# LS I +61°303: A precessing microblazar

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## Abstract

Changes in the radio morphology of the Be/X-ray binary system LS I +61303 suggested in the past the hypothesis of a precessing microquasar. However, in 2006, phase-referenced images from VLBA observations performed all around the orbit, have been taken as evidence for the alternative pulsar model. Recently though, a radio spectral index data analysis has fully confirmed the predictions of the two-peak microquasar model, which therefore does apply in LS I +61303. We now reanalysed the VLBA data set improving the dynamic range of the images by a factor of four, using self-calibration. The higher dynamic range of the self-calibrated maps reveals that the radio emission has in six out of ten images a double-sided structure. The pulsar model explains neither the double-sided morphology nor the change from double-sided to a one-sided structure. The microquasar model can explain them with variable Doppler boosting, i.e., with a precessing jet. Moreover, the astrometry, tracing an ellipse, indicates the path traced by the core of the precessing steady jet.

## LS I +61°303

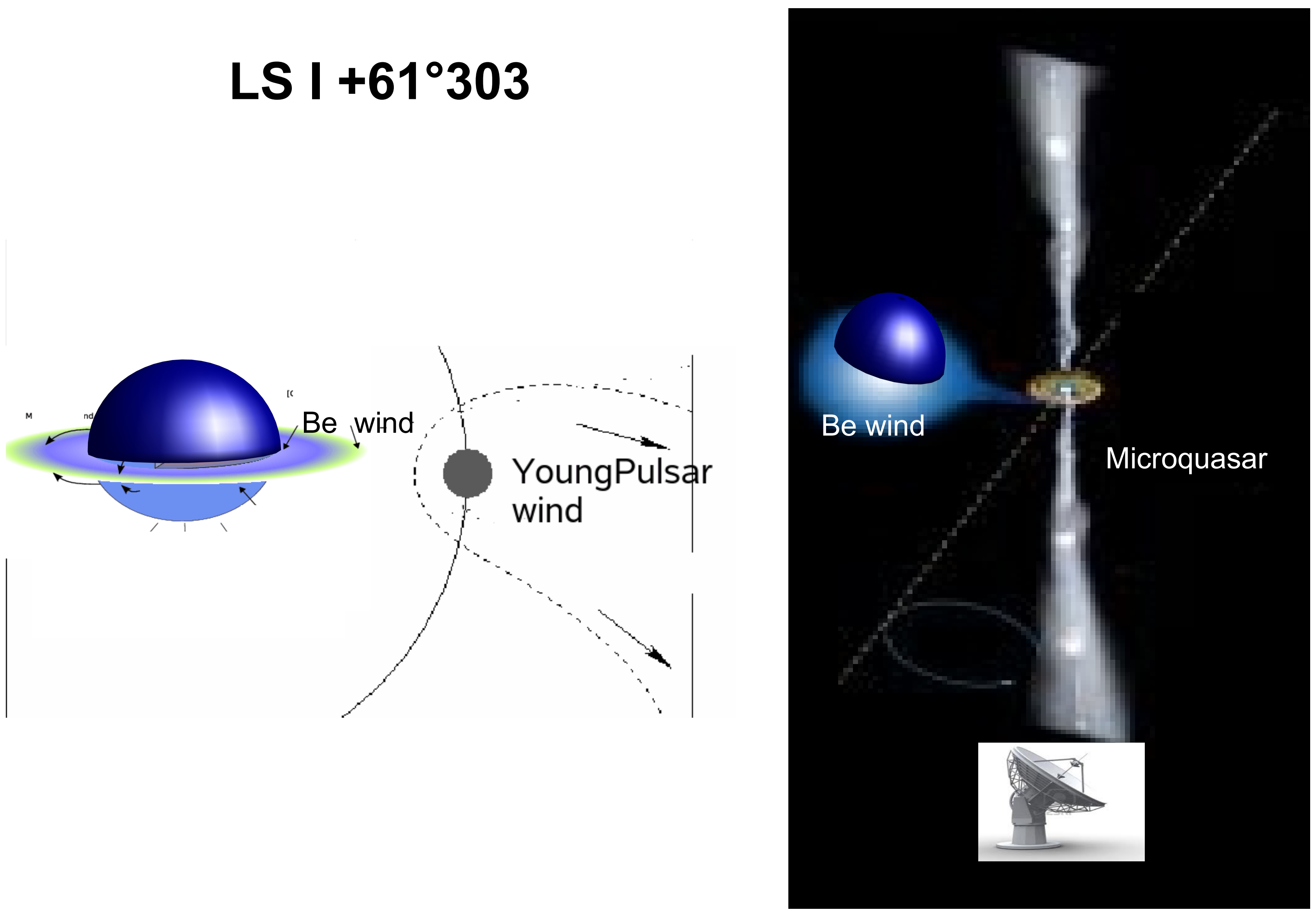


**Fig. 1:** Left: The commonly proposed millisecond pulsar model for LS I +61°303, where the interaction between the relativistic pulsar wind and the equatorial wind of the Be star is predicted to create a bow-shock around the pulsar with a sort of cometary tail extending away from the Be star (Dubus 2006, A&A, 456). Right: A microquasar model for LS I +61°303 with a precessing jet pointing close to our line of sight, i.e. a microblazar (Massi et al. 2004, A&A, 414).

## Re-analysed VLBA images of LS I +61°303

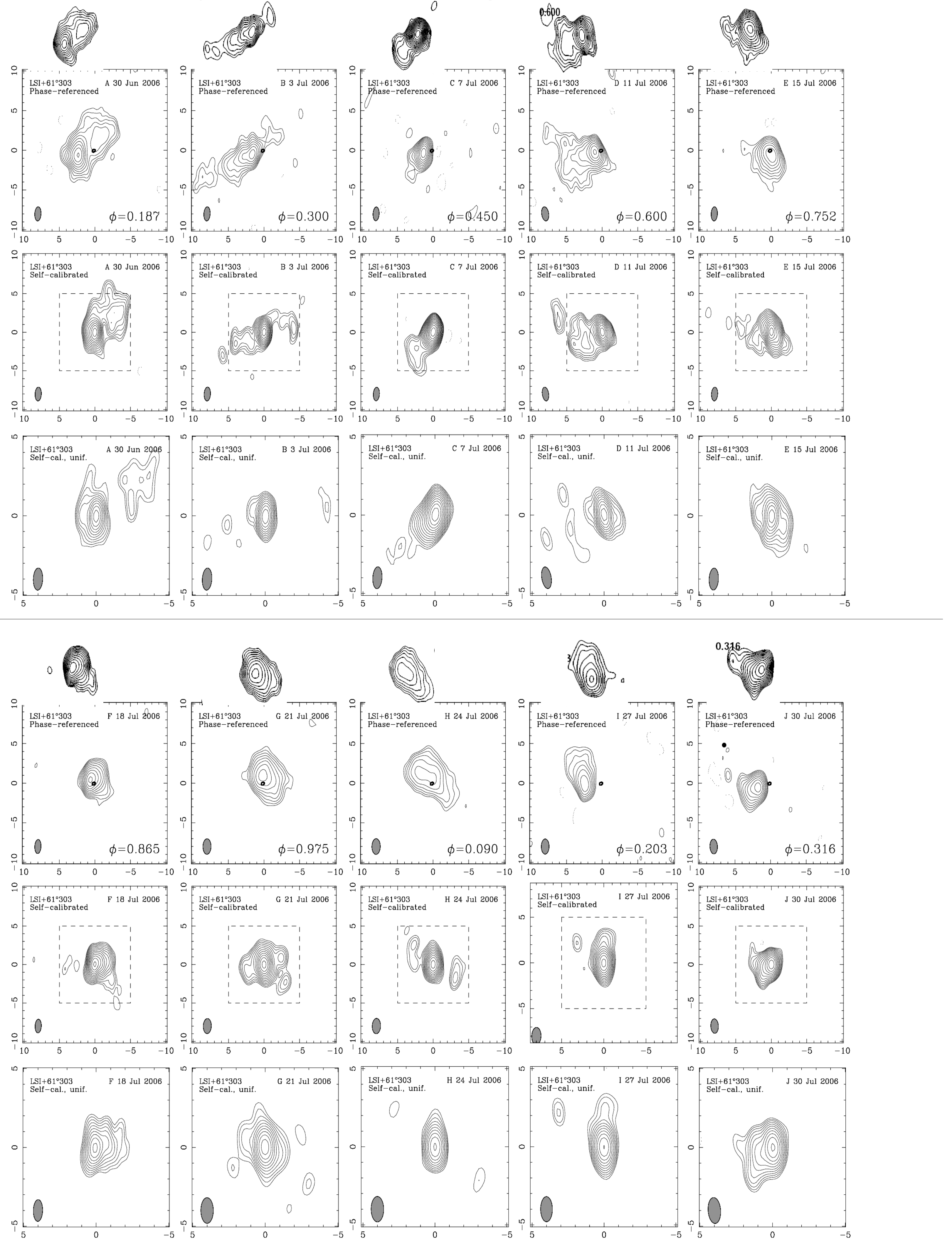
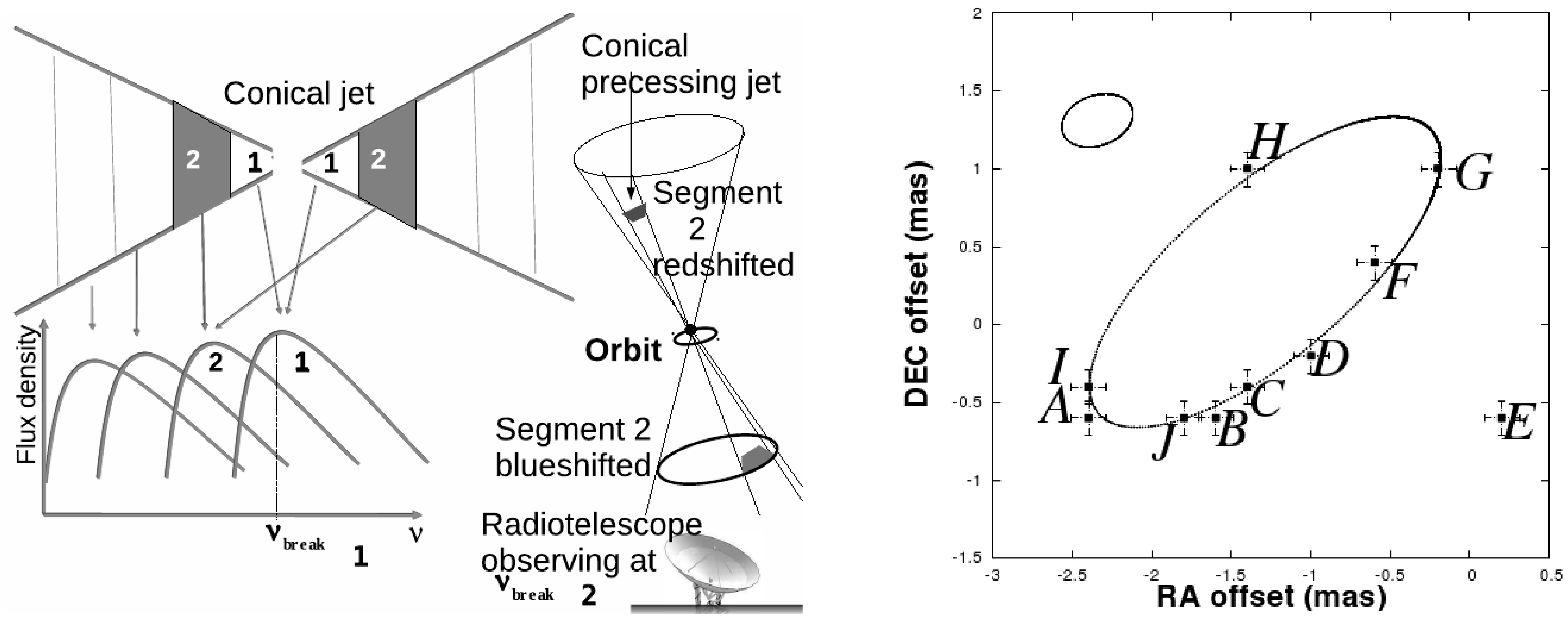


**Fig. 2:** Images of VLBA runs A-J at 3.6 cm (8.4 GHz) of LS I +61°303. For each run, three maps are presented, the phase-referenced map (beam of 1.8 mas x 0.9 mas, shown in the bottom left corner), the self-calibrated map at the same resolution and the self-calibrated map with a beam of 1.4 mas x 0.6 mas (Massi, Ros & Zimmermann, 2011, A&A, subm.). On top are displayed the corresponding images from Dhawan et al. (2006, Proceedings of the VI Microquasar Workshop, p. 52.1). Contour levels for all maps are -4, 4, 5.66, 8, 11.3, 16, 22.6, 32, 45.2, 64, 90.5 sigma (with 1 sigma=0.1 mJy/beam for Top and Bottom maps, and 1 sigma ~0.07 for the Middle maps). At the center of the phase-referenced images is traced, in scale, the orbit, which is clearly not resolved.

**Fig. 3:** Left: Superposition of individual spectra, each with a different break frequency associated with different segments of a steady jet. Middle: For a precessing microblazar, i.e. for small angle of ejection with respect to the line of sight, the core component, dominated by the approaching jet contribution because of Doppler boosting, will describe an ellipse during precession. Right: Astrometry of consecutive peaks of VLBA 8.4 GHz maps for runs A-J with the orbit drawn in scale at an arbitrary distance. The peak of map E, even if displaced from the other ones, and therefore likely affected by the approaching component of the transient jet, is at a position angle which is consistent with the other peaks. The fact that the precessing compact object is moving in an orbit with semimajor axis of ~0.2 mas introduces additional variations (Massi, Ros & Zimmermann 2011).



## Conclusions and Discussion

LS I +61°303 is one of the few established massive X-ray binaries that emit in the high and very high energy range. It is formed by a compact object of unknown nature (black hole or neutron star) travelling with a period of 26.495 d around a Be star (Gregory 2002, ApJ, 575; Casares et al. 2005, MNRAS, 360). Two models have been proposed in the past: a millisecond pulsar and a microquasar model. Recent analysis of the radio spectral index by Massi & Kaufman Bernadó (2009, ApJ, 702) has proven in LS I +61°303 the typical characteristic of microquasars of an optically thin outburst after an interval of optically thick emission twice along the orbit, as predicted by the two peak microquasar model.

Dhawan et al. (2006) suggested that their 3.6 cm (8.4 GHz) VLBA observations of LS I +61°303 could probe the cometary-tail of the pulsar model and that the peaks of all images traced an erratic ellipse. Re-analysis of this data set by Massi, Ros & Zimmermann (2011) have shown that the higher dynamic range of the self-calibrated maps reveals that the radio emission has in several images a double-sided structure (see. Fig. 2). A fit analysis show that the peaks of the images trace a well defined ellipse in (27-30) d (see Fig. 3). The pulsar model explains neither the double-sided morphology nor the change from double sided to a one-sided structure. The microquasar model can explain them with variable Doppler boosting, i.e., with a precessing jet. The cm-core of a precessing steady jet pointing close to our line of sight, as in a microblazar, is expected to describe an ellipse during the precession. During the transient jet phase there will be an additional shift due to the approaching jet component. We conclude therefore that the precession period is the time of (27-30) d necessary to complete the ellipse. Massi & Zimmermann (2010, A&A, 515) computed the precession period for the accretion disk in LS I +61°303 under tidal forces of the Be star and under the effect of frame dragging produced by the rotation of the compact object. By using those equations it was shown that a precessional period of 27-30 d induced by tidal forces, would require the unrealistic value for the size of the accretion disk of 0.5-0.8 x 10^13 cm, i.e, nearly the semi-major axis, and can therefore be ruled out. On the contrary, a precession period of 28 d could be compatible with being induced by the Lense-Thirring effect for a slow rotating compact object.