From Transitional Pulsars to ULXs –
radiation, jets, and outflows in accreting neutron stars

Description for the general public - W. Kluźniak

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Neutron stars, the densest known objects, are the ultimate actors of multi-messenger astronomy. When a pair of them comes to an end by merging to form a black hole, they are observed in the farthest reaches of the Universe in the form of powerful bursts of gamma-rays, an optical flash and a long X-ray and radio afterglow. The same event can be—and has been—observed with the gravitational wave detectors LIGO/Virgo. We now know that the heavy elements such as gold are formed uniquely in those merger events.

When a neutron star is born in a Supernova explosion, a burst of the elusive particles known as neutrinos is sent out and chemical elements such as oxygen, sulfur, iron and nickel are dispersed through the galaxy.

Between those two events, birth and destruction, neutron stars lead an active life as bright X-ray sources (first discovered in 1962) or radio pulsars (discovered in 1968), or both (in turn)! Many accept matter from a companion, an ordinary star, or a white dwarf, spinning ever more rapidly and gaining mass, and it is this phase of "accretion" which can only be understood by performing sophisticated numerical simulations on powerful computers. The simulations we perform take into account Einstein's gravity (general theory of relativity), the equations of fluid dynamics with the inclusion of magnetic fields, and various radiative processes which make the star shine in X-rays and other bands.

Using simulations we can find out which models explain observations, and which ones do not. In some instances we can even "observe" new phenomena, which can be used to build new models. Radiative simulations such as the ones we plan to do, have already proven to be useful for studying accretion onto black holes, and we want to extend that knowledge to neutron stars.

Not all of the incoming matter falls onto the neutron star. Some is expelled in the form of "winds" as well as narrow "jets" which can be observed with radio telescopes. In addition to the radiation from neutron stars accepting matter at a prodigious rate, we will be simulating such outflows.