Dependence of failed supernova on progenitor models

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Failed supernova

We study the ejection of mass during stellar core-collapse when the stalled shock does not revive and a black hole forms.

Phenomenon

Neutrino emission during the protoneutron star phase reduces the gravitational mass of the core, resulting in an outward going sound pulse that steepens into a shock as it travels out through the star.

Purpose

Identify the dependence on neutrino emission and progenitor model

Method and models

We use 1D stellar evolution code MESA and 1D time-dependent hydrodynamic simulation which can treat neutrino mass loss parametrically.

We use exponential neutrino cooling model which is same as Fernandez(2017)

$$\dot{M}_G = \dot{M}_B - \frac{BE_C(M_G)}{\tau_c} e^{-t/\tau_c}$$

M_G: gravitational mass of protoneutron star

M_B:the baryonic mass of protoneutron star

BE_C: the binding energy of a cold neutron star

τ_c: neutrino cooling time$(\sim 3s)$

$$BE_c = 0.084 \left(\frac{M_G}{M_\odot}\right) M_\odot{}^2$$

This model emit most of the energy as neutrino in τ_C.

Stop the neutrino emission once the black hole form

$\tau_C = 0.1s, M_{TOV} = 2.0M_\odot$

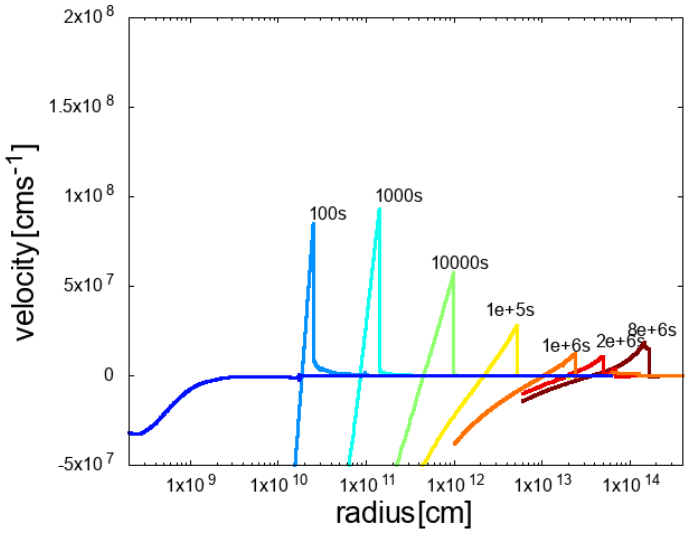

Fig 1:shock propagation

$M_{TOV} = 2.6M_\odot$

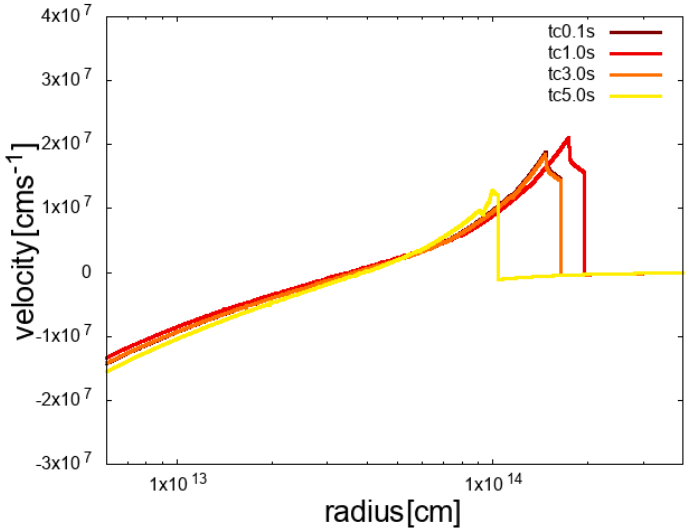

Fig 2: Dependence on τ_C

Results

Fig 1 is a velocity profile of the star. It shows the shock propagate toward the surface of the star.

The protoneutron star is also extremely hot and thus behaves in different manner from cold neutron stars.

change the paremeter neutrino cooling time τ_c ,maximum mass of neutron star systematically
$(0.1s \leq \tau_c \leq 5.0s, 2.2M_\odot \leq M_{TOV} \leq 2.8M_\odot)$

Fig2 shows the velocity profile with different τ_c after shock breakout.

the case, $\tau_c = 5.0s$ shows lower energy because the time reaching to the maximum mass of netron star is around 5s.

Although the shock decrease in strength by the time it reaches the surface,we can see maximum mass of neutron star and neutrino cooling time affects the final shock energy.