“This project has received funding from the European Union’s Horizon 2020 research and innovation programme for the period January 2019 until December 2022 under Grant Agreement No 824135 (SOLARNET)”

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Prepared	Francesca Zuccarello	UNICT	WP3 Leader	April 15th, 2020
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Control	Name	Organization	Function	Date
Approved	Tirtha Som	Leibniz-Institute for Solar Physics (KIS)	Project Manager	August 21st, 2020
Authorized	Markus Roth	KIS	Project Scientist	August 21st, 2020

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Issue	Date	Change Description
Version 1.0	April 15th, 2020	Initial Issue
Version 2.0	July 5th, 2020	Revised version

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1. Summary

This document presents the report regarding the **SOLARNET Mobility Programme**, aimed at promoting visits of PhD students, young post-docs and senior researchers at host Institutions.

The SOLARNET Mobility Programme has been designed as an additional aspect of the networking activities foreseen under Work Package 3 (WP3), to reinforce the contacts between different groups, to enable researchers to have access to first-class infrastructures, to foster joint research, collaboration and developmental activities where all relevant European research Institutions, as well as private companies and other non-EU organizations are involved. The aim of the Programme is also to enable highly qualified scientists from Europe to travel abroad to conduct research stays in other non-EU organizations and vice versa to strengthen EU's competence in scientific innovation and technological break-through and strengthen international collaboration. SOLARNET achievements are envisaged to be of paramount relevance to contribute towards the realization of the European Solar Telescope (EST).

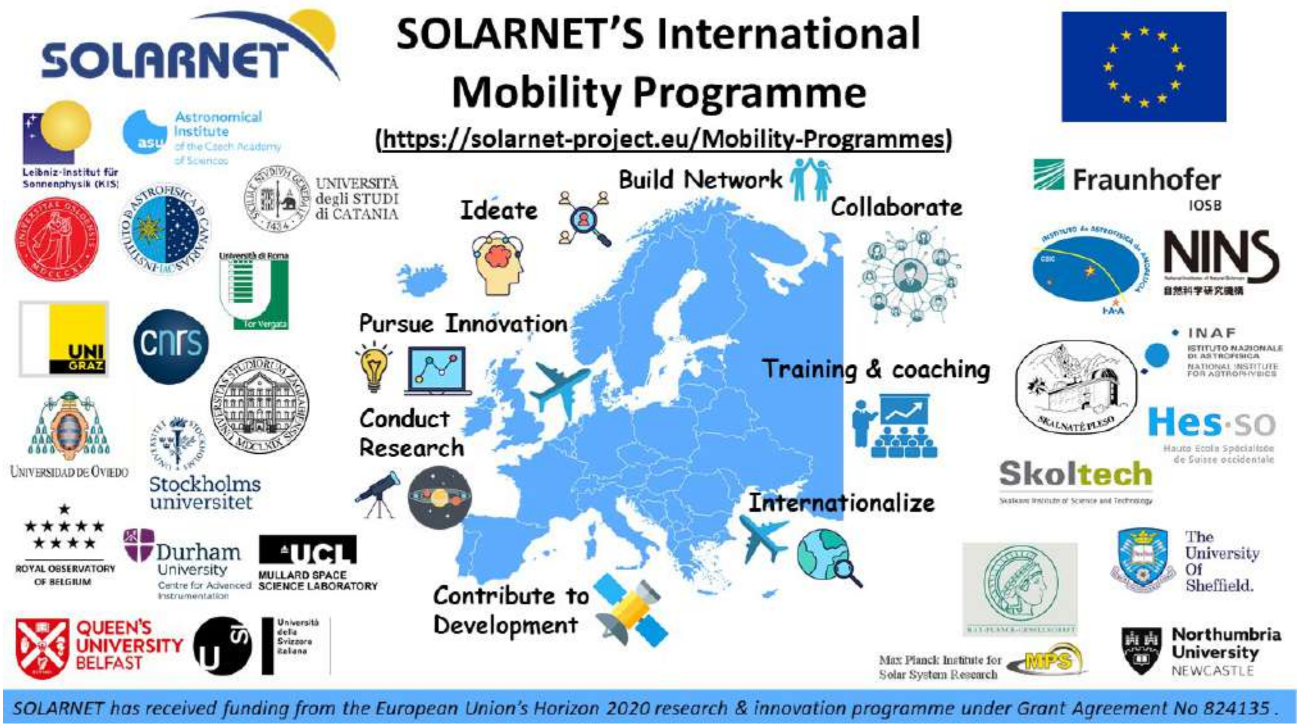

Fig. 1: Poster advertising the SOLARNET Mobility Programme

Mobility is achieved by means of a dedicated programme that is based on:
- Availability of Institutions to host early stage researchers (ESRs) and Senior Researchers for short stays (up to 2-3 months for ESRs and 2-3 weeks for more experienced researchers).
- Periodic calls aimed at selecting a number of candidates, preferentially directed at ESRs and senior researchers from European countries.
- Evaluation of the applicant's proposals by the Mobility Evaluation Committee (MEC), composed by representatives of partner Institutions.

Applications are welcome at any time during the execution of this project (01.01.2019 - 31.12.2022), with **two deadlines per year**: **May 31st** and **November 30th**.
The selection of the granted proposals is announced on June 15th and December 15th of each year.

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The mobility has to start, if approved, during the 6-month periods starting in September 1st and March 1st, so that the selected ESR or Senior Researcher has some time to organize the visit.

Applicants are expected to send a motivation letter, a CV and a brief summary of the proposed work at the host Institution. They are encouraged to contact the host Institution in advance to produce the above-mentioned summary of the proposal in liaison with them.

All Mobility Calls include a statement encouraging application by under-represented groups. Applications by female candidates are encouraged (thereafter of course all applicants would go through an identical assessment procedure).
EU funds for this activity (120 k€) contribute towards travel and accommodation costs of **30 ESRs** and **15 senior researchers** staying at the host Institutions.
The Work Package organizing the Mobility Programme (WP3.2) is led by UNICT.
Relevant information about the Mobility Programme are provided in the SOLARNET webpage (https://solarnet-project.eu/Mobility-Programmes) (see Fig. 2).

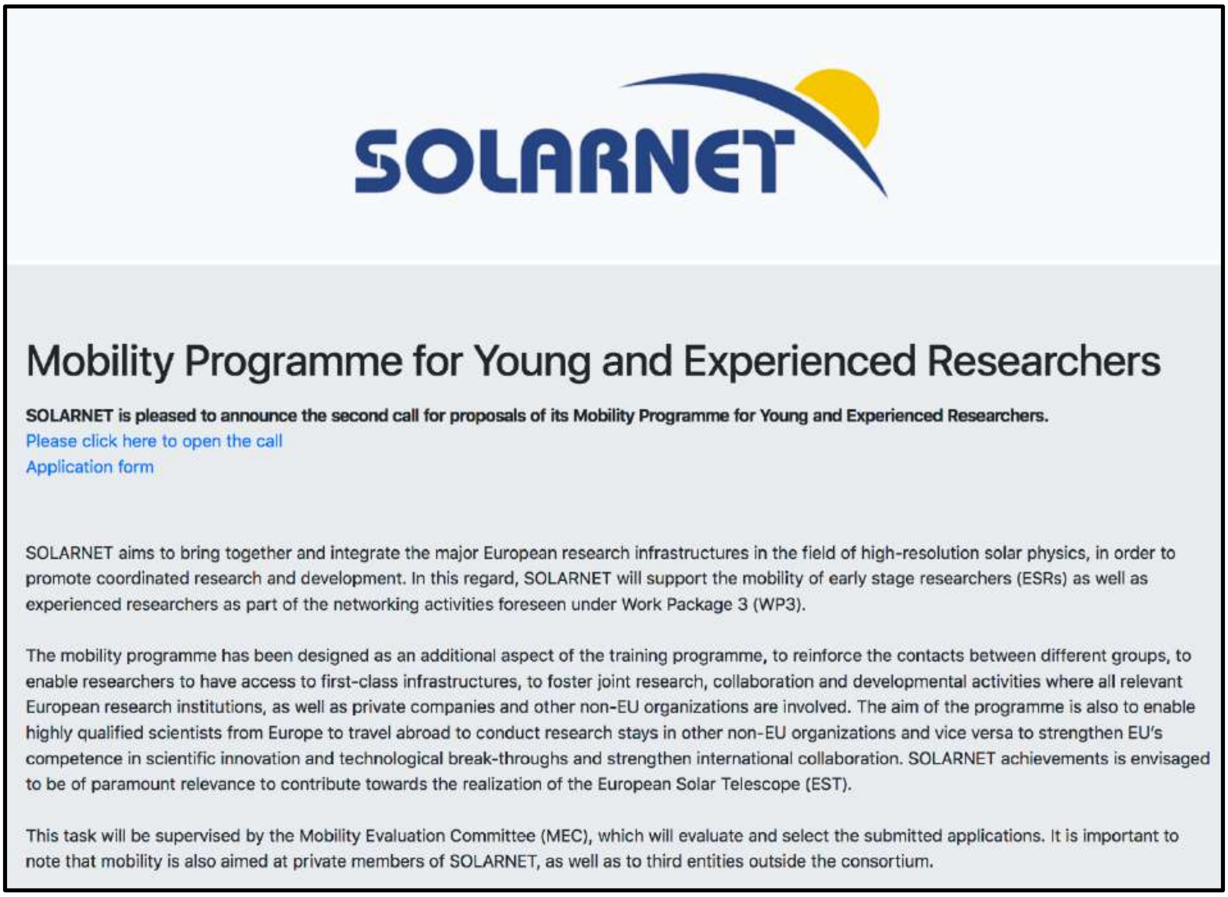

Fig. 2: Screenshot of the SOLARNET webpage describing the Mobility Programme

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2. Host Institutions

The first step in the organization of the Mobility Programme was to collect from each member of the SOLARNET Consortium a brief description of the research activities carried out at their own Institutions, including the details of a contact person.

It is worthwhile to stress that the hosting Institutions are mainly those involved in the SOLARNET project. However, research stays of researchers at non-EU institutes are also considered in order to allow the broadening of the scientist development where appropriate, as well as strengthening international community ties.

In Fig. 3 we report, as an example, the description of the **Leibniz-Institut für Sonnenphysik (KIS)**, which is provided in the SOLARNET webpage devoted to the Mobility Programme.

Table 1 lists potential Host Institutions, who provided information about them on the SOLARNET website. Besides them, other host institutions can be suggested in the proposal.

SOLARNET

Germany

Leibniz-Institut für Sonnenphysik (KIS)

The Leibniz-Institute for Solar Physics (formally known as the Kiepenheuer-Institut für Sonnenphysik, KIS) is a German foundation of public law specialised in basic research in astronomy and astrophysics with particular emphasis on solar physics and related science. The institute was founded in 1943. The institute receives joint funding from the German state of Baden-Württemberg and the federal government. KIS is a member of the Leibniz Association and its base funding is complemented substantially by third party funding, exclusively from public sources. KIS is established as a legally independent foundation of public law since 2002. The responsible state and federal departments are the Ministry of Science, Research and Arts (MWK) of the State of Baden-Württemberg and the Federal Ministry of Education and Research (BMBF). KIS has about 90 staff members of which 50 are scientists including graduate students and undergraduate research assistant students. KIS offers lectures on astronomy and astrophysics at the Albert-Ludwigs University in Freiburg and trains young scientists.
The institute's core competence is experimental and theoretical high-resolution solar physics and helioseismology. It operates two major high resolution solar observing facilities and one synoptic telescope at the Observatorio del Teide in Tenerife: the 1.5 m telescope GREGOR (largest solar telescope in Europe), the 70cm VTT, and the full-disc automated telescope CHROTEL. GREGOR and VTT are equipped with state-of-the-art instrumentation and adaptive optics. KIS has leading expertise in multi-conjugate adaptive optics (MCAO) which is needed to correct extended field-of-views of the Sun from atmospheric turbulence effects. KIS builds image stabilization systems for the balloon-borne SUNRISE mission and the PHI telescope on-board the Solar Orbiter space mission. KIS currently builds the Visible Tunable Filter (VTF), a large-aperture (35cm) Fabry-PérotInterferometer-based imaging spectro-polarimeter for the 4m DKI Solar Telescope (Haleakala Observatory in Hawaii, start of operations in 2020). KIS, together with the IAC (Spain), is leading the coordinated effort of 17 European institutions for the realisation of the European Solar Telescope (EST), and leads the development of the Solar Physics Research Integrated Network Group (SPRING). Furthermore, state-of-the-art models and data analysis tools are developed for studying the physics of the solar interior.

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Fig. 3: Description of the **Leibniz-Institut für Sonnenphysik (KIS)** provided in the SOLARNET webpage devoted to the Mobility Programme

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Table 1: List of Host Institutions

List of Host Institutions	Country
University of Graz	Austria
Koninklijke Sterrenwacht van Belgie	Belgium
Hvar Observatory, Faculty of Geodesy, University of Zagreb	Croatia
Astronomical Institute of the Czech Academy of Sciences, v.v.i. (ASU)	Czech Republic
Centre National de la Recherche Scientifique (CNRS)	France
Leibniz-Institut für Sonnenphysik (KIS)	Germany
Leibniz-Institut für Astrophysik Potsdam (AIP)	Germany
Max-Planck-Institute for Solar System Research (MPS)	Germany
Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (IOSB)	Germany
Istituto Nazionale di Astrofisica (INAF)	Italy
Università degli Studi di Catania (UNICT)	Italy
Università Roma Tor Vergata (UNITOV)	Italy
National Institutes of Natural Sciences / National Astronomical Observatory of Japan (NINS/NAOJ)	Japan
Universitetet i Oslo (UiO)	Norway
Skoltech - The Skolkovo Institute of Science and Technology	Russia
Instituto de Astrofisica de Canarias	Spain
Instituto de Astrofísica de Andalucía (IAA-CSIC)	Spain
University of Oviedo	Spain
Astronomical Institute, Slovak Academy of Sciences (AISAS)	Slovakia
Stockholms universitet	Sweden
Haute Ecole Specialisee de Suisse Occidentale / Haute Ecole d'Ingénierie et de Gestion du Canton du Vaud (HES-SO)	Switzerland
Università della Svizzera italiana / Istituto Ricerche Solari Locarno (USI/IRSOL)	Switzerland
Durham University (UDUR)	United Kingdom
University College London, UCL Mullard Space Science Laboratory	United Kingdom
University of Sheffield	United Kingdom
University of Northumbria at Newcastle	United Kingdom
Astrophysics Research Centre, Queen's University Belfast	United Kingdom

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3. Mobility Evaluation Committee (MEC)

According to the procedure indicated in the SOLARNET Grant Agreement, the applications submitted in response to the Periodic Calls have to be examined by the **Mobility Evaluation Committee** (MEC), which is responsible for the evaluation and selection of the candidates.
During the SOLARNET Kick-off Meeting, the SOLARNET Board agreed that the MEC is formed by representatives of the partner Institutions that are responsible for organizing the SOLARNET Summer/Winter Schools and by the WP3 Leader, acting as Chair. In Table 2 the MEC composition is reported.

Table 2: Mobility Evaluation Committee composition

Member	Institute and Country
Michele Bianda	IRSOL (Switzerland)
Robertus Erdélyi	University of Sheffield (UK)
Peter Gomory	AISAS (Slovakia)
Arnold Hanslmeier	University of Graz (Austria)
Sarah Matthews	UCL-MSSL (UK)
Francesca Zuccarello (Chair)	UNICT (Italy)

The MEC evaluates the applications by taking into account some basic criteria: a) relevance of the motivation letter; b) relevance of the proposed research to the PhD thesis, or post-doc research of the candidate; c) number and quality of publications; d) Summer/Winter Schools or Conferences attended; e) priority is given to applicants who have not already benefitted from previous SOLARNET Mobility Calls.

When there are situations that could imply conflict of interest (i.e., a candidate from the same Institute, previous PhD student, etc.), the MEC member does not participate in the relevant evaluation.

The evaluation is made individually by each MEC member using a spreadsheet where ranking is provided (from 1, indicating the best evaluation, to a grade equal to the number of candidates). The spreadsheets with the rankings are sent by e-mail to the MEC Chair and, in case there is a strong discrepancy between the grades provided by each MEC members, a videoconference is issued in order to reach a general agreement.

4. Mobility Periodic Calls

It is established that applications from young and experienced researchers can be submitted at any time during the SOLARNET project, until May 2022. However, intermediate deadlines are issued twice per year, in May and November, to make possible the evaluation of applications received until a specific date.

Applicants are expected to fill the online Application Form (https://solarnet-project.eu/application-form), to send a motivation letter, a CV and a brief summary of the proposed work at the Host Institution. They are encouraged to contact the Host Institution in advance to produce the proposal summary in liaison with them.

In order to promote the advancement of equal opportunities for women and men in science and, in particular, to increase gender equality within the SOLARNET Mobility Programme, young women astronomers are strongly encouraged to apply.

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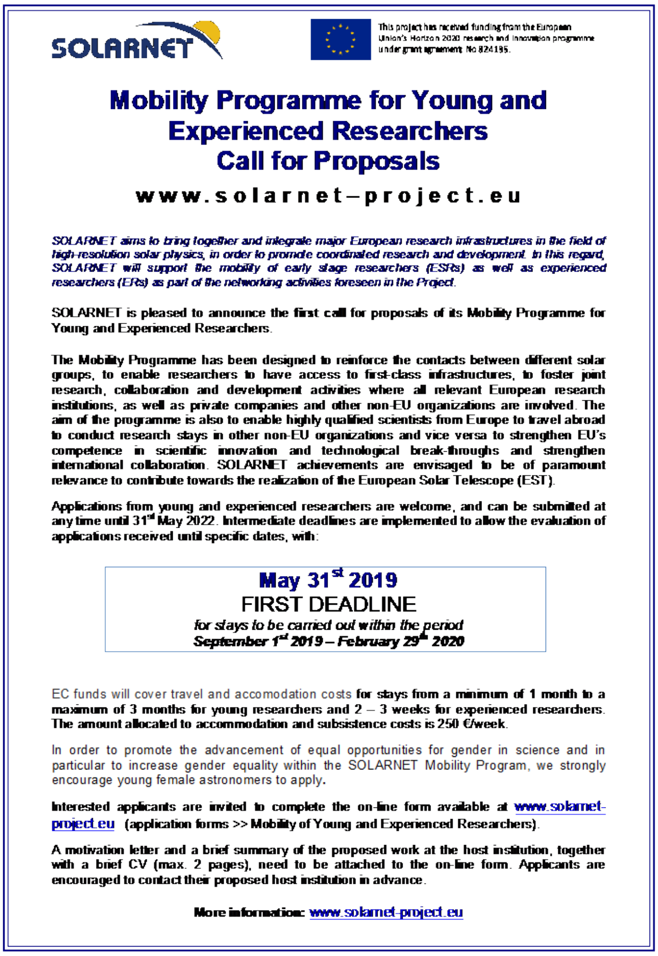
4.1 First Mobility Call

The First Mobility Call was released on April 15th, 2019 (see Fig. 4). The Announcement was posted on the SOLARNET webpage and promoted through different mailing lists and social media (i.e., Solar News, UKSP News, Facebook).

The applicants were requested to send their application within May 31st and were informed that the results of the selection would be notified within June 15th. It was also specified that the selected ESRs and Senior Researchers should have visited the Host Institution~~s~~ within the period September 1st, 2019 – February 29th, 2020.


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

Mobility Programme for Young and Experienced Researchers
Call for Proposals

www.solarnet–project.eu

SOLARNET aims to bring together and integrate major European research infrastructures in the field of high-resolution solar physics, in order to promote coordinated research and development. In this regard, SOLARNET will support the mobility of early stage researchers (ESRs) as well as experienced researchers (ERs) as part of the networking activities foreseen in the Project.

SOLARNET is pleased to announce the first call for proposals of its Mobility Programme for Young and Experienced Researchers.

The Mobility Programme has been designed to reinforce the contacts between different solar groups, to enable researchers to have access to first-class infrastructures, to foster joint research, collaboration and development activities where all relevant European research institutions, as well as private companies and other non-EU organizations are involved. The aim of the programme is also to enable highly qualified scientists from Europe to travel abroad to conduct research stays in other non-EU organizations and vice versa to strengthen EU's competence in scientific innovation and technological break-throughs and strengthen international collaboration. SOLARNET achievements are envisaged to be of paramount relevance to contribute towards the realization of the European Solar Telescope (EST).

Applications from young and experienced researchers are welcome, and can be submitted at any time until 31st May 2022. Intermediate deadlines are implemented to allow the evaluation of applications received until specific dates, with:

May 31st 2019
FIRST DEADLINE
for stays to be carried out within the period
September 1st 2019 – February 29th 2020

EC funds will cover travel and accomodation costs **for stays from a minimum of 1 month to a maximum of 3 months for young researchers and 2 – 3 weeks for experienced researchers. The amount allocated to accommodation and subsistence costs is 250 €/week.**

In order to promote the advancement of equal opportunities for gender in science and in particular to increase gender equality within the SOLARNET Mobility Program, we strongly encourage young female astronomers to apply.

Interested applicants are invited to complete the on-line form available at www.solarnet-project.eu (application forms >> Mobility of Young and Experienced Researchers).

A motivation letter and a brief summary of the proposed work at the host institution, together with a brief CV (max. 2 pages), need to be attached to the on-line form. Applicants are encouraged to contact their proposed host institution in advance.

More information: www.solarnet-project.eu

Fig.4: Announcement of the First Mobility Call

The number of applications received was: 7 ESRs and 1 Senior Researcher.
The MEC evaluated the applications and in Table 3 the main information concerning the selected candidates are reported.

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Table 3: First Mobility Call: selected candidates

Full Name	Gender	Nationality	Home Institute / University	Position / Function	Host Institution & Contact	Topic	Duration (weeks)
Early Stage Researchers							
Theodosios Chatzistergos	M	Greek	INAF	Post-doc	MPS (N. Krivova)	Relationship between magnetic field and Ca II over 20 years	7
Marianna Korsos	F	Hungarian	Eotvos Lorand University	Post-doc	UNICT (F. Zuccarello)	Flare and CME prediction	12
Philip Lindner	M	German	Leibniz-Institut für Sonnenphysik (KIS)	PhD Student	Stockholm University (J. De La Cruz Rodriguez)	Application of the STIC code to SST data (magneto-convective modes in ARs)	8
Tishtrya Mehta	F	British	University of Warwick	PhD Student	NSO (K. Jain and S. Tripathy)	Analysis of GONG data and solar dynamo	6
Jenny Marcela Rodriguez Gomez	F	Colombian	Skolkovo Institute of Science and Technology	Post-doc	University of Graz (A. Veronig)	Solar Extreme Events and Their Space Weather Impact	12
Senior Researchers							
Robertus Erdélyi	M	Hungarian	University of Sheffield	Senior Researcher	UNICT (F. Zuccarello)	Flare forecasting	1

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4.2 Second Mobility Call

The Second Mobility Call was released on October 15th, 2019 and the Announcement was posted on the SOLARNET webpage and promoted through different mailing lists and social media (i.e., Solar News, see Fig. 5, UKSP News, Facebook).

AAS AMERICAN ASTRONOMICAL SOCIETY
SOLAR PHYSICS DIVISION — SolarNews

SOLARNET Mobility of Young and Experienced Researchers Programme Announcement (1st Call)

The SOLARNET Mobility Evaluation Committee (MEC) is pleased to announce the 1st Call for Proposals of Mobility Programme of Young and Experienced Researchers (Deadline: May 31st, 2019).
SOLARNET (http://solarnet-project.eu/home) aims to bring together and integrate the major European research infrastructures in the field of high-resolution solar physics, in order to promote and development. In this regard, SOLARNET will support the mobility of early stage researchers (ESRs) as well as experienced researchers as part of the networking activities foreseen in the supervised by the MEC, which evaluates and selects the submitted applications.
This first Call is related to stays to be carried on during the period September 1st, 2019 – February 29th, 2020. Detailed information about the Young and Experienced Researchers Mobility Pr found at http://solarnet-project.eu/Mobility-Programmes.

Article ID: 4569 edit article 4569
Section: general
Volume: 2019 Number: 0 Sort: 0
Name and Email: Francesca Zuccarello francesca.zuccarello@inaf.it
Created on: 2019-04-29 05:20:25
Mod status:

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The mission of the American Astronomical Society is to enhance and share humanity's scientific understanding of the Universe.

Page rendered in 0.0527 seconds

Fig. 5: Screenshot of the Announcement of the Second Mobility Call posted in Solar News

The applicants were requested to send their application within November 30th and they were informed that the results of the selection would be notified within December 15th. It was established that the selected ESRs and Senior Researchers could visit the Host Institutions within the period March 1st, 2020 – August 31st, 2020.

Number of applications received: 11 ESRs and 4 Senior Researchers. The list of candidates selected by the MEC is reported in Table 4.

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Table 4: Second Mobility Call: selected candidates

Full Name	Gender	Nationality	Home Institute / University	Position/ Function	Host Institution & Contact	Topic	Duration (weeks)
Early Stage Researchers							
Eleanna Asvestari	F	Greek	University of Helsinki	Post-doc	MPS (T. Wiegelmann)	Modelling of the coronal magnetic field	6
Ryan Campbell	M	British	Queen's University Belfast	PhD Student	IAC (M. Collados)	Analysis of spectro-polarimetric data	5
Andrea Dircke	F	German	Leibniz-Institut für Sonnenphysik (KIS)	PhD Student	University of Graz (A. Veronig)	Neural networks for object detection in full-disk images	5
Senior Researchers							
Juan Manuel Borrero	M	Spanish	Leibniz-Institut für Sonnenphysik (KIS)	Staff Scientist	IAC (B. Ruiz Cobo)	Test of a new code for the radiative transfer equation	1
Mateja Dumbovic	F	Croatian	Faculty of Geodesy, University of Zagreb	Research Assistant	Skolkovo Institute of Science and Technology (A. Veronig)	Radial and lateral evolution of CMEs	3
Dominik Utz	M	Austrian	IGAM/Institute of Physics, Karl-Franzens University Graz	FWF Fellow	University of Sheffield (R. Erdelyi)	MHD simulation using MPI-AMRVAC	3

We stress however that, owing to the Covid-19 pandemic, which was spreading in Europe from the beginning of March, some of the visits had to be interrupted or postponed until the travel will become safe. More precisely, the situation as on June 30th was the following:

- Eleanna Asvestari – supposed to travel on 4th April – flights cancelled – stay postponed
- Ryan Campbell – left on 9th March – returned on 13th March – 1 week completed – 4 weeks left
- Andrea Diercke – left on 1st March – returned on 16th March – 2 weeks completed – 3 weeks left
- Juan Borrero – completed 24-29th February – 1 week – 0 weeks left
- Mateja Dumbovic – left on 8th March – returned on 15th March – 1 week completed – 2 weeks left
- Dominik Utz – left on 8th March – returned on 15th March – 1 week completed – 2 weeks left

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4.3 Third Mobility Call

The Third Mobility Call was released on April 15th, 2020. The applicants were requested to send their application within May 31st and the results of the selection was notified on June 15th. The selected applicants should visit the Host Institutions within the period September 1st 2020 – February 28th 2021.

Number of applications received: 8 ESRs, while no applications from Senior Researchers was received. The list of candidates selected by the MEC is reported in Table 5.

Table 5: Third Mobility Call: selected candidates

Full Name	Gender	Nationality	Home Institute / University	Position/ Function	Host Institution & Contact	Topic	Duration (weeks)
Early Stage Researchers							
Jose Ivan Campos Rozo	M	Colombian	Karl-Franzens University of Graz, Austria	PhD Student	Instituto de Astrofisica de Canarias, Spain (Andres Asensio Ramos)	Temporal evolution of a solar pore through the solar atmosphere	12
Saida Milena Diaz Castillo	F	Colombian	Leibniz-Institut f ̈ur Sonnenphysik (KIS), Germany	PhD Student	Instituto de Astrofisica de Canarias, Spain (Andr_es Asensio Ramos)	Training of Machine Learning (ML) models for analysis of solar magnetogram time series	4
Christopher Nelson	M	British	Astrophysics Research Centre, Queen's University Belfast, UK	Post Doc	Rosseland Centre for Solar Physics, Norway (Mats Carlsson)	Bursts and Jets in Bifrost Simulations - Small-Scale Umbral Brightenings	5

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5. Reports issued by participating scientists

The reports received so far are reported starting from page 19 of this document. We stress that many of the reports relevant to the 2nd Call are missing due to the interruptions of the researcher’s stays at the Host Institutions, caused by the lockdown in many Countries provoked by the Covid-19 pandemic.

Below we report a brief abstract of the research carried out by the scientists participating in the Mobility Programme (mainly those that were able to finish their stay at the Host Institutions).

5.1 Theodosios Chatzistergos

Abstract: It is of great importance to have information on the evolution of the magnetic field of the Sun in the past. Such information is essential for studies aiming at understanding the solar dynamo as well as the influence the Sun has on Earth's climate. High quality magnetograms exist since 1974, thus limiting our understanding of past solar magnetism. It would be of great value to extend the available series of magnetograms back in time.

5.2 Marianna Korsos

Abstract: It is generally accepted that the evolution of magnetic helicity has a close relationship with solar eruptions.

Here, we use the SDO/HMI (Helioseismic Magnetic Imager of Solar Dynamics Observatory) vector magnetic field measurements for our case study. In this work, we analyse the evolution of the normalised total, emergence and shearing helicity components in the case of two ``flare/CME productive'' and two ``quiet'' active regions (ARs). To reveal new properties of the three helicity injection components, we removed the 12-hour and 24-hour artefact oscillations of the SDO/HMI satellite from the helicity fluxes. First, we found that the variation of the emergence magnetic flux has an important role in the flare and CME occurrences compared to the shearing motion. Furthermore, we also identified a particular characteristic of the ``flare/CME productive'' ARs with Fast Fourier transform (FFT). The FFT revealed that a ``flare/CME productive'' AR has a period which strongly presents in the evolution of the normalised emergence, shearing and total helicity fluxes. However, the two investigated ``quiet'' ARs did not show any periodic behaviour.

5.3 Philip Lindner

Abstract: Inversion codes are essential for retrieving atmospheric parameters from spectropolarimetric solar data. The main reason for the applicant to use the mobility programme was to learn the STiC inversion code, which has been developed by the host. The aim was to apply STiC to data that were recorded at the Swedish Solar Telescope (SST), with the SOLARNET Access Programme, in April 2019.

5.4 Trishtrya Mehta

Abstract: Examining frequency shifts of solar p-modes using Empirical Mode Decomposition to investigate the quasi-biennial oscillation (QBO). Data from MDI/HMI, F 10.7, GONG and the composite Bremen Index were selected to look back at frequency shifts from Cycles 23, 24 (and 21, 22 where high quality data were available).

5.5 Jenny Marcela Rodriguez Gomez

Abstract: Extreme phenomena, specifically, fast CMEs and ICMEs are an important driver in the Space Weather and their forecast. Complex dynamics take place in the solar atmosphere driving these eruptive phenomena. The relationship between magnetic and kinetic pressure over some regions in the solar atmosphere gives clues about the origin of extreme events. We applied the Max-Spectrum and de-clustering methods on CMEs and ICMEs speed time series. Also, we will use the observational data from GREGOR telescope and Hinode spacecraft to obtain a detailed description of plasma β on Quiet Sun regions.

5.6 Robertus Erdélyi

Abstract: Space Weather forecasting is one of the key recently emerged hot topics of solar and solar-terrestrial research. During this short SOLARNET mobility we planned to address i) how we could incorporate ML techniques to improve flare and CME forecasting using EUV images; ii) how the networking opportunity provided by the SOLARNET Mobility helps towards building up a closer collaborative research between the research group at Catania and at SP2RC, Sheffield; iii) and evaluate the outcome so far of a joint research project on incorporating helicity into the WG_M method; iv) work on the draft of a research paper addressing iii).

5.7 Andrea Dircke

Abstract: During my research stay at the University of Graz, I benefited from the group's expertise in synoptic full-disk observations and machine learning. This new collaboration enables us to refine the object detection algorithm prepared at AIP for full-disk images of the Chromospheric Telescope and test it on the long-lasting full-disk Hα image series of the Kanzelhöhe Solar Observatory. In the end, the algorithm should be standardized so that it can be applied to other full-disk Hα images.

5.8 Juan Manuel Borrero

Abstract: We have successfully applied our new inversion code for the radiative transfer equation with magneto-hydrostatic constraints to spectropolarimetric data recorded with the Hinode/SP instrument. The subject of our investigation was a sunspot (NOAA AR 10944) observed on February 28th, 2007 at disk center ($\mu = 0.999$).

5.9 Mateja Dumbovic

Abstract: In the scope of the visit a study of the multi-spacecraft remote and in situ coronal mass ejection (CME) signatures associated to radial and lateral evolution of CMEs was partially carried out for a subset of CMEs. The method for robust smoothing to derive the impulsive dynamics of CMEs (radial and lateral velocity profiles) close to Sun was applied. Multi-spacecraft signatures of ICMEs were sought and a number of in situ properties were measured and calculated.

6. Gender Balance

In order to promote equal opportunities for men and women, each Mobility Call contains a statement about gender balance.
The applicant's gender distribution relevant to the 1st Call is: 4 females (4 ESRs) and 4 males (3 ESRs + 1 Senior Researcher) (see Fig. 6, left panel). The gender distribution of the selected researchers is: 3 females (3 ESRs) and 3 males (2 ESRs +1 Senior Researcher) (see Fig. 6, right panel).

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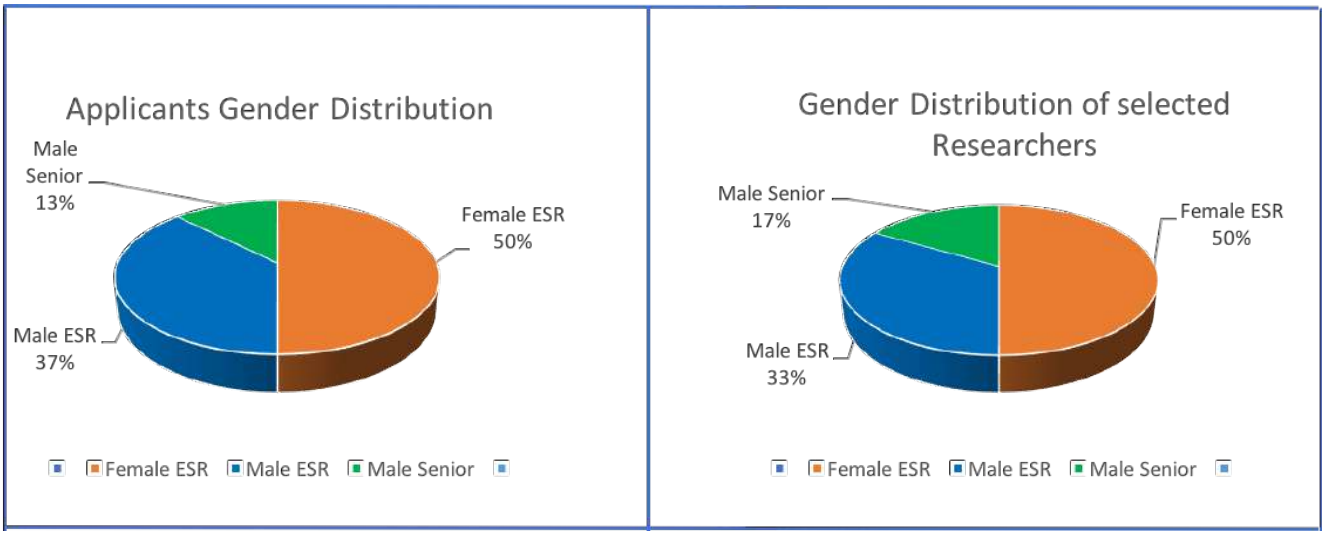

Fig. 6. 1st Mobility Call - Gender distribution of the applicants (left) and of the selected researchers (right).

As far as the 2nd Mobility Call, the gender distribution of the applicants is: 5 females (4 ESRs and 1 Senior Researcher) and 10 males (7 ESRs + 3 Senior Researchers) (see Fig. 7, left panel). The gender distribution of the selected researcher is: 3 females (2 ESRs and 1 Senior Researcher) and 3 males (1 ESR and 2 Senior Researchers) (see Fig. 7, right panel).

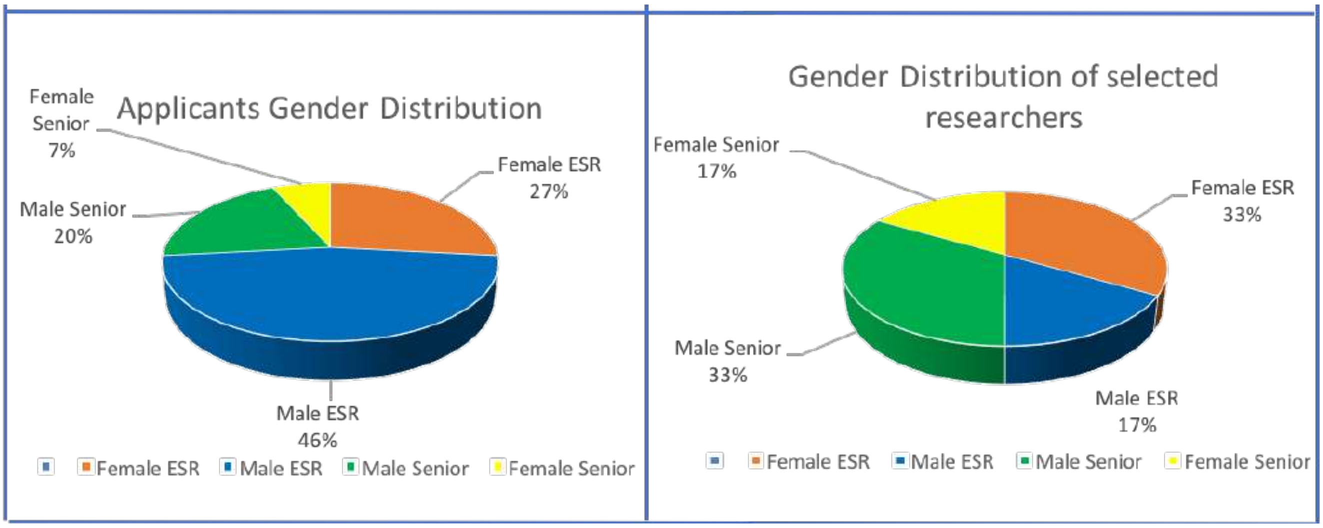

Fig. 7. 2nd Mobility Call - Gender distribution of the applicants (left) and of the selected researchers (right).

Finally, in the 3rd Mobility Call, the gender distribution of the applicants is: 3 ESR females and 5 ESR males (see Fig. 8, left panel). The gender distribution of the selected researcher is: 1 ESR female and 2 ESR males (see Fig. 8, right panel).

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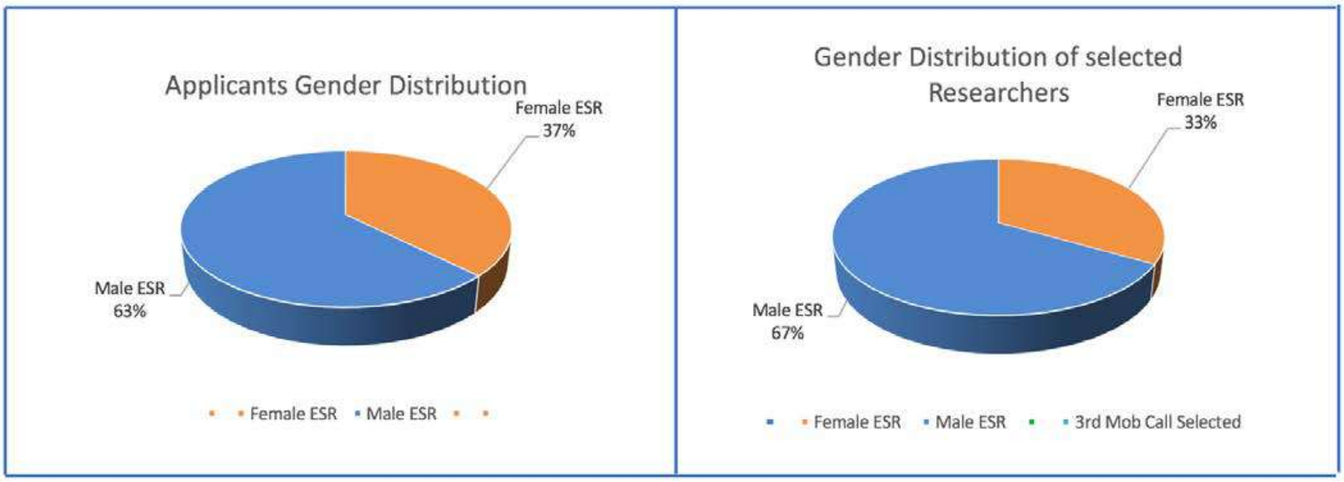

Fig. 8. 3rd Mobility Call - Gender distribution of the applicants (left) and of the selected researchers (right).

7. Brief Financial Report

Overview of the financial resources spent in supporting the research stays of the scientists under the mobility programme within the first reporting period (Jan 1st, 2019 – June 30th, 2020) is provided below.

Costs	Amount
Direct Costs	
Travel support to ESRs and Senior Researchers (KIS)	4,202.48 €
Fellowship provided to the ESRs and Senior Researchers, particularly to cover accommodation & subsistence costs (KIS)	15,750.00 €
Consumables (KIS)	0.00 €
Total direct costs incurred during first reporting period	19,952.48 €

8. Conclusions

The increasing trend in the number of applications received in response to the 1st and 2nd Calls of the SOLARNET Mobility Programme indicates that there was a rising interest in this opportunity. This was true for both ESRs and Senior Researchers, who strongly appreciate the possibility to receive support in order to spend some weeks doing research in another Institute.

Unfortunately, the number of applications received when the 3rd Call was released, was not following the same trend: we can notice in particular that no applications were sent by Senior Researchers. This result is imputable to the big uncertainties related to travel restrictions due to the Covid-19 pandemic, especially because several research institutes and Universities strongly discouraged, when not explicitly interdicted, travels.

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On the other hand, it is clear that the opportunity offered by the Mobility Programme reinforces the collaborations among the members of the Consortium and, in the case of ESRs, it allows training a new generation of solar physicists who will benefit from the new ground-based and space instruments that will become available in the next future.

The gender distribution among the selected researchers is quite satisfactory and reflects the strong interest of the SOLARNET Consortium to promote gender balance in science.

As a final note, we stress that the critical situation raised during the past months, due to the Covid-19 pandemic, has provoked an interruption in many of the stays and it has been necessary to reschedule some of them. From the project office side, necessary steps have been taken to minimize the financial damages and recover the travel amount as much as possible so that these interrupted research stays can be reorganized.

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Studying the effects of bandwidth on reconstructing unsigned magnetic field maps from Ca II K images

Theodosios Chatzistergos
INAF osservatorio astronomico di Roma

Basic Information

Host Institution: MPS
Names of Collaborators: Dr. Natalie A. Krivova
Dates of the Visit: 06/01/2020- 29/02/2020
Mobility completed: Y

Abstract (Max 500 characters)

It is of great importance to have information on the evolution of the magnetic field of the Sun in the past. Such information is essential for studies aiming at understanding the solar dynamo as well as the influence the Sun has on Earth's climate. High quality magnetograms exist since 1974, thus limiting our understanding of past solar magnetism. It would be of great value to extend the available series of magnetograms back in time.

Background and Aims of the Project (Max 2000 characters)

The general aim of this project is to improve our understanding of past irradiance variations and the evolution of the solar magnetic field by exploiting Ca II K observations.

Ca II K observations are a great proxy for solar surface magnetism (Babcock & Babcock 1955, Loukitcheva et al. 2009, Chatzistergos et al. 2019). Ca II K observations started being acquired in 1892 and are an integral part of various continuing observing programs (Chatzistergos 2017, Chatzistergos et al., 2020). Ca II K observations can provide information about the evolution of facular (or plage when seen in the chromosphere) areas for more than a century.

We have developed a process to accurately process Ca II K observations and perform the photometric calibration of the observations stored on photographic plates (Chatzistergos et al. 2018). We also studied the relationship between Ca II K brightness and magnetic field strength (Chatzistergos et al., 2019) by using higher quality and larger sample of data than in previous studies. We found a power law relation to describe the data best, in agreement with previous studies in the literature.

However, our analysis, as well as those from the literature, was limited to data from one Ca II K archive, while the observations from other sites have been performed with quite different setups. Indeed, the bandwidth of the observations varies considerably among the different archives and ranges between 0.1 to 9 Å, thus sampling different heights of the solar atmosphere. Therefore, within the framework of this project we wanted to study how the bandwidth of the observations affect the relation between the Ca II K brightness and the magnetic field strength.
This is essential to improve the reconstructed magnetograms and understand potential uncertainties.

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This would allow to reconstruct magnetograms back to 1892 as well as the solar irradiance variations with the SATIRE model (Krivova et al. 2003, Yeo et al. 2014).

Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)

The first important step in this project was to process Ca II K observations from different archives to perform the photometric calibration and compensate for the limb darkening. During the first weeks of this visit we finalized the work on an extensive analysis of 43 Ca II K archives. These images would be the ones which we want to eventually convert to magnetograms with the results on the relation of the magnetic field strength to the Ca II K brightness. We further analysed these images to study the evolution of plage areas and produce a composite plage area series over 1892-2019. A paper describing this work (Chatzistergos et al. 2020) was submitted in Astronomy and Astrophysics acknowledging the contribution from SOLARNET.

After the processing of all the images was completed, we randomly selected data from the archives of Baikal, Brussels, Calern, Kanzelhöhe, Pic du Midi, Brussels, Teide, Rome/PSPT, and SFO as well as data from Meudon taken off-centred at 4 different wavelengths, as well as Meudon filtergrams and spectroheliograms. We acquired also the SDO/HMI magnetograms and SDO/AIA continuum images taken closest in time to the Ca II K observations. The SDO/AIA images were processed to remove the limb-darkening. We removed the polarity from the magnetograms and resized all images to the typical conditions of the ground-based archives (at about 2''/pixel). All Ca II K images were compensated for ephemeris so to show the solar north pole at the top, while the SDO data are already provided with the solar north pole at the top of the images. Sunspots were identified in the SDO/AIA images and were removed from our further analysis, since we are interested only in the relation of bright features. We produced preliminary scatter plots, which made apparent that there are alignment issues with the data (Fig. 1 left panel). These alignment errors owe to potential errors in the timing of the observations, distortions of the images due to atmospheric effects, or even slightly different definition of the solar disc, which is also hampered by seeing. To address this, we made use of the "auto_align_images" routine from the SolarSoft suite (Freeland & Handy 1998) to align the observations. Unfortunately, this process is rather time consuming and requires manual input of a first guess for the alignment. This slightly delayed the further progress of this project. All Ca II K images have by now been accurately aligned to the magnetograms and we have produced preliminary scatterplots between the Ca II K brightness and the magnetic field strength. Figure 1 shows the scatter plot for the Meudon and San Fernando filtergrams before and after the alignment of the data with the "auto_align_images" routine. Our preliminary analysis of the data shows that the relation becomes steeper for observations taken with a narrower bandwidth, while the correlation reduces compared to observations taken with broad bandwidths.

The project aims to reconstruct magnetograms back to 1892 for the modelling of past solar irradiance variations. To this purpose, during the stay we also performed the work on reconstructing total solar irradiance (TSI) from 2 of the processed Ca II K archives in order to study the long-term trend of TSI over the last 3 solar cycles. This work also allowed us to investigate the variations of spectral irradiance over the red and blue continuum bands. A paper describing this work is currently being finalised and will be submitted to the topical issue of Journal of Space Weather and Space Climate Topical Issue on "Space Climate". The contribution of SOLARNET has also been acknowledged.

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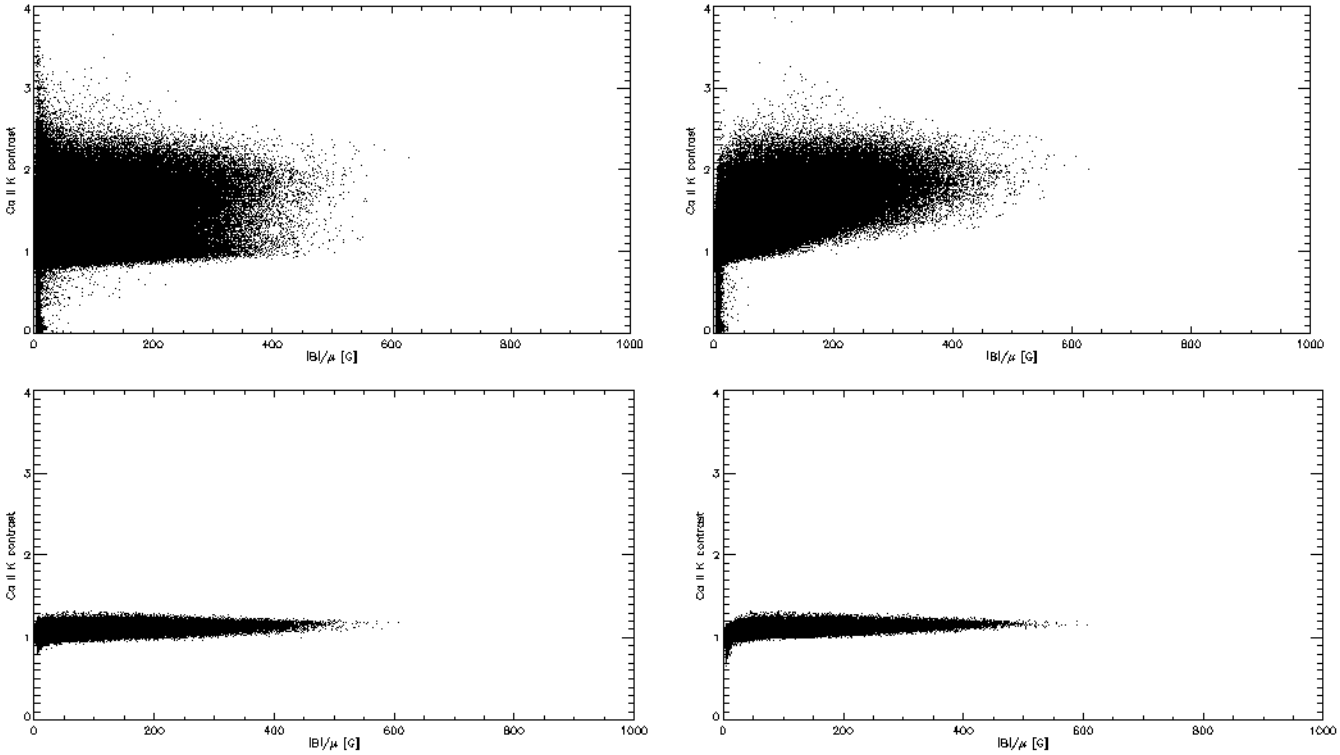

Figure 1: Ca II K brightness as a function of magnetic field strength derived from 103 pairs of Meudon (top) and 81 pairs of San Fernando (bottom) Ca II K filtergrams and SDO/HMI magnetograms. On the left is the scatter plot after the compensation for ephemeris for the Ca II K data, while on the right it is after the use of the "auto_align_images" routine to precisely align the Ca II K images to the magnetograms.

Future steps (Max 1000 characters)

The complete analysis of the data and evaluation of the relations for different bandwidths is still underway. Once this is finalised, we will use the relations to reconstruct magnetograms from the various Ca II K archives and directly compare our results to the actual magnetograms. This way we can also get an estimate of the improvement of the reconstruction of the magnetograms by taking into account the effect of the bandwidth of the Ca II K observations. A major difficulty in this process is that the values for bandwidths for the various archives are nominal, while the actual ones might differ or there might be drifts with time. We need to address this issue and identify the various instrumental inhomogeneities of the archives before being able to reconstruct magnetograms with the historical Ca II K archives. We have started drafting a paper describing the processing done so far, where SOLARNET will be acknowledged.

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Date:

02/04/2020

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Leap forward in Space Weather forecasting: Novel prediction of solar flares and CMEs

Dr Marianna Brigitta Korsos
Institute of Mathematics, Physics and Computer Science, Aberystwyth University, Ceredigion, Cymru, SY23 3BZ, UK1. Solar Physics

Basic Information

Host Institution: University of Catania, Via S. Sofia 78, I 95123 Catania, Italy
Names of Collaborators: Prof. Francesca Zuccarello and Dr Paulo Romano
Dates of the Visit: 2019.11.13-12.10 and 2020.01.24-2020.03.20
Mobility completed: (Y / N) Yes

Abstract (Max 500 characters)

It is generally accepted that the evolution of magnetic helicity has a close relationship with solar eruptions. Here, we use the SDO/HMI (Helioseismic Magnetic Imager of Solar Dynamics Observatory) vector magnetic field measurements for our case study. In this work, we analyse the evolution of the normalised total, emergence and shearing helicity components in the case of two ``flare/CME productive'' and two ``quite'' active regions (ARs). To reveal new properties of the three helicity injection components, we removed the 12-hour and 24-hour artefact oscillations of the SDO/HMI satellite from the helicity fluxes.
First, we found that the variation of the emergence magnetic flux has important role in the flare and CME occurrences compare to the shearing motion. Furthermore, we also identified a particular characteristic of the ``flare/CME productive'' ARs with Fast Fourier transform (FFT). The FFT revealed that an ``flare/CME productive'' AR has a period, which strongly present in the evolution of the normalised emergence, shearing and total helicity fluxes. However, the two investigated ``quite'' ARs did not show any periodic behaviour.

Background and Aims of the Project (Max 2000 characters)

In recent years, a number of new studies were initiated, with the aim to develop more accurate flare prediction methods by employing space-based (i.e. SOHO and SDO) magnetic field observations. Often, these methods are based on tracking changes of the solar surface magnetic configuration in δ-spots, as flare and CME precursors, with about an hourly temporal resolution. During my PhD period at Debrecen Heliophysical Observatory (DHO), we have developed our own *new prediction method* (called the WG_M method). The method itself is based on the calculation of the horizontal gradient of the line of sight component of the magnetic field between two opposite polarities in a δ-spot (Korsós et al. ApJ 2015). Two new characteristic pre-flare behaviours, i.e. *precursors*, were also discovered by the WG_M method (Korsós et al. ApJ 2015). These two precursors provide important diagnostic information about the *intensity and estimated onset time of expected flare eruptions*. Also, we further probed the concept of the WG_M method, by applying it to magneto-hydrodynamic (MHD) simulations modelling solar-like flares (Korsós et al. ApJ 2018a). The two flare precursors of the WG_M method were identified before every simulated flare occurrences in the simulation data.

Based on the above encouraging results, we now propose to compare the applicability of the WG_M method with that of the widely applied magnetic helicity flux ($\phi=dH/dt$) calculation method put forward by Ye et al. AdSR (2018). Our motivation is that the WG_M method is only applicable if the AR has a δ-spot. However, the ϕ-method is applicable to any AR. Therefore, the application of the ϕ-method may be more convenient because we do not have

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the restrictive δ-spot criterion. The helicity (*H*) itself is at the heart of several MHD relaxation theories, with applications to e.g. flare and CME eruptions. The conservation of *H* defines a constraint to the magnetic field evolution, in particular, a stressed magnetic field with finite total *H* cannot relax to a potential field. Accumulation of *H* above this upper threshold would result in non-equilibrium, eventually ending up with the expulsion of the excess of *H* as a flare or CME. We have already investigated and preliminary tested three ARs jointly with the WG_M and ϕ methods days before the eruptions (Ye et al. AdSR 2018). There, we clearly identified and confirmed a similar pre-flare behavior pattern of ϕ itself just as of the WG_M method has. We conjecture that this common pre-flare behavior pattern could be very practical tool of the ϕ-method for the flare onset time estimation, like in the case of WG_M method.

Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)

Magnetic helicity is a physical quantity that may capture information about the topology and complexity of the magnetic field structure of an AR. Furthermore, magnetic helicity plays an important role in the solar activity, but, it is not yet found to be effective to use it alone for the purpose of flare prediction (see e.g. Pariat *et al.* 2017, and references therein). Therefore, there is a natural task to find a way to better characterise the evolution of helicity injection inside an AR and turn this information into a practical tool in the context of flare forecast.

In this three months period, we found that the Helicity flux has periodicities which are not study before, therefore we changed the direction of the proposed work to reveal differences between flaring and non-flaring ARs . Maybe, the periodic behaviour of the Helicity flux can be useful for a flare prediction. We analysed the periodic behaviour of magnetic helicity fluxes in four different AR cases, but they have similar magnetic structure. These four investigated ARs are: AR 11890, 12192, 11785, and 12645. Among them, AR 11890 was a cradle of 3 X-class flares and one C-class which accompanied with a fast CME. AR 12192 produced six very intense solar flare eruptions, including 5 X-class and one larger M-class flare. Last but not least, ARs 11785 and 12645 had similar activity levels. They both produced only low- energetic flares, e.g. B- and C-class. Therefore, we label these latter as "quite" ARs in this study.

First, we calculated the total, emergence and shearing helicity components of these four ARs by using the Differential Affine Velocity Estimator for Vector Magnetograms (DAVE4VM) algorithm Schuck (2008). The three helicity components were normalised and smoothed by 12- and 24- hour moving averages (MA^{12} and MA^{24}) to remove the 12- and 24-hour artefact oscillations of the SDO/HMI satellite (Liu *et al.* 2012; Kutsenko & Abramenko 2016). Next, we analysed the evolution of the magnetic helicity fluxes to re- veal a distinctive feature(s) between the "flare/CME productive" and the"quiet" ARs.

First, we measured the correlations between the three normalised and smoothed helicity flux curves in the four AR cases. We found that the shearing and total helicity flux components are strongly correlated with $R^2 \geq 0.90$ in the four AR cases. It means that the normalised shearing and total helicity fluxes have a comparable progression in time regardless the activity level of an AR. Furthermore, the emergence component also show stronger correlation level with the shearing and total helicity fluxes, in the case of "quiet" ARs. However ,in the case of "flare/CME productive" ARs, the R^2 is less than 0.50 between the normalised emergence flux and the shearing/total helicity fluxes. From these results we could conclude that the variation of the emergence magnetic flux has much significant role in the flare and CME occurrences than the shearing processes. Next we further analysed the MA^{12} and MA^{24} smoothed data with Fast Fourier transform (FFT). The FFT analysis revealed another distinctive feature between the "flare/CME productive" and the"quiet" ARs. Namely, the "flare/CME productive" ARs have an own common period

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of the normalised emergence, shearing and total helicity fluxes. AR 11890 shows a common strong 27.3 hrs period in 12- and 24-hour smoothed data. Then, the AR 12192 has a 34.9 hrs relevant period in the two smoothed data series of the three helicity fluxes. However, the two studied "quiet" ARs do not show any period after the 24-hour smoothing.

Park *et al.* (2010) investigated the evolution of the magnetic helicity injection rate before flaring, for 378 ARs. They found that a significant helicity accumulation appeared during a phase of monotonically increasing helicity over 0.5 - 2 days. Furthermore, Goldvarg *et al.* (2005) found a 2-day periodicity of the energy release of ARs on a bigger statistical example. These time periods support our 27.3 and 34.9 hrs periodicity finding in the case of two "flare/CME productive" ARs.

Future steps (Max 1000 characters)

1) We are writing the manuscript.
2) We will continue the above study on a bigger data sample

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Date: 31 March 2020 **Signature** Marianna Brigitta Korsós

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Coupling between photospheric and chromospheric processes in different magneto-convective modes of Active Regions

Philip Lindner
Leibniz-Institut für Sonnenphysik (KIS)

Basic Information

Host Institution: Stockholm University (Institute for Solar Physics ISP)
Names of Collaborators: Jaime de la Cruz Rodriguez
Dates of the Visit: 25.10.2019 – 17.12.2019
Mobility completed: (Y / N) Yes

Abstract (Max 500 characters)
Inversion codes are essential for retrieving atmospheric parameters from spectropolarimetric solar data. The main reason for the applicant to use the mobility programme was to learn the STiC inversion code [1], which has been developed by the host. The aim was to apply STiC to data that was recorded at the Swedish Solar Telescope (SST), with the Solarnet ACCESS programme, in April 2019.

Background and Aims of the Project (Max 2000 characters)
The applicant was the PI of a campaign at the SST in April 2019, where a data set showing a pore in a dynamical stage was recorded that includes both photospheric (Fe I 617.3 nm, spectropolarimetry, obtained with the CRISP instrument) and chromospheric lines (Ca IR 854.2 nm, spectropolarimetry obtained with the CRISP instrument, and Ca K 393.4 nm, spectroscopy obtained with the CHROMIS instrument). This observing campaign received funding from the Solarnet ACCESS programme. Especially the Ca K line is difficult to invert, because partial redistribution (PRD) effects are significant in the line formation process [2]. The recently developed Non-LTE inversion codes STiC [1] is ideal for this data set. Although the code is publicly available, documentation and installation experiences for different systems are not as developed as for other codes like, e.g. the SIR inversion code [3]. Therefore, a personal visit was planned to learn how to install and use the inversion code.
The results of the inversion were planned to be analysed in order to gain information about the coupling between magneto-convective processes at different heights in Active Regions. This is the topic of the PhD project of the applicant. The data set to be inverted includes a pore that shows filamentary intrusions, although it does not develop a full penumbra. It is interesting because it shows at least three different types of magneto-convection (elongated granules/filaments, pore, quiet-sun).

Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)
The first step that was taken during the stay was to try compiling STiC on a local computer. With the help of different people from the group in Stockholm, that was achieved after the necessary C/C++ libraries were installed, linked, compiled, and the make-file for the STiC code was adjusted so that it calls the right libraries. The next step was to install STiC on the servers of the home institute (Leibniz-Institut fuer Sonnenphysik (KIS)). This proved to be more complex than expected, because of the different system architectures and the incompatibility of libraries with different versions. In addition, automatic compiling

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and installation programs could not be used, because we were not system administrators. After some discussion and advice from different people of the Stockholm group and the IT support from Freiburg, we successfully installed and ran the STiC code.
Before actually inverting profiles with STiC, the data had to be prepared before it could be given to the code. Intensities of the spectra had to be normalized to cgs units, which was done with a fit to a spectrum from the literature (ATLAS). In addition, the wavelength was calibrated to the ATLAS values using the line-centre wavelengths. The next step was to align the data from the CRISP instrument to the data from the CHROMIS instrument. The two instruments have different cadences, different image scales and there is a shift, rotation and flipping between the datasets, which has to be corrected using pinhole images and wideband images. It was of great benefit to use the python routines and explanations that the group in Stockholm shared with me.
As the STiC code is computationally intensive, single example pixels were inverted at first, which went successful. Step by step, more complexity was added to the inversion by adding additional cycles, trying different numbers of nodes and using different regularization modes. The applicant gained a lot of experience from discussing the results of different setups with the host. Towards the end of the stay an exemplary cutout of the data was inverted (see Fig. 1).

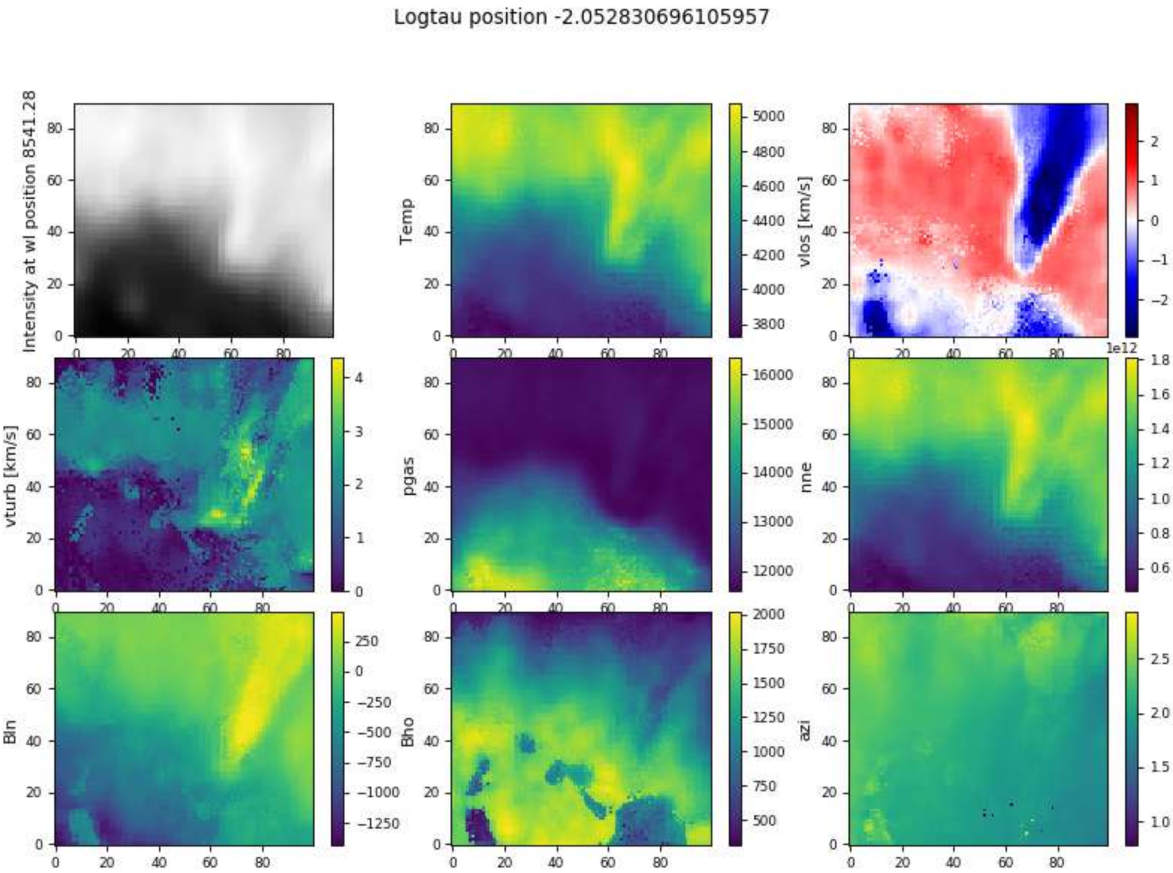

Figure 1 One of the first inversion results from an exemplary cutout of the dataset. The work on the maps is continued.

Future steps (Max 1000 characters)

The next steps after obtaining exemplary maps are to find a setup that decreases salt and pepper noise and still to focus on optimizing the spectral fits. At the moment, the selection of frames and regions of interest is taking place, so that the available computational resources are spent in the most efficient way. Bigger field of views, e.g. the area of the whole pore can be inverted for multiple timeframes. However, this takes a lot of computation time, so investigations and analysis of the polarization signal and Doppler shifts before running the inversions are important. After this is done, maps showing the whole pore will be inverted and analysed. In addition, a side project on quiet-sun project came up that might also profit from STiC inversions.

References

[1] de la Cruz Rodríguez, J., Leenaarts, J., Danilovic, S., & Uitenbroek, H. 2019, A&A, 623, A74

[2] Bjørgen JP, Sukhorukov AV, Leenaarts J, Carlsson M, de la Cruz Rodriguez J, ScharmerGB, Hansteen VH (2018) Three-dimensional modeling of the Ca II H and K lines in thesolar atmosphere. A&A611:A62, DOI 10.1051/0004-6361/201731926,1712.01045

[3] Ruiz Cobo,B & del Toro Iniesta,J.1992,ApJ,398,375

Date: 26.06.2020 **Signature**

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ANALYSIS OF GONG DATA AND SOLAR DYNAMO
MEHTA TRISHTRYA
UNIVERSITY OF WARWICK

Basic Information

Host Institution: National Solar Observatory (NSO), Boulder, CO, USA
Names of Collaborators: Kiran Jain, Sushant Tripathy
Dates of the Visit: 4/11/2019- 13/12/2019
Mobility completed: Y

Abstract (Max 500 characters)

Examining frequency shifts of solar p-modes using Empirical Mode Decomposition to investigate the quasi-biennial oscillation (QBO). Data from MDI/HMI, F 10.7, GONG and the composite Bremen Index was selected to look back at frequency shifts from Cycles 23, 24 (and 21, 22 where high quality data was available).

Background and Aims of the Project (Max 2000 characters)

Global helioseismology allows the internal structure of the Sun to be indirectly probed by examining the brightness or velocity perturbations seen at the photospheric level by instruments such as GONG or HMI/MDI. By examining these surface level phenomena, we are able to speculate on the behaviour of the sub-surface conditions, which will allow us to form a fuller understanding of the Sun's mechanisms. This, for example, could help us spatially confine the Sun's dynamo.

The QBO has been observed in Solar proxies over several solar cycles, perhaps most notably in F10.7cm flux, and has been investigated through global helioseismic methods (for example, see Simoniello et al, 2013[1]). This project partly aimed to improve the quantity of data available by GONG through rebinning procedures that have been pioneered by Dr. Sushant Tripathy[2]. It was hoped that this would allow for a better analysis of the QBO from GONG data. Another aim was to examine p-modes using the MDI/HMI data, of which Dr. Kiran Jain had a great amount of experience[3]. It was thought that the MDI/HMI data could provide extra clarity for ambiguous results seen by the GONG data. Finally, the project also aimed to look at depth and frequency dependence of p-modes on the QBO properties.

Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)

[1] https://iopscience.iop.org/article/10.1088/0004-637X/765/2/100/meta
[2] https://iopscience.iop.org/article/10.1088/2041-8205/711/2/L84/meta
[3] https://iopscience.iop.org/article/10.1088/0004-637X/739/1/6/meta

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During my time at the National Solar Observatory in Boulder, USA, I was able to examine the QBO in great depth. The initial research that myself and Dr. Tripathy started upon my arrival centred on increasing the wealth of data from the GONG instrument, which had a 108 day cadence. Dr. Tripathy was able to rebin the raw data into bins of varying time lengths, from 30 – 360 days. Each data set brought issues when analysed with Empirical Mode Decomposition as often the resolution was insufficient to draw meaningful results from, or my computer lacked the computational power to analyse such high cadence data. Following this exercise, Dr. Jain and I moved onto investigating the QBO using different instruments in order to see if the phenomena observed with GONG was corroborates from other sources.
As a result, we looked into HMI/MDI which produces higher cadence data and yielded a far greater number of solar p-modes than GONG. This allowed for fewer 'gaps' in the data in terms of depth and frequency.
Finally we also examined this behaviour in solar proxies. Proxies have the advantage of several more decades of data compared to MDI/HMI and GONG, and so acted as a useful comparative.

Future steps (Max 1000 characters)

Results of this paper are currently being written up for publication, intended for MNRAS. This investigation has led to further questions concerning other dependencies that may affect the periodicities. Following such a publication, it is expected that these results will be presented at conferences such as NAM and specialist RAS meetings.

References

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Dr. Kiran Jain: kjain@nso.edu

Dr. Sushant Tripathy: stripathy@nso.edu

Date: 14/04/2020 **e-Signature: TAM.**

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SOLARNET Mobility Programme for Young Researchers

Jenny Marcela Rodríguez Gómez
Skolkovo Institute of Science and Technology, Territory of innovation center Skolkovo (Skoltech).

Basic Information

Host Institution: University of Graz
Names of Collaborators: Astrid Veronig
Dates of the Visit: October 31 2019-February 08 2020
Mobility completed: Y

Abstract

Extreme phenomena, specifically, fast CMEs and ICMEs are an important driver in the space weather and their forecast. Complex dynamics take place in the solar atmosphere driving these eruptive phenomena. The relationship between magnetic and kinetic pressure over some regions in the solar atmosphere give clues about the origin of extreme events. We applied the Max-Spectrum and de-clustering methods on CMEs and ICMEs speed time series. Also, we will use the observational data from GREGOR telescope and Hinode spacecraft to obtain a detailed description of plasma β on Quiet Sun regions.

Background and Aims of the Project

Extreme solar phenomena and extreme space weather events are important to understanding the dynamics and variability of the Sun and in our attempts to understand the physical mechanisms behind these events. An extreme space weather event can be manifest itself in as fast Coronal Mass Ejections (CMEs). These fast CMEs can cause fast variations in geomagnetic indexes (Riley and Love, 2017). Multiple CMEs launched from complex active regions are not rare. Ruzmaikin et al. (2011) showed that fast CMEs tend to arrive in clusters. The interactions of successive CMEs happen regularly during the solar cycle. Solar observations reveal that CME-CME interaction occurs from the same active region. The CME-CME interaction can be related to enhanced particle acceleration and cause more intense geomagnetic storms (Lugaz et al.,2017).

The mobility programme of SOLARNET provide me an important opportunity to discuss and analyze the occurrence of extreme events and the high resolution solar observations with the Solar and Heliospheric Physics Group of the University of Graz, led by Prof. Astrid Veroning.

To provide a wide panorama about extreme events and their impact on space weather. For this purpose, we propose to analyze CME and ICME speed time series during solar cycles 23 and 24. Additionally, we propose to estimate the plasma β in Quiet Sun regions through the solar atmosphere. We will achieve these goals in two steps:

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1. Apply the Max-Spectrum and de-clustering threshold method over CMEs speed time series from the LASCO Catalogue (Gopalswamy et al., 2009). Following the extreme event analysis of Ruzmaikin et al. (2011). Also, apply this method in ICMEs speed time series from Richardson and Cane ICME Catalogue (Richardson and Cane, 2010). The main objective is to analyze the relationship between cluster distribution in extreme events and heliospheric disturbances.
2. Obtain the plasma β in different solar atmospheric heights using high resolution data from the GREGOR solar telescope observing time 2019B and Hinode spacecraft.

Description of the research carried out during the visit at the host institution

Together with the Graz group, we developed a code to implement the Max-spectrum and de-clustering threshold time methods. In the collaborative visit, we were applied both methods on CMEs and ICMEs speed time series and we discuss the physical implications of our findings. Also, I applied calibration on Hinode-SP, IRIS, XRT and EIS datasets using Solarsoft because in Solktech I do not have access to Solarsoft and IDL. Additionally, I start to work with the Solarnet project SEP-210489629, data homogenization and Center Limb Variation using data from Kanzelhohe Observatory.

1. Clustering of Coronal Mass Ejections:
We study the clustering properties of fast Coronal Mass Ejections (CMEs) that occurred during solar cycles 23 and 24. We apply two methods: the Max spectrum method can detect the predominant clusters and the de-clustering threshold time method provides details on the typical clustering properties and time scales (Figure 2). We build the time series from the hourly spaced time series of CME speeds from 1996 to 2018 using data from LASCO catalogue[1]. CMEs speeds reveal a non-Gaussian heavy-tailed distribution (Figure 1).

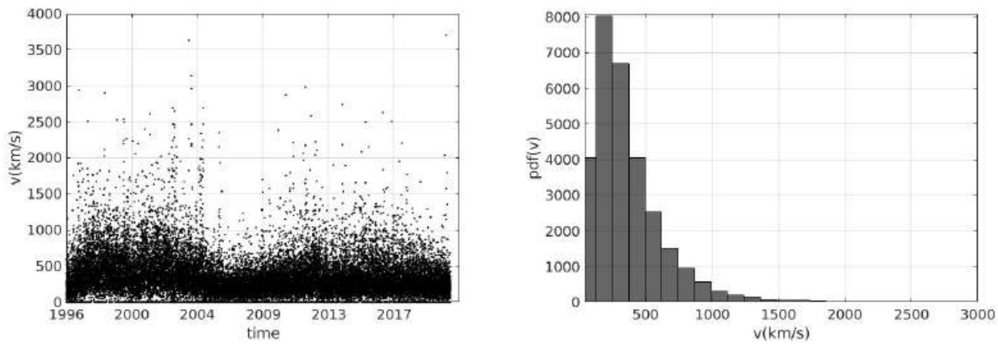

Figure 1. Time series of the CME speed (left) and distribution of the CME speed from SOHO/LASCO catalog for solar cycles 23 and 24 (right).

We found that fast CMEs occur as individual events and in clusters with 2 and 3 members during the whole interval (solar cycle 23 and 24) and during the maximum of solar cycle 23 and 24 and the solar minimum. Additionally, we study the relationship between clusters of fast CMEs and their potential geo-effectiveness by evaluating the geomagnetic Disturbance storm time (Dst) index. We found that

[1] https://cdaw.gsfc.nasa.gov/CME list/

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statistically fast CMEs that occur in close successions in clusters tends to produce larger storms than isolated events.

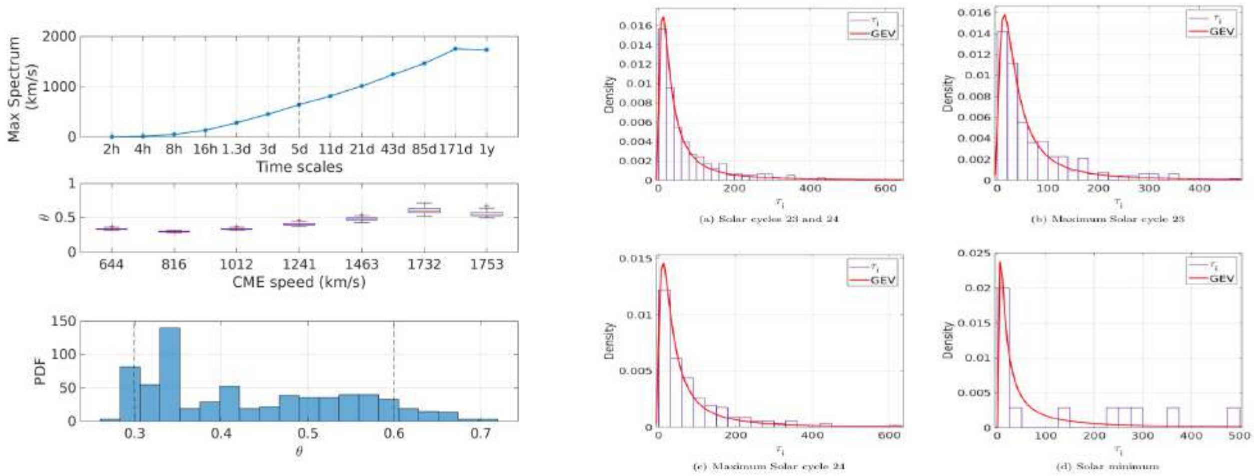

Figure 2. Left: The Max Spectrum method applied to the CMEs speeds during the full period covering the solar cycles 23 and 24. The vertical dotted line indicates the starting scale for the self-similar range (top). Boxplots of the extremal index (θ) obtained by the Max Spectrum method the speed range of 644 km/s to 1753 km/s interval (middle). The histogram of the extremal index (θ), the dotted vertical lines show the 95% empirical confidence intervals (bottom). Right: Determination of the de-clustering threshold time τ_c at each phase of the solar cycle using a threshold velocity $U \geq 1000\ km/s$. Probability Density Function (PDF) and Generalized Extreme Value (GEV) distribution (red line) of time intervals τ_i between consecutive fast CMEs. (a) Solar cycles 23 and 24, derived declustering time $\tau_c = 28.0\ hrs$, (b) Maximum of solar cycle 23, $\tau_c = 28.2\ hrs$, (c) Maximum of solar cycle 24 $\tau_c = 32.0\ hrs$, (d) Solar minimum $\tau_c = 32.5\ hrs$.

Our results were presented on 16th European Space Weather Week. 18-22 Nov, 2019. Liège-Belgium. Additionally, We submitted an article entitled: *Clustering of fast Coronal Mass Ejections during the solar cycles 23 and 24 and implications for CME-CME interaction*s on Astrophysical Journal, December 31, 2019. Now, it is under revision.

2. Clustering of Interplanetary Coronal Mass Ejections

We use data from the ICME catalog (Richardson & Cane, 2010)[2]. In this analysis, we used mean ICMEs speed from May 1996 to September 2018. However the PDF distribution of mean ICMEs speed does not show a heavy-tailed behavior, this is the main requirement to apply the Max-spectrum method. However, It is possible to apply the de-clustering threshold time method (Figure 3). The de-clustering threshold time was applied to ICMEs speeds with $U \geq 500\ km/s$.

[2] http://www.srl.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm

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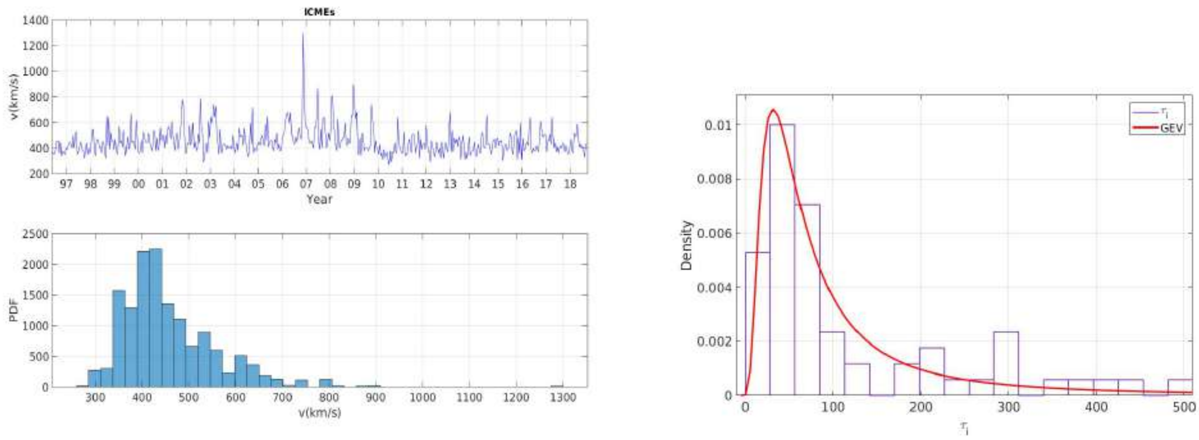

Figure 3. Mean ICMEs velocity from Richardson & Cane catalog from May 1996 to September 2018. Top: Mean ICMEs speed, based on solar wind speed observations. Bottom: Distribution of the mean ICME speed with threshold time τ_c during the solar cycles 23 and 24 correspond to ≤ 41.89 ± 6.62 hrs.

3. The plasma β in different solar atmospheric heights using high-resolution data

I apply calibrations in Hinode-SP, IRIS, XRT and EIS datasets using Solarsoft under IDL. Hinode calibrations from SP4D to SP3D, IRIS data calibrations (level 3), co-aligned XRT data using xrt_prep, eliminate contaminant spots on CCD with xrt_xpotcor and replaces each contamination spot with the median of the pixels at the edge of each spot on data using xrt_tup_contam routine. Calibrate EIS datasets using eis_prep.

Hinode **IRIS** **XRT**

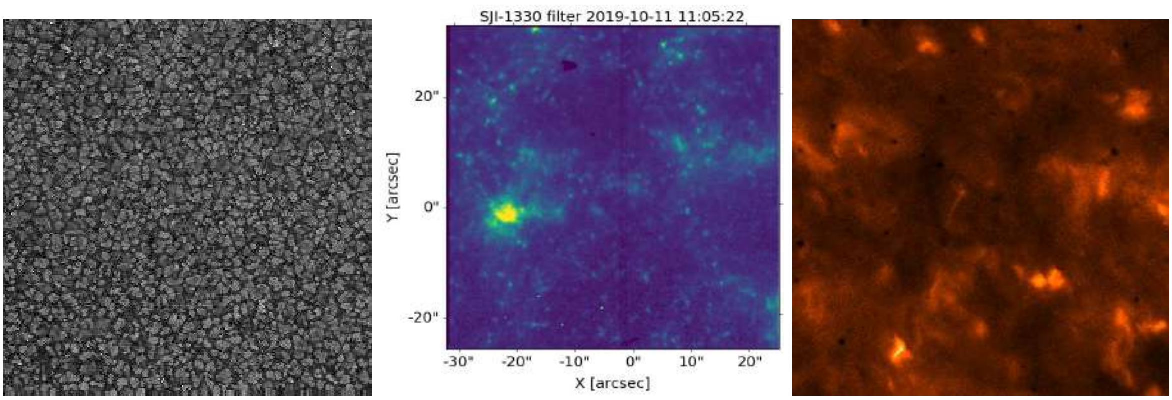

Figure 4. Hinode continuum (left), IRIS SJI-1330 filter (middle) and xrt (right) at 2019-10-11, coordinate observations HOP 381, 2019B.

4. Center Limb Variations

I am involved in the Solarnet project SEP-210489629 from October 2019. During this visit, I started the calculations of Center Limb Variation using data from Kanzelhohe Observatory, Austria. Also, prepare slides with preliminary results to the Solarnet annual meeting in January 2020.

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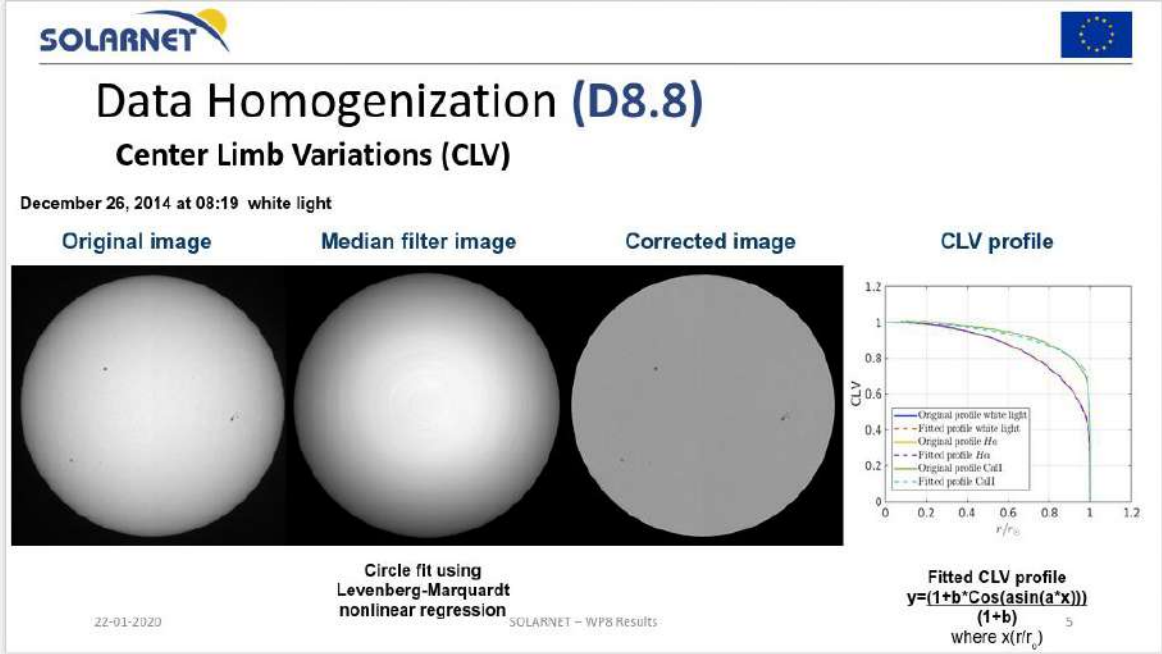

Figure 5. Center Limb Variations (CLV) from Kanzelhohe Observatory data on December 26, 2014, presented on Solarnet annual meeting 2020.

Future steps

- Obtain chromospheric magnetic field from GRIS datasets
- Obtain estimates of density and temperature from HIFI, IRIS, XRT and EIS datasets
- Obtain plasma β in QS regime at different heights in the solar atmosphere
- Write and submit an article about plasma β using high-resolution solar data
- Obtain CLV variations using available datasets from Kanzelhohe Observatory in the frame of Solarnet project SEP-210489629.

References

1. Rodríguez Gómez, J.M., Podladchikova, T., Veronig, A., Ruzmaikin, A., Feynman, J., and Petrukovich, A. 2020, ApJ, under revision.
2. Riley, P., & Love, J. J. 2017, Space Weather, 15, 53, doi: 10.1002/2016SW001470
3. Lugaz, N., Temmer, M., Wang, Y., & Farrugia, C. J. 2017, Solphys, 292, 64, doi: 10.1007/s11207-017-1091-6
4. Ruzmaikin, A., Feynman, J., & Stoev, S. A. 2011, Journal of Geophysical Research (Space Physics), 116, A04220, doi: 10.1029/2010JA016247

Date:

April, 3, 2020

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Flare forecasting

Robertus Erdélyi

University of Sheffield

Basic Information

Host Institution: U of Catania
Names of Collaborators: Prof Francesca Zuccarello
Dates of the Visit: 24 – 31 Jan 2020
Mobility completed: Y

Abstract (Max 500 characters)

Space Weather forecasting is one of the key recently emerged hot topics of solar and solar-terrestrial research. During this short SOLARNET mobility we planned to address i) how we could incorporate ML techniques to improve flare and CME forecasting using EUV images; ii) how the networking opportunity provided by the SOLARNET Mobility helps towards building up a closer collaborative research between the research group at Catania and at SP2RC, Sheffield; iii) and evaluate the outcome so far of a joint research project on incorporating helicity into the WG_M method; iv) work on the draft of a research paper addressing iii).

Background and Aims of the Project (Max 2000 characters)

There is now a considerable community effort devoted to predict the physical parameters in the interplanetary space, especially in the near-Earth plasma environment. The interaction of solar magnetic activity (or its consequences) with Earth’s upper atmosphere can be rather hazardous or even fatal. Therefore, developing a potentially reliable and accurate Space Weather forecasting tool is crucial.

In particular, using the opportunities provided by SOLARNET we requested to support 1-week mobility activity in order to collaborate on this problem with Prpf Zuccarello and her research group. The aims are briefly outlined in the Abstract above, i)-iv).

Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)

We i) discussed and evaluated how we could incorporate ML techniques to improve flare and CME forecasting using EUV images (see e.g. the controversial work by Kim et al Nat Com 2019). This is a very important task as our technosphere is rather vulnerable to space weather events. We already began to evaluate the implementation of supervised binary classification and regression ML techniques applied to study and generate 3D extrapolated magnetograms of ARs. ML models are employed because they are more powerful than traditional statistical techniques for complex nonlinear systems. During the mobility visit, w further discussed some aspects.

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Next, ii) we discussed how to exploit the networking opportunities provided by the SOLARNET Mobility towards building up a closer collaborative research between the two research groups involved, i.e. the research group at Catania and SP2RC at Sheffield; iii) We have began and progressed also evaluating the outcome of a joint research project on incorporating helicity into the WG_M method; Last but not least, iv) we worked on the draft of a research paper addressing iii). A manuscript was drafted and it is expected to be submitted in due course.

Some specific tasks are now completed:
T1 Assessment of the forecast sensitivity of the shortcomings of standard supervised binary classification-based (e.g multi-layer perceptrons, support vector machines, and random forests) ML models. The optimal ML model is now trained for using the precursors of the WG_M and ϕ-methods, by labelling whether ARs are/are not flare/CME associated. An initial draft is written up on this project re-visiting Kim et al. Shortcomings of their approach are identified and mitigation plan is put forward. Manuscript is under writing it up.
T2 Investigated and *critically evaluated* the pre-cursor validity of WG_M, ϕ and supervised/regression ML techniques based on the results of *T1.* Paper drafted.
T3 Delivered a research colloquium

Future steps (Max 1000 characters)

- Setting up a formal collaboration framework, sustainably beneficial to both institutions, f.e., explore the opportunities using the Erasmus+ EU instrument. Please note, ther I large uncertainty here as it is unclear what the UK position is because of Brexit.
- Continue the research collaboration initiated above
- Complete write-ups of research paper drafts

References

Korsós M.B. et al., `Differences in periodic magnetic helicity injection behaviour between flaring and non-flaring ARs', 8 pages draft in ApJ style

Liu, J. et al., ` Are AI-Generated Magnetograms from only EUV Images Reliable for Scientific Purposes?', 10 pages draft in Nature Astron style

Date: 26/03/20 **Signature:**

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Automatic Extraction of Polar Crown Filaments Using Machine Learning Techniques

Andrea Diercke
Leibniz-Institut für Astrophysik Potsdam (AIP)

Basic Information

Host Institution:	**University of Graz** **Institute of Physics & Kanzelhöhe Observatory**
Names of Collaborators:	**Prof. Dr. Astrid Veronig & Robert Jarolim**
Dates of the Visit:	**01/03/2020 – 16/03/2020**
Mobility completed:	**N**

Abstract (Max 500 characters)
During my research stay at the University of Graz, I benefited from the groups expertise in synoptic full-disk observations and machine learning. This new collaboration enables us to refine the object detection algorithm prepared at AIP for full-disk images of the Chromospheric Telescope and test it on the long-lasting full-disk Hα image series of the Kanzelhöhe Solar Observatory. In the end, the algorithm should be standardized so that it can be applied to other full-disk Hα images.

Background and Aims of the Project (Max 2000 characters)

In my PhD Project, I work on polar crown filaments and their behavior over the solar cycle with full-disk Hα data from the *Chromospheric Telescope* (*ChroTel*), Tenerife, Spain. The data covers in total eight years from 2012–2019, which is more than half of a solar cycle, whereby the observations started around the maximum of the Solar Cycle 24. We started to use the nearly 1000 observing days to automatically extract and analyze filaments, in particular polar crown filaments with morphological image processing (Diercke & Denker 2019). But because of insufficient results, we explored the possibilities to use deep learning techniques to extract fully automatically and reliably filaments from the full-disk Hα images. The first results with a supervised deep learning algorithm are very promising, however, not all filaments were detected, which could be caused by an insufficient amount of data. To produce better results with the object detection algorithm, more labeled input data is required. The University of Graz and the *Kanzelhöhe Solar Observatory* (*KSO*) hosts a large data base of full-disk Hα images which dates back to 1973, covering five solar cycles including a labeled data set of filaments (automatically segmented using the method of Riegler et al. 2013). For analyzing polar crown filaments it is of utmost importance to gather as many data sets as possible. Because of the comparable resolution, the data set of *KSO* will provide a perfect addition to the *ChroTel* data, which was used so far. The different resolution in the older and newer recorded images of *KSO* were uniformed with deep learning techniques, so that they can be easily adapted to the existing code.

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Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)

I could only carry out two weeks of the five weeks granted by the *SOLARNET Mobility Programme*. At University of Graz, I had access to the *Vienna Scientific Cluster* (*VSC*). To get started, I had to get familiar how the cluster works and how to adapt the object detection algorithm to the infrastructure of the cluster. As a first attempt of an object detection algorithm we used *You look only once version 3* (*Yolov3*, Redmon & Farhadi 2018) with the neural network framework D*arknet*, which has 53 convolutional layers. Our aim is to refine the training with *Yolov3* to get better results. *Darknet* is written in the programming language *C* and it is complicated to make changes in the neural network. Therefore, we used an implementation of *Yolov3* in the *Keras*, an open source *Python* library, to carry out changes in the neural network to improve the results for object detection on filaments. The network is trained with the full-disk Hα images of *ChroTel* and with the coordinates of the bounding boxes where the filaments are located. For *ChroTel*, we have 955 input images and 39782 bounding boxes. The data set is split in a training data set of 763 images and a test data set of 192 images, which were randomly selected. For the first results from the *Keras*-based *Yolov3*, we calculated the *Intersection over Unit* (IoU), which compares the location of the input bounding boxes with the location of the predicted bounding boxes by *Yolov3*. We compared these results with the results obtained with D*arknet*. At the moment the results from D*arknet* are still better, but further changes will be done to improve the results. With this work, we lay a basis for further work to develop an object detection algorithm to extract filaments from solar data.

Parallel to this, we sighted the Hα data set of *KSO*. The next step would be to transfer the data in a format that it can be used as input data for the object detection algorithm.

Future steps (Max 1000 characters)

Still, a lot of work has to be done to get satisfying results for the automatic detection of filaments in full-disk Hα data of *ChroTel*, which will be carried out in the remaining time (3 weeks) of the SOLARNET Mobility Programme. We will refine the training with *Yolov3* to get better results. Afterwards we will test the well trained object detection algorithm on the *KSO* data. A further step is to extract the shape of the filaments from the bounding boxes with a segmentation algorithm based on semi-supervised learning. In addition, the learned techniques and the improved algorithm will be used to detect and extract solar structures from high-resolution images from the GREGOR solar telescope as part of the SOLARNET work package 5.2.3 "Deep learning techniques for automatic identification and classification of solar features in observational data".

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Research results

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Results

Results

We have successfully applied our new inversion code for the radiative transfer equation with magneto-hydrostatic constraints to spectropolarimetric data recorded with the Hinode/SP instrument. The subject of our investigation was a sunspot (NOAA AR 10944) observed on February 28th, 2007 at disk center ($\mu = 0.999$). The analysis was carried out in two distinct stages:

1. In the first one we applied the inversion code FIRTEZ (Pastor Yabar et al. 2019) to fit the observed Stokes vector but employing hydrostatic equilibrium. This yields the physical parameters T, $\mathbf{B}$, etc. as a function of (x, y, τ_c), where τ_c refers to the continuum optical depth. Because hydrostatic equilibrium was employed, the inferred gas pressure P_g and density ρ, are not reliable, and thus a trustworthy conversion between τ_c and z cannot be established.

2. In the second step, we applied our Magneto-hydrostatic (MHS) approach (Borrero et al. 2019) to derive more accurate pressures and densities. An example of $P_g(z)$ and $\rho(z)$ for pixels in the umbra (blue), penumbra (green) and quiet Sun (red) are shown in Figure. 1.

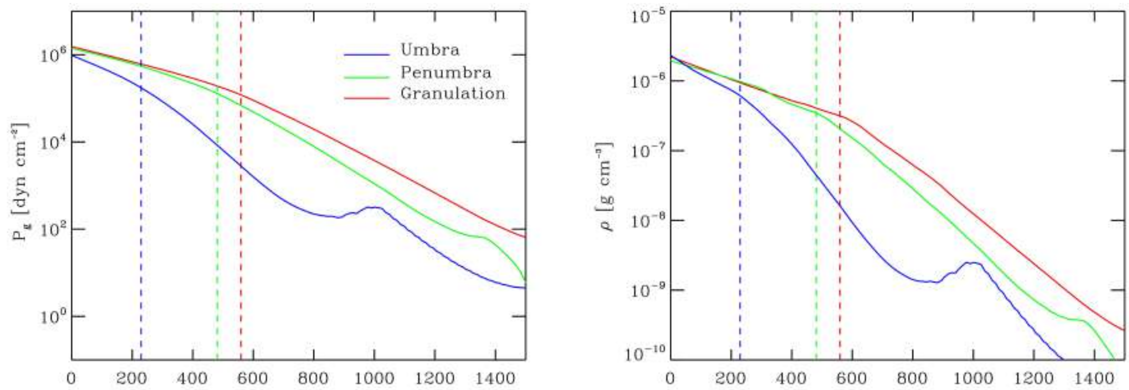

Figure 1: Vertical variation of the gas pressure (left) and density (right) in three pixels in the umbra (blue), penumbra (green), and quiet Sun (red) obtained under magneto-hydrostatic equilibrium. The vertical dashed lines correspond to the position of the $\log \tau_c = 0$-level (i.e. Wilson depression).

As it can be seen, our new method readily provides a Wilson depression (indicated by the vertical dashed lines in Fig. 1) where the $\tau_c = 1$ level is formed about 300-400 km deeper in the umbra (blue) than in the quiet Sun (red).

Figure 2 shows a two-dimensional map of the Wilson depression at every point on the solar surface across the observed region: $z(\log \tau_c = 0, x, y)$. The two panels in this figure show two different applications of our MHS approach. The one on the left spawns from considering the Lorentz-fore term ($\mathbf{j} \times \mathbf{B}$) in the MHS equilibria as inferred from the observations. We note that due the nature of the observations $\Delta x = \Delta y >> \Delta z$ (hopefully with DKIST and EST this will not be the case). Because of this, we have performed an additional analysis where the Lorentz-force term was smoothed vertically so as to have $\Delta x = \Delta y \approx \Delta z$. Results in this case are presented on the right panel of Fig. 2.

In both instances results are very similar, with a Wilson depression of some 400-450 km between the umbra and the quiet Sun. These results are very encouraging, and certainly demonstrate that our method works also with real observations (not only with synthetic data from MHD simulations). We are currently studying the origin of the lower Wilson depression towards the edges of the images and far from the center of the Sunspot. We believe this to be caused by the side boundary conditions we impose to the Poisson-equation that we solve to establish the MHS equilibria.

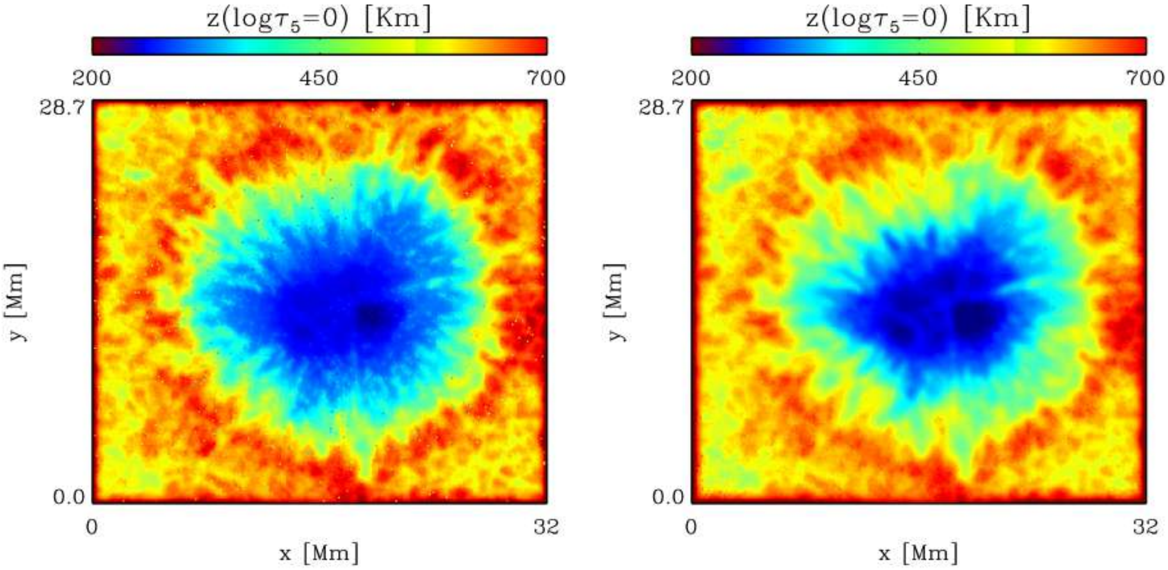

Figure 2: Wilson depression inferred from the analysis (using our Stokes inversion code coupled to MHS constraints) of Hinode/SP spectropolarimetric data of a Sunspot at disk center. The panel panel displays the results obtained by using the Lorentz-force term as inferred from the observations. On the right panel the Lorentz force was smoothed so as to have a more comparable grid along the three spatial dimensions.

Our next step will be to ascertain, now that we have a proper z-scale, whether the magnetic field inferred from the observations is solenoidal. Originally we intended to investigate this during our visit, but unfortunately it was shortened to one week, so we could not achieve all of our original goals. Nevertheless we are very satisfied with the results and we certainly appreciate the support provided by the Solarnet Mobility Programme.

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The radial and lateral evolution of CME fronts and the corresponding in situ ICME signatures

Dr. Mateja Dumbovic
Hvar Observatory, Faculty of Geodesy, University of Zagreb

Basic Information
Host Institution: The Skolkovo Institute of Science and Technology (Skoltech)
Names of Collaborators: Dr. Tatiana Podladchikova (+Dr. Astrid Veronig from the University of Graz)
Dates of the Visit: 8-15.3.2020.
Mobility completed: N (the visit was interrupted by the Covid-19 pandemic)

Abstract (Max 500 characters)
In the scope of the visit a study of the multi-spacecraft remote and in situ coronal mass ejection (CME) signatures associated to radial and lateral evolution of CMEs was partially carried out for a subset of CMEs. The method for robust smoothing to derive the impulsive dynamics of CMEs (radial and lateral velocity profiles) close to Sun was applied. Multi-spacecraft signatures of ICMEs were sought and a number of in situ properties were measured and calculated.

Background and Aims of the Project (Max 2000 characters)
Coronal mass ejections (CMEs) are the most violent eruptive phenomena in the solar system. The modern paradigm is that these are eruptions of the magnetic plasma structures with field lines helicoidally winding around the central axis, so-called flux ropes, caused by magnetic instabilities which trigger their eruption (Green et al. 2018). CMEs are also known to expand due to the pressure (im)balance with the surrounding medium (Démoulin et al. 2008). The kinematics as seen in the coronagraphs includes both contributions from the CME propagation and expansion and in order to understand the radial and lateral evolution of CMEs the two need to be disentangled. The most common assumption about CME expansion in interplanetary space is that they expand self-similarly, i.e. in a way that the plasma element at a later time is a scaled copy of it at some previous time (Démoulin et al. 2008). This assumption is suitable for magnetic structures where the frozen-in condition is preserved and can be applied remarkably well to a number of CMEs. In the in situ measurements lateral expansion can be observed by multispacecraft measurements from longitudinally separated spacecraft, whereas single spacecraft measurements or radially aligned spacecraft provide information on the radial expansion and propagation. The aim of the project is to study the multi-spacecraft remote and in situ CME signatures associated to radial and lateral evolution of CMEs. This research will help us understand if the fast overexpansion (fast lateral expansion) is associated with wide-spread solar energetic particle production.

Description of the research carried out during the visit at the host institution (Max 4000 characters; please add figures if needed)
Under supervision of T. Podladchikova and A. Veronig the Skoltech team performed the analysis of the CME impulsive phase on a subset of events focusing on the sample of well-studied CMEs with low coronal signatures, that occurred during 2010 - 2012, and that were observed on-disk by SDO/AIA, and close to the limb by at least one of the two STEREO s/c (Dissauer et al. 2018; 2019). The method for robust smoothing to derive the impulsive dynamics of CMEs (radial and lateral velocity profiles) close to Sun was developed and applied to those events. Next CME-ICME associations were found using multiple sources: Donki database of the NASA Community Coordinated Modelling Center (CCMC), EU FP7 project HELCATS catalog, Wood et al. (2017) list, Richardson & Cane (2010) list, and SCOSTEP/VarSITI/ISEST catalog. In addition, we compiled information about 3D CME geometry input using multiple sources: Donki database of

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the NASA/CCMC, Wood et al. (2017) list, EU FP7 project AFFECTS catalog of CMEs reconstructed using the Graduated Cylindrical Shell (GCS) model by Thernisien et al. (2006), Sachdeva et al. (2017) list, as well as own performed GCS reconstructions. Drag-based model (DBM, Vrsnak et al., 2013) was next run to see whether or not CME is likely to hit Earth, STEREO-A or STEREO-B (given its geometry) and with which part (head-on, flank).

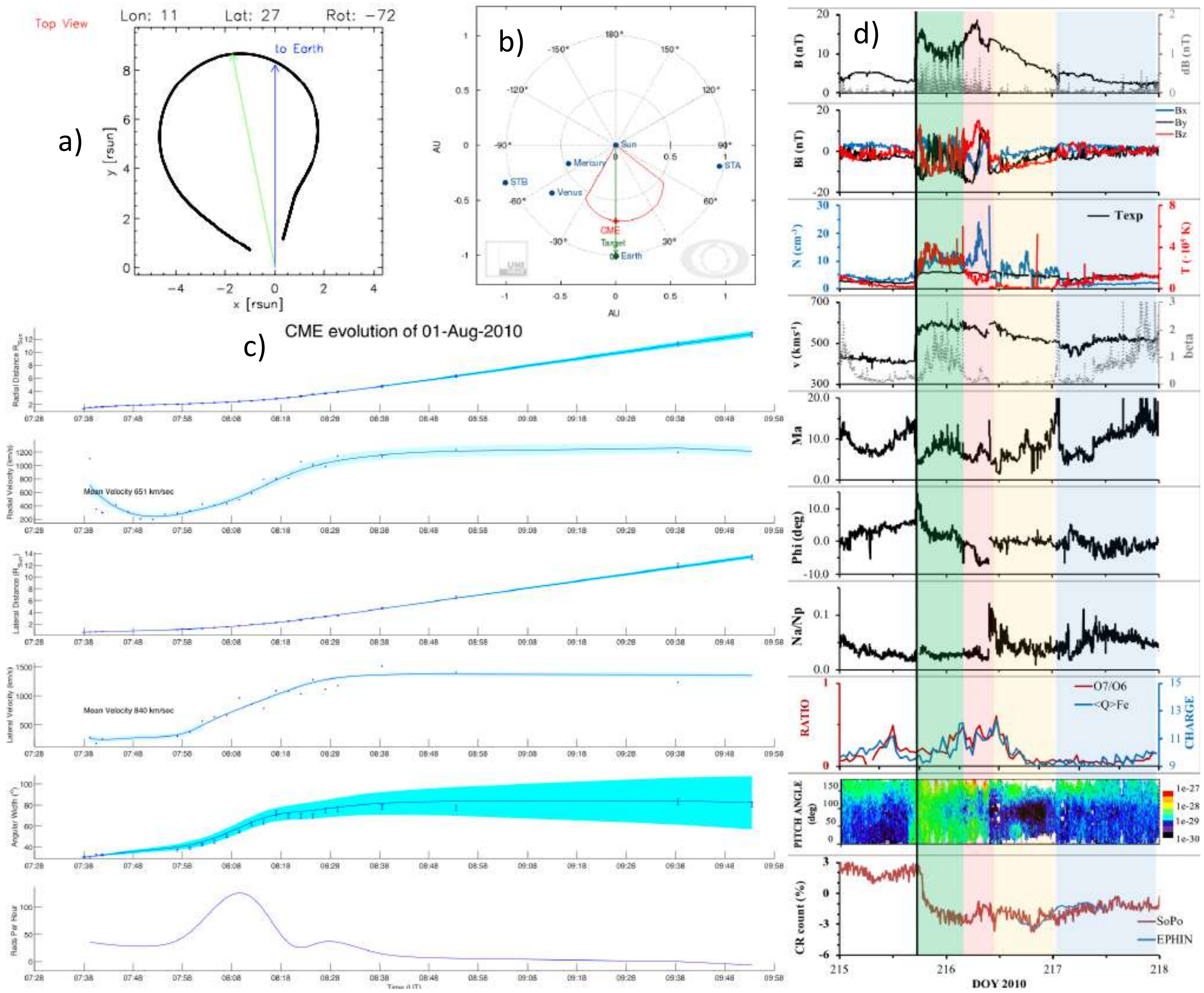

Figure 1 – measurements for the CME that erupted August 1 2010: a) an ecliptic cut of the GCS reconstruction showing the relative direction and opening angle of the CME with respect to Earth; b) DBM results showing relative direction and opening angle of the CME with respect to different spacecraft in the heliosphere; c) measurements of the CME kinematical properties (raw and smoothed; top-to-bottom: radial distance, radial velocity, lateral distance, lateral velocity, angular width, angular width change); d) in situ measurements of the ICME arriving at Earth August 3 2010 (top-to-bottom: magnetic field strength and fluctuations; three components of the magnetic field; plasma temperature and density; plasma speed and beta; Alfven mach number, flow angle, helium-to-hydrogen abundance ratio; O7 to O6 abundance ratio and Fe charge states; suprathermal (193 KeV) electron pitch angle distribution; cosmic ray counts with South Pole (SoPo) neutron monitor and SOHO/EPHIN detector

For events reaching Earth, M. Dumbović performed analysis of multi-spacecraft in situ measurements. The following information was compiled for each in situ event:
- arrival time of the structure and whether or not it is a flank hit
- whether or not the event has several interacting structures and of what type
- whether or not the shock was observed, and if observed - shock characteristics (angle of shock normal to the magnetic field, speed of shock, Alfven Mach number)
-whether or not the magnetic structure was observed, of what type, duration and size, average speed and magnetic field, speed of the leading and trailing edges, radial expansion speed, radial self-similar expansion factor

An example of performed research for the event on August 1 2010 is given in Figure 1. The research was performed in collaboration with Dr. Astrid Veronig from the University of Graz and is related to a very comprehensive ongoing collaborative study of the lateral expansion of CMEs and sources of widespread SEPs. Unfortunately, due to the Covid-19 pandemic, the visit was interrupted and lasted only one week instead of the planned three weeks. The research therefore had to continue remotely at a somewhat slower pace and is still ongoing.

Future steps (Max 1000 characters)

The study will continue remotely and will be eventually supplemented with additional analysis of SEP and radio observations. Cosmic ray data will be analysed in more detail using the ForbMod model (Dumbovic et al., 2018). We discussed employing Kalman filtering to drag-based model (DBM) developed at Hvar Observatory and a student, Kirill Shcherbakov, is working on it. Using Kalman filtering with DBM on heliospheric imager data could significantly improve CME arrival time forecast. This is especially important in the light of the potential L5 mission in future. Finally, we discussed future collaboration using the Parker Solar Probe data to identify and analyse ICMEs/CIRs, which will be performed by a student, Alexandros Adamis. Therefore, this research visit resulted in several joint research project that will ensure a long-standing collaboration between our two groups. We expect several publications related to the research discussed and performed during the visit and after.

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