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Radiative Transfer Analysis of Hyperspectral Image Cubes of Jupiter Acquired During Juno's 5th Perijove Pass

Emma Dahl (1), Nancy Chanover (1), Glenn Orton (2), Kevin Baines (2), David Voelz (1), Erandi Wijerathna (1), Robert Hull (1), Patrick Irwin (3)

(1) New Mexico State University, New Mexico, USA, (dahlek@nmsu.edu) (2) Jet Propulsion Laboratory, California, USA, (3) University of Oxford, Oxford, UK

Abstract

Since arriving at Jupiter in July 2016, The Juno spacecraft has measured the Jovian atmosphere with a powerful suite of instruments. As part of an international ground-based observing campaign in support of the Juno mission, we collected hyperspectral image cubes of Jupiter in the visible wavelength regime during 10 of Juno's close perijove passes. Such measurements probe the uppermost cloud deck of Jupiter's atmosphere (altitudes above $\sim$1.5 bar) and are highly complementary to Juno's measurements of infrared and microwave radiation from deeper in the atmosphere. Using a radiative transfer model and spectra from Juno's 5th perijove pass, we develop models of 3 atmospheric regions: the Equatorial Zone (EZ), the North Equatorial Belt (NEB), and the South Equatorial Belt (SEB). We base our model atmosphere on the "creme brûlée" model [5, 2] and use this input to retrieve properties of Jupiter's uppermost cloud deck.

1. Introduction

Jupiter's atmosphere is a highly dynamic system. Processes occurring in Jupiter's deep atmosphere, beneath the uppermost cloud deck, undoubtedly play a role in changes observed in the cloud tops. However, a consistent picture of the mechanism(s) in the deeper atmosphere that drive these changes remains elusive. Measuring the color and structure of the uppermost cloud deck can help us understand the changes that it undergoes and the processes that cause those changes.

Jupiter's tropospheric cloud layers, while difficult to measure directly, have been predicted through the use of thermochemical equilibrium models. In Jupiter's atmosphere, ammonia is expected to condense into a cloud at 0.7 bar [1]. Recent modeling and laboratory work point to a "creme brûlée" model as an explanation for the composition and distribution of the chromophores, or coloring agents, in this uppermost cloud deck [2, 5]. This model assumes a thin layer of a single, universal chromophore formed from photodissociated ammonia and acetelyne directly above the main cloud deck [3, 5]. The simplicity of this model, and the nature of the chromophores' layer makes it easily testable with our data.

2. Observations

The Juno spacecraft arrived at Jupiter in July 2016, and has since collected a multitude of data on the Jovian system. While Juno has used infrared and microwave instruments to measure Jupiter's atmosphere at depth (down to $\sim$100 bar), Juno's optical camera, Junocam, lacks the spectral resolution and photometric calibration to finely and accurately sample the uppermost cloud layer in Jupiter's atmosphere.

In order to better sample this region of the atmosphere, we use the New Mexico State University Acousto-optic Imaging Camera (NAIC) at the Astrophysical Research Consortium 3.5-m telescope at Apache Point Observatory in Sunspot, NM, to obtain hyperspectral image cubes of Jupiter from 470-950 nm. The data analyzed in this study were taken during Juno's 5th perijove pass on May 26, 2017. We extract spectra from 3 major atmospheric features: the EZ, the SEB, and the NEB, and produce atmospheric models to match those spectra.

3. Atmospheric Modeling

To model the belts and zones, we utilize the Non-Linear Optimal Estimator for Multi-variate Spectral Analysis (NEMESIS) radiative-transfer package [4]. We use a model atmosphere consisting of a main cloud layer with a base pressure set to 1.2 bar and a relatively thin layer of chromophore material directly above this main cloud. In our spectral regime, we are sensitive to several characteristics of the uppermost cloud layer, including but not limited to the cloud's base pressure, optical depth, and aerosol density, the ammonia gas volume mixing ratio at ∼1 bar, and the scattering properties of the aerosols (specifically, the complex index of refraction of the material). Using NEMESIS, we iteratively allow the clouds' pressures, densities, and scattering properties to vary, and retrieve the best-fit parameters. Initial fits to the 3 cloud features are shown in Figure 1.

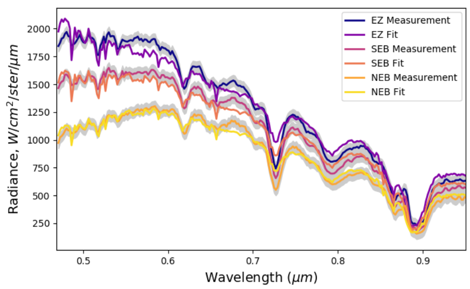

Figure 1: Preliminary spectral fits for each cloud feature

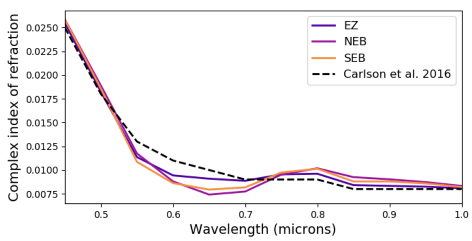

Figure 2: Retrieved complex indices of refraction for each cloud feature as compared to the input spectrum from [3]

4. Initial Results

By using the creme brûlée model as our input atmosphere, we can retrieve the parameters we are sensitive to in our spectral regime. Initial results (as in Figure 1) indicate that this atmospheric model can provide a good fit to our data. In this initial model, we allowed the complex index of refraction of the chromophore layer and a density scale factor for each cloud layer to vary. While the cloud density did change slightly between our spectra, the far more influential variable was the complex index of refraction. The retrieved complex indices are in Figure 2.

By using data taken in conjunction with Juno perijove passes and deriving characteristics of Jupiter's uppermost cloud layer, we will not only be able to provide context for Juno's measurements and other ground-based observations, but we can also explore connections between the deep atmosphere and processes observed at the cloud tops.

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