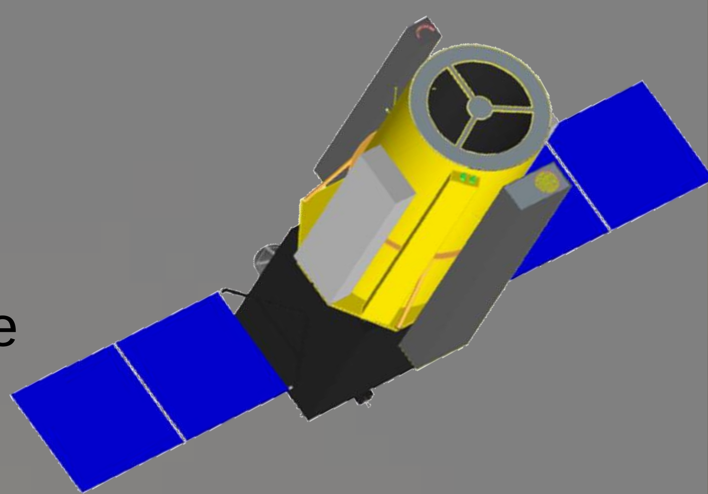
LEMUR/EUVST: the spectrograph for the Solar C mission



L. Teriaca(1), G.A. Doschek(2), L.K. Harra(3), C. Korendyke(2), U. Schühle(1), T. Shimizu(4) and the LEMUR/EUVST team.

(1) MPS, Katlenburg-Lindau, Germany; (2) NRL, Washington DC, USA, (3) UCL-MSSL, Holmbury St. Mary, UK, (4) ISAS-JAXA, Tokyo, Japan

Abstract: Understanding the complex and extremely dynamic environment of the solar outer atmosphere requires concerted, simultaneous solar observations from the visible to the vacuum ultraviolet (VUV) and soft X-rays, at high spatial resolution (between 0.1" and 0.3"), at high temporal resolution (on the order of 10 s, i.e., the time scale of chromospheric dynamics), with a wide temperature coverage (from 5000 K to several million K in order to cover the widely disparate regimes from the solar surface through the chromosphere and transition region to the corona during events such as flares), and the capability of measuring magnetic fields through spectropolarimetry. Simultaneous spectroscopic measurements, providing information on the thermodynamic state of the plasma over the entire temperature range, are crucially important. LEMUR/EUVST is a large VUV telescope feeding a scientific payload of high-resolution imaging spectrographs and cameras. It consists of two major components: a VUV solar telescope with a 30-cm diameter mirror and a focal length of 3.6 m, and a focal-plane package composed of VUV spectrometers covering six carefully chosen wavelength ranges between 17 nm and 127 nm. The slit length is 280", sampling with 0.14" per pixel on the Sun. LEMUR/EUVST will obtain spectra at 200 km resolution over lines formed at practically all temperatures between 10000 K and 20 MK with high spectral and temporal resolution. Thus, it has the capability of increasing enormously our understanding of coronal structures and of the physical mechanism(s) that maintain them.

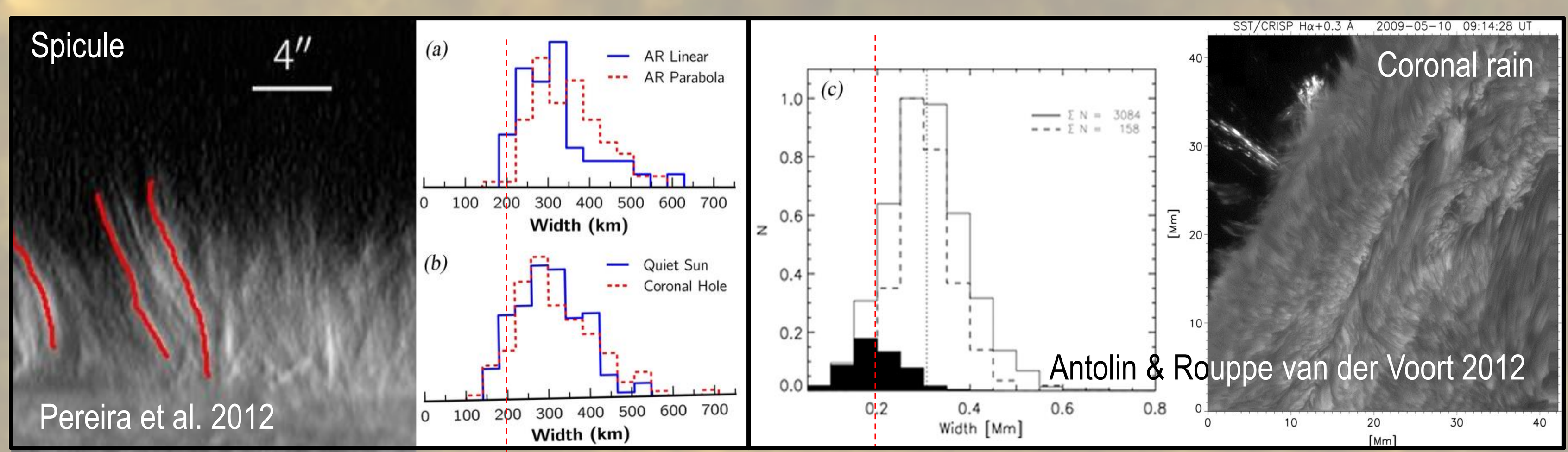
Introduction:

By providing the crucial link between the photospheric and chromospheric magnetic field and plasma characteristics obtained by the visible telescope and the high temporal and spatial resolution images of the corona provided by the X-ray/EUV telescope, LEMUR/EUVST is key in understanding "*How the magnetic field drives the flow of mass and energy from the thermally dominated lower atmosphere into the magnetically dominated corona and wind acceleration region?*". In fact, it will obtain the necessary spectroscopic observations to measure the flow and dissipation of energy from the top layers of the chromosphere into the transition region and corona, and to observe multi-million-degree flare plasmas.

From science goals to instrument requirements:

Energy and mass transport in the solar atmosphere:

- Impulsive heating in the corona (reconnection or wave dissipation) evaporating chromospheric plasma into the corona?
- Type-II chromospheric spicules heating up to coronal temperatures as they rise and supply mass to the corona?
  - Heating at loop footpoints should produce thermal instabilities that produce cool downflowing plasma due to condensation. Recent observations show cool plasma blobs with widths ≥ 150 km falling along magnetic field lines over large part of active regions.



Spatial sampling: at least 200 km (0.28").

Spectral range: include lines from the upper chromosphere to 2-3 MK.

Temporal resolution: 14"×180" (0.28 " steps) in 25 s on active areas.

Thermal structure of loops:

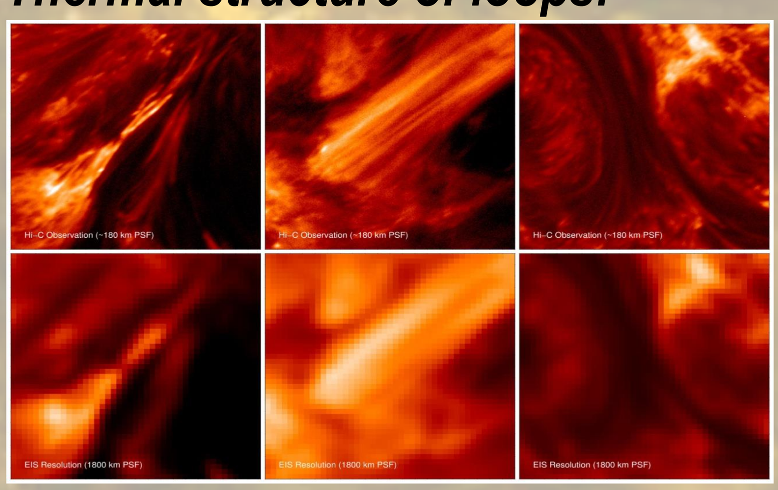


Figure 2: 46"×46" subfields of an Hi-C image both at native resolution (top) and convolved to EIS resolution (bottom). A PSF value of 0.2" to 0.3" is quoted by the Hi-C team. Here a value of 0.25" (180 km) was used.

Spatial sampling: at least 200 km (0.28").

Spectral range: include lines from the upper chromosphere to 10 MK as well as density and temperature diagnostics..

Field	Required value
Spatial resolution (67% encircled energy)	≤ 0.28" (0.14"/pixel)
Typical exposure times	0.1 – 20 s
Temperature coverage	0.01 to 20 MK
Spectral resolution	λ/dλ 16,000 to 30,000
Field of view	Slit length: 280" Raster coverage: 300" (without re-pointing) Coarse pointing mechanism for accessing features at off limb positions
Mirror micro-roughness	About 5 Å rms (target) or better
Slit imaging camera	A chromospheric line/band for co-alignment with other instruments

Instrument:

A two-element optical design (as pioneered by EIS/Hinode) that minimizes the number of reflections in the system – an essential feature in VUV instrumentation.

- Uniformly coated, optically stabilized, mirror reflecting radiation from 17 to 127.5 nm.
- A concave diffraction grating split into two halves figured and coated to optimize the image quality and efficiency of both short (SW) and long (LW) wavelength channels.
- Intensified cameras provide high throughput, order selection and visible light blindness in the LW channel.

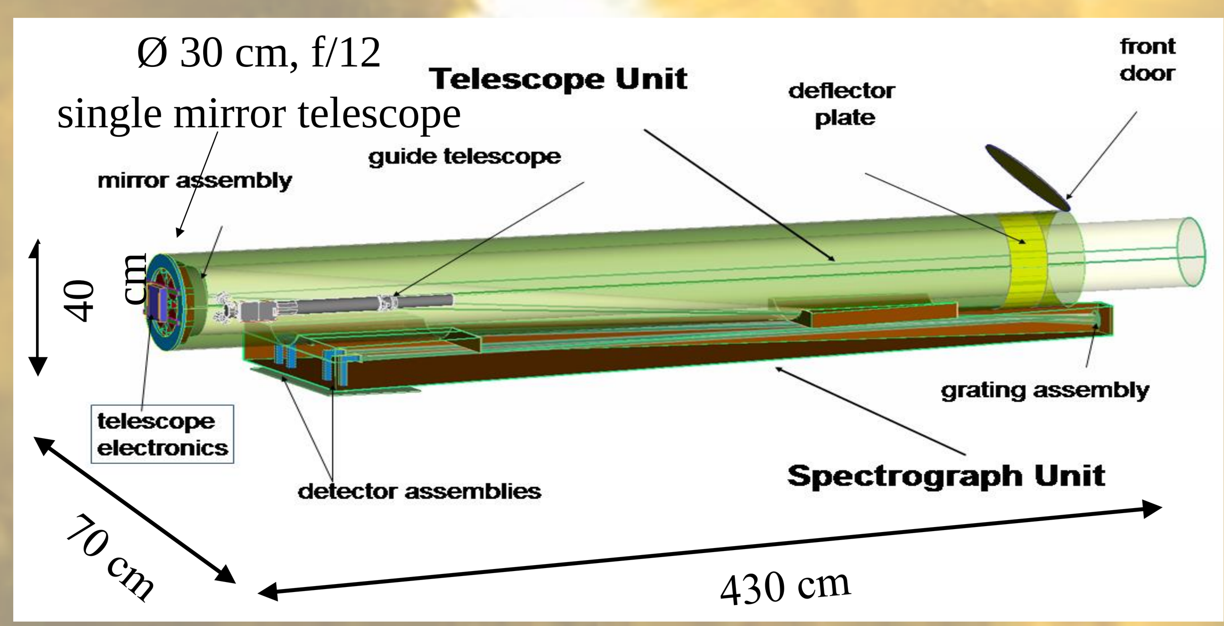


Figure 3: Instrument opto-mechanical layout.

	SW waveband	LW wavebands
Spectral ranges	170-215 Å	1st order: 690-850 Å, 925-1085 Å, 1115-1275 Å 2nd order: 463-542 Å, 557-637 Å
dispersion	11 mÅ /pixel	40 mÅ /pixel
Plate scale	0.14"/13.5 µm pixel	0.14"/20 µm pixel
Slit length	280" (2000 pixels)	280" (2000 pixels)

Performance:

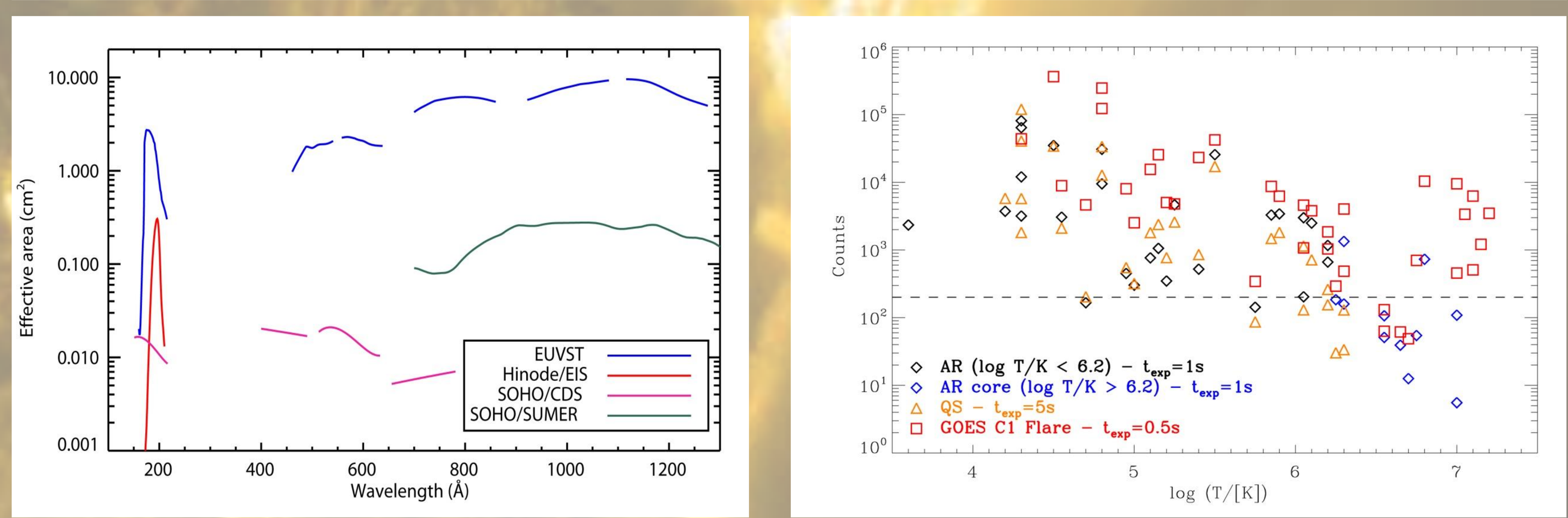


Figure 4: The effective area of LEMUR/EUVST compared with those of EIS, SUMER and CDS (right). Expected count rates (count/arcsec^2) in the indicated exposure times for different solar observational targets (5 s for the quiet Sun, 1 s for active regions, and 0.5 s for a small flare). The horizontal dashed line marks the 200 counts (in the spectral line) level necessary to determine line positions with a ≤ 2 km s^{-1} accuracy (left).

	Hinode/EIS	SOHO/SUMER	IRIS	Solar-C EUVST
Temporal resolution for a slit position(1)	10 – 60 s for AR 20 – 120 s for QS	≥15 – 60 s(2)	2-15 s for AR 15-60 s for QS	0.2(5) – 5 s for AR 0.2 – 20 s for QS
Spatial resolution (1"=725 km on the Sun)	2" – 3" 1" (pixel size)	1.5" 1" (pixel size)	0.33" 0.167" (pixel size)	0.28" 0.14" (pixel size)
Field of View (without repointing)	±290"×512"	±1920"×300"	120"×175"	±150"×280"
Primary temperature coverage ($\log_{10}$ T/[K])	4.9, 5.6 – 7.2	3.6 – 5.8, 6.8 – 7.0(3)	3.7 – 5.2, (6.2)(4), 7.0	4.1 – 7.2

(1)The values given here are typical exposure duration for multiple numbers of spectral lines covering a wide temperature range.
(2)Limited by telemetry.
(3)SUMER can record spectral lines in only one spectral window of ≈40 Å at a time.
(4)Rather faint line. Difficult to see on disk.
(5)Exposure time and time step of 0.2 s is for one line per camera (4 spectral lines).

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