SPECTRAL COMPARISON AND STABILITY OF RED REGIONS ON JUPITER. A. A. Simon[1], R. W. Carlson[2], and A. Sanchez-Lavega[3], [1]NASA Goddard Space Flight Center, [2]JPL/Caltech, [3]Universidad del País Vasco.

Summary: A study of absolute color on Jupiter from Hubble Space Telescope imaging data shows that the Great Red Spot (GRS) is not the "reddest" region of the planet. Rather, a transient red cyclone visible in 1995 and the North Equatorial Belt both show redder spectra than the GRS (*i.e.,* more absorption at blue and green wavelengths). This cyclone is unique among vortices in that it is intensely colored yet low altitude, unlike the GRS. Temporal analysis shows that the darkest regions of the NEB are relative constant in color from 1995 to 2008, while the slope of the GRS core may vary slightly. Principal component analysis shows several spectral components are needed, in agreement with past work, and further highlights the differences between regions. These color differences may be indicative of the same chromophore(s) under different conditions, such as mixing with white clouds, longer UV irradiation at higher altitude, and thermal processing, or may indicate abundance variations in colored compounds. A single compound does not fit the spectrum of any region well and mixes of multiple compounds including NH_4SH, photolyzed NH_3, hydrocarbons, and possibly P_4, are likely needed to fully match each spectrum.

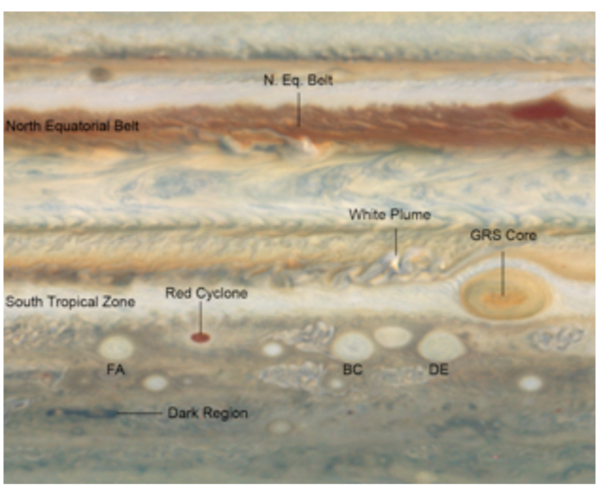

Figure 1. Regions of Interest on Jupiter, showing variable colors from near white to intense red and nearly black.

A Transient Red Cyclone: Hubble Space Telescope data shows a transient, intensely red, feature, hereafter the red cyclone (RC), which was visible on Jupiter for brief period in 1995, as seen in Fig. 1, and which formed the impetus for this study. This system formed as large anticyclones near 33° S planetographic latitude approached each other and possibly compressed a larger intervening cyclonic cell. The new feature was uncharacteristically round, and maintained its color for several months before clouding over. In comparison, most cyclonic cells on Jupiter have rough, ill-defined, edges, and vary in color but are generally muted in appearance [1-3].

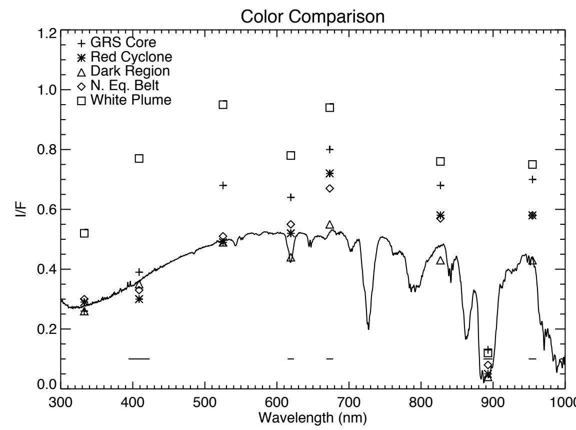

Figure 2. Absolute spectra for regions identified in Figure 1.

Regional and Temporal Spectral Variation: Spectral data acquired over multiple epochs and many wavelengths show that most regions on Jupiter are remarkably stable in color. No region appears to be truly black or white, but all show some absorption at UV and blue wavelengths, see Fig. 2. The most intense coloration is not in the Great Red Spot, but in the North Equatorial Belt, particularly dark cyclonic barges, and in rare transient cyclonic vortices at other latitudes, such as the 1995 RC. Regions with quite different cloud structure can show similar color, while regions with similar structure can vary in coloration. While this neither rules out nor confirms the presence of separate chromophores, it does indicate that multiple factors (variable composition or particle processing history) are involved; the best spectral match seems to require the presence of both NH_4SH and C_2H_2-NH_3 interactions, while various levels of irradiation or thermal processing may also explain some of the color variation. In addition, there is slight evidence that P_4 or a similar phosphorus-bearing compound is necessary to explain spectral variations at wavelengths beyond 600 nm; further spectral data are required, however.

Future Work: Further laboratory work is needed to determine the best mixtures of these and other compounds under exposure to variable irradiation and thermal histories and observed under a variety of viewing conditions. Ideally, candidate compounds with matching visible spectra would also be found to have unique near to mid-IR absorption features to allow unambiguous identification. To date only discrete NH_3 and water ice features have been positively identified [4-7], but these are spectrally white at visible wavelengths, and are only found in rare locations, perhaps because of particle riming [8,9]. Recent reanalysis of ISO data indicates that NH_4SH may also be spectrally identifiable near 3-microns [10,11], however, its spectrum alone does not fully explain the colored regions on Jupiter.

Finally, additional high spatial resolution spectroscopy and imaging of discrete regions are needed for more complete information. Analyses of spectra and vertical cloud structure over visible wavelengths for a multitude of red features are critical in determining the number of coloring components and their horizontal and vertical distribution. While some limited data do exist, primarily from ground-based facilities, it has been the lack of simultaneous spatial resolution and spectral coverage that has hampered further work. Continued to work to isolate small features, such as the GRS core or other small red cyclonic features, will aid comparisons with future laboratory mixtures.

References: [1] Peek, *The Planet Jupiter*, 1958; [2] Rogers, *The Giant Planet Jupiter*, 1995; [3] Morales-Juberias et al., *Icarus* **160**, 325–335, 2002; [4] Brooke et al., *Icarus* **136**, 1-13, 1998; [5] Simon-Miller et al., *Icarus* **145**, 454-461, 2000; [6] Baines et al., *Icarus* **159**, 74-94, 2002; [7] Wong et al., *Plan. and Space Sci.* **52**, 385-395, 2004; [8] Atreya et al., *Plan. and Space Sci.* **53**, 498-507, 2005; [9] Kalogerakis et al., *Icarus* **196**, 202-215, 2008; [10] Sromovsky and Fry, *Icarus* **210**, 211–229, 2010; [11] Sromovsky and Fry, *Icarus* **210**, 230–257, 2010.

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