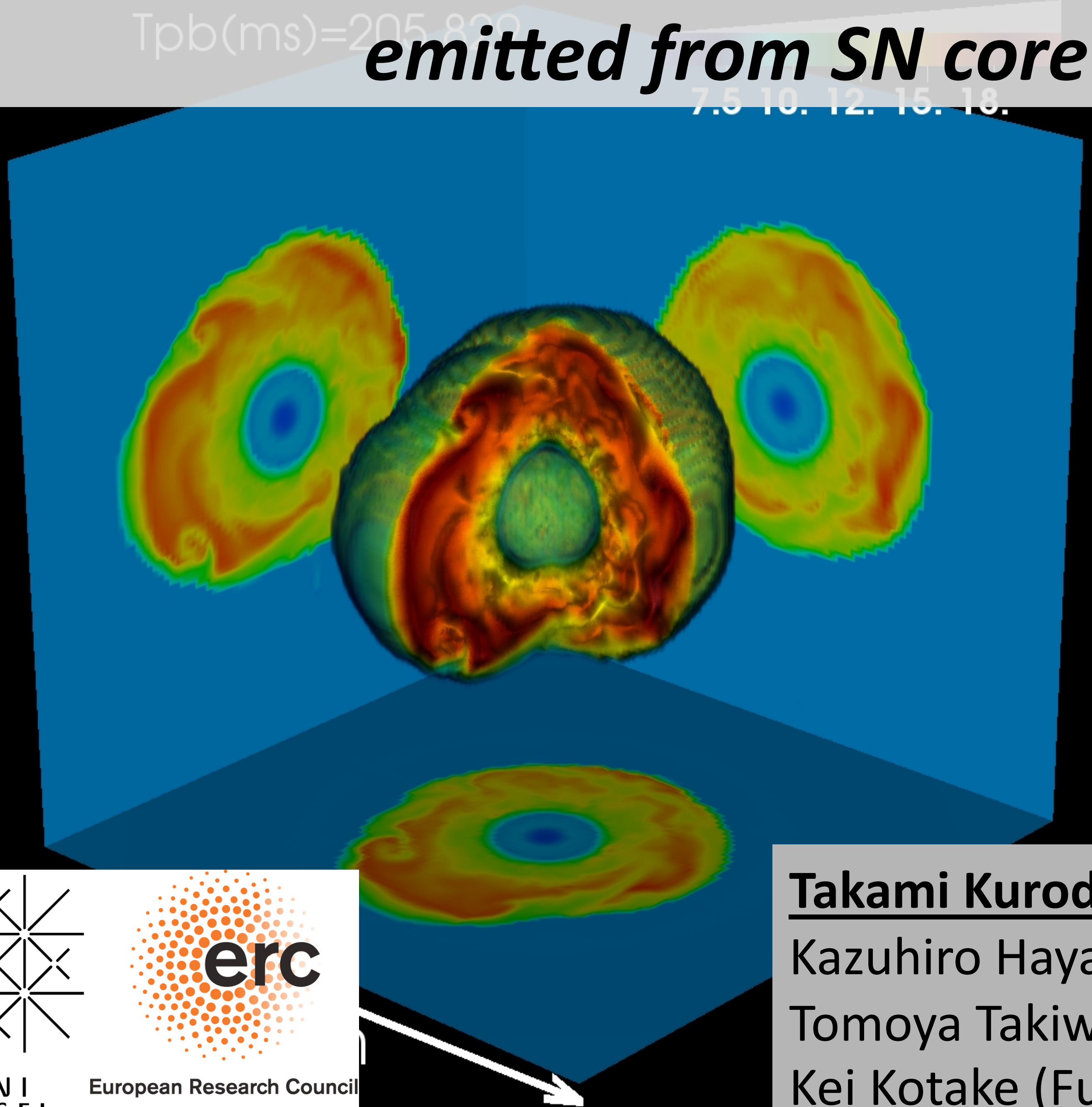
Correlation between GW and neutrino signals emitted from SN core



Takami Kuroda (Basel U.)
Kazuhiro Hayama (Osaka-city U.)
Tomoya Takiwaki (RIKEN)
Kei Kotake (Fukuoka U.)

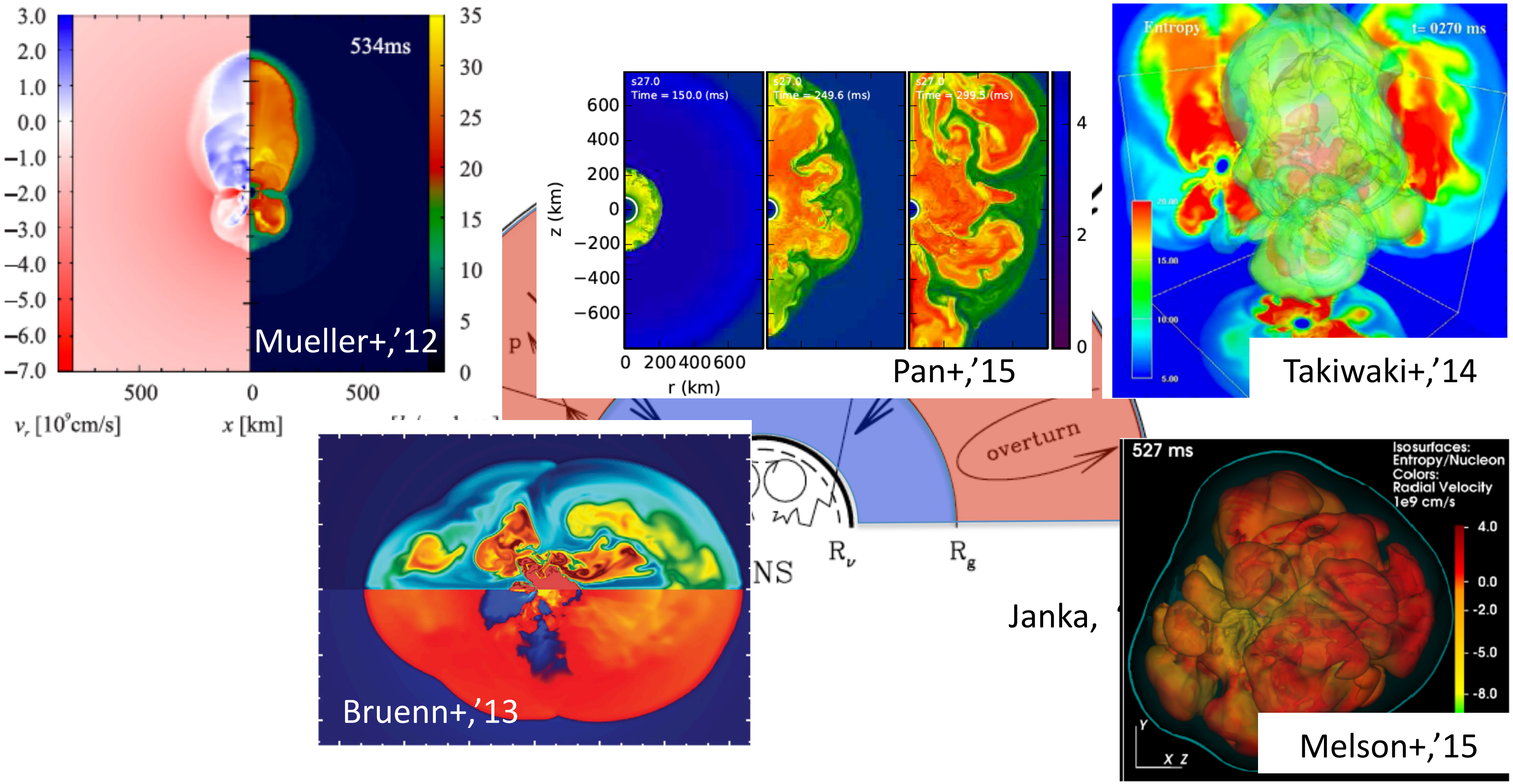
UNI BASEL

European Research Council
Established by the European Commission

Three Keys for Successful Explosion

primarily affect on

- •Multi Dimension → Gain region (M_{gain}, τ_{gain})
- •Progenitor profile → Mass accretion rate
- •Nuclear EOS → ν-luminosity & Acoustic mode



Three Keys for Successful Explosion

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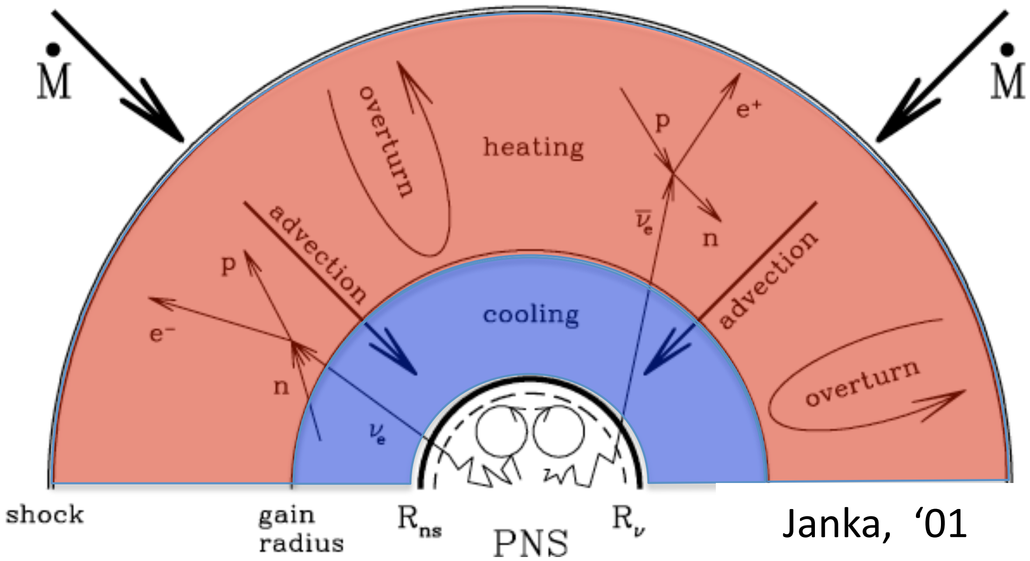
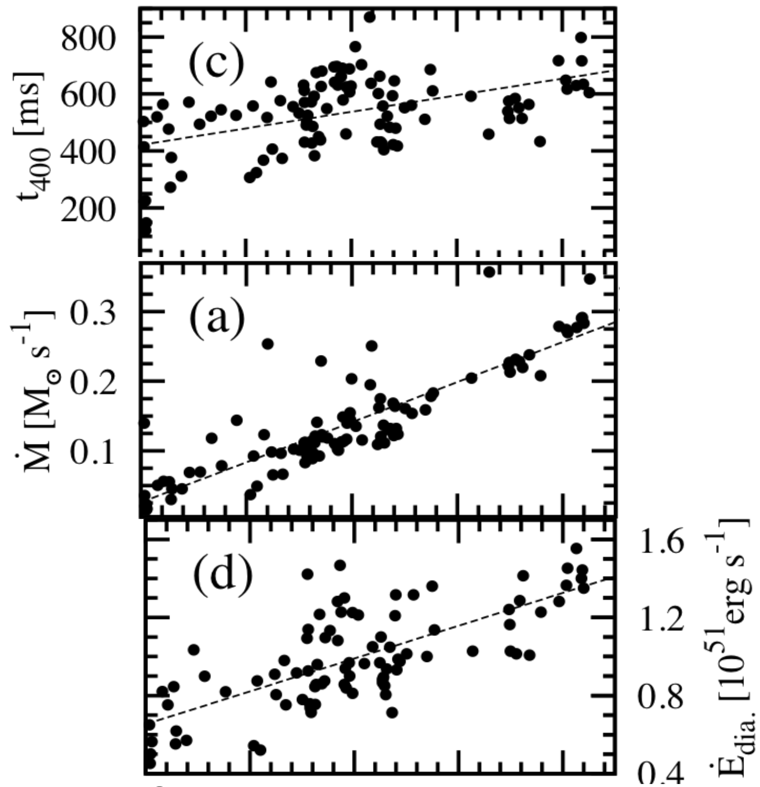


Janka, '01



Compactness parameter

Nakamura, Takiwaki, KT, Kotake, PASJ, '15

Three Keys for Successful Explosion

•Multi Dimension → Gain region (M_{gain}, τ_{gain})
•Progenitor profile → Mass accretion rate
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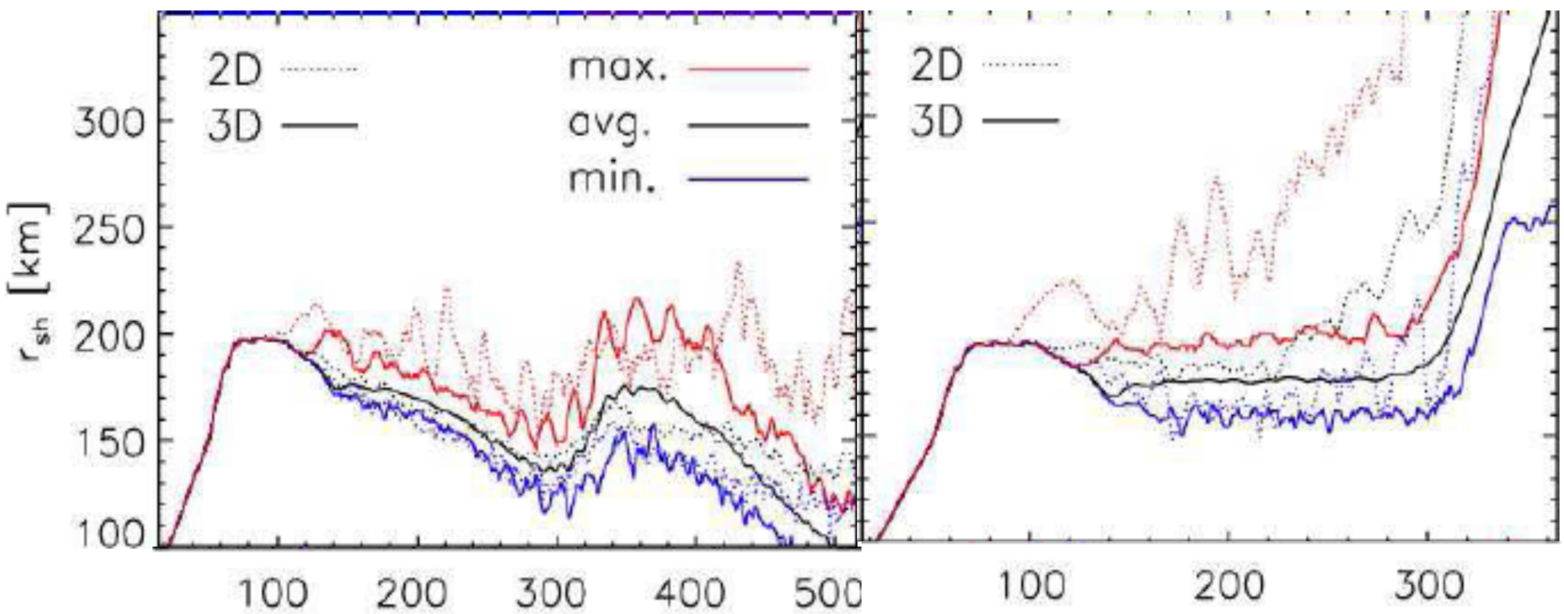
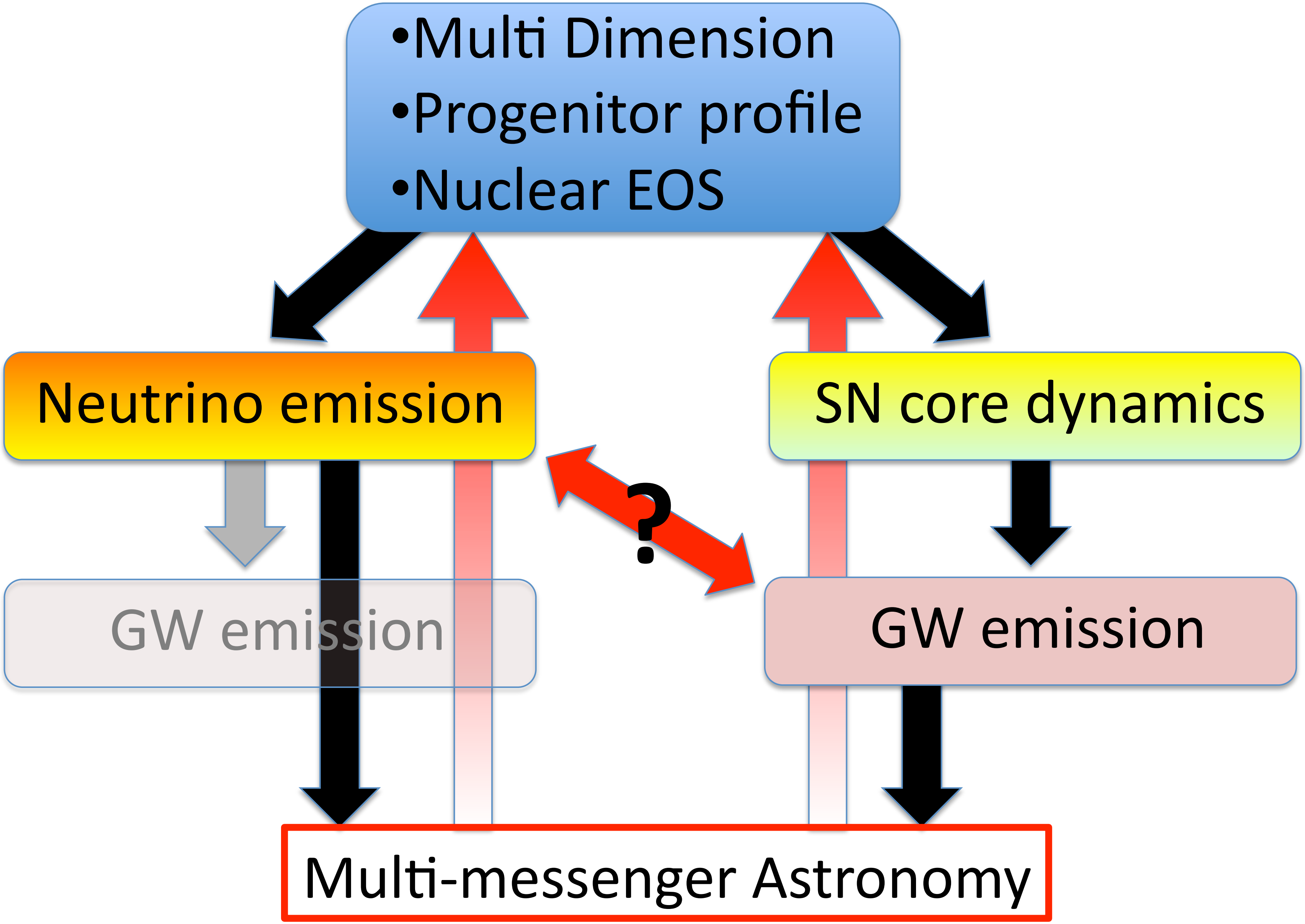
"Soft" PNS is considered to be more favorable
for the shock evolution in neutrino-driven explosion

Slow shrink (low luminosity) Rapid shrink (high luminosity)



Hanke+,'13

Aim of This Study



Numerical Setup

We performed 3D full GR gray-neutrino transport simulations

Sekiguchi, '10, KT+,'12

✓Progenitor: 11.2, 40.0$M_\odot$ (WHW02) & 15.0$M_\odot$ (WW95)

(~0.3, 2.10 & 1.05 Xi@1.5Msun)

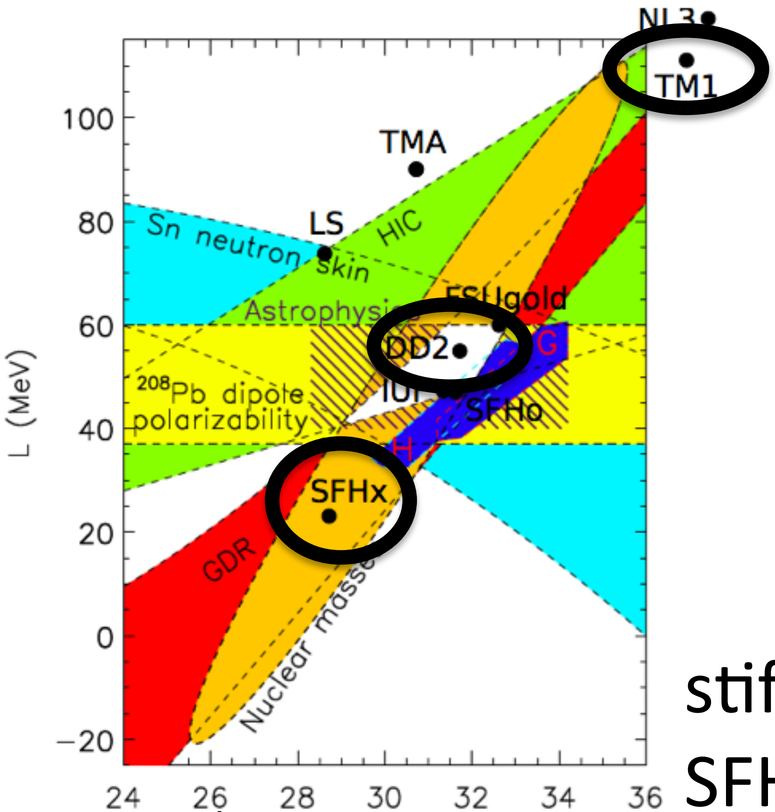
✓128^3cells*9 Level nested structure

($\{x,y,z\} \in [-7500,7500]$km, dx_{min}~450m)

✓EOS : HS(SFHx, DD2 & TM1) (Hempel+,'12 & Steiner+,'13)

Numerical Setups

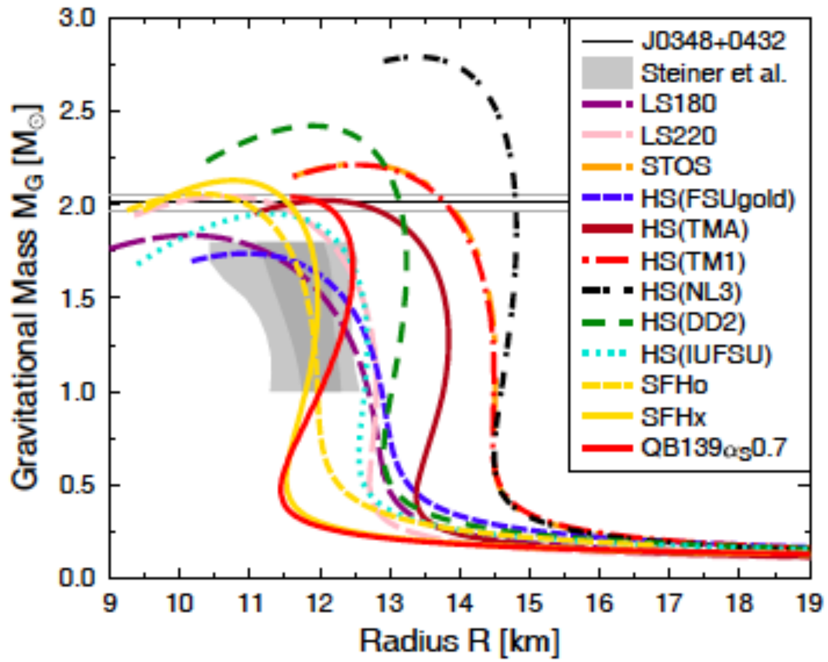
✓EOS : SFHx, DD2 & TM1(Hempel+,'12 & Steiner+,'13)



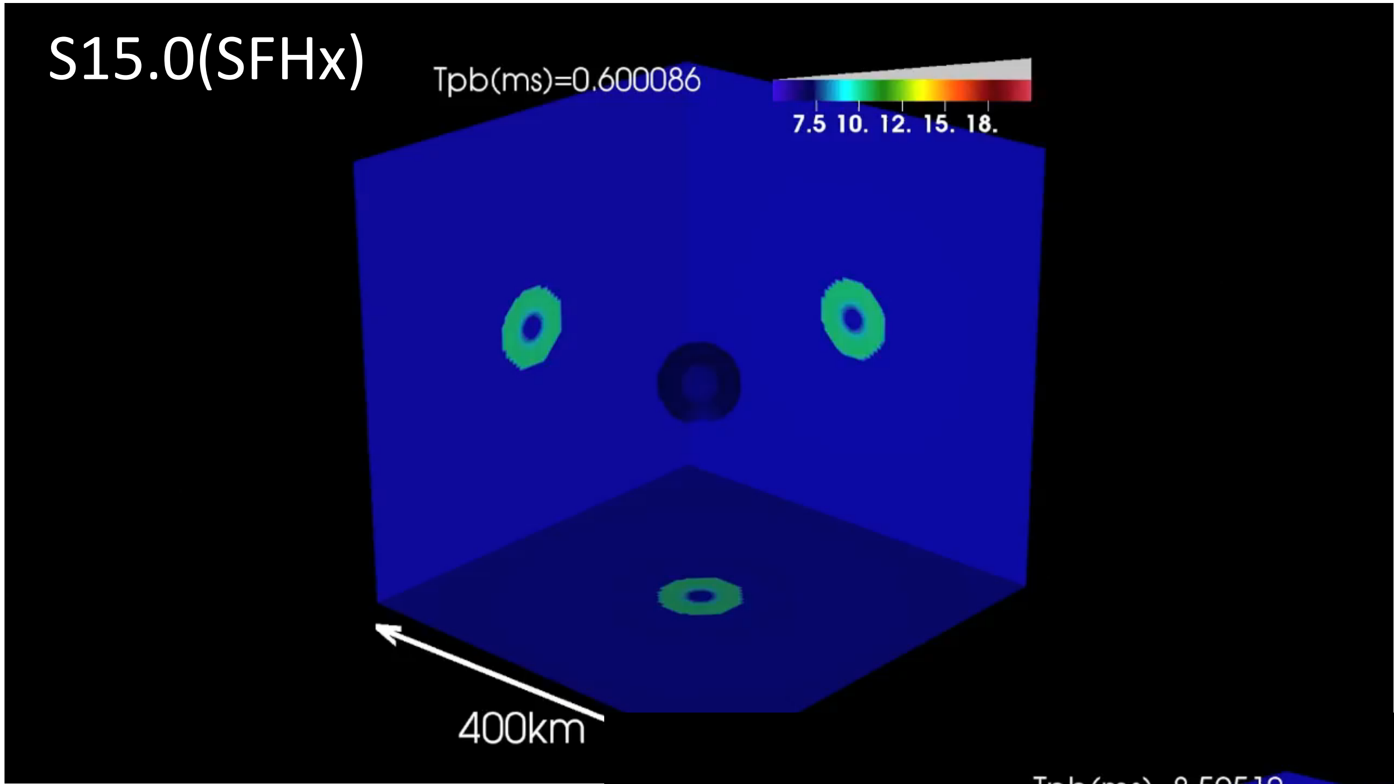
Lattimer+,'13

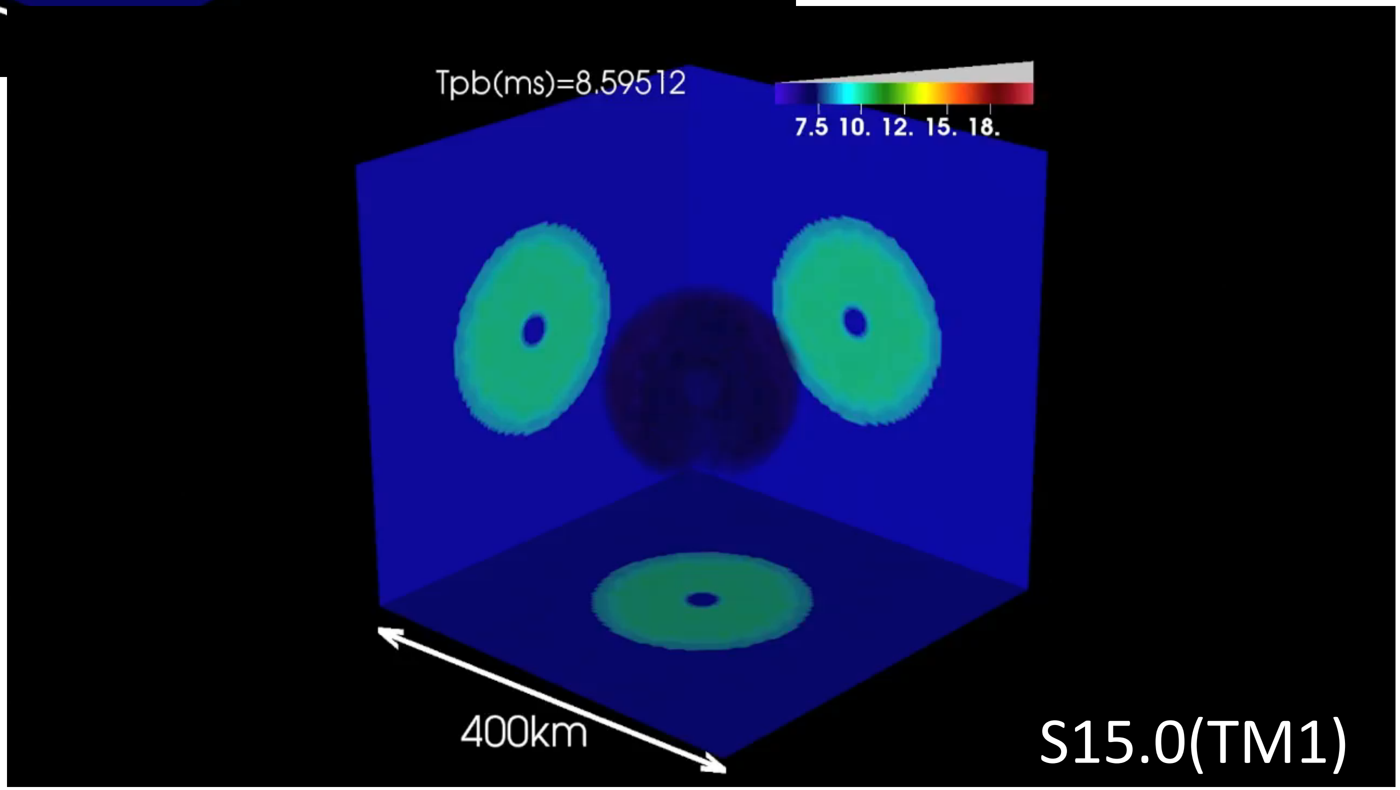
stiffness

SFHx<DD2<TM1

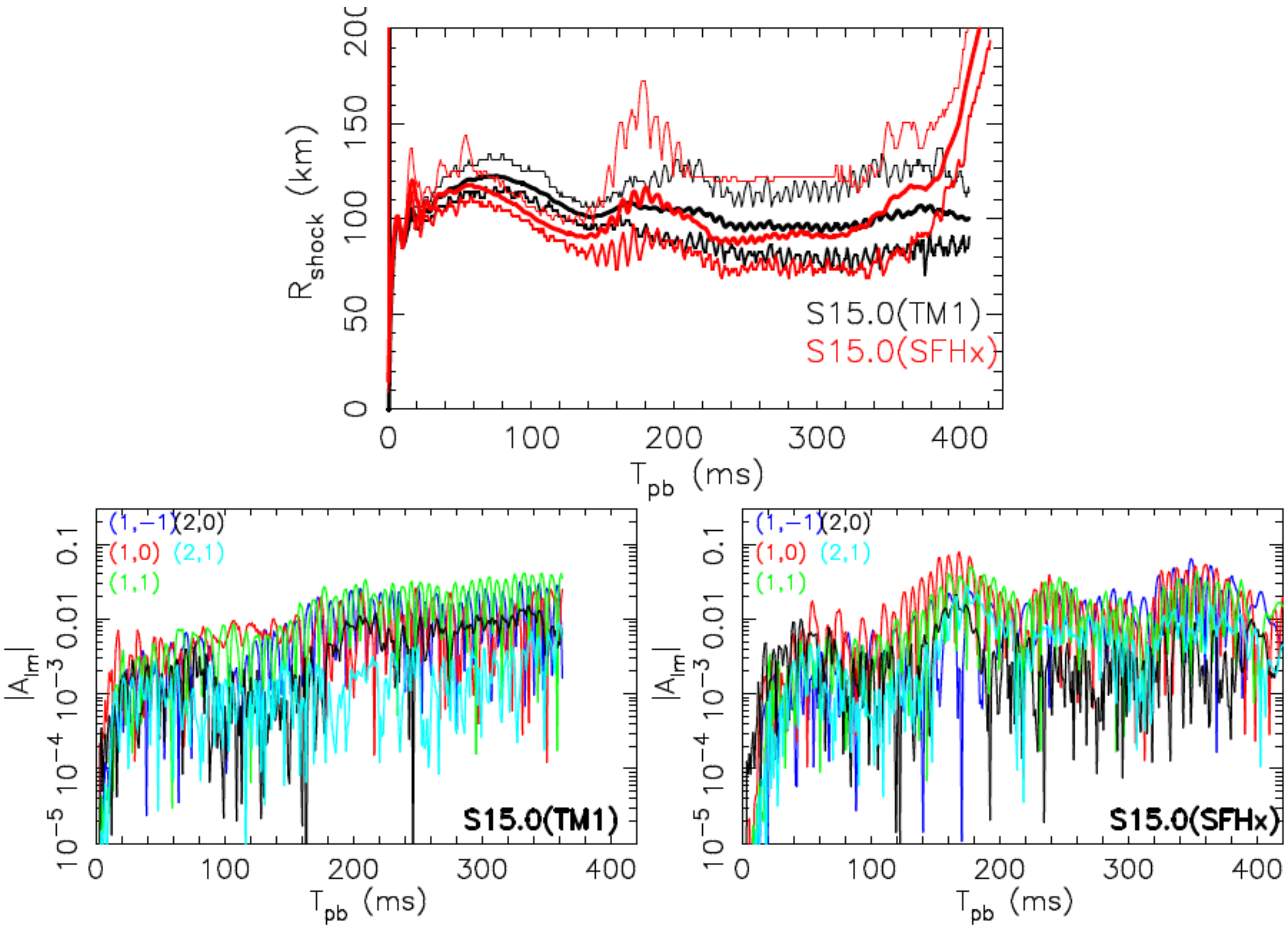


Fischer+,'14


S15.0(SFHx)
Tpb(ms)=0.600086
7.5 10. 12. 15. 18.
400km


Tpb(ms)=8.59512
7.5 10. 12. 15. 18.
400km
S15.0(TM1)

EOS Dependence on SN dynamics

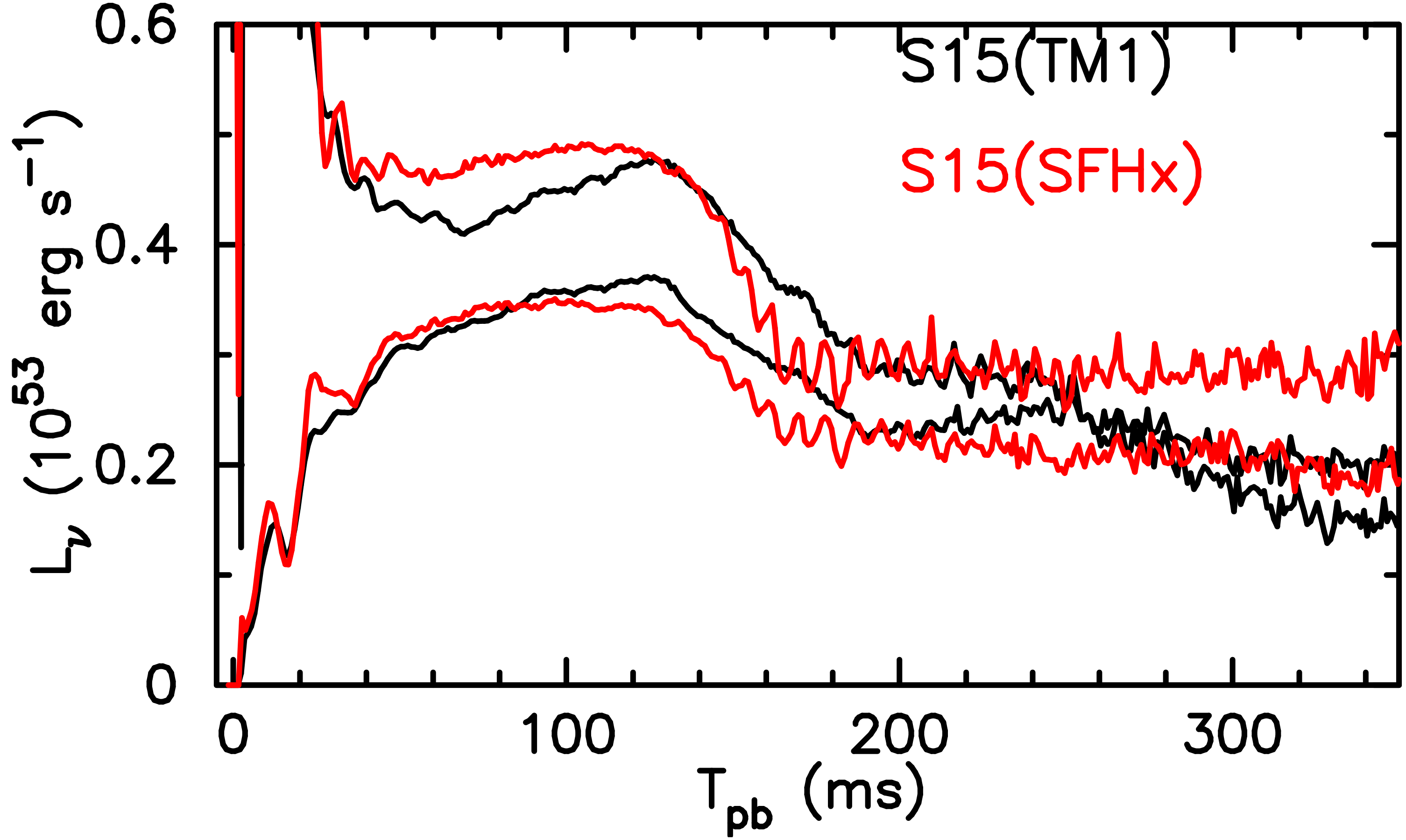


Vigorous SASI activity in the soft EOS model

EOS Dependence on SN dynamics

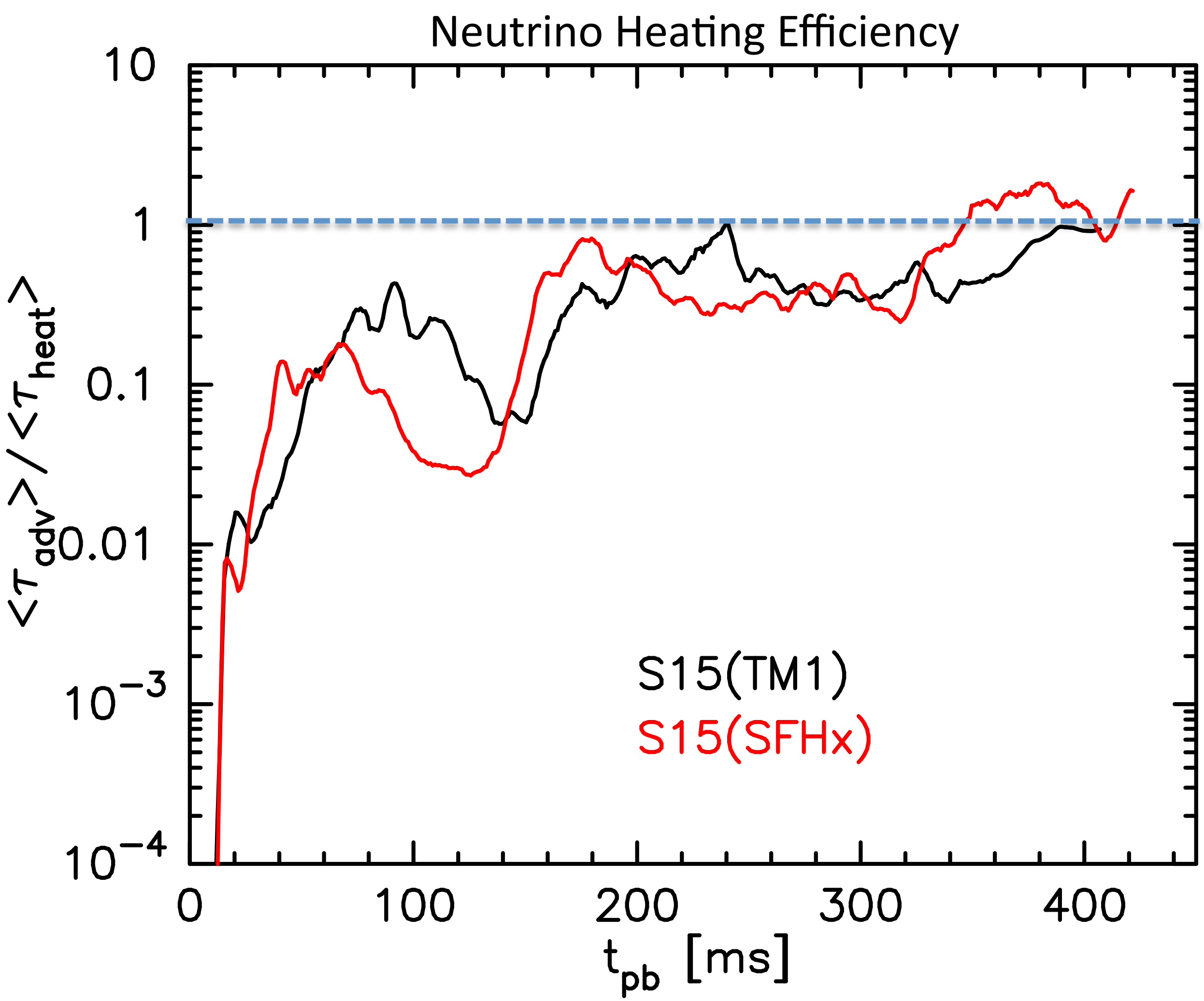
$$L(t) = 2 \int_{\text{vis.hem.}} dA \, \cos\vartheta \, F_e(\boldsymbol{R}, t) \left(1 + \frac{3}{2}\cos\vartheta\right)$$

Tamborra+,'14

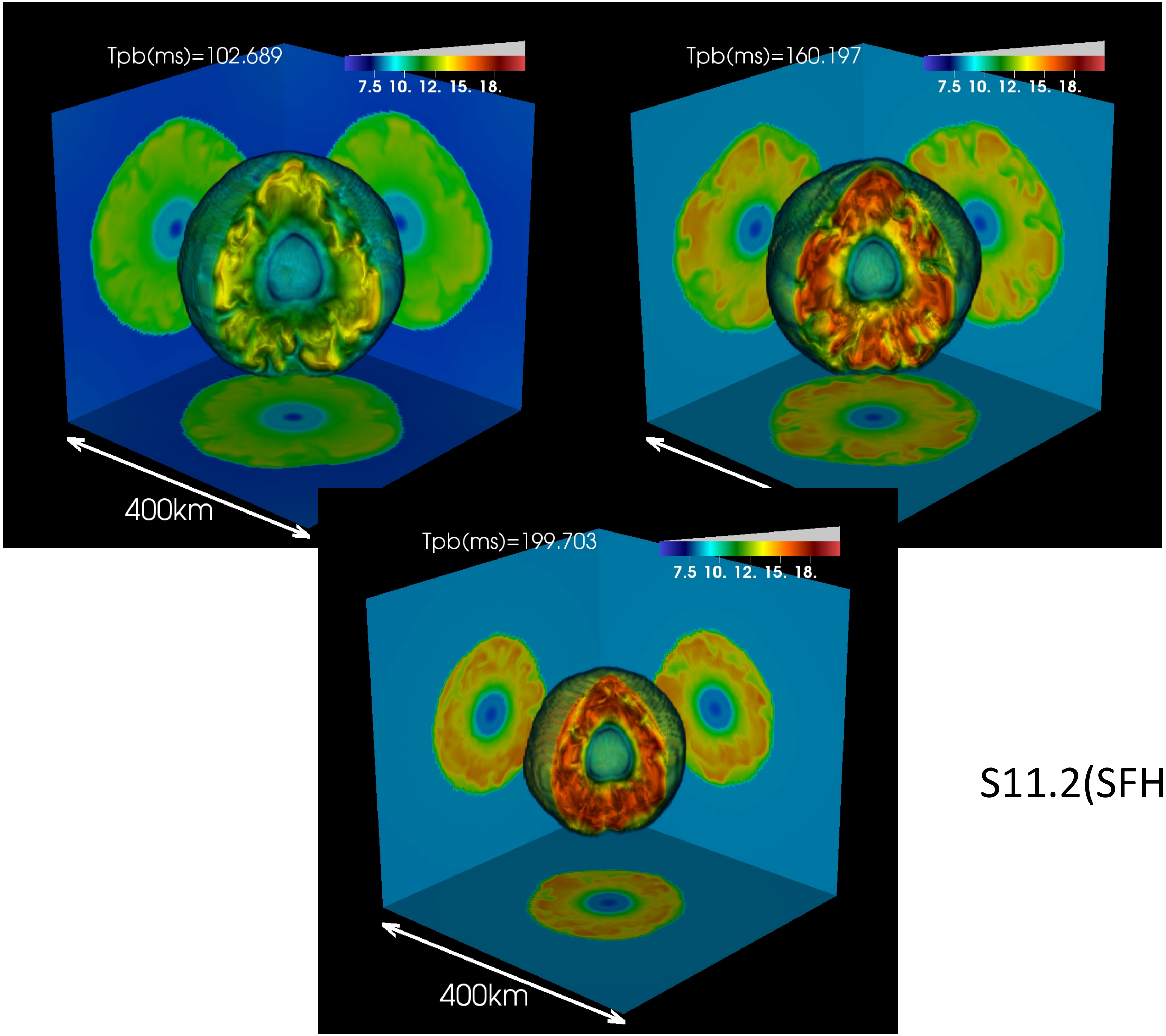


The softer EOS model shows higher neutrino luminosities

EOS Dependence on SN dynamics



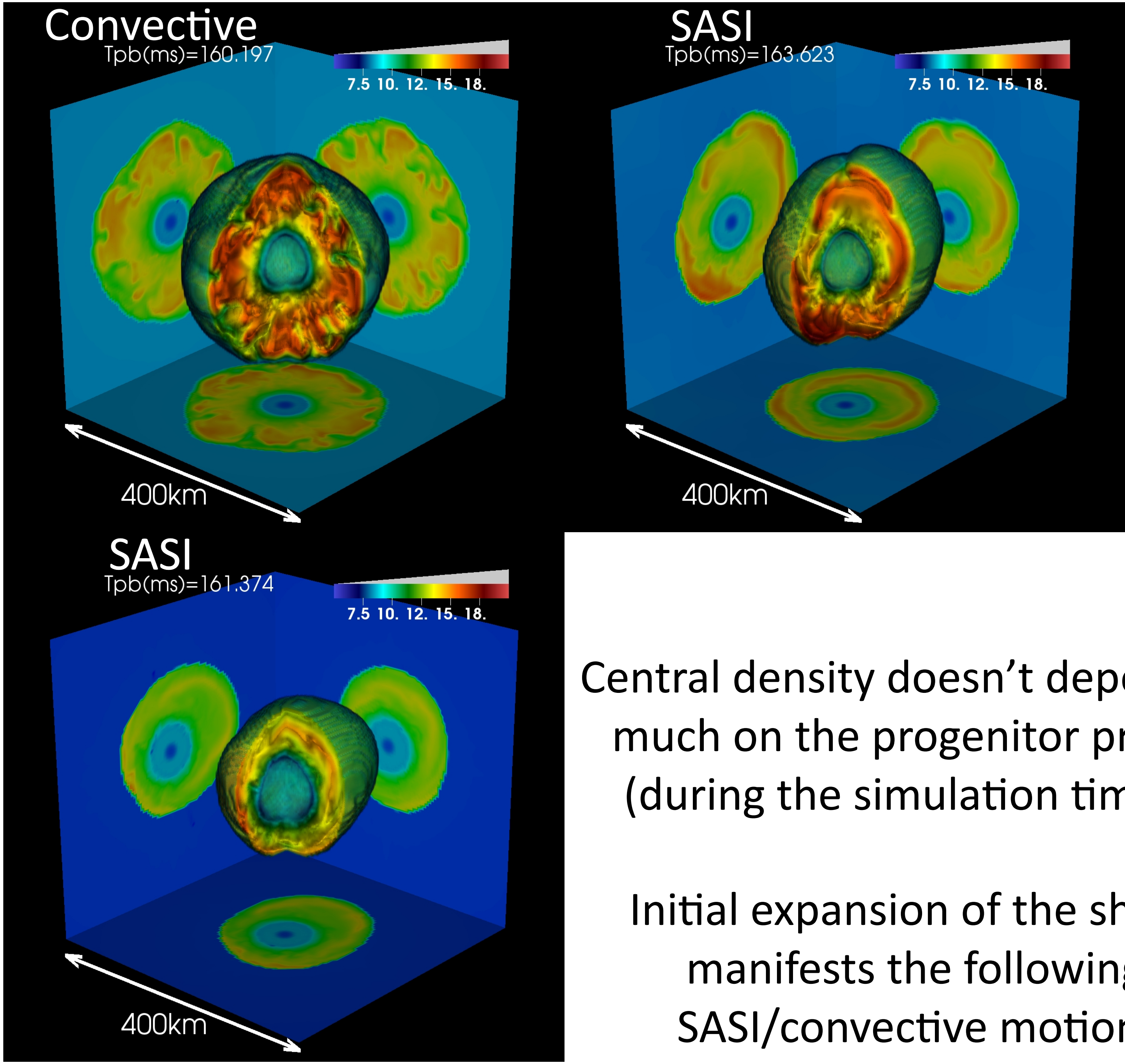
The softer EOS model shows higher efficiency in the neutrino heating


Tpb(ms)=102.689
7.5 10. 12. 15. 18.
400km
Tpb(ms)=160.197
7.5 10. 12. 15. 18.
Tpb(ms)=199.703
7.5 10. 12. 15. 18.
400km

S11.2(SFHx)

S11.2

S15.0

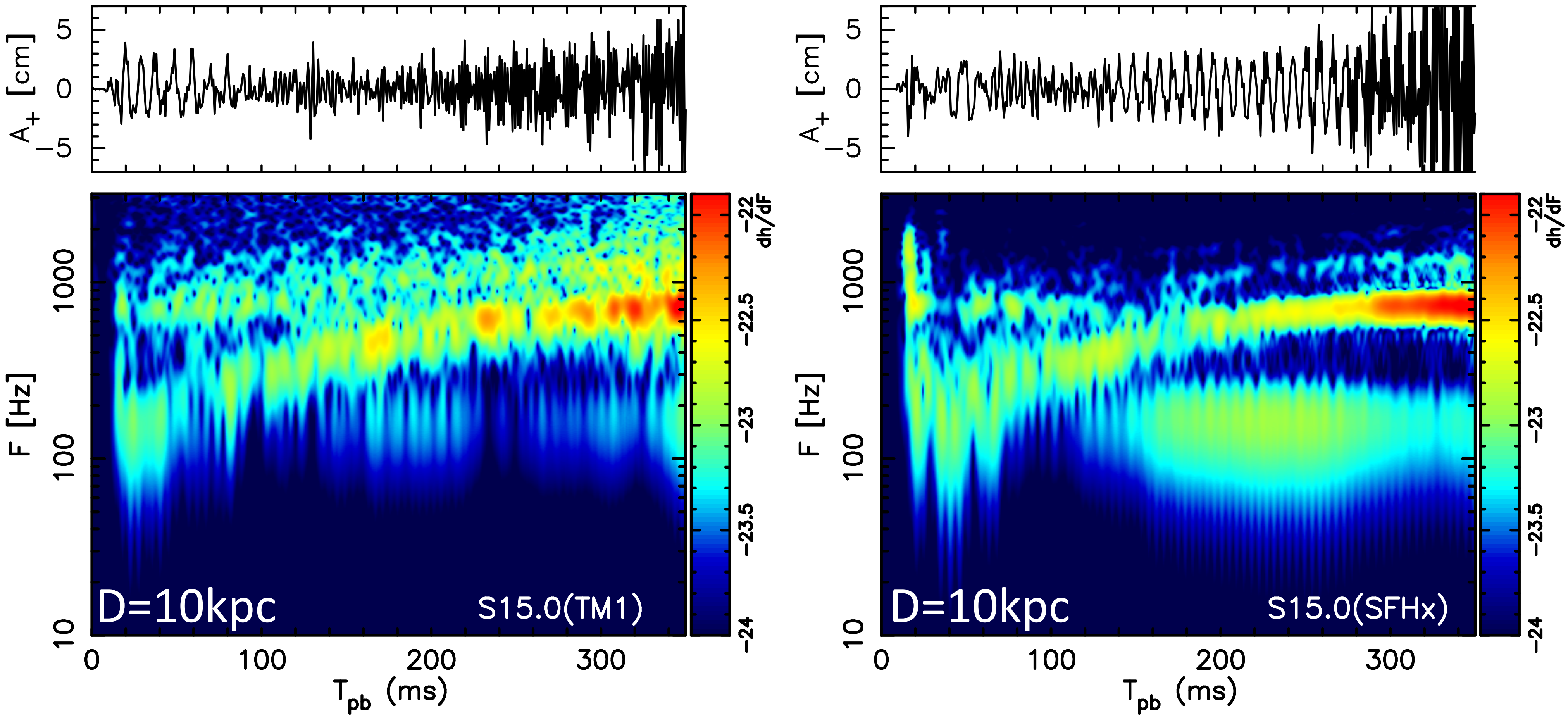


S40.0

Central density doesn’t depend so much on the progenitor profile (during the simulation time!!)

Initial expansion of the shock manifests the following SASI/convective motion.

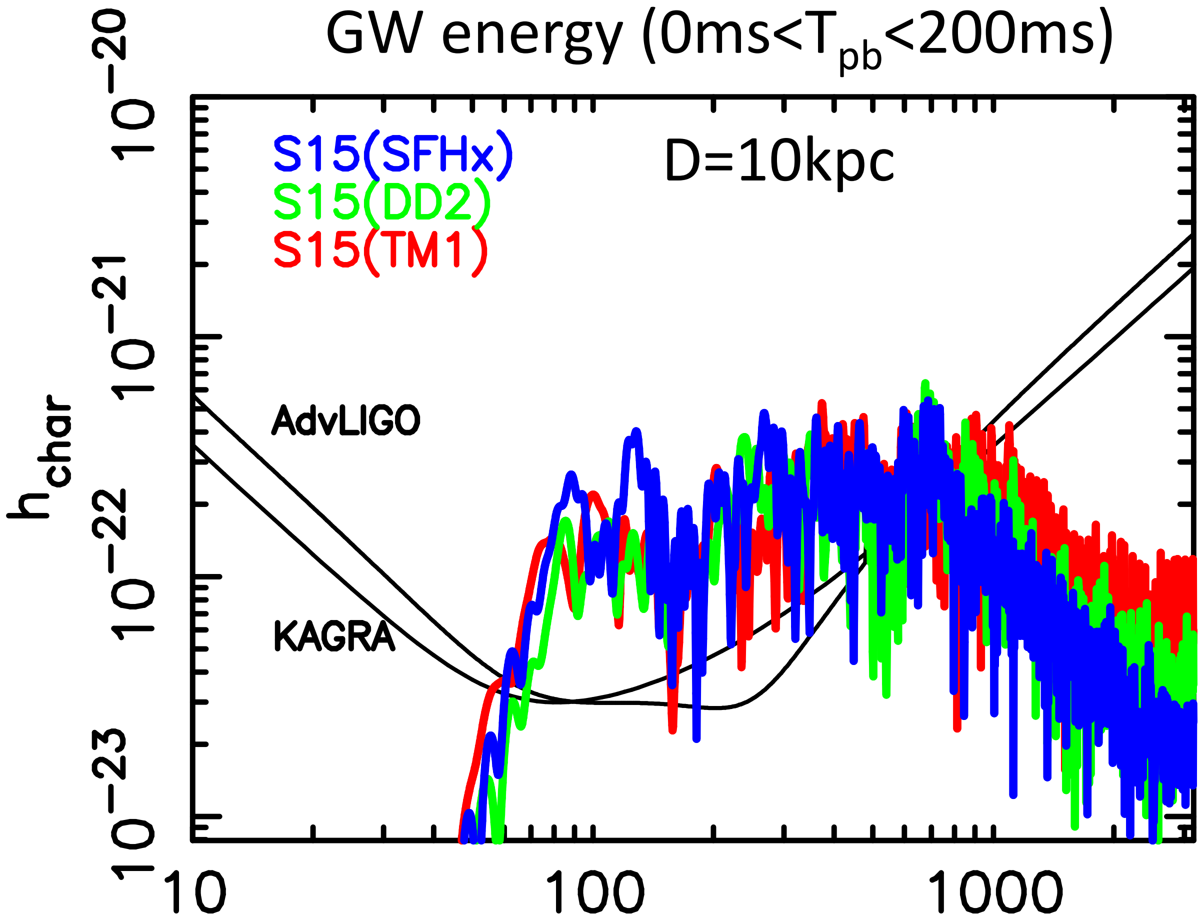
EOS Dependence on GW Emissions



Low frequency component appears
with the violent SASI activity.

EOS Dependence on GW Emissions

Spectra of cumulative
GW energy (0ms<T_{pb}<200ms)



Strength of GWs

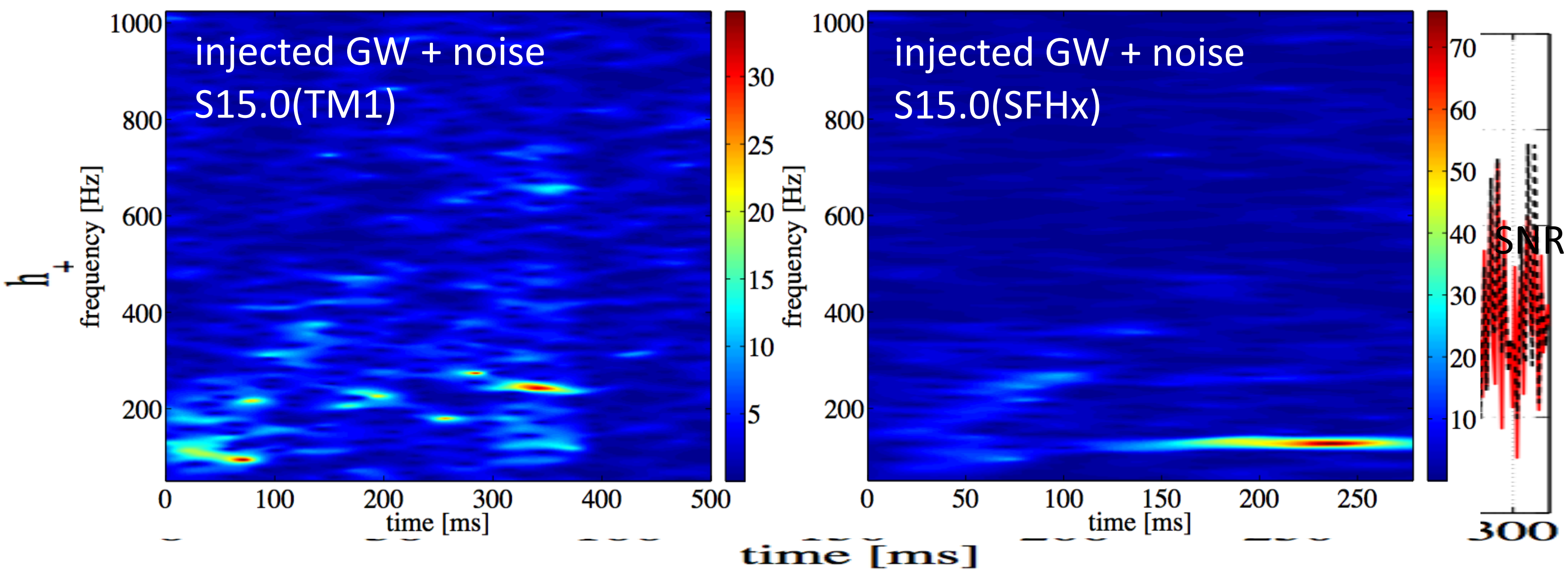
@ higher tail → TM1>DD2>SFHx

@ lower frequency → SFHx is the strongest

Coherent Network Analysis of GWs

We performed coherent network analysis
(Hayama, KT, Takiwaki & Kotake,’15, arXiv:1501.00966).

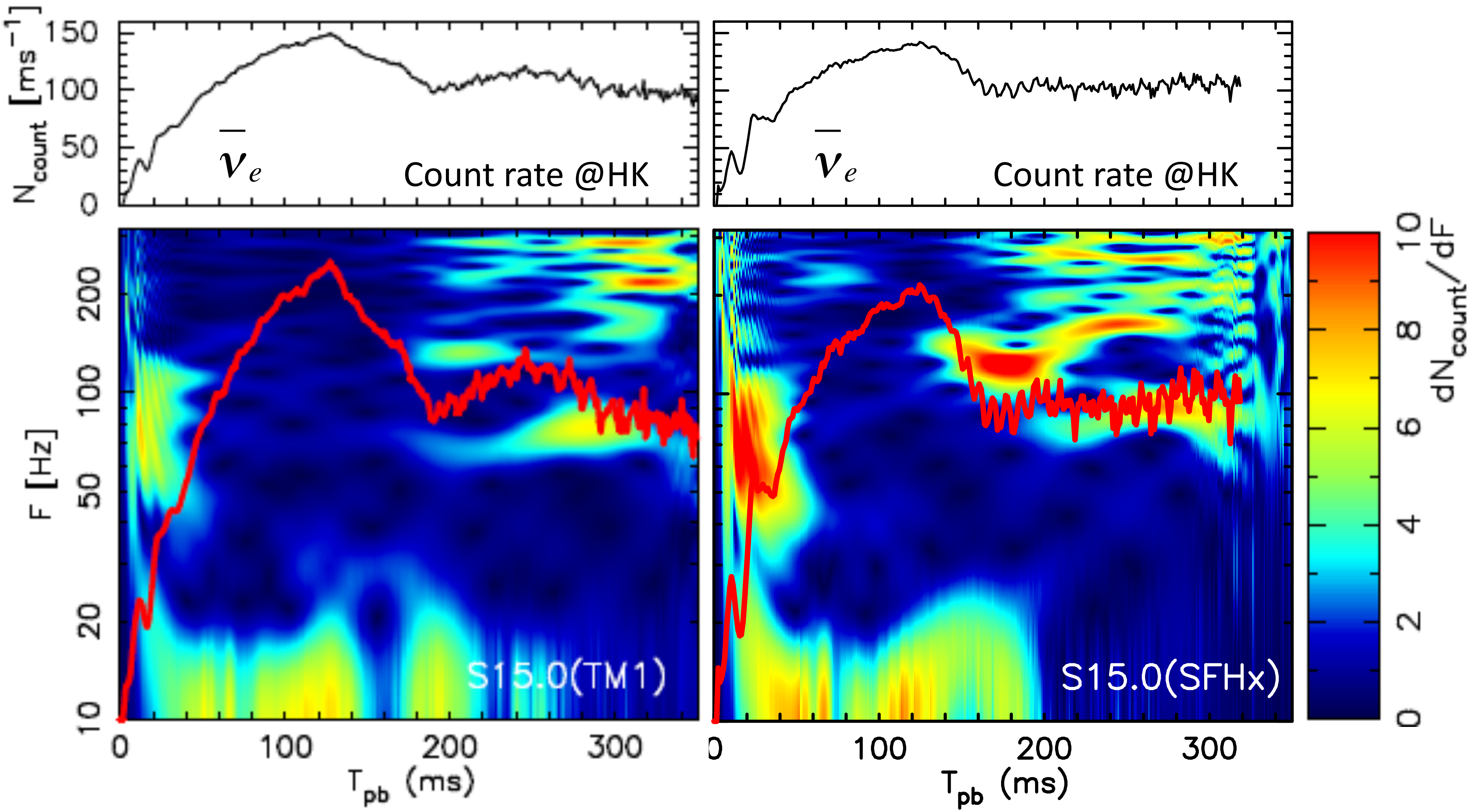
We used the RIDGE pipeline (Hayama+,’07)
which takes full advantage of the global network
of LIGO-(H/L), VIRGO & KAGRA. We consider location of each
detectors, sky-map position of the source, etc.



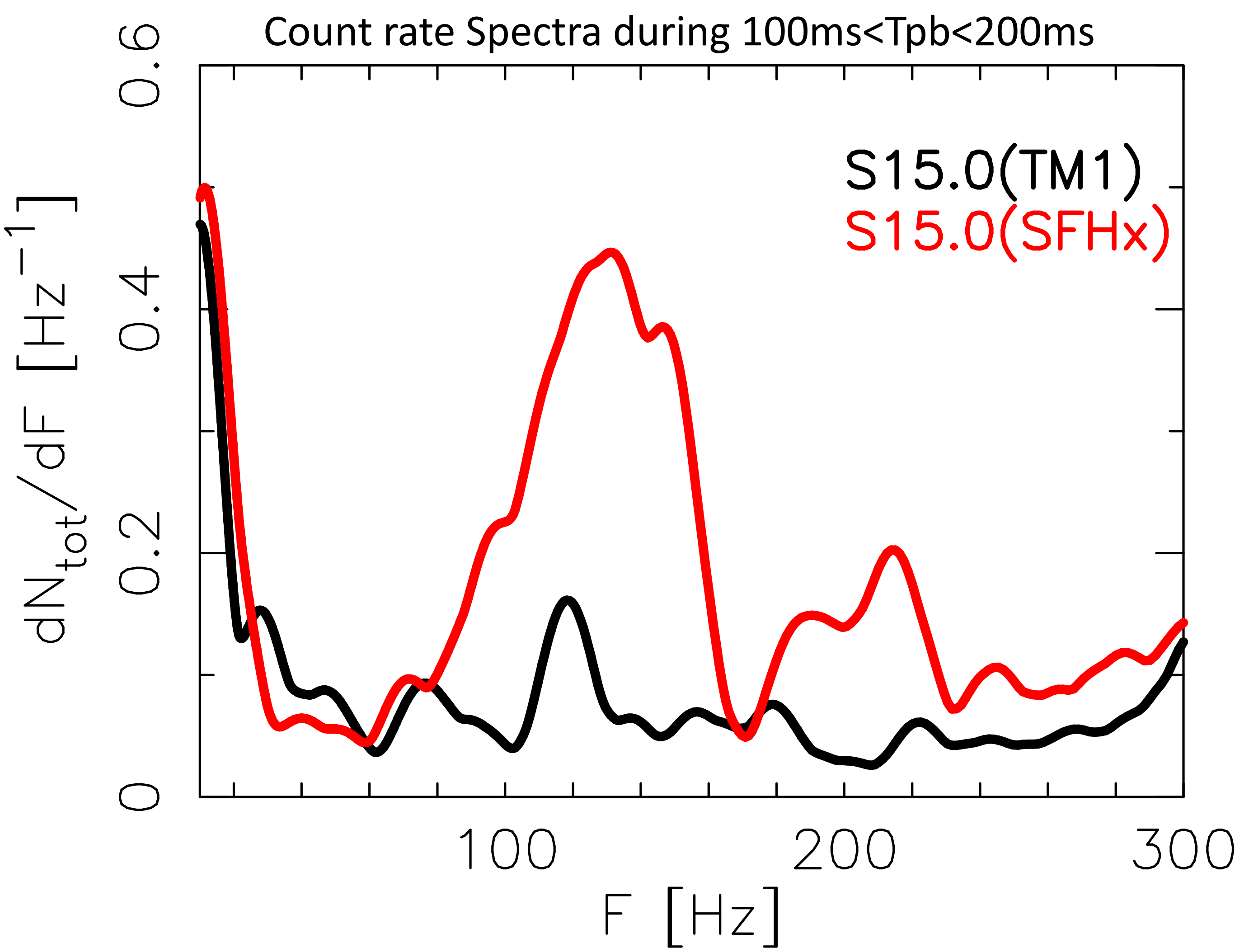
EOS Dependence on Neutrino Emissions

Tamborra+,'14

$$L(t) = 2 \int_{\text{vis.hem.}} dA \cos\vartheta \, F_e(\boldsymbol{R}, t) \left(1 + \frac{3}{2}\cos\vartheta\right)$$



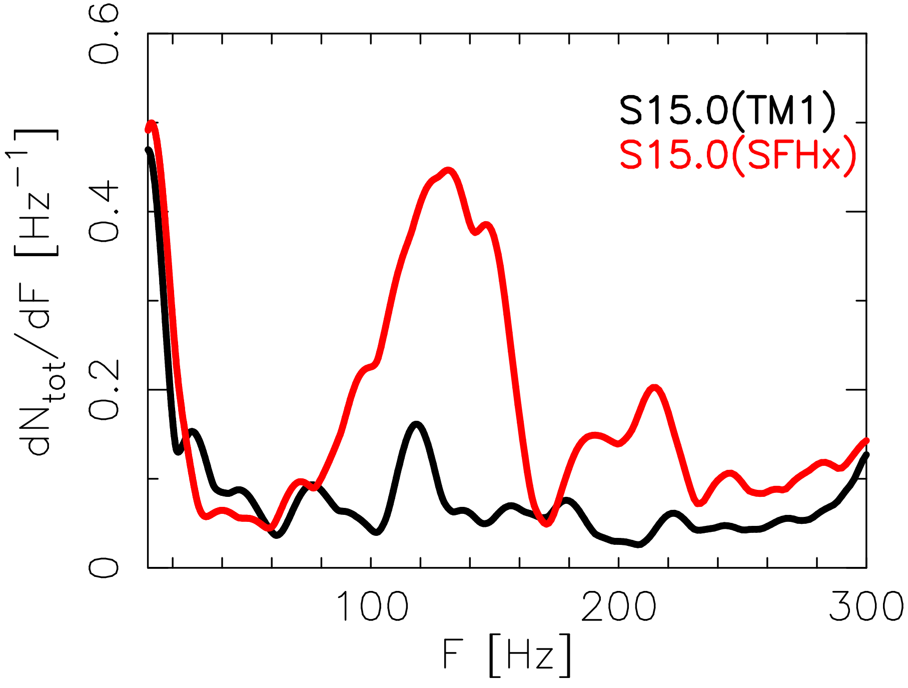
EOS Dependence on Neutrino Emissions

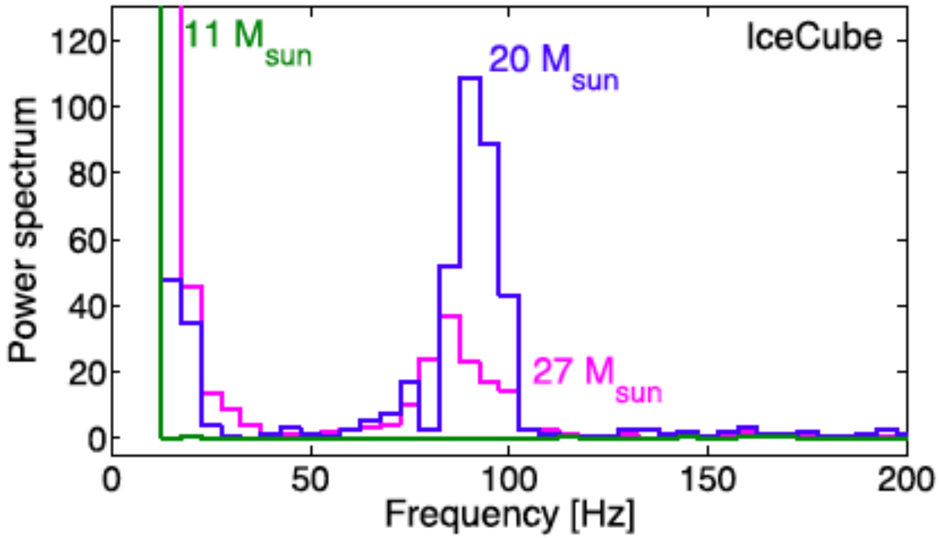


SASI modulation appears clearly at F~100Hz

EOS Dependence on Neutrino Emissions

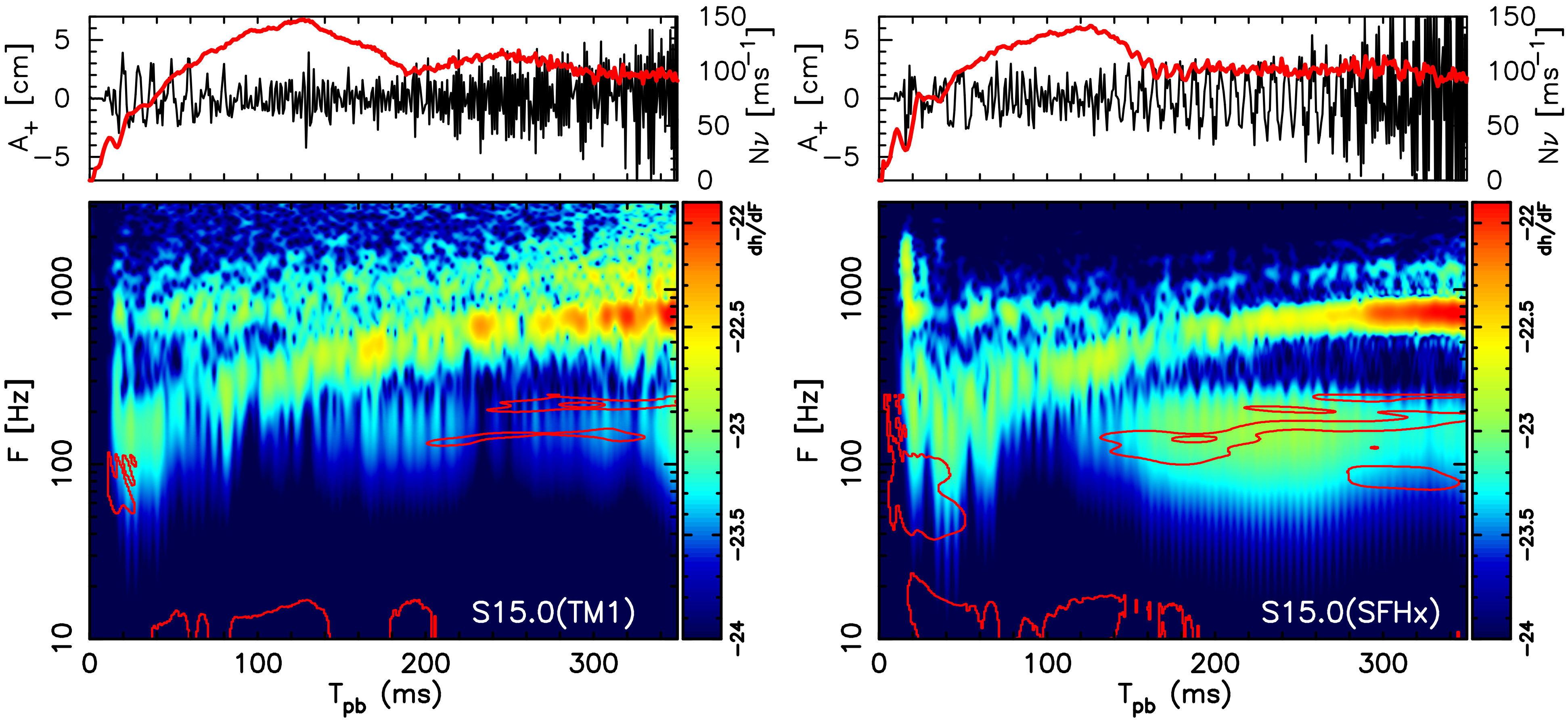
SASI modulation is also seen in more sophisticated neutrino-transport calculation





Tamborra+,'13

Coherence of GWs and Neutrinos associated with SASI modulation



SASI activity can actually be imprinted in both GW and neutrino profiles

Summary

•Softer EOS (more compact progenitor profile) instigate SASI activity more efficiently
•Rapid expansion of the prompt shock hinders SASI development
•SASI modulation is imprinted in both GW/Neutrino @~100Hz (@130Hz in S15.0(SFHx))
•From coherent network analysis, GW signals associated with SASI modulation, have SNR~70 (S15,SFHx) @D=10kpc.