International Team Proposal to ISSI 2010 Extracting physical information from spectropolarimetric observations. Comparison of inversion codes

J.M. Borrero[1] & A. Asensio Ramos[2]

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Abstract

One of the most powerful and successful tools to infer the thermodynamic, kinematic and magnetic properties of astrophysical plasmas is the analysis of the polarization properties of the light it emits in different absorption/emission atomic/molecular lines. Obtaining reliable information from the polarization signals (aka: Stokes profiles) is not an easy and direct task, because the observed Stokes profiles depend in a deep and intricate manner on the physical properties we aim at investigating. A crucial breakthrough was achieved in the last 30 years with the development of non-linear inversion codes that, with the aid of relatively simple models, are able to reliably extract information about the thermodynamic, kinetic and magnetic properties of the plasma. This technique has been systematically applied to the study of the solar Photosphere and Chromosphere. Many inversion codes are nowadays available to the Solar Physics community and their application has provided us with a better understanding of the outer layers of the solar atmosphere. Every inversion code is based on a specific model (with different degrees of complexity) and therefore the inferred physical properties have to be interpreted with some care and are conditioned to the reliability of the proposed model. Since a variety of models are employed to interpret observations, it is crucial to investigate, through a controlled and systematic experiment, which model is favored to produce inferences closer to the real physical conditions. To this end, we propose the following steps: (1) use the thermodynamic and magnetic parameters, obtained from recent 3D non-grey MHD simulations (of the quiet Sun, active regions and sunspots), to compute synthetic Stokes profiles that will be fed to several existing inversion codes; (2) each inversion code will analyze this data and attempt to retrieve the physical parameters, which will be then compared to the real values provided by the numerical simulations; (3) analyze the dependence of the results on the model assumed. Our team will comprise several experts and developers of the most widely used inversion codes, which guarantees the successful completion of this project.

1 Scientific rationale, goals and timeliness of the project

A large fraction of our knowledge of the thermodynamic and magnetic properties of solar plasmas comes from the interpretation of spectro-polarimetric observations carried out during the last decades. Very sensitive spectro-polarimeters mounted on ground-based telescopes have revolutionized the field by providing polarimetric sensitivities of the order of and sometimes better than 10^{-4} (this means detecting rates of one polarized photon per 10000). Ground-based telescopes and their success has been recently accompanied by a large interest on observations carried out with space-borne observatories, like the spectropolarimeter SP aboard Hinode or the IMaX magnetometer aboard the Sunrise balloon. These telescopes offer data without the

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influence of the atmosphere, with continuous observing periods and with unprecedented spatial resolutions. Altogether, ground-based and space-borne facilities are offering and will deliver data of very good quality that we should exploit to understand better the physical process taking place in the solar atmosphere.

The development of complex inversion codes to extract information from observations has evolved almost in parallel to the development of the instrumentation. This has served to deepen our understanding of the role the magnetic field plays in all sorts of solar structures: granulation, inter-network, sunspots, prominences, spicules, etc. Initial efforts resulted in inversion codes that were able to infer physical parameters proposing really simple models based on simple quantities that could be estimated observationally. As soon as the full Stokes vector was made observationally available, these codes evolved towards more complex models based, the majority of them, on a Milne-Eddington model atmosphere. Later, atmospheres in local (or non-local) thermodynamic equilibrium were used, producing the present state-of-the-art computer codes. In spite of their success, no systematic analysis of the capabilities of such codes has never been carried in controlled conditions. It is now the moment to analyze and compare different inversion codes, specially considering how wide-spread they are, and due to the vast amounts of data that already is and will be available in the near future. In our study, the team proposes the following goals:

1. Inter-comparison of codes and comparison of their inferences with numerical simulations.

   - Inversions rely on non-linear optimization procedures that can get trapped in local minima. For this reason a number of optimization schemes have been used: Levenberg-Marquardt, Neural Networks, Principal Component Analysis, Genetic algorithms, etc. We aim at identifying the best optimization schemes to improve convergence without increasing the computing time.
   - Each of the four Stokes parameters that enter the merit function being minimized can be weighted differently during the optimization. Different choices for these weights often yield somewhat different results in the inferred physical parameter. We plan on investigating what is the optimum weighting scheme.
   - It is manifest that inversions with a large number of spectral lines produce an improvement in the quality of the recovered physical parameters. However, only a few instruments are able to supply such multi-line observations and it is yet something to be exploited. Inversion of synthetic data with noise added will help us understand the gain obtained by adding more spectral lines.

2. Find a compromise between model complexity and reliability:

   - Simulations clearly show strong vertical gradients in the physical parameters. The gradients (specially in the magnetic field and velocity of the plasma) give rise to Stokes profiles that are asymmetric. Some models do not account for those gradients in the inversion, and therefore they can only fit symmetric profiles. Is it fundamental to fit these asymmetries to estimate correctly the average magnetic field? Can an inversion code based on a model that is able to fit the asymmetries be preferred with respect to other models that do not have this ability?
   - Present observing capabilities produce spatial resolutions of the order of 100 km on the solar surface. Specially in the quiet Sun, these resolutions are far larger than the expected organization scales of the magnetic field and cancellation of the observed signal occurs. It remains to be understood how to deal with such cancellations and if all models give consistent pictures.
   - When future telescopes and spectropolarimeters produce observations at a very high spatial resolution, will we need to change the models we now utilize? According to

the MHD simulations, we expect the complexity of the observations to increase as the spatial resolution is enhanced. Do we have to abandon our models and propose more complex models? What is the role of noise in the retrieval of physical information from such complex models?

3. Applications to current and future instrumentation:

   - With the present slit spectrographs it is possible to obtain high signal-to-noise and high spectral resolution at the cost of temporal cadence and spatial resolution. Other type of instruments (typically Fabry-Perot bidimensional filter-polarimeters) favor cadence and spatial resolution at the expense of signal-to-noise and spectral resolution. Inversion codes have been extensively tested with data from the former instruments, but a comprehensive study with the latter is missing. Therefore, we aim at studying the effect of the reduced spectral resolution of filter-polarimeters on the capabilities of inversion methods to infer the physical properties. Which is the minimum (or optimal) number of samples across a spectral line that one needs not to loose crucial information?
   - Filter-polarimeters do not obtain all wavelength information simultaneously and therefore the observed Stokes profiles can be affected by time changes in the physical conditions of the emitting plasma: how does this effect the retrieved physical parameters? What is the maximum time span for the filter instrument to scan the spectral line before the inferred physical parameters are affected?
   - Is it possible to apply recently developed multiplexing techniques to fill the gap between filter-polarimeters and spectro-polarimeters so that we end up with observing schemes that take advantage of the two techniques? Can they help us simplify or improve the capabilities of inversion codes?

Publications:
[**1**] Borrero, J. M.; Tomczyk, S.; Norton, A.; Darnell, T.; Schou, J.; Scherrer, P.; Bush, R.; Liu, Y. *Magnetic Field Vector Retrieval With the Helioseismic and Magnetic Imager*, 2007, Sol. Phys., 240, 177
[**2**] Borrero, J. M.; Tomczyk, S.; Kubo, M.; Socas-Navarro, H.; Schou, J.; Couvidat, S.; Bogart, R. *VFISV: Very Fast Inversion of the Stokes Vector for the Helioseismic and Magnetic Imager*, 2010, Sol. Phys., 35
[**3**] Asensio Ramos, A.; Martínez Gonzlez, M. J.; Rubiño-Martín, J. A., *Bayesian inversion of Stokes profiles*, 2007, A&A, 476, 959
[**4**] Asensio Ramos, A.; Trujillo Bueno, J.; Landi Degl'Innocenti, E., *Advanced Forward Modeling and Inversion of Stokes Profiles Resulting from the Joint Action of the Hanle and Zeeman Effects*, 2008, ApJ, 683, 542
[**5**] Socas-Navarro, H.; Trujillo Bueno, J.; Ruiz Cobo, B., *Non-LTE Inversion of Stokes Profiles Induced by the Zeeman Effect*, 2000, ApJ, 530, 977

2 List of expected output

Publications in refereed journals: **(1)** A review paper presenting the analysis of the reliability of inversion codes when presented with synthetic observations, comparing the convergence of each code and how each model is able to extract trustworthy physical information from the observations. All team members would be involved. As a topic of special interest for the Solar Physics community we will attempt to publish this review article in the *Living Reviews in Solar Physics* journal. **(2)** A paper on how the information encoded on the observed Stokes profiles changes with the number of sampled points and how inversion codes are able to extract such information. This can introduce strong constraints on how to design future instruments for the

observation of the solar atmosphere. **(3)** A paper analyzing the possibility that observed data can help us choose among a variety of models so that they correctly reproduce the observations without increasing too much the complexity.

Team members will also report some of the results at scientific meetings. In all meeting and publications the support of the ISSI will be acknowledged. A final report of the achievements of the team will be submitted.

3 What added value does ISSI provide for the implementation of the team activity ?

(1) The possibility to put together, in the same place, many specialists on the development and application of inversion codes for spectro-polarimetric data to confront their codes and generate a kind of "manual of style" for all users. (2) The facilities and reputation of the ISSI. (3) The financial support for the team.

4 List of confirmed participants (alphabetical order)

1. A. Asensio Ramos ; 2. J.M. Borrero; 3. T. Carroll; 4. A. Lagg; 5. B.W. Lites; 6. A. López Ariste; 7. M. Rempel; 8. R. Rezai; 9. H. Socas-Navarro; 10. N. Vitas; 11. B. Viticchié

5 Schedule of the project

The team considers that, during the duration of the project, two one-week sessions at ISSI should be required in order to correctly delineate the main objectives. The first one should take place not later than 3 months after the start of the team activity (end of summer-beginning of autumn 2010). This first meeting will be focused towards defining the strategy to be followed in terms of what snapshots are going to be used in the generation of the synthetic profiles, how to do the inversions and how they will be compared. The second one should ideally take place one year after the start of the activity. This meeting will be devoted to review the inter-comparison of the results. Additionally, the drafts of the output papers planed by the team will be initiated with the results of the meetings.

First session:

- Monday: code-developers will be asked to give short presentations about the main characteristics of the code, putting special emphasis on the model used, the output and the convergence properties. We think that 30-40 minutes talks should suffice to give enough details to the rest of members. The day will end with a 30-minute talk by our MHD expert who will introduce the available simulations and their main properties.

- Tuesday and Wednesday: it should be devoted to discuss which MHD simulation snapshots should be chosen for the inter-comparison and the exact strategy followed for the synthesis of Stokes profiles, including the spectral sampling, which instruments will be simulated, the noise level and the spatial resolution. The full team should also decide the complexity of the models associated to each inversion code. On Wednesday afternoon the team will designate the members who: **(a)** will be responsible for producing the simulated Stokes profiles out of the MHD simulations (including instrumental effects); **(b)** who will be responsible for analyzing the Stokes profiles with each inversion code and retrieving the physical parameters; **(c)** will be responsible for comparing the original physical parameters from the simulations with the values inferred from the inversion codes. The team members who will run the inversion codes will *not* have access to the MHD simulations whose

physical parameters were used. This will ensure that the comparison process is double-blind.

- Thursday: in the morning, the implementation of the inversion strategy to be followed for each inversion code will be discussed in separate splinter sessions according to the code's characteristics: Milne-Eddington type inversions or inversion codes that allow for gradients in the physical quantities. Estimations on the time and computer resources needed to carry out the inversions will be provided. Team members will address how to consider the instrumental effects (i.e.: spatial and spectral resolution) and implement them in their respective codes. In the afternoon the full team will decide on appropriate metrics to compare the original physical parameters with the values retrieved from the inversions (standard deviations, mean value of the differences, probability distribution functions). A decision about inversions with and without filling factors will be reached too.

- Friday: a working plan with action tasks will be configured after the previous work. It should include the steps to be taken by each member so that the final product (in the form of model atmospheres and comparisons between them and the physical properties available from the MHD snapshots) can be easily compared. This day we will also set up the web-page of the team with the results of the first meeting and the future actions to be taken. In addition, we will decide on an adequate date for the second meeting.

Second session:

- Monday and Tuesday: presentations of the results following the guidelines presented in the first session to all members of the team and subsequent discussion. The aim is to understand the behavior of each code and end up with the fundamental points to be clarified in the publications.

- Wednesday: all team members discuss about the influence of complexity on the inferred parameters. It is crucial to understand whether too simple or too complex models are able or not to extract the correct physical information from the observations.

- Thursday and Friday: team members will be assigned tasks for the preparation of the final manuscript of the planned publications. The team leaders will summarize the output of the two sessions and will point out the main conclusions. The web-page will be updated with the main outcomes from our investigations and links to the web-pages with more details will be added.

6 Facilities

(1) Meeting room at ISSI for plenary sessions that will constitute the majority of the planned sessions. (2) One additional room to arrange a possible splinter session in case the team considers it of interest. (3) Wireless network with Internet access (preferably with access to ADS and major astrophysical journals)

7 Financial support requested of ISSI

Living expenses of the team members through a per diem during the two planned meetings at ISSI in Bern. Travel costs of the team leader with the option of the team leader conceding travel costs to a team member if necessary. The rest of team members will be able to obtain funding for their travel costs to Bern.

8 Annexes: participant's short CV/Resumé

8.1 Dr. Andrés Asensio Ramos

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Areas of expertise
Development of inversion codes to infer the physical and magnetic properties in astrophysical plasmas. Zeeman and Hanle effect in atomic and molecular lines, including hyperfine structure. Creator of the HAZEL inversion code. Development of new tools for radiative transfer: Gauss-Siedel in spherical geometry, Bayesian inversion. Application of remote sensing to improve the performance of Fabry-Perot interferometers.

Education
2004: Ph.D. in Astrophysics, Instituto de Astrofísica de Canarias (Spain)
1999: Diploma Physics and Astrophysics with High Distinction, University of La Laguna (Spain)

Positions
2007-present: Post Doctoral Fellowship, Instituto de Astrofísica de Canarias (Spain)
2005-2007: PNAYA Post Doctoral Fellowship, Instituto de Astrofísica de Canarias (Spain)
2004-2005: ESMN Post Doctoral Fellowship, Osservatorio Astrofisico di Arcetri (Italy)
1999-2003: Ph.D. Fellowship, Instituto de Astrofísica de Canarias (Spain)

Honors, Awards and special appointments
2007: Career award of the Joint Organization for Solar Observations
2006: Award of the "Sociedad Española de Astronomía" (Spanish Astronomical Society, SEA) to the Best Spanish Thesis in Astrophysics (2004)
1999: Award of the University of La Laguna to the Best Degree in Astrophysics

Publication record
More than 40 publications in peer-reviewed journals (single or lead author in 20). 3 invited reviews in international conferences. 20 oral contributions in international conferences.

Selected Publications
Asensio Ramos, A.; Trujillo Bueno, J.; Carlsson, M. & Cernicharo, J. (2003). *The Astrophysical Journal*, 588, 61
Trujillo Bueno, J.; Shchukina, N. & Asensio Ramos, A. (2004). *Nature*, 430, 326
Asensio Ramos, A.; Martínez González, M.J. & Rubiño-Martín, J.A. (2007). *Astronomy and Astrophysics*, 476, 959
Asensio Ramos, A.; Trujillo Bueno, J. & Landi Dedl'Innocenti, E. (2008). *The Astrophysical Journal*, 684, 542

8.2 Dr. Andreas Lagg

Max Planck Institut für Sonnensystemforschung. Max Planck Str. 2. 37191. Katlenburg, Germany
Phone: +49 5556 979 465; Fax: +49 5556 979 240; e-mail: lagg@mps.mpg.de

Areas of expertise
Infrared polarimetry of the solar Photosphere and Chromosphere. Development of inversion codes for spectropolarietric data (Helix++,SPINOR). Analysis of Cassini MIMI/LEMMS and Galieo EPD data. Development of high resolution time-of-flight system for the Rosetta orbiter.
Education
1998: Ph.D. in Astrophysics, Max Planck Institut für Sonnensystemforschung (Germany)
1994: Diploma in Physics, University of Innsbruck, Austria
Positions
1999-present: Tenure position at the Max Planck Institut für Sonnensystemforschung (Germany)
1998-1999: Post Doctoral Fellowship at the Space Department of the Johns Hopkins University Applied Physics Laboratory, Maryland, USA
Honors, Awards and special appointments
2008: Visiting Professor at the National Astronomical Observatory of Japan (NAOJ), Tokyo, Japan
2009: Main lecturer at USO Inversion School in Abisko, Sweden
1999: Honorary member of the Space Physics Department of the Johns Hopkins University Applied Physics Laboratory
Publication record
60 publications in peer-reviewed journals (including co-author). 2 invited reviews in international conferences. 5 articles in books, PhD thesis and editorships. 90 contributed papers in conferences proceedings and other non-refereed publications.
Selected Publications
Solanki, S.K.; Lagg, A.; Woch, J.; Krupp, N. & Collados, M. (2003). *Nature*, 425, 692
Lagg, A.; Woch, J.; Krupp, N. & Solanki, S.K. (2004). *Astronomy and Astrophysics*, 414, 1109
Lagg, A.; Woch, J.; Solanki, S.K. & Krupp, N. (2007). *Astronomy and Astrophysics*, 462, 1147

8.3 Dr. Arturo López Ariste

THEMIS, S.L. C/ Saturno 3. La Laguna, Spain
Phone: + 34 922 314 456 ; Fax: +34 922 314 294; e-mail: arturo@themis.iac.es

Areas of expertise
Inversion codes for the inference of magnetic fields from spectral lines subject to Hanle and Zeeman effects. Developer of the DIAGONAL inversion code for spectropolarimetric data. Particularly interested in the application of pattern recognition and machine learning techniques to this task. Polarimetric instrumentation and polarimetric modulation design and data reduction. Solar magnetic fields: Prominence magnetic fields. Turbulent magnetism in the Sun.

Education
1999: Ph.D. in Astrophysics from the University of Paris 7 Denis Diderot. Degree awarded with the highest qualification (*Très honorable avec félicitations du jury*)
1995: Diploma in Theoretical Physics and Astrophysics from University of Zaragoza (Spain)

Positions
2003-present: Research (tenure) Scientist (CR1) at the Centre National de la Reserche Scientifique (CNRS, France)
2001-2003: Scientist I (tenure-track) at NCAR-High Altitude Observatory, Boulder, USA
2000-2001: Post Doctoral Fellowship with the Advanced Study Program (ASP) in NCAR, Boulder, USA
1995-1999: Fellowship from CNRS (Institut National des Sciences de l'Universe, INSU) with a THEMIS grant

Honors, Awards and special appointments
2010: Appointed to the Scientific Council of the French Programme Nationale Soleil-Terre (PNST)
2007: Bronze Medal of the CNRS in recognition of outstanding early scientific career
1999: Grant from the French Acadèmie des Sciences

Publication record
43 publications in peer-reviewed journals (including co-author). 2 invited reviews in international conferences. More than 40 contributed talks in international conferences and conference proceedings.

Selected Publications
López Ariste, Asensio Ramos, Manso Sainz, Derouich & Gelly (2009). *Astronomy and Astrophysics*, 501, 729
López Ariste, Aulanier, Schmieder & Sainz Dalda (2006). *Astronomy and Astrophysics*, 456, 725
López Ariste, Tomczyk & Casini (2002). *The Astrophysical Journal*, 580, 519
López Ariste & Casini (2002). *The Astrophysical Journal*, 575, 529

8.4 Dr. Matthias Rempel

High Altitude Observatory, 3080 Center Green Dr. CG-2. 80301 Boulder, Colorado (USA)
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Areas of expertise
Theoretical modeling of the solar Photosphere and Convection Zone. Special emphasis on the solar overshoot region and its implications for the magnetic flux storage. Solar dynamo and differential rotation. 3-dimensional magnetohydrodynamical simulations of sunspot umbra and penumbral structure. Co-developer of the MURaM radiative MHD code to properly address the numerical challenges in sunspot's simulations.

Education
2001: Ph.D. in Astrophysics from the University of Göttingen and the Max Planck Institut für Sonnensystemforschung in Katlenburg-Lindau (Germany)
1998: Diploma in Physics from the University of Göttingen (Germany)

Positions
2008-present: Scientist II (tenure) at the NCAR-High Altitude Observatory in Boulder, USA
2004-2007: Scientist I (tenure-track) position at the NCAR-High Altitude Observatory in Boulder, USA
2002-2004: Post Doctoral Fellowship with the Advanced Study Program in NCAR, Boulder, USA

Honors, Awards and special appointments
2009: Wempe award of the Astrophyiscal Institute Postdam (Germany)
2003: Otto Hahn medal of the Max Planck Society
2001: Award from University of Göttingen for outstanding Ph.D. thesis

Publication record
23 publications in peer-reviewed journals (including co-author). 40 oral contributions (including invited reviews) in international conferences.

Selected Publications
Rempel, M.; Schüssler, M.; Cameron, R. & Knölker, M. (2009). *Science*, 321, 171
Rempel, M.; Schüssler, M. & Knölker, M. (2009). *The Astrophysical Journal*, 691, 640
Schüssler, M. & Rempel, M. (2005). *Astronomy and Astrophysics*, 441, 337
Rempel, M. & Schüssler, M. (2001). *The Astrophysical Journal*, 552, 171

8.5 Dr. Juan M Borrero

Kiepenheuer-Institut für Sonnenphysik, Schöneckstr 6. 79104, Freiburg, Germany
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Areas of expertise
Radiative transfer and inversion methods and for spectropolarimetric data, with special emphasis in convergence analysis and speed performance. Developer of the VFISV (Very Fast Inversion of the Stokes Vector) code. Study of the sunspot magnetic structure through semi-empirical and analytical Magnetohydrostatic models. Development of instrumentation and its calibration for solar observations.

Education
2004: Ph.D. in Astrophysics from the University of Göttingen and the Max Planck Institut für Sonnensystemforschung in Katlenburg-Lindau (Germany)
2001: Diploma in Physics from the University of La Laguna (Spain)

Positions
2010-present: Tenure-track position at the Kiepenheuer-Institut für Sonnenphyisk (Germany)
2008-2010: Tenure-track position at the Max Planck Institut für Sonnensystemforshung (Germany)
2006-2008: Project Scientist at NCAR-High Altitude Observatory in Boulder (USA)
2004-2006: Post Doctoral Fellowship at NCAR-High Altitude Observatory in Boulder (USA)
2001-2004: Ph.D. student at the International Max Planck Planck School on Physical Processes in the Solar System and Beyond at the Universities of Braunschweig and Göttingen

Publication record
23 publications in peer-reviewed journals (including co-author). 5 invited reviews in international conferences. 19 oral contributions in international conferences and lectures and seminars in research institutions.

Selected Publications
Borrero, J.M.; Tomczyk, S.; Kubo, M.; Socas-Navarro, H.; Schou, J.; Couvidat, S. & Bogart, R. (2010). *Solar Physics*, 35
Borrero, J.M & Solanki, S.K. (2010). *The Astrophysical Journal*, 709, 349
Borrero, J.M.; Lites, B.W. & Solanki, S.K. (2008). *Astronomy and Astrophysics*, 481, L13
Borrero, J.M.; Bellot Rubio, L.R. & Müller, D.A.N. (2007). *The Astrophysical Journal*, 666, L133
Borrero, J.M. (2007). *Astronomy and Astrophysics*, 471, 967

8.6 Dr. Bartolomeo Viticchié

European Space Research & Technology Center (ESTEC). Keplerlaan 1. 2200 Noordwijk. Netherlands
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Areas of expertise
Analysis of spectropolarimetric data (Hinode/SP, IBIS) with emphasis on Quiet-Sun magnetism. Radiative transfer: experienced user and author of improvements in the synthesis module the MISMA (MIcro-Structure Model Atmosphere) inversion code (inclusion of hyperfine structure effects).
Education
2008: Ph.D. in Astronomy from the Università degli Studi di Roma Tor Vergata
2005: Diploma in Physics from Università degli Studi di Roma Tor Vergata
Positions
2009-present: Research Fellow at the European Space Agency
2008-2009: Post Doctoral Fellowship at the Università degli Studi di Roma Tor Vergata
2005-2008: Ph.D. Grant at the Università degli Studi di Roma Tor Vergata
Publication record
8 papers in peer-reviewed journals. 10 non-refereed papers in conference proceedings.
Selected Publications
Viticchiè, B.; Sánchez Almeida, J.; Del Moro, D. & Berrilli, F. (2010). *The Astrophysical Journal*, submitted
Viticchiè, B.; Del Moro, D.; Berrilli, F.; Bellot Rubio, L.R. & Tritschler, A. (2009). *The Astrophysical Journal*, 700, L145
Sánchez Almeida, J.; Viticchiè, B.; Landi Degl'Innocenti, E. & Berrilli, F. (2008). *The Astrophysical Journal*, 675, 906
Viticchiè, B.; Del Moro, D. & Berrilli, F. (2006). *The Astrophysical Journal*, 652, 1734

8.7 Nikola Vitas

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Areas of expertise
Spectral line formation in LTE (Local-Thermodynamic-Equilibrium) and NLTE (Non-Local-Thermodynamic-Equilibrium). Study of the solar abundance of Indium through the study of its hyperfine structure. Variations in Mn I spectral lines within the Solar cycle. Study of synthetic spectrum arising from 3-dimensional radiative MHD simulations from the MURaM code.
Education
2006-present: Ph.D. student at the Sterrenkundig Instituut (University of Utretch, Netherlands)
2005: M.Sc. in Astrophysics from the University of Belgrade (Serbia)
1999: Diploma in Physics and Astrophysics at the University of Belgrade (Serbia)
Positions
1999-2005: Teaching assistant at the University of Belgrade (Serbia)
Publication record
7 papers in peer-reviewed journals (including 2 in preparation). 3 papers in non-refereed conference proceedings.
Selected Publications
Vitas, N.; Viticchié, B.; Rutten, R.J. & Vögler, A. (2009). *Astronomy and Astrophysics*, 499, 301
Vitas, N.; Vince, I.; Lugaro, M.; Andriyenko, O.; Gosic, M. & Rutten, R.J. (2008). *Monthly Notices of the Rocal Astronomical Society*, 384, 370.

8.8 Dr. Reza Rezai

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Areas of expertise
Spectropolarimetry: observations of polarized signature o spectral lines using state-of-the-art telescopes and instrumentation (TIP, POLIS, Hinode/SP). Spectropolarimetry data reduction and calibration. Inversion of polarimetric signatures using the SIR inversion code. Study of synthetic spectrum arising from 3-dimensional radiative MHD simulations from the COBOLD code.

Education
2008: Ph.D. in Physics at the Kiepenheuer-Institut für Sonnenphysik and the Albert-Ludwig Universität Freiburg (Germany)
2000: M.Sc. in Physics, Institute for Advanced Studies in Basic Sciences, Zanjan (Iran)
1998: B.Sc. in Physics, Sharif University of Technology (Iran)

Positions
2008-present: Post Doctoral Fellowship at the Kiepenheuer-Institut für Sonnenphysik in Freiburg (Germany)
2005: Research assistant at the Kiepenheuer-Institut für Sonnenphysik in Freiburg (Germany)
2004-2005: Visiting researcher at the Max Planck Institut für Radioastronomie in Bonn (Germany)
2003-2004: Teaching assistant at the Damgha University of Basic Sciences (Iran)

Publication record
12 papers in peer-reviewed scientific journals. 10 papers in non-refereed conference proceedings. 10 contributed talks in international conferences.

Selected Publications
Rezaei, R.; Schlichenmaier, R.; Beck, C.: Bruls, J.H.M.J. & Schmidt, W. (2007). *Astronomy and Astrophysics*, 466, 1131
Steiner, O.; Rezaei, R.; Schaffenberger, W. & Wedemeyer-Böhm, S. (2008). *Astronomy and Astrophysics*, 680, L85
Rezaei, R.; Schlichenmaier, R.; Beck, C. & Bellot Rubio, L.R. (2006). *Astronomy and Astrophysics*, 454, 975

8.9 Dr. Bruce W. Lites

High Altitude Observatory, 3080 Center Green Dr. CG-2. 80301 Boulder, Colorado (USA)
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Areas of expertise
Physical interpretation of solar data: spectroscopic observations, both visible light spectra obtained at ground-based observatories and ultraviolet spectra obtained by spacecraft (early career). In recent decades most effort has been devoted to interpretation of polarized spectra. Heavily involved in development of instrumentation (e.g. the Advanced Stokes Polarimeter, Hinode Spectro-Polarimeter) that has enabled significant advancement of our knowledge of solar magnetic fields. Co-developer of the HAO/NCAR Stokes Inversion code, considered the benchmark against which later codes are measured.

Education
1972: Ph.D. in Astrophysics from the University of Colorado in Boulder (USA)
1969: M.Sc. in Physics from the University of Colorado in Boulder (USA)
1967: B.Sc. in Physics from the University of New Mexico in Alburquerque (USA)

Positions
1989-present: Senior Scientist (tenured) at the NCAR-High Altitude Observatory in Boulder (USA)
1984-1989: Scientist III (tenure) at the NCAR-High Altitude Observatory in Boulder (USA)
1980-1984: Associate Astronomer at the National Solar Observatory in New Mexico (USA)
1980: Visiting Scientist at the NCAR-High Altitude Observatory in Boulder (USA)
1979-1980: Project Scientist at the NCAR-High Altitude Observatory in Boulder (USA)
1974-1979: Research Associate at the University of Colorado (Laboratory for Atmospheric and Space Physics) in Boulder (USA)
1972-1974: Post-Doctoral Maître-Assistant at the Observatoire de Genève (University of Genève, Switzerland)

Honors, Awards and special appointments
2009-present: Co-Investigator of the Interface Region Imaging Spectrograph (NASA SMEX mission)
2005-present: Scientific Advisory Committee for the Kiepenheuer-Institut für Sonnenphysik in Freiburg (Germany)
2003: Chair of the THEMIS Visiting Committee
2002-present: Associate Investigator of the Helioseismic and Magnetic Imager instrument on the NASA's Solar Dynamics Observatory
2001-2007: Principal Investigator on the NASA's contribution Sunrise Antarctic balloon
1999-present: Deputy PI for the Solar-B/Hinode Optical Telescope Focal Plane Package

Publication record
155 publications in peer-reviewed scientific journals. 129 publications in non-refereed or conference proceedings. Dozens of oral contributions and many invited reviews in international conferences.

Selected Publications
Lites, B.W.; Kubo, M.; Socas-Navarro, H. et al. (2008). *The Astrophysical Journal*, 672, 1237
Lites, B.W.; G.B. Scharmer; T.E. Berger & Title, A.M. (2004). *Solar Physics*, 221, 65
Lites, B.W.; Socas-Navarro, H.; Skumanich, A. & Shimizu, T. (2002). *The Astrophysical Journal*, 575, 1131
Lites, B.W. (2002). *The Astrophysical Journal*, 573, 431

8.10 Dr. Héctor Socas Navarro

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Phone: + 34 922 605 5748; Fax: +34 922 605 200; e-mail: hsocas@iac.es

Areas of expertise
Solar spectropolarimetry. NLTE line formation. Chemical abundances. Inversion techniques. Developer of several inversion codes: MELANIE (Milne-Eddington type), LILIA (LTE code) and NICOLE (NLTE code). Structure and dynamics of active regions in the solar Chromosphere.
Education
1999: Ph.D. in Astrophysics at the Instituto de Astrofísica de Canarias and University of La Laguna (Spain)
1995: Diploma in Physics and Astrophysics at the University of La Laguna (Spain)
Positions
2007-current: Staff scientist (tenured) at the Instituto de Astrofísica de Canarias (Spain)
2003-2007: Scientist II (tenure-track) at the NCAR-High Altitude Observatory in Boulder (USA)
2001-2003: Project Scientist at the NCAR-High Altitude Observatory in Boulder (USA)
1999-2001: Associate scientist at the NCAR-High Altitude Observatory in Boulder (USA)
Honors, Awards and special appointments
2007: Walter O. Robert Scientific and Technical Achievement Award of the High Altitude Observatory in Boulder (USA), shared with the HAO/Hinode Team
2001: Award of the Canary Island government to the best young researcher
2000: Award of the "Sociedad Española de Astronomía" (Spanish Astronomical Society, SEA) to the Best Spanish Thesis in Astrophysics (1998)
Publication record
55 papers in peer-reviewed scientific journals. 38 papers in conference proceedings and non-refereed publications. 11 invited reviews in international conferences. Many more oral contributions in international conferences.
Selected Publications
Socas-Navarro, H. (2005). *The Astrophysical Journal*, 621, 545.
Socas-Navarro, H.; López Ariste, A. & Lites, B.W. (2001). *The Astrophysical Journal*, 553, 949
Socas-Navarro, H.; Trujillo Bueno, J. & Ruiz Cobo, B. (2000). *Science*, 288, 1398
Socas-Navarro, H.; Trujillo Bueno, J. & Ruiz Cobo, B. (2000). *The Astrophysical Journal*, 530, 977

8.11 Dr. Thorsten A. Carroll

Astrophysikaliches Institut Potsdam. An der Sternwarte 16. D-14482. Potsdam, Germany
Phone: +49 331 7499 207; Fax: +49 331 7499 200; e-mail: tcarroll@aip.de

Areas of expertise Solar and Stellar Magnetic fields, polarized radiative transfer, solar inversion methods : Stokes profile Inversion using Artificial Neural Networks and Zeeman-Tomography, stellar inversion methods : Doppler- and Zeeman-Doppler Imaging (Development of the iMap code). Stokes profile reconstruction and denoising using Multiresolution and Principal Component Analysis (MR/PCA).

Education

2004: Ph.D in Astrophysics from tge University of Potsdam (Germany)
2000: Diploma in Phyiscs from the Free University of Berlin (Germany)

Positions

2004-present: Post Doctoral fellow at the Astrophysical Institute Potsdam (Germany)
2002-2004: Scientist at the University of Potsdam (Germany)
2000-2002 : Ph.D. student at the Astrophysical Institute Potsdam (Germany)
1996-2000 : Teaching Assistant at Free University Berlin (Germany)

Honors, Awards and special appointments

2008-present: Lecturer at the University of Potsdam (Germany)
2002 & 2003: Visiting Researcher at the department of mathematical physics at the Technical University Berlin (Germany)

Publication record

14 publication in peer-reviewed journals. 1 invited talk and 10 contributed talks in international conferences.

Selected Publications

Carroll, T.A., Kopf, M. (2008),*Astronomy and Astrophysics*, 481, 37
Carroll, T.A., Kopf, M. (2007). *Astronomy and Astrophysics*, 468, 323
Carroll, T.A., Staude J.(2001). *Astronomy and Astrophysics*, 378, 316