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Origin of Cavities in Cosmic Spherules

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Cosmic spherules are extraterrestrial-origin round-shaped dust particles collected from the stratosphere, polar ice, and ocean floor sediments. When extraterrestrial dust particles enter the Earth atmosphere, they are heated by the gas friction and melted. Because of the surface tension, the molten particles become spherical and form cosmic spherules when they solidify.

Some cosmic spherules seem to bubble inside the particle, because there are some cavities in those cosmic spherules. However, it is not known well how cavities formed in the cosmic spherules.

If the dust particle solidifies before cavities formed in the cosmic spherules shrink completely, cavities remain in the cosmic spherule. Bubble size variation depends on the evaporation pressure of the dust particle and the pressure of the cavity. If the vapor pressure is lager than the pressure in the cavity, the bubble grows. On the contrary, if the vapor pressure is smaller than the pressure in the cavity, the gas molecule condenses and the cavity shrinks. In this shrink phase, the cavity disappears if the fluid motion is fast and the timescale of deformation is shorter than the timescale of condensation. On the other hand, if the fluid motion is slow and the time scale of deformation is longer than the timescale of condensation, the cavity survives. In both cases, it seems that the cavities remain in the cosmic spherule when the dust particle solidifies before cavities shrink completely.

In this study, we calculate variation of bubble size; specifically, we examine whether a bubble in a forsterite particle entering the Earth's atmosphere grows or not. Assuming that the inside of the dust particle is isothermal and isobaric, we examined the bubble size by simulating the temperature, the vapor pressure in the dust particle, and the pressure in the cavity. We take into account the effect of the negative curvature of the cavity surface.

We examine the cases with a wide variety of entry parameters: the initial radius (from 0.1 mm to 2 mm), the entry velocity (from 11.2 km/s to 20 km/s), and the entry angle (from 0 to 90 degrees, the angle 0 corresponds to the entry from the zenith direction). We have found that the bubble does not remain in the particle even if a bubble forms and grows, because gas molecules condense quickly and the cavity disappears before the particle solidifies. In our model, we considered that the dust particle is composed of only forsterite, which has high melting and boiling point. The timescale of the deformation is very short due to the low viscosity at the temperature where the gas molecules condense. So, the cavity shrinks at the moment.

Our results imply that the cavities are originated from other reason. One possibility is the volatile elements. If the volatile elements are contained in the precursor of the cosmic spherule, the cavity may be formed due to the evaporation of volatile elements when the dust particle is molten. Then, volatile elements may not condense in the particle when the dust particle re-solidifies. However, we need to clarify why the bubble is maintained in the dust particle while it is molten.