TITANIUM-46 PRODUCTION IN EXPLODING WHITE DWARF STARS.

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Introduction: Isotopic anomalies in ^{46}Ti and ^{50}Ti are correlated in CAIs and bulk Solar System objects [1,2]. The nucleosynthetic origin of these two isotopes is distinct: ^{46}Ti is made in oxygen and silicon burning in both hydrostatic and explosive burning phases of stellar evolution in massive stars while ^{50}Ti is made in s-processing in He-rich shells in massive stars, but even more abundantly in the dense cores of exploding white dwarf stars where electron capture reactions lead to the high degree of neutron richness necessary for direct ^{50}Ti production [3]. Their distinct nucleosynthesis production suggests different carriers brought these isotopes into the early Solar System and that selective thermal processing produced residual isotopic heterogeneity that gave rise to the correlated anomalies [1].

Production in Exploding White Dwarf Stars: Production of abundant ^{46}Ti is possible in the outer layers of an exploding white dwarf star where the peak temperature reaches values of 3-4 billion Kelvins. In these layers, the initial carbon and oxygen or oxygen, neon, and magnesium undergo explosive burning. If the matter is slightly neutron rich owing to CNO processing earlier in the star's life, the oxygen burning during the stellar explosion runs slightly neutron-rich of the alpha nucleus line. The strong neutron binding of ^{46}Ti allows it to compete effectively for abundance during the ~1 second explosion.

We have run reaction network calculations with NucNet Tools [4] to explore ^{46}Ti production in a setting similar to that expected in a thermonuclear explosion of a white dwarf star. In a reference calculation that started at $T_9=T/10^9$ K = 3.6, an initial density of 10^7 g/cc, an initial composition of 50% ^{12}C and 50% ^{16}O, by mass, and a density e-folding timescale of 1 second, the final ^{46}Ti mass fraction was $\sim10^{-8}$. If we added 2% ^{22}Ne by mass, an amount that could be left over from pre-explosion CNO burning and AGB phase s processing, the slight increase in the overall neutron richness of the matter led to a final ^{46}Ti mass fraction of $\sim10^{-4}$. Moreover, for this degree of neutron richness, ^{46}Ti is the most overproduced Ti isotope, so it is likely that ^{46}Ti strongly dominates the Ti abundance in the outer layers of the ejecta.

Possible Carrier: If ample ^{46}Ti is ejected in the outer layers of the exploding white dwarf, it is likely bathed in abundant unburned oxygen. Furthermore, highly abundant ^{50}Ti in the inner layers of the ejecta could mix with the outer layers. This could give rise to an oxide condensate carrying both ^{46}Ti and ^{50}Ti. While the ejecta from most thermonuclear supernovae may travel too rapidly to allow condensation of much dust, rare thermonuclear electron-capture supernovae (tECSN), which are likely candidates for strong ^{50}Ti production, are lower in energy [5]. The lower energy of tECSN and the high oxygen content of their ejecta might favor dust production [6], and if the outer layers are rich in ^{46}Ti due to the processing discussed above, that dust could carry coupled ^{46}Ti and ^{50}Ti. Such dust could be the source of the coupled ^{46}Ti-^{50}Ti in bulk Solar System objects.

Jupyter Notebooks: We are developing Jupyter notebooks that allow interested users to explore details of our nucleosynthesis calculations interactively [7]. The interested reader is invited to use those notebooks to study ^{46}Ti nucleosynthesis.

References: [1] Trinquier A. et al. 2009. *Science* 324:374-376. [2] Davis A. M. et al. 2018. *GCA* 221:275-295. [3] Clayton D. D. 2003. *Handbook of Isotopes in the Cosmos: Hydrogen to Gallium*, Cambridge: Cambridge Univ. Press. [4] https://sourceforge.net/projects/nucnet-tools/. [5] Jones S. et al. (2019) *Astron. Astrophys. 622,* A74. [6] Bermingham K. et al. 2021, in preparation. [7] https://github.com/mbradle/jupyter-notebooks.