Slow and Steady to Win the Race? High Mass X-ray Binary Feedback in Star-forming Giant Molecular Clouds

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Introduction

Wind-fed accretion onto the primary star within High Mass X-ray Binaries (HMXBs) leads to the formation of collimated jets. These jets are long-lived (~10s of Myr) and recent work[1] suggests they can deposit multiple times the mechanical energy of a supernova (SNa) into the surrounding interstellar medium (ISM) throughout their lifetime. This 'slow and steady' heating of the ISM has the potential to influence star formation in molecular clouds and interplay with SNe feedback. Giant molecular clouds offer unique environments to study HMXB feedback since their free-fall time is comparable to the lifetime of massive stars.

Key Elements of Method

- We use GADGET-3 to simulate $10^{5\text{-}6}$ $M_\odot$ molecular gas clouds with a typical particle mass of $0.4 M_\odot$.
- We use a kernel-weighted thermal SNe feedback scheme and a physical prescription for the mechanical HMXB feedback which includes stellar lifetimes and sampling of a Kroupa IMF[2].
- We use two metallicities: Z=0.001 and $Z=Z_\odot$.
- The clouds are seeded with a non-driven divergence-free turbulent velocity field[3].
- We also include sink particles and cooling to 20K.

Figure 1: Top plot: the time evolution of the ratio between the total sink particle mass to initial gas mass. Bottom plot: the number of sink particles created between snapshots versus time. Run A contains HMXB and SNe feedback, Run C contains just SNe feedback and Run D contains no feedback.

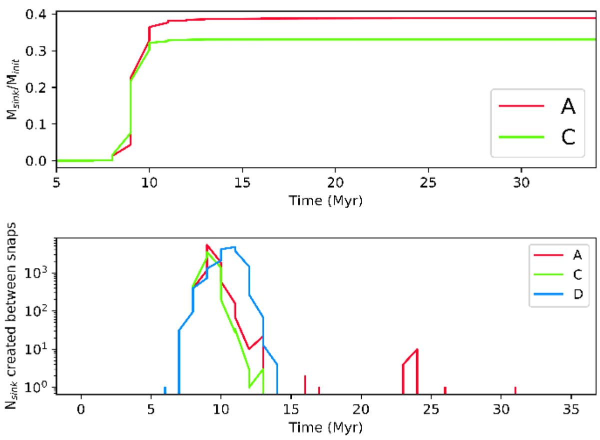
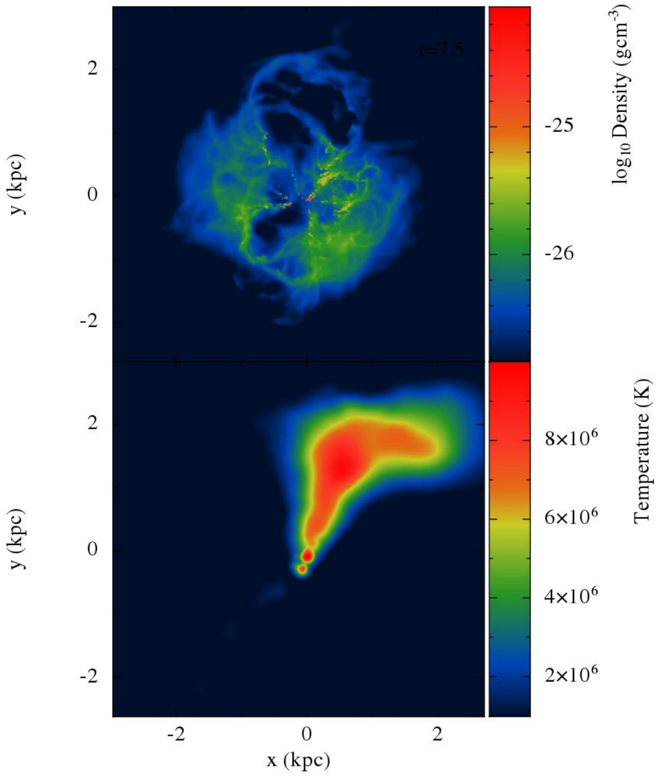


Figure 2: Density and temperature slices 35 Myr into a simulation with HMXB feedback included. The low density 'chimneys' in the density profile are visible, along with the hot gas being funnelled outwards.



Summary of Results

1. HMXBs can interplay with SNe feedback and form 'chimneys', funnelling hot gas from the inner star-forming regions of a cloud (Fig. 2).
2. The addition of HMXBs can prolong star formation and increase star formation efficiency (Fig.1).
3. This effect is greater in larger (> 10^6 $M_\odot$) molecular clouds and washed out in smaller clouds, where the energy injected via feedback is multiple times the binding energy of the cloud.
4. The location of the HMXB and SNa events alters the amount of gas unbound by the feedback.
5. The effects of HMXBs are more pronounced in runs at solar metallicity, due to lower numbers of both HMXBs and SNe compared with the Z=0.001 runs.
6. The number of HMXBs in a cloud is highly variable.

Our next paper looks at HMXB feedback in dwarf galaxies.

[1] E.g. Justham S. et al., 2012, MNRAS, 423 & references therein
[2] Method basis: Power C. et al., 2009, MNRAS, 395, 1146
[3] Method based on: Dubinski J., Narayan R., Phillips T. G., 1995