Multimessenger signals from core-collapse supernovae

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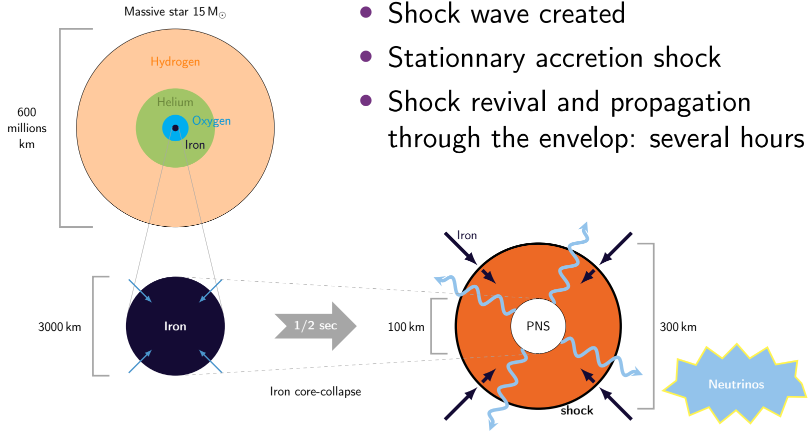
1. Core-Collapse Supernova
2. Multimessenger signatures of instabilities
3. Neutrino-driven convection
4. Conclusion

The collapse and the stalled shock

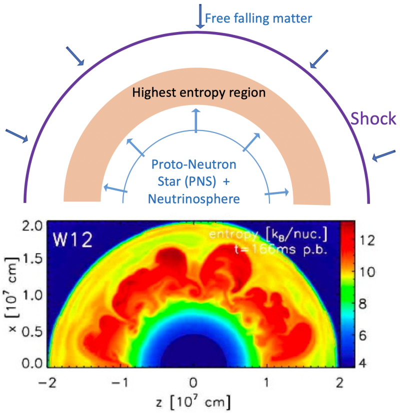
Massive stars end-of-life (8 to 40 $M_{\odot}$) :

- Iron core : 10^3km→ 10^1km in less than a second
- Shock wave created
- Stationnary accretion shock
- Shock revival and propagation through the envelop: several hours



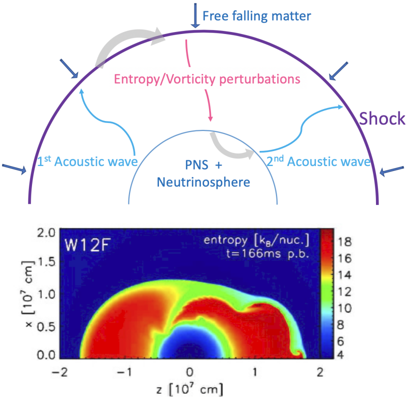
Neutrino-driven convection and Standing Accretion Shock Instability (SASI)

Neutrino-driven convection



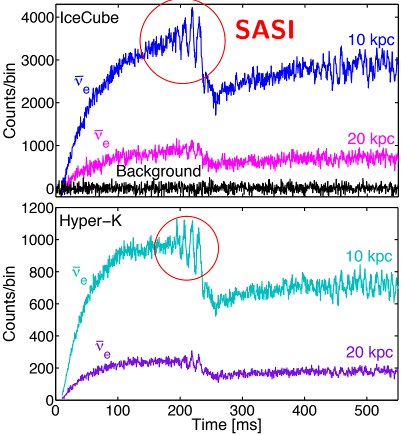
Foglizzo +2006

SASI



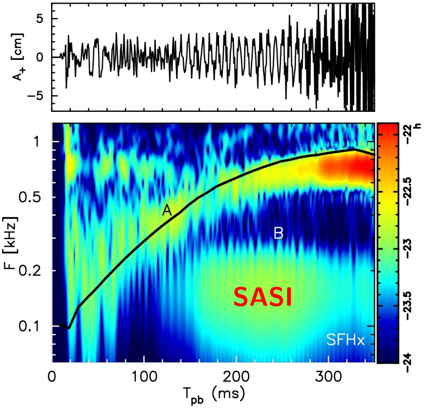
Expected observations of SASI

Neutrinos (27 $M_\odot$)



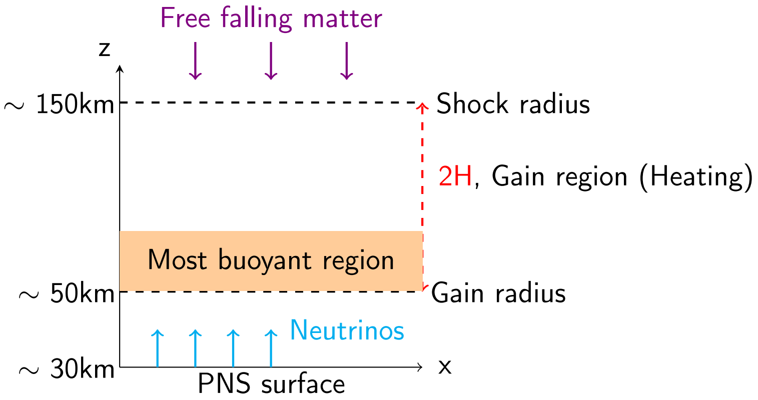
Tamborra +2013

Gravitational waves (15 $M_\odot$, 10kpc)



Kuroda +2016

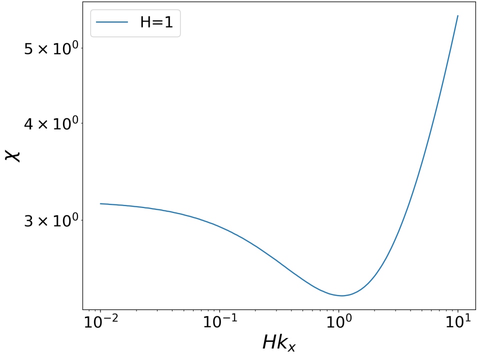
An idealised model of the gain region



The stability criterion and length scales

Stability criterion : $\chi \sim \frac{\tau_{adv}}{\tau_{buoy}}$

- $\tau_{adv} = \frac{H}{|v|}$, advection timescale
- τ_{buoy}, time required for the instability to develop
- M, the Mach number



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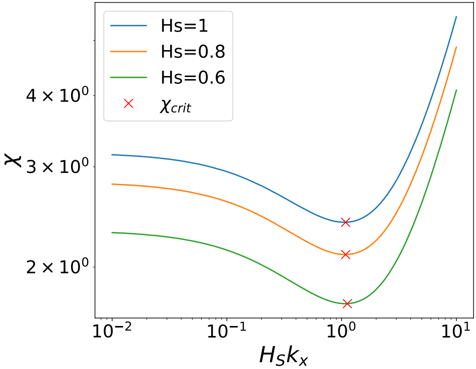
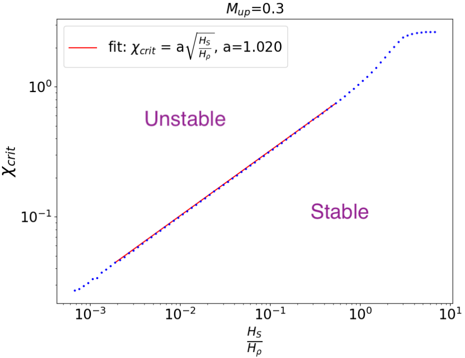


Toward a new criterion

Several length scales :

- H_S, the size of the most buoyant region
- $H_\rho = \frac{c_s^2}{g}$, the density scale-height

$$\chi_{\rm crit} = \left[\frac{\gamma-1}{\gamma}\frac{\Delta S}{\tanh\left(\frac{\gamma-1}{2\gamma}\Delta S\right)}\right]^{1/2} \times \sqrt{\frac{H_s}{H_\rho}}$$



Several methods:

- Planar / Spherical case
- Incompressible / Compressible
- Numerical / Analytical
- Perturbation / Energetic considerations
- Hydrostatic / Advection
- No rotation / Rotation

NASA/CXC/RIKEN/T. Sato et al.