Physics of Galaxies
ANSWERS: Exercise 8

1. The out-flowing photons exert a force on the in-falling matter. If the flux of photons is large enough, this force will exceed the gravitational attraction of the central mass and accretion cannot take place. **[4 marks]**

The power P released by converting matter into energy at a rate $\dot{m}$ is given by $P = \eta \dot{m} c^2$, where η is the efficiency of converting mass into energy. Equating this to the Eddington luminosity given in the equation of the question, we get $\eta \dot{m} c^2 = 4\pi \frac{GMm_{\rm p}c}{\sigma_{\rm T}}$ or $\dot{m} = \frac{4\pi}{\eta}\frac{GMm_{\rm p}}{\sigma_{\rm T}c}$. **[3 marks]**

2. Putting in numbers, we get

$$T_{\rm max}\,({\rm K}) = \left[\frac{1}{36} \times \frac{1.67\times10^{-27}\times\left(3\times10^{8}\right)^5}{6.67\times10^{-11}\times10^{8}\times2\times10^{30}\times5.67\times10^{-8}} \times \frac{1}{\times 6.65\times10^{-29}}\right]^{1/4} \approx 2\times10^{5}\,{\rm K}$$ **[3 marks]**

The spectrum of a black body at temperature T peaks at the wavelength $\lambda_{\rm max}$ which is given by Wien's law: $\lambda_{\rm max} T = 2.9\times10^{-3}\,{\rm m\,K}$.

Putting in numbers, we get for the wavelength of these peak photons,
$\lambda_{\rm max} = 2.9\times10^{-3}/2\times10^{5} = 1.45\times10^{-8}\,{\rm m} = 14.5\,{\rm nm}$, which is close to the *soft* X-ray region of the spectrum. (*X-rays* from about 0.12 to 12 keV i.e. 10 to 0.10 nm *wavelength*, are classified as *soft X-rays*). Strictly speaking, however, the *hard* X-rays (12 to 120 keV i.e. 0.10 to 0.010 nm wavelength are usually called *hard X-rays*) which are also observed, need the so called *two-temperature model* (not just a single plasma temperature with a blackbody spectrum), i.e. separate temperature for (much hotter) protons (which actually produce X-rays) and separate temperature for (much cooler) electrons. Electrons are usually much cooler (because they radiate energy off more efficiently than protons). **[3 marks]**

The size R of a region that varies on a timescale τ is given by
$R \lesssim c\tau$.

In this case, R is the inner radius of the disc, the last stable orbit, so that $\tau \gtrsim \frac{6GM}{c^3}$.

Assuming that the source is radiating at the Eddington limit, and using equation of the question, we get

$$\tau \gtrsim \frac{6}{c^3}\left(\frac{1}{4\pi}\frac{\sigma_{\rm T} L}{m_{\rm p} c}\right) = \frac{3}{2\pi}\frac{\sigma_{\rm T}}{m_{\rm p} c^4} L..$$ **[5 marks]**

Putting in numbers, we get for the reported source,

$$\tau \gtrsim \frac{3}{2\pi}\frac{6.65\times10^{-29}}{1.67\times10^{-27}\times\left(3\times10^{8}\right)^4} \times\left(10^{12}\times3.83\times10^{26}\right){\rm s}$$
$$\sim 907\,{\rm s} \sim 15\,{\rm min}$$

The reported variability *may* be suspect, although it's rather borderline. **[3 marks]**