TRIGGERING PRESOLAR CLOUD COLLAPSE AND INJECTION OF SHORT-LIVED RADIOISOTOPES WITH AN OUTFLOW FROM A MASSIVE STAR.

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Short-lived radioisotopes (SLRI) such as ^{26}Al and ^{60}Fe were alive at the time that primitive meteorites formed and are often thought to have been synthesized in a supernova [1,2,3,4] and then either injected into the presolar cloud [5,6] or onto the surface of the solar nebula [7]. Recently it has been proposed that the outflow from a massive Wolf-Rayet star may have been the source of the ^{26}Al [8], and that the ^{60}Fe was the result of the subsequent supernova explosion of the massive star. We consider here triggering the collapse of the presolar cloud and simultaneously injecting SLRI with a shock front derived from either a Wolf-Rayet star wind or a supernova. Previous work on this problem [5,6,9,10,11] used either fixed grid or smoothed particle hydrodynamics (SPH) codes with a limited ability to resolve fine scale structure in the Rayleigh-Taylor fingers that form at the shock/cloud interface and are responsible for SLRI injection into the collapsing presolar cloud [10]. Here we study the same problem with a new code, FLASH.

FLASH is based on adaptive mesh refinement (AMR) by the block-structured adaptive grid approach. AMR techniques automatically insert new grid points in regions of strong physical gradients, and remove them in regions without strong gradients, in order to maximize the spatial resolution in the crucial regions while minimizing the computational burden. Advection is handled by the piecewise parabolic method (PPM). PPM includes a Riemann solver at cell boundaries that handles shock fronts exceptionally well. In FLASH, PPM is incorporated in a form that is second-order accurate in space and time. The Poisson equation for the cloud's gravitational potential is solved by either a multipole or multigrid technique. We have tested the FLASH code's ability to reproduce the results of several different test cases that are relevant to the problem of triggering cloud collapse, namely the Sod shock tube problem and the collapse of a pressureless sphere. We have also used FLASH to verify the long-term stability of the target cloud in the absence of a triggering shock front.

We have reproduced the main results of [9,10] in 2D cylindrical coordinates with isothermal thermodynamics and a range of shock speeds (2 to 40 km/s), finding that shocks with speeds in the range of 5 to 30 km/s are able to both trigger collapse and inject shock wave material. The figures on the next page show the results for a 30 km/sec shock. Given that Wolf-Rayet star winds and supernova shocks both are launched with shock speeds on the order of 10^3 km/sec, these shock fronts can only trigger collapse after they have travelled some distance (typically about 10 pc) and been slowed down to 30 km/sec or less by snowplowing intervening interstellar cloud gas and dust.

We have now extended these isothermal runs to 3D Cartesian coordinates to learn what happens in a fully 3D cloud. To date the 3D calculations are similar to the 2D calculations, though the enormously increased computational burden associated with adding the third dimension has limited the number of grid points that can be employed, even with the FLASH code. We next intend to study nonisothermal shocks. [11] found that when nonisothermal shocks were employed in SPH calculations, it was not possible for a shock wave to simultaneously trigger collapse and inject SLRIs, a potentially fatal flaw for the triggering and injection scenario. However, [12] found that improvements in the dust grain cooling model led to rapid post-shock cooling, closer to the isothermal assumptions used in [5,6,9,10]. Our ultimate goal is to use FLASH to determine if the triggering and injection scenario [13] is consistent with post-shock cooling processes.

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FLASH CODE: Boss, Ipatov & Myhill