

LUMINOSITIES OF DISK-ACCRETING NON-MAGNETIC NEUTRON STARS

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Disk accretion onto a neutron star possessing a weak surface magnetic field ($B \leq 10^8$ G) provides interesting X-ray emission scenarios, and is relevant for understanding X-ray bursters and low-mass X-ray binaries (LMXBs). The standard (Newtonian) theory of disk-accretion predicts that the matter spiralling in from infinity loses one-half of its total gravitational energy in the extended disk, and the remainder in a narrow boundary layer girdling the neutron star. The ratio of the boundary layer luminosity to that from the disk ($E_{\text{BL}}/E_{\text{D}}$) is, therefore, unity. On incorporation of general relativity without rotation (Schwarzschild solution), $E_{\text{BL}}/E_{\text{D}}$ is seen to be as high as 6. We construct rotating sequences of neutron stars for three representative equations of state. We show here that for a neutron star rotating at a limit where centrifugal force balances the inward gravitational force, $E_{\text{BL}}/E_{\text{D}} \sim 0$.

1 Introduction

Low mass X-ray binaries (LMXBs) comprise either a neutron star or a black hole, revolving around and pulling in matter from the outer envelopes of, a binary companion star (M-K spectral type) that fills its Roche-lobe. The accretion takes place via a disk and in the case of a neutron star, the angular momentum of the incoming matter can spin it up to millisecond periods over 10^8 yrs..

In the standard theory of accretion disk, there exists a radial point r ($= r_{\text{iao}}$, here defined as the innermost allowed orbit) in the disk where the gradient of the angular velocity profile changes its sign. The accreting system, therefore, may be thought to comprise of (i) an extended accretion *disk*, which is a region extending from infinity inwards to r_{iao} and (ii) a *boundary layer*, a region between r_{iao} and the neutron star surface ($r = R$). In this talk, we examine how the incorporation of general relativity, rotation, and the relevant interior physics of neutron stars into the calculations, re-order the gravitational energy release from the boundary layer, and the extended disk.

To calculate the gravitational energy release we first obtain the effective gravitational potential from the radial equation of motion for a material particle orbiting the central object. The conditions of circularity and extremisation of energy yield the specific energy ($E(r)$) and specific angular momentum ($l(r)$) of particles in any orbit of radius r . The gravitational energy release in the disk is given by $E_{\text{D}} = E(\infty) - E(r_{\text{iao}}$ and that in the boundary layer is $E_{\text{BL}} = E(r_{\text{iao}}) - E^*(R)$; with $E^*(R)$ defined as the specific energy of the particle at rest on the stellar surface.

In Newtonian approximation, $r_{\text{iao}} = R$ (for all practical purposes) and the ratio: $E_{\text{BL}}/E_{\text{D}} = 1$.

2 General Relativistic Effects

2.1 Structure: Equation of State (EOS)

General relativity defines the structure of the compact object. A key input to solve the structure (hydrostatic equilibrium) equation is the equation of state (EOS): $P(\rho)$ of high density matter. For our purpose here, we use three models of EOS: (1) Bombaci (1995), BPAL12 (2) Wiringa, Fiks and Fabrocini (1988) UU (3) Sahu, Basu and Datta (1993). These models, widely spaced in their qualitative properties, make the results sufficiently general.

For Schwarzschild geometry, we solve the Tolman–Oppenheimer–Volkoff: TOV equations. For rapidly rotating neutron stars, taking the space–time geometry to be described by a general axisymmetric metric, we solve the hydrostatic equilibrium equations and Einstein equations numerically and self–consistently. We construct rapidly rotating configurations having rotation rates ranging from zero to centrifugal mass shed limit (e.g. Datta, Thampan & Bombaci 1998).

2.2 Equation of Motion

For general relativistic effective potentials, the minimisation condition is satisfied only marginally, implying the existence of a marginal stable orbit with $r = r_{\text{orb}}$. Neutron stars, described by realistic EOS models, may have $R > r_{\text{orb}}$ or $R < r_{\text{orb}}$ (Sunyaev & Shakura 1986; Kluźniak & Wagoner 1985). Accordingly, for accretion disks, (i) $r_{\text{iao}} = R$ for $R > r_{\text{orb}}$ and (ii) $r_{\text{iao}} = r_{\text{orb}}$ for $R < r_{\text{orb}}$.

For non–rotating neutron stars, $E_{\text{BL}}/E_{\text{D}}$ can be as high as 6 (Sunyaev & Shakura 1986). For neutron stars rotating at the mass shed limit, we obtain $E_{\text{BL}}/E_{\text{D}} \sim 0$ (Thampan 2000).

These results are expected to be important for modeling accretion disks in LMXBs.

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