UNDERSTANDING SOLAR ENERGETIC PARTICLE PROPAGATION TO CERES' DISTANCE TO PREDICT EXOSPHERIC PRODUCTION. M. N. Villarreal[1], J. G. Luhmann[2], M. L. Mays[3], T. H. Prettyman[4], N. Yamashita[4], C. A. Raymond[5], J. C. Castillo-Rogez[5], Y. D. Jia[1], C. O. Lee[2], and C. T. Russell[1]. [1]Earth, Planetary, and Space Sciences, University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles, CA 90095-1567, USA (mvillarreal@igpp.ucla.edu), [2]Space Sciences Lab, University of California, Berkeley. [3]Goddard Space Flight Center, Greenbelt, MD. [4]Planetary Science Institute, Tucson, AZ, [5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA .

Introduction: Measurements of the exosphere of Ceres by earth-based telescopes have shown it to be time varying [1, 2, 3]. The reported magnitudes of the vapor production rates do not correlate well with Ceres' heliocentric distance. In addition to telescopic observations, the Dawn spacecraft has observed energetic electron bursts following solar energetic particle (SEP) events. These burst events were interpreted as electrons reflecting from the surface of a bow shock caused by a transient exosphere [4]. Recently, Villarreal et al. [5] proposed that SEP events may be responsible for releasing water at or near the cerean surface, creating a transient exosphere through a sputtering process.

In order to test this hypothesis, how SEP events arrive at Ceres and their impact on the surface need to be better understood. Interplanetary shocks associated with solar coronal mass ejections are the sources of strong SEP events in interplanetary space. Solar energetic particles stream away from the shock surface along the Sun's interplanetary magnetic field (IMF) lines, allowing them to reach a wide range of heliolongitudes. A planet will experience a SEP event if the IMF lines at its location are connected to the shock surface. In this study, we analyze the magnitude of SEP events at the Ceres' distance as observed by Dawn and compare with 1 au measurements and potential real-time SEP prediction models. This work will lay the foundation for a reactive telescopic campaign to observe the cerean exosphere with earth based telescopes immediately following a large SEP event.

Method: Dawn's payload does not include traditional instrumentation used in studying space environment conditions including solar wind properties or energetic particle detectors. Despite this, Dawn is still capable of detecting energetic protons and electrons with its Gamma Ray and Neutron Detector (GRaND) [6]. Inelastic collisions of the energetic protons with spacecraft material leave nuclei in an excited state. The nuclei then emit gamma rays which are detected by the exterior scintillators and the center Bismuth Germanate (BGO) scintillator. For example, energetic protons will cause an increase in counts in the 4.4 and 6.1 MeV energy channels (C and O peaks) of the BGO spectrum due to the composition of the detector housing.

Dawn data from 2011-2017 were examined for solar energetic particle events. The passage of SEP events were confirmed by identifying the enhancment in gamma ray peaks at energies 4.4 and 6.1 MeV. The events are then compared to measurements on space weather monitoring spacecraft: Wind [7], STEREO A [8], and STEREO B [8], all located at different heliolongitudes near 1 au. Figure 1 shows a comparison between a SEP proton event measured at Wind (black line) and at Ceres with GRaND's exterior +Z Phoswich (cyan line). Not surprisingly, the Dawn data often show an onset several hours after the onset recorded at the satellite along or near its Parker spiral interplanetary magnetic field line and generally show similar responses. However, the events at Ceres' location appear to be more 'compressed' than the passage of the event at 1 au (i.e. they rise and fall more quickly).

In practice, real-time prediction models will be needed to anticipate whether a SEP event from the Sun will encounter Ceres. We will use Enlil [9], a magnetohydrodynamic model that uses solar coronograph images to predict how these solar disturbances will propagate in the solar wind. This model allows us to forecast if Ceres will be connected by interplanetary magnetic field lines to the shock surface, allowing for the propagation of SEPs to the body. The Enlil output will then be used in SEPMOD [10], which will give a predicted flux of energetic particles at the Ceres' location. To validate these predictions, we can retrospectively compare the model outputs to in-situ observations to understand the accuracy of the model and its usefulness for the reactive campagin.

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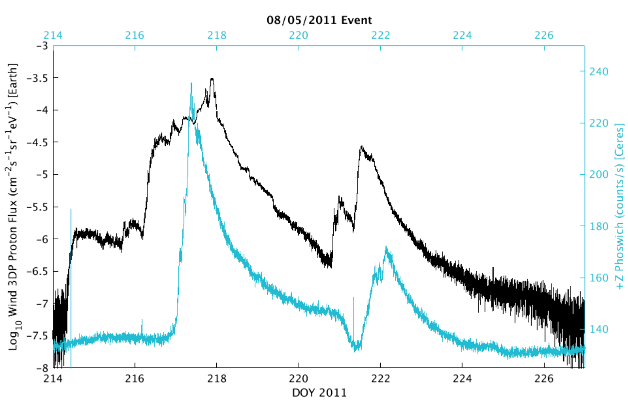

Figure 1. Comparisons of a solar energetic particle event observed by Wind at 1 au (black line; 4 MeV protons) and by Dawn's Gamma Ray and Neutron Detector at Vesta (cyan line).