RADIATIVE COOLING RATES IN PLANETESIMAL IMPACT EJECTA.

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Introduction: Chondrules, small igneous inclusions found in chondrites, formed within 6 Myr after the formation of the first solids in the protoplanetary disk of our solar system. The more common chondrules, porphyritic chondrules, formed in the first half of this period, and cooled over a timescale of hours[1][2], while cryptocrystalline and skeletal chondrules found in e.g., CH and CB chondrites formed near the end of this period[3][4], and had cooling rates of 2000 K/hour or higher[5]. Thus, these varieties of chondrules probe a different period of the protoplanetary disk and likely different formation mechanisms. Understanding the origin of chondrules therefore has implications for the history of our protoplanetary disk, and by analogy, planet formation in all protoplanetary disks.

Motivation: Here we pursue a numerical model of a formation scenario for CH/CB chondrules. This model considers melts in the ejecta fan caused by the collision of two protoplanetary bodies. Our simulations demonstrate the feasibility of this model for generating consistent cooling rates in the evolving ejecta fan. Unlike previous works[6][7], accurately predicting the cooling rate requires correctly evolving the scale height of the fan, and its interaction with the surrounding ambient disk as it cools via adiabatic expansion and radiative losses. Our previous work[8], which neglected cooling via radiative losses, predicted cooling rates of roughly 1,000-2,000 K/hour. Here we incorporate radiative transfer into our simulations to model the radiative losses, in order to determine how radiative cooling compares with adiabatic cooling, and to illustrate how their combined cooling rate is more consistent with the formation of CH/CB chondrules than with adiabatic cooling alone. To our knowledge, the numerical procedure discussed here is the first attempt to capture all of these processes directly.

Numerical Methods: We use the *Adaptive Mesh Refinement (AMR)* code `FLASH`[9] to model the ejecta fan, the ambient disk, the gravitational pull of the collision remnant, and radiative cooling using radiative transfer. The initial conditions are the result of a *Smoothed Particle Hydrodynamics (SPH)* simulation of a 30 km radius projectile colliding with a 100 km radius target[6]. The resulting ejecta fan is mapped from this simulation into the `FLASH` framework[10]. Only the AMR method is capable of resolving the lower density ejecta fan, its gravitational scale height, the ambient medium, and radiative transfer; all crucial components for accurately modeling the cooling rate. This study is pioneering the use of the `FLASH` Radiative Transfer module in tandem with gravity for modeling astrophysical phenomena.

Outline: We discuss in detail the cooling of an ejecta fan resulting from the collision of planetesimals as a possible formation scenario for CH/CB chondrules. We give an overview of the implementation in `FLASH` of radiative transfer within the ejecta fan and the challenges therein. We then discuss the predicted radiative cooling rates, placed in context with the cooling rates found previously due solely to adiabatic expansion of the fan, and compare to the inferred cooling rates of CH/CB chondrules.

References:

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