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Neutron Spectroscopy of Ganymede: Operating a ^{3}He detector in the Jupiter Ganymede Orbiter radiation environment

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Abstract

Neutron spectroscopy has the capability to map and characterize water ice deposits on the surface of Ganymede, a primary science goal for the Jupiter Ganymede Orbiter (JGO). The challenge to carrying out neutron spectroscopy at Ganymede is compensating for the detrimental effects of the intense charged particle radiation environment. To facilitate this, a solar energetic particle event observed by the Lunar Prospector (LP) Neutron Spectrometer (NS), which had similar magnitude and energy dependence to the Ganymede proton environment, is used as the basis for modeling the performance of an LP-style NS for JGO.

1. Science Motivation

Quantitative neutron spectrometer measurements of hydrogen concentrations at Ganymede can constrain a number of key science questions for understanding Jupiter's icy moons. These measurements would map the concentration and location of Ganymede's polar cap, as well as determine if it is a surficial frost or is macroscopically thick. By measuring the ice/non-ice fraction of the cap, NS measurements can constrain the processes responsible its creation [1]. Mapping the polar cap boundary location, and assuming that the cap is primarily due to hydrogen concentration variations, provides independent constraints on the parameters of an induced magnetic field and by extension Ganymede's subsurface ocean [1]. Additionally, by providing quantitative concentration information for one of the largest components of Ganymede's surface - namely hydrogen - neutron measurements can provide compositional closure data for quantitative abundance measurements for non-ice material using techniques such as x-ray spectroscopy.

2. Neutron Spectroscopy

Neutron spectroscopy measures planetary surface composition by identifying the presence of neutron absorbing elements (e.g. Fe, Ti) and neutron moderators (e.g. H). The LP mission demonstrated the capability of neutron spectroscopy to identify water ice deposits in lunar polar regions [2], and a neutron spectrometer on Mars Odyssey mapped surface hydrogen and CO_2 variations [3,4]. Neutron spectrometers are currently making measurements at Mercury [5] and the asteroids 4 Vesta and 1 Ceres [6].

3. Radiation Induced Background

A number of different types of neutron detectors exist; however, the extensive spaceflight heritage and inherent radiation tolerance of ^{3}He proportional counters make them the optimal choice for use in the radiation environment around Ganymede. For this study, the ^{3}He proportional counters used by LP serve as the basis for modeling background signals. The LP NS measured changes in the epithermal neutron flux emanating from the lunar surface, which is highly correlated to hydrogen abundance. These changes are observed in the 764 keV ^{3}He neutron capture peak, a signal which was 20 times larger than the nominal background for the detector.

On April 20th, 1998 a class M solar flare caused an increase in the charged particle radiation environment around the Moon. During this event, the background in the LP NS increased by three orders of magnitude as a result of the high proton flux in the detector, obscuring the neutron signal. Comparisons of the solar energetic particle (SEP) proton flux to the charged particle environment around Ganymede, as measured by the Galileo Energetic Particle Detector [7], reveal that the two proton environments were very similar in magnitude and energy dependence. Therefore, understanding the signal in the LP NS during this SEP event will shed light on the operation of a similar instrument around Ganymede.

Simulations of the LP NS backgrounds were compared to the measured nominal and SEP LP backgrounds. In the energy range around the 764 keV neutron capture peak (500 to 1000 keV), the simulations agree with measurements to 10%. Extending these simulations to the Ganymede radiation environment, compensating for the differences between the JGO and LP orbital altitudes and increased size of Ganymede relative to the Moon, we predict a signal-to-background of 2:100. Compared to the LP NS signal-to-background during nominal operations of 20:1, the simulated background is three orders of magnitude larger for an equivalent instrument operating around Ganymede.

4. Radiation Shielding

Simulations of radiation shielding schemes were carried out with varying materials and thicknesses. Results indicate that replacing the LP aluminum housing with three kg of stainless steel would lower the background by three orders of magnitude. This shielding will not have an effect on the signal, as the neutrons will rarely interact with stainless steel. The resulting signal-to-noise matches the 20:1 factor for the LP NS. This does not take into account the increased signal which results from the larger high energy proton flux incident on the surface of Ganymede as compared to the moon, an effect which is expected to raise the signal by at least an order of magnitude.

5. Instrument Performance

Using Ganymede geologic maps derived from Voyager and Galileo observations [8], and making assumptions about the water equivalent hydrogen (WEH) abundances for the varying geologic units, a neutron map of Ganymede for the JGO mission has been simulated (Figure 1). This map calculated the neutron flux in the proposed JGO detector by propagating the surface to the detector for the baseline JGO orbital parameters (180 days at 400 km altitude). This calculation assumes a signal-to-background of 20:1, which this study suggests is achievable with radiation shielding. The calculation assumed a similar neutron flux to the Moon, neglecting the higher signal expected at Ganymede. Geologic units are clearly discernible in the map, as are the relative WEH abundances.

6. Conclusions

With the addition of three kilograms of stainless steel shielding to each detector, a LP-style NS will be capable of mapping the surface hydrogen on Ganymede as part of the JGO mission. Such an instrument would provide unique information about the location, depth, and composition of the water-ice units on the surface.

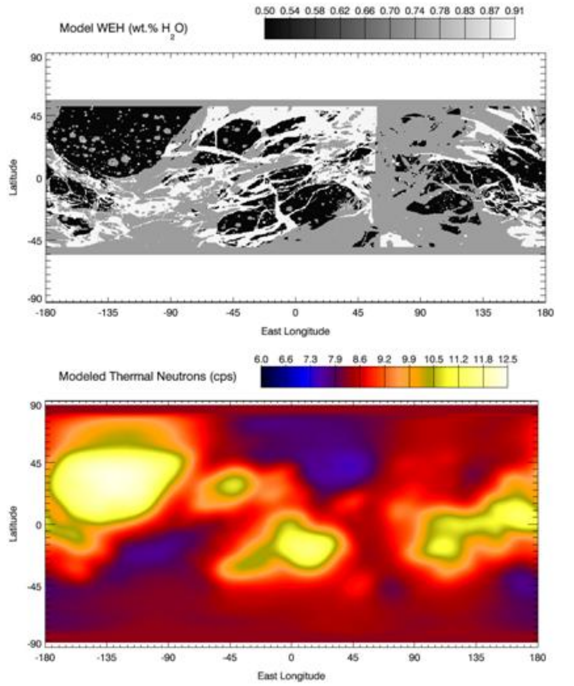

Figure 1 (top) Assumed water-ice abundances for geologic units on Ganymede, using the map of [7]. Bright regions have been assigned a water equivalent hydrogen (WEH) abundance of 90 wt%, dark regions 50 wt%, and all other regions an intermediate value of 75 wt%. (bottom) Simulated neutron flux map for the nominal JGO mission profile carrying a LP-style NS for the composition in (top).

References

[1] Khurana et al. (2007): The origin of Ganymede's polar caps, Icarus 191

[2] Feldman, W.C., et al. (1998): Fluxes of Fast and Epithermal Neutrons from Lunar Prospector: Evidence for Water Ice at the Lunar Poles, *Science* 281,1496-1500.

[3] Feldman, W. C,. et al. (2002): Distribution of hydrogen in the near surface of Mars: Evidence for subsurface ice deposits, *Science 207* 75-78.

[4] Prettyman, T. H., et al. (2004): CO2 frost cap thicknes on Mars during northern winter and spring, *J. Geophys. Res.*, 10.1029/2003JE002139.

[5] Goldsten, J. O., et al. (2007): The MESSENGER Gamma-Ray and Neutron Spectrometer, *Space Sci Rev 131*, 339-391.

[6] Prettyman, T.H., et al. (2003): Gamma-ray and neutron spectrometer for the Dawn mission to 1 Ceres and 4 Vesta, *Trans. On Nuc. Sci. 50*, 1190-1197.

[7] Mauk, B.H., et al. (2004): Energetic Ion characteristics and neutron gas interactions in Jupiter's magnetosphere, *J. Geophys. Res. 109* A109S12

[8] Patterson, G. W., et al. (2003): Global geologic mapping of Ganymede, *Icarus 207* 845-867