MULTI-WAVELENGTH INTEGRAL NETWORK (MINE) OBSERVATIONS OF THE MICROQUASAR GRS 1915+105

Yaël Fuchs¹, J. Rodriguez¹,², S. E. Shaw²,³, P. Kretschmar²,⁴, M. Ribó¹, S. Chaty¹,⁵, I. F. Mirabel¹,⁶, V. Dhawan⁷, G. G. Pooley⁸, I. Brown⁹, R. Spencer⁹, and D. C. Hannikainen¹⁰

¹Service d’Astrophysique, CEA/Saclay, Orme des Merisiers bât. 709, 91191 Gif sur Yvette cedex, France
²Integral Science Data Centre, Chemin d’Ecogia, 16, CH-1290 Versoix, Switzerland
³School of Physics and Astronomy, University of Southampton, Southampton, SO17 1BJ UK
⁴Max-Planck-Institut fuer Extraterrestrische Physik, Giessenbachstrasse, 85748 Garching, Germany
⁵Université Paris 7, 2 place Jussieu, 75005 Paris, France
⁶Instituto de Astronomía y Física del Espacio / CONICET, cc67, s/n 28. 1428 Buenos Aires, Argentina
⁷National Radio Astronomy Observatory, Socorro, NM 87801, USA
⁸Mullard Radio Astronomy Observatory, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, UK
⁹University of Manchester, Jodrell Bank Observatory, Macclesfield, Cheshire SK11 9DL
¹⁰Observatory, University of Helsinki, PO Box 14, FIN-00014, Finland

ABSTRACT

We present the international collaboration MINE (Multi-lambda Integral NEtwork) aimed at conducting multi-wavelength observations of X-ray binaries and microquasars simultaneously with the INTEGRAL γ-ray satellite. We will focus on the 2003 March–April campaign of observations of the peculiar microquasar GRS 1915+105 gathering radio, IR and X-ray data. The source was observed 3 times in the plateau state, before and after a major radio and X-ray flare. It showed strong steady optically thick radio emission corresponding to powerful compact jets resolved in the radio images, bright near-infrared emission, a strong QPO at 2.5 Hz in the X-rays and a power law dominated spectrum without cutoff in the 3–300 keV range. We compare the different observations, their multi-wavelength light curves, including JEM-X, ISGRI and SPI, and the parameters deduced from fitting the spectra obtained with these instruments on board INTEGRAL.

Key words: Stars: individual: GRS 1915+105 – X-rays: binaries – Gamma rays: observations – ISM: jets and outflows.

1. INTRODUCTION

Microquasars are X-ray binaries that produce relativistic jets and thus appear as miniature replicas of distant quasars [Mirabel & Rodríguez 1994]. Their emission spectra, variable with time, range from the radio to the γ-ray wavelengths. We present here the first multi-wavelength campaign on GRS 1915+105 involving the INTEGRAL satellite (3 keV–10 MeV). This campaign was conducted by the MINE (Multi-λ INTEGRAL NEtwork, see http://elbereth.obspm.fr/~fuchs/mine.html) international collaboration aimed at performing multi-wavelength observations of galactic X-ray binaries simultaneously with INTEGRAL.

2. GRS 1915+105

The microquasar GRS 1915+105 is extremely variable at all wavelengths (see Fuchs et al. 2003a for a review). It hosts the most massive known stellar mass black hole of our Galaxy with M= 14.0±0.4 M⊙ [Greiner et al. 2001; Harlaftis & Greiner 2004]. In the radio it can show superluminal ejections at arcsec scales [Mirabel & Rodríguez 1994] leading to a maximum distance of 11.2±0.8 kpc [Fender et al. 1999], and compact jets at milli-arcsecond scales (= a few tens of AU, Dhawan et al. 2000).

We conducted a multi-wavelength observation campaign of GRS 1915+105 on March 24–25, April 2–3 and April 17–18 2003 (see Fig. 1) corresponding to INTEGRAL revolutions 54, 57 and 62, respectively. Here we focus only on the April observations when ToO (Targets of Opportunity) were triggered by the MINE collaboration. This (nearly) simultaneous campaign involved the VLA, the VLBA, MERLIN and the Ryle Telescope (RT) in radio, the ESO/NTT in IR, RXTE and INTEGRAL in X/γ-rays. More details and description of the April 2 observations can be found in Fuchs et al. 2003b).

Fig. 2 shows the general radio and X-ray behaviour of GRS 1915+105 during our observing campaign.
After a period of X-ray oscillations (end of February – beginning of March) giant radio flares occurred around MJD 52714 (March 15) and MJD 52734 (April 5). The latter may be a double flare since there are two X-ray flares in the RXTE/ASM light curve, and it probably corresponds to major superluminal ejections. Despite these flaring episodes, our observations took place during the plateau state of GRS 1915+105. Fender et al. 1999, Klein-Wolt et al. 2002, i.e. quasi-steady RXTE/ASM (2–12keV) flux ~50cts/s and high steady radio level (>100mJy). This plateau state was observed on several past occasions in GRS 1915+105 (see e.g. Fig. 1 of Munoz et al. 2001) and was also called the radio loud low/hard X-ray state (Muno et al. 2001) and type II state (Trudolyubov 2001). It also corresponds to the $\chi_1$ and $\chi_3$ X-ray classes of Belloni et al. 2000 who used PCA color-color diagram, and indeed our April 2 observation appears as the $\chi_1$ class when plotted in such a diagram.

On April 2 (Fig. 3) & 18 (Fig. 4) the high energy emission shows a power law dominated spectrum (>60% at 3–20keV) with a photon index $\Gamma$=2.9 and 2.75, respectively. This state is much softer than the classical low/hard state of the other BH binaries and is closer to the very high or intermediate states McClintock & Remillard 2004. The INTEGRAL observations show that this power law spectrum extends up to 300keV without any cutoff during this
level was observed in the RXTE/PCA signal, which is consistent with the previous observations of the plateau state (see also Rodriguez et al. 2004).

The detailed light curves of our observations on April 2–3 (Fig. 5) and April 17–18 (Fig. 6) show nearly quiet flux densities when compared to flares or oscillations, with variations $\lesssim 20\%$ at all wavelengths (the peaks in the ISGRI and SPI light curves are not real). The most interesting phenomenon is on April 2, a moderate $\sim 25\%$ decrease (from 4.9 to 3.6 mJy) in the $K_s$ flux density lasting 20 min which precedes by 31 min a $\sim 20\%$ decrease in the RT signal (from 145 to 118 mJy) lasting 48 min. This may be due to instabilities in the jet inducing an immediate synchrotron response in the IR and the delay being due to the time for the material along the jet to become optically thin to the radio emission (Mirabel et al. 1998). The radio and near-IR flux densities are high in both observations.

The VLBA high resolution images on April 2 (Fig. 7) show the presence of a compact radio jet with a $\sim 7\,$–$\,$14 mas length (85–170 AU at 12 kpc). These jets are also observed in the radio images on March 24 and
April 19. The optically thick synchrotron emission from this jet is responsible for the high radio levels observed during the plateau state of GRS 1915+105 (see Fig. 2, Fig. 3 and Fig. 4). On April 18 the MERLIN image (Fig. 5) shows a radio extension of $\sim 0.3''$. This extension is likely the trace of a superluminal ejection occurred around April 4 (corresponding to the giant radio flare of April 5 on Fig. 2) since it would correspond to a mean velocity of $\sim 21$ mas/d compatible with the previous observations (Mirabel & Rodríguez 1999).

On April 2 the source was fairly bright in near-IR with an excess of 75–85% in the $K_s$-band compared to the $K=14.5–15$ mag. of the K-M giant donor star of the binary. According to the spectral energy distribution (Fig. 9), this IR excess is compatible with a strong contribution from the synchrotron emission of the jet extending from the radio up to the near-IR. Different components, however, contribute to the IR in addition to the jet, such as the donor-star, the external part of the accretion disc or free-free emission.

3. CONCLUSIONS AND PROSPECTS

Here for the first time, we observed simultaneously all the properties of the plateau state of GRS 1915+105: a powerful compact radio jet, responsible for the strong steady radio emission and probably for a significant part of the bright near-IR emission, as well as a QPO (2.5 Hz) in the X-rays and a power law dominated X-ray spectrum with a $\Gamma \sim 3$ photon index up to at least 300 keV. Forthcoming works will study detailed fits of the X-ray spectra, to determine for example whether this power law is due to an inverse Compton scattering of soft disc photons on the base of the compact jet or not. In order to better understand the unusual behaviour of GRS 1915+105, we need to carry out similar simultaneous broad-band campaigns during the other states, in particular during the sudden changes that correspond to powerful relativistic ejection events.

ACKNOWLEDGMENTS

Y.F. and J.R. acknowledge financial support from the CNES. M.R. acknowledges support from a Marie Curie individual fellowship under contract No. HPMF-CT-2002-02053. D.C.H. acknowledges the Academy of Finland for financial support. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. Based on observations collected at the European Southern Observatory, Chile (ESO N° 071.D-0073). We thank the ASM/RXTE team for providing the quick-look results. We thank Sergei Trushkin for the RATAN data, and Harry Lehto and Emílios Harlaftis for the Nançay data.

REFERENCES

Belloni T., Klein-Wolt M., Méndez M., van der Klis M., van Paradijs J., 2000, A&A, 355, 271
Cardelli J.A., Clayton G.C., Mathis J.S., 1989, ApJ, 345, 245
Dhawan V., Mirabel I.F., Rodríguez L.F., 2000, ApJ, 543, 373
Fender R.P., Garrington S.T., McKay D.J., et al., 1999, MNRAS, 304, 865
Fuchs Y., Mirabel I.F., Claret A., 2003a, A&A, 404, 1011
Fuchs Y., Rodriguez J., Mirabel I.F., et al., 2003b, A&A, 409, L35
Greiner J., Cuby J.G., McCaughrean M.J., 2001, Nature, 414, 522
Harlaftis E.T., Greiner J., 2004, A&A, 414, L13
Klein-Wolt M., Fender R.P., Pooley G.G., et al., 2002, MNRAS, 331, 745
McClintock J.E., Remillard R.A., 2004, in 'Compact Stellar X-Ray Sources', eds. W.H.G. Lewin and M. van der Klis, CUP, astro-ph/0306213
Mirabel I.F., Rodríguez L.F., 1994, Nature, 371, 46
Mirabel I.F., Rodríguez L.F., 1999, ARA&A, 37, 409
Mirabel I.F., Dhawan V., Chaty S., et al., 1998, A&A, 330, L9
Muno M.P., Remillard R.A., Morgan E.H., et al., 2001, ApJ, 556, 515
Rodriguez J., Fuchs Y., Hannikainen D.C., et al., 2004, this volume
Trudolyubov S.P., 2001, ApJ, 558, 276
Zdziarski A.A., Grove J.E., Poutanen J., Rao A.R., Vadawale S.V., 2001, ApJ, 554, L45