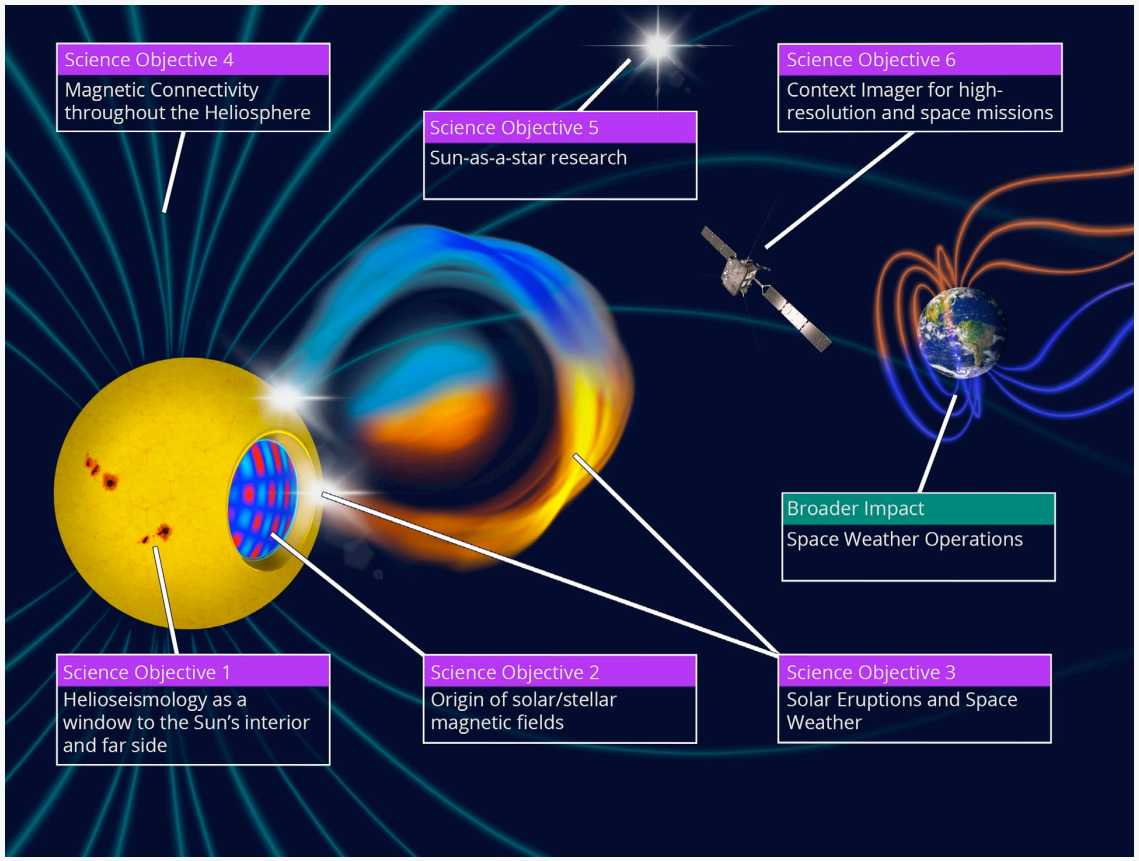
NSF's National Solar Observatory

Future Groundbased ngGONG Facilities for Research in Heliophysics and Space Weather Observations.

ALEXEI A. PEVTSOV, V. MARTINEZ-PILLET, H. GILBERT, A. G. DE WIJN, M. ROTH, AND NISP AND ngGONG TEAMS

What is ngGONG?

- 6-site groundbased network of solar instruments for research and SW ops (builds up on successful GONG, SOLIS, MLSO instrumentation)

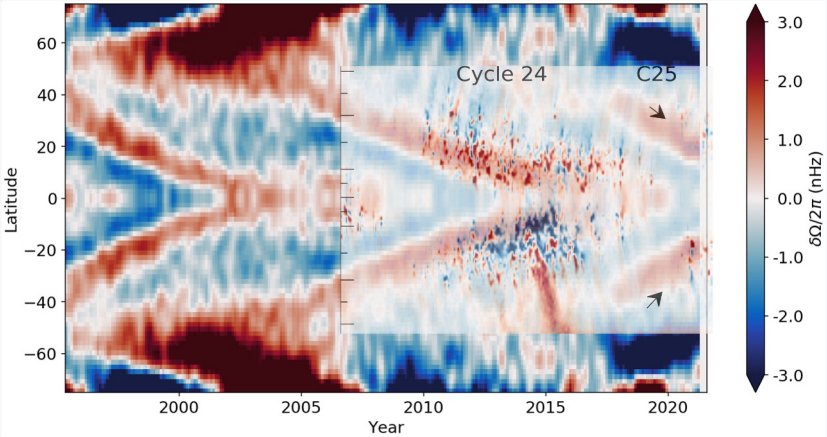


Objectives:

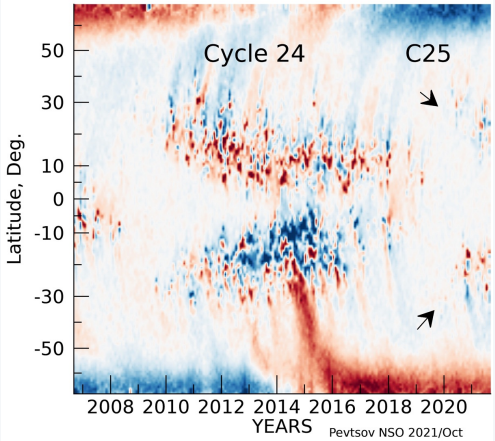
- Explore processes that drive activity from the solar interior, the atmosphere and throughout the heliosphere
- Bridge solar and stellar research
- Provide context for high-resolution
- Enable future discoveries
- Operational space weather forecast.

See presentations by L. Bertello, S. Criscuoli, K. Jain, S. Tripathy

Science Cases: benchmarking, systemic changes.



Pattern of torsional oscillations (TO) near the of the convection zone inside the Sun, for the declining phase of sunspot cycle 23, cycle 24, and the beginning of cycle 25; courtesy of Rachel Howe.

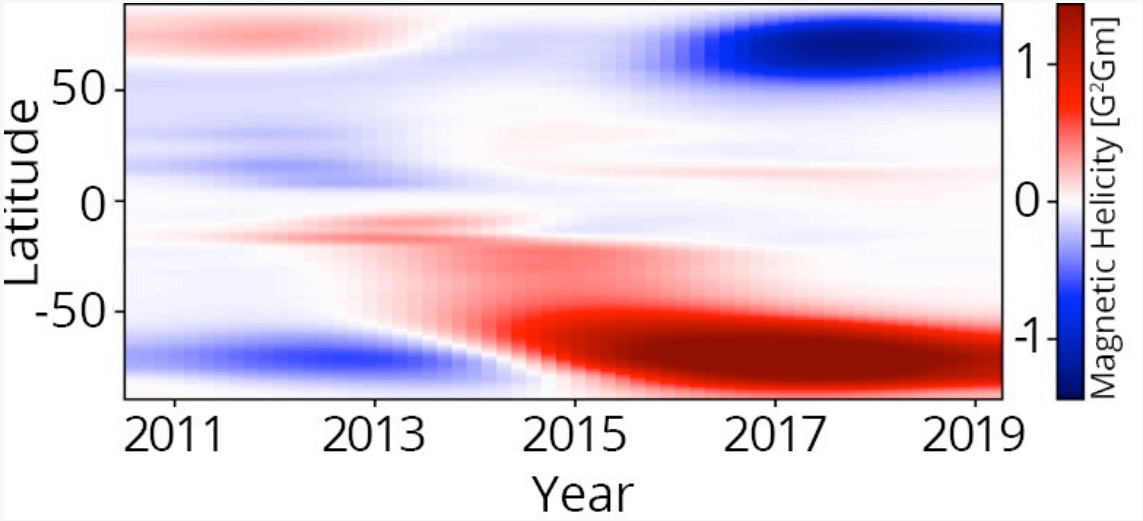


Super-synoptic map of magnetic field (GONG).

Major differences with previous cycle:

- No “rush-to-the-poles” branch
- Magnetic activity develops much early in TO branches

Science Cases: Enabling Exploration



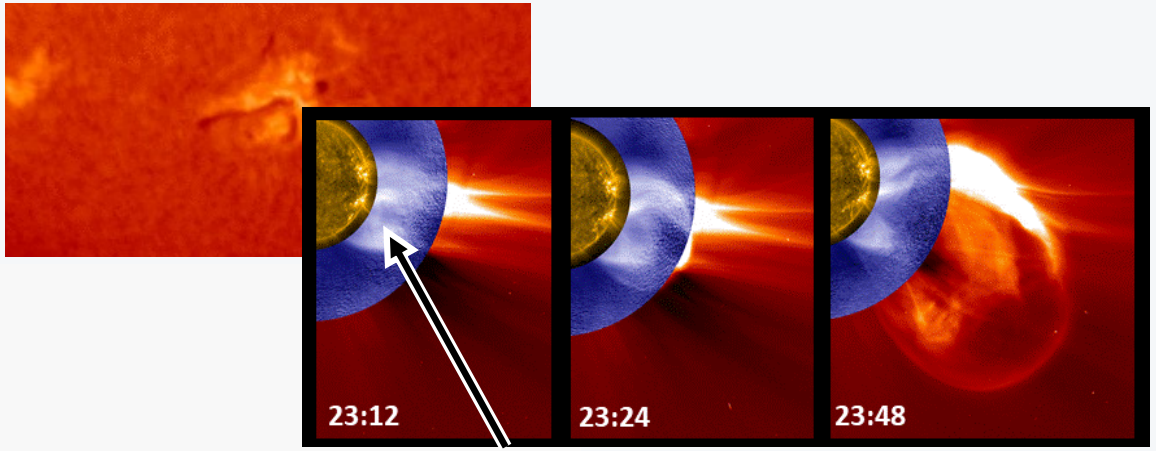
Some open questions:

- How helicity is transported through CZ and solar atmosphere, and how it is removed from the Sun?
- Why do we see large-scale helicity sign-reversals? What are the implications for dynamo?

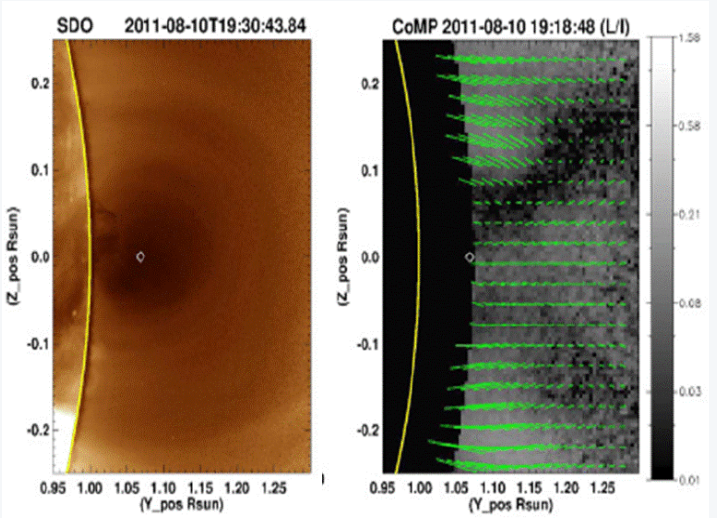
Large-scale magnetic helicity density in cycle 24 as function of solar latitude as derived using full vector magnetograms observations from SDO and SOLIS. On average, the sign of helicity is positive at high and polar latitudes, and there is an explained sign reversal in large-scale magnetic helicity after the polar field reverses its polarity. Pipin et al (2019).

Science Case: Solar Eruptions and Space Weather

- How, where, and why CMEs and flares erupt, and how they propagate from Sun to Earth?

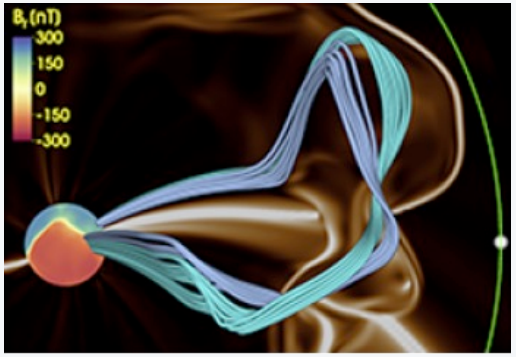


Missing observations for area of CME acceleration (low corona, MLSO K-coronagraph)



CoMP FeXIII

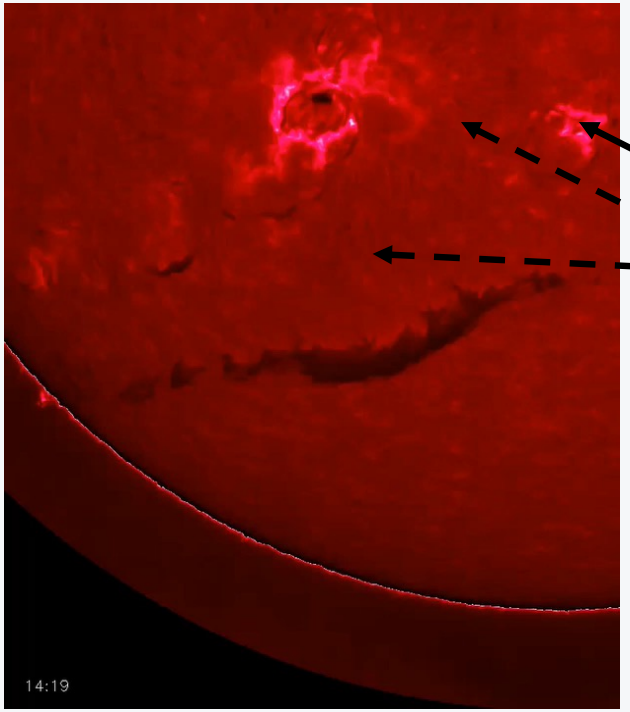
What is needed: (1) vector magnetic field in chromosphere and corona, (2) multi-height helioseismology



Example of magnetized CME propagation model (Shiota & Kataoka, 2016)

Science Case: Context imager to high-resolutions instruments

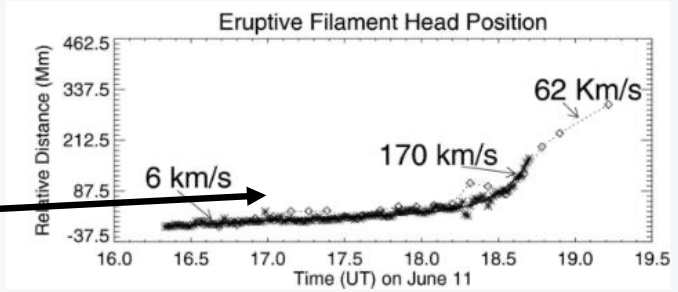
- Solar eruptions are often complex and interconnected events

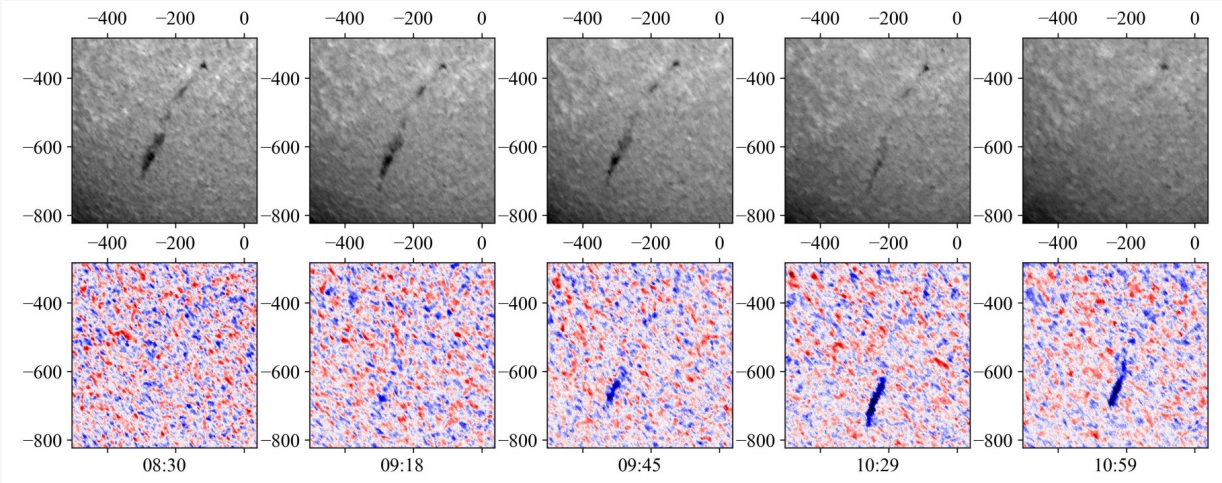


Approximate size of DKIST field of view

CME eruption timeline:

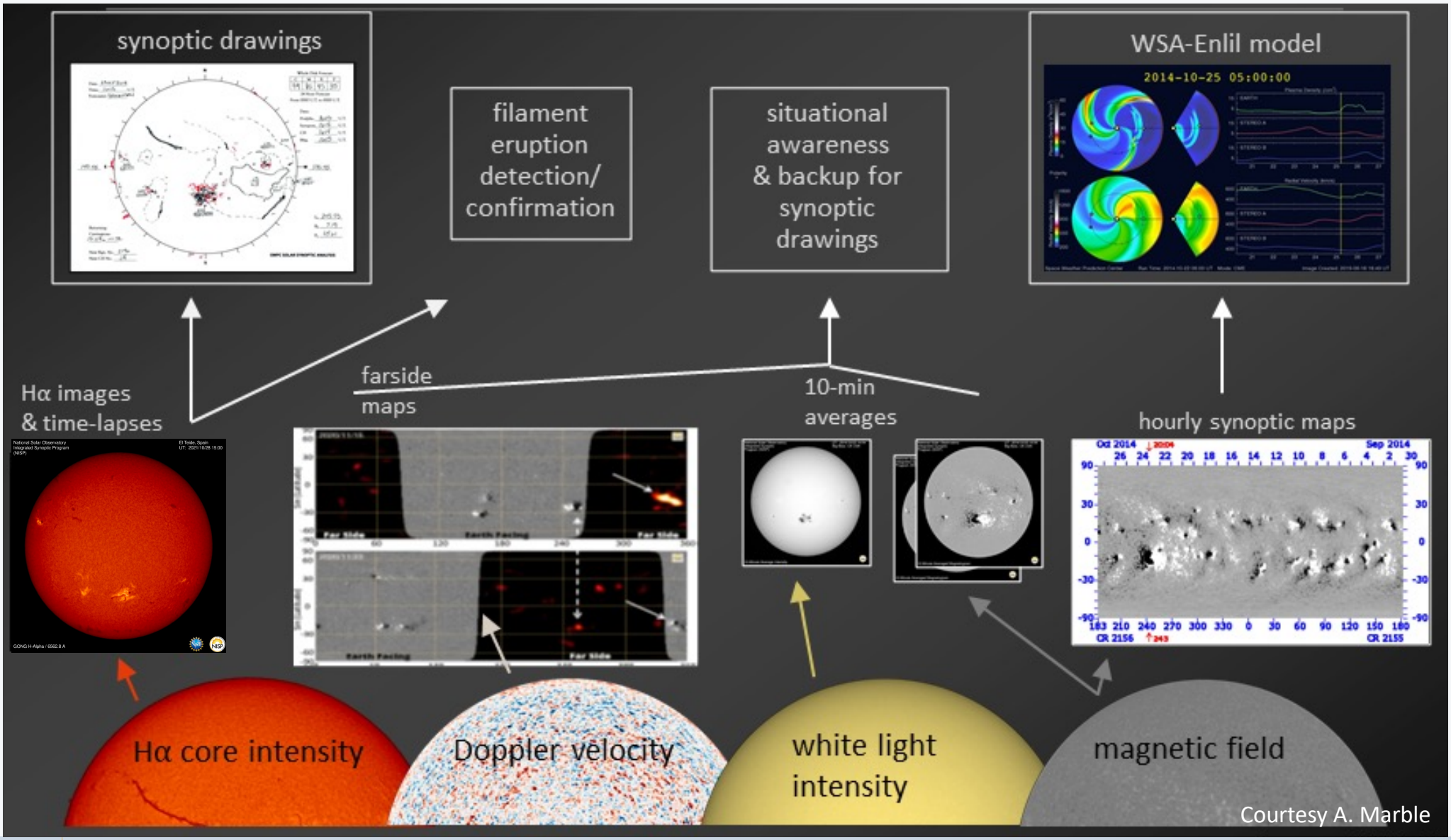
a) New active region emerges
b) Reconnection weakens arcade above filament
c) Filaments starts rising slowly
d) 17:09 UT – M4.5 flare starts
e) 18:30 UT – Filament erupts



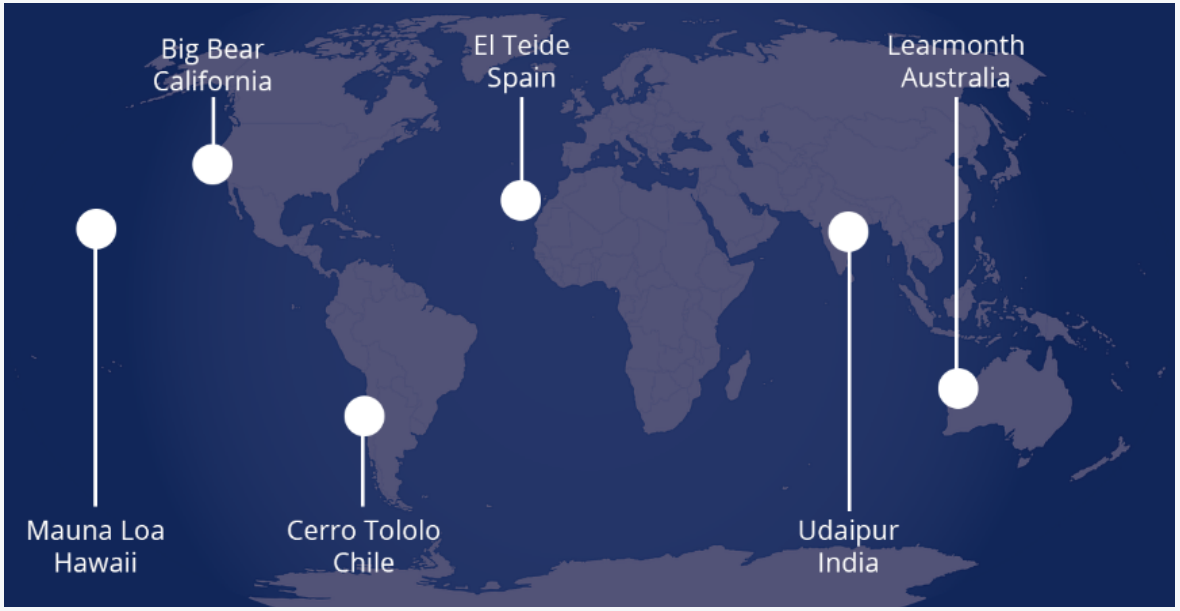


Tlatov et al (2022, in preparation)

Routine observations are critical for SW R&O



Current state (groundbased): GONG data for research & SW forecast



- Helioseismology: Plasma flows inside the Sun (dynamo, cycle prediction, far-side imaging etc)
- Magnetic fields: LOS photosphere, 3D structure and evolution, flare & CME initiation, irradiance, modeling of solar wind, geomagnetic disturbances etc

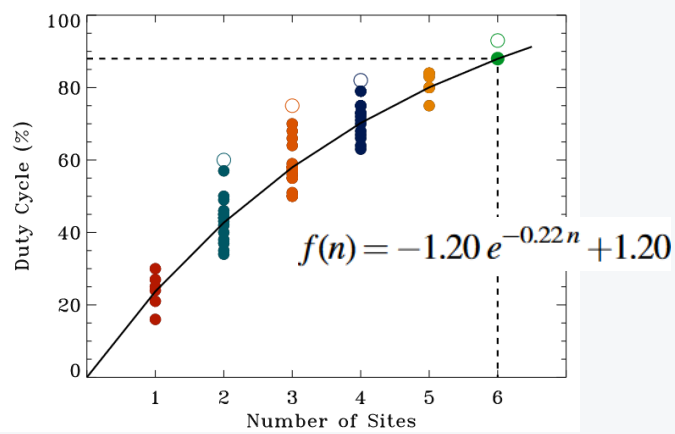
Why Now?

"If you fail to plan, you are planning to fail!" - Benjamin Franklin

- GONG is aging, 26+ years in operations
- GONG refurbishment will extend lifetime by 5-7 years
  - new cameras, improved polarization modulators, Data Center upgrades, new workstations, shelter cooling system upgrades, misc.
- New science and model requirements:
  - Vector magnetic field in photosphere and chromosphere
  - Doppler velocity for helioseismology (higher resolution, multi-height)
  - Polarimetry in the corona
  - Sun-as-a-star+disk-resolved spectra (same spectral lines)
  - Full disk (high duty cycle) and long-duration (1-2 full magnetic cycles)

ngGONG: Summary of Instruments and network

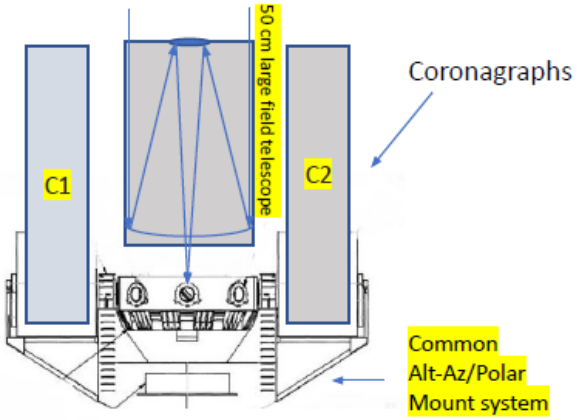
	S.O. #1 Solar Interior	S.O.#2 Origin Mag Fields	S.O.#3 Space Weather	S.O.#4 Heliospheric Connection	S.O.#5 Sun-as-a-star	S.O.#6 Context	B.I. SWx Operations
Visible/IR Full Disk Imager		x	x	x		x	x
IR spectropolarimeter	x	x	x	x	x	x	x
Helioseismic Doppler Imager	x	x	x	x	x	x	x
Full Disk Imaging Polarimeter	x	x	x	x	x	x	x
White Light Coronagraph		x	x	x		x	
Emission Line Coronagraph		x	x	x		x	
Sun-as-a-star Instrument	x	x			x		



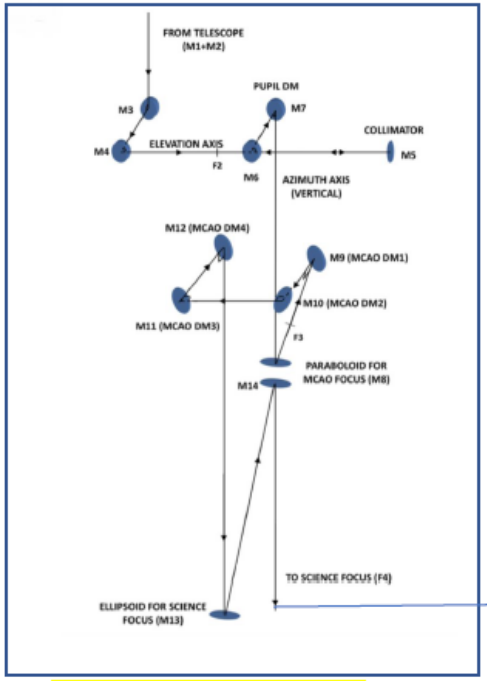
Dependence of the duty cycle on the number of sites. Filled circles represent values for each number of stations with different GONG-site combinations. Open circles are for the annual mean duty cycle computed using hypothetical networks as presented by Hill & Newkirk (1985).*(Jain et al., 2021).*

- 3-6 site network – existing GONG as a starting point
- 50 cm aperture main telescope, 2 smaller aperture coronagraphs; pixel (ph/ch) = 0.5”/1”
- 5-15 meter tower; Ground-Layer AO
- Full Stokes polarimetry (IR λ=1.56μ, Ca II 854.6nm, He I 1083.0 nm), cadence (30/10m-ph, 60/30m – ch)
- Doppler velocity measurements (60 sec cadence).
- Sun-as-a-star high-resolution spectra (R>150,000)

ngGONG Concept Ideas

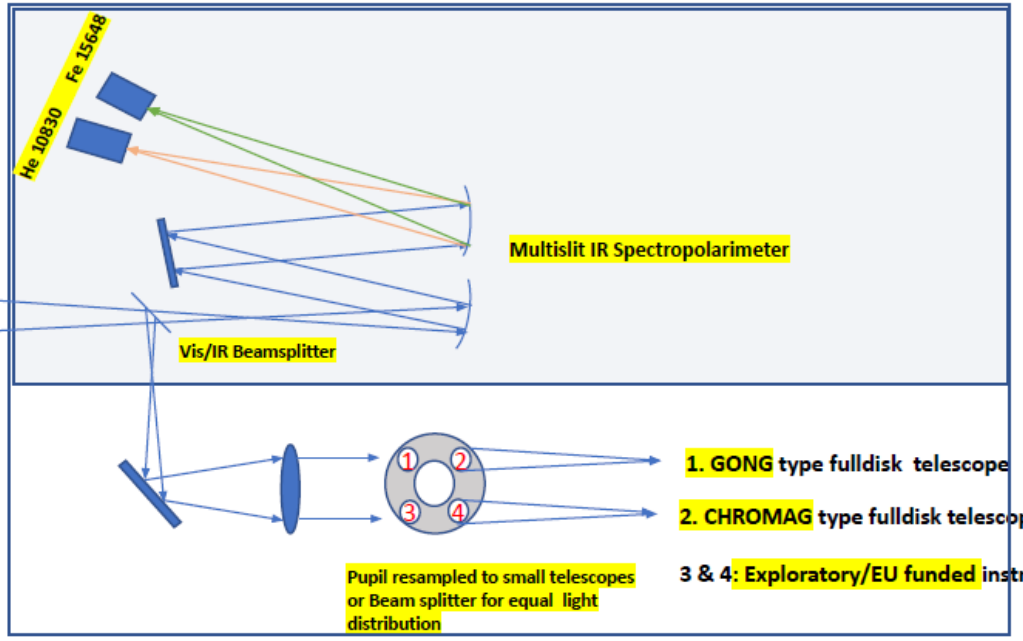


A concept of an ngGONG site with the telescopes in a fully retractable dome (shown open here), a structural element containing the transfer optics and the base building.



Transfer Optics (EST inspired)
(Polarization Free + rotation Free)

Instrument Layout (Observing Floor)

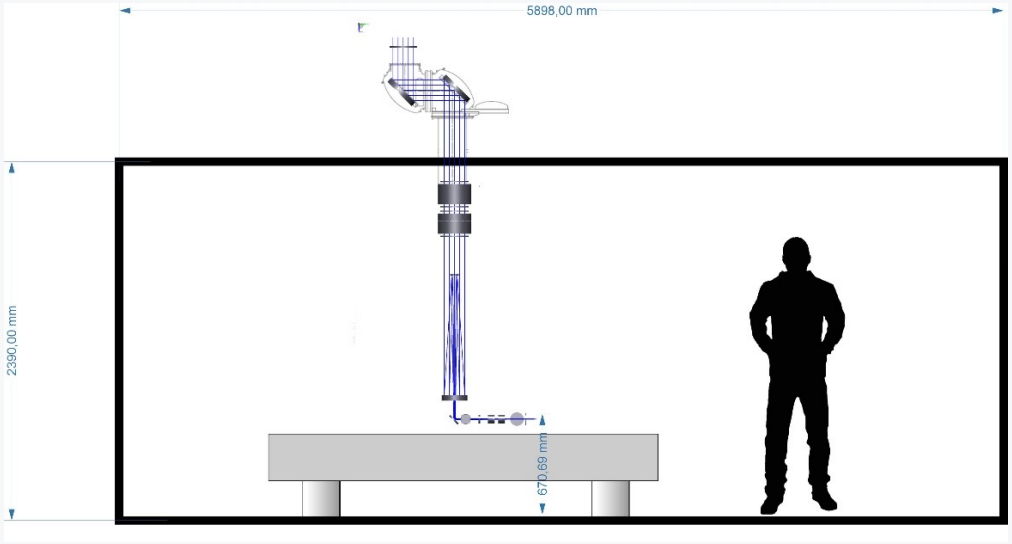


Courtesy S. Gosain

SPRING – Preliminary Instrument Design

Full-Disk Telescopes + Dopplergraph

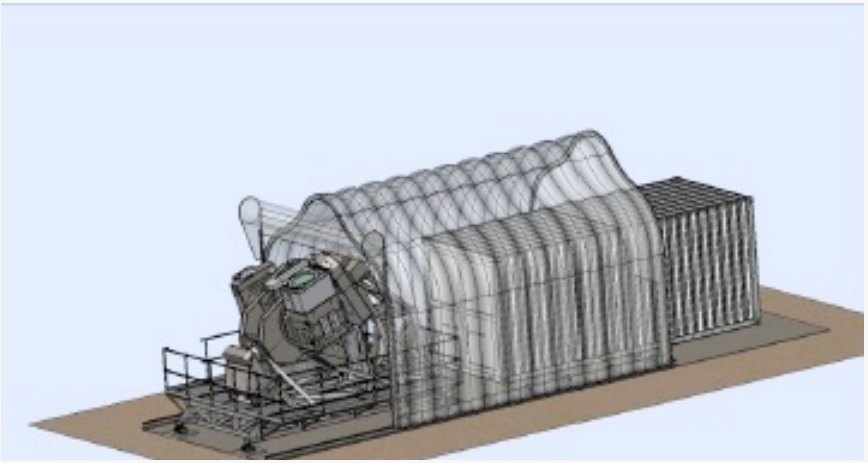
- 12 cm aperature
- Multi-line Doppler & spectro-polarimetry measurements
- Filtergraph: Fabry-Perot system



Design developed with industrial partner AMOS

50 cm Ritchey-Chrétien telescope + magnetograph

- Post-focus instrument: Multi-slit configuration
- NSO SOLIS telescope as the model
  - Larger detector



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Conclusions

"science is a marathon, not a sprint" – Brian Owens (2013)

- Comprehensive understanding of solar activity critically depends on continuous long-term (synoptic) observations (magnetic field, doppler velocities/helioseismology, imaging, sun-as-a-star).
- Some of these data are currently provided by GONG facilities, but GONG is aging and has limited capabilities for upgrade; new type of data are now required by heliophysics and SW modeling and research communities.
- **Suggested Concept for ngGONG**
  - World-wide network of 6 stations
  - Large telescope (>0.5m) for vector magnetic field measurements
  - Smaller telescopes (~0.2m) for Doppler velocities and full disk imaging
  - Coronagraph for linking lower and higher atmospheric layers
  - Strong domestic and international partnership

Why is it important for the Helio2024 Decadal

- How the WP links to the statement of task:
  - *The structure of the Sun and the properties of its outer layers in their static and active states*
  - *The characteristics and physics of the interplanetary medium from the surface of the Sun to interstellar space beyond the boundary of the heliosphere*
  - *The consequences of solar variability on the atmospheres and surfaces of other bodies in the solar system*
  - *The space weather pipeline from basic research to applications to operations, including the research-to-operations-to-research loop that strengthens forecasting and other predictive capabilities.*
- Describe the highest priority science goals to be addressed in the period of the survey.
  - *Design, construct, and start operations of ngGONG*
- White papers that include notional concepts for space missions or ground-based investigations should include the following.
  - *A description of the investigation including notional estimated costs and schedule, in as much detail is possible*
  - *MsRI vs MREFC*

Category: Infrastructure
Primary topic: Research Tools and Infrastructure
Secondary topic: Solar Physics