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VARIABILITY AND PROPERTIES OF THE QUIET SUN SUPERGRANULAR NETWORK AND INTERNETWORK

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Instruments : SUMER, CDS, MDI, (EIT) and TRACE

1 OBJECTIVE

The JOP proposes the simultaneous solar spectral line measurements in the chromosphere (SUMER), the transition region (SUMER,CDS) and in the corona (CDS). The aim is to trace the VARIABILITY and DYNAMICS of the solar quiet atmosphere in both THE SUPERGRANULAR NETWORK and INTERNETWORK focusing on the particular phenomena. The inevitable relevant MDI and TRACE photospheric information and UV imaging of TRACE (or alternatively EIT) are requested to be acquired at the same time with the highest possible spatial and temporal resolution.

2 SCIENTIFIC JUSTIFICATION

Previous observations performed with the CDS and SUMER instruments have revealed that the upper chromosphere and the transition region as well are not static, but display significant changes and variability even in case of the quiet solar atmosphere (see e.g. review Judge, 1997, contributions of Betta et al., 1997, Steffens et al., 1997, or Wikstol et al., 1997). These findings support few older results obtained from different instruments, e.g. HRTS time series (Cheng, 1991). Our previous observations of the chromosphere and the transition region made only with the SUMER spectrometer (UDP 8.1.2.66, Curdt et al., 1997a) have confirmed those results. They have shown additionally, that the temporal variability of the spectral lines originated in those layers is significantly different in the supergranular boundaries and internetwork (Curdt et al., 1997b, Kučera et al., 1998). MDI magnetograms taken simultaneously with the 2D CDS rasters of the coronal line intensities have shown that the occasional merging of the opposite magnetic polarities in the supergranular boundaries correlate with the coronal emission brightening above these quiet solar atmosphere regions. The concept of 'magnetic carpet' was proposed as the explanation of this phenomenon (e.g. Tarbell, 1997, Judge, 1997, Schrijver, 1997). The behaviour of these phenomena in the chromosphere and the transition region has not be revealed by observations till now.

Therefore the present JOP is proposed to trace such behaviour. Our aim is to study the supergranular network and internetwork, addressing the detailed temporal and spatial evolution of different events through the solar atmosphere. Significant volume of data obtained from the equatorial coronal holes as well as outside of them would be advantageous for the sufficiently reliable investigation.

The careful planing of the necessary data acquisition for the post-facto alignment has been performed in order to reach the highest possible adjustment of SUMER slit position within the field of view (FOV) of other instruments.

The proposed JOP is similar to some other ones which are focused mainly on the internetwork research (e.g. JOPs 013, 022) or on active regions (e.g. JOPs 017, 018, 034, 075).

3 DESCRIPTION OF THE JOINT OPERATION OF INSTRUMENTS

We propose simultaneous measurements of SUMER and CDS spectrometers for an interval of few hours and for several days in order to acquire sufficiently large material. This material is necessary for the studying of the variability and behaviour of spectral lines in the particular phenomena. The required MDI operation providing the photospheric information on interval of few hours is essential for the understanding of these phenomena. If the TRACE (or alternatively EIT) could cooperate with the proposed SOHO JOP at least for a part of the SOHO observing runs, it will be also very important.

The SUMER should use a fixed 1D slit position. The CDS should mostly provide information from a 2D FOV pointed around the SUMER position in order to overlap SUMER and CDS data post-facto. Special measurements, incorporated to this JOP, are proposed to reach a more precise determination of the SUMER slit position in the CDS 2D FOVs (the practical precision of CDS and SUMER pointing is roughly ±5").

The photospheric physical quantities are proposed to be measured with the MDI instrument simultaneously on a more extended FOV (300"x500") than in the case of SUMER and CDS instruments (SUMER : 1"x120", CDS : from 2"x140" to 124"x244"). The proposed TRACE operation includes also the collection of photospheric continuum images. The extended SUMER RSC measurements are scheduled for the co-alignment of the SUMER slit position with the photospheric images taken by MDI and TRACE.

SUMER and CDS observations are proposed to be carried out various modes (sequence parts) to determine both the temporal and spatial behaviour of the spectral lines. The MDI and EIT observations are proposed to be performed in a single mode over the whole JOP run. TRACE should work in 2 different modes carried out sequentially.

Basic summary of the simultaneous SOHO(MDI/SUMER/CDS/(EIT)) and TRACE operations :

- **MDI :** high resolution I_{cont}, V_{Dopp}, B_{long} measurements in the limited 2D FOV around the disk center
- **SUMER :** the spectral line profiles taken with the fixed slit pointed at the disk center at the beginning. The continuous on-line compensation of the solar rotation is required
- **CDS :** mostly the rasters of spectral profiles taken by 2D sequential scanning around the disk center (SUMER slit position) in a tall and narrow 2D FOVs. The continuous on-line compensation of the solar rotation should be also included
- **TRACE :** 2D images of the specified limited FOV with the highest possible cadence of frames
- **EIT :** 2D images in the selected spectral bandpasses taken from the specified limited FOV with the cadence of frames as high as possible.

Target region : the disk center, quiet region covering both the supergranular boundary and the internetwork, inside and outside of the equatorial coronal hole if possible.

4 MDI observing details

- operation mode : high resolution campaign mode during the daily 8-hour period for the SOI/MDI "associated" science objectives

- campaign type : cam_hr_t_ve_fe_me : 3 frames (the Doppler velocities, continuum intensities, the longitudinal magnetic field) taken and transfered in each minute
- dimensions : horizontal (EW) : 500 pixels = 300”, vertical (NS) : 1024 pixels = 500”
- tracking of the solar rotation
- telemetry : high rate telemetry (HRT) with the compressed data flow

5 SUMER observing details :

Various sequence parts are proposed to cover the behaviour of the selected spectral lines. The long-duration sequences of 1D measurements are chosen to measure behaviour of the spectral line intensities, velocities and widths. The fast changes of the most pronounced lines will be investigated by using of the short-duration sequences. The 100% duty cycle is planned for the measurements with the maximal exploitation of the available telemetry channel throughput.

5.1 SUMER 1 spectral lines set :

Spectral line	Wavelength [Å]	Temperature (Wilhelm, 1995)
H I Ly β	1025.400	2.0×10^4 K
O I	1027.430	$<1.0 \times 10^4$ K
O VI	1037.613	3.0×10^5 K
C II	1037.018	3.0×10^4 K
Si XII	520.666	2.0×10^6 K

Table 1: The SUMER 1 spectral line set : wavelength interval : 1020.5 – 1041.5 Å.

Spectral image positions : 6 spectral images, each 25pixels wide :
1/ 1025.4 Å : two 25pixels windows = 50pixels wide : H I Lyβ line core
2/ 1027.430 Å : one 25pixels window : O I line
3/ 1036.4-1038.6 Å : two 25pixels windows = 50pixels wide : C II, O VI lines
4/ 520.666 Å (1041.133 Å) : one 25pixels window : Si XII line, (2nd order)

Setup : slit 4 (1”x120”), S-N orientation
binning 1 1
rot_comp ON
KBr part of the detector (or H I line out of it)
number of pixels : spectral : six 25pixel windows
spatial : 120 pixels
image format : 14 (25 spectral x 120 spatial pixels)
compression m=5 quasilog(min,max)
Flat field correction onboard OFF
Almost 100% duty cycle of the data integration – T_{exp}=15 sec

5.2 SUMER 2 spectral lines set (SUMER & CDS co-alignment) :

The most favourite common spectral line (He I 584 Å), observable with both SUMER and CDS instruments, was selected for the simultaneous measurements. The reason is to get the highest possible post-facto determination of the SUMER slit position within the CDS FOVs (the post-facto alignment).

Spectral image positions : 2 spectral images, each 25pixels wide :
1/ 2x584.33 Å : two 25pixel windows = 50pixels wide : He I line in the second order

Spectral line	Wavelength [Å]	Temperature (Wilhelm, 1995)
He I	584.33 Å (2nd order)	2.0x10^4 K

Table 2: The SUMER 2 spectral line set : wavelength interval : 583.76 – 584.89 Å.

Setup : slit 4 (1"x120"), S-N orientation
binning 1 1
rot_comp ON
KBr part of the detector
number of pixels : spectral : two 25pixel windows
spatial : 120 pixels
image format : 14 (25 spectral x 120 spatial pixels)
compression m=5 quasilog(min,max)
Flat field correction onboard OFF
Almost 100% duty cycle of the data integration – T_{exp}=5 sec

5.3 SUMER RSC run (SUMER & MDI and TRACE co-alignment) :

The special long-term SUMER rear slit camera (RSC) measurements carried out before the simultaneous SUMER/CDS/MDI/(EIT) and TRACE observations are proposed for the post-facto alignment of the SUMER slit position with the MDI and TRACE FOVs. The SUMER RSC photospheric intensity image, constructed from the RSC measurements taken without the solar rotation compensation, would be later co-aligned with the MDI and TRACE continuum images that will be taken at least few seconds after the end of SUMER RSC data acquisition. We expect to identify some pores which could help us to improve specification of the SUMER slit position better than expected intrinsic ±5" in the MDI and TRACE continuum images.

Setup :

Slit	: slit 4 (1" x 300")
Steps	: x = 0.0" y=0"
Integration time	: to fill optimally the dynamic range (8bits)
Dwell time	: 10 sec

The matrix of at least 110x120 pixels (55″x120″) with the real resolution of about 2″and the SNR of about 4000 should be constructed on the ground. The proposed minimal parameters of the RSC run are :

5.4 SUMER & EIT co-alignment :

In principle, this alignment can be made in two ways. In both ways the described SUMER & CDS alignment has to be used to specify the SUMER slit in the CDS 2D FOVs. Then only the CDS & EIT co-alignment can be performed in order to obtain the required SUMER & EIT alignment.

1. The first way is based on the comparison of the CDS He I 584 Å 2D movies and rasters (described below) and the simultaneously taken EIT He II 304 Å bandpass images. The correlation of intensities of these lines was reported to be high - r>0.9 (Andretta et al., 1997).

2. The second approach is to exploit the CDS 2D rasters taken during the CDS density-sensitive diagnostics part (see CDS sequence part 6) in which also in the He II 304 Å line is included. These CDS rasters should be acquired simultaneously with the EIT imaging in the same line.

Both types of measurements were included to the present JOP, namely 584 Å line was included to all CDS sequence parts and the 304 Å line is proposed to be used in the CDS sequence part 6, but together with the 584 Å line.

Total time	: few hours (e.g. 5 hours 55″)
Total number of exposures	: (1800)
Number of exposures per Y=2 ″	: app. 50

5.5 SUMER auxiliary measurements :

Flat-field frames taken before and after the JOP runs and the information on the temporal behaviour of the SUMER internal temperature are essential for the precise data reduction including the estimation of noise (Curdt et al., 1997a).

5.6 Summary of the SUMER observing run sequences :

The brief description of the proposed procedure of the SUMER sequence parts, together with the timing, are given below in the following tables :

Sequence part	Type of measurements	Line set	Remarks
0	RSC measurements	–	SUMER & MDI and TRACE alignment
1	1D slit slow measurements	2	SUMER & CDS alignment
2	1D slit slow measurements	1	data downloaded on-line
3	1D slit position burst sequence	1	data stored in onboard RAM
4	–	–	Telemetry of data stored in RAM

Table 3: The brief description of the SUMER sequence parts.

		Sequence parts				
		0	1	2	3	4
Parameters	Units	RSC run	SUMER set 2	SUMER set 1		Telemetry
Integration time	sec	0.2	5	15	2.5	-
Compression + telemetry	sec	0.4	5	15	-	15
Number of exposures		(1800)	984	1200	300	-
Total time	min	(300)	82	300	12.5	75

Table 4: The timing and basic parameters of the SUMER sequence parts.

6 CDS observing details

Various modes of CDS observations (2D movies, 2D raster, 1D sequences) are proposed. All CDS data will be obtained with the normal incidence spectrometer (NIS). The CDS procedure is optimized in order to get the full spectral profiles of different spectral lines, originated in different layers of the solar atmosphere in the larger 2D FOV around the fixed SUMER 1D slit position. The 100% duty cycle is planned for the measurements to optimize the telemetry.

The brightest spectral lines were selected for the diagnostics of the plasma dynamics (*"dynamics diagnostics lines"*) with an attempt to cover wider range of temperatures : He I 584.33 Å (2.0x10^4 K), O V 629.74 Å (2.5x10^5 K), Mg IX 386.04 Å (1.0x10^6 K), Si XII 520.67 Å (2.0x10^6 K).

Measurements planned for the diagnostics of the plasma density (*"density diagnostics lines"*) are also included in the JOP (temperatures around 10^6 K, densities in the interval $10^{7.5}$-$10^{10.0}$ cm^{-3}). Namely 4 density-sensitive lines were selected for the plasma density estimation (after Mason, 1997) : Si IX 349.87 + 345.13 Å, Si X 356.03 + 347.40 Å.

The previous 4 "dynamics diagnostics lines" (He I 584.33, O V 629.74, Mg IX 386.04, Si XII 520.67 Å) and also 6 additional lines (He II 304 A, Fe XVI 335.40, Fe XV 360.76, Fe XII 354.47, O III 599.59, Mg X 624.94 Å) have been selected for the simultaneous measurements together with the density-sensitive lines. The reason is the check of the possible blends in some "dynamics diagnostics lines" which should appear at higher levels of activity (Brekke et al., 1997). The other reason is the co-alignment of the CDS and EIT data.

The He I 584 Å spectral line was selected for the fine SUMER & CDS post-facto co-alignment. The CDS should work in the movie mode and also in 2D rastering around the central slit position. As the telemetry allows to transfer other data too, the O V 629.74 and Mg IX 386.04 lines were included to the SUMER & CDS co-alignment sequence part.

CAUTION : The CDS dwell times are estimated ONLY on the base of different papers where such information was reported (e.g. Ruedi et al., 1997 and some JOPs). Therefore the introduced timing of CDS parts has to be calculated and the total number of exposures or scans must be optimized to fill the required duration of different parts of observations (SUMER & CDS Alignment, "dynamics diagnostics", "density diagnostics") in order to keep the proposed schedule of measurements.

6.1 CDS sequence part 1 : CDS & SUMER co-alignment

Large FOV movie of the disk center area :

Lines : He I 584.33, O V 629.74, Mg IX 386.04 Å
Slit : 90" x 240"
Detector Area (HxV) : 61 x 120 pixels = 124" x 244"
Steps : 0", 0"
Number of exposures : 60
Exposure Time : 25 seconds (+ app. 6 seconds overhead) -> 31 seconds
Duration : 60 x 31 = 1860 sec = 31 min
Telemetry/Compression : truncate to 12bits

6.2 CDS sequence part 2 : CDS & SUMER alignment

Small FOV movie of the disk center area :

Lines : He I 584.33, O V 629.74, Mg IX 386.04 Å
Slit : 90" x 240"
Detector Area (HxV) : 13 x 70 pixels = 26" x 142"
Steps : 0", 0"
Number of exposures : 300
Exposure Time : 5 seconds (+ app. 2 seconds overhead) -> 7 seconds
Duration : 300 x 7 = 2100 sec = 35 min
Telemetry/Compression : truncate to 12bits

6.3 CDS sequence part 3 : CDS & SUMER alignment

2D sequential raster of the disk center area :

Lines : He I 584.33, O V 629.74, Mg IX 386.04 Å
Slit : 2" x 240"
Detector Area (V) : 70 pixels = 142"
(H) : 21, 21, 25 pixels, respectively

Steps : 2", 0"
Number of positions per raster : 13
Number of rasters : 10
Number of exposures : 13 (per raster) x 10 (rasters) = 130
Exposure Time : 5 seconds (+ app. 7 seconds overhead) -> 7 seconds
Duration : 10 x (13 x 7) = 10 x 97 sec = 970 sec = 16 min
Telemetry/Compression : truncate to 12bits

6.4 CDS sequence part 4 : "dynamics diagnostics"

2D sequential raster of the disk center area :

Lines : He I 584.33, O V 629.74, Mg IX 386.04, Si XII 520.67 Å
Slit : 2" x 240"
Detector Area (V) : 70 pixs = 142"
(H) : 21, 21, 25, 15 pixels, respectively
Steps : 2", 0"
Number of positions per raster : 11
Number of rasters : 204
Number of exposures : 11 (per raster) x 120 (rasters) = 1320
Exposure Time : 5 seconds (+ app 3 seconds overhead) -> 8 seconds
Duration : 204 x (11 x 8) = 204 x 88 sec = 18000 sec = 300 min
Telemetry/Compression : truncate to 12bits

6.5 CDS sequence part 5 : "dynamics diagnostics"

1D position in the center of the previous 2D rasters of the disk center area :

Lines : He I 584.33, O V 629.74, Mg IX 386.04, Si XII 520.67 Å
Slit : 2" x 240"
Detector Area (V) : 70 pixs = 142"
(H) : 21, 21, 25, 15 pixels, respectively
Steps : 0", 0"
Number of exposures : 240
Exposure Time : 5 seconds (+ app. 3 seconds overhead) -> 8 seconds
Duration : 240 x 8 = 1920 sec = 32 min
Telemetry/Compression : truncate to 12bits

6.6 CDS sequence part 6 : "density diagnostics"

2D sequential raster of the disk center area :

Lines : A/ 4 density diagnostic lines : Si IX 349.87 + 345.13 Å, Si X 356.03 + 347.40 Å
B/ 4 dynamics diagnostic lines: He I 584.33, O V 629.74, Mg IX 386.04, Si XII 520.67 Å
C/ 6 additional lines : Fe XVI 335.40, Fe XV 360.76, Fe XII 354.47,
He II 304 A, O III 599.59, Mg X 624.94 Å
Slit : 2" x 240"
Detector Area (V) : 70 pixs = 142"
(H) : A/ interval : 344.5 - 351.0 Å = 6.5 Å = 82 pixels
A/ interval : 354.5 - 357.5 Å = 3.0 Å = 38 pixels

B/ dynamics diagnostics lines : 4 x 33 pixels
C/ additional lines : 6 x 33 lines

Steps : 2", 0"
Number of positions per raster : 11
Number of rasters : 5
Number of exposures : 11 (per raster) x 5 (rasters) = 55
Exposure Time : 55 seconds (+ app. 5 seconds overhead) -> 60 seconds
Duration : 5 x (11 x 60) = 5 x 660 sec = 3300 sec = 55 min
Compression/Telemetry : none, 16bits data transfered

6.7 Summary of the CDS observing run sequences :

The brief description of the proposed CDS procedure of the selected sequence parts, together with the timing, are given below in the following tables :

Sequence part	Type of measurements	Remarks
1	disk center large FOV movie	CDS & SUMER co-alignment
2	disk center small FOV movie	CDS & SUMER alignment
3	disk center 2D raster	CDS & SUMER alignment
4	disk center 2D raster	"dynamics diagnostics"
5	1D position at the disk center	"dynamics diagnostics"
6	disk center 2D raster	"density diagnostics"

Table 5: The brief description of the CDS sequence parts.

		Sequence parts					
Parameters	Units	1	2	3	4	5	6
Integration time	sec	25	5	5	5	5	55
Compress.+telem. time	sec	31	7	7	8	8	60
Exposures per raster		60	300	13	11	240	11
Rasters per part		1	1	10	204	1	5
Total time	min	31	35	16	300	32	55

Table 6: The timing and basic parameters of the CDS sequence parts.

7 EIT observing details

As a backup possibility for the case, if the TRACE is not available, the EIT imaging measurements in the limited FOV with the highest possible frame cadence are proposed. The EIT is worser (backup) alternative of the TRACE measurements due to the decrease of the frame cadence, decrease of the practical spatial resolution and also due to loosing of the Ly α bandpass.

FOV (HxV) : 2x4 32x32 sub-arrays (166.4" x 332.8")
Bandpasses : Fe IX-X 171 Å (1.3x10^6 K), He II 304 Å (8.0x10^4 K)
Compression : square root (roughly 1:2) and ADCT (1:5), frame volume decrease from 112 kb to roughly 12kb
Telemetry : $<$ 20 sec
Exposures : 171 Å : 12 sec, 304 Å : 52 sec
Dwell time : 8 sec (readout, CCD clearing)

Cadence : 171 Å : 20 sec, 304 Å : 9 min

Order : After each 27 Fe IX-X 171 Å frames acquired in a sequence (9 min) one He II 304 Å frame should be inserted with the resulting cycle time of 10 minutes

Total time : up to app. 7 hours

8 TRACE observing details

The TRACE observations are proposed to be acquired as the addition to this SOHO JOP. The reason is to perform imaging with higher spatial and temporal resolution comparing to the CDS and EIT instruments.

The limited FOV and the data compression are proposed in order to speed up the frame cadence. Therefore the data will be taken only in the nearest vicinity of the SUMER and CDS FOV. The proposed data compression should be nearly lossless.

The main TRACE sequence part is scheduled as a repetition of image acquisition in 3 wavelengths in a cycle for a longer time interval covering the SOHO observing run. The secondary TRACE sequence part should acquire almost continual flow of images in each selected wavelength in order to check possible changes on the shortest time scales. The TRACE visible continuum image is also included for the fine co-alignment of TRACE images with the SOHO data.

In case of some time schedule constrains the proposed TRACE operation (the sequence parts and their parameters) can be modified according to the other TRACE proposals.

Preliminary setup : FOV (EWxNS) : 127.5" x 255" (256 x 512pixels),
no binning,
compression : TraceQ=1, QT=1, HT=0, 3.85 bits/pixel

The main sequence part : acquisition of images in 3 wavelength channels in a cycle. The order can be modified to optimize the quadrant shutter and filter wheel operation.

selected channels : 1/ 5000 Å continuum (4.0-6.4x10^3 K)
2/ 1216 Å Ly α (10-30x10^3 K)
3/ 171 Å Fe IX-X (160-2000x10^3 K)

estimated exposure times : 1/ 5000 Å : 0.1 sec (for 1/2 well or 2084DN)
2/ 1216 Å : 15 sec (for 1/10 well or 410DN)
3/ 171 Å : 15 sec (for 1/20 well or 205DN)

estimated dwell time : readout + compression + data processing +
compression + transfer to mass memory : 1.25 sec
quadrant shutter movement : <=1.6 sec
filter wheel movement : <=1.7 sec
focusing : 2 sec

total time of the observing cycle : 1x1.25 + 2x13.75 + 3x5.3 = 44.2 sec

estimated data volume per hour : 14.4MB

The secondary sequence part : the sequential acquisition of images in channels 2/ and 3/, each for at least a half an hour. This will lead to almost 100% duty cycle in channels with the following parameters :

exposure time : 15 sec

estimated dwell time : none

total time of the observing cycle : 120 exposures x 15 sec = 1800 sec

estimated data volume per hour : 2 x 7.57MB = 15.14MB

total duration of this sequence part : 1.5 hours

9 SOHO AND TRACE SCHEDULE OF OBSERVATIONS

The following table provides the proposed combination of the required sequence parts of different instruments. Three basic observing regimes, planned for the CDS and SUMER instruments (SUMER & CDS alignment; "Dynamics diagnostics"; "Density diagnostics"), should be started roughly at the same time at the beginning of observations ! The MDI, EIT and TRACE measurements could also start at the same time, but definitely their measurements must start not later than the "dynamics diagnostics".

The MDI and EIT observing modes should be identical during the whole duration of the proposed run. For the TRACE it is supposed to run the main sequence part during both, the "alignment SUMER & CDS" and "dynamics diagnostics" observations. The TRACE secondary part is scheduled to start after the end of the main part.

It would be welcome to obtain long observing time for MDI and TRACE runs to have a possibility to map the evolution of the atmosphere over a longer time interval.

	Sequence parts				Total time [min]
Instrument (Time)	Alignment SUMER & MDI	Alignment SUMER & CDS	Dynamics diagnostics	Density diagnostics	
SUMER (minutes)	part0 (300)	part1 82	part2 300	parts 3+4 12.5+75	(300) + 469.5
CDS (minutes)	- 0	parts 1+2+3 31+35+16	part4 300	parts5+6 32+55	469
MDI (minutes)	- 0	Constant operation mode (82 + 300 + at least 32)			at least 414
TRACE (minutes)	- 0	Main part (82 + 300)		Secondary part 3x30	at least 472
EIT (minutes)	- 0	Constant operation mode (82 + 300 + at least 32)			at least 414

Table 7: SOHO & TRACE schedule of observations.

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