CIRCUMSTELLAR CHEMISTRY OF COOL EVOLVED STARS

A.E. Glassgold and G. Mamon
New York University
New York NY, 10003
USA

ABSTRACT. A status report is given of the continuing development of the photochemical model for circumstellar envelopes around cool evolved stars, with emphasis on molecular ions in both O-rich and C-rich envelopes.

1. THEORY

In the photochemical model, molecules that enter the circumstellar envelopes (CSEs) of giant stars beyond the region of dust formation are broken down by interstellar UV photons that penetrate the envelope from the outside (Huggins and Glassgold 1982a; see also the reviews by Omont 1985 and Glassgold and Huggins 1986). The initial focus was on the distribution of the molecules and their photo products. For example, the dependence of the location of the OH masers on mass loss rate can be understood in terms of the shielding by dust of the radiation which dissociates H_2O (Huggins and Glassgold 1982b). More recently it has been possible to confirm that the photo destruction products generate strong ion molecule chemistry at intermediate regions in the CSE, typically 10^{16} to 10^{17} cm from the central star (Glassgold, Lucas, and Omont 1986, henceforth GLO). In C-rich CSEs, GLO showed that a variety of molecular ions are produced by interstellar UV and cosmic rays, the most abundant being $C_2H_2^+$ and C^+ produced by photoionization of acetylene. GLO also suggested that HCO^+ ought to be marginally detectable in IRC +10216.

During the last year we have improved the chemical model by including new laboratory information on the temperature dependence of ion polar molecule reactions and on recombination, and by using a new treatment of CO line self shielding (Mamon, Glassgold, and Huggins 1987) based on the Sobelev approximation. We present below our refinements to the C-rich model of GLO and our first results on O-rich CSEs.

2. C-RICH CSEs

A sensitive search for the 89 Ghz J=1-0 transition of HCO^+ in IRC +10216 (Lucas et al. 1986) yielded an upper limit to the antenna temperature of 20 mK, well below the GLO prediction of 95 mK. The improved model with standard parameters (e.g. $\dot{M} = 4\times10^{-5}$ M yr^{-1}) gives 24 mk, which is consistent with the observations. Further details, including a investigation of the abundance of HNC, will be presented in a paper in press (Glassgold, Mamon, and Omont 1986).

3. O-RICH CSEs

The spatial distribution of the ionization is similar for O-rich and C-rich CSEs: Just outside the region of dust formation, the ions are produced by cosmic rays; at intermediate distances, by photoionization of H bearing molecules (i.e. H_2O or C_2H_2); and at large distances by photoionization of C (from CO and, in the C-rich case, from C_2H_2). The two most abundant molecular ions in O-rich CSEs are HCO^+ and H_3O^+; H_3O^+ is produced by photoionization of water followed by rapid hydogenation. The surprisingly large abundance of HCO^+, almost 10^{-7}, is orders of magnitude larger than in C-rich CSEs. The main source of HCO^+ is the reaction $C^+ + H_2O \longrightarrow HCO^+ + H$, where C^+ is generated by the CO photochain. The quantitative aspects of the abundance of C^+ are critically dependent on the theory of CO line self shielding (Mamon, Glassgold, and Huggins 1987). The main conclusion here is that HCO^+ and H_3O^+ ought to be detectable in O-rich CSEs. Omont has in fact reported the detection of HCO^+ in OH 231.8 + 4.5 at this meeting. A more complete discussion of the ionization of O-rich CSEs will be presented by Mamon, Glassgold, and Omont (1987).

REFERENCES
Glassgold, A.E. and Huggins, P.J. 1986, in M, S, and C
 Stars, Eds. H.R. Johnson and F. Querci (NASA and CNRS).
Glassgold, A.E., Lucas, R., and Omont, A. 1986,
        Astr. Ap. 157, 35.
Glassgold, A.E., Mamon, G. and Omont, A. 1986,
        Astr. Ap. in press.
Huggins P.J. and Glassgold, A.E. 1982a, Ap. J. 252, 201.
Huggins P.J. and Glassgold, A.E. 1982b, A.J. 87, 1828.
Lucas, R., Omont, A., Guilloteau, S., and NguyenQuang Rieu,
        1986, Astr. Ap. Lett. 154, 12.
Mamon, G., Glassgold, A.E., and Huggins, P.J. 1987, Ap.J.
        in press.
Mamon, G., Glassgold, A.E., and Omont, A. 1987, Ap.J.
        in press.
Omont, A. 1985, in Mass Loss in Red Giants, Eds. M. Morris
        and Ben Zuckerman (Reidel, Dordrecht), p. 269.