Computational light scattering (PAP315)

Lecture 1

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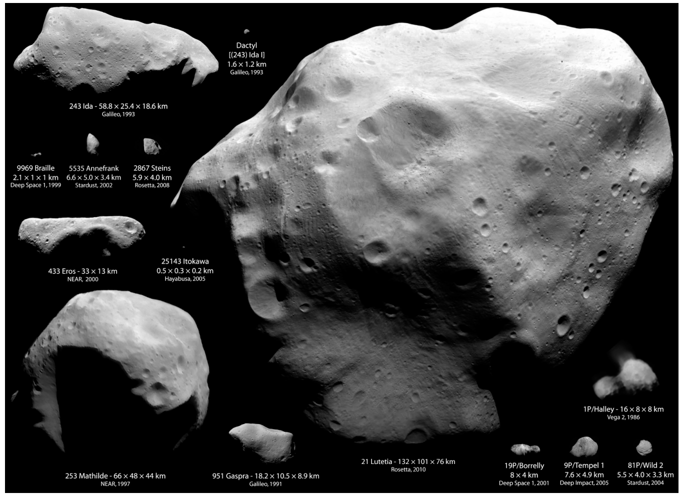

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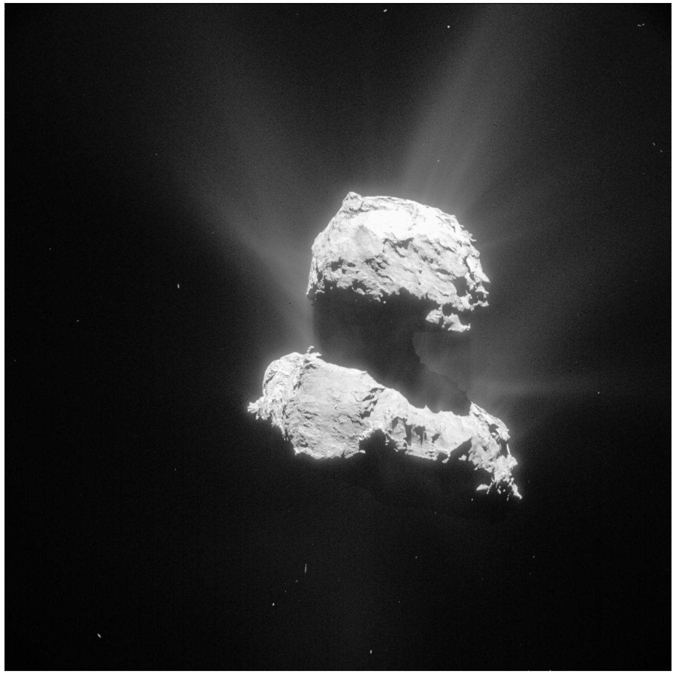
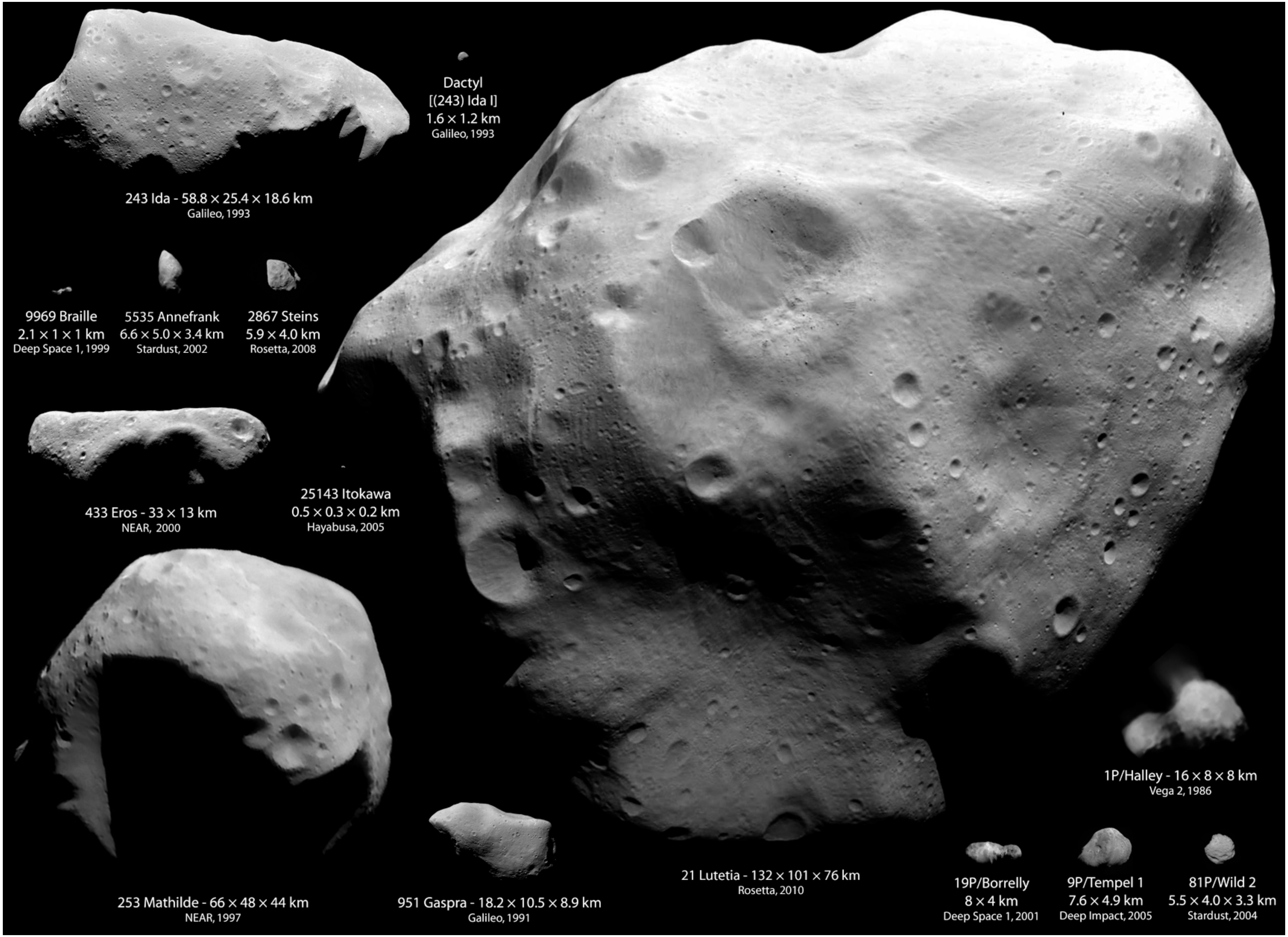
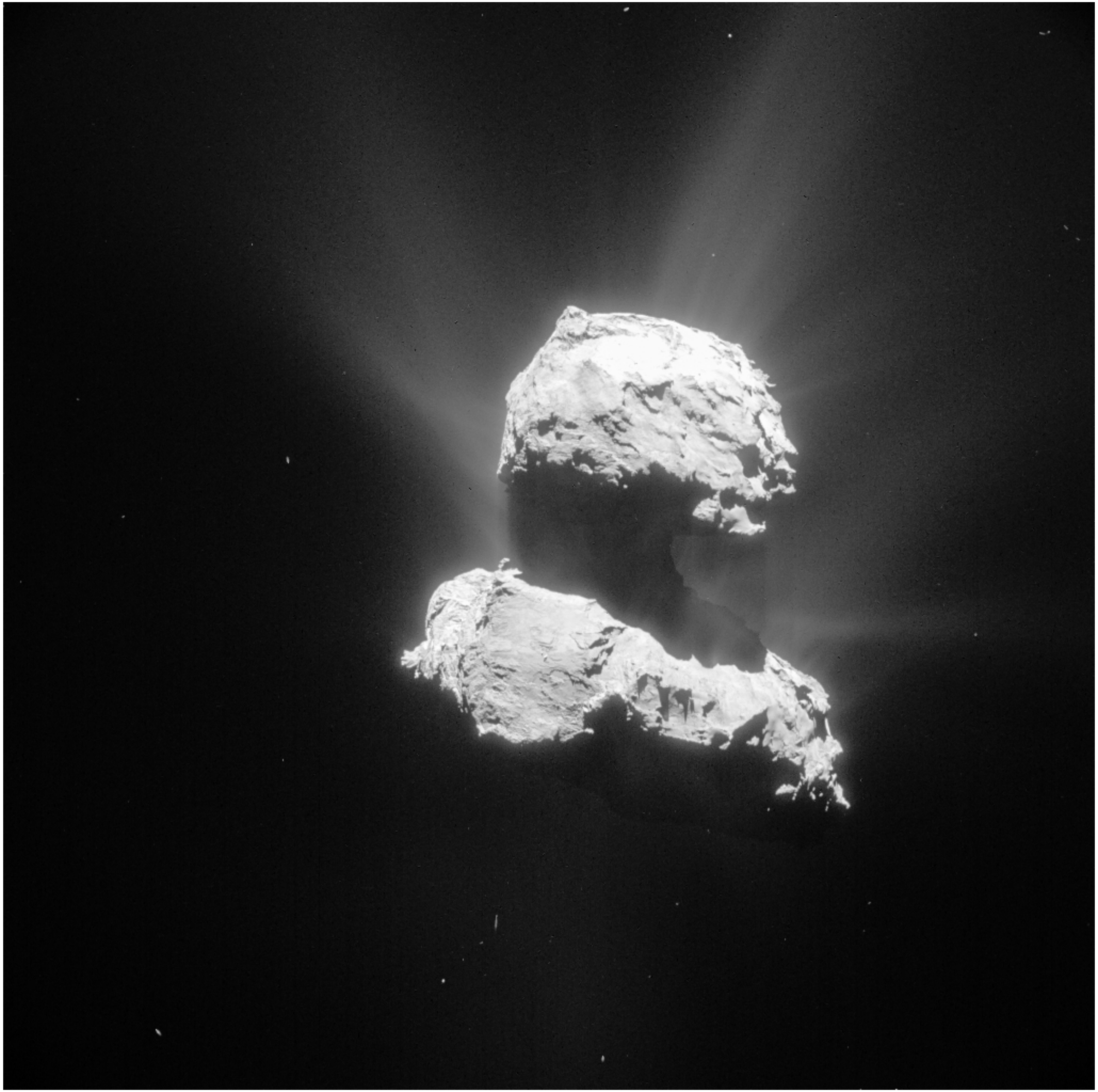


Introduction

- Physical characterization of the surfaces of airless planetary objects
- Direct problem of light scattering by discrete random media of particles with varying particle size, shape, refractive index, and volume density
- Inverse problem based on astronomical observations and/or experimental measurements
- Plane of scattering, scattering angle, solar phase angle, degree of linear polarization


Dactyl
[(243) Ida I]
1.6 × 1.2 km
Galileo, 1993
243 Ida - 58.8 × 25.4 × 18.6 km
Galileo, 1993
9969 Braille
2.1 × 1 × 1 km
Deep Space 1, 1999
5535 Annefrank
6.6 × 5.0 × 3.4 km
Stardust, 2002
2867 Steins
5.9 × 4.0 km
Rosetta, 2008
433 Eros - 33 × 13 km
NEAR, 2000
25143 Itokawa
0.5 × 0.3 × 0.2 km
Hayabusa, 2005
1P/Halley - 16 × 8 × 8 km
Vega 2, 1986
21 Lutetia - 132 × 101 × 76 km
Rosetta, 2010
19P/Borrelly
8 × 4 km
Deep Space 1, 2001
9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005
81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004
253 Mathilde - 66 × 48 × 44 km
NEAR, 1997
951 Gaspra - 18.2 × 10.5 × 8.9 km
Galileo, 1991



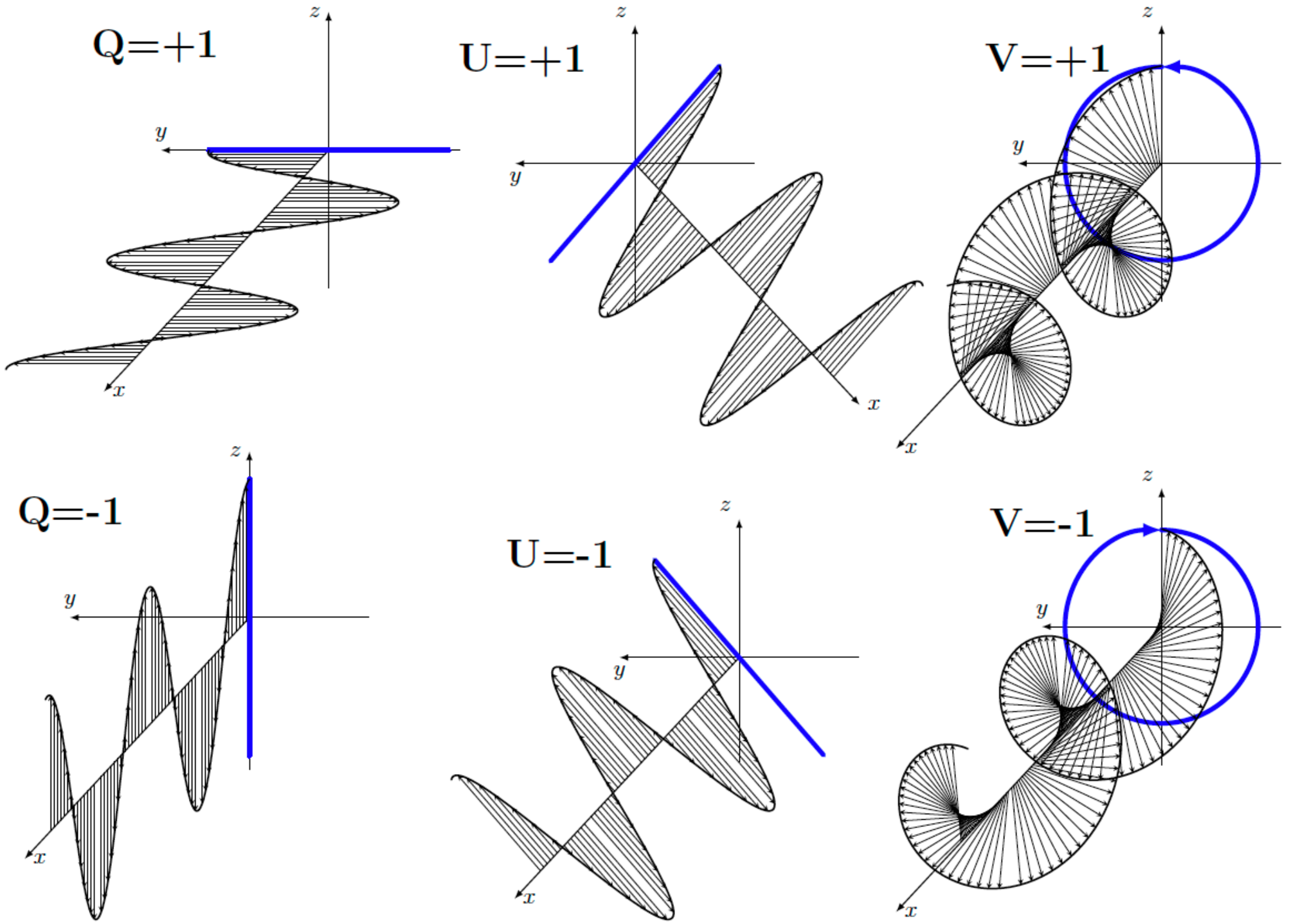


Figure 2.1: Stokes parameters explained visually by drawing the plane of propagation. While Q and U propagate in a plane, the plane of V rotates and thus has a circular pattern. The sign controls the orientation of the plane, whereas intensity I defines the amplitude of the oscillation. For a visual aid, U=-1 propagates in the same direction as U=+1, but the x-axis is shifted to make the pattern more distinctive.

Väisänen, Ph.D. thesis, 2020

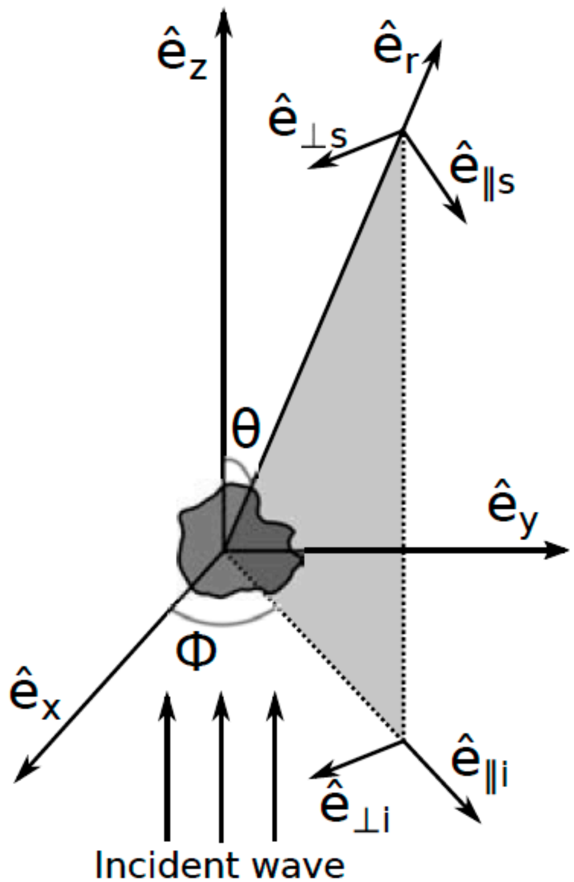


Figure 2.2: Illustration of the incident wave and the scattering plane. (Bohren and Huffman, 1983)

Väisänen, Ph.D. thesis, 2020

$$I \propto E_{\|}E_{\|}^{*} + E_{\perp}E_{\perp}^{*}$$

$$Q \propto E_{\|}E_{\|}^{*} - E_{\perp}E_{\perp}^{*}$$

$$U \propto E_{\|}E_{\perp}^{*} + E_{\perp}E_{\|}^{*}$$

$$V \propto i(E_{\|}E_{\perp}^{*} - E_{\perp}E_{\|}^{*})$$

I = intensity
Q and *U* = the degree and direction of linear polarization
V = the degree and handedness of the circular polarization.

$$\sqrt{Q^2 + U^2 + V^2} / I = \text{degree of polarization}$$

$$\sqrt{Q^2 + U^2} / I = \text{degree of linear polarization}$$

$$V / I = \text{degree of circular polarization}$$

Nousiainen and Zubko, Lecture Notes, 2011

With Stokes parameters, we obtain the 4×4 Mueller matrix form for the scattering equation:

$$\begin{pmatrix} I_s \\ Q_s \\ U_s \\ V_s \end{pmatrix} = \frac{C_{sca}}{4\pi d^2} \begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ P_{31} & P_{32} & P_{33} & P_{34} \\ P_{41} & P_{42} & P_{43} & P_{44} \end{pmatrix} \begin{pmatrix} I_i \\ Q_i \\ U_i \\ V_i \end{pmatrix}$$

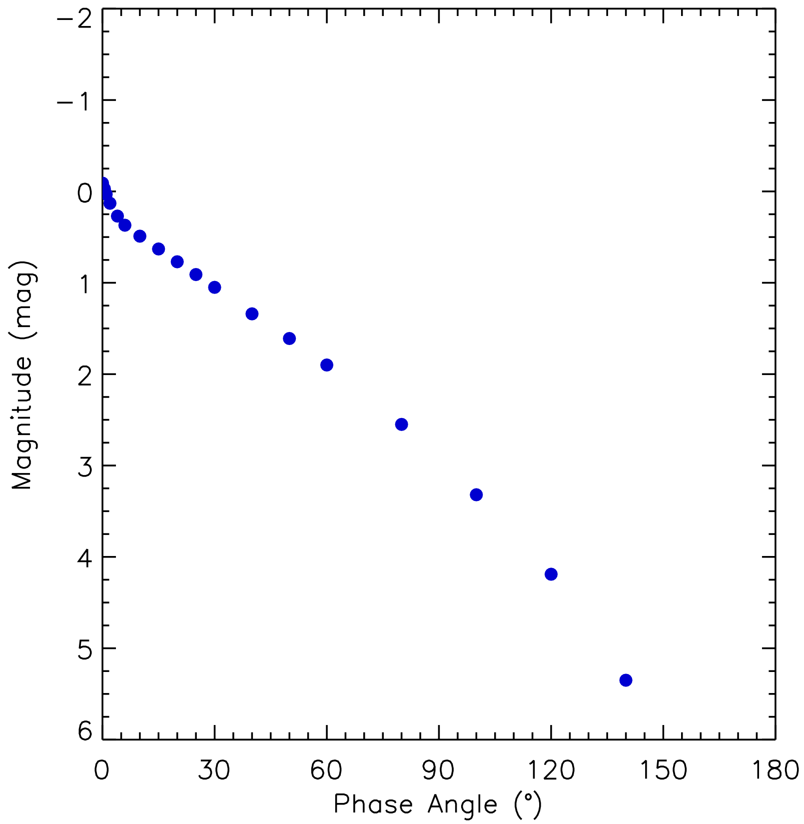
C_{sca} = scattering cross section
d = distance from the scatterer
P = phase matrix

Nousiainen and Zubko, Lecture Notes, 2011

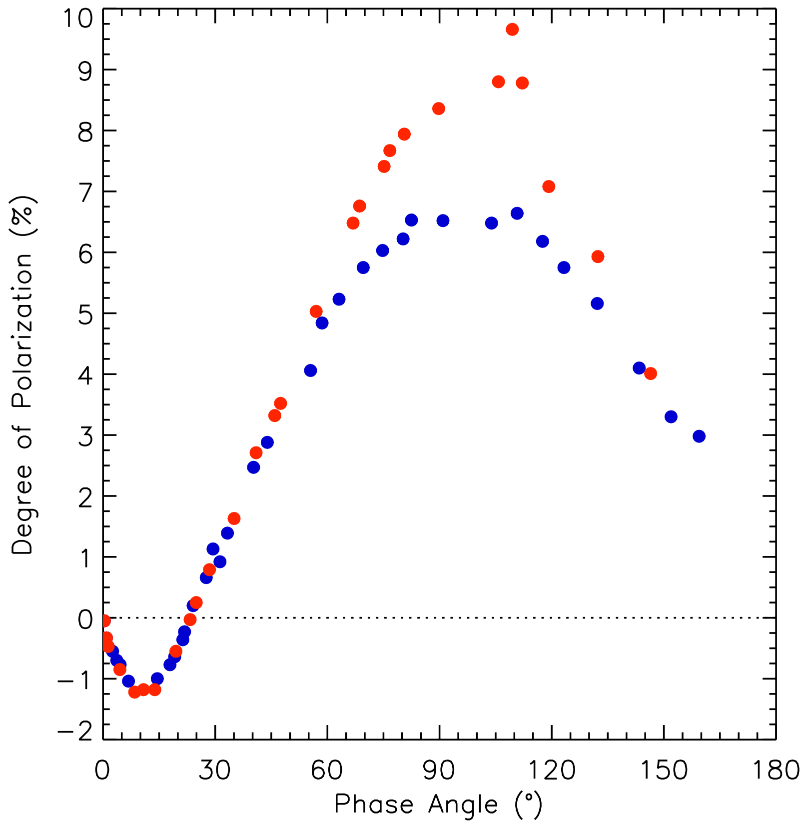
Polarimetric & photometric observations

Moon

Photometry



Polarimetry



Rougier (1933), Lyot (1929)