Extrasolar Planets and Astrophysical Discs
Problem Set 3

January 2010

Consider a dwarf–nova binary system consisting of two equal mass stars, the donor star being a 1 $M_\odot$ solar–type star, and the compact object being a 1 $M_\odot$ white dwarf. The system is observed to be quiescent for time scales of 1 month, and to undergo periodic outbursts with duration of 5 days.

Assume that the disc mass builds up to 10^{-11} $M_\odot$ before the outburst ensues, that the disc has a radius equal to 2/3 of the Roche lobe radius, and that the effective temperature is given by

$$T_{eff} = 6.6 \times 10^4 \left(\frac{R}{10^7 \text{ m}} \right)^{-3/4}$$

during the outburst. Assume also that the disc surface density is constant, and that $H/R = 0.03$.

Estimate the atomic mean free path, L, according to

$$L = \frac{1}{n\sigma}$$

where n is the particle number density and σ is the collision cross section for the atoms. For simplicity use $\sigma = \pi a^2$ where $a = 10^{-10}$ m is the radius of a hydrogen atom. Estimate the kinematic 'molecular' viscosity assuming a characteristic temperature of 6.6×10^4 K, and hence calculate the evolutionary time scale of a dwarf–nova disc evolving under the influence of a viscosity of this magnitude. Given this estimate of the evolutionary time, argue that a source of anomalous viscosity is required to explain the duration of dwarf–novae outbursts.

Using an 'α' model of turbulent viscosity, estimate the value of 'α' required to obtain an outburst duration of 5 days.

[The radius of the Sun is $1\,R_\odot = 6.96 \times 10^8$ m, the mass of the Sun is $1\,M_\odot = 1.99 \times 10^{30}$ kg, the mass of a hydrogen atom is $1\,m_H = 1.67 \times 10^{-27}$ kg, and the gas constant is $\mathcal{R} = 8.314$ J mol^{-1} K^{-1} .]