中国科学院
CHINESE ACADEMY OF SCIENCES

上海天文台
Shanghai Astronomical Observatory

VLBI Observations of a sample of EGRET-detected AGN

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Outline

1. Introduction
2. Sample
3. Observations
4. Results and Conclusion

1. Introduction

- One of the most significant results of EGRET was the detection of gamma--ray emission from active galactic nuclei (AGNs):
- All gamma--ray loud AGNs belong to the class of ‘blazars’.
- The fact that all EGRET sources are also radio loud is a striking result, and suggests a link between the emission in the two bands.
- It is commonly thought that the gamma--ray emission originates in the closest proximity of the central engine, both in the region of the accretion disk and in the inner part of the relativistic jet

- In particular, the relation between the radio and gamma --ray flux density is not fully established yet, and most important, it is still unclear why only a fraction of radio--loud AGNs are gamma --ray emitters, and the crucial question ``what makes a radio--loud AGN a gamma --ray source?” is unanswered yet.
- VLBI observations will help us to obtain the inner morphologies of the sources to understand the emission.

The alignment of EGRET-detected AGNs

- **The EGRET detected AGNs are aligned from pc-to kpc-scales (Hong et al. 1998)**
- **Most EGRET detected quasars have small ΔPA**
- **BL Lac Object and a few quasars of gamma ray sources have large ΔPA (projective effect).**

2. Sample

Table 1. A sample of EGRET-detected AGNs

Name(s)	ID	z	RA (hh mm) (2000)	Dec (dd.d) (2000)	Array EVN	VLBA	VLA	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
0202 + 149	Q	0.405	02 04 50.4139	+15 14 11.0437	EH02a/3	BH065		
0440 − 003	Q	0.850	04 42 38.6607	−00 17 43.4188	EH02a	BH065		
0446 + 112	Q	1.207	04 49 07.6711	+11 21 28.5974	EH02a	BH065		
0827 + 243	Q	0.939	08 30 52.0861	+24 10 59.8211	EH02b	BH065		
0829 + 046	B	0.180	08 31 48.8880	+04 29 39.0000	EH02b	BH065		
0954 + 556	Q	0.909	09 57 38.1900	+55 22 57.7000	EH02a	BH065	AH721	**BH096**
1229 − 021	Q	1.038	12 32 00.0000	−02 24 05.0000	EH003	BH065	AH635 AH721	**BH096**
1331 + 170	Q	2.084	13 33 56.7600	+16 49 04.2000	EH003	BH065	AH635 AH721	
1406 − 076	Q	1.494	14 08 56.4811	−07 52 26.6655	EH003	BH065	AH635 AH721	
1604 + 159	Q	0.357	16 07 06.4000	+15 51 34.0000	EH003	BH065	AH635 AH721	**BH096**
1606 + 106	Q	1.24	16 08 46.2031	+10 29 07.7760	EH02a	BH065	AH635 AH721	
1908 − 201	B	>0.2	19 11 09.6528	−20 06 55.1084	EH003	BH065	AH721	
2022 − 077	Q	1.388	20 25 40.4000	−07 35 40.0000	EH003	BH065	AH635 AH721	**BH096**
2209 + 236	Q	1.125	22 12 05.9663	+23 55 40.5436	EH003	BH065	AH635 AH721	
2356 + 196	Q	1.066	23 58 46.0000	+19 55 20.0000	EH003	BH065	AH635 AH721	

1156+295 **EH005, BH108, BH113A, BH113C, BH11D …**
NRAO 530 **EH004, …**

3. Observations

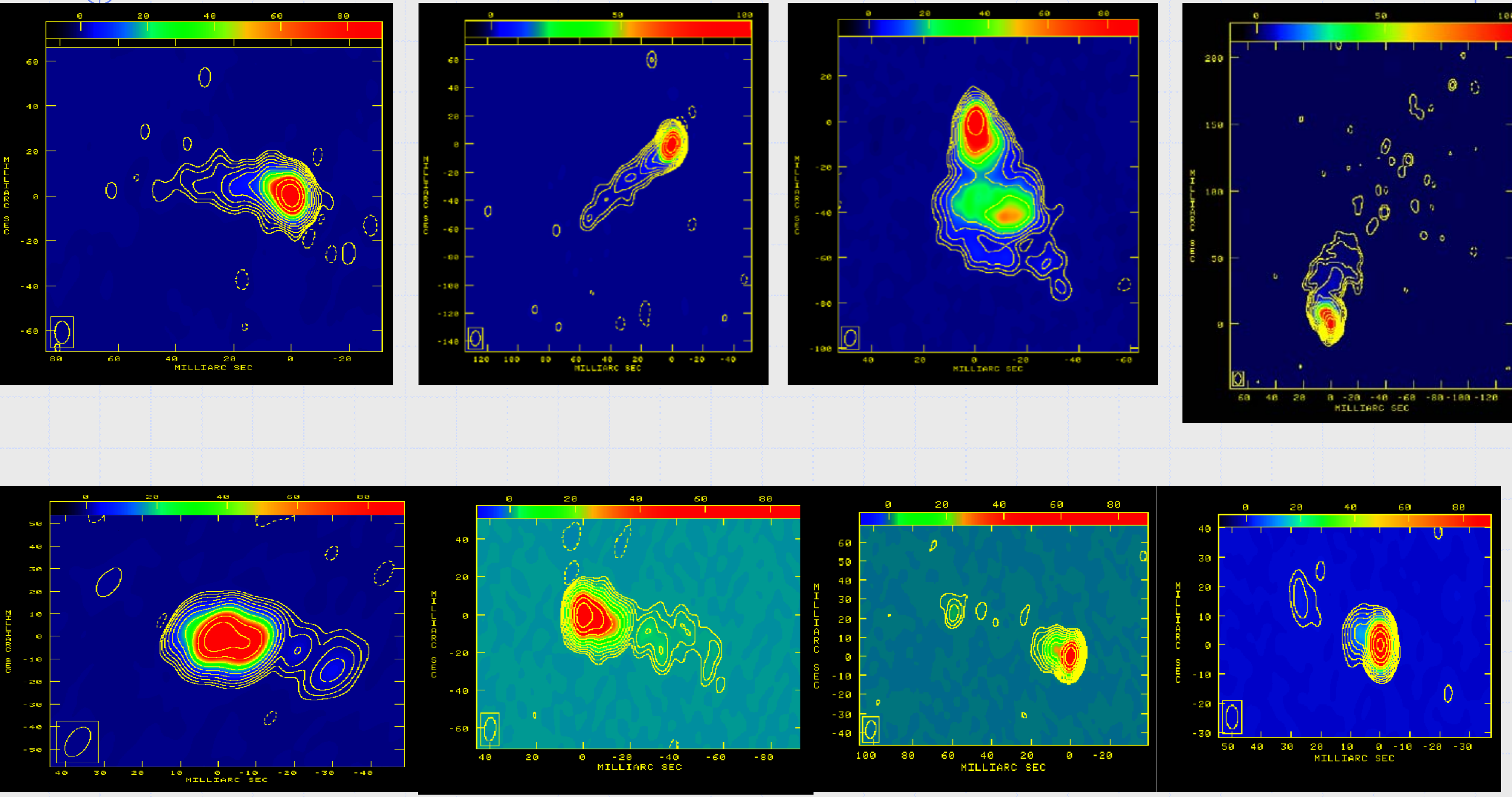
Table 2. Epochs, arrays and frequencies of the observations

Obs. Code (1)	Epoch (2)	Band[a] (GHz) (3)	B-width (MHz) (4)	t_{obs} (hrs) (5)	Array (6)	Telescopes[b] (7)	Correlator (8)
VLBI							
EH02a	1997.43	C	28	20	EVN	Sh Jb Mc Ht Sm Tr	MKIII[c]
EH02b	1997.44	C	28	5.5	EVN	Ef Sh Jb Mc Ht Sm Tr	MKIII[c]
EH003	1997.85	C	28	24	EVN	Ef Sh Jb Mc Nt Ht On Wb Ur Tr	MKIII[c]
BH065	2000.15	L	64	24	VLBA	All 10	VLBA[d]
VLA							
AH635	1999.06	X&K	50	2	VLA–C	full array	VLA
AH721	2000.92	X&K	50	3	VLA–A	full array	VLA

VLBA

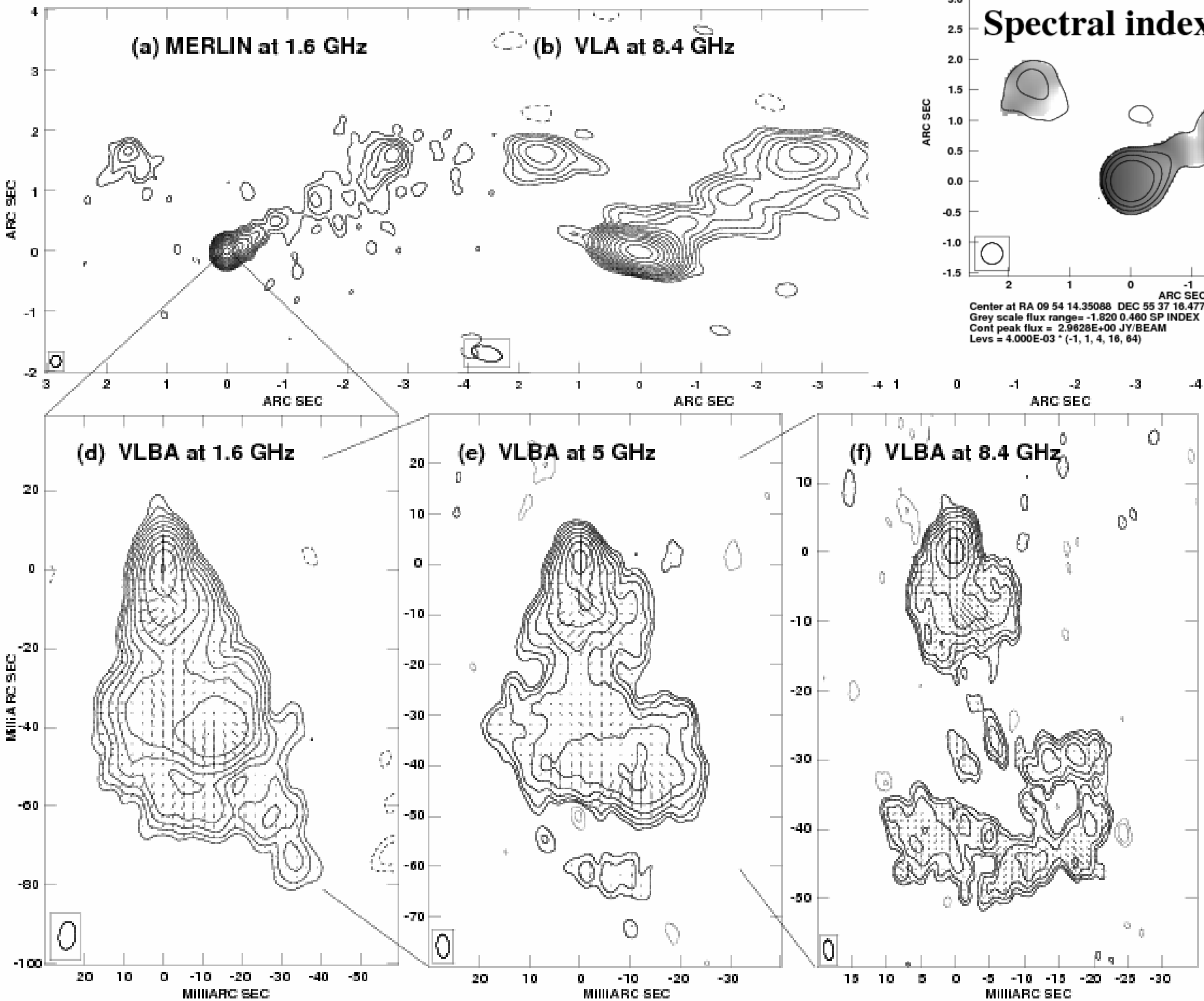
BH096: 5, 8, and 15GHz
BH108: 15,43,and 86GHz,
BH113A,C,D: 15,43,and 86GHz

4. Results
--VLBI images with VLBA at 1.6 GHz



0954+556

- z=0.909,
- a high--polarization 8.7% quasar
- It was detected over a broad range of wavelengths,
- from radio to X--rays, up to the EGRET gamma --ray detection.
- Differently from the majority of blazars, its total radio spectrum is steep.



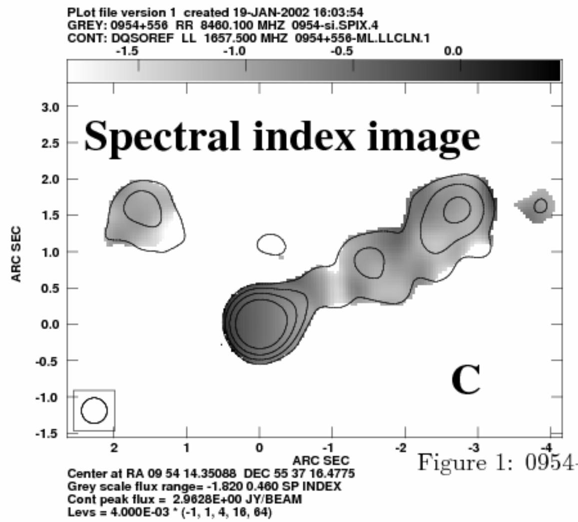


Figure 1: 0954+556

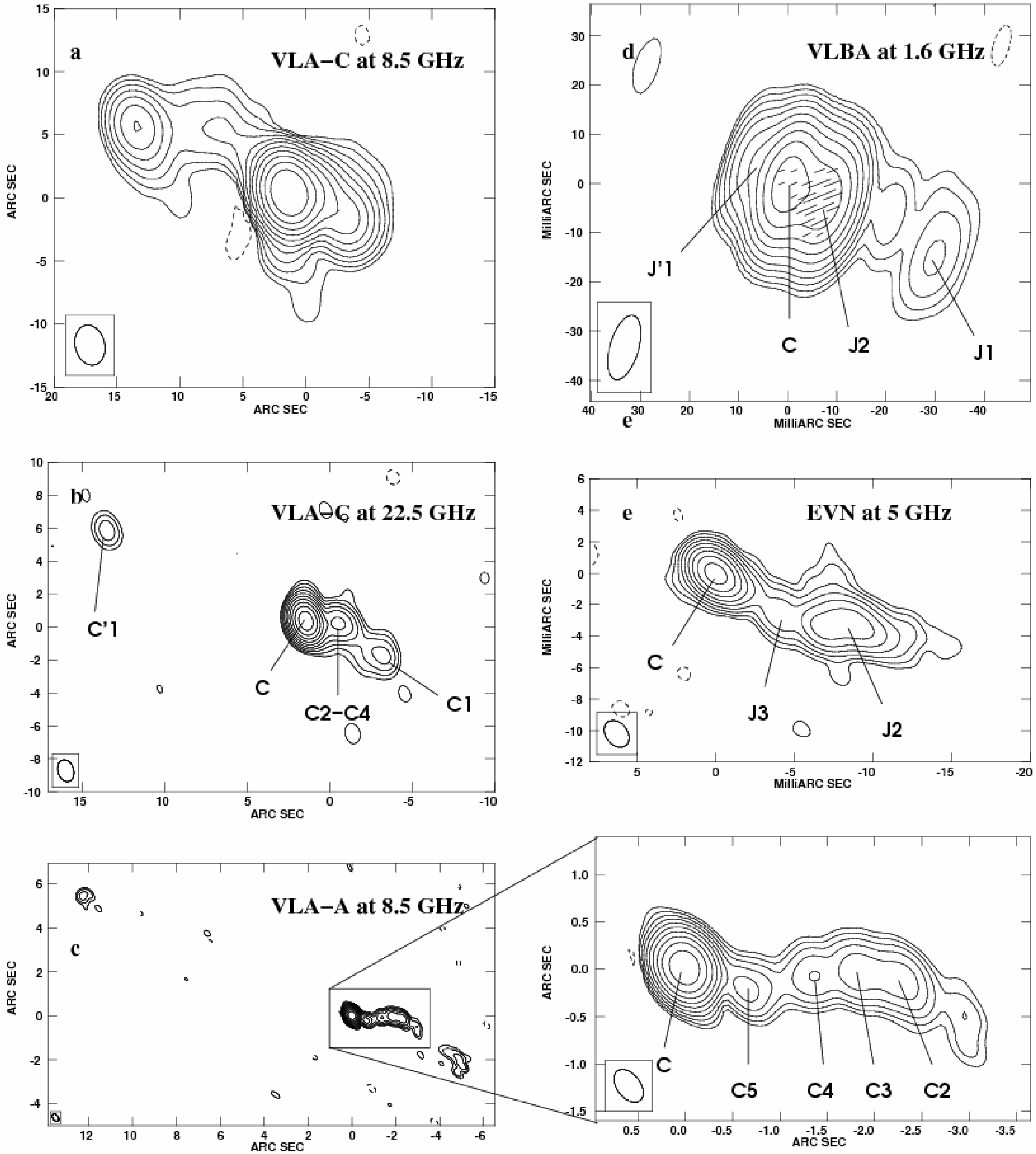
kpc: a 3 arcsecond jet, characterised by several components aligned in P.A. ~60° and culminating in an extended spot. Another extended component, similar to a "hotspot", is located at 2 arcsec from the core, in P.A. 40 °

pc: an extended and complex emission, which elongates south of the strongest component and bends towards west at 40 mas from the peak. The overall extension in this image is 100 mas.

- A high degree of polarization was detected in the whole structure . The direction of the electric vectors is almost perpendicular to jet (magnetic field is parallel with the jet)
- This morphology looks like that of a galaxy rather than of a quasar

1229-021

- The source is associated with a quasar at z=1.038
- The optical magnitude was 17.65th.



a
VLA–C at 8.5 GHz
ARC SEC
d
VLBA at 1.6 GHz
J'1
C
J2
J1
MilliARC SEC
b
VLA–C at 22.5 GHz
C'1
C
C2–C4
C1
e
EVN at 5 GHz
C
J3
J2
c
VLA–A at 8.5 GHz
C
C5
C4
C3
C2

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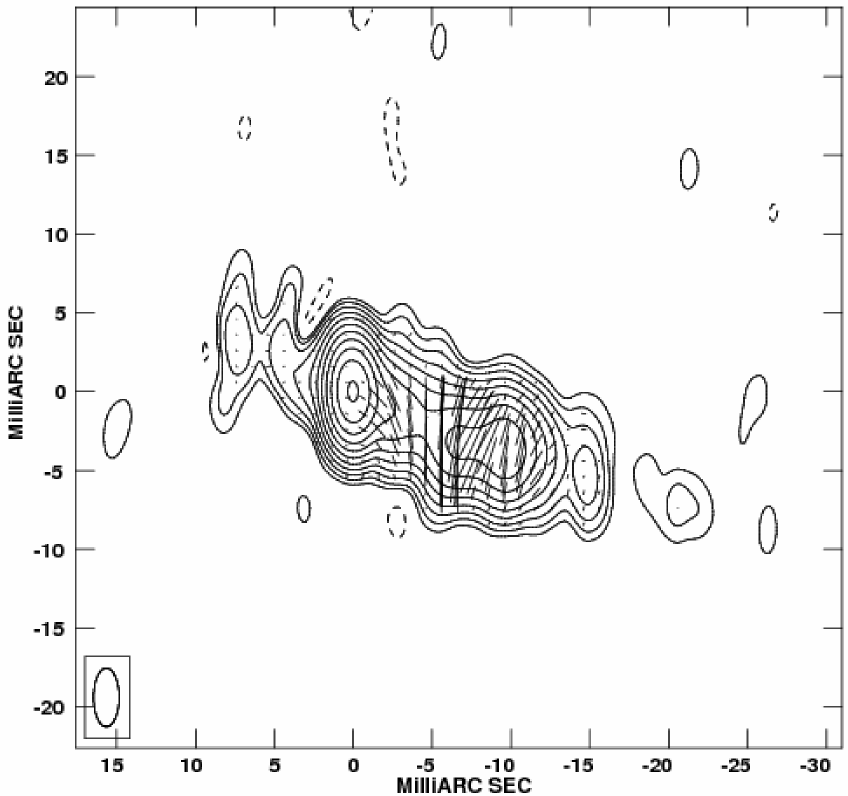

Center at RA 12 32 00.0160200 DEC -02 24 04.794170
Cont peak flux = 3.3011E-01 JY/BEAM
Levs = 2.955E-04 * (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024)
Pol line 1 milli arcsec = 1.0000E-03 JY/BEAM

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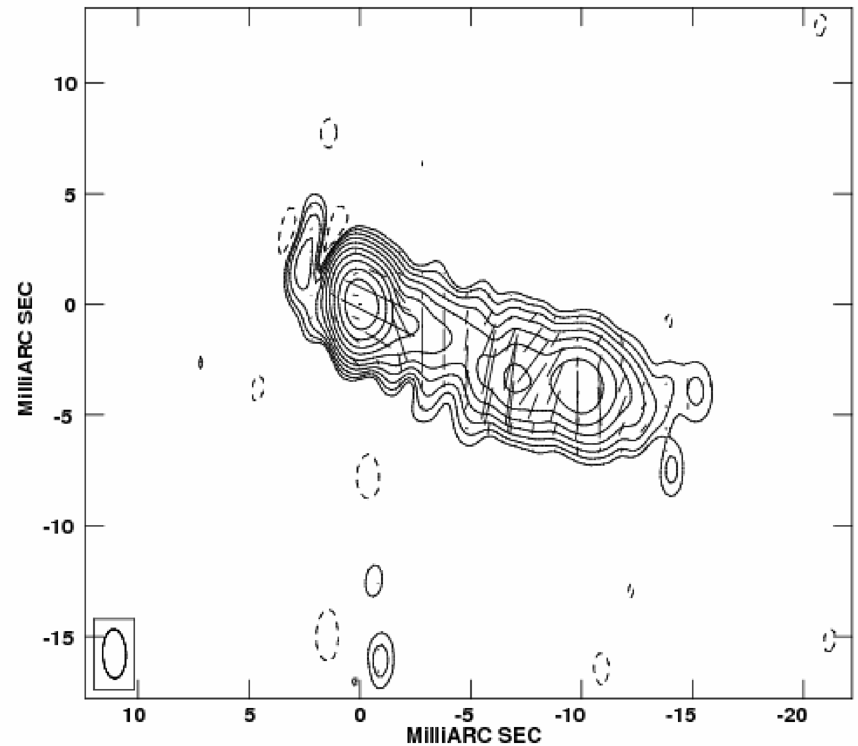
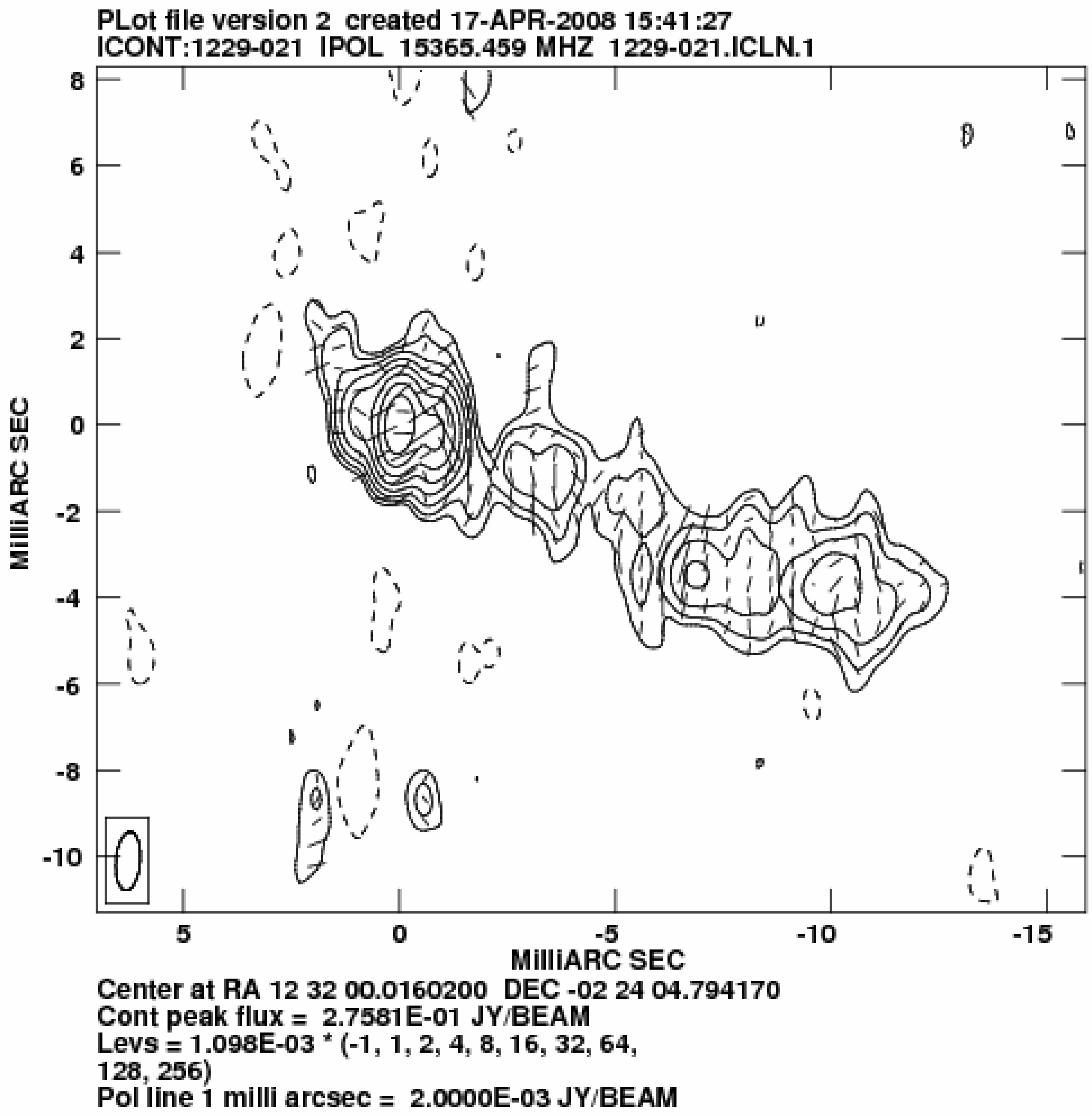


Center at RA 12 32 00.0160200 DEC -02 24 04.794170
Cont peak flux = 3.1780E-01 JY/BEAM
Levs = 3.096E-04 * (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024)
Pol line 1 milli arcsec = 1.0000E-03 JY/BEAM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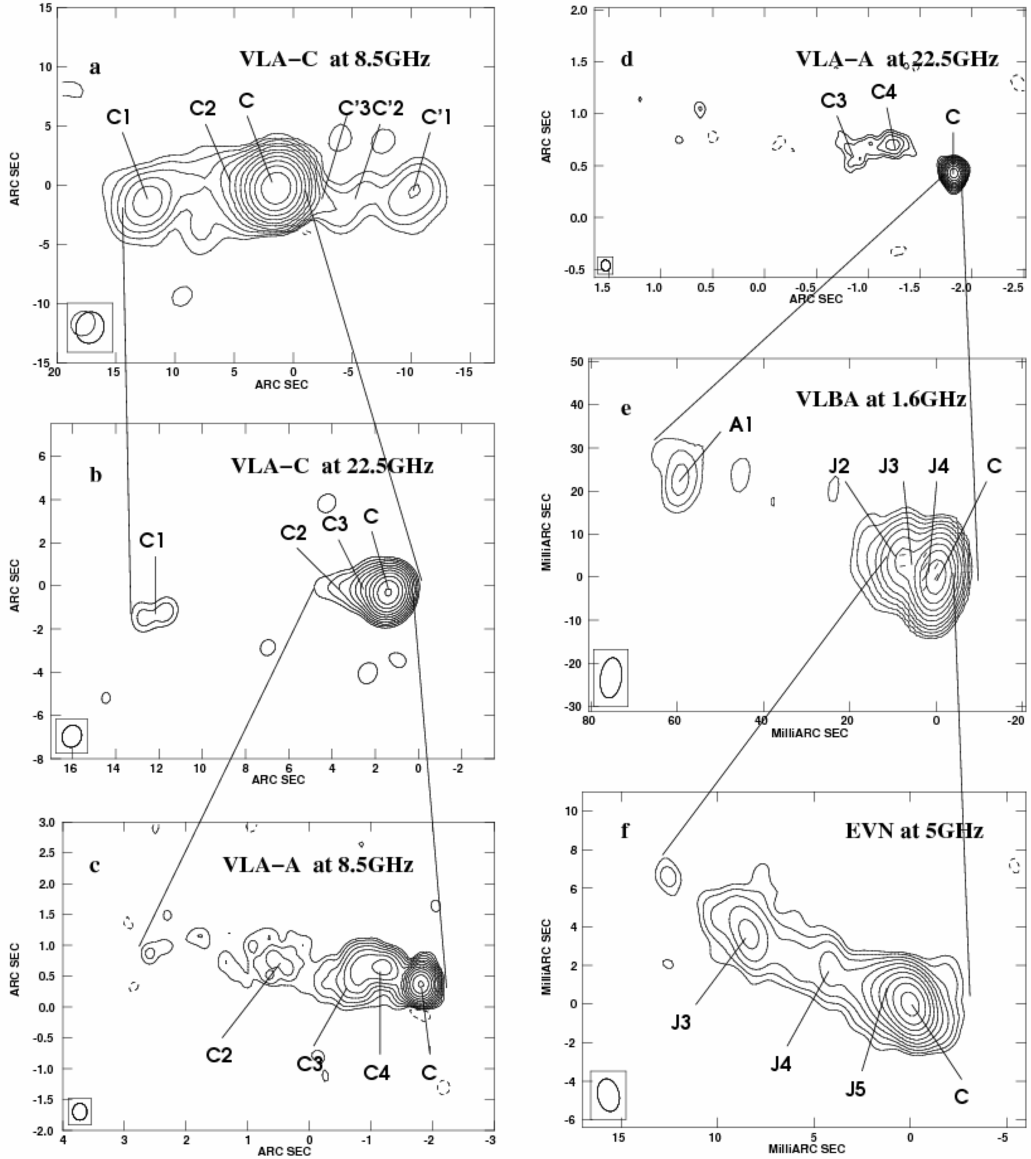
ICONT:1229-021 IPOL 15365.459 MHZ 1229-021.ICLN.1
MilliARC SEC
MilliARC SEC
Center at RA 12 32 00.0160200 DEC -02 24 04.794170
Cont peak flux = 2.7581E-01 JY/BEAM
Levs = 1.098E-03 * (-1, 1, 2, 4, 8, 16, 32, 64,
128, 256)
Pol line 1 milli arcsec = 2.0000E-03 JY/BEAM

1604+159

- PKS1604+159 is identified with a quasar at z=0.357,
- characterized by a high degree of optical polarization
- It is an 18m starlike object
- it was classified as a BL Lac object, on the basis of its continuum spectrum.



a
VLA–C at 8.5GHz
C1
C2
C
C'3C'2
C'1
ARC SEC
b
VLA–C at 22.5GHz
C1
C2
C3
C
c
VLA–A at 8.5GHz
C2
C3
C4
C
d
VLA–A at 22.5GHz
C3
C4
C
e
VLBA at 1.6GHz
A1
J2
J3
J4
C
MilliARC SEC
f
EVN at 5GHz
J3
J4
J5
C

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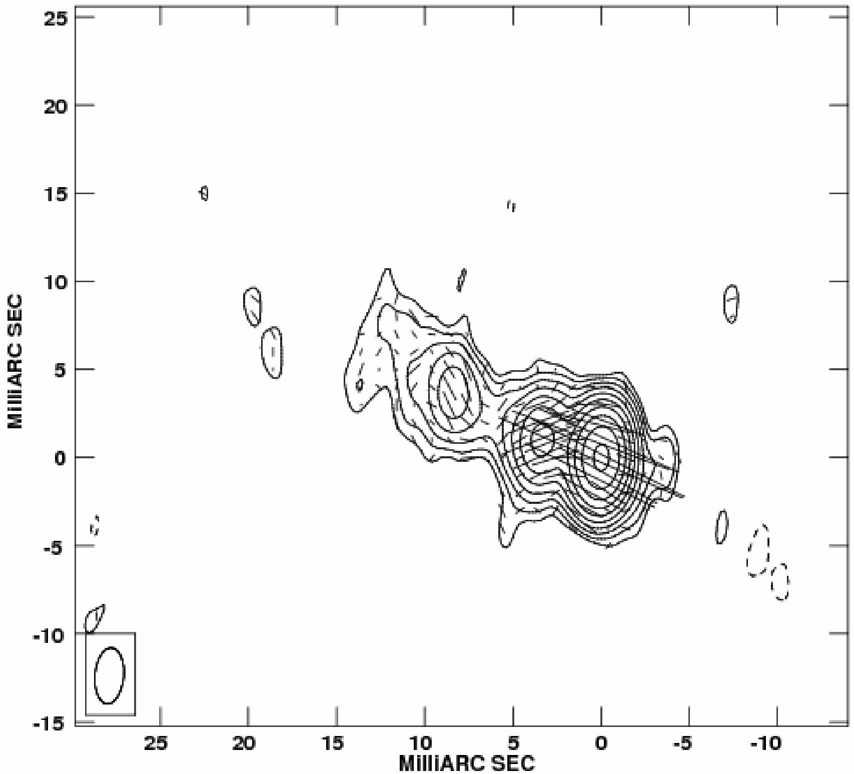
ICONT:1604+159 IPOL 4987.459 MHZ 1604+159.ICLN.1



Center at RA 16 07 06.4303920 DEC 15 51 34.485310
Cont peak flux = 2.3313E-01 JY/BEAM
Levs = 3.903E-04 * (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512)
Pol line 1 milli arcsec = 1.0000E-03 JY/BEAM

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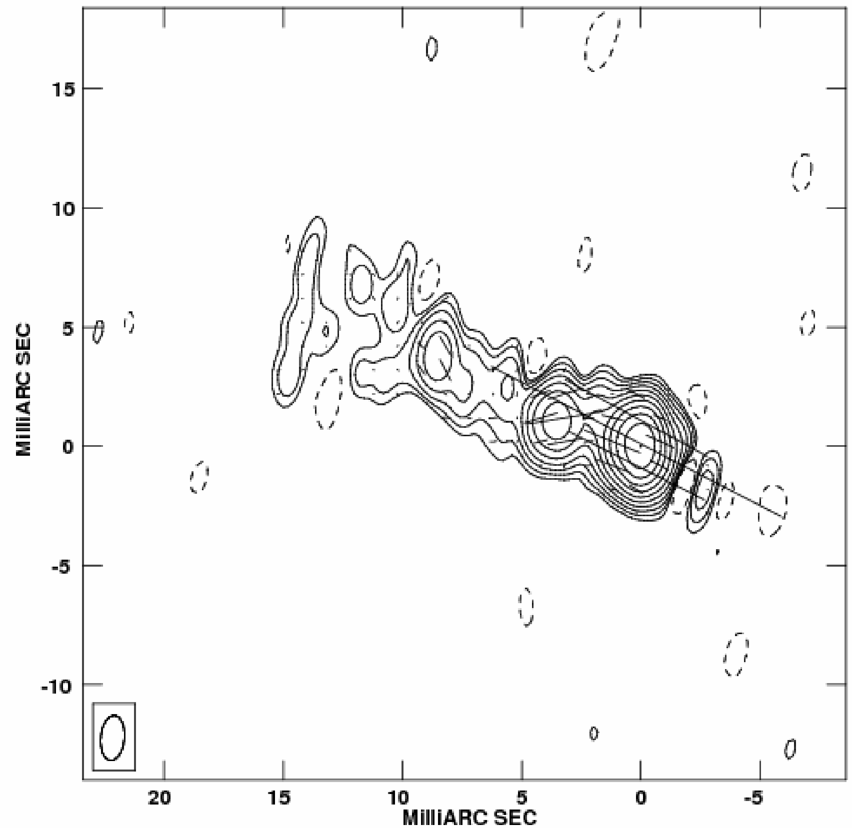
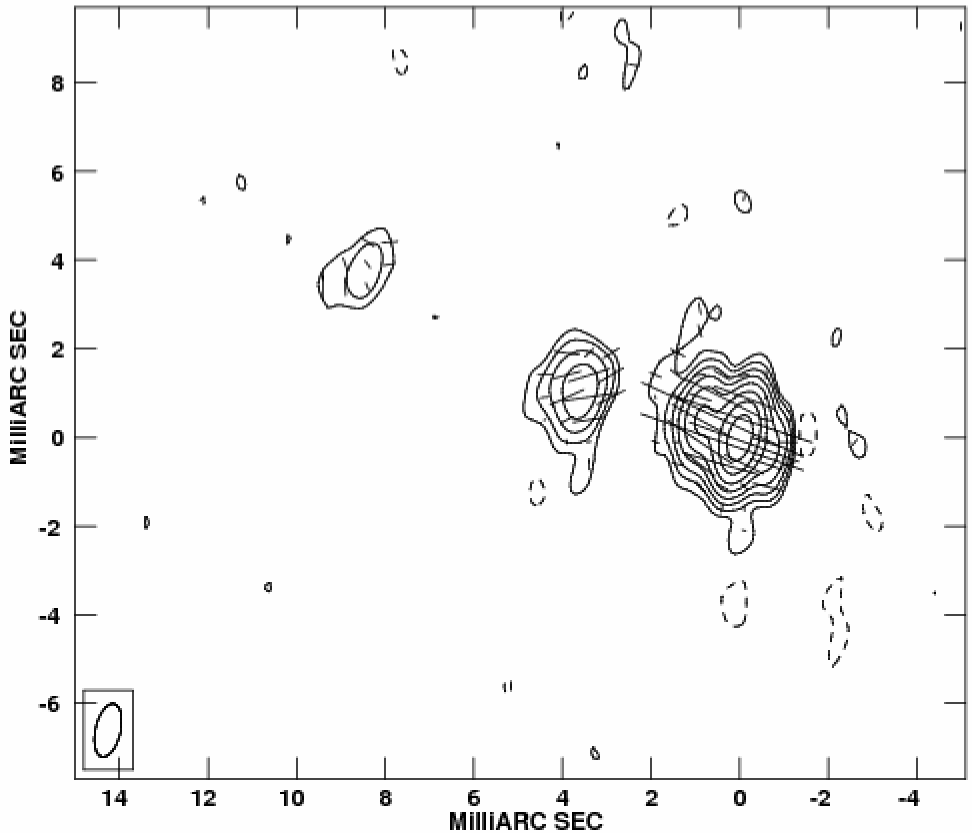
ICONT:1604+159 IPOL 8421.459 MHZ 1604+159.ICL001.1



Center at RA 16 07 06.4303920 DEC 15 51 34.485310
Cont peak flux = 2.1373E-01 JY/BEAM
Levs = 2.080E-04 * (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024)
Pol line 1 milli arcsec = 1.0000E-03 JY/BEAM

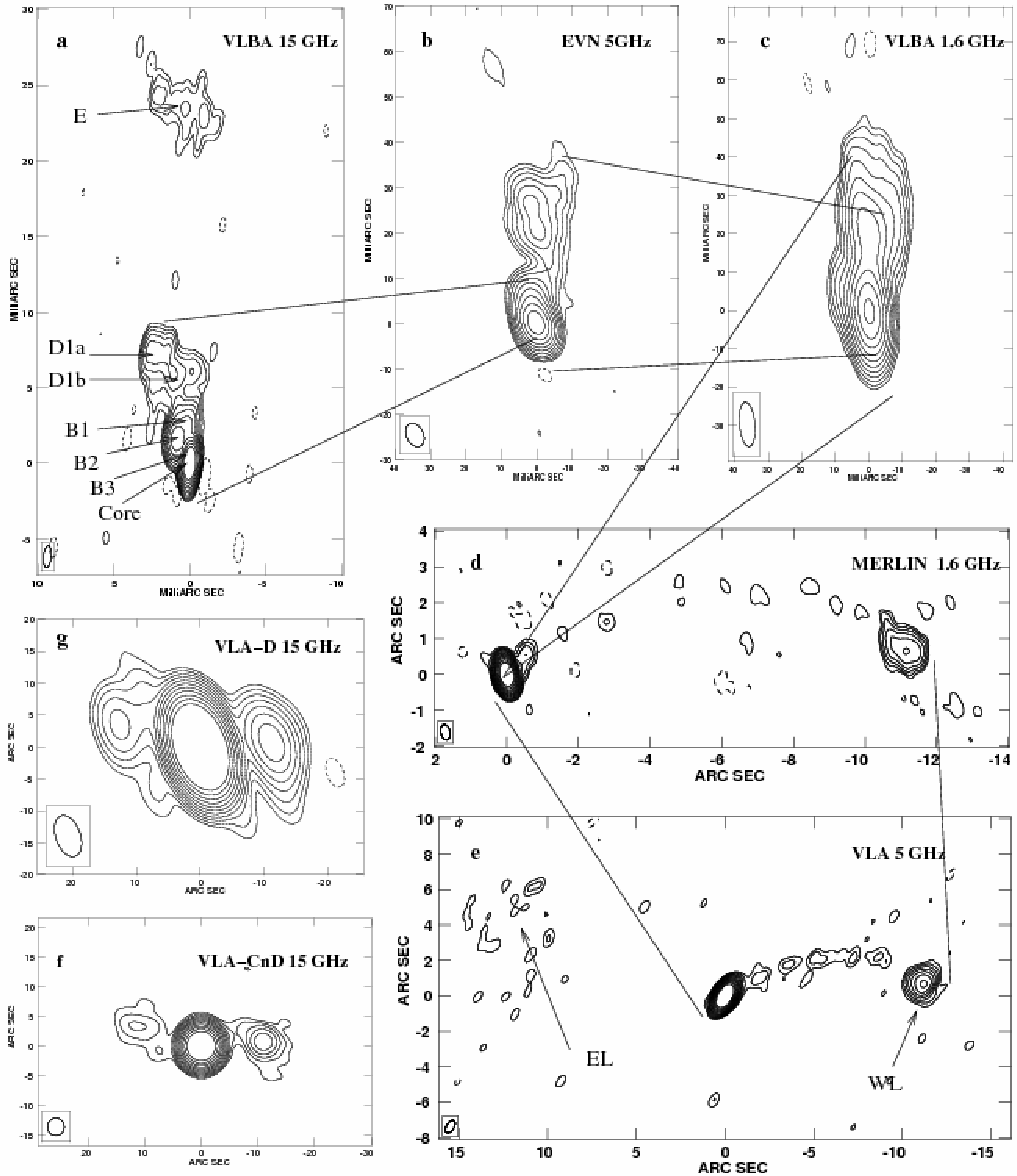
PLot file version 2 created 17-APR-2008 15:47:09
ICONT:1604+159 IPOL 15365.459 MHZ 1604+159.ICLN.2



Center at RA 16 07 06.4303920 DEC 15 51 34.485310
Cont peak flux = 2.2608E-01 JY/BEAM
Levs = 1.103E-03 * (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256)
Pol line 1 milli arcsec = 2.0000E-03 JY/BEAM

NRAO 530 (1730-130)

- The quasar, NRAO 530 is a well known optically violently variable (OVV) extragalactic source
- ~ 18.5mag
- z= 0.902
- This source has been observed at almost all
- wavelengths from radio to gamma -ray.


a
VLBA 15 GHz
E
D1a
D1b
B1
B2
B3
Core
MilliARC SEC
b
EVN 5GHz
c
VLBA 1.6 GHz
d
MERLIN 1.6 GHz
ARC SEC
g
VLA–D 15 GHz
f
VLA–CnD 15 GHz
e
VLA 5 GHz
EL
WL

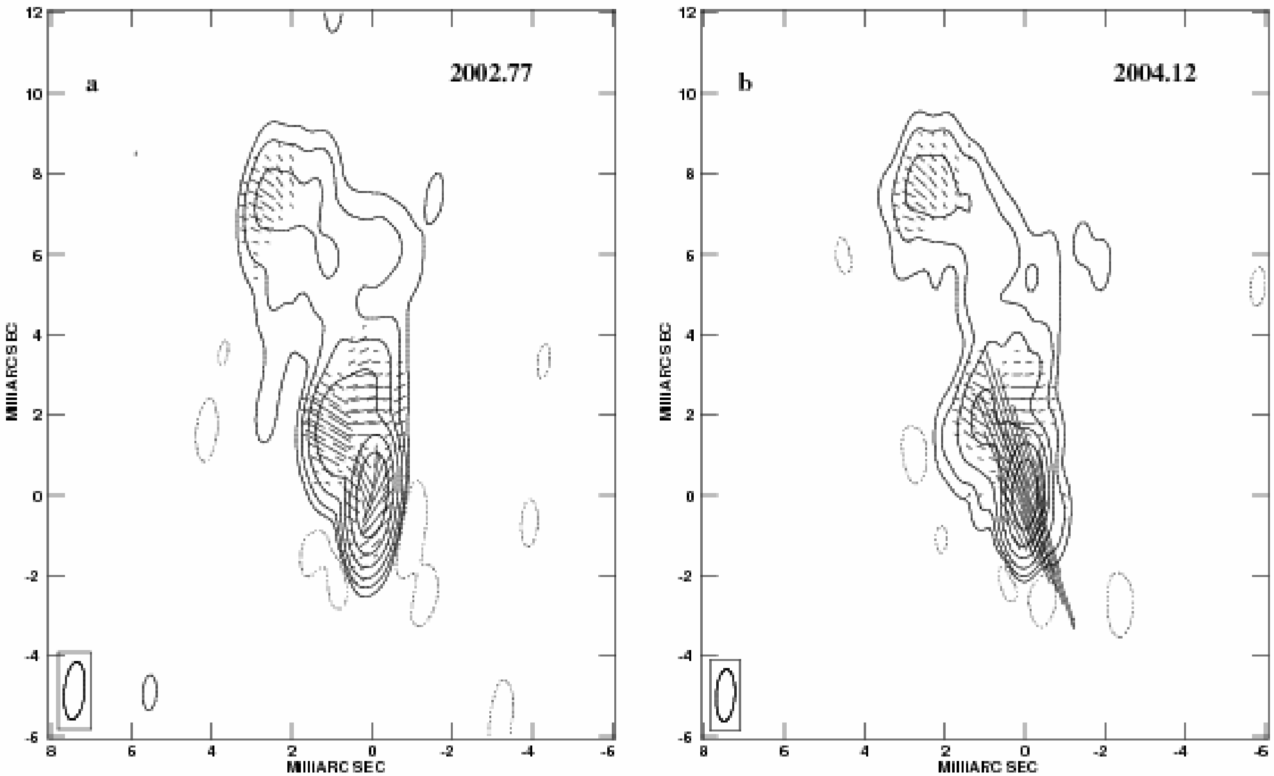
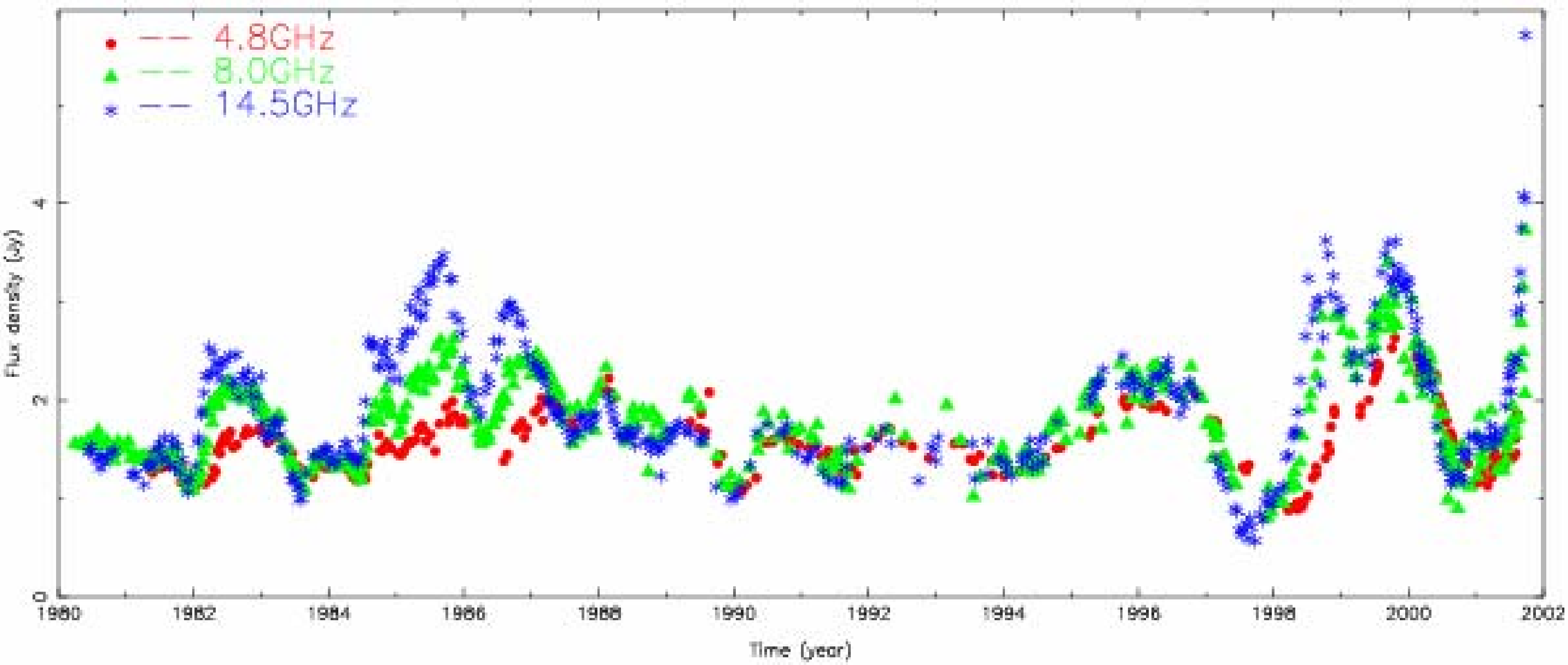


Fig. 1 VLBA images at 15 GHz with total intensity contours and superposed sticks show the orientation of electric vectors, a) epoch 2002.77 and b) epoch 2004.12. The lowest contour is 1.0 mJy/beam. The contours increase by a factor of 3. Polarization line 1 mas =15 mJy/beam. The peak polarization flux densities are 6.0 and 20.0 mJy/beam, respectively

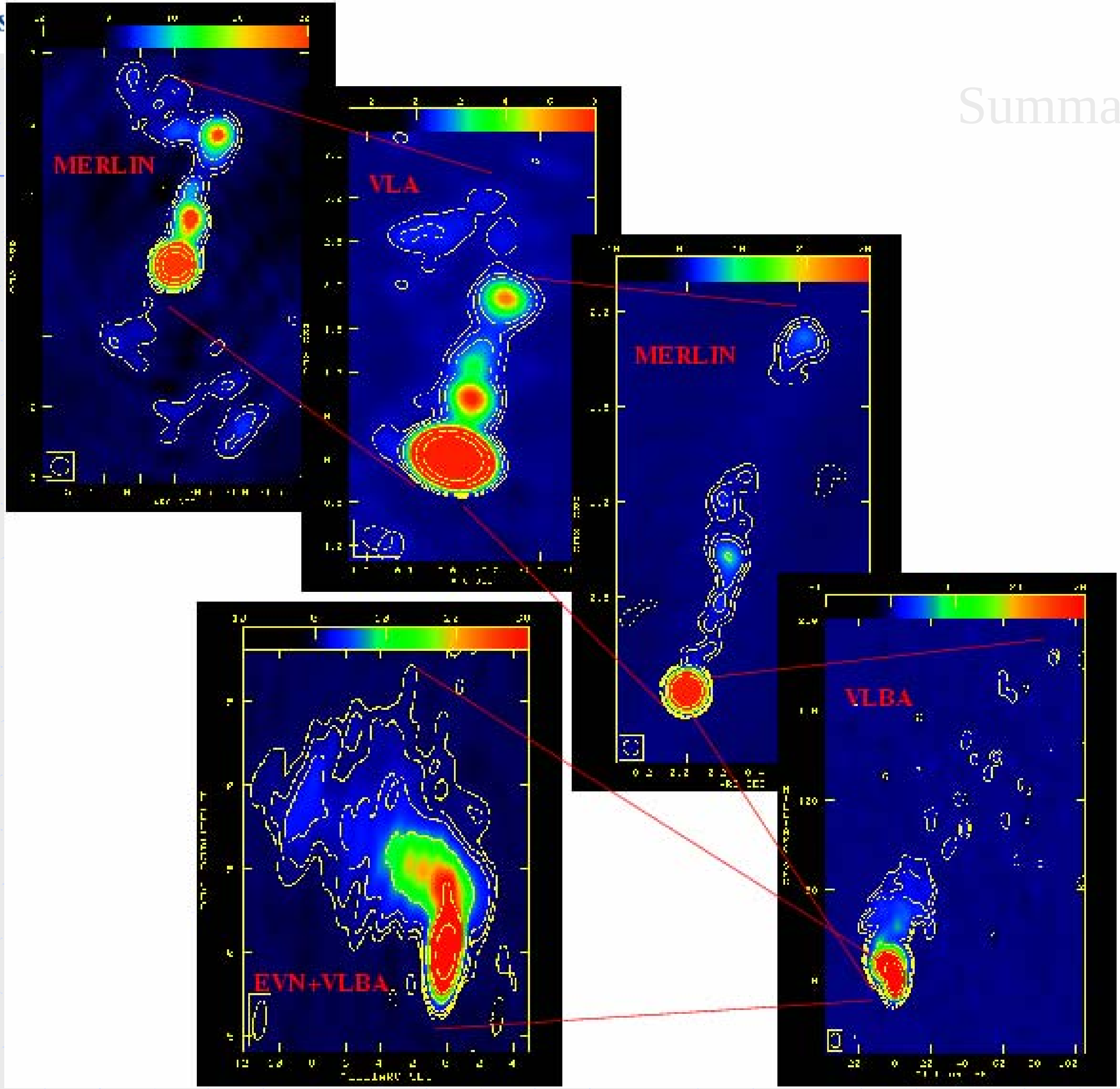
1156+295

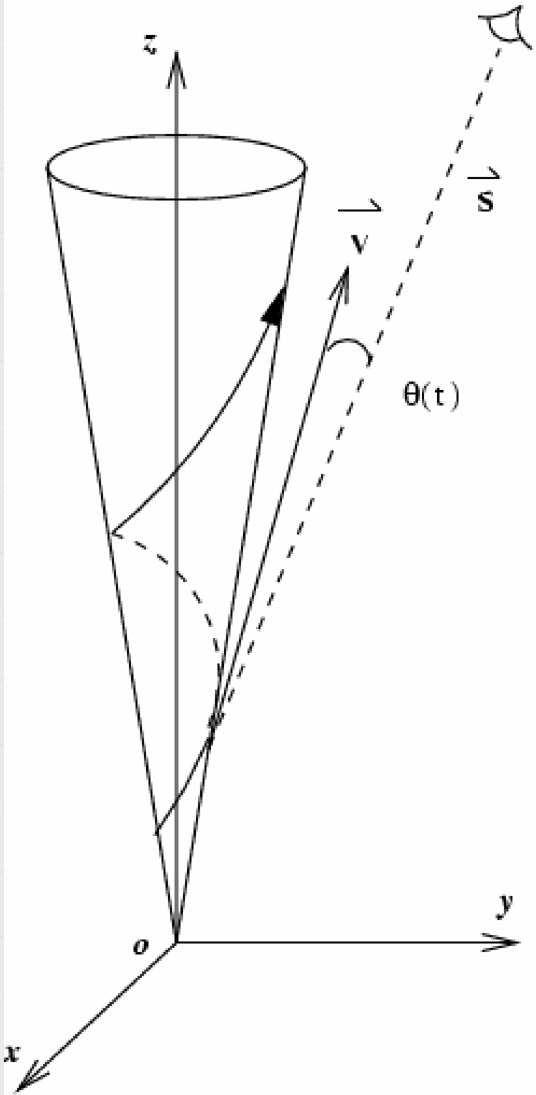
- The AGN 1156+295
- (from radio waves to gamma-ray)
- redshift z=0.729
- HPQ and OVV



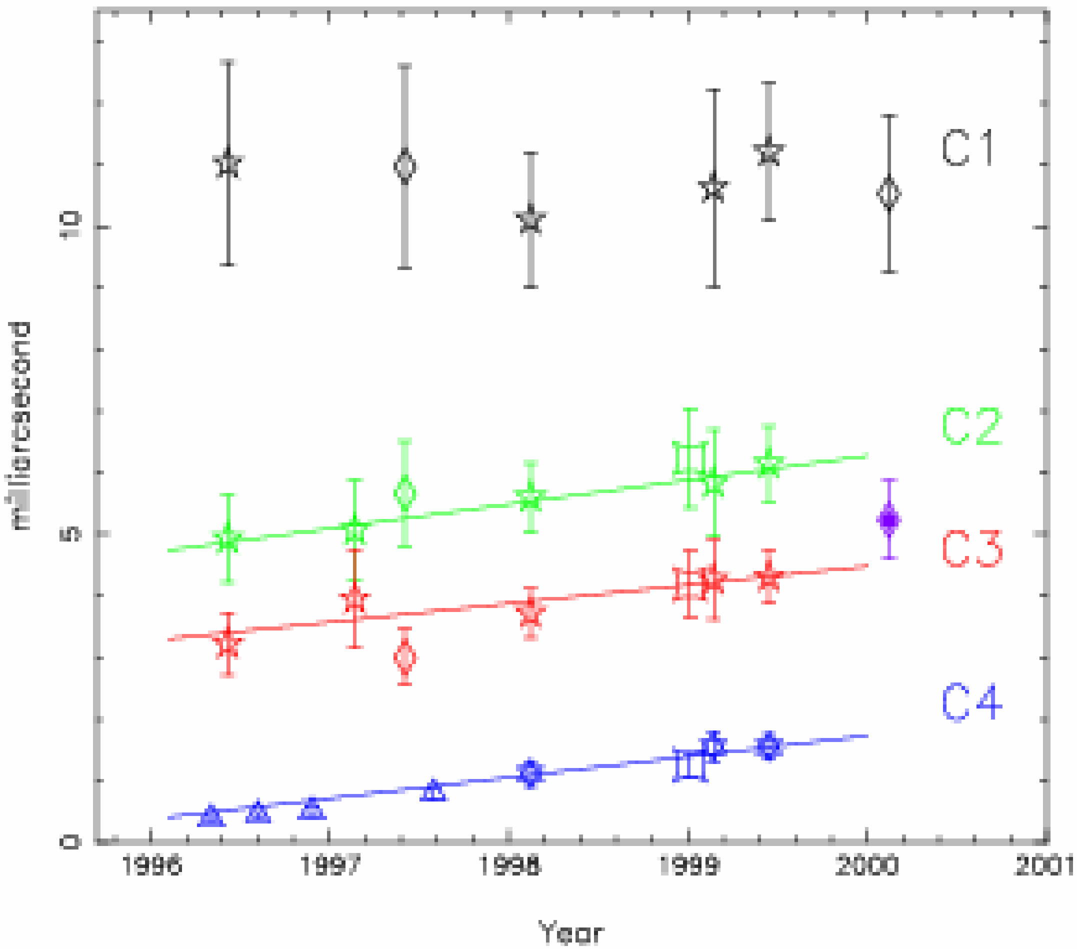
Light curves of 1156+295 at 4.8, 8.0 and 15~GHz from the monitoring data of the University of Michigan Radio Astronomy Observatory

Summary

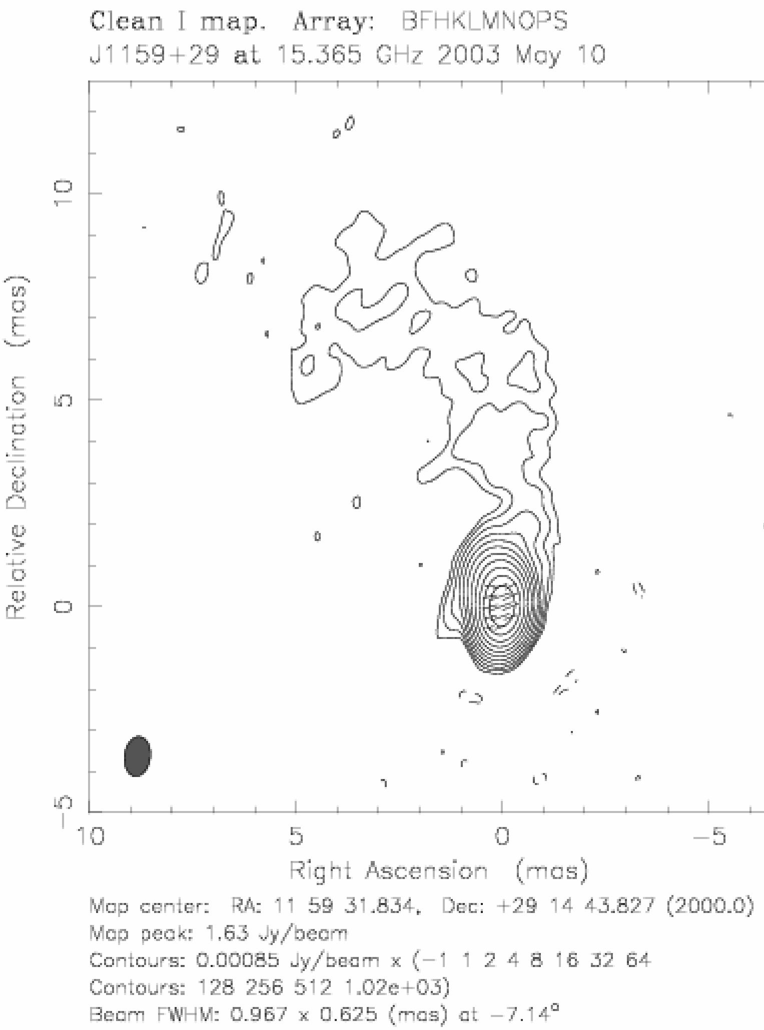


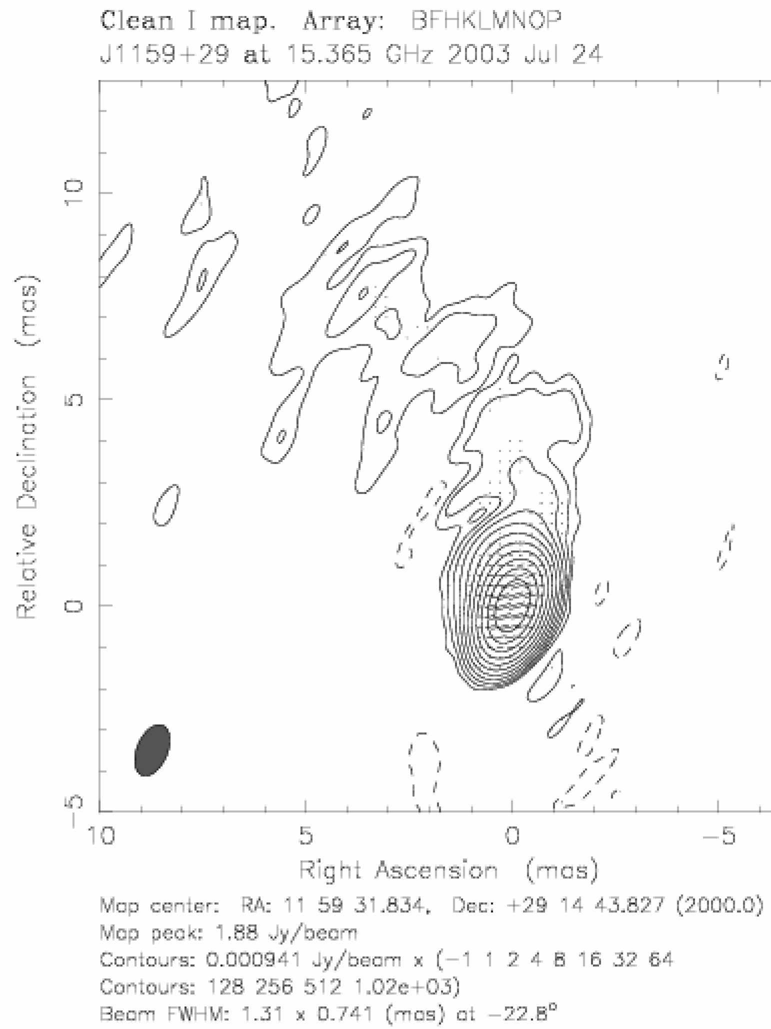


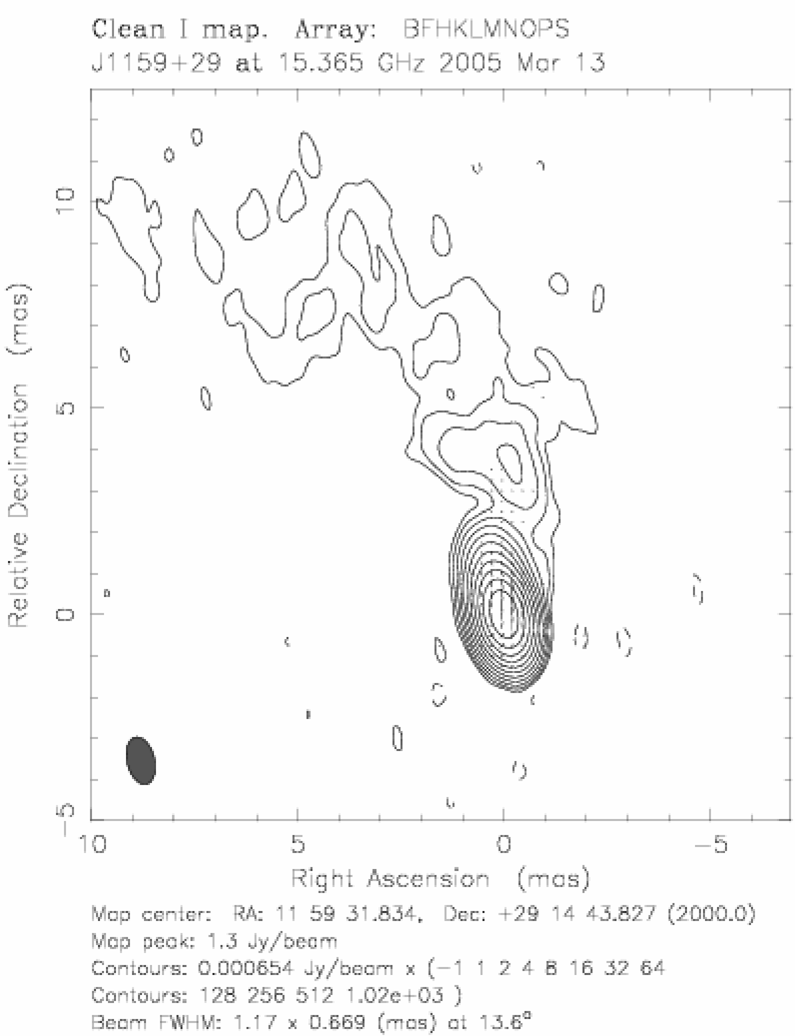
A helical pattern for 1156+295: vector S is the direction of the line of the sight, vector V is the direction of the velocity of the jet, theta(t) is the viewing angle between V and S.

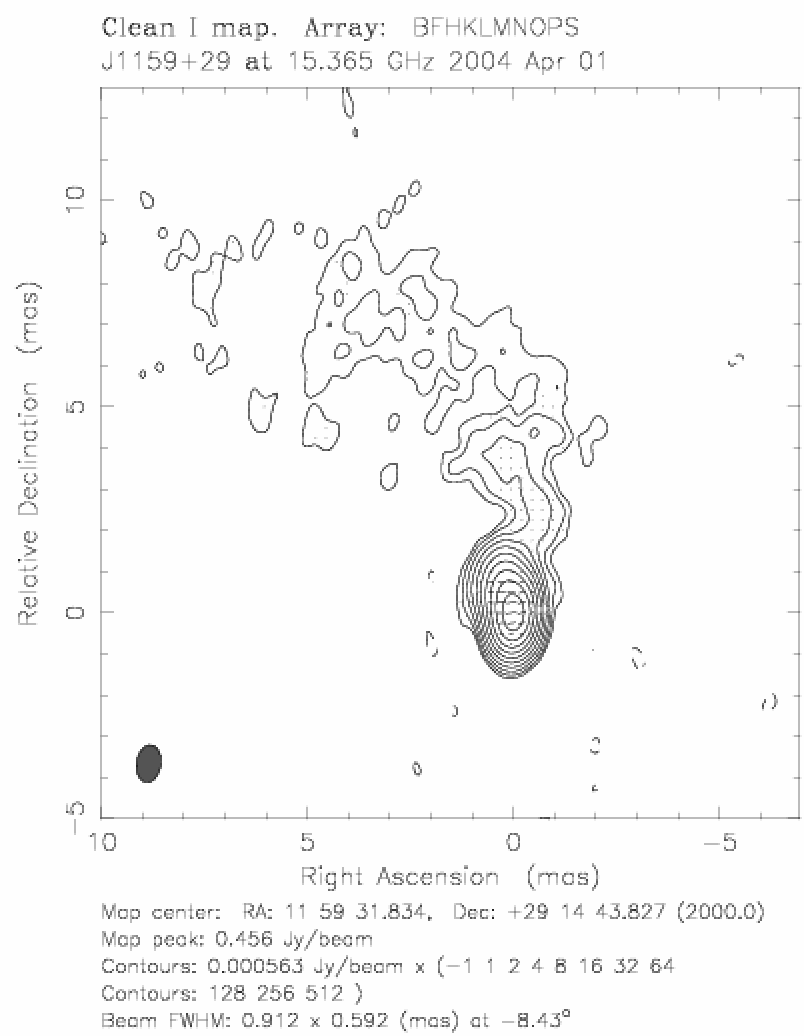


Apparent proper motion of the jet components: 1.6~GHz (diamond), 5~GHz (star), 15~GHz (square), 22~GHz (triangle, Jorstad, et al. 2001). Black for C1, Green for C2, Red for C3, and blue for C4.

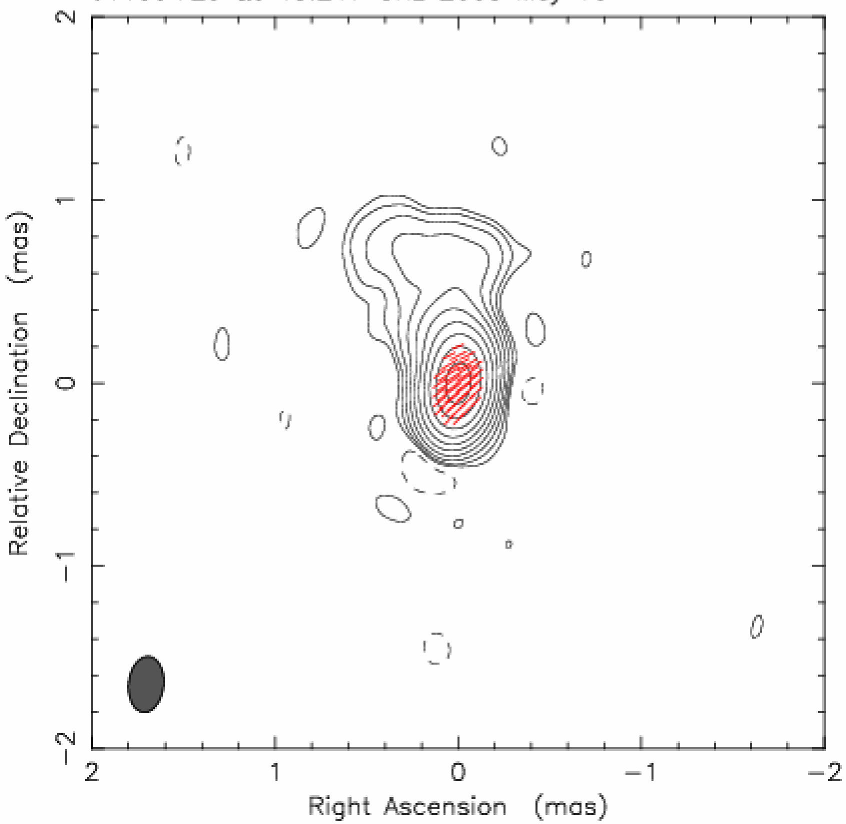

Clean I map. Array: BFHKLMNOPS
J1159+29 at 15.365 GHz 2003 May 10
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 1.63 Jy/beam
Contours: 0.00085 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256 512 1.02e+03)
Beam FWHM: 0.967 x 0.625 (mas) at −7.14°


Clean I map. Array: BFHKLMNOP
J1159+29 at 15.365 GHz 2003 Jul 24
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 1.88 Jy/beam
Contours: 0.000941 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256 512 1.02e+03)
Beam FWHM: 1.31 x 0.741 (mas) at −22.8°


Clean I map. Array: BFHKLMNOPS
J1159+29 at 15.365 GHz 2005 Mar 13
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 1.3 Jy/beam
Contours: 0.000654 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256 512 1.02e+03)
Beam FWHM: 1.17 x 0.669 (mas) at 13.6°

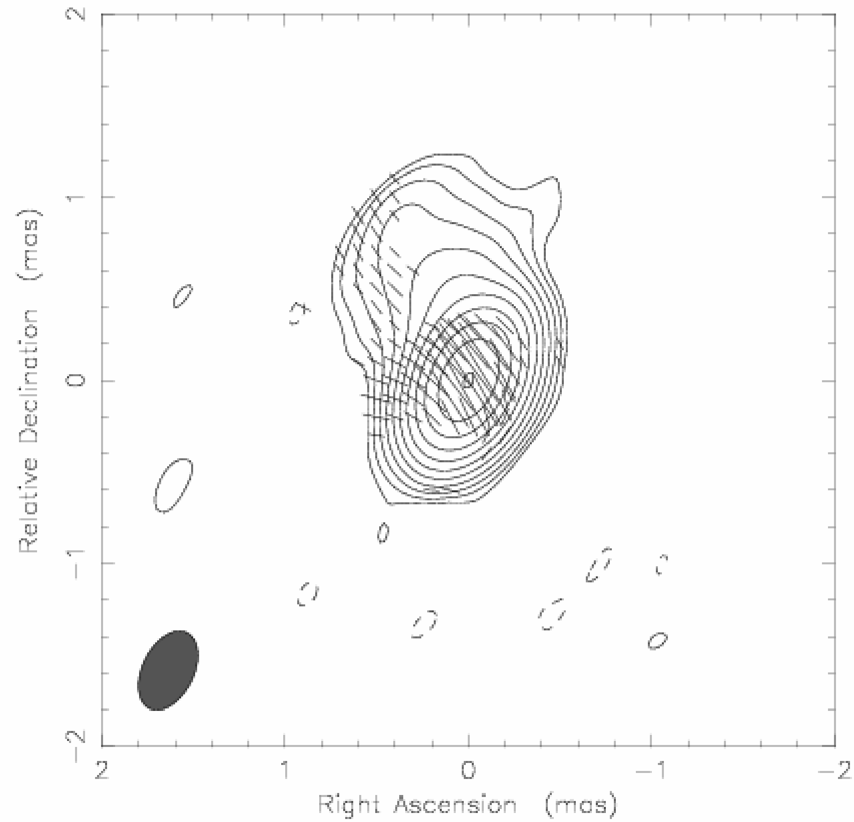

Clean I map. Array: BFHKLMNOPS
J1159+29 at 15.365 GHz 2004 Apr 01
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 0.456 Jy/beam
Contours: 0.000563 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256 512)
Beam FWHM: 0.912 x 0.592 (mas) at −8.43°

Clean I map. Array: BFHKLMNOPS
J1159+29 at 43.217 GHz 2003 May 10

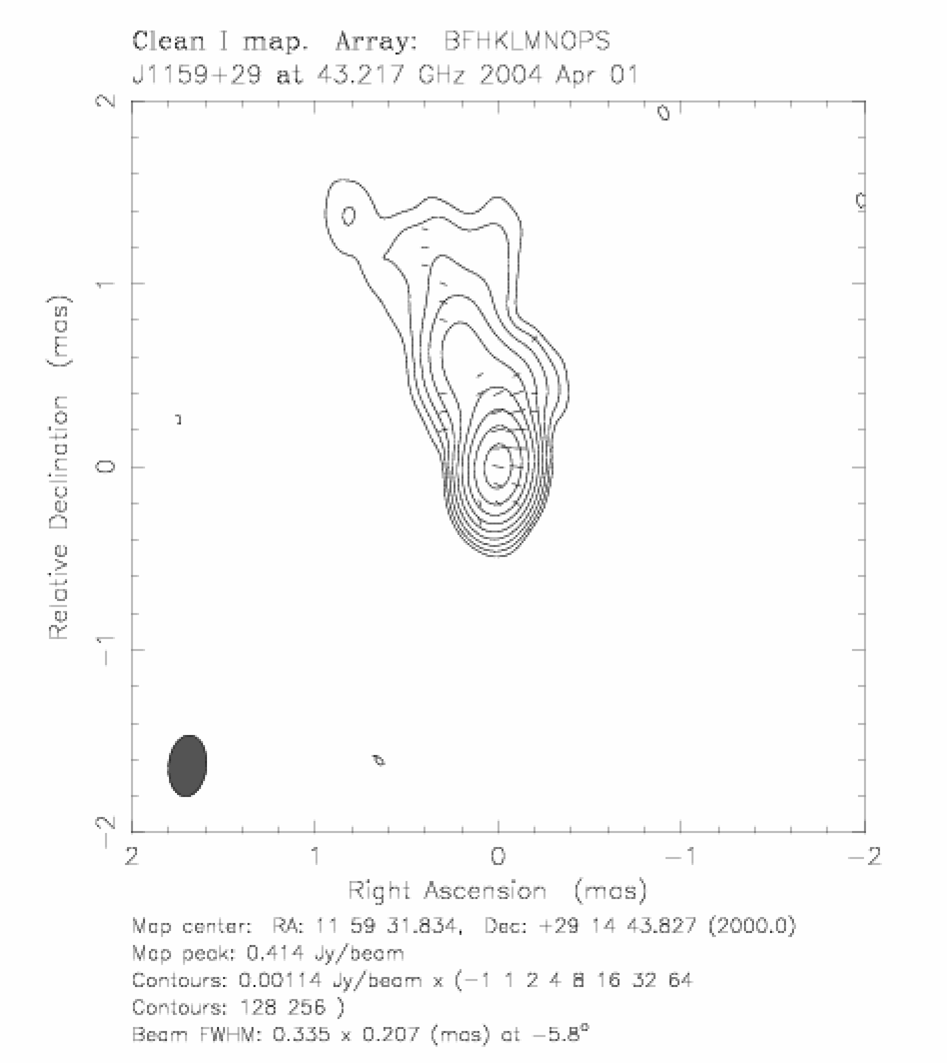


Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 1.57 Jy/beam
Contours: 0.00219 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256 512)
Beam FWHM: 0.305 x 0.192 (mas) at −6.16°

Clean I map. Array: BFHKLMNOP
J1159+29 at 43.217 GHz 2003 Jul 24



Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 2.19 Jy/beam
Contours: 0.0021 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256 512 1.02e+03)
Beam FWHM: 0.46 x 0.279 (mas) at −26.6°


Clean I map. Array: BFHKLMNOPS
J1159+29 at 43.217 GHz 2004 Apr 01
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 11 59 31.834, Dec: +29 14 43.827 (2000.0)
Map peak: 0.414 Jy/beam
Contours: 0.00114 Jy/beam x (-1 1 2 4 8 16 32 64
Contours: 128 256)
Beam FWHM: 0.335 x 0.207 (mas) at -5.8°

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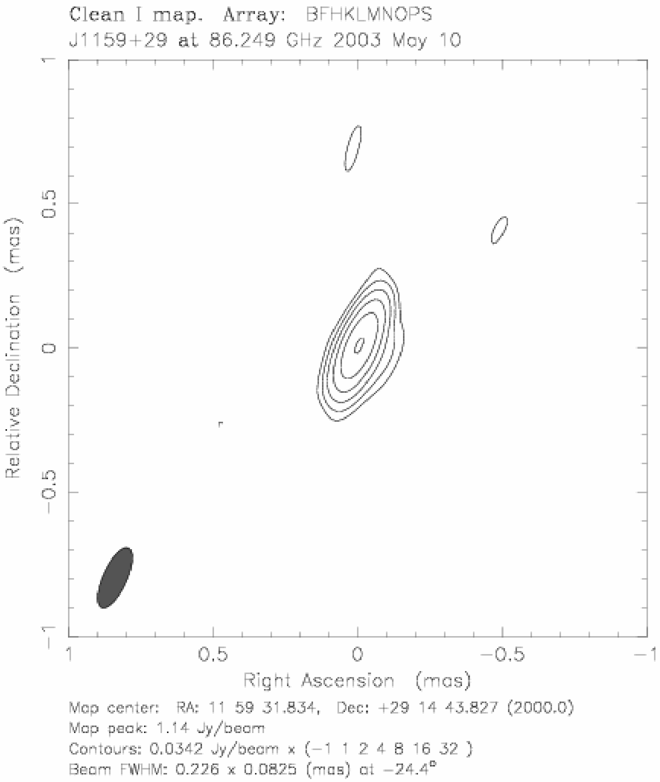

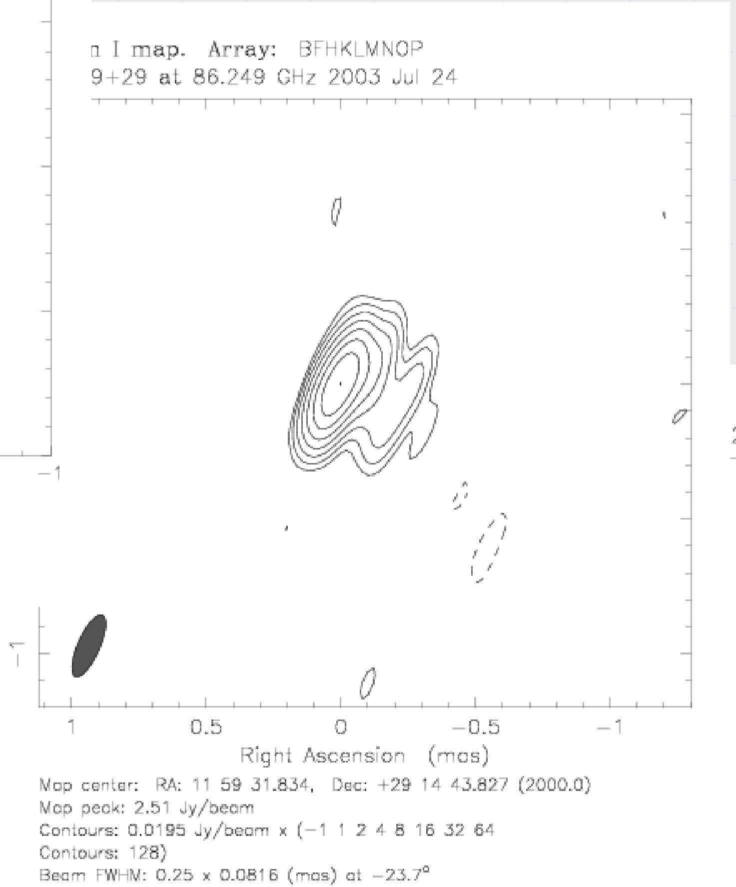

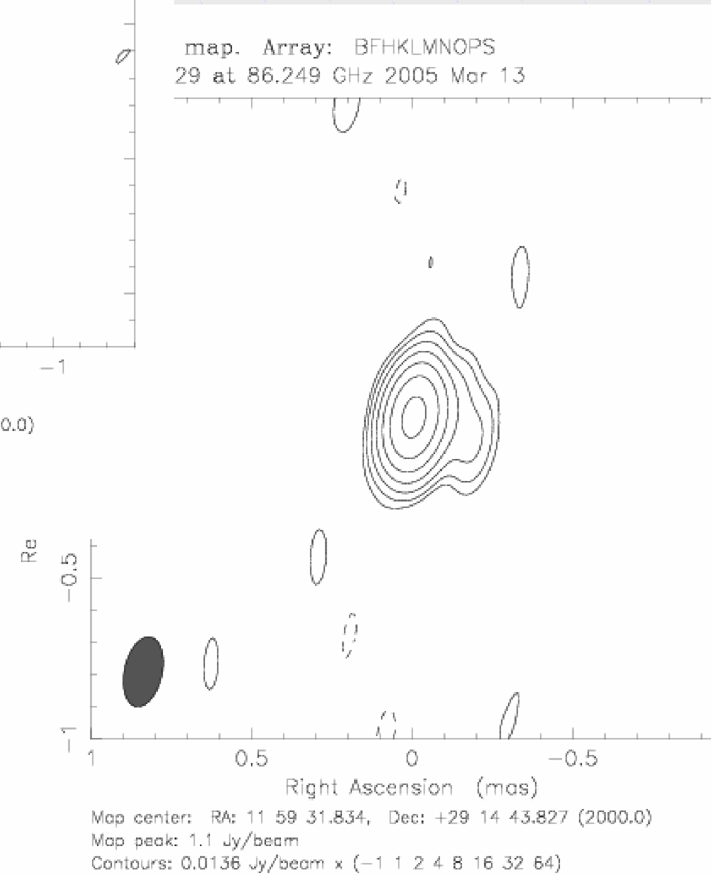

Conclusion

- Numbers of EGRET-detected AGN are double sides structure at kpc scale.
- Two side jets are also detected in some EGRET-detected AGNs
- Superluminal motions are very common.
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Thank you!