

## NOVAE AND GALACTIC CHEMICAL EVOLUTION

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### ABSTRACT

It is estimated that the ejected shell masses of novae are about one order of magnitude smaller than previously thought. The implications of this result for galactic chemical evolution are analyzed. It is found that novae may be important sources for the interstellar enrichment of  $^{15}\text{N}$  but not of  $^{14}\text{N}$ .

### 1. INTRODUCTION

Several authors have suggested that novae might be important sources of  $^7\text{Li}$ ,  $^{13}\text{C}$ ,  $^{15}\text{N}$ , and  $^{17}\text{O}$  enrichment of the interstellar medium (e.g. Truran 1982; Vigroux and Arnould 1979). Moreover Williams (1982) has suggested that novae might even be the main source of  $^{14}\text{N}$  in the ISM of our galaxy and other galaxies. Alternatively Aller *et al.* (1981) argue that the planetary nebulae, PN, of the Small Magellanic Cloud contribute nearly enough N to enrich the ISM, but that massive stars may also be involved. The N produced by novae would be of primary origin while most of that produced by PN would be of secondary origin (Peimbert 1984). The difference has profound implications for models of galactic chemical evolution since according to Serrano and Peimbert (1983) most of the N in the ISM has to be of secondary origin in order to explain the galactic and extragalactic N/O versus O/H diagram. Primary elements are those that are directly synthesized from H and He, and secondary elements are those synthesized from heavier elements that were already present in the star when it was formed. It is the purpose of this note to reevaluate the relative importance of novae and PN for the enrichment of N in the interstellar medium of the galaxy.

### 2. MASSES EJECTED BY NOVAE

Since the pioneering work of Pottasch (1959) determinations of the mass ejected by novae outbursts cluster around  $10^{-4} M_{\odot}$  (e.g. Pottasch 1959, Williams 1982). Most mass determinations are based on the intensity of recombination lines (mainly Balmer lines) at times when they are optically thin and therefore depend on the density square, that is they are root mean square masses given by

$$M(\text{rms}) = \mu_e m_H \int N_e(\text{rms}) dV, \quad (2.1)$$

where  $m_H$  is the mass of the hydrogen atom and  $\mu_e$  is the number of atomic units of mass per free electron.  $\mu_e$  is typically between 1.4 and 3 and is given by

$$\mu_e = \frac{N(\text{H}) + 4N(\text{He}) + 12N(\text{C}) + 14N(\text{N}) + \dots}{N(\text{H}) + aN(\text{He}) + bN(\text{C}) + cN(\text{N}) + \dots}, \quad (2.2)$$

where  $a, b, c$ , denote the number of free electrons provided by each atom. There are two other types of masses that can be derived: i)  $M(\text{Local})$  which is based on the  $N_e(\text{Local})$  density derived from two lines of the same ion that originate in different energy levels like  $\lambda\lambda 1663$  and  $5007$  of OIII, and ii)  $M(\epsilon)$  where it is assumed that only a fraction,  $\epsilon$ , of the observed volume is filled with  $N_e(\text{Local})$  and that the rest is empty. It can be shown that in the case of spatial density fluctuations (e.g. Peimbert 1966)

$$M(\epsilon) = \epsilon^{1/2} M(\text{rms}) = \epsilon M(\text{Local}); \quad (2.3)$$

equations 2.1 and 2.3 apply to spheres as well as to shells and in the second case  $\epsilon$  is the filling factor within the shell.

Snijders *et al.* (1984) have computed the gaseous mass of the shell of Nova Aquilae 1982 and have obtained an  $M(\epsilon) = 5 \times 10^{-6} M_\odot$  and a filling factor  $\epsilon = 1.7 \times 10^{-5}$ . This very low filling factor implies that most of the high density material responsible for the emission is in clumps, filaments or thin sheets and that the material in between is at much lower densities and presumably at higher temperatures. By considering the mass in the form of dust grains a total ejected mass of  $\sim 1 \times 10^{-5} M_\odot$  is obtained (Snijders *et al.* 1984).

We have determined  $M(\text{Local})$ ,  $M(\text{rms})$  and  $M(\epsilon)$  for Nova Cygni 1978 from the observations by Stickland *et al.* (1981) at  $D = 88$  days. By assuming a homogeneous sphere expanding at  $v = 760 \text{ km s}^{-1}$  a radius of  $6 \times 10^{14} \text{ cm}$  is obtained, which together with  $N_e(\text{Local}) = 8 \times 10^7 \text{ cm}^{-3}$  and the ionic composition given by Stickland *et al.* yields  $M(\text{Local}) = 9 \times 10^{-5} M_\odot$ . It is possible to determine  $N_e(\text{rms})$  from the recombination line fluxes of CII  $\lambda 1335$ , CIII  $\lambda 2297$  and NIV  $\lambda 1718$ , corrected for reddening according to the normal extinction law by Seaton (1979), and equations of the type

$$N_e(\text{rms}) = \left\{ \frac{I(1335)}{N(\text{C})} \frac{N(\text{H})}{V(\text{C}^{+2})} \frac{4\pi d^2}{\alpha(\text{C}^{+2})} \frac{\beta}{h\nu(1335)} \right\}^{1/2}, \quad (2.4)$$

where  $d$  is the distance to the object,  $\beta$  is the number of electrons per hydrogen atom in the region where the line is formed,  $\alpha$  is the effective recombination coefficient for  $\lambda 1335$  and  $V(\text{C}^{+2})$  is the volume where the line originates and for a homogeneous sphere is equal to  $V N(\text{C}^{+2})/N(\text{C})$  where  $V$  is the total volume. With the input data to eq.2.4 by Stickland *et al.* we obtain  $N_e = 2.5 \times 10^7 \text{ cm}^{-3}$  which together with  $M(\text{Local})$  and eqs. 2.1-2.3 yield  $M(\text{rms}) = 3 \times 10^{-5} M_\odot$ ,  $\epsilon = 0.1$ , and  $M(\epsilon) = 9 \times 10^{-6} M_\odot$ . By adopting a higher velocity of expansion we would have obtained a larger

