FINAL PERFORMANCE REPORT

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Investigator: Dr. Lawrence Sromovsky
Institution: University of Wisconsin - Madison
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I. SUMMARY OF PROJECT ACTIVITIES:

1. Brief description of the primary objectives and scope of the project:

Our objectives were to answer the following questions about Uranus: (1) How has its band structure changed since equinox? (2) What happened to the large 34-deg S feature (the Berg)? Did it continue drifting northward or enter a new oscillation state? (3) What happened to the dark spot discovered in 2006? Are there any new dark features? (4) Will new bright features seen in 2007 continue to develop north of the new northern bright band? (5) How will the circulation change after equinox? Will the asymmetry begin to reverse as the band structure already has? (6) Will new dynamical features develop? (7) Will a northern polar cap begin to form, replacing the faded south polar cap? To help answer these questions we originally proposed a 9-orbit program consisting of 3 orbits of WFC3 imaging of cloud bands and potential dark features, and 6 orbits of NICMOS imaging to track and characterize bright discrete cloud features. This was later amended to use only the WFC3 UVIS and IR cameras because of uncertainty regarding the availability of the NICMOS camera after the last servicing mission. We used repeated imaging with the F845M filter to obtain improved S/N that compensated for loss of the inherently higher contrast of the NICMOS imaging and used the IR camera (limited by much lower spatial resolution) to constrain the vertical structure of the broader cloud bands. In addition to dynamical and morphological characterizations of the clouds and their motions, the observations at different wavelengths and different view angles were designed to constrain models of the vertical distribution of aerosols in the atmosphere. The original program was executed in November 2009, but because of program execution problems resulting in lost data, selected repeat observations were made in June 2010.

2. Brief description of the findings:

Images taken in November of 2009 captured a number of interesting features. We were able to acquire 16 dithered F845M images each of six HST orbits (each spanning ~90 minutes). The results of combining the images provided high S/N images revealing an inventory of nine trackable features that are well resolved. Wind vectors derived from these images are in a paper currently under review by the Astronomical Journal. These vectors are close to the best-fit profile determined from prior observations (Sromovsky et al. 2009, Icarus 203, 265-286), but in best agreement with the profile inverted about the equator. A feature found near 32 N is very likely the long-lived feature observed previously (Sromovsky et al. 2009, Icarus 203, 265-286), which was also associated with a dark spot (Hammel et al. 2009, Icarus 210, 257-271). However, eight F658N images and one each with F467M and F547M filters, filters which had previously recorded the 2006 Uranus dark feature and Neptune dark spots, failed to detect any dark features either near this bright feature or anywhere else. In the June images we found a small bright feature at 28 deg N, which may be related to the 32 deg N feature seen in November, but the brightness is much higher than was seen in November and may be an indication of another dramatic brightness increase for the long-lived feature that was extremely bright in 2005 (Sromovsky et al. 2007, Icarus 192, 558-575). The June data also achieved the spectral coverage needed to provide the constraints on the vertical distribution of aerosols.

We also found in the November images a longitudinally-extended feature just south of the equator, which is plausibly the remnant of the Berg (Sromovsky et al. 2009; de Pater et al. 2011, Icarus 215, 332-345). On November 11 it was at a latitude of approximately 5.4 deg. S, which is 2.5 deg north of where a similar feature was seen in Keck images taken about three months earlier. The survival of the feature this close to the equator is surprising because numerical simulations of the atmospheric dynamics suggests dissipation should occur before getting much closer to the equator than 15 deg. This feature was not seen in the June 2010 images, although that might be due to significantly lower S/N levels in that data set. The November images also provide a much sharper definition of the bright near-equatorial band, which is roughly bounded by the equator and the 3.5 deg N latitude circle. Based on 2006 STIS spectral imagery, this feature appears to be located in the 0.1-1.2 bar region (Karkoshka and Tomasko 2009, Icarus 202, 287-309). The fact that the feature cannot be seen in K' images suggest that the feature is at the higher pressure half of this range, although its visibility in FQ889N images implies that it is closer to the middle than at the high-pressure end of the range.

Unlike the southern bright band, the northern bright band has remained quite broad, extending from about 38-43 deg N (the southern band appears to extend from about 40 to 48 deg S centric). Comparisons of the NICMOS F160W image made in 2007 with the WFC3 F160W image made in 2009, indicate that the southern bright band has declined in brightness while the northern band now exceeds the brightness of the southern band. It also shows much more limb brightening. That fact, coupled with the fact that the southern band is still the brighter of the two at more penetrating wavelengths, such as F845M and F658N, means that the northern band is brightening faster at higher altitudes and that it is translucent (at least at high altitudes). In the F845m image, the southern band exhibits limb darkening, while the northern band shows limb brightening, confirming a substantially different vertical distribution. One factor that has complicated the analysis of the higher latitude cloud features on Uranus has been the discovery that at least high southern latitudes on Uranus are substantially depleted in methane relative to low latitudes (Karkoshka and Tomasko 2009, Icarus 202, 287-309), and that this depletion is restricted to the upper troposphere (Sromovsky et al. 2011, Icarus 215, 292-312). The possibility of methane variations as well as cloud aerosols requires stronger constraints than provided by just band-pass filtered images. Additional STIS spectra are needed to determine if high northern latitudes also exhibit a methane depletion.

3. Name and date (or anticipated date) of the publication of results:

Fry, P.M., L.A. Sromovsky, I. de Pater, H.B. Hammel, and K.A. Rages 2010. Detection and tracking of subtle cloud features on Uranus. Bull. Am. Astron. Soc. 42, p 1022 (partly supported by STScI and partly supported by NASA's Planetary Astronomy Program).

Fry, P.M., L.A. Sromovsky, I. de Pater, H.B. Hammel, and K.A. Rages 2012. Detection and tracking of subtle cloud features on Uranus. Astronomical Journal, submitted (partly supported by STScI and partly supported by NASA's Planetary Astronomy Program). Publications is expected in early 2012.

I. de Pater, H.B. Hammel, L.A. Sromovsky, P.M. Fry, R.P. LeBeau, M. Showalter, and K. Rages. 2011. Post-Equinox Observations of Uranus: Berg's Track Towards the Equator. Icarus 215, 332-345. This was partly supported by STScI and partly by NASA's Planetary Atmospheres and Planetary Astronomy programs, as it involves both ground-based Keck observations and HST observations).

4. Suggestions and additional comments:

PRINCIPAL INVESTIGATOR NAME:
Lawrence A. Sromovsky

Please note that a copy of the report should be forwarded to the Authorizing Official of your Institution.