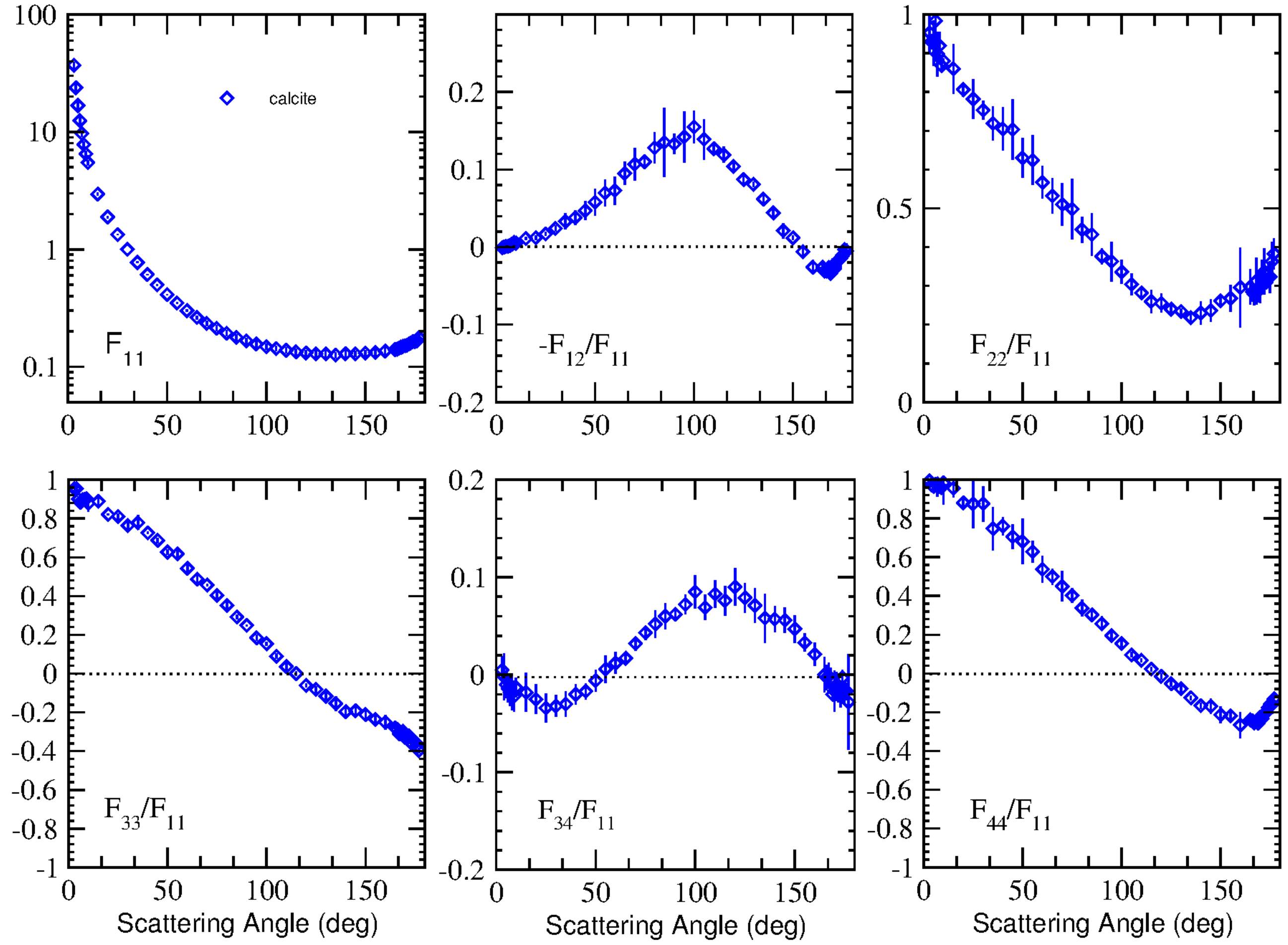
- Calcite
- Basalt
- JSC0
- JSC200



Laboratory measurements

- Calcite
- Basalt
- JSC0
- JSC200

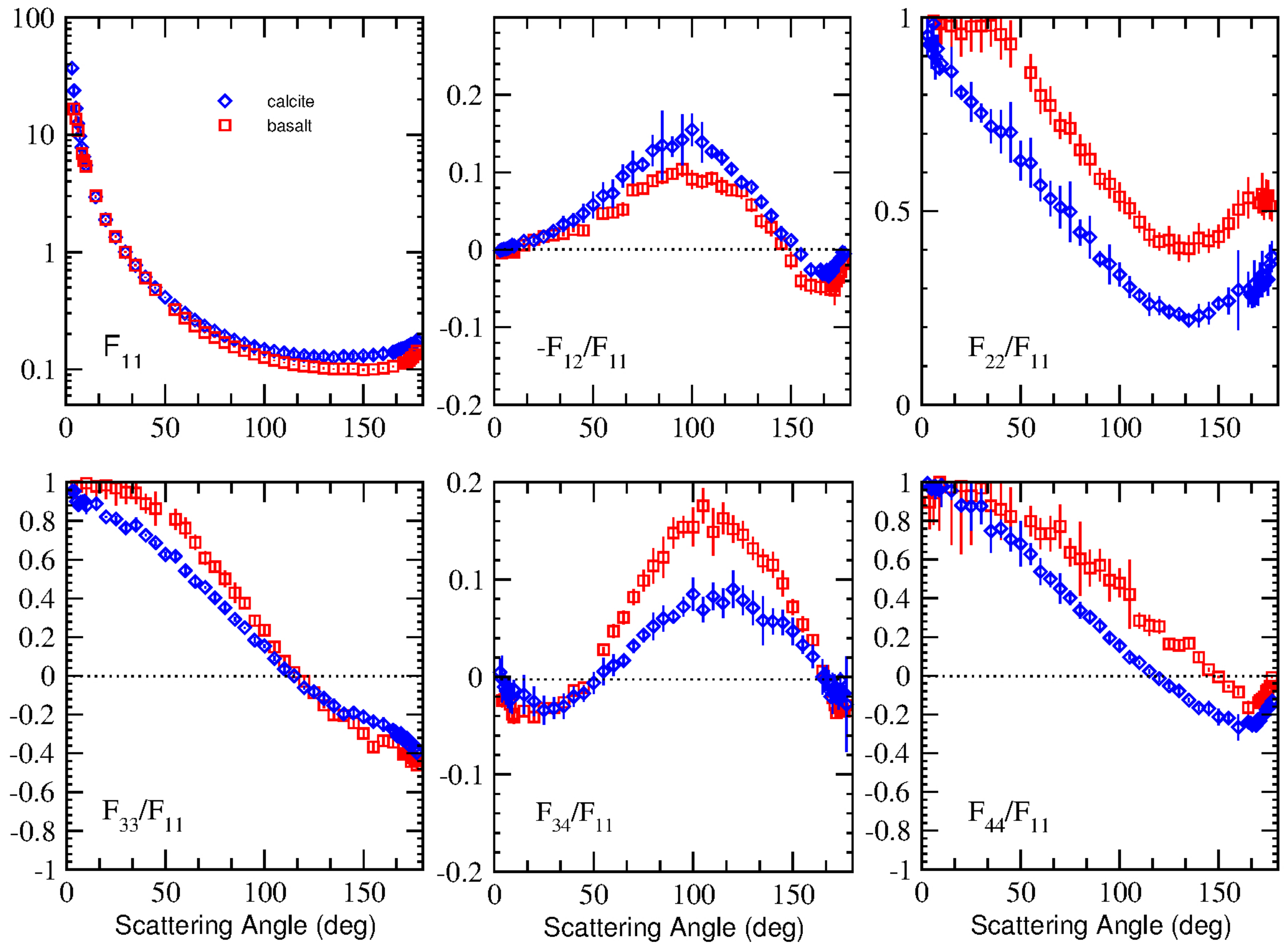
FR:
Reff=1.7, veff=7.6



Laboratory measurements

- Calcite
- Basalt
- JSC0
- JSC200

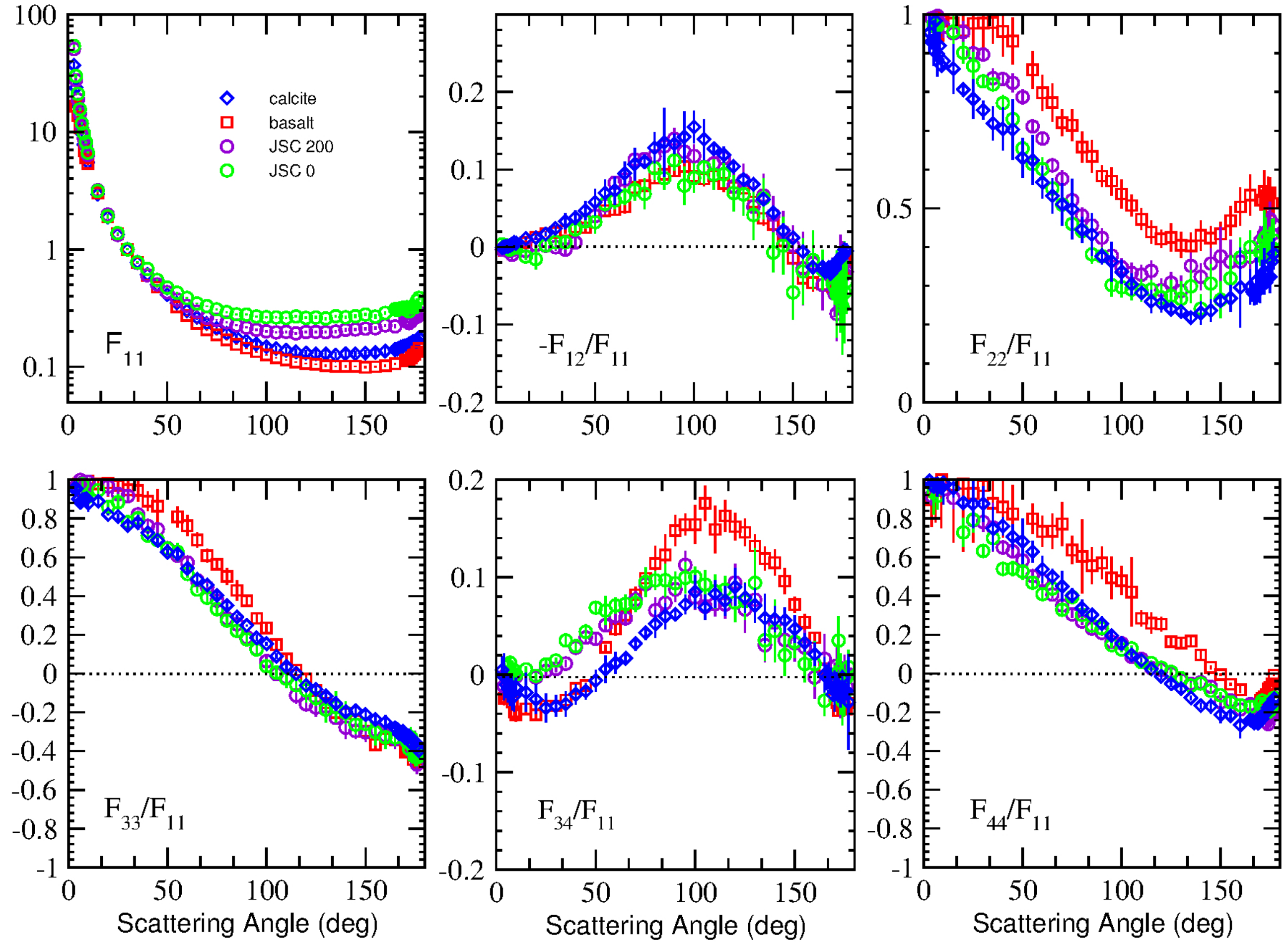
FR:
Reff=1.7, veff=7.6
Reff=3.0, veff=15.



Laboratory measurements

- Calcite
- Basalt
- JSC200
- JSC0

FR:
Reff=1.7, veff=7.6
Reff=3.0, veff=15.0
Reff=18.2, veff=2.4
Reff=20.3, veff=2.0

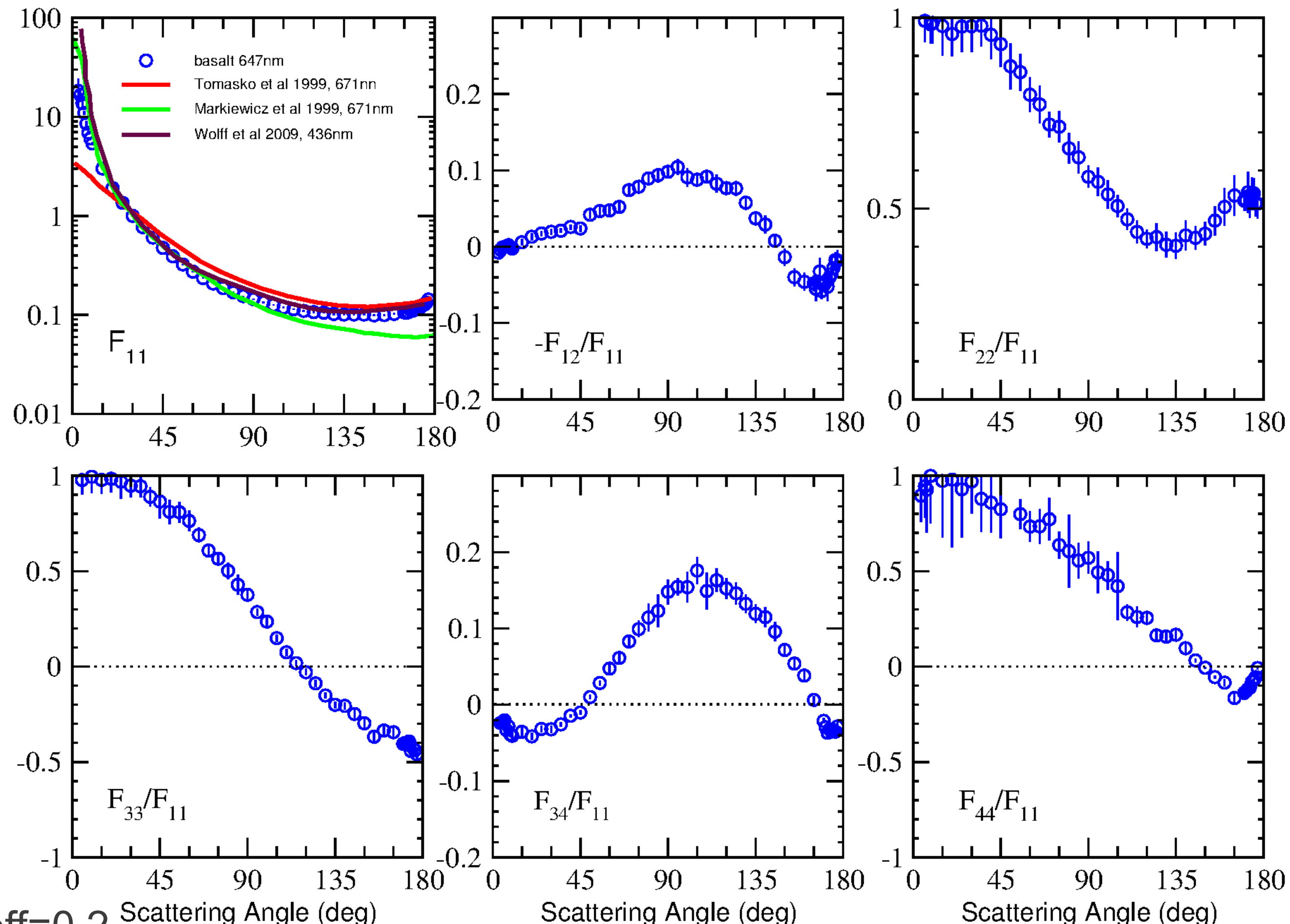


Observations

- Phase function: F11
- Degree of lineal polarization for incident unpolarized light:

  -F12/F11

Comparison with observations, F11



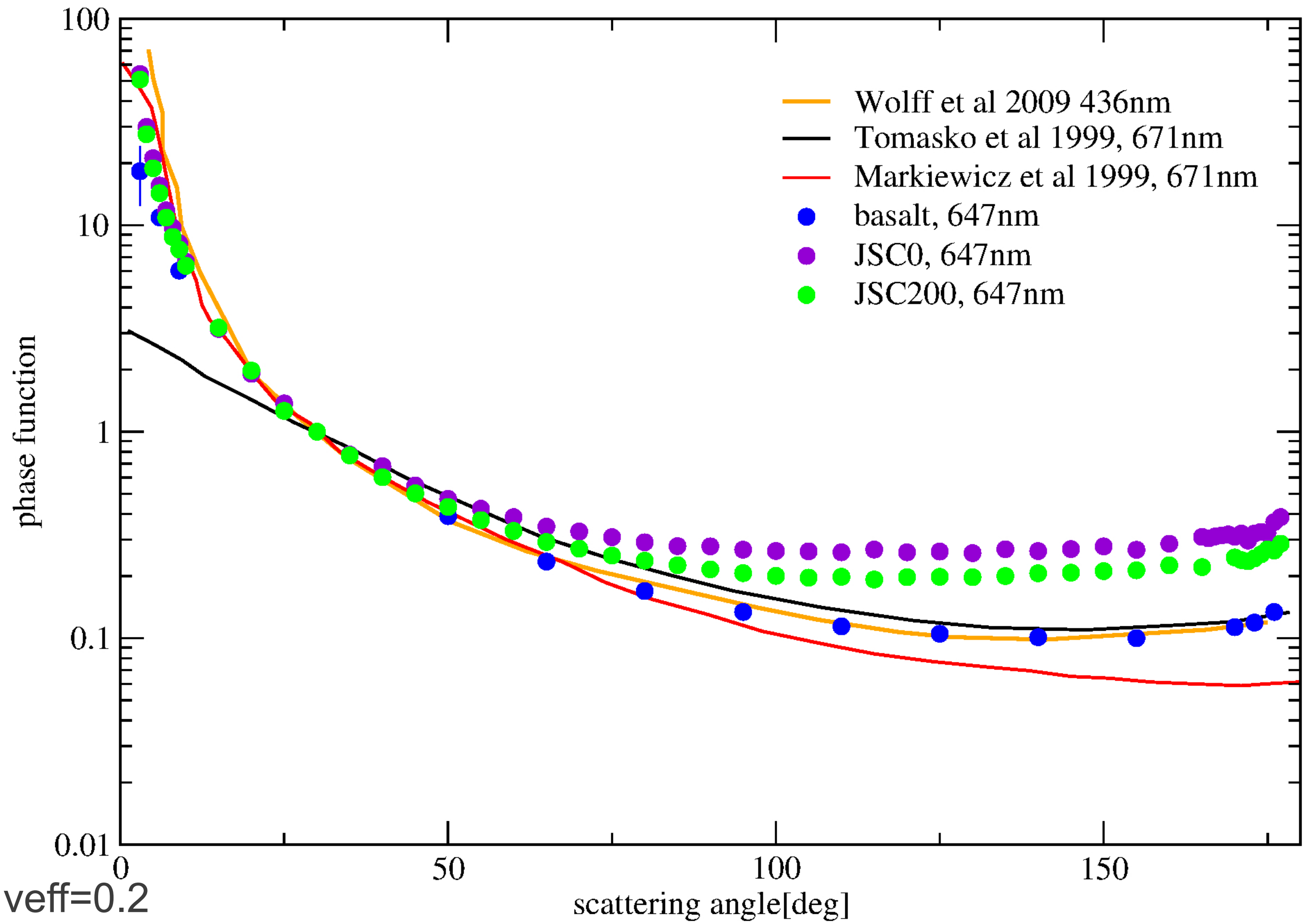
Tomasko et al. 1999, reff=1.6, veff=0.2
Markiewicz et al. 1999, reff= 1.6 μm, veff=0.15
Wolff et al. 2009, 1.8 μm

Comparison with observations, F11

Basalt and Markiewicz et al-

Quite good at side and back scattering angles!

- different wavelength
- different reff/veff



Basalt reff=3, veff=15 (FR)

Tomasko et al. 1999, reff=1.6, veff=0.2
Markiewicz et al. 1999, reff= 1.6 μm, veff=0.15
Wollf et al. 2009, 1.8 μm

Comparison with observations, F11

Palagonite and Tomasko et al 1999

Good agreement at all scattering angles!

- similar wavelength
- different reff/veff

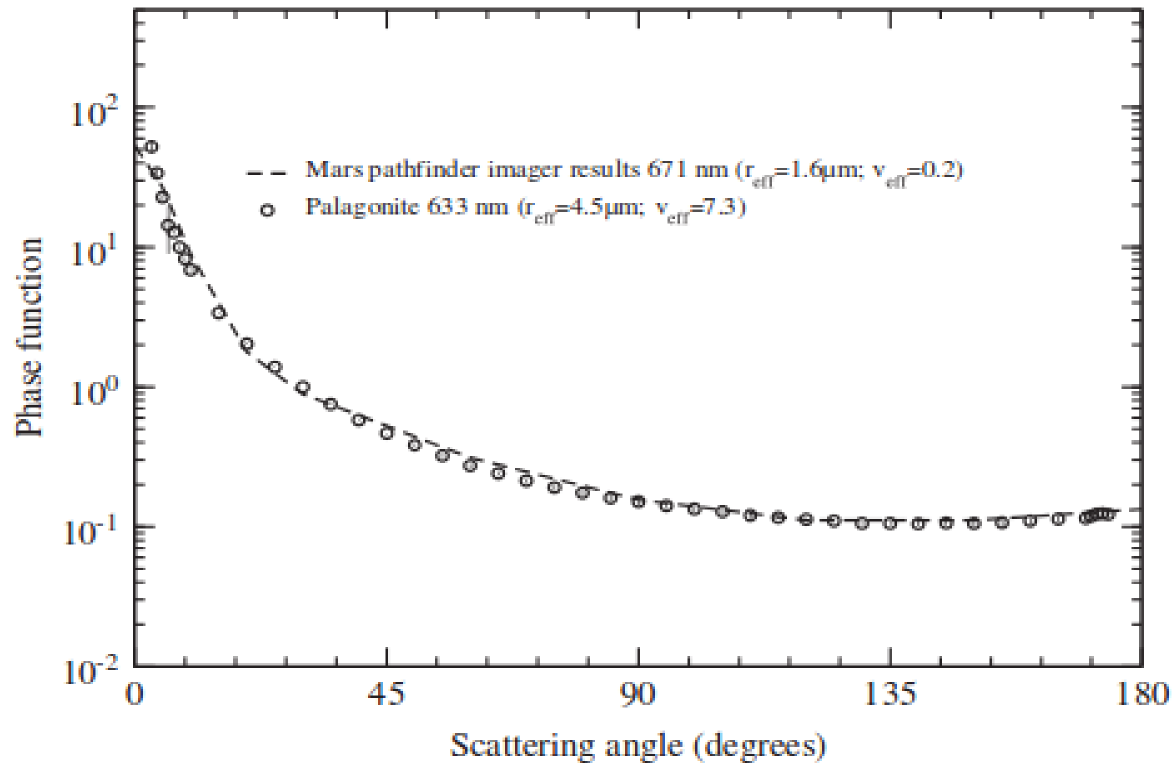


Fig. 8. Measured phase function of the Martian analog (palagonite) sample compared to the phase function derived by Tomasko et al. [59] for Martian dust particles. Both phase functions are normalized to 1 at 30° scattering angle.

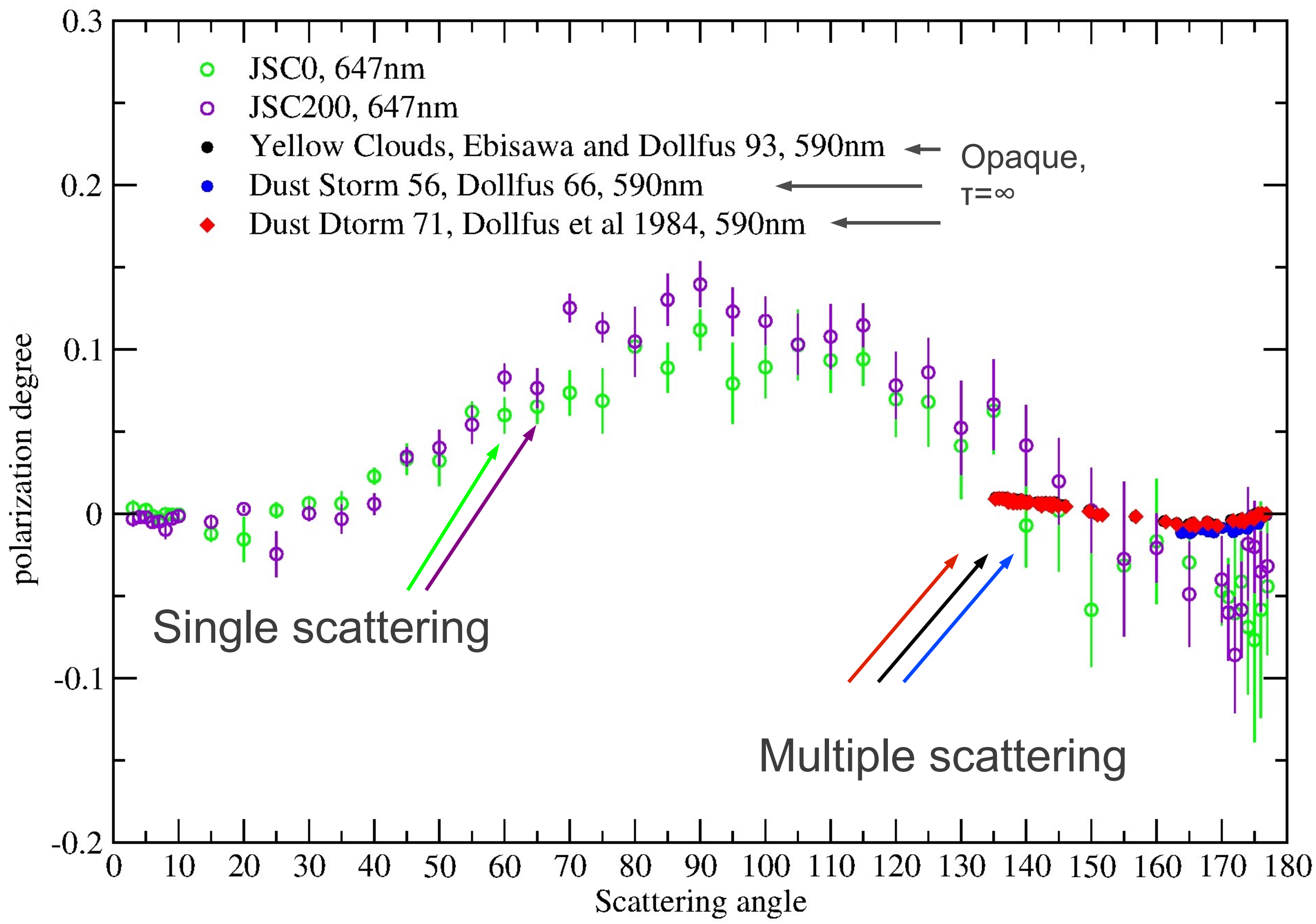
Muñoz et al 2012

Comparison with observations, -F12/F11

- From Earth
- HST
- From Mars

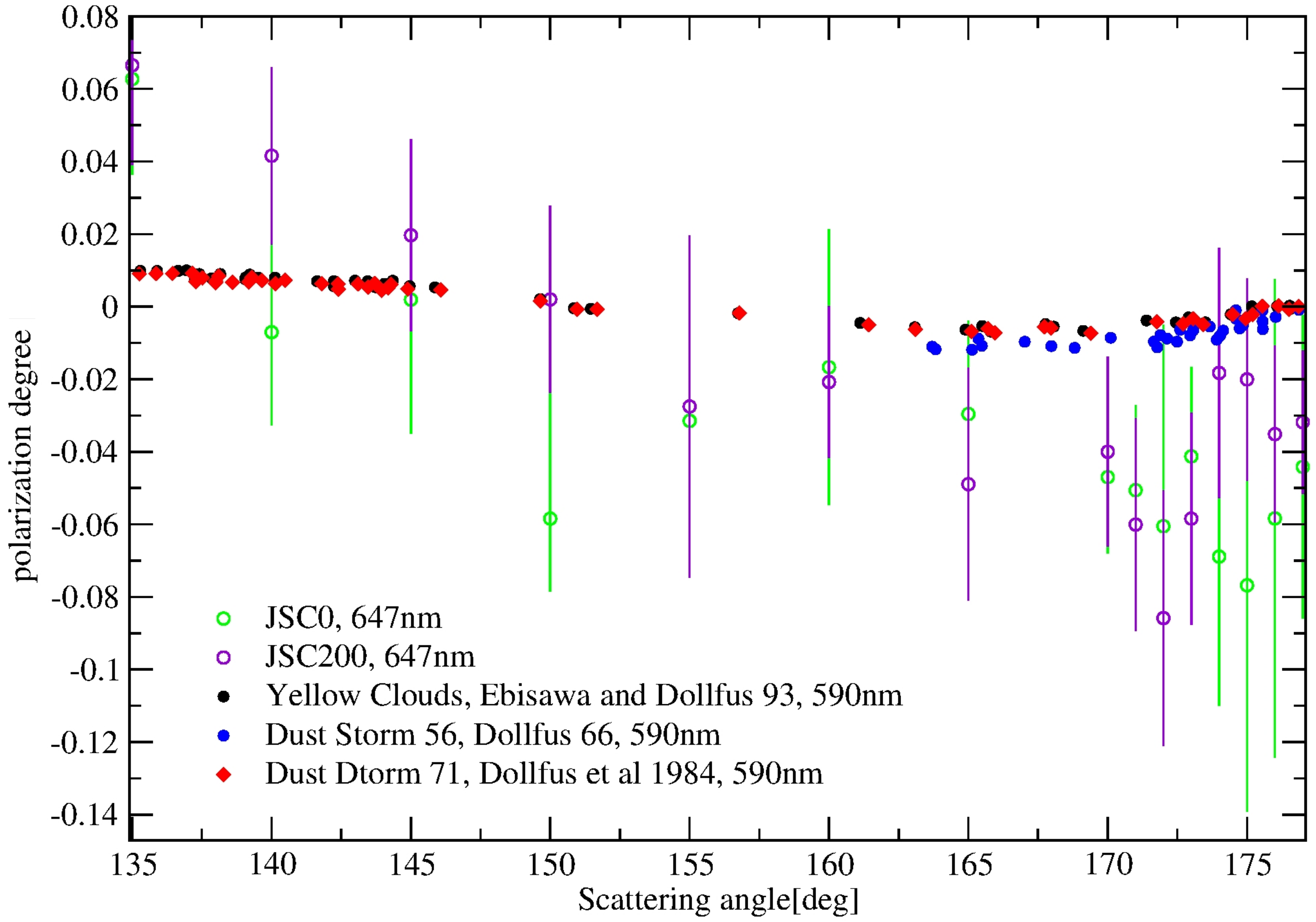
Comparison with observations, -F12/F11, Earth

Cannot be directly compared



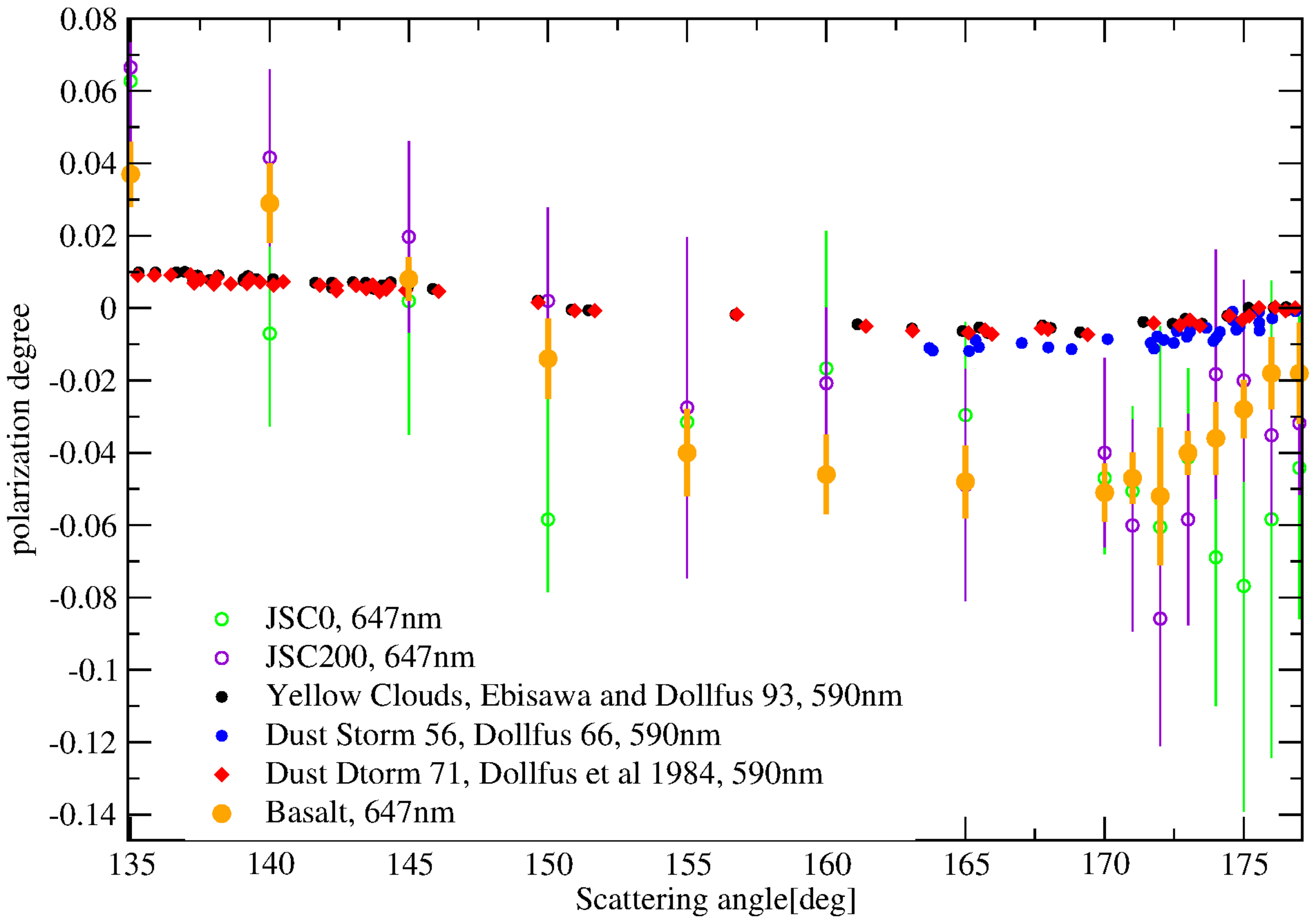
Comparison with observations, -F12/F11, Earth

Cannot be directly compared

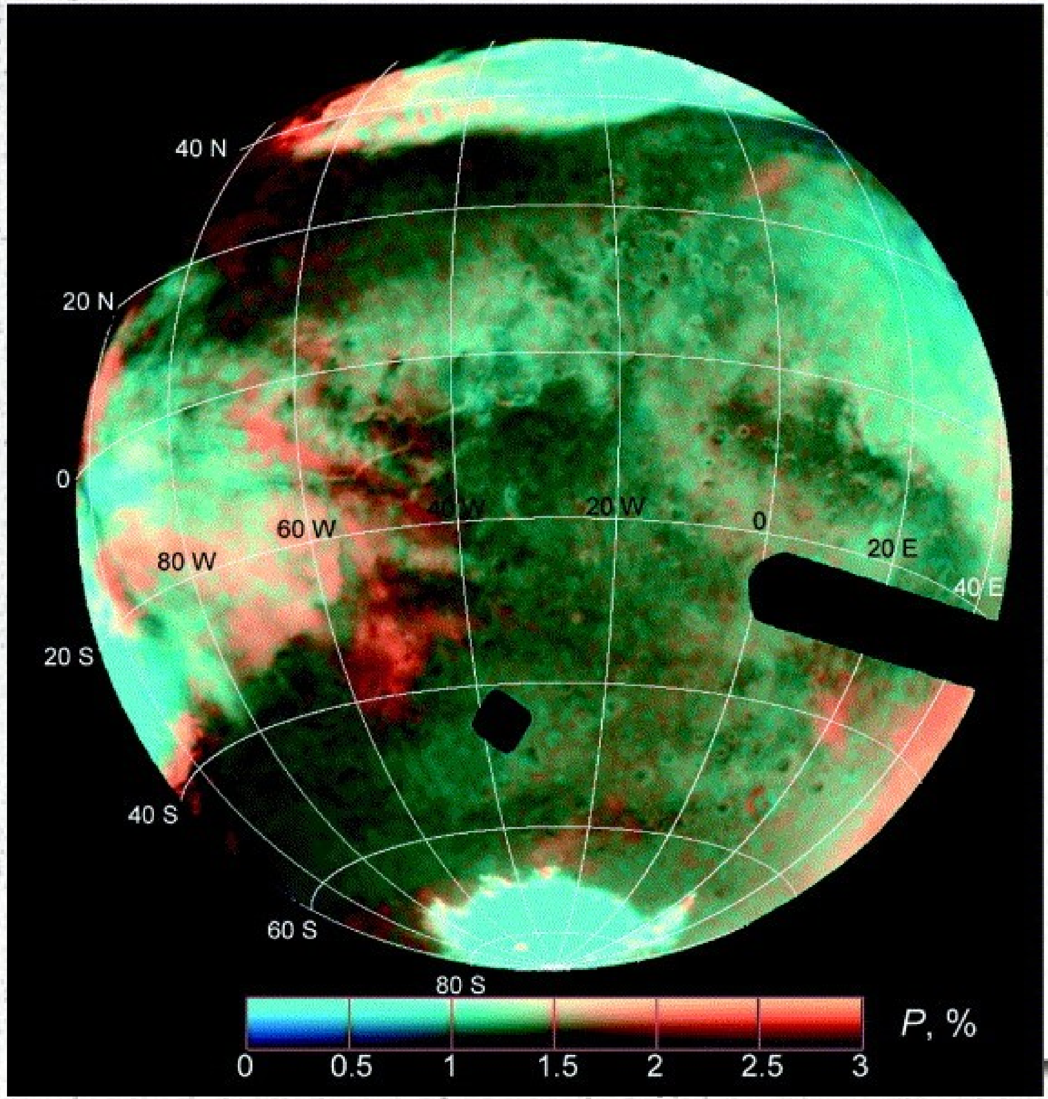


Comparison with observations, -F12/F11, Earth

Cannot be directly compared



Observations, -F12/F11, HST



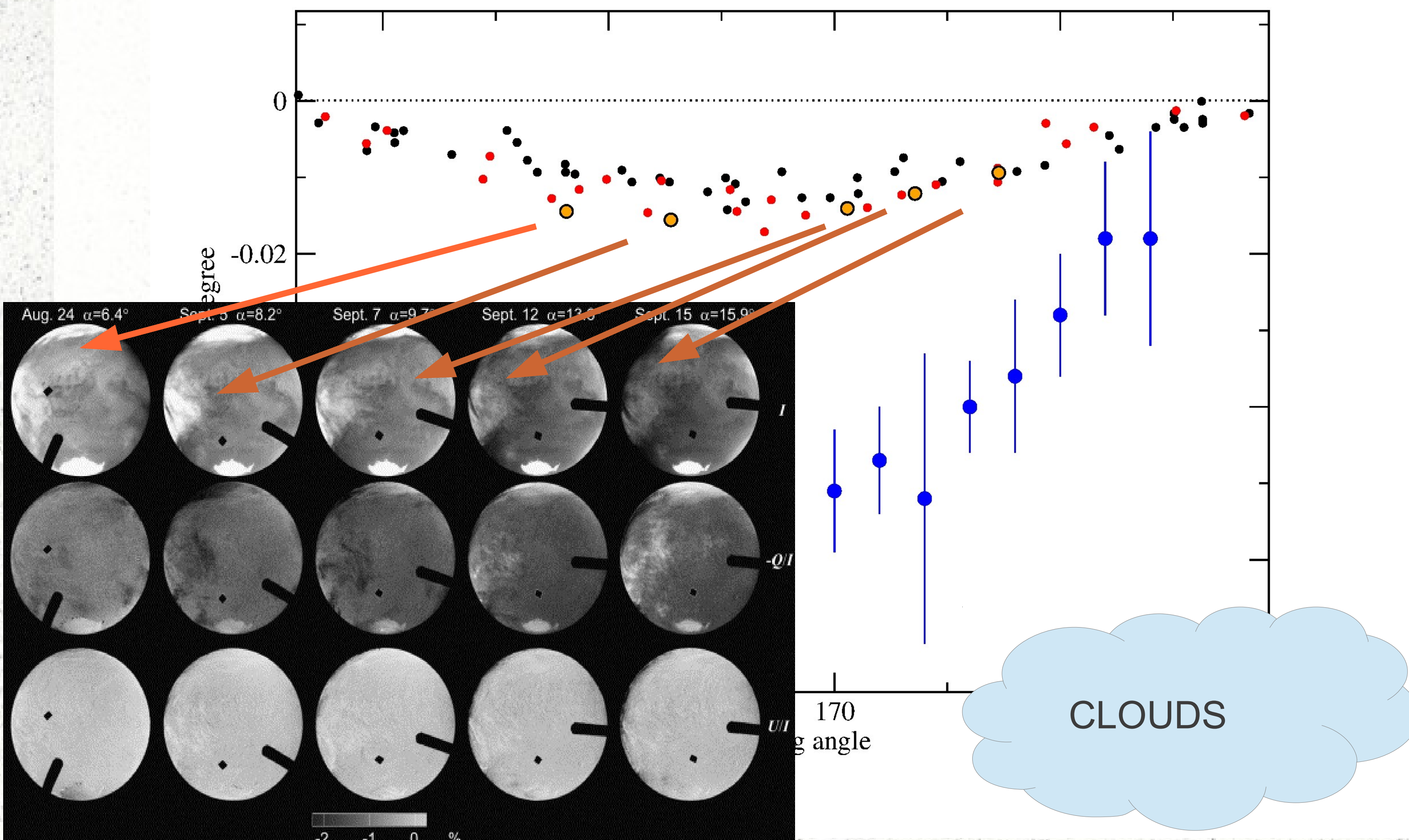
Clear atmosphere

No dust events-

polarization of surface and clouds

Shkuratov et al 2005 Hubble Space Telescope imaging polarimetry of Mars during the 2003 opposition

Comparison with observations, -F12/F11, HST



Polarization, -F12/F11, Orbiter

Mars 5,

in general dust free condition, τ_0=0.04±0.03,

but fortunately some dust clouds

Polarimetry,
Phase angle=60 deg

Photometry,
Phase angle=60 deg

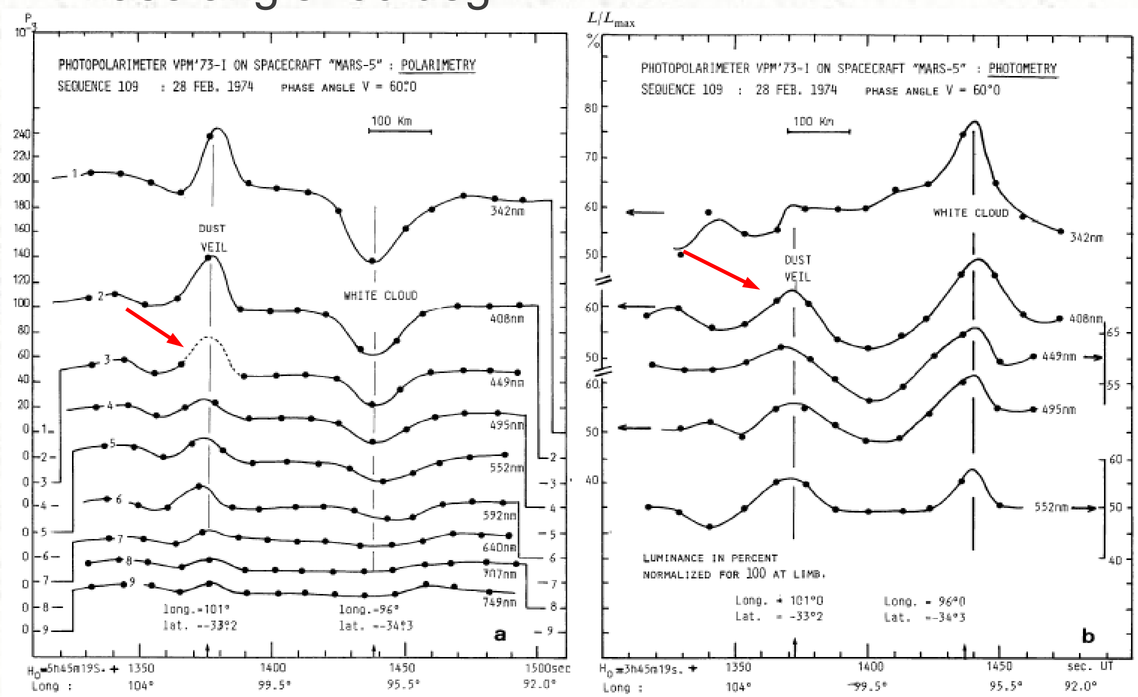
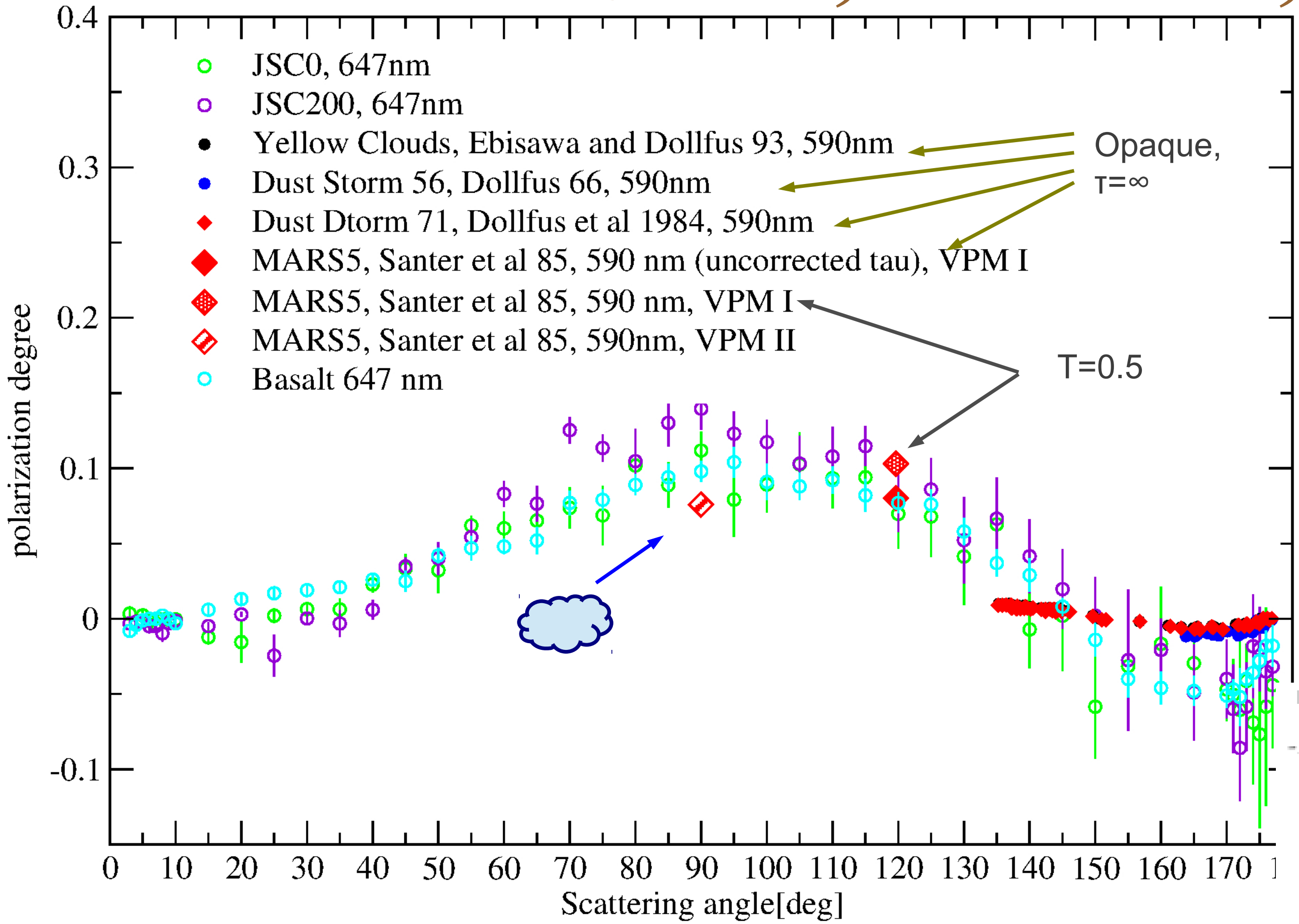


Fig. 5a and b. Photopolarimetric scans of a dust veil and of an adjacent white haze, at phase angle 60°. The measurements for different wavelengths are shifted vertically to avoid overlaps. At the shortest wavelength, the ground-surface albedo is as low as 0.05, the veils and hazes prevail in the signals, the white cloud increases the reflectance and decreases the polarization. The dust veil has the same reflectance as for the surface but increases the polarization. At the longest wavelengths, the surface albedo is increased by a factor 5, the white cloud remains slightly brighter than the surface, but its polarization does not depart from the value given by the ground-surface. The dust veil is also slightly brighter and its increase of polarization remains noticeable. **a** Degree of polarization, in units of 10^{-3}. **b** Reflectance, normalized for the value at limb

Santer et al. 1985

Polarization, -F12/F11, Orbiter



VPM-I Phase angle 60°	λ (nm)	342	408	449	495	552	592
	P_D for $\tau = 0.3$	38	32	25	21	14	11
	P_D for $\tau = 1.0$	31	23	18	15	11	8
	P_D for $\tau = \infty$	25	16	12	10	7.5	6

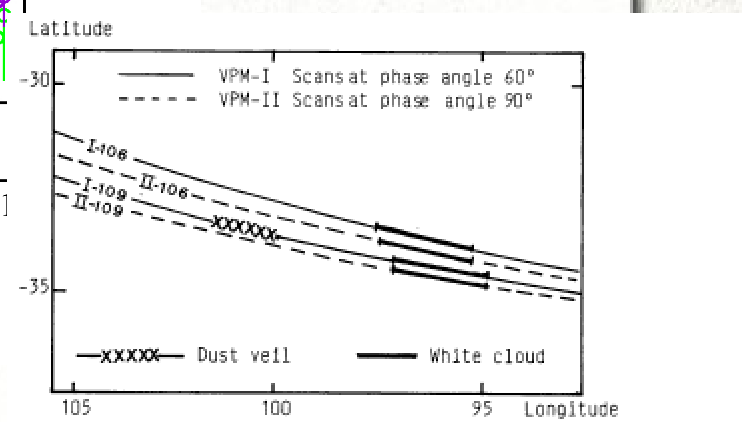
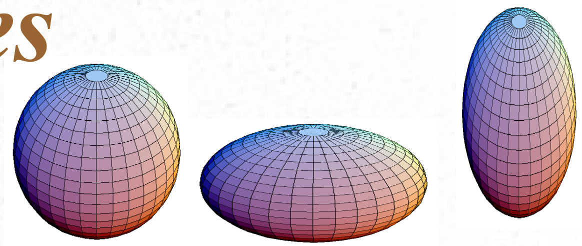
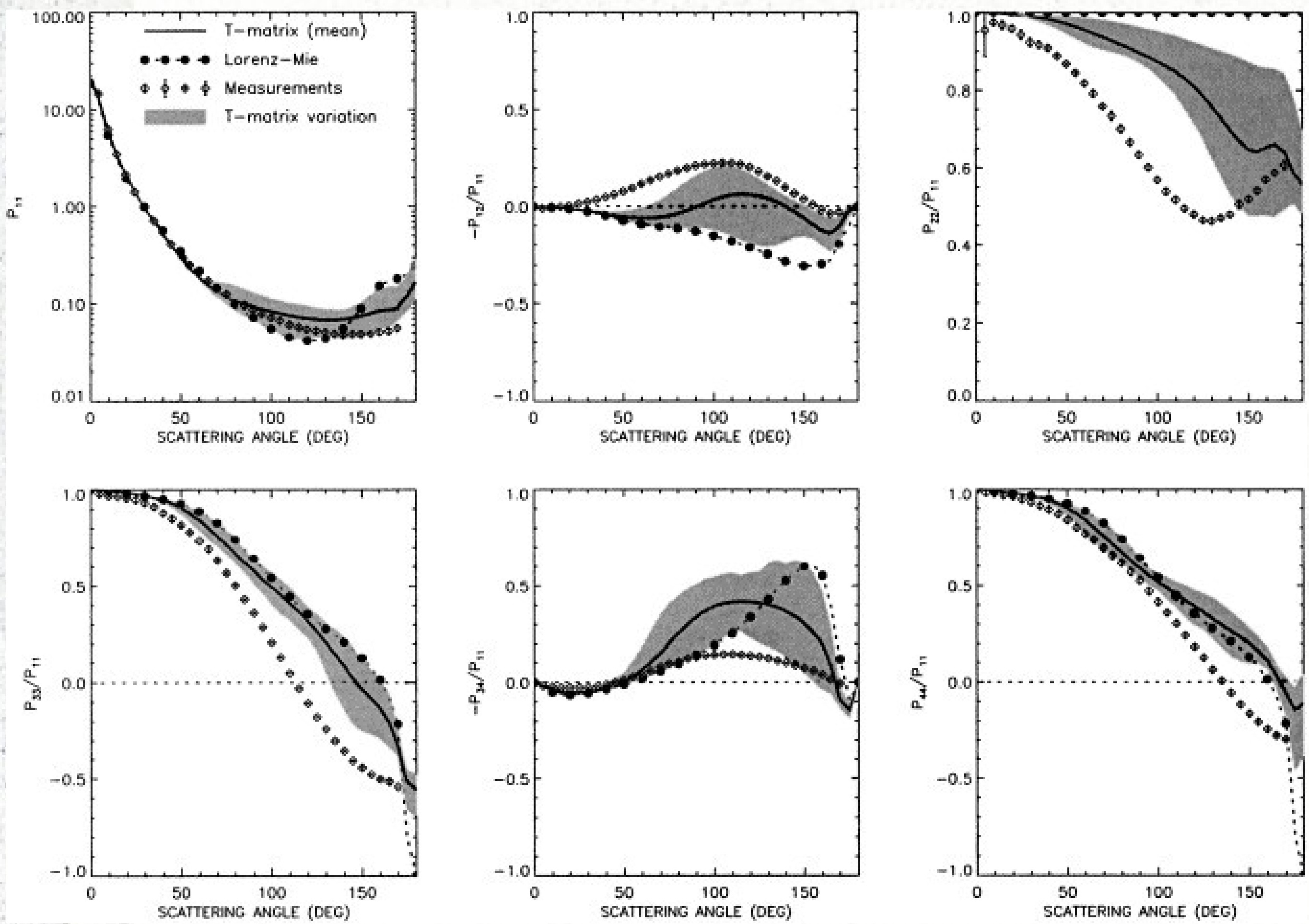
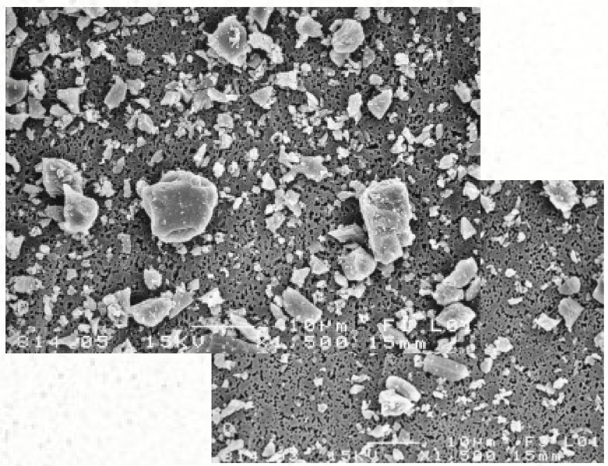


Fig. 13. Tracks at the surface of Mars for the scans VMP-I and II for the sequences 106 and 109, in an area where a dust veil is adjacent to a white cloud. The dust veil produces a polarimetric signature on VPM-I scan 109 at phase angle 60° but is not detected to depart from the nearly ground surface polarization at phase angle 90°, on the VPM-II scans 106 and 109

Laboratory measurements vs simulations on regular shapes



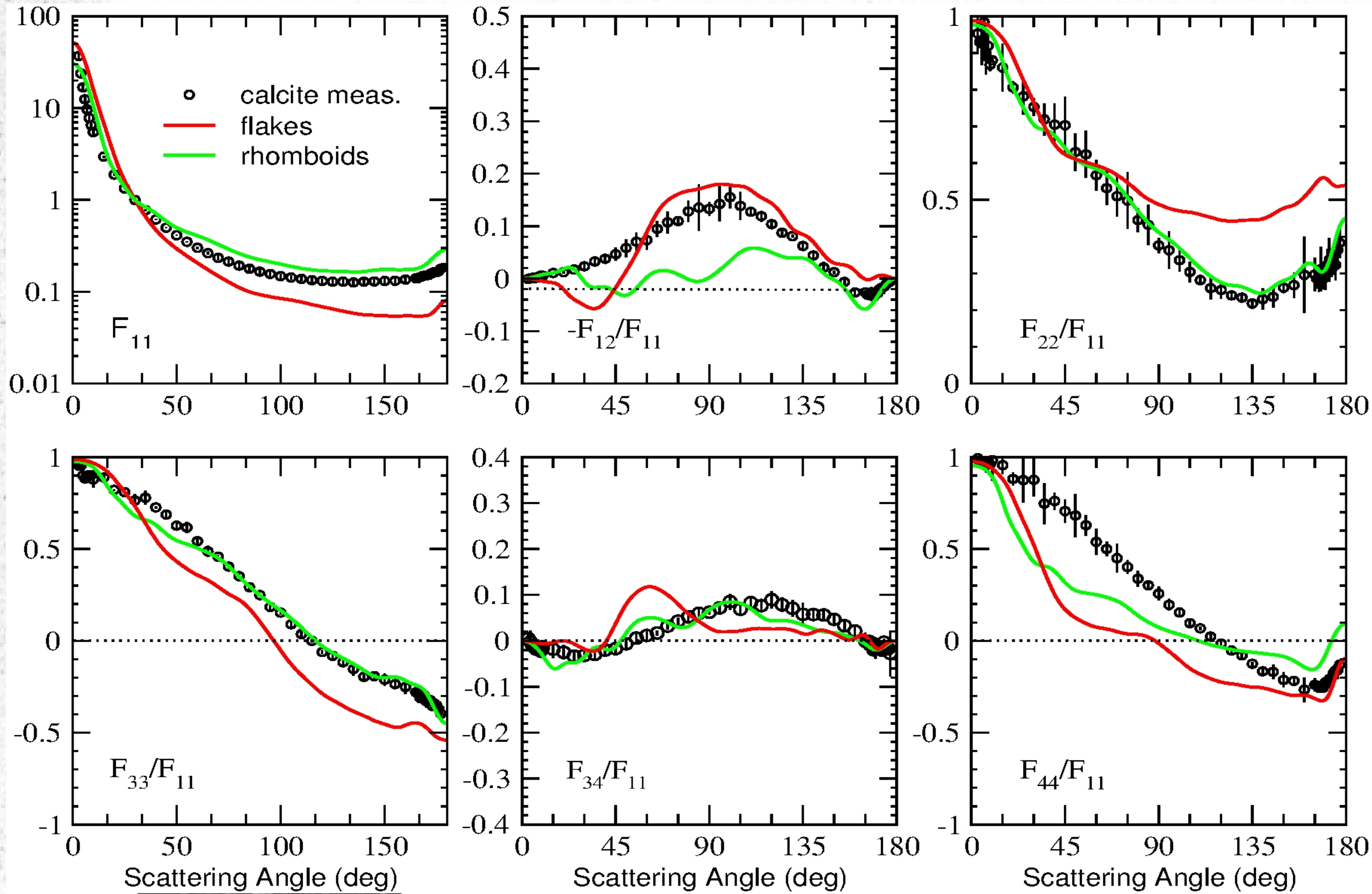




Nousiainen, Vermeulen 2002.

Comparison of the measured phase matrix elements for feldspar and the T-matrix simulations with oblate spheroids of varying axis ratios and m=1.5+i0.001. The corresponding Lorenz–Mie solution for spheres is also shown for comparison. All phase functions are normalized to unity at θs=30°.

Laboratory measurements vs simulations on irregular shapes



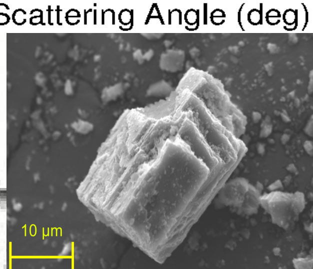
Discrete Dipole Approximation

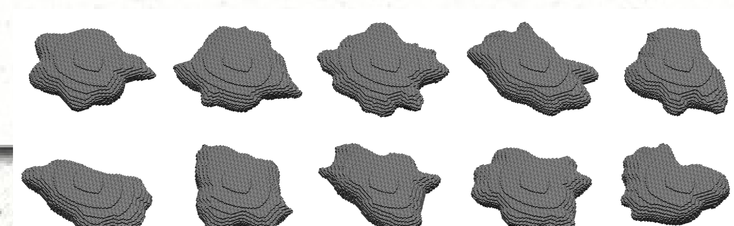
15 geometries

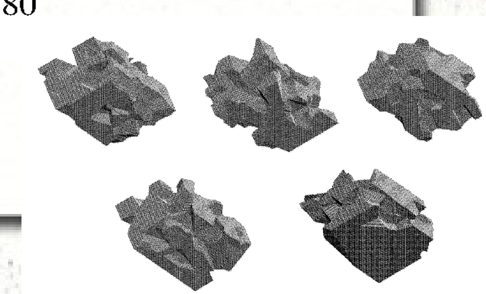
SD up to 1.2 μm

Time & memory consuming calculations

Dabrowska et al 2013







Summary and conclusions

- Interest of scattering properties of dust
- Scattering matrix important way to study dust
- Scattering laboratory unique place to obtain entire 4x4 scattering matrix of irregular particles
- Measurements compared with observations
  - F11, basalt measurements reproduce quite good F11 derived by Wolff et al. 2009 at side and backscattering scattering angles (need of perform measurements in blue)
  - F11, palagonite sample (Muñoz et al 2012) represents well F11 obtained by Tomasko et al at all scattering angles
  - Degree of linear polarization cannot be directly compared (multiple scattering should be concerned)
- Simulations of scattering matrix of irregular particles with regular shapes- if used may cause problems and uncertainty in models
- Simulations of scattering matrix of irregular particles with irregular shapes- time and memory consuming