Physical properties of the nuclear region in Seyfert galaxies derived from EVN observations

Marcello Giroletti (1), Francesca Panessa (2), Monica Orienti (1, 3), Akihiro Doi (4)
(1) INAF Istituto di Radioastronomia (2) INAF IAPS, Rome (3) University of Bologna (4) ISAS/JAXA

Background

We are studying a sample of 28 local Seyfert galaxies to understand the physical properties of their nuclear regions.
X-ray observations reveal nuclear activity at low luminosity levels in most of them (Cappi et al. 2006), but what about the radio emission? Ho&Ulvestad (2001) revealed flux density at the milliJansky level in ~80% of them, using the VLA at 1.4 and 5 GHz. Various authors exploited the high resolution of VLBI to clarify the nature of the cores of the brightest sources. Possible interpretations include thermal free–free emission from an X-ray heated corona or two-sided jet-like structures with low speeds, indicating non-relativistic jet motion, possibly due to thermal plasma as in NGC 4151.

EVN enters the game

For the faintest sources in the sample, the extraordinary sensitivity of the European VLBI Network is a key resource. We reported in Giroletti & Panessa (2009) the results of dual-frequency EVN observations for 5 objects, resulting in clear detections for 4 of them, at least at one frequency.

New EVN observations

Motivated by the success of the previous experiment, we observed eight more targets with the same setup, including also the Arecibo radio telescope for sources with suitable declination. We clearly revealed three sources at two frequencies, plus one source at 5 GHz only. Low significance components are found also in other sources but it is hard to claim real detections in these cases.

Table 2. Summary for non-detected sources. We report the peak position in columns 6 and 7 only for components that are most significant (all at 5 GHz); however, given the large searched area, it is well possible that these excesses are simple statistical fluctuations and we do not consider them to be real detections.

Source	Phase tracking position (h m s)	(° ′ ″)	1.7 GHz 3σ rms (μJy beam^{-1})	5 GHz 3σ rms (μJy beam^{-1})	Peak position (h m s)	(° ′ ″)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
NGC 3185	10 17 38.660	21 41 17.400	20	27	–	–
NGC 3941	11 52 55.363	36 59 10.890	114	88	11 52 55.347	36 59 11.908
NGC 4639	12 42 52.363	13 15 26.750	30	50	12 42 52.381	13 15 26.604
NGC 4698	12 48 22.919	08 29 14.550	160	95	12 48 22.938	08 29 14.623
NGC 5194	13 29 52.804	47 11 40.065	75	160	–	–

Table 3. Summary for detected sources. We report the astrometric position for the main component in columns 2 and 3, the total flux density of the source in EVN data in columns 4 and 5, and the core flux density in VLA data from Ho & Ulvestad (2001) in columns 6 and 7.

Name	RA (h m s)	Dec. (° ′ ″)	$S_{1.7\,GHz,\,EVN}$ (mJy)	$S_{5\,GHz,\,EVN}$ (mJy)	$S_{1.4\,GHz,\,VLA}$ (mJy)	$S_{5\,GHz,\,VLA}$ (mJy)
NGC 3227	10 23 30.573	19 51 54.274	9.0	1.12	78.2	25.9
NGC 3982	11 56 28.165	55 07 30.917	3.2	1.3	3.56	1.79
NGC 4138	12 09 29.802	43 41 06.875	1.3	0.74	0.45	0.78
NGC 4477	12 30 02.203	13 38 12.856	–	0.14	–	0.18

NGC 3227

This Sy1.5 core shows a compact (1.2 mas), flat spectrum (α~0.6) component, with brightness temperature ~$10^{7.5}$ K, so presumably of non thermal nature. At about 12 pc in PA 170 and 9 pc in PA -45, we find two more extended, steep spectrum regions. This VLBI structure connects nicely to the larger scale emission observed in literature MERLIN images (Mundell et al. 1995).

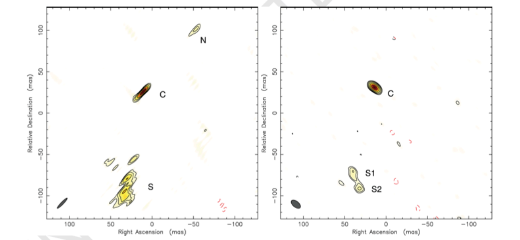

Figure 1. Images of NGC 3227 at 1.7 GHz (left) and 5 GHz (right). The contours are traced at (−1, 1, 2, 4, . . .) × the ~3σ noise level, which is 0.13 and 0.08 mJy beam^{-1} at 1.7 and 5 GHz, respectively. The half-peak beam widths (HPBW) are shown in the lower-left corner, and their size is 2.9 × 17.3 mas in PA −44° and 7.2 × 13.5 mas in PA 50° at 1.7 and 5 GHz, respectively.

NGC 3982

The nuclear region of this Sy1.9 is resolved in two components, one with more compact structure (0.9 mas) and flatter spectrum (α~0.4); the T_B is ~$10^{8.5}$ K, suggestive of non thermal emission. The other component is 8.5 pc away and it is more resolved and with steeper spectrum

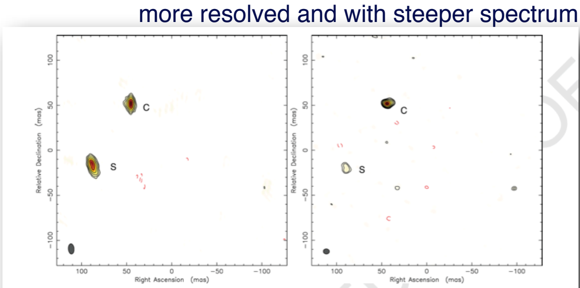

Figure 2. NGC 3982 at 1.7 GHz (left) and 5 GHz (right). The contours are traced at (−1, 1, 2, 4, . . .) × the ~3σ noise level, which is 0.20 and 0.09 mJy beam^{-1} at 1.7 and 5 GHz, respectively. HPBW are shown in the lower-left corner, and their size is 6.4 × 11.4 mas in PA 4° and 5.7 × 6.8 mas in PA 85° at 1.7 and 5 GHz, respectively.

NGC 4138

NGC4138 is Sy1.9 galaxy. Our EVN observations reveal a main component, detected at the two frequencies, with size ~1.4 mas, flat spectral index (α~0.3) and T_B ~$10^{9.1}$ K. At 1.6 GHz, a second component is detected ~50 mas westward (3.5 pc), more extended.

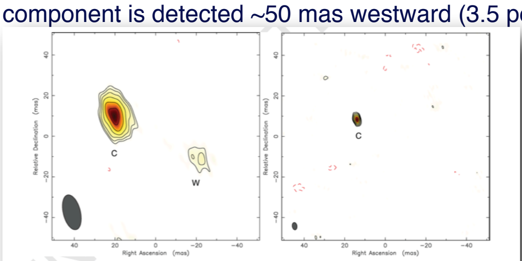

Figure 3. NGC 4138 at 1.7 GHz (left) and 5 GHz (right). The contours are traced at (−1, 1, 2, 4, . . .) × the ~3σ noise level, which is 0.14 and 0.09 mJy beam^{-1} at 1.7 and 5 GHz, respectively. HPBW are shown in the lower-left corner, and their size is 8.5 × 17.7 mas in PA 14° and 2.4 × 3.7 mas in PA 8° at 1.7 and 5 GHz, respectively.

Physical properties

All the sources detected at both frequencies, i.e. NGC3227, NGC3982 and NGC4138, present one component with high brightness temperature (log T_B> 7.5) and flat spectral index (0.3 ≤ α ≤ 0.6), which we ascribe to non-thermal emission from the immediate vicinity of the central black hole; steep spectrum extended components are also detected within some tens of parsecs from the core, suggesting the presence of jets or outflows on parsec scales. The physical parameters estimated under the assumption of minimum energy are reasonable; e.g. the equipartition magnetic field is of a few mG.

In NGC 4477, detected only at 5 GHz, the brightness temperature is lower, and the physical parameters are at odd with an SSA scenario, mainly because of the too high magnetic field required; a thermal free–free origin for its radio emission seems more viable, similar to NGC 1068 (Gallimore et al. 2004).

The undetected sources remain a mystery; since they have weak but compact cores in VLA images, e-MERLIN observations would be ideal to investigate their nature.

Table 5. Physical quantities at 1.7 GHz.

Source	Component	log T_B (K)	log L (W Hz^{-1})	log V (cm^{-3})	log U_{min} (erg cm^{-3})	B_{eq} (mG)
NGC 3227	C	7.5	19.8	54.1	−5.76	4.3
	S	6.5	20.5	56.9	−6.90	1.2
	N	6.1	19.7	55.9	−6.83	1.3
NGC 3982	C	9.1	19.8	52.0	−4.53	17.8
	S	7.2	20.0	54.9	−6.14	2.8
NGC 4138	C	8.5	19.4	52.1	−4.86	12.2
	W	6.6	18.8	54.8	−6.73	1.4

Table 6. Physical quantities at 5 GHz.

Source	Component	log T_B (K)	log L (W Hz^{-1})	log V (cm^{-3})	log U_{min} (erg cm^{-3})	B_{eq} (mG)
NGC 3227	C	7.5	19.5	52.4	−4.96	10.9
	S1	5.4	19.1	54.9	−6.61	1.6
	S2	5.8	19.1	54.4	−6.31	2.3
NGC 3982	C	7.6	19.7	52.5	−4.93	11.2
	S	5.7	19.3	54.7	−6.37	2.1
NGC 4138	C	7.8	19.2	51.4	−4.52	18.1
NGC 4477	C	6.5	18.7	52.7	−5.59	5.2

References & Acknowledgments

For more details, see **Bontempi, Giroletti, Panessa, Orienti & Doi (2012, MNRAS, 426, 588)**. Other references:

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