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Project (Grant) Number:	824135
Project Acronym:	SOLARNET
Project Title:	Integrating High Resolution Solar Physics

Document Details	
Document Title:	Report on networking activities for instrumentation I
Prepared by (Institution's Name):	Instituto de Astrofísica de Canarias (IAC)
Work Package number & Title:	WP2 – Coordination for improved exploitation of solar physics infrastructures sWP2.2 Coordination and dissemination of results sWP2.2.1 Networking for instrumentation activities
Deliverable Number & Title:	D2.11 Report on networking activities for instrumentation I
Serial Number of Deliverable:	D17
Document code: (inserted by project office)	D2.11_Version 1.0
File name: (inserted by project office)	SOLARNET_D2.11_V1.0_NAI_Public_20200707
Date uploaded: (inserted by project office)	July 7th, 2020

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SCIENTIFIC APPROVAL CONTROL FROM SUB-WP & WP LEAD

Control	Name	Organization	Function	Date
Prepared	M. Collados	IAC	WP6 Leader	June 30th, 2020
Prepared	C. Quintero	IAC	EST Support Scientist	June 30th, 2020
Prepared	M. Roth	KIS	WP8 Leader	June 30th, 2020
Revised	R. Schlichenmaier	KIS	EST SAG Chair	June 30th, 2020
Revised	M. Roth	KIS	Project Scientist	June 30th, 2020
Approved	D. Kiselman	SU	WP2 Leader	June 30th, 2020
Authorized	D. Kiselman	SU	WP2 Leader	June 30th, 2020

ADMINISTRATIVE APPROVAL CONTROL FROM PROJECT OFFICE

Control	Name	Organization	Function	Date
Approved	R. Schlichenmaier	Leibniz-Institute for Solar Physics (KIS)	Coordinator	July 3rd, 2020
Authorized	M. Roth	KIS	Project Scientist	July 7th, 2020

HISTORY OF DOCUMENT CHANGES

Issue	Date	Change Description
Version 1.0	June 30th, 2020	Initial Issue

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Table of Contents

List of Abbreviations (if applicable)

FBI	Fixed Band Imager
FoV	Field of View
IFU	Integral Field Unit
OP	Observing Program
PO	EST Project Office
RP	Review Panel
SAG	EST Science Advisory Group
SNR	Signal-to-Noise Ratio
SRD	Science Requirement Document
TBI	Tunable Band Imager

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Introduction

H2020 SOLARNET sWP2.2.1 is devoted to networking activities related to development of scientific instrumentation. These developments are carried out in WP6 and WP8.

For WP6 one is having in mind the options that can provide the most advanced solutions to guarantee that EST achieves its scientific requirements. The most challenging alternatives are progressing thanks to the works performed within WP6, namely in the fields of Integral Field Units (IFUs) and Tunable Band Imagers (TBIs). Fixed Band Imagers (FBIs) will also form part of the suite of instruments of EST and represent minor technological challenges, except for the type of (large-format, low-noise, fast-readout) detectors that they require.

To achieve the goals of sWP2.2.1. and WP6, a close collaboration with the H2020 PRE-EST project is mandatory. Within PRE-EST, two groups have been formed that have relevance for the networking activities described in this report: the EST Science Advisory Group (SAG) and the EST Project Office (PO) team. A number of virtual meetings have been held during this first reporting period to define the instruments that best suit the EST science requirements. The SAG revised and updated the EST scientific requirements and the new version of the SRD was released in December 2019. As a consequence, the requirements for the instruments also needed to be revised, as well as the most efficient light distribution system. These are the most important discussion topics of the meetings described below.

In addition to the SAG and the PO team, two more groups have been established with the goal of making the communication between the PO and the SAG more efficient for the EST instrument definition:

- A Review Panel (RP) formed by experienced European researchers of the EST partners with proven skills in the development and operation of state-of-the art instruments for solar telescopes. The groups working in WP6 have a lead representation in this group.
- A local SAG formed by IAC researchers. The aim of this group is to give advice to the PO on concrete questions that can help clarify the goals, performance and requirements of the instruments.

Finally, three more groups have been created with the goal of defining the requirements of each type of instrument:

- Integral Field Unit developers team
- Tunable Band Imager developers team
- Fixed Band Imager developers team

In WP8 networking is relevant as the development of a new world-wide network of telescopes for synoptic observations of the Sun requires coordination of the activities of the Project partners but also international coordination.

A planned workshop on instrumentation was postponed due to the COVID-19 pandemic. It can hopefully take place during the reporting period 2.

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Networking activities related to WP6

Virtual meetings

Review Panel Meetings

Attendees (some members missed some meetings):

Mary Barreto. Instituto de Astrofísica de Canarias
Luis Bellot Rubio. Instituto de Astrofísica de Andalucía
Manuel Collados. Instituto de Astrofísica de Canarias
Hans-Peter Doerr. Max Planck Institute for Solar System Research
Robertus Erdelyi. Department of Applied Mathematics, The University of Sheffield
Alex Feller. Max Planck Institute for Solar System Research
Luca Giovannelli. University of Rome Tor Vergata
Jorrit Leenaarts. Institute for Solar Physics, Stockholm University
Mihalis Mathioudakis. Astrophysics Research Centre, Queen's University, Belfast
Michiel van Noort. Max Planck Institute for Solar System Research
Miguel Núñez. Instituto de Astrofísica de Canarias
Carlos Quintero Noda. Instituto de Astrofísica de Canarias
Rolf Schlichenmaier. Leibniz-Institut für Sonnenphysik
Peter Sütterlin. Institute for Solar Physics, Stockholm University

Meetings:

1) May 13th.
2) May 20th.
3) May 22nd.
4) May 27th.
5) May 29th.

Local SAG Meetings

Attendees (some members missed some meetings):

Andrés Asensio Ramos. Instituto de Astrofísica de Canarias
Mary Barreto. Instituto de Astrofísica de Canarias
Manuel Collados. Instituto de Astrofísica de Canarias
Sergio González Manrique. Instituto de Astrofísica de Canarias
María Jesús Martínez González. Instituto de Astrofísica de Canarias
Elena Khomenko. Instituto de Astrofísica de Canarias
Miguel Núñez. Instituto de Astrofísica de Canarias
Tanausú del Pino Alemán. Instituto de Astrofísica de Canarias
Carlos Quintero Noda. Instituto de Astrofísica de Canarias
Javier Trujillo Bueno. Instituto de Astrofísica de Canarias

Meetings:

1) May 18th
2) May 25th
3) June 1st

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EST SAG-PO meeting

Attendees (a few SAG members missed the meeting):

Full EST SAG , PO team
and
Shahin Jafarzadeh. Rosseland Centre for Solar Physics
David Jess. Queen's University Belfast

Meeting:

1) June 3rd

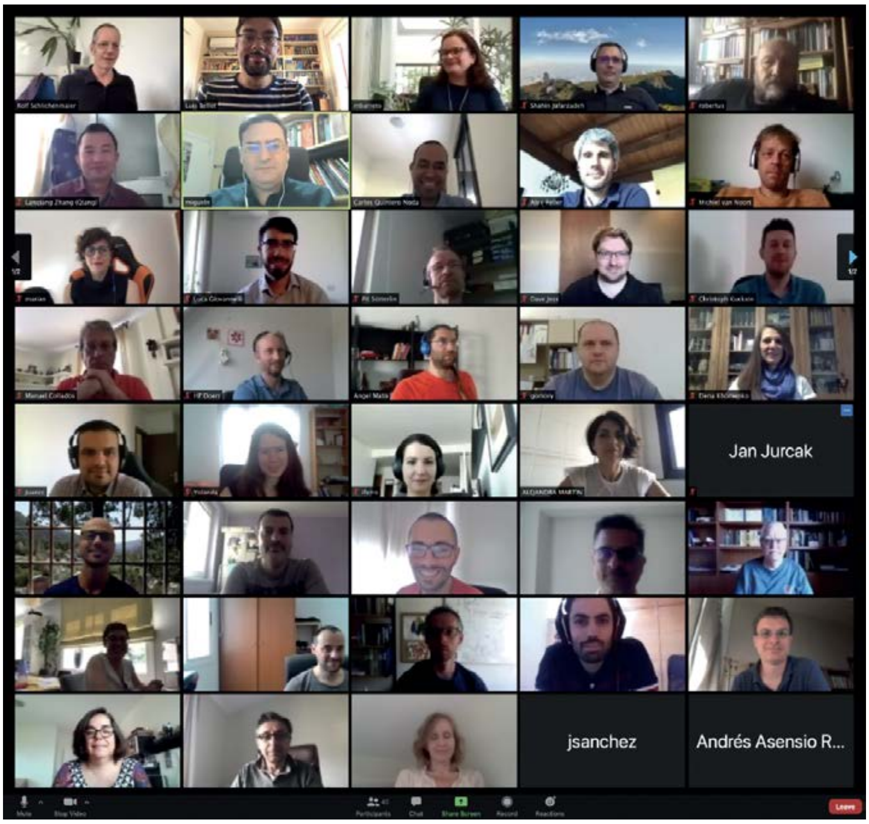

Figure 1. Picture taken during the virtual meeting of June 3rd between the Science Advisory Group and the Project Office. More than 40 people attended.

IFU developers team meetings

Attendees:
Andrés Asensio Ramos. Instituto de Astrofísica de Canarias
Mary Barreto. Instituto de Astrofísica de Canarias
Manuel Collados. Instituto de Astrofísica de Canarias
Hans-Peter Doerr. Max Planck Institute for Solar System Research
Carlos Domínguez Tagle. Instituto de Astrofísica de Canarias
Michiel van Noort. Max Planck Institute for Solar System Research
Miguel Núñez. Instituto de Astrofísica de Canarias
Carlos Quintero Noda. Instituto de Astrofísica de Canarias
Rolf Schlichenmaier. Leibniz-Institut für Sonnenphysik

Meetings:

1) June 12th (IFU group-EST PO).
2) June 30th (IFU group-EST PO)

FBI developers team meeting

Attendees:

Mary Barreto. Instituto de Astrofísica de Canarias
Manuel Collados. Instituto de Astrofísica de Canarias
Ilaria Ermolli. Osservatorio Astronomico di Roma, INAF
Mihalis Mathioudakis. Astrophysics Research Centre, Queen’s University, Belfast
Matteo Munari, Università degli Studi di Catania, INAF
Miguel Núñez. Instituto de Astrofísica de Canarias
Carlos Quintero Noda. Instituto de Astrofísica de Canarias
Salvo Scuderi. Università degli Studi di Catania, INAF
Francesca Zuccarello. Università degli Studi di Catania, INAF

Meeting:

1) June 26th (BBI group-EST PO)

TBI developers team meeting

Attendees (expected):

Mary Barreto. Instituto de Astrofísica de Canarias
Nazaret Bello González. Leibniz-Institut für Sonnenphysik
Francesco Berrilli. Università degli Studi di Roma "Tor Vergata"
Luis Bellot Rubio. Instituto de Astrofísica de Andalucia, CSIC
Manuel Collados. Instituto de Astrofísica de Canarias
Luca Giovannelli. Università degli Studi di Roma "Tor Vergata"
Miguel Núñez. Instituto de Astrofísica de Canarias
David Orozco Suárez. Instituto de Astrofísica de Andalucia, CSIC

Carlos Quintero Noda. Instituto de Astrofísica de Canarias
Rolf Schlichenmaier. Leibniz-Institut für Sonnenphysik
José Carlos del Toro Iniesta. Instituto de Astrofísica de Andalucia, CSIC

Meeting:

1) Scheduled for July 2nd (NBI group-EST PO)

In addition, further meetings in smaller teams were held.

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Main outcomes of the meetings

Prominent topics of discussion were centred on a definition of optical quality that can be common to engineers and scientists, to understand the technical constraints on the size of the central obscuration, to decide how the beam is to be delivered to the instruments, and whether certain requirements can be relaxed to ease technical feasibility. The interaction between the PO and the RP, and the RP and the SAG is crucial to optimise the optical design of EST. The Project Office and the Review Panel started to develop a concept for the light distribution and the suite of instruments, which was later presented to the SAG. First preliminary concepts on light distribution and instrument suite, which are compatible with the SRD, were discussed and approved at the meeting between the Science Advisory Group, the Review Panel, and the Project Office on June 3, 2020, which had more than 40 participants.

Following the Science Requirement Document (SRD) delivered by the SAG to the EST PO in December 2019, a total of 61 science cases are presented in the SRD, with 93 Observing Programs (OP). There, the SAG specified the required measurements in detail, e.g. which wavelength regions need to be observed, what types of instrument should be used, their spatial resolution, their cadences, etc. The information provided by the SRD is essential to define the light distribution system and the instrument suite of EST. This can be done using the OPs as a baseline, trying to satisfy as much as possible the observational requirements. The PO presented the results from a statistical analysis of the OPs and a proposal for the light distribution and the instrument suite of the telescope.

OP statistics

The statistics of the OPs took into consideration the different spectral regions requested in the SRD. The results are shown in Figure 1, where it can be seen that certain regions are much more demanded than others. In particular, the Ca II spectral line at 854 nm is requested in 80% of the observing programs. There are additional lines that follow in popularity, like He I 1083 nm, the Fe I pair at 630 nm, and the Ca II H and K transitions in the blue at 390 nm. In addition, there are various OPs that request to observe those spectral lines at the same time. In particular, the most common scenarios are Ca II 854 nm (in general with He I 1083 nm), together with a photospheric line at 630 nm (sometimes the one at 1565 nm instead) and context images in Ca II H at 390 nm. These results are the baseline for the light distribution system proposed by the EST PO.

Light distribution

Figure 3 shows the light distribution design based on the previous results. The solar light from the telescope comes from the left. Light is divided by a dichroic beamsplitter that sends part of the spectrum to a first arm and the rest to a second arm. This wavelength division is repeated again to create the red and near-infrared arms (top dichroic) and the visible and blue arms (bottom dichroic). The reason for dividing the light in four is based on the results presented in Figure 1. This design allows multi-wavelength observations to be performed. In particular, observers can have access to the Ca II 854 nm and He I 1083 nm lines simultaneously. It also makes it possible to have the most demanded photospheric lines –the Fe I pair at 630 nm– and the requested context chromospheric observations at 390 nm in separate instruments. Therefore, those transitions could be observed strictly simultaneously for the first time ever in any solar telescope.

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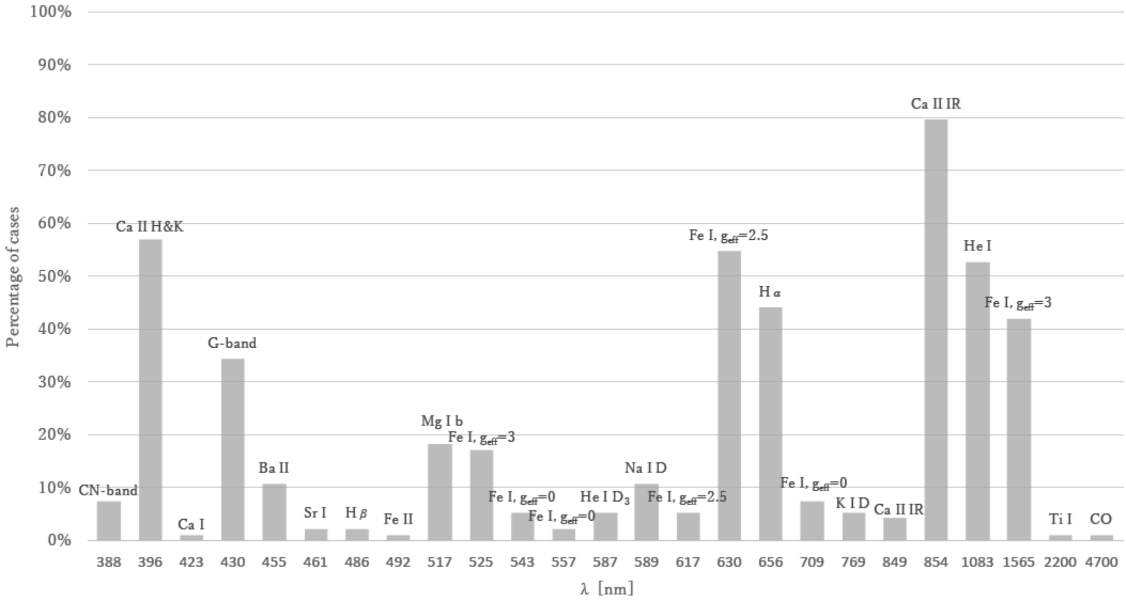

Figure 2: Spectral lines required by the observing programs described in the SRD.

Instrument suite

After designing how the light is distributed in wavelength, discussions were next focussed on the definition of the instruments in each spectral arm. To that end, the OP tables in the SRD were checked again to identify how the community wants to observe the different spectral lines. For the Ca II 854 nm and He I 1083 nm lines, more than 75% of the OPs require an Integral Field Unit (IFU) instrument, while the rest of cases request to observe the spectral lines with Tunable Band Imagers (TBI). A similar ratio of instruments was found for the visible photospheric lines at 630 nm. Thus, it was decided to have one IFU system per arm in the visible, red, and near-infrared. On top of that, a fourth IFU in the blue to perform multiwavelength observations with state-of-the-art IFU systems (orange boxes in Figure 3) seemed straightforward. In fact, EST is going to be the first telescope equipped with one IFU system per spectral region. Currently, microlens arrays and image slicers are the two IFU systems baselined for EST.

The statistics related to the context instruments, the so-called Fixed Band Imagers (FBIs) revealed that most of the OPs request to use FBIs in the blue and visible arms (see Figure 3). Thus, these instruments were considered in those regions only. Since simultaneous observations of the photosphere at 430 nm and the chromosphere at 390 nm are requested, two instruments of this type are allocated in the blue arm, allowing for the possibility of strict simultaneity between these two spectral regions (see the green boxes in Figure 3).

TBI instruments are less requested than IFU systems but these are the only instruments that can provide a large field of view (FOV), e.g. 40x40 arcsec^2, with high spatial resolution, complementing the limited FOV of IFU systems. Aiming to fulfil the seamless multi-wavelength coverage philosophy of EST, it was decided to go for one TBI per arm. Since there was not a strong demand in the infrared arm, neither at 1083 nor at 1565 nm, a TBI was not included in that arm, defining a system with 3 TBIs instead (blue boxes in Figure 3).

Finally, there is a low demand for traditional long-slit spectrographs and this option was rejected for the moment.

Regarding how the light is distributed within each of the arms, a pentagon symbol is included in Figure 3 to represent up to three different possible optical elements depending on the observer's needs. The pentagon

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could be a dichroic beamsplitter (like the white trapezoids) that sends part of the spectrum to one instrument and the rest to the other. It could also be a mirror (or nothing at all), sending all the light to one single instrument. As an alternative option, it could be an intensity beamsplitter that sends the same wavelength range (with a different amount of intensity) to two different instruments. This way, following the EST philosophy, the users are provided with the largest number of combinations possible, not limiting the type of observations that EST will allow. These optical elements will be exchangeable and set up at the beginning of every campaign.

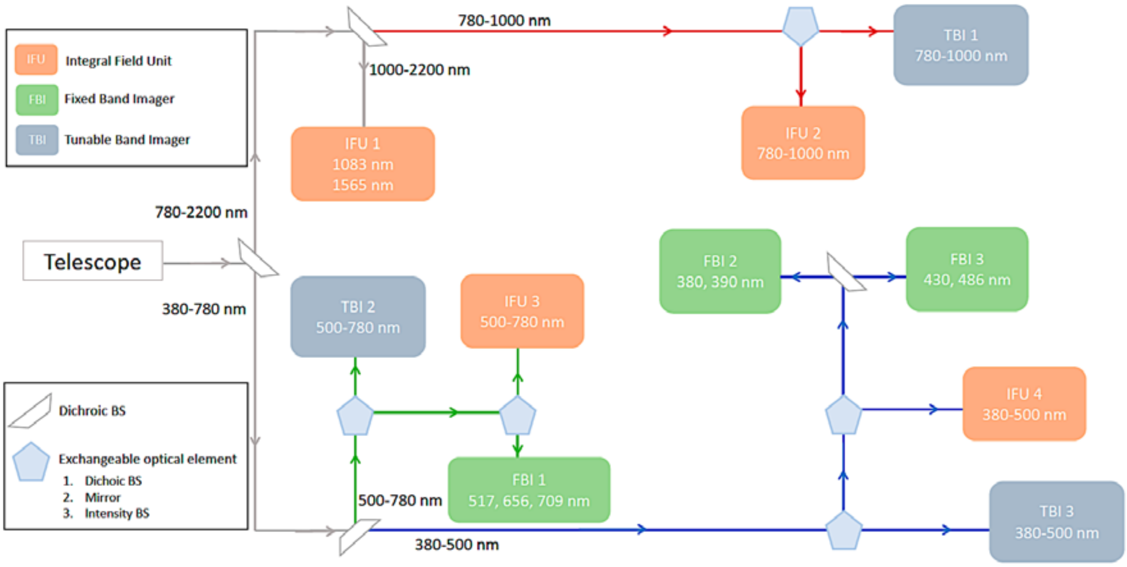

Figure 3. Proposed light distribution system and instruments suite.

IFU developers team

Initial discussions were held around the spatial resolution, field of view (FoV) and signal-to-noise ratio (SNR) of this type of instruments.

The following two options were identified:

a) IFU suite working at the diffraction limit based on the wavelength of highest science impact of each arm

Pros:

1. EST spatial capabilities are pushed to the limit and spatial resolution will be the best EST will be able to achieve

Cons:

1. The FoV will be small, smaller than 10×10 arcsec^2
2. The SNR will be reduced. At diffraction limit, there are not enough photons to go fast.
3. The FoV will be different for the four proposed IFU systems. The smallest FoV will correspond to IFU 4. Thus, the physics that can be done using multi-wavelength observations will be limited.

b) IFU suite working at a fixed spatial resolution for all the systems (for example, the diffraction limit at 1565 nm; this option was the strategy proposed in the SRD of 2011)

Pros

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1. The FOV can be increased
2. The FOV of each IFU system is exactly the same. A proper multi-wavelength analysis is thus favoured.
3. The SNR is larger and, hence, the required SNR for polarimetry in chromospheric lines can be achieved with reasonable integration times.

Cons

1. The impact on spatial resolution is going to be clearly noticeable, mainly in the blue and the visible.

The RP tended to favour option 1 and reach the maximum spatial resolution that EST can achieve. Better SNR can be achieved by binning the data.

MPS, SU and IAC agreed on pursuing these alternatives, either in the form of microlens- or slicer-based IFUs. These developments could form part of the corresponding in-kind contribution by these institutions.

FBI developers team

INAF members (both at University of Catania and Rome) expressed their interest in taking the lead of the optomechanical design, the instrument control and user interphase of the FBIs foreseen in the instrument suite. The Queen's University members confirmed they would like to use the experience gained on DKIST to lead the development of the sensors and the interference filters for the FBI systems.

Since a rough estimation of the instrument's volume is needed to proceed with the design of the telescope's pier, the optomechanical design from the conceptual design phase combined with the sensor information from DKIST cameras will be used. For now, it is assumed that each FBI will have two sensors that could be used for Phase Diversity (PD) reconstruction.

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Networking activities related to WP8

At the beginning of the Project a planning meeting was held in Freiburg on April 29 & 30, 2019. This allowed to coordinate the work and to discuss the concepts: The workshop was split into three sessions dealing with the design of telescopes and instrument platform, the post-focus instrumentation, and the data recording and processing.

The detailed agenda is given below:

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European Commission

Agenda

Monday, April 29, 2019		
09:00	Markus Roth	Welcome & Overview on WP8: SPRING
	Design of telescopes and instrument platform	
09:30	Sanjay Gosain & Dirk Soltau	Review of SPRING telescope concepts
10:00	Alfred de Wijn	GBSON concept
10:30	***Coffee break***	
11:00	Michal Sobotka	Synoptic observations in Ondrejov and the cloud detection
11:30	Discussion	
12:30	***Catered Lunch***	
	Post-focus instrumentation	
14:00	Dirk Soltau	SPRING and HELLRIDE - cont'd - Status and activities at KIS
14:30	Ilaria Ermolli	Instrumentation and data that will be available to the project
15:00	Alfred de Wijn	Coronographs and ChroMag
15:30	***Coffee break***	
16:00	Daniele Calchetti	MOF-based synoptic telescopes for LoS velocity and magnetic fields at different heights in the Sun's atmosphere
16:30	Discussion	
17:30	Adjourn	
19:15	***Dinner***	Kartoffelhaus Freiburg Basler Str. 10, 79100 Freiburg im Breisgau
Tuesday, April 30, 2019		
	Data Recording and Processing	
09:00	Robbe Vansintjan	Plans for Lucky Imaging
09:30	Sabrina Bechet	Data Homogenization
09:50	Astrid Veronig	Automatic Flare Detection at Kanzelhöhe Observatory
10:10	Werner Pötzi	Limb-darkening and flat-field correction
10:30	***Coffee Break***	
11:00	Robert Jarolim	Deep Learning for Multi-Site Solar Observations: from Quality Estimation to Image Reconstruction
11:30	Luis Bellot Rubio	Plans for the Development of the Stokes Inversion Algorithms
12:00	Discussion	
12:30	***Catered Lunch***	
14:00	***Workshop End***	

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The material discussed is available online on the workshop website.

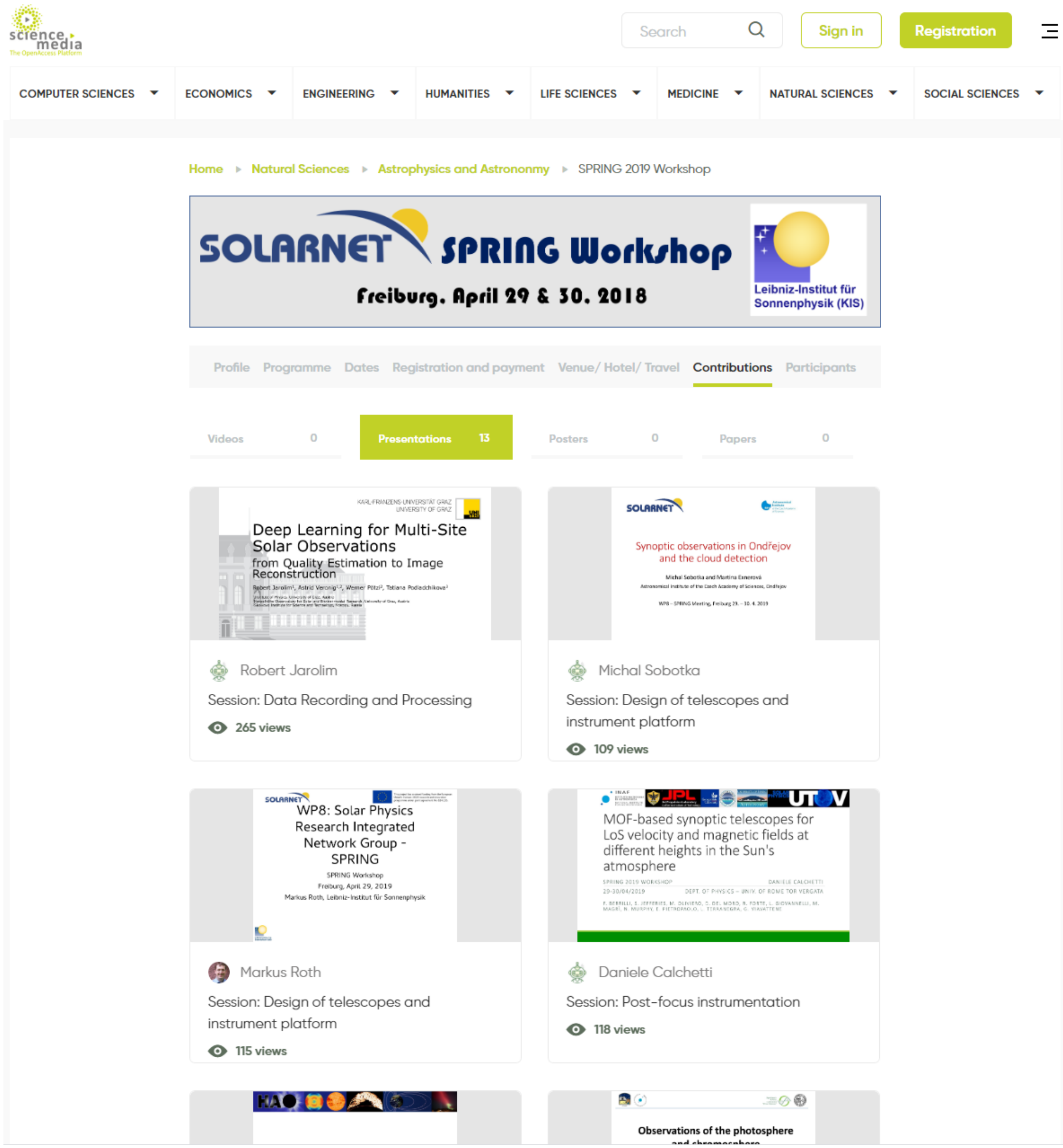

Figure 4. Workshop website with all presentations

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Figure 5. Participants at the WP8 SPRING workshop in Freiburg on April 29, 2019.

Moreover, a videoconference with the US partners took place afterwards on May 15, 2019.

Further details on the SPRING technical concept were discussed at the workshop in Boulder with participants from NSO, HAO, NOAA, and the Airforce on September 26 & 27, 2019 at HAO and NSO in Boulder, USA.

Questions regarding the Fabry-Perot post-focus instrumentation were discussed in Rome on November 26, 2019 between the partners UTOV and KIS. Following this a videoconference focusing on the Fabry-Perot protype instrument HELLRIDE was held on February 3, 2020 with participants from INAF, UTOV, and KIS.

For updating the design for the front-end telescopes, a ZEMAX model for small telescopes was created at KIS in consultation with NSO and HAO, and a meeting to discuss this concept was held on December 18, 2019 in Liège to allow AMOS to start elaborating details.

The original plan to hold a further workshop to discuss the progress in WP8 in May 2020 could not be realized because of the COVID-19 pandemic. Discussions took therefore place in smaller groups online.
A first design concept was discussed again between AMOS and KIS on June 24, 2020 during a video conference.

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