

First Results from the EUNIS 2013 Sounding Rocket Campaign

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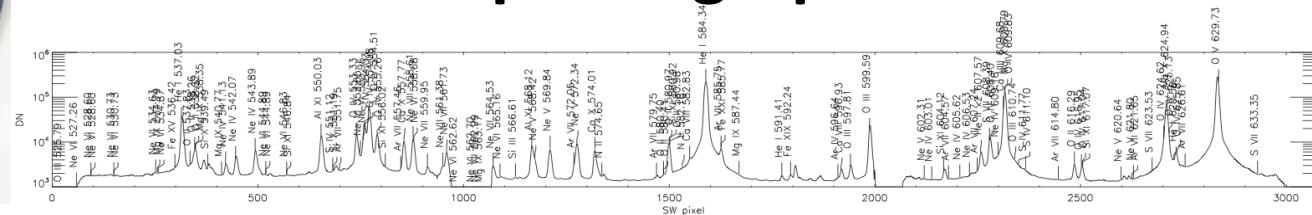
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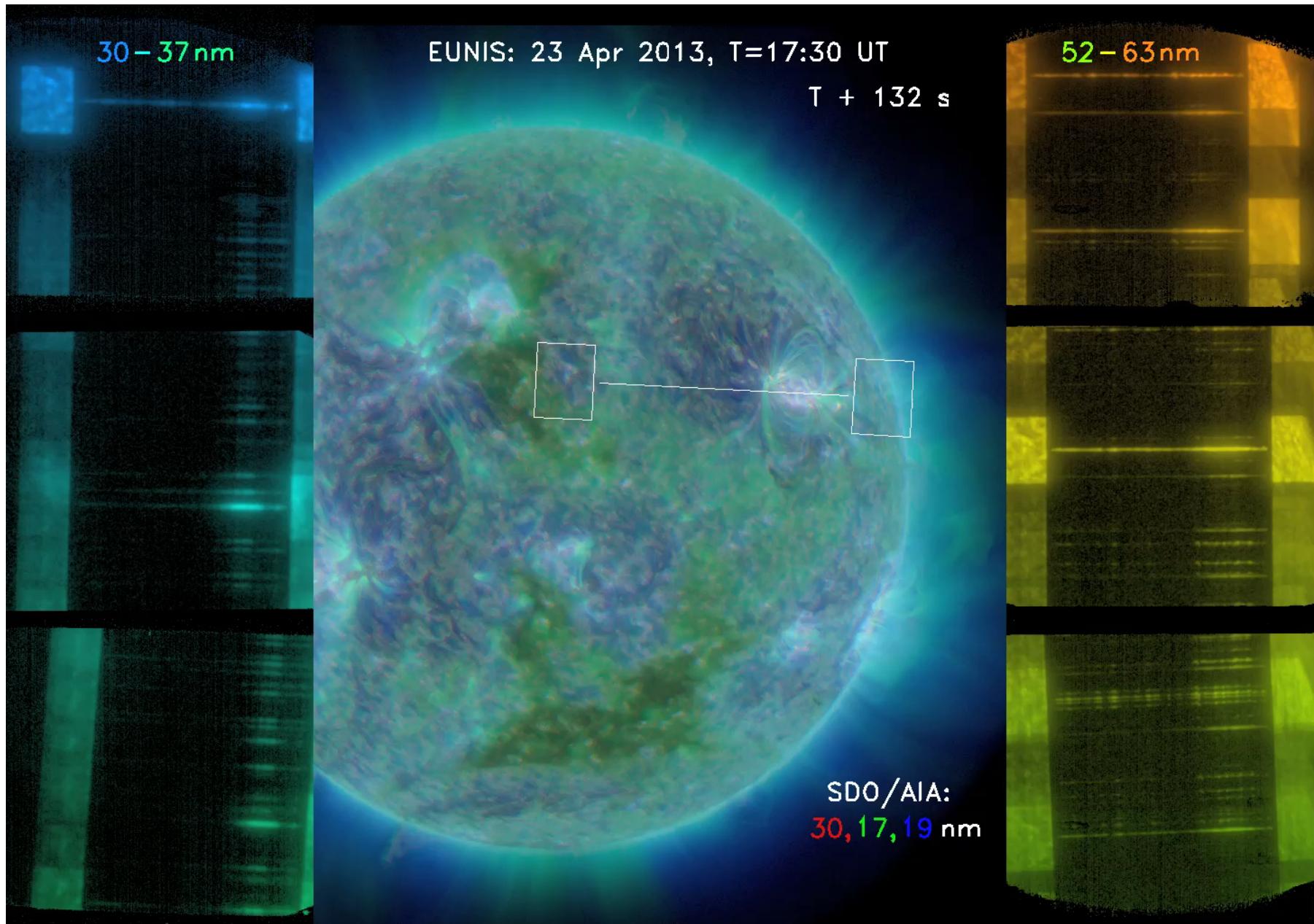
EUNIS-2013

Extreme Ultraviolet Normal Incidence Spectrograph

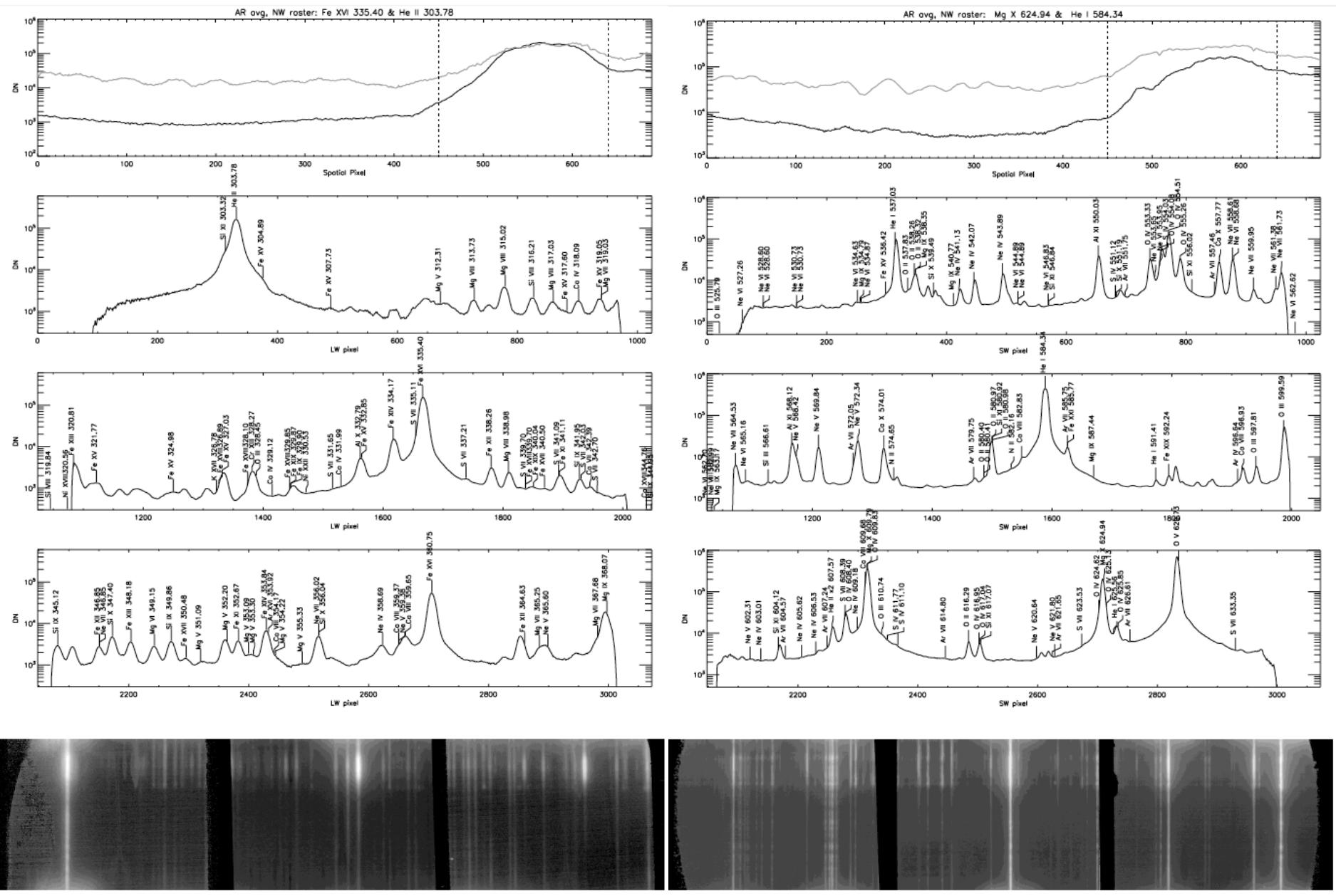


- Successful Mission, 23 April 2013, 17:30 UT from WSMR
 - Two-channel imaging spectrograph that observes the solar corona and transition region with high resolution and rapid 1.3 s cadence.
 - **Highest resolution observations of the 52-63 nm spectral region of the Sun to date** - new channel incorporating toroidal varied line space (TVLS) grating yields $\lambda/\Delta\lambda=3000$ with high throughput
 - **First flight demonstration of cooled CMOS active pixel sensors**
 - **Radiometric calibration** using NIST-calibrated AXUV photodiode
 - Provides ‘under-flight’ calibration for orbital instruments:
 - SDO/AIA**, by using 30-37 nm channel
 - SoHO/CDS**, by using 52-63 nm channel
 - Hinode/EIS**, using DEM from EUNIS wide temperature range

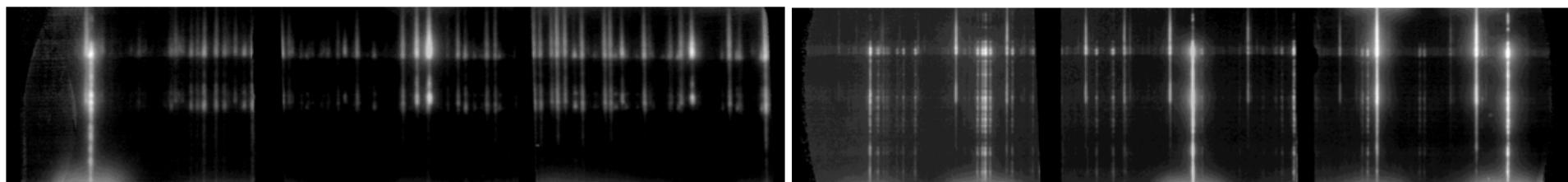
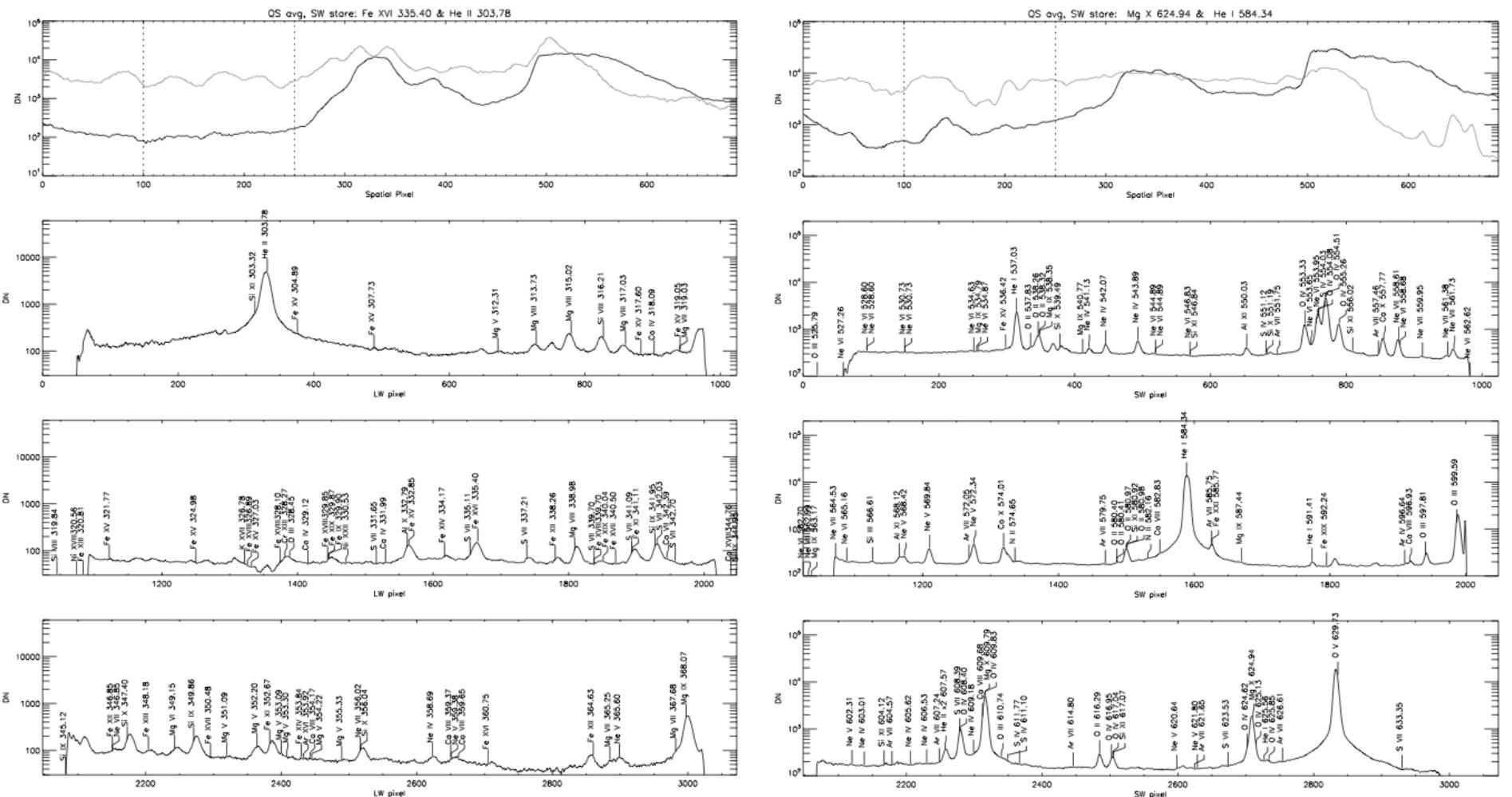
Flight Data / Observation Sequence



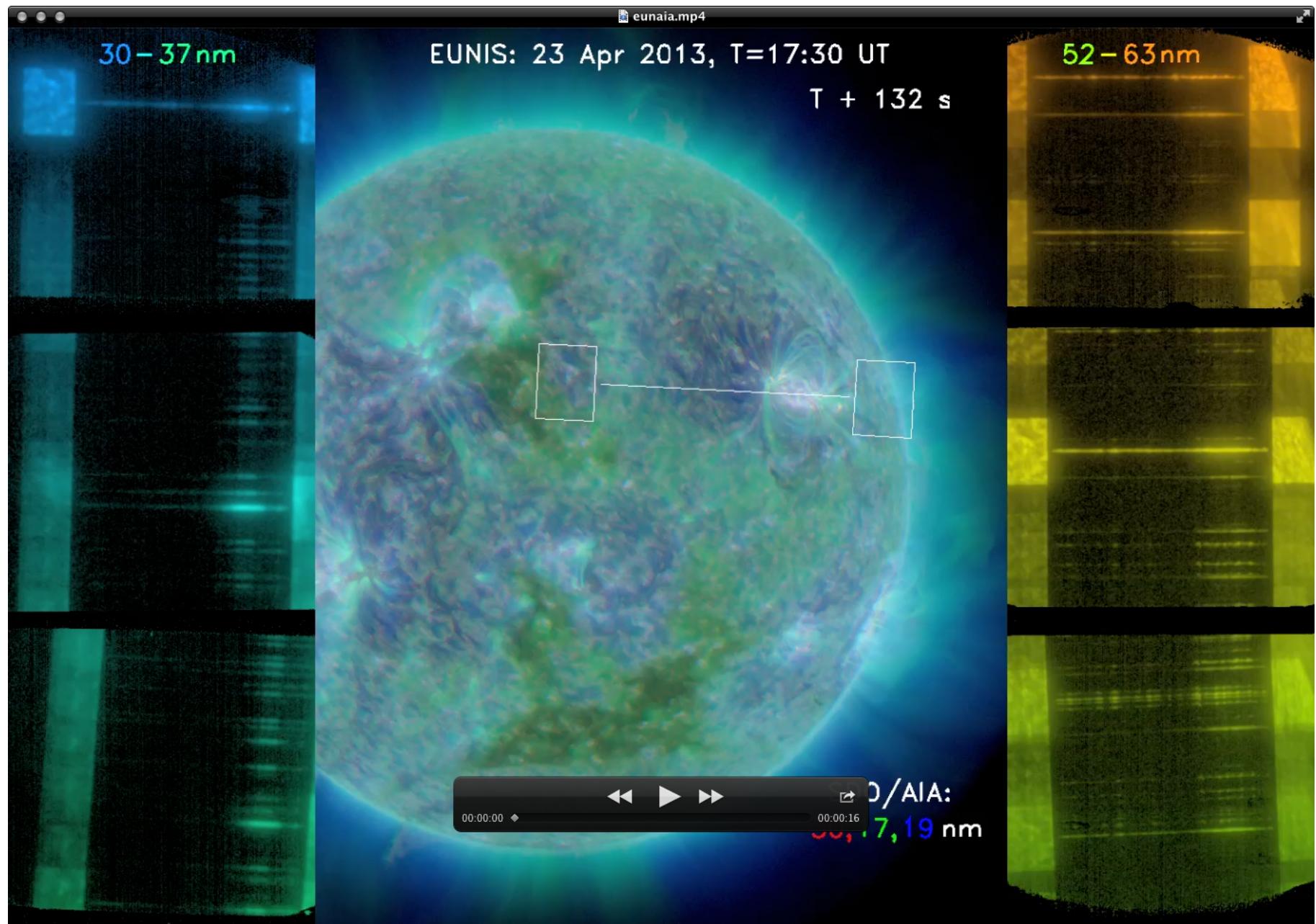
Example Spectrum - NW Active Region



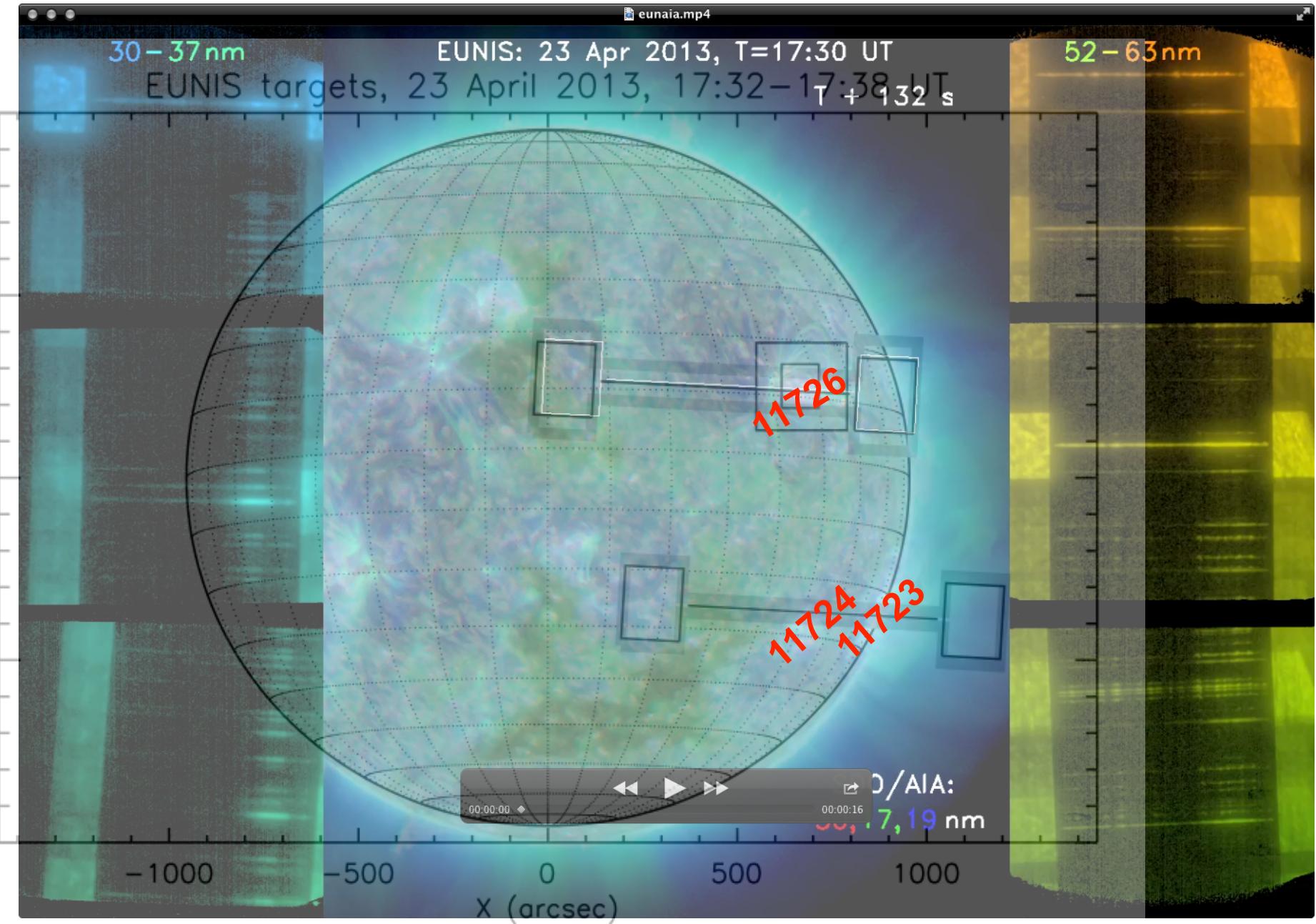
Example Spectrum - SW Quiet Sun



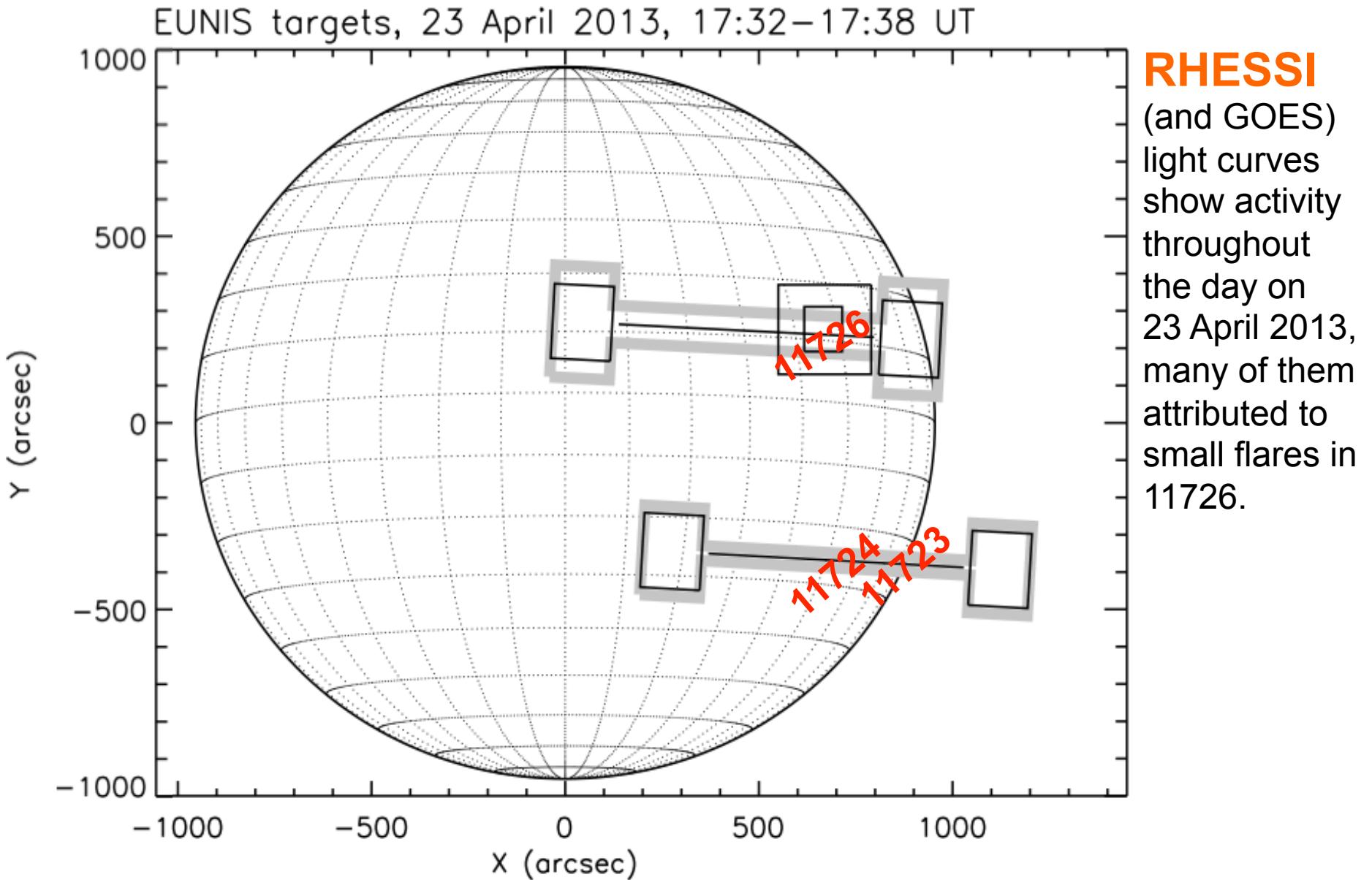
Why call it a ‘Campaign’?



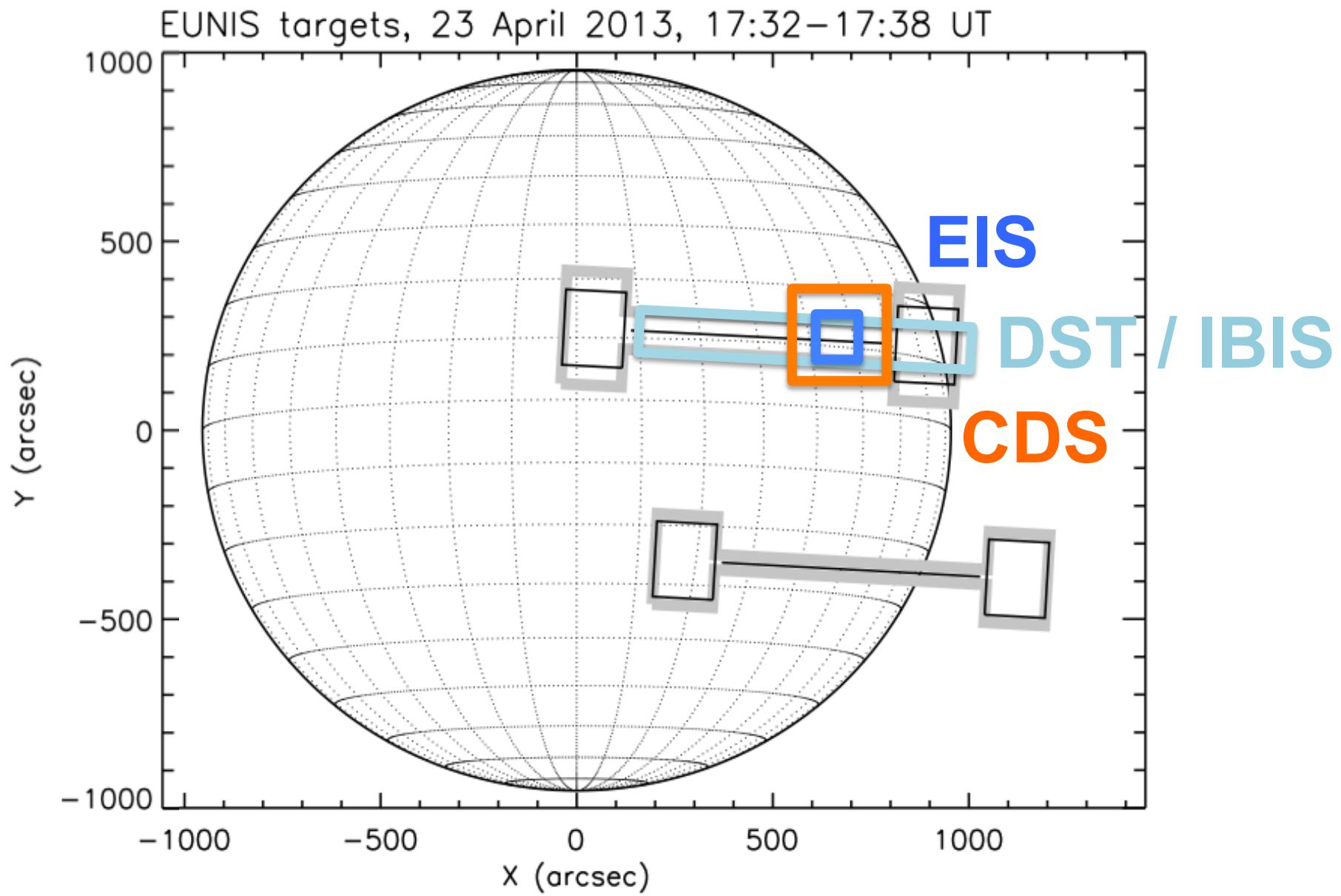
... because three active regions were observed?



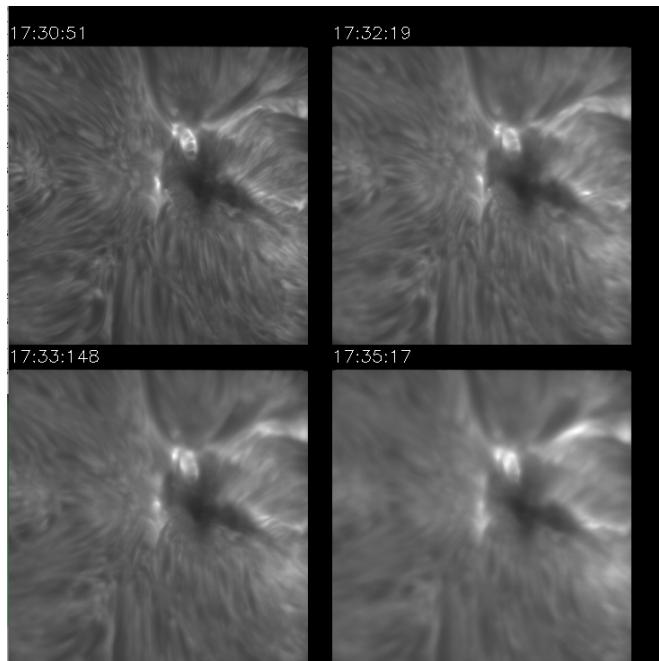
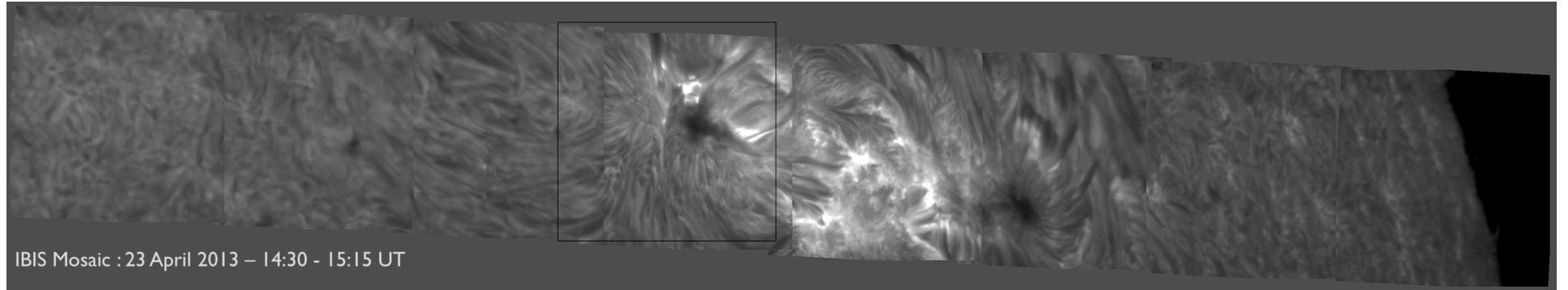
Co-Observations ... in addition to SDO/AIA & EVE



Co-Observations



Interferometric Bidimensional Spectropolarimeter (IBIS)



Line scans of:

- **H-alpha** 6563 Å (see pictures for core)
- **Ca II** 8542 Å
- **He I D3** 5876 Å
- **Na I D1** 5896 Å

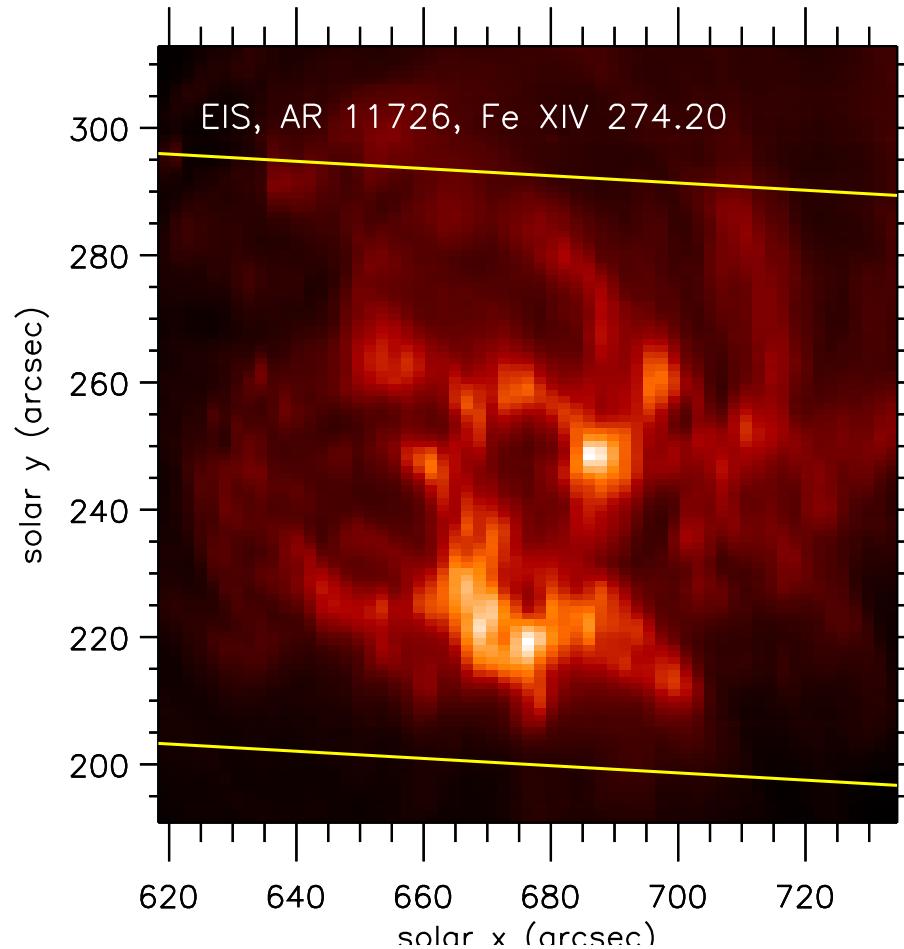
*Above: mosaic taken prior to launch.
Left: H-alpha core during flight.*

Calibration of Orbital Instruments by EUNIS-2013

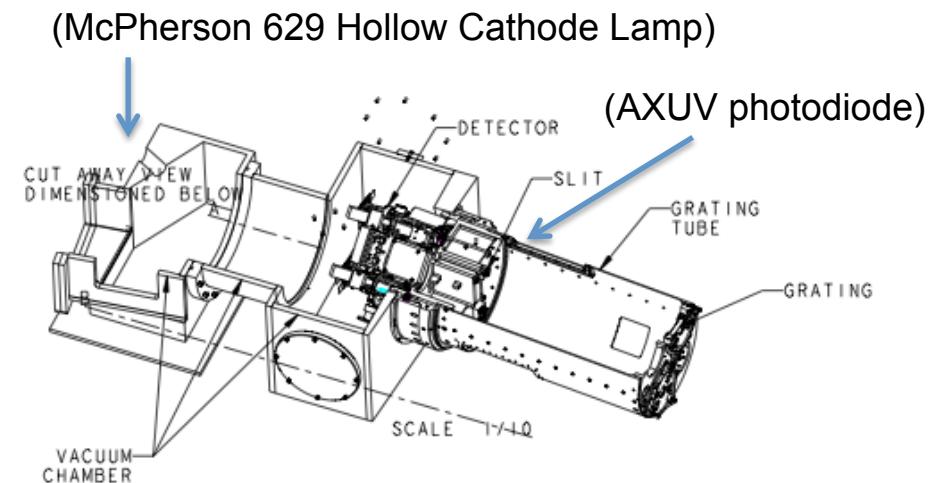
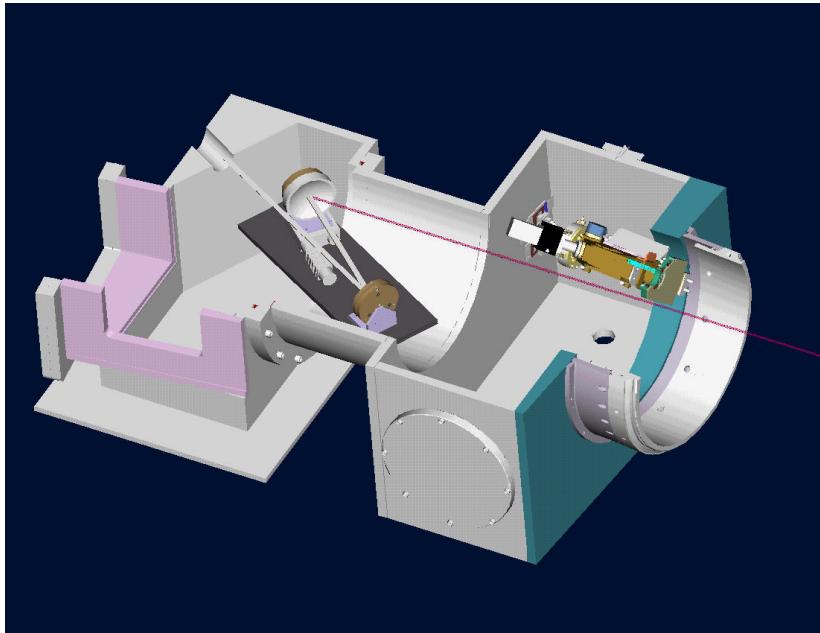
SoHO/CDS, by direct comparison to EUNIS
52-63 nm channel

SDO/AIA, A304 and A335 allow direct comparison to 30-37 nm channel, and there are other techniques as well (see below).

Hinode/EIS, using ‘insensitive’ line ratios, and DEM constructed from EUNIS wide temperature range



EUNIS Radiometric Calibration



Optical alignment and component/subsystem measurements are performed using the EUNIS calibration chamber shown above.

Absolute radiometric calibration of the spectrographs are performed using a hollow cathode discharge lamp to produce He I 584 Å and He II 304 Å, and a NIST-calibrated AXUV-100G photodiode placed behind the slit. The spectrograph calibration is then combined with reflectivity measurements of the telescope OAPs to provide the absolute radiometric calibration of the instrument.

EUNIS Radiometric Calibration

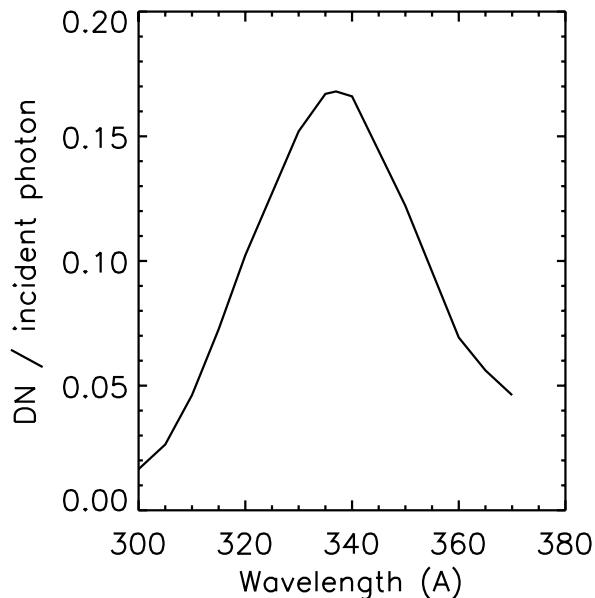
300-370 Å channel:

25 mÅ/pix

$G=3600 \text{ mm}^{-1}$

Ir/Si multilayer (aperiodic)

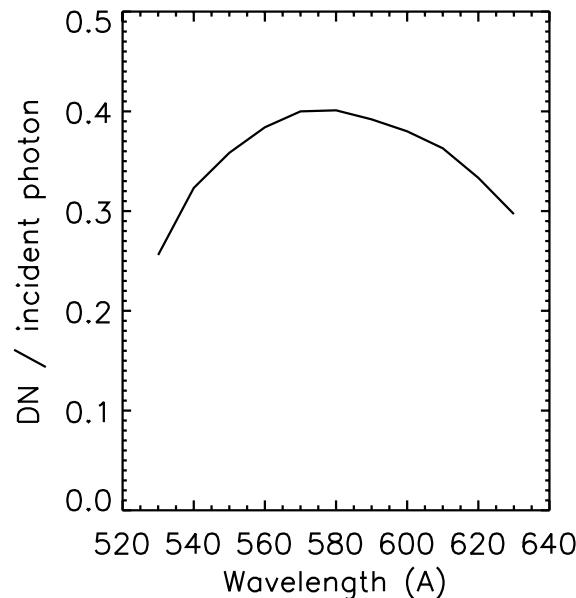
Also calibrated previously at RAL.



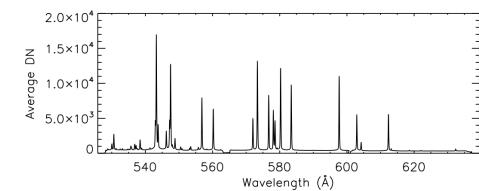
527-634 Å channel:

38 mÅ/pix

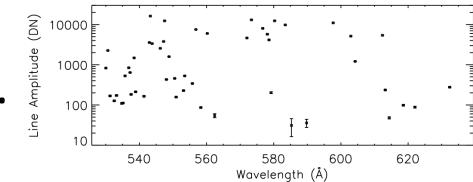
TVLS with $G_o = 2340 \text{ mm}^{-1}$
broad-band B_4C/Ir coating



- **Absolute radiometric calibration** from Lab observations of He II 304 Å and He I 584 Å
- **Spectral responsivity** from line pairs with known intensity ratio in Flight and Lab spectra:
 - 30-37 nm:
He I-II, Ne II-III
 - 52-63 nm:
He I, Ne I, III,
Ar II-III, Kr II-III



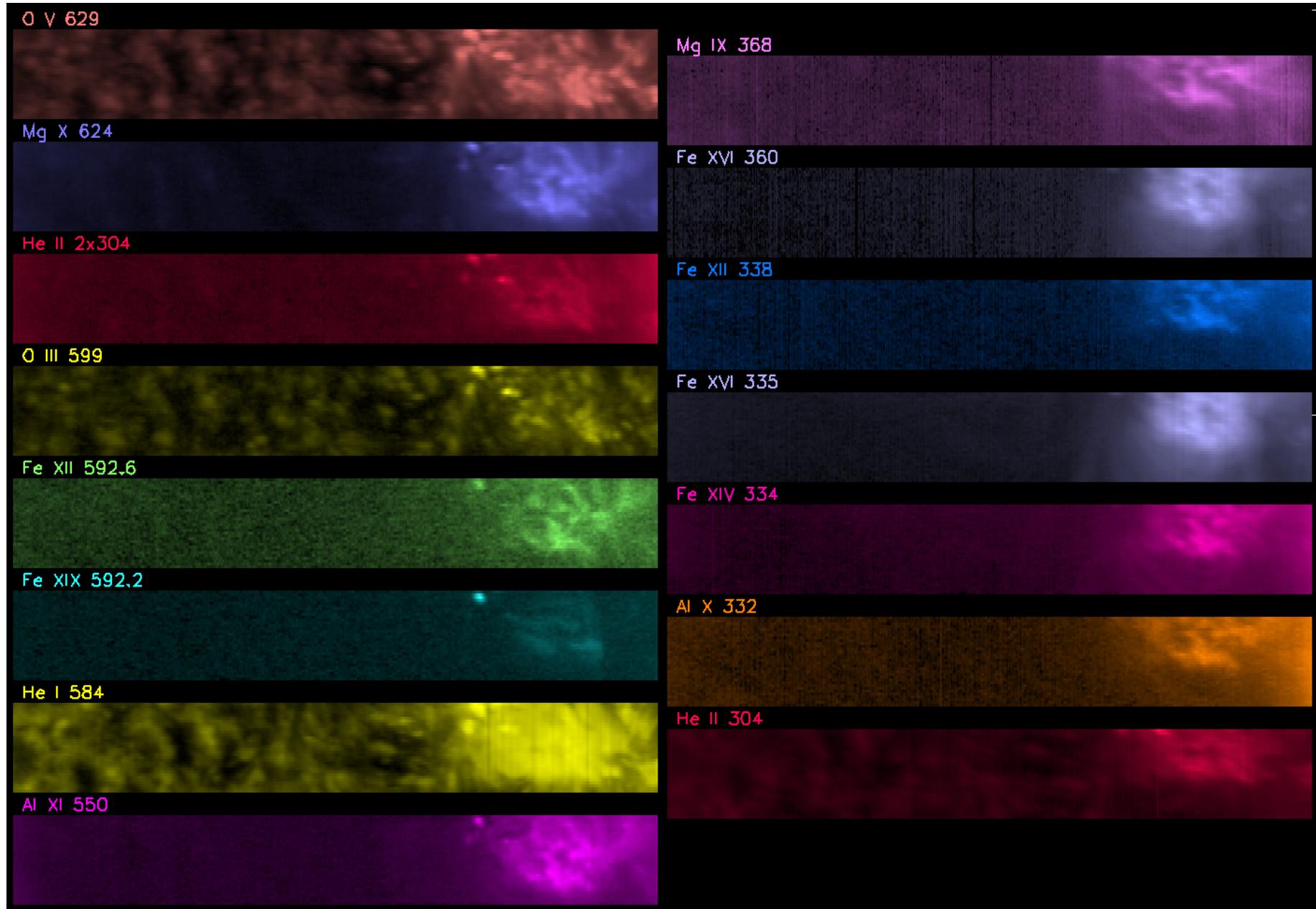
Each detector assembly is a KBr-coated MCP intensifier fiber-optically coupled to three 1Kx1K active pixel sensors.



EUNIS covers a wide temperature range: 2×10^4 to 10^7 K

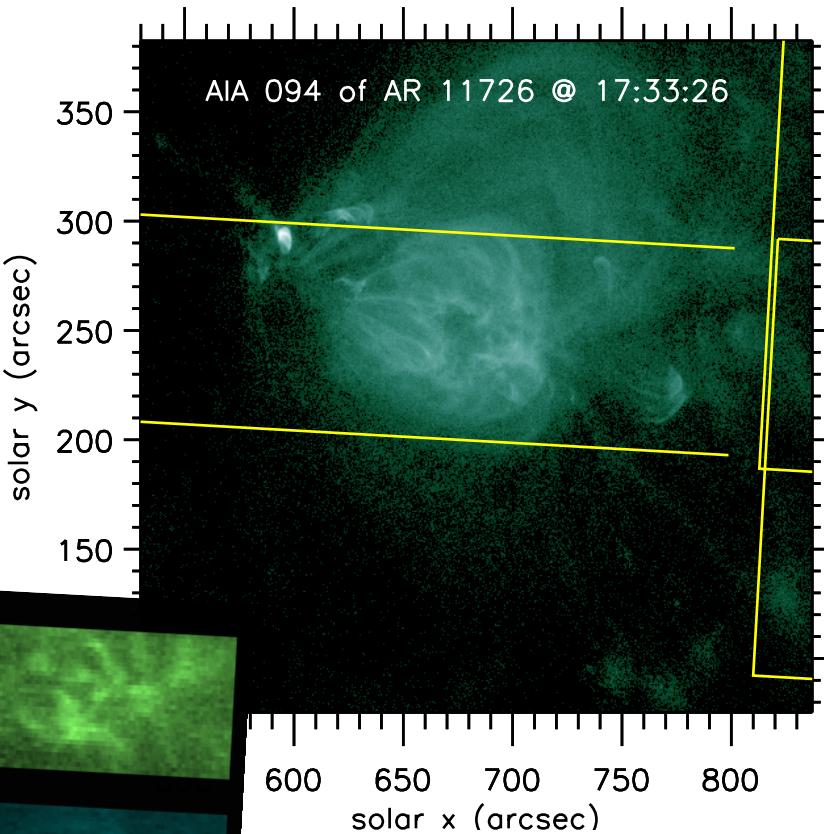
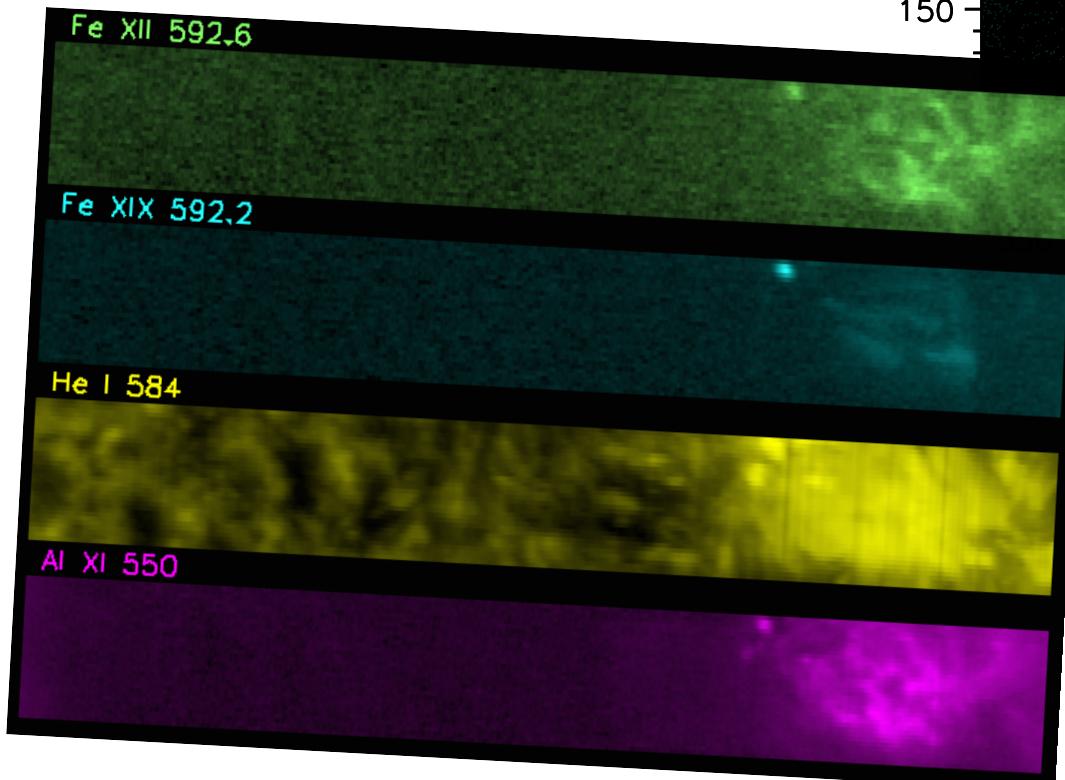
52.4 – 63.0 nm Channel						30.0 – 37.0 nm Channel					
Ion	λ (nm)	log T	Int	I	S	Ion	λ (nm)	log T	Int	I	S
O III	52.579	4.96	330	✓		Si XI	30.332	6.20	16700	✓	
He I	53.703	4.51	260	✓		He II	30.378	4.67	197500	✓	
Al XI	55.003	6.16	1030	✓		Mg VIII	31.373	5.91	510	✓	
O IV	55.333	5.21	350	✓	✓	Mg VIII	31.502	5.91	1300	✓	
O IV	55.408	5.21	1750	✓	✓	Si VIII	31.621	5.93	507	✓	
O IV	55.526	5.21	360	✓	✓	Si VIII	31.984	5.93	650	✓	
Ca X	55.777	5.87	690	✓		Ni XVIII	32.056	6.52	608		
Ne VI	55.868	5.63	290	✓		Fe XIII	32.081	6.20	841	✓	✓
Ne VI	56.270	5.63	530	✓		Fe XV	32.703	6.33	530	✓	✓
Fe XX	56.786	6.97	^b			Fe XIV	33.417	6.27	3950		✓
Al XI	56.812	6.16	520	✓		Fe XVI	33.540	6.43	35800	✓	
Ca X	57.401	5.87	350	✓		Fe XII	34.685	6.14	555	✓	✓
Si XI	58.091	6.20	660	✓		Si X	34.740	6.14	1330		✓
He I	58.433	4.51	7240	✓		Fe XIII	34.818	6.20	561	✓	✓
Fe XXI	58.579	7.02	^b			Mg VI	34.915	5.64	431		
Fe XIX	59.224	6.90	^b			Fe XI	35.267	6.06	970	✓	✓
O III	59.960	4.96	890	✓		Fe XVI	36.075	6.43	17200	✓	
Si XI	30.332 ^a	6.20	800	✓		Fe XII	36.463	6.14	1790	✓	✓
He II	30.378 ^a	4.67	7900	✓		Mg IX	36.807	5.98	4900		
O IV	60.840	5.21	300	✓	✓	Int: approximate relative intensity in units of detected photon s ⁻¹ pix ⁻¹					
Mg X	60.979	6.05	12400	✓		^a 2 nd order ^b flare line					
O IV	60.983	5.21	550	✓	✓	I: part of a density-insensitive line ratio					
Mg X	62.494	6.05	6280	✓		S: part of a density-sensitive line ratio					
O V	62.973	5.38	6480	✓							

15 Emission Lines from One Scan in the NW



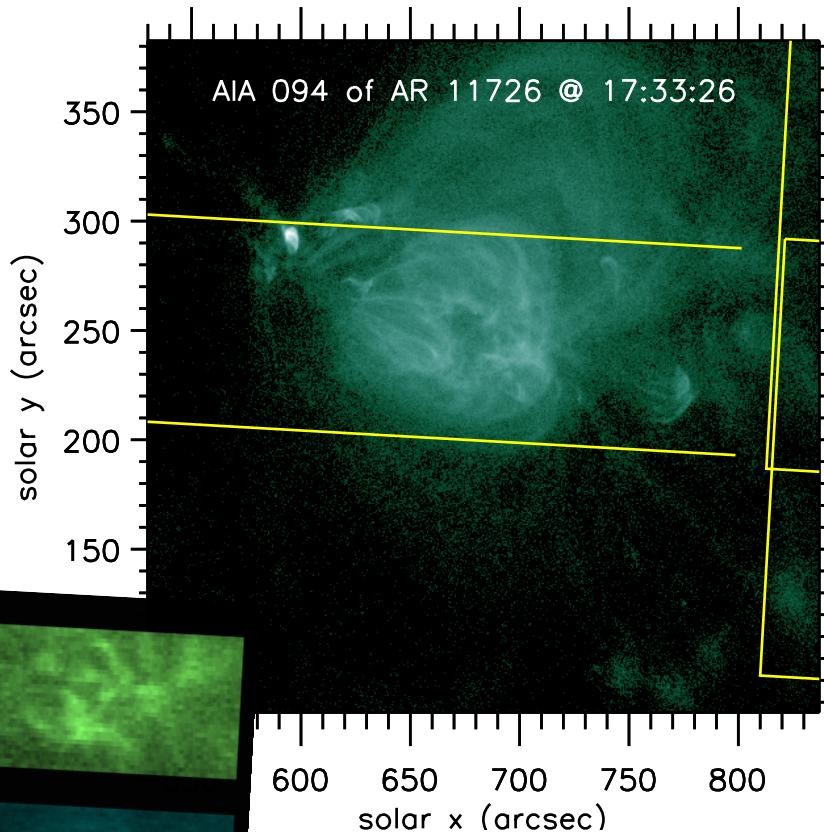
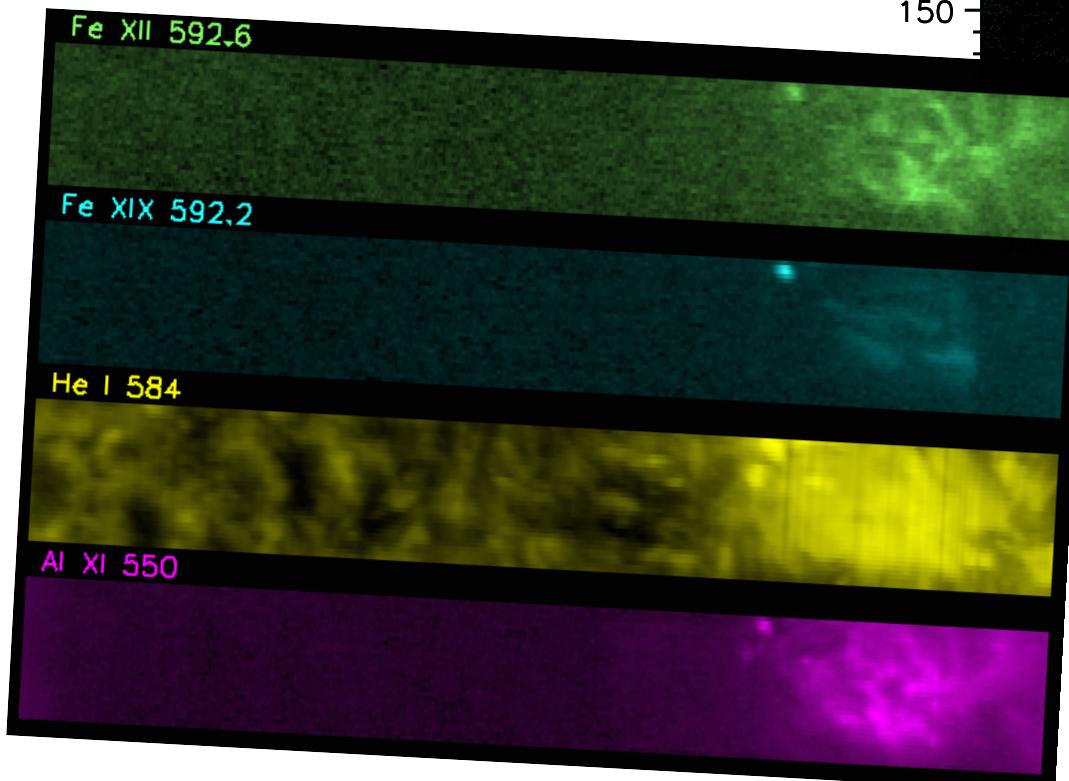
Do the AIA 94 & 131 Å
channels see hot stuff?

Yes.



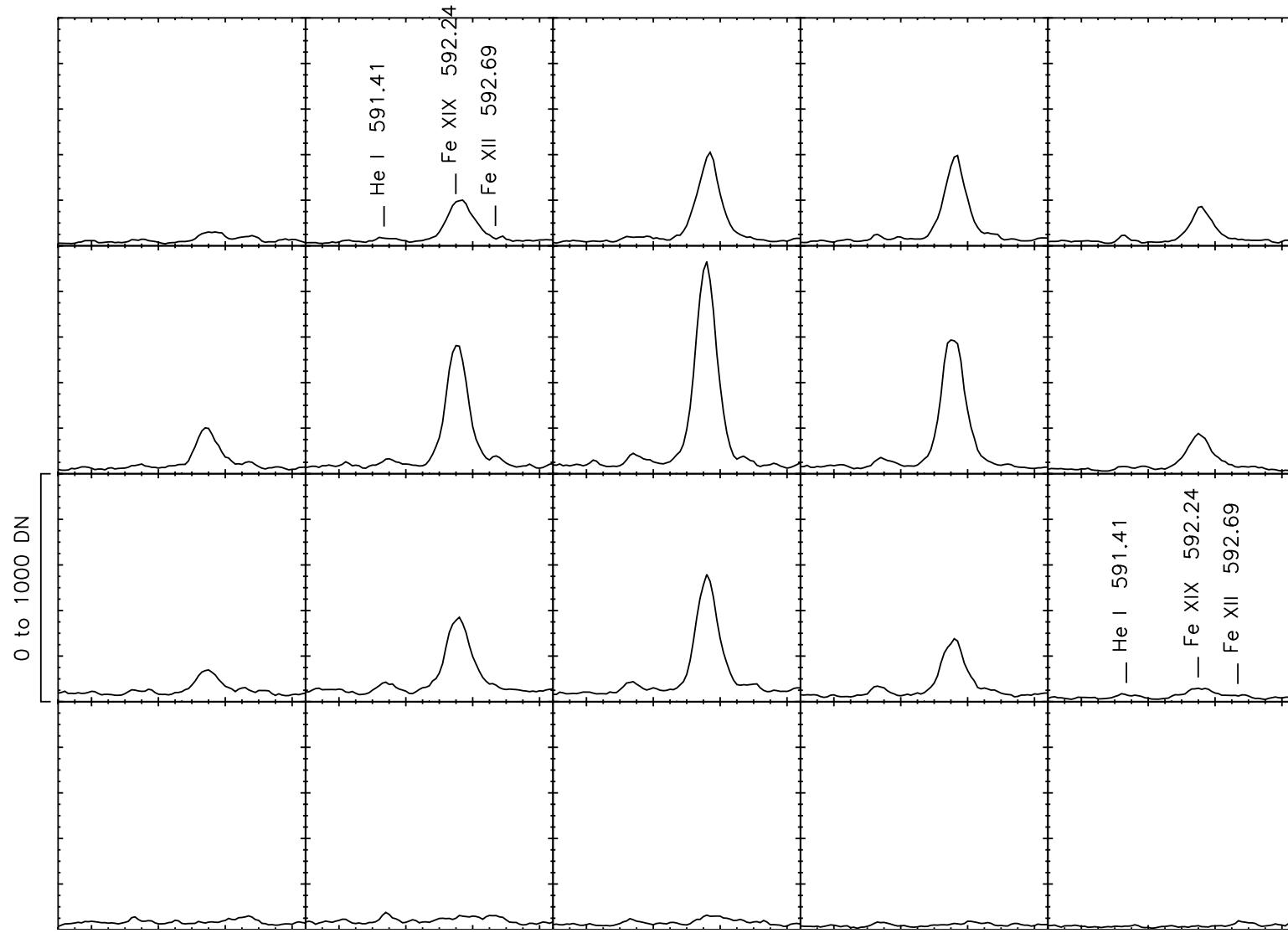
Do the AIA 94 & 131 Å
channels see hot stuff?

Yes, but they see
cooler stuff too.



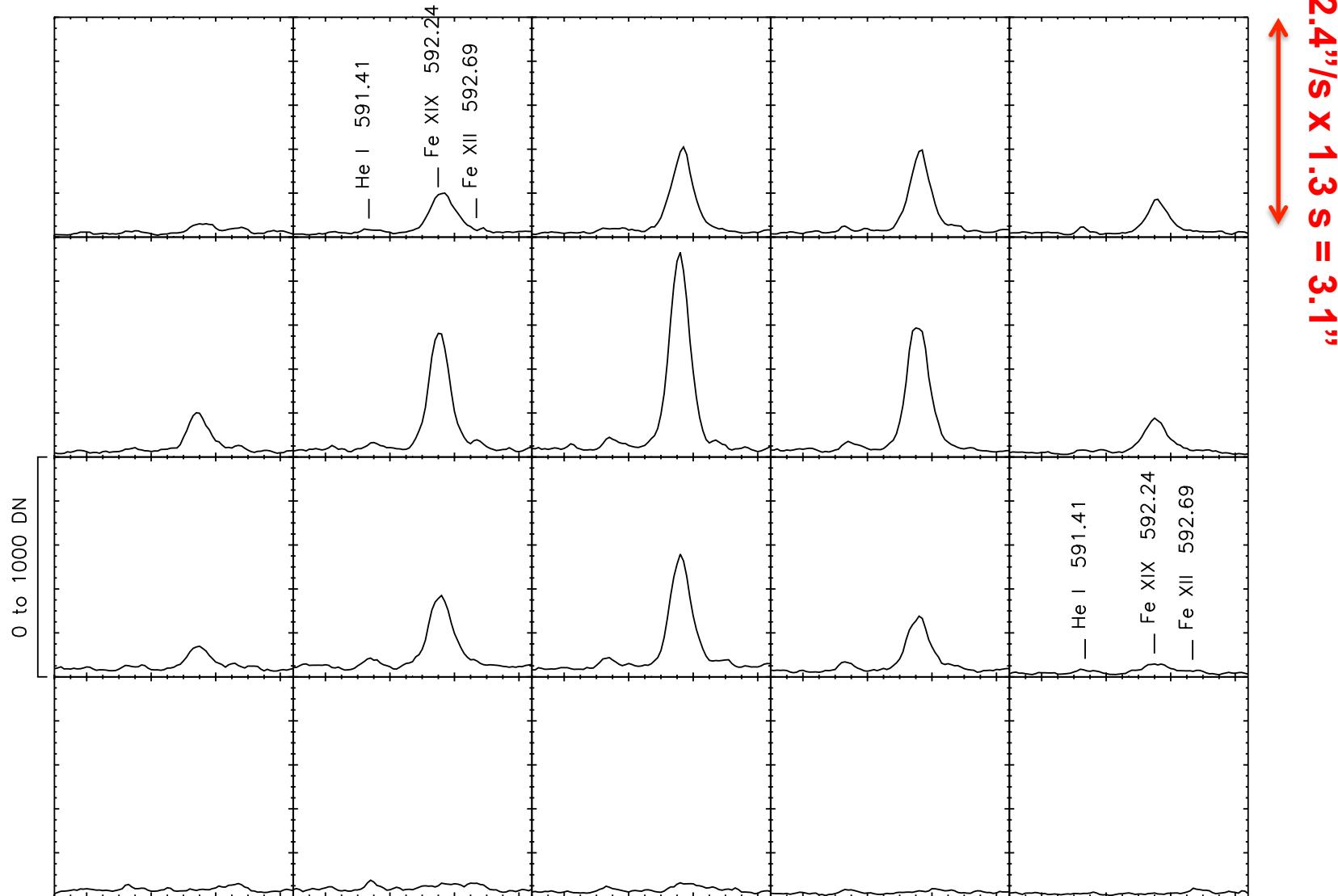
EUNIS can
resolve the
lines.

A Closer Look at the Fe XIX ‘Hot Spot’

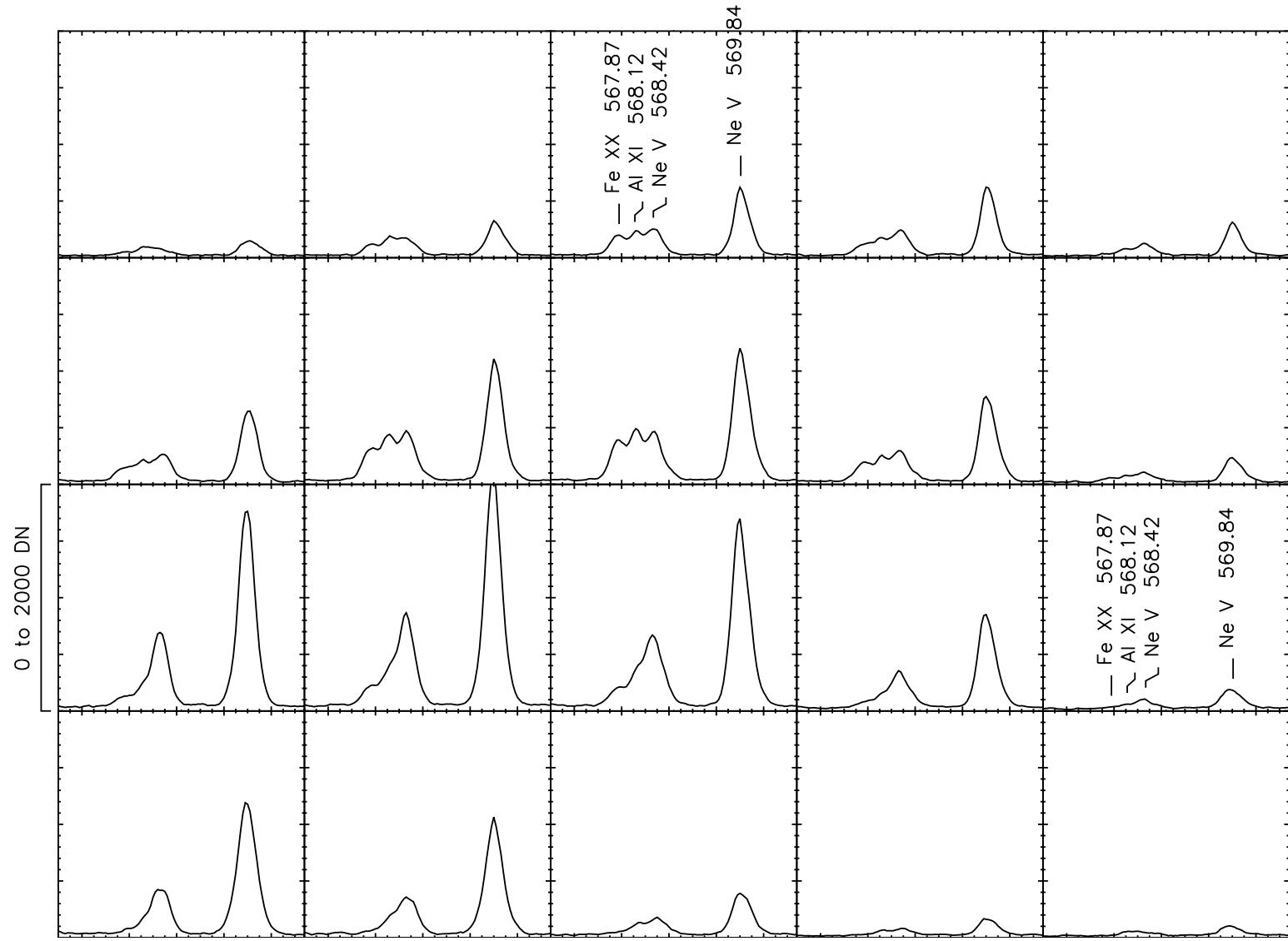


How Close?

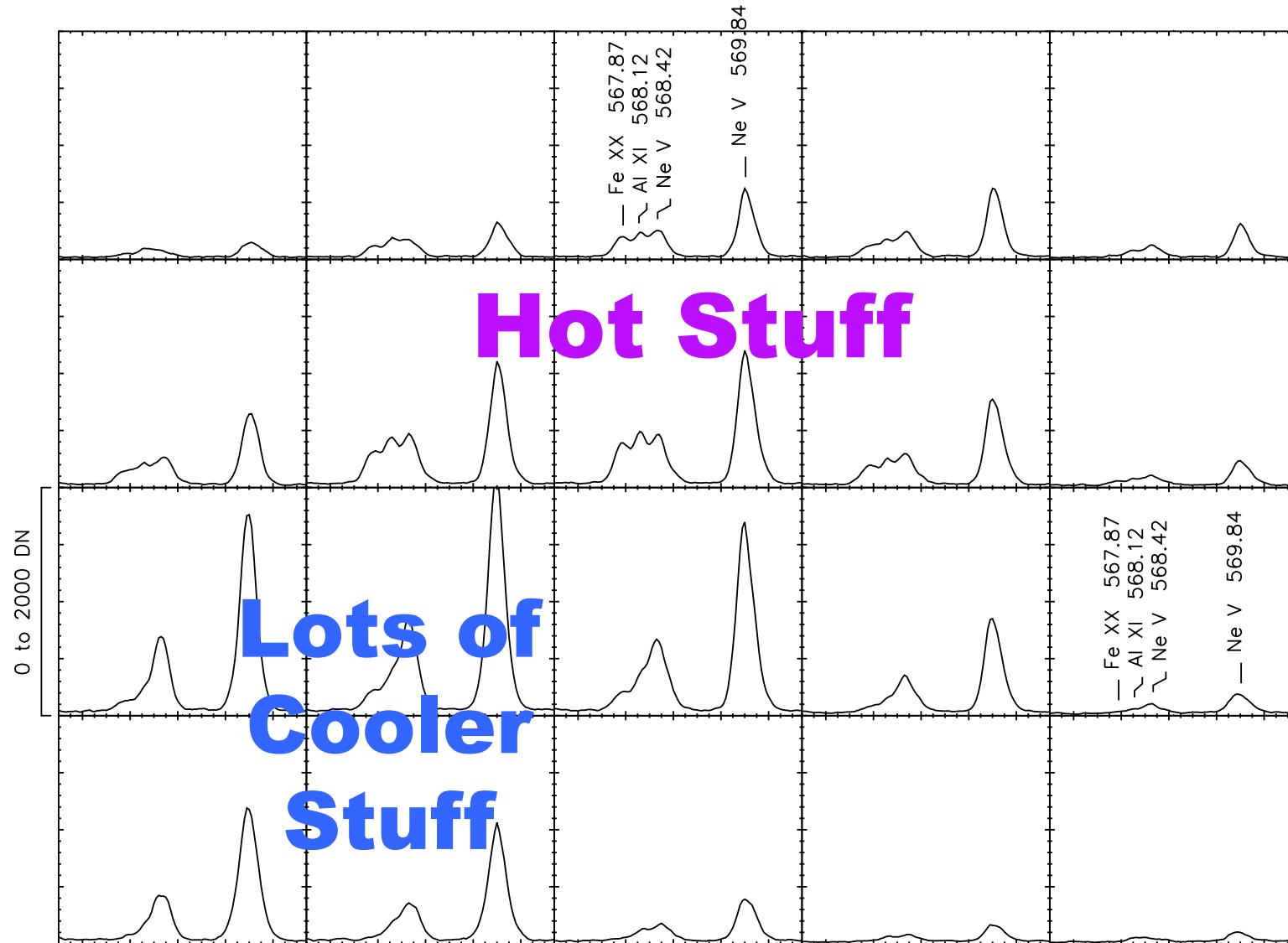
$3 \times 0.9'' \text{ pixels} = 2.7''$



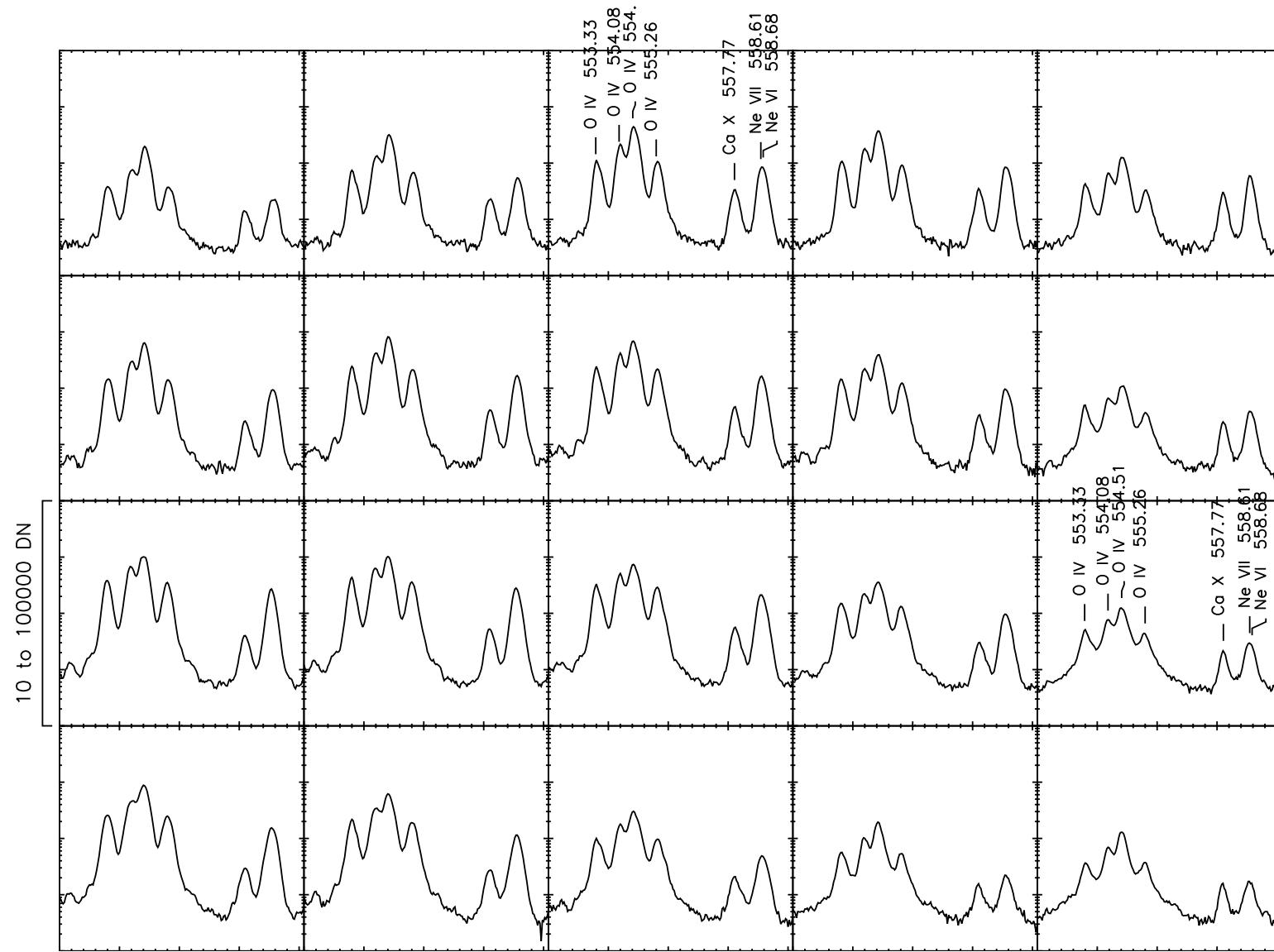
Fe XX is spotted too



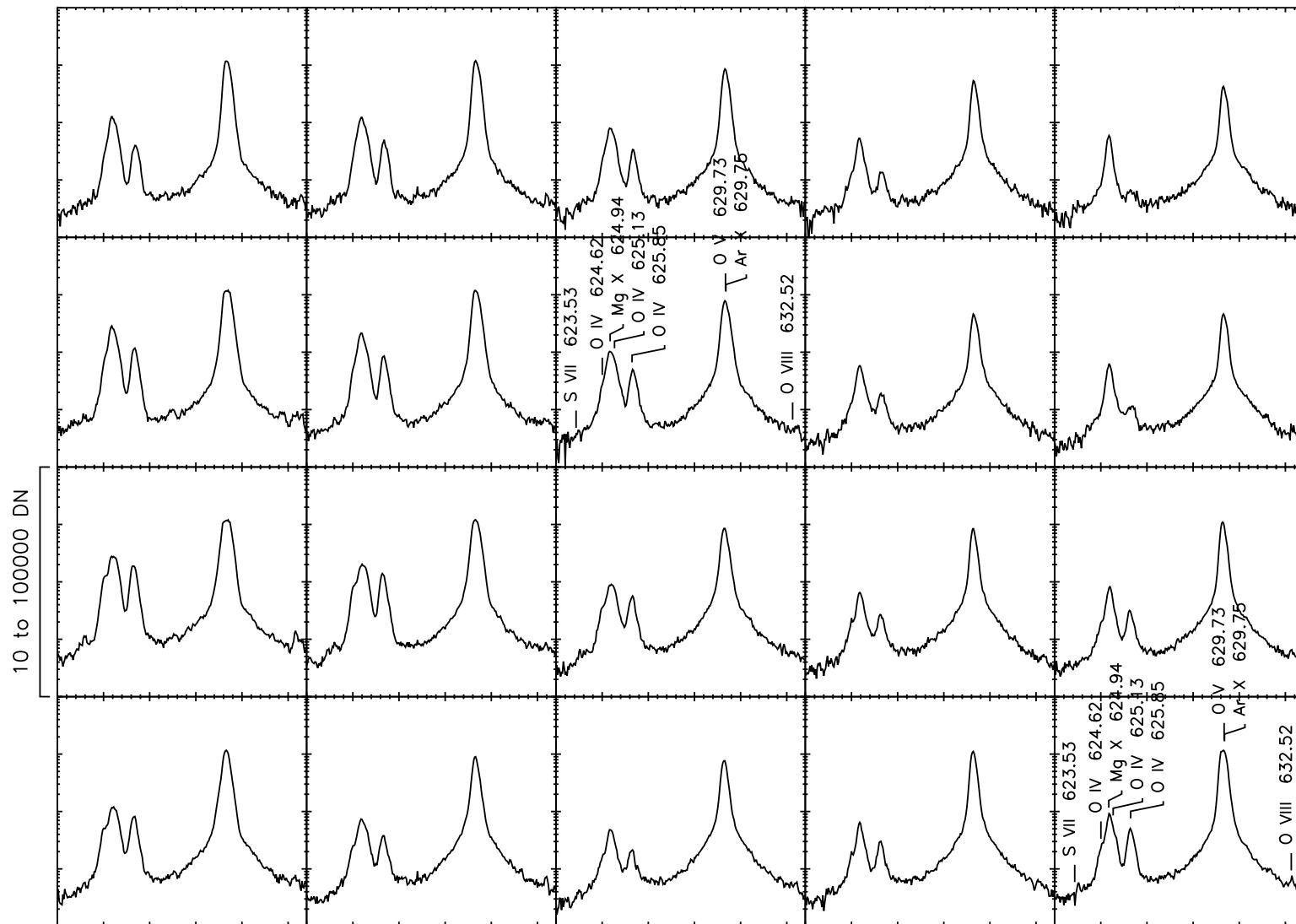
Fe XX is spotted too



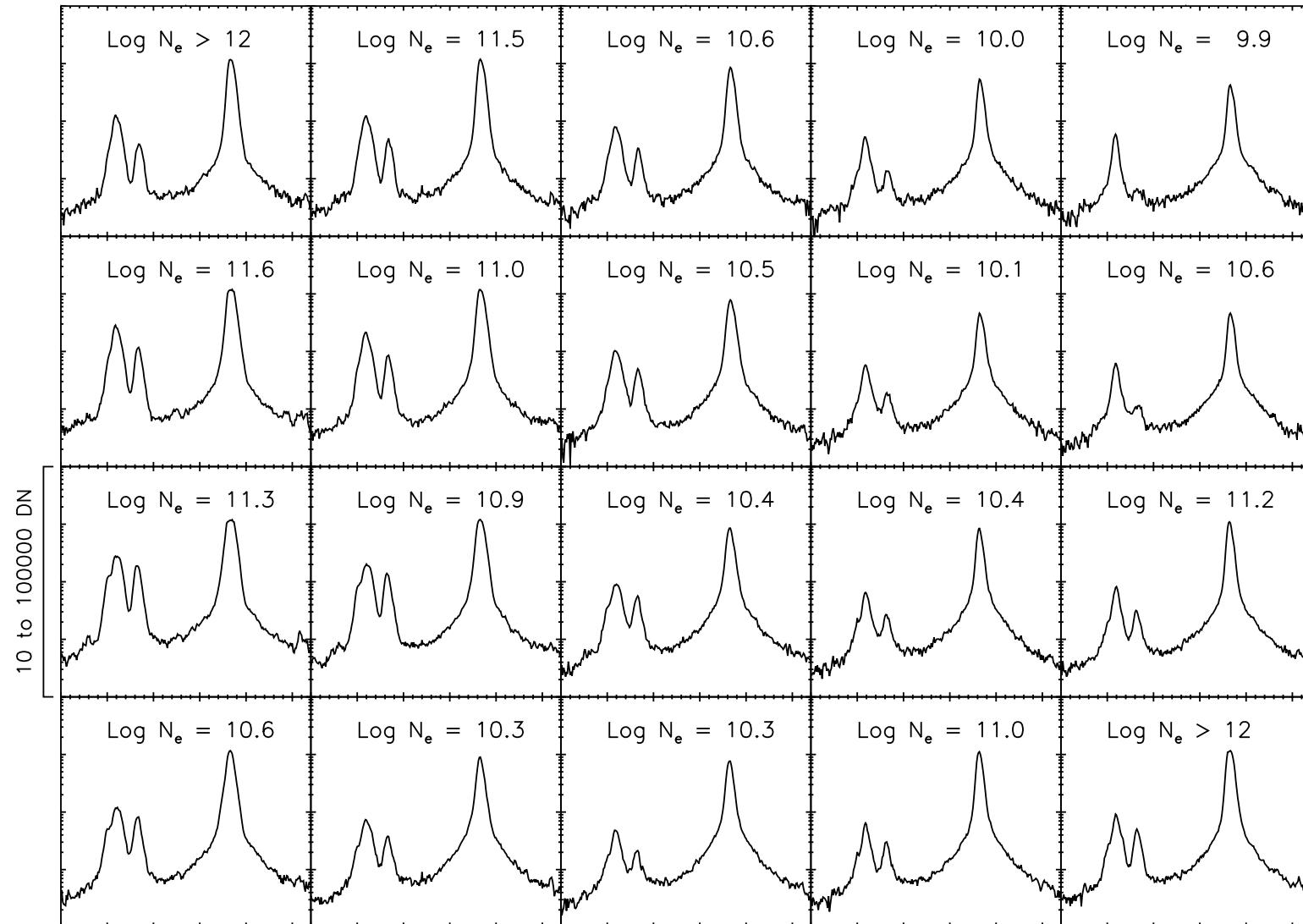
O IV multiplet at 553-555 Å is clearly resolved (note log scale).



Ratio to O IV 625 is density-sensitive



... the densities ...
(This is only one example of many useful line ratios.)



EUNIS-2013 ... stay tuned for level 1 data release

- EUNIS-2013 Incorporates a new 525–630 nm channel covering a wide temperature range of 0.025 to 10 MK.
- Provides the highest resolution observations of this important solar spectral region to date.
- Sees Fe XIX and Fe XX emission in flaring (and non-flaring?) ARs *
- Co-observed dynamic coronal AR and QS phenomena with DST/IBIS, Hinode/EIS, SoHO/CDS, RHESSI and SDO
- Will provide absolute radiometric calibration of EIS, CDS, and AIA
- Provides the first flight demonstration of cooled (-20 C) APS/CMOS arrays to achieve read-noise limited performance

* What about elsewhere? Hard to say, but noting the strongest lines of Fe XVIII–Fe XXIII are all in the 90–140 Å band ...

EUNIS-2013 ... to see more, please stop by poster #10

Future flights of EUNIS can:

- Explore the poorly-known 90–140 Å wavelength band, which has never been observed with an imaging spectrograph.
- Test theories of coronal heating by quantifying the faint signature of sub-resolution impulsive events, using the brightest of the hot (4–10 MK) emission lines.
- Derive accurate and reliable temperature-response curves for the two shortest wavelength bands of the SDO Atmospheric Imaging Assembly

Many thanks for the support of co-observers and folks at WSMR, WFF, GSFC and HQ!

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First Results from the EUNIS 2013 Sounding Rocket Campaign

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¹NASA Goddard Space Flight Center, ²National Solar Observatory, ³Catholic University of America at NASA-GSFC, ⁴INAF-Osservatorio di Arcetri

Abstract. The Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS) sounding rocket launched 23 April 2013 at 17:30 UT, as part of a campaign including co-ordinated observations with the Dunn Solar Telescope/IBIS, Hinode/EIS, SoHO/CDS, RHESSI and SDO. EUNIS obtained the highest-resolution observations of the solar spectrum from 52-63 nm observed to date, as well as observations with the previously-flown waveband from 30-37 nm. The broad spectral coverage of the EUV observations includes emission lines of ionization stages from He I to Fe XIX, and thus a wide temperature range of 0.025 to 10 MK. Absolute radiometric calibration of EUNIS provides underflight calibration of CDS, EIS and AIA. Spectra were obtained with a 1.3 s cadence as the 660-arcsec long slit was rastered across two different regions. The observations captured a B-class flare in active region NOAA 11726 as well as active regions 11723, 11724, off-limb, quiet sun and a coronal hole. We discuss first results from analysis of this rich and extensive data set.