Understanding Systematics and Sensitivity in Predicting GWs from CCSNe

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Key questions:

What level of fidelity is needed in modeling?

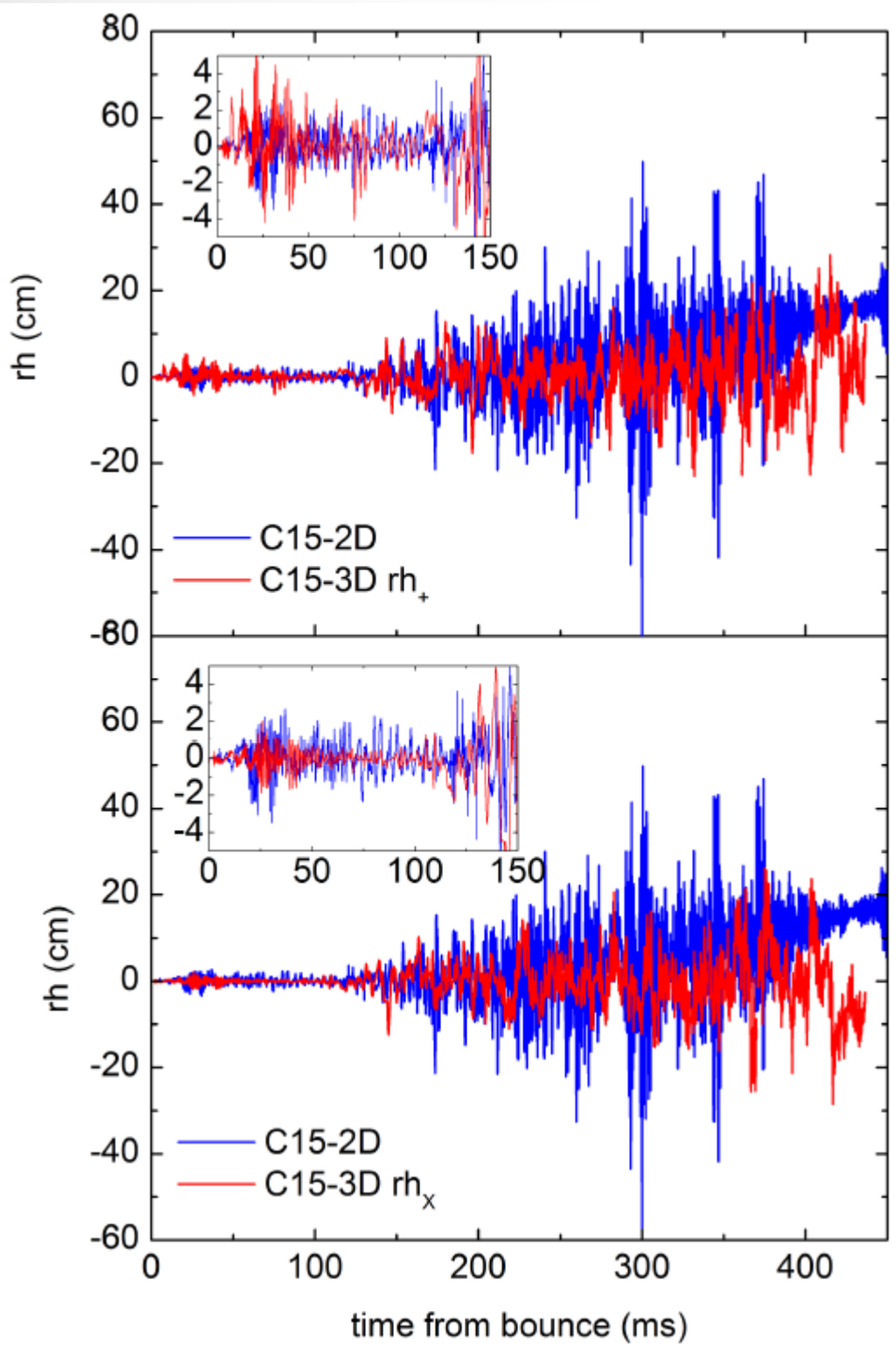
Is 3D required?

How sensitive are GW detectors to: EOS, weak physics, progenitor, rotation, electron capture rates, etc.?

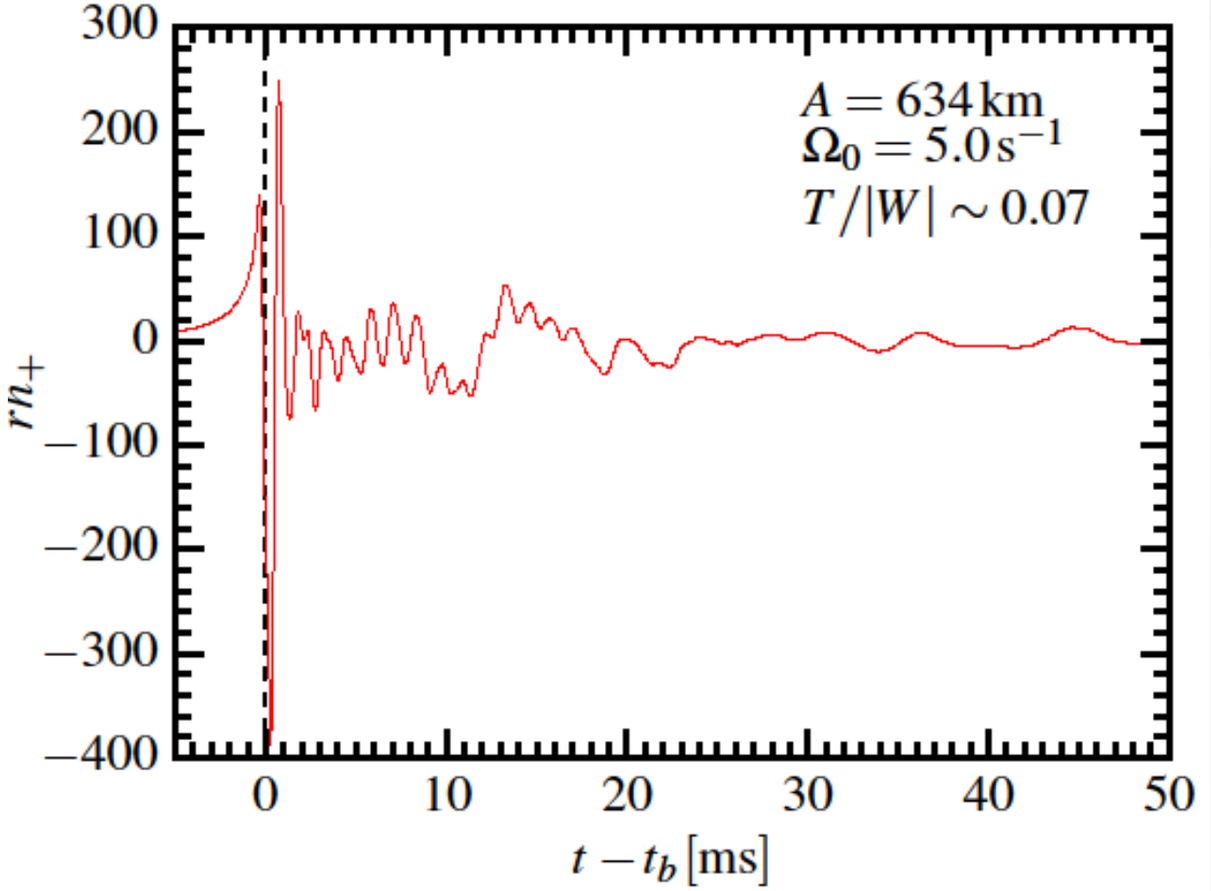
Can correlations between neutrino and GW emission be used to improved likelihood of CCSN detection?

Can we use long timescale emission to improve detection likelihood?

What is “Rapidly Rotating”?



Yakunin+17

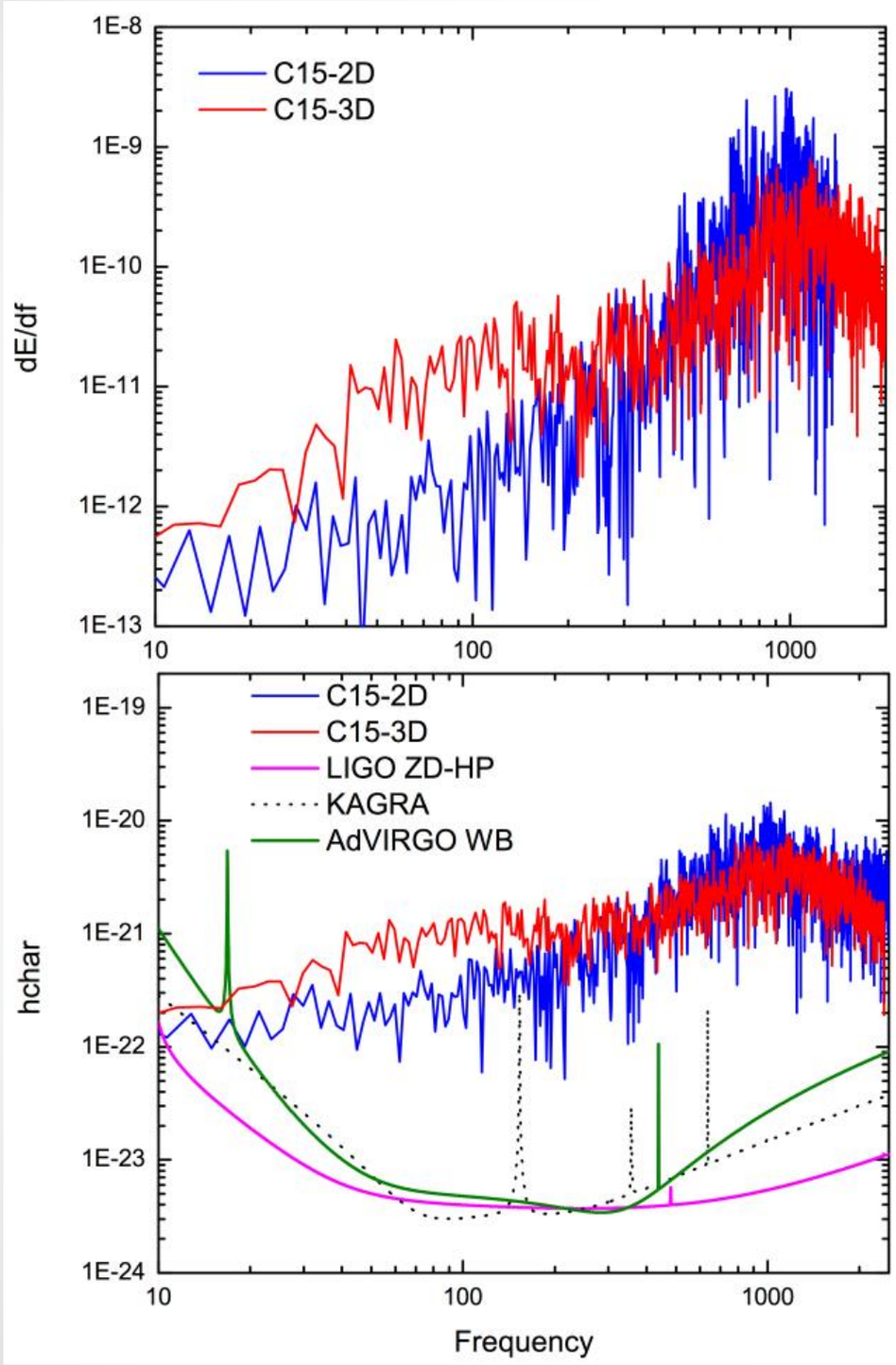


Similar h when $\frac{T}{|W|}$ ~0.1%

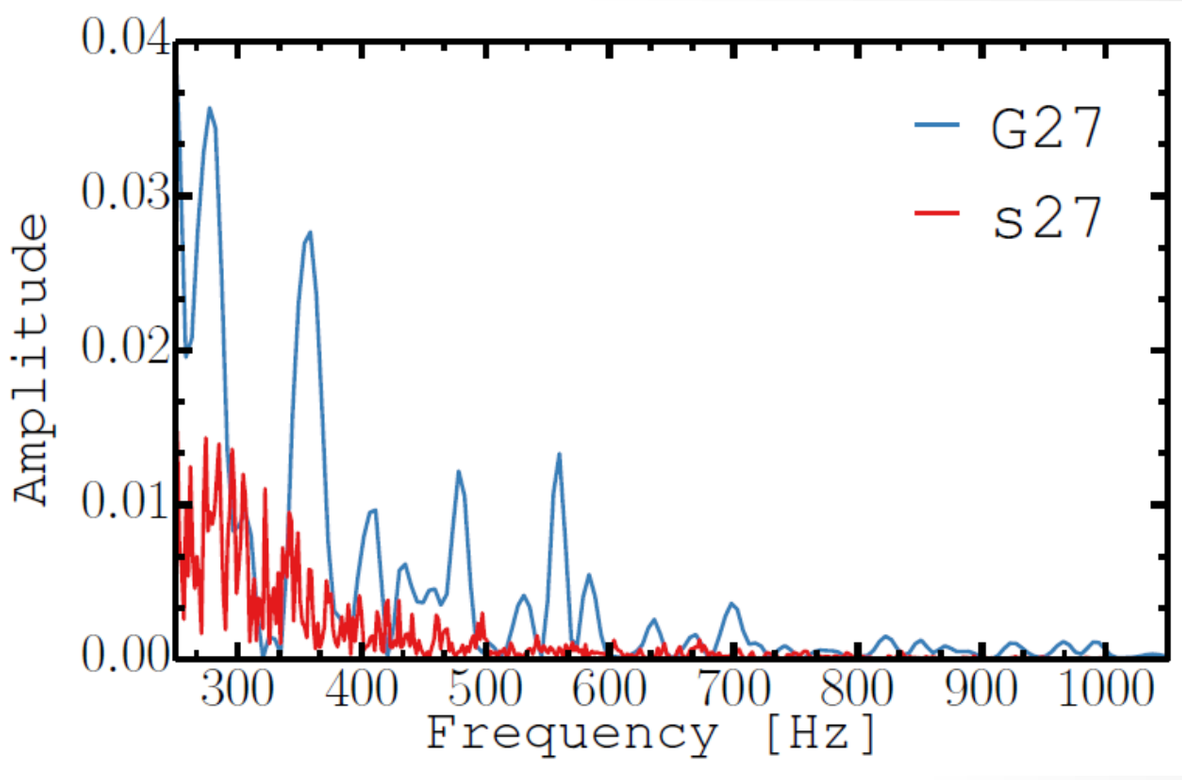
→ Rotating SNR≈ 0.1 @10kpc

Rapid rotation is rare (~1%)

2D vs. 3D (Non-rotating)



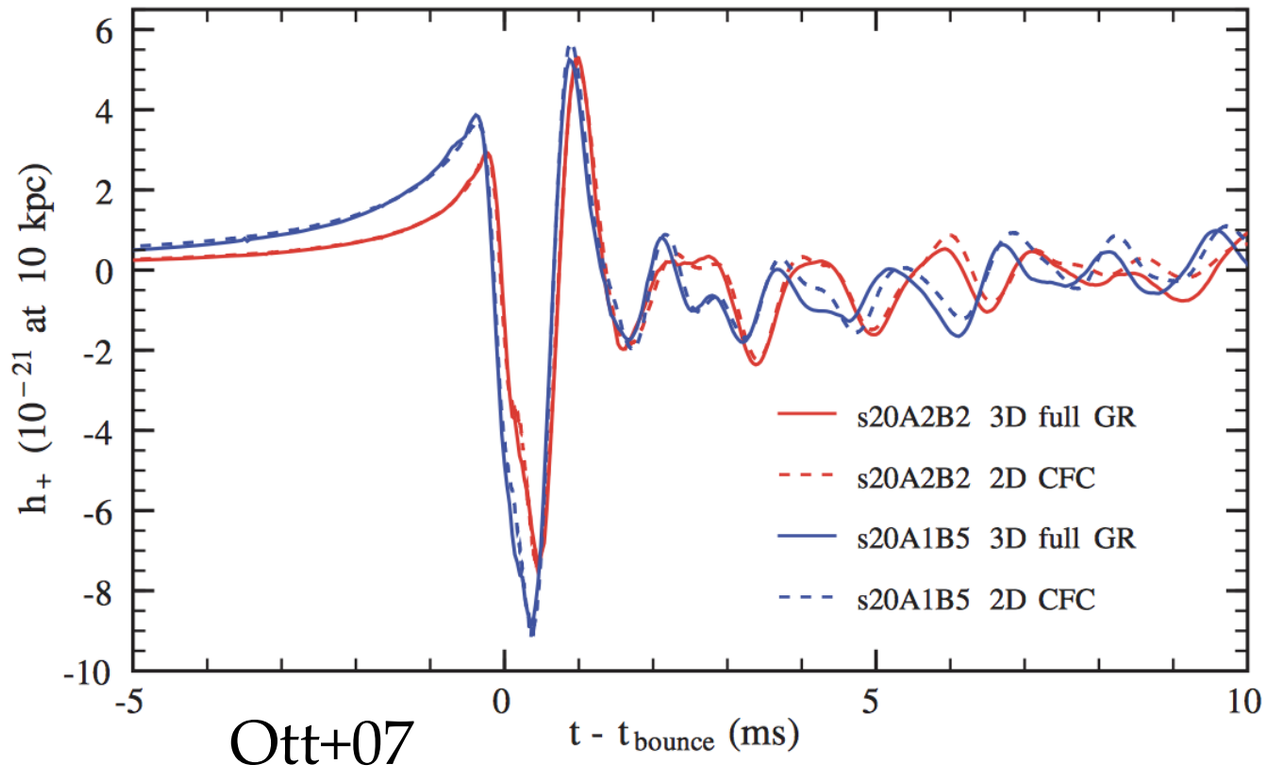
Yakunin+17



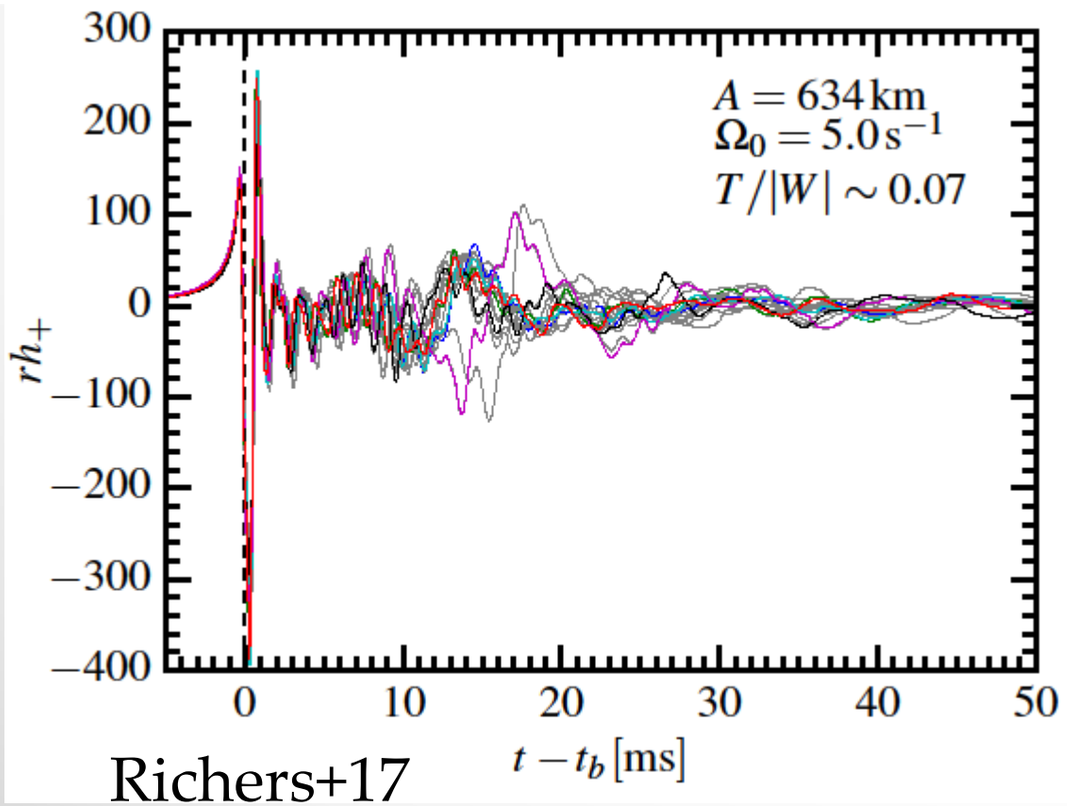
Andresen+16

- 2D turbulence → large scales
- 3D turbulence → small scales
- 2D GWs have larger amplitude, more SASI

2D vs. 3D (Rotating)



Ott+07



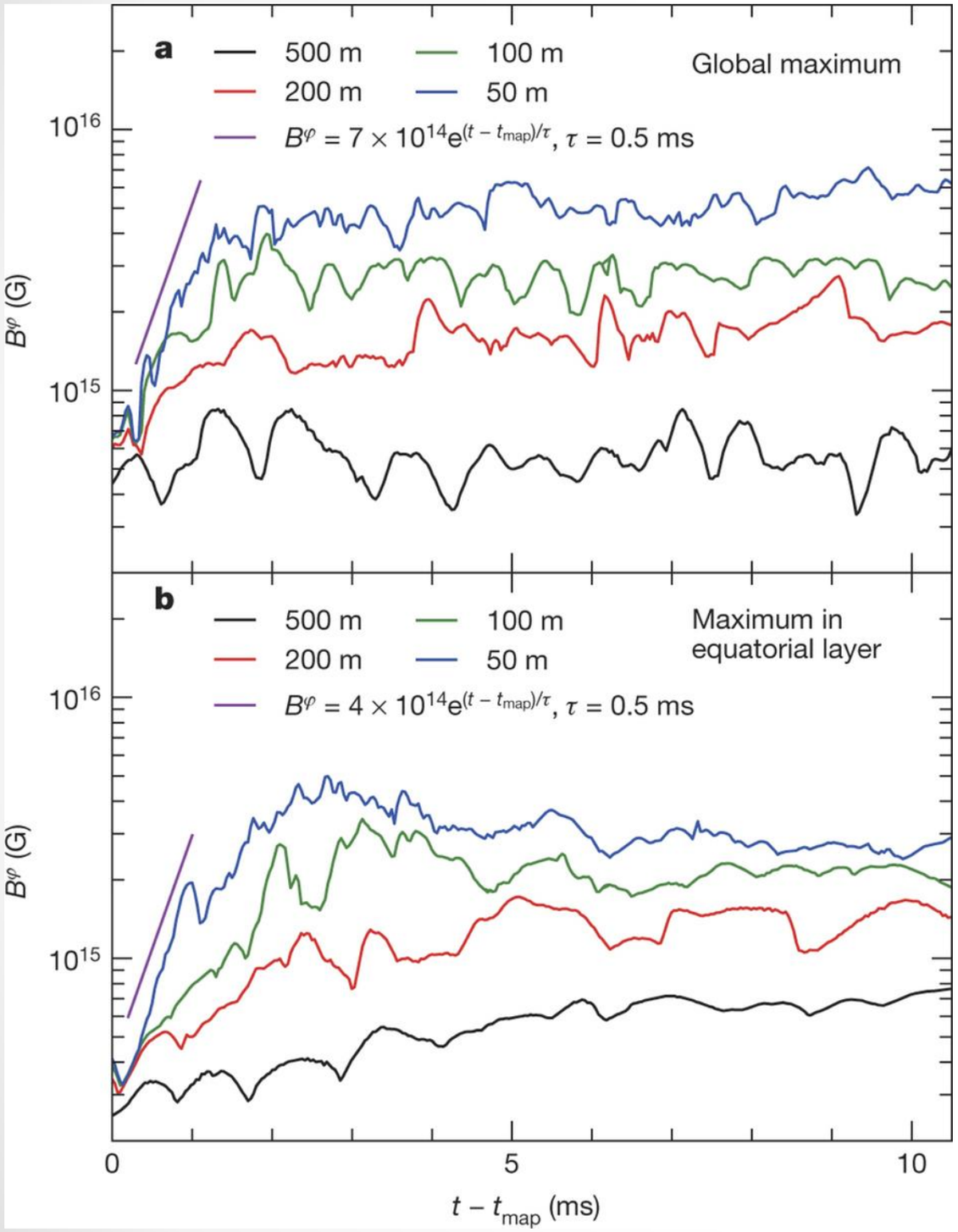
Richers+17

Little effect on early (deterministic) signal (~1%)

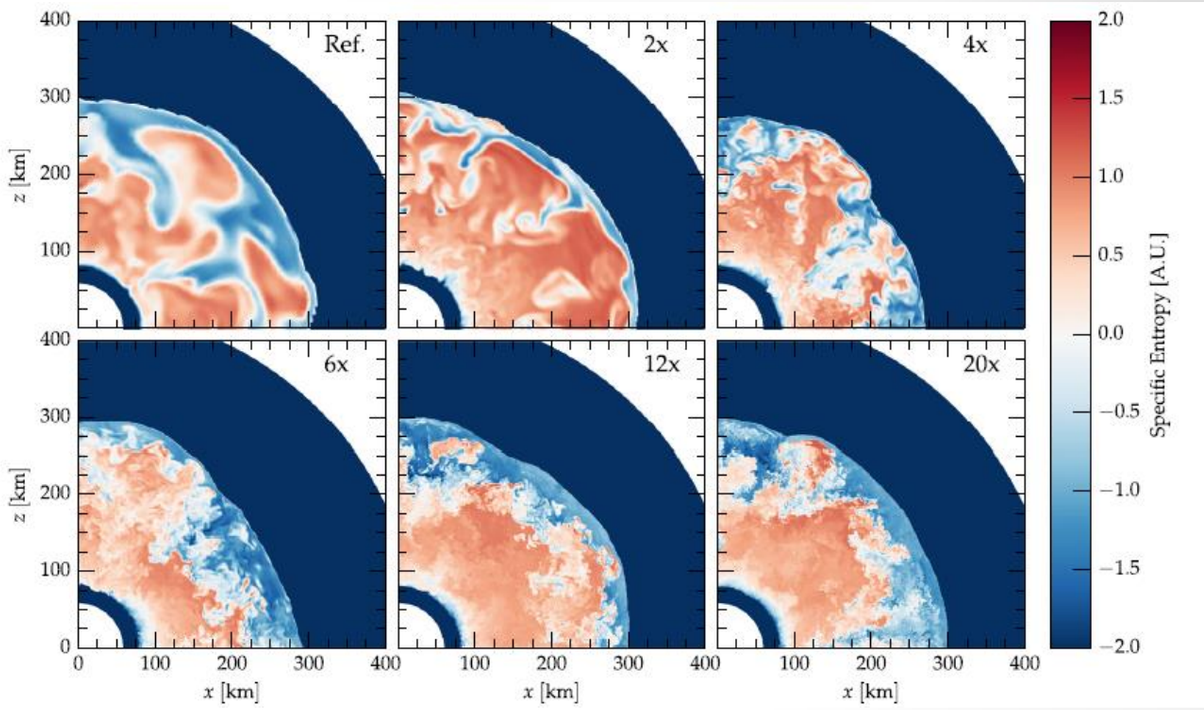
Later (turbulent) signal dependent on 3D

[not well-explored]

Numerical Resolution



Mösta+15



Radice+16

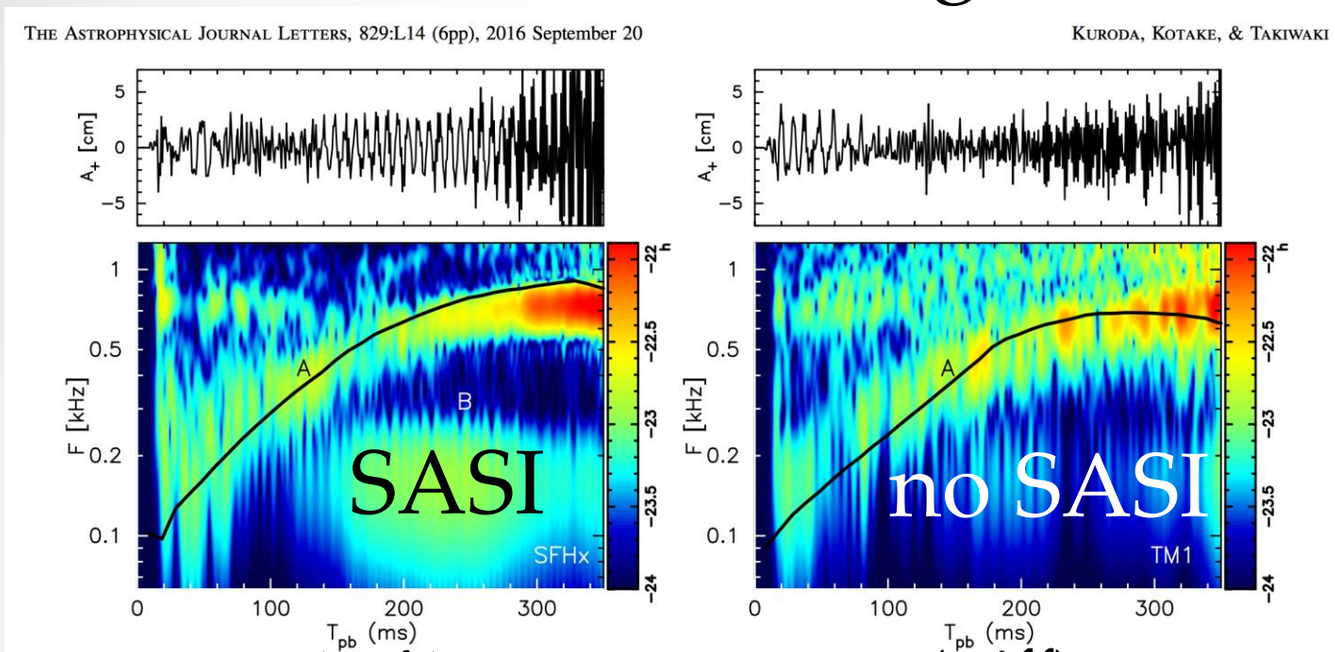
3D simulations require 10M+ core hours.

Many are still under-resolved

Affects long-term evolution of GWs

Equation of State

Non-Rotating

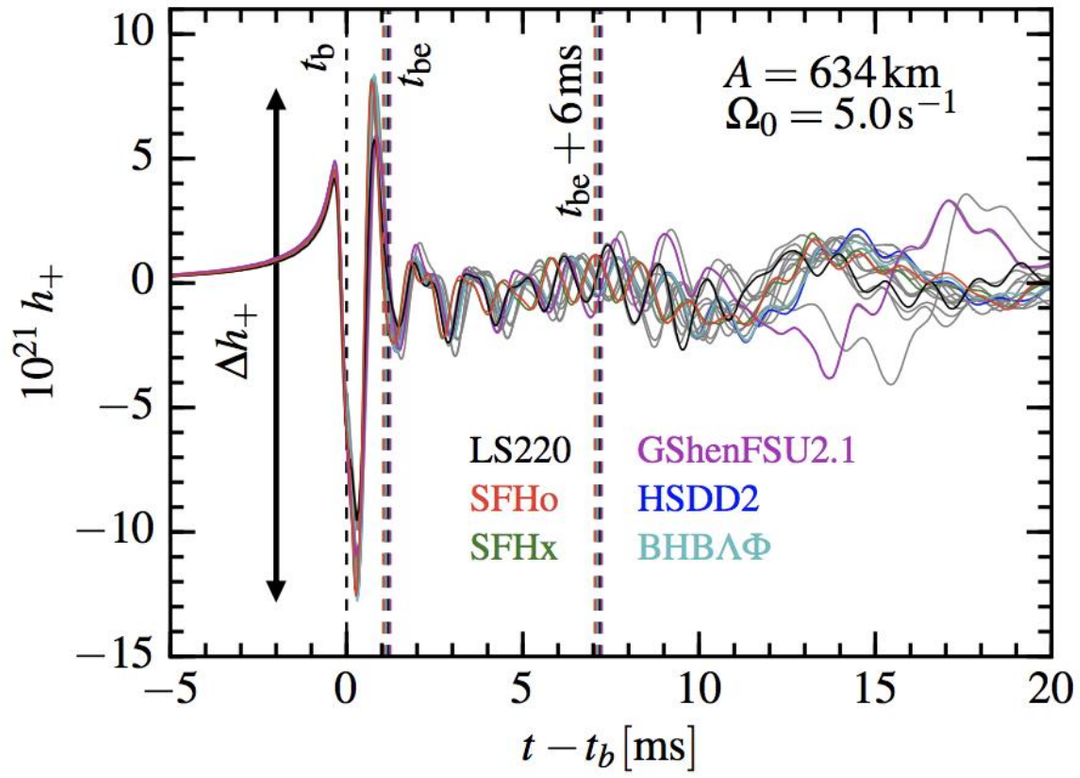


(soft) (stiff)

Kuroda+16

- Soft EOS → Strong SASI at later times
- SASI → low-frequency GWs

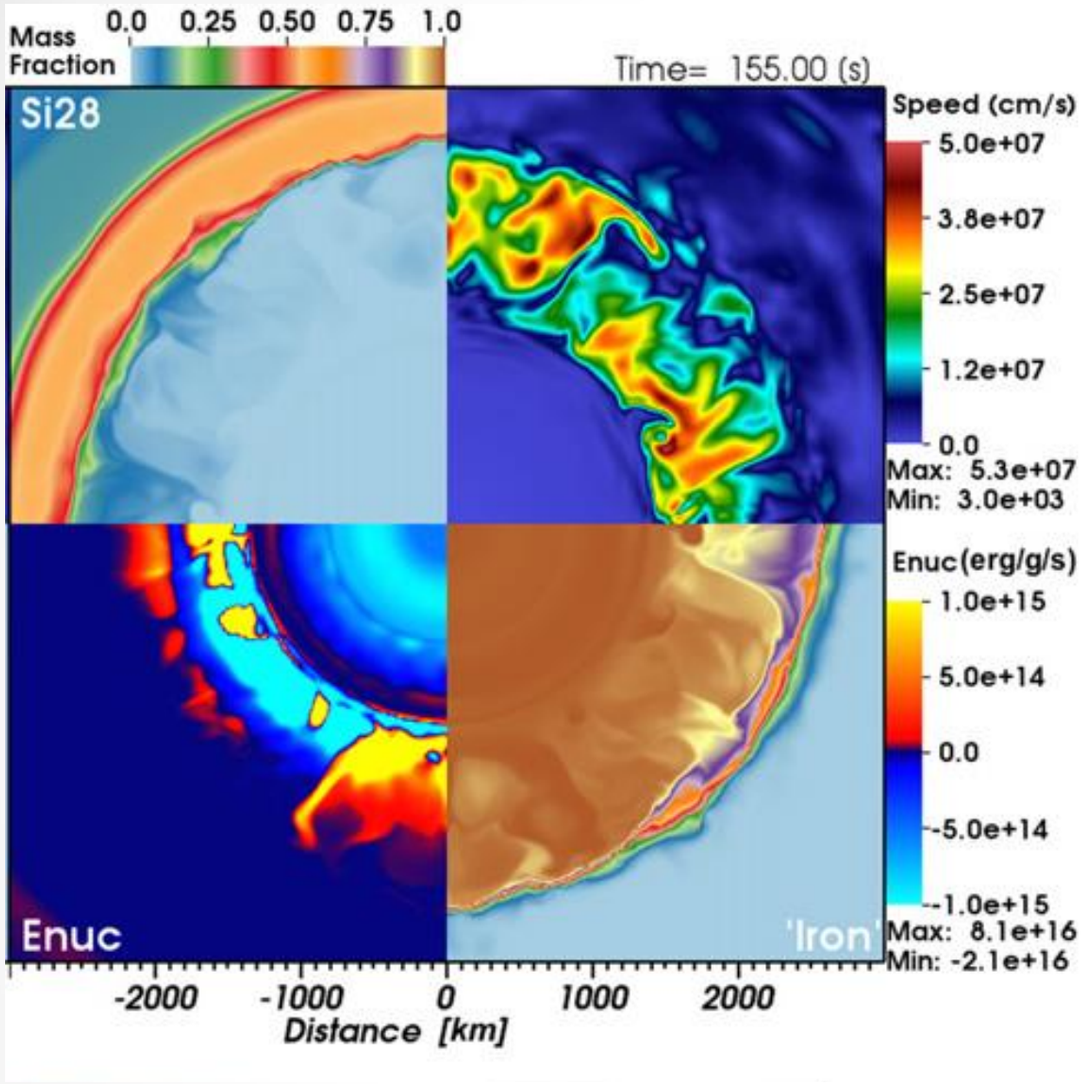
Rapidly Rotating



Richers+17

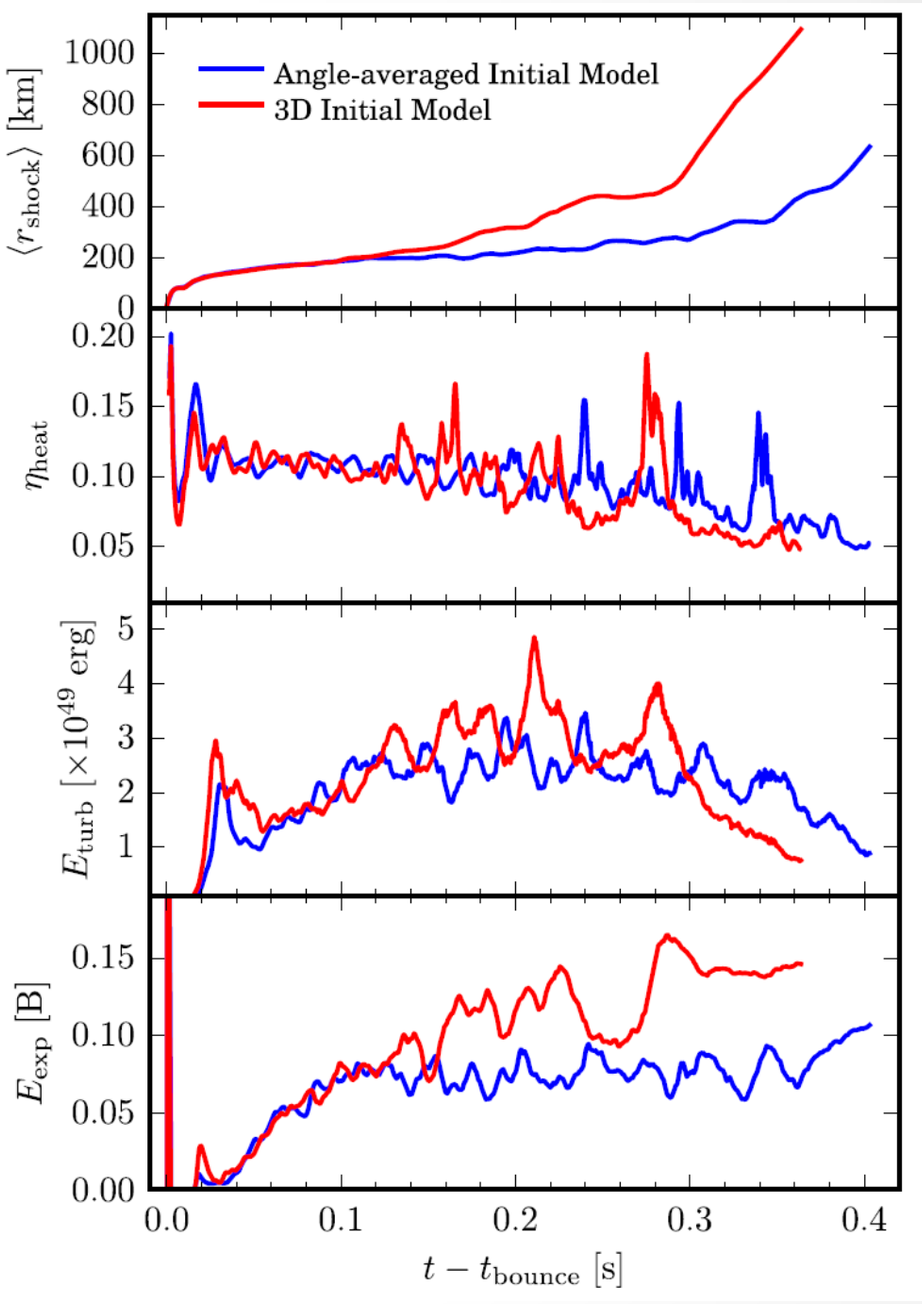
Small impact (~10%) on rotational bounce signal

Progenitor (Non-rotating)



Couch+15

Convection generates waves in iron core that are amplified during collapse.

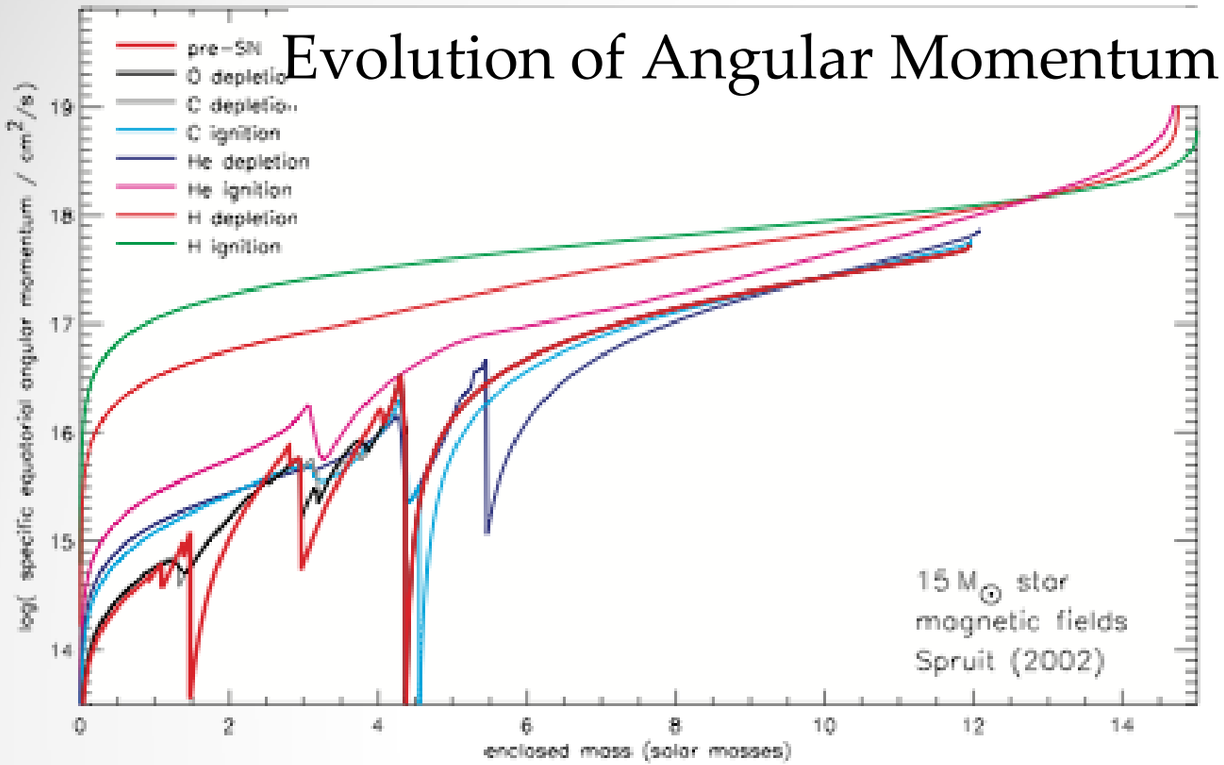


Might have an impact on bounce GW signal.

Progenitor (Rotating)

Heger+05

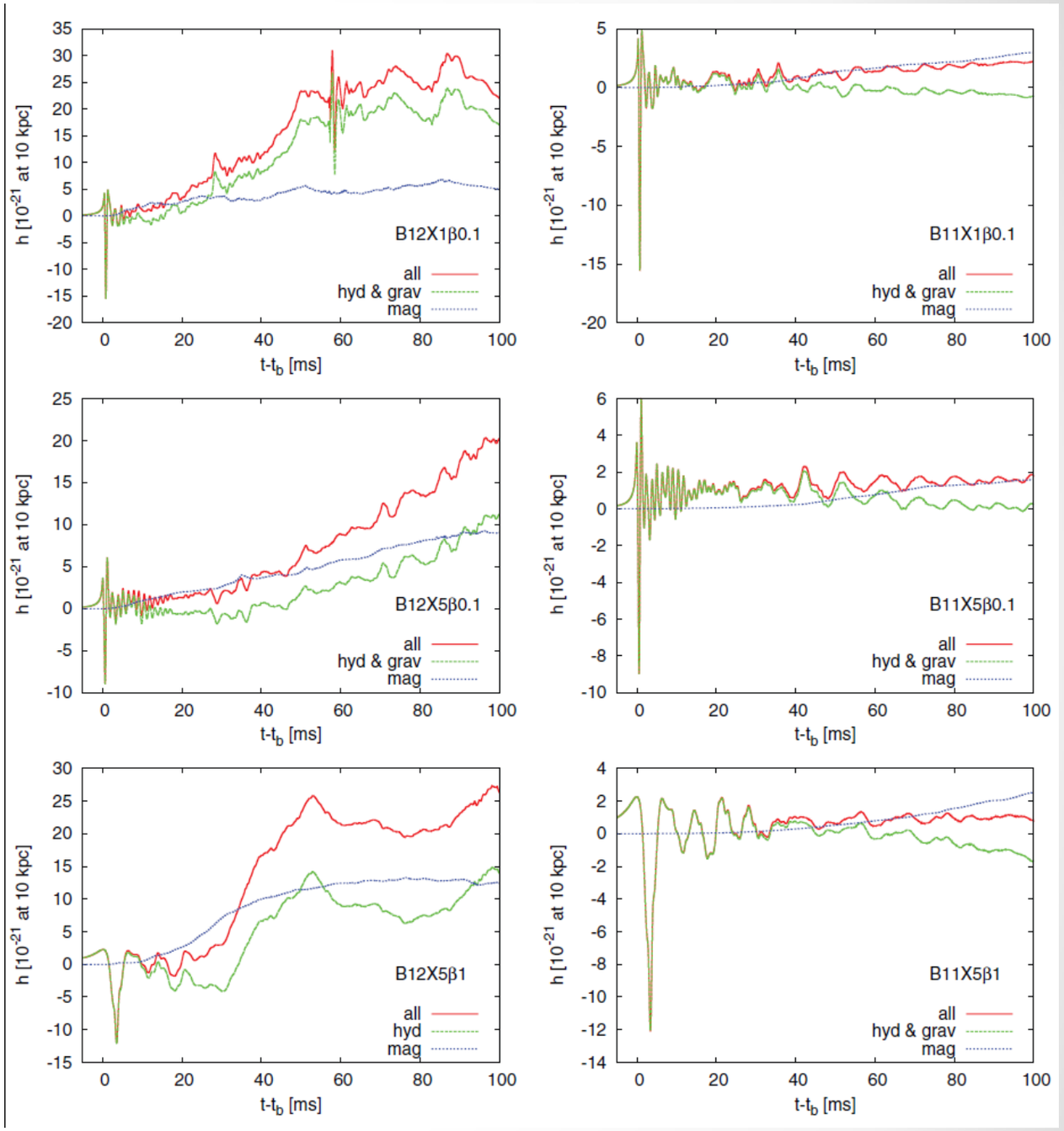
Evolution of Angular Momentum



Magnetic fields during evolution transport angular momentum out of core

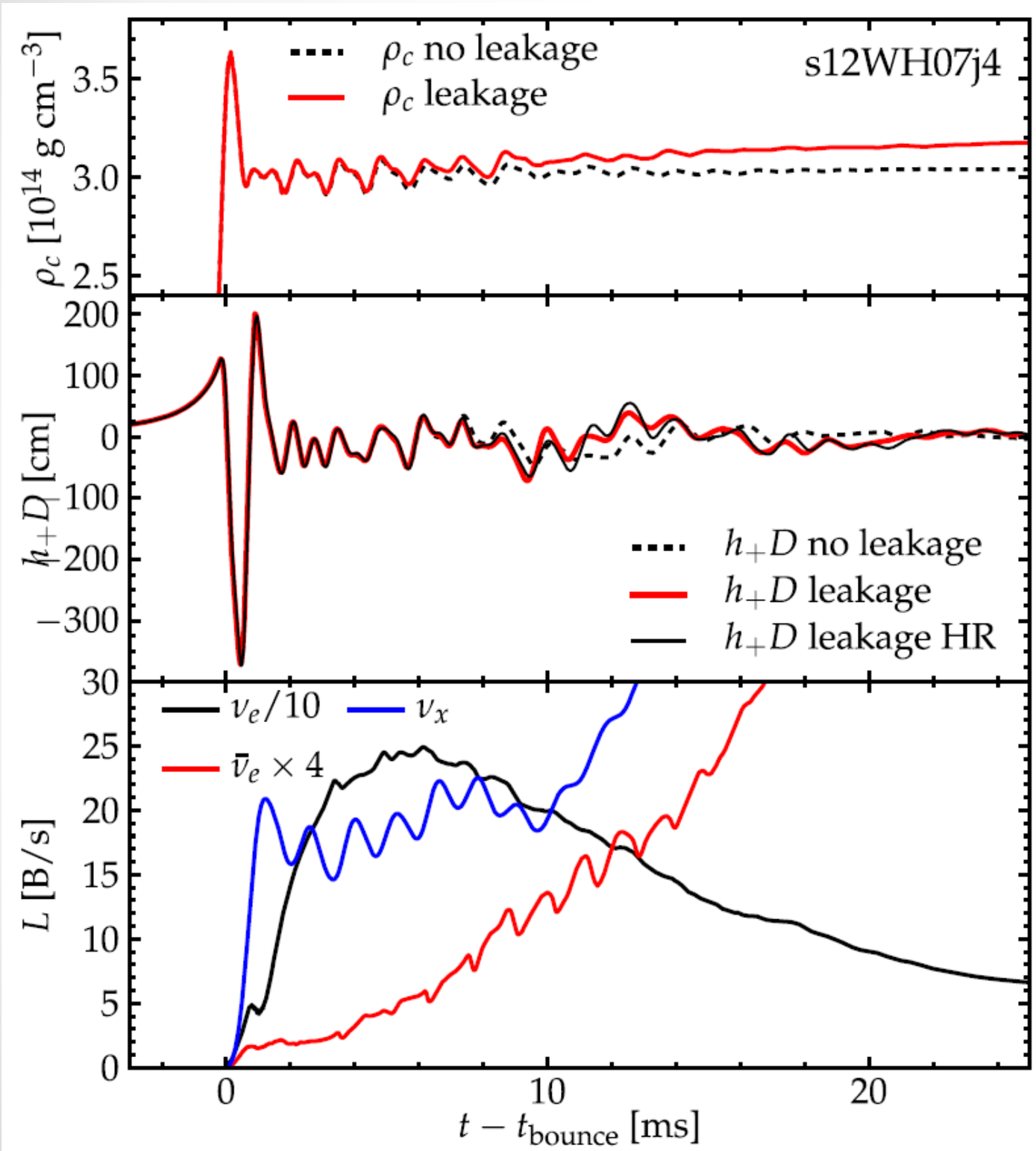
Most massive stellar cores not rotating rapidly at collapse (<1.0 rad/s)

Takiwaki+11



Only large seed fields affect GWs

Neutrino-GW Correlations



Ott+12

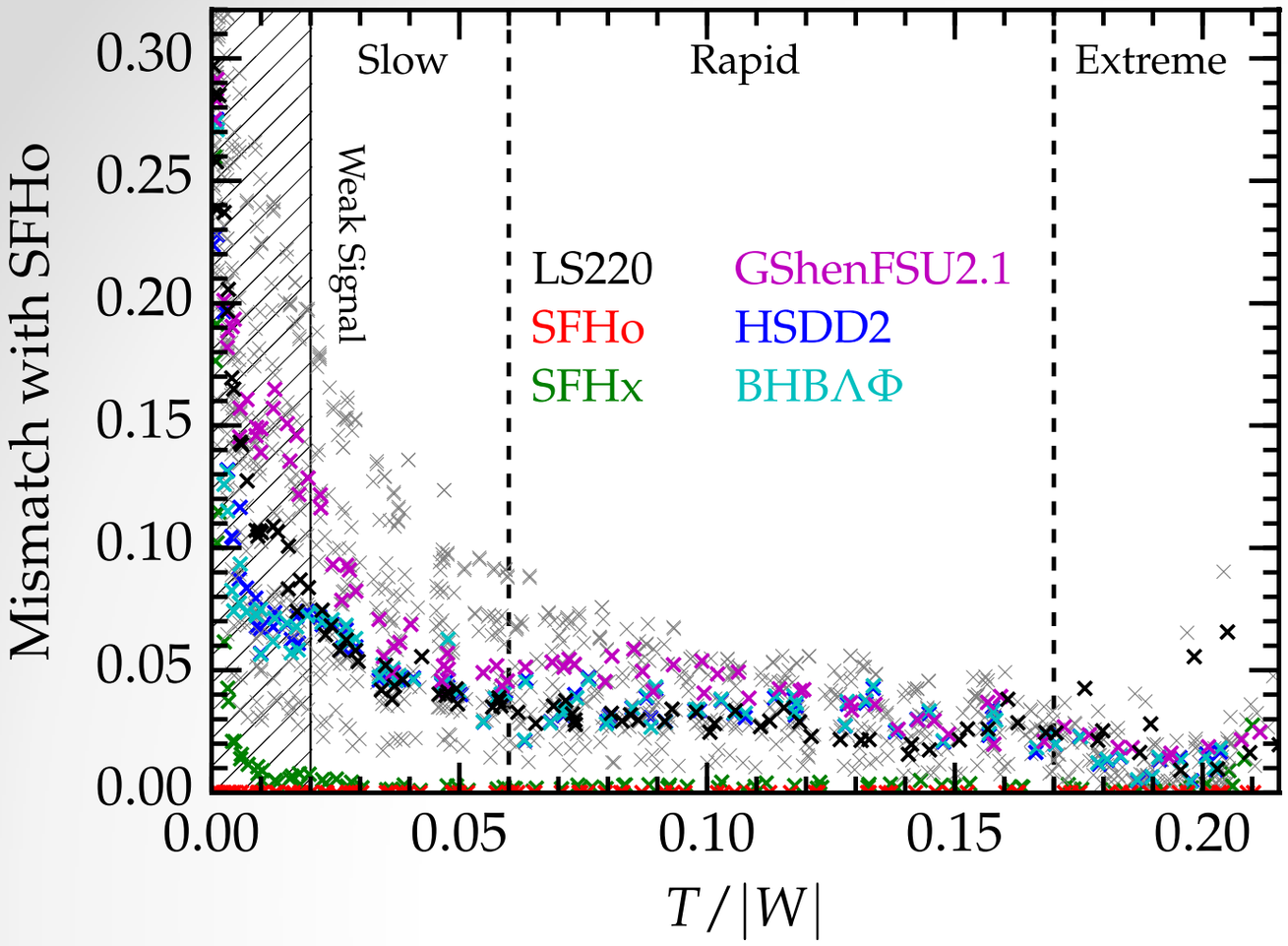
GW → dynamics
ν → thermodynamics

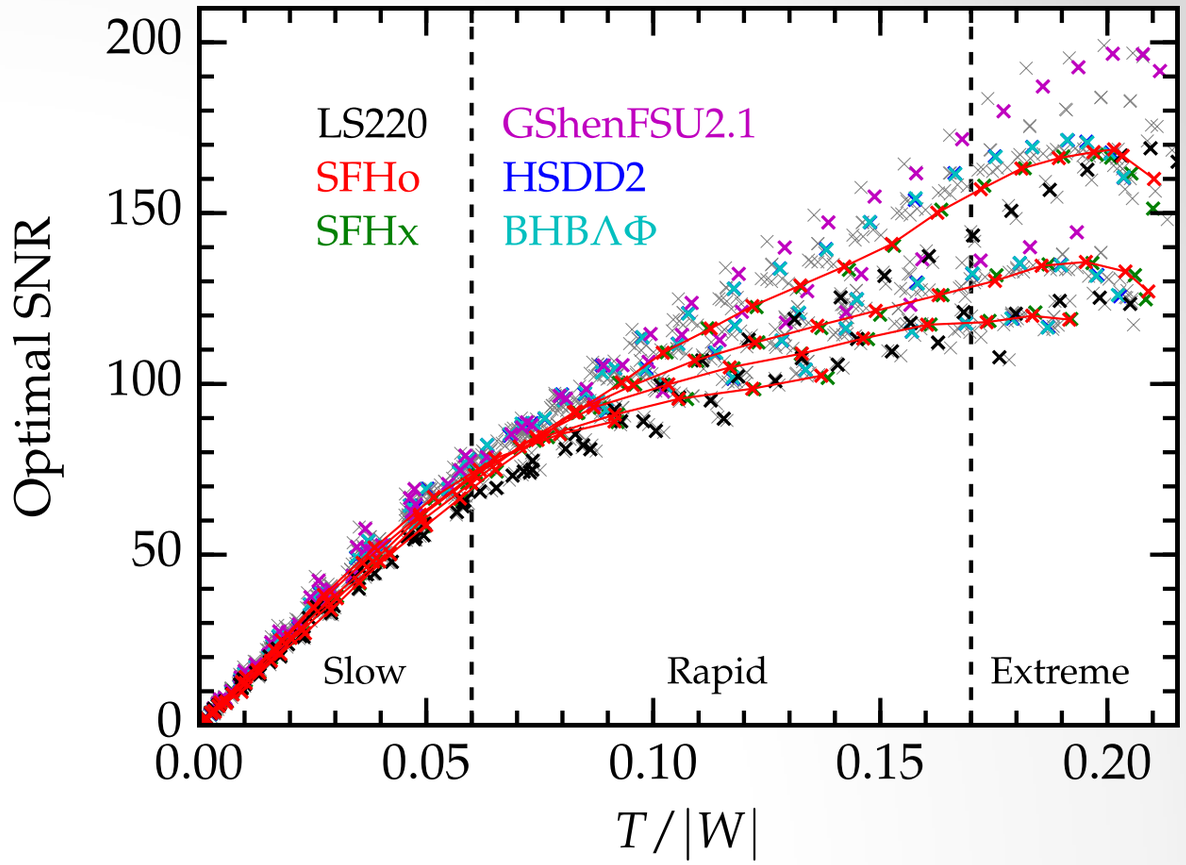
Correlated oscillations in rapidly rotating CCSNe

How much SNR is gained by triggering using neutrinos?

Need Large Parameter Sweeps

- To explore uncertainties, need large sets of long time evolution simulations
- Only achievable with approximations
- What approximations yield *small enough* errors?


Mismatch with SFHo
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Slow
Rapid
Extreme
Weak Signal
LS220
SFHo
SFHx
GShenFSU2.1
HSDD2
BHBΛΦ
0.00
0.05
0.10
0.15
0.20
$T/|W|$


Optimal SNR
200
150
100
50
0
LS220
SFHo
SFHx
GShenFSU2.1
HSDD2
BHBΛΦ
Slow
Rapid
Extreme
0.00
0.05
0.10
0.15
0.20
$T/|W|$

$f_{\rm peak}$ [Hz]
1050
1000
950
900
850
800
750
700
650
Weak Signal
LS220
SFHo
SFHx
GShenFSU2.1
HSDD2
BHBΛΦ
0
5
10
15
20
25
30
$10^{21}\ \Delta h_+$

$\widetilde{h}_+\sqrt{f}\,[\mathrm{Hz}^{-1/2}]$
10^{-22}
10^{-23}
Virgo
bKAGRA
aLIGO
10^2
10^3
f [Hz]