

## **H<sub>2</sub> SPECTROSCOPY IN THE PHOTODISSOCIATION REGION OF M17 NORTHERN BAR**

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**ABSTRACT** We present results of long slit spectroscopy, from 2.0 to 2.5 microns, of the photodissociation region in the northern bar of M17. The observations give us an insight into the physical conditions in the region and provide evidence which suggests that the ortho to para ratio of molecular hydrogen does not equal 3. We briefly discuss the astrophysical relevance of this.

### **INTRODUCTION**

Photodissociation Regions (PDRs) are found at the surfaces ( $A_v \leq 10$ ) of molecular clouds which are irradiated by an ultraviolet (UV) flux. The absorption of a UV photon by a H<sub>2</sub> molecule in the cloud results in infrared emission from rotational-vibrational transitions of the fluorescently decaying molecule. The observations which we present here were taken with the new cooled grating spectrometer, CGS4, on the United Kingdom Infrared Telescope (UKIRT), on the summit of Mauna Kea, Hawaii. The PDR which we have observed is at the interface between the HII region and molecular cloud in the northern bar of M17, some 2.2 kpc away.

### **PHYSICAL CONDITIONS IN THE PDR**

The spectrum which we obtained is shown in Figure 1 and represents the addition of 19 rows ( $\sim 60$  arcsecs of the slit) over which H<sub>2</sub> emission falls. From this spectrum we can measure the diagnostic  $v=1-0$  S(1) to  $v=2-1$  S(1) line intensity ratio. The value of this ratio is  $3.3 \pm 0.2$ , larger than the ratio for purely fluorescent emission ( $\sim 1.8$ ; Black & van Dishoeck 1987). This ratio implies that the gas density is high enough such that collisional interactions are influencing the emission spectrum. This will only occur in gas which is denser than the critical density, the density when deexcitation by collisions equals the spontaneous

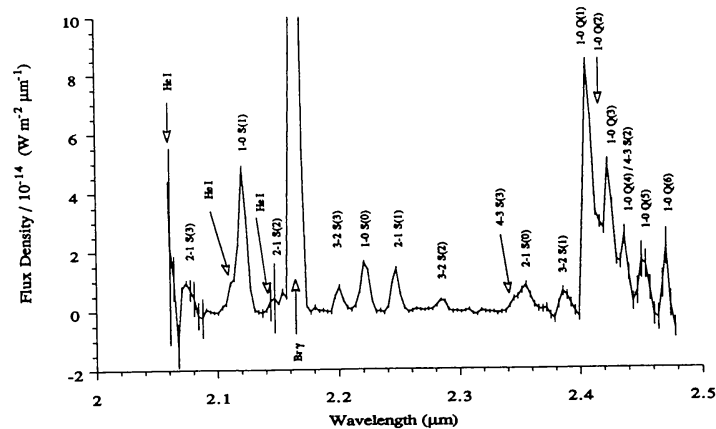


Fig. 1 The K band spectrum obtained using CGS4 on the PDR in the northern bar of M17.

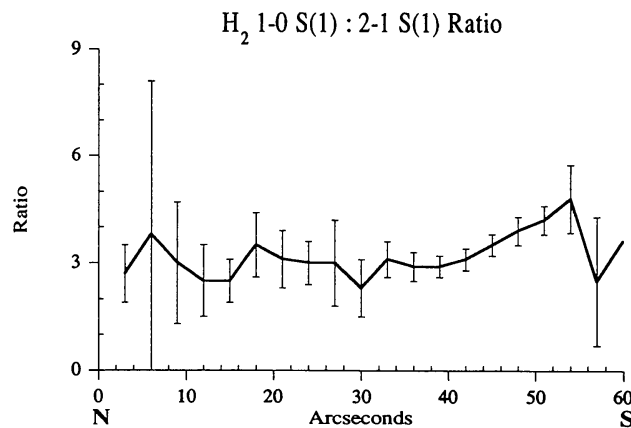


Fig. 2 The diagnostic  $H_2$   $v=1-0$  S(1) to  $v=2-1$  S(1) line ratio over the region where the molecular emission extends.

radiative decay rate. Furthermore, the value of this ratio does not significantly change along the extent of the molecular emission (Figure 2) suggesting that the deexcitation rate, and perhaps the physical conditions, are constant.

We have attempted to gain an insight into the degree of clumping by using a two component PDR model (Burton, Hollenbach & Tielens 1990), one component at high density while the other is at a lower density. Different beam area filling factors are applied to each component to reproduce the observed emission. Six line ratios from the data set were fitted to this model and the results suggest that the gas is clumpy with clump densities and beam area filling factors of  $10^5 \text{ cm}^{-3}$  at 76% and  $10^6 \text{ cm}^{-3}$  at 16%.

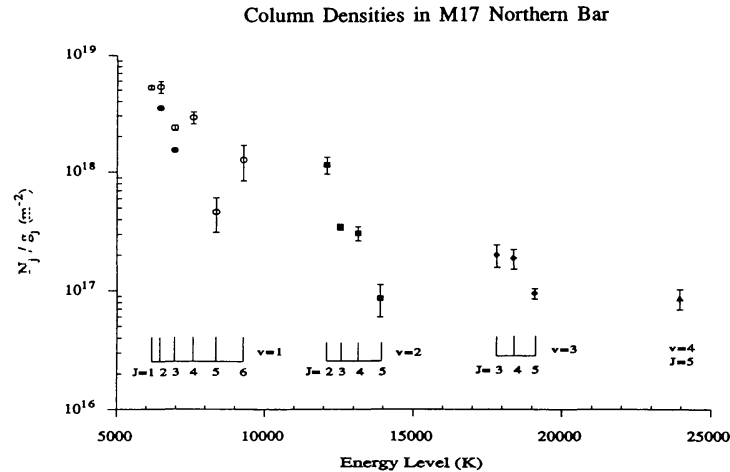


Fig. 3 A plot of column density against energy level for the excited levels of the  $H_2$  molecule. The column densities have been divided by the level degeneracies assuming an ortho to para ratio of 3. The open circle points represents untrustworthy measurements of the column densities for those levels and should be ignored

### THE ORTHO TO PARA RATIO AND ITS IMPORTANCE

Figure 3 shows the column densities in the rotation-vibration levels of  $H_2$  inferred from the data, plotted against the energy of the level above the ground state. The column densities have been divided by the statistical weights of the levels assuming an ortho to para (O/P) ratio of 3. The O/P ratio is first set in the  $H_2$  formation process and can only subsequently be altered via spin exchange collisions with  $H^+$  and  $H$ . It is possible to calculate the O/P ratio of  $H_2$  from the data for the 2nd and 3rd vibrational levels (the 1st vibrational level has an insufficient number of data points which are trustworthy for the calculation - filled circles). In Table 1, the results show that these levels have O/P ratios which are lower than the LTE values of 3. Therefore the O/P ratio *cannot* be equal to 3. Other observations by Tanaka *et al.* (1989) have shown that an O/P ratio of less than 3 is common in PDRs and that for dense PDRs ( $n > n_{crit}$ ) this ratio may differ with vibrational level (see also review by Hasegawa in these proceedings).

Figure 4 shows the column densities after being corrected for the O/P ratios given in Table 1. The ortho and para populations line up as is expected for a  $H_2$  population whose O/P ratio is known and suggests that the O/P ratio is subject to little understood physical interactions (eg. formation, collisions) which make it different from the LTE value of 3.

The O/P ratio becomes crucial when interpreting line ratios in terms of physical conditions. If the O/P ratio is less than 3 and different for different separate vibrational levels, the ratio of two lines can be either over- or underestimated, leading to a misinterpretation of the physical conditions. This makes the O/P ratio an important quantity of the  $H_2$  emission spectrum which needs to be measured if the data is not to be misinterpreted, leading to false

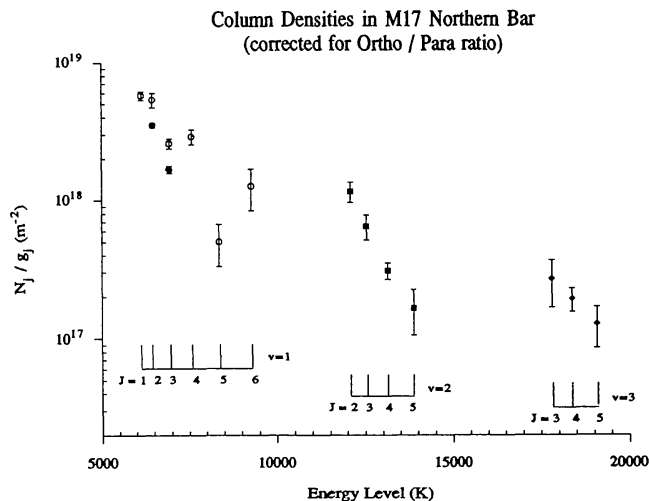


Fig. 4 The same as for Figure 3 but the level degeneracies have been corrected for according to the ortho to para ratios given in Table 1.

conclusions.

TABLE 1 : ORTHO/PARA RATIOS AS FUNCTIONS OF VIBRATIONAL LEVEL

Vibrational Level ( $v$ )	(Ortho : Para) ratio
2	1.63 ( $^{1.94}_{1.40}$ )
3	2.18 ( $^{2.90}_{1.56}$ )

## REFERENCES

- Black J.H., and van Dishoeck E.F. 1987, *ApJ*, **322**, 412  
 Burton M.G., Hollenbach D.J., and Tielens A.G.G.M. 1990, *ApJ*, **365**, 620  
 Tanaka M., *et al.* 1989, *ApJ*, **336**, 207