Milliarcsecond Core Size Dependence of the Radio Variability of Blazars

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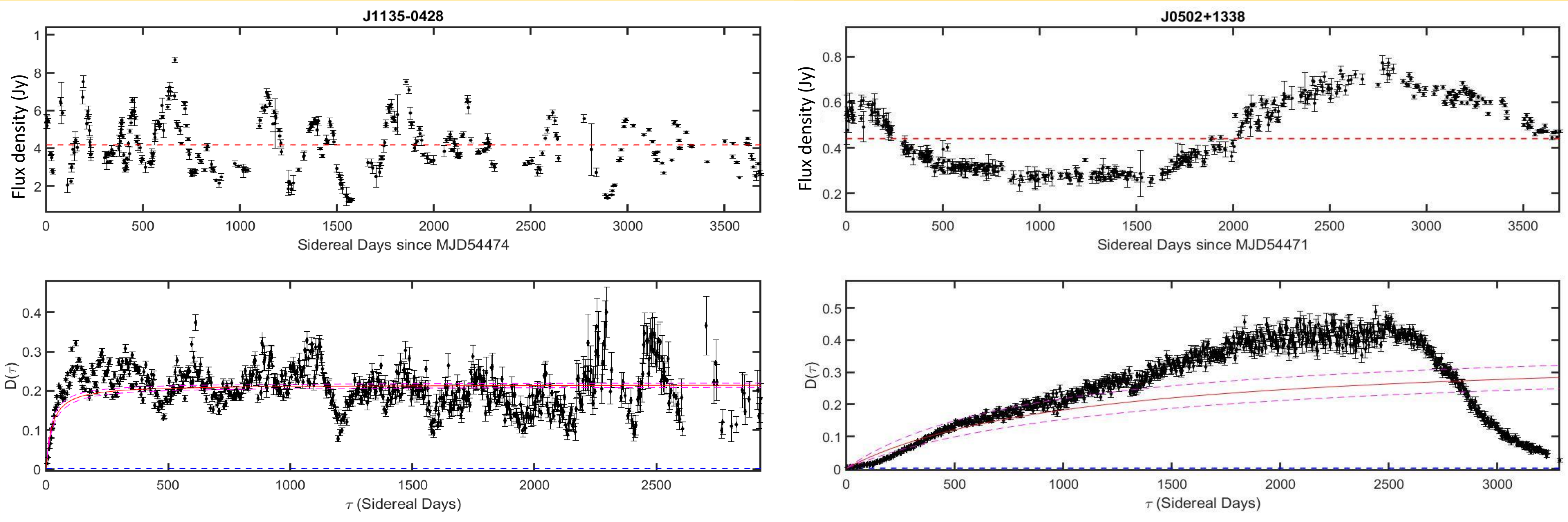
Introduction

Studying AGN variability on timescales of months to years enables us to better understand the physical structure of AGNs on sub-parsec scales, and the physics of supermassive black holes. In this study, we focus on the radio variability of 1158 blazars observed at 15 GHz through the Owens Valley Radio Observatory (OVRO) Blazar Monitoring Program (Richards et al., 2011), where these sources have been observed about twice a week over the past decade. We investigate why some blazar sources have relatively long variability timescales (~years), while others have shorter variability timescales (~months), by examining the dependence of the variability timescales on milliarcsecond source size measured using VLBI (Pushkarev & Kovalev, 2015).

Analysis

- Using structure function (SF) at 1000 day (such that it saturates for the majority of sources) to characterize variability amplitude.
- Using following model equation fit model of SF. $$D_{\mathrm{mod}}(\tau) = D(1000\mathrm{d})\,\frac{1+\tau_{\mathrm{char}}/1000}{1+\tau_{\mathrm{char}}/\tau} + D_{\mathrm{noise}}$$
- Using model fit of SF to derive characteristic timescale (τ_{char}), as SF amplitude reaches half of the value of saturation.
- We convert characteristic timescale to intrinsic timescale and apparent core size to linear core size by taking account of sources' redshift.



- Core size of all sources are obtained from VLBI derived by Pushkarev & Kovalev (2015) at 2, 5, 8, 15, 24, and 43 GHz.

Figure 1.
Light curve (top) and SF (bottom) of blazar source J1135-0428 (fast variable) and J0520+1338 (slow variable). Red dashed line shows the mean flux density. Solid line shows the model fit of SF, pink dashed line shows 95% confident bounds for the fit, and blue dashed line shows the variability amplitude of systematic and instrumental errors (D_{noise}).

Result

We separate sources into strong and weak variables by the median of SF amplitude (D(1000d)) .

- We compare the distribution of the linear VLBI core size (fig. 2) measured at 2, 5, 8, 15, 24, and 43 GHz, for strong and weak variable.
- Two sample K-S test result shows that strong variables has significantly smaller core size at 8 and 15 GHz (table 1 left panel).

We separate sources into fast and slow variables by the median of intrinsic timescale (τ_{src}).

- We compare the distribution of the linear VLBI core size (fig. 3) measured at 2, 5, 8, 15, 24, and 43 GHz, for fast and slow variable.
- Two sample K-S test result indicates that fast variables has significantly smaller core size from 2 to 24 GHz (table 1 right panel).

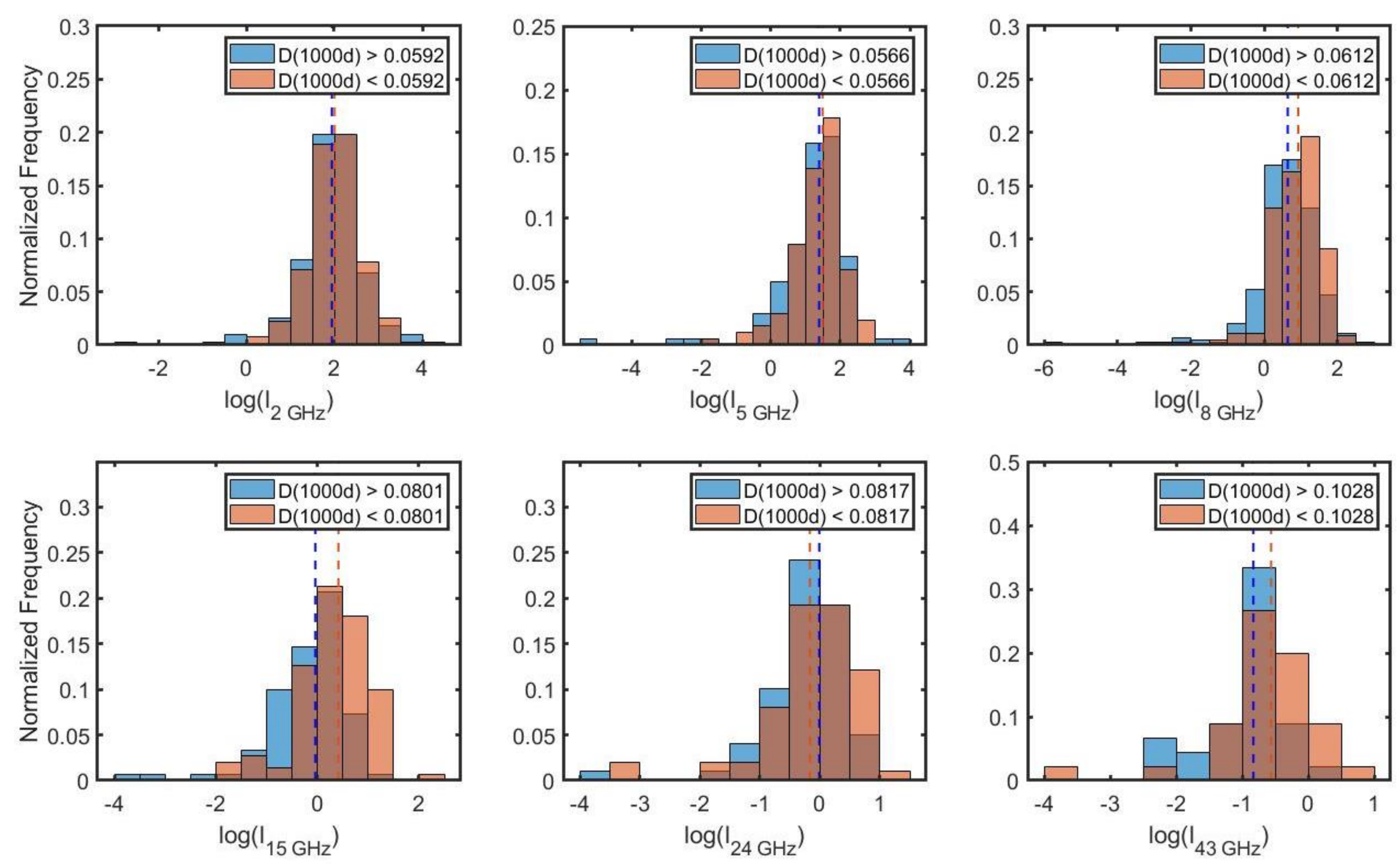


Figure 2.
Distribution of linear VLBI core size (l), in the unit of parsec, measured at various frequencies, separated by strong (blue) and weak (orange) variables.

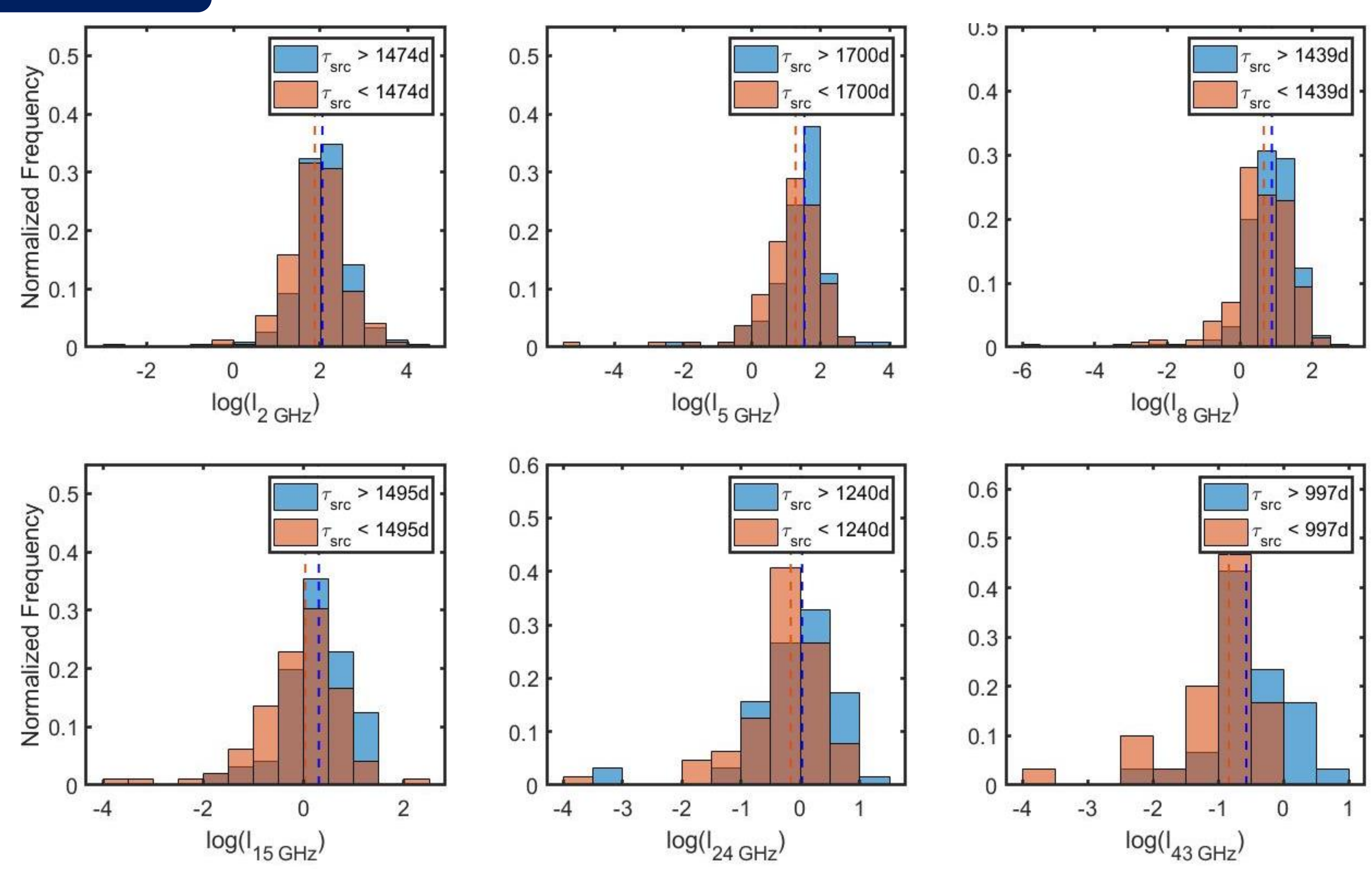


Figure 3. Distribution of linear VLBI core size (l) , in the unit of parsec, measured at various frequencies, separated by fast (orange) and slow (blue) variables.

Table 1. Result of two sample K-S test, where we compare the distribution of core sizes of strong vs weak variables (separated by the median of SF amplitude *D*(1000d)) and the core size of fast vs slow variables (separated based on the median of intrinsic timescale (τ_{src})).

Freq.	Median D(1000d)	Sample number	P value	Median τ_{src}	Sample number	P value
2 GHz	0.0592	482	1.01×10^{-1}	1747.17	482	5.36×10^{-4}
5 GHz	0.0566	223	8.72×10^{-1}	1700.43	223	9.20×10^{-3}
8 GHz	0.0612	551	6.12×10^{-6}	1439.50	551	2.66×10^{-4}
15 GHz	0.0801	192	1.91×10^{-6}	1495.50	192	4.01×10^{-2}
24 GHz	0.0817	129	2.21×10^{-1}	1240.70	129	1.75×10^{-2}
43 GHz	0.1028	61	3.69×10^{-2}	997.02	61	5.50×10^{-2}

Conclusion

Our result shows that the most compact sources have larger variability amplitude and shorter variability timescales. The finite travel time across the sources places a lower limit on its variability timescale, and can smooth out the observed variation.

Reference

- Richards J. L., et al., Blazars in the Fermi Era: The OVRO 40 m Telescope Monitoring Program, 2011, ApJS, 194, 29
- Pushkarev A. B., Kovalev Y. Y., Milky Way scattering properties and intrinsic sizes of active galactic nuclei cores probed by very long baseline interferometry surveys of compact extragalactic radio sources, 2015, MNRAS, 452, 4274

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