The Structure of Micro-Variability in the WEBT BL Lacertae Observation

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INTRODUCTION

1. The author present the results of an in-depth analysis of the **Whole Earth Blazar Telescope (WEBT)** micro-variability observations made during a campaign done in 2020 on the blazar BL Lacertae.

2. They then **fit each individual micro-variability curve** with model pulses from turbulent cells using the turbulent jet model. Each micro variability light curve is a realization of the underlying turbulent plasma jet.

Obesrvation

The WEBT collaboration observed BL Lacertae over a period of 231 nights during the 2020 campaign. During that period, WEBT telescopes around the world collaborated to make a nearly continuous light curve.

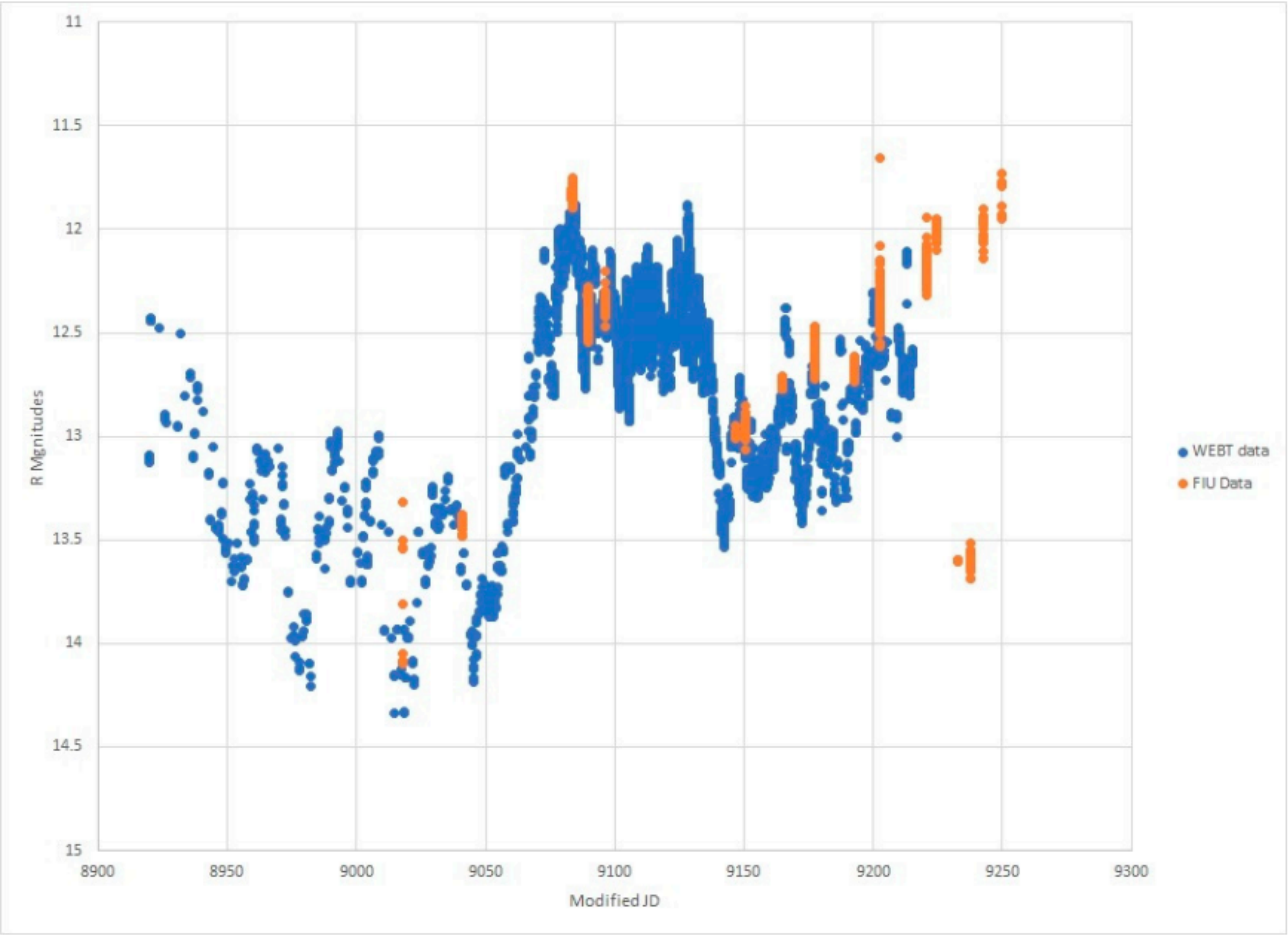


Figure 1. WEBT light curve of BL Lac with FIU data superimposed.

Theory of Shock Waves Encountering Turbulent Cells

1. They applied the model: **micro-variations are modeled as a convolution of pulses of synchrotron radiation emitted as a shock propagating down the relativistic jet.**
2. The model predicts that a shock wave encountering a cylindrical density enhancement in the plasma accelerates the electrons, which then cool by emitting synchrotron radiation.
3. Individual turbulent cells being energized by a plane shock propagating down the jet as computed following **Kirk et al. (1998) (hereafter KRM)** became the basis of our model.
4. The burst profiles described by the KRM model **matched the micro-variability pulse profiles** seen in the actual blazar light curves.

Theory of Shock Waves Encountering Turbulent Cells

The profile for a single KRM pulse is shown in Figure 2.

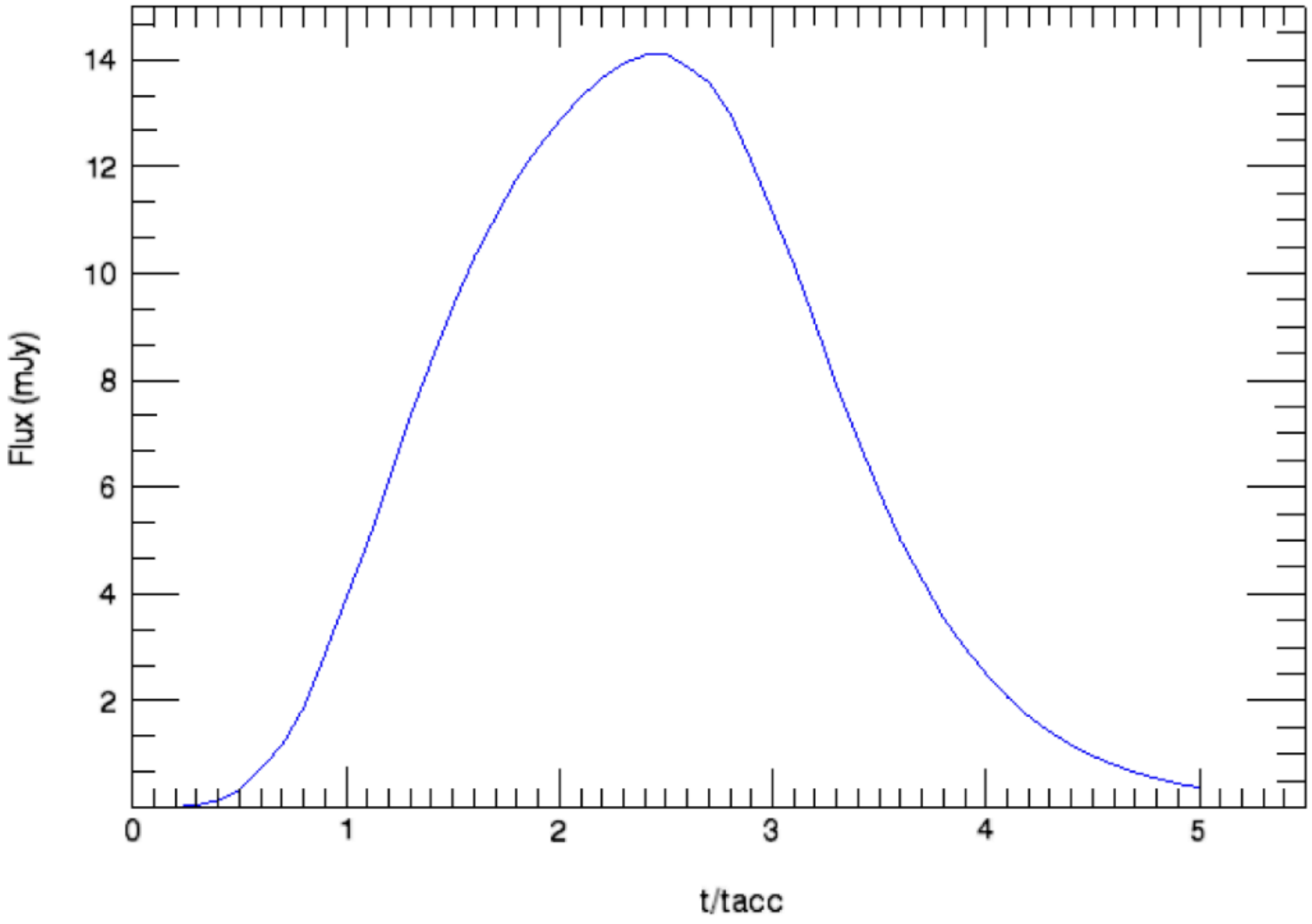


Figure 2. A typical pulse profile for shock encountering a density enhancement.

Theory of Shock Waves Encountering Turbulent Cells

The KRM solutions constrain the shape of the pulse and give the amplitude of an individual pulse, representing the emission from a single turbulent cell.

$$I(\nu,t) = I_{laminar} + \sum I_{cell(\nu,t)}$$

$$S_{cell} = \frac{\tau_{flare}^{obs}\beta_s c}{\Gamma(1-\beta\cos\theta)(1+z)}$$

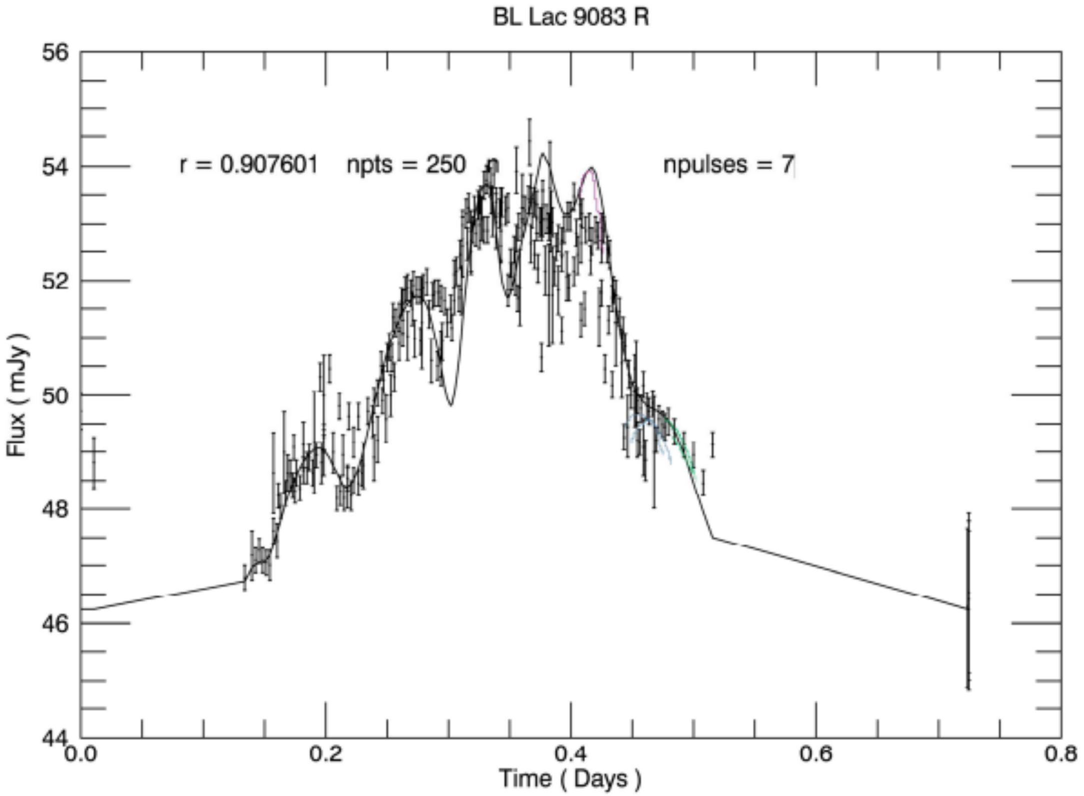
Fitting the Individual Light Curves

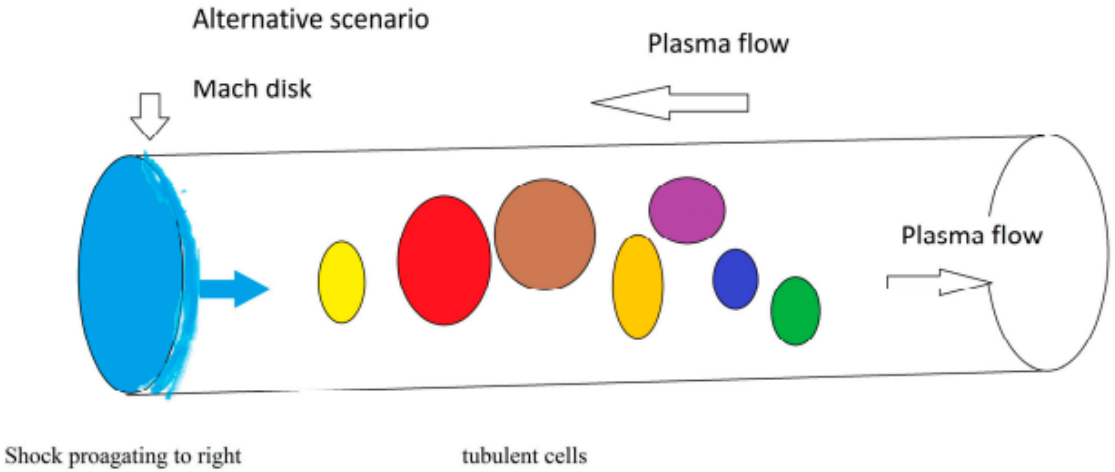
Parameter	Symbol	Value
Redshift	z	0.069[a]
Minimum electron energy	γ_0	2×10^3
Maximum electron energy	γ_{max}	1×10^4
Magnetic field intensity	B	0.4 Gauss[b]
viewing angle	θ	3.3°[c]
Shock speed	β_s	$0.1c$
Bulk Lorentz Factor of the jet	Γ	14[c]

Theory of Shock Waves Encountering Turbulent

They re-calculated the pulse shape using the expected pulse profile for our frequency band and then compared these profiles to our micro-variability curves.

The average correlation coefficient of the fits was 0.948, while the best fit yielded a correlation coefficient of r = 0.995.





Fitting the Individual Light Curves

Table 1. Fit result.

Mod JD	Npts	r	# Pulses	F-Test
9081	141	0.949	5	<0.0001
9082	209	0.9623	5	<0.0001
9083	250	0.9076	7	<0.0001
9084	161	0.941915	7	<0.0001
9086	299	0.95053	8	<0.0001

The results of the model fitting of the 41 individual light curves (here lists five sample).

Fitting the Individual Light Curves

Table 2. Pulse FWHM results.

	amp	**Width AU (v_{rel} = 0.3 c)**	**Width AU (v_{rel} = 0.9 c)**
average	37.22	1.24	3.732
min	0.016	0.150618	0.451
max	19.27	4.01647	12.049
st.dev	3.377	0.77	2.31

Discussion and Conclusion

Given the plasma flow speed relative to the shock, they estimated the turbulent cell size.

1. The extreme apparently random shifts in optical polarization angle and intensity seen in blazar observations are consistent with this interpretation: **the amplitude of the pulse is related to both the particle density in that cell and the angle of the magnetic field relative to the observer.**

2. The polarization behavior seen suggests: **the observed "micro-variability originated in a small and local region of the jet".**

3. The general polarimetric behavior of blazars as seen by the WEBT observers led them to conclude: **the magnetic field must have a turbulent component**.

Thanks!