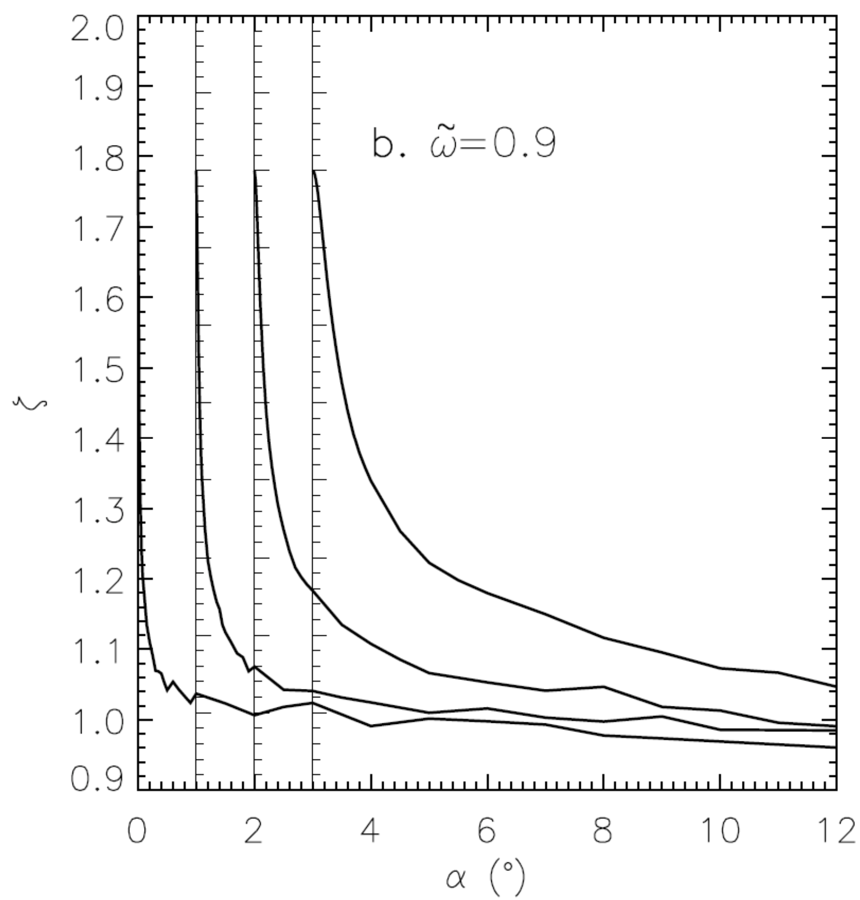
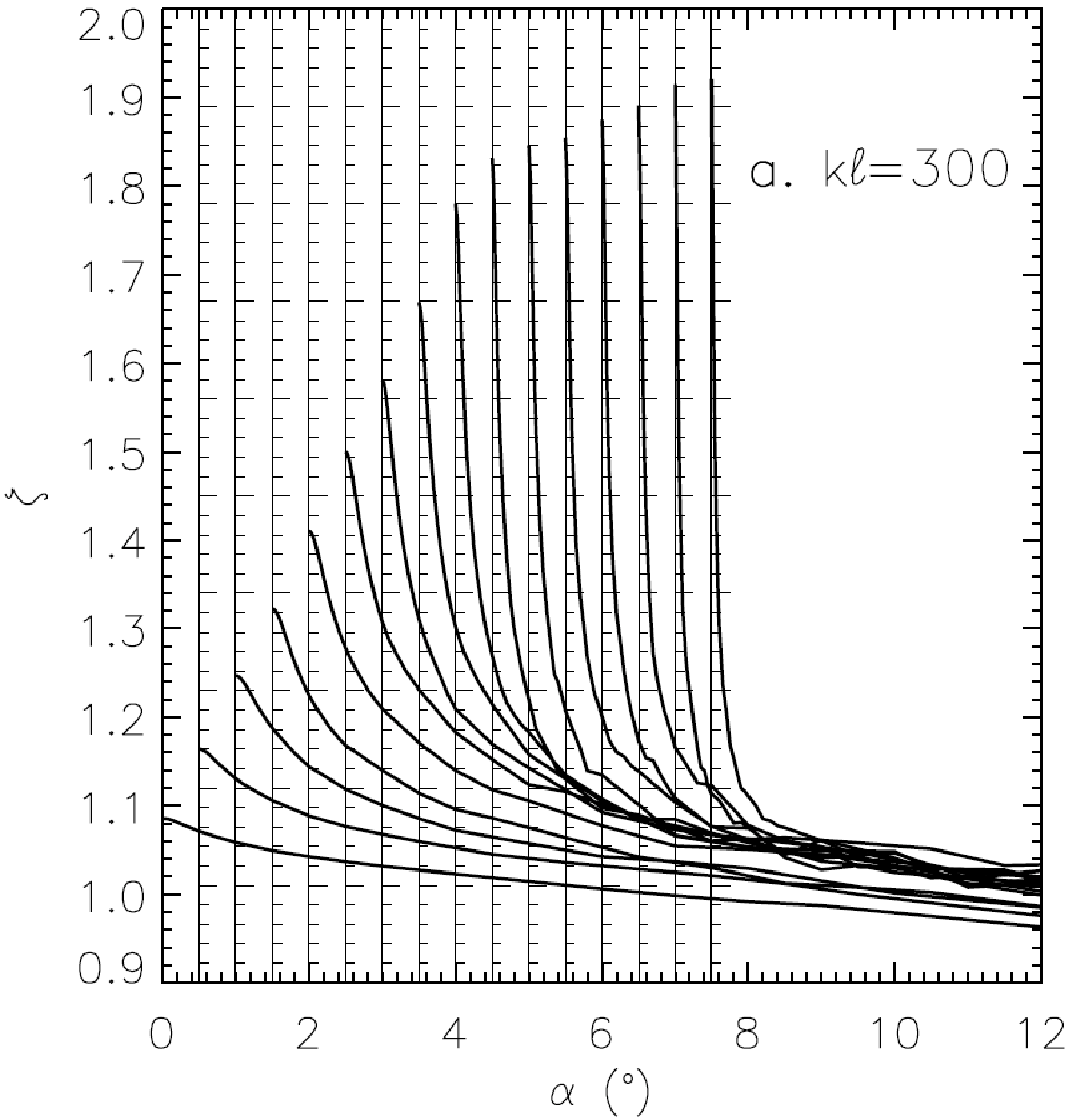
RT-C with intensity only

- Intensity surges due to interference in multiple scattering for a spherical medium
- Monte Carlo for radiative transfer and coherent backscattering
- Full angular profiles for the scattering phase function
- Double- and triple-Henyey-Greenstein single scattering

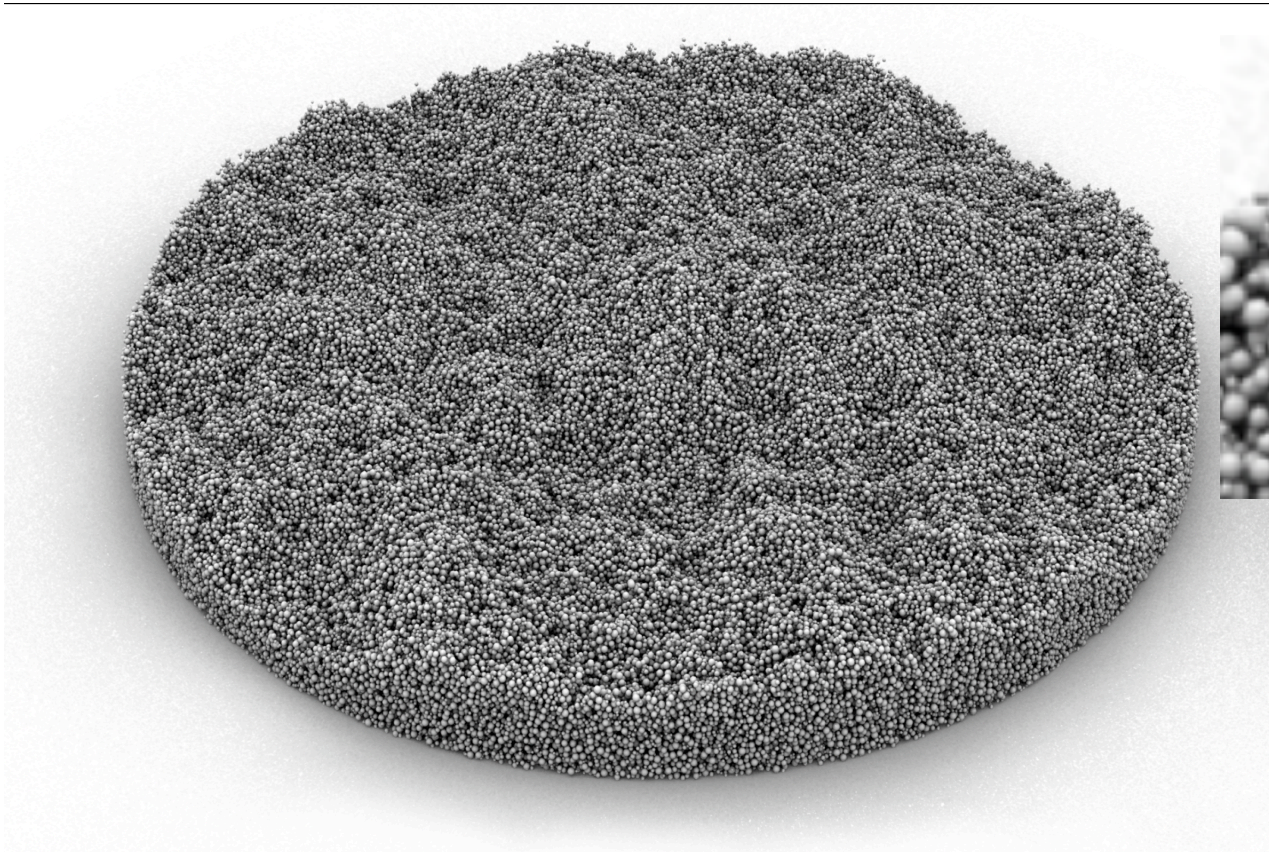


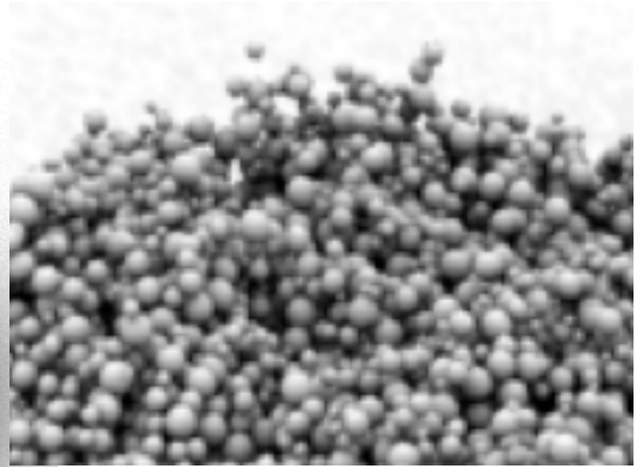
Muinonen et al., Light Scattering Reviews 5, 377, 2010



a. kℓ=300
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
ζ
0
2
4
6
8
10
12
α (°)

Stochastic Surface Geometry

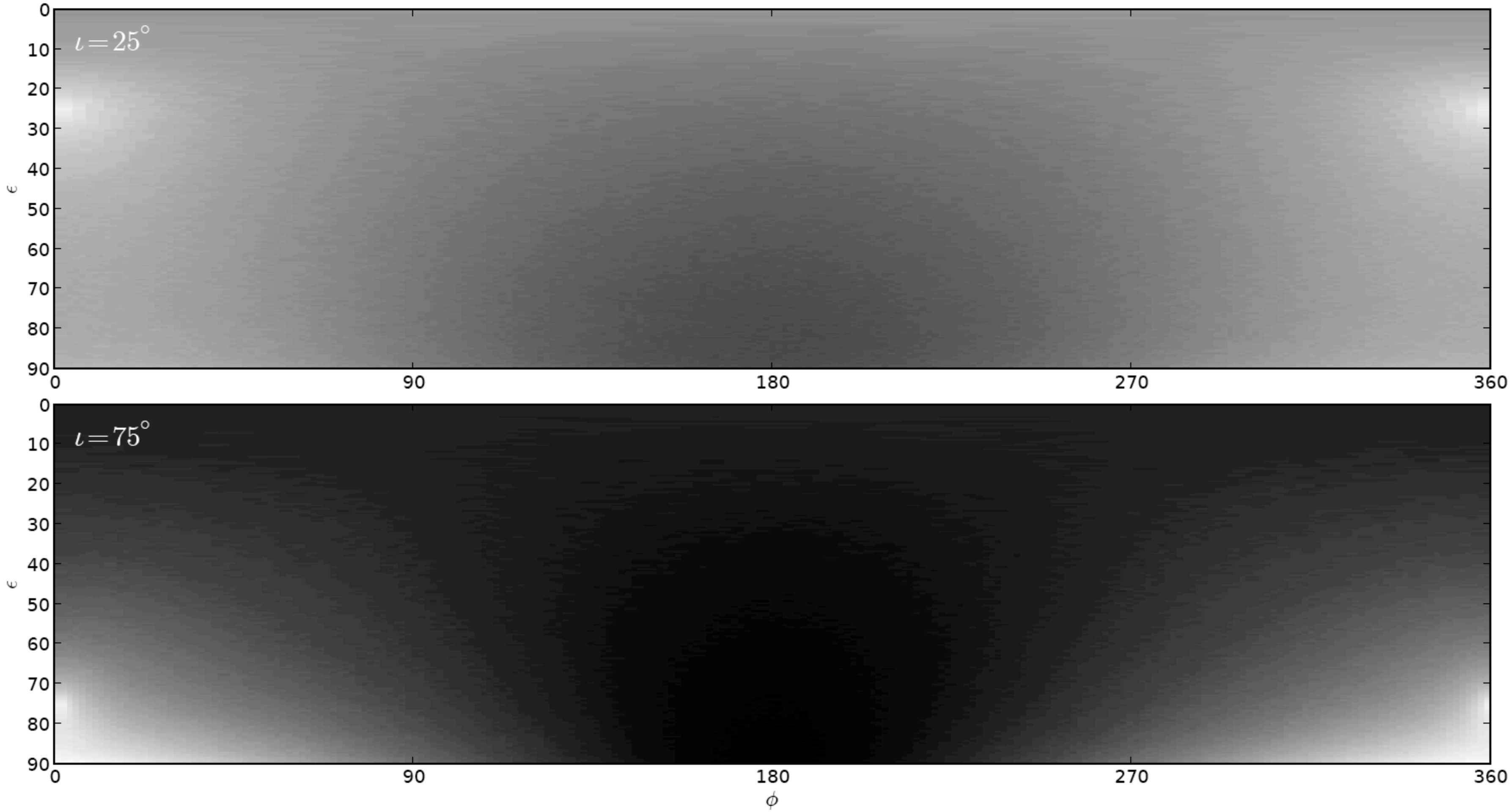




H. Parviainen,
K. Muinonen,
JQSRT 2009

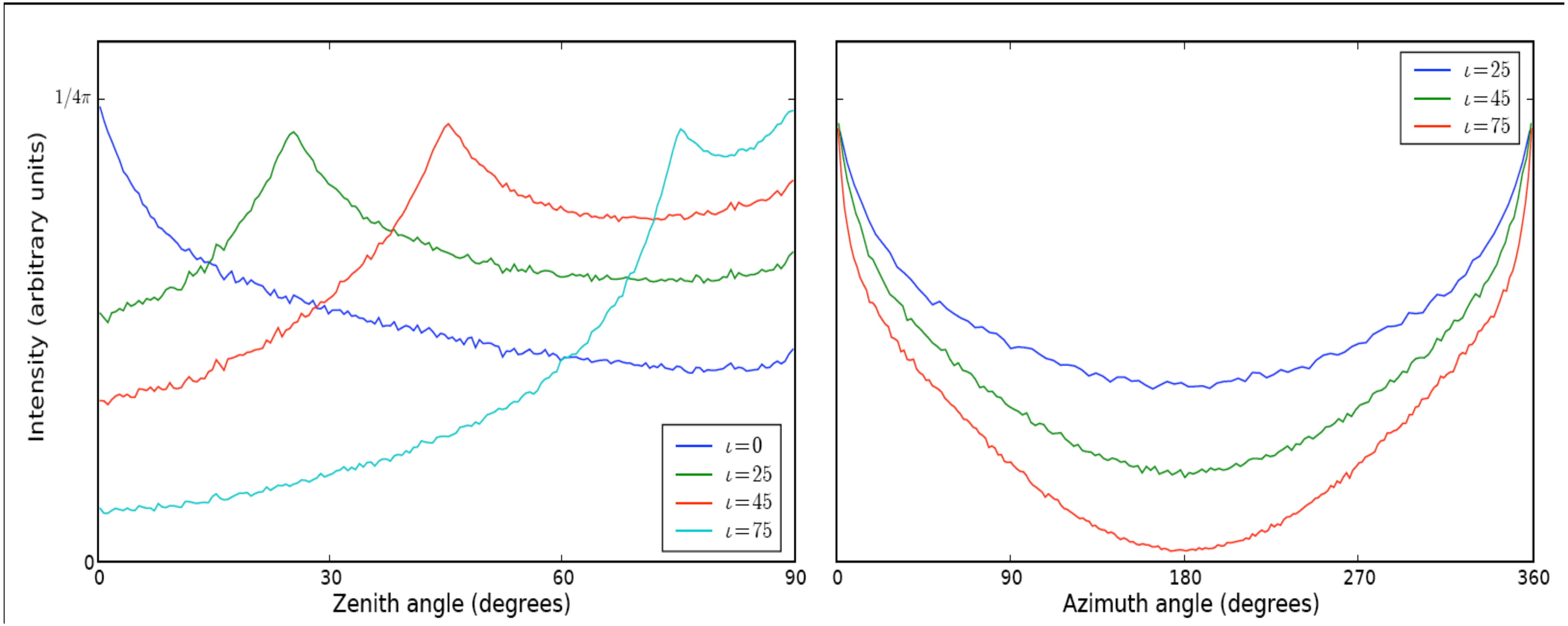
Densely-packed random media of spheres, fractional-Brownian-motion boundary surface

Stochastic Surface Geometry



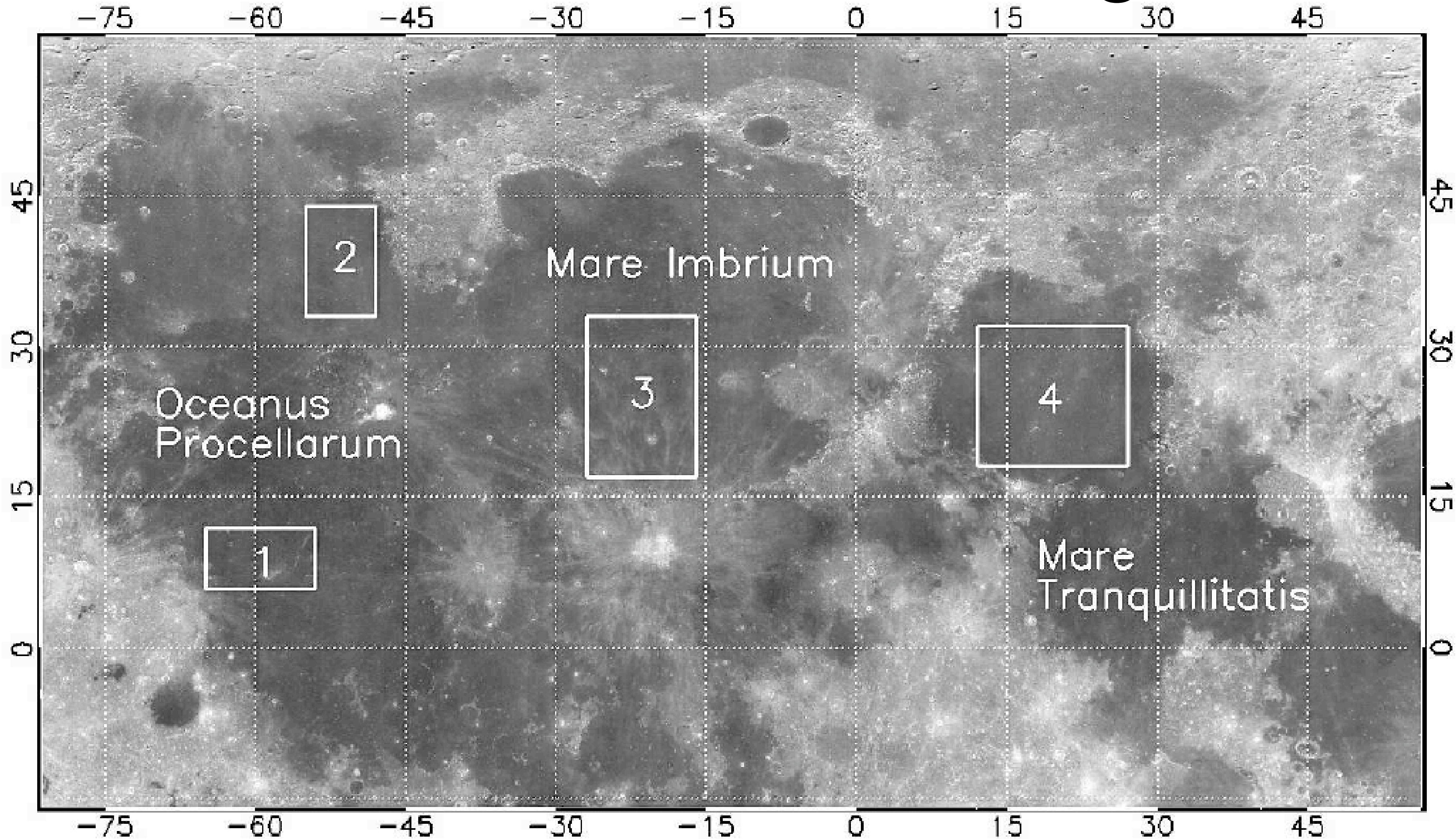
Dependence of shadowing on angles of incidence and emergence, as well as on the azimuthal angle

Stochastic Surface Geometry

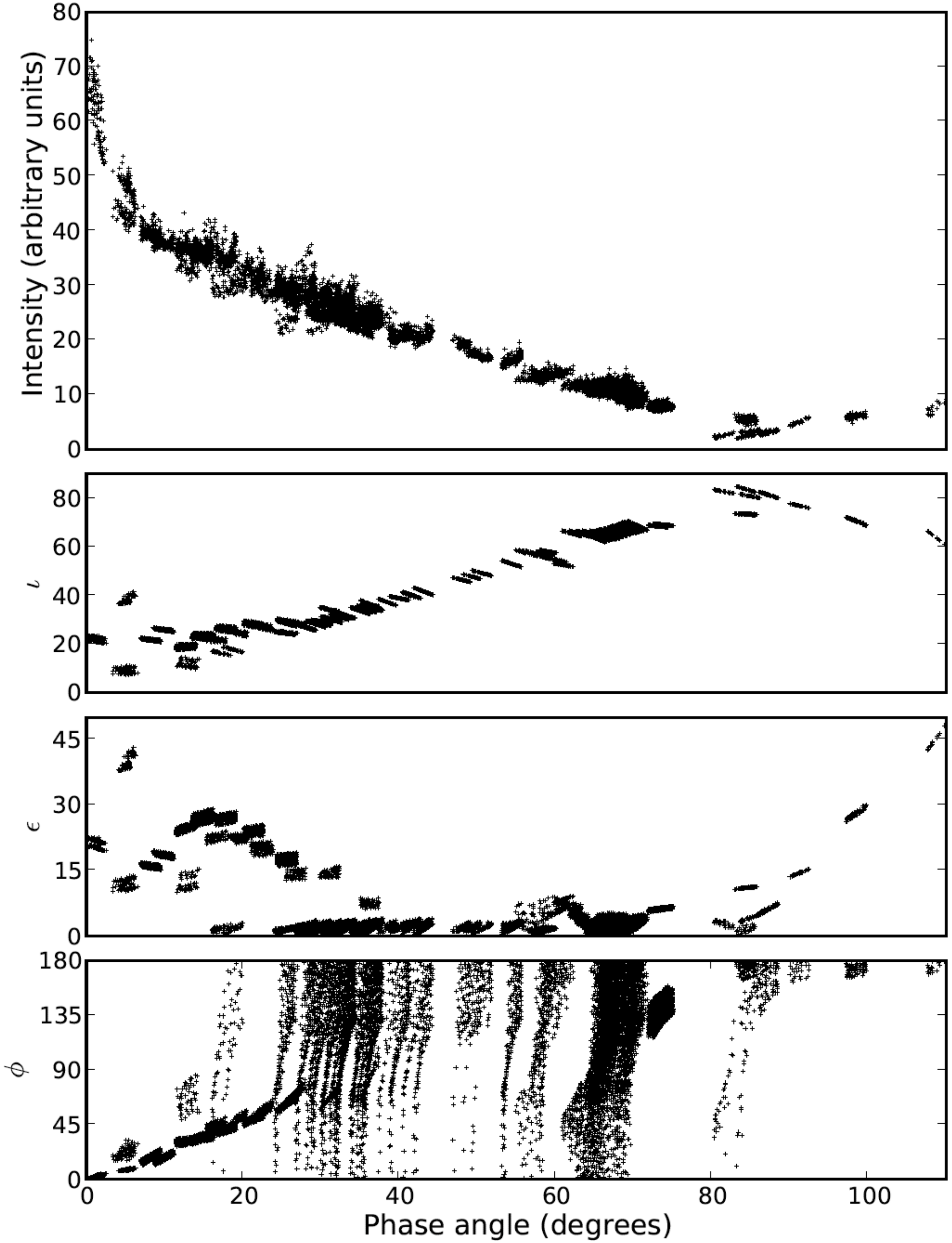


Slices in constant azimuthal angle and in constant emergence angle

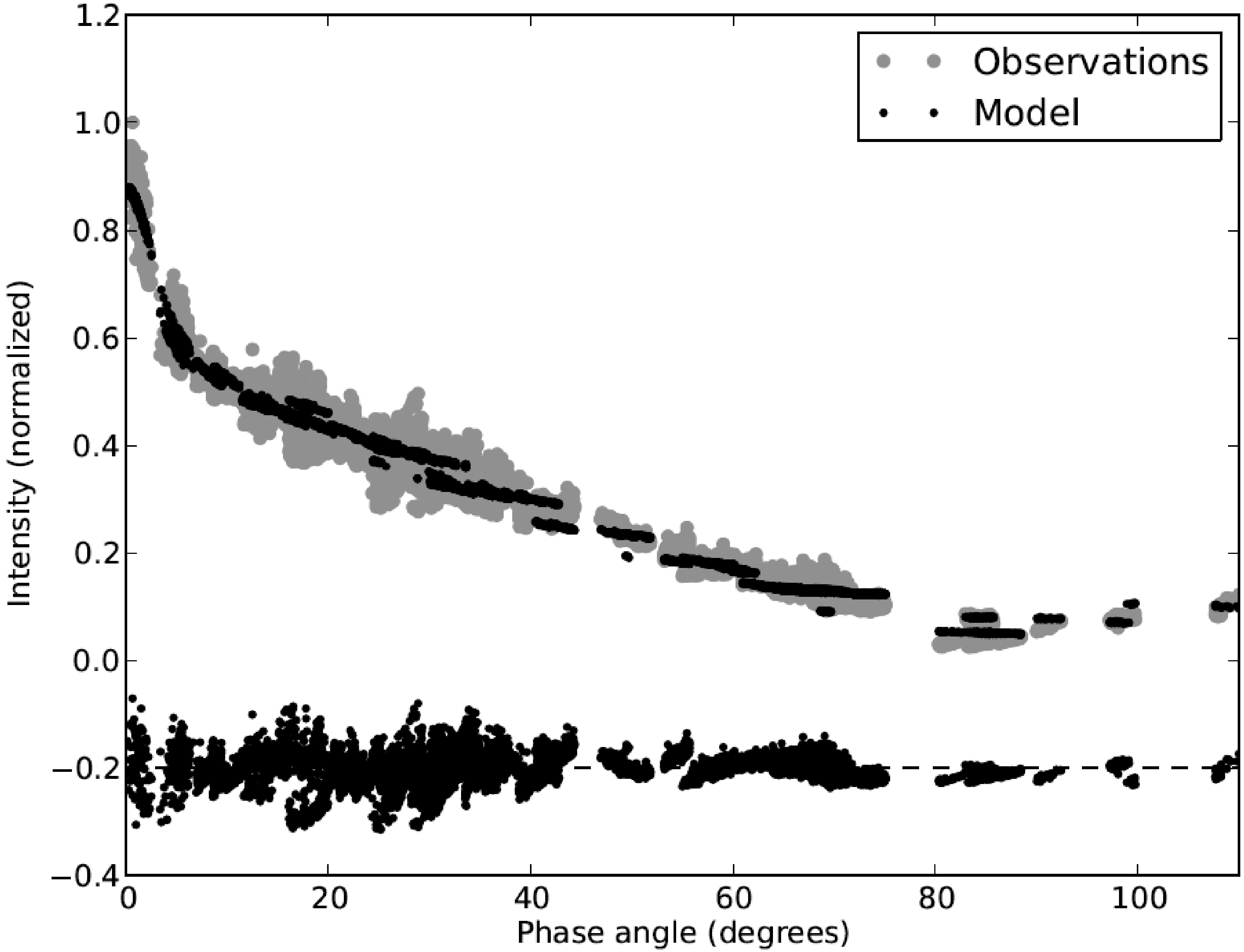
Lunar modeling with SMART-1 AMIE images



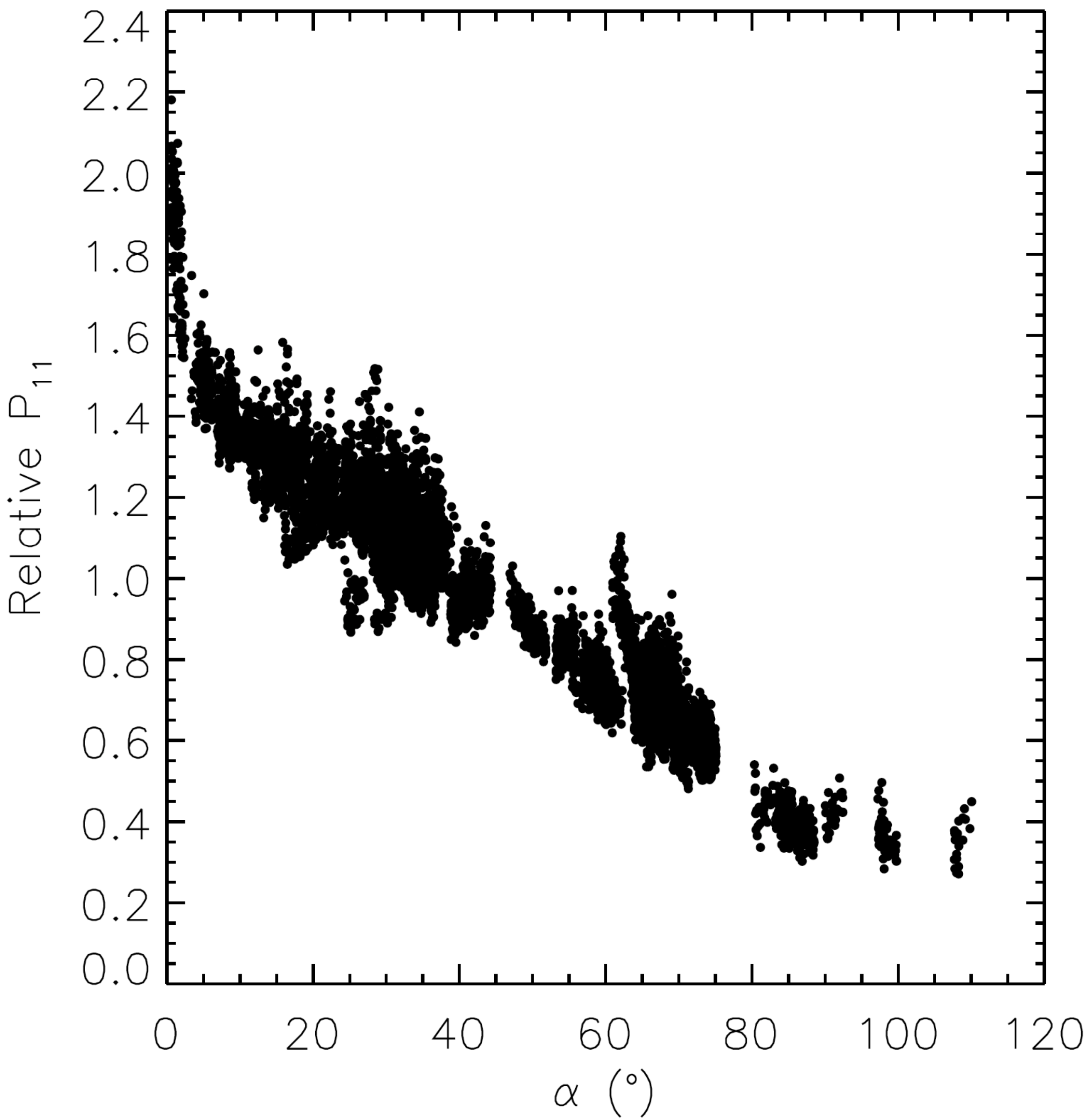
Muinonen et al., A&A, submitted



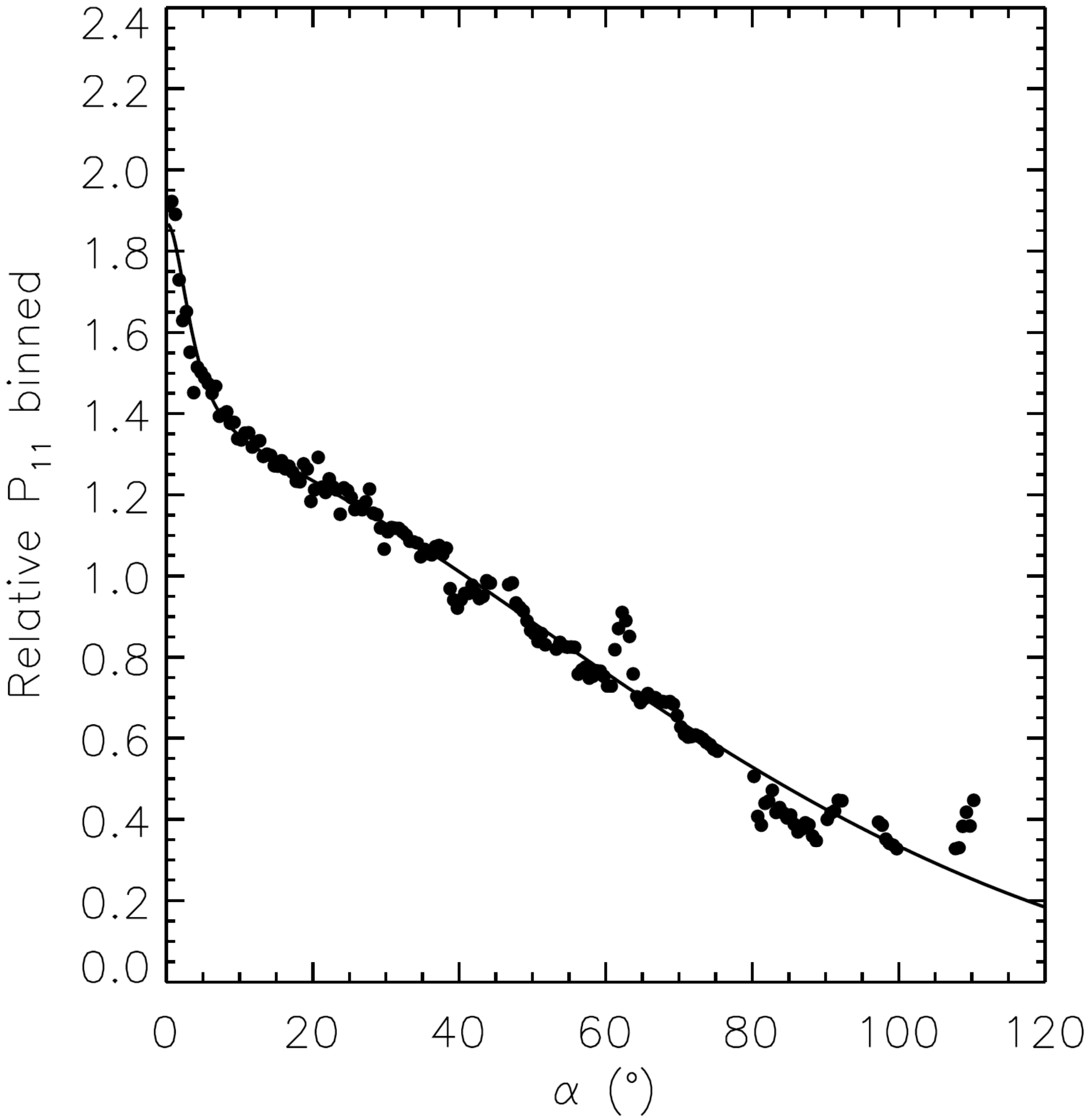
Intensity (arbitrary units)
80
70
60
50
40
30
20
10
0
ι
80
60
40
20
0
ϵ
45
30
15
0
ϕ
180
135
90
45
0
0
20
40
60
80
100
Phase angle (degrees)



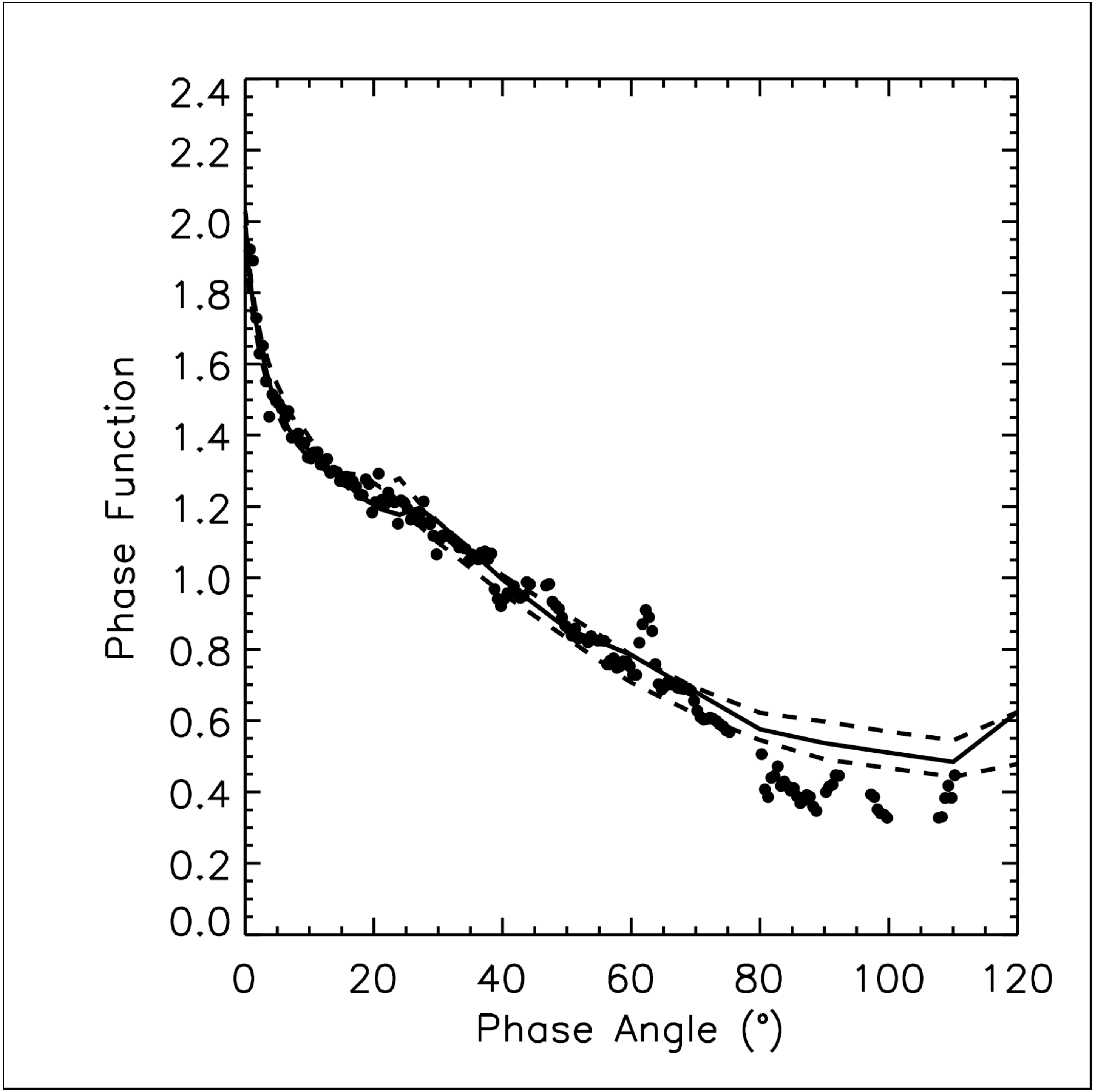
Observations
Model
Intensity (normalized)
Phase angle (degrees)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
0
20
40
60
80
100

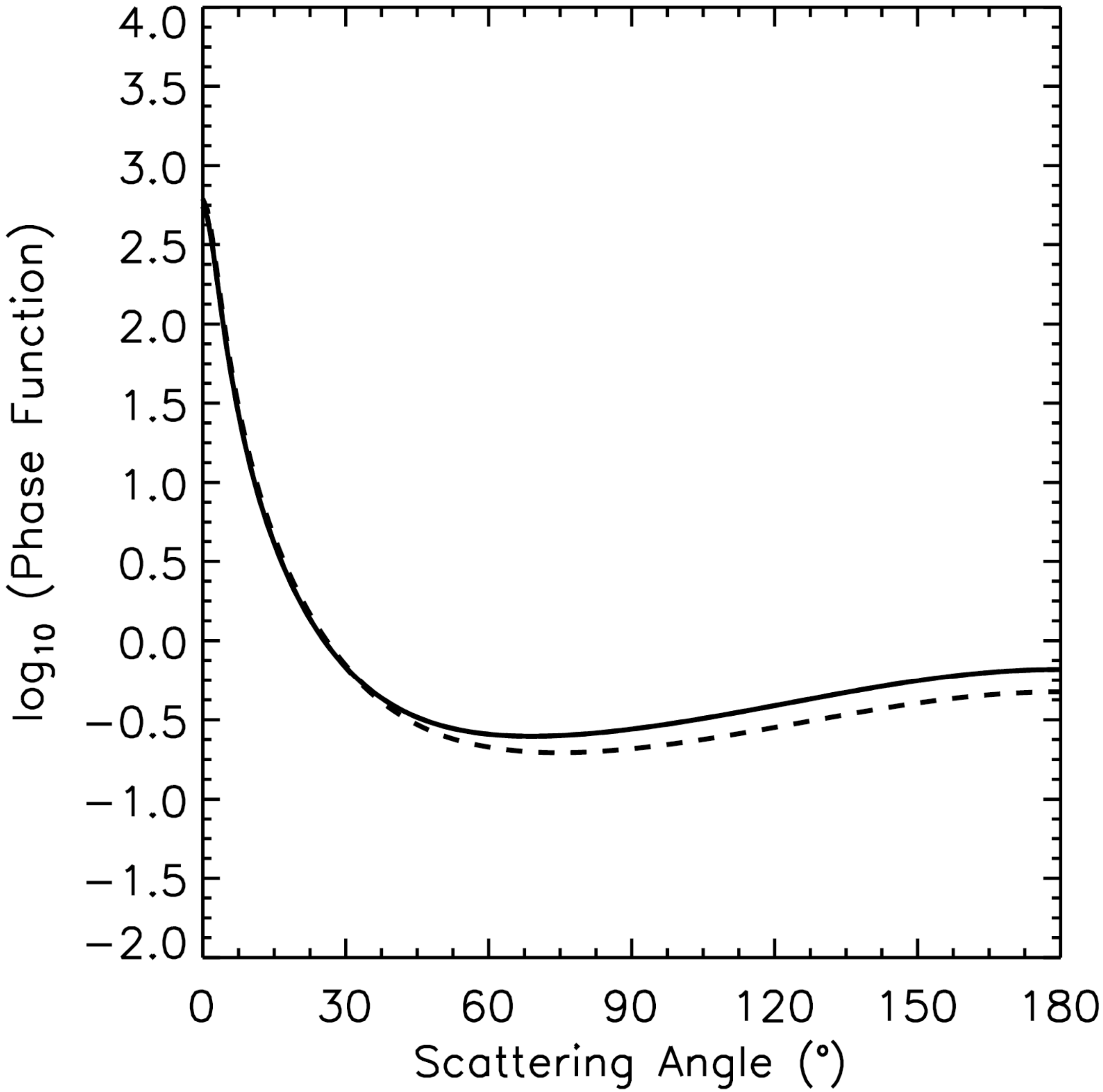


Relative P_{11}
α (°)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
0
20
40
60
80
100
120



Double-Henyey-Greenstein P_{11} for lunar volume-element phase function


Phase Function
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Phase Angle (°)



Double-Henyey-Greenstein P_{11} for lunar single scattering phase function

Coherent-backscattering radiative-transfer method vs. T-matrix method

- Coherent backscattering by a spherical medium of spherical particles
- RT-C equivalent to computing multiple scattering using amplitude scattering matrices and exponential attenuation
- Preliminary comparison to superposition *T*-matrix computations by Mishchenko et al. (2009)

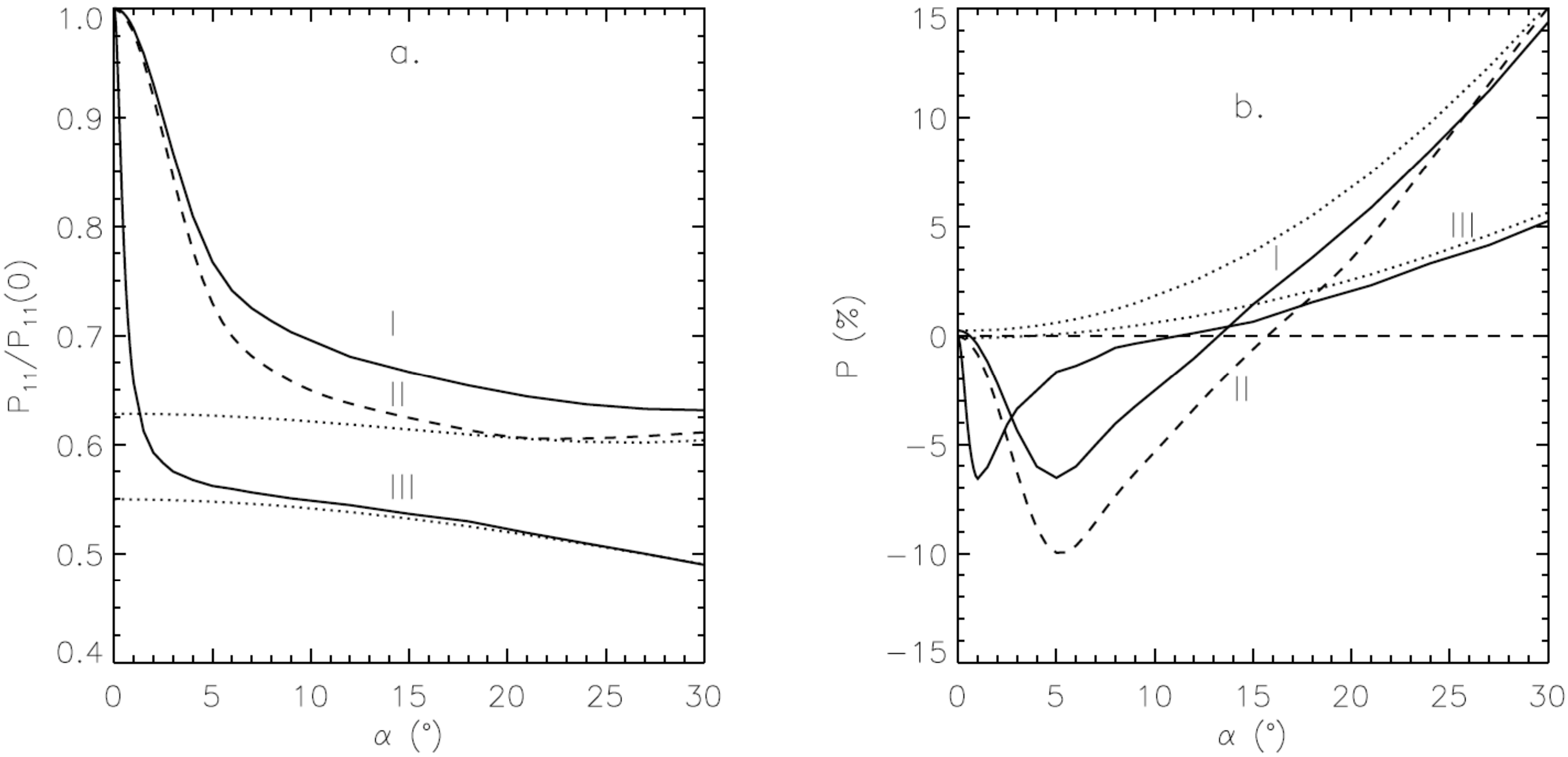
First comparisons

- RT-C and superposition *T*-matrix computations for a spherical cloud of 500 spheres with packing density 6.25%
- Cloud size parameter is X = 40 or X = 10^7 (RT-C)
- Constituent spheres have a size parameter x = 2 and refractive index 1.31 (X = 40) or 1.31+i0.01 (X = 10^7)
- 10^5 rays utilized in Monte Carlo computations
- Lumme, Penttilä, and Muinonen (2005) compared exact and RT-C computations for media of a small number of constituent spheres (size parameter x = 7) - results discouraging

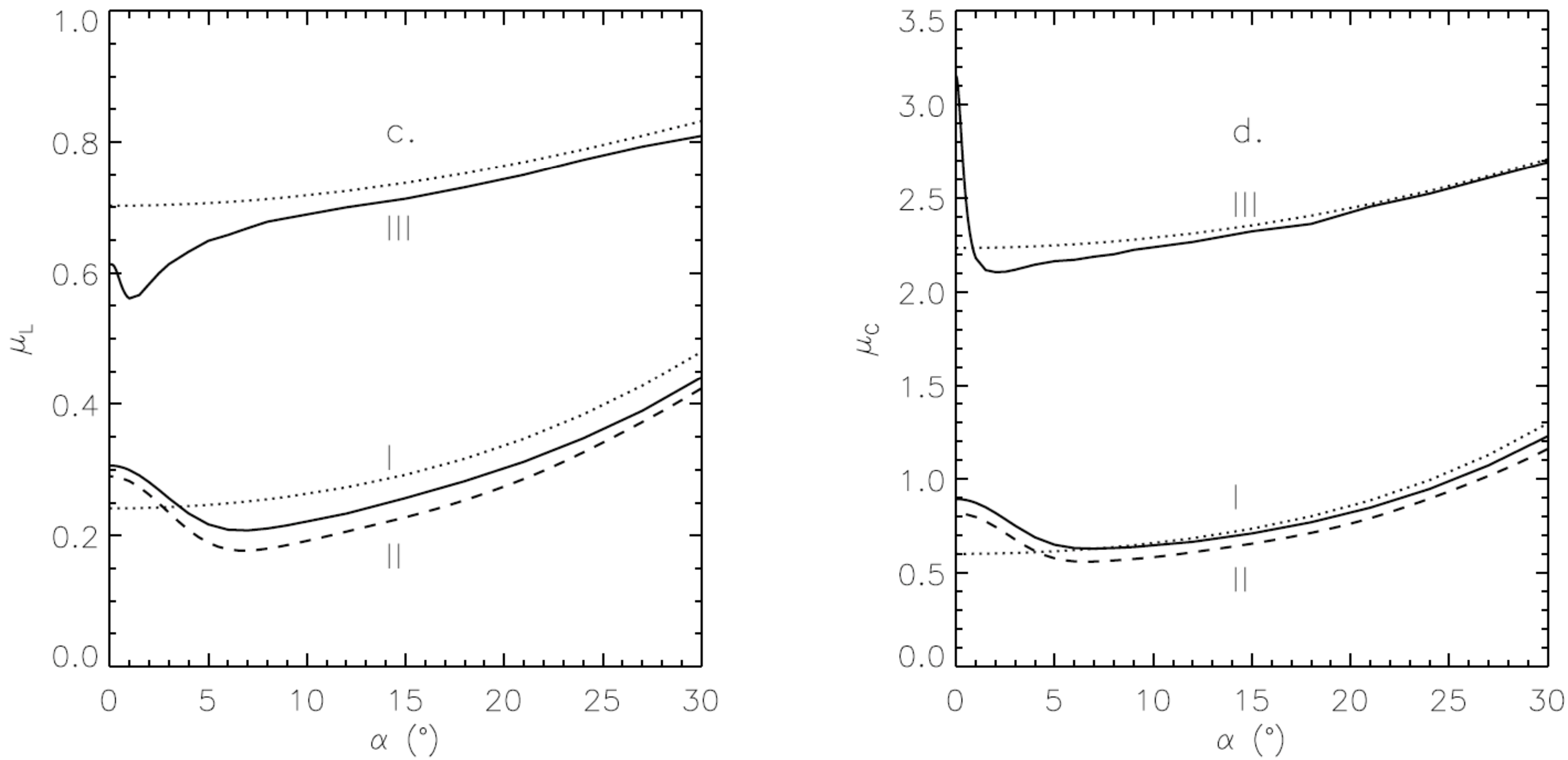
I: X = 40, m = 1.31

II: Superposition *T*-matrix by Mishchenko et al. (2009)

III: X = 10^7, m = 1.31+i0.01

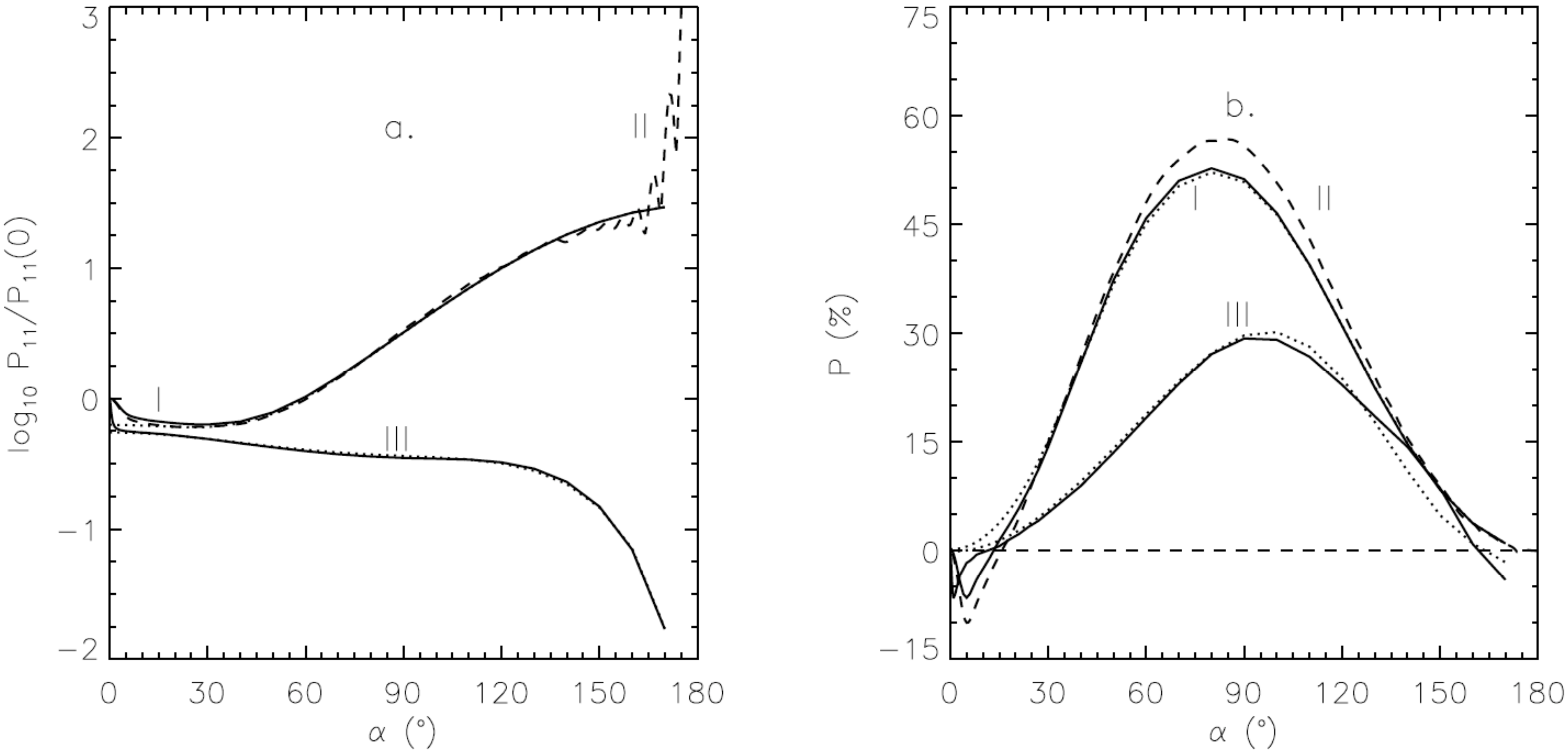


$$P = -P_{21}/P_{11}$$

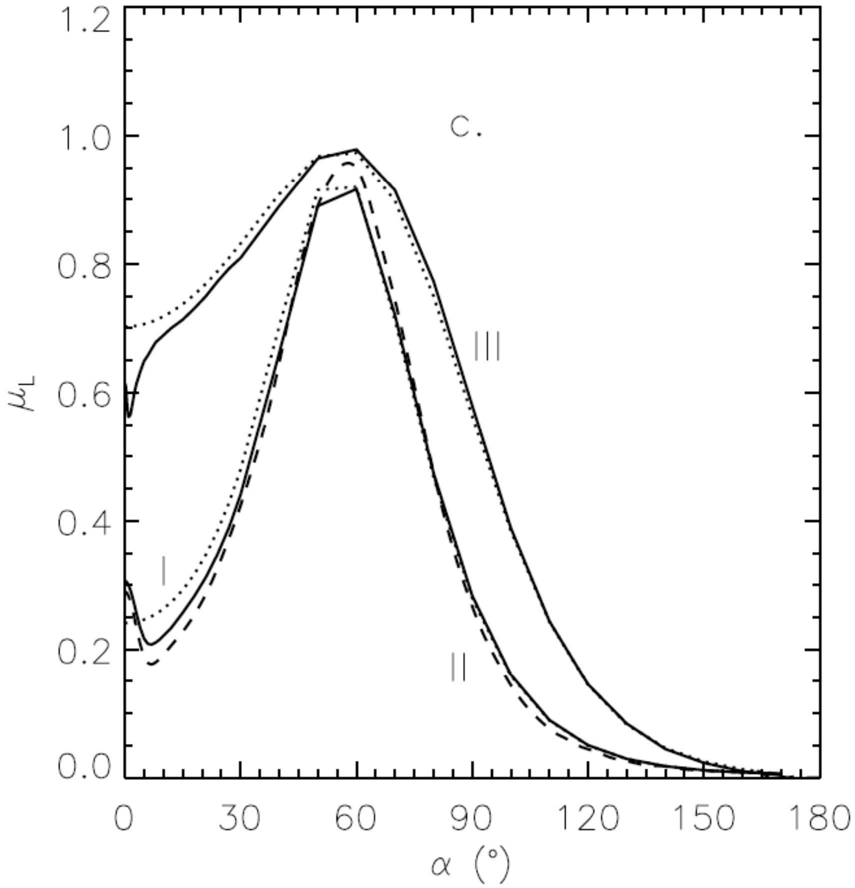


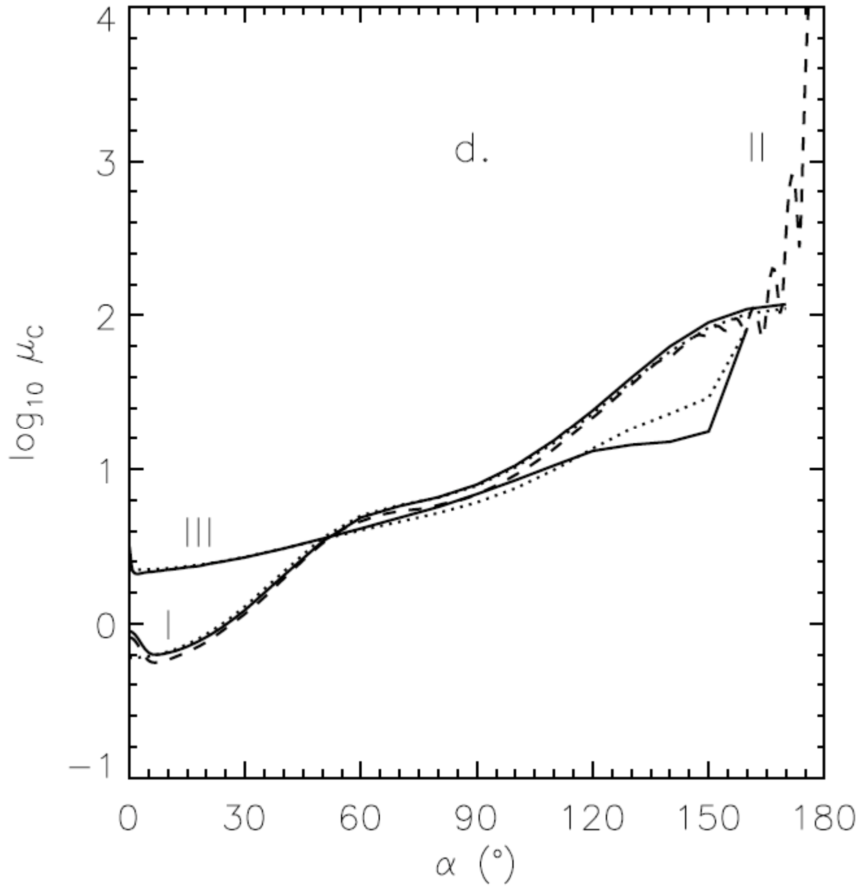
$$\mu_{\mathrm{L}} = (P_{11} - P_{22})/(P_{11} + 2P_{21} + P_{22})$$

$$\mu_{\mathrm{C}} = (P_{11} + P_{44})/(P_{11} - P_{44})$$



a.
b.
I
II
III
$\log_{10} P_{11}/P_{11}(0)$
P (%)
α (°)
3
2
1
0
−1
−2
75
60
45
30
15
0
−15
0
30
60
90
120
150
180


c.
I
II
III
1.2
1.0
0.8
0.6
0.4
0.2
0.0
μ_L
0
30
60
90
120
150
180
α (°)


d.
I
II
III
4
3
2
1
0
−1
$\log_{10} \mu_C$
0
30
60
90
120
150
180
α (°)

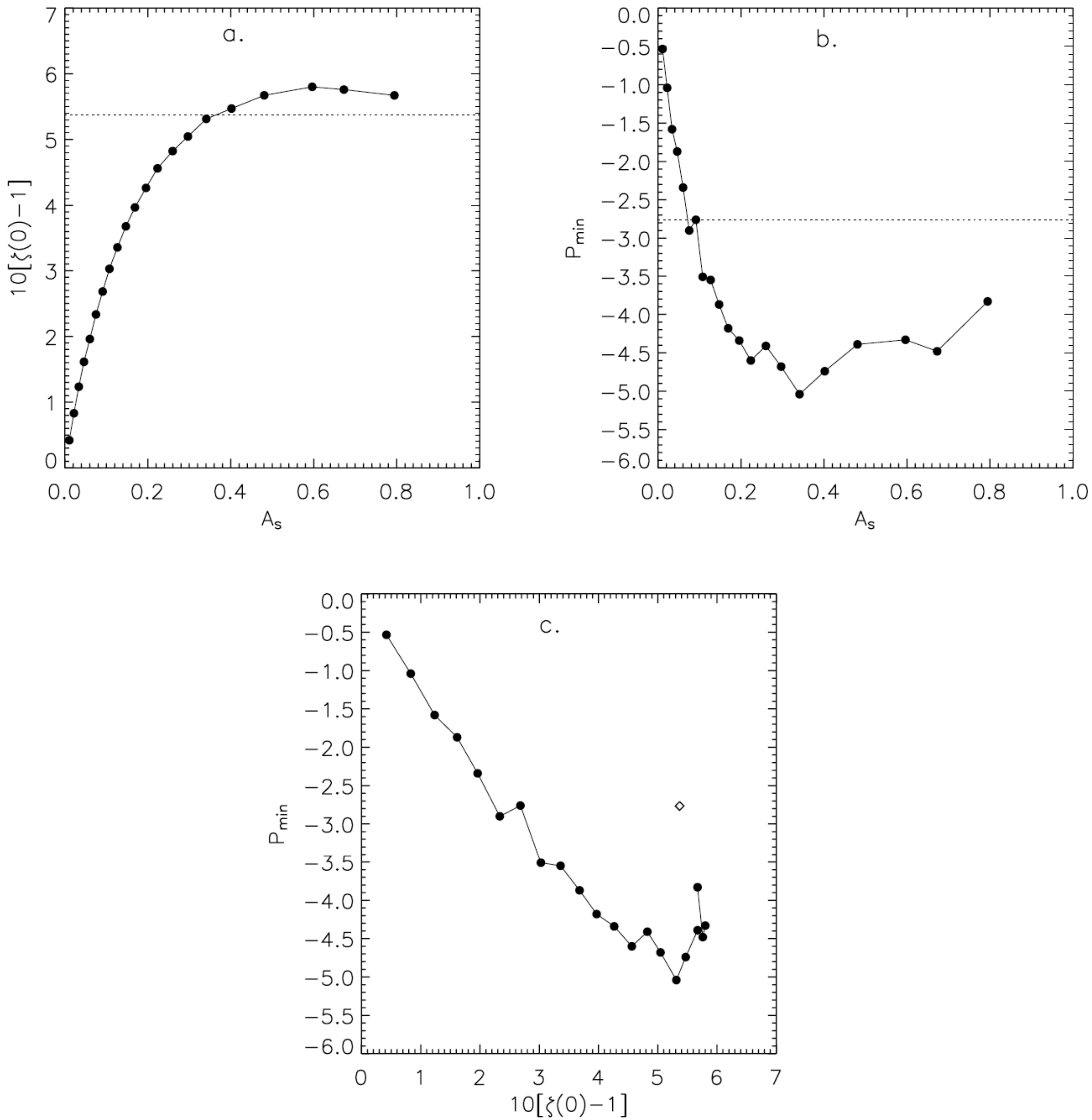
Conclusions

- Exact negative polarization and opposition effect explained to large extent with RT-C for microscopic scattering media
- Angular widths of the backscattering phenomena are rather insensitive to porosity because of the forward-scattering tendency of the constituent spheres
- In the same spirit, wavelength dependence can be small for clouds with size distributions of spheres

Conclusions

- Lunar photometry to be modeled together with polarimetry
- Coherent backscattering by a close-packed medium of spherical media (regolith)
- TNO polarimetry re-modeled using a novel more complicated single-scattering matrix
- Interrelation of interference phenomena at size parameters ~5 and ~50 open

Thank you!


a.
10[ζ(0)−1]
A_s
b.
P_min
A_s
c.
P_min
10[ζ(0)−1]