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Influence of the Active Nucleus on the Multiphase Interstellar Medium in NGC 1068

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The luminous spiral NGC 1068 (14.1 Mpc; 1″ ≈ 68 pc) has now been imaged from x-ray to radio wavelengths at comparably high resolution ($\lesssim 5''$ FWHM). The bolometric luminosity of this well-known Seyfert ($\sim 2\times 10^{11} L_\odot$) is shared almost equally between the active nucleus and an extended 'starburst' disk[1]. In an ongoing study, we are investigating the relative importance of the nucleus and the disk in powering the wide range of energetic activity observed throughout the galaxy. Our detailed analysis brings together a wealth of data: ROSAT HRI observations[2], VLA $\lambda\lambda$6–20cm[3] and OVRO interferometry[4], $\lambda\lambda$0.4–10.8μm imaging, and Fabry-Perot (Hα, [NII], [OIII]) spectrophotometry.

In earlier papers[5,6], we have shown that a 'diffuse ionized medium' (DIM) pervades the inner 10 kpc disk of NGC 1068. Throughout this warm phase, the strengths of low ionization lines (N^+, O^+, S^+) with respect to Hα, the line dispersions (150–250 km s^{-1} FWHM) and the inferred scale height (~400 pc) are all considerably enhanced with respect to the adjacent HII region population, while the O^{++} emission is much weakened (see Fig. 1). After removing the influence of HII regions, the [NII] surface brightness profile is well described by an inverse square law. Others have shown

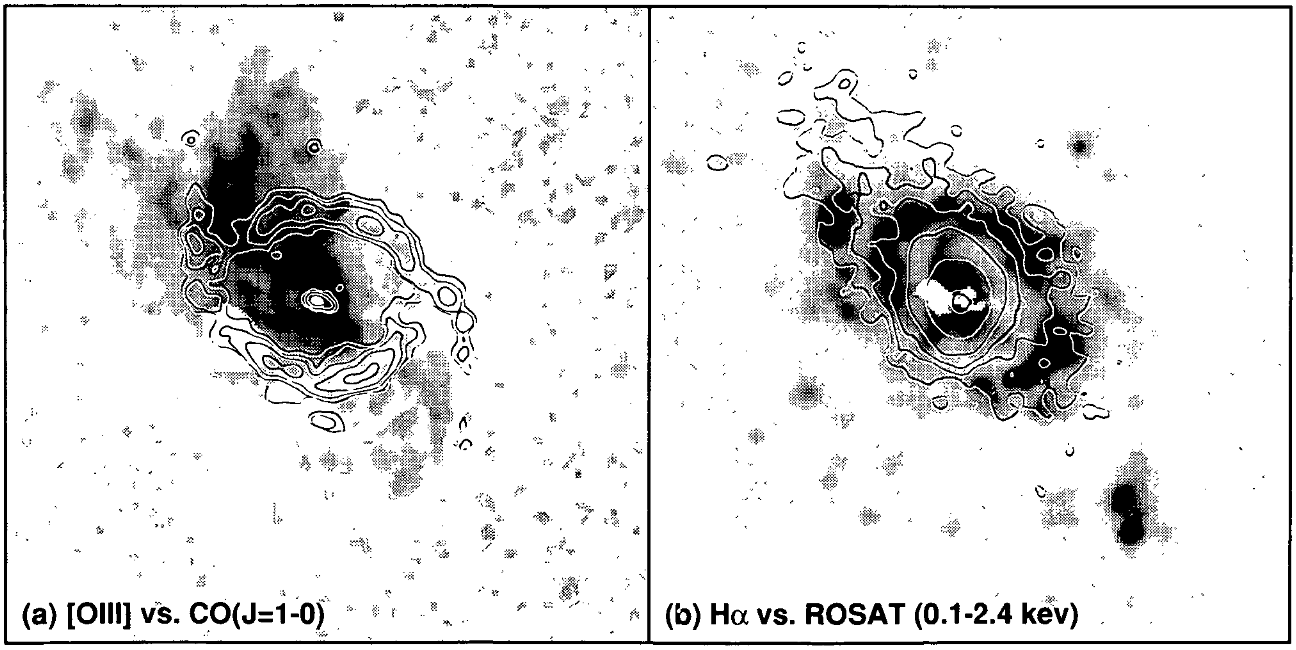

Fig. 1*a*.– Contours of OVRO CO (J=1–0) data (beam ≈ 3″ FWHM) overlaid on new CTIO Fabry-Perot [OIII] observations (≈1″ FWHM). The horizontal E–W axis is 100″ in length. The hole 15″E of center arises from an internal reflection. *b*.– Contours of ROSAT (0.1–2.4 kev) HRI data (≈4.5″ FWHM) overlaid on HIFI Fabry-Perot Hα observations (≈1″ FWHM).

that the brightest O^{++} emission[7,8] and higher ionization species[9] (Ne^{++}, Ne^{4+}, He^{+}, etc.) are confined to a narrow sector aligned with the radio[10]/optical[11] jet axis (PA $\approx 45°$; see Fig. 1*a*).

Two distinct mechanisms have been proposed to explain the DIM phase. While both models suppose that the enhanced line widths reflect turbulent motion in the large-scale ISM, they differ in the source of excitation for the low ionization emission. Sokolowski *et al.*[6] contend that the same electron-scattering medium that gives rise to the observed x-ray spectrum and the polarized broad-line spectrum can produce a dilute, hard ionizing continuum that is sufficiently energetic to power the low ionization emission. Slavin *et al.*[12] have considered the coronal emission arising from the turbulent 'mixing layers' in the multiphase ISM which naturally produces a slew of strong, low ionization lines. Both ideas are highly model dependent: in particular, the former depends on the scattering geometry while the latter requires a high rate of mass injection to provide sufficient enthalpy flux. Halpern[13] has suggested that the extended x-ray disk observed by ROSAT[2] may not be sufficient to balance the implied cooling rate of the DIM ($\sim 10^{42}$ erg s^{-1}).

Under the assumption that the DIM is photoexcited by the active nucleus, the [OIII]/[NII] line ratio and the observed x-ray spectrum can be used to predict the local ionization parameter, U, throughout the disk. The computed map demonstrates that the general disk is characterized by a value of U one or two orders of magnitude smaller ($\sim 10^{-4}$) than along the radio axis, consistent with the very different distributions of high and low ionization species. Figures 1*a*,*b* illustrate that the bipolar anisotropy in the radiation field is oriented so as to illuminate the near side of the ISM to the NE and the far side to the SW, as deduced from the optical jet[11]. In particular, *notice how the [OIII] emission to the SW is evidently blocked by the CO ring.* There is a clear association between the [OIII]/CO distributions and kinematics. This has led us to consider a model in which the hot wind detected by ROSAT (Fig. 1*b*) is irradiating and driving shocks into giant molecular clouds within the disk. Such a model may explain the hot dust[14] and high CO(J=2−1)/CO(J=1−0) excitation temperatures[4] associated with clouds along the radio axis.

In Fig. 1*a*, we find bisymmetric counterparts in the SW to the brightest [OIII] 'plumes' to the NE. The SW filaments are systematically fainter by $A_V \approx 2$–3 mag indicating a column depth of $\sim 5\times10^{21}$ cm^{-2} in the general disk away from the CO ring. In this case, with due attention to the sharp oxygen edge within the ROSAT (0.1−2.4 kev) bandpass, we determine that the optical depth to x-ray absorption is close to A_V. Therefore, we conclude that *the one-sided distributions of both the [OIII] and the x-ray emission arise from intervening absorption by the large-scale disk to the south west.* In contrast to the [OIII] emission, the 10.8μm emission is symmetric about the nucleus. This is consistent with our picture since the molecular clouds are optically thin to mid-infrared radiation since, from the OVRO observations, we determine the cloud column density in the CO ring to be $\approx 1.2\times10^{23}$ cm^{-2} for which $A_V \approx 62$ mag and $A_{10.8\mu m} \sim 0.5$ mag.

1. Telesco, C.M. *et al.* 1984, ApJ, 282, 427.
2. Wilson, A.S. *et al.* 1992, ApJ, 391, L75.
3. Wynn-Williams, C.G., Becklin, E.E., and Scoville, N. 1985, ApJ, 297, 607.
4. Planesas, P., Scoville, N., and Myers, S.T. 1991, ApJ, 369, 364.
5. Bland-Hawthorn, J., Sokolowski, J., and Cecil, G. 1991, ApJ, 375, 78.
6. Sokolowski, J., Bland-Hawthorn, J., and Cecil, G. 1991, ApJ, 375, 583.
7. Balick, B. and Heckman, T.M. 1979, AJ, 90, 197.
8. Pogge, R.W. 1988, ApJ, 328, 519.
9. Bergeron, J., Petitjean, P. and Durret, F. 1989, A&A, 213, 61.
10. Wilson, A.S. and Ulvestad, J. 1983, ApJ, 275, 8.
11. Cecil, G., Bland, J. and Tully, R.B. 1990, ApJ, 355, 70.
12. Slavin, J.D., Shull, M. and Begelman, M.C. 1992, ApJ, submitted.
13. Halpern, J. 1991, In Testing the AGN Paradigm, eds. S. Holt, S. Neff, and M. Urry, p. 524.
14. Telesco, C.M. and Decher, R. 1988, ApJ, 334, 573.