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Vibrationally Excited HC_3N in NGC 4418

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Luminous infrared galaxies (LIRGs) emit most of their radiation in the infrared region of the spectrum in the form of dust thermal continuum, with typical luminosities of $L_{\rm IR} > 10^{10}$ $L_\odot$. The central power source responsible for the total energy output is deeply buried in the dusty central regions of these objects and its origin still unclear. Recent studies by Spoon *et al.* (2007) and Aalto *et al.* (2007) suggest that some LIRGs might represent early obscured stages of active galaxies, either AGNs or starbursts, and thus play a fundamental role in galaxy formation and evolution.

NGC 4418 is an almost edge-on Sa-type LIRG with deep mid-infrared silicate absorption features suggesting that the inner region is enshrouded by large masses of warm (85 K) dust (Evans *et al.* (2003)). *This object has one of the highest luminosities of* HC_3N $J = 10$–9 *emission (compared to HCN* $J = 1$–0*) found for an external galaxy and a tentative detection of a vibrational* HC_3N *line was reported by Aalto et al. (2007).*

Here we report the first confirmed extragalactic detections of vibrationally excited HC_3N in the LIRG NGC 4418. The observations were carried out in December 2007 and August 2008 with the IRAM 30m telescope on Pico Veleta, Spain. We detected the HC_3N rotational transitions $J = 10$–9, 16–15, 17–16, 24–23, 25–24, 28-27, 30-29. For the $J = 10$–9, 17–16, 25–24 and 28-27 lines, we also detected rotational transitions of the $v_7 = 1$ vibrationally excited levels. For the $v_6 = 1$ lines we generally have upper limits, the only clear detection being in the $J = 25$–24 band.

When observed lines are plotted on a population diagram, they show three main temperature components. The $v = 0$ rotational levels clearly show two temperature components at 20 K (for $E_u < 100$ K) and 529 K (for larger E_u). The $v_7 = 1$ transitions have an excitation temperature of 80 K that is consistent with the dust temperature of 85 K found by Evans *et al.* (2003) for the inner $0.5''$. This rotational temperature can either be due to the IR radiation field dominating the excitation, or it can reflect the gas kinetic temperature in the case that gas and dust are in thermal equilibrium. The low temperature, 20 K, component, could be coming from more extended gas, further away from the nuclear warm dust. If we compare the populations of different rotational levels with the same J, we can get the vibrational temperature, that describes the excitation of the vibrational modes. This can be done for the $J = 25$–24 band, for which we have both $v_6 = 1$ and $v_7 = 1$ lines. The resulting vibrational temperature is 500 K, comparable to the value fitted to the high-J levels of the $v = 0$ state. The bending modes v_6 and v_7 have both critical densities greater than 10^8 cm^{-3} and are thus most likely radiatively excited. The derived vibrational temperature then reflects the temperature of a radiation field. Assuming that our 500 K component represents the temperature of the IR continuum, the required source size θ for the emitting region can be estimated by the relation $L_{IR} \propto \theta^2 T^4$, that gives $\theta = 0.01''$, that corresponds to a linear diameter of 1.45 pc. This is an upper limit to the size of the emitting region, in the case of it being responsible for all the observed IR flux. Our interpretation of the HC_3N excitation then leads to an extremely compact radiation source in the core of NGC 4418. From the population diagram, the hot component has a column density of 8.3×10^{15} cm^{-2}, that can be assumed to be a lower limit to the total HC_3N column. The HC_3N excitation and abundances seem similar to those found for hot cores in Sgr B2 in the Galactic

Centre (de Vicente *et al.* (2000)). That the hot (500 K) component could be associated with a buried AGN cannot be excluded, but the large HC_3N abundances may prove to be difficult to reconcile with an AGN.

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