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Sensitivity assessment of MAJIS VIS-NIR for the aerosols properties of Jupiter’s atmosphere

Miriam Estefanía Cisneros González[1], Justin Erwin[2], Ann Carine Vandaele[2], François Poulet[3], Clément Lauzin[1], and Séverine Robert[2]
[1](1) Institute of Condensed Matter and Nanosciences (NAPS), Université Catholique de Louvain, Louvain-la-Neuve, Belgium (miriam.cisneros@aeronomie.be)
[2]Royal Belgian Instiutute for Space Aeronomy, Planetary Atmospheres, Brussels, Belgium
[3]Institute of Space Astrophysics (IAS), Orsay, France

The study of Jupiter’s atmosphere, its composition, evolution, distribution, structure, and dynamics around the planet, is of interest to the scientific community. The JUICE (JUpiter ICy moons Explorer) mission from the European Space Agency (ESA) launched in April 2023, will make detailed observations to characterize Jupiter’s atmosphere that are complementary to those from Juno. In preparation for its arrival in July 2031, we upgraded ASIMUT-ALVL, a line-by-line Radiative Transfer (RT) code developed at BIRA-IASB that has been extensively used to characterize terrestrial atmospheres (1), to also allow the characterization of Jupiter’s atmosphere. Since VIS-NIR spectrometry has a remarkable potential for characterizing the composition and dynamics of planetary atmospheres, we focused on the wavelength range between 0.5μm and 2.5μm, which will also be covered by the VIS-NIR channel of MAJIS (Moons And Jupiter Imaging Spectrometer), a hyperspectral camera on board JUICE.

To define Jupiter and its atmosphere into ASIMUT-ALVL, the reference atmospheric profile was taken from González et al. (2) which was extrapolated with constant values below the pressure level of 1bar, and the temperature profile was taken from Moses et al. (3) supplemented with data from Seiff et al. (4) for pressure levels down to 20bar. Since Jupiter’ upper atmosphere is mainly composed of hydrogen (H2), helium (He), and minor traces of other gases such as methane (CH4), ammonia (NH3) and water (H2O), its VIS-NIR spectrum is dominated by absorption bands due to the CH4 and NH3; Rayleigh scattering due to H2 and He; Mie scattering due to aerosols and haze; and Collision-Induced Absorption (CIA) due to H2-H2 and H2-He molecular systems (5). ASIMUT-ALVL calculates the molecular absorption cross-sections for each molecule by considering line broadening through collisions against H2 and He in Jupiter’s atmosphere. Although HITRAN is one of the most complete and widely used spectroscopic databases, it is incomplete for wavelengths shorter than 1μm. Therefore, the band models of Karkoschka et al. (6) and Coles et al. (7) were implemented for CH4 and NH3, respectively. The extinction coefficient for Rayleigh scattering is based on the calculation of its cross-section from the refractive indexes of H2 and He, determined from the refractivities measured by Chubb et al. (8) and Coles et al. (9), respectively, and the atmospheric King correction factor, obtained from the depolarization ratio of H2 as measured by Parthasarathy (10). The CIA contribution was implemented directly as a cross-section from Borysow (11) and Abel et al. (12) for H2-H2, and Abel et al. (13) for H2-He.

To model aerosols and hazes in Jupiter’s atmosphere, we implemented the Crème Brulee (CB) model of Baines at al.(14) and the aerosols model from López-Puertas et al. (5). The CB model offers a solution for chromophores in Jupiter, consisting of three layers of similar composition but different particle size distributions, with the chromophore layer just above the tropospheric cloud. The composition of the chromophore layer is defined as proposed by Carlson et al. (15), formed by the interaction of NH3 and acetylene (C2H2). The model of López-Puertas et al. (5) consists of a crystalline H2O ice cloud below 0.1mbar with particle sizes of □10nm and three haze layers based on a refractive index obtained from the combination of Martonchik et al. (16) (NH3 ice) and Zhang et al. (17) (CH4 and H2), with particle sizes between 0.1 and 0.6μm.

The updated performances of ASIMUT-ALVL were individually validated against KOPRA, an RT code developed by the Astrophysics Institute of Andalusia (IAA) already used for the study of Jupiter (18). The validation of the RT model finished with the comparison of the resultant spectrum against observational data from VIMS (Visible and Infrared Mapping Spectrometer) (19). Now it is possible to include the performances of other instruments in the VIS-NIR range, such as MAJIS (20), and simulate realistic observational scenarios to assess the impact of its capabilities on the characterization of the aerosols present in the atmosphere in comparison with previous instruments. The study of aerosols is mainly possible in the VIS-NIR range, and ASIMUT-ALVL is a new available tool to retrieve their detailed optical properties and vertical distribution, complementary to other models. Moreover, during this assessment, it is possible to optimize the spectral sampling of MAJIS, and provide valuable information for the data return of the instrument, planned during the science operations.

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