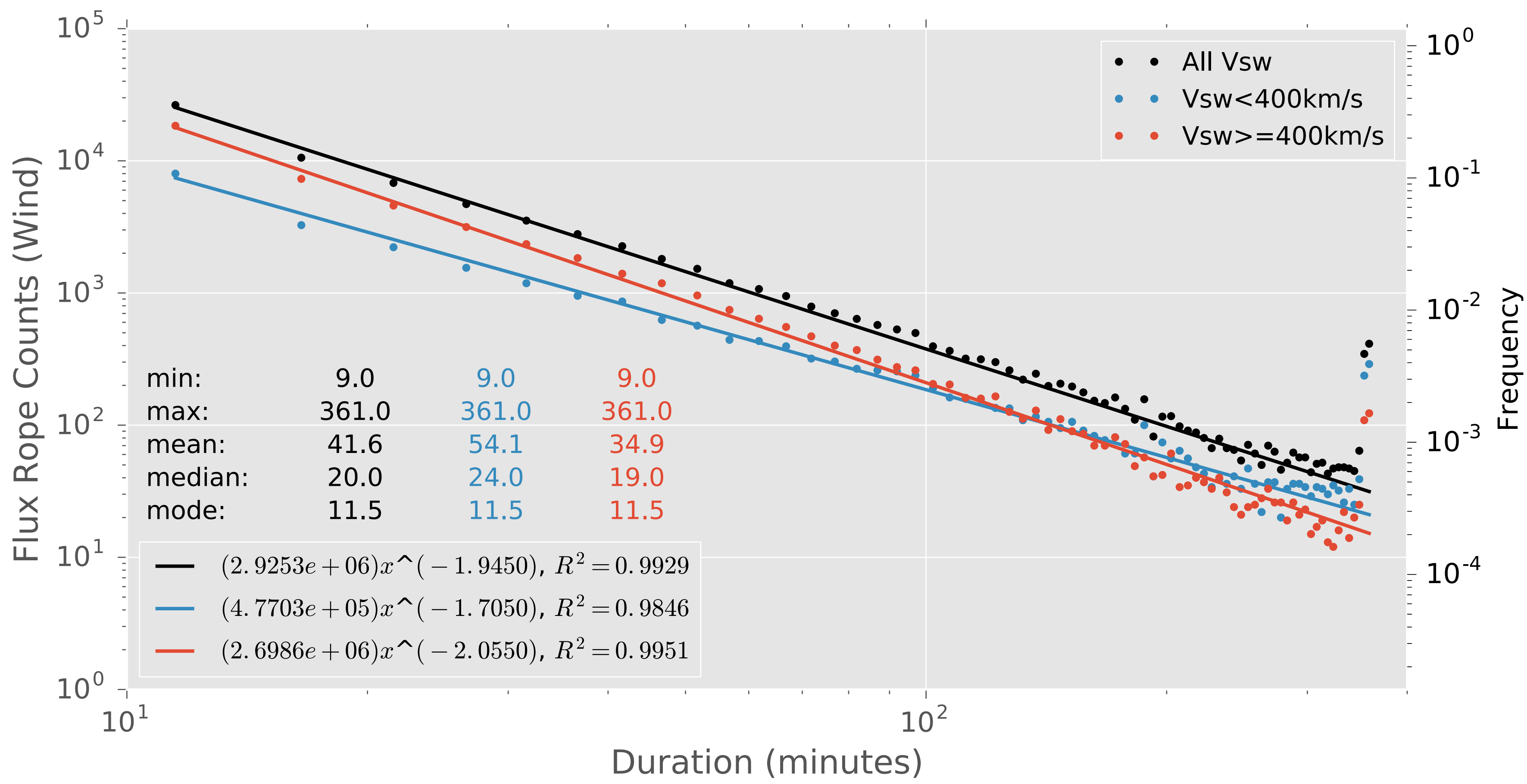
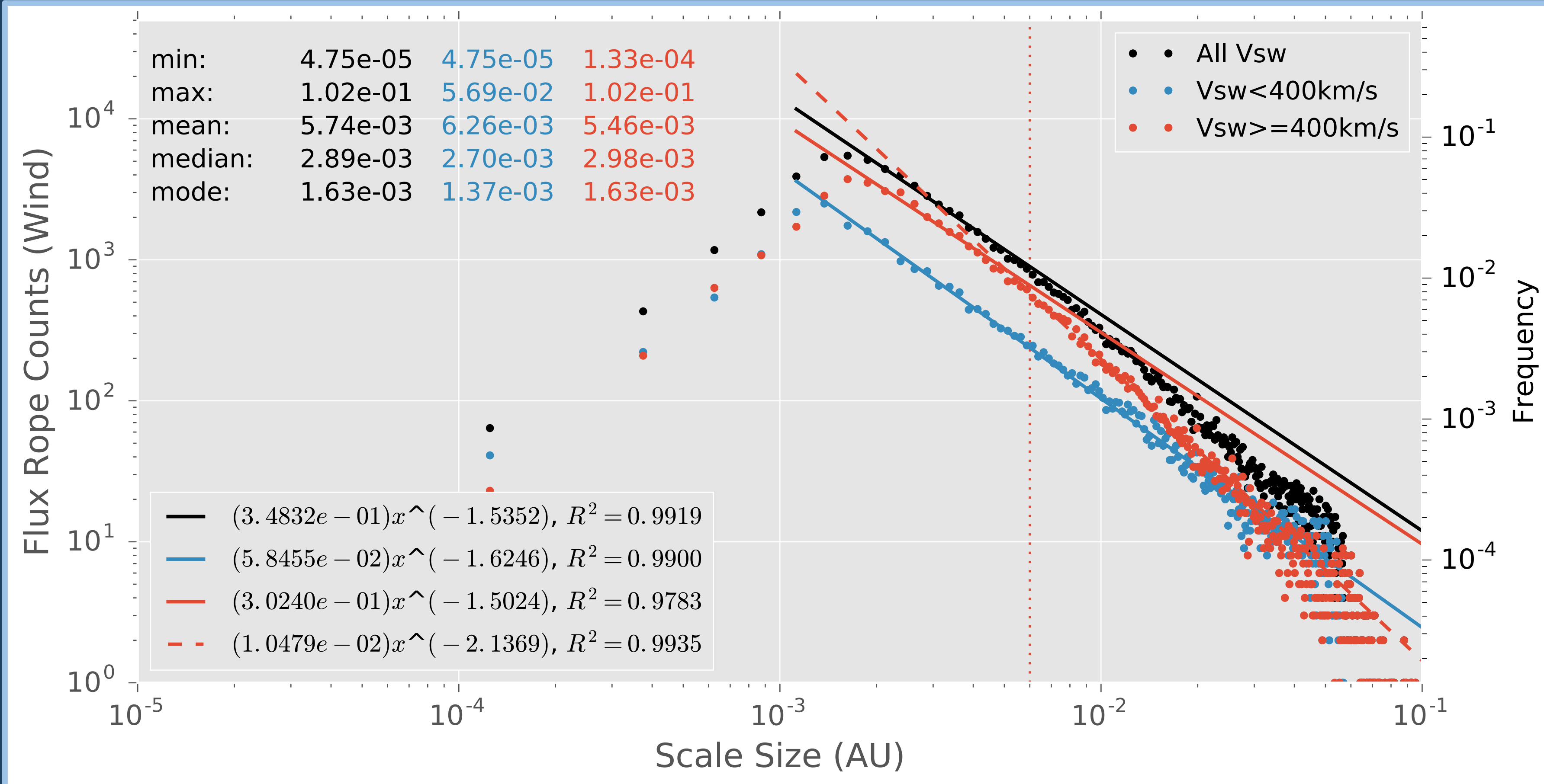
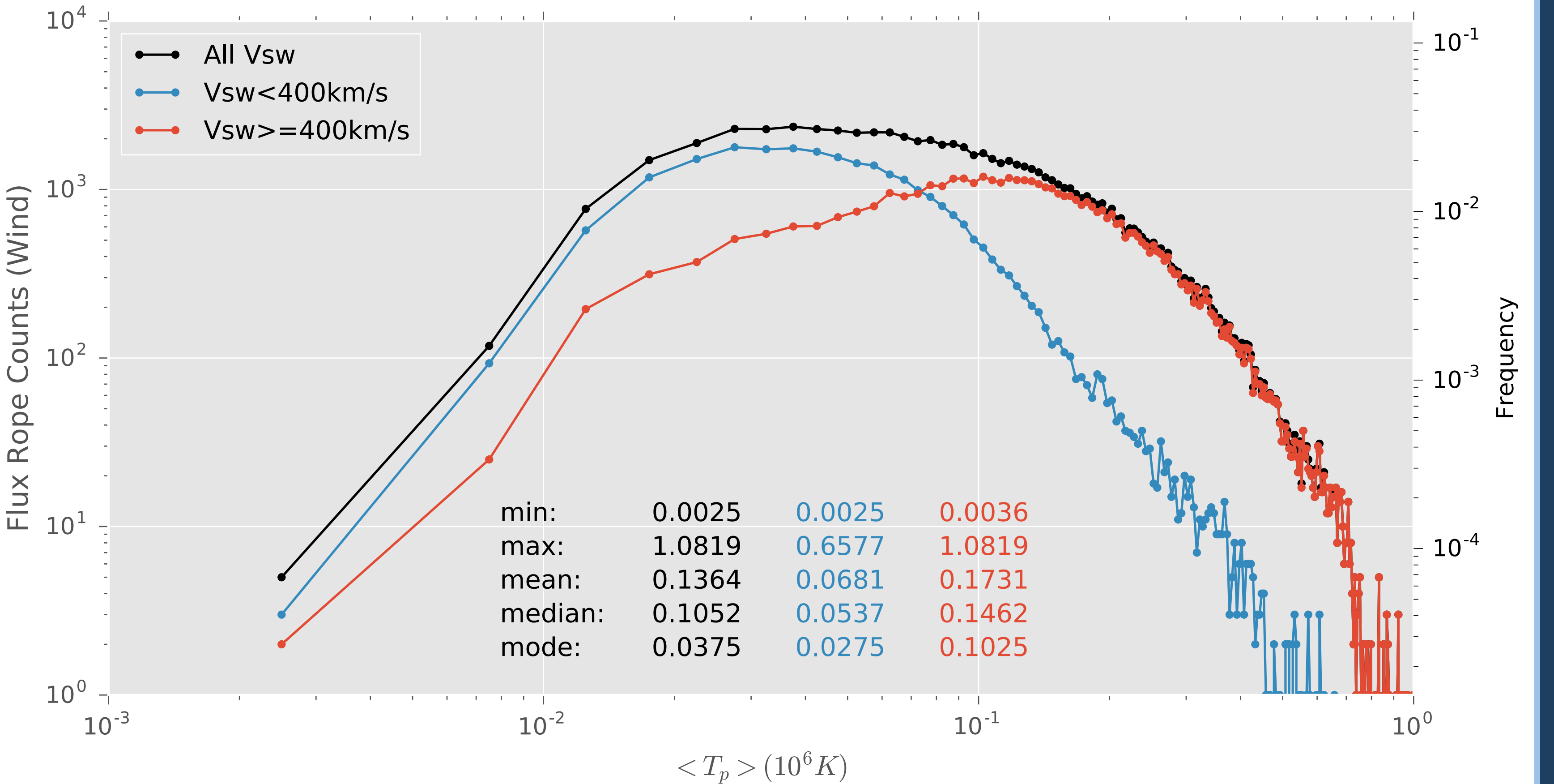
STATISTICAL ANALYSIS



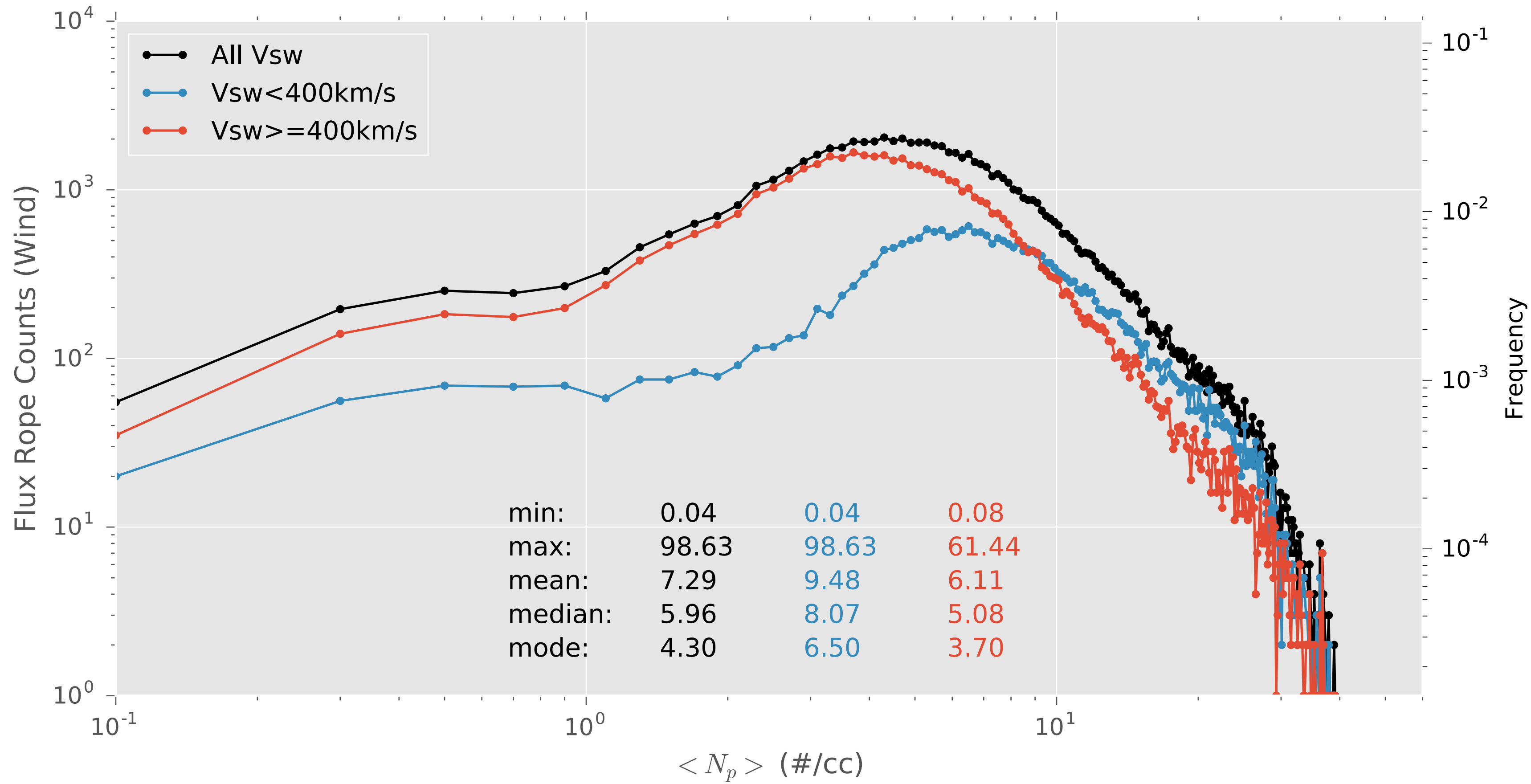
STATISTICAL ANALYSIS



STATISTICAL ANALYSIS



STATISTICAL ANALYSIS



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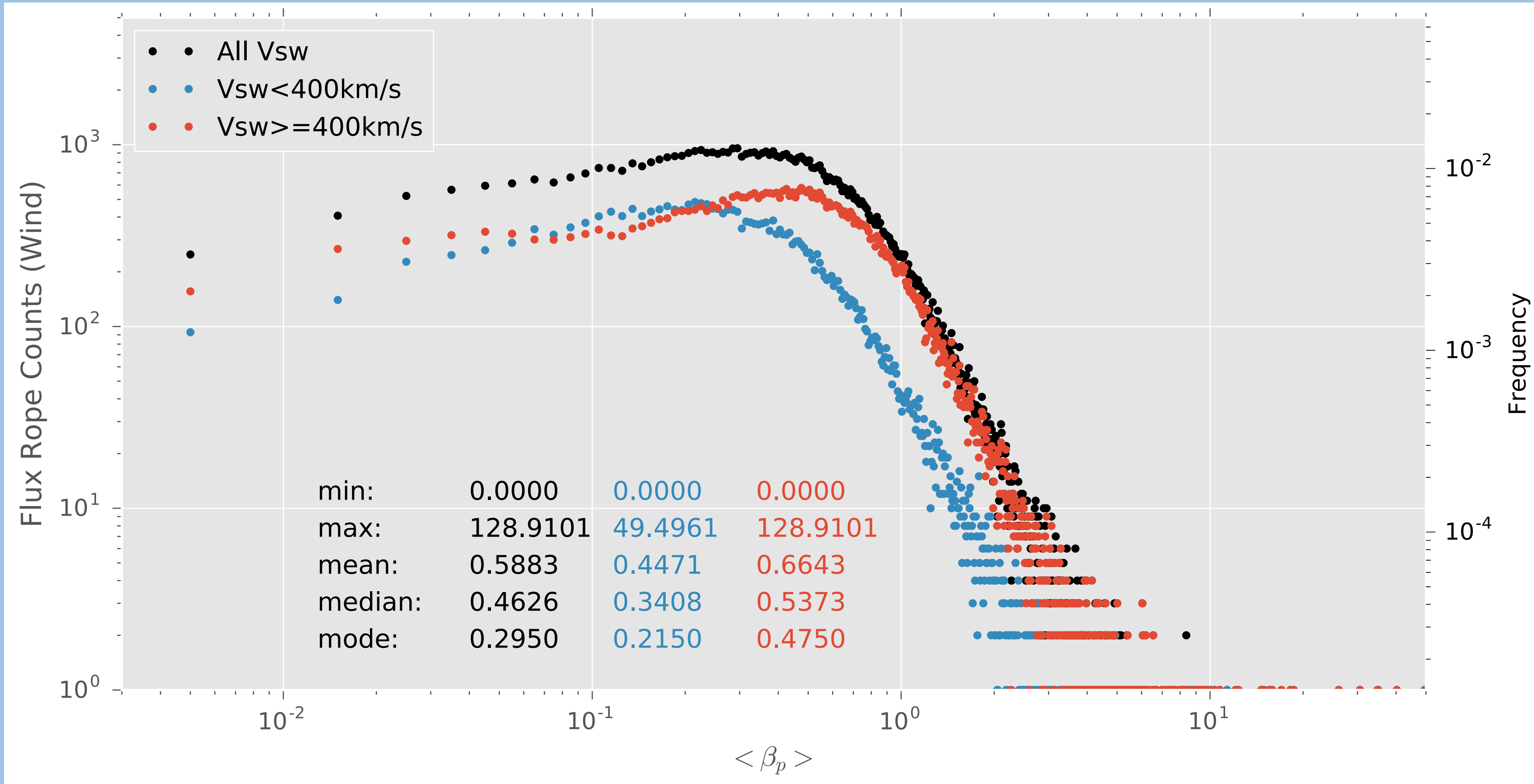

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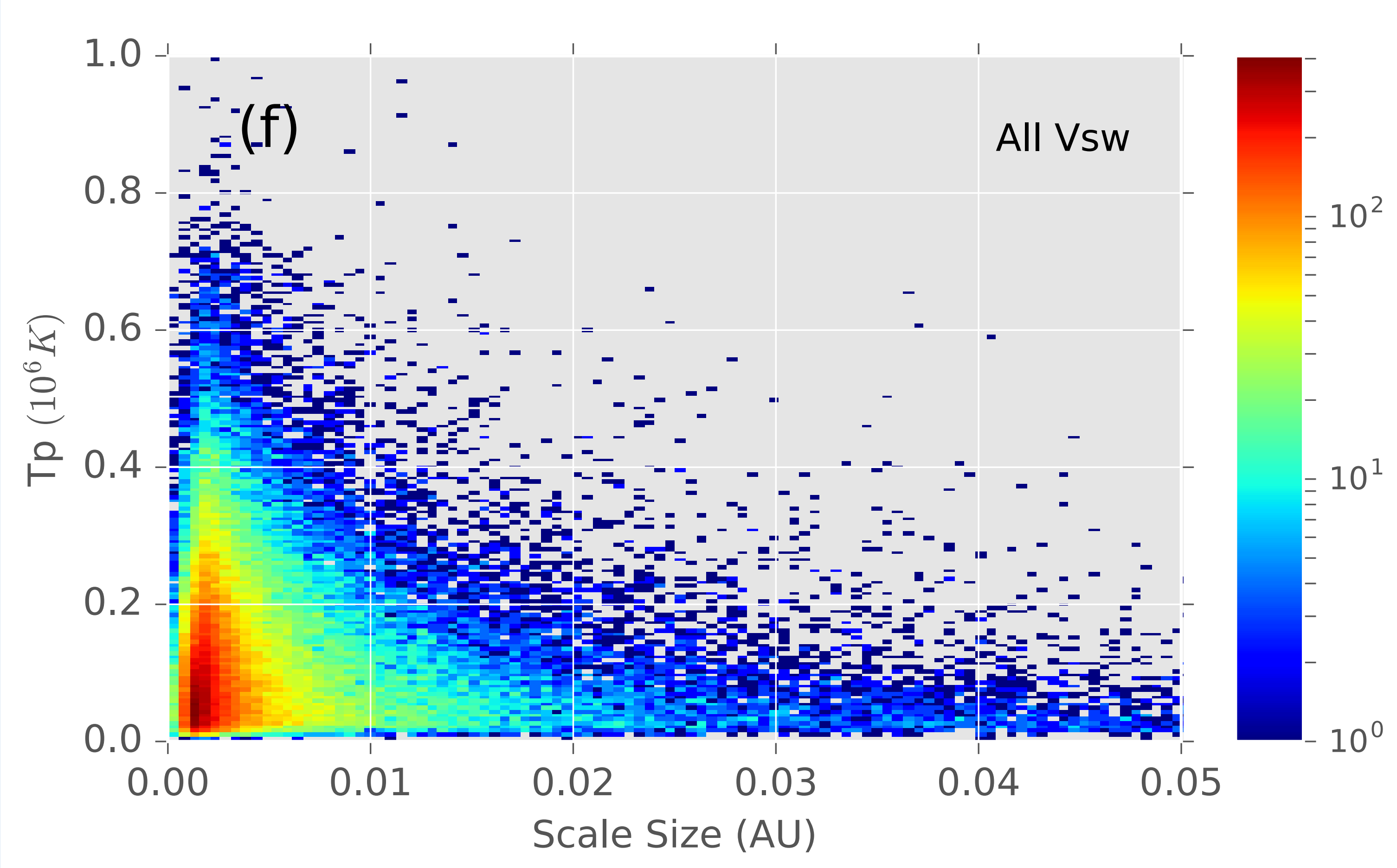
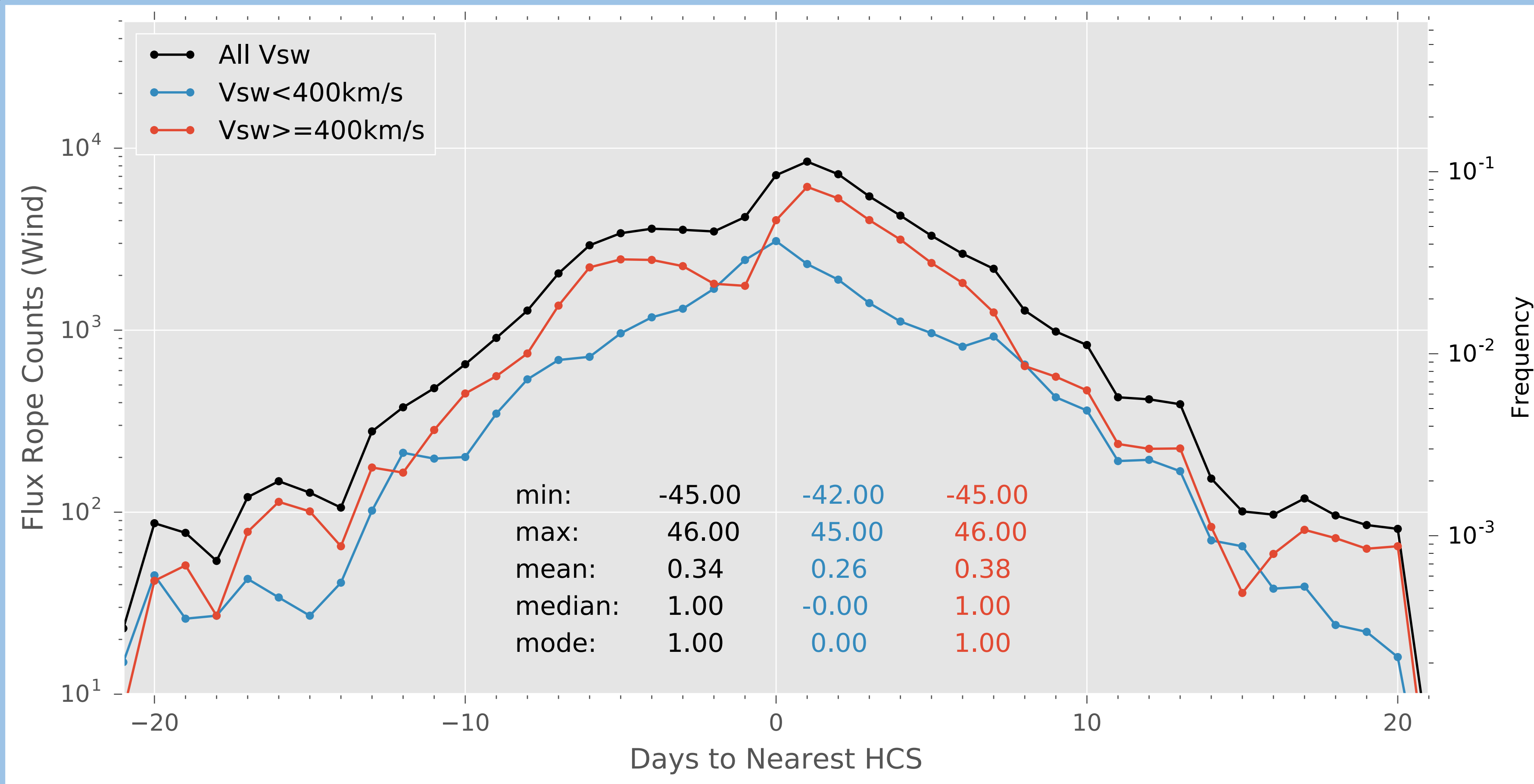


STATISTICAL ANALYSIS



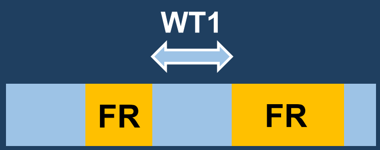
STATISTICAL ANALYSIS

Waiting Time Distribution (WTD) Analysis

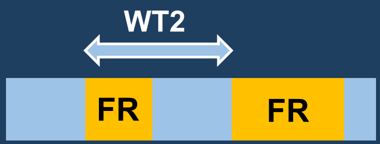
WTD: The distribution of time intervals or separations between discrete events.

Exponential	Power Law
⇩	⇩
Pure Poisson Process	Intermittency Clustering

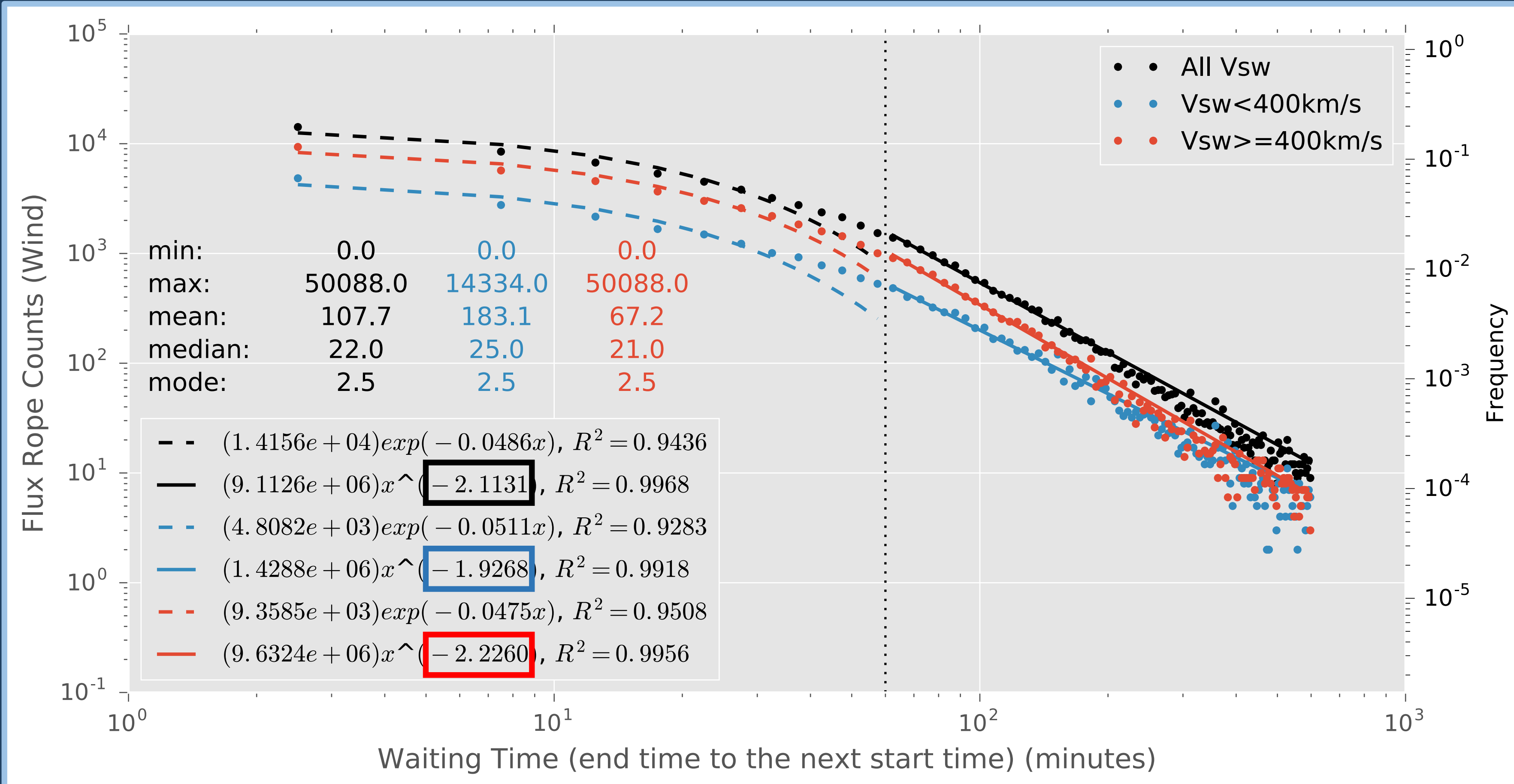
Waiting time of 1st kind: End time of one flux rope to the start time of the next one.



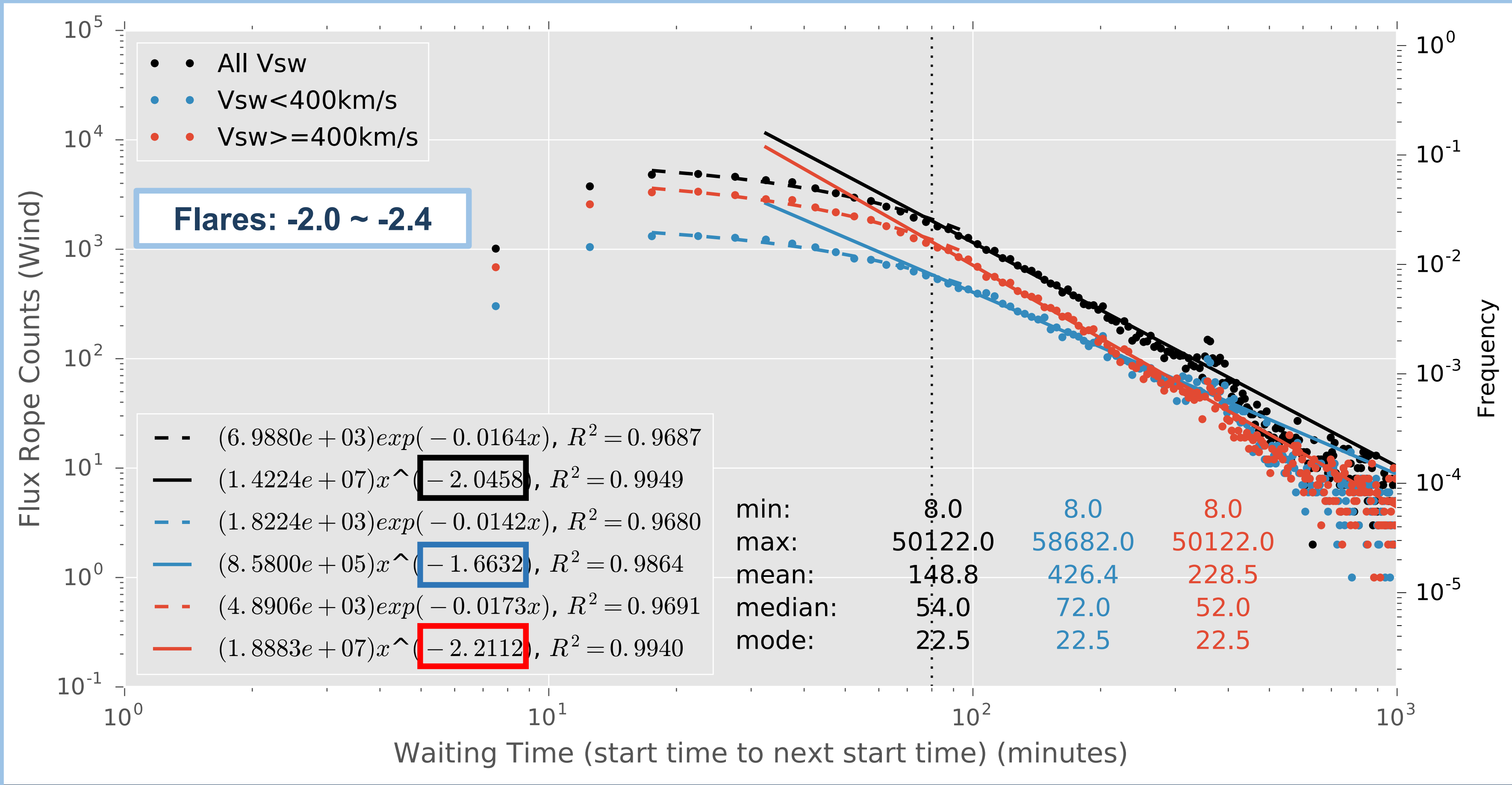
Waiting time of 2nd kind: Start time of one flux rope to the start time of the next one.



STATISTICAL ANALYSIS

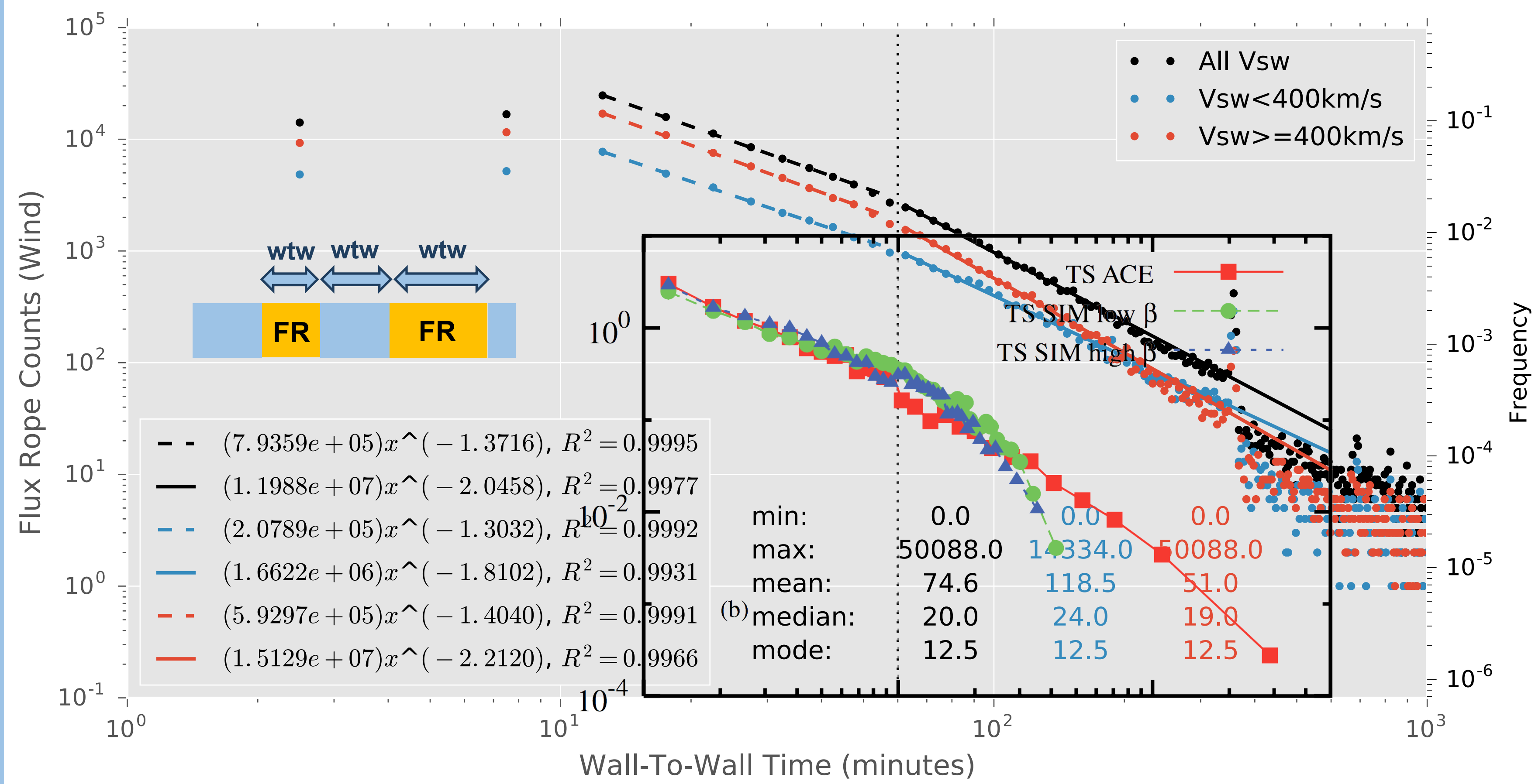


STATISTICAL ANALYSIS



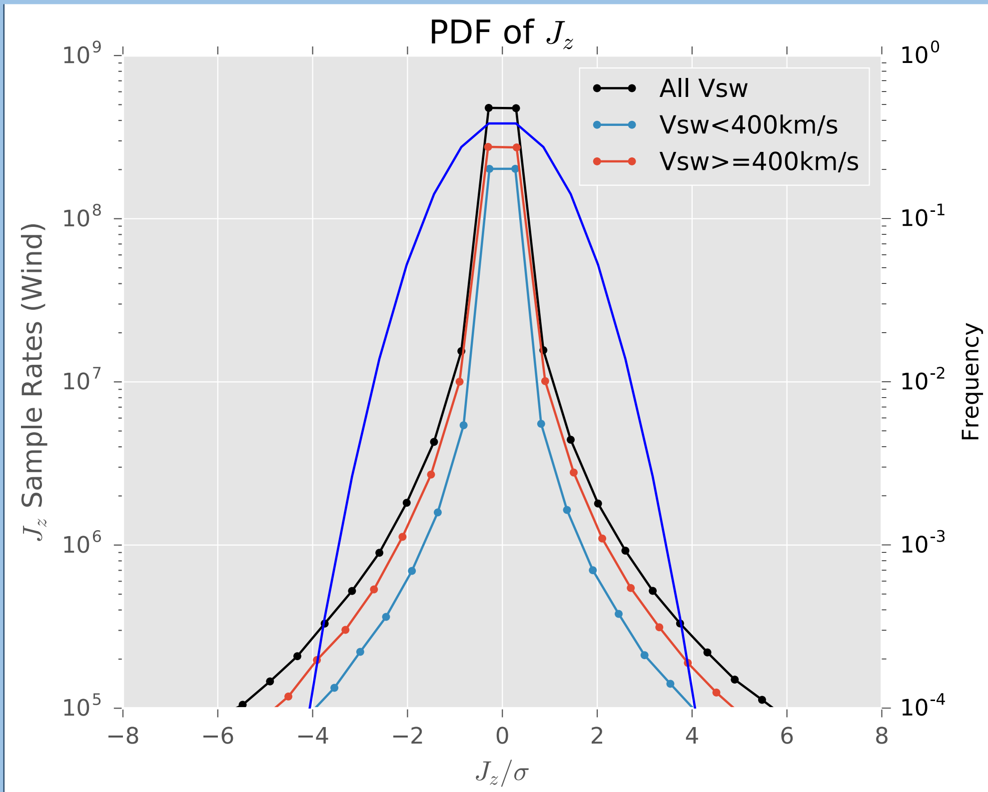
Li et al. (2002); Boffetta et al. (1999)

STATISTICAL ANALYSIS

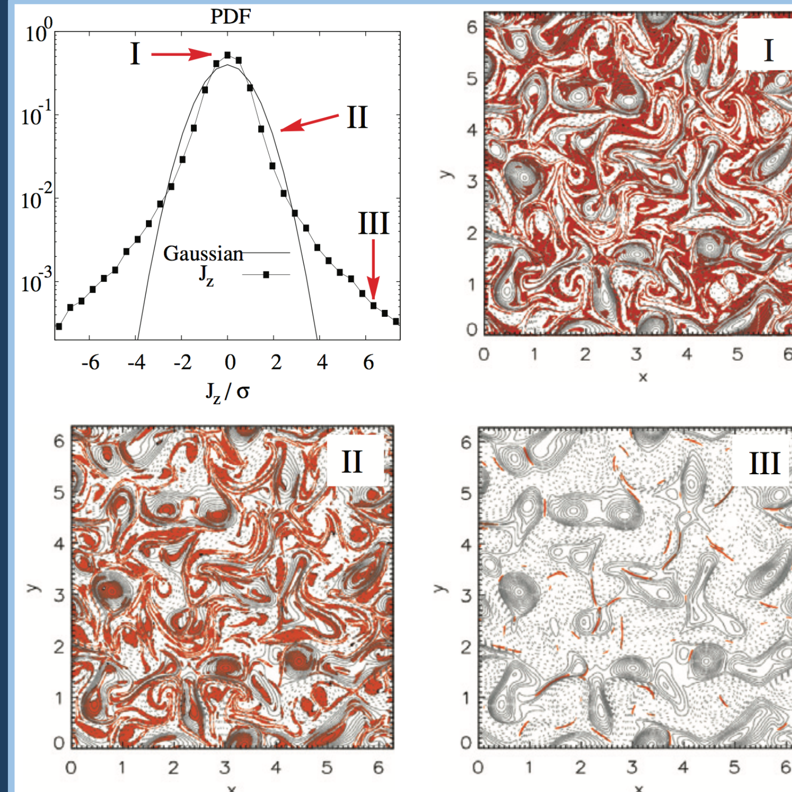


STATISTICAL ANALYSIS

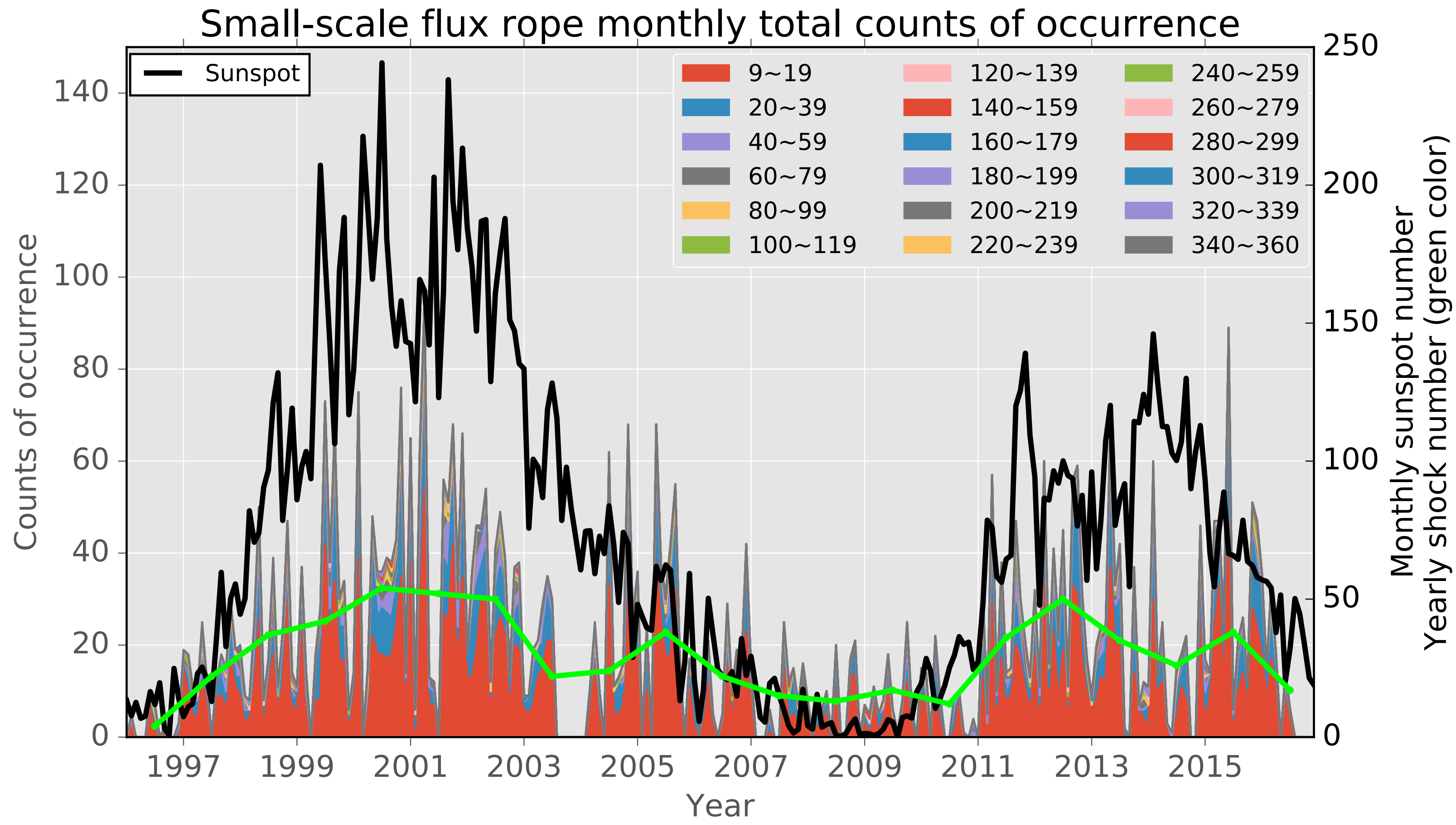
Current Density Jz Derived From Our Database



MHD Simulation (Greco et al., 2009)



ASSOCIATION WITH SHOCKS



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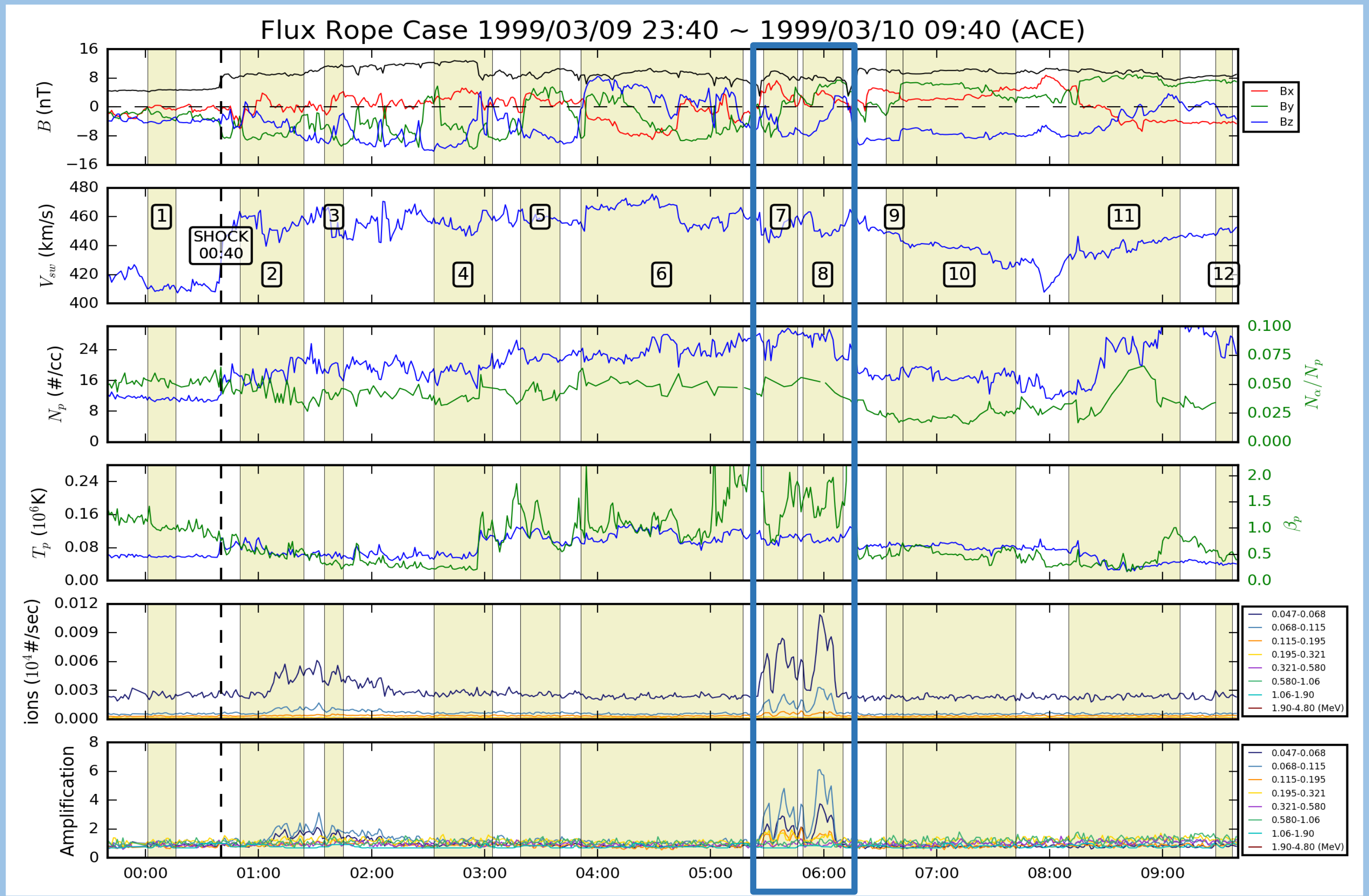
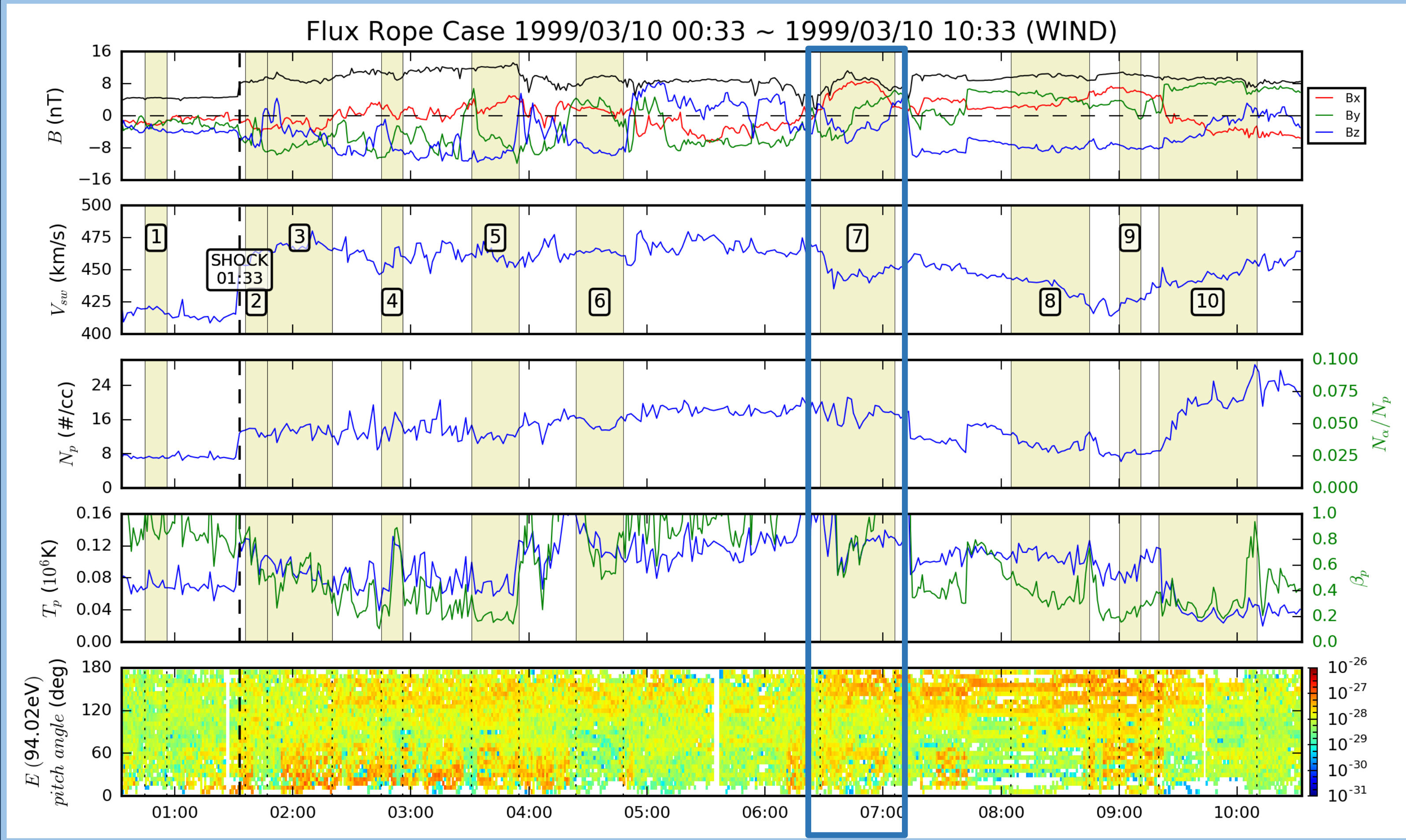
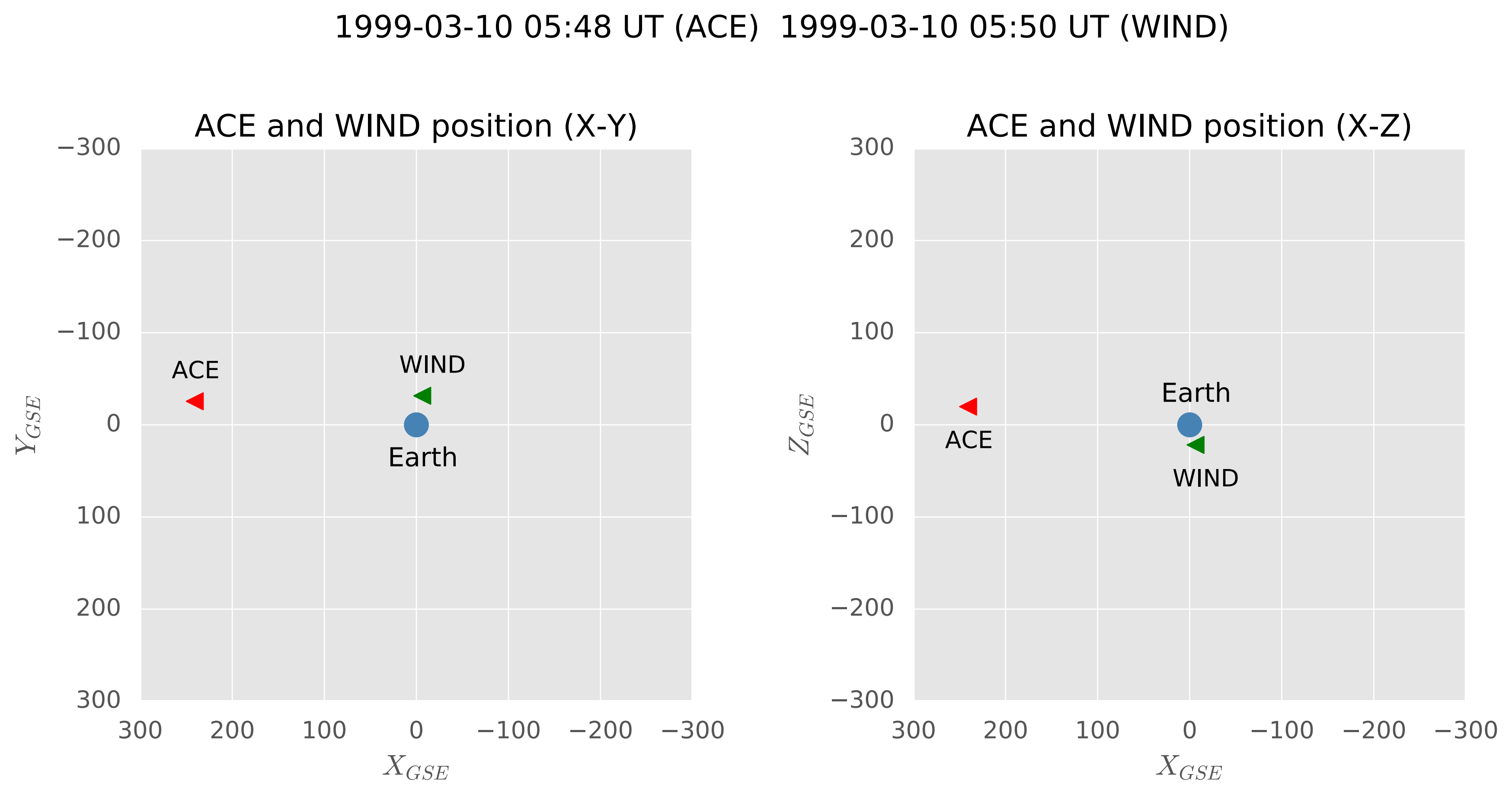


It seems the duty cycle is very high

ASSOCIATION WITH SHOCKS

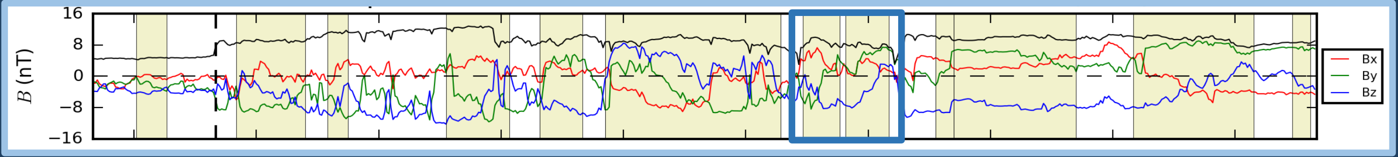


ASSOCIATION WITH SHOCKS

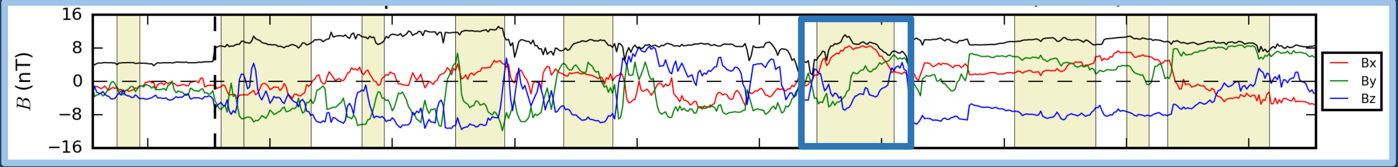


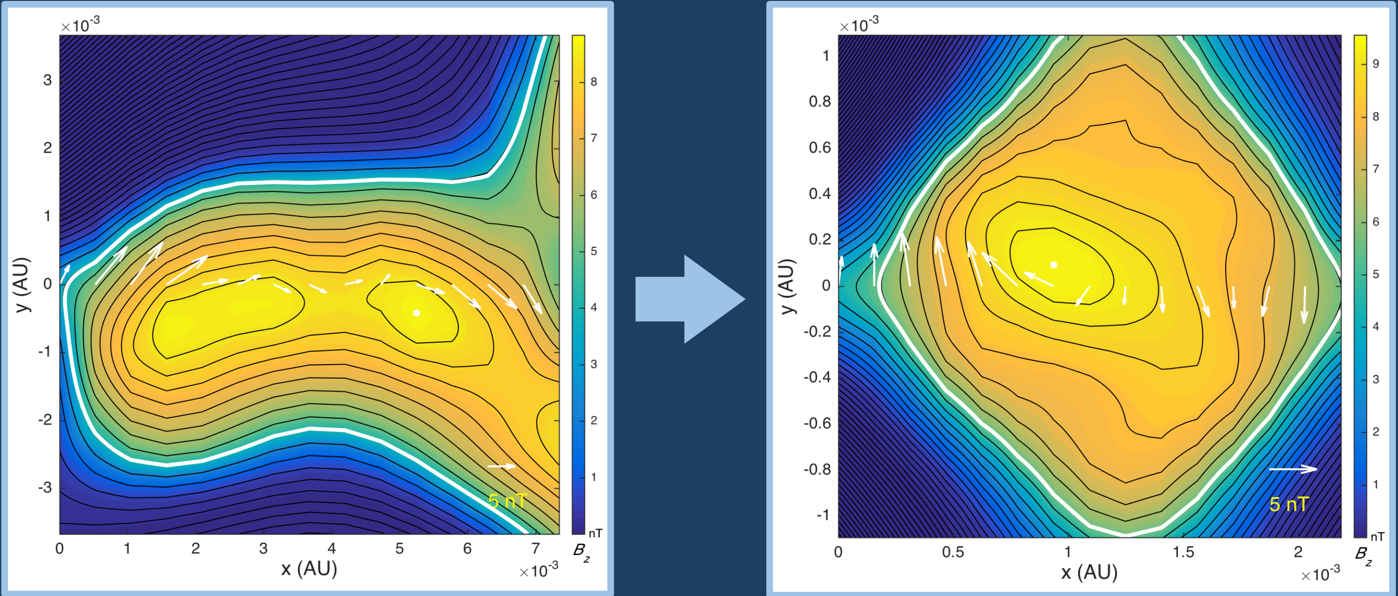
ASSOCIATION WITH SHOCKS

ACE



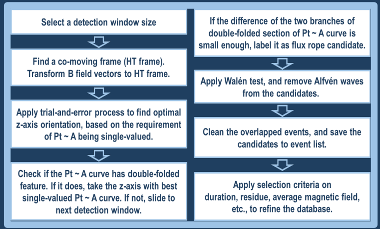
Wind





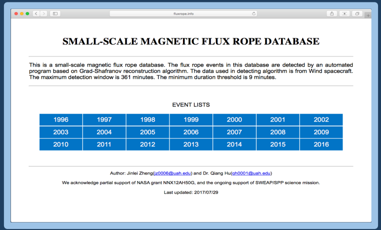
CONCLUSION

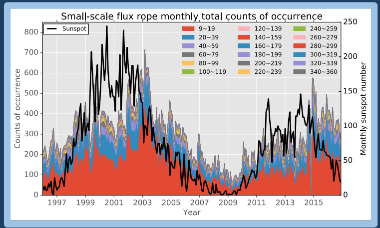
What We Did



A New Automated Small-Scale FRs Detection Algorithm.

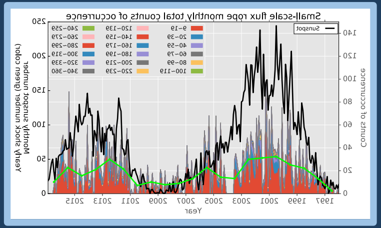
An Online Database with Large Number of Small-Scale FRs.



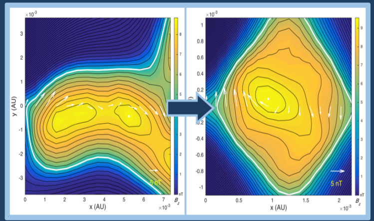


Statistical Analysis on Small-Scale FRs in Our Database.

Statistical Analysis on Small-Scale FRs Downstream of Shocks.



Case Studies on Small-Scale FRs Merging and Particle Acceleration.



CONCLUSION

What We Found

Solar Origin	versus	Created Locally
Align along the Parker spiral		Agreement with Greco et al.

- Occurrence Rate Has Solar Cycle Dependency
- Flux Ropes Under Different Vsw Show Different Statistical Properties
- Accumulation of flux ropes near HCSs

- Both the Duration and Scale-size Distributions Obey the Power Law
- WTD Can Be Fitted By Exponential and Power Law Functions
- Flux Ropes Interaction Regions Coincide with the Peak of Enhanced Ions Flux

FUTURE WORK

Future Work

Extend Duration to 7 ~ 12 Hours

Apply to ACE, Ulysses, Parker Solar Probe, etc.

Particle Acceleration

Geoeffectiveness

Publications

Zheng, Jinlei & Hu, Qiang & Chen, Yu & le Roux, Jakobus. (2017). Automated Detection of Small-scale Magnetic Flux Ropes and Their Association with Shocks. Journal of Physics: Conference Series. 900. 012024. 10.1088/1742-6596/900/1/012024.

Zheng, Jinlei and Hu, Qiang. Observations and analysis of small-scale magnetic flux ropes in the solar wind. Journal of Physics: Conference Series, 767(1):012028, 2016.

Zheng, Jinlei & Hu, Q & Mckenzie, J & Webb, G. (2014). Hydromagnetic Waves in a Compressed Dipole Field via Field-Aligned Klein-Gordon Equations. Annales Geophysicae. 34.10.5194/angeo-34-473-2016.

To be submitted

Zheng, Jinlei and Hu, Qiang and Lulu Zhao. Building a Small-scale Magnetic Flux Rope Database via the Grad-Shafranov Reconstruction Technique. *To be submitted to JGR*.

Zheng, Jinlei and Hu, Qiang. Observational evidence of self-generation of small-scale magnetic flux ropes from intermittent solar wind turbulence. *To be submitted to ApJL.*

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CSPAR
CENTER FOR SPACE PLASMA & AERONOMIC RESEARCH
THE DEPARTMENT OF SPACE SCIENCES

Thank you all for attending!

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SAO Subcontract No. SV4-84017.

ACE Science Center for ACE spacecraft data.
NASA CDAWeb for Wind spacecraft data.
The University of Helsinki for interplanetary shock list.
Leif Svalgaard's IMF sector boundary list for HCSs data.
Royal Observatory of Belgium for the sunspot data.

1 Numerical Solution of GS Equation

Use Taylor expansion [Hau and Sonnerup,1999],

$$A(x, y \pm \Delta y) \approx A(x, y) + (\frac{\partial A}{\partial y})_{x,y}(\pm \Delta y) + \frac{1}{2}(\frac{\partial^2 A}{\partial y^2})_{x,y}(\pm \Delta y^2), \tag{1}$$

From GS Equation, we have,

$$\frac{\partial^2 A}{\partial y^2} = -\frac{\partial^2 A}{\partial x^2} - \mu_0 \frac{d}{dA}(p + {B_z}^2/2\mu_0), \tag{2}$$

Use Taylor expansion on B_x ($\partial A/\partial y = B_x$),

$$B_x(x, y \pm \Delta y) \approx B_x(x, y) + (\frac{\partial^2 A}{\partial y^2})_{x,y}(\pm \Delta y^2), \tag{3}$$

Now all three terms on RHS of the first equation are known.

2 The de Hoffman-Teller (HT) Frame

The de Hoffmann-Teller (HT) frame is a frame of reference in which all three components of the electric field vanish, i.e.,

$$\mathbf{E} = 0, \tag{4}$$

GS method requires the magnetohydrostatic condition, i.e.,

$$\frac{\partial \mathbf{B}}{\partial t} = 0, \tag{5}$$

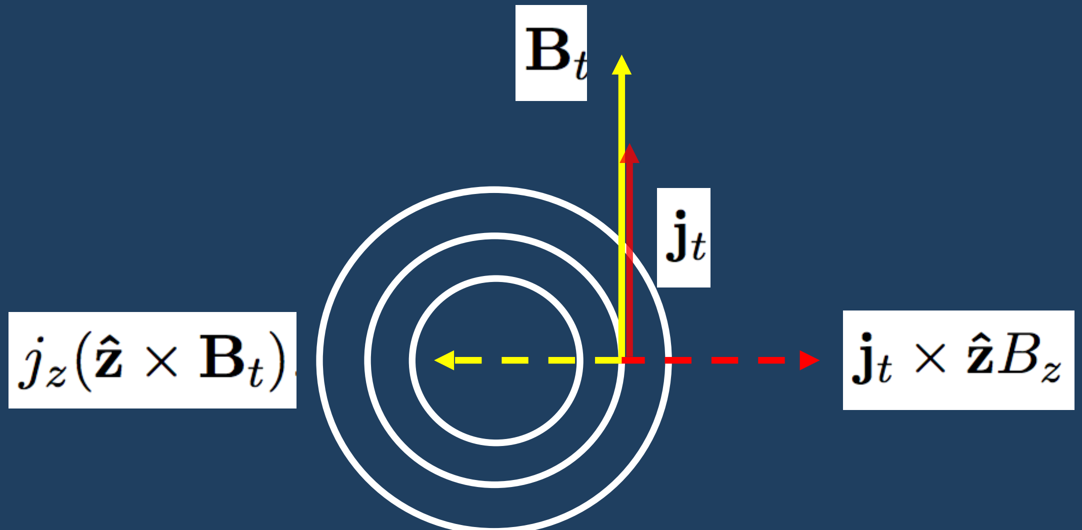
In de Hoffmann-Teller (HT) frame, since $\mathbf{E} = 0$, according to Faraday's law, we have

$$\frac{\partial \mathbf{B}}{\partial t} = -\nabla\times\mathbf{E} = 0, \tag{6}$$

Note that, $\mathbf{E} = 0$ is a stricter condition than $\nabla\times\mathbf{E} = 0$.

BACKUP

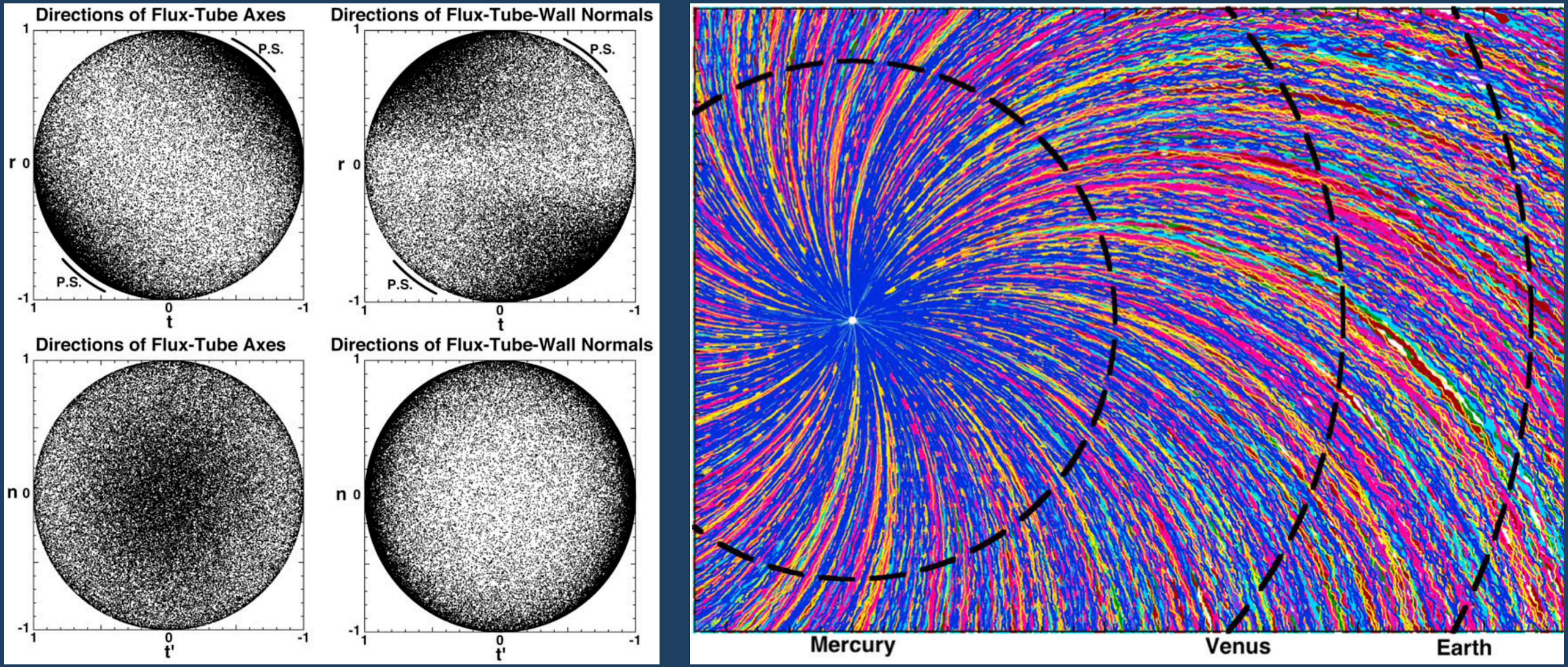
Force Balance



$$\nabla p = \mathbf{j} \times \mathbf{B} = (\mathbf{j}_t + j_z \hat{\mathbf{z}}) \times (\mathbf{B}_t + B_z \hat{\mathbf{z}})$$
$$= \mathbf{j}_t \times \hat{\mathbf{z}} B_z + j_z (\hat{\mathbf{z}} \times \mathbf{B}_t).$$

BACKUP

- Axial Orientations of Small-scale Magnetic Flux Ropes.



[Borovsky et al. 2008, 2010]