A Search for ^{70}Zn Anomalies in Meteorites. Frederic Moynier[1,2], Nicolas Dauphas[3,4], and Frank Podosek[1,2]. [1]Earth and Planetary Sciences, Washington University in St Louis; [2]McDonnell center for the Space Sciences; [3]Origins Laboratory, Department of Geophysical Sciences and Enrico Fermi Institute the University of Chicago; [4]California Institute of Technology, Division of Geological & Planetary Sciences. moynier@levee.wustl.edu.

Introduction: Since the 1970s various isotopic anomalies have been observed at the mineral scale for many elements in certain types of Ca-Al rich inclusions (CAIs) from the Allende chondrite named FUN inclusions [1]. These mineral scale anomalies illustrate centimeter size heterogeneity in the early solar system. More recently, improvements in analytical methods and instrumentation have permitted smaller isotopic anomalies in several elements (Cr, Ti, Ni, Mo, Ru, Ba) to be detected in whole rock meteorites [2-11].

Measuring the isotope compositions of different isotopes produced by the same process can provide useful constraints on the origin of isotopic anomalies. Neutron rich nuclides such are ^{58}Fe, ^{60}Fe and ^{64}Ni have the same origins and can only been formed in stars (supernova or AGB stars) by neutron capture reactions and cannot be formed inside the solar system by irradiation; thus their potential nucleosynthetic anomalies should be correlated. Dauphas et al. [12] measured the isotopic composition of ^{58}Fe together with ^{64}Ni and ^{60}Ni (produced by decay of ^{60}Fe $t_{1/2}$=1.5 My) to quantify the possible heterogeneity in the distribution of the ^{60}Fe at the bulk meteorite scale in the early solar system. ^{58}Fe and ^{64}Ni did not show any departure from terrestrial composition at precisions of ~0.3 to 0.5 ε. These results together with the absence of fossil ^{60}Fe in the same samples (at the whole rock scale) argue in favor of the injection of ^{60}Fe in the early solar system and its homogenization to a 10% level before the formation of the planetary bodies, in agreement with dynamic modeling [13].

In this report we expand the study to ^{70}Zn, which is another neutron rich nuclide from the Fe peak. Zn has 4 stable isotopes, ^{64}Zn (48.63%), ^{66}Zn (27.90%), ^{67}Zn (4.10%), ^{68}Zn (18.75%). ^{70}Zn (0.62%) is a radioactive isotope with a half life (5×10^{14} yr) sufficiently long in comparison to the age of the solar system that it can be considered stable.

^{70}Zn isotopic anomalies have already been measured in two FUN inclusions C1 and EK1-4-1 by thermal ionization mass spectrometry (TIMS) whereas no anomalies were reported in other CAIs or whole rocks samples with a precision > 2 ε [14-16].

Recent studies conducted by multi collector inductively coupled plasma mass spectrometer (MC-ICP-MS) showed that the 4 most abundant isotopes of Zn are homogeneously distributed [17-19] at a precision of >0.5 ε (2σ); however these studies were mostly focused on mass dependent isotopic fractionation and did not report the very low abundant ^{70}Zn for technical reasons.

We measured the isotope composition Zn isotopes by MC-ICP-MS in 5 whole rock chondrites and did not observe any departure from terrestrial composition. ^{70}Zn is homogeneously distributed in the early solar system at a precision of ca. 0.70 ε (2σ), which confirms the homogeneity in planetary bodies of neutron rich isotopes around the iron peak. If Fe and Zn were not decoupled during their injection these results constrain the homogenization of the ^{60}Fe/^{56}Fe ratio to a 10% level before the formation of the planetary bodies.

Samples and analytical methods: We analyzed the Zn isotope compositions of whole-rock samples of Ornans (CO3), Allende (CV3), Murchison (CM2), Forest Vale (H4) and Indarch (EH4). For each sample ~500 mg have been dissolved under pressure in Paar bombs in a mixture of HNO_3/HF. A subsequent step in aqua regia were carried out to ensure the dissolution of refractory phases. The protocol for chemical purification was guided by the necessity of minimizing isobaric interferences with Zn isotopes, particularly with ^{64}Ni on mass 64 and ^{70}Ge on mass 70. Zn was purified by anion-exchange chromatography using a procedure described in [18]. Zn isotopic compositions were measured on a Finnigan Neptune MC-ICP-MS at the Origins Laboratory of the University of Chicago. The Neptune was coupled with an Apex desolvating nebulizer. Because the ion beam array was incompatible with the acquisition of ^{62}Ni (used for correction of isobaric interferences on ^{64}Zn) and ^{70}Zn simultaneously, a dynamic mode of 2 cycles was applied. The intensities on the masses 64, 66, 67, 68 and 70 were measured during the first cycle and the intensities on the masses 62, 64, and 66 were measured during the second cycle. All collectors but L4 (^{64}Zn) were connected to 10^{11} Ω amplifiers. To get a high signal on the minor isotope ^{70}Zn and avoid saturation on the most abundant Zn isotope (^{64}Zn) a 10^{10} Ω amplifier was connected to L4. The resulting ion beam intensity was ~1 V on ^{70}Zn.

Results and discussion: Isotope ratios are expressed in ε per 10,000 units after internal normalization to ^{68}Zn/^{64}Zn ratio of 0.568828. The reference material was JMC-Lyon 3-0749L standard. The typical errors reported are 0.30 ε on both $^{66}Zn/^{64}Zn$ and $^{67}Zn/^{64}Zn$ ratio and 0.70 ε on $^{70}Zn/^{64}Zn$.

As shown in Fig. 1 all the meteorites analyzed in this study have isotopic compositions identical to terrestrial. The average of $\varepsilon^{70}Zn$ between the 5 chondrites is -0.01 ±0.72. The absence of ^{70}Zn at the whole rock scale in meteorites agrees with previous studies [14, 16] but with a significant improvement in the analytical precision (Fig.2).

These results imply that at the scale of the chondrite parent bodies the $^{70}Zn/^{64}Zn$ ratio was homogenously distributed in the early solar system. If we consider that Fe and Zn have not been decoupled during the injection, the collateral effect on ^{70}Zn produced by heterogeneous distribution of ^{60}Fe can be calculated (Fig. 3). If some parts of the solar system did not incorporate ^{60}Fe from a type IIsupernova, then one would predict ^{70}Zn anomalies of the order of several ε (except for a star of 25Mo and an injection mass cut between 6.7–7.1Mo), which is not observed in meteorites which have terrestrial composition at ±0.70 ε. This limits the possible heterogeneity of the initial $^{60}Fe/^{56}Fe$ ratio to be within 10% and confirm previous conclusions from [12] inferred from ^{64}Ni and ^{58}Ni isotopic measurements.

One must however keep in mind that Zn is a moderately volatile element with a temperature of 50% condensation temperature of 730 K [20] and fractionation between dust and vapor may have occurred in the circumstellar envelops [21]. Thus, Zn behaviors might have been decoupled from Fe and Ni and its isotopes may have been more thoroughly homogenized than Ni and Fe. In that respect, ^{58}Fe provides the most stringent constraints on the distribution of ^{60}Fe.

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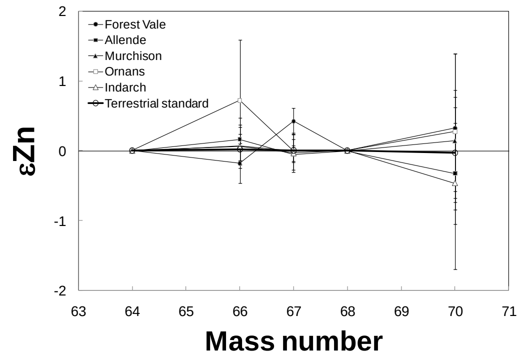

Figure 1: Zn isotopic data in chondrites. No ^{70}Zn anomalies have been detected at a ~70ppm precision.

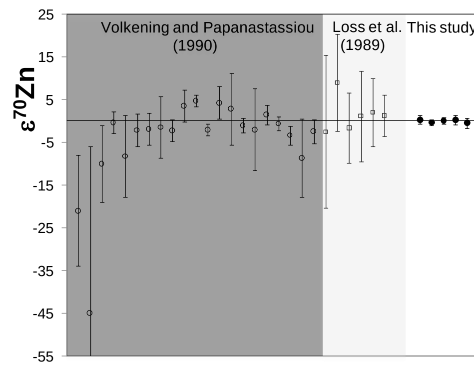

Figure 2: Comparison between ^{70}Zn data from this study and [15, 16].

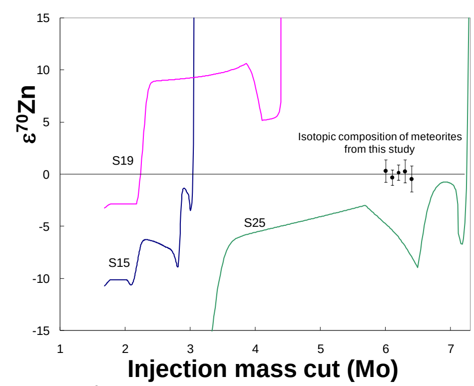

Figure 3: $\varepsilon^{70}Zn$ in function of the injection mass cut (mass coordinate above which matter from the type II supernova ejecta is injected into the solar system). We computed the yields for 15, 19, and 25 $M_{☼}$type II Supernova progenitors (data from [22]). This figure shows the collateral effect on ^{70}Zn if ^{60}Fe was injected by a supernova and some parts of the solar system did not incorporate any ^{60}Fe (see [12] for details of the equations).