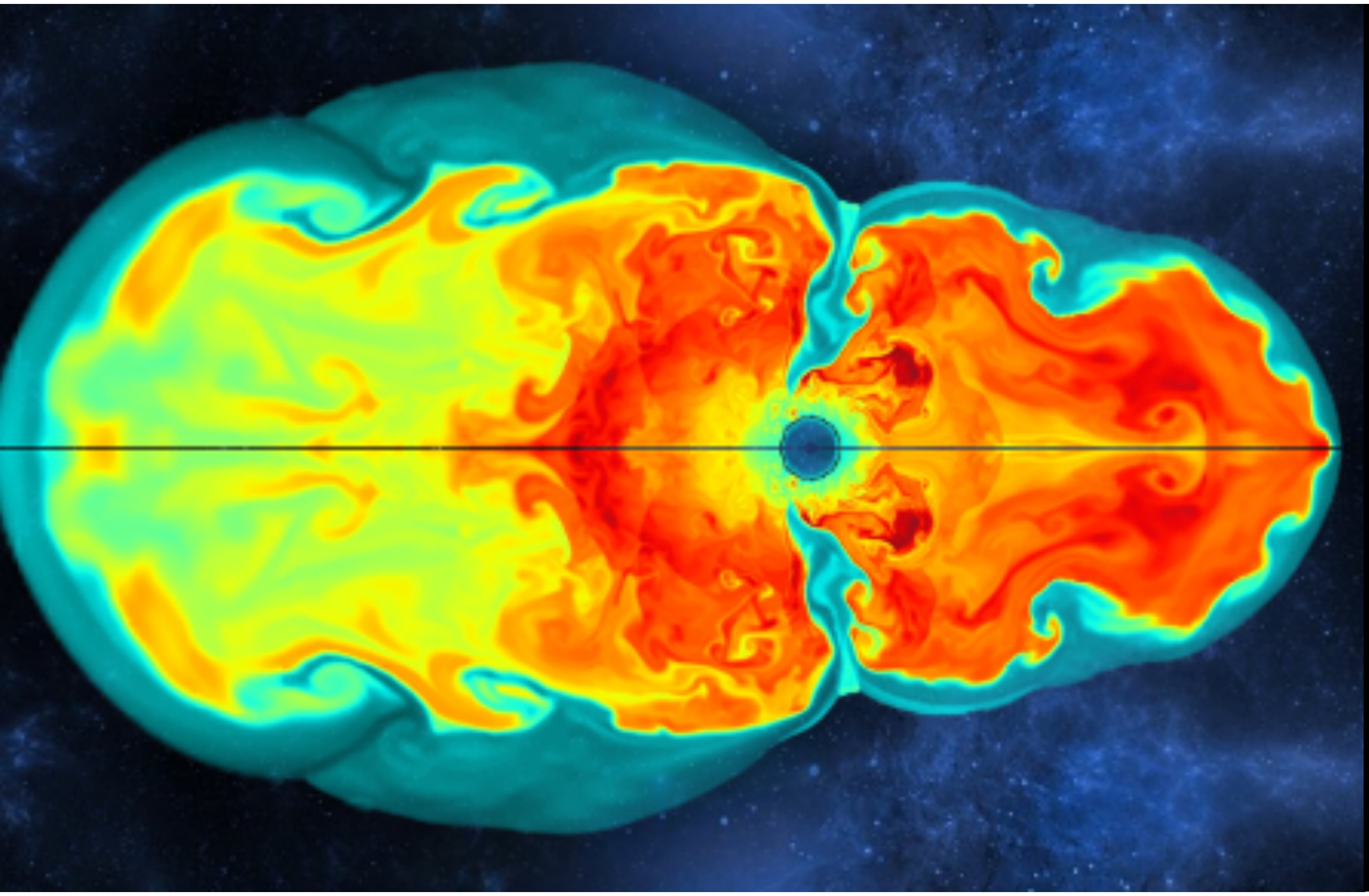
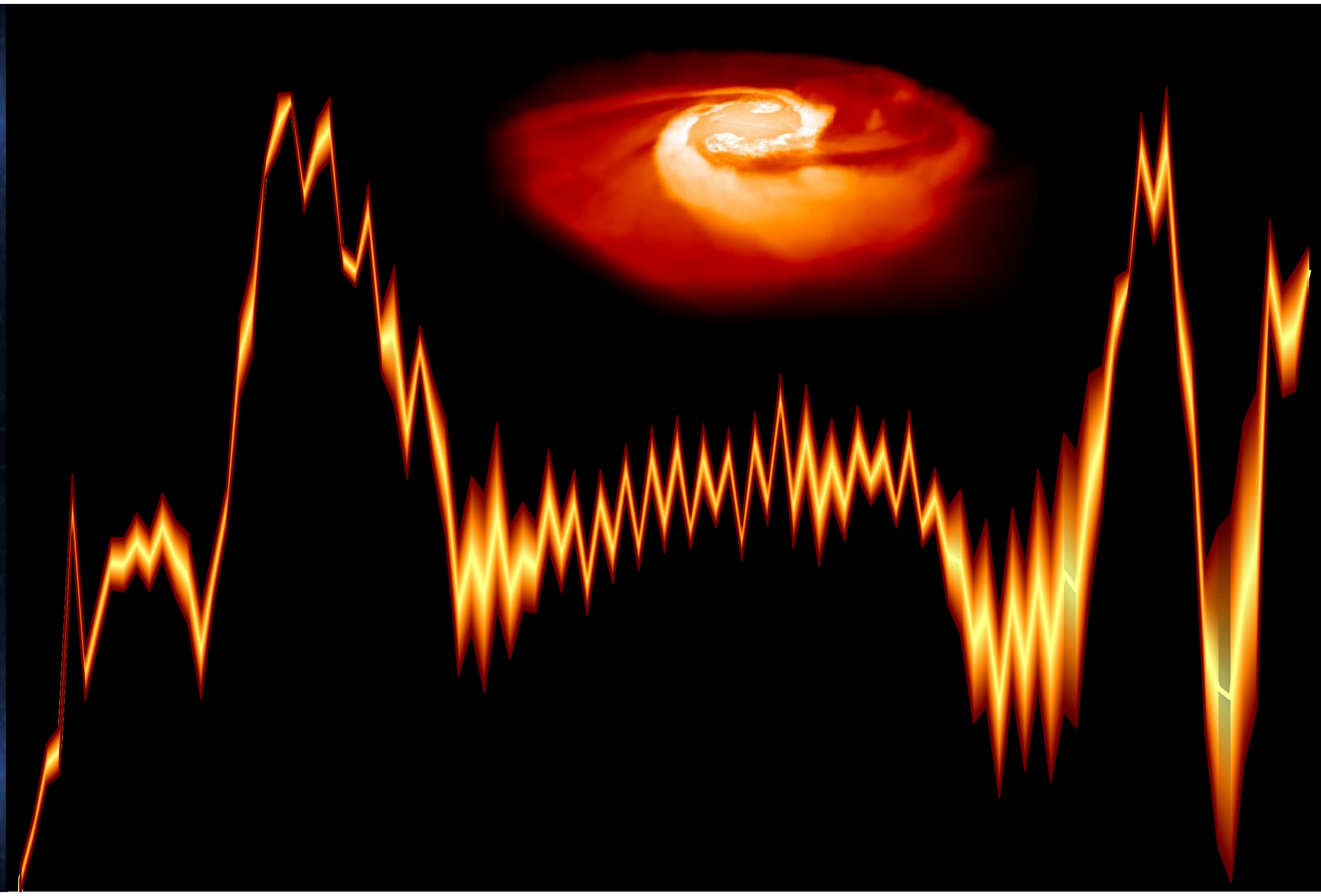
Extreme matter
in core-collapse supernovae and neutron star mergers





Almudena Arcones

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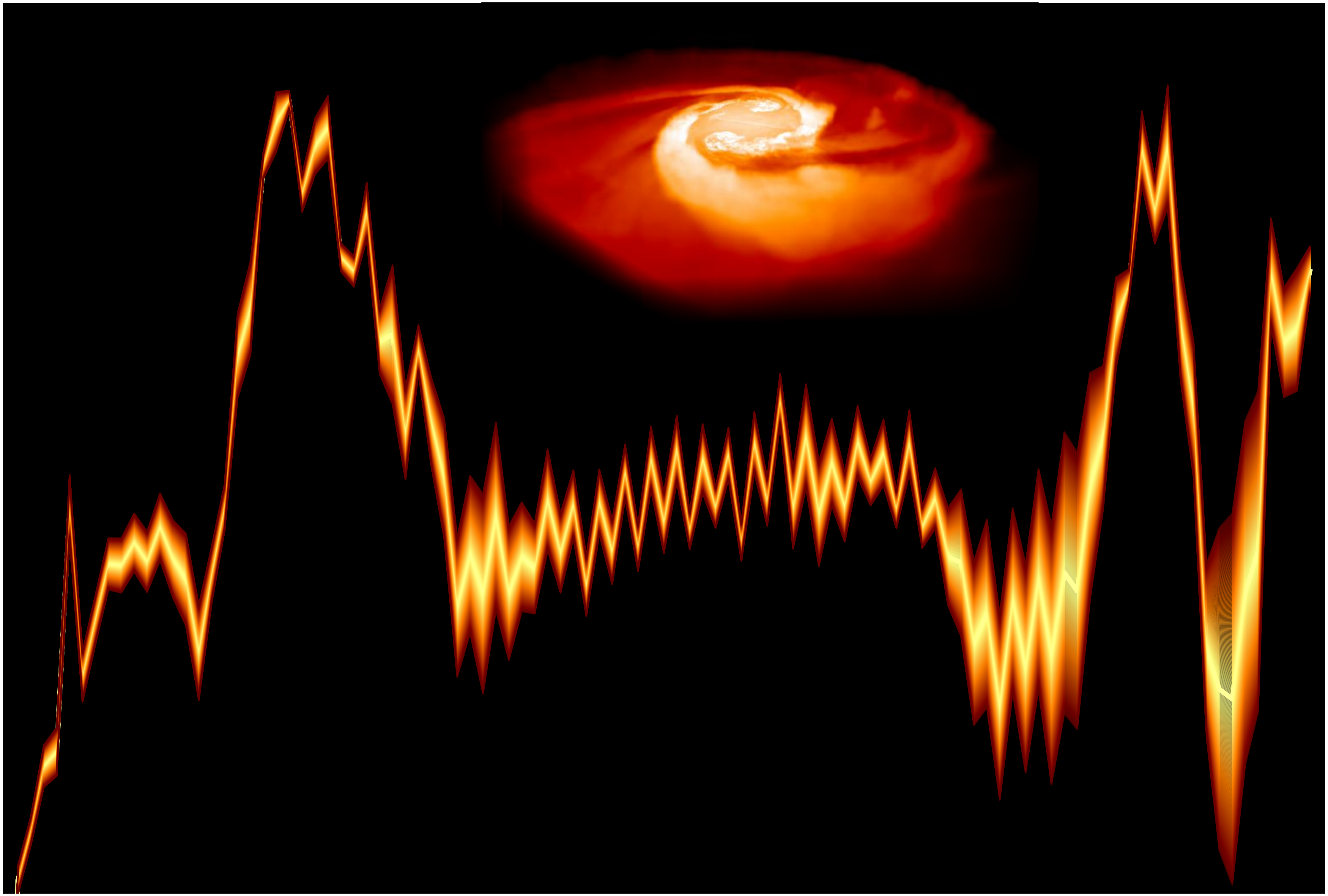
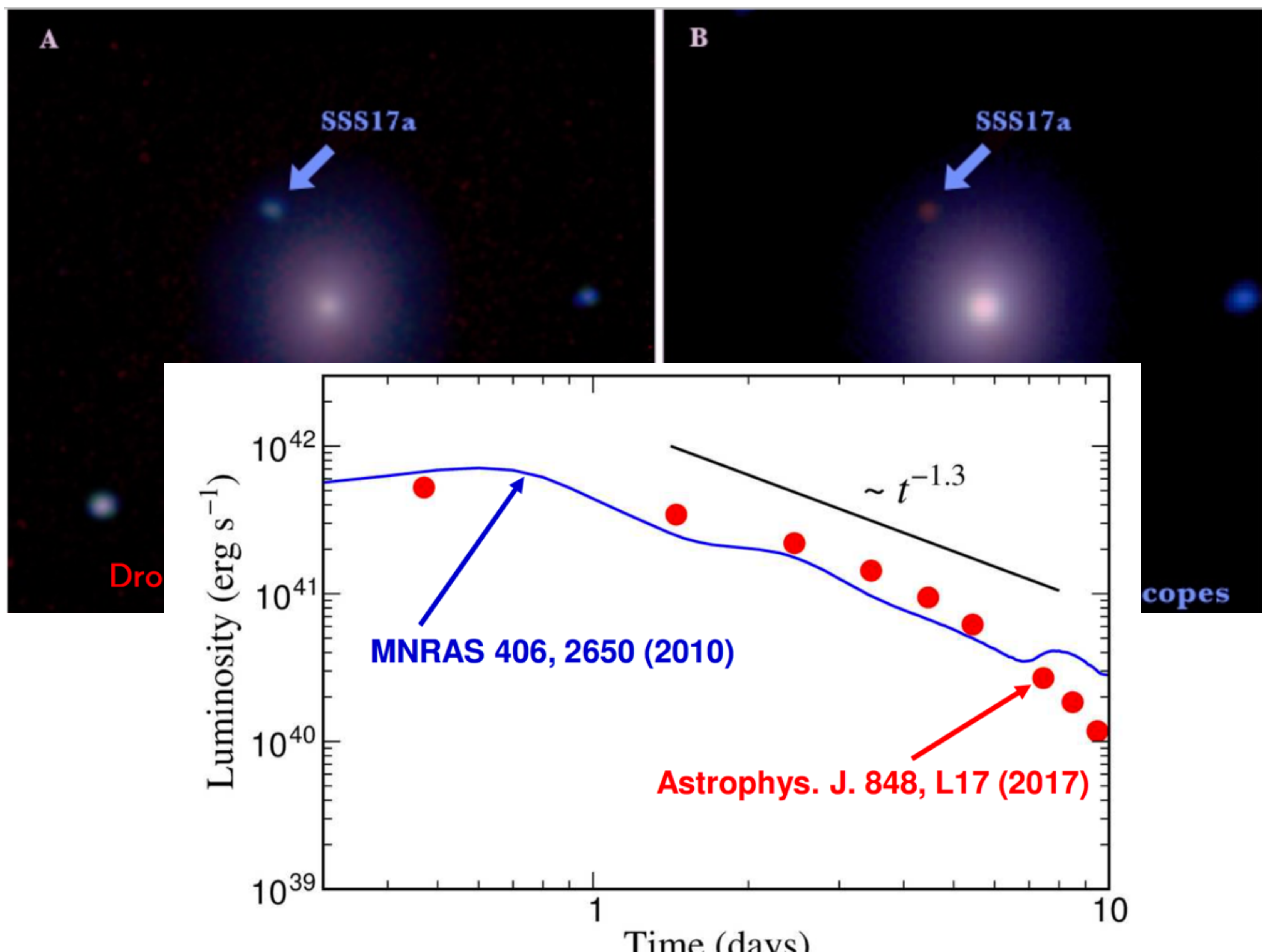


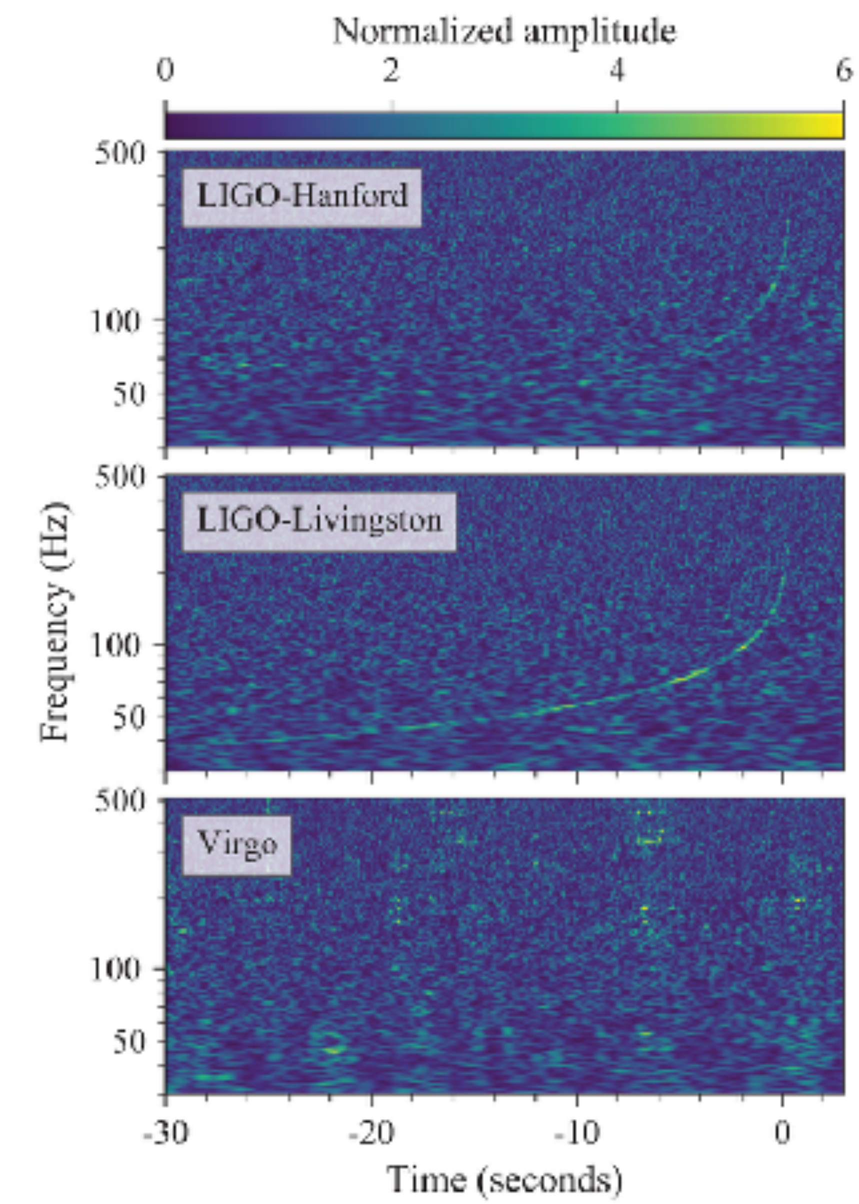
Extreme matter in neutron star mergers

Ejecta:

extreme neutron-rich conditions —> successful r-process

kilonova observation after GW170817: weak and strong r-process





Extreme matter in neutron star mergers

Ejecta
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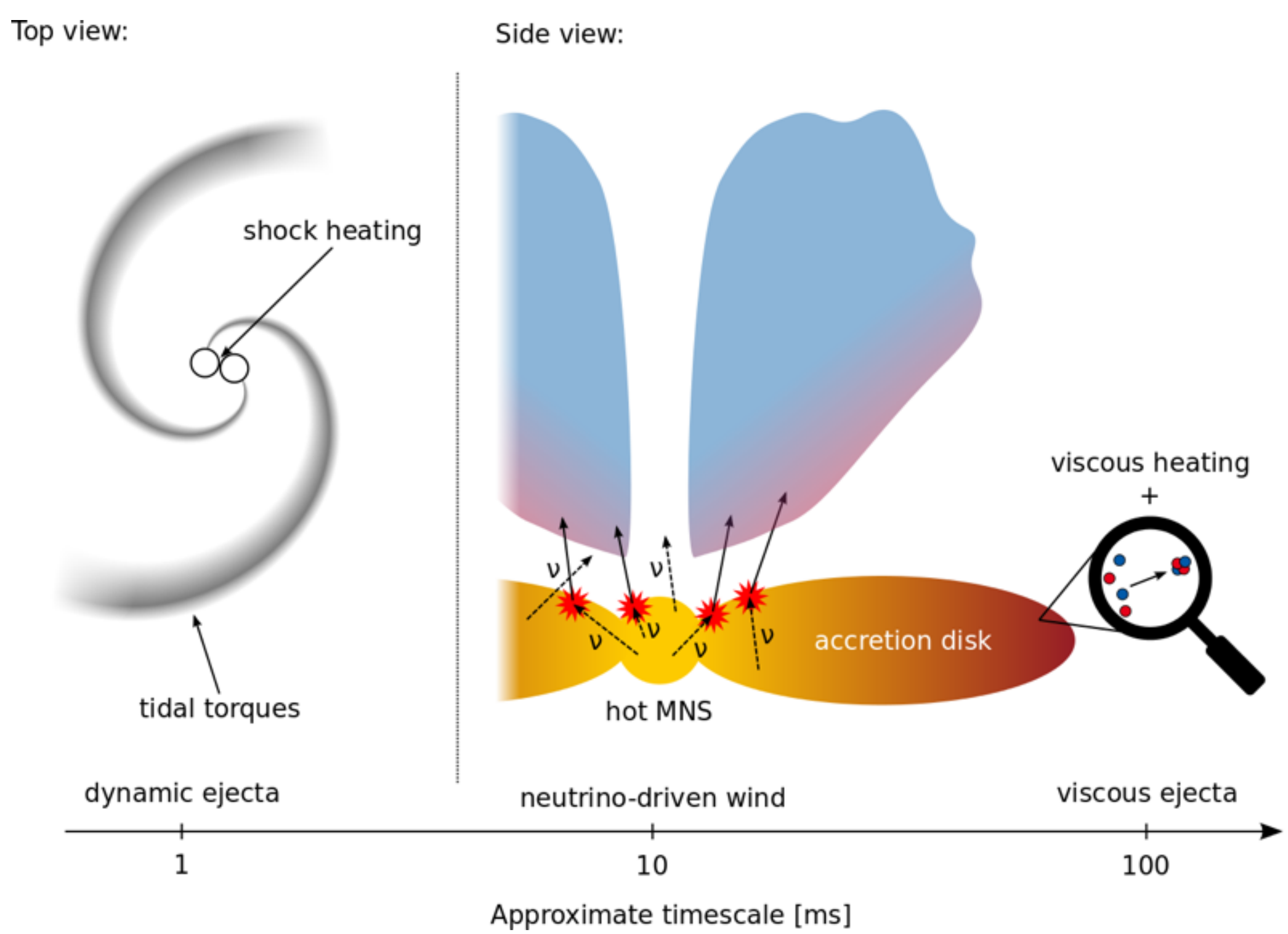
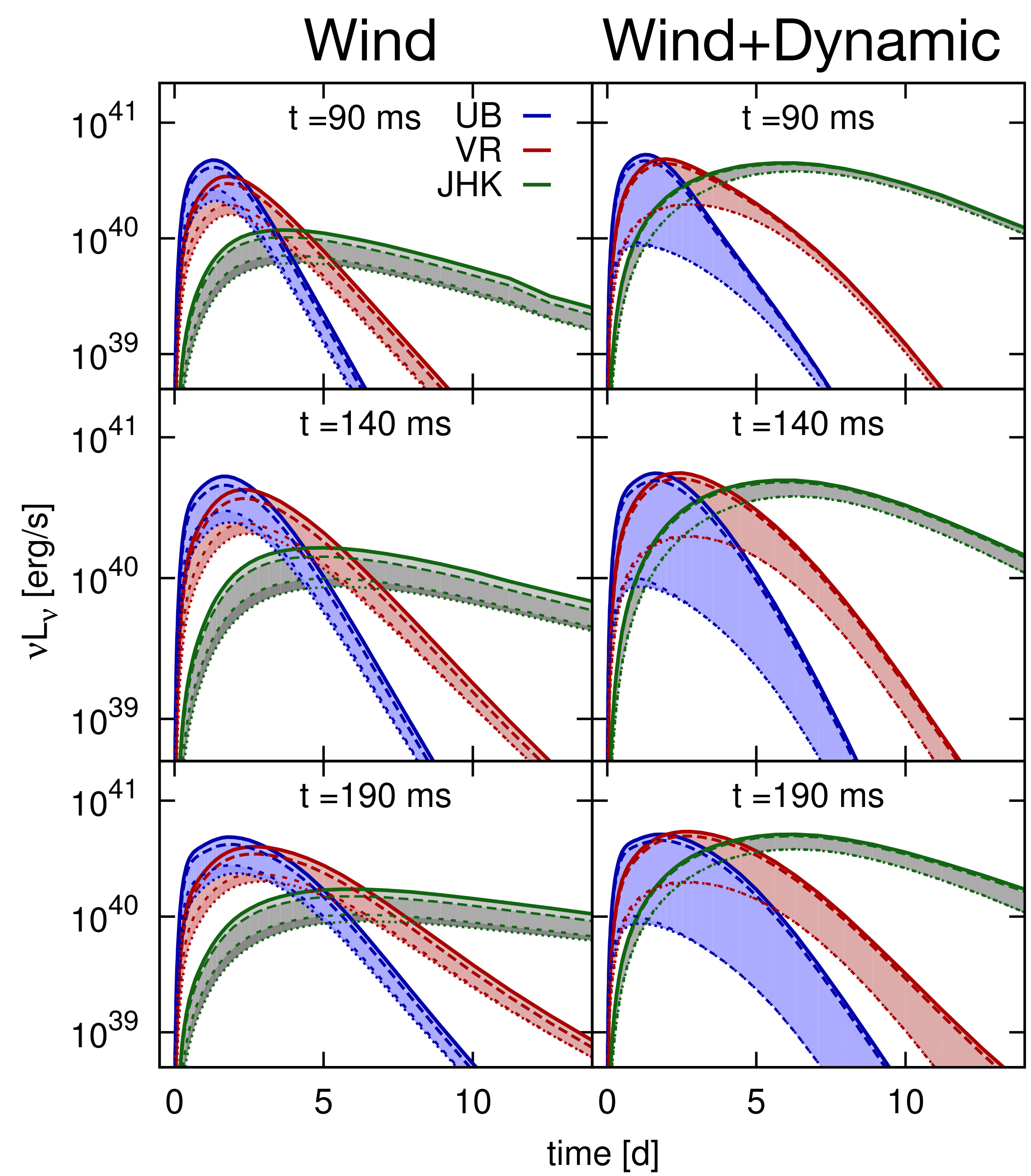
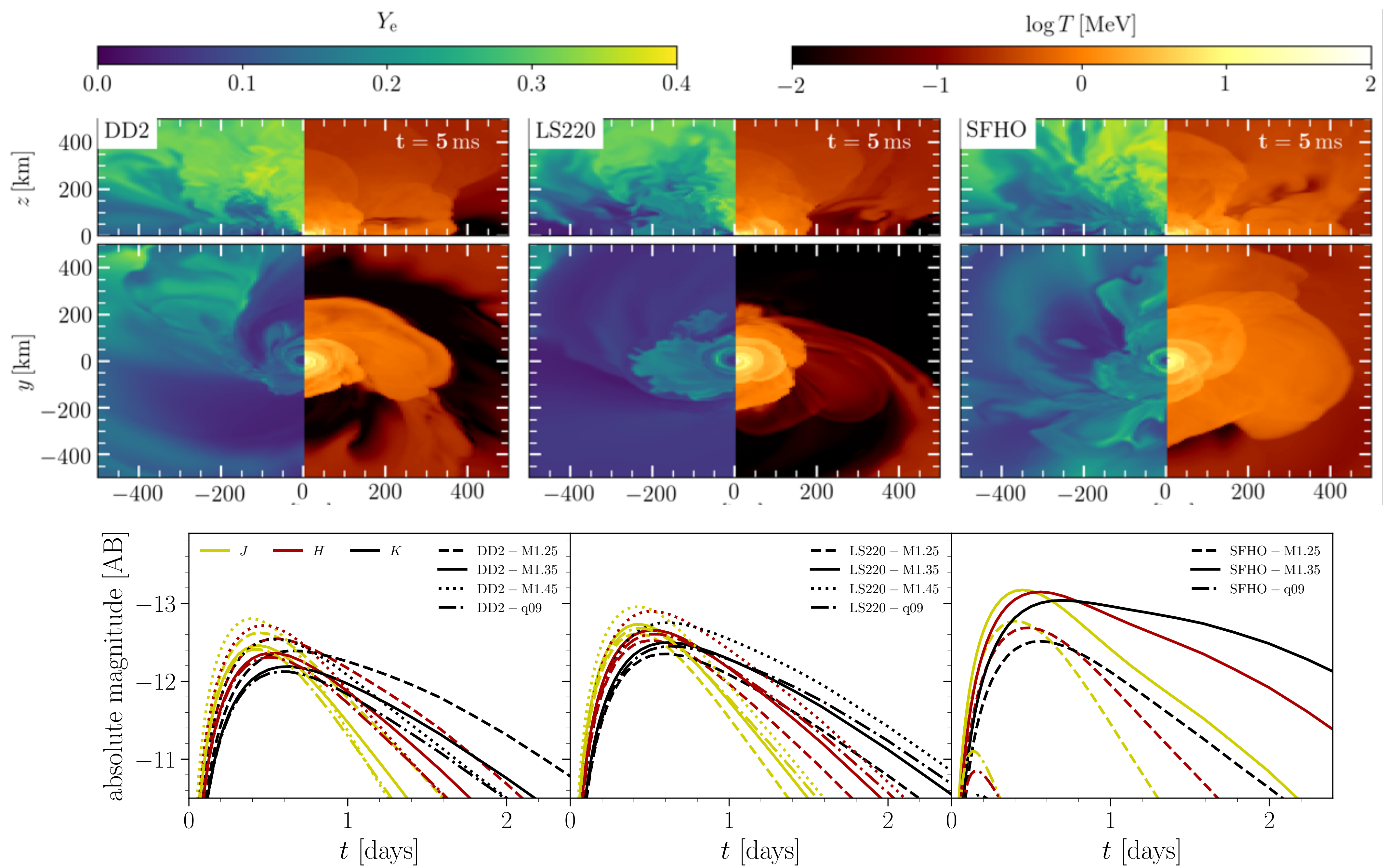




Equation of state and neutrinos

GR simulations: different EoS (Bovard et al. 2017)

impact of neutrinos (Martin et al. 2018)



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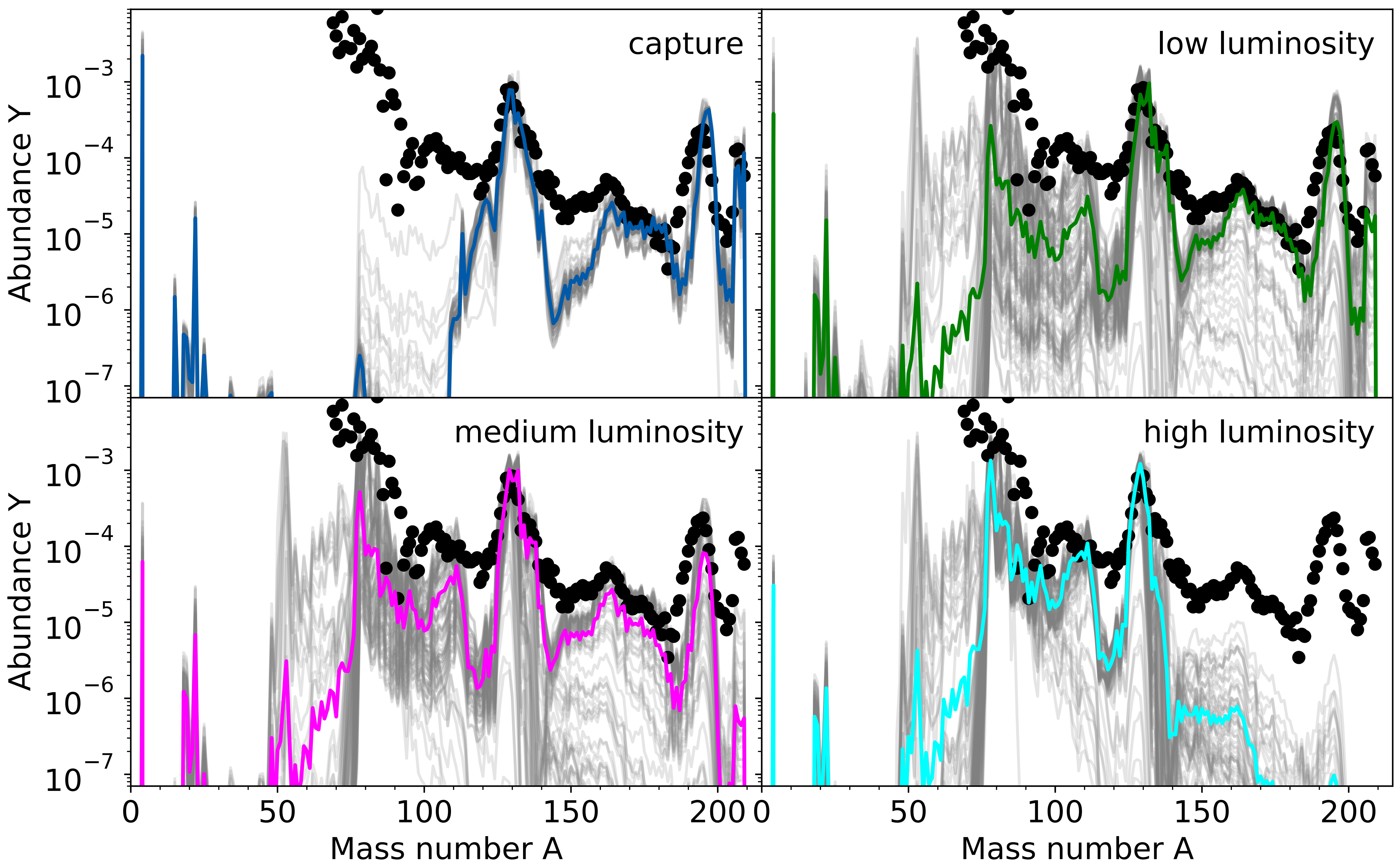
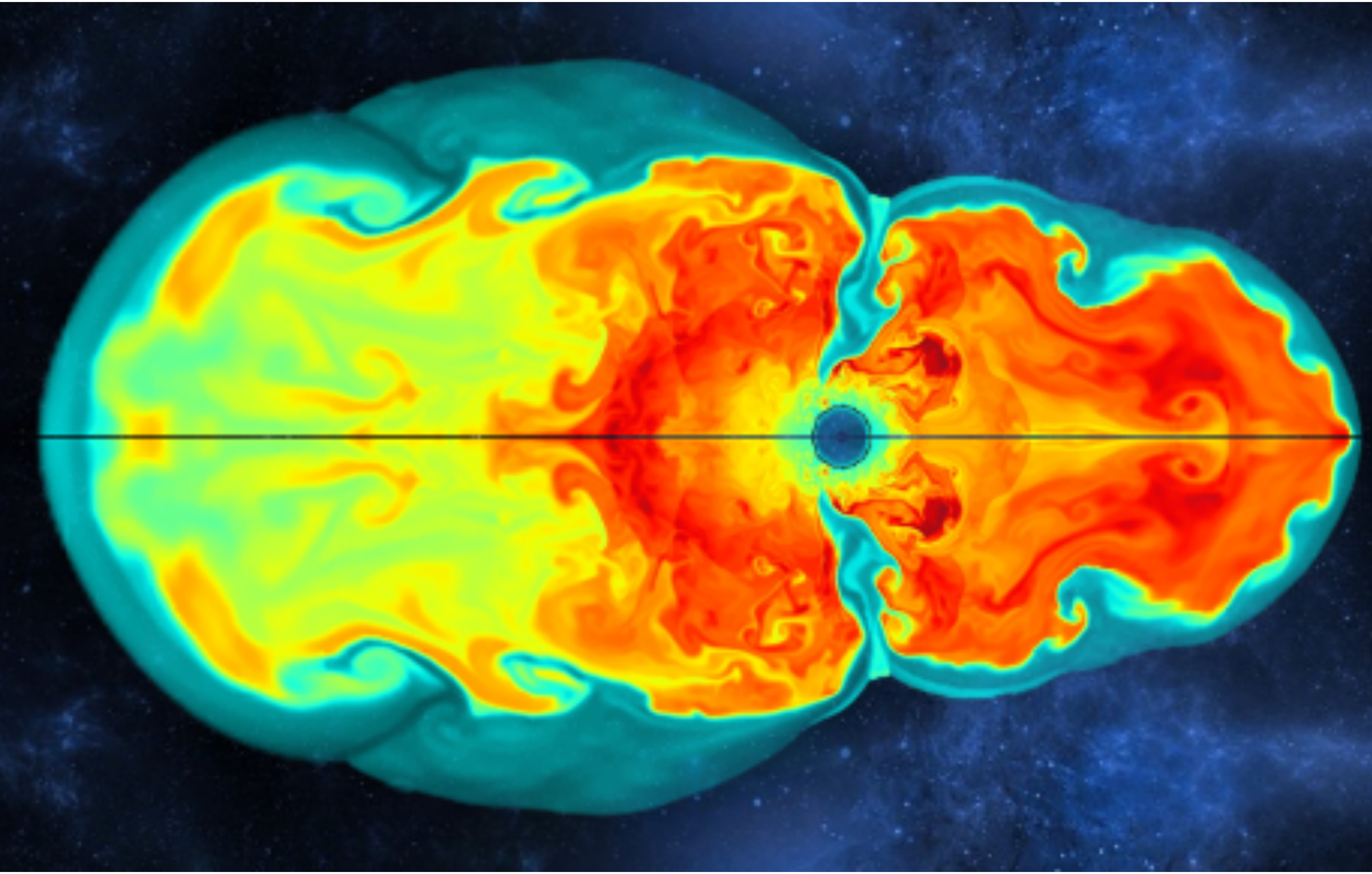
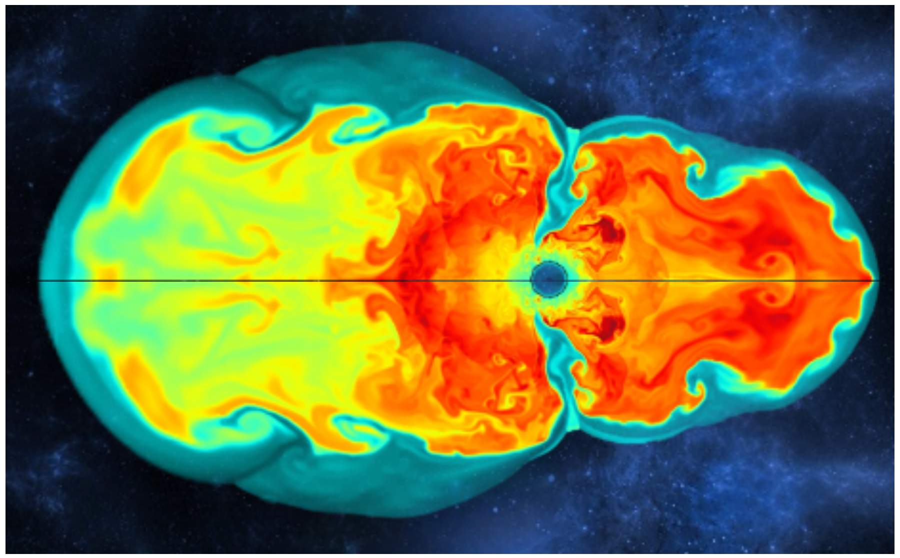




Core-collapse supernovae: ejecta

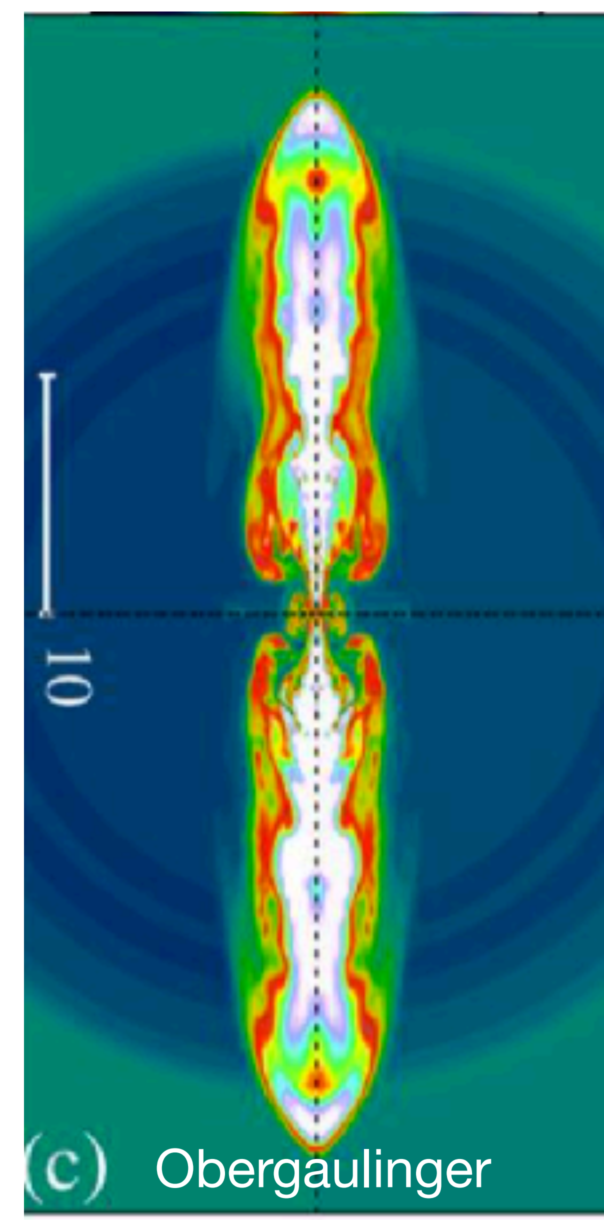


Standard **neutrino-driven supernova**:
Weak r-process and νp-process
Elements up to ~Ag

Magneto-rotational supernovae
Neutron-rich matter ejected by strong magnetic field
(Cameron 2003, Nishimura et al. 2006)

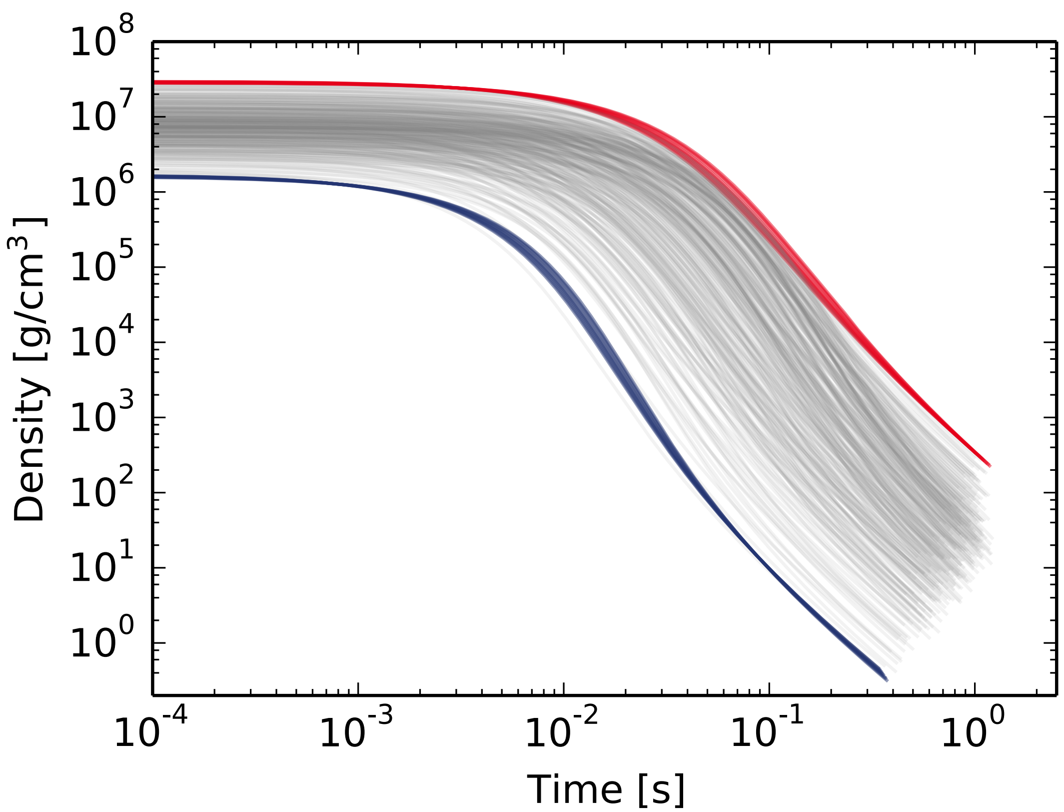
2D and 3D + parametric neutrino treatment :
- jet-like explosion: heavy r-process
- magnetic field vs. neutrinos: weak r-process

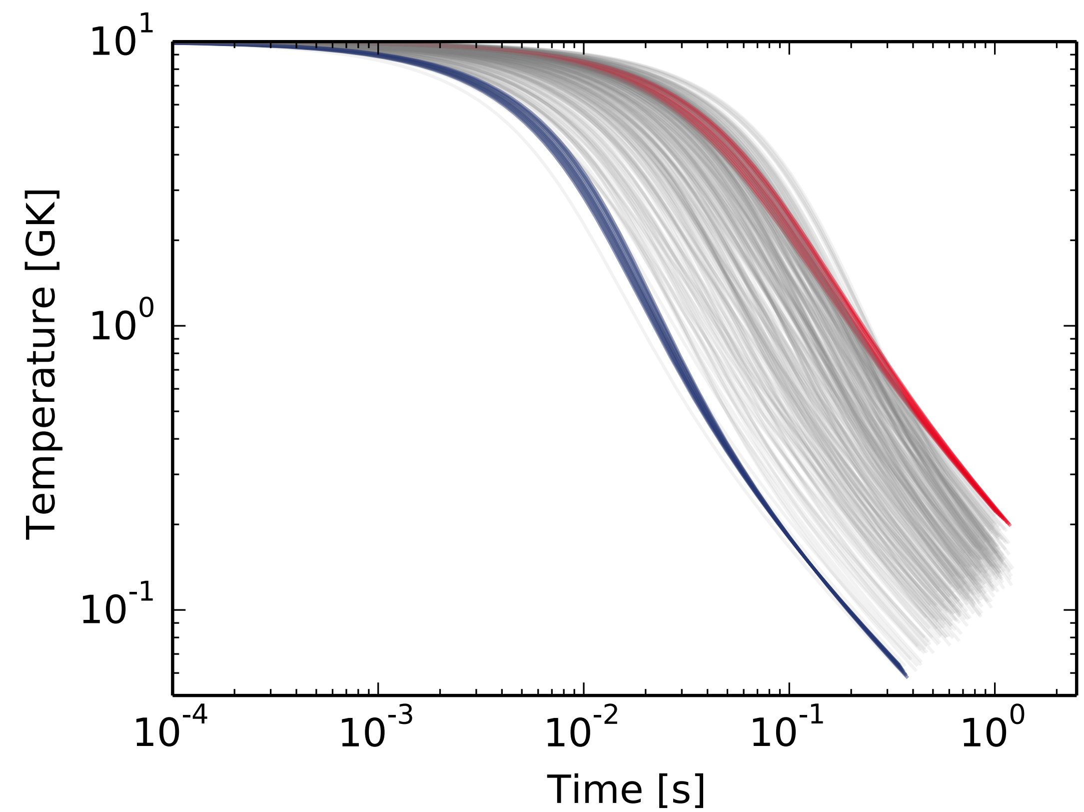
Nishimura et al. 2015, 2017, Winteler et al. 2012, Mösta et al. 2018



Impact of astrophysical uncertainties

Steady-state model to explore possible nucleosynthesis patterns in supernova neutrino-driven ejecta



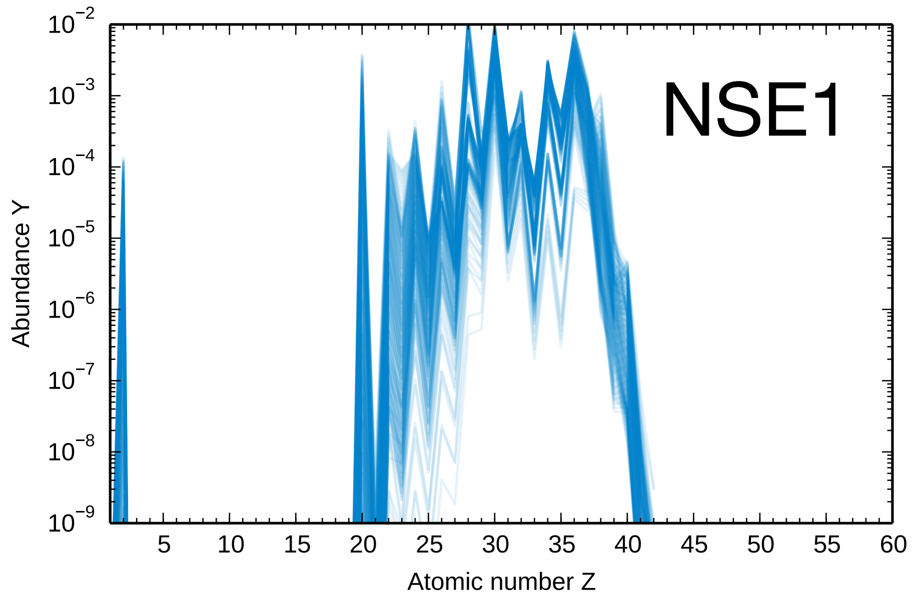


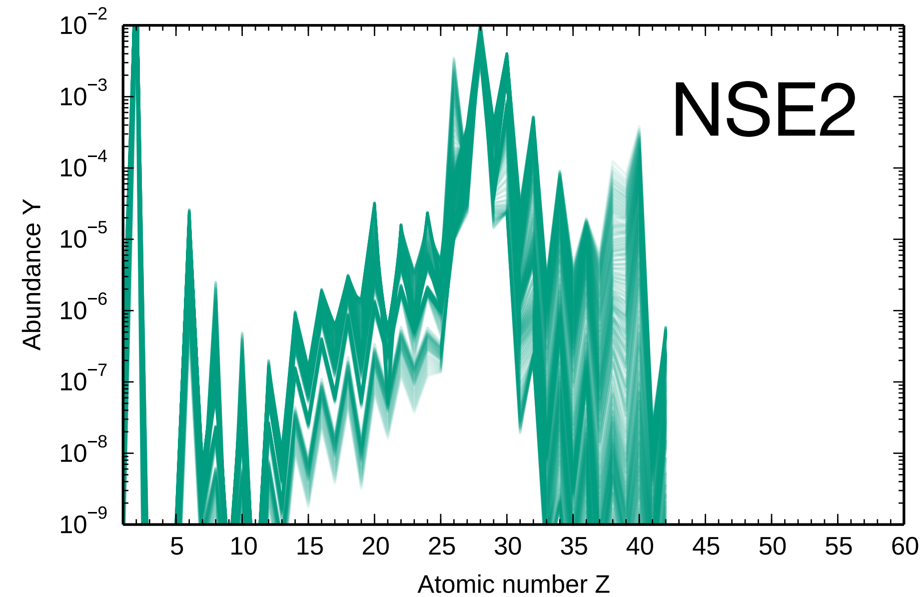
Input parameters: M_{ns}, R_{ns}, Y_e

Nucleosynthesis ~3000 trajectories

Bliss, Witt, Arcones, Montes, Pereira (2018)

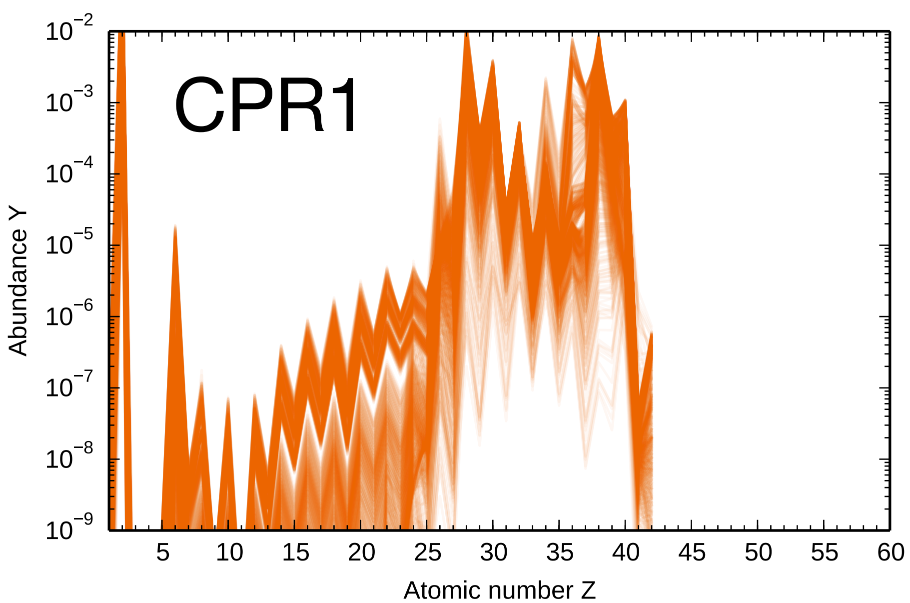
Characteristic nucleosynthesis patterns

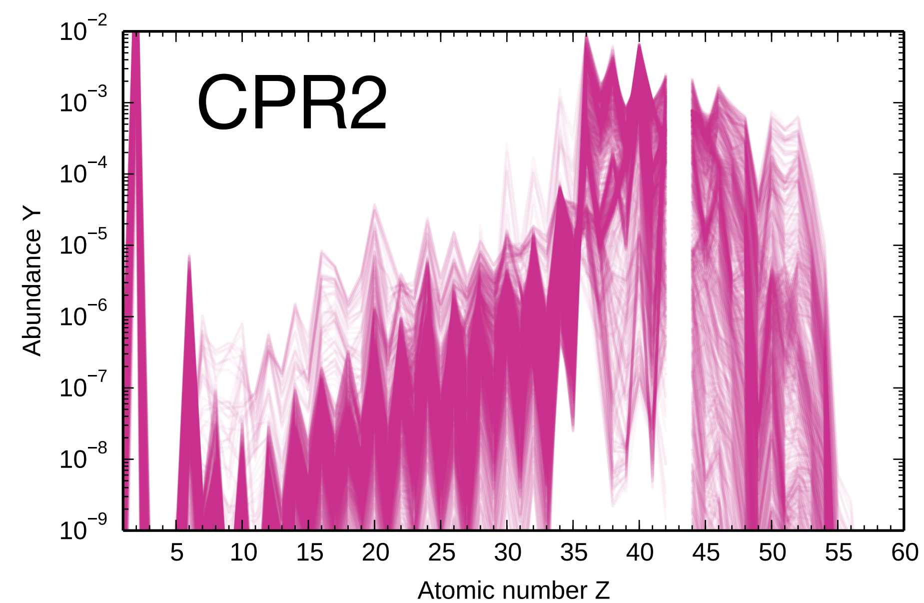




NSE:
nuclear statistical equilibrium

binding energies
partition functions





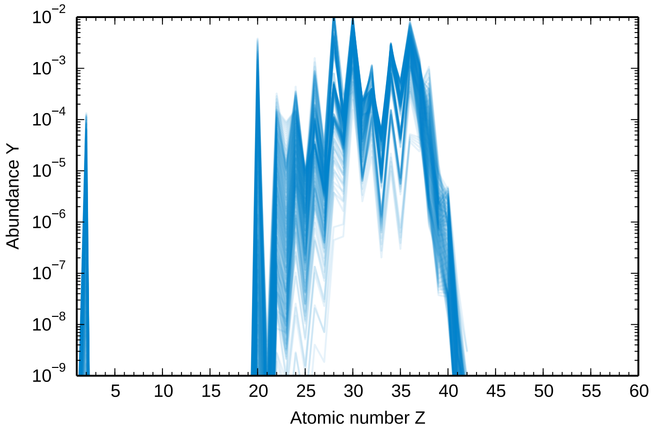
CPR:
charged particle reactions

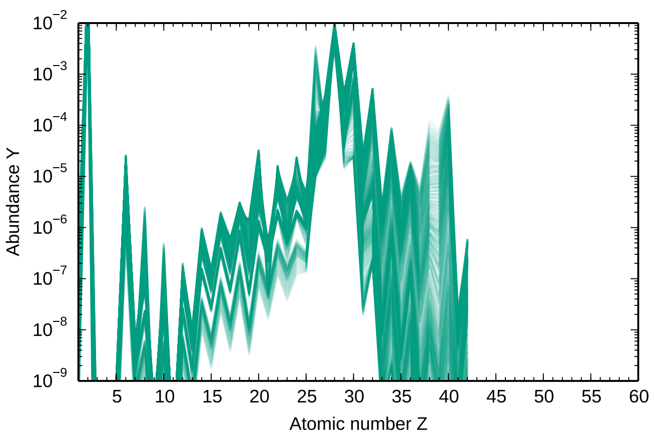
Q-values of (α,n) reactions

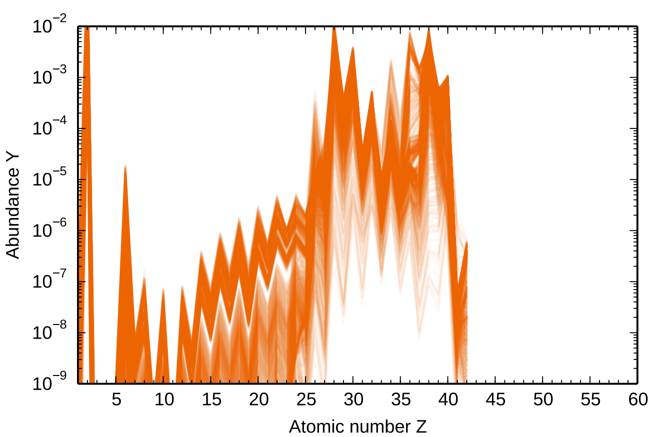
Individual reactions

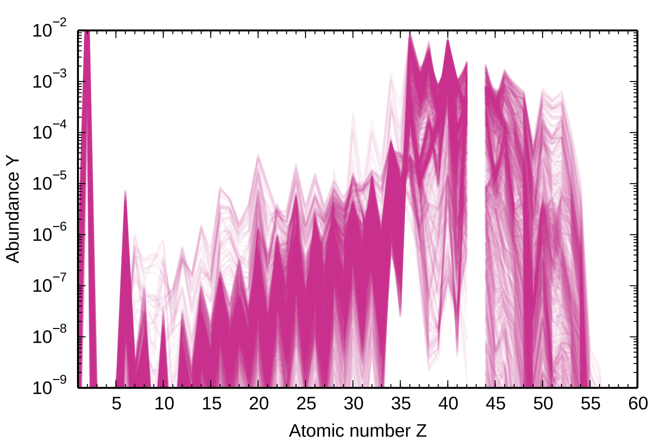
Bliss, Witt, Arcones, Montes, Pereira (2018)

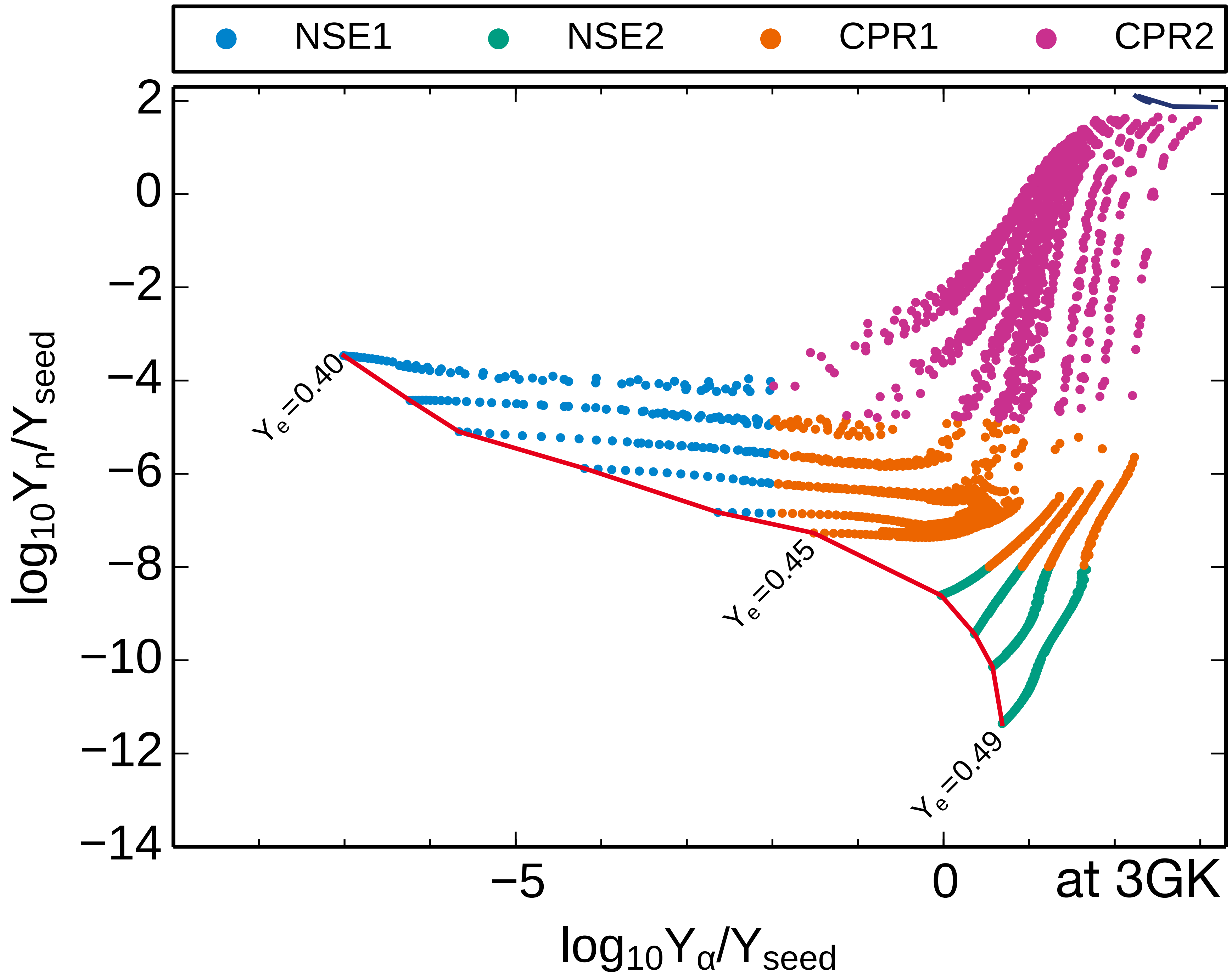
Classification of nucleosynthesis patterns









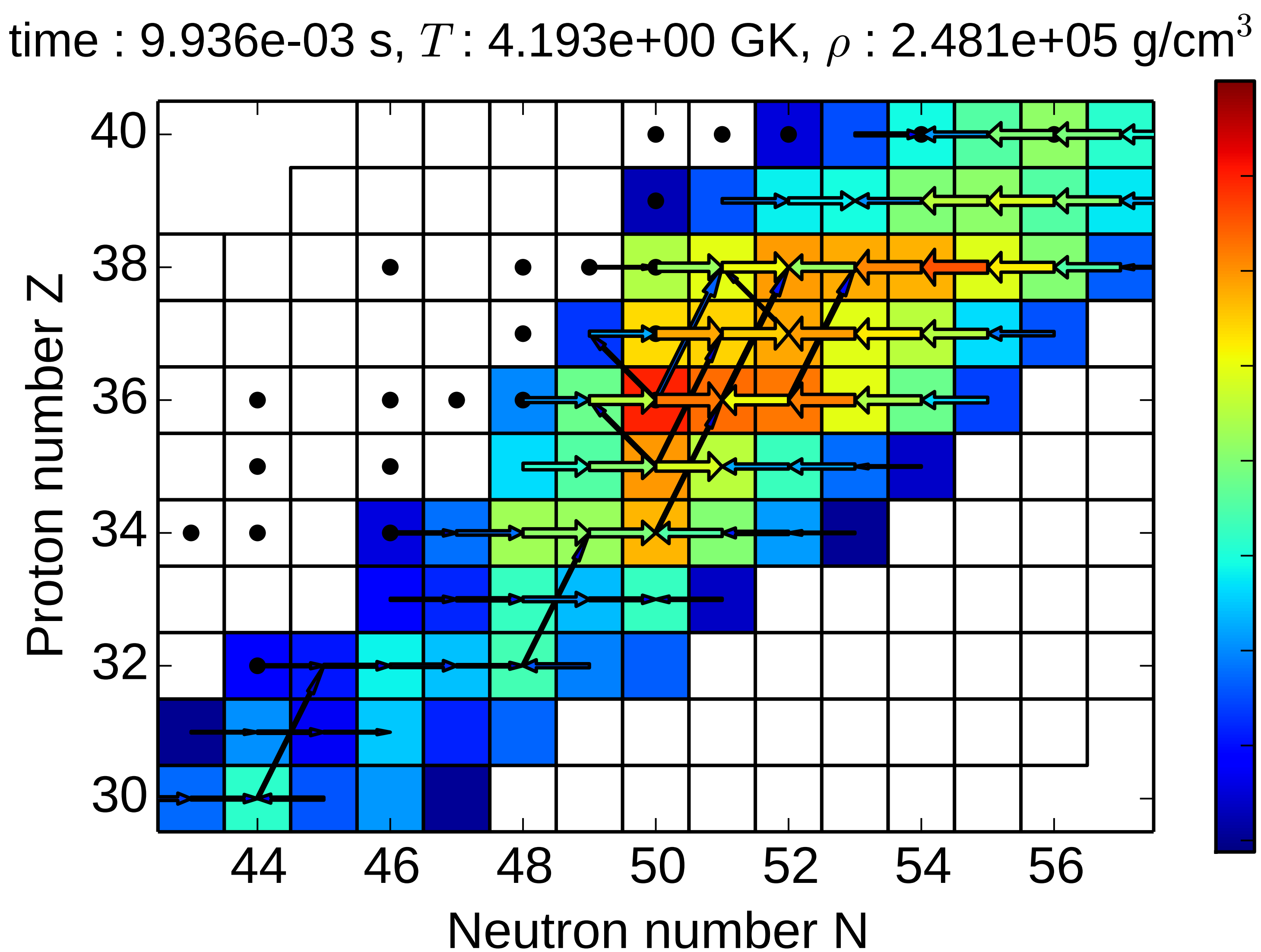


Bliss, Witt, Arcones, Montes, Pereira (2018)

- Estimate nucleosynthesis based on Y_n, Y_{alpha}, Y_{seed}
- Provide representative trajectories to explore impact of nuclear physics input (nuc-astro.eu)

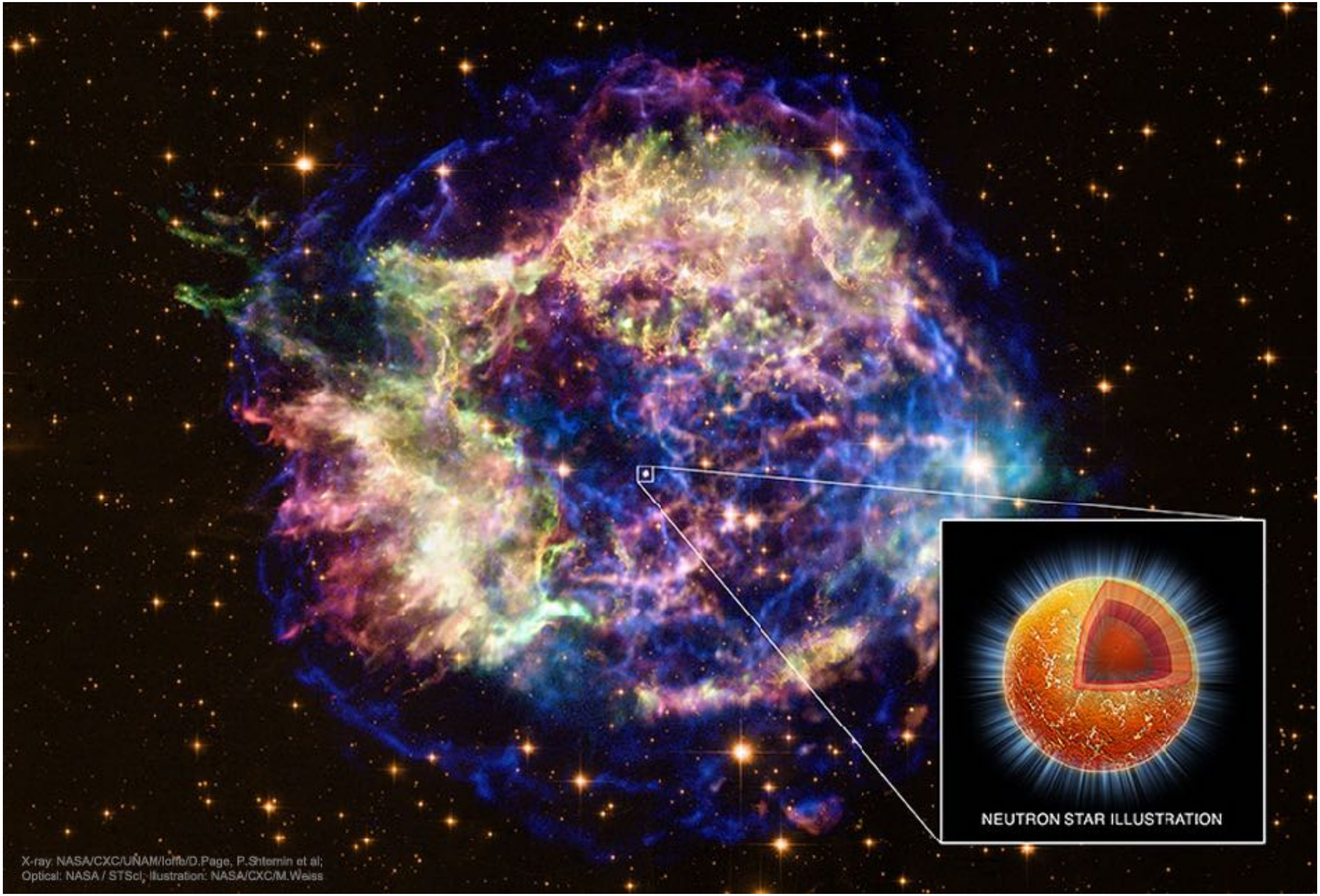
Reactions in neutrino-driven supernova ejecta

- Important reactions: α-, n-, p-capture reactions, β-decays
- $\tau_{expansion} << \tau_{\beta}$ → (α,n) are key reactions
- α-process (Hoffman & Woosley 1992)
- Absence of relevant experiments
  → theoretical reaction rates based on Hauser-Feshbach model



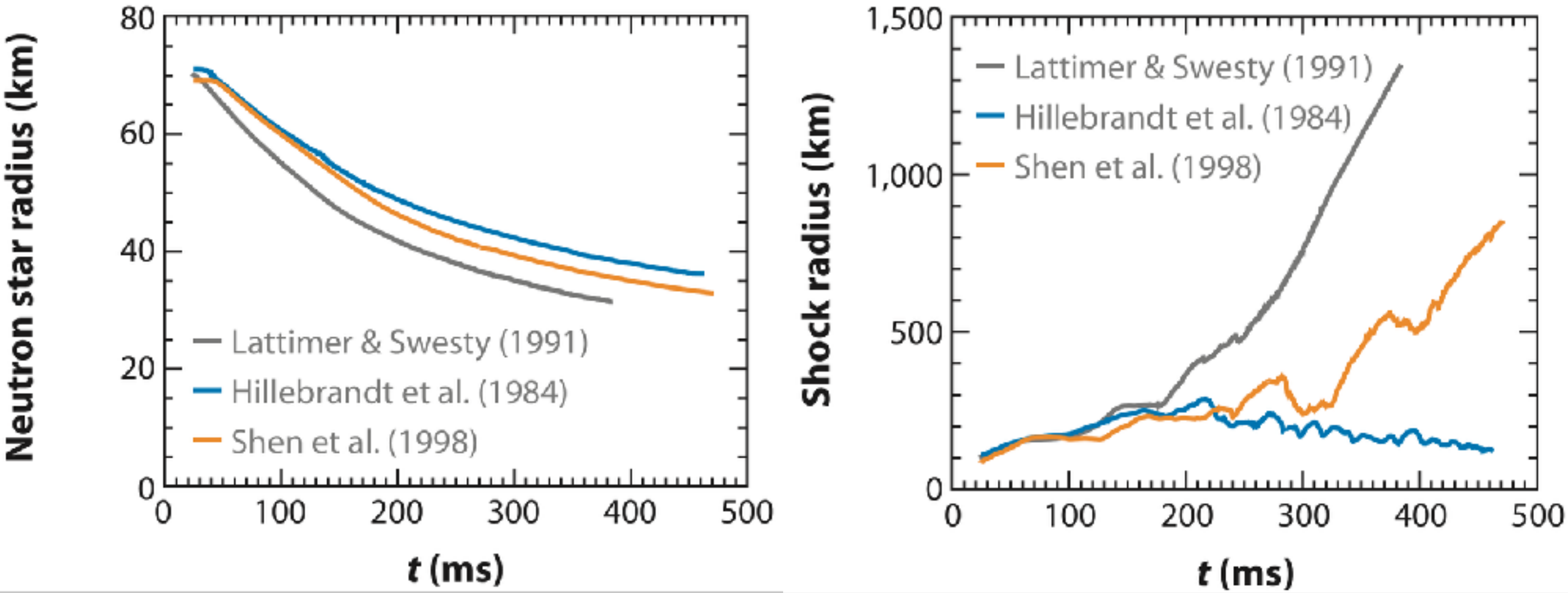
J. Bliss, A. Arcones,
F. Montes, and J. Pereira (2017)

Equation of State



Core-collapse supernovae: Equation of State

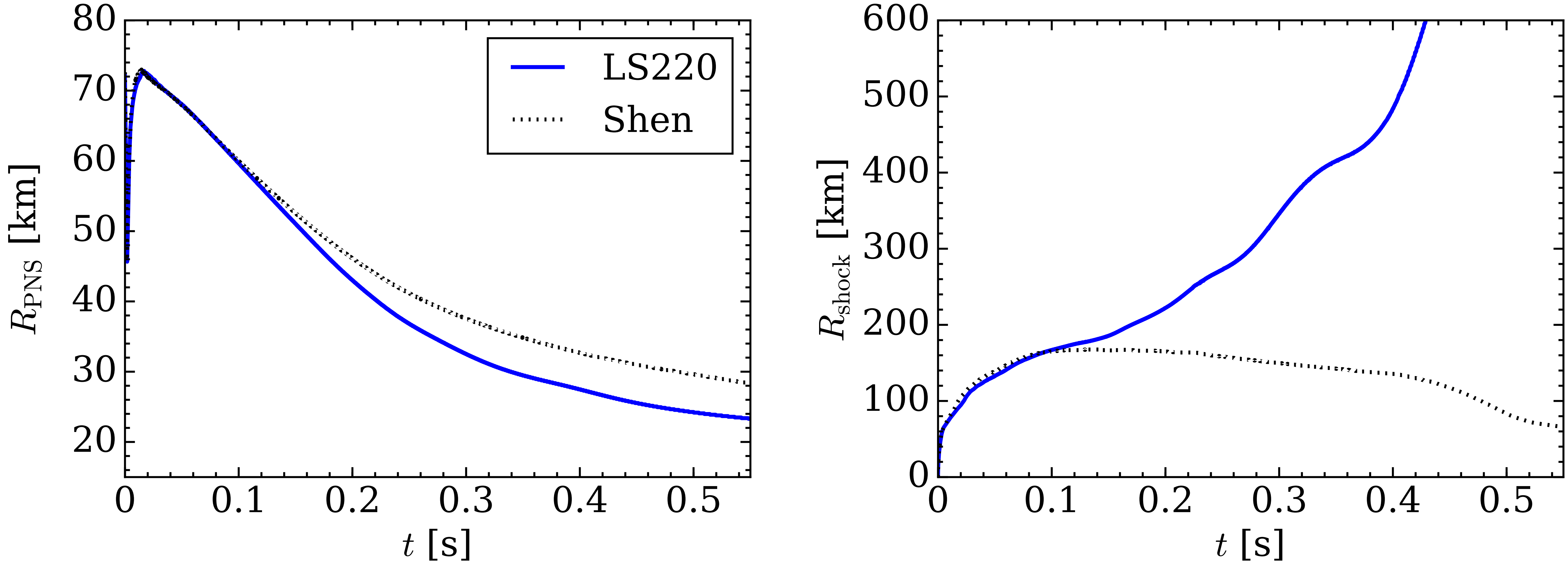
There are several studies based on different EoS
- different underlying theory or
- all nuclear physics inputs changed simultaneously



Janka (2012)

Core-collapse supernovae: Equation of State

Spherically symmetric supernova simulations
with FLASH, M1 neutrino treatment, enhanced neutrino energy deposition
(Couch & O'Connor, 2018)



Yasin, Schäfer, Arcones, Schwenk (in prep.)

Equation of State effects

First exploration of individual nuclear physics input
Skyrme functional: Lattimer & Swesty (1991)

EOS	n_s [fm^{-3}]	B [MeV]	K [MeV]	J [MeV]	L [MeV]	m^*	M_{NS} [$M_\odot$]	$R_{1.4\mathrm{M_{NS}}}$ [km]
LS220	0.155	16.00	220.0	28.61	73.7	1	2.06	12.2
Shen	0.145	16.26	281.2	36.89	110.8	0.634	2.22	14.6
χ EFT	0.157 - 0.171	15.29 - 16.43	175 - 254	28.4 - 35.7	32.4 - 69.8	$\sim$ 0.8		9.7 - 13.9
LL 2013				29.0 - 32.7	40.5 - 61.9			10.7 - 13.1
Exp.	0.15 - 0.16	$\sim$ 16	220 - 260					

χEFT: Hebeler et al 2010, Hebeler et al 2013, Drischler et al 2017
Lattimer & Lim, 2013
Exp: Shlomo et al 2006

Conclusions

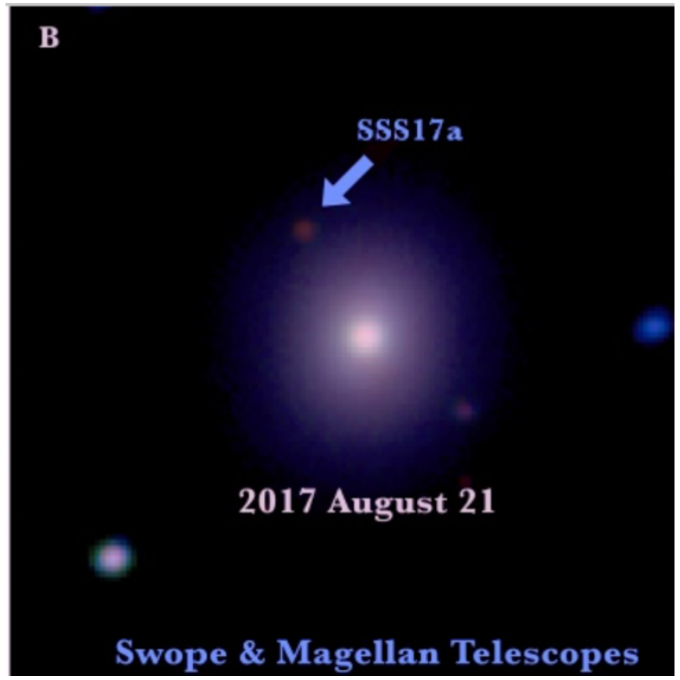
Neutron star mergers

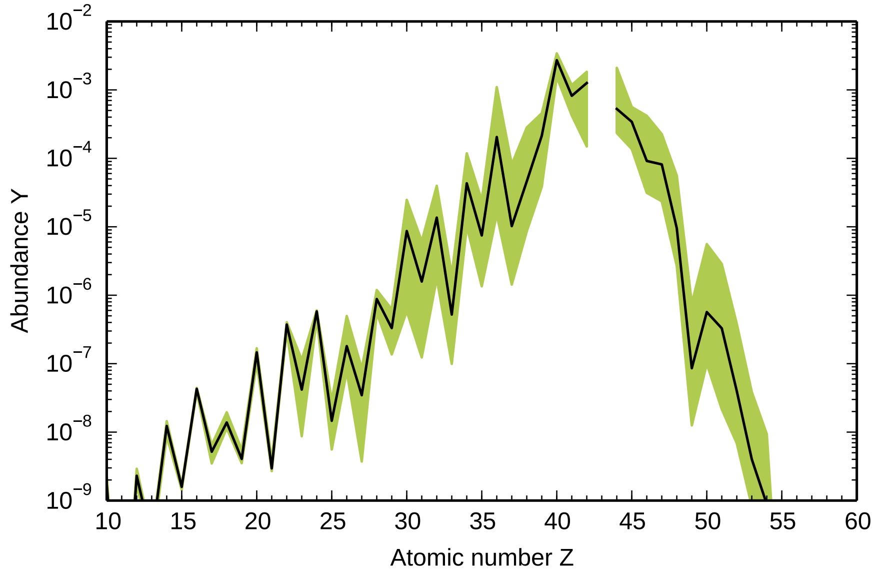
r-process and kilonova
microphysics in simulations (EoS and neutrinos): improvement necessary

Core-collapse supernovae

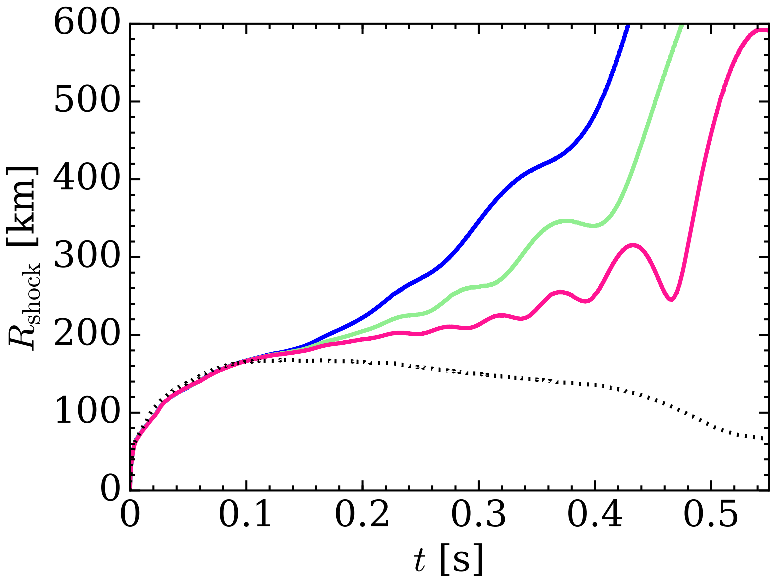
Nucleosynthesis of lighter heavy elements: astro and nuclear uncertainties

EoS: First exploration of individual nuclear physics input
Effective mass determines PNS contraction





Julia Bliss



Hannah Yasin,
Sabrina Schäfer