Physics of Galaxies Exercises 8

1. Explain briefly and qualitatively why there is a limit to the luminosity of an object that derives its power from accretion. **[4 marks]**

The Eddington luminosity $L_{Eddington}$ of an object of mass M was obtained in lectures

$$L_{Eddington} = 4\pi \frac{GMm_p c}{\sigma_T},$$

Deduce that the mass-flow rate $\dot{m}$ through an accretion disc that is radiating at the Eddington limit is given by

$$\dot{m} = \frac{4\pi}{\eta} \frac{GMm_p}{\sigma_T c},$$

where η is the efficiency of converting mass into energy. **[3 marks]**

2. It can be shown (consider this as given) that when the accretion disc extends down to the last stable orbit of a non-rotating black hole, the maximum temperature to be found in the disc is given by

$$T(r) = \left[\frac{1}{36} \frac{m_p c^5}{GM\sigma\sigma_T}\right]^{1/4}.$$

[You may assume without proof that $\eta = 1/12$ under these circumstances.]
What is the maximum temperature for a $10^8 \, M_{sun}$ black hole? **[3 marks]** Show that this part of the disc would radiate in the X-ray region of the spectrum. **[3 marks]**
Show that the time-scale τ for X-ray variability of the disc is given by

$$\tau \gtrsim \frac{6GM}{c^3} = \frac{3}{2\pi} \frac{\sigma_T}{m_p c^4} L. \qquad \textbf{[5 marks]}$$

You are asked to referee a paper in which an astronomer claims to have detected an X-ray variability on a time-scale of minutes from a source whose X-ray luminosity is reported as $10^{12} \, L_{sun}$. Comment on the claim made. **[3 marks]**

21 marks in total