

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
December 3, 2020
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?

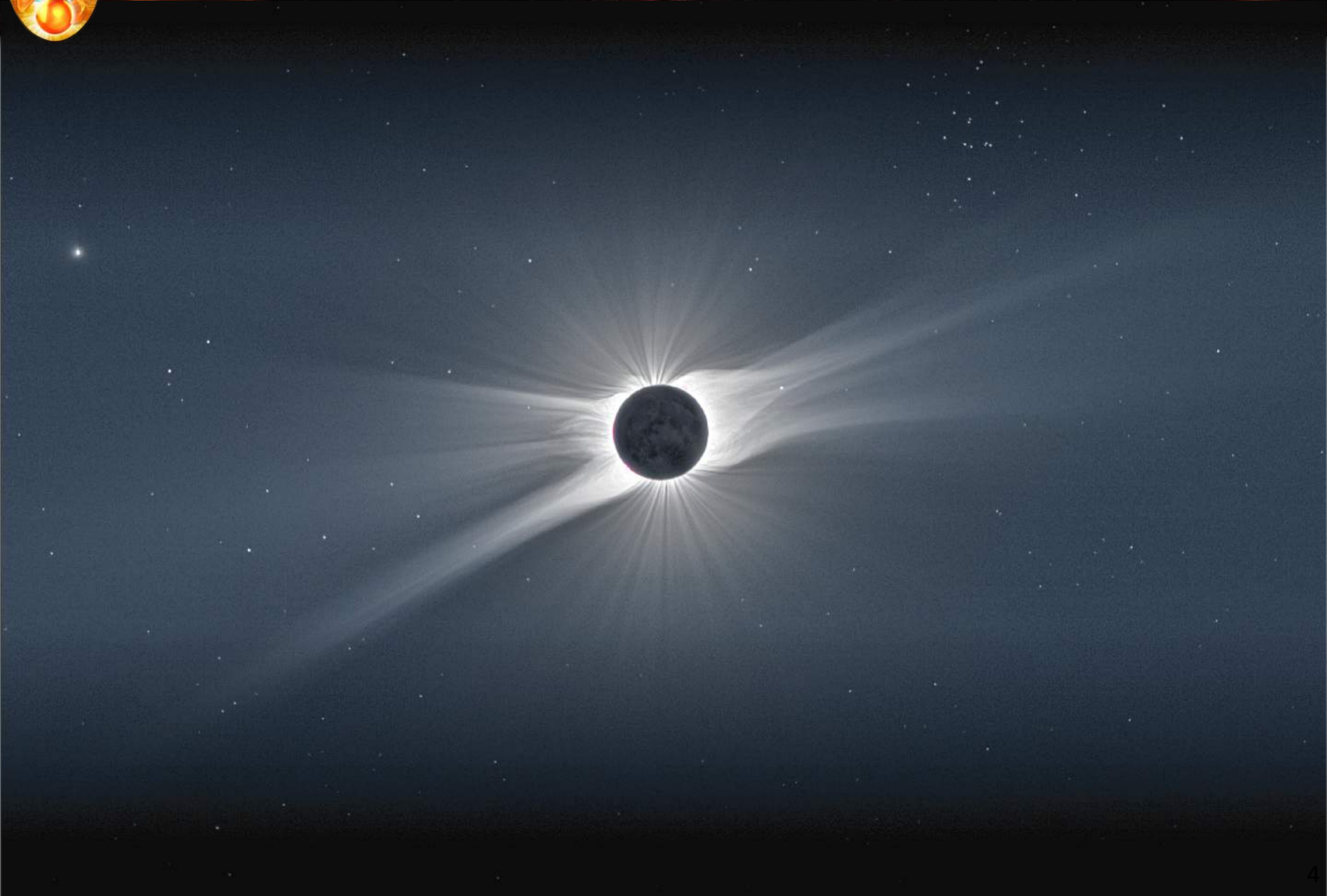


WG 1C Science Team Members

<u>Scientist</u>	<u>Role</u>
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



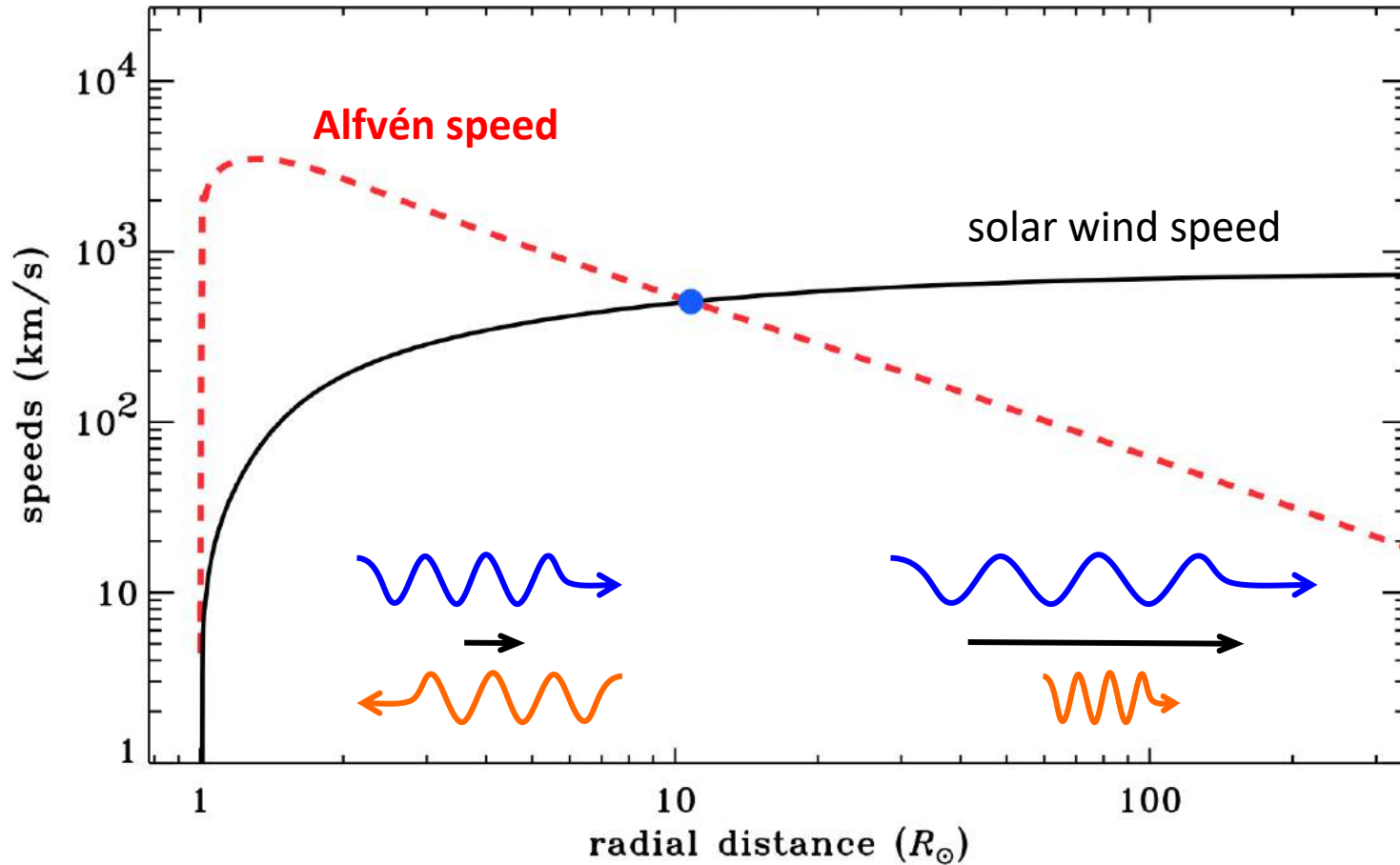
Corona vs. wind: where's the boundary?





Corona vs. wind: where's the boundary?

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





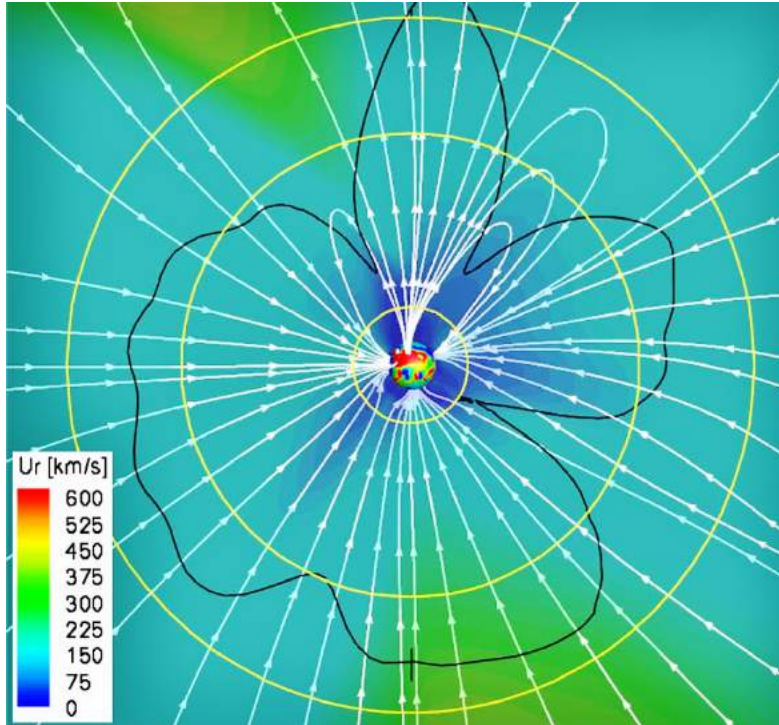
Why is it important?

- Below r_A , information (waves) can propagate both in & out. Above r_A , the solar wind drags out both inward & outward modes, and nothing can propagate back down to the Sun.
- If field lines cannot retract back down to the Sun, (I think) this means there can be no closed fields above r_A . Thus, it's the true "source surface" of the heliosphere.
- It's the angular momentum "lever-arm" of the corona. Below r_A , the magnetic field maintains \sim 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.

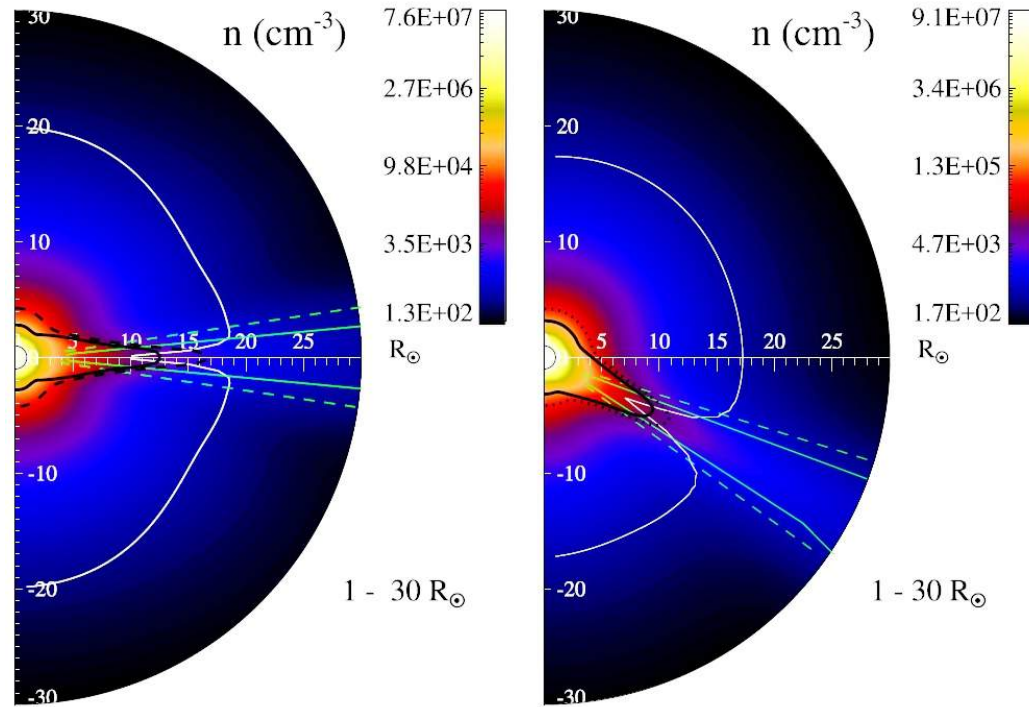


2. Where is the Alfvén surface?

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



Cohen (2015)
solar max. (black contour)

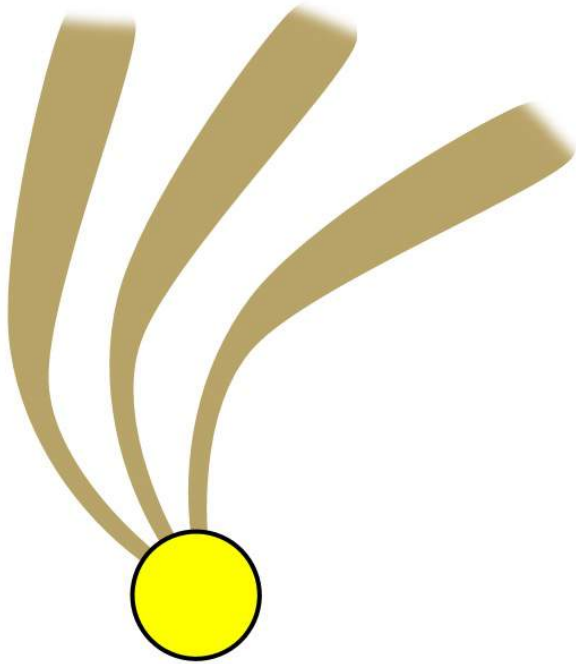


Chhiber et al. (2019)
solar min. (white contours)

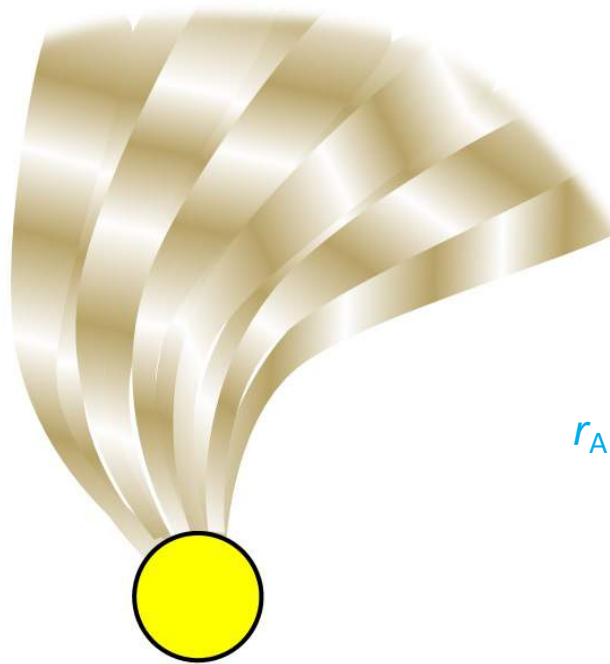


2. Where is the Alfvén surface?

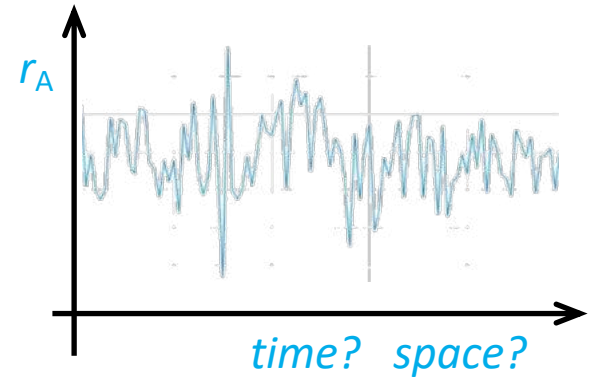
- Time/space inhomogeneity turns it into a frothy “Alfvén zone.”
- Along a given radial line, maybe there are >1 points where $u=V_A$



field-aligned
“striations”

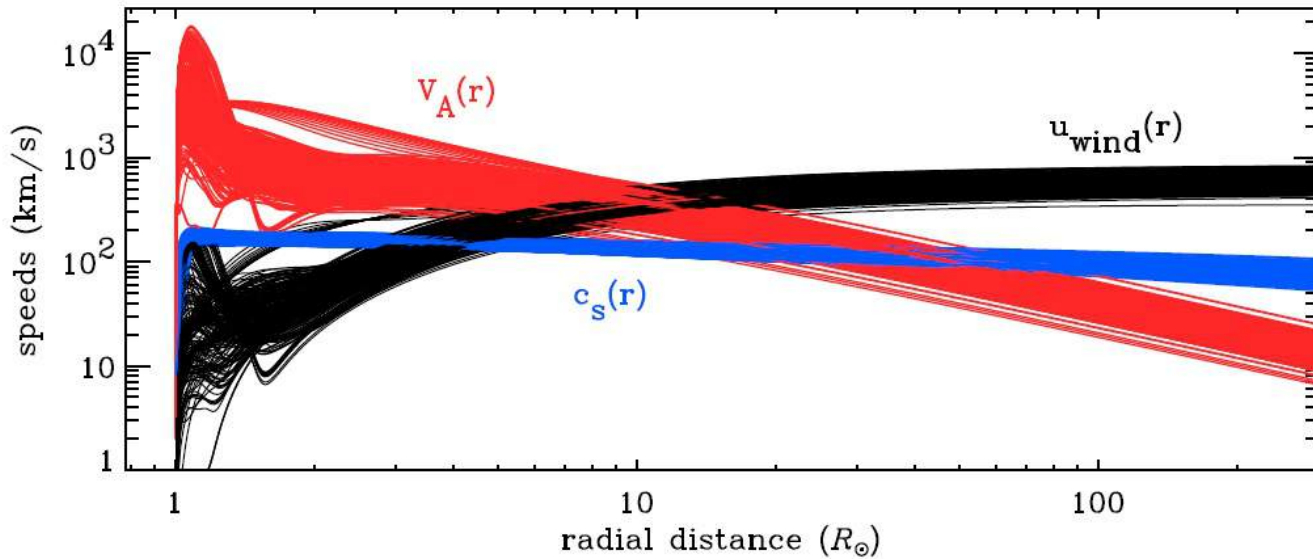


blobs, puffs, shocks,
waves, jets, etc.

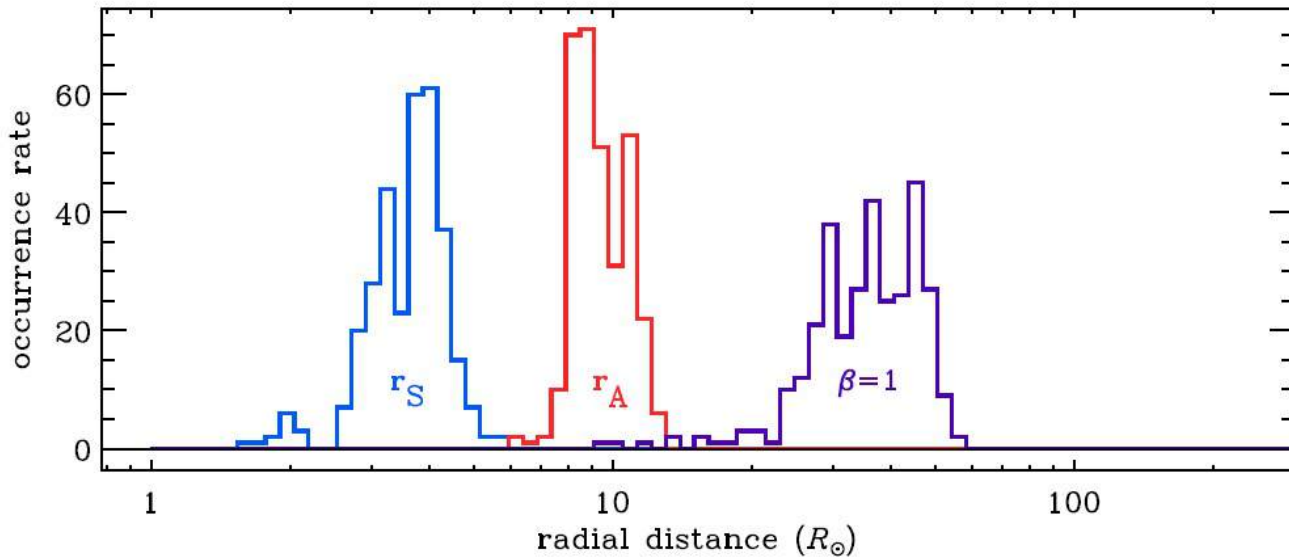




2. Where is the Alfvén surface?



318
ZEPHYR
models
Cranmer et al.
(2007, 2013)

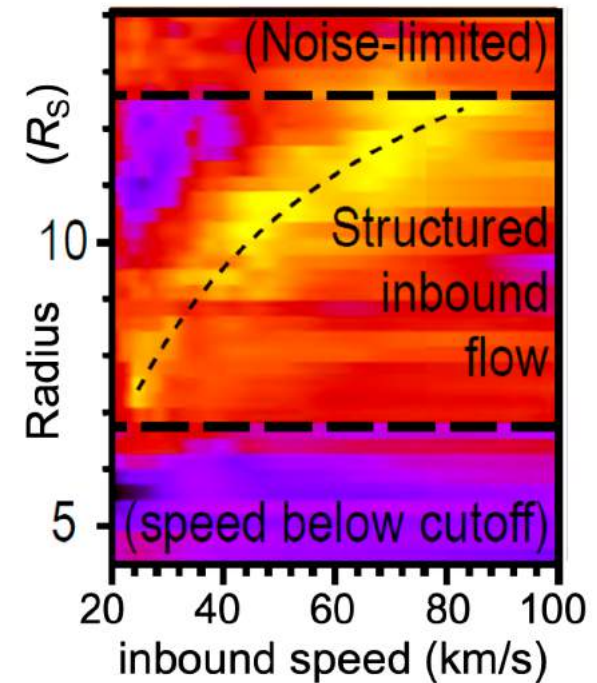
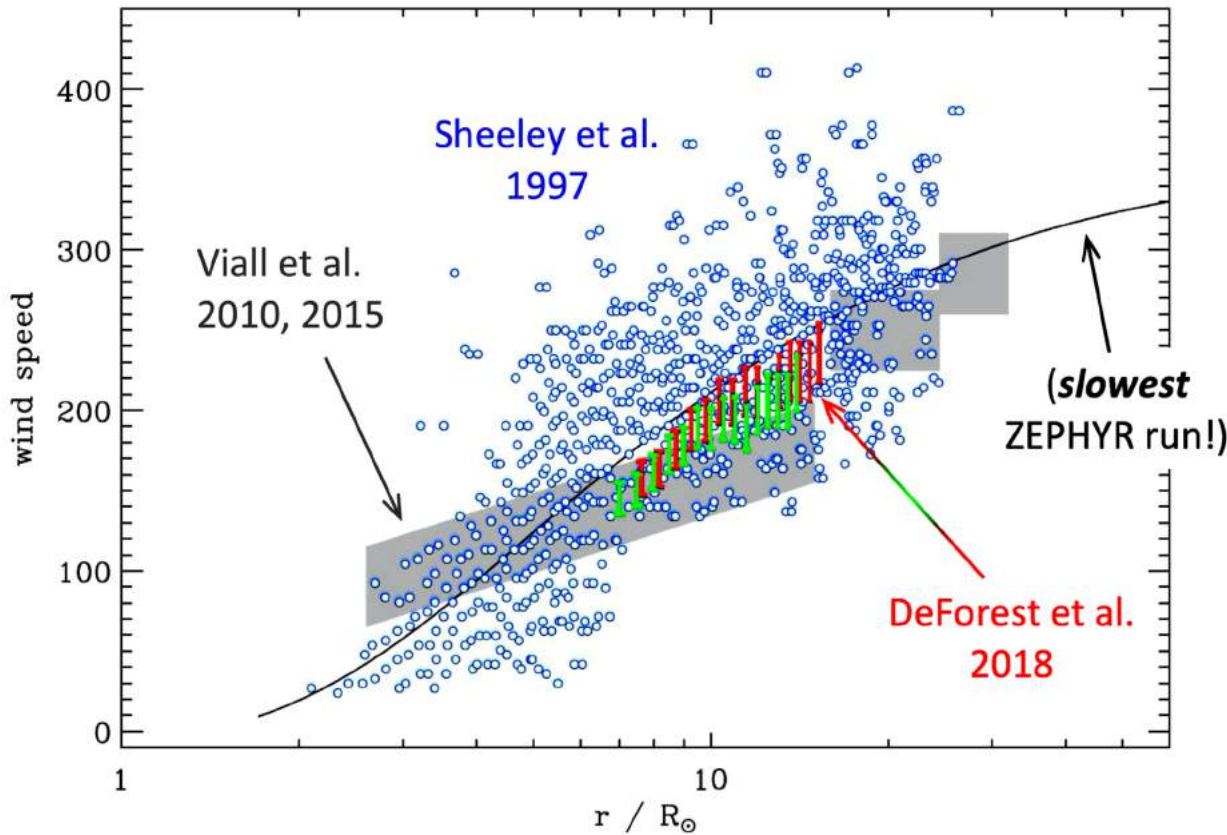


Extrapolating
inward from
OMNI data
at 1 AU gives
~comparable
distributions



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 ($M_A > 1$)?
- 3D wavenumber distribution of compressible MHD **turbulence**... with the visibility along some directions enhanced relative to others (LOS-scattering "caustics")?
- Thermal **conduction fronts** (as suggested for polar jets)?

A lot more modeling is needed...

2021 edit: see [arXiv:2103.12039](https://arxiv.org/abs/2103.12039) !



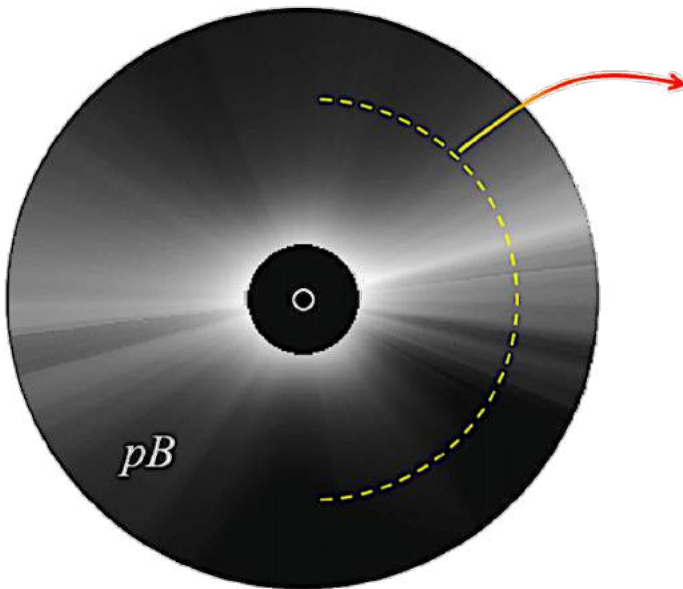
4. What can we accomplish with PUNCH?

- 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 both $(u + V_A)$ 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.
- Example 3D \rightarrow pB **testbed** model of solar rotation + radial striations, mapped from high-resolution magnetograms:



CR 2058: Carrington longitude

- Next step: add blobs that flow in & out... & test flow-mapping codes on them.

See the work of PUNCH AI Chris Gilly.

These testbed models will be incorporated into FORWARD (Gibson et al. 2016)

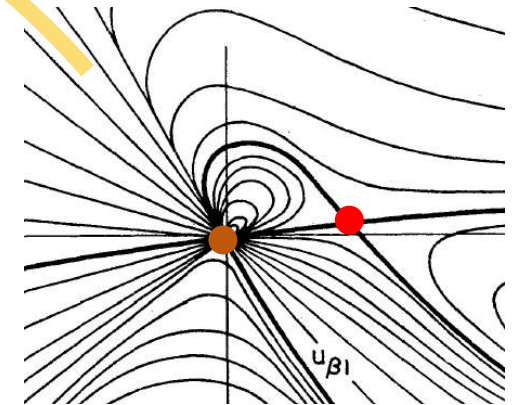
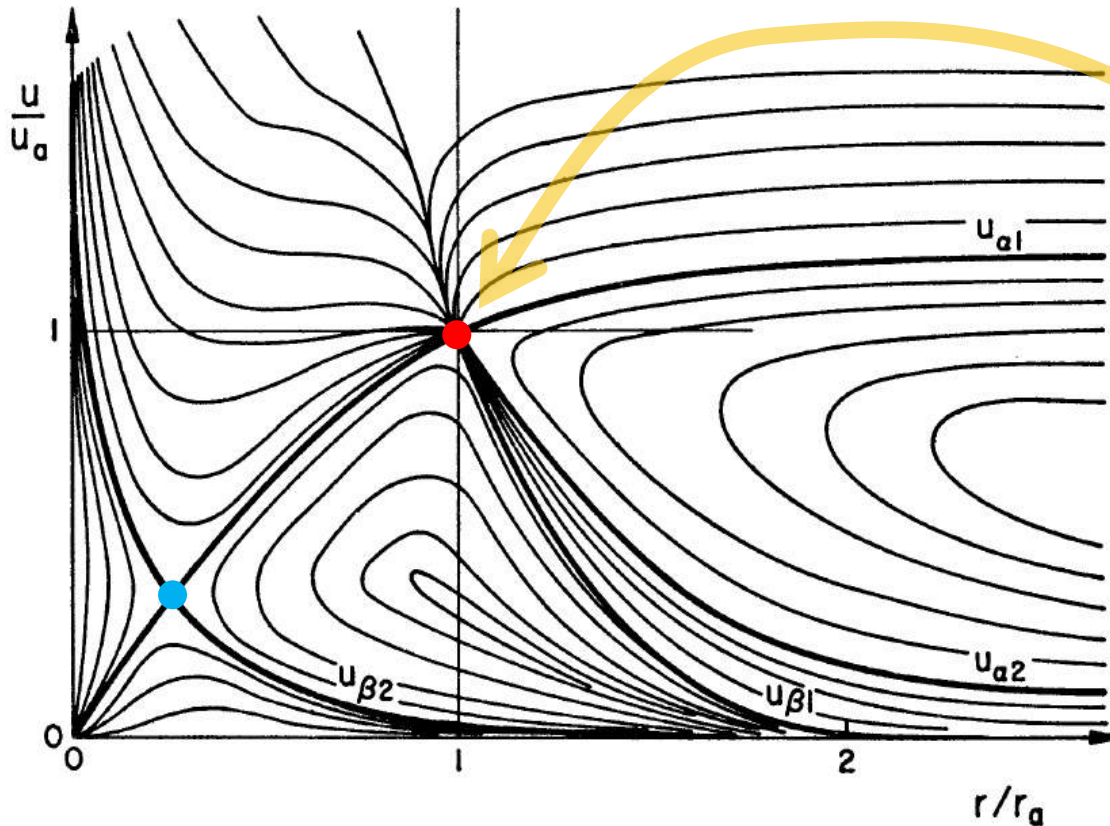


Extra slides



Alfvén vs. fast-mode surface?

- “Alfvén surface” is a shorthand for “fast-mode MHD surface.”
- Strictly speaking... there are (at least) 3 “critical points”



Weber & Davis (1967)



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