ISOTOPIC CONSTRAINTS ON THE BUILDING BLOCKS OF THE SOLAR SYSTEM. K. R. Bermingham[1,2], B. S. Meyer[3], K. Frizzell[1], K. Mezger[4,5]. [1] Department of Earth and Planetary Sciences, Rutgers University, Piscataway, NJ 08854, USA (katherine.bermingham@rutgers.edu); [2] Department of Geology, University of Maryland, College Park, MD 20742, USA; [3] Physics and Astronomy, Clemson University, Clemson, SC 29634, USA (mbradle@clemson.edu); [4] Institut für Geologie Universität Bern, Bern CH-3012 Switzerland; [5] Center for Space and Habitability, Universität Bern, Bern CH-3012 Switzerland.

Introduction: To understand the origin and early evolution of our Solar System, identification and characterization of its stellar building blocks is required. The isotopic composition of the stellar events that contributed material to the Solar nebula can be identified from the nucleosynthetic isotope variations of meteorites and their refractory components (e.g., calcium aluminum inclusions, CAIs). This is because these isotopic variations are caused by heterogeneous distribution of presolar grains throughout the protoplanetary disk, where presolar grains originate from distinct stellar contributors to the Solar nebula.

Most meteorite groups possess nucleosynthetic isotope variations, with exceptions including enstatite chondrites and IAB non-magmatic iron meteorites (see review by [1]). Based on nucleosynthetic isotope variations documented in ^{50}Ti, ^{54}Cr, ^{58}Ni, it was recognized that meteorites and some planetary bodies fall into either the non-carbonaceous chondrite (NC) group or the carbonaceous chondrite (CC) group [2]. Where CC bodies are defined to be more isotopically anomalous in multi-element space compared to NC bodies. This fundamental isotopic dichotomy has since been identified in iron meteorites [3-7] and other isotopes that trace nucleosynthetic isotope variability in the disk (e.g., [4-11]).

The process that led to the NC-CC bimodality remain debated. Warren (2011) proposed that the NC-CC dichotomy may reflect the division between materials that accreted in the outer Solar System (CC) *vs.* materials that accreted in the inner Solar System (NC), separated by an early formed proto-Jupiter. Subsequent studies proposed causes for the distinct isotopic character of the NC and CC reservoirs (e.g., [11,13,14]), and examined the likelihood that Jupiter caused the separation between the NC and CC groups (e.g., [12]).

Regardless of the cause of nucleosynthetic isotopic variability in the disk, the identity of isotopes that are variable is central to detecting the building blocks of the Solar System. This is because these isotopes are markers of stellar events and environments that contributed material to the Solar nebula. For example, the slow (*s*-) process active during He and C shell burning in massive stars (>10 $M_\odot$, where $M_\odot$ is the mass of the Sun) or He shell burning in lower mass stars ($M < 10\ M_\odot$) can create large enrichments of ^{50}Ti, ^{54}Cr, and neutron-rich Ni isotopes [e.g., 15,16]. Calcium-48, however, must be produced in a low-entropy, neutron-rich environment [17]: deflagrations of dense C/O white dwarf stars [18], electron-capture supernovae [19], or thermonuclear electron-capture supernovae in O/Ne/Mg white dwarf stars [20].

To date, a comprehensive multi-element isotopic dataset has not been synthesized with astrophysical models of likely stellar building blocks. This step, however, would produce robust constraints on the nature of the Solar System's building blocks.

Present study: The present study synthesizes new nucleosynthesis models with a broad selection of high precision nucleosynthetic isotope data. A compilation of published high precision isotopic data from a range of whole rock meteorites and CAIs, is used to assess interelement isotopic correlations between and within NC and CC groups and CAIs. The isotopic relations are interpreted in the context of new nucleosynthesis models of Neutron-Rich Low-Entropy matter Ejectors (NRLEEs, e.g., thermonuclear supernovae). For details of these models, see accompanying LPSC2021 abstracts by coauthors Meyer and Frizzell.

Results and Discussion: The multielement dataset reveals systematic interelement isotopic relations. Interelement isotopic plots show ^{48}Ca and ^{50}Ti, ^{54}Cr and ^{58}Ni linear correlations between NC, CC, CAI that indicate coupling of neutron-rich species in presolar grains. NRLEE events are proposed to be the source of presolar carriers responsible for ^{48}Ca, ^{50}Ti, ^{54}Cr, ^{58}Ni nucleosynthetic isotope variations in meteorites. The nucleosynthetic reaction pathways in NRLEEs that produce these isotopes are developed based on the structure shown in **Fig. 1**. The broad relation between NC, CC, CAI remains intact between ^{84}Sr, ^{96}Zr, ^{135}Ba, but within-group linear correlations are not evident.

The isotopic correlations observed in NRLEE products are likely a consequence of the heterogeneous distribution of presolar grains throughout the bulk Solar System. Linear interelement isotopic variations are expected if the isotopes are hosted in components with similar or identical chemical compositions. The mineralogy of these presolar phases may be determinable by considering the elements' geochemical properties and the isotopes' nucleosynthetic environment. Possible presolar grain mineralogy includes corundum/perovskite (^{48}Ca and ^{50}Ti), spinel/Fe alloys (^{54}Cr and ^{58}Ni), or compound grains including these mineral types.

Heavier isotopes (^{84}Sr, ^{96}Zr) originate from *s*-process dominated presolar grains, however, an additional source of ^{84}Sr and ^{96}Zr is identified in NRLEEs (**Fig. 1.**). The source of ^{135}Ba is likely a neutron star merger events, products of which could be coupled with preexisting presolar grains in the interstellar medium via implantation or coating.

Consequently, in addition to the source of short-lived radioactive nuclides (e.g., ^{26}Al, ^{60}Fe, ^{99}Tc), the primary stellar building blocks of the Solar System are detectable on the bulk meteorite sampling scale include NRLEE, AGB, SNIIa, and a neutron star merger event.

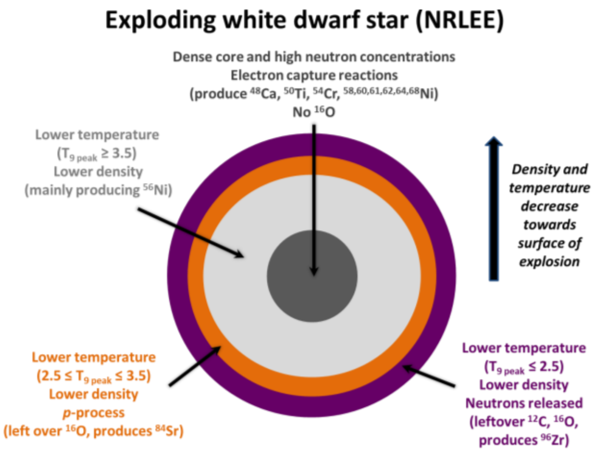

Fig. 1. Schematic nucleosynthetic structure of the ejecta from an exploding white dwarf star, (a NRLEE).

Sequence of Chemistries: Combining findings from the present study with concepts in cosmochemistry and nucleosynthesis, a "Sequence of Chemistries" is identified (**Fig. 2.**). This sequence delineates the five primary environments where the chemical and isotopic compositions of presolar grains are established. Each stage in the sequence involves a coupling or decoupling of atoms or their constituent's compound. As atoms progress through the Galaxy from their nucleosynthetic site to their final cosmochemical setting in the Solar System, they pass through the "Sequence of Chemistries". Any isotopic anomaly in a cosmochemical sample retains some chemical memory of the sequence it traversed. Hence, the isotopic abundances preserved in Solar System material preserve information about this evolution and are guides for the reconstruction of the history of elements that are the chemical building blocks of the Solar System. This distillation of chemical history may help constrain how processes couple or decouple isotopes over Galactic history.

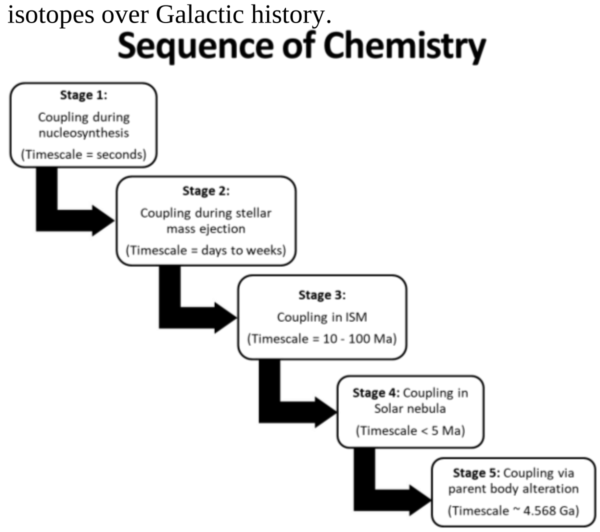

Fig. 2. "Sequence of Chemistries" which delineates the five main environments where the chemical and isotopic compositions of presolar grains are established.

Acknowledgments: K.R.B: NASA Emerging Worlds grant 80NSSC18K0496. K.R.B. and K.F: The Department of Earth and Planetary Sciences, Rutgers University. B.S.M: 80NSSC20K0338. K.M: NCCR PlanetS SNF grant 51NF40-141881.

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