Blowouts of Nascent Wind Bubbles in Pulsar-Driven Supernovae

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Rapidly rotating, strongly magnetized newborn neutron stars (NSs) may form in diverse stellar-collapse channels and shape related high-energy transients. If such an NS deposits rotational energy comparable to the supernova (SN) explosion energy before the ejecta becomes transparent, its wind bubble can catch up with the outer ejecta. Hydrodynamic instabilities can then trigger a wind-bubble blowout.

We develop a minimal semi-analytic model for this post-blowout phase. Guided by multidimensional simulations, the model follows the admixture-layer dynamics and radiation using an approximately radius-independent kinetic-energy flux. We use it to map the blowout conditions across ejecta and NS parameters, and to compute survey-ready multiband light curves.

For stripped-envelope SNe with $M_{\rm ej}\sim 10,M_\odot$ and $E_{\rm sn}\sim 10^{51},{\rm erg}$, blowout occurs for $B_{\rm dip}\gtrsim 10^{13},{\rm G}$ and $P_{\rm NS}\lesssim$ a few milliseconds. Weak-field cases with $B_{\rm dip}\lesssim 10^{14},{\rm G}$ produce luminous double-peaked UV/optical light curves, consistent with LSQ14bdq. Stronger-field cases with $B_{\rm dip}\gtrsim 10^{14},{\rm G}$ produce hypernovae with early X-ray blowout precursors.

The same mechanism becomes more efficient in low-mass explosions, including ultra-stripped SNe, accretion-induced collapse, and merger-induced collapse (AIC/MIC). These systems can produce fast X-ray transients lasting (10^2)–$(10^4,{\rm s})$, with peak luminosities of (10^{42})–$(10^{48},{\rm erg,s^{-1}})$. Early UV, optical, and X-ray follow-up can therefore directly test the birth of the most energetic newborn NSs and provide a practical handle for finding rare engine-driven explosions.