HIGH-ENERGY ASTROPHYSICS (582)

(Spring 2006: Fulvio Melia)

Problem Set 4

Problem 4.1:

Centaurus A is an extended source of synchrotron radio emission. The $1 - 100$ MHz radio data can be fit to a curve of the form

$$F_{radio}(\nu) \approx K_{radio}\nu^{-0.9} \ \ \text{ergs/cm}^2\text{/s/Hz} \ ,$$

with $K_{radio} \approx 1 \times 10^{-12}$. The upper limit on the $1 - 10$ keV X-ray emission from the extended source implies that the flux due to the Compton spectrum produced by scattering the microwave background radiation off the synchrotron electrons is

$$F_{X-ray} \approx 7 \times 10^{-13} \ \ \text{ergs/cm}^2\text{/s} \ .$$

Using a temperature $T = 2.7\ ^o$K, find the lower limit on the magnetic field in the extended source.

Problem 4.2:

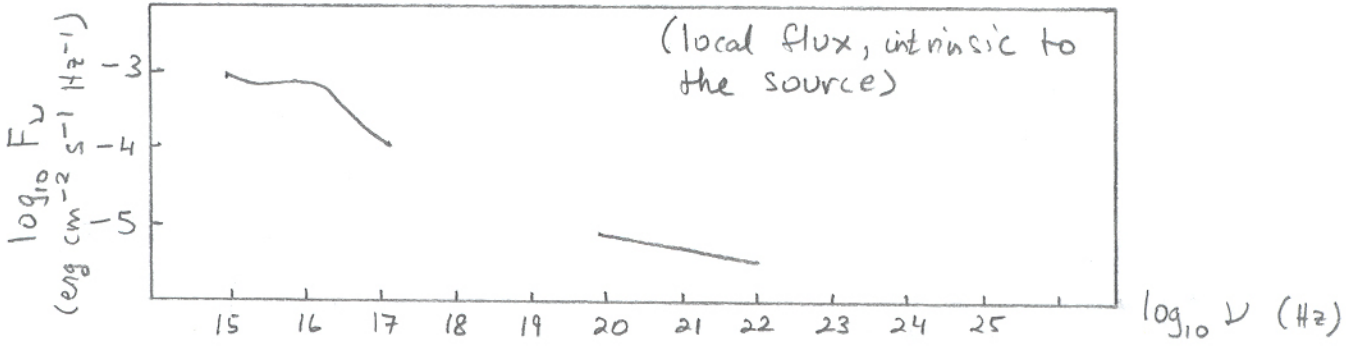
When a synchrotron source is sufficiently compact, the synchrotron radiation photons are inverse Compton scattered by the relativistic electrons, and the emergent spectrum is known as synchrotron-self Compton radiation. Suppose the electron distribution in such a source may be written

$$N(\gamma)\, d\gamma = \begin{cases} \mathrm{N}_0 \gamma^{-x}\, d\gamma & \gamma_1 \leq \gamma \leq \gamma_2 \\ 0 & \text{otherwise} \end{cases}$$

What will the observed spectral index be in this source? (Hint: ignore angles in the scattering process).

Problem 4.3:

An active galactic nucleus is observed to have the following spectrum:



The emission at $\nu \approx 10^{16}$ Hz is believed to be thermal emission from an accretion disk, whereas the high-energy emission is most likely associated with the relativistic jet.

(a) Assuming that the "ambient" radiation field is dominated by the accretion disk emission, what is the minimum Lorentz factor in the jet?

(b) Assuming that only 1% of the jet power is emitted at high-energy, estimate the number density of electrons in the jet (i) if the jet composition is electrons and positrons, and (ii) if the composition is electrons and protrons.

(c) Calculate the jet transverse optical depth for each case in (b), assuming the jet has a diameter of 100 r_g for a 10^8 $M_\odot$ black hole. Is this value of τ consistent with the model assumed here?