Magnetic energy stored in relativistic force-free magnetosphere

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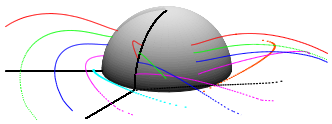

Figure 1: Three-dimensional magnetic field-line structure in the upper half-plane. The lines are twisted by current flow in the force-free magnetosphere. As an example, four lines starting from the stellar surface at azimuthal angles $\phi = 0, \pi/3, 2\pi/3$ are displayed. Field lines on the torus are also displayed. They start from $\phi = 0, \pi/3$, and $2\pi/3$ on the equator return to it.

Magnetars are a class of neutron stars, and have strong magnetic fields. Their activities are supplied by the strong fields. Study of the magnetosphere and long term evolution is one of very important issues. Magnetar magnetospheres are gradually twisted due to shearing motion at the surface. At the same time, the energy is stored there. When it exceeds a threshold, the energy is abruptly released on a much shorter dynamical timescale as observed in energetic flares. The process is analogous to solar flare, and is so far discussed as a giant flare model on magnetars. The objects are however relativistic ones. Here, their magnetospheres are calculated by taking into account general relativistic effect. Static and axially symmetric force-free magnetospheres are calculated in the exterior of non-rotating stars. The magnetic energy increases by the twist degree. In a highly twisted case, a magnetic flux rope, in which large amount of toroidal field is confined, is detached in vicinity of the star. Numerical result for twisted structure is demonstrated in Figure. It is found that larger amount of energy is capable to be stored in the relativistic magnetosphere. In an extreme case, the magnetic energy increment in presence of current flow exceeds that of current-free dipole. There is an upper limit in any model, and a catastrophic event like a giant flare would occur, when the field is further twisted.

References

[1] Y. Kojima, *Axisymmetric force-free magnetosphere in the exterior of a neutron star* (2017) in preparation

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