



SYNERGY OF 3D REALISTIC MODELING OF THE TURBULENT DYNAMICS OF THE SUN AND OBSERVATIONS FROM SDO, HINODE, AND IRIS SPACE MISSIONS

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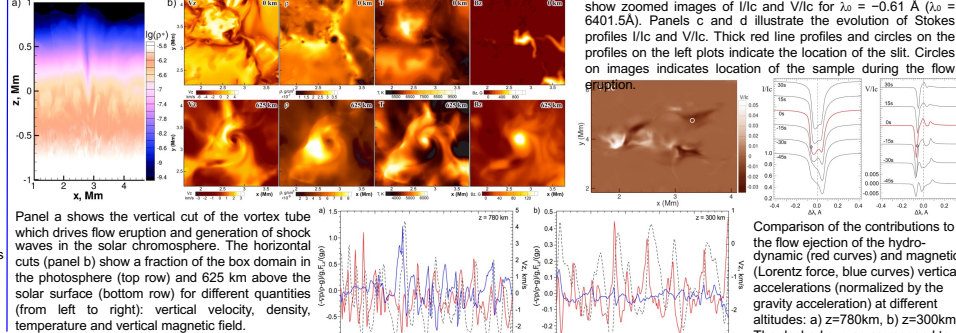
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The current computational capabilities allow us to reproduce the turbulent dynamics of the Sun with a high degree of realism from the interior to the corona. At the same time, the variety of available observations allows us to probe the subsurface dynamics and observe a wide range of phenomena in the solar atmosphere, from the photosphere to the corona. However, interpreting observations remains challenging due to the non-linear coupling of the turbulent dynamics with magnetic fields and radiation. Using the output from the realistic 3D radiative MHD simulations, we generate synthetic observables for different instruments to enable comparison of observations and models. This presentation will discuss examples of a synergetic analysis of the models, synthetic observables, and observational data from different space missions: SDO, Hinode, and IRIS. Specifically, we will discuss the center-to-limb variations of spectroscopic data, subsurface flow measurements by the ring-diagram analysis, effects of the local dynamo, the origin of small-scale eruptions, and dynamics of the solar corona.

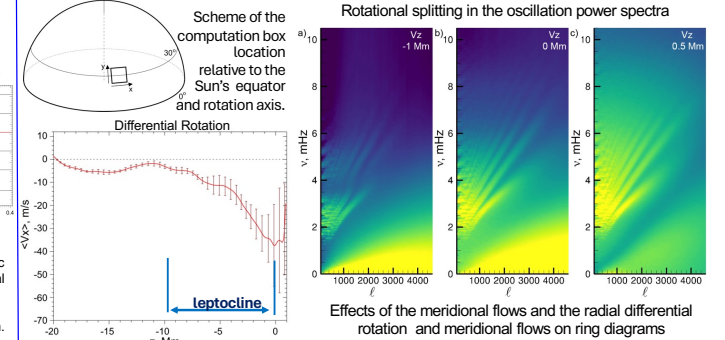
StellarBox code (Wray et al 2015, 2018)

- ✓ 3D rectangular geometry
- ✓ Fully conservative compressible
- ✓ Fully coupled radiation solver:
- LTE using 4 opacity-distribution-function bins
- Ray-tracing transport by Feautrier method
- 14 ray angular quadrature
- ✓ Non-ideal (tabular) EOS
- ✓ 4th order Padé spatial derivatives
- ✓ 4th order Runge-Kutta in time
- ✓ LES-Eddy Simulation options (turbulence models):
- Compressible Smagorinsky model
- Compressible Dynamics Smagorinsky models
- MHD subgrid models
- ✓ DNS+Hyperviscosity approach
- ✓ MPI parallelization

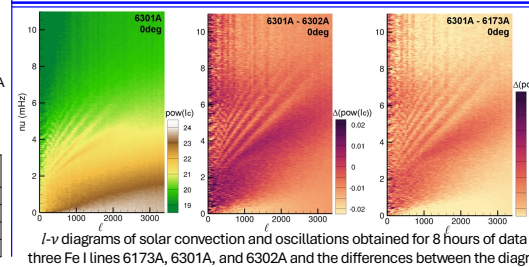
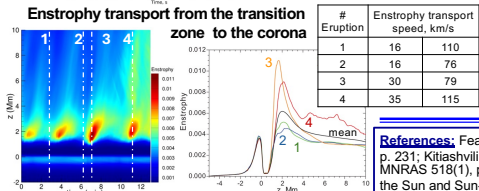
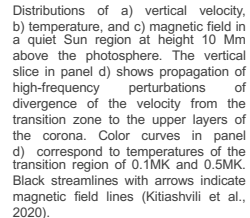
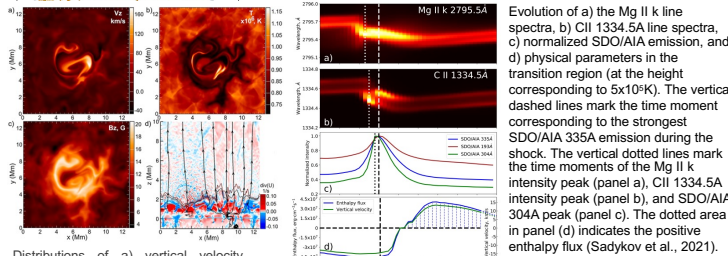
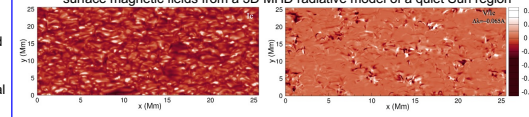
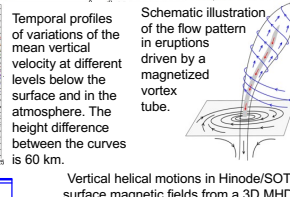
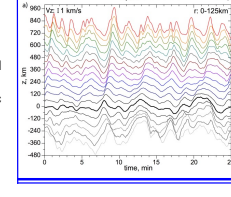
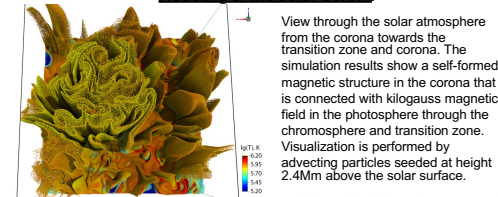
Small-scale eruptions



Effects of the solar rotation



Modeling of the Solar Corona



References: Feautrier P. 1969. Proc. "Theory and Observation of Normal Stellar Atmospheres", Ed. Gingerich O., p. 231; Kitiashvili et al., 2013, ApJ 770, article id. 37; Kitiashvili et al., 2014, PASJ 66, id S8; Kitiashvili et al. 2023, MNRAS 518(1), pp 504-512; Sadykov et al., 2021, ApJ 909, id 35; Wray A.A., et al. 2018. In Book: "Variability of the Sun and Sun-like Stars: from Asteroseismology to Space Weather, 2018. p.39-62. ArXiv: 1507.07999.

Conclusions

The multidimensional nature of flows from granulation and supergranulation to meridional flows and differential rotation, as well as their coupling to magnetic fields, are building blocks of the Sun's dynamics on global scales and crucial for tracing and understanding the solar magnetic activity from the interior to the surface and corona. Current computational capabilities enable modeling of various phenomena observed with different instruments. In this poster, we present examples of 'ob-initio' 3D radiative MHD and hydrodynamic models obtained with the StellarBox code, as well as synthetic observables to link simulations and observations of SDO/HMI, Hinode/SOT, and IRIS.