NSF's National Solar Observatory

Priorities for ground-based heliophysics research in the coming decade

Astro2020 Panel on Enabling Foundation for Research

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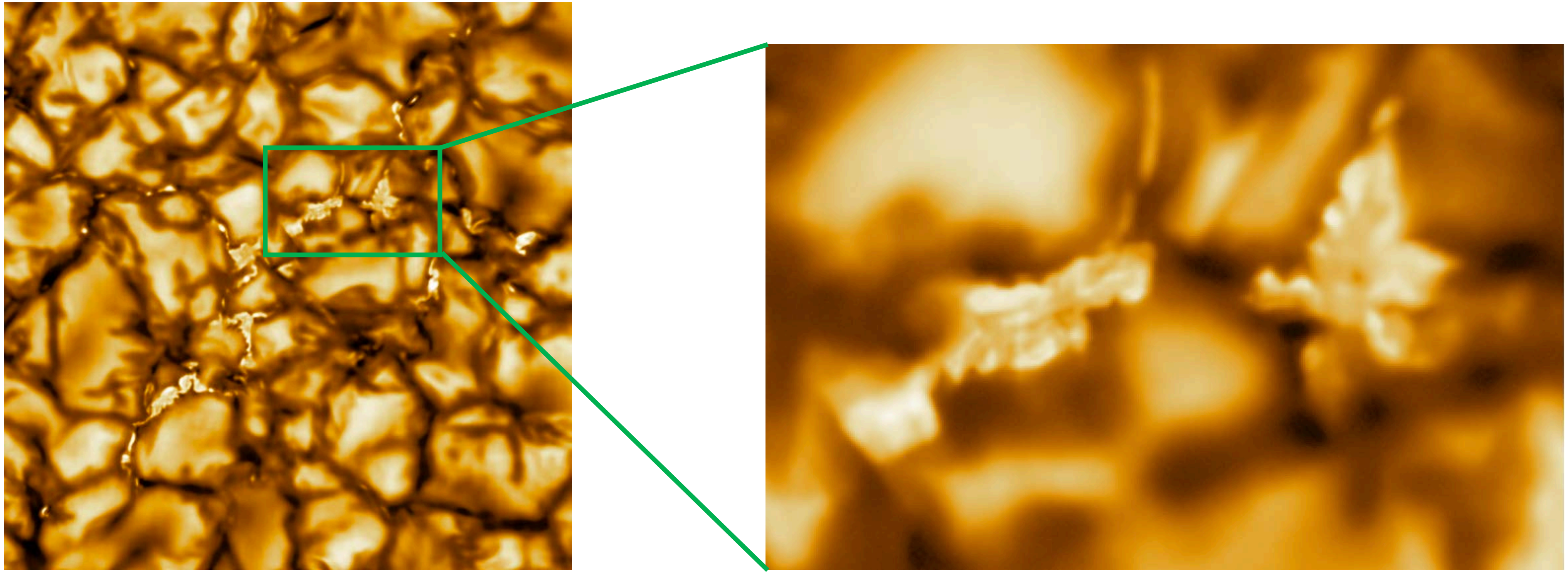
NSO AURA

1. What are the plans for **DKIST operatio**ns and analysis?
2. What are the challenges to supporting the **software** necessary for the analysis. (Sunpy, IDL -> Python)
3. What do you see as the challenges for ground-based **heliophysics** in the coming decade?
4. What are the challenges to integrating space-based and ground-based **archival data**?
5. Are we supporting the necessary **laboratory astrophysics** work needed to interpret the observations?
6. What are the challenges in supporting the relevant **theoretical work**?
7. What are the challenges to **training** the next generation of solar astronomers?

Inouye solar telescope first light



- Telescope is still under construction: Operations start in July 2020
- Images obtained as part of the functional verification of the telescope & instruments (AO)
- *Diffraction limited* achieved

DKIST operations and analysis

- DKIST is first ground-based solar telescope that uses **Service Mode** as the basis for operations
- **Access Mode** restricted to new instruments, Target of Opportunities, etc.
- **Level-1** (instrument calibrated) data is served from the DKIST Data Center
- **Level-2** (physical parameters) 2-3 years funding pilot program available
- DKIST is **open access** and **open data** (2014 AAAC recommendations)
- DKIST policies establishes a **six month proprietary** period for observing proposals
- DKIST policies excludes **ToO**, **DDT**, and **synoptic data** from proprietary periods
- DKIST policies prioritize **US participation** in TAC rankings for same scientific merit
- Service mode is resource intensive: deficit **$1M/year**
- Descopes: **second generation** instruments or upgrades to existing (MCAO is funded).

https://www.nso.edu/wp-content/uploads/2019/12/NSO_MidTerm_Report_and_Long_Range_Plan_FY20-FY24_FullDocument.pdf

Challenges to Support Software

- Solar astronomers heavily use **IDL** (which grew from the solar community)
- DKIST data center uses **Python**: SunPy (UK centric, voluntary): Pipelines, User tools, etc.
- Aligned with the younger generations, but a challenge.
- *'Best way to provide an enhanced user experience and a better way forward to work with DKIST data: might drive further adoption of Python as a solar data analysis tool.'*
- Most likely will stay open and free.

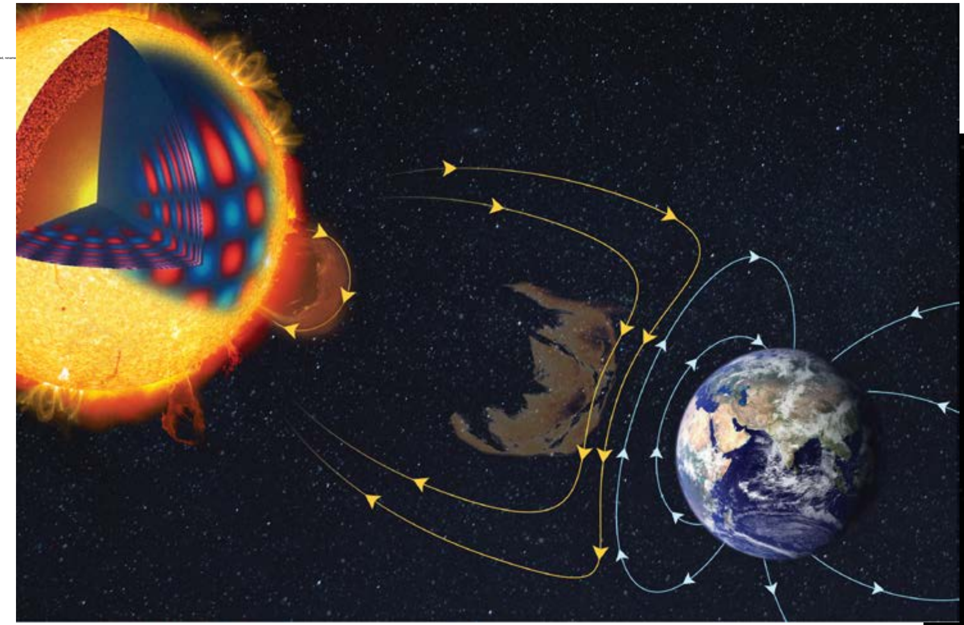
SolarSoft/IDL
NASA

→

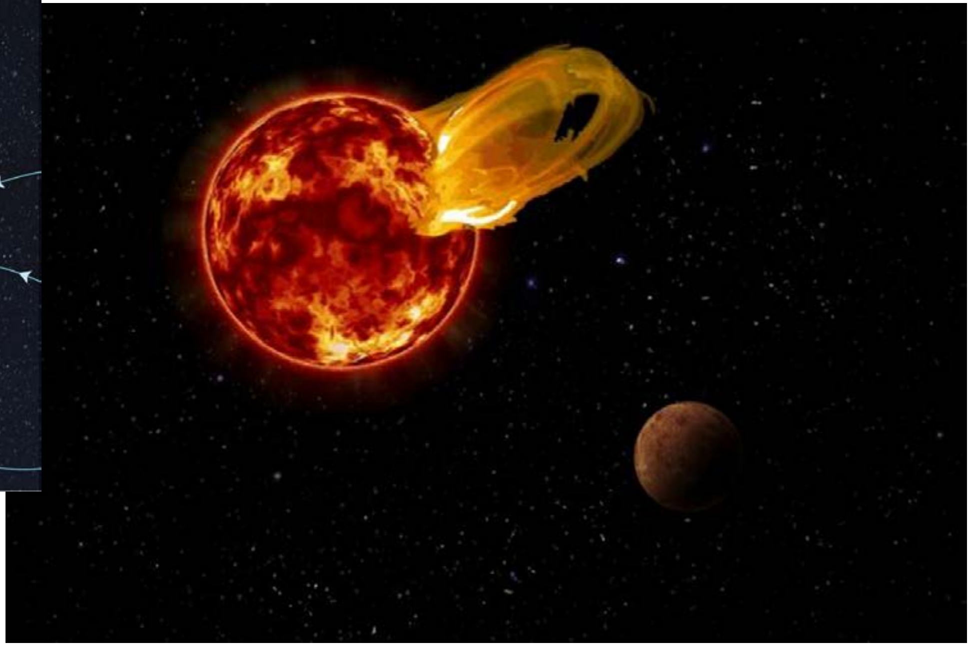
DKISTPy/SunPy/Python
NSF/NASA

- Funding (SolarSoft, SunPy) available on a mission by mission basis (NASA).
- Only for development, not support (SolarSoft maintained at LMSAL; SunPy DKIST supported)
- Challenges: Funding, community adoption (inertia), coordination, future NASA missions.

Challenges for ground-based heliophysics



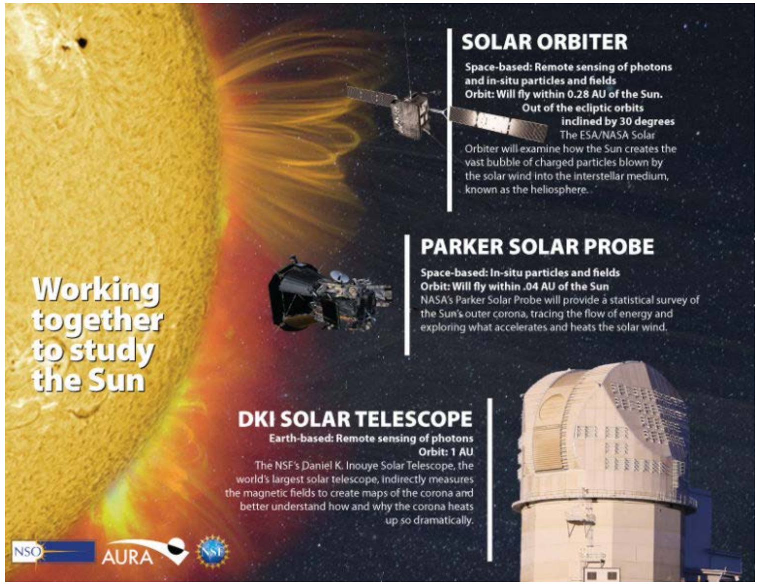
How stars and planets are…



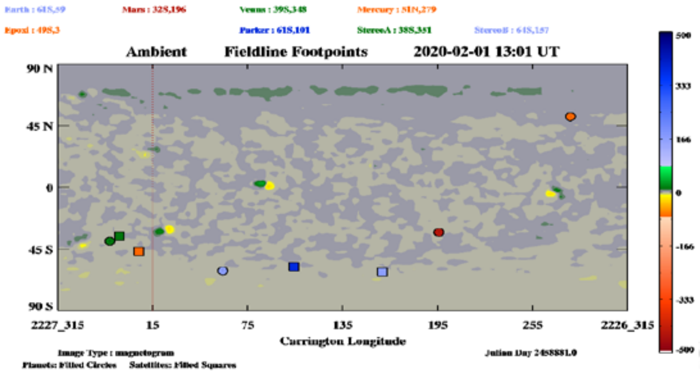
…magnetically connected?

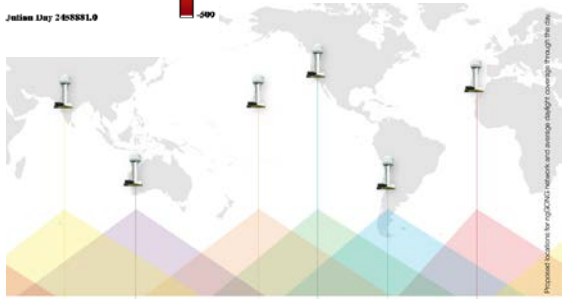
A multi-messenger era for Solar & Heliospheric Physics

Challenges for ground-based heliophysics



Particles & fields vs. electromagnetic counterpart





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The Solar Flare Myth

J. T. GOSLING

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Many years of research have demonstrated that large, nonrecurrent geomagnetic storms, shock wave disturbances in the solar wind, and energetic particle events in interplanetary space often occur in close association with large solar flares. This result has led to a paradigm of cause and effect - that large solar flares are the fundamental cause of these events in the near-Earth space environment. This paradigm, which I call "the solar flare myth," dominates the popular perception of the relationship between solar activity and interplanetary and geomagnetic events and has provided much of the pragmatic rationale for the study of the solar flare phenomenon. Yet there is good evidence that this paradigm is wrong and that flares do not generally play a central role in producing major transient disturbances in the near-Earth space environment. In this paper I outline a different paradigm of cause and effect that removes solar flares from their central position in the chain of events leading from the Sun to near-Earth space. Instead, this central role is given to events known as coronal mass ejections.

Next Generation Synoptic Solar Physics Network

Challenges for ground-based heliophysics

Community engagement: Good News

- US community funded via NASA mission-specific Guest Investigator programs have "engaged" the solar community.
- Space-based solar community has actively participated in the DKIST Critical Science Plan workshops.

Community engagement: Concerns

- NSF funding model differs from that of NASA: for NSF, apply for grants & separately apply for observing time
- You might succeed in one, but not in the other
- Without targeted funding for DKIST observations, there is some risk of losing the participation of the community, particularly space-based solar scientists

Community engagement: More Good News

- NSF/AST AAG has provided good support in the recent years
- DKIST unique coronal capabilities align well with the NASA community

Space- and ground-based archival data?

- Space based ahead of ground based (exception of NSO’s GONG)
- Ground based data: atomized in individuals and Observatories.
- Solarsoft/IDL has made space-based data seem far more integrated
- Will DKISTPy/SunPy serve as a catalyst?
- VSO helpful in trying to federate the data. NASA funded.
- VSO includes both ground and space based data. Historical series.
- Space based data NASA & ground based is NSF. <u>Helio & Astro Decadal Surveys.</u>
- *‘There is a belief you shouldn't cross the (funding) streams’*

NASA & NSF Coordination

Laboratory work to interpret observations

- DKIST will regularly observe the Solar Corona in the [0.5-5] µm range.
- Forbidden lines from highly ionized atoms (Fe XIII, Si IX, SiX,…).
- Laboratory determination of the Landé factors for coronal lines.
- Atomic and collisional parameters for ion excitation/ionization.
- Ionization/recombination rates
- Solar Orbiter connectivity studies relies on unreliable atomic data
- Synergies between the laboratory plasma physics and multi-messenger solar and heliospheric physics are evident
- Discussed at multidisciplinary opportunities (SHINE, others)

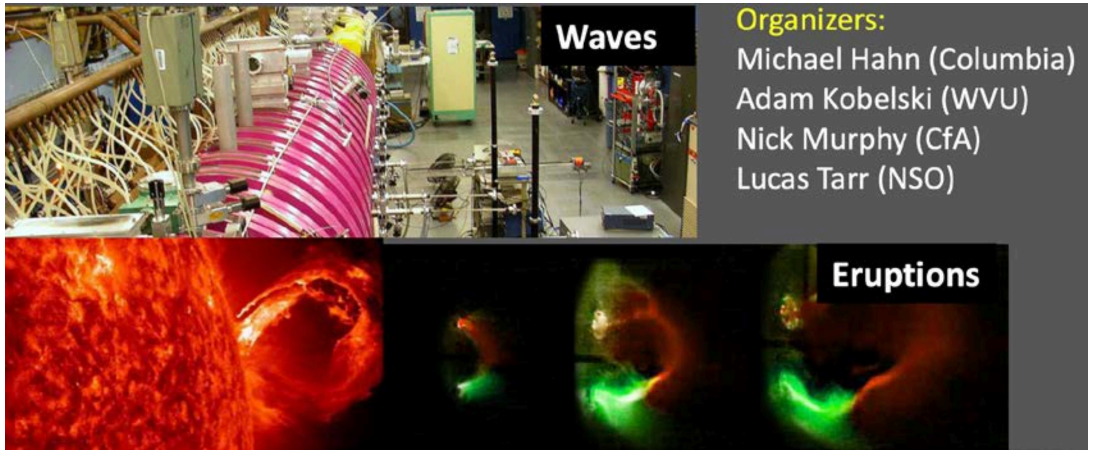
Electron Beam Ion Trap (EBIT)

More opportunities for cross-fertilization (workshops)
More reasons to collaborate (funding opportunities)

Laboratory work to interpret observations

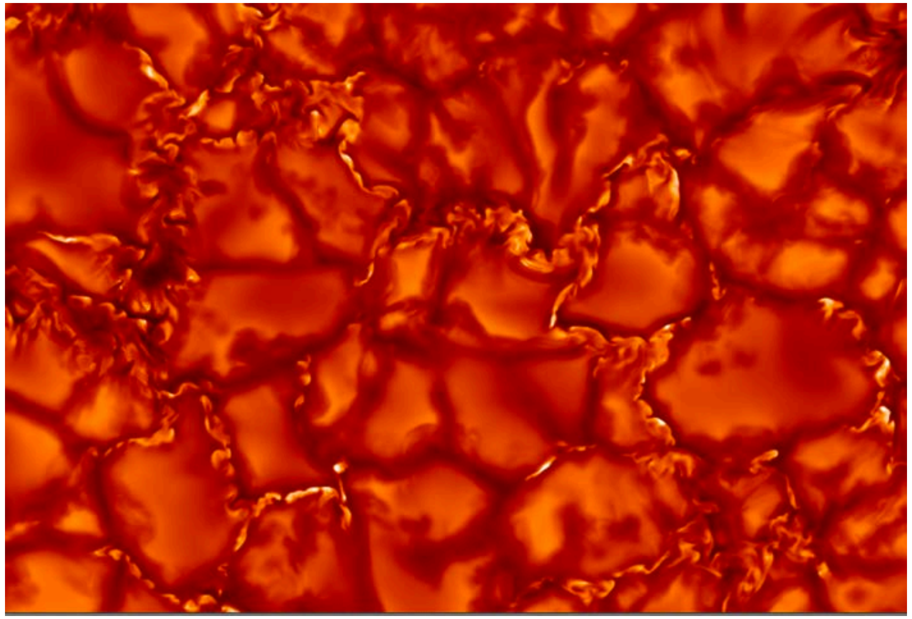
SHINE 2019 Session on connecting Heliophysics and Laboratory Plasma Studies

• Experimental Characterization of Energy Transfer by **Three-Wave Coupling** in 2D Plasma Turbulence	Mel Abler
• Threshold for the **torus instability** of arched, line-tied flux ropes	Andrew Alt
• How solar eruptions generate X-rays and **energetic particles**	Paul Bellan
• Effect of viscosity on **propagation of MHD waves** in astrophysical plasma	Alemayehu Cherkos
• Plasma and **Radio Wave Generation** by an Electron Beam in a Laboratory Plasma	Seth Dorfman
• Nonlinear Interactions of **Alfven Waves in Multi-ion Plasmas**	Xiangrong Fu
• Laboratory measurements of **Alfven wave propagation through a transverse density gradient**	Michael Hahn
• Three-dimensional Evolution and **Formation of Multiple Current-filaments** in a Laboratory Arched Magnetized Plasma	Kamil Krynski
• Direct Observations of Particle Dynamics in **Magnetized Collisionless Shock** Precursors in Laser-Produced Plasmas	Derek B Schaeffer
• Sausage to kink instability transition-induced **fast magnetic reconnection** resulting in plasma jet eruption	Pakorn Wongwaitayakornkul
• **Rayleigh Taylor instability** in the solar corona loop experiment	Yang Zhang
• Developing a PIN Photodiode Detector to Image **Transient X-ray Bursts** From the Caltech Jet Experiment	Yi Zhou



Supporting the relevant theoretical work

- DKIST observations and state-of-the-art numerical simulations **interplay**
- Observations: High cadence imaging, multi-line spectroscopy, polarimetry → inversion codes
- Numerical Simulations: dynamo, convection, turbulence, wave generation, partial ionization
- Compare observed (x,y,z,t) cubes with simulated (x,y,z,t) cubes is a formidable task



- Numerical codes are often proprietary
- Community access is limited at best
- Access by the community will require infrastructure, and funding…

How do we extend the open access, open data model to numerical simulations?

Training the next generation of solar astronomers

- Solar Physics presence in the University system is low → access to students difficult
- Recent efforts: CU Boulder (2+2+1), NMSU (2+1), UH (1+1), GSU (1+1), NJIT (1)

60% male, 40% female

#NSFfunded DKIST level-2
Harnessing the Data Revolution

12 #DKISTambassadors

Summary

- DKIST incorporates modern operations and software approaches into solar physics.
- DKIST will start operations in 2020 and will produce unprecedented detail and sensitive observations of the Sun and the microphysics that occurs on our local stellar archetype.
- In combination with single point inner-heliospheric space missions, it will help us understand the fundamental processes that create the heliosphere.
- A complete understanding of the magnetic connectivity between starts and planets, requires to put this microphysics in the context of synoptic solar data.
- Synoptic data holds the key to advancing our understanding of the structure and dynamics of the solar magnetic field and interior, and to provide input data for heliospheric models
- We thus encourage Astro2020 to specifically endorse the need for a next-generation global solar monitoring system like ngGONG.

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THANKS

DKIST operations and analysis

Operations Commissioning Phase

MREFC Construction

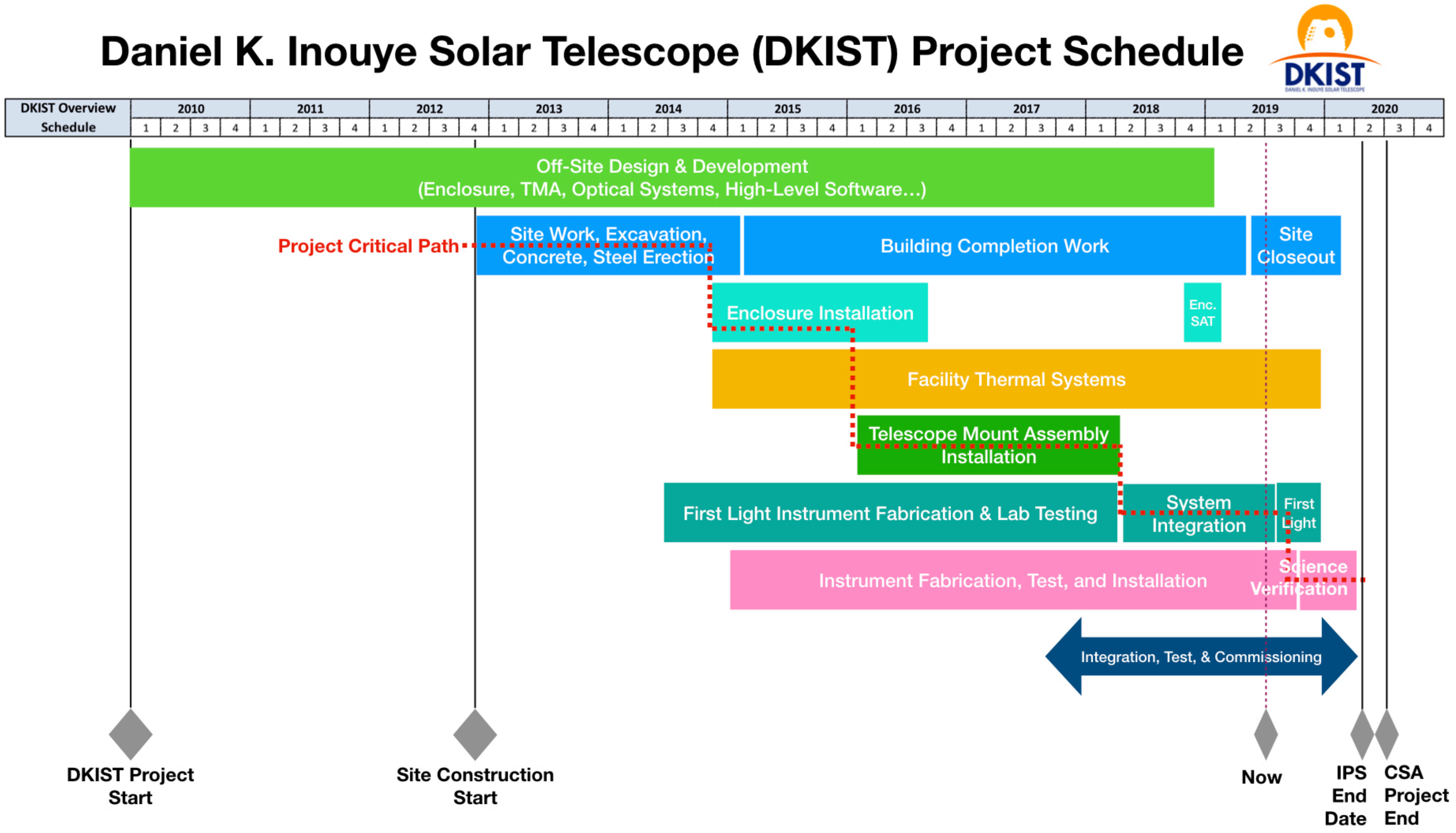
Shared Risk Period

Regular Operations

Q1 & Q2 2020	Q3 & Q4 2020	Q1 & Q2 2021	Q3 & Q4 2021
- Contractual Science Verification of instruments - Does not demonstrate full capabilities - Does not use the DKIST DC - Polarization calibration - **1st call for proposals in *shared risk mode*** - **Selection via pre-TAC**	-Instrument I in modes 1,2,3 - Instrument II in mode 1 - Instruments' pipelines - Commissions Data Center - Obs Props: adapted CSP/SUC, others - **Cont'd calls for proposals in *shared risk mode*** - **Selection via pre-TAC**	- Instrument II in modes 2,3 - Instrument III in modes 1, 2 - Instruments' pipelines - Commissions Data Center - Obs Prop: adapted CSP/SUC, others - **First regular call** - **TAC selection**	- Obs Prop from CSP/SUC, others - All instruments - Data Center delivers Level-1 products

Under NSF Operations CSA

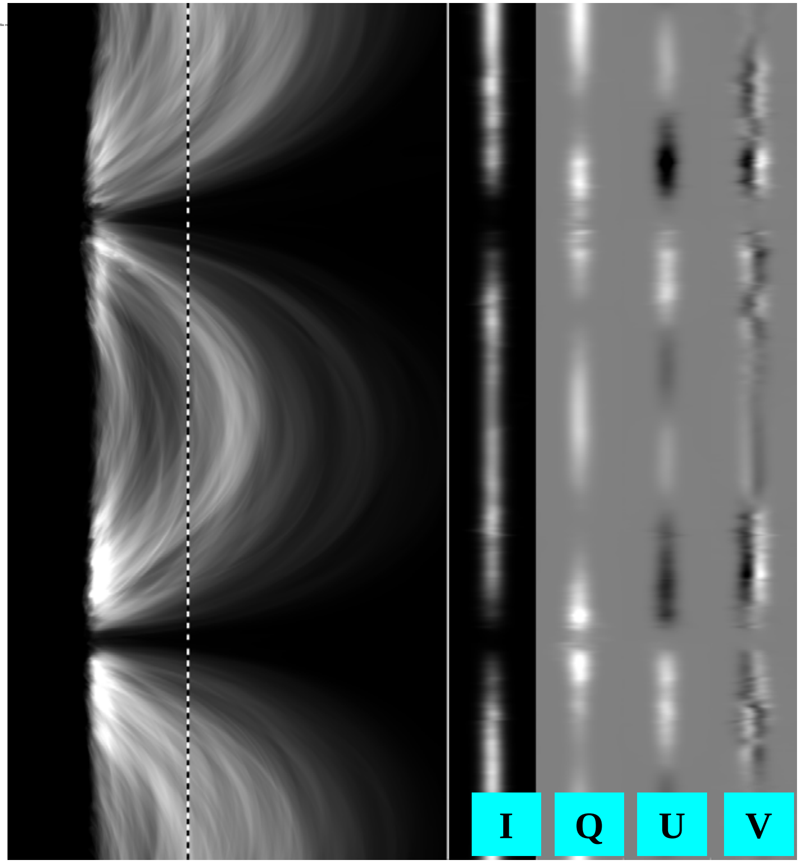
DKIST is on time & on budget ($344M)

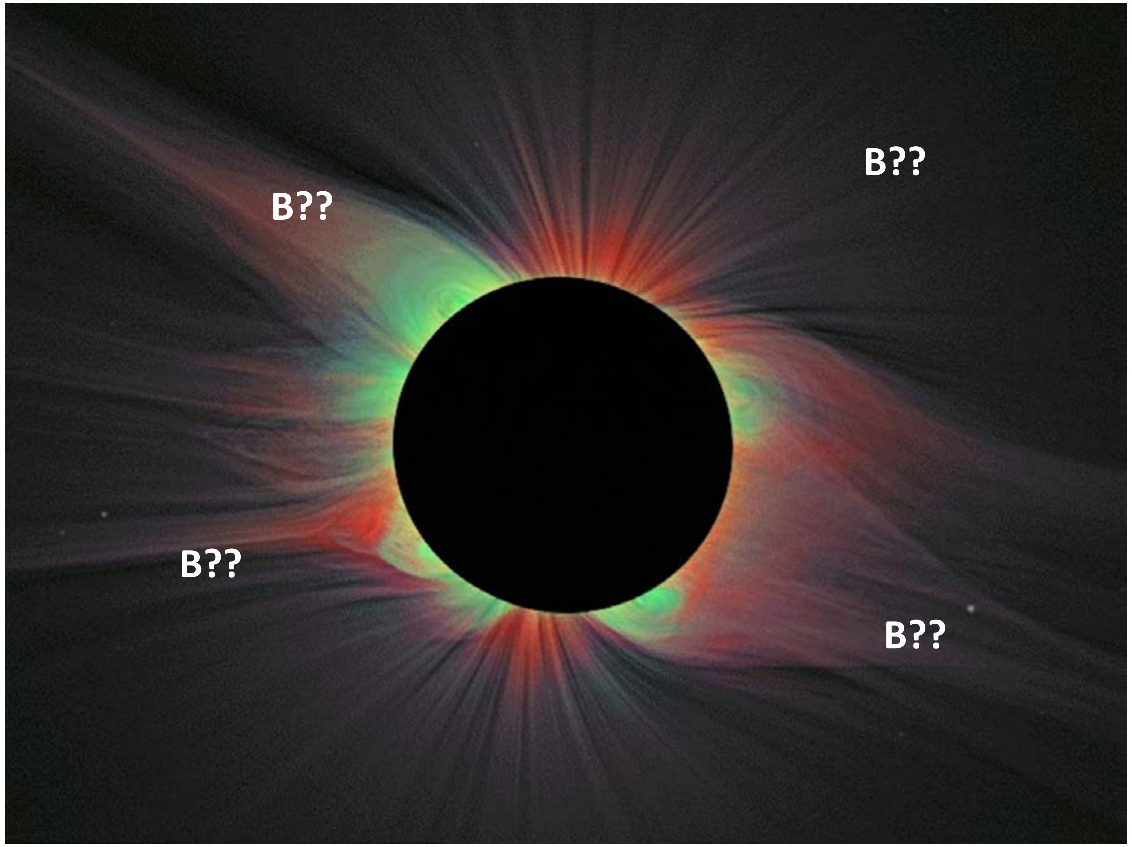


DKIST Construction 94% complete!

Thanks to the excellent team!

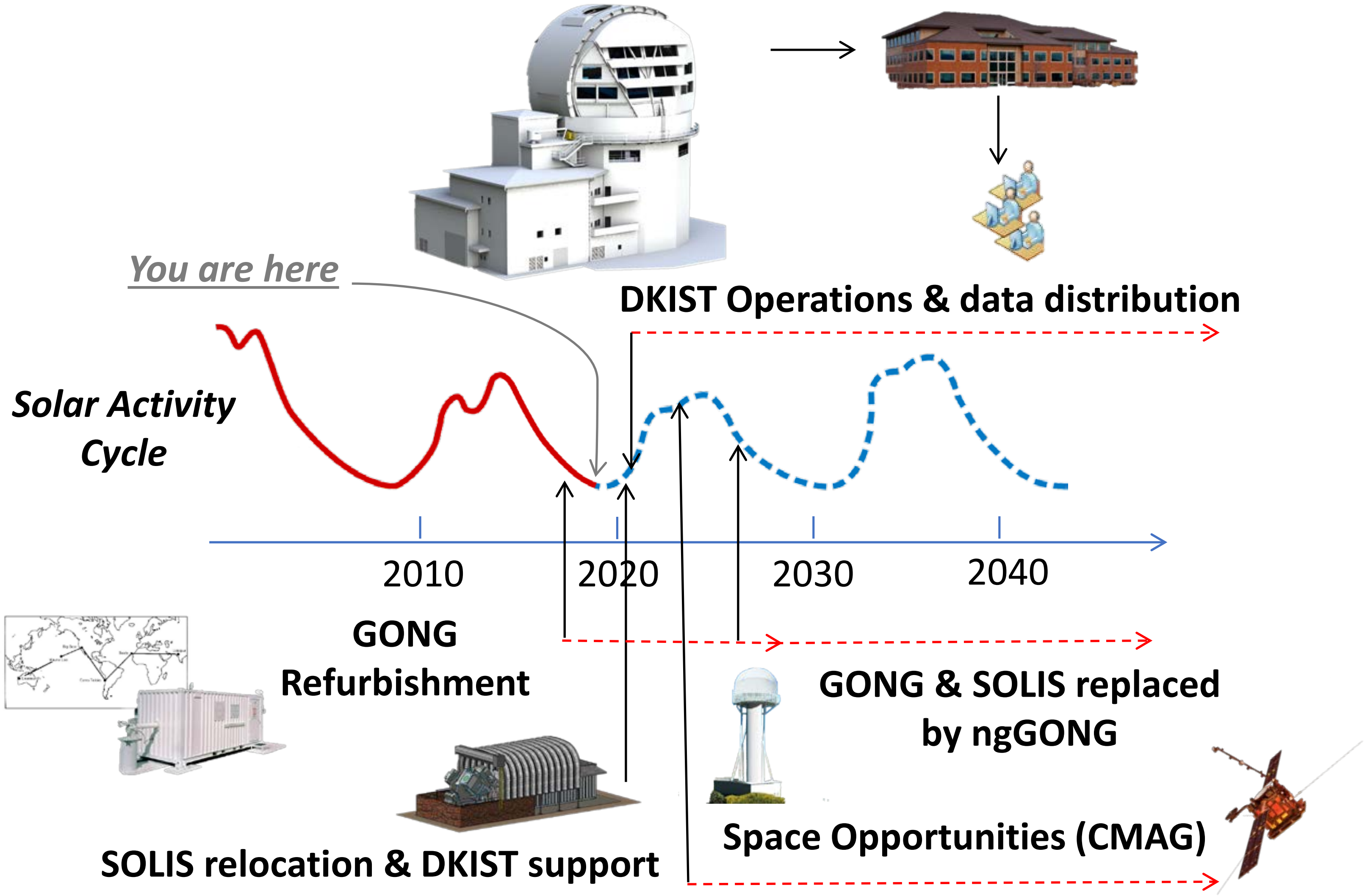
DKIST main focus is solar magnetism





Imaging, spectroscopy, and polarimetry of a faint object at unprecedented resolution and precision

The NSO’s Vision



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