



Figure 7.6: Observed X-ray spectrum.

7.8 Exercises for Chapter 7

1. (RL 7.1 & 7.2) In problem 2 of werkcollege 6 (RL 5.2) we looked at an optically thin plasma cloud of temperature T that was in hydrostatic equilibrium around an object of mass M . The observed spectrum (sketched in Fig. 7.6) was hypothesized to be caused by Bremsstrahlung. We derived expressions for the size R and the density ρ of this cloud using the Bremsstrahlung assumption. We furthermore put a limit on the mass M such that the cloud was indeed optically thin, for self-consistency with the optically thin Bremsstrahlung assumption.

In this problem, we will look at the question whether electrons scattering, and inverse Compton scattering in particular, can indeed be neglected (if it can't, the assumptions above were incorrect because cooling of the plasma through inverse Compton losses should have been included).

The general situation that we need to look at is the following: A cloud of nonrelativistic electrons is maintained at temperature T . The cloud is thick to electron scattering, $\tau_{\text{es}} \gg 1$, but very thin to absorption, $\tau(h\nu = kT)_* \ll 1$. A copious supply of “soft” photons, each of characteristic energy $\epsilon_i \ll kT$, is injected into the cloud (e.g., the cosmic microwave background, or any other interstellar radiation field). As a result of inverse Compton scattering, these initially soft photons emerge from the cloud with characteristic energies $\epsilon_f \gg \epsilon_i$. It is found that ϵ_f increases rapidly with increasing τ_{es} as the latter is varied, until τ_{es} reaches a critical value τ_{crit} , above which the Comptonization process “saturates”.

- a. Find an approximate expression for ϵ_f as function of ϵ_i , τ_{es} , T , and fundamental constants.
- b. Find an approximate expression for τ_{crit} .
- c. Find a single parameter of the fixed medium that determines whether inverse Compton scattering is a significant effect.
- d. Now let's return to the specific case of the X-ray source discussed in werkcollege 6. From the deduced characteristics of this source, determine a lower limit to the central mass M such that inverse Compton scattering effects in the emission mechanism are indeed negligible.