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A BURIED QUASAR IN IRAS 09104+4109

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RESUMEN

Presentamos los resultados de polarimetría de banda ancha, espectropolarimetría y espectrofotometría de la galaxia de líneas angostas, ultraluminosa en el infrarrojo IRAS 09104+4109 ($L = 6 \times 10^{12}\ L_\odot\ h^{-2}$, $z = 0.442$). Concluimos que esta galaxia cD esconde un cuasar luminoso que da energía a la emisión infrarroja (posibilidad sugerida por primera vez por Kleinmann et al. 1988) — un agujero en el polvo permite a la luz del cuasar escapar ionizando la región extensa de líneas angostas. Parte de la luz emergente del cuasar se observa como contínuo ultravioleta altamente polarizado (dispersado), y como una línea de emisión ancha de MgII.

ABSTRACT

We present the results of broad band polarimetry, spectropolarimetry, and spectrophotometry of the narrow-line, IR-Ultraluminous galaxy IRAS 09104+4109 ($L = 6 \times 10^{12}\ L_\odot\ h^{-2}$, $z = 0.442$). We conclude that this cD galaxy hides a luminous quasar that powers the infrared emission (a possibility first suggested by Kleinmann et al. 1988) — a hole in the dust allows the quasar light to escape, ionizing the extended narrow line region. Some of the emerging quasar light is seen as highly-polarized (scattered) ultraviolet continuum and a broad MgII emission line.

Key words: **GALAXIES: ACTIVE — GALAXIES: NUCLEI — POLARIZATION — QUASARS: INDIVIDUAL (IRAS 09104+4109)**

1. INTRODUCTION

IRAS 09104+4109 is the second most luminous AGN so far discovered by IRAS, with $L = 6 \times 10^{12} L_\odot h^{-2}$ ($z = 0.442$) between 0.3μm and 70μm, of which 99% is emitted at wavelengths longer than 1μm (Kleinmann et al. 1988, hereafter K88). It is also the most luminous known radio-loud IRAS AGN, and has a double-lobed radio structure (Hines & Wills 1993). IRAS 09104+4109 has a rich narrow emission line spectrum, and the ratio [OIII] λ5007/Hβ = 24 associated with the extended [OIII] $\lambda\lambda$4959,5007 emission (K88) implies photoionization by a strong ultraviolet (UV) continuum. However, K88 found no broad emission lines, even for Hα. They suggested that the strong infrared emission is reprocessed radiation from a hidden QSO-like broad line region and strong featureless UV continuum.

2. OBSERVATIONS

We have obtained broad band polarimetry using the Breger photopolarimeter (Breger 1979) on the 2.1m Struve telescope, and spectrophotometry and spectropolarimetry using the Large Cassegrain Spectrograph/polarimeter (Goodrich 1992) on the 2.7m telescope at McDonald Observatory. Instrumental polarization, absolute position angle, and flux calibration were obtained from observations of null, polarized, and flux standards respectively.

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We find high, non-time-variable and wavelength-dependent polarization increasing from 4% at 7900Å to 21% at 3600Å (Fig. 1). We also find broad MgII emission (FWHM = 10,000 ±1000 km s^{-1}) with quasar-like equivalent width ~ 38Å in our blue total flux spectrum (Figs. 2 & 3), and unpolarized narrow emission lines in our redder spectropolarimetry data (Fig. 3).

3. DISCUSSION

Since the optical continuum is dominated by starlight, we have used a typical E/S0 spectrum, matched to the observed 4000Å break in IRAS 09104+4109, to remove the stellar contribution. After correction for both the unpolarized emission lines and starlight, the broad band polarization is nearly wavelength independent (p~ 18%) — the residual featureless continuum is a power law $F_\nu \propto \nu^{-0.6}$, typical of the featureless continuum in quasars with little or no reddening. This, and the presence of broad MgII emission, suggests that we are seeing a buried quasar in scattered (polarized) light.

Since the polarization position angle is perpendicular to the extended [OIII] emission, we suggest that the scattering material is within this "ionization cone." We relate the polarization to the extended [OIII] region in IRAS 09104+4109 by a model in which a broad line region and UV continuum source are obscured from direct view by dust. A hole in the dust allows the UV continuum emission to escape and photoionize a cone of gas. The polarization is produced in a uniformly filled optically thin scattering cone (associated with, but not necessarily identical to, the ionization cone), with half-opening angle $0 \lesssim \theta_c \lesssim 39°$ inclined $i \sim 35°$ to the line-of-sight, and illuminated by the UV continuum and the broad line region (assumed a point source) at its apex. Our model predicts that the broad MgII emission line will be found to be highly polarized (~ 18%).

The rest-frame equivalent width of [OIII] λ5007 (1950Å) of the galaxy-subtracted spectrum is ~ 20 times that of the largest observed values for typical luminous quasars. This suggests that the nucleus would be quite luminous in the visual if viewed from the direction of the extended [OIII] emission region, $M_v < -24.7$.

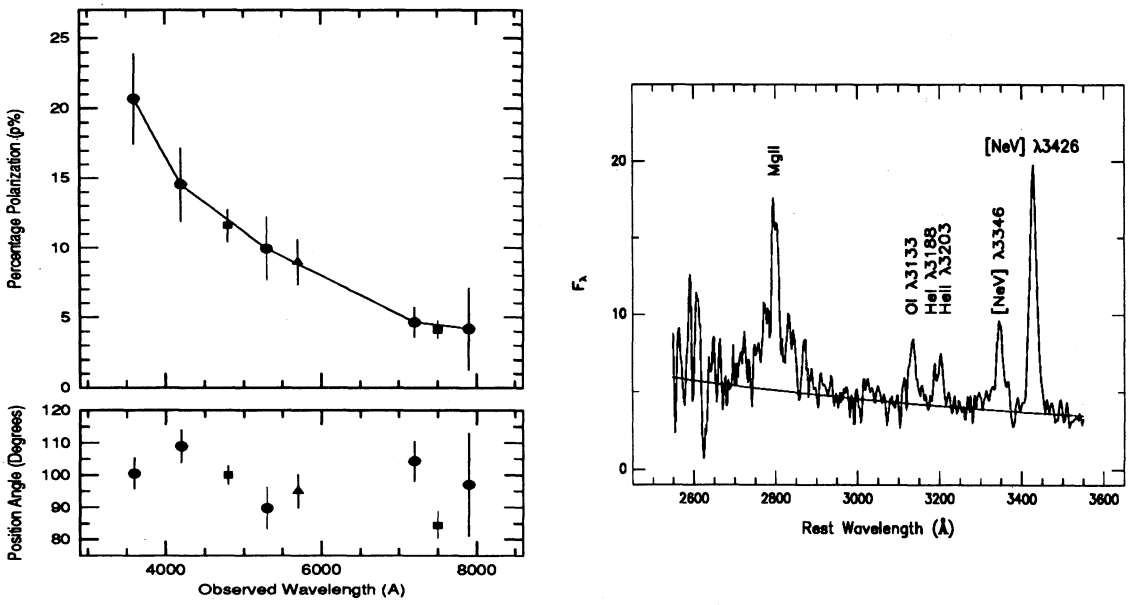

Figure 1 — Left: Observed broad band, optical linear polarization: circles represent measurements made with the *UBVRI* filters, the triangle represents the "open" filter observations, and the squares represent the obeservations made with the $CuSO_4$ and RG630 filters. The observed polarizations have been bias-corrected using the prescription of Wardle & Kronberg (1974). Error bars are 1σ (pure photon-counting statistics). The position angle errors are 1σ errors except for the *I*-band, which are not well-defined because of the low significance of the measurement. These errors do not include the $\pm 2°$ absolute position angle calibration error. Right: Observed total flux spectrum showing the broad MgII emission line. The flux densities are in arbitrary units. A fitted power law continuum is shown.

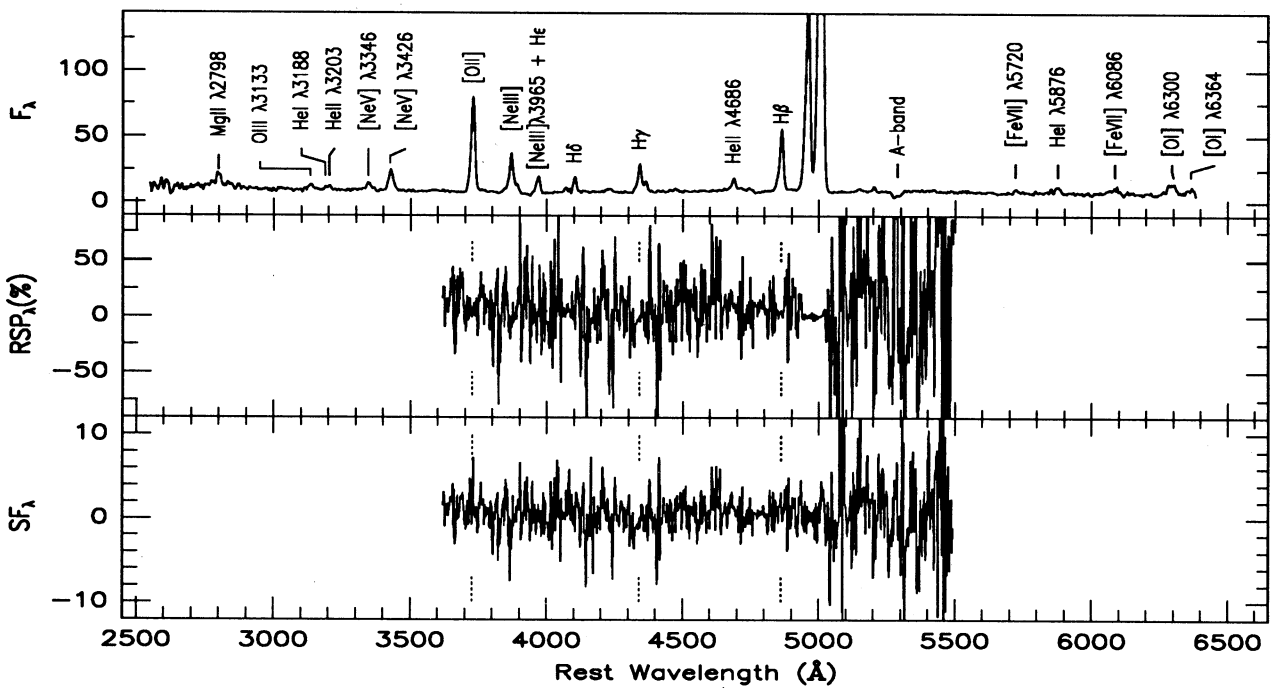

Figure 2 — Top: The total flux spectrum combining our data with the redder data from K88. Middle: The rotated Stokes parameter (%). Bottom: The Stokes flux. The observed total and Stokes flux densities have units 10^{-17} erg s^{-1} cm^{-2} A^{-1}.

4. SUMMARY

IRAS 09104+4109 represents a radio-loud Type II quasar — an object with QSO-like luminosity, but dominated by narrow optical emission lines. In a manner analogous to the simple unified schemes for Seyfert galaxies (e.g., Antonucci & Miller, 1985; Antonucci 1993), if IRAS 09104+4109 were viewed from a direction less obscured by dust (i.e., as viewed from the location of the extended [OIII] and scatterers), it would be classified as a luminous quasar (Type I AGN).

Our observed polarization wavelength dependence for IRAS 09104+4109 represents quite well the increase in polarization with increasing redshift noted for radio galaxies by Tadhunter et al. (1992), assuming that this is a result of observing shorter rest wavelengths at higher redshifts. This suggests that the scattering geometry deduced for IRAS 09104+4109 may apply to many other radio galaxies, and that the UV spectrum of low redshift radio galaxies may be highly polarized. This possible similarity in polarization properties supports suggestions that other narrow line radio galaxies contain buried quasars (e.g., Antonucci, 1993 and references therein).

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