The Acceleration and Collimation Zone of FSRQ 1928+738

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Abstract

Here, we present our observational results of the jet of flat spectrum radio quasar (FSRQ) 1928+738. We explored the structural evolution and the kinematics of the 1928+738 jet, using various archival and our own VLBI observations. The multi-frequency observations made it possible to analyze the jet across a wide distance range, from < 1 to ~ 40 mas (corresponding to ≈ 800 pc in de-projection). We find that the jet is being collimated and accelerated continuously out to an angular distance of ~ 5 mas. We note that 1928+738 is the first FSRQ and only the fourth radio-loud AGN for which the presence of a spatially extended "acceleration and collimation zone" (ACZ) is now confirmed.

Introduction

➢ The current paradigm of magnetohydrodynamic (MHD) jets suggests that the bulk jet acceleration is intimately associated with the jet collimation. The putative jet acceleration and collimation zones of AGN are believed to be located at distances $z \lesssim 10^{5-6}\ R_g$, where $R_g (= GM_\bullet/c^2)$ is gravitational radii.

➢ Recently, it has been successful to discover the coexistence of the acceleration and collimation (ACZ), but only in a limited number of radio-loud AGNs.

✓ 3 Radio Galaxies (M87, NGC315, Cygnus A)
✓ 1 Narrow-line Seyfert 1 galaxy (1H0323+342)
✓ 0 Flat Spectrum Radio Quasar yet …

→ ***Motivation !!***

Source Selection : FSRQ 1928+738

➢ *Why ACZ of FSRQ jets are not investigated ?*

✓ Luminous, but mostly ***distant*** → ***mostly not suitable***

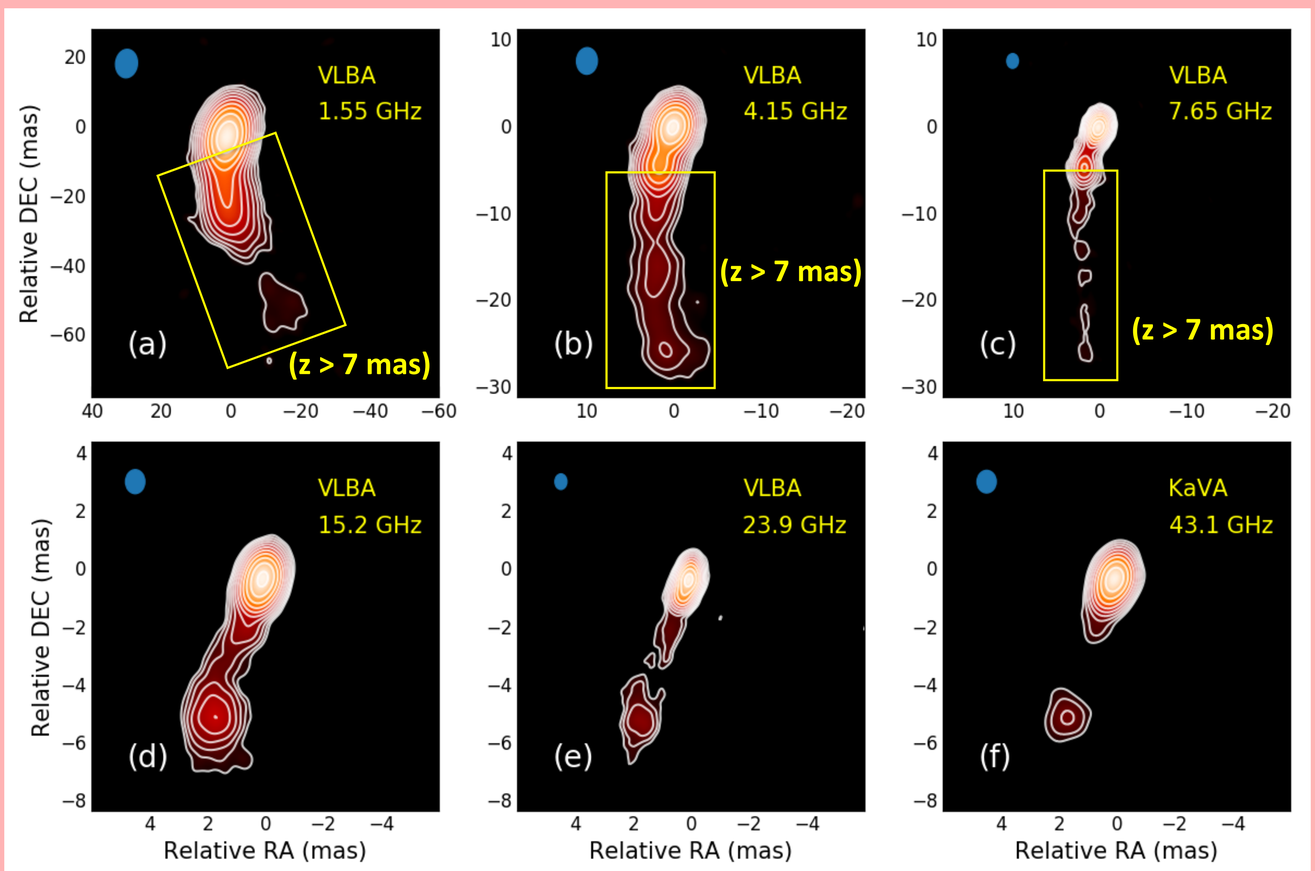
➢ *Why FSRQ 1928+738 (4C +73.18)?*

✓ Radio bright (e.g., ≳ Jy @ 43 GHz)
✓ (relatively-) nearby, z ~ 0.3 (Lawrence + 1986)
✓ Black hole mass $M_\bullet \sim 4 \times 10^8\ M_\odot$ (e.g., Park + 2017)
✓ Jet viewing angle $\theta \sim 13°$ (e.g. Hovatta + 2009)

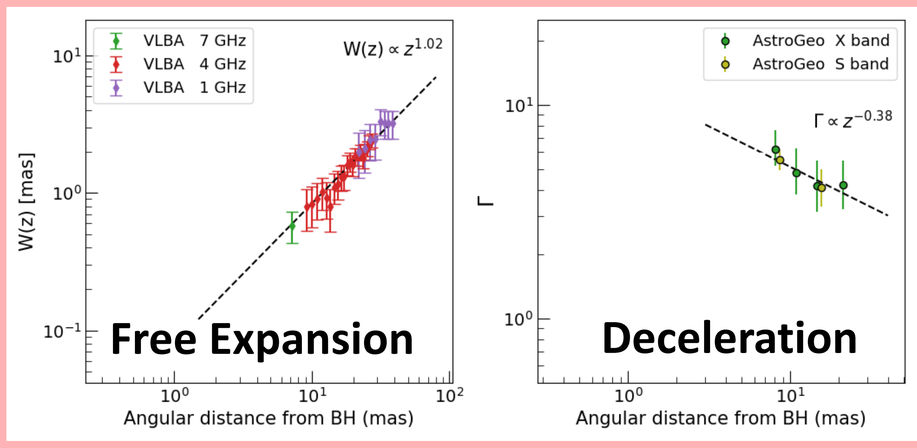
→ *1 mas* $\sim 1 \times 10^6\ R_g$ *(in de-projection)*

: Challenging Target !!

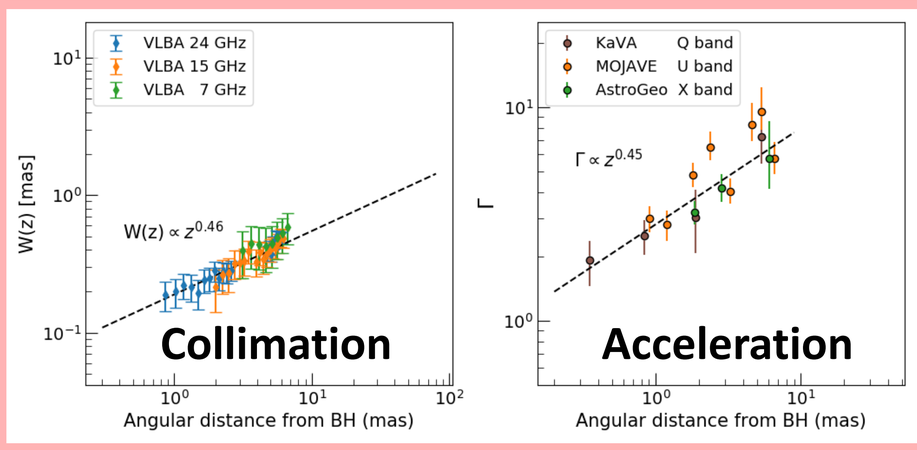
Observational Results



(z > 7 mas)



(z < 7 mas)



➢ High Sensitivity VLBA Images @ 1~24 GHz
✓ Jet width (W) measurements (FWHM)
✓ $W \propto z^a$, $a < 1$ (= collimation)
✓ or $a \sim 1$ (= Free expansion)

➢ Multi-Epoch Images @ Q ~ S band
✓ KaVA, MOJAVE, AstroGeo database
✓ Proper motion ($\mu \rightarrow \Gamma$) measurements
✓ Radial trend : increase or decrease

➢ ***Coexistence*** of the acceleration and collimation
✓ $W \propto z^{0.46}$: (nearly-) parabolic geometry
✓ $\Gamma \propto z^{0.45} \propto W$: Efficient acceleration
cf) $\Gamma \propto z^{0.30}$: NGC 315, $\Gamma \propto z^{0.17}$: M87

Co-spatial Transitions

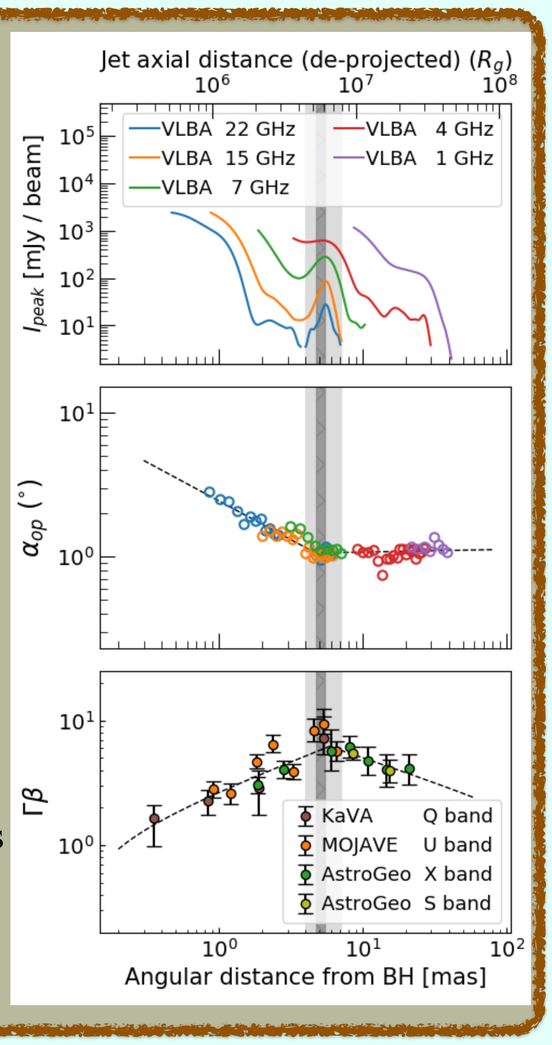
➢ Intensity profile (concentric peaks)
✓ *Systematic Decrease as a function of z*
✓ ***But local enhancement*** @ 6 mas
✓ ***Observable at all frequencies!!***
(except 1 GHz : limited resolution)

➢ Half opening angle $\alpha_{op} = \tan^{-1}(W/z)$
✓ α_{op} decreases (= ***collimation***)
✓ Collimation breaks when $\alpha_{op} \sim 1°$
✓ ***Jet Collimation Break*** @ 4.72 ± 0.72 mas

➢ Four-velocity $\Gamma\beta$ (deformation of Γ)
✓ Γ increase (= ***acceleration***)
✓ Acceleration breaks when $\Gamma \sim 10$
✓ ***Jet Acceleration Break*** @ 5.87 ± 1.15 mas

3 Transitions @ ≈ a few $10^6\ R_g$

Locational Coincidence ?



Discussion

➢ **SMBH's Sphere of Gravitational Influence (SGI)**
✓ Assumption : $\sigma_{[OIII]} \sim \sigma_v$
✓ $\sigma_{[OIII]} = 166$ km/s
✓ $R_{SOI} = GM_\bullet/\sigma_v^2 \approx 3 \times 10^6\ R_g$
✓ Inside R_{SOI} ⟷ outside R_{SOI} : *external gas captured by gravity*
: ***The jet is subjected to the confining medium***

Origin of transitions?

Standing Shock Scenario

➢ **Stationary shock @ The End of ACZ**
✓ Intensity enhanced, suggesting an "*energy supply*"
✓ Sudden mismatch in pressure can form ***a stationary shock***
✓ *Passage of superluminal knots through the shock → "flare"*
: similar to other blazar jet "cores" or HST-1 in M87 jet

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