ASTEROID MATERIAL SHIELDING POTENTIAL AGAINST HIGH ENERGY PARTICLES. L. Pohl1, 2 and D. T. Britt1, 2, 1University of Central Florida, Orlando FL, 32816, pohl@Knights.ucf.edu, 2Center for Lunar and Asteroid Surface Science.

Introduction: Duration and accessible distances of deep space human missions are significantly limited by exposure of astronauts to the space radiation environment, in particular to energetic particles. The sources of energetic particles are predominantly Galactic Cosmic Rays (GCR) and Solar Energetic Particles (SEP). In order to prevent the particles from damaging the astronaut’s health, sufficient shielding is necessary. The shielding provides an environment where the energetic particles can interact with the shield material but these interactions further result in production of secondary particle showers with their own detrimental health effects, possibly far worse than the original incident particles. A shield produces a positive net radiation attenuation only with sufficient thickness and mass. Costs of transporting a sufficiently massive shield into orbit are one of the major limiting factors in human interplanetary exploration.

We are investigating the feasibility of using asteroid material as a shield against energetic particles, protons in particular. In general, it is possible to use three approaches to determine ability of some material to attenuate incident particles (the so called stopping power of the material [1]). First, with several approximations, we can approach the problem analytically with the help of Bethe theory. Second, we can simulate interactions between the incident particles and the target material using numerical approach. And finally, we can use experimental measurements. Each of these approaches has its advantages as well as its disadvantages.

Method: Our initial approach to the problem is analytical, employing Bethe theory [1]. The advantage of this approach is that we can quickly reproduce results for different asteroid materials. However, we have to be aware of its limitations.

First, the theory is only applicable in a certain energy range of the incident particles; although this can be in part mitigated by adding various correction terms. The two most important correction terms are the shell and density corrections. The shell correction is significant for low energy particles (1 – 100 MeV) for which the velocity is no longer considered relativistic and consequently the original assumption of the theory that the velocities of the incident particles is far greater than those of bound electrons in the material is no longer valid. This correction term decreases quickly with increasing energy [1]. Because of the spectrum of radiation in space, we are more concerned about high energies and thus we can neglect this correction. The other important correction term deals with the fact that as the energy of the incident particle increases the target material becomes polarized, this reduces the stopping power of the target material. This correction term is only important for kinetic energies higher than the rest energy of the incident particle [2]. For very low energies (below MeV range) there is currently no usable theory [1]. Similarly for ultrarelativistic energies the analytical approach is imprecise at best. In the mid energy range (from MeV to GeV for protons) the analytical approach gives results comparable within a few per cents to experiment [1]. For our initial study, this poses a negligible problem as we want to determine the feasibility of using asteroid material in comparison to the standard spacecraft material - Aluminium. Thus, if the material has comparable stopping properties in the energy range where we can employ the analytical approach, it is very likely to behave in a similar way at higher energies.

Another important issue arises from the fact that the original Bethe theory was developed for “pure” materials, i.e. materials that consist of a single chemical element and without any crystal structure (no interatomic bonds are considered). The underlying assumption of the theory is that most of the kinetic energy of the incident particle is lost due to interactions with electrons while interactions with nuclei only bend the incident path without a significant energy transfer [3]. The usual treatment of compound materials is by using Bragg additivity which assumes that the stopping power of a compound can be determined as a superposition of stopping powers of “pure” materials with appropriate weights.

An important quantity that characterizes the target material is called the mean excitation energy. Determining this quantity from the first principles is non-trivial and for many compounds effectively impossible. Algorithms have been suggested to calculate this quantity for compounds [4], but they lack strong experimental verification. A similar issue arises in the case of the density correction.

Last, this method does not consider secondary showers that we have mentioned above. In order to treat the full problem with secondary showers, complex numerical simulations would be required.

Despite the many pitfalls of the Bethe theory, it has several advantages. First, it is straightforward and relatively easy to implement. Second, once implemented,
the actual calculation for a given meteorite type is very fast. For this reason, we started with analytical approach to estimate stopping power of asteroid material in comparison with Aluminium.

**Materials:** As we started applying the Bethe’s model, we have come across a lack of comprehensive data on the bulk mineralogy of meteorites which we in turn use to infer the composition of asteroids. Some authors provide only mass ratios of selected minerals; others provide only oxides and elements or partial mineralogical composition (such as olivine instead of the detailed ratio of Mg and Fe in the solid solution or no data on volatiles or organics). We have thus started compiling the compositions from various sources to use as our reference values.

**Results:** So far we have been able to successfully verify that L-Chondrite and H-Chondrite materials perform equally well as Aluminium in the energy range where the Bethe theory is usable. We show the results in the following plot (we include only H-Chondrite against Aluminium for presentation purpose; L-Chondrite results almost copy the Aluminium plot).

![Graph](image)

**Further work:** The results obtained so far suggest that should an effective mining technique of material from asteroids become available, the material itself has sufficient properties to act a radiation shield. Future work on this issue should be considered in the following areas:

1. Experimental verification of the results obtained by the simplified Bethe theory on meteorite samples.
2. Extending the theoretical work by implementing a numerical simulation that would also be able to take into account secondary showers and determine the particles produced as well as their energy spectrum.
3. Determining reference compositions of meteorite taxonomy groups and expand the number of meteorite types with available stopping power data. Volatile rich carbonaceous chondrites are of particular interest since stopping power increases with increasing content of low atomic mass elements. Another aspect of this work will evaluate the effect of processing options on stopping power (such as removing elemental iron from ordinary chondrites).
4. Evaluating possible health risks from using asteroid material; and if such a risk exists, suggesting ways of mitigating it.