STARTPAGE

HUMAN RESOURCES AND MOBILITY (HRM)
ACTIVITY

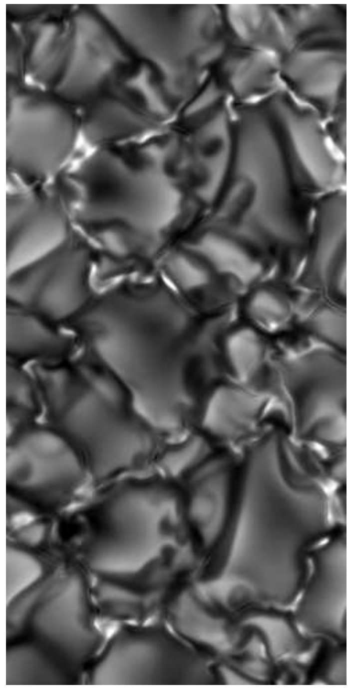
MARIE CURIE ACTIONS

Host fellowships for Early Stage Research Training
(EST)

PART B

STAGE 1 – OUTLINE PROPOSAL

“USO–SP”



The three principal training assets of the proposed USO–SP Graduate School in Solar Physics. Left: KVA's Swedish 1-m Solar Telescope (SST). Middle: UiO computation of solar granulation. Right: UU's Dutch Open Telescope (DOT).

The two telescopes stand close together on a 2300 m high volcano on the Canary Island of La Palma. They differ strongly in concept (the SST is a vacuum refractor, the DOT an open reflector) but both perform supremely well. They are complementary in capabilities and together constitute a powerful tandem facility unparallelled anywhere. The SST is the sharpest solar telescope worldwide, and is presently being extended with adaptive-optics spectropolarimetry. The DOT is a superb tomographic movie producer through multi-camera speckle imaging. The SST + DOT combination offers comprehensive science opportunities at unprecedented angular resolution. Images and movies from these telescopes are available at URLs < http://www.solarphysics.kva.se > and < http://dot.astro.uu.nl >.

Many major research quests in solar physics require combination of such holistic high-resolution diagnostics with advanced numerical simulation of the type in which the UiO team excels. The middle panel shows a beautiful example of synthetic G-band observations, computed from a high-resolution three-dimensional magnetohydrodynamics simulation of solar convection in the presence of magnetic field. The computation reproduces solar surface granulation and intergranular magnetic elements with astounding realism.

These three assets epitomize our USO–SP training. The telescopes form an ideal combination for training in instrumentation, observation, and data processing. The simulation efforts provide advanced training in computational physics. The combination permits first-class physical scientist training.

B1 SCIENTIFIC QUALITY OF THE RESEARCH TRAINING AREA

Overview of the proposed project. The USO–SP Consortium is a formally established collaboration between Utrecht University (UU), the Royal Academy of Sciences of Sweden (KVA) in Stockholm and Oslo University (UiO). Its mission is to advance solar physics. With this proposal it aims to start an international graduate school in solar physics.

The Utrecht, Stockholm and Oslo solar physics groups together constitute a world-class research team, combining unique assets into a coherent package:

- KVA's Swedish 1-m Solar Telescope (SST) on the Canary Island of La Palma, the sharpest solar telescope worldwide;
- UU's Dutch Open Telescope (DOT) on La Palma, producing superb tomographic movies of the Sun;
- UiO's renowned expertise in numerical simulation of solar radiative transfer, hydrodynamics, and magnetohydrodynamics.

These assets make the USO–SP Consortium a resourceful combination to provide graduate training in a broad range of subjects, encompassing solar physics and stellar-atmosphere astronomy, advanced optics and polarimetry, real-time and post-detection wavefront restoration, large-volume image acquisition and processing, and numerical simulation techniques in in radiation hydrodynamics and magnetohydrodynamics.

We seek EST funding to expand our USO–SP training into a *USO–SP Graduate School in Solar Physics* through:

(a) 6 three-year PhD studentships, two at each of our institutes, to obtain PhD's in solar physics;

(b) 72 personmonths of short-term traineeships for graduate training complementary to early-stage research elsewhere.

Description and justification of the proposed research training. Our USO–SP research addresses the complex interactions between the solar photosphere and the outer solar atmosphere that are controlled by solar magnetism. Magnetic fields break through the solar surface in a hierarchy of magnetic elements ranging from Earth-sized sunspots down to the slender fluxtubes that at high resolution appear as tiny bright points. These magnetic elements are organised in intricate, continuously evolving patterns that constitute solar activity, control the structure and dynamics of the solar corona and the solar wind, and affect the extended heliosphere including the near-earth environment and possibly the terrestrial climate. Their role gives threefold motivation to study solar magnetism: *(i)* – astrophysics, employing the Sun as "Rosetta Stone" to investigate conditions and processes that are commonplace in the wider universe but are seen close-up only in the Sun, a direct view into the rich enigmas of cosmic magnetism; *(ii)* – magnetohydrodynamics and plasma physics, with the Sun a relatively close-by "cosmic laboratory" that adds length, time, temperature and density regimes not attainable in earthbased laboratories such as Tokamaks; *(iii)* – the solar modulation of the human environment through "space weather", i.e. the combined effects of solar cosmic-ray modulation, solar particle storms, and solar irradiance variations that affect our terrestrial neighbourhood and possibly climate on both short and long time scales. The latter interests make solar physics directly socially relevant, have created an unsatisfied job market, and imply an urgent need for increased training.

The human product of USO–SP training will consist of young researchers who are well qualified to tackle complex problems in (astro-)physics, instrumentation, image processing, and numerical modelling. Offering such high-quality graduate-level training in Europe counteracts the persistent brain drain to the US.

Originality and innovation. The SST and the DOT are newly completed, revolutionary telescopes for high-resolution observation of the solar atmosphere at the frontier of solar physics. Each telescope combines a pioneering design with superb optics and advanced imaging techniques to push the angular resolution limit to unprecedented sharpness. They do this in different ways, making them complementary in their science capabilities. Jointly, the SST and the DOT constitute the premier high-resolution facility worldwide in optical solar physics the coming years and a splendid feat of European innovation. They are co-operated in close USO–SP collaboration from adjacent control rooms in the SST building and frequently co-observe in tandem to exploit their complementary data gathering, usually in concert with co-pointed ultraviolet and X-ray imaging from space platforms.

The UiO team is at the forefront in numerical modelling of the solar atmosphere from the subsurface convection zone to the heliospheric solar wind. The major three-dimensional radiation magnetohydrodynamics code developed at UiO in collaboration with experts elsewhere includes a realistic equation of state and a detailed description of the coupling between matter and radiation. Other codes achieve detailed diagnostic reproduction of observables, including departures from LTE, time-dependent ionisation and recombination, and molecular equilibria. The combination of these simulation and diagnostics codes enables direct comparison with the high-resolution observations from the SST and the DOT. UiO has therefore obtained formal partnership in the SST and has started observationally oriented research incuding advanced image processing.

Research methods and interdisciplinary aspects. The patterning and evolution of solar magnetic fields are dictated by the subsurface dynamo and convective flows but in turn they dictate the structure, dynamics, and heating of the outer atmosphere. This switch in field role occurs in the optically observable photosphere–chromosphere regime, so that ground-based imaging permits charting the magnetic "footpoint" topology and dynamics. The basic building blocks are slender magnetic elements that are imaged sharpest at the base of the solar atmosphere (photosphere) when observed in the Fraunhofer G-band. They consist of magnetic flux ropes which can be traced up to the chromosphere through imaging in the Ca II H&K lines and then spread out as magnetic fibrils seen in the H I Balmer-α line. In the solar corona the field is structured in extended loops that are observable with space-based ultraviolet and X-ray imaging (presently the SOHO, TRACE and RHESSI missions, in future the Solar-B, Solar Dynamics Observatory and Solar Orbiter missions). The same multi-wavelength diagnostics serve to analyse the structure and dynamics of the magnetic-element assemblies causing solar activity phenomena such as sunspots, filaments, flares.

The DOT employs simultaneous imaging in the G band, Ca II H and Hα to produce synchronous speckle-restored multi-wavelength movies that often reach 0.2 arcsec angular resolution. The SST achieves even higher image resolution thanks to its twice larger aperture and adaptive optics. The SST will also provide high-resolution spectropolarimetry to obtain precise magnetic field quantification.

Numerical simulation represents the principal strategy to achieve quantitative interpretation at comparable levels of sophistication and resolution. Thanks to the computer revolution, numerical magnetohydrodynamics is now able to tackle the structure and dynamics of magnetic elements in the photosphere through ab-initio simulation. Higher up, the physics of and exchange processes between magnetic structures are becoming amenable to realistic modeling including sophisticated treatments of radiative transfer and topological field evolution.

The proposed USO–SP training aims to integrate these observational and theoretical advances within the PhD research projects in order to train scientists with an interdisciplinary grasp of both observation and theory. The USO–SP training will also be interdisciplinary in wider context through the proposed short-term USO–SP traineeships. They will cater to early-stage researchers from astronomy, physics (including technical physics), and information technology.

Importance, timeliness, and relevance of the research training. Training in solar physics represents investment in an exciting science with direct relevance for mankind. Solar physics presently experiences a worldwide boom, thanks to the advent of continuous solar monitoring from space, the advent of wavefront restoration to remove the effects of turbulence in the Earth's atmosphere on telescopic image quality, and the advent of sophisticated modelling in the form of increasingly realistic numerical simulations. These complementary advances are fully exploited in our USO–SP collaboration. High-resolution analysis combining multi-wavelength imaging, spectropolarimetry and MHD simulation is required in virtually *every* solar physics program addressing magnetic fields. Our proposed PhD training will deliver solar physicists with the in-depth background to perform independent research across the whole research area, and in particular to exploit the next-generation facilities that are now in construction or development both in Europe and the US.

In addition, our USO–SP training is pertinent to many areas of astronomy, to industries concerned with similar nonlinear restoration problems, and generally to research areas requiring advanced computer solution methods. The proposed short-term traineeships aim to such wider training.

B2 QUALITY OF THE TRAINING ACTIVITIES

Research training programme. The USO–SP research areas, specialities, assets, and academic environments provide an excellent base for comprehensive research training in a wide range of topics: solar physics, advanced telescope technology, astronomical instrumentation, wavefront restoration, data acquisition and data processing, numerical simulation techniques, astrophysical radiation hydrodynamics and magnetohydrodynamics.

The proposed training programme involves EST–funded USO–SP Fellows of two types:

1. six PhD studentships for pursuing PhD degrees in solar physics, each funded during three years from the proposed EST project;
2. USO–SP traineeships of 3–6 month duration for training that is complementary to external early-stage education, with a total volume of 72 personmonths funded from the proposed EST project.

The USO–SP Consortium will provide a variety of training elements to its Fellows:

- *research training*: each Fellow's research topic will be selected from the USO–SP research area described in Section B1. The topic and detailed work plan including course work will be contractually defined in a Fellow's personal career development plan. The content will depend on the precise research topic and on the previous education of each Fellow;
- *regular graduate courses*:
  - theory of stellar atmospheres (UU, KVA, UiO)
  - plasma astrophysics (UU, UiO)
  - radiative transfer (UU, KVA, UiO)
  - polarimetry and polarised radiative transfer (UU)
  - solar magnetism, activity, and cycle (UiO, UU)
  - solar wind and heliosphere (UiO)
  - numerical methods (UiO, UU)
  - astronomical instrumentation (KVA, UU)
  - image processing (KVA, UiO)

  Many of the above courses are given regularly at the specified institutes as part of the astronomy curriculum or are presently planned as such. Some will be organised by the specified partner specifically for USO–SP training. Their size and duration differ between partners[1]. These courses will be appropriate to local and visiting Fellows. All courses are mutually recognised between the USO–SP partners;
- *concentrated USO–SP courses*: every year the USO–SP will decide which topics are most urgent to be taught USO–wide in concentrated form. The format will consist of one to two weeks of intensive teaching to assembled USO–SP Fellows. These courses will be preferentially hosted by KVA on La Palma using its SST building, otherwise by UU or UiO on their premises. The schedule is to have two concentrated USO courses in the first year of the programme during the PhD student start-up phase, one per year in the remaining years;

[1] At Utrecht University and Stockholm University most graduate courses are 7.5 ECTS and vary in duration from a few months to a full semester. At Oslo University most graduate courses are 10 ECTS and take a full semester, but some are 5 ECTS.

- *on-site training*: many of the USO–SP Fellows will be trained hands-on in instrumentation and observing techniques at the SST and DOT as part of their research project. This training activity is shared by all three partners;
- *exchange training*: many of the USO–SP Fellows will spend short-term visits to the other partners for specific research training. These visits will be defined in each Fellow's career development plan;
- *science management training*: USO–SP Fellows that are involved in observing campaigns will also participate in the campaign planning;
- *presentation training*: all USO–SP Fellows will be required to present their work in local seminars and the USO Seminars on La Palma. USO–SP PhD students will be required to also present their research at national and international meetings. At least one USO–SP assembly will take place per year – usually on La Palma – in which all USO–SP Fellows must present their research. The USO–SP Fellows will also be frequently involved in public outreach;
- *education training*: some USO–SP PhD students will be involved in undergraduate teaching according to local practices and regulations.

USO–SP PhD training. The PhD students will be admitted to the PhD programmes of the USO institutes according to the local rules. The PhD training programmes will also adhere to the local rules. These still differ between the three sites: at UU and KVA (effectively Stockholm University with respect to PhD regulations) PhD training presently takes four years, at UiO three. However, the Dutch and Swedish education systems will undoubtedly converge to the Norwegian one as part of the harmonisation process of European higher education. In the meantime, both UU and KVA guarantee that PhD students funded during three years by the proposed EST project will be granted a fourth year from other sources as long as this is required by local regulations.

The three PhD training programmes also differ in the volume of required graduate courses. In Dutch astronomy it presently amounts to participation in the yearly Dutch astronomy school, the Dutch astronomy conference, and in local seminars. The formal course requirements are 30 ECTS at Oslo and as much as 90 ECTS at Stockholm. However, the USO–SP courses described above can be fitted into these local schemes and represent a much better match to the needs of young USO–SP researchers than other courses taken typically sofar for fulfilment. We also expect leverage from our USO–SP setup to trigger appropriate curriculum changes that will also benefit other international programmes.

USO–SP short-term training. We propose to offer three- to six-month training placements in solar physics, stellar-atmosphere theory, optics, polarimetry, real-time and post-detection wavefront restoration, image acquisition and processing, and numerical simulation techniques in radiation hydrodynamics and magnetohydrodynamics. These traineeships are intended to be complementary to early-stage training elsewhere and will cater to a large clientele of early-stage researchers with varied backgrounds. Examples are: young researchers that are yet undecided about whether and where to pursue PhD training; advanced PhD students that find they are in need of specialist training in a specific topic on which USO–SP offers expertise; PhD students from EU countries without access to first-class telescopes who desire intensive training in SST and/or DOT data analysis; academic engineers in nighttime astronomy who desire solar instrumentation expertise; USO–SP graduate students on other than EST funding who pursue secondments at USO–SP partners for specialist training.

Quality of the proposed research training. The USO–SP Consortium collectively harbours a renowed group of astrophysicists with formidable experience in both research and education: at KVA Prof. Göran Scharmer, Dr. Dan Kiselman and Dr. Mats Löfdahl, at UiO Prof. Mats Carlsson, Prof. Viggo Hansteen, Prof. Oddbjorn Engvold, Prof. Egil Leer and Prof. Øystein Lie-Svendsen, at UU Prof. Robert Rutten, Dr. Robert Hammerschlag, Prof. Johannes Goedbloed, Dr. Rony Keppens and, starting in 2005, Prof. Christoph Keller. Together, they guarantee high quality to the USO–SP training (and look forward to such international teaching).

The USO groups also harbour considerable experience in international meeting and school organisation (e.g., the schools at Oslo, Dwingeloo, and Tatranska Lomnica of the EC–RTN *European Solar Magnetism Network* in which the three groups partner also).

Benefits to the USO–SP Fellows. The USO–SP Consortium is a principal player on the solar physics world scene. The proposed PhD students will receive PhD training of outstanding quality thanks to our large collective expertise in solar physics, our telescope proprietorships which make our telescopes unparallelled training assets, and our powerful hydrodynamics and magnetohydrodynamics computer codes. One can hardly think of a better or more inspiring start into a solar physics career.

Likewise, the USO–SP short-term placements will provide high-calibre complementary training to early stage researchers from a wide range of interests. They will obviously benefit in experience and scope.

Benefits to the USO–SP hosts. The USO–SP Consortium has been established in order to profit most fruitfully from the observational complementarity of the DOT and the SST and the scientific complementarity of the expertise in our three groups. In their formal Memorandum of Understanding the three USO–SP partners have contractually agreed *"to intensify their linkage in undergraduate and graduate student education, including student exchange and sharing course materials, data, and analysis software, to define joint PhD projects exploiting their combined research expertise and facilities, to collaborate in graduate student recruitment, and to foster collaborations between graduate students"*.

The proposed EST project presents a major step forward in fulfilling these collaborative goals.

International aspects. The USO–SP Consortium submits the present proposal as the initialisation of an international *USO–SP Graduate School in Solar Physics*. Our aim is to combine roughly equal numbers of PhD students contributed from local university funding, from national science foundations, and from the EST funding requested here into a coherent international graduate school of 15–20 PhD students. This size is both appropriate to the European solar physics research area and to the USO–SP training capacity.

The additional training that USO–SP will offer through the proposed short-time placements will give valuable expertise to young researchers pursuing studies and careers in the wider astronomy and physics research areas. By furnishing three-to-six month slots of advanced training to graduate students pursuing PhD degrees in other European countries it also actively fosters the notion of European PhD's.

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