Solar-C meeting, 11 Nov. 2013 in Takayama

Solar UV-Visible-IR Telescope (SUVIT)

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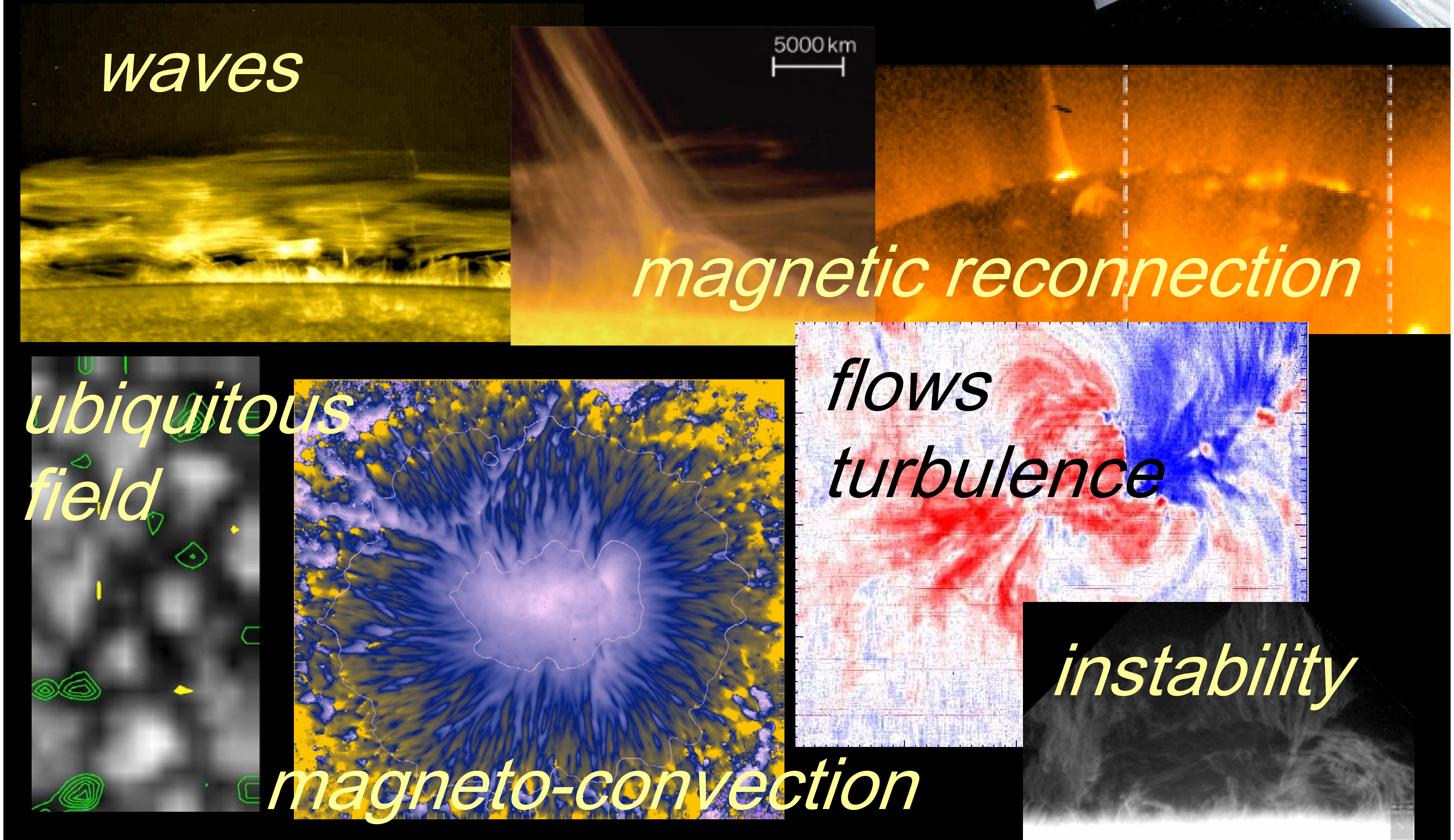
and Solar-C WG

Many Hinode results are related to fundamental MHD processes.



But,, they are not yet contributed to our full understanding of chromosphere and corona..

Limitations of SOT;

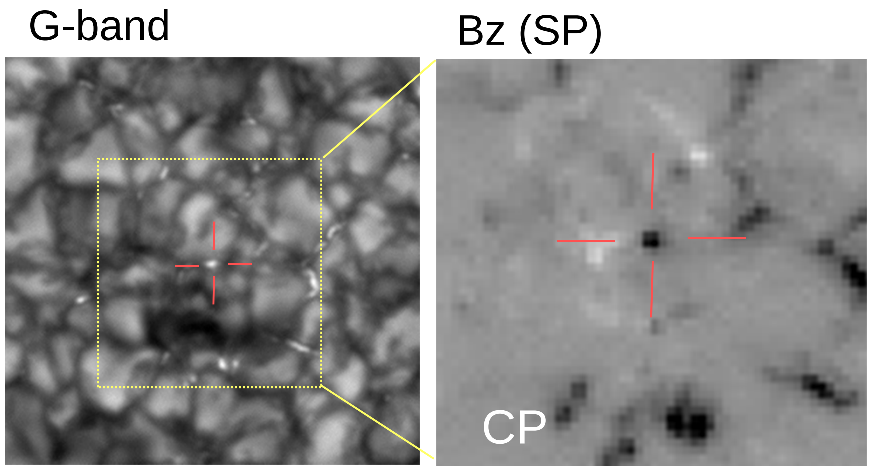
- Many features are unresolved.

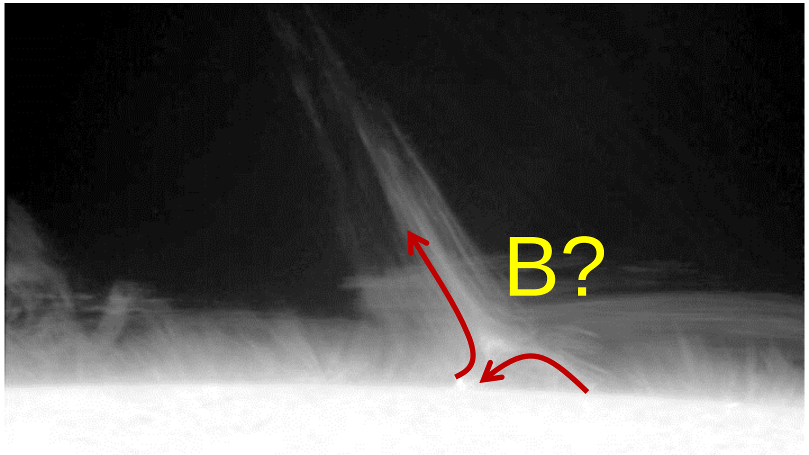
  > 80% of flux are invisible to Hinode/SP (Pietarila Graham+. 2010)

- Hinode is blind to chromosphere in terms of diagnostics.

  No information of physical quantities, *v, B, T, n*.

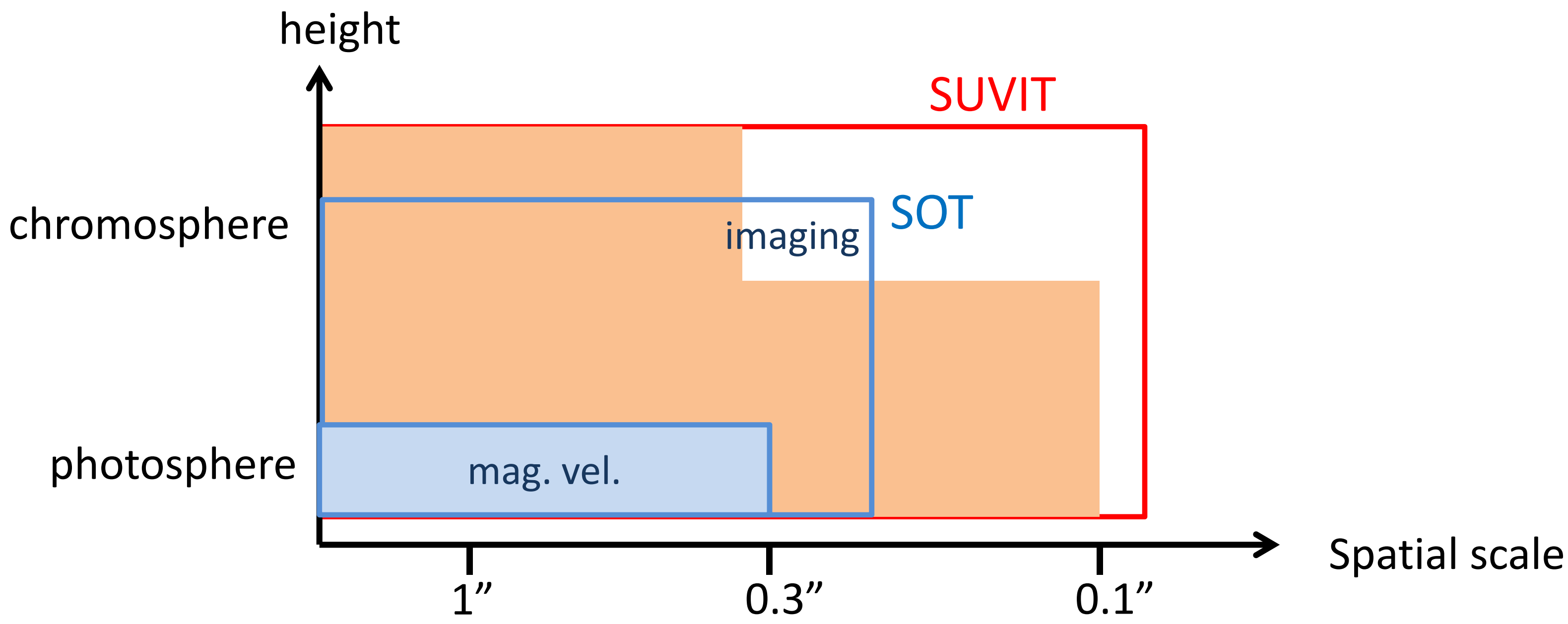
- Insufficient time resolution of spectroscopic observations





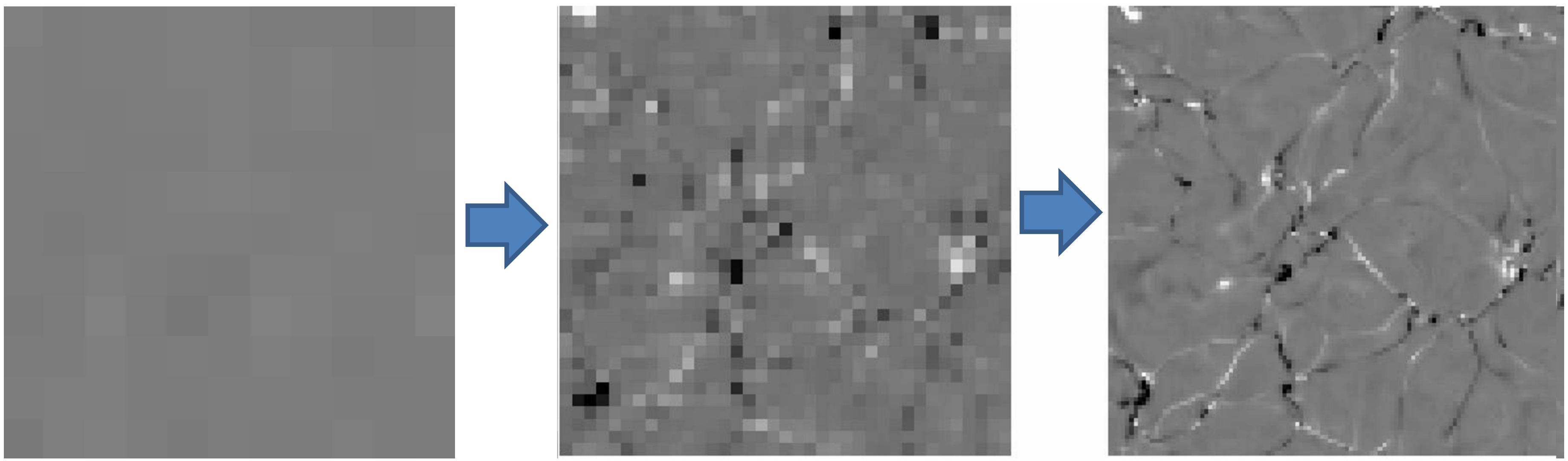
The most significant jump of SUVIT from the SOT

- 3 times higher spatial resolution
  → resolve elementary density / temperature structures
- High precision spectro-polarimetry of chromosphere
  → Zeeman / Hanle diagnosis of chromospheric mag. field
- Time cadence (especially magnetic field data)
  → capture dynamic evolution of physical conditions in fundamental plasma process



Gain with a higher spatial resolution (photosphere)

3 times higher resolution compared to SOT
→ 10 times higher sensitivity to magnetic elements



ground 1”

SOT 0.3”
mag.elements [x,y]

SUVIT 0.1”
+ vortex , current、mix.pol.
0.1”～ photon mean free path

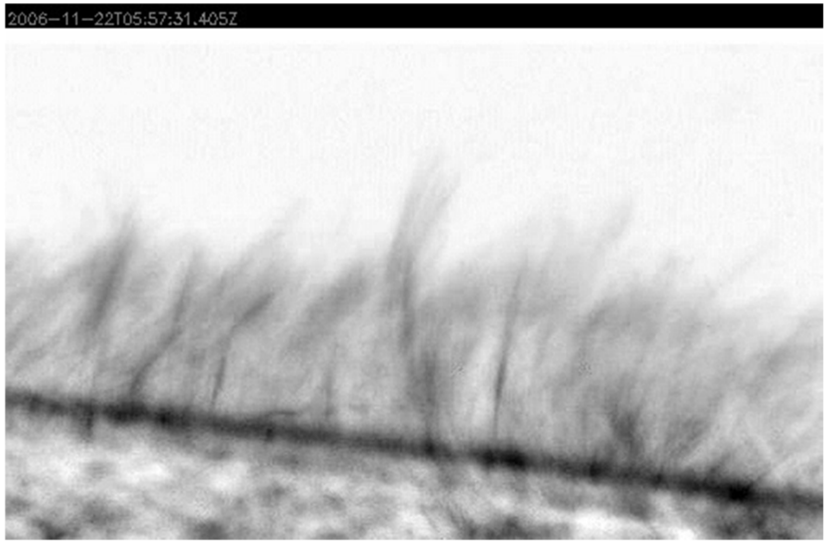
# of detectable mag. elements x 7 (from power-low PDF −1.8)

# of detectable interactions x 50 (courtesy by Iida)

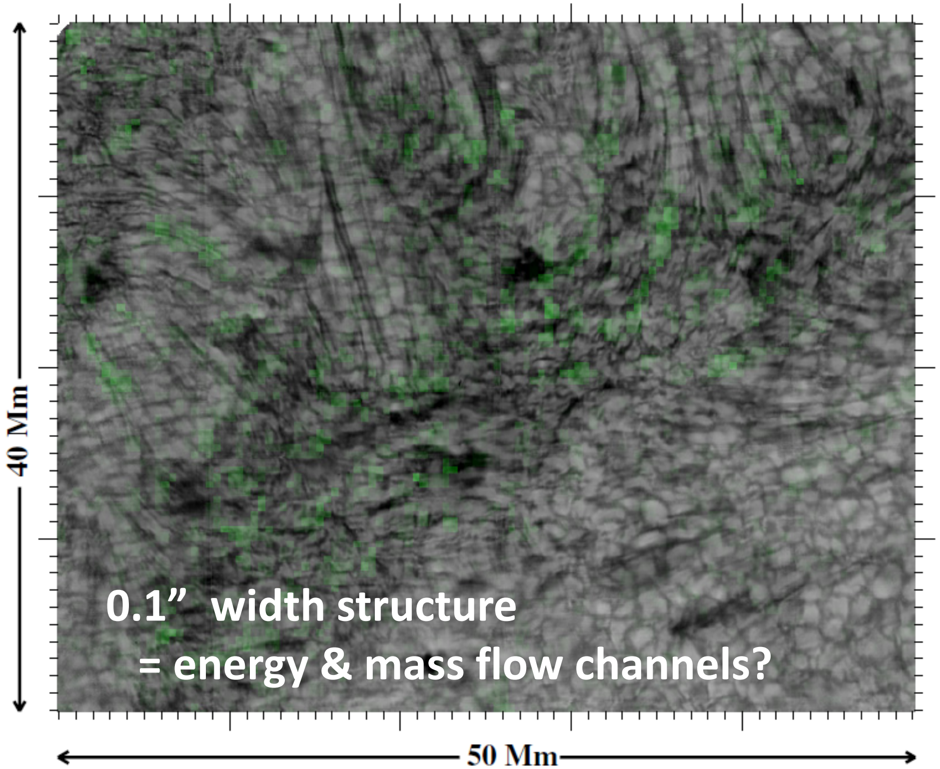
With uninterrupted observation, SUVIT will unveil for the first time the whole picture of magnetic energy generation in the photosphere.

Gain with a higher spatial resolution (chromosphere)

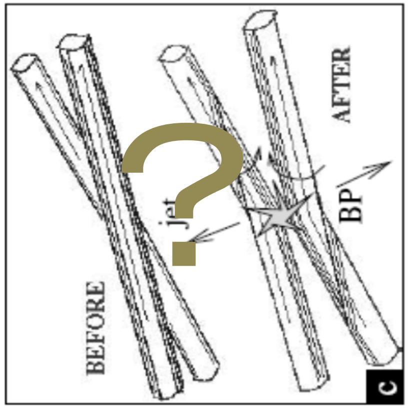
Mysterious spicule



Suematsu, SOT 0.2", CaH



Ji+ 2012, BBSO 1.6m NST 10830A & AIA 171A



Ryutova+ 2008

SUVIT will detect the fine scale channels connecting photo. /chrom./corona, current sheets, mag. reconnection, shock fronts,,,

→ First quantitative understanding of energy flows in the chromosphere!

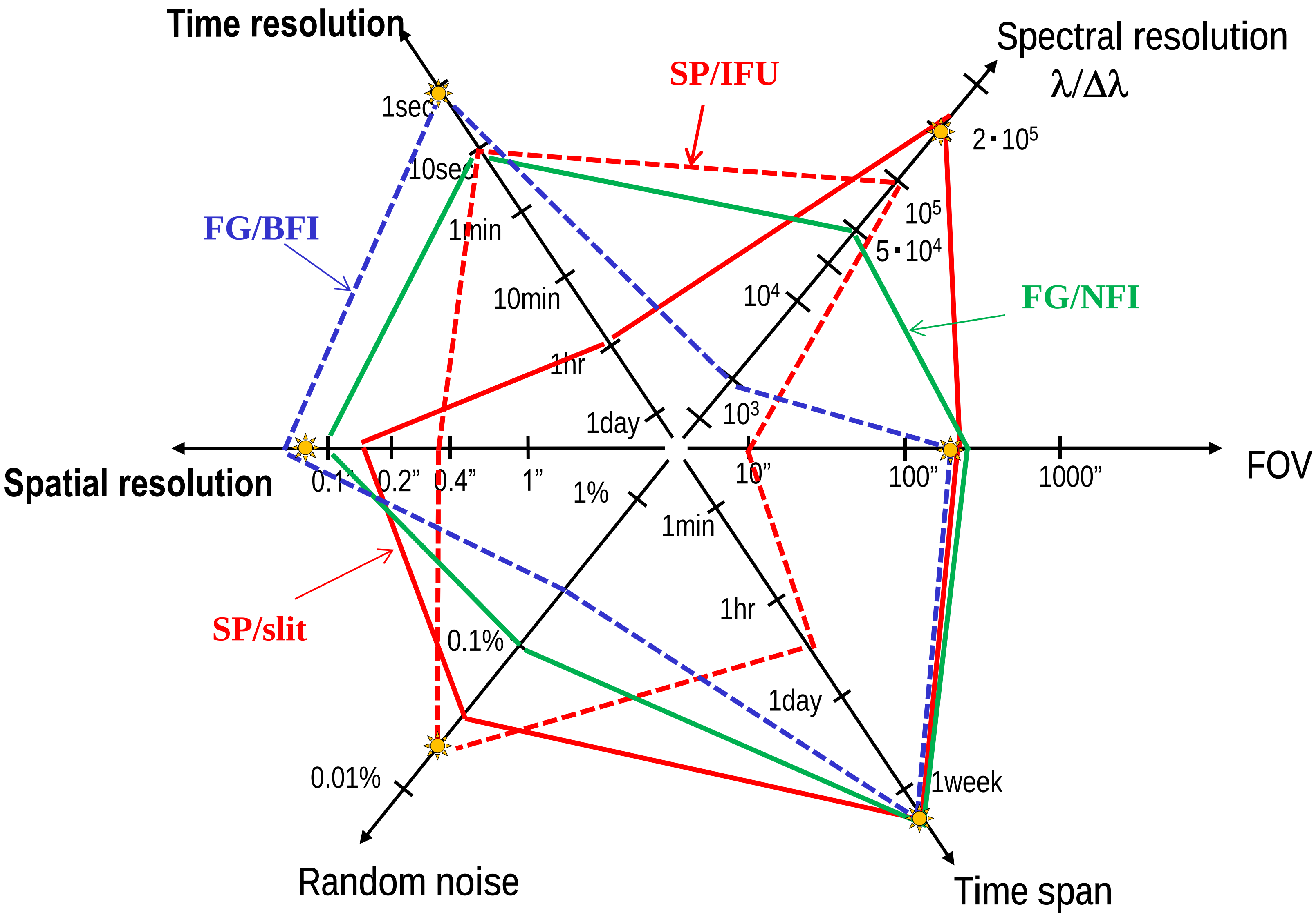
Science requirements

	requirement (goal)	reason
Spatial resolution	0.07" for imaging obs. 0.1" for mag. field obs. 0.36" for 2D chrom. mag. field	resolve chrom. T & ρ fine structures resolve photo. mag. elements (β<1) scale of divergent chrom. mag. field (β >1)
Field of view	180"x180" (200"x200") for AR study 8"x8"(10"x10") for elementary structures	Size of a moderate AR Size of a spicule
Wavelength coverage	393 nm (280nm) – 1083nm	high res. contrast chrom. imaging photo. & chrom. mag, measurement
Wavelength resolution	200,000 for precise photo. mag. field 100.000 for precise chrom. mag. field 50,000 for high res. mag./vel. field	Thermal width of spectral lines in photo,/chrom. Zeeman signal
Polarimetric sensitivity	$3 \cdot 10^{-4}$ (10^{-4}) for chrom. mag. field 10^{-3} (10^{-4}) for photo. mag. field	$B_{//}$~10G, $B_{\perp}$~100 G $B_{//}$~2G, $B_{\perp}$~70 G
Time resolution	1sec for imaging obs. 10sec for small FOV mag. obs. 1hr for large FOV mag. obs	Flare evolution Chrom. dynamic features AR mag. evolution
Data rate	~2.5 Mbps in average (after compression) ~50 Mbps at peak (")	ex. Track long term evolution of AR ex. Diagnose the evolution of dynamic process

Instrument requirements

	requirement (goal)	Impact on instrument design
Spatial resolution	0.07" for imaging obs. 0.1" for mag. field obs. 0.36" for 2D chrom. mag. field	Telescope diameter ~ ϕ1.4m diffrac. limited optics Str. > 0.8 @633nm sufficient spatial sampling 0.015~0.02"/pix
Field of view	180"x180" (200"x200") for AR study 8"x8"(10"x10") for elementary structures	Large acceptance angle of optical system Large format camera Dual mode (high reso. & wide FOV)
Wavelength coverage	393 nm (280nm) – 1083nm	Wide l coating, (restricted glass for 280nm) chromatic design of imaging optics
Wavelength resolution	200,000 for precise photo. mag. field 100.000 for precise chrom. mag. field 50,000 for high res. mag./vel. field	Grating size ≥ 20cm, spectrograph f x slit width Narrowband filter width ~ 0.1A @520nm
Polarimetric sensitivity	$3 \cdot 10^{-4}$ (10^{-4}) for chrom. mag. field 10^{-3} (10^{-4}) for photo. mag. field	Telescope diameter ~ ϕ1.4m, High throughput Fast camera (~50fr/s), onboard demodulation High pol. modulation efficiency & calibration
Time resolution	1sec for imaging obs. 10sec for small FOV mag. obs. 1hr for large FOV mag. obs	High speed camera 2D spectroscopy (IFU in SP) + 2D scan mech.
Data rate	~2.5 Mbps in average (after compression) ~50 Mbps at peak (")	Large telemetry Efficient data compression w/ 12bit JPEG

Science requirements are realized by two complementary instruments;
Filtergraph (FG) & Spectro-polarimeter (SP)



Wavelength coverage

- Measure the magnetic field of chromosphere by Zeeman effect

  → extension to longer wavelength is inevitable

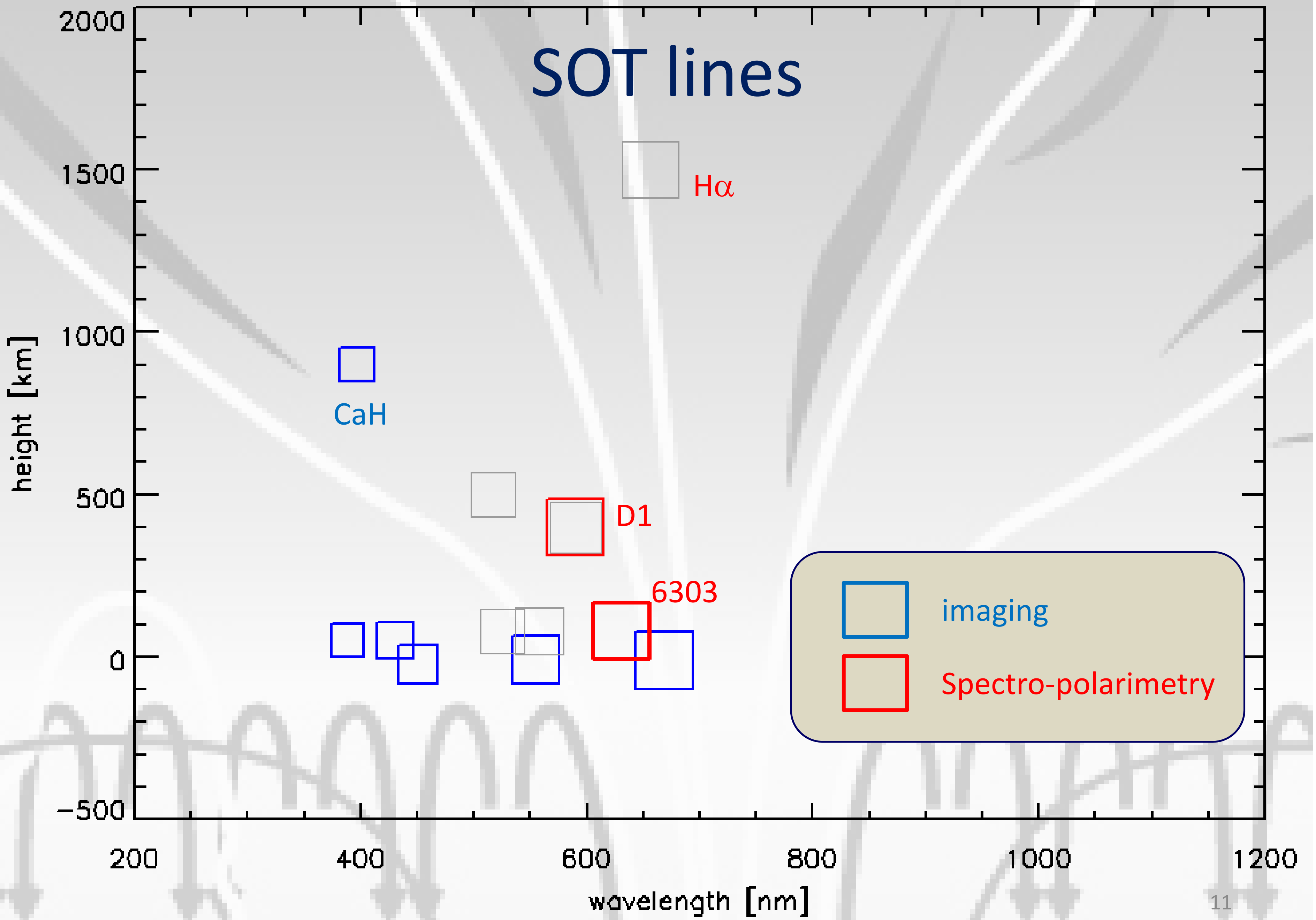
- Observe chromospheric dynamics with a highest resolution and contrast → demand for shorter wavelength, i.e. MgII 280nm

SUVIT candidate lines

Spectrum bands		SP	BF	NF	Purpose
Continuum	TBD		(x)		T in the upper photosphere
Mg II k	279 nm	(x)	(x)		T and V in the chromosphere
CN band	388 nm		x		Magnetic elements in the photosphere
Ca II K	393 nm		x		Structures in the chromosphere
Blue cont.	450 nm		x		Imaging and T in the photosphere
Mg I b	517 nm			x	V and B in the low chromosphere
Fe I	525 nm	x		x	V and B in the photosphere
Na I D	589 nm			TBD	V and B in the low chromosphere
Fe I	630 nm			TBD	V and B in the photosphere
H I α	656 nm			x	Structures in the chromosphere
Ca II	854 nm	x		x	T, V, and B in the chromosphere
He I	1083 nm	x			V and B in the chromosphere

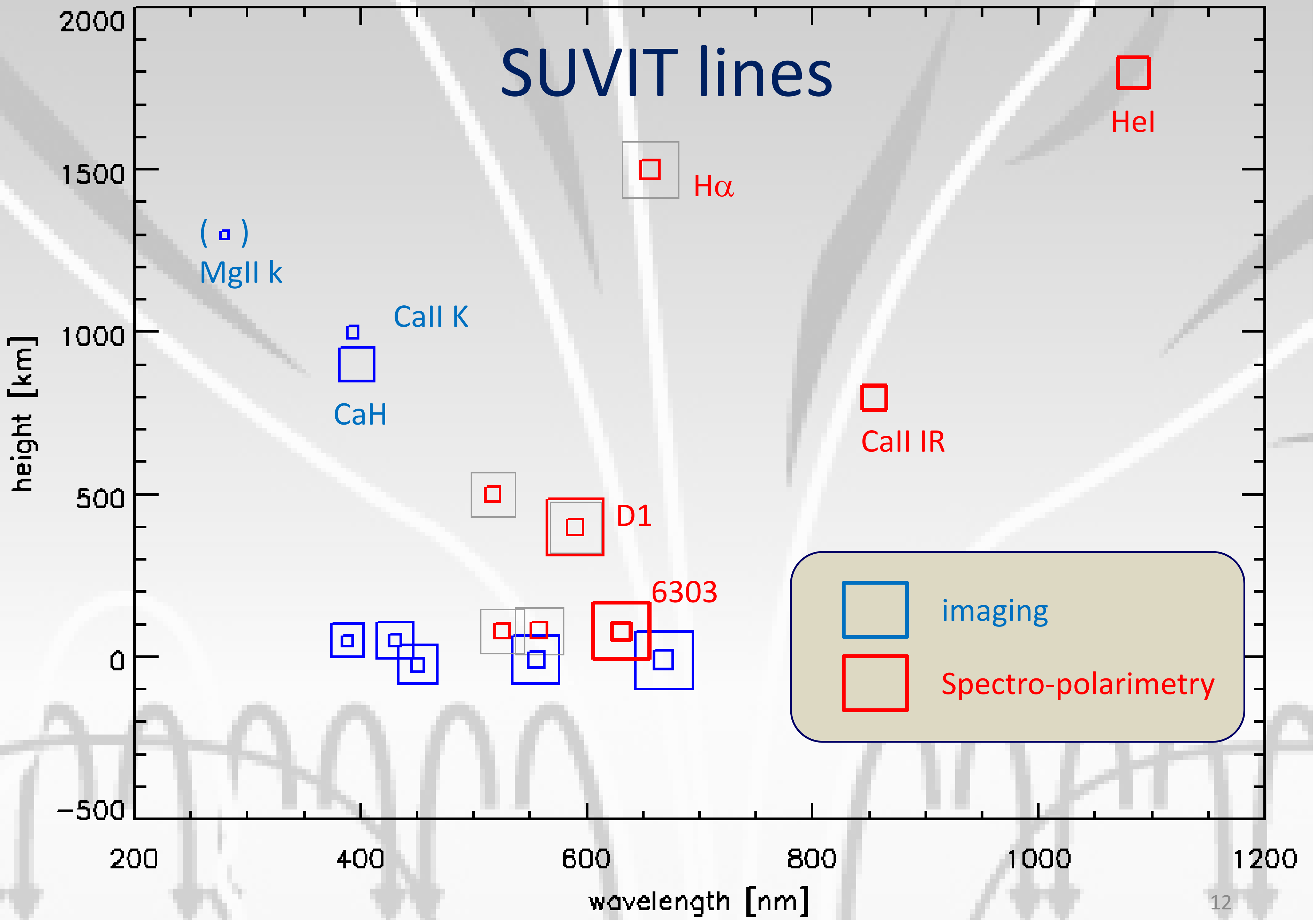
280nm is optional. Technical issues not fully settled down..

SOT lines



2000
1500
1000
500
0
−500
height [km]
200
400
600
800
1000
1200
wavelength [nm]
Hα
CaH
D1
6303
imaging
Spectro-polarimetry

SUVIT lines



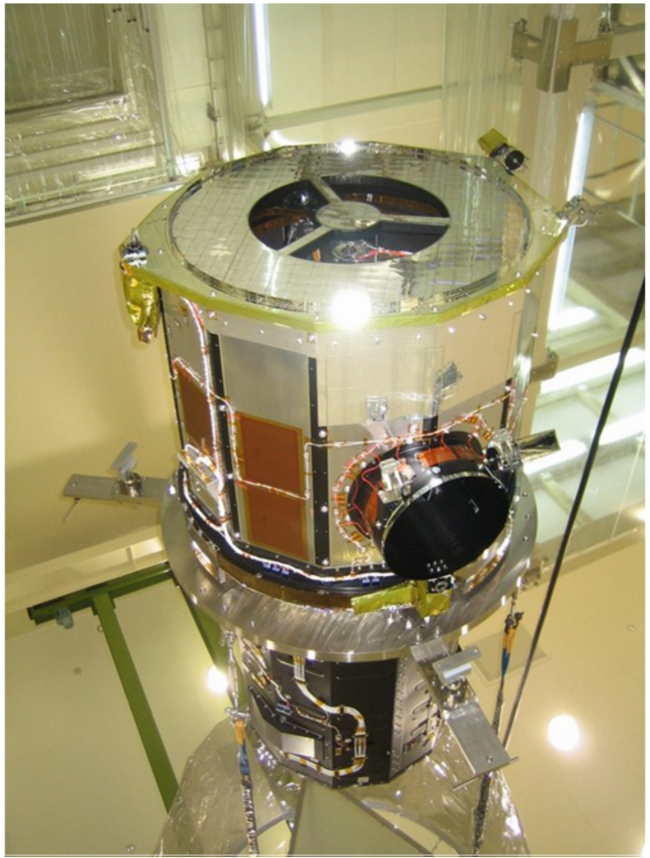
2000
1500
1000
500
0
-500
200
400
600
800
1000
1200
height [km]
wavelength [nm]
HeI
Hα
MgII k
CaII K
CaH
CaII IR
D1
6303
imaging
Spectro-polarimetry

SUVIT basic design concept

- Maximum usage of the Hinode heritage
  - An axi-symmetric aplanatic Gregorian telescope with 1.4m aperture
  - Heat dump mirror and 2nd field stop to minimize the heat lord to FG & SP
  - FG & SP are connected with the telescope assy. (TA) by collimated beam via OBU
  - Common rotating waveplate as a pol. modulator
  - Image stabilizing system with a tip-tilt mirror
  - Same testing strategy;

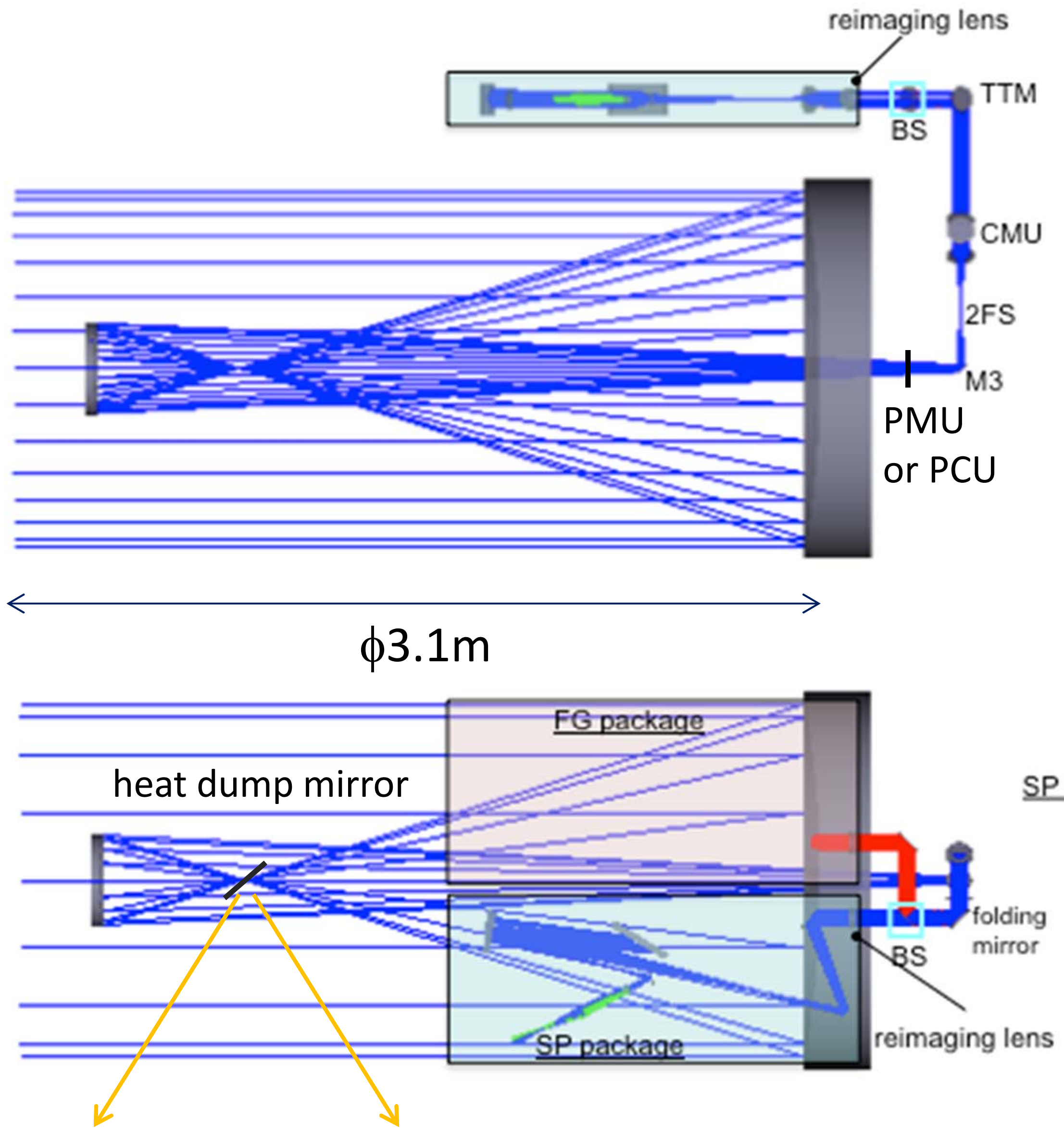
    optical alignment, opto-thermal vac.,

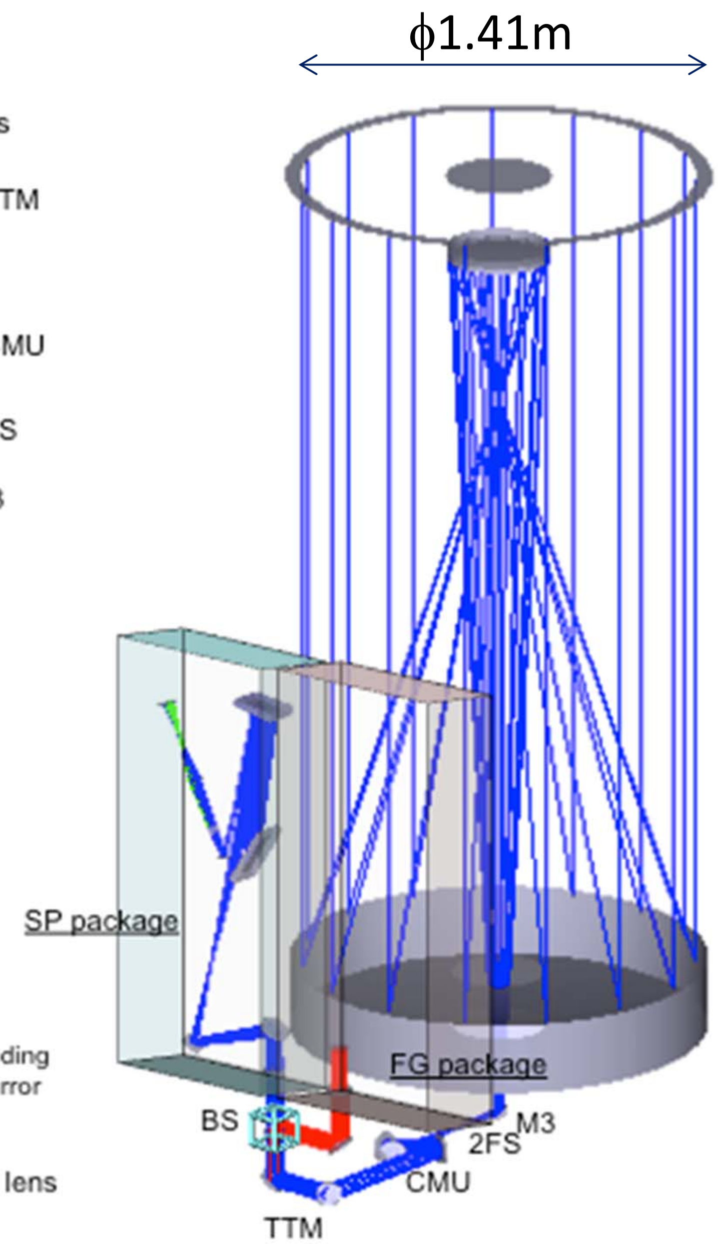
    microvibration, contamination control,,,



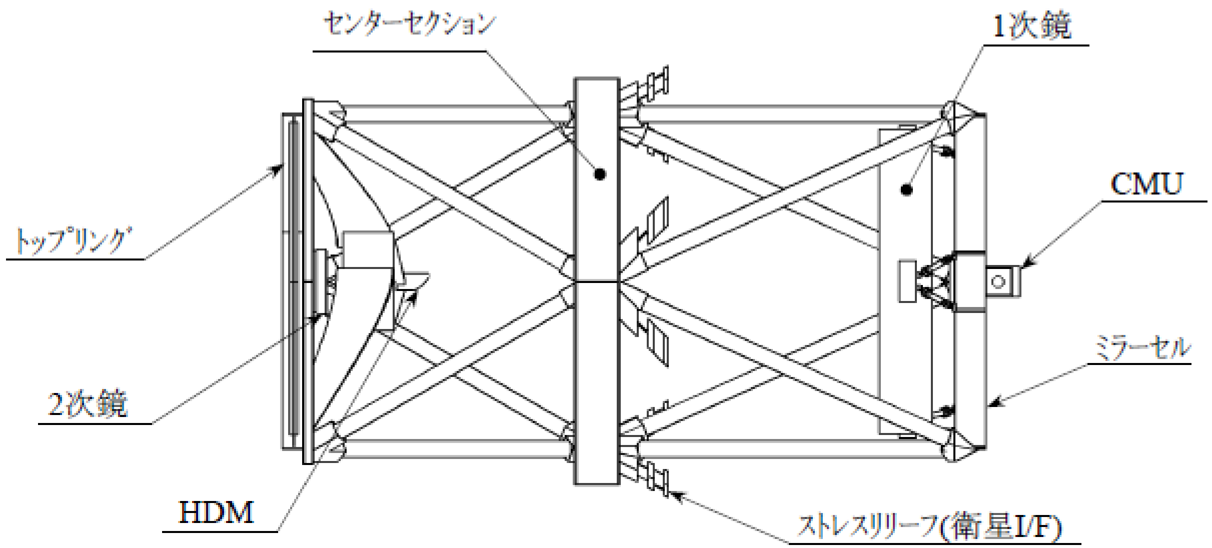
- But, the new demands make SUVIT a much more challenging instrument than SOT/Hinode!

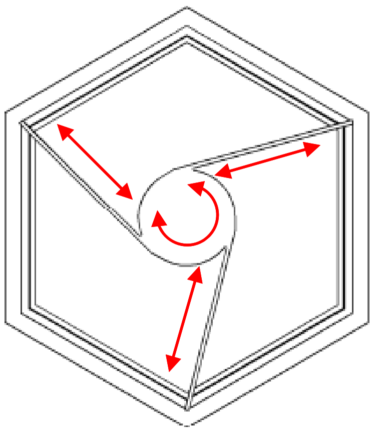
SUVIT layout

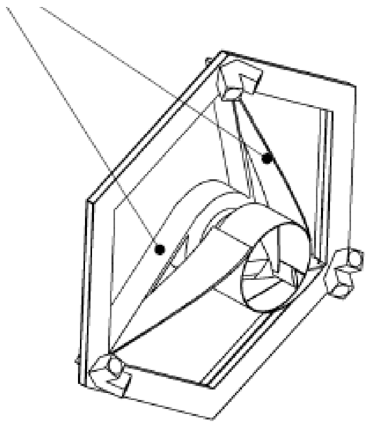




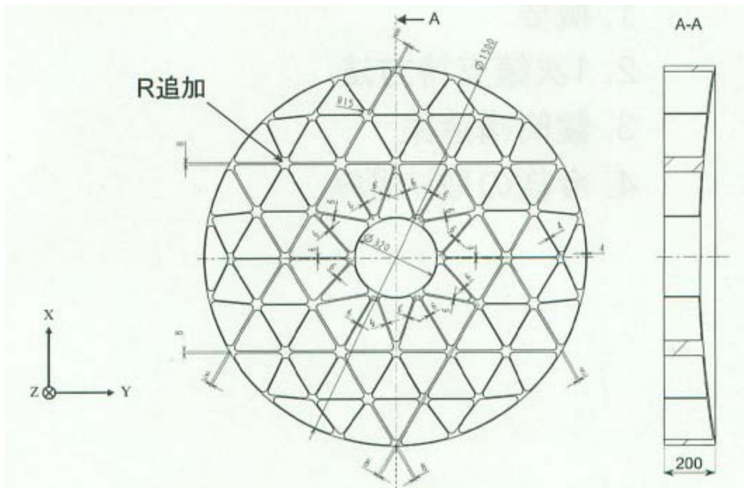
Telescope structure





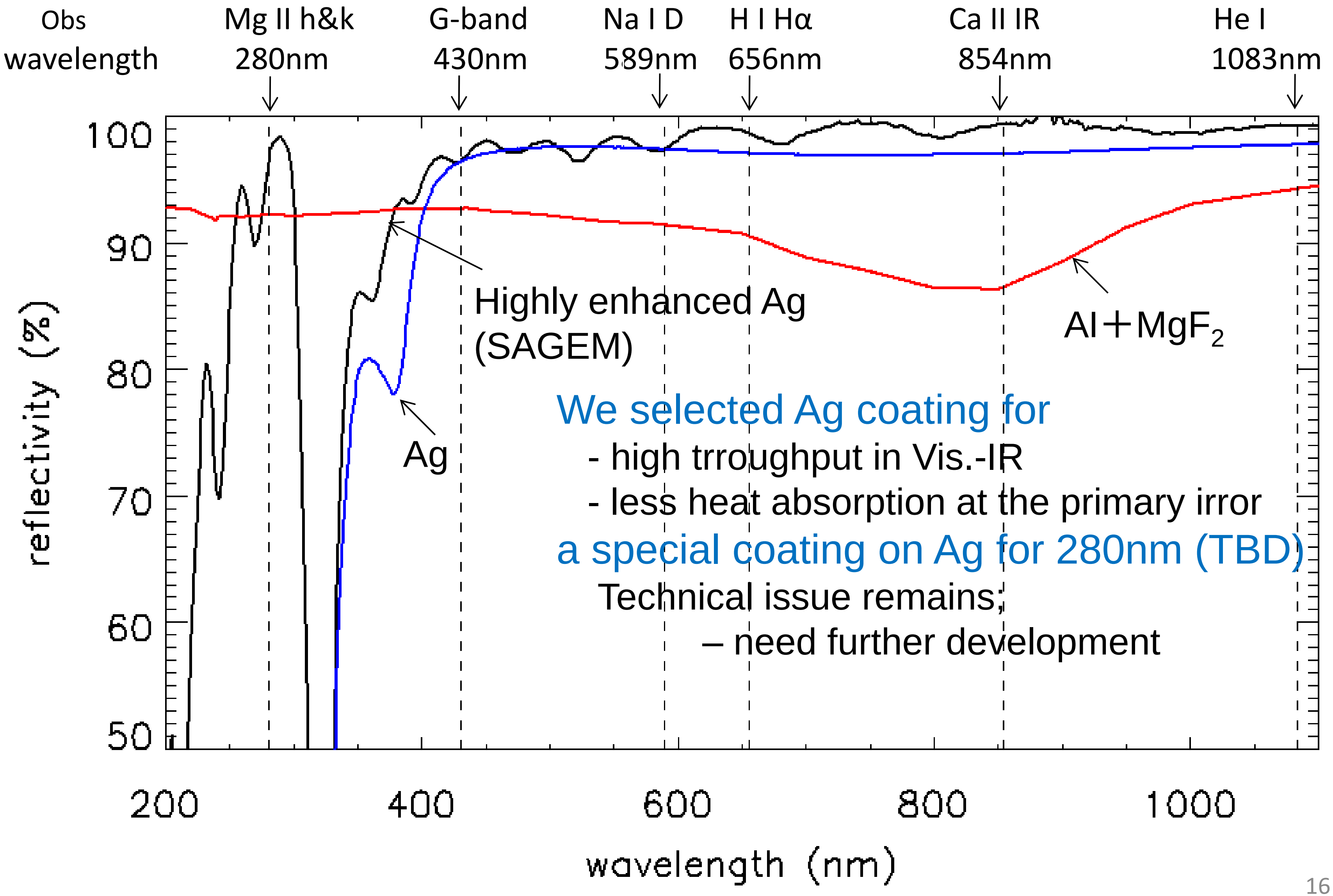


Tangential support of M2 to prevent the defocus caused by a thermal effect



Light waighted (~90%)
Minimum gravitational deformation when the mirror is in vertical.

Coating on the mirrors



We selected Ag coating for

- high trroughput in Vis.-IR
- less heat absorption at the primary irror

a special coating on Ag for 280nm (TBD)

Technical issue remains;

– need further development

Mg II 280nm

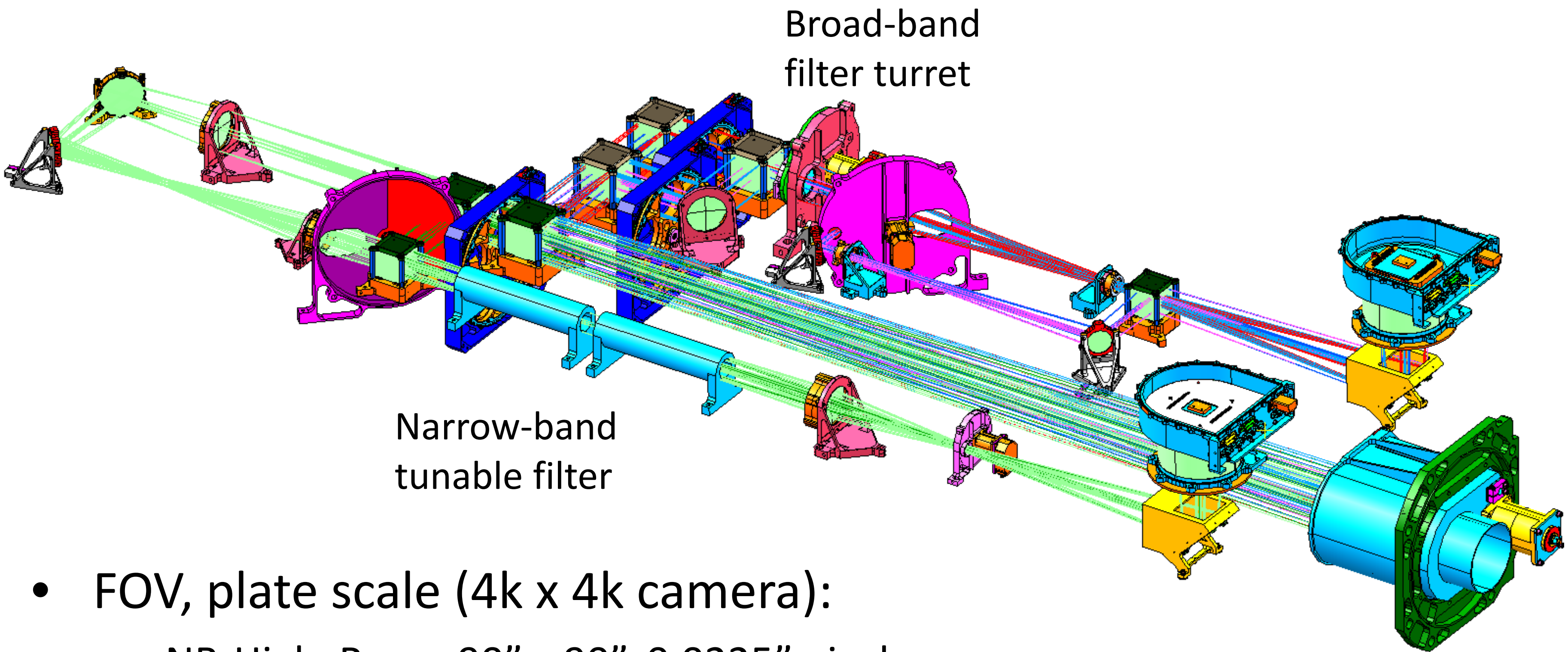
In the current study,
we optimize the system design for 380-1100nm w/o 280nm

280nm will be included when

- definitive scientific justification is made after the study of IRIS data
- it is proven that inclusion of 280nm does not degrade the performance in Vis.&IR nor introduce significant risk

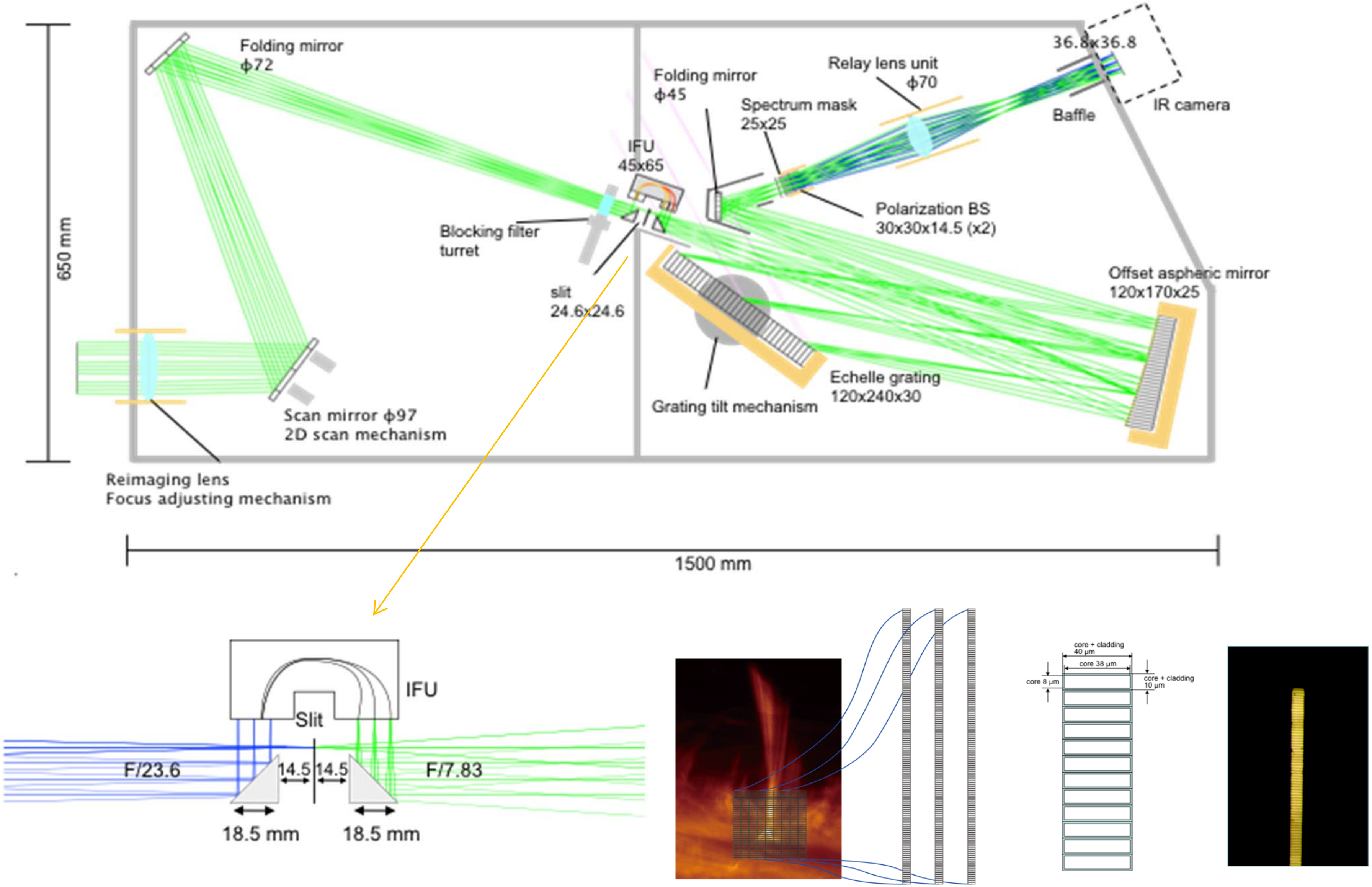
Decision will be made by spring in the next year

Filtergraph layout

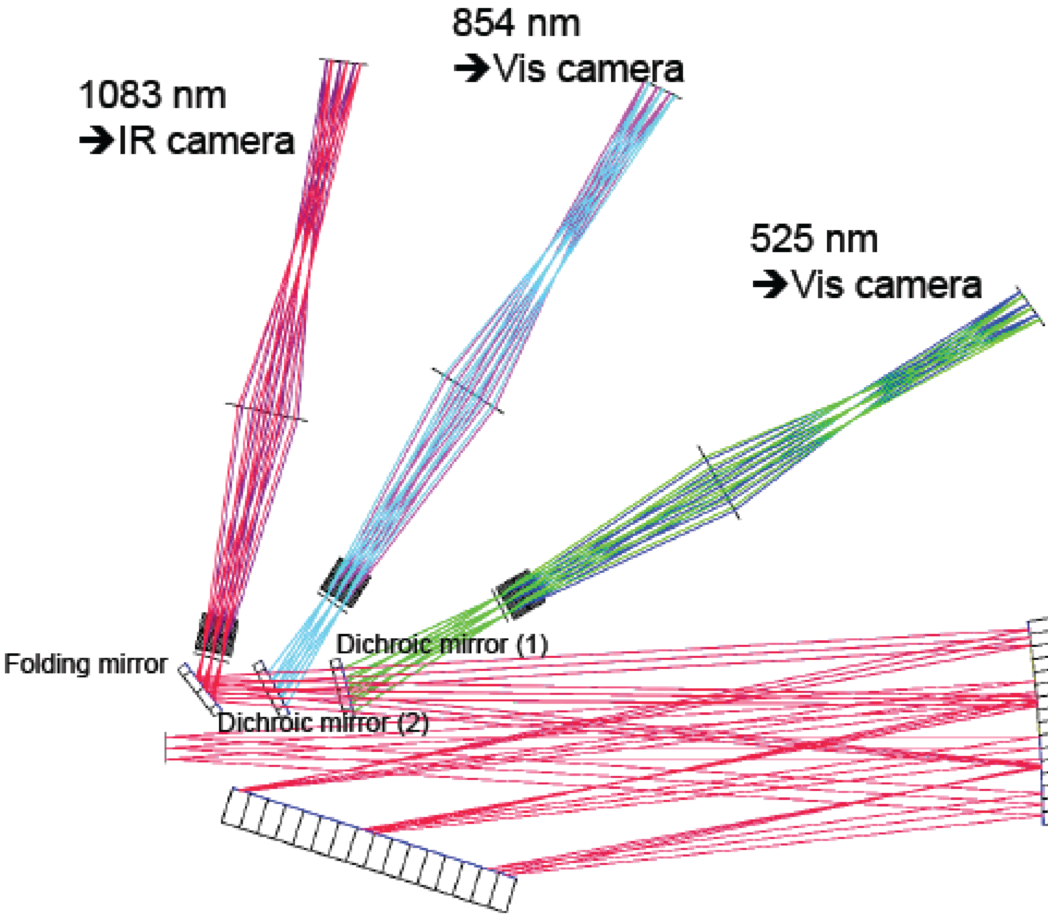


- FOV, plate scale (4k x 4k camera):
  - NB-High Res: 90” x 90”, 0.0225” pixels
  - NB-Wide FOV: 180” x 180”, 0.045” pixels
  - WB-High Res: 60” x 60”, 0.015” pixels
  - WB-Wide FOV: 180” x 180”, 0.045” pixels

Spectro-polarimeter



Another option; three cameras

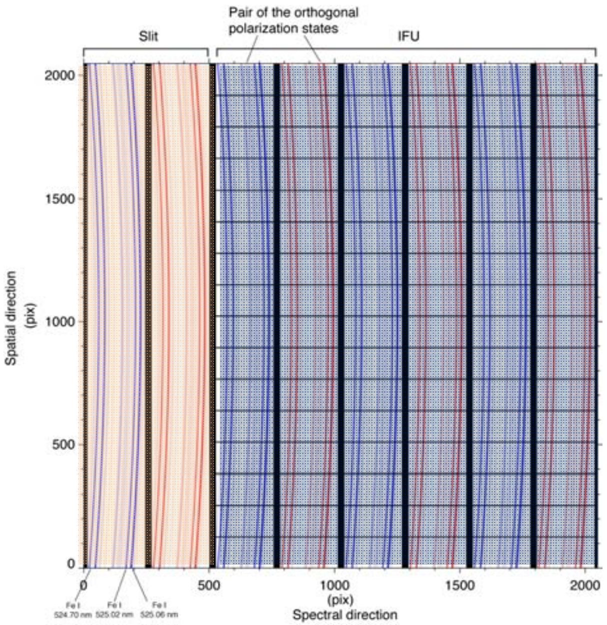


- Advantages
  - Simultaneous obs of the three spectrum lines.
  - No need of the filter wheel.
  - The tilt adjust mechanism of the grating can be simpler.
  - The PBS consisting of the calcite blocks can be optimized at each wavelength.
  - Optical design of the relay optics becomes easy because there is no chromatic aberration at each optical path.

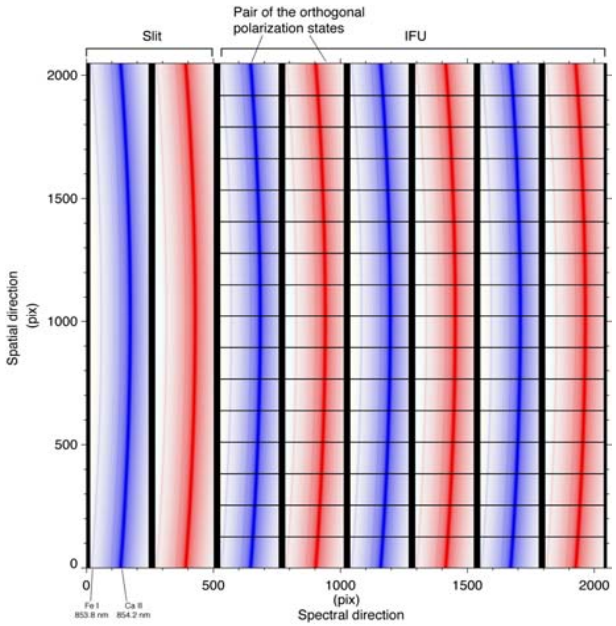
- Disadvantages
  - Three cameras are necessary (resources).
  - Three optical paths are necessary (fabrication and alignment, resources).

Spectral product

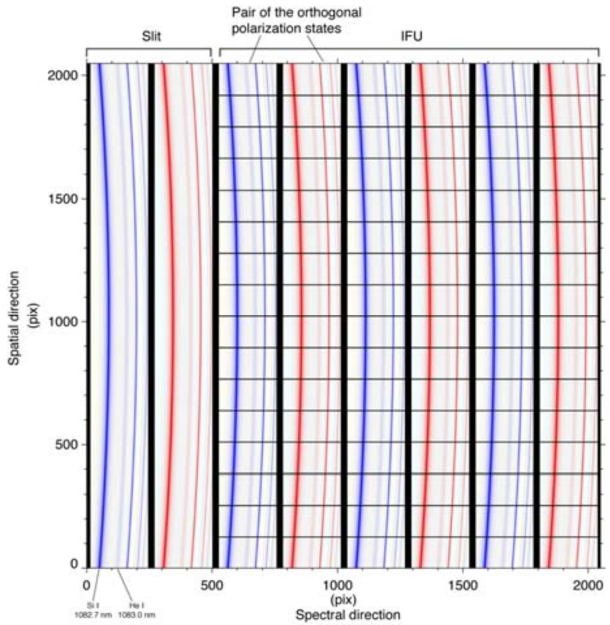
FeI 525nm



CaII 854nm



HeI 1083nm



Long slit IFU

4 sets of orthogonally polarized spectrum

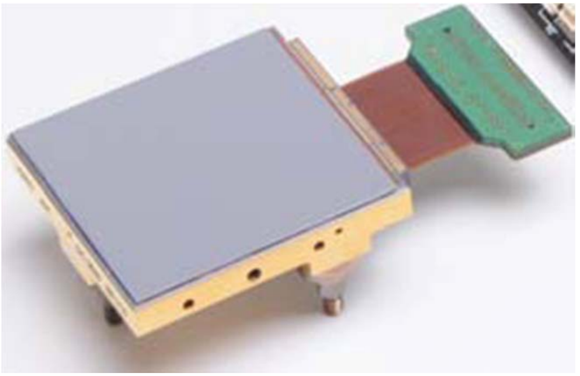
Data acquisition

To achieve S/N~ 10^4, we need to collect 10^8 photons

→ high IR sensitivity

→ fast readout, onboard accumulation (~1000 frames!)

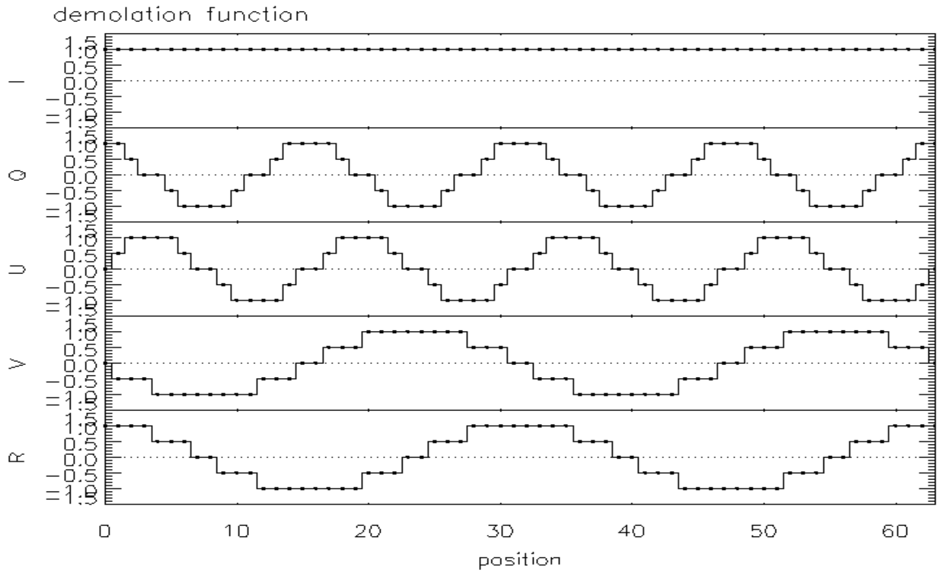
IR camera



Teledyne Co.
H2RG FPA, SIDECAR ASIC,
HgCdTe, 2k x 2k pixels, 18μm/pix

Space qualified
(TRL-6 for H2RG, TRL-9 for SIDECAR)

Onboard demodulation → IQUVR



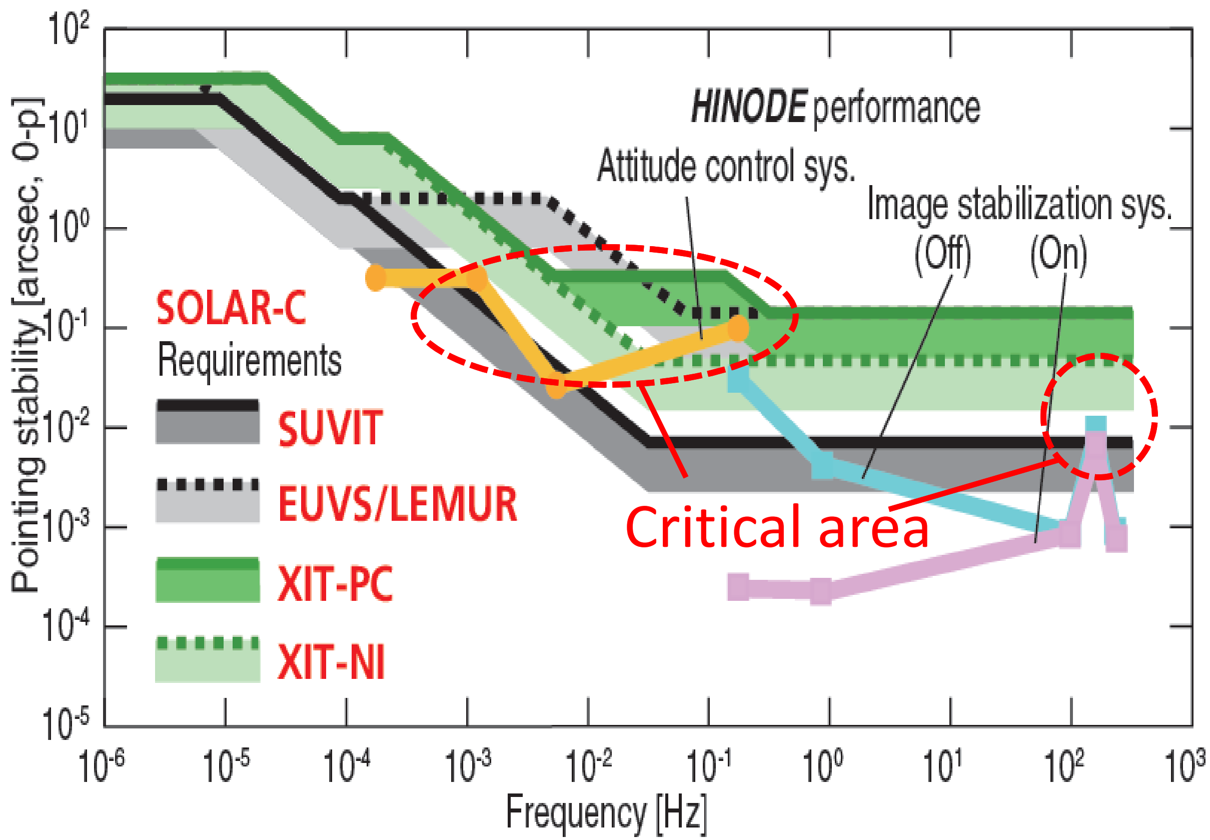
Readout 64 frames/sec, (WP 1 sec/rot)

Lesson from Hinode;

Pointing stability

SOT/Hindoe achieved ~0.02” rms.

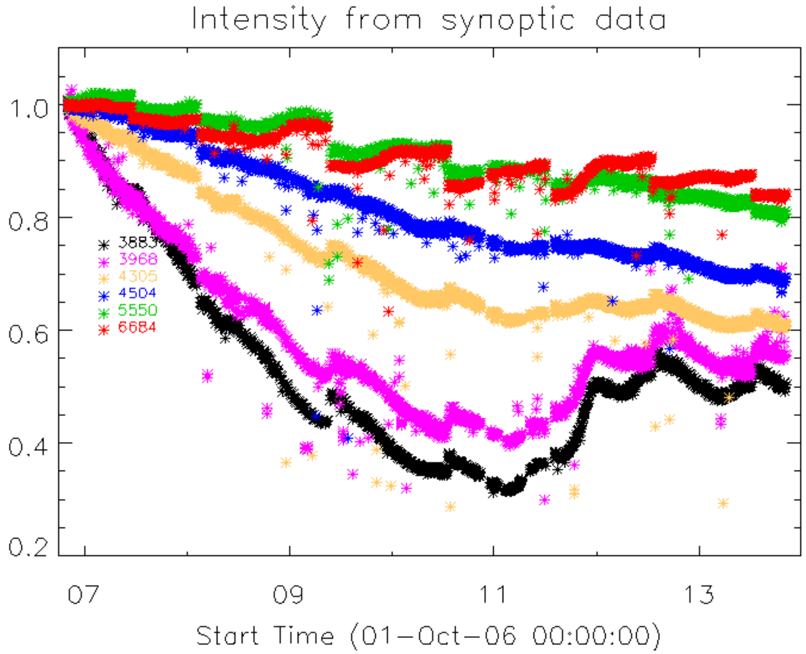
SUVIT requires 2 – 3 times higher pointing stability



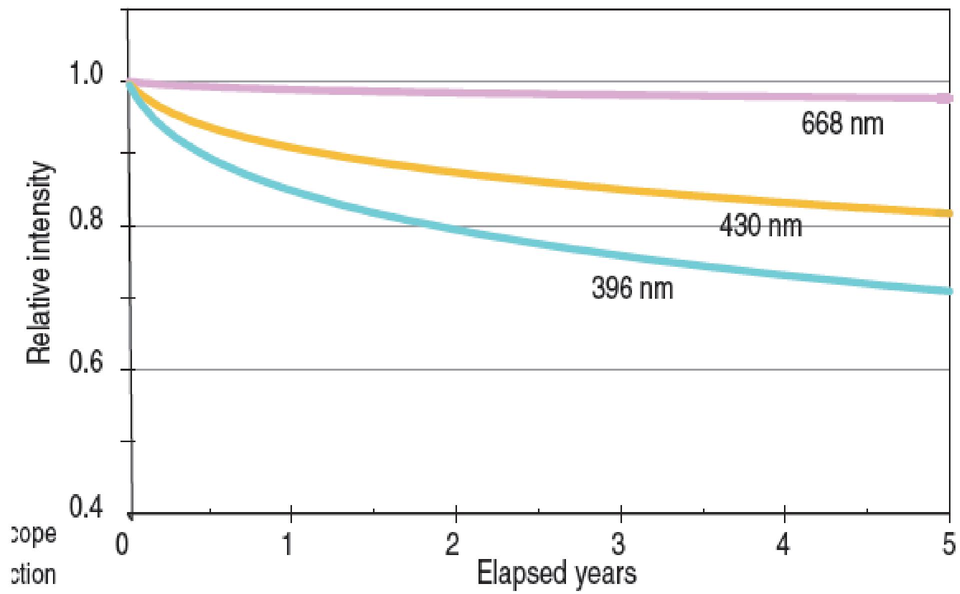
Lesson from Hinode;

Contamination control;

SOT throughput (real)



SOT contamination model



We do not understand exactly the cause of degradation of SOT throughtput.

→ Need further experiments for Solar-C!

Critical issues

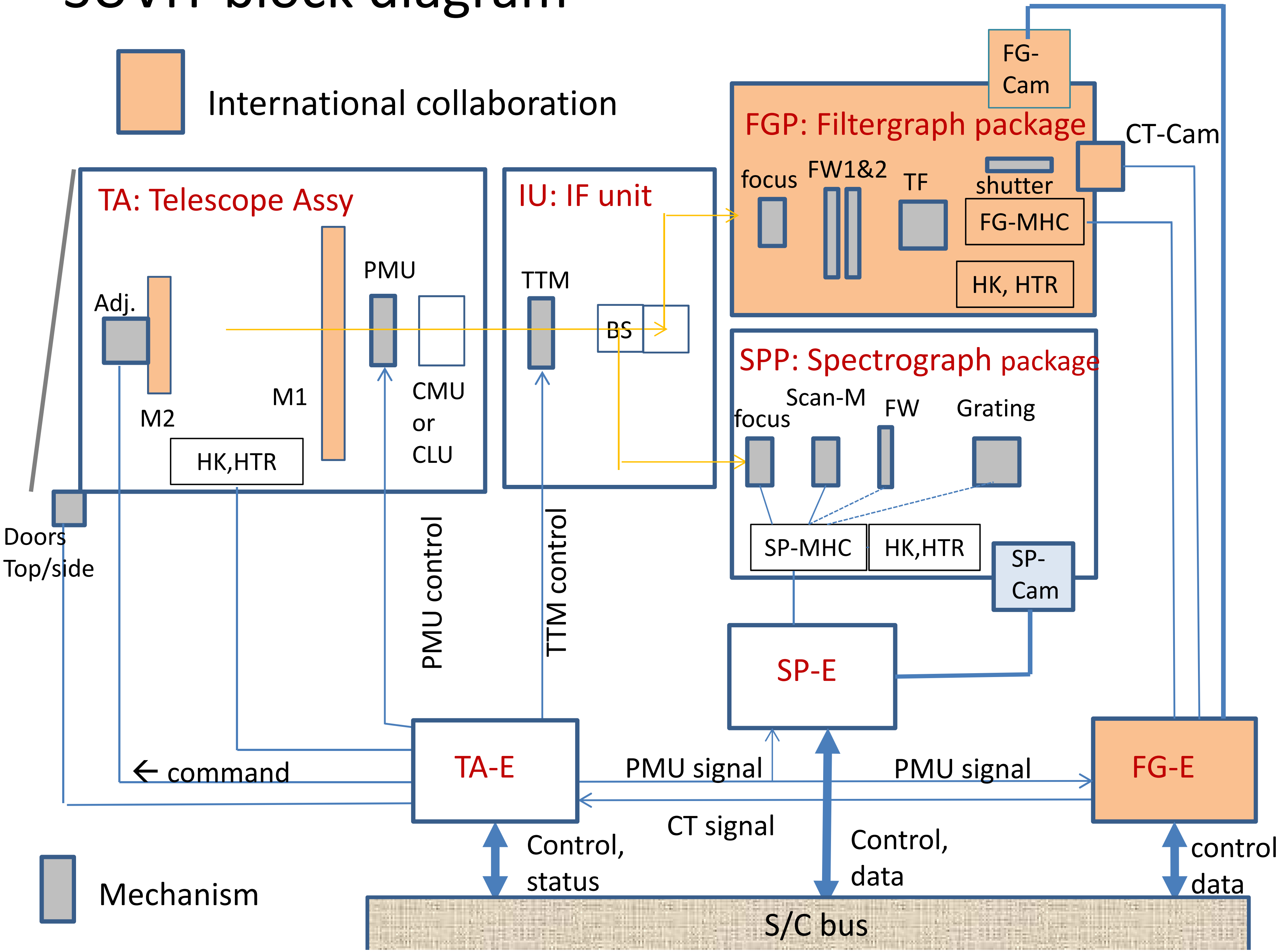
Technical;

- Realization of a diffraction limited large space telescope
- Pointing stability, 3 times tight compared with SOT/Hinode
- Optics to accommodate the MgII 280nm
- Contamination control (especially for UV)
- Weight & cost!
- :

Scientific;

- Reliable Stokes inversion for chromosphere to reveal
  - energy carried by waves to solve the heating problem.
  - good boundary condition for field extrapolation.
  - direct evidence of magnetic reconnection
  - origin of spicule, prominence, flare,,
- How the MgII 280nm contribute to the Solar-C science goal?
- What does SUVIT's spatial resolution really see?
- :

SUVIT block diagram



International collaboration

- JAXA/NAOJ/Univ's -- telescope, SP, integration
- NASA/ LMSAL/ HAO -- FG
- Hawaii-U -- IFU experiemnt
- ESA -- telescope mirrors (TBD)
- MSSL / MPS -- SP cameras, mechanism
- IAC / IAA -- Stokes inversion
- Oslo -- MHD modeling
-

Need extensive international collaboration and strong supports from you!

Thank you