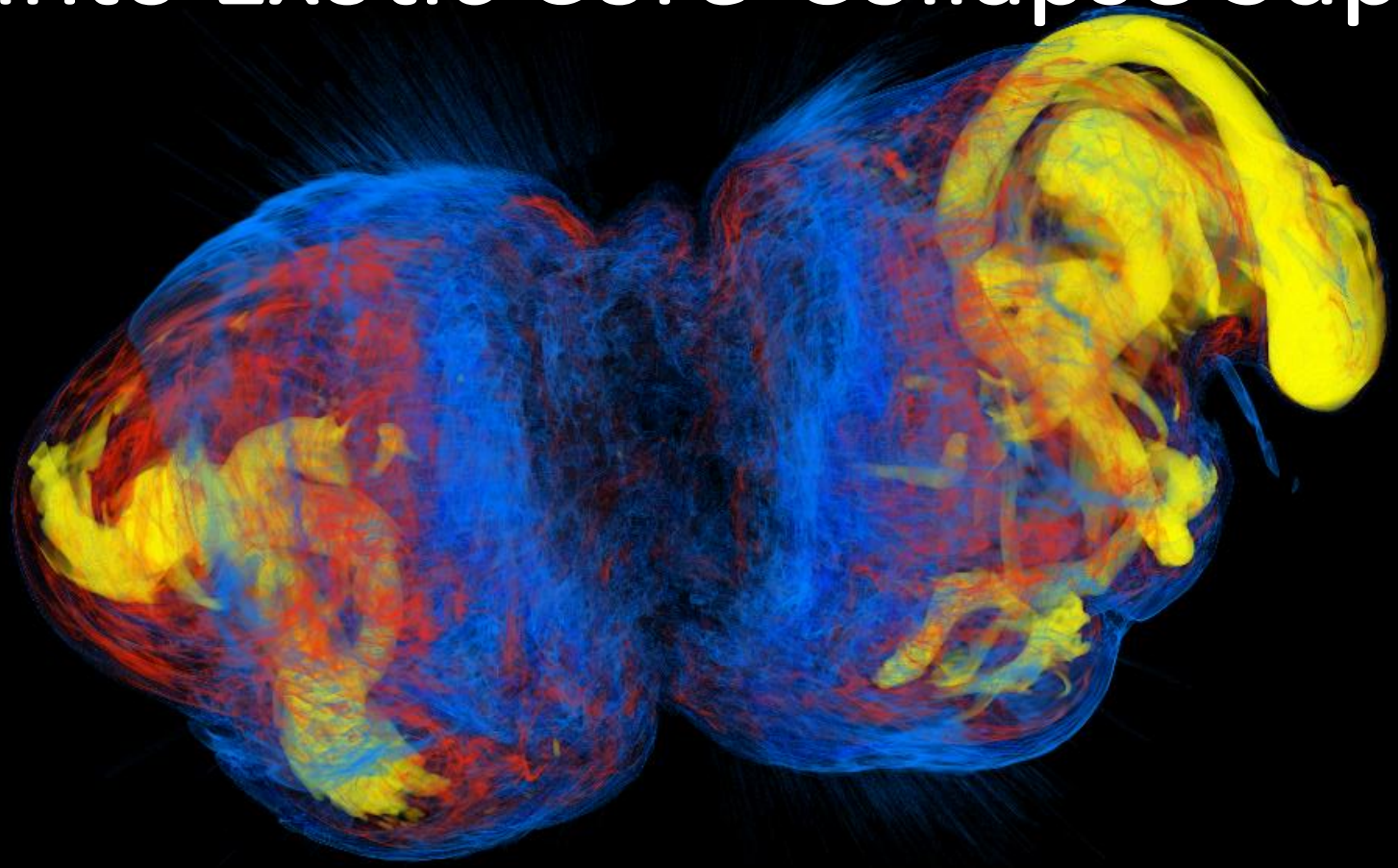
Insights into Exotic Core-Collapse Supernovae



Sherwood Richers

Caltech, LANL

Christian Ott, Philipp Mösta, many more

Massive stars explode

© Anglo-Australian Observatory

Supernova 1987a

Most recent nearby supernova

10^{35} times the explosion energy of all nuclear tests ever

~20 neutrinos detected

Long Gamma Ray Bursts = Hypernovae?

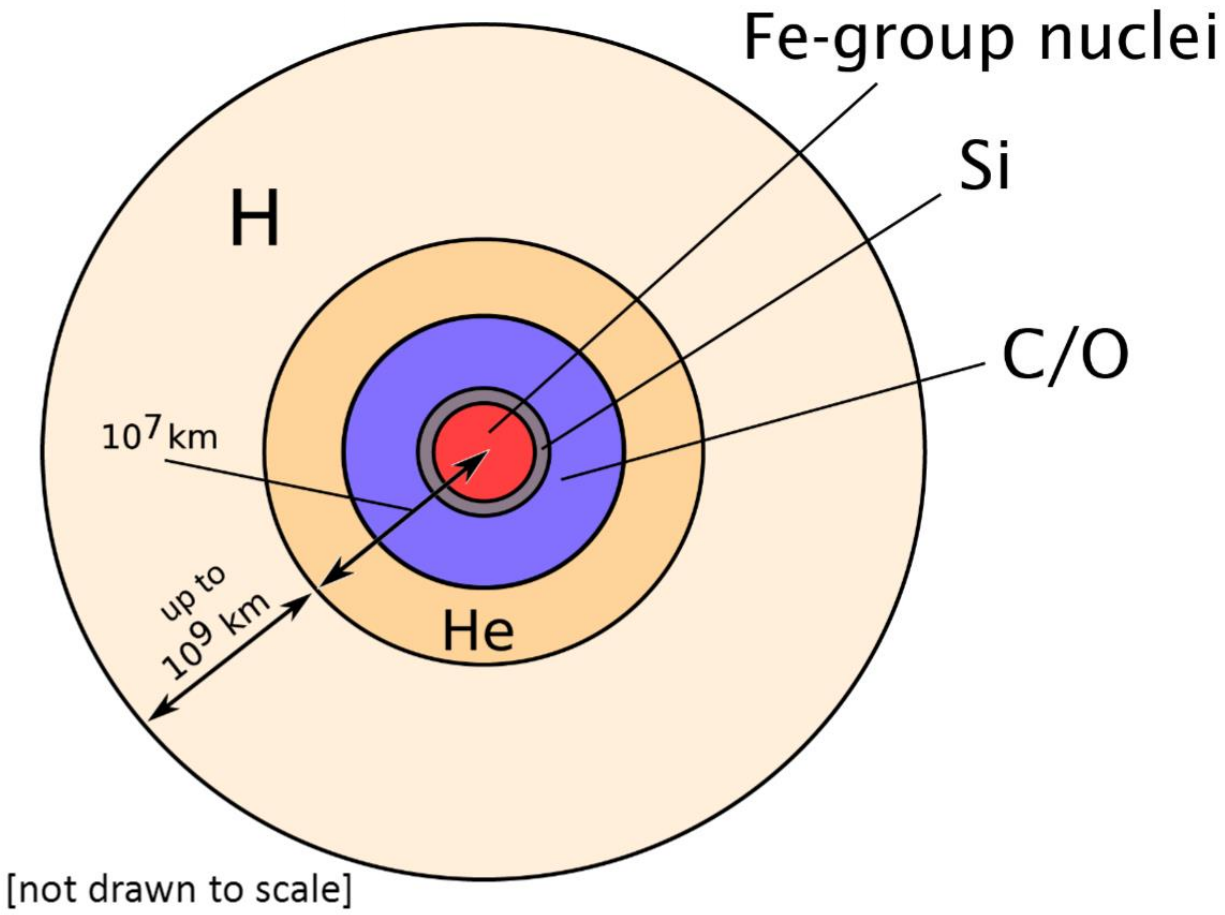
SN1998bw
(European Southern Observatory)

Ic-bl supernova → no H or He, broad lines

Most hypernovae (10x explosion energy) are type Ic-bl

11 Supernova + gamma-ray burst connections (all type Ic-bl)

Explosion Mechanisms



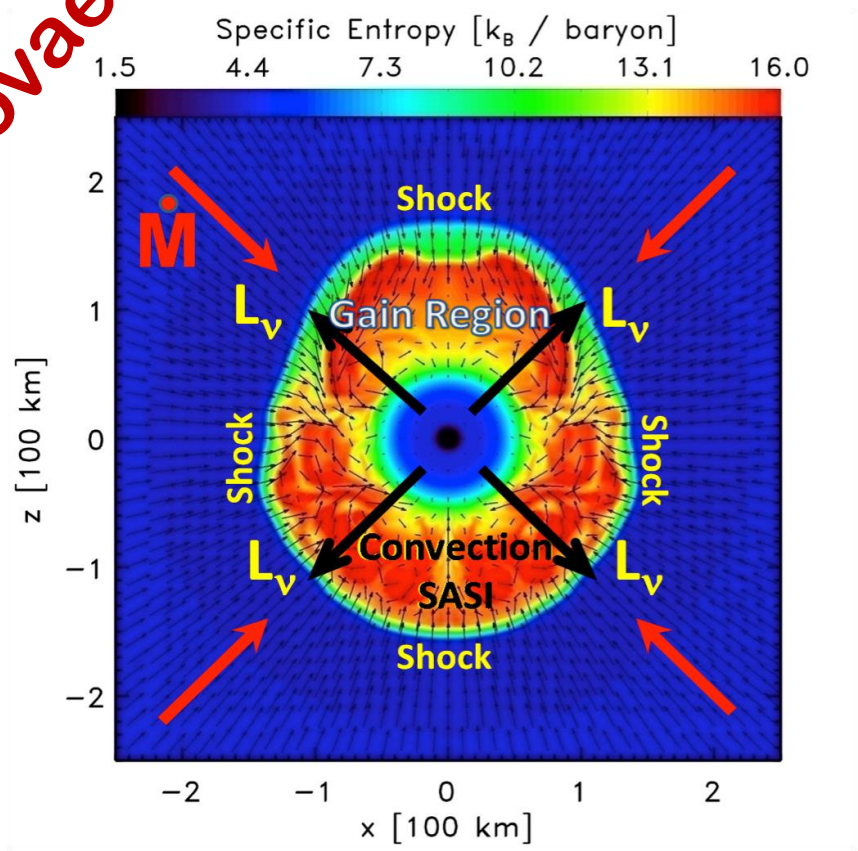
(Christian Ott)

Explosion Mechanisms

Neutrino-Driven

10^{51} erg available energy

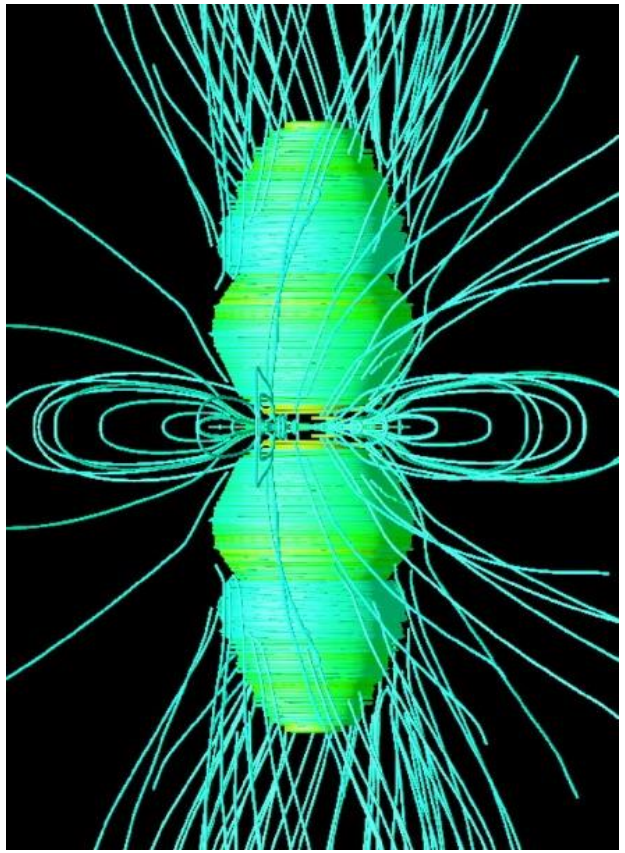
Supernovae



(Ott 2009)

Magnetorotational

10^{52} erg available energy



Hypernovae + GRBs

(Burrows et al. 2007)

56 Years of Computational Effort

Physics

- Progenitors / Rotation
- Nuclear Physics
- General Relativity
- Magnetohydrodynamics
- Neutrino Transport

Computation

- 3D Hydrodynamics
- 7D Neutrino Transport
- Resolution

New Insights

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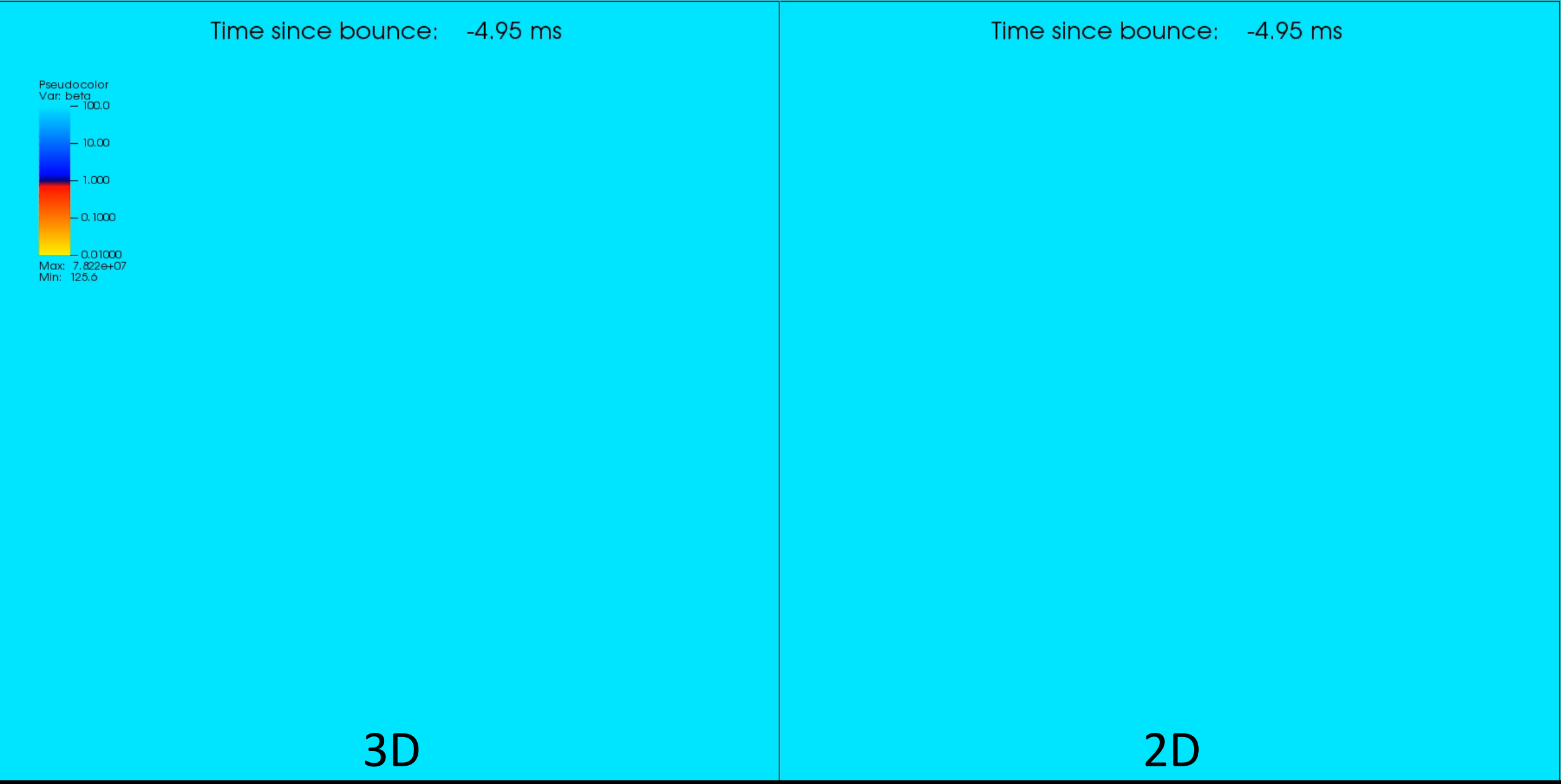
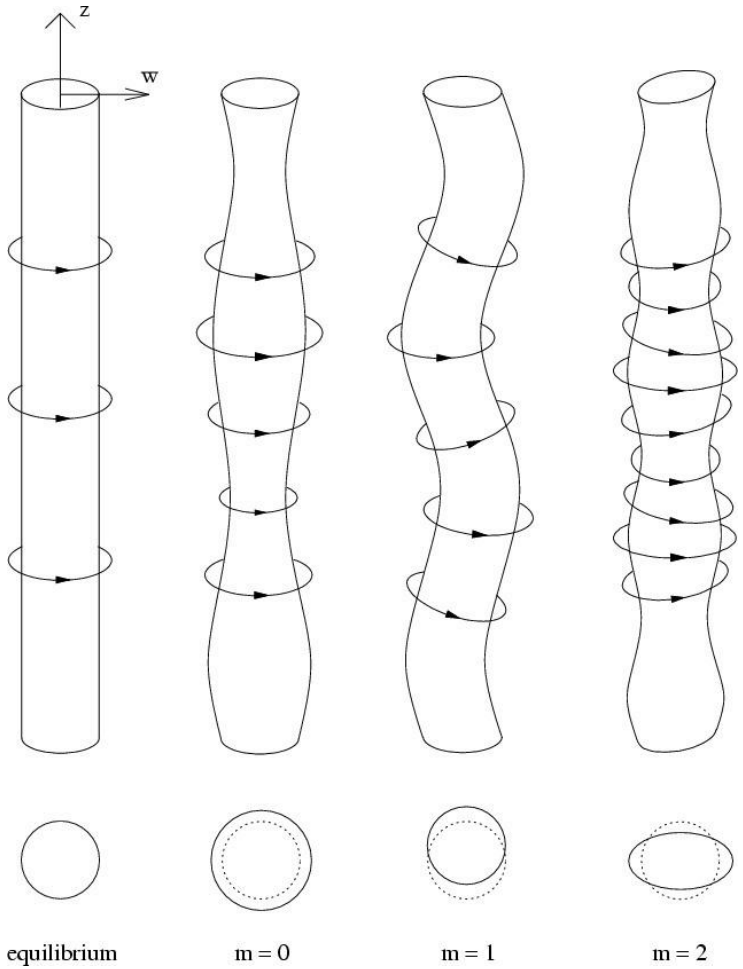
Magnetorotational Core-Collapse Supernovae in 3D

Global 3D GRMHD Simulations


Time since bounce: -4.95 ms
Pseudocolor
Var: beta
100.0
10.00
1.000
0.1000
0.01000
Max: 7.822e+07
Min: 125.6
3D
Time since bounce: -4.95 ms
2D

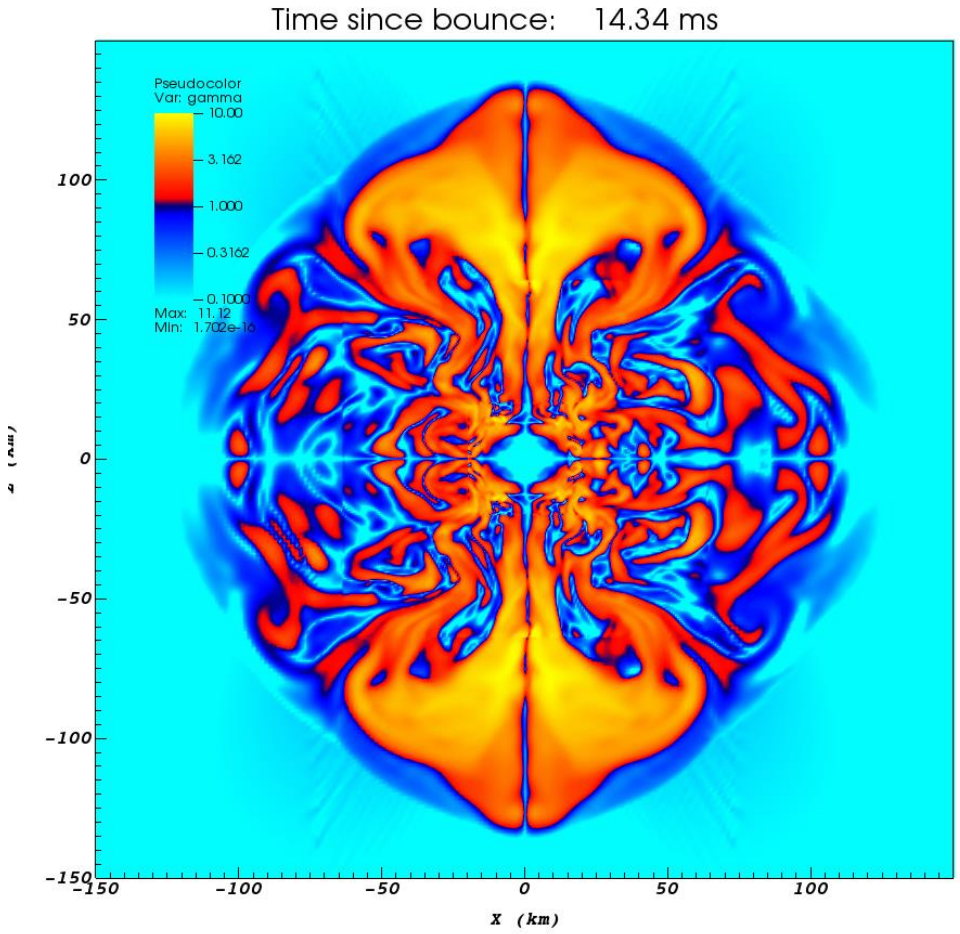
Jet Instability

Kink Instability



(Braithwaite 2006)

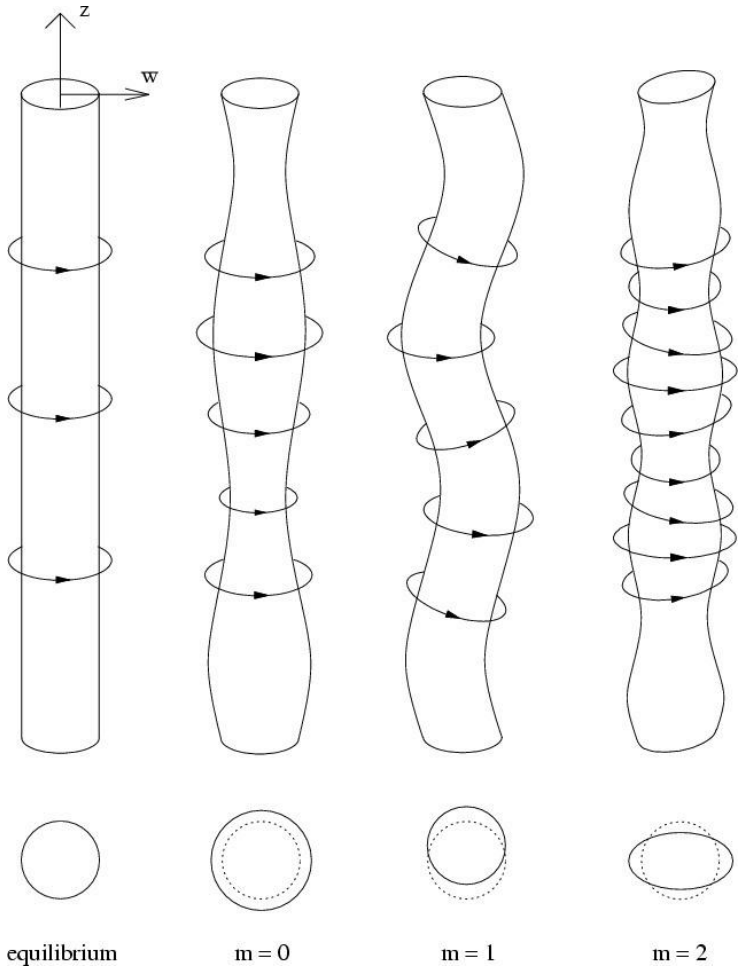
(growth rate) x time



growth rate: $\gamma_{max} = \frac{1}{2a}\frac{B_z}{B_\varphi}$

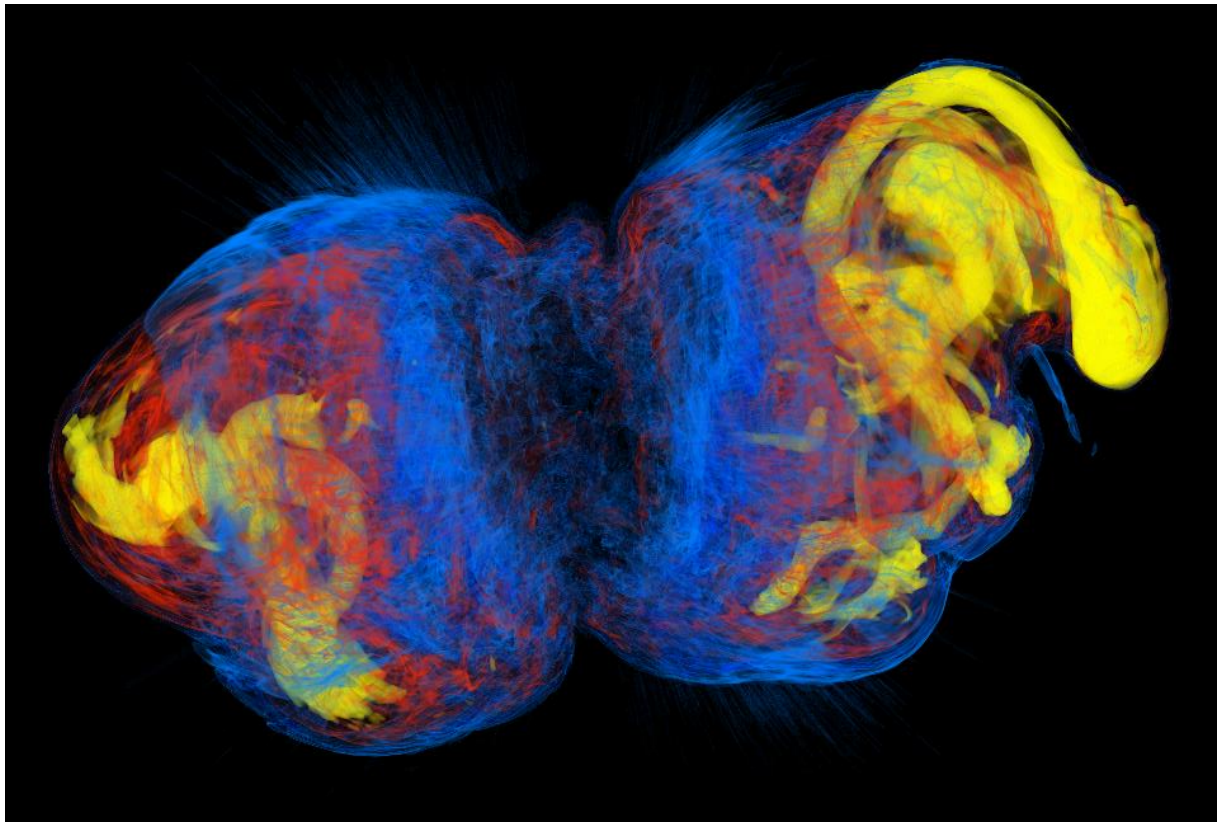
Jet Instability

Kink Instability



(Braithwaite 2006)

Tangled Flux Tubes
(not coherent jet)



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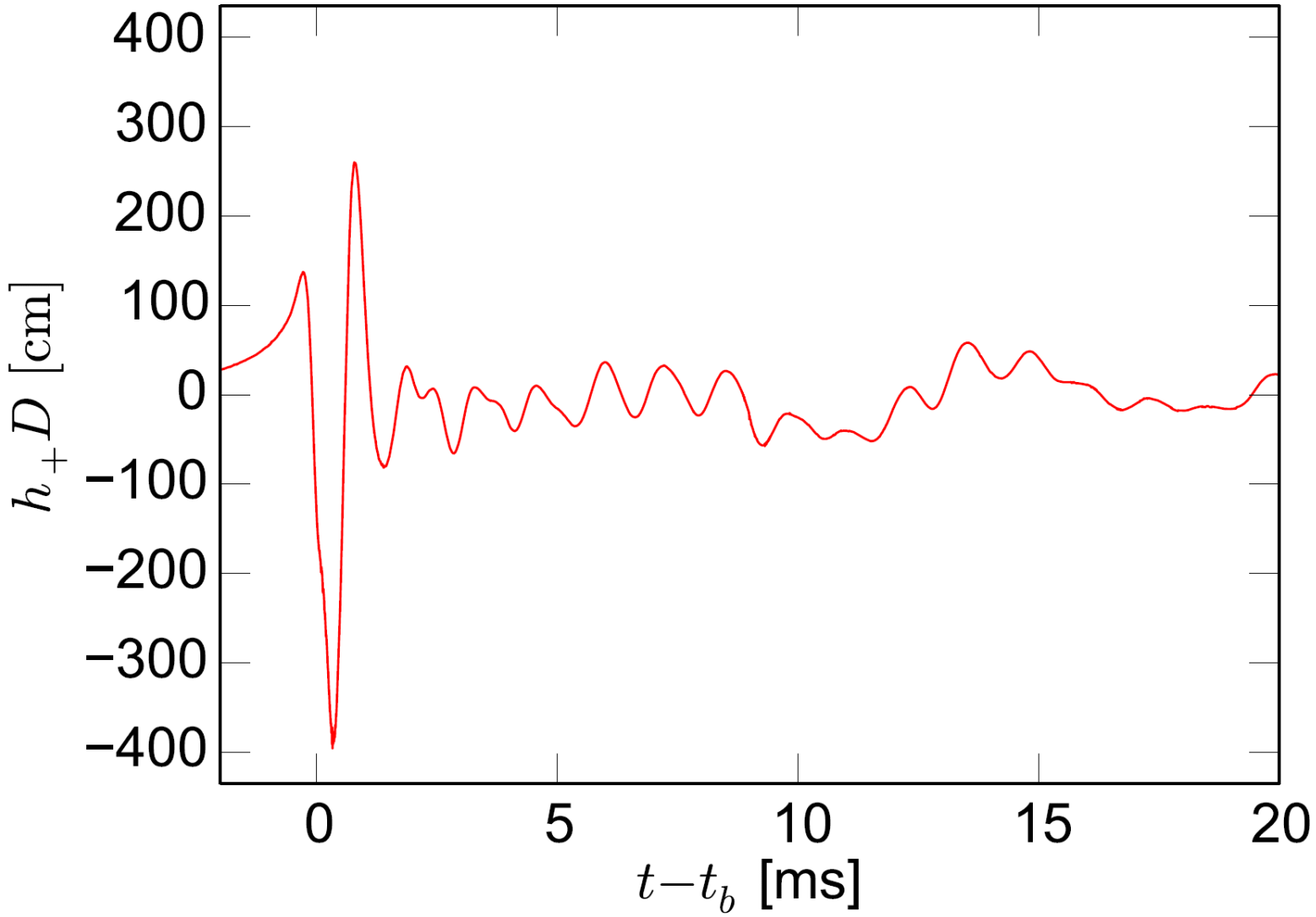
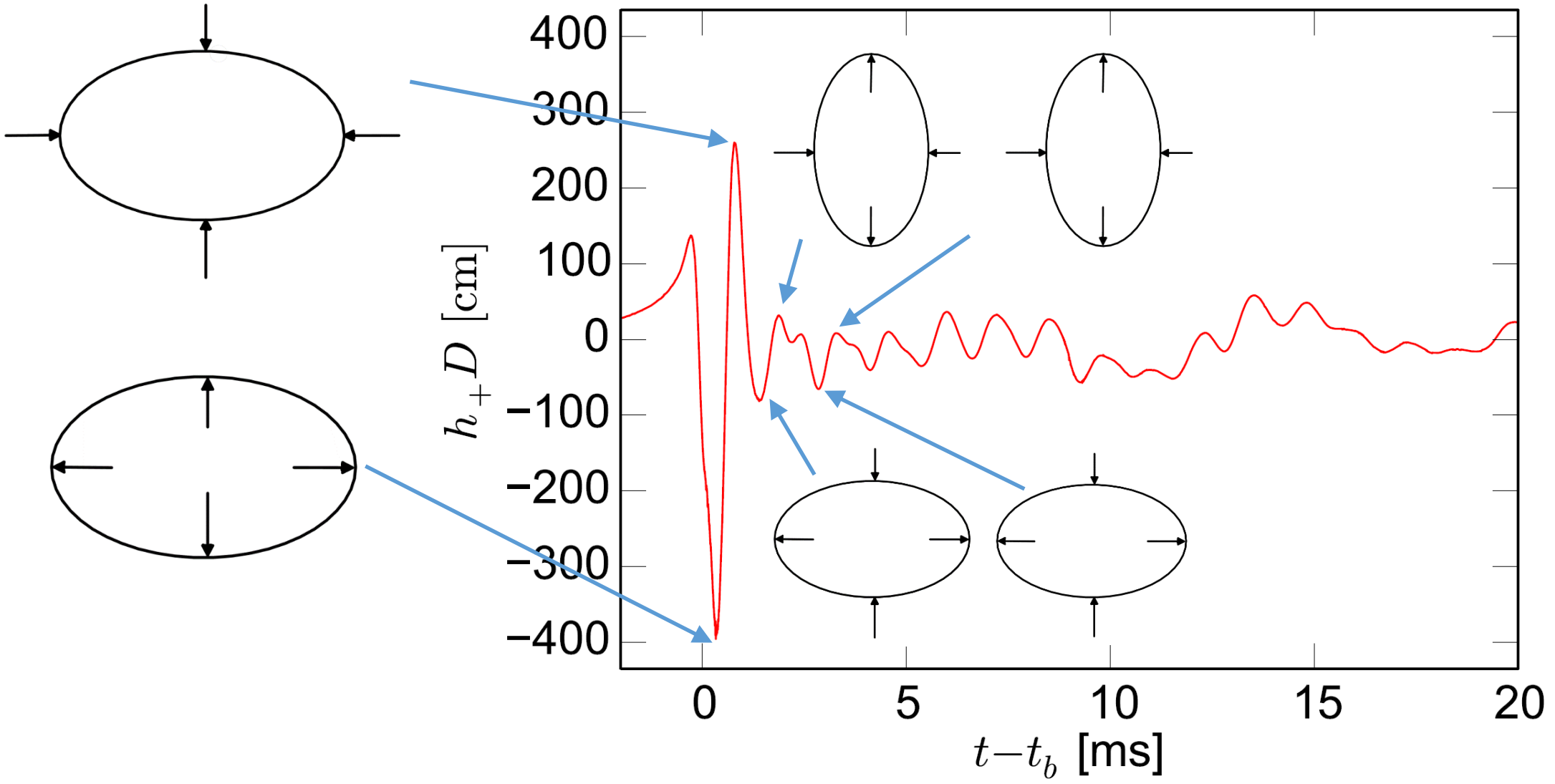
Gravitational Waves from Rapidly Rotating Core-Collapse Supernovae

1764 2D Simulations in a Parameter Sweep

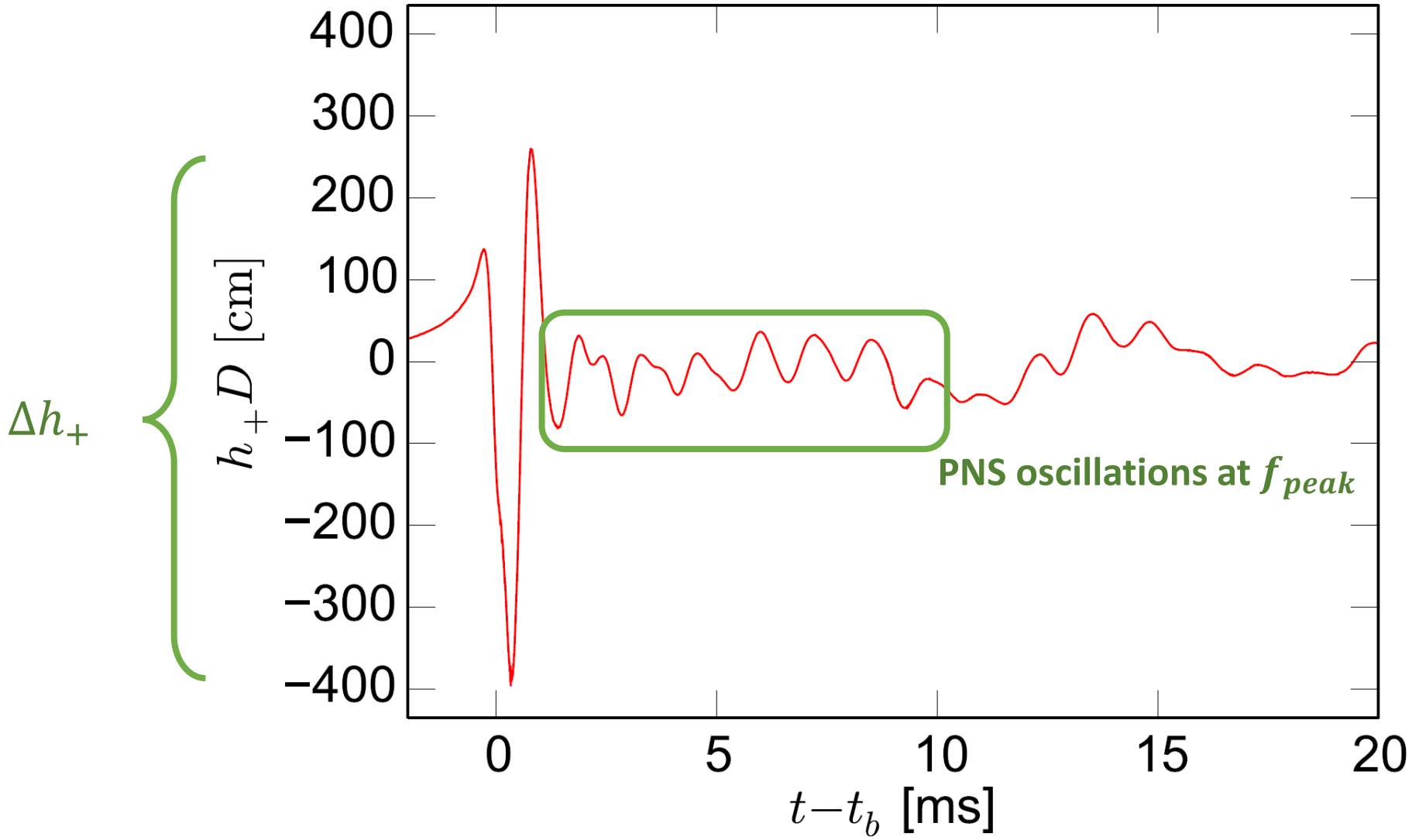
Gravitational Waves from Rotating Supernovae



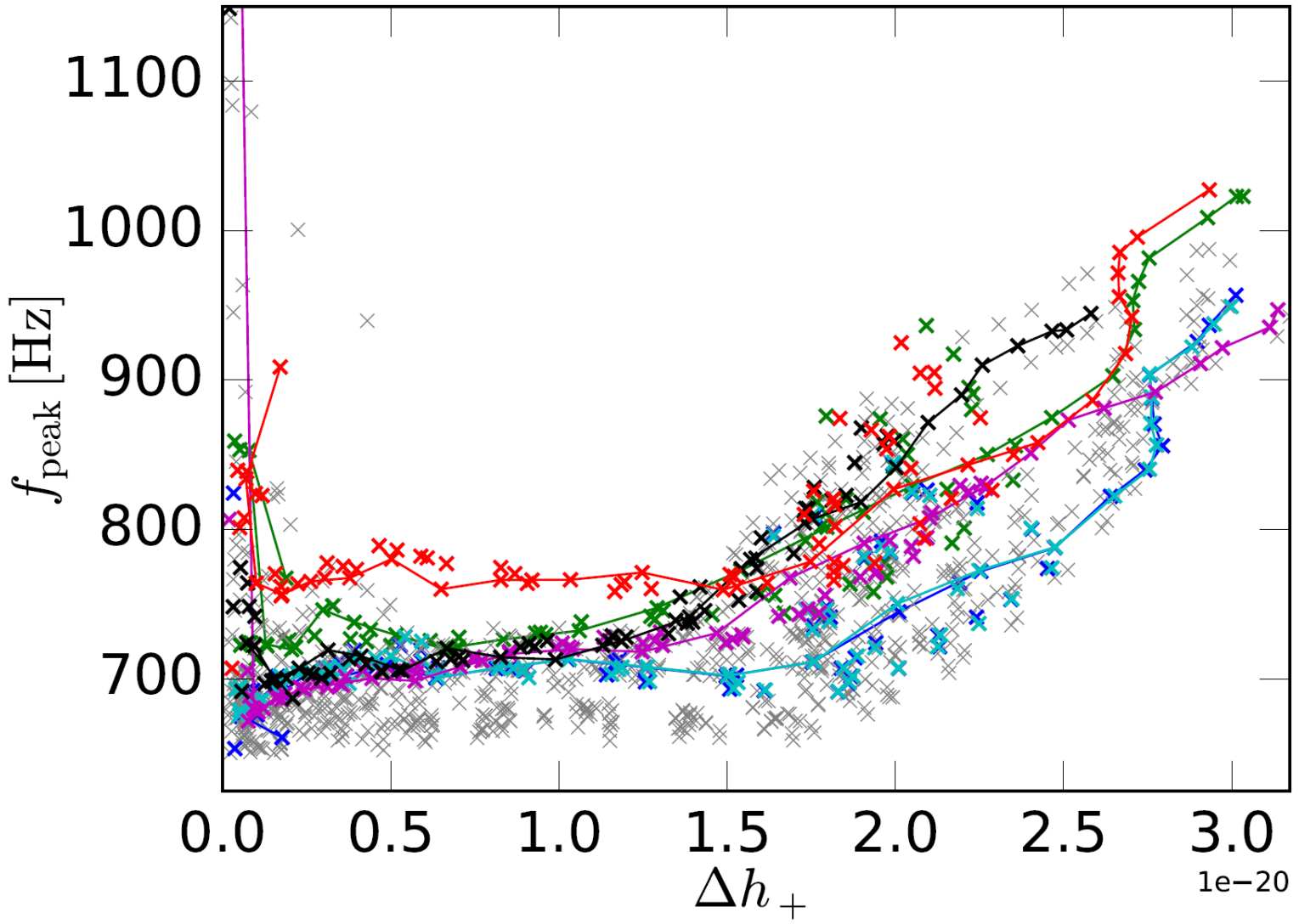
Gravitational Waves from Rotating Supernovae



Gravitational Waves from Rotating Supernovae



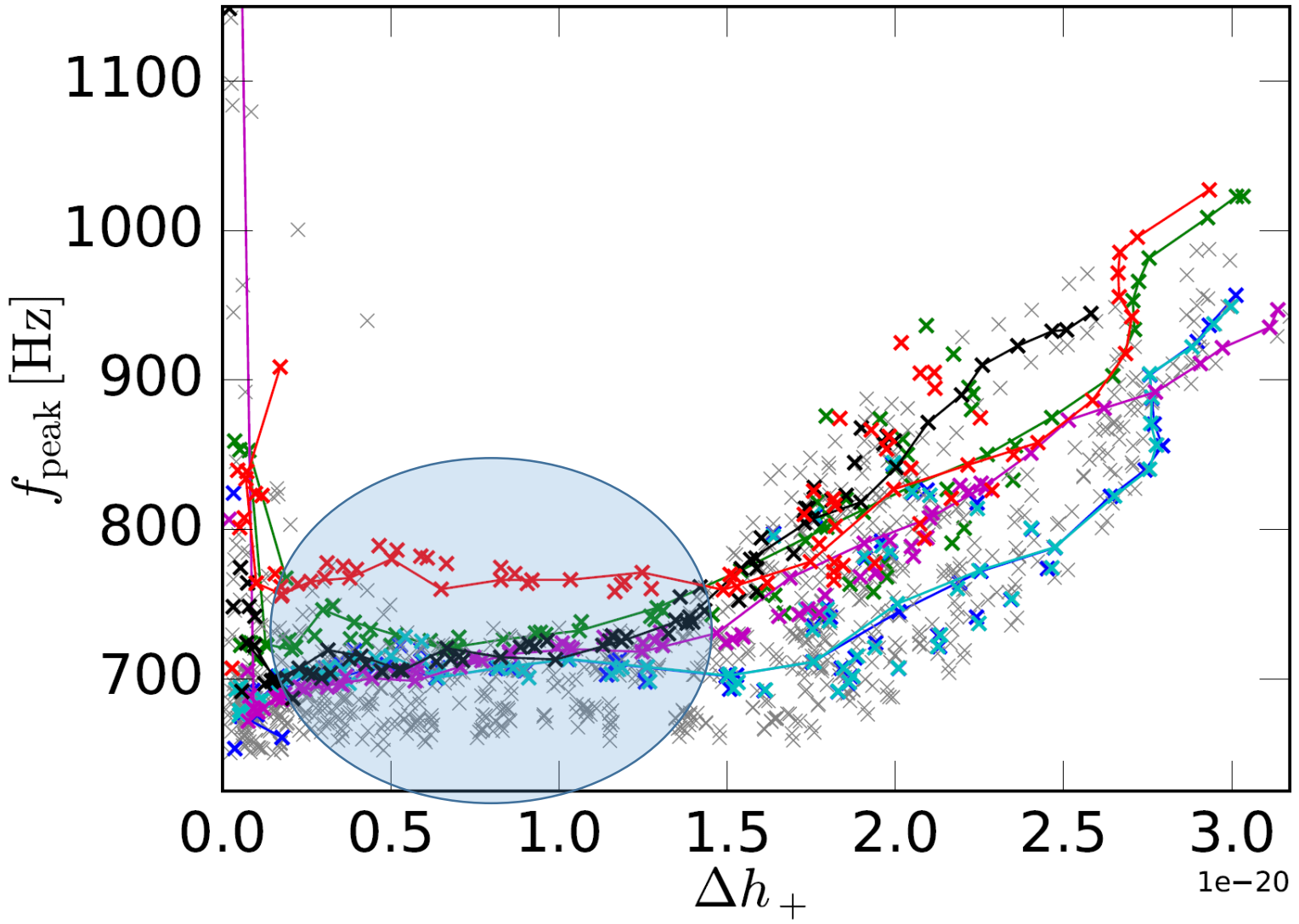
Gravitational Waves inform Nuclear Physics



98 Rotation Profiles
x <u>18 Nuclear Equations of State</u>
1764 Simulations

- Constrained Expectations for GW Observations

Gravitational Waves inform Nuclear Physics



98 Rotation Profiles
x 18 Nuclear Equations of State
1764 Simulations

- Constrained Expectations for GW Observations
- Could constrain the nuclear equation of state if lucky

New Insights

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Coming Soon

General Relativistic Monte Carlo Neutrino Transport

Novel Transport Method for Large-Scale Global Supernova Simulations