ELPASOLITE PLANETARY ICE AND COMPOSITION SPECTROMETER (EPICS): A LOW-RESOURCE COMBINED GAMMA-RAY AND NEUTRON SPECTROMETER FOR PLANETARY SCIENCE.
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Introduction: The Elpasolite Planetary Ice and Composition Spectrometer (EPICS) is an innovative, low-resource gamma-ray and neutron spectrometer for planetary science missions, enabled by new scintillator and photodetector technologies. Neutrons and gamma-rays are produced by galactic cosmic ray (GCR) interactions with planetary bodies and their subsequent interactions with the near-surface materials produce distinctive energy spectra. Measuring these spectra reveals details of the planetary near-surface composition that are not accessible through any other phenomenology. EPICS will be the first planetary science instrument to fully integrate the neutron and gamma-ray spectrometers. This integration is enabled by elpasolite scintillators, that offer gamma-ray spectroscopy energy resolution as good as 2.9% FWHM at 662 keV [1], thermal neutron sensitivity through the ^{6}Li(n,α)T reaction, and the ability to distinguish gamma-ray and neutron signals via pulse shape discrimination (PSD). The scintillation light will be detected with silicon photomultipliers (SiPMs) rather than traditional photomultiplier tubes (PMTs). With these new technologies, EPICS will have significantly reduced size, weight, and power (SWaP) while providing similar neutron performance and improved gamma energy resolution compared to previous scintillator instruments.

EPICS is under development with Los Alamos National Laboratory (LANL) internal research and development funding. Here we report on the EPICS design, provide an update on the current status of the EPICS development, and discuss the expected sensitivity and performance of EPICS in several potential missions.

Gamma-ray and Neutron Spectroscopy: Gamma-ray and neutron spectroscopy are used to perform geochemical analysis of planets and solid bodies such as moons or asteroids. Neutrons are produced by the interaction of galactic cosmic rays (GCRs) with matter. Leakage neutron fluxes provide a sensitive measure of the near-surface hydrogen abundance as well as the average atomic mass of the near-surface. Gamma-rays are produced at characteristic energies by radioactive decay and by the interactions of neutrons with elements in the surface material. These characteristic gamma-rays indicate the presence and abundance of most major and minor rock-forming elements.

Previous gamma-ray spectrometer instruments have ranged from scintillators with ~10% energy resolution (FWHM at 662 keV) like BGO to HPGe systems with exquisite energy resolution but requiring cryo-cooling systems. Previous neutron spectrometers have used ^{3}He and/or borated plastic or ^{6}Li glass scintillators. Many of the planetary science gamma-ray or neutron spectrometers built and flown in the United States derive significant design heritage from Los Alamos instruments or in fact were designed at LANL, leveraging national security expertise in space-based radiation detection.

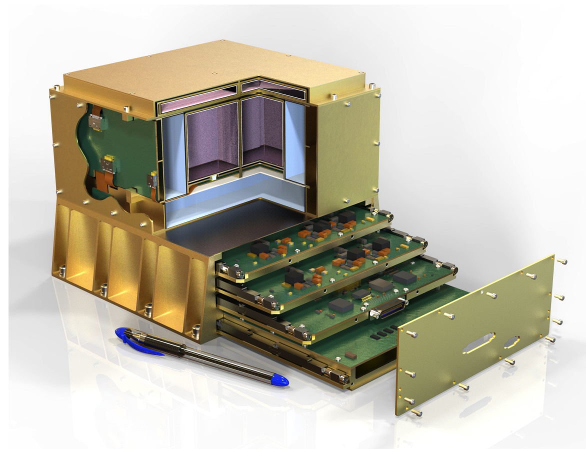

Figure 1: Rendering of the EPICS instrument.

EPICS Instrument: The EPICS instrument, shown in Fig. 1, is designed to be a modular instrument that can be scaled to meet mission and performance requirements. Figure 1 features a 2×2 array of modules optimized for orbiting missions, where each module features a thin (0.6 mm) front elpasolite layer facing the nadir direction for thermal neutron detection and a large central elpasolite volume (5 cm cube) for gamma-ray spectroscopy and epithermal/fast neutron detection. Plastic scintillator surrounds the 5 non-nadir sides for fast neutron coincidence with the central volume and GCR monitoring. With supporting electronics, shielding, and packaging, the instrument in this configuration weighs approximately 7 kg. Baselined with the more mature CLYC scintillator, EPICS has a gamma-ray energy resolution of 5–6% FWHM at 662 keV in the temperature range of −30°C - +60°C, even after accounting for radiation damage incurred over a five-year mission.

Prototype Development: We have started building a prototype of EPICS, consisting of one module (thin CLYC, central CLYC, and surrounding plastic). As part

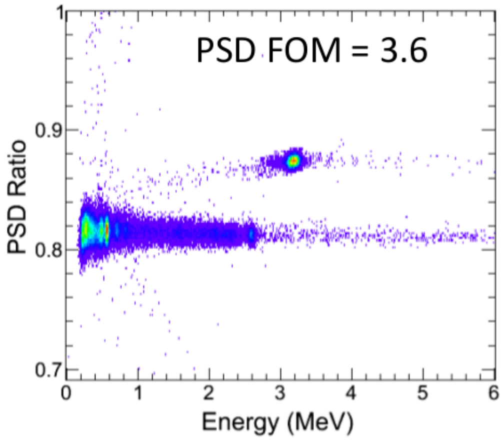

Figure 2: PSD from the central CLYC crystal and optimized SiPM array readout.

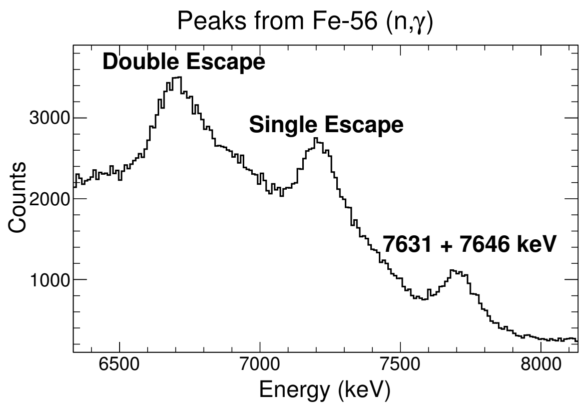

Figure 3: Measurement of the ^{56}Fe(n,γ) lines near 7.6 MeV from the $5{\times}5{\times}5$ cm^3 CLYC read out with the optimized SiPM array.

of this effort, we have optimized an amplification and combining circuit that reads out a 64-element SensL J-series array on a $5{\times}5{\times}5$ cm^3 CLYC crystal. With four amplifiers and a single readout channel, the performance of this system approaches results for energy resolution and PSD figure of merit (FOM) when the same crystal is read out with a 2" super-bialkali PMT. We achieve an energy resolution of 5.5% FWHM at 662 keV and a FOM of 3.6 (see Fig. 2). In addition, we have measured excellent linearty of this system up to 8 MeV and can cleanly detect the 7.6 MeV iron doublet and associated single and double escape peaks, as shown in Fig. 3.

Performance Simulations: We have performed preliminary simulations to estimate the sensitivity and performance of the EPICS instrument in several potential missions. Figure 4 shows the neutron spectra from three possible compositions of the Martian moons based on different origin hypotheses. With neutron detection efficiencies of 120 cm^2 for thermal neutrons, 30 cm^2 for epithermal neutrons, and 1 cm^2 for fast neutrons in the $2{\times}2$ configuration, EPICS would be able to distinguish hydrogen enrichments in the three origin hypotheses in much less than one Earth day in orbit. Another example, shown in Fig. 5, shows how EPICS can distinguish between three asteroid groupings within a 2-week measurement of Fe, Si, and O gamma-ray lines.

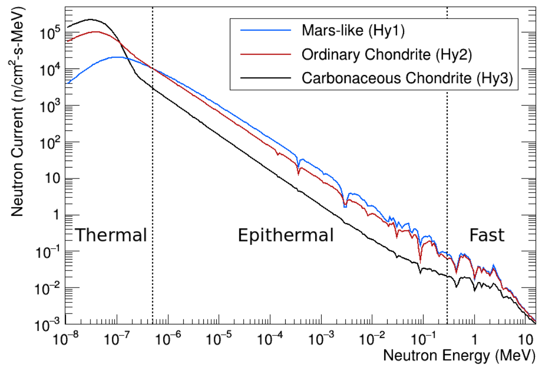

Figure 4: Prism 2 (top) and Prism 4 (bottom) counting rates at the south pole $< -85°$) as a function of solar longitude for the newly processed MONS data.

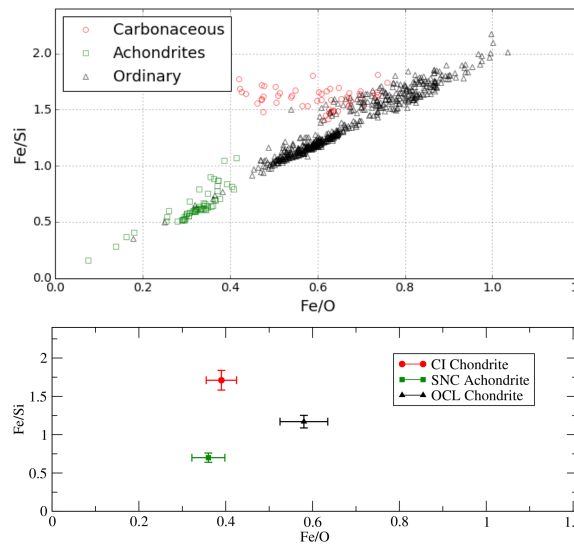

Figure 5: (Fe/Si vs. Fe/O in meteorite compositions (top) show groupings, which can be distinguished in a 2-week measurement using EPICS (bottom).

References: [1] J. Glodo *et al.* (2011), *IEEE TNS, 58.*

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