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GRMHD Simulations of Black Hole–Disk Systems: Heavy Element Nucleosynthesis and Implications for r-Process Sites

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The astrophysical origin of heavy elements in the universe synthesised through the rapid neutron capture process (r-process) remains an open question, with several compact object environments such as neutron star mergers, collapsars, and magnetorotational supernovae proposed as potential sites. Systems involving accreting black holes and surrounding disks are particularly promising, as they can give rise to neutron rich outflows capable of producing lanthanides and actinides, which power observable transients such as kilonova.
We investigate heavy element production in black hole–disk systems using general relativistic magnetohydrodynamic (GRMHD) simulations. Our tool is the HARM-EOS code, developed in the CTP PAS astrophysics group. The code incorporates a tabulated, composition-dependent, 3-parameter equation of state. Our simulations study how the accretion disk and black hole parameters influence the dynamics and composition of the outflows. Thermodynamic and kinematic conditions extracted from the disk winds are post-processed with the nuclear reaction network SkyNet to compute detailed r-process abundance yields. By characterising the heavy element production from disk-driven outflows in relativistic accretion environments, we offer insight into the range of astrophysical sites contributing to the origin of the universe's heaviest elements.

Primary author: SAJI, Joseph (Center for Theoretical Physics, Polish Academy of Sciences)

Co-authors: JANIUK, Agnieszka (Center for Theoretical Physics, PAS); Dr URRUTIA, Gerardo (Center for Theoretical Physics, PAS)

Presenter: SAJI, Joseph (Center for Theoretical Physics, Polish Academy of Sciences)

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