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The vertical structure of deep cloud features on Uranus

J.H.Kim, L. A. Sromovsky and P. M. Fry
Space Science and Engineering Center, University of Wisconsin - Madison, Madison, Wisconsin (USA)
(joohyeon.kim@ssec.wisc.edu, larry.sromovsky@ssec.wisc.edu, pat.fry@ssec.wisc.edu / Fax: 608 262-5974)

Abstract

Discrete cloud features in the southern hemisphere of Uranus are generally much deeper than those in the northern hemisphere and likely of a different composition. The most prominent of the southern features is the Berg, which has been observed since 1994 in Hubble Space Telescope images ([5], [6]). Here we use the ratio of spatial variations in brightness in 2007 HST images at CCD wavelengths taken with filters of differing penetration depths to estimate the pressure level of the Berg to be near 2 bars. This is in good agreement with pressures estimated at near-IR wavelengths [1] and is compatible with particles of condensed H_2S if the H_2S mixing ratio is $\sim 10^{-7}$ or greater [4].

1. Introduction

The bright cloud feature on Uranus called the Berg oscillated between 32° S and 36° S, probably from at least 1994 until 2005. At that point the Berg began drifting toward lower latitudes and reached 26° S on the equinox of Uranus in December 2007, when intensive observation from ground and space provided excellent constraints on its vertical structure. Based on near-IR observations with the Keck II NIRC2 camera, de Pater et al. [1] estimated the Berg vertical location to range from 3.5 bars in 2004 to 1.8–2.5 bars in 2007, with some components reaching pressures as low as 0.6–0.8 bars. They inferred cloud pressures from the ratio of spatial variations in two different filters having different penetration depths. In applying a similar technique to HST observations at CCD wavelengths, we first needed to use radiation transfer modeling to infer the relationship between the spectral ratio and the pressure of the cloud.

2. Modeling spectral ratio vs. P

We carried out radiation transfer modeling for the 0.55–1.0 μm spectral range, using code that includes Raman scattering and an accurate approximation for polarization effects. We used the coefficients of [2] to characterize methane absorption and most of the vertical 5-layer cloud structure of [4] as a general vertical structure of Uranus. This is also very similar to the vertical structure model of Karkoschka and Tomasko [2]. The models contained two upper haze layers described by Mie scattering and three cloud layers characterized by Henyey-Greenstein scattering. We took most model parameters, including optical depth, radius of mie particles, pressures, and occultation profile of F1, from Sromovsky et al. [4]. What we varied in this study was the pressure and optical depth of the deepest cloud in the model. We performed calculations with various optical depths (0.0–5.0) as a parameter of a deep cloud layer for each pressure level between 1.8 and 5.0 bars in order to derive I/F correlation slopes between two filters (F658N and F791W). We then fit the variation of model slope as a function of cloud pressure to simple empirical functions (a second-order polynomial in $log(I/F)$), which we subsequently used to infer pressure from the measured slopes.

3. Pressures derived by correlation for a pair of filtered images

The pressure is derived from correlation of two filtered images (HST Program 11118, P.I. : Sromovsky). Each image is subtracted by another image observed with same filter at a different time (Fig. 1) in order to remove the large latitudinal variation associated with the background zonally symmetric cloud bands. We also investigated pairs with good correlations from various filtered images which were observed by HST/WFPC2 and HST/ACS instruments. Each image was smoothed with a 3-pixel boxcar in order to reduce noise. We calculated the I/F correlation slope between the image pairs for a normal and a brighter feature in the Berg with linear fitting, and the derived slope was used with the empirical formula derived from modeling to obtain the cloud pressure. According to ratios measured in F791W and F658N filtered images, which provide the best correlation accuracy, the pressures of a normal and a brighter feature are inferred to be 1.66–2.13 bar

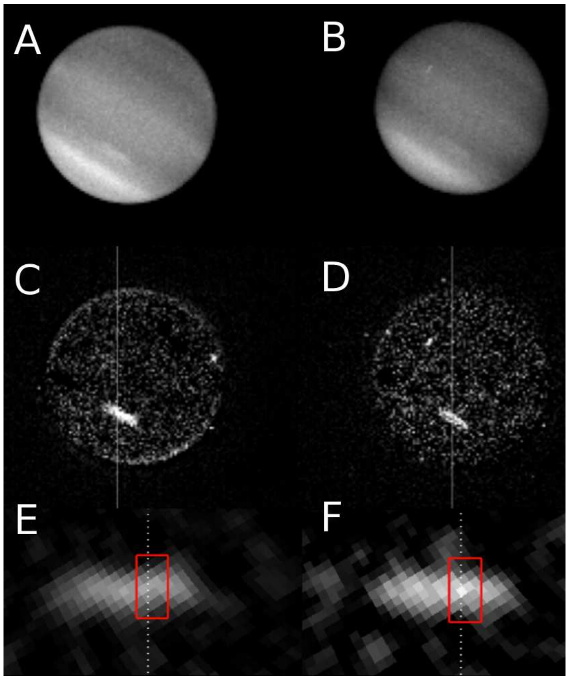

Figure 1: Images of the deep cloud features. A, B: Original images. C, D: Subtracted images. E, F: Box shows to be extracted in order to derive a pressure in the Berg. A, C, E: Uranus image through F791W(u9z70307m, subtracted by u9z70401m). B, D, F: Uranus image through F658N(u9z70305m, subtracted by u9z70405m). HST/WFPC2 observations on July 28, 2007.

and 1.74–2.23 bar, respectively. These are not statistically significant pressure differences and are in good agreement with near-IR results [1].

4. Summary and Discussion

We derived the pressure levels of two distinct features in the Berg of Uranus with I/F correlations in HST images taken with F791W and F658N filters, yielding pressures near 2 bars, which is too deep for methane condensation. The cloud particles might be composed of H_2S, if present at mixing ratios of 10^{-7} or more [4].

Acknowledgments

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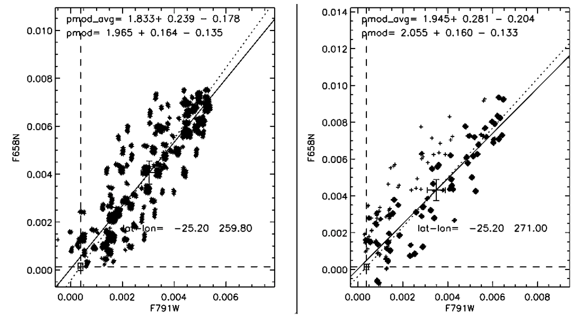

Figure 2: I/F correlations of normal and brighter features in the Berg. Left: Normal feature, Right: Brighter feature. Solid line is derived with all data points in the box(E and F of Fig. 1), and Dotted line is the correlation between an averaged I/F in the box and an averaged background I/F.

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