Astronomy 208 v.Y2K Meeting #20

4.4. "Effect(s) of High Energy Photons" (& X-ray shadows)

when $\nu \sim 10^{20}$ then $h\nu \approx m_e c^2$

FYI **An example**

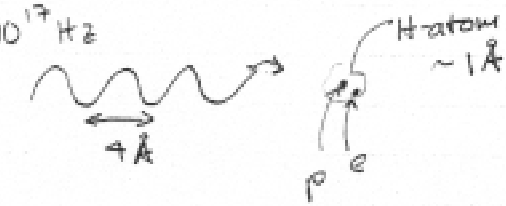
Consider: $h\nu = 3\,\mathrm{keV}$ $= k\,(3.5\times10^7\,\mathrm{K})$ $\left(\frac{h\nu}{m_e c^2} = 6\times10^{-3}\right)$

$= 4.8\times10^{-9}$ erg / photon!!

(recall OVI 114 eV was uv)

$\Rightarrow \nu = 7\times10^5$ THz $= 7\times10^{17}$ Hz

$\lambda = 4\,\text{Å}$



This photon hardly sees the atom as a unit any more...

? How would/do such short-λ photons interact w/ ISM?

Not exactly like ionizing photons @ shorter λ...

At high energies (e.g. $h\nu \gtrsim 3$ keV) a_ν, the "standard" bound-free abs. x-sectn becomes vanishingly small (see eq 2.4 and fig 2.2 of Osterbrock

but, a Compton scattering term becomes important

(see handout)

Cross sections for this

$$a_\nu \doteq a_T \left(\frac{h\nu}{E_0}\right)^{-s} \qquad h\nu > E_0$$

r_0 = classical radius of e^-

$s \sim 3$

s, a_T } tabulated in Table 11.6 of Osterbrock

Note: At very high energies ($\nu \gtrsim 10^{20}$ Hz) ~ MeV photons

$\frac{h\nu}{m_e c^2} \gtrsim 1$ and yet more complications arise

In Summary, the
Whole process by which ~keV X-rays interact w/ ISM:

1. incident X-ray w/ $h\nu \gtrsim 3$ keV removes an inner electron of some heavy element, X (1 e⁻ ejected, photon λ↓)

2. X undergoes re-distribution of e⁻ by Auger transition → produces no photon instead ejects another very energetic e⁻

3. e⁻'s from ① & ② interact w/ surrounding gas, causing production of additional photons, those photons can still go back & start from ① again

4. Ultimately 1 energetic X-ray produces many e⁻

Approximations are possible
e.g. Joan Najita tells me ~ 30 e⁻ per keV of photons

Where does one care about X-rays interacting w/ ISM?

(1) X-ray shadows

- very low E X-rays can be absorbed in the usual way (processes involving valence electrons)

- higher energy ($\gtrsim 3$ keV) X-rays scattered (& ultimately diluted) by scattering, primarily off inner e^- in heavy elements

(2.) Near X-ray sources

(a) AGNe accretion disks

(b.) (smaller than) black hole & other compact object accretion disks

(c.) young star accretion disks & "envelopes"

↑ e.g. WTTS detected in X-rays

(1) "Thermal" vs "Non-Thermal" (Definitions)

history: 2 broad classes do whole page

"Thermal"

a (quasi-) equilibrium process with an associated Temperature

e.g. Early obs of the ⊙ thermal emission at cm-λ's is from ionized solar atmosphere's Free-free = bremsstrahlung

Note: various components can have their own T's eg T_e, T_i

"Non-thermal"

non-equilibrium processes not easily characterized by a temperature

e.g. meter-λ ⊙ emission in big outbursts - spectrum cannot be modeled as "thermal"

also: SNRs, radio jets, etc.

often power-laws...

Examples & Origins

Thermal

Continuum rad'n from dust e.g. in a dark cloud characterized by T_{dust}

Free-free (bremsstrahlung) from ionized gas characterized by T_e

e.g. H II Region

Non-thermal

Emission from transiently-heated dust, not characterized by a real "T"

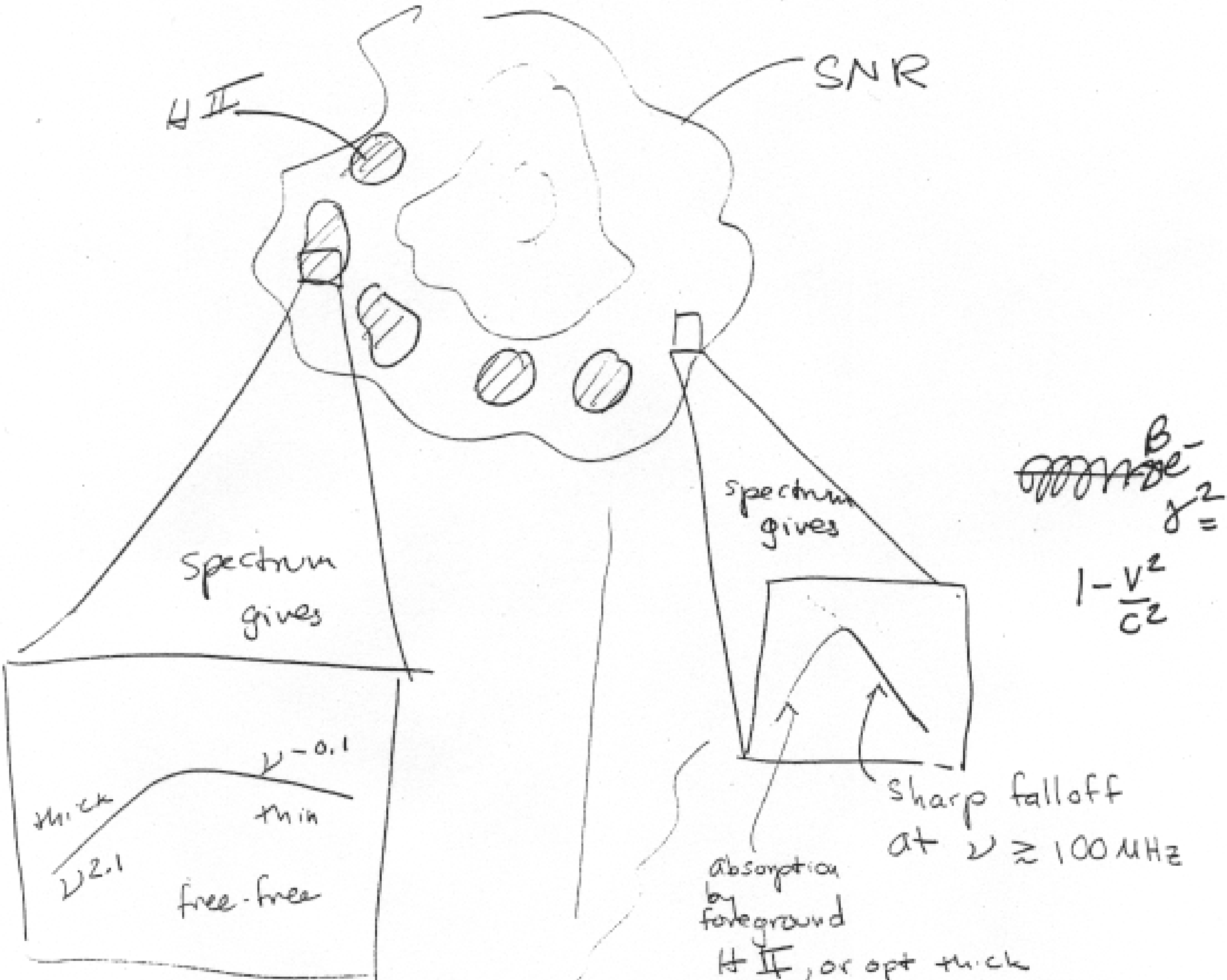
Synchrotron emission from ionized gas w/ relativistic electrons

e.g. SNR

see Kassim & Weiler 1990 example for "some of each"

b) "Mixed" Cases

e.g. SNR + H II Regions see (Kassim & Weiler handout)

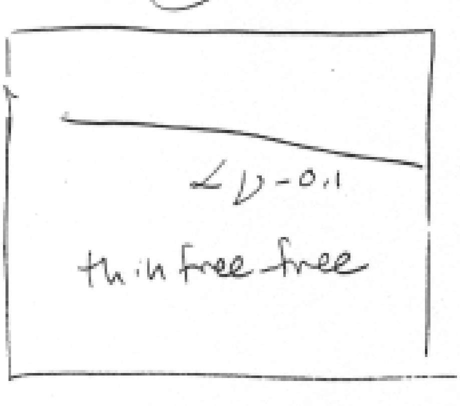


H II, or opt thick

(+ some contrib from SNR)

typical of synchrotron

or



γ = spectral energy index

$N(\varepsilon) \propto \varepsilon^{-p}$

then $S \propto \nu^{(1-p)/2}$

e.g. $\gamma = 2.4$

$S_\nu \propto \nu^{-0.7}$