THE CHEMICAL EVOLUTION OF TI ISOTOPES IN THE GALAXY: PRESOLAR GRAINS, LOCAL M DWARF STARS, AND MODEL PREDICTIONS. F. Gyngard[1], [1]McDonnell Center for the Space Sciences and Department of Physics, Washington University, One Brookings Drive, St. Louis, MO 63130, USA, fgyngard@gmail.com.

Introduction: The imprint of galactic chemical evolution (GCE) can be observed in both primitive samples from meteorites (e.g., presolar grains [1]) and optical spectra from local galactic disk stars [2], and has been extensively modeled [3].

Titanium is an important diagnostic element for the understanding of GCE, as it is comprised of five stable nuclei, each of which is the result of multiple astrophysical sources that contributed to the isotopic inventory of the Solar System (SS). Titanium-48, a primary nucleosynthesis nuclei, is principally the result of successive α-captures during explosive Si burning in Type II supernovae (SNe); ^{46,47,49,50}Ti are secondary nucleosynthesis products produced in various proportions by massive star explosions, SNIa, and neutron irradiations (e.g., the *s*-process) in low-mass asymptotic giant branch (AGB) stars [4]. Deconvolving these GCE components provides insights into the relative contributions of multiple stellar objects to the SS and, in turn, the evolution (with time) of the metallicity of our local galactic environment.

Here we discuss laboratory measurements of the Ti isotopic composition of an ever-growing number of presolar SiC grains from primitive meteorites and compare the data to spectral measurements of Ti in local M (red) dwarf stars and models of the GCE of Ti isotopes calculated with updated physics and nucleosynthetic yields.

Results and Discussion:

Laboratory measurements of Ti in presolar SiC. Presolar SiC grains are posited to come from a variety of astrophysical sources (e.g., AGB stars, SNe, novae, J-stars), and have been placed into groups based on their supposed stellar origins [5]. Due to high Ti abundances in the SiC grains' host matrices (up to 20,000 ppm) and the relative ease (owing to comparatively large grain sizes) with which Ti can be measured, these grains provide highly precise constraints on models of Ti nucleosynthesis in their parent stars.

Excluding SiC grains from SNe (type X and C) and those of uncertain origin (type AB), about 400 mainstream, Y, and Z grains – thought to be from low mass (1-3 M⊙) AGB stars of ~Z⊙, 1/2 Z⊙ and 1/3 Z⊙, respectively – have had their Ti isotopic compositions determined by secondary ion mass spectrometry [6-12]. The small nuclear cross-sections of ^{46,47,49,50}Ti allow for the ability to distinguish between n-capture nucleosynthesis (which produces isotopic effects of only several 10s of permil [13]) from GCE. The grain data exhibit much larger isotopic effects, with $\delta^{46,47,49,50}$Ti/^{48}Ti values between approximately -200 and +400 permil (Fig. 1), which can only be attributed to a significant GCE component. Isotopic anomalies in ^{47,49}Ti are also correlated with those of ^{46}Ti (and ^{29}Si), as predicted by models of GCE (see below).

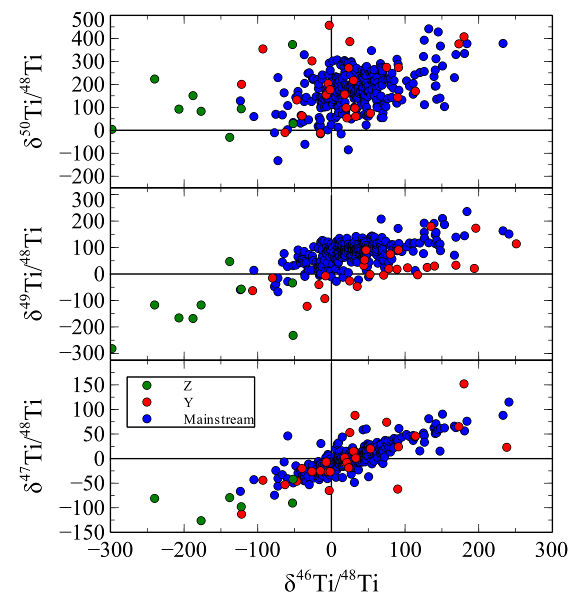

Fig.1. Titanium isotopic compositions of mainstream, Y, and Z SiC grains [14] expressed as δ-values (‰).

Spectral measurements of M dwarf stars. M dwarfs are characterized by their low luminosity (at most 10% L⊙) and mass (≲ 0.8 M⊙), and comprise ~ 75% of the main sequence stars in the galaxy. These stars burn H predominately via the pp chain, and, in their later stage, become fully convective (i.e., little or no radiative energy transfer). This effectively prohibits the formation of a substantial He core, thereby increasing their lifetime on the main sequence and limiting the n-capture component of their composition. Therefore, these stars are particularly excellent snapshots of a star at a given metallicity, as they have experienced little-to-no isotopic shifts from n-capture nucleosynthesis, which would occur in more massive and evolved stars. For inferring GCE, red dwarfs are ideal because they are virtually frozen in composition for a given metallicity and age.

Titanium isotopic abundances for 11 local M dwarfs were determined by [15], based on spectroscopic observations of the TiO molecular 0-0 band between 7045 – 7094 Å. Greater spectral broadening in these stars allows for more straightforward deconvolution of isotopic compositions by spectral fitting because of higher signal-to-noise ratios for a given exposure time. The measured Ti isotopic compositions show essentially no correlation between isotopic ratios and [Fe/H], with $\delta^{46,47,49,50}Ti/^{48}Ti$ values of roughly solar composition within errors.

Updated models of GCE. Hughes et al. [16] has calculated the GCE of Ti using a dual-infall model of the Milky Way, with updated physical models and nucleosynthetic yields using GETOOL [17]. The dual-infall model is calculated by including both a galactic halo and disk component, each contributing at different times with different rates to the overall evolution of the Galaxy's metallicity. Similar to the results of [18], positive correlations of $^{46,47,49,50}Ti$ with metallicity are predicted. While details remain, these calculations succeed in reproducing the ^{50}Ti abundance relative to SS values; however, this model still underproduces the solar ^{47}Ti abundance, possibly reflecting remaining uncertainties in SNIa nucleosynthesis and/or the initial mass function.

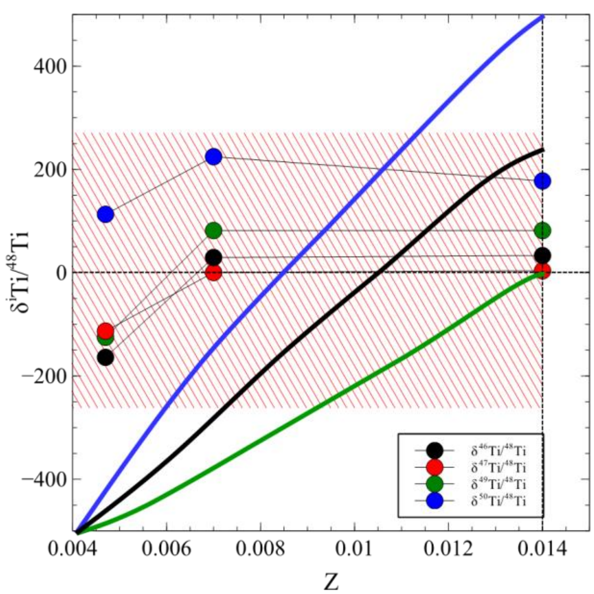

Fig. 2. Plot of the average Ti isotopic compositions of mainstream, Y, and Z grains as a function of metallicity (solid colored circles). The red hatched region represents the Ti compositions measured in local M dwarf halo stars (including measurement uncertainty) and the solid blue, black, and green lines are the predicted GCE trends the $^{50,46,49}Ti$ isotopes, respectively. Note that the GCE trend for ^{47}Ti is not shown, as it below the scale of this graph due to its underproduction in the model.

Summary: In Fig. 2, GCE model predictions are shown compared with the SiC grain data and the spectral measurements of M dwarfs. While both the laboratory measurements and GCE calculations exhibit an increasing evolution (and correlation) in the secondary Ti isotopes with metallicity, the spectral data do not. While uncertainties in the details of GCE models remain, the presolar grain data provides ground truth experimental evidence for the positive connection between Ti isotopic ratios and metallicity. Thus, inferring GCE from local M dwarf stars requires more detailed study and measurements.

References:

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