Ultra-compact blazar AO 0235+164

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QUASARS AT ALL COSMIC EPOCHS
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Derived VLBI kinematics and geometry of the jet in the blazar provide clear signatures of significant acceleration and collimation within the central 10 parsecs. Extreme brightness of the core detected by RadioAstron challenges the inverse Compton limit even after being corrected for boosting.

Observational data

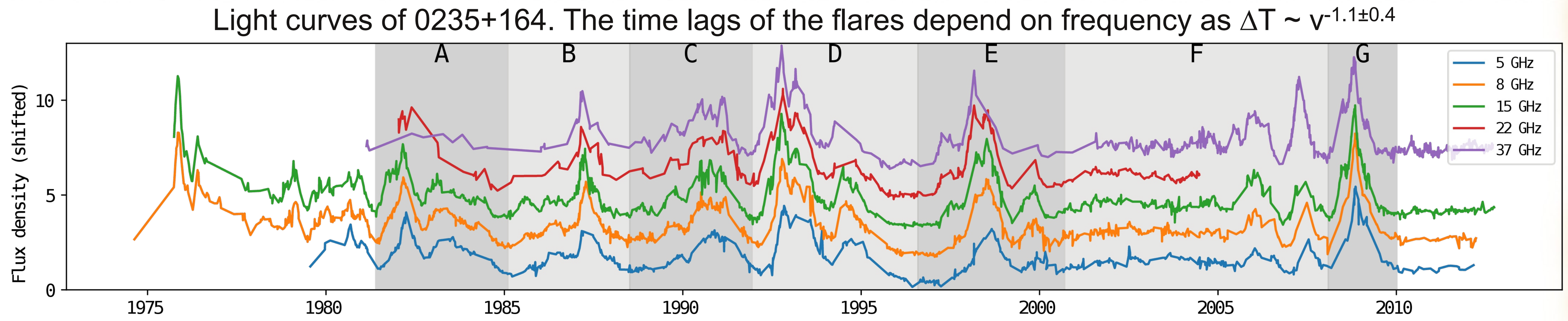
•Single-dish light curves
Univ. of Michigan Radio Observatory (5, 8, 15 GHz)
Metsahovi Radio Observatory (22, 37 GHz)
Owens Valley Radio Observatory (15 GHz)

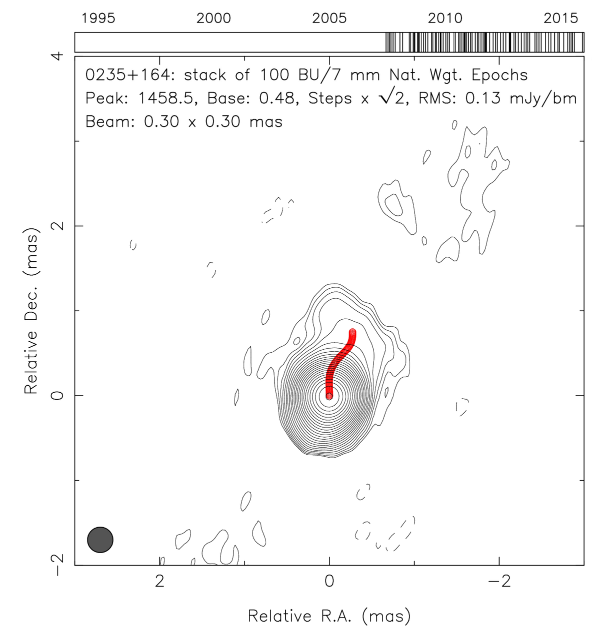
•Multi-frequency VLBI
VLBA (2008-09-02): 4.8 - 43 GHz
EVN (2008-10-19): 1.6 - 8.4 GHz

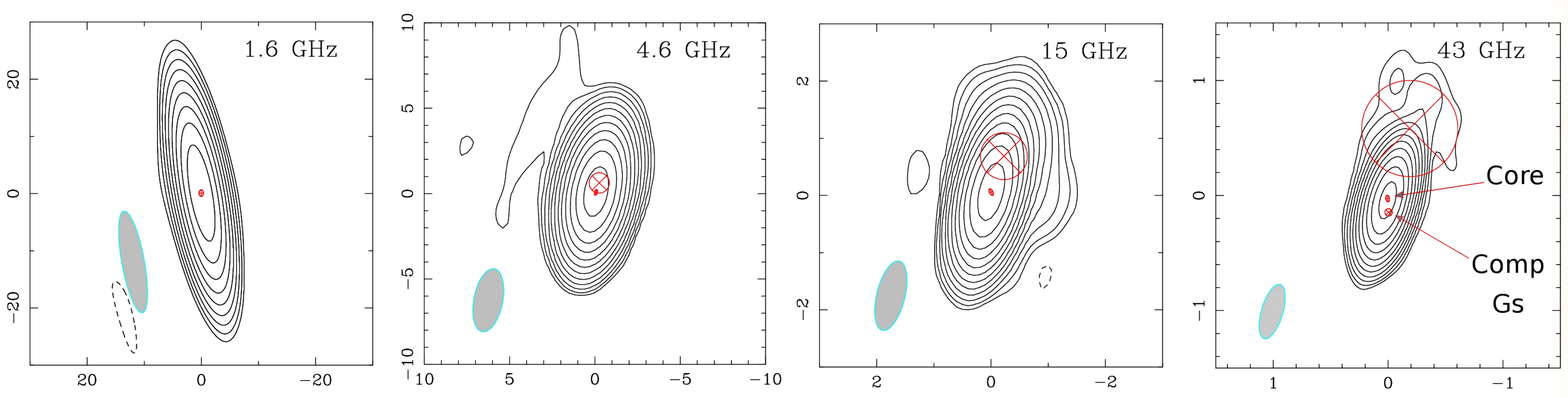
•Multi-epoch VLBA at 43 GHz
Data from the Boston Univ. blazar group (100 epochs)

•Radioastron Space-VLBI
12 epochs, 1.6, 4.8, 22 GHz, baselines up to 14 Gλ (15 Earth diameters at 22 GHz)

Light curves of 0235+164. The time lags of the flares depend on frequency as $\Delta T \sim \nu^{-1.1\pm0.4}$





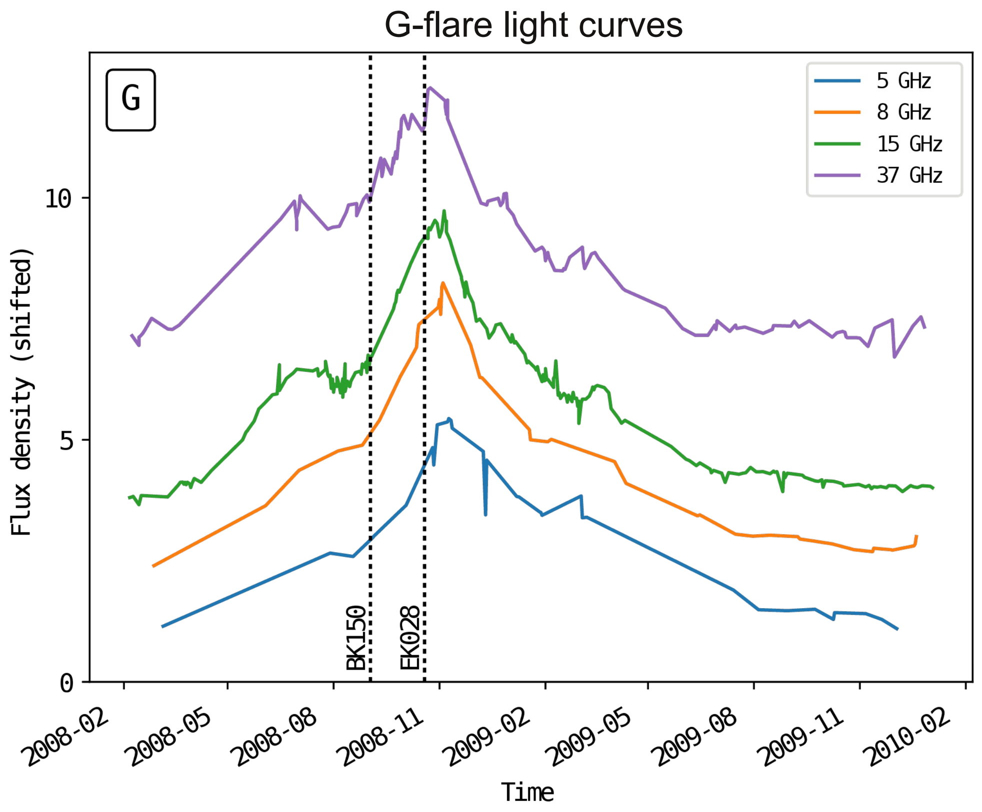


Stacked 43 GHz image with the ridgeline (left) and CLEAN maps with model components. Note the Gs component on 43 GHz map observed in the opposite jet direction (right).

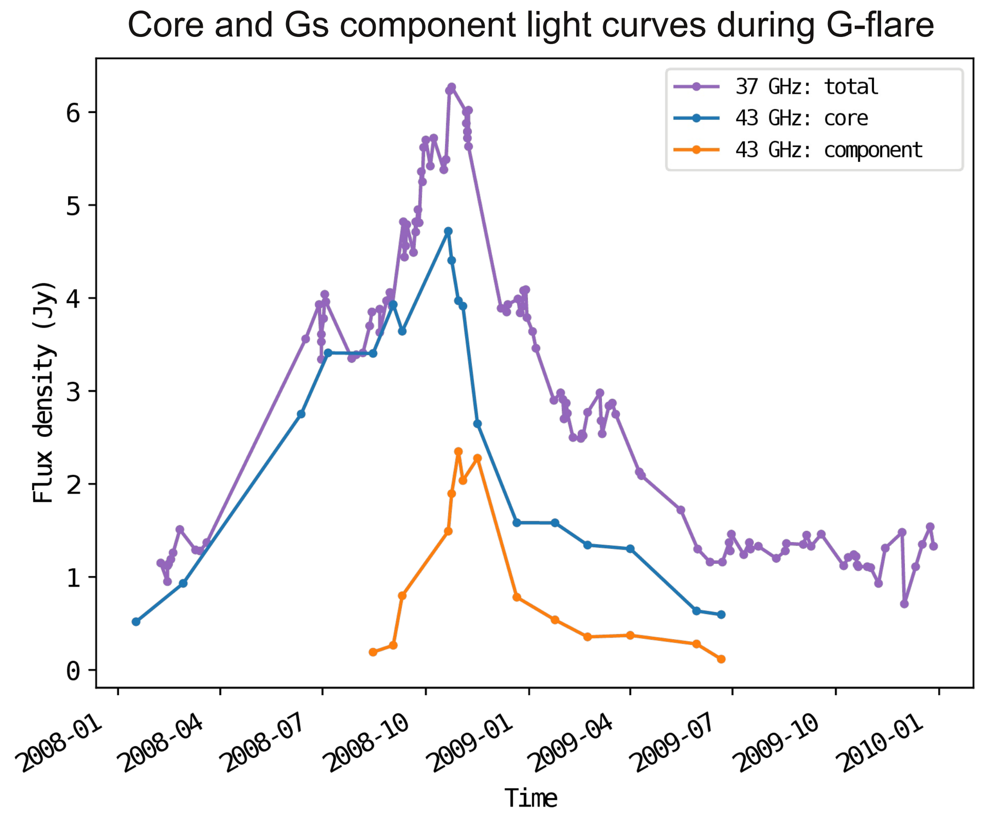
Time lags and core size

Time lags of the flares at different frequencies are measured using Gaussian process regression. VLBI structure is modeled with elliptical and circular Gaussian components.

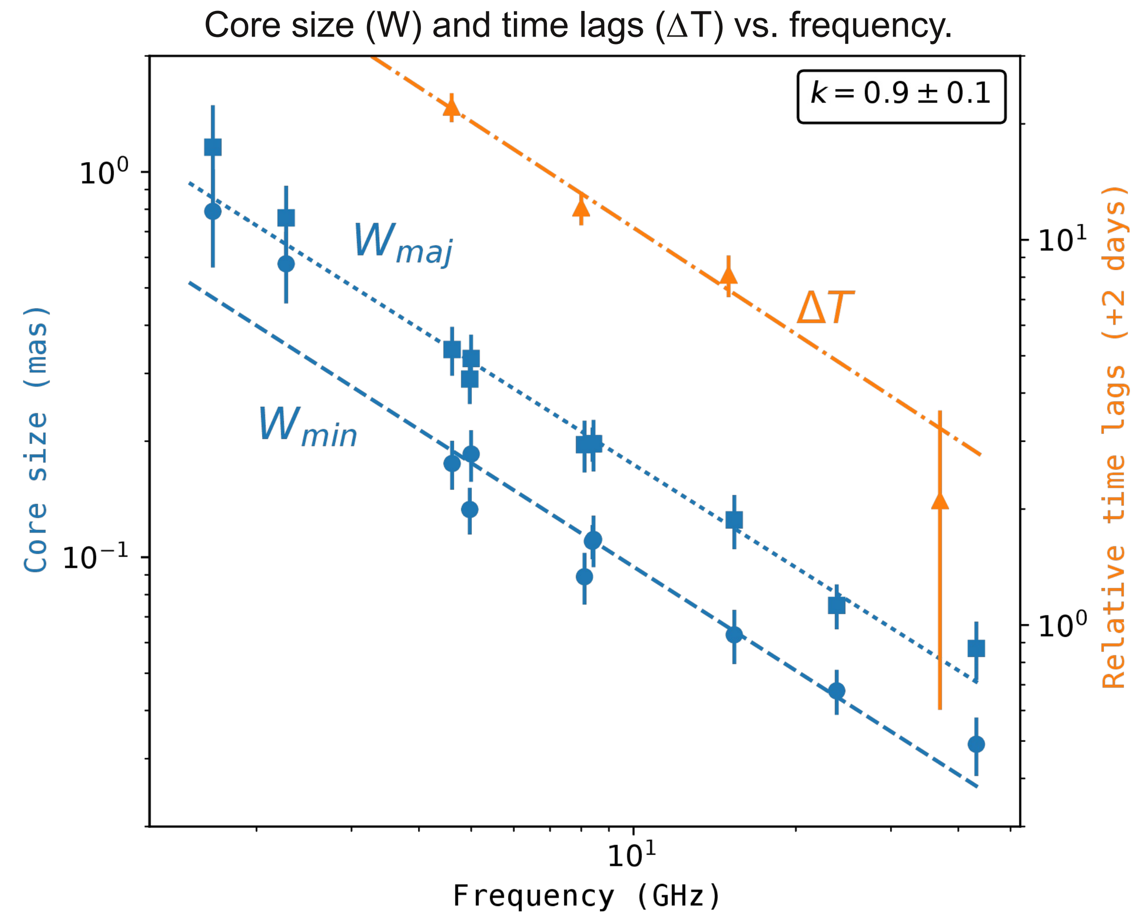
G-flare light curves



Core and Gs component light curves during G-flare



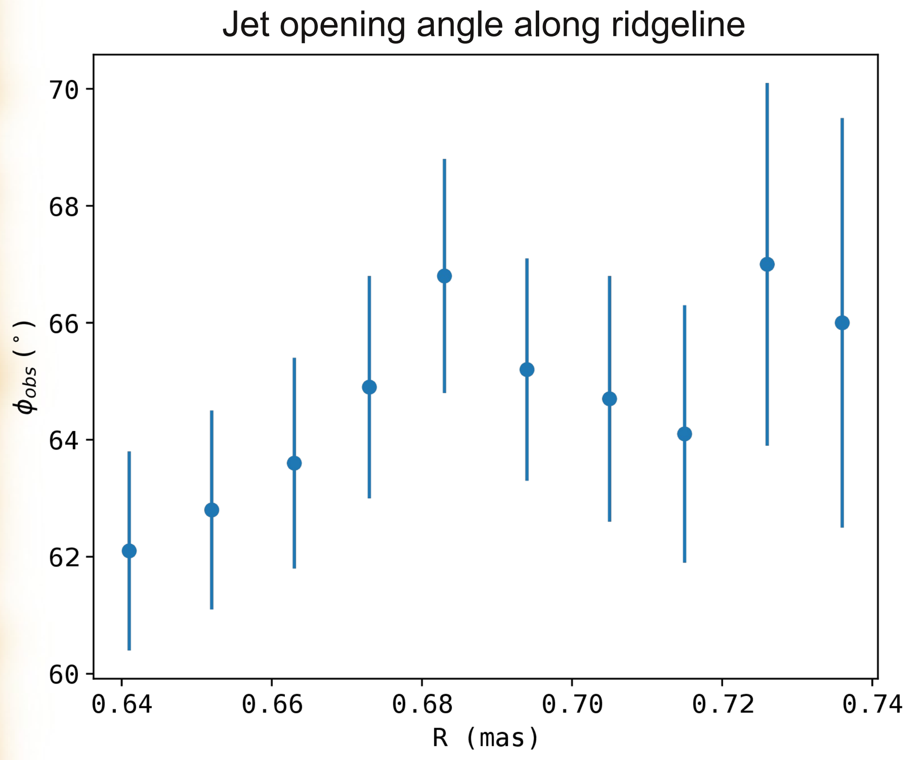
Core size (W) and time lags (ΔT) vs. frequency.



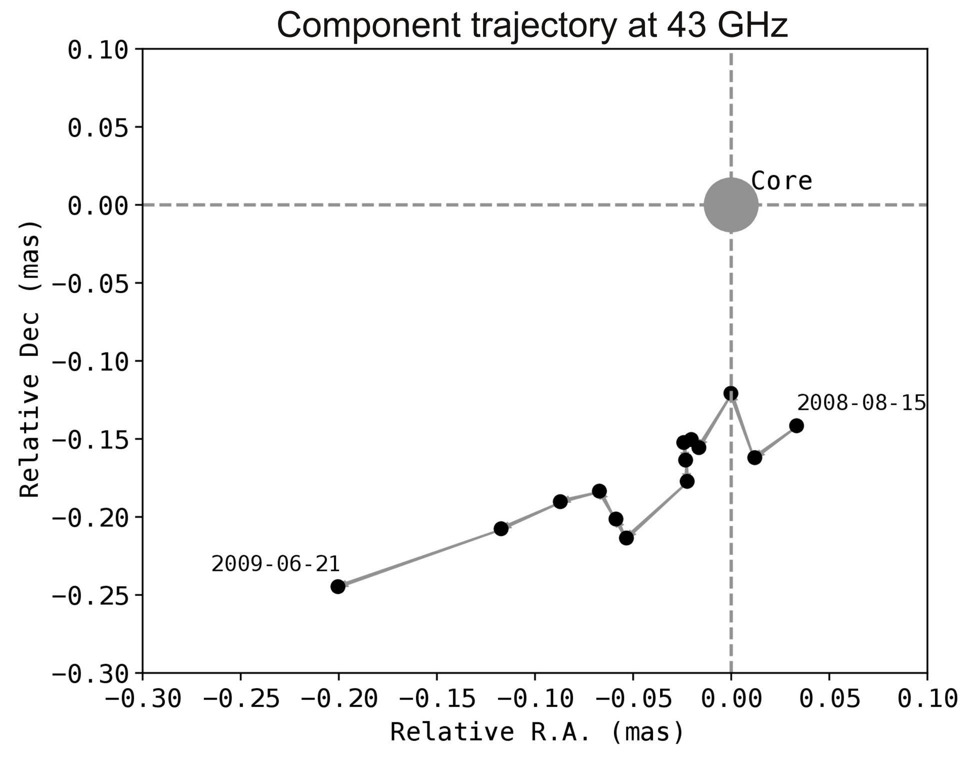
Jet geometry and kinematics

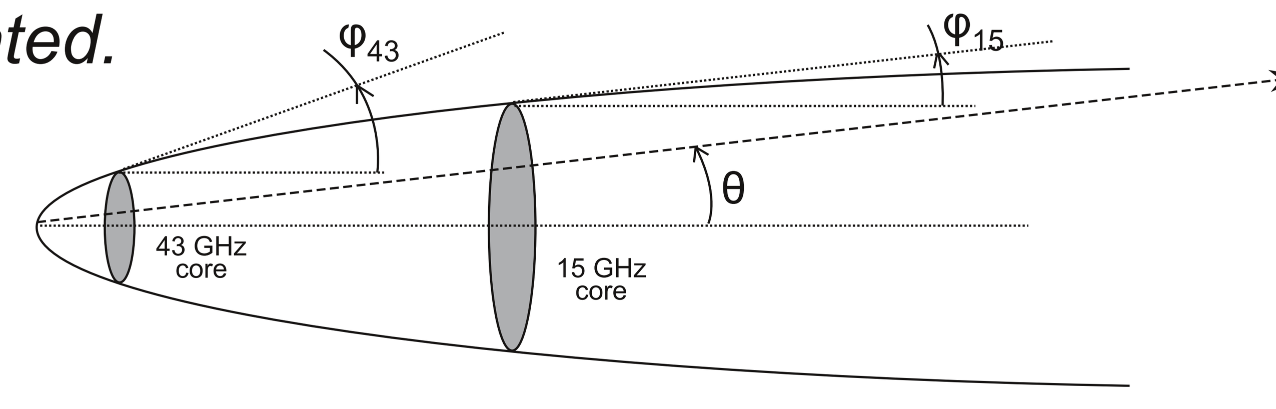
Stacked 7mm image is used to obtain jet opening angle φ. Doppler factor δ, Lorentz factor Γ and viewing angle θ are estimated.

Jet opening angle along ridgeline



Component trajectory at 43 GHz





Transition from $\varphi_{43GHz} > \theta$ to $\varphi_{15GHz} < \theta$ in the collimated jet

• Core size and flares time lags ~ $\nu^{-0.9}$. The shift between 43 GHz and 15 GHz core is $\Delta R \sim 0.05$ mas.

• Accelerated and collimated jet observed at $\theta \sim 1.2^o$

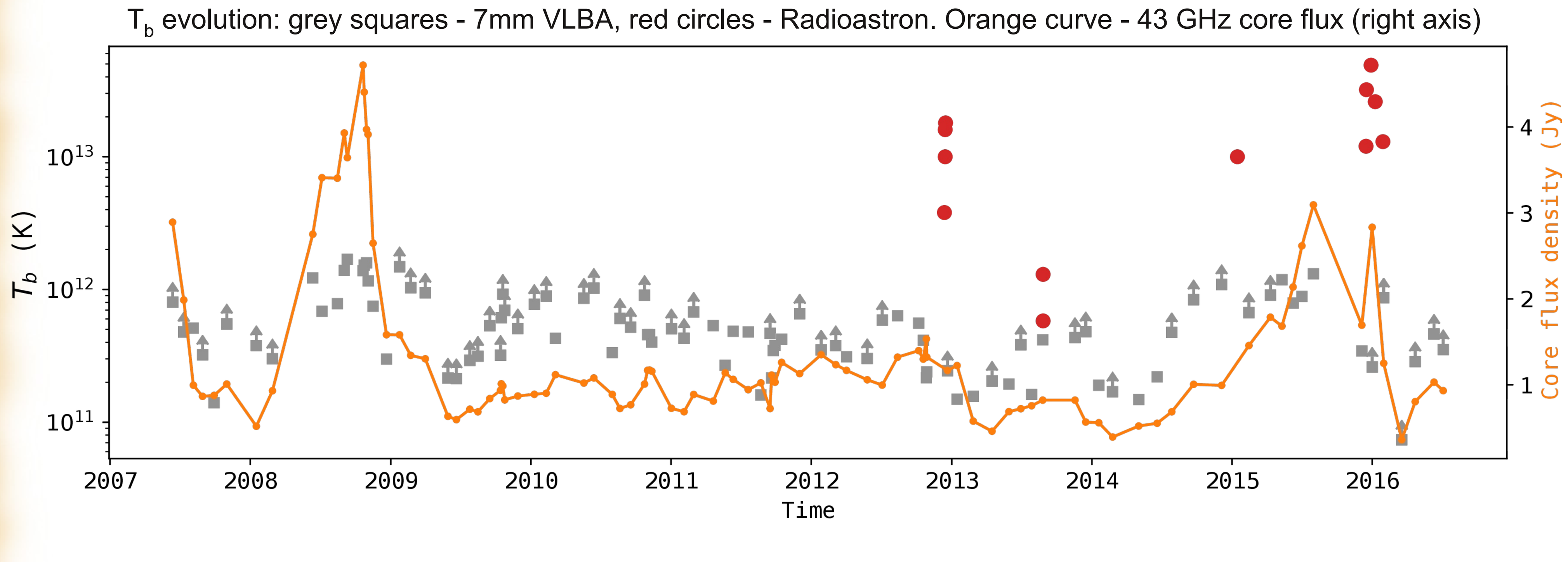
$$\begin{cases}\delta_{core} \sim 10,\ \Gamma_{core} \sim 5\\ \delta_{comp} \sim 30,\ \Gamma_{comp} \sim 18\end{cases} \qquad \begin{cases}\varphi_{obs,\,7mm} = 65^o\\ \varphi_{obs,\,2cm} = 30^o\end{cases}$$

• Brightness temperature measured by RadioAstron and corrected for boosting $T_{b,int} > 10^{12}$ K - exceeds significantly the inverse Compton limit. Fringe detections on bases up to 14 Gλ imply a complex structure of the innermost jet.

Brightness temperatures

are measured using VLBI models and visibility amplitudes on the longest RadioAstron baselines.

T_b evolution: grey squares - 7mm VLBA, red circles - Radioastron. Orange curve - 43 GHz core flux (right axis)



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More details available online at https://goo.gl/wVYY6J

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