

Exercises in γ Ray Astronomy

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Some of these problems can be solved with basic university physics, others are a bit more demanding and require some web search or educated guesses.

1. What are the frequency and wavelength of a photon of 1 TeV?
How does it (most likely) interact when impinging on matter?
2. A proton (rest mass $m_p = 938 \text{ MeV}/c^2$) moves with a velocity $v = 0.7c$.
Calculate its relativistic mass, momentum, kinetic and total energy. Show that for $v \ll c$ the relativistic momentum and kinetic energy approach the classical values.
3. In a satellite detector like Fermi, photons are detected via the measurement of the e^+e^- pairs they produce. A pair is observed with the following direction unit vectors \vec{d}_i and energies E_i . What are the energy and direction of the incident photon?
$$\vec{d}_1(x,y,z) = (-0.65, 0.14, -0.75) \quad E_1 = 2.93 \text{ GeV} \quad \text{and}$$
$$\vec{d}_2(x,y,z) = (0.66, -0.04, -0.75) \quad E_2 = 2.27 \text{ GeV}.$$
4. What is the energy threshold for a high energy photon to produce an e^+e^- pair when colliding with an infrared photon of 1100 nm wavelength?
5. What is the average amount of air (in g/cm^2) traversed by a TeV photon to its first interaction in the atmosphere? What is the distribution of first interaction points? To what height (in km) does this roughly correspond for a vertical primary photon?
6. How can astrophysical photons in satellite and ground-based Cherenkov experiments be separated from the overwhelming background of charged cosmic rays?
7. In 2007 the gamma-ray source PKS 2155-304 was observed to double its output within 5 min. Estimate the size of the emission region.
What if the emission region is moving towards us with a Lorentz γ factor of 15?
8. The energy spectrum of the Crab nebula (the strongest steady TeV gamma ray source) is about $J = 3.2 \times 10^{-7} (\text{E}/\text{TeV})^{-2.5} \frac{1}{\text{m}^2 \text{ s TeV}}$. Can you explain the units? Estimate roughly how many photons above 500 GeV a single Cherenkov telescope would detect per minute from the Crab. (assume the detection efficiency ε_γ is 100%.)
9. How does CTA achieve better performance than existing Cherenkov experiments?
In what sense (and why) is it superior to the Fermi LAT observatory?
10. How are the fluxes of gamma rays and neutrinos from an astrophysical source linked?

Send me your solutions and/or questions. I promise a swift feedback.

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