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Near-infrared spectra of Saturn's ring spokes from Cassini-VIMS data

E. D'Aversa (1), G. Bellucci (1), G.Filacchione (1), P.Cerroni (1), P.D.Nicholson (2), F.G.Carrozzo (1), F.Altieri (1), F.Oliva (1), A.Geminale (1), G.Sindoni (1), and M.M.Hedman (3)

(1) IAPS-INAF, Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy, (2) Cornell University, Ithaca, NY, USA, (3) University of Idaho, Moskow, USA (emiliano.daversa@iaps.inaf.it / Fax: +39-06-45488383)

Abstract

Saturn's ring spokes are still a not fully understood phenomenon, observed so far only during the three Saturnian equinoxes in the space era (every ~14 years). Cassini-VIMS observations during the 2009 equinox widened for the first time the spoke investigations to the near-infrared spectral range longward of 1 μm. Two sets of spoke sequences, at different solar phase angles, will be discussed here. The coverage of water ice and methane absorption bands of the VIMS spectra seems to suggest that further illumination sources other than direct sunlight are significant in producing the observed spoke reflectance, and the consequences for microphysics retrievals will be discussed.

1. Introduction

Saturn's B ring is known to sometime host some elongated ephemeral features appearing close to the Saturnian equinoxes. They have been imaged in the past in only three occasions: during 1980 equinox by Voyager cameras [1], during 1995 equinox through Hubble Space Telescope [2], and during 2009 equinox by Cassini camera [3]. Images showed spokes being darker than the ring at small solar phase angles and brighter at high phase angles. Moreover they move partially pushed by Saturn's magnetic field, suggesting that they are composed of very small charged dust/ice grains.

Physical models, based on electrostatic lifting of fine sub-micron grains from the regolith of ring's particles, have been developed since Voyager observations. However, there is not yet unanimous consensus on the formation mechanisms for spokes, in particular about the triggering process. Meteoroids bombardment has been earlier invoked as trigger ([4]), as well as precipitation of electrons from Saturn's lightning storms ([5]), while collisional cascade models have been proposed to trigger the formation of spokes from the debris of other spokes ([6]). In any case, the dynamical evolution of spoke's grains is driven by their mass and their charge, and both these parameters are rather poorly constrained by observations.

1.1 Spokes by Cassini-VIMS

Cassini mission allowed for the first time to observe spokes in the near-infrared, by means of the *Visual and Infrared Mapping Spectrometer* (VIMS). This is an imaging spectrometer providing data cubes in the 0.35-5.1 μm range with a 7 to 20 nm spectral resolution, and able to acquire images of the Saturn's ring with discrete flexibility in terms of spatial resolution, phase angle, and pointing. Dozens of spokes are detectable in VIMS images acquired for several months across the 2009 August equinox. They allow unprecedented studies on their spectral properties, with the purpose of retrieving composition and structure of spoke grains from the way they modify the B ring reflectance. Earliest analysis of this data suggested the presence in spokes of a population of micron-sized grains larger than previously thought ([7]). However, the retrieval of spoke properties from spectra is not straightforward as they act as a small perturbation of the ring's reflectance, often smaller than the strong radial variation of B ring. At the VIMS moderate spatial resolution, spokes often cover an unknown fraction of few VIMS pixels.

2. VIMS spectra of spokes

We will report here about two significant VIMS-IR spoke datasets (0.8-2.8 μm), acquired at very different solar phase angles, showing two sequences of bright and dark spokes.

A bright spokes sequence (figure 1) has been identified in a long staring data sequence of images at high phase angle (110°), where at least 7/8 spatially unresolved spokes can be found shining against a dark B ring. A dark spokes sequence (figure 2) has been found by mosaicking a low phase angle (40°) data sequence at much higher spatial resolution. Both sequences have been acquired by staring pointing to the morning ring ansa for a duration long enough to cover about one full rotation of Saturn.

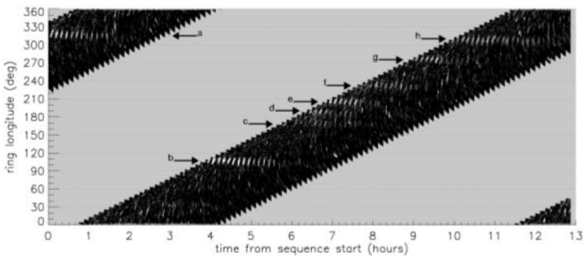

Figure 1: a sequence of bright spokes extracted from a VIMS data sequence at 110° phase angle.

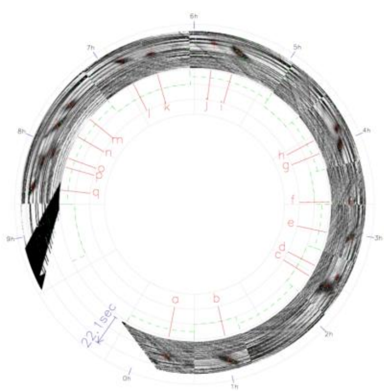

Figure 2: a sequence of dark spokes in a mosaic of VIMS data at 40° phase angle.

3. Multiple reflections

In the observing condition of the bright spokes sequence, the light scattered by the rings appear strongly contaminated by the illumination from Saturn (Saturn-shine), and this is particularly true for the B ring. Even when B ring reflectance is removed, bright spokes spectra clearly show reversed residual methane bands suggesting the spokes would be dark if viewed in Saturn's light only. Moreover, the spectra over both bright and dark spokes show enhanced water ice absorption bands_in respect to the B ring in the same observing conditions. At the current stage of analysis, the most likely explanation invokes ring-shine as a further illumination source, able to directly enhance the water ice signatures, as observed.

4. Summary and conclusions

Detection of multiple illumination sources for spokes other than direct sunlight is discussed. VIMS is the first instrument sensitive to these multiple shines on spokes thanks to the coverage of near infrared range. However these multiple shines can also affect the visible wavelength range, where all the results from previous studies about spokes microphysics rely, and where these effects are hardly recognizable. As a consequence, previous retrieval of spoke properties based on visible observations may be somewhat biased. De-biased retrievals require more complex models of radiative transfer, but may yield to spoke particles more isotropically scattering than previously thought, possibly confirming the higher concentration of µm-sized particles as suggested in [7].

Acknowledgements

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References

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