NLTE-EFFECTS IN SUPERNOVAE TYPE II PHOTOSPHERES

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ABSTRACT. In order to provide accurate fluxes of supernovae Type II as needed for the application of the Baade-Wesselink method we have constructed spherical model photospheres for these objects under the assumption that hydrogen and helium are in statistical equilibrium. Although the densities are very low it is found that NLTE effects on the continuum radiation are small, because the temperature stratification is sufficiently flat and the strong scattering makes the radiation field rather local.

1. INTRODUCTION

One of the fundamental astronomical problems is the establishment of a reliable cosmic distance scale. However, in spite of strong efforts and the use of many different methods the accuracy is often not yet satisfactory (see e.g. Rowan-Robinson, 1985). This is in particular true for distances to remote galaxies.

Since expansion velocities and colors of supernovae can be measured with high precision for distances up to about 1000 Mpc the application of the Baade-Wesselink-method (Baade, 1926) to these objects can provide significant improvements (Wagoner, 1980), if it is possible to determine effective temperature T_{eff} and the absolute emitted flux F_λ at one wavelength λ.

Approximate values for T_{eff} can be obtained if a color temperature is interpreted as T_{eff} and F_λ is calculated by means of the Kirchhoff-Planck-function B, i.e. it is assumed $F_\lambda = B_\lambda\ (T_{eff})$.

For more accurate calculations it is necessary to model the emitting region in a way similar to stellar atmospheres. As a first step Shaviv,

J.-P. Swings (ed.), Highlights of Astronomy, 625–627.

Wehrse and Wagoner (1985) have constructed a number of supernova Type II photospheres under the following assumptions:

1.) stationarity
2.) LTE level populations
3.) radiative equilibrium
4.) spherical symmetry
5.) power law for the density $\rho \propto r^{-n}$, n = 10, which is valid for the coasting phase.
6.) expansion velocity $v(r) \propto r$
7.) solar composition

The opacity of hydrogen lines is taken into account in a rough way. The models also showed that in layers where the continuum is formed the density is very low (about 1.e-13 gr/cm3) so that strong deviations from local thermodynamical equilibrium (LTE) should be expected.

2. THE NLTE MODELS AND DISCUSSION

In order to investigate the NLTE effects we calculated a set of models (for parameters see Table I) in which the assumption 2.) was replaced for hydrogen and helium by the assumption of statistical equilibrium. In total we considered explicitly 8 levels of H with 28 lines between them and 2 levels of He. For details see Höflich (1983) and Höflich, Wehrse and Shaviv (1985).

TABLE I: Details of Supernova envelopes for T_{eff}=8000 K.

model number	R{cm}	L_{bol} {erg s^{-1}}	ρ {g cm^{-3}} (τ_{abs}=1)	τ_{scatt} (τ_{abs}=1)
1	$1\ 10^{14}$	$2.92\ 10^{40}$	$1.83\ 10^{-12}$	7.9
2	$5\ 10^{14}$	$7.30\ 10^{41}$	$9.13\ 10^{-13}$	20.3
3	$1\ 10^{15}$	$2.92\ 10^{42}$	$7.64\ 10^{-13}$	32.9
4	$3.5\ 10^{15}$	$3.58\ 10^{43}$	$5.81\ 10^{-13}$	94.5

The resulting flux distributions are surprisingly similar to those of the LTE models: For a given color the differences d T_{eff} between the LTE and the NLTE models amount only to about 250 K (Note that the geometrical extension, which is of the order 0.25, leads to much larger effects). The reason for this behaviour can be seen from Fig. 1, where the departure coefficient for the H n=1 level and the absorption optical depth at λ = 5000 Å are plotted against the extinction optical depth: At the optical depths at which the continuum is formed ($\tau_{abs} \approx 1$) the deviations from LTE are very small.

Corresponding diagrams for the higher levels and other wavelengths show the same behaviour. This in turn is caused by a rather flat temperature distribution due to the large geometrical extension and by the large ratio of scattering to absorption processes (of the order of 100 as seen from Fig. 1) which makes the radiation field rather local (Test scattering cross-section leads to an appreciable increase in the

https://doi.org/10.1017/S1539299600007024 Published online by Cambridge University Press

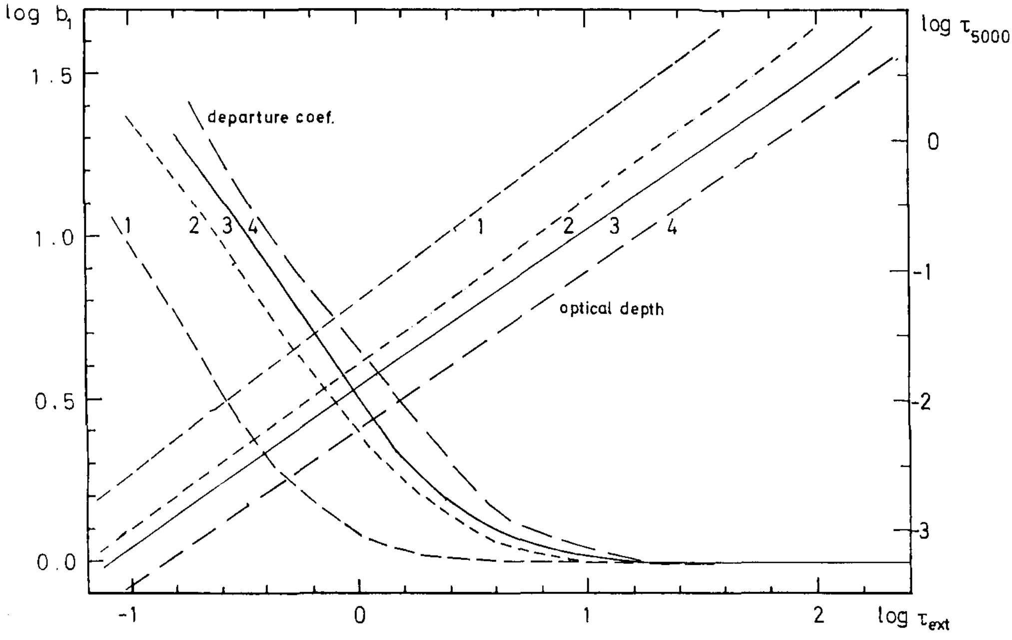

Fig. 1. The departure coefficients of the hydrogen n=1 level are shown as a function of the optical depth τ_{ext} for extinction (left scale). In addition, the optical depth τ_{abs} for true absorption at 5000 Å is given (right scale). The lines are marked by the model number as given in Table I.

departure coefficients).

We therefore have to conclude that the continuum radiation from SN Type II during the coasting phase can be calculated under the assumption of LTE. We also expect from these calculations that lines which are formed not too high up in the photosphere are not very much affected by NLTE effects. We are presently incorporating a large line list and are improving the radiative transfer. The resulting models should enable us to determine distances to within about 10 percent.

Acknowledgements. This work was supported by the Deutsche Forschungsgemeinschaft.

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https://doi.org/10.1017/S1539299600007024 Published online by Cambridge University Press