Polarimeter to Unify the Corona and Heliosphere

PUNCH-6 Science Meeting

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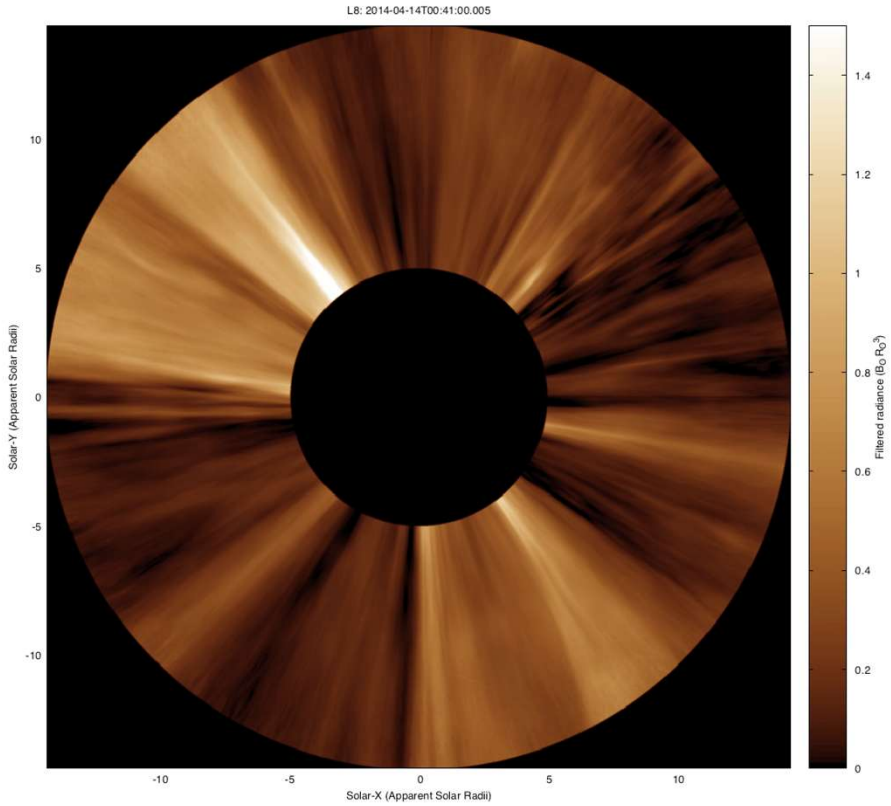
July 7, 2023

Boulder, CO

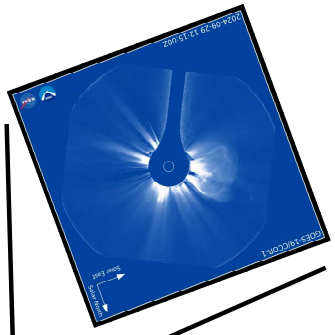
PUNCH Working Group 1B

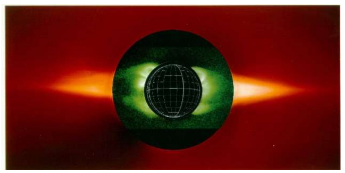
- PUNCH determines how much and what types of mesoscale structures are solar in origin, and how much and what types develops en route (e.g. the ‘quiescent’ but turbulent solar wind session)
- Answering these questions is important for:
  - Understanding solar wind formation
  - Providing critical insight into where and how kinetic energy becomes available to drive a turbulent cascade
  - Understanding the ground state of space weather: the solar wind variability impacting Earth’s magnetosphere and other inner planets on a daily basis. There are no quiet days on the Sun or in the Heliopshere.



DeForest et al. 2018 deep field STEREO campaign is similar to PUNCH/NFI’s resolution, demonstrating the structured solar wind PUNCH will measure

The Inner Heliosphere is Enormous!

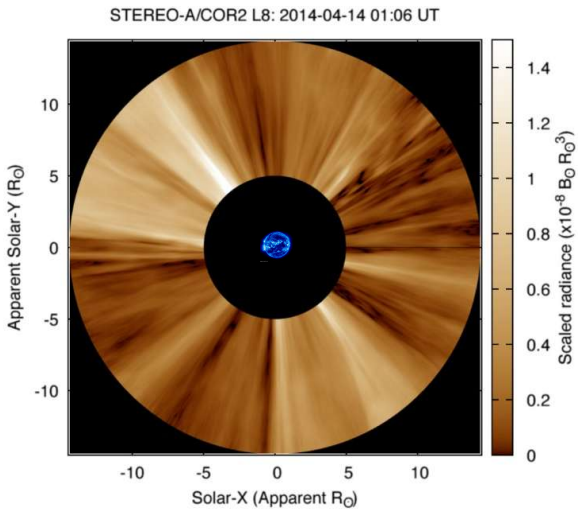




93 million miles, several days and
a whole lot of physical processes

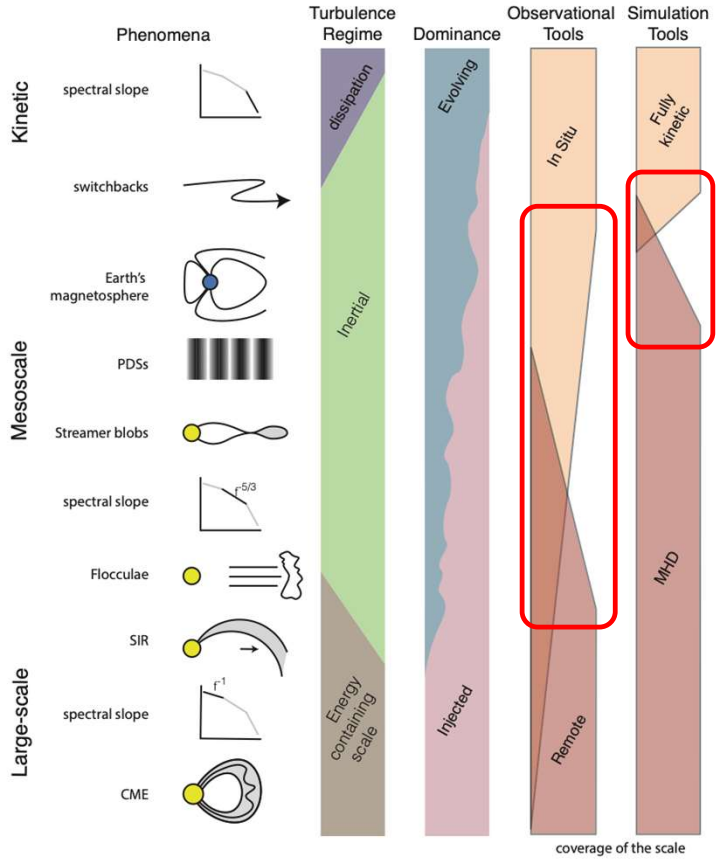
Earth

Mesoscale solar wind structures: they are tiny compared to the inner heliosphere and existing imagers



DeForest et al. 2018

Spans ~ **8 orders of magnitude** in the inner heliosphere



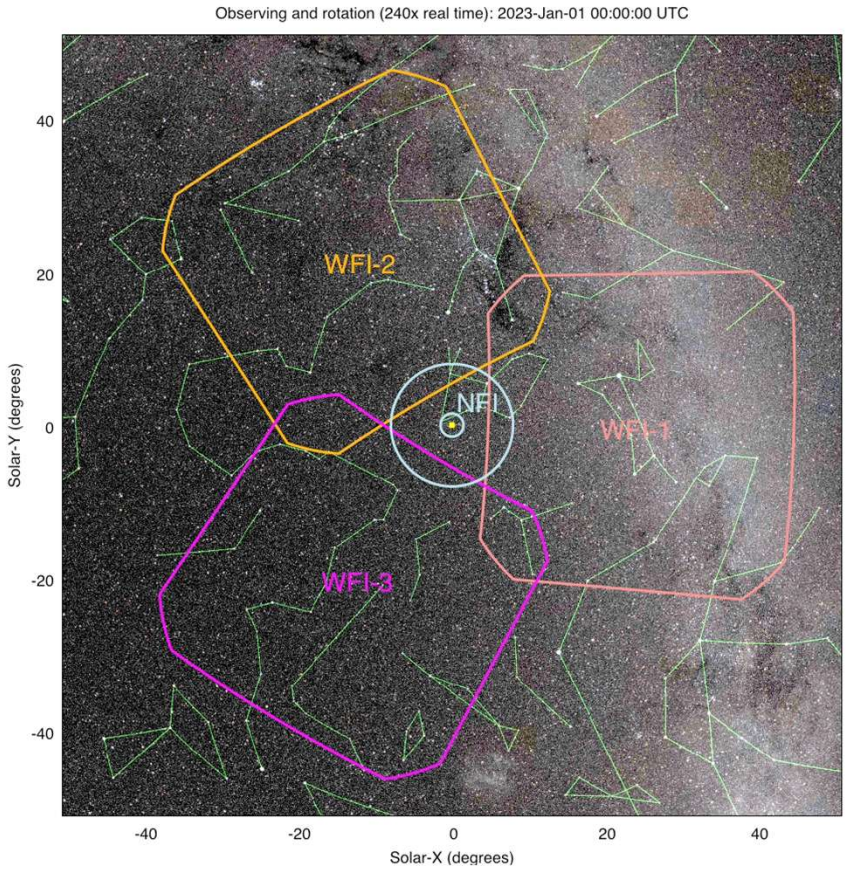
Viall, DeForest, and Kepko, 2021

Current Observations and Simulations are missing the Mesoscales

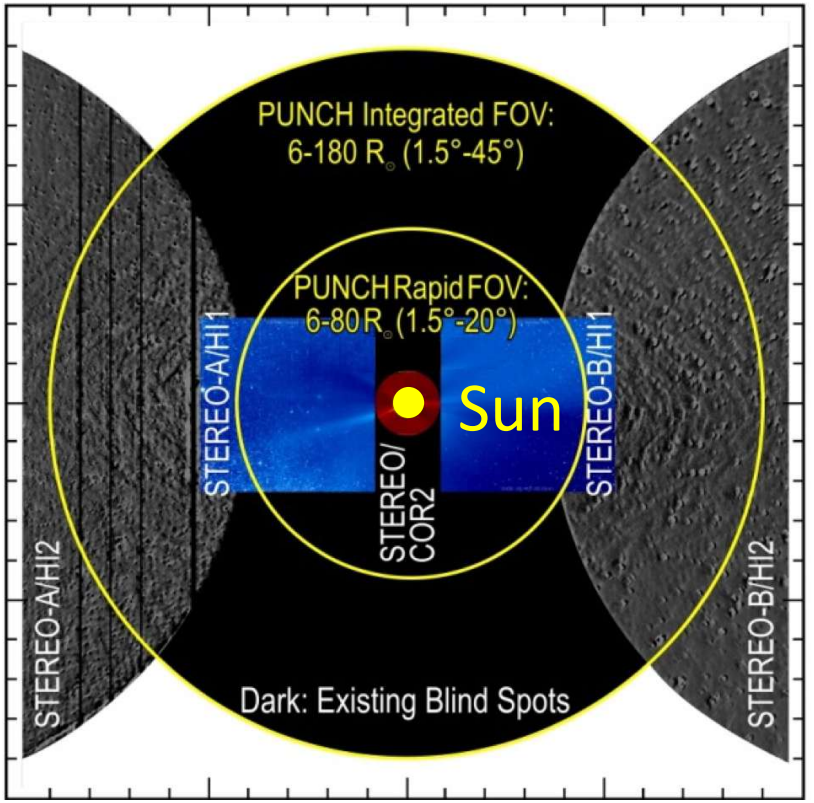
PUNCH fills in this gap!

1 Solar Radii = 0.25 degrees
PUNCH resolution requirement inner is 3' ~ 140 Mm
140 Mm advecting at 400 km/s = 350s (6 minutes)

Polarimeter to UNify the Corona and Heliosphere (PUNCH)

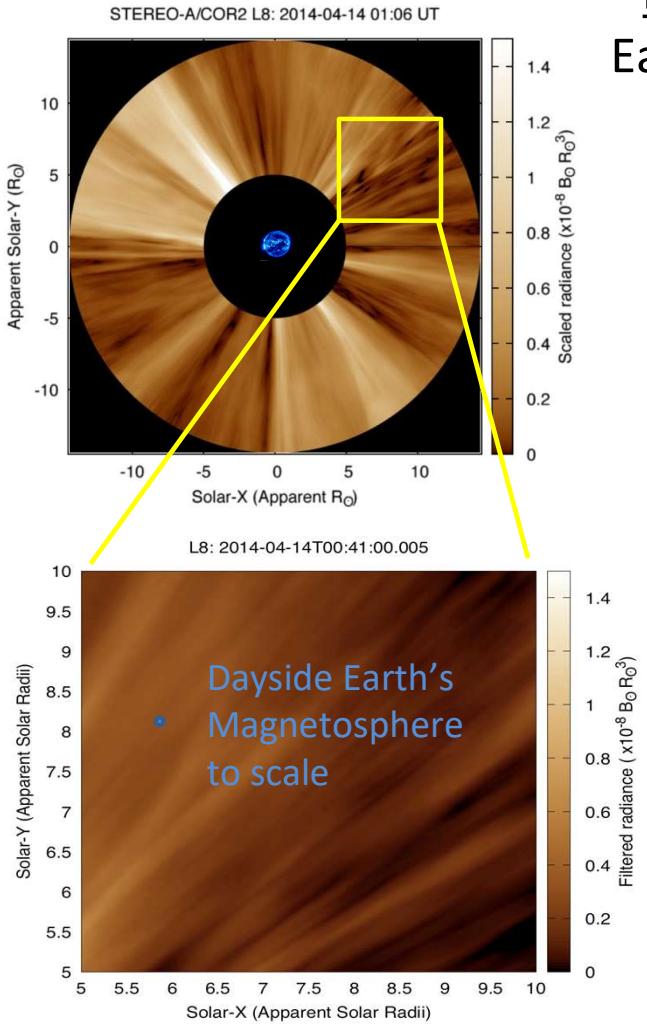


- Each flash: complete white light polarization sequence
- Green circle: 4-min cadence coverage inside ~80 solar radii



2017 total solar eclipse from Oregon

Mesoscale solar wind structures: they are large compared to Earth's magnetosphere, thus are important drivers of Geospace.



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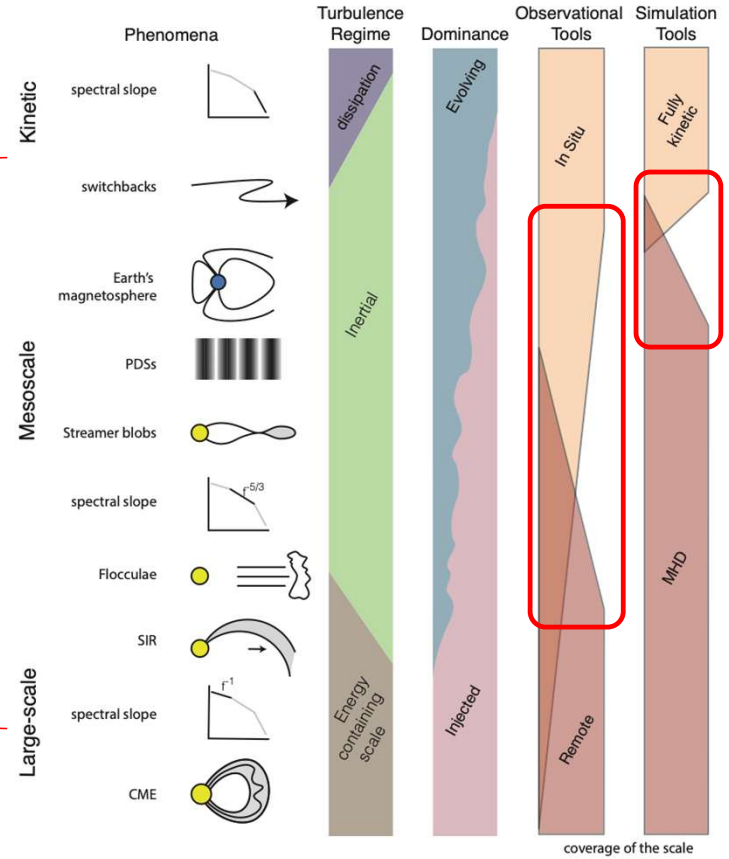

Viall, DeForest, and Kepko, 2021

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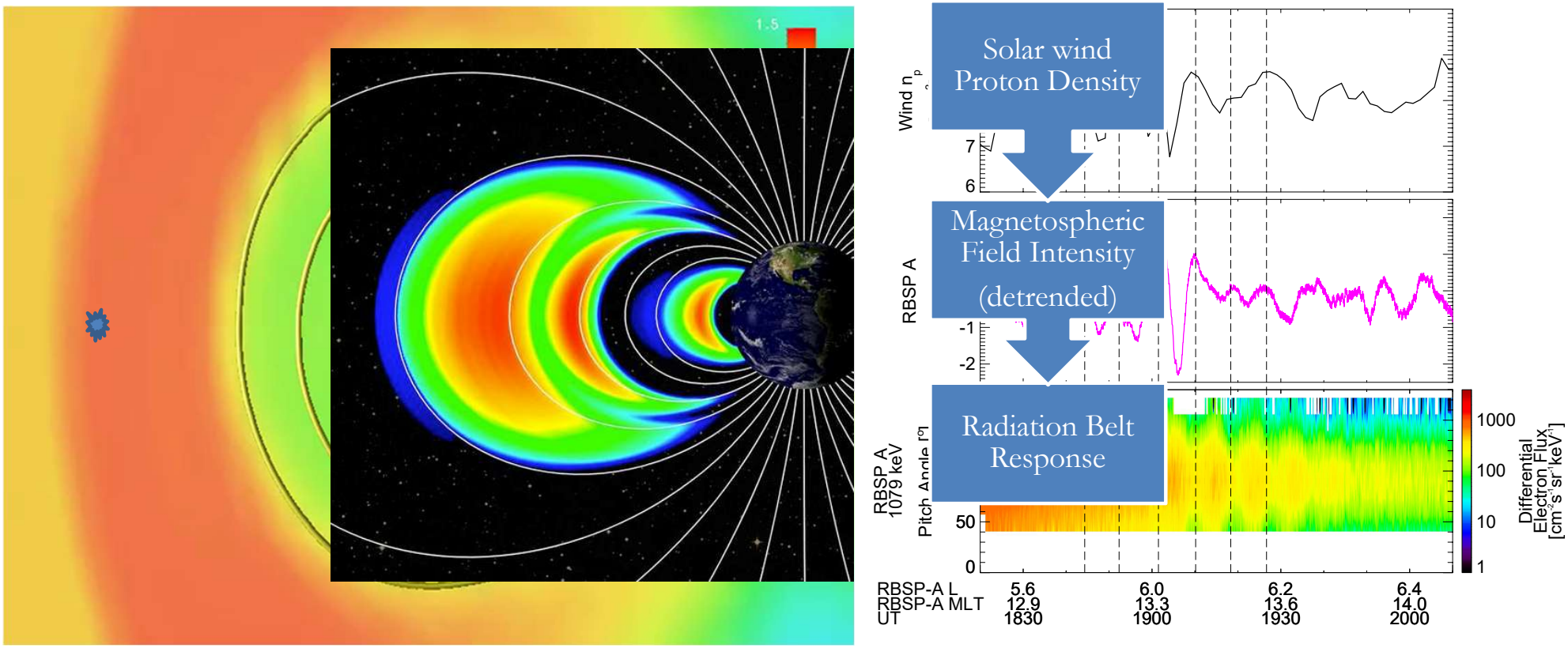
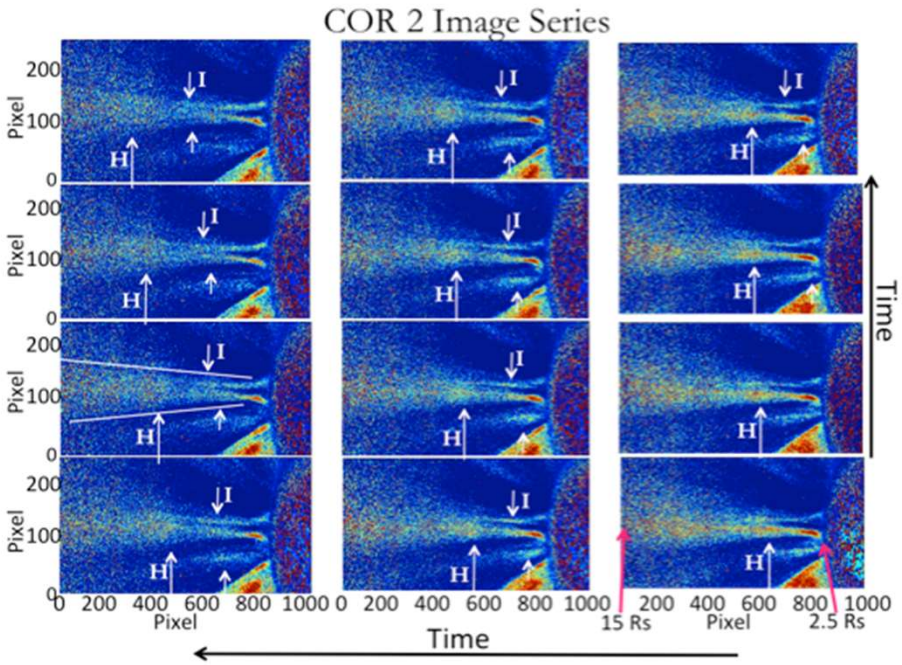
Fundamental science for real world impacts:
One type of mesoscale solar wind structures, Periodic Density Structures, drive ULF waves in the magnetosphere and lead to periodic particle precipitation into Earth's atmosphere



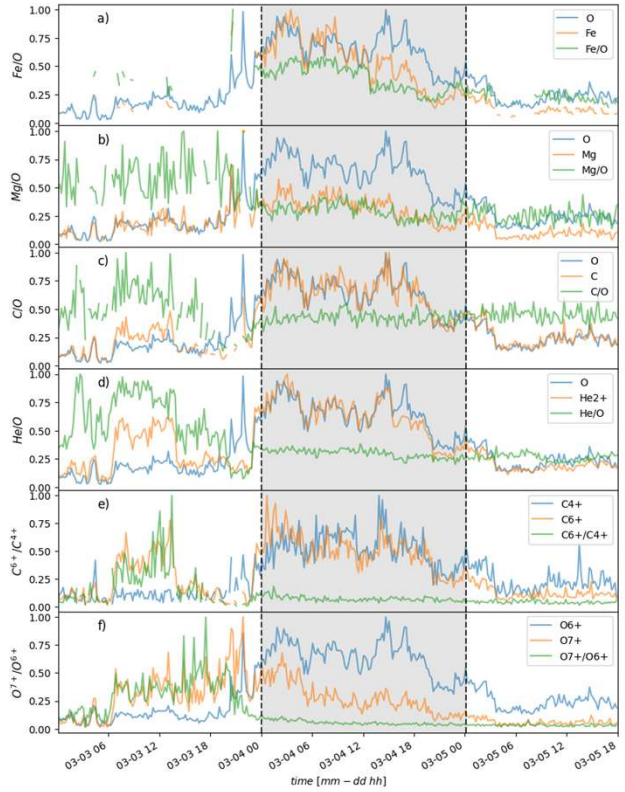
L. Kurien, S. Kanekal, DiMatteo, A. Greeley, Schiller, Shumko, Viall and Kepko, 2024

Large-scale (~1-2 hour) Periodic Solar Wind Density Structures Come from the Sun and survive to 1 AU: PUNCH will Measure their evolution through the inner heliosphere



Viall & Vourlidas 2015

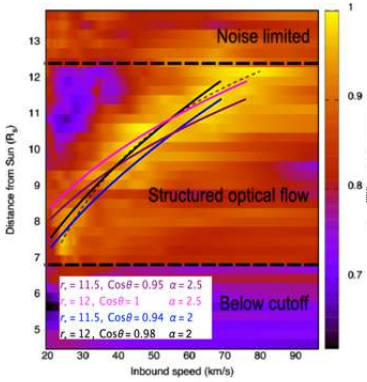
STEREO COR2/HI1 shows solar wind periodic mesoscale structures have a characteristic periodicity ~1-2 hours, and are formed at the HCS/helmet streamers



Elemental abundance variations measured by ACE shows that Earth-impacting solar wind periodic mesoscale structures were formed in the corona (Gershkovich et al. 2022). Gershkovich, Lepri, Viall, Kepko and DiMatteo, (Solar Physics, 2023) found ~ 90 min, and ~30min to be characteristic periodicities in ACE statistics

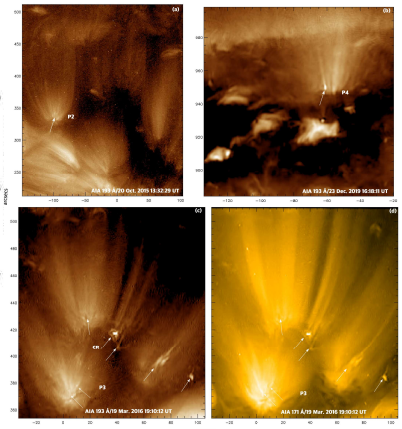
Magnetic Reconnection in the Solar Corona Creates a Plethora of Structures in the Heliosphere: Enormous Range of Conditions and Consequences

Nanoflares



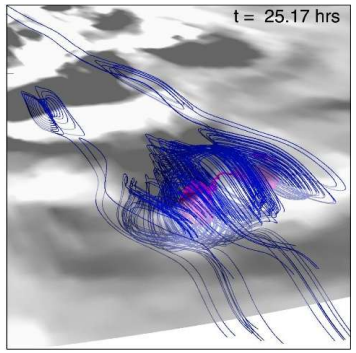
e.g. DeForest et al. 2014
Tenerani et al. 2016

Jets/Jetlets/plumes



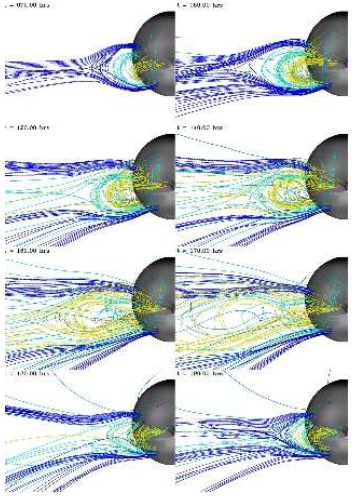
e.g. Kumar et al. 2022
Raouafi & Stenborg 2014

Helmet Streamer Blobs



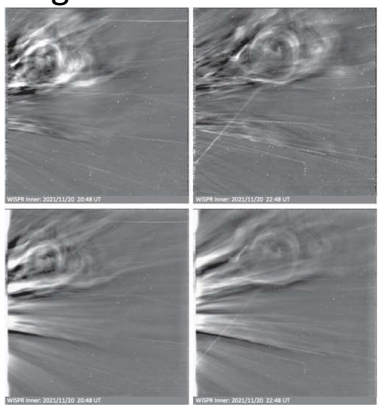
e.g. Rouillard et al.
Higginson et al. 2018

Stealth CMEs



e.g. Lynch et al. 2016
Palmerio et al.

Big Flares and CMEs

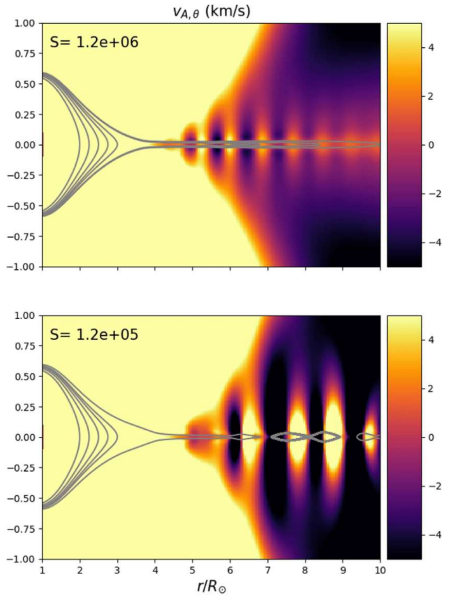


e.g. Howard et al. 2022
PSP/WISPR CME

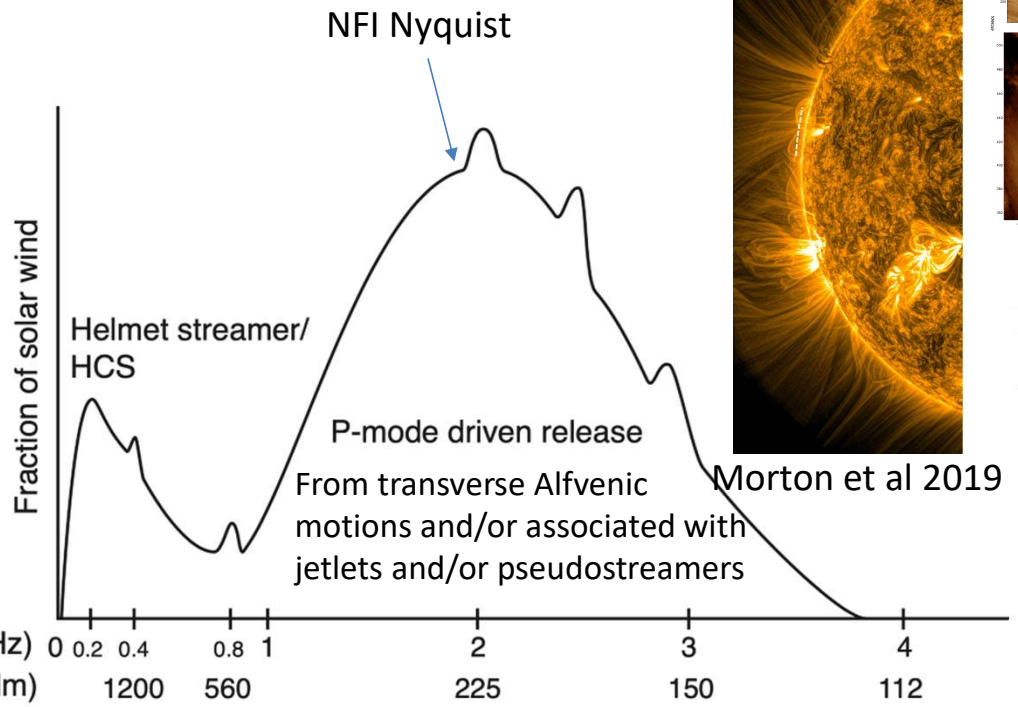
All examples of coronal reconnection, but there are enormous differences in:

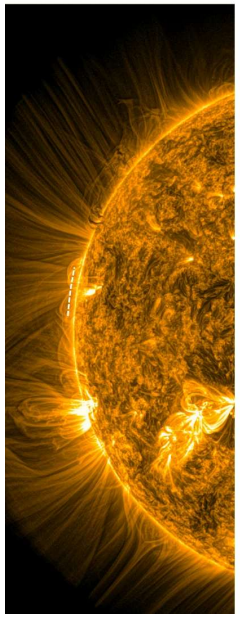
- Magnetic topology - component reconnection; interchange reconnection; anemone; antiparallel
- Energy injection – small-scale flux emergence, AR-scale flux emergence, foot point mixing/shear on granular scales, foot point mixing/shear on super granular scales, shear from differential rotation…
- Energy released - spans nine (at least) orders of magnitude
- Mass released into the heliosphere – zero (open-open reconnection), 10^8 kg (Raouafi 2023 jetlets), up through 10^13 kg (CMEs)
- Periodicities – random/red noise, 3-5 min, 90 min, singular

(at least) Two kinds of periodic reconnection-released solar wind; PUNCH will image many of these structures

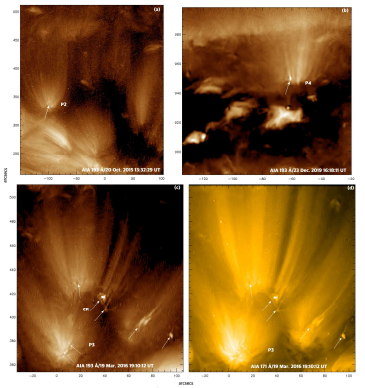


Reville et al. 2022

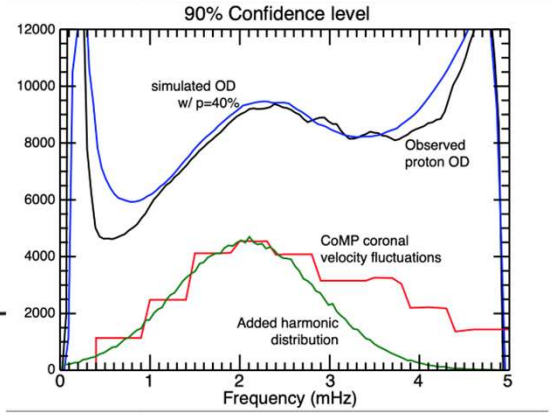




Morton et al 2019



Kumar et al 2022



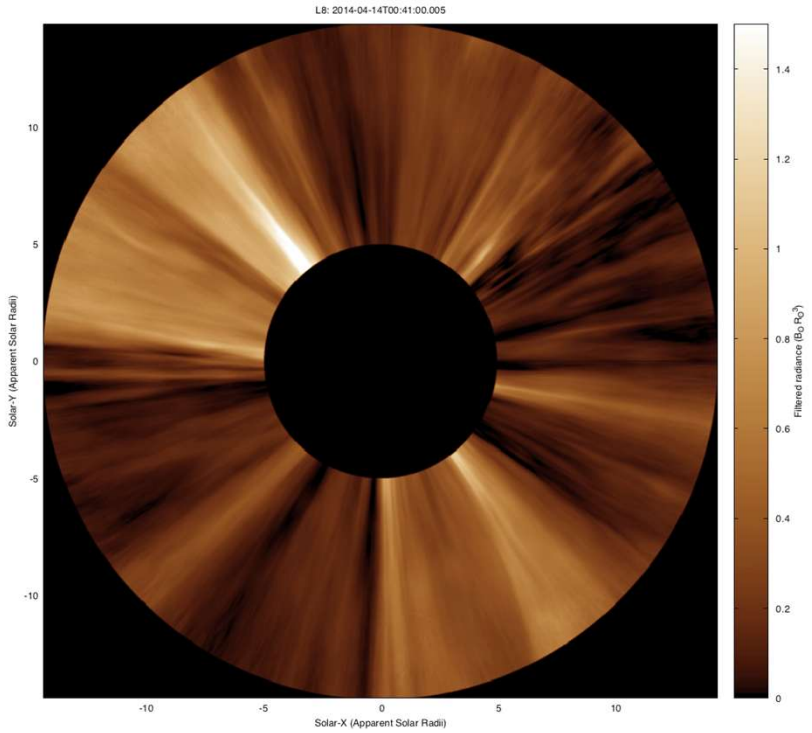
Kepko, Viall and DiMatteo, 2024

PUNCH's SNR and Resolution will Provide Measurements of the ground state of space weather

PUNCH will image Streamers Blobs, Periodic Density Structures, Pseudostreamer outflows, Plumes, and Jet/Jetlet outflows.

PUNCH will also determine the creation and evolution of turbulence en route to 1 AU. (see Yan Yang's poster; Bill's talk)

PUNCH will determine the relationship and interplay between the two.



PUNCH will image the formation and evolution of the ground state of space weather