Determination of the characteristics of the BBH system using VLBI observations

3C 273, 1994, J Roland, R Teyssier & N Roos

0420-014, 2001, S Britzen, J Roland, J Laskar, K Kokkotas, R Campbell & A Witzel

3C 345, 2005, A Lobanov & J Roland

1803+784, 2008, J Roland, S Britzen, N Krudryavtseva & A Witzel

1823+568, C Glueck, S Britzen & J Roland

3C 279, C Fromm, J Roland & E Ros

VLBI observations show that the jet is not ejected along a straight line, but seems to be precessing.

We explain the precession of the VLBI jet by a BBH system in the nucleus of the radio galaxy.

A BBH sytem produces three perturbations of the VLBI ejection:

- due to the precession of the accretion disk,
- due to the motion of the BH ejecting the VLBI jet around the gravity center of the BBH system,
- due to the slow motion of the BBH system around the gravity center of the galaxy

The BBH model

Ω = 0 : VLBI ejection do not follow a straight line

- BBH system induces a motion of M1 and M2
- BBH system mouves around the gravity center of the galaxy

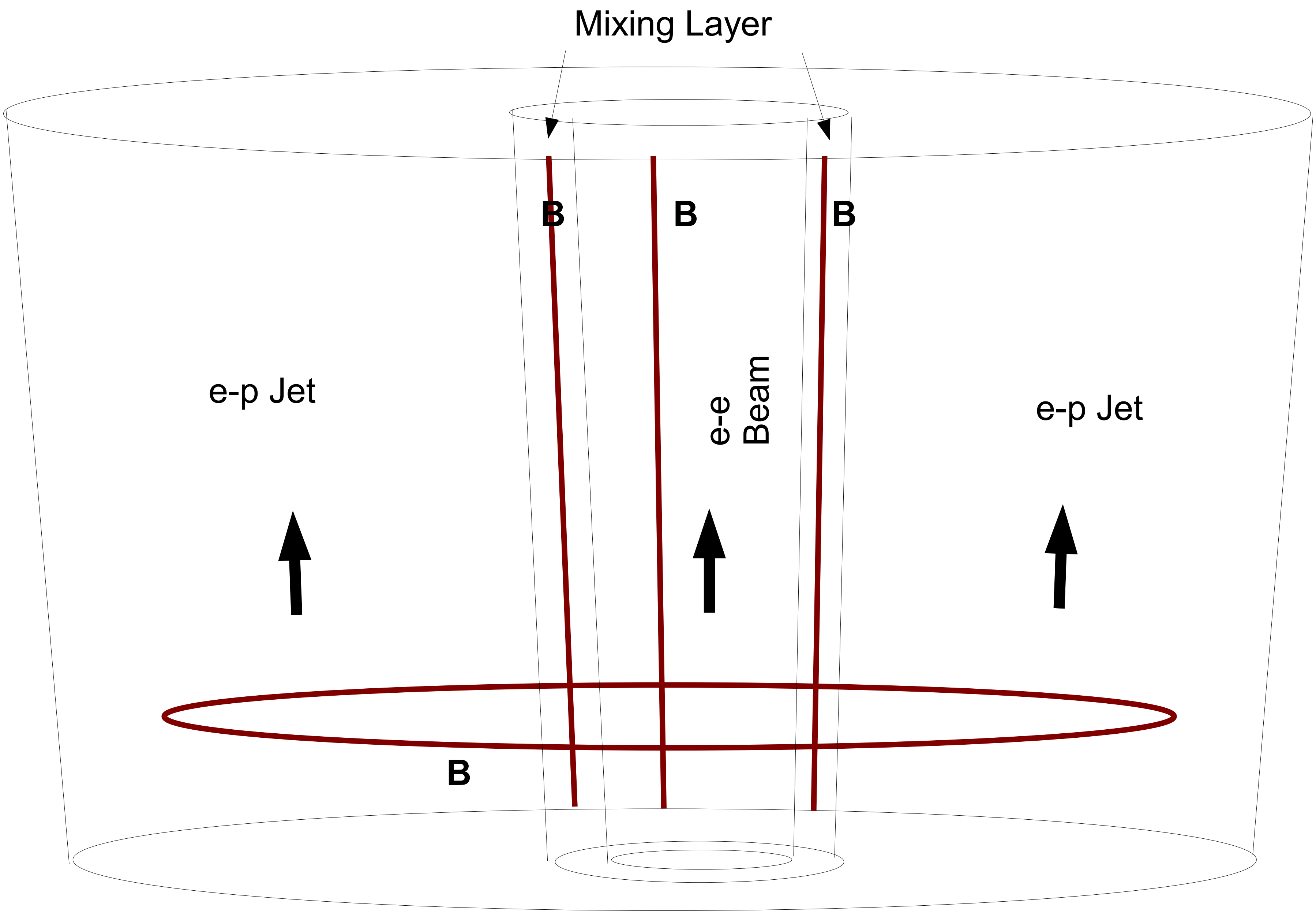
Consequences of the BBH model

If the two BH eject VLBI components:

- 2 famillies of trajectories (different Omega, ...)
- a possible offset of the origin of the VLBI ejection (VLBI ejection is different from the VLBI core)

  → detection of the Radius of the BBH system and the positions of the 2 BH

The Two-Fluid Model



The two-fluid model

We will assume that nuclei of ERS eject:

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

- an *e*-*e* plasma (*beam*), which speed is : $v_b \approx c$

The jet carries most of the mass and the kinetic power ejected by the nucleus, it is responsible for the formation of kpc jets, hot spots and extended lobes.

The beam is responsible for the formation of superluminal sources and their emission from radio to γ-ray.

The model (geometrical model)

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

- the precession of the accretion disk,
- the motion of the black hole in BBH system,
- the motion of the BBH system around the Gravity Center of the galaxy (few mas wiggles)

The amplitude of the perturbation increases at the beginning and is latter damped.

So the coordinates are given by :

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

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

$$z(t)=z$$

Where $$R(z)=\frac{R_o z(t)}{a+z(t)}$$

and $$x_1(t)=\frac{M_2}{M_1+M_2}\left[\frac{T_b^2}{4\pi^2}G(M_1+M_2)\right]^{(1/3)}$$ e = 0

From, $$v^2=\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2+\left(\frac{dz}{dt}\right)^2$$

we obtain $$A\left(\frac{dz}{dt}\right)^2+B\left(\frac{dz}{dt}\right)+C=0$$

equation which allow to calculate the trajectory, the flux, the relativistic effects ...

Indeed : $$\delta(t)=1/(\gamma[1-\beta\cos(\theta)])$$

where $$\cos(\theta)=\left(\frac{dy}{dt}sini_o+\frac{dz}{dt}cosi_o\right)/v$$

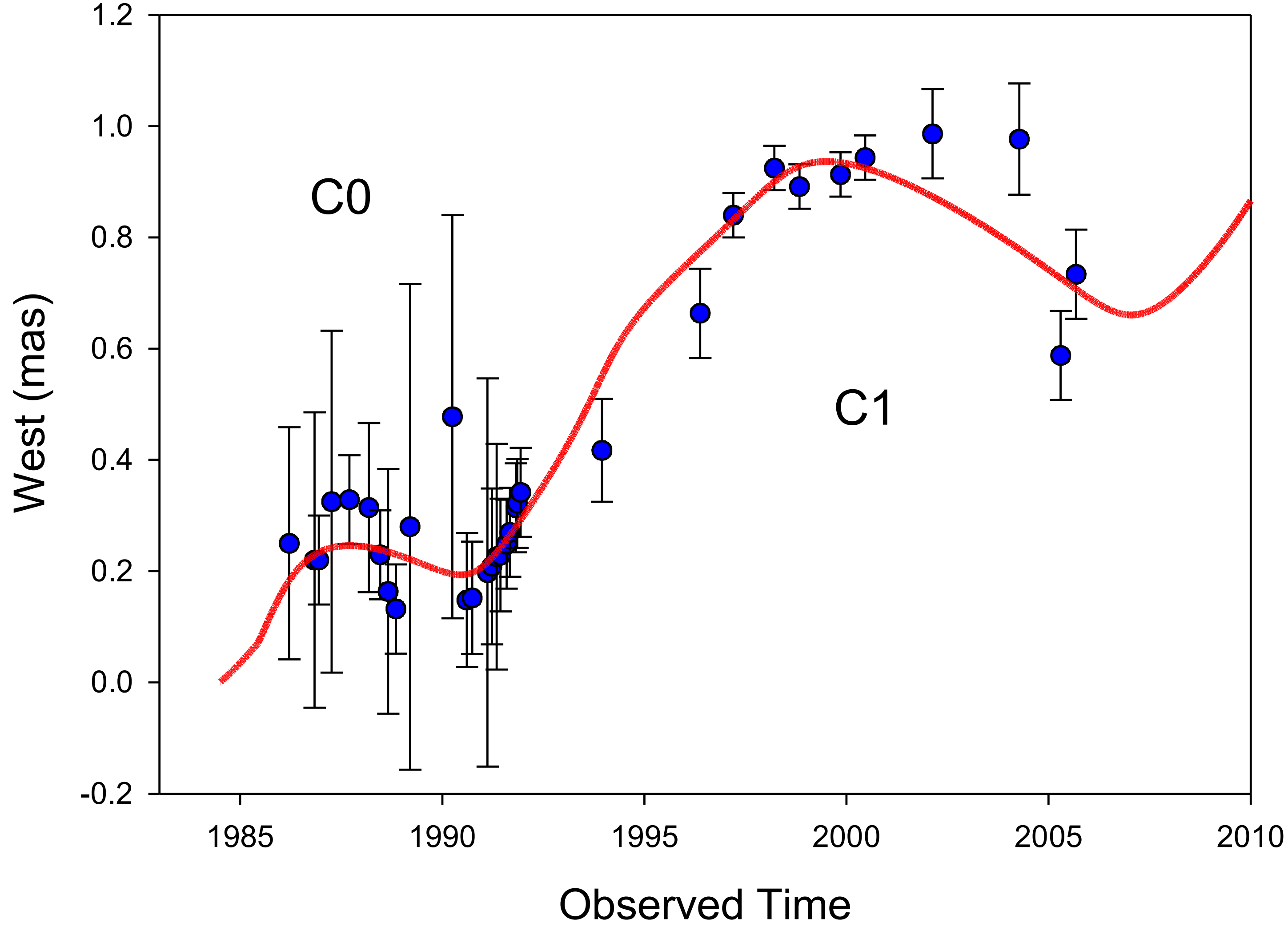
From VLBI observations, we have X(t) and Y(t) for VLBI components:

→ the trajectory and the cinematic are known

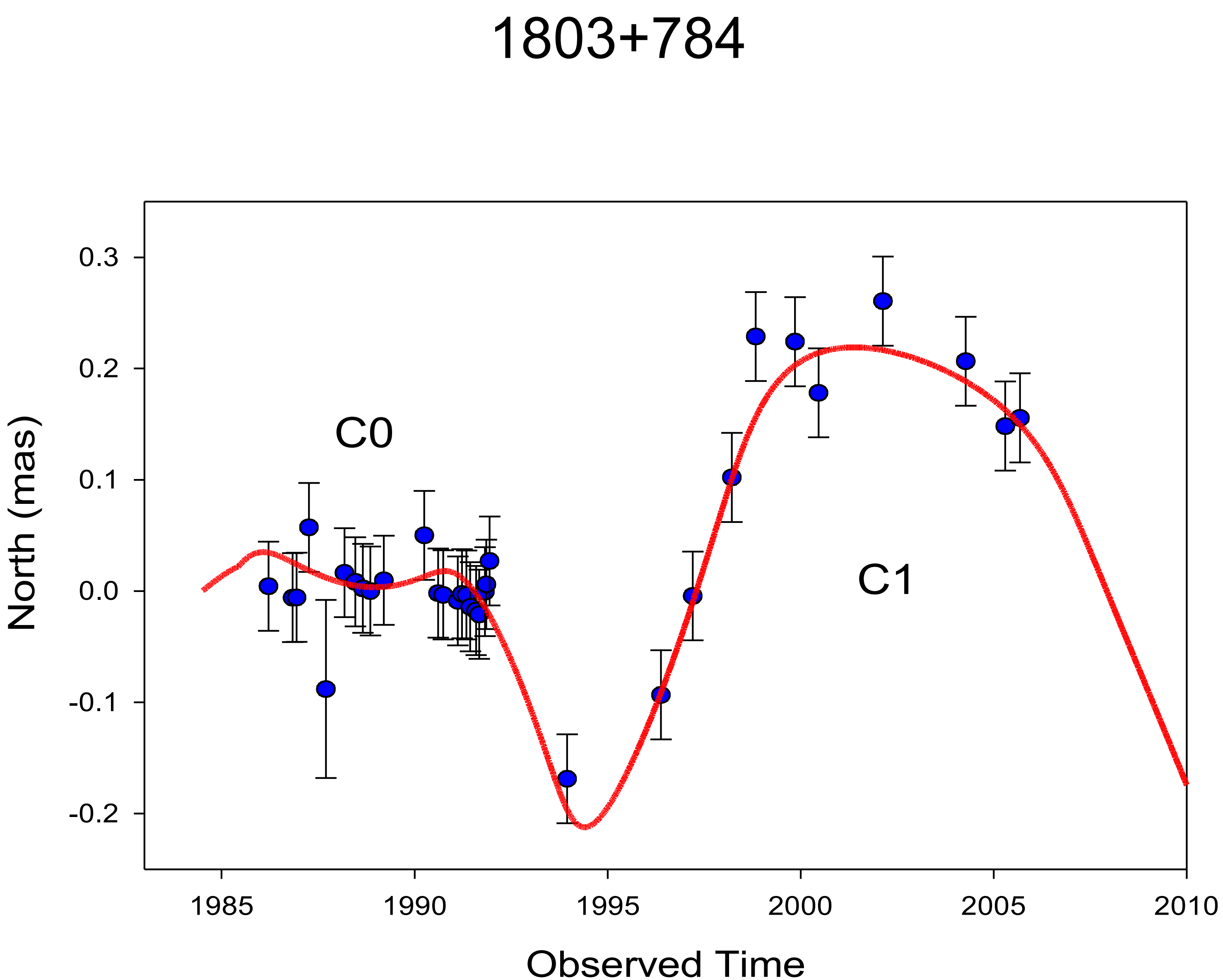
→ we can find the inclination angle and the bulk Lorentz factor

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

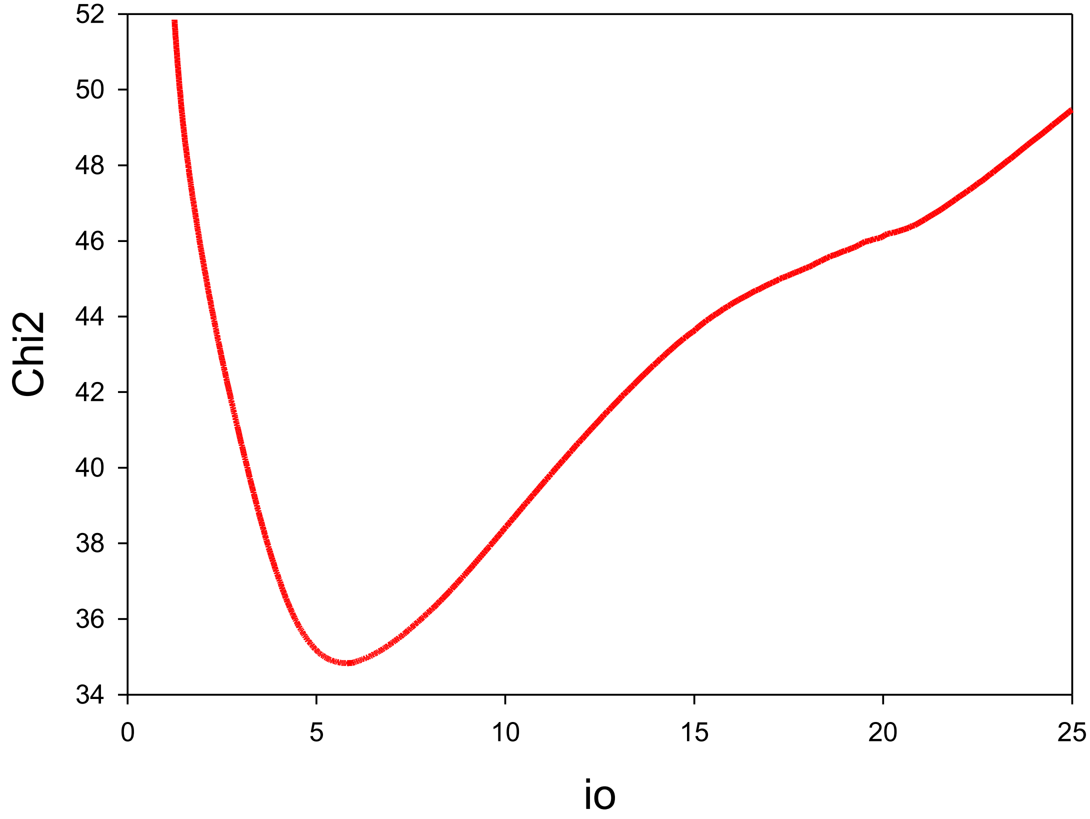
1803+784



C0
C1
West (mas)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1985
1990
1995
2000
2005
2010
Observed Time

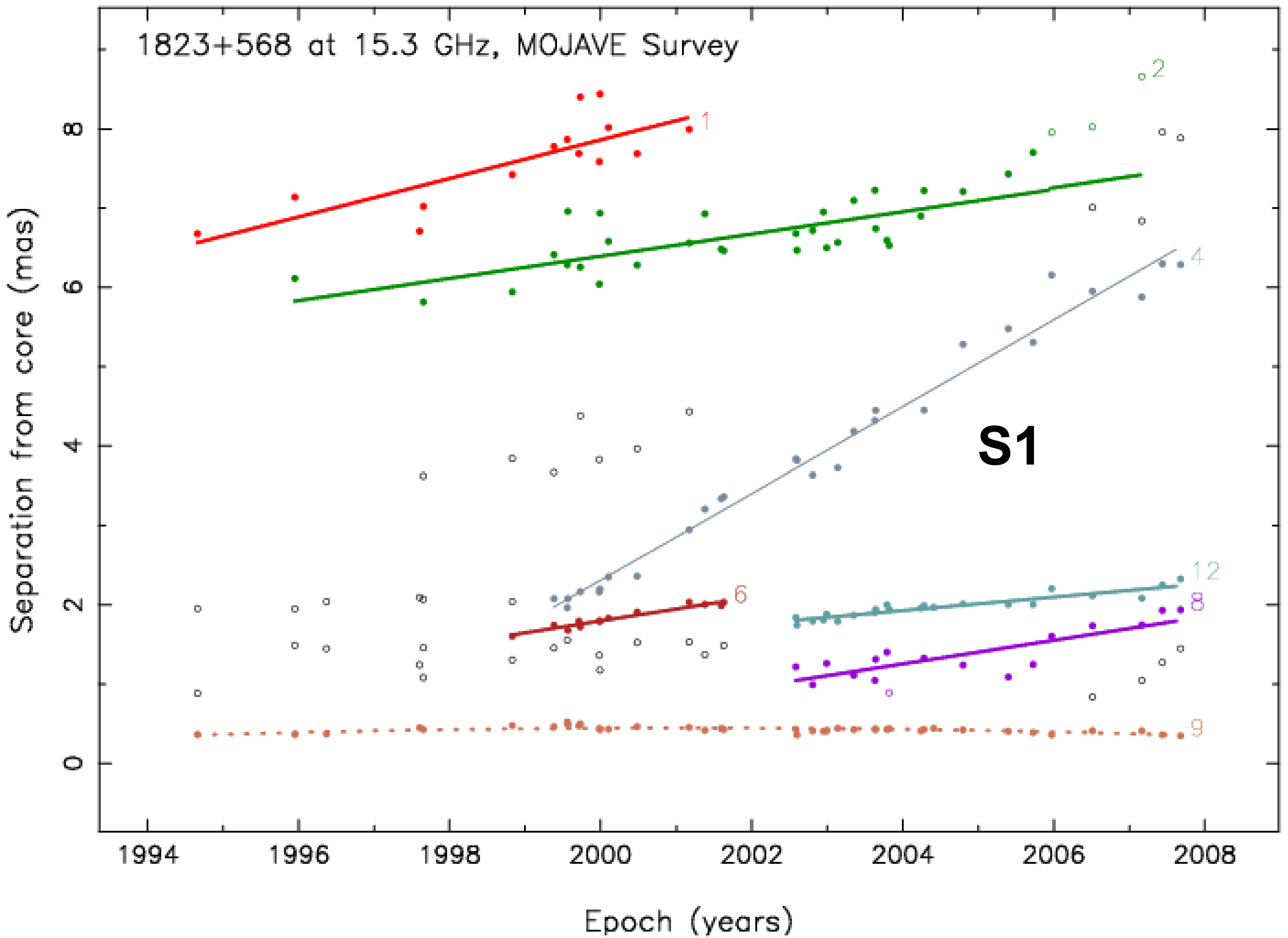

1803+784
North (mas)
0.3
0.2
0.1
0.0
-0.1
-0.2
C0
C1
1985
1990
1995
2000
2005
2010
Observed Time

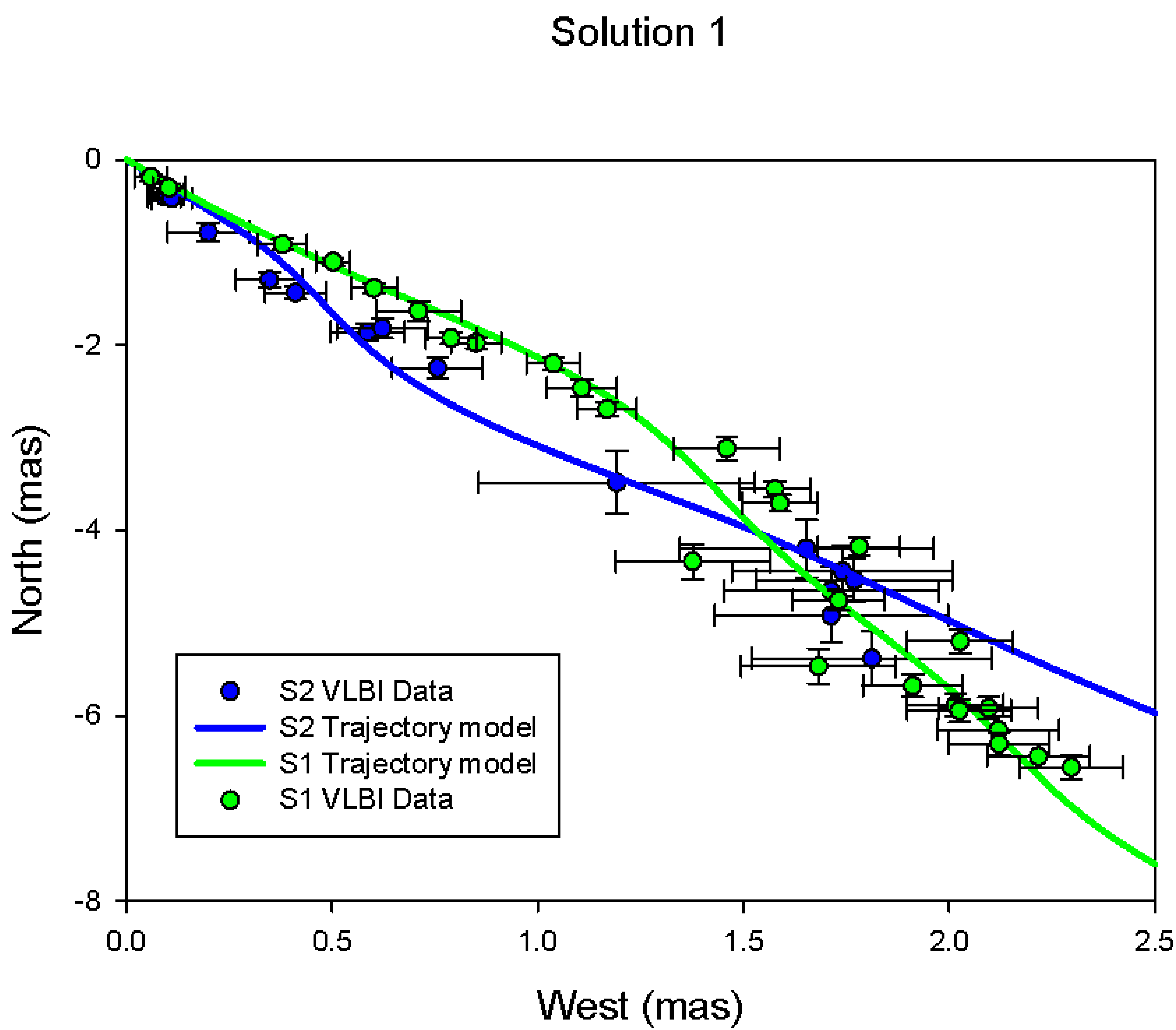
Determination of io



For 1803+784, we find io = 5.8 ± 1.8 and Gamma = 3.7

1823+568 : Two fast moving components S1 and S2



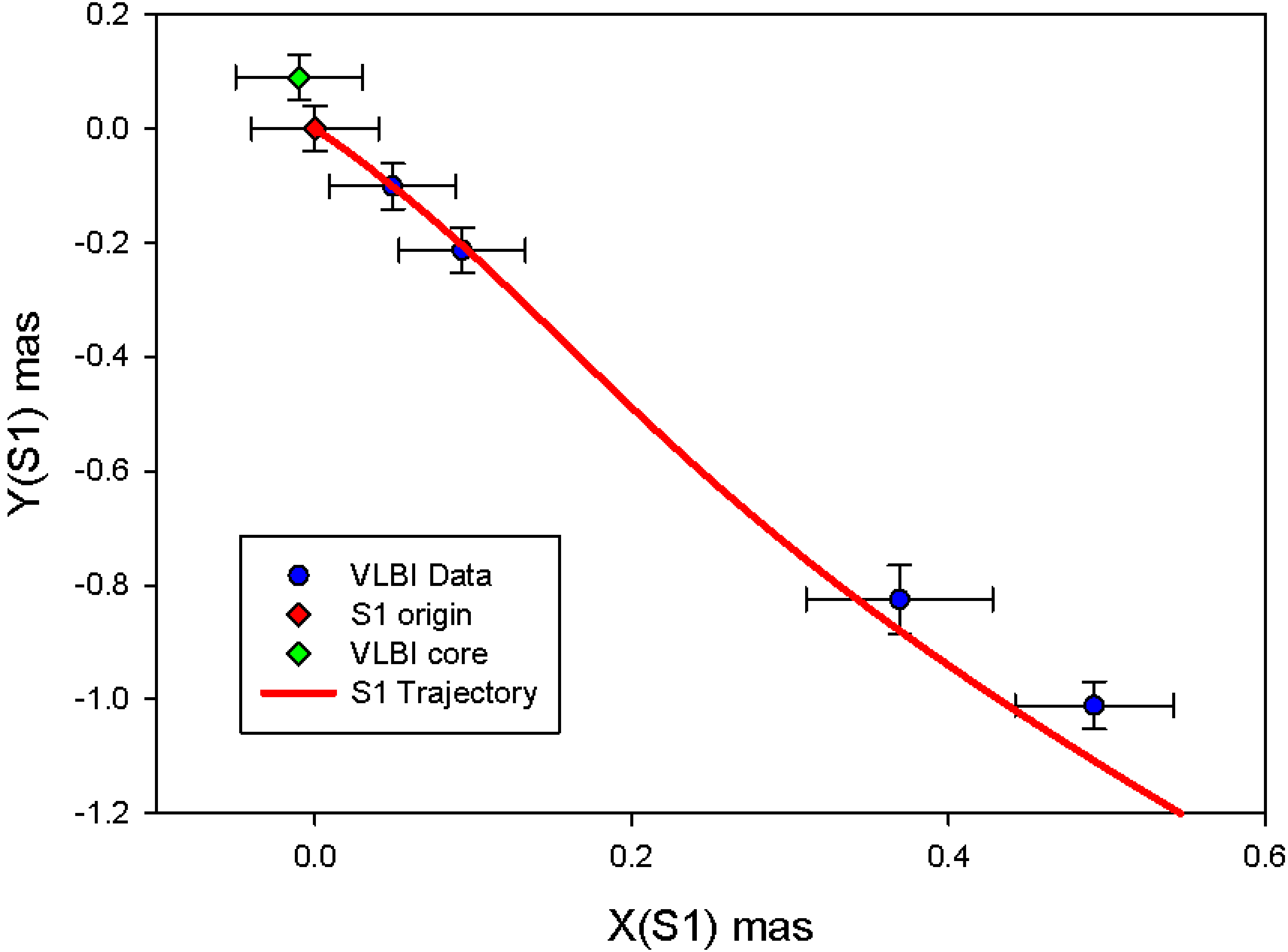


Solution 1
North (mas)
West (mas)
0
-2
-4
-6
-8
0.0
0.5
1.0
1.5
2.0
2.5
S2 VLBI Data
S2 Trajectory model
S1 Trajectory model
S1 VLBI Data

Results for S1 and S2

- The 2 components are ejected by the same BH and belong to the same familly of trajectories (all the geometrical parameters are the same) only, the phases of the precession and of the BBH system are different, to and gamma are also different.
- The origin of the ejection of S1 and S2 is not the VLBI core
  The offset is between 70 and 90 micro arc sec.

→ the size of the BBH system is about 80 micro arc sec and the positions of the 2 BH are known



0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
Y(S1) mas
0.0
0.2
0.4
0.6
X(S1) mas
VLBI Data
S1 origin
VLBI core
S1 Trajectory

Origin of the VLBI ejection

0917+624 – 1823+568 – 3C 279

In the case of 1823+568 we are able to detect an offset of 80 μas

VLBI Observations mm (15 Ghz for 1803+784, 1823+568)
- At 15 GHz : Resolution : 0.4 mas; positions : 40 μas
- At 43 Ghz : positions : > 25 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)**