SOHO Joint Observing Plan 002
TEMPERATURE GRADIENT IN A CORONAL HOLE

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Objective: To determine the onset region of the solar wind by measuring the vertical temperature gradient in a polar coronal hole.

Scientific Justification: Our knowledge of coronal temperatures in open-field (coronal hole) regions is very limited. The intensity of spectroscopic emission is very small, perhaps between 20 and 100 times less than the closed field regions, due to the lower density by a factor of the order 5 or more. SKYLAB observations have shown that ions typical of temperatures around 1 10^6 K dominate, but clearly these temperatures are limited by sensitivity to the first density scale height in the corona. Important questions regarding the role of coronal holes in the acceleration of the solar wind demande better information on the variation with height of the coronal temperature.

Thermal models (eg Parker) of the solar wind acceleration require high temperatures at the base of the wind. To explain the observed wind velocity we need temperatures of the order 4 10^6 K. Such high temperatures are not excluded by the present observations if the maximum occurs at heights not yet observed in emission. However some recent models of the wind acceleration propose direct transfer of momentum from Alfven waves to the medium, without dissipation; that is without requiring high temperatures. In this case the 1 10^6 K observed could be the maximum, and the temperature could fall progressively at greater heights. Thus the determination of the temperature gradient between 1' and 5' above the limb becomes a critical measurement.

Method: To measure the temperature, we depend upon a temperature-dependent spectral line ratio. As the line-of sight is perpendicular to the principal temperature gradient, we can propose to use a very sensitive line ratio, and interpret the ratio in terms of a local isothermal plasma. We avoid using ionisation ratios or differential emission measure analyses, since these are based on the assumption of ionisation equilibrium, which might not be valid in low density solar wind conditions. However, we include a set of Iron ion lines for a DEM complementary analysis, which might give added information. Since the region scanned (0 to 5 arcmin) could cover a range of temperatures, we choose a lithium-like ion, which is generally present over a wide range. The most sensitive ratio, taking account of solar abundance is that of oxygen VI, 2s-2p / 2s-3d.

This ratio of lines at 1036 Å and 173 Å requires that one of the lines is observed by the SUMER instrument and the other by the CDS. There will clearly be some concern about the relative calibration at these two wavelengths, since they arise from different instruments, with perhaps inprecise fields of view. However we do not need absolute information for this ratio. It will be sufficient to see how the temperature increases or decreases above the limb, and to rely on the sun itself to provide the absolute temperature calibration at the base.

Pointing and Target Selection: In view of the low emission of this part of the corona, the only means to measure the temperature is by observations tangentially at the limb. Coronal holes can exist at the poles of the sun, particularly around solar minimum when SOHO will be launched. Holes will also exist from time to time at lower latitudes. However, such low latitude holes will in general have a much smaller extent in the line of sight. In view of their low emissivity, their brightness will normally be contaminated by non-hole regions in the line-of-sight in front of, and behind, the hole. For reliable observations we are thus limited to the polar holes, which will not suffer from this line-of-sight effect.

Since the SUMER and CDS slits are normally aligned N-S, it is necessary for this measurement to rotate (roll) the spacecraft by 90 degrees, in order to place the slits tangential to the limb at the poles. This manoevre has been discussed and approved by the SWT, on the basis of a maximum period of 16 hours in the rolled position every 2 months.

Operating Details: Measurements of 1032 Å and 1038 Å lines with SUMER present no problems as the lines are intense. For the 173 Å line from CDS however there is a problem of intensity. If we choose the 8" $\times$ 240" slit (provided for the NI channel) with the grazing incidence channel, and align this parallel to the solar limb, then it is possible to propose a sequence of 80 stepped positions starting just inside the limb with 25 s exposures and finishing at 5 arcmins above the limb with 2500 s exposures. This sequence takes a total of 13 hours and gives 5% photon counting statistics per position. It is however necessary to re-orient the roll position of SOHO by 90 degrees to achieve this measurement.

CDS Programme :

PHASE 1

Spectrometer:	Grazing Incidence
Slit:	4 $\times$ 240 arcseconds
Raster Area:	80 $\times$ 240 arcseconds
Step (DX, DY):	4 arcseconds, 0 arcseconds
Raster Locations:	20 $\times$ 1 = 20
Exposure Time:	100 seconds
Duration of Raster:	2020 scconds
Number of Rasters:	1
Total Duration:	2020 seconds (incl. overheads)
Line Selection:	Full GIS output
Bins Across Line:	N/A
Telemetry/Compression:	No compression

PHASE 2

Spectrometer:	Grazing Incidence
Slit:	4 $\times$ 240 arcseconds
Raster Area:	144 $\times$ 240 arcseconds
Step (DX, DY):	8 arcseconds, 0 arcseconds
Raster Locations:	18 $\times$ 1 = 18
Exposure Time:	1000 seconds
Duration of Raster:	18200 seconds
Number of Rasters:	1
Total Duration:	18200 seconds (incl. overheads)
Line Selection:	Full GIS output
Bins Across Line:	N/A
Telemetry/Compression:	No compression

PHASE 3

Spectrometer:	Grazing Incidence
Slit:	4×240 arcseconds
Raster Area:	96×240 arcseconds
Step (DX, DY):	12 arcseconds, 0 arcseconds
Raster Locations:	$8 \times 1 = 8$
Exposure Time:	5000 seconds
Duration of Raster:	40400 seconds
Number of Rasters:	1
Total Duration:	40400 seconds (incl. overheads)
Line Selection:	Full GIS output
Bins Across Line:	N/A
Telemetry/Compression:	No compression
Grand Total Duration:	16.8 hours
Pointing	Phase 1: FOV centre to 24 arcsec above limb Phase 2: FOV centre to 136 arcsec above limb Phase 3: FOV centre to 256 arcsec above limb NOTE SPACECRAFT ROLL
Flags:	Will not be run in response to inter-instrument flag and should not be run with CDS as flag Master or Receiver.
Solar Feature Tracking:	Not required
Frequency:	Should be run on a few occasions during mission especially when spacecraft rolled by 90°

Product: Scan of all GIS spectrum from 16 arcsec within limb to 304 arcsec above limb, from a 240 arcsec wide swath.

SUMER Programme Item 1:

Interruption or flag mode:	No interruption.	
Slit 1 with	1*300 arcsec^2.	
Initial pointing:	(x_{ii}) = 0.00 arcsec	
	(y_{ii}) = 986.00 arcsec	
SOHO roll angle:	90.0000 deg	
Solar rotation:	No compensation.	
Binning	(spectral) = 1	
	(spatial) = 1	
Compression:	5. Quasilog_min_max	(0.92 s)
Reference pixel 1:	500 on detector A	
Flat-field correction:	OFF	
Ion(s) in band 1:		
	O VI .... 1031.91 Å	
	O VI .... 1037.61 Å	
Spectral window(s) (pixel)	50	
Image format:	Format #8 (50*360, B1);	2 time(s)
Spectrohelio mode:	Spectrohelio 1	
Scan from South to North.		
Integration time:	25.0000 s	
Step size:	0.380000 arcsec or 1 units.	
Step number:	52	
Step mode:	Normal steps	
Repetition number:	1	
Staggering:	1	
Your selection requires		
a telemetry rate:	11.5200 kbit/s	
Bitrate:	10.0000 kbit/s	
This item will run		
for approximately:	22.3818 minutes	
and will cover a solar area defined by		
300 px time(s)	19.76 arcsec ^{2}	

Note that the memory monitoring and the run times are not very accurate. The run times just give the total exposure times with a margin of 1%. More detailed information can be provided by the SUMER Simulator.

All items up to now will run	
for approximately	22.3818 minutes

SUMER Programme Item 2:

Interruption or flag mode:	No interruption.	
Slit 1 with	4*300 arcsec^2.	
Initial pointing:	(x_{ii}) = 0.00 arcsec	
	(y_{ii}) = 1148.00 arcsec	
SOHO roll angle:	90.0000 deg	
Solar rotation:	No compensation.	
Binning	(spectral) = 1	
	(spatial) = 1	
Compression:	5. Quasilog_min_max	(0.92 s)
Reference pixel 1:	500 on detector A	
Flat-field correction:	OFF	
Ion(s) in band 1:		
	O VI .... 1031.91 Å	
	O VI .... 1037.61 Å	
Spectral window(s) (pixel)	50	
Image format:	Format #8 (50*360, B1);	2 time(s)
Spectrohelio mode:	Spectrohelio 1	
Scan from South to North.		
Integration time (low):	25.1355 s	
Integration time (high):	2903.23 s	
Step size:	3.80000 arcsec or 10 units.	
Step number:	80	
Step mode:	Normal steps	
Repetition number:	1	
Staggering:	1	
Your selection requires		
a telemetry rate from:	0.0991997 kbit/s	
to:	11.4579 kbit/s	
Bitrate:	10.0000 kbit/s	
This item will run		
for approximately:	840.971 minutes	
and will cover a solar area defined by		
300 px time(s)	304.000 arcsec ^{2}	

Note that the memory monitoring and the run times are not very accurate. The run times just give the total exposure times with a margin of 1%. More detailed information can be provided by the SUMER Simulator.

All items up to now will run	
for approximately	863 353 minutes

EIT Programme:

Programme objectives :

- to distinguish the temperatures of plume and inter-plume regions
- to delineate the coronal hole boundaries
- to obtain additional information on temperature versus height

(images required in all 4 channels)

UVCS Programme:

PURPOSE:
Measure velocity, density and temperature gradient above ≥ 1.5 $R_\odot$ (at completion of UVCS calibration an initial heliodistance of 1.4 $R_\odot$ might be chosen).

- *grad T* – Gradient of the kinetic temperature of protons (mirror scan).
  – Kinetic temperature of protons and minor ions: Mg X, O VI, Fe XII, Si XII, N V, S X at 1.5 (or 1.4 if possible) $R_\odot$ (sit and stare).
- V - Velocity through Doppler dimming technique (mirror scan) (Ly-alpha and O VI measurements (O VI 1032/1037))
- n_e - Visible light 4500 - 6000 Å (polarized) (mirror scan).

OBSERVATION:
consisting of **1 Mirror Scan up to 2.5 $R_\odot$**, to map the kinetic temperature of protons, and **2 Sit and Stare** observations for line profiles.
Total time 11.5 h.

a) MIRROR SCAN

	Ly α Channel	OVI channel
Initial instantaneous FOV	30' x 14"	30'x 82" at 1.5 $R_\odot$ (possibly 1.4 $R_\odot$)
2–D resolution	28" x 14"	28"x82"
Spectral resolution	0.28Å	0.36 Å
Dwell time	variable with height	
Instantaneous FOV stepped by	0.1 $R_\odot$ up to 1.9 $R_\odot$	
then by	0.2 $R_\odot$ up to 2.5 $R_\odot$	
Total time	6.3 h	

b) SIT AND STARE

	Ly α Channel	OVI channel
Fixed Instantaneous FOV	30' x 14"	30'x14" at 1.5 (possibly 1.4) $R_\odot$
Pixel	28" x 14"	28" x 14"
Spectral resolution	0.28Å	0.18 Å
Dwell time	2.6h	

Observing Sequence JOP–2–CH :
Temperature in Coronal Holes
Mirror Scan

Exposure time	200 sec	
Dwell time	variable with height	(see counting rate table)
Total pxls	40.000	available for transmission
Polarizer motion	at a cadence	1/3 dwell time
	Channel 1 (Ly alpha)	Channel 2 (OVI)
Slit Width	0.05 mm (0.28 Å, 14 ")	0.3 mm (1.11 Å, 82 ")
Grating Position	100000	175000
Mask:		
Binning along the slit	4 pxls= 28"	4 pxls= 28"
Binning in λ	2 pxls= 0.28 Å	4 pxls= 0.36Å
Full spatial range	90 bins	90 bins
Selected spatial range	64 central bins (1792" = 30 arcmin)	64 central bins (1792" = 30 arcmin)
Spectral pxls	625	available for transmission
Spectral Range	column interval (434-1023) (295 b) Mg X 625–FeXII 1242–NV 1239–Lyα 1216–SX 1196	column interval full spectral window (256 b) Si XII 521–OVI 1037, 1032–Ly β 1026–Si XII 499 Mg X 610, Lyα 1216
Total spectral bins	295 bins	256 bins
Bins per channel	64x295 = 18880	64x256 = 16384
Total bins	35264	
Field of View	30'x 1.0 $R_\odot$	
Scan step	0.1–0.2$R_\odot$	
Scan time	(for photon integration)	22200sec =6.2 h
Scan time	(including polarizer motion)	22680sec = 6.3h
Number of scans	1	
Total time	6.3 h	

Sit and Stare

Exposure time	600 sec	
Dwell time	variable with height	(see counting rate table)
Total pxls	40000	available for transmission
Polarizer motion	each	600 sec
	Channel 1 (Ly alpha)	Channel 2 (OVI)
Slit Width	0.05 mm (0.28 Å, 14")	0.05 mm (0.18 Å, 14")
Grating Position	100000	175000
Mask:		
Binning along the slit	4 pxls=28"	4 pxls=28"
Binning in λ	2 pxls=0.28 Å	2 pxls=0.18 Å
Full spatial range	90 bins	90 bins
Selected spatial range	64 central bins	64 central bins
Spectral pxls	625	available for transmission
Spectral Range	column interval	column interval
	434–878 Mg X 625–	230–1022 Si XII 521–
	Fe XII 1242–NV 1239–	OVI 1037,1032–Ly β 1026–Si XII 499
	Lyα 1216–SX 1196	Mg X 610, Lyα+wings
Total spectral bins	220 bins	396 bins
Bins per channel	64x222= 14208	64x396= 25344
Total bins	39552**	
Field of View	30'x 14"	
Scan step	0.0	
Scan time	(for photon integration)	9000s (2.5 h)
Scan time	(including polarizer motion)	9300s (2.6h)
Number of scans	1	
Total time	2.6 h	

CORONAL HOLE
Mirror Scan
Predicted Counting Rate

$R_\odot$	Δt	Ch1	$N_{Ly\,\alpha}$	Ch2	$N_{OVI1032}$	$N_{OVI1037}$
	(sec)	pxl^2		pxl^2		
Mirror Scan						
1.5	1200	4x 2	1.3e+03	4x12	5.6e+02	3.2e+02
1.6	1200	4x 2	1.2e+03	4x12	4.7e+02	2.7e+02
1.7	1800	4x 2	1.5e+03	4x12	5.1e+02	2.9e+02
1.8	2400	4x 2	1.6e+03	4x12	5.1e+02	2.8e+02
1.9	2400	4x 2	1.3e+03	4x12	4.1e+02	2.2e+02
2.1	3600	4x 2	1.3e+03	4x12	4.2e+02	2.0e+02
2.3	3600	4x 2	9.3e+02	4x12	3.1e+02	1.4e+02
2.5	6000	4x 2	1.0e+03	4x12	3.6e+02	1.5e+02

Sit and Stare
N–Predicted Counting Rate

$R_\odot$	Δt	Ch1	$N_{Ly\,\alpha}$	Ch2	$N_{OVI1032}$	$N_{OVI1037}$
	(sec)	pxl^2		pxl^2		
1.5	9000	4x 2	9.5e+03	4x 2	7.0e+02	4.0e+02

Note:
The counting rate can be multiplied by a factor of 8.6 which means an integration along the slit comparable to the spatial resolution of CDS. It can be multiplied by an additional **factor of 2** in the case of the Sit and Stare observation being this observation repeated.

LASCO Programme

Objectives :

- establish any fine structures in the field covered by CDS/SUMER
- measure the distribution of ion temperatures

method: use planned synoptic programme, with the possibility of optimising the data rate from the polar region chosen.

MDI Programme:

To map the line-of sight magnetic field

Ground-based observations (optional):

Magnetic fields, 10830 Å and Ca K maps for coronal hole morphology.