Department of Astronomy & Astrophysics, University of Toronto

RADIATION PROCESSES – AST1440F

Review Questions for Section 5

1. Apply the conservation of energy and momentum to find the energy of a Compton scattered photon as a function of the scattering angle θ.
2. What is the asymptotic behavior of the Compton scattering coefficient $\sigma_e(\epsilon)$ as $\epsilon = h\nu$ becomes much larger than mc^2 ?
3. Does the Compton scattering (cross-section) formula on p77 allow for relativistic electron velocities? Explain. How, in principle, would you evaluate the power scattered by a relativistic electron for *arbitrary* incident photon energy?
4. Are my sketches here showing the geometry of electron scattering in the observer's frame and the electron's frame OK or not? (Some have objected that a photon moving at an angle to the electron's path can't possibly catch up to an ultra-relativistic electron!!)
5. In calculating the energy of a photon after inverse Compton scattering, what is the advantage of transforming to the electron's frame and then back again to the observer's frame?
6. By what factor can a *low energy* photon be boosted by inverse Compton scattering? What is the factor for a very high energy photon ($\epsilon \gg mc^2$)?
7. In the electron's frame, scattering is always Compton and not the "inverse". Why?
8. In the observer's frame, how can you tell in a particular situation whether photons will be red-shifted (Compton) or blue-shifted (inverse Compton)?
9. Why do we ignore the possibility that $\gamma\epsilon$ can exceed mc^2 when computing the inverse Compton scattered power? Why is $\gamma\epsilon$ used here and not just ϵ?
10. Ultra-relativistic electrons can lose energy at a prodigious rate by both synchrotron emission and inverse Compton scattering. How does the power radiated by the two mechanisms depend on γ and what is the ratio of the two powers?
11. Explain why the brightness temperature of synchrotron sources hits a relatively hard "ceiling" around $10^{12}\,^\circ$K no matter how much energy in the form of relativistic particles is pumped in.
12. How can the scattered radiation field in a synchrotron source increase the drain of electron energies?
13. Why are only the first 2 or 3 scatterings important in this situation? That is, why can't a photon that has been scattered 5 times (say) drain any more energy from the electrons?
14. For the scattered radiation field to be important, the ratio $R \equiv U_{\rm R}/U_{\rm M}$ must be close to unity. Why? On the other hand, one shouldn't expect R to be much above unity even in powerful sources such as quasars. Why?

15. Describe the Sunyaev-Zel'dovich effect. In what way is it similar to the inverse Compton effect? In what way does it differ?
16. The S.-Z. effect predicts a drop in brightness temperature of the CMB as a millimeter telescope scans across a cluster of galaxies. What is the magnitude of the drop $\delta T/T$? Why, in principle, does it depend on the Hubble constant? Why, in practice, is it so small?
17. How does the magnitude of $\delta T/T$ (due to the S.-Z. effect) compare with the magnitude of the recently measured fluctuations in the CMB? How can the observer distinguish between the two effects?