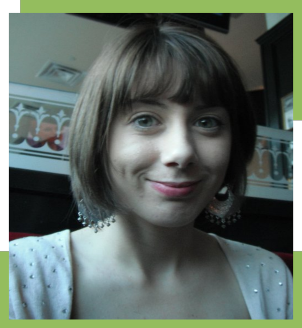
Simulating Bonnor-Ebert Sphere Collapse in Realistic Environments using AstroBEAR2.0

Erica Kaminski[1], Adam Frank[1], Jonathan Carroll[1], Phil Myers[2]



INTRODUCTION

Bonnor-Ebert (BE) spheres are simple models for protostellar cloud structure, whose reality have some observational support (Fig. 1). Much work has focused on studying their collapse properties by beginning with stable clouds and imposing perturbations. We seek to understand the relationship between ambient medium dynamics and embedded Bonnor-Ebert sphere collapse. Our simulations tested whether the dynamics of the ambient medium alone could change the Bonnor-Ebert (BE) sphere stability properties.

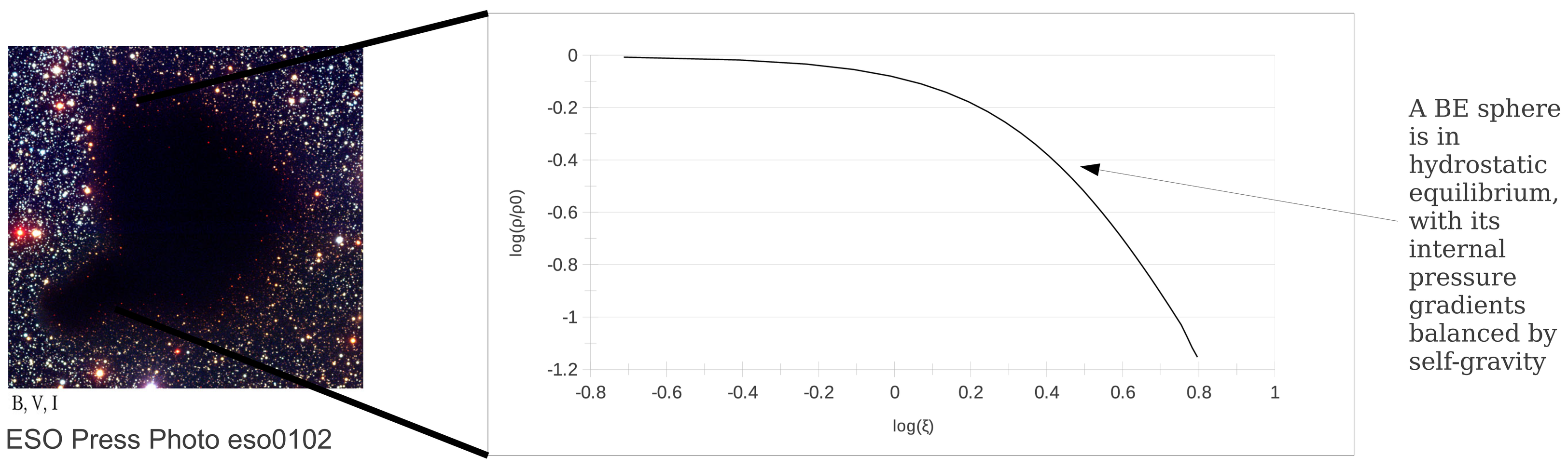


Figure 1. Potential protostellar core, Bok Globule B-68, has been found to resemble the Bonnor-Ebert sphere's hydrostatic density profile.

CONCLUSIONS

1. Gravitational dynamics (infall or "settling") of the ambient medium can drive BE sphere collapse

2. Only BE spheres embedded in low density environments can be long-lived

3. BE spheres driven to collapse by ambient infall via strong compression waves eventually progress through the "classic" outside-in collapse mode

MODEL

- Hydrodynamic, Eulerian mesh with self-gravity
- Initialized a critical BE sphere in pressure equilibrium with the ambient environment (Fig. 2)
- Ambient densities were uniform and ranged from the density of the BE sphere at its outer edge, to 1/100th of that value
- Simulations proceeded effectively isothermally (γ=1.001), with NO applied perturbation

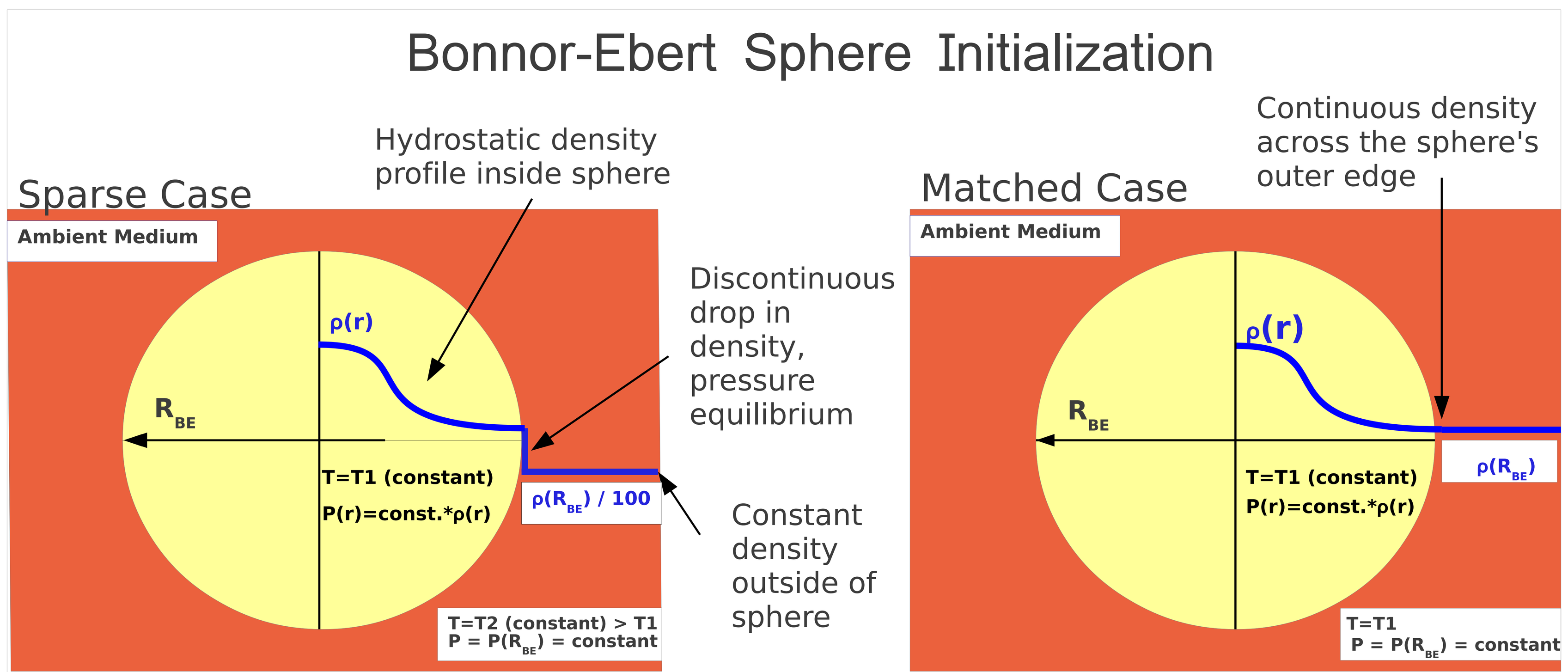


Figure 2. Schematic showing the initialization of the Bonnor-Ebert sphere and encompassing ambient mediums. Our runs ranged between a 'Sparse' ambient case (left), where the density was 1/100 that at the sphere's outer radius, to a 'Matched' case, where the density was continuous across the boundary. Given pressure equilibrium at the sphere's edge, the Sparse case had a hotter ambient than the sphere, whereas the Matched case had 1 temperature through-out. Once initialized, the spheres evolved with no perturbation applied to the simulation box.

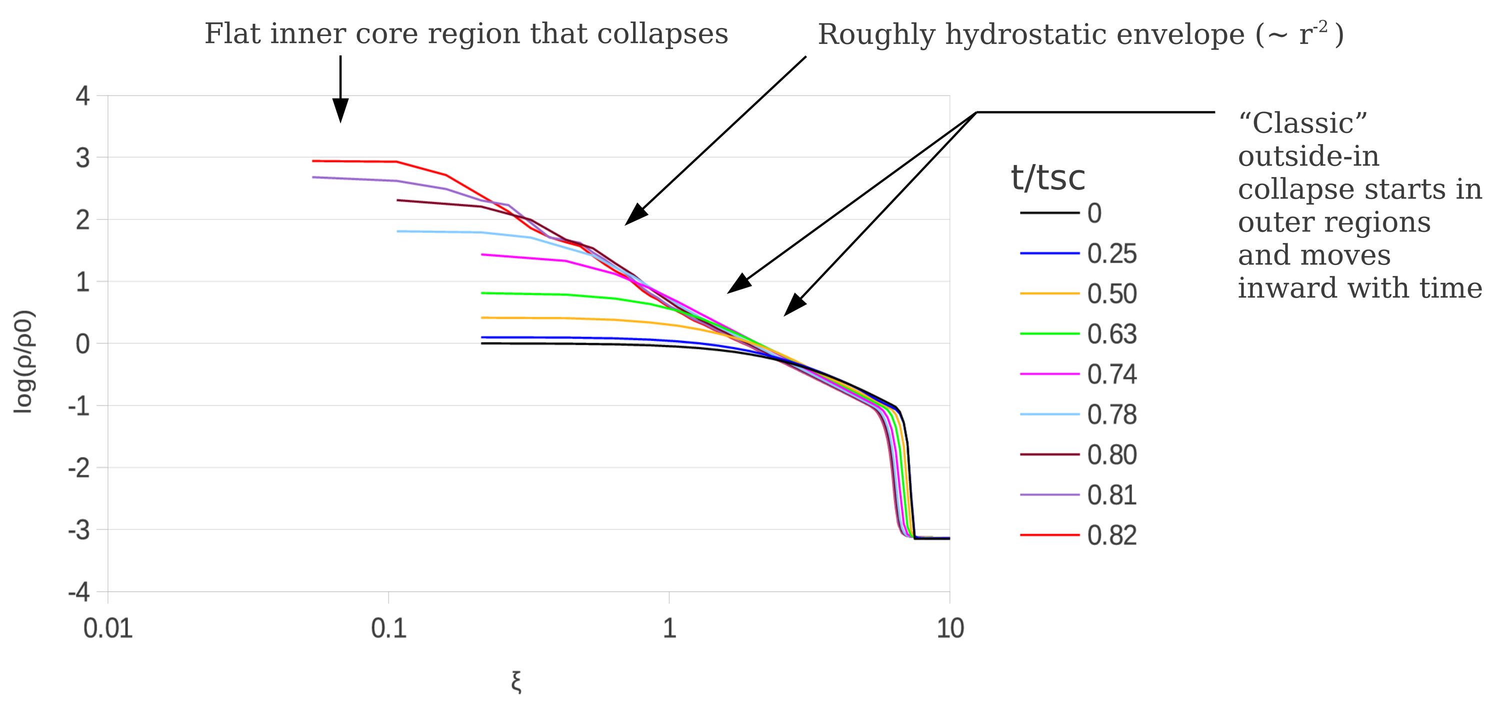
References: Alves, J., Lada, C., & Lada, E. 2001, Nature, 409, 159 (Bok Globule observational properties). Banerjee, R. Pudritz, R., & Holmes, L. 2004, MNRAS, 355, 248 (BE sphere collapse model), Photo credit, Bok Globule B68: ESO Press Photo "eso0102", http://www.eso.org.

1. **University of Rochester**, 500 Wilson Blvd., Rochester, NY 14627, USA
2. **Harvard-Smithsonian Center for Astrophysics**, 60 Garden St., Cambridge, MA 02138, USA

RESULTS

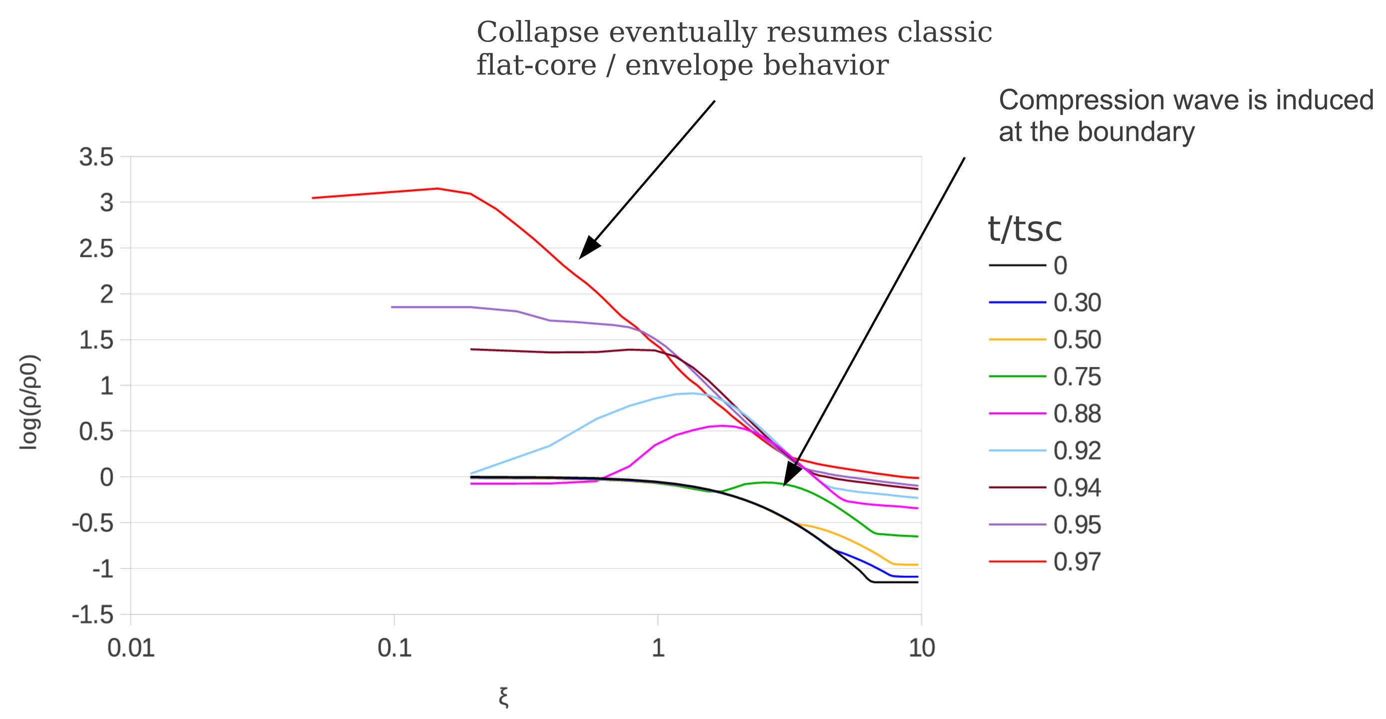
The interaction between the sphere and ambient medium was sufficient in triggering collapse in all but the sparsest case. Collapse was qualitatively different, depending on the density of the ambient medium. In all cases, profiles resembled the well-established features of BE collapse by the end of the simulation.

What are the Established Properties of BE Sphere Collapse?



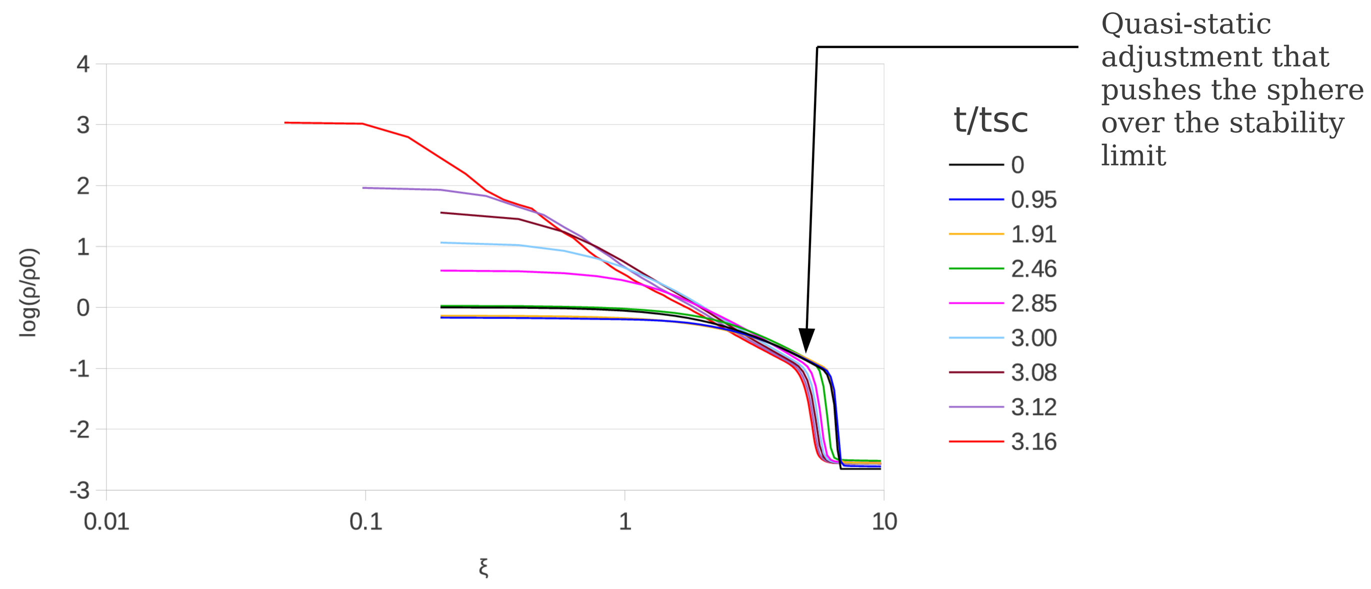
Density profile for the critical BE sphere embedded in an ambient medium of $\rho=0.01\rho(R_{BE})$ and perturbed into collapse with a 10% over-density. We prescribed this perturbation to check that our code reproduced the collapse properties found in other studies (e.g. Banerjee, Pudritz, & Holmes, 2004). Collapse proceeded in the well established outside-in pattern. The x-axis is in units of non-dimensional radius, $\xi = r\,(4\,\pi\,G\,\rho_0)^{1/2} / C_s$, where ρ_0 is initial central density and C_s is the isothermal sound speed. The legend is time, in units of the sphere's sound crossing time.

Does the Sphere Collapse in a Continuous Medium, and how?



Density profile for the critical BE sphere embedded in an ambient medium of $\rho=\rho(R_{BE})$. This collapse is qualitatively different than the "Classic" collapse. Here, the ambient collapses under its self-gravity, inducing a compression wave that travels inward, destabilizing the sphere. No perturbation was necessary to induce the collapse. After the compression wave phase, "Classic" outside-in collapse then followed.

Does the sphere collapse in a sparse ambient medium, and how?



Density profile for the critical BE sphere embedded in an ambient medium of $\rho=1/3\rho(R_{BE})$. Placing the sphere in a sparser ambient still led to collapse without applying a perturbation, but of a different nature. A mild redistribution of material rendered the sphere unstable and it collapsed in the Classic outside-in manner. However, we found collapse did *not* occur when the ambient density was 1/100 $\rho(R_{BE})$ (over 5 BE sphere crossing times).

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Further Information: Living documentation on AstroBEAR and its associated projects can be found at: https://astrobear.pas.rochester.edu/trac/astrobear