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Investigating circular patterns in linear polarization observations of Venus

G. Mahapatra (1), D.M. Stam (1), Loïc Rossi (1), Michiel Rodenhuis (2), Frans Snik (2) and C.U.Keller (2)
(1) Faculty of Aerospace Engineering, Delft University of Technology, Kluywverweg 1, 2629HS Delft, The Netherlands
(2) Sterrewacht Leiden, Leiden Observatory, Leiden, The Netherlands

Abstract

In this work, we analyse linear polarization data of the planet at a distance, obtained with the Extreme Polarimeter (ExPo) on the William Herschel Telescope on La Palma. These spatially resolved, high-accuracy polarization observations of Venus show faint circular patterns centered on the sub-solar point that are absent in the flux observations. So far, careful analyses have ruled out instrumental effects which leaves us to wonder about atmospheric properties on Venus as the cause of the circular patterns. Using numerical simulations of the flux and polarization of sunlight that is reflected by Venus, we have investigated the relation between the observed patterns and several atmospheric properties, such as variations in particle sizes, composition, density and altitude. We discuss the plausibility of the possible causes in the view of the current knowledge of the composition and dynamical processes in Venus's atmosphere.

1. Introduction

The dynamic nature of Venusian climate has been a source of constant study due to its dense CO_2 atmosphere combined with sulphuric acid clouds and hazes. Gravity waves of various shapes and sizes have been observed on the clouds starting with Mariner 10 and Pioneer Venus ([3]), the Venera mission and the Magellan spacecrafts. The European VEx mission has studied such waves in great detail and has reported the fluctuations to be in temperature and cloud layers ([1]). Recently planetary wide gravity waves were detected by the Japanese Akatsuki mission ([2]).

Photopolarimetry as a tool, has played a vital role in constraining the cloud and haze particle properties of Venus as was shown by [4]. In this work we present the ground-based observations of Venus using the Extreme Polarimeter (ExPo) instrument at the William Herschel Telescope on La Palma at different wavelengths in visible, using both narrow and broad-band filters. We also present our modelling efforts to explain the observed fluctuations in polarized flux using our doubling-adding radiative transfer code (see [8]) which accounts for multiple scattering of light from the Venusian atmosphere and computes all the components of polarized light for a spatially resolved disk with multiple layers of cloud and gas with definable particle properties.

2. Observations of Venus

Our Venus observations have been carried out with the ExPo imaging polarimeter installed at the William Herschel Telescope on La Palma. This instrument has been designed for the observation of faint, linearly polarized light scattered by circum-stellar material. The instrument is very sensitive to linearly polarized light, capable of reaching a sensitivity of 10^{-4} provided enough photons are available. At the time of observations, the Venus phase angle was 48.7° and its angular diameter 12.5". Six different filters were used, four narrow-band and two broadband. The results we report are not suspected to be caused by physical effects in the corresponding spectral lines.

In all our observations we see increased polarization in regions near both poles. A second feature, observed only in the narrowband images, is an intriguing structure consisting of several thin rings extending across the illuminated disk of Venus. Calibrated polarized intensity images are shown for two filters in Fig. 1.

3. Model simulations

We describe the sunlight that is incident on a planet and the scattered light by the planet by Stokes vectors I, Q, U and V ([9]). Our radiative transfer code computes all the components of polarized flux for a wavelength of choice from a spatially resolved planet with a horizontally homogeneous but vertically inhomogeneous atmosphere (see [8]). It assumes a plane-parallel approximation.

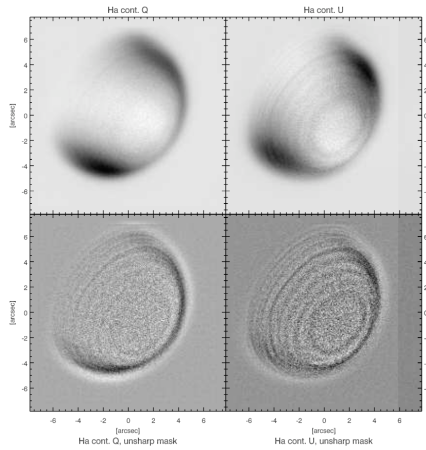

Figure 1: Calibrated Stokes Q and U images (top) and with an unsharp mask subtracted (bottom).

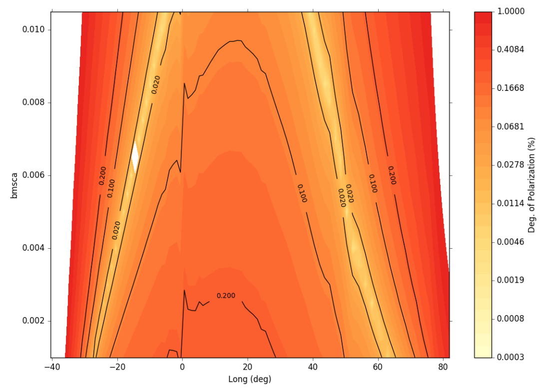

Figure 2: Contour plot showing fluctuations degree of polarization with increasing scattering optical thickness for a model Venus atmosphere. The spikes around 0° longitude are a numerical effect.

We carry out our simulations for a model Venus CO_2 atmosphere with cloud layers of aerosol optical thickness, b_{aer}=256, to simulate a semi-infinite cloud layer. The haze layers above the cloud deck has a scattering optical thickness, b_{aer}=0.1. Finally we set our model with another gas layer above the haze layer to simulate Venus conditions, with a standard molecular scattering optical thickness, b^m_{sca}=0.005. Since the observations show planet-wide faint fluctuations in polarized flux, we rule out the possibility of variations observed to be caused by clouds and hazes. Fig. 2 shows the simulations of increasing b^m_{sca} above the base cloud+haze+gas layer model with respect to the standard value, along the longitude.

Our model simulations show the sensitivity of changes in b^m_{sca} to the resulting polarized flux. We find that slight changes in b^m_{sca} (in the order of 10^{-3}) results in significant changes (in the order of 10^{-1}) in polarized flux. Such changes might be explained due to the density variations in the gas layer above the clouds and haze.

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