A Multiwavelength Study of the OH Megamaser Galaxy IRAS16399-0937

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Abstract - We present a multiwavelength study of the morphology and spectral energy distribution (SED) of the OH Megamaser galaxy (OHMG) IRAS16399-0937, based on new HST ACS broad band (F814W) and emission line (Hα+[NII]) images and archive data from HST, 2MASS, Spitzer, Herschel and the VLA (Fig. 1). This system has a double nucleus, whose northern (IRAS16399N) and southern (IRAS16399S) components have a projected separation of ~ 6″ (3.4 kpc) and have previously been optically identified as a Low Ionization Nuclear Emission Line Region (LINER) and Starburst (SB) nucleus, respectively. The nuclei are embedded in a tidally distorted common envelope, in which star formation activity is widespread, but mostly heavily obscured (Fig. 1). The infrared spectrum is dominated by strong polycyclic aromatic hydrocarbon (PAH) features, but deep silicate absorption and absorption features due to water ice and hydrogenated amorphous carbon grains are also present, and are strongest in the IRAS16399N nucleus (Figs 2 and 3). The radio emission, including the compact component associated with IRAS16399N, is generally consistent with star formation. The global star formation rate (SFR) is ~ 20$M_\odot$/yr, with the two nuclei accounting for ≈ 40% of the total (Table 2). The 0.435 - 500μm SED was fitted with a model including stellar, dusty+PAH ISM and AGN torus components using our new Markov Chain Monte Carlo code, *clumpyDREAM* (Fig. 4). The results indicate that the IRAS16399N nucleus contains an AGN of bolometric luminosity (L_{bol} ~ 10^{44} ergs/s), which is deeply embedded in a quasi-spherical distribution of optically thick clumps with a covering fraction ≈ 1 (Table 1). We suggest that these clumps are the source of the OH megamaser emission in IRAS16399-0937. The high torus covering fraction precludes AGN photoionization as the origin of the LINER spectrum, however, the spectrum is consistent with shocks of velocity ~ 100 − 200 km/s. The SED fits indicate SFRs of ~ 2.9 and 2.4 $M_\odot$/yr for IRAS16399N and IRAS16399S, respectively, roughly consistent with the rates derived from the observed 8μm PAH and 1.49 GHz radio luminosities (Table 1 and 2). The low accretion rate and modest nuclear star formation rates suggest that while the gas-rich major merger forming the IRAS16399-0937 system has triggered widespread star formation, the massive gas inflows expected from merger simulations have not yet fully developed.

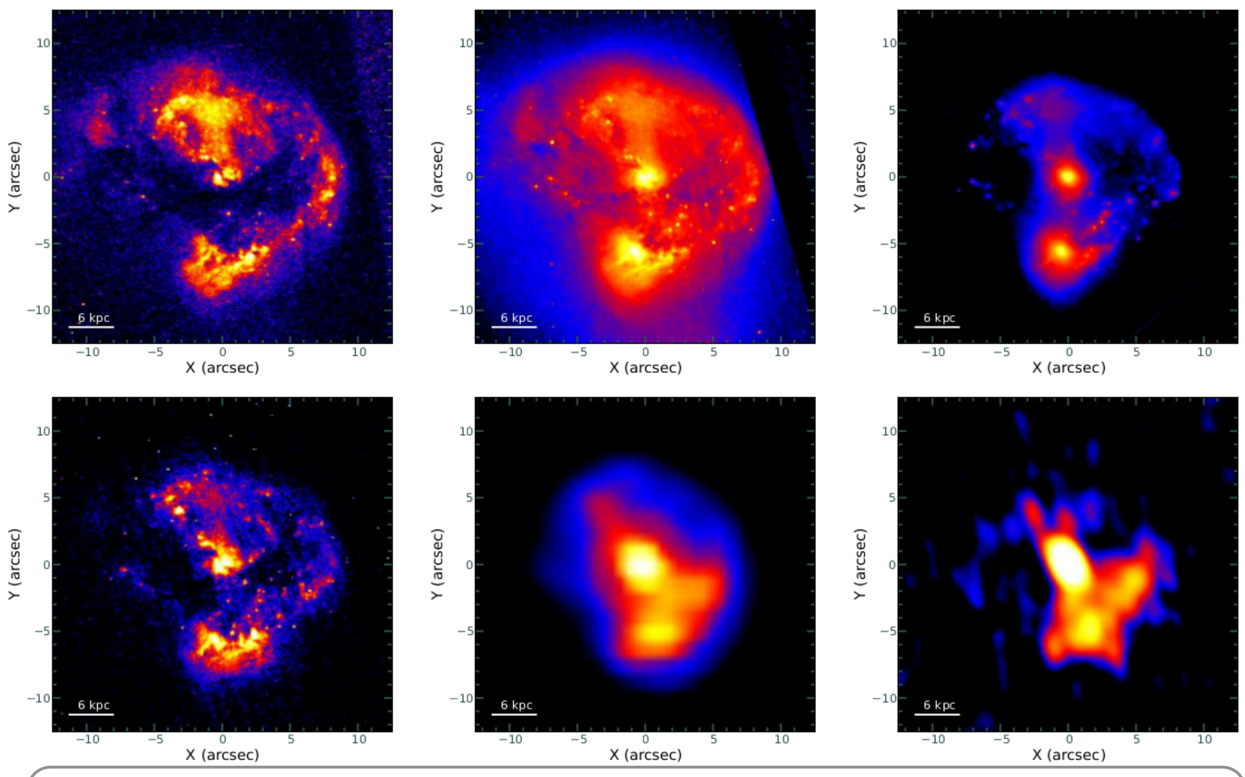
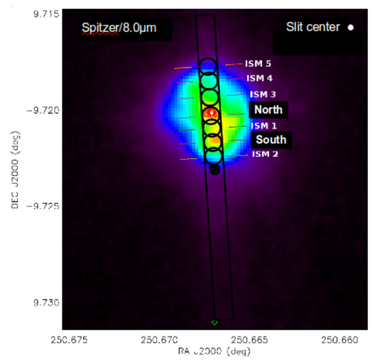


Fig. 1 - Multiwavelength images of IRAS16399-0937. Top panels, from the left to the right: HST images obtained with ACS F435W (left), ACS F814W (middle), NICMOS F160W (1.6μm, right). Bottom panels: Continuum-subtracted Hα+[NII], from HST ACS (left), ISM PAH-dust 8.0 μm emission, from Spitzer IRAC (middle), VLA 1.49 GHz (right). North is up and East is to the left.

Mid-IR Spectroscopy

Fig. 2 - Spitzer IRAC 8μm image showing the apertures used to extract IRS SL module spectra. The slit position is indicated by solid parallel lines. The apertures are circular, each having a radius of 2.0″ . Two apertures are centered on the IRAS16399N (LINER) and IRAS16399S (SB) nuclei, respectively, the other 5 (ISM 1, 2, 3, 4, and 5) sample the extended envelope. The corresponding spectra are shown in Fig. 3.



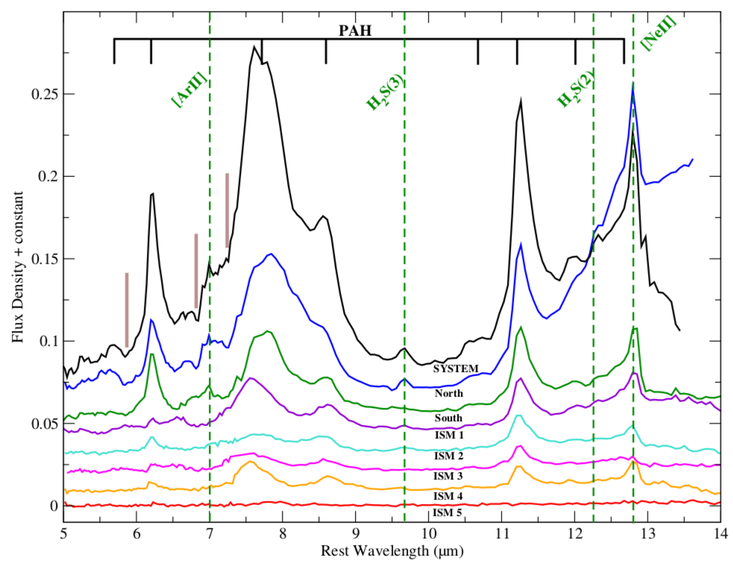


Fig. 3 - Low-resolution (SL module) Spitzer spectra of IRAS16399-0937. The integrated spectrum of the system (labeled system), extracted from an aperture of radius 7″ is shown, along with spectra extracted from the apertures shown in Fig. 2 centered on the IRAS16399N and IRAS16399S nuclei, as well as several locations in the extended envelope (ISM 1–5). The PAH bands and emission lines are labeled. The vertical brown solid lines show the positions of the water ice (~ 6.0μm) and HAC (~ 6.85μm and 7.25μm) absorption bands.

SED decomposition using *clumpyDREAM*

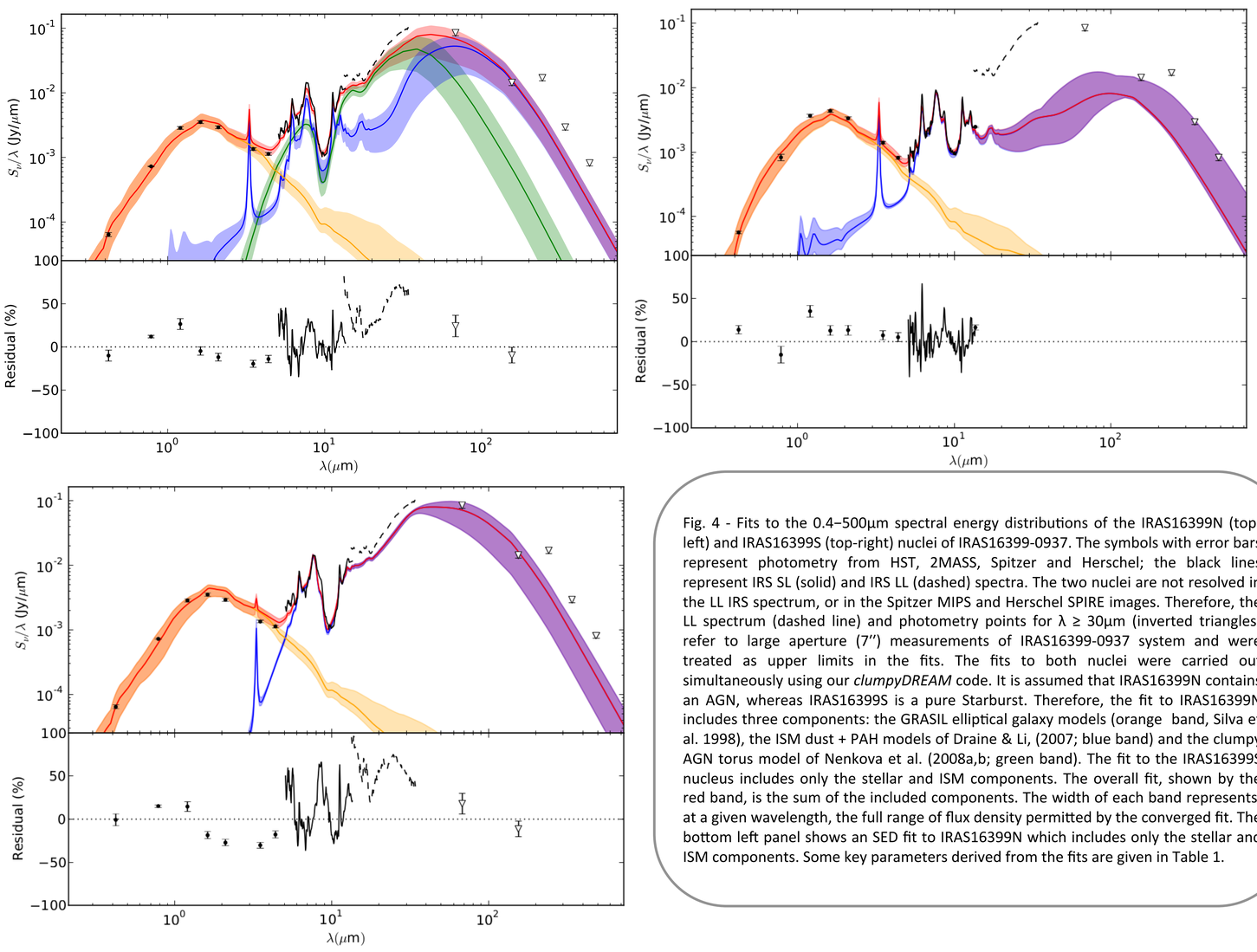


Fig. 4 - Fits to the 0.4–500μm spectral energy distributions of the IRAS16399N (top-left) and IRAS16399S (top-right) nuclei of IRAS16399-0937. The symbols with error bars represent photometry from HST, 2MASS, Spitzer and Herschel; the black lines represent IRS SL (solid) and IRS LL (dashed) spectra. The two nuclei are not resolved in the LL IRS spectrum, or in the Spitzer MIPS and Herschel SPIRE images. Therefore, the LL spectrum (dashed line) and photometry points for λ ≥ 30μm (inverted triangles) refer to large aperture (7″) measurements of IRAS16399-0937 system and were treated as upper limits in the fits. The fits to both nuclei were carried out simultaneously using our *clumpyDREAM* code. It is assumed that IRAS16399N contains an AGN, whereas IRAS16399S is a pure Starburst. Therefore, the fit to IRAS16399N includes three components: the GRASIL elliptical galaxy models (orange band, Silva et al. 1998), the ISM dust + PAH models of Draine & Li, (2007; blue band) and the clumpy AGN torus model of Nenkova et al. (2008a,b; green band). The fit to the IRAS16399S nucleus includes only the stellar and ISM components. The overall fit, shown by the red band, is the sum of the included components. The width of each band represents, at a given wavelength, the full range of flux density permitted by the converged fit. The bottom left panel shows an SED fit to IRAS16399N which includes only the stellar and ISM components. Some key parameters derived from the fits are given in Table 1.

Table 1 - Parameters derived from SED fits assuming AGN and Starburst nuclei (left) and dual Starburst nuclei (right)

	North	South
Clumpy	**AGN**	**Torus**
σ	69°	-
i	76°	-
Cfrac	99.9%	-
	ISM	
q_{PAH}	1.4	4.0
	Lum/SFR	
L_{AGN} (erg/s)	$3.4x10^{44}$	-
L_{ISM} (erg/s)	$2.9x10^{44}$	$8.9x10^{43}$
SFR_{FIR} ($M_\odot$/yr)	11.6	3.6

	North	South
	ISM	
q_{PAH}	0.5	4.3
	amplitude	
L_{ISM} (erg/s)	$5.1x10^{44}$	$8.2x10^{43}$
SFR_{FIR} ($M_\odot$/yr)	20.3	3.3

Table 2 – Observed SFRs in IRAS16399-0937

	North	South	System
$SFR_{0.5-2\ keV}$ ($M_\odot$/yr)	10.3±3.7	2.5±1.6	47.1±9.0
$SFR_{8\mu m}$ ($M_\odot$/yr)	4.2±0.6	3.0±0.4	19.4±2.9
$SFR_{24\mu m}$ ($M_\odot$/yr)			123.2±3.2
$SFR_{1.4GHz}$ ($M_\odot$/yr)	6.0±0.7	2.7±0.2	13.7±1.5