

## Progress Report on NAG5-6788.

## Clouds on Neptune: Motions, Evolution, and Structure

Period of Performance (year 1): 4-9-98 through 3-31-99

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## 1 Specific Aims

The aims of our original proposal are these: (1) improving measurements of Neptune's circulation, (2) understanding the spatial distribution of cloud features, (3) discovery of new cloud features and understanding their evolutionary process, (4) understanding the vertical structure of zonal cloud patterns, (5) defining the structure of discrete cloud features, and (6) defining the near IR albedo and light curve of Triton. Towards these aims we proposed analysis of existing 1996 groundbased NSFCAM/IRTF observations and nearly simultaneous WFPC2 observations from the Hubble Space Telescope. We also proposed to acquire new observations from both HST and the IRTF.

## 2 Results

**Analysis of 1996 Observations.** New techniques for precise navigation of groundbased images, needed for coordinated analyses with HST images, have been fully developed and successfully tested. We have now demonstrated an ability to locate Neptune in IRTF images made at the nominal "0.15 arcsecond/pixel" image scale to within about 0.015 arcseconds, even when no planetary limb is visible. This is accomplished by offsetting from Triton, but getting that method to work required an extremely accurate determination of image scale and how it varies with focus, filter, and position within the image. We found that the NSFCAM image has a barrel distortion large enough that offsets from Triton were sometimes in error by a full pixel or more. We used multiple star images and interstellar angular separation measurements in different beam positions to establish a distortion correction with a residual error of only 0.1 pixels. To meet our offset navigation error budget, we also had to determine the image scale to within about 0.065%, and the orientation of the image y axis with respect to celestial north to within 0.655 milliradians (about 0.04°). Uranian satellite observations were used to accomplish both objectives. We found a somewhat surprising but unambiguous dependence of image scale on filter. For example, the average J-filter scale of  $0.1470 \pm 0.0001''/\text{pixel}$  is nearly 0.7% smaller than the average K-filter scale of  $0.14780 \pm 0.0001''/\text{pixel}$ , which is a  $10\text{-}\sigma$  difference. We verified our navigational accuracy by comparisons of discrete cloud feature positions in successive images taken with different beam positions and with features in HST images made nearly simultaneously with the groundbased images. These comparisons achieve their greatest accuracy when deconvolutions are used to sharpen the groundbased images. Considerable effort

was invested in studying the properties of the IRTF deconvolutions to determine what artifacts were produced and what effects they had on disk-integrated and discrete feature brightness levels and on feature positions.

An extensive investigation of the far wing point spread function of the IRTF/NSFCAM system was undertaken to determine appropriate seeing-dependent aperture corrections for the photometric analysis. We found good agreement with previous disk-integrated measurements of Triton's geometric albedo (e.g. Buratti et al. 1994, Cruikshank et al. 1993, Hillier et al. 1990), but found that Neptune's albedo in the J-K spectral range was about 50-60% of that reported by Fink and Larsen (1978). We found an inconsistency between narrow-band CVF results and broadband results in the K window when using Arvesen's (1969) measurements as our solar irradiance reference, while much better consistency was obtained using the synthetic irradiance spectrum of Kurucz (1994), or Labs and Neckel (1970). We are now ready to determine individual cloud feature I/F values and coordinate them with the nearly simultaneous HST images at shorter wavelengths. We have also completed comparisons between disk-integrated I/F values for the 1996 HST images and previous groundbased results, obtaining very close agreements with Fink and Larsen (1978) and Karkoschka (1994). We also completed navigation for all the HST observations, and made preliminary wind field determinations.

The results of the analysis to date have been documented extensively in a working draft of a paper that we intend to submit to *Icarus* in 1999. The draft currently has 100 pages, 39 figures, 18 tables, three appendices, and 103 references, and thus will be abbreviated or split into two or three papers prior to submission.

**Acquisition of New Observations.** We carried out observing runs at the IRTF during four nights in September 1997, four nights in June 1998, and four nights in August 1998, the latter overlapping and nearly simultaneous with HST observations using WFPC2 and NICMOS cameras. While quick look results for 1998 were presented at the 1998 DPS meeting (Sromovsky et al. 1998), detailed analysis will not start until the coming year. We also succeeded in getting an additional four nights of time on the IRTF in July 1999.

### 3 Plans for the Coming Year

Our two primary goals will be (1) planning and execution of the July 1999 IRTF observing run and (2) the completion of the paper(s) on the coordinated 1996 HST and IRTF observations. Remaining tasks for that paper are completion of cloud tracking in the IRTF images, systematic measurement of I/F at both HST and IRTF wavelengths for each significant discrete feature and cloud band, which would be the first such measurements, and radiation transfer calculations to infer vertical structure constraints from the spectrum of I/F measurements.

We will also apply the techniques we refined during the first year to begin the navigation and detailed analysis of the 1997 and 1998 observations, and a preliminary analysis of the 1999 observations. The 1998 observations are particularly interesting because we were able to obtain grism spectra of Neptune and Triton. The preliminary form of the Triton spectra are mainly consistent with previous results (e.g. Cruikshank et al. 1993). In comparison to Fink and Larsen (1978), we hope to obtain a much improved signal/noise ratio and a significantly improved Neptune disk-integrated spectrum, after we complete spectral and radiometric calibrations. In addition we hope to obtain some spatially resolved spectra of Neptune, although at relatively low resolution from the 1998 observations, but perhaps with better resolution in 1999 with a fully functional tip-tilt system at the IRTF.

## 4 Publications

Sromovsky, L.A., P.M. Fry, S.S. Limaye, K. H. Baines, and T. Dowling, 1998. HST and IRTF Observations of Neptune during 1998 *Bull. Am. Astron. Soc.* **30**, 1098.

Sromovsky, L.A., P.M. Fry, S.S. Limaye, K. H. Baines, and T. Dowling, 1999. Coordinated 1996 HST and IRTF Observations of Neptune. In preparation for submission to *Icarus* (100-page draft is available).

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