ABSTRACT:

Magnetic flux ropes (MFR) on the solar surface are thought to be the precursors of coronal mass ejections (CMEs). In some cases where an MFR is torus-unstable, magnetic self-organization events may reduce the energy and prevent an eruption. These self-organization events conserve helicity over their timescales, and for toroidal plasmas Taylor showed that the profile of $\mu \equiv \mathbf{J.B}/B^2$ is constant for the minimum-energy state.[1] The Magnetic Reconnection Experiment (MRX) was outfitted with electrodes in order to create MFR. An array of over 300 in-situ magnetic probes was used to capture a 2D cross-section of the magnetic field.[2] In this poster, the dynamics of $\mu \equiv \mathbf{J.B}/B^2$ is more closely examined for correlations with the behavior of the MFR and for signals of Taylor relaxation.

1. Taylor, *Rev. Mod. Phys.* **58**, 741-763 (1986)
2. Myers, et. al. *Nature* **528**, 526-529 (2015)

Laboratory Experiment for Exploring Solar Flux Rope Stability

Joshua Latham (Princeton University),

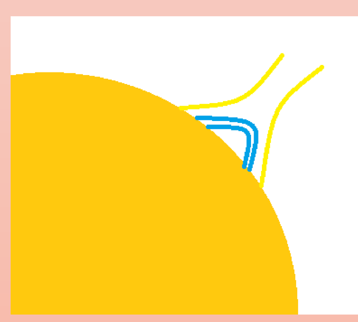
advised by Andrew Alt and Professor Hantao Ji (Princeton Plasma Physics Laboratory)

GOALS

- **Explore the ramifications of Taylor Relaxation in solar flux ropes.**
- **Discover predictive indicators of eruption in solar flux ropes.**

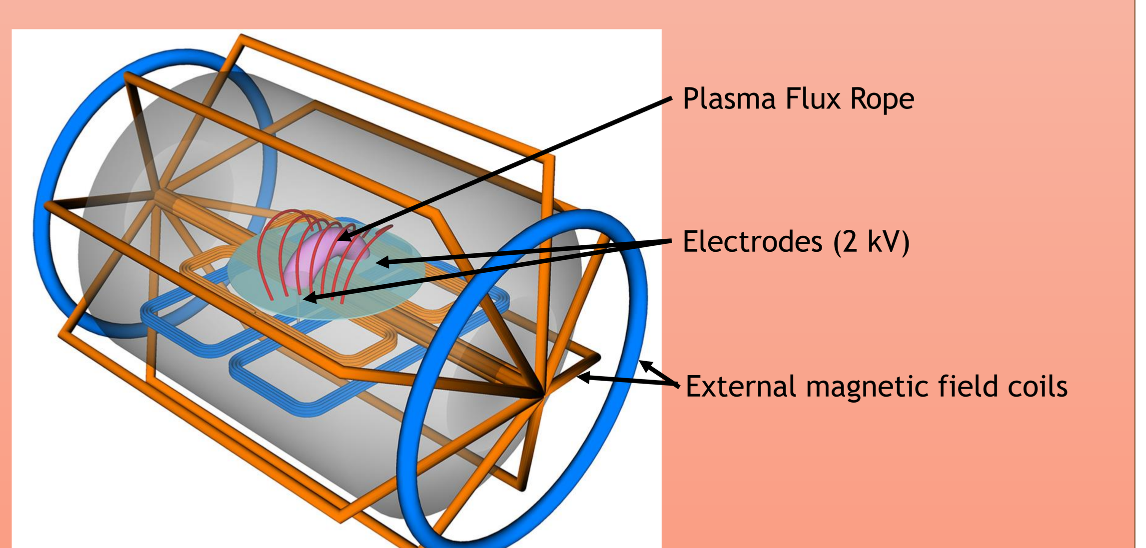
BACKGROUND: Flux Rope Experiment (Myers[1])

- The surface of the sun emits bursts of plasma called Coronal Mass Ejections (CME's). These are caused by a release of magnetic energy in the corona[2].

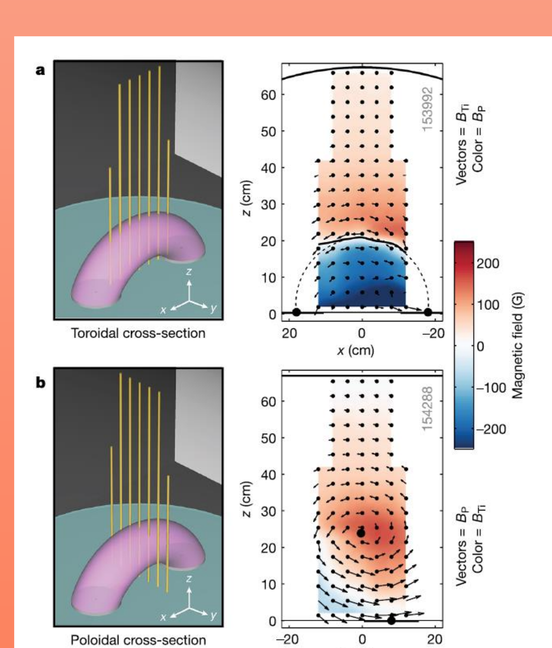


Magnetic fields (blue) store and release energy, leading to an ejection of plasma (yellow).

- Clayton Myers modeled this solar phenomenon in the Magnetic Reconnection Experiment (MRX), featuring over 300 in-situ magnetic probes.



Probes directly measure the magnetic field and capture 2D cross-section every 0.4 μs over the course of 450 μs.



Myer's conclusion: *helicity conservation* leads to *magnetic tension force* which restrains eruption.

$$F_{down} = J_p \times B_T$$

PEAKEDNESS OF μ

$$\mu \equiv \frac{\boldsymbol{J} \cdot \boldsymbol{B}}{B^2}$$

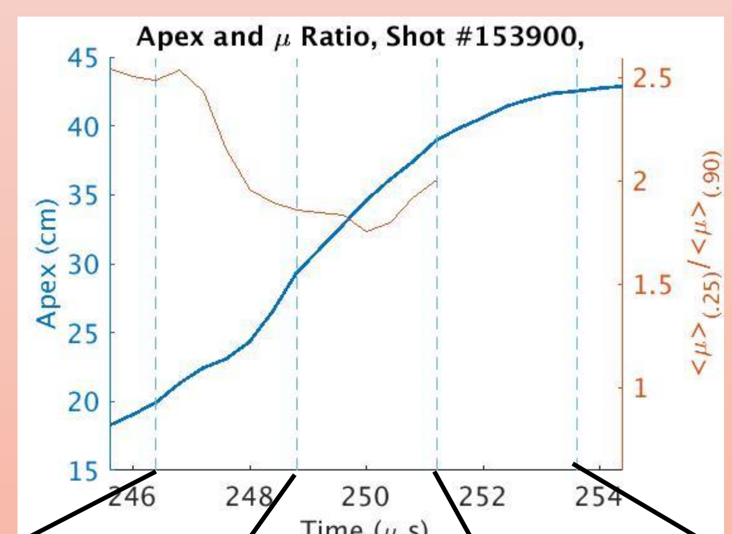
- μ describes the twistiness of the magnetic field.
- According to Taylor, when the plasma falls to lower energy state, helicity is conserved[3] $K_0 = \int \boldsymbol{A} \cdot \boldsymbol{B} d\tau$

1. *The lowest energy state has μ constant over all space (FLAT)* $\nabla \times \boldsymbol{B} = \mu_T \boldsymbol{B}$
2. *Peaked μ (high at center) is not the relaxed state.*

$$\nu = \frac{\bar{\mu}_{0.25}}{\bar{\mu}_{0.90}}$$

Average μ within a circle containing (25%/90%) of the total current

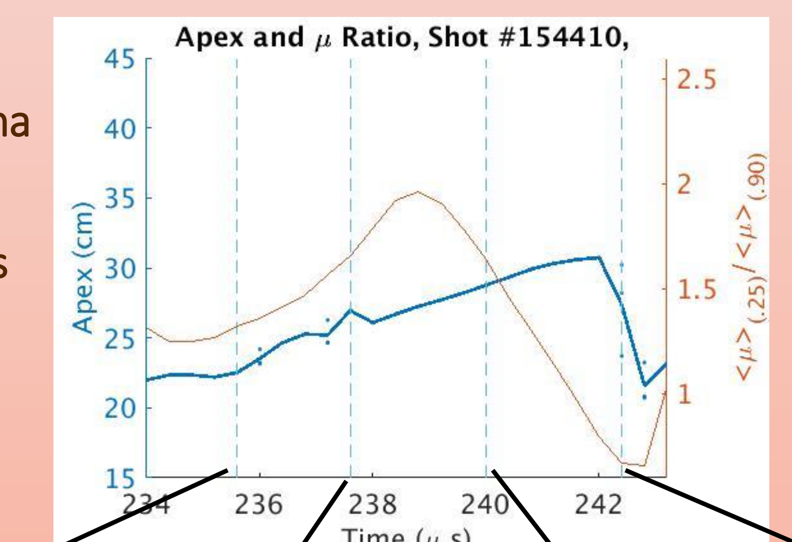
ERUPTIVE



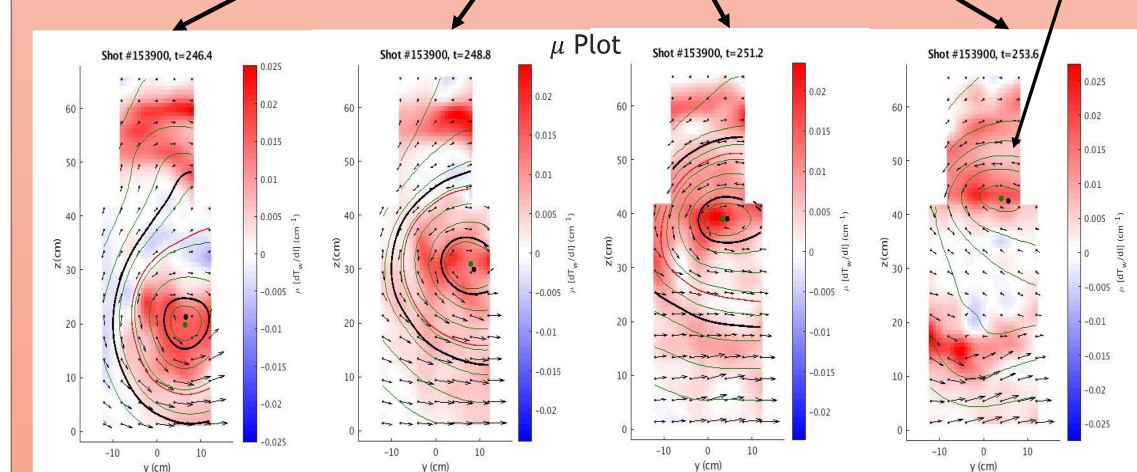
Blue: Height of plasma

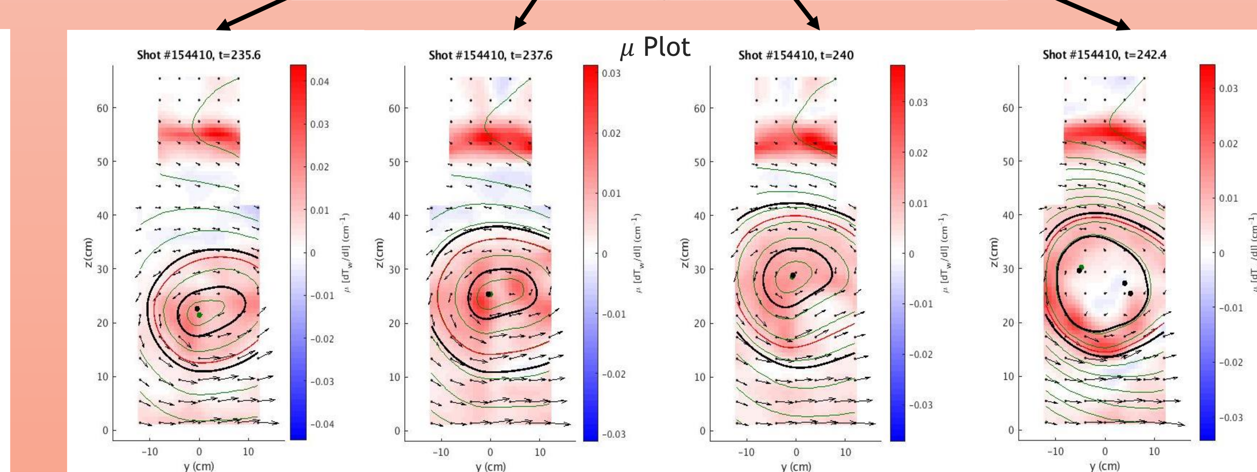
Orange: Peakedness

FAILED TORUS



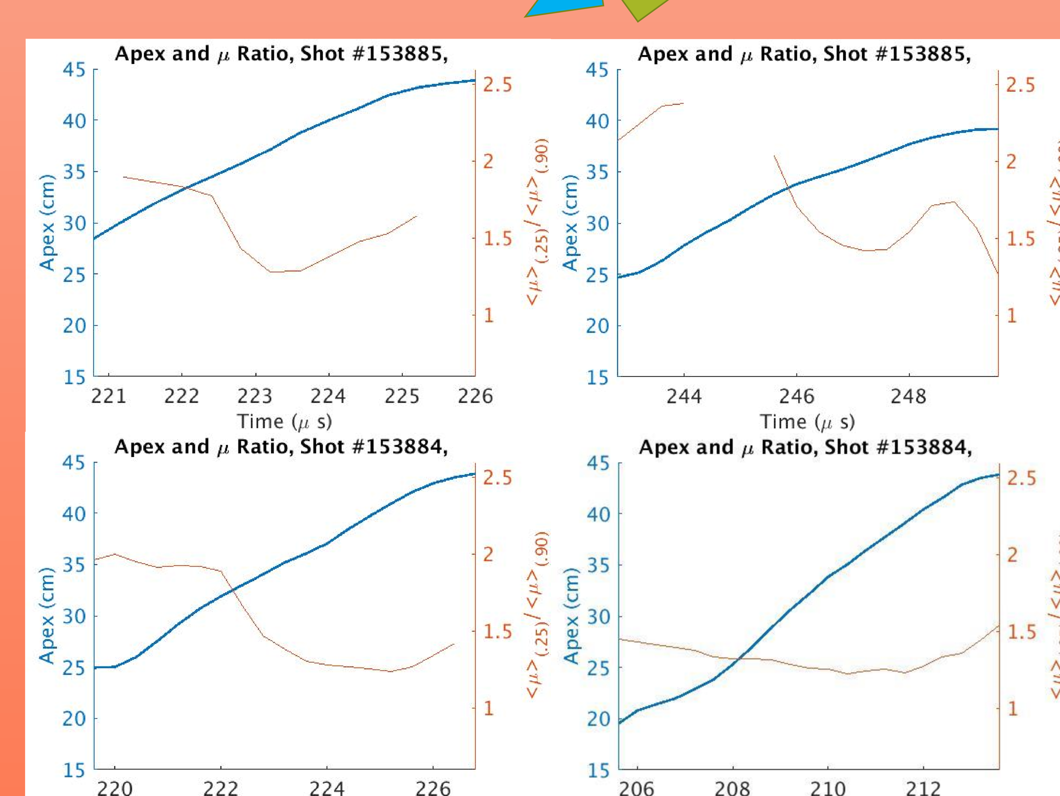
Eruption





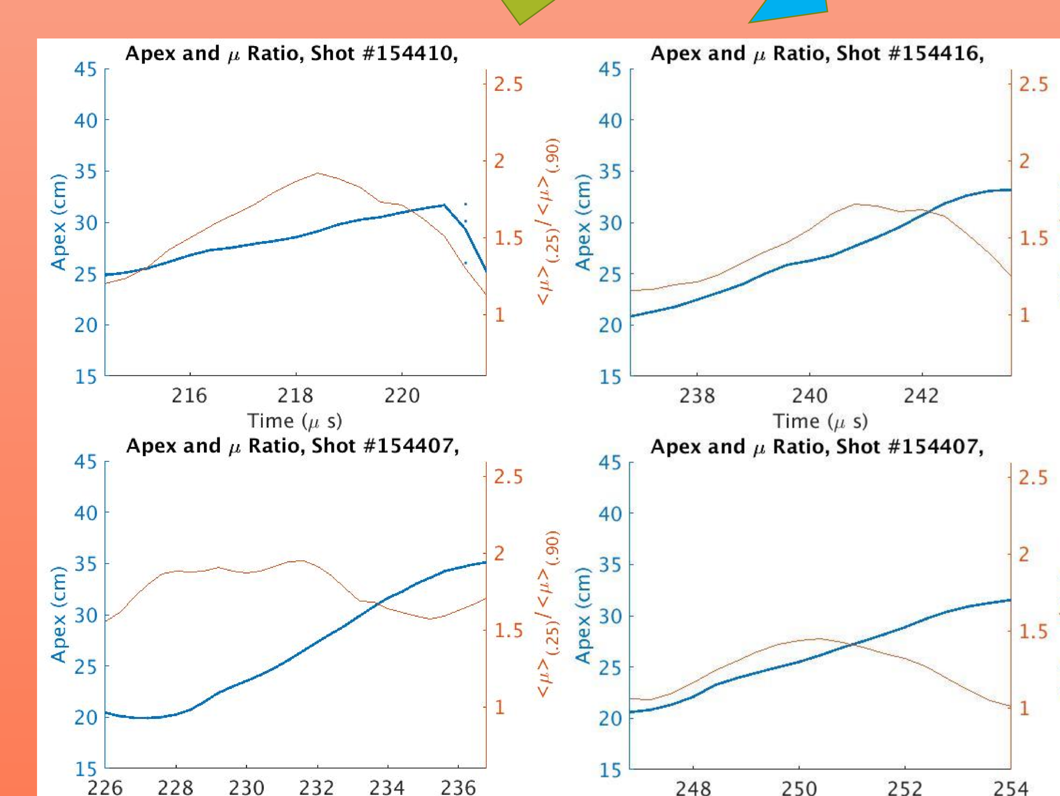
ERUPTIVE

μ slowly flattens, then re-peaks.



FAILED TORUS

μ slowly peaks, then flattens.



CONCLUSIONS

The behavior of μ for the failed torus cases behaves as predicted by Taylor Relaxation hypothesis.

Solar flux ropes that fail to erupt may undergo magnetic relaxation processes such as Taylor Relaxation.

For eruptions, μ profile is not that of Taylor Relaxation. Perhaps a helicity-conserving energy transfer is happening to the eruptive plasma.

NEXT STEPS

- **Redo experiment with 3D magnetic probe array to more accurately compute flux surfaces**
- **Compare magnetic results to solar CME data**
- **Perform statistical analysis of μ profile**

ACKNOWLEDGEMENTS

Thank you Andrew Alt and Prof. Hantao Ji and for advice and guidance.

Thank you Clayton Myers and Andrew Alt for the analysis and plotting libraries.

This work was made possible by funding from the Department of Energy Workforce Development for Teachers and Scientists (WDTS) for the Summer Undergraduate Laboratory Internship (SULI) program. This work is supported by the US DOE Contract No. DE-AC02-09CH11466.

REFERENCES

[1] Myers, et al., *Nature* **528**, 526 (2015).

[2] Kunow, H., Crooker, N. U., Linker, J. A., Schwenn, R. & von Steiger, R. (eds) *Coronal Mass Ejections* Ch. 2, 12 (Springer, 2006).

[3] Taylor, *Phys. Rev. Lett.*, **58** 741-763 (1986).

CONTACT

- Joshua Latham: jlatham@princeton.edu