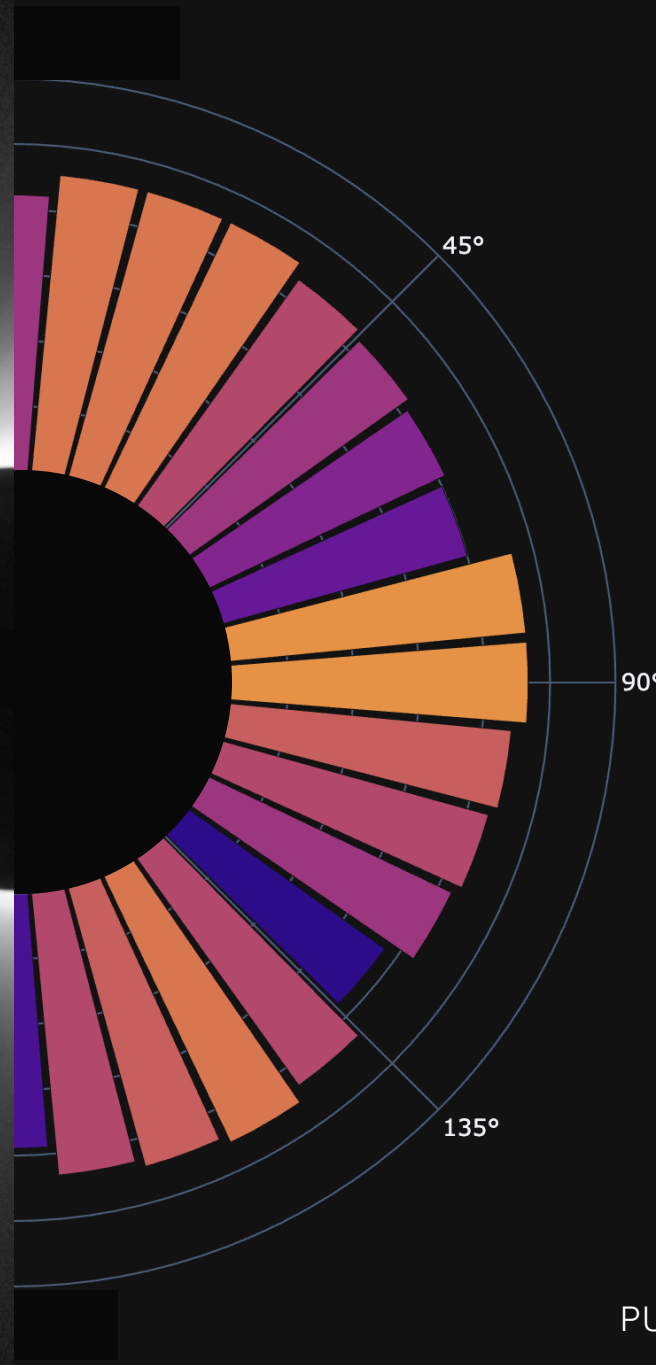
Tracking Solar Wind Evolution with PUNCH Flow Maps



Raphael Attié

Co-authors:

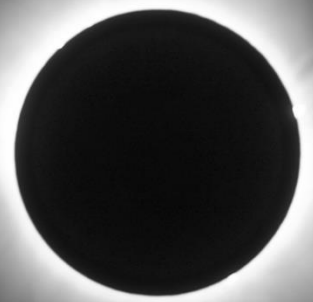
Barbata Thompson
Craig Deforest
Nicholeen Viall
Valmir Moraes Filho
Vadim Uritsky

Raphael Attié. PhD
Research Assistant Professor
Lead of PUNCH WG-1A (Ambiant Solar Wind)
NASA GSFC [671] / George Mason University

PUNCH 6, Boulder 2/25/2025

Mapping Solar Wind Flows with PUNCH

- Reminder on Science Goals of Working Group (WG) 1A
- Solar Wind Flow Maps from PUNCH SOC
- More Advanced Flow Maps Open to the Community
- Scientific Overlaps with other WGs

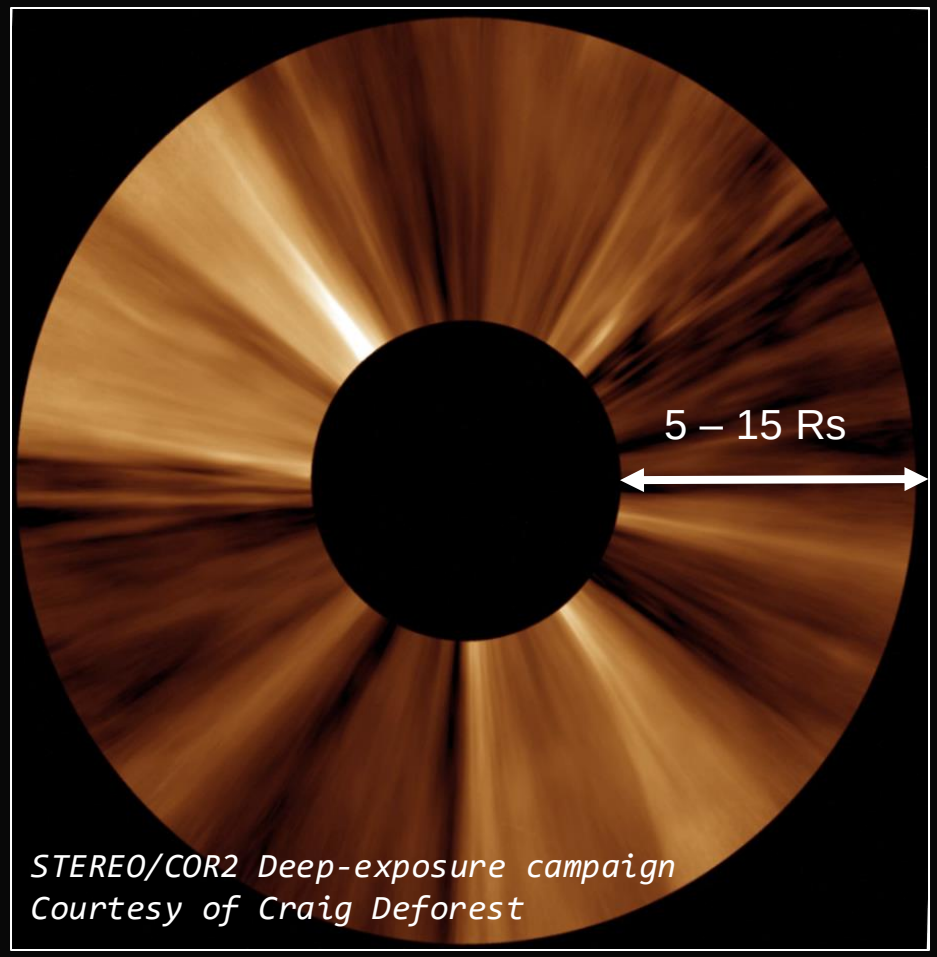


Mapping Solar Wind Flows with PUNCH

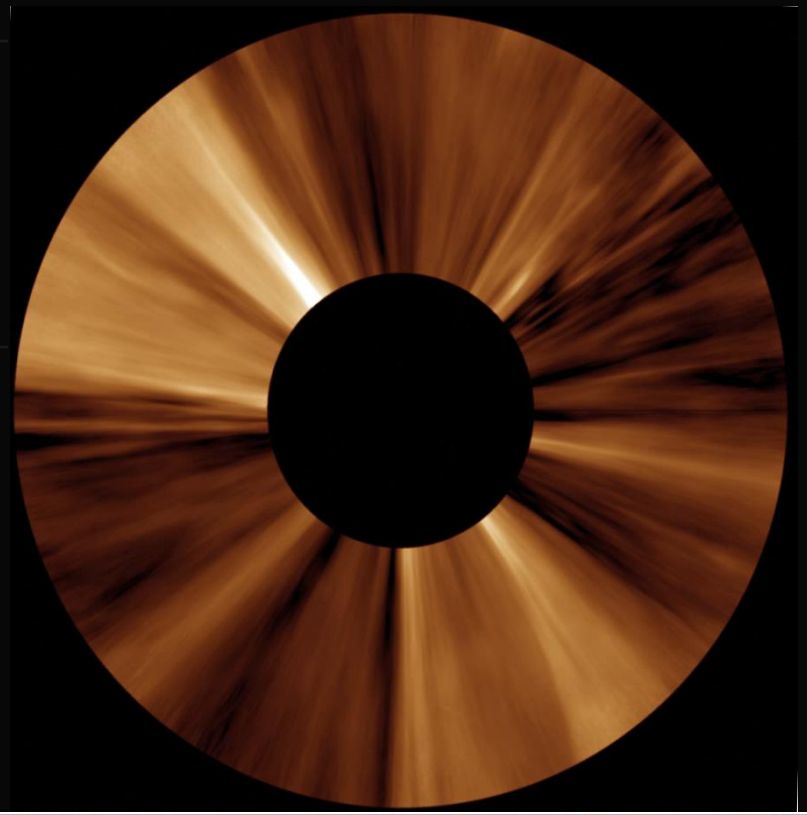
WG-1A has *4* Science Goals:

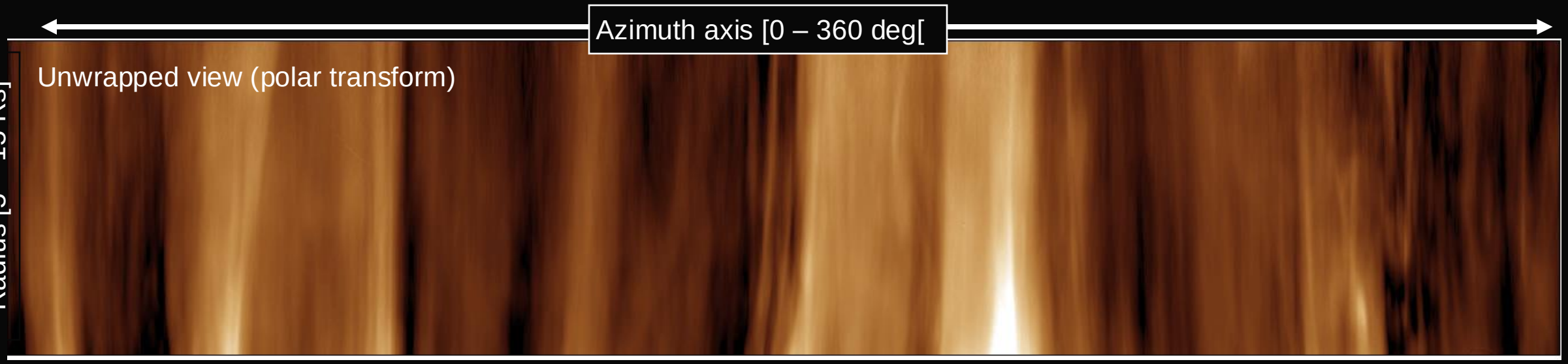
1. Measure time-dependent solar wind acceleration from outer corona to inner heliosphere
2. Identify the changing boundaries between fast/slow solar wind
3. Determine large-scale flow context necessary to relate coronal structure to heliospheric structure
4. Characterize the global solar wind conditions through which transient structures propagate.

MAPPING SOLAR WIND FLOWS: **HOW?**

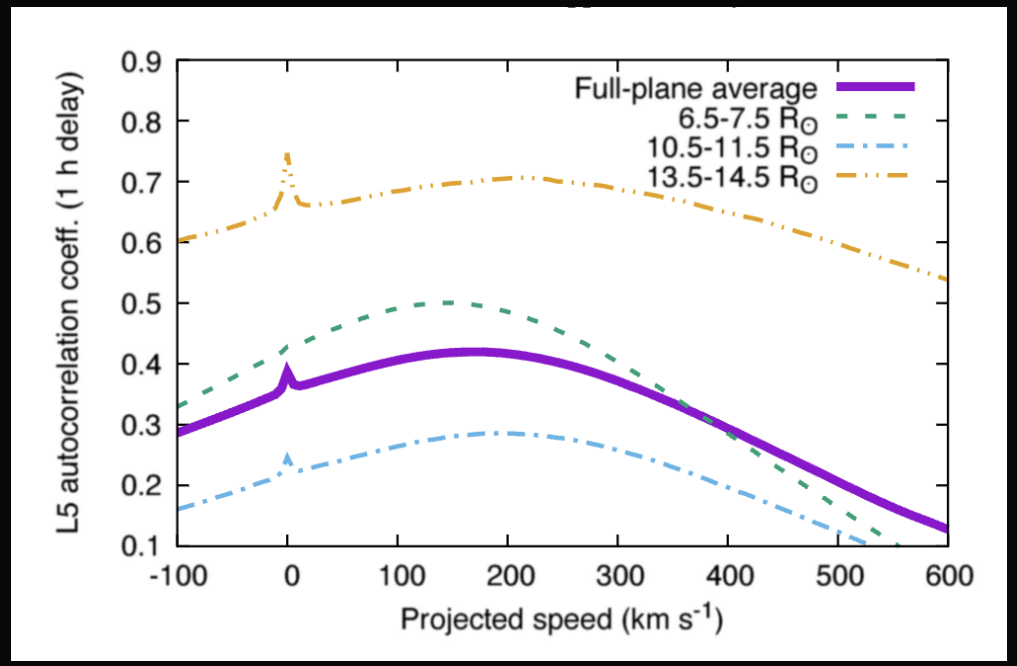


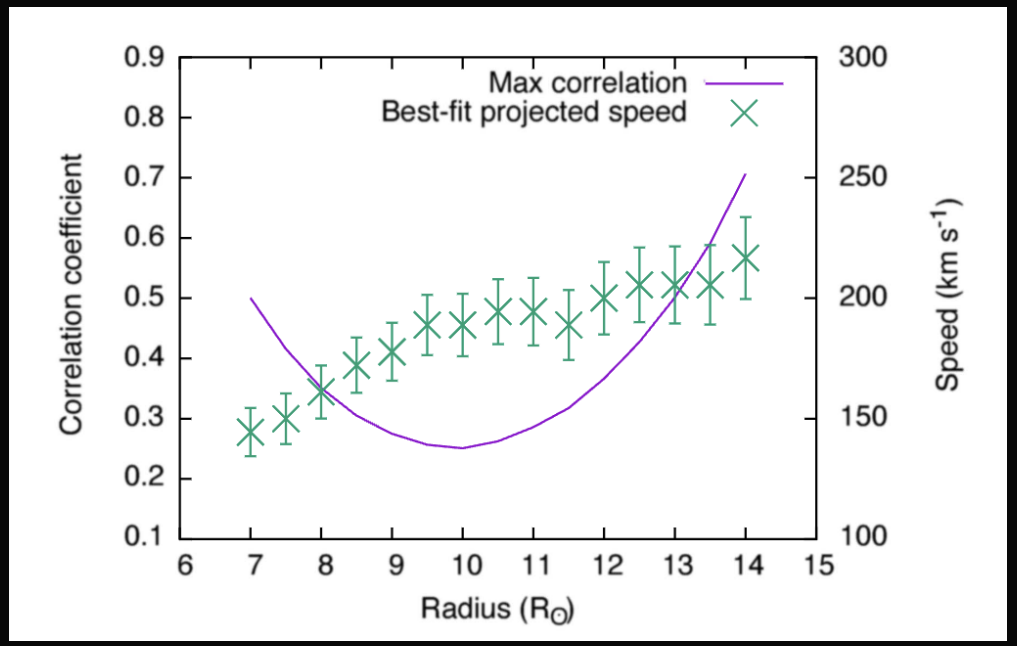
MAPPING SOLAR WIND FLOWS: **HOW?**

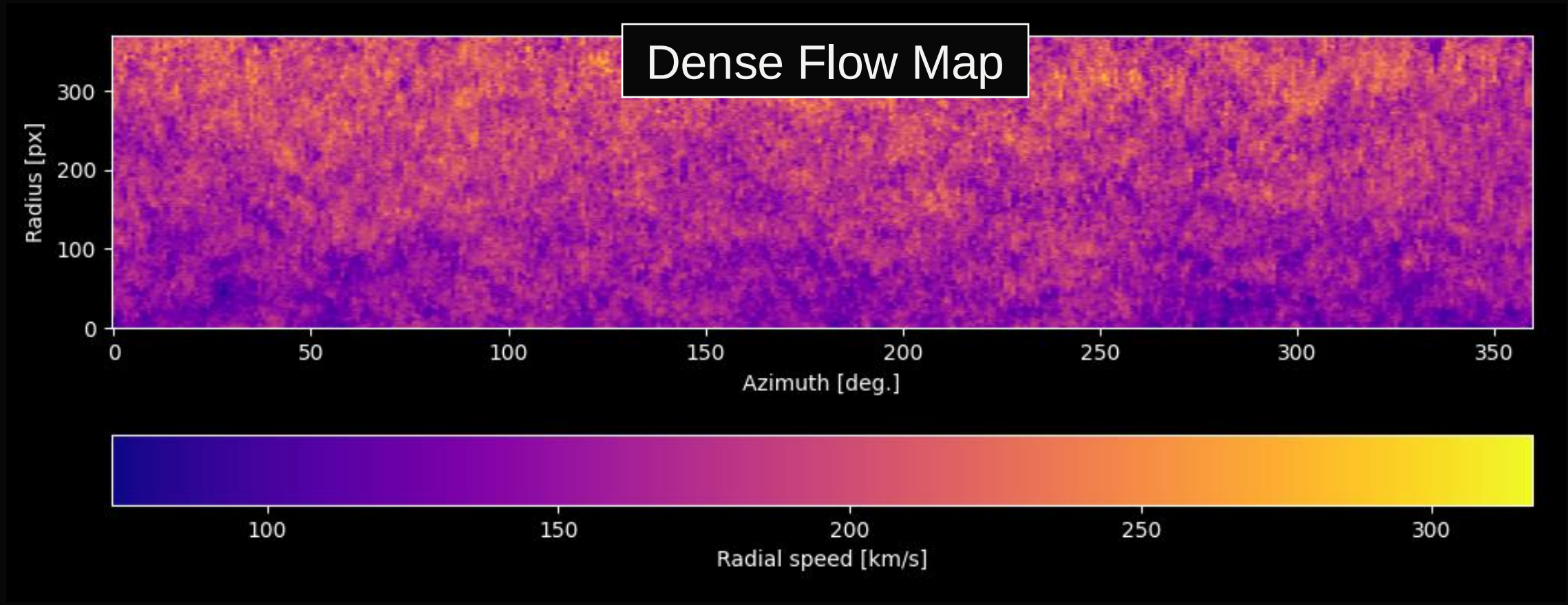


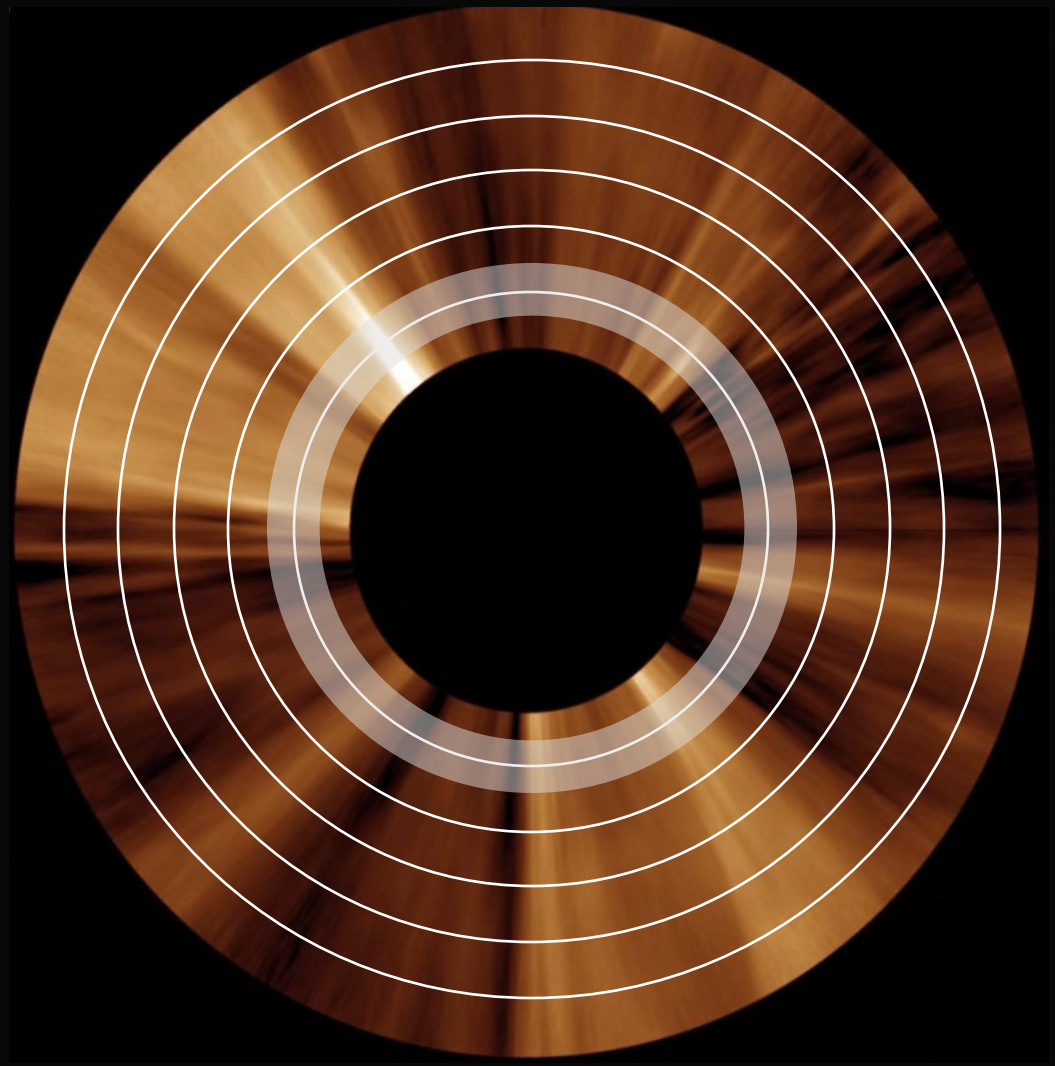


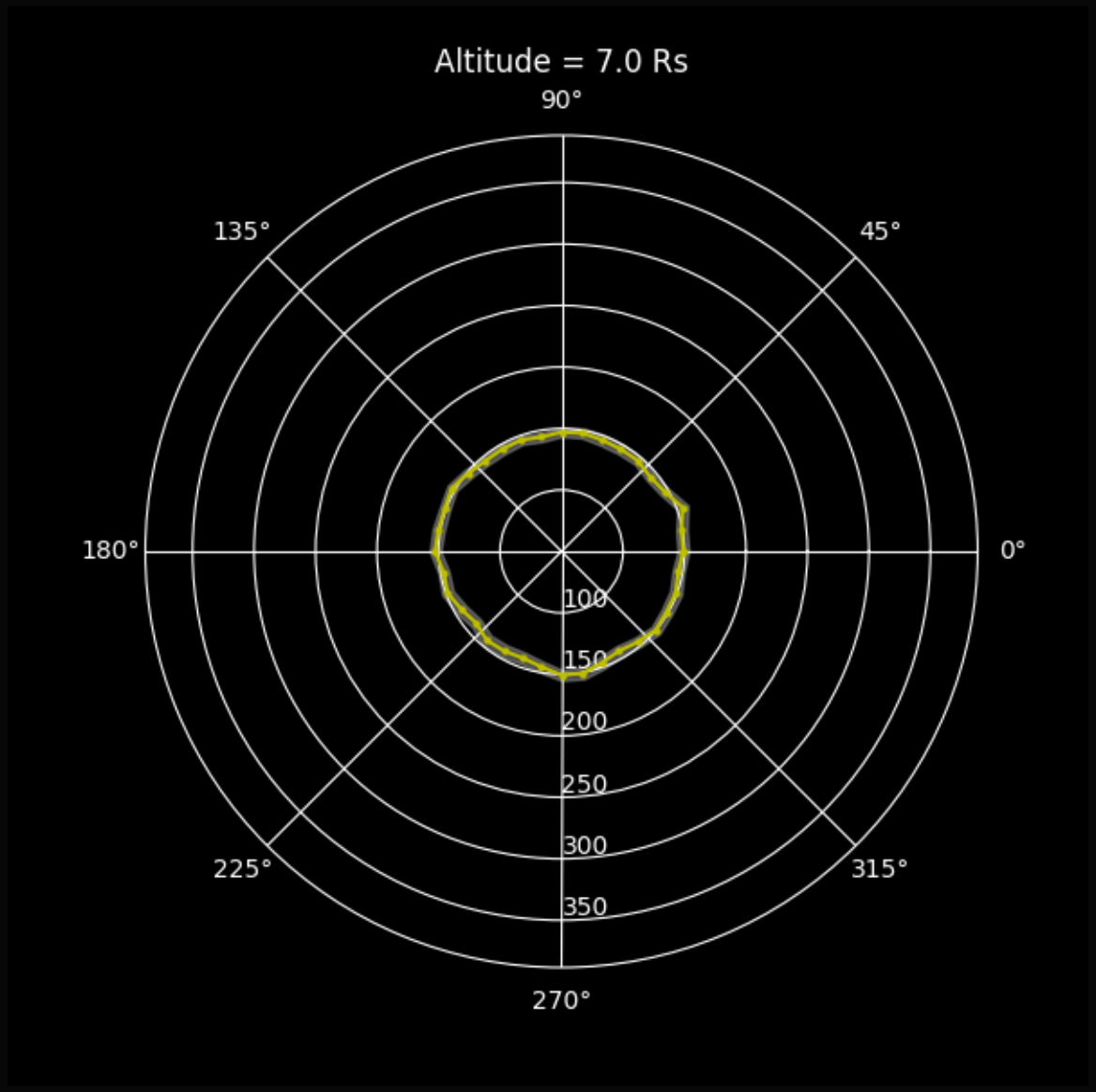
Dense flow maps @ PUNCH SOC: correlation tracking (Deforest et al., 2018)






Dense Flow Map
Radius [px]
0
100
200
300
0
50
100
150
200
250
300
350
Azimuth [deg.]
100
150
200
250
300
Radial speed [km/s]

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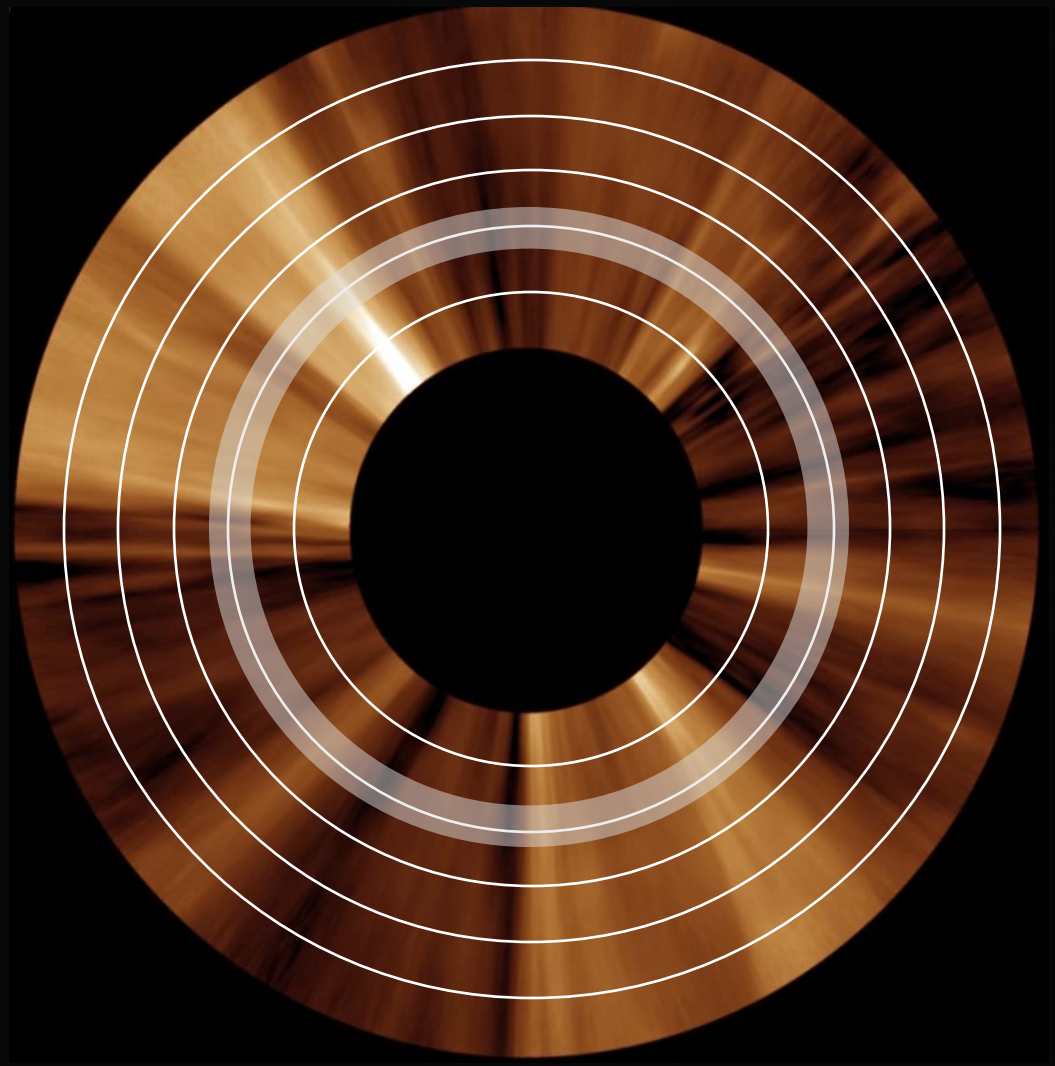
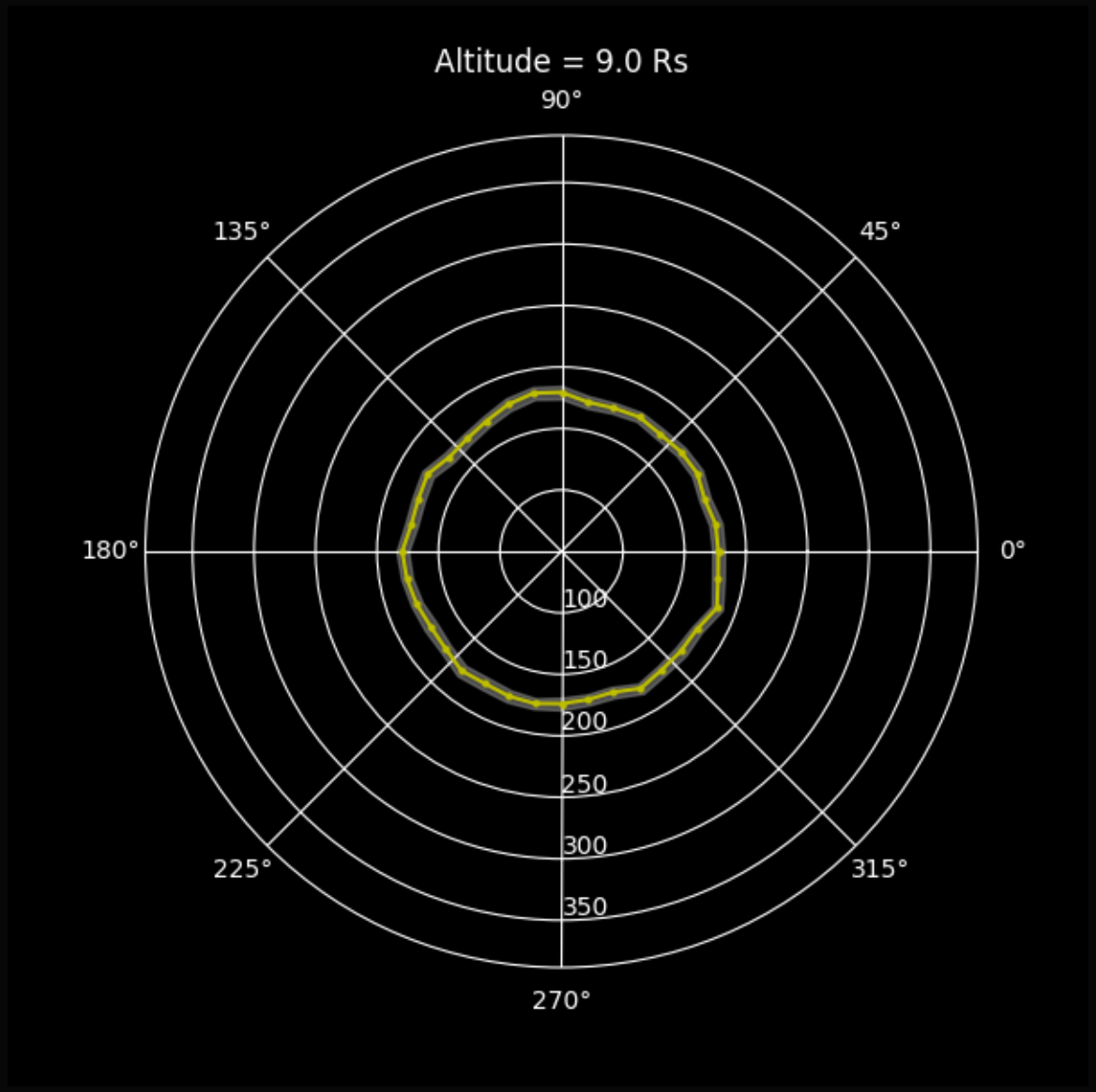
45°
180°
0°
225°
315°
270°
100
150
200
250
300
350

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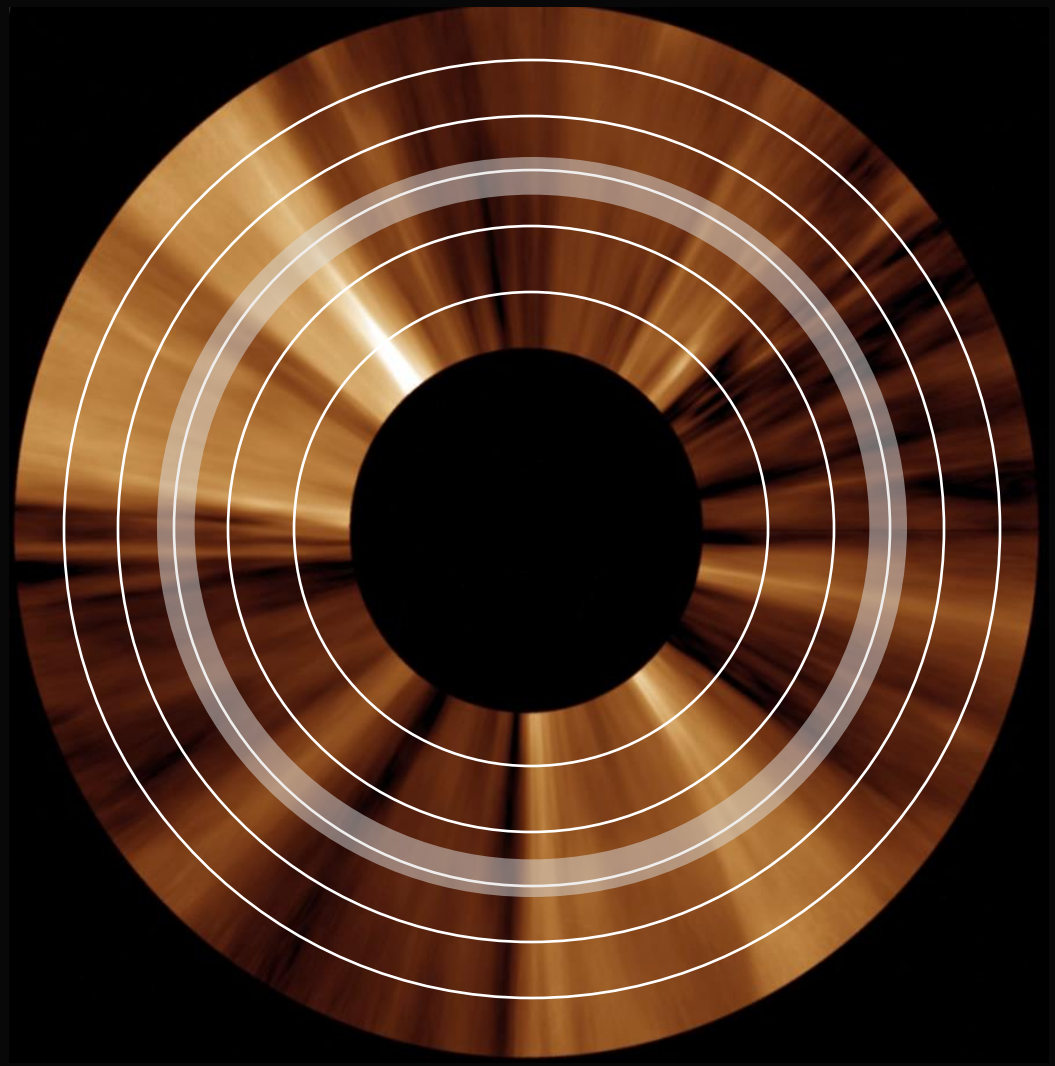

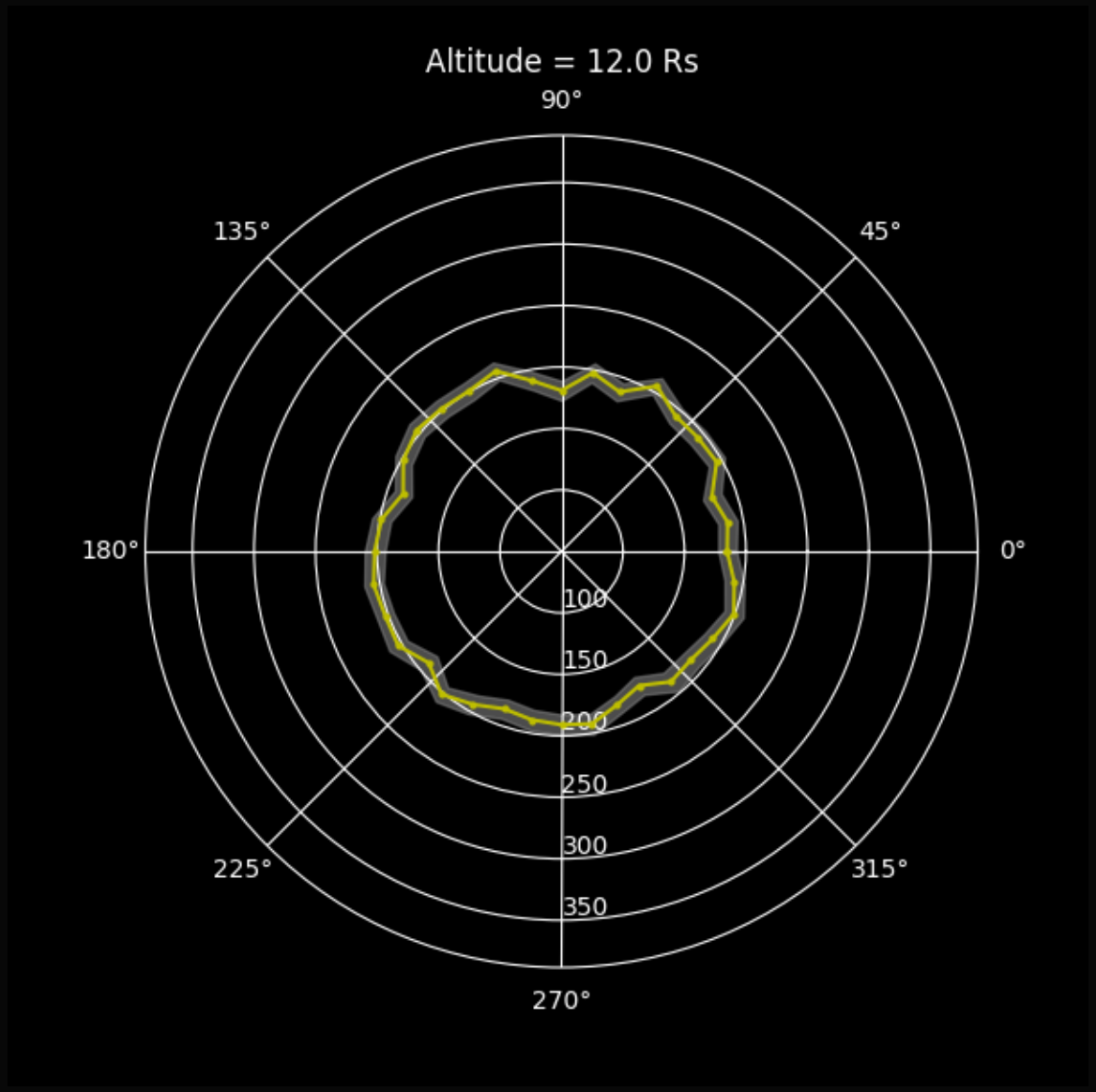
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135°
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180°
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225°
315°
270°
100
150
200
250
300
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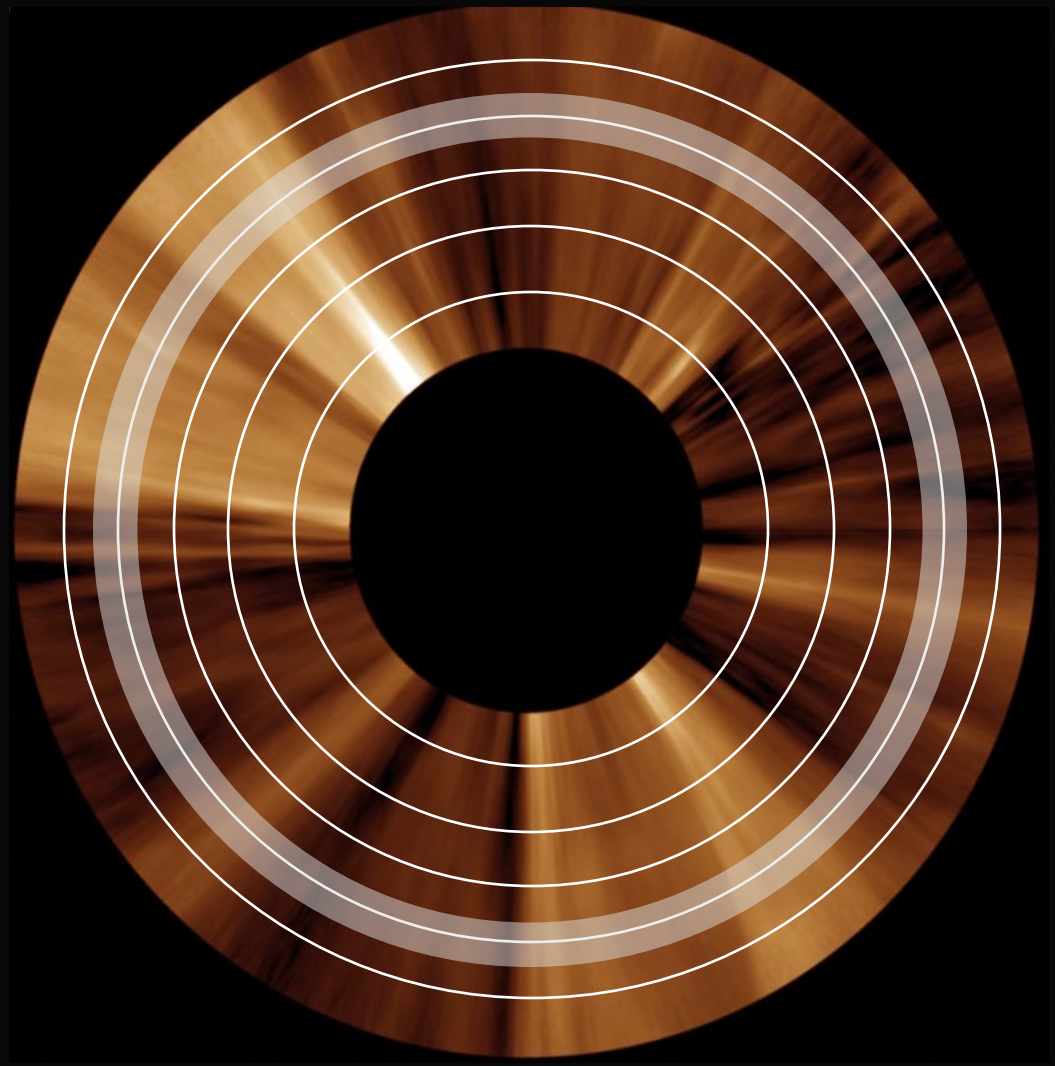

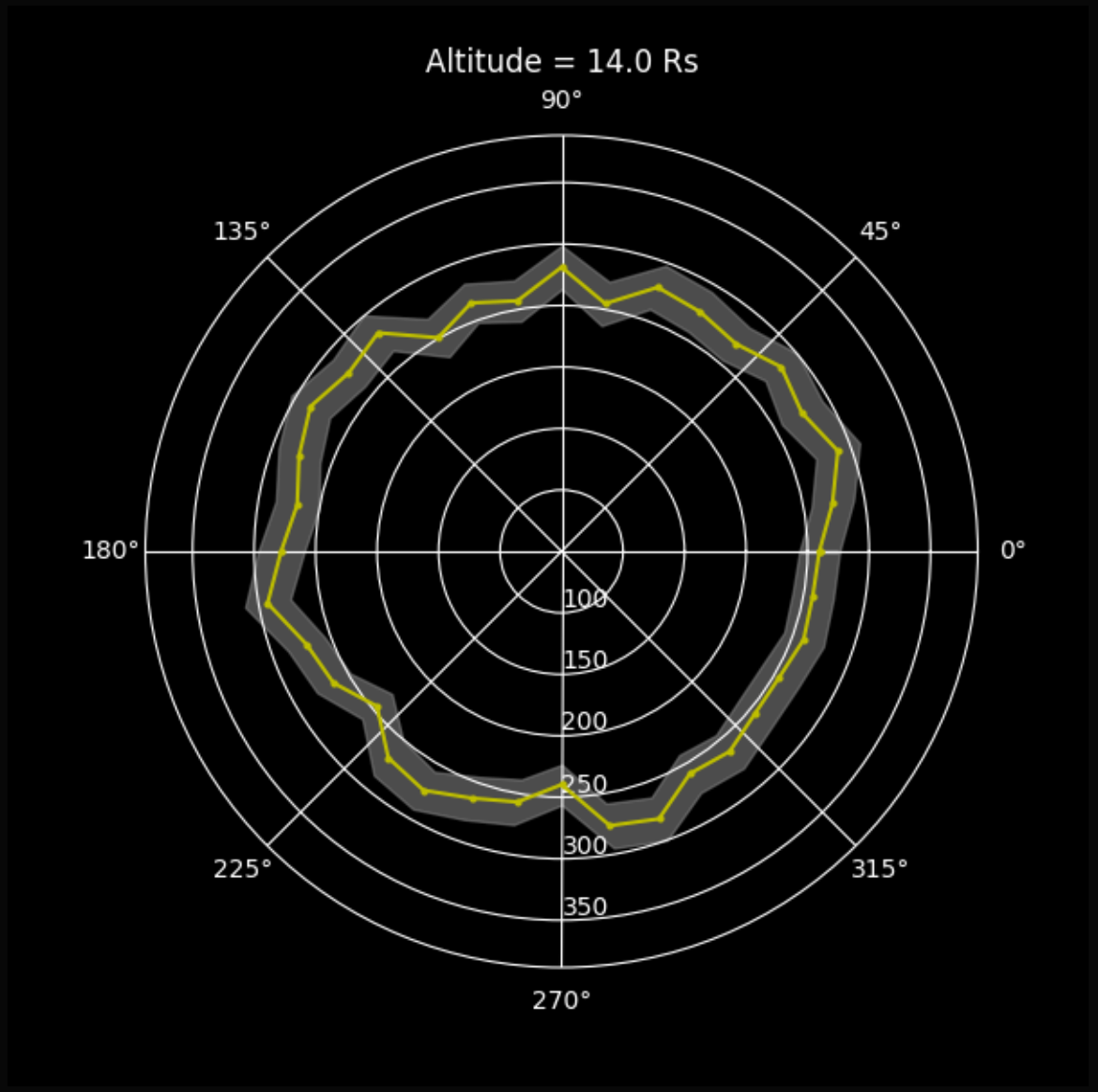
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315°
270°
100
150
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300
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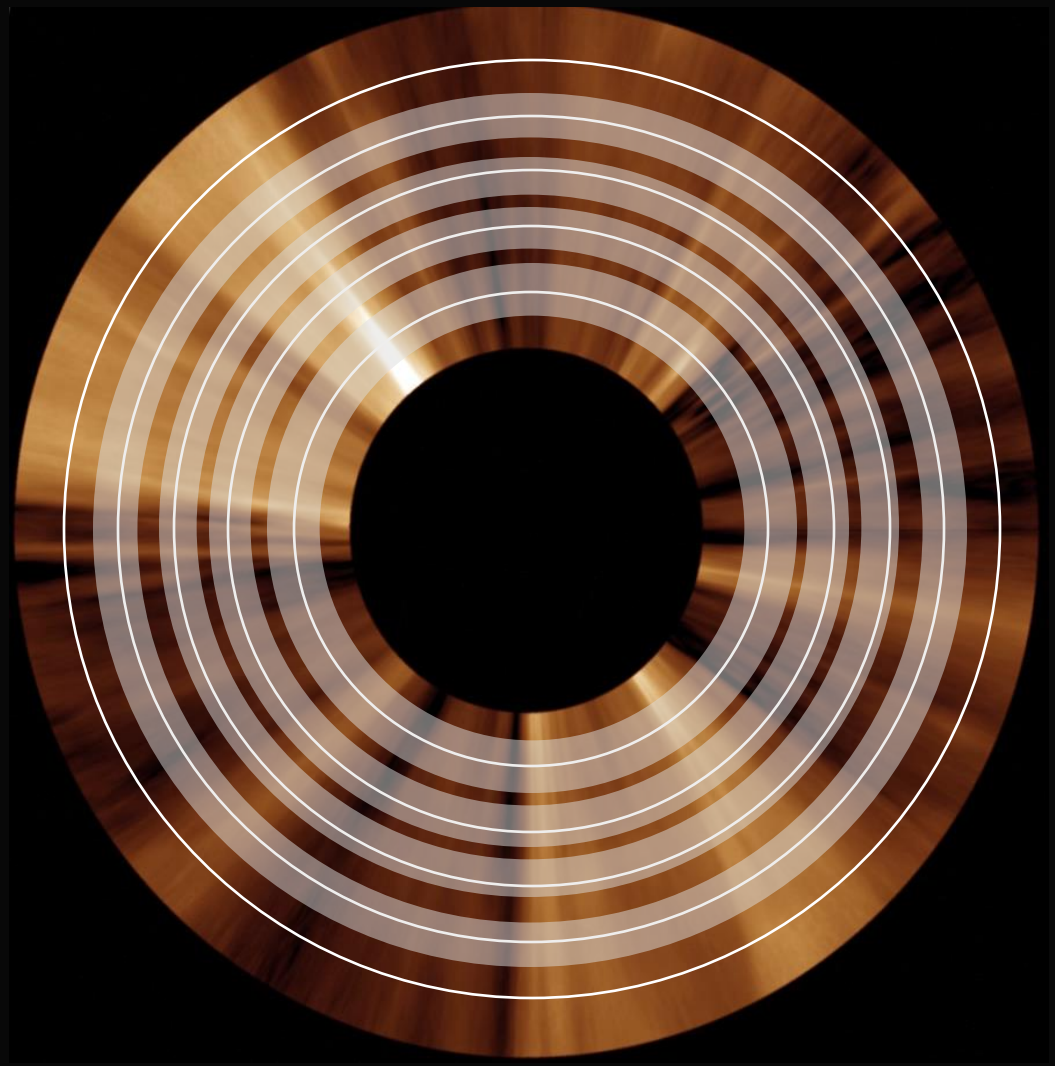
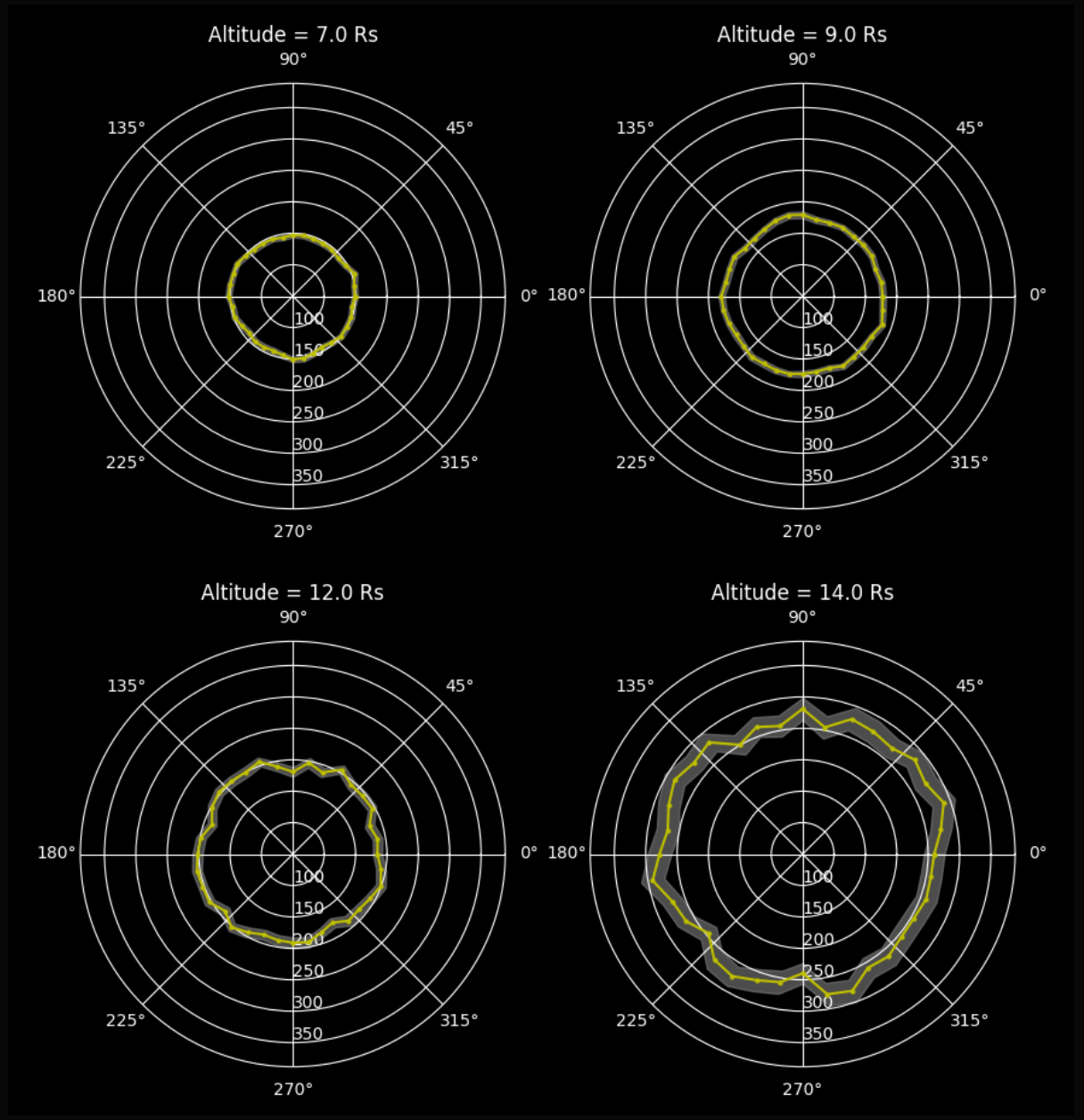
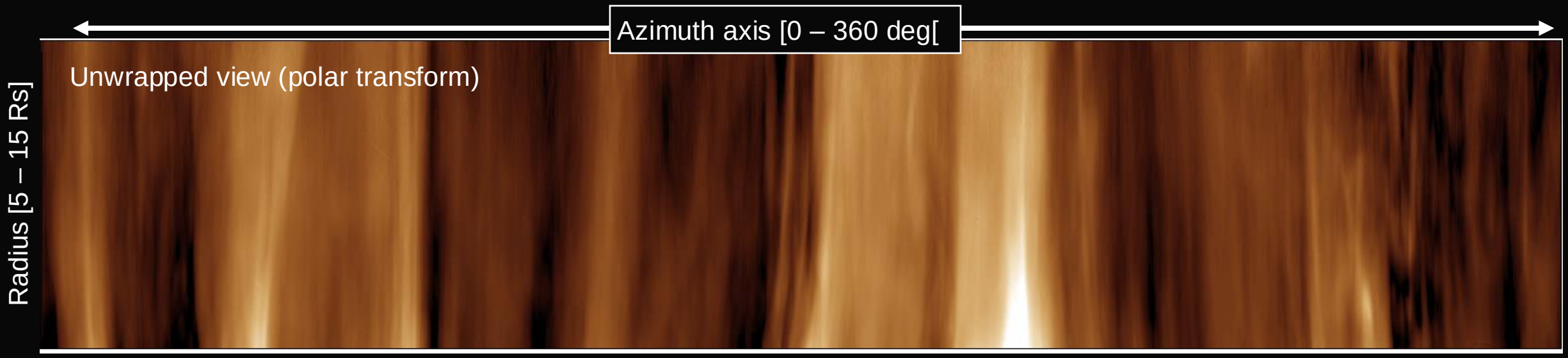
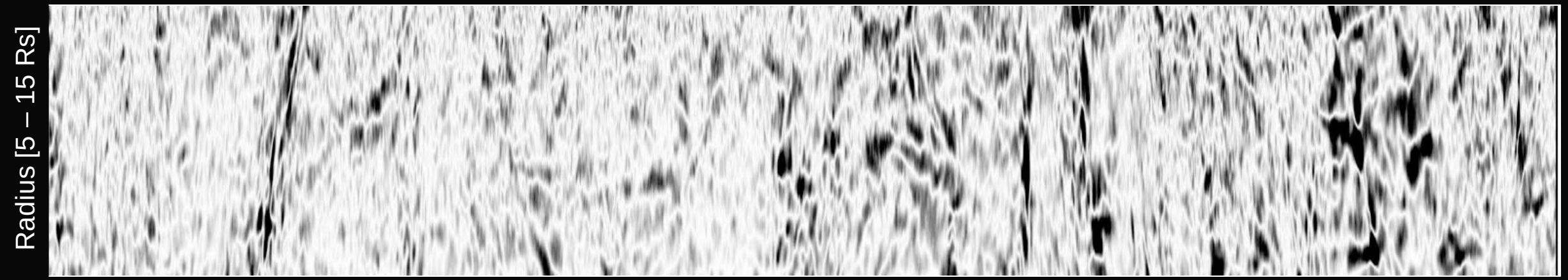



Altitude = 7.0 Rs
Altitude = 9.0 Rs
Altitude = 12.0 Rs
Altitude = 14.0 Rs
90°
45°
0°
315°
270°
225°
180°
135°
100
150
200
250
300
350

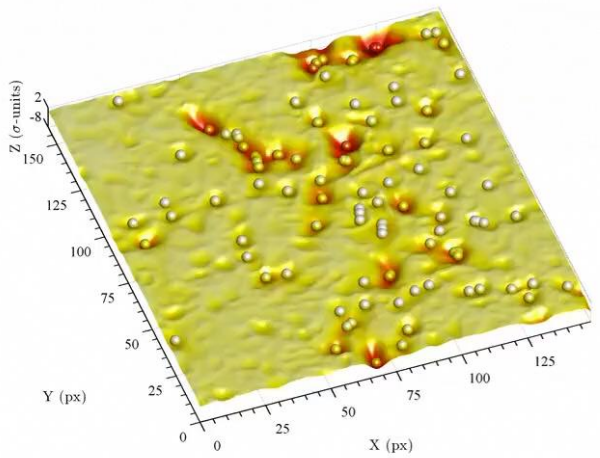
Method 2: “Balltracking”: Lagrangian 2D motion vectors of enhanced density structures (not just the periodic ones) (**mesoscale blobs**) openly available outside of the SOC pipeline.

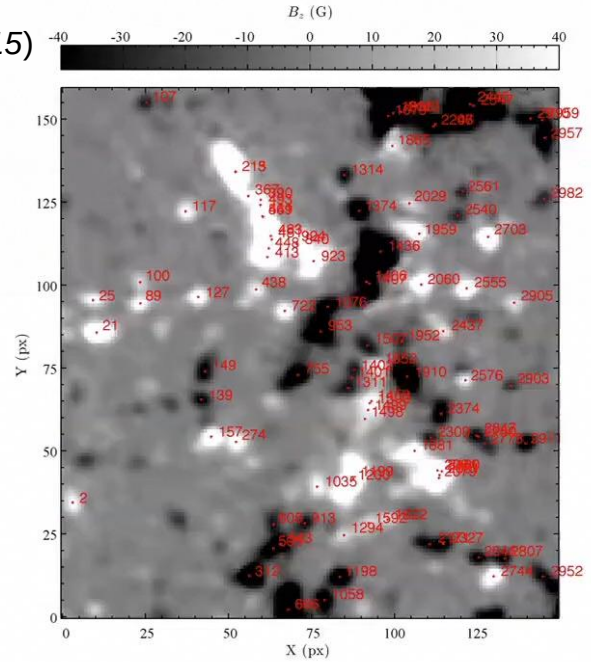


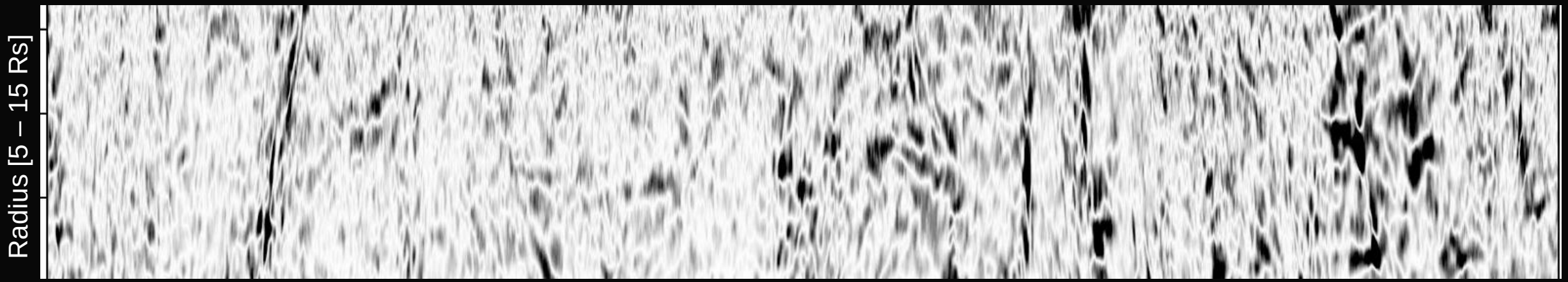
Filtered version, enhanced density structures



Magnetic Balltracking (*Attie & Innes, 2015*)
Tracking of Moving Magnetic Fragments







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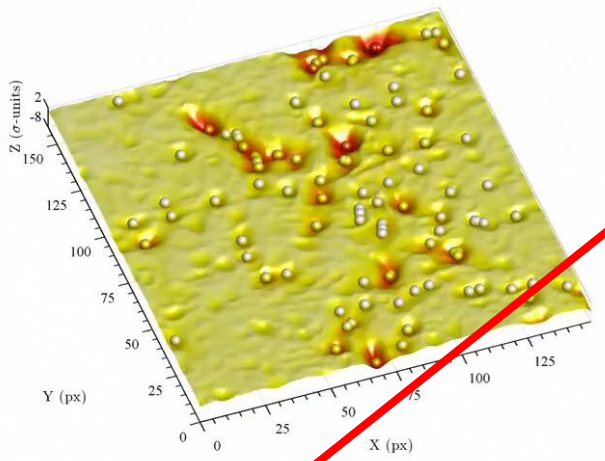
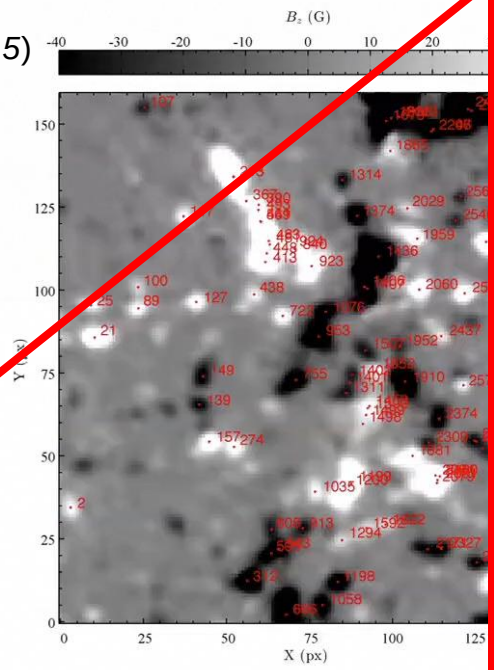
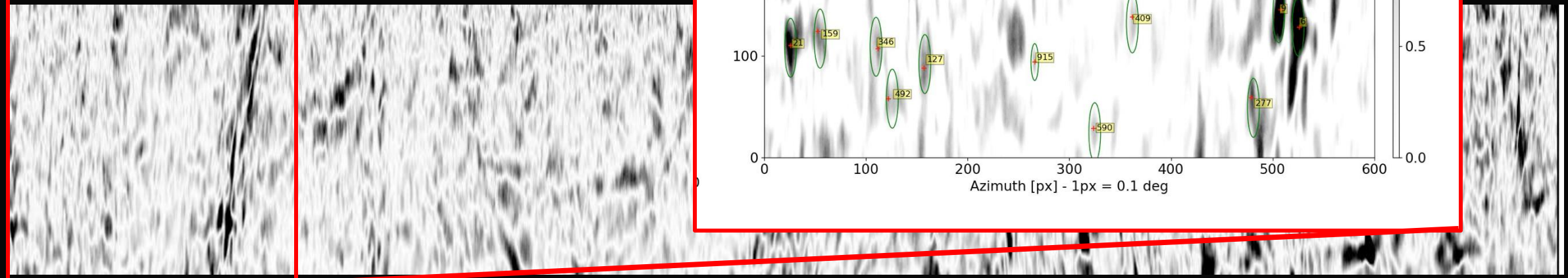


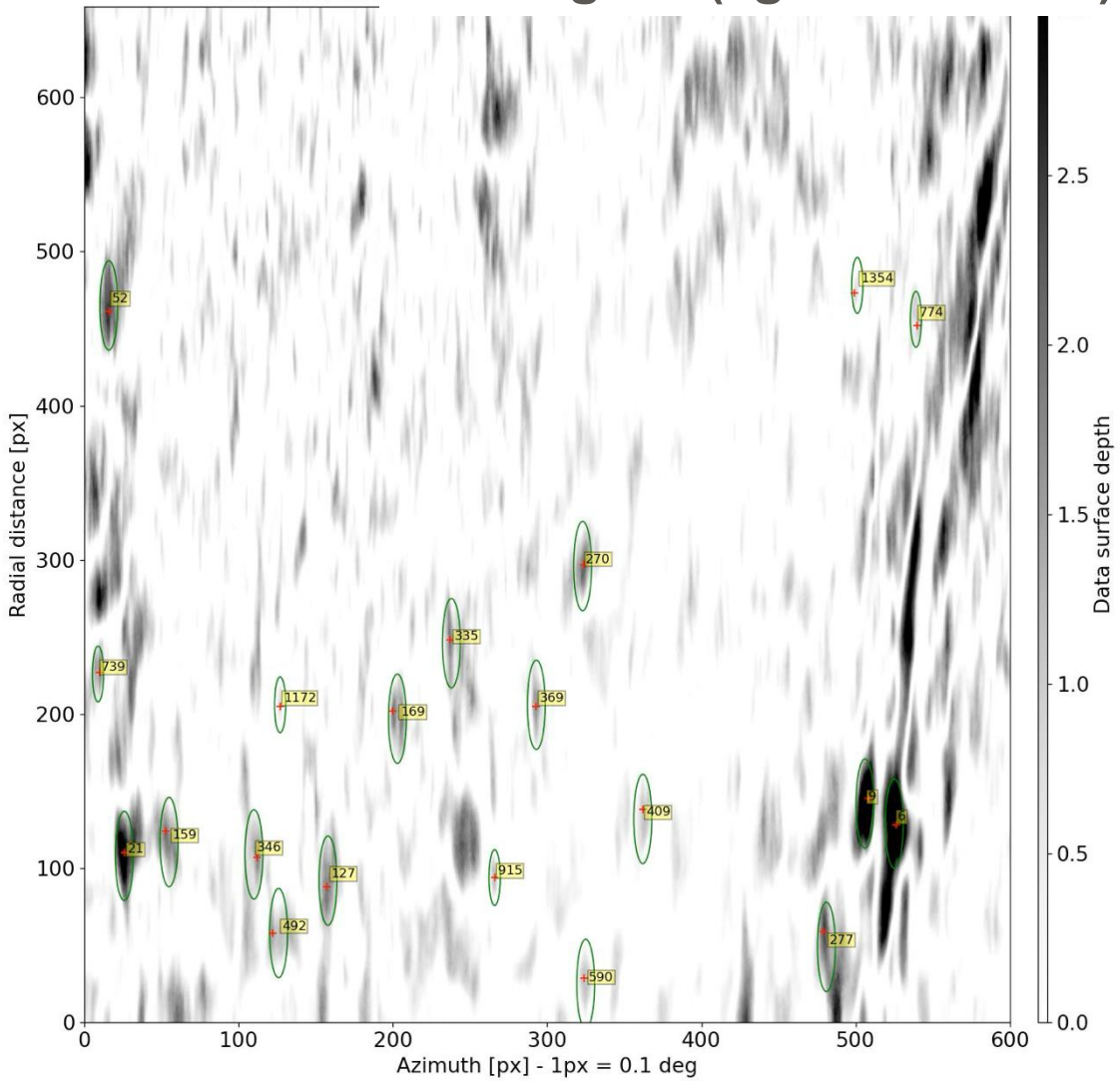


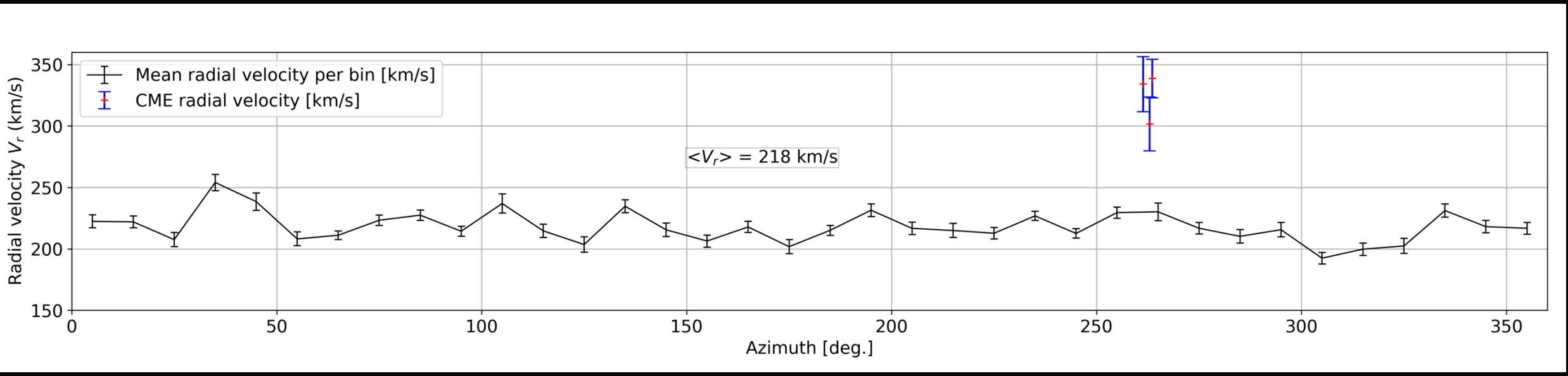
Radius [5 – 15 Rs]

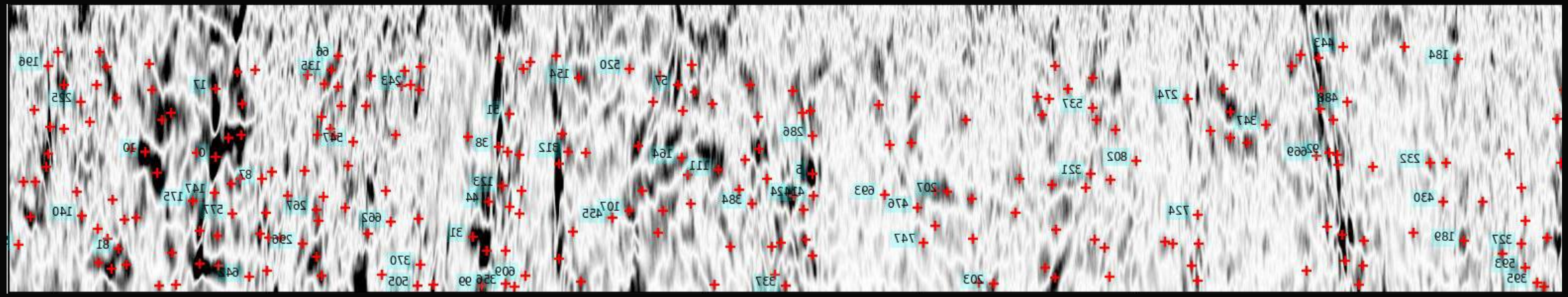


Selected blo

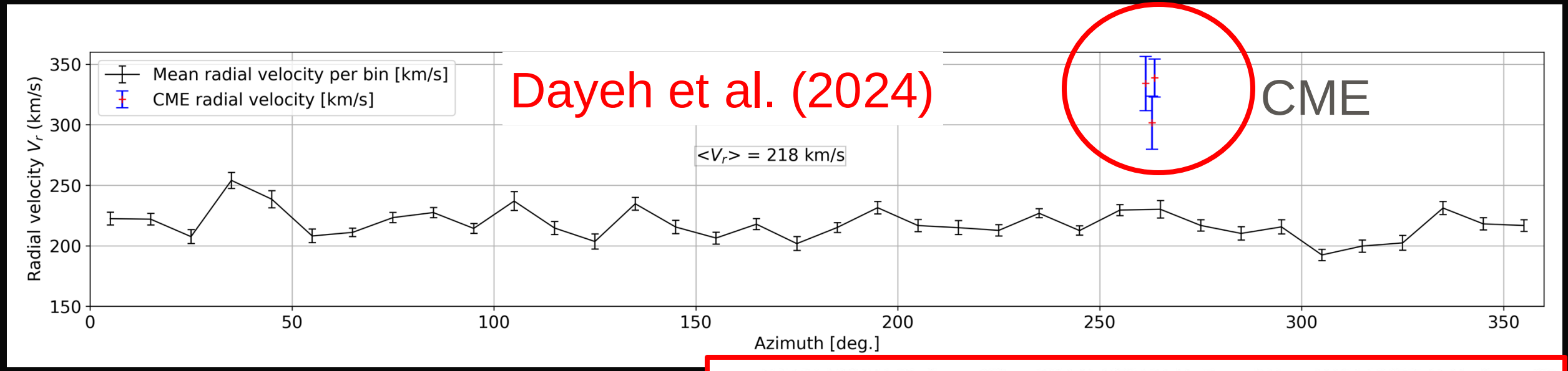
Training set (“ground truth”)

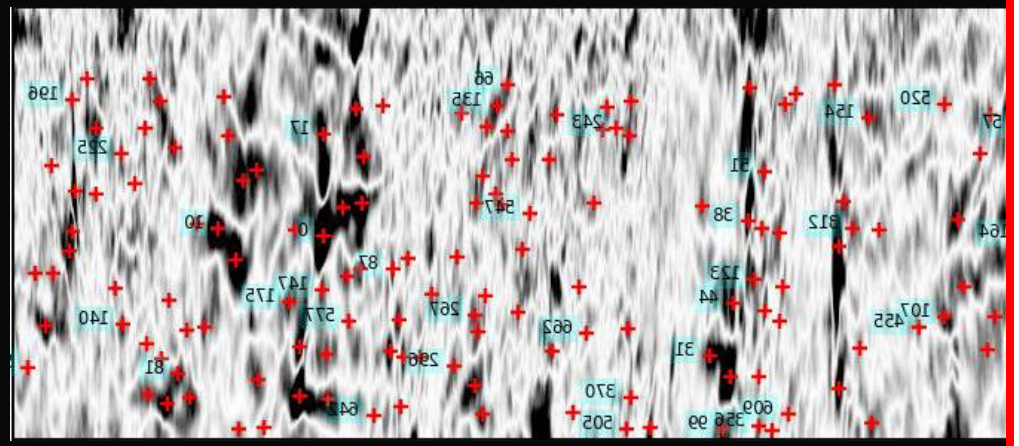


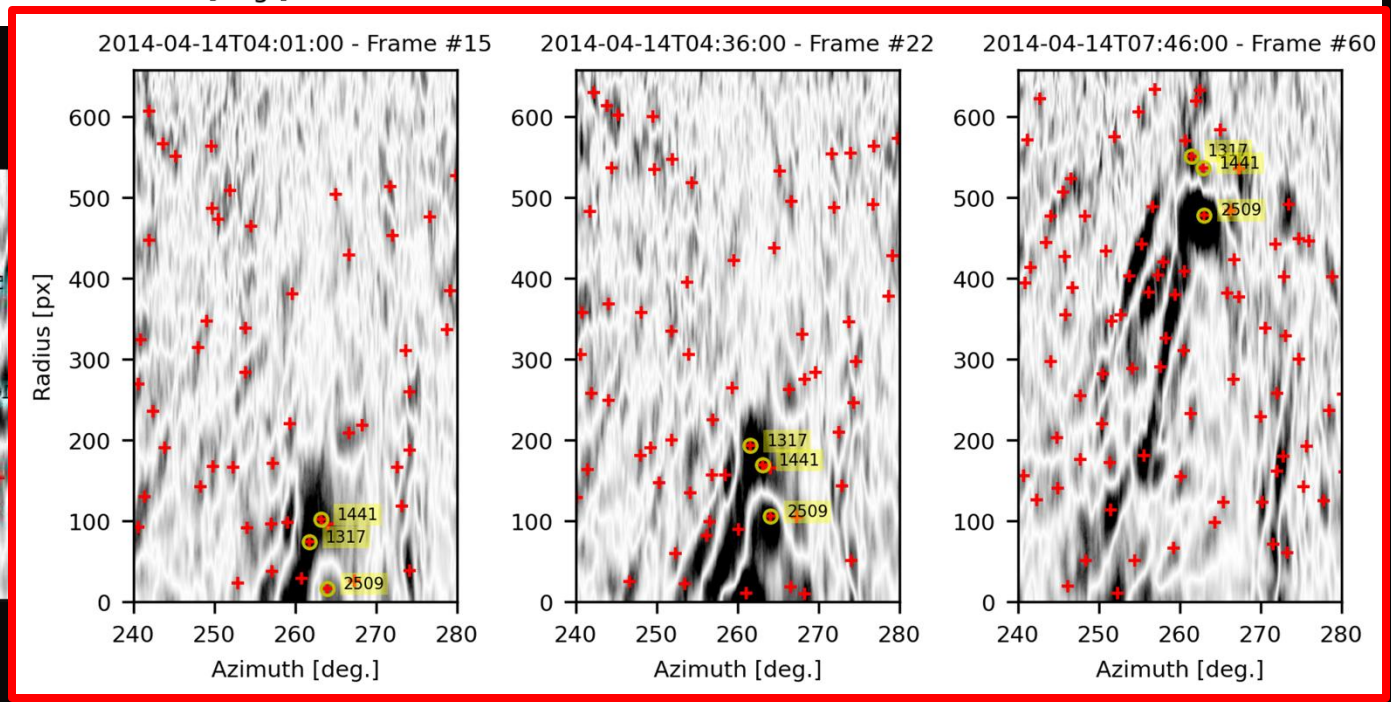




Magnetic Balltracking applied to plasma density structures in the solar wind

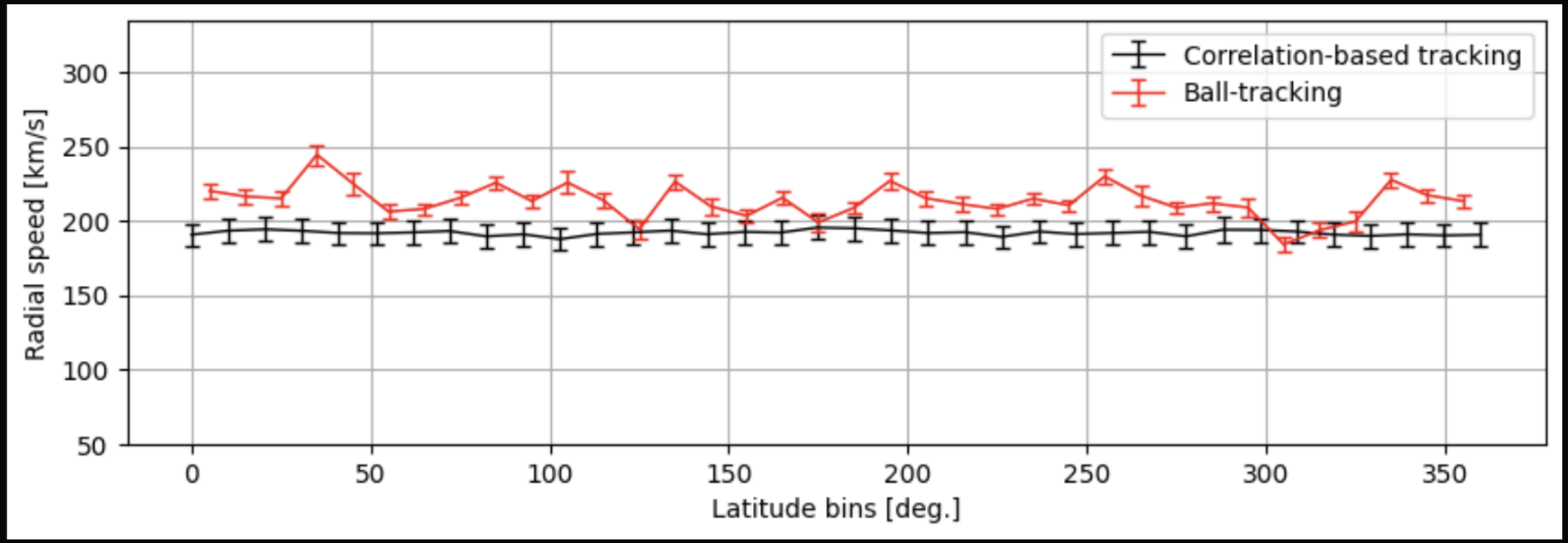






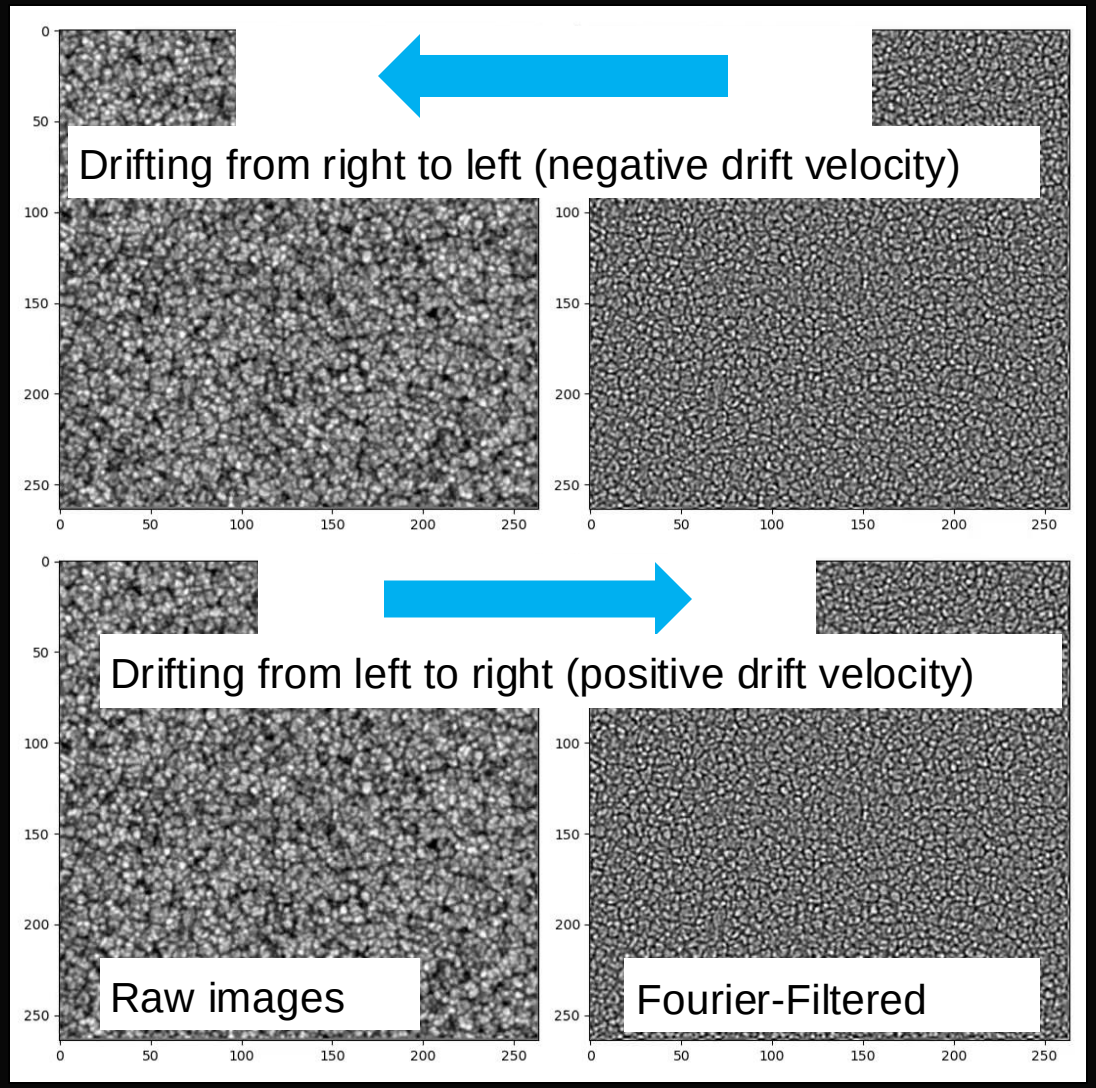
Magnetic Balltracking applied to plasma density structures in the solar wind

Method 1 (Correl.) vs. Method 2 (Balltrack)



Method 1 (Correl.) vs. Method 2 (Balltrack)

Heritage from Analysis of Photospheric Flow Tracking



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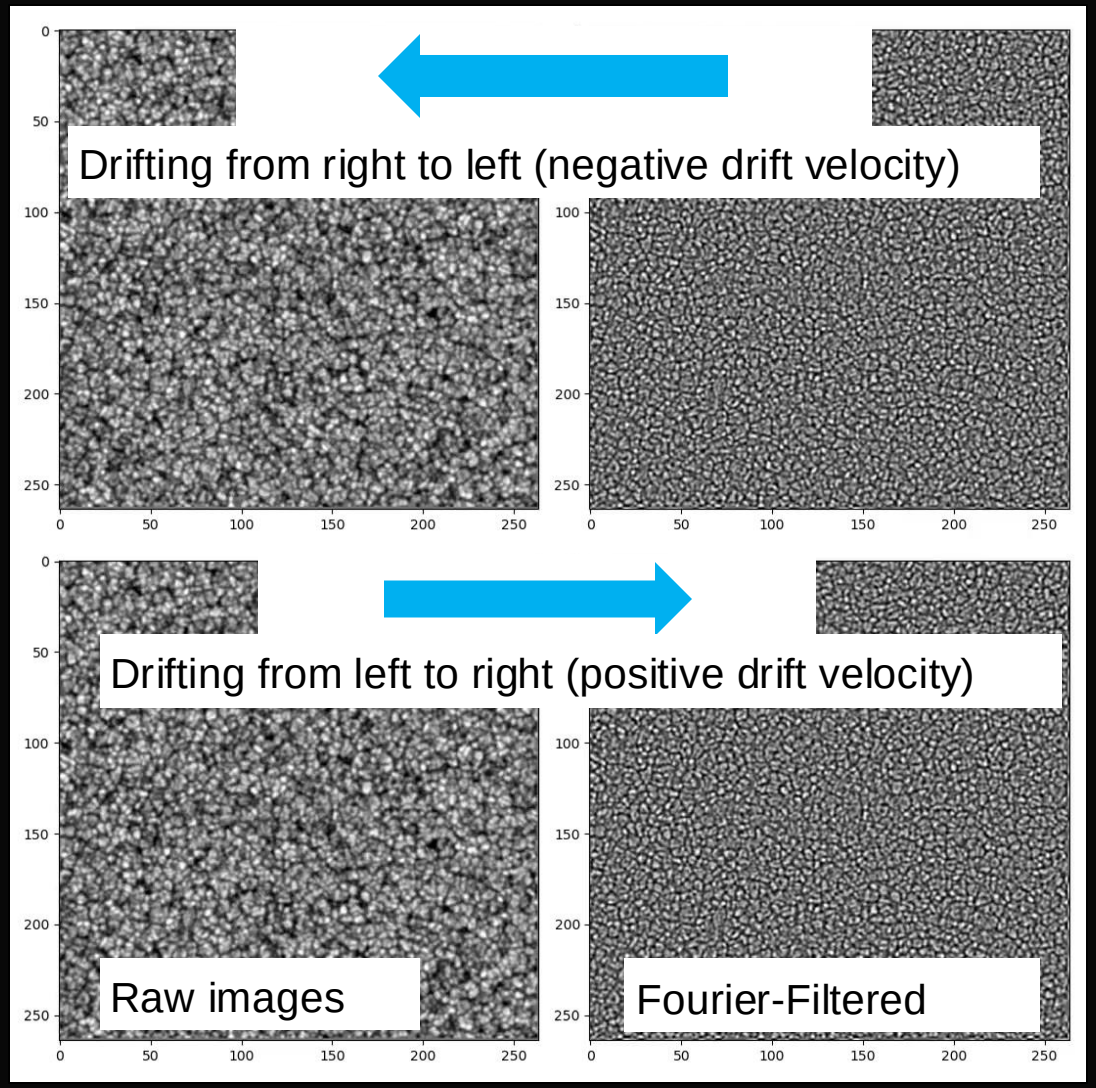

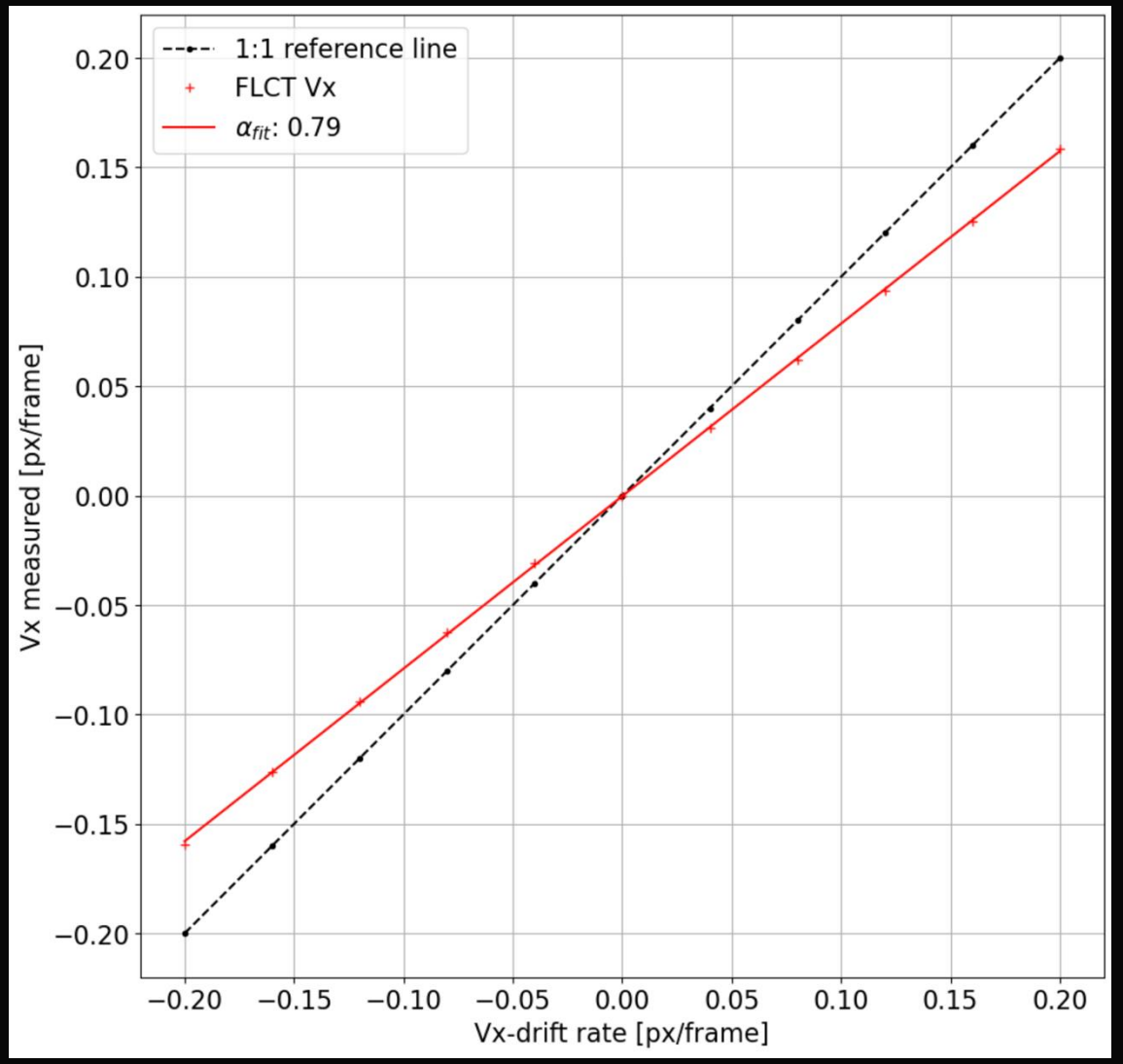

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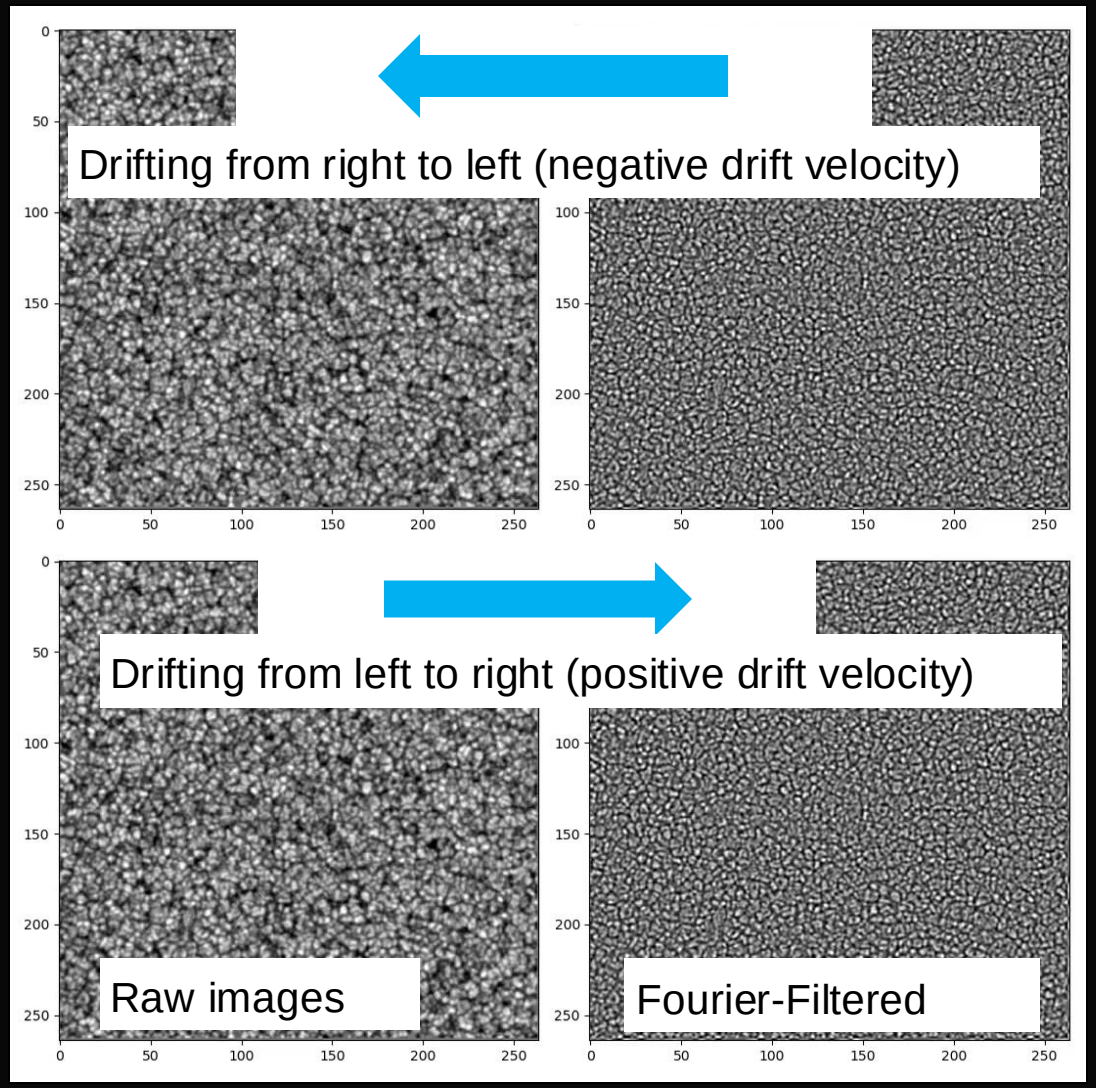

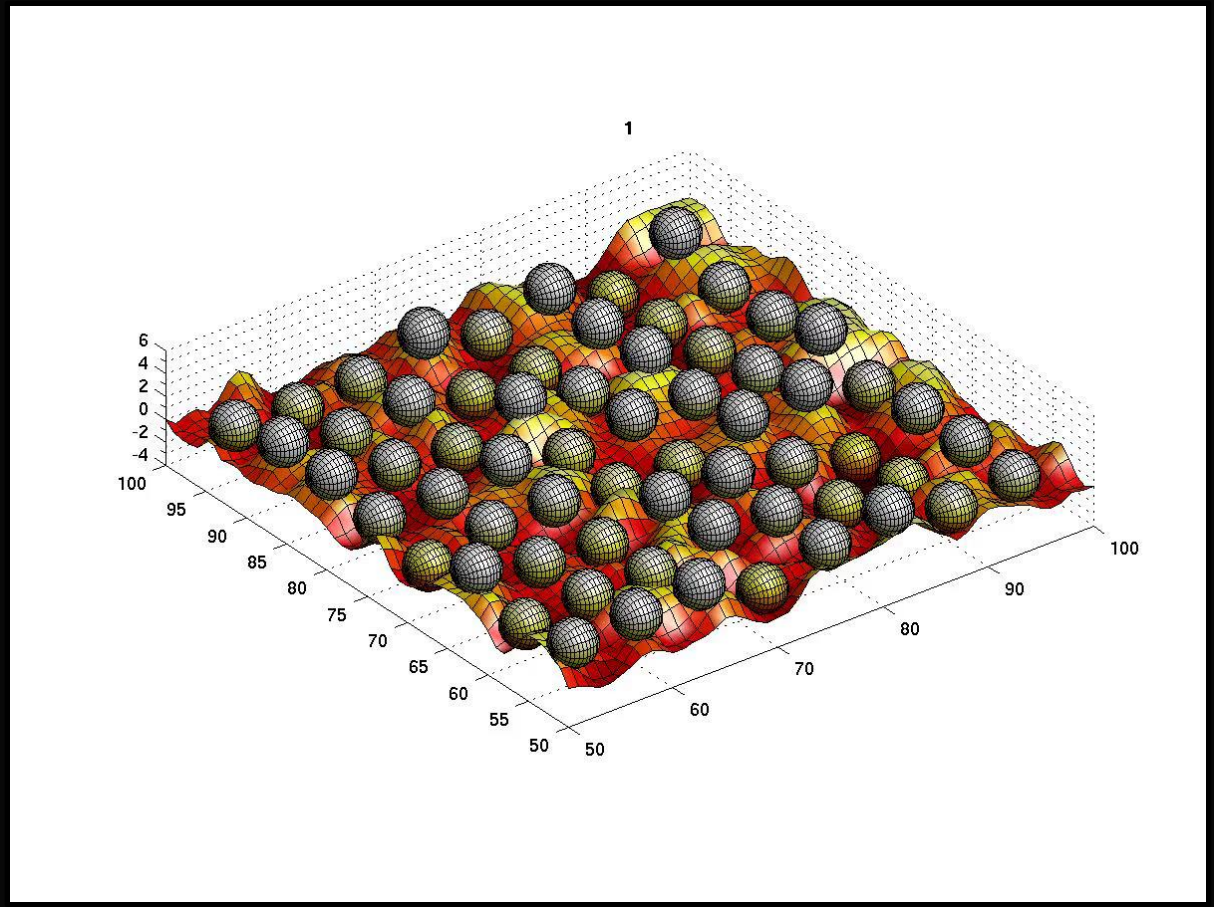

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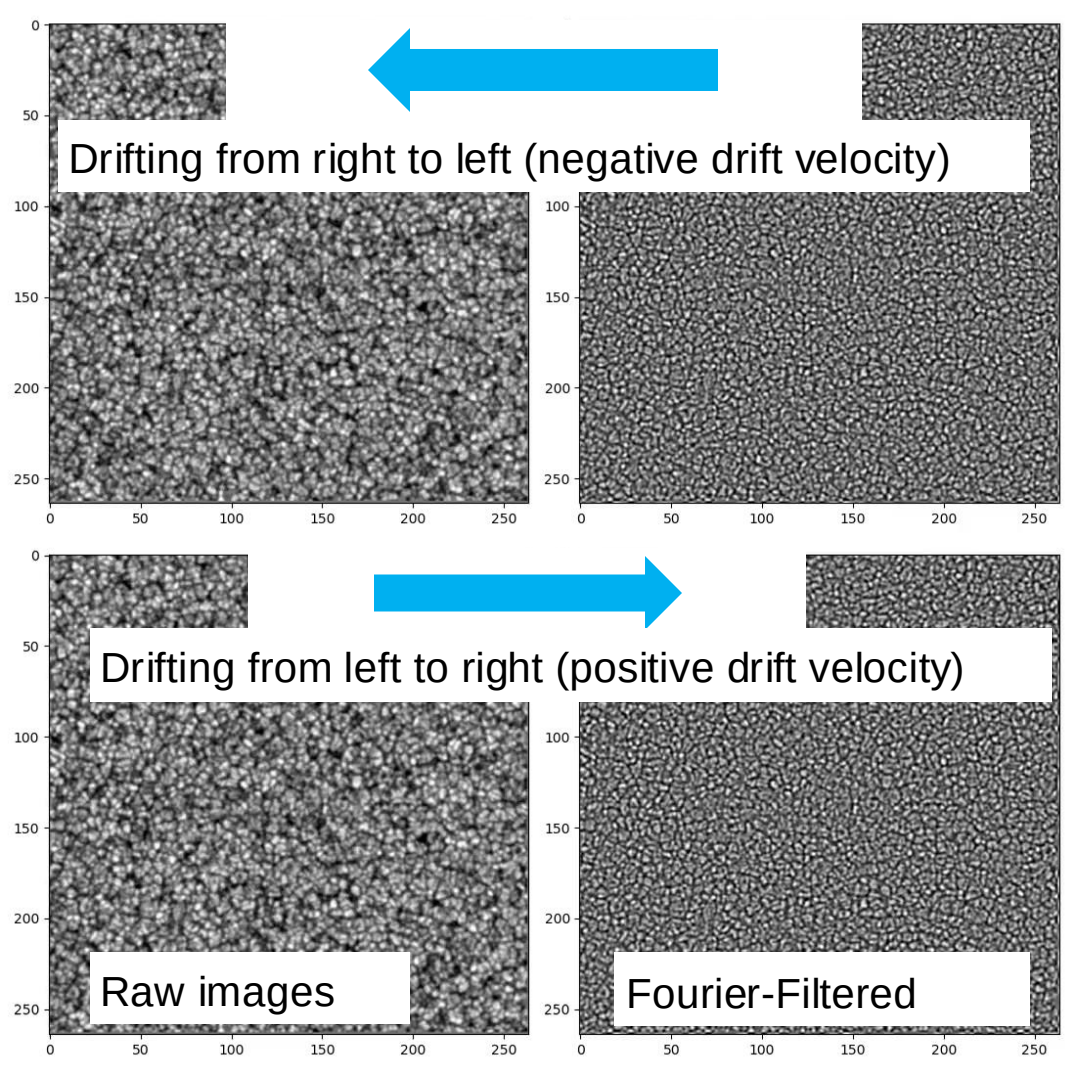
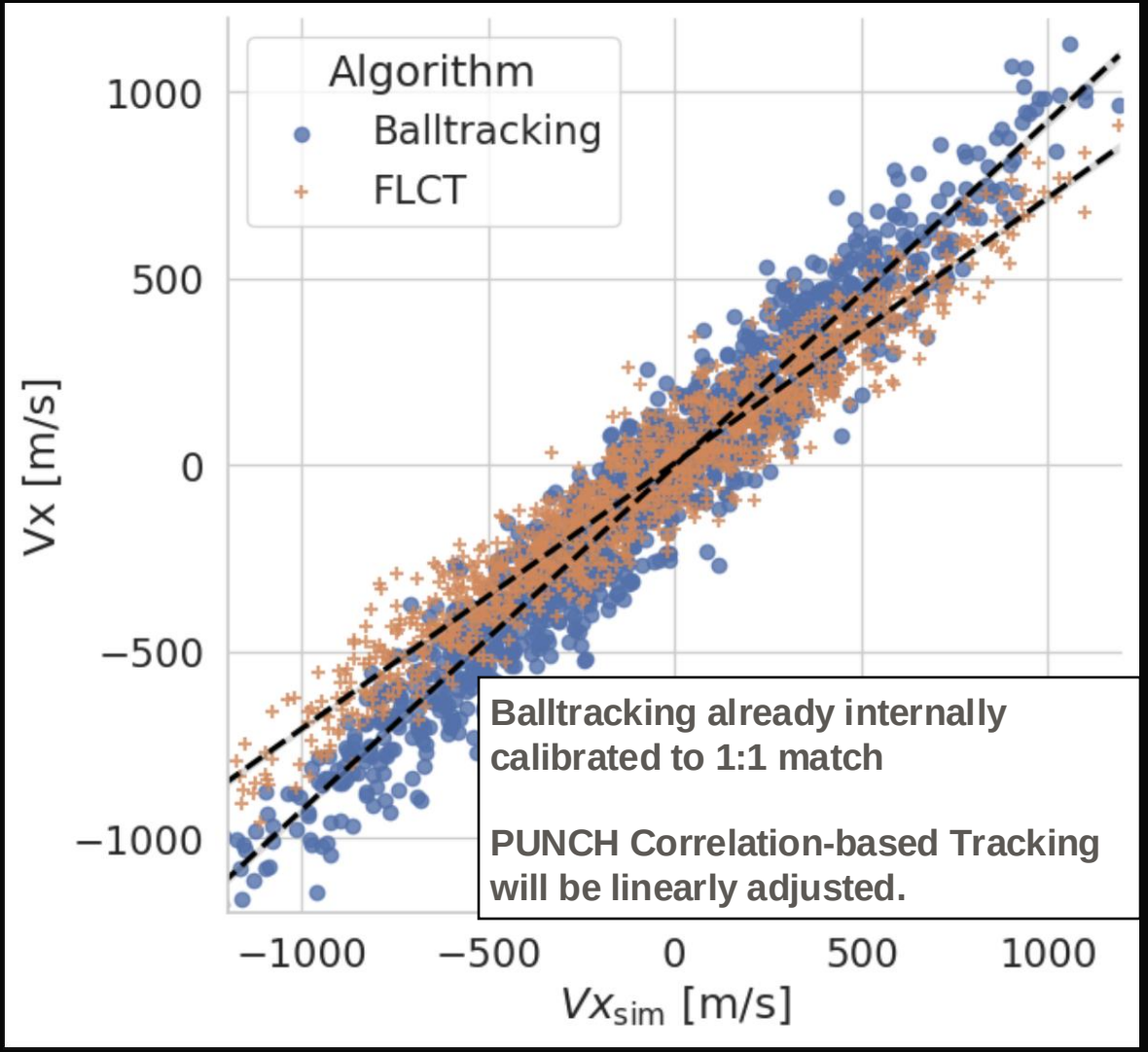
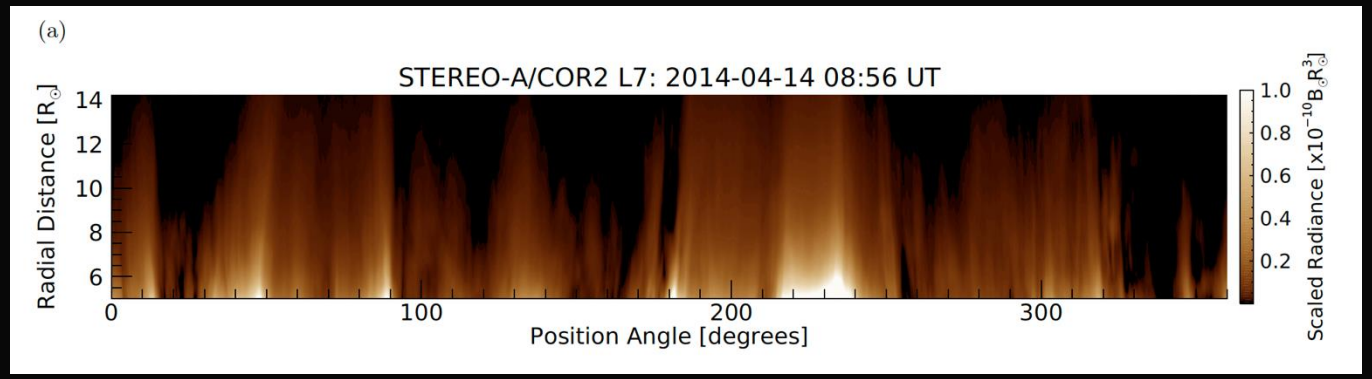




Accuracy estimates with Flow Tracking Challenge (Valmir Moraes Filho, Vadim Uritsky)

Accuracy estimates with Flow Tracking Challenge

(Moraes Filho et al., 2024) – Special thanks to Vadim Uritsky!



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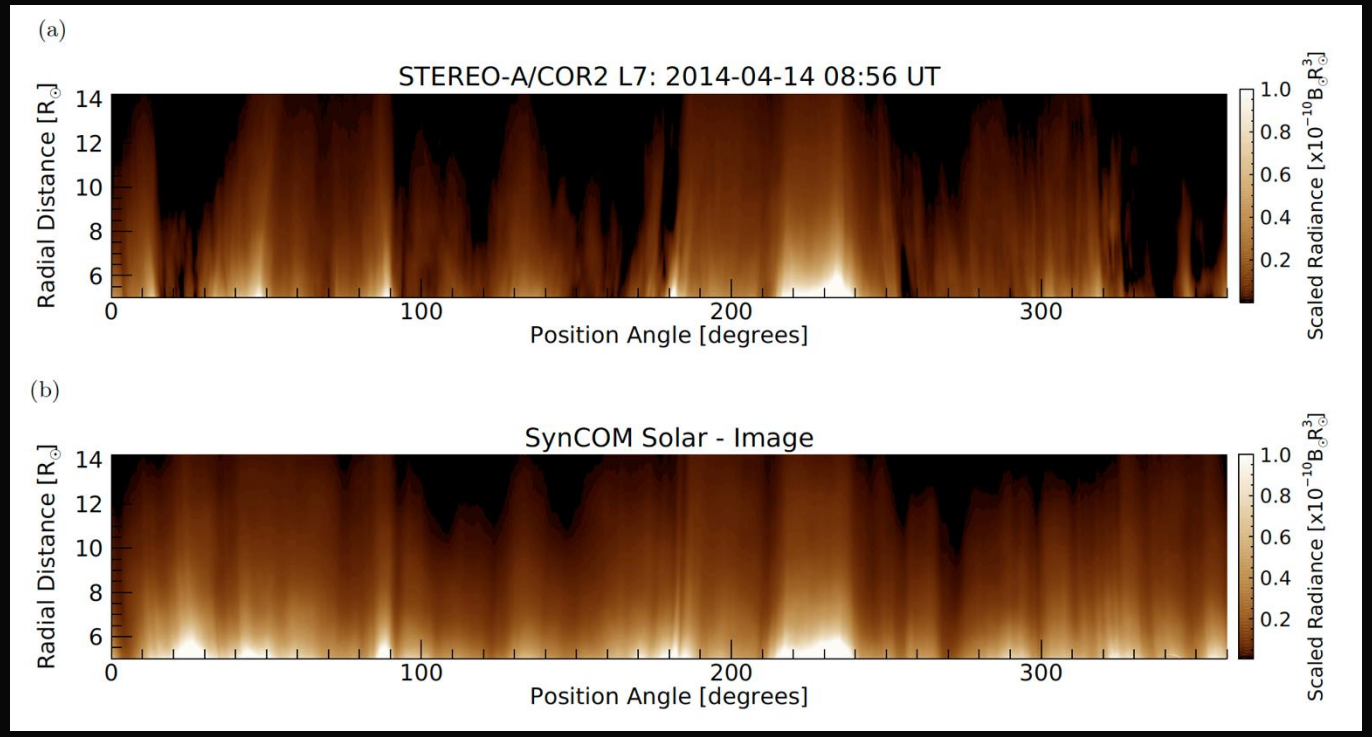

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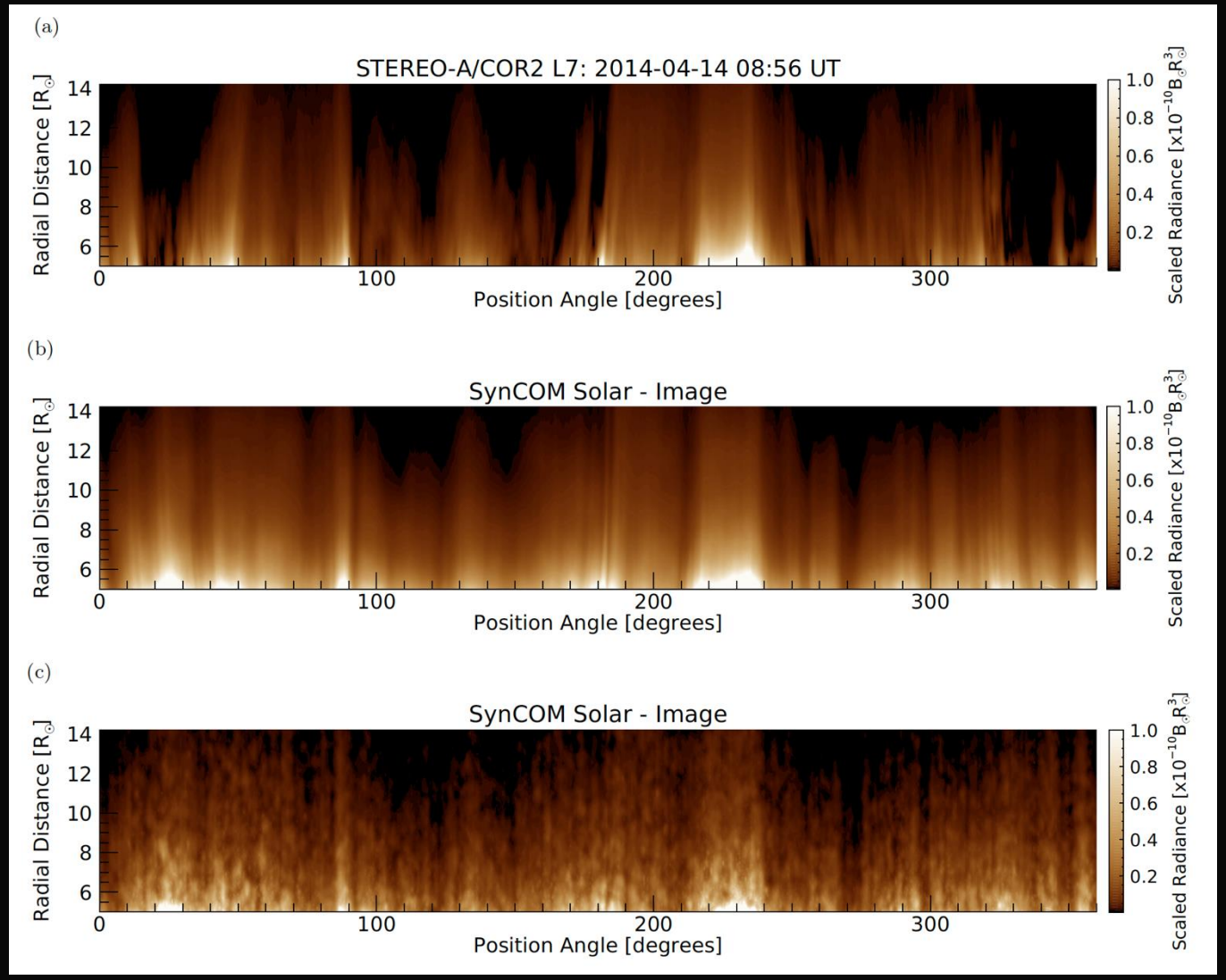

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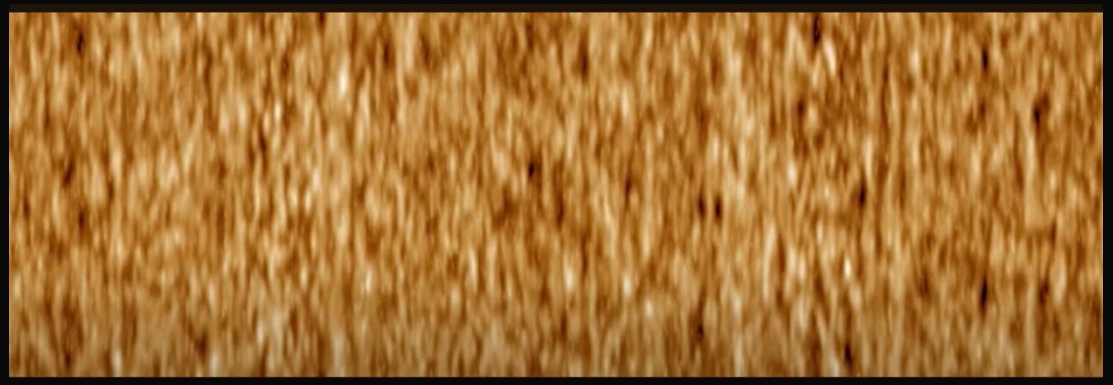
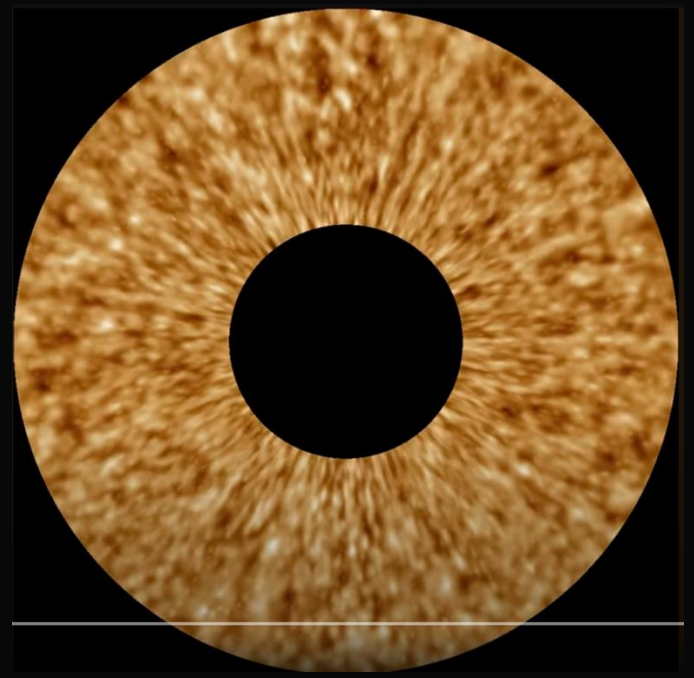
Synthetic realistic imagery with known “ground-truth” flows





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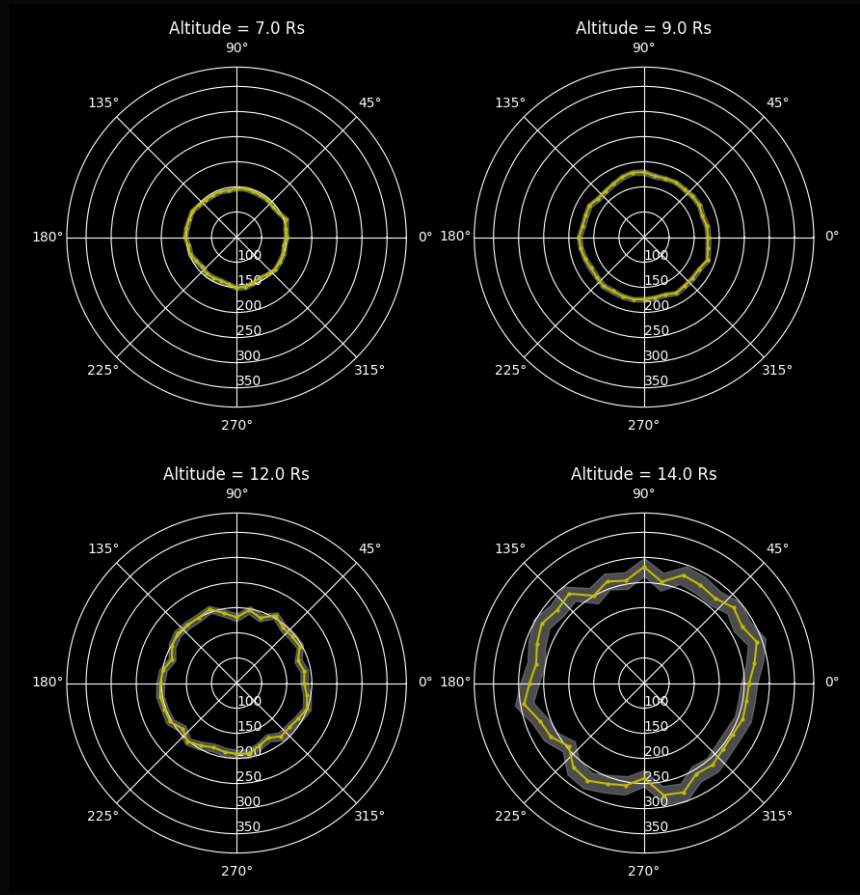
https://youtu.be/cw154Po_J40?si=zlnloIxwPpHQsf7M

Characteristics of PUNCH Flow Maps

- Correlation-based radial flows:
  - **@SOC:** **Ring-Average radial speed** of the ambient solar wind over at least 4 different radial bins between 5 to 80 Rs, 6-hr cadence, over 1440 latitudinal bins.
  - Large-scale solar wind acceleration-deceleration with radial distances



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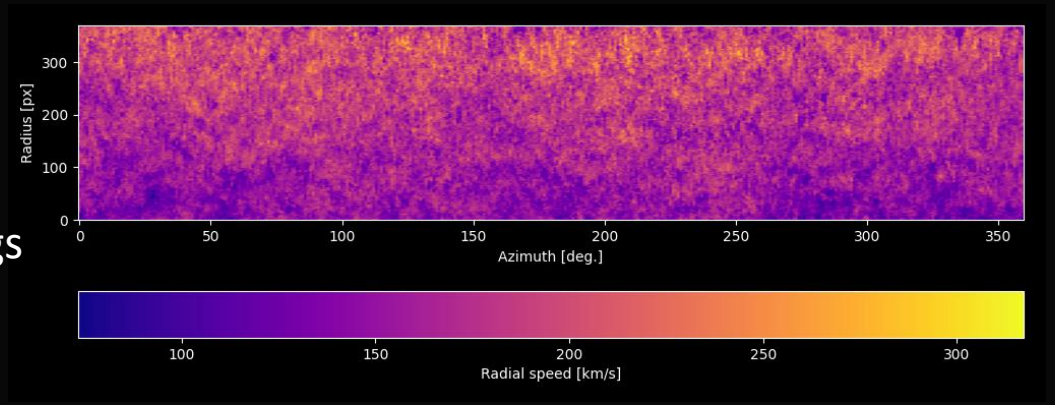

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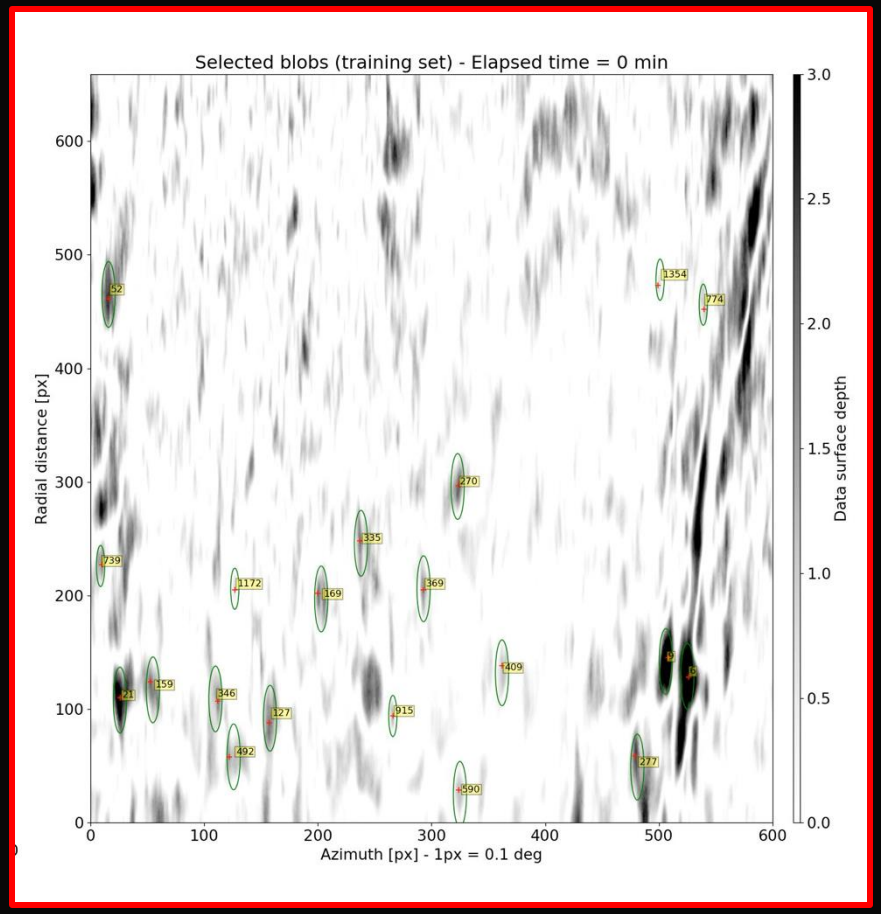
  - Forecast of CME travel times and trajectories



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