Abstract

The subject of this thesis is the numerical simulation of ultraluminous X-ray sources (ULXs), that are powered by neutron stars with moderately strong dipolar magnetic fields.

A numerical test has been conducted, evaluating the performance of codes in astrophysics, the General Relativistic Radiative Magnetohydrodynamics (GRRMHD) code `Koral` and the Newtonian code `Pluto` through simulations of the Orszag-Tang problem–a simple yet well-established test for magnetohydrodynamics (MHD) codes. A qualitative and quantitative comparison of codes has been performed between the results obtained from simulations in different MHD models, resolutions, and dimensions. Numerical diffusion has been estimated and the resolution at which the results are physical with the least impact of numerical error has been determined using resistive MHD simulations in `Pluto`. It has been demonstrated that `Koral` excels in capturing substructures in numerical simulations with higher accuracy and exhibits reduced numerical dissipation compared to `Pluto`. Consequently, it has been concluded that it is feasible to conduct simulations using `Koral` at lower resolutions than in `Pluto`.

Ten numerical simulations of super-Eddington accretion onto the neutron star with a dipolar magnetic field of moderate strengths (10^{10-11} G) have been conducted using the `Koral` code. The goal was to find the magnetic dipole strength and accretion rate at which the accreting neutron star exhibits the apparent luminosity of observed ULXs. The study has been divided into two parts: In the first part, the simulations have been performed with six different dipole strengths and mass accretion rates of not less than 200 Eddington luminosities. It has been found that the weaker dipole simulation results in higher apparent luminosity compared to the stronger dipole. In weak dipole simulations (10^{10} G), the apparent luminosity is about 120 Eddington units. For the dipole one order of magnitude stronger (10^{11} G) this value is only 40 Eddington units. In the second part, the impact of the accretion rate has then been investigated by comparing three accretion rates for two different dipole strengths, 3×10^{10} and 10^{10} G. The apparent luminosity increases with the increase of the accretion rate. However, for both dipole strengths with accretion rates beyond 300 Eddington luminosities, apparent luminosity is exceeding ~ 100 Eddington units, which is compatible with ULX observations.