

# Did Mesosiderites See the FU Orionis Outbursts of the Solar Nebula? N. Sugiura<sup>1</sup>, <sup>1</sup>University of Tokyo.

## Introduction:

FU Orionis outbursts are considered to be a high mass accretion phase of a T-Tauri star [1] that lasts typically many tens of years. During this phase the luminosity increases  $\sim 100$  times. The early solar nebula may also have experienced the outbursts. But so far solid meteoritic evidence for the outbursts has not been reported. Here, I examine the possibility that mesosiderites may have seen the outbursts.

## Accretion age and accretion location of the parent body and the depth of mesosiderite formation:

In order for mesosiderites to see the outbursts, they have to have accreted early and located close to the sun. Also, mesosiderites have to be located very close to the surface of the parent body to feel the heat of the outbursts.

There are many studies on chronologies of mesosiderites. W isotopic compositions of metals, Pd-Ag systematics, Mn-Cr age of Vaca Muerta clasts, Pb-Pb age of zircons, Al-Mg model ages and Sm-Nd ages have been reported. The inferred ages from these various systems are not necessarily consistent with each other. This is mainly due to differences in the closure temperatures and partly due to the complicated thermal history. Overall, the silicate clasts seem to have formed before 4563 Ma and the accretion of the parent body occurred within 1 Ma of CAI formation. Since inner solar nebula existed until  $\sim 3.5$  Ma after CAI formation [2], the accretion of mesosiderite parent body was early enough for seeing the outbursts.

The accretion location of mesosiderite parent body is rather uncertain. Oxygen,  $^{54}\text{Cr}$  and nitrogen isotopic anomalies provide clues to this problem. The oxygen isotopic compositions and  $^{54}\text{Cr}$  anomalies of mesosiderites are similar to those of the other achondrites. In contrast, the nitrogen isotopic composition of a mesosiderite is significantly heavier than those of iron meteorites and is nearly normal, possibly suggesting its non-core origin. Generally, achondrites (including iron meteorites) are considered to have formed early, close to the sun [3]. Therefore, the similarity of oxygen and  $^{54}\text{Cr}$  anomalies to the other achondrites suggests that the mesosiderite parent body also formed close to the sun. (The present location of the mesosiderite parent body is not certain because the orbit is likely to have been gravitationally disturbed.)

The depth of formation of mesosiderites from the surface of the parent body can be estimated from the cooling rates, excess cosmogenic nuclides and excess neutron flux. All mesosiderites cooled rapidly [4] at high temperatures after a reheating event, suggesting shallow burial. Vaca Muerta clasts have excess cosmogenic rare gases, suggesting  $2\pi$

irradiation on the parent body [5].  $^{150}\text{Sm}$  and  $^{158}\text{Gd}$  isotope anomalies of Vaca Muerta are also consistent with shallow  $2\pi$  irradiation [6]. These cosmic ray effects are effective only at a very shallow ( $\sim 1\text{m}$ ) depth. At such shallow depths, if FU Orionis outbursts occurred in the inner solar system, mesosiderites could feel the heat. It is to be noted, however, that the inferred  $2\pi$  irradiation duration is much longer than the duration of the solar nebula.

## Heat source of reheating:

It is known that all mesosiderites have experienced a reheating event after (or at the time of) the addition of metal, after which they cooled rapidly. The heat source is a matter of controversy. Radiogenic heating is not effective at a shallow depth. It can also be excluded based on the rapid cooling rate. Therefore, hot materials (molten metal) deposited on the surface have been proposed as the heat source [7]. However, presence of small metal grains ( $\sim 200\ \mu\text{m}$  in diameter) in some mesosiderites suggests that the metal was solid at the time of mixing. In the case of FU Orionis heating, the surface temperature of the parent body is expected to rise  $\sim 3$  times (up to  $\sim 1000\ \text{C}$  at  $\sim 1\ \text{AU}$ ) as the luminosity increases  $\sim 100$  times. The heat would penetrate  $\sim 50$  meters in 100 years which is consistent with the depth estimated from the cooling rates.

## Summary:

The accretion age, the accretion location in the nebula, the depth from the surface and the thermal history at and after the reheating event seem to be consistent with the hypothesis that mesosiderites witnessed the FU Orionis outbursts in the early solar system.

## References:

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