Using Machine Learning to Infer Transverse Velocities and Compute Poynting Flux in the Quiet Sun

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Motivation & Background

We want to compute vertical Poynting flux, i.e. the flux of magnetic energy, in the quiet Sun (QS). Similar studies have been done in active regions, but QS is challenging due to typically low signal strength.

Poynting flux is defined as $$S = \frac{c}{4\pi} E \times B$$

Under ideal MHD assumption, we can write vertical Poynting flux as

$$S_z = [v_z B_h^2 - (\mathbf{v}_h \cdot \mathbf{B}_h) B_z]/4\pi$$

We can see that transverse (or horizontal) velocity is crucial for computing Poynting flux.

We use two methods to infer v_h:

- **Fourier Local Correlation Tracking (FLCT)**, which is a cross-correlation method for measuring proper motions of plasma (Fisher & Welsch 2008). In FLCT, **we can change the parameter σ to set the width of correlation window;**
- **DeepVel** (Asensio Ramos et al. 2017), which is a machine learning (ML) velocity inversion method trained on STAGGER MHD simulations (Magic et al. 2013).

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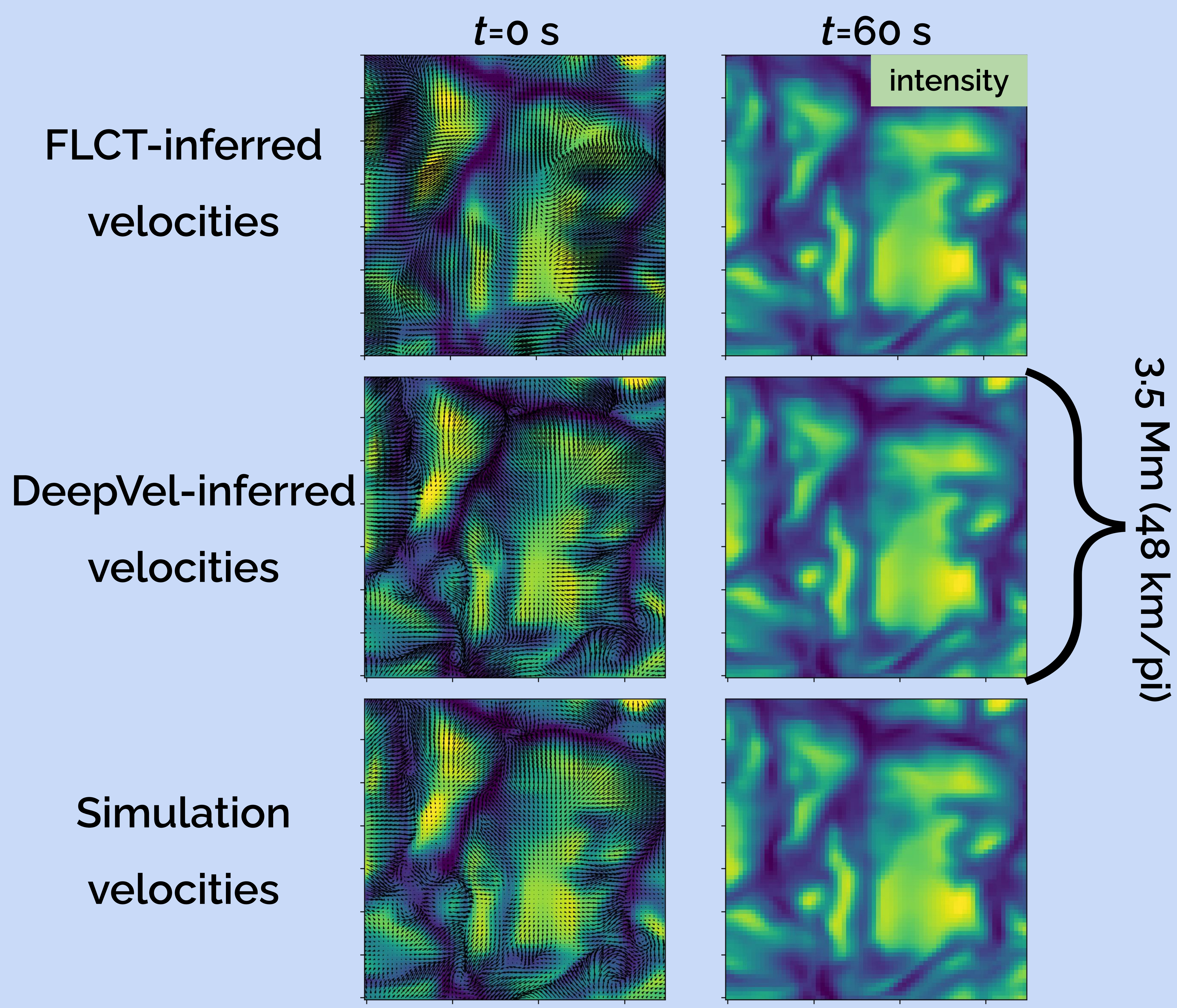
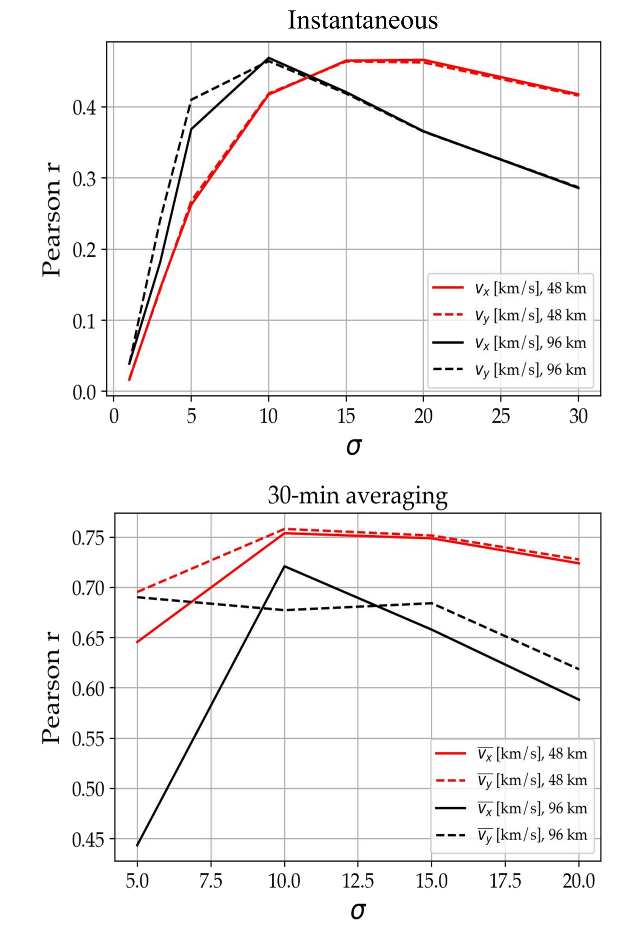
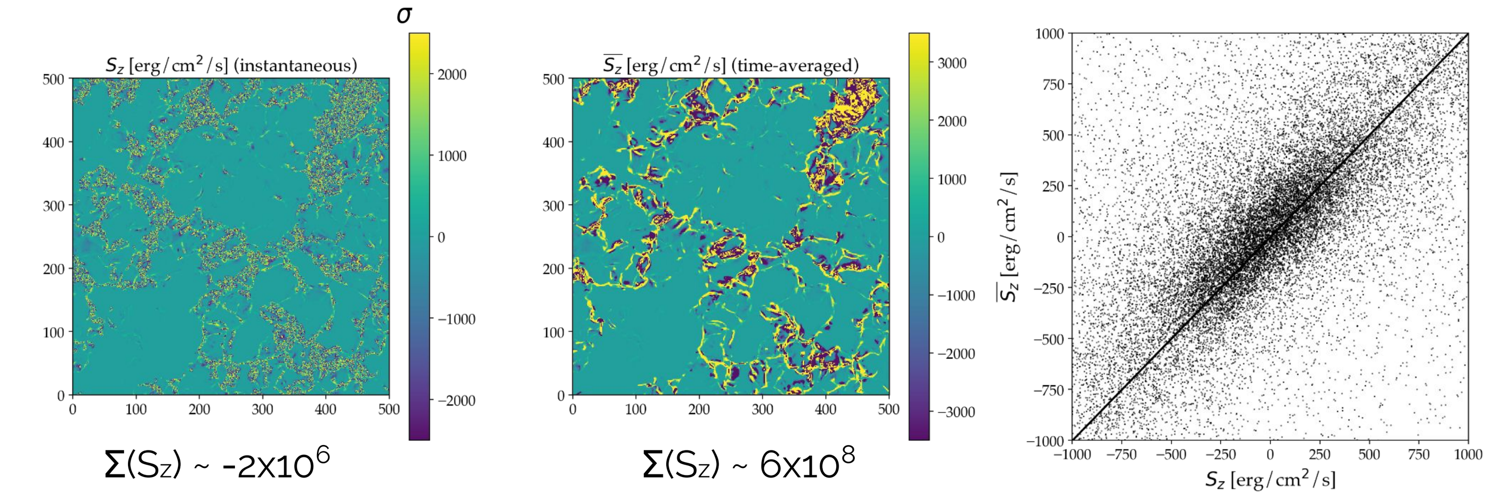
Key takeaway: ML-based velocity inversion algorithm DeepVel performs better than correlation tracking algorithms and allows us to compute Poynting flux in the quiet Sun



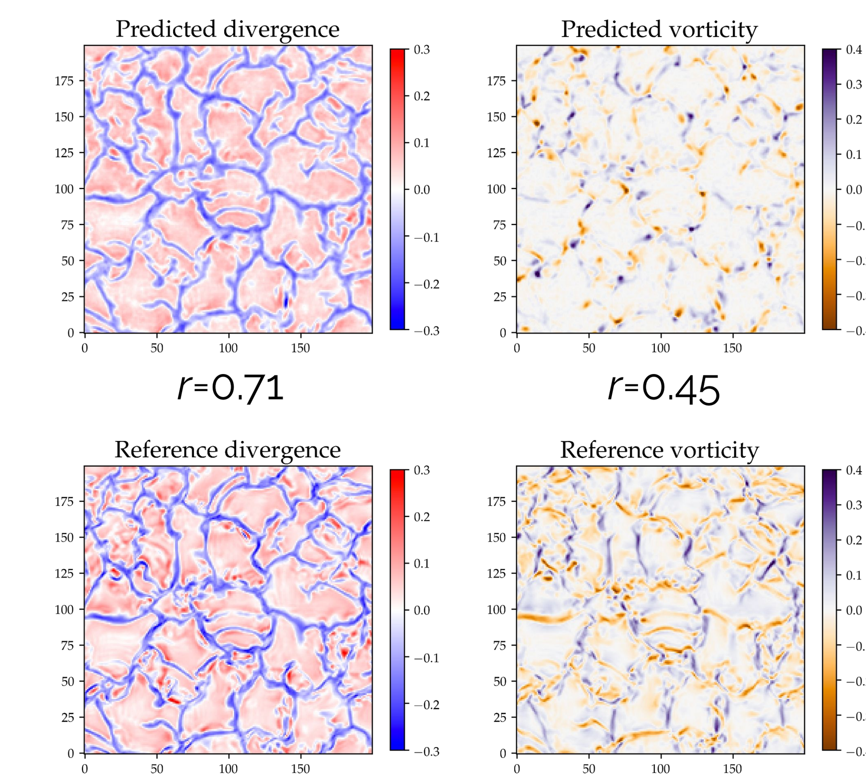
Method Validation

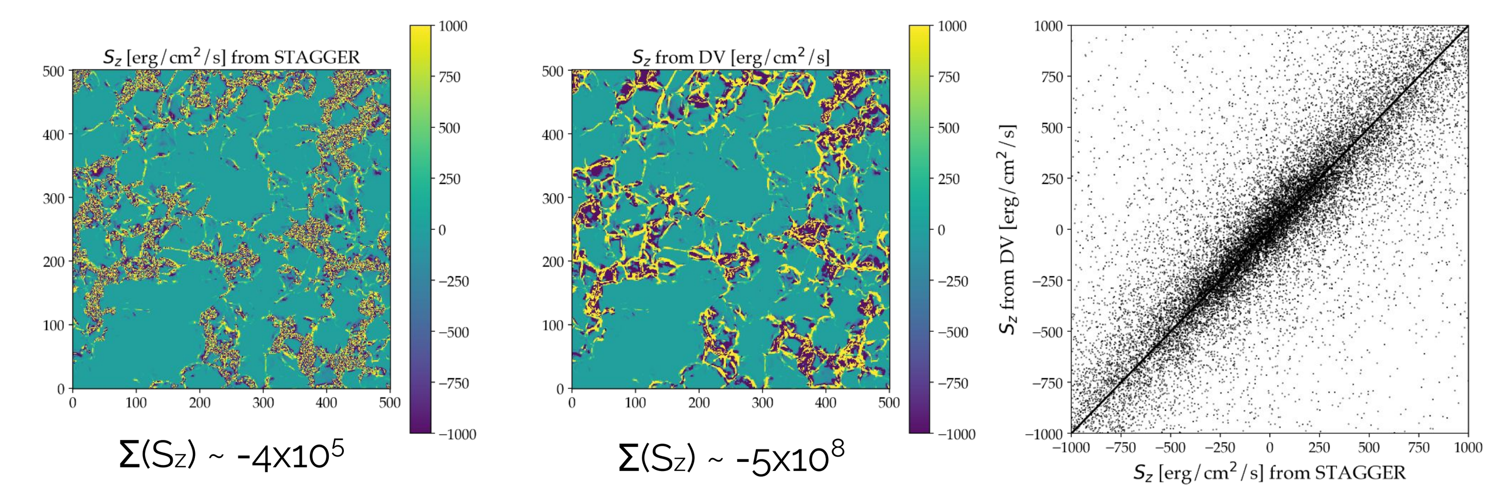


FLCT-inferred flows are weakly correlated with reference STAGGER velocities. Correlation increases for time-averaged velocities. **However, time-averaging negatively affects our Poynting flux computations.**



DeepVel-inferred instantaneous velocities are highly (*r*>0.9) correlated with simulation velocities, but divergence and vorticity are not.





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