NGSPM-SOT

Topic-I:
Formation mechanisms of chromosphere, corona, and solar wind

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Science objects of Solar-C (revised)

I. Formation mechanism of chromosphere, corona and solar wind		
I-1	Origin of chrom.jets and heating	Foot point B topology, shock, twist,,
I-2	Nano-flare heating	Tiny brightening, non-thermal plasma
I-3	Wave heating	Wave mode, energy flux, dissipation
I-4	Solar wind acceleration	B topology in CH, Alfven wave in corona
I-5	Mechanism of prominence	B field structure, mass circulation
II. Physical origin of large-scale eruptions and algorithm for prediction		
II-1	Energy storage	Photo./chrom. B field maps
II-2	Trigger mechanism	Emerging flux, interaction with chrom.B
II-3	Mechanism of explosion	Large scale dynamics, current system
II-4	Physics of fast reconnection	Current sheet, plasmoid, shock
III. Origin of solar cycle and space climate variability		
III-1	Mechanism of UV variability	UV emissions at fine scale B structure
III-2	Grow/decay of AR, flux transport	Emergence/submergence of flux
III-3	Origin of alpha effect	Small scale & large scale helicity

I. Formation mechanisms of chromosphere, corona, and solar wind

Sub-objectives;

1. Formation mechanism of spicules and their influence in the corona
2. Nanoflare heating
3. Wave heating
4. Acceleration mechanism of solar winds
5. Formation mechanism of prominence
6. Role of vortex motions on energy transport
7. Non-ideal MHD effect on the heating
8. Mechanism of flux emergence

Topic IV fundamental plasma processes

- Magnetic reconnection
- Non-ideal MHD effect
- Wave generation, propagation and dissipation
- Particle acceleration
- MHD instability
- MHD turbulence

1. formation mechanism of spicules and their influence in the corona

task	Key observation	requirements	instrument
I-1-1: Observe magnetic topology and dynamics at the foot point of spicules to see the discontinuity and shears of magnetic structure, and observe the interaction of magnetic field and convection by which those topologies are formed.	・Images and velocity field resolving photospheric magnetic elements ・Vector magnetic fields from photosphere to the base of chromosphere ・FOV to cover several spicules with high cadence	Spectro-pol. $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.1$”, FOV > 10” T: 5000 ~ 10000K $\Delta t < 20$s, Time span ~ 2hr	SOLAR-C/SUVIT 1.4m DKIST EST Sunrise-3
I-1-2: Observe propagation of slow mode MHD waves and/or torsional Alfvén waves along spicules, and identify driving mechanism of jets and evaluate the heating in chromosphere	・Images and velocity fields resolving magnetic elements in photosphere to upper chromosphere with chromospheric vector magnetic fields ・Comparison of observations with different view angle μ (= cos θ)	Spectro-pol. $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.1$”, FOV > 20” T: 5000 ~ 10000K $\Delta t < 20$s, Time span ~ 2hr	SOLAR-C/SUVIT 1.4m DKIST EST Sunrise-3
I-1-3: Observe the response of coronal above the spicule and measure the supplied mass and thermalization process	・TR-corona images and velocity fields resolving elementary structures of TR ~ corona at multiple temperatures (10^5~5×10^6K) ・Comparison of disc and limb observations	$\Delta x \sim 0.3$”, FOV > 50” T: 10^5~5×10^6K $\Delta t < 20$s, Time span ~ 5hr $\lambda/\Delta\lambda$ ~ **	SOLAR-C /EUVST/HCI
I-1-4: Derive statistical properties of the spicules from the viewpoint of energizing and structuring the entire solar atmosphere, and understand their role in different environments.	・Images and velocity fields resolving magnetic elements in photosphere to upper chromosphere with chromospheric vector magnetic fields ・Comparison of observations with different environments: AR, QS, and CH.	Spectro-pol. $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.1$”, FOV > 20” T: 5000 ~ 10000K $\Delta t < 20$s, Time span ~ 2hr Total duration ~ 200hr	SOLAR-C/SUVIT 1.4m DKIST EST Sunrise-3

2. Verify the Nanoflare hypothesis

task	Key observation	requirements	instrument
I-2-1: Observe tiny brightening in TR and corona with sensitivity of ~ 10^{22} erg, determine the power-law energy spectrum down to ~ 10^{22} erg, and verify the total deposited thermal energy in active regions.	・High sensitivity images resolving elementary structures of TR ~ corona at multiple temperatures (10^5~10^7K)	Δx ~ 0.3” , FOV > 300” T: 10^5~10^7K Δt < 20s, Time span ~ 5hr	SOLAR-C/HCI
I-2-2: Observe intermittent process to produce 10^7K temperature plasmas and high velocity plasma motions	・Images and velocity fields resolving elementary structures of TR ~ corona at multiple temperatures (10^5~10^7K)	Δx ~ 0.3” , FOV > 50” T: 10^5~10^7K Δt < 20s, Time span ~ 5hr $\lambda/\Delta\lambda$ ~ **	SOLAR-C /EUVST/HCI
I-2-3: Observe time-series of sub-arcsec structures in corona and verify relations of tangling structures and nanoflares	・Images resolving elementary structures of TR ~ corona at multiple temperatures (10^5~5×10^6K)	Δx ~ 0.3” , FOV > 50” T: 10^5~5×10^6K Δt < 20s, Time span ~ 5hr	SOLAR-C/HCI
I-2-4: Verify causal relations between nano-flares and photospheric magnetic activity caused by convection and consequent changes of chromospheric magnetic fields	・Simultaneous high resolution observations of photosphere, chromosphere, and corona ・Photospheric magneto-convective activity and chromospheric response ・FOV to cover several super-granulation cells	Spectro-polarimetry ε ~ 10^{-4} Δx ~ 0.1”- 0.3” , FOV > 50” T: 5000 ~ 5×10^6K Δt < 20s, Time span ~ 5hr	SOLAR-C/SUVIT+HCI DKIST+(EUV)

3. Verify the Wave heating

task	Key observation	requirements	instrument
I-3-1: Measure time-series of physical quantities at different heights in photosphere-chromosphere-corona with sub-arcsec resolutions, investigate amplitude vs. phase correlation by not only event studies but also statistical studies, and evaluate wave modes and energy fluxes in frequency domain	・Simultaneous images and velocity/magnetic field observations of photosphere, chromosphere, and corona, resolving their elementary structures ・Cadence to catch up wave propagation ・Comparison of observations with different view angle μ (= cos θ)	Spectro-polarimetry $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.1$"- 0.3" , FOV > 30" T: 5000 ~ 5×10^6K $\Delta t < 20$s, Time span ~ 5hr Total duration ~ 200hr	SOLAR-C Sunrise-3 + corona
1-3-2: Observe discontinuous structures of motions and physical quantities in chromsophere and corona to see non-linearization processes	・Images and velocity fields resolving elementary structures in chromosphere ~ corona	$\Delta x \sim 0.1$"- 0.3" , FOV > 30" T: 5000 ~ 5×10^6K $\Delta t < 20$s, Time span ~ 5hr	SOLAR-C Sunrise-3 + corona
I-3-3: Observe TR & coronal response (plasma motions and temperature changes) in fine structures to waves propagating from below, and verify thermalization process	・Images resolving elementary structures of TR ~ corona at multiple temperatures (10^5~5×10^6K)	$\Delta x \sim 0.3$" , FOV > 30" T: 10^5~5×10^6K $\Delta t < 20$s, Time span ~ 5hr	SOLAR-C/EUVST/HCI
I-3-4: Observe large scale traveling waves in corona (by using chromospheric features i.e. filaments or prominences), and evaluate their modes and energy fluxes	・Images and velocity field of prominence ~TR ~ corona at multiple temperatures (10^4~5×10^6K)	$\Delta x \sim 0.3$" , FOV > 200" T: 10^4~5×10^6K $\Delta t < 20$s, Time span ~ 5hr	SOLAR-C

4. Understand the formation mechanism of solar winds

task	Key observation	requirements	instrument
I-4-1: Observe magnetic fields in photosphere and chromosphere under coronal holes that initiate solar winds, and determine geometry of flux tubes connected to corona	・Vector magnetic fields resolving photospheric and chromospheric magnetic elements under coronal holes	Spectro-polarimetry $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.1$"- 0.3" , FOV > 30" T: 5000 ~ 5×10^6K $\Delta t < 20$s, Time span ~ 5hr	SOLAR-C
I-4-2: Identify relations of source regions of fast solar winds and coronal density structure (plumes)	・Images and velocity fields resolving elementary structures of corona at multiple temperatures (10^5~5×10^6K) ・wide FOV covering coronal holes	$\Delta x \sim 0.3$" , FOV > 300" T: 10^6~5×10^6K $\Delta t < 20$s, Time span ~ 5hr	SOLAR-C/EUVST/HCI
I-4-3: Confirm propagating coronal Alfvén waves and measure their energy fluxes	・Time-series of high-resolution coronal images and velocity fields ・Time cadence of ~10 seconds to measure periods of waves	$\Delta x \sim 0.3$" , FOV > 300" T: 10^6~5×10^6K $\Delta t < 20$s, Time span ~ 5hr	SOLAR-C/EUVST/HCI
I-4-4: Identify the source regions of solar winds.	- Measure the intensity of spectral lines from different FIP elements at corona base and compare with in situ measurements - High sensitivity	$\Delta x \sim 1$" , FOV > 300" T: 10^6~5×10^6K $\Delta t \sim 1$hr, Time span ~ 5hr Sensitivity??	Solar Orbiter SOLAR-C/EUVST
I-4-5: Observe the anisotropy of temperature and turbulence at the coronal base.			Solar Orbiter SOLAR-C/EUVST

5. Understand the prominence formation mechanism

task	Key observation	requirements	instrument
I-5-1: Measure magnetic structure supporting prominences	・Magnetic fields inside prominences ・Photospheric magnetic fields below prominences ・Comparison of AR vs QS and disk vs limb observations	Spectro-polarimetry $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.3$”, FOV > 300” T: 5000 ~ 10^4K $\Delta t < 10$min, Time span ~ 5hr	SOLAR-C/SUVIT ASOT Medium size ground telescopes
I-5-2: Detect mass circulation among chromosphere – prominence - corona	・Images and velocity fields of prominences (10^4K) ・Images and velocity fields resolving elementary structures of TR ~ corona surrounding prominences at multiple temperatures (10^5~5×10^6K)	$\Delta x \sim 0.1$”- 0.3”, FOV > 300” T: 5000 ~ 5×10^6K $\Delta t < 60$s, Time span ~ 10hr	SOLAR-C
I-5-3: Track evolution of photospheric and chromospheric magnetic fields near neutral lines, and clarify condition of prominence formation	・Photospheric velocity fields and vector magnetic fields ・High-resolution images, velocity fields, and magnetic fields of chromosphere ・wide FOV continuous observation for several days	Spectro-polarimetry $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.3$”, FOV > 300” T: 5000 ~ 10^4K $\Delta t < 10$min, Time span ~ 5day	SOLAR-C ASOT

6. Understand the role of vortex motions on energy transport

task	Key observation	requirements	instrument
I-6-1: observe small scale kinetic and current helicity in photosphere			
I-6-2: twisting magnetic field in chromosphere			
I-6-3: propagation into the corona and dissipation			

7. Understand the non-ideal MHD effect (ambipolar effect) on the heating

task	Key observation	requirements	instrument
I-7-1: Measure differences between dynamics of neutral atoms and ions in MHD waves, and verify the effect of neutral atoms on the damping of the wave	・Images and velocity fields in ion and neutral atoms resolving spatial and temporal scale of decoupling of neutral atoms from plasma ・Choromospheric vector magnetic and electric fields	Spectro-polarimetry $\varepsilon \sim 10^{-4}$ $\Delta x \sim 0.01''$, FOV > 20” Δt < 1sec, Time span ~ 2hr T: 5000 ~ 10^4K Multi-lines of ion & neutral atom	SOLAR-C/SUVIT DKIST EST

8. Mechanism of flux emergence

task	Key observation	requirements	instrument

Spicule and waves

I-3-4: large scale traveling waves in corona, their modes and energy fluxes

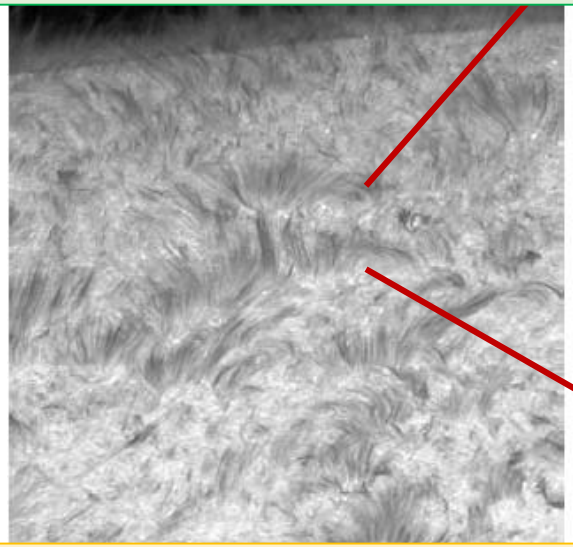
I-1-3: coronal response to spicules

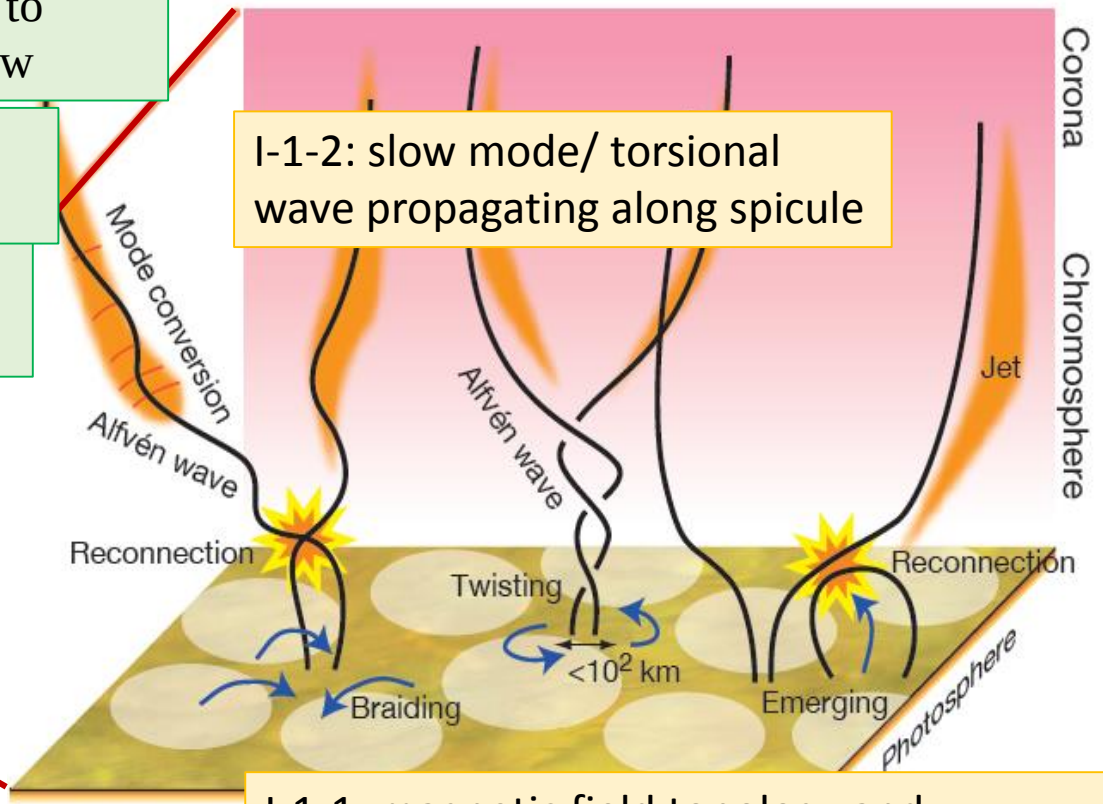
I-3-3: TR & coronal response to waves propagating from below

I-3-2: shock front and non-linearization processes in chromos.

I-1-2: slow mode/ torsional wave propagating along spicule

I-3-1: wave mode and energy flux in sub-arcsec resolution



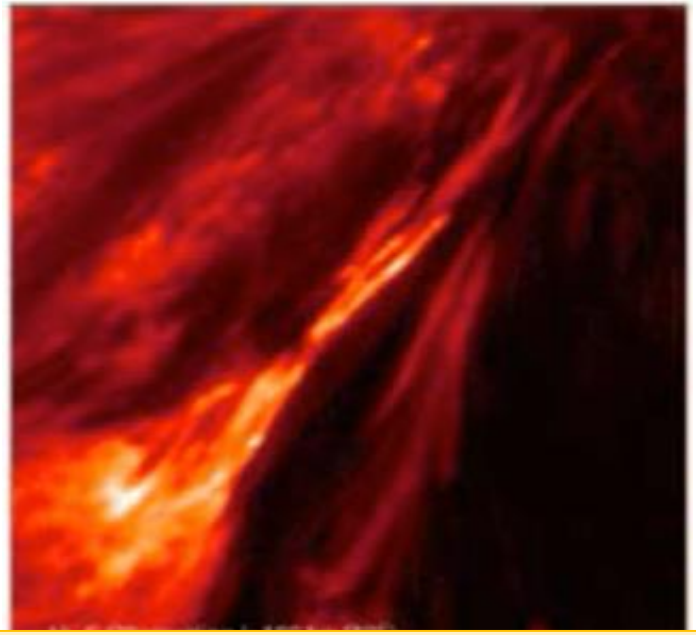


I-1-1: magnetic field topology and dynamics at the foot point of spicules, and photospheric activities as their source

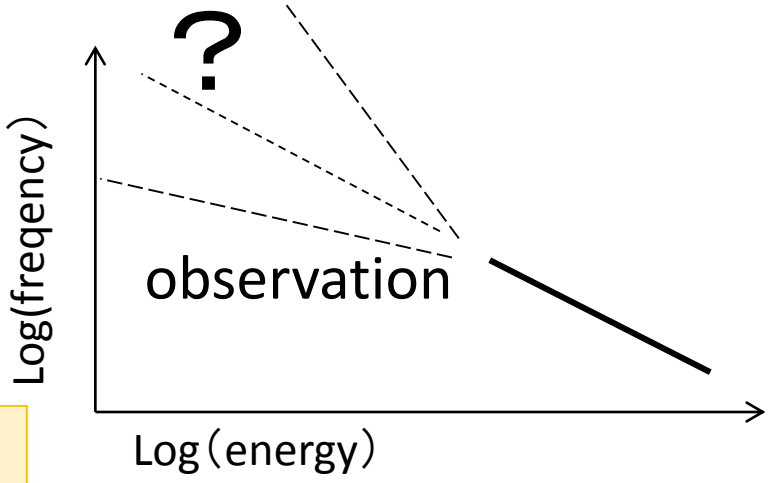
I-1-4: statistical properties of the spicules and their role in formation of large scale structures

Nano-flare heating

I-2-2: Observe intermittent process to produce 10^7K temperature plasmas and high velocity plasma motions



I-2-3: Observe time-series of sub-arcsec structures in corona and verify relations of tangling structures and nanoflares



I-2-4: Verify causal relations between nano-flares and photospheric and chromospheric magnetic activities

I-2-1: determine the energy spectrum down to ~ 10^{22} erg to verify the total deposited thermal energy

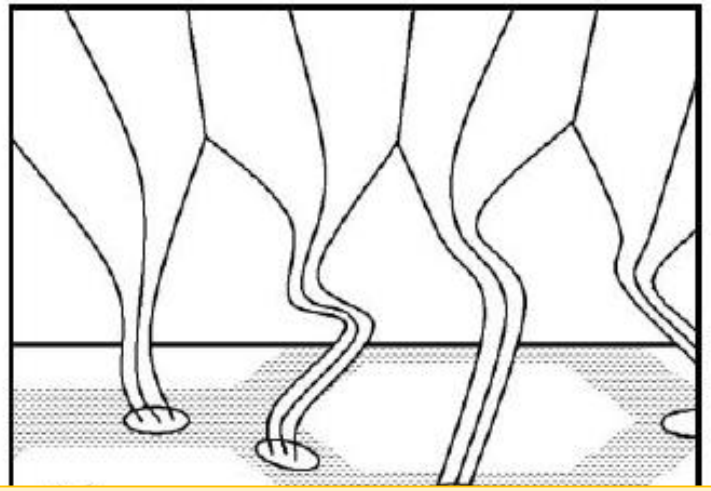
Solar wind

I-4-4: Identify the source regions of solar winds observed by in-situ measurements

I-4-3: Confirm propagating coronal Alfvén waves and measure their energy fluxes

I-4-5: Observe the anisotropy of temperature and turbulence at the coronal base.

I-4-2: Identify relations of source regions of fast solar winds and coronal density structure (plumes)

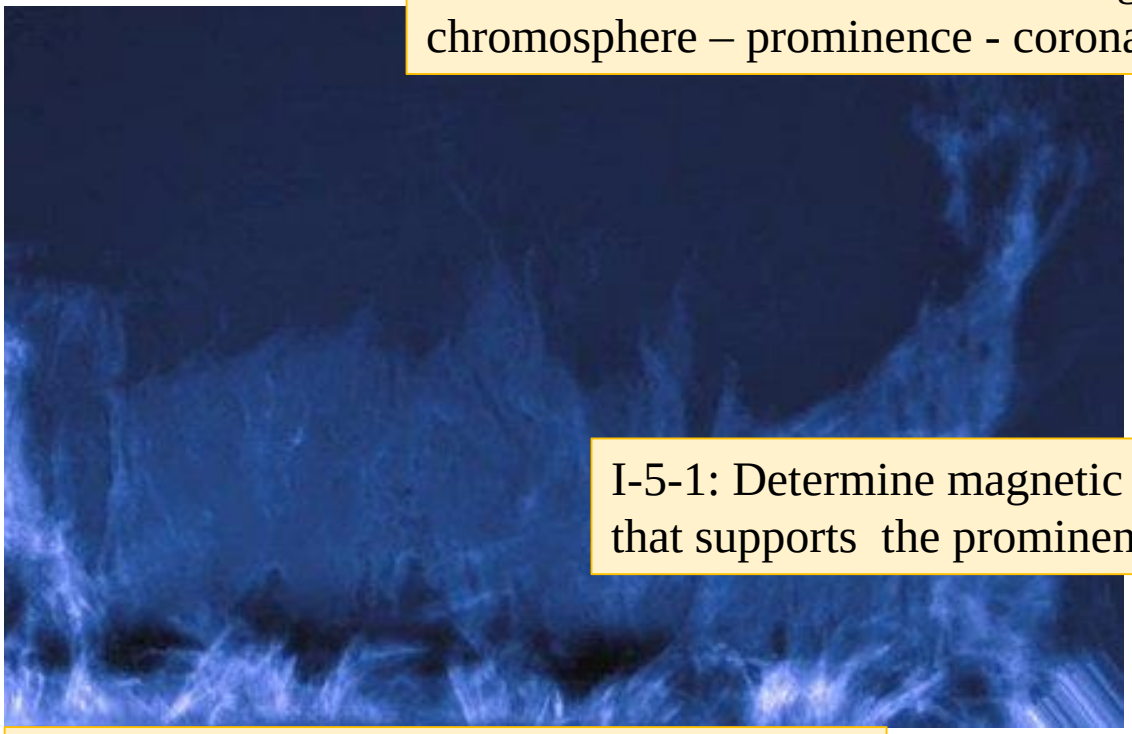


I-4-1: magnetic fields configuration in photosphere and chromosphere under coronal hole

Cranmer and van ballegooijen 2005

prominence

I-5-2: Detect mass circulation among chromosphere – prominence - corona

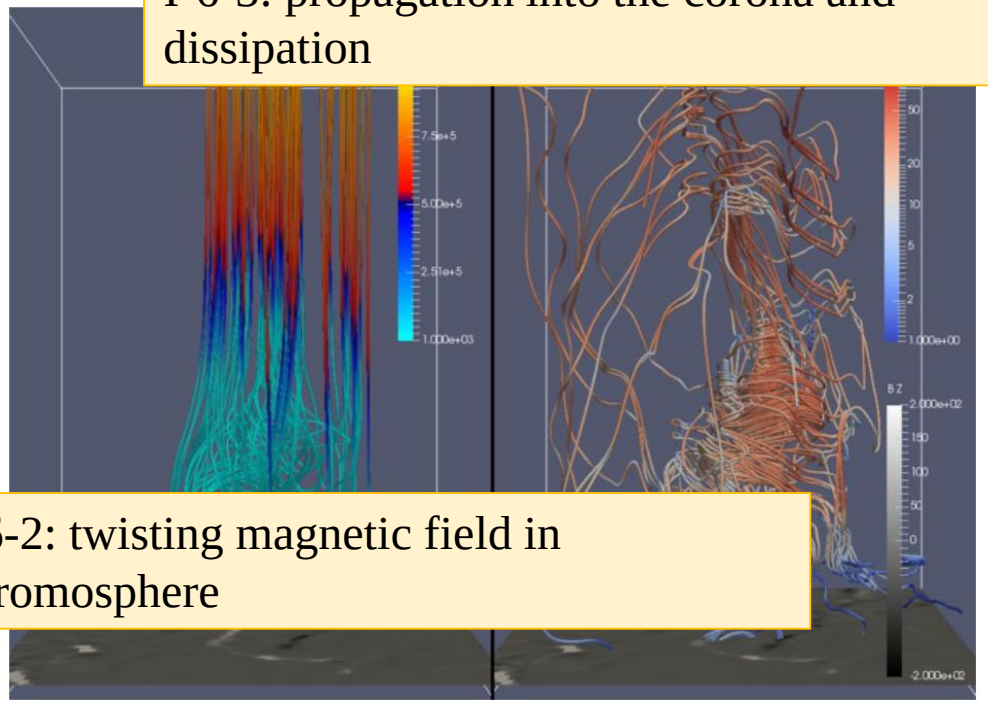


I-5-1: Determine magnetic structure that supports the prominences

I-5-3: Track evolution of photospheric and chromospheric magnetic fields near neutral lines, and clarify condition of prominence formation

Role of vortex

I-6-3: propagation into the corona and dissipation



I-6-2: twisting magnetic field in chromosphere

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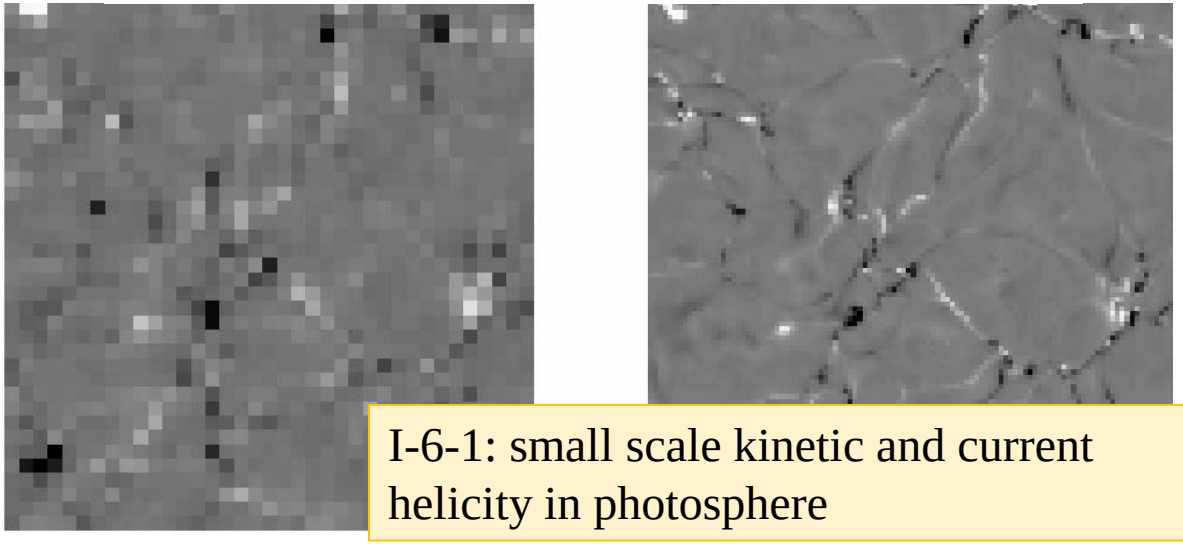


I-6-1: small scale kinetic and current helicity in photosphere

Spicule and waves; what is needed?

I-3-4: large scale traveling waves in corona, their modes and energy fluxes

I-1-3: coronal response to spicules

Solar-C/HCI,EUVST

I-3-3: TR & coronal to waves propagating from below,

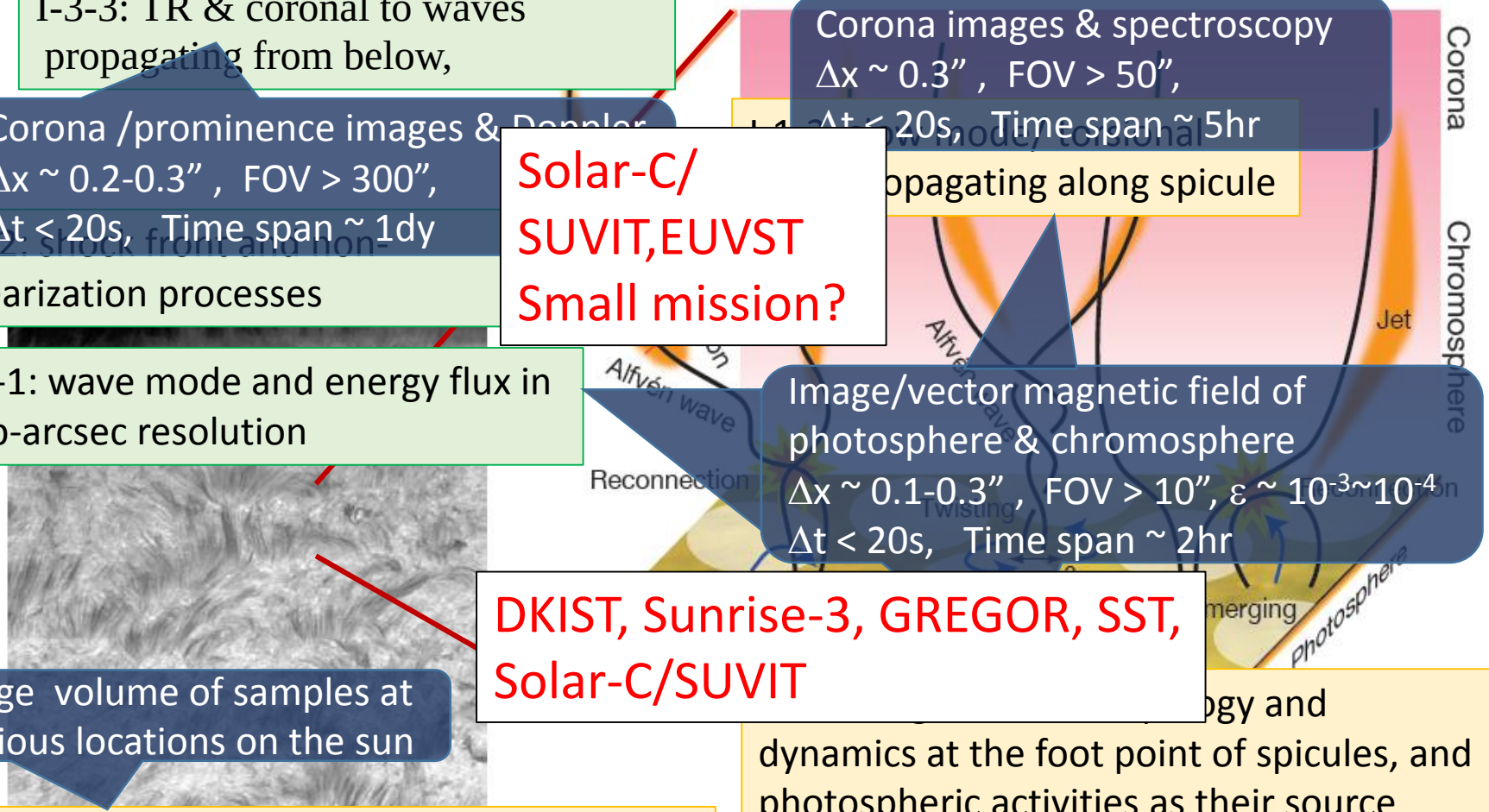
Corona images & spectroscopy
$\Delta x \sim 0.3''$, FOV > 50",
$\Delta t < 20s$, Time span ~ 5hr

Corona /prominence images & Doppler
$\Delta x \sim 0.2\text{-}0.3''$, FOV > 300",
$\Delta t < 20s$, Time span ~ 1dy

Solar-C/
SUVIT,EUVST
Small mission?

I-3-2: shock front and non-linearization processes

I-3-1: wave mode and energy flux in sub-arcsec resolution



Image/vector magnetic field of photosphere & chromosphere
$\Delta x \sim 0.1\text{-}0.3''$, FOV > 10", $\varepsilon \sim 10^{-3}$~10^{-4}
$\Delta t < 20s$, Time span ~ 2hr

DKIST, Sunrise-3, GREGOR, SST, Solar-C/SUVIT

Large volume of samples at various locations on the sun

ogy and dynamics at the foot point of spicules, and photospheric activities as their source

I-1-4: statistical properties of the spicules and their role in formation of large scale structures

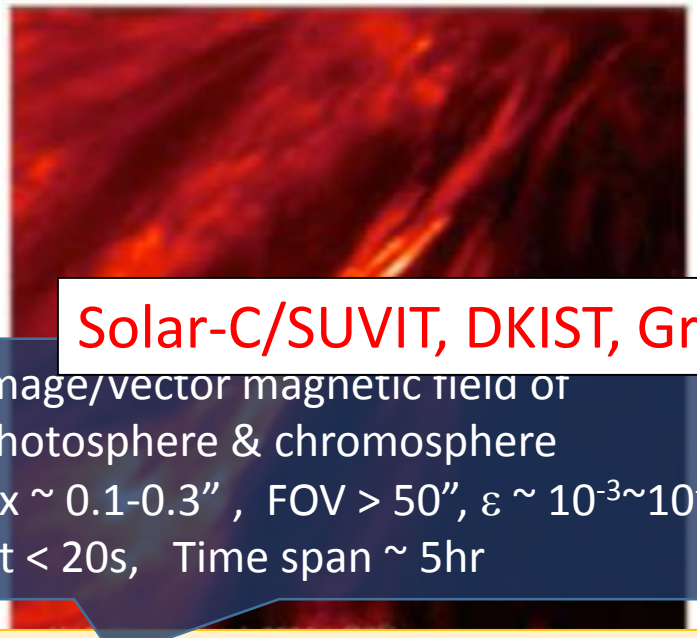
Nano-flare heating; what is needed?

I-2-2: Observe intermittent process to produce 10^7K temperature plasmas and high velocity plasma motions

Corona spectroscopy
$\Delta x \sim 0.3''$, FOV > 50", T: 10^5~10^7K
$\Delta t < 20s$, Time span ~ 5hr

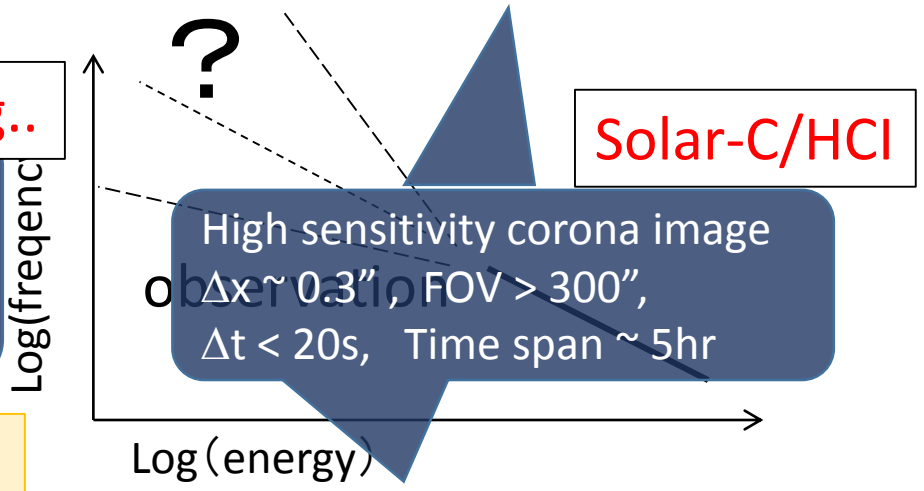
Solar-C/EUVST, HCI

I-2-3: Observe time-series of sub-arcsec structures in corona and verify relations of tangling structures and nanoflares



Solar-C/SUVIT, DKIST, Greg..

Image/vector magnetic field of photosphere & chromosphere
$\Delta x \sim 0.1$-$0.3''$, FOV > 50", $\varepsilon \sim 10^{-3}$~10^{-4}
$\Delta t < 20s$, Time span ~ 5hr



Solar-C/HCI

High sensitivity corona image
$\Delta x \sim 0.3''$, FOV > 300",
$\Delta t < 20s$, Time span ~ 5hr

I-2-4: Verify causal relations between nano-flares and photospheric and chromospheric magnetic activities

I-2-1: determine the energy spectrum down to ~ 10^{22} erg to verify the total deposited thermal energy

Solar wind; what is needed?

Solar-C/EUVST, HCI

Corona images & spectroscopy
Δx ~ 0.3” , FOV > 300”, Δt < 20s,
Time span ~ 5hr

I-4-3: Confirm propagating coronal Alfvén waves and measure their energy fluxes

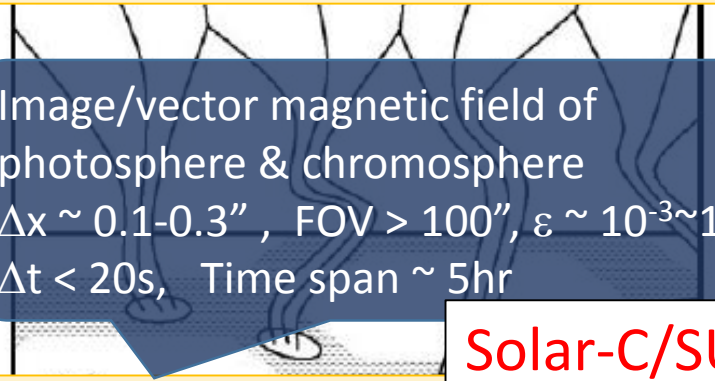
I-4-2: Identify relations of source regions of fast solar winds and coronal density structure (plumes)

Coronal spectroscopy
Abundance of different FIP elements
Stereoscopic obs.
Δx ~ 0.3” , FOV > 300”, Δt ~ 1hr,
Time span ~ 1week

Solar-C/EUVST, HCI
+ SO, Sol.Probe

I-4-4: Identify the
winds observed by in-situ measurements

I-4-5: Observe the anisotropy of temperature and turbulence at the coronal base.



Image/vector magnetic field of
photosphere & chromosphere
Δx ~ 0.1-0.3” , FOV > 100”, ε ~ 10^{-3}~10^{-4}
Δt < 20s, Time span ~ 5hr

Solar-C/SUVIT

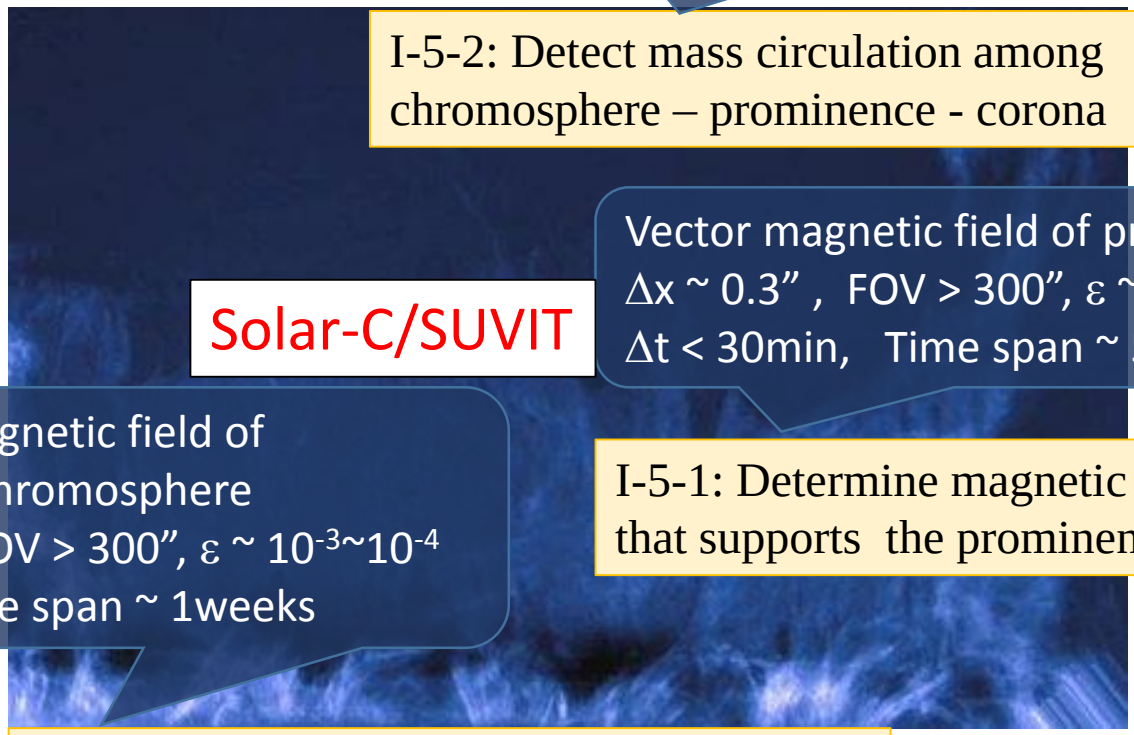
I-4-1: magnetic fields configuration in photosphere and chromosphere under coronal hole

Cranmer and van Ballegooijen 2005

prominence; what is needed?

Solar-C/EUVST/HCI

images and velocity fields of TR ~ corona
$T = 10^5 \sim 5 \times 10^6$K
$\Delta x \sim 0.3''$, FOV > 300”,
$\Delta t < 1$min, Time span ~ 10hr



I-5-2: Detect mass circulation among chromosphere – prominence - corona

Solar-C/SUVIT

Vector magnetic field of prominence
$\Delta x \sim 0.3''$, FOV > 300”, $\varepsilon \sim 10^{-3} \sim 10^{-4}$
$\Delta t < 30$min, Time span ~ 5hr

Image/vector magnetic field of photosphere & chromosphere
$\Delta x \sim 0.1\text{-}0.3''$, FOV > 300”, $\varepsilon \sim 10^{-3} \sim 10^{-4}$
$\Delta t \sim 30$min, Time span ~ 1weeks

I-5-1: Determine magnetic structure that supports the prominences

I-5-3: Track evolution of photospheric and chromospheric magnetic fields near neutral lines, and clarify condition of prominence formation

Role of vortex; what is needed?

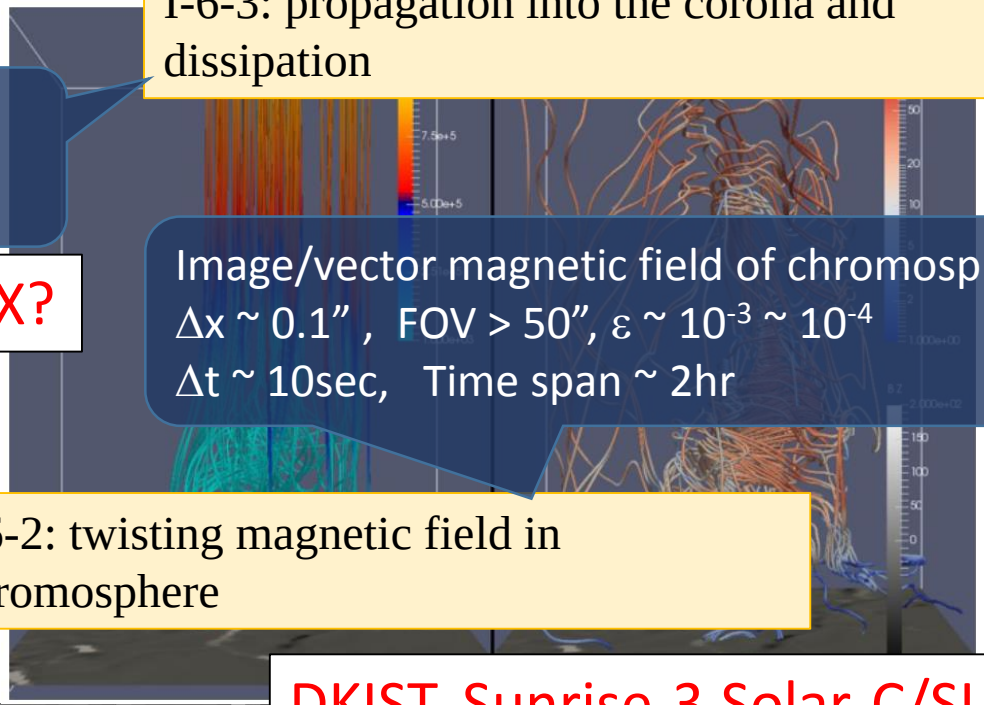
I-6-3: propagation into the corona and dissipation

Corona images & spectroscopy
$\Delta x \sim 0.3''$, FOV > 300”,
$\Delta t < 20s$, Time span ~ 5hr

Solar-C/EUVST/HCI, SMEX?

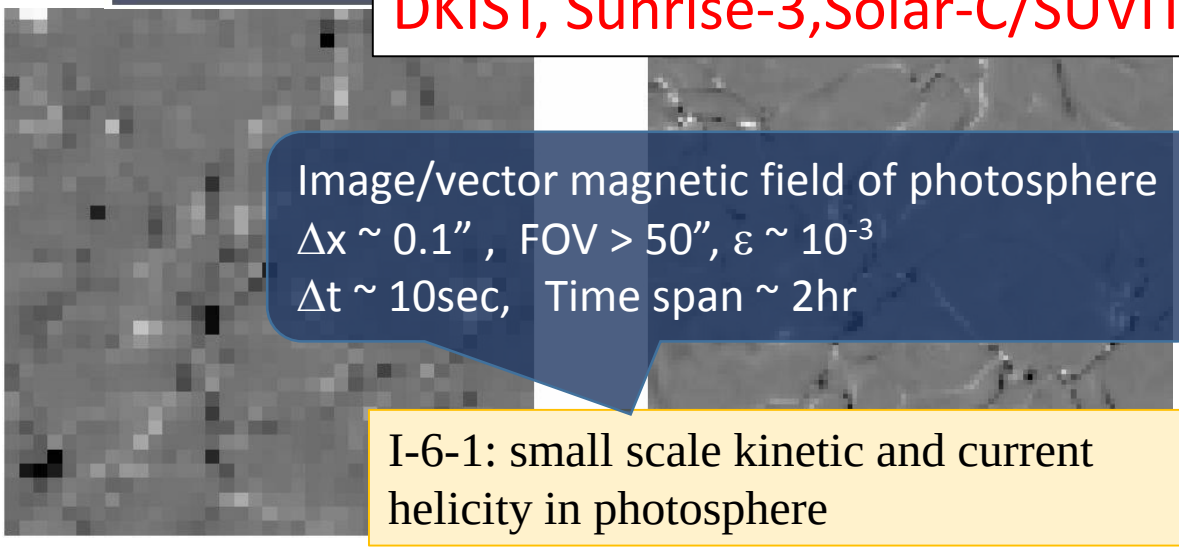
Image/vector magnetic field of chromosphere
$\Delta x \sim 0.1''$, FOV > 50”, $\varepsilon \sim 10^{-3} \sim 10^{-4}$
$\Delta t \sim 10sec$, Time span ~ 2hr

I-6-2: twisting magnetic field in chromosphere



Iijima+ 2015

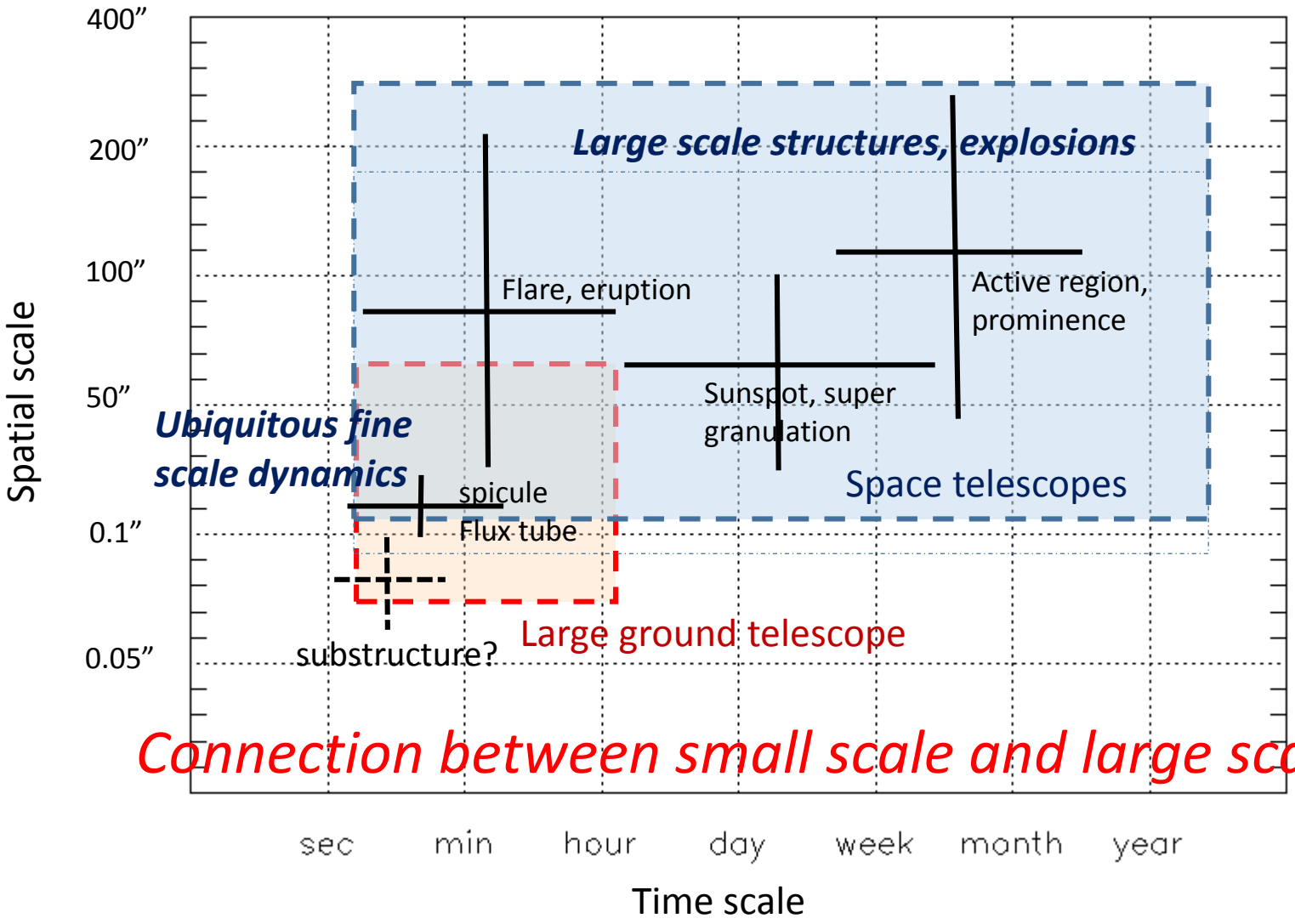
DKIST, Sunrise-3,Solar-C/SUVIT



Image/vector magnetic field of photosphere
$\Delta x \sim 0.1''$, FOV > 50”, $\varepsilon \sim 10^{-3}$
$\Delta t \sim 10sec$, Time span ~ 2hr

I-6-1: small scale kinetic and current helicity in photosphere

Spatial and temporal scales covered by SUVIT and DKIST



Connection between small scale and large scale