FIR SPECTROSCOPY OF THE NUCLEUS AND IR-RING OF THE AGN/STARBURST NGC 4945

S. D. Lord(1), S. J. Unger(2), J. Brauher(1), P. E. Clegg(2), P. Cox(3), J. Fischer(4), M. Greenhouse(5), M. L. Luhman(4), M. A. Malkan(6), S. Satyapal(5), H. A. Smith(7), L. Spinoglio(8), G. J. Stacey(9), M. Wolfire(10)

1 California Institute of Technology, Pasadena, USA
2 Queen Mary and Westfield College, London, UK
3 Institut d'Astrophysicque Spatiale, France
4 Naval Research Laboratory, Washington, USA
5 NASA Goddard, Greenbelt, USA
6 University of California, Los Angeles, USA
7 Smithsonian Astrophysical Observatory, Cambridge, USA
8 Istituto di Fisica dello Spazio Interplanetario-CNR, Frascati, Italy
9 Cornell University, Ithaca, NY, USA
10 University of Maryland, College Park, USA

Abstract

We have a obtained low resolution (R=200) fully sampled far-infrared (FIR) 42-197 um spectra of the southern AGN/starburst SB(s)cd galaxy NGC 4945 with the Long Wavelength Spectrometer (LWS) on the Infrared Space Observatory (ISO). The galaxy was observed at a central, NE, and SW position, each separated by 165" with the instrument's ~ 75" aperture. The forbidden fine-structure transitions of [CII] 158 um and [OI] 63 um lines were detected at each position. Detections of the [OI] 145 um and [OIII] 88 um lines were also obtained at some positions. Using these lines and the total FIR continuum flux, we have modeled the properties of the warm atomic gas with photodissociation region (PDR) models (Tielens and Hollenbach, 1985; Wolfire et al. 1990; Kaufman et al. 1998). The low-J rotational transitions of OH at 53 um and 119 um are seen in absorption at the nuclear position. The total OH column density and the role of these lines in the pumping of the OH radio maser are considered for these two transitions. The NE and SW positions lie on the massive molecular ring. The ring and the nuclear conditions are analyzed by comparing the CII/OI, CII/CO, and (CII+OI)/FIR ratios.

NGC4945 is thought to have a combination AGN and starburst nucleus, and also displays dramatic FIR and CO hot--spots at ~180'' from the nucleus. Our ISO observations show strong [OI] 63 um and [CII] 158 um fine structure emission lines at all three positions. These may be result of the heating of interstellar clouds by massive stars. The nuclear position shows a very low CII line/total FIR-continuum ratio (less than 0.1 %). More typical line/continuum ratios (~0.5) are seen in the hot--spots. All three positions show [OI]/[CII] ratios near unity.

From our observations, gas heating in the nuclear position from a central AGN can not be ruled-out. (Shorter wavelength, higher excitation FIR transitions observed by ISO will be used to help define the role of an AGN here). If the dominant heating nuclear source is from massive star formation, then strong interstellar UV radiation fields, 3 x 10^4 times the typical Milky Way field, are required to produce the line/continuum ratios seen. These are high field strengths even for starburst galaxies. The NE and SW hot-spot positions show rather typical starburst UV fields, 3 x 10^3 times the Milky way value, and somewhat higher atomic gas densities (n ~10^$).

The clouds in these three regions are small, R ~ 1-10pc, have warm neutral gas surfaces, T ~ 200K, and are concentrated with high volume filling factors in the nucleus (0.5) and smaller filling factors in the hot--spots: ~ 10^-4. In the nucleus, either there are several clouds along a line of sight, or the gas is arranged in sheets or filaments.

In the nucleus, five transitions of OH are seen (mostly absorption lines) and these provide a consistant excitation and de-excitation picture for the low--level energy. Also in the nucleus we observe two transitions of ortho-water in absorption: at 101 um and 179 um.