University of Glasgow

Department of Physics and Astronomy

High Energy Astrophysics II: Example Sheet 1

1. Explain what is meant by the terms **high mass X-ray binary** and **low mass X-ray binary.** What is believed to be the X-ray power source for both classes of object? Describe how HMXBs and LMXBs in the Milky Way are distributed with galactic longitude and latitude, and explain why these observed distributions are consistent with our understanding of the star formation history of the Milky Way.

2. Show that the energy yield per unit mass from gravitational accretion onto a 2 solar mass neutron star of radius 10km is approximately $0.3c^2$ - i.e. 30% of the rest mass energy. Give some reasons why in practice this theoretical energy yield would not be achieved.

3. Verify equation (1.9) in your lecture notes, i.e. show that the impact of radiation pressure is to reduce the effective gravitational force to

$$F_{\mathrm{grav}} = \frac{GMm_P}{r^2}\left[1 - \frac{L}{L_{\mathrm{crit}}}\right]$$

   where the **Eddington luminosity**

$$L_{\mathrm{crit}} = \frac{4\pi GMm_P c}{\sigma_T}$$

   Show that $L_{\mathrm{crit}} \sim \left(\frac{M}{M_\odot}\right) \times 3\times10^4\, L_\odot$

4. Given that the accretion luminosity satisfies $L_{\mathrm{acc}} = \frac{GM}{r}\left[1 - \frac{L_{\mathrm{acc}}}{L_{\mathrm{crit}}}\right]\dot{M}$ show that $L_{\mathrm{acc}} = \dfrac{L_{\mathrm{crit}}}{1 + \dfrac{L_{\mathrm{crit}}}{GM\dot{M}/r}}$

   Verify that, for small $\dot{M}$, $\dot{M} \sim \frac{L_X}{GM/r} \sim 6\times10^{-9}\left(\frac{L_X}{10^{31}\ \mathrm{W}}\right) M_\odot\ \mathrm{year}^{-1}$

5. Solve equation (1.21) of your notes to verify that, at distance s from the optical companion, the wind speed is

$$\upsilon_{\mathrm{w}}(s) = \upsilon_\infty\left(1 - \frac{R_{\mathrm{opt}}}{s}\right)^{1/2}$$

   Verify that the relative speed of the wind and neutron star can be written in terms of the dimensionless scaling parameters x and y as

$$\upsilon_{\mathrm{rel}} = \upsilon_\infty\left[\frac{x+y-1}{x}\right]^{1/2}$$

6. A ‘quasisoft’ X-ray source of temperature $T = 2 \times 10^6$ K in the galaxy M101 (at a distance of 4.6 Mpc) delivers an X-ray flux of 7.86×10^{-15} Wm^{-2} at the Earth.

   a. Estimate the X-ray luminosity of the quasisoft source, stating clearly any assumptions that you make.

   b. Calculate the Eddington luminosity for a source of 5 solar masses, and compare your answer to the luminosity you computed in part (a). What does this suggest about the mass of the quasisoft source? Estimate the mass of the quasisoft source required in order that its luminosity is sub-Eddington.

   c. Estimate the radius of the X-ray emitting region; what does your answer suggest about the nature of the quasisoft source?

   d. Can you think of a mechanism that could explain how the observed X-ray flux from the quasisoft source might originate from a 5 solar mass source?