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# Development of a Monte-Carlo Radiative Transfer Code for the Juno/JIRAM Limb Measurements

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## Abstract

The Juno/JIRAM instrument will acquire limb spectra of the Jupiter atmosphere in the infrared spectral range. The analysis of these spectra requires a radiative transfer code that takes into account the multiple scattering by particles in a spherical-shell atmosphere. Therefore, we are developing a code based on the Monte-Carlo approach to simulate the JIRAM observations. The validation of the code was performed by comparison with DISORT-based codes.

## 1. Introduction

All the clues about the vertical distribution of gaseous species and aerosols in the planetary atmospheres have been discovered by nadir measurements of instruments aboard spacecrafts, ground-based observations, or predicted by models. Currently, the lack of robust radiative transfer codes able to simulate limb measurements (on Venus, Mars, Jupiter and Saturn) prevents a direct retrieval of the vertical structure of the atmospheres. The difficulty in modelling the radiative transfer for limb geometries is caused by the treatment of multiple scattering, which becomes very important in the infrared range when the atmosphere contains dust and/or ice aerosol particles.
The aim of our work is to develop a new robust algorithm able to take into account the multiple scattering by aerosols particles by using a radiative transfer code for optically spherically-symmetric and parametrically-defined atmosphere. This is the case of the "Monte-Carlo"-based codes, which calculate the spectral monochromatic intensity by a statistical modeling.

## 2. Instrument and Atmospheric Model

The JIRAM, Jovian InfraRed Auroral Mapper, is an imager/spectrometer aboard the NASA/Juno spacecraft. The JIRAM instrument is composed by an IR imager (IMG) and a spectrometer (SPE) [1]. The spectrometer, based on grating diffraction of a pixel size slit, covers the spectral interval 2.0-5.0 µm and has a FOV of 3.5° (across track) x 50" (along track) [1].

The Jupiter atmosphere is modeled using spherical shells having the thermal profile suggested by [2] and [5]. The composition of the gaseous atmosphere is the one adopted by [3], whereas the aerosol component is represented by one ammonia-ice cloud having the properties suggested by [11].

## 3. Method

The code is written in IDL and it is based on the SCATRD_OFOS [6, 10] routine. It calculates spectral monochromatic intensity for optically spherically-symmetric and parametrically-defined atmosphere using the statistical Monte-Carlo approach. The current version does not implement thermal radiation, non-LTE emission, refraction and polarization processes. The monochromatic spectrum so obtained is finally convoluted for the instrumental function.

The MCRT (Monte Carlo Radiative Transfer) codes are more sensitive to the optical depth than the other ones. To decrease the loss of photons in the crossing of an optically-thick atmosphere (Jupiter case), i.e., to increase the probability that a photon can reach the detector, we split each atmospheric layer in several sub-layers. We developed this algorithm dynamically: the total number of atmospheric layers changes for different grid points and the computational time is optimized. Applying this algorithm the code results to be stable even in optically thick atmospheres.

The validation of our MCRT code was performed by comparing its spectra, obtained for different nadir and slant geometries, with the ones computed using a DISORT-based code [4]. The limb validation was performed by comparison with the SARTre code[7, 8] results.

The procedure for the retrievals of gaseous species distributions and clouds properties is obtained by replacing the radiative transfer module in the algorithm developed and described by [9].

## 4. Conclusions and Future Work

We are developing a code to retrieve direct information by limb measurements using a code based on the Monte Carlo approach. This code is suitable for the application on all the planetary atmospheres, since it takes into account the multiple scattering in a spherical-shell atmosphere and it is optimized for the near infrared spectral range.

In future, we plan to improve our MCRT code by the implementation of the thermal radiation, the air refraction of the line of sight (Ray Tracing) and the polarization effects.

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