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Energy flow and radiation luminosity in the simulations of neutron star Ultraluminous X-ray sources

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ULXs are non-nuclear extragalactic sources that emit X-rays at luminosities exceeding $10^{39}\ erg/s$. One of the most accepted models to explain the extraordinary luminosity of ULXs is the super-Eddington accretion onto stellar-mass compact objects. This model with the central object of a neutron star revived interest in 2014, after the discovery of the neutron star-like pulsation period in some ULX emissions (e.g. ULX M82 X–2).

Both numerical simulations and analysis of observational data are necessary to explore the physics responsible for the pulsation and high-rate X-ray emission of these objects. We investigate the energy flow and radiation efficiency of accreting magnetized neutron stars as ULXs through numerical simulations. In this investigation ten GRRMHD simulations are performed with six different magnetic dipole strengths ranging from 10 to 100 GigaGauss, and three accretion rates—100, 300, and 1000 times the Eddington luminosity units.

The key takeaway from this study is that variations in accretion rate and magnetic dipole strength influence the accretion structure and luminosity efficiency of the system which in turn, affects the inferred luminosity, allowing us to categorize the system as either a ULXs or not. The magnetic dipoles in order of 10 GigaGauss and the accretion rates above 300 Eddington luminosity units lead to the development of strong radiatively driven outflows. These outflows enhance geometric beaming, resulting in apparent luminosities that are consistent with those observed in ULXs. We found that in the simulation with the magnetic dipole of 10 GigaGauss, the apparent luminosity is about 120 Eddington units. For the dipole one order of magnitude stronger this value is only 40 Eddington units. Increasing the accretion rate to 1000 Eddington luminosity in the weak magnetic dipole simulation results in the apparent luminosity of about 250 Eddington units.

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