2012-2013 NC State Office of Undergraduate Research Grant Proposal

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Proposal Title:Observational Constraints on the Origin of Light Neutron-Capture Elements in Metal-Poor Stars		
Funding will be for Fall 2012 and Spring 2013 Only.		

Please submit your research proposal below. Please limit your proposal to 3 pages! Include the following:

1. Your research hypothesis, question, design goals, or research thesis
2. Your research or design plan
3. State the importance and implications in advancing disciplinary knowledge
4. State the connection between this project and your curricular interests

Save the completed document as a pdf or Word file with your name in the file name. Upload the proposal and the completed budget to http://www.ncsu.edu/undergrad-research/research_awards/login.php. Your recommendation by your mentor should be emailed directly to Judy Day at judy_day@ncsu.edu.

Proposal:

Research Question

The origin of elements heavier than iron has been a long-standing open question in Astrophysics. The Big Bang resulted in hydrogen, helium and small amounts of lithium. Intermediate –mass and iron-group elements are synthesized during stellar evolution and are ejected in subsequent supernova explosions. The elements beyond iron are generally attributed to the rapid neutron-capture process (r-process) and the slow neutron-capture process (s-process) thought to occur in supernovae and asymptotic giant branch stars, respectively. A few proton-rich isotopes are attributed to the p-process.

Abundances observed in metal-poor stars allow us to study the very first nucleosynthetic events (e.g. events associated with r-process) independent of the later nucleosynthetic events (e.g. events associated with s-process) [1]. Recent observations of the abundance pattern of heavy elements in metal-poor stars have revealed an interesting situation: the elements heavier than barium exhibit a robust r-process pattern [2], whereas the elements from copper to tin show a more complicated behavior, which has led to the proposition of an additional nucleosynthetic process at low metallicity, the Lighter Element Primary Process (LEPP) [3].

My research addresses the question how and where the elements from copper to tin are made**.** In particular, we want to constrain the possibility of having an additional nucleosynthetic process such as the LEPP for the elements from copper to tin. This question can be broken down into three parts. First, we want to make sure that these elements are not formed in the r-process, which would support a new process that could instead form these elements. Next, we will address the question whether we need more than one process, in addition to the r-process, to form the elements from copper to tin. Third, we want to know which of these elements might be formed in the same process and which ones in different processes.

Methods

We propose to analyze observational abundance data compiled in the freely available online database Stellar Abundances for Galactic Archaeology (SAGA) [4, 5] as well as data in the current literature, to pursue our research question. We can plot the abundance data as shown in Figure 2 below to study correlations between different elements. In these graphs, the abundance information of different elements is presented using the bracket notation, for example, for two elements A and B, $[A/B] = \log_{10}[(A/A_{\odot})/(B/B_{\odot})]$ where $A_{\odot}$ is the abundance of element A in the Sun.

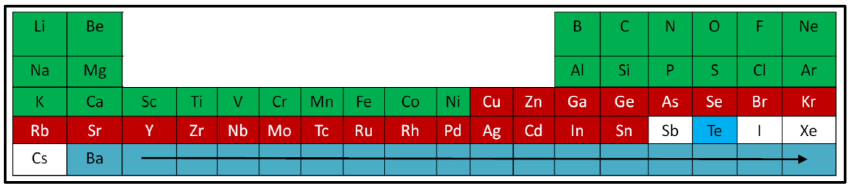

Figure 1

Figure 1 shows part of the periodic table highlighting in red the elements relevant to this project. Blue indicates r-process elements and green indicates intermediate-mass and iron-group elements.

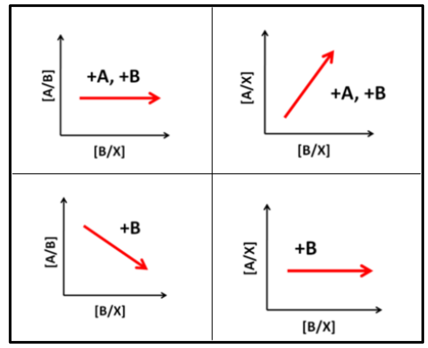

Figure 2

Figure 2 shows schematics of elemental abundance trends (denoted by arrow) indicating the production of elements (denoted by +) in different processes.

To study the correlation of an element A of unknown origin to an element B of known origin (e.g. r-process), we will plot them as shown in the left column of Figure 2. A flat trend as in above, left indicates that the elements A and B are formed in the ***same*** process and/or site, whereas the trend in below, left indicates that the elements A and B are formed in ***different*** processes and/or sites. We can do this for A = any element marked red in Figure 1, B = Europium (Eu) and X = Fe. Eu is an r-process marker, therefore, in this way we can make sure that the elements we are interested in are ***not*** formed in the r-process.

To study the correlation between two elements A and B of known or unknown origin, we will plot them as shown in the right column of Figure 2. In this case, a trend as in above, right indicates that the two elements A and B are formed in the ***same*** process and/or site, whereas a flat trend as in below, right indicates that the elements A and B are formed in ***different*** processes and/or sites. We can do this for A and B being any two elements we are interested in and X = Fe to find out if we need more than one process to explain the formation of the elements from copper to tin and also which elements are formed in the same versus different processes.

We tested the above approach for Molybdenum (Mo) using data from SAGA and [6]. Our preliminary results are consistent with an additional nucleosynthetic process, such as the LEPP.

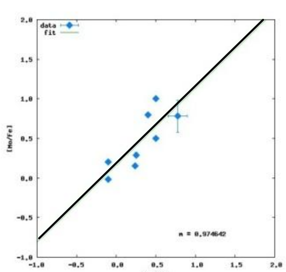

Figure 3

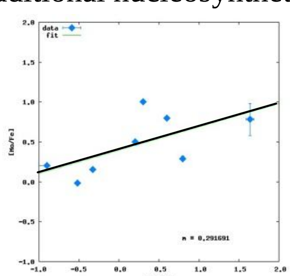

Figure 4

Figure 3 shows that Mo and Zr are formed in the same process or site.

Figure 4 shows that Mo and Eu are formed in different processes or sites. This further confirms that Mo is ***not*** an r-process element.

Here, we propose to analyze more light neutron-capture elements, starting with silver (Ag) and palladium (Pd). We are excited because abundance data for Ag and Pd in 56 different stars was recently published by [7] which increased the amount of available data by factors. Next, we will systematically collect abundance data for the other elements marked red in Figure 1, from the literature. These data will then be analyzed in the same way to further constrain an additional process such as the LEPP.

Importance

This research addresses the important unanswered question of how the heavy elements between copper and tin are formed at low metallicity. It will put constraints on the number of processes we need to sufficiently explain the formation of these elements. The correlations between different elements can identify which elements might be formed in the same or different processes. Thus, this work has the potential to guide both theory calculations and observational work in future. Theorists can use the results from this research to determine the conditions under which the different processes operate. This work will guide future observations, recommending observation of either additional elements in the same star or a given element in additional stars, to achieve a larger sample set of data. For example, say that our results predict that an element M is not an r-process element, observers can try to observe the r-process marker, Eu in the same stars as they observe element M to verify this.

Relevance to Curricular Interests

Working on a research project like this gives me the opportunity to be, at an undergraduate level, what I have always wanted to be – a scientist. When I came into college, I took classes in the B.S. program in physics as well as in chemistry. I completed the first two years of both majors, and then in my junior year, decided to focus on physics. I am scheduled to graduate with a B.S. in physics (with honors) in May 2013. I still pursue research in a chemistry lab. My point is that I like both physics and chemistry, and an interdisciplinary project such as this, interests me very much.

I believe this project is an excellent opportunity for me to learn the very intriguing subject of astrophysics. I took PY 543, a graduate level course in astrophysics in Spring 2012. The coursework we covered in class provides me with the background necessary for this project. My previous undergraduate research experience has been experimental in nature; this project would be a good exposure to theoretical work. When I graduate with my degree in physics, I want to have not only learned as much physics as possible, but also all the ways in which real physics problems can be approached and/or solved. I am confident this project will help me in my preparation for graduate school in physics.

References

1. Beers & Christlieb (2005) ARA&A 43, 531
2. Cowan et al (2011) Carnegie Obs. Astr. Ser. 5, 223
3. Travaglio et al (2004) ApJ 601, 864
4. Suda et al (2011) MNRAS 412, 843
5. Suda et al (2008) PASJ 60, 1159
6. Peterson (2011) ApJ 742, 21
7. Hansen & Primas (2011) A&A 525, L5