Constraining the limiting brightness temperature and Doppler factors for the largest sample of radio bright blazars

I. Liodakis

Collaborators: T. Hovatta, D. Huppenkothen, S. Kiehlmann, W. Max-Moerbeck, A. Readhead

Monitoring of the non-thermal Universe v2.0
September 2018

Stanford University

Introduction: Maximum intrinsic brightness temperature.

THE ASTROPHYSICAL JOURNAL, Vol. 155, February 1969

THE SPECTRA OF OPAQUE RADIO SOURCES

K. I. KELLERMANN AND I. I. K. PAULINY-TOTH
National Radio Astronomy Observatory*

Received December 16, 1968

ABSTRACT

Radio spectra are shown for thirty radio sources that show evidence of synchrotron self-absorption. As a result of inverse Compton cooling and adiabatic expansion, all opaque components have a maximum brightness temperature in the range 10^{11}–10^{12} ° K. The magnetic field deduced from the surface brightness and cutoff frequency in these sources is generally about $10^{-4\pm1}$ gauss. The variable components appear to have somewhat stronger magnetic fields.

$$T_{intr} \sim 10^{12}\,K$$

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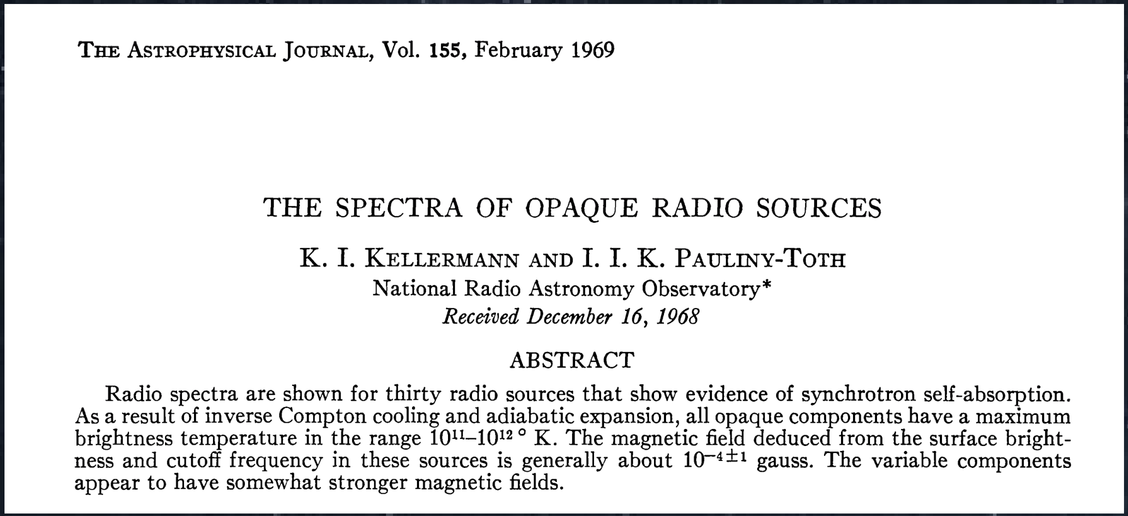
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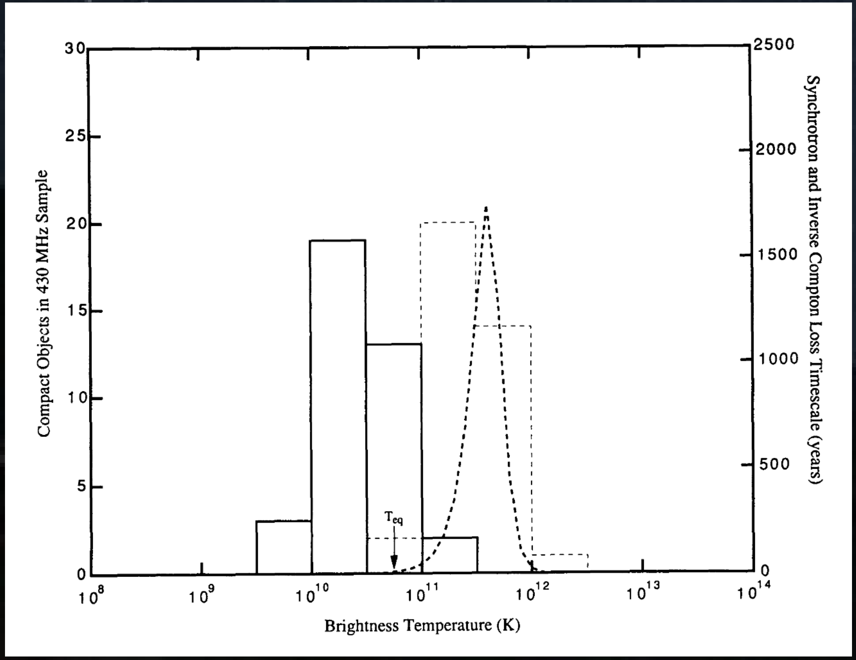
Readhead (1994)



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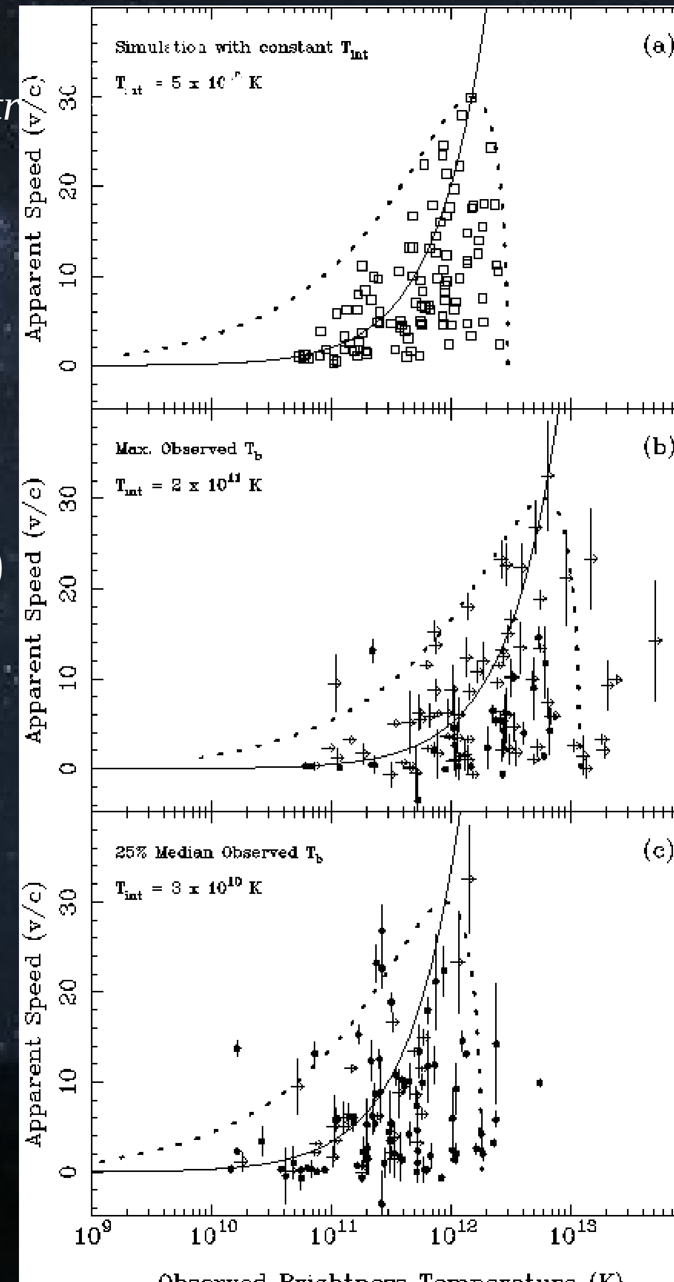
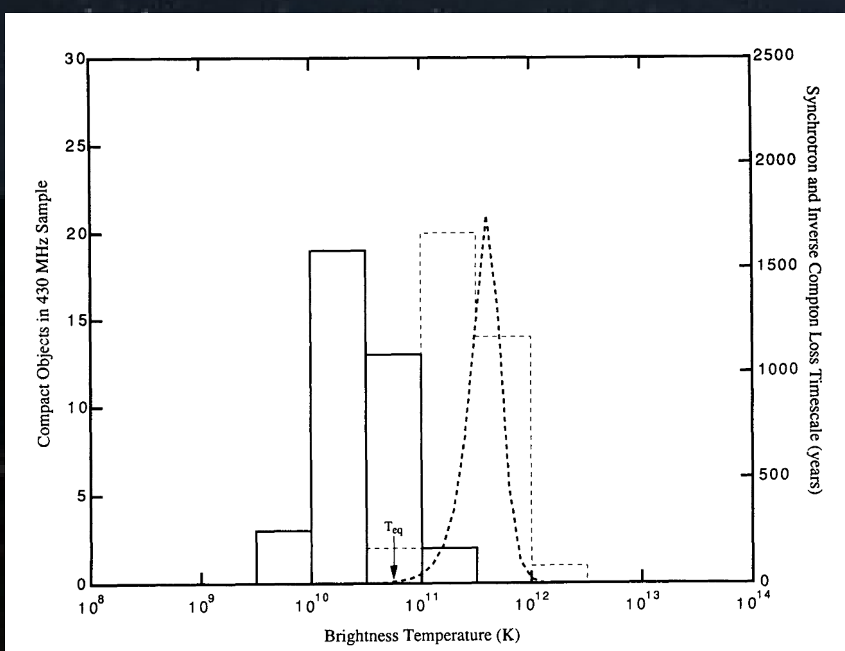
T_{intr}

Homan et al (2006)



Readhead (1994)



Introduction II: Equipartition Doppler factors.

Readhead (1994)

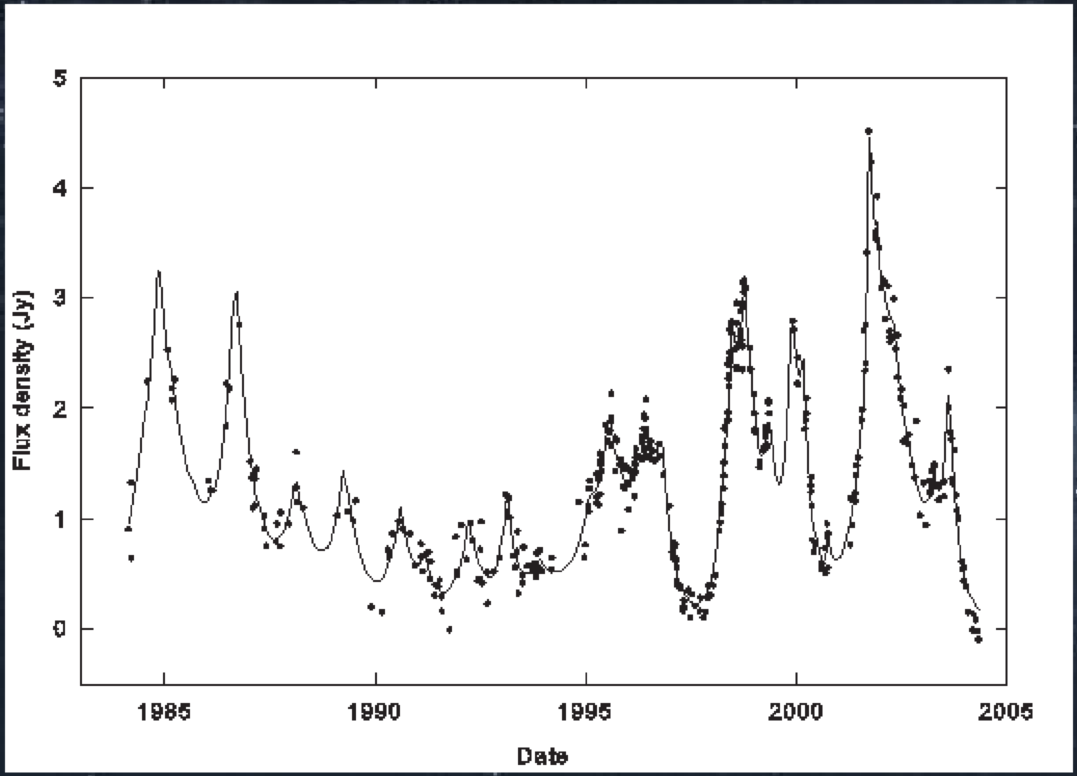
-VLBI equipartition

$$\delta_{eq} \propto \frac{T_{VLBI}}{T_{eq}}$$

-Flux density variation

$$\delta_{var} \propto \sqrt[3]{\frac{T_{var}}{T_{eq}}}$$

Valtaoja et al (1999)



Hovatta et al (2009)

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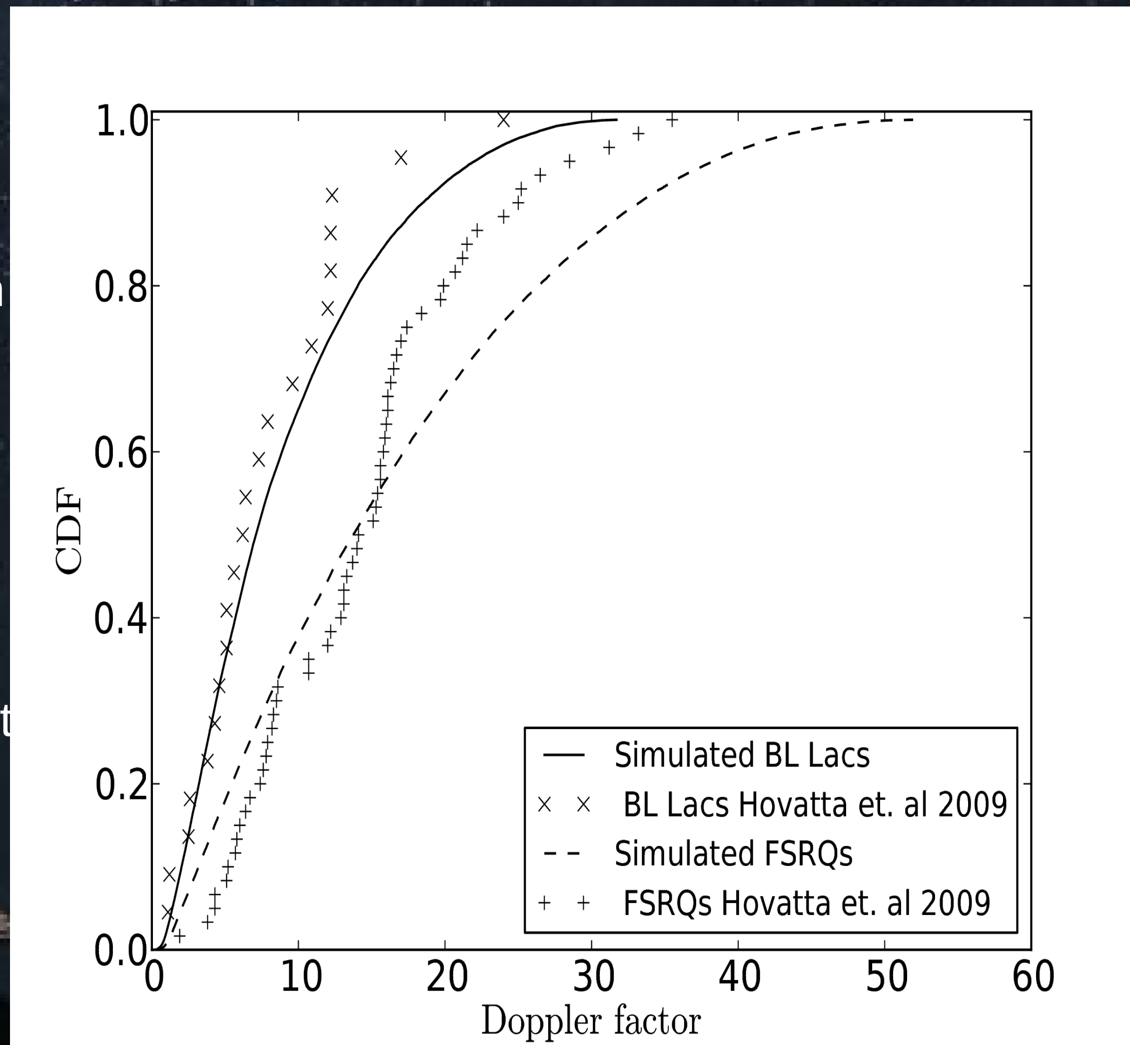
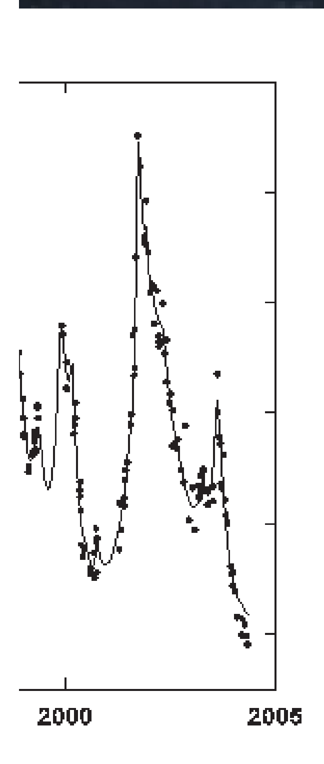


Liodakis & Pavlidou (2015b)



ta et al (2009)

The OVRO-40m monitoring program.

– Monitoring blazars **since 2008** in support of Fermi gamma-ray space telescope:

– At **15 GHz**

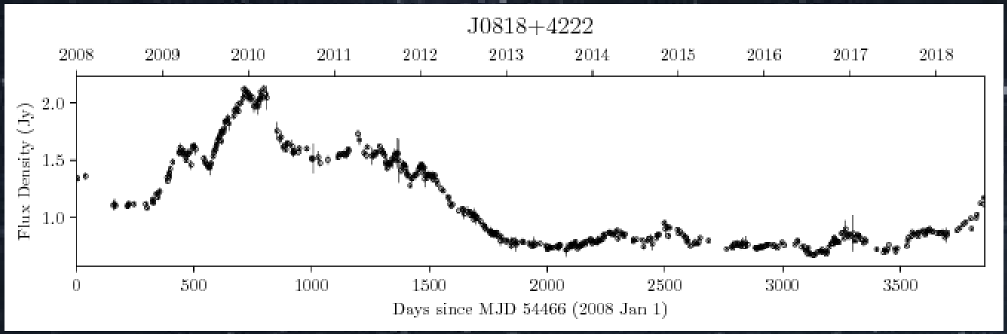
– 1158 sources from the Candidate Gamma-Ray Blazar Survey (CGRaBS, a complete sample)

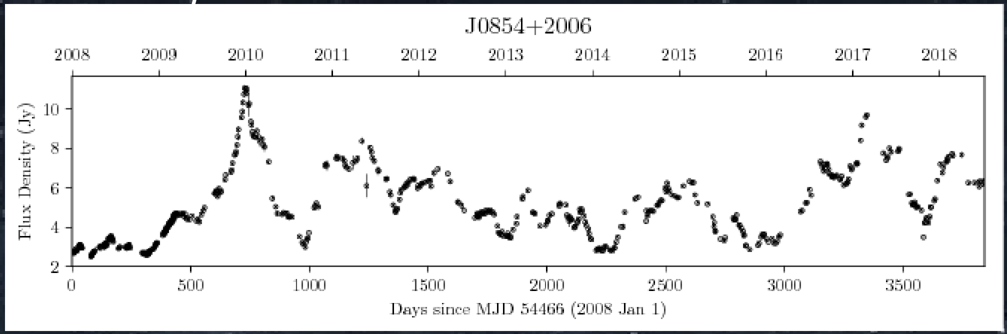
– additional gamma-ray loud sources resulting in sample of **>1800** sources

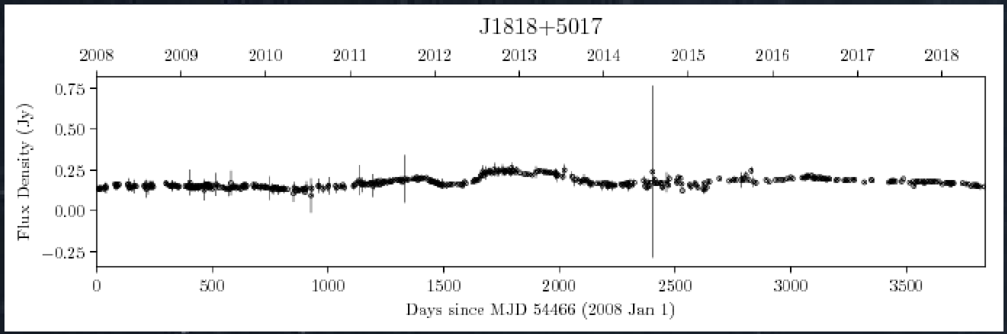
– cadence of **twice per week**

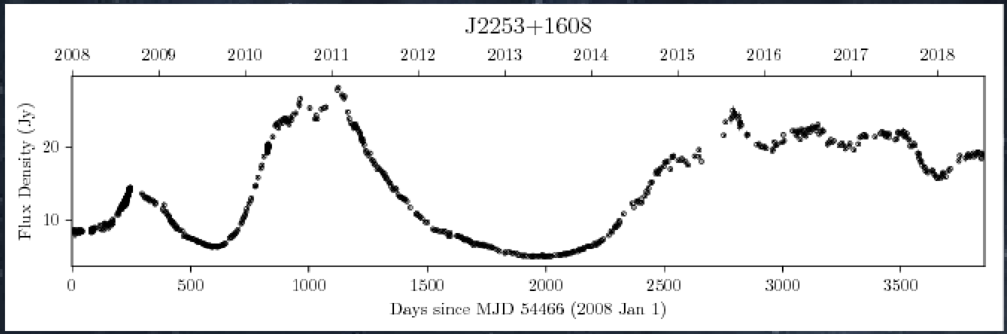
Sample

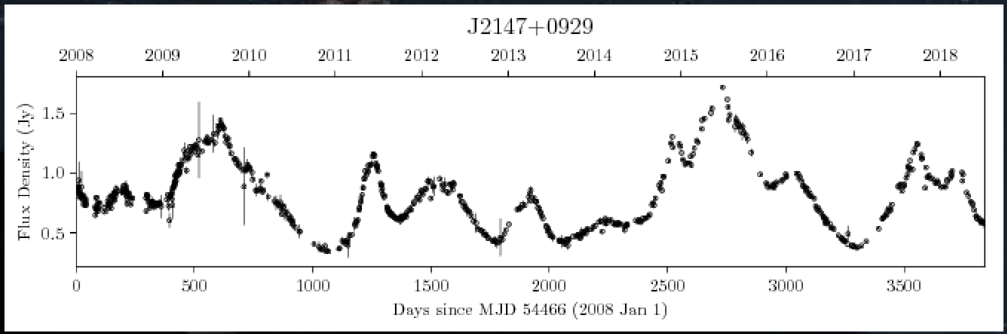
http://www.astro.caltech.edu/ovroblazar
/

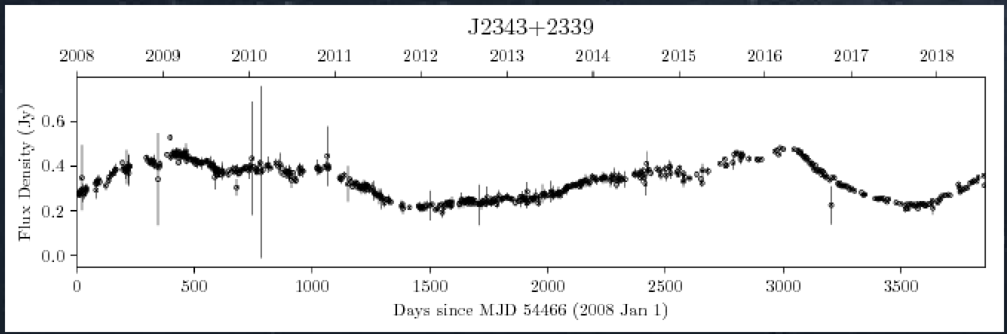










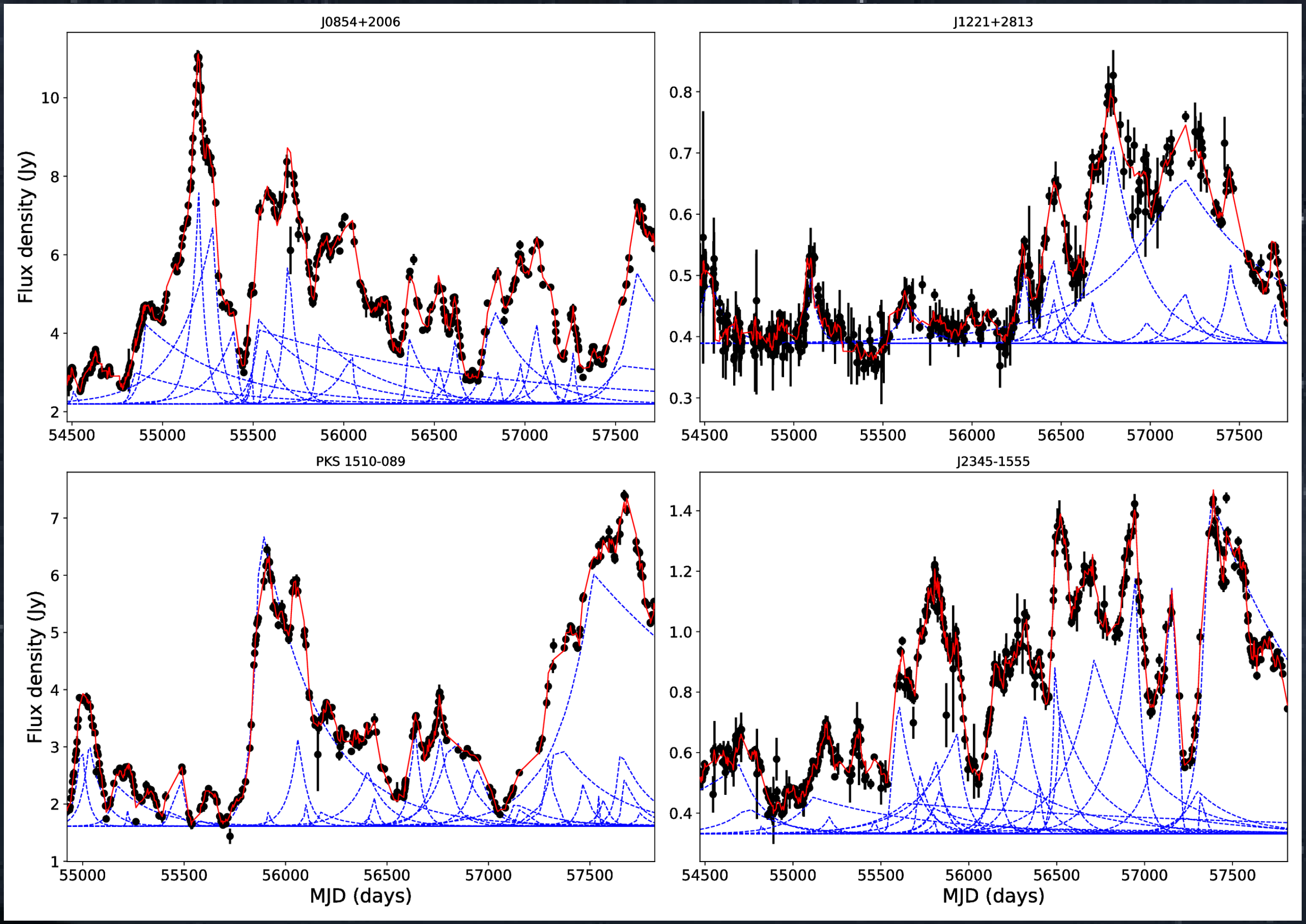


1029 sources, 837 blazars (670 FSRQs, 167 BL Lacs), 58 radio galaxies, 134 unclassified sources

Magnetron.

Magnetron: Bayesian hierarchical model implemented in python.

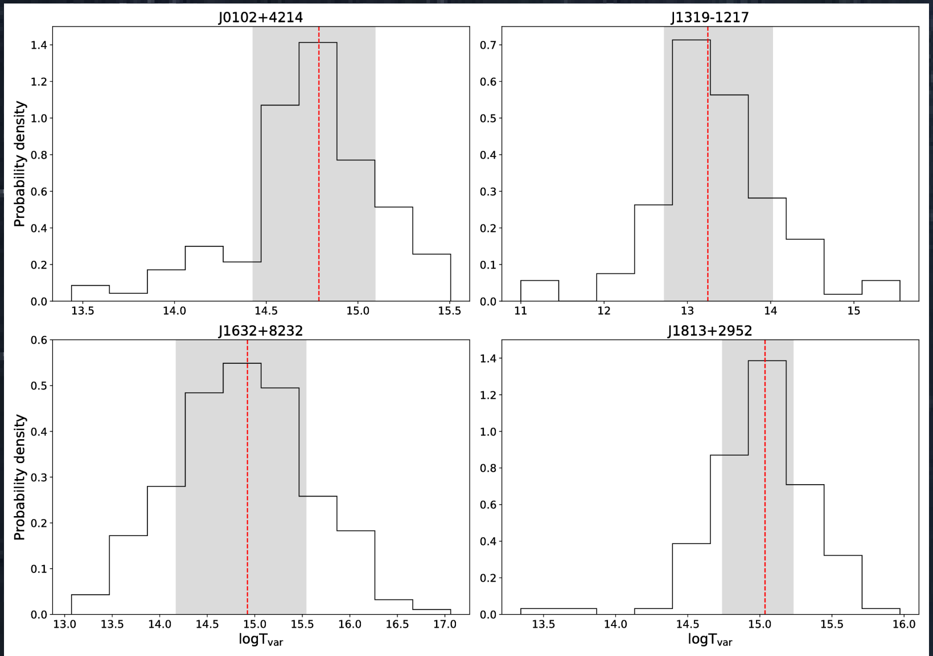
~10^2 models per source

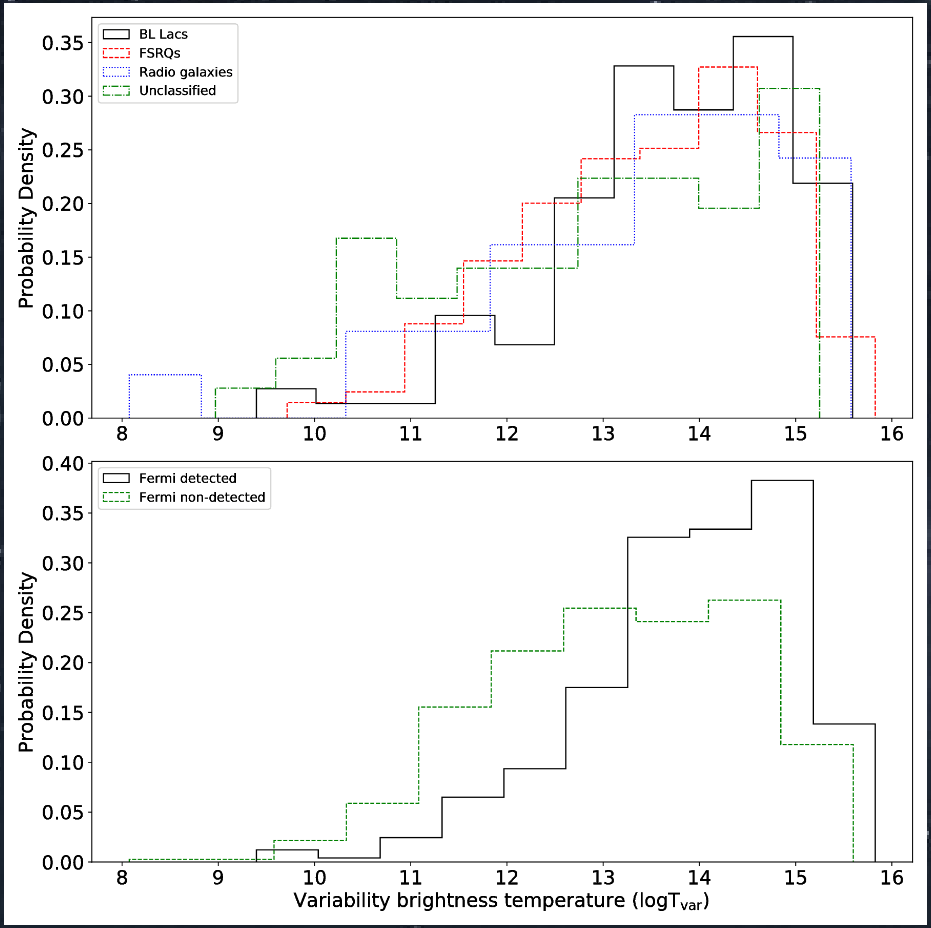


https://github.com/dhuppenkothen/magnetron2/tree/blazars

Maximum brightness temperature.

Distribution of the maximum brightness temperature for each source.

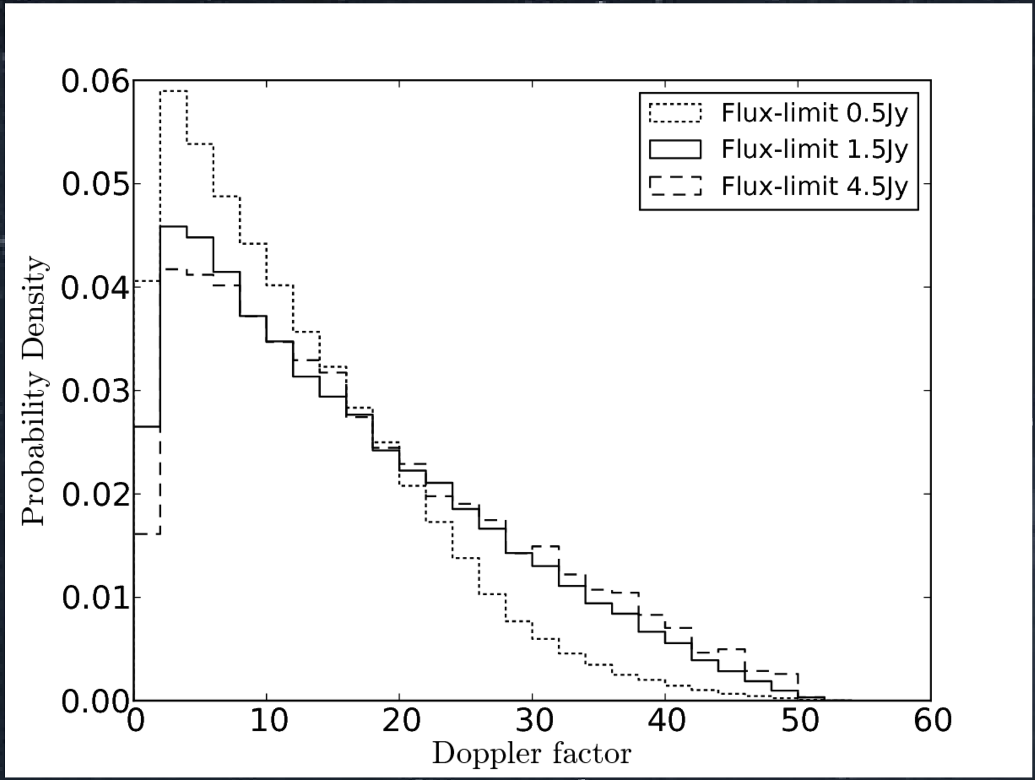




γ-ray loud sources have faster and brighter flares than γ-ray quiet sources!

Equipartition brightness temperature.

Liodakis & Pavlidou (2015a)



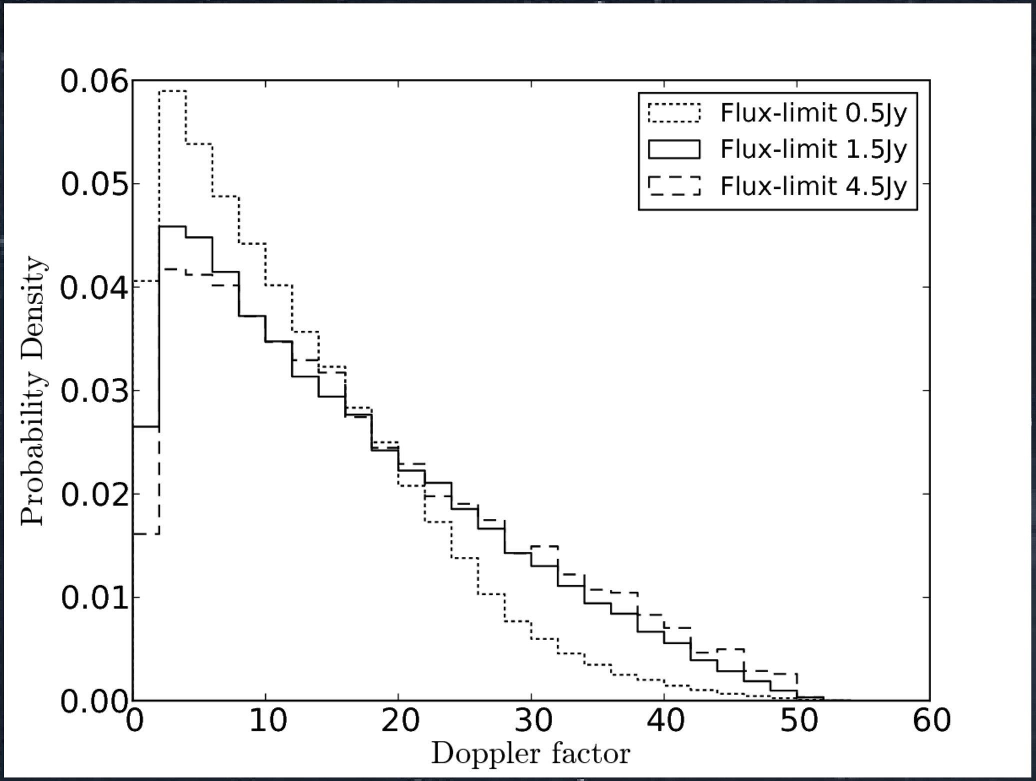
Use population models to constrain the intrinsic maximum brightness temperature.

Best model for the equipartition brightness temperature is Gaussian!

$$T_{eq} = 2.78 \times 10^{11} K \pm 26\,\%$$

Equipartition brightness temperature.

Liodakis & Pavlidou (2015a)



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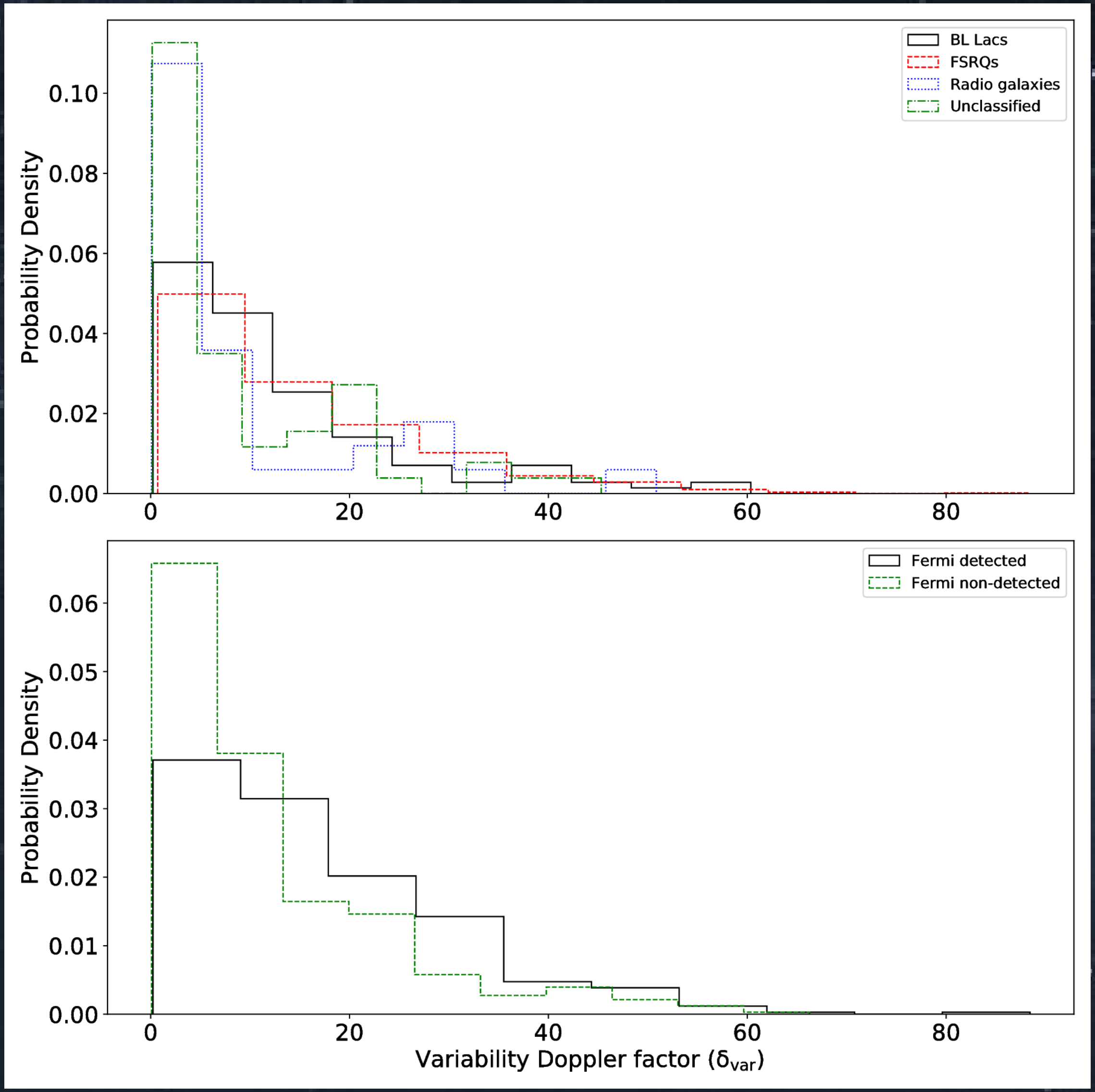
Homan et al (2006) $2\times10^{11}\,K < T_{eq} = 2.78\times10^{11}\,K \pm 26\,\% < 3\times10^{11}\,K$ Singal et al (1986)

Doppler factors.

Estimate the Doppler factor for each source by marginalizing over the maximum observed and equipartition brightness temperature distributions.



There is no difference between the Doppler factors of BL Lacs and FSRQs!

γ-ray loud sources are more beamed than γ-quiet sources!

Doppler factors.

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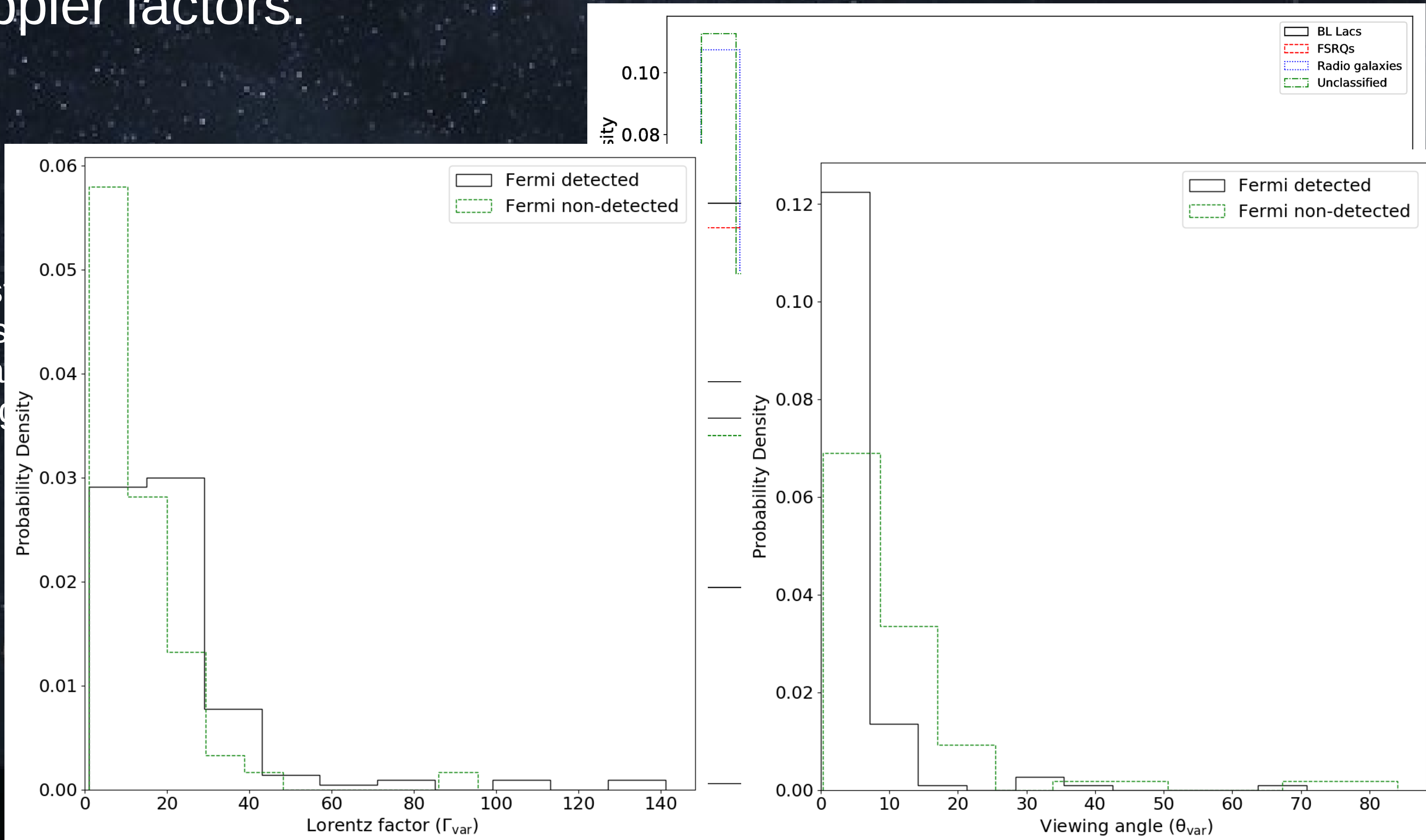

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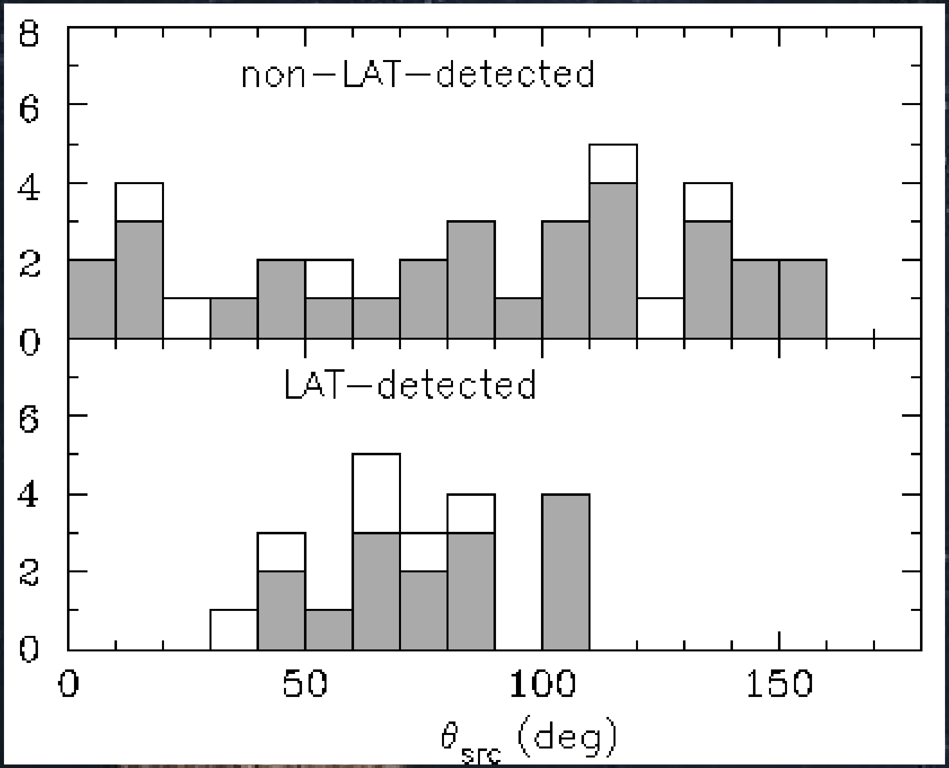
Comoving frame viewing angle.



Savolainen et al. (2010)

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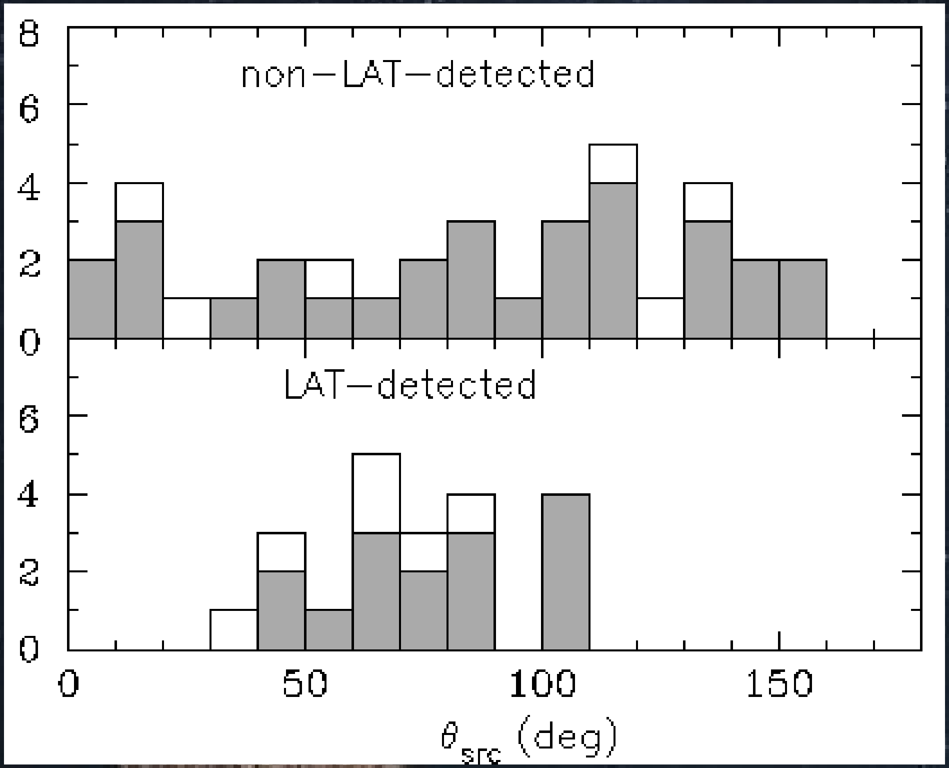

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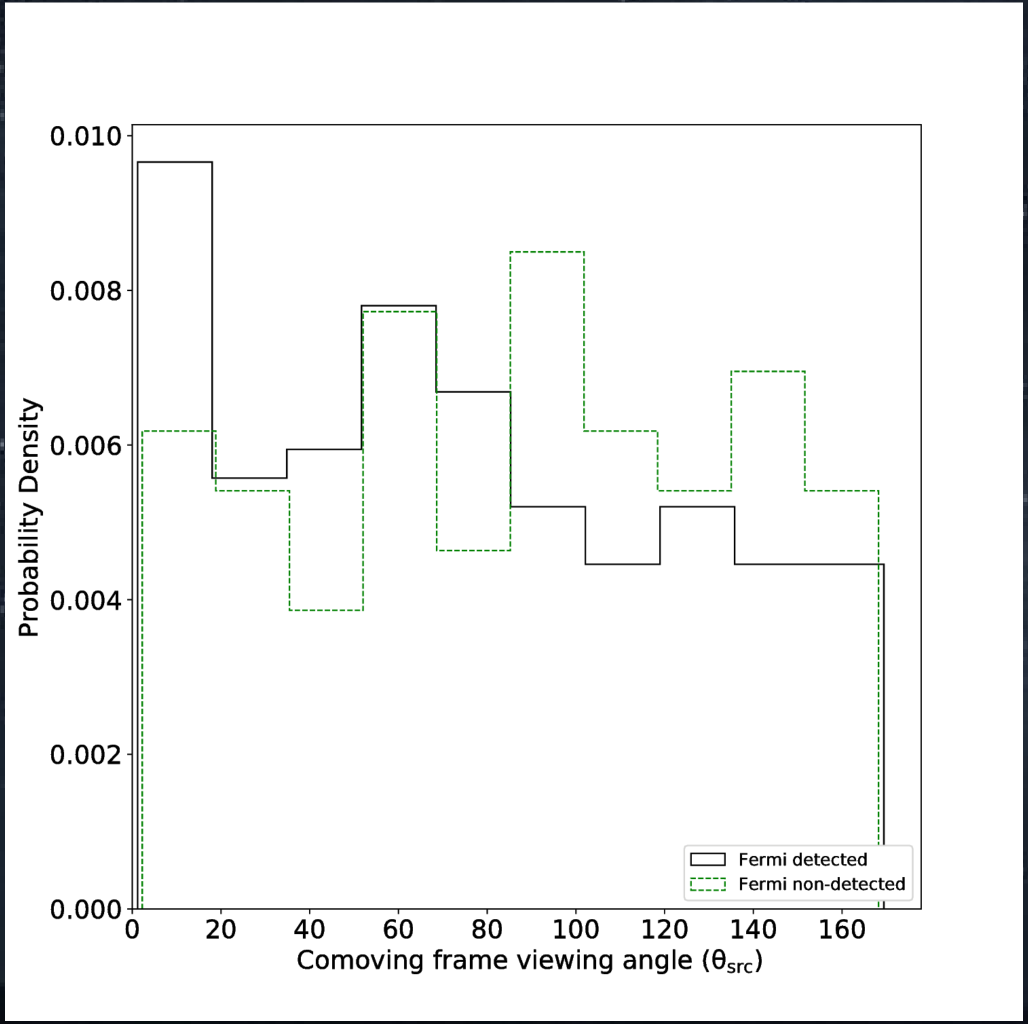

Summary

Analyzed the radio light curves of **1029 sources** observe by OVRO

Constraint the equipartition brightness temperature:

$$T_{eq} = 2.78 \times 10^{11} K \pm 26\,\%$$

Increased the number of Doppler factor estimates by **an order of magnitude!**

γ-ray loud sources have **higher brightness temperatures** than γ-ray quiet sources!

γ-ray loud sources are **more beamed** than γ-ray quiet sources!

There is **no evidence for anisotropy** in the rest-frame γ-ray emission.