Polarimetry of Jupiter: observations and modelling

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Contents

Introduction

- Observations were taken with the 1 metre Calern telescope, France, over a period of two nights, from 25/02/15 - 26/02/15.
- Polarimetric maps were produced from the data.
- Modelling was carried out using a code written by Daphne Stam, whom I was able to work with thanks to two STSM grants.

Image from http://www.beyond.fr/sitephotos/cerga-observatory-photo-gallery.html

Motivation: what can the polarisation of light reflected by Jupiter tell us?

- The polarisation depends on the properties of the scattering particle, mainly the size, shape, and chemical composition. It is also wavelength, and phase angle, dependant.
- Additionally, polarimetric studies of the Solar-System planets represent a benchmark for future polarimetric observations pertaining to the characterisation of exoplanet surfaces and atmospheres.

Phase angle

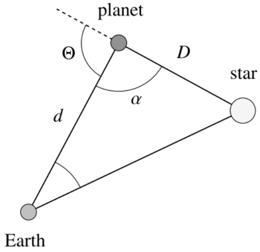
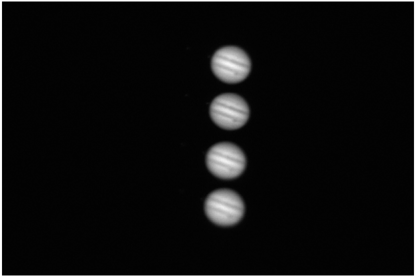


Image credit: Stam, D.M., Hovenier, J.W., & Waters, L. B. F. M. 2004, A&A, 428, 663

In the Solar System α is the angle between the Sun, the target, and the observer (known as the phase angle, or STO angle). Θ = (180° - α)

Observations I

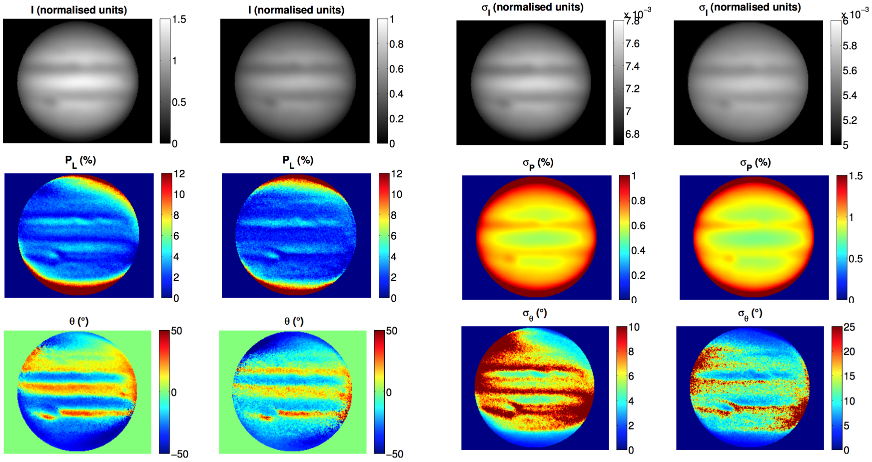
- Three sets of data were taken, in the B, V, and R filters.
- To increase the signal-to-noise ratio, six images at the start were combined, and six images at the end of each set.



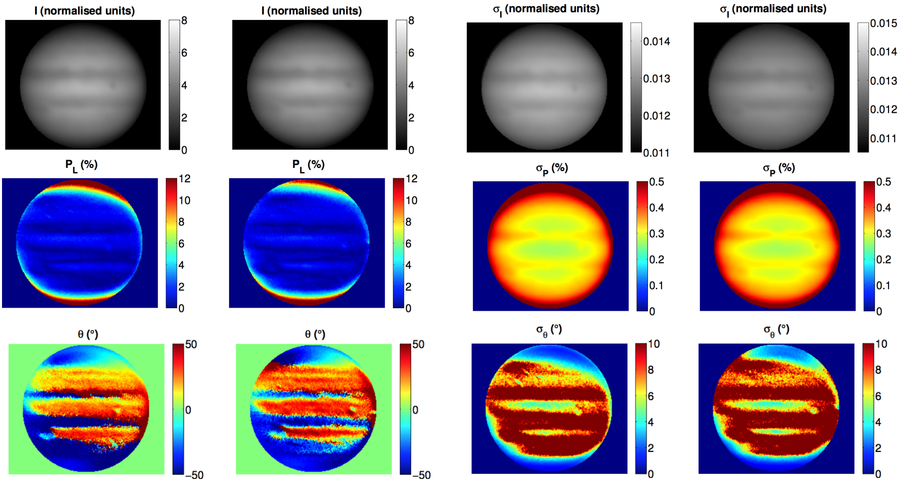
Observations II

Date	Time (UT)	STO (°)	Filter	Phase	P_L (%)
25/02/2015	21:52	3.94	R	0	0.13±0.22
25/02/2015	22:02	3.94	R	0.0167	0.14±0.22
25/02/2015	22:03	3.94	V	0.0179	0.29±0.23
25/02/2015	22:13	3.94	V	0.0346	0.29±0.23
25/02/2015	22:14	3.94	B	0.0366	1.86±0.21
25/02/2015	22:24	3.95	B	0.0537	1.87±0.21
26/02/2015	00:03	3.96	R	0.2183	0.04±0.22
26/02/2015	00:13	3.96	R	0.2350	0.12±0.22
26/02/2015	00:13	3.96	V	0.2355	0.30±0.23
26/02/2015	00:23	3.96	V	0.2522	0.28±0.24
26/02/2015	00:23	3.96	B	0.2532	1.88±0.21
26/02/2015	00:33	3.96	B	0.2699	1.83±0.21
26/02/2015	21:13	4.13	V	0.3509	0.55±0.24
26/02/2015	21:24	4.13	V	0.3684	0.55±0.24
26/02/2015	21:24	4.13	R	0.3687	0.75±0.23
26/02/2015	21:35	4.13	R	0.3869	0.73±0.28
26/02/2015	21:35	4.13	B	0.3873	2.41±0.47
26/02/2015	21:40	4.13	B	0.3958	2.39±0.66

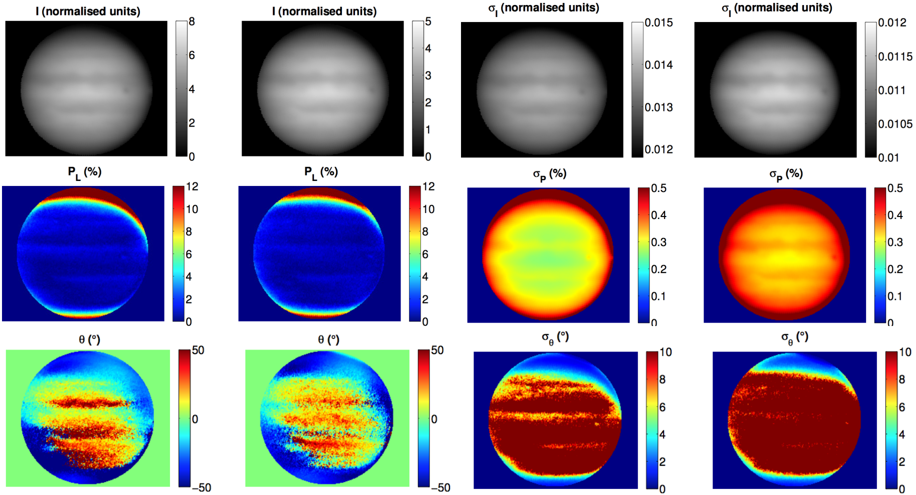
Polarimetric maps: B filter



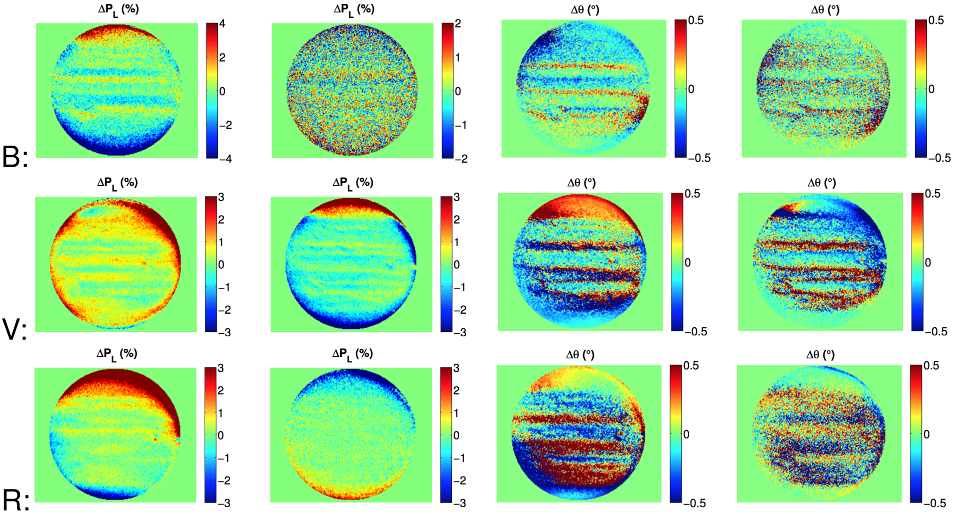
Polarimetric maps: V filter



Polarimetric maps: R filter

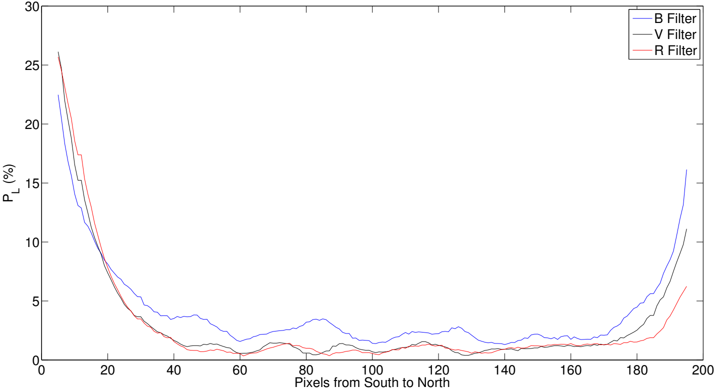


Null images


ΔP_L (%)
4
2
0
−2
−4
ΔP_L (%)
2
1
0
−1
−2
Δθ (°)
0.5
0
−0.5
Δθ (°)
0.5
0
−0.5
B:
ΔP_L (%)
3
2
1
0
−1
−2
−3
ΔP_L (%)
3
2
1
0
−1
−2
−3
Δθ (°)
0.5
0
−0.5
Δθ (°)
0.5
0
−0.5
V:
ΔP_L (%)
3
2
1
0
−1
−2
−3
ΔP_L (%)
3
2
1
0
−1
−2
−3
Δθ (°)
0.5
0
−0.5
Δθ (°)
0.5
0
−0.5
R:

Latitudinal cuts

Mean latitudinal cuts of P_{L} in each filter:



What do these results mean?

- It has been shown before that the polarisation of Jupiter increases towards the polar regions (see for example Dollfus (1957), Shalygina et al. (2008), and most recently Schmid et al. (2011)).
- Previous studies have shown that Jupiter has ammonia ice clouds, with a higher cloud layer in the zones than the belts (for example, see Ingersoll (2004)).
- The poles are covered by a thick haze, the composition of which is still unknown.
- Models can help to constrain the properties of these hazes; polarisation is sensitive to the size, shape, refractive index, and density of these hazes.

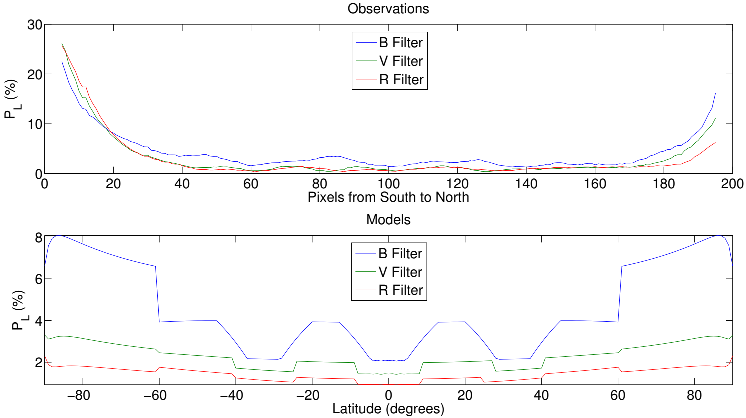
The radiative transfer model

- An adding-doubling radiative transfer code, fully incorporating multiple scattering and polarisation (see Stam (2008), and references therein).
- Atmosphere of Jupiter is divided into discrete layers. Each layer contains molecules (hydrogen, helium, and methane), the amount of which is specified by the pressure at that atmospheric height.
- Other types of particle can be added into the code, through additional input files.
- A separate code is used to integrate the results across the planetary disk. For this study, the polarisation for each pixel across a latitudinal cut was calculated. Different input files were used, depending on which region of the planet is considered.

Model parameters

- Divide planet into belts and zones. All regions have a thick layer of ammonia ice cloud, with the cloud deck higher in the zones.
- The term 'cloud' is used to describe thick layers of large particles ($\geq$ 1μm), whilst 'haze' is used in relation to optically thin layers of sub-micron sized particles.
- Belts have a thin haze layer present. Polar zones have the same haze, but much thicker.
- All cloud and haze particles considered are spherical, with their scattering properties calculated from a separate Mie algorithm.

Model results



Interpretation

- Observations in all three filters show a steep increase in polarisation toward the polar regions. Consistent with previous studies.
- Models replicate this, using a thin haze layer in the belts, and a thick haze in the polar regions. Increase in polarisation not as great as in the data, but this is possibly due to image alignment errors.

Future work

- Different models will be carried out, with other haze particle types, and will eventually be published.
- The effect of non-spherical particles will also be investigated.
- Further observations at different rotation phases can help constrain particle properties in the Jovian atmosphere.
- Spectropolarimetric models of other giant planets: Saturn, Uranus and Neptune will be attempted using the same code.

Conclusion

- Models show a good fit to the latitudinal variation of Jupiter's polarisation.
- A big thank you to Dr Daphne Stam for granting me the use of her code, and for teaching me how to use and modify it appropriately for my applications.
- I'd like to acknowledge my gratitude to the COST action, without the two STSMs I was granted, this work would not have been possible, and ultimately will be a major factor in completing my PhD.
- Thank you for listening. Are there any questions?