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The 2010-2011 Revival of Jupiter's South Equatorial Belt: Perturbations of Temperatures, Clouds and Composition from Infrared Observations

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Abstract

On 2010 November 9, a perturbation appeared in Jupiter's South Equatorial Belt (SEB), which began a classical "revival" of the SEB, returning the entire axisymmetric region to its normal dark color from its anomalous, light, "faded" state. The early revival is marked by strong upwelling gas at the outbreak location, to the west of which appear alternating clear and cloudy regions. Clear regions are correlated with dark clouds near the outbreak and in a southern retrograding branch but less so in a northern prograding branch. A 5-µm image from 2010 March 1 shows much of the SEB closer to a pre-faded state.

1. Introduction

Dramatic changes of the albedo and color of the typically dark brown band known as Jupiter's South Equatorial Belt (SEB) took place between 2009 and 2010 [1], as it faded to a white appearance that is similar to the adjacent "zones". We obtained infrared images of Jupiter, including regions affected by the outbreak at wavelengths between 1.64 and 24.3 µm, starting November 11, 2010, and ending March 1, 2011. We used the NASA Infrared Telescope Facility (IRTF), the Gemini North and South Telescopes, the Very Large Telescope (VLT), and Keck Observatory.

2. The initial revival phase

Two days after the initial outbreak that was detected on 2010 November 9, the outbreak region appeared as a compact feature that was cold and cloudy near 600 mbar of pressure near the NH_3 gas condensation level. After two further days, we detected the upwelling plume in reflected sunlight (1.64 and 2.23 µm) and a newly clear region at 4.78 µm in a spectral window in Jupiter's atmosphere that is sensitive to thermal emission from deep cloud tops. Subsequent observations disclosed secondary high-altitude plumes to the west of the original upwelling, interleaved with regions of high 5-µm radiance, indicating regions of subsiding air.

Images made from 1 to 20 µm on Nov. 30 and December 1 showed a complex of alternating plumes - highly reflective regions and clearings – noted by high 5-µm radiance (Fig. 1, central panel). Regions that were highly reflective in the near infrared, diagnosing high-altitude particles, were often but not always correlated with bright visible regions (Fig. 1, upper panel). Bright 5-µm regions appeared to be consistently correlated with visibly dark regions, for those nearest the original outbreak and for dark regions propagating to the south and retrograde. This was not necessarily true of similar dark regions propagating north and prograde. Areas that were cold (Fig. 1, lower panel) were correlated with the plumes, and areas that were warm were correlated with the regions of higher 5-µm radiance and presumed subsidence; this is all consistent dynamically with adiabatic response to forced upwelling and downwelling. Upwelling regions also appeared to be more "humid" with NH_3 gas and were cloudier at the ~600-mbar condensate level. Follow-on mid-infrared observations on December 5 with the IRTF/MIRSI showed an expanding area associated with cold, presumably upwelling regions that correlated well with visibly bright regions.

Figure 1. The outbreak region after 21-22 days. Top panel: taken from an RGB image composite by D. Parker. Middle panel: Gemini N/NIRI composite filters - M (5 µm, "thermal red"- sensitive to deep cloud radiance), J (1.6 µm, green – sensitive to particle albedo) and K (2.1 µm, blue – sensitive to upper-level particle abundances. Bottom panel: VLT/VISIR composite mid-infrared radiances, 8.60 µm (red – sensitive to 600-mbar cloud opacity), 10.77 µm (green – sensitive to 300-mbar NH_3 gas abundance) and 13.04 µm (blue – sensitive to 400-mbar temperatures).

3. The Propagating Revival Phase

We tracked the revival for the remainder of Jupiter's apparition (through March 1) in the near infrared. Visibly dark central regions and a dark southern, retrograding branch continued to be bright at 5 µm, but this was not consistently the case for a northern, prograde-propagating branch.

By mid-February (Fig. 2), the southern branch, warm at 5 µm, had encountered and was beginning to surround the Great Red Spot (GRS). In this image, there is a strong correlation between the darkest visible features and the brightest 5-µm features, implying that the clearing of the atmosphere was revealing dark-colored clouds at depth. The center of the SEB west of (following) the GRS was also filling in with similar clear regions. Our last image of Jupiter on 1 March shows that the GRS is nearly fully surrounded by clear regions that are bright at 5 µm, and the center of the SEB west of the GRS was increasingly filled in with clear regions. No turbulent region northwest of the GRS had been established.

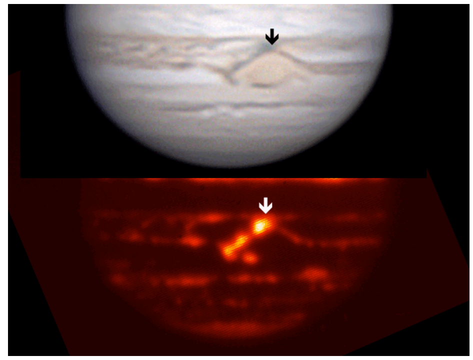

Figure 2. Top panel: RGB composite image by D. Parker, 17 February 2011. Bottom panel: 4.8-µm image on the same night from IRTF/SpeX guide camera. Note the coincidence between the visibly dark regions and those that are bright at 5 µm. The location of the Great Red Spot is given by the arrows.

4. Summary and Conclusions

For small-scale regions that were rapidly changing in the revival sequence, the large-scale correlation still holds between strong upwelling and relatively cold, cloudy and saturated air, and between strong downwelling and warm, dry, desiccated air. There is also a strong connection between visible color and the state of cloudiness in small-scale regions that has been recognized for axisymmetric regions and large-scale features. We need to assess, however, whether the correlation between visually dark and clear areas that suggests that Jupiter's deepest clouds are dark in color, is universal; although it appears robust for the central and southern branches of the SEB disturbance, it is not so clear for the northern branch.

Acknowledgements

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References

[1] Fletcher, L. N., et al.: Jovian haze variability during the 2009-2010 fade of the South Equatorial Belt. Icarus, 213, 564-580. 2011.