Gravitational Wave Signatures of Magnetohydrodynamically Driven Core-collapse Supernova Explosions

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Core-collapse supernovae are now expected to be opening a new branch of astronomy, gravitational-wave (GW) astronomy. Currently, long baseline laser interferometers LIGO, VIRGO, GEO600, TAMA300, AIGO and KAGRA with their international networks of observatories are beginning to take data at sensitivities where astrophysical events are predicted. For these detectors, corecollapse supernovae have been proposed as one of the most plausible sources of gravitational waves.

Although the explosion mechanism of core-collapse supernovae has not been completely clarified yet, magnetohydrodynamic (MHD) explosion mechanism gathers great attention for special explosions associated with birth of magnetars instead of ordinary pulsars.

By performing a series of two-dimensional, special relativistic MHD simulations, we study signatures of gravitational waves in the MHD mechanism. The simulation code utilized here is developed at Takiwaki et al 2009 [1]. We choose to take precollapse magnetic fields less than 10^{12} G and rapid rotation based on a recent GRBoriented progenitor models. By this choice, the rotation of the central proto-neutron star amplifies magnetic fields enough strong to overwhelm the ram pressure of the accreting matter, leading to the MHD explosions. Figure 1 shows the bipolar jet generated by the magnetic field in our simulations.

We found that the total GW amplitudes show a monotonic increase after bounce for models with a strong precollapse magnetic field (10^{12} G) also with a rapid rotation imposed. Figure 2 shows the time evolution of the gravitational wave denoted above. We pointed out that this trend stems both from the kinetic contribution of MHD outflows with large radial velocities and also from the magnetic contribution dominated by the toroidal magnetic fields that predominantly trigger MHD explosions. The feature can be clearly understood with a careful analysis on the explosion dynamics. It was pointed out that the GW signals with an increasing trend, possibly visible to the next-generation detectors for a Galactic supernova, would be associated with MHD explosions exceeding 10^{51} erg. For detail, see the original paper of Takiwaki and Kotake 2011 [2].

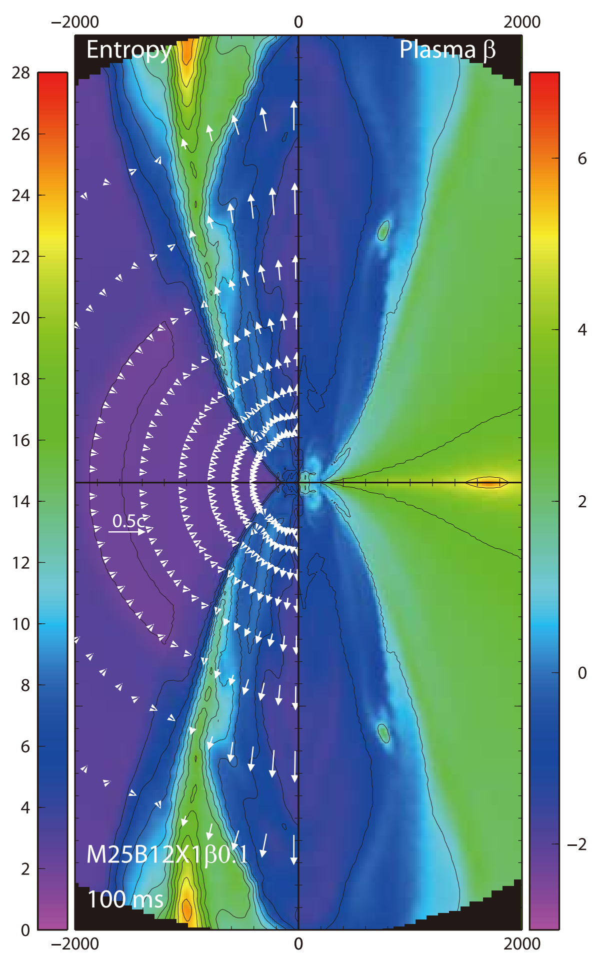

Figure 1: Time snapshot of MHD explosion: Entropy [kB] and plasma β are shown in the left and right panel, respectively.

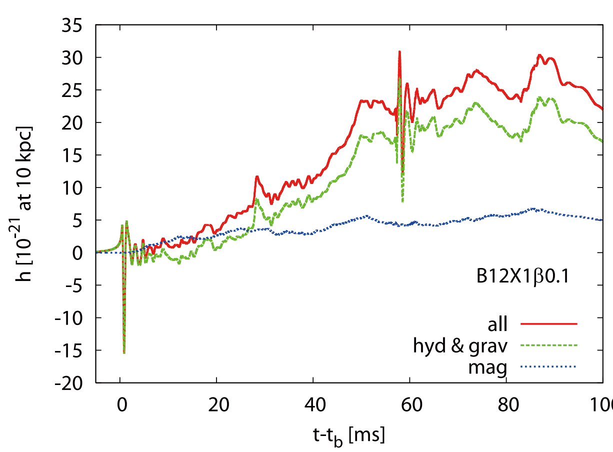

Figure 2: Amplitude of the gravitational wave as a function of time (Red line). Green and blue lines depict the contributions of hydrodynamical part and magnetic part, respectively.

References

[1] Takiwaki, T., Kotake, K., Sato, K.: 2009, *ApJ*, **691**, 1360.
[2] Takiwaki, T., Kotake, K.: 2011, *ApJ*, **743**, 30.