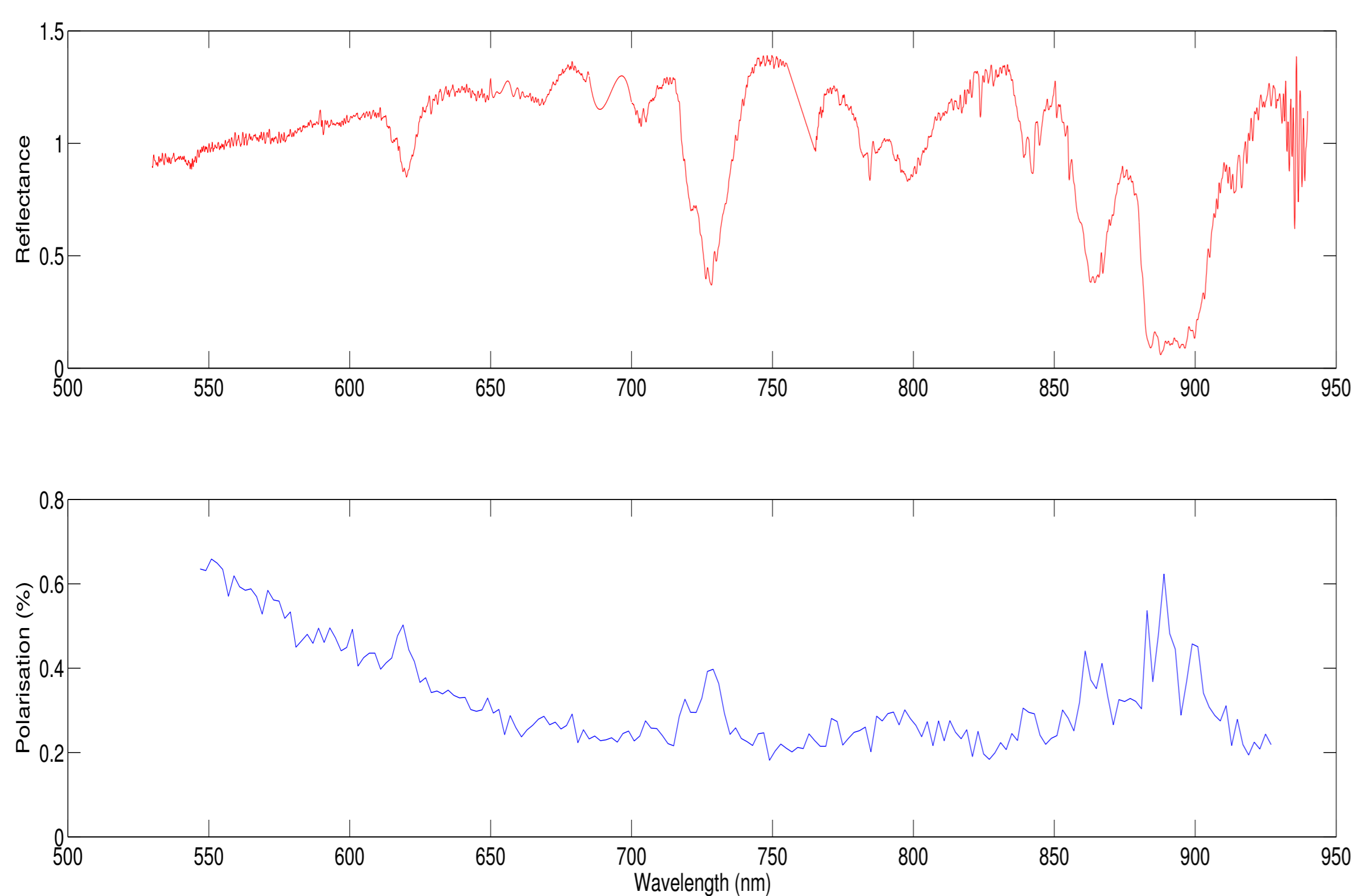


## Introduction

- ▶ Spectropolarimetry is a complementary method to traditional intensity measurements, which can yield additional diagnostic content.
- ▶ Integrated over the disk of the star, stellar light is generally unpolarised. This means that polarised signatures from a system with an exoplanet could be due to light scattered by the atmosphere, and/or surface of the planet.
- ▶ The application of spectropolarimetry to exoplanet science is at the limit of current instrumentation, but in the meantime the planets of the solar system provide an excellent opportunity to take benchmark data, with which future observations of exoplanets can be compared with.

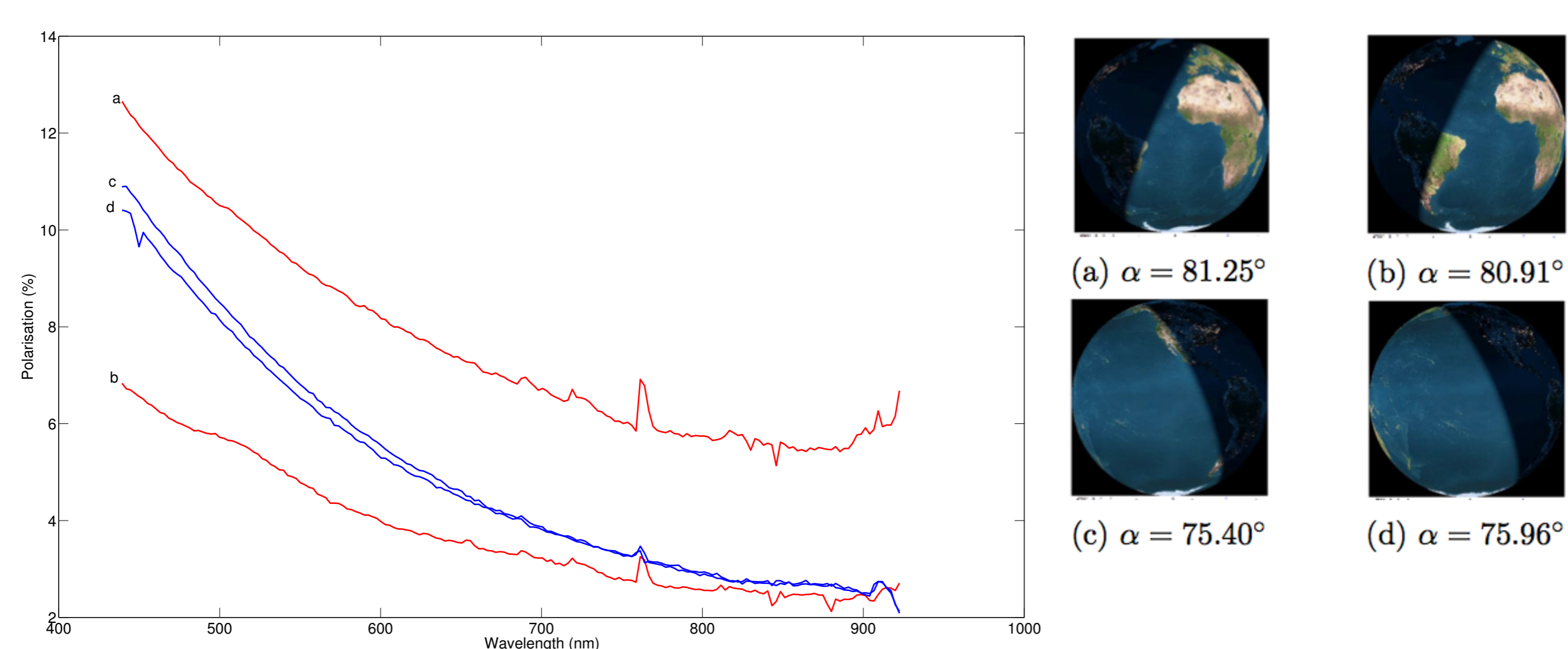
## Solar System Observations I: Saturn

- ▶ Polarimetry can be used for characterising exoplanets, since the planet's degree of polarisation as a function of wavelength and/or planetary phase angle is sensitive to the structure and composition of the planetary atmosphere and surface. This application of polarimetry is well known from remote sensing of solar system planets<sup>1,2</sup>.
- ▶ Due to our location in the solar system, the outer planets are only accessible to us at small phase angles, where the disk-integrated polarisation is almost zero. Even with such low polarisation values, features due to atmospheric absorption are still visible in the polarisation spectra.



- ▶ The top figure shows the reflected flux spectrum of Saturn, with strong absorption in several methane bands around 620nm, 728nm, and 890nm. The same features are also present in the polarised intensity, in the lower figure.
- ▶ Since it will be difficult to disentangle the flux of an exoplanet from its parent star, and if the orbital geometry is not favourable for transit spectroscopy measurements, spectropolarimetry may be an alternative method with which to probe the structure of these planets.

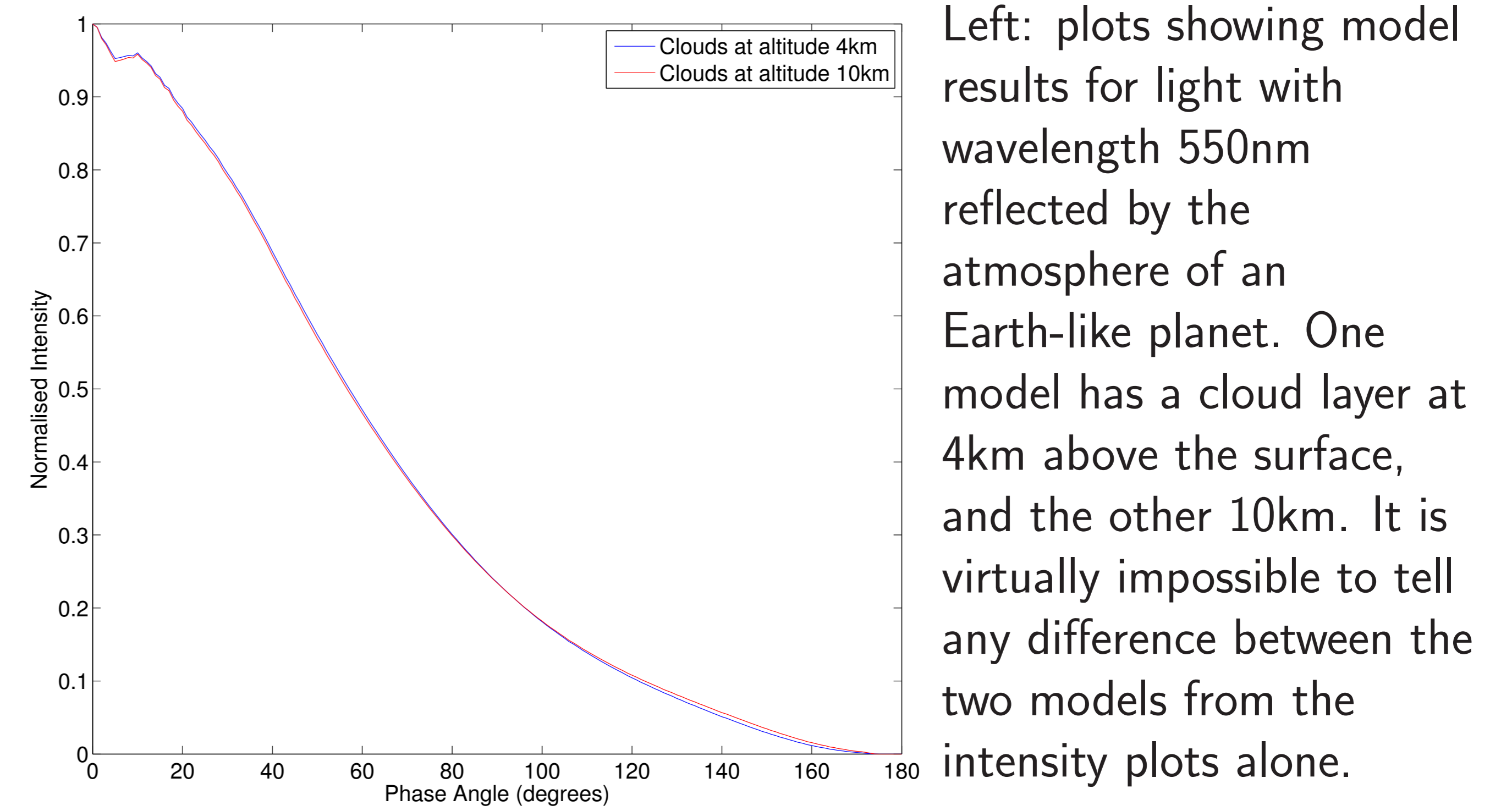
## Solar System Observations II: Earth



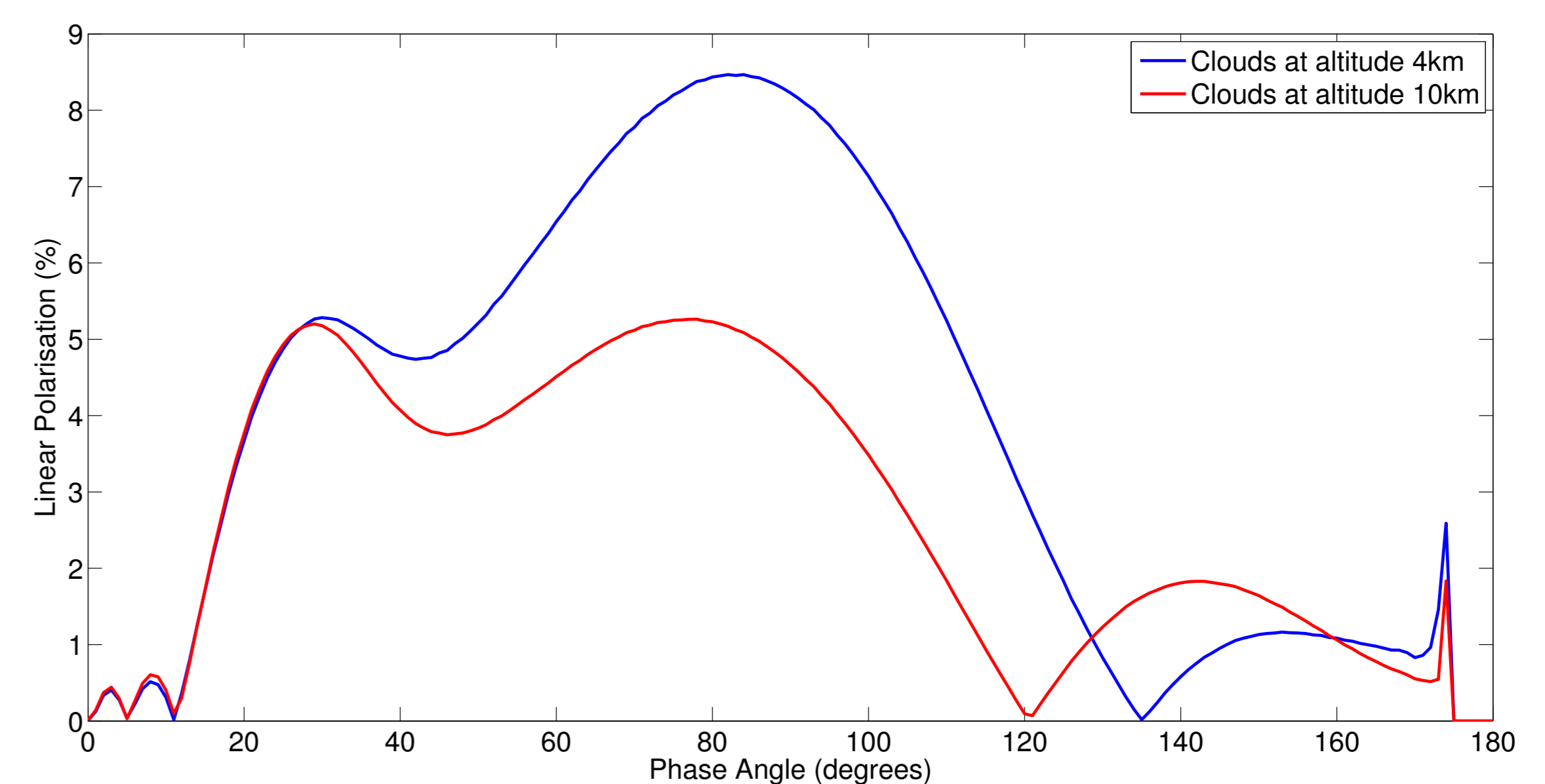
- ▶ Earthshine is sunlight which has first been reflected by Earth, and then reflected back to Earth by the Moon.
- ▶ Observations of earthshine allow the the fractional contribution of clouds and ocean surface to be determined, and are sensitive to visible areas of vegetation as small as 10 percent<sup>3</sup>.
- ▶ The red plots (a and b) are for when the African continent is most dominant on the lit part of Earth, and the blue plots (c and d) are for when the Pacific ocean is most prevalent.
- ▶ Earthshine observations represent a benchmark for studying the atmospheric composition, cloud height and surface properties of exoplanets.

## Modelling the polarised light from exoplanets

The polarisation of light reflected by planets with different atmospheric configurations has been modelled<sup>4,5,6</sup>, and these models show that changes in the atmospheric structure can have a large impact on the polarisation.



Left: plots showing model results for light with wavelength 550nm reflected by the atmosphere of an Earth-like planet. One model has a cloud layer at 4km above the surface, and the other 10km. It is virtually impossible to tell any difference between the two models from the intensity plots alone.



Above: plots showing the corresponding linear polarisation for the same two models. The plots at the two cloud-heights illustrate the difference in linear polarisation caused by differing cloud altitudes in the atmosphere. Also clearly visible are the peaks in the polarisation due to the primary rainbow feature, something which is completely masked in intensity measurements. The sharp zero-points indicate a change in direction of polarisation, and at 180 degrees, the flat curve is due to a loss of numerical accuracy.

## Future Work

- ▶ Further polarimetric observations of the planets and moons of the solar system are planned, for different filters.
- ▶ The polarisation of the light reflected by these planets will be modelled, with the idea to build up a database of what to expect from polarimetric observations of exoplanets.
- ▶ Models of the polarisation of light due to reflection by exoplanets with different types of surface and atmosphere will be carried out.

## Summary and Conclusions

- ▶ Polarimetry is a successful technique for characterising objects of our solar system, including the planets - even at very small phase angles.
- ▶ Polarimetry can be used to detect and characterise exoplanets. If the reflected light from an exoplanet is lost in the overwhelming glare of the stellar flux, then polarisation may be used to disentangle the planet's signal, since the stellar light is virtually unpolarised.
- ▶ Observationally, the polarimetric study of exoplanets is still in its early stages, with the recent installation of SPHERE<sup>7</sup> at the VLT, and planned instrumentation for larger telescopes such as the E-ELT.

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