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Presolar grains and their implications for the study of solar nebula heterogeneity

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Abstract. Presolar grains are grains that have isotopic ratios of some elements different from those found in the Sun. Such isotopic ratios along with the stellar nucleosynthesis give clues of the stellar source of the grains. In the paper, we analyzed two presolar grain species, SiC and graphite, of Murchison and Orgueil meteorites. The main goal was to identify the solar nebula heterogeneity from distribution of presolar grains from differents sources.

Resumo. Grãos pressolares são grãos que possuem razões isotópicas de alguns elementos diferentes daquelas encontradas no Sol. Tais razões isotópicas, aliadas à previsões da nucleossíntese estelar, dão indicações do tipo de estrela que produziu determinada espécie de grão. Neste trabalho analisamos duas espécies de grãos pressolares, SiC e grafite, dos meteoritos Murchison e Orgueil. O objetivo principal deste estudo foi comparar as abundâncias das diferentes espécies de grãos formados em determinadas fontes estelares para procurar indícios de algum favorecimento a grãos de uma fonte estelar qualquer em uma região da nebulosa solar, mostrando uma heterogeneidade da nebulosa. Assim, analisamos as razões isotópicas presentes em cada grão a fim de identificar suas fontes estelares e comparar as quantidades obtidas para cada meteorito.

Keywords. Meteorites, meteors, meteoroids – Nuclear reactions, nucleosynthesis, abundances – circumstellar matter

1. Introduction

Presolar grains are stardust formed in stellar outflows or ejecta which traveled through the interstellar medium and contributed to the enrichment of the solar nebula. They are recognized for their anomalous isotopic ratios when compared to solar isotopic ratios and they are found in primitive bodies of the Solar System (Lodders & Amari 2004). Through these grains it is possible to identify the sources that enriched the solar nebula and also if the solar nebula was heterogeneous or not. The present of presolar grains in primitive meteorites and primitive bodies of the Solar System that suffered little differentiation is an indication that some regions of the solar nebula may have undergone little processing. The goal of this work was to identify the stellar sources of the presolar grains found in two primitive meteorites of different class, Murchison (CM2) and Orgueil (CI1), and investigate if there would be any favoritism to grains formed in a particular stellar source.

2. Methodology

The creative stellar source of the presolar grain is identify through the isotopic ratios that together form a kind of signature of the stellar nucleosynthesis that originated the elements that formed the presolar grain. Thus, by combining these isotopic ratios with tstellar nucleosynthesis information, it is possible to point out the creative stellar source. In this work we used the method of analysis through isotopic ratio graphs for to classify the grains according to your stellar source. For such classification, we produced graphs according to previous works by different authors. We separated the presolar grains according to stellar source and, from this we analyzed if there was any kind of favoritism in the amount of presolar stardust formed in a given stellar source in the sample meteorites. For such investigation, we chose SiC (silicon carbide) and graphite presolar grains. This choice was made based on the amount of bibliographic information that available on these grains. Presolar SiC is the species that was best studied among the presolar grains. Graphite is still the target of several studies and, from SiC grain data it's possible to compare them and identify the graphite stellar sources (Amari 2017). The sample used in this work is composed of SiC and graphite grains found in samples of the meteorites Murchison (CM2) and Orgueil (CI1). Our sample contains 14873 SiC grains and 2216 graphite grains. The data were collected from the University of Washington presolar grains database. In Table 1 indicates the quantities of grains separated by meteorite.

Table 1. Presolar SiC e graphite grains from Murchison and Orgueil meteorites.

Meteorites	SiC	Graphite
Murchison	14704	1850
Orgueil	169	366

Table 2. Presolar SiC e graphite grains from Murchison and Orgueil meteorites classified by stellar source.

Meteorites	Supernovae	J-Type C stars	Pos-AGB	AGB
Murchison	140	119	131	169
Orgueil	125	20	27	155

In addition to the main goal, we tried to classify graphite grains according to a filter of selected isotopic ratios. With our filter we found the results of Table 2.

Many grains could not be classified due to lack of information. These results show that it is possible that Orgueil meteorite was formed in a region not as homogeneous as the region in which Murchison meteorite was formed. After classifying the graphite grains from the filters, we followed to the graph of isotopic ratios. In work, we made countless combinations for the graphs. Here, we will show the two main results for both grains. To interpret the graphs, we used the characteristic isotopic signatures of each stellar source based on existing SiC grain data (Henning 2010).

3. Conclusions and Perspective

With respect to the classification of graphite presolar grains, we presented a new criterion to identify the stellar sources from one or two characteristic isotopic ratios. We got satisfactory results, but more date is needed to classify grains from other stellar sources (Wolf-Rayet star, for example). Whether or not to validate the solar nebula heterogeneity, we saw that most grains are of AGB stars origin reinforcing the idea that cold evolved stars are the largest stardust producers in the interstellar medium. Comparisons of the grain quantities of each meteorite indicate that Orgueil meteorite is richer in supernova grains than Murchison meteorite. This leads us to the conclusion that Orgueil meteorite could have formed in a region rich in supernovae grains than Murchison meteorite. For the future, we will analyze the presolar grains sizes because they were larger than the expected grains in circumstellar envelopes of AGB stars.

References

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Lodders, K. Amari, S. 2004, Chemie der Erde – Geoch., 65, 93-166
Presolar database: https://presolar.physics.wustl.edu/presolar-grain-database/

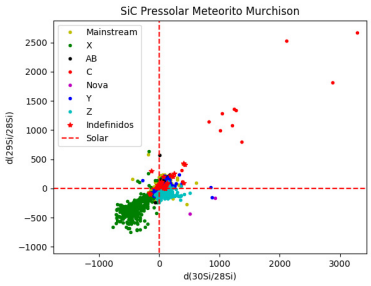

Figure 1. Si isotopic ratios graph for Murchison meteorite SiC presolar grains separated by group. Y axis indicates the ratio delta-value (29Si/28Si) and the X axis represents the ratio delta-value (30Si/28Si). Solar values shown in graph with dashed lines.

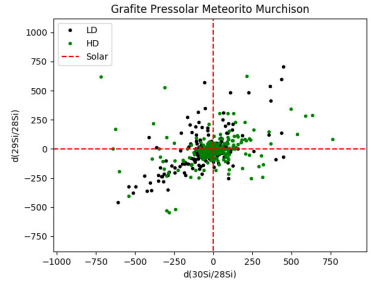

Figure 2. Si isotopic ratios graph for Murchison meteorite graphite presolar grains separated by density.

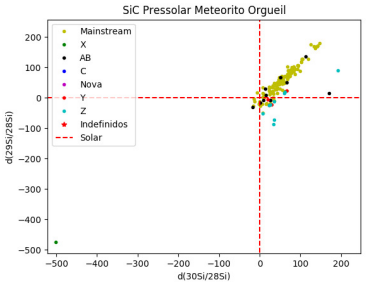

Figure 3. Si isotopic ratios graph for Orgueil meteorite SiC presolar grains separated by group.

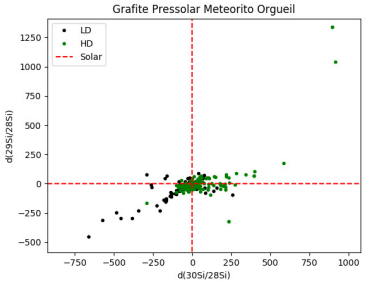

Figure 4. Si isotopic ratios graph for Orgueil meteorite graphite presolar grains separated by density.

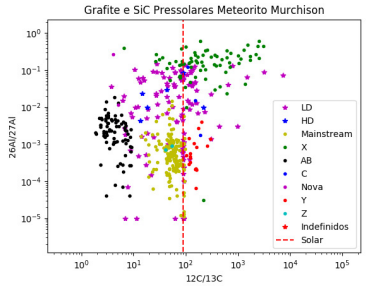

Figure 5. Graph of the isotopic ratios of Al and C for graphite and SiC grains of the Murchison meteorite. Graphite distributed according to their density and SiC grains separated by group. Y axis indicates the 26Al / 27Al ratio and the x axis represents the 12C / 13C ratio. Solar value indicated in graph with dashed line.

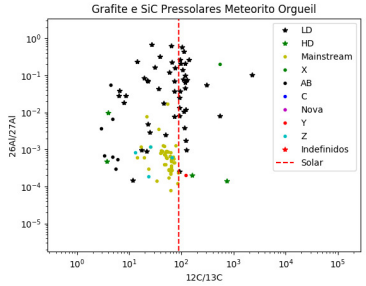

Figure 6. Graph of the isotopic ratios of Al and C for graphite and SiC grains of the Orgueil meteorite.