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REALISTIC INITIAL CONDITIONS FOR STAR-FORMATION SIMULATIONS

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Observations of star-forming regions show that they are turbulent, with complex morphologies and velocity structures. Nonetheless, published calculations of the collapse and fragmentation of molecular cloud cores have either assumed highly symmetric, quiescent initial conditions or have included turbulence on scales too large to resolve the details of collapse and fragmentation. We present a method for the first step in producing realistic, turbulent molecular cloud core models. Simulated observations of these models show excellent agreement with observed cores.

Our simulated molecular cloud cores begin as smooth Bonnor-Ebert spheres in virial equilibrium, including the effects of turbulence. We inject kinetic energy into the spheres on large scales, adjusting the rate of energy injection to produce a chosen turbulent Mach number. To prevent the onset of small-scale collapse before the spheres reach equilibrium, we maintain a smooth gravitational potential during energy injection. After several crossing times, we turn off energy injection. The system at this point provides the initial conditions for a collapse calculation. Figure 1 shows a core at this stage.

We simulate observations of our cores in an optically thin tracer with a $40''$ beam, assuming the cores are located in Taurus, and compare the results to observed cores using four tests. First, the Mach number must be typical for the region we are simulating. Our procedure allows us to choose the Mach number, and the values we give below are for cores with a 3-D Mach number of 1, comparable to those in Taurus (Jijina, Myers, & Adams 1999). Second, the cores' aspect ratio must match the observed value of roughly 0.5, or slightly higher for isolated cores (Myers et al. 1991). Typical aspect ratios of cores produced in our simulations are 0.6 to 0.9. Third, the ratio of rotational kinetic energy to gravitational potential energy must match the observed distribution, with a mean of 0.02 and a mode of 0 to 0.02 (Goodman et al. 1993). Our simulated cores show values of 0.001 to 0.03. Fourth, Ossenkopf & MacLow (2002) find an exponent of 0.5 ± 0.04 for the linewidth–size relation over a wide range of length scales. Our simulated observations produce exponents of 0.42 to 0.55. Our simulated cores thus show excellent agreement with observed cores.

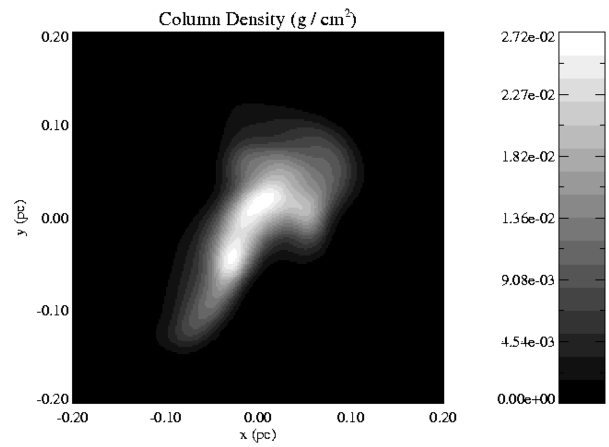

Fig. 1. Simulated observation of a molecular cloud core.

Previous simulations with unrealistically quiescent and symmetric initial conditions artificially suppressed fragmentation, favoring collapse to a single star, thereby producing binaries too rarely and massive stars too easily. Simulations based on initial cores produced by our method do not suffer from these limitations. Our cores have self-consistently generated turbulence in their velocity and density fields, and properties that match observations. Combined with adaptive mesh refinement, which allows us to follow collapse to very small scales, these initial conditions allow calculations far more realistic than has previously been possible. This approach is a first step toward even more realistic initial conditions for simulations of star-forming regions.

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