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Note

New cloud activity on Uranus in 2004: First detection of a southern feature at 2.2 μm

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Abstract

On 4 July 2004 UT, we detected one of Uranus' southern hemispheric cloud features at K′ (2.12 μm); this is the first such detection in half a decade of adaptive optics imaging of Uranus at the Keck 10-m telescope. When we observed again on 8 July UT the feature's bright core had faded. By 9 July UT it was not seen at K′ and barely detectable at H. The detection and subsequent disappearance of the feature indicates rapid dynamical processes in the localized vertical aerosol structure.

Keywords: Uranus; Atmosphere

1. Introduction

In 1994 the Hubble Space Telescope (HST) turned to the uranian system to search for faint satellites (Zellner et al., 1994). The serendipitous discovery of discrete clouds on Uranus in the satellite-search images revitalized interest in the planet's atmosphere (Hammel, 1997), which had been muted since the Voyager Uranus encounter showing little atmospheric activity (Smith et al., 1986). Ground-based images in 1995 from the NASA Infrared Telescope Facility (IRTF) had resolved the disk, but discrete features were not detected (Baines et al., 1998). Beginning in 1997, however, HST observed Uranus with both the Near-Infrared Camera and Multi-Object Spectrograph (NICMOS) and the Wide Field Planetary Camera 2 (WFPC2), revealing many atmospheric features in both hemispheres (Karkoschka, 1998, 2001; Hammel et al., 2001). Northern[1] hemispheric features were detected at a wavelength of 2 μm; southern features were seen only at shorter wavelengths. By 1999, improvements in IRTF image quality permitted detection of a few features in the planet's northern hemisphere with that facility (Forsythe et al., 1999; Sromovsky et al., 2000). Since 2000, Uranus has been a target of the W.M. Keck II 10-m telescope using adaptive optics (AO) imaging (de Pater et al., 2002; Hammel et al., 2001, 2005).

Over the past decade, the inventory of discrete cloud features on Uranus has grown, though some have argued this is due to wavelength choice or changes in viewing angle (e.g., Karkoschka, 2001). During a four-night run in October 2003, over three dozen features were seen in Keck Uranus images (Hammel et al., 2005). None of the 11 features seen in the southern hemisphere in 2003 was detected at K′, even though some of these features were among the largest and most easily observed features on the disk at shorter wavelengths. Indeed, no southern-hemisphere features have *ever* been detected at or longward of 2.0 μm (Karkoschka, 1998, 2001; Hammel et al., 2001, 2005; de Pater et al., 2002) until now. We report the first detection at K′ of a discrete southern-hemisphere feature on Uranus.

2. A surprising observation on the 4th of July

We obtained images of Uranus on 3, 4, 8, and 9 July 2004 UT using the 10-m Keck telescope with the NIRC2 camera. The AO system produced

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[1] We use the IAU convention for defining the pole position, where the southern hemisphere has been pointing toward the Sun and Earth for the past few decades.

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Table 1
Selected Uranus atmosphere images in 2004[a], along with contrast and I/F for feature 2004-B

Panel	Date	Filter[b]	UT start	Cont[c,d]	I/F[d,e]	Filter[b]	UT start	Cont[c,d]	I/F[d,e]
Fig. 1a	4 July	H	11:21:22	0.9	0.025	K′	11:52:04	3.2	0.00069
Fig. 1b	"	"	13:00:43	1.0	0.026	"	13:21:45	4.5	0.00091
Fig. 1c	"	"	15:03:14	1.4	0.030	"	15:23:55	2.9	0.00069
Fig. 1d	8 July	H	13:25:39	0.8	0.023	K′	13:45:10	1.0	0.00035
Fig. 1e	"	"	14:54:51	0.5	0.019	"	15:15:31	1.5	0.00035
Fig. 1f	9 July	H	10:35:19	0.2	0.015	K′	10:50:59	<0.9[f]	<0.00026[f]

[a] Data from 3 July are not shown because features 2004-A (extended feature) and 2004-B (bright core) were not visible during our observing window that night. Images are shown in Fig. 1; rectilinear maps extracted from the images are shown in Fig. 2.

[b] All H-filter integration times were 60 s; K′-filter integration times were 120 s.

[c] Peak contrast was defined $DN_{feature}/DN_{background} - 1$, where $DN_{feature}$ is the feature's single brightest pixel and $DN_{background}$ is the mean background value at that latitude.

[d] Since the feature was not resolved, the actual contrast and I/F values are probably higher. These "peak" values are provided for comparative estimates of night-to-night variation (the values have not been corrected for viewing geometry).

[e] Wavelength-dependent conversion factors for peak I/F were derived from observations of photometric standard star HD 201941.

[f] In the K′ case on 9 July, the contrast and I/F values correspond to a single bright pixel which is probably statistical noise; in actuality, the feature appears much fainter than these values would indicate (see Figs. 1 and 2).

spatial resolutions of ~0.05″ (about 700 km at Uranus). We obtained three sets of images each night, where a set typically contained three exposures each at J, H, and K′ (1.25, 1.63, and 2.12 μm). These filters are sensitive to aerosols at or above ~2, ~1, and ~0.3 bars,[2] respectively. Images were navigated and features located using the procedures described in Hammel et al. (2001, 2005).

On 4 July, a bright feature—dubbed 2004-A—was detected in the southern hemisphere of Uranus (Fig. 1 and Table 1). In H-band images,[3] feature 2004-A bore a superficial resemblance in overall size and extended nature to features near this latitude in previous years (e.g., s4 in de Pater et al., 2002; 2000-6 and 1994-2 in Hammel et al., 2001; 2003-A and 2003-N in Hammel et al., 2005). None of those features was detected longward of 2 μm. To our astonishment, feature 2004-A was easily detected at K′.

We obtained images for several more hours on 4 July as the feature transited the disk, and determined that the K′ feature was co-located with a condensed core (hereafter 2004-B) that was significantly brighter than the surrounding extended feature in the H-band images (Fig. 2). Features near this latitude in earlier years have been measurably extended at H, with sizes noticeably larger than a resolution element, but have never exhibited a distinct bright core as is seen in these 2004 images (de Pater et al., 2002; Hammel et al., 2005).

3. Another surprise a few days later

When we observed Uranus again on 8 July UT, the feature was again visible at K′ and H, but had faded, significantly at K′ and slightly at H. Contrasts and I/F values quantifying this change are listed in Table 1. By 9 July, we were unable to detect the feature at K′; at H the extended feature was seen but the core was barely detected (if detected at all). The relevant 9 July data were taken at moderate airmass (ranging from 1.78 to 1.63); also the feature was rotating off the disk. Nevertheless, had the feature been as bright as seen on 4 July, it would have been easily detected.

[2] These are the approximate pressures below which the two-way atmospheric transmission drops to <25% (de Pater et al., 2002). For complete filter characteristics, see Gibbard et al. (2005) or Hammel et al. (2005).

[3] We discuss and show only H-band images, but J-band data were also obtained on all nights. Because they are similar in appearance to the H-band data, they are not included in this note, but each reference to "H-band" should be understood to mean "H-band and J-band."

4. Characteristics of features 2004-A and 2004-B

4.1. Velocities

Given the interval between the 4 and 8 July observations and the point-like nature of 2004-B, we were able to determine the bright core's zonal wind velocity with high accuracy: 103 ± 2 m/s at latitude $-36.0° \pm 0.4°$. This velocity is somewhat slower than the velocities of features near this latitude in the past (Smith et al., 1986; Hammel et al., 2001, 2005; de Pater et al., 2002). The feature showed no variation of location or zonal velocity from J (~2 bars) to K′ (~0.3 bars), consistent with earlier results by Hammel et al. (2005) over this wavelength (altitude) range; similarly, Hammel et al. (2001) reported no difference between near-IR (Keck) and visible-wavelength (HST) velocities.

Determining a velocity for the northern H-band feature 2004-A was challenging due to its extended nature, but that was mitigated somewhat by the 4-day baseline; a preliminary estimate for this feature was 112 ± 3 m/s with an estimated central latitude at approximately $-33.7° \pm 0.4°$. This velocity is reasonably consistent with the velocities of nearby features (see references above). One interesting note: the velocity of 2004-A is higher than that of 2004-B, even though 2004-B is further south. This is the opposite of the usual trend of velocity with latitude for southern mid-latitudes. Such a reversal was seen before for two Voyager measurements near these latitudes (features 1986-4 and 1986-5 in Hammel et al., 2001). Such reversals may indicate complex structure in the zonal wind profile of Uranus.

4.2. Latitudes

No features have been reported at these two latitudes to date. Either 2004-A and 2004-B are completely new features or else they are long-lived features that have changed their velocities as they drifted in latitude. Such wandering behavior is not unheard of: indeed, several features on Neptune "wandered" in latitude with concomitant velocity changes (Hammel et al., 1989; Sromovsky et al., 1993). Rages et al. (2004) examined HST data taken from July 2003 to June 2004. They demonstrated that the extended feature, 2004-A, in fact existed for at least a year prior to the July 4th event, and confirmed that its latitude does change accompanied by a change in zonal velocity. A detailed analysis of the HST observations is in progress.

4.3. Feature morphologies

As noted above, the "feature" had two components, the condensed core and the more extended material seen in H. K′ images on the 4th hint at