Large-scale rotation of the corona and solar wind
Impacts on magnetic field inversions

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Solar wind and coronal rotation more variable/complex than photospheric rotation

Solar cycle / mag. topology dependent

Coronal response to differential rotation (e.g. injecting shear)

Conditions for the generation and propagation of waves, switchbacks, flux-ropes

Synoptic UVCS campaings revisited (plans for SO/Metis synoptics)

Synergies with PSP (WISPR, in-situ)

Angular momentum transport across the solar corona (complex, badly understood)

Consequences for sun-to-spacecraft connectivity
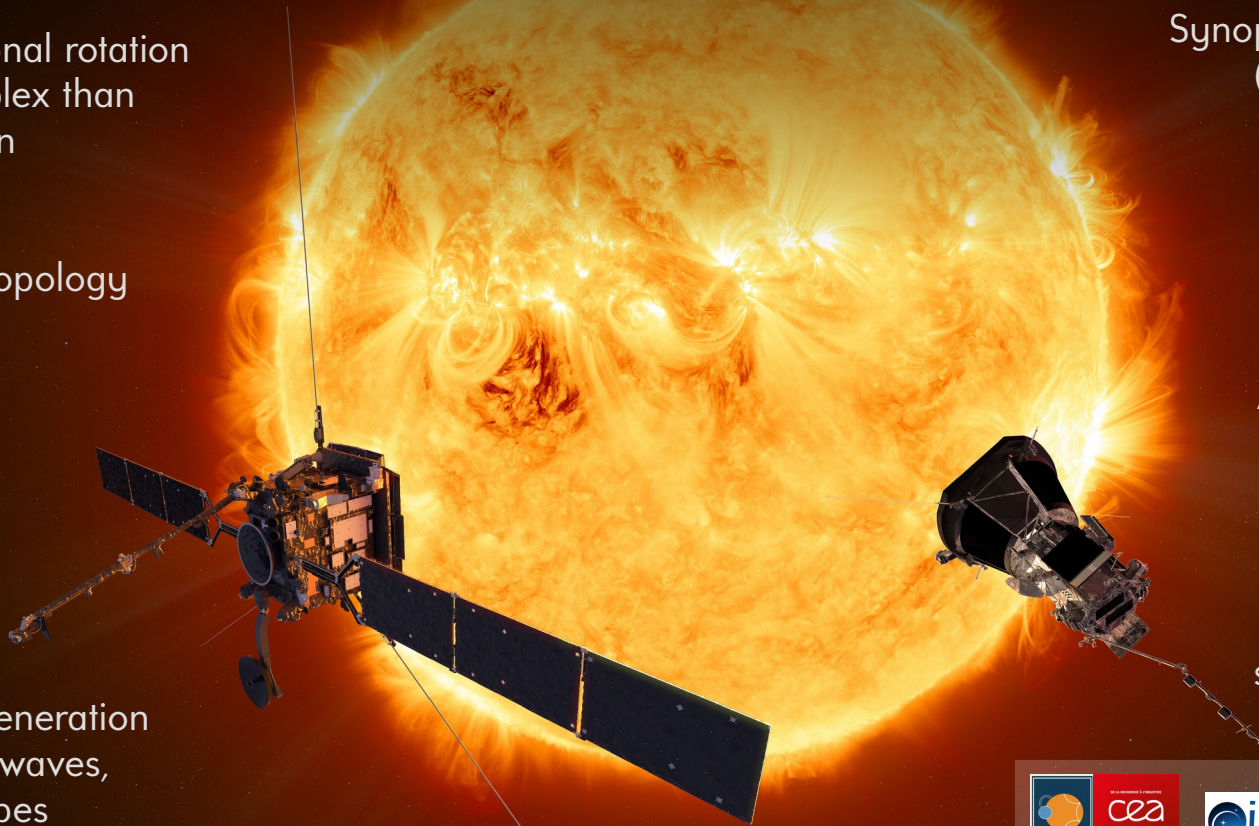
Overview

Corona and solar wind rotation
Global MHD simulations covering a full solar cycle,
response of the solar corona to different surface rotation patterns,
formation of spatially extend wind shearing regions.

SolO and PSP connectivity, solar wind sources
PSP E1 to E6, SolO LTP01: solar minimum conditons, s/c connected most of the time to
boundaries between equatorial streamer and polar CH (with some exceptions).
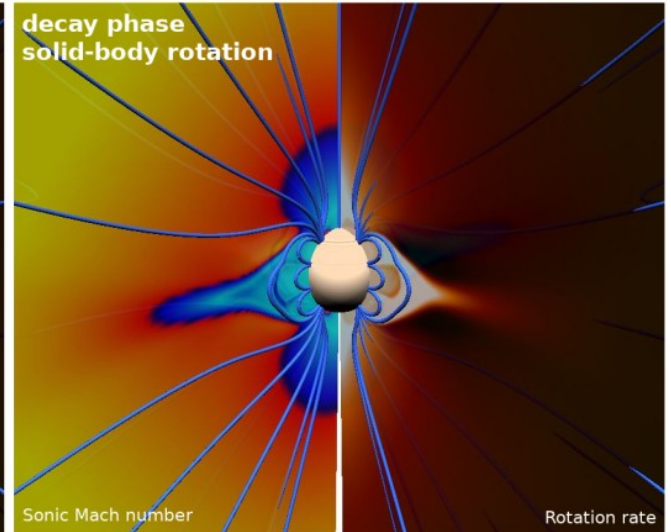
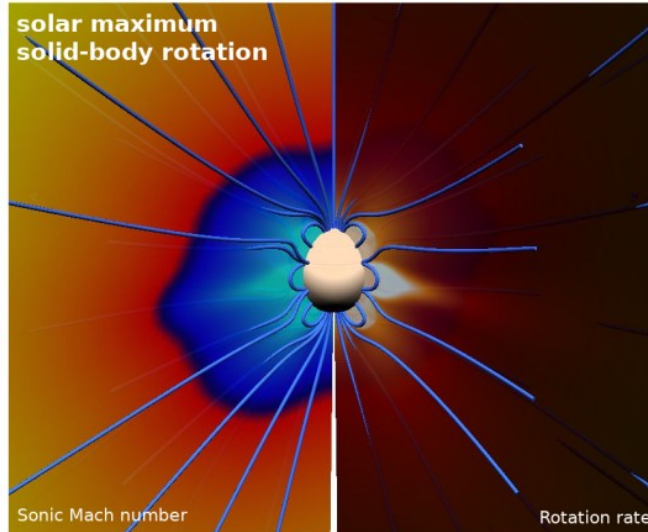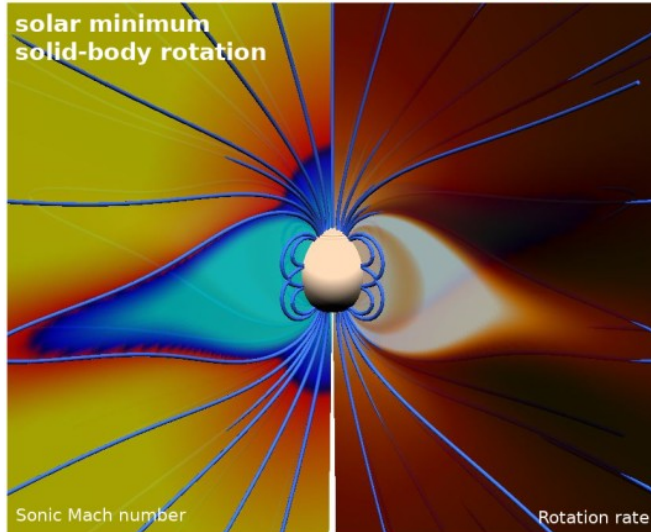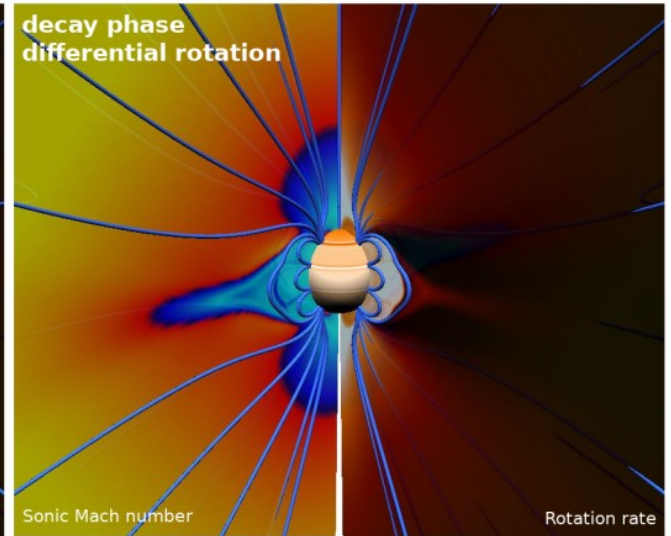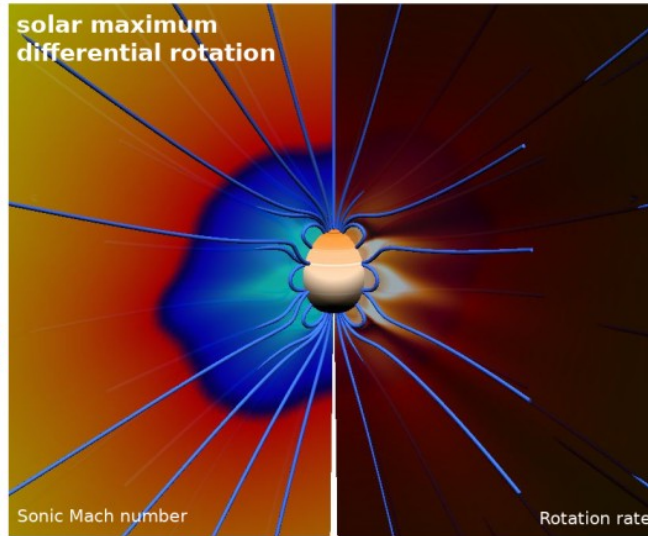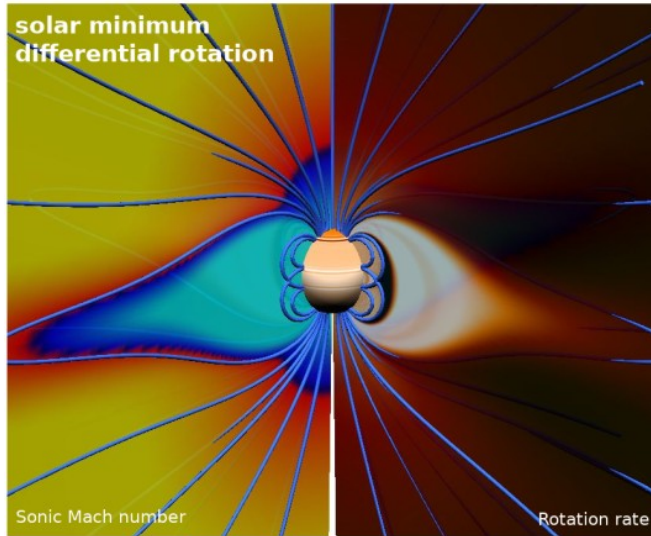Sequential probing of the same wind streams.

Modeling the source regions of the probed solar wind
Need a closer inspection to CH/streamer boundaries,
Conditions for the formation and propagation of magnetic perturbations
(flux-ropes, switchbacks),
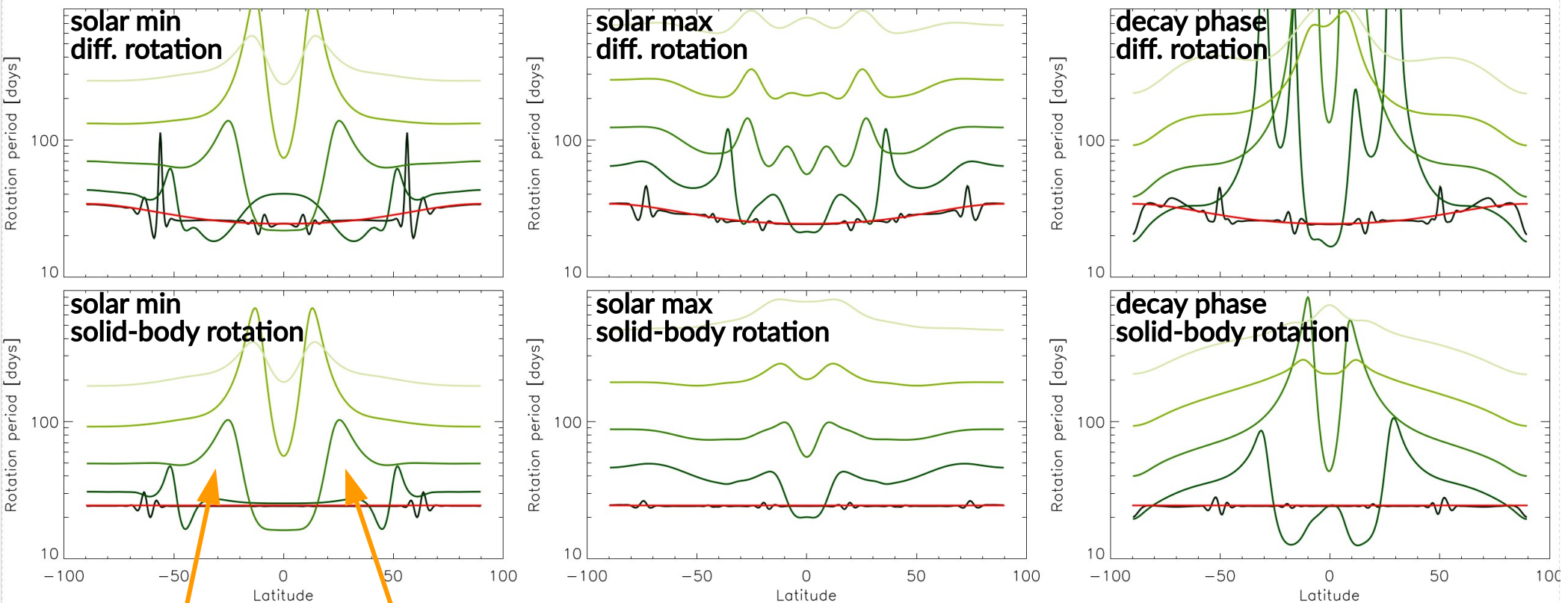Monitoring, full Sun to s/c solar wind modelling.

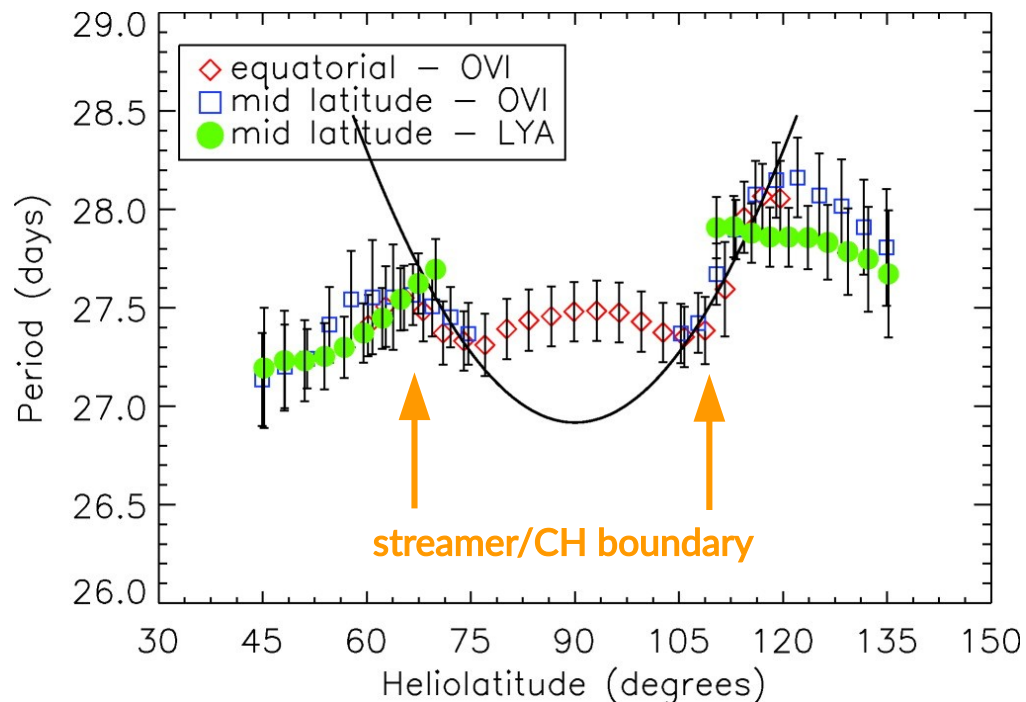# Coronal rotation, MHD simulations, full solar cycle

Rotation period from low to high corona

streamer/CH boundary

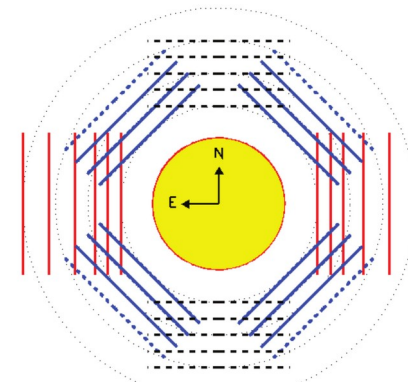dark to light green: r=1.03, 2.0, 4.0, 8.0 and 16 R_{sun}
red: surface rotation profile

(Pinto et al, 2021, A&A)

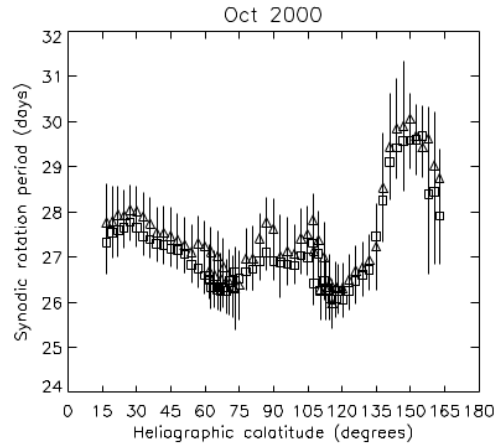# Differential rotation in the corona, observations

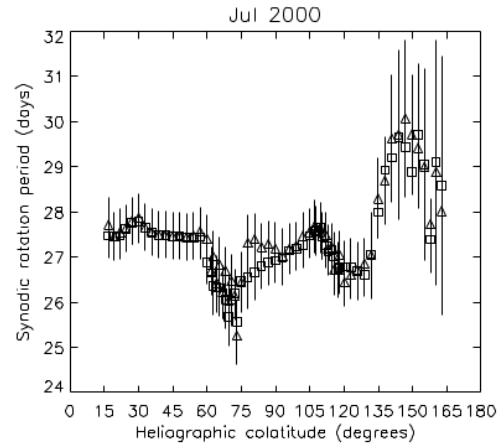

UVCS derived rotation periods (at 1.5 R$_{sun}$), solar minimum

(Giordano & Mancuso, ApJ 2008)
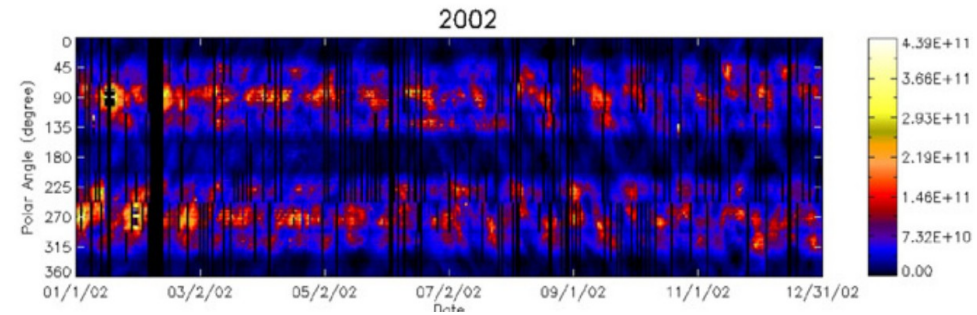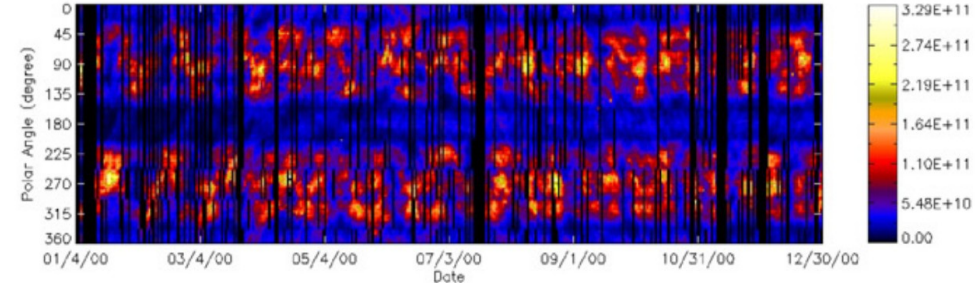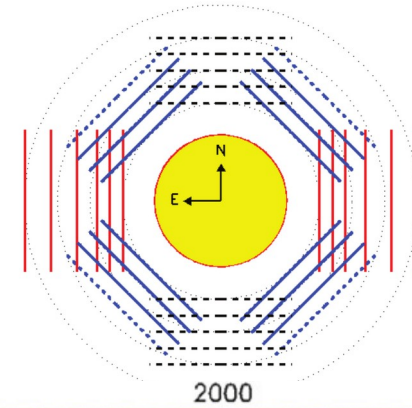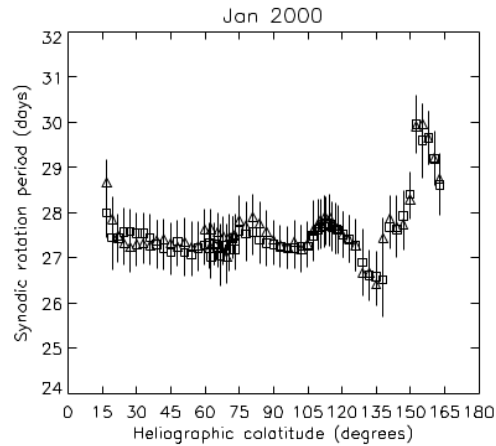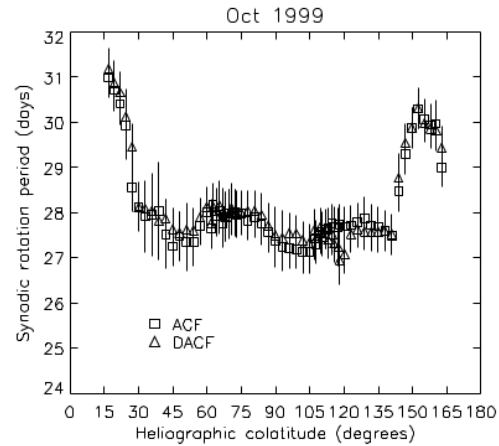
UVCS derived rotation periods (at 1.5 R_{sun}), solar maximum

(Mancuso & Giordano, ApJ 2011)

MHD: Wind speed and rotation rate gradients

solar min | grad(u) |

solar max | grad(u) |

solar min | grad(Ω) |

solar max | grad(Ω) |

(Pinto et al, 2021, A&A)
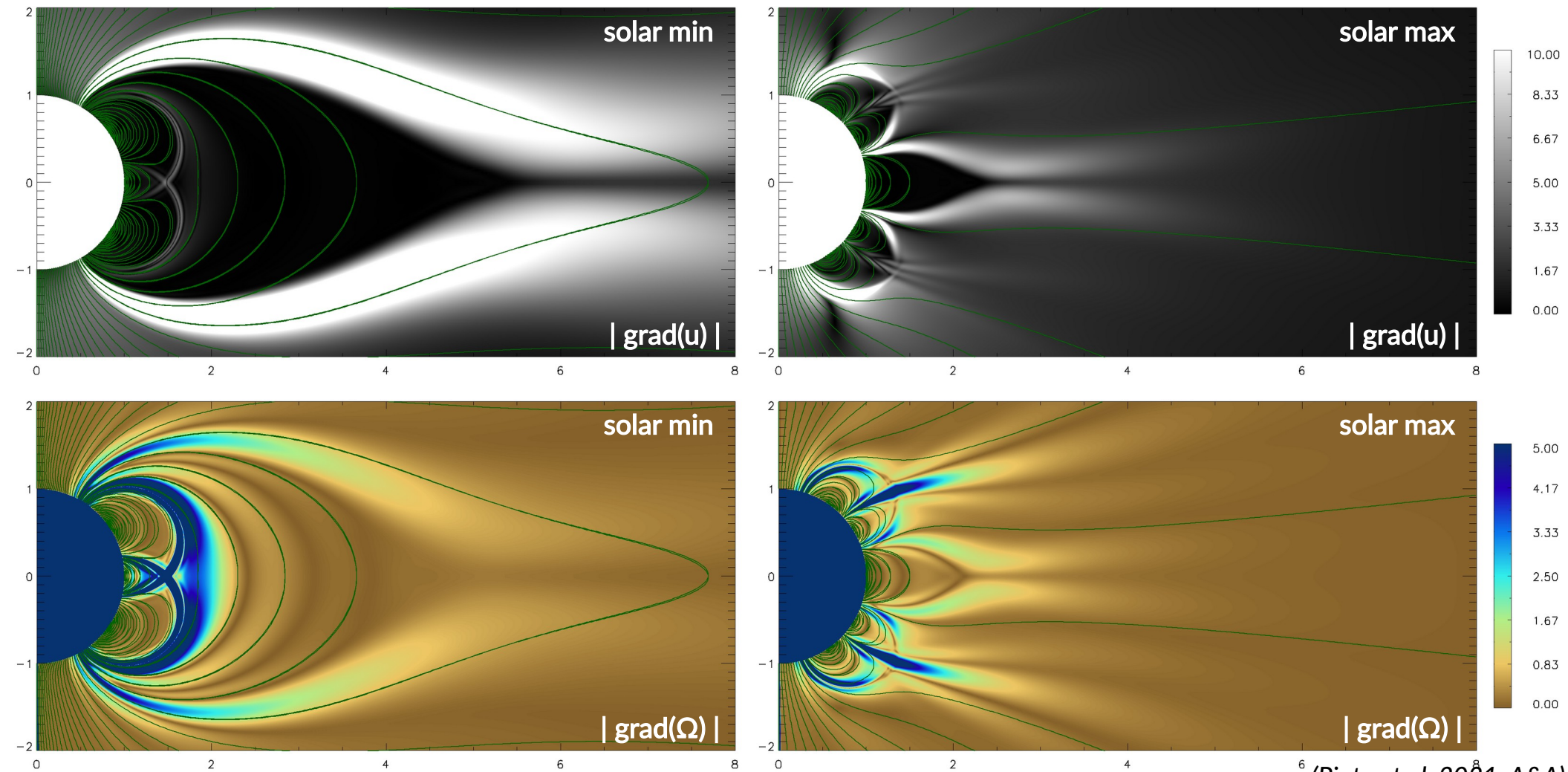
MHD: Vorticity amplitude and orientation

solar min

solar max

$| \, rot(u) \, |$

$| \, rot(u) \, |$

solar min

solar max

$vort_{//} \, / \, vort_{\perp}$

$vort_{//} \, / \, vort_{\perp}$

(Pinto et al, 2021, A&A)
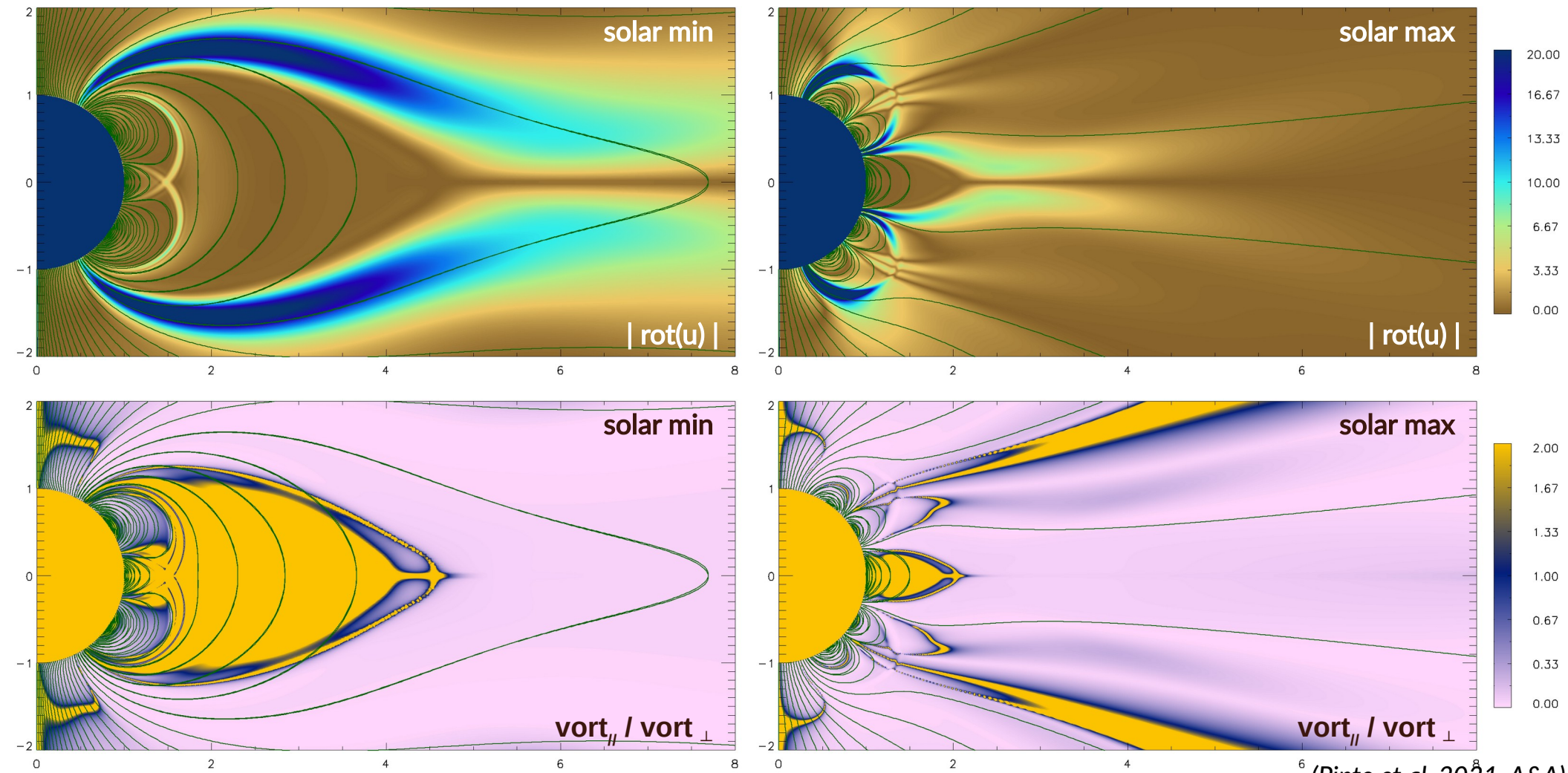
Connectivity: PSP, March 2019 (E02)

Connectivity Tool www.connect-tool.irap.omp.eu

Surface layer: AIA 193 Å
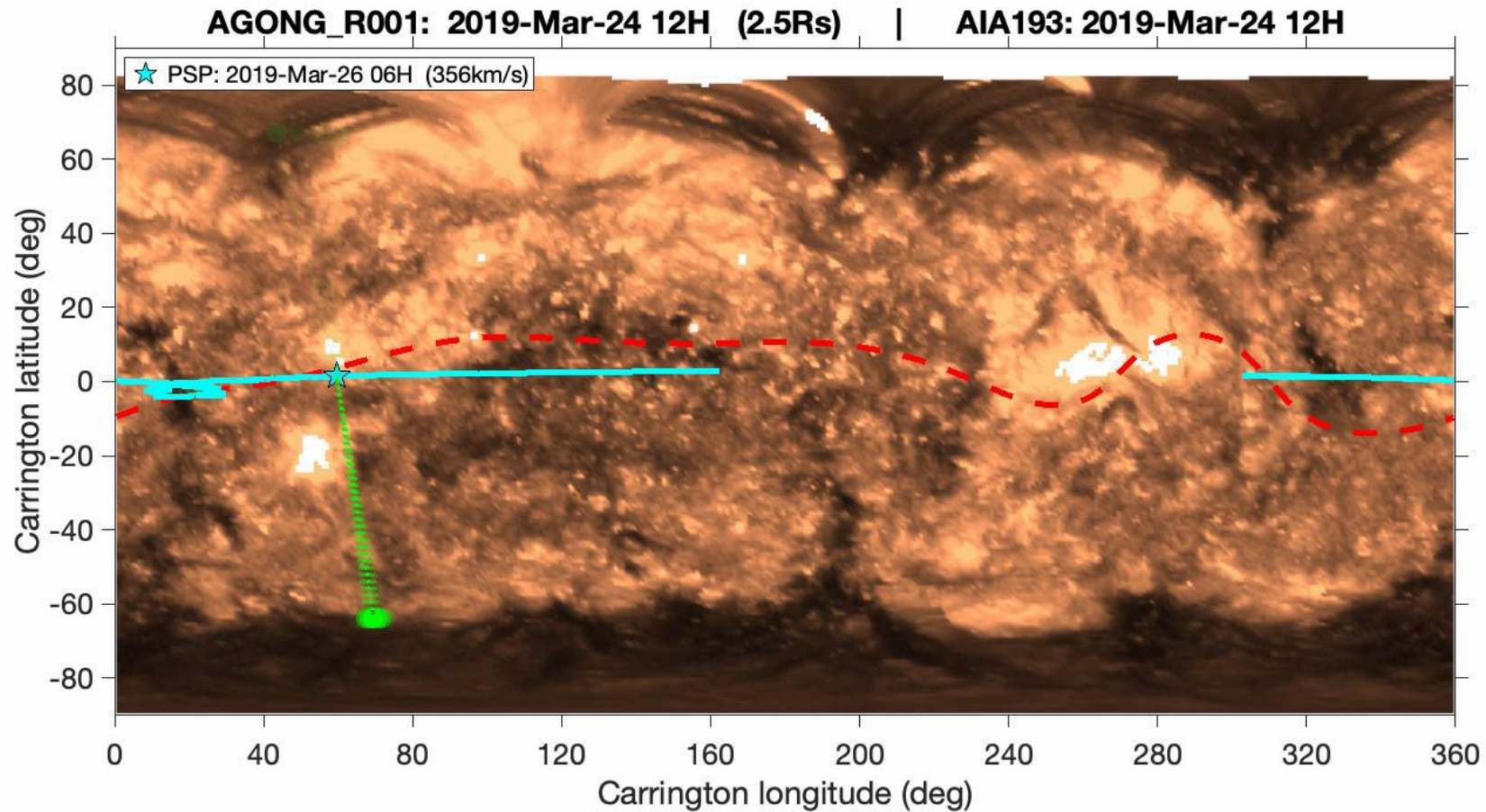
Connectivity: PSP, 23 March 2019

side view

top view
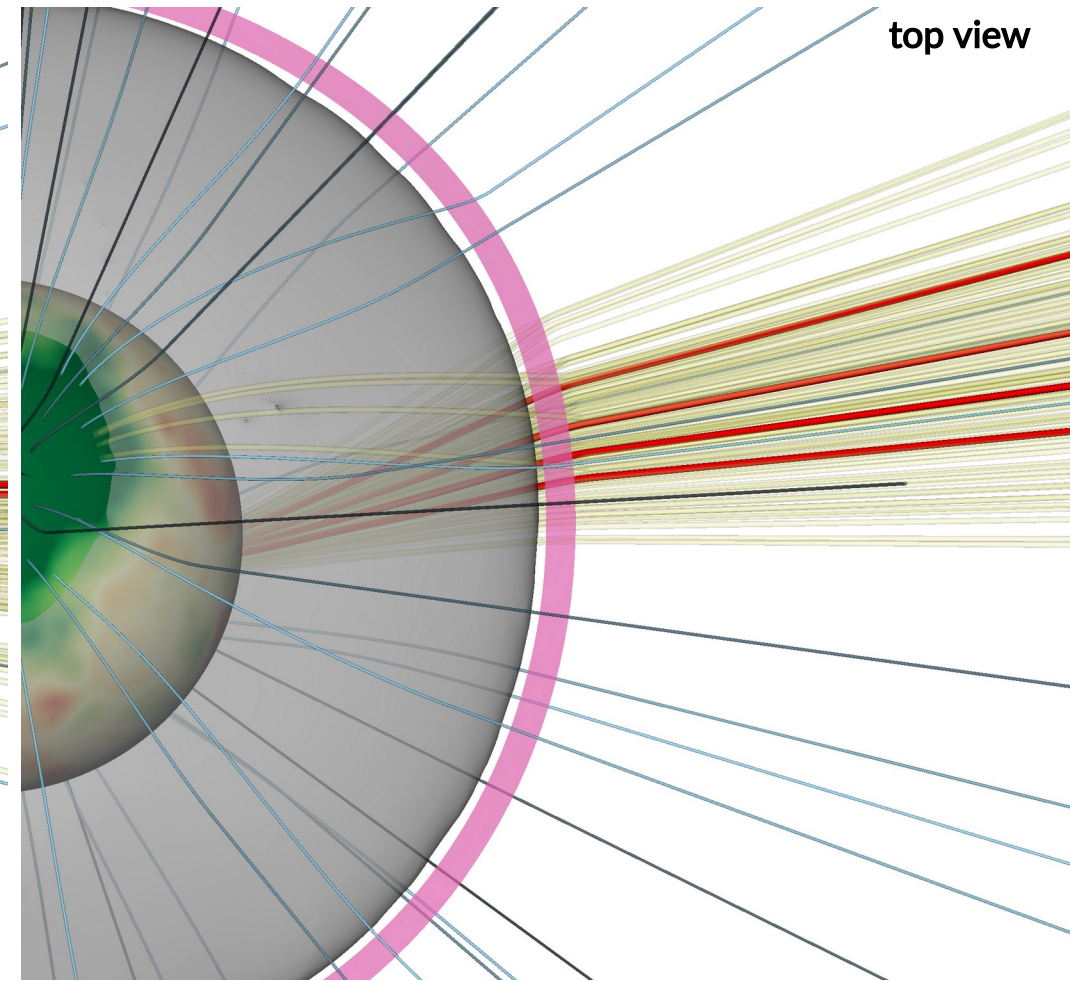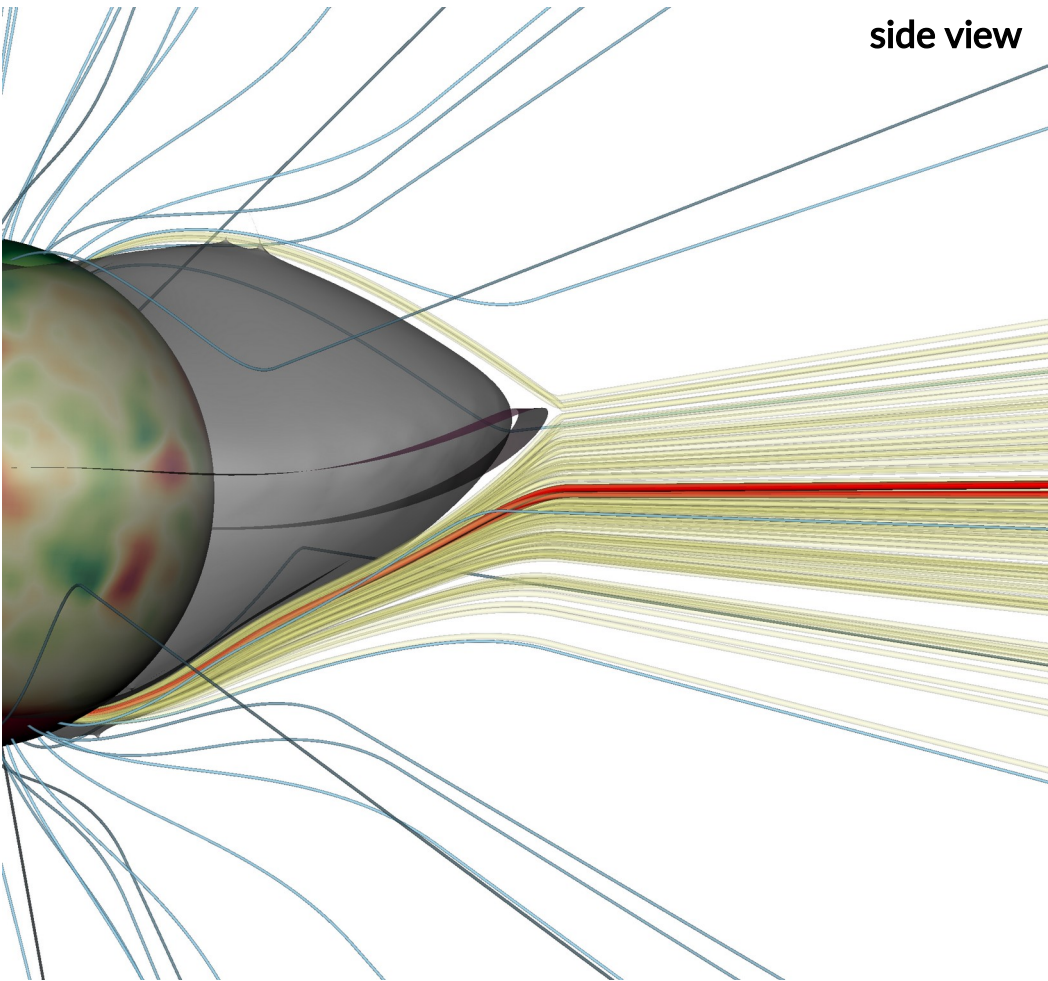
yellow lines: uncertainty ellipse
red lines: highest connectivity probability
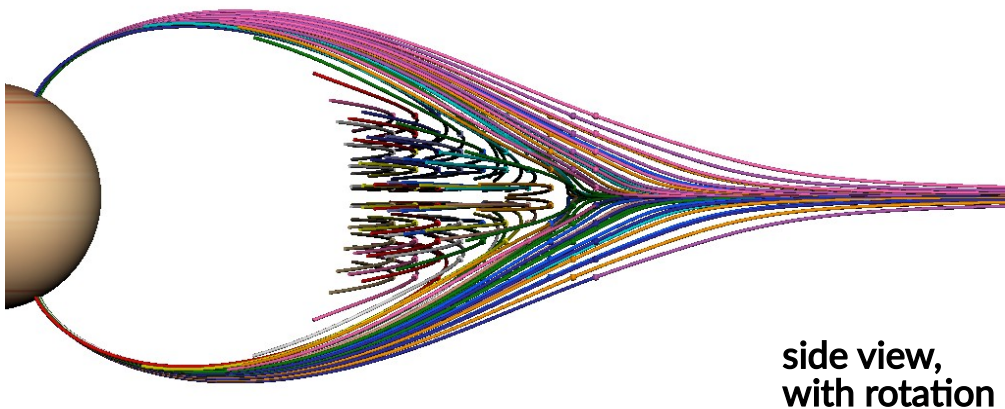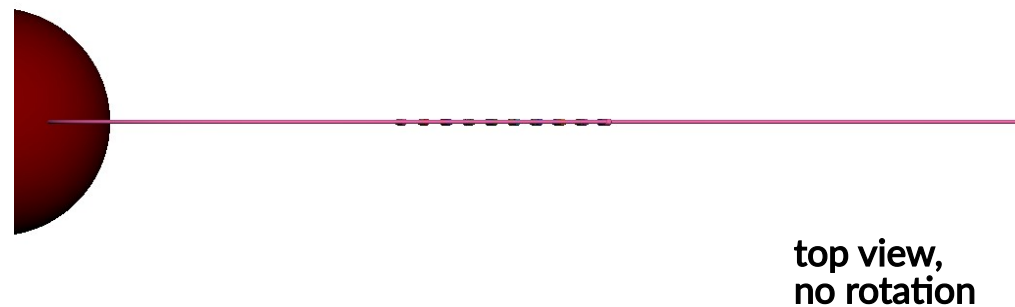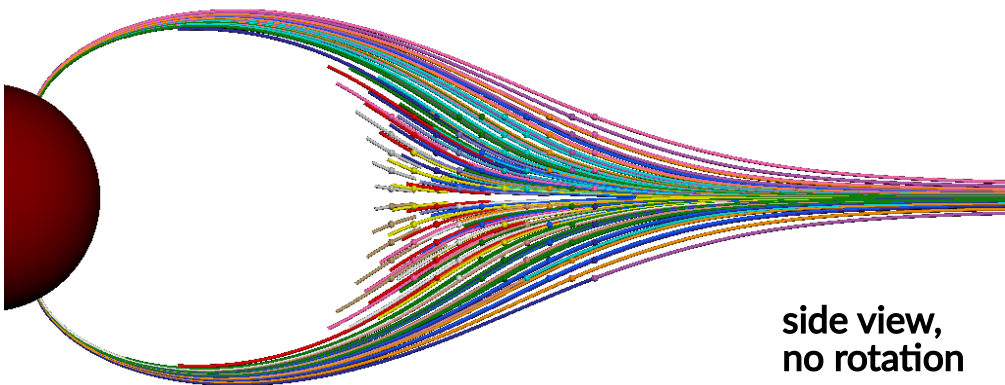
Connectivity Tool www.connect-tool.irap.omp.eu

Rotation shear: flow lines (inertial frame)

side view,
no rotation

top view,
no rotation

side view,
with rotation

top view,
with rotation

Rotation shear: flow lines (inertial frame)

side view,
no rotation

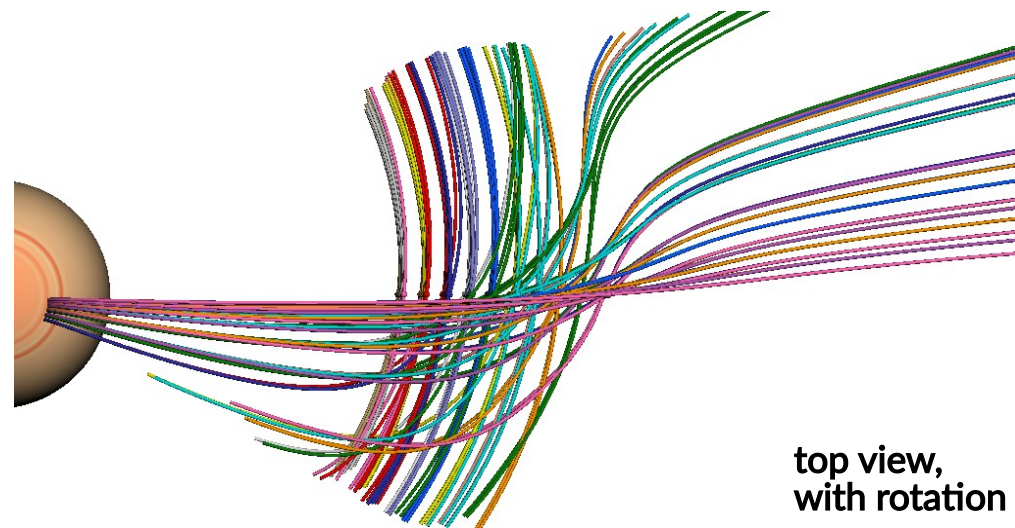top view,
no rotation

side view,
with rotation

sense of
rotation

wind outflow

max shear

wind accel. region

top view,
with rotation

(Pinto et al, 2021, A&A)
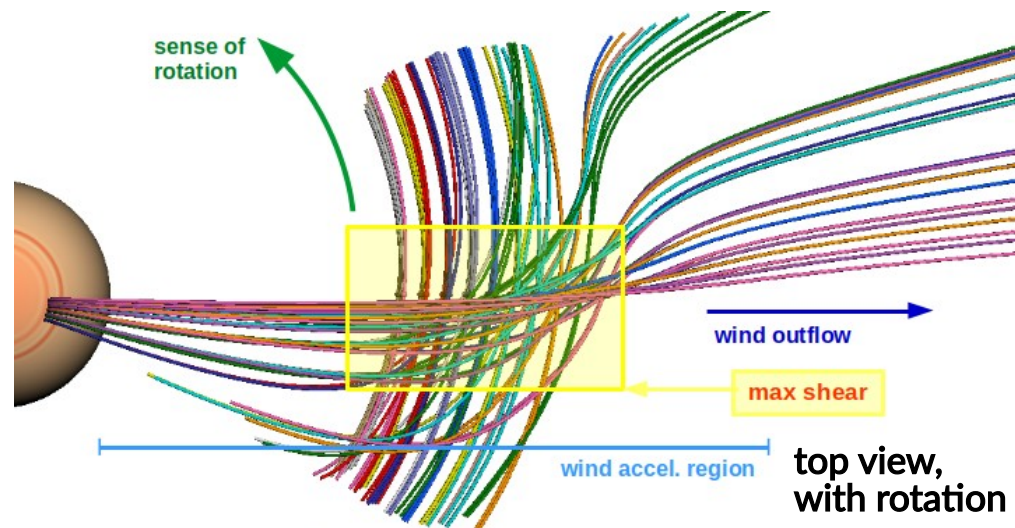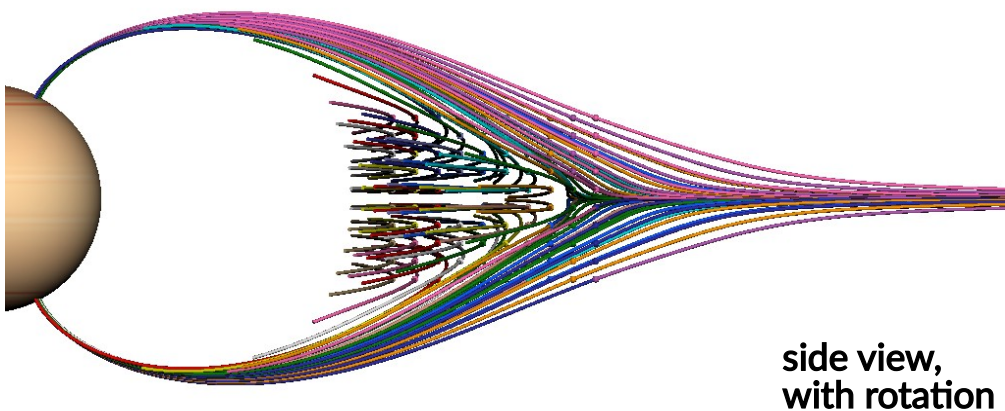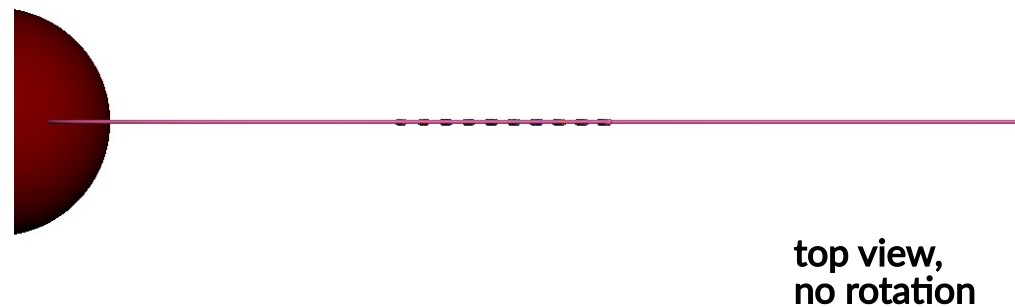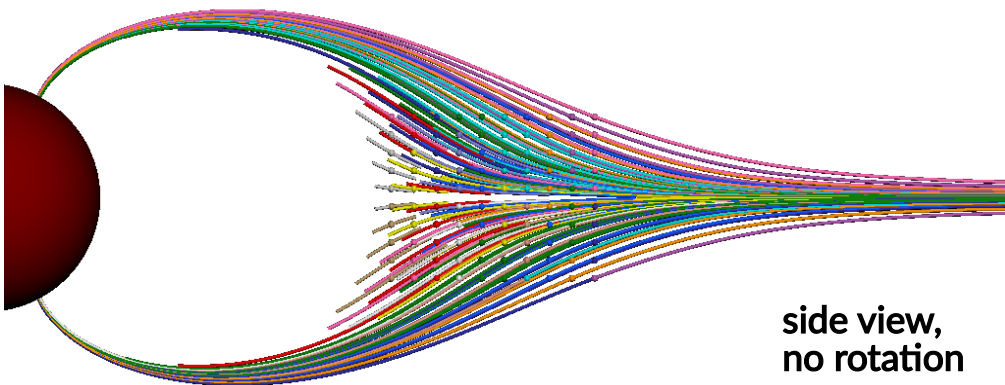
Solar Orbiter detection of KH waves *(Kieokaew et al, A&A, accepted)*
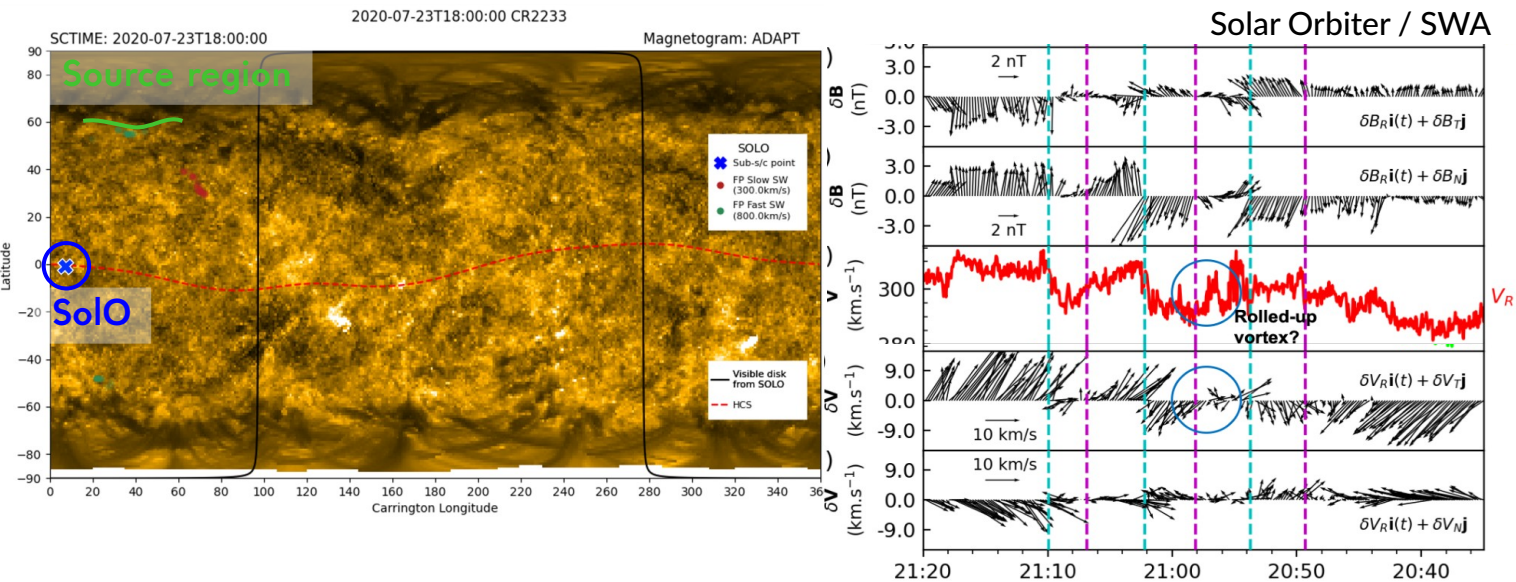
Large-scale solar wind shear

Solar Orbiter / SWA

Shear Flows
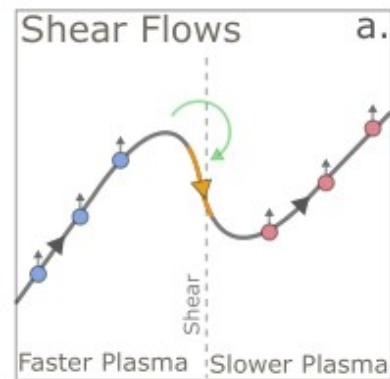
Global wind shear important to **sustain/amplify mag. inversions** through the heliosphere

Source of magnetic inversions?

(Macneil, et al, 2020)

Similar solar wind source region:
- azimuthally-aligned polar CH boundary

Solar wind develops KH vortices:
- detected at SolO/SWA position
- confirmed by local box MHD

Local box MHD simulation

Global rotation of the corona and solar wind

Key for many science problems, but largely understudied:

– **enhanced shear forced at streamer/pseudo-streamer boundaries**, at all moments of the activity cycle

– rotation periods peak at the outside of streamer boundaries, **as observed by SoHO/UVCS**
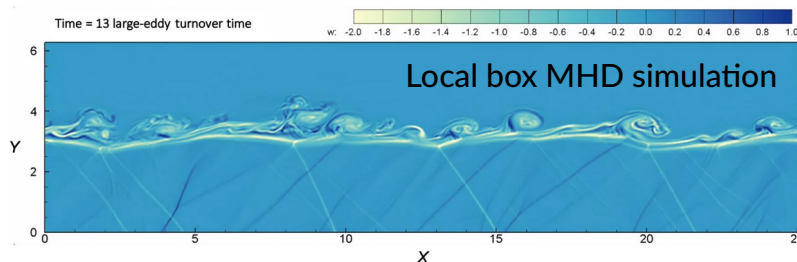
– overall, **rotation rate of the corona is very structured** in these regions **(high and low rotation rates co-exist)**

– streamer and pseudo-streamer stalks support **radially elongated shearing zones** (up to high heliocentric distances)

– magnetic pitch angles can be high at some locations; **shearing in blob/flux-rope formation zones**

– should **affect magnetic field inversion** formation and propagation

– important for angular momentum balance (solar/stellar evolution)

Remote sensing diagnostics:

- SolO/Metis synoptics: distribution of obs. windows (use LLD?), SolO orbits, non-uniform solar longitude scanning,

- WISPR: crossings of HPS/streamer belt, connect transients to shear sources

Synergies with in-situ:

- SolO/SWA, PSP, BepiColombo – several quadrature / quasi-quadrature configurations expected

Modelling support

- Numerical models (daily SWiFT/MULTI-VP, per-event full MHD), IRAP's connectity tool

- Tomography