The diagnostic value of polarisation spectra

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What is polarisation?

Light is fully described by a vector: **F**=[*F*, *Q*, *U*, *V*]

The degree of linear polarisation of the light is:

$$P(\lambda) = \frac{\sqrt{(Q^2(\lambda) + U^2(\lambda))}}{F(\lambda)}$$

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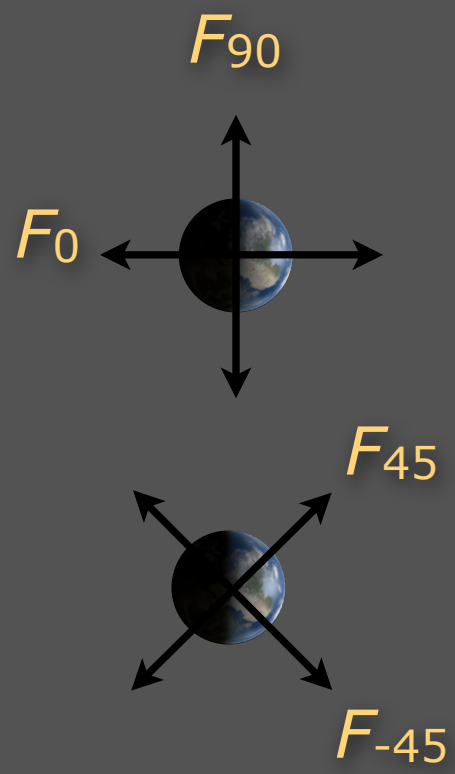
How to measure polarisation



$$F = F_{90} + F_0$$
$$Q = F_{90} - F_0$$

$$F = F_{45} + F_{-45}$$
$$U = F_{45} - F_{-45}$$

Important:

- With e.g. polarizing beamsplitters you do not lose photons!
- Polarimetry can be independent of instrument parameters!
- Polarimetry is also independent of Earth atmosphere transmission!

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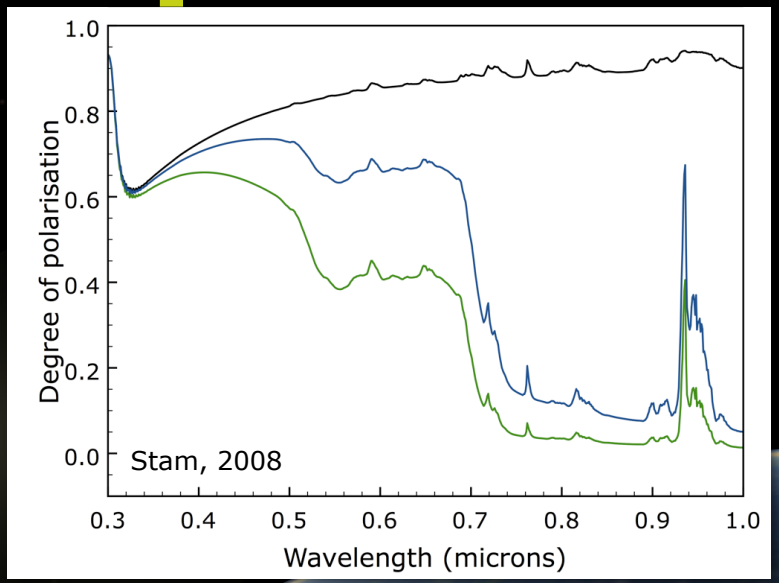
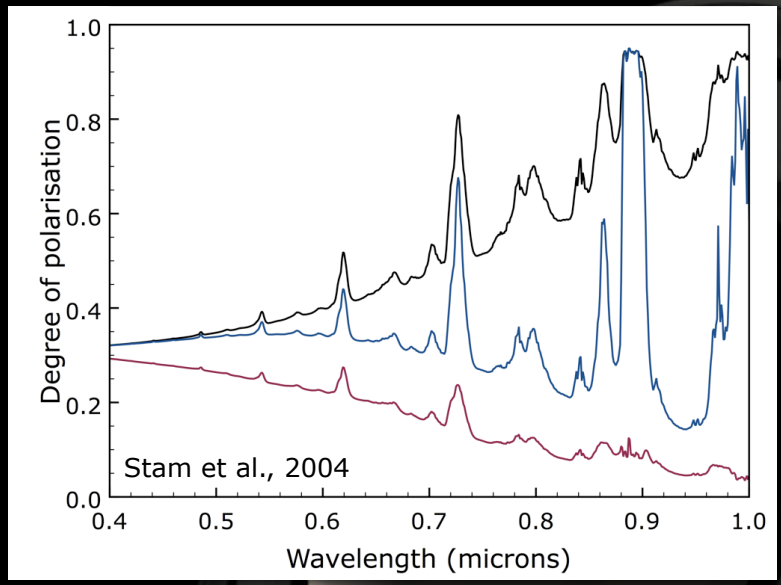
Sources of polarisation in planetary systems

- ✗ Direct starlight
- ✓ Scattered starlight
- ✓ Reflected starlight

?





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Numerical simulations

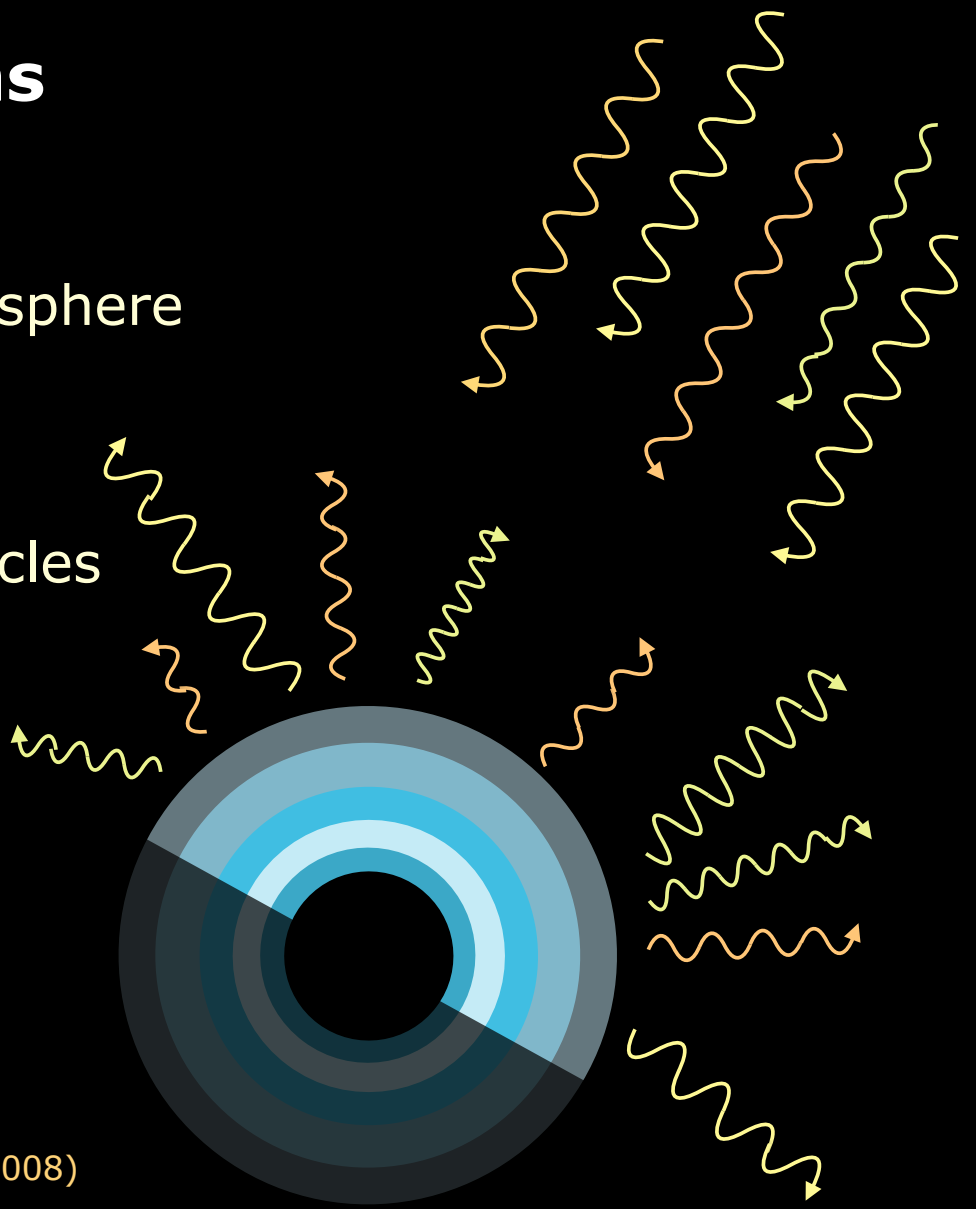
Planet models:

- locally plane-parallel atmosphere
- horizontally homogeneous
- vertically inhomogeneous
- gases, aerosol, cloud particles
- planetary rings

Radiative transfer code:

- adding-doubling algorithm
- fluxes and polarisation
- efficient disk-integration

(for details, see e.g. Stam et al. 2004, 2006, 2008)



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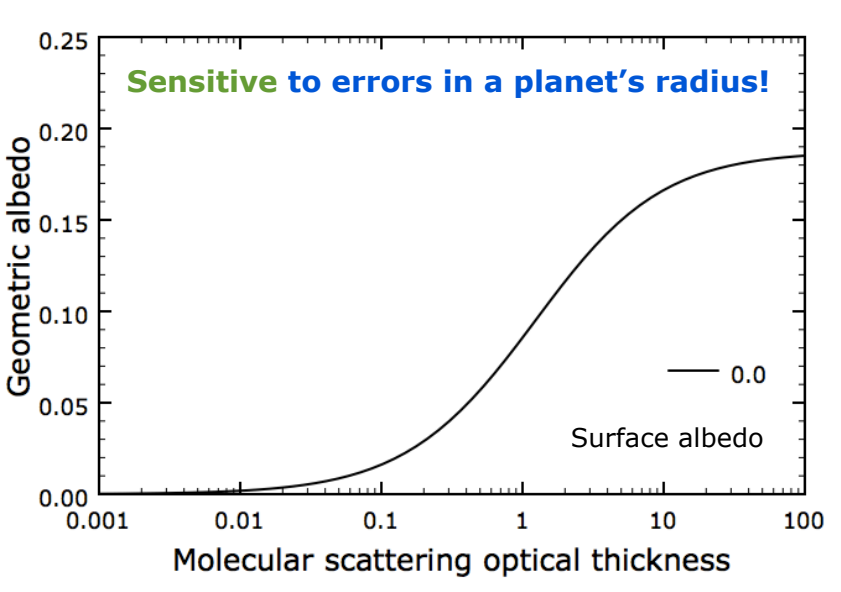
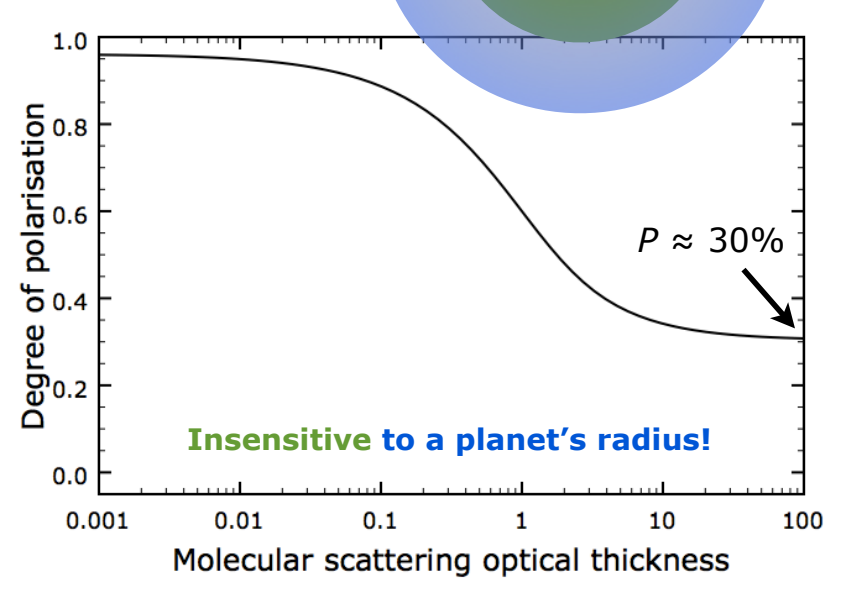
Surface pressure

The surface pressure can be derived from an atmosphere's molecular scattering optical thickness:





Rayleigh scattering atmosphere, no absorption.
Phase angle is 90° (included in albedo).

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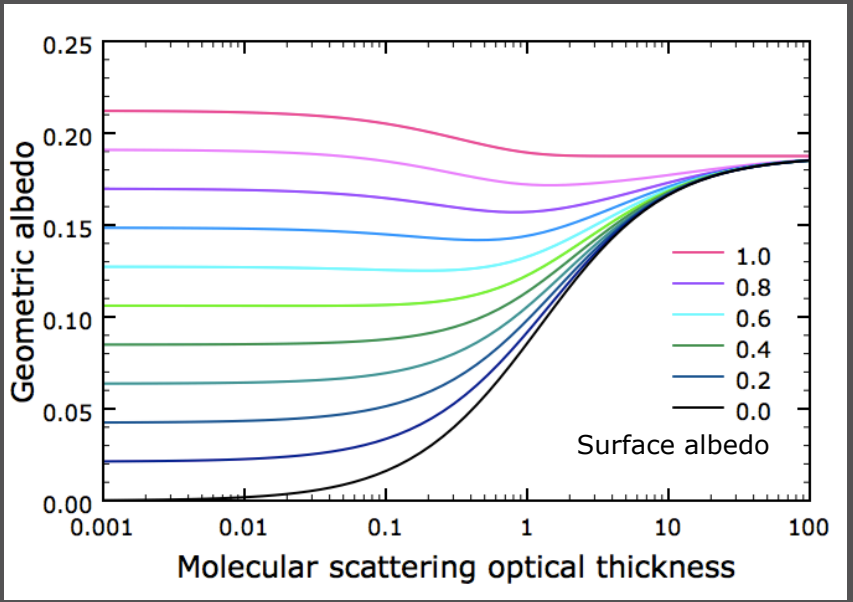
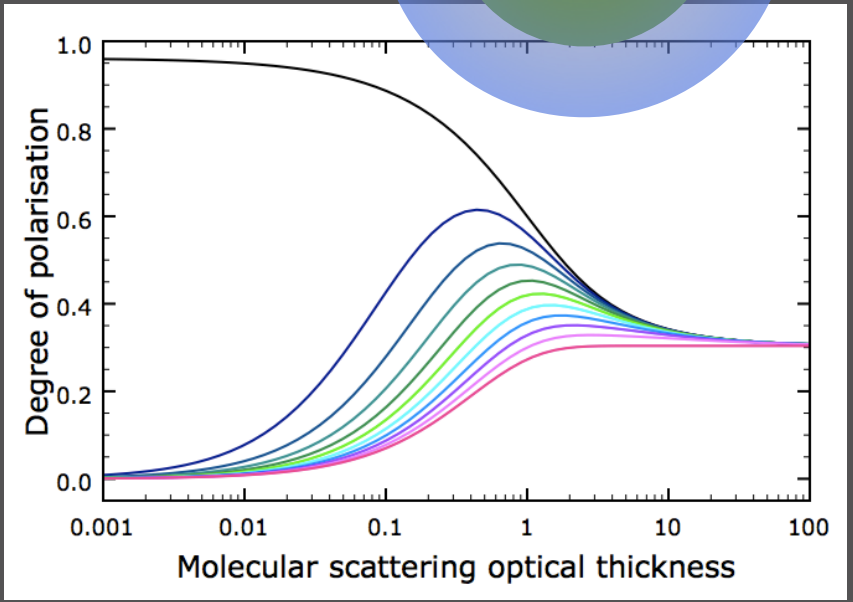
Surface pressure

The influence of the surface albedo:





Rayleigh scattering atmospheres, no absorption, Lambertian surfaces.
Phase angle is 90° (included in albedo).

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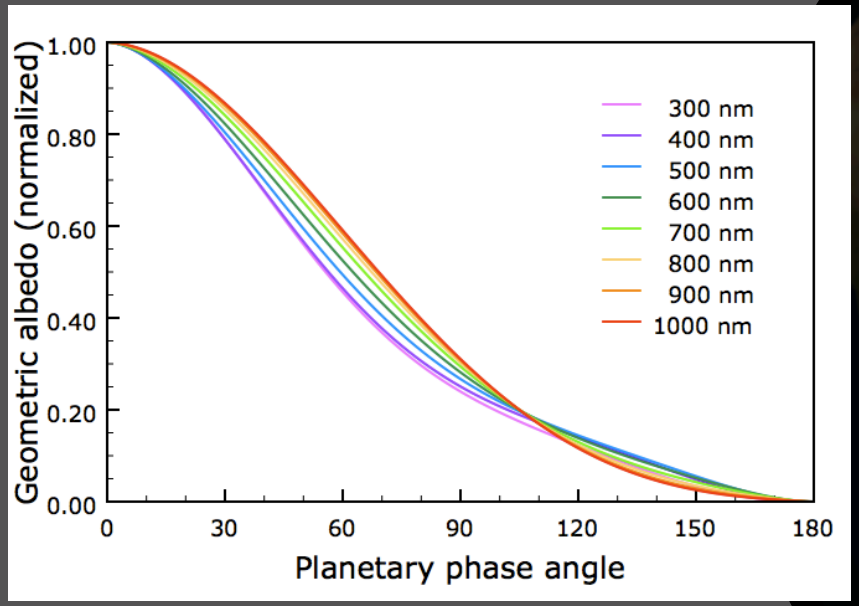
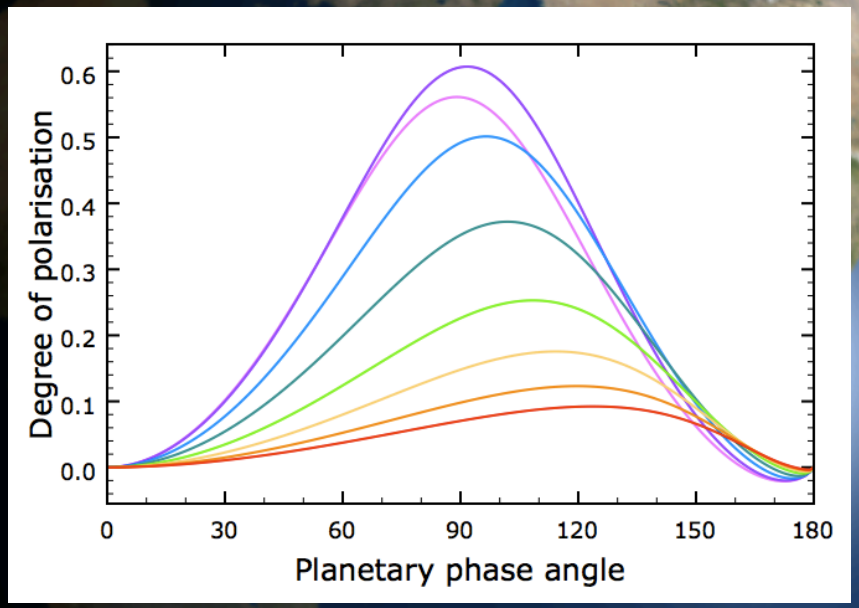
... for a planet without clouds

The albedo and degree of polarisation of the Earth at various wavelengths, i.e. optical thicknesses:





Rayleigh scattering atmosphere, no absorption, no clouds, surface albedo 0.1.

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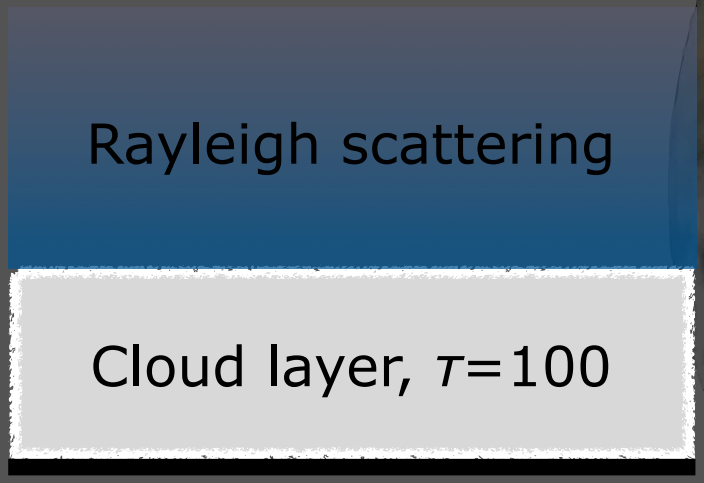
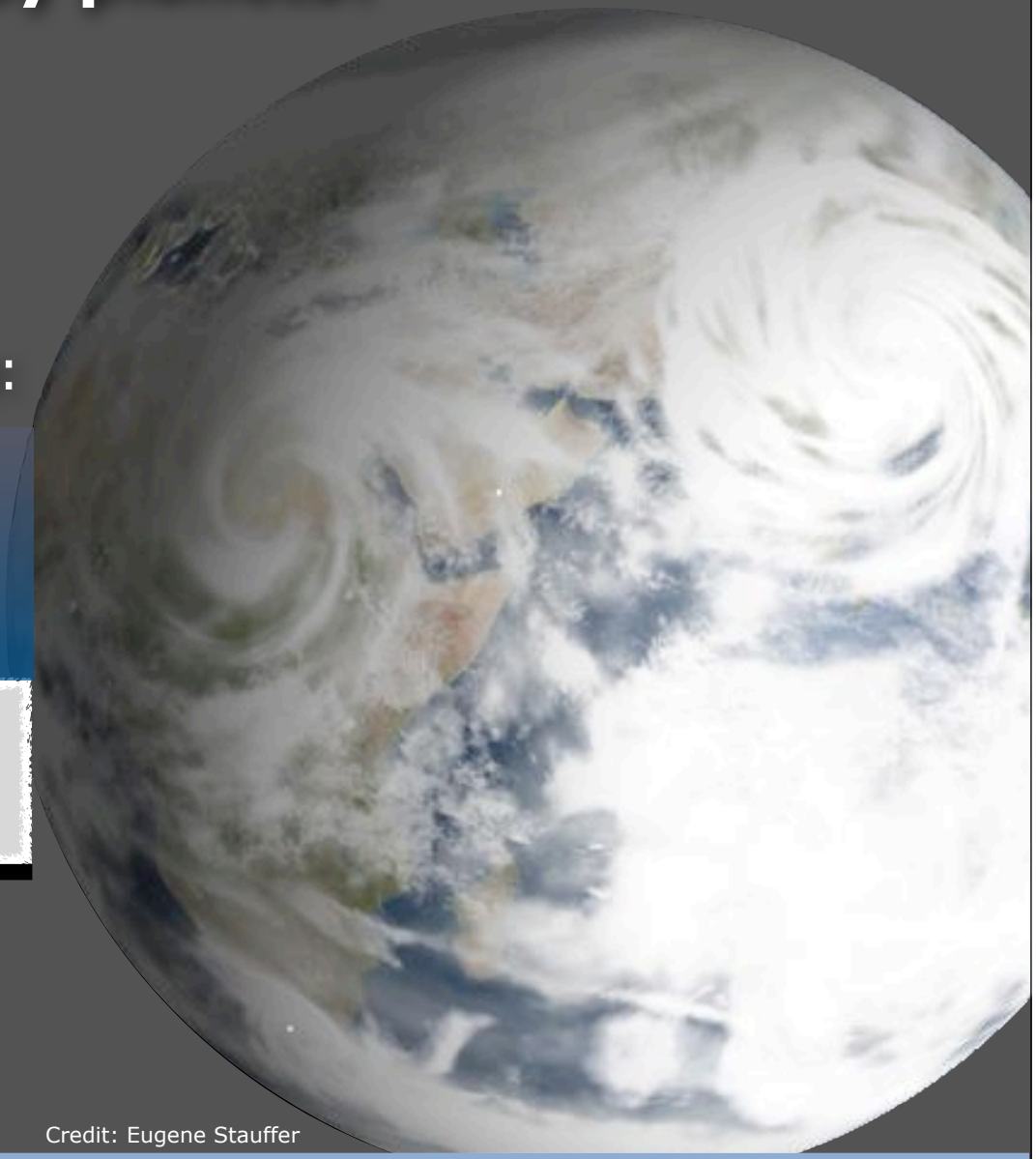
… what about cloudy planets?

The model atmosphere:





Credit: Eugene Stauffer

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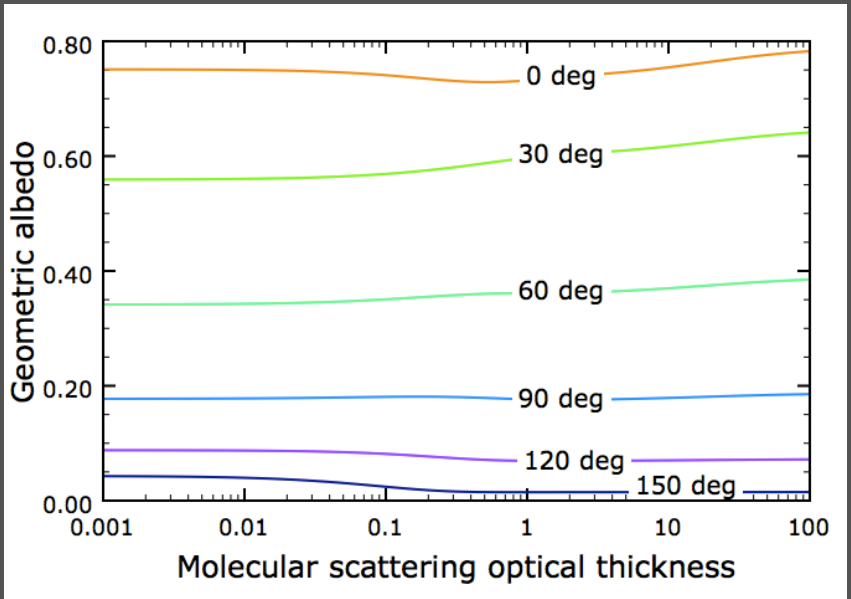
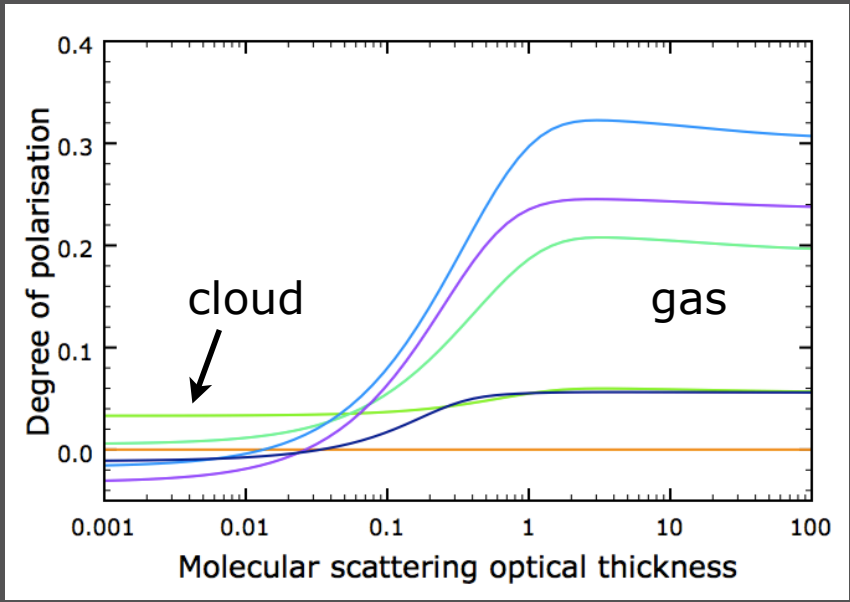
Cloud top pressure

The cloud top pressure can be derived from
the molecular scattering optical thickness above the cloud:





Rayleigh scattering atmosphere, bounded below by a τ=100 cloud layer.
Spherical cloud droplets, with r_{eff}=2.0 μm, n_r=1.3 and n_i=0.00001.

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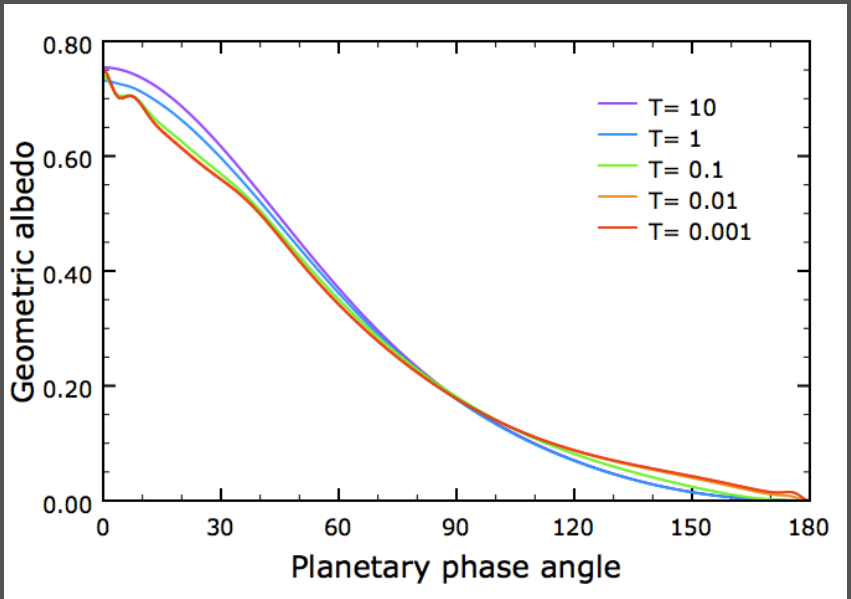
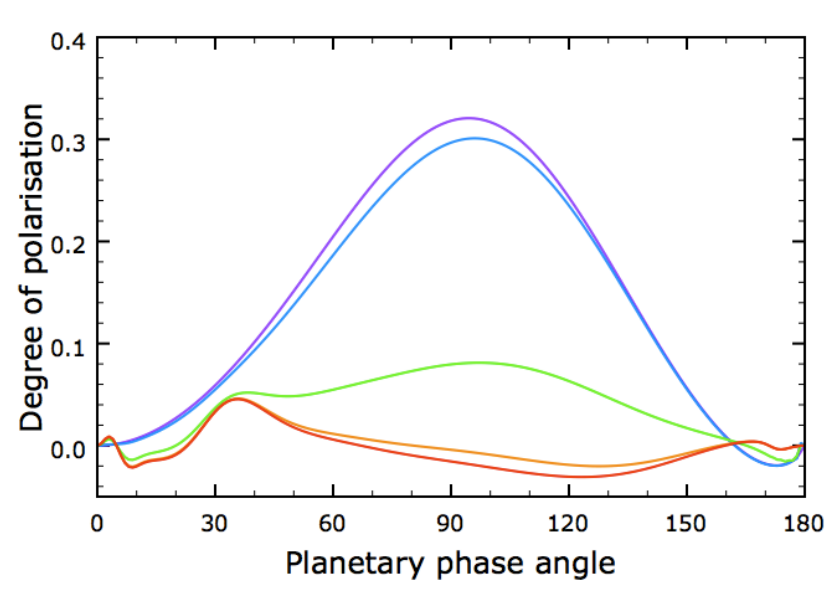
… as functions of a planet's phase angle

The albedo and degree of polarisation of a cloudy planet at various molecular scattering optical thicknesses τ:





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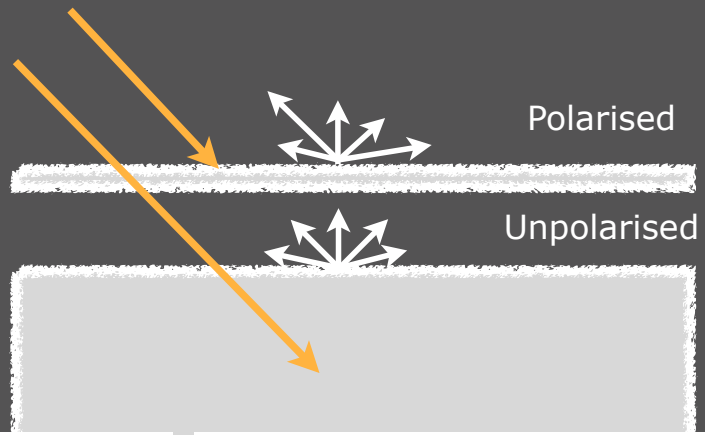

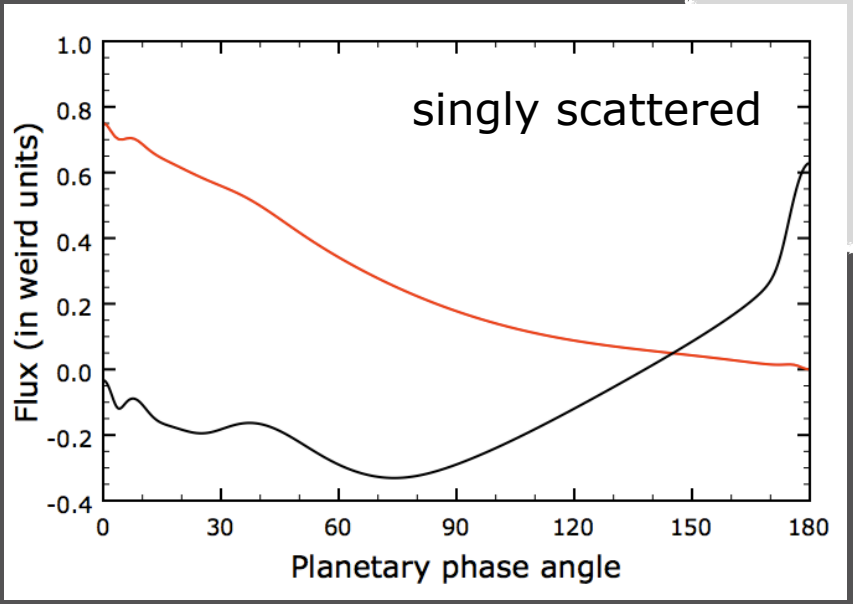

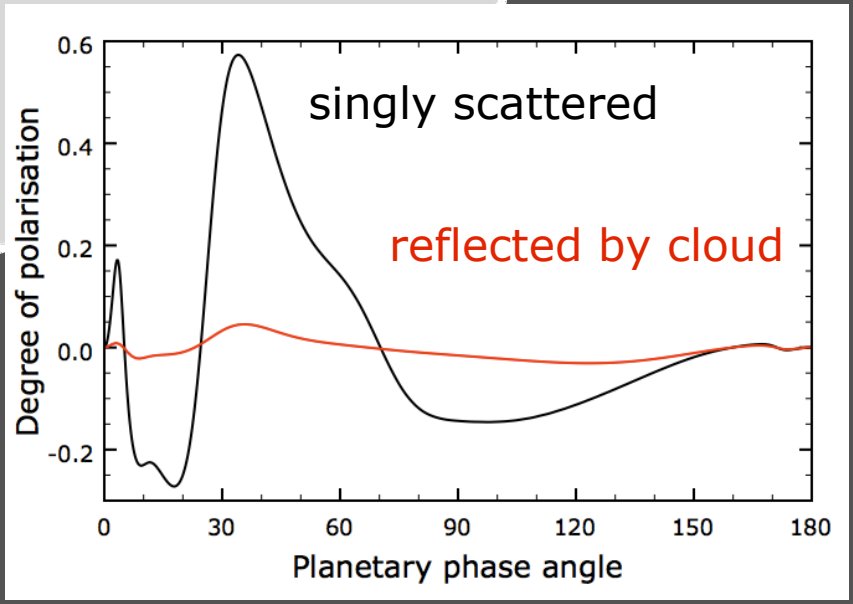

Rayleigh scattering atmosphere, bounded below by a τ=100 cloud layer.
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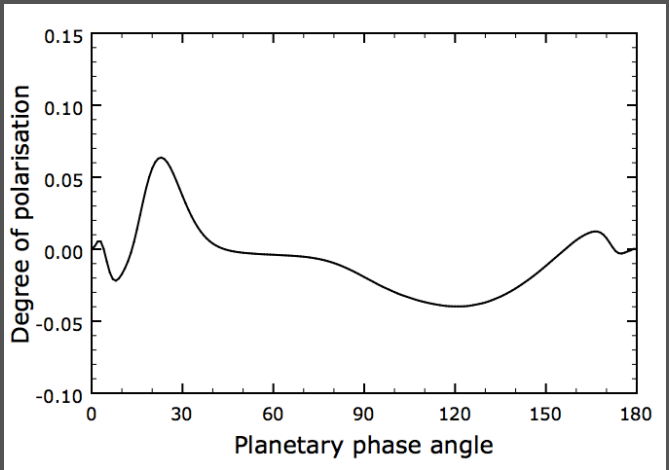
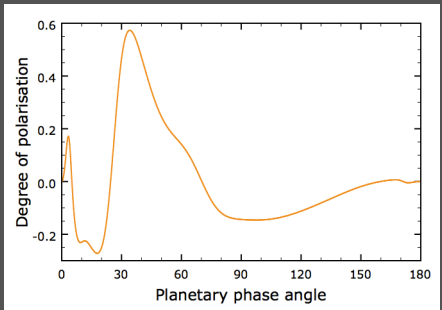
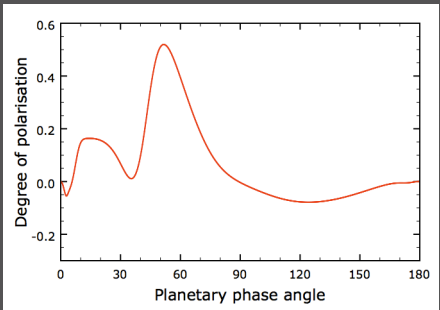
Quiz

Which particles are found on this planet?

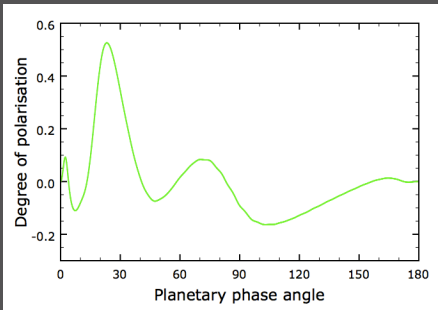




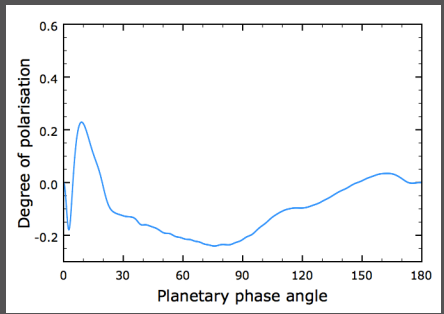
A



B



C



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Summary

- The degree of polarisation of planetary light contains information that cannot be obtained from the flux:
  - surface pressure
  - cloud top pressure/altitude
  - cloud particle microphysical properties

- The degree of polarisation should be measured at several, at least 2, wavelengths

- The degree of polarisation should be measured with a precision better than 5%, preferably better than 1%

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