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ON THE HIGH METALLICITY PRODUCED BY CSNRS

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We present semi-analytic models for the hydrodynamic and chemical evolution of compact supernova remnants (cSNRs). Explosions of two progenitor stars of 15 and 25 $M_\odot$ are explored. We find the metallicity of the cSNRs to be high ($1.0 \leq Z/Z_\odot \leq 6.0$) if oxygen is used as a tracer. These values are close to the metallicities of highly redshifted QSOs (Ferland et al. 1996; Hamann & Ferland 1999).

Spectra of highly redshifted QSOs present broad line emission. The metallicities of the associated fast-moving gas derived from the spectral analyses are surprisingly high for such young objects and fall into the range $Z \sim 1$ to $9\,Z_\odot$ (Hamann & Ferland 1999). This implies an effective contamination of the interstellar gas within a short timescale at the pre-QSO phase. QSO gas metal enrichment is usually related to violent star formation (Ferland et al. 1996). However, this model is limited by the short time required to produce enough metals and mix them with the ambient medium. We analyze another approach based on the possible association of QSOs with cSNRs (Terlevich et al. 1992).

We developed a semi-analytical model for cSNR evolution and examined the explosion of $15\,M_\odot$ and $25\,M_\odot$ progenitors into a dense ($10^7\,\mathrm{cm}^{-3}$) circumstellar medium (CSM) (Rodríguez-González 2002). The density and the velocity of the ejecta were taken from Franco et al. (1991):

$$\rho_{\mathrm{ej}}(r \geq R_{\mathrm{c}},\ t) = \frac{M_{\mathrm{ej}}}{4\pi r^3 \ln\left[R(t)/R_{\mathrm{c}}\right]},$$

$$V_{\mathrm{ej}}(r \geq R_{\mathrm{c}},\ t) = \frac{r - R_{\mathrm{c}}}{R(t) - R_{\mathrm{c}}} V_{\mathrm{m}},$$

and $\rho_{\mathrm{ej}}(r < R_{\mathrm{c}},\ t) = V_{\mathrm{ej}}(r < R_{\mathrm{c}},\ t) = 0$, where $R(t) = R_{\mathrm{m}} + V_{\mathrm{m}} t$, R_{m} is the initial radius, V_{m} is the maximum ejecta velocity, and R_{c} is the inner radius of the ejecta.

In both cases, soon after the explosion cooling becomes important and dense shells form after $\sim 1\,\mathrm{yr}$ of evolution. Then, we calculate the characteristic diffusion time $t_{\mathrm{d}} = L^2/D$ needed to mix the ejected metals with the swept-up CSM. The thickness, L, of the cSNR has been taken from our hydrodynamical model and two different approximations for the diffusion coefficient, D, have been used. The metallicity of the cSNR has been calculated from

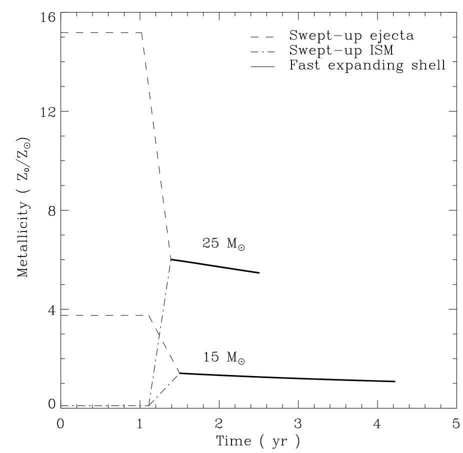

Fig. 1. The cSNR metallicity as function of time if oxygen is used as a tracer.

$$Z_{\mathrm{A}}(t)/Z_\odot = \frac{M_{\mathrm{A,ej}}(t)/Z_{\mathrm{A},\odot} + Z_{\mathrm{CSM}} M_{\mathrm{CSM}}(t)}{M_{\mathrm{CSM}}(t) + \chi M_{\mathrm{ej}}(t)},$$

where $M_{\mathrm{CSM}}(t)$ and $\chi M_{\mathrm{ej}}(t)$ are masses of the swept-up CSM and the ejecta, respectively, and $M_{\mathrm{A,ej}}(t)$ is the mass of the element A that has been accumulated within a shell.

The calculations show that effective metal diffusion occurs soon after dense shell formation. The resultant shell metallicity was found to be within the range $1.0 \leq Z/Z_\odot \leq 6.0$ if oxygen is used as a tracer and $0.65 \leq Z/Z_\odot \leq 1.3$ if iron is used as a tracer of the gas metallicity. We speculate that the observed QSO metallicities could be related to the cSNRs.

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