Istituto Ricerche Solari Locarno

Rapporto 2017

Rapporto alla Fondazione Istituto Ricerche Solari Locarno sulla situazione dell'Istituto alla fine del 2017 e sul piano di lavoro per il 2018

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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 che prevedono l'utilizzo dei supercalcolatori del centro di calcolo CSCS di Lugano. Il lavoro sinergico in queste attività permette di sviluppare nuove tecniche diagnostiche per lo studio dei campi magnetici presenti nell'atmosfera solare.

Sono state individuate e approfondite nuove tematiche scientifiche di interesse comune, che possano permettere all'IRSOL di consolidare la propria cooperazione con la realtà accademica svizzera. In particolare, si sono ulteriormente stretti i rapporti con l'Università della Svizzera Italiana, USI. Sono stati supervisionati due lavori di Master, uno con il Politecnico di Losanna, e uno con con la Scuola Universitaria Professionale della Svizzera Italiana, SUPSI.

Un finanziamento del Fondo Nazionale Svizzero, SNF, ci ha permesso di assumere un postdoc ed una dottoranda per studiare la fattibilità di un progetto in collaborazione con il National Solar Observatory, NSO, statunitense che prevede la realizzazione e l'installazione di uno strumento sviluppato all'IRSOL sul grande telescopio solare del NSO in costruzione alle isole Hawaii.

Una proposta, in larga parte connessa con il progetto internazionale Chromospherc Layer Spectro-Polarimeter (CLASP-2), un esperimento di tipo razzo-sonda frutto della collaborazione tra le agenzie spaziali americana (NASA) e giapponese (JAXA), e di vari istituti Europei (tra cui l'IRSOL), è stata accettata dal Fondo Nazionale e permetterà di assumere per tre anni un postdoc a partire dal 2018.

Alla luce dei pareri positivi espressi dagli esperti chiamati a valutare la precedete versione, è stato nuovamente sottomesso un progetto al programma Sinergia del SNF, tenendo conto dei suggerimenti e delle critiche ricevuti. Il progetto prevede una stretta cooperazione tra l'IRSOL, l'Istituto di Scienze Computazionali (ICS) dell'USI e l'Instituto de Astrofisica de Canarias (IAC) di Tenerife (Spagna).

È inoltre iniziata la procedura per prendere parte a un progetto Europeo (Integrating Activity Proposal, SOLARNET 2), attraverso cui sarà possibile richiedere nuovi fondi per la ricerca, e che permetterebbe di stringere ulteriormente i legami con l'USI e il CSCS.

Dopo un lavoro distribuito su vari anni, i dati relativi alla misure della variazione dell'intensità dello spettro solare misurato dal centro al bordo del Sole, sono stati pubblicati sul nostro sito.

L'IRSOL ha partecipato al progetto Estage organizzato dal canton Ticino ed inteso a mettere in contatto studenti che hanno studiato in Ticino con le realtà economiche ed accademiche del territorio.

Il workshop annuale della sezione svizzera dell'ente Scientific Committee on Solar Terrestrial Physics (SCOSTEP) si è tenuto a Locarno, organizzato dall'IRSOL.

Con i Comuni del Locarnese abbiamo potuto instaurare un costruttivo dialogo che ha permesso di definire le modalità del loro supporto per i prossimi anni.

Alcuni dei posti di lavoro all'IRSOL sono provvisori, in quanto il loro finanziamento è previsto nel quadro di progetti limitati nel tempo sostenuti dal Fondo Nazionale. Nel 2017 sono giunti al termine i progetti del Dr. Edgar Carlin, postdoc all'IRSOL per 4 anni, come pure il lavoro di dottotato di Flavio Calvo che ha sostenuto la difesa della tesi nel 2018.

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
Dando seguito ai consigli espressi durante le valutazioni dell'IRSOL da parte di esperti internazionali e nazionali del Consiglio svizzero della scienza e dell'innovazione, la direzione dell'IRSOL è affidata ad un direttorio composto da:

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

Dr. Michele Bianda

Prof. Dr. Jan Olof Stenflo

Staff scientifico

Dr. Luca Belluzzi (pure affiliato al KIS)

Dr. Michele Bianda

Dr. Edgar Carlin *) (fino a novembre 2017)

Dr. Daniel Gisler (part time con il KIS)

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_ 163405.
**) Finanziato tramite il progetto del Fondo Nazionale, 200020_ 169418.

Staff amministrativo e tecnico

Katya Gobbi (segretaria)

Gianpaolo Mari

Dottorandi

MSc. Flavio Calvo ***) (dal 1 novembre 2013)

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

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

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

Stages scientifici, lavori a tempo determinato

Christian Bertoni (dal 10 luglio al 28 luglio): stage nell'ambito del programma Estage

Collaborazione con il Politecnico di Losanna

Riccaro Di Campli (dal 13 febbraio al 8 settembre) lavoro di Master seguito dal Prof. Dr. Ivo Furno

Collaborazione con la SUPSI

Andrea Raso (dal 5 gennaio al 20 luglio) lavoro di Master seguito dal Prof. Igor Stefanini

Christian Valles, (dal 18 settembre) lavoro di Master seguito dal Prof. Roberto Gardenghi

Collaborazione con il Kiepenheuer Institut für Sonnenphysik, KIS

Da Aprile il Dr. Daniel Gisler è stipendiato solamente dall'IRSOL. D'accordo con il KIS, continuerà un loro progetto dedicato al telescopio statunitense DKIST.

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

MSc. Ernest Alsina Ballester (in visita all'IRSOL dal 3 aprile al 14 maggio) dottorando all'IAC; il Dr. Luca Belluzzi è co-direttore di tesi.

Civilisti
Nel corso del 2017 hanno lavorato all'IRSOL:

Jonathan Besomi (dal 31 luglio 2017 al 22 settembre 2017)

MSc. Riccardo Di Campli (dal 1 ottobre 2017 al 17 dicembre 2017)

Azeglio Diethelm (dal 2 luglio al 5 agosto)

MSc. Damiano Kuthan (dal 1 gennaio al 15 febbraio)

MSc. Federico Ibach (dal 15 maggio al 14 luglio e dal 18 settembre al 11 dicembre)

MSc. Guido Lob (dal 5 giugno al 9 agosto)

MSc. Valentin Stadler (dal 1 gennaio al 21 gennaio)

Ringraziamenti

Il 30 novembre il Dr. Edgar Carlin ha terminato il suo periodo di quattro anni quale postdoc all'IRSOL. Il suo contributo alla crescita dell'IRSOL in questi anni è stato particolarmente marcato. Ha contribuito nel mettere in evidenza in modo originale l'importanza di considerare in modo adeguato effetti cinematici dell'atmosfera solare sui segnali di polarizzazione, specialmente nella cromosfera. Tutto lo staff scientifico ha potuto apprezzare le approfondite discussioni durante le quali quasi immancabilmente emergevano spiegazioni innovative. La sua disponibilità a collaborare con tutti è sempre stata apprezzata. Gli auguriamo una brillante carriera scientifica che anche ci permetta di rimanere in contatto.

Dopo un intenso lavoro di quattro anni, Flavio Calvo ha concluso brillantemente il suo lavoro di dottorato. Il suo carattere solare, la sua straordinaria competenza e la disponibilità ad aiutare chi gli chiedeva un consiglio saranno sicuramente ricordati. Pure a lui auguriamo una carriera scientifica che gli permetta di esprimere le sue non comuni qualità.

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.

IRSOL is the home basis of the Zurich Imaging Polarimeter, ZIMPOL, one of the world's leading instruments in the field of high-precision solar spectropolarimetry. In order to keep this leading role, it is crucial to continue improving the instrument. One of the projects carried out at IRSOL concerns the upgrade of the electronics of the instrument, in order to fully exploit the performance of the camera (see Sect. 4.1). At the same time, we are in close contact with colleagues of other institutes, who are investigating new technologies for the development of the new generation of detectors. Our know-how in the field of high-precision spectropolarimetry allows us to be actively involved in a series of projects related to the new American and European large-aperture solar telescopes: we are in contact with the National Solar Observatory (NSO) for the development of a filter-polarimeter to be installed on the Daniel K. Inouye Solar Telescope (DKIST) (see Sect. 3.4.3), and we are involved in a series of European projects/committees aimed at the construction of the European Solar Telescope (EST).

Observations with ZIMPOL are performed both at the in-house Gregory-Coudé solar telescope of IRSOL, and at the 1.4 m GREGOR solar telescope in Tenerife (see Sect. 3.4.1). Most of the research activity carried out at IRSOL is focused on specific topics that require the unique polarimetric accuracy of ZIMPOL, as well as the possibility to have free-access to the telescope at IRSOL. A particularly important project is a synoptic program (started 12 years ago) for the investigation of the hidden magnetism of the quiet solar photosphere, by exploiting the differential Hanle effect in C_2 lines (see Sect. 3.3.1). The investigation of these fields (which cannot be revealed with the standard Zeeman effect techniques) is quite a hot topic today, as it may allow us to better understand the possible existence and impact of local dynamo processes. The turbulent fields of the quiet photosphere can also be investigated by exploiting the Hanle effect in the Sr I line at 4607 Å: the project aimed at developing a filter polarimeter for the observation of this line (see Sect. 3.4.3) is therefore fully complementary to the previous one. Such instrument will likely be based on a Fabry-Perot. In order to increase our experience and know-how with such devices, we offered a Master work aimed at performing 2D spectropolarimetry of prominences, using the Fabry-Perot system of IRSOL (see Sect. 3.4.4).

Another important project that is carried out at IRSOL, and which necessarily requires the high polarimetric sensitivity of ZIMPOL, concerns the investigation of the linear polarization of the continuum spectrum (see Sect. 3.4.5). This observational project is perfectly complemented by theoretical studies (see Sect. 3.3.2), as well as by the research activity carried out in the field of the numerical simluations of the solar photosphere (see Sect. 3.3.3).

ZIMPOL is one of the few instruments capable of detecting the weak, enigmatic scattering polarization signal produced by the Na I D_1 line, whose physical origin has been debated for more than 20 years. A project conjugating observations (carried out both at IRSOL and at GREGOR) and theoretical modeling of this signal is presently ongoing (see Sect. 3.1.2). The theoretical part of this project is carried out in close synergy with the activity focused on the modeling of the scattering polarization signals of the H I Ly-alpha line and of the Mg II h and k lines (CLASP experiments, see Sect. 3.3.4). Indeed, all these works require the application of complex theoretical frameworks, capable of taking the impact of partial frequency redistribution (PRD) phenomena into account, as well as the development of efficient methods for the numerical solution of the problem. A PhD project focused on the modeling of scattering polarization and the Hanle effect in the presence of PRD phenomena was concluded in 2017 (see Sect. 3.2.1).

The involvement of IRSOL in the CLASP experiment has also offered the opportunity to strengthen our collaboration with USI and ICS, by starting a joint project aimed at developing a new radiative transfer (RT) code for the modeling of scattering polarization and the Hanle effect in three-dimensional models of the solar atmosphere, taking PRD effects into account (see Sect. 3.2.2). The development of efficient numerical methods for the soution of the RT problem for polarized radiation is a very important topic, and several works carried out at IRSOL would benefit from progresses in this field. A PhD project focused on the development of new methods for the formal solution of the RT equations for polarized light in the presence of discontinuities is presently ongoing (see Sect. 3.2.3).

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 Physics of polarization and theoretical interpretation of peculiar signals

3.1.1 Observation and theoretical interpretation of anomalous double-peak V/I signals in strong chromospheric lines

Several important advances were made in 2017 in the research project concerning the observation and theoretical modeling of anomalous circular polarization signals in strong chromospheric lines. We recall that this work has been carried out thanks to a SNF-founded project, which allowed us to offer a two-year post-doc position to Dr. Edgar Carlin Ramirez. The SNF project concluded at the end of October 2017.

In 2017, Dr. Carlin Ramirez continued working on the identification of possible physical mechanisms that could be responsible for the appearance of this kind of signals, analyzing in detail different theoretical schemes capable of describing the physical effects of interest, and studying the relevant literature on this topic. A particularly interesting work is the one carried out by Steiner (2000, Sol. Phys., 196, 245). In that paper, the author investigated the possibility of producing asymmetries in Stokes V signals by considering a two-layer model atmosphere, where one layer is magnetized while the other is field-free (magnetopause), and where a velocity gradient is present between the two layers. In particular, the author noticed the possibility of producing "two-humped" V profiles when the temperature of the magnetic layers surpasses the temperature of the line-core forming region. In the work of Steiner (2000), the effect of dichroism in Stokes V is one of the key ingredients at the origin of anomalous circular polarization signals. Atomic polarization was, however, neglected and dichroism was only produced through the Zeeman effect. On the other hand, dichroism in Stokes V can also be produced because of the presence of atomic polarization (atomic orientation) in the lower level, a circumstance that further motivated our initial idea of investigating the role of this physical ingredient for generating double-peaked Stokes V profiles.

Dr. Carlin thus started considering an optically-thick, constant-property slab model, illuminated from below by the underlying solar photosphere, and took RT effects inside the slab into account. He analyzed this problem both through an approximated analytical approach, and by performing numerical experiments using the HAZEL code (Asensio Ramos et al. 2008, ApJ, 683, 542). This work allowed Dr. Carlin to discover the possibility of generating double-peaked Stokes V profiles thanks to the presence of atomic polarization in the lower level, also in the absence of magnetic fields. This is a very interesting result, which shifted our attention to the problem of understanding how atomic orientation can in fact be induced in the lower level. In this respect, we considered two different mechanisms that had been previously proposed by Martinez Gonzalez et al. (2012, ApJ, 759, 16). We further analyzed them, and we verified that they are actually suitable also for our problem. The investigation of these mechanisms, especially from a quantitative point of view, is still in progress.

At the same time, we wished to find observational evidences of the impact of the proposed mechanism. The three Mg I b-lines at around 5170 Å are interesting in this regard. These lines, which show broad profiles in the intensity spectrum with extended wings, and are therefore good candidates for showing double-peak V profiles (see below), belong to the same multiplet, and thus form at similar heights. On the other hand, they are produced by atomic transitions between levels with different total angular momenta: 0-1, 1-1, and 2-1 (the first and second number indicating the total angular momentum, J, of the lower and upper level, respectively). The new mechanism cannot be at work in the line produced by the 0-1 transition, since, by definition, not atomic level polarization can be present in a level with $J = 0$. However, it can play a role in the other two lines. It is thus clear that a possible observation of double-peaked V profiles in these lines would provide very important indications on the possible impact of the mechanism discussed above. Observations of these lines have been carried out during the last campaign at GREGOR (October 2017), and indeed double-peaked Stokes V profiles have been detected in all of them. The analysis of these data is presently ongoing. A paper in which all the results of the above-mentioned work will be detailed is in preparation.

The observations carried out during the 2016 and 2017 GREGOR campaigns, together with those carried out at IRSOL, confirmed that the double-peak V profiles are a peculiarity of strong lines with broad wings, in which the transition from the Gaussian shape of the Doppler core to the Lorentzian shape of the extended wings could be clearly appreciated.

In order to discriminate the new mechanism from the others that have been proposed, we have also considered two lines with vanishing effective Landé factor (i.e., lines that are insensitive to the Zeeman effect). These are the Fe I 5434.5 Å line, and the Fe I 5576 Å line. Unfortunately, these lines do not show particularly broad profiles and no conclusive results could be obtained. The observational campaigns also provided useful information regarding the locations on the solar disk where such signals are most likely observed, which was another important goal of the project. The double-peaked V signals have always been observed close to the limb, either in very quiet regions close to the north pole, or at lower latitudes, in the neighborhood of relatively more active regions (i.e., regions showing weak antisymmetric signals produced by the longitudinal Zeeman effect). This is another important observational result of our work, which will drive our next steps in the theoretical interpretation of these signals. A paper highlighting the most relevant observational results of this project is also in preparation.

Publications: Carlin Ramirez & Belluzzi (in preparation), Carlin Ramirez et al. (in preparation)

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

The theoretical and observational investigation of the scattering polarization signal of the Na I D_1 line continued during 2017. New observations of this signal were performed at IRSOL: we emphasize that its detection remains a challenging task, and that ZIMPOL remains the best instrument today available for its observation. The analysis of the large amount of observational data about the Na I D_1 line collected at IRSOL during the last years is now a priority. During the first months of 2017, we continued working on the development of a series of methods for extracting the D_1 signal from the noise (e.g., non-parametric kernel regression techniques, spline smoothing, etc.). Most of this work was carried out by MSc. Valentin Stadler (Master in mathematics at ETH Zurich) during his civil service at IRSOL (September 2016 - January 2017). We gladly take the opportunity to thank once more MSc. Stadler for his excellent work. In the following months, we started applying these methods to the observations, with the aim of carrying out a statistical analysis of the occurrence rate of a clear scattering polarization signal in the core of this line, as well as of its amplitude, shape, and wavelength position. This work clearly requires a substantial amount of manpower and progresses have been quite slow so far. This lead Dr. Belluzzi to include the analysis of the Na I D_1 data available at IRSOL among the scientific goals of a proposal that was submitted to SNF in April 2017. The project, with title "The magnetic sensitivity of strong chromospheric lines: from the CLASP experiments to the Na I D_1 line", has been accepted, and the requested three-year post-doc position has been offered to Dr. Ernest Alsina Ballester, who started his activity at IRSOL on February 1st, 2018.

From the theoretical point of view, the mechanism proposed by Belluzzi and Trujillo Bueno (2013, ApJL, 774, 28) and Belluzzi et al. (2015, ApJ, 814, 116) represents a very promising ingredient for interpreting the observed signals. The above-mentioned investigations were limited to the unmagnetized case, and it would be of high interest to include now the impact of the magnetic field in our approach. This implies the development of a numerical code for solving the radiative transfer (RT) problem for polarized radiation in non-local thermodynamical equilibrium (NLTE) conditions, for a two-term atom with hyperfine structure, in the presence of arbitrary magnetic fields, taking partial frequency redistribution (PRD) phenomena into account. This is a challenging task, and it is another goal of the above-mentioned SNF-founded project.

3.2 Numerical modeling of the generation and transfer of polarized radiation

3.2.1 Partial frequency redistribution in scattering polarization; PhD work of Ernest Alsina Ballester

The PhD work of Dr. Ernest Alsina Ballester (Thesis carried out at IAC, under the co-supervision of Dr. L. Belluzzi and Prof. J. Trujillo Bueno) has successfully concluded in 2017. During his PhD, Dr. Alsina Ballester developed a numerical code for solving the RT problem for polarized radiation in NLTE conditions, for a two-level atom in the presence of arbitrary magnetic fields, taking PRD effects into account. This code, which is described in detail in a paper published in 2017 (Alsina Ballester et al. 2017, ApJ, 836, 6), has been applied to model the scattering polarization profiles of various chromospheric lines (e.g., Mg II k at 2795 Å, Sr II at 4077 Å, Ca I at 4227 Å), and to investigate in detail the physics of generation and transfer of polarized radiation in the presence of PRD phenomena. One of the most interesting results of this work was the discovery that the large polarization lobes produced by PRD effects in the wings of strong resonance lines are not insensitive to the presence of a magnetic field (as it was generally believed, considering that the Hanle effect only operates in the line-core region), but have a clear magnetic sensitivity through magneto-optical (MO) effects. During 2017, the impact of this physical mechanism on the Ca I 4227 Å line has been investigated in detail. In particular, through this effect, it was possible to interpret a series of observations carried out at IRSOL, which showed clear variations of the Q/I wing lobes along the slit, as well as wing polarization signals in U/I, of both positive and negative sign. This investigation has been detailed in a paper published in early 2018 (Alsina Ballester et al. 2018, ApJ, 854, 150).

About three months have been dedicated to the preparation of the PhD Thesis, which was submitted in December 2017, and successfully defended in January 2018.

Publications: Alsina Ballester et al. 2017, ApJ, 836, 6; Alsina Ballester et al. 2018, ApJ, 854, 150; PhD Thesis of Dr. Alsina Ballester

3.2.2 Development of a 3D non-LTE radiative transfer code taking PRD effects into account

In 2016, a cooperation among IRSOL, the Institute of Computational Sciences (ICS) of USI, and the Instituto de Astrofísica de Canarias (IAC) was started with the aim of developing a numerical code for modeling scattering polarization and the combined action of the Hanle and Zeeman effects in realistic three-dimensional (3D) models of the solar atmosphere, taking PRD effects into account. This is a very challenging task, especially from the computational point of view. Given the interdisciplinary character of the problem, a proposal was submitted to the "Sinergia" program of SNF in 2016. Unfortunately, the proposal was not accepted. The project included three co-applicants (Dr. L. Belluzzi (IRSOL), Prof. R. Krause (ICS), and Prof. J. Trujillo Bueno (IAC)), and one partner (Dr. J. Štěpán (Astronmical Institute of the Academy of Sciences of the Czech Republic)).

Our cooperation with ICS, IAC and Dr. Štěpán on this topic continued in 2017. In March, Prof. Trujillo Bueno and Dr. Štěpán visited IRSOL and ICS, and a meeting with Prof. Krause (ICS) was organized. We agreed to improve and resubmit the proposal to the "Sinergia" program, and we started planning in more details our joint activity. During the following months, the most critical aspects of the problem were better identified, and we started a series of preliminary investigations of possible approaches and strategies to overcome them. In June 2017, MSc. Simone Riva (Master in applied mathematics at ETHZ) started a stage at ICS and joined our group. Working under the supervision of Dr. Belluzzi, MSc. Riva has been familiarized with the physical problem and started investigating the possibility to speed-up the calculation of the so-called redistribution matrix (a key step of the project) by using GPUs. The results of his work are definitely encouraging, and they have been clearly described in the new proposal. This was submitted at the following call of the "Sinergia" program (December 2017). In the new proposal, we asked funding for opening three post-doctoral positions (one in the institute of each applicant) of four years each, plus a PhD position. The PhD will be carried out at USI, under the co-supervision of Dr. Belluzzi (IRSOL) and Prof. Krause (ICS).

If approved, it will be offered to MSc. Riva. The results of the evaluation will be communicated at the end of May 2018.

3.2.3 Radiative transfer in discontinuous media; PhD work of Gioele Janett

MSc. G. Janett carries out research work at IRSOL as part of a PhD-thesis to be submitted to ETH-Zürich. In the present report period, he carried out a thorough numerical analysis of conventional and alternative methods for the formal numerical integration of the radiative transfer equation for polarized light. The advantages and drawbacks of various formal solvers have been characterized in terms of order of accuracy, stability, and computational cost. While a first paper (Janett et al., 2017a) paid special attention to numerical methods of the Diagonal Element Lambda Operator (DELO) family, a second paper (Janett et al., 2017b) focused on high-order methods, in particular the fourth-order accurate RK4 Runge-Kutta method, the cubic Hermitian method, and high order DELO and DELO-Bézier methods. A fourth-order accurate hybrid technique was proposed. A third paper (Janett & Paganini, 2018) was dedicated to the problem of stiffness and stability. A hybrid numerical scheme is proposed that uses an inexpensive explicit method as long as the integration of the radiative transfer equation is not limited by stability requirements and it switches to an implicit method when stiffness appears. In optically thick layers, the method switches to an L-stable method for correctly reproducing exponential attenuation. The numerical performances of some of the schemes analyzed and proposed in papers I to III are applied to a few real-life problems in a fourth paper (Janett et al., 2018). It was found that the high intermittency of atmospheric models from radiation magnetohydrodynamic simulations might thwart high-order convergence even when using fine numerical grids, making the application of high-order schemes pointless or even noxious. In such circumstances the second order accurate hybrid or DELO-linear schemes perform most satisfactorily.

G. Janett attended the Canary Islands Winter School of Astrophysics on "Applications of Radiative Transfer to Stellar and Planetary Atmospheres", where he presented a poster with the title Formal Solutions for the Polarized Radiative Transfer Equation.

Publications: Janett, Carlin Ramirez, Steiner, & Belluzzi 2017, ApJ, 840, 107; Janett, Steiner, & Belluzzi 2017, ApJ, 845, 104; Janett, & Paganini 2018, ApJ, 857, 91 Janett, Steiner, & Belluzzi 2018, Proc. SPW8 (in press); Janett, Steiner, & Belluzzi 2018, ApJ (submitted)

3.3 Development and application of new diagnostic techniques

3.3.1 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 514.0 nm, generally taken every month. Our results now span almost one complete solar cycle, and the program is still being continued.

In 2017, in order to study these effects in more detail, we started a collaboration with Andrei Gorobets at KIS in Freiburg, in agreement with Prof. Svetlana Berdyugina.

The greatest advantage of measuring the C_2 molecular lines is that it provides the opportunity to use the differential Hanle effect, because we can take into account the ratio of Q/I signatures between several lines within a wavelength interval of two ansgtroms. However, these lines form in cool layers of the solar atmosphere where the magnetic fields of granules and intergranular lanes begin to mix. The information we could potentially gain by measuring the Sr I 4607.3 Å line (which forms in hotter layers, including those where the granular contrast is high) would better address the question of whether the variation of the magnetic field is correlated with the solar cycle.

We proposed a method of observation based on the measurement of the Sr I line together with the Ca II 4227 Å line wings, but instrumental troubles were encountered. Moreover, Alsina Ballester et al. (2018, A&A, 854, 150) has shown that the wing scattering polarization of the Ca II line can be modified by the impact of a magnetic field, calling into question its suitability as a reference for the non-magnetic properties of the solar atmosphere.

A possible alternative to measuring the Sr I line has nevertheless been found, and will be followed next years. The method is based on a low frequency modulation technique already used in the project described in 3.4.5.

Publications: Ramelli et al. 2018, ASP conf.ser. (in press)

3.3.2 Magnetohydrodynamic solar model atmospheres; PhD work of Flavio Calvo

MSc. F. Calvo carries out research work at IRSOL as part of a PhD thesis that was submitted to the University of Geneva on March 7, 2018. In the present report period, he continued the production runs at the Swiss Supercomputing Center CSCS in Lugano, which has resulted by now in a collection of seven different three-dimensional radiation magnetohydrodynamic (R-MHD) time series of solar atmospheric models. In the same time period, he finalized a paper about the structure of the Balmer jump in the continuous solar spectrum (Calvo et al., 2018). Using a modern atomic physical formulation, the total cross-section (for the interaction between photons and an isolated Hydrogen atom) was computed fully analytically and it was shown that there exists no discontinuity at the Balmer limit. The Balmer jump is produced by a rapid drop of the total Balmer cross-section, yet this variation is smooth and continuous when both bound-bound and bound-free processes are taken into account, and its shape and location is dependent on the broadening mechanisms.

F. Calvo also post-processed R-MHD simulation data with regard to the center-to-limb variation (CLV) of linear polarization in the continuum radiation. The results were compared to CLVs from one-dimensional static models, previously published results, and recent, as of now unpublished, measurements at IRSOL. The comparisons revealed differences that are not yet understood and also a non-negligible contribution to the polarization of the red far wing of Lyman-β that was missed in some of the previous works. He also synthesized polarization maps from simulation snapshots. A precondition for the polarization of the continuous radiation is an anisotropy in the radiation field, which is given when displacing the line-of-sight away from disk center. However, in the case of a dynamic, three-dimensional model atmosphere, the corrugated (not plane-parallel) solar surface causes symmetry breaking even at disk center, which leads to anisotropy in the radiation field and consequently to polarization of scattered photons. Correspondingly, maps of the continuum polarization at disk-center show polarization of up to 6×10^{-5} of the continuum intensity varying over granular spatial scales. Although very small and hardly measurable, this polarization level is important to know for the calibration of future polarimeters for the precise measurement of magnetic fields in the solar atmosphere.

F. Calvo gave an oral presentation of this subject at an international conference of the US National Solar Observatories on Sacramento Peak (NM), in a colloquium at the National Solar Observatories

Headquarters in Boulder (CO), and to a few interested scientist at the High Altitude Observatory in Boulder (CO). He also presented a poster at the PASC 17, Platform for Advanced Scientific Computing Conference in Lugano and gave an oral presentation at Meteo Svizzera in Locarno-Monti. He defended his PhD thesis at the Observatory of the University of Geneva on March 29, 2018 with the best possible grade "très bien".

Publications: Calvo, Belluzzi, & Steiner 2018, A&A (in press)

3.3.3 Other results from numerical simulations and ongoing studies

We investigated the behavior of the root-mean-square (rms) contrast and distribution of the continuum intensity of solar granulation in function of spatial resolution of numerical simulations (O. Steiner with R.G. Salhab, F. Calvo, G. Vigeesh, and M. Franz). Surprisingly, we found that this rms contrast is fairly insensitive to the spatial resolution and its value stays close to the maximal expected value as derived from observations. The shape of the contrast distribution, however, is dependent on the spatial resolution of the simulation.

Another ongoing study is dedicated to the generation of vorticity occurring in various dynamical models of the solar atmosphere (O. Steiner et al.).

Numerical simulations of magneto-convection in the surface layers of main sequence stellar atmospheres (K to F) and a thorough analysis of the simulation sequences were carried out (O. Steiner with R. Salhab, S. Berdyugina, and the CO5BOLD collaborators) and published (Salhab et al. 2018). It is found that for mean magnetic flux densities of approximately 50 G, the small-scale magnetism of stars in the spectral range from F5V to K8V produces a positive contribution to their bolometric luminosity as is the case for the Sun. The modulation seems to be most effective for early G-type stars.

Publications: cited in the text

3.3.4 The CLASP projects

The activity of IRSOL within the framework of the Chromospheric Ly-Alpha SpectroPolarimeter (CLASP-1) and the Chromospheric Layer SpectroPolarimeter (CLASP-2) international projects continued during 2017. As in the past years, our work was focused on the theoretical modeling of the scattering polarization profiles of the H I Ly-α line (CLASP-1) and of the Mg II h and k lines (CLASP-2), taking PRD effects into account. In order to make further progresses on this topic, it is necessary to develop a NLTE RT code for polarized radiation, for the case of a two-term model atom in the presence of arbitrary magnetic fields, taking PRD effects into account. The development of such a code is a non-trivial task. On the other hand, it must be observed that the code needed for investigating the Na I D_1 line discussed in Sect. 3.1.2 would be perfectly suitable also for modeling H I Ly-α and Mg II h and k. In fact the application of such code within the framework of the CLASP projects has been included as an additional goal of the project submitted in April 2017 and approved by SNF (starting date February, 1st, 2018).

Interestingly, new theoretical frameworks suitable for modeling PRD effects in complex atomic models (e.g., multi-term atoms, atoms with hyperfine structure, etc.) have been recently proposed (Bommier 2016, A&A, 591, 59; Bommier 2017, A&A, 607, 50; Casini et al. 2017, ApJ, 835, 114; Casini et al. 2017, ApJ, 848, 99). In 2017, we have started a careful analysis of such new approaches, with the aim of identifying the most suitable one for the development of the above-mentioned codes.

It must be observed that part of the activity carried out within the framework of the PhD work of Dr. Alsina Ballester (see Sect. 3.2.1), though not directly related to the CLASP experiments, is of high interest also for such projects, and that the development of a 3D PRD RT code (see Sect. 3.2.2) would clearly be a key step for the theoretical interpretation of the CLASP observations.

Publications: Kano et al. (28 co-authors including Belluzzi) 2017, ApJ, 839; Giono et al. (28 co-authors including Belluzzi) 2017, Sol Phys. 292; Ishikawa et al. (29 co-authors including Belluzzi) 2017, ApJ, 841; Rachmeler et al. (21 co-authors including Belluzzi) 2017, Proc. SPD, 4811010; Stepan et al. (28 co-authors including Belluzzi) 2018 (submitted)

3.4 Observational projects

3.4.1 Observations campaign at GREGOR

From October 14^{th} to the 28^{th}, we conducted an observation campaign at GREGOR in Tenerife using ZIMPOL, installed on the spectrograph. The days dedicated to ZIMPOL observations were shared with IAC (Prof. Javier Trujillo Bueno). Observations with GREGOR are especially valuable for obtaining high spatial resolution spectropolarimetric data, since the spatial resolution is significantly higher than that which can be achieved at IRSOL. Unfortunately, this year we were "victims" of Hurricane Ophelia, because of the atmospheric instability that it caused in the Canary Islands, which lasted for several weeks. The first days the sky was cloudy, and during the following sunny days the atmospheric turbulence did not allow for a single minute of good seeing. Nevertheless, it was possible to perform measurements for the observing program on anomalous circular polarization signals in strong chromospheric lines (see Sect. 3.1.1), which did not require high spatial resolution, but strongly benefitted from the precise pointing system enabled by the adaptive optics of GREGOR.

Publications: Bianda et a. 2018, A&A (in press)

3.4.2 Atlas of the Sun's center-to-limb intensity spectrum variation (CLV)

This project started several years ago, and the data of the atlas is finally available on our web page, both in the form of PDF figures and as digital data. The data spans across the wavelength interval comprised between 4384 Å and 6610 Å. It consists of the spectral intensity profile measured at disk center and of the ratios of intensity profiles measured at $\mu = \cos\theta$ going from 0.1 to 0.9 (with θ the heliocentric angle) with respect to those measured at disk center.

The information on the center-to-limb variation of the intensity in the solar spectral lines, which can be extracted from this data, has applications in many fields. For instance, it is possible to study the radiation anisotropy in the solar atmosphere that produces the scattering polarization measured near the limb (i.e., the Second Solar Spectrum). The data also provides a benchmark for many numerical models.

Data can be accessed and downloaded at http://www.irsol.ch/data-archive/clv-ss3/.

Publications: Ramelli et al. 2018, ASP conf. Ser. (in press)

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

This project is financed by the Swiss National Foundation, thakns to which a postdoctoral position (Dr. Dhara Sajal Kumar) and a PhD position (MSc Emilia Capozzi) have been made available, both of which were filled in late spring.

The goal of this project is to study the feasibility of the construction of an instrument to be installed on the Daniel K. Inouye Solar Telescope (DKIST), in construction in Maui, Hawaii, by the US National Solar Observatory. The purpose of this instrument is to provide measurements for the study of the scattering polarization in the Sr I 4607.3 Å line. Its expected spatial resolution is on the order of 0.1″, which is suitable for investigating its behavior inside the granular structure. The observations would allow for a synoptic program, complementary to our synoptic C_2 molecules program (see 3.3.1), intended to study the evolution of scattering polarization signatures along a solar cycle. This would enable the study of the existence of the local dynamo effect, predicted by theoretical models and numerical simulations at granular scale. The existence and measurability of spatial variations of the polarization signatures in the Sr I line at subgranular scales was already proved during our 2016 campaign at GREGOR (see Section 3.5.1 in the 2016 Report). The paper reporting this result has been accepted and will be published in 2018.

The foreseen plan is to check if a wavelength bandpass of 200 mÅ (a company claims to be able to develop a filter capable of achieving this, while being technologically simpler than a Fabry Perot system) would permit these observations. A campaign at GREGOR with this goal is foreseen in 2018. An internal theoretical study (Belluzzi and Alsina Ballester) has shown that, under these conditions, the fractional polarization signals of the Sr I line can be satisfactorily observed. The expected delivery of the filter in September was shifted by 4 months, and the delivered instrument did not meet the specifications (the transmission 100 times lower than expected), rendering it unsuitable for our test. We are currently waiting for the repaired filter.

Our experience in 2D imaging spectropolarimetry was minor compared to the knowledge we gained with spectropolarimetry performed with the spectrograph. Partially with the intent of overcoming this gap, we put some effort into observing with our Fabry Perot system (see 4.3). In particular, a challenging observation program was performed within a Master's degree project (see 3.4.4).

We are in frequent contact with the National Solar Observatory (NSO) regarding our DKIST collaboration. The optical design and an observing strategy for measuring at GREGOR have been prepared, and the necessary optical components have been purchased.

3.4.4 2D imaging spectropolarimetry of prominences

The availability of the Fabry Perot system (see 4.3) permits us to perform 2D imaging spectropolarimetry of prominences, thus expanding the experience that we have gained from spectrographic measurements carried out in recent years. Such observations were performed by Riccardo Di Campli, a physics student at Ecole polytechnique fédérale de Lausanne (EPFL), within the framework of his Master's project. This project was co-supervised by Prof. Ivo Furno of Swiss Plasma Center and IRSOL personnel.

The first step was to measure the prominences in the Hα line, in which these solar structures present the largest intensity emission peaks in the visible wavelength range. The observational results were positive, but the fact that this line is optically thick in prominences complicates the reduction of Hα data. Difficulties arise because radiative transfer must be taken into account in the inversion process, through which the magnetic field is inferred from the measured polarimetric data.

A line that avoids this problem is He I D3. The existing inversion code HAZEL, developed at IAC in Tenerife (Dr. Andres Asensio Ramos), allows for the inference of the magnetic field from the polarization of optically thin lines, such as the D3 in prominences. The lower number of photons emitted by the prominence in D3 compared to that emitted in Hα was a challenge that was overcome through several instrumental and observational techniques. Such techniques are described in the Master's project of Di Campli and in a paper in preparation. The polarization profiles of the prominence images were analyzed with HAZEL, through which magnetic fields, whose orientation and strength are compatible with measurements obtained with other techniques (e.g., spectrograph measurements), were inferred. The Master's project was graded with the highest qualification.

Publications: Di Campli 2018, Master project; Di Campli et al. 2018 (in preparation)

3.4.5 Center-to-limb variation (CLV) of continuum polarization

Precise measurements of the center-to-limb variation of continuum polarization are required by several projects in solar and stellar astrophysics. However, obtaining this kind of measurements is very challenging because of the small amplitude of the signals and various disturbing instrumental effects. In 2013, in collaboration with KIS, we started a measurement project at IRSOL, and since then we have continually worked on improving the method of measurement, so as to increase the precision of the results.

In order to minimize all instrumental effects, a rotatable half-wave retarder foil was placed in front of the telescope. The device is now motorized (see 4.4), and thanks to this the measurements can be automized. This technique has indeed led to the minimization of systematic instrumental effects, and no apparent inconsistencies have been found in the data. Due to the scientific relevance of these observations, we are still investigating all possible sources of non-solar effects, to optimize the results.

3.4.6 Spectrographic study of prominences

The project, which was started by Dr. E. Wiehr and Dr. G. Stellmacher, is ongoing and continues to be improved. Taking advantage of the quality of the spectrograph at IRSOL, as well as of the low level of instrumental scattered light, it is possible to obtain high-precision measurements of faint emission lines originating in prominences. Studying the ratio of different line parameters, it is possible to measure properties such as the electron density. In June, observations were performed mainly in the Na I 5890 Å (D2) and the Sr II 4078 Å lines. It is possible to switch between these two lines without moving the grating, just by changing a prefilter in the spectrograph. This can be done because the two lines are displayed in the same position on the spectrograph, in different orders. By choosing particular geometrical orientations, it is possible for the shift (generated by the atmosphere dispersion) to be produced along the slit, thus permitting the observation of the same portion of the prominence in the two colors.

Publications: Wiehr et al. 2018 (in preparation)

3.5 Specola Solare Ticinese

Scientific work at Specola Solare Ticinese is focused on the determination of the solar index data, or Wolf number, Ri. In this respect, Locarno is the reference station of Solar Influences Data Analysis Center, SIDC, in Brussels. 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 2016, 296 drawings were performed; 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, in case of need, for the execution of the solar drawings and their reduction. Ramelli acts also as Web Master for the Specola web pages .

The Sunspot Number (SSN) time series, for which Specola is presently the world reference station, was included in the new implementation plan of the Global Climate Observing System (GCOS). Taking that into account, Swiss GCOS accepted to finance a safe long term archiving project of the observational data, currently kept at Specola Solare Ticinese, in collaboration with ETH Zurich University Archives.

Publications: Svalgaard, Cagnotti, Cortesi 2017, Solar Physics, 292, 34

3.6 Education

At IRSOL we offer young students the opportunity to visit a research institute, because that can generate interest for a scientific educational path. Every year we give the opportunity to young students to perform a one day stage before they start the high school. Moreover, we offer support for maturity works with astronomical topics. In sub-chapter 7.5 are listed works performed in collaboration with IRSOL.

In particular in 2017 we have joined a program organized by the cantonal administration of Canton Ticino started, “Estage”, intended to connect students of the Swiss Italian area with local industries and research institutes. Chrisitian Bertoni worked at IRSOL within this successful program.

IRSOL promotes an outreach program together with Specola Solare Ticinese, organizing observation events supervised by an astronomer.

4 TECHNICAL WORKS

4.1 ZIMPOL project

The main goal of 2017 was to test many scientific functionalities that were engineered on the laboratory version of the camera in 2016, before deploying them in final observation instrumentation planned in late 2018.

The debugging of many components of the camera was necessary, because many design rules were not respected and honored in the former implementation.

4.1.1 Camera EP1/EP3 hardware

Only small corrections to the legacy EP1/EP3 PCB set have been done, mainly the removal of historical mistakes and patches to increase stability;

The ports to connect an additional humidity and temperature sensor have been added to schematics, and were tested offline (Colibri EVAL). The implementation on a scientific PCB set is pending in late 2018;

The possibility to reprogram the FPGA from the CPU Colibri and also to rewrite the EPCS boot code on-the-fly has been added;

Due to aging of the Intel StrataFlash memory chips, 5 of 8 available Colibri boards are currently in an unusable state. Two of them could be fixed by a software workaround (compression of the code with an algorithm that circumvents damaged and stuck bits). One could be repaired by replacing one of the two StrataFlash chips;

The expected temporal resolution of 2ns (virtually 500MHz) has been reached and the new implementation of the STE-2.0 (synchronous timing engine) replacing the former TSP-1.0 is working properly, passing all the internal tests. Currently the design implements both TSP-1.0 and STE-2.0 engines on the same FPGA, but they can fit both at same time only from cell size density of EP1C12 upwards, but require C6N speed grade of the chip to work properly at 250MHz . Our scientific cameras wit EP1C6 can only run one of the two engines at a time, and FPGA needs to be reprogrammed in order to switch engine. Moreover, we found out that some scientific camera boards still have C8N speed grade and thus do not work anymore with the new configuration. An upgrade to C6N speed of all our scientific hardware is planned in late 2018.

4.1.2 Camera EP4 hardware

The road-map started in 2016 to upgrade the whole camera core to a Cyclone-V SoC (EVAL by DENX) has been abandoned, mainly because the same goal can be achieved with a simpler Cyclone-IV FPGA interfaced to a very powerful external 4-core ARM processor;

The porting of the Z3 camera server code from Colibri to Ralink RT5350 has been only partially completed, because in mid 2017 a new product came to market which was much more suitable to be an excellent successor of the Colibri PXA270 processor;

Starting in June, the main code (boot loader, kernel, buildroot toolchain target and libraries) was moved to the new candidate, the XunLong Allwinner H2+/H3 quad core 1.2GHz family of ARM processors, which can manage 2x GLAN PHY directly, has hardware SPI bus, and many other synchronous data interfaces for managing the rest of the Zimpol hardware from a single chip;

The main advantage of this ARM family is the ability to boot from 40MHz SPI-NOR flash memory, which has extreme endurance, persistence and stability at a very low cost. The boot process consists in copying the whole compressed kernel and BSP root FS (uClibc based) from the read-only SPI-NOR to DDR2 memory, where the uncompressed image is then executed. During operation the SPI-NOR is never accessed again, so no wear-out takes place. The only drawback is that the PHY is off-chip and has to bee engineered and tuned separately;

One collateral goal of employing the Allwinner H2+/H3 family is that this ARM core is suitable for a multitude of small decentralized servers performing different decentralized tasks like controlling sensors, motors, power supplies, meteo stations and many other stand-alone functionality that we aim to manage over independent TCP/IP sockets.

4.1.3 Camera FPGA configuration

The whole FPGA circuitry was checked for timing constraints and critical paths, but until now only about 40% of the original Zimpol circuits could be redesigned in a synchronous way in order to meet the built-in timing closure checks of the Quartus IDE;

Some sub-units have been migrated to their own synchronous clock domains and fully checked. The H-Clock engine (HCE, former HCLK) is one of them. A main improvement is that now the unused samples (header and trailer of a cropped image) can be shifted out of the CCD at a 2.5x higher rate, compared to the sampling rate which is currently still limited to 1.73Mpix/s;

The implementation of the clock source switch from legacy 48MHz to the Colibri master clock (synchronous 50MHz) and the addition of the PEM-based PLL clock has been added but not tested yet, as the priority of this task has been lowered due to observational campaign requirements;

The addition of a GIT-versioning into the FPGA image was studied but is not yet functional.

4.1.4 Camera firmware

The firmware is now unified for running on both legacy Toradex Colibri and Sunlong AllWinner H2+/H3, using the same versions of Das U-Boot (boot loader), specific BSP (with same config) and same system libraries. Thus, code compiled for Toradex Colibri also runs seamlessly on Sunlong AllWinner H2+/H3. Azeglio Diethelm contributed also to this project;

The firmware is able to detect the absence of the FPGA hardware and run in a sandbox mode for debugging purposes on the JTAG-Enabled EVAL board.

4.1.5 Camera software

The Zimpol camera now operates with only two programs (Z3server and Z3driver), one in user space and one in kernel space for interfacing all FPGA registers, which are easier to maintain;

The software is now fully documented and tracked in own GIT-repository. Before there was one big GIT-repository containing just everything about the Zimpol camera project. The software is aware of its own version and GIT-hash, and is able to self-upgrade in a safe way if required;

Testing of new software is now possible without altering the contents of the Intel StrataFlash memory chips, as the Z3 programs can be loaded directly into ramdrive;

All useless commands have been removed from the Z3server program;

A strict syntax check parser to all commands and arguments has been introduced, with very verbose error messages for debugging;

Some maintenance and software version management commands have been added;

On-the-fly code reload of the TSP-1.0 and STE-2.0 units has been added;

4.2 Computer and networking

The capacity of the NAS (network attached storage) has been upgraded from 2 units to 5 units (bringing the total RAID5 capacity up to 64TB);

The project of the universal diskless workstations (iPXE booting) has been postponed to beginning of 2019;

Some LTPoE++ switches have been successfully added to some of the instruments, and are currently being tested;

About 30% of the infrastructure has been upgraded from a 100Mbit wired LAN to a 1Gbit fiber connection, using SM 9/125um fibers with SC/UPC connections;

The switches in the data center have all been upgraded to 1Gbit capacity, mixing wired and fiber in the same rack as suitable;

The firewall has been upgraded to meet the switching capacity between networks;

One modem was replaced in order to support vectoring VDSL2+, a further upgrade to get the best performance out of our copper lines will take place in October 2018;

Some improvements of the IRSOL web site layout were introduced by Jonathan Besomi.

Guido Lob improved data reduction codes used to filter regulat fringes and to calculate the demodulation matrix required by a new calibration technique used in GREGOR observations.

In order to better organize the information exchange between IRSOL staff, an internal WIKI page was created.

4.3 Fabry Perot filter

The 2D spectropolarimeter filter system is based on the CSIRO lithium niobate Fabry-Perot etalons, as well as on ZIMPOL and on the 10 m focal length spectrograph at IRSOL. The former system, described in Kleint et al. (A&A, 2011, **529**, 78), was upgraded in order to be compatible with the last version of ZIMPOL. This work was was performed as a Master's project in 2016 (MSc Mathis Engelhard, Hochschule ReinMain) and was followed by the civilist work of MSc Damiano Kuthan, who was able to prepare a user-friendly manual and introduce some improvements. Their work, done in collaboration with IRSOL staff, made it possible to have the system ready for the Master's project of Riccardo Di Campli (see 3.4.4).

4.4 Miscellaneous instrumentation

Master work of Andrea Raso.

The topic of the Master's project was to develop a prototype for a step motor controller based on power over ethernet (LTPoE++). The prototype is working successfully, and this technique can be generalized and applied to other instruments at IRSOL.

The motorization of the rotatable retarder film (used for high-precision measurements of absolute polarization) was tested using our legacy motor controllers. The development of this device will be undertaken within a European Project (SOLARNET).

The main and secondary mirrors of the telescope were re-coated with a special protected silver coating, permitting reflectivity also in the violet and close UV part of the solar spectrum. The mirrors were inserted during the telescope optics adjustment phase.

Adjustment of the telescope optics.

Previously the optical adjustment of the telescope mirrors was performed with the aid of a theodolite. This year the adjustment technique was improved by using a digital camera located on a mechanical device with 4 degrees of freedom (2 rotations and 2 translations) together with special tools (x-y moveable crosses and tiltable mirrors) which can be placed along the optical path of the telescope. Most of this work was done within the civil service work of Federico Ibach, who prepared the mechanical parts and also improved the adjustment technique.

The code of the guiding system, also based on the encoders coupled to the hour axis and declination axis motors, was updated in order to decrease the required CPU time. This work was done in a collaboration between IRSOL personell and Riccardo di Campli. Other codes, to be implemented, have been developed by Johnathan Besomi.

Heat rejection mirror.

The water cooling of the heat rejector mirror located at F1 was discontinued once the new silver coated mirrors were inserted; water was at the origin of damages occurred to the former silver coating of the M1 and M2 mirrors in 2014.

The original metallic mirror will be substituted by a new one with a protected silver coating. The cooling of the heat rejection mirror (at F1) using heat pipes was not efficient as expected. Therefore, we abandoned this strategy and opted for using a high-reflectivity coated mirror with added temperature sensors.

Wiring at the observatory.

During the last years more electronic devices have been added. Where possible, they have been collected in a new electronics rack and the wiring has been improved.

4.5 Infrastructure work

- The institute's electrical power system was upgraded in order to fulfill the current national regulations, which also made it possible to update the missing documentation.
- The top floor apartment of the institute, previously occupied by the housekeeper, will be free starting at the end of the year and will be used to improve the working space.

- Minor improvements to avoid dry leaf infiltrations were made to the technical room next to the observatory.
- Damage to the water conduct at the entrance of the offices building was identified and fixed.

5 WORKS FORESEEN IN 2018

- **Association with Università della Svizzera Italiana**

  The application to the "Sinergia" program of the Swiss National Foundation was resubmitted, after taking into account the suggestions expressed by the experts. The project foresees a strong collaboration with the Institute of Computational Sciences at USI, and with Instituto de Astrofisica de Canarias (IAC).

  USI, IRSOL and CSCS are participating to the European "Integrating Activity Proposal for Advanced Communities" SOLARNET 2.

- **Collaboration with SUPSI**

  The Master's project of Christian Valles is currently ongoing and will be pursued.

  The possibility of a collaboration intended to develop a new sensor that could be the successor of the ZIMPOL CCD will be investigated.

- **Development of the scientific program**

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

- **Instrumentation**

  IRSOL instrumentation will be maintained and improved. In particular, attention will be dedicated to the improvement of ZIMPOL.

- **Infrastructure**

  Renovation works at the upper rooms of the institute are foreseen.

  Afterwards, it will be possible to repurpose a room in the observatory as an optical laboratory.

  The access road requires significant works and reforms (including canalization, installation of optical fiber, and asphalting).

6 SCIENTIFIC ACTIVITY

6.1 Visits

16.02 Giambattista Ravano, Andrea Salvadè, Manuela Maffongelli, SUPSI

24.02 Marina Battaglia, FHNW

27.02-08.03 Javier Trujillo Bueno, IAC, e Jiri Stepan, ASCR

06.04-09.04 Reza Rezaei, IAC

03.04-14.05 Ernest Alsina Ballester, IAC

18.06-02.07 Eberhard Wiehr, Göttingen

20.06-28.06 Goetz Stellmacher, Paris

28.08-31.08 Parameswaran Venkatakrishnan, IIA

09.11 Lia Sartori, ETHZ

21.11-24.11 Andrei Gorobets, KIS

6.2 Visits to other institutes

16.01-21.01 F. Calvo, Kiepenheuer-Institut für Sonnenphysik, Freiburg

06.03 L. Belluzzi, M. Bianda, R. Ramelli, J. Trujillo Bueno, J. Stepan, USI-CSCS

02.04-06.04 F. Calvo, Kiepenheuer-Institut für Sonnenphysik, Freiburg

01.06-09.06 E. Carlin, Toulouse

10.06-17.06 E. Carlin, MPS, Gottingen

18.06-07.07 IAC, Tenerife

17.07 M. Bianda, E. Capozzi, Observatoire de Genève

14.08-18.08 F. Calvo and O. Steiner, High Altitude Observatory, Boulder (CO), USA

6.3 Organization of workshops, schools or assemblies

10.10-11.10 Workshop SCOSTEP and board meeting

6.4 Participation to workshops, meetings, schools and talks

17.01 F. Calvo, Kiepenheuer-Institut für Sonnenphysik, Freiburg, colloquium, talk *Linear polarization of the solar continuum spectrum.*

24.04 L. Belluzzi, SCOSTEP meeting in Locarno, *Synoptic programs for investigating the hidden magnetism of the quiet solar photosphere*

24.04 M. Bianda, SCOSTEP meeting in Locarno, *The Sunspot Number and the role of the Specola Solare Ticinese in Locarno*

24.04 Dhara Sajal Kumar, SCOSTEP meeting in Locarno, *Trigger and instability mechanisms of active region filament eruptions*

24.04 G. Janett, SCOSTEP meeting in Locarno, *Numerical integration of the radiative transfer equation*

17.01 F. Calvo, Kiepenheuer-Institut für Sonnenphysik, Freiburg, colloquium, talk *Linear polarization of the solar continuum spectrum.*

12.06-16.06 O. Steiner, 14th Potsdam Thinkshop, *Stellar Magnetism: Challenges, Connections and Prospects*, invited talk *Simulation of the small-scale magnetism in main sequence stellar atmospheres.*

26.06-28.06 F. Calvo and O. Steiner, PASC 17, Platform for Advanced Scientific Computing Conference in Lugano, poster presentation *The linear polarization of the solar continuum radiation from numerical simulations of the solar atmosphere.*

07.08-11.08 F. Calvo, O. Steiner, 30th NSO Workshop, "High-resolution Solar Physics: Past, Present, Future", Sacramento Peak National Solar Observatory, oral presentaions *Center-to-limb variation of the polarization in the continuum at high spatial resolution* and *Intensity contrast and distribution on the solar surface: old wisdom with a surprising twist.*

16.08 F. Calvo and O. Steiner, National Solar Observatory, Boulder (CO), USA, colloquium talk by F. Calvo *Center-to-limb variation of the polarization in the continuum at high spatial resolution*

13.09-16.09 O. Steiner, Rocks & Stars II Conference at the Max-Planck-Institut für Sonnensystemforschung, Göttingen, invited talk *Why numerical simulations?.*

18.09-22.09 O. Steiner, Annual Meeting of the German Astronomical Society in Göttingen.

06.10 M. Bianda, R. Ramelli, O. Steiner, General Assembly of the Swiss Society for Astrophysics and Astronomy, ETH-Zürich.

09.10-11.10 O. Steiner, EST meeting in Bairisch-Kölldorf (AU), invited talk *Science challenges for EST.*

16.-20.10 O. Steiner, "Stellar Convection and Oscillations and their Relationship" (SCORe17) workshop in Heidelberg, oral presentations *Intensity contrast and distribution on the solar surface: old wisdom with a surprising twist* and *Simulation of the small-scale magnetism in main sequence stellar atmospheres.*

13.11-17.11 G. Janett, Canary Islands Winter School of Astrophysics on "Applications of Radiative Transfer to Stellar and Planetary Atmospheres", poster presentation *Formal Solutions for the Polarized Radiative Transfer Equation.*

23.11 M. Bianda, Freiburg, KIS, SOLARNET meeting

6.5 Talks at IRSOL

24.02 Marina Battaglia, FHNW,"X-ray and EUV observations as diagnostic of accelerated electrons and atmospheric response in solar flares"

07.04 Reza Rezaei, IAC, "Structure of sunspot light bridges in the chromosphere and transition region"

28.08-31.08 Parameswaran Venkatakrishnan, Hon. Prof. IIA, Bangalore, "Multi Application Solar Telescope (MAST)"

09.11 Lia Sartori, ETHZ, "The study of Active Galactic Nuclei variability on multiple timescales"

6.6 Observing campaigns

14.10-28.10 Belluzzi, Bianda, Capozzi, Carlin, Gisler, Liver, Ramelli, Sajal at Tenerife, Spain, telescope GREGOR

6.7 Participation in exam boards

20.08 Michele Bianda and Boris Liver exam board members for the Master of Andrea Raso at SUPSI

08.09 Michele Bianda and Renzo Ramelli exam board members for the Master of Riccardo di Campli at Physique des Plasmas de Base at EPFL Lausanne

7 ATTIVITÀ DIVULGATIVA

7.1 Visite guidate

07.04 Gerd Küveler

01.09 Ditta EcoControl

05.09 Studenti Liceo Bellinzona, due classi

15.09 Istituto di Geografia, UNI Zurich

11.10 Visita di partecipanti al workshop SCOSTEP

7.2 Stages informativi

20.01 Giacomo Mastroddi, studente Liceo Diocesano di Breganzona, stage

7.3 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.

Visite a carattere divulgativo sono organizzate all'IRSOL solamente su esplicita domanda. Una lista di eventi é riassunta al punto 7.1.

7.4 Partecipazione ad eventi e conferenze divulgative

21.03 Renzo Ramelli, giornata autogestita Liceo Bellinzona, "Eclissi di sole"

26.04 Flavio Calvo e Gioele Janett, giornata autogestita Liceo Lugano 1,"Dal liceo alla fisica solare, da studenti a ricercatori"

29.11 Renzo Ramelli, “Techday” al Liceo di Lugano 1, “Cosa ci svela la luce delle stelle”

7.5 Lavori di Maturità seguiti all'IRSOL

Stefan Oljaca: “Velocità orbitale di Venere determinata con l'effetto Doppler”

7.6 Presenza nei media

7.6.1 Radio

03.04 Intervista a Renzo Ramelli su Rete 3

24.07 Intervista a Renzo Ramelli su Radio 3iii

7.6.2 Articoli apparsi sulla stampa

- “Quando il Sole sbuffa”, La Regione, 20 luglio
- “Fra la Terra e il Sole”, La Regione, 10 Ottobre

7.6.3 Articoli apparsi online

- “Si studia il sole in Ticino”, News di Meteosvizzera, 2 aprile
- “Gleich zwei Sonnenforschungsstellen sind im Tessin beheimatet”, di Nicolai Morawitz, Agence Télégraphique Suisse SA - ats , 7 aprile.

  L'articolo è stato ripreso da 42 siti di informazione quali: 1815.ch, aargauerzeitung.ch, appenzellerzeitung.ch, ..., swissinfo.ch, tagblatt.ch, ecc.

7.6.4 Altri eventi

06.09 Riunione all'IRSOL del Convivio intercomunale dei sindaci del Locarnese

8 PUBLICATIONS

appeared in 2017

Trujillo Bueno, J., Landi Degl'Innocenti, E., **Belluzzi, L.**: 2017, *The Physics and Diagnostic Potential of Ultraviolet Spectropolarimetry*, Space Science Reviews, **210**, 183

Rachmeler, L. and 20 coauthors (included **Belluzzi, L.**): 2017, *CLASP2: The Chromospheric LAyer Spectro-Polarimeter*, American Astronomical Society, SPD meeting, **48**, 110.10

Ishikawa, R., and 28 coauthors (included **Belluzzi, L.**): 2017, *Indication of the Hanle Effect by Comparing the Scattering Polarization Observed by CLASP in the Ly and Si III 120.65 nm Lines*, The Astrophysical Journal, **841**, 31

Giono, G., and 27 coauthors (included **Belluzzi, L.**): 2017, *Polarization Calibration of the Chromospheric Lyman-Alpha SpectroPolarimeter for a 0.1% Polarization Sensitivity in the VUV Range. Part II: In-Flight Calibration*, Solar Physics, **292**, 57

Kano, R., and 27 coauthors (included **Belluzzi, L.**): 2017, *Discovery of Scattering Polarization in the Hydrogen Ly Line of the Solar Disk Radiation*, The Astrophysical Journal Letters, **839**, 10

Alsina Ballester, E., **Belluzzi, L.**, Trujillo Bueno, J.: 2017, *The Transfer of Resonance Line Polarization with Partial Frequency Redistribution in the General Hanle-Zeeman Regime*, The Astrophysical Journal, **836**, 6

Carlin, E. S., **Bianda, M.**: 2017, *Spatiotemporal Evolution of Hanle and Zeeman Synthetic Polarization in a Chromospheric Spectral Line*, The Astrophysical Journal, **843**, 64

Dhara, Sajal Kumar, Belur, Ravindra, Kumar, Pankaj, Banyal, Ravinder Kumar, Mathew, Shibu K., Joshi, Bhuwan: 2017, *Trigger of Successive Filament Eruptions Observed by SDO and STEREO*, Solar Physics, **292**, 22

Janett, G., **Carlin, E.**, **Steiner, O.**, and **Belluzzi, L.**: 2017, *Formal solutions for polarized radiative transfer. I. The DELO family* , The Astrophysical Journal, **840**, 107

Janett, G., **Steiner, O.**, and **Belluzzi, L.**: 2017, *Formal Solutions for Polarized Radiative Transfer. II. High-order Methods*, **845**, 104

Stenflo, J. O.: 2017, *History of Solar Magnetic Fields Since George Ellery Hale*, Space Science Reviews, **210**, 5

Jafarzadeh, S., Solanki, S.K., Stangalini, M., **Steiner, O.**, Cameron, R.H., Danilovic, S.: 2017, *High-frequency oscillations in small magnetic elements observed with Sunrise/SUFI*, The Astrophysical Journal Supplement Series, **229**, 10

Svalgaard, L., **Cagnotti, M.**, and **Cortesi, S.**: 2017, *The Effect of Sunspot Weighting*, Solar Physics, **292**, 34

Vigeesh, G., **Steiner, O.**, **Calvo, F.**, Roht, M.: 2017, *On the effect of vorticity on the propagation of internal gravity waves*, Memorie della Societa Astronomica Italiana, **88**, 54

Steiner, O., **Calvo, F.**, Salhab, R., Vigeesh, G.: 2017, *CO5BOLD for MHD: progresses and deficiencies*, Memorie della Società Astronomica Italiana, **88**, 37

Sampoorna, M.,**Nagendra, K. N.**, **Stenflo, J. O.**: 2017, *Polarized Line Formation in Arbitrary Strength Magnetic Fields Angle-averaged and Angle-dependent Partial Frequency Redistribution*, The Astrophysical Journal, **844**, 97

Vigeesh, G., Jackiewicz, J., and **Steiner, O.**: 2017, *Internal gravity waves in the magnetized solar atmosphere. I. Magnetic field effects*, The Astrophysical Journal, **835**, 148

In press or already published 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*, ApJ, **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

Bianda, M., **Ramelli, R.**, **Gisler, D.**, **Belluzzi, L.**, **Carlin, E.S.**: 2018, *Second Solar Spectrum observations with ZIMPOL*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

Calvo, F.: 2018, *High-resolution simulations of the solar photosphere with focus on the polarimetry of the solar continuum*, PhD thesis, Université de Genève

Calvo, F., **Belluzzi, L.**, **Steiner, O.**: 2017, *Structure of the Balmer jump. The isolated hydrogen atom*, A&A, in press

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

Janett, G., **Steiner, O.**, and **Belluzzi, L.**: 2018, *Numerical methods for the radiative transfer equation of polarized light*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

Janett, G., **Steiner, O.**, **Belluzzi, L.**: 2018, *Formal Solutions for Polarized Radiative Transfer. IV. Numerical Performances in Real-Life Problems*, The Astrophysical Journal, submitted

Ramelli, R., Setzer, M., Engelhard, M., **Bianda, M.**, **Paglia, F.**, **Stenflo, J. O.**, Küveler G., Plewe R.: 2018, *Atlas of the solar intensity spectrum and its center to limb variation*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, press.

Ramelli R., **Bianda M.**, Berdyugina S., **Belluzzi L.**, and Kleint L.: 2018, *Measurement of the evolution of the magnetic field of the quiet photosphere during a solar cycle*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

Salhab, R.G., **Steiner, O.**, Berdyugina, S., Freytag, B., Rajaguru, S.P., Steffen, M.: 2017, *Simulation of the small-scale magnetism of main sequence stellar atmospheres*, A&A, in press

Sowmya, K., **Nagendra, K.N.**, Sampoorna, M., **Stenflo, J.O.**: 2018, *Partial frequency redistribution theory with Paschen-Back effect: Application to Li I 6708 Å lines*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

Stenflo, J.O: *The Kramers-Heisenberg coherency matrix*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

Stenflo, J.O: 2018,*Summary talk: Looking ahead*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

Stephan, J., Trujillo Bueno, J., **Belluzzi, L.**, (25 co-authors): 2018, *A statistical inference method for interpreting the CLASP observations*, ApJ, submitted

Supriya, H.D., Sampoorna, M., **Nagendra, K.N.**, **Stenflo, J.O.**, Ravindra, B.: 2018, *Effects of lower-level polarization and partial frequency redistribution on Stokes profiles*, in: L. Belluzzi et al. (eds.), "Solar Polarization 8", *ASP Conf. Ser.*, in press.

8.1 Other publications

Andrea Raso, *Stepper motor to measure CLV*, Master work in Engineering

Riccardo Di Campli, *2D Imaging Spectropolarimetry of Solar Prominences Using Monochromatic Interferometric Fabri Pérot Filter*, Master work in Physics at EPFL

Salhab, R.G., **Flavio Calvo**, Vigeesh, G., **Oskar Steiner**: 2017, *On the rms contrast of granulation*, The CO5BOLD Quarterly Companion, issue 6

Ch. Bertoni: 2017, *Discontinuities in ODEs with discrete right hand side*, IRSOL internal report

Renzo Ramelli, *L'Istituto Ricerche Solari Locarno (IRSOL) presentazione all'attenzione del CISL sull'attività dell'Istituto e sul suo finanziamento*, report over IRSOL for the local municipalities

8.2 Atlas and scientific data on our website

On the page "http://www.irsol.ch/data_archive" one can find several atlas in digital form. In particular since 2017 the atlas of the center to limb variation of the intensity spectrum can be downloaded (see 3.4.2).