

Final Report  
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Jupiter Systems Data Analysis Program  
Galileo Multi-Spectral Analysis of the Galilean Satellites  
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Amanda Hendrix (formerly at University of Colorado, now at JPL)  
Robert Carlson (JPL)  
William Smythe (JPL)

Progress was made on this project at the University of Colorado, particularly concerning analysis of data of the galilean moons Io and Europa. The goal of the Io portion of this study is to incorporate Near Infrared Mapping Spectrometer (NIMS) - measured sulfur dioxide (SO<sub>2</sub>) frost amounts into models used with Ultraviolet spectrometer (UVS) spectra, in order to better constrain SO<sub>2</sub> gas amounts determined by the UVS. The overall goal of this portion of the study is to better understand the thickness and distribution of Io's SO<sub>2</sub> atmosphere. The goal of the analysis of the Europa data is to better understand the source of the UV absorption feature centered near 280 nm, which has been noted in disk-integrated spectra primarily on the trailing hemisphere. The NIMS data indicate asymmetric water ice bands on Europa, particularly over the trailing hemisphere, and especially concentrated in the visibly dark regions associated with chaotic terrain and lineae. The UVS data, the first-ever disk-resolved UV spectra of Europa, shown that the UV absorber is likely concentrated in regions where the NIMS data show asymmetric water ice bands. The material that produces both spectral features is likely the same, and we use data from both wavelength regions to better understand this material, and whether it is endogenically or exogenically produced. This work is still in progress at JPL.

## IO.

A previous study using UVS data (Hendrix *et al.*, 1999) modeled a spectrum of Io taken by the UVS in terms of SO<sub>2</sub> gas and frost. In that study, the SO<sub>2</sub> frost coverage was assumed to be 35% for the longitude region observed, and it was also assumed that the SO<sub>2</sub> frost corresponded with a white-colored region in the corresponding visible image of the area. The observed area (centered on 120°W and extending from pole to pole) was broken up into three regions: the equatorial region, covered by SO<sub>2</sub> frost and some amount of SO<sub>2</sub> gas, a mid-latitude region, with a spectrally flat surface reflectance (i.e., not SO<sub>2</sub> frost) and some amount of SO<sub>2</sub> gas, and the high latitude region, which also has a spectrally flat surface reflectance; it was assumed that no SO<sub>2</sub> frost exists in this high-

latitude region. The amounts of SO<sub>2</sub> gas in the low- and mid-latitude regions were allowed to vary to achieve the best fit to the UVS-measured spectrum. The best fit was achieved for a column density of  $N=4.e17 \text{ cm}^{-2}$  overlying the low-latitude frost region and a column density of  $N=1.e19 \text{ cm}^{-2}$  overlying the mid-latitude non-frost regions. This thick column density is larger than has been determined by spectral band matching at shorter wavelengths using higher spectral resolution data (Ballester *et al.*, 1990; Trafton *et al.*, 1996), but is necessary to fit a broad peak in the UV spectrum near 2400 Å.

In the present study, we are using information about the SO<sub>2</sub> frost coverage as measured by the Galileo NIMS. This may enable us to better constrain the SO<sub>2</sub> gas column densities that are present at Io because we no longer must assume SO<sub>2</sub> frost amounts at any given location. A significant difference from our earlier method results from the fact that NIMS finds that SO<sub>2</sub> frost exists almost everywhere on Io, not only where white patches are seen. We use information made available to us by Sylvain Douté (formerly at UCLA, currently at Laboratoire de Planetologie de Grenoble, CNRS) concerning SO<sub>2</sub> frost distributions on Io as measured by NIMS, as published in "Mapping SO<sub>2</sub> frost on Io by the modeling of NIMS hyperspectral images," (Douté *et al. Icarus*, 2000). These maps show SO<sub>2</sub> frost grain size distribution as well as concentration across the majority of the surface of Io. For the UVS Io observation discussed above, we averaged the SO<sub>2</sub> frost distributions from NIMS results for several latitude bins. We then used these average frost amounts in the model to solve for best-fit amounts of SO<sub>2</sub> gas. Our results indicate that a relatively thick column density ( $\sim 10^{19} \text{ cm}^{-2}$ ) is still required to fit the UVS data. This column density covers a small region of the observed area. We also require a thinner column density region ( $\sim 10^{17} \text{ cm}^{-2}$ ), which is consistent with results from HST (Ballester *et al.*, 1990; Trafton *et al.*, 1996). These results were presented in a talk at the Fall 2000 AGU meeting.

We have modifications yet to make on our model, but find that so far, even using more accurate SO<sub>2</sub> frost coverage amounts in the model, we still require relatively large SO<sub>2</sub> gas column densities to fit the UVS-measured spectrum of Io. In particular, to fit the broad spectral feature near 2400 Å, we have tried using SO<sub>2</sub> frost, SO<sub>2</sub> gas, and sulfur, and get an adequate fit only by using a thick SO<sub>2</sub> gas amount.

We have eight additional UVS Io observations from several Galileo orbits to fit: 4 covering a central longitude of  $\sim 90^\circ\text{W}$ , 2 centered near  $150^\circ\text{W}$ , and 2 centered near  $210^\circ\text{W}$ . Because these observations were performed on different orbits and at varying longitudes, we will look for correlations between SO<sub>2</sub> gas column densities and volcanic activity.

## EUROPA.

We focus on the European hydrated compound measured by NIMS, and the associated dark material concentrated on Europa's trailing hemisphere. The hydrate has

been postulated to be hydrated sulfuric acid (Carlson *et al.*, 1999) generated by radiolysis acting on a water ice surface enriched with either endogenic or exogenic sulfur. An alternative suggestion for this material is hydrated salt minerals (McCord *et al.*, 1999). We look for correlations between these IR features and absorptions in the UV. In particular, we investigate whether the same process that causes the asymmetric hydrate bands in the NIMS data causes a broad absorption feature in the UVS data, centered near 0.28 microns (Hendrix *et al.*, 1998). This feature has also been detected in IUE (Lane *et al.*, 1981) and HST data (Noll *et al.*, 1995) and has generally been thought to be related to energetic particle bombardment, particularly sulfur ion implantation. Correlation of the IR and UV absorptions may help to confirm the nature of the dark material, and whether it is primarily endogenic or exogenic in source.

Because many Europa observations by UVS and NIMS were performed simultaneously, we can compare spectra from each instrument that were taken at the same time and under the same lighting conditions. The UVS has lower spatial resolution than the NIMS; to compare IR and UV spectra of the same surface area, we average the spectra from the NIMS pixels covering the UVS FOV. We look for correlations in spectra and where possible, in images from both instruments. We compare IR and UV spectra with laboratory spectra of candidate materials.