EPSC Abstracts
Vol. 9, EPSC2014-300, 2014
European Planetary Science Congress 2014

Optical linear polarimetric observations of Solar System bodies using a Wedged Double Wollaston

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Abstract

The gases and aerosols contained in a planetary atmosphere leave characteristic signatures on the radiation reflected from the planet. The technique of polarimetry utilizes the polarization state of emergent radiation (degree and direction for linearly polarized light) to investigate the atmospheric optical properties of the planet [3]. Polarimetry complements the more extended technique of photometry by probing different atmospheric altitudes, and is very well suited to characterize the particles in suspension in the atmosphere. A classical example for the latter is the identification of the Venus cloud composition as a combination of H2SO4/H2O droplets from the disk-integrated polarization phase curves of the planet [2]. In observations with spatial resolution of the planet disk, polarimetry may be sensitive to the phenomenon of limb polarization and to the occurrence of polar hazes (as for Jupiter, [5]). Despite the potentialities of the technique, there has been no systematic survey of the Solar System planets in polarimetric mode.

We report on the first polarimetric tests of Jupiter we have recently carried out with a Wedged Double Wollaston (WeDoWo) prism attached to the ALFOSC instrument, currently mounted at the 2.5m Nordic Optical Telescope (NOT) [4]. In the near future we plan to extend the use of this device to other objects of the Solar System, where polarimetric observations could provide valuable physical information.

1. Introduction

Very recently our collaboration, formalized as "Unidad Asociada Grupo Ciencias Planetarias" (*http://www.iaa.es/es/content/unidad-asociada-grupo-de-ciencias-planetarias*), has just acquired the Wedged Double Wollaston (WeDoWo, [5]) of the 2.5m Nordic Optical Telescope (NOT; *http://www.not.iac.es*). The goal is to perform polarimetric studies of objects of different origin, ranging from the most distant Gamma-Ray Bursts [6], to the closest bodies in the Solar System. In this framework, our group has just kicked out this new scientific adventure by gathering data of Jupiter using the WeDoWo (see Sect. 2).

The WeDoWo is a smart combination of two Wollaston prisms and two glass wedges which allows simultaneous polarimetric polarization at 0, 45, 90 and 135 degrees. The WeDoWo that we used is included in the ALFOSC instrument currently mounted at NOT. The most important advantage of the WeDoWo with respect to other traditional imaging polarimeters (polarizer platers, calcite prisms or Wollaston prism) is its capability to determine the linear polarimetric parameters (Q,U) with a single exposure. This assures that (Q,U) are simultaneously determined, hence at identical atmospheric conditions. Another important advantage is the lack of movable pieces (like λ/2 retarder plates present in many optical polarimeters) which makes the WeDoWo a very mechanically robust device.

The input photons of the WeDoWo emerge at 4 different angles which relative intensities depend on the polarization angle and degree of the input light. This is translated into 4 images on the CCD (see Fig. 1). In order to avoid overlap between the 4 images, a field mask is used, limiting the effective field of view to 10"x6.4'. The WeDoWo can be combined with a broad set of filters mounted on ALFOSC. The WeDoWo is specially designed to gather polarimetric information of variable phenomena. In the particular case of Jupiter the device is ideal to study short time-scale events (like impacts or rapidly variable phenomena). In addition, for the typical Jupiter exposure times (max. 20s) the data would be basically free of the effect of planetary rotation. The calculation of the (Q,U) Stokes parameters is immediate since they are obtained just by arithmetic operations using the intensities of the four images.

2. First observations of Jupiter

Two observing runs were carried out on 2014 Feb. 11 and March 6 using a wide set of filters (Strömgren *u,b,v,y*, among others). The data reduction was carried out with IRAF [7] by performing standard bias and flat field corrections. Polarimetric standards HD25443 and G191B2B were observed in order to correct possible instrumental polarization effects. Currently, the polarimetric data are being analyzed.

3. Modelization of the WeDoWo polarimetric data

The observational work is being complemented with modelling. For that purpose, we are using a novel Pre-conditioned Backward Monte Carlo (PBMC) algorithm [1] that computes the full Stokes vector for multiple scattering. The model handles spherical, stratified atmospheres. As all backward-integration MC algorithms, the PBMC model builds the solution by tracing the simulated photons from the observer through the atmospheric medium. By exploring the space of input model parameters, we intend to constrain the optical properties of the planetary atmospheres under investigation.

Acknowledgements

The data presented here were obtained with ALFOSC, which is provided by the Instituto de Astrofisica de Andalucía (IAA) under a joint agreement with the University of Copenhagen and NOTSA. We wish to thank the Euskampus and the Ikerbasque foundations for their support to the Unidad Asociada UPV/EHU-IAA/CSIC. This study has been supported by Spanish research projects AYA2012-39362-C02-02, AYA2012-39727-C03-01, AYA2009-14000-C03-01, AYA2012-36666 with FEDER support, Grupos Gobierno Vasco IT765-13 and UPV/EHU UFI11/55. We thank M. Jelínek and A. Márquez Lugo (both at IAA-CSIC) for acquiring the Jupiter images. We also thank the NOT staff, specially Thomas Augusteijn and John Telting for very valuable help with the WeDoWo tests.

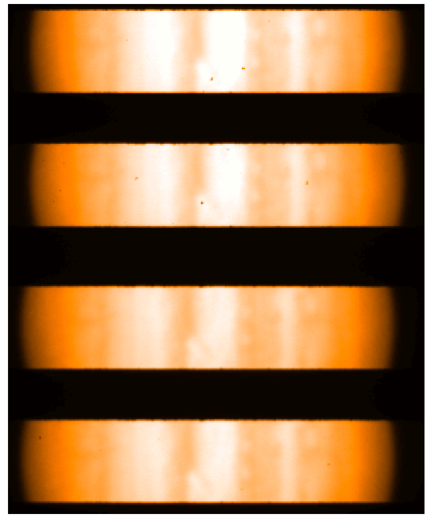

Figure 1:. Jupiter imaged with the WeDoWo using a narrow-band filter centred at 7510Å. ALFOSC was intentionally rotated so the WeDoWo slit did contain both Jupiter poles. The exposure time is 20s. For broader filters the exposure times can be as short as 0.1 s.

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