PROPOSAL FOR OBSERVING PROGRAM 2008
for the Dutch Open Telescope (DOT)
combined with RHESSI/SoHO/Hinode/TRACE observations

Title of the program: Physical mechanisms driving solar microflares and network dynamic fibrils – relevance for coronal heating and mass supply

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Type of the program: DOT chromospheric and photospheric high-cadence imaging

Targets: active regions and chromospheric network.

Cooperating instruments: RHESSI; SoHO: CDS, EIT, MDI; Hinode: SOT, EIS, XRT; TRACE; Kanzelhöhe Solar Observatory (KSO): Hα telescope. SoHO, Hinode, and TRACE time will be applied for once the DOT time will be allocated.

Scientific objectives:

This proposal merges together attempts to observe two kinds of solar structures – solar microflares and network fibrils – which are planned to be investigated to address common open questions of their dynamics, drivers, and their impact on the coronal heating.

Microflares are small-scale dynamic events potentially important for the heating of the solar corona as well as for the mass supply to the corona and the solar wind. At present, mainly two types of models are invoked to understand the heating of the corona: a) AC (alternate current) models in which the energy is transported by (various) types of waves in a magnetized plasma from the convection zone to the corona where they dissipate their energy; b) DC (direct current) models in which magnetic free energy is accumulated in the corona by (slow) footpoint motions, and explosively released via magnetic reconnection in numerous small-scale flare events, so-called microflares or nanoflares. Intrinsically, due to their small sizes and fast dynamics, the analysis of microflares demands high spatial resolution observations combined with good temporal cadence. Our objective is to analyse the dynamics and plasma evolution during microflares by studying the chromospheric response to electron beam and/or conductive heating (flare footpoints: RHESSI hard X-rays, DOT Hα and Ca II H) together with the transition region and coronal response (flare loops: RHESSI and Hinode XRT soft X-rays, post-flare loops: TRACE EUV) in imaging data combined with X-ray spectral analysis (RHESSI soft and hard X-rays). These observations will allow us to draw inferences on the plasma temperature and emission measure evolution as well as on the importance and energetics of accelerated electrons in microflares. The RHESSI instrument has an unprecedented spectral resolution of 1 keV as well as unprecedented sensitivity in the range 3–20 keV, where the transition between thermal and non-thermal emissions is supposed to take place, which makes it a highly valuable instrument for the analysis of microflares (cf. the RHESSI microflare studies by Stoiser et al. 2007, Solar Phys. 246, 339; Benz & Grigis 2002, Solar Phys. 210, 431; Krucker et al. 2002, Solar Phys. 210, 225; Liu et al. 2004, ApJ 604, 442; Qiu et al. 2004, ApJ 612, 530). In addition, we also plan to use CDS and EIS spectroscopy in order to study mass motions related to the chromospheric evaporation process. The comparison of these observational data with theoretical predictions in the frame of electron-beam-driven and conductively driven chromospheric evaporation for individual microflares can help us to better understand: a) whether non-thermal electrons are present in microflares which hints at magnetic reconnection as the underlying physical process, b) how much plasma is brought into the corona by microflares, c) which process (electron beams or heat conduction from the hot coronal microflare plasma) dominates the mass transport, d) how much energy is deposited during microflares which is available for the heating of the corona.

Network dynamic fibrils (DFs) display in the chromosphere repetitive mass loading by acoustic shocks driven by the global oscillations in the underlying photosphere (De Pontieu et al. 2007, ApJ 655, 624). This scenario assumes that considerable power of photospheric 5-min oscillations is concentrated at the bases of inclined magnetic fluxtubes giving rise to the chromospheric DFs. Using Hα filtergrams obtained by the Dutch Open Telescope we have shown that the DFs exhibit also significant variations in orientation, which are faster for shorter DFs (Koza et al. 2007, ASP. Conf. Series 368, 115). Recently, downflows and upflows occurring at the base and tops of mottles, respectively, were reported (Tziotziou et al. 2003, A&A, 402, 361). To explain this dynamic structure their suggested magnetic reconnection as a potential driver of mottles. The same mechanism is likely to be at work also in the case of Type II spicules discovered by De Pontieu et al. (2007, 2007arXiv0710.2934D) in Hinode CaII H images of solar limb.

As an extension of the works mentioned above, in this proposal we aim at identification of the center-to-limb variation of kinematic properties of dynamic fibrils and also center-to-limb variation of terminal wavelength shift of visibility of the fibrils and mottles in the Hα line profile. Thus, the spectral observations of chromosphere with the best, spatial and spectral resolution possible are needed.

Planned analysis:

Microflares: we plan to use the high-resolution images acquired by the DOT in the center of the Hα and Ca II H spectral lines in a high time cadence mode in order to study the chromospheric signature of microflares in terms of geometry/topology, source sizes, and evolution. These data shall be combined with observations from RHESSI, Hinode XRT, SoHO/EIT-MDI-CDS, TRACE and KSO. RHESSI and KSO data will be available in the desired mode. As regards the TRACE, SoHO/EIT-MDI-CDS and Hinode/SOT-XRT-EIS observations, we will propose a JOP campaign and ask for allocating the observing time in case that DOT observing time for the planned project is allocated.

The RHESSI instrument will be used to study the high energy-component of the microflares: evolution of the integrated full-Sun soft and hard X-ray fluxes (thermal-nonthermal behaviour); imaging of the soft X-ray flare loop and, if possible, also of the hard X-ray footpoints (which depends on the count statistics which is intrinsically low in microflares); X-ray spectroscopy in the range 3–20 keV to study the thermal flare plasma and the energetics and importance of accelerated electrons.

Hinode XRT SXR images will be used to study flare loops in terms of connectivity and source sizes.

TRACE 195 Å EUV images will be used to study post-flare loops in terms of connectivity and source sizes. The delay between the impulsive phase and the appearance of the post-flare loop in the TRACE 195 Å (Fe XII) channel together with the flare peak temperatures inferred from RHESSI spectroscopy also allows us to get insight into the cooling of the flare plasma.

High resolution longitudinal photospheric magnetograms from the MDI/SoHO instrument studied in combination with the chromospheric and coronal flare emission (DOT, RHESSI, TRACE, Hinode XRT) will allow us to get insight into the magnetic topology and connectivity of the microflares.

CDS and EIS spectroscopy will be applied in order to study mass motions related to chromospheric evaporation in microflares.

Network dynamic fibrils: The following observational procedure is planned to be used for determination of the center-to-limb (CL) variation of kinematic properties of the dynamic fibrils - for a given CL position to run a time sequence with the fastest possible cadence switching between -0.3 Å and +0.3 Å. This procedure will be repeated for different CL positions, e.g. 1., 0.8, 0.6, 0.4, 0.2. Using such observational data and procedures already developed (Koza et al. 2007) a resulting plot: max. initial velocity versus deceleration for different CL positions is expected to be constructed.

For determination of the center-to-limb variation of terminal wavelength of visibility of fibrils and mottles in Hα line profile another observational procedure is prepared: for a given CL position to tune the DOT Hα Lyot filter to the blue wing and acquire a time sequences with the fastest possible cadence in several wavelength shifts (e.g. -0.25 , -0.5, -0.75, -1.0 Å). This procedure will be repeated again for different CL positions, e.g. 1., 0.8, 0.6, 0.4, 0.2. Appearance of dynamic fibrils for different wavelength shifts and CL positions including determination of the terminal wavelength of visibility will be investigated.

The CDS spectroscopy, although of low spectral resolution, provides a perfect temperature coverage of the line emission from chromosphere up to the corona. Therefore, the CDS data are planned to be used for the study of dynamics/waves in the upper solar atmosphere related to fibrils.

Complementary SOHO/MDI magnetograms will be also used for the study of the evolution of the photospheric magnetic fields.

TRACE measurements will be used mainly for searching for the transition region and coronal responses of the dynamic fibrils.

Co-alignment of the data: The spatial co-alignment of the data taken by different instruments will be primarily performed in the following way:

- CDS → EIT: using CDS rasters taken in the He I 584 Å line and EIT filtergrams taken in the He II 304 Å line
- EIT → TRACE: using EIT and TRACE data taken in 195 Å channel
- TRACE → DOT: using TRACE data taken in 1600 Å channel and the DOT filtergrams taken in the Ca II H line (or using white light images if at least some significant pores will be available in the field-of-view of both instruments)

Time allocation request:

Number of days needed: 14 days
Preferred times: 1-14/9/2008 (outside of the SoHO keyholes and the Hinode eclipse)
Impossible times:

03	Mar	2008	–	04	May	2008	MDI 60 Day Continuous Contact Period
11	Jun	2008	–	15	Jun	2008	MDI 5 Day Continuous Contact
09	Jul	2008	–	13	Jul	2008	MDI 5 Day Continuous Contact
03	Feb	2008	–	03	Mar	2008	SoHO Keyhole
06	May	2008	–	26	May	2008	SoHO Keyhole
31	Jul	2008	–	31	Aug	2008	SoHO Keyhole
04	Nov	2008	–	23	Nov	2008	SoHO Keyhole
09	May	2008	–	03	Aug	2008	Hinode eclipse (estimated from the 2007 data)

(Source: Future MDI Continuous Contact Periods - http://mdisas.nascom.nasa.gov/coordination.txt, SoHO Keyholes - http://sohowww.nascom.nasa.gov/soc/keyholes.txt, Hinode Eclipses - http://solar-b.nao. ac.jp/operation_e/eclipse_e/).

We note that we can perform our study also using MDI full-disk images, i.e. also during the listed time of the MDI 5/60 Day Continuous Contact Periods in case that the remaining periods are in conflict with other observations (although, of course, high-resolution MDI maps are preferred).

Observing procedures and requirements:

DOT:

As the main goal we plan to observe with the highest possible time cadence in the Ca II H and Hα spectral lines – cadence of 10 s for speckled images - microflares. Procedures prepared for observations of the fibrils were described above. For further context information on photospheric layers and magnetic flux concentrations (as well as for co-alignment between the various instruments) continuum and G-band images are planned to be acquired, for which a lower time cadence than in Hα and Ca II would suffice.

The support of cooperating instruments (i.e. TRACE, SoHO/CDS-EIT-MDI, Hinode/SOT-XRT-EIS) will be requested only when our DOT observing time will be allocated. The same procedure will be applied for the Hinode instruments.

RHESSI:

RHESSI observes the Sun in soft and hard X-rays (as well as γ-rays) with a full-Sun field of view. Interruptions of the observations are due to the spacecraft day/night cycle (1 RHESSI orbit $\sim$97 min) and passages over the South Atlantic Anomaly. The maximum spatial resolution is 2.3$''$ and the highest time resolution is 2 s depending on count statistics. For microflares the spatial resolution is usually restricted to 7$''$ and the time resolution in imaging and spectroscopy to $\gtrsim$20 s. The temporal resolution for the flux evolution in X-rays may be as good as 2 s also for microflares. Microflare studies with RHESSI require that there is no attenuator in the detectors field of view (A0 state) in order to ensure highest sensitivity at low X-ray energies. The A0 state is the default RHESSI observing mode during times of low solar activity which is expected to be the case during the phase of solar cycle minimum in 2008.

SoHO: CDS, EIT, MDI:

The observing sequences of the CDS, EIT and MDI instruments on-board SoHO are planned in the same mode as described in the proposal of the JOP 189 observing program which is available at `http://sohowww.nascom.nasa.gov/soc/JOPs/jop189`.

Hinode: EIS, SOT, XRT:

EIS: images of the limited field-of-view, slot 40", FOV 40x200", centred at the CDS slit position, lines: He II 256.32 A, Si VII 275.35 A, Fe XII 195.12 A, Ca XVII 192.82 A, cadence 12 sec. Provided information: line emission - chromosphere, transition region, corona - 2D.

XRT: fast cadence, small FOV (100×100 arcsecs) imaging in one of the low enery emission filters.

SOT: Broad Filter Imager: channels: G-band, Ca II H, Blue cont, sequentially in time if possible, if only one channel, can be selected then G-band channel is preferred, cadence of a set of these 3 channels: 10-15 sec, needed FOV: only 60x109 arc secs.

Total duration of the common observational run: 3.5 hours. Program for the Hinode instruments already prepared as the HOP 020 and it is planned to repeat it with its optimal performance run already on Aug 18, 2007.

TRACE:

We are interested to acquire high resolution EUV images ($0.5''$) in the Fe XII 195 Å spectral channel with high temporal cadence (5–10 s). A set of white light and UV 1600 Å continuum images shall be acquired as context information as well as for co-alignment purposes.

KSO Hα:

The Kanzelhöhe Solar Observatory (KSO) takes regularly Hα full-disk images ($2.2''$/pixel) with a cadence of 5 s. These images will be used as further context observations with a more extended field as compared to the DOT Hα.

DOT operation: We apply for the external usage of the DOT in a external-user mode in which the proposer performs the observing and data processing on-site with guidance from the DOT team. Peter Gömöry will be present performing the DOT operation with personal assistance of the DOT team members on La Palma. The planned JOP campaign shall be run from the proposer home institutions by other members of the team.

Previous campaigns: In the years 2006 and 2007 campaigns led by P. Gömöry, A. Veronig, and J. Rybák were performed by the DOT. Some very promising data were obtained during the DOT 2006 campaign. Data were briefly analyzed and the list of priority was prepared listing 4 different data sets. Data are currently under detailed analysis. Details of the performed campaign and a brief summary of the acquired data sets are available at `http://www.astro.sk/~choc/open/06_dot/06_dot.html`. Preliminary results from this campaign based on the DOT observations were not published yet but work is in progress to do so in the year 2008. Unfortunately, the 2007 campaign was not so successful in the microflare part due to extremely low solar activity in the whole August 2007 (`http://www.astro.sk/~choc/open/07_dot/07_dot.html`) and corresponding very low occurrence of microflares. This re-application for the DOT time is mostly motivated in order to acquire more data sets, and better co-spatiality of the CDS data with the microflare occurrence. The network dynamic fibril part of the proposal is new in our DOT proposals.

Two parts of the proposal were selected to be complementary according to different level of the solar activity in order to exploit also the observing days when no significant solar activity will be present on the visible side of the Sun.