

A GMRT study of an extended sample of X-shaped radio sources



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A GMRT study of an extended sample of X-shaped radio sources

 Biny Sebastian (NCRA-TIFR), Dharam V. Lal (NCRA-TIFR), C.C. Cheung (NRL), A. Pramesh Rao (NCRA-TIFR) and Sanjay Bhatnagar (NRAO) 

Abstract

The nature of X-shaped radio galaxies is a matter of considerable debate in the literature. From a GMRT study of 12 X-shaped sources, Lal & Rao (2007) show that the spectral characteristics of these sources, seem to fall into three categories. (A) the wings have faster spectral indices than the active lobes, (e.g. J0223-1), (B) the wings and the primary lobes have comparable spectral indices, (e.g. J0403) and (C) the wings have steeper spectral lines compared to the active lobes (e.g. J0523). The low surface brightness wings having faster radio spectral index than the active lobes in X-shaped sources is not compatible with any of the currently accepted models for their formation. The statistical understanding of nature of these sources is a must in order to investigate the mechanism of the formation of X-shaped sources in detail and hence we extended the sample of (candidate) X-shaped sources. Here, we present our preliminary results.

Few sample sources



X-shaped sources and suggested formation scenarios

- A peculiar and a small subclass of extragalactic radio sources branded the X-shaped, or "winged" sources are characterized by two low-surface-brightness lobes ("wing") oriented at an angle to the "active", or high surface brightness (active) radio lobes, giving the total source an "X" shape. These two sets of lobes usually pass symmetrically through the centre of the associated host galaxy. Merritt & Extern (2002) noted that majority of these sources are of Fanaroff-Riley type II (FR II) (Fanaroff & Riley 1974) and rest are either FR I or mixed.
- Several authors have attempted to explain the unusual structure in X-shaped sources. These have been put forth as derivatives of central engines that have got reoriented, perhaps due to a minor merger (Merritt & Extern 2002; Denzot-Thorpe et al. 2002; Gopal-Krishna et al. 2003). Alternatively, they may also result from two pairs of jets, which are associated with a pair of unresolved AGNs (Lal & Rao 2005, 2007). These, however, are not the only interpretations for the unusual morphologies; some authors suggest a hydrodynamic origin (Leahy & Williams 1984; Wierall et al. 1990; Capetti et al. 2002; Kaa' et al. 2005) and some suggest a conical precession of the jet axis (Dias 1978; Parma et al. 1985; Mark et al. 1994).
- 56 new X-shaped sources selected from a larger sample of candidate X-shaped sources (Cheung, C.C. 2007) were observed at both 240 MHz and 610 MHz. We present few of the images and spectral index maps.

Preliminary Results

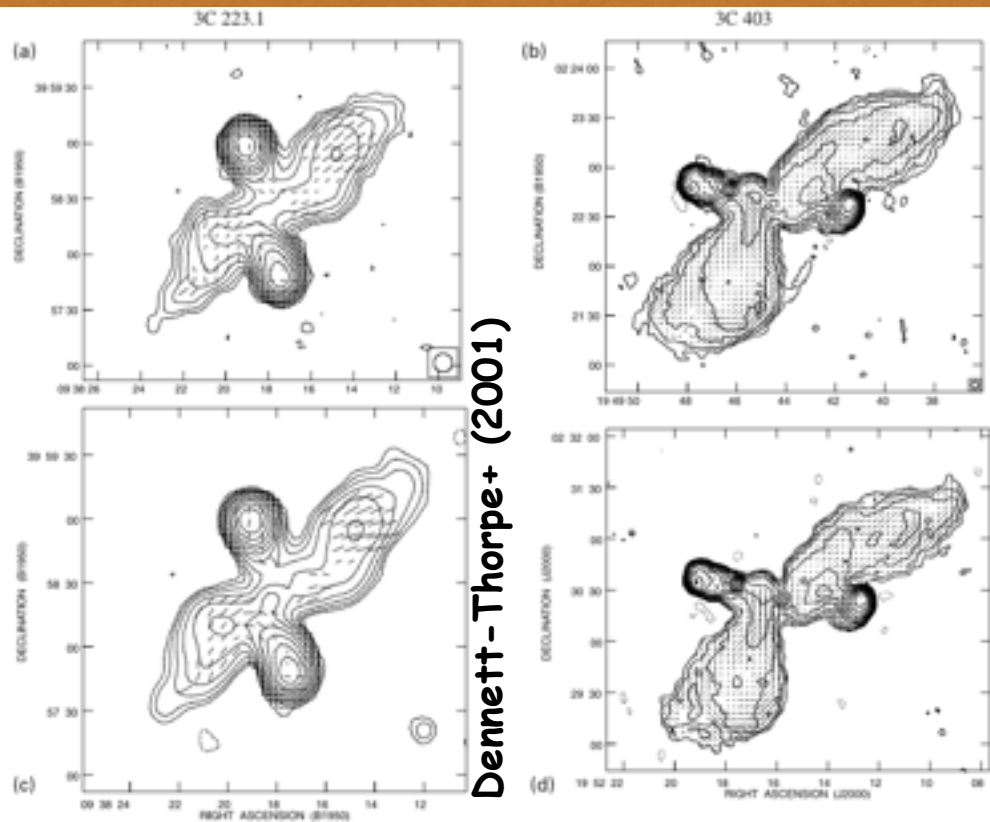
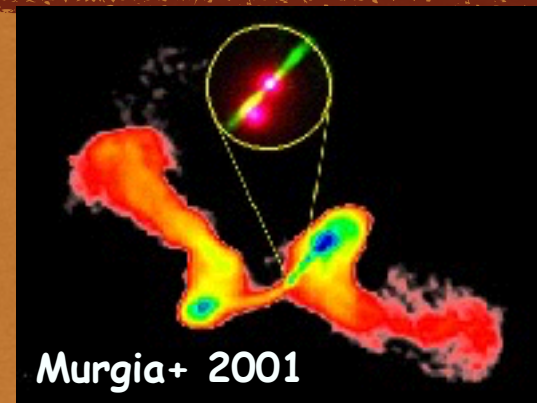
A)  **B)**  **C)** 

Intensity contours (610 MHz) and spectral index maps of A) J0115+0000 B) J1218+0915, C) J0113+0906. Above images show examples from (A) the wings have faster spectral indices than the active lobes, (B) the wings and the active lobes have comparable spectral indices, and (C) the wings have steeper spectral lines compared to the active lobes.

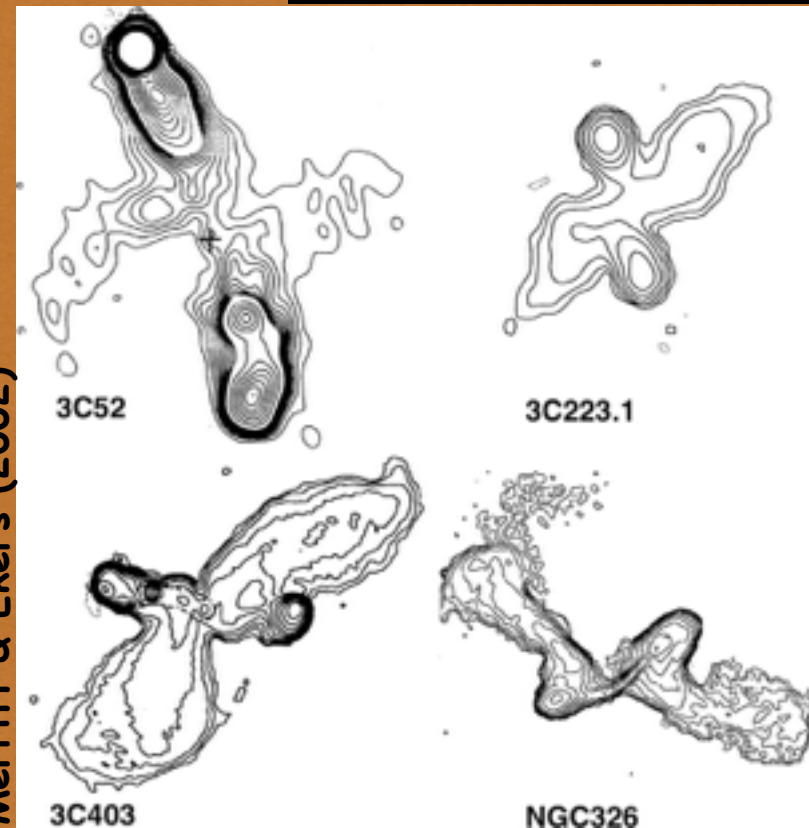
- Imaging analysis shows clear X-shaped morphology in 14 out of 16 sources.
- Majority of these are FR-II type sources. Two of the FR-II sources in our sample are shown in first row of the upper left panel.
- Morphologically only two out of our sample do not show a connection between the wings and the primary lobes, one of which has faster spectrum wings and are candidate twin AGNs. These are shown in the second row.
- Preliminary analysis shows the spectral indices in 1014 of the X-shaped are comparable implying a shorter age gap. (Denzot-Thorpe(2002)). 1/14 has steeper spectral index and 3/14 have faster spectral indices in wings.
- However, it is hard to explain the steeper spectra in the primary lobes. This could be explained using a difference in injection spectra over time or reacceleration of particles in the wings. Another possibility is simply that our current understanding of spectral aging in radio lobes, particularly at low frequencies, is incorrect.

X-shaped radio galaxies

✚ What are X-shaped radio galaxies?



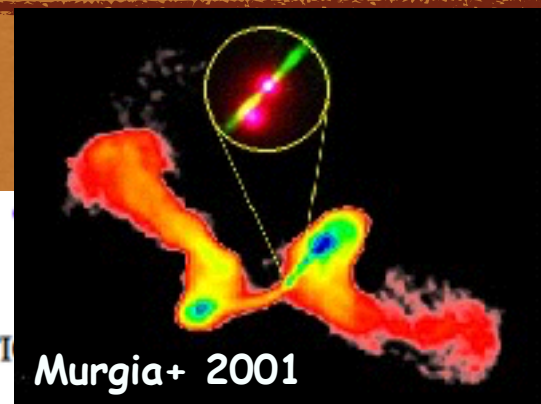
Merritt & Ekers (2002)



X-shaped radio galaxies



- ✦ What are X-shaped radio galaxies?
- ✦ Why are they important?



Murgia+ 2001

THE ASTROPHYSICAL JOURNAL LETTERS, 810:L6 (5pp), 2015 September 1

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THE ABUNDANCE OF X-SHAPED RADIO SOURCES: IMPLICATIONS FOR THE GRAVITATIONAL WAVE BACKGROUND

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ABSTRACT

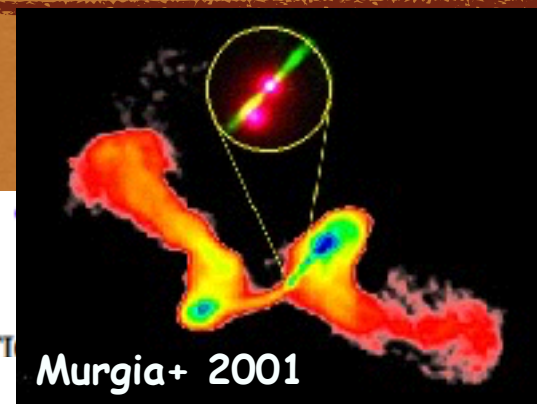
Coalescence of supermassive black holes (SMBHs) in galaxy mergers is potentially the dominant contributor to the low frequency gravitational wave background (GWB). It was proposed by Merritt & Ekers that X-shaped radio galaxies are signposts of such coalescences and that their abundance might be used to predict the magnitude of the GWB. In Roberts et al. we presented radio images of all 52 X-shaped radio source candidates out of the sample of 100 selected by Cheung for which archival VLA data were available. These images indicate that at most 21% of the candidates might be genuine X-shaped radio sources that were formed by a restarting of beams in a new direction following a major merger. This suggests that fewer than 1.3% of extended radio sources appear to be candidates for genuine axis reorientations (“spin flips”), much smaller than the 7% suggested by Leahy & Parma. Thus, the associated GWB may be substantially smaller than previous estimates. These results can be used to normalize detailed calculations of the SMBH coalescence rate and the GWB.

Key words: galaxies: active – gravitational waves – radio continuum: galaxies

X-shaped radio galaxies



- ✚ What are X-shaped radio galaxies?
- ✚ Why are they important?



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Title: What X-Shaped Sources Tell Us About Gravitational Waves

Authors: [Kohler, Susanna](#)

Publication: AAS Nova Highlight, 18 Sep 2015, id.296

Publication Date: 09/2015

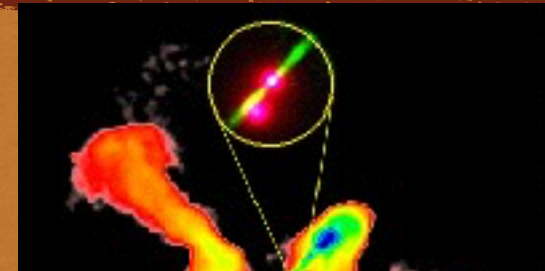
Origin: [AAS](#)

Keywords: Highlights, black holes, galaxy mergers, gravitational waves, jets, radio galaxies

Bibliographic Code: [2015nova.pres..296K](#)

X-shaped radio galaxies

- What are X-shaped radio galaxies?
- Why are they important?
- How many are known in the literature?



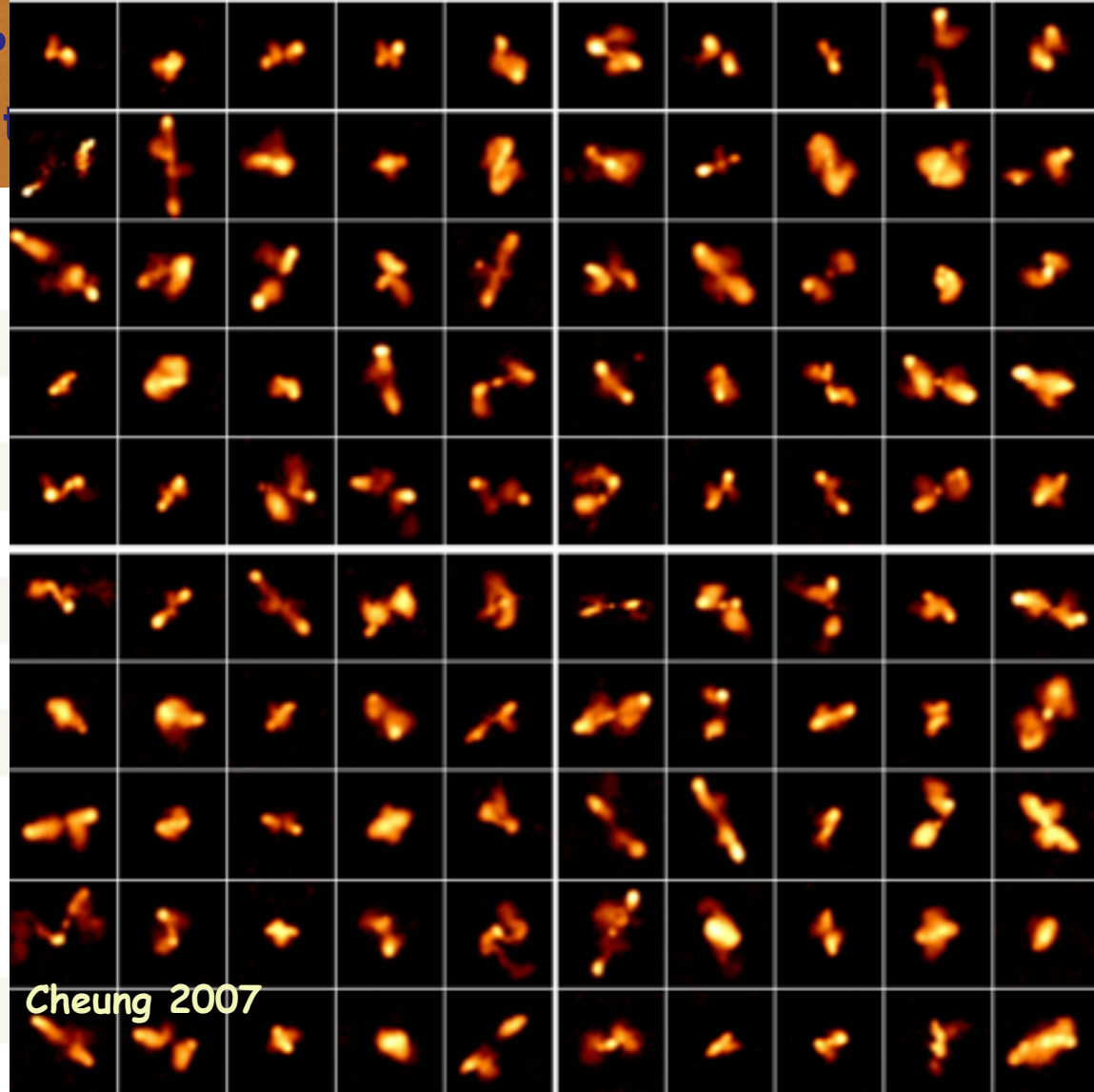
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3C52	0.2854	18.5		Dust disk
3C136.1	0.0640	17		Double nucleus or merger remnant
3C223.1	0.1075	16.6	<35 My (20)	Dust disk
3C315	0.1083	18.3		Substructure
3C403	0.0590	16.5	<17 My (20)	
3C433	0.1016			Dust/star formation
4C12.03	0.1100	17.8		
4C48.29	0.0530	16.0		
B2 0055+26	0.0487	13.0	~70 My (26)	Double galaxy
(NGC 326)				
B2 0828+32	0.0527	15.1	<75 My (27)	
B1059+169	0.0677	15.2		
(Abell 1145)				

X-shaped radio galaxies

- What are X-shaped radio galaxies?
- Why are they important?
- How many are known in the universe?



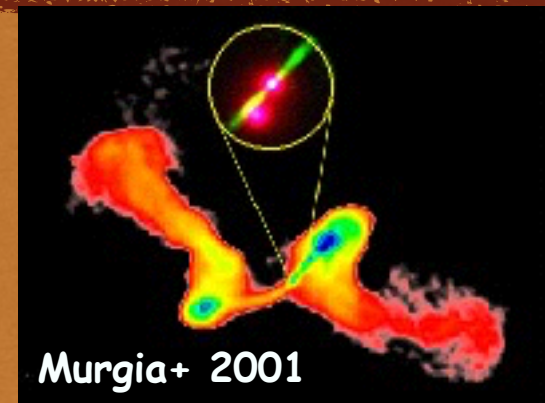
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Cheung 2007

X-shaped radio galaxies

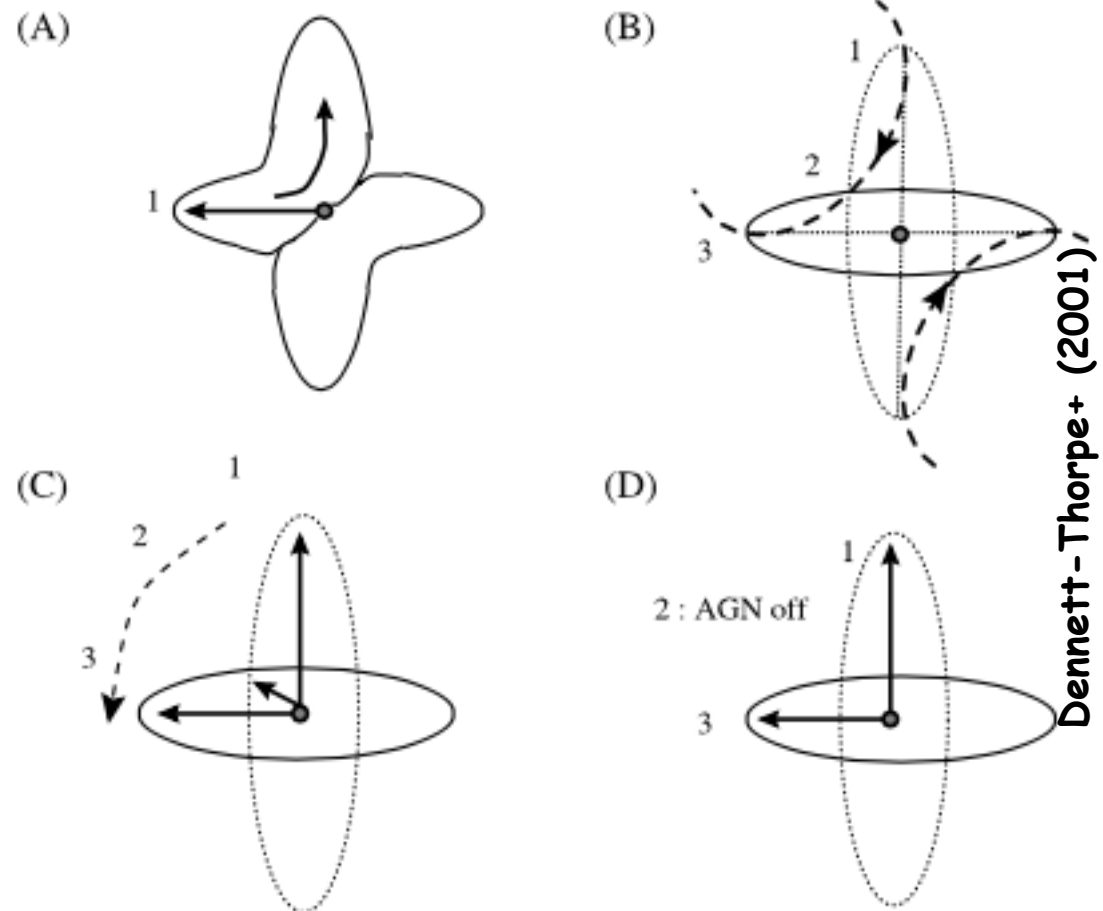
- ⊠ What are X-shaped radio galaxies?
- ⊠ Why are they important?
- ⊠ How many are known in the literature?
- ⊠ What are their formation mechanisms?



X-shaped radio galaxies

Formation models

- ⊠ - Backflow from the active lobes into the wings.
- ⊠ - Slow, conical precession of the jet axis.
- ⊠ - Reorientation of the jet axis during which the flow continues.
- ⊠ - As model C, but with the jet turned off or at greatly reduced

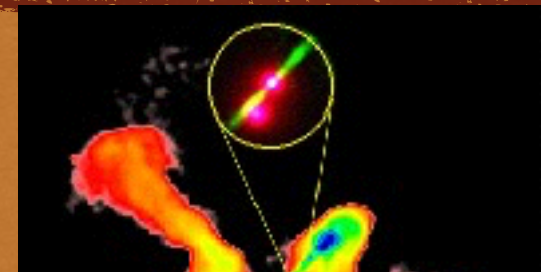


Dennett-Thorpe+ (2001)

Figure 7. Sketch of formation models. (A) Backflow from active lobes. (B) Slow 'conical' precession of jet axis. In order to see the X-shaped morphology, the surface of the precession cone has to pass close to the line of sight at point 2. (C) A reorientation of the jet axis, during which the AGN continues jet production. (D) A reorientation of the jet axis between two distinct phases of AGN activity.

X-shaped radio galaxies

- What are X-shaped radio galaxies?
- Why are they important?
- How many are known in the literature?
- What are their formation mechanisms?



- Spectral index maps as a test - formation models?

Features

Dust disk

Double nucleus or merger remnant

Dust disk

Substructure

<17 My (20)

Dust/star formation

Double galaxy

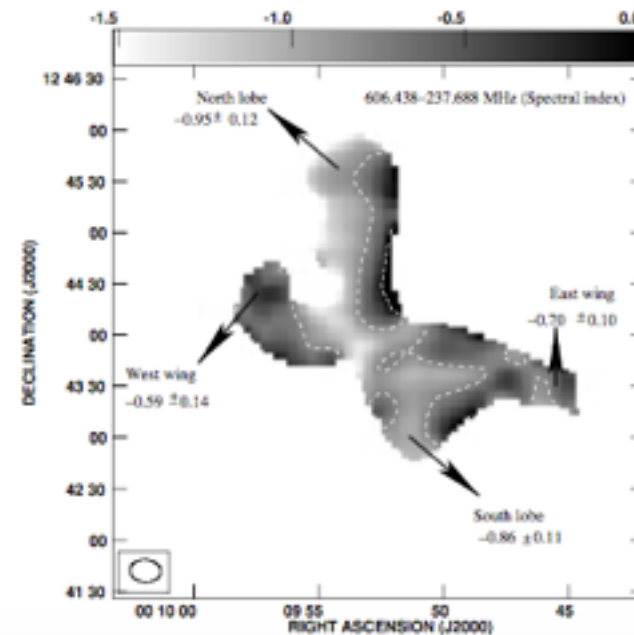
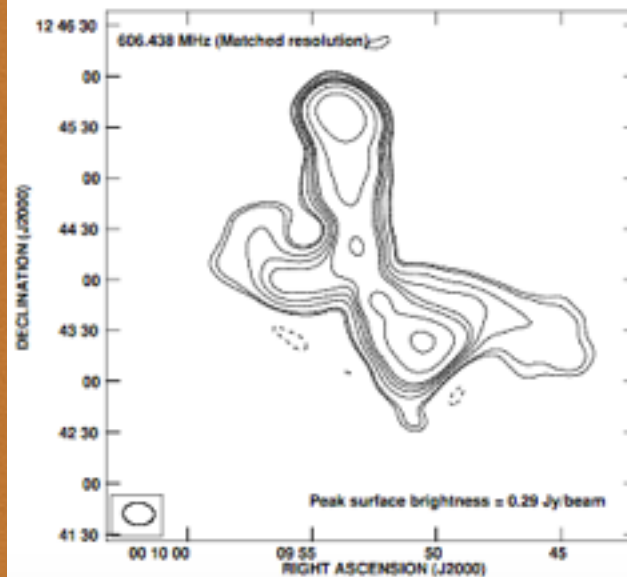
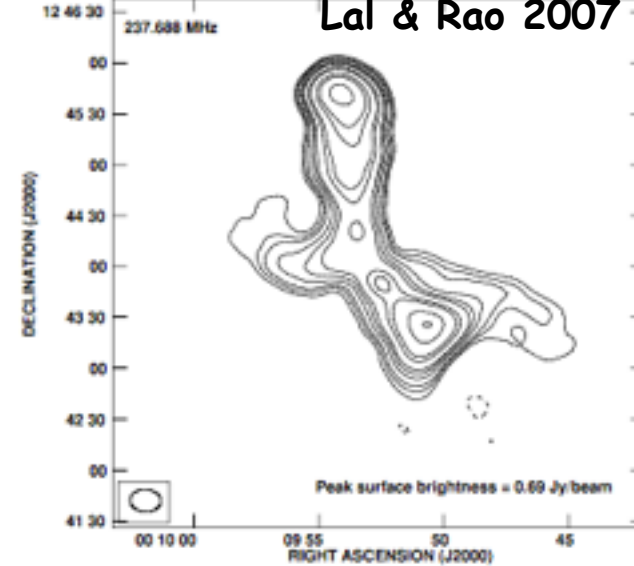
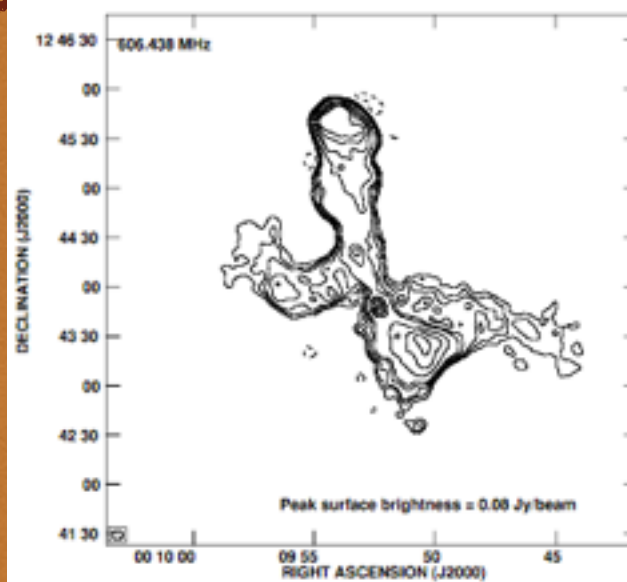
Merritt & Ekers (2002)

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X-shaped radio galaxies

- ⊕ A The wings are flatter than the active lobes

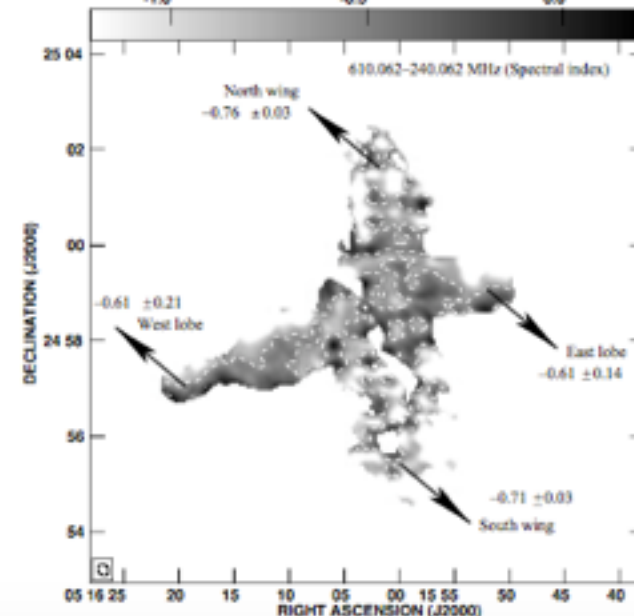
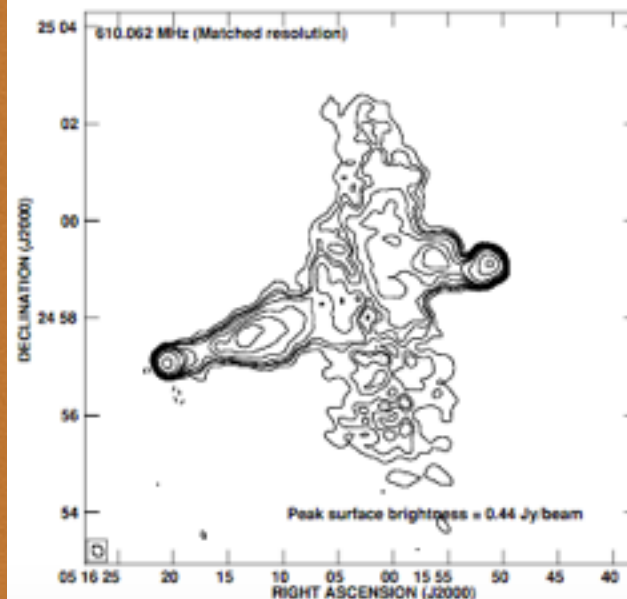
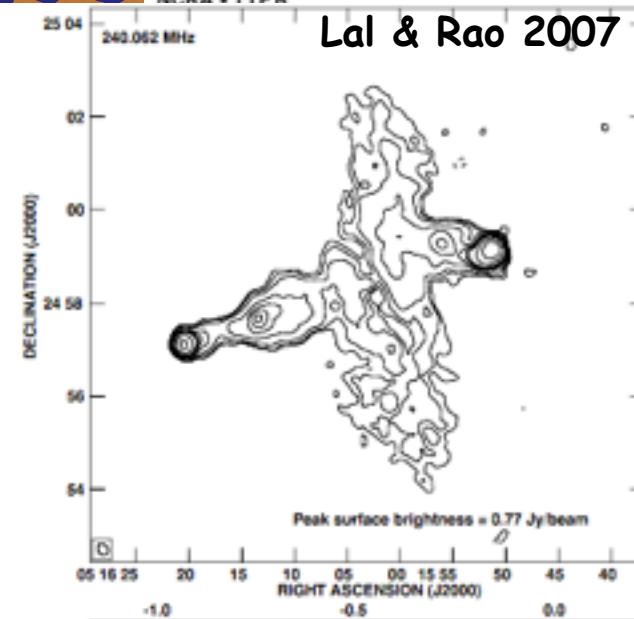
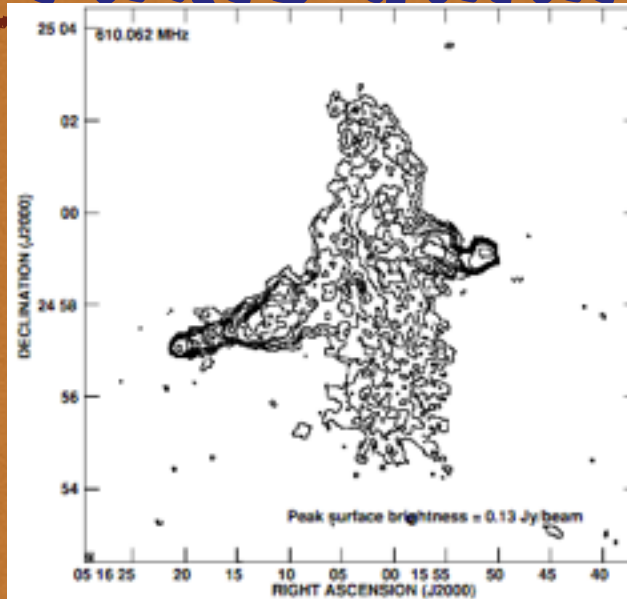
Lal & Rao 2007



X-shaped radio galaxies

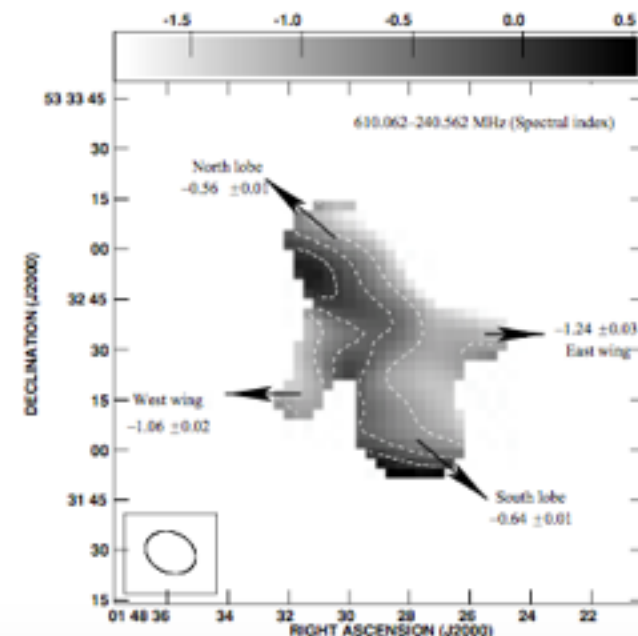
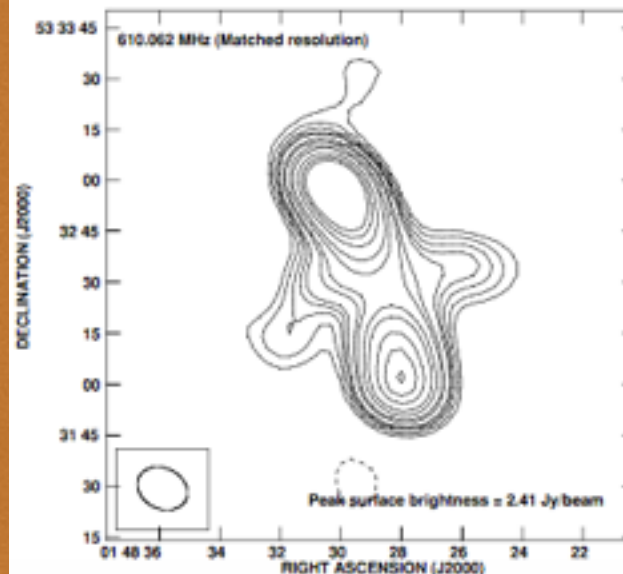
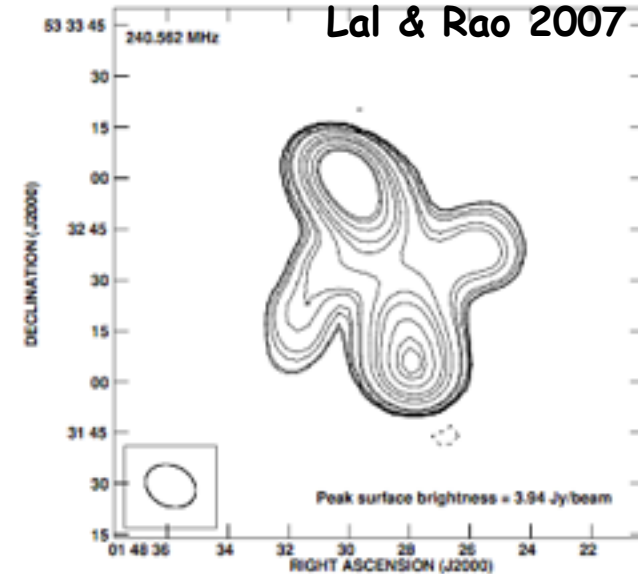
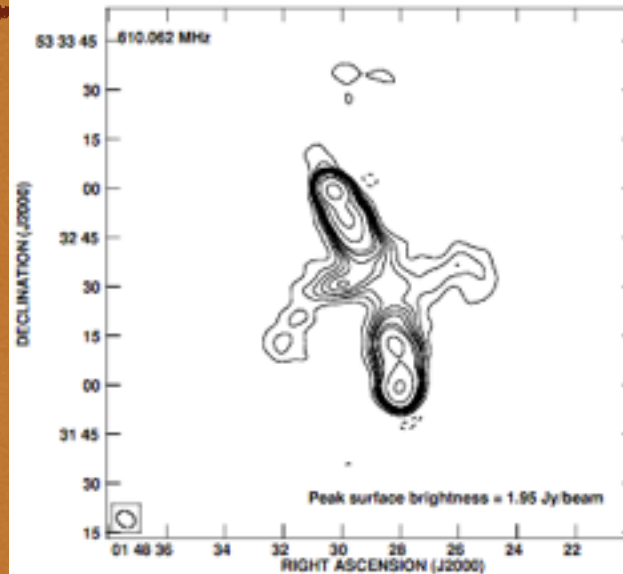
Lal & Rao 2007

- ⊞ A The wings are flatter than the active lobes
- ⊞ B The wings and the active lobes have comparable spectral indices



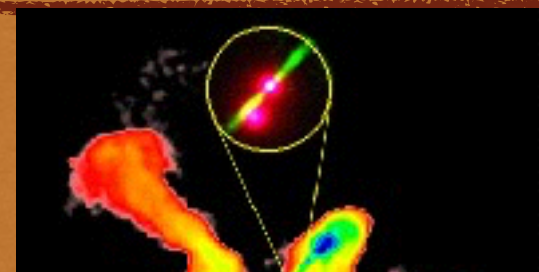
X-shaped radio galaxies

- ⊞ A The wings are flatter than the active lobes
- ⊞ B The wings and the active lobes have comparable spectral indices
- ⊞ C The wings are steeper than the active lobes



X-shaped radio galaxies

- What are X-shaped radio galaxies?
- Why are they important?
- How many are known in the literature?
- What are their formation mechanisms?



- Spectral index maps as a test - formation models?

Features

Dust disk

Double nucleus or merger remnant

Dust disk

Substructure

Dust/star formation

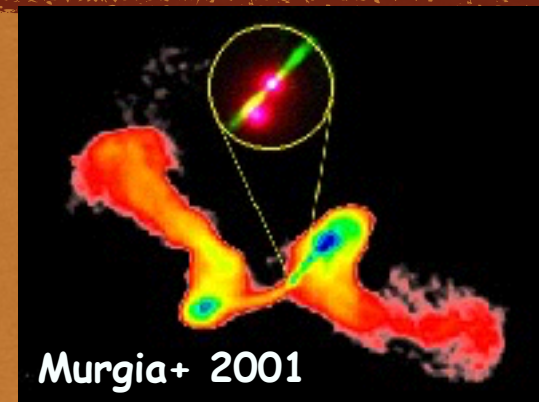
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X-shaped radio galaxies

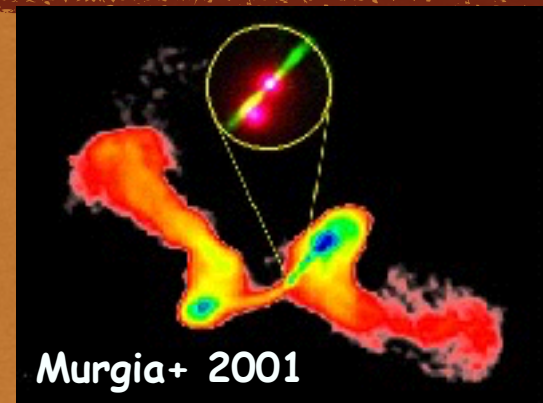
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	A	B	C
known sample of 12 sources			

X-shaped radio galaxies

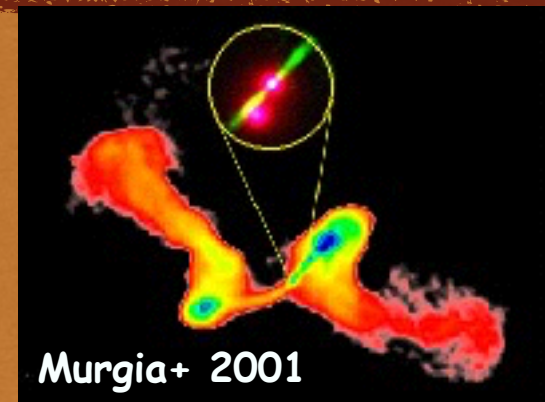
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	A	B	C
known sample of 12 sources	3	5	4

X-shaped radio galaxies

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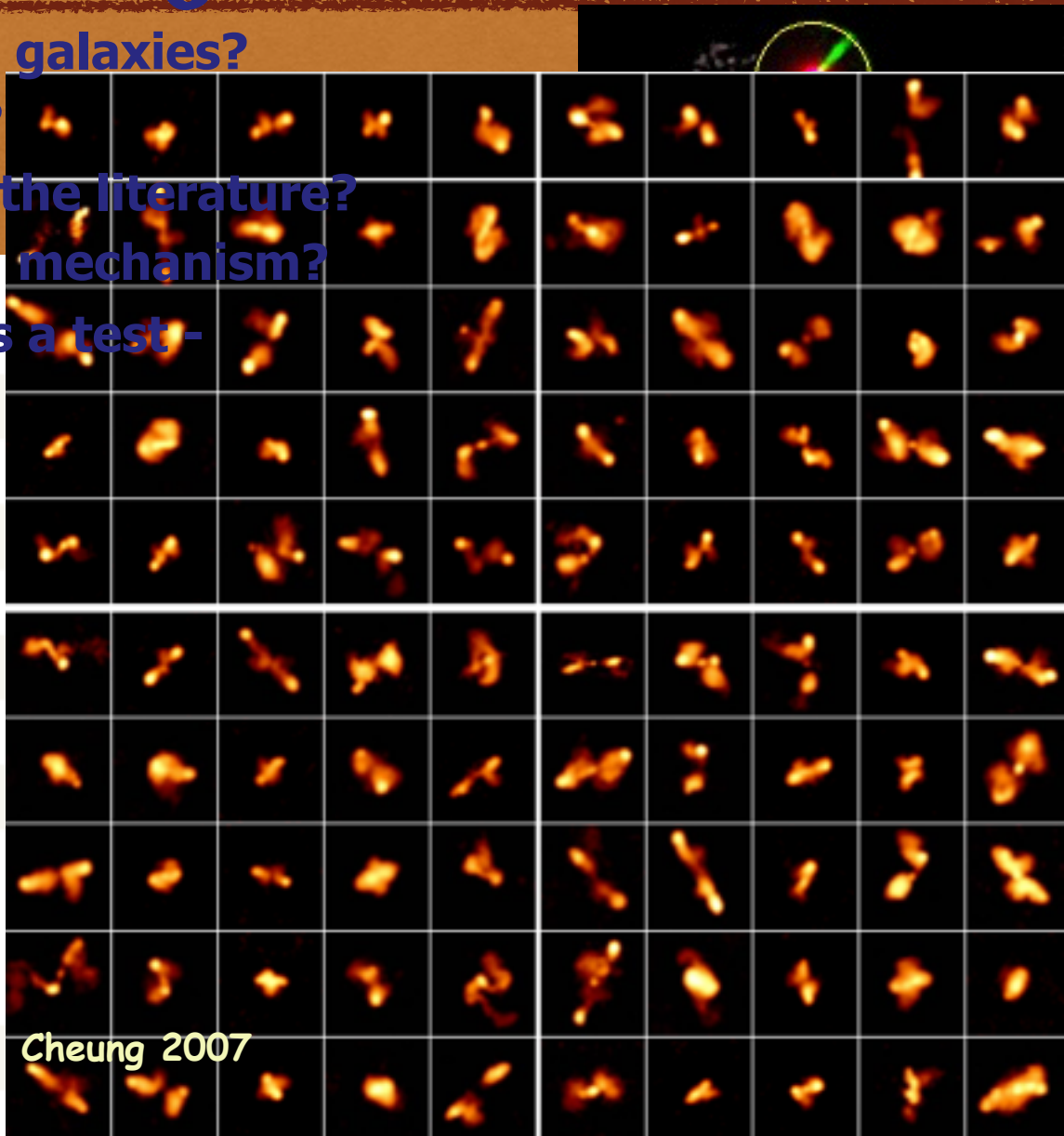


	A	B	C
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X-shaped radio galaxies

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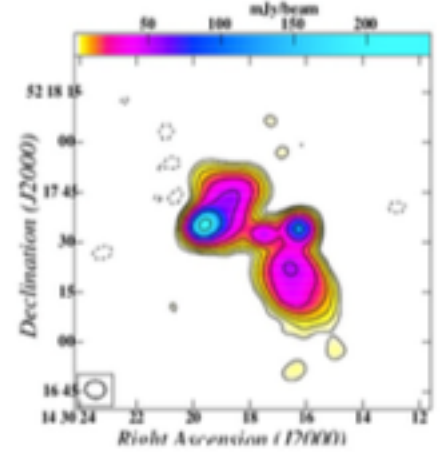
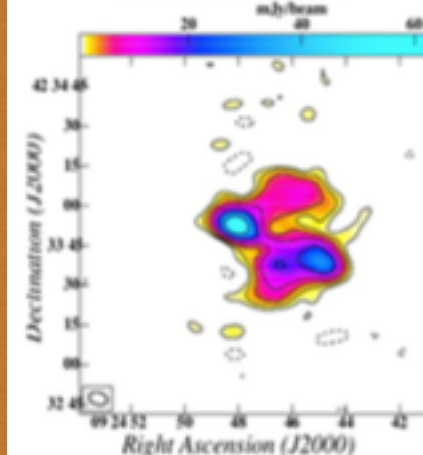
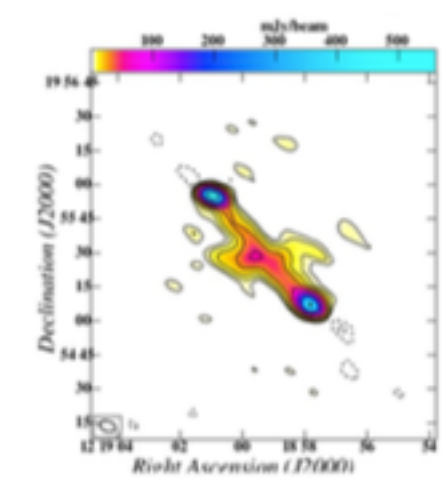
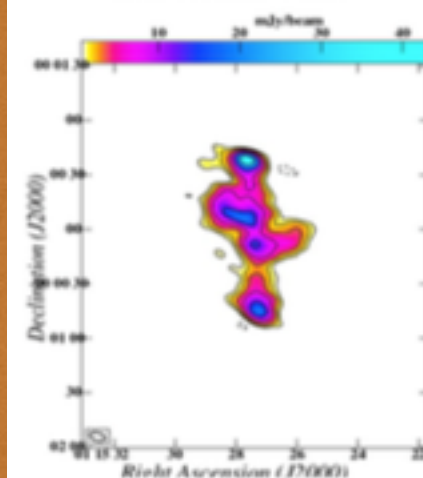
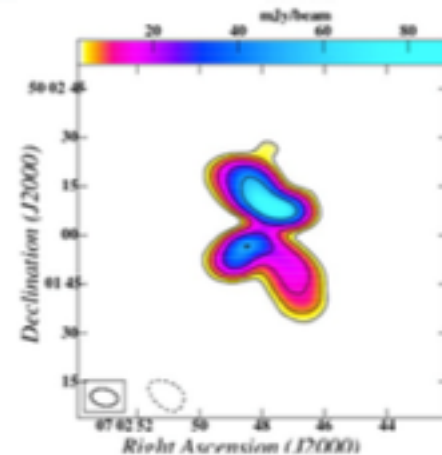
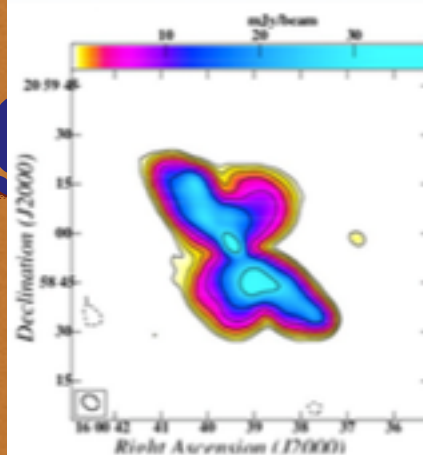


Cheung 2007

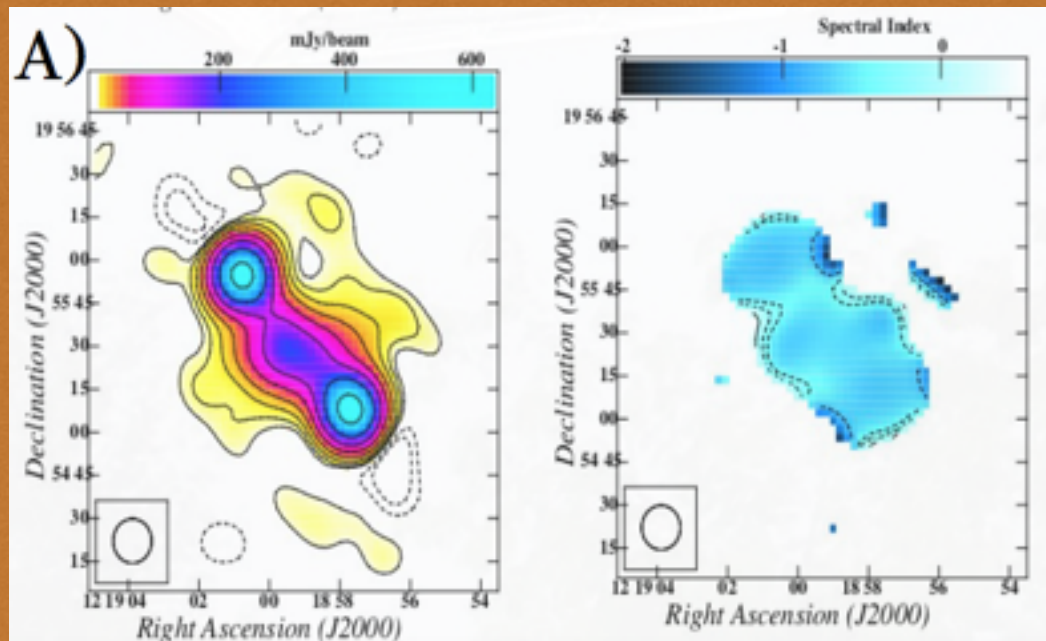
X-shaped radio

Extended X-shaped radio galaxies sample

Name	RA (J2000)	Dec. (J2000)
J0113+0106	01:13:41.08	+01:06:09.0
J0115-0000	01:15:27.33	-00:00:01.1
J0702+5002	07:02:47.92	+50:02:05.3
J0859-0433	08:59:50.19	-04:33:06.9
J0914+1715	09:14:05.19	+17:15:54.4
J0917+0523	09:17:44.32	+05:23:09.5
J0924+4233	09:24:47.01	+42:33:47.4
J1055-0707	10:55:52.56	-07:07:19.1
J1130+0058	11:30:21.41	+00:58:23.0
J1218+1955	12:18:59.15	+19:55:28.1
J1309-0012	13:09:49.65	-00:12:35.2
J1339-0016	13:39:34.26	-00:16:35.8
J1406-0154	14:06:48.63	-01:54:17.3
J1430+5217	14:30:17.32	+52:17:35.3
J1600+2058	16:00:38.94	+20:58:51.9
J1606+0000	16:06:12.70	+00:00:27.1

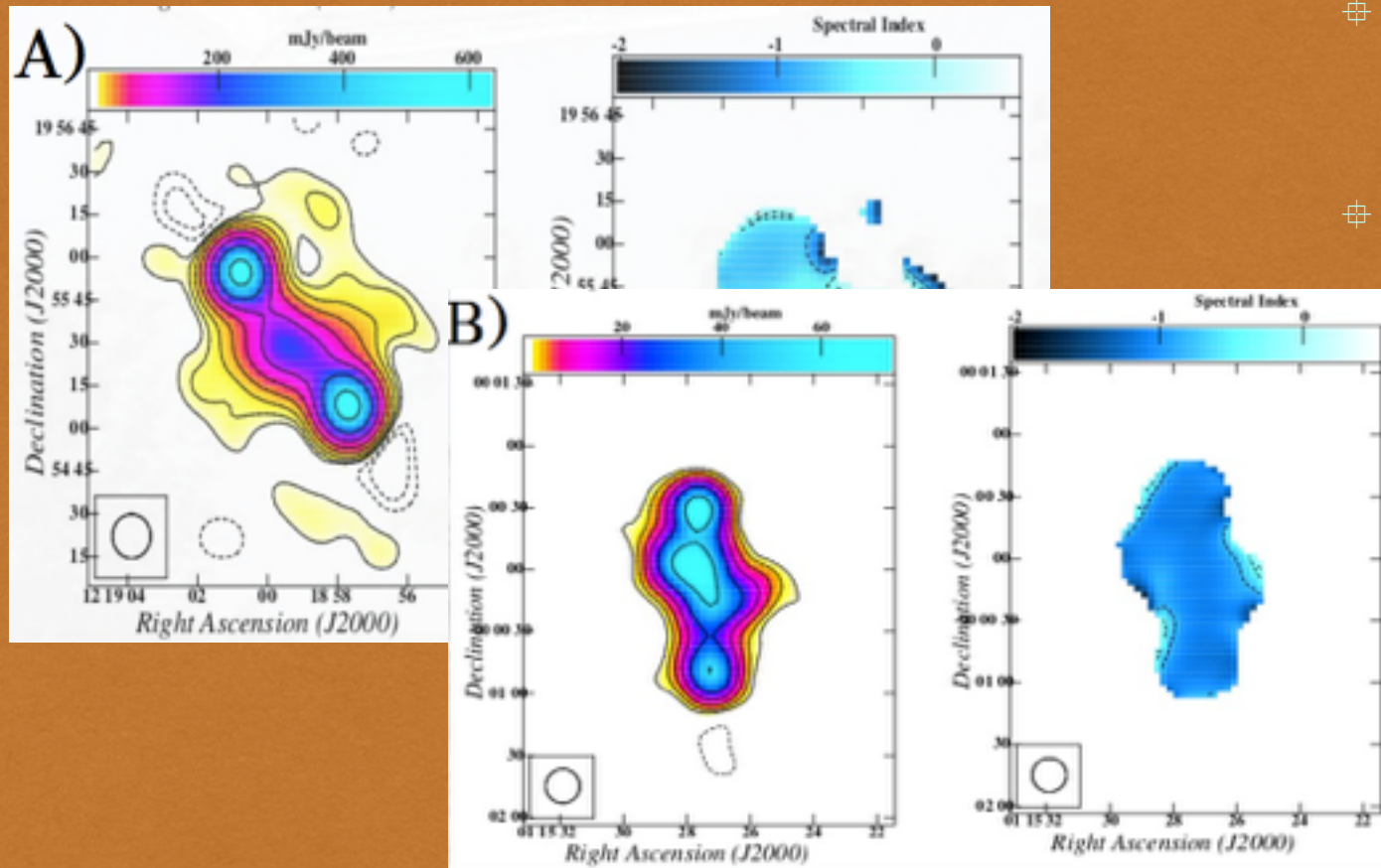


X-shaped radio galaxies



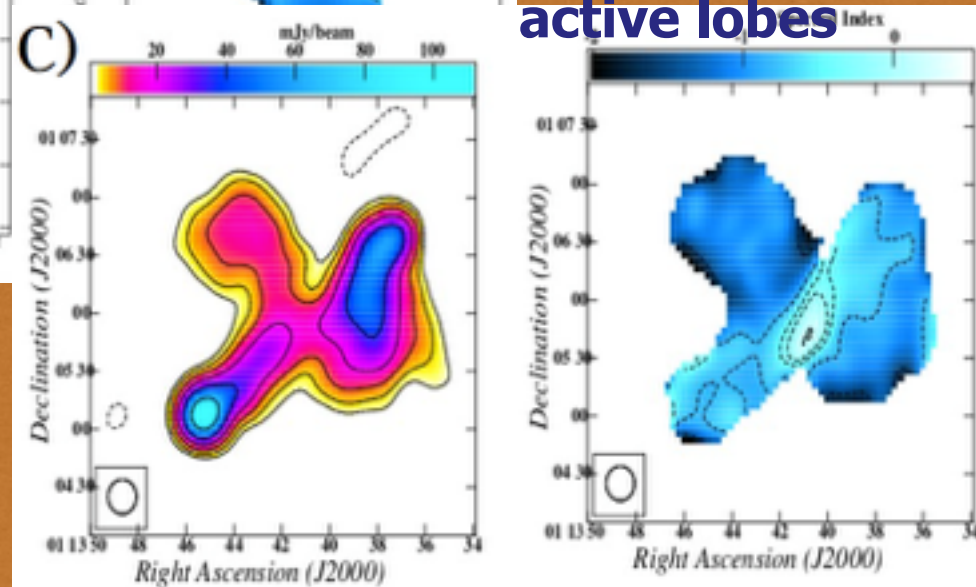
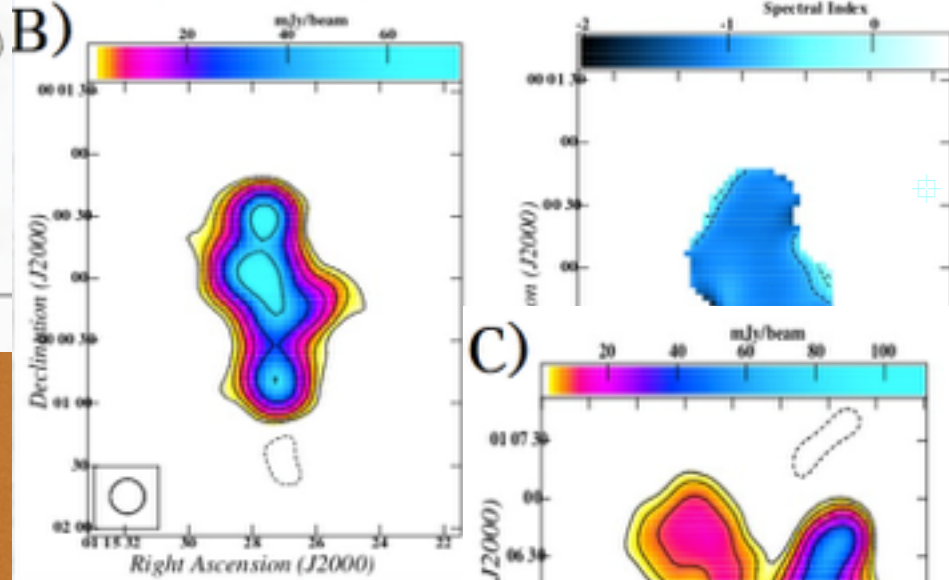
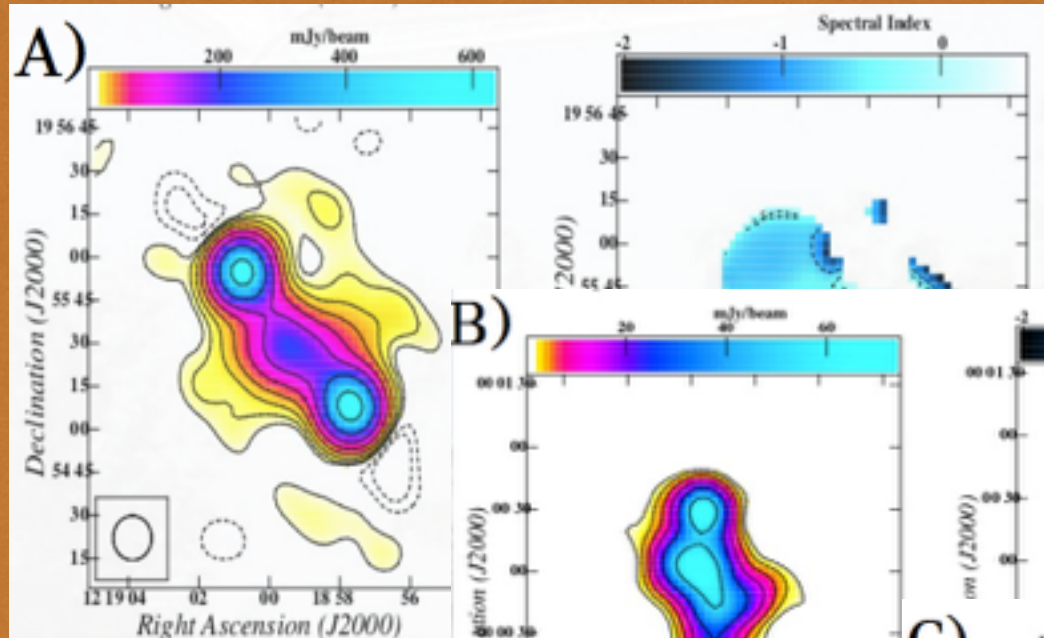
- ⊞ A The wings are flatter than the active lobes

X-shaped radio galaxies



- ✦ **A** The wings are flatter than the active lobes
- ✦ **B** The wings and the active lobes have comparable spectral indices

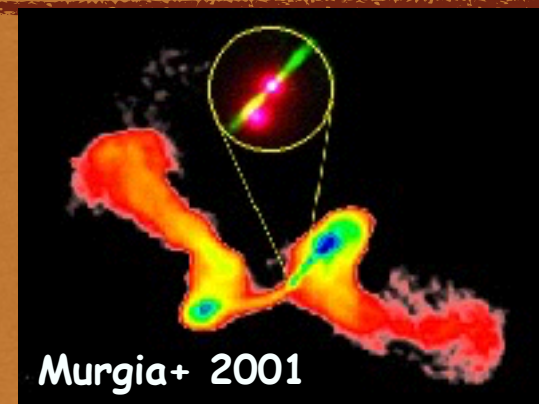
X-shaped radio galaxies



- ✦ **A** The wings are flatter than the active lobes
- ✦ **B** The wings and the active lobes have comparable spectral indices
- ✦ **C** The wings are steeper than the active lobes

X-shaped radio galaxies

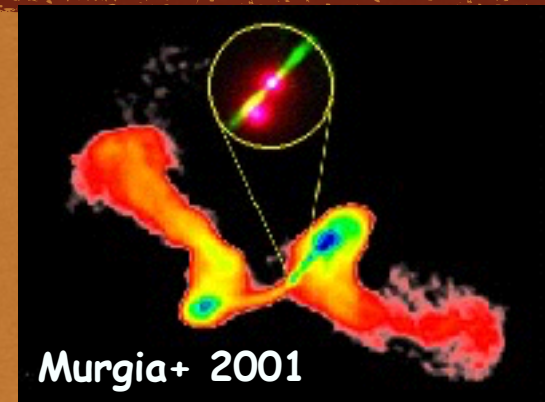
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 - ⊠ => these are probably two pairs of jets which are associated with two unresolved AGN systems



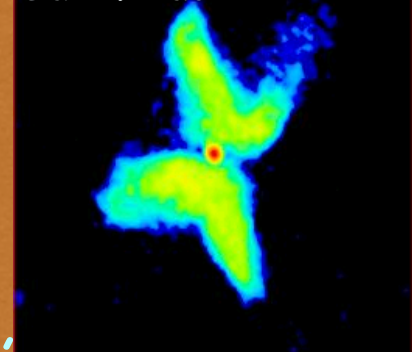
	A	B	C
known sample of 12 sources	3	4	5
extended sample (16 more sources)	3/14	10/14	1/14

X-shaped radio galaxies

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- ⊠ => these are probably two pairs of jets which are associated with two unresolved AGN systems
 - ⊠ Independently, a study (Roberts+ 2015) of 51/100 sources
 - ⊠ 20/100 candidates are genuine X-shaped sources
 - ⊠ restarting of jets in a new direction following an interruption and axis flip.
 - ⊠ mas-scale imaging?



Lal & Rao 2007



Thank you

SPARCS VII,