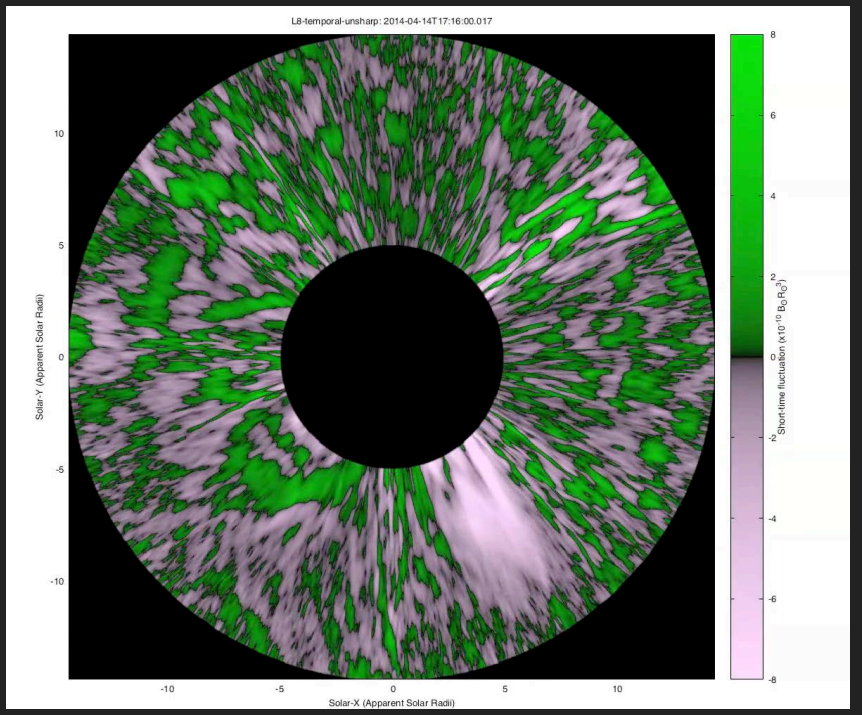

# A NEW VIEW ON THE MIDDLE CORONA




*Sarah Gibson and the PUNCH team*

*AGU Fall Meeting 2019*

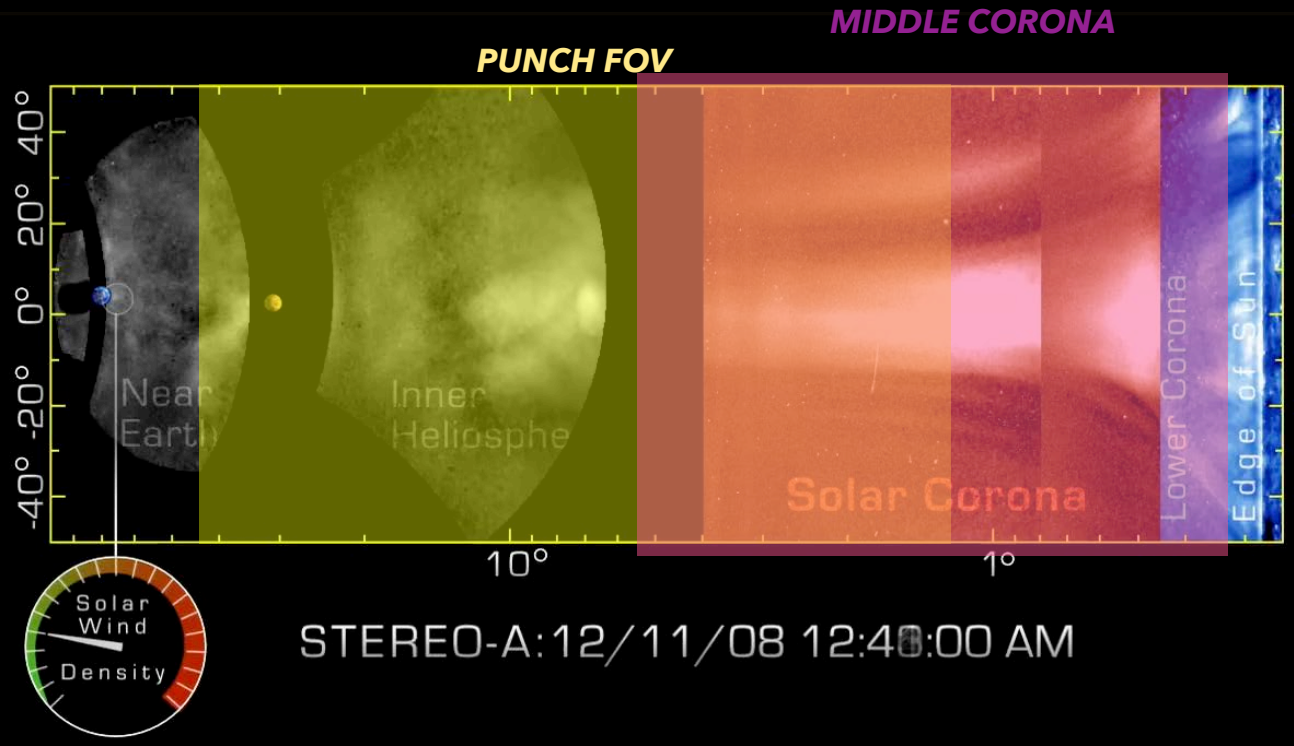
U.S. NAVAL RESEARCH LABORATORY

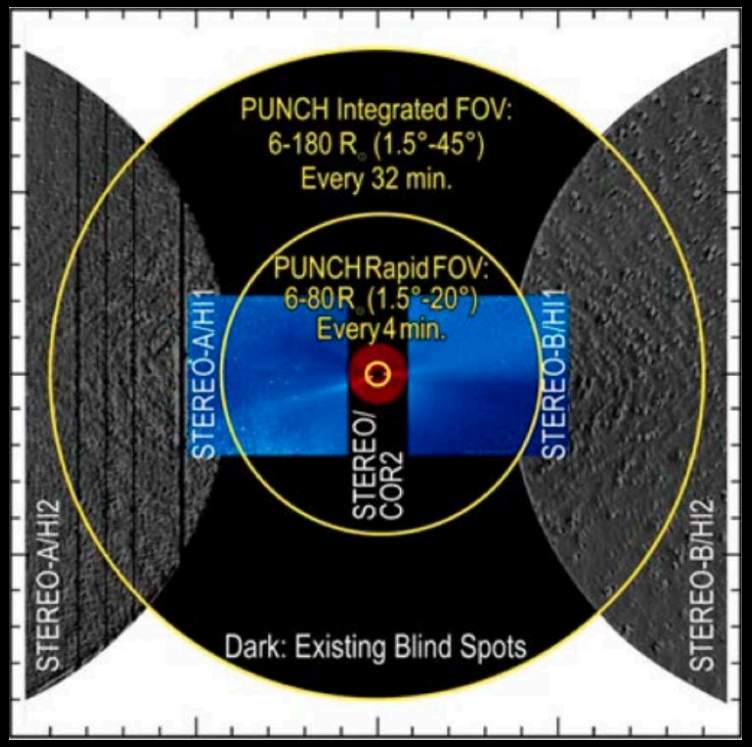
SwRI

RAL Space

NCAR UCAR HIGH ALTITUDE OBSERVATORY

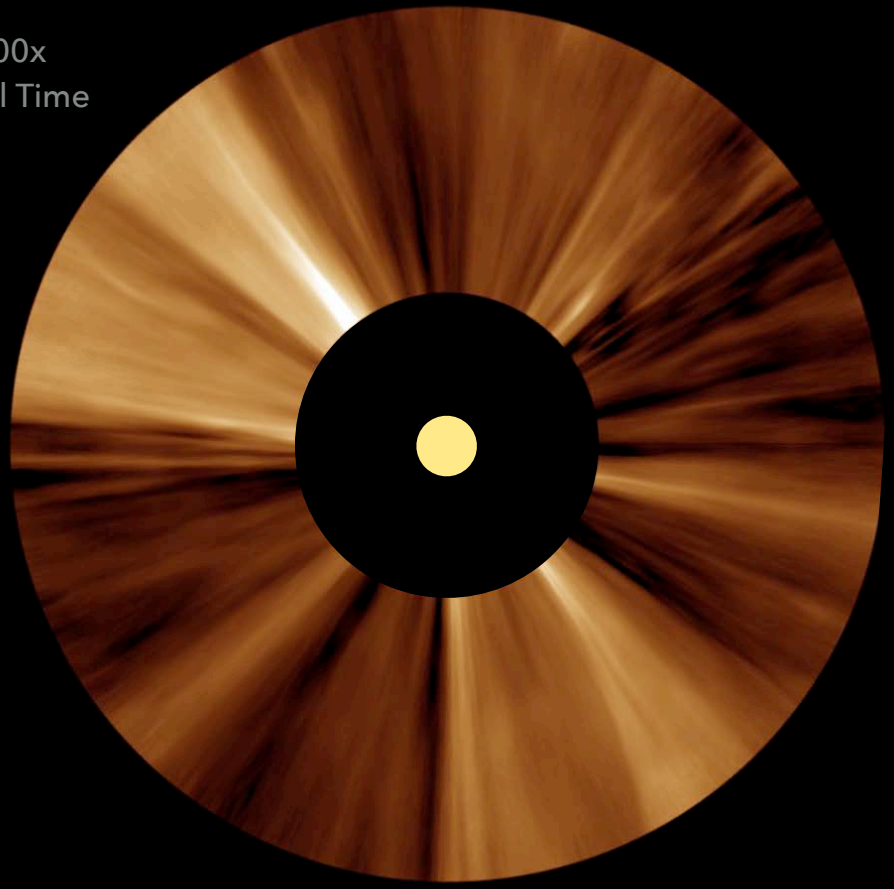
# THE PUNCH FIELD OF VIEW: CONTINUOUS AND POLE-TO-POLE



# THE SOLAR CORONA SEEN BY STEREO/COR2

8,000x
Real Time



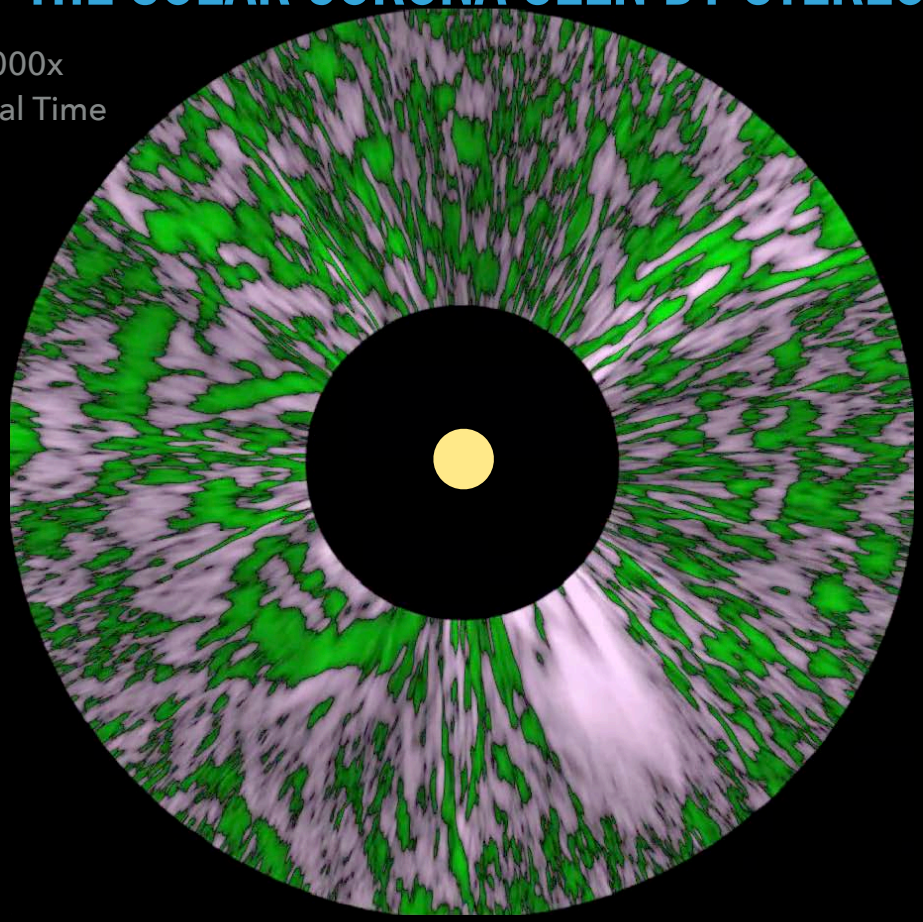
*10 million miles*

- Outflow is visible everywhere because of small moving features.
- The outer corona is dominated by fine “woodgrain” structure.
- Smooth background and stars removed; movie is 3% of imaged light.

THE SOLAR CORONA: A DEEPER LOOK REVEALS… THE YOUNG SOLAR WIND IS A RIOTOUS TORRENT

# THE SOLAR CORONA SEEN BY STEREO/COR2 WITH MOTION FILTERING

8,000x
Real Time



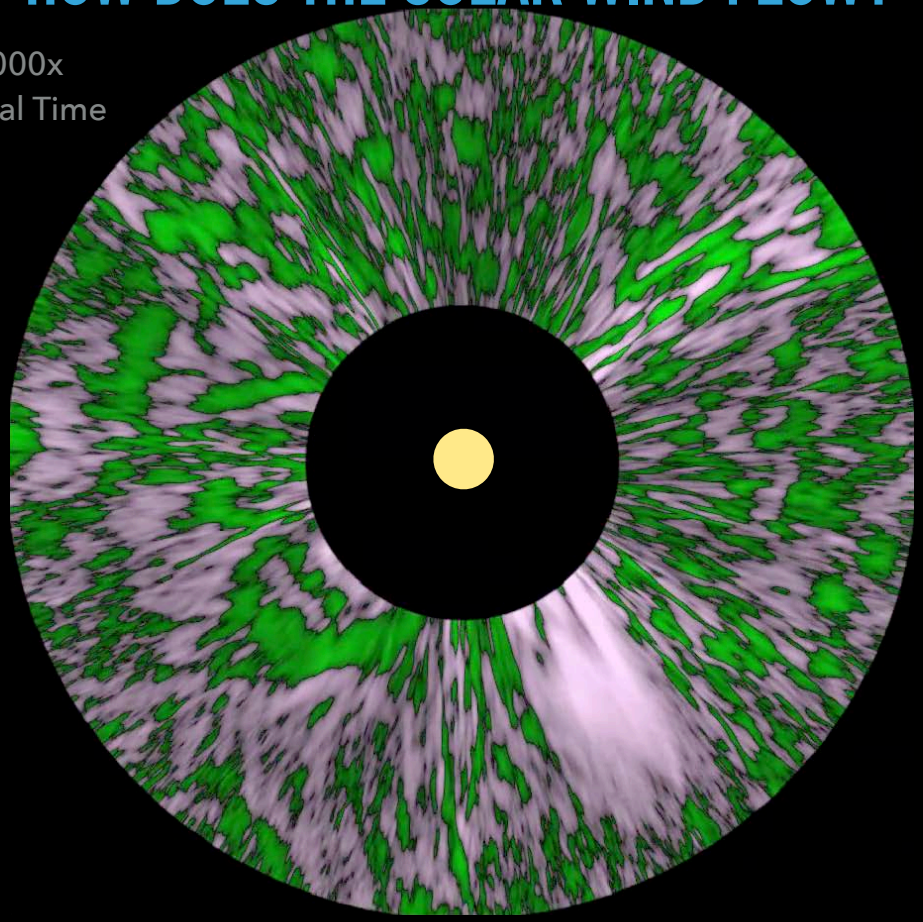
*10 million miles*

- Outflow is visible everywhere because of small moving features.
- The outer corona is dominated by fine “woodgrain” structure.
- The outer corona is a riotous torrent of blobs and variable streams: the young solar wind.

THE YOUNG SOLAR WIND REVEALED

# HOW DOES THE SOLAR WIND FLOW?

8,000x
Real Time



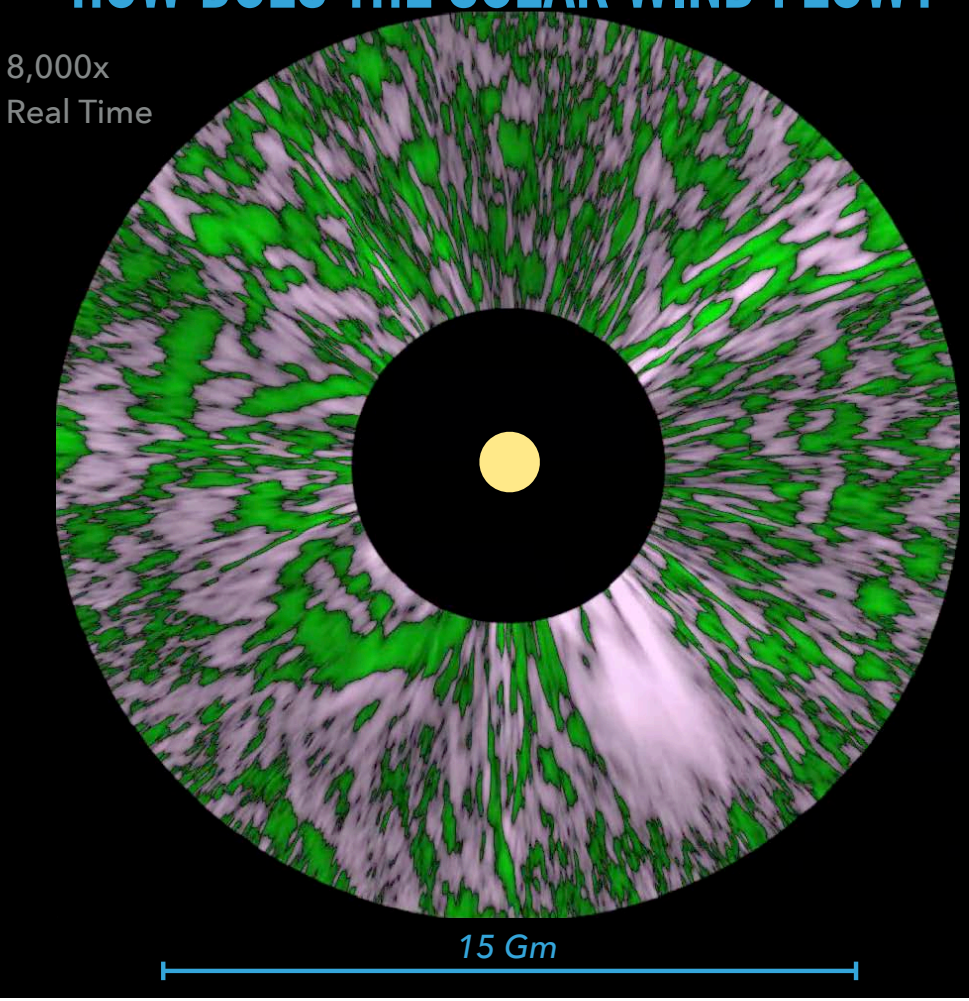
*10 million miles*

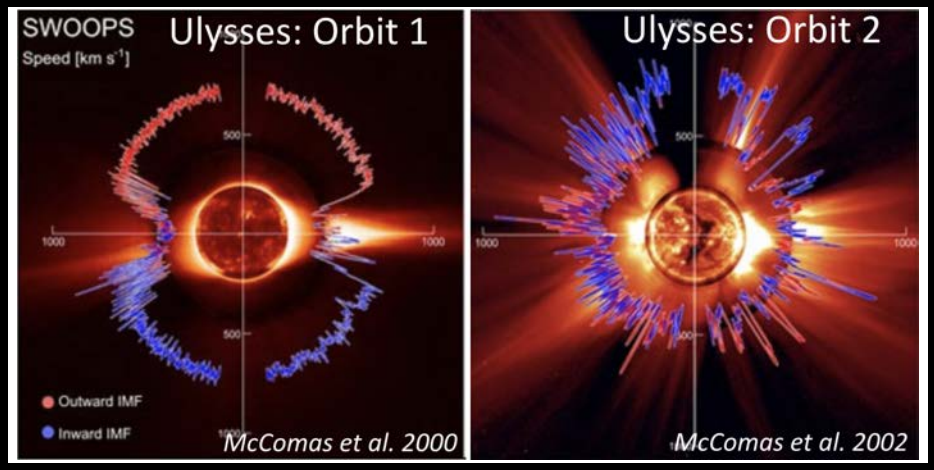
- Outflow is visible everywhere because of small moving features.
- PUNCH exploits these features to map the flow of the young solar wind in the middle corona every six hours.

- Poster Monday: Barbara Thompson

SA11C-3231 - The PUNCH Bowl: Data System and Data Products for NASA's PUNCH Mission

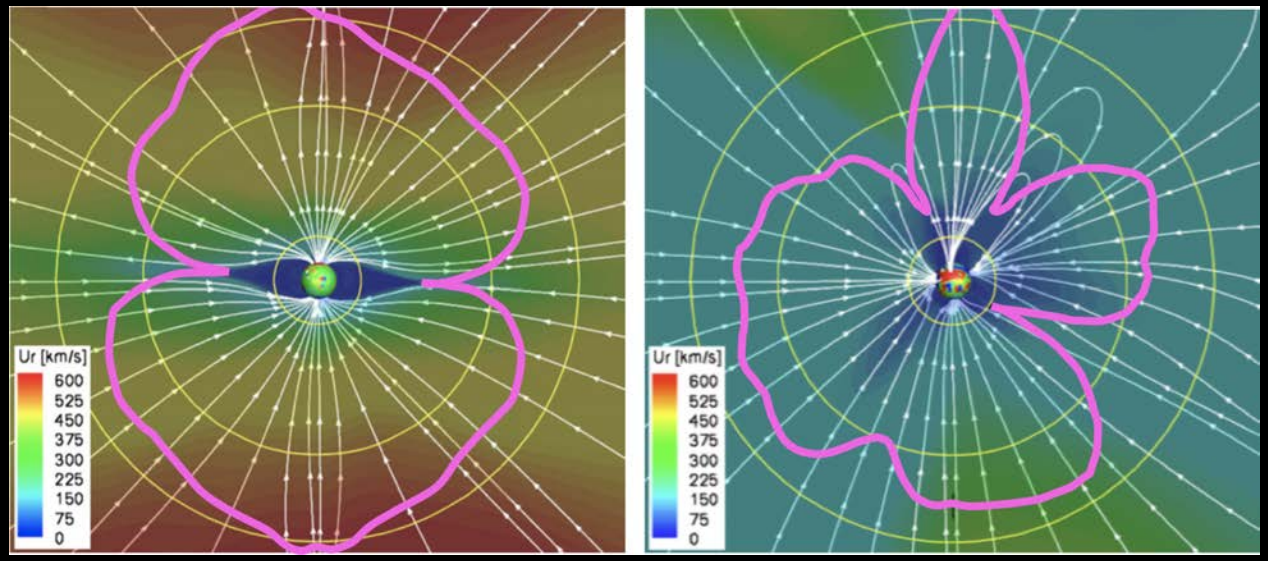
# HOW DOES THE SOLAR WIND FLOW?




- PUNCH exploits these features to map the flow of the young solar wind in the middle corona every six hours.
  - Our best current data is from Ulysses … once every six years … at 1AU.

# IDENTIFYING THE MYSTERIOUS ALFVÉN ZONE

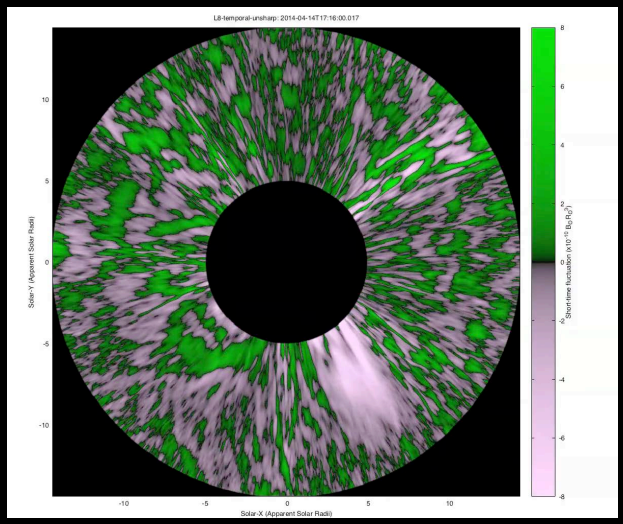



A natural dynamical boundary where the solar wind disconnects from the solar corona.

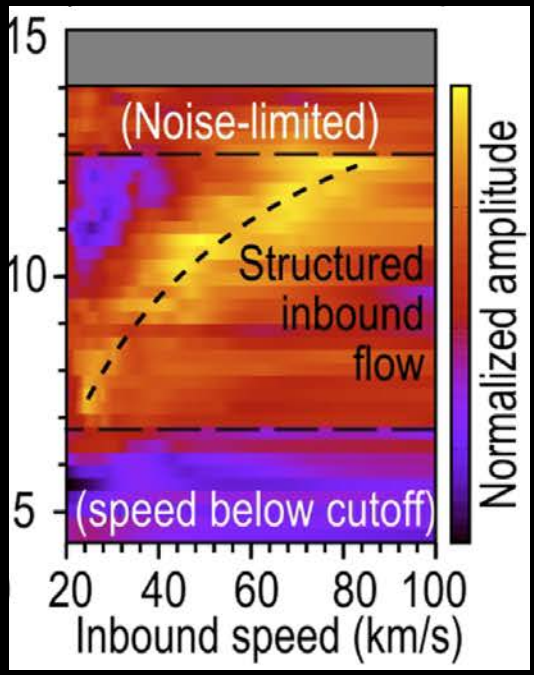
- Location where speed of the solar wind exceeds that of the fast MHD waves
- It is complex and changes with solar magnetic evolution
- It has never been observed; models are largely unconstrained

# IDENTIFYING THE MYSTERIOUS ALFVÉN ZONE

- Since the Alfvén speed depends on density, the “riotous torrent” seen in the COR2 deep-exposure campaign indicates there is likely a fractal “Zone” rather than a surface.



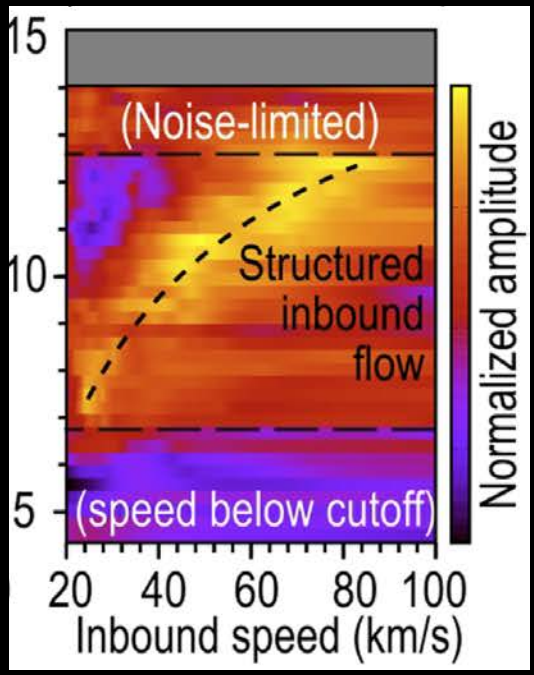
# IDENTIFYING THE MYSTERIOUS ALFVÉN ZONE




- No measurement of magnetic field is required.
- Above the Alfvén zone all plasma must propagate outwards. Below, motion in both directions is possible
- Fourier in/out filtering can be used to identify wave speed directly.

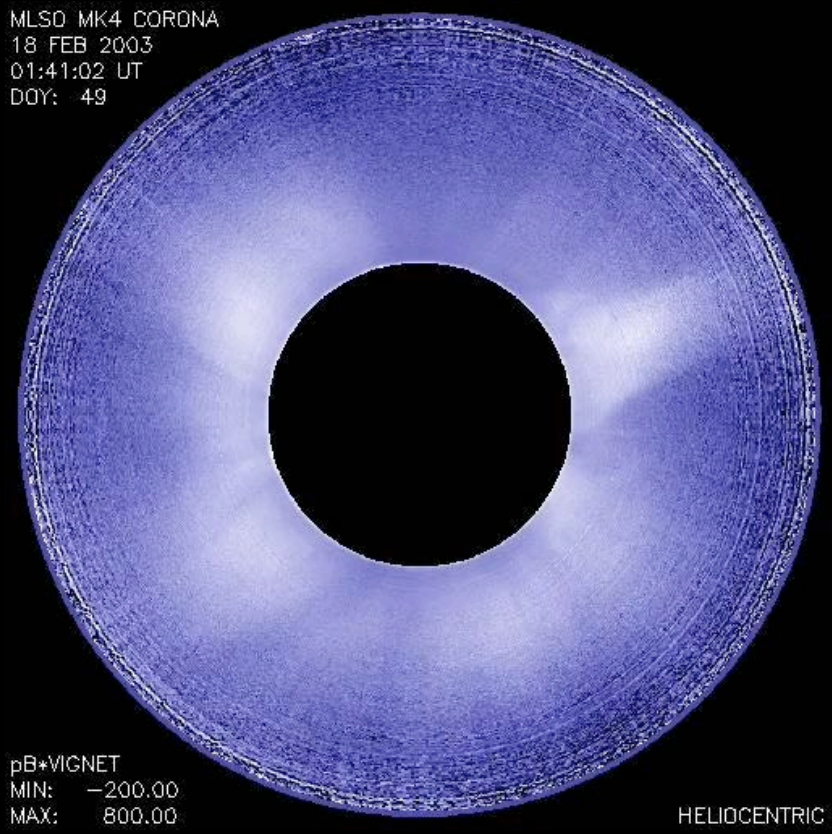
# IDENTIFYING THE MYSTERIOUS ALFVÉN ZONE

- **Existing observations yield lower limits on Alfvén zone.** STEREO COR2 analysis detected inward motions for all heights with detectable signal.
- Zone > 15 R for streamer, > 12 R for coronal hole.




# PSP COMPLEMENTARITY: GLOBAL VIEW OF ALFVÉN ZONE

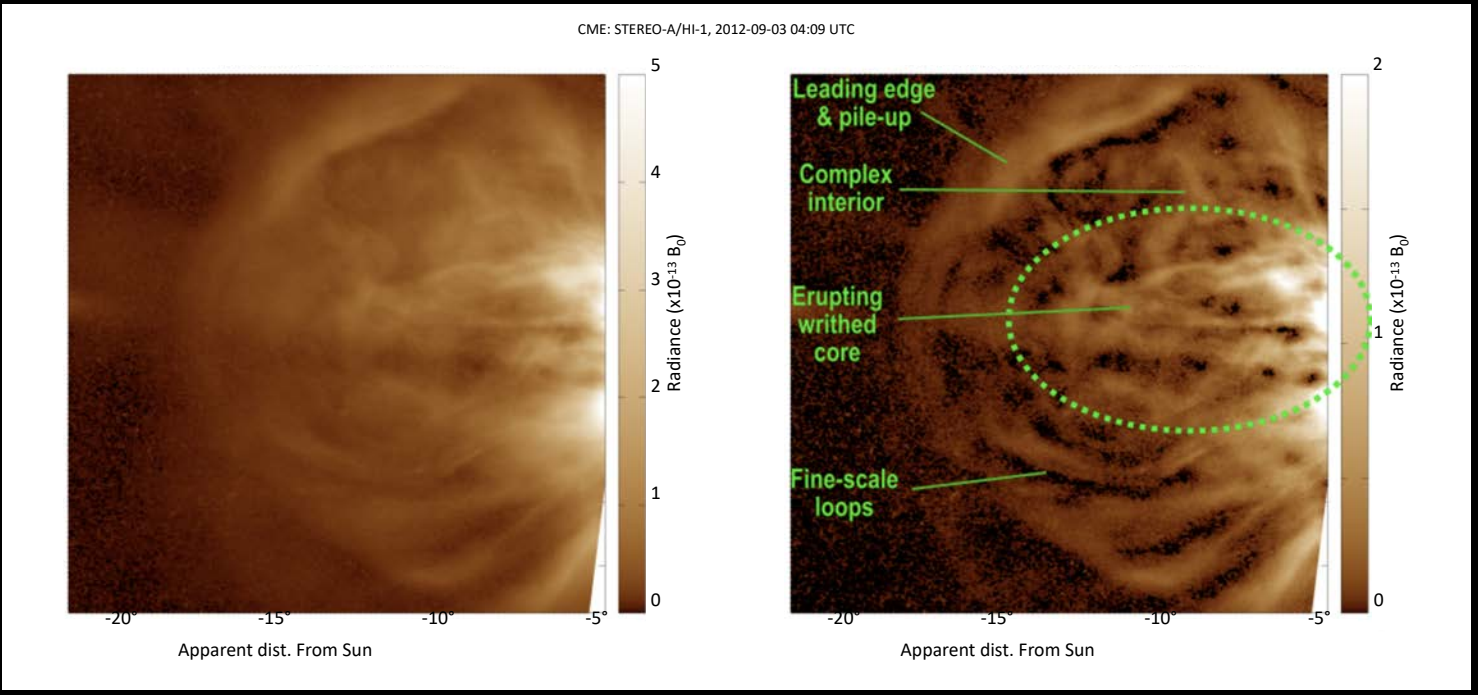
# TRACKING CMES' EVOLVING STRUCTURE IN 3D




- CMEs are quite complex
- Interior structure evolves - even rotates - as the CME propagates

CME INTERIOR STRUCTURE

# TRACKING CMES' EVOLVING STRUCTURE IN 3D

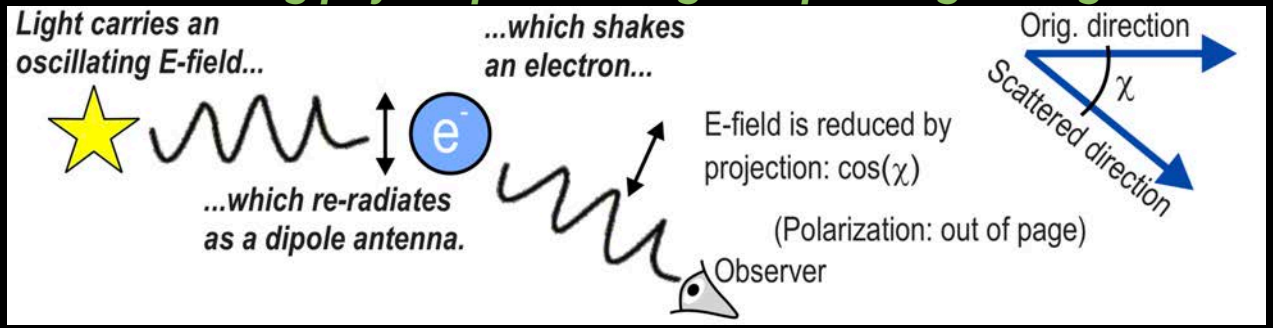



- CMEs are quite complex
- Interior structure evolves - even rotates - as the CME propagates
- PUNCH has 10X higher sensitivity - will see little flux ropes
- PUNCH has polarization at all heights

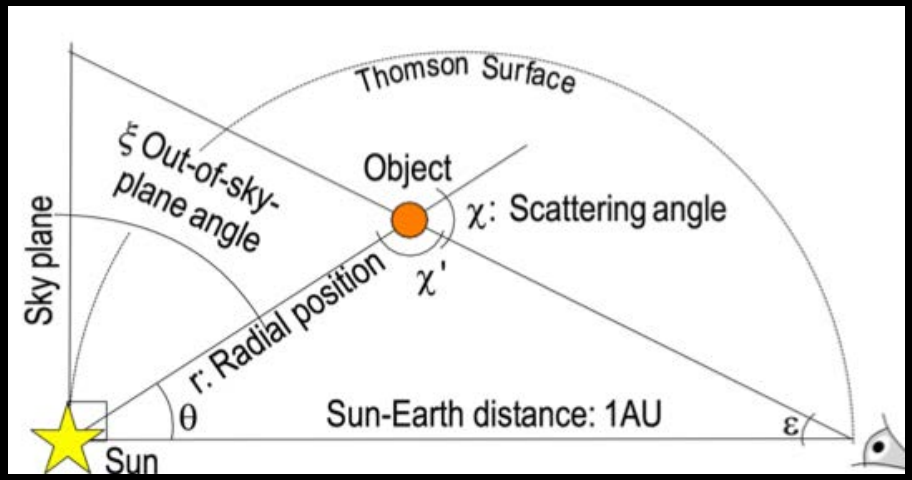
# PSP COMPLEMENTARITY: GLOBAL (TIME/SPACE) ANALYSIS OF LITTLE FLUX ROPES

# 3D IMAGING WITH POLARIZATION

***Scattering physics polarizes light depending on angle.***




***Other angles can be determined from geometry***




***The ratio of polarized brightness in each visible feature thus determines scattering angle.***

**Polarization ratio:**

**PR = (1-p)/(1+p), where p=pB/B**

$$PR = B_R/B_T = 1 - F(r) * \sin^2\chi.$$

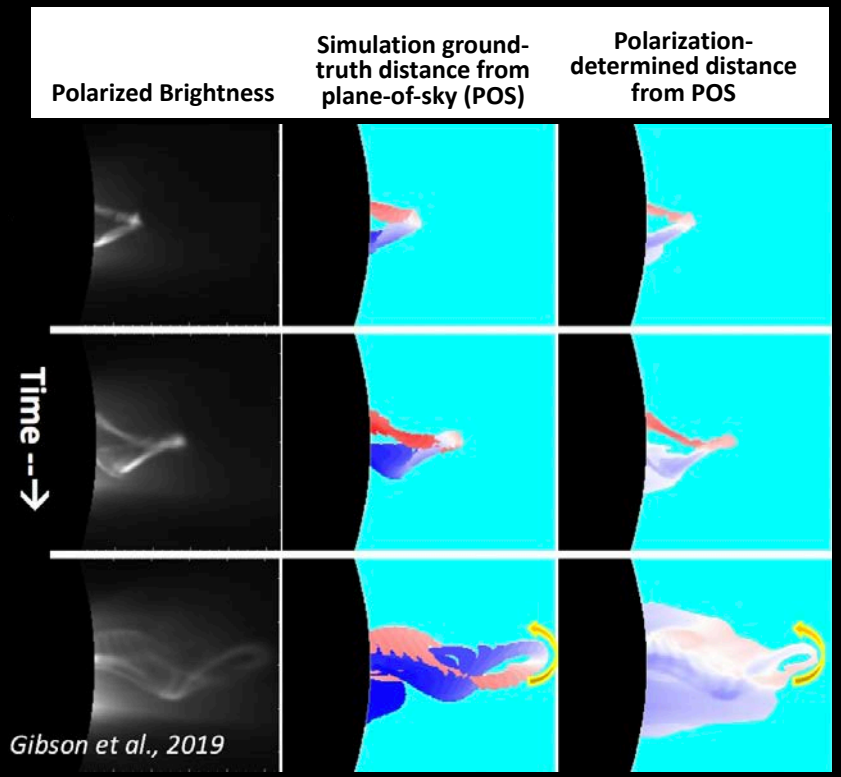
**For a point-source Sun (> 2-3 $R_\odot$):**

$$\chi \approx \text{acos}(\sqrt{PR}).$$

***3D position is fully specified***

- **Y, Z from sky-plane projection**
- **X = r cos θ**

# 3D IMAGING WITH POLARIZATION




Test chirality technique with MHD erupting-flux-rope model (Fan 2018)

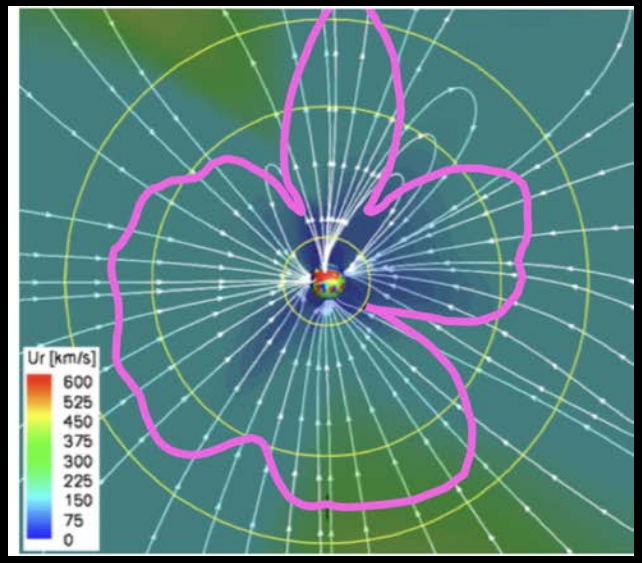
Front (red) vs. back (blue) is clear.

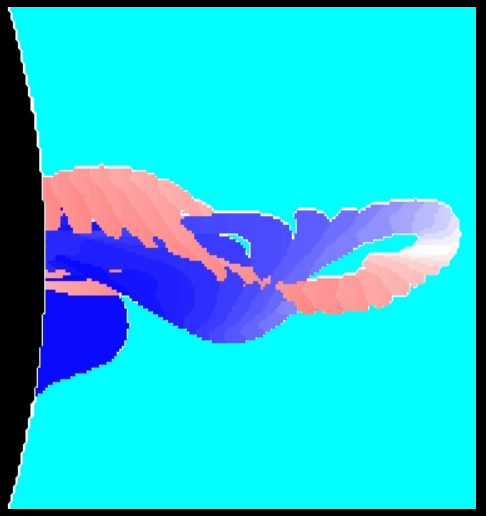
Circulation about axis correctly identifies a left-handed flux rope.

***3D polarized imaging diagnoses chirality!***

CONCLUSIONS

# PUNCH REVEALS THE (OUTER) MIDDLE CORONA



- Sufficient sensitivity for deep-field imaging of flow and Alfvén zone
- Polarization to pin-point and track CME sub-structure and evolution

CONCLUSIONS

# THERE'S MORE!

- Posters Thursday: Robin Colaninno and Glenn Laurent

SH41E-3299 - Wide-Field Imager (WFI) for the Polarimeter to Unify the Corona and Heliosphere (PUNCH)

SH41E-3300 - Narrow Field Imager (NFI) for the Polarimeter to Unify the Corona and Heliosphere (PUNCH)

- Talks Thursday PM: Craig DeForest

A43F-03 - Big Science with Small Satellites: The Polarimeter to UNify the Corona and Heliosphere (Invited)

SH43B-06 - Polarimeter to UNify the Corona and Heliosphere (PUNCH): Imaging the Corona and Solar Wind as a Single System

- E-lightning Wednesday: Lea Griton

SH31B-13 - Transient coronal heating as a source of density fluctuations imaged by STEREO and future space missions

- Poster Friday: Bill Matthaeus

SH53B-3374 - Flocculation, switchbacks, and loss of Alfvenicity: Indicators of shear-driven turbulence in the young solar wind?