Free (unbound) electron interactions

- **Electron Scattering with photons**
  - **Thompson Scattering** At photon E << 511 keV **elastic scattering** with e^- (photon E does ***NOT*** change). (Thompson cross-section ***not*** a function of ν)
  - **Compton Scattering** At photon E >~ 511 keV **inelastic scattering** with e^- (photon E decreases, e^- E increases). (Klein-Nishina cross-section function of ν)
  - **Inverse Compton Scattering** low E photons scatter **inelastically** with hot relativistic e^- (photon E increases, e^- E decreases)
    - Thermal photons from Black Hole accretion disk are scattered into X-rays (0.2-10 keV power-law spectrum observed)
    - CMB photons passing through HIM in clusters of galaxies scattered into higher energies. (Sunyaev-Zel'dovich effect). Change of CMB brightness toward cluster.

- **Free-Free Emission/Absorption in Plasma**
  - Electrostatic **Bremsstrahlung** ("breaking radiation")
    - free charges accelerated by electrostatic force (scatter with ions)
    - Typically thermal (e^- energies Maxwell-Boltzmann Distribution)
  - Manetobremsstrahlung: **Cyclotron** (non-relativistic) or **Synchrotron** (relativistic) Radiation
    - free charges accelerated by magnetic force
    - Typically non-thermal (e^- energies a Power-law)

Electron acceleration Pulse

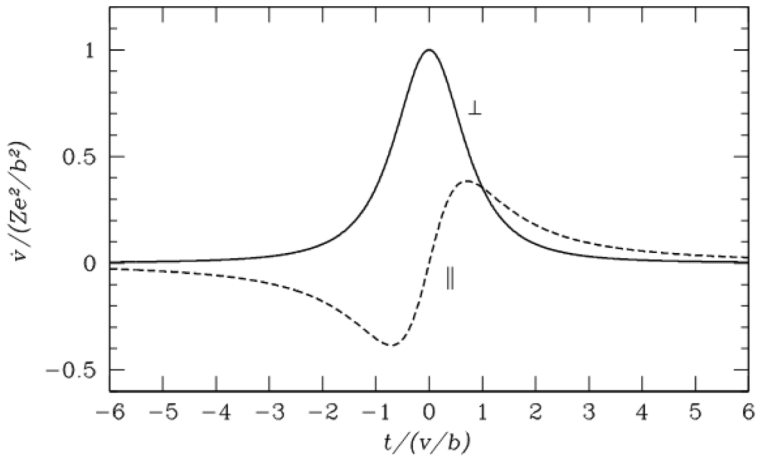
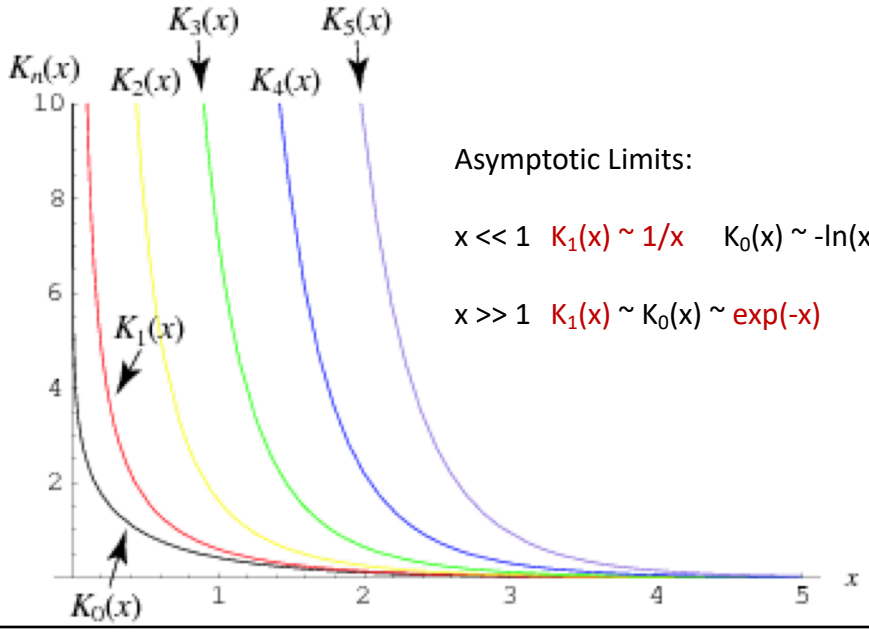


Figure 4.3. The acceleration of an electron by an ion may be resolved into components perpendicular (⊥) to and parallel (∥) to the electron's velocity. The perpendicular acceleration (Equation 4.16) yields a roughly Gaussian pulse whose power spectrum extends to low (radio) frequencies. The parallel acceleration (Equation 4.15) gives a roughly sinusoidal pulse with no "DC" component, so the resulting radiation is strongest at higher (infrared) frequencies and very weak at radio frequencies.

Modified Bessel Functions 2nd Kind

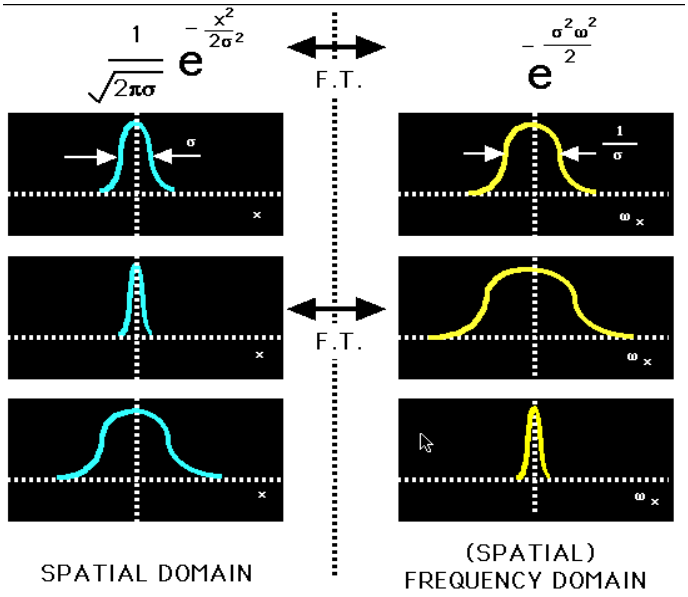


Asymptotic Limits:

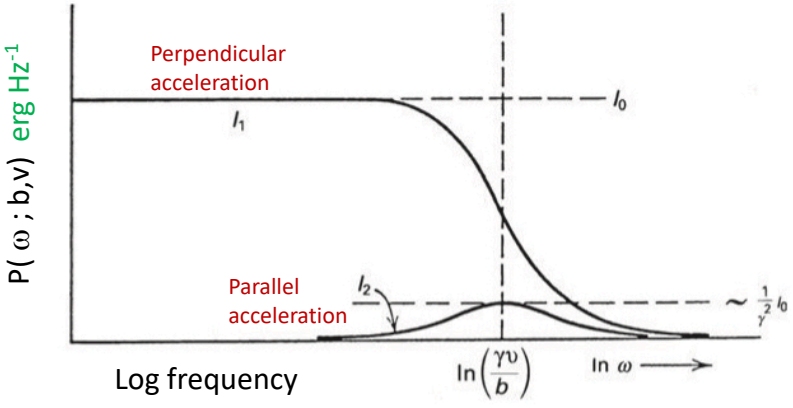
$x << 1$ $K_1(x) \sim 1/x$ $K_0(x) \sim -\ln(x)$

$x >> 1$ $K_1(x) \sim K_0(x) \sim \exp(-x)$

Fourier Transforms Basic Property



Power Spectrum of Electron Acceleration



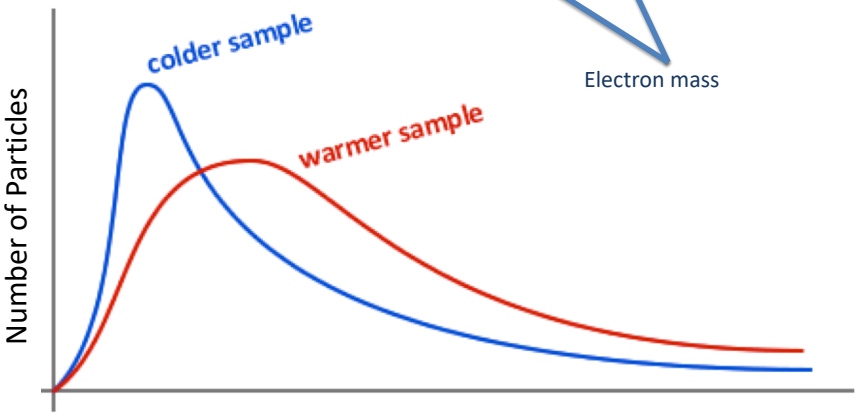
The spectrum of bremsstrahlung resulting from the acceleration of the electron parallel and perpendicular to its initial direction of motion (Jackson, 1999).

Note: this is for the relativistic version of the calculation $\gamma \equiv \frac{1}{\sqrt{1-\beta^2}} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

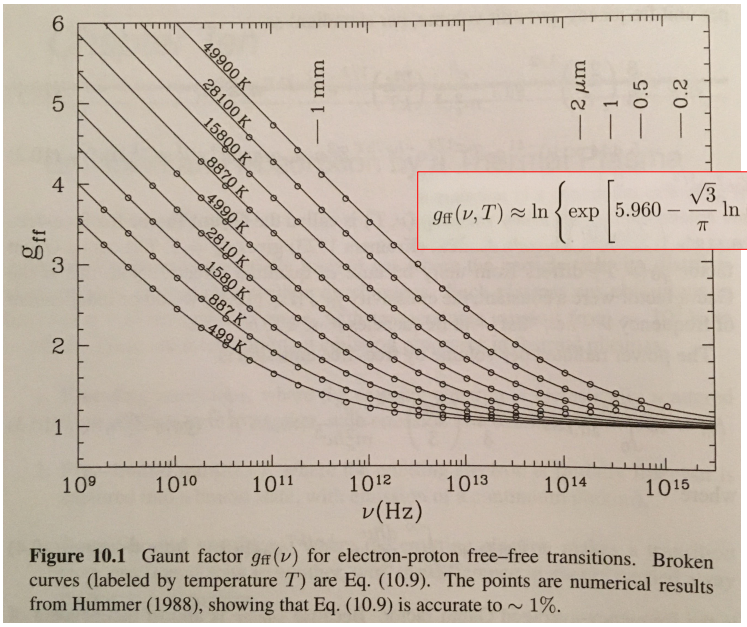
Maxwell Boltzmann Distribution

$$f(v) = 4\pi\left[\frac{m}{2\pi kT}\right]^{3/2} v^2 e^{-mv^2/2kT}$$

Electron mass



Gaunt Factors



$$g_{\rm ff}(\nu, T) \approx \ln\left\{\exp\left[5.960 - \frac{\sqrt{3}}{\pi}\ln\left(Z_i \nu_9 T_4^{-3/2}\right)\right] + \mathrm{e}\right\}$$

Figure 10.1 Gaunt factor $g_{\rm ff}(\nu)$ for electron-proton free–free transitions. Broken curves (labeled by temperature T) are Eq. (10.9). The points are numerical results from Hummer (1988), showing that Eq. (10.9) is accurate to $\sim 1\%$.