JOURNAL OF THE KOREAN ASTRONOMICAL SOCIETY
29: S215 ~ S216, 1996

SMALL-SCALE REGULAR STRUCTURES IN SUPERNOVAE PROGENITORS

O. A. TSIOPA
Central Astronomical Observatory of the Russian Academy of Sciences, Pulkovo 196140, St. Petersburg, Russia

ABSTRACT

The wind-formed features observed in the early SNe spectra type II and Ia give an evidence of the existence of an ellipsoidal shell formed by the stellar wind prior to the explosion. Such non-spherical shell can occur not only at scales of parsec (the case of SN 1987A progenitor), but at the scales of 1000 times less. Such shells can be the result of the radial pulsation. The prolate multi-shell structures are interpreted as a result of a pulsation processes with recurrent wind ejections with velocity increasing.

Key Words : supernovae, mass loss

I. INTRODUCTION

Though both type II and type Ia SNe proved to be originated by precursors, which may be subjected to very strong mass-loss processes, the structure of their circumstellar matter differs significantly.

The variability of the antique SNe precursors winds was proved by the radio observations of SNe at the large time-scales (1979c) and at the shorter those (1993j).

Spectral observations of the SNe were not systematic, unfortunately. Hence, we do not have a complete dynamic picture of spectral features evolution.The most important observational results are the following:

Dopita et al (1984) discovered so called “superwind”, which had been ejected with the extremly high velocities of 3000 km/s immediately prior to the SN event. The fascinating change of the velocity shifts in SNe 1983K (Niemela et al, 1985) and 1990M (Polcaro and Viotti, 1991) witness to the existence of complicated, but rather regular structures in the wind at the scales of less than 10^{16} sm. Recently (Tsiopa,1995) these observational facts were united in common dynamical model.

II. THE WINDS OF SNE TYPE II

Though the SN envelope velocities of SNe type II are less than those in SNe type I,their winds are extremely fast (up to 2000-4000 km/s). The wind being higly variable and dense, the pronounced colliding wind-formed structures can occur close to the SN progenitor. The development of the system of interacting wind layers with different deviation of symmetry and increasing velocities may result in three general types of shell geometry; oblate, quasi-spherical, and prolate. The SN envelope expands inside the wind shell formed by SN progenitor just before the explosion. As the SN envelope velocity is much higher than the wind velocity (about 10 times), the wind-formed shell is being swept by the envelope, starting from the inner parts. The wind originated lines are generated in the region about to be swept. These parts of the wind matter are excited by the fast electrons, produced by the SN expanding envelope.The outer regions of the wind shell cannot exhibit Balmer lines, because hydrogen is not excited there up to the second level.

The presence of the distinct prolate ellipsoidal shell can explain the narrow $H\alpha$ absorption lines, being observed in the spectra of SN 1983K. The lines are forming in the parts of the shell closest to the expanding SN envelope, where hydrogen is exited up to the second level, with previous regions being already swept by the SN envelope. According to position of line-of-sight the velocity shift had been increasing during the period of observation (two months) with the accelaration of 40 km/s per day due to the velocity distribution in the ellipsoidal wind formed shell.

The quasi-spherical shell can be reponsible for "superwind" P Cyg lines observed in 1984e. The line-of-sight orientation is not important in this case.

III. THE WINDS OF SNE TYPE Ia

The presupernova winds of SN type I are very difficult to be detected: they are less massive, slower (hundreds km/s) and almost immediately are swept by the SN envelope expanding with very high speed. Taking into account, that even the identification of SN envelope originated lines themselves is often problematic in SNe type Ia spectra, it is not surprising, that the detection of hydrogen lines attributed to the circumstellar shell is denied by M.Della Valle et al (1996).

For the case of 1990m our model implies an existance of a shell formed by the matter with maximum velocity of 1200 km/s and the minimum one of 600 km/s and inclination to the line-of-sight of 40^o

The observed emission hydrogen line by Branch et al (1983) can also find its place within the framework of the same model. The small narrow feature was located at the rest wavelength of $H\alpha$.Pure emission with zero velocity shift implies the wind ellipsoid axis perpendicular to the line-of-sight with most of it already swept by the SN envelope. Such spectral line is supposed to disappear in a very short time (5 days later the feature was not detected).

IV. DISCUSSION

Judging from the SN envelope expansion velocity the wind formed structures under consideration are situated at the radii from the explosion centre of $10^{14}-10^{15}$ cm for SN 1983K and $3-6\times10^{15}$ cm for SN 1990M. The time of shell ejection can be estimated as 6×10^{6} sec for SN 1983K and 5×10^{7} sec for SN 1990M. Such rather small distances and short periods of the regular structurs formation imply the presence of high initial gradient of density and velocity in the wind matter.

Thus an extraordinary activity of the precursor can be suspected even for a single star. During the periods of interior reconstruction (preceding the SN type II event, for example) even the outer parts of the star are likely to be in the unstable state. The strong pulsation with different modes can be evoked. Such processes as several-mode resonant coupling are probable to determine the mass-loss rates in critical periods of stellar evolution. When expanding the star throws away the very outer part of its envelope (or, in other words, the stellar wind increases dramatically) and a flying away shell is formed. In this case the precursor would be surrounded by a system of interacting shells (Tsiopa, 1990)

One type of steady stellar wind flow is changed to another one (with different wind velocity and density) not in a smooth way. During the period of reconstruction the star produces strongly inhomogeneous wind. It's possible that the explosion itself is encouraged by its resonance pulsation.

As for the SN type Ia precursors some other mechanisms are certainly to be attracted. However the close systems burried in a common envelope (or one compact object inside the extended atmosphere of the other component) is in some sense undistinguishable from the rotating pulsating star. The forming circumstellar environs may occur rather simular. Perhaps, the eccentricity of the orbit in binary system can be treated as a trigger in generating instabilities and resonance effects.

In the close binary supernova precursor the shell ejections can be sooner connected with the mass loosing component (red giant in its final period of evolution, for example), than with the mass accreting white dwarf. The strongly variable accretion rate might promote the degenerate object to approach the Chandrasekhar limit.

The recurrent ejections of matter with different velocities can result in formation of axial colliding wind formed structures. A very energetic individual pulsation of supernova precursor just before the explosion event produces a shell, perhaps, discovered in the early spectra of SN 1984E.

The only way to find a supernova progenitor in the Galaxy before the explosion is to understand the structure of its wind and to compare it with the known peculiar wind producing stars.

The kind hospitality of the Organizing Committee and the IAU grant are highly appreciated.

REFERENCES

Branch, D., Lacy, C. H., McCall, M. L., Sutherland, P. G., Wheelen, J. C., Wills, B. J. 1983, ApJ, 270, 123

Della Valle, M., Benetti, S., Panagia, N. 1996 ApJ, 459, L23

Dopita, A. M., Evans, R., Cohen, M., Schwarts, R. D. 1984 ApJ, 287, L69

Niemela, V. S., Ruiz, M. T., Phillips, M. M. 1985 ApJ. 289. 52

Polcaro, V. F., Viotti, R. 1991 A&A, 242, L9

Tsiopa, O. A. 1990, Astronomicheskj Tsirkular N1554, 23

Tsiopa, O. A. 1995 in: K. A. van der Hucht and P. M. Williams (eds.), Wolf-Rayet Stars: Binaries, Colliding Winds, Evolution (Dordrecht:Kluwer) 425