A **wave-turbulence-driven** solar wind model validated against **Parker Solar Probe** measurements

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The solar wind – a proxy for low-mass stars

- Stellar winds shape exoplanet atmospheres over evolutionary time-scales
- Accurate models of the solar wind are necessary to study the properties of the tenuous winds of solar analogues
- The complex problem of coronal heating is still not fully incorporated in modeling efforts

What Drives the Wind?

- Polytropic wind models implicitly assume the heating of the wind through their equation of state
- Explicit coronal heating requires an energy contribution to accelerate the solar wind
- Characterising this contribution through dissipating Alfvén-waves drives the solar wind as a physically motivated process

Objective

Link the 3D MHD code NIRVANA with a wave-turbulence driven heating mechanism to generate a model description of the solar wind (NIRwave) and validate the result against measurements from the Parker Solar Probe.

Setting up a model

1. We couple NIRVANA (Ziegler 2008) with an established wave-turbulence-driven heating routine (Cranmer 2010)
2. We use an axisymmetric dipole to represent the solar wind as a single-fluid plasma
3. We evaluate the results from NIRwave, and a comparable polytropic wind model created with NIRVANA
4. We constrain our model through observations of the SPC and SPAN-I instruments, covering heliocentric distances between 40 $R_\odot$ and 15.9 $R_\odot$ (Fig. 1)

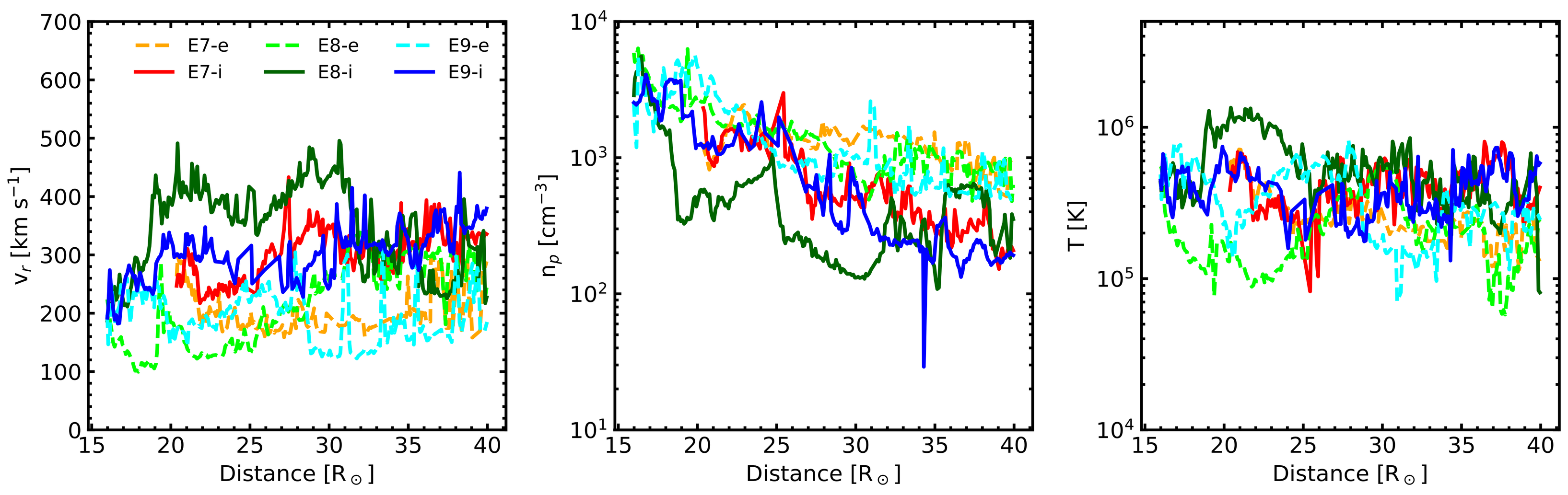

Fig. 1: SPC and SPAN-I measurements during ingress and egress of the Parker Solar Probe encounters 7, 8 and 9

NIRwave – results and outlook

Our Model Results show:

- The characteristic bimodal structure of the solar wind (Fig. 2)
- Mostly open field lines within the domain, except for distances near the domain centre (Fig. 3)
- A global mass-loss rate of $2.6 \times 10^{-14}\ \mathrm{M_\odot yr^{-1}}$ in agreement with previous models
- Good agreement between the wind parameters of NIRwave and the empirical constraints
- A better representation than the results of a comparable polytropic wind

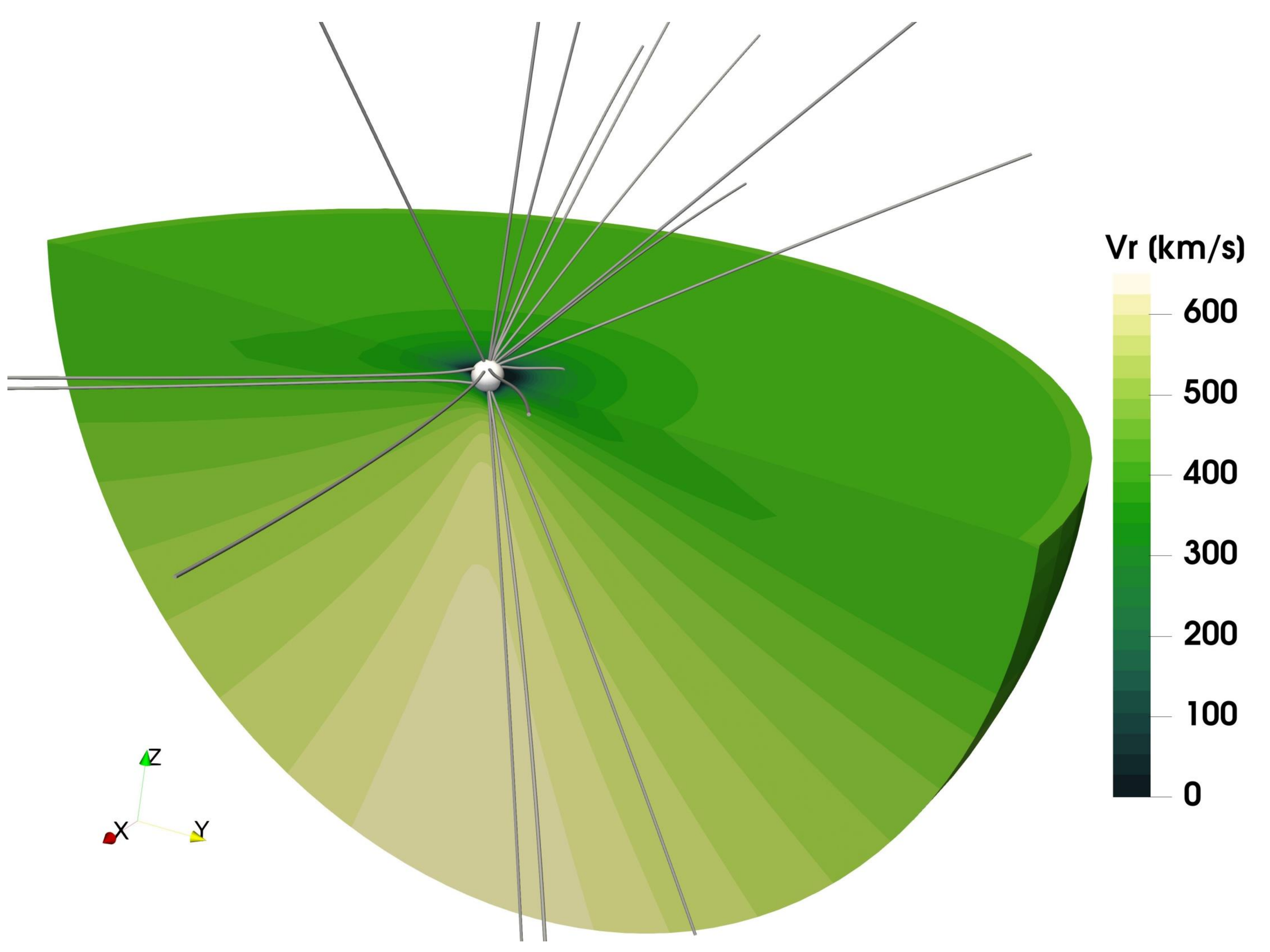

Fig. 3: Three-dimensional radial velocity distribution within the simulation domain

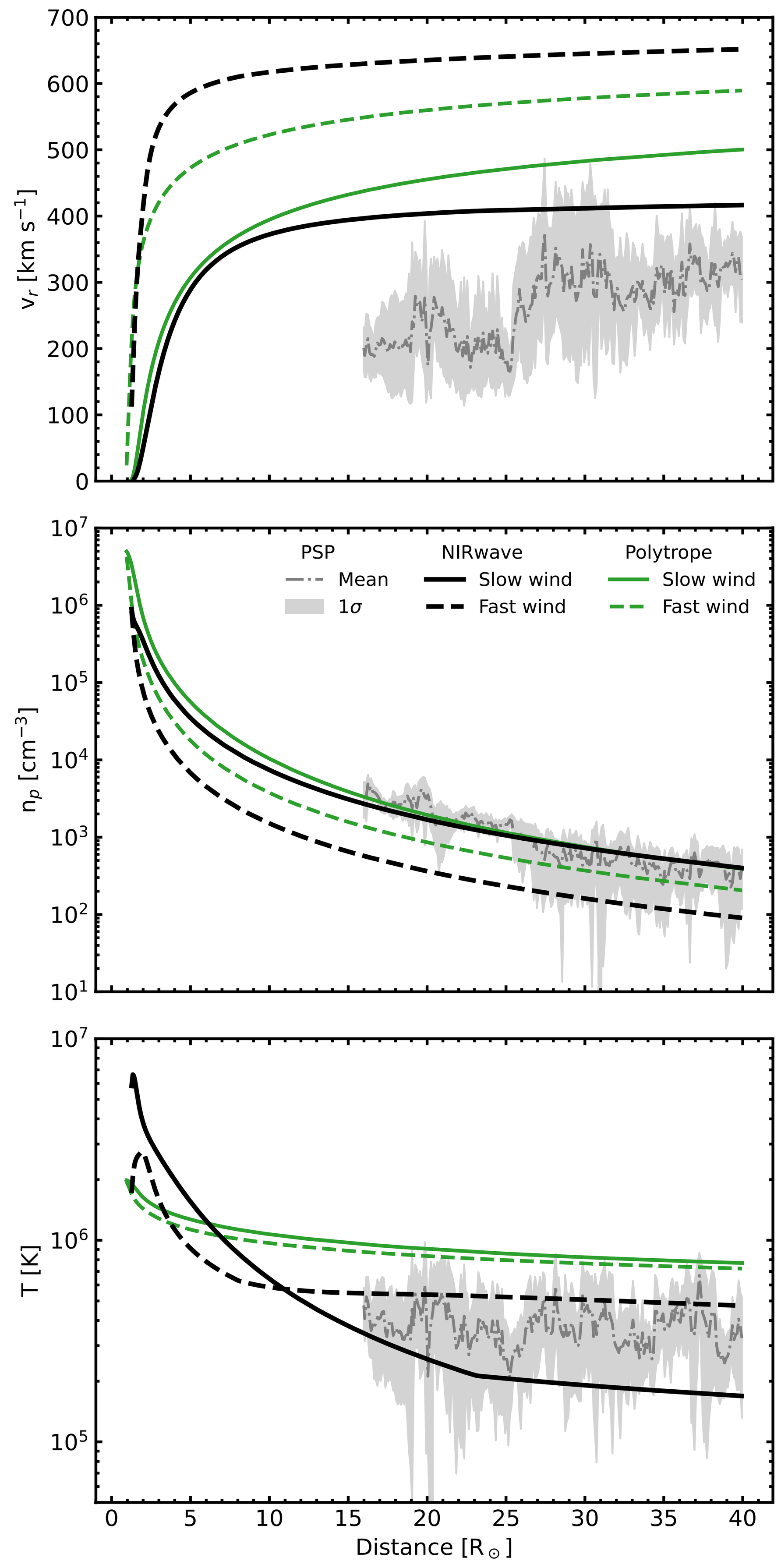

Fig. 2: Slow and fast wind parameters resulting from our NIRwave simulation (black) and a polytropic wind model (green) compared to observations (grey). The three panels show radial velocity (top), number density (middle) and temperature (bottom)

Outlook

- Solar wind models constrained by in-situ observations are fundamental in studying the winds of low-mass stars.
- Constraints in the grid decomposition and set-up limit the accuracy of our results and leave room for future improvement
- As a model relying in simplified assumptions, NIRwave provides the potential to derive the wind parameters of a wide range of solar-type stars, including targets of upcoming exoplanet missions such as Ariel and PLATO.

Poster by S. Schleich

References:
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