UV/EUV Spectroscopy

Science requirements, strawman instrument design and its feasibility

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high throughput UV/EUV spectroscopy sub-WG

High throughput UV/EUV spectroscopy s-WG

Task:

- Establish science cases for the UV/EUV range in terms of the Plan B mission purpose and develop plans for a model payload for high-resolution, high-throughput, and high-cadence spectroscopy.
- Science cases and instrument for the plan A mission may be included in the scope of the working group.

Members:

- s-WG was organized with scientists and instrument experts from various institutes over the world.

Luca Teriaca, Udo Schuehle (MPS)
Louise Harra (MSSL)
George Doschek (co-chair for this sub WG) , Clarence Korendyke (NRL)
Joe Davila (NASA/GSFC)
Ted Tarbell (LMSAL)
Hiroaki Isobe (Kyoto University)
Shinsuke Imada (ISAS/JAXA)
Tetsuya Watanabe, Hirohisa Hara (NAOJ)
Toshifumi Shimizu (ISAS/JAXA, Chair for this sub WG)

Top-level Science Goals

1. Trace energy flow at natural dynamic solar time scales over a large dynamic range from the photosphere into the corona through small spatial-scale elementary solar structures and determine the resulting large-scale structures
2. Understand physical processes such as magnetic dissipation and reconnection in astrophysical plasmas, under a wide variety of physical conditions
3. Understand and spatially resolve elementary atmospheric structures over each temperature domain of the atmosphere and determine how they are created and evolve
4. Understand how small-scale physical processes initiate large scale dynamic phenomena that affect the environment around the Earth (space weather)
5. Understand how physical processes alter coronal properties such as variations in its composition
6. How are energetic particles accelerated during magnetic reconnection?

Top-level Science Goals

1. **Trace energy flow at natural dynamic solar time scales over a large dynamic range from the photosphere into the corona through small spatial-scale elementary solar structures and determine the resulting large-scale structures [Harra]**

2. **Understand physical processes such as magnetic dissipation and reconnection in astrophysical plasmas, under a wide variety of physical conditions [Imada]**

3. **Understand and spatially resolve elementary atmospheric structures over each temperature domain of the atmosphere and determine how they are created and evolve [Doschek]**

4. **Understand how small-scale physical processes initiate large scale dynamic phenomena that affect the environment around the Earth (space weather) [Teriaca]**

5. **Understand how physical processes alter coronal properties such as variations in its composition [Doschek]**

6. **How are energetic particles accelerated during magnetic reconnection? [Watanabe]**

Plan B
High throughput UV/EUV spectrometer

- Science requirements for the spectrometer

1. ***High temporal resolution (cadence)***
   - For quantitatively understanding the physics of dynamical phenomena.
   - High throughput, one order of magnitude or more higher than the existing spectrometers (EIS and SUMER).

2. ***With spectral lines from a broad temperature range, covering all relevant temperatures***
   - The chromosphere, the transition region, low corona and flare temperatures, in order to track the flow of energy from the chromosphere into the corona.
   - With adequate plasma diagnostics

Plan B
High throughput UV/EUV spectrometer

- Science requirements for the spectrometer

3. ***High spatial resolution***
   - To resolve structures with 0.5” or better (hopefully 0.2-0.3”)
   - Roughly equivalent to the chromospheric spicules observed with SOT
4. ***A field of view as large as possible***
   - The best resolution may be restricted to ~5x5 arcmin (a medium size AR)
   - Lower resolution should cover a larger FOV, in order to link dynamics to space weather topics

Plan B
High throughput UV/EUV spectrometer

- Science requirements for the spectrometer

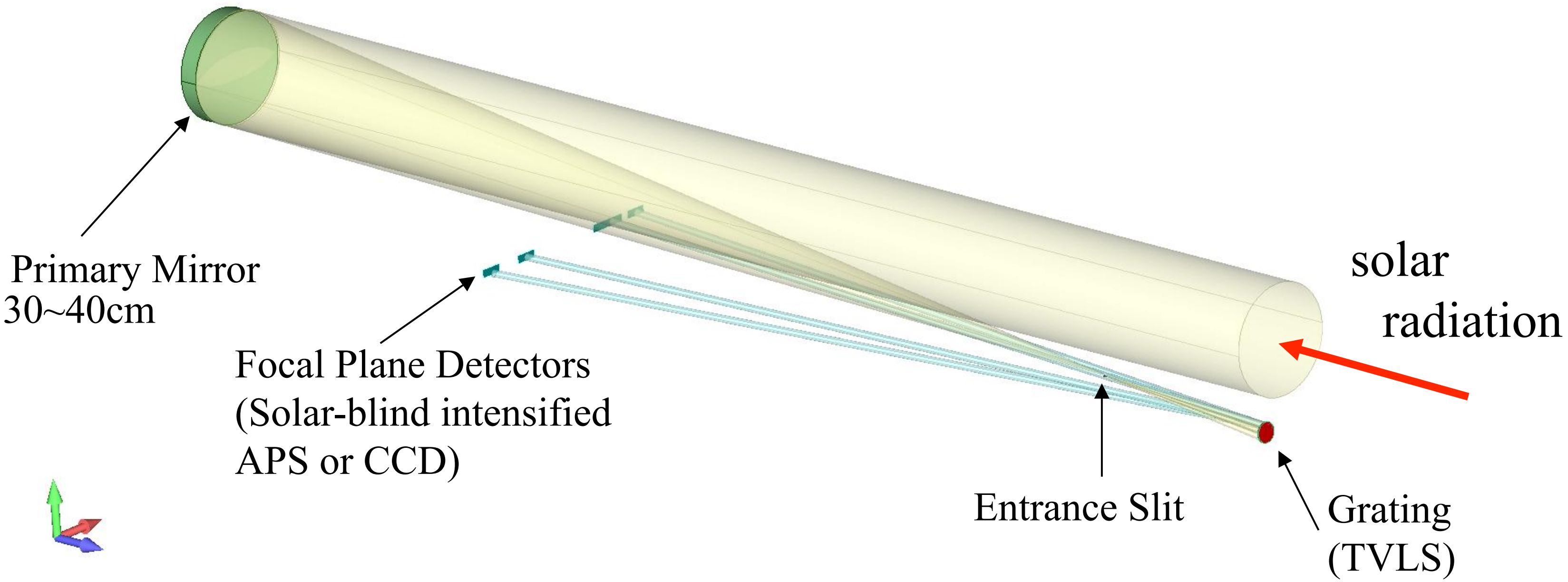
5. ***Observations with low-scattering optics***
   - ◆ Diagnostics of Low EM areas.
   - ◆ Faint reconnection outflow region, coronal holes, off-limb observations (solar wind acceleration, shock formation)

6. ***Precise co-alignment***
   - ◆ Spatial alignment of the spectrometer data with the data from other onboard telescopes.

High throughput UV/EUV spectrometer

To archive higher throughput

Schematic view of strawman spectrometer



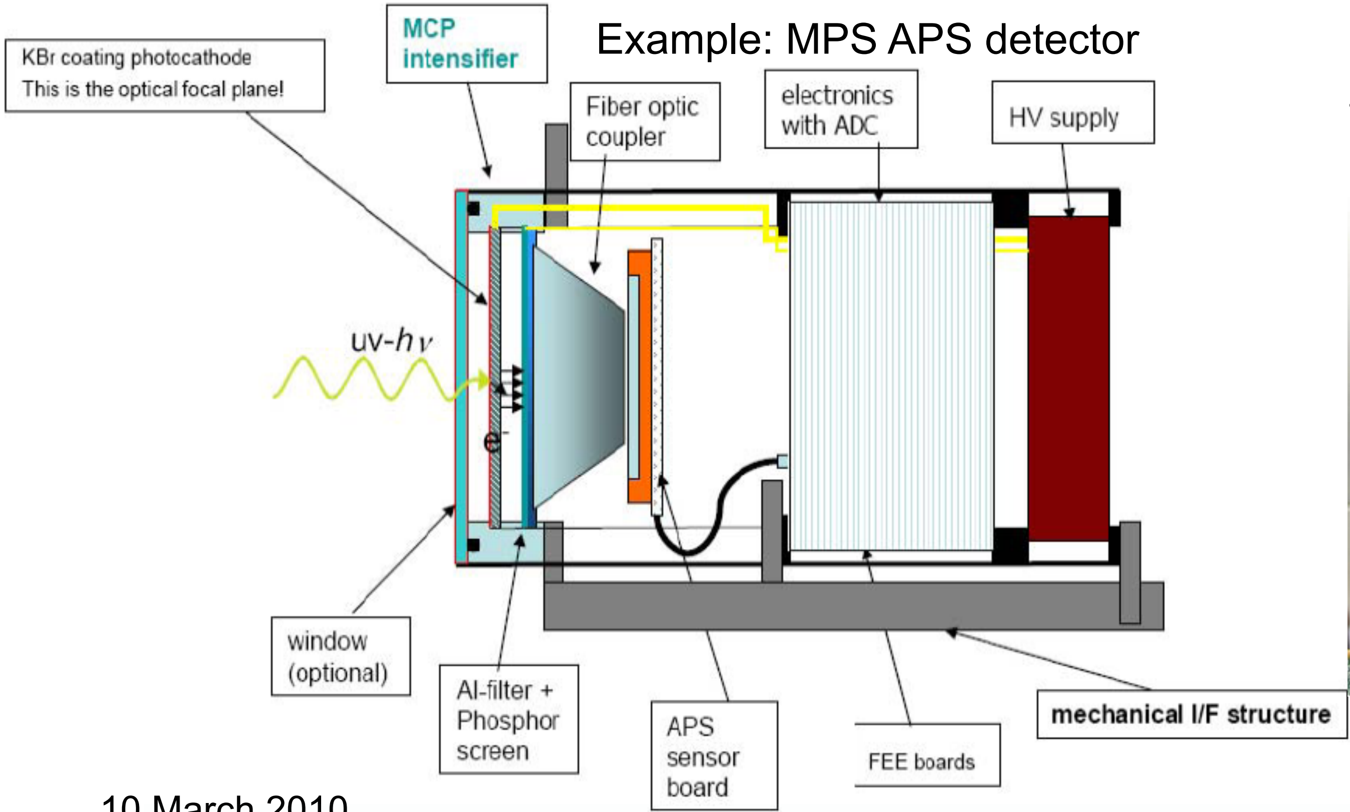
- Two element optical layout: off-axis primary and grating minimizing the number of optical elements, same as EIS.
- The diameter of the primary mirror is 30-40cm, which gives a 4 times or larger area, compared with EIS.

High throughput UV/EUV spectrometer

Some key technologies available

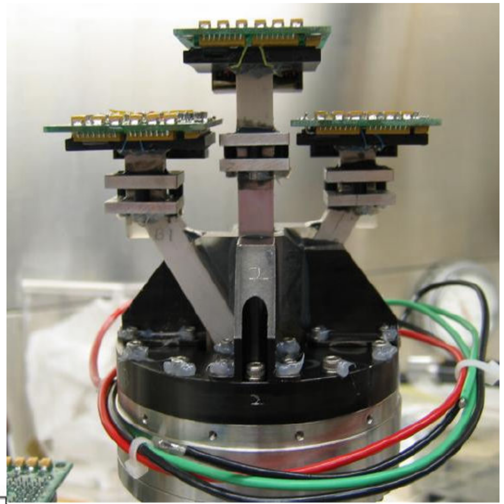
- The strawman design removes the metal prefilters, to achieve higher throughput, low scatter and broad wavelength coverage.
- The opaque photocathode ensures that the detector is solar blind.
- Intensified CCD or APS (CMOS active pixel sensor)

Example: MPS APS detector



A photocathode separated by a small gap on the input side of a micro-channel plate (MCP) electron multiplier and a phosphorescent output screen on the reverse side of the MCP.

Sensor section of EUNIS rocket with intensified APS

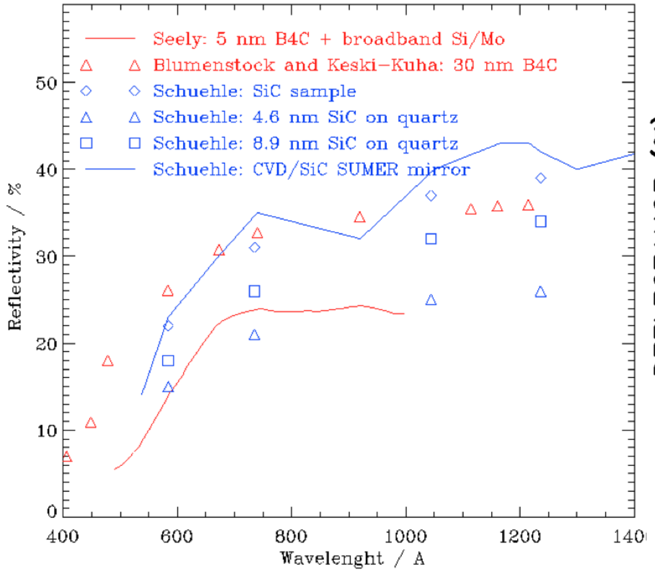


High throughput UV/EUV spectrometer

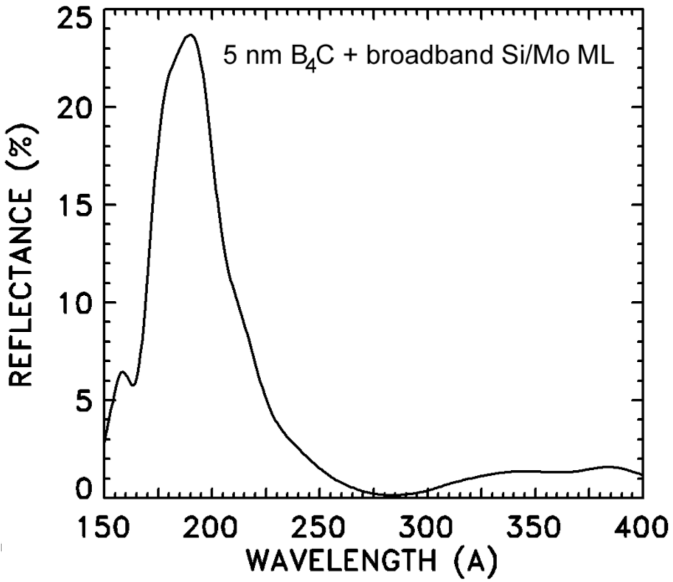
Some key technologies available

- A single coating on the mirror available for covering a broad EUV-UV range.

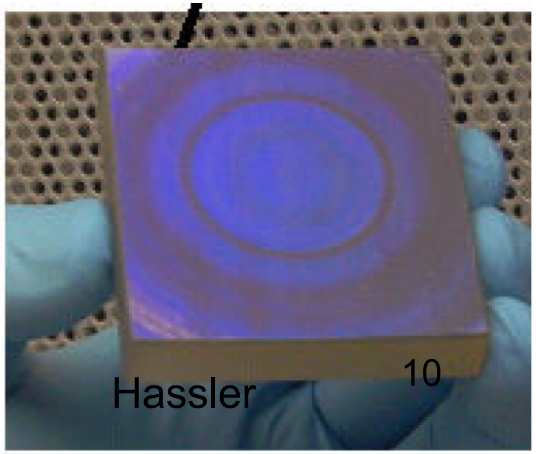
Reflectivity: 500-1200A



150-400A



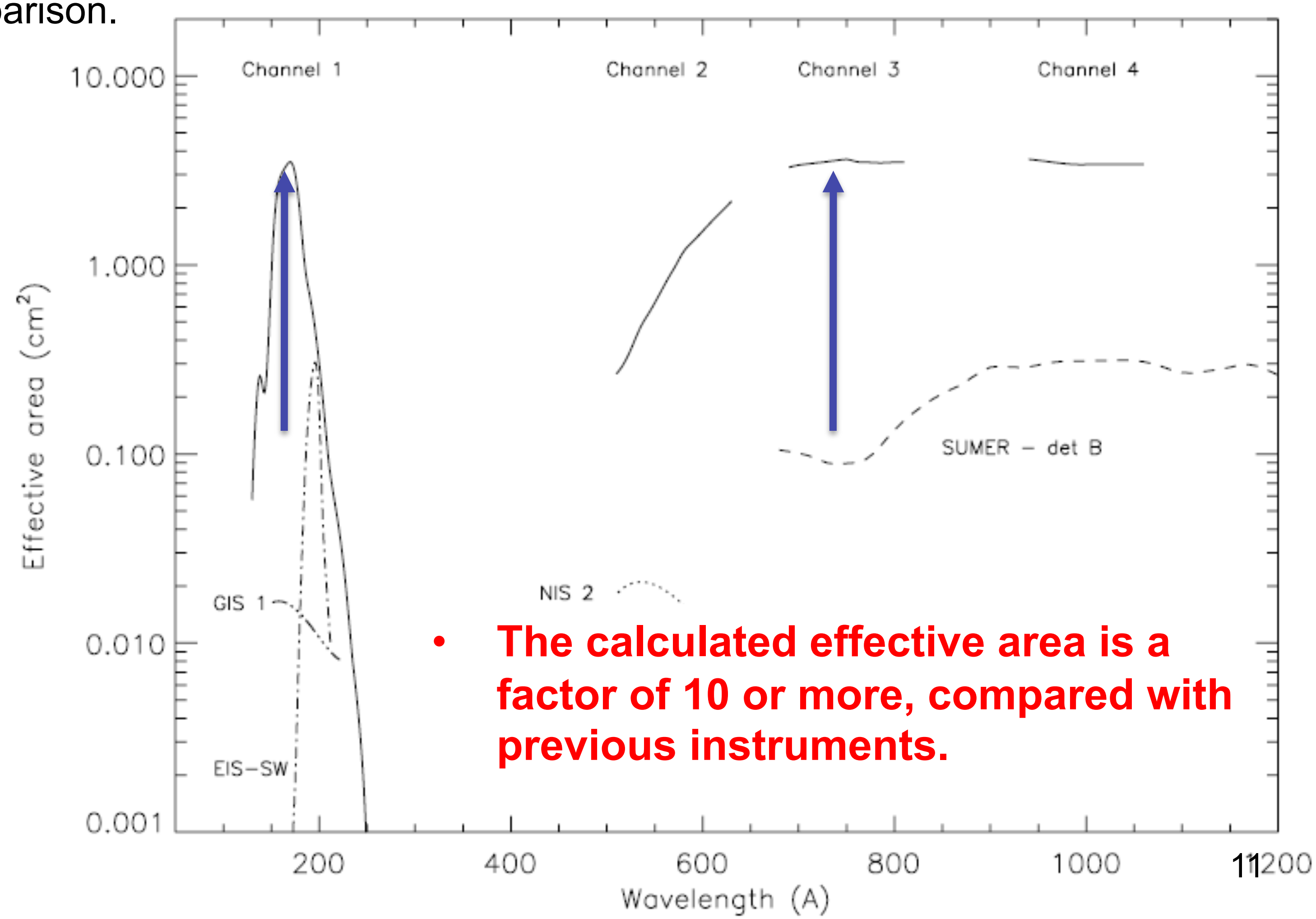
- TVLS (Toroidal Varied Line-Space) grating with optical magnification, providing the optical layout for realizing sub-arcsec resolution.
- The grating divided into segments for 2-4 bandpasses.



High throughput UV/EUV spectrograph

Performance much improved from previous instruments

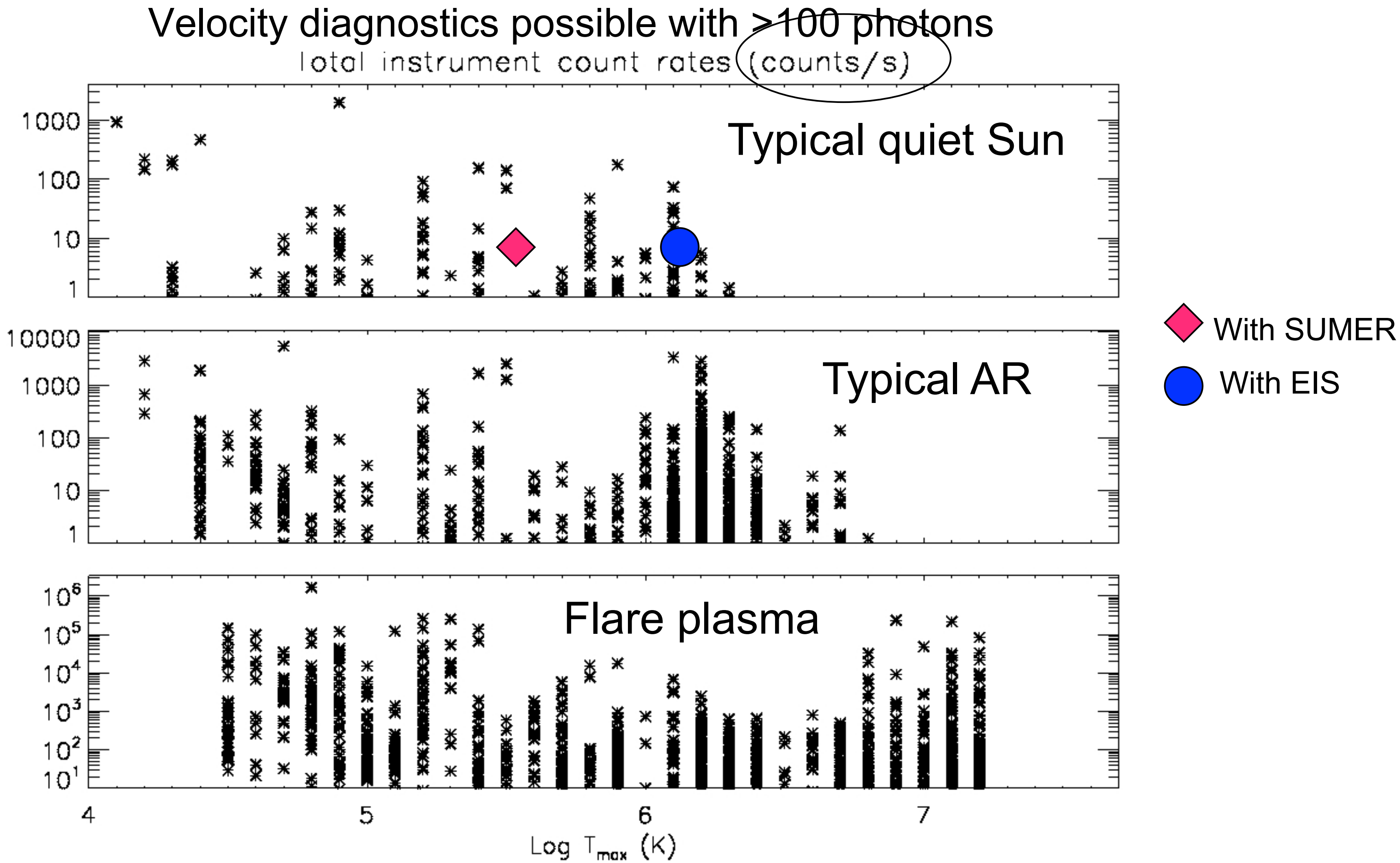
Effective area of the strawman instrument (solid lines).
Previous comparable effective areas for EIS, CDS and SUMER are plotted for comparison.



- **The calculated effective area is a factor of 10 or more, compared with previous instruments.**

Expected count rates of spectral lines

as a function of ionization temperature for a spatial sampling of 0.33”



- Temporal resolution can be more improved with observing **bright lines**, which are available in wide temperature range in 10^4-10^7 K.

Plan B: ***High throughput UV/EUV spectrometer***
Strawman design: scientific characteristics

Plate scale	~0.16"/pixel (sampling comparable to Hinode SOT)
Simultaneous Field of view	Slit: 0.16", 0.32", 0.96"; Slot: 10", 40", 200" Slit/slot length: 200" nominal, >300" extended
Maximum raster width	+/- 75" nominal, +/- 200" extended
Wavelength range	four channels (Å):130-250; 510-630; 690-810; 940-1060;
Exposure times	1-5s active regions with 0.33" spatial sampling 0.1-0.5s active regions with 1.0" spatial sampling
Velocity resolution (with adequate counts)	Doppler (centroid) shift measurement accuracy <3km/s Turbulent velocity (width) <10km/s
Temperature coverage	$10^4 – 10^7$ in active regions with $\Delta(\log T) < 0.3$

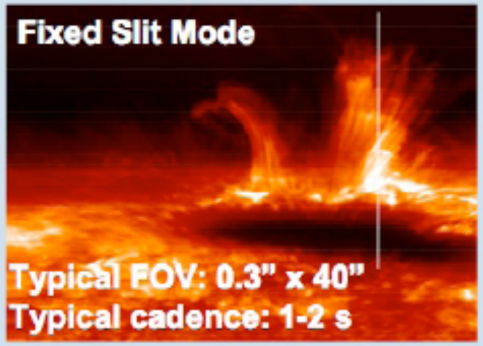
Plan B: ***High throughput UV/EUV spectrometer***
Strawman design: scientific characteristics

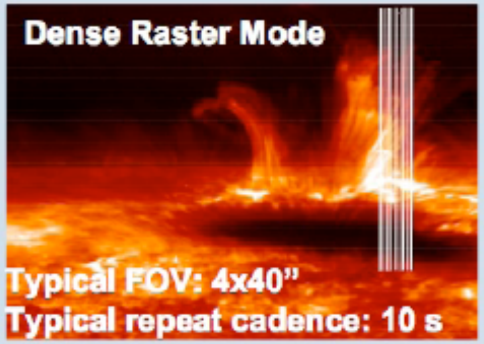
- **> 10 improvement in effective area**
  - This means > 10 improvements on temporal resolution if observed with the same sampling scale (~1”).
  - This means
- **> 18 improvement in spatially resolved area on the solar disk**
  - Roughly equivalent to the chromospheric spicules observed with SOT.
- **Spectral lines provides complete temperature coverage in 10^4-10^7 K**, although the bands need to be further optimized.

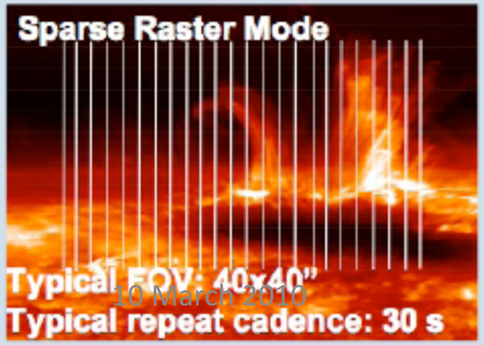
Substantial jumps from IRIS?

- IRIS (Interface Region Imaging Spectrograph) is approved for launch in 2012.
  - Spectral lines in 120-280nm with 0.3” and 1-5s cadence to discover how an outer stellar atmosphere is energized.
  - The spectral lines observed with IRIS are suitable to explore the interface between upper chromosphere and lower transition region.
- Still substantial jumps from IRIS, because the S-C plan-B can provide unique observations which have never been realized:
  - Quantitative measurements of magnetic fields in the chromosphere
  - EUV/UV spectral lines used in Solar-C spectrometer will seamlessly cover from chromospheric temperature through the coronal temperature with 0.1-0.5” and 1-5 s cadence.
  - Energy spectral (thermal and non-thermal) diagnostics in 10^6-10^7 K plasma for flares and active region dynamics.

IRIS spectra and slit-jaw imaging covers the photosphere, chromosphere, transition region and corona - 4,500 to 10,000,000 K







Ion Spectrum	λ Å	Δλ mÅ	Log T K	Estimated Count Rate (counts/s/line/spatial pixel) Quiet Sun	Active Region	Flare	Detector
UV Spectra (effective area of 2.8 cm^2 for far-UV, 0.3 cm^2 for Mg passband, continuum is 1 Å) †: Count rates for Mg II wing, h and k are in counts/s/spectral pixel/spatial pixel							
Si I (3P) Cont	1335	12.5	3.7	40	80	---	1
Mg II wing	2820	25	3.7-3.9	2100†	7500†	7500†	3
O I	1356	12.5	3.8	50	100	250	1
Mg II h	2803	25	4.0	870†	3400†	13000†	3
Mg II k	2796	25	4.0	1100†	4500†	10000†	3
C II	1335	12.5	4.3	540	1970	22000	1
C II	1336	12.5	4.3	500	1780	20000	1
Si IV	1403	12.5	4.8	400	1000	1e6	2
Si IV	1394	12.5	4.8	640	2200	3e6	2
O IV	1401	12.5	5.2	65	116	2e5	2
O IV	1400	12.5	5.2	25	60	1e5	2
Fe XII	1349	12.5	6.2	30	50	500	1
Fe XXI	1354	12.5	7.0	10	40	4e4	1
UV Slit-Jaw Images				**Estimated Count Rate (counts/s/pixel)**			
Effective area 0.005 cm^2 with 5 Å FWHM filter for Mg II; 0.7 cm^2 with 40 Å FWHM for far-UV.							
Mg II wing	2816		3.7-3.9	1500	3500	3500	4
Mg II k	2796		4.0	750	3500	8500	4
C II	1335		4.3	400	1300	13000	4
Si IV	1400		4.8	300	1200	2e5	4

High Throughput UV/EUV Spectrometer

- The common desire that all the s-WG members have is to realize a large-scale EUV/UV spectrograph with high throughput performance as soon as possible, which requires plan B.
- A desired spectrometer can be designed with key technologies available, as demonstrated as the strawman design.
- Substantial improvements from IRIS is possible, although needs clearer explanations.