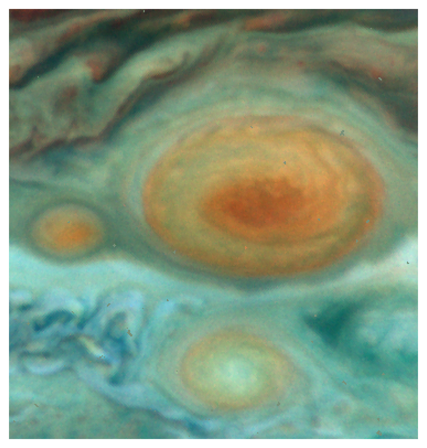

Jovian Chromophore Characteristics from Multispectral HST Images

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1. Introduction

Characterizing the chromophores responsible for coloring the Jovian atmosphere remains a challenging problem. Knowledge of their spectral shapes and 3-dimensional distributions can provide important clues as to their chemical identities. In this study, HST WFPC2 data were fit with radiative transfer models to find spectral shapes and vertical distributions of Jovian chromophores and aerosols. The results are discussed in the context of the current model of the vertical aerosol structure (**Figure 1**).

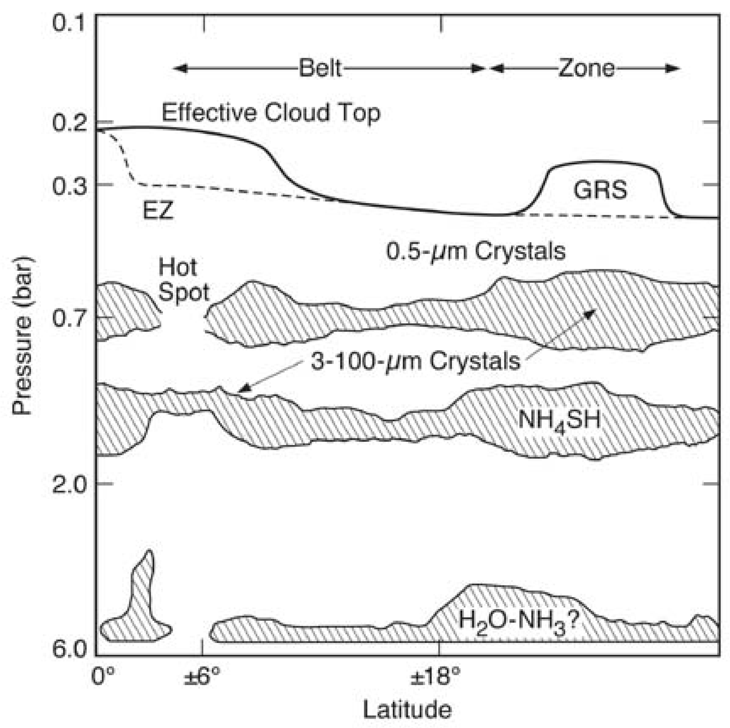

Figure 1: The current model of Jupiter's tropospheric vertical aerosol structure (West *et al.* 2004, Figure 5.15).

2. Data

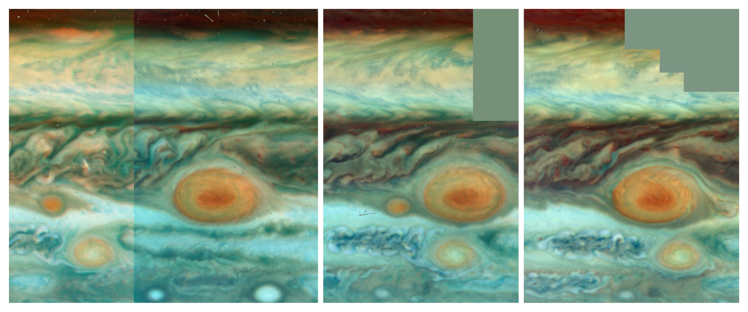

Figure 2: Multispectral HST WFPC2 observations of Jupiter's Great Red Spot and Oval BA on 15 May, 28 June, and 8 July 2008 (left to right).

The observations (**Figure 2**) were made on 15 May, 28 June, and 8 July 2008, covering a passage of Oval BA and the Great Red Spot (GRS). Nine filters sampled the continuum — F255W, F343N, F375N, F390N, F410M, F437N, F469N, F502N, and F673N — making this data set ideal for color studies at high spatial resolution. An 889-nm methane absorption filter (PCFQCH4P15) provided first-order cloud height information. **Figure 3** plots the transmissivity of each filter due to methane absorption and Rayleigh scattering.

3. Radiative Transfer Model

The radiative transfer code used was originally developed by Banfield *et al.* (1998) to analyze *Galileo* SSI data. Each model aerosol layer was parametrized by a base pressure, an optical depth, and a particle radius. Simon-Miller *et al.* (2001b) supplemented the model by including the single-scattering albedo (ϖ_0) at 410 nm. This work extends the model to HST data and adds ϖ_0 at 255, 343, 375, 390, 410, 437, 469, and 502 nm. The ϖ_0 spectrum defines the color of the chromophore(s) within each aerosol layer.

Due to the large number of model parameters (11 possible per aerosol layer), the following fitting constraints were necessary:

- Only two- and three-layer models were fit to the data. Two-layer models contain a single stratospheric/tropospheric haze and a tropospheric sheet cloud. Three-layer models have separate stratospheric and tropospheric hazes and a tropospheric sheet cloud.
- The bottom sheet cloud layer in all models was assumed to be attached to the base of the above layer.
- The particle radius was fixed to be 0.05 μm in the stratospheric haze, 0.5 μm in the tropospheric haze, and 1.0 μm in the tropospheric sheet cloud.
- The ϖ_0 at all wavelengths were fixed at unity in the sheet cloud in all models and also in the stratospheric haze of the three-layer model.

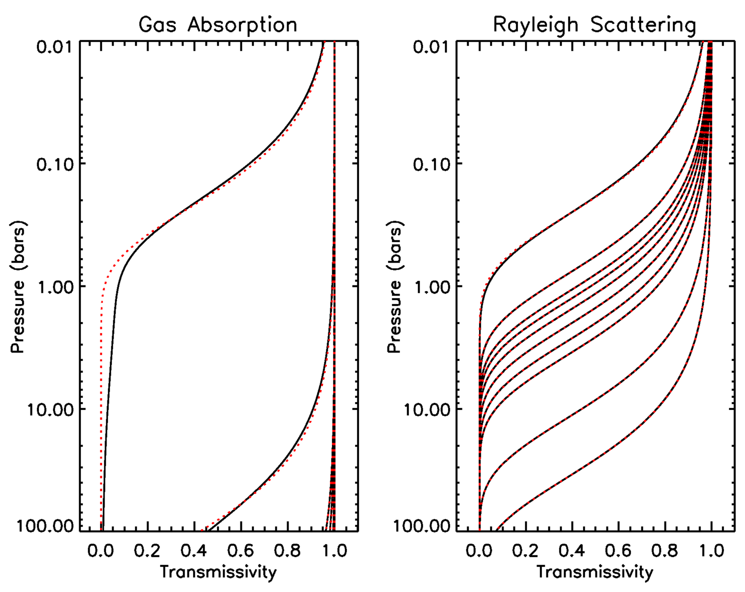

Figure 3: Two-way gas transmissivity due to gas absorption (left) and Rayleigh scattering (right) from space to the indicated Jovian pressure level for ten HST filters (see §2). The gas absorption is calculated from the Karkoschka (1998) methane absorption coefficients. The dotted lines are fits to Beer's Law profiles, which are used in the radiative transfer calculations.

4. Results

We derived best-fit models for both two- and three-layer aerosol structures for the GRS, Oval BA, a small red anticyclone that passed through the perimeter of the GRS (red oval), a white oval, the Equatorial Zone (EZ), the South Equatorial Belt (SEB), and the North Equatorial Belt (NEB) (**Figure 4**). The data were well fit by both two- and three-layer models (reduced $\chi^2 < 0.5$), except for a few models that did not converge. Note that degeneracy exists in all radiative transfer solutions to tropospheric structure (West *et al.* 2004).

The models provide a physically realistic context for deriving chromophore spectra. The optical depths of the sheet clouds exhibit the expected variation between belts and zones, and the optical depths of the hazes are reasonable. One obvious exception is that the sheet clouds were consistently located at ~350 mbar, which is a considerably lower pressure than the main cloud at ~700 mbar in the West *et al.* (2004) model (**Figure 1**). This discrepancy is not surprising, however, because the vertical sensitivity of the models is quite poor due to measurements at only one methane absorption band.

Large discrepancies exist between two- and three-layer models in values derived for ϖ_0(255 nm) and ϖ_0(343 nm). This is indicative that ϖ_0 in the UV is significantly less than unity in the stratospheric haze.

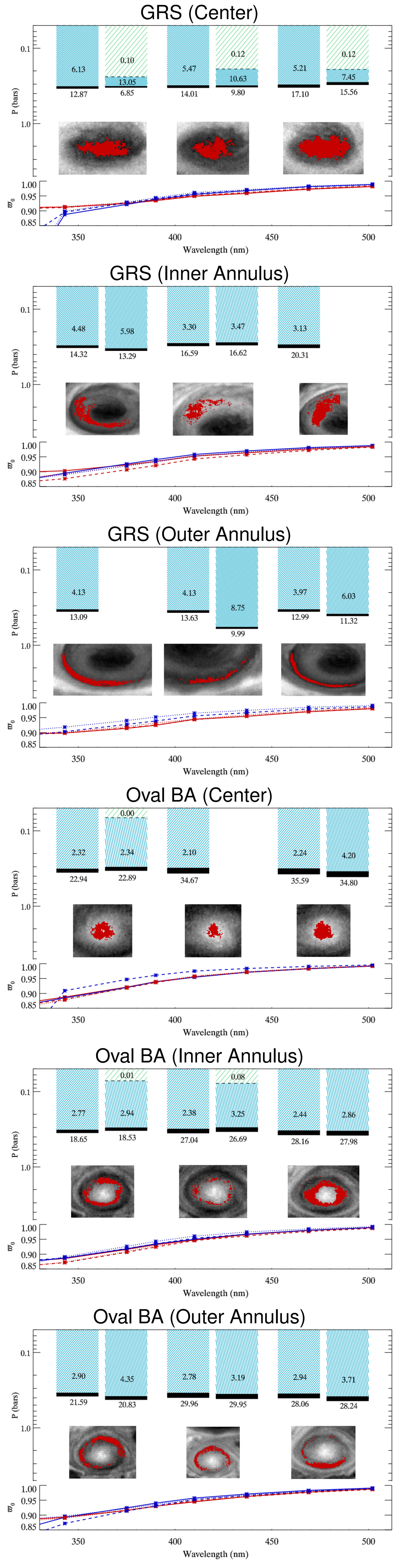

Figure 4: Model results. The hashed plots are schematics of the best-fit vertical aerosol structure for two-layer models (left in each pair) and three-layer models (right in each pair). The blue hashes represent haze layers with colored particles, green hashes are white haze layers, solid black lines are white sheet clouds, and the dashed black lines denote boundaries. Optical depths are labeled in the hazes and below the sheet clouds. The location modeled by each pair is marked in red in F410M images centered below (arbitrarily sized), with epoch increasing from left to right. Missing models denote non-convergence, and missing images denote a feature's disappearance. The line plots contain the best-fit ϖ_0 spectra. Two-layer models are in red, and three-layer models are in blue. The epochs are plotted from first to last as solid, dotted, and dashed lines, respectively.

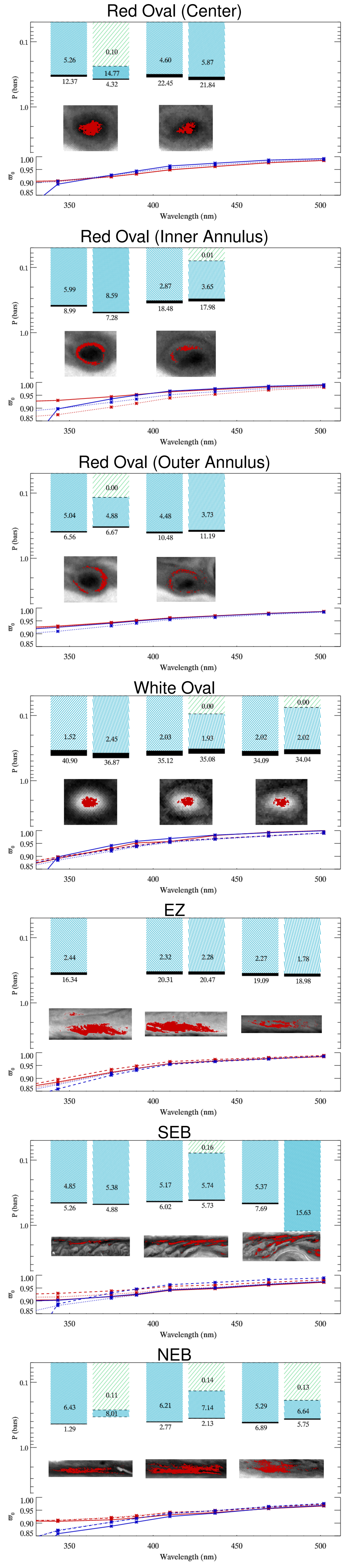

Figure 4 (continued): Model results.

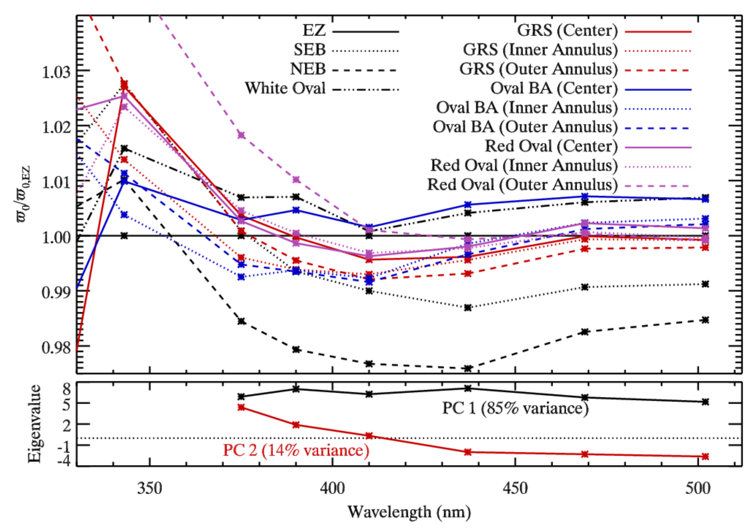

Figure 5: Average ϖ_0 spectrum for each feature divided by the EZ's ϖ_0 spectrum (top). Results from a principal component analysis of ϖ_0 spectra 375 nm and redward (bottom).

However, the small difference between two- and three-layer models in the spectral shape of ϖ_0 redward of 343 nm supports the idea that coloration in the visible is primarily due to chromophores in the troposphere.

The relative spectral shapes (**Figure 5**, top) of the chromophores are quite similar (within ~2%) for areas with a large range of visible coloration. This demonstrates the large effect that vertical structure has on the apparent color. A principal component analysis of ϖ_0 spectra 375 nm and redward yielded only two significant components (**Figure 5**, bottom), which is consistent with the conclusion of Simon-Miller *et al.* (2001a) that one or two chromophores are necessary to explain Jupiter's color variation.

5. Conclusions

- HST WFPC2 data were well fit by both two- and three-layer models (reduced $\chi^2 < 0.5$) in an updated radiative transfer code.
- The model needs to account for significant UV absorption in the stratosphere.
- We derived chromophore spectral shape in the visible wavelength regime for individual planet locations.
- We found two significant principal components to the chromophore spectral shapes.
- Although ~2% variation between chromophore spectral shapes was found, a significant amount of the observable color variation in Jupiter's clouds may be due to differences in vertical aerosol structure and *not* to differing chromophores.

Acknowledgments

This work was supported by NASA's Planetary Atmospheres Program through grant number NNX08AF53A. This work is based on observations made with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. These observations are associated with program #GO/DD11498.

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