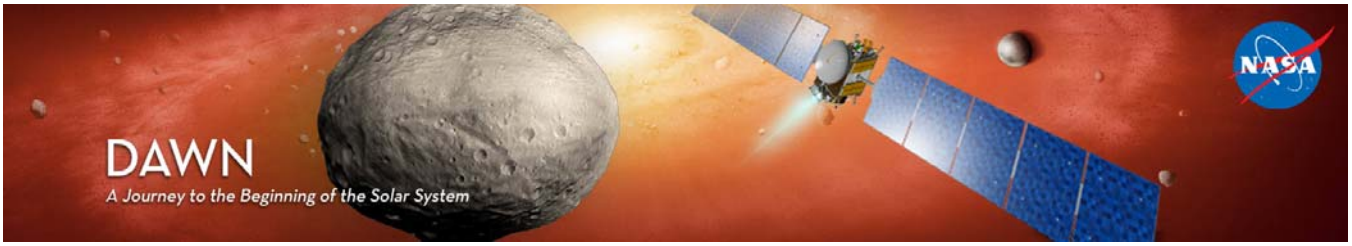

Interactions of Energy and Matter: Dawn Instrumentation

GRaND
Gamma Ray and Neuron Detector

STUDENT SCRIPT TO ACCOMPANY POWERPOINT

This text is designed to accompany the PowerPoint presentation that describes the design and function of the Gamma Ray and Neutron Detector (GRaND) that is part of the Dawn Spacecraft Instrumentation Package. This information will help you answer the questions in the GRaND Student Report Sheet.

> ***Note: Some of the slides in this presentation include animation effects. The instruction to {click} indicates that you should use either a "keystroke" or a mouse depression to advance the animation.***

Slide 1
GRaND is one of the scientific instruments in the payload of the Dawn spacecraft. The Dawn Mission is designed to increase our understanding of the conditions and processes that were happening during the solar system's earliest epoch. Geochemical data from GRaND will give scientists a better understanding about the material forming Vesta and Ceres, two large asteroids.

{click to Slide 2}

GRaND is a Gamma Ray Spectrometer and a Neutron Detector. In this section, we will be learning more about the GRaND, including what it does and how it works.

{click to Slide 3}

Write your answers to these questions on your *GRaND Student Report Sheet*

What region of ***electromagnetic radiation*** (EMR) from Ceres and Vesta will the GRaND measure?

What frequency and wavelength regions of EMR are classified as ***gamma rays***?

How does the ***energy*** of gamma rays compare with the energy of the rest of the EMR waves?

{click to Slide 4}

What will the GRaND do when Dawn gets to Vesta and Ceres?

From a circular, polar-mapping orbit, the Gamma Ray and Neutron Detector (GRaND) will measure the chemical composition over the entire surfaces of Vesta and Ceres. Using a combination of gamma ray and neutron spectroscopy, the GRaND will measure the abundance of many elements:

{click}
- near-surface major rock-forming elements such as oxygen, magnesium, aluminum, silicon, calcium, titanium, and iron;

{click}
- long-lived radioactive elements such as potassium, thorium, and uranium; and,

{click}
- ***volatile*** elements such as hydrogen, carbon, nitrogen, and oxygen, which are the major constituents of ices.

{click to Slide 5}

What is the origin of the gamma rays that GRaND will detect?

{click}
Some of these gamma rays that GRaND will detect and measure result from natural decay of radioactive elements close to the surface of Ceres and Vesta.

{click}
Other gamma rays are produced by a “Splat!” of galactic ***cosmic rays*** that interact with the nuclei of chemical elements within the first few meters of the surfaces of Vesta and Ceres. Since neither Vesta nor Ceres have an atmosphere, cosmic rays can penetrate the asteroids’ surface to depths of several meters.

{click}
The energies of galactic cosmic ray protons are many times greater than that of nuclear binding energies. When these protons collide with the protons and neutrons of an atomic nucleus within the first few meters of the asteroid’s surface, a cosmic ray shower of many kinds of particles and energy is released. ***Fast neutrons*** are a part of this shower. These neutrons are intact particles of matter with very high kinetic energy.

These fast neutrons interact with other atomic nuclei within the asteroid’s surface, losing energy in one of three different mechanisms.

{click}
One mechanism is call ***neutron capture***. In this interaction, a neutron is absorbed into the nucleus of an atom, releasing gamma rays. Because each element emits unique and

characteristic gamma rays, so those gamma ray “signatures” can be used to identify the element.
{click}
Fast neutrons can also undergo ***inelastic collisions*** with atomic elements. These collisions also produce unique, identifiable gamma rays.

{click}
Fast neutrons can also lose energy through ***moderation*** in nearly elastic collisions, similar to billiard-ball collisions. No gamma rays are given off in these collisions.

{click}
Some of the fast neutrons produce ***thermal*** and ***epithermal neutrons*** as they lose energy during scattering collisions with other nuclei in the first few meters of the asteroid’s surface.

Thermal neutrons have lost sufficient energy to be in thermal equilibrium with the asteroid’s surface.

Epithermal neutrons have undergone energy losses but are still not in thermal equilibrium with the asteroid’s surface.

Neutrons in all three energy ranges—fast, thermal, and epithermal—leak from the asteroid’s surface and can be detected by the sensitive neutron detectors in GRaND.

Write your answer to this question on your GRaND Student Report Sheet

Describe the interactions of matter and energy illustrated in the *GRaND Splat!* slide.

{click to Slide 6}

This is a cut-a-way view of the Dawn GRaND instrument.

It can help us understand how GRaND measures the abundance of major rock-forming elements, as well as radioactive and volatile elements in Vesta’s and Ceres’ surfaces. Each chemical element has a unique pattern of gamma rays, a “fingerprint” which GRaND can analyze to determine not only the element’s presence but also its abundance.

That’s a pretty big job for an analytical instrument that is only 25.7 cm long, 18.0 cm wide, and 26 cm tall.

{click}
And GRaND has a mass of only 10 kg!

GRaND has two ***gamma ray spectrometers***. Each of them has its own specific detection range. These detectors will detect gamma rays escaping

{click}
from the surfaces of Vesta and Ceres.

{click} {click}
A 4x4 array of ***semiconducting*** cadmium zinc tellurium crystals is sensitive to gamma rays over a fairly restrictive energy range, 0 to 3 MeV, but it has high energy resolution and is more accurate in the low energy region of the spectrum, the region where gamma rays from many radioactive decay and nuclear reactions are found. CZT crystals detect gamma rays

{click}
from naturally radioactive elements like potassium, thorium, and uranium.

{click} {click}
The sensor that contains bismuth germanium oxide (BGO, also called bismuth germanate) crystals is a high efficiency gamma ray detector. It can measure gamma radiation over a wide energy range of frequencies.

{click}
BGO crystals are sensitive to gamma rays from elements like hydrogen, oxygen, aluminum, silicon, calcium, titanium, and iron.

Write your answer to this question on your GRaND Student Report Sheet

What interactions of matter and energy are described in this explanation of GRaND's Gamma Ray Spectrometers?

{click to Slide 7}

GRaND also has two kinds of ***neutron detectors*****.**

{click}
Four boron-loaded plastic ***scintillators*** surround the

{click}{click}
BGO crystal and

{click}{click}
the CZT array. When

{click}
fast and

{click}
epithermal neutrons interact with

{click}
two of these

{click}
borated plastic scintillators, they generate

{click}
gamma rays.

{click}
A layer of ^{6}Li-loaded glass, which shields the borated plastic scintillators,

{click}
detects and absorbs thermal neutrons. The interaction

{click}
also produces gamma rays.

{click}{click}{click}
The gamma rays generated by the interactions of neutrons with the scintillators are measured by the

{click}
BGO and

{click}{click}
CZT detectors.

{click}{click}
Neutrons that leak from the asteroid's surface produce gamma rays that can indicate the presence of H, C, N, O, Fe, Ti, Cl, Gd, and Sm.

Write your answer to this question on your GRaND Student Report Sheet

What interactions of matter and energy are described in this explanation of GRaND's neutron detectors?

{click to Slide 8}

Gamma rays measured by the GRaND show up as sharp ***emission lines*** in the instrument's spectrum output.

{click}

The energy (Pulse height in MeV) represented in these emission lines determines which elements are present; and

{click}
the intensity of the emission lines (Counts/sec) is related to the element's concentration.

{click}
Emission Spectrum a is an energy distribution of a neutron source similar to that which may leak from an asteroid's surface.

{click}
Emission Spectrum b shows an ore sample spectrum of gamma rays from the decay of ^{214}Bi, one product of the ^{238}U decay chain.

{click}
Neutrons interacting with iron nuclei produced the BGO spectrum shown in emission Spectrum c.

{click}
The Dawn Mission is designed to yield a significant increase in the understanding of the conditions and processes acting at the solar system's earliest epoch by examining the geophysical properties of two asteroids—Ceres and Vesta. Data from GRaND will provide information about the asteroids' accretion materials, thermal evolution, and differentiation processes.

{click to Slide 9}
GRaND is one of the instruments on the Dawn Spacecraft that will utilize the interactions of energy and matter to collect scientific data about Vesta and Ceres.

{click}
What energy and matter interactions are involved in the scientific measurements made by GRaND?

Write your answer to this question on your GRaND Student Report Sheet

What energy and matter interactions are involved in the scientific measurements made by GRaND?