Leibniz-Gemeinschaft

# Final report

## Centre for Advanced Solar Spectro-polarimetric Data Analysis
## *CASSDA*

Leibniz-Institute: Kiepenheuer-Institut für Sonnenphysik
Reference number: SAW-2012-KIS-5 149
Project period: July 2012 – July 2017
Contact partner: Dr. Nazaret Bello-González

## Centre for Advanced Solar Spectro-polarimetric Data Analysis (CASSDA)

**Nazaret Bello González**
*Kiepenheuer-Institut für Sonnenphysik*

### 1. What is CASSDA?

The Kiepenheuer-Institut für Sonnenphysik (KIS) is the leading institute operating the German solar telescopes at the Observatorio del Teide (Tenerife) for the observation of the photosphere and chromosphere of the Sun with high spatial resolution: (1) With an aperture of 1.5m, GREGOR is the largest ground-based solar telescope in Europe, making it possible to resolve structures with sizes down to 60 km on the solar surface, and (2) the Vacuum Tower Telescope (VTT) is a reference for solar observations in the international solar physics community since 30 years now. In addition, KIS is developing the Visible Tunable Filter (VTF) instrument to become operative at the Daniel K. Inouye Solar Telescope (DKIST, NSO), under construction at the Haleakala Observatory (Hawaii). For these reasons, the KIS is committed to train students and young scientists in the observing procedure and data handling, to further exploit the observing and data processing facilities.

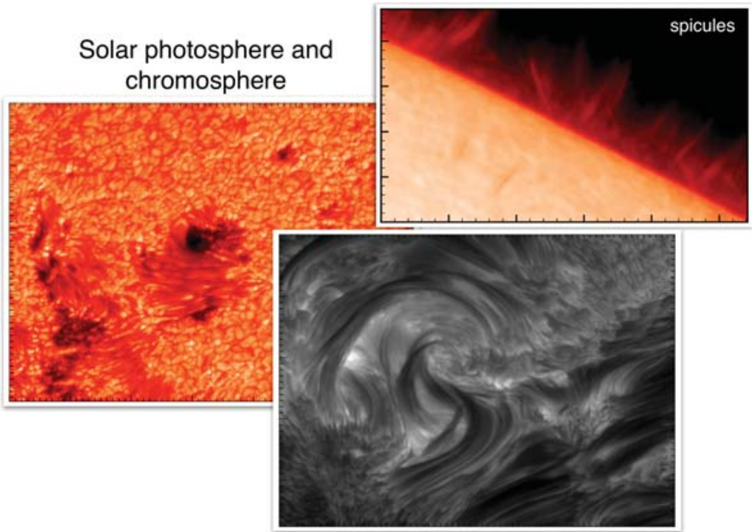


Figure 1: Snapshots of the solar photosphere and chromosphere as observed with the GFPI at the German VTT in H$\alpha$ (*B. Sánchez-Andrade*, IAG).

The Centre for Advanced Solar Spectro-polarimetric Data Analysis (CASSDA) is a startup project funded by the Leibniz Association. CASSDA was conceived to provide the solar physics community with the most accurate spectroscopic and spectro-polarimetric data sets observed at the German telescopes and to train young researchers in the use and scientific exploitation of ground-based observations.

### 2. The CASSDA Team

CASSDA has been constituted by a working team within the Experimental Solar Physics Department of the Kiepenheuer-Institut für Sonnenphysik. The CASSDA Team has been composed by young scientists with expertise in instrumentation and/or data handling:


Figure 2: The CASSDA core team by March 2015. *Photo, from left to right:* Johannes Löhner-Böttcher, Nazaret Bello González, Christian Bethge & Catherine Fischer.

- Torsten Waldmann (Post-Doc Researcher, Nov 2011 – May 2012):
  Expert in image-reconstruction techniques and partial developer of the CASSDA GUI for Fabry-Pérot (FPI)-based instruments.

- Johannes Löhner-Böttcher (PhD student, Aug 2012 – Feb 2016):
  Johannes completed his PhD degree within the framework of the CASSDA project in *Wave phenomena in sunspots*, and developed the CASSDA GUI data-pipeline for spectroscopic FPI-based instrumentation.
  Supervisor: Nazaret Bello González.
  Referee: Wolfgang Schmidt. Degree: *Magna cum laude*

- Catherine Fischer (Post-Doc Researcher, Jan 2013 – June 2015):
  Researcher focused in the magnetism of the quiet Sun, and developer of the polarimetric part of the CASSDA GUI for FPI-based instrumentation.
  Catherine is by today still engaged 10% of her time at KIS in the CASSDA project.

- Christian Bethge (Post-Doc Researcher, April 2013 – March 2016):
  Instrument scientist, developer of the CASSDA GRIS data-pipeline for slit-based instrumentation and developer of the GRIS data archive.

- Nazaret Bello González (Project Scientist and Coordinator, July 2012 – July 2017)

CASSDA Associated: Morten Franz (Post-Doc Resarcher, KIS & SOLARNET funded):
Researcher focused in the physics of sunspots and current manager of the GRIS data archive.

## 3. Data-pipelines – The hardcore of the CASSDA Project

In order to efficiently exploit the solar observing facilities and to make use of the outcome data as favourable as possible, it is essential to feature reliable and powerful automated data-pipelines. At CASSDA, a significant effort is being made to provide the scientific community with ready-for-science data and user-friendly data calibration packages to guarantee the maximum of scientific outcome in the field of solar physics.

## – The CASSDA GUI for imaging spectro-polarimetric data

CASSDA has developed a code for processing imaging spectro-polarimetric data. The software, initially planned for the analysis of TESOS/VTT* data, has been coded to eventually be integrated in the data pipeline for the VTF/DKIST** instrument, currently in the construction phase. The code is at present capable of providing *level 2* data (see Fig. 5), i.e., ready for

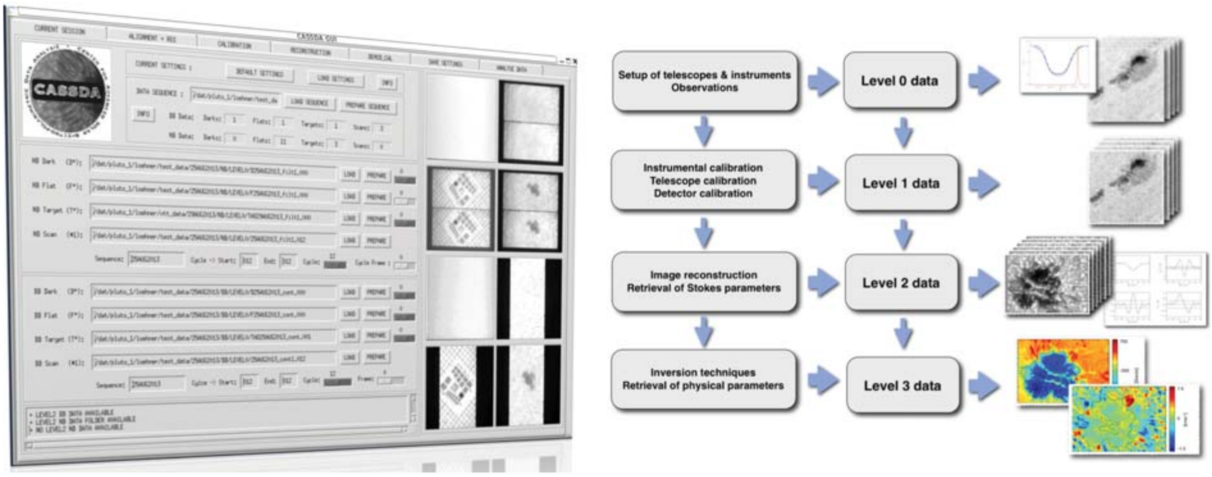


Figure 3: *Left:* Main window of the CASSDA GUI developed for the processing of imaging spectro-polarimetric data. *Right:* Scheme of the different data levels after the different processing and analysis techniques are applied.

the retrieval of the physical parameters of the observed solar atmosphere. Efforts to further implement inversion techniques are currently undertaken.

The code is based on a Graphical User Interface (GUI) through which advanced processing techniques to handle 2D spectro-polarimetric data as well as image reconstruction techniques can be applied. The code is at present in the test phase and it has been presented to the international community. The major project of implementing this software into the VTF/DKIST data pipeline is being carried out in collaboration with the DKIST Data Center in Boulder (USA), currently under development.

*Triple Etalon SOlar Spectrometer (TESOS, http://www.leibniz-kis.de/de/observatorien/vtt/vtt-instrumentation/

**Visible Tunable Filter (VTF, http://www.leibniz-kis.de/de/projekte/visible-tunable-filter

## – The CASSDA GUI for slit spectro-polarimetric data

We developed a graphical user interface (GUI) initially thought for the GRIS/GREGOR* instrument data. The GUI allows the visualisation, correction, and analysis of GRIS data and the preparation of context data. The graphical user interface for GRIS was developed with the goal to provide an intuitive tool to enable observers (and the community, as GRIS data became eventually available) to quickly assess the scientific content of GRIS data and to easily perform simple corrections and analyses of the data. A second, updated version of this tool allows for visualisation and exploration of the slit-based spectro-polarimeter (SP) on board the Hinode space-based solar observatory. Figure 4 shows screenshots of the GUI for GRIS/GREGOR infrared data (*left*) and Hinode/SP visible data *(right)*. The main core of the GRIS data calibration is based in the code by one of our main collaborators, M. Collados (IAC).

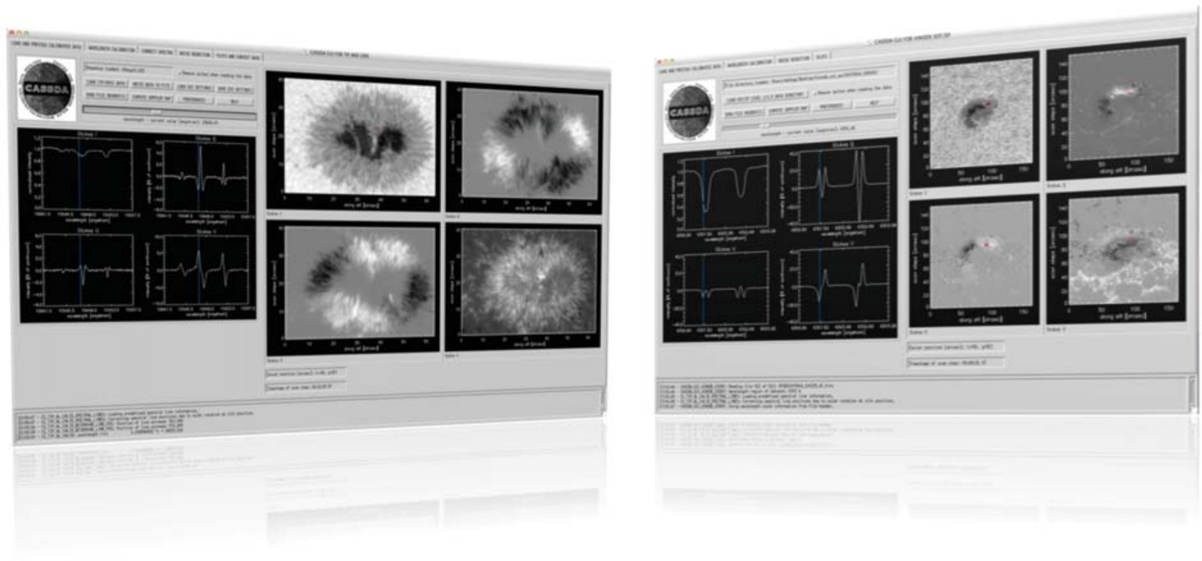

Figure 4: *Left:* Screenshot of the CASSDA GUI for TIP/VTT and GRIS/GREGOR infrared data. *Right*: CASSDA GUI for visible Hinode/SP data.

Features of the GUI include: removal of spikes, gradients, and fringes in the spectra, noise reduction, wavelength calibration, computation of Doppler maps, export of (corrected) data and regions of interest in all dimensions, import/export of GUI settings, flexible plotting, additional features for time series, HMI/MDI context data, cross-correlation of the GRIS and Hinode/SP scans with HMI/MDI data to find the location and orientation of the scans on the solar disc. Due to the similar nature of data from GRIS and the preceding TIP/VTT instrument, the GUI is backward compatible and can also be used with TIP/VTT (archived) data.

*GRegor Infrared Spectrograph (GRIS, http://onlinelibrary.wiley.com/doi/10.1002/asna.201211738/pdf)

## 4. The GRIS Data Archive – First steps towards GREGOR data dissemination

The amounts of data coming from the GREGOR telescope required a solid concept for data archiving and dissemination. The goal is to unify the formatting, processing, and access of all data coming from solar ground-based observational facilities. Efforts were combined between CASSDA and the SOLARNET project. In order to keep track of all observations and to minimise the obstacles for a scientific exploitation of the data, an interim concept has been developed. We developed a data archiving concept for the GRIS instrument at the GREGOR telescope for the purpose of facilitating the access to the data for all partner institutes. After a given period of embargo, the data were opened to the scientific community. Automatically, it created overview webpages providing the most important information for each observational dataset.

The GRIS archive, originally developed at CASSDA is currently maintained by the Science Data Centre, the follow-up project of CASSDA at KIS.

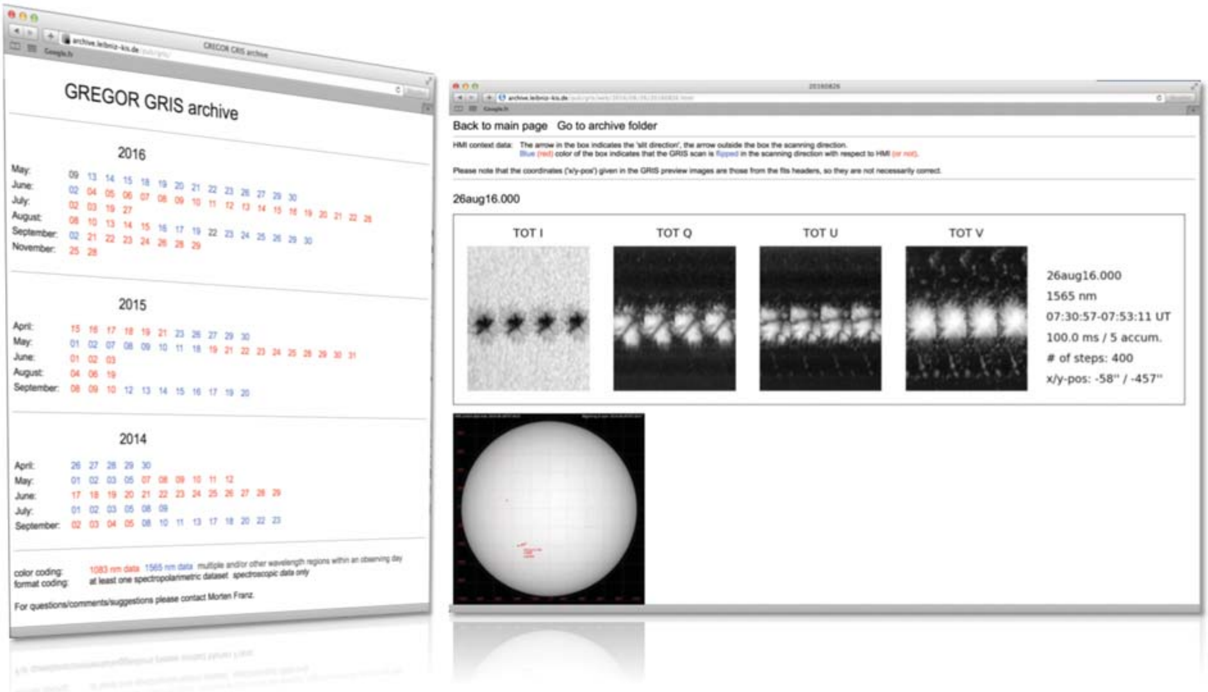


Figure 5: *Left:* Screenshot of the GRIS data archive main webpage. It displays the dates of all available GRIS observations since 2014 for different wavelength bands (*red* for 1.8$\mu$, *blue* for 1.5$\mu$). *Right:* Example of the quick-look data provided by the archive for a given observing run selected in time: maps of Stokes parameters, basic info on the observing run and an HMI/SDO image of the solar disc displaying the position of the field-of-view of the given observations.

## 5. Scientific research – The driver behind the CASSDA Project

CASSDA has been constituted by scientists with research interests based on the observation of the Sun.The scientific motivation behind an observing run and a precise analysis of the data is the key driver to optimise the instrument and data-pipeline output.

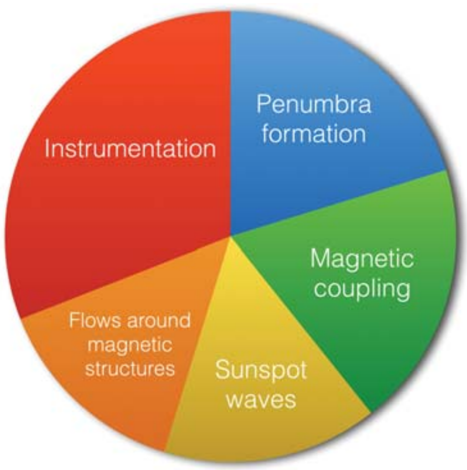


Figure 6: Science topics at CASSDA based on the number of publications (Sect. 8).

At CASSDA the duality *data handling + scientific research* has been the common approach and various scientific topics have been investigated. They are schematically outlined by the chart in Fig. 6 (see also Sect. 8 for the full list of publications in which CASSDA members have been involved). In the following, some of the main results are summarised:

**Penumbra formation.** Fully-fledged penumbrae are a well characterised phenomenon from an observational point of view. Also, MHD simulations reproduce the observed characteristics and provide us with insights on the physical mechanisms possibly running behind the observed processes. Yet, how this penumbral magneto-convection sets in is still an open question. Due to the fact that penumbra formation is a relatively fast process (of the order of hours), it has eluded its observation with sufficient spatial resolution by both, space- and ground-based solar observatories. Only recently, some authors have witnessed the onset of both orphan and sunspot penumbrae in detail. We are one of those. In July 2009, we observed at the German VTT Telescope (Tenerife) the early stages of the NOAA 11024 leading sunspot while developing its penumbra. The spectro-polarimetric dataset lead us to new ob- servational findings. We have put our observational results into context with other authors' results to draw the overall picture of sunspot formation. Most important, the comparison on the properties of different types of penumbrae lead us to the conclusion that the formation of penumbrae is not just one mechanism. The sole ingredient necessary for penumbral magneto-convection is a stably inclined magnetic field. Observations show that inclined fields can be caused by flux emergence, to form orphan penumbrae, or by field lines dragged down from upper photospheric layers, to form sunspot penumbra. This conclusion, together with the recent finding by Jurcak et al. on a canonical value of the vertical component of the magnetic field blocking the action of penumbral magneto-convection in umbral areas, has lead us to shed new light onto our understanding on the coupling of solar plasmas and magnetic fields in penumbral atmospheres.

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**Waves in sunspots.** The dynamic atmosphere of the Sun exhibits a wealth of magnetohydrodynamic (MHD) waves. In the presence of strong magnetic fields, most spectacular and powerful waves evolve in the sunspot atmosphere. The most prominent and fascinating phenomena are the 'umbral flashes' and 'running penumbral waves' as seen in the sunspot chromosphere. Their nature and relation have been under intense discussion in the last decades. Two-dimensional spectroscopic observations were performed with the interferometric spectrometers IBIS/DST and TESOS/VTT. Multiple spectral lines were scanned co-temporally to sample the dynamics at the photospheric and chromospheric layers. The obtained wave characteristics of umbral flashes and running penumbral waves strongly support the scenario of slow-mode magnetoacoustic wave propagation along the magnetic field lines. Signatures of umbral flashes and running penumbral waves are found already in the middle to upper photosphere. The shock wave behavior of the umbral flashes is confirmed by the evolving saw-tooth pattern in velocity and the strong downward motion of the plasma right after the passage of the shock front. The power spectra and peak periods of sunspot waves vary significantly with atmospheric altitude and position within the sunspot. The innovative reconstruction of the sunspot magnetic field inclination based on the peak period distribution lead us to consistent results with the inferred photospheric and extrapolated coronal magnetic field.

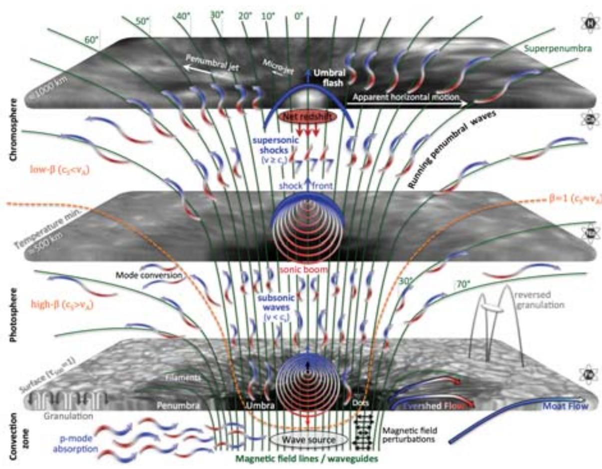


Figure 7: Scheme of the wave phenomena in sunspot. *From JLB's PhD Thesis.*

The obtained wave characteristics of umbral flashes and running penumbral waves strongly support their nature as slow-mode magnetoacoustic wave propagation along the magnetic field lines.

**Atmospheric coupling.** In August 2014, an active region was observed with the GFPI/GREGOR instrument. Time-series of filtergrams along the H$\alpha$ line provided spectroscopic information of three solar phenomena flashing in unison and nearly co-spatial: (1) an Ellerman bomb (EB), (2) a microflare most prominent in the higher chromospheric layers, and (3) a *surge* ejecting material into the chromosphere and corona. The GREGOR data were complemented with space-based data from the Solar Dynamical observatory (SDO). The microflare coupled various structures along the atmosphere as seen at the multivalength observations: (1) in the low photosphere, a facula embedded in the plages network and stably anchored in a highly dynamic region of flux emergence, (2) a cospatial brightening bursting in the high photosphere, with signatures of a bi-directional flow, (3) a conspicuous microflare flashing at chromospheric level with a mass downflow at chromospheric level redirected into a mass upflow during the outburst. The microflare appears to be the footpoint of a surge developing at chromospheric level, (4) a microflare bursting as the footpoint of a coronal loop which materialises during its outburst. In view of the results, we surmise that the microflare and observed counterparts along the solar atmosphere are driven by the same phenomenon, namely, the interaction of newly emerging and the pre-existing plage magnetic flux. The EB and the microflare photospheric counterpart burst as the result of the local reconnection of the field lines at (high) photospheric, while the microflare chrosmospheric and coronal counterparts are triggered by the quasi-simultaneous reconnection of the field lines, yet, at a large scale, i.e, at coronal level.

The interaction of pre-existing and newly emerging magnetic fields lead to the simultaneous observation of Ellerman bombs as photospheric counterparts of a microflare bursting at chromospheric and coronal levels and the ejection of a surge as seen in H-alpha.

**Flows around magnetic regions.** Fully-fledge sunspots are known to be surrounded by a radial outflow – the moat flow. We investigated the evolution of the horizontal flow field around 9 sunspots during sunspot decay. All fully-fledged sunspots are surrounded by a flow field whose horizontal velocity profile decreases continuously from 880 $m\dot{s}^{-1}$ close to the sunspot, down to 200 $m\dot{s}^{-1}$ at a mean distance of 11.9,Mm to the spot boundary. The obtained values are characteristic for the moat flow. Each sunspot decays influencing the evolution of its surrounding flow region in a different manner. Yet, the flow field shows a common behaviour: The maximal horizontal velocity decreases before the penumbra is fully dissolved. After the penumbra is fully dissolved, the velocity profile of the flow field changes: The horizontal velocity increases for larger distances to the spot boundary until a maximal value of around 400 $m\dot{s}^{-1}$ is reached. Then, the horizontal velocity decreases for further distances

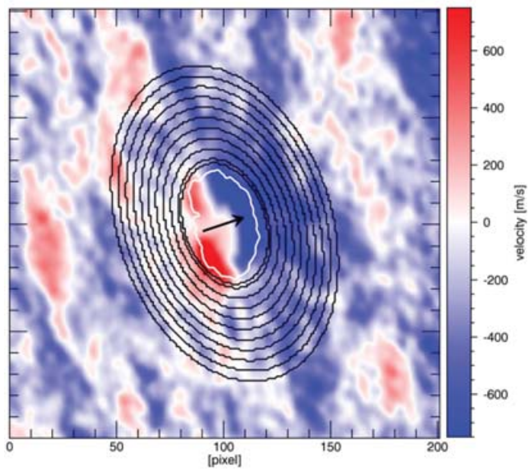


Figure 8: Dopplergram of an H-class AR. The flow is studied along ellipses around the spot. *From Strecker (2015), Master Thesis. Supervisor: NBG.*

to the spot boundary. In supergranules, the horizontal velocity increases for larger distances to their centre up to a mean maximal velocity of 355 $m\dot{s}^{-1}$. For larger distances the horizontal velocity decreases. Therefore, we find that the velocity profiles of sunspots after loosing their penumbra are similar to those of supergranular flows. The observed characteristics suggest that as long as the penumbra is present, the sunspot with its moat cell is embedded within the network. The disappearance of the penumbra and the surrounding flow cells have a significant role in the evolution of the flow field. The moat cell transforms into a cell with characteristics similar to that of a supergranule hosting the remaining (decaying) pore.

Observations of the flow around decaying sunspots indicate that sunspots and their moat cell are host by supergranules/net-work cells. Penumbra and moat flow decay together and a supergranular flow remains after the sunspot disappears.

**Instrumentation.** The CASSDA Team has been strongly involved in the upgrade, calibration and/or use of various instruments at VTT and GREGOR. This is especially the case for the GFPI/GREGOR in collaboration with the AIP Solar Group lead by C. Denker, and the implementation of the ZIMPOL instrument at GREGOR in collaboration with the IRSOL Team (Locarno), lead by M. Bianda.

## 6. Activities

In the following, the main activities carried out at CASSDA in parallel to the data calibration, data archiving and scientific research are listed and shortly described.

### – Observations

The CASSDA Team has been actively involved in a number of observing campaigns at VTT and GREGOR since 2012. Typically, twice a year for at least a week per campaign. The purposes have been diverse: participation in instrumental calibration campaigns during ‘technical time’ (typically for the GFPI/GREGOR instrument), scientific observations as PIs and observing assistance in other campaigns. Especial efforts have been carried by the CASSDA Team during the First Science GREGOR observing campaign in 2014, with long observing runs (of about a month in a row).

Figure 9: German solar telescopes. Left: GREGOR. Right: VTT.

The CASSDA Team strongly enjoys the observing life at the mountain with a especial interest in the success of the observing runs and to engage in collaborations with scientists from other solar institutions.

The CASSDA Team also participated in the SOLARNET ACCESS programme for the observation with the IBIS and ROSA instruments a the DST Telescope (Sac Peak, New Mexico, USA) by applying for observations in the service mode.

### – 1st CASSDA Workshop (Freiburg, Feb 2014)

http://www.leibniz-kis.de/en/projects/cassda/1st-cassda-workshop

Title: *The challenge of retrieving ready-for-science data from ground-based solar observations – Getting the most out of your data.*

With this title in mind, CASSDA organised an assembly of international experts in the processing, analysis and archiving of solar spectro-polarimetric data. The workshop resulted in a wealth of prolific discussions and lead to new collaborations under the spirit of the SOLARNET project. The workshop dealt during a week with the following topics:

- Image reconstruction
- Data dissemination
- Data calibration
- Upcoming instrumentation
- Data pipelines
- Stray-light contamination


Figure 10: *Participants of the CASSDA Workshop*: J. de la Cruz Rodríguez (SU), A. López Ariste (THEMIS), J. Staiger (KIS), M. Roth (KIS), Ch. Beck (NSO), A. de Wijn (HAO), R. Centeno (HAO), A. Winiewska (KIS), A. Bell (KIS), K. Reardon (NSO), D. Elmore (HAO), J. Jurcák (ASU), B. Fleck (ESA), F. Giorgi (INAF), M. van Noort (MPS), R. Rezaei (KIS), A. Lagg (MPS), J.M. Borrero (KIS), D. Müller (ESTEC), G. Schramer (SU), M. Löfdahl (SU), B. Bentley (UCL), M. Stangalini (INAF), S. Danilović (MPS), F. Kneer (IAG), S. Esteban Pozuelo (IAA), W. Schmidt (KIS), J. Blanco Rodríguez (GACE), C. Fischer (CASSDA/KIS), J. Löhner-Böttcher (CASSDA/KIS), Ch. Bethge (CASSDA/KIS), N. Bello González (CASSDA/KIS). *Not in the picture*: M. Collados (IAC), R. Schlichenmaier (KIS), B. Gelly (THEMIS), S.V. Haugan (UiO), F. Wöger (NSO), T. Berger (NSO), A. Feller (MPS), T. Waldmann, H.-P. Doerr (KIS), S. Hoch (KIS), Th. Berkefeld (KIS), D. Soltau (KIS), O. von der Lühe (KIS), S. Berdyugina (KIS), D. Gisler (KIS).

### – Data pipeline workshop – CASSDA meets SOLARNET (Stockholm, June 2014)

The CASSDA Team met the SOLARNET data-pipeline developers with the aim of discussing and unifying efforts for the optimisation and automation of efficient data pipelines. Different (instrument) teams exchanged information on their data-pipeline activities, searched for commonalities and discussed possible improvements. The discussion was focussed in pipelines for FPI-based instrumentation.

Participants: Alexandra Tritschler (NSO), Dan Kiselman (ISP), Fabrizio Giorgi (INAF), Ilaria Ermoli (INAF), Jaime de la Cruz Rodríguez (ISP), Kevin Reardon (NSO), Marco Stangalini (INAF), Mats Löfdahl (ISP), Tomas Hillberg (ISP) and the CASSDA Team.

### – IAC student short-term visit (Freiburg, July – Sept 2014)

Melania Cubas (IAC student) visited CASSDA/KIS granted with a VIP/KIS Stipendium for a 2-months stay. She worked on the analysis of GRIS/GREGOR data by making use of the CASSDA GRIS datapipeline and investigated the properties of light-bridges in sunspots as seen in the 1.5$\mu$ range. From the polarimetric signals, she found different magnetic properties in a forming light bridge to those observed in stable light bridges.

Supervisor: Nazaret Bello González
Collaborators: Juan Manuel Borrero (KIS), Morten Franz(KIS) & David Orozco (IAC)

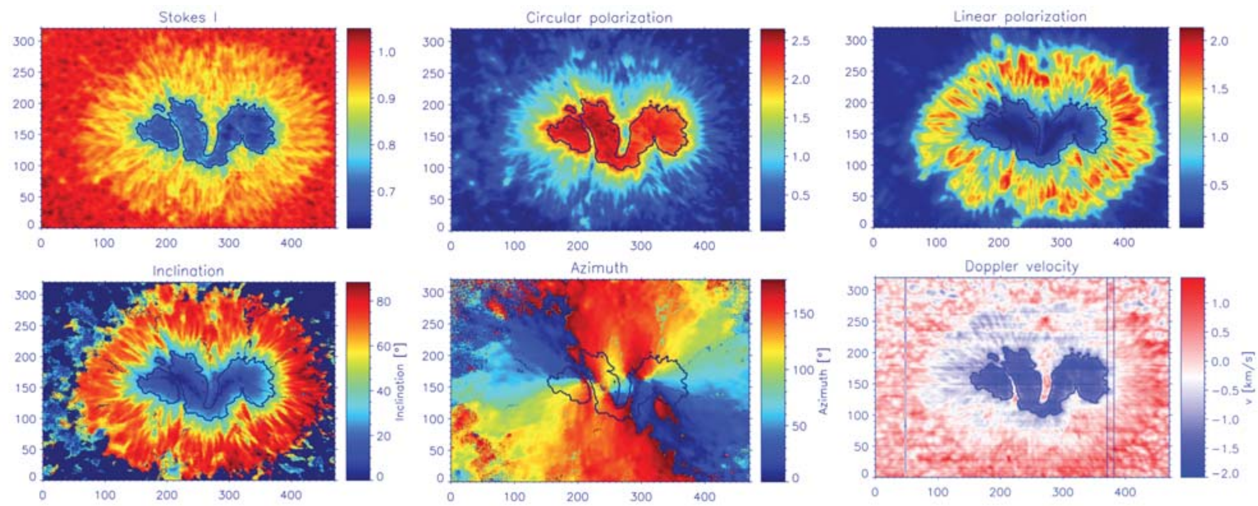


Figure 11: Maps of physical parameters computed for the sunspot NOAA 12049 by Melania Cubas, short-term student at CASSDA/KIS. The data were obtained with the GRIS/GREGOR instrument in the 1.5$\mu$ range and calibrated using the CASSDA GRIS data pipeline.

### – 1st CASSDA School for Solar Observers – *A week above the clouds*

(Teide Observatory/Tenerife, April 2015) http://www.leibniz-kis.de/en/projects/cassda/1st-cassda-school/

One major aim of the CASSDA Project has been to foster the training of young researchers on ground-based observations, from the familiarisation with and direct use of the observing facilities up to the analysis of the observed data.

Following this line, CASSDA organised in April 2015 the *1st CASSDA School for Solar Observers – A week above the clouds* at the Observatorio del Teide in Tenerife. Due to limitation

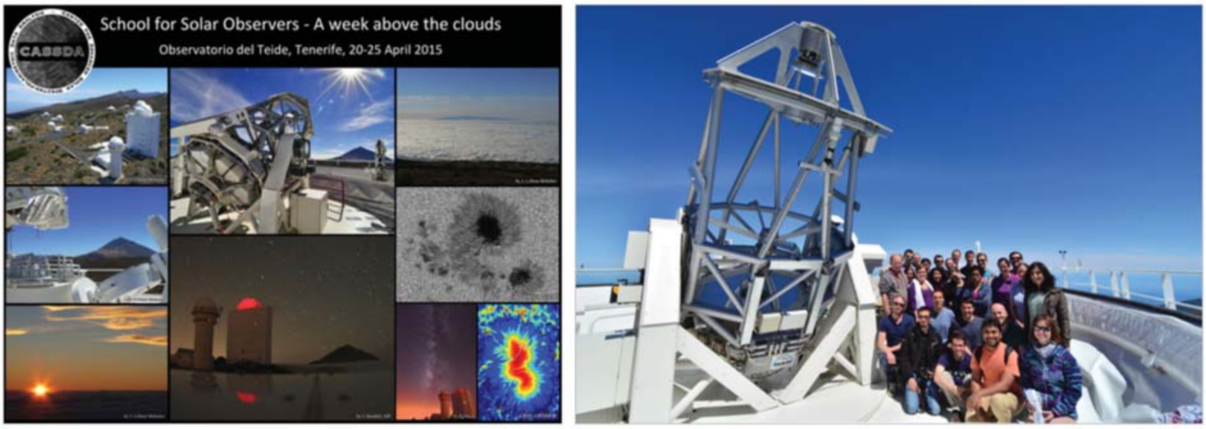


Figure 12: *Left*: Poster of the 1st CASSDA School. *Right:* Group photo at the GREGOR telescope dome.

in accommodation at the observatory, 14 participants (PhD students and young post-docs) were selected from all over in Europe. During one week, the participants could take part in real observations at the GREGOR and VTT German telescopes and analysed the data using the existing data-pipelines. They also learned how to coordinate ground- with space-based data, and the fundamental physics behind the retrieval of parameters like the magnetic field and velocities from the observed spectro-polarimetric data.

We counted on the expertise of 12 lecturers from 6 different institutions with renown competences in ground-based and space-based observations.

### – Master Thesis (October 2014 – October 2015)

http://www.leibniz-kis.de/fileadmin/user_upload/forschung/publikationen/diplom/Master_Thesis_Strecker.pdf

Hanna Strecker carried out her Master Thesis on *The evolution of the moat flow around sunspots – Is the network cell hosting the sunspot moat cell?*. In this work, she studied the possible relation between the moat and supergranular flows by investigating the flows around decaying sunspots. For that, she analysed the HMI/SDO data of 8 H-class sunspots across the solar disc. She found that indeed, once sunspots loose their penumbra, the moat flow also disappears and the remnant outflow is similar to that measured in quiet supergranular/network cells. The results have been partially published in Strecker & Bello González (ASPC SPW8, *submitted*) and two more articles to A&A are in preparation (one is ready for submission).

Supervisor: N. Bello González.

After her Master Thesis, Hanna Strecker was granted with a PhD position at KIS under the supervision of R. Schlichenmaier & N. Bello González to investigate the properties of MMFs as observed in the IR with GRIS/GREGOR.

### – Lecture on Python – The VTF/DKIST programming language (Freiburg, Feb 2017)

https://github.com/SolarDrew/freiburg-2017-02#installation-and-setup

The DKIST is a 4m-class solar telescope currently under construction at the Haleakala Observatory (Maui, USA) by the NSO. The main contribution of KIS to the DKIST will be the Visible Tuneable Filter (VTF), an imaging spectro-polarimeter FPI-based instrument. CASSDA is in charge of the development of an efficient data-pipeline for VTF data. The DKIST Data Center in Boulder explicitly requests the use of Python as the coding language for the pipeline software. Driven by the necessity of adapting our existing CASSDA data-pipeline to the VTF instrument (mostly coded in IDL programming language) as well as by the growing interest of the scientific community in making use of this open-source programming language, CASSDA organised a 2 full-day *Lecture on Python* opened to all KIS members.

Lecturers:
Stuart Mumford, SunPy head developer and DKIST Data Center Python developer
Andrew Leonard, Post-Doc Researcher and Python expert (Sheffield University, UK)

## 7. CASSDA funds – The Competitive SAW Procedure* for Leibniz Projects

*https://www.leibniz-gemeinschaft.de/en/about-us/leibniz-competition

The CASSDA project was fully granted in 2011 by the *Competitive SAW Procedure for Leibniz Projects under the Joint Initiative for Research and Innovation* with **751 000 EUR**, within the funding line *Women in Leadership Position*.

| Cost type [EUR] | 2012 | 2013 | 2014 | Total |
|---|---|---|---|---|
| Personnel costs | 144.000 | 200.000 | 204.000 | 548.000 |
| Material & travel costs | 18.000 | 30.000 | 30.000 | 78.000 |
| **Subtotal:** | 162.000 | 230.000 | 234.000 | 626.000 |
| Overheads (20%) | | | | 125.000 |
| **TOTAL:** | | | | **751.000** |

Figure 13: Original financial plan included in the CASSDA project proposal to the Leibniz Competitive SAW Procedure. The project got fully funded.

The CASSDA project has been extended in time – not in funds–, from originally Jan 2012– Dec 2014 into July 2012 – July 2017, according to the 24 months of parental leave taken by the project coordinator (NBG) and in agreement with the Leibniz Association regulation.

## 8. CASSDA Publications

### Technical notes

- Manual – *The CASSDA GUI for slit-spectrograph data*
- Manual – *The CASSDA GUI for imaging spectro-polarimetric data*
- Manual – *Solar Observations with VTT and TESOS*
- Technical note – *Narrow-band reconstruction of TESOS/VTT data*
- Video tutorial – *How to observe with the TESOS instrument attached to the VTT Telescope*

### In refereed journals


1. *Atmospheric coupling of an H$\alpha$ microflare*
**Bello González, N.**, Kuckein, C., Denker, C., and 29 more, A&A, submitted

2. *Chromospheric impact of an exploding solar granule*
Fischer, C., **Bello González, N.** & Rezaei, R. A&A, 602, L12 (2017)

3. *High-resolution imaging spectroscopy of two micro-pores and an arch filament system in a small emerging flux region*
González Manrique, S., **Bello González, N.** & Denker, C., A&A, 600, 38 (2017)

4. *A distinct magnetic property of the inner penumbral boundary. II. Formation of a penumbra at the expense of a pore*
Jurčák, J., **Bello González, N.**, Schlichenmaier, R. & Rezaei, R., A&A, 597, 60, (2017)

5. *Flow and magnetic field properties in the trailing sunspots of active region NOAA 12396*
Verma, M.,Denker, C., Böhm, F. and 27 more (including **Bello González, N.**), AN, 337, 1090 (2016)

6. *Fitting peculiar spectral profiles in He I 10830Å absorption features*
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## 9. Collaboration with other institutes

The SOLARNET WP20 and WP50 Community
Institut für Astrophysik Potsdam: C. Denker, H. Balthasar & Ch. Kuckein
Max-Planck Institut für Sonnensystemforschung: H.-P. Doerr
Instituto de Astrofísica de Canarias: M. Collados & R. Rezaei
Cezch Astronomical Institute of the Academy of Sciences: J. Jurcak National Solar Observatory: V. Martínez Pillet, D. Harrington, S. Sueoka & the DKIST Data Center Team
Institut für Astrophysik Göttingen: F. Kneer
Istituto Ricerche Solari Locarno: M. Bianda & R. Ramelli
Instituto de Astrofísica de Andalucía: J.C. del Toro Iniesta & L. Bellot Rubio
Valencia University: J. Blanco Rodríguez

## 10. Miscellaneous

### CASSDA members – life after the CASSDA project

**Johannes Löhner-Böttcher** developed the data-pipeline for FPI-based instrument data based on existing codes from the 'Göttingen' FPI. The data-pipeline was originally conceived for TESOS/VTT data. He applied for observations with IBIS/DST* within the SOLARNET ACCESS programme and observed with TESOS/VTT in various campaigns. He calibrated and analyse all data making use of the CASSDA data-pipeline. He studied the properties of waves in the atmosphere of sunspots, resulting in a major contribution in the origin of umbral flashes and penumbral running waves. He also developed a method to estimate the inclination of the magnetic field in sunspots from the analysis of the measured wave peak periods. Johannes successfully defended his PhD Thesis in February 2016 (*'magna cum laude'*).

> The experience gathered in instrumentation, observations, data calibration and scientific research during his CASSDA years qualified him to immediately obtain a position as a Post-Doc Researcher at KIS leading the use and science of the prototype LARS/VTT** instrument.

*Interferometric BIdimensional Spectropolarimeter (IBIS, http://www.arcetri.astro.it/science/solar/ibis/)
**Lars is an Absolute Reference Spectrograph (LARS, http://www.leibniz-kis.de/en/observatories/vtt/lars/)

**Catherine Fischer** lead the development of the polarimetric part of the CASSDA data-pipeline for FPI-based instrument data. She carried out observations and analysis of data from the TESOS/VTT instruments as well as observations with the IBIS/DST instrument within the SOLARNET ACCESS programme. During a ESTEC/ESA Visitorship in July 2014 she worked on solar image compression for the purpose of data archiving and distribution. Catherine was strongly involved in the organisation of the 1st CASSDA Workshop and the 1st CASSDA School as local and scientific organiser as well as a speaker contributor and lecturer.

Catherine got successfully granted with a Postdoctoral Fellow (253 kEUR) by the German Science Foundation for his own research position at KIS focused in the connectivity of magnetic events taking place in quiet Sun atmospheres. 10% of her position at KIS is devoted to the CASSDA Project in the development of an efficient polarimetric calibration for the VTF/DKIST instrument.

**Christian Bethge** developed the CASSDA GUI for analysis of GRIS, TIP and Hinode data. He also set the basis of the GREGOR data archive by developing the concept, currently in extensive use, of the dissemination of GRIS/GREGOR data among the GREGOR Consortium. It shall be opened to the community soon, after embargo will be over.

Christian currently works as a contractor for the USRA (Universities Space Research Association) in the US, doing work for the sounding rocket group at MSFC (NASA Marshall Space Flight Center), mostly data calibration, coding, and some instrumentation, e.g., for AIA, CLASP and MaGIXS.

**Nazaret Bello González** (CASSDA Project leader and coordinator) became tenure scientist at KIS in October 2017. She continues her research on the physical processes of the Sun as seen with high resolution and engaged in the further development of data processing and data dissemination tools as coordinator of the Science Data Centre steadily developing at KIS.

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