H_2 LINE EMISSION IN THREE SEYFERT NUCLEI: EVIDENCE AGAINST UV-EXCITATION

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1. Introduction

Line emission from vibrationally excited molecular hydrogen has been detected in a considerable number of active galactic nuclei (AGNs), including those generally believed to contain compact and luminous central engines (e.g., Seyfert nuclei) and those in which the luminosity is believed to arise from massive bursts of star formation (starburst nuclei). In most of these AGNs, only the bright 1-0 S(1) line (rest wavelength 2.12 μm) has been searched for and detected to date.

Line-emitting H_2 can be excited directly either by energetic collisions created by shock waves or by absorption of UV radiation. Each of these excitation mechanisms has been clearly identified in galactic and extragalactic regions. In active galactic nuclei strong sources of UV and (in some case) X-rays are present. If the nuclear molecular matter is quiescent (i.e., isolated from the active nucleus and not set into motion by episodes of star formation) the H_2 line emission will be dominated by fluorescence, or possibly by thermal emission due to heating by X-rays (Krolik, this conference). However, it is expected or indeed observed that a significant fraction of the interstellar medium in and near these nuclei is undergoing rapid motions; either generated by the central engine or by a nuclear starburst, which are capable of producing strong shock phenomena in nearby molecular gas. Thus, a priori it is not obvious which mechanism is responsible for the H_2 line emission from the nucleus of an active galaxy.

2. Observations

The standard way of discriminating between thermal and non-thermal H_2 line emission is by measuring the relative intensities of H_2 lines whose ratios are sensitive to the excitation mechanism. Three lines are commonly chosen for this comparison, the above mentioned 1-0 S(1) line and the 1-0 S(0) and 2-1 S(1) lines, whose intensities are enhanced relative to 1-0 S(1) in the case of fluorescence compared to their intensities in collisionally heated gas.

In March 1989 these three lines were observed at UKIRT in the nuclei of three Seyfert galaxies, NGC 4051, NGC 3227, and Mkn 273, in which different admixtures of star-forming activity are superposed on the activities of central

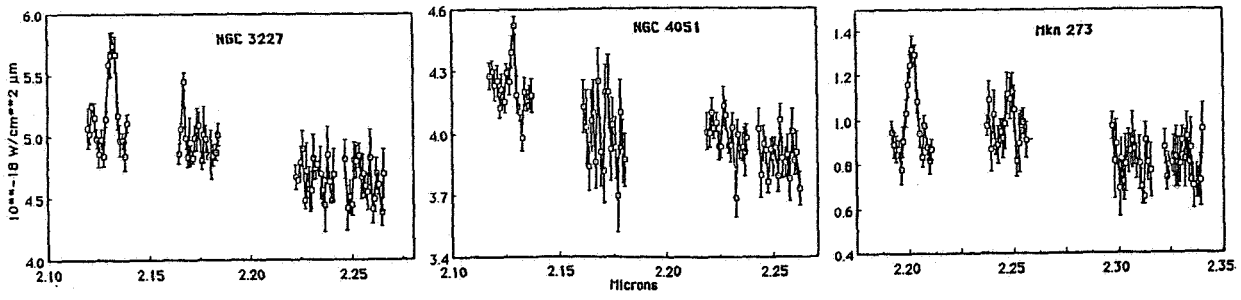

Fig. 1 Spectra of three Seyfert galaxies at the wavelengths of H_2 and H I lines. In wavelength order, the four spectral intervals are centered on H_2 1-0 S(1), H I Br γ, H_2 1-0 S(0) and H_2 2-1 S(1).

engines (Mkn 273 has the most dominant starburst and the highest luminosity in H_2 lines, NGC 4051 the least in both respects). The spectra were obtained using the facility seven-channel cooled grating spectrometer (5" beam), which recently was outfitted with a low noise integrating amplifier. The resolution was 0.0034 μm (~ 450 km/s) and the spectra were sampled every 1/3 resolution element. The H I 7-4 (Br γ) line was observed along with the three H_2 lines.

3. Results

The spectra are shown in Figure 1; line intensities are given in Table 1. In all three cases a prominent 1-0 S(1) line is present, and the 1-0 S(0) and 2-1 S(1) lines are either weak or absent. In shocked gas the relative intensities of these lines are roughly 1.0 : 0.3 : 0.1; when purely fluorescent (no collisional relaxation) the relative values are 1.0 : 0.64 : 0.52. The observed values are consistent only with the former set of values. However, if UV excitation of H_2 occurs in dense ($> 10^5 cm^{-2}$) molecular gas, the relative intensities approximate the former values (Sternberg and Dalgarno 1989). The densities of molecular clouds in Seyfert nuclei are uncertain, and hence on the basis of these H_2 line intensities alone, one cannot determine at present if the excited H_2 in each of these AGN is collisionally or radiatively excited.

The weakness of Br γ relative to 1-0 S(1) in all three AGNs may be a more effective discriminant, however. Fischer et al. (1987) have demonstrated that in Seyfert nuclei producing a power law ultraviolet spectrum a criterion that fluorescence can be a major contributor to the H_2 line emission is [Br γ]/[1-0 S(1)] > 5. This limit is more than an order of magnitude higher than the values reported here. In a starburst the above threshold value depends on the nature and present state of the starburst; a limited theoretical study yields lower limits ranging roughly from 1 to 2.5 (Puxley et al. 1988). Indeed, in the seven starburst galaxies found by Puxley et al. to have fluorescent H_2 line emission, [Br γ]/[1-0 S(1)] ranges from 1 to 4.

Therefore, it may be concluded that the excited H_2 in NGC 3227, NGC 4051, and Mkn 273 is not fluorescent and that it is not in gas that is heated by absorption of UV photons.

Further details of this research will be given by Wilson et al. (1989).

Table 1

Line	Observed Flux (10^{-22} W/cm^2)		
	Mkn 273	NGC 4051	NGC 3227
1-0 S(1)	22.3 +/- 1.5	8.3 +/- 2.0	34 +/- 4
Br gamma	7.6 +/- 2.5	< 4.	< 7
1-0 S(0)	3.3 +/- 2.0	< 3.	< 7
2-1 S(1)	< 2.0	< 3.	< 7

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