Joint Observing Program

Solar Abundances from EUV Spectra

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Scientific Justification

There is ample evidence that the abundances of elements in the solar corona differ systematically from those in the photosphere. The general coronal/photospheric fractionation appears to be related to the first ionization potential (FIP) of the element. Measurements of SW and SEP established that, on average, the ratio of abundances of low FIP elements (FIP < 10 eV) to high FIP elements (FIP > 11 eV) in the corona is a factor of 3 to 4 higher than in the photosphere (Breneman and Stone 1985, Meyer 1985a, 1985b). Similar evidence came from the spectroscopic study of coronal abundances (Veck and Parkinson 1981, Feldman 1992, Fludra and Schmelz 1995).

An important issue is whether the low FIP elements are enhanced or the high FIP elements are depleted in the corona relative to their photospheric abundances. Since the bulk of the plasma is hydrogen, the question hinges on their relative behaviour to hydrogen. Recent SEP observations seem to imply that the low FIP elements are enhanced in the corona by a factor of 3 to 4 and the high FIP elements have photospheric abundances (e.g. Reames 1994). On the contrary, spectroscopic results (Veck and Parkinson 1981; Fludra et al. 1991, 1993; Fludra and Schmelz 1995) suggest that the average coronal enhancement of low-FIP calcium is only a factor 1.5–2, abundances of silicon, magnesium and iron are probably close to their photospheric values, while sulphur (intermediate FIP) is depleted in the corona by a factor of about two and high-FIP elements (oxygen, neon) are depleted by a factor of four. Moreover, the fractionation pattern is not always step-like, but may exhibit a gradual dependence on FIP (Fludra and Schmelz 1995).

Possibly even more surprising than the systematic differences in the coronal and photospheric composition is the growing evidence for abundance variability in the corona itself. Variations in calcium abundances from flare to flare were reported for the first time from the spectra from the Bent Crystal Spectrometer on SMM (Sylwester, Lemen and Mewe 1984, Lemen et al. 1986). Later, variations of abundances of other elements have been found in SMM data for active regions and flares (Strong et al. 1991, Fludra et al. 1991, Schmelz and Fludra 1993) and P78-1 and Skylab data (Feldman 1992 and references therein), with some indication that the abundance may depend on the type of coronal structure, being different for an open magnetic configuration, active regions, and gradual or impulsive flares.

References:

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Joint Observations:

Frequent spectroscopic observations of various features on the disk/limb jointly by CDS, SUMER and possibly UVCS will be carried out. We propose to perform a systematic mapping of abundances in all possible coronal targets, repeated at regular time intervals.
The following targets will be chosen: quiet Sun, active region loops seen both on the disk and on the limb, bright points, polar plumes, streamers, coronal holes.
Below we outline the contribution from each participating instrument.

Coronal Diagnostic Spectrometer

The wavelength range of the Coronal Diagnostic Spectrometer includes many spectral lines of most of the important elements both from the low-FIP group (Na, Ca, Si, Mg, Fe) and the high-FIP group (O, N, Ne, C, Ar, He), and the intermediate sulphur. We envisage performing the abundance studies for different targets both on the solar disk and on the limb to investigate the following features of the elemental abundances: dependence on FIP (step-like pattern or gradual dependence, exceptions from the pattern), variability with time, spatial variability and dependence on the type of observed structures and the magnetic field configuration.

50 lines from 13 elements in the Normal Incidence range have been selected. Full Grazing Incidence spectrum will also be recorded, and about 30 lines of Ne, Mg, Si and Fe ions, plus 22 lines from other elements (S, Na, Cr, C, Ca, P, Ar, N, O) have been suggested for analysis. This choice of lines has been made so as to avoid line blending where possible.

A general approach to this study will involve deriving the differential emission measure distribution based on a set of Mg and Ne lines covering the temperature range $\log(T) = 4.4 - 6.0$. This analysis will use the Mg/Ne abundance determined from Mg VI 399.27, 400.68, 403.32 Å lines which have similar G(T) functions to Ne VI 399.83, 401.14, 401.94, 403.26 Å lines (Feldman 1992) and can give Mg/Ne abundance independently of the DEM distribution. Iron lines will be used to derive DEM in the range $\log(T) = 5.6 - 6.5$, and the overlapping part of DEM(Fe) and DEM(Mg+Ne) will determine Fe/Mg abundance. Using this combined DEM distribution, relative abundances of all other elements (Si, Ca, Al, S, C, O, N, Ar) will be derived from line fluxes in the Grazing Incidence and Normal Incidence range.

A simpler, more robust approach could involve deriving the emission measures for temperatures corresponding to the peak of G(T) functions, and comparing these emission measures for lines which have similar peak temperatures.

Other selected line pairs, whose emissivity functions have similar dependence on temperature, can be used independently of DEM analysis (as proposed in other abundance studies in the Blue Book) and will serve as a test of the DEM approach.

When running this JOP, CDS will use the observing sequence ATRIC (Blue Book).

CDS Study Details (Example)

PHASE I

Spectrometer:	Grazing Incidence
Slit:	2 x 2 arcsec
Raster Area:	10 x 10 arcsec
Step (DX, DY)	2 arcsec, 2 arcsec
Raster Locations:	5 x 5
Exposure Time:	60 s
Duration of raster:	25 min
Number of rasters:	1
Total duration:	25 min
Line selection:	full GIS output
Bins Across Line:	N/A
Telemetry/Compression:	straight copy 13 s/exposure = 4 bands x 2048 bins x16 bits /10 kbits/s
Pointing:	quiet sun/AR loop/C. hole/polar plume
Flags:	Will not be run in response to inter-instrument flag and will not be run with CDS as flag Master
Solar Feature Tracking:	not required
Frequency:	Regular intervals

Product:

Full GIS output: a 10x10 arcsec map

PHASE II

Spectrometer:	Normal Incidence
Slit:	2 x 240 arcsec
Raster Area:	10 x 240 arcsec
Step (DX, DY)	2 arcsec, 0 arcsec
Raster Locations:	5 x 1
Exposure Time:	120 sec
Duration of raster:	617 sec
Number of rasters:	1
Total duration:	10.3 min
Line selection:	'NIS Abundance' Line List (50 lines)
Bins Across Line:	15
Telemetry/Compression:	truncate to 12 bits

	617 s/exposure =
	50 lines x15 bins x120 pixels x12 bits /10 kbits/s
Pointing:	the same target as Phase I
Flags:	Will not be run in response to inter-instrument flag and will not be run with CDS as flag Master
Solar Feature Tracking:	not required
Frequency:	

Product:

Intensities in selected lines suitable for abundance analysis, taken from the same area as GIS lines.

SUMER

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UVCS

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