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Composition Measurements with Neutrons, γ-Rays and X-rays: Geophysical Instrument Suite for Ganymede

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Abstract

Measuring and mapping the surface composition of Ganymede is required in order to achieve several of the fundamental science objectives of the Jupiter Ganymede Orbiter (JGO) mission [1]. These objectives include:

- Characterisation of the icy surface environments and water beneath the surface.
- Measuring the surface composition and chemistry particularly with reference to environments that are suitable for life to evolve.
- Understanding the evolution of surface features and how geologic processes have shaped the surface.
- Constraining landing sites for future surface exploration missions.

Neutron, gamma ray and X-ray spectroscopy are analytical methods that can provide surface and subsurface composition information on a global scale. Neutron, gamma ray and X-ray spectrometers have been considered for JGO

In this study we describe a single hybrid geophysical instrument suite based on existing technologies (with a high technology readiness level) that could measure or detect neutrons, gamma rays and X-rays.

1. Introduction

Nuclear analytical techniques commonly used in terrestrial geology include neutron activation analysis (NAA) and gamma-ray spectroscopy (GRS). These analytical methods can be used to determine elemental composition, elemental concentrations and the distribution of water in rocks and soils [1]. Neutron emissions, from airless planetary bodies and those with thin atmospheres, result from the interaction of galactic cosmic rays (GCR) and energetic solar protons (SP) with the planetary surfaces [2, 3]. Gamma ray emissions result from neutron activation, inelastic neutron or proton scattering interactions [4]. Numerous successful missions have incorporated neutron and gamma ray instrumentation including: Mars Odyssey [2] and Lunar Prospector [3].

Alpha particle, electron or proton induced X-ray emission as well as X-ray fluorescence spectroscopy are well established methods for determining the composition of geological samples. X-ray detectors have been developed for in-situ probes, such as the Spirit and Opportunity Mars Exploration Rovers [5], and for X-ray astronomy missions, such as the NASA Swift Gamma Ray Burst Observatory [6] and the ESA XMM-Newton Telescopes [7].

X-ray diffraction can be used to obtain data on the mineralogical content of a geologic sample [8].

ESA's Bepi-Colombo mission to Mercury [9] will carry the Mercury Imaging X-ray Spectrometer (MIXS) as well as a separate Mercury Gamma Ray Neutron Spectrometer (MGNS). The former will exploit solar X-ray induced X-ray fluorescence to map the composition of Mercury.

In this study, the hybrid detector proposed is a single structure that detects X-rays, neutrons and gamma rays.

2. Hybrid Detector System

In this study, the hybrid detector proposed is a single structure that detects X-rays, neutrons and gamma rays. As in the case of MIXS it will exploit square pore radially packed microchannel plate (MCP) optics to focus both X-rays and neutrons onto a multilayer detector structure, shown schematically in Figure 1. The X-ray detector also a microchannel plate detector system would be transparent to the neutrons detected by the boron loaded MCP based detector system forming the second layer. Both X-ray and neutron detectors would be non imaging. The direct detection of X-rays and neutrons in the MCP structures would result in the release of electrons which would be multiplied by an avalanche process in the MCP structure. MCP detectors for direct detection of X-rays and neutrons have significant heritage [10, 11]. A Helium-3 gas detector could be used instead of the boron loaded MCP. Depending on the configuration or geometry, gamma rays would pass through both the thin X-ray and neutron detectors and would interact with a scintillator based gamma ray sensor situated on the rear end of the hybrid structure an alternative a coplanar gamma ray and neutron detector geometry could be explored. A single scintillator structure could be coupled to photomultiplier or alternatively silicon drift or avalanche photodiodes could be used to save mass and power.

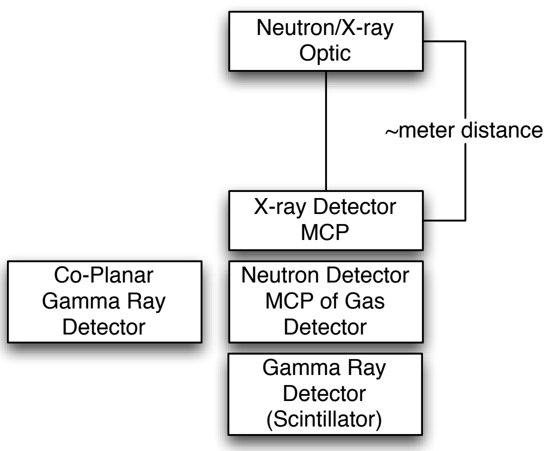

Figure 1: Schematic diagram of the detector system.

MCP optics can focus X-rays and neutrons [11, 12] and these properties will be exploited to increase the signal to background by concentrating the X-ray and neutron emissions onto the detector. The swath of the detector system will be determined by the field of view of the optic. Gamma ray detector swath will be driven by the physical dimension of the detector. The focal length of the concentrator is of order meters.

The detector geometry, performance, signal to background, radiation tolerance and technology readiness levels are all being examined in detail and preliminary results will be presented at the European Planetary Science Congress, Rome, September 2010.

6. Summary and Conclusions

A hybrid detector capable of mapping the surface composition of Ganymede is proposed. X-rays, gamma rays and neutrons can provide compositional information that cannot be obtained by other methods. The proposed detector system will not be imaging the surface and will be operated in a spectroscopic or counting mode. In order to achieve the JGO mission science goals X-ray, gamma ray and neutron spectroscopy should be considered.

References

[1] ESA Jupiter Ganymede Orbiter Assessment Report, ESA-SRE(2008)2, 2009.

[2] Boynton, W. V. et al.: The Mars Odyssey Gamma-Ray Spectrometer Instrument Suite, Space Science Reviews, Vol. 110, pp. 37-83, 2004.

[3] Lawrence, D. J., Feldman, W. C., Barraclough, B. L., et al.: Global Elemental Maps of the Moon: The Lunar Prospector Gamma-ray Spectrometer, Science, Vol. 281, pp. 1484- 1489, 1998.

[4] Masarik, J. and Reedy, R. C.: Gamma-ray Production and Transport in Mars, Journal of Geophysical Research, Vol. 101, pp. 18,891–18,912, 1996.

[5] Erickson, J. K., Callas, J. L., Haldemann, A. F. C.:The Mars Exploration Rover Project: 2005 surface operations results, Acta Astronautica, Vo. 61 (7-8) pp. 699-706, 2007.

[6] Burrows, D. N., Hill, J. E., Nousek, J. A., Wells, A. A., Short, A. D. T., Ambrosi, R. M., et al.: The Swift X-ray Telescope, SPIE, Vol. 4851, p. 1320, 2003.

[7] Turner, M. J. L., Abbey, A., Arnaud, M., et al.: The European Photon Imaging Camera on XMM-Newton: The MOS cameras, Astronomy and Astrophysics, Vol. 365, pp. L27-L35, 2001.

[8] Delhez, R., Marinangeli, L., van der Gaast, S., Int. Union of Crystallography Newsletter, Vol. 30, pp. 7–10, 2005.

[9] Fraser, G. W., Carpenter, J. D., Rothery, D. A., et al.: The mercury imaging X-ray spectrometer (MIXS) on bepicolombo, Planetary and Space Science, Vo. 58, pp. 79-95, 2010.

[10] Ambrosi, R. M., Street, R., Feller, B., G.W. Fraser, et al., X-ray tests of a microchannel plate detector and amorphous silicon pixel array readout for neutron radiography, Nuclear Instruments and Methods in Physics Research A, Vol. 572 (2) pp. 844-852, 2007.

[11] Fraser, G. W.: X-ray Detectors in Astronomy, Cambridge University Press, 1989.

[13] Wilkins, S. W., Stevenson, A. W., Nugent, K. A., et al.: On the concentration, focusing, and collimation of x-rays and neutrons using microchannel plates and configurations of holes, Review of Scientific Instruments, Vol. 60 (6), pp. 1026-1036, 1989.