DISCRIMINATION OF HEAVY CHARGED PARTICLES IN A MIXED IRRADIATION USING OPTICALLY STIMULATED LUMINESCENCE METHODS. B. Yount[1,2], E. Yukihara[2], S. W. S. McKeever[2]. [1]Dept. of Chemistry and Physics, Arkansas State Univ., State University, Arkansas 72467. [2]Arkansas-Oklahoma Center for Space and Planetary Sciences and Dept. of Physics, Oklahoma State Univ., Stillwater, Oklahoma 74078.

Introduction: Astronauts are subjected to many different types of radiation. In an effort to keep track of the dose an astronaut receives, they wear dosimeters that can be read by different means. The newest method, termed Optically Stimulated Luminescence, entails using a known wavelength of light to stimulate the dosimeter material causing it to emit light of a different wavelength. By measuring the amount of light emitted, we can infer the dose received. The material we used for OSL dosimetry is aluminum oxide, Al_2O_3. In this study, we investigated the potential of Al_2O_3 for discrimination of different types of radiation (alpha and beta in this study).

Heavy charged particles (HCP), such as alpha particles, deposit energy in a different way than do other forms of radiation, such as beta, gamma, or X-ray. Where non-HCP's deposit most of their energy uniformly across the material, HCP's deposit most of their energy along linear tracks following the path of the particle. This results in a possible low dose averaged over the entire material, but very high dose in small volumes along the particle track. HCP's are more prone to cause radiobiological damage [1]. By discriminating between how much dose was from HCP's, we can determine more accurately the health risk to an astronaut. This study is also applicable to airline pilots subjected to cosmic rays, since this is the main source of HCP radiation.

Experimental Techniques: One of the objectives of this study was to compare two OSL techniques. One system, called Continuous Wave Optically Stimulated Luminescence (CW-OSL), involves using a Risø system in which blue light emitting LED's illuminate a sample continuously and a non-gated photon counting system measures the light emitted. Appropriate filters were used to allow only light centered in the UV range to pass. The other system used is called a Pulsed Optically Stimulated Luminescence system (POSL). This system is composed of a Nd:YAG laser Q-switched to deliver 300 ns short pulses at a frequency of 4 kilohertz, and an average power of ~2.5 mW / $cm^{\wedge 2}$. The emitted signal is measured between the pulses using a gated photon counting system, filtered appropriately to allow detection centered at 420 nm (sample emission wavelength). We irradiated all samples with particles emitted from radioactive isotopes. Beta particles came from a ^{90}Sr source and alpha particles came from a ^{241}Am source, with energies of approximately 1.413 MeV and 5.6 MeV respectively.

CW-OSL Results: Using the Risø CW-OSL system, we irradiated 10 sample sets; each set with 3 samples, with equal doses of radiation, but varying the percentage of alpha-to-beta and took the OSL signal immediately following. Figure 1 is a combination graph of all of the luminescence curves from the different percentages of alpha-to-beta. This graph shows that as the percentage of dose from alpha particles increases in the sample, the light emitted has a faster decay curve. Because each sample was also given a reference dose from pure beta, we defined a value R such that $R = (A_{mixed} / I_{mixed}^{avg(3)}) / (A_{ref.} / I_{ref.}^{avg(3)})$ where A is the area of the first 100 seconds of OSL, and $I^{avg.(3)}$ is the initial intensity averaged over the first three seconds, referring to the mixed dose and reference dose. This value, R, is the ratio of the area under the mixed irradiation curve to the area under the pure beta curve, both normalized to their initial intensity. Figure 2 shows these R-values plotted against the percentage of alpha in the sample. By taking ó (standard deviation of R) as the highest deviation recorded, we concluded that given an experimentally measured R_{ex} such that $R_{ex} < R_{â} - 3ó$, we can affirm with approximately 99% confidence the existence and proportion of dose in the sample from alpha, where $R_{â}$ is the graphed R-value at 0% alpha (pure beta irradiation).

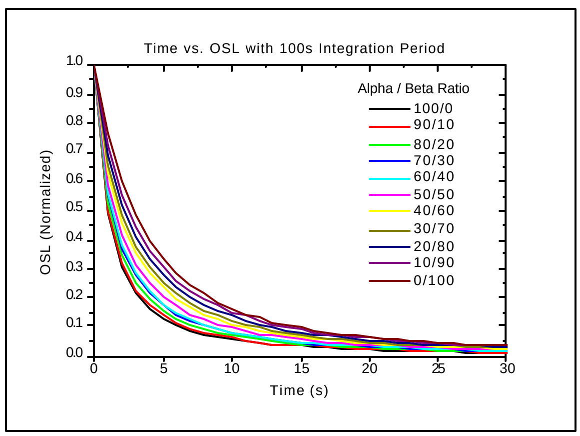

Figure 1: OSL luminescence decay curves of samples irradiated with mixed á and â particles ranging from 100% á (bottom) to 100% â (top), normalized to their initial intensity.

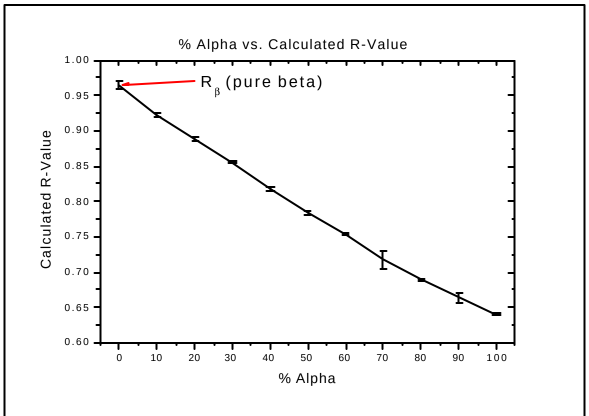

Figure 2: Calculated R-Values versus the percent of alpha in the mixed irradiation. Error bars showing the standard deviation of each point (averaged over 3 samples each) are shown.

POSL Results: One advantage to the POSL system is that this system has much better sensitivity to low doses than the CW-OSL system. This is due to the fact that we measure the OSL signal when the laser is off, therefore improving the signal–to–noise ratio. We concluded, however, that this system has very poor resolution between the alpha and beta irradiations. To compare the resolution capabilities of the two systems statistically, we took signals from multiple samples in each system and defined a value called X / Ó where X is the difference between the R-values of the two decay curves (1 pure beta, 1 pure alpha) and Ó is the standard deviation of the X differences, i.e. $X = (R^{beta} - R^{alpha})$ and $Ó = (Ó_{Rbeta}{}^{\wedge 2} + Ó_{Ralpha}{}^{\wedge 2})^{\wedge 1/2}$. X / Ó for the CW-OSL system was 28.84 where for the POSL system, it was 4.35. This means that the difference between the R-values from the CW-OSL system was approximately 30 times the standard deviation, where in the POSL system the difference was only around 4 times the standard deviation, thus showing the CW-OSL technique has much better resolution.

In attempting to optimize the system, and also determine why it has such poor resolution, we changed the filters to the same set used in the CW-OSL method (detection in the UV). This modification showed a large improvement, but still lacked the resolution available with the CW-OSL system. By further investigation, we were able to show that the OSL signal is composed of two (one fast, one slow) components. The fast component occurs only microseconds after the laser illuminates the sample, in fact during the laser pulse. The slow component occurs much later. The OSL components from a beta irradiation are shown in Figure 3 below. We observed that in a pure beta irradiation, the fast component comprises only 20% of the total OSL signal. In a pure alpha irradiation, however, the fast component comprises 50% of the signal. Therefore, from the nature of the POSL technique, in not measuring the OSL while the laser is on, we were unknowingly ignoring a major factor causing the difference between alpha and beta signals. This is a problem the CW-OSL technique does not have, since by its nature it measures OSL continuously. This explained why we could not increase the resolution of the POSL technique by simply adjusting the parameters of the system. We propose using a two-detector system in which one detector would measure the slow component and one would measure the fast component, allowing the opportunity to achieve high resolution with the POSL system. This provides for very interesting possibilities in the future.

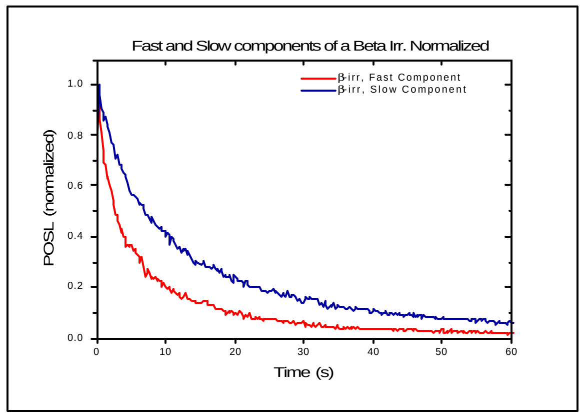

Figure 3: The fast and slow OSL components of a pure beta irradiation. Both are normalized to their initial intensity.

Concluding Remarks: Although the POSL system has a better sensitivity to low doses of radiation than the CW-OSL system, its current configuration does not allow it to resolve the difference between alpha and beta doses with the precision available using the CW-OSL technique. This is due to the presence of two separate components of the OSL decay curve, a phenomenon we discovered while attempting to optimize the system. The POSL system, however, still has the opportunity to become a more useful technique in the future by combining its current sensitivity with a more capable resolving power, possibly with the use of a two-detector system.

Acknowledgments: I would like to thank the National Science Foundation for playing such a large role in my enjoyable summer experience, and all the people who made it challenging and also exciting.

References: [1] Benton, E. R., Benton, E. V. (1999). Space Radiation Dosimetry in Low-Earth Orbit and Beyond. *Nucl. Instr. and Meth. In Phys. Res.* 257.