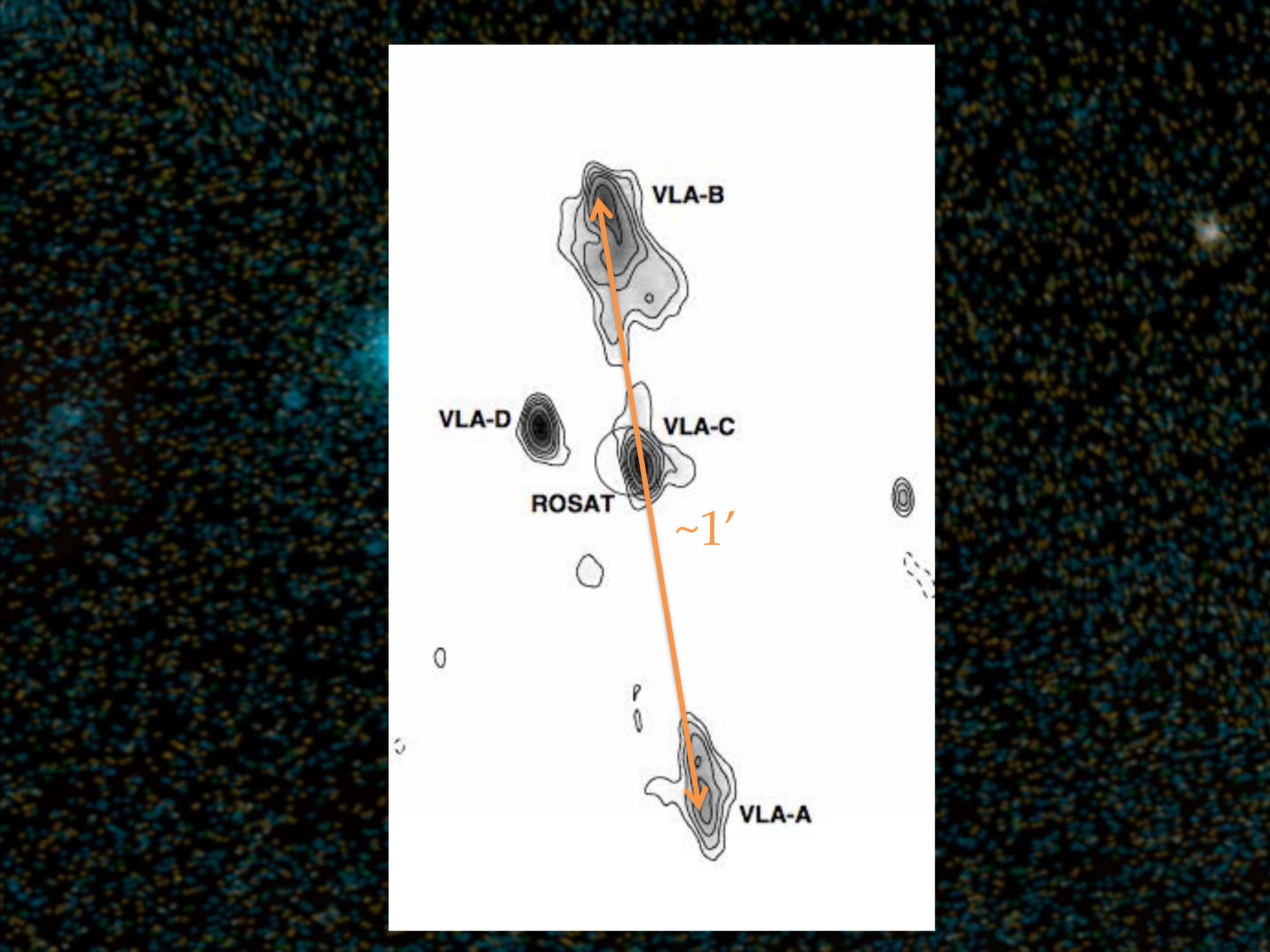
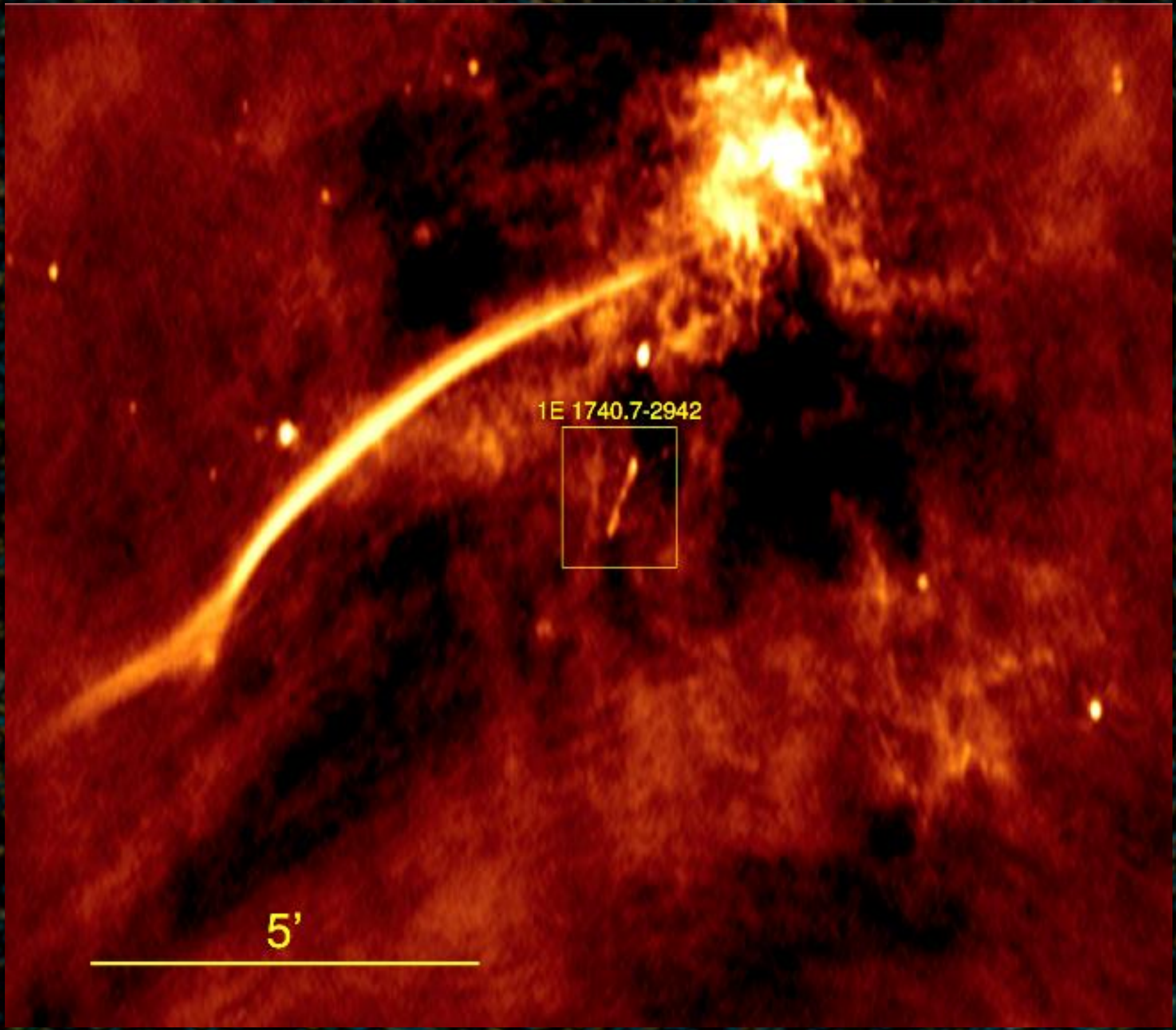
Real time evolution of large-scale relativistic jets

Pedro Luis Luque Escamilla


VLA-B
VLA-D
VLA-C
ROSAT
~1′
VLA-A

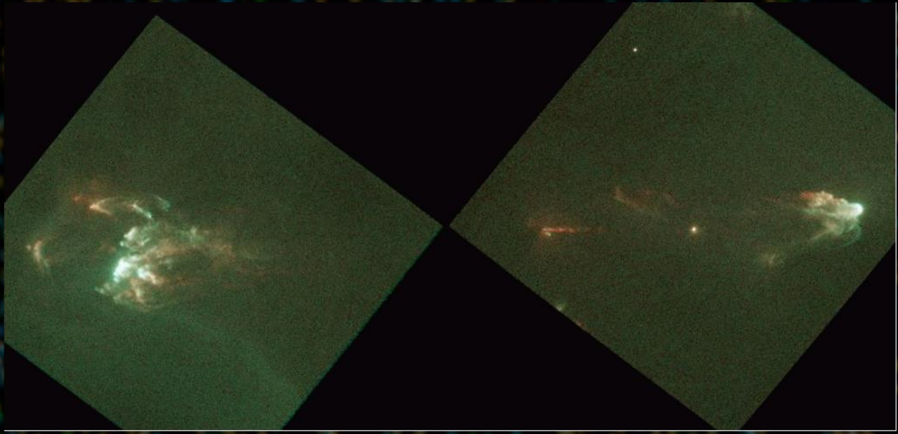
Very close to GRS 1758-258 is another prototypical microquasar

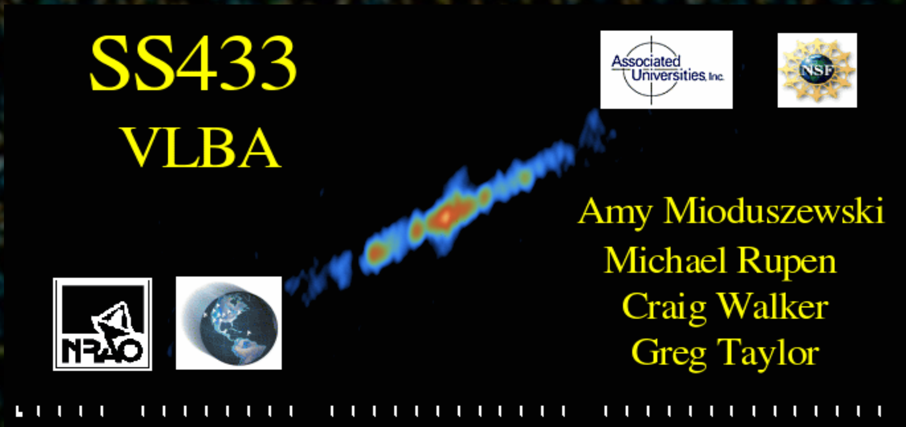


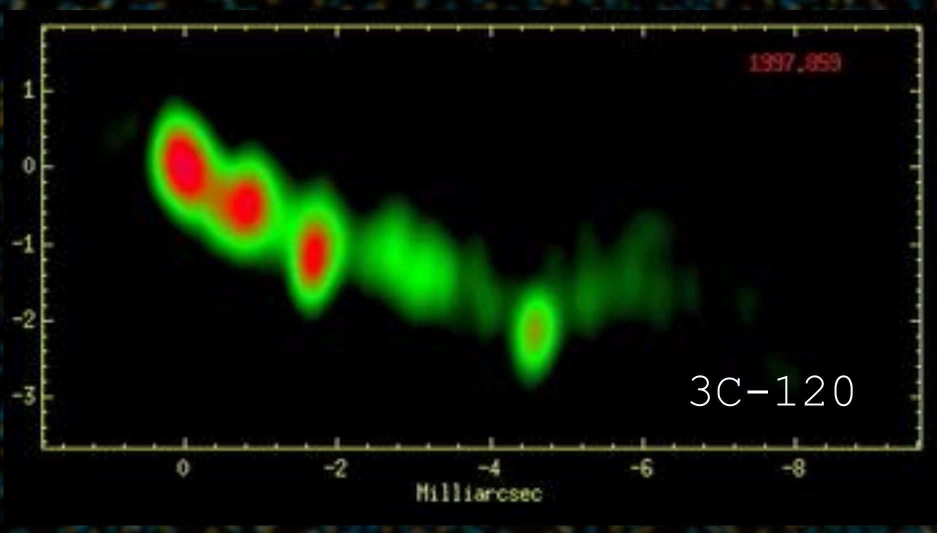
Let's state the problem!

- Modeling an ubiquitous process such as jets is a very interesting task in Astrophysics.
- But it needs observation to validate models

- Ejection of jets have been observed close to the central source from nearby Herbig-Haro objects to distant radio galaxies
- That's nice, because all the stuff happen "very fast"…
- But…



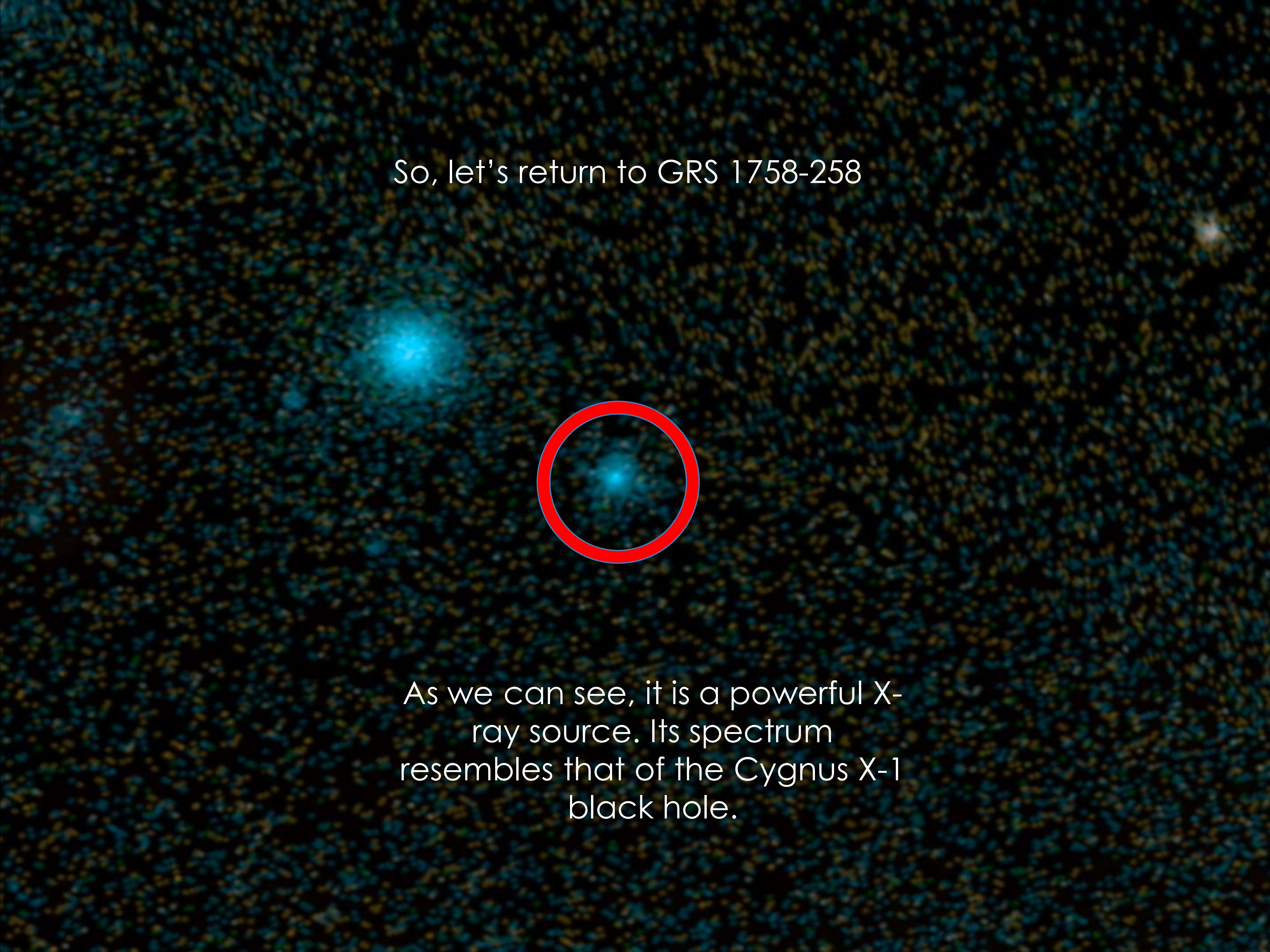


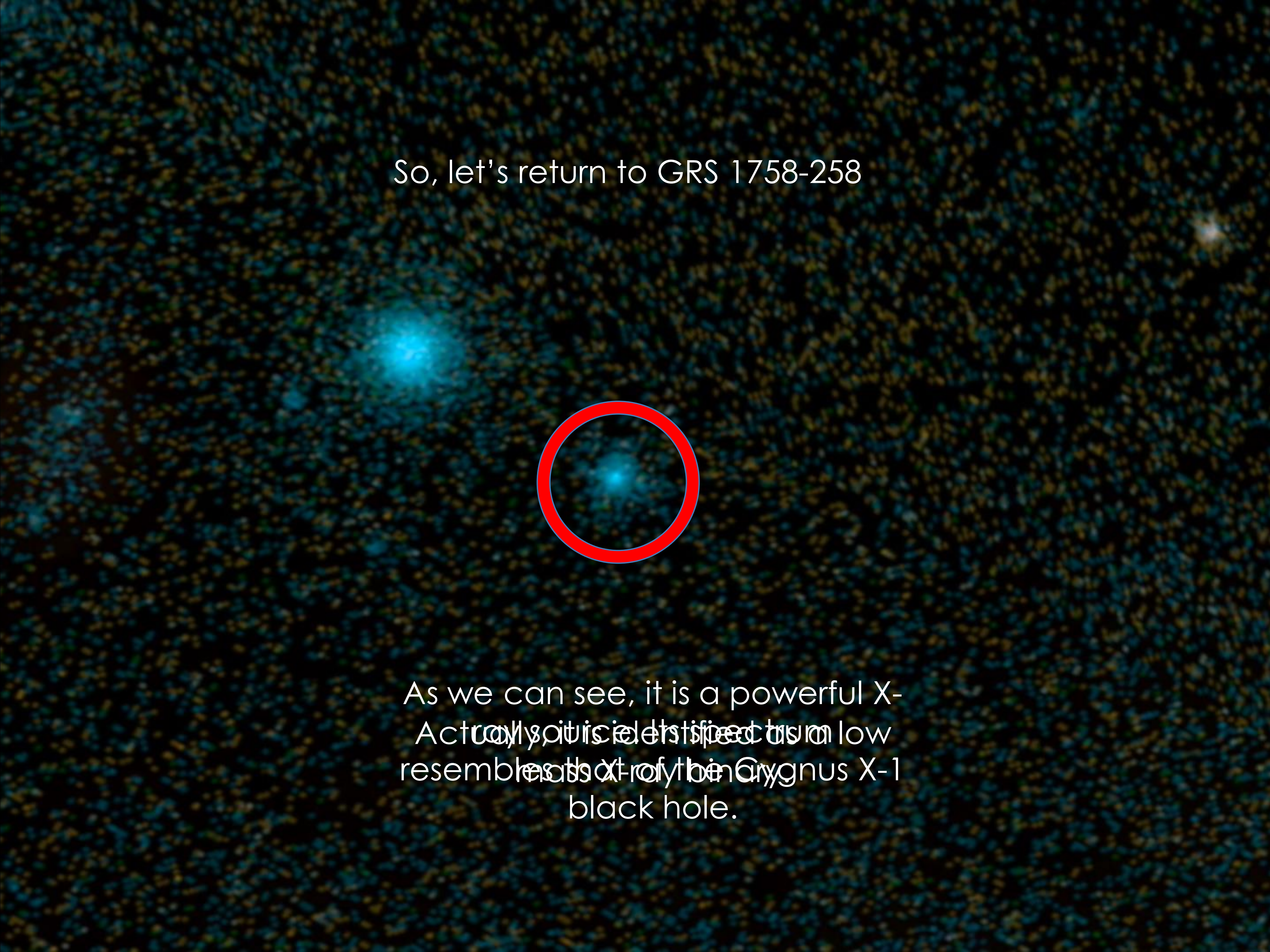


What’s happening at larger scales?

- I mean really far away from the compact central source, just when the jet interacts with surrounding medium… What’s happening just there?
- And, how does the terminal hotspots structures change, in the case they exist?
- This is a big deal still not completely solved…
- …just because we cannot test the theory, considering that it is not easy to observe the jet evolution at large scales.
- For instance, AGN jets are so huge and are so far that we cannot see them to evolve unless we wait for thousands of years! Even though jets are fully relativistic!
- It’s like what we observe in extragalactic jets were still photograms in a extremely slow-motion movie

- On the other hand, Herbig-Haro and young stellar objects are much more closer, and their jets are much shorter, but they are also much slower…
- …so, to see a noticeable evolution of jets at large scale we must wait again for hundreds or even thousands of years…
- …too much for me! However, we have nearby objects emitting relativistic jets, so that we could observe their structural variations at large scales on even "real time"!
- I'm talking about **microquasars**! There, timescales are proportional to the central compact object mass. Thus, we expect to see the jets evolution on human timescales!


So, let's return to GRS 1758-258
As we can see, it is a powerful X-ray source. Its spectrum resembles that of the Cygnus X-1 black hole.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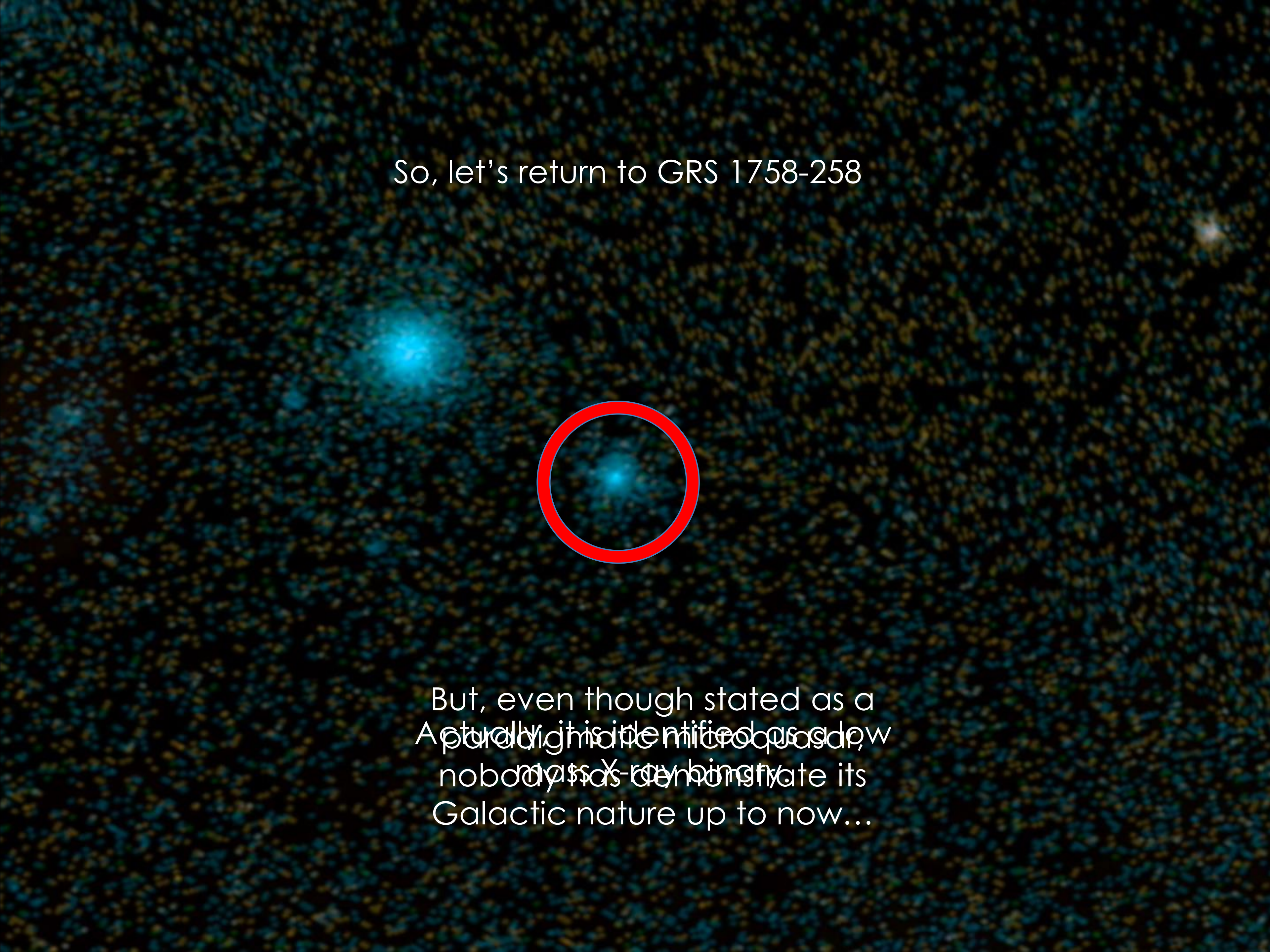
Actually, it is identified as a low mass X-ray binary.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Actually, it is identified as a low mass X-ray binary.
But, even though stated as a paradigmatic microquasar, nobody has demonstrate its Galactic nature up to now…

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LUQUE-ESCAMILLA, MARTÍ, & MUÑOZ-ARJONILLA

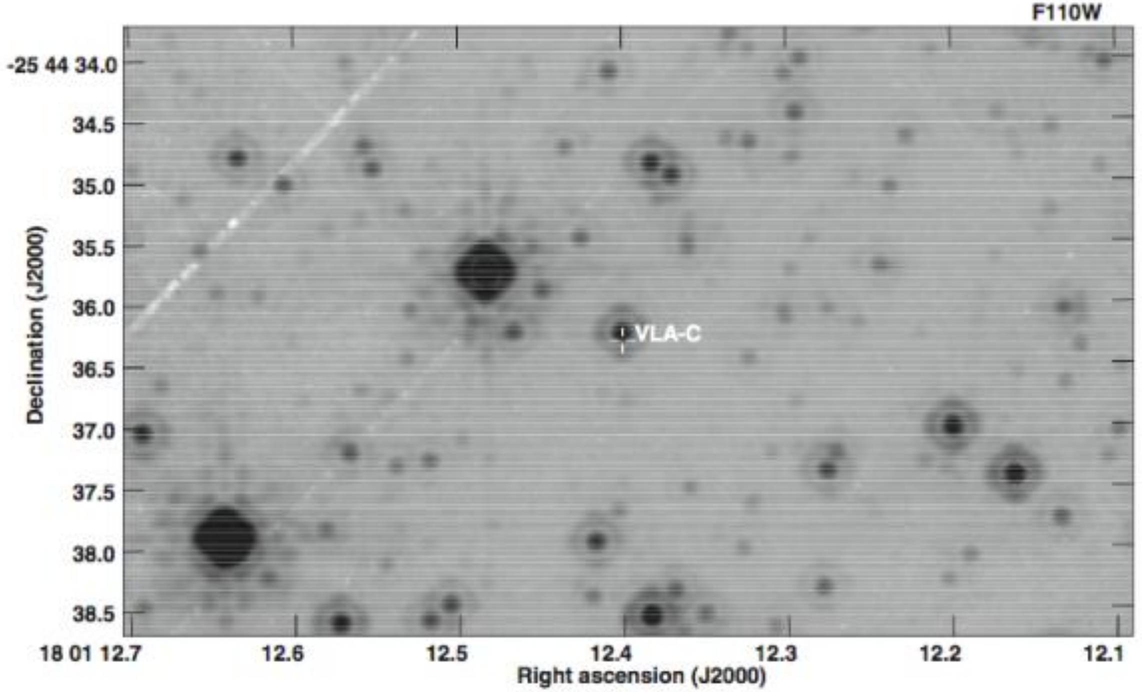
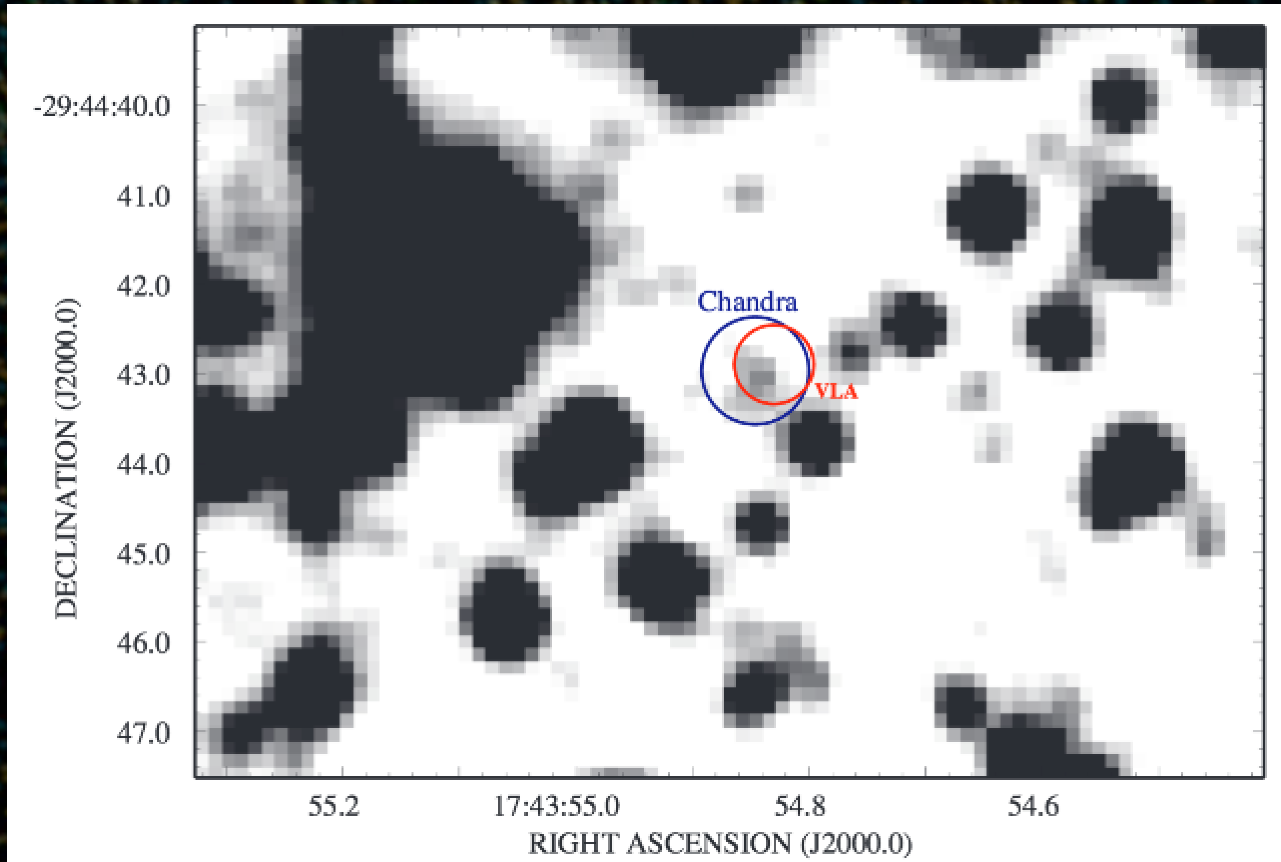


Figure 1. Representative view of the GRS 1758−258 field as observed with NICMOS in the F110W filter. This image corresponds to the first observation date reported in this Letter. Only one conspicuous point-like source is consistent with the ±0."1 accurate VLA radio position shown as a white cross. The 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.

That's because it has no obvious counterpart. Only recently, our team was capable to propose a Galactic infrared one.

But, even though stated as a candidate to microquasar, nobody has been able to probe its stochastic nature up to now...



This powerful X-ray emitter also exhibits bipolar radio jets, but nobody has demostrated its Galactic nature!

The same is true for the other paradigmatic microquasar, 1E 1740.7-2942

Recently, my group proposed a possible infrared counterpart for trying to made a spectroscopic analysis but the region is so absorbed!

Show me those changing jets!

- We chose VLA archival data with enough angular resolution (5" at 6 cm) and sensitivity to extended emission (C configuration) for both GRS 1758-258 (rigth) and 1E 1740.7-294 (down)
- They span for several years
- Some D, CD and C projects were used for a deep map of GRS 1758-258

Project Id.	Array Conf.	Observation Date	On-Source Time (s)	Central JD
AM345	C	1992 Mar 21	5280	
		1992 Apr 09	13410	2448719
		1992 Apr 11	5130	
AM415	C	1993 Aug 24	8180	
		1993 Aug 27	8150	2449226
		1993 Aug 28	8160	
AM453	C	1994 Dec 13	11260	2449707
		1994 Dec 27	12690	
AM565	C	1997 Jul 25	15070	2450657
		1997 Jul 28	16850	
AL511	C	2000 Apr 07	4490	2451642

Project Id.	Array Conf.	Observation Date	On-Source Time (s)	Central JD
AM345	C	1992 Mar 21	1770	
		1992 Apr 09	6040	2448710
		1992 Apr 11	2610	
AM560	C	1997 Aug 03	2440	
		1997 Aug 05	2440	
		1997 Aug 08	2440	
		1997 Aug 11	2160	
		1997 Aug 14	2170	2450674
		1997 Aug 15	1860	
		1997 Aug 18	2450	
		1997 Aug 20	2430	
		1997 Aug 24	2420	
AR458	C	2001 Jul 08	473	
		2001 Jul 24	533	
		2001 Aug 4	673	
		2001 Aug 9	603	
		2001 Aug 16	453	2452135
		2001 Aug 26	413	
		2001 Aug 30	403	
		2001 Sep 07	533	
AR476	C	2002 Oct 15	1453	
		2002 Oct 16	1513	2452581
		2002 Nov 11	1623	
		2002 Dec 2	1533	
AS930	C	2008 Apr 01	4840	
		2008 Apr 07	4840	2454563
		2008 Apr 12	4840	
AM345	D	1992 Sep 26-27	5690	2448892
AM428	CD	1992 Oct 3-4	6460	2448899
AR523[a]	C	2004 Apr 30	953	2453126
		2004 May 05	953	2453131

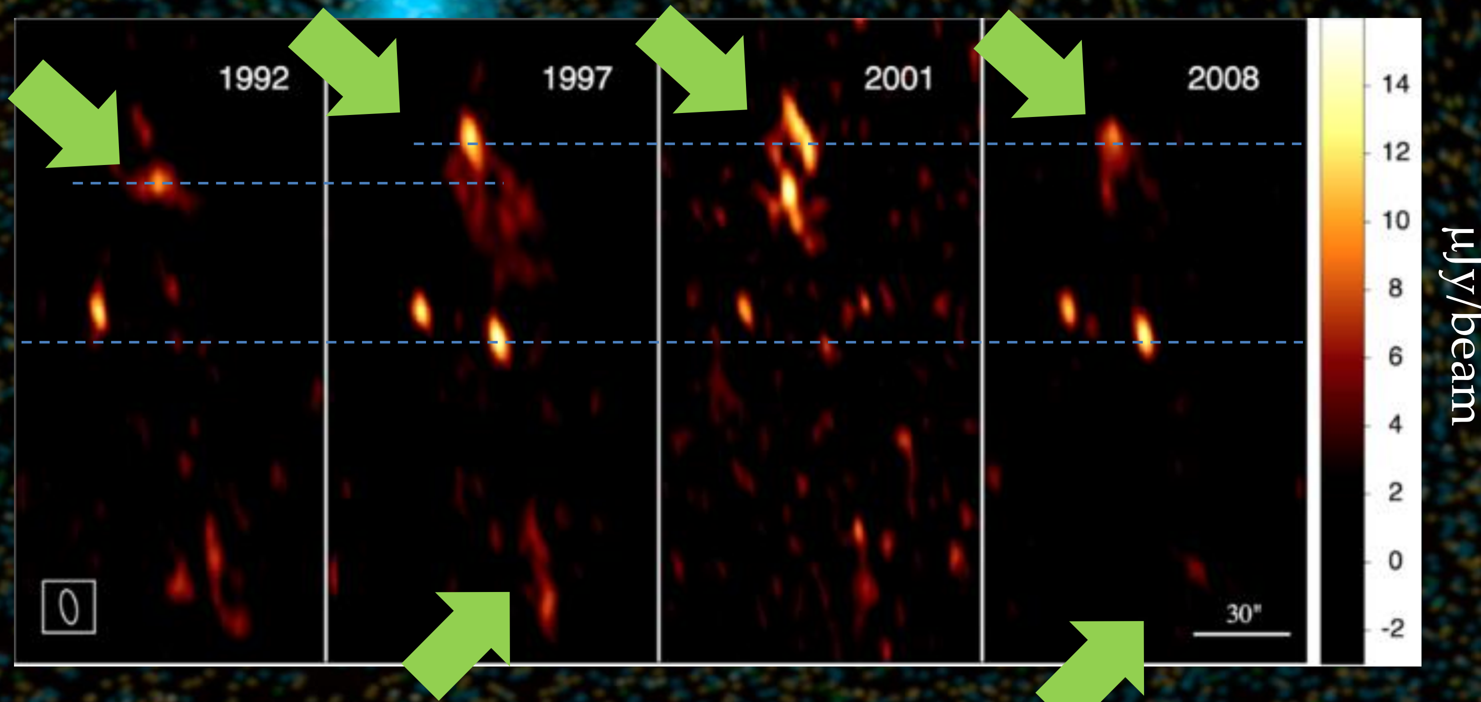
[(a)] This project had insufficent *uv* data to provide another acceptable C-configuration detection of the GRS 1758−258 jets.

- Data was recalibrated using AIPS, and taking special care to remove corrupt visibilities in both the target and the calibrator sources
- We concatenated short time slots (less than 2 months) of different VLA monitoring projects into a single observing epoch, assuming no important structural changes took place in such a period.
- We use the same angular resolution and PSF (matching beam) in each map so that they could be compared to each other.
- And thus a 6 cm radio map sequence were obtained… To maximize extended emission we applied natural weighting of the interferometric visibilities.
- Do you want to see them?

GRS 1758-258

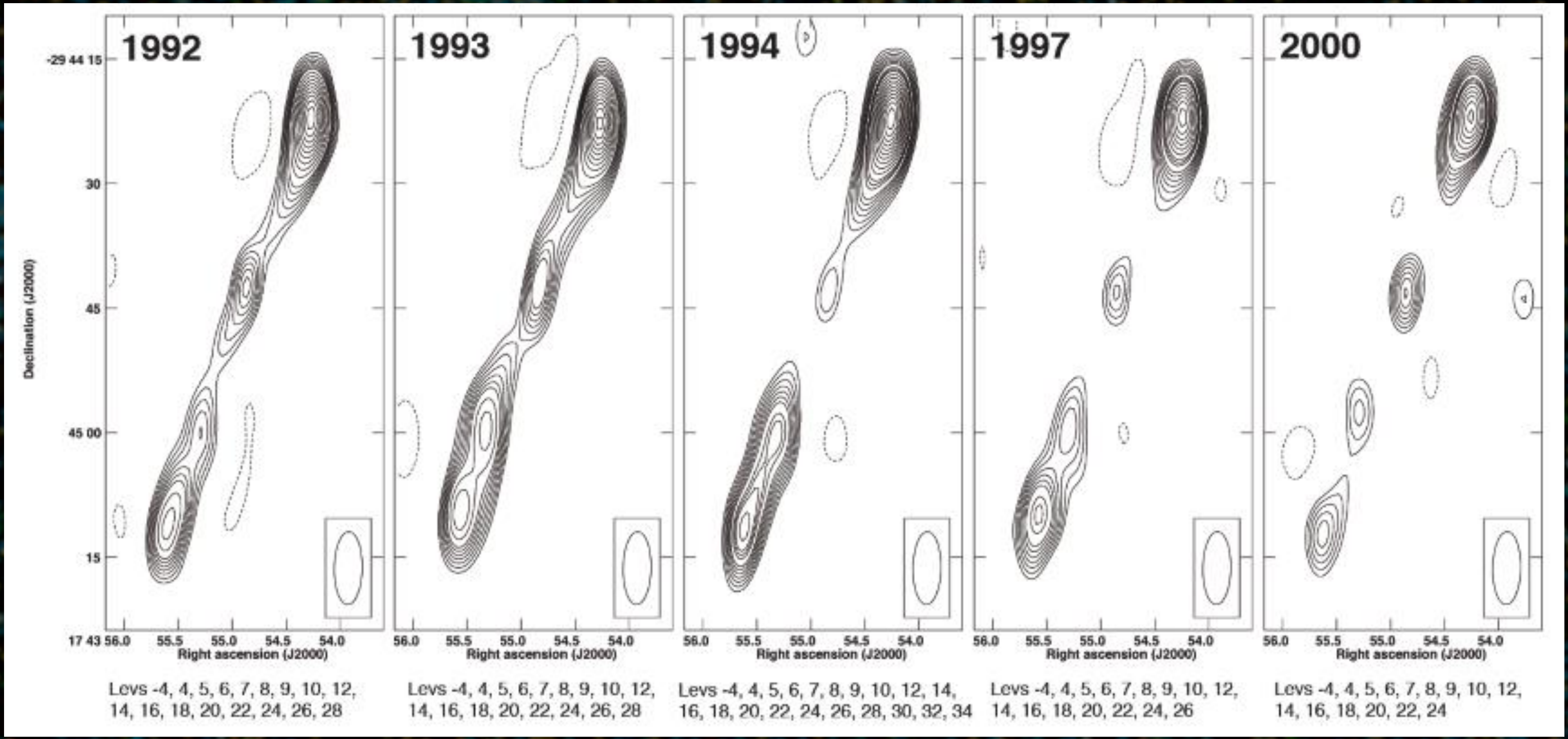
This13'' displacement in 5.4 years implies a projected velocity of 0,32c

North lobe breaks into fragments in 2001 and a new hotspot appears in 2008, 2'' away from the former one in 1997



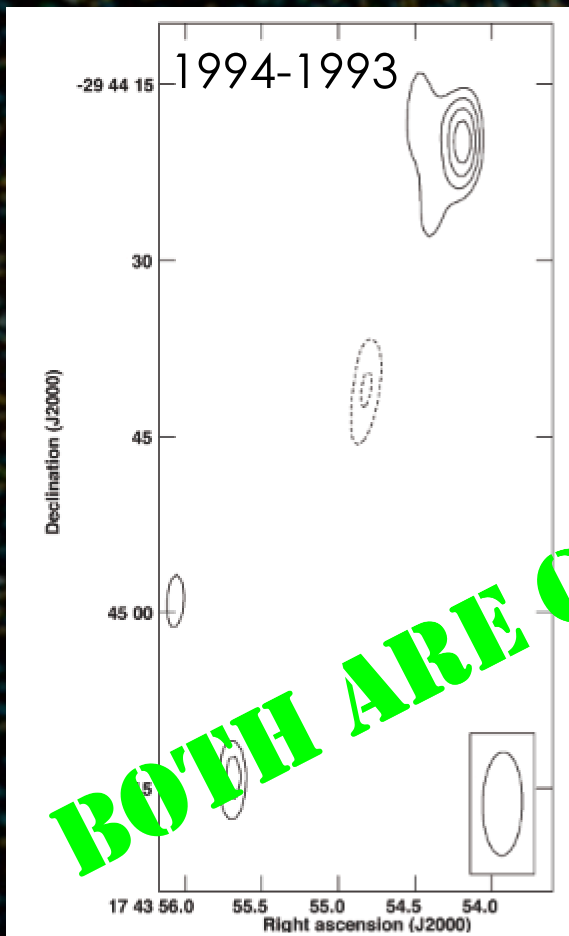
South lobe is fainter and does not exhibit a so defined structure as the North lobe. Maybe hints of precession are shown. But it dissapears in 2008, which is our more sensitive image.

1E 1740.7-294



The more continuous jet in this object changes more subtly

Are differences significative?



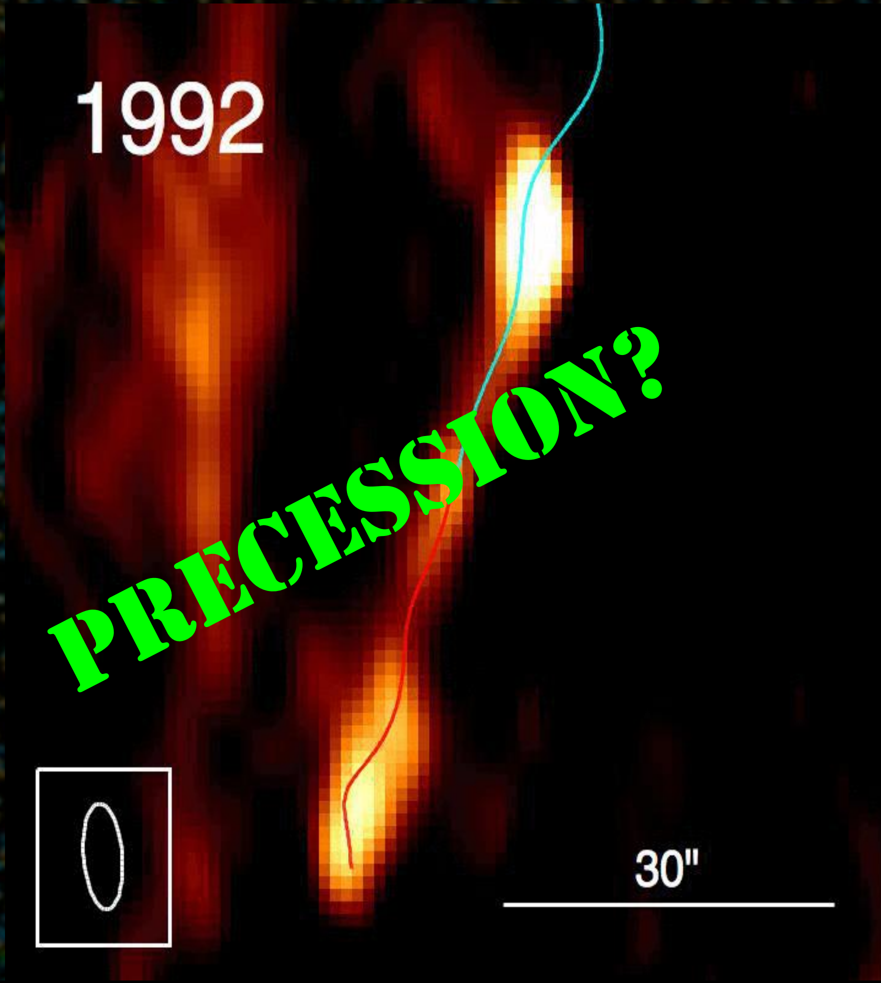
1E 1740.7-294

GRS 1758-258

BOTH ARE GALACTIC AFTER ALL!

What causes these changes?

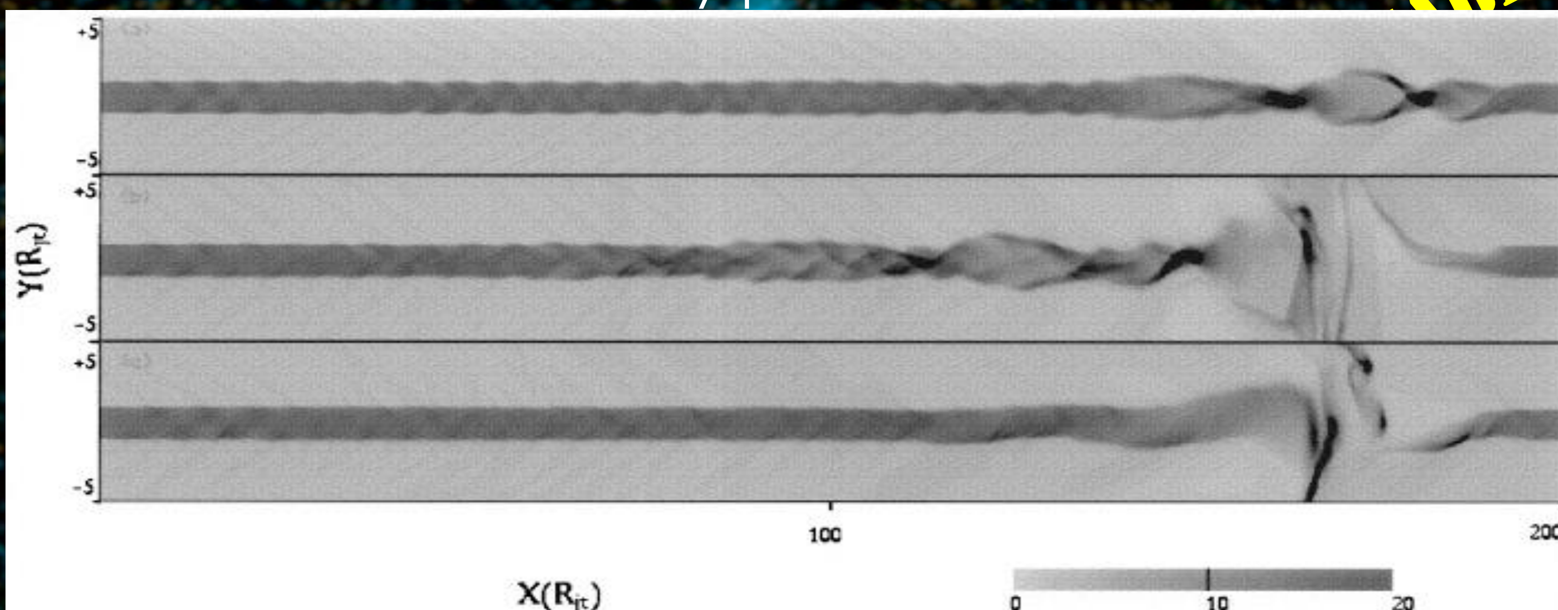
GRS 1758-258



1E 1740.7-2942

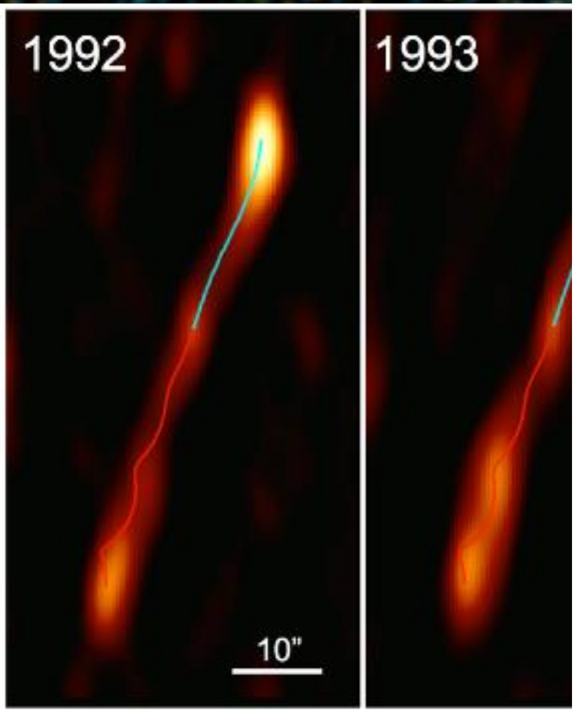
What if disruption?

- Given that cooling time for relativistic electrons by synchrotron radiation in the jet head is too long (million of years), we suggest that hydrodinamical instabilities (RT and/or KH) are responsible for the observed disruption.
- We define the instability parameter as:



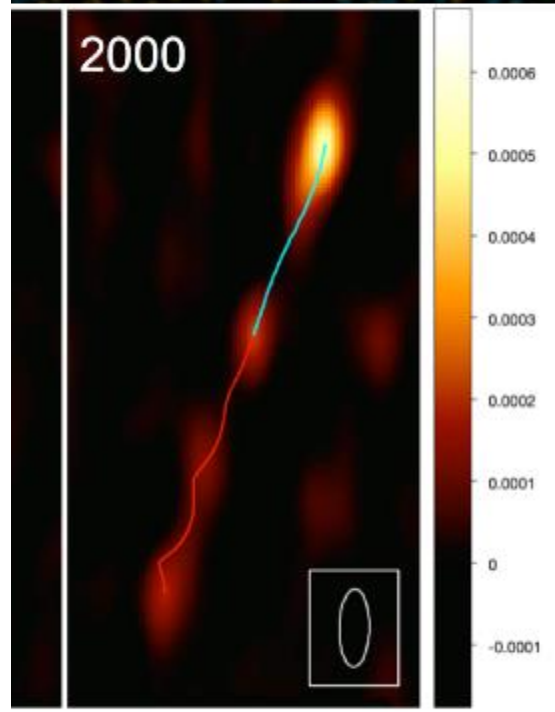
matter of months

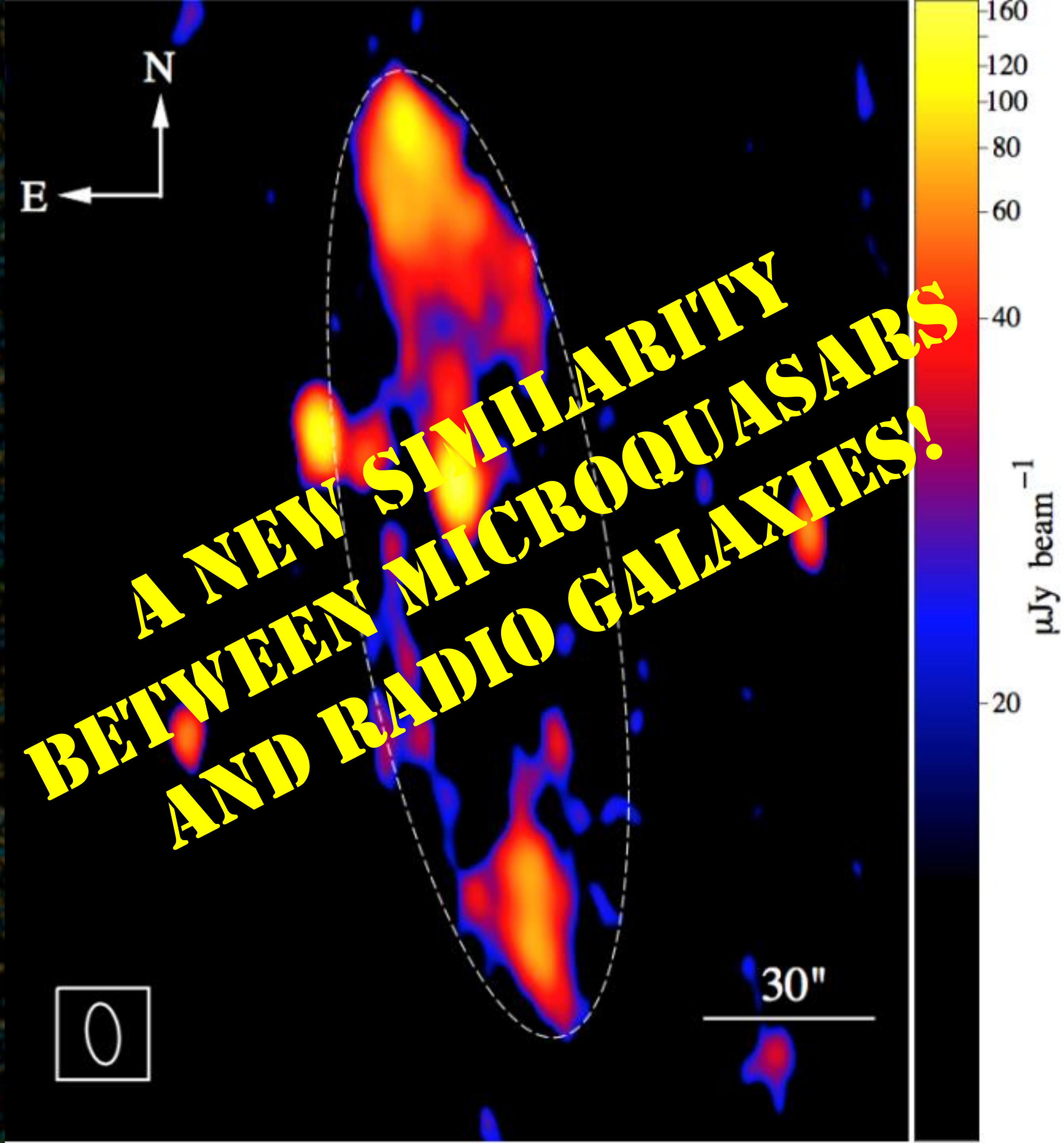
...and what if precession?



Parameter	Mathematical morphology skeleton	Maxima skeleton
Angle of the precession cone	$\psi = 1.^{\circ}8$	$\psi = 2.^{\circ}3$
Inclination of the jet precession axis with the l.o.s.	$i = 65.^{\circ}1$	$i = 63.^{\circ}0$
Position angle of the jet precession axis	$\chi = 339.^{\circ}6$	$\chi = 338.^{\circ}5$
Precession period	$P_p = 481.8$ d	$P_p = 485.5$ d
Reference JD(**)	$t_{ref} = 2448303.51$	$t_{ref} = 2448307.85$
Jet velocity	$v_{jet} = 0.96c$	$v_{jet} = 0.88c$
Distance	$d = 5$ kpc	$d = 5$ kpc
Approaching jet (N)	$s_{jet} = +1$ (fixed)	$s_{jet} = +1$ (fixed)
Receding jet (S)	$s_{jet} = -1$ (fixed)	$s_{jet} = -1$ (fixed)
Sense of rotation (counterclockwise)	$s_{rot} = +1$ (fixed)	$s_{rot} = +1$ (fixed)
Goodness of fit	$\chi^2_{red} = 1.26$	$\chi^2_{red} = 0.91$

(*) Adapted from Hjellming & Johnston (1981).
(**) Corresponding to zero precession phase.

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BETWEEN MICROQUASARS
AND RADIO GALAXIES!
N
E
30"
160
120
100
80
60
40
20
μJy beam⁻¹

Further information:

Real-time evolution of a large-scale relativistic jet

A&A 578,L11(2015) arxiv:1505.07641

The precessing jets of 1E 1740.7-2942

A&A (accepted, 2015) arxiv:1511.01425