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Investigating Jupiter's Aerosol Structure with Rotationally-averaged HST WFC3 Images

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Abstract

A chromophore produced when NH3 reacts with acetylene (C2H2) was proposed in [2] as a possible coloring agent in Jupiter's Great Red Spot (GRS). It was shown in [4] that a it had the optical properties that could fit a variety of features on the planet. Here we use the same chromophore in fitting the possible vertical structure and composition of several belts and zones on Jupiter using HST Wide Field Camera 3 observations. The Hubble Space Telescope's Wide Field Camera 3 (WFC3) has imaged Jupiter from 2015 to the present as part of the Outer Planets Atmospheres Legacy program (OPAL, Amy Simon PI, [3]). The program takes advantage of HST's UV and shorter visible wavelenth range, has annual observations of the solar system's giant planets, and has good longitudinal sampling over two full rotations of the targets. The lack of multiple methane band filters and limited number of views of discrete features each rotation limits retrieval of cloud properties somewhat. Averaging all images over the two rotations homogenizes the features of many planet-encircling bands and allows a wider and denser sampling of observer view angles, allowing better constraints on cloud properties.

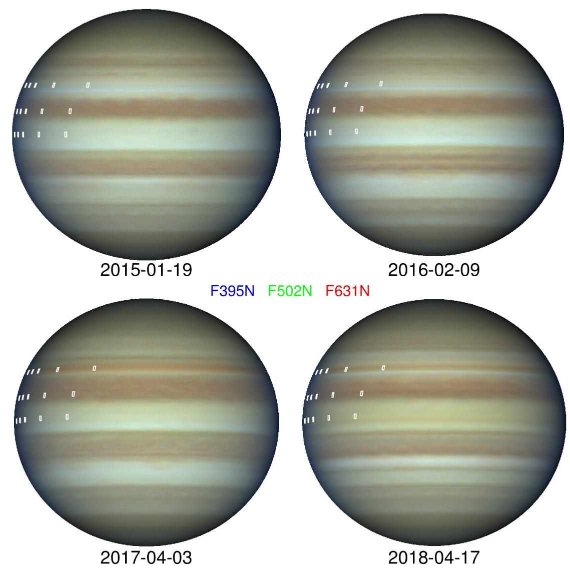

Figure 1: Rotationally-averaged images of Jupiter from two full rotations, where images were acquired with eight filters every 60 degrees of rotation. Boxes are extraction locations for observer zenith angle cosines of 0.8, 0.6, 0.4, 0.3, and 0.2

1. Observations and sampling

For each of the years 2015 through 2018, we averaged by filter all images over two planetary rotations. Filters used include: F275W, F395N, F467M, F502N, F547M, F631N, F658N, and FQ889N. Figure 1 shows three-color composites from all four years. We extracted and averaged boxes two degrees in latitude high and 1 degree in longitude wide, at five observer zenith angle cosines from 0.8 to 0.2. Sampled locations initially included the Equatorial Zone (EZ, planetocentric latitude 0°N), North Equatorial Belt (NEB, 10°N), and North Temperate Belt (NTB, 21.75°N).

2. Cloud structure model

The details our radiative transfer and parameter fitting code can be found in [4]. Cloud particles are modeled by Mie theory as spheres of single composition. Our initial modeling utilizes three cloud layers, 1) an upper conservative scattering cloud, possibly of NH3 with a real refractive index $n_r = 1.4$, 2) a lower conservative scattering cloud possibly containing some fraction of NH4SH with $n_r = 1.6$, and 3) a layer of chromophore particles as described in [2]. We allow the cloud layers to overlap in pressure.

Setting $n_r = 1.6$ for the bottom cloud was originally to better fit the very red core of the GRS while retaining the Carlson chromophore. Modifying the chromopore refractive index was the approach of [1] to the same problem. In other regions (especially "whiter" regions like the EZ), setting $n_r = 1.4$ can produce very similar fit quality, and may be more appropriate.

Cloud layers are characterized by their base pressures (p_1, p_2, p_3), cloud-top pressures (p_{1T}, p_{2T}, p_{3T}), optical depths (τ_1, τ_2, τ_3), and particle radii (r_1, r_2, r_3). We fixed p_2 at 3 bar, r_2 at 0.7 μm , and the pressure thicknesses of clouds 1 and 3 ($\sim$ 0.8 times their respective base pressures), to limit the number of free parameters. Additionally, the scale height of the cloud opacity concentration was equal to the pressure scale height (fractional scale height = 1). For the computation of fit quality χ^2, we assumed a combination of a fixed value and a fraction of the observation I/F of 0.005 and 0.03, respectively, based on published values of WFC3 per-filter sensitivity.

3. Fit quality examples and initial fit results

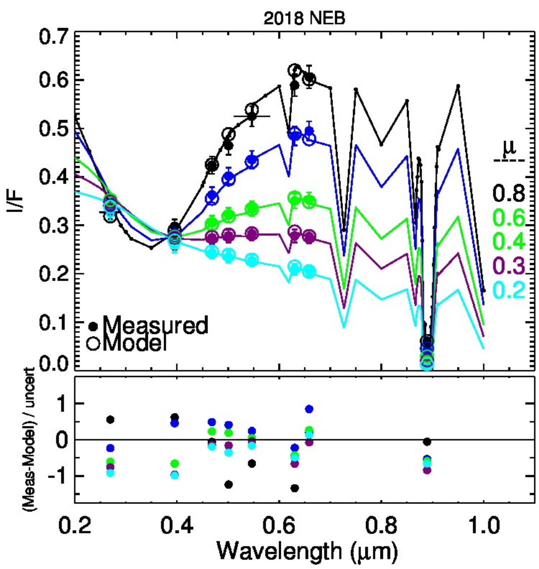

Figure 2: Example of fit quality for NEB region for 2018. Observer zenith angle cosine is indicated by color.

4. Conclusions and future work

For the regions explored so far, we are able to obtain high quality fits using the Carlson chromophore. The chromophore layer (cloud 3) is found to be located slightly inside and just below the top of the bottom conservative cloud layer (cloud 2). The EZ coloration change from 2015 to 2018 may be the result of an increase in chromophore layer optical depth. The same is true for the NTB reddening, along with a reduction in upper cloud conservative cloud opacity.

We intend to explore the ability of other candidate chromophore materials to fit these observations, as well as variations in the vertical opacity structure of

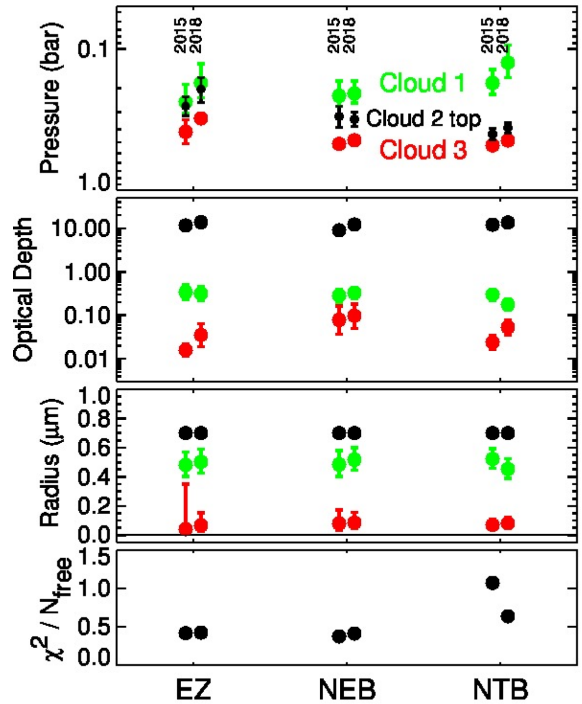

Figure 3: Fit results for three regions for 2015 and 2018.

the cloud layers. We also plan to model additional belts and zones, along with the GRS.

Acknowledgements

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References

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