

Astro 300b
Homework Assignment # 9
Prof. Bechtold
Due: April 13, 2009

1. Photoproduction of a pair by a single photon.

(a) A gamma ray (high energy photon) can carry an energy greater than the rest energy of an electron-positron pair. (Recall that a positron, e^+ , has the same mass as the electron, e^- but opposite charge.) Nevertheless, the process

$$\gamma \text{ ray} \rightarrow e^+ + e^-$$

cannot occur in the absence of other matter or radiation. Prove that this process violates the law of conservation of momentum and energy in the lab frame.

(b) In the presence of other matter, a γ ray *can* produce a $e^+ - e^-$ pair. What is the threshold energy at which a γ ray becomes capable of bringing about the often observed process

$$\gamma \text{ ray} + e^- \text{ at rest} \rightarrow e^+ + 2e^- \text{'s?}$$

The rest energy of the electron – and of the positron – is about one-half MeV.

(c) Trevor Weekes (SAO) and collaborators have pioneered the use of optical telescopes on Mt. Hopkins south of Tucson to detect atmospheric “Cerenkov” radiation which result from very high energy γ ray photons from cosmic sources – $E \sim 100 \text{ GeV} - 10 \text{ TeV}$. Given the result of part (b) comment on the expected detectability of extremely high energy γ ray photons from cosmic sources.

2. Astrophysical Jets and Beaming

Hale Bradt has written a book called Astrophysical Processes, which covers a lot of the same material as Rybicki and Lightman. For this problem, read his section 7.6 (copy is attached) and answer his problem 7.63 (also attached).

3. CMB opacity to high-energy photons and protons

Read Bradt’s section 7.7 (attached) and answer 7.73.