CIRCUMSTELLAR NEBULAR LINES IN THE OPTICAL SPECTRUM OF SN 1987A*

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The nebulosities surrounding SN 1987A have a morphological structure strongly resembling some planetary nebulae (e.g. NGC 2392, NGC 3242).

Shock breakout from the photosphere of SN 1987A resulted in an intense UV flash of several 10^5 K and a duration of 2 to 4 hours. This pulse ionized the circumstellar shell which has been formed by the interaction of the tenuous fast wind (≈ 550 km s^{-1}) from the blue supergiant phase sweeping up the dense slow wind (15 km s^{-1}) from the red supergiant phase of the progenitor.

Supernova spectra in the range 350 – 970 nm were obtained on days 605-607 after outburst with the ESO 1.52 m telescope and a Cassegrain spectrograph. The spectrum consists of narrow nebular lines from the ionized circumstellar shell, superimposed on broad emission lines of the supernova itself. Line fluxes of the broad lines of [C I], [O I], Mg I], [Ca II] are compared with theoretical predictions by Fransson (1987) and Fransson and Chevalier (1989); we suggest an 18 $M_\odot$ progenitor. Fluxes of the narrow nebular lines of [N II], [O II], [O III], [S II], [S III], [A III], [Fe II] and [Fe III] were also measured and a weak [Fe VII] line at λ5159 was possibly detected. Other optical observations were made by Wampler and Richichi (1989) and Wang (1991).

An electron density $N_e = 2 \cdot 10^4$ cm^{-3} is derived from the narrow circumstellar [S II] lines. Temperatures on days 605-607 obtained from the [N II] and [O III] lines differ ($1.22 \cdot 10^4$ K and $3 \cdot 10^4$ K, respectively) and show that these lines originate in different regions (clumps?) of the circumstellar shell, and thus meaningful abundance determinations are not feasible.

N_e at different epochs (days 313 – 750) was $(1-3) \cdot 10^4$ cm^{-3}. The temperatures remained fairly constant between days 500 and 1285, the average derived from the [N II] lines is about 12500 K, and from [O III] about 26000 K.

The mass loss rate from the progenitor during its red supergiant phase was estimated from the [S II] lines. It is $\dot{M} = 4\pi R^2 N_e m_H v$, where R is the radius of the spherical emitting volume of [S II]. The volume of the forbidden line emitting region can be obtained from the emission measure (EM) and N_e; EM is calculated from the [S II] line fluxes and atomic parameters. Then, $\dot{M}$ for the SN 1987A progenitor is $6 \cdot 10^{-6}$ $M_\odot$ yr^{-1}.

References

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* based on observations collected at the European Southern Observatory, La Silla, Chile