Triggerring jet-driven explosion of core-collapse supernovae by accretion from convective regions

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Abstract
We derive an approximate expression for stochastic angular momentum in convection layers of stars, using the assumptions of mixing length theory. Applying this for an evolved massive star at core-collapsing epoch, we show that some convective regions have sufficient angular momentum to form an intermittent accretion disk around the newly formed neutron star (NS) or BH. This accretion disk may form jets that can explode the star even after BH formation.

Our Scenario
We consider a scenario where the core of a massive red giant star fails to explode the star, and argue that when the convective envelope is accreted an intermittent accretion disk will be formed around the newly born black hole, that will trigger a violent jet-driven supernova. Our claim is contrary to previous claims arguing that when the core fails to explode then most of the envelope will be accreted, resulting in only a very low energy supernova (Nadezhin 1980; Lovegrove & Woosley 2013). We argue that when the gas from the vigorous-convective envelope regions is accreted, an accretion disk with varying angular momentum direction will be formed. Such a disk can launch jetting jets that are efficient in exploding the star (Papish & Soker this meeting). We further argue that in most cases the convective regions in the silicon or oxygen burning shell will already form an intermittent accretion disk that will trigger the jetting-supernova explosion mechanism. Instabilities, such as the SASI (Blondin et al. 2003; Blondin & Mezzacappa 2007; Hanke et al. 2013) might facilitate the formation of an intermittent accretion disk, causing even earlier triggering of the jetting-supernova explosion mechanism.

Numerical Method
We evolve a 40M_⊙ star up to the Si burning stage with the MESA code (Paxton et al. 2011). The structure of the star at this stage gives the convective speed and mixing length for the convective regions. Using these, we estimate the ratio between the stochastic specific angular momentum (at different radii) and the Keplerian specific angular momentum around the newly born compact object.

Stochastic Angular Momentum

\[
\vec{\Omega}_s = \left\{ \begin{array}{ll}
\vec{\Omega}_{s,0} + \Delta \vec{\Omega}_s & \text{if } r < r_{\text{crit}} \\
\vec{\Omega}_{s,0} & \text{if } r \geq r_{\text{crit}}
\end{array} \right.
\]

Where \(\vec{\Omega}_{s,0}\) is the angular momentum at the initial core, \(\Delta \vec{\Omega}_s\) is the stochastic angular momentum, and \(r_{\text{crit}}\) is the critical radius.

References

See also poster by Oded Papish.