Isotopic analysis of presolar graphite from the Murchison meteorite

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I. Presolar grains

- ♥ Stardust in meteorites
- ♥ Formed in the stellar outflow or stellar ejecta
- ♥ Remain (almost) intact throughout the journey from stars to the interstellar medium, and finally to the earth
- ♥ Born before the solar system formation (4.6 billion years ago)
- ♥ Mineral types of presolar grains include diamond, SiC, **graphite**, oxides, refractory carbides, silicates, and Si_3N_4.
- ♥ Abundances: a few ppb to a few hundred ppm in meteorites

II. Presolar graphite

- ♥ Range of density (1.6 – 2.2 g/cm^3)
- ♥ Abundance: ~one ppm in the Murchison meteorite (CM2)
- ♥ Two morphological types

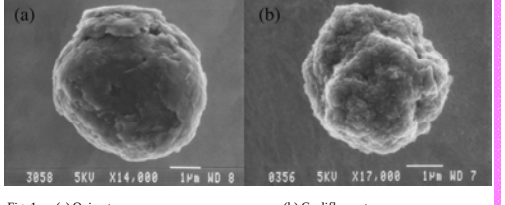

Fig. 1 (a) Onion type (b) Cauliflower type

- ♥ Individual grains, more than a thousand of them, were analyzed using the IMS-3f and the NanoSIMS at Washington University in St. Louis.
- ♥ We have analyzed grains from KE3 (1.65 – 1.72 g/cm^3), KFA1 (2.05 – 2.10 g/cm^3), KFB1 (2.10 – 2.15 g/cm^3), and KFC1 (2.15 – 2.20 g/cm^3) extracted from the Murchison meteorite.

III. Isotopic ratios of graphite grains

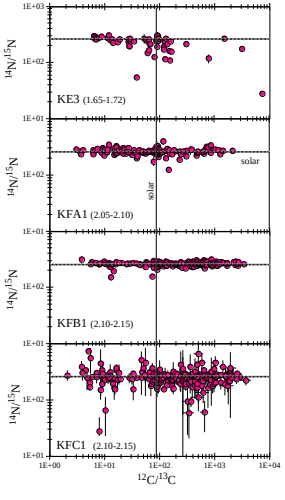

Fig. 2 Carbon and N isotopic ratios

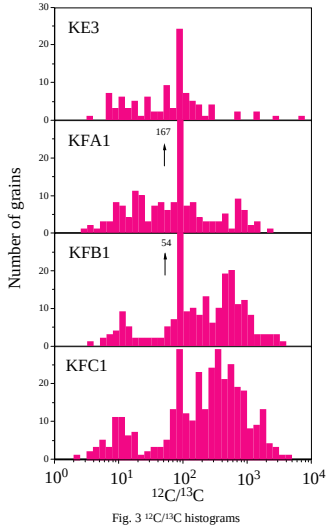

Fig. 3 $^{12}C/^{13}C$ histograms

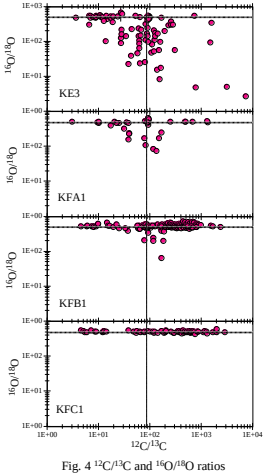

Fig. 4 $^{12}C/^{13}C$ and $^{16}O/^{18}O$ ratios

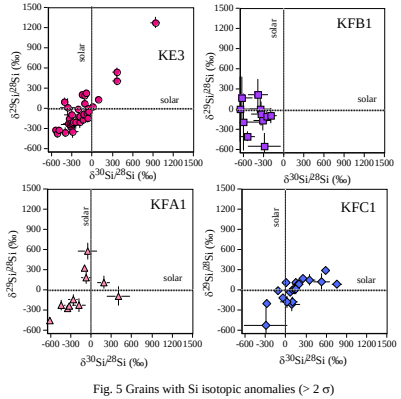

Fig. 5 Grains with Si isotopic anomalies (> 2 σ)

$\delta^i Si/^{28}Si \equiv [(^iSi/^{28}Si)_{grain}/(^iSi/^{28}Si)_{solar} - 1]\times 1000$

$\delta^i Ti/^{48}Ti \equiv [(^iTi/^{48}Ti)_{grain}/(^iTi/^{48}Ti)_{solar} - 1]\times 1000$

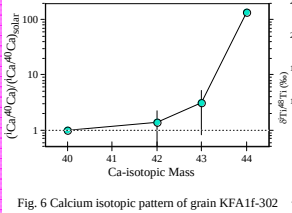

Fig. 6 Calcium isotopic pattern of grain KFA1f-302

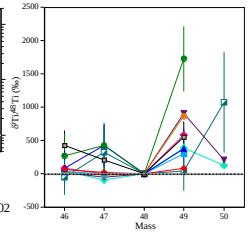

Fig. 7 Titanium isotopic patterns of KE3 grains

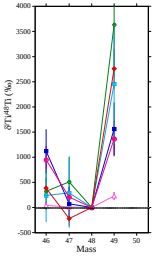

Fig. 8 Titanium isotopic patterns of KFC1 grains

- ♥ Carbon isotopic ratios vary by a few orders of magnitude (**Figs. 2** & **3**).
- ♥ Grains with lower $^{12}C/^{13}C$ ratios than solar are more abundant in the lower-density separates, while those with higher $^{12}C/^{13}C$ ratios are more abundant in the higher-density separates (**Figs. 2** & **3**).
- ♥ Nitrogen isotopic ratios in many grains are close to normal (air: 272) (**Fig. 2**).
- ♥ Grains with ^{18}O excesses are mainly observed in the lower-density separates, especially in KE3. In KE3, grains with larger ^{18}O excesses tend to have higher $^{12}C/^{13}C$ ratios (**Fig. 4**).
- ♥ Grains with ^{28}Si excesses are mainly found in the lower-density separates, especially in KE3. In KFC1, many grains show $^{29,30}Si$ excesses (**Fig. 5**).
- ♥ Grain KFA1f-302 shows the $^{44}Ca/^{40}Ca$ ratio 138 times solar, whereas the other Ca isotopic ratios are normal within 2σ (errors in **Fig. 6** are 1σ). It indicates that the excess is due to the decay of ^{44}Ti ($T_{1/2}$ = 60 a), which is produced only by explosive nucleosynthesis in supernovae.
- ♥ Titanium isotopic patterns of KE3 and KFC1 grains show signatures of neutron capture in massive stars for KE3 grains, and in low-metallicity asymptotic giant branch stars for KFC1 grains (**Figs. 7** & **8**).
- ♥We compared the isotopic signatures of the graphite grains to predicted ratios in various types of stars.
- ♥From the comparison, we conclude, in general,
- ♠ Oxygen-18 and ^{28}Si excesses in many **KE3** grains as well as the initial presence of ^{44}Ti indicate that the grains from separate KE3 most likely formed in supernovae.
- ♠ High $^{12}C/^{13}C$ ratios and excesses in $^{29,30}Si$ in the **KFC1** grains indicate that they formed in low-metallicity (~0.007 < Z < 0.02, Z_{solar} = 0.02) AGB stars.

References: Amari et al. (1993) Nature 365, 806-809. Amari (unpublished data). Hoppe et al. (1995) GCA 59, 4029-4056. Travaglio et al. (1999) ApJ 510, 325-354.