r-Process Nucleosynthesis from Post-Merger Disks with Monte Carlo Neutrino Transport: Effects of Magnetic Field Strength

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Context

- Neutron star mergers are a preferred site for the synthesis of the heaviest elements via the rapid neutron capture (r-process). Post-merger disks can provide conditions necessary for r-process

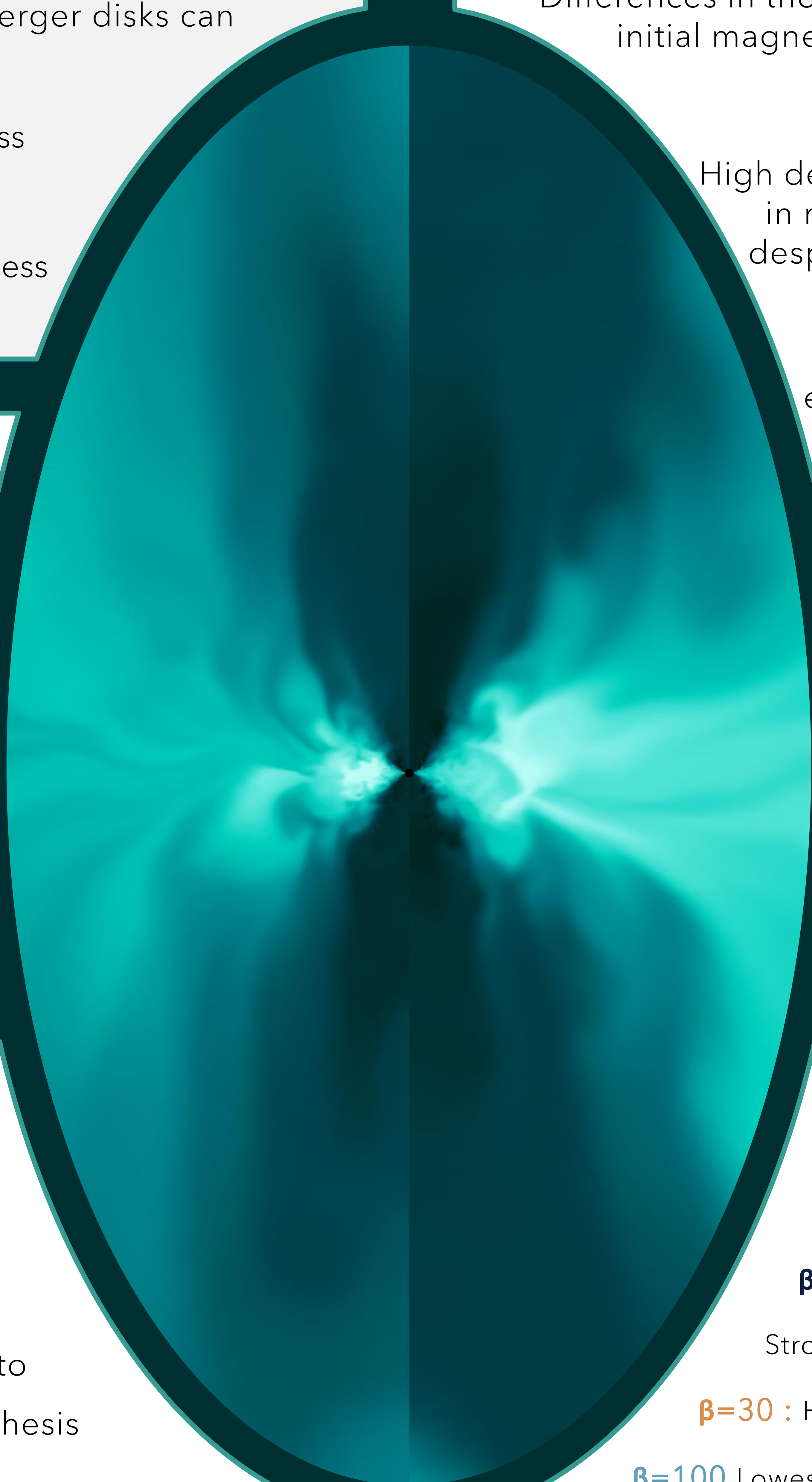
Neutrino vs. Fluid vs. Magnetic → time scales → Electron fraction Y_e → ↑ less robust r-Process / ↓ more robust r-Process

Open Questions

Uncertainty concerning the robustness of r-process produced in post-merger disk environments

- Do the conditions necessary to favor lanthanide and actinide production depend on the initial conditions of the disk?
- Are there certain regions of the outflow that are more favorable for different r-process components?

Center: Volume rendering of electron fraction from binary NSM outflow for weaker (left) and stronger (right) initial magnetic field strength



Magnetohydrodynamics → Nucleosynthesis

nubhlight [1]

3D GRMHD with Monte Carlo neutrino transport

All disks: 0.12 $M_\odot$, uniform Y_e = 0.1; vary β_{plasma}

→ **Intermediate :** convert Lagrangian tracers to thermodynamic trajectories for nucleosynthesis

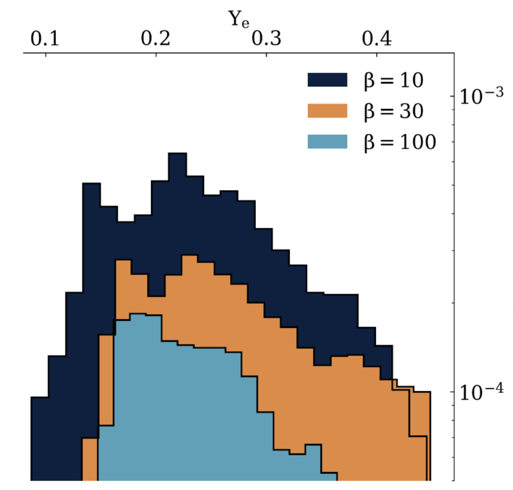
→ **PRISM** [2]

Nuclear reaction network x400K+, obtain abundances at 1Gyr

Effect on Abundances

Differences in the outflow of each disk caused by varying initial magnetic field strength result in differences in nucleosynthetic conditions

Right: Distribution of Ye for each disk

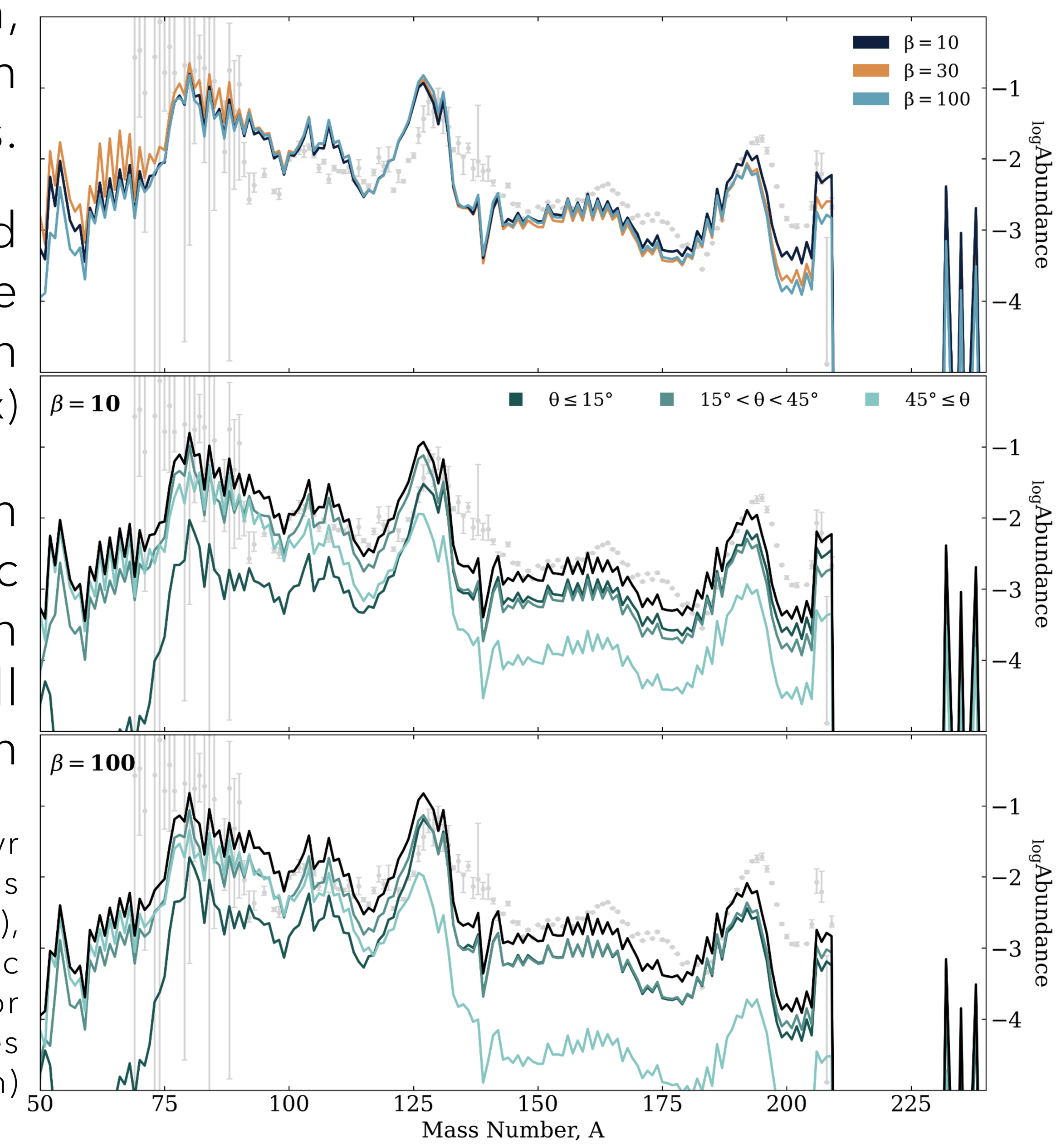


High degree of similarity in rare-earth pattern, despite differences in initial conditions.

Strong initial field enhances actinide production (by almost 6x)

Variation in geometric contribution to overall pattern

Right: 1Gyr abundance patterns for all disks (top), geometric contributions for extreme cases (middle, bottom)



Concluding observations

We simulate three post-merger disks with varying initial magnetic field strength and carry out nucleosynthesis calculations out to 1 Gyr post-merger on unbound tracers.

β=10: Large overlap between lanthanide, actinide production

Strongest case of high (>0.16) $\chi_{lanthanide}$, best at producing actinides

β=30 : Highest first peak abundances

β=100 Lowest ejected mass, least effective at producing actinides

- Stronger magnetic field unbinds more mass compared to a weaker field, effectively unbinding more lanthanide mass.
- Actinide production highly sensitive to initial magnetic field strength.

This work was possible due to support by the U.S. DOE through Los Alamos National Laboratory (LANL), operated by Triad National Security, LLC, for the NNSA of the U.S. DOE.
This work was supported through the Laboratory Directed Research and Development program under project numbers 20220564ECR and 20230052ER, as well as through the Center for Nonlinear Studies.
We acknowledge support from the NSF (N3AS PFC) grant No. PHY-2020275, as well as from U.S. DOE contract No. DE-FG0202ER41216.
This work was partially supported by the Fission in r-Process Elements (FIRE) topical collaboration in nuclear theory, funded by the U.S. DOE, contract No. DE-AC5207NA27344.

[1] Miller+ 2019 : 10.3847/1538-4365/ab09fc
[2] Mumpower+ 2017 : 10.1088/1361-6471/44/3/034003
This work: Lund+2024: 10.3847/1538-4357/ad25ef

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