JetKAT: The MeerKAT monitoring of the jets from GRS 1915+105

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Abstract

The Galactic microquasar GRS 1915+105 entered an unprecedented, persistent X-ray-obscured state in 2019 [1]. This phase is characterized by suppressed X-ray emission, with continued radio activity, and distinctly different outflow characteristics. GRS 1915+105 was historically known for hosting fast, highly relativistic jet ejections ($\Gamma\beta \geq 2$) [2], however, recent observations suggest these jets have slowed considerably and exhibit varying spatial orientations. To investigate this obscured phase, we analyse a 12-epoch S-band MeerKAT monitoring campaign to track the discrete jet components during a period of radio flaring in 2025. Modelling the jets as ballistic ejecta at an assumed distance of 9.4 ± 1.0 kpc [3], we obtain a proper velocity of $\Gamma\beta \approx 0.39$ and a viewing angle of $\theta \approx 68.4°$. These results provide kinematic evidence that slow, precessing jets may be a sustained characteristic of heavily obscured accretion states.

Introduction

The Galactic black hole X-ray binary GRS 1915+105 entered an unprecedented, persistent X-ray-obscured state in 2019 [1]. This state is characterized by heavily suppressed X-ray emission while maintaining activity in the mid-infrared and radio bands [4, 1]. Leading interpretations attribute the obscuration to a thickened or warped and precessing outer accretion disk [5].

Historically known as the first Galactic source to exhibit apparent superluminal ejections ($\Gamma\beta \geq 2$) [2], the system's jet kinematics have changed significantly during this recent obscured phase. The jets have slowed to mildly relativistic speeds ($\Gamma\beta \approx 0.37$–0.40) and exhibit varying spatial orientations [6, 7]. These findings reinforce an emerging accretion–ejection paradigm: canonical fast, relativistic jets are launched along a fixed axis in relatively low-density environments, whereas slower, precessing jets are coupled to obscured states [8]. To probe this dichotomy and resolve the intrinsic kinematics of the jets in the obscured phase, we track the discrete jet components across consecutive MeerKAT epochs during a 2025 period of radio flaring.

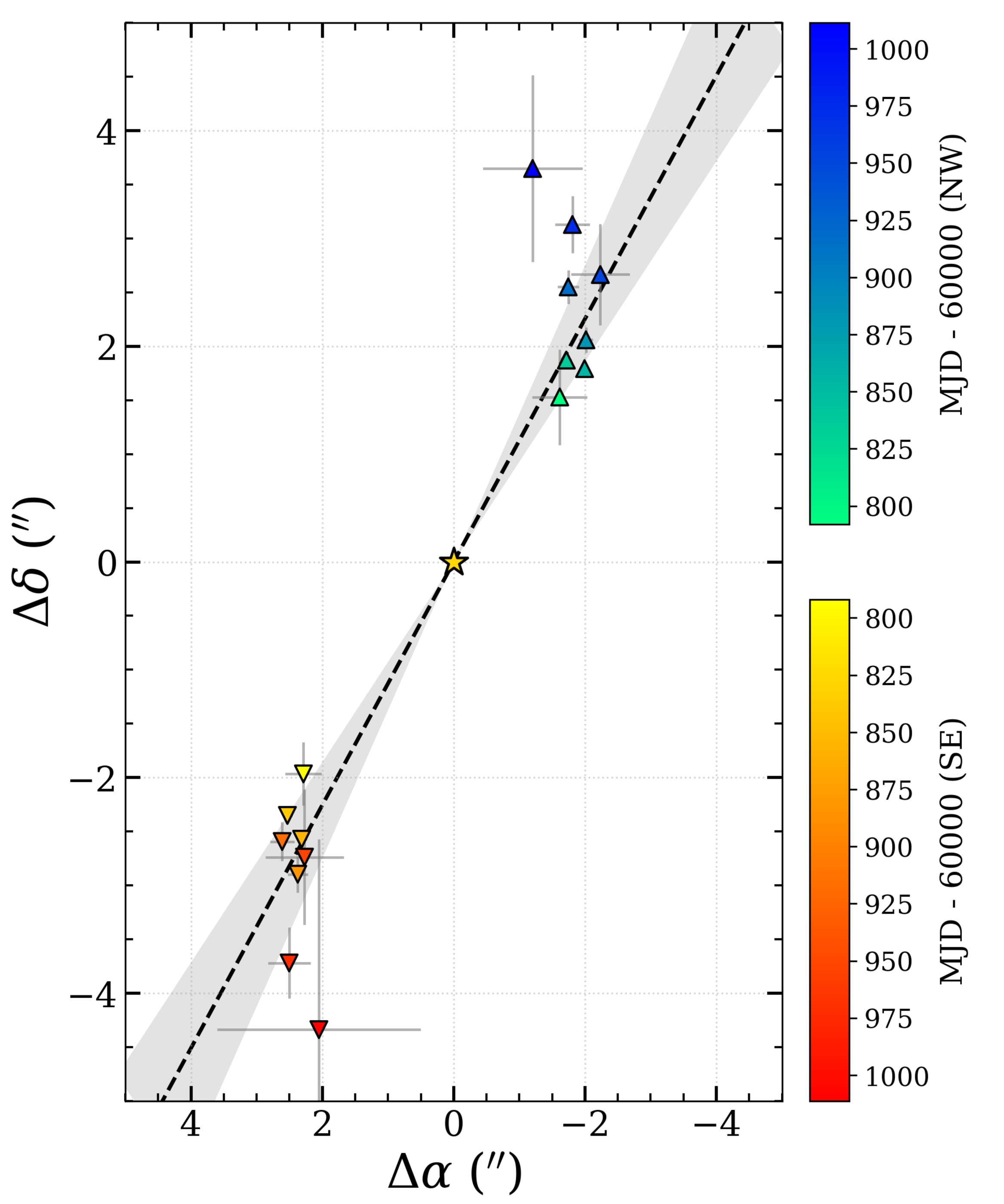

Figure 1: Relative RA and Declination offsets of the Northern (receding) and Southern (approaching) jet lobes. The colour gradient represents the temporal evolution of the ejections. The dashed line indicates the modelled mean kinematic axis, and the shaded envelope represents the 1σ transverse scatter of the discrete ejecta trajectories.

Dataset and Kinematic Modelling

This study utilizes 12 primary S-band (2.6 – 3.5 GHz) MeerKAT observations from the JetKAT project executed in 2025. Outflows were indistinguishable from the core in the initial four epochs, so only the subsequent eight epochs (5–12) are used for the purposes of this study.

Bayesian Information Criterion (BIC) selection favoured a 1st-order ballistic model with a fixed position angle. The angular separation of the approaching ($\Delta\theta_\parallel^S$) and receding ($\Delta\theta_\parallel^N$) lobes along the jet axis is then defined as:

$$\Delta\theta_\parallel^N(t) = \mu_r(t - T_{\text{ej}}) \quad \text{and} \quad \Delta\theta_\parallel^S(t) = \mu_a(t - T_{\text{ej}})$$

where μ_r and μ_a are apparent proper motions and T_{ej} is the launch time. Following standard relativistic formulations for symmetric ejections [2], the line-of-sight and transverse velocity components are:

$$\beta \cos\theta = \frac{\mu_a - \mu_r}{\mu_a + \mu_r} \quad \text{and} \quad \beta \sin\theta = \frac{D}{c}\frac{2\mu_a\mu_r}{\mu_a + \mu_r}$$

Assuming $D = 9.4$ kpc [3], we applied Markov Chain Monte Carlo (MCMC) sampling to fit the kinematic model and extract the extrapolated launch time, apparent proper motions, and the jet viewing and position angles.

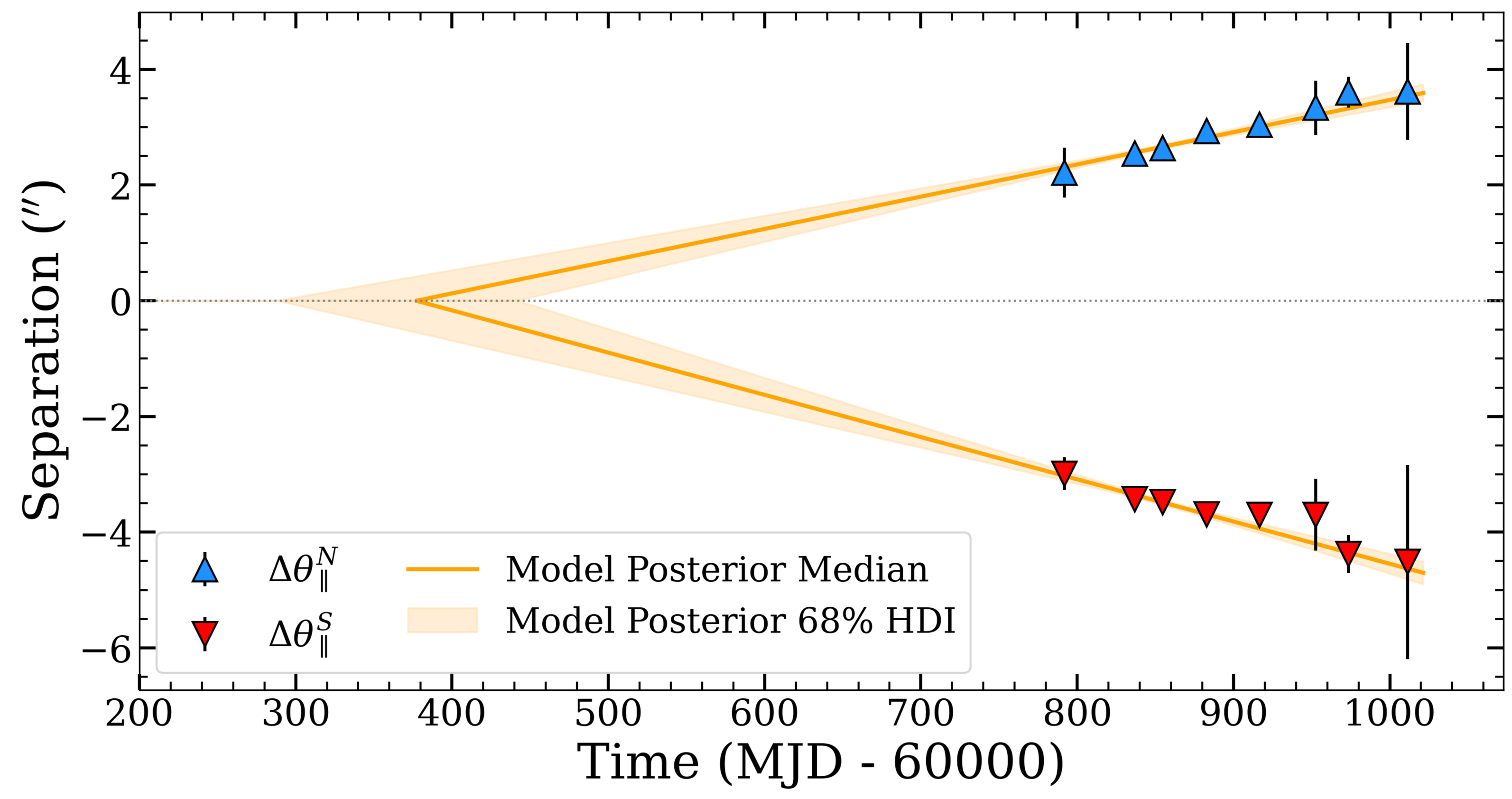

Figure 2: Axis-parallel spatial separation ($\Delta\theta_\parallel$) of the receding (NW, blue triangles) and approaching (SE, red triangles) jet lobes over time. The solid orange lines and shaded regions represent the median posterior linear ballistic fit and the 68% HDI.

Results and Conclusions

Our modelling yields a proper velocity of $\Gamma\beta \approx 0.39$ and a viewing angle of $\theta \approx 68.4°$ (Table 1). These ejections are significantly slower than the historical, highly relativistic outflows ($\Gamma\beta \geq 2$) observed prior to 2019. Our velocity result aligns with recent obscured-state measurements of $\Gamma\beta \approx 0.37$–0.40 [6, 7]. Furthermore, our modelled position and viewing angles appear to have a continued shift from the orientations reported in 2023 (PA=$118° - 188°$, VA≈ $87°$) [9, 6]. Ultimately, while it is uncertain whether the jets are indeed precessing, the persistent sub-relativistic speeds provide evidence for an emerging paradigm in which X-ray-obscured phases maybe be inherently associated with distinctly slower, and possibly precessing, jets. [8].

Table 1: Kinematic Properties of the GRS 1915+105 Bipolar Jets

Parameter	Symbol / Units	Value (68% HDI)
Global Ejection & System Parameters		
Extrapolated Launch Time	T_{ej} (MJD)	60375.6 ± 75.5
Intrinsic Jet Speed	$\beta = v/c$	0.37 ± 0.06
Lorentz Factor	Γ	1.07 ± 0.03
Jet viewing angle	θ (°)	68.4 ± 4.0
Receding Lobe (NW) & Approaching Lobe (SE)		
Proper Motion Speed (NW)	μ_r (mas/day)	5.56 ± 0.89
Position Angle (NW)	PA$_n$ (°)	139.1 ± 2.4
Proper Motion Speed (SE)	μ_a (mas/day)	7.29 ± 1.17
Position Angle (SE)	PA$_s$ (°)	137.7 ± 2.5

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