USO – SP

MEMORANDUM OF UNDERSTANDING
on
UTRECHT – STOCKHOLM – OSLO
COLLABORATION IN SOLAR PHYSICS

CONSIDERING that

- the Solar Physics group of the Sterrekundig Instituut Utrecht, Faculteit Natuur- en Sterrenkunde, Utrecht University, Utrecht, The Netherlands (henceforth abbreviated to SIU),
- the Institute for Solar Physics of the Kungliga Vetenskapsakademien at the AlbaNova University Center, Stockholm, Sweden (henceforth abbreviated to ISP), and
- the Solar Physics group of the Institutt for Teoretisk Astrofysikk, Det Matematisk-Naturvitenskapelige Fakultet, Oslo University, Oslo, Norway (henceforth abbreviated to ITA)

possess long-standing and actively pursued collaborations in solar physics research and education, abbreviated USO–SP and described in the Appendix to this document, and

RECOGNISING that future USO–SP collaborations, in particular those exploiting the innovative Dutch DOT and Swedish SST solar telescopes on La Palma and the ITA expertise in numerical solar physics, will benefit from formally established, closer ties between the SIU, ISP, and ITA solar physics research and education programs,

the following three Parties

- Universiteit Utrecht, established in The Netherlands,
- Universitet i Oslo, established in Norway, and
- Kungliga Vetenskapsakademien, established in Sweden

DECIDE to enter into an agreement in the form of this Memorandum of Understanding, the terms and conditions of which are recorded in Articles 1–8 on page 2.

Articles

Article 1: Duration. This Memorandum shall enter into force on the date on which it is signed by all three Parties and shall continue in force during the five-year period 2004 through 2008, contingent on the continuation of the solar physics research programs at the three Parties and of adequate funding for DOT and SST. Subsequent renewal may be agreed upon by the three Parties.

Article 2: Joint DOT and SST development. SIU, ISP and ITA undertake to continue and intensify their collaborations in developing instrumentation and software for the Dutch Open Telescope (DOT) and the Swedish 1-m Solar Telescope (SST) on the Canary Island La Palma.

Article 3: Coordinated DOT and SST utilisation. SIU, ISP and ITA undertake to continue and intensify their collaborations in exploiting the DOT and SST in solar physics research. In particular, ISP will continue its hospitality to the DOT team on La Palma, SIU and ISP will partner in each other's Time Allocation Committee, and SIU and ISP will facilitate co-pointing of their telescopes to enable full exploitation of their complementary capabilities.

Article 4: Joint program definition, data analysis and interpretation, and research. SIU, ISP and ITA undertake to continue and intensify their collaborations in defining science programs exploiting the DOT and SST, in joint formulation of strategies for observing and interpretation, in analysis of data from DOT and SST, in interpretation including numerical simulation, and in joint solar physics research in general, also including utilisation of data from solar space missions.

Article 5: Joint organisation of on-site education. SIU, ISP and ITA undertake to collaborate in the realisation of a joint on-site education program, bringing undergraduate and graduate students to La Palma for hands-on instruction in astronomical observing techniques and tutoring in related research.

Article 6: Education sharing. SIU, ISP and ITA undertake to intensify their linkage in undergraduate and graduate student education, including student exchange and sharing course materials, data, and analysis software.

Article 7: Joint PhD projects. SIU, ISP and ITA undertake 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.

Article 8: Joint solicitation of external funding. SIU, ISP and ITA undertake to exploit the existence of this Agreement in joint proposals to funding agencies such as the EU, in particular the Marie Curie programmes for external postdocs and graduate students.

Signatures

Signed expressing consent by:

Director, Faculteit Natuur- en Sterrenkunde, Universiteit Utrecht

Date and place Signature

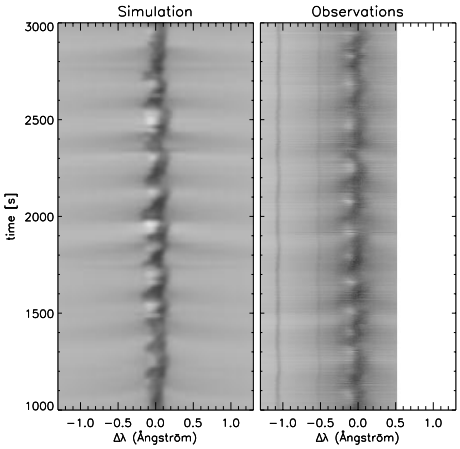
Secretary General, Kungliga Vetenskapsakademien, Sweden

Date and place Signature

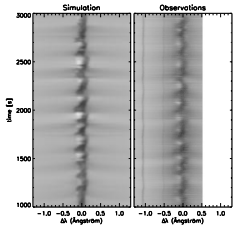
Director, Det Matematisk-Naturvitenskapelige Fakultet, Universitet i Oslo

Date and place Signature

APPENDIX: USO–SP INFORMATION



Contents



Cover pictures – left: SIU's Dutch Open Telescope (DOT), middle: ITA simulation of solar spectra, right: ISP's Swedish Solar 1-m Telescope (SST).

The two telescopes stand close together on a 2300 m high volcano on La Palma, often well above the oceanic inversion layer confining clouds to lower altitude. Stratospheric jet streams are usually absent above the Canary Islands. Both telescopes point their primary imaging element at the sun from a platform raised above the solar-heated turbulent boundary layer near the ground, which is unusually thin at La Palma thanks to the strong upslope oceanic trade winds. These atmospheric properties make La Palma a superb site for high-resolution solar observing.

The two telescopes differ strongly in concept (the DOT being an open reflector, the SST a vacuum refractor) but they are complementary in capabilities and together form a powerful tandem facility – with adjacent control rooms in the SST building. In particular, high-resolution polarimetry with the SST combined with tomographic DOT context imaging offers comprehensive science opportunities at unprecedented angular resolution. Many major quests in solar physics research require combination of such holistic diagnostics. The optimum interpretative strategy is to combine these with numerical simulations of the type in which the ITA team excels.

Left: the DOT on its 15 m open tower. The clamshell bad-weather canopy is folded down. The 45 cm primary mirror feeds elaborate filter optics and digital cameras housed in the telescope top besides the incoming beam. The strong trade wind flushes both mirror and telescope and so inhibits internal turbulence. The parallactic telescope mount is extraordinarily stiff to avoid wind shake. The images are transferred through optical fibers to the nearby SST building. Speckle reconstruction using a large-capacity processor cluster removes remaining image distortions caused by atmospheric turbulence. This image-plane restoration technique permits correction of the full field of view up to the 0.2 arcsec diffraction limit defined by the DOT aperture. The DOT produces superb synchronous tomographic movies sampling the solar atmosphere at multiple heights over long durations and a large field. More information is given at http://dot.astro.uu.nl.

Middle: ITA simulation. This celebrated example shows simulated spectral line evolution at left, observed actual solar behaviour at right. The very good agreement between the ITA simulation at left and the SIU observation at right became solid proof that the solar atmosphere is pervaded by acoustic shock waves. More information is given at http://www.astro.uio.no/∼matsc.

Right: the SST turret. The 1 m singlet objective lens is pointed toward the sun employing precision drives in altitude-azimuth configuration. Two 45 degree mirrors deflect the beam vertically down through the 17-m high tower to the observing room in the basement. The telescope is evacuated from the objective down so that internal turbulence cannot develop. Schupmann optics corrects the chromaticity of the singlet objective. A rapidly deformable adaptive-optics mirror corrects the remaining atmospheric turbulence in real time. This pupil-plane technique permits the use of spectrometers and spectropolarimeters next to imaging at or close to the SST 0.1 arcsec diffraction limit. The SST is the first solar telescope reaching this angular resolution, which corresponds closely to basic measures as the solar-atmosphere scale height and mean-free photon path. More information is given at http://www.astro.su.se/groups/solar.

A USO–SP Research

A.1 Past and present collaborations

SIU–ISP–ITA. A direct link between the three groups was laid in the eighties through common interest in the theory and diagnostic usage of radiative transfer, in particular numerical solution methods. All three group leaders are experts in this field. In the nineties this common science interest expanded to radiation hydrodynamics and solar magnetism.

The three groups work together formally, with other European groups, since 1998 in the *European Solar Magnetism Network* (ESMN) funded by the EC through successive FP4 TMR (1998–2002) and FP5 RTN (2002–2006) grants coordinated by SIU. For example, the present ESMN postdoc at ITA graduated at SIU and obtained his PhD at ISP. The present USO–SP agreement represents concentration on the complementary key research assets of three principal ESMN partners.

SIU–ISP. The Dutch Open Telescope (DOT) and Swedish 1-m Solar Telescope (SST) are neighbours at the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias. The DOT and SST teams work closely together. The DOT is operated from the Swedish building, where the teams share many facilities including the library, computers, communication, copier, kitchen, etc. DOT optics solutions were tested at the SVST (the SST's predecessor until 2002). The DOT team supervised the construction of the SST turret drives and contributed SST guider hardware.

SIU–ITA. The long-standing collaboration between team leaders Rutten and Carlsson (ten joint papers, frequent mutual visits) has been formalised in Rutten's visiting professorship at ITA, with the intent to enhance observational expertise including DOT linkage. Two current ITA postdocs graduated at SIU. Carlsson has been member of a Utrecht PhD committee.

ISP–ITA. There are strong research ties between ISP and ITA. For example, Scharmer was Carlsson's PhD adviser; after Rouppe van der Voort, also Gudiksen (ESMN PhD student at ISP) will transfer to ITA as postdoc. ITA is a formal partner in the SST, having shared in the original SST investments and presently sharing in the SST exploitation through a specific ISP–ITA agreement. The ITA group is widening its scope by including La Palma observing and data analysis in its science program.

A.2 Research plans and strategy

USO–SP research context. In general, USO–SP research will address the 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 network 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; *(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 on both short and long time scales. The latter interests make solar physics currently a growth industry, booming especially in the USA.

Achieving high angular resolution over long duration in direct imaging and polarimetry is a principal quest of such studies. At the same time, detailed numerical simulations of commensurate resolution is required to properly diagnose and interpret the multitude of physical processes at work.

USO–SP research content. Specific research topics of USO–SP interest, all major quests of modern solar physics, are:

- solar wave dynamics: network and internetwork oscillations, gravity waves, umbral flashes, wave pistoning;
- solar surface fields: fluxtube patterns, fluxtube dynamics, magnetic carpet topology and evolution, sunspot structure and dynamics, prominence stability and eruptions;
- topology and evolution of active regions: plage emergence and disappearance, eruption precursor topology, sunspot breakup;
- canopy transitions: wave penetration and heating, moss structure and dynamics, spicule physics, tube-loop coupling.

The USO–SP agreement aims to address these by exploiting its three major strengths:

- the DOT operated by SIU;
- the SST operated by ISP;
- the ITA expertise in numerical simulations.

The DOT and SST will both reach their intended full-science capability in the course of 2004, the DOT upon the completion of its multi-wavelength tomographic imaging and large-volume speckle processing systems, the SST with the completion of a spectrometer as the first of its planned suite of instruments for spectropolarimetry. Together, they represent a unique facility for studying the solar atmosphere comprehensively at unprecedented angular resolution. Adding the renowned ITA expertise in pertinent numerical simulation gives the USO–SP collaboration research competiviness at the forefront of solar physics far beyond the team sizes and telescope investments, which are small compared to other solar observatories and institutes.

Solar-B. In fact, the DOT and SST combination delivers, with groundbased telescopes thanks to the advent of image restoration techniques, the type of research capability that was expected to become available only after 2006 when the Japanese-led international Solar-B mission will operate in Earth orbit. Solar-B will combine polarimetry and imaging with a 50-cm above-the-atmosphere, hence turbulence-free telescope. It will reach the same 0.2 arcsec resolution as the DOT, less than the SST's 0.1 arcsec, but it will obtain such data every day during 24 hours per day whereas our La Palma tandem needs low atmospheric turbulence ("good seeing") next to sunshine to obtain maximal resolution. The upshot is that the DOT–SST combination permits us to start on Solar-B science already now using data sequences of sub-day duration, and so become fully prepared well in time for the much larger future Solar-B yield including continuous long-duration sampling. The ITA simulation techniques are a prerequisite for analysing and interpreting this type of data. ITA indeed has already a large formal stake in the Solar-B mission.

ATST. On a longer time scale, the USO–SP collaboration may play an important role in European participation in the US *Advanced Technology Solar Telescope* (ATST) project, which aims to realise a 4-meter telescope by 2010. ATST is currently budgeted at 160 M$. A location near the DOT and SST on La Palma is one of the three candidate sites that was recently selected for further testing.

A.3 Research actions

Joint DOT and SST development. USO–SP collaborations have been of great benefit in the realisation of both the DOT and the SST and will remain highly beneficial in further development and perfection of the two telescopes, both with regard to telescope hardware and instrumentation and with regard to software for data acquisition, image restoration, and data analysis.

Coordinated DOT and SST utilisation. The close SIU–ISP collaboration on La Palma, with the DOT team housed in the SST building, the DOT and SST control rooms adjacent, and the two telescopes sharing identical weather conditions, is beneficial to both groups and permits a high degree of coordination in scheduling and executing joint observing programs. This aspect will be strengthened by mutual participation in the DOT and SST Time Allocation Committees, which divide telescope time on the basis of scientific merit, by setting up specific procedures for co-pointing, and by announcing such co-pointing as an option to external users.

Joint program definition, data analysis and interpretation, and research. A major goal of the USO–SP Agreement is to intensify collaboration in the SIU, ISP, and ITA solar physics research programmes, not only in defining DOT and SST observing strategies, but also in defining complementary research programmes and in sharing data, analysis and interpretation software, and including use of other solar telescopes such as those in space.

B USO–SP Education

B.1 Past and present collaborations

The USO–SP groups already have a long history in sharing course materials including lecture notes, problem sets, numerical exercise material, and even examination questions.

Student exchange has been frequent at the graduate level, and has also taken place at the undergraduate level for Masters' thesis research.

The USO–SP groups already recognise each other's existing degrees and presently participate in the Europe-wide Bachelor-Master reorganisation of their study programs, permitting credit sharing and student exchange down to individual course level.

In the spring of 2003, SIU and ITA offered to share supervision of future graduate students at the ISP. The USO–SP collaboration will extend such joint tutoring to students at all three teams.

The SIU group shared (on the teacher level as well as in the organisation) in the three prestigious international Oslo spring schools held so far (1995, 1999, and 2003; the latter two under ESMN auspices).

Students from all three groups have already worked at and with the La Palma telescopes.

B.2 Education plans and strategy

The USO–SP research topics and specialities provide an ideal base for comprehensive solar physics teaching covering an exceptionally wide range: instrumentation, observation, interpretation, and theoretical modelling.

Its ownership of the two La Palma telescopes enables the USO–SP collaboration to offer an attractive joint program teaching state-of-the-art astronomical observing with first-class research facilities at the largest observatory in Europe.

The broad scope and international flavour of the USO–SP collaboration should enhance student recruitment. The collaboration will also widen a student's options to pursue science- and/or technology-oriented careers.

The Bachelor–Master synchronisation permits intensification of international student exchange already at the undergraduate level.

At the graduate level, USO–SP offers just the right level of internationalisation, comprehensiveness, and size to compete successfully for EU funding in the Marie Curie EST Programme.

B.3 Education actions

Joint organisation of on-site education. The mid-2004 completion of the DOT and SST into their full-science configurations makes the present time an excellent one to start an USO–SP on-site education program bringing students to La Palma. The USO–SP DOT and SST proprietorships permit easy scheduling. The availability of work space, computers, and an excellent library in the SST building permit students to work on appropriate projects. The environment (the largest and most modern observatory in Europe) and good relations to the

nighttime astronomers permit instructive excursions. A likely format is to have students visit singly or in pairs during one to two weeks and be tutored on-site by USO–SP staff, both in observing techniques and in related research including student project work.

Education sharing. At the undergraduate level, the USO–SP collaboration will exploit international Bachelor-Master course credit validity to foster much student exchange.

At the graduate level, the wide range of expertise covered by the USO–SP collaboration will be exploited through frequent exchange, not only of the PhD students themselves but also of data and of analysis and interpretation software, and by having close contact in project definitions through consulting per PhD project startup and organising regular "show-and-tell" meetings,

Joint PhD projects. Collaboration-wide PhD student recruitment will help to suit EU transnationality restrictions. Joint PhD project definition will be a very effective way of combining different research expertise at the different groups.

C USO–SP Funding

ESMN. The membership of all three groups in the EU-funded (FP5) European Solar Magnetism Network implies that ESMN funding can be used for exchanges, in particular for ESMN and other postdocs.

OPTICON. Since both the DOT and the SST share in the EU-funded (FP6) OPTICON Access program, funding is available for telescope utilisation by USO–SP partners. It includes both the daily expenditures for telescope exploitation and the travel costs for on-site participation in observing campaigns.

Marie Curie. The USO–SP combination will be highly suited in competence, complementarity, and size to bid for additional funding from supra-national agencies such as the EU's (FP6) Marie Curie programmes. A prime motivation for such joint solicitation is the strong desire at all partners to increase the number of PhD students and postdocs.

D USO–SP Partner Profiles

D.1 Solar physics at Utrecht

Overview. Solar astrophysics at Utrecht University has a long tradition of excellence in spectroscopy, radiative transfer, magnetohydrodynamics, and plasma astrophysics since the first half of last century (Minnaert). Over the past decades, the originally strong observational tradition in optical spectroscopy, radio spectrometry, and X-ray imaging of the sun evolved to predominantly theoretical orientation emphasising cool-star magnetic activity, filament magnetohydrodynamics and coronal plasma physics. In the meantime, Hammerschlag built a revolutionary

"open" solar telescope, now the DOT on La Palma. At present, Utrecht solar physics consists of a relatively small group devoted to exploiting the frontline research capabilities of this telescope. There are close links with a nearby theoretical plasma physics group interested in the solar corona and the solar wind (FOM Instituut Rijnhuizen). In addition, a new full professor's chair has been allocated to solar physics. Negotiations with a high-level candidate are presently underway. The yearly influx of Utrecht astronomy students has not suffered any systematic decline over the past decade. The group continues to attract top-quality PhD students from these.

Plans and strategy. With the imminent (spring 2004) completion of its six-camera multi-wavelength speckle imaging system and its large-capacity (1.8 Terabyte/day) speckle processing cluster, the DOT becomes the premier tomographic solar-atmosphere movie producer worldwide. The group plans to vigorously exploit this facility, with special emphasis on joint DOT–SST observing, while aiming at program expansion with the new chair. The group also aims to maintain Utrecht's fame as a producer of first-class solar physicists. The planned on-site education program is likely to attract many undergraduate students, also from other universities in The Netherlands and from other fields (such as technical physics).

SIU team at 01–01–2004

Name	Position	Funding
vacancy	Professor	NOVA/UU
R.J. Rutten	Senior Scientist	UU
R.H.Hammerschlag	Scientist/Engineer	UU
F.C.M. Bettonvil	Scientist/Engineer	NWO/ASTRON
P. Sütterlin	Post Doc	NWO
K. Tziotziou	Post Doc	ESMN
J. Leenaarts	PhD Student	UU
A.G. de Wijn	PhD Student	UU

ASTRON = Netherlands Foundation for Research in Astronomy
ESMN = European Solar Magnetism Network
NOVA = Netherlands Research School for Astronomy
NWO = Netherlands Organisation for Scientific Research
UU = Utrecht University

R.J. Rutten also has a part-time appointment as visiting professor at ITA. He is the coordinator of the EU-funded (FP5–RTN) European Solar Magnetism Network.

There is no DOT personnel resident on La Palma. However, much technical support is furnished at Utrecht by the workshop of the Faculteit Natuur- en Sterrenkunde (IGF).

D.2 Solar physics at Stockholm

Overview. The solar group at Stockholm is a research institute of The Royal Swedish Academy of Sciences, but it is housed together with Stockholm Observatory at the new AlbaNova University Center and has close links to Stockholm University sharing in education. It trains graduate students on solar physics PhD projects of both observational and theoretical nature. The group became famous through its former Swedish Vacuum Solar Telescope, the predecessor of the SST. The latter has twice larger aperture, therefore reaches twice better angular resolution, is now the sharpest solar telescope in the world, and was heralded at its completion in 2002 as one of the top ten performers in all of science worldwide.

Plans and strategy. A vigorously pursued SST instrumentation program presently adds state-of-the art polarimeters and aims to add advanced high-order adaptive optics in the near future. The SST science yield is maximised through international collaboration including much guest observing, also by USO–SP partners. The coming years this will include tandem observing with the DOT, to be effectuated through coordinated allocation of observing time.

With respect to education, the ISP group aims to exploit its SST ownership to enhance its role in undergraduate education at Stockholm Observatory as part of the proposed USO–SP on-site education program.

The group aims to considerably expand its graduate-student program through the USO–SP collaboration.

ISP team at 01–01–2004

Name	Position	Funding
G.B. Scharmer	Professor	KVA
D. Kiselman	Research Associate	KVA
M. Löfdahl	Research Associate	KVA
P. Dettori	Science Engineer	KVA
K. Langhans	Post Doc	ESMN
B. Gudiksen	PhD student	KVA

ESMN = European Solar Magnetism Network
KVA = The Royal Swedish Academy of Sciences

The addditional SST team resident on La Palma (funded by KVA) consists of a software engineer, an electronics engineer, a part-time programmer and a part-time administrator.

D.3 Solar physics at Oslo

Overview. With five full professors the Oslo solar physics group is the largest within USO–SP. There is additional interest at ITA in closely related plasma physics. Oslo has a very strong track record in both theoretical and observational solar physics ever since ITA's foundation by Rosseland. After the discontinuation of science utilisation of the Harestua Solar Observatory

(North of Oslo) in 1986, the group's observational activities rely on foreign observatories and to an increasing degree on instrumentation in space, including an important role in the Coronal Diagnostic Spectrometer onboard the ESA–NASA SOHO mission and full partnership in the Japanese Solar-B satellite project. In parallel to these space activities, ITA has built a strong group in numerical astrophysics, with special emphasis on numerical radiation hydrodynamics and magnetohydrodynamics.

Plans and strategy. ITA's numerical simulations now achieve a degree of realism in modelling the solar atmosphere that necessitates close linkage with solar observations of very high spatial resolution. ITA has therefore contributed to the realisation of the SST and has recently (December 2003) agreed on a five-year share in the SST with the Royal Swedish Academy of Sciences. R.J. Rutten (SIU) was appointed part-time professor in November 2002 to enhance ITA's observational expertise. Combined SST magnetometry and DOT tomography will most likely produce exciting material for interpretation through numerical simulation. The USO–SP agreement is expected to offer attractive international collaboration at the solar physics forefront for students at all levels. It is especially important to offer such high-visibility and high-profile education possibilities at a time of low recruitment in the physical sciences, now recognised as a severe problem in Norway.

ITA team at 01–01–2004

Name	Position	Funding
M. Carlsson	Professor	UiO
O. Engvold	Professor	UiO
V. Hansteen	Professor	UiO
O. Kjeldseth-Moe	Professor	UiO
E. Leer	Professor	UiO
E. Endeve	Post Doc	NFR
D. Müller	Post Doc	TOSTISP
M. van Noort	Post Doc	NFR
L.H.M. Rouppe van der Voort	Post Doc	ESMN
A. Fossum	PhD Student	NFR
M.A. Killie	PhD Student	NFR
Saadatnejad Bard	PhD Student	UiO

ESMN = European Solar Magnetism Network
NFR = Norsk Forskningsråd
UiO = Oslo University
TOSTISP = Theory, Observations and Simulations of Turbulence In Space Plasmas