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UNIVERSITY OF BARCELONA

GRS 1758-258 as a winged microquasar

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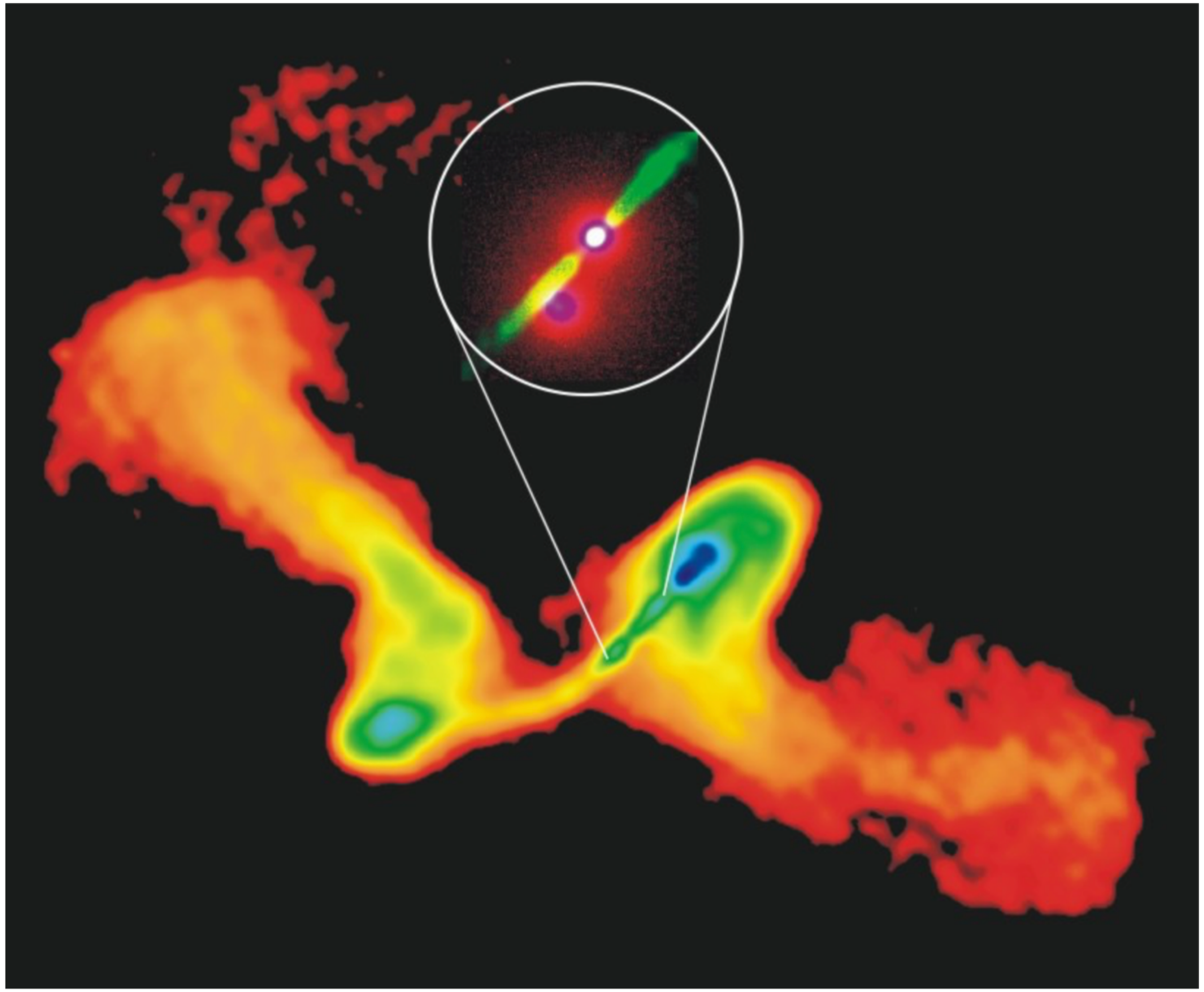
Outline of the talk

1. Winged radio galaxies
2. The microquasar GRS 1758-258
3. JVLA observations and historical data
4. The first winged microquasar
5. Conclusions

Winged radio galaxies



WRG

Two pairs of radio lobes, clearly misaligned

- WRG are the most bizarre class of FRII radio galaxies
- Represent about 23% of the total population known

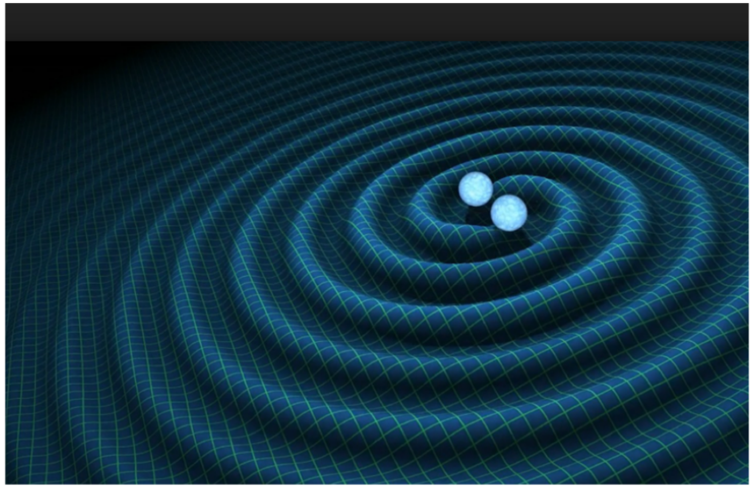
Radio image of the X-shaped galaxy NGC 326. VLA Radio image. Credit: National Radio Astronomy Observatory / AUI, observers Murgia et al.

Winged radio galaxies

- One of the most popular theories about winged radio galaxies is the **spin-flip** of rotation axes following the merger of two super-massive black holes.

- As a result, the winged radio galaxies are often considered to be key to estimate the **background of gravitational waves** in the Universe.

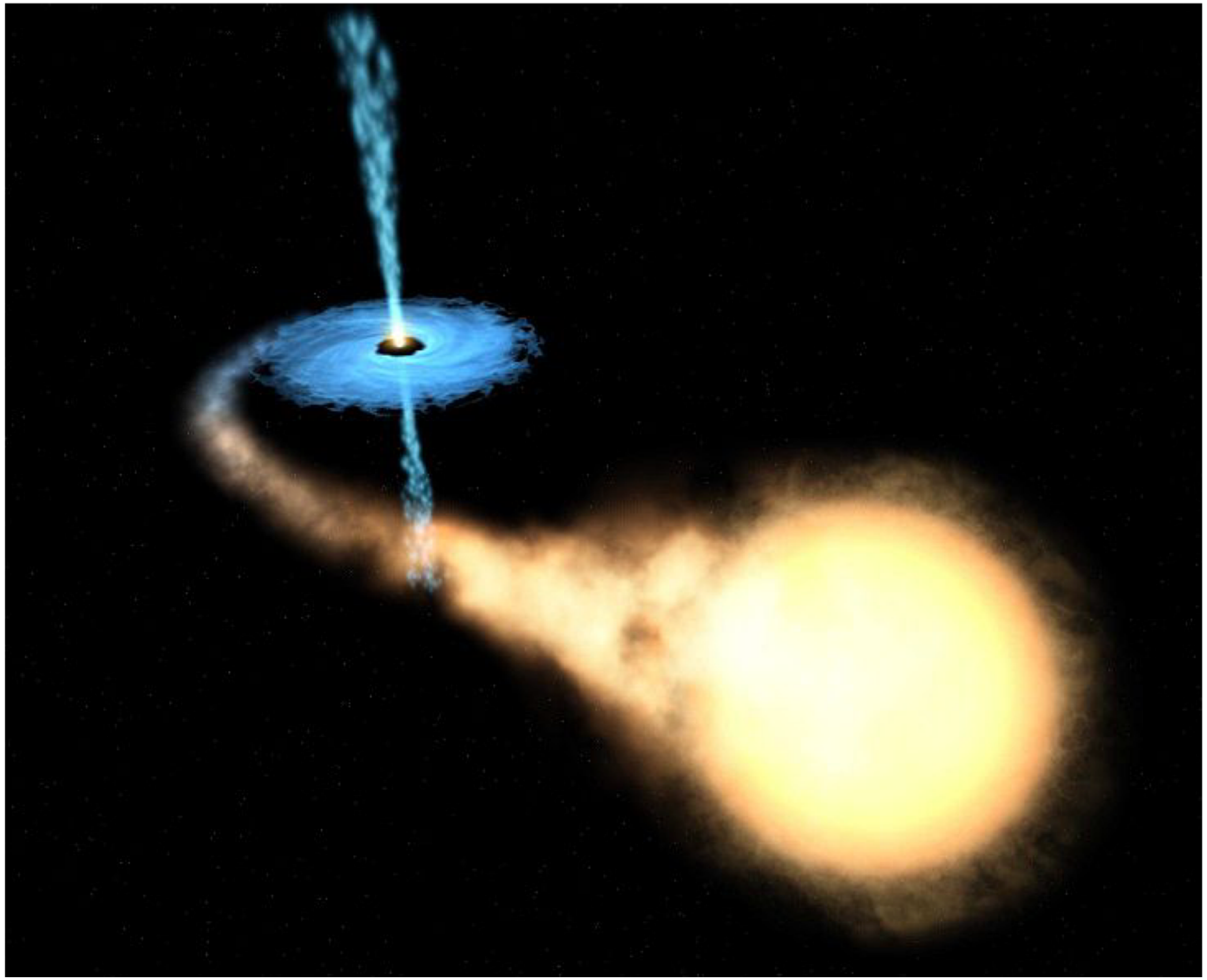
- But, the spin-flip model is not the only possible explanation. Alternative scenarios include, among others: strong jet precession, a pair of unresolved Active Galactic Nuclei, and simple **hydrodynamic back-flow**.

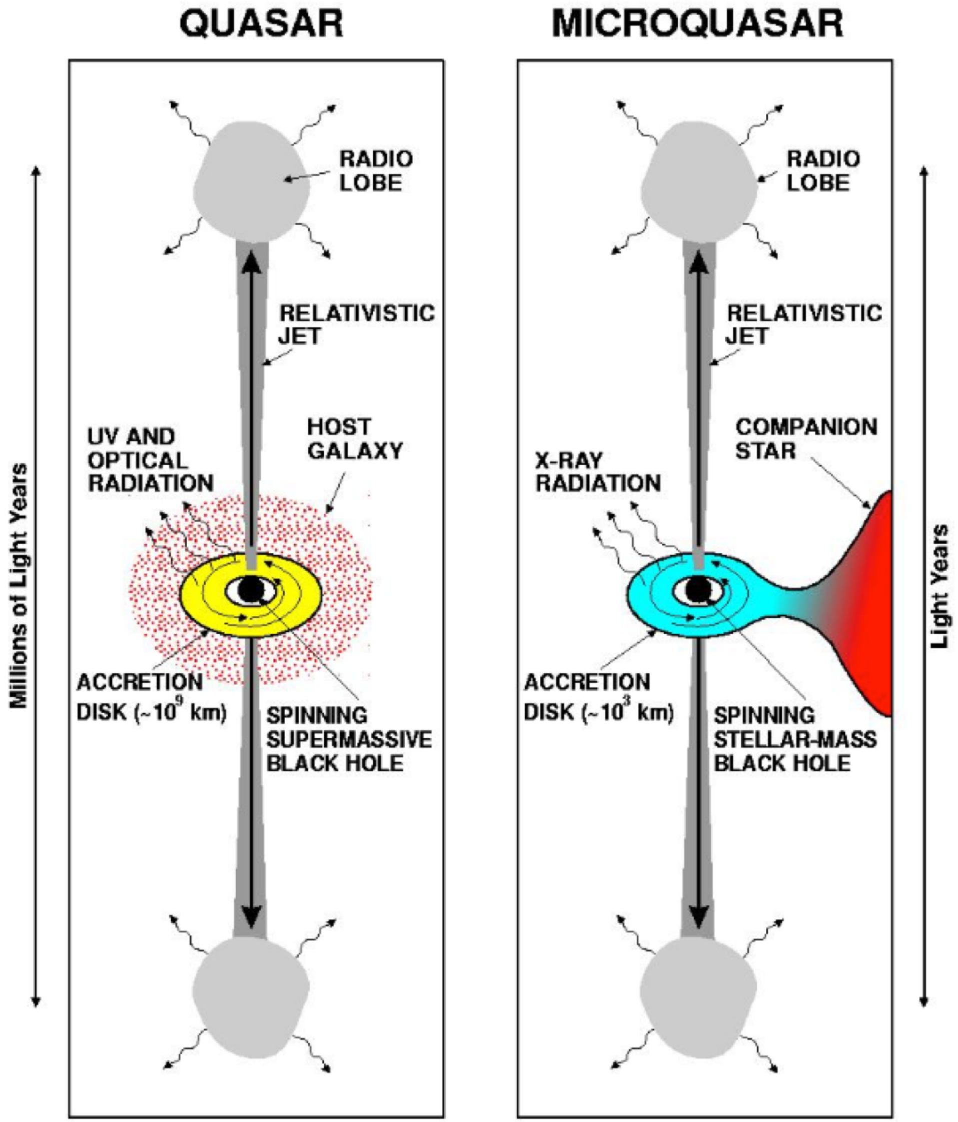


Backflow is a very common phenomenon in jets of daily life

Microquasars

Microquasars, quasars and radiogalaxies are very close relatives …





Mirabel & Rodríguez (1998), Nature, 371, 46

The microquasar GRS 1758−258

Discovery

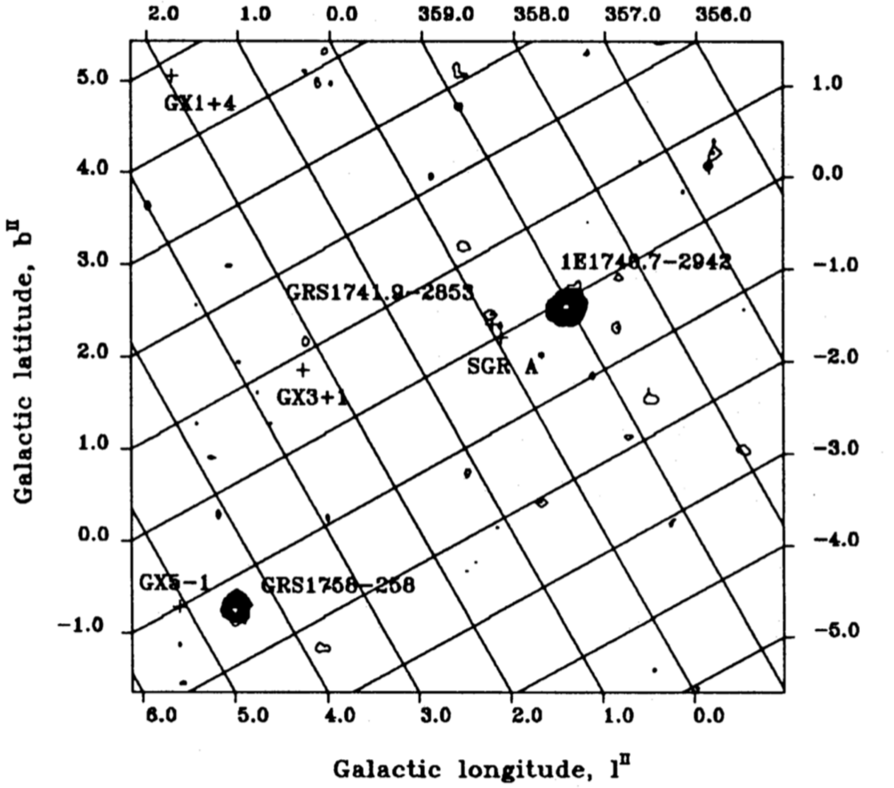
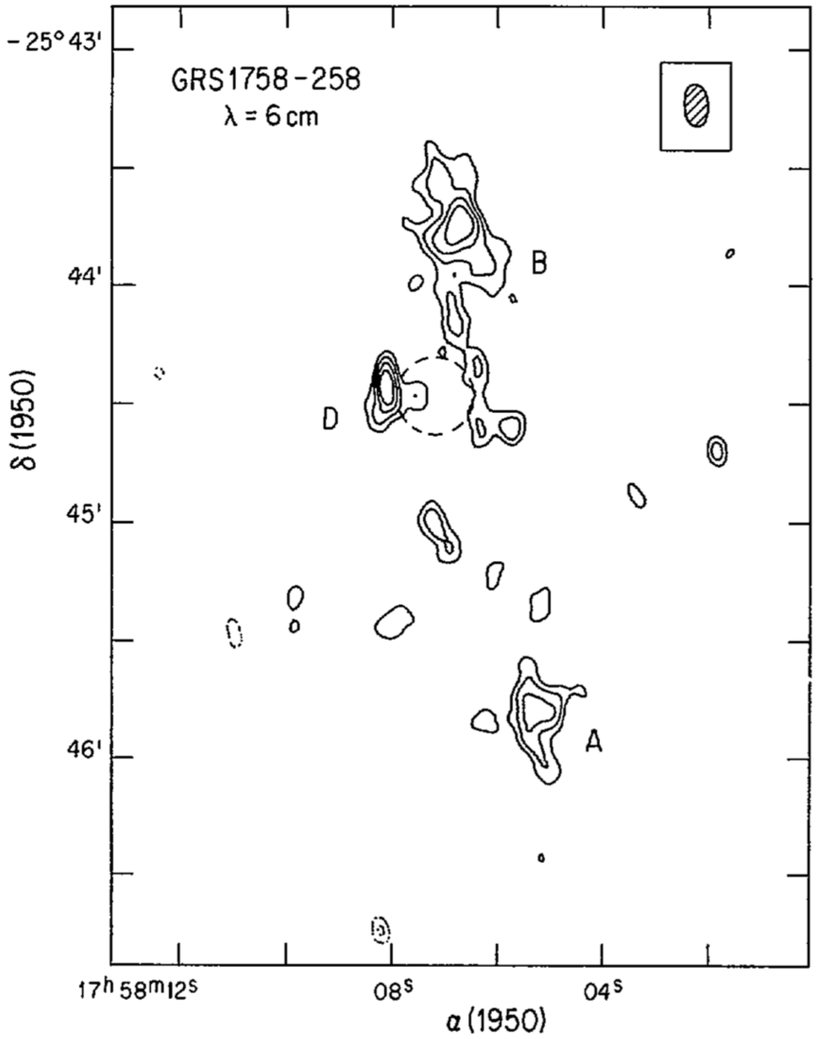


Fig. 2: The hard (35-120 keV) X-ray image of 8°.2 by 8°.2 region around GC, obtained by SIGMA telescope during March/April 1990 observations. Contours are 3, 4, 5... standard deviations.

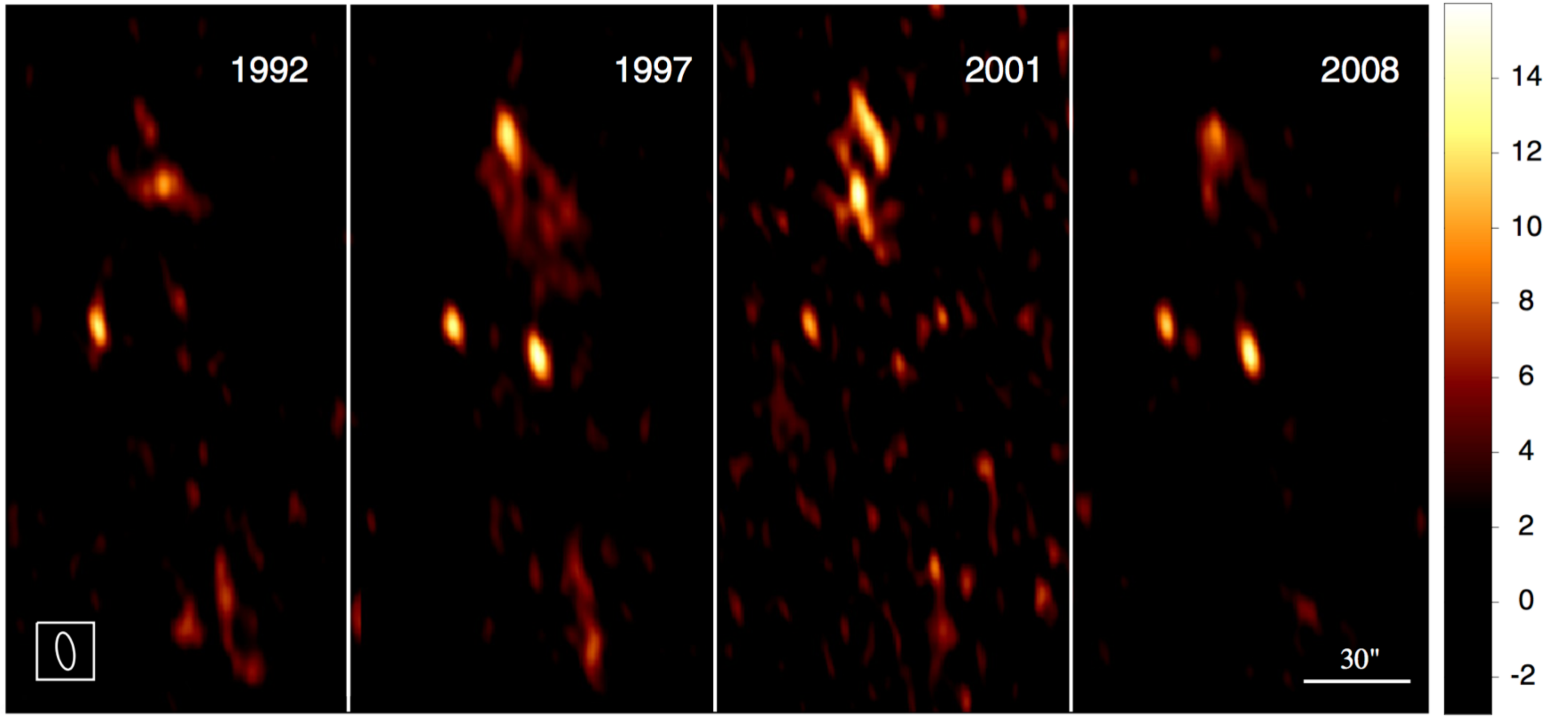
Sunyaev et al. 1991, A&A, 247, L29

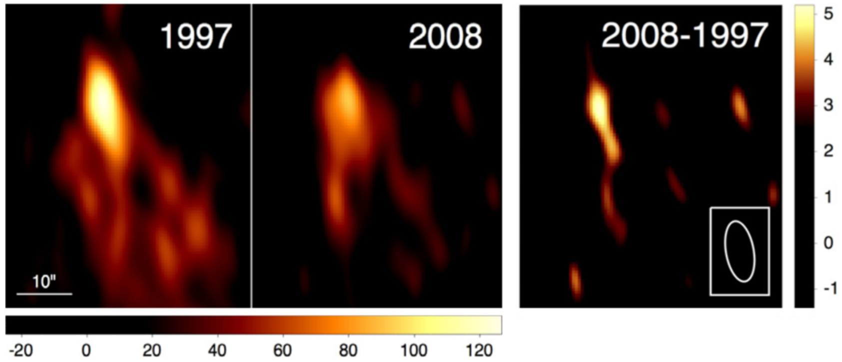
Radio counterpart



VLA discovery map of the GRS 1758−258 radio counterpart (Mirabel, Rodríguez, & Martí, 1992, ApJ, 401, L15)

The microquasar GRS 1758−258: morphology changes





Morphology changes in the large scale jets of GRS 1758−258 in a matter of few years (Martí et al. 2015, A&A, 578, L11)

The microquasar GRS 1758−258: IR counterpart

- Interstellar extinction → difficult to identify its optical/infrared counterpart
- Identified by Luque-Escamilla et al. 2014, ApJ 797, L1
- Variable IR counterpart using archival HST-NICMOS data,
- Very faint in the optical domain (*R* about 22.6 mag).

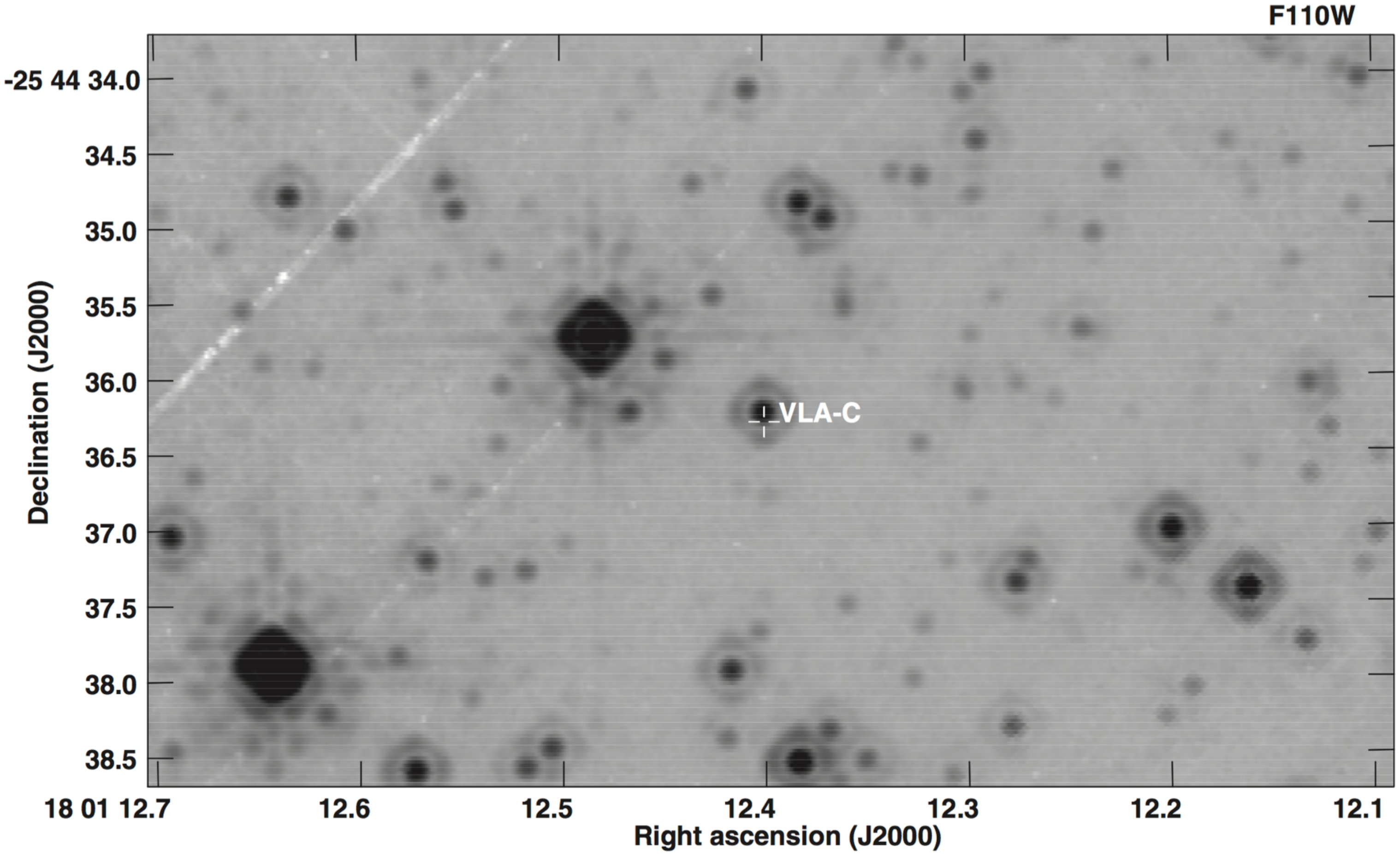


Figure 1. Representative view of the GRS 1758−258 field as observed with NICMOS in the F110W filter. This image corresponds to the first observation date reported in this Letter. Only one conspicuous point-like source is consistent with the ±0.″1 accurate VLA radio position shown as a white cross. The circular features around each star correspond to the rings of the Airy disk since this is a diffraction-limited image. Angular scale is given by the included right ascension and declination axes.

The microquasar GRS 1758−258: intermediate mass + A-type

According to GTC observations, GRS 1758-258 is possibly an
intermediate-mass system with an A-type Main Sequence companion

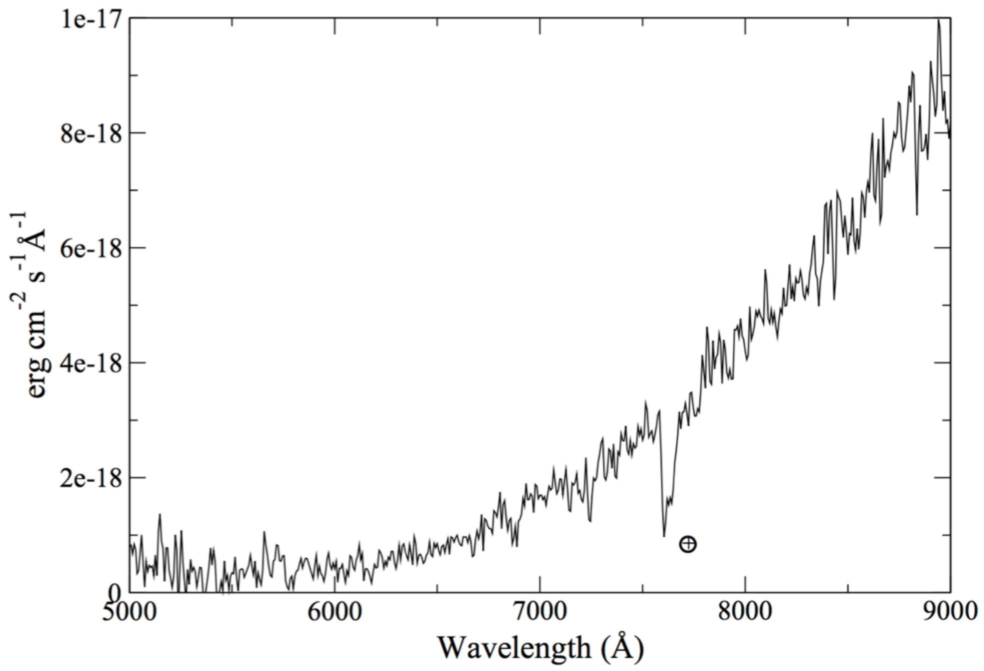


Fig. 1. GTC+OSIRIS spectrum of GRS 1758−258 obtained with the R300R grism. The microquasar is barely detected at wavelengths shorter that 6000 Å. The prominent absorption feature at approximately 7600 Å marked with the Earth symbol ⊕ is of telluric origin.

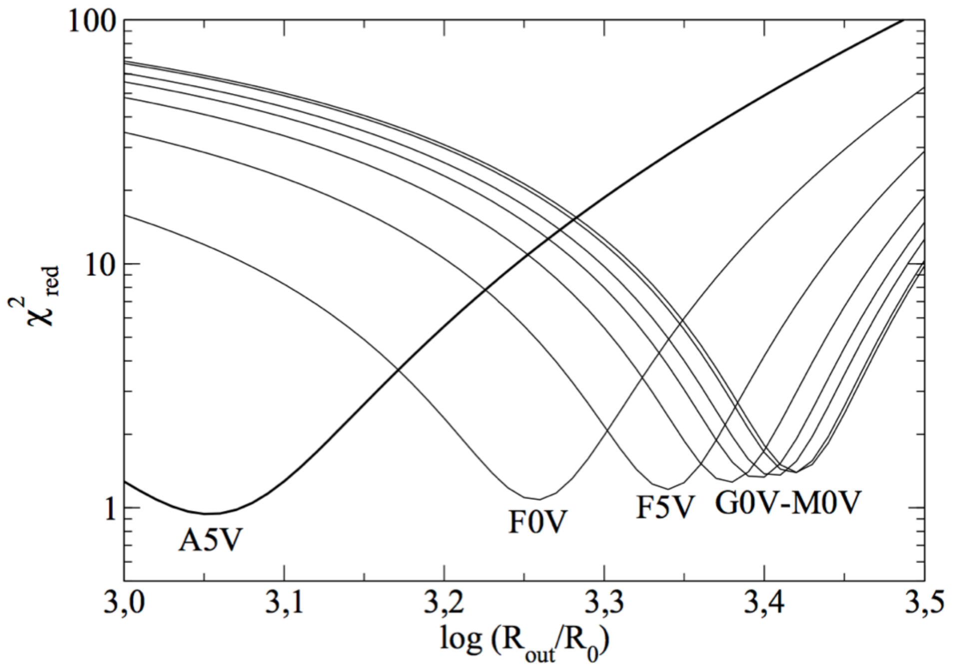
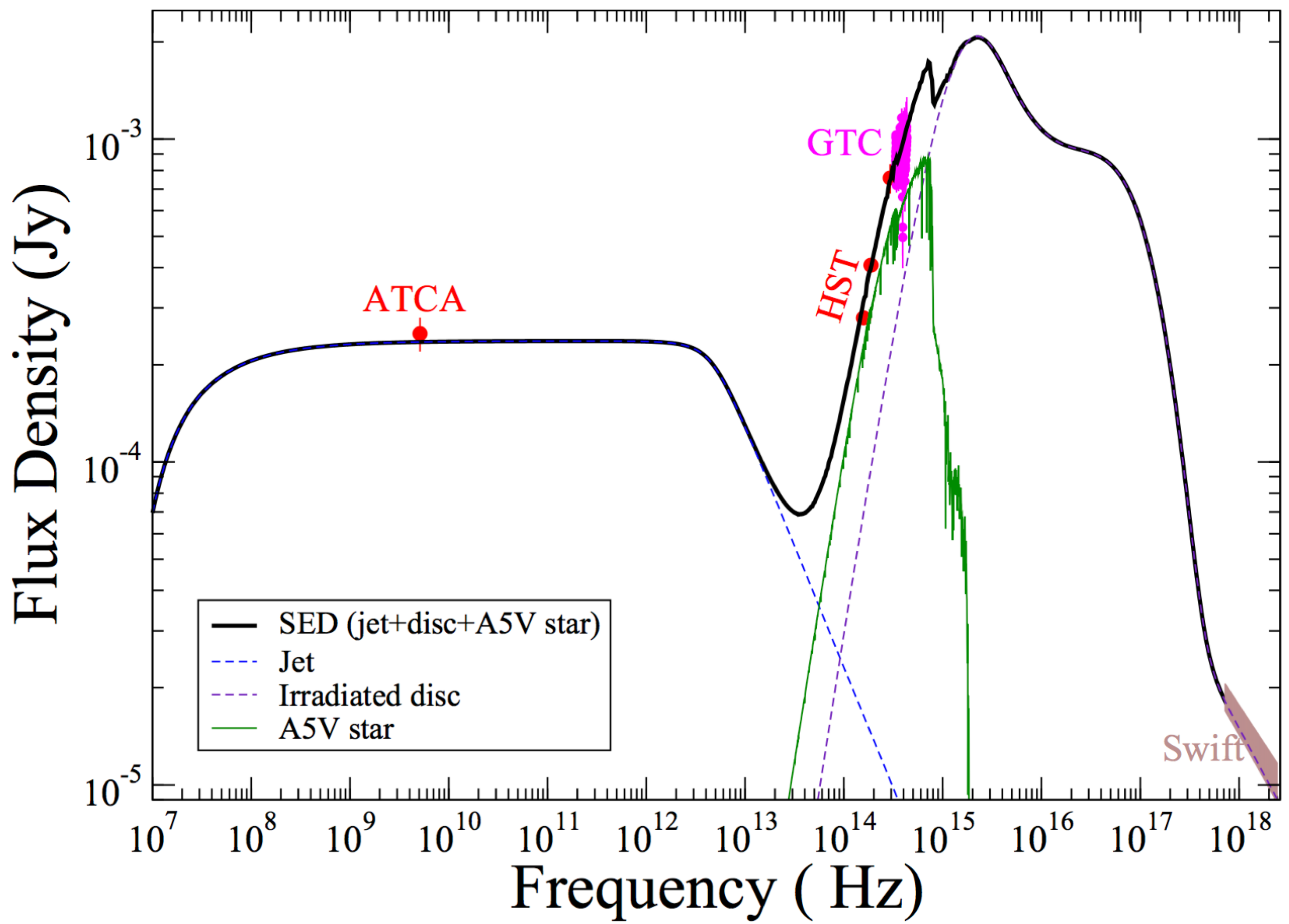


Fig. 3. Values of χ^2_{red} for the range of outer radii and spectral types explored in this paper. The SED assuming an A5V companion star provided the smallest value of this statistical indicator. The curves corresponding to B and early-type A stars are above and outside the range of this plot.

Martí et al. (2016), A&A, 596, A46

The microquasar GRS 1758−258: SED



Martí et al. (2016), A&A, 596, A46

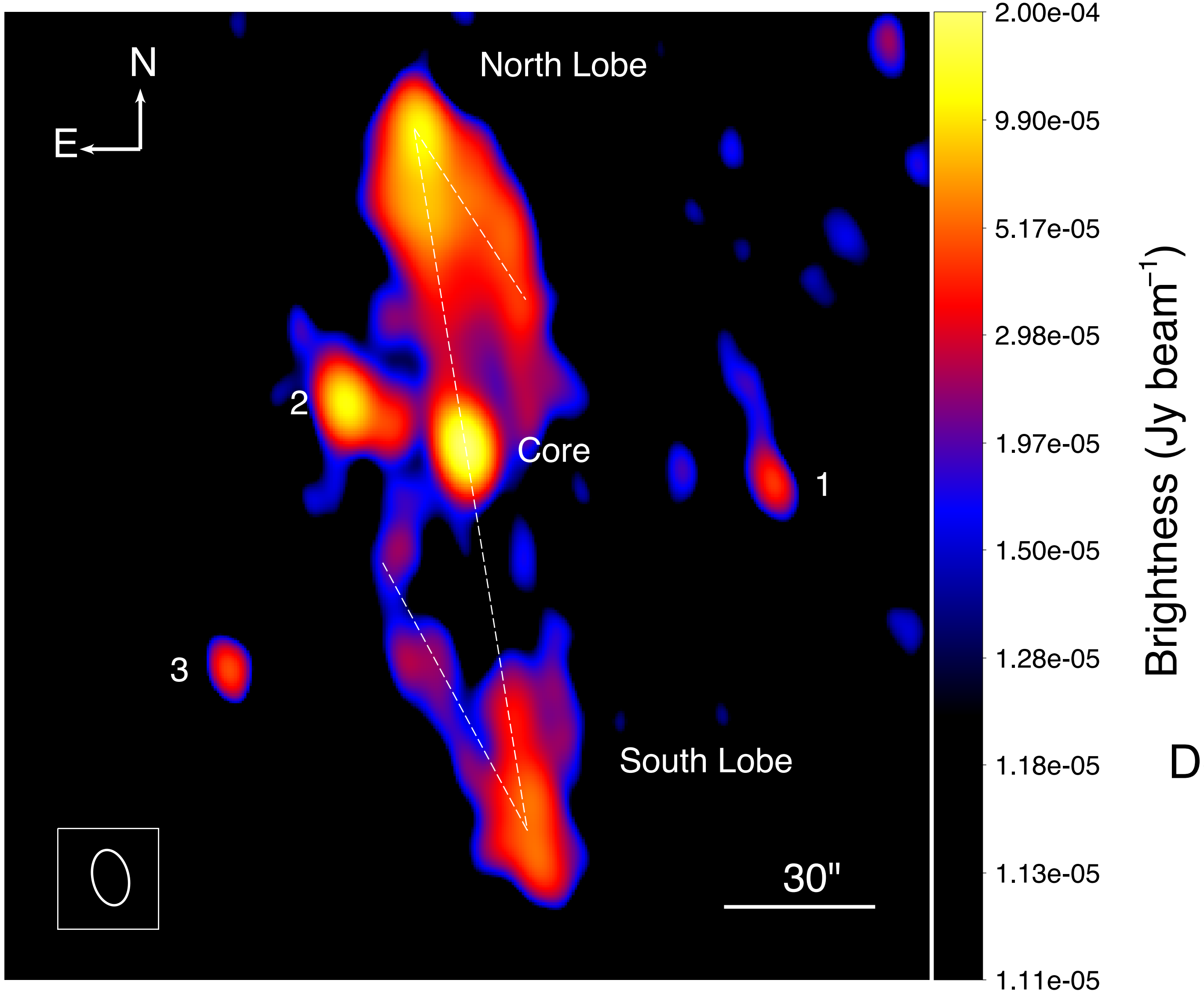
JVLA observations and historical data

Table 1. Log of VLA 6 cm observations used in this work

Project Code	VLA Conf.	Observation Date	On-Source Time (s)	Bandwidth (MHz)	rms Noise (μJy/beam)	Relative Weight*
16A-005	C	2016 Mar 04-22	7659	2048	4.3	75%
AS930	C	2008 Apr 01-12	14505	50	9.4	**
AM560	C	1997 Aug 03-24	20810	50	9.2	17%
AM428	CD	1993 Oct 03-04	6460	50		
AM345	D	1992 Sep 26-27	5690	50	11.8	8%
AM385	D	1992 Sep 10-11	8550	50		

(*) Weight indicative of contribution to final image shown in Fig. 1. For CD-D configuration data, the stated value is for the three available projects combined.
(**) Not used for imaging in Fig. 1.

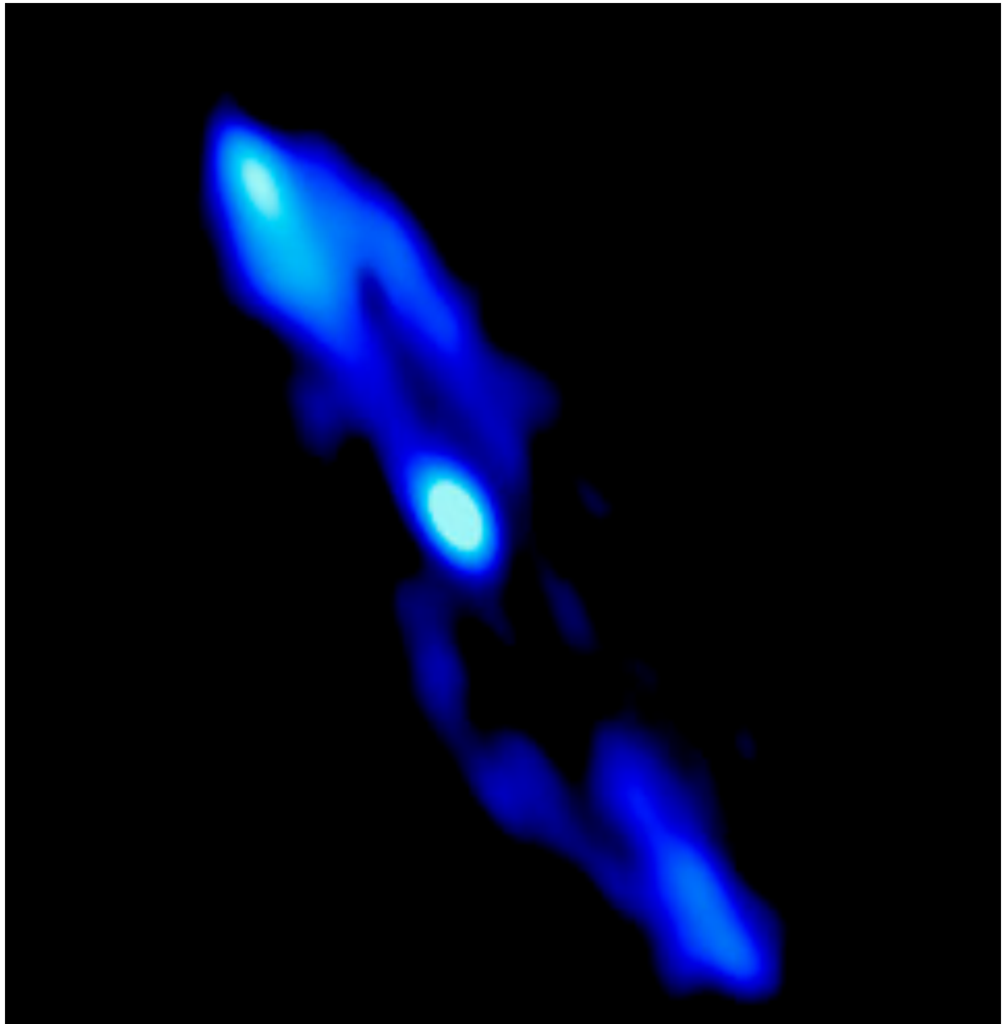
The first winged microquasar



Deep radio view of GRS 1758−258

Martí et al. 2017, Nature Communications

The first winged microquasar



GRS 1758−258 with
background sources removed

Our deep radio image reveals that GRS 1758−258 exhibit the characteristics of a Z-type winged radio galaxy

GRS 1758−258 is a galactic microquasar mimicking winged radio galaxies

- Never been observed in a microquasar, first time detection
- No merger of black holes has ever occurred in a stellar binary system such as GRS 1758−258

Consequences:

1) The analogy of quasars and microquasars extends to their terminal jet lobes
2) The spin-flip scenario is for the first time ruled out in a downsized winged jet flow

MENU

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A galactic microquasar mimicking winged radio galaxies

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Galaxies and clusters
High-energy astrophysics

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The first winged microquasar

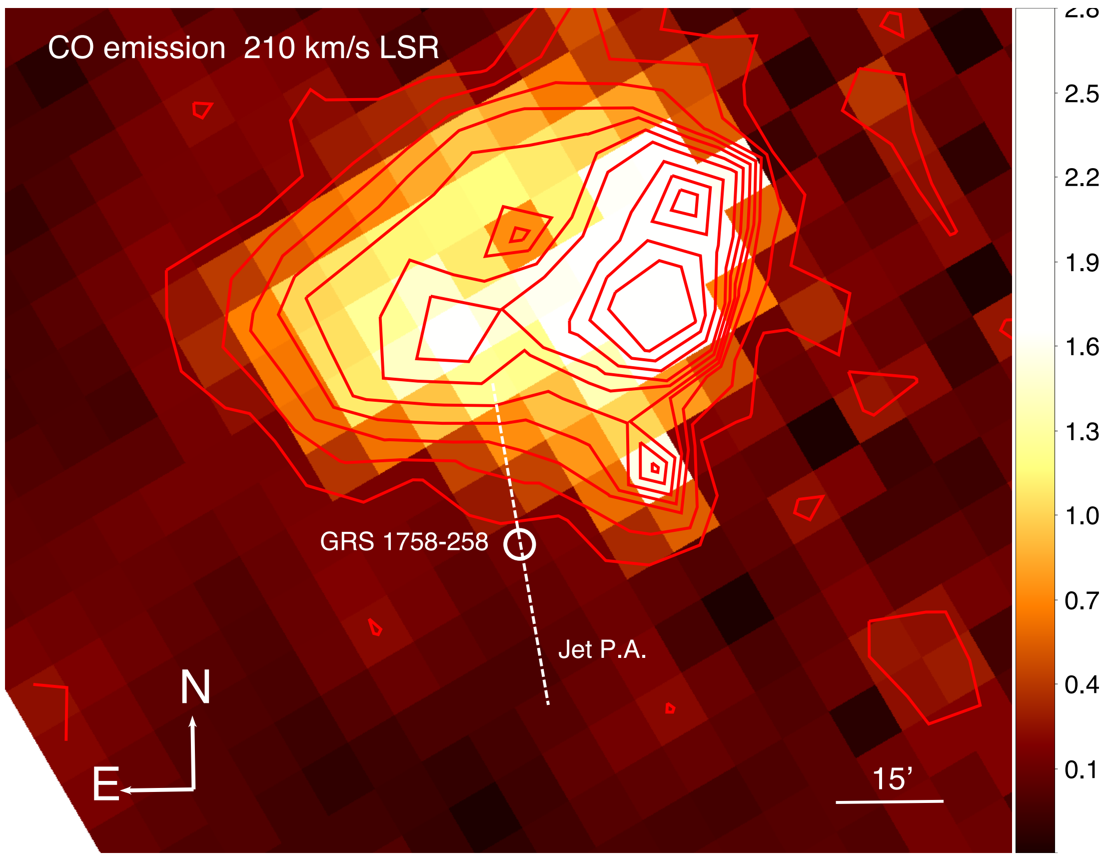
Follow-up work indicates that the jets of GRS 1758−258 are colliding with a gas cloud in the Inter Stellar Medium (ISM).

The cloud radial velocity is consistent with a distance of about 8.5 kpc, which is remarkably close the the value often adopted for GRS 1758−258.

We have thus a clear case of a relativistic jet impinging on the ISM. This renders the **hydrodynamic backflow** as the most plausible explanation of the very, very long secondary lobes of GRS 1758−258.

Martí et al. 2017, Nature Communications

ISM cloud north of GRS 1758-258



Conclusions

- **First** discovery of **Z-type** winged features in a microquasar (GRS 1758−258)

- Hydrodynamic **backflow** is the most physically plausible explanation

By extrapolating our results to its extragalactic relatives, we further conclude that:

- The quasar-microquasar **analogy** is further enhanced as it encompasses very long range effects in collimated jet flows. Relevant for radio galaxy evolution

- The winged radio galaxies **ARE NOT** secure signposts of black hole mergers

- The **gravitational wave** background must be lower than predicted. Revision needed

Acknowledgements

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Follow-up work

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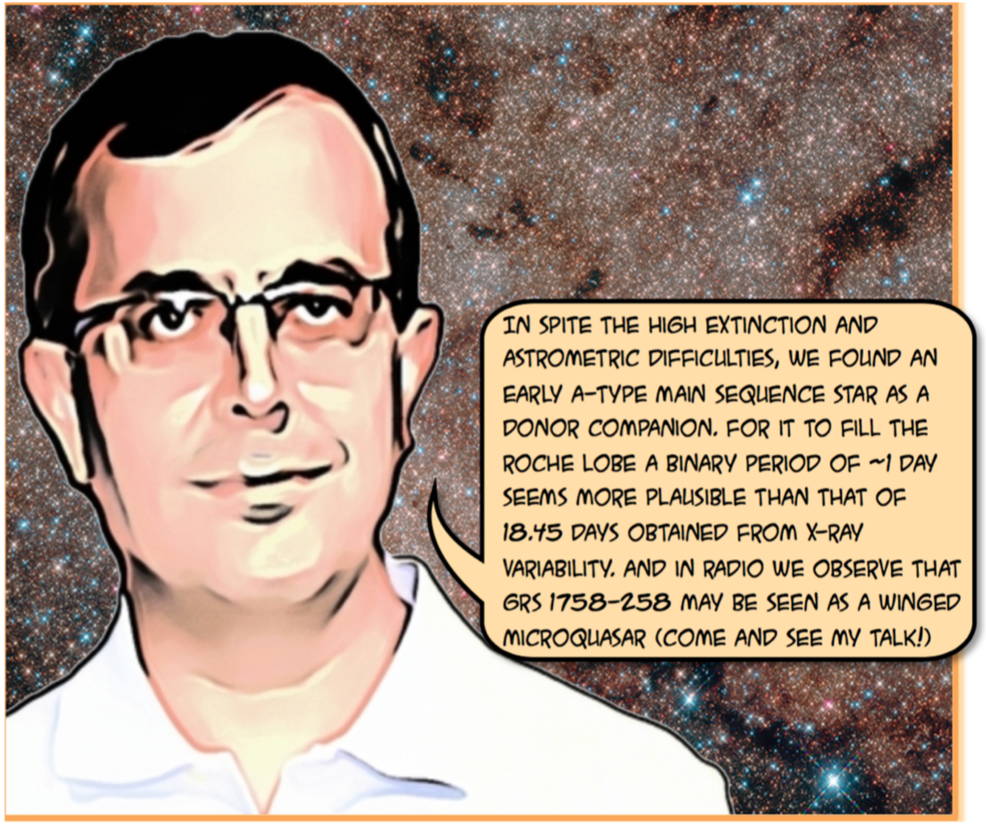
Follow-up work



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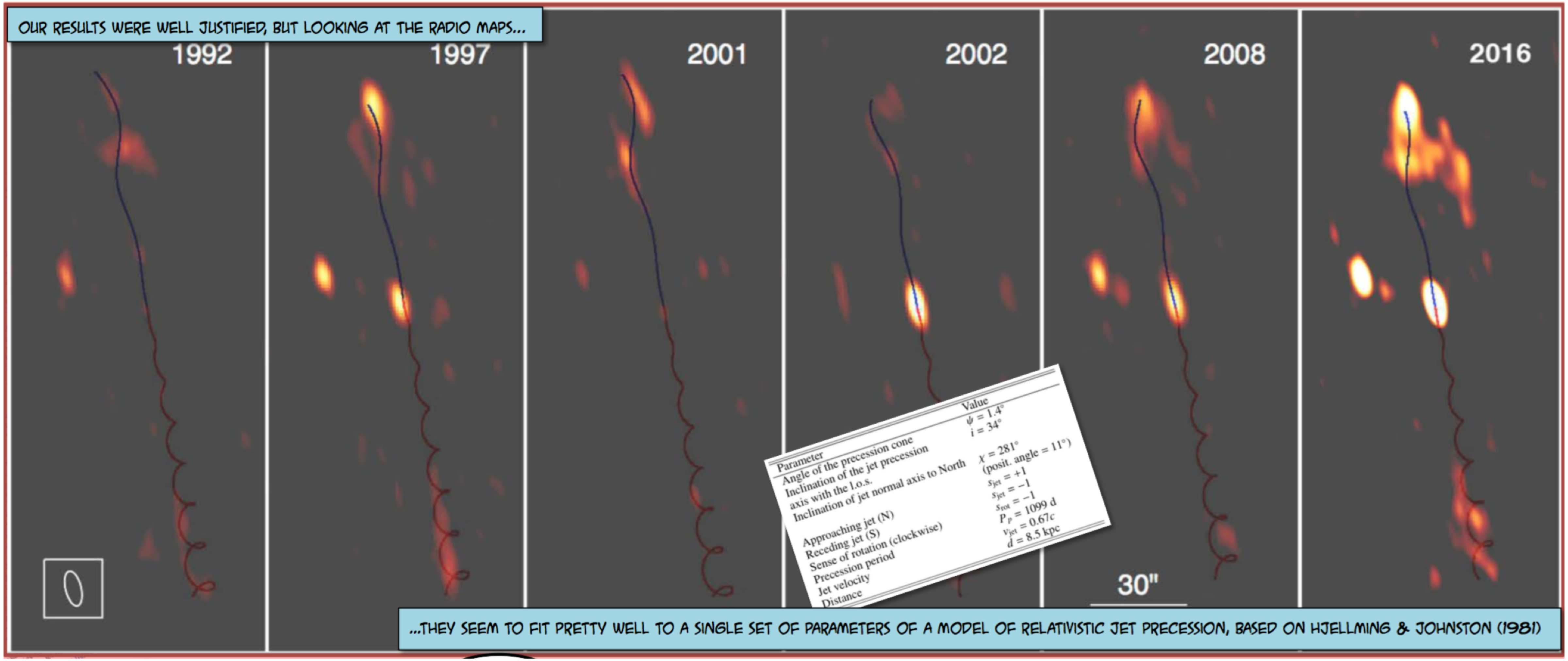
Follow-up work



Parameter	Value
Angle of the precession cone	$\psi = 1.4°$
Inclination of the jet precession axis with the l.o.s.	$i = 34°$
Inclination of jet normal axis to North	$\chi = 281°$ (posit. angle $= 11°$)
Approaching jet (N)	$s_{jet} = +1$
Receding jet (S)	$s_{jet} = -1$
Sense of rotation (clockwise)	$s_{rot} = -1$
Precession period	$P_p = 1099$ d
Jet velocity	$v_{jet} = 0.67c$
Distance	$d = 8.5$ kpc

Follow-up work