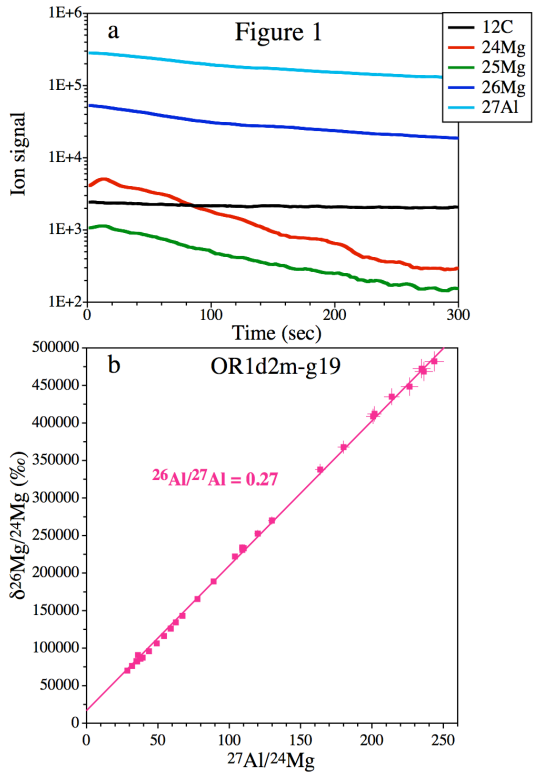
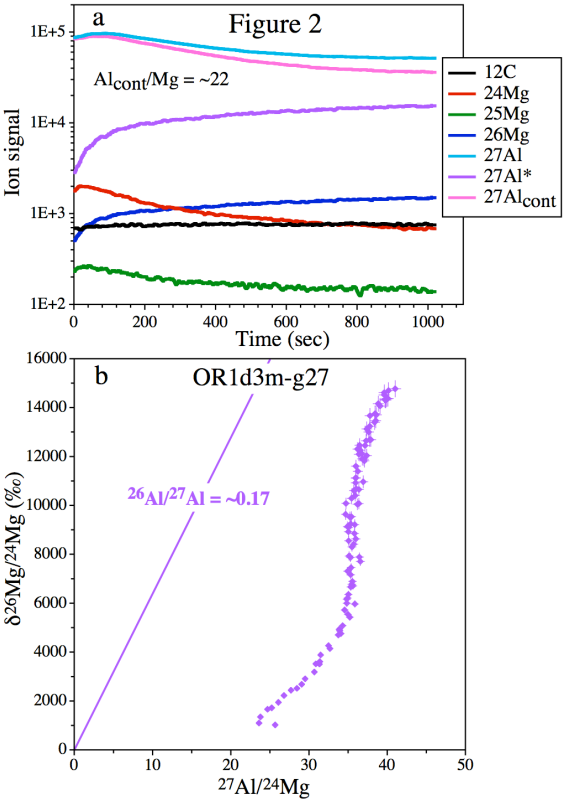
INTERNAL "ISOCHRONES" WITHIN PRESOLAR DUST GRAINS. E. Zinner[1] and M. Jadhav[1,2], [1]Laboratory for Space Sciences and Physics Dept., Washington University, St. Louis, MO, USA. e-mail: ekz@wustl.edu, [2] Hawai'i Institute of Geophysics and Planetology, Univ. of Hawai'i, Honolulu, HI 96822, USA.

Introduction: Presolar grains contain evidence for the presence of short-lived radioisotopes at the time of their formation in stellar environments. ^{26}Al [1], ^{41}Ca [2], and ^{44}Ti [3] have been identified from huge excesses in the daughter isotopes (^{26}Mg/^{24}Mg up to >1000×solar, ^{41}K/^{39}K up to >50×solar, ^{44}Ca/^{40}Ca up to >100×solar) in presolar SiC and graphite grains. The fact that during ion microprobe isotopic analysis the primary ion beam removes sample material layer by layer allows us to obtain depth profiles of isotopic ratios in presolar grains. If parent to daughter elemental ratios vary throughout such profiles we can construct "isochrone"-type correlation plots, although we emphasize that such plots do not have any temporal information but, instead, give us the initial radio-to-stable isotopic ratios at the time of grain formation. We present and discuss some examples of the Al-Mg, Ca-K, and Ti-Ca systems.

Experimental: Depth profiles of Al-Mg, Ca-K, and Ti-Ca isotopes were obtained with the NanoSIMS for Orgueil carbon grains from the density fractions OR1d (1.75-1.92 g/cm^3) and OR1f (2.02-2.04 g/cm^3) [4, 5]. For these analyses a primary O^- beam was rastered over the whole cross section of a given grain and positive secondary ions were detected.

Results: Depth profiles of ion signals and "isochrone" correlation plots are shown in the figures. For the latter we binned counts in 5 or 10 analysis cycles. The time in the profiles correspond to depth in the grains; the typical depth traversed in one of the profiles is ~ 1µm. In most of the Al-Mg plots, such as in Fig. 1, the Al signal is fairly constant and the variation in the ^{27}Al/^{24}Mg ratio is the result of variation in the isotopically normal Mg, most likely contamination. What is inexplicable in Fig. 1b is the fairly large positive intercept of 14,000 ‰. The intercept should be the isotopic ratio of normal Mg. The essentially perfect correlation in Fig. 1b and in other grains indicate that the initial ^{26}Al/^{27}Al ratio is uniform throughout the grains and radiogenic ^{26}Mg is quantitatively retained in the grains without any loss or redistribution. Some correlation lines are shifted to the right and intercept the x-axis at a positive ^{27}Al/^{24}Mg ratio while the data points maintain a perfect correlation. This shift can be explained by the addition of Al and isotopically normal Mg with a constant Al/Mg ratio. As long as the Al contamination is small compared to the intrinsic Al (originally with ^{26}Al) the correlation is maintained and the slope of the line is the initial ^{26}Al/^{27}Al ratio of the intrinsic Al. An extreme case where the Al contamination is much larger than the intrinsic Al is shown in Fig. 2, where the data do not fall on a linear correlation line. While in most cases such as in Fig. 1 the ^{26}Mg signal follows the ^{27}Al signal, this is not the case in Fig. 2,

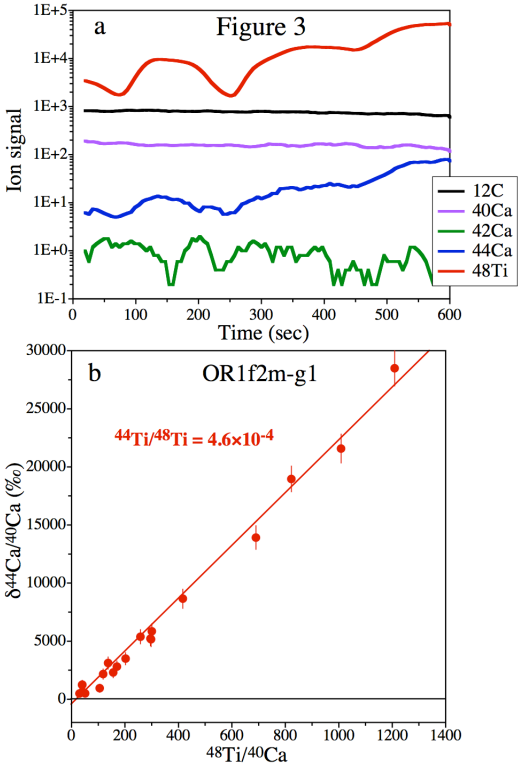


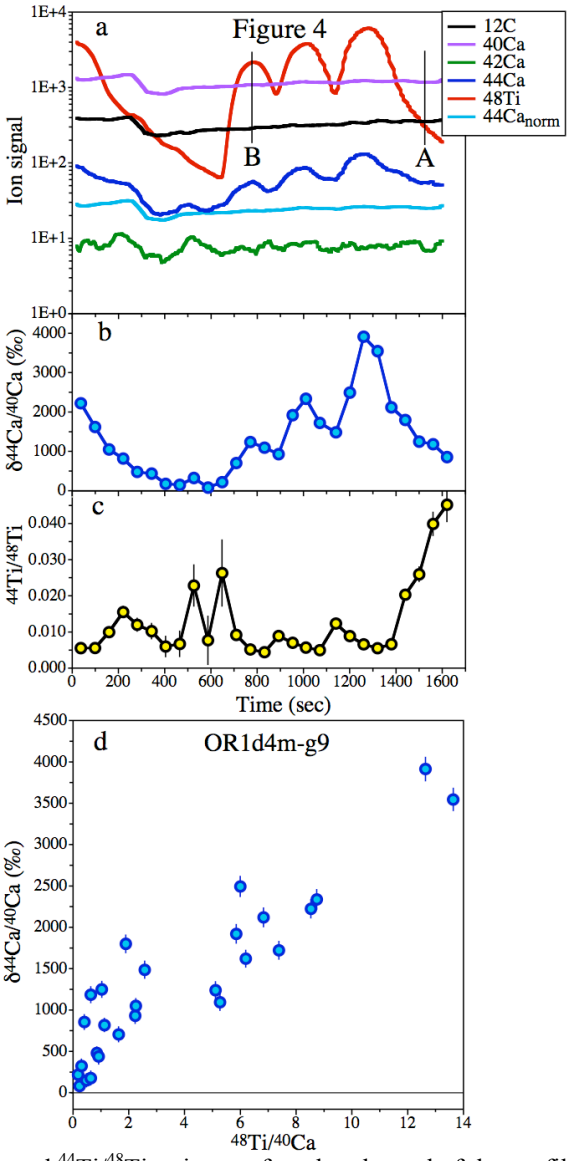


indicating a large amount of Al contamination. To make sense of these data we assume a uniform $^{26}Al/^{27}Al$ ratio and subtract the thus derived intrinsic ^{27}Al ($^{27}Al^*$ in Fig. 2a) from the total ^{27}Al signal to obtain the contaminating ^{27}Al (Al_{cont}). By varying the assumed $^{26}Al/^{27}Al$ ratio we can achieve a fairly uniform $Al_{cont}/^{24}Mg$ ratio throughout the grain; for a $^{26}Al/^{27}Al$ ratio of 0.17 (see Fig. 2b). This indicates that most of the ^{24}Mg signal is from isotopically normal contamination with $Al_{cont}/Mg = \sim 22$ (Fig. 2a).

The situation for the Ca-K system is similar to that of the Al-Mg system in that the ^{40}Ca signal is constant throughout the grains and ^{39}K (mostly contamination) varies, leading to a large range in $^{40}Ca/^{39}K$ ratio. $^{41}K/^{39}K$ ratios throughout the grains are well correlated with $^{40}Ca/^{39}K$ ratios, indicating that radiogenic ^{41}K is retained in the grains without redistribution.

The Ti-Ca system differs from the others in that here the Ti, initially containing the radioisotope ^{44}Ti, varies as the primary beam sputters away TiC subgrains, while ^{40}Ca is fairly uniform (Fig. 3a). In several grains studied, $^{44}Ca/^{40}Ca$ ratios are well correlated with $^{48}Ti/^{40}Ca$ ratios (Fig. 3b), indicating quantitative retention of radiogenic ^{44}Ca. However, there are notable exceptions as shown in Fig. 4. In this grain, the data points do not show any good correlation (Fig. 4d). Although ^{44}Ca excesses are largest in regions with TiC subgrains (Fig. 4a and 4b; $^{44}Ca_{norm}$ is the expected ^{44}Ca signal if the $^{44}Ca/^{40}Ca$ ratio is normal), the inferred $^{44}Ti/^{48}Ti$ ratios obtained by connecting the data points in Fig. 4d with the origin do not show any correlation (Fig. 4c). It is especially puzzling that the highest inferred $^{44}Ti/^{48}Ti$ ratios are found at the end of the profile beyond the last TiC subgrain, where the Ti concentration, and thus the $^{48}Ti/^{40}Ca$ ratio, is low, but where there is a substantial ^{44}Ca excess. We cannot unambiguously determine whether ^{44}Ca redistribution or heterogeneity of the initial $^{44}Ti/^{48}Ti$ ratio is the reason for this result. If it is the former, why is it not observed in other grains that show perfect correlations? Furthermore, why should this redistributed (diffused?) ^{44}Ca, away from the last subgrain (spot A), be as high as right in a subgrain (spot B)? If it is isotopic heterogeneity, we have to conclude that the initial $^{44}Ti/^{48}Ti$ ratio was higher in some Ti-poor regions of the graphite grain than in individual TiC subgrains that were incorporated into the carbon grain during its growth.





References: [1] Zinner E. et al. (1991) *Nature* 349, 51-54. [2] Amari S. et al. (1996) *ApJ* 470, L101-L104. [3] Nittler L. R. et al. (1996) *ApJ* 462, L31-L34.[4] Jadhav M. et al. (2006) *New Astron. Rev.* 50, 591-595. [5] Jadhav M. et al. (2008) *ApJ* 682, 1479-1485.