COMMENT S ON SOME POSSIBLE MODELS OF TMC-1

(Letter to the Editor)

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Abstract. Chemical differences between cores in the dark ridge TMC-1 have been attributed to the cores being in different stages of chemical evolution with those having high NH3 to cyanopolyne abundance ratios being the most evolved. We suggest several alternative models including one in which the highest NH3 to cyanopolyne abundance ratio obtains in the youngest TMC-1 core; in this and in one of the other models the evolution of the chemistry as depletion increases is supposed to lead to a lower NH3 to cyanopolyne ratio. The possibility that the cyanopolyynes exist primarily in an interface between dark core material and the wind of a low mass star is considered; this wind interface model may account for the sharp cyanopolyne emission gradient on the side of the ridge away from the star. Implosion of the cores by the ram pressure of the wind may have caused them to collapse more rapidly than gravity could and more rapidly than chemistry evolves so that the chemistry reflects a core’s state at a lower density.

1. Introduction

TMC-1 is an elongated dark molecular region containing six dark cores of which five are roughly aligned on the plane of the sky (e.g. Hirahara et al., 1992). The distribution of cyanopolyynes and the distribution of NH3 in TMC-1 are anticorrelated (Little et al., 1979; Tölle et al., 1981; Avery, MacLeod and Broton, 1982; Schloeb, Snell and Young, 1983; Olano, Walmsley and Wilson, 1988) with the NH3 and HC3N peaks coinciding with the dark cores labelled B and D, respectively, by Hirahara et al. (1992). Multiline studies of C2S and C3S have been used by Hirahara et al. (1992) to estimate the H2 number density in core B (located to the northwest) to be $4 \times 10^5$ cm$^{-3}$ and in core D (located to the southeast) to be $4 \times 10^4$ cm$^{-3}$; higher angular resolution mapping of core D has shown it to be fragmented with its highest density fragments having $n(H_2) \approx 1 \times 10^6$ cm$^{-3}$ though larger features have $n(H_2) \approx 3 \times 10^4$ cm$^{-3}$ to $8 \times 10^4$ cm$^{-3}$ (Langer et al., 1995).

The total extent of TMC-1 is about $12' \times 35'$ (Langer et al., 1995) with $1' \approx 0.041$ parsec for a distance of 140 pc. The diameter of each core is roughly 0.1 pc and each is separated from its nearest neighbor by several arcminutes. On the plane of the sky a star is nearly enclosed in the triangle formed by the lines passing through the three most northerly cores.

The chemical differences between core B and core D have been attributed to a difference between the ages of the cores (Hirahara et al., 1992; Taylor, Howe and Williams, 1996). The denser core B is nearer a star and has been supposed to be more evolved dynamically and chemically than core D. Time dependent models of gas phase dark core chemistry (e.g. Taylor et al., 1996) show that the abundances of cyanopolyynes peak at a time early relative to that at which the NH$_3$ abundance peaks.

We do not necessarily believe the explanation considered by Hirahara et al. (1992) and Taylor et al. (1996) for the chemical difference between cores B and D to be wrong. However, in this note we point out that several other plausible explanations require examination.

2. The Young Core B–Old Core D Model

The similarity of the brightness distributions of HCO$^+$ emission (Guélin, Langer and Wilson, 1982) and NH$_3$ emission and the displacement of the HCO$^+$ peak from the cyanopolyyne peak probably indicate that the electron number density in core B is not much (if at all) higher than the electron number density in core D (the HCO$^+$ fractional abundance is inversely proportional to the electron number density because HCO$^+$ is removed primarily by dissociative recombination). Thus, if core B is denser than core D (as seems to be the case) core B’s fractional ionization is lower than that of core D. When grain-neutral friction can be neglected, the ambipolar diffusion timescale is directly proportional to the fractional ionization (e.g. Mouschovias, 1979). Hence, core B is almost certainly evolving dynamically considerably more rapidly than core D and, thus, cannot be much older than core D. Core D could be much older than core B, and given that the gas phase chemical timescale does not depend on the density core D could be the chemically more evolved of the two cores. Consequently, there are dynamical reasons to dismiss the argument that high cyanopolyyne abundances in core D reflect its relative gas phase chemical youth.

Hartquist and Williams (1989) and Rawlings et al. (1992) considered the problem of the observation of regions in which collisions and sticking of gas phase species with dust grains have greatly reduced the gas phase abundances of elements more massive than helium. They showed that as the gas phase abundances of the elements carbon and oxygen decrease the gas phase abundances of C$^+$ and of CH rise until the depletion becomes so great that the gaseous CO ceases to contain most of the gas phase carbon. No computations exist for the behavior of the cyanopolyyne abundances as depletion increases, but we anticipate that they will go up as dramatically as the CH abundance does. The work of Rawlings et al. (1992) showed the NH$_3$ abundance to go down as depletion occurred.

The increase of the cyanopolyyne to NH$_3$ abundance ratio as depletion occurs might account for some of the chemical differences between cores B and D if core