RevMexAA (Serie de Conferencias), **20**, 23–24 (2004)

RESULTS OF A SEARCH FOR NEW MICROQUASARS IN THE GALAXY

M. Ribó,[1] J. M. Paredes,[2] J. Martí,[3] J. Casares,[4] J. S. Bloom,[5,6] E. E. Falco,[7] E. Ros,[8] and M. Massi[8]

RESUMEN

Presentamos los resultados de una búsqueda de nuevos microcuasares en bajas latitudes galácticas con base en una identificación cruzada entre el ROSAT Bright Source Catalogue (RBSC) de todo el cielo y NRAO VLA Sky Survey (NVSS) y las observaciones de seguimiento. Los resultados obtenidos hasta ahora sugieren que los microcuasares persistentes/silenciosos tales como LS-5039 son objetos raros en nuestra Galaxia e indican que exploraciones futuras a mayores profundidades y en rayos X más duros que los del RBSC jugarán un papel fundamental en su descubrimiento.

ABSTRACT

We present here the results of a search for new microquasars at low galactic latitudes, based on a cross-identification between the *ROSAT* all sky Bright Source Catalog (RBSC) and the NRAO VLA Sky Survey (NVSS) and follow-up observations. The results obtained up to now suggest that persistent/silent microquasars such as LS 5039 are rare objects in our Galaxy, and indicate that future deeper surveys, and harder than the RBSC in X-rays, will play a fundamental role in order to discover them.

Key Words: **RADIO CONTINUUM: STARS — X-RAYS: BINARIES**

1. INTRODUCTION

Microquasars are X-ray binary systems with the ability to generate relativistic jets (see Mirabel & Rodríguez 1999 and Fender 2004 for detailed reviews on the topic). These sources mimic, on smaller scales, many of the phenomena seen in AGNs and quasars, but with timescales several orders of magnitude shorter (since t scales with M). This property allows us to study, in a few minutes, the accretion/ejection processes that take place near galactic compact objects. Unfortunately, the population of known microquasars is still very small with merely around 15 cases. Therefore, it is worth to search for new microquasars in order to increase the known population to allow meaningful statistical studies.

2. CROSS-IDENTIFICATION METHOD

In order to identify new microquasar candidates we have to find new radio emitting X-ray binaries. To this end, we have performed a cross-identification between the X-ray catalog RBSC (Voges et al. 1999) and the radio catalog NVSS (Condon et al. 1998), which covers the sky north of $\delta = -40°$. We have adopted the following selection criteria: 1) Absolute galactic latitude $< 5°$; 2) No screening flags about nearby sources contaminating measurements or problems with position determinations in the RBSC; 3) Hardness ratios, $HR1 + \sigma(HR1)$, higher than 0.9; 4) NVSS sources within the 2σ error boxes of the RBSC sources; 5) Unresolved by the NVSS. The sources selected with the RBSC/NVSS cross-identification, a total of 35, were then filtered with complementary optical information using the following criteria: 1) No extragalactic information within SIMBAD and NED; 2) No extended appearance in the Digitized Sky Survey, DSS1 and DSS2-red images. Only 17 sources fulfilled all the selection criteria, including the well known microquasars LS 5039, SS 433 and Cygnus X-3, and the new microquasar LS I +61 303. Therefore, our method recovered all persistent radio emitting high mass X-ray binaries except Cygnus X-1, which was too faint during the NVSS observations.

3. FOLLOW-UP OBSERVATIONS

Follow up VLA A configuration multifrequency and multiepoch observations of 6 of the remaining 13 unknown sources, performed in July 1999, provided accurate positions, as well as spectral and variability information. This allowed us to discover optical counterparts for all of them with probabilities of random coincidence below 0.3% after our own optical observations conducted with the 1.5 m OAN

[1] Service d'Astrophysique, CEA Saclay, Bât. 709, L'Orme des Merisiers, 91191 Gif-sur-Yvette, Cedex, France.
[2] Universitat de Barcelona, Barcelona, Spain.
[3] Universidad de Jaén, Jaén, Spain.
[4] Instituto de Astrofísica de Canarias, La Laguna, Spain.
[5] Harvard Society of Fellows, Cambridge, USA.
[6] Harvard-Smithsonian CfA, Cambridge, USA.
[7] F. L. Whipple Observatory, Amado, USA.
[8] MPIfR, Bonn, Germany.

TABLE 1

SUMMARY OF THE OBTAINED RESULTS[a]

1RXS name	VLA obs.		Optical obs.		EVN+MERLIN obs.			Opt. spec.
	Structure	α	Structure	I	Structure	β	$\theta[^\circ]$	
J001442.2+580201	compact	-0.2	point-like	19.9	2-sided jet	> 0.20	< 78	Featureless
J013106.4+612035	compact	-0.1	point-like	17.9	1-sided jet	> 0.31	< 72	Featureless
J042201.0+485610	compact	$+1.5^*$	extended*	17.5	not detected*	···	···	Seyfert 1
J062148.1+174736	compact	$+0.1$	extended*	17.6	compact	···	···	Featureless
J072259.5−073131	1-sided jet*	-0.2	point-like	16.8	bent 1-sided jet*	> 0.29	< 73	BL Lac (?)
J072418.3−071508	compact	$+0.1$	point-like	17.2	bent 1-sided jet*	> 0.51	< 60	FSRQ

[a]An asterisk indicates a non-expected behavior for microquasars.

(November 1998) and 2.2 m CAHA (December 1999) telescopes at Calar Alto (Paredes et al. 2002).

With the aim of revealing possible jet-like features at milliarcsecond scales, we observed these six sources with the EVN and MERLIN on 2000 February 29th/March 1st at 5 GHz. We detected five of the six observed sources, which showed different morphologies: one source with a two-sided jet, three sources having a one-sided jet and a compact source (Ribó et al. 2002).

Finally, we performed optical spectroscopic observations of these six sources with the 4.2 m WHT and 6.5 m MMT telescopes (Martí et al. 2004).

4. SUMMARY AND CONCLUSIONS

After a detailed analysis of all the follow-up observations, we show in Table 1 a summary of the obtained results. The first two sources, 1RXS J001442.2+580201 and 1RXS J013106.4+612035, show featureless spectra indicative of an extragalactic nature. Nevertheless, the possibility of having highly reddened stars cannot be completely excluded (see Martí et al. 2004 for details). 1RXS J042201.0+485610 is a Seyfert 1 galaxy with broad Hydrogen emission lines and $z = 0.114$. The source 1RXS J062148.1+174736 is probably an extragalactic object due to the featureless spectrum and extended nature of the optical counterpart. 1RXS J072259.5−073131 shows properties common to BL Lac objects, while 1RXS J072418.3−071508 is an already identified Flat Spectrum Radio Quasar (FSRQ) with $z = 0.270$.

Assuming that none of our candidates is galactic, it appears that the population of new and persistent microquasars is not very numerous in the Galaxy. The corresponding density of new (bright) Cygnus X-3 and (faint) LS 3039-like system is constrained to be $\lesssim 1.1 \times 10^{-12}$ pc^{-3} and $\lesssim 5.6 \times 10^{-11}$ pc^{-3}, respectively. Although we plan to expand our cross-identification studies to $5^\circ \leq |b| \leq 10^\circ$, the basic limitation of the RBSC low-energy range, where X-ray photons are highly absorbed, will persist. Therefore, sensitive surveys in hard X-rays and γ-rays, such as the current *INTEGRAL* Galactic Plane Survey or the planned *EXIST* mission, will play a fundamental role in order to reveal the *real* population of persistent microquasars in the Galaxy.

M. R., J. M. P. and J. M. acknowledge partial support by DGI of the Ministerio de Ciencia y Tecnología (Spain) under grant AYA2001-3092, as well as partial support by the European Regional Development Fund (ERDF/FEDER). M. R. acknowledges support by a Marie Curie Fellowship of the European Community programme Improving Human Potential under contract number HPMF-CT-2002-02053. J. M. is supported by the Junta de Andalucía (Spain) under project FQM322, and has been also aided in this work by an Henri Chrétien International Research Grant administered by the AAS.

REFERENCES

Condon, J. J., Cotton, W. D., Greisen, E. W., et al. 1998, AJ, 115, 1693

Fender, R. P. 2004, in 'Compact Stellar X-Ray Sources', eds. Lewin, W. H. G. & van der Klis, M., Cambridge University Press, in press [astro-ph/0303339]

Martí, J., Paredes, J. M., Bloom, J. S., Casares, J., Ribó, M., & Falco, E. E. 2004, A&A, 413, 309

Mirabel, I. F., & Rodríguez, L. F. 1999, ARA&A, 37, 409

Paredes, J. M., Ribó, M., & Martí, J. 2002, A&A, 394, 193

Ribó, M., Ros, E., Paredes, J. M., Massi, M., & Martí, J. 2002, A&A, 394, 983

Voges, W., Aschenbach, B., Boller, Th., et al. 1999, A&A, 349, 389