Three Possible Stellar Explosions Beyond Hypernovae

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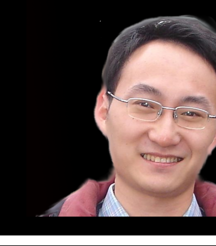


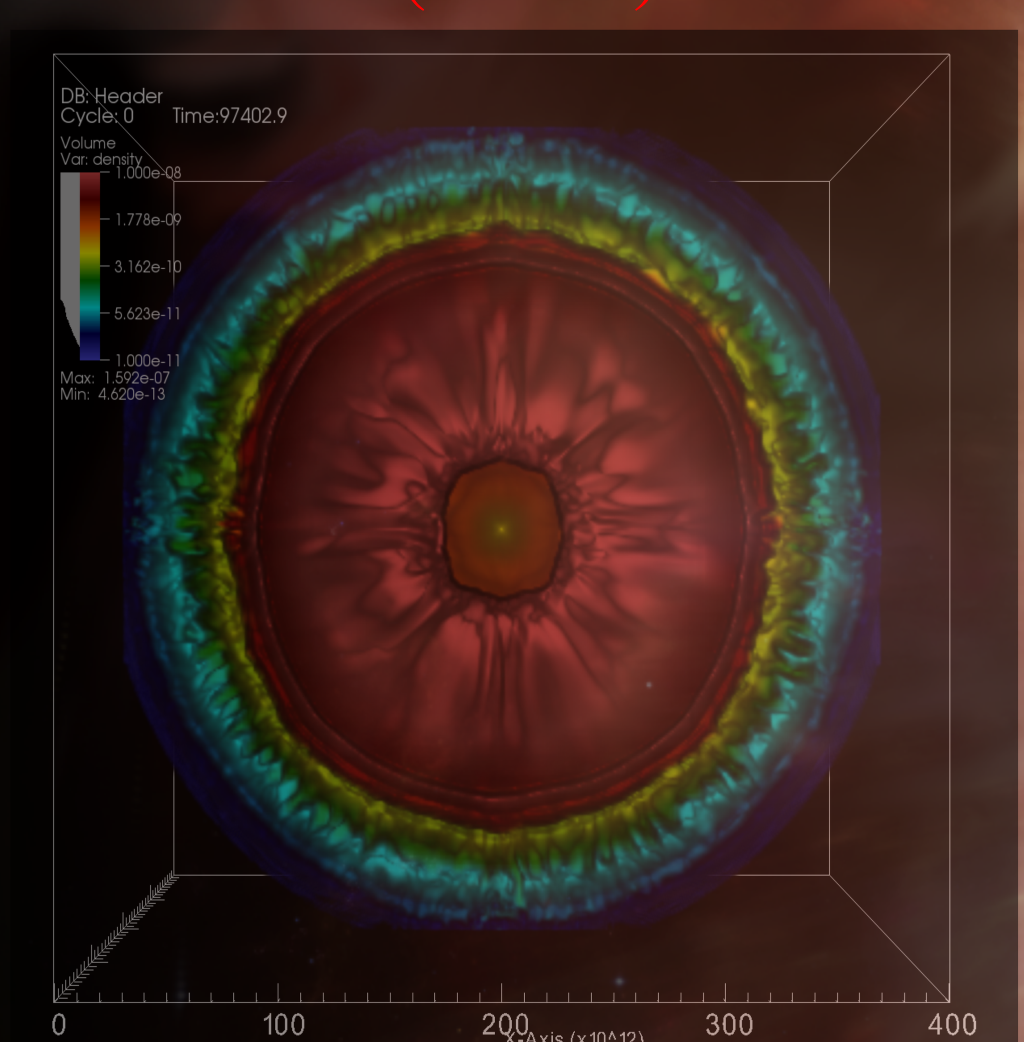
Abstract

We present the results from our 3D simulations of thermonuclear supernovae from the stars with initial masses above 80 M⊙ by using CASTRO. We first use 1D Kepler models to explore the possible explosions beyond hypernovae. These explosions include two types of electron/positron production instability supernovae and one type of general relativity (GR) instability supernovae. Our 3D simulations model the explosive burning and resolve the fluid instabilities that occur during the explosion. In this poster, we discuss the energetics, nucleo-synthesis, and possible observational signatures of these supernovae.

Explosive Fates of Extremely Massive Stars

One of the most fundamental questions in modern astrophysics is understanding the fates of massive stars. For massive stars with initial masses of 10-80 M⊙, simulations suggest many of them die as Fe-core collapse SNe or HNe. For those with initial masses above 80 M⊙, after central helium burning, their cores encounter electron/positron creation instabilities, leading the stars to a catastrophic collapse; the final fates of these stars are determined by the explosive burning during collapse. For the stars with initial masses between 80 M⊙ and 150 M⊙, they die as pulsational pair-instability supernovae (PPSNe). The collisions between shells of matter ejected by PPSNe might produce the superluminous SNe. For the stars with initial masses between 150 M⊙ and 250 M⊙, they die as pair-instability supernovae (PSNe), completely unbinding the stars and leaving no compact remnant. For the super massive stars (10,000+ M⊙), their cores encounter the GR instability, where the supporting pressure turns into the source term of gravity. Our recent study shows an unusual SN explosion occurs for a super massive star with masses around 55,000 M⊙.

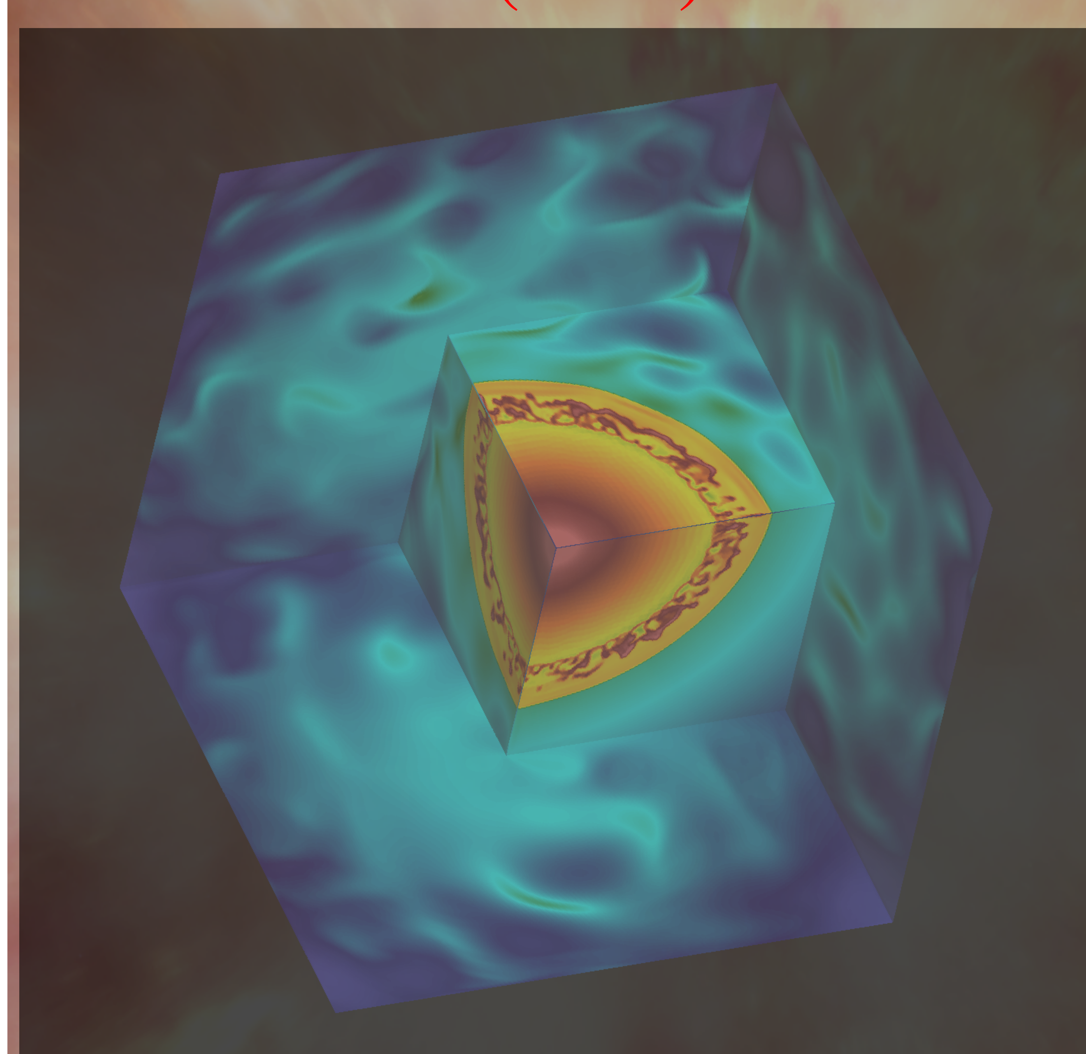
Pulsational Pair-Instability SN (PPSN)



80 M⊙ < M* < 150 M⊙

1. e+/e- creation instability
2. Several eruptions
3. Die as Fe-core collapse SNe
4. Multi-SNe (one superluminous)
5. Mixing during shell collisions

Pair-Instability SN (PSN)

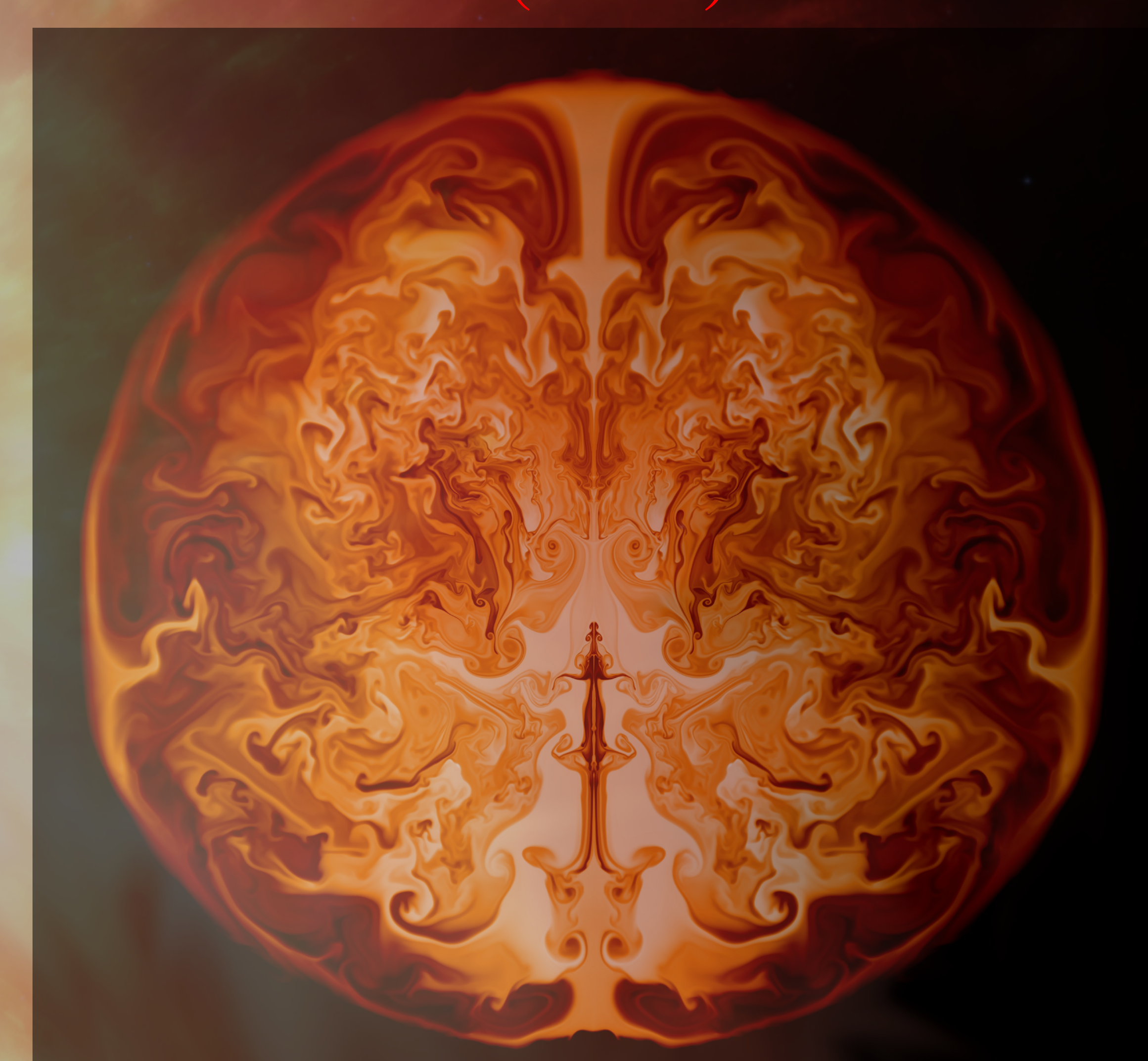


150 M⊙ < M* < 250 M⊙

1. e+/e- creation instability
2. One powerful explosion
3. Lots of Ni (up to 30+ M⊙)
4. Mixing due to burning and hydro instabilities

See Poster:
Mixing of Pair-Instability Supernovae

GR-Instability SN (GSN)



M* ~ 55,000? M⊙

1. GR instability
2. Explosive burning of oxygen
3. One giant explosion
4. Mixing due to burning instability

Explosion energy ~ 10^{55} erg

Significant impacts to the early universe!?

Conclusions

We have presented the results from our 3D simulations of supernovae from very massive stars by using CASTRO. Although the existence of stars above 100 M⊙ is still being debated, the stellar evolution models and multi-D simulations show the explosion of some of these very massive stars. The (P)PSNe models agree with the recent observations of super-luminous SNe. Motivated by the formation of super massive black hole problems, we study their stellar seeds by simulating super massive stars with masses over 10,000 M⊙ and find an unusual explosion of such massive stars. If super massive stars did form in the early universe, the exploding super massive stars could significantly impact the later universe through their chemical enrichment. The future high-z observations will provide more data to examine the above explosions.

Because of the enormous explosion energy and large out-shining radius, the (P)PSN and GSN can be 10 ~ 100 times brighter than a normal type Ia SN.

Acknowledgments

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