SHINE “Solar and Corona”: Toward the Future

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2021 has been a year of reflection, when we have been thinking on the future of solar/coronal research.

- **Decadal Survey & Helio 50 goal:** to define heliophysics science goals for *next 10-50 years* (link to [Heliophysics 50 white papers](#))

- **Critical Science Plan of the DKI Solar Telescope goal:** to anticipate science that will accompany extraordinary observations from *DKIST* (link to overview [Rast et al. 2021](#) paper)

- **The goal of this talk:** think together what *SHINE*, as a community, could do to foster progress in solar/coronal research.

- NB: **Unique strength** of SHINE is its cross-disciplinary community
What science areas do we want to make progress in?

SHINE goal: “Enhanced understanding of how energy in the form of magnetic fields and particles is produced by the Sun and transported/accelerated in interplanetary space to the Earth”

For simplicity, out of many, I have chosen three solar/corona topics related to eruptions where SHINE, as a community, could contribute.
Talk Outline: advancing our understanding of solar eruptions

• **Constraining 3D magnetic structure with new observations:** With DKIST we will invert $B$ in the photosphere, chromosphere and corona at unprecedented resolution. How could we use these $B$ and other observations (SDO, SO, PSP) to advance our understanding of magnetism of campaign-events eruptions?

• **Increasing realism of simulations of solar eruptions from Sun to Earth:** many models. Which one to chose to advance our understanding of reconnection, energy partition, propagation?

• **Statistical analysis of existing datasets:** comparison of solar-source and CME/ICME/in-situ properties for many observed events.

_During the talk: I encourage you to think on the question “What SHINE, as a community, could do to foster progress in solar/coronal research?” If there is any specific science question that you think should be addressed at SHINE, please share your thoughts via zoom chat or verbally during the discussion._
I. Constraining 3D magnetic structure with new observations
Example of Quiet Sun observations with DKIST. Imagine an active region?!

14 cm aperture, SDO

1m aperture, Canary Islands

4 m aperture, DKIST Starting 2022

First light from DKIST observations, VBI red, 789 nm, 0.04”, Woeger+(2020)

DKIST will resolve structures on the Sun as small as 20 km!
I. Constraining 3D magnetic structure with DKIST: questions for SHINE community

DKIST will measure IQUV in the corona (limb!) and the chromosphere/photosphere (disk).

Which fundamental science questions would these observations advance?

- What is the magnetic structure of ARs before/after CMEs? What is the twist distribution? Is magnetic structure consistent with eruption models?

- **Tools**: multi-messenger campaign events (requires luck!); comparison of coronal $B$ at the limb from DKIST with SDO, Solar Orbiter, LASCO, STEREO.

- **Community effort**: Analysis of ground based observations is hard by itself! But community effort would help to maximize scientific return. E.g., bringing experts to analyze CME properties to see how original coronal structure evolves.

*Example of an Eruption model.*

Karpen, Antiochos, & DeVore 2012

DKIST/Cryo-NIRSP: 3’ x 4’ FOV pointed at [1-1.5] $R_{\text{sun}}$
Problem statement:

• Since coronal fields observations are hard, models are used to understand eruptions.

• Historically most of solar eruption models tried to mimic typical eruption scenarios. “Data-inspired” simulations.

• With HMI vector $B$, “data-driven” simulations flourished. These simulations use observed $B$ properties as a lower boundary condition.

• How could we evaluate the quality of these models?
II. Increasing realism of simulations of solar eruptions from Sun to Earth

Community effort:

• To **assess quality** of these models we need **cross-comparison of different models** and observations of campaign events. *Right:* Example of such tests using emergence simulation dataset.

• How sensitive are the modeled CME properties and energy budget to initial conditions (both local AR and global)? Does the exact AR structure matter? Or are we fine with synthetic ad-hoc flux rope as long a global properties are “correct”?

• How does magnetic structure evolve as CMEs/ICMEs? What is the energy partition evolution?

**Provornikova et al. (HAO talk):** MHD simulations of 144 GL ICMEs with varying angular width, Vcme, B etc.

**Toriumi et al. 2020:** testing DD models with synthetic data

**Jin et al. 2017:** propagation of CME-driven shock.
III. Statistical analysis of existing datasets: comparison of solar source with CME/ICME/in-situ properties

- Campaign events are great! But! Sun has many faces and we have a lot of data.

- SDO: full solar disk 24hrs/day since 2010 (EUV, B, etc)! Statistics of solar source properties: AR sizes/magnetic fluxes, dimming properties, reconnection fluxes and ratios, durations, AR B direction, currents, Lorentz forces etc. as f(t).

- We also have datasets of CME and ICME/MC properties: speeds, acceleration, masses, magnetic fluxes etc.

- Multi-dimensional statistical analysis of ICME/CME/source region properties is essential to move forward. Some examples.

- What is the best way to share these datasets? DOI-issued datasets?

- What is the best way to compare these datasets? Hackathon-style SHINE sessions?
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• Constraining eruptions’ 3D magnetic structure with DKIST: multi-messenger (ground + space, multi-vantage) observations of campaign events.

• Increasing realism of simulations of solar eruptions from Sun to Earth: cross-comparison of simulations outputs & observations for campaign events.

• Statistical analysis of existing datasets: more temporal analysis; datasets virtual library; hackatons;

• Thank you!

Now let us brainstorm!

“What SHINE, as a community, could do to foster progress in solar/coronal research?”