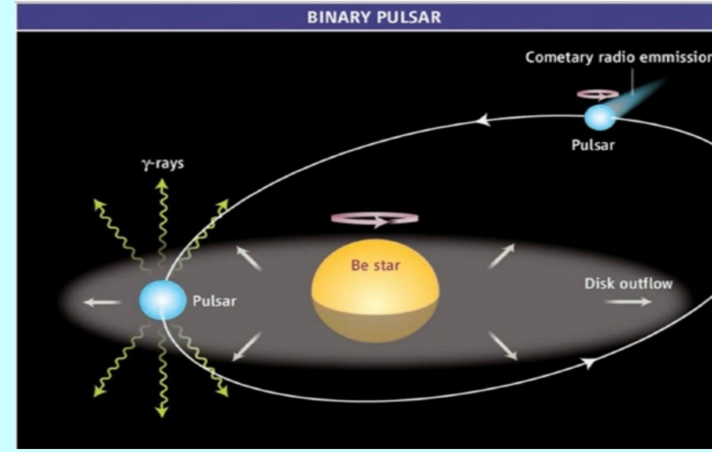


Revisit LSI+61303
with radio data, X-ray data and new VLBA astrometry

Maria Massi
(MPIfR)

Black hole
Or
strong B neutron star

?

LSI+61303

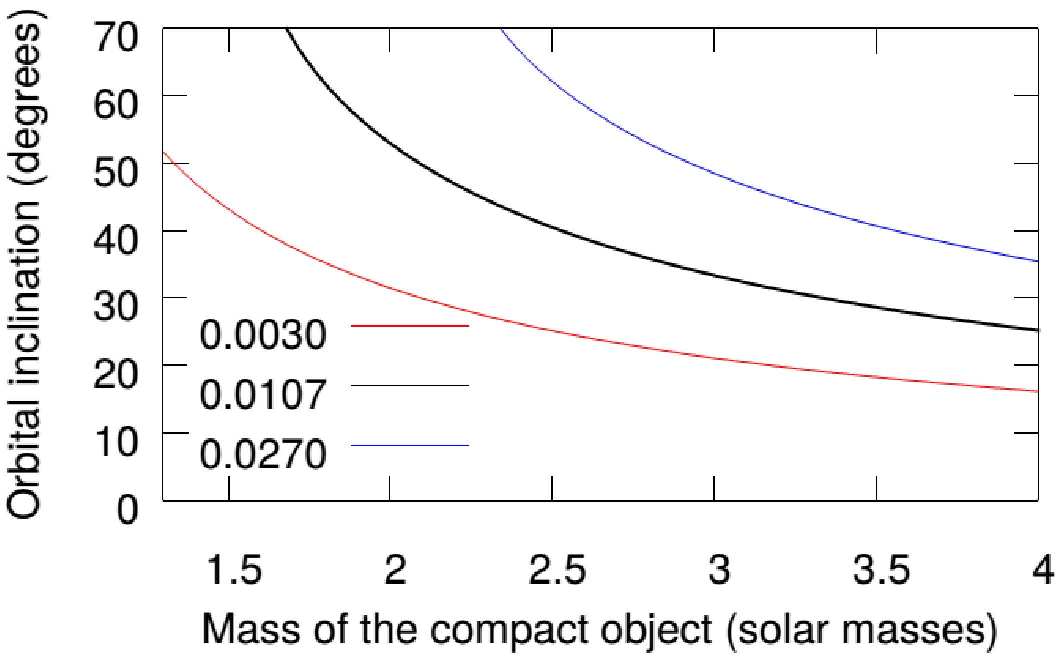
A neutron star more massive than M_{max} (**2.2-2.9** M_0) collapses to a BH (Kalogera & Baym 1996)

Then the method to distinguish a BH from a neutron star is measuring the mass

$\rightarrow$ if $M > M_{max}$ it is a BH

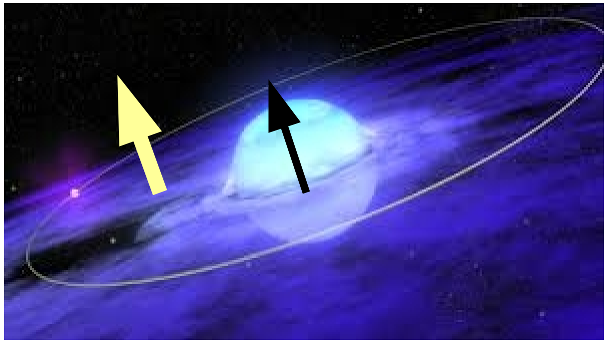
OPTICAL OBSERVATIONS

One measures radial velocities of the companion star with optical spectroscopy and determine the mass function



Mass function from Casares et al 2006, Massi, Migliari, Chernyakova 2017

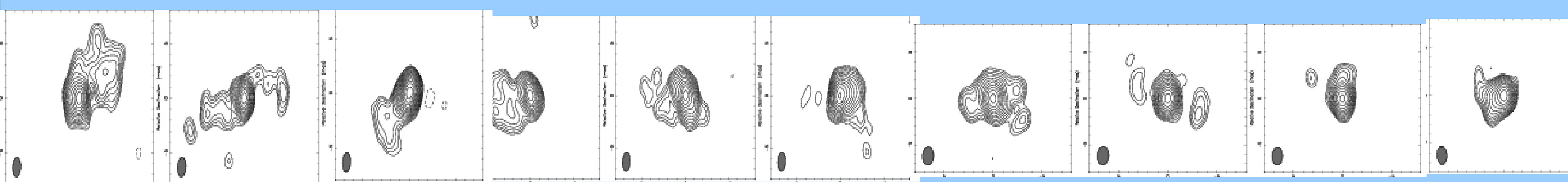
Rotational axis, *r*, of the Be dis, r=25 degrees (Nagae et al 2006)



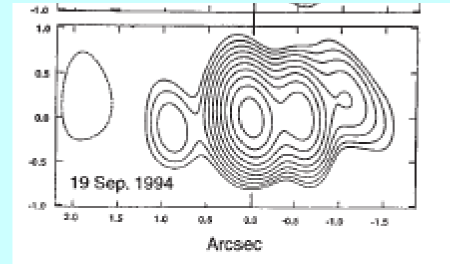
If Be spin axis aligned with orbital axis

i.e., if i=r=25 then M=4 solar masses

RADIO IMAGES



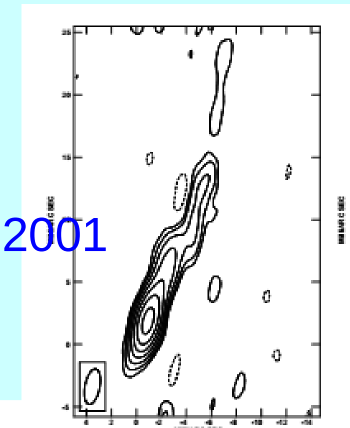
Microquasars, i.e., X-ray binaries with radio emitting jets

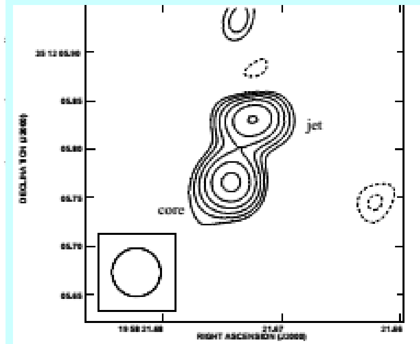


LMXB:
GRO J1655-40
Hjellming and Rupen 1995

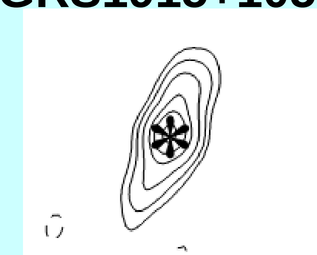
HMXB: Cyg X-1
Fender et al 2006

Stirling et al 2001

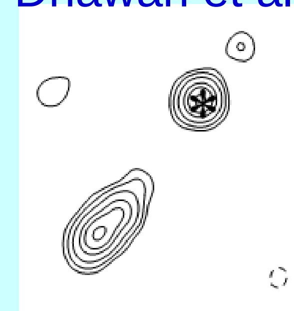




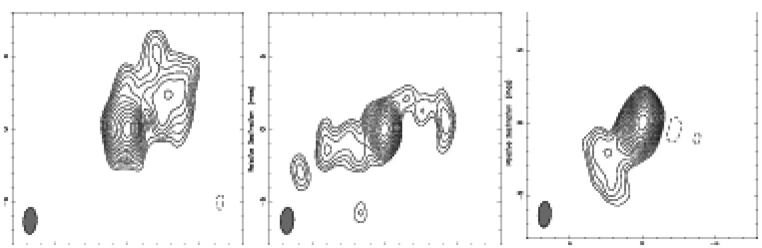
LMXB:
GRS1915+105

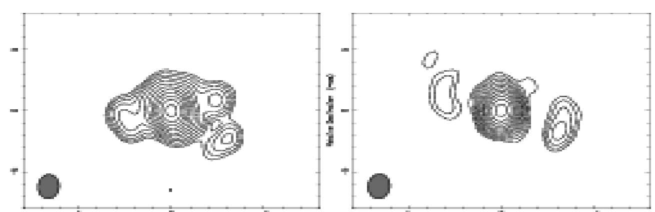


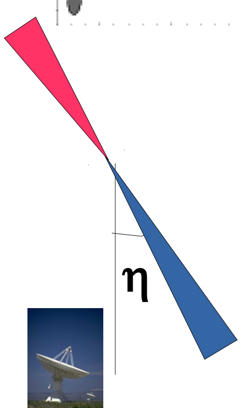
Dhawan et al 2000

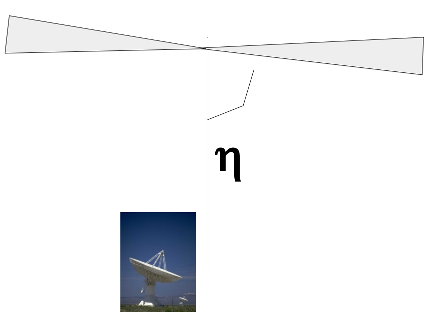


LSI61303









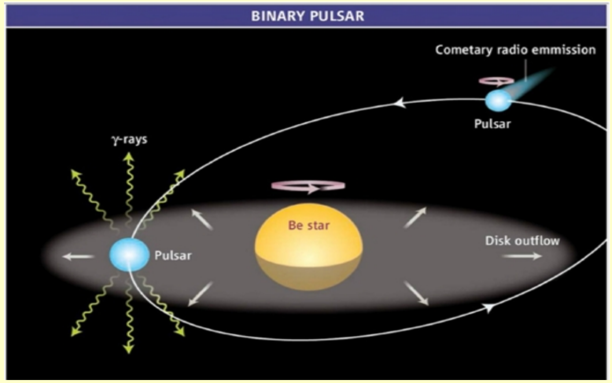
“VLBA images of the precessing jet of LS I +61303”
Massi, Ros, Zimmermann 2012

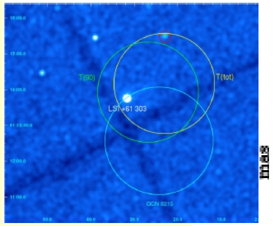
“Hints for a precessing relativistic radio jet in LS I +61303”
Massi et al. 2004

Kaufman Bernadó,Romero, Mirabel 2002

Radio OBSERVATIONS: Morphology

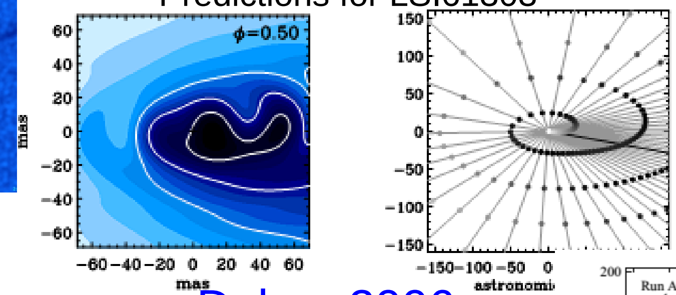
Non-Accreting young Pulsar





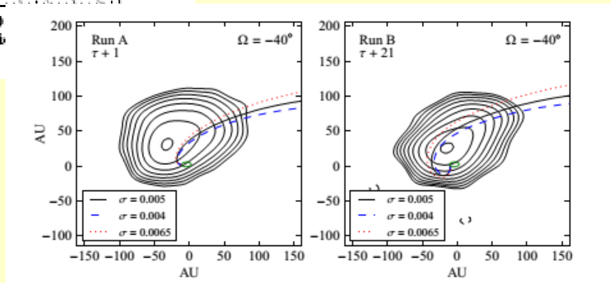
Magnetar
Torres+2012

Predictions for LSI61303



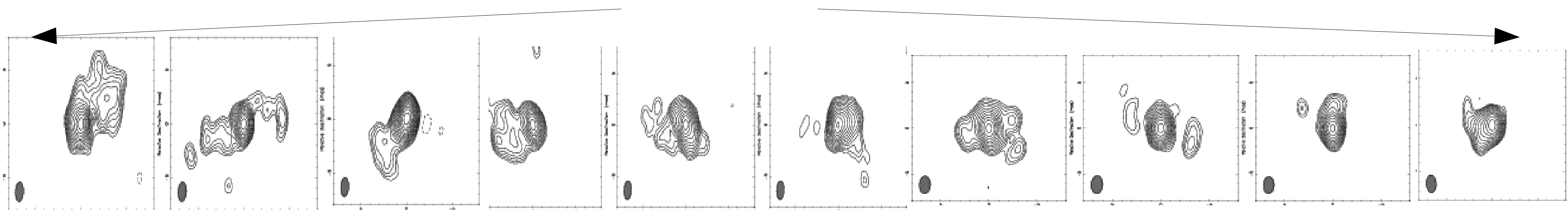
Dubus 2006

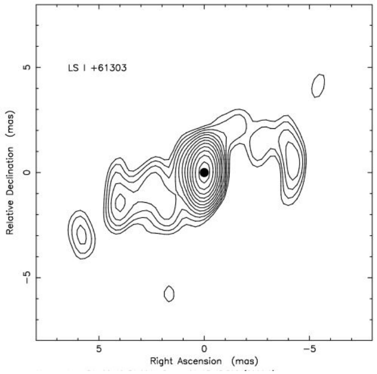
PSR B1259−63



Moldon 2012

LSI61303

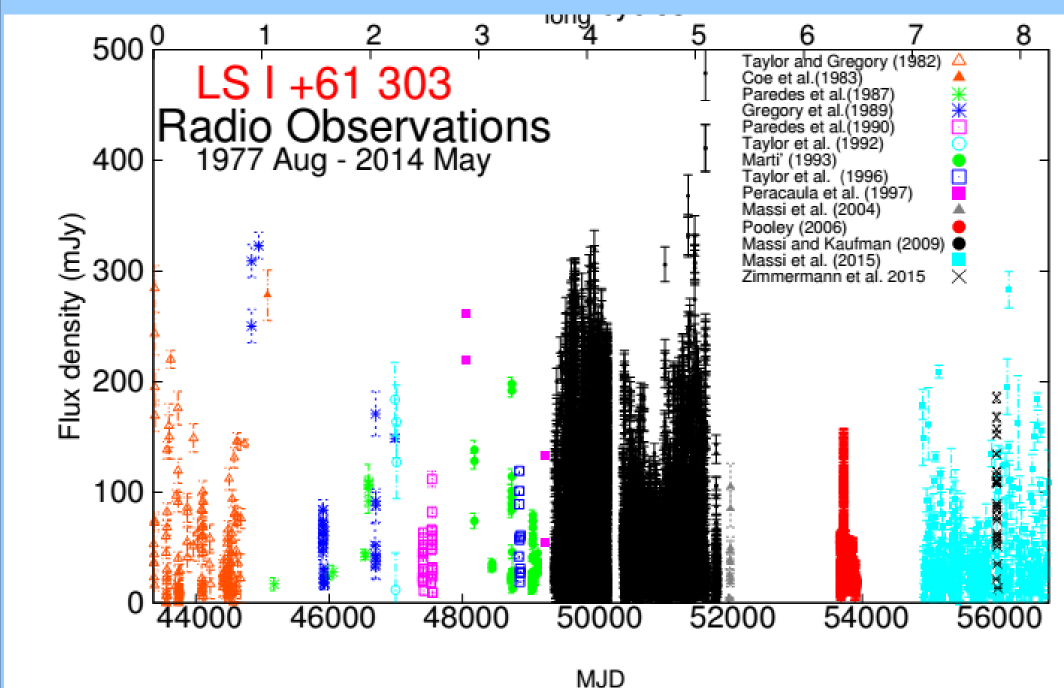




-Rapid position angle variations of the large scale structure
-switchs from a two-sided to a one-sided structure
-ejections

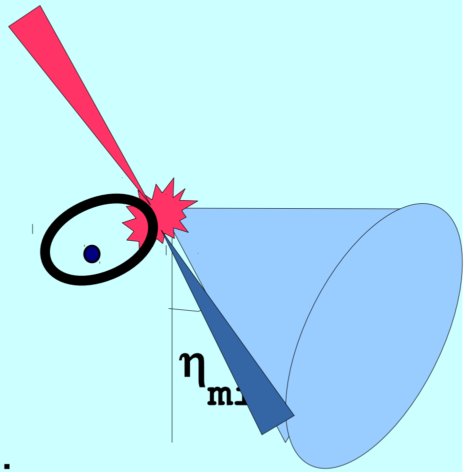
Massi,Ros,Zimmermnn 2012

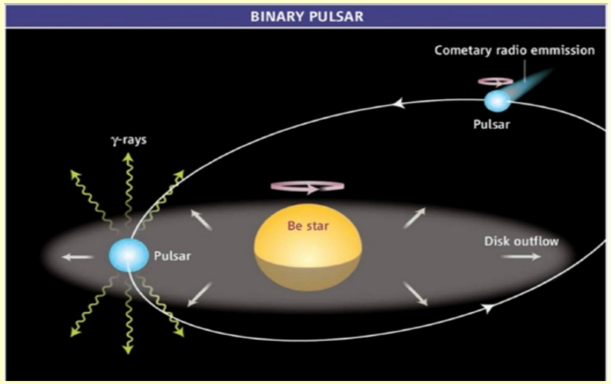
Radio monitoring



Radio OBSERVATIONS: Timing analysis

Accretion along eccentric orbit:
Taylor et al. 1993,
Marti' & Paredes 1995
Bosch-Ramon et al. 2006,
Romero et al. 2007

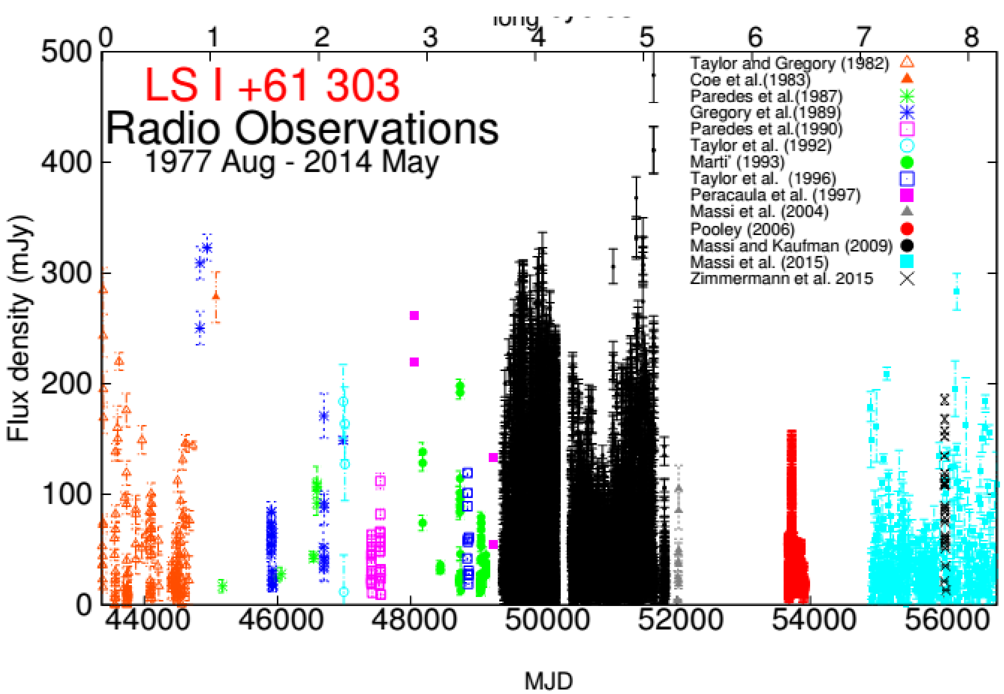


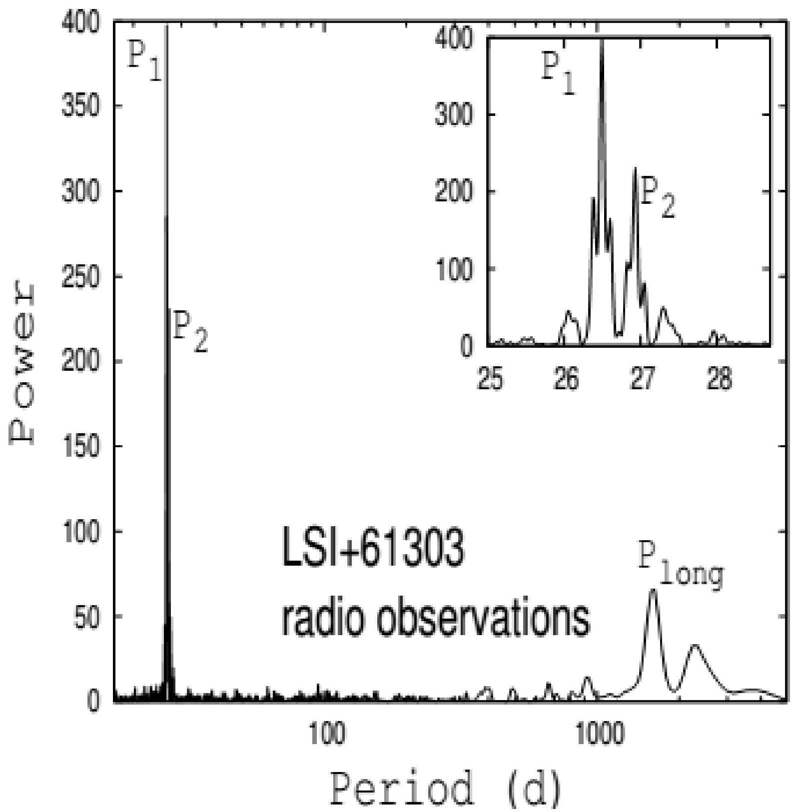


Precessing jet prediction:
S = Sintrinsic(Porbit) DB(Pprecession)

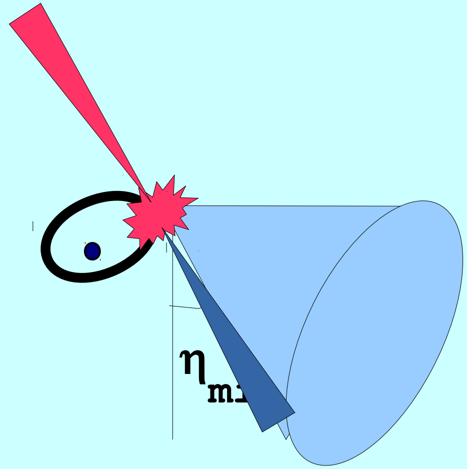
Non-Accreting young Pulsar prediction:
S = Sintrinsic(Porbit)

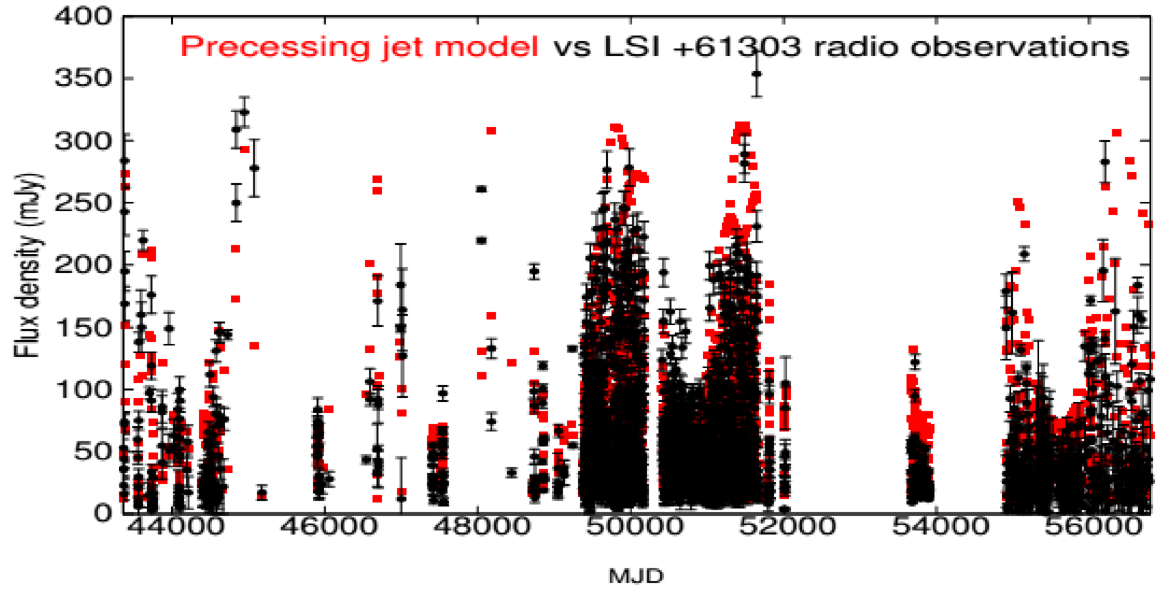
Massi & Torricelli-Ciamponi 2016





The precessing jet model: I





$$S_a = \int^{L} r_0 x_0 I_{\nu_a}(\eta, l) \frac{\sin(\eta - \xi)}{D^2} l dl$$

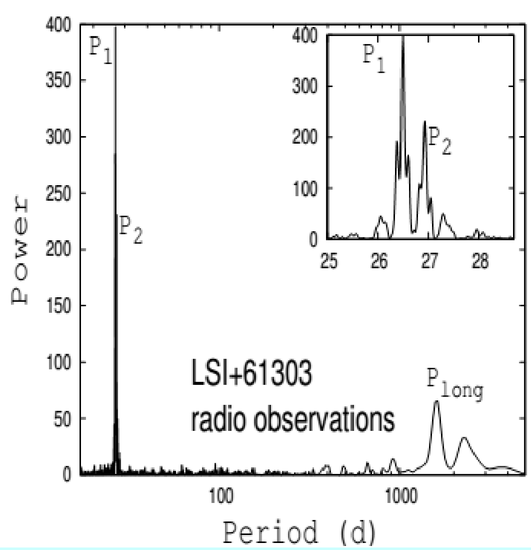
$$J_0 = 2.3\ 10^{-25} (1.3\ 10^{37})^{(p-1)/2} a(p) B_0^{(p+1)/2} \kappa_0$$

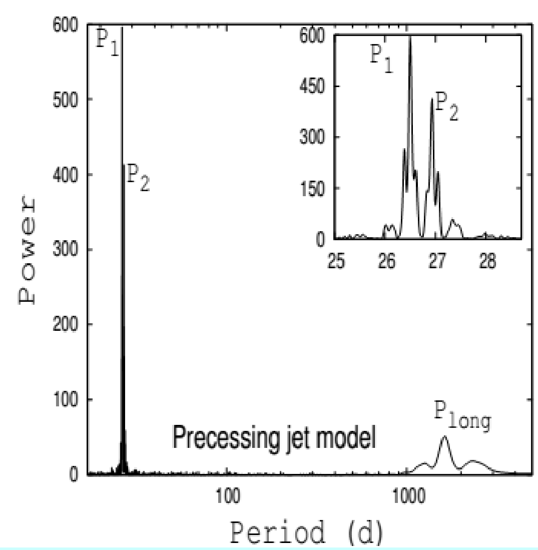
$$I_\nu(\eta, l) = \int_0^{\tau_{end}(l)} \frac{J_\nu}{\chi_\nu} e^{-\tau'/\cos\ \eta} \, d\left[\frac{\tau'}{\cos\ \eta}\right]$$

$$\kappa = \kappa_0 l^{-a_3} \quad B = B_0 l^{-a_2} \quad N_{rel} = \kappa E^{-p}$$

S = Sintrinsic(Porbit) DB(Pprecession)

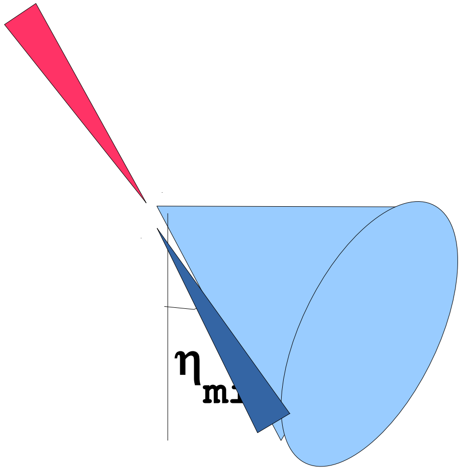
$$S_{model}(t) = S_a(t)(\delta_a(t))^{k-\alpha} + S_r(t)(\delta_r(t))^{k-\alpha}$$

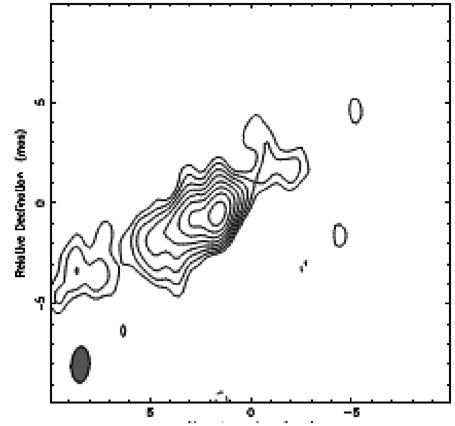


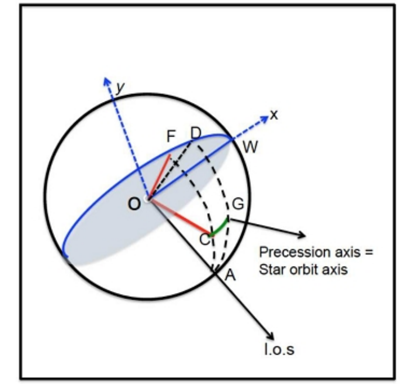


Massi & Torricelli-Ciamponi 2014, 2016

The precessing jet model: II

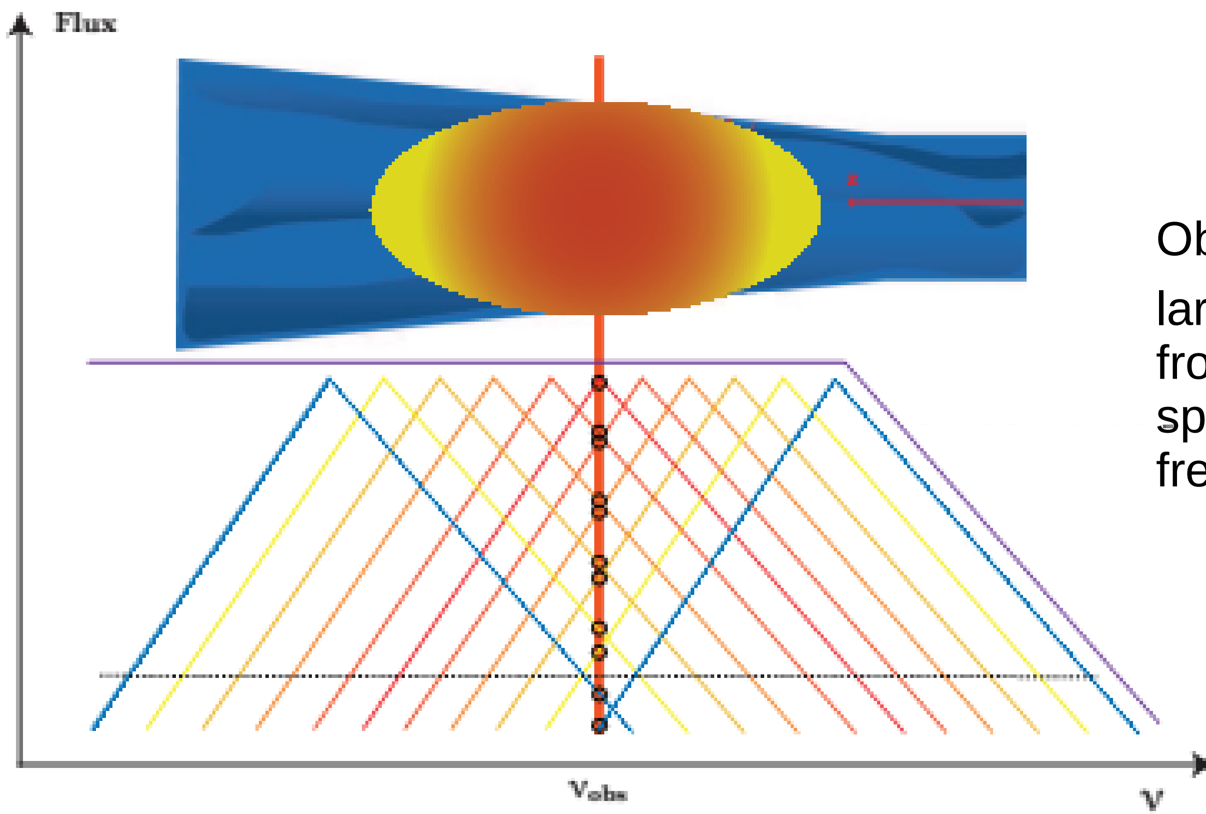






$$\tau_0 = \tau(l=1) = \frac{\chi_0 x_0}{-[1 - a_3 - (p+2)a_2/2]}\nu^{-(p+4)/2}.$$

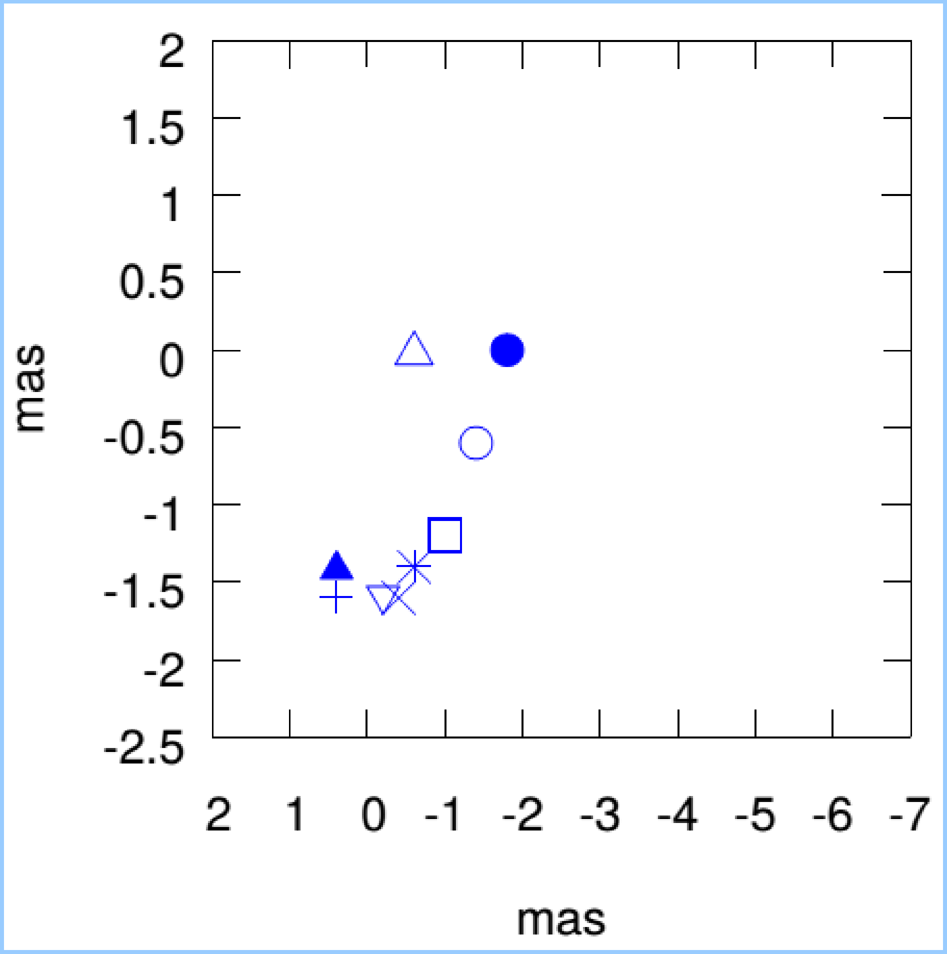
Y.W. Wu et al. 2017

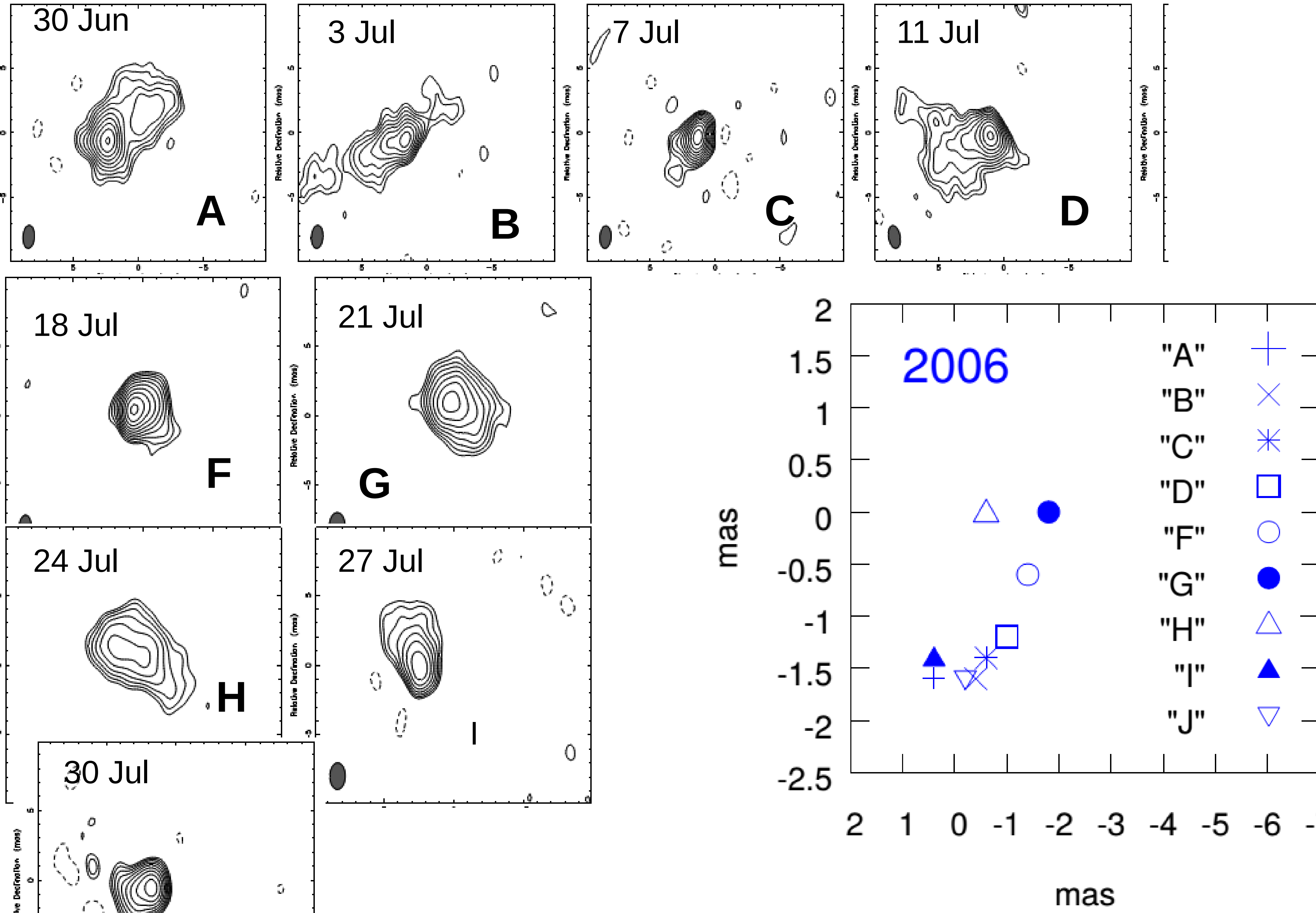


Observing at ν_{obs} the largest contribution is from the segment whose spectrum peaks at that frequency

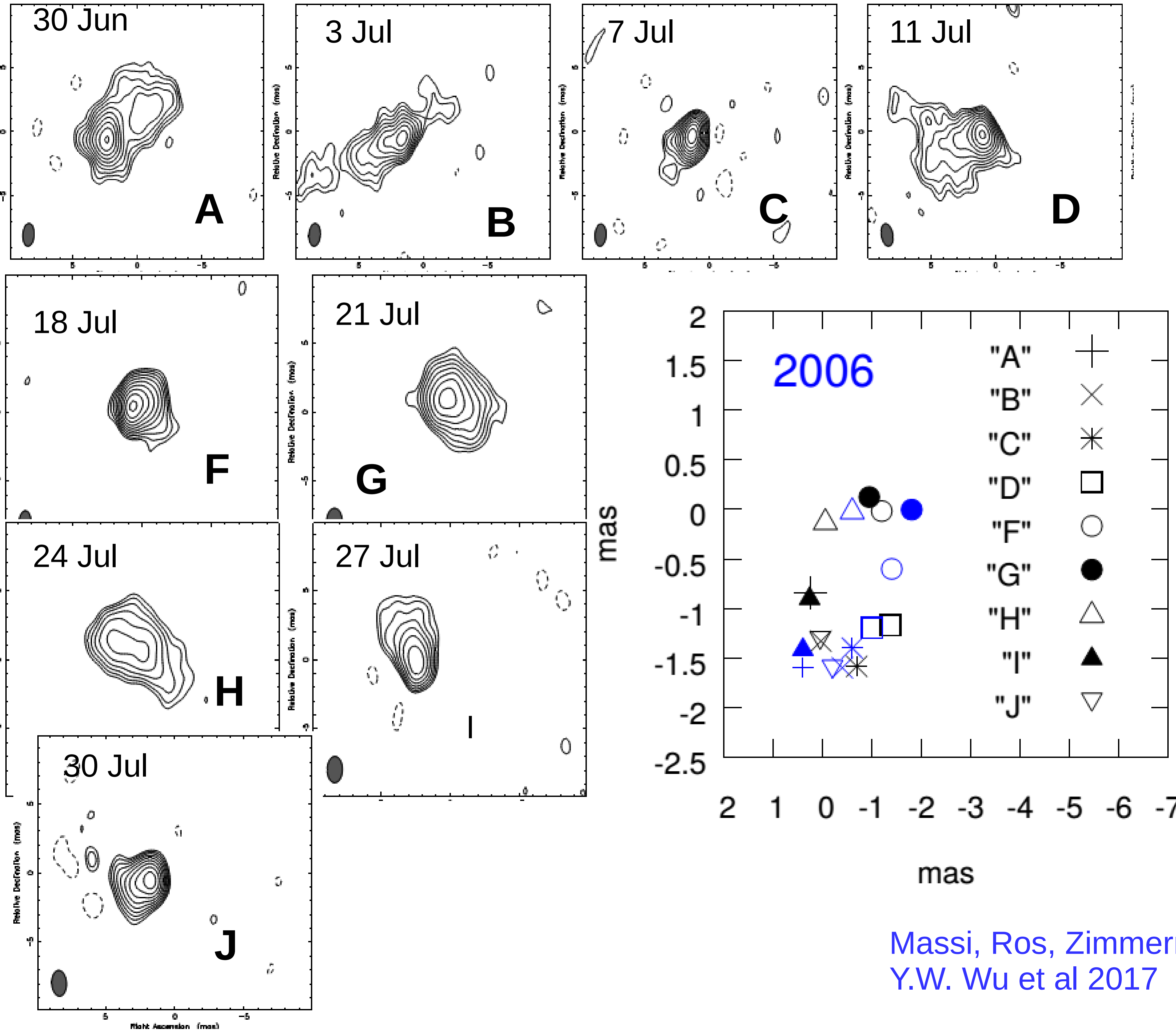
Markoff 2010

ASTROMETRY



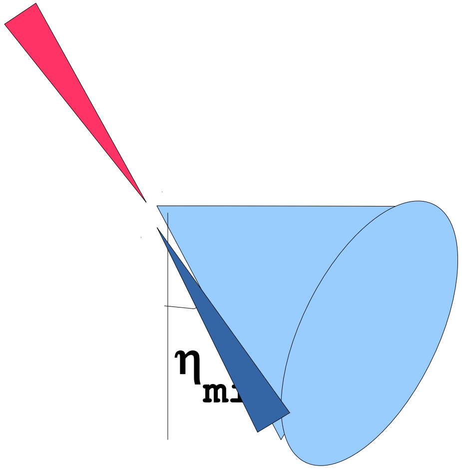


Massi, Ros, Zimmermann 2012
Y.W. Wu+2017

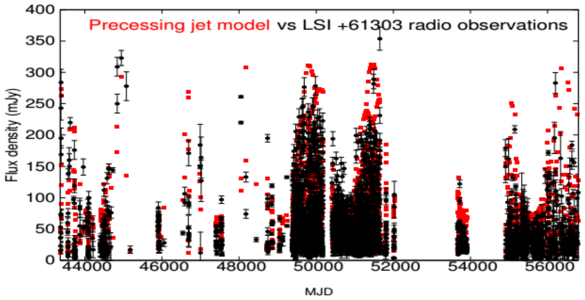


Massi, Ros, Zimmermann 2012
Y.W. Wu et al 2017

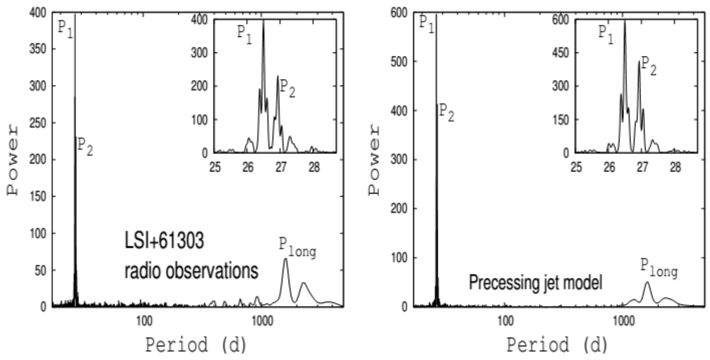
Precessing jet model reproduces:



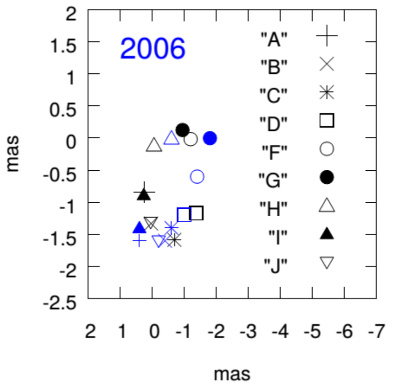
Flux density light curve



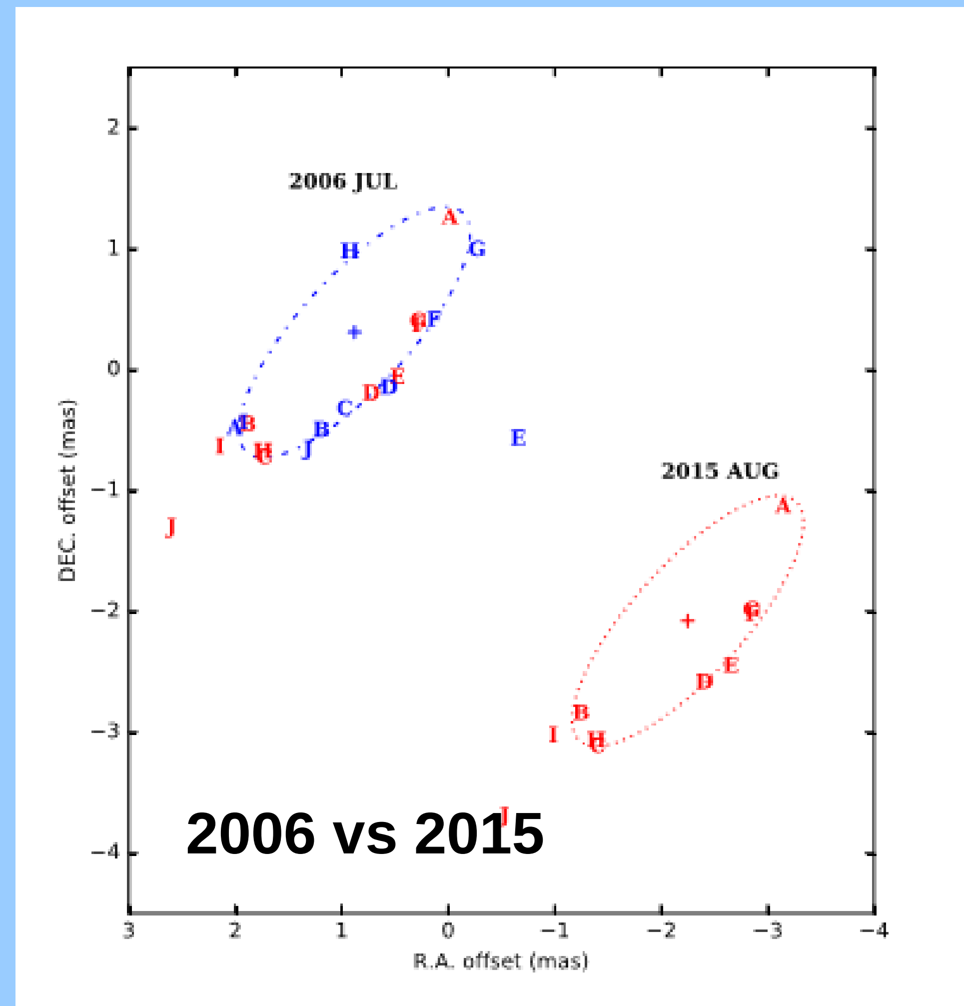
Timing analysis



Astrometry



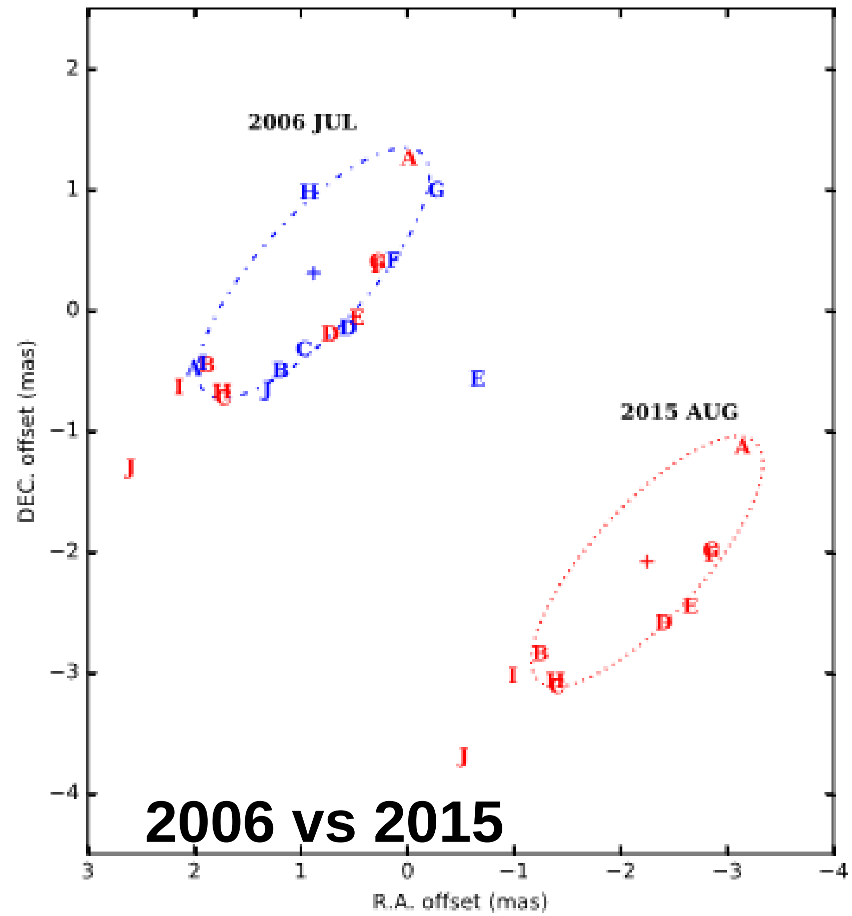
NEW VLBA ASTROMETRY



Y. W. Wu[1]★ G. Torricelli-Ciamponi[2], M. Massi[3]†, M. J. Reid[4], B. Zhang[5], L. Shao[6], X. W. Zhen

2017

Radio OBSERVATIONS: Astrometry



We measure the LS I +61°303 absolute proper motion to be −0.1500 ± 0.0055 mas yr^{-1} east-ward and −0.2636 ± 0.0055 mas yr^{-1} northward. Removing Galactic rotation, this reveals a small, < 20 km s^{-1}, non-circular motion, which indicates a very low kick velocity when the

Velocity < 20 km s^{-1}

Y.W. Wu et al 2017

Neutron stars: kick velocity usually above 100 km sec^{-1} Hobbs+2005

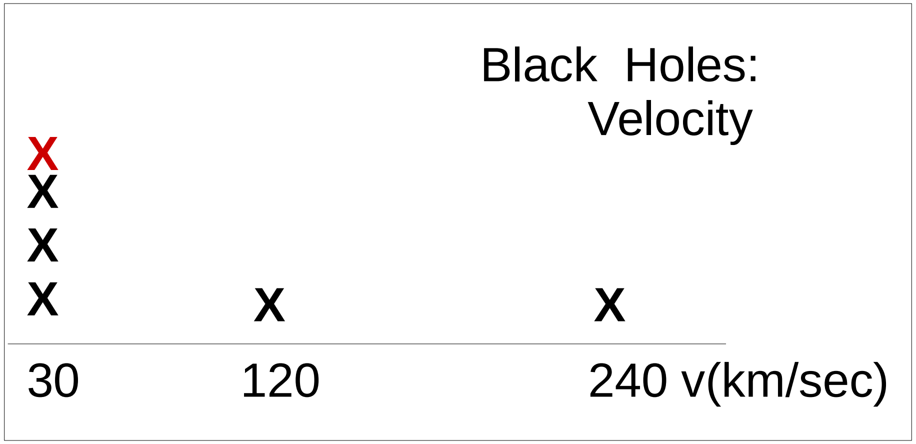
Theory: To explain some HMXBs with low eccentricity (e <0.2) and long period (P>30 d) Pfahl et al. (2002) suggest that neutron star in these systems could have received a small kick (< 50 km/sec).

LSI61303 eccentrity e=0.72+-0.15 (Casares+2006) (only He I and He II lines in the spectral range 3850 – 5020 Å to avoid contamination from the emission lines of the disk of the Be star)

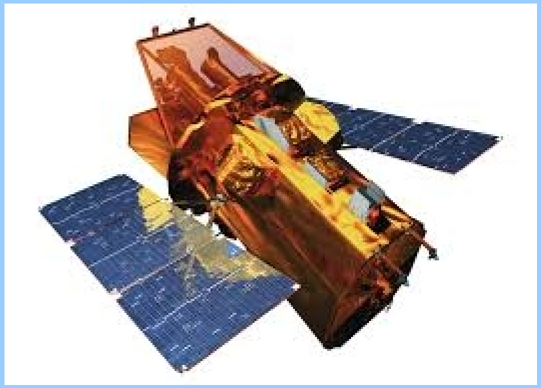
Low velocity and eccentricity of LSI61303 at odd with neutron stars scenarios

Black holes : velocity
(Mirabel 2016 and references therein)

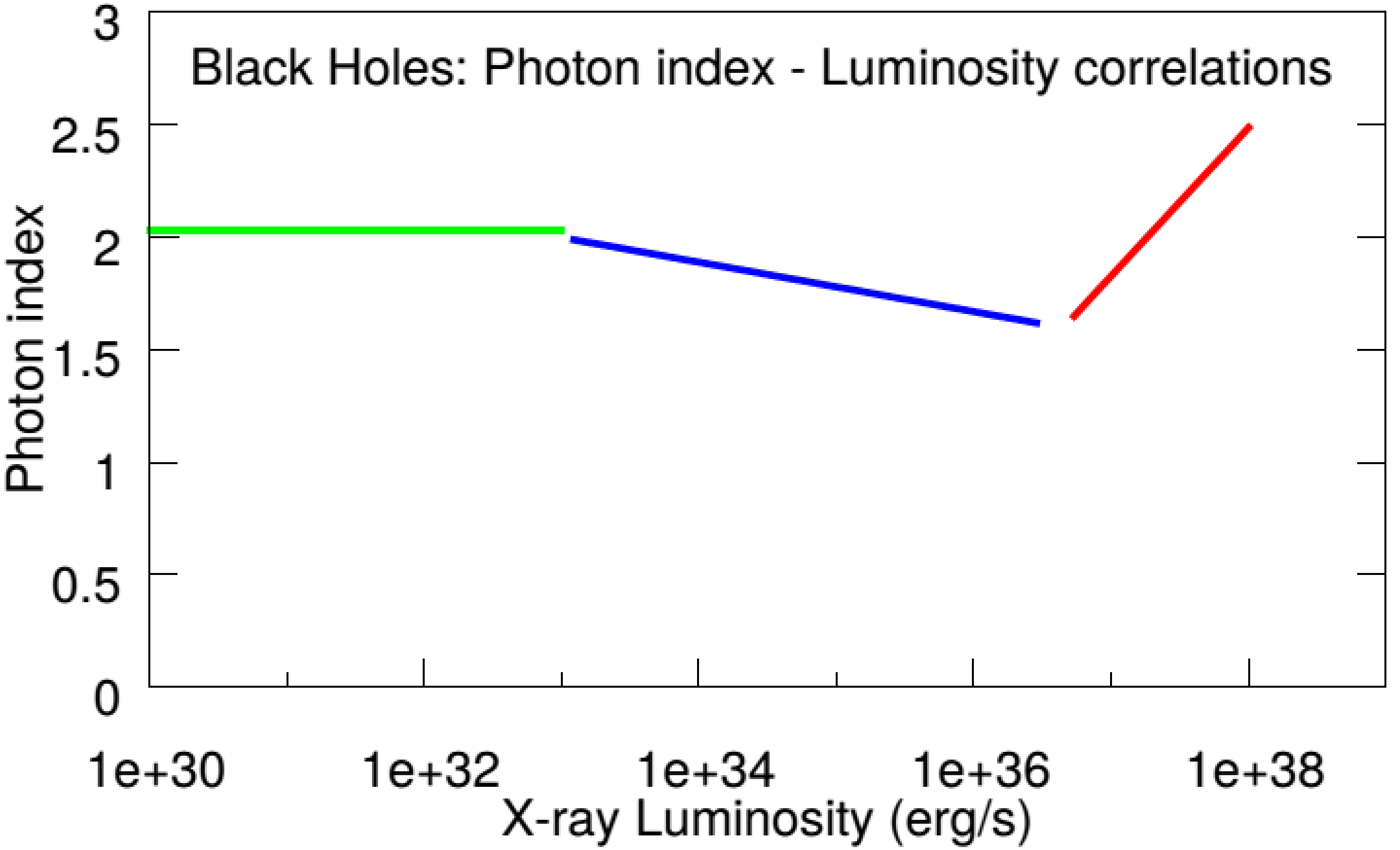
Cygnus X-1 9 +- 2 km sec^{-1} HMXB
GRS1915+105 22 +- 24 km sec^{-1}
V404 Cyg 29.9 +- 5.5 km sec^{-1}
XTE J118+480 217+- 18 km sec^{-1}
GRO J1655-40 112 +- 18 km sec^{-1}

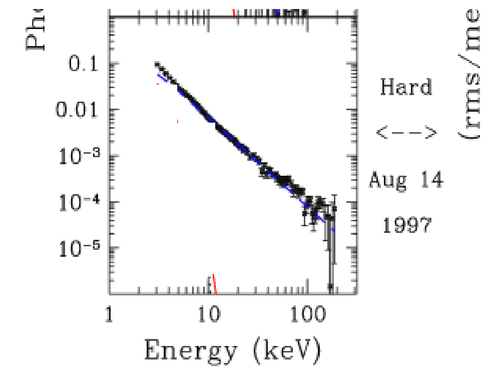


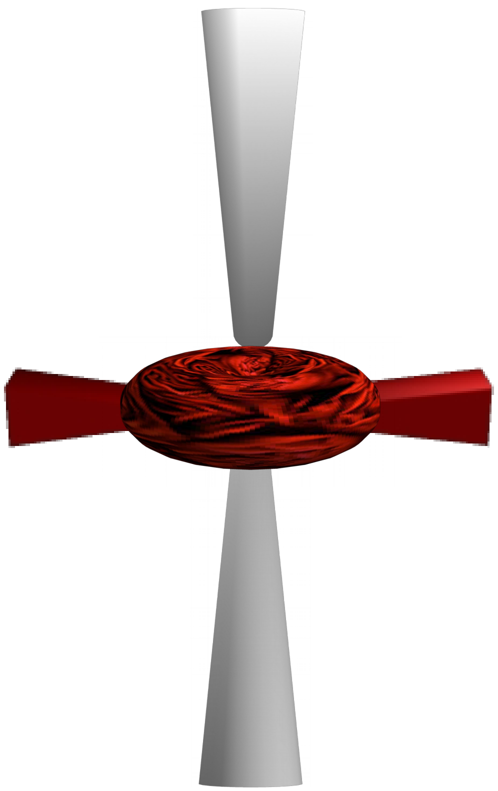
...If the runaway BH X-ray binaries were formed in dense stellar clusters, the anomalous velocities ….could have been caused by dynamical interactions in the stellar cluster
Mirabel 2016



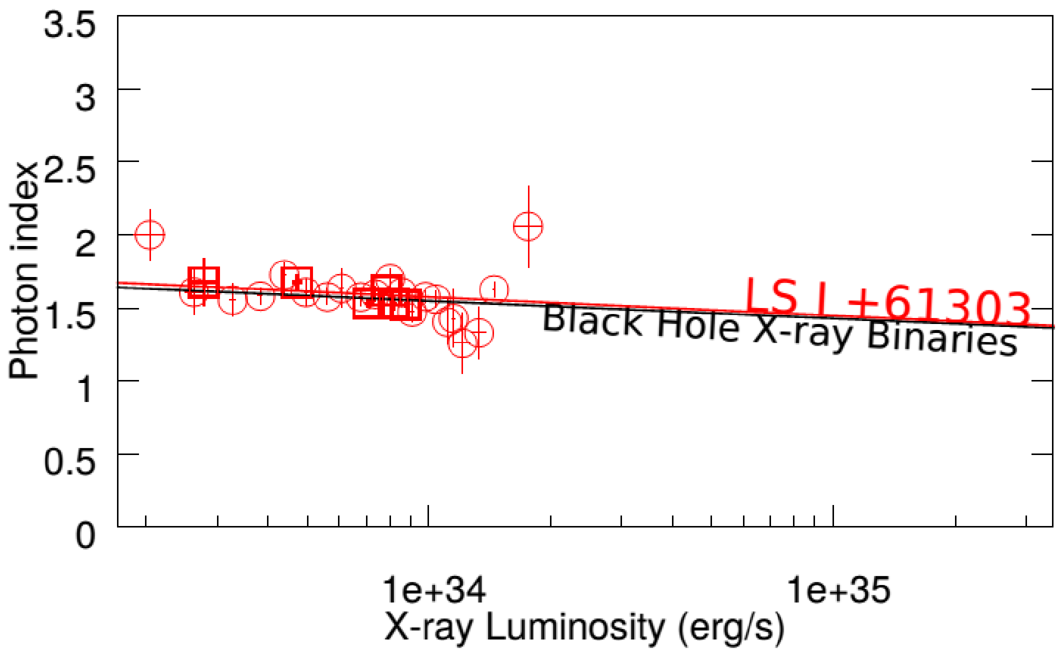
X-ray observations
(Swift, XMM)

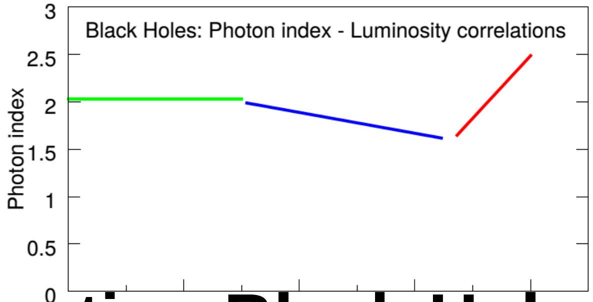






Yang et al 2015

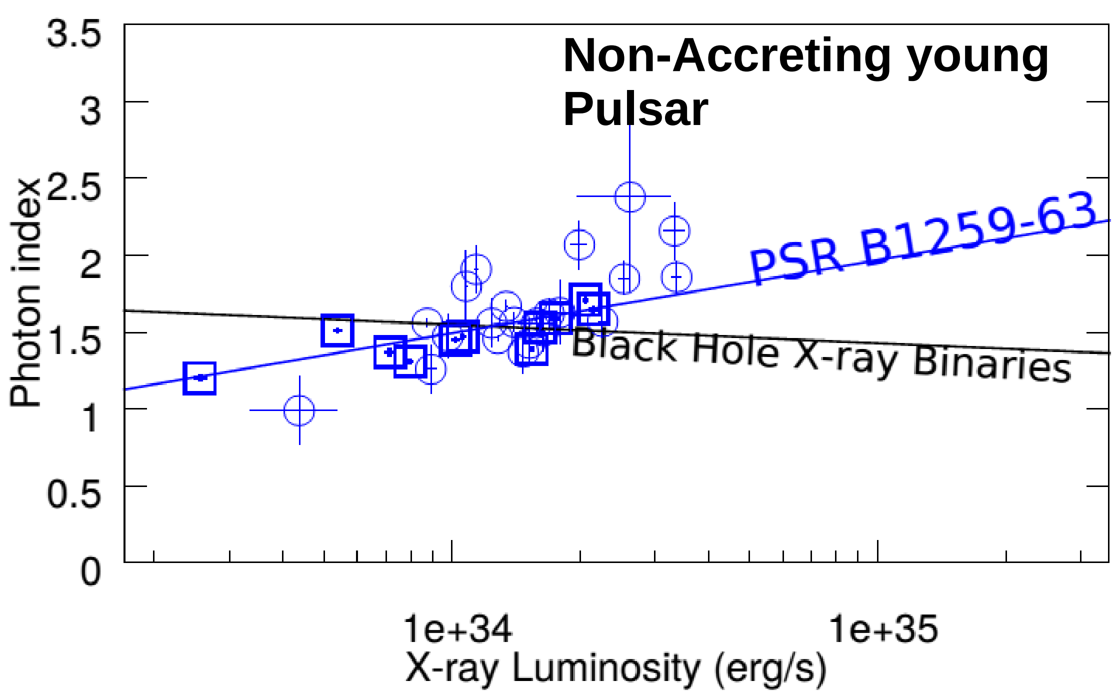




Accreting Black Holes

Massi, Migliari, Chernyakova 2017

P < 0.05 indicates that the two slopes are significantly different from each other.

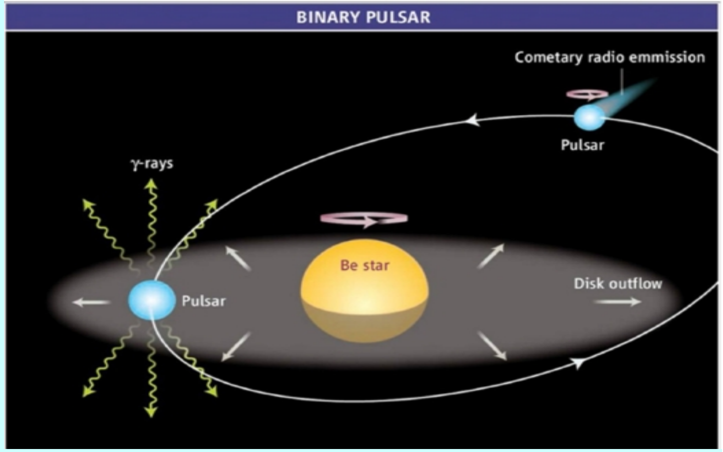


Pulsar
PSR B1259-63 vs BH
P=1.0e-6

LSI+61303 vs BH
P=0.8

CONCLUSIONS

The observations indicate LS I +61303 is a black hole X-ray binary with a precessing jet


BINARY PULSAR
Cometary radio emmission
Pulsar
γ-rays
Be star
Disk outflow
Pulsar

THANK YOU !

M. Massi and G. Torricelli-Ciamponi: Origin of the long-term modulation of radio emission of LS I +61°303

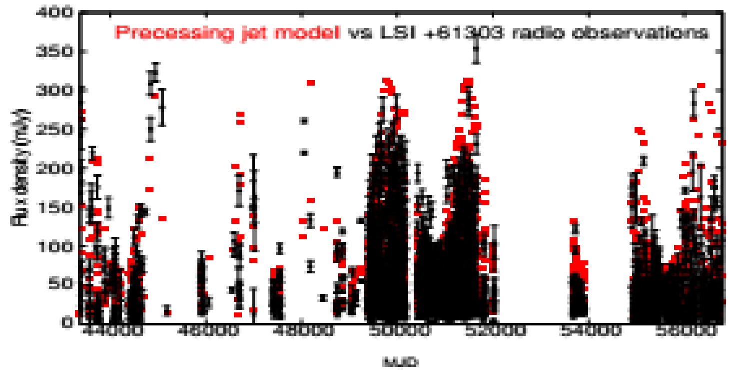


Fig. 3. Model data (red) and radio observations (black) of LS I +61°303 averaged over one day (Sect. 5).

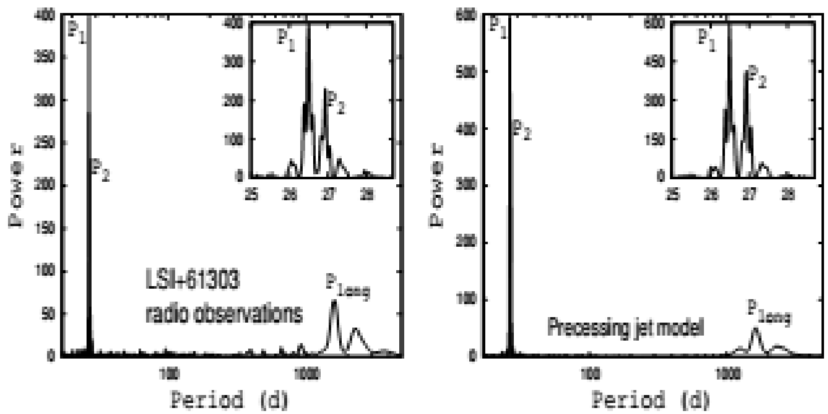


Fig. 4. Lomb-Scargle timing analysis of the observations (left) and the model data (right) of Fig. 3.

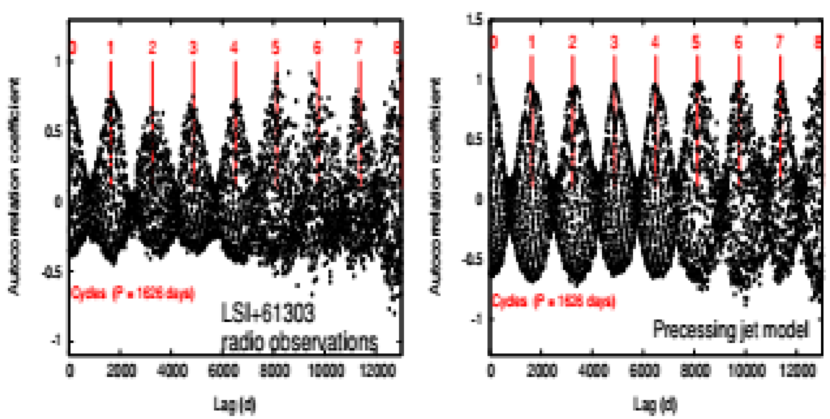


Fig. 5. Correlation coefficient vs time for observations (left) and model data (right), both averaged over three days.

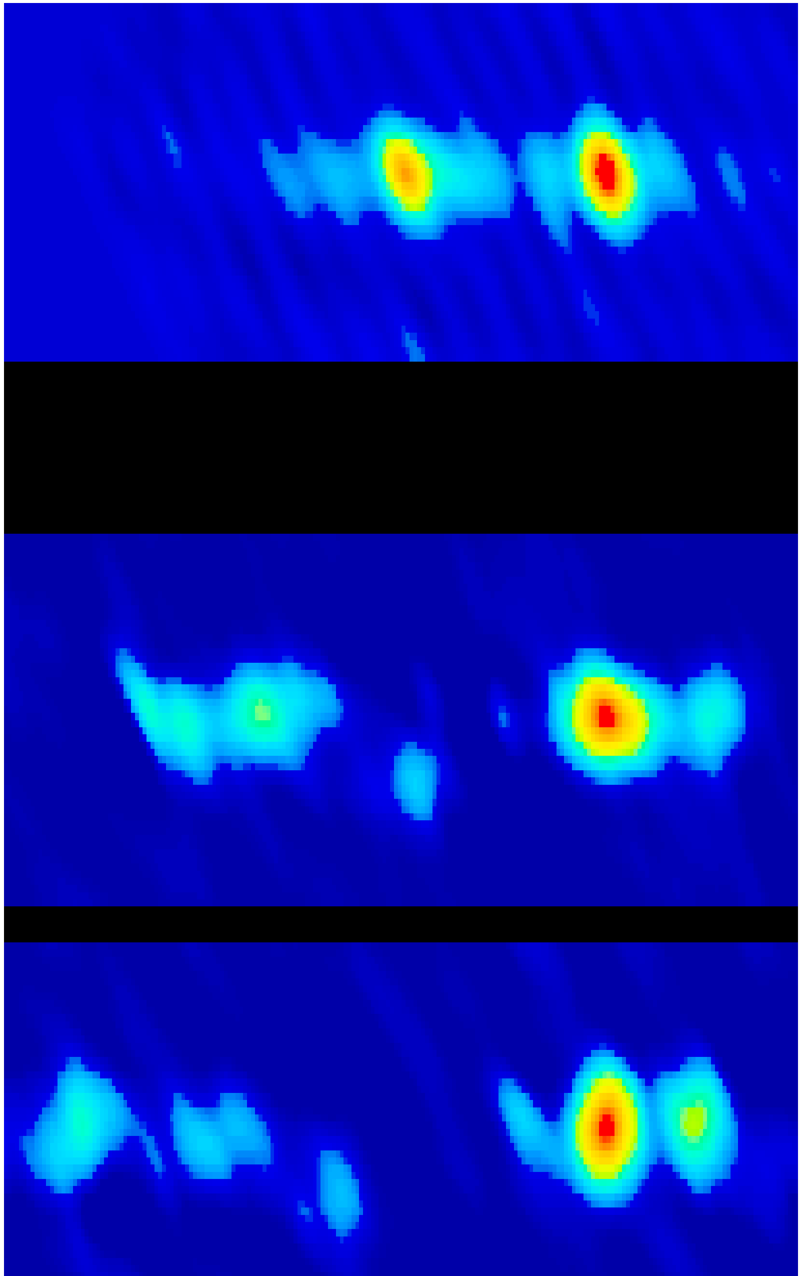
5

Massi and Torricelli-Ciamponi 2016

GRO J1655 – 40

Hjellming and Rupen 1995

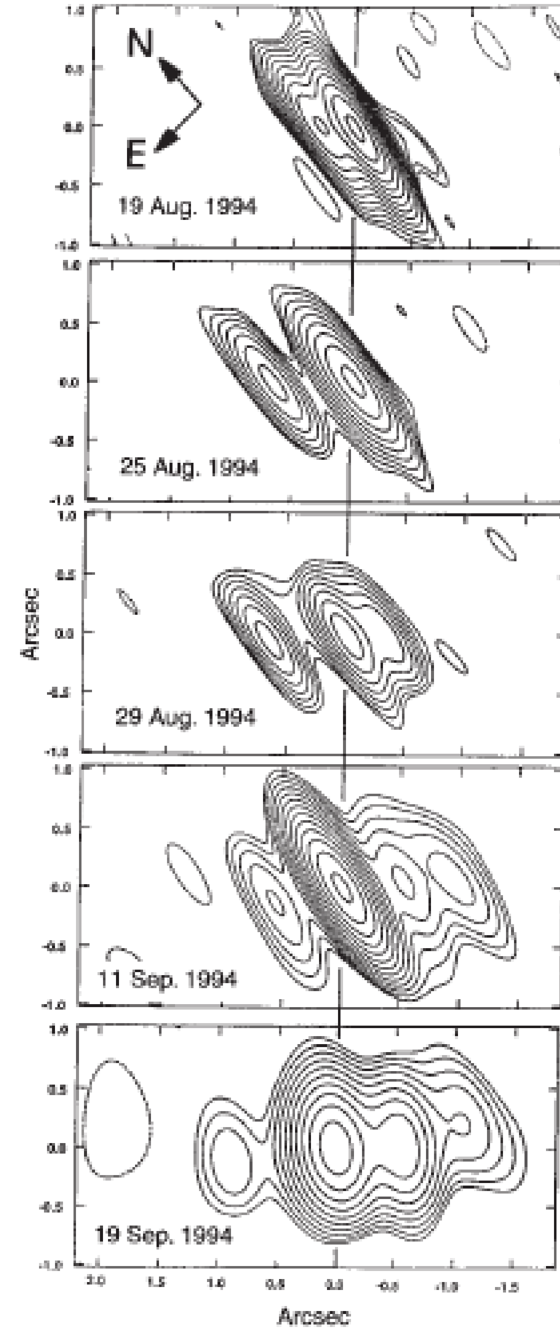
NATURE · VOL 375 · 8 JUNE 1995



Precession: Jets are rotating about the jet axis with a period of 3.0 ± 0.2 d

Orbital period

2.62 ± 0.02d (Baylyn et al. 1995)



Radio images: R. Hjellming and R. Rupen, NRAO.