Comments for a preliminary EIS science plan

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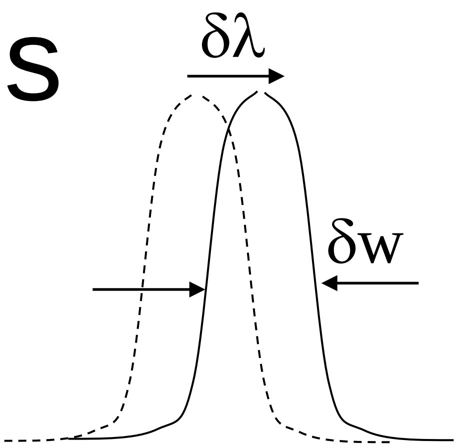
2005 Oct 31

For the science meeting at ISAS

Observables



- Line intensity
- Line shift by Doppler motion
- Line width temperature, nonthermal motion

Information from selected two line ratio

- Temperature
- Density

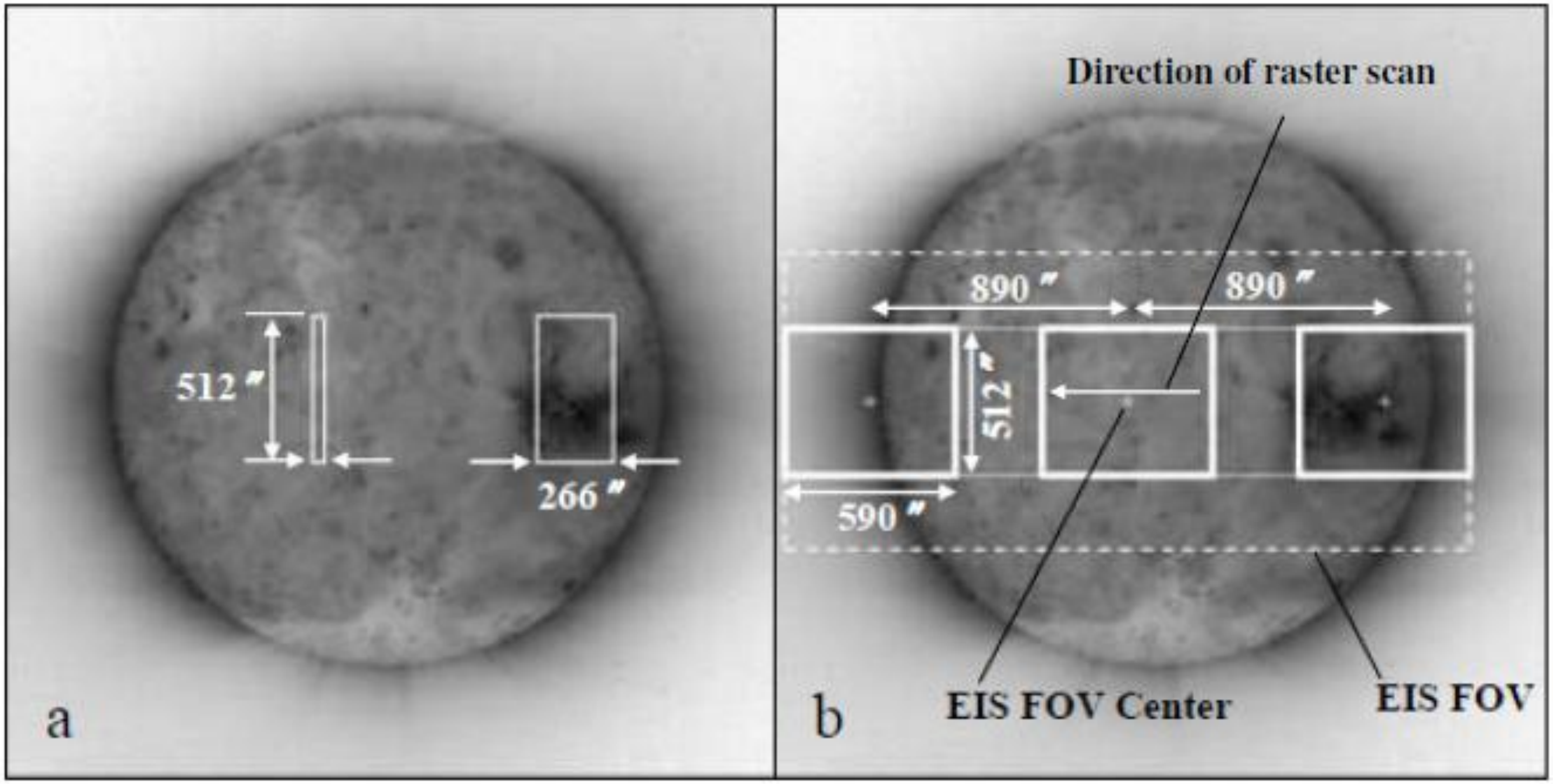
EIS Slit/Slot

- Four slit selections available

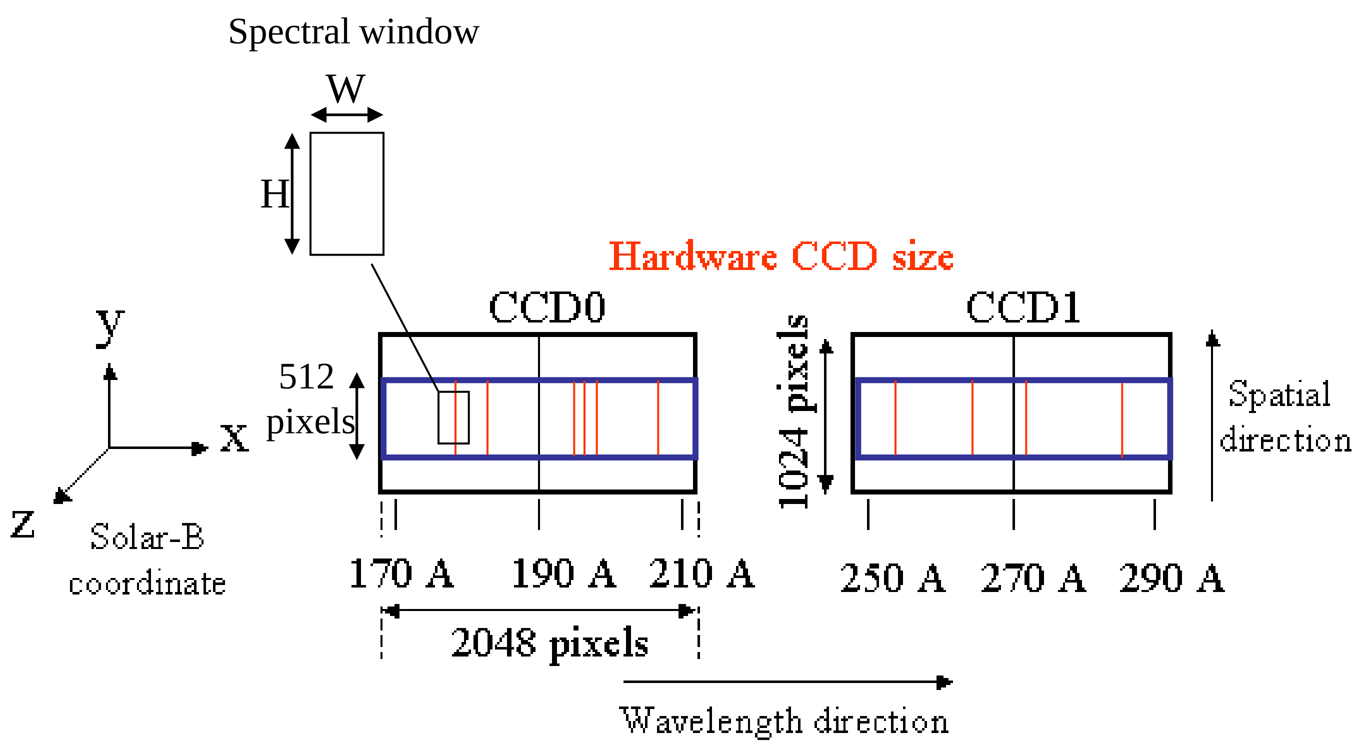
- EUV line spectroscopy
  - 1 arcsec × 512 arcsec slit for the best image quality
  - 2 arcsec × 512 arcsec slit for a higher throughput

- EUV Imaging (overlappogram; velocity info. overlapped)
  - 40 arcsec × 512 arcsec slot for imaging with little overlap
  - 250 arcsec × 512 arcsec slot for hunting transient events

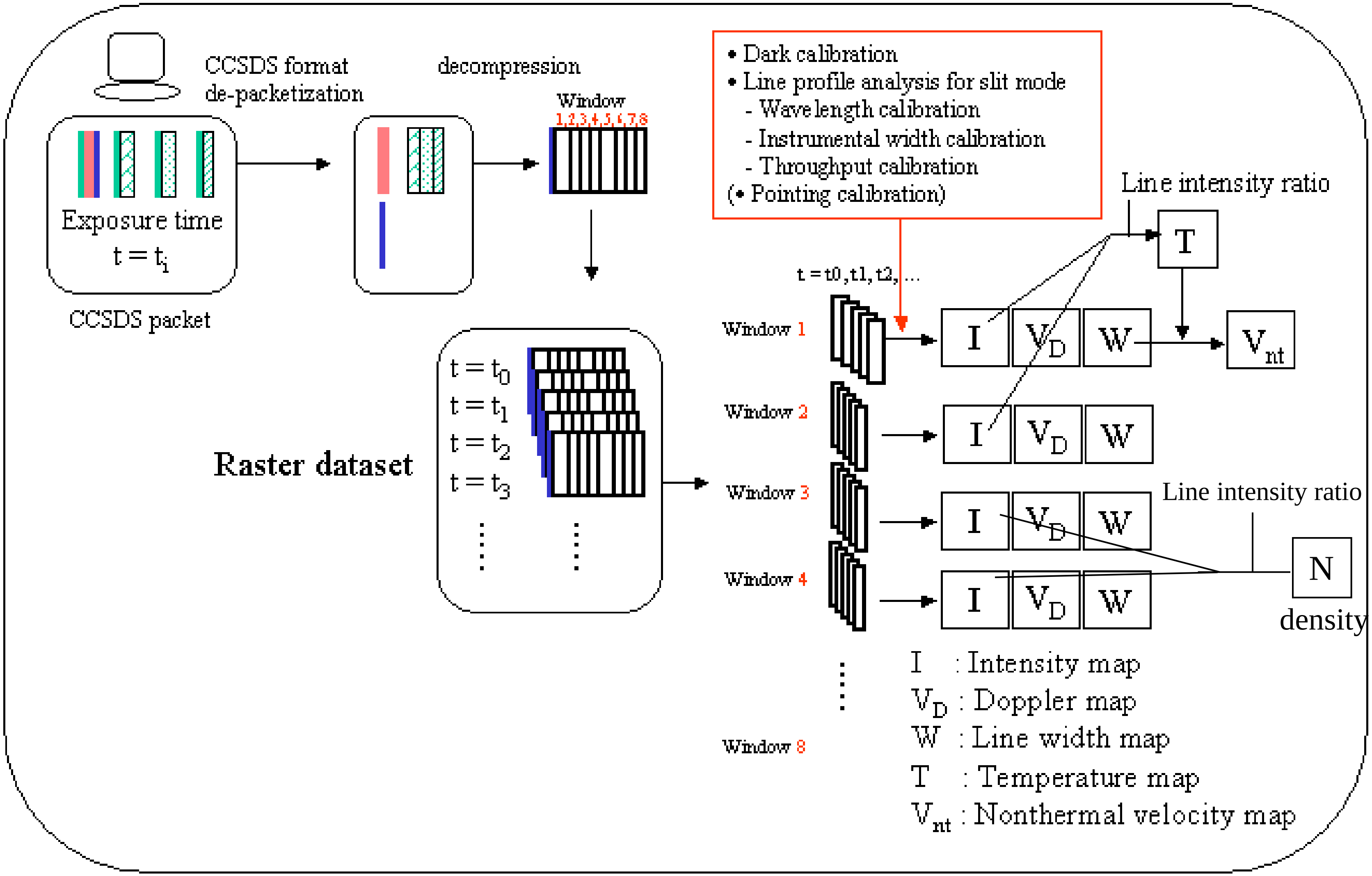
EIS Field-of-View (FOV)



EIS Spectral Windows



EIS Data Processing



CDS vs EIS

EIS has

- A larger effective area: $A_{EIS} \sim 10\ A_{CDS}$
- Higher spatial resolution: EIS: 2 arcsec CDS: > 5arcsec (out-of-focus)
- Higher spectral resolution: $R_{EIS} \geq 3\ R_{CDS}$

  $\Rightarrow$ measurement of emission-line width
- Larger FOV (EW$\times$NS): EIS 590”x512” CDS 240”$\times$240”
- Higher telemetry rate
- High compression performance: EIS DPCM/JPEG CDS loss-less
- Flare-temperature lines
- Automatic observation controls:

  Automatic exposure control, XRT flare response, EIS flare trigger

  EIS event trigger, anti-solar rotation compensation

EIS science plan

- EIS core science program

  http://www.mssl.ucl.ac.uk/www_solar/solarB/core.htm

  Category: Active Regions, Quiet Sun, Flares, CME, LSS

- EIS initial science plan (for the first 3 months)

  http://www.mssl.ucl.ac.uk/www_solar/solarB/eis_swg1.htm

  Core lines: Ca XVII 193, Fe XII195, He II 256

  Topics: AR heating, QS and CH, Flare

  Hara is thinking that the plan has not yet been optimized.

AR

- (i) connect **the photospheric velocity** field to **signatures of coronal heating** observed in the corona. This will be carried out on other coronal brightenings, such as **bright points**.
- (ii) search for evidence of **waves** and loop **oscillations** in loops. Use EIS observations for coronal seismology.
- (iii) study dynamic phenomena within active region loops. Discriminate between **siphon flows**, **bi-directional flows** and **turbulence**.

QS

- (i) link **quiet Sun brightenings** and **explosive events** to the magnetic field changes in the network and inter-network to understand the origin of these events. We will search for responses to small changes in the photospheric magnetic and velocity fields.
- (ii) determine the variation of **explosive events** and **blinkers** with temperature.
- (iii) search for **evidence of reconnection and flows** at junctions between open and closed magnetic field at coronal hole boundaries.
- (iv) determine the impact of quiet Sun events on larger scale structures within the corona.
- (v) determine physical size scales with generally diffuse quiet Sun coronal plasmas using density diagnostics.

Flare

- (i) determine the source and location of flaring and identify the source of energy for flares. EIS will measure the **velocity fields** and observe coronal structures with **temperature** information. This information will help us address the flare trigger mechanism.

- (ii) detection of **reconnection inflows**, **outflows** and the associated **turbulence** which play the pivotal role in flare particle acceleration.

CME

- (i) determine the location of **dimming** (and the subsequent velocities) in various magnetic configurations. We will determine the magnetic environment that leads to a coronal mass ejection and measure the low altitude component of the coronal mass ejection mass budget.

- (ii) The situations to be studied include filaments, flaring active regions and trans-equatorial loops.

LLS

- (i) determine the temperature and velocity structure in a **coronal streamer**
- (ii) determine the **velocity field** and **temperature** change of a trans-equatorial loop, and search for evidence of large-scale **reconnection**.
- (iii) using a low latitude coronal hole, search for the source of the **fast solar wind**.

EIS Initial Science Plan

- **Core line list**: we will include 3 lines in ALL studies

  He II 256, Fe XII 195, Ca XVII 192.8
- **Flare trigger/dynamics:** spatial determination of **evaporation** and **turbulence** in flares
- **AR heating:** **spatial determination of the velocity field** in active region loops over a range of temperatures
- **QS & CH:** determination of the relationship between the various categories of **quiet Sun brightenings** (e.g explosive events and blinkers) both in the quiet Sun and coronal holes. EIS has the spatial and velocity resolution to solve this mystery.

- The observing time will be split evenly between the topics. If there is an active region **we will track it** otherwise we will observe quiet Sun and coronal holes for long periods of time (at least 12 hrs).
- When there is an active region we will track it, and if there is highly sheared magnetic field then we will go into flare trigger mode to respond to XRT's trigger.
- If there are no active regions but there is a quiet prominence we concentrate on this.

EIS Data Flow

CCD Readout Electronics

Large hardware CCD window

control

Small spectral window (25 max)

EIS ICU

Observation table

2Mbps max

~1.3 Mbps

Data compression

DPCM(loss less) or 12bit-JPEG

S/C MDP

~ 260 kbps max for short duration,

~ 45 kbps average

Average rate depends on number of downlink station.

Telemetry data format

	1″ slit obs.	40″ slot obs.	250″ slot obs.
Spec.width	16	40	250
Spatial width	256″	512″	256
No. of lines	8	4	4
Compression*	25%	20 %	20%
Cadence	3 sec	6 sec	20 sec
Rate	42.7 kbps	42.7 kbps	40 kbps

*** for 16 bit/pixel data**

13 min cadence for 4′×4′ rastering

EIS Data Rate

Data rate = CCSDS format data size / cadence

~ [EIS data size to MDP] * [Compression Ratio] / Cadence

EIS data size to MDP = total sum of software windows

$= \sum (\text{window width})_i * (\text{window height})_i$

Compression ratio = compressed data size/ input data size to MDP

Cadence = setup time + exposure duration [+ data transfer time]

Low data rate | High data rate

SW width/SW height/Number of SW

small ↔ large

JPEG compression

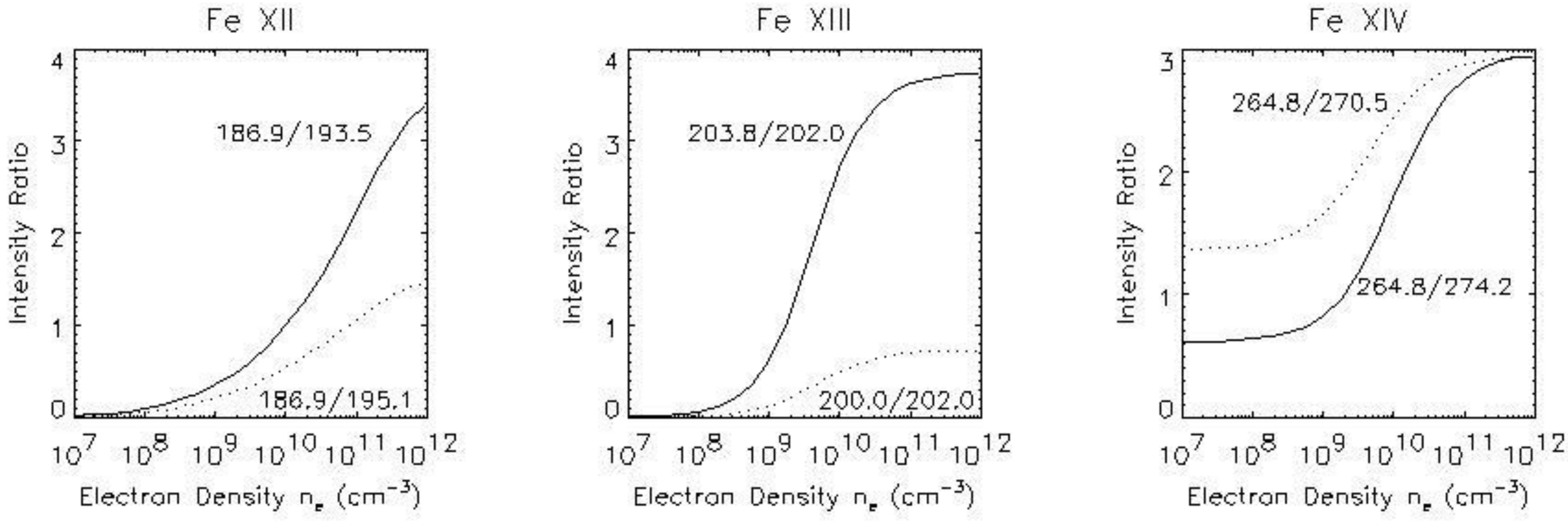
Large Q-factor (Small compression error) ↔ Small Q-factor (Large compression error)

Exposure duration

Long ↔ Short

Density Sensitive Line Ratio

Density sensitive line ratio with two forbidden lines



Filling factor of coronal loop will be estimated in 2 arcsec resolution.

CHIANTI is used for this estimate.

Fe XI line ratios 182.17/188.21 and 184.80/188.21 will also be useful.
(Keenan et al. 2005)

AR Heating

- Line list 1: Fe XII195
- Line list 2: Fe XI188, Fe XXIV192, Fe XII195, Fe XIII202, Fe XIII203, HeII256,Fe XV284
- Line list 3: LL2+ FeX184,FeVIII185,FeXII186,CaXVII193,FeXVI263,FeXIV264,FeXIV274,
- SiVII275

PRG	Slit	Window λ (pixels)	Window h (pixels)	LL	Exp (sec)	Cadence (sec)	Raster steps	Duration of single raster
1A	1”	16	256	1	2	3	0	2 sec
1B	1”	16	256	2	4	5	0	5 sec
1C	1”	16	256	3	10	11	0	5 sec
2A	1”	16	256	3	10	11	256	47 min
2B	1”	16	256	3	10	11	60	11 min
3	1”	16	256	3	40	41	256	2.9 hr
4	40”	40	256	2	10	11	6	1 min

AR Heating

PRG Name	Parameters of science data	**Data rate [kbps]** for each Compression Ratio (CR)			
		CR=1.0	CR=0.5	CR=0.25	CR=0.125
1A	1”slit, 1 linex16x256pixels,3s cadence	32	16	8.0	4
1B	1”slit, 7 linesx16x256pixels,5s cadence	89.6	44.8	22.4	11.2
1C 2A 2B	1”slit, 15 linesx16x256pixels,11s cadence	87.3	43.6	21.8	10.9
3	1”slit, 15 linesx16x256pixels, 41s cadence	23.4	11.7	5.9	2.9
4	40”slit, 7 linesx40x256pixels, 11s cadence	101	50.9	25.5	12.7

Flare

- Line list 1: Core (Fe XII195, CaXVII193, HeII256), FeX184,Fe XXIV192,FeXV284
- Line list 2: Core, FeX, FeXV284, FeXXIV+FeXXIII+FeXXII (253) for 266” slit, 5 segments

PRG	Slit	Window λ (pixels)	Window h (pixels)	LL	Exp (sec)	Cadence (sec)	Raster steps	Duration of single raster
1	2”	32	200	1	1	1.5	100	2.5 min
2	40”	40	512	1	1	5.0*	2	10 sec*
3	266”	152	152	2	1*	10	0	10 sec

PRG Name	Parameters of science data	**Data rate [kbps]** for each Compression Ratio (CR)			
		CR=1.0	CR=0.5	CR=0.25	CR=0.125
1A	1”slit, 6 linex32x200 pixels,1.5s cadence	402	201	101	50.3
1B	1”slit, 6 linesx40x512pixels,5s cadence	385	192	96.2	48.1
3	1”slit, 5 segsx152x152pixels, 10s cadence	182	90.8	45.4	22.7

Quiet Sun

- Line list 1: Core (Fe XII195, CaXVII193, HeII256), FeX184,FeVIII185, Fe XII186
  FeXI188,FeXXIV192,FeXII196,FeXIII202, Fe XIII203, FeXVI263,S X264
  FeXIV264,SiVII275,FeXV284
- Line list 2: Fe XII195,HeII256,FeXV284
- Line list 3: whole CCD area

PRG	Slit	Window λ (pixels)	Window h (pixels)	LL	Exp (sec)	Cadence (sec)	Raster steps	Duration of single raster
1A	40”	40	512	2	50	60*	2	2 min
1B	1”	24	512	1	50	51*	80	68 min*
2	40”	40	512	2	50	51*	0	51 sec*
3A	40”	40	512	2	50	51*	0	51 sec*
3B	1”	24	512	1	50	51*	0	51 sec*
4A	40”	40	512	2	50	60*	2	2 min
4B	2”	24	512	1	15	16*	5	80 sec*
5	1”	4096	512	3	50	60*	0	60 sec*

Quiet Sun

PRG Name	Parameters of science data	**Data rate [kbps]** for each Compression Ratio (CR)			
		CR=1.0	CR=0.5	CR=0.25	CR=0.125
1A/2/3A/ 4A	40”slit, 3 linex40x512pixels,60s cadence	16.0	8.0	4.0	2.0
1B/3B	1”slit, 16 linesx24x512pixels,51s cadence	60.4	30.2	15.1	7.5
4B	2”slit, 16 linesx24x512pixels,16s cadence	192	96.2	48.1	24.0
5	1”slit,4096x512pixels, 60 s cadence (Cadence will be much more longer in the actual operation.)	547	274	137	68.4

EIS Sensitivity

Detected photons per 1″×1″ area of the sun per 1 sec exposure.

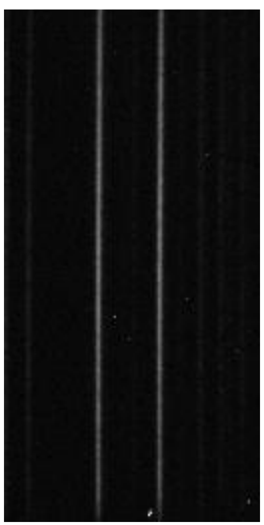
AR: active region

Ion	Wavelength (A)	logT	$N_{photons}$ AR	$N_{photons}$ M2-Flare
Fe X	184.54	6.00	15	36
Fe XII	186.85 / 186.88	6.11	13/21	105/130
Fe XXI	187.89	7.00	-	346
Fe XI	188.23 / 188.30	6.11	41 / 15	110/47
Fe XXIV	192.04	7.30	-	4.0×10^4
Fe XII	192.39	6.11	46	120
Ca XVII	192.82	6.70	31	1.8×10^3
Fe XII	193.52	6.11	135	305
Fe XII	195.12 / 195.13	6.11	241/16	538/133
Fe XIII	200.02	6.20	20	113
Fe XIII	202.04	6.20	35	82
Fe XIII	203.80 / 203.83	6.20	7/20	38/114

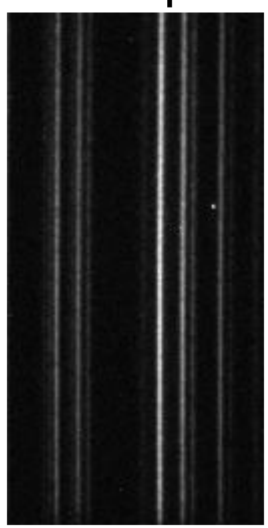
Ion	Wavelength (A)	logT	$N_{photons}$ AR	$N_{photons}$ M2-Flare
Fe XVI	251.07	6.40	-	108
Fe XXII	253.16	7.11	-	71
Fe XVII	254.87	6.60	-	109
Fe XXVI	255.10	7.30	-	3.3×10^3
He II	256.32	4.70	16	3.6×10^3
Si X	258.37	6.11	14	62
Fe XVI	262.98	6.40	15	437
Fe XXIII	263.76	7.20	-	1.2×10^3
Fe XIV	264.78	6.30	20	217
Fe XIV	270.51	6.30	17	104
Fe XIV	274.20	6.30	14	76
Fe XV	284.16	6.35	111	1.5×10^3

EIS CAL data

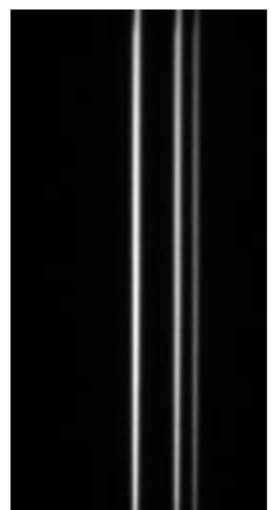
- EIS end-to-end calibration was performed at RAL. One of CAL images (md_data.028; given by J. Mariska) was used to check the MDP compression capability.
- The following four images are taken from md_data.028.
- CAL1: x= 860: 860+127, y=90:90+255 ; on CCD11
- CAL2: x=1270:1270+127, y=90:90+255; on CCD10
- CAL3: x=2940:2940+127, y=90:90+255; on CCD01
- CAL4: x=3670:3670+127, y=90:90+255; on CCD00
- CAL 2,3,and 4 were set in the EIS simulator PC during FM MDP integration for testing of compression.



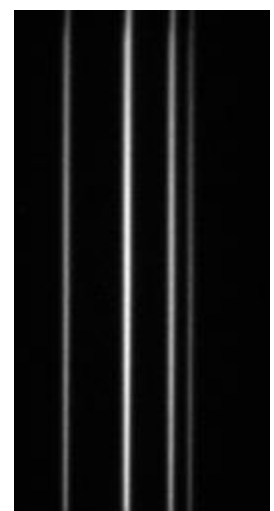
CAL1



CAL2



CAL3



CAL4

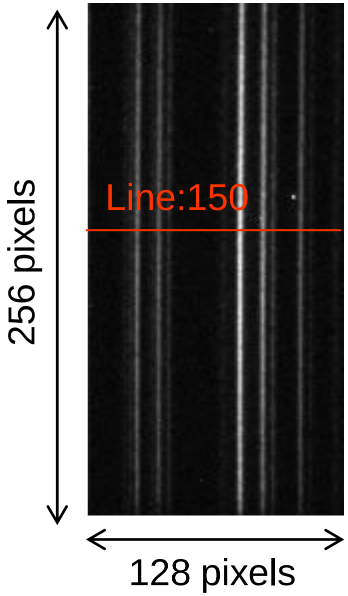
MDP compression parameters

- Bit compression table7 parameters.
- A= 1877.50, B = 341.00, C= -6692998, Nc=2048.
- 12bit_data = 14bit_data for value ≤ Nc
  12bit_data = round(A + sqrt(B*14bit_data +C)) for value>Nc

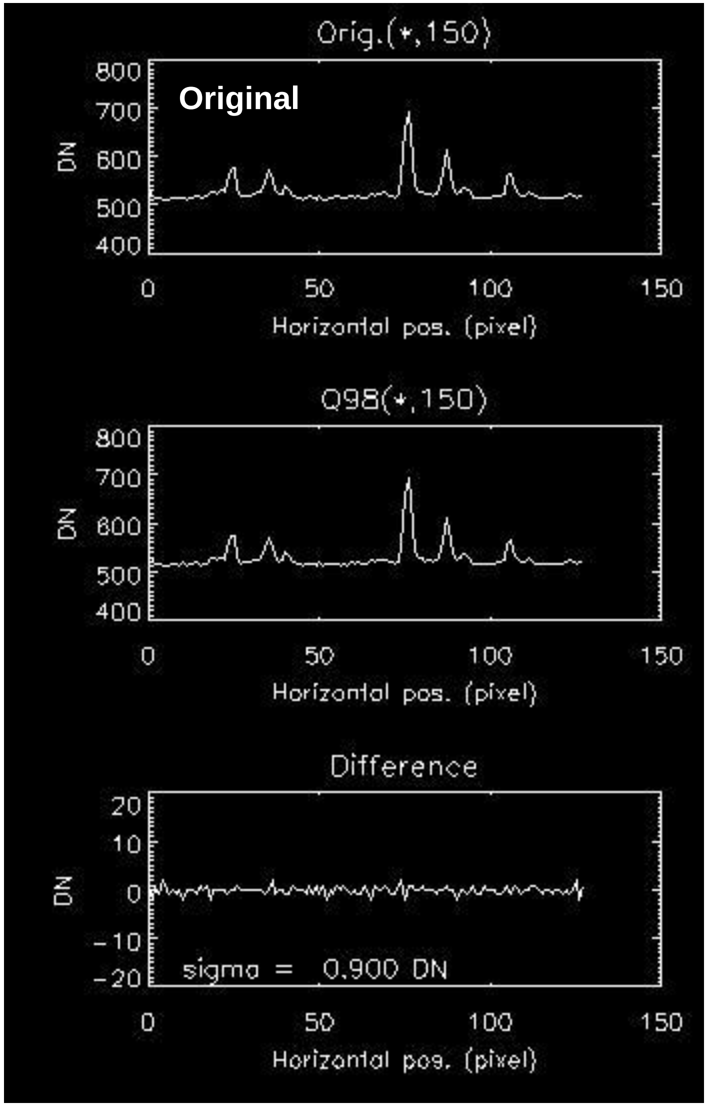
- No bit & image compression : 0x0000
- No bit & DPCM : 0x0328; extraction of lower 12bits data
- Bit table7 & DPCM : 0x3B28
- Bit table 7 & JPEG (Q=98) : 0x3F28
- Bit table 7 & JPEG (Q=90) : 0x3F29
- Bit table 7 & JPEG (Q=75) : 0x3F2A
- Bit table 7 & JPEG (Q=50) : 0x3F2B
- Bit table 7 & JPEG (Q=95) : 0x3F2C
- Bit table 7 & JPEG (Q=92) : 0x3F2D
- Bit table 7 & JPEG (Q=85) : 0x3F2E JPEG Q-tables are shared with
- Bit table 7 & JPEG (Q=65) : 0x3F2F SOT and XRT teams.

Q=98

CAL2



128x256x2
= 65536 bytes

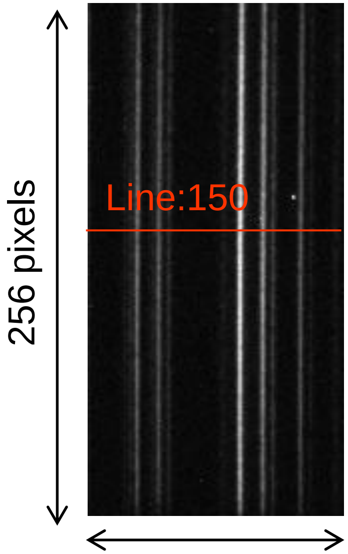


JPEG data size
Spec:
65536 bytes
→15058 bytes

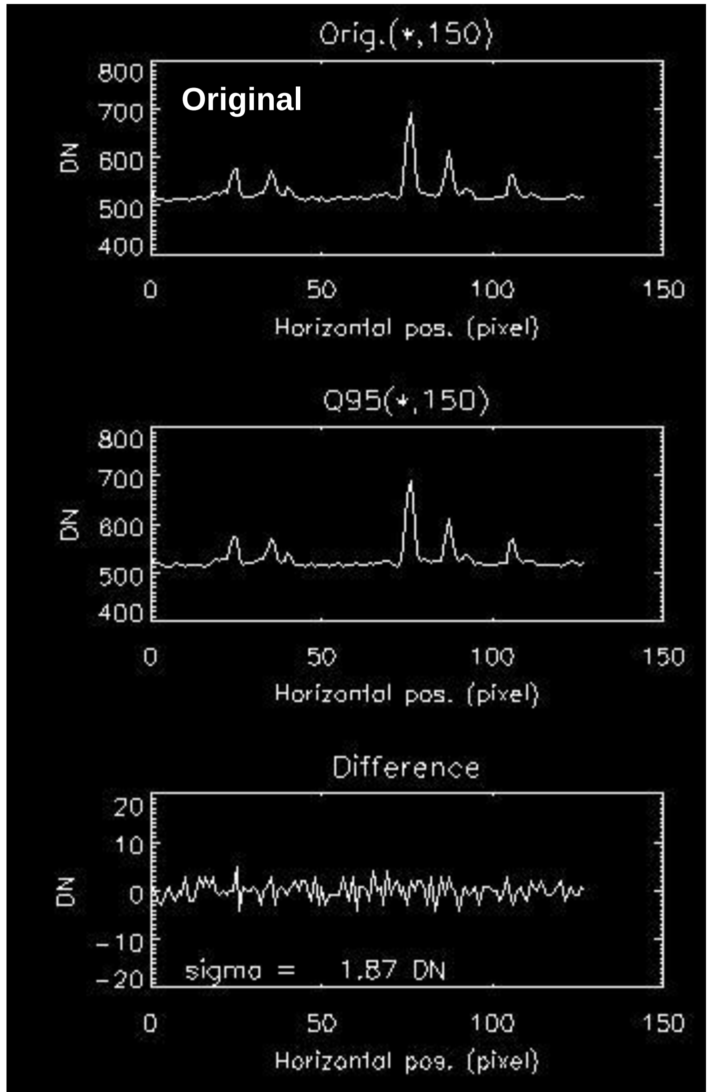
Comp. Factor = 4.35
or 23.0 % of original data

Q=95

CAL2



128x256x2
= 65536 bytes



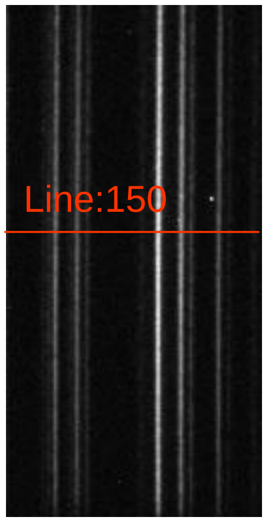
JPEG data size
Spec:
65536 bytes
→10096 bytes

Comp. Factor = 6.49
or 15.4% of original data

Q=92

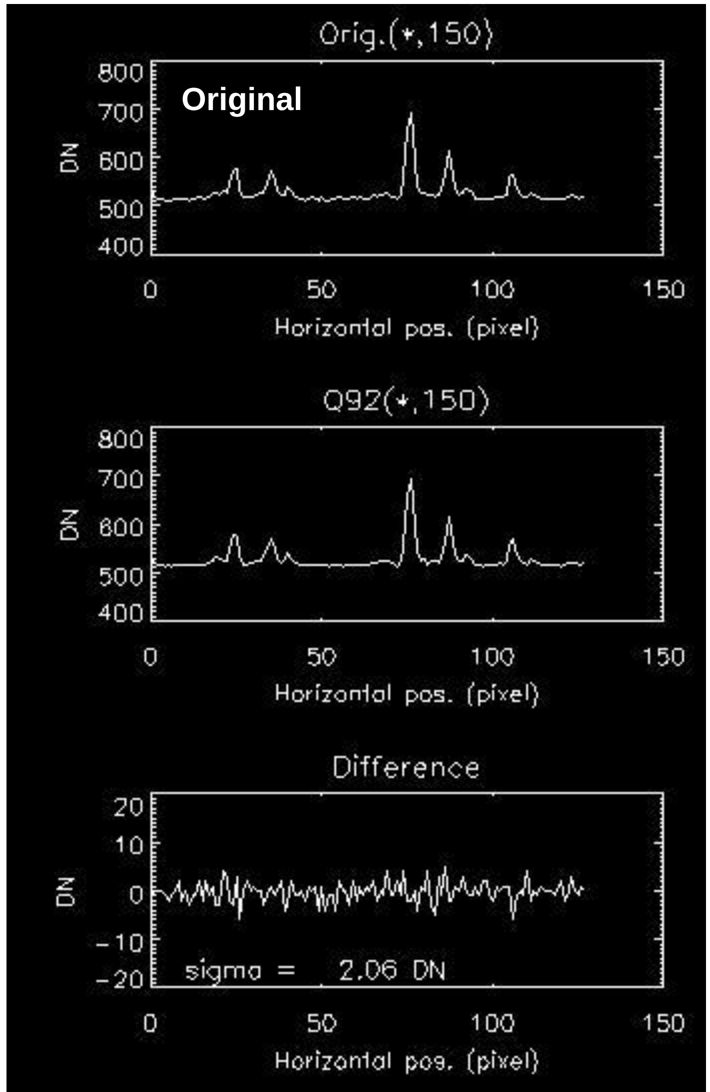
CAL2

256 pixels



128 pixels

128x256x2
= 65536 bytes

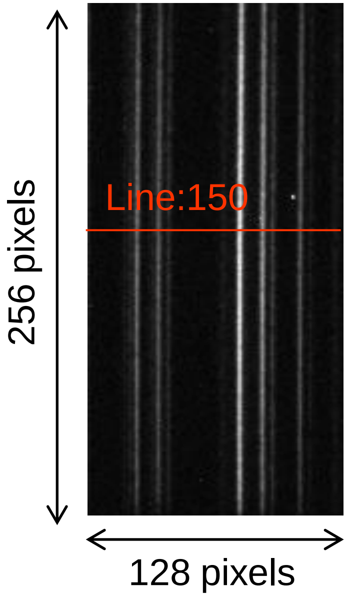


JPEG data size
Spec:
65536 bytes
→ 7252 bytes

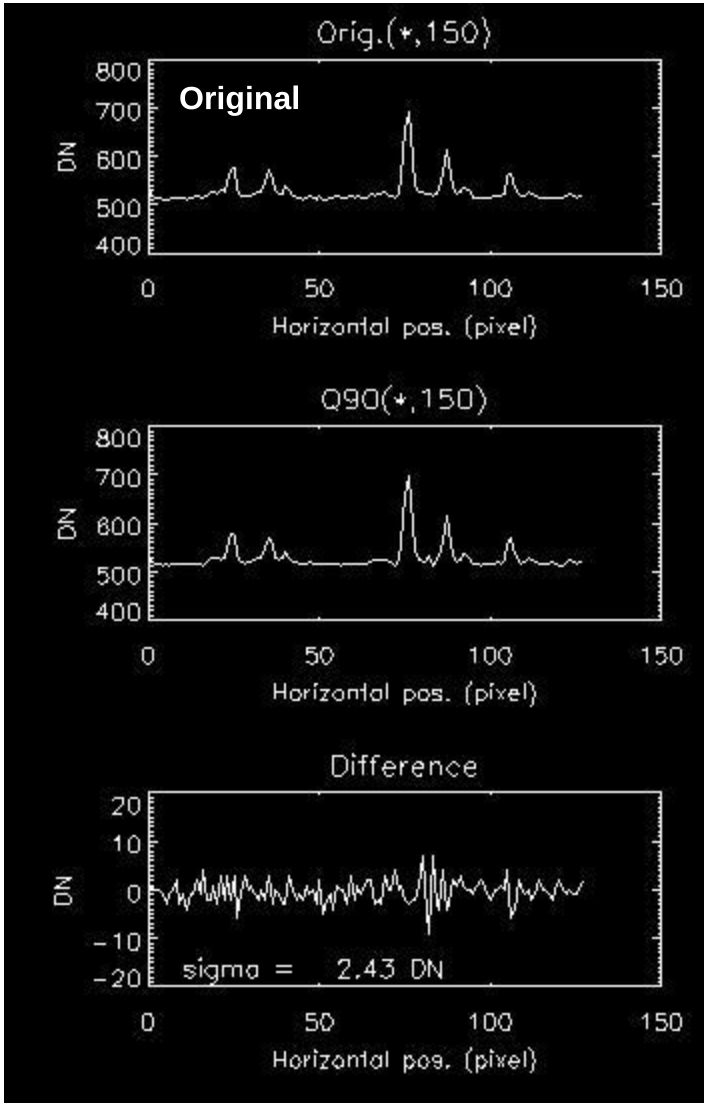
Comp. Factor = 9.04
or 11.1% of original data

Q=90

CAL2



128x256x2
= 65536 bytes

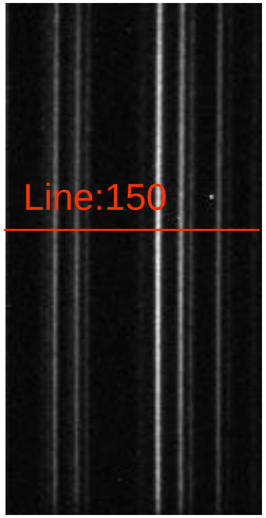


JPEG data size
Spec:
65536 bytes
→ 6368 bytes

Comp. Factor = 10.3
or 9.7% of original data

Q=85

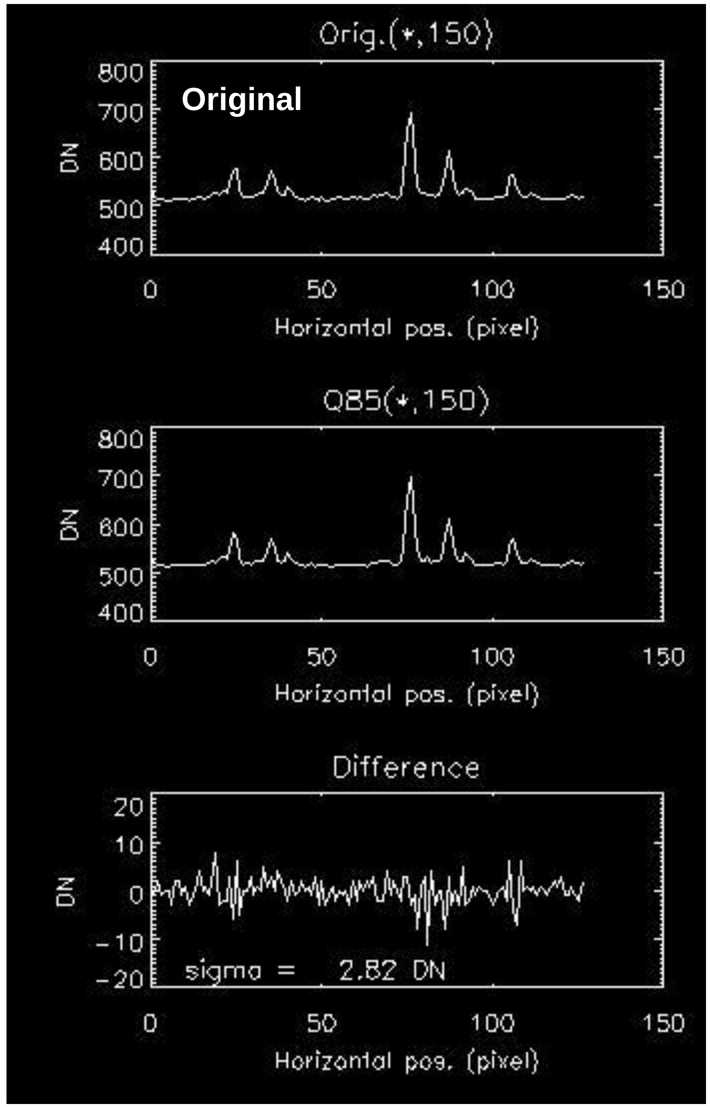
CAL2



256 pixels

128 pixels

128x256x2
= 65536 bytes

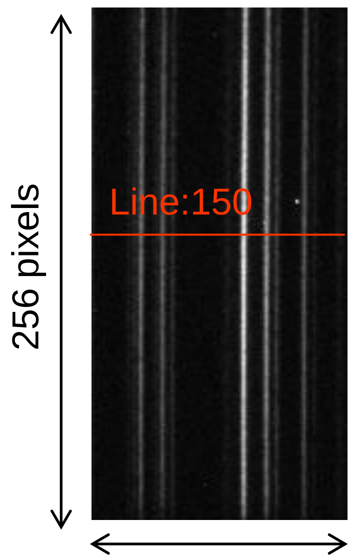


JPEG data size
Spec:
65536 bytes
→ 4832 bytes

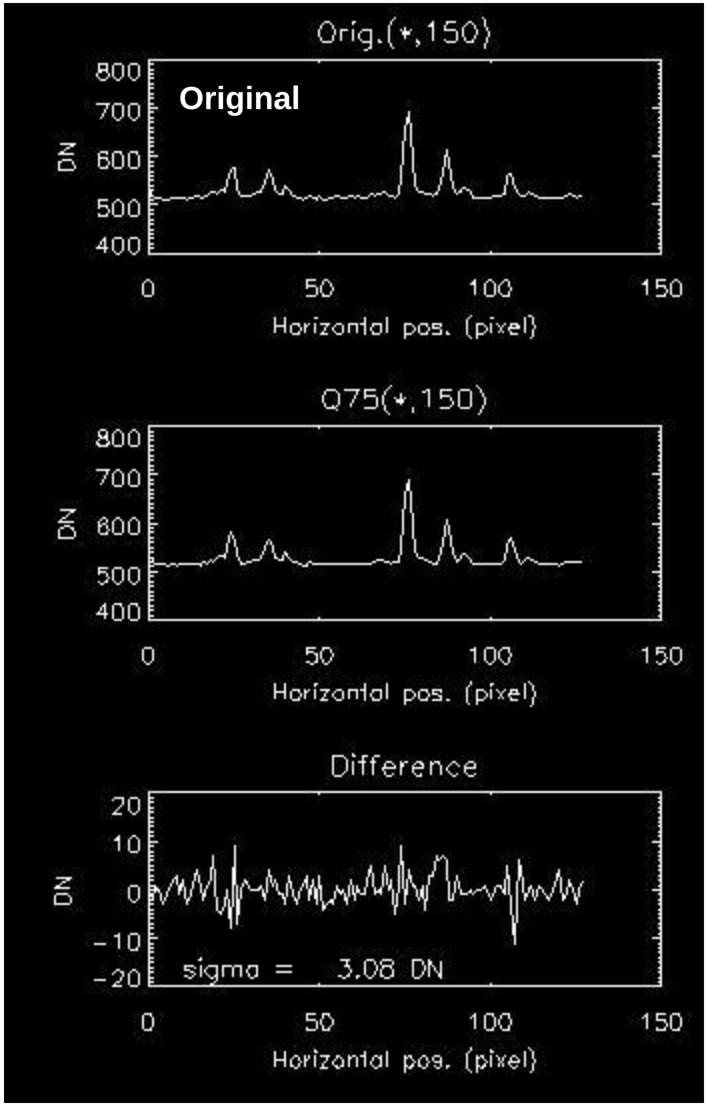
Comp. Factor = 13.6
or 7.4% of original data

Q=75

CAL2



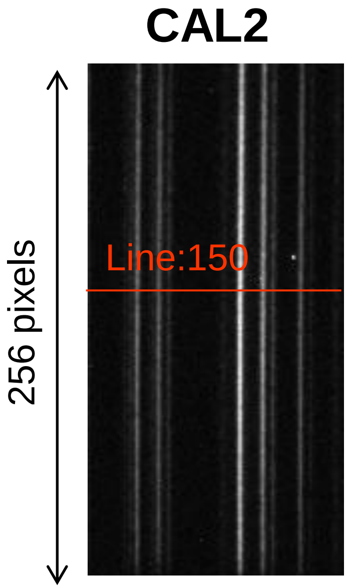
128x256x2
= 65536 bytes



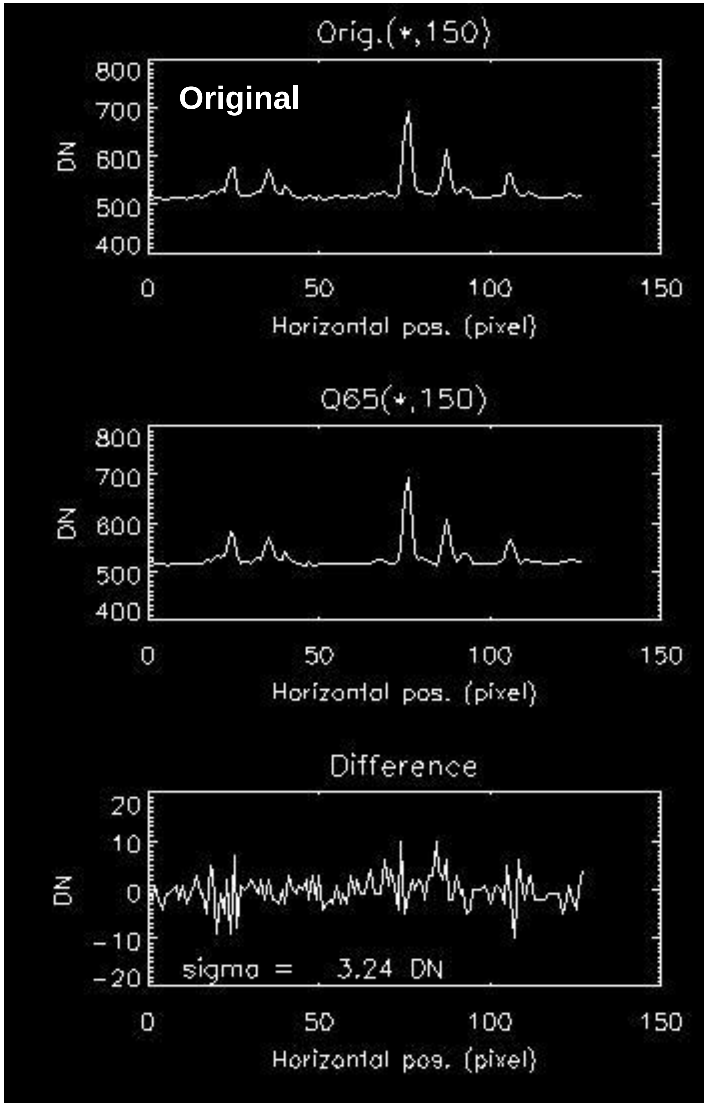
JPEG data size
Spec:
65536 bytes
→ 3588 bytes

Comp. Factor = 18.3
or 5.5% of original data

Q=65



128x256x2
= 65536 bytes

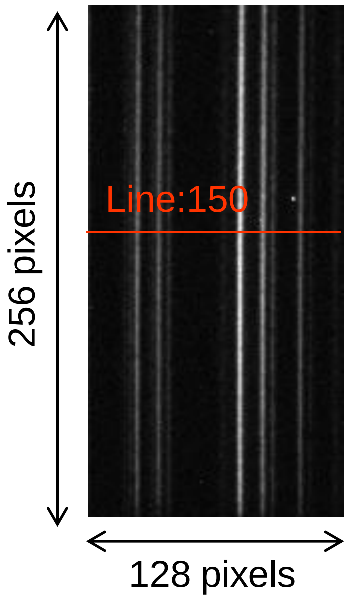


JPEG data size
Spec:
65536 bytes
→ 2962 bytes

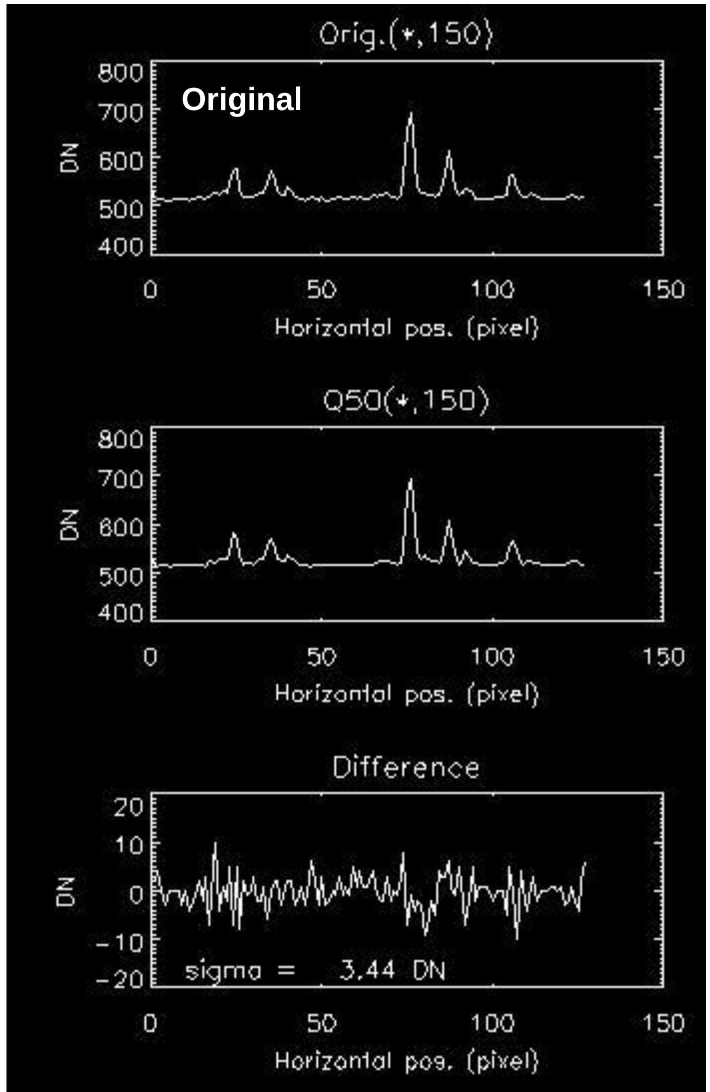
Comp. Factor = 22.1
or 4.5% of original data

Q=50

CAL2



128x256x2
= 65536 bytes



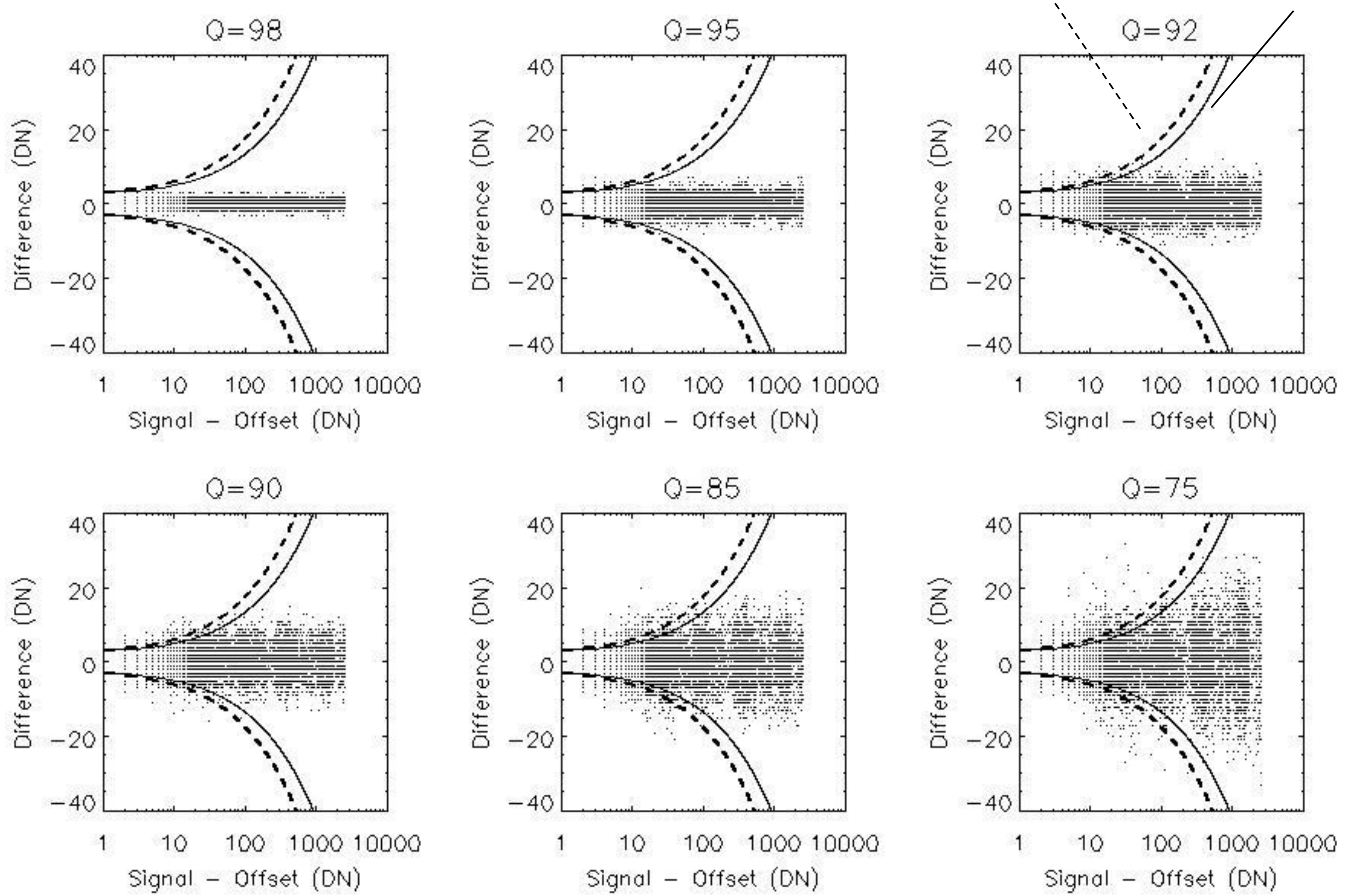
JPEG data size
Spec:
65536 bytes
→ 2496 bytes

Comp. Factor = 26.3
or 3.8% of original data

JPEG: Compression Error

X: signal – offset [DN] ; offset~ 500

Y: decomp(comp(Original)) – Original [DN]



Line Parameters by Gaussian Fitting

Data: **CAL2**

	Line 1 Peak (DN)	Center (pixel)	FWHM (pixel)	**Line 2** Peak (DN)	Center (pixel)	FWHM (pixel)	**Data size** (bytes)	**Comp. factor**
Raw	176.0	75.75	2.32	87.6	87.15	2.20	65536	1.00
	δ=±20	δ=±0.10	δ=±0.25	δ=±15	δ=±0.15	δ=±0.33		
		(± 3.7km/s)	(± 9.2km/s)		(± 5.6km/s)	(± 12km/s)		
DPCM	176.0	75.75	2.32	87.6	87.15	2.20	20436	3.21
JPEG								
Q=98	176.8	75.74	2.30	86.3	87.15	2.21	15058	4.35
Q=95	176.5	75.74	2.32	84.7	87.15	2.22	10096	6.49
Q=92	178.5	75.76	2.29	89.9	87.20	2.10	7252	9.04
Q=90	180.3	75.76	2.11	91.9	87.19	2.11	6368	10.29
Q=85	175.5	75.78	2.30	87.0	87.12	2.38	4832	13.56
Q=75	174.9	75.75	2.24	85.6	87.24	2.22	3588	18.27
Q=65	180.7	75.75	2.23	85.3	87.19	2.30	2962	22.13
Q=50	178.7	75.76	2.24	82.5	87.19	2.19	2496	26.26

Line Parameters by Gaussian Fitting

Data: **CAL3**

	Line 1 Peak (DN)	Center (pixel)	FWHM (pixel)	**Line 2** Peak (DN)	Center (pixel)	FWHM (pixel)	**Data size** (bytes)	**Comp. factor**
Raw	2383.37	62.08	2.56	513.1	91.77	2.67	65536	1.00
	$\delta=\pm 68$	$\delta=\pm 0.03$ (± 1.1km/s)	$\delta=\pm 0.08$ (± 2.9km/s)	$\delta=\pm 31$	$\delta=\pm 0.07$ (± 2.6km/s)	$\delta=\pm 0.17$ (± 6.3km/s)		
DPCM	2383.7	62.08	2.56	513.1	91.77	2.67	21406	3.06
JPEG								
Q=98	2385.8	62.08	2.56	512.7	91.77	2.66	16828	3.89
Q=95	2382.4	62.08	2.57	514.3	91.77	2.64	11784	5.56
Q=92	2381.7	62.08	2.57	518.5	91.78	2.60	8764	7.48
Q=90	2371.1	62.08	2.59	512.4	91.77	2.65	7818	8.38
Q=85	2378.4	62.09	2.58	522.2	91.79	2.66	6042	10.85
Q=75	2354.3	62.09	2.60	516.3	91.80	2.61	4432	14.79
Q=65	2329.5	62.09	2.62	522.1	91.78	2.62	3714	17.65
Q=50	2334.1	62.09	2.62	522.0	91.78	2.59	3110	21.07

CDS vs EIS

EIS has

- A larger effective area: $A_{EIS} \sim 10\ A_{CDS}$
- Higher spatial resolution: EIS: 2 arcsec CDS: > 5arcsec (out-of-focus)
- Higher spectral resolution: $R_{EIS} \geq 3\ R_{CDS}$

  $\Rightarrow$ measurement of emission-line width
- Larger FOV (EW$\times$NS): EIS 590”x512” CDS 240”$\times$240”
- Higher telemetry rate
- High compression performance: EIS DPCM/JPEG CDS loss-less
- Flare-temperature lines
- Automatic observation controls:

  Automatic exposure control, XRT flare response, EIS flare trigger

  EIS event trigger, anti-solar rotation compensation

Summary

- Use of JPEG compression is unavoidable even for EIS spectroscopic observations.
- Need more investigation on JPEG performance for a high data rate.