Ex 8.61

Cas A (SNR)

$B_\perp = 2\,mG$

(?) what ν is $\tau_\nu = 1$

Solve eq 8.39 for ν

$$\underbrace{\tau_\nu}_{} = \alpha_\nu l = C_6(\Gamma) N_0 B_\perp^{\frac{\Gamma+2}{2}} \left(\frac{\nu}{2C_1}\right)^{-\frac{(\Gamma+4)}{2}} l$$

use fig 8.14 to measure α

$$\alpha = -0{,}77 = -\frac{(\Gamma-1)}{2}$$

$$\Rightarrow \underline{\Gamma = 2{,}54}$$

$C_1 = 6{,}27 \cdot 10^{18}$
$C_5 = 9{,}51 \cdot 10^{-24}$
$C_6 = 8{,}09 \cdot 10^{-41}$

} Table 8.2, use linear interpolation

Assume Cas A spherical $\Rightarrow$ los $l = \varnothing = 4\,pc$ (see caption of fig 1.2)

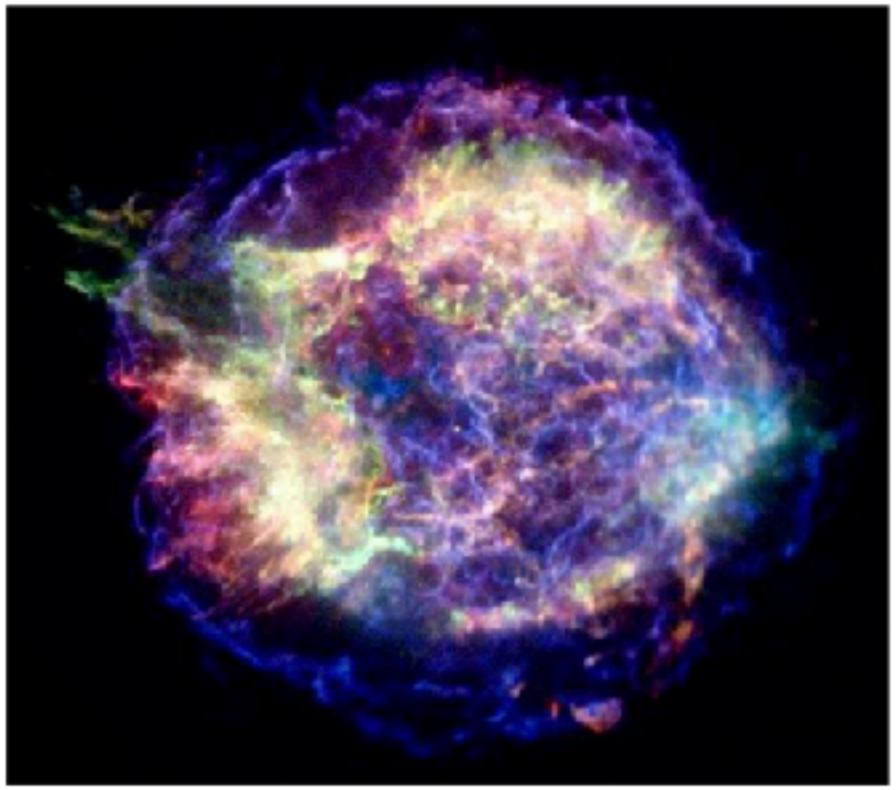


Figure 1: A 1.1 Ms, color-coded, ACIS image of the supernova remnant Cas A. The red, green and blue features are associated with the 0.5–1.5 keV (O, Fe L, Ne and Mg emission-line), 1.5–2.5 (Si and S emission-line) and 4–6 keV (continuum) energy bands, respectively.

Also, need N_0, pick a point on curve of fig 8.14 where $\tau_\nu << 1$

$\nu = 10^{10}$ Hz $\Rightarrow I_\nu = 4 \cdot 10^{-15}$ erg/s/cm^2/Hz/sr

eq 8.42: $I_\nu = j_\nu l \Rightarrow \frac{I_\nu}{l} = c_5 N_0 B_\perp^{\frac{p+1}{2}} \left(\frac{\nu}{2c_1}\right)^{\frac{p-1}{2}}$ solve for N_0

$\Rightarrow N_0 = 2{,}01 \cdot 10^{-13}$ erg/cm^3

eq 8.39, now we have everything to solve for ν

$\Rightarrow \nu = 8{,}3$ MHz $\tau_\nu = 1$

---

generally observe synchrotron emission in optically thin limit, @ low ν (radio) where emission is strongest.

8.6 Inverse Compton radiation / scattering

Still non-thermal

Compton: interaction of particle with photon, resulting in a photon

$h\nu \rightsquigarrow e^- \Rightarrow e^- \rightsquigarrow h\nu'$ lower E photon

↘ higher E_{kin}

$(h\nu \geq m_e c^2)$

$\nu' < \nu$

Inverse this process ⟹ IC radiation

$\rightsquigarrow h\nu$ low energy

$\rightsquigarrow e^-$ high E ↘ e^- less energy

⟹

e^- ↘ less energy

$\rightsquigarrow h\nu'$ higher E

$\nu' > \nu$

in other words: photon has been blueshifted "up-scattering"

$\nu_{IC} \simeq \gamma^2 \nu$

Lorentz factor

ν of photon before scattering

(scattering but, new photon $h\nu'$ appears as new emission — emission process)

ex : photon ν : 1GHz

high energy e^- $\gamma = 10^4$

$\Rightarrow$ new photon $\nu_{IC} = 10^{17}$ Hz (x-ray)

redistribution of photon frequencies

(less photons in radio, more in x-ray)

If B — also synchrotron present

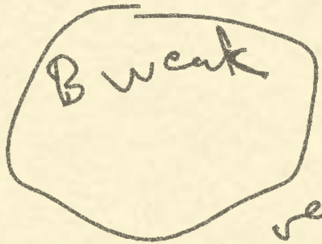
so $\Rightarrow$ e^- will lose energy faster $\Rightarrow$

higher radiation output over all ν.

synchrotron

depends on B

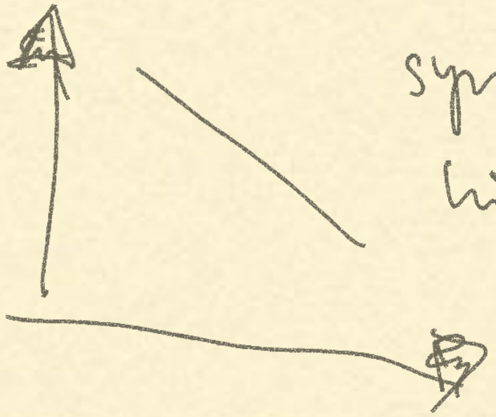
low radiation
- mainly synchrotron



strong radiation
IC dominating

IC

depends on # of low E photons that can be scattered and get energy (be 'up-scattered')



synchrotron is higher @ low γ

energy density of radiation field

$$\frac{L_{IC}}{L_S} = \frac{u_{rad}}{u_B} \approx \left(\frac{T_{B\,max}}{10^{12}}\right)^5 \left(\frac{\nu_{max}}{10^{8,5}}\right) \qquad \text{eq } 8{,}45$$

energy dens of magn. field

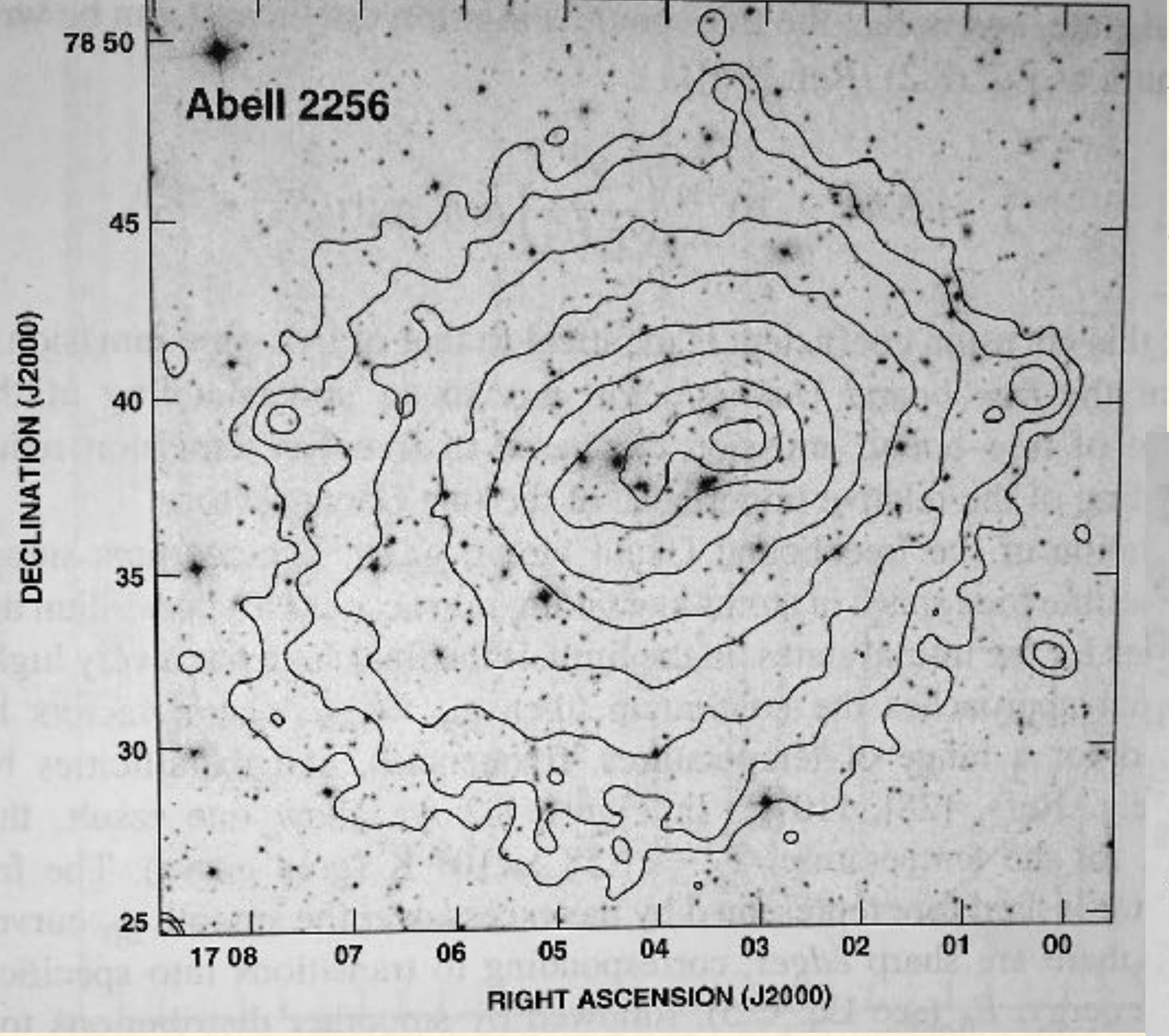
T_B & ν @ peak (turnover of spectrum)

Fraction of L
relationship b/w energy dens fraction and lum.

Very strong dependence on T_B for IC losses

IC is not very important until $T_B \to 10^{12}$ K

Exceeding 10^{12} K : Compton catastrophe - where e^- lose energy very rapidly. 10^{12} K upper limit



CMB photons 2.7K
up-scattering by e^- in ICM
The CMB photons shift to
higher frequencies (prob 8.15)

CMB spectrum is distorted →
from perfect BB (fig 4.3)
effect is small $\Delta T < 1\,\mathrm{mK}$

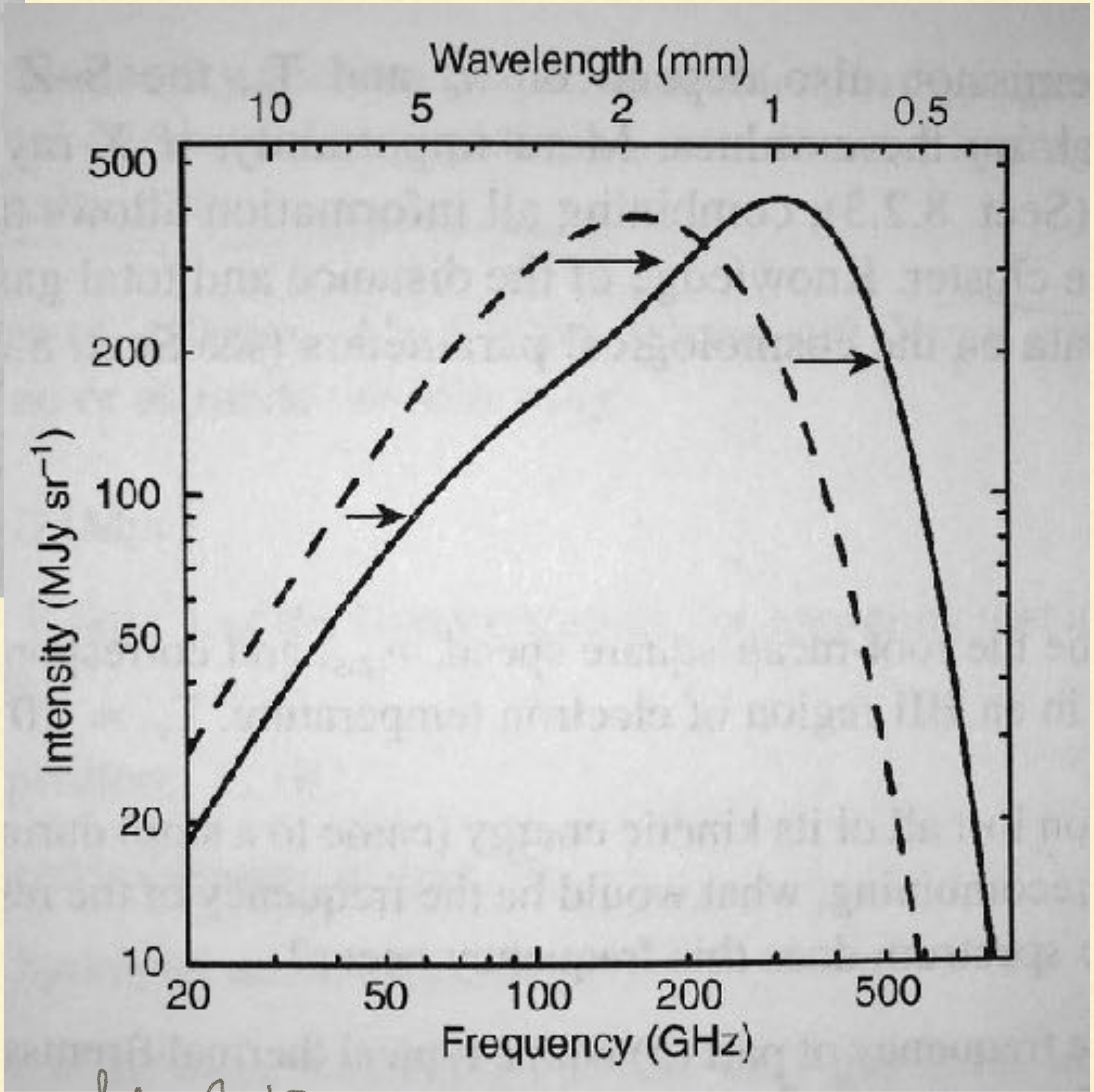


fig 8.17

Chapter 9: Line emission

ch focuses on spectral lines formed in atoms (and molecules) and what we can learn from the sources that emit them.

Only bound-bound transitions — atoms, molecules, ions, isotopes

- electric transitions — most often optical (H: UV-radio)
- vibrational } molecules — IR
- rotational } molecules — mm
- nuclear — X-ray

electronic e^- changes from higher to lower energy states — appendix C hydrogen