Chondrule Formation by Planetesimal Collisions

WAKITA, Shigeru, MATSUMOTO, Yuji, OSHINO, Shoichi
(NAOJ)

HASEGAWA, Yasuhiro
(Jet Propulsion Laboratory, California Institute of Technology)

Chondrules are sub-mm sized spherical materials found in primitive meteorites, chondrites. Chondrules had once heated and melted in the solar nebula. Several theories are proposed for the formation process of chondrules. Planetesimal collisions are one of candidates of chondrule formation: impact jetting, which can be induced by planetesimal-protoplanet collisions, could produce chondrules, when the impact velocity of the collisions exceeds 2.5 km/s [1].

We investigate the abundance of chondrules formed by impact jetting and their formation timing [2]: both of them are derived from semi-analytical calculations of planetesimal-protoplanet collisions and the subsequent formation of protoplanets. We find that the planetesimal-protoplanet collisions with the impact velocity higher than 2.5 km/s would occur around 2 au in the protoplanetary disk at 3 million years. This timing is consistent with the isotopic studies of chondrules [3]. We also constraint on the mass of the disk and planetesimals to trigger impact jetting [4], using the strength of magnetic fields in the solar nebula based on the measurements of chondrules [5].

It is need to consider undifferentiated planetesimal-planetesimal collisions, not potentially differentiated protoplanet-planetesimal ones. This is because chondrules is not differentiated, and their precursors also would be undifferentiated. Thus, we examine whether planetesimal-planetesimal collisions can produce chondrules or not [6]. We perform various kind of collisions with the parameters of the impact velocity and the size of target planetesimal using iSALE-2D shock physics code [7,8,9]. Our numerical results show that planetesimal-planetesimal collisions with 2.5 km/s can also produce chondrules [Figure 1(a)]. The mass of chondrule would increase as the impact velocity increases and it would vary with the size of target planetesimals. We also find that the original position of chondrules is in a region of a few hundreds depth from the surface [Figure 1(b)] and the progenitor of chondrules originates from the impactor planetesimals than the larger target planetesimals.

We also check the fate of produced chondrules semi-analytically and find that the half of produced chondrules accrete on the protoplanet, and the other half would do on the planetesimals [10]. Those results indicate that target planetesimals or protoplanet are very important to consider chondrule formation via impact jetting.

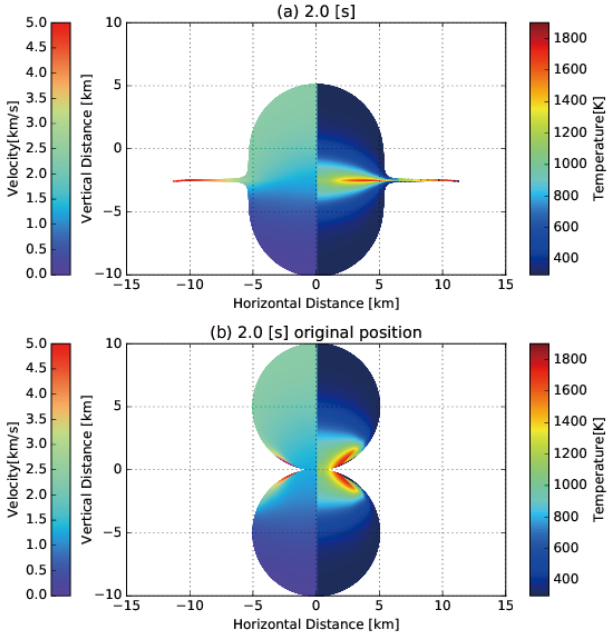

Figure 1: Results of 10 km sized planetesimals colliding each other with a impact velocity of 2.5 km/s. Right side of panels show temperature and left ones show velocity. (a) 2.0 seconds after collision. (b) Tracing back to original position of materials.

References

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