$^3He^+$ IN GALACTIC H II REGIONS: POSSIBLE EVIDENCE FOR NON-CONVECTIVE MIXING IN LOW MASS STARS

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ABSTRACT

We have detected the 8.7 GHz hyperfine line of $^3He^+$ in the HII regions W43, W51, and W3 and obtained significant upper limits for M17, W49, and Orion A. Even though the abundances derived from measured line parameters can have large uncertainty due to the detailed structure of the sources, it seems almost certain that the $^3He^+$ abundance in W3, 12 kpc from the galactic center is significantly higher than in sources closer to the galactic center. If this is the result of general chemical evolution of the galaxy, it is exactly the opposite of what is expected.

I. OBSERVATIONS

Our observations were mostly done in August 1982 with the 43 m telescope of the NRAO at Green Bank. The excellent signal/ noise achieved is typified by the spectrum for W3 shown in the figure.

Since the strength of the $^3He^+$ feature depends on $n_3/n_H \times \int n_e dl$ and all measures of the total amount of ionized material in our beam depend on $\int n_e^2\, dl$, obtaining an abundance ratio from the observations is non-trivial. We have modeled the regions we observed and find that the uniform sphere models previously used sometimes significantly underestimate the ^3He abundance. Not only are the corrections for W3 and W51 large; they are quite uncertain with just the 1σ error in the measured continuum temperature introducing a 40% error in the structure correction. It is difficult to assign errors to the abundances. From the structure corrections alone, the W51 value could range from $6 - 14 \times 10^{-5}$ and the W3 value could range from $30\text{-}70 \times 10^{-5}$. It does seem safe to conclude that the abundance in W3 is significantly higher than in W43 and that there are source to source variations. The W43 value appears to be the best determined. Our results are summarized in the table.

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Source	Galactocentric distance (kpc)	$T_B(^3He^+)$ (mK)	Structure Corrections	$^3He/H$ (x 10^{-5})
W43	6	11	0.9	4
M17S	8	< 6	1.0	< 2
W51	8	9	2.4	10
W49	9.5	< 5	1.2	< 2
Orion	10.5	< 8	1.0	< 6
W3	12	15	2.7	50

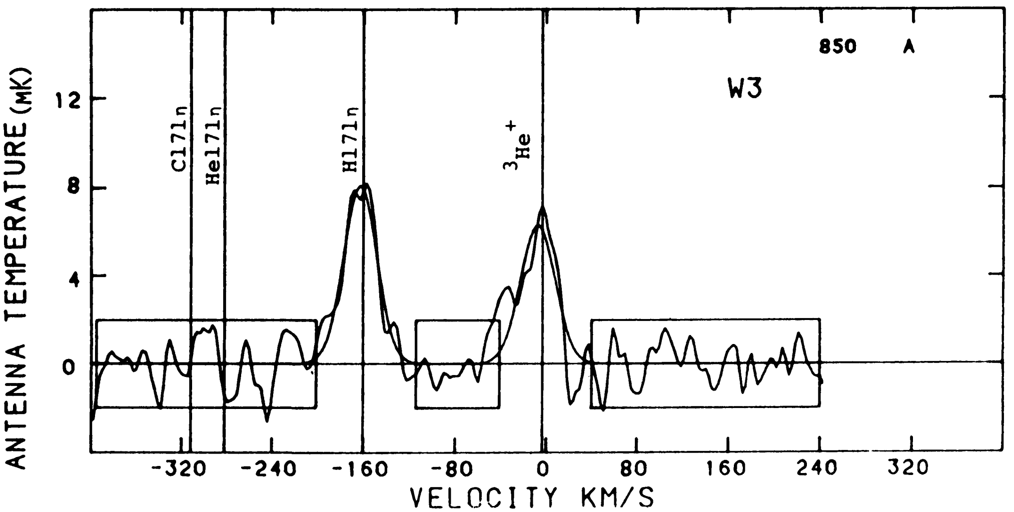

Figure 1. The region of the spectrum containing the 171n recombination lines and the He line. The expected rest frequencies are denoted by vertical lines. The spectrum has been smoothed by a gaussian smoothing function FWHM = 8 km s^{-1}.

II. CONSEQUENCES

Rood, Steigman, and Tinsley (1976) suggested that ^3He in the present ISM should be enhanced over the solar value. Schatzman (1984) has suggested some problem with the surface ^3He in the standard solar model. Both of these arguments require a knowledge of the protosolar $^3He/H$ which is generally derived by subtracting some estimate of the protosolar D/H from the current solar wind ^3He. Because of the uncertainty in D the protosolar $^3He/H$ could range from 0 to 4 x 10^{-5}. We thus see that there may or may not have been any enrichment of the ISM in the past 5 billion years. Further from the range of ^3He now, we conclude the sun could well have formed with whatever ^3He is required to match the current value. No matter what other problems may exist with the standard solar model, $^3He/H$ certainly is not a problem.

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The puzzle at the moment is the high abundance in W3. Is it a pecularity of the source itself? W3 is indeed an odd H II region. W3A is a ring-like source containing a 50-100 $M_\odot$ of gas. If all of our signal comes from W3A then $^3He/H \sim 10^{-3}$ in that source. This value is near the maximum which might occur in planetary nebulae with $\sim 1M_\odot$ progenitors.

If the high abundance in W3 is due to the general chemical evolution of the galaxy, the result is exactly the oposite of what would be expected. This is shown by observations of ^{13}C which should be produced in the same stars which produce ^3He. Observations of H_2CO (Henkel, Wilson, Bieging, 1982) show $^{13}C/^{12}C$ enhanced by about a factor of two at galactocentric distances of 5 kpc over the approximately solar value found near W3. This seems to agree with the generally held belief that there is more stellar processing toward the galactic center. The simplest interpretation of our observations of ^3He which is consistent with the ^{13}C observations is that stars destroy ^3He. This would place an important constraint on diffusive mixing models, since, for example, the formulation for turbulent diffusion described by Schatzman (1983) does not lead to the destruction of ^3He. It seems possible that a diffusive mixing may occur just maintaining the ^3He gradient required for the onset of the overstable oscillations first found by Dilke and Gough (1972). Such a mechanism might lead to the destruction of ^3He and the transport of ^{13}C and perhaps Li. Further it would address the comments made by Roxburgh at this meeting pointing out that the ^3He peak provides an adequate energy reservoir for diffusive mixing whereas rotation, for example, does not.

We should emphasize that the role of ^3He as a probe of stellar or cosmological nucleosynthesis or of stellar mixing mechanisms will be determined only by further observations.

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Henkel, C., Wilson, T. L., and Bieging, J. H. 1982, Astr. Ap., 109, 344.
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Schatzmann, E. 1984, this volume, p. 491.

DISCUSSION

Bochsler: There is direct evidence for the existence of solar-system-^3He prior to deuterium burning by the sun: Some carbonaceous meteorites contain "planetary" helium with a uniform $^3He/^4He$-ratio of $\sim 1.4 \cdot 10^{-4}$ (cf. Anders et al. 1970, Geochim. Cosmochim. Acta 34, 127; Eberhardt, 1982).

Rood: Yes, this was also noted by Black (1972, Geochim. Cosmochim. Acta 36, 347), who identified three components of ^3He in carbonaceous chondrites: implanted solar wind $^3He/^4He \sim 3.9 \cdot 10^{-4}$, solar flare $\sim 4.1 \cdot 10$ and "primordial" $\sim 1.5 \cdot 10^{-4}$.

Renzini: Let me mention that there are stellar models which destroy ^3He. These are AGB stars experiencing the so-called Envelope-Burning process.

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