Session 3: Diagnostics of High Gravity Objects with X- and Gamma Rays

3-2. Black Hole Binaries

https://doi.org/10.1017/S0074180900114603 Published online by Cambridge University Press

GALACTIC RADIO-JET SOURCES: MULTIWAVELENGTH OBSERVATIONS

PH. DUROUCHOUX
CE. Saclay, DSM, DAPNIA, Service d'Astrophysique
91191 Gif sur Yvette, Cedex France

AND

D. HANNIKAINEN
Observatory, PO Box 14
University of Helsinki, Finland

1. ABSTRACT

So far, seven X-ray sources have been identified to be radio-jet sources. We present a review of the observations of 1E 1740-2942, GRS 1758-258, GRS 1915+105, GRO J1655-40, SS 433, Cir X-1, Cyg X-3.

2. Introduction

About 200 X-ray binaries have been discovered and, a radio counterpart has been detected for 15% of them. Of these 30 radio binary sources, four exhibit either periodically or continuously a radio-jet structure. In the three other cases (among the seven identified jet sources), binarity has not (yet?) been found, but due to their location (Galactic center or Galactic disk region) the large visual absorption could explain the lack of detection of a companion.

3. SS 433

SS 433, a 13.1-day orbital period X-ray binary, is a weak X-ray source at the center of a very large complex of radio (W50) emission (Konigl 1983; Baum & Elston 1985). This radio emission is persistent and occasionally undergoes huge radio bursts with the flux increasing by factors of 10. The most important characteristic of SS 433 is the continuous ejection of matter at a velocity of 0.26c in the form of radio jets (Hjellming & Johnson,

K. Koyama et al. (eds.), The Hot Universe, 131-134.

https://doi.org/10.1017/S0074180900114603 Published online by Cambridge University Press

1988). In X-rays, Watson et al. (1983) found two bright diffuse lobes with the EINSTEIN satellite, symmetrically displaced east and west of SS 433, and aligned along the axis of W50. Recent observations performed with the X-ray ASCA satellite of the eastern lobe of W50 (see Fig. 1 in Yamauchi, Kawai and Aoki, 1994) reveal the nonthermal nature of the lobes, as evidenced by the absence of emission lines. More recently, Safi-Harb and Ogelman (1997) reanalyzed 1991 ROSAT observations of the SS 433 eastern lobe, and found a knotty structure (see Fig. 2 in Safi-Harb and Ogelman, 1997), with additional soft X-ray emission from this lobe at 1 degree east of SS 433 and coincident with the radio "ear", which is interpreted as the region associated with the terminal shock of the SS 433 jet.

4. Cyg X-3

Cyg X-3 is also a persistent radio source, with huge outbursts (factor 50) on a time scale of days. During such a flaring period, Hjellming et al. (1997) found Cyg X-3 to be an expanding radio source with an expansion velocity of 0.9c.

5. Cir X-1

The radio emission of Cir X-1 is less known. The source was observed several times in the 70's, exhibiting repeating radio flares every 16.6 days (the orbital period of the system). By the end of 1990 and the beginning of 1991, Steward et al. (1993) observed Cir X-1 and the nearby supernova remnant G321.9-0.3, and found clear evidence for jet-like structure within the nebula surrounding Cir X1. As mentioned by the authors, the jets originate at a compact source at the position of the binary, then extend outwards about 30 arcsec before curving back several arcmin towards the nearby supernova remnant G321.9-0.3. The optical counterpart of Cir X-1 is a faint red star (Moneti 1992), and the high ratio of the X-ray to optical luminosity indicates that Cir X-1 is a low mass X-ray binary (Oosterbroek et al. 1995). Recently, Shirey et al. (1996) studied the timing and spectral evolution of Cir X-1 versus orbital phase with the ROSSI X-ray Timing Explorer and found quasi-periodic oscillations.

6. GRO J1655-40

GRO J1655-40 was detected as an X-ray transient in July 1994 (Zhang et al. 1994). Soon after this observation, Tingay et al. (1995) reported the detection of two radio components moving away from each other at an angular speed of 65 ± 5 mas d^{-1}, corresponding to superluminal motion at the estimated distance of 3.2 kpc (Hjellming et al. 1995). A multiwavelength analysis showed delays between the X-ray and radio outbursts interpreted by Tingay et al. (1995) to be the ejection of material at relativistic speeds occuring during a stable phase of accretion onto a black hole, followed by an unstable phase with high accretion rate. The existence of a black hole as the compact star of a binary system with a 2.62 day orbital period was verified after measurement of its mass function(Bailyn et al. 1995).

7. 1E 1740.7-2942 and GRS 1758-258

Both 1E1740.7-2942, the Great Annihilator, and GRS 1758-258 are bright Galactic Center hard X-ray sources as well as clearly variable radio sources with arcmin scale radio jets. No optical/IR counterparts have been discovered probably because of the high visible absorption towards the Galactic Center. This does not rule out the possibility that these sources are binary systems.

8. GRS 1915+105

The X-ray transient GRS 1915+105 was discovered by the WATCH instrument onboard the GRANAT satellite in 1992 (Castro-Tirado et al. 1994), and soon after, SIGMA measured an accurate position allowing radio observations. VLA observations led to the discovery of relativistic ejections of plasma with an ejection velocity of 0.92c (Mirabel and Rodriguez, 1994). Analyzing carefully the timing of the ejections, we found a repetitivity around 28 days. Ryle radio observations (15 GHz) as well as Nancay (3.2 & 1.4 GHz) and GBI (2 & 8 GHz) exhibit large outbursts associated with these ejections, fitting with this repetitivity relatively well and leading to the idea that these ejections could be associated with the saturation of an accretion disk, filled by a hidden companion orbiting the compact object with a 28-day orbital period (Hannikainen and Durouchoux 1998).

9. Conclusions

It appears that, for binary systems, the jet sources have different types of compact objects (NS and BH), companions (early and late type stars) and orbital periods (from hours to tens of days). From Table 1 we also note two ranges of ejection velocities: the lower velocities could be associated with neutron stars and the higher with black holes. If large radio outbursts seem to be correlated with plasmoid ejections, there is no obvious correlation between radio and X/gamma-rays, and more correlated observations are strongly needed to better understand the physics which drives the behavior of the radio-jet sources.

10. References

Baum & Elston, 1985, in The Crab Nebula and Related Supernova Remnants, eds M.C Kafatos and R. Henry (Cambridge U. Press), P 251

Bailyn et al. 1995, IAU Circ. No. 6173

Castro-Tirado et al. 1994, ApJS, 92, 469

Fender et al. 1995, MNRAS, 274, 633

Fender, Brocksopp & Pooley, 1997, IAU Circ 6544

Han and Hjellming, ApJ, submitted

Hannikainen and Durouchoux, 1998, to be published

Hjellming & Wade. ApJ, 1971, 168, L21

Hjellming & Johnson, 1981, ApJ,246, L141

Hjellming & Johnson, 1988, ApJ,328, 600

Hjellming et al. 1995, Nature, 375, 464

Hjellming et al. 1997, this symposium

Konigl, 1983, MNRAS, 205, 471

Margon, 1984, Ann. Rev. Astron. Astrophys., 22, 507

Marti, Mirabel, Rodriguez, Parades, 1997, Vistas in Astronomy, vol 41

Mirabel & Rodriguez, 1994, Nature, 371, 46

Oosterbroek, van der Klis, Kuulkers, van Paradijs, Lewin 1995, A&A, 297, 141

Shirey et al. 1996, ApJ, 469, L21

Steward, Caswell, Haynes, Nelson, 1993, MNRAS, 261, 593

Watson et al., 1986, MNRAS, 222, 261

Zhang et al. 1994, IAU Circ. No. 6052

PROPERTIES OF THE RADIO-JET X-RAY SOURCES (1)

SOURCE	DISTANCE (Kpc)	COMPANION	COMPACT OBJECT	PERIODICITIES	REMARKS
SS 433	5.1	OB (?)	NS (?)	13.1 d (o), 164 d (p)	ejection ≈ 0.26 c
CYG X3	8.5-12	WR	NS (?)	4.8 h (o)	ejection 0.3-0.5 c
1E 1740.7-2942	8.5 (GC)	binary (?)	BH (?)		
GRS 1758-258	8.5 (GC)	binary (?)	BH (?)		
CIR X1	> 5.5	LMXRB (?)	NS	16.6 d (o)	
GRS 1915+105	12.5	Be (?)	BH (?)	28.2 d (o)	superluminal 0.92 c
GRO J1655-40	3.2	F or G	BH	2.6 d (o)	superluminal 0.92 c

https://doi.org/10.1017/S0074180900114603 Published online by Cambridge University Press