Evidence of a Supermassive Black Hole Binary system in PG 1553+113

Zulema Abraham
Astronomy Department
University of São Paulo, Brazil

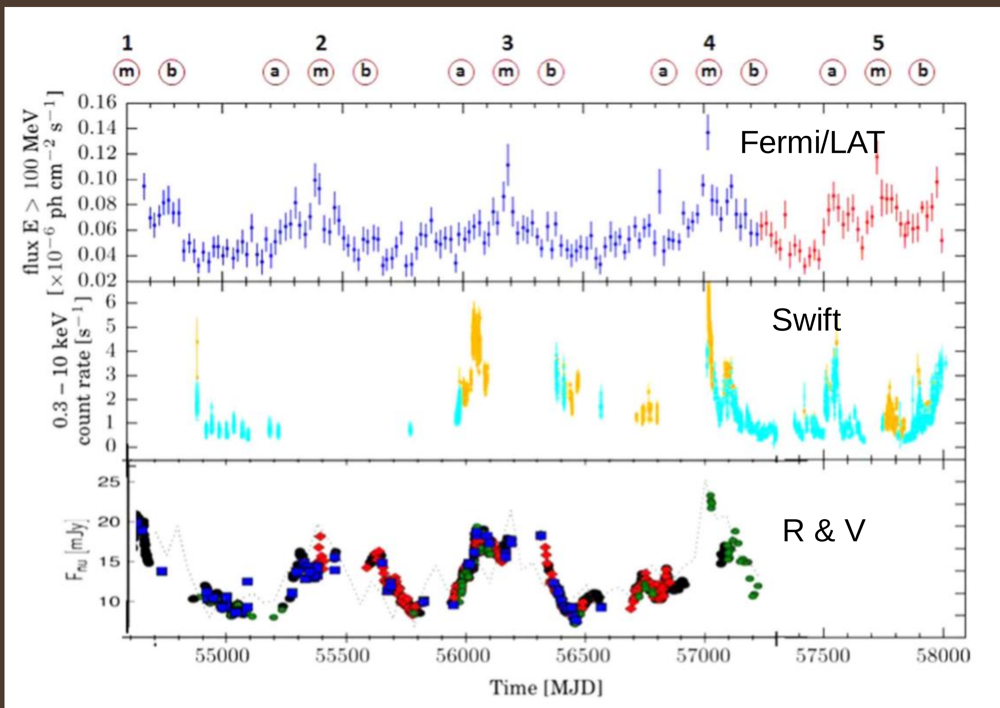
Anderson Caproni,
Juliana C. Motter,
Hektor Monteiro

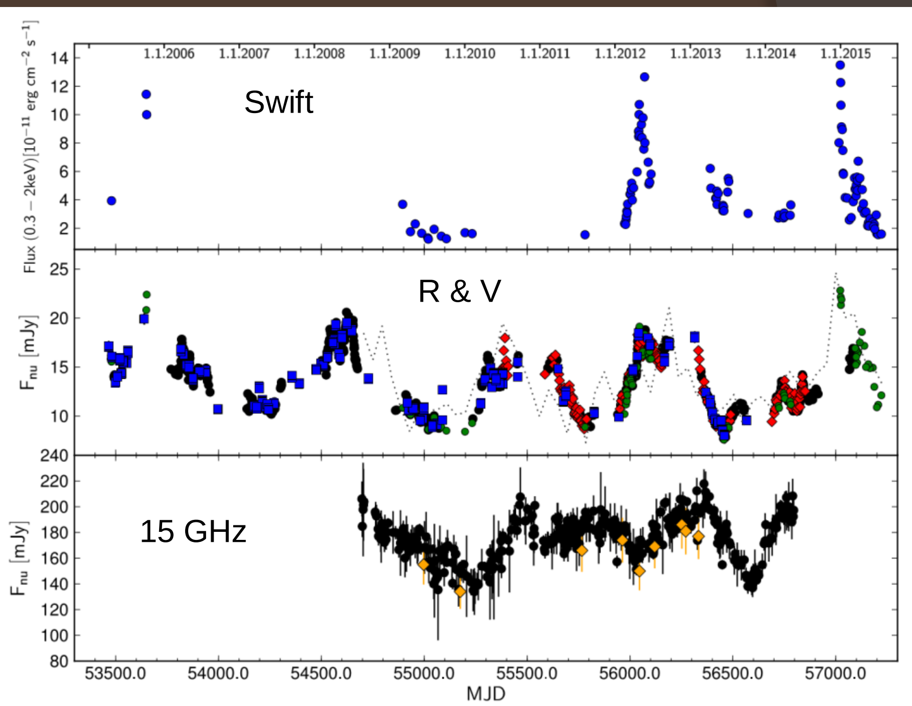
Based on : Caproni et al. ApJ 851, L39 (2017)

Periodic variability

Tavani et al. (2018)

Ackermann et al. (2015)





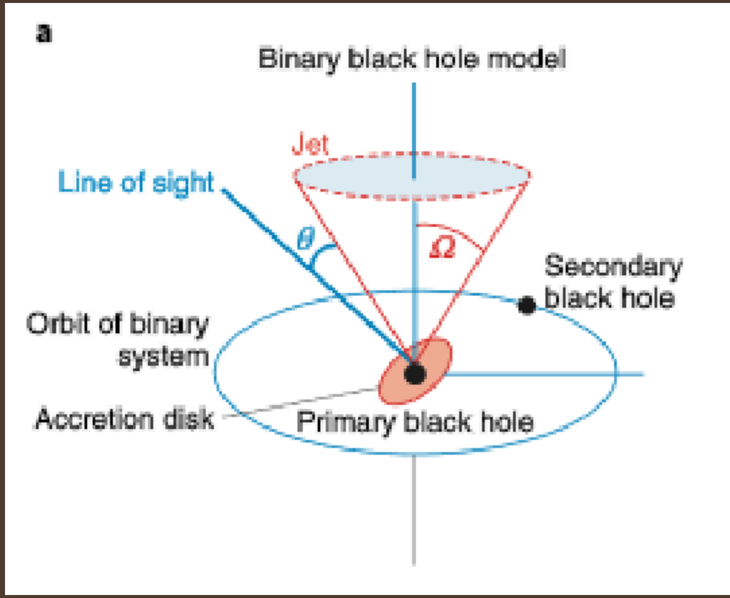
All the radio emission comes from the compact core and jet

Periodic variability

- Periodic variability is generally attributed to gravitational interaction
- In the case of blazars, variability is often explained in terms of changes in the beaming factor, due to changes in the angle that the jet forms with the line of sight.
- If we put the two conditions together we came out with a binary BH model

BH Binary system

- Assume that the accretion disk around the primary BH is not coplanar with orbital plane.



- Jet will precess under the action of the secondary BH torque.
- Radiation will be beamed, and reach a maximum when the jet forms the smallest angle with the line of sight.

Jet precession

- Assume that each jet components Cj was ejected from the core at a given time $t_{0\,j}$, and moves with constant velocity β in the direction the jet had when the component was ejected.

- The observed velocity will be:

$$\beta_{\mathrm{obs}} = \frac{\beta \sin\theta}{1 - \beta\cos\theta}$$

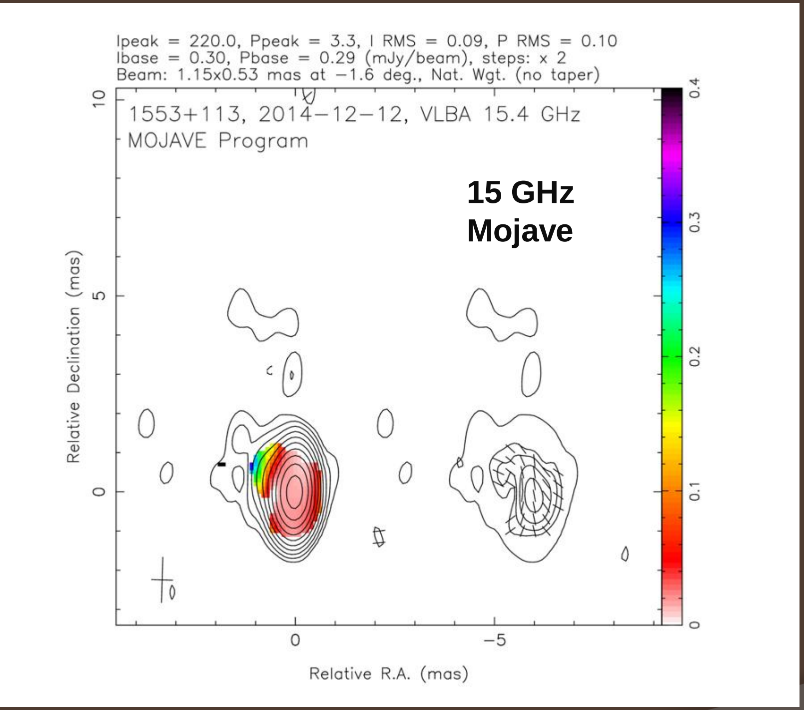
- We will assume that β and therefore Γ is the same for all components

$$\Gamma = \frac{1}{\sqrt{1-\beta^2}}$$

- By measuring β_{obs} we can determine θ. The other angle necessary to test a precession model is η, measured in the plane of the sky.

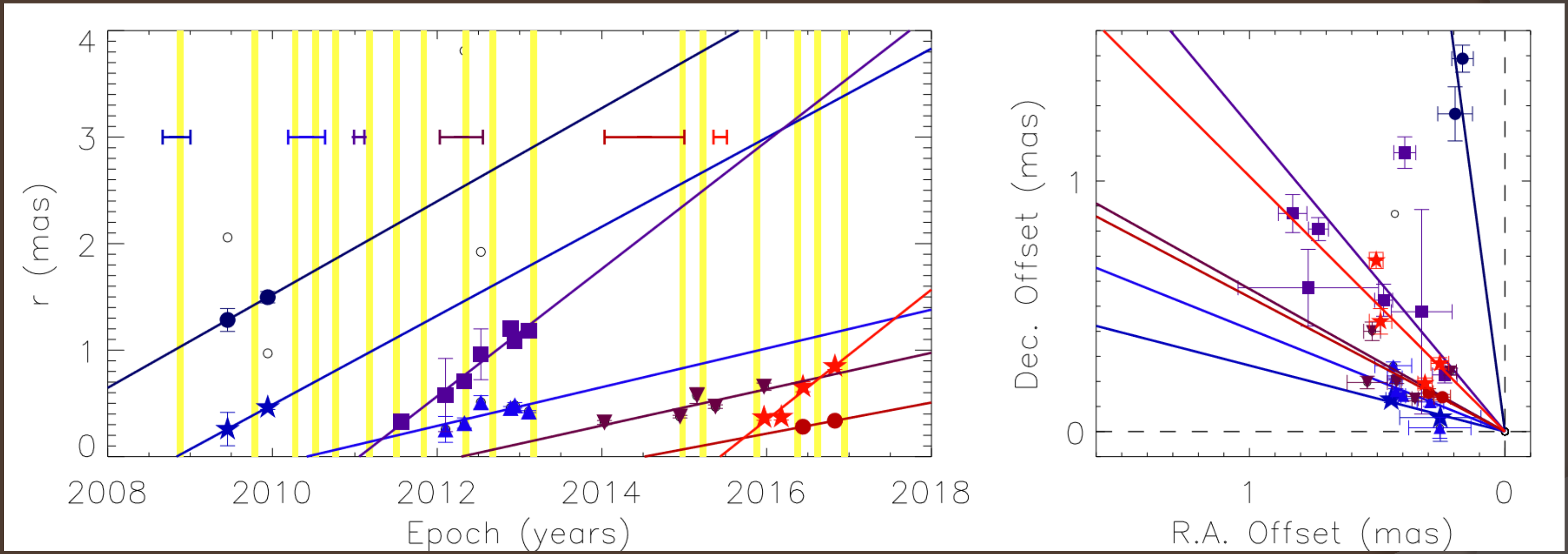
Determine the component velocities

- First we have to identify the components
- We used the 15 GHz images of the MOJAVE program



Results

- We used the Cross Entropy method to determine the number and physical parameters of two dimensional gaussian components.

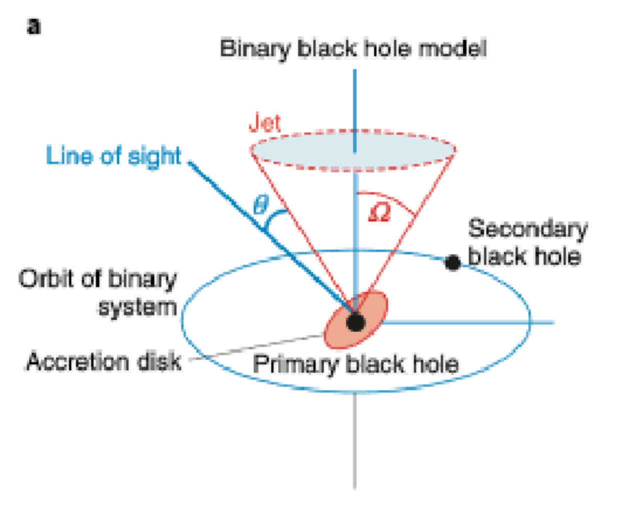


- Yellow lines are possible γ-ray flares.
- Horizontal lines are uncertainties in the components ejection epochs

Precession model

- To construct the precesion model we will use a variable that is invariant in both source and observer frames:

$$d\tau = \frac{dt_s}{P_s} = \frac{dt_{\mathrm{obs}}}{P_{\mathrm{obs}}}$$



Where P is the period.

but

$$dt_s = \frac{dt_{\mathrm{obs}}}{(1 - \beta\cos\theta)}$$

and

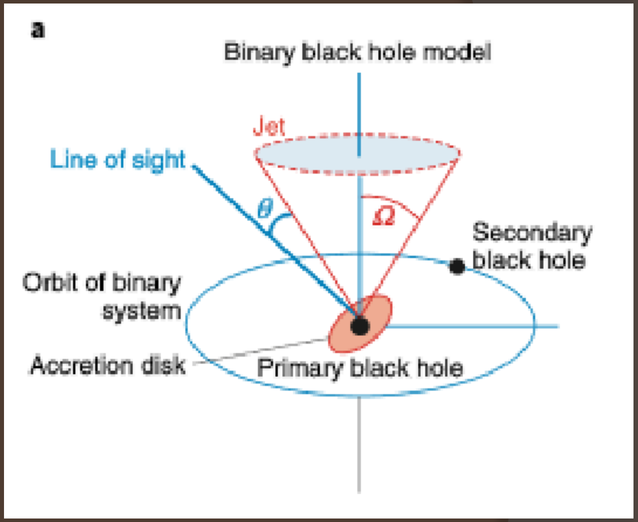
$$\cos\theta = \sin\Omega\sin(2\pi\tau) + \cos\Omega\cos\theta_0$$

Integrating over one period

$$P_s = \frac{P_{\mathrm{obs}}}{(1 - \beta\cos\Omega\cos\theta_0)}$$

Precession Parameters

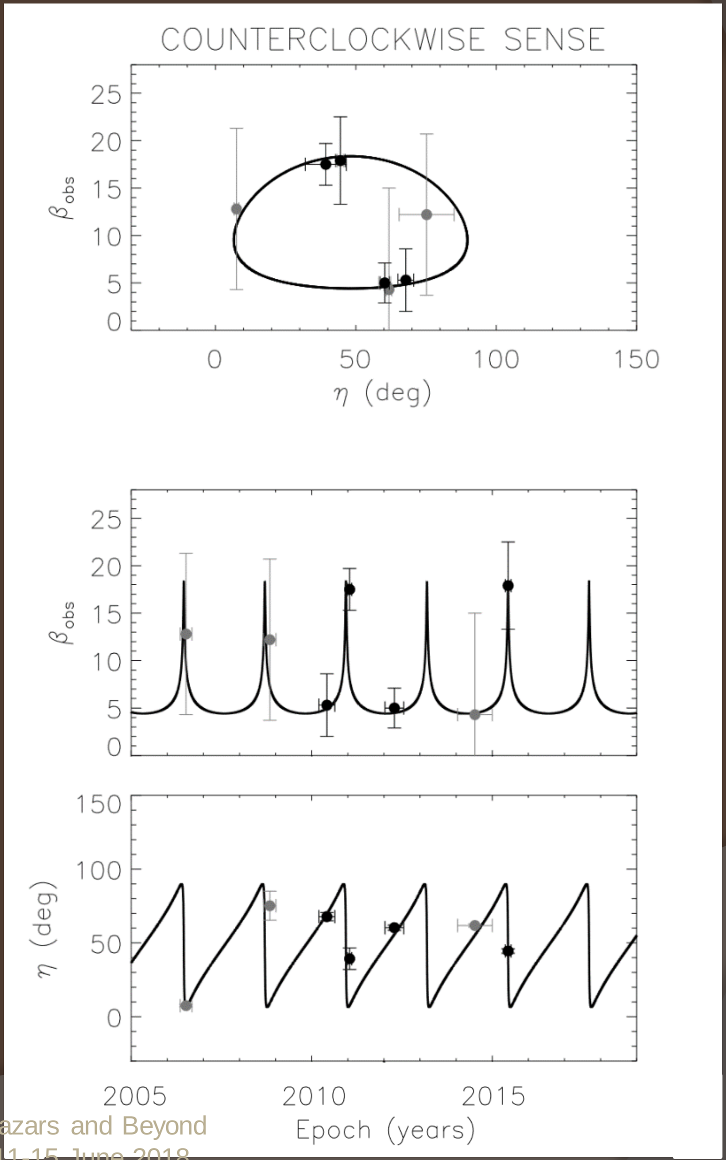
- Period
- Aperture of the precessing cone Ω
- θ_0 and η_0 angles of the cone axis
- Γ



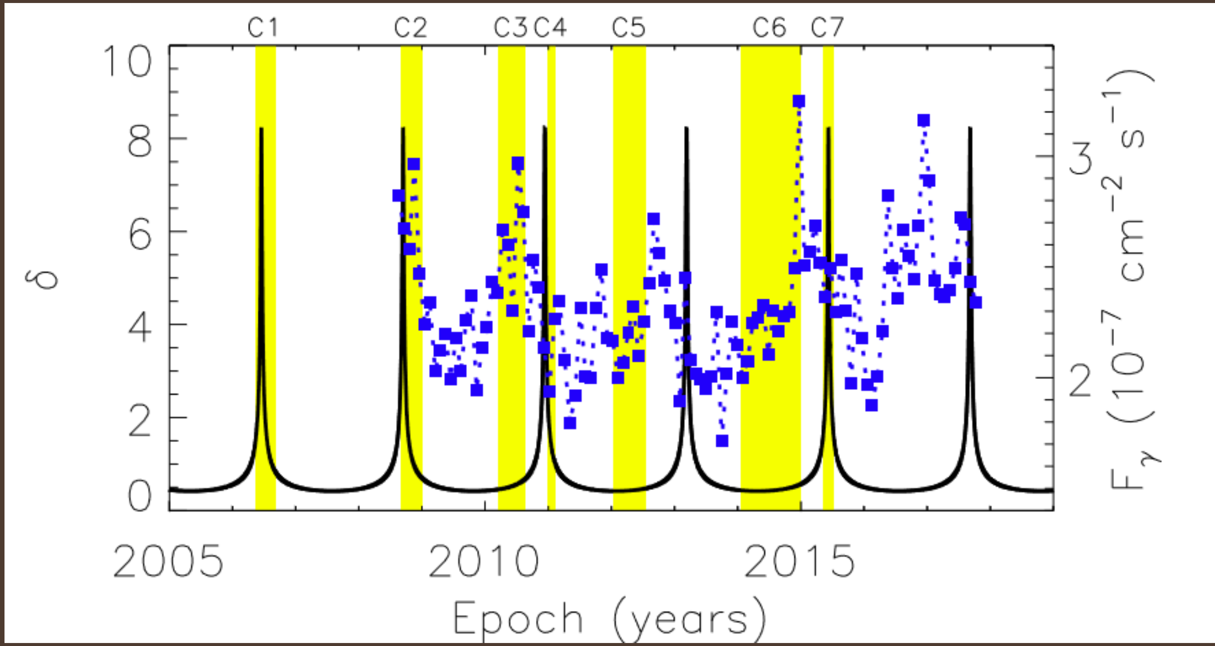
- Data
- Component velocities β
- Component positions angles η
- Component ejection time t_{0j}
- Initial phase

Results of the Precession Model

P_{obs}	2.25 ± 0.01 days
P_{source}	29.63 ± 0.56 days
Γ	24.6 ± 3.9
η_0	48.1 ± 0.9
θ_0	15.3 ± 0.2
Ω	10.1 ± 0.2



Results of the Precession Model



- γ-ray maxima do not coincide with the maxima in the Doppler factor.
- But they do coincide with the ejection of superluminal components

Conclusions

- We analyzed all the available 15 GHz VLBA images of PG 1533+113
- We fitted two dimensional Gaussian components using the CE method and identified 7 different components.
- We determined the velocity of these components and the epochs of ejection.
- We assumed jet precession in a binary BH system, where the accretion disk of primary BH does not coincide with the orbital plane.
- We obtained the best parameters for the precessionl using the CE method
- We found a very good agreement with the observations with a precession period o 2.2 years, the same as the periodicity of the γ-rays and optical emission.
- However, the maxima in the light curves did not coincide with the maxima in the Doppler factor, showing that boosting is not the origin of the periodicity.
- On the other hand, the maxima in the light curves coincide with the ejection of new jet components.
- Therefore, it is possible that some interaction between the secondary BH and the primary accretion disk causes a periodic formation of superluminal components, which are the real origin of the periodic γ-ray and optical emission.