Gravitational Waves from Simulations with Multi-Dimensional and Ray-by-Ray-plus Neutrino Transport

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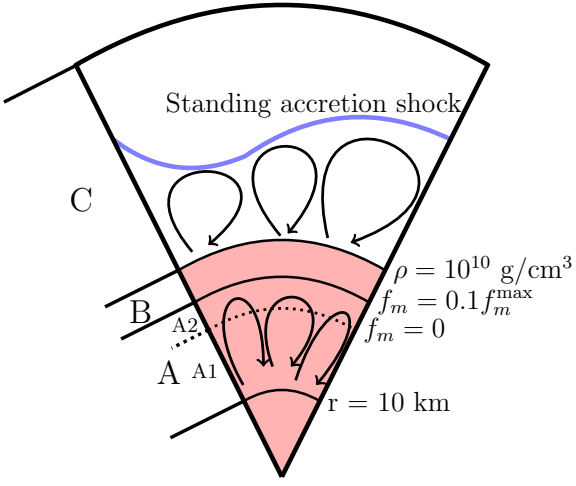
23.10.2019

AEI

Gravitational wave excitation

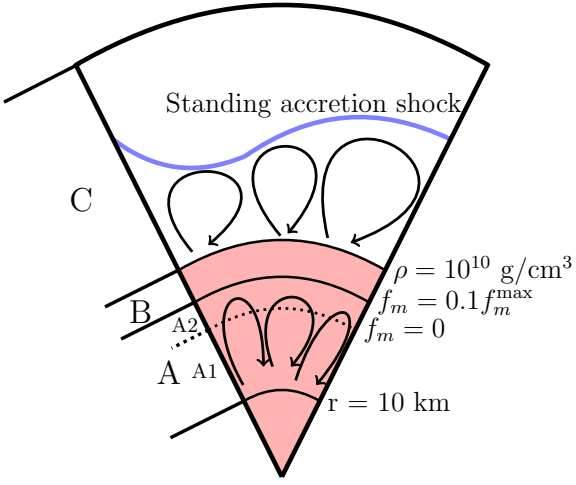
- SASI (Kuroda+16, Andresen+17)
- PMS oscillations (Marek+09, Murphy+09, Müller+13)



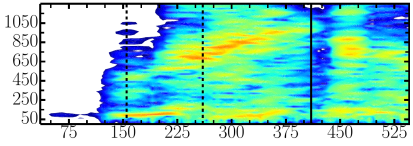
The SASI

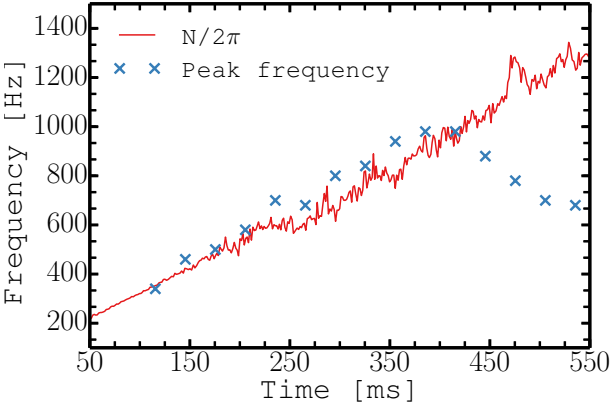
- Advective-acoustic cycle
- $\tau = \int_{r_0}^{R_s} \left[\frac{1}{|v_r(r)|} + \frac{1}{c_s(r)} \right] \mathrm{d}r$
- To first order: $v(r) \sim \sqrt{\frac{GM}{R_S^3}} r$

$$f_{\mathrm{SASI}}^{\mathrm{GW}} \approx \sqrt{\frac{GM}{R_S^3}} \left[\ln\left(R_S/R\right) \right]^{-1}$$



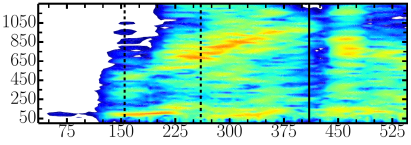
PNS oscillations

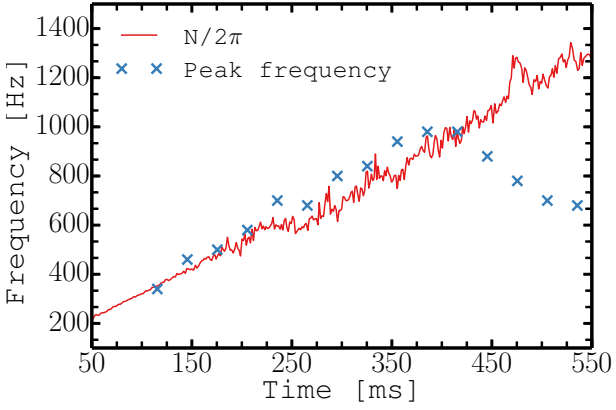




$$f_N = N/2\pi = \frac{1}{2\pi}\sqrt{\frac{1}{\rho}\frac{\partial \Phi}{\partial r}\left[\frac{1}{c_s^2}\frac{\partial P}{\partial r} - \frac{\partial \rho}{\partial r}\right]}$$

PNS oscillations



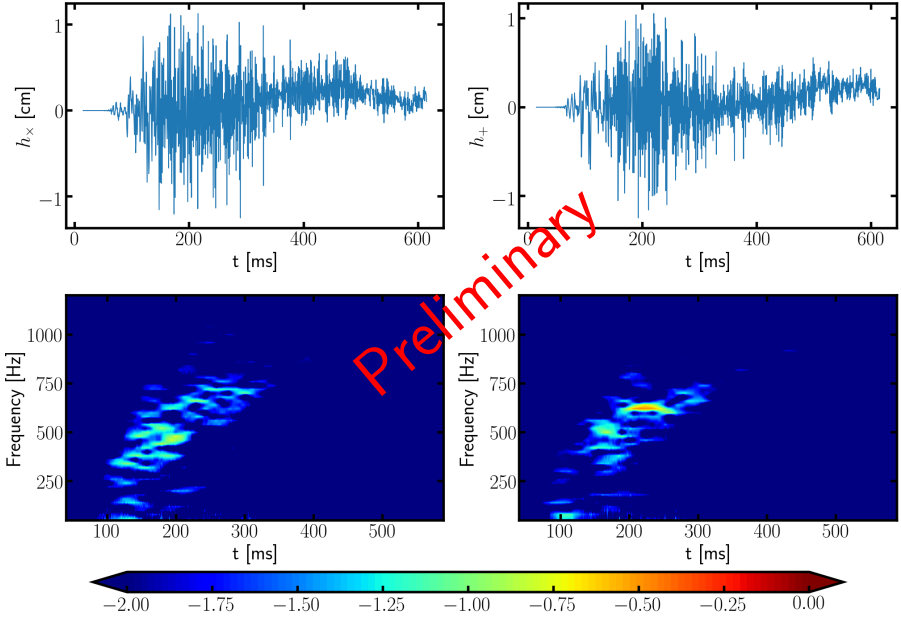


$$f_p = \frac{1}{2\pi}\frac{GM}{R^2}\sqrt{1.1\frac{m_n}{< E_{\bar{\nu}} >}}\left[1-\frac{GM}{R^2}\right]^2$$

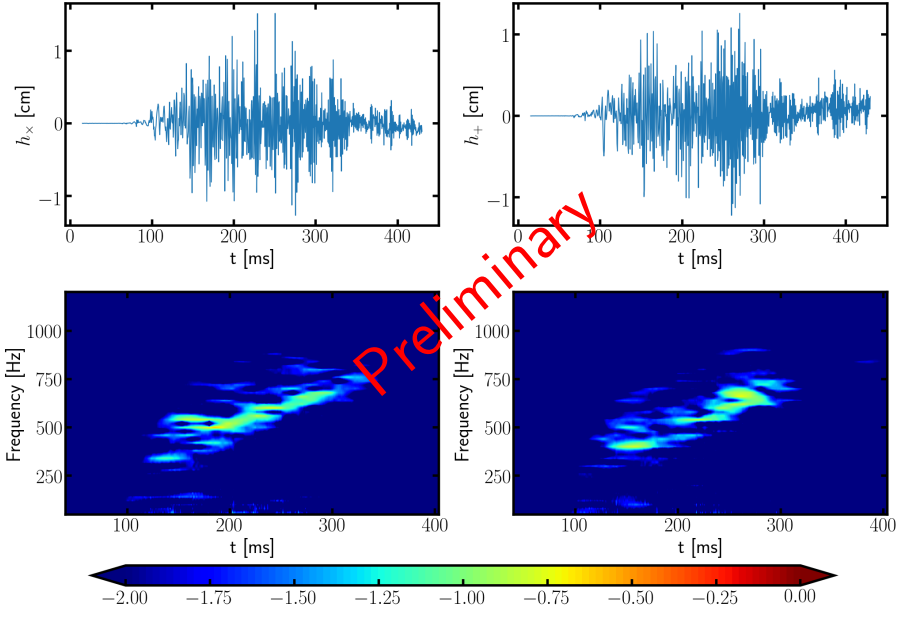
Neutrino schemes

- Artifacts (Skinner+16)
- Glas+19
- Eight simulations (20 and 9 $M_{\odot}$)
- Resolution and neutrino transport

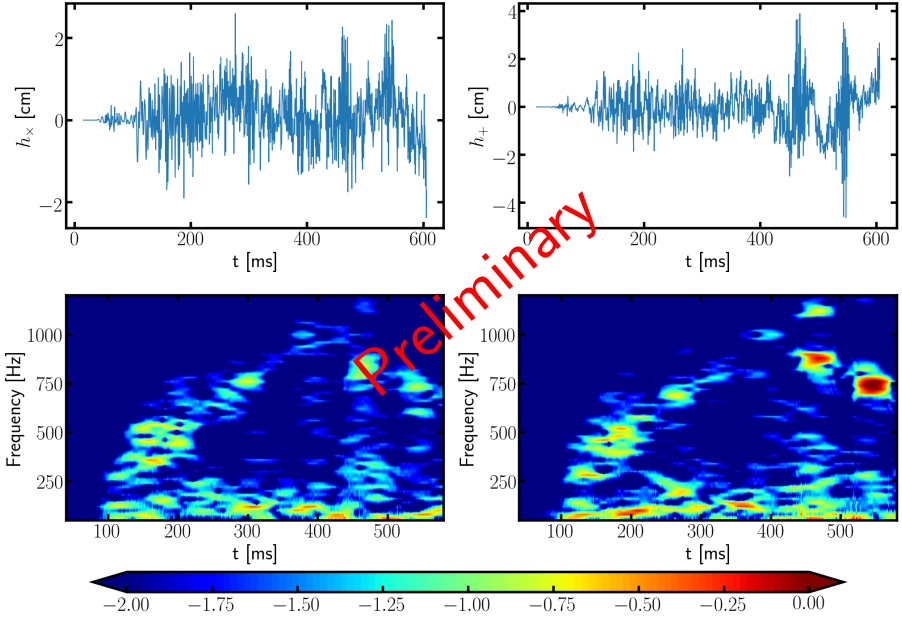
s9.0-FMD: Gravitational wave signal



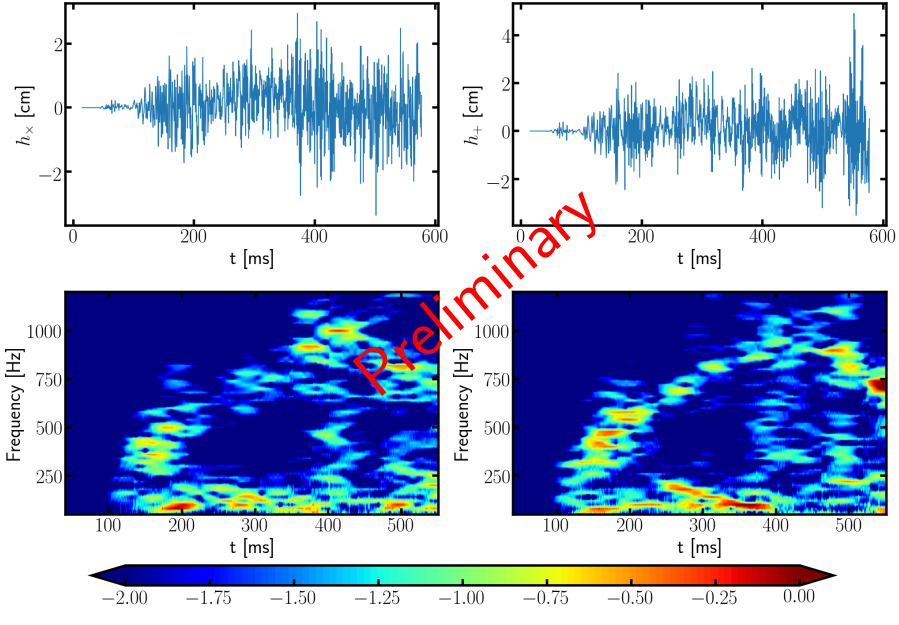
s9.0-RbR+: Gravitational wave signal



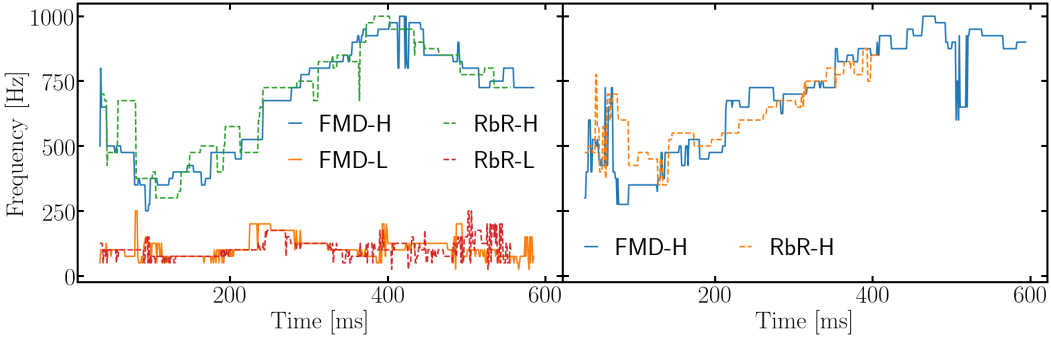
s20.0-FMD: Gravitational wave signal



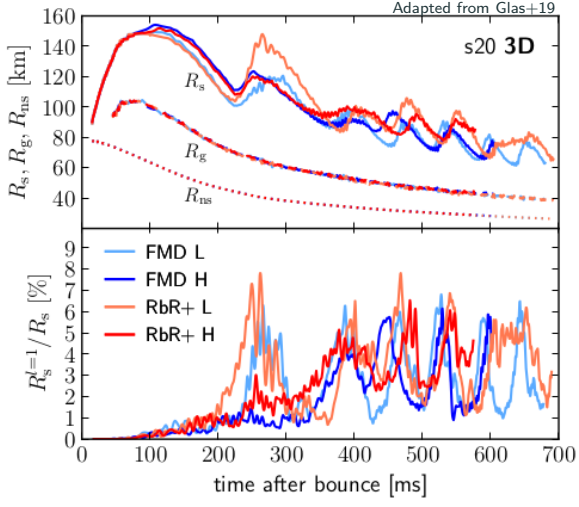
s20.0-RbR+: Gravitational wave signal



FMD versus RbR+



Neutrino schemes: Differences?



Take home points

- Small scale differences
- Overall agreement in the evolution of the global properties
- Very similar gravitational wave signals

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