MOLECULAR HYDROGEN EMISSION IN GALAXIES: THE CASE OF NGC 6240

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The ISO SWS spectrometer has enabled us to detect for the first time the emission lines from the pure rotational transitions of molecular hydrogens (H_2). We have been investigating the physical conditions and the excitation mechanisms of H_2 in bright IR galaxies. Here, we present the preliminary results for NGC 6240, which is probably the most interesting object in our sample because of its largest known H_2 luminosity.

Figure 1(a) shows the H_2 excitation diagram for NGC 6240 constructed from both the ISO data and the ground data. It was possible to combine the two data sets because they detected lines originating from the same upper level. There are two things to note: (1) there is a large amount of cooler ($\leq$ 400 K) H_2, and (2) the v=0 and the v=1 levels are not in LTE.

There are mainly three known processes which can produce such a non-LTE level population: (1) UV pumping in the photon-dissociated-region (PDR), (2) H_2 formation pumping in J-shock, and (3) C-shock. Figure 1(b)–(d) show the first comparison of the three models with the data.

First, the PDR model seems to be ruled out because it overproduces H_2 in the higher vibrational levels. This is a robust feature of the PDR models, and cannot be changed by adjusting the model parameters. On the other hand, the shock models seem to work significantly better. The J-shock model can fit the overall shape because a variety of temperature is possible in the shocked region, depending on the distance from the shock front. Looked at in detail, however, this model also deviates significantly from some data points. The C-shock model can fit the higher vibrational levels very well, but it cannot fit the lower temperature component. This is because a C-shock is more isothermal than a J-shock. However, a two-

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component C-shock model may work. In fact, it is not at all surprising if single-velocity shock models turn out to be too simplistic to fit the data.

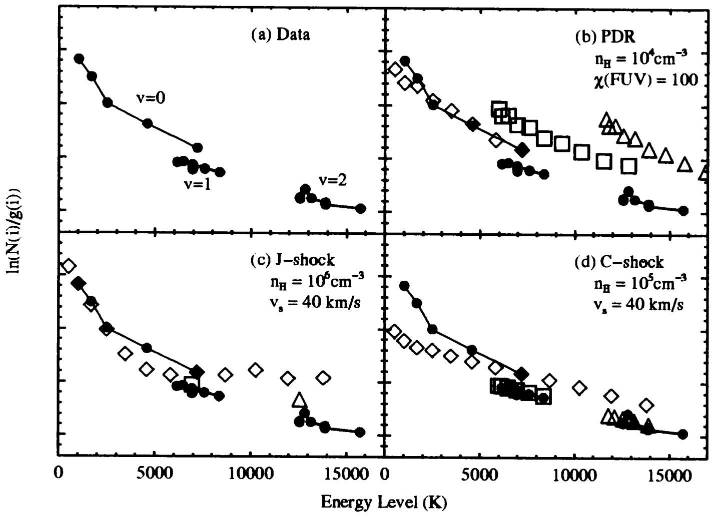

Figure 1. (a) The data are from Egami et al. (1998), Sugai et al. (1997), and van der Werf (1996); (b) a PDR model calculated by the code of Sternberg & Dalgarno (1989); (c) a J-shock model calculated by the code of Hollenbach & McKee (1989); (d) a C-shock model from Kaufman & Neufeld (1996). All the models are normalized at $v = 0, j = 9$. The $\diamond$, $\square$, and $\triangle$ correspond to $v = 0, 1, 2$ levels, respectively.

Our tentative conclusion, therefore, is that H_2 in NGC 6240 is excited by shock, and the shock speed is *slow* ($\sim$ 40 km/s). This is important because the shock is not powerful enough to produce the high-excitation [O IV] 25.9 μm line, which was detected only in NGC 6240 among the ultraluminous IR galaxies observed (Egami et al. 1998). Unless there is an additional strong component of fast ionizing shocks, the [O IV] line must come from an AGN. Also, such a slow shock cannot produce a significant amount of [Ne II] 12.8 μm line, which could have jeopardized our analysis of the underlying stellar population.

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