Universität Bonn Summer Term 2009

Physics of the ISM

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Exercises V

In-class problems

1 Heating and cooling

- Why is the heating $\propto n$ while cooling is $\propto n^2$?
- Please discuss the shape of the cooling curve (Fig. 1).
- What is the reason for the steep step of the cooling curve?

Fine–structure lines are discussed in the lecture as important cooling lines

- What is the physically necessary condition to produce fine-structure lines?
- Estimate the temperature regime where fine-structure line radiation becomes an important coolant.

Order the photons according to their penetration depth into molecular gas (cf. Fig. 2)

__ γ–rays
__ soft X–rays
__ visible light
__ infrared
__ far–infrared

Calculate the cooling time of CNM and WNM gas clouds of a column density of $N_{\mathrm{HI}} = 2 \cdot 10^{20}\,\mathrm{cm}^{-2}$. CNM clouds have a typical linear extent of 3 pc while WNM clouds have a size of 660 pc. The cooling efficiency is, according to Wolfire et al. (2003):
$\Lambda = 5.7 \cdot 10^{-26}\,\mathrm{ergs\,s^{-1}cm^3} \times \left(\frac{T}{[10.000\mathrm{K}]}\right)^{0.8}$.

$$t_{\mathrm{cool.}} = \frac{5}{2} \cdot \frac{1.1\, n\, \mathrm{k}\, T}{n^2\, \Lambda}$$

Compare the results with

- the shock excitation period of a gaseous volume of $6 \cdot 10^6$ yrs triggered by supernovae
- the shock frequency produced by density waves assuming four spiral arms

2 Dust

The degree of polarization produced by interstellar dust grains is in the order of

- ☐ a few percent
- ☐ about 10 percent
- ☐ always more than 10 percent

Extinction denotes

- ☐ absorption
- ☐ reflection
- ☐ absorption and reflection

Albedo denotes

- ☐ ratio of $\frac{Q_{\rm sca}}{Q_{\rm abs}}$
- ☐ ratio of $\frac{Q_{\rm abs}}{Q_{\rm ext}}$
- ☐ ratio of $\frac{Q_{\rm sca}}{Q_{\rm ext}}$

Large dust grains in the Milky Way halo have, on average, a temperature of 30 K. Determine the optimal wavelength/frequency range to observe their distribution across the sky.

Observational evidence for **large** dust particles is provided by:

- ☐ interstellar polarisation of optical light
- ☐ Black-Body spectrum
- ☐ near–infrared emission lines
- ☐ radio radiation
- ☐ wavelength dependence of extinction

Observational evidence for **small** dust particles is provided by:

- ☐ interstellar polarisation of optical light
- ☐ Black-Body spectrum
- ☐ near–infrared emission lines
- ☐ radio radiation
- ☐ wavelength dependence of extinction

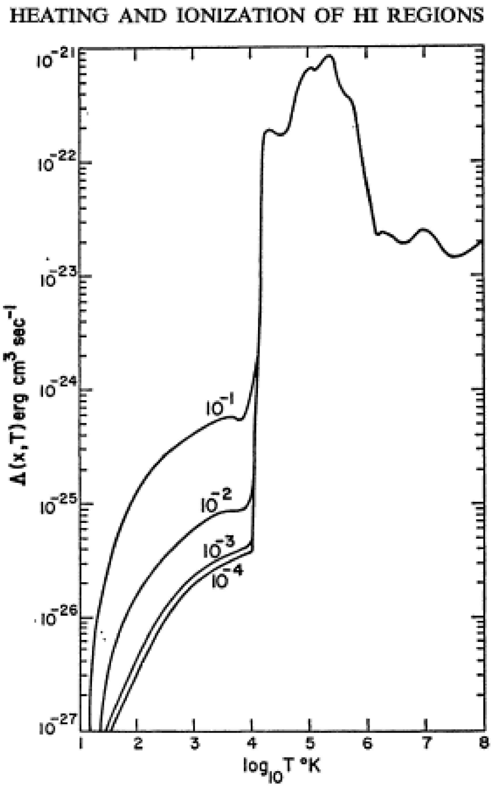

Figure 1: Dalgarno & McCray (1972, ARA&A, 10, 375): The interstellar cooling function $\Lambda(x, T)$ for various values of the fractional ionization x. The labels refer to the values of x.

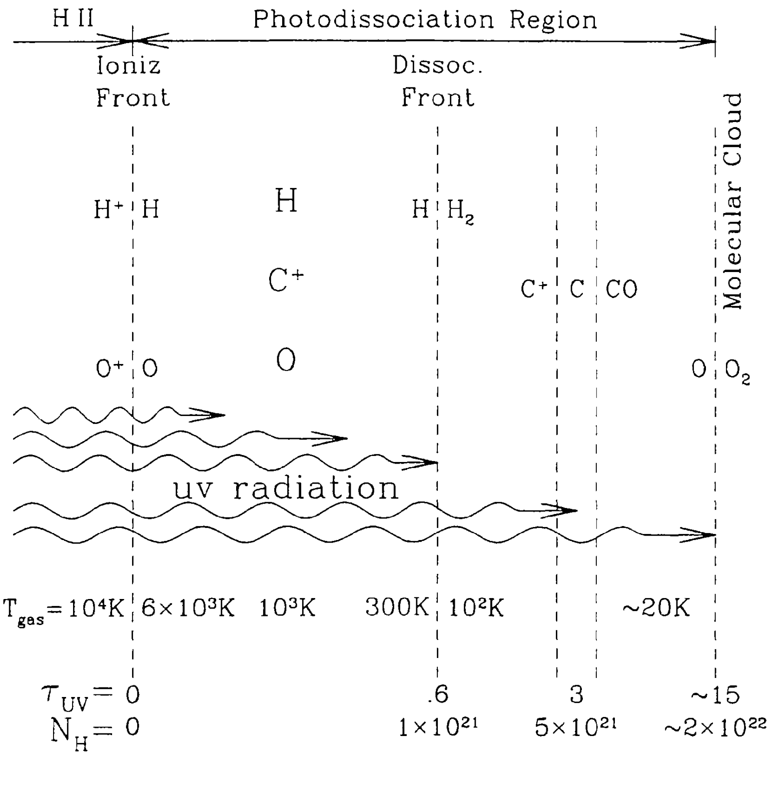

Figure 2: Draine & Bertoldi (1999, The Universe as Seen by ISO, 427, 553): The structure of a PDR produced by radiation from a star which also emits enough ionizing photons to produce an HII region. The ionization front separates the HII region from the PDR. Typical values of the effective far–ultraviolet optical depth, and H nucleon column density are shown.