Jet-disk collision as a possible driven mechanism of kpc-scale bubbles in NGC 3079

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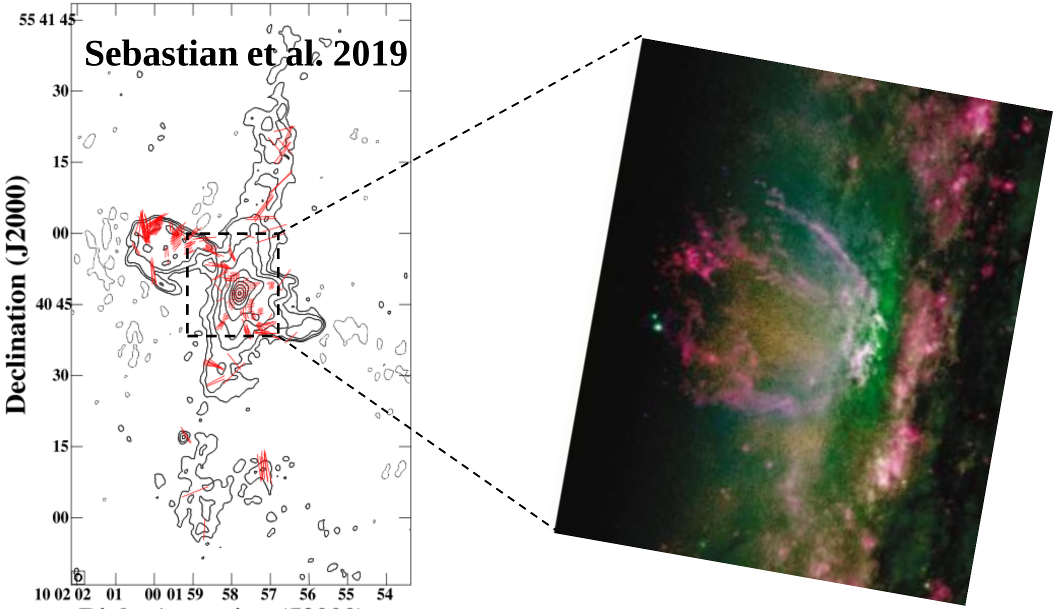
Introduction and Motivation

What drives the Kpc-scale radio structure of NGC3079?
Superwinds from its nucleus.
What drives the "Superwinds" ?
Supernovae and massive stellar winds? Not enough.
Radiation from AGN? Not enough.
Jets? Quite possible, but still some difficulties:
The misalignment between the pc and the kpc-scale radio structure.



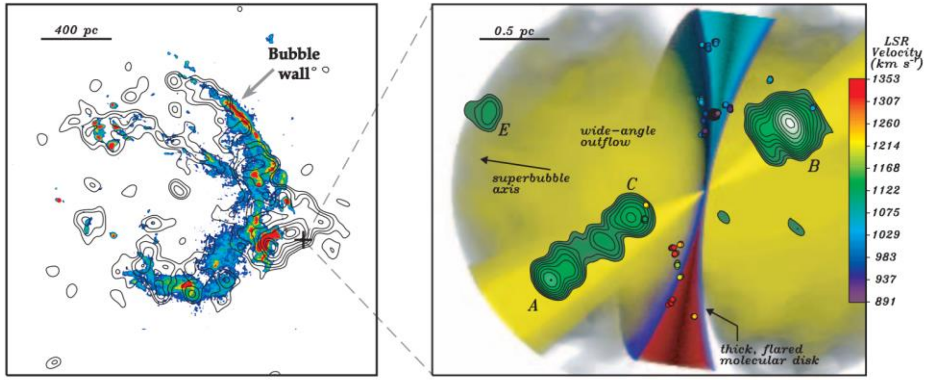
Cecil et al. 2004

When an inclined jet encountering a gas disc with large column depth, the jet will: (Mukherjee et al. 2018)

1. be decelerated (observed by Middelberg et al. 2007) ;

2. be deflected towards the minor axis;

3. the outward vertical component of the momentum of jet will be transferred to the disc; gas in the disc will be lifted and form a super-wind.



Kondratko et al. 2005

Methodology: phase-reference VLBI

Table 1. Observation logs.

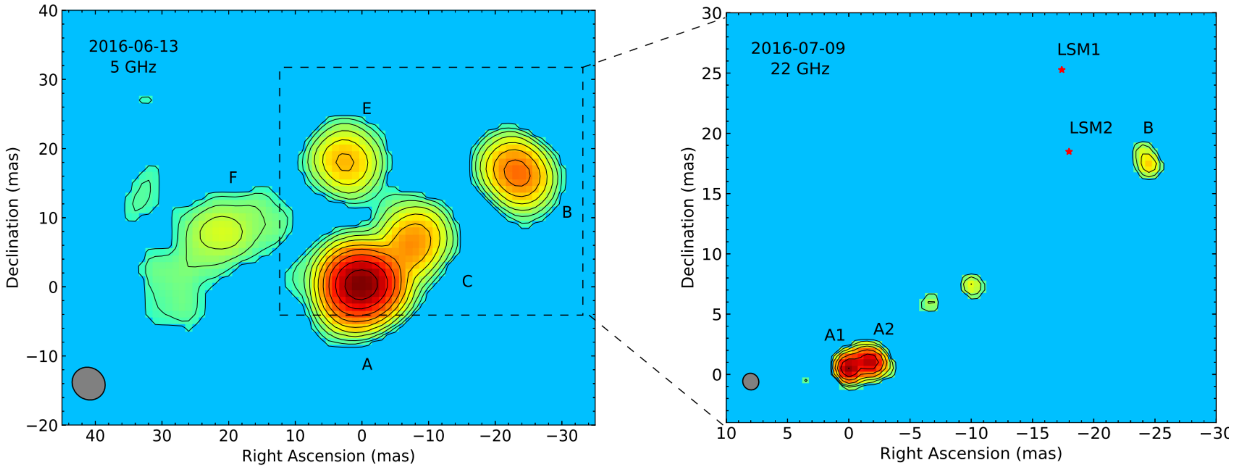
Obs.Code	Array[a]	Date	Epoch (Year)	ν (GHz)	Aggregate data rate (Mbit s^{-1})	τ (h)	Synthesized Beam[b] (mas×mas, degree)	rms[c] (mJy $beam^{-1}$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BZ061A	VLBA-Sc,Mk,Hh	2016-06-13	2016.45	5.0	512	7.8	5.08×4.60, 59.2	0.027
BZ061B	VLBA	2016-07-09	2016.52	22.0	512	7.8	1.39 ×1.30, 21.0	0.230
archived VLBI data								
BM107	VLBA-Sc, Mk,Hn	2002-09-22	2002.73	5.0	256	1.5	4.73×4.39, 75.6	0.075
BM208A	VLBA-Fd,Mk,Pt,Sc	2004-06-14	2004.45	5.0	256	2.8	3.95×3.50, 8.38	0.085
BM208B	VLBA-Sc,Mk,Hn	2004-11-03	2004.84	5.0	256	3.3	4.37×4.17, 41.5	0.063
BM208C	VLBA-Sc	2005-04-04	2005.26	5.0	256	2.6	4.39×3.98, 61.3	0.070
BM208D	VLBA-Mk	2005-08-18	2005.63	5.0	256	3.2	4.56×4.13,76.6	0.068

Note:
a: Only antennas with detected fringes are listed.
b:Size of the Synthesized beam of the CLEANed images.
c:rms noise level of the CLEANed images.

Results

Morphology

5GHz: A, B, C, E and F are clearly detected;
22GHz: E and F are not detected.



Maser emissions

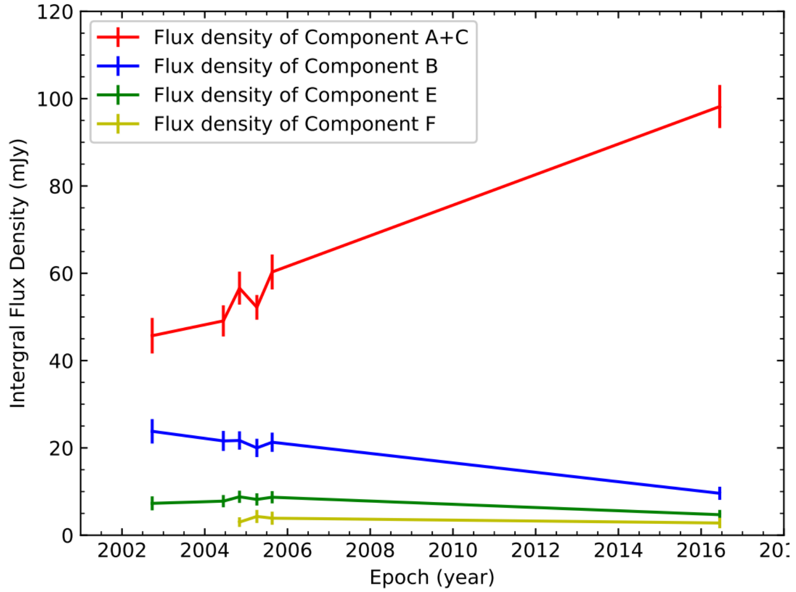
We detected 86 maser features with peak intensity higher than 6 mJy/beam.   These features belong to two blueshifted clusters, named as LSM1 and LSM2 by Yamauchi et al. 2004, in velocity ranges 995-1048 km/s and 946-1010 km/s respectively.

Spectral index between 5 and 22GHz

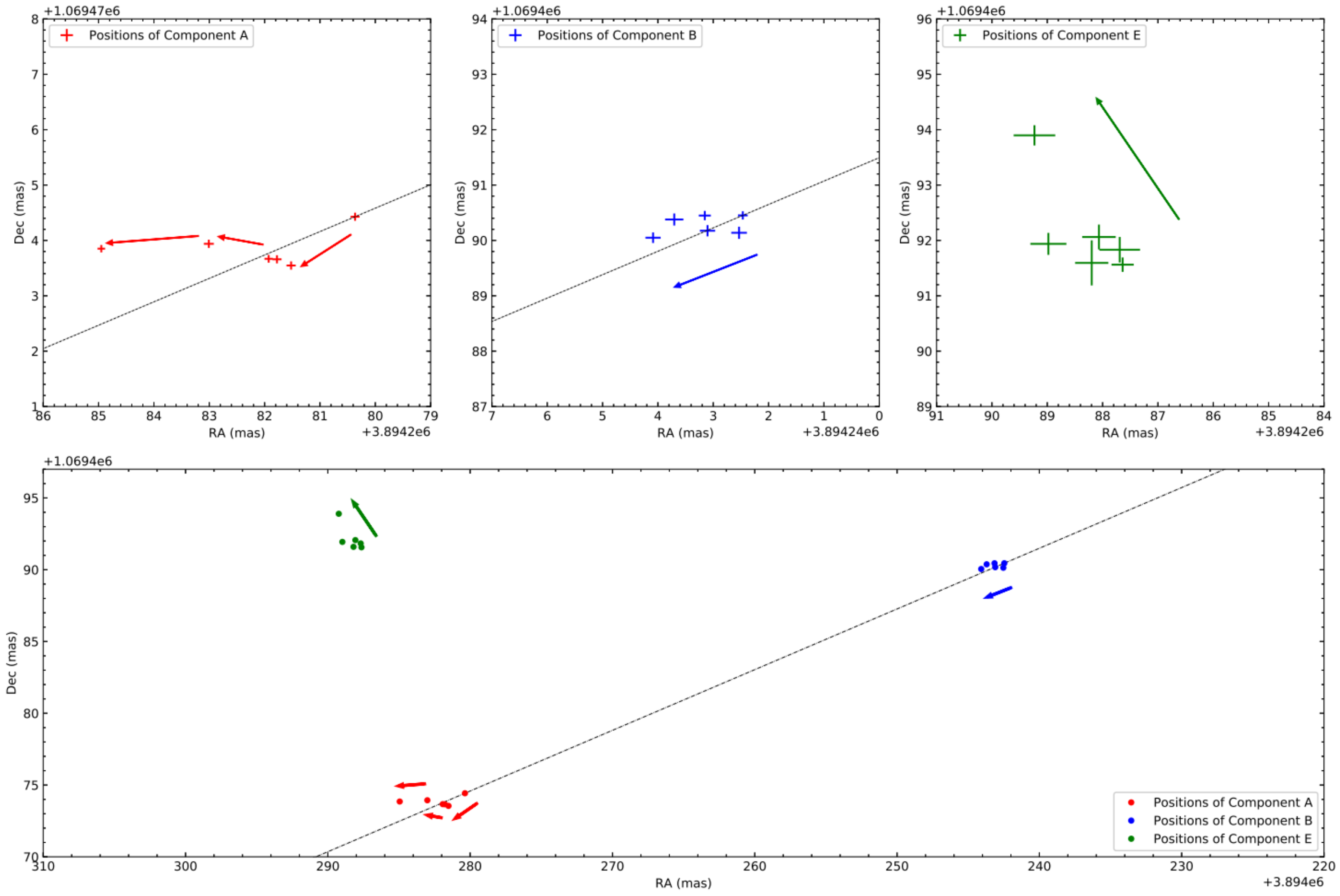
Nearly zero for "A+C" and B; suggesting a spectral turnover between 5 and 22GHz

Evolution Flux Density at 5GHz

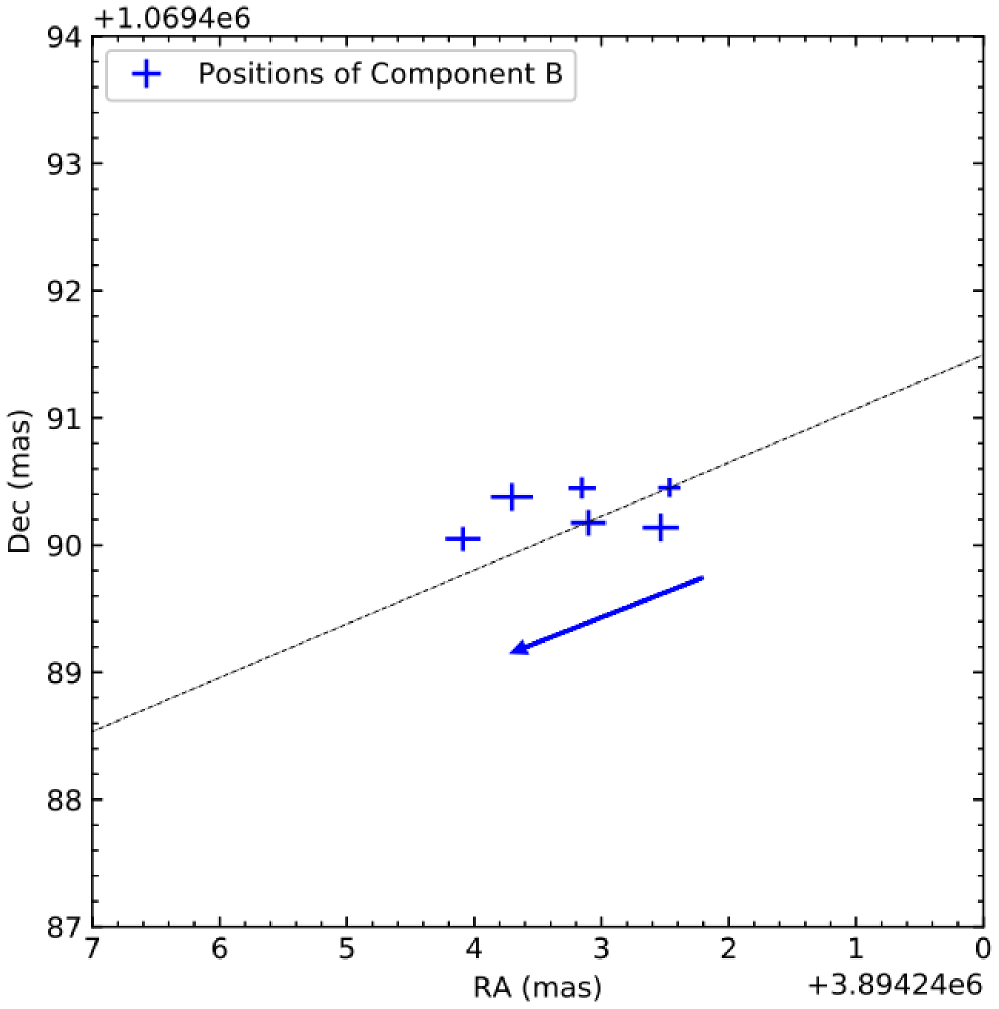
A+C: increased by a factor of 2.2;
B: decreased by a factor of 2.5 ;
E: decreased by a factor of 1.9 ;
F: No evolution



Motion of Continuum Components with respect to 4C +55.17



Motion of Continuum Components: B with respect to 4C +55.17



B had moved inward along the co-axis?

We compared the position of B to the brightest maser feature and found a similar result with that of 5GHz.

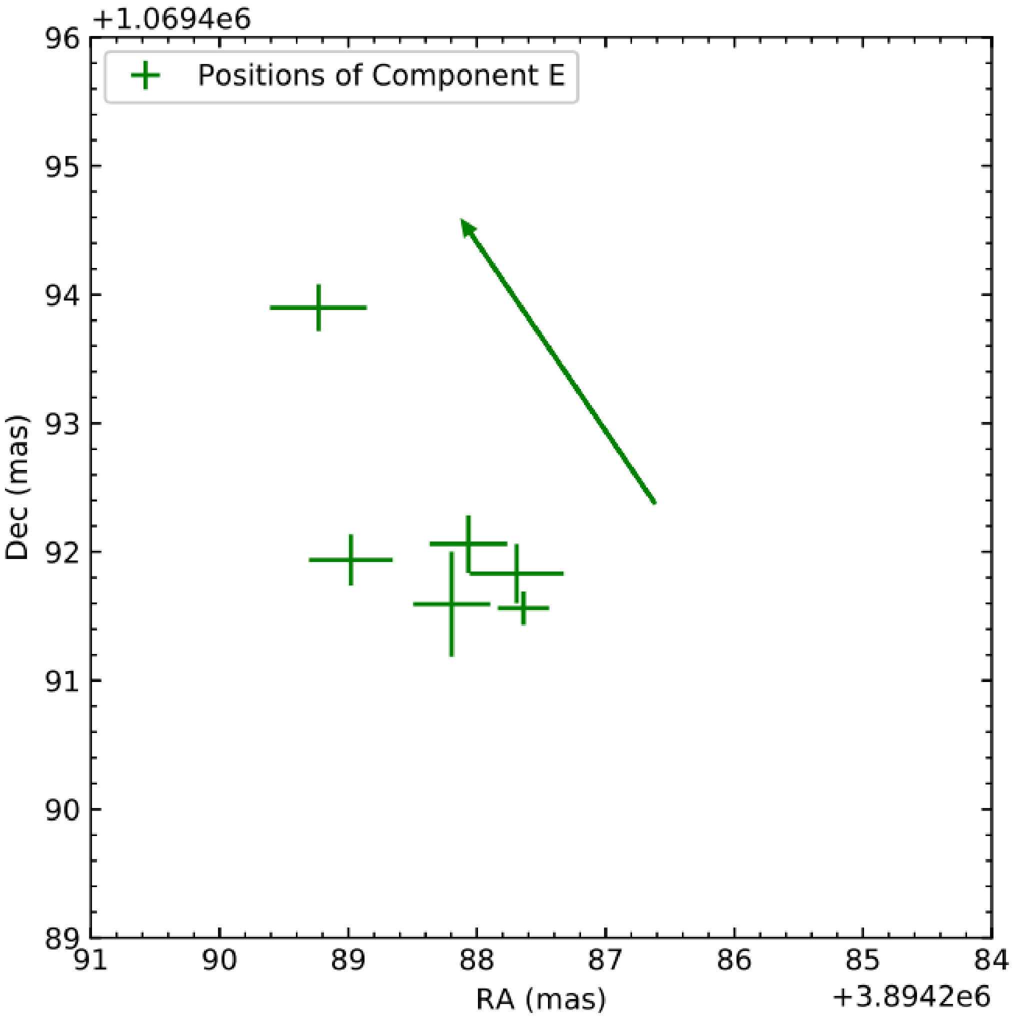
The inward motion is unusual for a CSO-like radio source.

The change might be true, but it is too tiny comparing with the size of B at 5GHz (~5mas).

It might just reflect a re-distribution of surface brightness, indicating a change of its inner structure, or optical depth.

No reliable motion is detected for B

Motion of Continuum Components : E with respect to 4C +55.17



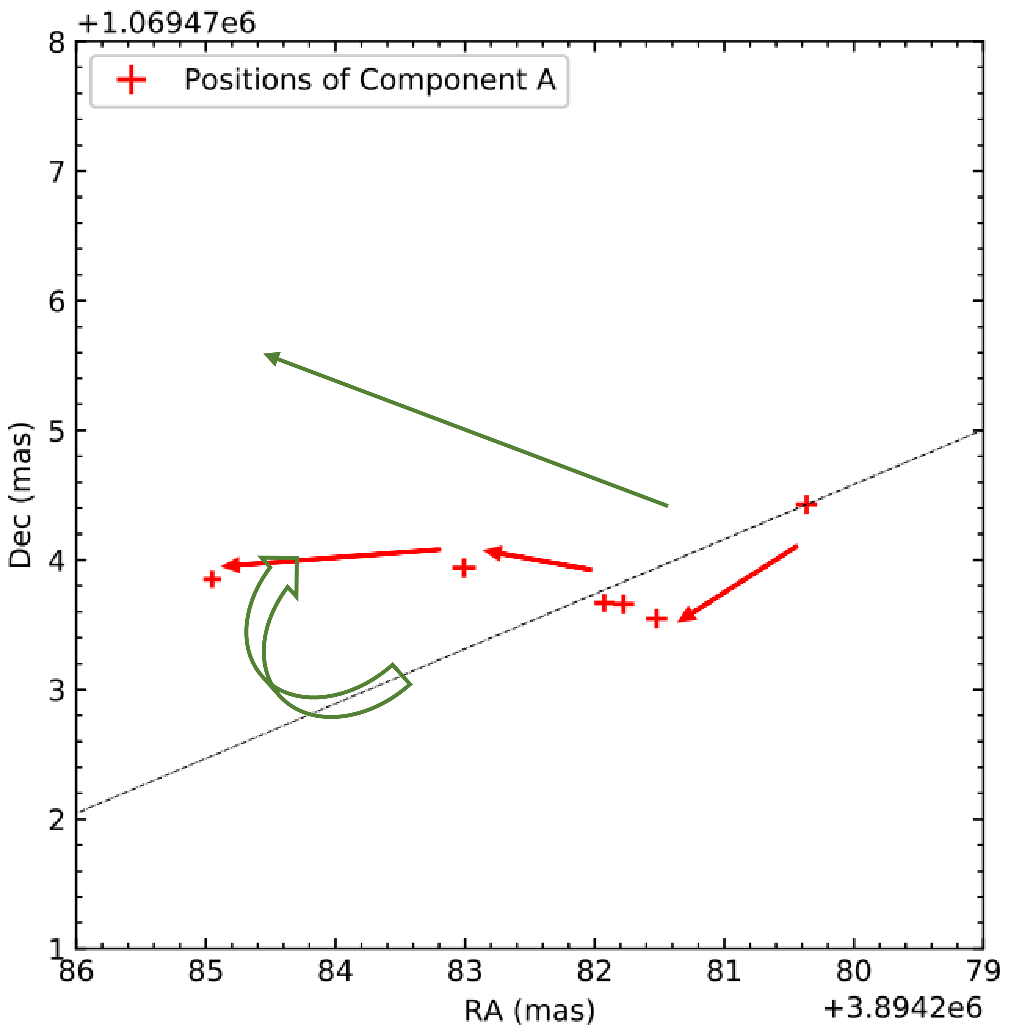
The trajectory of component E is tortuous, but the trend of its motion is clear:

E had moved for 1.38 mas (0.1 pc) towards a direction which is about 60◦ respect to the north (as the green arrow shows). Such a direction is almost coincident with the orientation of the kpc-scale supperbubble.

If we divide the displacement by the time duration between the last and first epoch, the average velocity of E was 0.10 mas/year, i.e., 0.02 *c*.

A direct evidence for the pc-scale subrelativistic outflow in the nucleus of NGC 3079.

Motion of Continuum Components : A with respect to 4C +55.17

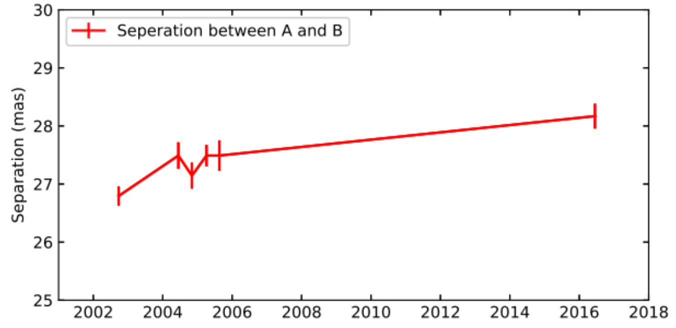


From epoch 1 to 2, A moved along the co-axis;

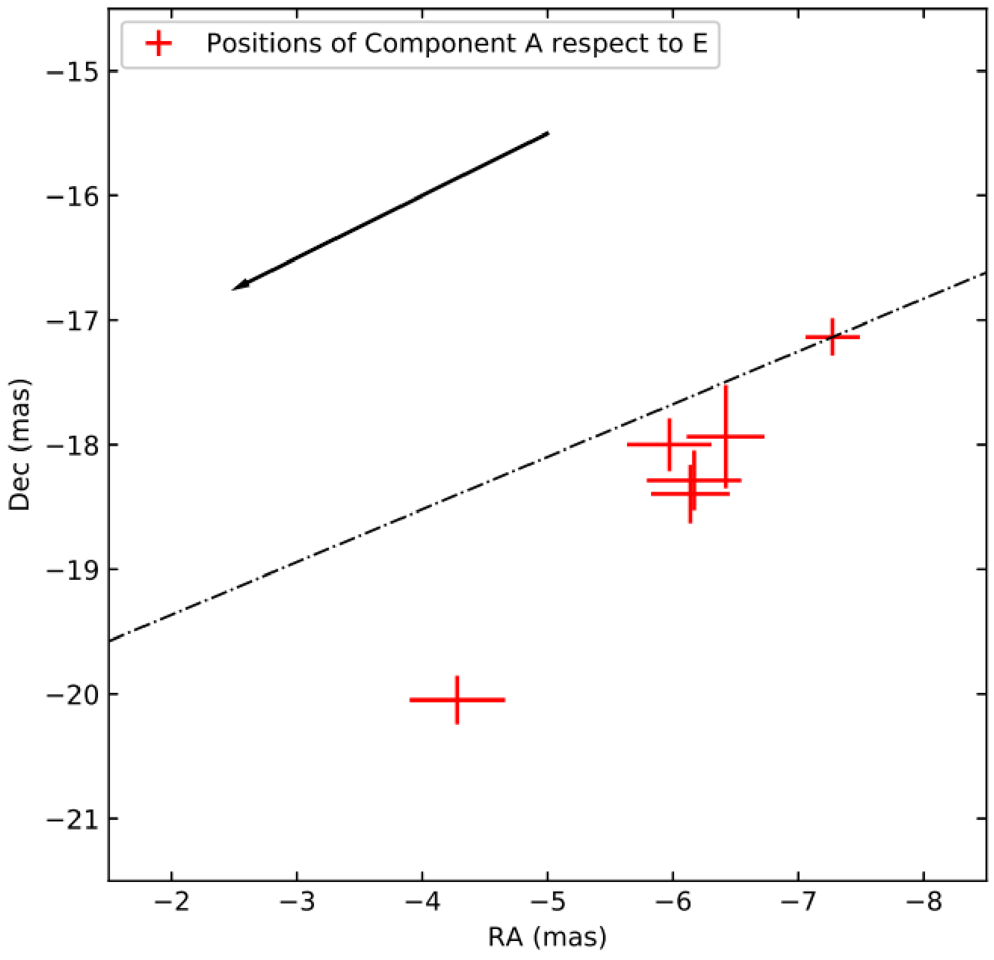
Since epoch 2, A drifted eastward; from epoch 2 to 5, the separation between A and B had almost not increased, but PA had changed;

From epoch 5 to 6: a result of time-averaging, A had experienced alternations between two phases in a time longer than 11 yr.

As a component of the pc-scale jet of NGC3079, A is deflected towards the direction of the minor axis of the disc i.e., the superbubble.



Motion of Continuum Components : A with respect to E



The motion of A relative to E is just along its original direction of motion i.e., the co-axis of A and B.

Then the motion of A could be decomposed into: a component in its original direction + another component consistent with the motion of E.

The motion of E is related to the motion of A.

An indirect evidence of transferring of momentum from jet to the outflow, if E is associated with the outflow?

But of course, it's not the only interpretation.

Conclusion

When an inclined jet encountering a gas disc with large column depth, the jet will:

- be decelerated; √
- be deflected towards the minor axis; √
- the outward vertical component of the momentum of jet will be transferred to the disc; gas in the disc will be lifted and form a super-wind. ? √

Jet-disk collision is a possible driven mechanism of kpc-scale bubbles in NGC 3079.

Collisions between inclined jets and discs might be common in Seyfert galaxies like NGC3079, since in these galaxies, orientation of the jet is arbitrary respect to the gaseous or stellar disc. And that is why Seyfert galaxies often tend to develop large-scale bipolar structure with spherical or oval morphology.

Thanks! If you have any question, please sent it to ***weizhao@shao.ac.cn***