Technical Report
University Of Wisconsin-Madison

(To be completed by RSP or the Department)

Project Title:	**Analysis of New Spectral Constraints on Jupiter's Cloud Structure**
Award Number:	**NNX09AE07G**
UW Account Number:	**PRJ23YA**
For the Period of:	**5/1/2011 through 4/30/2012**
Principal Investigator:	**Lawrence Sromovsky**
Date Submitted:	**5/4/2012**
Location:	**University of Wisconsin - Madison** **Space Science and Engineering Center** **1225 West Dayton Street** **Madison, WI 53706**
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SSEC Number (Internal)	***6453*** **I:/jennys/6453Yr2.doc**

(To be completed by the Principal Investigator)

<u>Inventions Report:</u>

☒ No Inventions resulted from this award
☐ Yes

Inventory Report:

☒ No federally owned equipment is in the custody of the PI
☐ Yes

Publications: (Please list)

Peer Reviewed Publications:

Sromovsky, L.A., and P.M. Fry 2010. The source of 3-micron absorption in Jupiter's clouds: a reanalysis of ISO observations with new NH3 absorption models. *Icarus* **210**, 211-229.

Sromovsky, L.A., and P.M. Fry, 2010. The source of 3-micron absorption in Jupiter's clouds: constraints from 2000 VIMS observations. *Icarus* **210**, 230-257.

Sromovsky, L.A., and P.M. Fry, V. Boudon, A. Campargue, and A. Nikitin 2011. Near-IR methane absorption in outer planet atmospheres: comparison of line-by-line and band models. *Icarus* **218**, 1-23. (Partially supported by a Planetary Atmospheres Grant)

Sromovsky, L.A., P.M. Fry, I. de Pater, and M. H. Wong, 2010. Jupiter's low-latitude cloud structure: implications of 2005 NICMOS observations. In preparation for submission to Icarus.

Abstracts/Conference Presentations:

Sromovsky, L.A. and P.M. Fry. 2009. Evidence for widely distributed ammonia ice on Jupiter. *Bull. Am. Astron. Soc.* **41**, 1006.

Sromovsky, L.A. and P.M. Fry. 2010. Evidence for NH_4SH as the primary 3-micron absorber in Jupiter's Clouds. *Bull. Am. Astron. Soc.* **42**, 1010.

Sromovsky, L.A. and P. M. Fry. 2011. Comparison of line-by-line and band-model calculations of methane absorption in outer-planet atmospheres. Presented at the EPSC-DPS Joint Meeting in Nantes, France (43rd DPS meeting).

Summary of Technical Effort: (Usually several paragraphs. Please feel free to attach additional pages if you wish.)

OBJECTIVES: We aimed to develop improved models of Jovian cloud structure using a combination of imaging and spectral observations acquired during the New Horizons 2007 flyby of Jupiter, and complementary data provided by Galileo and Cassini imaging and spectral observations acquired during the Cassini flyby of Jupiter at the end of 2000. The main New Horizons instrument of interest to this investigation is named Ralph, and includes a visible and near-IR multi-spectral images (MVIC) and a near-IR Linear Etalon Imaging Spectral Array (LEISA). The latter is analogous to the Cassini VIMS and Galileo NIMS instrument but covers the 1.25-2.5 micron spectral range, compared to 0.3-5 microns for VIMS and 0.7-5.2 microns for the Galileo NIMS. LEISA's great advantage is the vastly better spatial resolution, with sub-spacecraft resolution ranging from 137 km/pixel at 32.44 RJ to 350 km at 82.3 RJ. VIMS best at Jupiter was 4900 km. Thus these data provide complementary spectral ranges, spatial coverages, and spatial resolutions. Variations in methane, ammonia, and collision-induced absorption with wavelength will be used to probe the vertical structure of clouds; we also plan to use high-resolution observations will to infer vertical location from the ratio of spatial variations in cloud reflectivity at wavelengths with different penetration depths.

TASKS: (1) Image and Spectral Data Processing; (2) Characterization of spectral types, (3) Inversion of cloud structure from near-IR spectra, (4) Characterization of differences between New Horizons and Cassini Epochs, and (5) Combined analysis of CCD imagery and spectra.

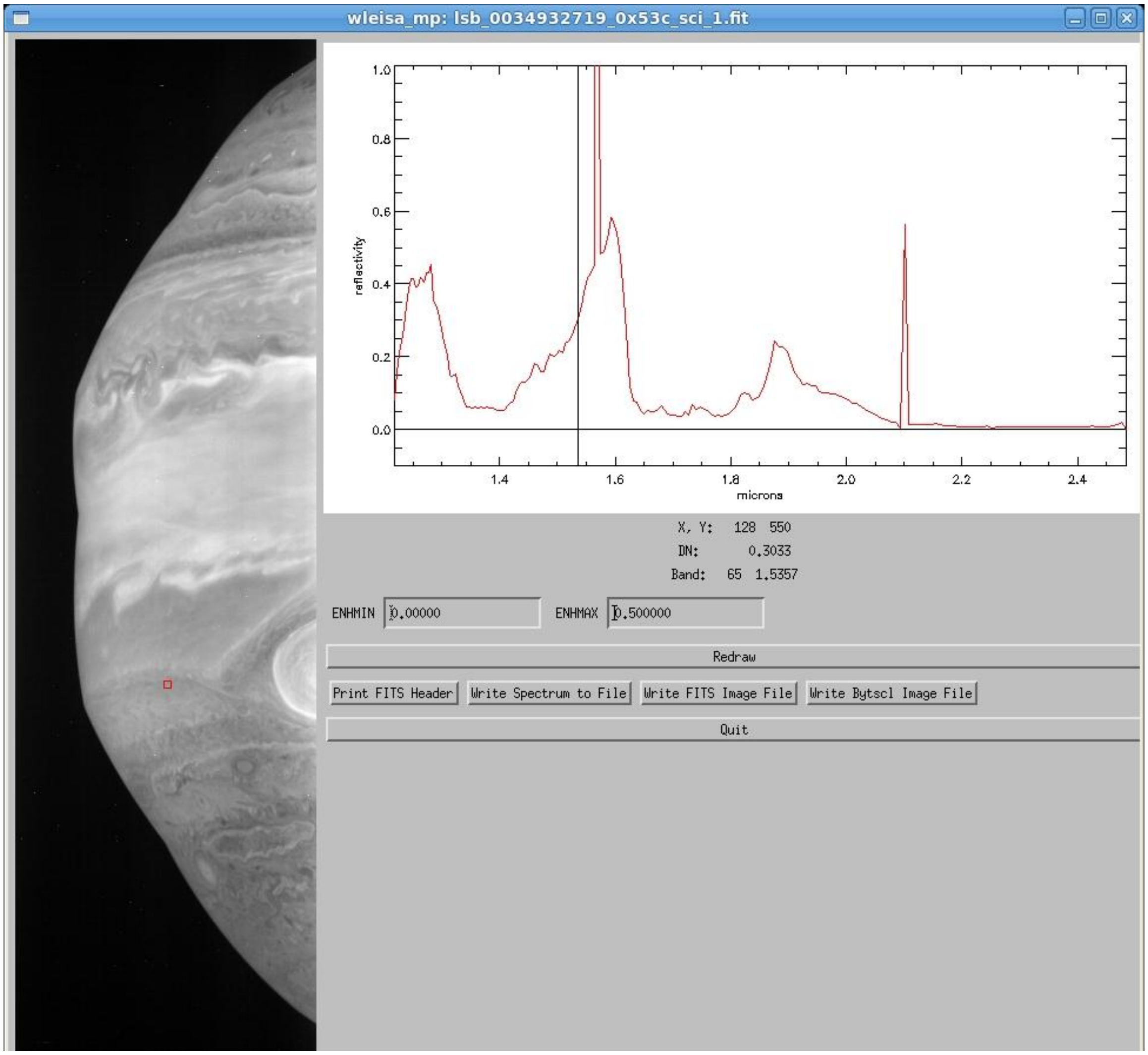
PROGRESS DURING YEAR 3:

An abstract on the comparison of line-by-line and band models near-IR methane absorption was presented at the joint EPSC-DPS meeting in Nantes in early October 2011. We also completed and submitted the Icarus paper on the same topic, then withdrew it and resubmitted an improved version with inputs from additional authors who were brought on board in recognition of their primary responsible for the laboratory measurements and theoretical modeling of methane absorption line properties. After reviews were received, the paper was slightly revised, resubmitted, accepted on 9 December 2011, and subsequently published. This was the main accomplishment of Year 3, as progress on other tasks was greatly slowed by resource conflicts with other projects. To allow time to complete the remaining tasks we asked for and received a no-cost extension until 30 April 2013.

Analysis of CCD image data in combination with spectra (Task 5) is still in its initial stages, remaining at essentially the same state as described in last year’s progress report.

The in-preparation paper on analysis of NICMOS observations of Jupiter has also not progressed, primarily because of uncertainties in how to handle potential absorption by NH_4SH and/or NH_3 particles in the F204M filter band, complicating the spatial modulation analysis, which is only simple if the aerosol properties can be assumed the same for both filter bands. As noted in last year’s report, we also applied the spatial modulation technique to Cassini ISS images of Jupiter, using MT2 and CB2 filters initially. However, the result of applying this empirical model result to the observed ratios resulted in unexpectedly high pressures, roughly twice the values expected from the near-IR analysis. This visible-near IR inconsistency in modulation pressure inferences needs to be understood, and the New Horizons LEISA observations might provide a good data set for reaching that understanding. By selecting near-IR wavelengths that provide useful vertical sensitivity ranges but avoid potential particulate absorption features, we may be able to make a clean comparison with the Cassini ISS CCD results.

Our progress has also been slow in making needed corrections to New Horizons LEISA spectral imaging observations that are needed to obtain calibrated spectra of discrete features. The image in the following figure comes from an acquisition sequence of 1354 256x256 multiwavelength images, each with an exposure time of 0.349 sec, for a total observation duration of 472 sec (7.87 min, or 4.76 deg of longitude). The image is recorded in two spatial dimensions, with a wedge filter that makes one dimension also vary with wavelength. A full spectrum for the target region thus requires spatial scanning in the direction in which wavelength varies, taking image frames at each scan step. A monochromatic image can then be formed by assembling from top to bottom, line by line, the same wavelength row from each successive frame of the observation. The consequences of this are that each row of a monochromatic image has an effective acquisition time different from all other rows, and that different monochromatic images have different start times. This means that a specific cloud target can, and generally will, appear at different image locations at different wavelengths. This would be true even if the camera pointing did not vary during the image scan, which it does, and even if the cloud target stayed at the same latitude and longitude, which it does not. The waviness seen at the edge of the image is a result of variations of camera axis pointing during a scan of the planet.



wleisa_mp: lsb_0034932719_0x53c_sci_1.fit

X, Y: 128 550
DN: 0.3033
Band: 65 1.5357

ENHMIN 0.00000
ENHMAX 0.500000

The calibrated PDS observation cubes have, however, all the information necessary to determine a given pixel's coordinates in space and time. First, for every pixel of the multiwavelength 256x256 pixel frame, there is a vector for that pixel relative to the optic axis of the instrument. In addition, for each frame of the observation, there is the ephemeris time and pointing information for optic axis of the instrument. These data will allow us to account for planetary rotation when extracting spectra from the planet, so that a spectrum will have a fixed latitude and longitude on the planet, and also to remove the waviness seen in the sample monochromatic image. We have yet to apply and test these corrections for efficacy, however.

PLANS FOR NEXT YEAR:

The first priority will be to implement and test the many corrections that are needed to model the LEISA observations (Task 1). The first step will be to extract and process pointing information so that observations can be remapped to a latitude-longitude grid for each wavelength, with backplanes of time and viewing geometry. This takes out the major factor that causes cloud features to appear at different image locations in different wavelengths. A further refinement is needed to take out the displacements caused by zonal wind motions. After this is done, there remains the residual displacement caused by non-zonal motions, which can be manually measured for individual targets at three window wavelengths, then fit to a smooth curve to apply to intermediate wavelengths. Once these corrections are verified, we can then proceed to apply spatial modulation analysis to the LEISA observations at multiple wavelengths and hopefully demonstrate a consistency between these near-IR observations and the Cassini ISS results at shorter (CCD) wavelengths. This will hopefully lead to a paper on spatial modulation results from both data sets. It is not clear whether we will be able to use these results to reach a satisfactory explanation for the NICMOS analysis, nor whether the remaining issues in the NICMOS paper in preparation can be sufficiently resolved to allow completion.

We will apply inversion techniques to determine cloud structure parameters, going beyond the pressure level of modulating layers, to infer optical depth, particle size, and to some degree, composition (Task 3). We will also adapt our automated fitting algorithm to handle the band-pass filter CTL observations and apply that to CTL results obtained from Cassini ISS images as described previously (Task 5).