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REXIS First Results: Regolith X-ray Imaging Spectrometer Aboard OSIRIS-REx

Richard P. Binzel (1), Branden Allen (2), Jaesub Hong (2), Daniel Hoak (2), David Guevel (2), Jonathan Grindlay (2), Rebecca Masterson (1), Mark Chodas (1), Carolyn Thayer (1), Madeline Lambert (1), Andrew Cummings (1), Lucy F. Lim (3), Beth E. Clark (4), Timothy J. McCoy (5), Dante S. Lauretta (6), and the OSIRIS-REx Team.
(1) Massachusetts Institute of Technology, Cambridge, MA, USA. (2) Harvard University, Cambridge, MA, USA. (3) NASA Goddard Space Flight Center, Greenbelt, MD, USA. (4) Ithaca College, Ithaca, NY, USA. (5) Smithsonian Institution National Museum of Natural History, Washington, DC, USA. (6) Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA.

Abstract

The Regolith X-ray Imaging Spectrometer (REXIS) is the student collaboration experiment flying aboard OSIRIS-REx. REXIS measures x-ray fluorescence stimulated by solar x-rays itmpinging on the surface of asteroid Bennu. We will present REXIS's first results in measuring elemental abundances in the regolith of Bennu and discuss how these results complement the suite of other payload instruments. Here we introduce REXIS and its asteroid science operation scheduled to begin in July 2019.

1. Introduction

The Regolith X-ray Imaging Spectrometer (REXIS) instrument was competitively selected in October 2010 as a Class-D student collaboration experiment to complement the remote sensing payload of NASA's OSIRIS-REx asteroid sample return mission. REXIS came to reality through multiple partnerships across many elements of the Massachusetts Institute of Technology, Harvard University, NASA Goddard Space Flight Center, and the University of Arizona. REXIS's primary objective is to directly engage students at the undergraduate and graduate levels in the conception, design, implementation, and operation of space flight instrumentation for the mission. To date, more than 80 students have worked on the REXIS project, and more than a dozen master's and doctoral theses have resulted.

1.1 REXIS Instrument Description

REXIS is an x-ray spectrometer designed to take advantage of the incident solar x-ray flux that generates a diagnostic fluorescence signature from the asteroid's surface. REXIS joins a lineage of x-ray fluorescence experiments flown in space dating back to the Apollo era and previously demonstrated for asteroid science [1]. As illustrated in Figure 1 and more fully described in [2], REXIS consists of two components: a main imaging spectrometer with a coded aperture mask and a separate solar X-ray monitor to account for the Sun's variability. The REXIS main spectrometer employs a detector array consisting of four MIT Lincoln Laboratory CCID-41 charge-coupled devices (CCDs) in a 2×2 array allowing measurement of the x-ray spectrum over the range of 0.4 to 8 keV with an energy resolution (FWHM) of <220 eV at 5.9 keV. REXIS seeks to measure fluoresced lines in the Fe-L, Al-K, Mg-K, S-K, and Si-K complexes. The detector array was protected from background radiation during the cruise phase by a cover that was successfully opened in September 2018, approximately 2 years into flight.

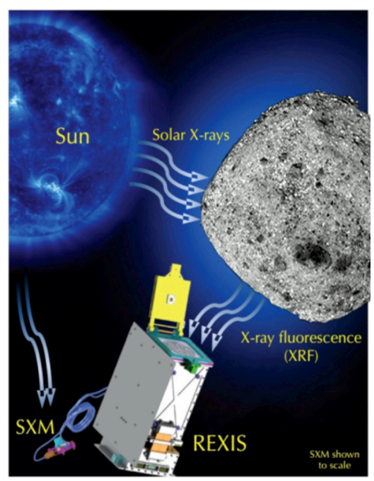

Figure 1: Illustration of the REXIS instrument and its concept of operation. See [2] for a complete description.

Characterization of the X-ray fluorescence measured from Bennu requires knowledge of the incoming solar X-ray flux. REXIS's second component is a solar X-ray monitor (SXM) designed to measure the variable incoming solar flux and its energy distribution. The SXM utilizes an Amptek XR-100SDD silicon drift diode (SDD) with a collimated effective area of about 0.8 mm^2, providing spectral coverage over the range of 1 to 20 keV.

2. REXIS Operation

2.1 Instrument Calibration

REXIS utilizes measurements of astrophysical x-ray sources (Crab Nebula, Sco X-1) to measure the boresight offset of the instrument and calibrate the quantum efficiency of the CCDs. Internal sources of Fe-55 enabled performance monitoring during the cruise phase and continue to provide an ongoing measure of the detector charge transfer efficiency. In flight at Bennu, six nodes of 256 x 1024 pixels each are delivering low noise and a stable energy resolution signal for the acquisition of science data. Figure 2 presents a REXIS "first light" image of the Crab Nebula establishing the instrument boresight well within the designed accuracy.

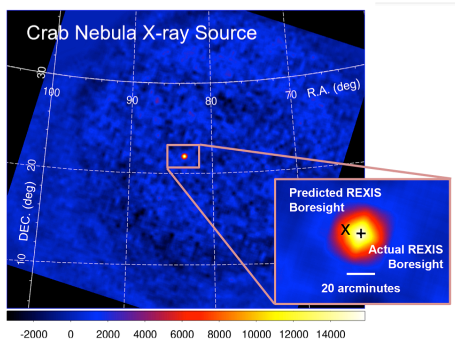

Figure 2: REXIS "first light" image of the Crab Nebula x-ray source and boresight calibration.

2.2 Asteroid Science Measurements

REXIS asteroid science measurement operations at Bennu are scheduled to begin with the Orbital B phase of the OSIRIS-REx mission, planned for July 2019, producing approximately 450 hours of integration time on the asteroid. The first science results to be produced are a global average "spectral mode" characterization of the elemental abundance ratios (relative to Si) of Bennu's regolith. Laboratory reference measurements for meteorite elemental abundance ratios [3] form the foundation for interpreting the REXIS results. Key ratios to be measured by REXIS include Mg/Si and Fe/Si to independently determine whether the asteroid's composition more closely resembles that of carbonaceous chondrites or low-albedo ureilites. Measured ratios of S/Si and O/Si may further distinguish where the composition of Bennu falls among the suite of CV, CM, and CI carbonaceous chondrites.

A step beyond the global average "spectral mode" results is to achieve spatially resolved information on elements present in Bennu's regolith. "Collimator mode" resolved imaging of Bennu is achieved by binning the measured x-ray flux data in time followed by correlating the time bins with the pointing knowledge of the instrument. Concentrations of elements over surface units resolvable at the scale of ~200 m may be revealed by the collimator mode analysis.

A coded-aperture mask extends over the front of REXIS main spectrometer. Consequently, all incident x-ray flux produces a shadow pattern across the detector array. Given the known pattern of the mask, cross-correlation of the changing shadow pattern that is repeatedly imaged provides a method for higher-resolution mapping of Bennu's surface. Using this "imaging mode" method, a resolution of up to ~50 m may be achieved for regions that may have high concentrations of measureable elements.

Acknowledgements

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