Lα RADIATION AND CaII IONIZATION IN THE TYPE II SUPERNOVAE AT LATE TIMES

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Abstract: The ionization of CaII by the Lα quanta in the envelope of the type II supernova 1970g on 270th day is considered. The ratio CaII/CaIII is found to be very low (<0.1). This results in the low theoretical intensities of the CaII emission lines; they are at least an order of magnitude weaker than the observed ones. The implications are discussed.

An interpretation of the strong [CaII] λ 7300 and λ 8600 emissions in the late time spectra of SNII, e.g. SN1970g on 270th day after the explosion (see: Kirshner et al., 1973; Kirshner and Kwan, 1975) is related closely to the value of CaII fractional ionization. Yet the situation with the ratio CaII/Ca is indefinite because the contribution of Lα quanta into the ionization of CaII has been ignored so far. This process is studied here for the case of SN1970g on 270th day.

A following simple model for the envelope is adopted (see: Chugai, 1987): a homogeneous sphere with the expansion law $v = r/t$, boundary velocity $v_0 = 4000$ km s^{-1}, hydrogen mass $M_H = 2.5M_\odot$ (total mass is $\approx 4M_\odot$), electron concentration $n_e = 3.5\cdot 10^7$ cm^{-3}, electron temperature $T_e = 7000$K. The hydrogen population on the second level is $n_2 > 7$ cm^{-3} (Kirshner and Kwan, 1975; Chugai, 1987).

Lα quanta ionize CaII from 3d level ($\lambda_{3d} = 1218$Å). The density of Lα quanta with $\lambda < \lambda_{3d}$ at some point inside the envelope is determined by their creation and scattering in the local region of a "sound" radius $v_{th}t \ll v_0 t$. The Lα spectrum is specified by: the local optical depth $\tau = k\lambda t = 2.5\cdot 10^9$, Voight parameter $a = 5.6\cdot 10^{-4}$; collisional destruction probability $\varepsilon = C(2p,2s)/A(2p,1s) = 10^{-5}$, continuous absorption parameter $\omega_c = k_c \Delta\nu_D / k \lesssim 10^{-12}$. In the selective absorption of Lα the most pronounced effect is produced by FeII λ1217.85 line with the absorption parameter $\omega_s = k_s/k \approx 2\cdot 10^{-9}$. For the parameters indicated above the rate of CaII photoionization with the Lα quanta is found to be $P_{3d} > 0.020(M_H/2.5M_\odot)$ s^{-1}.

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The photoionization balance of CaII in the SN1970g on 270th day is calculated in the "two level (4s and 3d) plus continuum" approximation. A lower limit for P_{3d} and the solar ratio for Ca/H are adopted. We found that: (1) the ionization of CaII with $L\alpha$ radiation in SN 1970g on 270th day is the very effective process which results in CaII/CaIII < 0.1; (2) the theoretical intensity of [CaII] λ7300 emission is at least an order of magnitude lower than the observed one. The latter refers to CaII λ 8600 as well. Both results are stable against variation of the hydrogen mass in the range 1.5 ÷ $3.5M_{\odot}$.

The discrepancy between predicted and observed intensities of the CaII emissions in the case of SN1970g on 270th day requires some modification of the model applied above. Three possibilities are conceivable.

1) Ca is overabundant, i.e. $Z_{SN}(Ca) \approx 10Z_{o}(Ca)$.

2) The CaII fractional ionization is controlled with the charge exchange $Ca^{++} + H + 1.7eV \rightleftarrows Ca^{+} + H^{+}$ which results in CaII/CaIII $\approx$ 1.5 provided the cross-section for the reaction from the right to the left $\sigma \gtrsim 2 \cdot 10^{-17}$ cm^2. Unfortunately the value of σ is not known.

3) The SN1970g envelope is chemically inhomogeneous and consist of the two main components: (a) H-rich gas and (b) He-rich filaments which are inserted into the H-rich background. CaII emission lines presumably originate from He-rich component where Ca is ionized singly. To account for the observed CaII emission an order of $1M_{\odot}$ in the form of He-rich filaments is required. Such inhomogeneous structure might be produced by the Rayleigh-Taylor instability during the supernova explosion when the H-rich red supergiant envelope is shocked with the fast expanding He-rich matter.

The third possibility is favoured by the absence of the strong absorption component of $H\alpha$ in the spectra of SN1970g at earlier phase which is consistent with the idea of the inhomogeneous distribution of the hydrogen in the supernova envelope (see: Chugai, 1982).

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