JOP055: CDS, SUMER, UVCS, EIT, MDI

Coronal Holes Versus Normal Quiet Sun

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Scientific Justification

Coronal holes are enigmatic structures. Fundamental parameters of the coronal plasma such as temperature, density, solar wind velocity, etc. change drastically over a short distance at the edge of the hole and retain the new value over large parts of the solar surface. Coronal holes are best seen in X-rays at relatively high temperatures, where they appear very dark, i.e. their high-temperature plasma is at an extremely low density. At lower temperatures the contrast between coronal hole and the normal quiet sun decreases, although holes are still clearly visible in the He II line observed by EIT and a marked signature is present in count-histograms of transition zone and other chromospheric lines (Huber et al. 1974). Coronal holes also have a significantly lower differential rotation than the photospheric plasma (e.g. Sime 1986, Insley et al. 1995). This is intriguing since it implies that in some cases at least coronal holes move relative to the underlying photosphere and hence are probably not always bounded by the same field lines. If this is correct it would imply reconnection processes taking place at the coronal-hole boundaries.

We propose to follow coronal holes and the adjacent quiet sun through a range of temperatures starting at normal coronal temperatures and going to increasingly lower temperatures until they are indistinguishable. Also, by comparing scans outside the limb with scans on the disk it should be possible to at least partially disentangle the various effects of height, horizontal spatial position and temperature, so that a better understanding of the coronal-hole phenomenon can be obtained. At solar activity minimum polar coronal holes are the largest. Hence, in order to avoid contamination by the brighter non-hole material off-limb observations are to be limited to polar holes. In addition, by combining CDS and SUMER off-limb observations of O VI lines (1032 Å and 1038 Å by SUMER and 173 Å by CDS) it may be possible to determine the density of the coronal hole material relative to the normal quiet sun. Furthermore, the O VI lines observed by SUMER can be followed by UVCS to much greater distances from the sun, so that combining SUMER and UVCS will allow us to map a coronal hole and its boundary right from the solar surface to a couple of solar radii. These joint observations will rely heavily on the intercalibration between the 3 instruments CDS, SUMER and UVCS.

The magnetic field must hold the key to why certain parts of the quiet sun atmosphere form a coronal hole, while others do not. We plan to look for possibly subtle differences between magnetic structure under coronal holes and in the normal quiet-sun. Such an investigation will be two-fold. On the one hand we plan to look closely at the region near the coronal hole boundary. On the other hand we also propose to carry out statistical investigations of the magnetic fields generally found under coronal holes and compare with the results of similar studies of the field in non-hole quiet-sun. Care will be taken to compare like with like; for example only regions at similar distances from the limb will be compared. The planned investigation will be complementary to that of, e.g., Harvey et al. (1982).

The main aims of this JOP are thus to determine the basic properties of coronal holes and their boundaries as a function of temperature and height. We also hope to determine which is the lowest temperature at which coronal holes are visible and search for (statistical) relations between the presence of a coronal hole and the underlying magnetic field.

Operational Considerations

Both disk and off-limb observations are planned. On the disk we propose to use EIT, SUMER and CDS. The slits of the two spectrographs are to be placed across a coronal hole boundary and short scans are to be made as nearly along the boundary as possible. The scans are to be repeated in spectral lines formed at different temperatures. SUMER and CDS are to scan contemporaneously the same region as far as possible. EIT will provide the global view, putting the scanned regions into context within the geometry of the complete coronal hole and the rest of the solar disk.

A series of such scans is to be made at different positions on the solar disk. Coronal holes as close to disk centre as possible are to be observed, but also at the limb.

A series of scans are also to be made beyond the solar limb. These involve UVCS, CDS and SUMER. If possible, the slits should be placed parallel to the solar limb across a coronal hole boundary and are to be moved perpendicular to the limb. In the case of SUMER this will only be possible for the polar coronal hole. In the case of UVCS it would be interesting to both extend the scan started at the location of the SUMER scan out to 5 $R_\odot$ as well as to do a similar scan starting above the coronal hole boundary and moving perpendicularly outwards in the expected direction of its extension. Further scans made between these two would also be of interest to complete the "image" of the coronal hole off the limb.

The role of MDI will be to provide magnetograms.

Study Assumptions

The success of this JOP depends on the presence of coronal holes at different latitudes. If coronal holes are not present at the relevant locations (there may well be problems finding mid- and low-latitude holes at the current phase of the solar cycle) then we plan to carry out as much of this JOP as possible in the coming period, but may request that it or parts of it be repeated at a future date.

References

Harvey K.L., Sheeley N.R.,Jr., Harvey J.W., 1982, *Solar Phys.* **79**, 149–160.

Huber M.C.E., et al., 1974, *Astrophys. J.* **194**, L115–L118.

Insley J.E., Moore V., Harrison R.A.,1995, *Solar Phys.* **160**, 1-18.

Sime D.G.,1986, in *The Sun and Heliosphere in Three Dimensions*, R.G. Marsden (Ed.), Reidel, Dordrecht, p.45

Operational Sequence

Ideal period for observations: last week of November 1996. If this period is not possible, then first two weeks of December.

Please note that all integration times are rough estimates only.

Disk observations

CDS sequence

Spectrometer	Normal incidence
Initial pointing	To pre-selected location (coronal-hole boundary determined using EIT image)
Slit	2×240 arc sec^2
Raster area	240×240 arc sec^2
Mirror/slit step size	2 arc sec
Raster locations	120
Dwell time	60 s
Duration of raster	150 min or less
Number of rasters	5
Re-pointing	To a new pre-selected location after each raster (next coronal hole boundary)
Compression	16 bits → 12 bits
Co-operation required	SUMER (IIF), EIT (IIF)
No. of lines	12
Line selection	He I 584 Å, O V 629 Å, Ne VI 562 Å, Si IX 341 Å, 349 Å Mg IX 368 Å, Fe VIII 370.4 Å, Fe X 365.5 Å, Fe XII 364.5 Å, 338.2 Å, Fe XIV 334.2 Å, Fe XVI 335.4 Å
Pixels per line	21

SUMER sequence

Initial pointing	To co-ordinates of IIF from CDS
Slit	1×300 arc sec^2 (slit 2)
Raster area	300×240 arc sec^2
Scan step	1.14 arc sec (=3× 0.38 arc sec)
Raster locations	210
Duration of raster	150 min. (for all lines, i.e. 3 rasters, at one location)
Number of rasters	3×6 (6 different locations at 150 min. each)
Pixels per line	25×300
Repointing	After one coronal hole has been rastered in all spectral lines, repoint to another coronal hole boundary and repeat sequence
Compression	16 bits → 12 bits
Co-operation required	CDS (IIF), EIT (IIF)

Raster 1:

Line selection	Ly β 1025.7 Å, O VI 1031.9 Å
Dwell time	4 sec
Total time for raster	20 min.

Raster 2:

Line selection	C II 1334.5 Å, 1335.7 Å
Dwell time	4 sec
Total time for raster	20 min.

Raster 3:

Line selection	N V 1238.8 Å, 1242.8 Å, Si 1260.4 Å, Si I 1256.5 Å, C I 1266.4 Å, 1275.0 Å
Dwell time	30 sec
Total time for raster	110 min.

EIT sequence

Full-disc images at full resolution in all 4 spectral lines at the normal rate throughout the period of these observations.

MDI sequence

Magnetograms at the normal resolution and at the usual rate during the whole period of observations.

Limb observations

SUMER sequence

Initial pointing	At limb in a coronal hole (10 arc sec inside limb)
Slit	1×300 and 4×300 arc sec^2
Raster area	300×40 arc sec^2 for 1×300 slit
	300×280 arc sec^2 for 4×300 slit
Scan step	2.28 arc sec for 1×300 slit
	3.8 arc sec for 4×300 slit
Raster locations	18 for 1×300 slit
	74 for 4×300 slit
Duration of raster	approximately 13h (depends on the success of proposal 8.1.2.7 by Gabriel and Bely-Dubau), in conjuction with CDS
Number of rasters	1
Compression	16 bits $\rightarrow$ 12 bits
Co-operation required	EIT (IIF), UVCS (IIF), CDS (IIF)
Line selection	O VI 1031.9 Å, O VI 1037.6 Å

UVCS sequence

Initial pointing	At IIF of SUMER (when SUMER slit is at 1.2 $R_\odot$)
Primary obs., i.e.	
Ly-α channel:	H I 1216 Å
O VI channel:	O VI 1032 Å, 1037 Å, Mg X 610 Å, 625 Å
	Si XII 499 Å, 521 Å, Fe XII 1242 Å
Raster	from 1.2 $R_\odot$ out 5 $R_\odot$
Raster step	standard
Dwell time	standard (for coronal hole)
Number of rasters	As many as possible during the rasters by SUMER and CDS
Co-operation required	EIT (IIF), SUMER (IIF)

CDS sequence

Initial pointing	At IIF of SUMER (10 arc sec inside limb)
Spectrograph	GIS
Slit	8×50 arc sec^2
Scan step	4 arc sec
Raster	50×310 arc sec^2
Scan step	2.28 arc sec
Raster locations	80
Duration of raster	approximately 13h (in conjuction with SUMER)
Number of rasters	1
Compression	16 bits $\rightarrow$ 12 bits
Spectral line	O VI 173 Å