GAMMA RAYS IN A SPECTRUM FROM THE MARS ODYSSEY GAMMA-RAY SPECTROMETER*.

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Summary: The gamma-ray spectrum from a long sum over the middle latitudes of Mars measured by the Mars Odyssey Gamma Ray Spectrometer was analyzed. About 250 peaks and features were observed, including many seen during the cruise to Mars. The sources of about 85% of these gamma rays were identified. Most were background lines from the Ge detector or from Ti, Mg, and Zn near the detector.

Introduction: The gamma rays measured from a planet can be used to infer the composition of the top few tens of centimeters of the surface [1]. Some gamma rays are made by the decay of the naturally radioactive elements K, Th, U. Many gamma rays are made by fast and thermal neutrons produced by cosmic-ray particles. The energy of a gamma ray identifies the isotope from which it was emitted, and the flux is proportional to that element's concentration.

The Mars Odyssey Gamma-Ray Spectrometer (GRS) consists of a large germanium crystal cooled passively to ~85 K [2]. The Ge crystal is enclosed in a titanium can. Much of the structural material around the GRS is a magnesium-zinc alloy. Many gamma rays are produced in the material in and near the GRS. Preliminary results near the hydrogen neutron-capture gamma ray at 2223 keV are presented in [3].

Spectrum: The Mars spectrum shown in Fig. 1 was accumulated over the mid-latitudes (from –45° to 45°) from 8 June 2002 to 30 September 2002, except for a two-week period during and following a solar proton event. On 16 July 2002, a large solar proton event occurred that caused a large increase in count rate and a distortion of the spectrum for several days. After the events, activation of the detector and surrounding materials kept the count rate high for many more days [4]. The regions near the pole were omitted because of the seasonal polar CO_2 caps and the higher fluxes of thermal neutrons.

Martian gamma-ray spectra are collected about every 20 seconds. A few percent of the spectra sent to Earth could not be used. The individual spectra are routinely corrected for the non-linear effects of temperature before summing. However, the energy versus channel scale is not perfectly linear, especially below ~500 keV. Thus, some gamma-ray energies are often a little different than the nominal one.

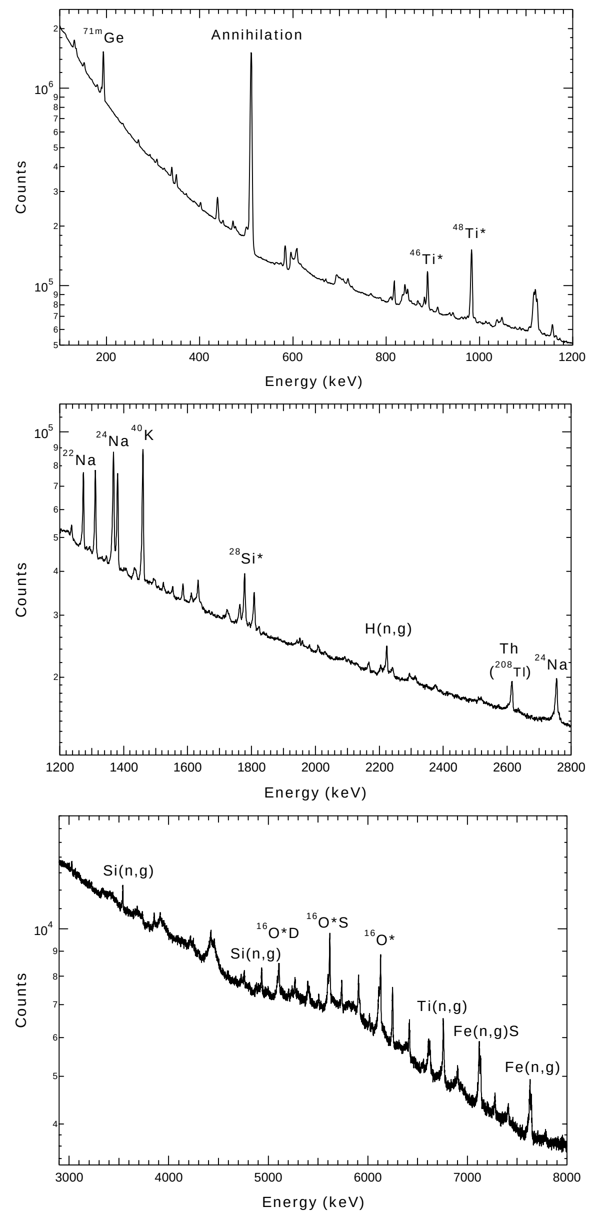

Fig. 1. Gamma-ray spectrum from a 3-month sum over the middle latitudes of Mars for 3 energy regions. The sources of stronger peaks are identified. A * indicates an inelastic-scatter gamma ray. S and D indicate single and double escape peaks, respectively.

Spectral Analysis: The peaks in this spectra were analyzed using the interactive spectral unfolding code Ganymed designed for radiation-damaged Ge detectors [5]. A small part of the spectrum was analyzed at a time. The code fits both a continuum and the peaks. The spectrum and fit for each region is visually examined, and the fit adjusted as needed. About 230 peaks and 20 broad features were observed.

Energy regions at about 834-850 and 1115-1125 keV had many peaks and features so close together that it was very difficult to analyze individual peaks. Weak peaks very close to large peaks were hard to analyze. The area under a peak occasionally was hard to determine because of uncertainties in the location of the continuum and the shape of the peak.

At higher energies, many escape peaks were observed when one or both of the 511 keV photons that are made by pair production escape from the Ge. These peaks are identified in Fig. 1 with an S or D, for the single and double escape peaks, respectively.

Several broad features were not fitted, such as sawtooth peaks and very broad peaks. A sawtooth peak appear in the spectrum when a neutron excites a Ge nucleus to an excited level and the recoil energy is summed with the gamma ray and produces a long tail above the gamma ray's energy [6]. Strong sawtooth peaks above 596, 692, 834, and 1039 keV make peak analyses near those energies difficult. Weaker sawtooth peaks were observed above 563 and possibly 1204, 1215, and 1464 keV. Broad gamma rays due to decay from very short-lived excited states made by energetic reactions or from reactions in the martian atmosphere included 4438 (and its first escape peak), 6129 (and its escape peaks), 3685, and 2210 keV.

Identification of Peaks: Observed peaks were identified using lists of expected planetary gamma rays [1], comparisons with the GRS spectra from the cruise of Mars Odyssey [7] or other gamma-ray spectrometers in space [8], and compilations of gamma rays. For gamma rays made by the decay of radionuclides or from nuclear levels excited by energetic reactions, several nuclear databases were searched. Gamma rays from the capture of thermal neutrons were taken from recent evaluations [9,10]. Gamma rays observed during and just after solar particle events [4] helped to confirm identifications of some gamma rays made near the GRS.

Observed Gamma Rays:

Background gamma rays. Most gamma rays were from material around the GRS. Many had been observed during cruise [7]. Gamma rays made by electron-capture decay in the Ge crystal were usually observed at an energy that is higher by the capturing-nucleus' K-binding energy. Gamma rays made by the decay of isomers like ^{71m}Ge or by neutron-capture reactions were also observed in the Ge detector.

Many gamma rays come from the matter near the GRS, especially from the Ti can and the Mg-Zn structures. For example, the gamma rays labeled ^{22}Na and ^{24}Na in Fig. 1 were made in this Mg. Gamma rays made by neutron capture reactions in local material were often confirmed from spectra above thick CO_2 polar caps.

Martian gamma rays. Many of the stronger observed gamma rays from Mars were made by neutron-capture reactions with H, Si, Cl, and Fe in the martian surface. Gamma rays made by reactions of fast neutrons with O and Si were also observed. Radioactive decay gamma rays were seen from ^{40}K and the daughters of Th and U. A very weak gamma ray was seen from sulfur in the martian surface. A few other gamma rays needed to be confirmed as coming from the martian surface.

Many of the gamma rays seen or expected from Mars are also made from material in or near the GRS. Measurements from cruise and from spectra collected over thick seasonal polar caps are being used to quantify the strengths of the backgrounds for these gamma rays.

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