

Lecture 10 (ADV): Photoionisation Models

10-1

10.1 Numerical Radiative Transfer

The problem of radiative transfer in real astrophysical situations is a complex one. This is generally because of the sheer number of possible transitions that can occur in a typical astrophysical plasma that may contain many ionisation species with a multitude of energy states. Various numerical methods have been developed to treat the general problem of radiative transfer. We will use one particular code, called MAPPINGS, that specifically treats the problem of photoionisation equilibrium (i.e. balancing rates of photoionisation and recombination). It is available online at

www.ifa.hawaii.edu/~kewley/Mappings

We will use a very simple application of the code.

10-2

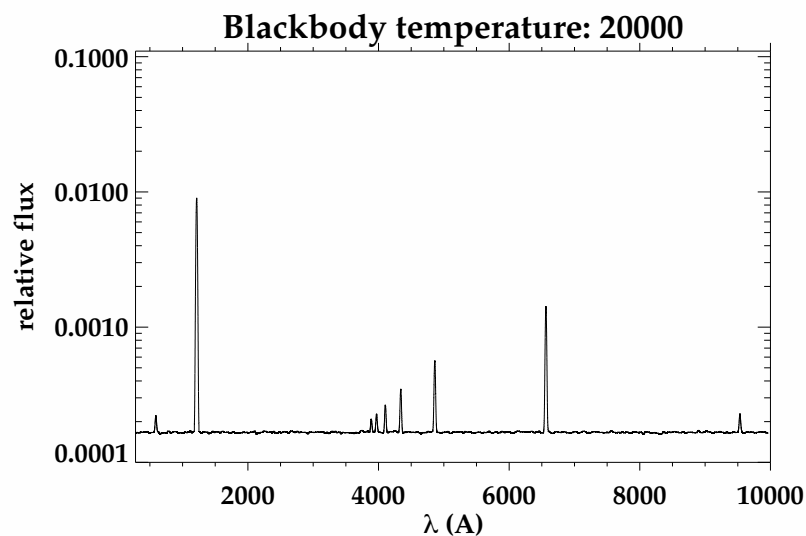
Example: HII regions

We will use MAPPINGS to calculate the emission line spectrum from a typical HII region in the interstellar medium. We click on “run your own photoionisation model” and specify the parameters in the form as follows:

- default solar abundances (1.00 x solar)
- ignore dust
- default depletion factors
- no to evaluation of dust temperature and IR flux
- blackbody ionising radiation field
- for this example, we'll choose a blackbody temperature 20,000 K
- spherical ISM geometry, with $\log(\text{total luminosity})=42$ and Strömgren inner radius fraction=0.1
- isochoric density structure with $N_e = 10 \text{ cm}^{-3}$
- choose filling factor 1.0 and standard output files

10-3

We use the IDL code spectrum.pro, which reads the MAPPINGS output data file photn0001.ph5 containing the fifty strongest lines, with their fluxes. Below is the resulting emission line spectrum:



Of the fifty strongest lines, the most prominent ones are:

10-4

species	λ (Å)	E (eV)	flux (relative to $H\beta$)
He I	584.345	21.2176	7.6297×10^{-2}
He I	591.423	20.9637	0.1269
HI	1215.67	10.1988	22.08
O II	3726.03	3.32752	2.7270×10^{-2}
O II	3728.73	3.32510	4.0478×10^{-2}
HI	3750.15	3.30611	2.9417×10^{-2}
HI	3770.63	3.28816	3.8178×10^{-2}
HI	3797.90	3.26455	5.0696×10^{-2}
HI	3835.38	3.23265	6.9813×10^{-2}
HI	3889.05	3.18803	0.1004
HI	3970.07	3.12297	0.1521
HI	4104.73	3.02052	0.2472
HI	4340.46	2.85648	0.4537

10-5

species	λ (Å)	E (eV)	flux (relative to $H\beta$)
HI	4861.32	2.55042	1.00
N II	6547.96	1.89348	2.2275×10^{-2}
HI	6562.80	1.88920	3.138
N II	6583.34	1.88330	6.5590×10^{-2}
S II	6716.31	1.84602	1.4147×10^{-2}
HI	8862.79	1.39893	1.4738×10^{-2}
HI	9014.91	1.37532	1.9772×10^{-2}
S III	9069.29	1.36708	6.0116×10^{-2}
HI	9229.02	1.34342	2.7408×10^{-2}
S III	9532.03	1.30071	0.1464

10-6

10.2 Interpretation of Spectra

Problem: Helium in HII regions

The spectra of HII regions ionised by hot O/B stars show evidence of Helium recombination lines.

The ionisation potential for Helium is $\xi = 24.6$ eV. So only very hot stars can ionise helium.

Using the Saha relation (Lec. 4), we can calculate the ratio N_{He^+}/N_{He} of singly-ionised helium to neutral helium number densities:

$$\frac{N_{He^+} N_e}{N_{He}} = \frac{g_{He^+} g_e}{g_{He}} \left(\frac{2\pi m_e kT}{h^2} \right)^{3/2} \exp\left(\frac{-\chi}{kT}\right)$$

We use $g_e = 2$, $g_{He^+} = 2$, $g_{He} = 1$ (since generally, $g_n = 2J + 1$). We also use the ideal gas equation of state: $N_e = P_e/kT$, with the pressure $P_e = 10 \text{ N m}^{-2}$ (see Lec. 4). We can compare the relative ionisation fractions for 3 different temperatures:

T	N_{He^+}/N_{He}
10,000 K	5×10^{-5}
20,000 K	500
40,000 K	4×10^6