**Proposal for SOHO-NSO/SACRAMENTO PEAK Joint Observing Program**

**DYNAMICAL STUDIES OF MINOR SOLAR ACTIVITY PHENOMENA**

by

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# 1 Scientific rationale

Solar activity is associated with the appearance, temporal evolution and spatial modifications of the magnetic field at the solar surface and its interactions with plasma flows.

Global properties of solar activity have been extensively investigated and much information has been acquired especially for large flares, where *ALL* manifestations are visible and the collective phenomena may alter the final observables.

If the various manifestations of solar activity can be attributed to the same basic physical mechanism (viz., the currently fashionable magnetic reconnection), then the study of the small spatial scale and short time-constant phenomena is particularly valuable for a better understanding of solar activity, since the basic mechanisms will be primarily at work.

In this context, minor transient activity (such as Ellermann bombs, persistent bright points, microflares, etc.) are interesting targets of investigation due to their importance in clarifying basic mechanisms of energy storage, release and transfer occurring in an apparently simple structure. In other words, they may be considered as the *low energy tail* of a wide phenomena distribution in which major flares represent the *high energy asymptote*.

An international coordinated observing campaign was organized during September and October 1992 by some of the proponents, mainly using the observing capabilities of the NSO-Sacramento Peak Observatory Vacuum Tower Telescope (see MAXFACTS, no.8, July 1992); 17 research groups actively cooperated together with the YOHKOH SXT experiment in targeting minor emission phenomena in ARs. The same observing campaign has been repeated at the beginning of February 1995, although the cooperation was limited to the NSO observing sites (SP and KP), the Hawaii Mees Observatory and YOHKOH S/C.

One of the first results of these campaigns was the detection of sudden upward mass motions occurring at the onset of Ellerman bombs ( - 5 Km/s), changing to downward motion of + 6 Km/s few minutes after the maximum emission. Similar results were also detected in flares, where upward motions were measured in small localized areas with values of about - 20 Km/s at the flare onset, changing to downward motions of about + 40 Km/s within few tens of seconds.

Coronal counterparts of the Ellerman bombs have not been clearly identified but there are indications that the weak coronal loops overlying the Ellerman bomb were "activated" some tens of minutes before the Ellerman bomb development.

The primary limitation of all the existing studies of minor solar phenomena is that they have been observed at isolated height regimes using ground-based techniques; at photospheric and low chromospheric layers, where the $\beta$ plasma parameter is $\approx 1$ and, at the coronal layers where the $\beta$ is $<< 1$. It is also of crucial importance to follow the height variations of these phenomena in the intermediary layers but maintaining the highest possible spatial resolution.

# 2 SOHO-NSO/SP coordinated observing program

## 2.1 Overview

Among the large cluster of instruments on-board SOHO, SUMER represents the most obvious connection with ground-based observations since it attains a spatial resolution of 1 $''$, viz. at the limit of good seeing at ground. Spectral signatures formed at heights near the very top layers reachable with ground-based observations overlap with SUMER, allowing a smooth continuation of the height exploration of the solar atmosphere. Hence it will be easy to monitor the small scale activity manifestations occurring at the photosphere and relate their effects at coronal levels and vice-versa.

Other SOHO instruments has to be used in order to achieve a complete set of new physical information on the phenomena we would like to study:

- The CDS can supply typical coronal observations, even if at lower spatial resolution, continuing the height exploration started by SUMER. It should be important to observe the HeI lines (at 584 and 537 Å) with a spatial resolution of 2 $''$(slit $2'' \times 240''$on NIS) for comparison with the 18380 Å maps, which may be obtained at the NSO/KP, and our chromospheric mapping capabilities. It would also be interesting possibility to use the O VI line at 173 Å(with a $2'' \times 2''$resolution on GIS) as a temperature diagnostic.
- The EIT time series images (especially those ones at He II 304 Å) will be of great value for the localization of the emission structures and for comparison with the global evolution of the AR in which the studied structures are embedded.
- The SOI-MDI time series of the longitudinal magnetic field (area scans) will be extremely usefull since they provide clear evidence of any variations of the longitudinal magnetic field pattern.

We propose to jointly and simultaneously observe a pre-selected AR with the above mentioned SOHO instruments and at NSO/SP. The AR must show some extended spots or pores (spatial distribution) to facilitate the image registration procedures between the SUMER-FOV and NSO/SP FOVs (see details given below).

We plan to develop this observing program in three stages of increasing difficulty and complexity:

1. The first attempt is the simplest; we plan to use the SOHO instruments in their most standard way (but suitable to be efficiently compared with the ground-based data) and a ground-based observing site (NSO/SP). Several of us have had a wide and consolidated experience of successful observations and also of coordinated observing campaigns. This aspect will be examined in detail, in the next subsection.
2. The SOHO instrument observing modes will be implemented depending on the results of the phase (1). Additionally, in this phase, we also wish to include the THEMIS telescope. This will increase the longitude coverage of our ground-based capability and will use the new THEMIS performances. The experience acquired during phase (1) would be of importance for coordinating this phase of the program.
3. The results obtained during phases (1) and (2) may suggest changes and improvements in the planning and observing modes of the SOHO instruments. The observing program could then be extended to other targets of solar activity.
   As far as ground-based observations are concerned we can either use both NSO and THEMIS sites or one of those ones, according to the efficiency demonstrated during the phase (2) campaign.

## 2.2 First Stage of the Observing Program

A crucial aspect of the coordinated observing is represented by the accuracy with which we might be able to co-align and register the SOHO FOVs with the NSO/SP VTT FOV in order to establish a realiable data continuitiy between the various FOVs. Some of the proposed measurements are totally new and we cannot use any previous experience and/or correspondence.
The SOHO instrument that closely matches the NSO/SP VTT FOV is SUMER and consequently we will focus our attention on an observing sequence, that exploits this aspect.

From to our past experiences it is difficult to accurately syncronize a space-borne FOV with a gound-based FOV. We then propose to split the observing sequences of SUMER instrument into three parts:

**(a)** a set of observing sequences solely devoted to image registration and alignment purposes. We propose 4 different mappings;

- (i) spectral profiles of the 2 lines used for the normal observations, viz. Ly$\beta$ and O VI 1032 Å line, and of the Si II 1020.7 Å line (to increase the mapping capability of chromospheric spectral signatures) in 8 equidistant points along the slit, with dweel time of 1 s and spectral windows of 50 pxls. The bit rate is
  8 (spat px) x 3 (lines) x 50 (spec) x 8 = 9.4 Kbits/s
  These profiles will be mainly adopted in the center of strong lines.
- (ii) idem as (i) but increasing the dwell time to 3 s in order to achieve higher precision in the wings of strong lines and for the weak Si II 1020.7 Å line.
- (iii) line profile moments mapping along the 120 $''$portion of the SUMER slit. This map will be later compared with the intensity maps derived from scans (i) and (ii) to check the values of the moments. It will help us understand the practical *meaning* of a moment map with respect to the localization of known solar features. With a dwell time of 2 s the bit rate will be
  120 (spat px) x 3 (lines) x 4 (spec) x 8 = 11.52 Kbits/2s= 5.76 Kbits/s

(iv) a sort of *Dopplergram* mode, viz. observing with a 4 pxls window on wither side of the line center of the two strong lines in order to detect the intensity maps in their wing radiation. This is important for registration and alignment constraints as this wing radiation originates at lower heights in the solar atmosphere, much closer to the formation height of the chromospheric spectral signatures used at the VTT NSO/SP than to those corresponding to the strong line center. The 5 spectral windows (each 4 pxls wide) will be located at:
1025.546 Å(Ly$\beta$-0.177 Å), 1025.898 Å(Ly$\beta$+0.177 Å), 1031.780 Å(O VI-0.133 Å), 1032.044 (O VI+0.133 Å), 1020.699 Å(Si II line center).
We can use the outputs of scans (i) and (ii) for the correct localization of those wavelengths in pxls positions. With a dwell time of 3 s the bit rate will be
120 (spat px) x 5 (lines) x 4 (spec) x 8 = 19.2 Kbits/3 s = 6.4 Kbits/s

All the above 4 observing modes for SUMER are described in SUMER Scientific Sequences enclosed here below.

The "images" of the SUMER FOV (obtained during the 4 above described observing setups) will be transferred via ftp to NSO/SP, where at the same time an area of 4x4 arcmin$^2$, centered on the heliographic coordinates of the SUMER FOV, will be mapped with the observing program described here below. By using suitable IDL procedures we can ensure that the SUMER FOV is located within the SPO-VTT scanned area. Once this proceedure is developed, we can switch to the next phase of observations; if not we can displace the NSO/SP VTT FOV till the SUMER FOV is found in its center.

**(b)** SUMER can activate the observing cycle by measuring the line profile moments of the Ly$\beta$ and O VI 1032 Å lines continuously. Simultaneously the other cooperating SOHO intruments will activate their observing programs.

This phase may last 3 to 6 hours, depending on the speed with which phase **(a)** may have been completed.

With a dwell time of 1 s the bit rate will be
120 (spat px) x 2 (lines) x 4 (spec) x 8 = 7.68 Kbits/s
Correspondly the total time resolution for all the scan will be 105 s, since the data compression for one slit step may be done during to successive slit step exposure.

- **(c)** Repeat again the phase **(a)** observing set for overlaying tests of the various FOVs at the end of the observing shift.

We request to repeat this coordinated joint observing program (JOP) for one week in order to get a sufficient statistics of the phenomena and to have the probability of good seeing conditions at NSO/SP. We request observing time during the beginning of next fall for assuring good observing conditions at NSO/SP.

At the NSO/SP VTT the main goal is to observe simultaneously the same area both with a spectrograph and with different narrow band, tunable filters. Hence, the optical beam of the NSO/SP VTT will feed simultaneously:
(i) the Universal Spectrograph (USG), spectral range 3900-3976 Å, dispersion = 2.7 Å/mm. The spectra can be acquired, for the first time, on a 2K$\times$2K pxls CCD camera, allowing a spectral resolution of 0.038 Å/pxl;
(ii) the Universal Birefringent Filter (UBF), FOV = 120$''$, 0.5$''$/pixel, passband $\Delta\lambda$ = 0.25 Å at H$_\alpha$, with 4 frames/series (He I-D$_3$ + Na-D$_2$ line center + H$_\alpha$ - 1.5 Å + H$_\alpha$ + 0.0), with a time resolution of 10 s/series. Cycled at the end of every four series we will to obtain one image at the continuum (5878.79 Å) and one image at H$_\alpha$ + 1.5 Å for comparison with the Zeiss high time resolution series;
(iii) a broad-band continuum filter ($\lambda_0$ = 5500 Å, $\Delta\lambda$ = 100 Å), same FOV and image linear scale as the UBF, frames simultaneous to the UBF ones, time resolution 2.5 s, mainly for destretching purposes;
(iv) H$_\alpha$ Zeiss Filter, tuned at H$_\alpha$ + 1.5 Å ($\Delta\lambda$ of 0.25 Å), same FOV and image linear scale as the

UBF, frames simultaneous to the UBF ones, time resolution 2.5 s . This series will help in obtaining the highest time resolution monitoring of the observed area.
Observing and instrumental test runs will be activated in the next months; an engineering observing run will be requested for next August.

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### SOHO Scientific Sequence [Phase a)-i)]

Initial Pointing: Pre-selected AR according to previous day observations and GBO magnetic data. Attention has to be paid to the presence of small spots, spatially distributed in order to facilitate the overlay procedures with NSO/SP-FOV

SUMER:

Slit: $1 \cdot 120$ arcsec$^2$ (slit #4)

Scan Area: $2 \cdot 2$ arcmin$^2$

Step Size: triple half-step size, viz. 1.14 arcsec/step

Resulting Number of Scan Locations: 105

Dwell Time: 1 s

Duration of Scan: 105 s (105 s dwell time; data compression time during next exposure)

Number of scans: (till the NSO/SP observing group "recognize" the SUMER FOV in their extended FOV)

Number of Scan Mirror Settings: 1

Repointing: continuously on the target (with the standard solar rotation compensation)

Total duration: less than 20 minutes

Line selection: Ly$\beta$, O VI 1032 Å and Si II 1020.7 Å

Bins Across Line: 50

Estimated Reduction Factor
* Selection: 8 equidistant points along the slit
* Compression : # 5
* Reduction: no

SOHO-CDS: The SPOTV program with its Sunspot Line Selection would be fine; if possible the exposure time should be decreased to a value of a few seconds AND the size of the raster increased to 120 . 120 arcsec, leaving the duration of the raster unchanged (or decreased);
SOHO-EIT (for localization of bright structures): field of 8 . 8 arcmin; at least one for this preliminary phase;
SOHO-MDI (for simultaneous on-board longitudinal magnetic field maps) : at least one for phase 1 to 4;.

Co-operation Requirements: NSO-Sacramento Peak VTT (with the T367 set-up, viz. UBF and USG in parallel) simultaneously on the same AR; NSO-Kitt Peak for simultaneous magnetic maps

### SOHO Scientific Sequence [Phase a)-ii)]

Initial Pointing: Pre-selected AR according to previous day observations and GBO magnetic data. Attention has to be paid to the presence of small spots, spatially distributed in order to facilitate the overlay procedures with NSO/SP-FOV

Slit: $1 \cdot 120$ arcsec$^2$ (slit #4)

Scan Area: $2 \cdot 2$ arcmin$^2$

Step Size: triple half-step size, viz. 1.14 arcsec/step

Resulting Number of Scan Locations: 105

Dwell Time: 3 s

Duration of Scan: 315 s (315 s dwell time; data compression time during next exposure)

Number of scans: about 10 (till the NSO/SP observing group "recognize" the SUMER FOV in their extended FOV)

Number of Scan Mirror Settings: 1

Repointing: continuously on the target (with the standard solar rotation compensation)

Total duration: less than 20 minutes

Line selection: Ly$\beta$, O VI 1032 Å and Si II 1020.7 Å

Bins Across Line: 50

Estimated Reduction Factor
* Selection: 8 equidistant points along the slit
* Compression : # 5
* Reduction: no

SOHO-CDS: The SPOTV program with its Sunspot Line Selection would be fine; if possible the exposure time should be decreased to a value of a few seconds AND the size of the raster increased to 120 . 120 arcsec, leaving the duration of the raster unchanged (or decreased);
SOHO-EIT (for localization of bright structures): field of 8 . 8 arcmin; at least one for this preliminary phase;
SOHO-MDI (for simultaneous on-board longitudinal magnetic field maps) : at least one for phase 1 to 4;.
Co-operation Requirements: NSO-Sacramento Peak VTT (with the T367 set-up, viz. UBF and USG in parallel) simultaneously on the same AR;

NSO-Kitt Peak for simultaneous magnetic maps

**SUMER Scientific Sequence [Phase a)-iii)]**

Initial Pointing: Pre-selected AR according to previous day observations and GBO magnetic data. Attention has to be paid to the presence of small spots, spatially distributed in order to facilitate the overlay procedures with NSO/SP-FOV

Slit: $1 \cdot 120$ arcsec$^2$ (slit #4)

Scan Area: $2 \cdot 2$ arcmin$^2$

Step Size: triple half-step size, viz. 1.14 arcsec/step

Resulting Number of Scan Locations: 105

Dwell Time: 2 s

Duration of Scan: 210 s (210 s dwell time; data compression time during next exposure)

Number of scans: about 10 (till the NSO/SP observing group "recognize" the SUMER FOV in their extended FOV)

Number of Scan Mirror Settings: 1

Repointing: continuously on the target (with the standard solar rotation compensation)

Total duration: less than 20 minutes

Line selection: Ly$\beta$, O VI 1032 Å and Si II 1020.7 Å

Bins Across Line: 50

Estimated Reduction Factor: image format #44 (line profile moments map)
* Selection: no
* Compression : # 5
* Reduction: no

SOHO-CDS: The SPOTV program with its Sunspot Line Selection would be fine; if possible the exposure time should be decreased to a value of a few seconds AND the size of the raster increased to 120 . 120 arcsec, leaving the duration of the raster unchanged (or decreased);
SOHO-EIT (for localization of bright structures): field of 8 . 8 arcmin; at least one for this preliminary phase;
SOHO-MDI (for simultaneous on-board longitudinal magnetic field maps) : at least one for phase 1 to 4;.

Co-operation Requirements: NSO-Sacramento Peak VTT (with the T367 set-up, viz. UBF and USG in parallel) simultaneously on the same AR;

NSO-Kitt Peak for simultaneous magnetic maps

**SUMER Scientific Sequence [Phase a)-iv)]**

Initial Pointing: Pre-selected AR according to previous day observations and GBO magnetic data. Attention has to be paid to the presence of small spots, spatially distributed in order to facilitate the overlay procedures with NSO/SP-FOV

Slit: $1 \cdot 120$ arcsec$^2$ (slit #4)

Scan Area: $2 \cdot 2$ arcmin$^2$

Step Size: triple half-step size, viz. 1.14 arcsec/step

Resulting Number of Scan Locations: 105

Dwell Time: 3 s

Duration of Scan: 315 s (315 s dwell time; data compression time during next exposure)

Number of scans: about 10 (till the NSO/SP observing group "recognize" the SUMER FOV in their extended FOV)

Number of Scan Mirror Settings: 1

Repointing: continuously on the target (with the standard solar rotation compensation)

Total duration: less than 20 minutes

Line selection: 1025.546 Å, 1025.898 Å, 1031.780 Å, 1032.044 Å, 1020.699 Å

Bins Across Line: 4

Estimated Reduction Factor:
* Selection: no
* Compression : # 5
* Reduction: no

SOHO-CDS: The SPOTV program with its Sunspot Line Selection would be fine; if possible the exposure time should be decreased to a value of a few seconds AND the size of the raster increased to 120 . 120 arcsec, leaving the duration of the raster unchanged (or decreased);
SOHO-EIT (for localization of bright structures): field of 8 . 8 arcmin; at least one for this preliminary phase;
SOHO-MDI (for simultaneous on-board longitudinal magnetic field maps) : at least one for phase 1 to 4;.

Co-operation Requirements: NSO-Sacramento Peak VTT (with the T367 set-up, viz. UBF and USG in parallel) simultaneously on the same AR;

NSO-Kitt Peak for simultaneous magnetic maps

**SUMER Scientific Sequence [Phase b) Obs. run]**

Initial Pointing: Pre-selected AR according to previous day observations and GBO magnetic data. Attention has to be paid to the presence of small spots, spatially distributed in order to facilitate the overlay procedures with NSO/SP-FOV

Slit: $1 \cdot 120$ arcsec$^2$ (slit #4)

Scan Area: $2 \cdot 2$ arcmin$^2$

Step Size: triple half-step size, viz. 1.14 arcsec/step

Resulting Number of Scan Locations: 105

Dwell Time: 1 s

Duration of Scan: 105 s (105 s dwell time; data compression time during next exposure)

Number of scans: 100-170 (depending on the observing time available after the preliminary tests for FOVs overlay have been completed)

Number of Scan Mirror Settings: 1

Repointing: continuously on the target (with the standard solar rotation compensation)

Total duration: 3-5 hours

Line selection: Ly$\beta$, O VI 1032 Å

Bins Across Line: 50

Estimated Reduction Factor: image format #44 (line profile moments map)
* Selection: no
* Compression : # 5
* Reduction: no

SOHO-CDS: The SPOTV program with its Sunspot Line Selection would be fine; if possible the exposure time should be decreased to a value of a few seconds AND the size of the raster increased to 120 . 120 arcsec, leaving the duration of the raster unchanged (or decreased);
SOHO-EIT (for localization of bright structures): field of 8 . 8 arcmin; at least one every half an hour;
SOHO-MDI (for simultaneous on-board longitudinal magnetic field maps): at least one for the observing run; if the target is in the high-resolution MDI FOV, frequent magnetograms at high resolution would be of great value;
Co-operation Requirements: NSO-Sacramento Peak VTT (with the T367 set-up, viz. UBF and USG in parallel) simultaneously on the same AR;

NSO-Kitt Peak for simultaneous magnetic maps