Let me start by telling you a little bit about where neutrons and gamma rays come from. And this diagram, I like to call “SPLAT,” simply because it describes the interaction of cosmic rays with planetary surfaces and atmospheres, and that’s best described with the word SPLAT. Because what happens is that you’ve got the entire solar system as being pelted by energetic particles—mostly protons—and they have energies in the giga-electron volt range. And they come in—and they’re many, many times the energy, binding energy of a nucleus—and when they interact with a nucleus, they cause it to explode. And you get a spray of particles out, and you get what we know as a cosmic ray shower. And planets with no atmosphere—such as Vesta and Ceres—well, their solid surfaces are directly exposed to these particles and to depths of several meters [that] you see evidence for cosmic ray interactions. So here’s a diagram of a cosmic ray coming into the surface of one of our asteroids, interacting with a nucleus via the spray of particles that come out. Many of them are neutrons, and these neutrons come out and they ravel around in the surface, undergoing scattering collisions with the nuclei that are there. And, in some instances, they’ll undergo inelastic collisions and lose energy and at the same time a gamma ray is emitted. Sometimes the particles that are emitted escape the asteroid and can reach orbital altitudes where they can be detected by the orbiting spectrometer. Other times, you’ll have a neutron come out and undergo a succession of collisions, in the end undergoing what we call neutron capture, where the neutron is actually absorbed by a nucleus in the surface and a gamma ray comes out. And, of course, the neutrons themselves can ravel around in the surface and actually leak away and then be detected by the orbiting spectrometer. There are other sources of gamma rays in the surface. All around us, in your bodies and in the room are radioactive materials. For example, people are famous for having potassium as a radioactive element in their bodies. If you eat a lot of bananas, maybe you’re a little bit more radioactive than someone who doesn’t eat so many bananas. And you’re probably thinking to yourself, “Well, that just sounds bananas.” And we’re in a sea of thorium on earth. There’s thorium and uranium, and you can kind of imagine that the isotopes of these elements are undergoing radioactive decay, and in the process, emit gamma rays. And, of course, this is going on, depending on the concentration of natural radioactivity in the surface of the asteroid, to some degree on Ceres and Vesta—and so, you get gamma rays coming out of the surface from thorium. So, you look at the information that’s conveyed by these radiations, both the radiation from radioactive decay and the radiation from cosmic rays, and you can start assigning some information. For example, if you look at radiation or gamma rays that are produced by neutron interactions, those gamma rays give you the abundances of the major elements in the surface—magnesium, aluminum, silicon, oxygen, iron. And, that kind of information is extremely important to constrain the geochemistry of the planets you are looking at, which tells you something about how the planet evolved. In addition, the thorium is tied up in geochemistry. For example, on the moon, thorium has a large ionic radius, and as the moon—the moon started out, we think, as kind of a melted body—and as the moon began to crystallize, different minerals formed, and those minerals that involved thorium, which has a very large ionic radius, formed last, because thorium’s just very difficult to incorporate into the crystal matrix. So you end up with this layer that we call “creep”—potassium rare earth-elements and phosphorous on the moon—that also contain these radioactive materials and were probably responsible for the volcanism that gave rise to the Maures. So, thorium is important for geochemistry. The neutrons, as we’ll see in a bit, are very
sensitive to light elements such as hydrogen and carbon. Those elements, as you know, are the major constituents of ices that we find in the solar systems—just dry ice and water ice. So, you get these radiations coming off the surface, leaking into space, and you have some sort of detector or spectrometer to look at the radiation. You can map the entire surface of the planet. Using these radiations is just like having an army of Harrison Schmitt’s on the surface of the asteroid. These remote sensing techniques are very powerful in that they are able to derive global data sets—in instances like the moon—to supplement the sample of meteoritic data that we have in hand. Of course, we don’t have sample data for Vesta and Ceres, but we certainly have samples in the form of meteorites that we’ll compare the data to.