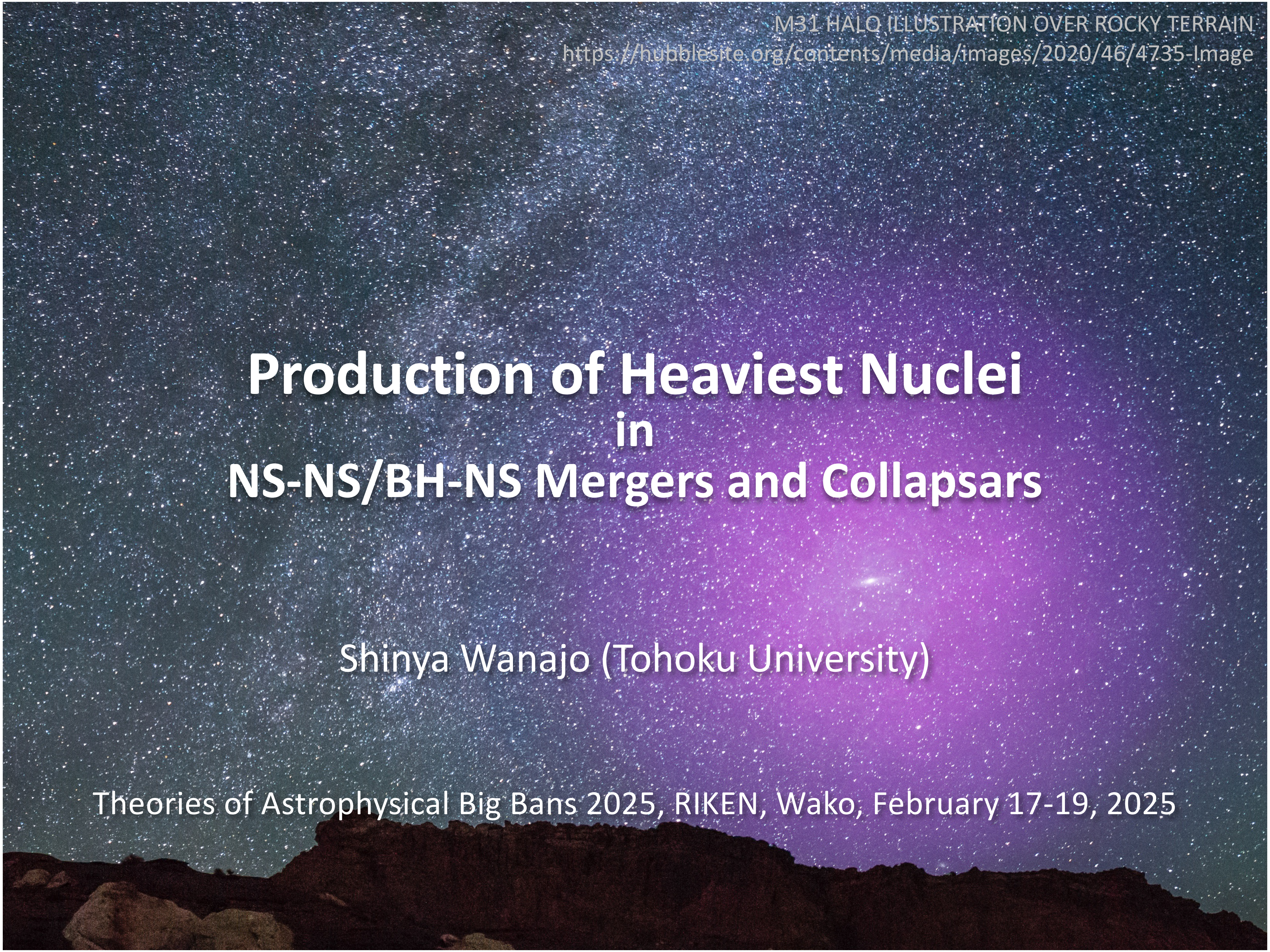

M31 HALO ILLUSTRATION OVER ROCKY TERRAIN
https://hubblesite.org/contents/media/images/2020/46/4735-Image

Production of Heaviest Nuclei in NS-NS/BH-NS Mergers and Collapsars

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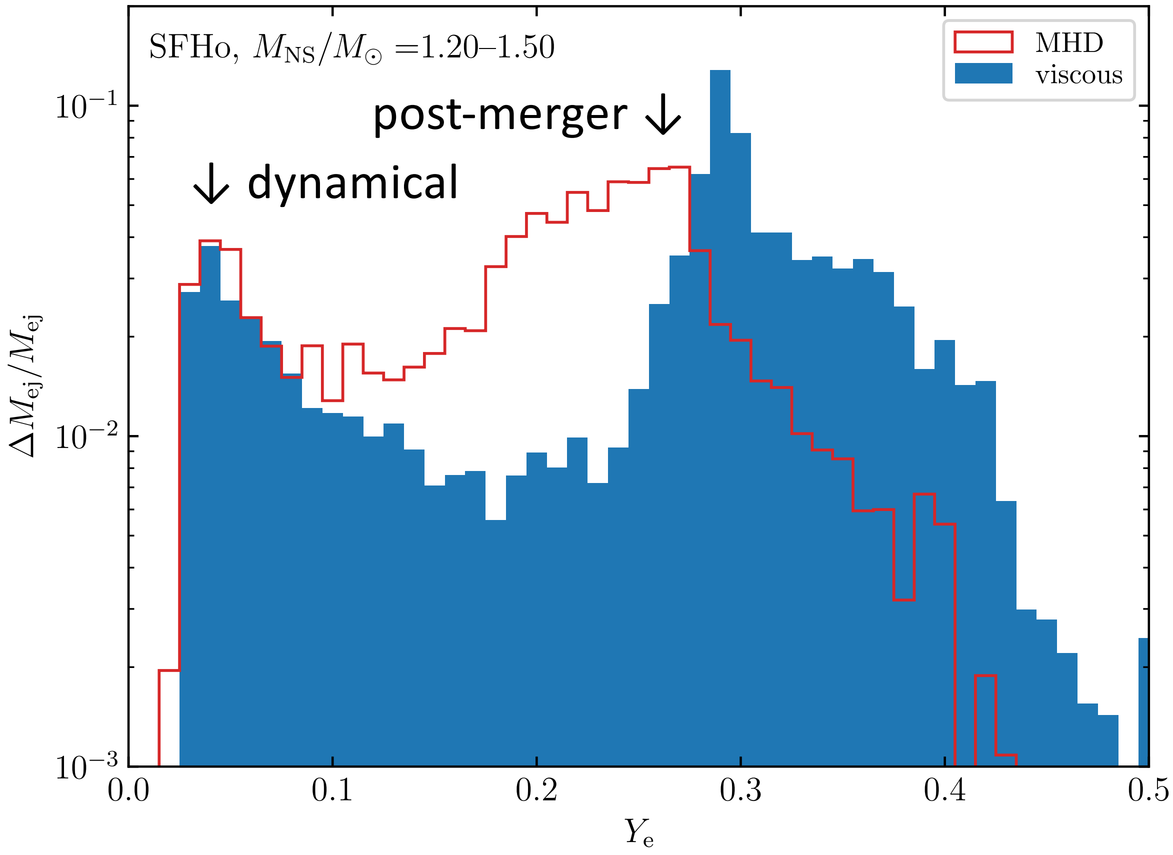
Theories of Astrophysical Big Bans 2025, RIKEN, Wako, February 17-19, 2025

Y_e distribution in MHD model (NS-NS)

MHD vs viscous models; Wanajo+ in prep.



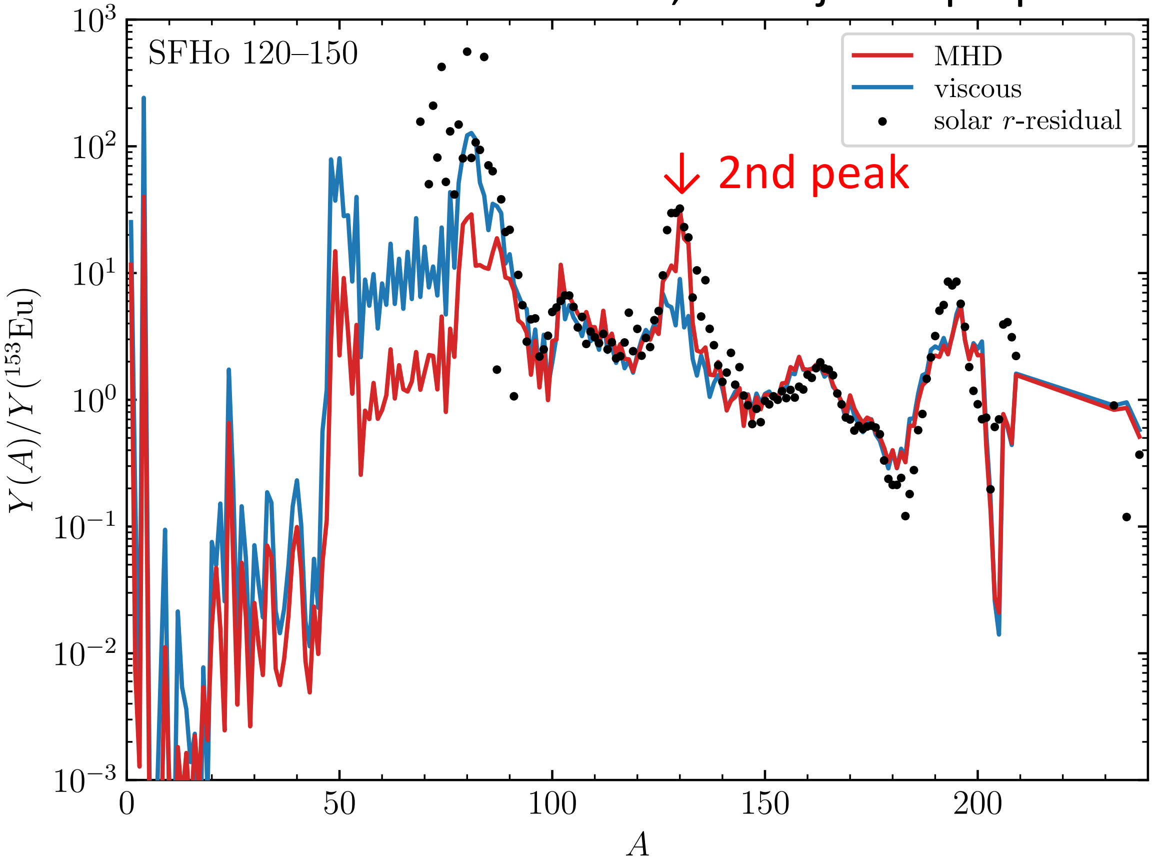
Y_e = *N*(proton)/*N*(proton+neutron)

1st self-consistent 3D simulation of a neutron star merger over 1s (including both dynamical and post-merger ejecta; Kiuchi+2023)

❖ MHD model results in Y_e = 0.2-0.26 (and ~0.01 $M_{\odot}$) instead of ~ 0.3 in viscous model (Fujibayashi+2023)

nucleosynthesis in MHD model (NS-NS)

MHD vs viscous models; Wanajo+ in prep.

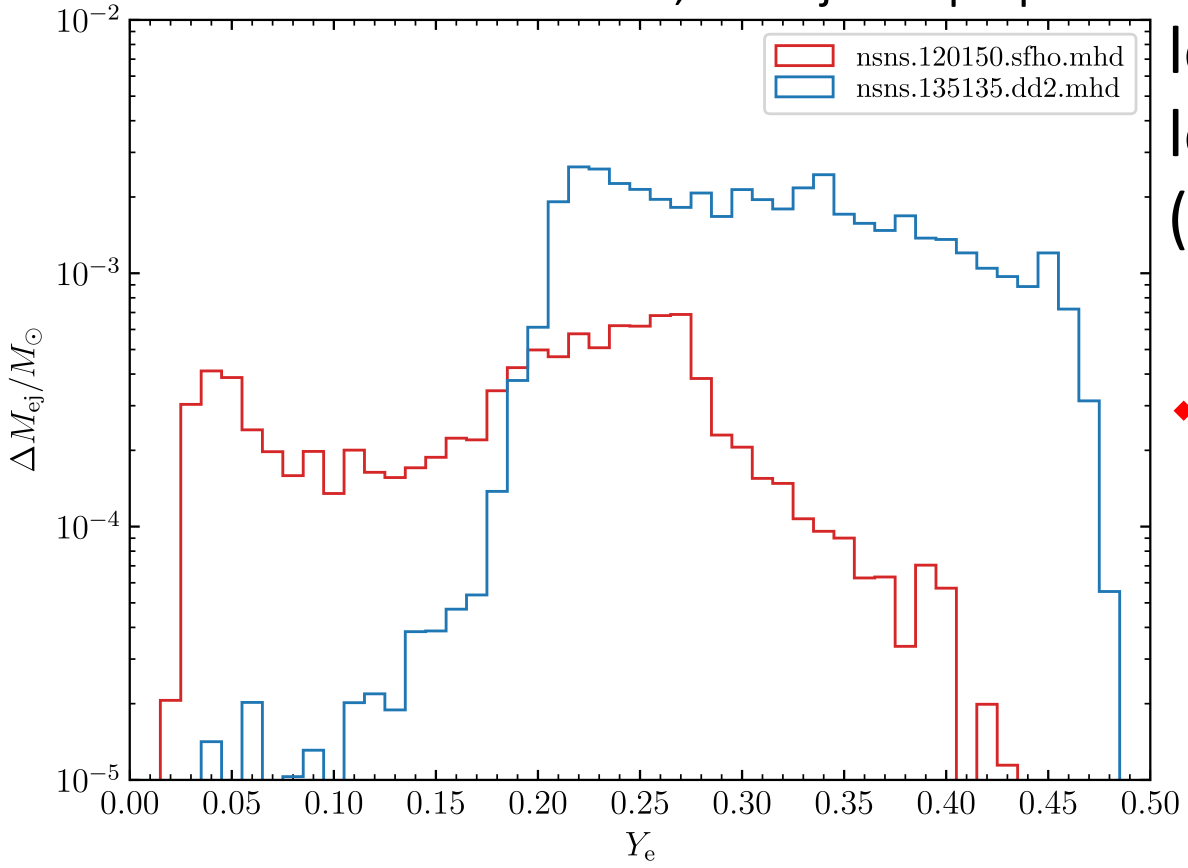


~16000 tracer particles are used for nucleosynthesis calculations

- MHD model results in very good agreement with solar r-process pattern including 2nd peak (*A*~ 130)

long- vs short-lived remnant NS (NS-NS)

MHD vs viscous models; Wanajo+ in prep.



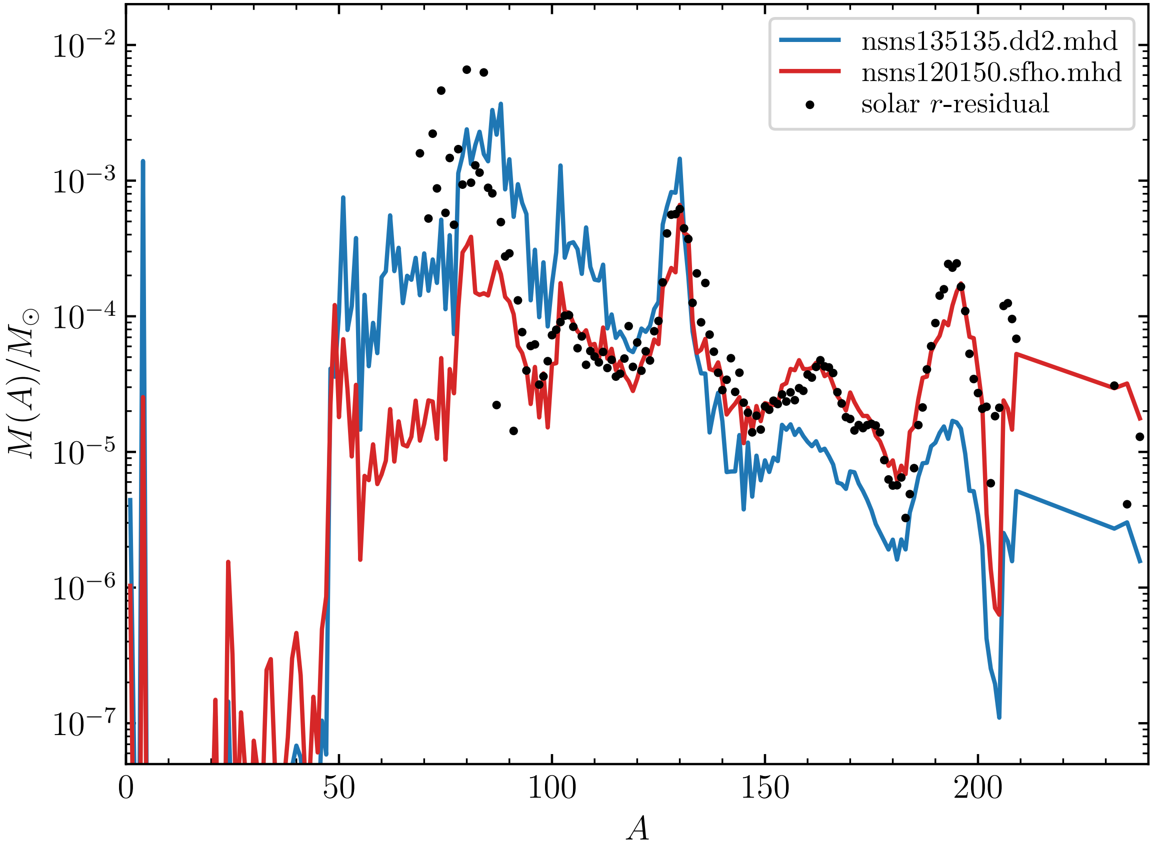
Y_e = N(proton)/N(proton+neutron)

long-lived remnant NS (> 0.3 s) leads to more massive ejecta (~0.05 $M_\odot$)

- ejecta for long-lived case are dominated by post-merger component with higher Y_e (> 0.2)

long- vs short-lived remnant NS (NS-NS)

MHD short- vs long-lived NS; Kiuchi+ in prep.

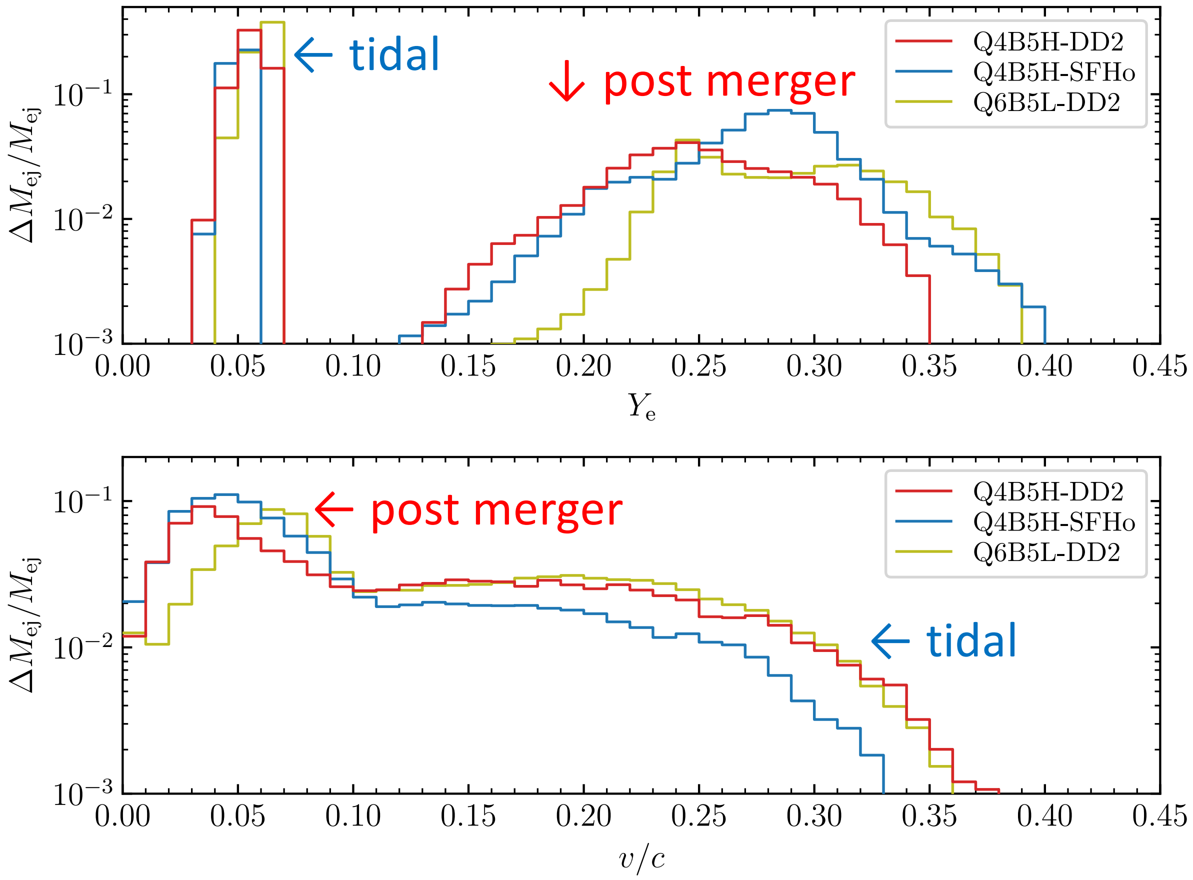


ejecta for long-lived remnant NS (> 0.3 s) is dominated by post-merger ejecta ($Y_e > 0.2$) with A ~ 90-110 (~0.05 $M_\odot$)

- short-lived remnant NS should be the outcome of typical mergers (but with ~0.01 $M_\odot$)

ejecta compositions (BH-NS)

Wanajo+2024; adopted from Hayashi+2022



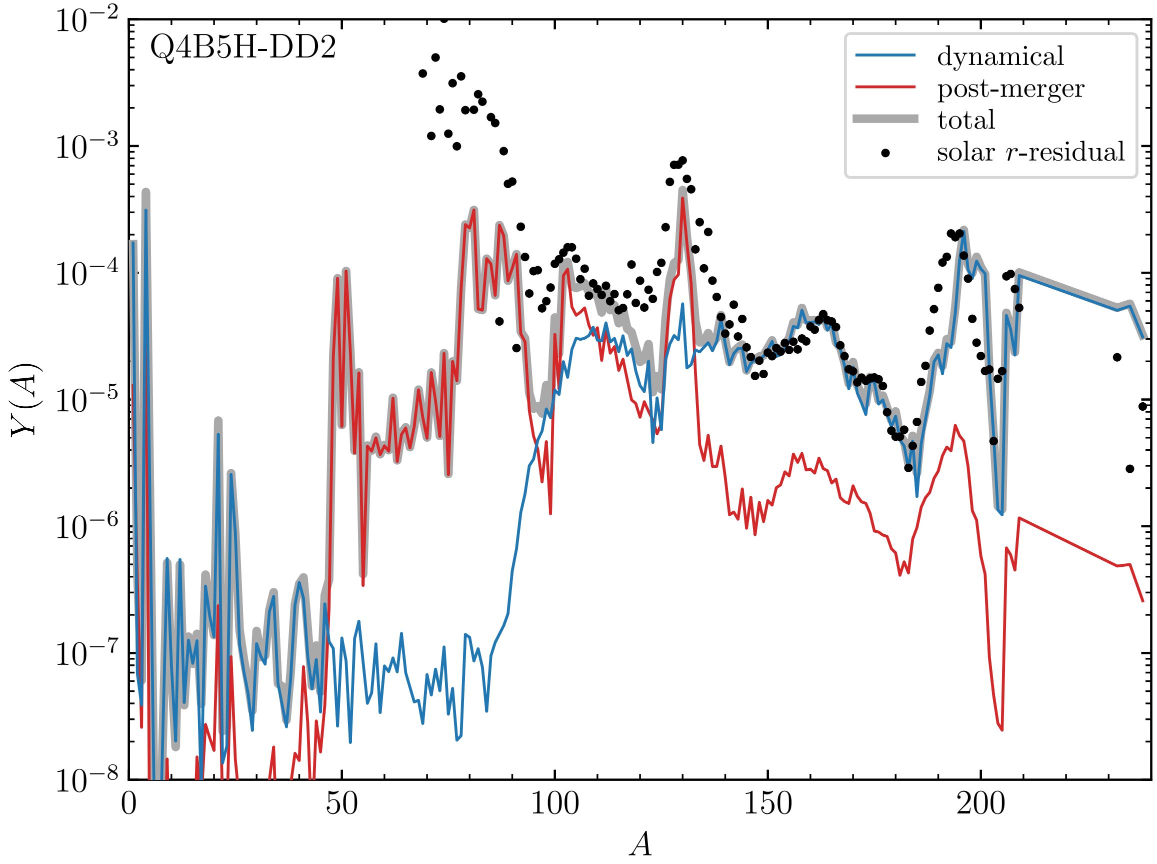
self-consistent, 3D GRMHD BH-NS simulations over 1 s (with DD2 or SFHo EOSs)

❖ tidal (cold) component: $Y_{\rm e}$ ~ 0.05-0.06 (pure NS material without weak interaction)

❖ post-merger (hot) component: $Y_{\rm e}$ ~ 0.2-0.3 (weak-processed material)

comparison with solar abundance (BH-NS)

Wanajo+2024

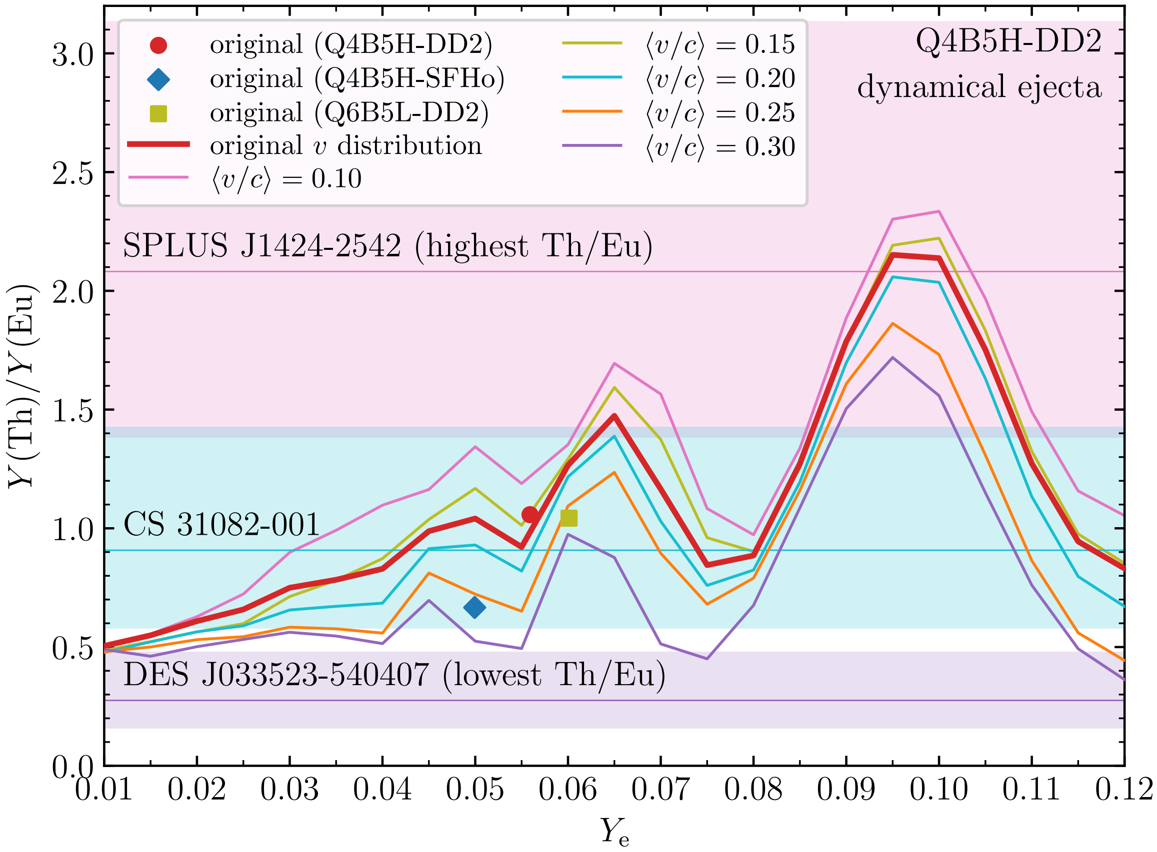


good agreement with the solar r-process abundance

- ❖ tidal (cold) component: responsible for *A* > 140
- ❖ post-merger (hot) component: responsible for *A* = 90-140

Y_e constraint from actinide (BH-NS)

Wanajo+2024

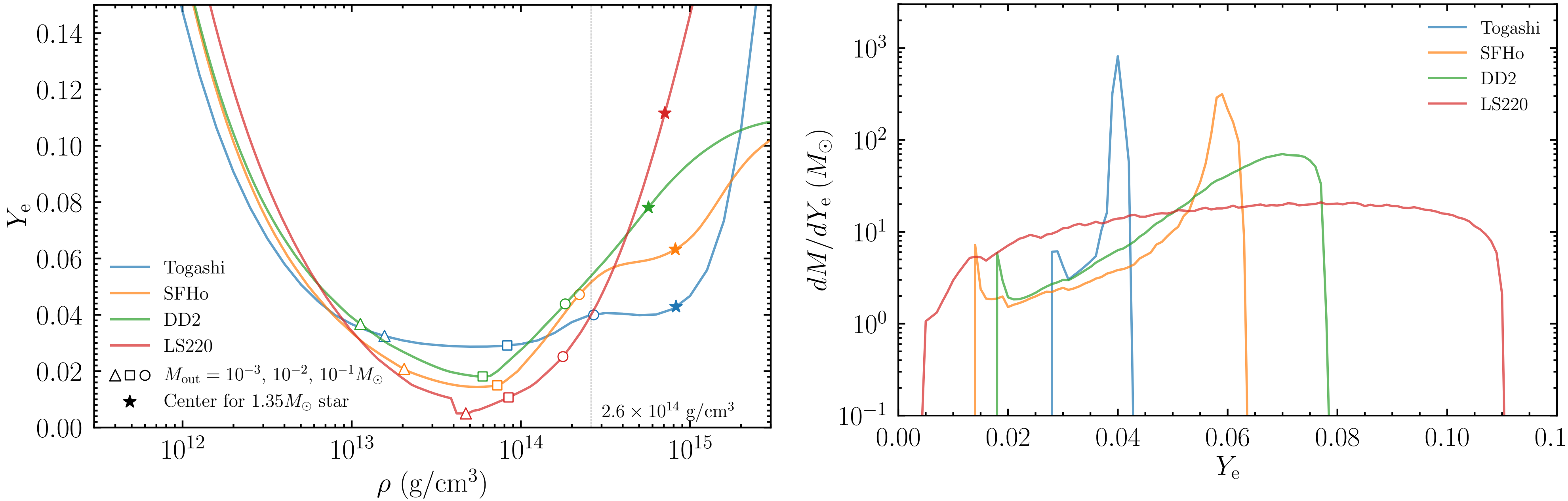


tests with Y_e = 0.01, ..., 0.1 are consistent with Th/Eu in metal-poor stars (13 Gyr ago)

- presence of actinide-boost stars (Th/Eu > 0.9) implies Y_e ~ 0.05-0.1 in the dynamical ejecta

constraint on nuclear EOS (BH-NS)

Wanajo+2024



- range of Y_e ~ 0.05-0.1 excludes some nuclear equations of state (e.g., Togashi EOS)

GR-MHD collapsar models (collapsars)

Shibata, Fujibayashi, Wanajo+2025, submitted

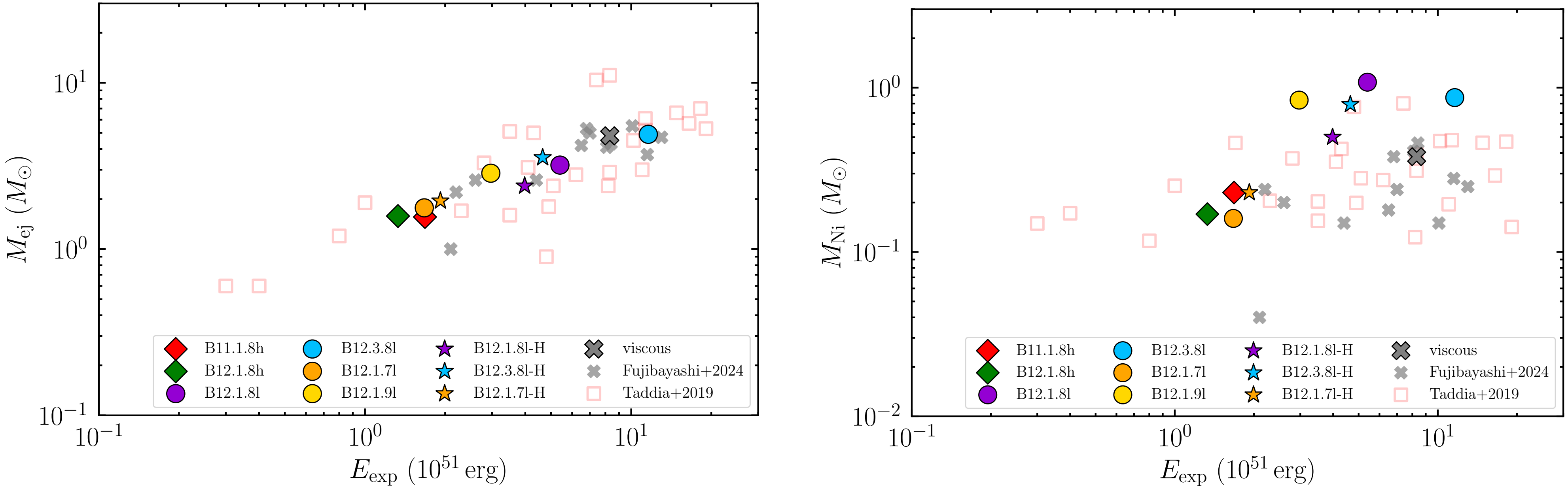
Model	$B_{\rm max}$ (G)	$\alpha_{\rm d}$	$\sigma_{\rm c}$ ($\rm s^{-1}$)	$\rho_{\rm cut}$ ($\rm g/cm^3$)	Δx (m)	Explosion	Jet
B11.1.8h	10^{11}	10^{-4}	10^8	10^8	360	Yes	Yes
B12.1.8h	10^{12}	10^{-4}	10^8	10^8	360	Yes	Yes
B12.1.8l	10^{12}	10^{-4}	10^8	10^6	360	Yes	Yes
B12.3.8l	10^{12}	3×10^{-4}	10^8	10^6	360	Yes	Yes
B12.1.7l	10^{12}	10^{-4}	10^7	10^6	360	Yes	Weak
B12.1.9l	10^{12}	10^{-4}	10^9	10^6	360	Yes	Yes
B12.1.8l-H	10^{12}	10^{-4}	10^8	10^6	300	Yes	Yes
B12.3.8l-H	10^{12}	3×10^{-4}	10^8	10^6	300	Yes	No
B12.1.7l-H	10^{12}	10^{-4}	10^7	10^6	300	Yes	Weak
viscous	—	—	—	—	360	Yes	No

long-term (> 10 s) 2D neutrino-radiated, GR-MHD simulations of BH-forming SNe (collapsars) from a 35 $M_\odot$ star (Aguilera-Dena+2020) with phenomenological dynamo parameters (Shibata+2021)

- all models explode with or without jets (depending on the stochastic nature of magnetic field evolution)

explosion energy and Ni (collapsars)

Shibata, Fujibayashi, Wanajo+2025, submitted

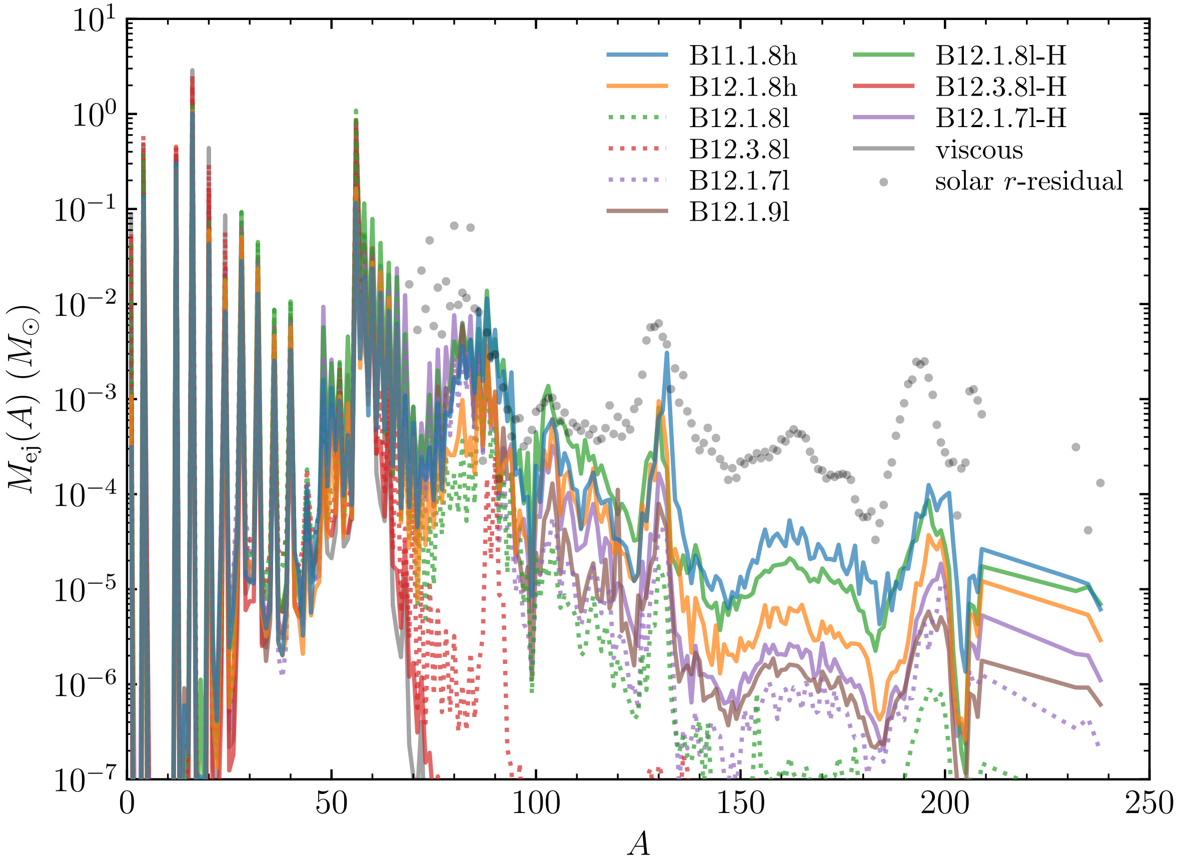


observed SNe Ic-BL (hypernovae) exhibit large explosion energies and large ^{56}Ni masses (Taddia+2019)

- models well reproduce the observational trends for explosion energy, ejecta mass, and ^{56}Ni mass

unknown nucleosynthesis? (collapsars)

Shibata, Fujibayashi, Wanajo+2025, submitted



high entropy and mild neutron-richness in ejecta for models with jets

- no r-process in non-GRB SNe
- weak r-process in GRB-SNe
- no kilonova-like transients because of low lanthanides (consistent with observation of SNe Ic-BL; Rastinejad+2024)