HIGH ENERGY ASTROPHYSICS

Compulsary Home Exercises. Problem set 4.

Turn in Exercises by Friday, October 11, 2024

Problems

4.1: Consider a LMXRB that shows X-ray bursts. Estimate the interval between bursts if the accretion persistent uminosity is 1% of $L_{\rm Edd}$. Assume a neutron star mass of $1.4M_{\odot}$ and radius 10 km. Assume the efficiency of nuclear burning during the burst of 0.7% and you may also assume that the burst is a 5-second 'spike' at $L_{\rm Edd}$. Estimate (using Stefan-Boltzmann law) the maximum effective temperature (in keV) reached during the burst.

4.2: Neutron star in an X-ray burster EXO 0740–676 rotates 552 times a second. Estimate what would be the observed physical width of the emission line due to the Doppler effect for an observer at an inclination $i = 0$, 60, 90 degrees to the rotational axis. Assume that the line energy in the star frame is 1 keV, the neutron star mass is $M = 1.5M_{\odot}$ and the radius $R = 12$ km. Ignore light bending.

4.3: The observed Eddington flux corresponds to the Eddington luminosity reached at the neutron star surface:

$$F_{\rm Edd,obs} = \frac{L_{\rm Edd,obs}}{4\pi D^2} = \frac{GMc}{D^2\kappa_e(1+z)},$$

where $\kappa_e = 0.2(1+X)$ cm^2 g^{-1} is the electron scattering opacity, X is the hydrogen mass fraction, D is the distance, M is the neutron star mass and z is the surface redshift. Derive the relation between the neutron star radius R and the compactness $u = R_S/R$ (here $R_S = 2GM/c^2$):

$$R = 14.138\,\mathrm{km}\ \frac{(1+X)D_{10}^2 F_{-7}}{u\sqrt{1-u}},$$

where $F_{-7} = F_{\rm Edd,obs}/10^{-7}$ erg cm^{-2} s^{-1}, $D_{10} = D/10$ kpc. What would be the neutron star radius and mass if the redshift is measured from the spectral lines $z = 0.26$? Assume $F_{\rm Edd,obs} = 6\times10^{-8}$ erg cm^{-2} s^{-1}, solar abundance $X = 0.73$, and distance $D = 5$ kpc.

4.4: The spectrum of the photospheric radius expansion burst from 4U 1724–307 is well described by a black body. From the touchdown flux the observed Eddington limiting flux was determined as $F_{\rm Edd,obs} = 0.58\times10^{-7}$ erg cm^{-2} s^{-1}. The blackbody normalization in the cooling tail was $K = 220$ (km/10 kpc)^2. Estimate the neutron star mass and radius. Assume distance $D = 5.0$ kpc, solar abundance, the color correction factor in the tail $f_c = 1.4$.