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AN UPPER LIMIT ON THE CONCENTRATION OF MOLECULAR HYDROGEN IN INTERSTELLAR SPACE

It has been conjectured for some time that molecular hydrogen might be an important constituent of the interstellar medium; theoretical estimates of Gould and Salpeter (1963) and Gould, Gold, and Salpeter (1963) have placed the ratio of molecular to atomic hydrogen in the range 0.1 to 10. Hence, according to these estimates, molecular hydrogen could form a significant part of the total mass of our Galaxy.

Perhaps the most sensitive method for detecting molecular hydrogen is by its resonance absorption in the Lyman bands ($B^1\Sigma_u^+ \leftarrow X^1\Sigma_g^+$), occurring in the far ultraviolet shortward of about 1108 Å (Spitzer, Dressler, and Upson 1964; Field, Somerville, and Dressler 1966). This Letter reports the results of an attempt to observe the Lyman bands in the absorption spectra of early-type stars using an all reflecting image converter spectrograph flown on an Aerobee rocket on March 16, 1967.

The instrument which was used for this study was of the objective-grating type, with a Schwarzschild optical system and electronographic recording. A front-surface KBr photocathode (Carruthers 1966) was used, which (with the mirror reflectances) provided a sensitivity range of 950–1400 Å, with a maximum over-all detection efficiency of about 15 per cent near 1050 Å. The instrument was directed at eight positions in the sky during the flight by a Space-General Corporation attitude control system, including the stars γ Velorum (O7 + WC7, $m_v = 1.82$) and ζ Puppis (O5f, $m_v = 2.27$). Spectra of these stars extending to about 1030 Å were obtained.

Comparison of these spectra with comparison spectra taken with the same instrument in the laboratory, using an absorption cell and an argon continuum light source (Fig. 1, Pl. L9), indicates that the number of hydrogen molecules in the line of sight to these stars is less than about $10^{19}/\mathrm{cm}^2$. Although the resolution of the stellar spectra is limited to about 2 or 3 Å by rocket motion during the exposures, as compared to better than 1 Å resolution in the laboratory spectra, a concentration of H_2 as high as $10^{19}/\mathrm{cm}^2$ should still have been detectable. Under the low-temperature conditions expected in interstellar space, the lines corresponding to absorption from the two lowest rotational levels (corresponding to the short-wavelength head of each band) are the only ones which would be strong. Strong bands are, however, observed in the stellar spectra in the range 1110–1140 Å; comparison spectra taken with an "empty" absorption cell (containing low-pressure air and water vapor) indicate that these bands were probably produced by water vapor which outgassed from the rocket during the exposure. Less than 10^{17} water molecules/cm^2 are required to produce bands of this strength.

Morton (1967) estimates the number of hydrogen atoms in the line of sight to Orion to be about $1.5 \times 10^{20}/\mathrm{cm}^2$, based on the width of the interstellar Lyman-α absorption line. Our observation of this line in ζ Puppis indicates an amount of atomic hydrogen somewhat less than in the direction of Orion, though not by more than a factor of 2. Hence the concentration of molecular hydrogen in this direction in space appears to be less than 10 per cent of that of atomic hydrogen.

The measurements of atomic hydrogen by Morton (1967) are about a factor of 10 below that indicated by the 21-cm measurements and that used as the basis of the theoretical estimates of Gould, Gold, and Salpeter. Since the recombination of hydrogen on dust grains is a two-body process, a decrease in the concentration of atomic hydrogen by a factor of 10 would result in a corresponding factor of 100 decrease in the concentration of molecular hydrogen, provided that the rate of dissociation of H_2 is unchanged. Alternately, it may be that the dust grains are much less efficient as third bodies in the recombination process than was expected.

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PLATE L9

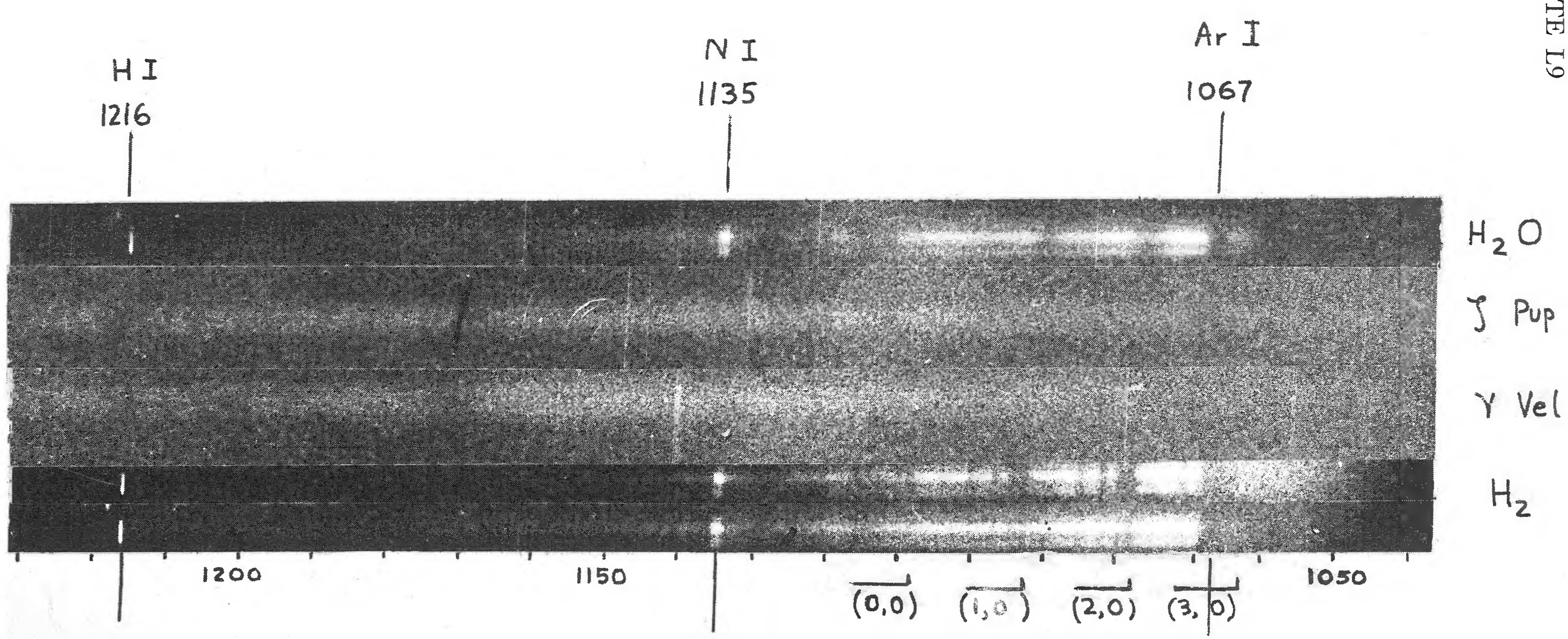

FIG. 1.—Comparison of stellar ultraviolet spectra with laboratory spectra of H_2 and H_2O. The two H_2 spectra were made with 6×10^{19} and 1.2×10^{19} molecules/cm^2, respectively, in the absorption cell.

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G. R. CARRUTHERS

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E. O. HULBURT CENTER FOR SPACE RESEARCH
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

REFERENCES

Carruthers, G. 1966, *Rev. NRL Prog.*, p. 7.
Field, G., Somerville, W., and Dressler, K. 1966, *Ann. Rev. Astr. and Ap.*, **4**, 207.
Gould, R., Gold, T., and Salpeter, E. 1963, *Ap. J.*, **138**, 408.
Gould, R., and Salpeter, E. 1963, *Ap. J.*, **138**, 393.
Morton, D. 1967, *Ap. J.*, **147**, 1017.
Spitzer, L., Dressler, K., and Upson, W. 1964, *Pub. A.S.P.*, **76**, 387.

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