Solar Magnetometry Network

L.S.,

This document contains the text of an EU Network proposal for the 1996/1997 round in Activity 1 of the TMR (Training and Mobility of Researchers) Fourth Activity of the Fourth Framework Programme (1994-1998) of the EU that is administrated by the European Commission.

The proposal concerns collaboration and postdoctoral training in solar physics. It aims to advance the measurement and understanding of solar magnetism by integrating the development and usage of the European solar telescopes on the Canary Islands, the usage of ESA's SOHO Mission, and pertinent data interpretation and analysis.

This proposal has been forwarded to the European Committee for funding on July 4, 1997. The success rate was about 15%; this proposal is one of the four that were selected in the field of astronomy. A formal contract will be negotiated during September 1997; the start of the Network activities will be in late spring 1998. The requested duration will be four years.

This copy contains the proposal text on pages 21–44. The official EU forms that make up the first twenty pages of the proposal have been replaced by a summary.

The full title of the proposal is:
European Network to Measure and Understand Solar Surface Magnetism through Coordinated Use of the Canary Island Telescopes and the SOHO Mission

The short title of the proposal is: SOLAR MAGNETOMETRY NETWORK.

The partner institutes and further details are defined on the next page. Utrecht University holds the coordinatorship and will act as Network Contractor to the EU.

Network partners:

Code	Institute, Organisation	Location
UU	Sterrekundig Instituut, Universiteit Utrecht	Utrecht
IAC	Instituto de Astrofísica de Canarias	La Laguna
OAC	Osservatorio Astronomico di Capodimonte	Napoli
UiO	Institutt for teoretisk astrofysikk, Universitet i Oslo	Oslo
KVA	Research Station for Astrophysics, Kungsliga Vetenskapsakademien	Stockholm
AIP	Sonnenobservatorium Einsteinturm, Astrophysikalisches Institut	Potsdam
OP	Observatoire de Paris, section Meudon	Meudon
ESA	Solar System Division, ESA Space Science Department	Noordwijk

Proposal allocations (the actual allocations to be negotiated will differ somewhat, depending on actual current salaries):

Code	Type	Region (less-favoured)	postdoc[1] support man-months	Total EC Funding kECU
UU	EDU		36	186
IAC	ROR	Islas Canarias	36	161
OAC	ROR	Campania	48	168
UiO	EDU		36	166
KVA	ROR		72	162
AIP	ROR	Ost-Berlin	36	175
OP	EDU		36	171
ESA	INT		24	122
totals	8		324	1311

[1] KVA: one postdoc and one graduate studentship

Contacts:

Code	Person	Telephone	Fax	Email
UU	Dr. Robert J. Rutten	31–30–2535226	31–30–2535201	rutten@fys.ruu.nl
IAC	Dr. Javier Trujillo Bueno	34–22–605378	34–22–605210	jtb@iac.es
OAC	Dr. Giuseppe Severino	39–81–293266	39–81–456710	severino@astrna.astro.it
UiO	Prof. Mats Carlsson	47–22856536	47–22856505	carlsson@astro.uio.no
KVA	Prof. Göran Scharmer	46–8–164473	46–8–164228	scharmer@astro.su.se
AIP	Prof. Dr. Jürgen Staude	49–331–2882300	49–331–2882310	jstaude@aip.de
OP	Dr. Pierre Mein	33–1–45077801	33–1–45077959	mein@obspm.fr
ESA	Dr. Bernhard Fleck	31–71–5653574	31–71–5654698	bfleck@soho.estec.esa.nl

Summary of research content:

Solar magnetism is one of the great challenges of physics. Its intricate field structure exemplifies cosmic magnetic fields. Its modulation affects the human environment. Solar surface magnetometry aims to understand solar magnetism in the regime from which it controls the heliosphere. The Solar Magnetometry Network will exploit the European solar telescopes at the Canary Islands and ESA's SOHO mission to chart the topology of solar magnetic structures, to identify the basic processes underlying the dynamical behaviour of solar magnetism, and to constrain the solar dynamo mechanism. Solar magnetometry techniques will be improved to unprecedented angular resolution and sensitivity; comprehensive solar magnetometry data will be obtained in multi-telescope campaigns; data interpretation will employ sophisticated numerical modelling. These efforts strengthen European leadership in solar observation, polarimetry and computer modelling.

Summary of training content:

The human product of the Solar Magnetometry Network consists of young researchers who are well qualified to tackle complex problems in (astro-)physics, space weather, image processing and numerical modelling. Their training programme includes hands-on training at the Canary Island telescopes and the SOHO operations centre, Network-organised summer/winter schools and meetings, intensive collaborations in joint observing and analysis campaigns, and a mid-term team switch where feasible. Offering such postdoctoral training in Europe counteracts a persistent brain drain to the US.

5. PROPOSAL DESCRIPTION

1. Research Topic

Science reasons. The Network efforts are devoted to understanding solar magnetism. Magnetism lies at the root of most solar and heliospheric physics. The intricate structure of the solar field, the activity cycle and the influence of the field on the heliosphere represent major quests of (astro-)physics which bear directly on the human environment. The sun's magnetic field is generated by enigmatic dynamo processes in the solar interior, is organised into the highly complex patterns of solar activity observed in the solar photosphere, dominates the structure of the outer solar atmosphere (chromosphere, transition region, corona), regulates the solar wind, and affects the whole extended heliosphere.

Solar magnetism poses questions that require answers in the context of different human endeavours. In terms of pure science, solar magnetism provides the Rosetta stone of cosmic magnetism, not only in other stars but also in accretion disks, cataclysmic variables, galactic dynamics, active galactic nuclei and other cosmic objects in which MHD and plasma processes control the structure and energy partitioning. The sun is close enough to study these processes in observable detail.

Terrestrial plasma confinement machines do not reach the scales, densities and temperatures exhibited in the solar atmosphere. Solar physics complements plasma instability studies in fusion research, the sun representing a non-terrestrial plasma physics laboratory.

Space weather (the American policy term for solar influence on the near-earth environment and the earth's climate) is set by solar magnetism. Solar activity modulation affects satellite orbits, influences jet stream patterns and contributes to the causes of minor, possibly major, ice ages.

Our Network collaborations go for the roots of space weather and coronal plasma behaviour: the magnetic field structure and dynamics in the solar photosphere and chromosphere. Solar surface magnetism is the key for advance in the areas listed above. At the solar surface, the magnetic field gains dominance over the gas pressure. Its characteristics at the surface control what happens further out. The Network integrates complementary European efforts to map and understand the structure and dynamics of solar surface magnetism and the patterns by which it betrays subsurface dynamo properties. This integration will advance the field considerably. It is implemented through joint development, joint observing, and joint analysis programmes for the European solar telescopes on the Canary Islands and the SOHO mission.

Technological reasons. Solar observing with the Canary Island telescopes operates at the edge of technology in optics, liquid-crystal polarimetry, high-speed image acquisition and large-volume data processing. The Network tasks encompass various technological innovation programmes, also involving industry. The SOHO mission is the state of the art in space technology. Network postdocs will receive extensive training in these technologies.

Socio-economic reasons. At present, European solar physics leads the world in spacebased observation, groundbased observation, polarimetry and numerical modelling. The Network integrates these efforts and strengthens the European leadership. It fully exploits the opportunities offered by the world's premier solar telescope park (Canary Islands) and the ESA Cornerstone SOHO mission by moulding these considerable European investments into a coherent all-telescope programme of attack on solar surface magnetism.

In addition, the Network counteracts a persistent brain drain from Europe—most recent European solar physics PhD's are now in the US. It contributes to the training of a new generation of scientists, enabling Europe to exploit its investments and fully participate in the rising global interest in space weather and its causes. More in general, Network postdocs will be well trained in solving complex problems involving large amounts of data, skills that are crucial for many future science challenges.

Timeliness. The timing is right because the Canary Island facilities, presently being enhanced with THEMIS and DOT, and the SOHO mission, presently operating very successfully, constitute a unique combination of facilities at this moment. Exploiting their combined capabilities in collaborative programmes advances solar physics in the holistic approach dictated by the complexity of solar magnetism.

2. Project Objectives

Overview. The Network science goal is to get at the root of solar magnetism by establishing its structure and dynamics in the solar photosphere and chromosphere. In this regime, the plasma β parameter (ratio of gas to magnetic pressure) flips from large to small across unity, so that the field role switches from being dominated by gas motions to dominating gas motions. At the solar surface, the field displays patterning imposed by the subsurface dynamo and convective flows while, at the same time, it controls flows and wave motions to the outer atmosphere. Solar surface magnetometry aims to understand the fundamental how and why of the field topology and dynamics. The corresponding science objectives are:

(a) chart the topology of solar magnetic structures at all scales of emergence at the solar surface;

(b) identify the basic processes underlying the dynamical behaviour of solar magnetic structures;

(c) measure solar activity patterns to constrain the solar dynamo mechanism.

They are detailed below. We are confident that breakthroughs are in reach by teaming up in a coordinated attack combining effort and expertise in the following magnetometry implementation objectives:

(d) improve solar magnetometry to unprecedented angular resolution and sensitivity;

(e) obtain comprehensive high-resolution solar magnetometry data in concert with space data;

(f) achieve observationally constrained numerical modelling.

These objectives are detailed in Section 4 (Research Method). They require specific cooperations of which the effectuation, with a key role for the Network postdocs, capitalises on Europe-wide know-how and intensifies Europe-wide collaborative research.

Topology of magnetic structures [objective (a)]. Solar surface magnetism consists of a remarkable hierarchy of discrete strong-field structures. The basic entity is the *flux tube*, a key concept of astrophysics that was developed in Europe. Solar flux tubes have tiny cross-sections (0.1–0.2 arcsec) but have become observable with the Canary Island telescopes nevertheless (Fig. 1). The flux tubes are arranged into a coarse network pattern regulated by surface flows, and occur in larger density in solar plage (faculae). The flows are imposed by the turbulent convection of which the granulation pancake pattern is the most evident characteristic. The solar granulation is now understood (also a European achievement) but the dynamical interaction between convection and flux tubes is not. Nor is the topology of the flux tubes themselves. They supposedly expand upwards to merge into magnetic canopies just above the photosphere, but this prediction has not been verified. Thus, charting flux tube topology has high priority in understanding the basics of solar magnetism.

The same holds for the larger elements in the magnetic hierarchy, pores, umbrae, large spots with penumbrae, and fully-developed active regions. Current results on spot topology indicate the presence of much shear between horizontally and upwards directed penumbral field bundles (Fig. 1), while the nature and cause of umbral fine structure has not been identified. Active regions possess complex cycle-dependent topology (Fig. 1, righthand panel) that requires mapping with high-resolution Stokes vector magnetometry now in reach (Section 4 on page 26).

Dynamics of magnetic structures [objective (b)]. The paradigm of stellar activity says that stellar coronas and chromospheres are heated magnetically. Since the fields are anchored in the dense gas at the surface, the dynamics of flux tubes, pores and spots lie at the root of outer-atmosphere heating. Thus, a fundamental goal in solar magnetism research is to measure the motions that convection imposes on the magnetic elements and to find how these control the dynamics in of the outer atmosphere. By combining high-resolution surface magnetometry (Canary Island telescopes) with ultraviolet spectrometry and imaging of the chromosphere (SOHO), we are now in the position to correlate and trace surface motions and corresponding chromospheric dynamics in magnetic structures tomographically (Fig. 1). It is already clear that the internetwork, network and active region chromospheres differ markedly in dynamic characteristics and response to the surface pistons and their reshuffling. New insight gained from UiO simulations has upset the canonical concept of a quiet-sun chromospheric temperature rise, replacing it by a very dynamical picture of acoustic shock interference. These breakthrough simulations emulated

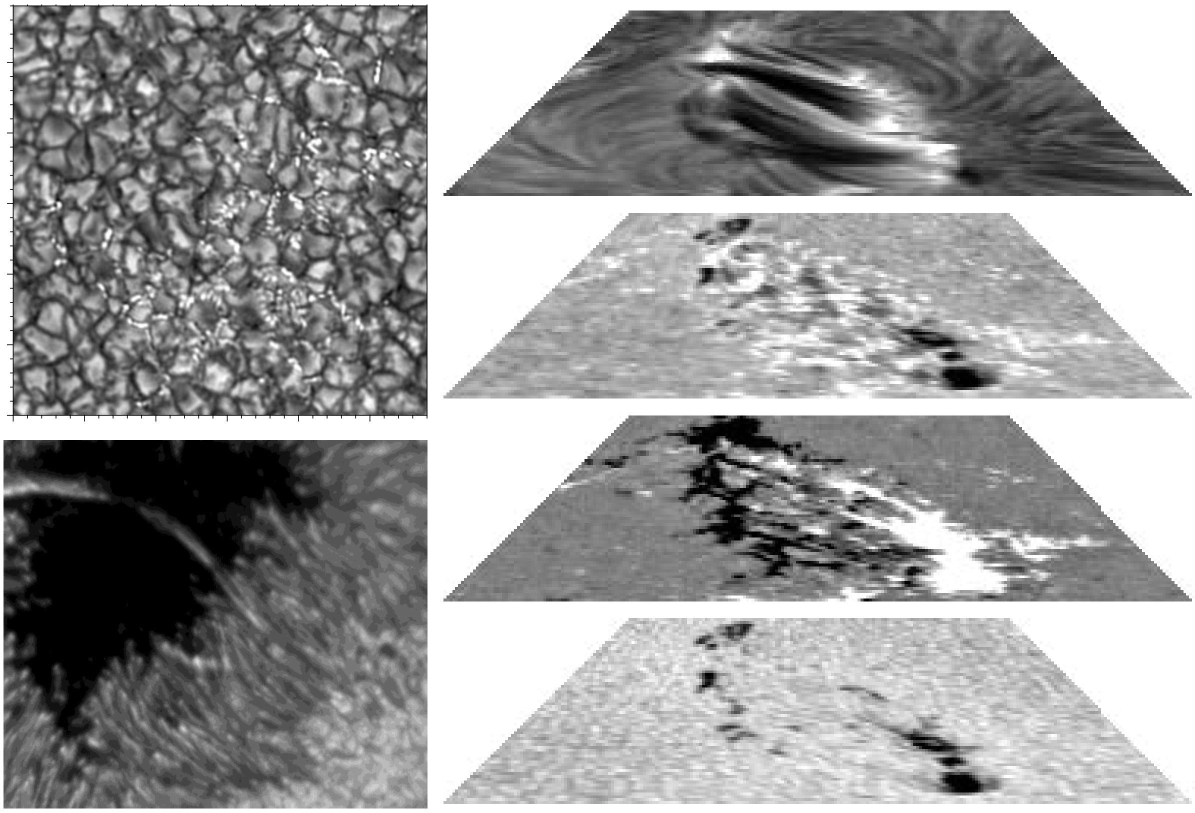

Figure 1: Overview of solar magnetic structures. Images taken with the SVST. • Top left: high-resolution G–band image of the photospheric granulation. Scale: 22 Mm (30 arcsec) to a side. This image has been restored for atmospheric wavefront deformation through phase diversity registration. The resolution reaches the telescope diffraction limit of 0.2 arcsec. The tiny bright points in the dark intergranular lanes mark strong-field (150 mT) flux tubes. • Bottom left: high-resolution image of a sunspot penumbra. Scale: 35 Mm (50 arcsec) to a side. The filamentary structures mark complex topology consisting of horizontally as well as upwards tilted fans of field bundles. One bundle arches over the umbra. • Right: tomography of an active region. Pseudo-perspective projection of a photospheric image (bottom, continuum near $\lambda = 557$ nm), the photospheric magnetic field measured from Fe I 630.2 nm, the intensity at the center of this line, and the chromospheric topology displayed by Hα 656.3 nm (top). Scale: 54 Mm (75 arcsec) to a side.

actual photospheric pistoning and then compared simulated behaviour of the chromosphere to the actual behaviour sampled by the Ca II H & K lines. The Network dynamics goal is to combine photospheric piston mapping, magnetometry and SOHO spectrometry with similarly realistic data-constrained modelling for different magnetic regimes.

Patterns of solar activity [objective (c)]. The emergence and disappearance patterns of magnetic flux on the solar surface betray the workings of the solar dynamo. Active regions are assembled from emerging flux bundles that drain through convective collapse. The nearly E–W orientation of the great majority of bipolar active regions together with Hale's polarity laws indicate that Ω-shaped loops emerge from toroidal flux ropes which probably originate in an overshoot shell underneath the solar convection zone. Currently, helioseismology boosts global dynamo insight by mapping subsurface flows and temperature gradients. Solar surface studies should establish the required upper boundary constraints to the dynamo by identifying the processes and topology of flux emergence and disappearance at the fundamental level of individual flux tubes. This is now in reach through combining high-resolution groundbased magnetometry with the continuous low-resolution magnetometry provided by SOHO (SOI/MDI).

3. Scientific Originality

Canary Island Telescopes. A Europe-wide effort (in the Joint Organisation for Solar Observations JOSO) has established the Canary Islands as the "most-favoured" region for solar observing, offering the world's premier sites with regard to atmospheric tranquillity. The unique solar telescope array that has now been assembled there is portrayed in Fig. 2. It delivers the state of the art in groundbased solar physics (Fig. 1). The Network teams either control these telescopes or have frequent access to them. The Network collaborations aim to achieve high-resolution and high-sensitivity magnetometry with these facilities.

The newest Canary Island telescopes are the THEMIS and the DOT. Both become operational in 1997. THEMIS is the major enterprise of French and Italian groundbased solar physics. It is the first large-aperture telescope specifically designed for magnetometry and it has very sophisticated post-focus equipment including the IPM tunable narrow-band filter and an elaborate double spectrometer optimised for high-sensitivity high-resolution Stokes vector magnetometry and for 2D spectrometry (MSDP mode). This telescope will considerably advance the state of the art in spectrometric magnetometry and tunable-filter imaging. The Network collaborations will enhance its usage Europe-wide.

THEMIS also advances the state of the art in archiving solar groundbased data. The OAC team's ARTHEMIS procedures and data base management developed for the IPM set an example world-wide and will be expanded into a Network archive, guaranteeing on-line access to comprehensive data sets.

The DOT is a much smaller project but revolutionary in nature. Its open structure represents the first test of the technology needed for future solar telescopes whose aperture exceeds the size limit set by vacuum windows. The DOT will optimally exploit the excellent seeing at La Palma to obtain high spatial resolution in proxy magnetometry (Section 4, page 26). The state of that art is now set by the SVST; Network UU–KVA cooperation should bring the DOT to the same level. In addition, the OAC–UU collaborative aim of putting a MOF (Magneto-Optical Filter) magnetograph on the DOT advances the state of the art in MOF magnetometry from full-disk to high-resolution applications.

Figure 2: The state of the art in groundbased solar physics: portrait gallery of the European Canary Island telescopes in order of increasing aperture. The newest additions are at the ends of the array. From left to right: • DOT (Dutch Open Telescope), La Palma, aperture 45 cm, installed in 1996. Its fully open design aims to minimise disturbance of the excellent atmospheric conditions at La Palma. Suited to high-resolution proxy magnetometry. • GCT (German Gregory Coudé Telescope), Tenerife, aperture 45 cm. Vacuum reflector that is especially suited to spectrographic magnetometry. • SVST (Swedish Vacuum Solar Telescope), La Palma, aperture 47 cm. Vacuum refractor offering outstanding image quality. Stokes vector magnetometry is in development. • VTT (German Vacuum Tower Telescope), Tenerife, aperture 70 cm. General-purpose solar telescope with extensive post-focus equipment for imaging and spectrometry. • THEMIS (French-Italian Télescope Héliographique pour l'Etude du Magnétism et des Instabilités Solaires), Tenerife, aperture 90 cm, installed in 1996. Large new-generation telescope specifically designed for high-resolution magnetometry. Post-focus equipment includes the IPM (Italian Panoramic Monochromator, tunable birefringent filter in tandem with a Fabry-Perot) and the multi-channel spectrometer designed for very sensitive Stokes vector magnetometry as well as MSDP (Multichannel Subtractive Double Pass) 2D spectrometry.

Spatial resolution enhancement. The state of the art in beating the bad influence of the earth's atmosphere, a limiting factor to image quality even at the Canary Island sites, consists of the phase diversity plus speckle restoration technique developed by the KVA team at the SVST. It is still in the demonstration stage but it appears highly promising for regular applications at all imaging telescopes, and it may even be extended through multi-channel techniques to MSDP spectrometry at THEMIS. By advancing this technique, Network collaboration may effectively enhance the frequency of top-resolution data gathering at the Canaries by as much as a factor of three to four, a capital increase in telescope efficiency.

Stokes magnetometers. The state of the art in Stokes vector spectrometry (measuring all four Stokes parameters I, Q, U and V through complex polarisation modulation schemes) is currently set by the Advanced Stokes Polarimeter of the US High Altitude Observatory and US National Solar Observatory. Having much experience with this US instrument, the IAC team has started on European counterparts that will exploit the good seeing at the Canary Islands to reach higher resolution and that employ new modulation technology in the form of liquid crystal retarders. These will be used on the SVST and the VTT. The expectation is that these liquid-crystal magnetometers will excel in high spatial resolution and speed. They do not compete with the more sensitive Stokes vector spectrometry of THEMIS but represent complementary instruments, as does a MOF magnetometer at the DOT. The complementarity makes it desirable to combine these instruments in joint programmes.

SOHO mission. The state of the art in spacebased solar physics is, obviously, the Solar and Heliospheric Observatory. It was launched in December 1995 and operates highly successfully while orbiting the first Lagrangian point of the sun-earth system. The following three instruments of its extended equipment are of specific Network interest:

– SOI/MDI, producing photospheric images, longitudinal magnetograms and Doppler maps at up to 1.2 arcsec resolution. Its magnetograms are complementary to the Canary Island instruments (which reach much higher resolution at good seeing and will achieve four-component Stokes vector measurement) by virtue of its continuous operation (no nights or bad weather) and the absence of pattern deformations by seeing. Close involvement of the UU team.

– SUMER, producing near-ultraviolet emission-line spectrograms of the chromosphere and transition region. The UiO, UU, AIP and OP teams have already obtained extensive SUMER data sets and have built up the experience needed to exploit SUMER most efficiently during its remaining lifetime.

– CDS, producing far-ultraviolet spectrograms of the transition region and corona. Specific expertise at the UiO team.

In ESA-led campaigns, spacebased and groundbased observing is combined to achieve tomography of the solar atmosphere from bottom to top. Our Network (encompassing the ESA team) will extend such tomography with high-resolution high-sensitivity multi-telescope magnetometry.

Polarised radiative transfer. Europe is world leader in the theory and numerical modelling of polarised radiative transfer, with much effort by the IAC and OP teams on new inversion methodology (next section). These programmes strengthen the diagnostic value of solar magnetometry. Stokes vector magnetographs require sophisticated spectral-line modelling to derive the magnetic field vector amplitude and orientation. The new generation of magnetographs (THEMIS multi-channel spectrometer, IAC–KVA liquid-crystal magnetometers, OAC MOF; details in next section) require such elaborate methods for optimum data interpretation. Network collaboration will optimise their quality, efficiency and dissemination.

Numerical modelling. Direct confrontation of observations with comparable numerical modelling has proven to be a particularly fruitful solar physics venue. It led to the understanding of solar granulation, insight in flux tube dynamics, and the recent UiO conclusion that the non-magnetic chromosphere is filled with acoustic shocks. These are all European accomplishments. The Network collaborations (with the UiO team as simulation pivot) aim to follow the UiO strategy of using actual data as simulation input in order to enable direct comparison with the complementary diagnostics in comprehensive tomography data. The magnetometry will provide detailed input constraints; SOHO data add chromospheric response.

4. Research Method

The implementation objectives listed under (d)—(f) in Section 2 on page 22 define Network tasks that together make up the methodology of our approach. They are described here and charted in Table 1 (page 29). They have strong interdisciplinary character, bringing together advances in optics, liquid-crystal technology, image restoration, information technology, space science, radiative transfer, fluid dynamics, magnetohydrodynamics and computational physics. Within the displine of solar physics they have strong complementary character, bringing together instrumentalists, observers and theorists.

Magnetometry techniques [objective (d)]. These tasks develop and spread new techniques that aim to improve the spatial resolution and sensitivity of solar magnetometry, capitalising (and even improving) on the good seeing at the Canary Island telescopes:

- *THEMIS and DOT performance optimisation.* The two new telescopes become operational at the Network start. A collaborative Network task is to assist the OP and UU teams in optimising telescope performance through real-time quality comparison with other telescopes (THEMIS: GCT and VTT; DOT: SVST).
- *Magnetometry calibration.* A key OP–IAC task is to model the sensitivity of polarimetric diagnostics to the topology and dynamics of the magnetic structures, in order to develop the multi-line polarimetry calibration by which the sensitivity of the Stokes vector magnetometers to weak fields may surpass the level reached by the HAO-NSO ASP in the US. Such calibration requires detailed polarised line formation modelling in order to enhance the reliability of the sophisticated numerical data inversions by which line formation constraints deliver the magnetic field properties.
- *Liquid-crystal magnetometry.* Liquid crystal retarders are new technology in Stokes vector polarimetry. The first tests of LC Stokes spectrometry and LC Stokes imaging, both performed at the SVST, have been highly promising. The development path is well defined (IAC–KVA collaboration).
- *MOF magnetometry.* Magneto-Optical Filter technology consists of twin Na I or K I resonance scattering cells used in transmission to permit full-field magnetometry. A collaborative OAC–UU project is to install a high-resolution version of the present OAC full-disk instrument on the DOT.
- *G–band magnetometry.* Proxy magnetometry of the deep photosphere is illustrated by the G–band image in Fig. 1. The many CH lines in the Fraunhofer G–band around $\lambda = 430.5$ brighten considerably in tiny patches marking locations where strong-field flux tubes jut through the solar surface. G–band imaging permits tracing the locations and migrations of individual flux tubes in quiet-sun areas, quiet and active network, and active region plage. The KVA team will assist the UU team in implementing this technique at the DOT.
- *IPM magnetometry.* Proxy magnetometry of the upper photosphere is exemplified by the Fe I 557.6 nm image in Fig. 1. At the larger height of formation the plage stands out. With proper observing and calibration procedures, the IPM on THEMIS will achieve such magnetometry with high sensitivity thanks to THEMIS' large aperture. An OAC–OP collaborative task.
- *Image restoration.* The frequency with which the very best resolution is attained can be significantly increased by image restoration using phase diversity plus speckle interferometry to correct for the wavefront distortions imposed by the earth's atmosphere. The technique was demonstrated at the SVST in pioneering work by the KVA team (Fig. 1); it should now be spread to the other telescopes and be developed for large-volume application. It may even be extended to the 2D spectrometry feasible with the THEMIS spectrometer in MSDP mode.

Comprehensive ground-space observing [objective (e)]. Over the past year of initial SOHO operation, the ESA team and various other partners have gained considerable experience in running Joint Observing Programmes which combine SOHO data gathering with groundbased observing. The complexity of solar surface magnetism requires such a holistic approach. Our aim is to realise Network-wide observing campaigns in order to obtain comprehensive data sets charting solar magnetic field topologies and dynamics with complete atmospheric tomography. This requires intensive networking, as is also the case for the subsequent joint data analysis and interpretation. Tasks:

– *Campaign coordination.* The multi-telescope joint programme procedures will follow the mechanisms and use the utilities evolved by the ESA team for SOHO. The coordination will be fully electronic and rely heavily on WWW, while the necessary face-to-face brain storming will take place at pre- and post-campaign get-togethers and Network meetings.

– *Instantaneous planning imagery.* Observing campaigns aiming to chart solar active structures often fail in not realising space-time co-alignment of the different telescopes to the required precision. The Network will make a special effort to establish co-registration from real-time on-line images accessible through WWW. It will be an extension of the current OP service for the daily SOHO planning and the comparable SOHO MDI and EIT services on WWW. The IAC computers will serve as groundbased hub (being directly connected to all telescopes). The WWW page construction will profit from the ESA expertise gained with the very effective SOHO pages (URL `http://sohowww.nascom.nasa.gov/`).

– *Joint multi-telescope campaigns.* These represent a major Network activity in which all teams participate. The campaigns will mostly take place during May–October when the probability of excellent seeing at the Canary Island sites is highest. The campaign durations will typically be 1–3 weeks.

– *Data archiving and data dissemination.* The data stream from the Canary Island telescopes is considerable, up to 10 Gbyte per day per telescope when the seeing is good. Just as is the case for SOHO data, the data streams must be properly archived with easy Network-wide electronic access. The Network will utilise the ARTHEMIS expertise (and hardware) of the OAC team and heavily use the SOHO data centers.

– *Data reduction.* Considerable data reduction is a necessary step towards the actual research constituted by objectives (a)—(c) on page 22. It includes detector calibration, magnetometry calibration, image restoration, tracking error correction and field co-registration. Additional steps that are often desirable are local-area tracking (to correct seeing-induced pattern deformations) and multi-dimensional Fourier filtering (to remove solar oscillation patterns). A Network task is to increase the efficiency of these reduction steps by Network-wide spreading of expertise and software. This is feasible because all teams use the same computer language for these tasks (IDL).

Data-constrained modelling [objective (f)]. Numerical inversions and numerical simulations provide the theoretical framework in which the observations must be placed for full understanding. Suitable topics are the line-formation processes fundamental to magnetometry, line formation in inhomogeneous media, canopy effects on chromospheric lines, the formation of proxy-magnetometry lines, flux tube dynamics, sunspot dynamics, network tessellation processes, etc. Obviously, this plate is too full for a three-year network effort emphasising observational magnetometry. However, the Network theme permits the definition of specific tasks that are in reach of collaborative efforts within a relatively brief time span:

– *Definition of boundary conditions.* The UiO strategy in time-dependent radiative hydrodynamics simulations is to impose actually observed boundary conditions, in order to permit straightforward comparison with complementary data in comprehensive tomography sets. The strategy requires definition and measurement of suitable observable constraints.

– *Comparing modelling with observations.* The primary topics for data-constrained modelling are the dynamics of umbral chromospheres, flux tube shocks in the context of spicules, the formation of the G–band CH lines, and the formation of the chromospheric lines measured by SOHO in the context of network and internetwork dynamics. Collaborative tasks are to achieve these and, when in hand, analyse their results in just the same way as the corresponding data are analysed.

5. Work Plan

Table 1 (next page) specifies the work division, Table 2 specifies the manpower investments and a scheduling chart is given in Fig. 3. The collaborative Network tasks in Table 1 are split between the science tasks making up the objectives (a)—(c) of Section 2, the implementation tasks (d)—(f) described in Section 4, and the training tasks defined on page 42. The implementation and training tasks are more sharply time-constrained than the science tasks and therefore scheduled in Fig. 3.

Timing aspects. The starting moment of the Network is not strongly constrained from our side; it may be set by EU preferences. However, the multi-telescope campaigns will mostly take place during the May–October good-seeing season. Within these periods, they will be set by telescope scheduling, in particular for SOHO. Therefore, the timing schedule in Fig. 3 may slide within the three-year frame. The campaigns cannot yet be specified precisely.

Network get-togethers will take place as pre-and post-campaign planning meetings at the IAC and at autumn ASPE or ASPE-like meetings (Section 7).

Summer schools may actually take place in winter, especially when part of the IAC's regular winter school programme.

Milestones and mid-term review. The various implementation and training tasks define obvious milestones such as the moments at which a magnetometry technique becomes operational or the occurrence of a multi-telescope campaign, a Network summer/winter school, a Network meeting. The science tasks are less easily scheduled into milestone timings, but as a whole, the programme has a major milestone about half way. During the first eighteen months of the Network operation THEMIS and DOT commence observations while the techniques of wavefront restoration, polarimetry calibration, and numerical modelling are being developed and disseminated throughout the Network. During the second period, with the sun cooperating by reaching higher activity, the emphasis shifts to all-telescope campaigns employing the newly developed magnetometry techniques and to data analysis and interpretation.

Thus, the mid-term review comes at a natural shift of emphasis and offers an excellent opportunity to assess the accomplishments of the first stage and to fine-tune the plans for the second half. Suitable assessment criteria are:
- are the Network postdoctoral researchers indeed diffusing expertise between the teams?
- has the Network instituted the foreseen training programme?
- are THEMIS and DOT functioning properly?
- is SOHO still producing high-quality space data?
- have the developments in Stokes vector and proxy magnetometry met their design goals?
- does the Network succeed in running joint observing campaigns?
- does the Network succeed in on-line data dissemination?
- has the Network magnetometry and modelling produced significant scientific results?
- has the Network set up on-line WWW reporting?
- does the Network popularise its findings to the general public?
- are the Network meetings productive?
- does the Network configuration permit mid-term team switches for Network postdocs?

Subcontracting. None.

Science Objective	Task	Teams
(a) Magnetic-Structure Topologies	flux tubes	KVA + UU
	network	UU + IAC + OP
	sunspots	AIP + OAC + UiO + IAC
	active regions	OP + AIP + ESA
(b) Magnetic-Structure Dynamics	flux tubes	IAC + KVA + UU
	network	UiO + UU
	sunspots	AIP + OAC + IAC
	active regions	ESA + OP + OAC
(c) Dynamo Patterning	high-resolution patterns	KVA + UU + OAC + OP
	pattern evolution	ESA + UU
	dynamo constraints	AIP + OAC
Implementation Objective	**Task**	**Teams**
(d) Magnetometry Techniques	THEMIS optimisation	OP + others
	DOT optimisation	UU + KVA
	magnetometry calibration	OP + IAC + AIP
	liquid-crystal magnetometry	IAC + KVA
	MOF magnetometry	OAC + UU
	G–band magnetometry	KVA + UU
	IPM magnetometry	OAC + OP
	image restoration	KVA + others
(e) Comprehensive Observing	campaign coordination	ESA + UU + others
	on-line imagery	OP + IAC + OAC
	multi-telescope campaigns	all teams
	data archiving & dissemination	OAC + ESA + others
	data reduction	all teams
(f) Numerical Modelling	boundary conditions	UiO + AIP + others
	comparison with modelling	UiO + AIP + others
Training Objective	**Task**	**Teams**
Magnetometry Techniques	Canary Island telescopes	all teams
	SOHO	ESA
	data reduction & analysis	all teams
Post-Doctoral Schooling	summer/winter schools	UU, UiO, IAC
	advanced seminars	all university teams
Exchange	postdoc exchange	all teams
	mid-term team switch	where feasible
	training at industry	KVA, UU, others
	Network meetings	UU + all teams

Table 1: Network tasks and team collaborations. The first part of this table splits the science objectives (a)—(c) into tasks in the form of topics. The teams listed in the third column are the primary ones involved in the corresponding collaborative research, although it should be noted that most teams are in fact interested in all topics. The second part splits the implementation objectives (d)—(f) into the tasks defined in Section 4. The team abbreviations specify the pertinent specialists. For example, the last implementation entry indicates that UiO and AIP are the modelling specialists while the other teams should collaborate on diagnosing modelling results. The third part splits the training objectives into the programme items detailed in Section 10 (page 42) and specifies the responsible teams.

Team	Network	Other: tasks	total
UU	36	82	145
IAC	36	114	228
OAC	48	93	162
UiO	36	65	137

Team	Network	Other: tasks	total
KVA	72	72	96
AIP	36	75	126
OP	36	78	142
ESA	24	45	105

Table 2: Estimated extent of the professional Network research effort in man-months per team. The columns 'Network' specifies the effort of the EU–funded young visiting researchers. The columns 'Other' specify man-months of research funded by other sources. The columns 'tasks' estimate the effort that will be devoted to specific Network implementation and training tasks while the columns 'total' estimate the total non-EU-funded research efforts spent on solar surface magnetometry.

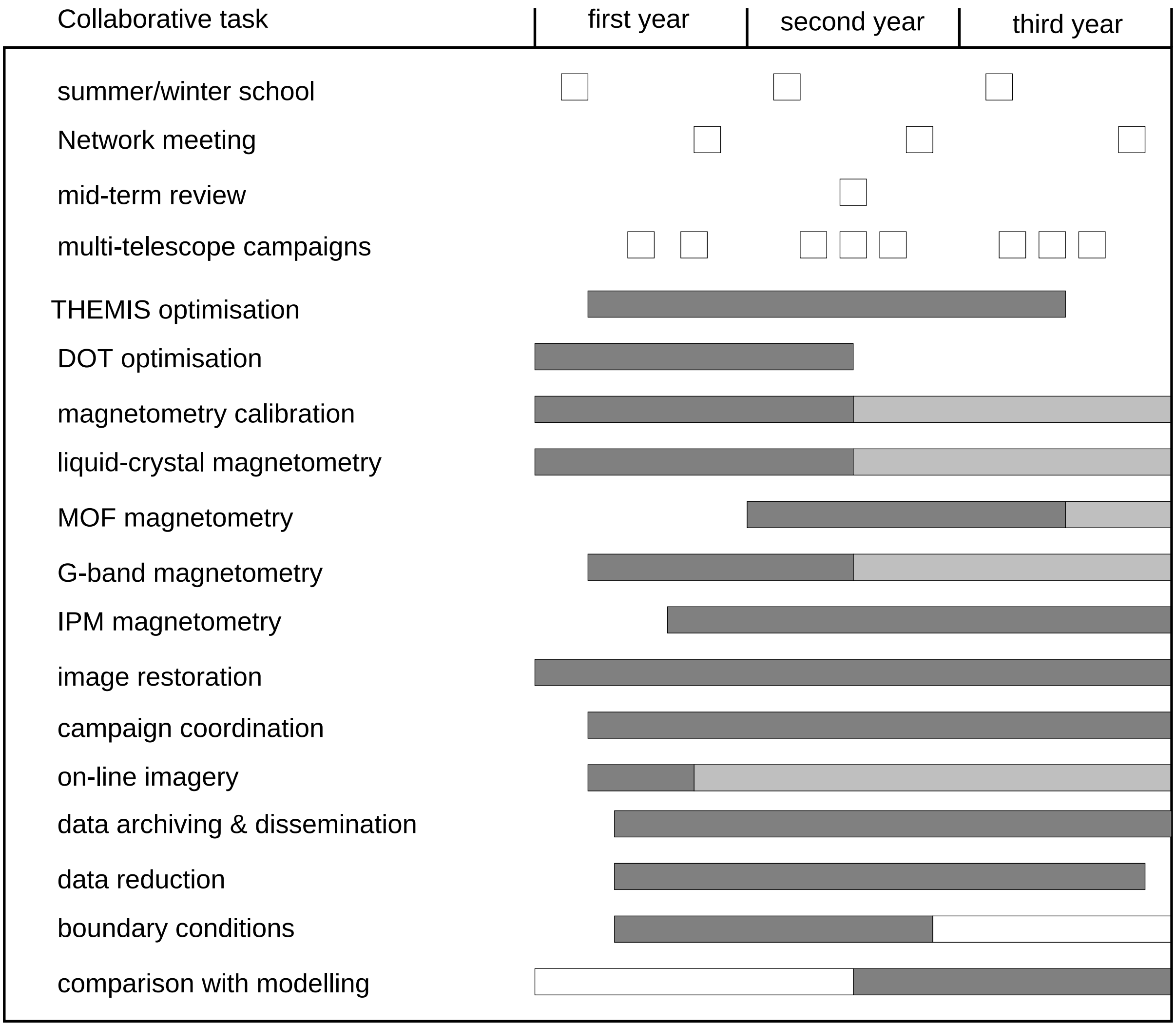

Figure 3: Planning schedule for joint activities and implementation tasks. The squares denote short-duration get-together activities of which the actual timing within each of the three Network years may shift, since the start of the activities is not constrained to January as is assumed here. It may be set by EU preferences. The multi-telescope campaigns will mostly take place in the May–October good-seeing seasons. Each will start and end with joint sessions at the IAC. The summer/winter schools are here entered in spring. The bars specify task time-lines, with their shading representing collaborative intensity. For example, the magnetometry calibrations get more attention during the earlier phase whereas the comparisons of observations with results from numerical modeling receive largest emphasis towards the end.

6.1 Collective Experience: participant UU (number 1)

Expertise. The Utrecht Sterrekundig Instituut is renown in solar physics, for applications of solar MHD and plasma physics to other objects in the cosmos, and for its production of top astrophysicists. The UU efforts in solar physics now concentrate on solar instrumentation, solar surface magnetism, chromospheric dynamics and chromospheric line formation. Network-specific expertise is in plasma astrophysics, spectral line formation, radiation hydrodynamics, solar instrumentation and solar observing. The team excels in advanced teaching.

Instrumentation. The UU team presently installs the DOT (Dutch Open Telescope) on La Palma, a novel solar telescope of highly innovative design (Fig. 2 on page 24). The telescope and 15 m high support structure have no enclosure but are transparent to the strong winds that bring the best seeing to La Palma, in order to minimise locally-induced disturbance. The DOT is operated from the nearby SVST building (KVA) and becomes operational in the summer of 1997.

Network role. The UU team will, in addition to coordinating the Network, concentrate on objectives (a) and (c)—(e). Specific UU collaborative tasks are to equip the DOT for Network campaigns and to operate it for these in tandem with the KVA operation of the SVST. The DOT is well suited to SOHO-supportive G–band proxy magnetometry. Other collaborative Network tasks are to enhance the effective DOT resolution by applying the image restoration techniques pioneered at the SVST and to embark on high-resolution Magneto-Optic Filter (MOF) magnetometry with the OAC team. UU undergraduate and graduate students will extensively be involved in Network activities, and the UU team will spend extra effort on Network training activities including summer school organisation, in addition to organising the Network meetings. The team will also act as Web curator for the Network.

Research linkages. The UU team has had collaborations with the OAC, IAC and UiO teams. It collaborates at present with the ESA and KVA teams (usage of SUMER and SVST, respectively) and with the solar physics group at the Lockheed-Martin laboratories (analysis of SOI/MDI data). The DOT installation enjoys hospitality of the IAC and KVA. The Network tasks will bring closer contact with the other teams, in particular KVA and OAC whose expertise will enhance DOT usage. A multidisciplinary link regarding the DOT concerns plans of the Abteilung Planetforschung of the German Forschungsgemeinschaft für Luft- und Raumforschung (East Berlin) to equip the DOT with a larger mirror (76 cm) for its nighttime applications (precise orbit determination of comets, asteroids and minor planets). There are also links to industry.

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
<u>Dr. R.J. Rutten</u>	line formation	28 years	27	coordination, DOT, SOHO
Dr. R.H. Hammerschlag	instrumentation	27 years	33	DOT instrumentation
Prof. M. Kuperus	plasma astrophysics	35 years	9	MHD theory and modelling
Prof. C. Zwaan	solar magnetism	emeritus	6	field topology
Network postdoc	(astro)physics	PhD	33	JOP execution & analysis

Current temporary staff working on Network topics: postdoc G.H.J. van den Oord, graduate students H.J. Hagenaar, N.M. Hoekzema, N.A.J. Schutgens and K. Tziotziou, engineer F.C.M. Bettonvil, and undergraduate students.

Relevant publications

N. M. Hoekzema, R. J. Rutten, J. W. Cook: 1997, "Ultraviolet Jets and Bright Points in the Solar Chromosphere. II. Statistical Correlations", Astrophys. J. 474, 518

Rutten, R. J., Schrijver, C. J. (Eds.): 1994, "Solar Surface Magnetism", NATO ASI Series C 433, Kluwer, Dordrecht

6.2 Collective Experience: participant IAC (number 2)

Expertise. The Instituto de Astrofísica de Canarias in La Laguna has internationally recognised experience in astrophysics and contains one of the largest (and youngest) solar physics groups in Europe. In particular, the magnetometry team listed in the table has wide Network-relevant expertise in precise spectropolarimetry encompassing sophisticated techniques to overcome the instrumental polarisation of telescopes, diagnostic methods for the investigation of solar magnetic fields, NLTE spectral line formation, polarised radiative transfer, and the numerical inversion techniques that are needed for spectropolarimetry calibration. The IAC has also much experience in organising meetings, including well-known young-astronomer winter schools, and puts much effort in disseminating science results to the general public.

Instrumentation. Through international agreements the IAC controls 20% of the observing time at each Canary Island telescope. In addition, it has access to 5% more through international collaborations. The IAC team has successfully contributed to solar instrumentation and to its improvement at various telescopes including the German GCT and VTT. At present, the IAC team is involved in the construction of two high-precision polarimeters based on liquid-crystal variable retarders (LCVR). They will be used for Stokes vector magnetometry with the SVST and VTT.

Network role. The IAC tasks are to concentrate on the development of improved magnetometry diagnostics based on both the Zeeman and the Hanle effect [objective (e)], on the development of the two LCVR Stokes magnetographs [objective (d)], and on their deployment at the SVST and VTT [objective (e)]. Promising Ph.D. students will be also involved in Network activities. The IAC team will extensively contribute to Network training, including winter school organisation. In addition, the team will function as Network pivot, facilitating the Network use of all Canary Islands solar telescopes and contributing to electronic networking through WWW.

Research linkages. The IAC team has good contacts with all other network teams, with at present a close collaboration with the KVA team in the development of the LCVR Stokes magnetograph for the SVST. The radiative transfer interests will gain from collaboration with the UiO and OAC teams. The industrial links concerning LCVR technology will be expanded.

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
Dr. J. Trujillo Bueno	radiative transfer	11 years	24	NLTE physics
Dr. M. Collados Vera	solar magnetism	11 years	24	observation & data analysis
Dr. V. Martínez Pillet	solar magnetometry	9 years	18	observation & data analysis
Dr. J. Sánchez Almeida	polarimetry	10 years	24	instrumentation & diagnostics
Dr. J. C. del Toro Iniesta	Stokes diagnostics	11 years	18	LCVR's, interpretation
1 network postdoc	(astro)physics	PhD	33	observation & interpretation

plus currently on non-permanent positions two scientists (B. Ruiz Cobo and P. Fabiani Bendicho) and four graduate students (L. Bellot Rubio, C. Westendorp Plaza, H. Socas Navarro and R. Manso) all involved in Network topics.

Relevant publications

Trujillo Bueno, J., Fabiani Bendicho, P.: 1995, "A novel iterative scheme for the very fast and accurate solution of Non-LTE radiative transfer problems", Astrophys. J. 455, 646,

Sánchez Almeida, J., Landi Degl'Innocenti, E., Martinez Pillet, V., Lites, B.W.: 1996, "Line Asymmetries and the Microstructure of Photospheric Magnetic fields", Astrophys. J. 466, 537

6.3 Collective Experience: participant OAC (number 3)

Expertise. The Osservatorio Astronomico di Capodimonte in Naples has put much emphasis over the past decades on diagnostical applications of the alkali resonance lines to solar and stellar atmospheric modelling and wave phenomena. More recently, the OAC team has expanded its interests to solar magnetometry, in particular building up its experience in the acquisition and analysis of extended multiwavelength data sets for active region studies. Pertinent research topics are the comparison with models of subsurface magnetic fields, flaring events, and the effects of active regions on global velocity measurements.

Instrumentation. The OAC team presently installs the VAMOS (Velocity and Magnetic Observations of the Sun) instrument at Naples. It is based on a magneto-optical filter (MOF) and obtains full-disk Dopplergrams and magnetograms simultaneously. The OAC is also responsible for the development and maintenance of the solar data archive (ARTHEMIS) for the large data stream from the Italian Panoramic Monochromator (IPM) on THEMIS.

Network role. The OAC team will concentrate on the comparison between observed and simulated spectra from quiet and active solar structures [objective (f)], on studies of active structures at various scales of emergence [objectives (a),(c)], and it will actively participate in Network observing campaigns [objective (e)]. VAMOS will be used to provide solar full-disk magnetograms in Network data support. Another Network collaborative task consists of the installation of a similar MOF-based instrument at the DOT for high-resolution magnetometry. In addition, the ARTHEMIS archive will be expanded to provide an efficient medium to store and share Network data in a centralised on-line repository. The OAC training contribution will emphasise line formation, active region topology, MOF technology and database management.

Research linkages. The OAC team has had collaborations with the UU team and collaborates at present with the OP team. The team hopes to establish Network collaborations with other teams, especially the IAC and AIP teams for studies of radiative transfer, active region topology and the solar dynamo. In addition, it will develop a collaboration with the UU team for the deployment of MOF magnetometry on the DOT. The team houses the secretariat of the Joint Organisation for Solar Observations (JOSO).

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
<u>Dr. G. Severino</u>	spectral line diagnostics	20 years	24	modelling, MOF instrumentation
Dr. G. Cauzzi	solar magnetism; JOSO	8 years	24	observation & data analysis
Dr. M.-T. Gomez	stellar atmospheres	21 years	24	theory and diagnostics
Network postdocs	(astro)physics	PhD	44	observation & interpretation

plus currently two postdocs (T. Straus and E. Gavryuseva), one graduate student (M. Oliviero) and three co-workers (K. Reardon, M. Dolci and A. Tripicchio) involved in Network topics.

Relevant papers

C. Marmolino, M. Oliviero, G. Severino, and L. A. Smaldone: 1997, "Active Region Effects on Solar Irradiance at Na I D Lines", Astron. Astrophys. Suppl., in press

van Driel-Gesztelyi, L., Schmieder, B., Cauzzi, G., Mein, N., Hofmann, A., Nitta, N., Kurokawa, H., Mein, P., and Staiger, J.: 1996, "X-Ray Bright Point Flares Due to Magnetic Reconnection", Solar Phys. 163, 145

6.4 Collective Experience: participant UiO (number 4)

Expertise. The Institute of Theoretical Astrophysics of the University of Oslo has a strong position in solar physics. The UiO efforts in this field now concentrate on solar surface magnetism, chromospheric dynamics, chromospheric line formation, transition region and coronal physics and the solar wind. The team has an excellent track record in these areas. Network-specific expertise is in spectral line formation, radiation hydrodynamics and observing. The Oslo team is word leader in realistic radiation hydrodynamics simulations of chromospheric dynamics. It runs an extensive education programme including successful summer schools.

Instrumentation. The UiO team is co-investigator in both CDS and SUMER on SOHO, which provide excellent spacebased observations. Access to groundbased telescopes through peer review includes the SVST on La Palma and various telescopes in the US. The team's numerical simulations are very demanding in computer power. Access to powerful computing platforms is secured at the institute level through powerful workstations and a mini-supercomputer server, at the faculty level through a workstation cluster and a parallel server, and at the national level through a CRAY-T3E computer linked to the institute through a 100 Mbit/s network.

Network role. The key task for the UiO team consists of the interpretation of Network observations by performing pertinent radiation hydrodynamics simulations [objectives (b) and (f)]. Promising undergraduate students will be involved in these activities. The team will contribute Network training in advanced numerical techniques, also in the form of a Network summer school.

Research linkages. The UiO team has long-standing intensive collaboration with the UU team and close contact with the OP and ESA teams. The Network activities will enhance its contacts with the other teams, especially AIP whose experience with magnetic structure dynamics complements the UiO radiation hydrodynamics expertise. The team is involved in the definition of benchmark tests for the computer industry.

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
Prof. M. Carlsson	radiation hydrodynamics	17 years	24	modelling
Prof. O. Engvold	solar physics	32 years	9	observations
Dr. V. Hansteen	radiation hydrodynamics	12 years	18	modelling
Prof. P. Maltby	solar physics	37 years	6	observations & interpretation
Network postdoc	(astro)physics	PhD	33	modelling

plus currently one postdoc (Q.Q. Cheng) and three graduate students (R. Skartlien, S. Bard, A. Botnen) all full-time involved in Network topics, plus parttime-involved undergraduate students.

Relevant publications

Carlsson, M., Stein, R.F.: 1995, "Does a Non-magnetic Solar Chromosphere Exist?" Astrophys. J. Letters 440, L29

Carlsson, M., Stein, R.F.: 1997, "Formation of Calcium H and K Bright Grains" Astrophys. J. 481 (in press)

6.5 Collective Experience: participant KVA (number 5)

Expertise. The KVA team belongs to the Royal Swedish Academy of Sciences but is effectively part of the Stockholm Observatory (Stockholm University). Over the past 15 years, the team has developed world-leading competence in radiative transfer methods, atmospheric modelling and diagnostics, innovative image restoration techniques (phase diversity), and solar physics instrumentation.

Instrumentation. The KVA team runs the Swedish Vacuum Solar Telescope (SVST) on La Palma which is widely recognised as one of the best and most productive solar telescopes worldwide (Fig. 2 on page 24). This is due to its high optical quality, the domeless design, the mirrors being all within the vacuum system, and the excellent atmospheric quality of the site. A sophisticated image acquisition system has been developed which allows up to five large-array CCD cameras (up to 2000×2000 pixels each) to operate simultaneously. The instrumentation also includes a spectrograph reaching high spatial resolution, a fast correlation tracker servoing the third telescope mirror, phase-diversity wavefront sensors and tunable narrow-band filters.

Network role. The KVA team will contribute to objectives (a)—(e). It will run the SVST in Network observing campaigns, and it will not only continue its pioneering efforts to significantly improve the spatial resolution of solar magnetometry (by developing image stabilisation, frame selection, phase diverse wavefront restoration and an adaptive mirror system for low-order wave-front correction) but also assist the other telescope-owning teams in adopting these new techniques. In addition, the KVA team will put large effort in the completion and application of liquid-crystal Stokes vector magnetometers in cooperation with the IAC team, and it will support the UU effort to use the DOT in proxy-magnetometry. The team also aims to share in the development of the interpretative methodology to obtain the field topology of magnetic structures from high-resolution observations. Collaboration with industry will be part of the training programme.

Research linkages. The advanced Stokes polarimeter is being developed in close collaboration with the IAC team. The DOT (team UU) is operated from the SVST building and joint observations are planned to start in 1997. SVST observing time is regularly provided to research groups from *e.g.,* Norway (UiO), Spain (IAC), The Netherlands (UU), Switzerland, and Germany. Over the last years approximately 80 % of the observing time has been used by non-Swedish scientists. The KVA group collaborates intensively with industry (Digital Europe and the Lockheed-Martin Palo Alto laboratories).

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
<u>Prof. G. Scharmer</u>	rad. transfer, instrumentation	17 years	18	instrumentation, analysis
Dr. D. Kiselman	atmospheric modelling	7 years	18	observation, interpretation
Mr. Wang Wei	instrumentation	11 years	33	instrumentation
Network postdoc	(astro)physics	PhD	33	observation, interpretation
KVA student	astrophysics	–	27	observation, interpretation
Network student	astrophysics	–	27	observation, interpretation

Relevant publications

Kiselman, D.: 1994, "High spatial resolution solar observations of spectral lines used for abundance analysis", Astron. Astrophys. Suppl. Ser. 104, 23

Löfdahl, M., Scharmer, G.: 1994, "Wavefront sensing and image restoration from focused and defocused solar images", Astron. Astrophys. Suppl. Ser. 107, 243

6.6 Collective Experience: participant AIP (number 6)

Expertise. The Astrophysikalisches Institut Potsdam has a long tradition in investigations of activity phenomena induced by magnetic fields; this concerns solar active regions and global phenomena as well as other astrophysical applications. The topology of solar magnetic structures has been investigated for more than a century, and more than 5 decades ago the famous 'Einsteinturm' at Potsdam was the first place in Europe where solar magnetic fields were measured by means of spectropolarimetric methods. After that, while East Germany was a part of the Eastern bloc, the Potsdam solar continued working on instrumental and theoretical aspects of magnetometry (e.g., deriving effective methods for compensating instrumental polarisation and for modelling dynamic phenomena), but they were forcibly kept away from up-to-date techniques and telescopes and from cooperation with colleagues in the West. Only in the last few years have they gained access to the Canary Island telescopes and to space data, in particular from SOHO. A strong point of the team is its cooperation with other astrophysics groups such as the solar radio astronomers and the MHD turbulence and dynamo theorists at Potsdam. Training activities include lecturing at the new Potsdam University and at the Berlin universities as well as hands-on training in observation techniques at the Einsteinturm.

Instrumentation. The AIP team shares access to the German telescopes on Tenerife (Vacuum Tower Telescope VTT and Gregory Coudé Telescope GCT, see Fig. 2 on page 24). Moreover, the Potsdam Einsteinturm provides an old but large (60 cm aperture) and directly accessible instrument at home which enables the team to test new instrumentation and to train young solar physicists.

Network role. The AIP team contributes its expertise in Stokes vector spectropolarimetry [objective (d)], in investigating the topology of active regions and global signatures of the dynamo [objectives (a) and (c)] as well as in modelling atmospheres in active region structures and in dynamical processes such as oscillations and flares [objective (b)]. The team will increase its participation in SOHO plus groundbased telescope observing campaigns [objective (e)], and take part in the Network training programme.

Research linkages. The AIP team already has a close collaborations with the the OP team and is also involved in SOHO. It looks forward to closer collaboration with the other teams. Together with other German solar physics groups, the AIP has links with industry, *e.g.,* Carl Zeiss, for developing adaptive optics, fast synchronised CCD cameras, and modulators for 2D spectropolarimetry at the GCT and in future space experiments.

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
<u>Prof. J. Staude</u>	solar magnetism	30 years	18	modelling, interpretation
Dr. A. Hofmann	solar physics	20 years	24	observation, analysis
Dr. H. Balthasar	solar physics	15 years	24	observation, analysis
Network postdoc	(astro)physics	PhD	33	observation, analysis

plus currently three PhD students (T. Horn, D. Maleki, J. Rendtel), one graduate student (I. P. Czycykowski), and two engineers (H. Detlefs, H.U. Schmidt, both permanent).

Relevant publications

Staude, J.: 1994, "Interpretation of sunspot oscillations", in R. J. Rutten and C. J. Schrijver (Eds.): *Solar Surface Magnetism*, NATO ASI Series C 433, Kluwer, Dordrecht, 189

Horn, T., Hofmann, A. and Balthasar, H.: 1996, "High resolution polarimetric measurements in a sunspot", Solar Phys. 164, 321.

6.7 Collective Experience: participant OP (number 7)

Expertise. The solar physics group at the Observatoire de Paris at Meudon is expert in spectropolarimetry techniques for solar magnetometry. Current research addresses a new method for polarised non-LTE line formation and radiative transfer using the density-matrix formalism, diagnosis of weak magnetic fields by the Hanle effect, and the measurement of intermediate and strong magnetic fields accounting for Faraday rotation and magneto-optic effects. The modification of polarisation by the velocity field of the radiating matter is also under study. Magnetic field measurements for flux tubes using the Zeeman effect is investigated by using sets of several lines in order to disentangle temperature effects in the case of unresolved structures. The OP team is also expert in chromospheric velocity measurements, derived from non-LTE line profile analysis, and in numerical modelling of the flows along evolving magnetic field lines in the chromosphere.

Instrumentation. The OP team played a key role in conceiving and realising the French–Italian THEMIS telescope (Fig. 2 on page 24) and will be its principal operator. This instrument will provide high-resolution spectropolarimetry owing to the Cassegrain telescope, the fast tilting mirror, and the two large spectrometers. These three capabilities are essential for magnetic field measurements in fine structures. Moreover, many spectral lines can be recorded simultaneously so that all physical quantities can be investigated tomographically, at different heights in the atmosphere. The spectrographs can be used in subtractive mode (MSDP) in which line profiles are obtained strictly simultaneously across a 2D field, permitting to trace very fine structures without differential seeing shifts. The 2D-character of the MSDP can also be exploited in phase-diverse and speckle image restoration techniques.

Network role. The OP team will share in the Network efforts to observe and model solar magnetic structure, with emphasis on the quiet and active network and active regions. It adds its expertise in spectropolarimetry to the Network efforts and it will obtain data using THEMIS in coordination with the other Canary Island telescopes. The THEMIS observing modes will be especially dedicated to magnetic and dynamic measurements in very fine structures.

Research linkages. The OP team presently collaborates with the AIP, OAC, UiO and ESA teams. The Network activities will intensify the contacts with the remaining partners. The team chairs the Joint Organisation for Solar Observations (JOSO). It has links to industry that will be expanded when THEMIS is fully functioning, in particular concerning new CCD technology.

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
<u>Dr. P. Mein</u>	solar physics	30 years	21	observation, modelling
Dr. V. Bommier	line formation theory	11 years	18	radiative transfer
Dr. P. Démoulin	plasma physics	10 years	10	MHD, modelling
Dr. J. Rayrole	instrumentation	30 years	24	observation, modelling
Dr. S. Sahal	line formation	25 years	18	spectral line polarisation
Dr. B. Schmieder	solar physics; JOSO	24 years	12	observation, modelling
Dr. M. Semel	solar polarimetry	31 years	18	observation, modelling
G. Aulanier	solar physics	student	21	observation, modelling
Network postdoc	(astro)physics	PhD	33	observation, modelling

Relevant publications

Mein, N. and Sahal, S. (Eds.): 1997, THEMIS Forum “Science with THEMIS”, Meudon, in press.

Mein, P., Démoulin, P., Mein, N., Engvold, O., Molowny-Horas, R., Heinzel, P., Gontikakis, C.: 1996, “Dynamics of solar magnetic arches in the photosphere and the chromosphere”, Astron. Astrophys., 305, 343

6.8 Collective Experience: participant ESA (number 8)

Expertise. The ESA Solar System Division at Estec (Noordwijk, the Netherlands) supports solar space missions for the whole European solar physics community. It encompasses a solar physics research unit which conducts acquisition and analysis of groundbased and spacebased solar data as well as the development of new solar instrumentation. The unit includes the SOHO Project Scientist and his team; five staff members are SOHO Co-Investigator. The ESA team has broad expertise in solar physics ranging from flux-tube dynamics, chromospheric dynamics, MHD simulations, UV spectroscopy and UV imaging to helioseismology and solar variability. In addition, there is much expertise in solar-related stellar physics (solar/stellar connection, stellar magnetic activity, flare stars, etc.).

Instrumentation. At present the ESA team is mainly involved in the SOHO mission, for which it has also provided hardware. Various team members take part in the daily SOHO operations. In addition, the team has interests in groundbased instrumentation, using engineering models of space instruments and a breadboard fast CCD camera for imaging and spectrometry.

Network role. An obvious Network-specific task is to utilise the unique opportunities offered by the various instruments onboard SOHO [objective (e)]. The ESA team will play an integrating role by co-ordinating Joint Observing Programmes (JOP's) combining groundbased observatories (THEMIS, VTT, GCT, SVST, DOT) and SOHO (in particular SOI/MDI, SUMER and CDS). The team will also take part in data analysis and interpretation. In addition, the fast ESA CCD camera will be used at Canary Island telescopes in collaboration with other Network teams. The team will contribute substantially to the Network training by letting Network postdocs participate in the daily SOHO scheduling and operation.

Research linkages. The ESA team has ongoing collaborations with the OP, IAC and UU teams and, as space pivot of European solar physics, maintains close scientific interactions with all other Network teams. These will be further intensified in the joint Network programmes. The CCD camera project includes R&D linkage to industry.

Scientific staff & involvement in Network research (coordinator underlined)

Scientist	Specialism	Experience	Involvement (man-months, topics)	
<u>Dr. B. Fleck</u>	chromospheric dynamics	10 years	18	coordination SOHO–GBO's
Dr. B.H. Foing	UV imaging/spectroscopy	17 years	12	data analysis, instrumentation
Dr. P. Martens	MHD simulations	17 years	12	SOHO observations, modelling
Dr. V. Domingo	solar variability	32 years	3	SOHO Project Scientist
Network postdoc	solar physics	PhD	33	observation & interpretation

plus currently two postdocs (L. Fletcher, K. Muglach) graduate, undergraduate students and engineers.

Relevant publications

Fleck, B., Domingo, V., Poland, A.I. (eds.), 1995: "The SOHO Mission", Solar Phys. 162, Nos. 1–2

Domingo, V., Fleck, B., Poland, A., 1996: "The First Results from SOHO", ESA Bull. 87, 7

7. Collaboration

In a broad sense, it may be stated that the various teams are of high quality and contain outstanding astrophysicists (as evidenced by the team descriptions in Section 6) — but that the sharing of expertise and effort between the teams can yet be considerably improved. That is what this proposal aims to accomplish. The Network postdocs play a key role. Their collaborative efforts and the relative ease with which they may move around (being not hampered by teaching and management duties) represent the major mechanism to establish intensive networking.

Joint tasks. The various team collaborations are defined in Table 1 on page 29. There are many tasks in which teams collaborate pairwise in order to gain most of each other's expertise and assets. Other tasks require collaboration of more than two teams, or multiple pair-wise collaborations. For example, the various collaborations on THEMIS polarimetry always involve the OP team which runs the THEMIS spectrometer, and collaborations around SOHO data gathering always involve the ESA team.

The implementation collaborations form the backbone of our proposal. They advance solar surface magnetometry to the level that is desired for the science objectives, and they will gain much from intensive networking. The Network postdocs will all take part in these specific tasks, in addition to pursuing the more general science goals.

Multi-telescope campaigns. The observing campaigns are both the most intensive and the most extensive collaborations of the Network, involving all partners in the landmark activity of this proposal. Networking is a conditio sine qua non for these campaigns. The observers from each team will have detailed planning and evaluation meetings before and after each campaign (at the centrally located IAC), and they will maintain intensive contacts during the campaigns. The Network postdocs will perform a special role by participating frequently at other telescopes than the one contributed or used by their team. This not only enhances their training, but also spreads detailed knowledge of each facility's characteristics across the Network.

Postdoc exchange. A working principle of the Network will be to fully take advantage of the fact that the postdocs are not burdened by other duties They will frequently work at the institute or the telescope of a task partner, and so play a key role in the joint development and spreading of expertise, in particular the extensive data reduction software needed to analyse the comprehensive data sets efficiently.

Postdoc team switch. As detailed in Section 8 (next page), the Network aims to have a mid-term team switch for some, perhaps most, of the young visiting researchers. This is not only advantageous from the training point of view, but also intensifies the inter-team collaborations. With such a mid-term switch, a Network postdoc brings detailed expertise gained from one team to another team.

Integration of fresh teams. It would be a gross insult to call the OAC and AIP teams "less experienced", but they actually are relative newcomers on the scene in the sense that they have a less long history of involvement with Canary Island and space observing than the other teams. That has changed recently, for the AIP team obviously due to political reasons, for the OAC team thanks to a widening interest and the influx of new staff. Both teams are fully integrated in European solar physics and both add specific expertise to the Network.

8. Organisation and Management

Mid-term switches. The Network aims to establish the following appointment policy, subject to negotiations with the Commission: to hire its young visiting researchers for a period of eighteen months with the possibility of extension by another eighteen months (subject to approval and satisfactory performance), but with the proviso that the Network strives for a mid-term team switch so that the second period is spent with a different team. This will not be feasible for the OAC and ESA teams which hire temporary staff at two-year durations, and the implementation is also constrained by obvious requirements of nationality and specialism. Thus, the possibility of a mid-term team switch must be assessed per appointment. Where feasible, they enhance postdoc training and information exchange between teams.

Network meetings. Yearly Network meetings are planned in addition to the more frequent before- and after-campaign planning and evaluation meetings at the IAC. The first one (October 1998) will be combined with the third EU-funded ASPE (Advances in Solar Physics Euroconferences) meeting that will be organised at the AIP. The ASPE meetings are chaired by the OP team in JOSO context (Joint Organisation for Solar Observations); the first one was held last autumn at the IAC and was very successful. Together with JOSO, the Network will strive for continuation of the ASPE meetings programme after 1998. It aims to combine its own meetings with such community-wide ones in order to boost efficiency as well as visibility.

Internet communication. It is obvious that the Network communicating will heavily use the Internet. Email and the WWW are completely integrated in solar physics. For example, the completion of this proposal was eased by frequent draft transfer from the provisional Network WWW page set up by the coordinator. The campaign scheduling, daily planning images, data archiving and reduction software dissemination will all be handled through WWW pages. Each team will have a local coordinator responsible for the team pages. In addition, Majordomo mail list serving will be used throughout the Network.

Reporting. The Network meetings will constitute the primary progress report mechanisms from all teams to all other teams with regards to science results. More frequent reporting on the implementation and training aspects will be institutionalised in the form of an electronic bulletin, accessible on WWW for Network members only, that will be maintained by the coordinator. He will require frequent updates from all teams.

The coordinator will also maintain a more general and more glossy WWW page that is intended for outsiders and for the general public. It will report on the Network activities and serve as a source for the latest images and results, and for Network reports and preprints.

At the completion of the Network activities, a final reporting session will be set up at a general solar physics meeting such as an ASPE one. The Network may also negotiate for a special issue of *Solar Physics* devoted to its results.

In addition, the Network will make a special effort to report on its activities to the general public in the form of popular-science articles. The combination of Canary Island telescopes, the SOHO mission and beautiful solar imagery make this a desirable and worthwhile (and actually pleasant) activity.

Mid-term review. As mentioned on page 28, the mid-term review will be the largest milestone in the science activities. It will also be an organisational milestone, combining EU assessment with the mid-term appointment switches detailed above.

Coordinator management experience. R.J. Rutten (UU) is a well-known organiser of successful scientific meetings (director and principal editor of two NATO Advanced Research Workshops, coordinator of the Dutch Astronomers Conference during five years, numerous science organising committees), was the founding editor of the EPS European Solar Physics Newsletter, coordinated NATO Collaborative Research and NWO CIS (former USSR) grants, has been member of ESA advisory committees and of ESA project teams, has managed computer services, is DOT project scientist, is chairman of the education board of his institute, and was one of the instigators of the successful yearly Dutch post-doctoral astronomy school. He was also the first astronomer in Holland to set up a personal WWW page, using it to spread an advanced course that is now part of astrophysics teaching throughout Europe. He knows all Network team members personally.

9. Training Need

Utilisation of European facilities. A straightforward economic reason at the Community level to invest in young-researcher training in the Network research topic consists of the telescope array in Fig. 2 on page 24 plus the SOHO mission. These are large investments that have brought Europe to the forefront in the field, taking over the worldwide leadership in both groundbased and spacebased solar physics from the US. This position must be exploited and strengthened.

Solar physics on the upswing. More in general the new facilities, together with the advances brought by numerical simulation on powerful computers, give a new impulse to solar physics that changes the content of the field. During the greater part of this century, after solar physics inspired the great developments of astrophysical radiative transfer theory, progress in solar physics was hampered by the great complexity of the solar surface phenomena. It deteriorated into "solar dermatology" for lack of insight in the basic physics processes that lie at the root of the observed phenomena. This changes now, thanks to the high resolution obtained with the Canary Island telescopes, the diagnostics available from SOHO, and the realism attained by numerical simulations: solar physics is on the upswing. Possessing the best current facilities worldwide, it behoves Europe to train and fund manpower in this growth area.

Space weather. Solar physics is part of astrophysics and in principle a pure science—but since solar magnetism affects the geosphere, it also has direct consequences to the human environment. It is now clear that the jet stream patterns that influence the major weather systems are modulated by the solar activity cycle. Solar activity affects satellite orbits in more direct fashion; for example, SOHO's predecessor, the *Solar Maximum Mission*, was brought down prematurely by increased solar activity. The increasing importance of this "space weather" increases the need to understand solar magnetism—and increases the need for young researchers that are trained in gathering and analysing solar magnetism data.

Manpower. The current manpower situation in European solar physics is not optimal. The team tables on the partner description pages illustrate that in many teams (UU, OAC, UiO, AIP, OP) the senior staff is overly senior. An influx of young researchers is needed to let Europe retain its current leadership and to let Europe fully participate in the future expansion of the field. It should be added here that over the last decade a persistent brain drain has moved young solar physicists from Europe to the US. Most of the recent European solar physics PhD's have taken up postdoc positions across the Atlantic. Experience shows that once they are there, many do not return (often having found American spouses). Those that leave academia tend to end up in American rather than European industry. Reversing this trend is an implicit goal of our Network.

General socio-economic reasons. Our Network activities will train the young visiting researchers in techniques that are highly valuable also outside solar physics or space weather applications. They will be very computer-literate, having much experience in high-speed data acquisition, large-volume data handling, sophisticated analysis techniques, and more generally in complex problem solving including numerical simulations at the forefront of computational physics. They will be an asset to Europe's high-technology economy.

10. Training Programme

Table 3 below gives a breakdown of Network-funded young-visiting-researcher man-months. In addition to these 288 man-months of postdoctoral training and 36 man-months of graduate student training, the Network training programme includes the following elements:

– *Telescope training.* By participating in the magnetometry implementation tasks and sharing in the joint observing campaigns, the Network postdocs will receive extensive hands-on telescope training. They will also take part in the pre- and post-campaign planning and evaluation meetings at the IAC. Some of then will also join the daily planning and operations at the SOHO Experiments and Operations Facility and so receive (non-hands-on) training in space mission control.

– *Reduction and analysis techniques.* These collaborative tasks imply extensive training in sophisticated computer methods to handle large amounts of data.

– *Network-organised summer/winter schools.* Three postdoctoral schools are planned, one per year: "Observational Solar Physics", "Radiation Hydrodynamics" and "Solar and Stellar Polarimetry", to be organised by the UU, UiO and IAC teams, respectively. These schools will draw on the complementary expertise that is available Network-wide and also exploit the considerable teaching experience of some partners. The schools are Network-inspired and Network-organised but will in principle be open to the whole astrophysics community, especially if additional funding is obtained (*e.g.,* from the Fourth TMR Activity). Most or all of the school syllabuses will be offered on WWW.

– *Advanced seminars.* Postdocs located at the university partners may also take part in the advanced seminars run at these institutions.

– *Postdoc exchanges.* The Network will establish frequent postdoc exchange between partners, and also between partner telescopes, in order to efficiently diffuse magnetometry techniques as well as data reduction and analysis software expertise.

– *Training at industry.* See next page.

– *Mid-term team switch.* The intention to let the postdocs switch team at the mid-term point wherever that is feasible effectively implies double research training content.

– *Meetings.* All postdocs will of course take part in the yearly Network meetings, and in other (wider) meetings of interest such as the ASPE meetings and their successors.

Team	graduate	postdoc	specialism
UU	–	36	(astro-)physics
IAC	–	36	(astro-)physics
OAC	–	48	(astro-)physics
UiO	–	36	(astro-)physics

Team	graduate	postdoc	specialism
KVA	36	36	astrophysics
AIP	–	36	(astro-)physics
OP	–	36	(astro-)physics
ESA	–	24	solar physics

Table 3: Network training: man-months of graduate studentship and postdoctoral appointment per partner. Most postdocs will be drawn from astrophysics but a few may have graduated in physics. The 36-month postdoc assignments will be split into 18-month appointments with the intention of mid-term team switches where feasible. OAC and ESA work with two-year appointments. The single graduate studentship enhances the smallest team.

11. Connection to Industry

Existing links. As detailed in the partner descriptions (Section 6), partners UU, IAC, KVA, AIP, OP and ESA are all involved in industrial technology development in connection with the Canary Island telescopes.

The UU completes the DOT telescope on a grant from the Dutch “Stichting Technische Wetenschappen” that encompasses direct technology transfer to industry. For example, a patent will be sought for the DOT bad-weather canopy (folded open clamshell-wise in Fig. 2 on page 24). This advanced fabric-plus-steel structure was developed in collaboration with Poly Nederland and is designed to withstand hurricanes over Beaufort 12. It has indeed weathered its first La Palma icings and storms.

KVA and UU are intensively involved in joint R&D with Lockheed–Martin (USA). This company uses the SVST frequently to test hardware that is being developed for solar observations from space platforms, and it intends to use the DOT similarly. In addition, Lockheed-Martin participates in running the SOI/MDI instrument on SOHO, of which the UU group is a heavy user.

Future links. The solar physics requirement of acquiring and transferring huge amounts of image data within speckle freezing times (10 ms) to image-processing hardware represents a prime topic for links with industrial R&D. The ESA, AIP, OAC and KVA teams are all involved in industrial linkages concerning CCD technology (see partner descriptions in Section 6) that aim to improve on the current technology limits. For example, the IAC and KVA teams operate custom-designed CCD cameras and controllers in their collaborative liquid-crystal projects that were developed for fast magnetometry by the US High Altitude Observatory. Future replacements of this technology should come from industry and need to be negotiated.

A particularly important link is the formal collaboration that the KVA team is presently starting with Digital Equipment International Limited through the External Technology Grants Program of Digital Europe, with additional (informal) involvement of the IAC and the Leonardo de Vinci University in Paris. The purpose of this collaboration is to develop a general purpose DMA (Direct Memory Access) interface for the PCI bus in order to enable fast data acquisition, real-time data processing and servo control using standard work-station hardware operating under UNIX. On the Network side, this programme aims to achieve an important breakthrough in the data-flow problem between large-array CCD cameras with fast readout and the computer controllers that handle the digital images by engineering a general solution that is applicable at all telescopes with standard hardware. DEC’s interest lies in yet wider multi-media applications.

The IAC team is involved in contract R&D with Construcciones Aeronauticas S.A. concerning space qualification of the new liquid crystal retarder technology for future space projects.

For both THEMIS and DOT, the current stage of initial completion and first operation will be followed by extension of the post-focus equipment. For THEMIS, multi-channel phase-diverse speckle restoration will again require dialog with industry about fast synchronised CCD cameras. For the DOT a 2D spectrometer option is being researched that relies on optical fiber transformation of a square input field to a linear spectrometer slit. The present indication is that the requirements are at the limit of current fiber technology; contacts with industry are now sought (Schott Fiber Optics Inc., UK).

Training programme. The KVA team will let Network young visiting researchers take part in its formal R&D collaboration programme with Digital Europe.

The UU regular sends graduate and undergraduate students to Lockheed-Martin (Palo Alto) on external funding. It seems a good policy to send Network postdocs there as well, giving them experience of how a top US industry is run while returning to their European base.

The other partners also aim to let Network postdocs participate in their links with industry.

12. Financial Information

The Network realises its aim of maximum collaboration and diffusion of expertise by assigning, in principle, one postdoctoral young visiting researcher to each team. Differences between partner constraints produce some deviations from this principle that are explained below. The resulting distribution of the Network budget over the participants and over the main titles of expenditure is, in kECU units:

Team	Country	YVR cost (per month)	man-months	personnel A	NWC B	DRC C	OH D	total
UU	NL	3.336	36	120	30	6	30	186
IAC	ES	3.111	36	112	18	6	25	161
OAC	IT	2.468	48	119	18	6	25	168
UiO	NO	3.245	36	117	18	6	25	166
KVA	SE	1.905+1.236	36+36	113	18	6	25	162
AIP	DE	3.509	36	126	18	6	25	175
OP	FR	3.390	36	122	18	6	25	171
ESA	INT/NL	3.336	24	80	18	6	18	122
Totals	8	25.536	324	909	156	48	198	1311

Table 4: Network financing. The basic expenditure is set by allocating one postdoc (in two eighteen-month slots) to each team. OAC and ESA work with two-year appointments. The larger man-month allocations to OAC and KVA balance their lower man-month costs. ESA's smaller allocation will be compensated from other sources.

Explanation:

- Third column (*YVR cost*): typical monthly cost of a young visiting researcher = gross Category 30 personnel cost per man-month. The second number for KVA is for a Category 20 (graduate student) appointment. Sweden deviates from the other countries in not taxing postdocs. If this policy changes in the near future, the specified total will be a good estimate for a single Category 30 appointment.
- Next column (*man-months*): total allocation of man-months, all Category 30 (postdoc) except for Sweden (36 man-months Category 30 plus 36 man-months Category 20). The basic allocation is 36 man-months per team. The KVA and OAC exceptions produce better balancing of the total allocations. The ESA allocation is smaller because the team relies on the existing ESA postdoctoral grant programme for additional support.
- Next column (*personnel*): total costs of young visiting researchers.
- Next column (*NWC*): networking costs. The UU allocation includes organisation of summer schools and Network meetings. For the other teams the allocations are set equal because their team sizes, travel distances and resources roughly balance. Additional funding for the concerted observing campaigns will come from the EU "Access to large-scale Facilities" TMR Activity.
- Next column (*DRC*): other direct running costs. Primarily data storage consumables (DAT cartridges and on-line juke-box CD-roms).
- Next column (*OH*): overheads.
- Final column: total allocations per partner.

These allocations do not deviate from the financial guidelines.