Istituto Ricerche Solari Locarno

Rapporto 2018

Rapporto alla Fondazione Istituto Ricerche Solari Locarno sulla situazione dell'Istituto alla fine del 2018 e sul piano di lavoro per il 2019

Relatori: Dr. Michele Bianda
e lo staff dell'IRSOL

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*) *AIRSOL, Associazione Istituto Ricerche Solari Locarno*

Indice

1 PREMESSA

L'Istituto Ricerche Solari Locarno (IRSOL) svolge attività di ricerca scientifica nel campo della spettropolarimetria solare. Misure spettropolarimetriche della radiazione solare di alta precisione sono eseguite con lo Zurich Imaging Polarimeter (ZIMPOL), strumento leader in questo campo, in costante aggiornamento e sviluppo all'IRSOL. I dati osservativi vengono interpretati applicando e sviluppando sofisticate teorie per la generazione e trasporto di radiazione polarizzata, come pure attraverso l'ausilio di modelli numerici 3D dell'atmosfera solare, la cui realizzazione richiede l'utilizzo dei supercalcolatori del centro di calcolo CSCS di Lugano. L'obbiettivo del lavoro sinergico in questi campi di ricerca è quello di studiare il magnetismo del Sole, mediante l'applicazione di diverse tecniche diagnostiche, e lo sviluppo di nuove.

Nel corso dell'anno vi sono stati eventi molto significativi che influenzeranno l'attività dell'IRSOL per i prossimi anni. Importanti domande di finanziamento di progetti di ricerca sono stati accettati. Un progetto nell'ambito del programma "Sinergia" del Fondo Nazionale, diretto dal Dr. Luca Belluzzi, permetterà una stretta collaborazione con l'Istituto di Scienze Computazionali dell'USI e con Instituto de Astrofísica de Canarias (IAC). Il progetto comprende il finanziamento di tre posizioni post-doc (una per ogni Istituto), di quattro anni ciascuna, più una posizione PhD, sempre di quattro anni, per l'IRSOL. Un progetto di ricerca sottoposto dal Dr. Oskar Steiner al Fondo Nazionale è pure stato accettato (prevede i posti di un dottorando e di un postdoc). Il progetto europeo H2020 SOLARNET, sottomesso dalla European Association for Solar Telescopes (EAST) e che interessa la comunità europea attiva nel progetto del telescopio solare EST, ha avuto un responso favorevole. Da parte svizzera, il co-richiedente è l'USI, avendo come partner l'IRSOL ed il Centro Svizzero di Calcolo Scientifico (CSCS). Un ulteriore parther elvetico è la Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD) che collabora nello sviluppo dell'ottica adattiva prevista per EST. Questi progetti permettono di rafforzare la collaborazione con l'USI e, allo stesso tempo, di incrementare il livello di partecipazione della Svizzera nel progetto EST. L'obiettivo è quello di avere l'USI nel ruolo di partner accademico di riferimento per la Svizzera in tale progetto. Il progetto EST è stato accettato nella roadmap europea di ESFRI (European Strategy Forum on Research Infrastructures).

Un gruppo di lavoro misto, USI e IRSOL, ha iniziato i lavori per redarre un documento strategico sul futuro dell'IRSOL. Il documento è stato consegnato alla direzione dell'USI in maggio 2019.

Flavio Calvo ha brillantemente difeso la sua tesi di dottorato all'Università di Ginevra, ed ha scelto quale istituto nel quale continuare i suoi studi il Department of Astronomy dell'università di Stoccolma dove ora lavora come postdoc.

È stato individuato un sensore che potrebbe permettere di realizzare un polarimetro di nuova generazione in collaborazione con la SUPSI ed il Max Planck Institut für Sonnenforschung (MPS) di Göttingen. Approfondite discussioni si sono tenute con i vari responsabili a Monaco di Baviera presso l'istituto che sta sviluppando il sensore.

Grazie ad un lascito ereditario abbiamo potuto iniziare lavori di rinnovamento interno per trasformare l'appartamento al primo piano in uffici più una stanza ospiti, come pure per migliorie all'osservatorio, compresa la trasformazione del locale camera oscura in un laboratorio di ottica.

2 PERSONALE

Organizzazione generale
L'organizzazione generale è diretta dal presidente della FIRSOL, Prof. Dr. Philippe Jetzer (Istituto di fisica dell'Università di Zurigo).

Direttorato
La direzione dell'IRSOL è affidata ad un direttorio composto da:

Prof. Dr. Svetlana Berdyugina (direttrice del Leibniz-Institut für Sonnenphysik, KIS, già Kiepenheuer Institut für Sonnenphysik)

Dr. Michele Bianda

Prof. Dr. Jan Olof Stenflo

La vice-direzione è affidata al Dr. Renzo Ramelli

Staff scientifico

Dr. Ernest Alsina Ballester (dal 1 febbraio 2018) *)

Dr. Luca Belluzzi (pure affiliato al KIS)

Dr. Michele Bianda

Dr. Daniel Gisler

Ing ETHZ Boris Liver

Dr. Renzo Ramelli (part time)

Dr. Dhara Sajal Kumar (dal 1 maggio 2017) **)

Dr. Oskar Steiner (part time con il KIS)

Prof. Dr. Jan Olof Stenflo, emeritus ETHZ, affiliato all'IRSOL

Prof. Dr. K. Nagendra, emeritus Indian Institute for Astrophysics, affiliato all'IRSOL

*) Finanziato tramite il progetto del Fondo Nazionale, 200021_175997
**) Finanziato tramite il progetto del Fondo Nazionale, 200020_169418.

Staff amministrativo e tecnico

Katya Gobbi (segretaria)

Gianpaolo Mari

Dottorandi

Dr Flavio Calvo *) (dal 1 novembre 2013 al 31 marzo 2018)

MSc. Emilia Capozzi *) (dal 1 aprile 2017)

MSc. Gioele Janett **) (dal 1 settembre 2015)

MSc. Simone Riva ***) (dal 1 ottobre 2018)

Questi progetti di dottorato sono finanziati dal Fondo Nazionale.
*) Direttore di tesi: Prof. Dr. Georges Meynet dell'Università di Ginevra
**) Direttore di tesi: Prof. Dr. Mishra Siddhartha, SAM, Politecnico di Zurigo
***) Direttore di tesi: Prof. Dr. Rolf Krause, USI, Lugano

Stages scientifici, lavori a tempo determinato

Andrea Battaglia (dal 13 settembre al 31 settembre): stage nell'ambito del programma Estage

Loris Pedrelli (dal 2 settembre al 21 settembre): stage nell'ambito del programma Estage

Collaborazione con la SUPSI

Christian Valles, lavoro di Master seguito dal Prof. Dr. Roberto Gardenghi

Collaborazione con il Leibniz-Institut für Sonnenphysik, KIS

Regolato da un contratto con il KIS, il Dr. Daniel Gisler continuerà a lavorare a tempo parziale a Freiburg su un progetto dedicato al telescopio solare statunitense DKIST.

Collaborazione con l'Instituto de Astrofísica de Canarias (IAC)

Il Dr. Ernest Alsina Ballester ha difeso in gennaio la sua tesi all'IAC; il Dr. Luca Belluzzi era co-direttore di tesi. Il Dr. Alsina Ballester è stato in seguito assunto all'IRSOL, finanziato da un progetto del Fondo Nazionale per la ricerca scientifica.

Collaborazione con l'Observatoire de Genève

Beatriz Alvarez Restrepo e Rahel Baugartner hanno svolto un lavoro pratico all'università di Ginevra che prevedeva osservazioni all'IRSOL dal 12 al 16 febbraio

Civilisti

Nel corso del 2018 hanno lavorato all'IRSOL:

Azeglio Diethelm (dal 8 gennaio al 10 febbraio)

Aleksi Bossart (dal 3 settembre al 19 dicembre)

RINGRAZIAMENTI

Nel corso dell'anno Flavio Calvo ha brillantemente concluso i suoi studi di dottorato presso l'IRSOL difendendo la sua tesi all'Osservatorio di Ginevra. Il titolo gli è stato conferito dall'Università di Ginevra. Aveva conosciuto l'IRSOL grazie ad un lavoro pratico organizzato con l'Osservatorio di Ginevra nel 2010. Oskar Steiner ha seguito la sua tesi, che presto lo ha portato a programmare sui calcolatori del centro di calcolo CSCS a Lugano. I risultati scientifici da lui ottenuti sono significativi. Ha prodotto modelli numerici dell'atmosfera solare di grande interesse, che vengono tutt'ora utilizzati e studiati. Grazie ad essi ha potuto individuare delle strutture vorticanti nell'atmosfera solare virtuale. La novità consiste nel fatto che i modelli utilizzati erano privi di campo magnetico, lanciando la sfida di verificarne l'esistenza sul Sole reale con la nuova generazione di telescopi solari. Ha risolto un problema teorico rimasto da decenni in sospeso legato alla struttura del salto di Balmer nell'ultravioletto. Ha simulato la polarizzazione che ci si aspetta misurare nel continuo al centro del Sole e a varie distanze dal bordo solare. Questo dato era cruciale per ricercatori che stanno sviluppando tecniche osservative e strumentazione per il telescopio solare statunitense DKIST. Ma di lui si ricorderà all'IRSOL non solo l'acume scientifico, o le discussioni su svariati temi non necessariamente scientifici nelle quali faceva emergere punti di vista raramente o mai ascoltati prima, ma pure il carattere estremamente simpatico e sempre pronto a dare una mano con un grande sorriso appena si accorgeva di poter aiutare qualcheduno. Tutti all'IRSOL, e chi ivi lo ha conosciuto, gli auguriamo una brillante carriera scientifica di successo, cominciata con un postdoc a Stoccolma.

3 SCIENTIFIC WORK

The overall goal of the scientific activity carried out at IRSOL is a better physical understanding of the magnetic fields present in the solar atmosphere. Solar magnetic fields can be investigated by analyzing the signatures that they leave, through different physical mechanisms, on the spectral and polarization properties of the electromagnetic radiation. In general, the development and application of a given diagnostic method requires:

a) modeling the generation and transfer of polarized radiation in the solar atmosphere, taking the above-mentioned mechanisms into account, in order to identify specific polarization signals encoding information on the magnetic fields;

b) developing instruments capable of observing such signals, and performing precise observations;

c) comparing the observed signals with the results of theoretical calculations performed with realistic simulations of the solar atmosphere.

The research work at IRSOL builds on three pillars: observations and instrument development, theoretical modeling, and numerical simulation, yet they are all focused on the unique topic of polarimetry of the solar atmosphere.
A detailed description of all the scientific works that are presently carried out at IRSOL, together with the result obtained in the past year, is provided below.

3.1 Theoretical and numerical modeling of polarization signals

3.1.1 Investigation of the enigmatic scattering polarization signal of the Na I D_1 line

The observation of non-zero scattering polarization signals in the core of the Na I D_1 line reported by Stenflo & Keller (1997, A&A, 321, 927) was a highly unexpected result, since this line was considered intrinsically unpolarizable. Clarifying the physical origin of this signal remains an open question, requiring attention from both a theoretical and observational standpoint. The relatively small amplitude of the linear polarization signals of this line make the acquisition of spectropolarimeteric measurements a challenging task; on the other hand, this also makes it an ideal target for observations with ZIMPOL, both at IRSOL and at GREGOR. During this year, further measurements have been taken, adding to the considerable volume of observational data currently available to us. One of our short-term goals is to conduct a statistical analysis of all our data, taking advantage of the methods devised by MSc. Valentin Stadler (Master in Mathematics at ETH Zurich) during his civil service at IRSOL for extracting the D_1 signal from the noise (based on techniques such as non-parametric kernel regression and spline smoothing). The focus of this analysis will be to study the occurence rate, shape, amplitude, and wavelength position of the line-core linear polarization signals. This work represents one of the pillars of the SNF project "The magnetic sensitivity of strong chromospheric lines: from the CLASP experiments to the sodium D_1 paradox" (P.I. Dr. Luca Belluzzi), in which Dr. E. Alsina Ballester began working as a postdoctoral researcher in February 2018.

This SNF-funded project also includes a theoretical package, oriented towards the interpretation of the aforementioned signals. This work is motivated by the promising physical mechanism proposed by Belluzzi and Trujillo Bueno (2013, ApJL, 774, 28) and Belluzzi et al. (2015, ApJ, 814, 116),

based on the combined impact of the atomic hyperfine structure of sodium and partial frequency redistribution (PRD) phenomena in scattering processes. However, such investigations were restricted to the non-magnetic case. The next step is to study the role played by the magnetic field in such physical processes. Such an investigation is currently being carried out by developing a radiative transfer code accounting for all the relevant physical ingredients. The development of this code is better described in Sect. 3.2.2.

3.1.2 Theoretical interpretation of the CLASP-1 data

Work on the theoretical interpretation of the CLASP-1 data continued during 2018, with the publication of the first results. A particularly interesting finding of CLASP-1 is that the scattering polarization signal observed in the core of the H I Ly-α line does not show any clear center-to-limb variation. By applying a statistical approach (Štěpán, Trujillo Bueno, Belluzzi, et al. 2018), this surprising observational result could be interpreted as a clear indication that the chromosphere-corona transition region observed by CLASP-1 is characterized by a high level of "corrugation", much larger than that predicted by a state-of-the art radiation MHD model (Trujillo Bueno, Štěpán, Belluzzi, et al. 2018).

Publications:

Štěpán, J., Trujillo Bueno, J., Belluzzi, L., et al. (the CLASP team) 2018, ApJ, 865, 48

Trujillo Bueno, J., Štěpán, J., Belluzzi, L., et al. (the CLASP team) 2018, ApJ Lett., 866, L15

3.1.3 Theoretical prediction of the magnetic sensitivity of the wing scattering polarization signals of the H I Lyman-α line

The CLASP-1 observation confirmed the existence of large scattering polarization signals in the extended wings of Ly-α, as predicted by theoretical calculations (Belluzzi et al. 2012, ApJ, 755, L2). These signals, which are produced by the combined action of PRD and J-state interference effects, may offer a window into the magnetic and thermodynamical properties of increasingly deep layers of the solar atmosphere.

The CLASP-1 measurements show clear spatial fluctuations of the Q/I and U/I wing signals, but while the Q/I signal shows a clear center-to-limb variation (CLV), this is not observed in U/I.

One of the most interesting results of the PhD Thesis work of Dr. Alsina Ballester is the discovery that the large scattering polarization signals produced by PRD effects in the wings of strong resonance lines are not insensitive to the presence of a magnetic field as previously thought (considering that the Hanle effect vanishes outside the line-core region), but they have a clear magnetic sensitivity due to the magneto-optical (MO) effects. Such effects manifest as a rotation of the plane of linear polarization as the radiation propagates through the solar atmosphere, even in the presence of comparatively weak magnetic fields. Within the framework of the SNF project "The magnetic sensitivity of strong chromospheric lines: from the CLASP experiments to the sodium D_1 paradox", we have investigated whether the wing scattering polarization signals of the H I Ly-α line are significantly modified by MO effects. Although a correct modeling of the scattering polarization profiles of the Ly-α line requires considering a two-term model atom (i.e., an atomic model accounting for the various fine structure - FS - components of this line, as well as for quantum interferences among different FS levels), we have shown that outside the Doppler core, the line can be correctly modeled by neglecting FS, and considering therefore a two-level 0-1 transition. During this step, we also demonstrated

(both theoretically and numerically) that one must fully account for the incomplete Paschen-Back effect when modeling this line by means of a two-term atom, even when the magnetically-induced splitting of the energy levels is much smaller than the separation between FS J-levels.

Our investigation showed that the wing scattering polarization profiles of the H I Ly-α line are appreciably modified by MO effects even in the presence of relatively weak magnetic fields. This result, which was not obvious given that this line falls in the EUV and forms in a very hot plasma, was readily explained by demonstrating (through analytical arguments) that, by contrast to the Zeeman effect, the overall impact of MO effects is in fact independent of the Doppler width of the considered spectral line.

This work, which has been accepted for publication (Alsina Ballester, Belluzzi, & Trujillo Bueno 2019), highlights the importance of accounting for the impact of MO effects for a correct interpretation of the CLASP-1 observations.

Publications:

Alsina Ballester, E., Belluzzi, L. & Trujillo Bueno, J., 2019, ApJ, accepted

3.2 Numerical methods and computing techniques for modeling the generation and transfer of polarized radiation

3.2.1 Numerical Methods for the Transfer Equation of Polarized Radiation; PhD work of Gioele Janett

MSc. G. Janett is conducting research at IRSOL as part of a PhD-thesis to be submitted to ETH-Zürich in 2019. In the two years preceding the present report period, he carried out a thorough numerical analysis of conventional and alternative methods for the formal numerical integration of the transfer equation for polarized radiation in terms of order of accuracy, stability, and computational cost (Janett et al., 2017, ApJ 840, 107; Janett et al., 2017, ApJ 845, 104; Janett & Paganini, 2019; Janett et al., 2018). This analysis has led to deep insights into why some schemes have been observed to expose instability and what the actual order of accuracy of some of the schemes are for which this was not clear before. A hybrid scheme was created that performs accurately and stable and it was tested for smooth and also for intermittent atmospheric models from radiation magnetohydrodynamic simulations.

In the present report period, the work concentrated on discontinuous atmospheres and atmospheres featuring steep gradients in physical parameters such as magnetic field, temperature, and bulk velocities. A first paper (Janet, 2019) exposes the limitations of standard convergence analyses for this problem and identifies the relevant issues. Specific numerical tests show that discontinuities in the atmospheric physical parameters effectively induce first-order discontinuities in the radiative transfer equation with the result of an order breakdown where all the numerical methods drop to first-order convergence, making the application of high-order schemes pointless.

A second paper (Janett et al., 2019) expands on different nonlinear interpolation techniques capable of guaranteeing high-order accuracy and handling discontinuities in an accurate and non-oscillatory fashion, suitable for applications in the context of numerical radiative transfer. In particular, a novel well-performing fourth-order WENO interpolation technique for both uniform and nonuniform grids was outlined and tested. This interpolation technique might be particularly suitable for several problems, including a number of radiative transfer applications such as multidimensional problems, multigrid methods, and formal solutions.

G. Janett presented results of his work in colloquia at the Kiepenheuer-Institut and Meteo Svizzera under the title "Numerical integration of the polarized radiative transfer equation".

Publications:

Janett, & Paganini 2018, ApJ 857, 91;

Janett, Steiner, & Belluzzi 2018, ApJ 865, 16;

Janett 2019, A&A 622, A162;

Janett, Steiner, Alsina Ballester, Belluzzi, & Mishra 2019, A&A 624, A104

3.2.2 Development of a 1D PRD RT code for a two-term atom with HFS

The theoretical investigation on the Na I D_1 line described in Sect. 3.1.1 requires the development of a numerical code capable of solving the NLTE radiative transfer problem for polarized radiation in 1D models of the solar atmosphere, for a two-term atom with HFS, taking PRD effects into account. For the sake of simplicitly, PRD effects are treated under the "angle-averaged" approximation. Finally, the code must include scattering polarization as well as the combined action of the Hanle and Zeeman effects, in the presence of arbitrary magnetic fields (i.e., in the incomplete Paschen-Back effect regime).

The development of this code, carried out by Dr. Alsina Ballester, began in the second half of 2018, after having identified a suitable theoretical framework. The theory of Bommier (2017, A&A, 607, 50) was finally chosen and deeply analyzed before starting the implementation of the relevant equations. The previous PRD RT code for a two-level atom has been used as starting point for this work. The code is presently in the debugging phase.

Although the development of this code was motivated by the investigation of the scattering polarization signal of the Na I D_1 line, it must be emphasized that it will allow us to model several other interesting signals, for which a two-level atomic model is not suitable. In particular, it will be perfectly suitable to model the Mg II h and k lines at 2800 Å, which have been recently observed thanks to the CLASP-2 experiment, or the whole profile of the H I Ly-α line (i.e., without the limitation of considering the line-wings only, as discussed in Sect. 3.1.3).

The first version of the code will be far from optimal in terms of computing speed. Improvements in this sense, through the implementation of faster algorithms and high-performance computing techniques, are planned in the medium term, taking advantage of the close cooperation with the Institute of Computational Sciences (ICS) of the Università della Svizzera Italiana (USI).

3.2.3 Development of HPC techniques for 3D modeling of scattering polarization with PRD (SNSF Sinergia project).

The SNSF project "HPC techniques for 3D modeling of scattering polarization with PRD", submitted to SNSF at the end of 2017, has been approved in June 2018. The project aims at combining competences and expertise in the fields of theoretical and numerical spectropolarimetry and in computational sciences in order to develop novel solution methods for the 3D RT problem for polarized radiation with PRD. The project, which involves IRSOL (Dr. L. Belluzzi), ICS (Prof. R. Krause), and IAC (Prof. J. Trujillo Bueno), started on October 1st, 2018, with the PhD contract of MSc. Simone Riva (Thesis carried out at USI, under the co-supervision of Prof. Krause and Dr. Belluzzi).

During 2018, MSc. Riva focused his attention on the development of a fast and accurate algorithm for calculating the so-called R_{II} redistribution matrix and the emission coefficient (in the four Stokes parameters), for a two-level atom in the presence of arbitrary magnetic fields, for the general angle-dependent case. The most critical aspects of this calculation have been identified, and a series of solutions have been devised and tested. Interesting progresses have also been performed from the hardware standpoint (e.g., through the use of GPU), achieving a significant speedup of the algorithm with respect to its initial version.

3.3 Magnetohydrodynamic Simulations of the Solar Amosphere

Based on a high-cadence high-resolution simulation sequence, computed by F. Calvo at IRSOL, we studied the formation of vortical flows in the subsurface and atmospheric layers of the solar atmosphere. In particular, we studied differences between simulations with and without magnetic field and the coupling of vortical flows among different layers of the atmosphere.

It seems that the visible, chromospheric swirls are driven by magnetic fields that are anchored in the deeper layers, the convection zone, of the Sun. We analyzed the simulation sequence regarding the origin of these swirls, which we surmise in the convective motion and interaction with magnetic fields that supposedly drive these swirls. We visualized vorticity and swirling strength and tried to reduce the complexity of the processes to an analytical model in terms of circulation. The processes turned out to be more complicated than anticipated but a number of highly interesting behaviors and correlations, were found. We plan to continue this work (O. Steiner with A. Bossart);

3.4 SOLARNET project

This project of the Horizon 2020 research framework of the European Union started on January 2019. It aims at integrating the major European infrastructures in the field of high-resolution solar physics in view of the realization of the European Solar Telescope (EST). The project is managed by the European Association for Solar Telescopes (EAST), which was founded in 2006 and now includes members from 18 European nations. Switzerland is represented in the EAST by IRSOL.

The main Swiss participant in SOLARNET is the Università della Svizzera italiana (USI), while IRSOL and Swiss National Supercomputing Center (CSCS) are third parties. The Piz Daint Supercomputer at CSCS will be made available to the solar community to facilitate numerical investigations of the solar atmosphere, including magneto-hydrodynamic and radiative transfer simulations. IRSOL and USI will organize a summer school under the title "Solar spectropolarimetry: From real to virtual observations" during the second week of September (see http://solarnet-project.eu/Solar-spectropolarimetry-From-virtual-and-real-observations). IRSOL is also working on an innovative technology capable of performing high precision absolute polarimetry with low systematic errors. The Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD) is also participating to the project and is involved in the work package devoted to the development of a high-performing adaptive optics device.

3.5 Observational projects

3.5.1 Observational campaign at GREGOR

Our ZIMPOL campaign at GREGOR took place from 13^{th} June to 1^{st} July; the last 4 days were dedicated to projects of the group lead by Javier Trujillo Bueno at IAC. The weather conditions were good and only impeded observations on a single day but we were faced with some bad seeing days cased by a jet-stream. The seeing was generally enough fr us to work well, but was never excellent.

We fulfilled following programs:

- 2D imaging polarization on an optical bench, using an optical layout similar to the one that could be used on the DKIST telescope (see 3.5.3)
- investigation of spatial variations in the scattering polarization of molecular lines (see 3.5.2);
- measuring the spatial variations of the scattering polarization in the Sr I 4607 Å line at different distances from the limb (CLV); see 3.5.3 ;
- search of magneto optical effects in the wing scattering polarization of the Ca I 4227 Å line (see 3.1.3)

3.5.2 Spatial stability in the scattering polarization in molecular line

During the GREGOR campaign (see 3.5.1) observations were performed for a project led by Prof. Svetlana Berdyugina, which intended to study small spatial scales variations in the scattering polarization of molecular lines, originated by local variations in the (turbulent) magnetic field. The advantage of the method is that it allows to distinguish between magnetic field effects and local atmospheric effects, thanks to the use of the differential Hanle effect.

The ongoing synoptic program (3.5.5) is also based on this principle. However in this program we are not searching for spatial variations; instead we are trying to determine if there are temporal changes correlated to the solar cycle.

An open question is related to the possibility of using molecular lines to measure the magnetic field variations at sub-granular scale using a 4m telescope. Taking into account the amplitude of the signals, the required precision, and the available integration time it is apparent that these observation will represent a real challenge. To gain further insight into these difficulties, observations in the granulation at different distances from the solar limb were performed at GREGOR. We could find hints of spatial variations (at scales substantially larger than the granular scale) measuring close to the limb. These data are still being analyzed, and need to be verified by other observations at high spatial resolution.

3.5.3 Feasibility study for measuring granular scattering polarization in the Sr I 4607 Å line at DKIST

This project, financed by the Swiss National Foundation (SNF) until April 2019, is devoted to study the feasibility of developing an instrument to be installed at DKIST to carry ouut asynoptic program. The goal of this project would be to verify if the amplitude of subgranular fields changes with the solar cycle.

For this GREGOR campaign the original plan was to have measurements of the Sr I 4607 Å line using a filter produced by the DayStar company. The specifications offered by the company led us to conclude that such a filter would allow us to obtain the data required by our scientific goal. Unfortunately DayStar failed, not being able to produce the filter within the specifications. A Fabry Perot filter suitable for this project was offered by NSO, but we did not have enough time to test it.

The alternative solution we found was to use the prefilter with a wavelength bandwidth of about 1.5 Å. The filter is centered at 4607 Å tilting it its transmission can be shifted and it can be centered in the continuum. Theoretical investigations carried out in the framwork of the thesis work of Flavio Calvo predicted that the signals observed at disk center are well below the expected variations of the scattering polarization expected to be measured in our project. Thus the observed polarized images were expected to be flat, without structures above the noise level we planned to reach.

The observations were performed with two cameras: our ZIMPOL camera, and a fast camera (already used by Daniel Gisler at GREGOR for measuring the polarization images of planets). A further goal was to test the general optical setup (a setup similar to the one foreseen for DKIST was prepared), as well the advantages and drawbacks of the two camera systems.

Unexpectedly, both cameras revealed signatures in the order of several 10^{-4}, that means in the order of the signal we expect to measure. They appear to be related with the intensity patterns (granular patterns in a non-tryvial manner making their removal during the data reduction but not in an easy way, thus difficult to be removed in the data reduction procedd difficult. This is a crucial problem, which must be solved for the realization of the project. The main suspects are the FLC retarders used as modulator elements.

Publications:

Bianda et al. 2018, A&A, 614, 89;

Kumar et al., A&A accepted

3.5.4 Observing Proposal for the DKIST

A detailed science use case (observing proposal) for the upcoming 4-m DKI Solar Telescope was created and submitted to the National Solar Observatories (NSO). It concerns the magnetohydrodynamic fine structure of faculae. The observations are planned to take place using the blue channel of the Visible Broadband Imager (VBI) at high cadence, the Visible Tunable Filter (VTF) for polarimetry in the spectral line Fe I 630.25 nm and spectroscopy in Ca II 854.21 nm, the Visible Spectropolarimeter (ViSP) in the lines Fe I 525.02 nm and Fe I 524.70 nm for another magnetic field and velocity diagnostics, and the Diffraction-Limited Near Infrared Spectropolarimeter (DL-NIRSP) for two-dimensional spectropolarimetry in the line Fe I 1565 nm (O. Steiner with M. Franz (KIS)).

3.5.5 Synoptic program to measure the evolution of the photospheric magnetic field during a solar cycle

Since 2007 we have been carrying out a synoptic program in order to determine if the magnetic flux of the quiet photosphere varies with the solar cycle. With this goal in mind, we apply a differential Hanle effect technique, based on observations of scattering polarization in C_2 molecular lines around

5140 Å, generally taken every month. Our results now span a complete solar cycle, and the program is still being continued.

For the data analysis we started in 2017 a collaboration with Andrei Gorobets, PhD student at KIS in Freiburg. In the 2018 the work of Gorobets focussed on the study of the influence of the neighbour lines and of the continuum polarization on the measured peak amplitudes of the scattering polarization signals in C_2, with the goal to improve the data analysis.

3.5.6 Cooperation with the Istanbul University

The Zerodur mirrors installed on the telescope at IRSOL were delivered by the Department of Astronomy and Space Sciences at Istanbul University (Prof. Dr. Adnan Ötken). We thus started a collaboration agreement, and in July Dr. Nurol Al and Dr. Asuman Gültekin Annak, working at Department of Astronomy and Space Sciences, visited IRSOL for a scientific project. A precise measurement of the intensity in selected iron lines was performed at different solar positions. Data will be used by students of the University to perform scientific work at the Department, such as studing solar atmosphere models.

3.5.7 Ca II observations in the infrared

Observations in the Ca II 8542 Å line, in collaboration with Dr. Jan Jurčák, Dr. Jiri Štěpán, Prof. J. and Javier Trujillo Bueno, were performed at IRSOL in 2015. At the Astronomical Institute of the Academy of Sciences in Ondřejov, Czech Republic, and at IAC in Tenerife, detailled comparison of the observations with simulated profiles calculated with the code PORTA was carried out. The synthetic profiles were degraded to match the instrumental and observing conditions and qualitatively similarities were found. The main difference is in the fact that the widths of all observed Stokes profiles are larger than the theoretical ones, which suggests that the symmetry -reaking effects in the solar chromosphere are stronger than in the model atmosphere. This implies that the isosurfaces of temperature, velocity, and magnetic field strength and orientation are more corrugated in the solar chromosphere than in the currently available 3D radiation magnetohydrodynamics simulation.

3.5.8 Two-fluid scenario in prominences

The observations performed in June 2017 at IRSOL on a prominence provided data of unprecedented quality. A method suggested by Dr. E. Wiehr allowed to alternate between intensity spectrum images of the Sr II 4077 Å line and of the D1, D2 Na I lines at timescales of around 40 seconds. In stellar material at temperatures of around 9000K, strontium is almost entierly ionized, and neutral strontium is practically absent. That permits to distinguish between 'cold' and 'hot' atmospheres. By observing a quite stable prominence at different heights for about one hour we were able to detect oscillations in which the velocity of the neutral and ionized atoms were different, suggesting that we are in presence of two fluids moving at different velocities, with the hotter moving faster than the colder. The oscillations are found at all points along the slit which, being at different distances from the solar limb, correspond to different heights. The excellent quality of the data provides information on important parameters, such as the electron density which is releted to the common formation region of the Sr II and Na I lines.

Considerations regarding the synchronicity of the oscillations suggest that the motion of the ions is exerted by the Lorentz force, while the motion of neutrals by friction to the ions.

Publications:

Wiehr, Stellmacher, Bianda, 2019, ApJ, 873, 125

3.6 Miscellaneous, science

Prof. Jan Olof Stenflo besides his solar physics works is exploring new research fields, and his interest is now devoted to the

"Nature of dark energy and dark matter"

Publications:

J.O. Stenflo 2019, arXiv e-prints: 1901.01317v1 [physics.gen-ph]

3.7 Specola Solare Ticinese

Scientific work at Specola Solare Ticinese is focused on the determination of the international Sunspot Number (SSN) released by the SILSO World Data Center at the Royal observatory in Brussels, for which Specola is the international reference station. The experience of Sergio Cortesi, who worked under the direction of Max Waldmeier starting in 1957 till 1980, gave continuity to the counting method defined in Zurich from Rudolf Wolf in the mid 1800s. This know-how has been transmitted to Marco Cagnotti.

In 2018, 279 sunspot drawings were made; the drawings and the calculated Wolf number can be seen on the web (www.specola.ch).

IRSOL staff collaborates with Specola for outreach activities and, when required, for making the solar drawings and performing their reduction. Ramelli acts also as Web Master for the Specola web pages.

The Sunspot Number (SSN) time series is now included in the new implementation plan of the Global Climate Observing System (GCOS). Taking that into account, Swiss GCOS office at MeteoSwiss accepted to finance a project for the safe and long term archiving and digitization of the observational data, currently stored at Specola Solare Ticinese. The project, done in collaboration with ETH Zurich University Archives, started officially in August 2018 and will last for the next 5 years. Ramelli acts as project coordinator.

The SILSO responsible Dr. Frédŕic Clette, visited Specola Solare and IRSOL twice in 2018 to discuss this project and on the available data. Furthermore it was agreed that SILSO will offer a new software called Digisun for the processing and a deeper analysis of the digitized sunspot drawings, that will be released in 2019.

Publications:

Ramelli et al., 2018, IAUS, 340 129

3.8 Education

At IRSOL we offer young students (secondary and high school) the opportunity to visit a research institute, which can generate interest for a scientific educational path. Every year we give the opportunity to young secondary school students to perform a one day stage before they start the high school. In collaboration with a local company we offered a one day stage at IRSOL to secundary school students of a school in Ascona reporting the best marks in scientific courses. Moreover, we offer support for maturity works dedicated to astronomical topics.

In 2017 the cantonal administration of Canton Ticino started the program "Estage", intended to better connect students of the Swiss Italian area with local industries and research institutes promoting stages announced on a web page (www4.ti.ch/can/oltreconfiniti/dal-1990-a-oggi/estage/). IRSOL participated to this project and two students could spend several weeks at IRSOL working successfully on specific topics within the framework of the scientific projects 3.2.1 and 3.2.2.

An ongoing collaboration with University of Applied Sciences and Arts of Southern Switzerland (SUPSI) foresees to guide a master work; the official director is prof. Roberto Gardenghi and the work is supervised by Boris Liver at IRSOL (see 4).

With the Observatoire de Genève we have a long ongoing collaboration intended to offer students of the university in Geneva to perform practical exercises (traveaux practique) at IRSOL. This year two students carried out work on: "Mesure de la température de taches solaires" by Rahel Baumgartner, and "Measurement of the Doppler effect of selected bright stars" by Beatriz Alvarez Restrepo .

With "L'ideatorio", Università della Svizzera italiana, IRSOL is starting a cooperation intended to promote an outreach activity. A first explorative meeting was hold on December.

IRSOL promotes an outreach program together with Specola Solare Ticinese, organizing observation events supervised by an astronomer. In particular on July 27, on the occasion of the lunar eclipse, a special event was organized at Specola Solare offering the opportunity to visitors to watch the Moon, Mars and other objects in the sky with telescopes installed there.

4 INSTRUMENTAL WORK

4.1 ZIMPOL project

Our mission in 2018 was completing the final enhancement and removal of all operating system and firmware issues of the instruments core.

4.1.1 Camera EP1/EP3 hardware

All currently available Colibri core boards have been fixed, the damaged and aged strataflash chips have been successfully replaced.

All Zimpol front-end boards have been upgraded to a 40MHz AFE, only the observing camera still carries the slower 20MHz version of the converter. In the meantime a 70HMz edition is available on the market and tests have to been done to upgrade the conversion datarate to the physical limits of the sensor.

Thus, in 2019 we plan to redesign the front-end board to integrate the temperature, pressure and humidity sensors, upgrade the AFE to the 70MHz compatible release and make some necessary improvements on some power supply lanes and bias regulators for the sensor.

The planned upgrade of all cameras to C6N (6ns) speed grade FPGAs has not yet taken place due to backwards compatibiliy constraints.

Further engineering work considers implementing a new generation of ultrasonic multi-channel AFEs into the front-end, mainly for reducing the converson noise.

4.1.2 Camera EP4 hardware

We develop a project which implements the RMII bridge directly from the Cyclone-IV FPGA to the ethernet connector, and at the same time we are also testing to drive the ethernet interface (PHY) from both the Allwinner H2+ (1Gbps) and the STM32F4xx processors (100Mbps), to speed up the data transfer from camera to the host computer for post-processing.

Producing an EP4-based backend board hardware was currently postponed to late 2019 due to the large load of work to be done with higher priorities.

4.1.3 Camera FPGA

The unified clock network between Colibri (PXA) board and FPGA, running at 50MHz synchronous, has been successfully tested. This allows to remove all former synchronisazion circuitry between the components, simplifying substantially the design and the timing calculations and closures, and freeing up an important quantity of FPGA cells.

The available cells have been reused to run the high-resolution QDR timer necessary for the STE-2.0 unit, based on a 2.5x PLL creating a 125MHz clock source with 4 phase-shifted output taps, one at every 90 delay, thus generating one usable rising and one falling edge every 1.000ns.

The PEM-based master clock source has not been tested yet, the stability of the PEM oscillator is proven to be suitable for being the reference input to an EP4 PLL circuit.

The migration to clean GIT-versioning has now been completed for all components of the camera.

4.1.4 Firmware

No further improvements were necessary.

4.1.5 Software

A general cleanup of the command handler and interpreter has been completed.

The new time basis and resolution is now tuned to 1.000ns and managed by a centralized high-resolution timer running in the FPGA and accessible by the CPU. All software timings are based on the new integer unit representing 1.000ns of time. The inaccurate floating-point conversions for time measures, conversions and slicing have been removed.

An external debugging client has been attached to the camera's software in order to track the internal state in almost real time.

4.2 Quadropix DePFET sensor

In 2014, the Halbleiterlabor (HLL) of the Max-Plank-Gesellschaft in Munich proposed a new sensor technology based on Depleted P-channel Field Effect Transistors (DePFET) that allows on-sensor demodulation, similarly to the ZIMPOL sensors. Within the framework of the European Horizon 2020 project"Getting Ready for EST" (GREST) and in collaboration with the Max Planck Institute for Solar System Research in Göttingen (MPS), a two year feasibility study has been carried out on small prototypes, revealing the potential of the new sensor technology. In 2018, IRSOL and SUPSI carefully analyzed the results of the GREST feasibility study of the innovative Quadropix DePFET sensor concept. Our conclusion was that the new sensor technology matches the capabilities of the ZIMPOL technique with masked CCD sensors. In addition it provides several advantages that would overcome certain limitations of the ZIMPOL sensor technology, e.g., symmetric pixels, much faster read-out rates, high quantum efficiency without micro-lens, very fast demodulation also with larger sensor size. In view of the fruitful cooperation between IRSOL and MPS on several scientific topics, IRSOL was offered to be PI in the development of a polarimeter based on the new sensor technology. A working plan was designed by IRSOL, MPS, HLL and SUPSI. In 2019 we will apply for funding the development of the camera (IRSOL and SUPSI) and for the first sensors ready for scientific use (IRSOL, SUPSI, MPS and HLL).

4.3 Cooperation with KIS for the VTF

The Visible Tunable Filter (VTF) is a Fabry-Perot based spectro-polarimeter. It will be a first light instrument for DKIST, designed for high spatial resolution 2D imaging spectropolarimetry and spectroscopy. It is currently under development at KIS, and on-site installation and commissioning is planned for 2021. Due to our good expertise in fast polarization modulator technology KIS asked IRSOL for support. IRSOL agreed to a collaboration and provides a certain amount of manpower to this project. In return and according to the amount of work done in the construction phase, IRSOL will be granted observing time with VTF at DKIST. Until the end of 2018 IRSOL contributed the following tasks to VTF:

- Optical design and modeling of the modulator
- Component evaluation
- Component characterization and testing
- Support of the mechanical and electronical design
- Pre-alignment of the component and first performance tests

4.4 Test observations for an optical component of Sunrise

In order to test the optical properties of a component foreseen to be installed on the new Sunrise mission of MPS, Dr. Achim Gandorfer and Dr. Alex Feller of MPS performed an observational run at IRSOL. The goal was to verify that this optical component would not produce polarized fringes in Stokes images. The IRSOL setup combined with ZIMPOL was an ideal configuration, and the results, obtained with ZIMPOL, confirmed that the tested component can be used without producing the feared signatures.

4.5 Master work with SUPSI

Specific electronics are required to drive ferroelectric modulators (FLC) a specific electronics is required. We are currently using an commercial device that is no longer on the market, and therefore we are developing a specific driver.

An intelligent, space contained, and powered over Ethernet driver for step motors and sensors is being developed. This will let to more unified electronics for controlling our instrumentation.

Topics related to these projects are part of the master thesis of Christian Valles. He is realizing the required electrical boards in a modular way, so that can be easily used in for other projects. Goal of the thesis will be to realize the hardware, write the software, and do the first tests for the FLC controller and a step motor controller.

4.6 Miscellaneous instrumentation

Heat rejection mirror.

The mirror located at the primary focus reflects 99% of the solar image laterally away from the telescope main tube. Only 1% of the image (an area with a diameter of of about 200") passes through a hole and is reimaged on the scientific focus. Almost the entierity of the energy collected by the main mirror (diameter of 45 cm) is concentrated on this mirror on a disk with a diameter of about 2.5cm, and the absorbed light heats the mirror. The former solution to keep the temperature of the mirrors low was a water circulation inside the former metallic mirror (with a poor reflection index). The cracking a tube inside the telescope caused serious damage to the optics, and, to avoid similar problems, we chosed as alternative solution to substitute the mirror with a protected silver coated metallic mirror improving the reflection. The result is very good, and the mirror only heats round 10 Celsius on that of the telescope structure. That permits to renounce to external cooling avoiding the need of water pipes in the telescope.

5 TECHNICAL WORK

5.1 Computer and networking

The NAS capacity has not been extended, but a new 19" server with 8x 5TB RAID-6 disks (available disk capacity: 30TB) is in preparation.

During the infrastructure works, the necessary cable shafts and junction boxes to bring fiber connection to all offices have been installed.

One working server ("core4") has been upgraded to 64GB of fastest possible working RAM capacity and a GTX-1080 graphic card with 2k CUDA cores will be added.

5.2 Infrastructure work

Thanks to the additional found permitted of an inheritance we could perform renovation works at IRSOL. Gianpaolo Mari took the direction ans supervision of the works, and following improvements have been made:

- The top floor of the main building, previously used as apartment, has been restructured into offices plus a guest room. In particular a smaller new bathroom was installed in the guest room, allowing for more space for a new office.
- The electrical wiring in the top floor was reconfigured in order to be conformed to the new construction rules
- A water pipeline located below the floor broke, and an alternative solution had to be found. The new pipeline is partially located in the crawlspace and reaches the first floor through a dedicated path.
- The former photographic darkroom laboratory in the main building was transformed in an office.
- These works required partially unexpected activities that slowed down the expected work rate.
- In the observatory building the former second darkroom laboratory is transformed in an optical laboratory.
- At the end of the year the institute was almost an open construction side, with consequences on the normal activity of the institute. Further works are scheduled for 2019.

6 WORKS FORESEEN IN 2019

- **Collaboration with Università della Svizzera Italiana**

  The accepted SNF Sinergia and the European SOLARNET projects illustrate the strong cooperation between USI and IRSOL. In order to improve the organization of IRSOL, also in view of the future retirement of the director, a working group composed by FIRSOL and USI members will prepare a strategic document. That will also permit to individuate strategies to improve the work in cooperation with the Faculty of Informatics at USI.

  The scientific co-work related to the Sinergia project will be optimized (see 3.1.3).

  The H2020 project Solarnet starts in January 2019. A sommer school, foreseen within this project, will be organized in September together with the Institute of Computational Science.

  An outreach program organized together with "L'ideatorio" will be prepared with the aim to submit an application to SNF Agora.

- **Collaboration with SUPSI**

  Conclusion of the ongoing Master's project of Christian Valles.

  Preparing applications for the construction of the new polarimeter (see 4.2).

- **Development of the scientific program**

  The topics already developed and described in section 3 will be continued.

- **Infrastructure**

  The initiated infrastructure works will be finished during the year.

  Maintenance works on to the access road of the institute (new asphalting) will be made. That would require improving the canalization, and installing the tube to provide the optical fiber connection.

7 SCIENTIFIC ACTIVITY

7.1 Visits

18-19.01 A. Gandorfer, A. Feller, MPS Göttingen

12-16.02 B. Alvarez Restrepo, R. Baugartner, university Geneva

29.05 N. Schaad, C. Girardin, SERI Bern, J.O. Stenflo, B. Lepori

09.07 G. Cauzzi, K.Reardon, NSO

09-17.07 Nurol Al, Asuman Gültekin Annak, Istanbul University

20.07 F. Clette, Royal Observatory Belgium

17-28.07 E. Wiehr, Astro Physik Göttingen

02-31.08 L. Pedrelli, EPFL, Estage

13-31.08 A. Battaglia, EPFL, Estage

03.09 A.Bossart, UniGe, civil service

04.10 J.O. Stenflo

09.10 D. Lorigett, USI

09.11 S: Berdyugina, KIS

27-29.11 F. Clette, Royal Observatory Belgium

07.12 G. Pellegri, USI

7.2 Visits to other institutes

23-26.01 Gioele Janett, Kiepenheuer-Institut für Sonnenphysik, Freiburg. Talk: *Numerical integration of the polarized radiative transfer equation.*

1-7.07 Ernest Alsina Ballester, IAC, Tenerife

2-3.07 Michele Bianda, IAC, Tenerife

2-5.7 Renzo Ramelli, IAC, Tenerife, Seminar talk on 04.07

7.3 Participation to workshops, meetings, schools and talks

16-18.01 O. Steiner, DKIST Critical Science Plan Workshop, Freiburg. Preparation of the science use case UC-125 *Magnetohydrodynamic fine structure of faculae*;

25.01 R. Ramelli, Swiss GCOS Roundtable, Bern

5-9.02 Dhara Sajal K., Meeting of the Astronomical Society of India, Osmania University, Hyderabad, India. Poster presentation: *Narrow-band Imaging Spectropolarimetric Observations of an Active Region at Fe* I *6173 Å*

5-9.02 R. Ramelli, IAU Symposium 340: Long-term datasets for the understanding of solar and stellar magnetic cycles, Jaipur, India. Talk: *Sunspot data collection of Specola Solare Ticinese in Locarno*

17-19.04 M. Bianda, PRE-EST meeting, Belfast

23.05 G. Janett, talk at Meteosvizzera , Locarno, *Numerical integration of the polarized radiative transfer equation*

25.05 M. Bianda, M. Cagnotti, R. Ramelli, Zurich, ETH library

04.06 M. Bianda, R. Gardenghi (SUPSI), D. Gisler, B. Liver, Munich, meeting at the Halbleiter Labor, HLL

11-15.06 E. Alsina Ballester, L. Belluzzi, O. Steiner, EST science meeting, Giardini Naxos, Sicily, Italy. Talks: *Magnetic sensitivity of the scattering polarization signal in the wings of the Ca* I *line at 4227 Å* by E. Alsina Ballester; *The quest of the horizontal magnetic field* by O. Steiner; and *SRD: Report from WG7* by L. Belluzzi;

2-4.07 O. Steiner, Platform for Advanced Scientific Computing Conference, PASC18, Basel

17.07 P. Jetzer, R. Ramelli, signature of the contract ASST/GCOS, Meteoswiss, Zurich

19-29.08 M. Bianda, XXX IAU General Assembly, Vienna. Poster: *Spatial variations of scattering polarization signals at subgranular scales*

19-29.08 O. Steiner, J.O. Stenflo, XXX IAU General Assembly, Vienna.

11.09. O. Steiner, CSCS User Lab Day, Lucerne

9-11.10 L. Belluzzi, DKIST Critical Science Plan Workshop "Long Term Studies of the Sun", Boulder, USA. Preparation of the science use case UC-243 *Monitoring of turbulent field during the solar cycle*. Working Lunch Talk: *IRSOL synoptic program for investigating the small-scale magnetism of the quiet solar photosphere.*

12.10 M. Bianda, L. Jolissaint, Discussion at USI with the head of the Research Service about the SOLARNET project

12.10 R. Ramelli, J. Stenflo, O. Steiner, Swiss Society for Astrophysics and Astronomy, General Assembly, Bern;

16-18.10 M. Bianda, O. Steiner, J.O. Stenflo, Solar Activity, Irradiance, and Magnetism (SAMI18) conference at MPS in Göttingen. Invited talks: *On flux tubes and irradiance: reminiscences and news* by O. Steiner and *The ETH years: of line ratios and other beasts* by J.O. Stenflo;

28-30.10 L. Belluzzi, E. Capozzi, and Dhara Sajal K., 3rd Meeting of the Italian Solar and Heliospheric Community, Turin, Italy. Invited talk: *The Hanle effect as a diagnostic tool for the investigation of the solar magnetism* by L. Belluzzi. Talk: *Spatial variations of the Sr* I *4607 Å scattering polarization signals at subgranular scale observed with ZIMPOL at GREGOR telescope*, by Dhara Sajal. Poster: *Feasibility study for a dedicated filter based polarimeter system for large telescopes: comparing two different cameras*, by E. Capozzi;

28.11 M. Bianda, R. Gardenghi (SUPSI), D. Gisler, B. Liver, Munich, meeting at the Halbleiter Labor, HLL

30.11 M. Cagnotti, R. Ramelli, F. Clette (OMA, Be), Zurich, ETH library

12-14.12 E. Capozzi, S. K. Dhara, *GREGOR meeting 2018 GREGOR meeting*, Staufen, Germany. Oral presentation: *Spatial variations of the Sr* I *4607 Å scattering polarization signals at subgranular scale observed with ZIMPOL at GREGOR telescope* by K. Sajal.

7.4 Talks at IRSOL

5.02 Sandeep Kumar Kataria, Indian Institute of Astrophysics "The impact of bulges on bar formation in Milky Way type galaxies"

24.07 Eberhard Wiehr, Institut fur Astrophysik, Göttingen, "The velocity excess of ions over neutrals in solar prominences"

28.11 Frédéric Clette, World Data Center SILSO Royal Observatory of Belgium, Brussels, "The Sunspot Cycle from past to future"

7.5 Observing campaigns

12.06-03.07 E. Alsina Ballester, M. Bianda, E. Capozzi, D. Gisler, R. Ramelli, Dhara Sajal K. at Tenerife, Spain, telescope GREGOR (presence distributed over different time intervals)

7.6 Participation in exam boards

29.03 M. Bianda and O. Steiner, exam board members for the thesis defense of Flavio Calvo at the Geneva university

10.10 O. Steiner, first opponent and principal reporter for the Ph.D. thesis of Charalambos Kanella, University of Oslo.

7.7 Participation in international scientific committees

L. Belluzzi: member of the Science Advisory Group (SAG), appointed to update the Science Requirement Document (SRD) for the European Solar Telescope (EST). This document will be the scientific base for the Technical Requirement Document (TRD), which will set the constraints and specification for the final design of EST. Belluzzi worked together with Dr. Alex Feller and Prof. Javier Trujillo Bueno (sub-group 8), on the chapter "Scattering Physics and Hanle-Zeeman diagnostics".

O.Steiner: member scientific advisory committee of the Rosseland Center for Solar Physics (RoCS) of the University of Oslo

8 ATTIVITÀ DIVULGATIVA

8.1 Visite guidate, visite di cortesia

24.04 F. Kuthan (English group)

26.04 O. Daldini (gruppo 3^a età)

08.05 J. Tacchella (stage 4^a media)

13.09 D. Staps (Wiesbaden)

20-22.10 M. Setzer

8.2 Stages informativi

08.05 J. Tacchella (stage 4^a media)

31.08 stage premio per le migliori note in scienze in 4^a media al Collegio Papio (DFD Solutions SA Tecnologia e sistemi di Sicurezza - IRSOL): Asmara Beck, (Eloisa Inauen), Marusca Schatt

8.3 Organizzazione di eventi

Il lavoro di divulgazione è coordinato con la Specola Solare Ticinese e fa capo ad un gruppo di animatori composto dal personale scientifico di IRSOL e Specola, nonché da collaboratori volontari. Ci si presenta al pubblico sotto il nome di Centro Astronomico del Locarnese (CAL). Sono state organizzate osservazioni solari e notturne seguite da una presentazione alla Specola Solare Ticinese.

Attività divulgativa in occasione dell'eclisse lunare di venerdì 27 luglio. Animatori presso la Specola Solare Ticinese: Ernest Alsina Ballester, Dhara Sajal Kumar, Renzo Ramelli, Michele Bianda, Boris Liver.

Visite a carattere divulgativo sono organizzate all'IRSOL solamente su esplicita domanda. Una lista di eventi é riassunta al punto 8.1.

8.4 Partecipazione ad eventi e conferenze divulgative

12.05 Renzo Ramelli, "Cosa ci svela la luce del Sole", public lecture at Skymeeting, Monte Lema, 12 May **2018**

22.11 Renzo Ramelli, "Cosa ci svela la luce delle Stelle", Techday 2018, Liceo Cantonale di Mendrisio

22.11 *The Sun, our star*, public lecture at the Swiss-Anglo-Club of Locarno, November 22, 2018, Locarno (O. Steiner)

8.5 Presenza nei media

8.5.1 Televisione

13.03 RSI, riprese del telescopio (A. Isola)

8.5.2 Articoli apparsi sulla stampa

"Quando il Sole sbuffa", La Regione, 20 luglio

8.5.3 Articoli apparsi online

"L'Europa dell'astrofisica guarda a Locarno e a Lugano", 18 ottobre 2018, USI, Servizio comunicazione e media.

www.usi.ch/it/feeds/9062

"Simulating polarized light", 9 novembre 2018, University of Oxford, Mathematical institute.

www.maths.ox.ac.uk/node/30617

9 PUBLICATIONS

Appeared in 2018

Alsina Ballester, E., **Belluzzi, L.**, Trujillo Bueno, J.: 2018, *Magneto-optical Effects in the Scattering Polarization Wings of the Ca* I *4227 Å Resonance Line*, The Astrophysical Journal, **854**, 150

Bianda, M., Berdyugina, S., **Gisler, D.**, **Ramelli, R.**, **Belluzzi, L.**, **Carlin, E. S.**, **Stenflo, J. O.**, Berkefeld, T.: 2018, *Spatial variations of the Sr* I *4607 Å scattering polarization peak*, A&A, **614**, 89

Calvo, F., **Belluzzi, L.**, **Steiner, O.**: 2018, *Structure of the Balmer jump. The isolated hydrogen atom*, A&A, **613**, 55

Ishikawa, R., Sakao, T, Katsukawa, Y., Hara, H.; Ichimoto, K., and other 33 coauthors (included **Belluzzi, L.**, and **Alsina Ballester, E.**): 2018, *Current State of UV Spectro-Polarimetry and its Future Direction*, in *42nd COSPAR Scientific Assembly. Held 14-22 July 2018, in Pasadena, California, USA*, Abstract id. E2.3-6-18., 1564

Janett, G., Paganini, A.: 2018, *Formal Solutions for Polarized Radiative Transfer. III. Stiffness and Instability*, The Astrophysical Journal, **857**, 91

Janett, G., **Steiner, O.**, **Belluzzi, L.**: 2018, *Formal Solutions for Polarized Radiative Transfer. IV. Numerical Performances in Practical Problems*, The Astrophysical Journal, **865**, 16

J. Jurčák, J.; Štěpán, J.; Trujillo Bueno, J.; **Bianda, M.**: 2018, *Comparison of theoretical and observed Ca* II *8542 Stokes profiles in quiet regions at the centre of the solar disc*, A&A, **619**, 60

Ramelli, R., Cagnotti, M., Cortesi, S., **Bianda, M.** Manna, A.: 2018, *Sunspot data collection of Specola Solare Ticinese in Locarno*, in *Long-term Datasets for the Understanding of Solar and Stellar Magnetic Cycles, Proceedings of the International Astronomical Union, IAU Symposium*, **340**, 129

Salhab, R.G., **Steiner, O.**, Berdyugina, S., Freytag, B., Rajaguru, S.P., Steffen, M.: 2018, *Simulation of the small-scale magnetism of main sequence stellar atmospheres*, A&A, **614**, A78

Sarkar, R.; Srivastava, N.; **Dhara, Sajal K.**: 2018, *On the Dynamics of the Largest Active Region of the Solar Cycle 24*, in *Space Weather of the Heliosphere: Processes and Forecasts, Proceedings of the International Astronomical Union, IAU Symposium*, **335**, 32

Schmid, H. M., Bazzon, A., Roelfsema, R., Mouillet, D., Milli, J., Menard, F., **Gisler, D.**, Hunziker, S., (and other 54 co-authors): 2018, *SPHERE/ZIMPOL high resolution polarimetric imager. I. System overview, PSF parameters, coronagraphy, and polarimetry*, A&A,**619**, 9

Štěpán, J., Trujillo Bueno, J., **Belluzzi, L.**,Asensio Ramos, A., (and other 24 co-authors): 2018, *A statistical inference method for interpreting the CLASP observations*, ApJ, **865**, 48

Trujillo Bueno, J., Štěpán, J., **Belluzzi, L.**, Asensio Ramos, A., Manso Sainz, R., (and other 23 co-authors): 2018, *CLASP Constraints on the Magnetization and Geometrical Complexity of the Chromosphere-Corona Transition Region*, ApJ Lett., **866**, 15

In press or already published in 2019

Alsina Ballester, E., **Belluzzi, L.**, Trujillo Bueno, J., *Magnetic sensitivity in the wing scattering polarization signals of the hydrogen Lyman-alpha line of the solar disk radiation*, in press on ApJ

Dhara, Sajal K., **Capozzi**, E., **Gisler, D.**, **Bianda, M.**, **Ramelli, R.**, Berdyugina, S., **Alsina, E.**, **Belluzzi, L.**, in *Proceeding of Third Meeting of the Italian Solar and Heliospheric Community, OCTOBER 28-31, 2018 - TURIN*, arXiv:1904.03986

Janett, G., 2019,*Discontinuities in numerical radiative transfer* published on A&A, **622**, 162

Janett, G., **Steiner, O.**, **Alsina Ballester, E.**, **Belluzzi, L.**, Mishra, S., 2019, *A novel fourth-order WENO interpolation technique. A possible new tool designed for radiative transfer*, published on A&A, **624**, 104

Ramelli, R.; **Bianda, M.**; Berdyugina, S.; **Belluzzi, L.**; Kleint, L., 2019, *Measurement of the evolution of the magnetic field of the quiet photosphere during a solar cycle*, Proceedings paper of the Solar Polarization Workshop 8, held in Florence (I), September, 12-16 2016, in press, arXiv:1708.03287

Stenflo, Jan O., *Dark energy as an emergent phenomenon*, arXiv:1901.01317

Wiehr, E.; Stellmacher, G.; Bianda, M., *Evidence for the Two-fluid Scenario in Solar Prominences*, ApJ, **873**, 125

Vigeesh, G., Roth, M., **Steiner, O.**, and Jackiewicz, J.: 2019, *Internal gravity waves in the magnetized solar atmosphere. II. Energy transport*, ApJ **872**, 166

9.1 Other publications

Calvo, F.: 2019, *High-resolution simulations of the solar photosphere with focus on the polarimetry of the solar continuum*, Ph.D. thesis, Université de Genève,

archive-ouverte.unige.ch/unige:115257/ATTACHMENT01

9.2 Atlas and scientific data on our website

On the page *www.irsol.ch/data_archive* one can find several atlas in digital form.