THE LARGE-SCALE ACTIVITY IN NGC 1068

J. Bland[1] and G. N. Cecil[2]
[1]Institute for Astronomy, Hawaii
[2]Institute for Advanced Study, Princeton

While NGC 1068 has received much attention in recent years, little is known of the large-scale dynamics and physical state of the ionized gas in this nearby Seyfert galaxy and, in particular, its connection with the nuclear activity. We have used the Hawaii Imaging Fabry-Perot Interferometer (HIFI) at the CFHT to obtain detailed spectrophotometry at 65 kms^{-1} resolution (FWHM) over the $H\alpha$ and neighbouring $[NII]$ lines. The final maps are derived from 100 000 fits to spectra taken at 0.4″ increments over a 200″ field-of-view. (A higher resolution study which concentrates on the circumnuclear, optical emission and its relation to the radio jet is presented at this conference by Cecil & Bland.)

Deep images of NGC 1068 reveal an outer θ−shaped ring with inclination, $i \simeq 20° - 40°$, and position angle, $\alpha \simeq 75° - 90°$, and a bright central disk with diameter $\sim$ 20 kpc (230″) oriented perpendicular to the outer ring. The $H\alpha$ flux map clearly shows the luminous starburst ring ($1.5 \times 10^{11} L_\odot$) with diameter $\sim$ 3 kpc and major axis $\sim$ 45°. This same region is marked by high concentrations of molecular gas and an oval bar aligned with the starburst torus. The $[NII]\lambda6583$ emission map shows a spoke-like pattern of filamentation which covers the central disk. The darkest areas in the $[NII]/H\alpha$ map shown in Figure 1(a) correspond to bright HII regions. These are characterized by narrow lines (FWHM $<$ 100 kms^{-1}) and $[NII]/H\alpha \leq 0.5$. The lighter areas in the map arise from a "warm", diffuse substratum which pervades the central disk. This component is distinguished by broader lines (FWHM $\simeq$ 350 kms^{-1}) and $[NII]/H\alpha \simeq 1 - 2$.

Figure 1(b) reveals, for the first time, a series of concentric "spiral waves" which appear superimposed on an ordered, large-scale velocity field. The latter is well described by a rotating disk which undergoes flat rotation with $V(R_{max} = 20'') = 170/\sin i \; kms^{-1}$. The disk orientation is consistent with the outer ring such that $i = 37°$ and $\alpha = 80°$. Once we subtract the model from Figure 1(b), the kinematic waves become very pronounced with residual motions $\simeq 60/\sin i \; kms^{-1}$. The north-western feature, also evident in the $H\alpha$ flux map, exhibits continuity in velocity as it crosses the starburst torus to the north. The outer ring suggests that the bar is strong enough to influence the large-scale dynamics of the galactic disk. Thus it may be possible to explain the sites of star formation and discrete HII regions in terms of density waves driven into the ISM by the rotating stellar bar (Combes & Gerin 1985). However, the large residual velocities are inconsistent with the predicted streaming motions in a classical 2-phase ISM.

We have used models developed by Dopita to show that the overall distribution of $[NII]/H\alpha \simeq 1 - 2$ can be understood in terms of a dilute field of ionizing

D. E. Osterbrock and J. S. Miller (eds.), Active Galactic Nuclei, 343–344.

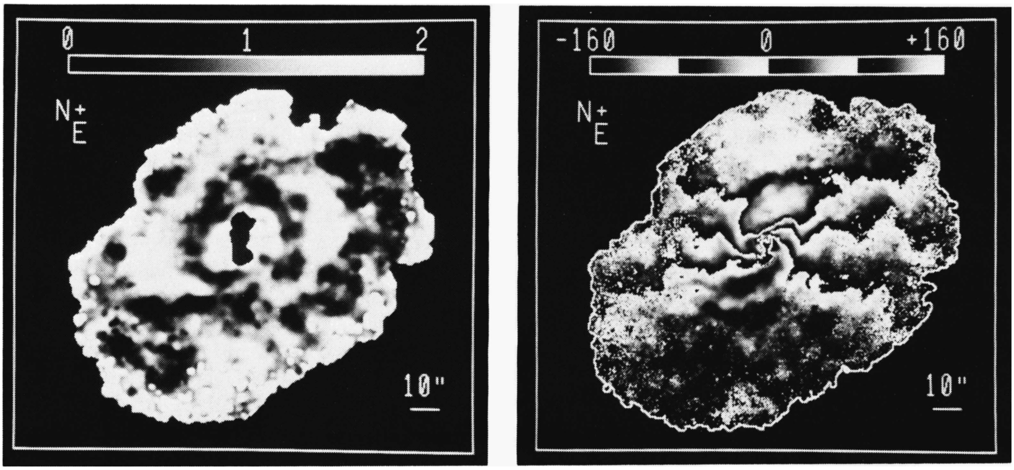

Fig. 1. (a) $[NII]/H\alpha$ ratio map. *(b)* $H\alpha + [NII]$ velocity map (west receding).

photons from a $T_{\star} \sim 56\,000\ K$ thermal source, presumably the starburst torus. The flat distribution of line ratios suggests a fairly constant ionization parameter (ϕ/n) across the disk. McKee & Ostriker (1977) conjectured that the ISM in the Galaxy has three distinct phases which are in approximate pressure equilibrium. Wang & Cowie (priv. comm.) find that a prolonged starburst phase may lead to a breakdown in the mass or energy balance of the multi-phase medium, leading ultimately to turbulence in the ISM. Consequently, the observed line broadening may suggest that the warm component is supported by turbulence rather than thermal pressure.

At diametric locations along the jet axis, we find $[NII]/H\alpha \geq 2$, where the north-eastern anomaly is coincident with the $[OIII]$ "plume" (Balick & Heckman 1985). The lack of an extended radio continuum beyond the inner starburst argues against an $[NII]$ enhancement induced by Coulomb interactions with a nuclear beam of relativistic electrons (Ferland & Mushotzsky 1984). As the HII regions over the inner disk have roughly solar abundance (Evans & Dopita 1987), a possible explanation is that these regions see a somewhat harder source of ionizing photons, e.g., a dilute power-law continuum with $\phi \propto \nu^{-3/2}$, which would explain the presence of $[NeV]\lambda3426$ and $HeII\lambda4686$ (Evans & Dopita 1986). That these anomalous regions are roughly confined to the radio axis suggests that a nuclear, non-thermal source is loosely collimated in the direction of the radio jet. This supports earlier observations of $[OIII]/H\beta$ which indicate preferential ionization from the nucleus along the radio axis (Baldwin, Wilson & Whittle 1987).

Baldwin, J. A., Wilson, A. S., and Whittle, M. 1987. *Ap. J.* , **319**, 84.
Balick, B. and Heckman, T. M. 1985. *Astron. J.* , **90**, 197.
Combes, F. and Gerin M. 1985. *Astron. Astr.* , **150**, 327.
Evans, I. N. and Dopita, M. A. 1986. *Ap. J. Lett.*, **310**, L15.
Evans, I. N. and Dopita, M. A. 1987. *Ap. J.* , **319**, 662.
Ferland, G. J. and Mushotzsky, R. F. 1984. *Ap. J.* , **286**, 42.
McKee, C. F. and Ostriker, J. P. 1977. *Ap. J.* , **218**, 148.