Size distributions of chondrules and the energy source of chondrule-forming shock waves

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Chondrules are silicate spherules with a size less than millimeters and are contained ˜70-80 % by volume in primitive chondrites. Understanding the formation mechanism of chondrules leads us to know the early solar system. Thus, based on their chemical, physical, and mineralogical features, numerous mechanisms have been proposed. Shock wave heating is one of the most plausible mechanisms to explain the various properties of chondrules and several energy sources that drive appropriate shock waves are proposed such as bow shocks by planetesimals, clumpy cloud collision, gravitational instability of the nebula, and X-ray flares. However, which source is the most plausible still remains unclear. Here, we focus on the size distributions of chondrules, which have the same form as those of droplets dispersed by the interaction with high-velocity gas-flow, and find from laboratory experiments that the hydrodynamic pressure to produce the chondrule size distributions is ˜10^4 Pa. In a minimum solar-nebula mass model, this hydrodynamic pressure indicate that chondrules were formed within ˜1 AU. However, if the solar nebula had larger masses and gravitational instabilities occurred, this pressure can be realized in the spiral arms at 2 - 3 AU and chondrules may be formed in Asteroid belt.