Stellar Mass Black Hole Formation and Multimessenger Signals from Magnetized Core-collapse Supernova Simulations

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Abstract

Core-collapse supernovae (CCSNe) are among the most energetic events in the Universe and the birthplaces of neutron stars and stellar-mass black holes in extreme conditions. In this poster, we present the lastest results of our two-dimensional magnetized CCSN simulations with self-consistent neutrino transport. In our preliminary results, we found that simualtion outcome ends in four scenarios: bipolar jet-driven scenario, one-arm jet scenario, neutrino-driven scenario, and failed supernova scenario. Each scenario shows unique gravitational signatures.

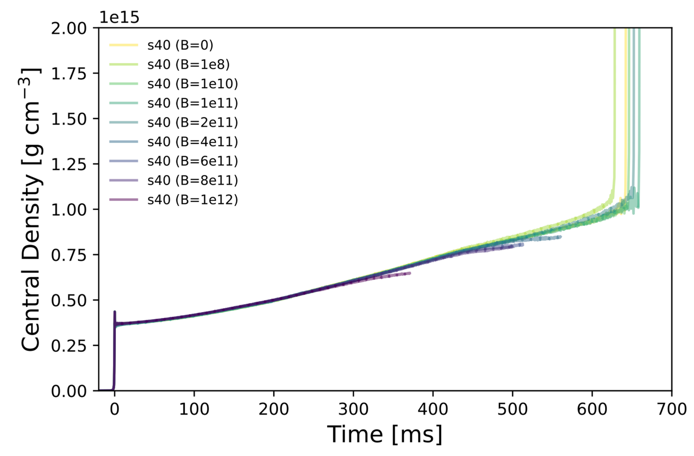
Supernova Shock Dynamics

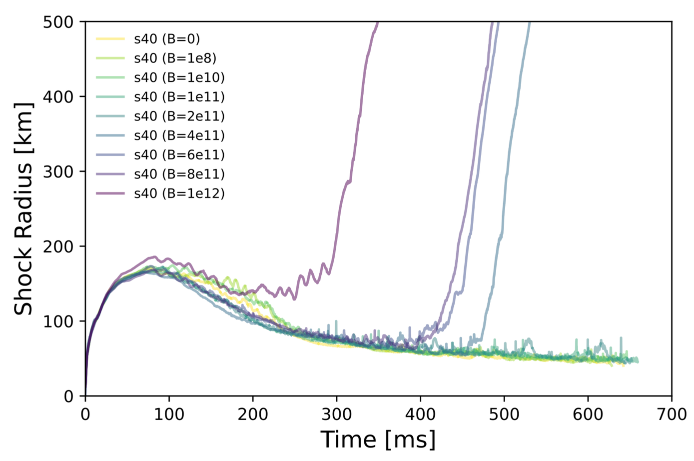
SN Code

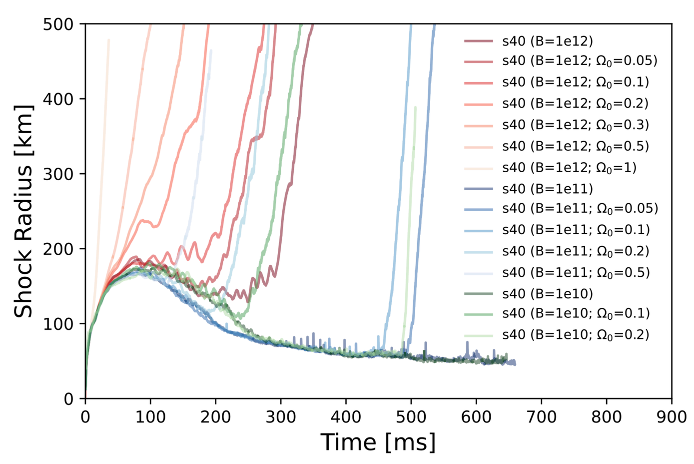
We use the the open-sourced grid-based hydrodynamics code FLASH [1] with the Isotropic Diffusion Source Approximation (IDSA) [2] for the transport of neutrinos. A general relativistc correction [3] on the gravitational potential is enbaled as well. The nuermical setup is similar to [4,5] but included magnetic fields. We have also enabled OpenACC to accelerate the 2D/3D neutrino radiation solver in the IDSA with GPU [6]. The inital magnetic field has the form $A_\phi = \frac{1}{2} r b_{\phi,0} \left(\frac{r_0^3}{r_0^3+r^3}\right)$,

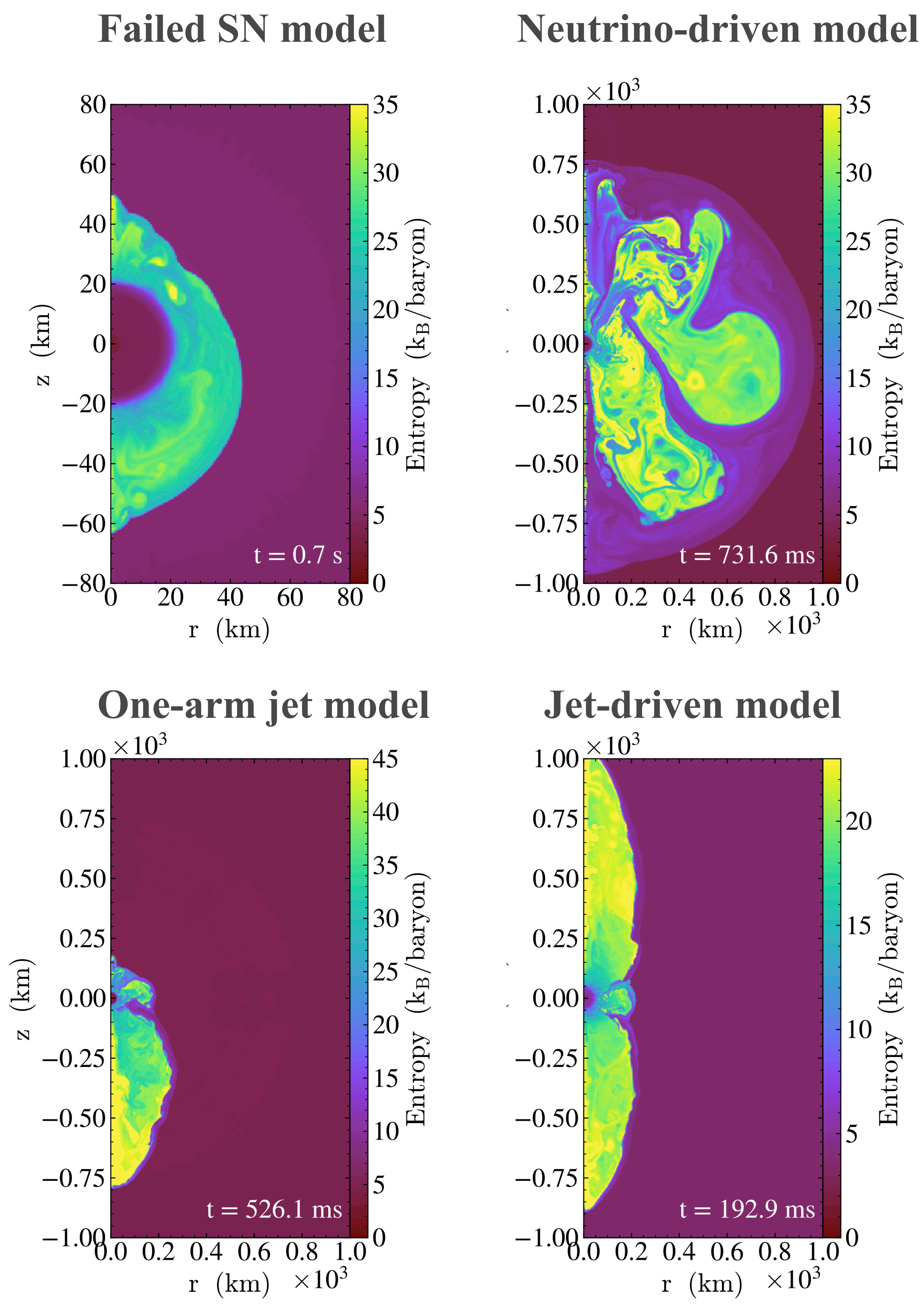
Dynamics

We perfrom 2D CCSN simulations with a wide range of inital magentic fileds and rotation rates. From the middle upper panel, we could see that the magetic field has little effects on the central density evolution pripr to BH formation. If the model remains unexploded, the BH formation time could be delayed for about 50 ms. However, when the initial field strength higher than about 2x10^{11} gauss, fast explosion could be happened due to either strong magnetic fields or fast rotation. Bipolar or one-arm jets could be launched as well.









Gravitational Wave Emissions

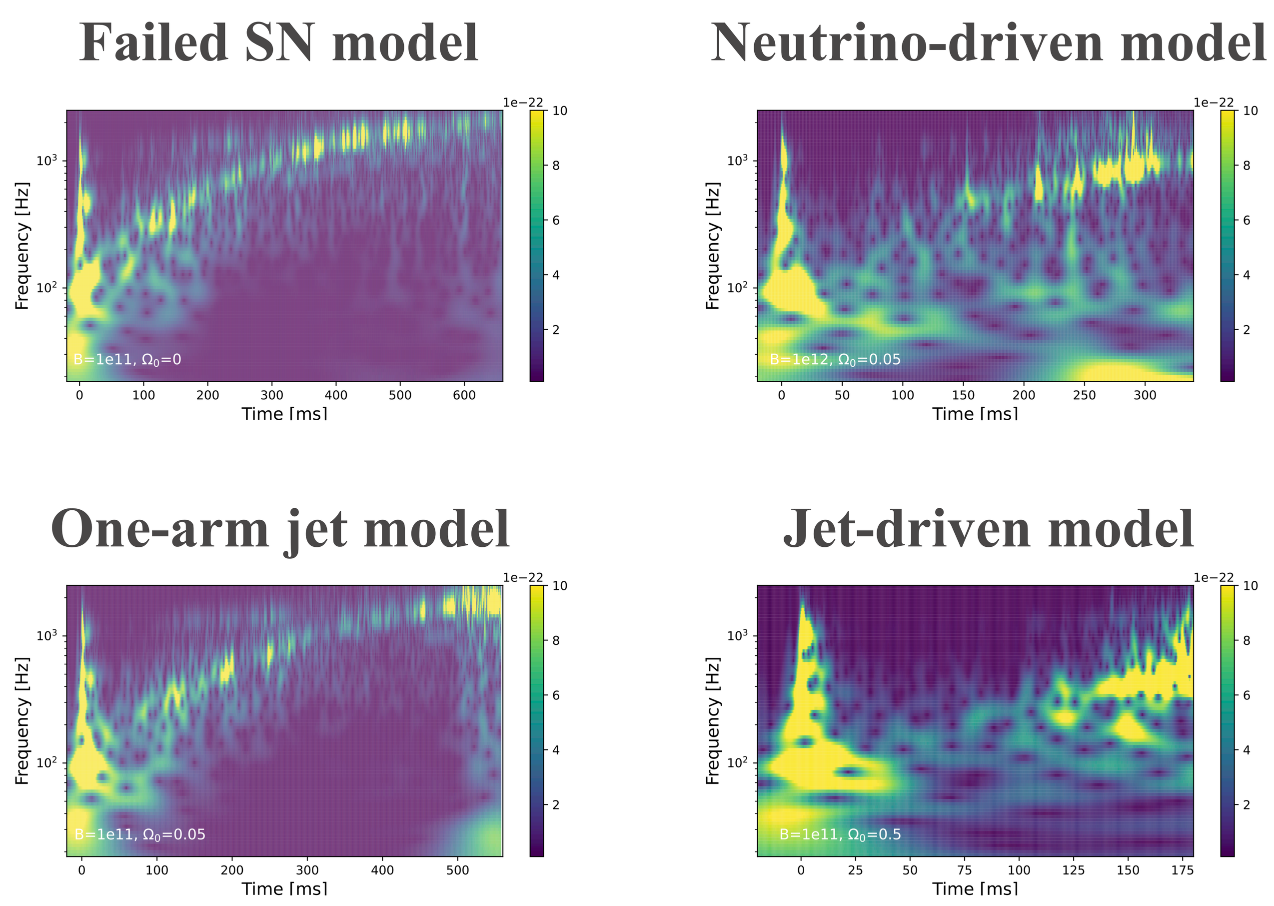
Depending on the exploding scenarios, they could emit unique gravitational wave (GW) signatures.

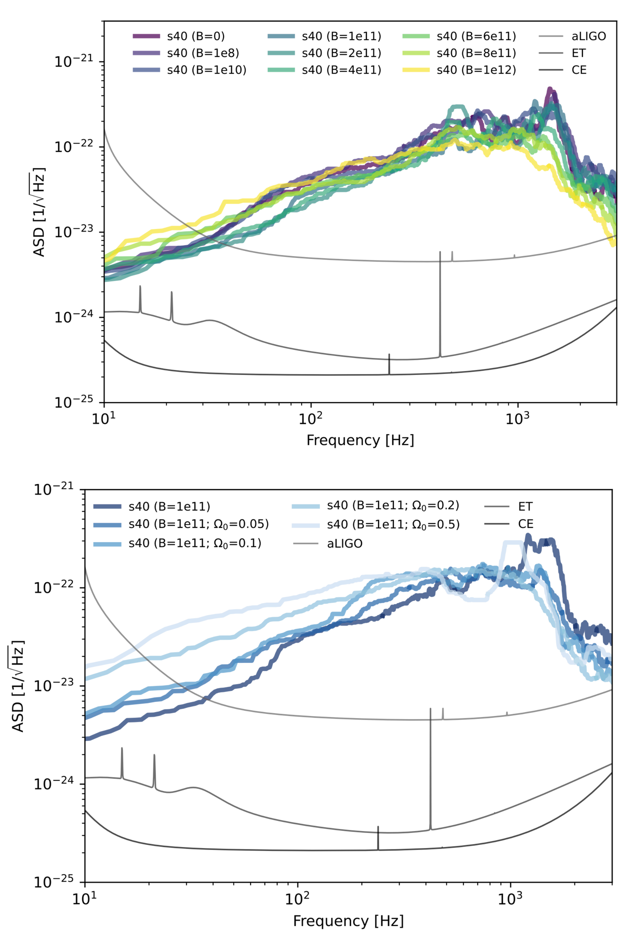
Failed SN model: the GW features are simlar to non-MHD and non-rotating models in [4,5].

Neutrino-driven model: the GW features are simlar to the failed SN model but with much louder singals at low-frequeny due to the explsoin.

One-arm jet model: Before the one-arm jet launched, the GW signals are simlar to the failed SN model. Once the one-arm jet is laucnhed, a louder f-mode and low frequency feature show up.

Jet-driven model: the bipolar jets provide extreme loud signals on the f-mode signals.





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