

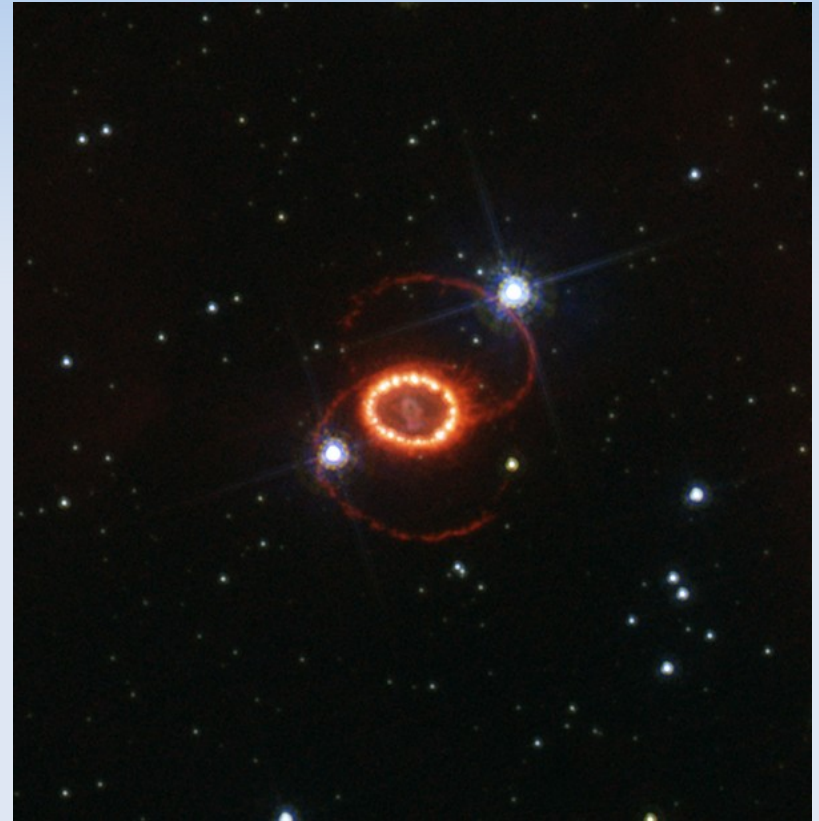
Neutrino Signatures of Supernova SASI

- now in 3D

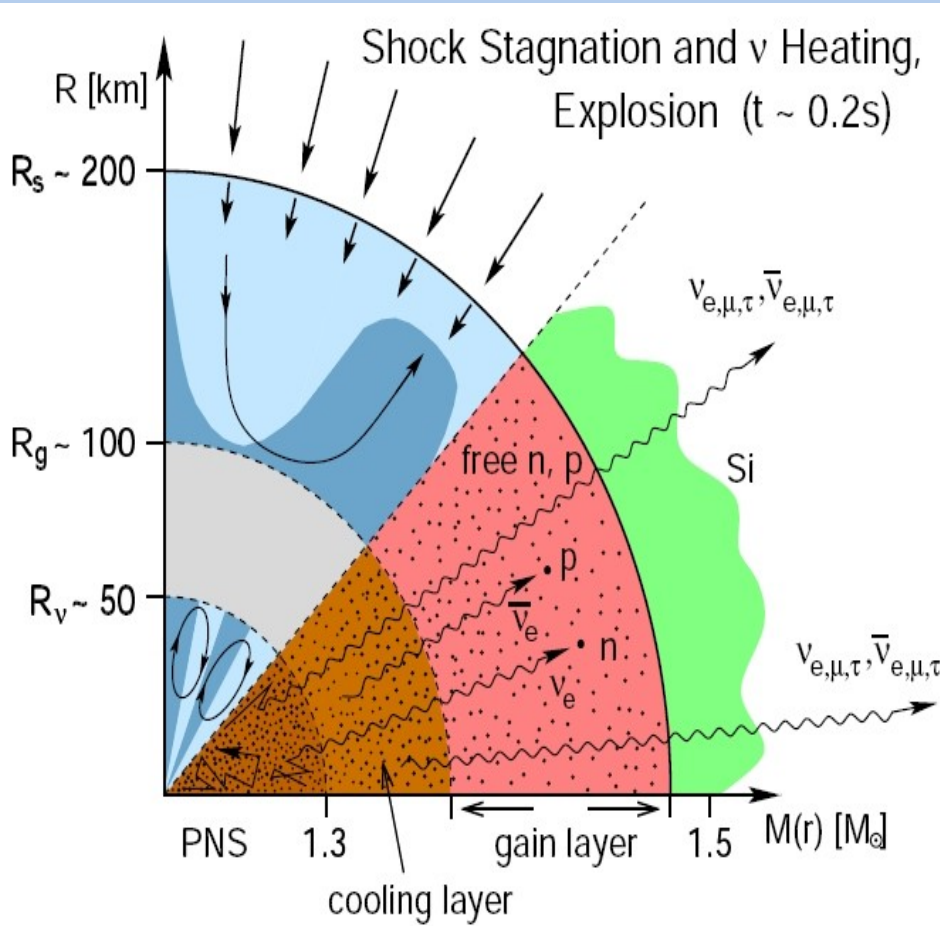
HAvSE 2011, Hamburg
July 20th, 2011
Tina Lund

Neutrino Signatures of Supernovae SASI

- Standing Accretion Shock Instability - SASI
- 2D vs 3D
- Observable signals in IceCube
- Conclusions



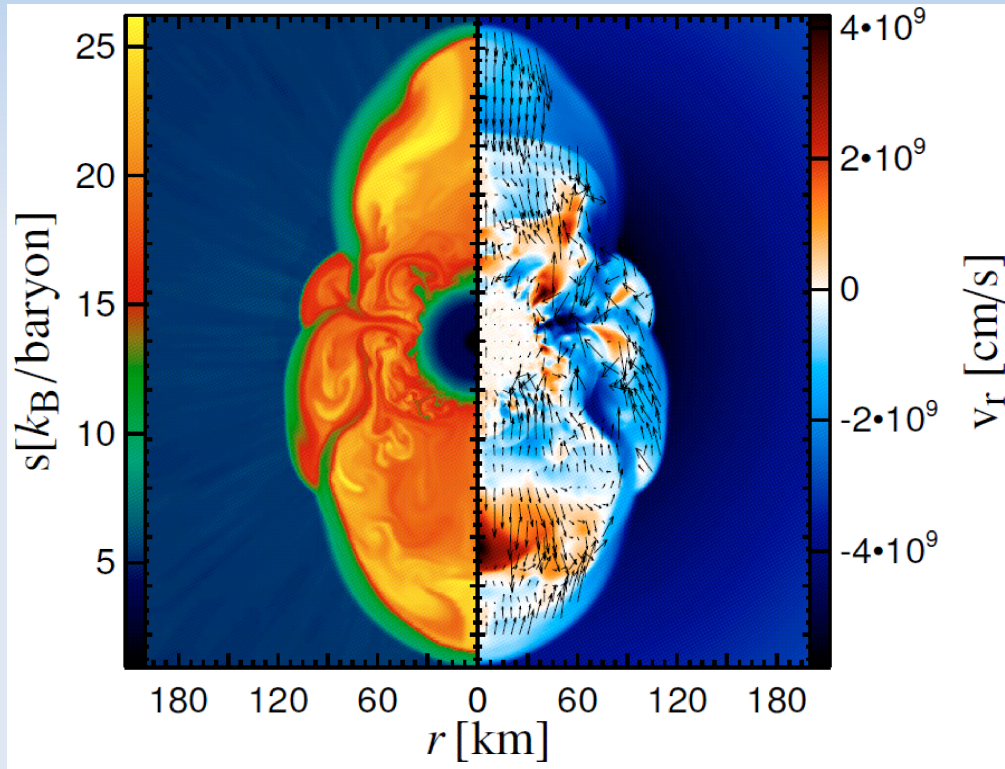
Standing Accretion Shock Instability



- Energy loss halts shock wave \rightarrow Standing Accretion Shock.
- SASI : instability \rightarrow perturbs shock front $\rightarrow R_{shock}$ increases and pulsates.
- Large $R_{shock} \rightarrow$ infalling material longer time in neutrino heating area.
- More energy \rightarrow shock wave revived \rightarrow final explosion.

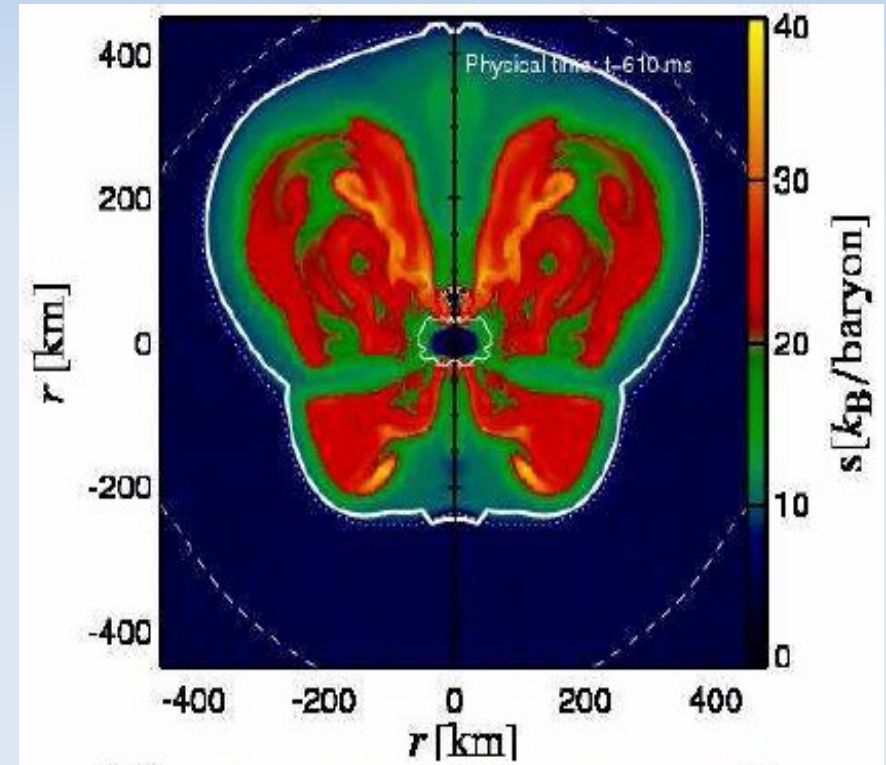
SASI – in 2D

Non-rotating $15 M_{\text{sun}}$



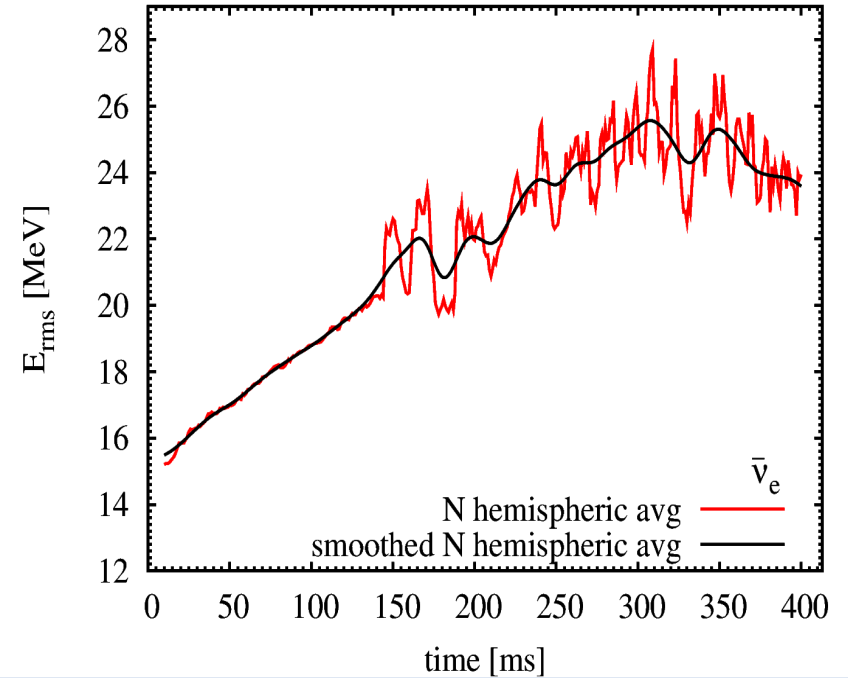
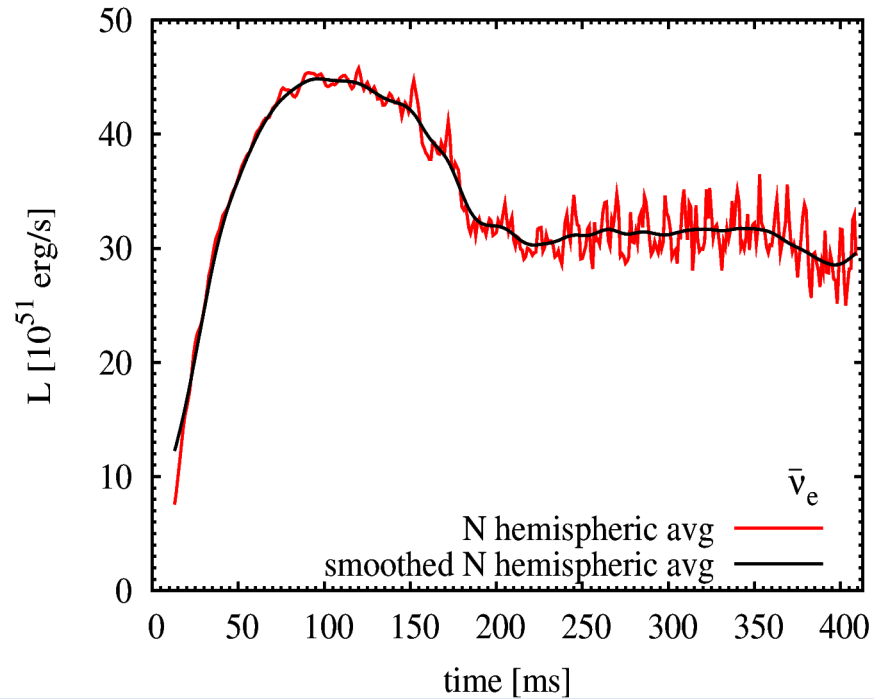
[A. Marek, H.-Th. Janka & E. Müller, 2009]

Rotating $15 M_{\text{sun}}$



[A. Marek & H.-Th. Janka, 2008]

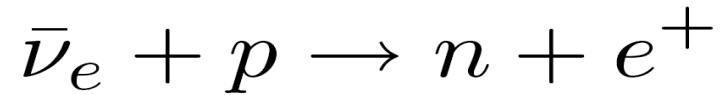
Effects of SASI



[Lund et al, 2010.]

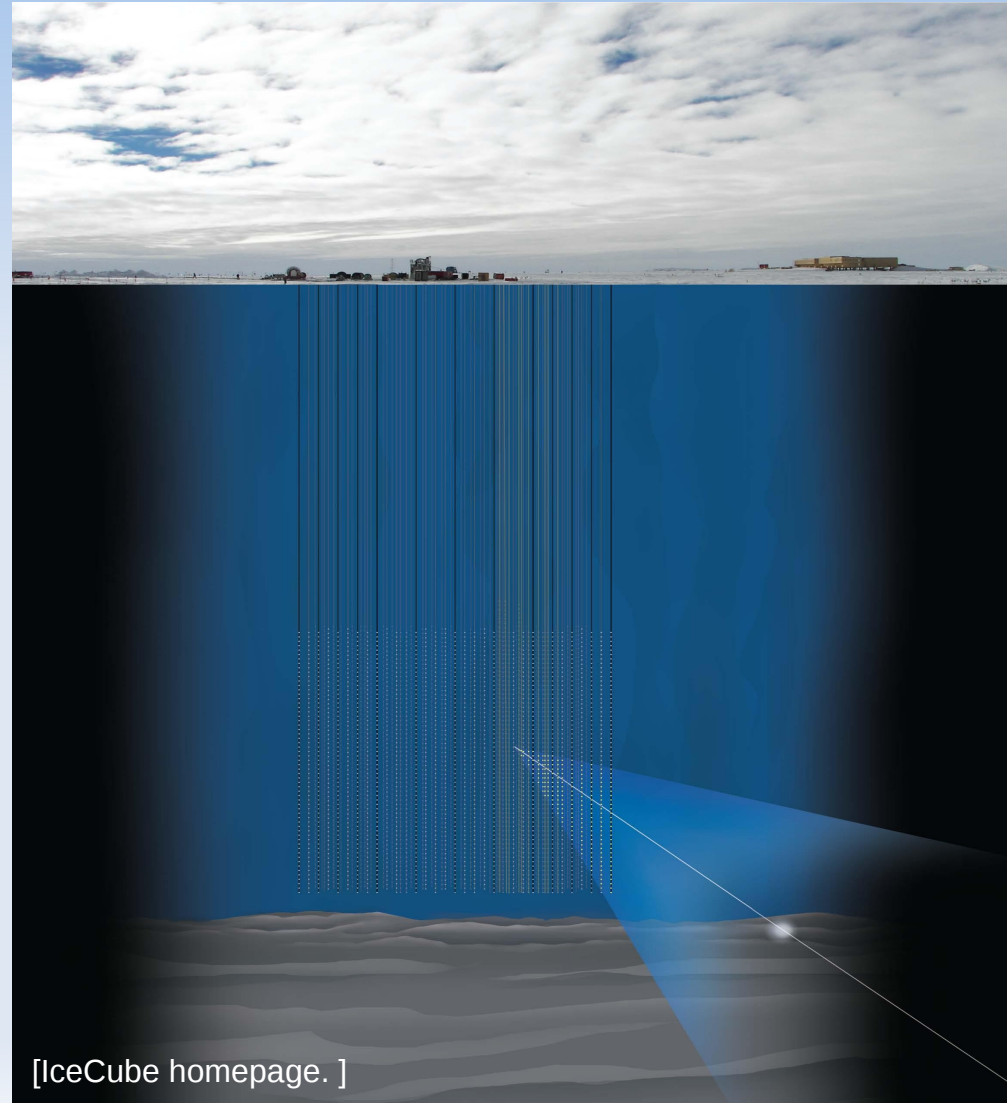
IceCube – Cherenkov telescope

- Digital Optical Modules with photo-multiplier tubes.



- Optimized for energy range:
 $1 \text{ TeV} \leq E \leq 1 \text{ PeV}$
- SN anti- ν_e energy:
 $E \sim 12 - 18 \text{ MeV}$
- Not entire Cherenkov cone only one photon per interaction.
- Dark Current noise in IceCube:

$$\Gamma_{\text{noise}} = 1344 \text{ ms}^{-1}.$$



IceCube event rates

Expected event rate in IceCube:

$$R_{\bar{\nu}_e} = 114 \text{ ms}^{-1} \frac{L_{\bar{\nu}_e}}{10^{52} \text{ erg s}^{-1}} \left(\frac{10 \text{ kpc}}{D} \right)^2 \left(\frac{E_{\text{rms}}}{15 \text{ MeV}} \right)^2$$

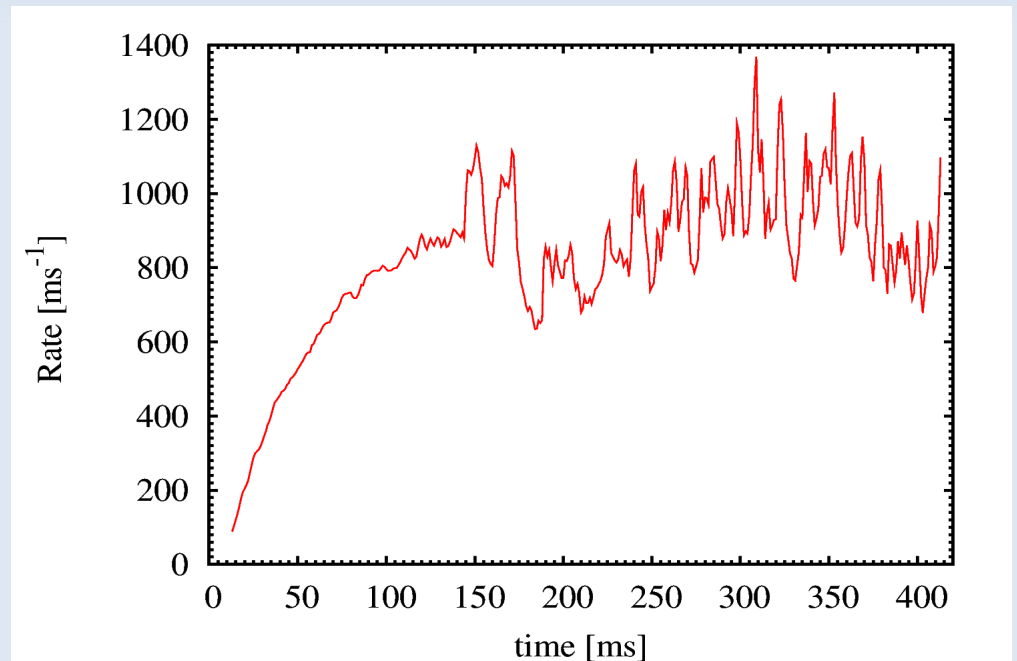
$$E_{\text{rms}}^2 = \frac{\langle E^3 \rangle}{\langle E \rangle}$$

- Instantaneous rate for 2D at 10 kpc:

$$\Gamma_{\text{SN}, 2\text{D}} \sim 900 \text{ ms}^{-1}$$

- Instantaneous rate for 3D at 1 kpc:

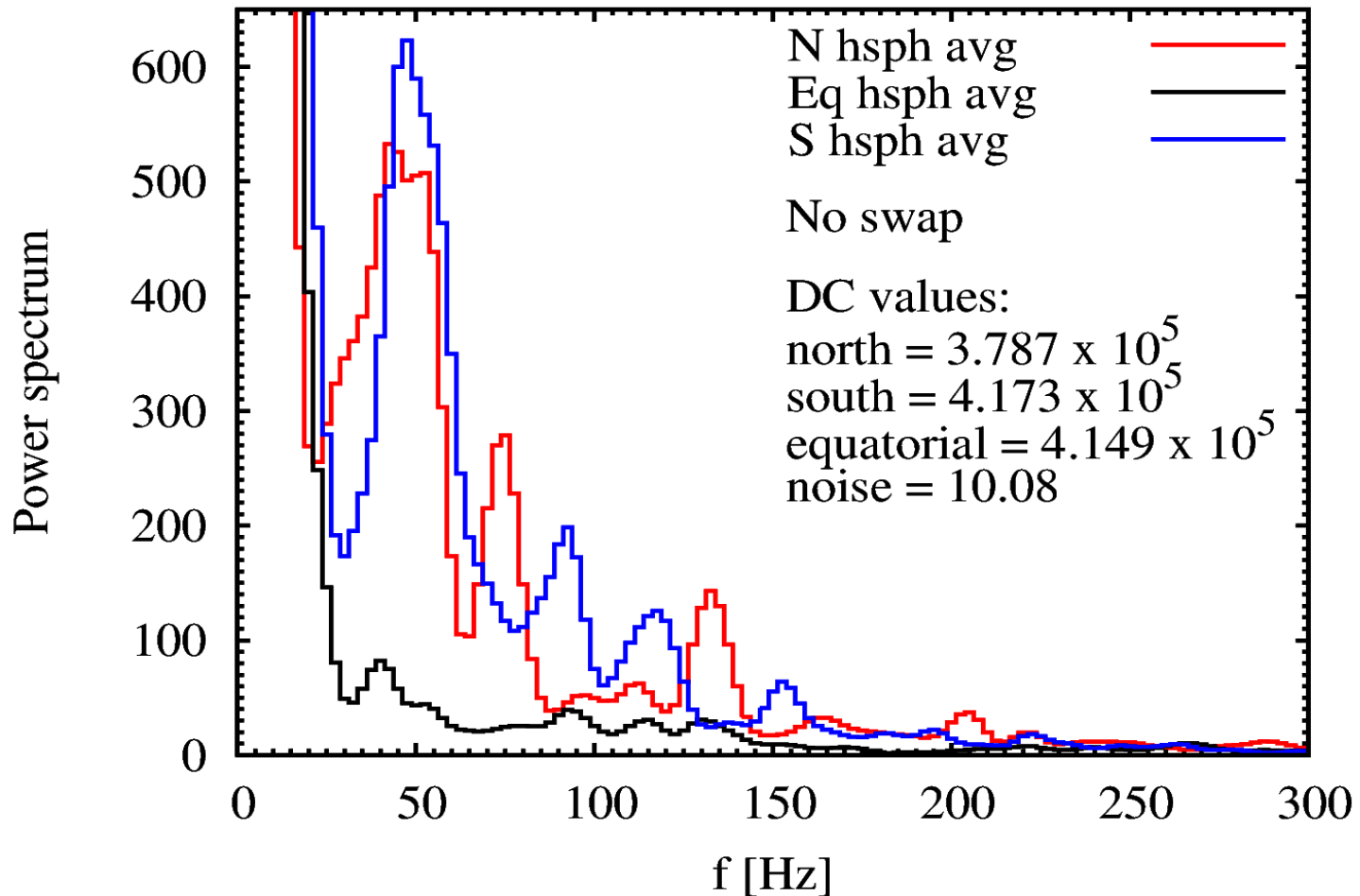
$$\Gamma_{\text{SN}, 3\text{D}} \sim 55000 \text{ ms}^{-1}$$



Power spectrum

- Fourier transform to investigate features in the time signal.
- Nyquist frequency is 300 Hz due to IceCube binning.
- Used Hanning window to avoid edge effects.

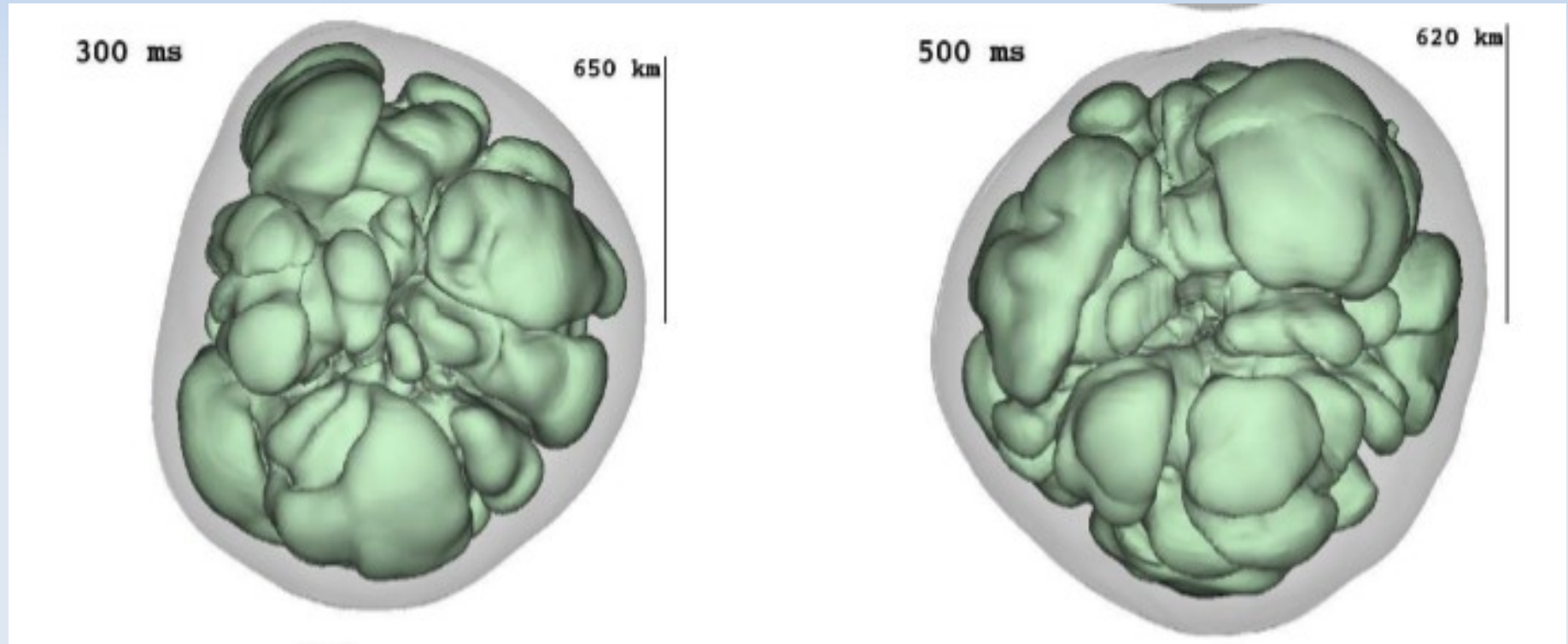
Results - 2D



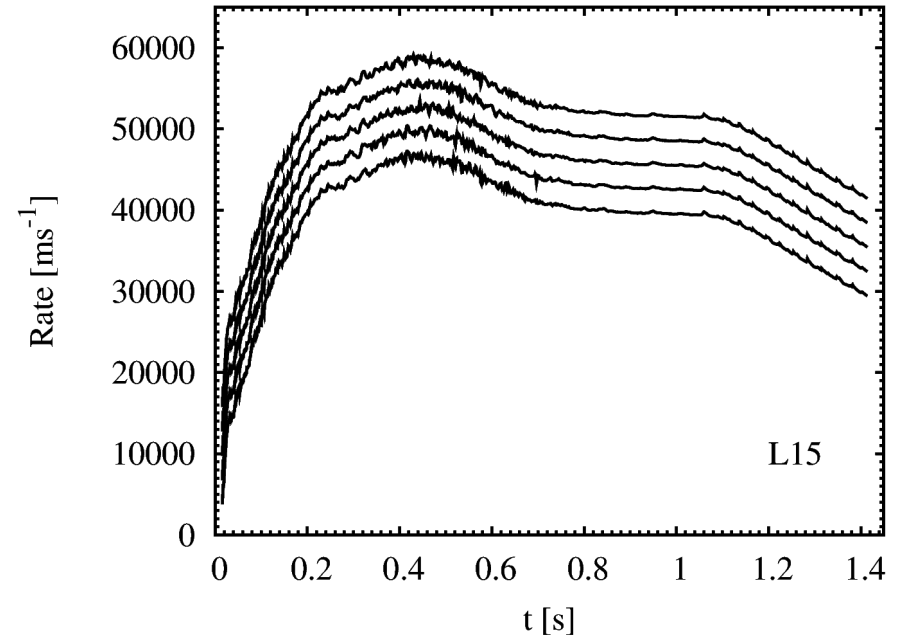
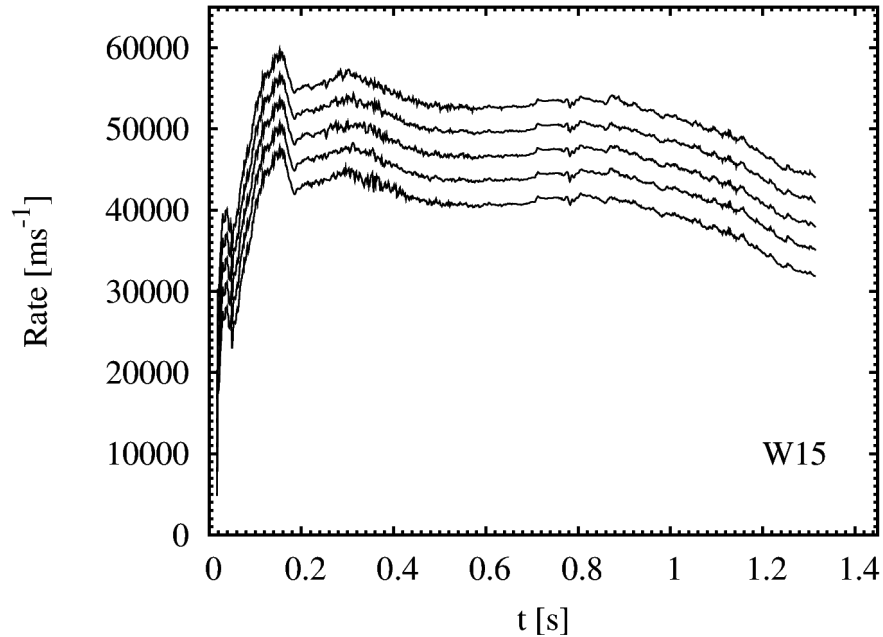
SASI – in 3D

W15-4

L15-3



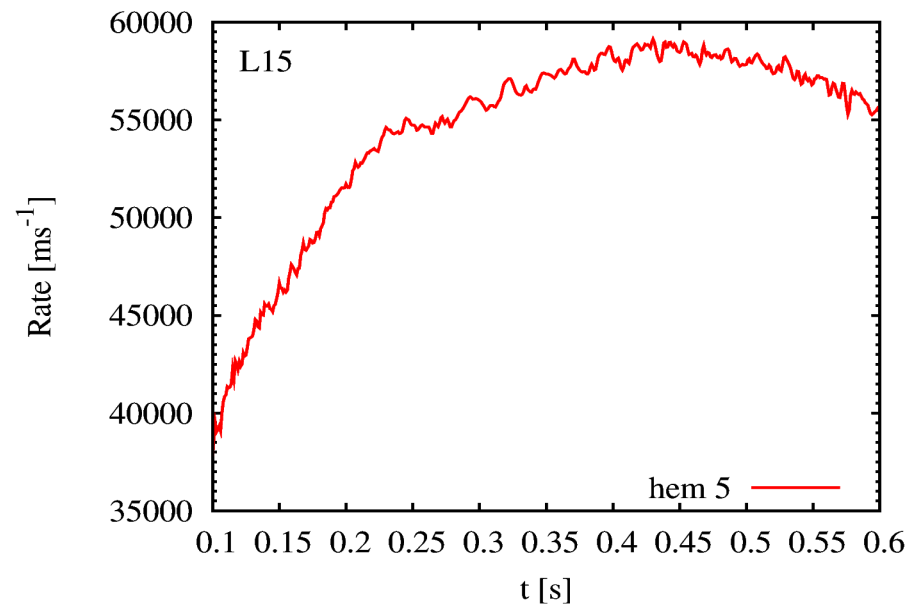
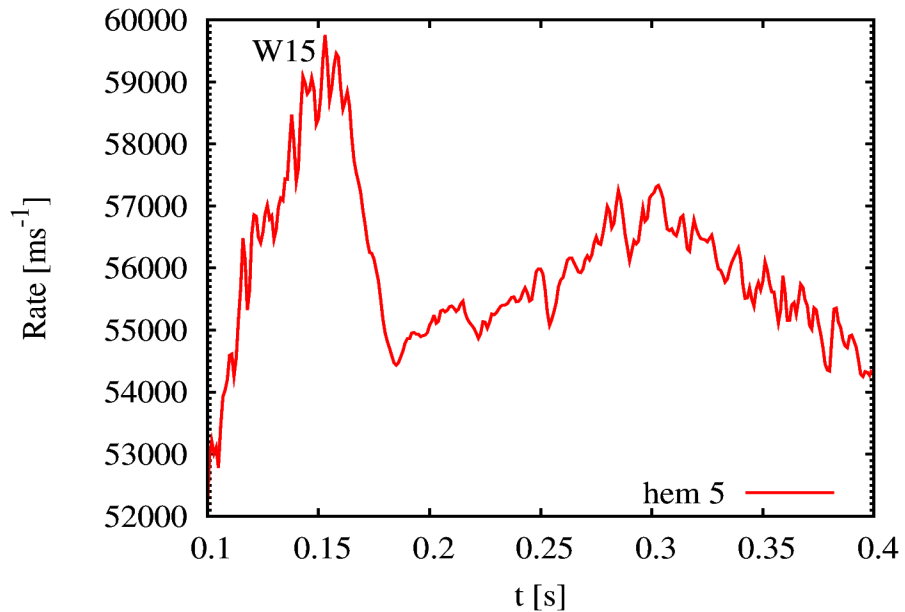
Rates in 3D



At 1 kpc

[Lund et al, 2011, *in preparation.*]

3D pre-explosion phase rate

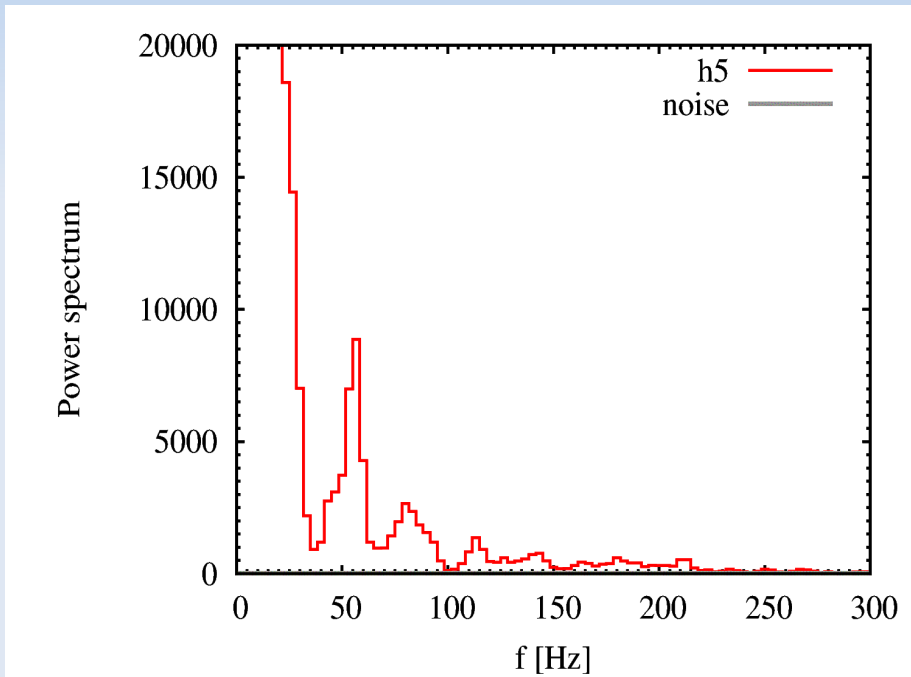


At 1 kpc

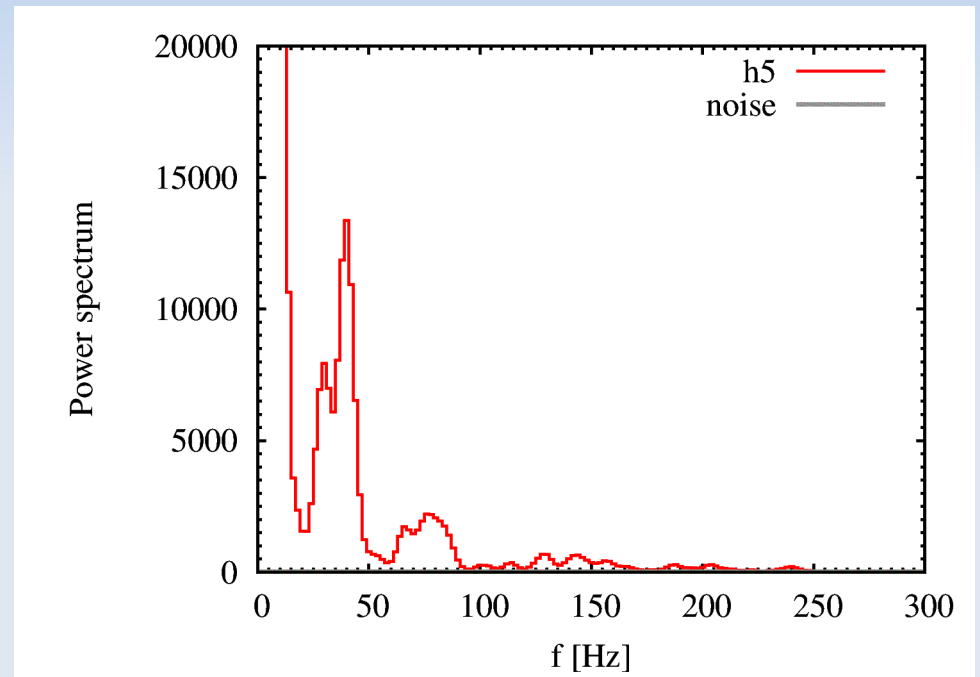
[Lund et al, 2011, *in preparation.*]

Results - 3D

W15-4



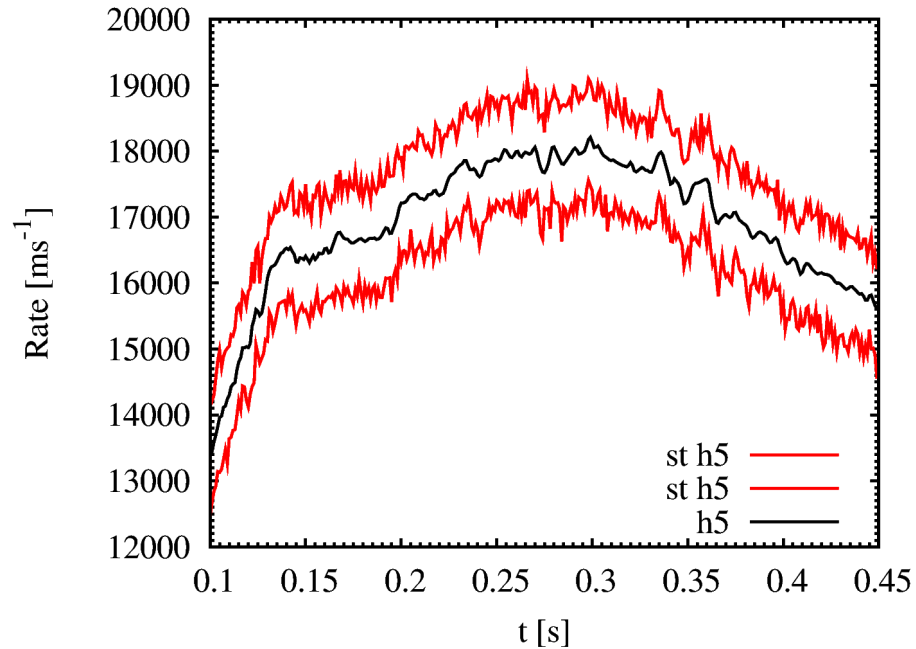
L15-3



At 1 kpc

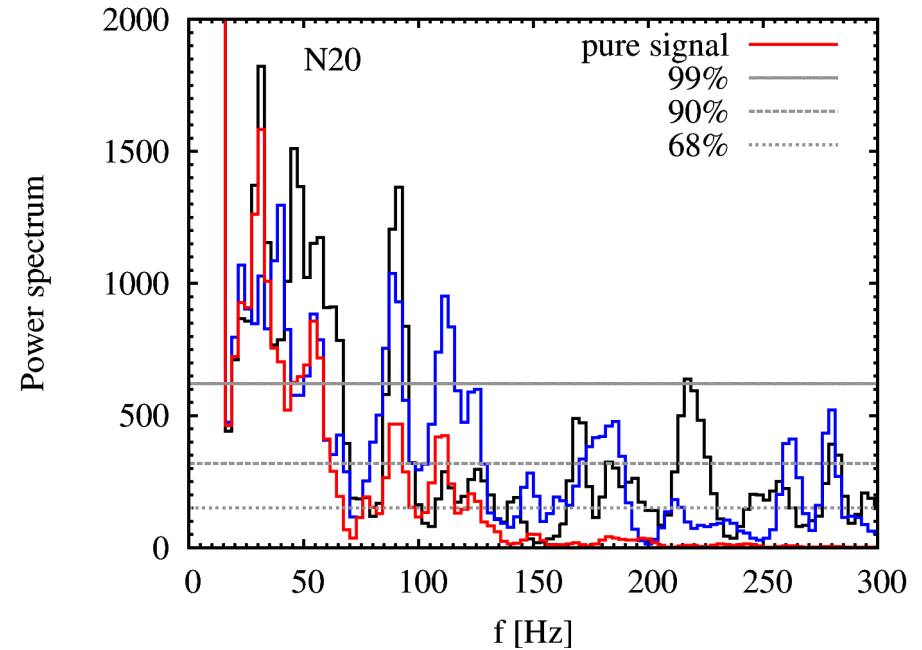
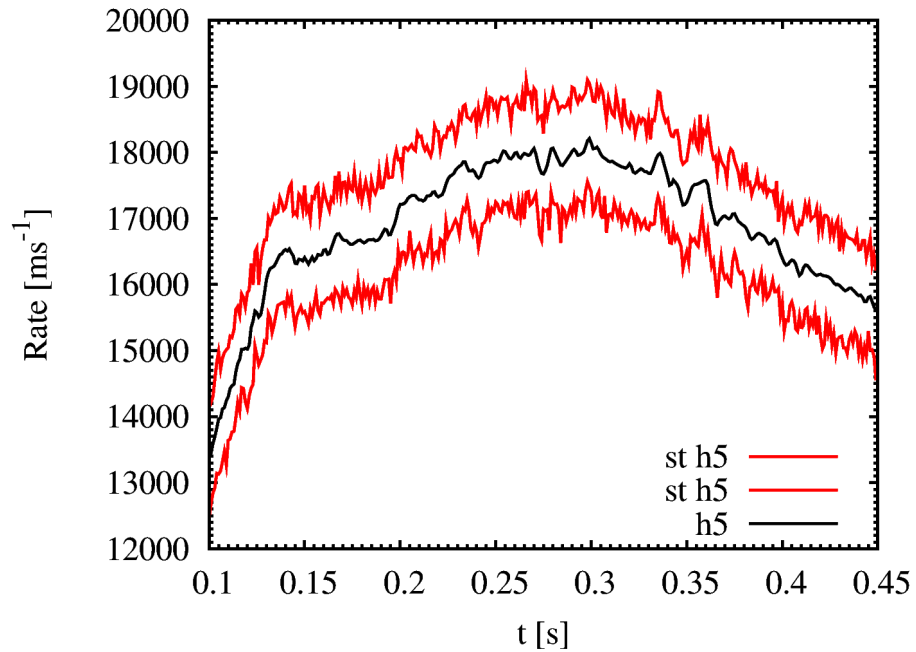
[Lund et al, 2011, *in preparation*.]

Statistical effects



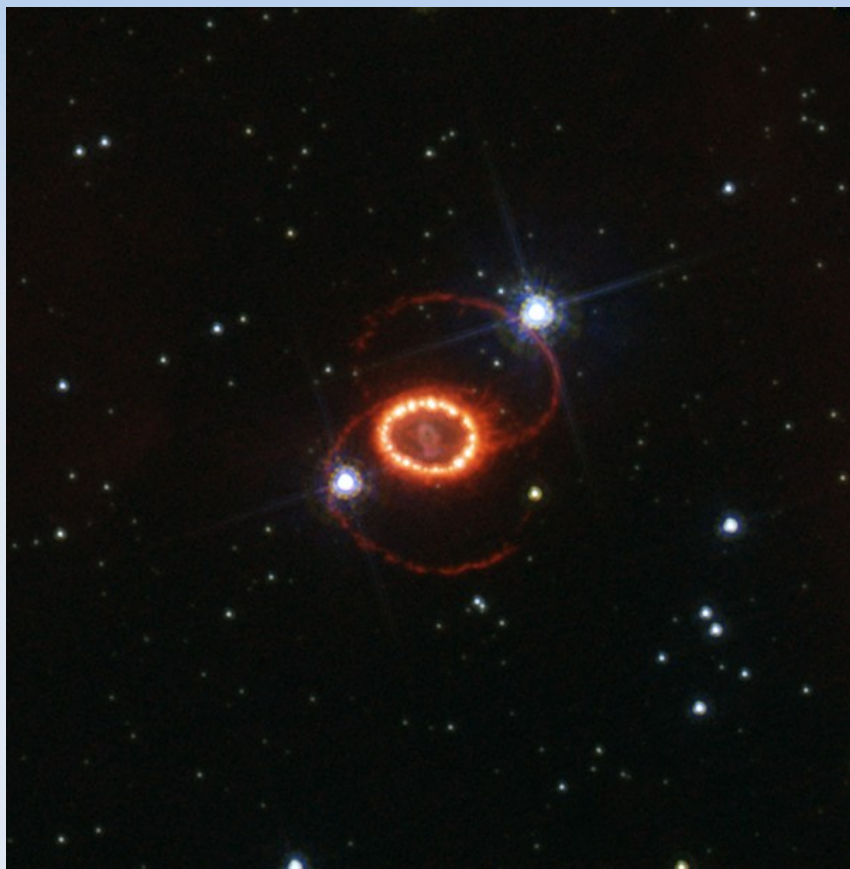
N20 at 2 kpc

Statistical effects



N20 at 2 kpc

Conclusion



- IceCube usefull despite lacking energy information.
- Weaker SASI in 3D models.
- SASI effects can be observed → better understanding of SN.
- If observed short-lived mechanisms ruled out.
- Need Milky Way SN.

**Thank
you!**



References

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- IceCube webpages: <http://icecube.wisc.edu/> and <http://gallery.icecube.wisc.edu/external/icecube-concept/>