# Nucleosynthesis in exploding massive Wolf-Rayet stars

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Recent observations of the young supernova remnant Cas A (Fesen et al., 1987) suggest an exploding Wolf-Rayet (WR) star of WNL type as a progenitor of this object. The majority of the WR stars seems to originate from massive O-stars of $M > 40\,M_\odot$. According to current investigations (Schild and Maeder, 1984; Langer, 1987; cf. also: Langer, this volume) WNL stars rank among the most massive WR stars. Hence, it is possible to assume that the stellar progenitor of Cas A was indeed a very massive star.

As shown by Langer and El Eid (1986), (see also Woosley, 1986) a population I star of initially $100\,M_\odot$ may loose enough mass during its evolution up to core He exhaustion to become a WN star of $\sim 45\,M_\odot$, which then mainly consists of oxygen (more than 80%) synthesized during He burning.

In a previous work (El Eid and Langer, 1986) we have shown that such a star encounters the $e^\pm$-pair creation instability at central oxygen ignition. During the ensuing collapse oxygen burning proceeds explosively on a typical time scale of $\sim 40\,s$, and may release enough energy to reverse the collapse into a supernova explosion. We note that such explosion would be a peculiar type II event when a WNL star is envolved, since it retains part of its hydrogen rich envelope but has a compact structure.

Our present calculations are basically similar to the previous ones (El Eid and Langer, 1986) except of two modifications: (i) we have followed the nucleosynthesis in more detail by extending the nuclear reaction network (cf. El Eid and Prantzos, 1987), which now includes 39 nuclei between $^4$He and $^{56}$Ni instead of only $\alpha$-nuclei as previously. (ii) The opacities have been calculated taking into account inelastic compton scattering and degeneracy in the electron distribution (Buchler and Yueh, 1976). At temperatures encountered during oxygen burning these corrections reduce appreciably the electron scattering cross section over the Thomson value, which enhances the radiative energy transport.

The main results of the present calculations are sketched as follows:

During the collapse phase of the $45\,M_\odot$ WN star higher peak values of temperature $(3.37 \cdot 10^9\,K)$ and density $(2.05 \cdot 10^6\,g\,cm^{-3})$ are achieved mainly due to the reduced opacities. Consequently, the amount of consumed oxygen is higher $(\sim 3\,M_\odot)$. Hence, the energy release from explosive oxygen burning is enough to disrupt the star. The resulting kinetic energy was $\sim 3 \cdot 10^{51}\,erg$, and the surface velocity $\sim 6900\,km\,s^{-1}$.

The resulting nucleosynthetic yield from such explosion is compared with the abundances inferred for Cas A from the optical observations of specific fast moving knots (FMKs). In Fig. 1, the abundances of several FMKs are superimposed on the calculated profiles. Several features are compatible with observations: (a) the observed ratios for S, Ar, and Ca of various knots correspond to layers in the model which have undergone incomplete oxygen burning. (b) Knot KB115 lies between that of [OIII] filament and knot KB33. (c) The layers accommodating the observed ratios for S, Ar, and Ca show substantial amounts of both, O and Si. (d) The upper limits of C and Ne are found in the outer layers around $M_r = 20\,M_\odot$. This means that the layers which are needed to explain all observed abundances of the FMKs comprise enough mass to account for the estimated lower limit $(\sim 15\,M_\odot)$ of the remnant mass inferred from the X-ray observations (Fabian et al., 1980; Markert et al., 1983).



https://doi.org/10.1017/S025292110009432X Published online by Cambridge University Press

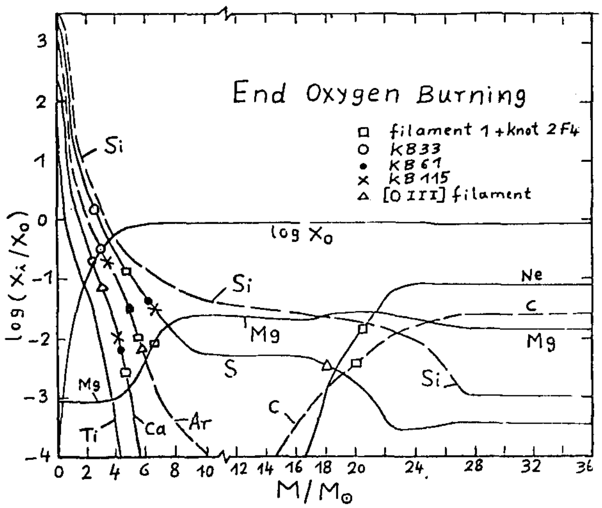


**Fig. 1:** Comparison of the observed abundance ratios relative to oxygen in the fast moving knots of Cas A with calculated values for the exploding $45\,M_\odot$ WN star (only $36\,M_\odot$ are shown). The observed values taken from Chevalier and Kirshner (1979) are plotted on the calculated profiles. The oxygen profile ($\log X_O$) is also shown.

In summary, though we cannot claim to have found the evolutionary scenario for the complicated object Cas A, several features in the present model of an exploding WN star are compatible with the available observations of this object. It appears, that the explosion of WNL stars as a pair creation supernova can be envisaged as a possible explanation for some extragalactic supernova remnants of Cas A type, like the one in NGC 4449 (Kirshner and Blair, 1980), or for supernovae showing spectra resembling the WN classification. It seems worthwhile to extend the present calculations by including detailed radiation transport in order to calculate the light curve of such explosions.

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https://doi.org/10.1017/S025292110009432X Published online by Cambridge University Press