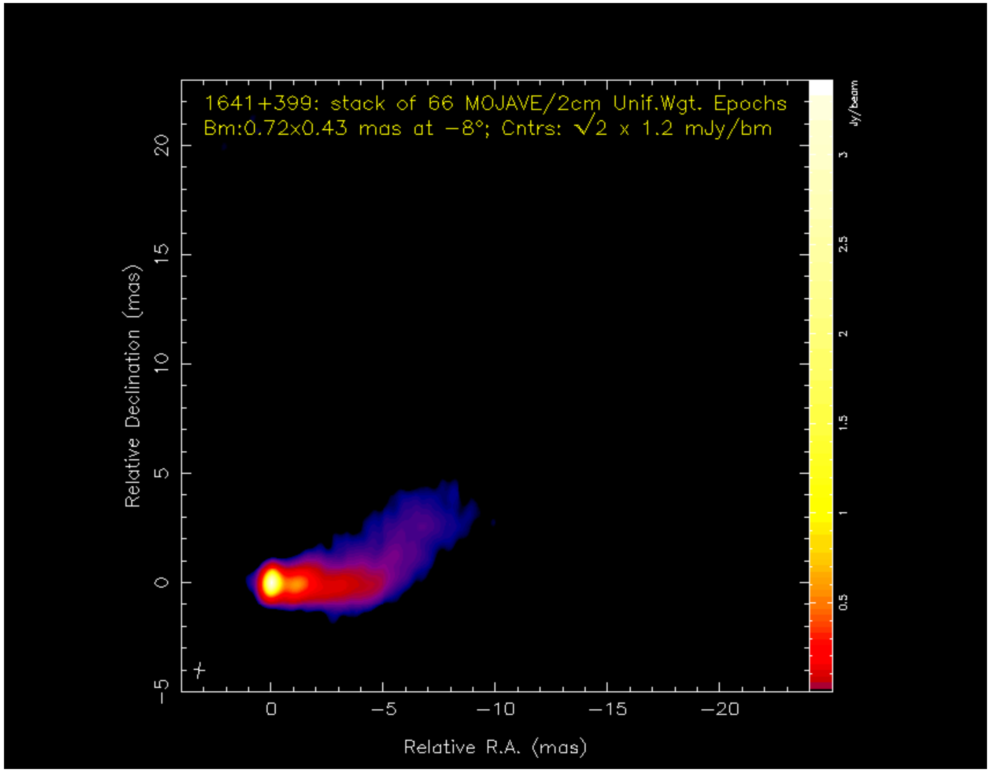
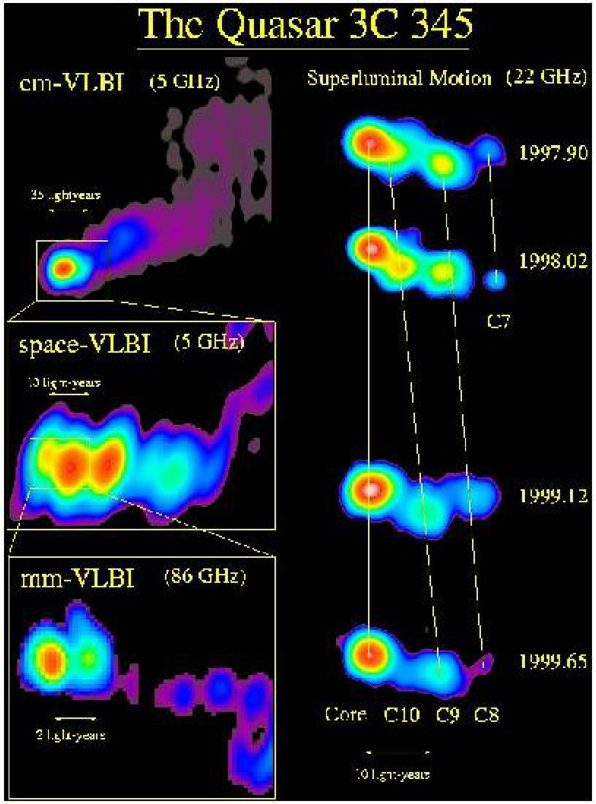
Binary black holes in nuclei of extragalactic radio sources

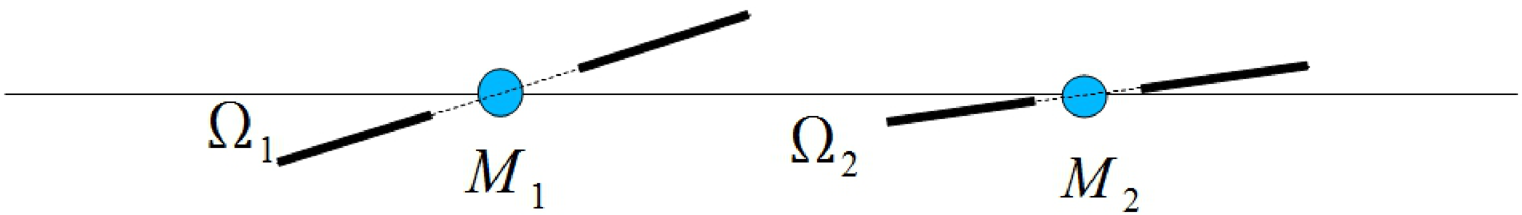




3C 345

VLBI component = radio blob
superluminal motion = apparent motion

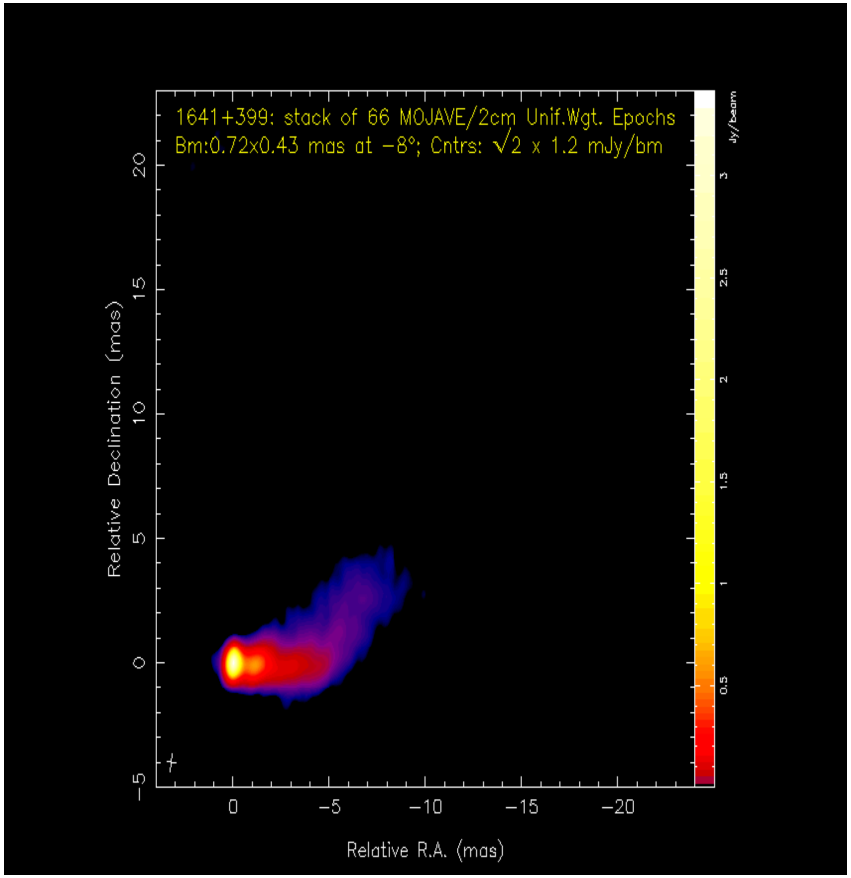
VLBI observations of compact radio sources show that the ejection of VLBI components does not follow a straight line, but undulates. These observations suggest a precession of the accretion disk. To explain the precession of the accretion disk, we will assume that the nuclei of radio sources contain BBH systems (binary black hole).



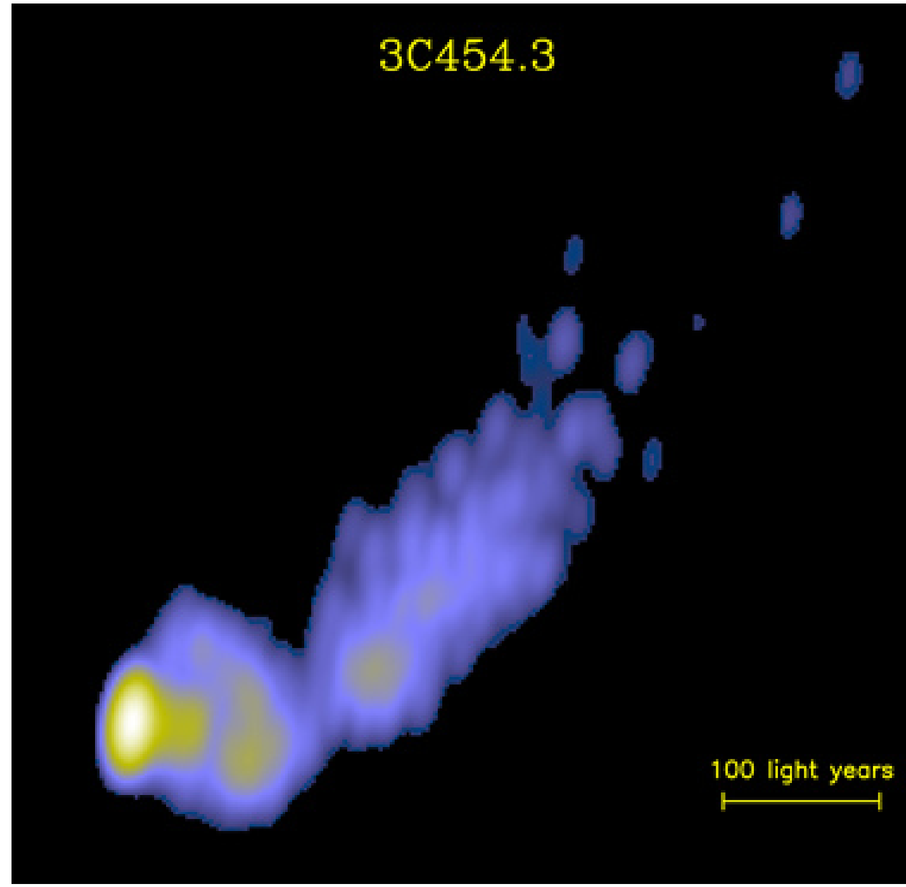
A BBH system produces three perturbations of the VLBI ejection due to

- the precession of the accretion disk,
- the motion of the two black holes around the gravity center of the BBH system, and
- the motion of the BBH system around something.

3C 345

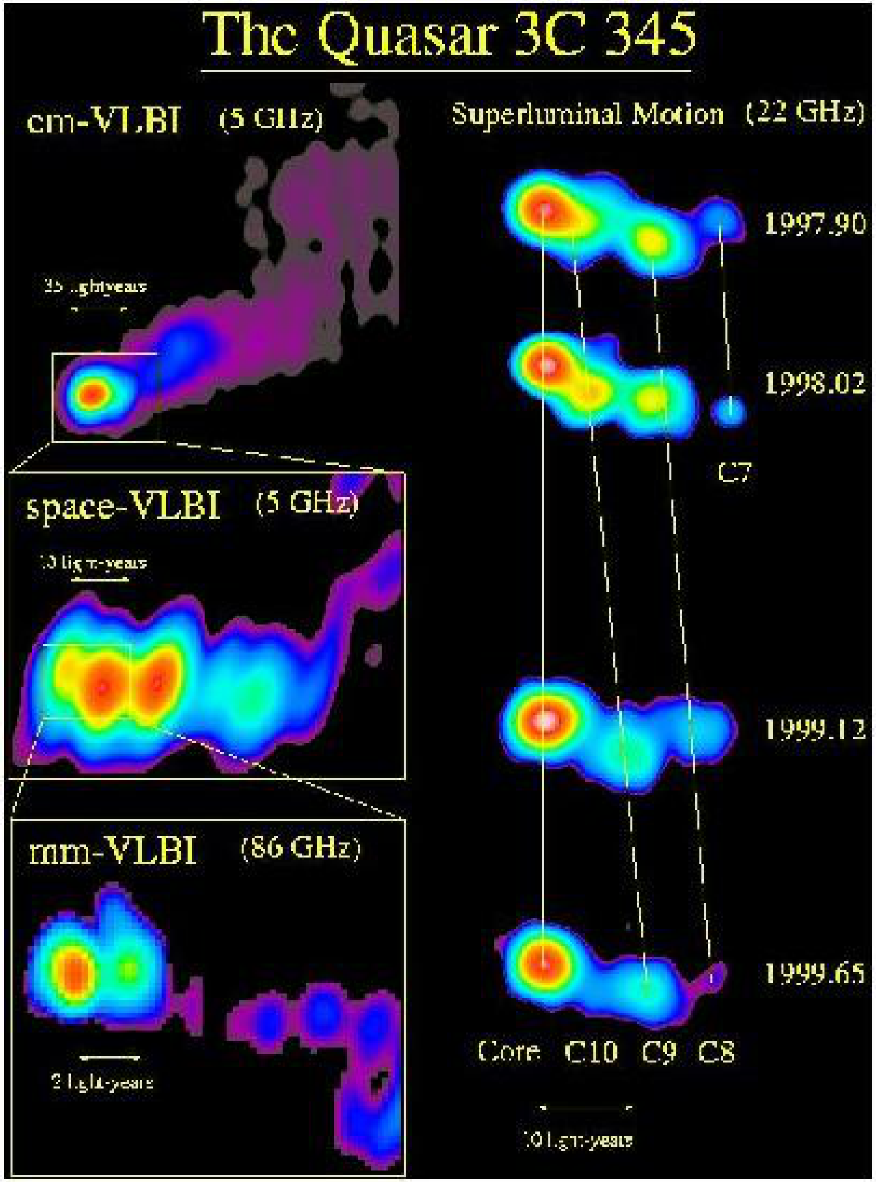


3C 454.3



Slow motion of the BBH system
around something

- Precession of the accretion disk
- Motion of BH around the center of gravity fo the BBH system

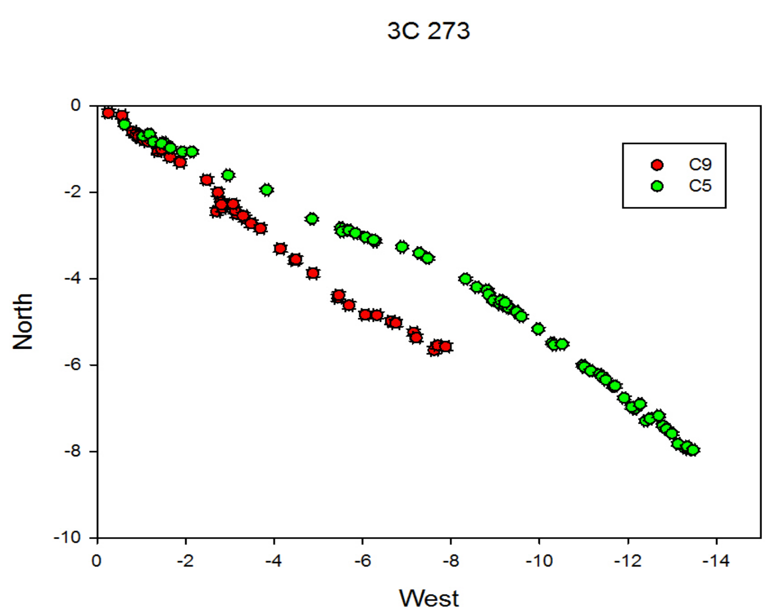


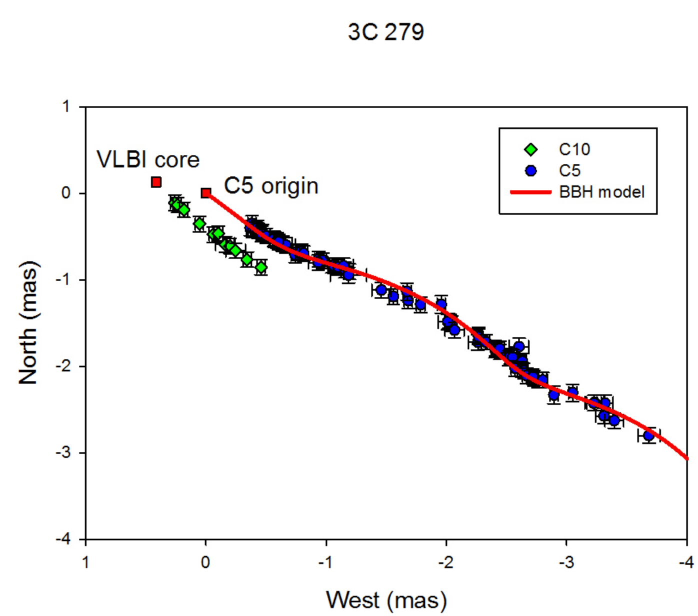
Consequences of the BBH model

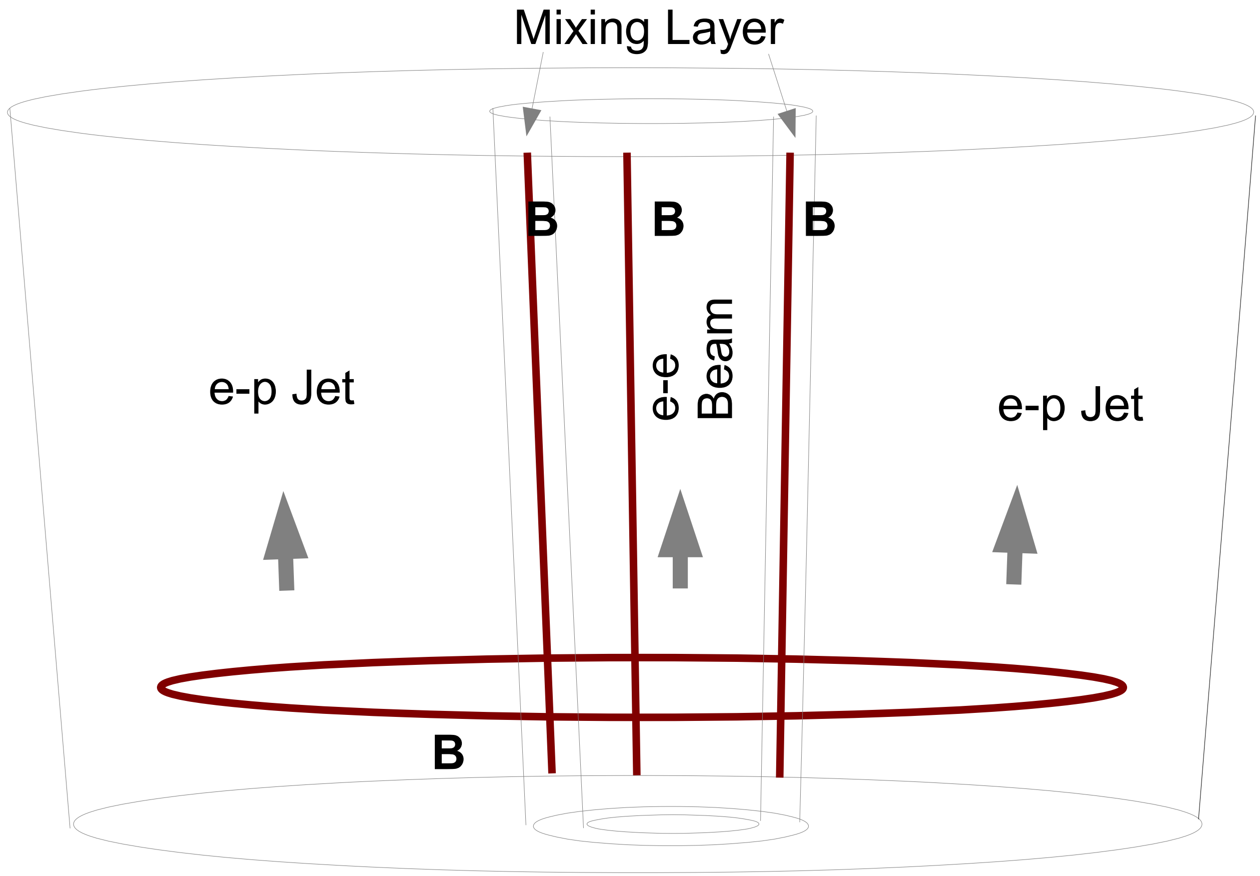
1) – Even if Ω = 0, the VLBI component does not follow a straight line,

2) – If the two BH eject VLBI components, we will observe

- 2 families of trajectories (different Omega, …), 3C 273, 3C 279 ...
- a possible offset of the origin of the VLBI ejection, (the origin of the VLBI ejection is different from the VLBI core), → detection of the radius of the BBH system and the positions of the 2 BH, 3C 279 ...







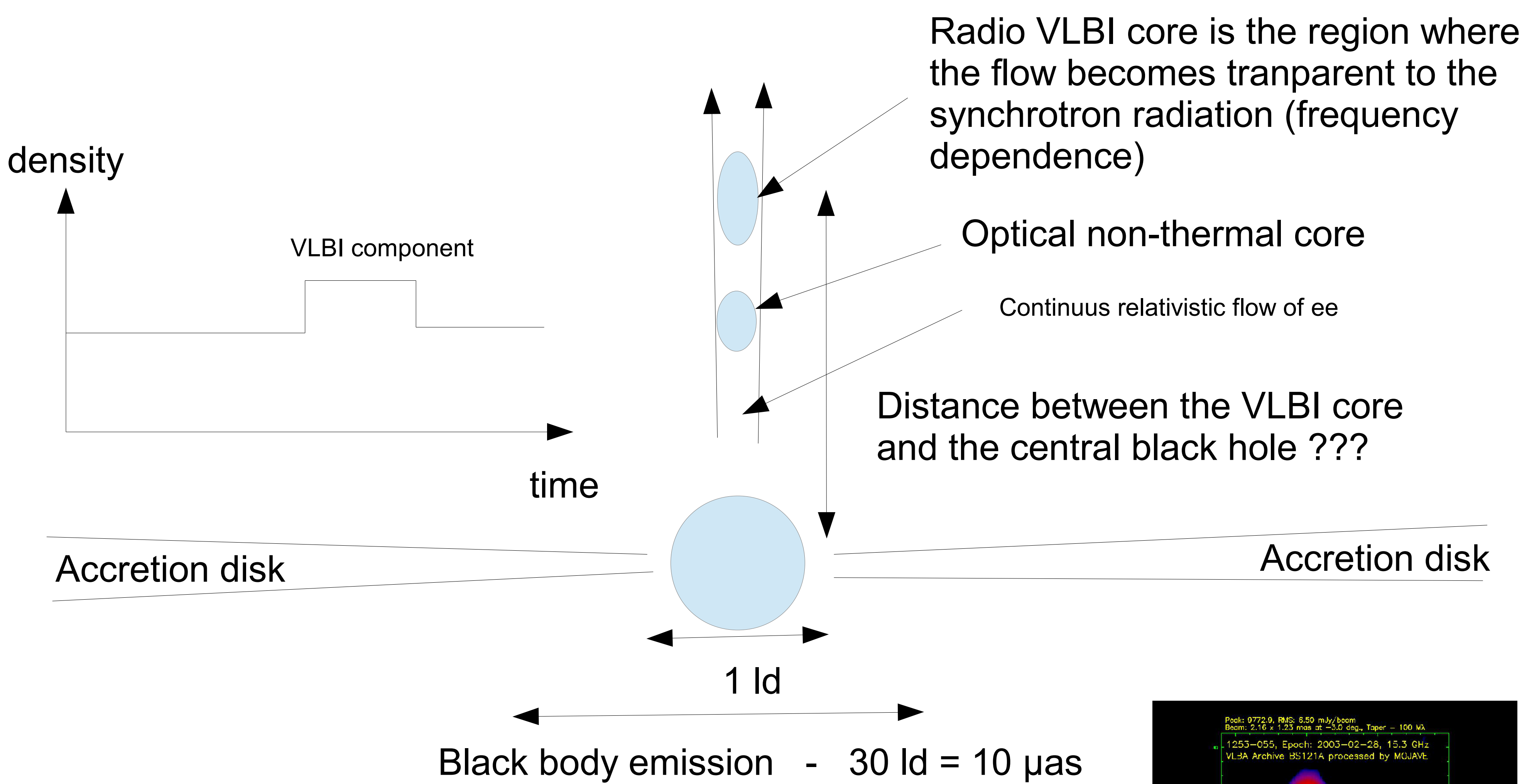
- an *e* - *p* plasma (*jet*), which speed is : $v_j \leqslant 0.4\, c$
- an *e* - *e* plasma (*beam*), which speed is : $v_b \approx c$

Important problems for GAIA : the opacity effect and the nature of the radiation detected

-) What is the distance between the VLBI core and the central black hole ???

-) What is the relation between the optical detection of GAIA and the radio core ???

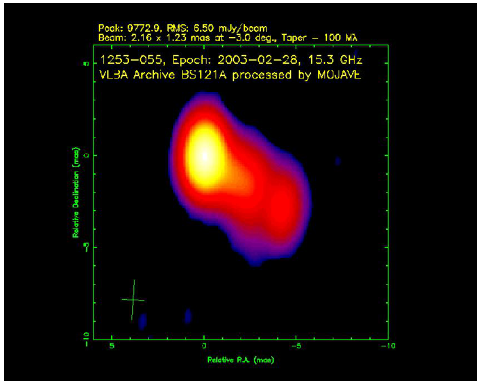
What is the VLBI core ??? and where the optical emission come from ???



3C 279 - z = 0.536 - Ho = 72

1 pc = 155 µas - 1 ld = 8.4 10^(-4) pc = 0.3 µas

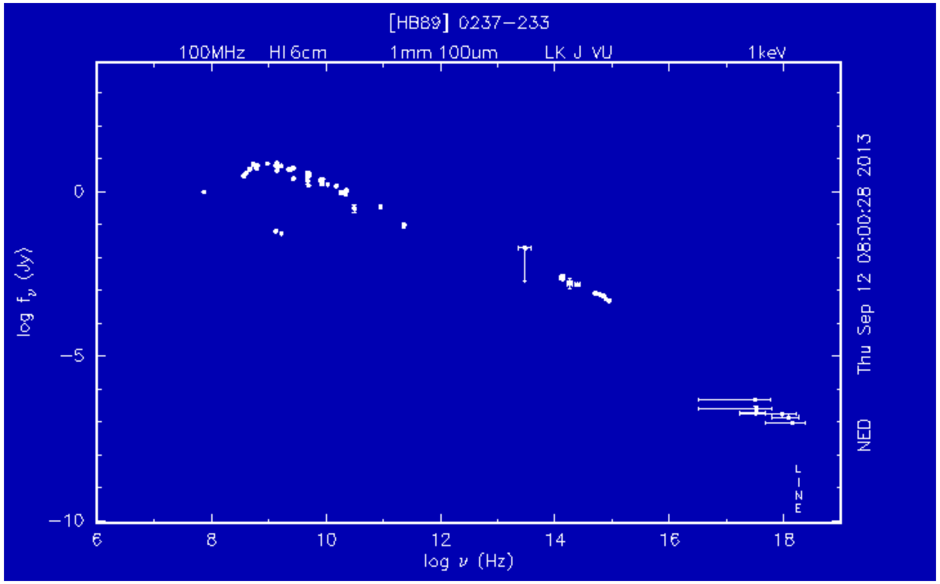
M = 10^9 Mo → Rg = 10^(-4) pc



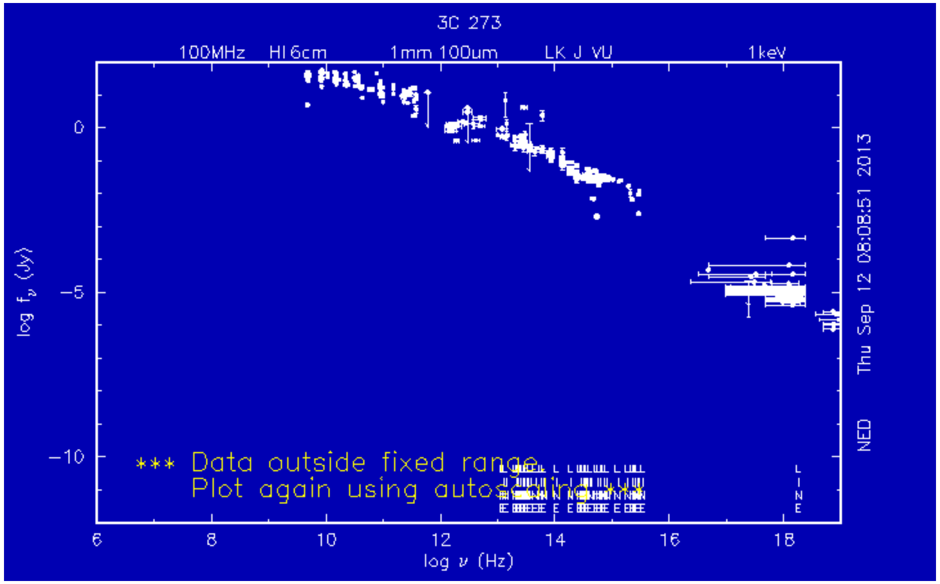
VLBI core

The optical spectrum of a radio quasar is dominated by non-thermal radiation (synchrotron + IC)

This is shown by the power law distribution and the linear polarization



PKS 0237-233



3C 273

Optical emission = optical non-thermal core (synchrotron + IC) +
black body emission of the central parts of the accretion disk +
BL region emission +
stellar emission …

→ Distance between the radio core and the optical core ???
(the optical core is not the central black hole !!!)
Problem if you have a BBH system with the two BH ejecting VLBI components

The model (geometrical model)

The plasma ejected relativistically follows the magnetic field lines, which are perturbated by :

- the precession of the accretion disk, and
- the motion of the black hole in BBH system.

So the coordinates of a *point source* are given by :

$$x(t) = (R_o(z)\cos(\omega_p t - k_p z + \phi) + x_1(t)\cos(\omega_b t - k_b z + \psi))\exp(-t/T_{beam})$$

$$y(t) = (R_o(z)\sin(\omega_p t - k_p z + \phi) + y_1(t)\sin(\omega_b t - k_b z + \psi))\exp(-t/T_{beam})$$

$$z(t) = z$$

-) Definition of a *VLBI component*: Xc = ∑*x(t)*/n, Yc = ∑*y(t)*/n and Zc = ∑*z(t)*/n

-) From VLBI observations, we have X(t) and Y(t) for VLBI components:

⟶ the trajectory and the kinematic are known,

⟶ we can find the inclination angle and the bulk Lorentz factor

⟶ we can find the characteristics of the BBH system in the nucleus (generally, there is not a unique solution, but a family of solutions)

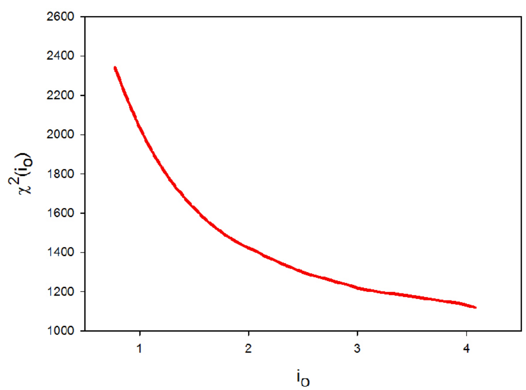
If two components ejected by the same BH only the phases of the precession and the BBH system change and we can predict the phase changes.

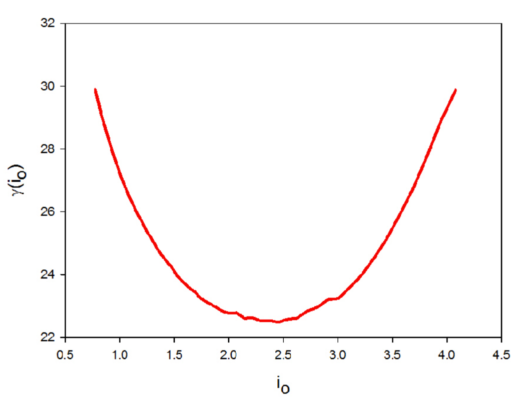
General problem

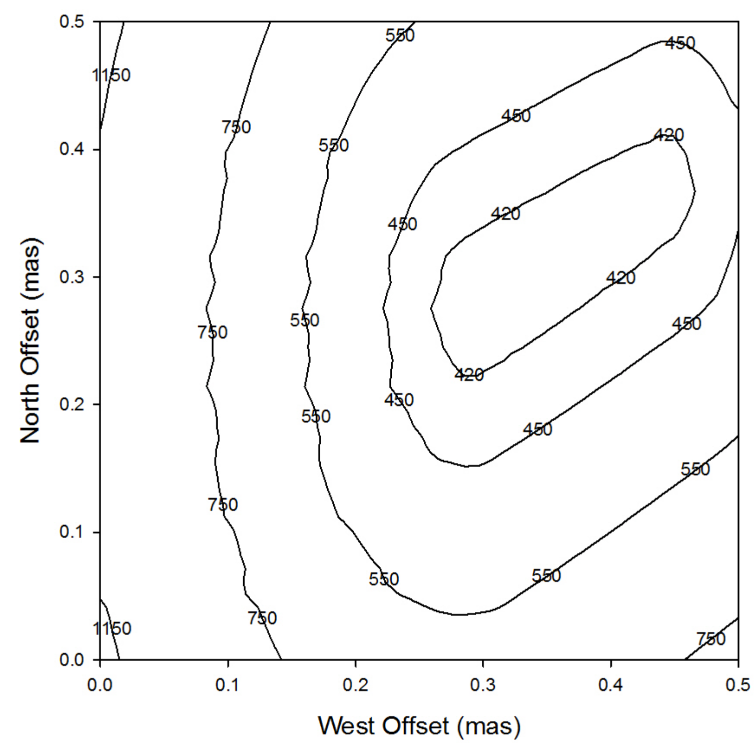
Precession model applied to component C5 of 3C279

The results of the precession model are
- 1) the curve $\varkappa^2(io)$ is convex → there is no stable solution, and
- 2) there is an offset of the origin of the ejection → the ejection origin is not the VLBI core.

→ to explain the observations, we have to assume that the nucleus contains a BBH system.



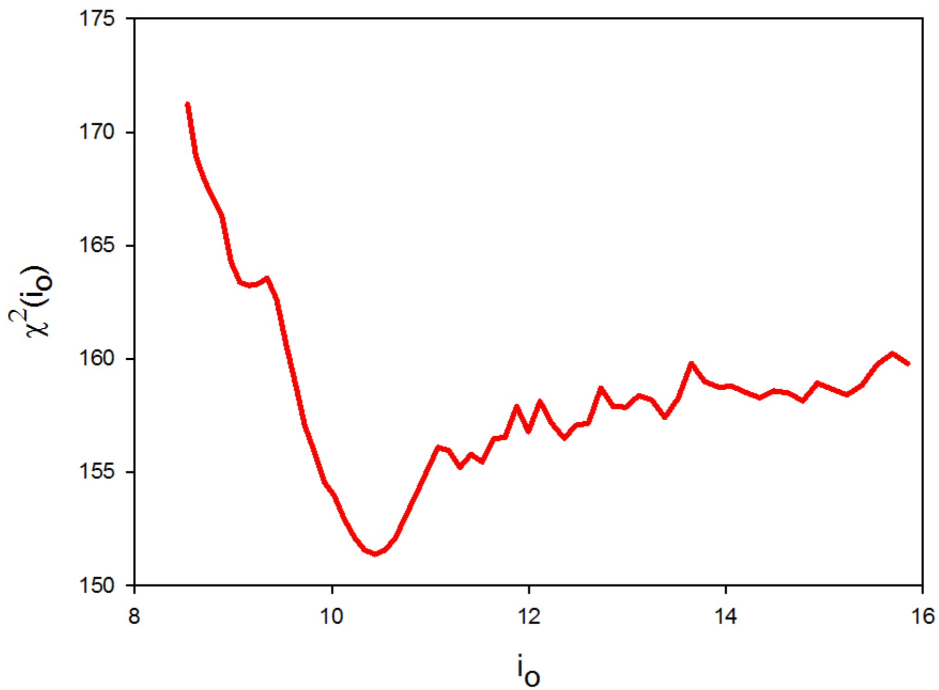


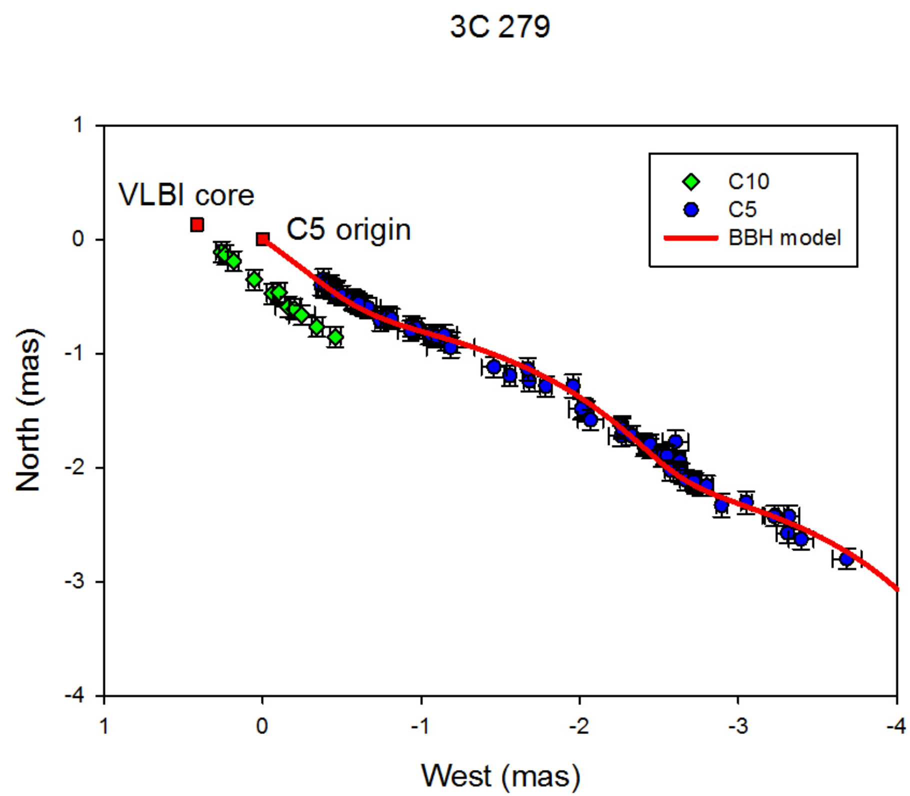


BBH model applied to component C5 of 3C279

The main results of the BBH model are
- 1) the curve $\varkappa^2$(io) is concave for io ≈ 10, and
- 2) the radius of the BBH system is Rbin ≈ 420 µas and the positons of the 2 BH are known

In the case of 3C 279, there are two families of trajectories and the origin of C5 coincides with a stationary component





Results and conclusion

PKS 0420-014	contains a BBH system (Britzen et al 2001)
3C 345	contains a BBH systen (Lobanov & Roland 2005)
S5 1803+784	contains a BBH system of size Rbin ≈ 100 µas (Roland et al 2008)
1823+568	contains a BBH system of size Rbin ≈ 60 µas (Roland et al 2013)
3C 279	contains a BBH system of size Rbin ≈ 420 µas (Roland et al 2013)
PKS 1741-03	contains probably a BBH system with Rbin ≈ 180 µas (work in progress)
1928+738	contains a BBH system of size Rbin ≈ 230 µas (work in progress)
3C 345	contains 3 BH or 2 BBH systems (work in progress)

-) All radio sources contain a BBH system !!!

-) In the case of 1823+568, at 15 GHz we are able to detect an offset of 60 µas
VLBI Observations mm
- At 15 GHz : Resolution : 0.5 mas; positions : 40 µas
- At 43 GHz : positions : > 20 µas ?

-) Within 1 mas with a resolution of 25 µas, one can expect to be able to find BBH systems in most of nuclei of radio sources

→ Link between Local Reference Frame and distant radio sources - GAIA (25 µas)
An important security will be to observe simultaneously the radio quasars with GAIA and the VLBA (suggested in Porto 2011) and the VLBI geodetic observations ?