Polarimeter to Unify the Corona and Heliosphere

WG 1C Overview:

How will PUNCH map the Sun's Alfvén surface/zone/region?

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PUNCH Science Meeting
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The Zoomiverse

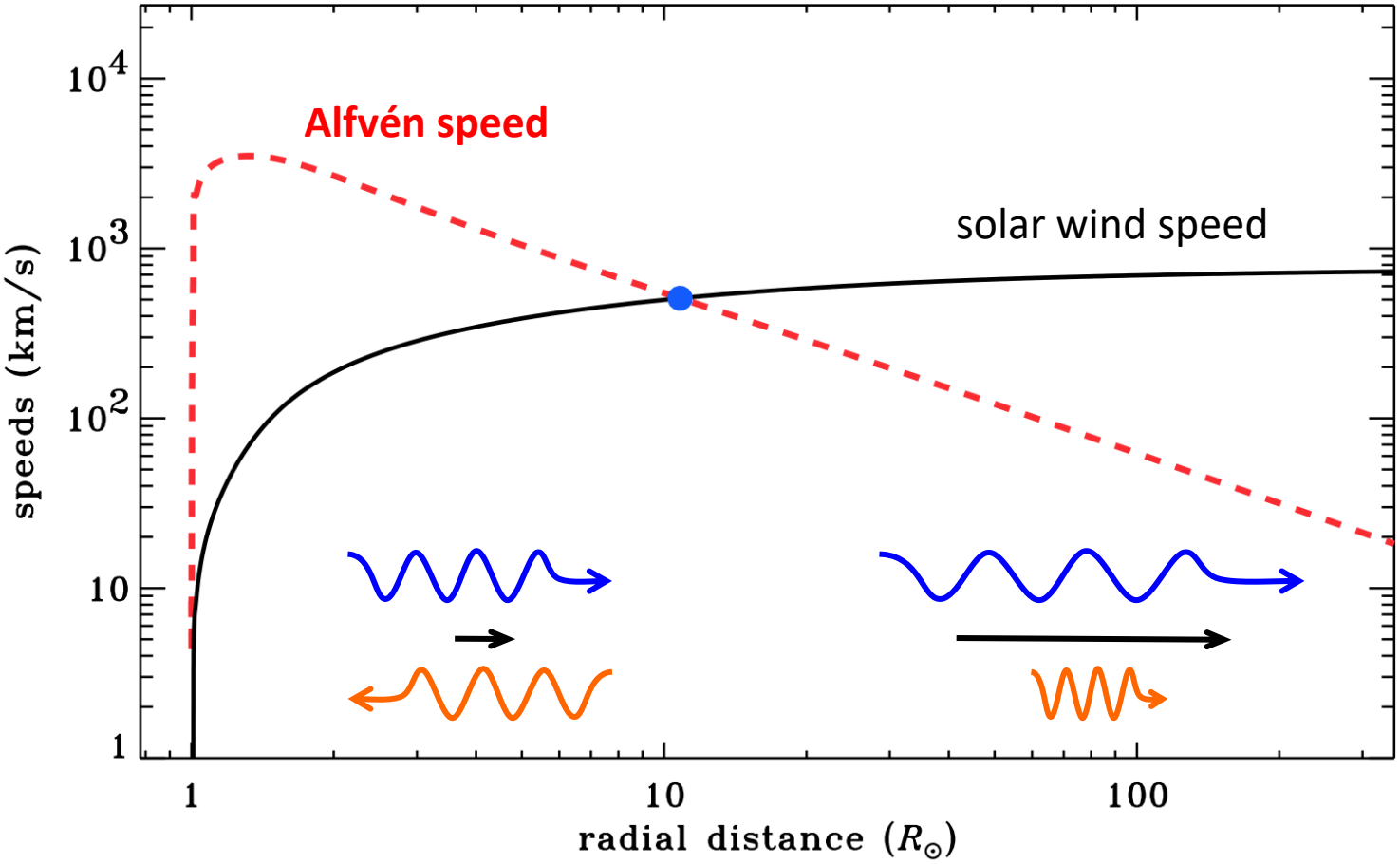
Outline

1. What is the Alfvén surface? Why is it important?
2. Where do we expect to find the Alfvén surface?
3. What have existing imaging data told us (*SOHO, STEREO*)?
4. What can we accomplish with PUNCH?

Corona vs. wind: where's the boundary?

Corona vs. wind: where's the boundary?

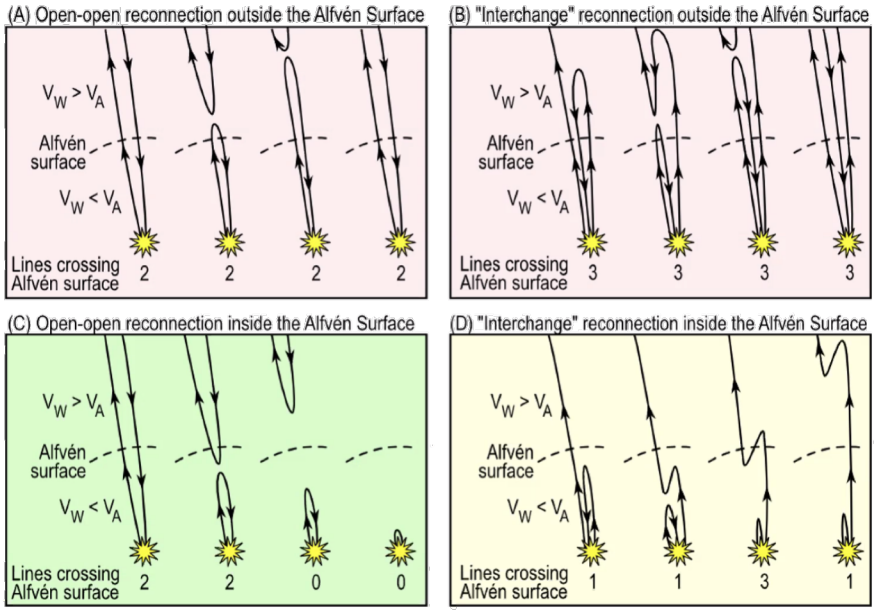
- The Alfvén surface is a useful place to draw that distinction...



Why is it important?

- Below r_A, information (waves) can propagate both in & out. Above r_A, solar wind drags out both inward & outward modes, and nothing can propagate back down to the Sun.

- If field lines can't retract back down to the Sun above r_A, it's going to be rare to find closed fields there. Essentially the heliosphere's "source surface."

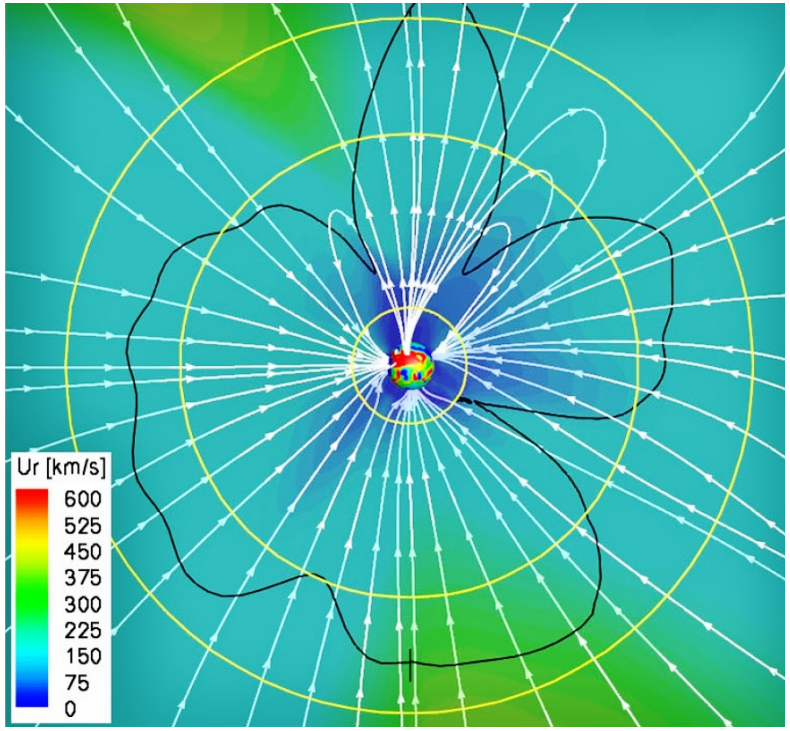


- It's the angular momentum "lever-arm" of the corona.
  Below r_A, the magnetic field maintains ~rigid rotation.
  Above r_A, ang. mom. is conserved & the Parker spiral trails...

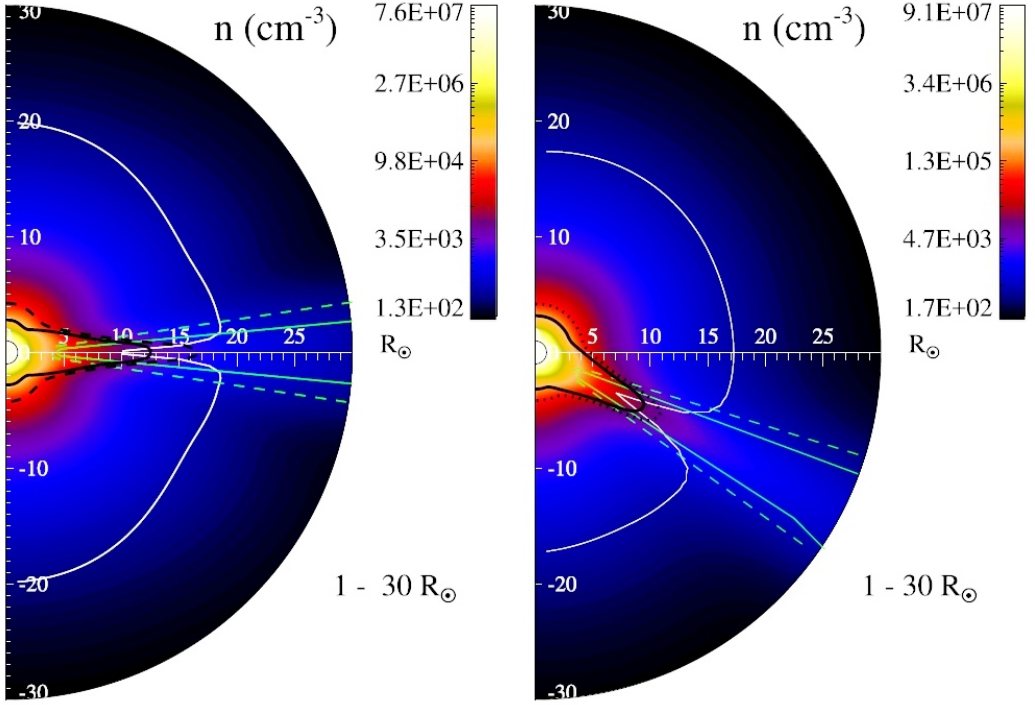
- Measuring the wind speed at r_A gives us V_A, which puts constraints on the magnetic field & density there.

2. Where is the Alfvén surface?

- Even in time-steady models, it's never just a constant radius:

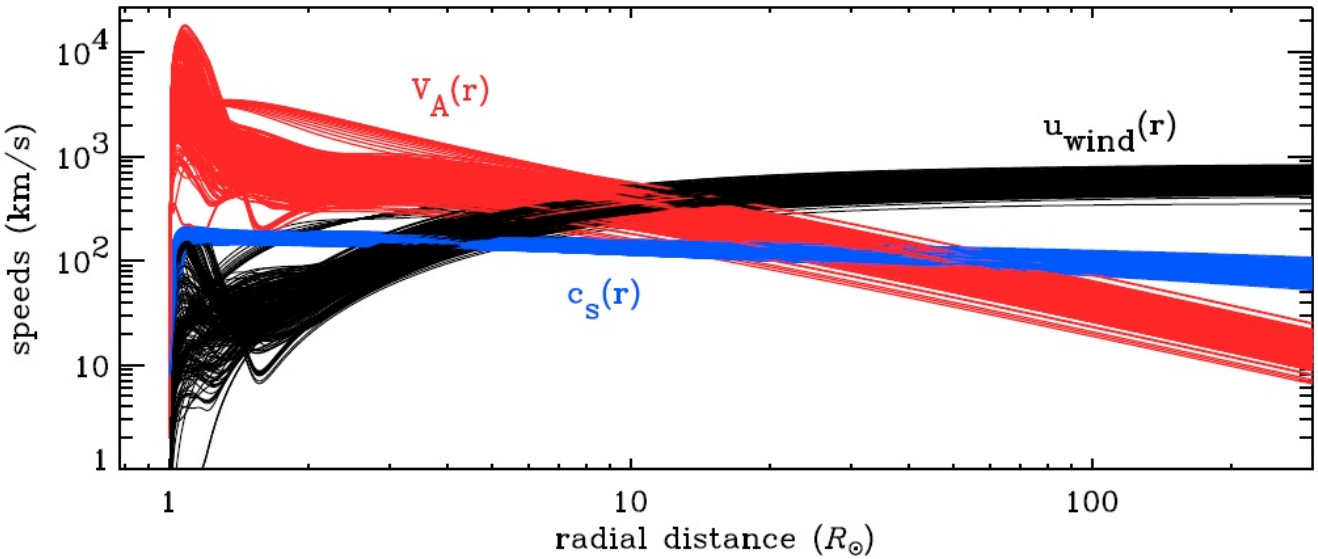


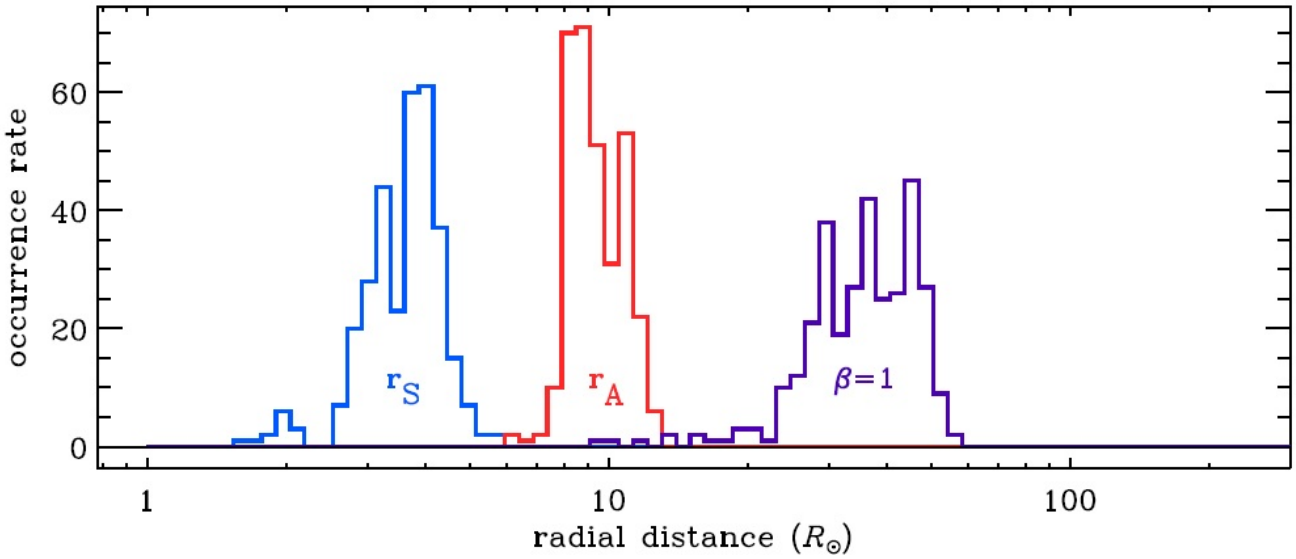
Cohen (2015)
solar max. (black contour)



Chhiber et al. (2019)
solar min. (white contours)

2. Where is the Alfvén surface?



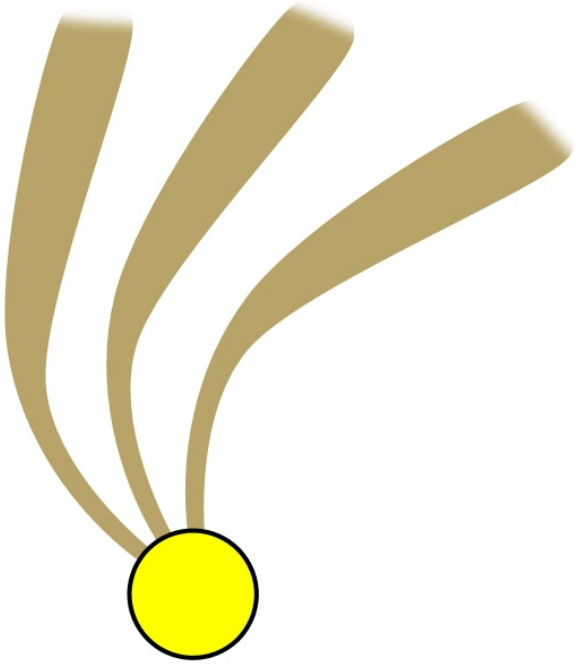


319 ZEPHYR models Cranmer et al. (2007, 2013)

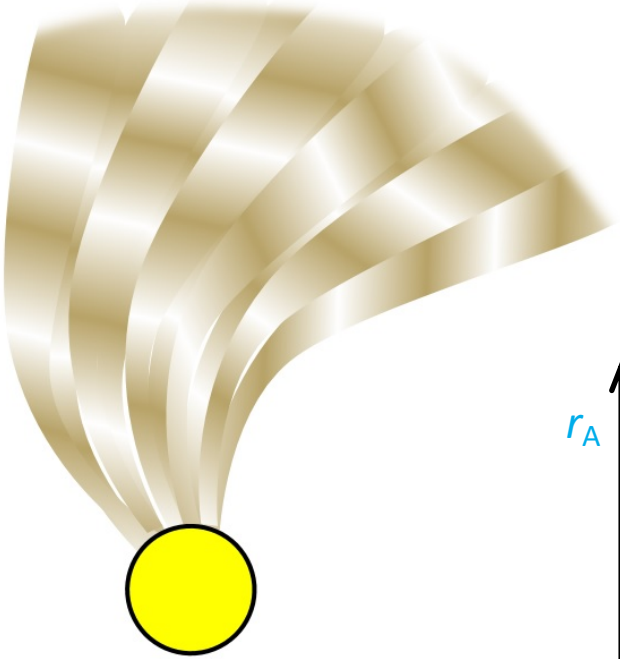
Extrapolating inward from OMNI data at 1 AU gives ~comparable distributions

2. Where is the Alfvén surface?

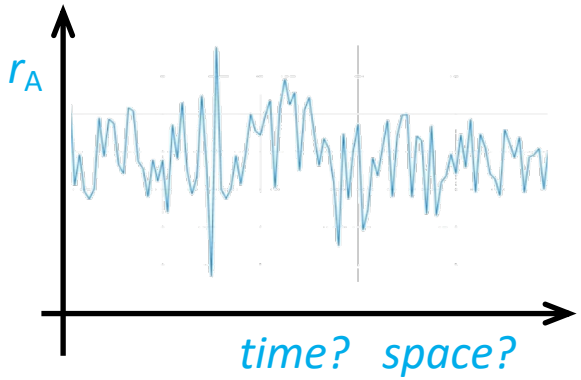
- Time/space inhomogeneity turns it into a frothy "Alfvén zone."
- Along a given radial line, maybe there are >1 points where $u=V_A$



field-aligned "striations"

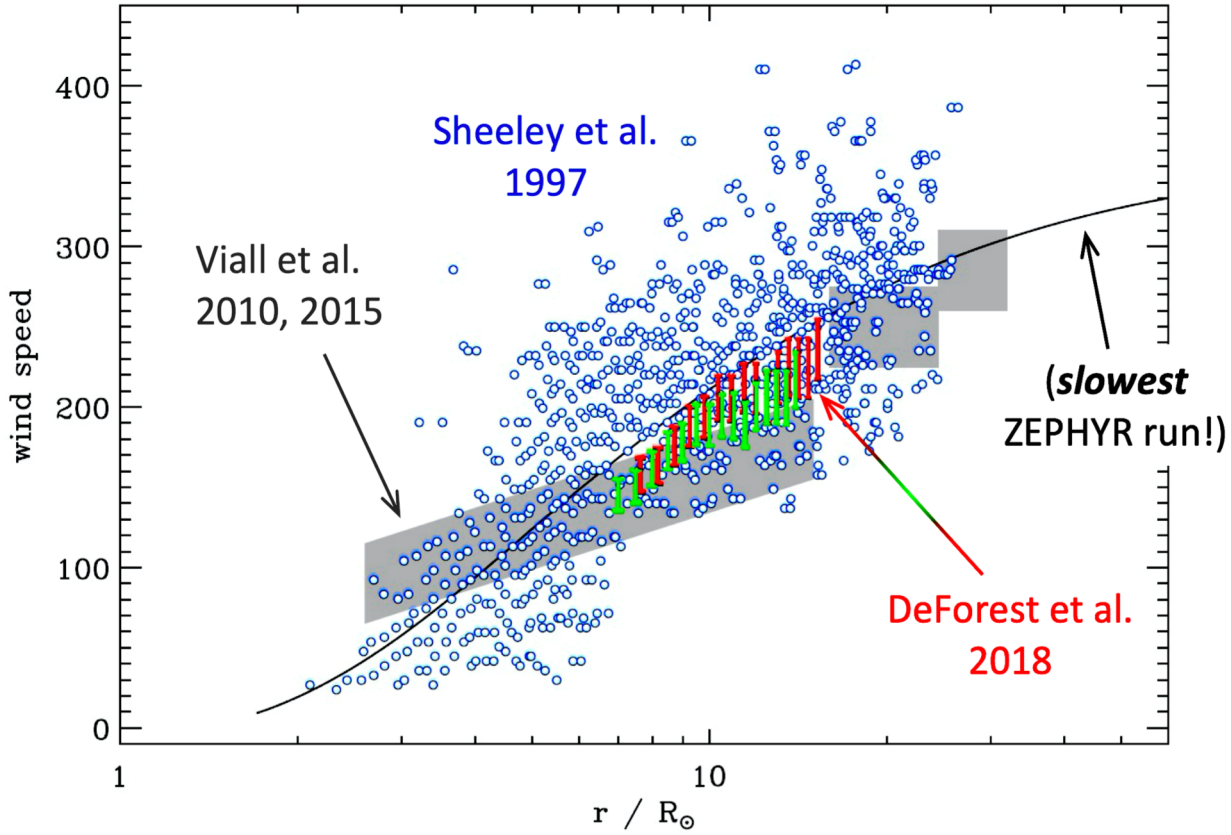


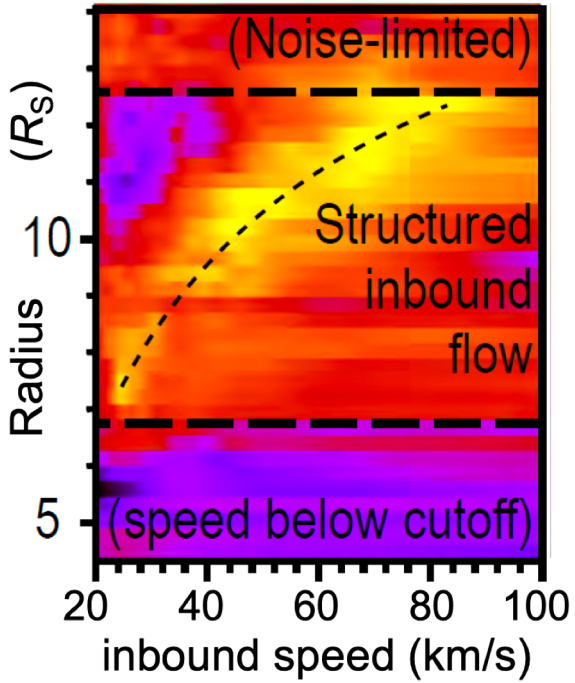
blobs, puffs, shocks, waves, jets, etc.



3. What have existing data told us?

- Coronagraphs & heliospheric imagers provide both outflow & inflow speeds, but data so far have been sporadic & noisy…

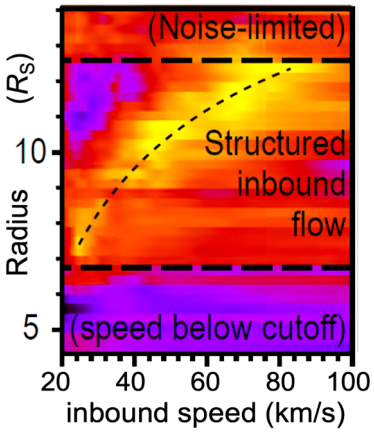




DeForest et al. 2014

3. What have existing data told us?

Explanations for the decelerating inflows...



- Tenerani et al. (2016) ruled out linear **MHD waves,** but we still need to investigate waves undergoing *refraction* through the complex/striated background corona.
- **Reconnection** exhausts/blobs that "snowplow" after they are ejected high in the corona? Initially super-Alfvénic ($M_A > 1$)?
  New models explore parameters (Cranmer et al. 2021, ApJ, 913, 4)
- 3D wavenumber distribution of compressible MHD **turbulence**... with the visibility along some directions enhanced relative to others (LOS-scattering "caustics")?

A lot more modeling is needed!

4. What can we accomplish with PUNCH?

- The main goal is to map the Alfvén surface as a function of time, solar activity, fast-vs-slow acceleration mechanisms, etc.

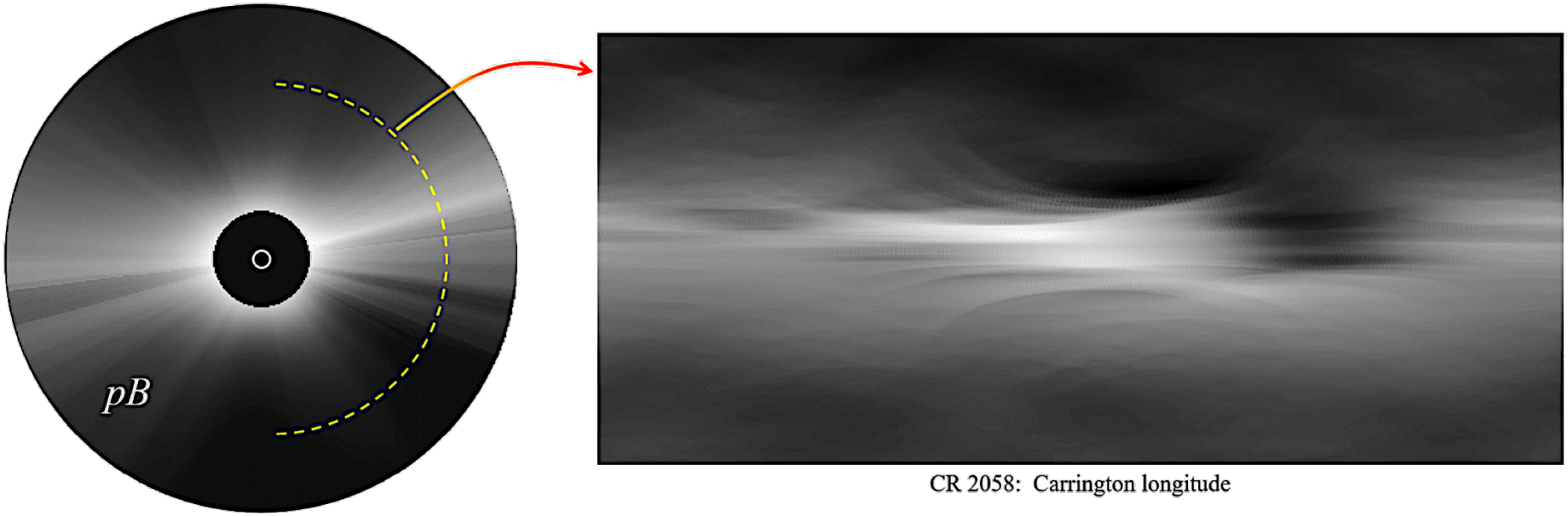
- Below r_A: NFI will obtain a large database of "inflow ridges" (r vs. v) for the full range of solar-wind source regions.

- Above r_A: can PUNCH detect <u>*both*</u> $(u + V_A)$ and $(u - V_A)$ outwardly propagating modes?

- Can we extract $\delta I/I_0$ (or $\delta pB/pB_0$) from PUNCH data?
  It could tell us a lot about the "parcels" moving up & down.

4. What can we accomplish with PUNCH?

- Line-of-sight projection effects need to be understood with forward models, in which 3D "ground truth" is known.
- Example 3D → pB testbed model of solar rotation + radial striations mapped from high-resolution magnetograms.



Next step: blobs… see AI talk by Chris Gilly (Wed., August 11, 8:00am PDT)

WG 1C Science Team Members

Scientist	Role
Steven Cranmer	WG leader; Solar wind theory; Interpretation of solar wind data
Robin Colaninno	Coronal structure
Craig DeForest	Alfven surface measurement and interpretation
Sarah Gibson	Working Group coordination
Dusan Odstrcil	Modeling of solar wind structure
David McComas	Solar wind structure; Analysis of Alfven surface location and effects; PSP coordination
Nour-Eddine Raouafi	Corona-wind relation; image analysis; Analyze small-scale structures, plumes, and jets in the solar corona; PSP liason
Iver Cairns	Solar wind structure; Coordination with radio observations