HI continued

$n = 1$

- $\bar{t} = \frac{1}{n\gamma} = 350\,yr$ mean time b/w collisions

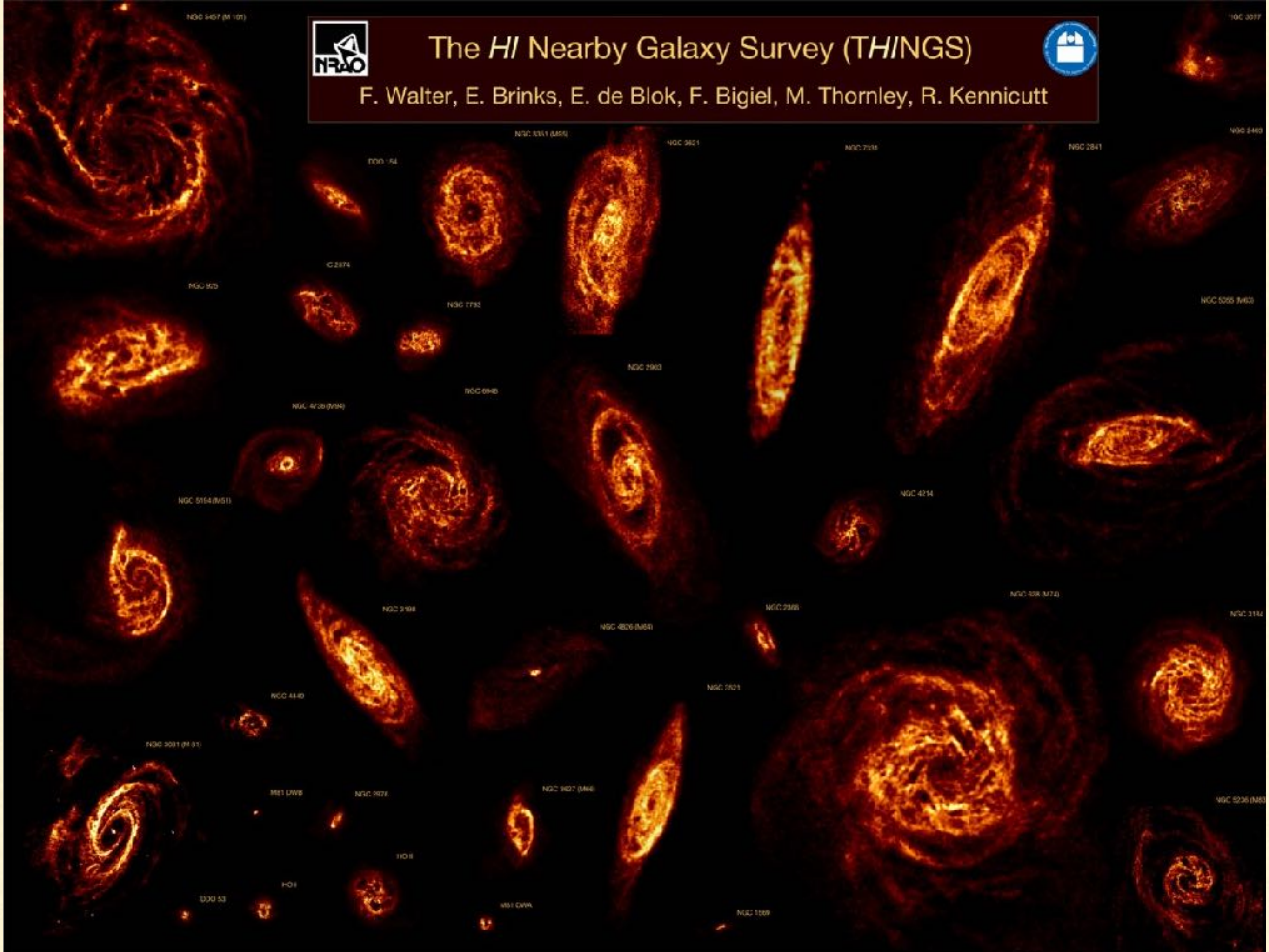
density

- spontaneous de-excitation

$$t = \frac{1}{A_{21cm}}$$

Einstein coefficient
measure of the probability of emission of light by atom or molecule
A: spontaneous emission

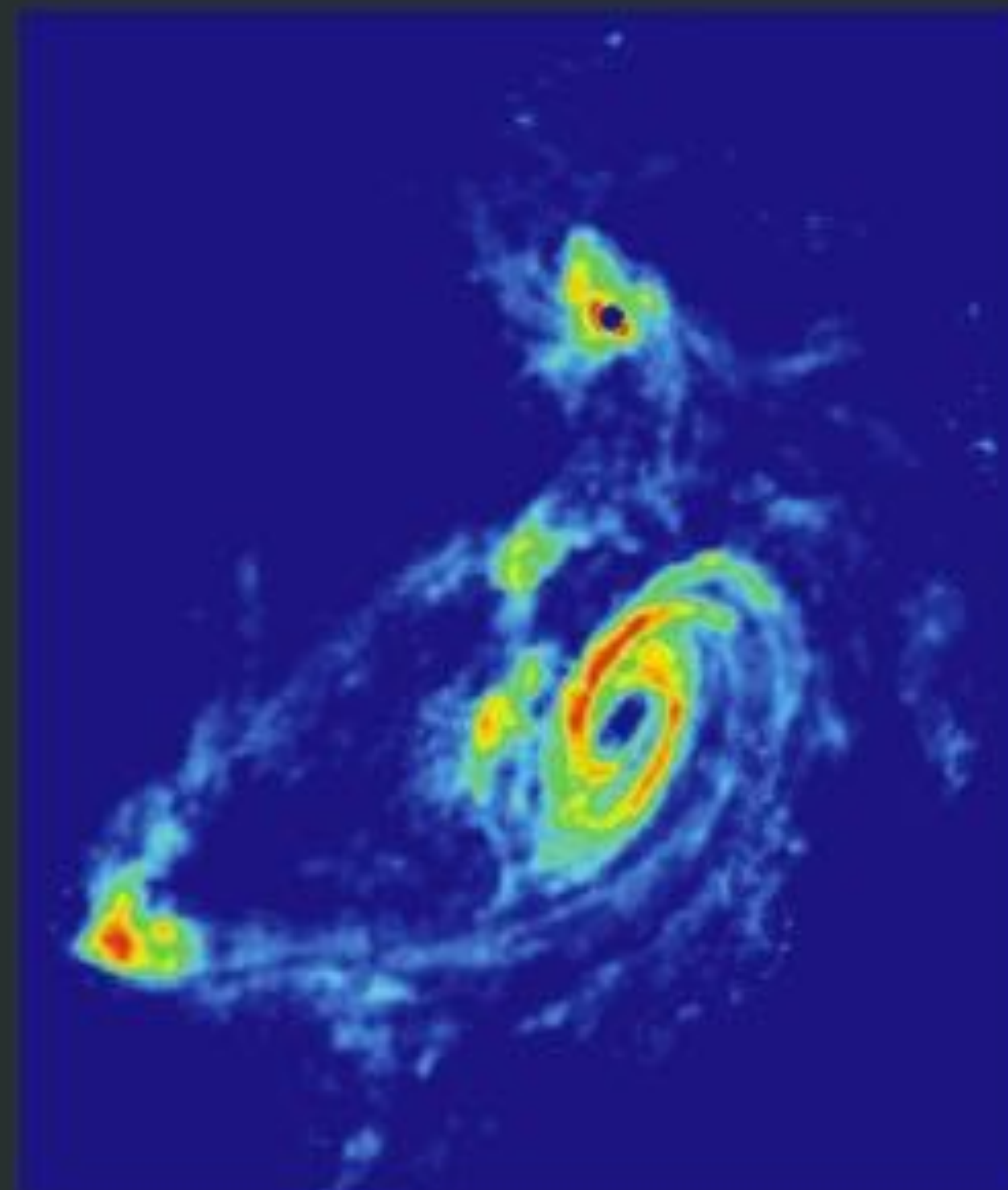
$$= [\text{table C.1}] = \frac{1}{2{,}876\cdot 10^{-15}/s} = 10^{7}\,yrs$$


The *HI* Nearby Galaxy Survey (T*HI*NGS)
F. Walter, E. Brinks, E. de Blok, F. Bigiel, M. Thornley, R. Kennicutt

TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution

21 cm HI Distribution



21 cm spectral line strong - why? Because there's so much HI! (App C ☺)

Ex) What T is required (LTE) in order for equal # of particles in $n=2$ and $n=1$ states

eq 3.23 Boltzmann's equation

$$\frac{N_2}{N_1} = \frac{g_2}{g_1} e^{-\frac{\Delta E}{kT}} = \frac{n_2}{n_1} = 1$$

$$= \left[g_n = 2n^2\right] = \frac{8}{2} e^{-\frac{1.6\cdot 10^{-11}}{kT}} =$$

[get ΔE from eq C6
$\Delta E = E_{n'} - E_n =$
$= -13.6 \left(\frac{1}{n'^2} - \frac{1}{n^2}\right) [eV] = -1.6\cdot 10^{-11}$ erg]

higher state   lower state

HOT!

Solve for T = T = 83 634 K

$T = 83000K$

How many particles are ionized at this T?

eq 3.27

$$\frac{N_{HII}}{N_{HI}} = 2.41 \cdot 10^{15} \frac{T^{3/2}}{n_e} \cdot e^{\frac{-1.58 \cdot 10^5}{T}} = \left[T = 83634K\right]$$

e^- density $\rightarrow n_e$

Special case of Saha eq. 3.26.

part in $k+1$ state compared to k state

$$= \frac{8.81 \cdot 10^{21}}{n_e}$$

for $n_e \sim 10^{20}/cm^3$ we require solar interior

So, H gas starts to become appreciably ionized at T lower than what's needed to excite the atom (because more possible states available for a free e^- than for a bound one in first excited state

HI "all" particles are in ground state

How many particles are in state $n=2$ compared to all other states

$$\frac{N_2}{N_{tot}} = \frac{N_2}{N_{HI} + N_{HII}}$$

Balmer absorption lines

2 -> 3

2 -> 4

around

T = 8-10 000 K

highest # of particles w/ e^- in state $n=2$

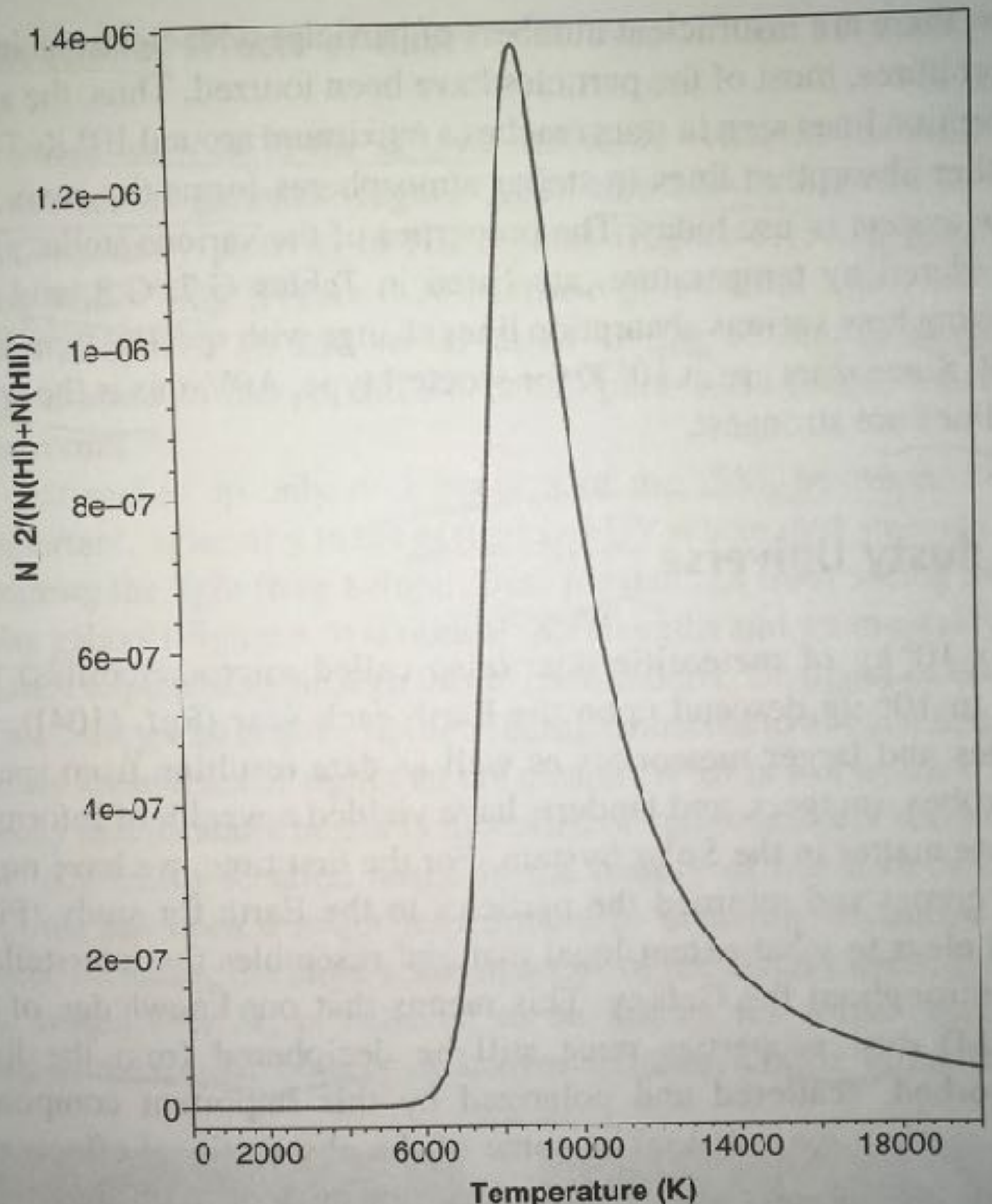


Figure 3.18. Fraction of hydrogen atoms that are in the first excited state, N_2, in comparison to the total number of hydrogen atoms, $N_{HI} + N_{HII}$. The adopted electron density at all temperatures has been taken to be constant at $n_e = 10^{13}$ cm^{-3} (in reality, this will also vary with temperature). This distribution indicates how the strength of the Balmer absorption lines varies with stellar surface temperature. Note that the fraction is still quite low, even at the peak.

3.5 Dust — extinction (dimming)
— reddening (dust extinction ~~et~~ more effective @ short λ than long ones $\Rightarrow$ redder.

origin stars & SNe

3.6 Cosmic rays — later. (synchrotron rad)

CHAPTER 4: RADIATION ESSENTIALS

- Black body – Planck curve
- Rayleigh-Jean & Wien laws

TE absorption & emission rates in balance
T same!
⇒ radiation field isotropic and the spectrum depends only on T
= Black body radiation
Planck function / curve

Planck function

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\left(\frac{1}{e^{\frac{h\nu}{kT}}-1}\right)\left[\mathrm{erg}/\mathrm{s\,cm^2\,Hz\,sr}\right] = I_\nu \quad 4.1$$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\left(\frac{1}{e^{\frac{h\nu}{kT}}-1}\right)\left[\mathrm{erg}/\mathrm{s\,cm^2\,cm\,sr}\right] = I_\lambda \quad 4.2$$

Must be enough interaction in the gas b/w matter & radiation $\Rightarrow$ must be opaque

$\bar{l}$ < size of the object

BB is a perfect absorber — no reflection
— no passing through

perfect emitter. abs & emission in balance

Single T

= BB

reminder (of I_ν & I_λ):

$I_\nu \, d\nu = I_\lambda \, d\lambda$ convert but need eq 1.5

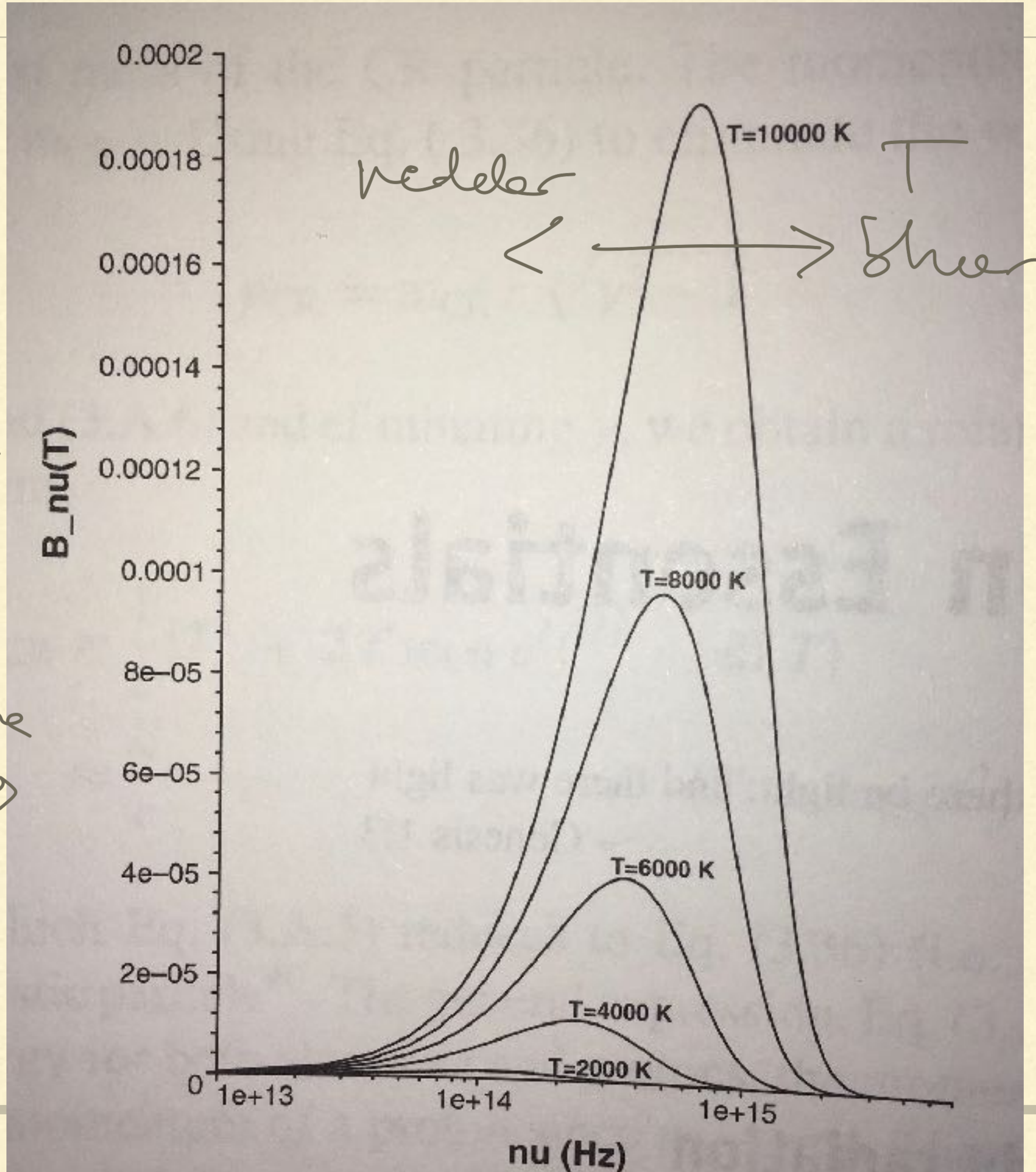
$B_\nu(T) d\nu = B_\lambda(T) \, d\lambda$ $\qquad d\lambda = \frac{-c}{\nu^2} \, d\nu$

BB continuous Planck spectrum

shape depends on temp

Perfect BB: CMBR.

despite T gradient stars also good BB examples with some departures



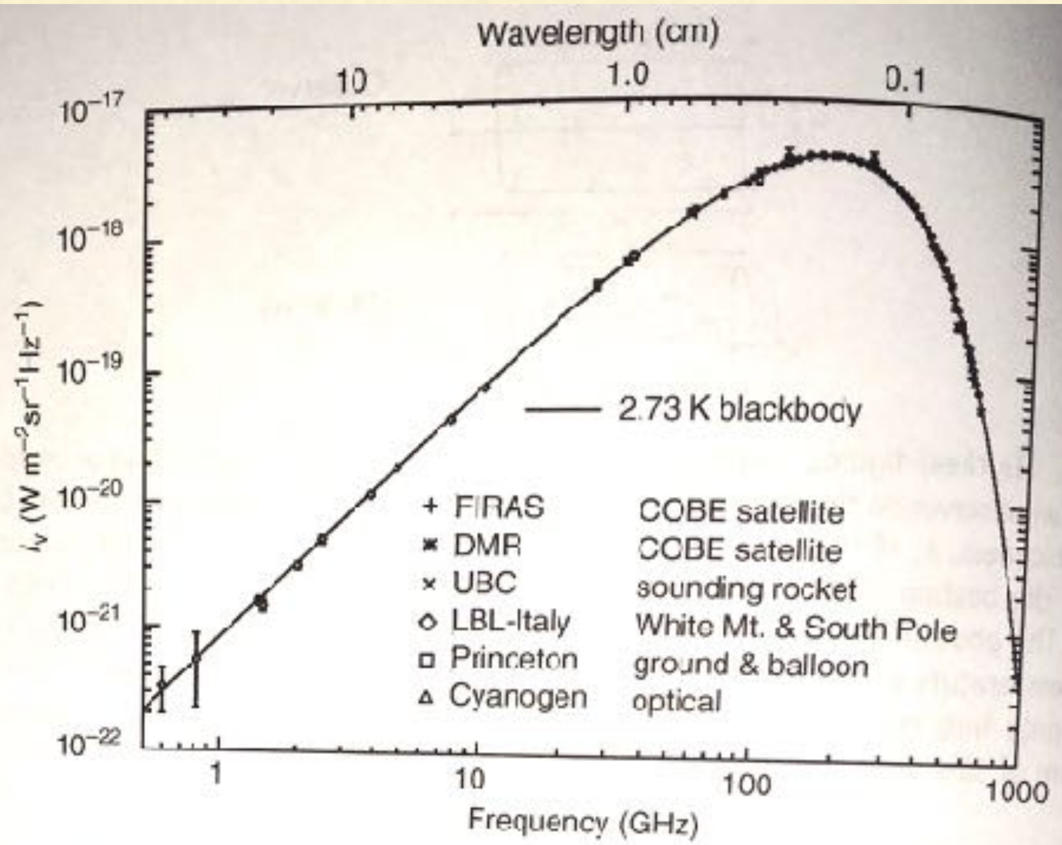


Figure 4.3. Data points for this curve are measurements of the
radiation from a variety of sources that are listed on the plot. The sc
body spectrum, corresponding to a temperature of 2.73 K (G.F. Smo
Review of Particle Physics, K. Hagiwara *et al.*, Phys. Rev. **D66**. 01000

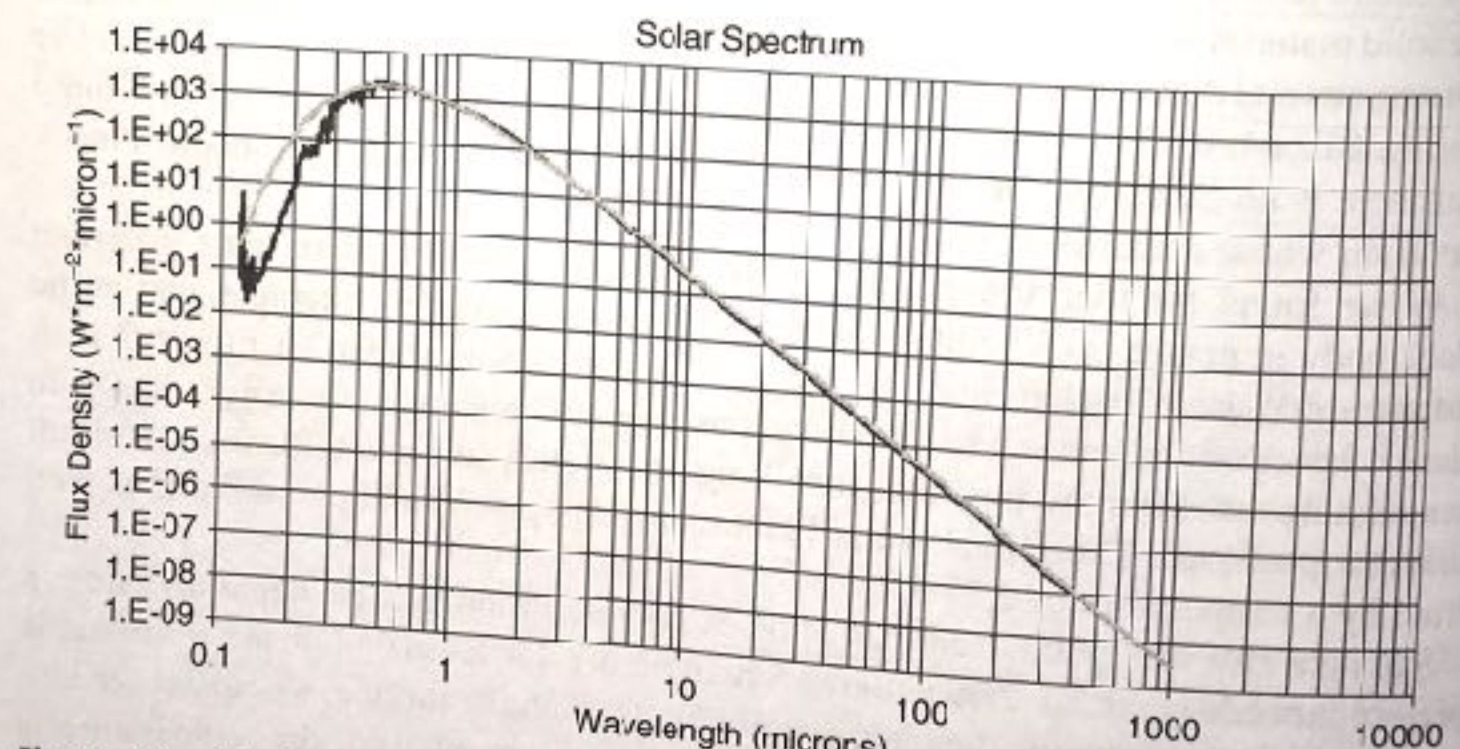


Figure 4.4. The Solar spectrum, shown as a function of increasing wavelength
plot. The plot is of flux density as measured