INITIATING SOLAR SYSTEM FORMATION THROUGH STELLAR SHOCK WAVES. A. P. Boss & E. A. Myhill, DTM, Carnegie Institution of Washington, 5241 Broad Branch Road N.W., Washington DC 20015.

Isotopic anomalies in presolar grains and other meteoritical components require nucleosynthesis in stellar interiors, condensation into dust grains in stellar envelopes, transport of the grains through the interstellar medium by stellar outflows, and finally injection of the grains into the presolar nebula. The proximity of the presolar cloud to these energetic stellar events suggests that a shock wave from a stellar outflow might have initiated the collapse of an otherwise stable presolar cloud. We have begun to study the interactions of stellar shock waves with thermally supported, dense molecular cloud cores, using a three spatial dimension (3D) radiative hydrodynamics code. Supernova shock waves have been shown by others to destroy quiescent clouds, so we are trying to determine if the much smaller shock speeds found in, e.g., asymptotic giant branch (AGB) star winds, are strong enough to initiate collapse in an otherwise stable, rotating, solar-mass cloud core, without leading to destruction of the cloud.

INTRODUCTION. The presence of noble gas isotopic anomalies in presolar SiC grains seems to require nucleosynthesis in a red giant star [1,2,3] and subsequent ejection of the products in the strong stellar wind that accompanies the asymptotic giant branch (AGB) phase of stellar evolution. A few SiC grains have C, N, and Si isotopic abundances quite different from the majority, possibly requiring their production in a supernova explosion [4]. Cr isotope anomalies in carbonaceous chondrites seem to require mixing products from several nucleosynthetic sources [5]. Given the need for rapid injection of certain newly-synthesized isotopes (e.g., ^{26}Al) into the presolar cloud [2], the evident proximity of the presolar cloud to these energetic stellar sources suggests that collapse may have been initiated by the very stellar shock wave that injected the isotopically anomalous grains [2,6]. Previous hydrodynamical studies of the interaction of stellar shock waves with molecular clouds have been limited to supernova shock fronts ($\sim$ 1000 km/sec) that completely destroy even massive molecular clouds [7-10]. Here we begin an investigation of the interaction of much slower shock waves ($\sim$ 25 km/sec) characteristic of, e.g., AGB star winds [11], protostellar outflows, or distant supernovae, with the hope of finding shock waves that can initiate collapse without destroying the cloud.

NUMERICAL METHODS. The calculations are being performed with a temporally and spatially second-order accurate radiative hydrodynamics code written in spherical coordinates [12]. The equations of hydrodynamics, self-gravitation, and radiative transfer in the Eddington approximation are solved by finite-differences on an Eulerian grid. Extensive testing on a variety of test cases has verified the accuracy of the code [12]. The numerical grid used for the present calculations spans 51 points in radius, 23 points in latitude ($\pi/2 \geq \theta \geq 0$ assuming equatorial symmetry), and 64 points in azimuth ($2\pi \geq \phi \geq 0$).

INITIAL MODELS. The quiescent presolar cloud consists of a spherically symmetric, $1M_\odot$, cold (10 K), centrally condensed ($\rho_c = 20\rho_R$), molecular cloud core. The cloud is assumed to be in solid body rotation such that $E_{rot}/|E_{grav}| = 0.04$; the density is perturbed by a low level of random noise. Instead of introducing a gas pressure perturbation [13] to represent the shock wave, the ram pressure of the shock wave is modeled by introducing an initial radial *velocity* perturbation over one hemisphere of the cloud's spherical boundary (at $R = 10^4$ AU) with $v_R = v_s sin\theta\ cos\phi$, $v_s = 10$ to 25 km/sec.

RESULTS. Figure 1 shows the results for a model with $v_s = 25$ km/sec. The initial cloud (a) is strongly compressed by the shock front but is not destroyed during the interval calculated so far (d). The central density (ρ_c) increases by a factor of 34 during this early phase; a sustained increase in ρ_c will indicate the successful initiation of collapse. The velocity shear between the rapidly infalling shocked gas and the initial cloud core may lead to Kelvin-Helmholtz (KH) instability [14] and hence mixing. We find that the Richardson number is of the order necessary for instability.

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CONCLUSIONS. Impacting a quiescent, rotating molecular cloud core with a shock front in the range of 10 to 25 km/sec may lead to the initiation of cloud collapse without totally destroying the collapsing cloud – continued calculations are necessary to determine the final result. If we determine that sustained collapse is possible, we will focus on following the trajectories of presolar dust grains injected into the cloud by the shock front, with the goal being to gain a preliminary understanding of the processes of mixing and transport during solar system formation.

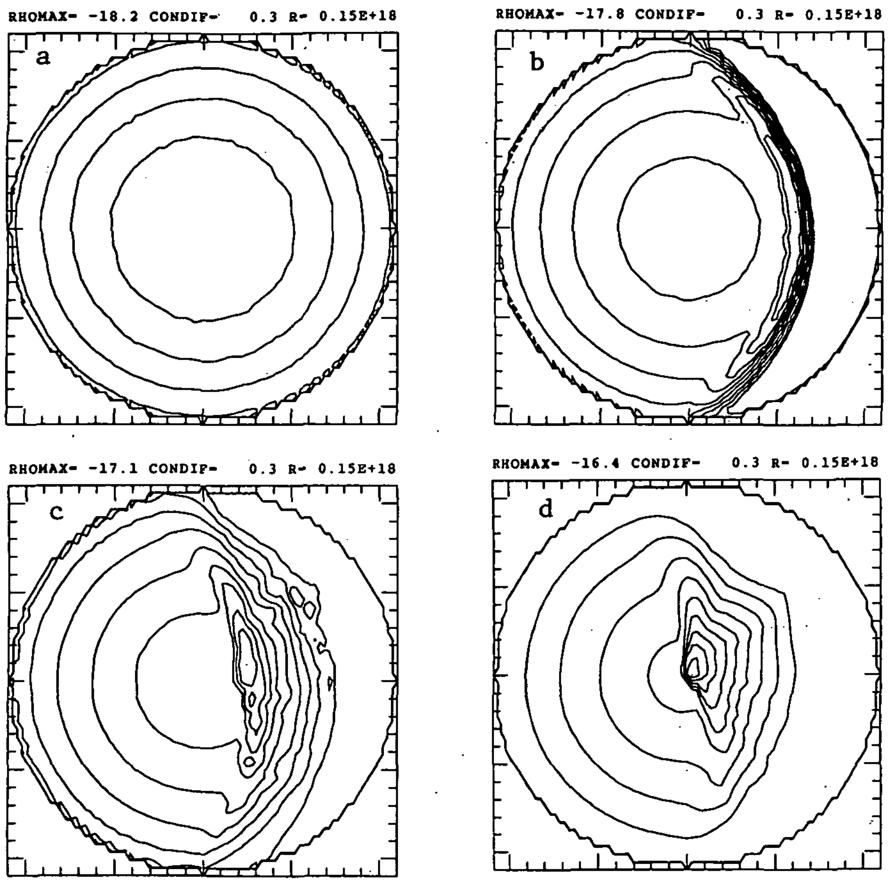

Figure 1. Equatorial density contour plots for the model with $v_s = 25$ km/sec at four times: (a) 0.0, (b) 0.16, (c) 0.51, and (d) 0.62 free fall times. The initially stable cloud (a) rotates counterclockwise. The shock wave converges (b,c) on the center of the cloud (d), driving it toward gravitational collapse.

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