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

Report on WP8: Solar Physics Research Integrated Network Group SPRING

SOLARNET General Assembly

Prague, January 23, 2020

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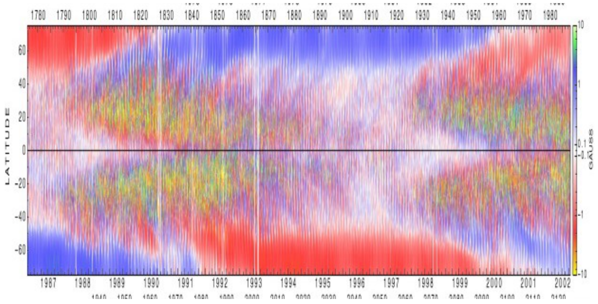
The Need for Synoptic Observations of the Sun

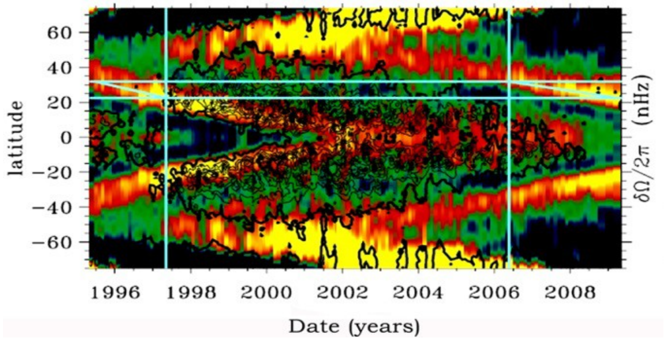
- **Long term monitoring of the solar magnetic fields**
  - to understand solar dynamo
  - evolution with solar cycle (polar and active region fields)
  - Active region evolution for space weather studies
  - surface flows via feature tracking

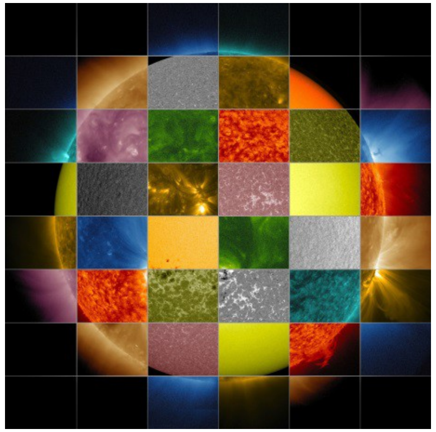
- **Long term monitoring of velocity fields**
  - subsurface flows via helioseismology
  - solar cycle variations and relationship to solar dynamo
  - Flows beneath emerging flux regions and active regions for space weather studies

- **Context imaging for next generation high-res telescopes such as DKIST and EST**
  - Large scale effects (flares, filament eruptions) of small scale events such as flux emergence
  - Technically the fulldisk image could support the pointing system

Current synoptic facilities cannot serve all these new demands!







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Objectives

The objective of this work package is to translate the technical concept for SPRING (Solar Physics Research Integrated Network Group), a new ground-based network of telescopes developed under SOLARNET during the EU FP7 funding period 2013 – 2017, into a preliminary design. The key scientific areas supported by this facility are:

1. Solar awareness (arc-second resolution context images)
2. Synoptic magnetic fields (activity complexes, solar magnetic cycle)
3. Synoptic velocity fields (surface and interior dynamics, wave phenomena, helioseismology)
4. Transient events (flares, active region evolution, space weather)

The next steps required towards building such a network are

- Design of the mounting
- Design of telescopes
- Design and proto-typing of the post focus instruments
- Definition of the data processing pipelines

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Activities

The next steps required towards building such a network are

- WP8.1 Design of the mounting and telescopes
  Partners: AMOS, KIS, AURA, UCAR, ASU, INAF, USFD, UNITOV
- WP8.2 Design and proto-typing of the post focus instruments
  Partners: KIS, UNITOV, INAF, USFD, AURA, UCAR, BDP E&M
- WP8.3 Definition of the data processing pipelines
  Partners: CSIC-IAA, KIS, NSO, INAF, UNITOV, UNICT, USFD, UCAR, ORB,UNIGRAZ, ASU, SKOLTECH

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SPRING Planning Meeting

- Workshop held in Freiburg on April 29 & 30, 2019
- For planning the first steps and discussing concepts
- All material online

SOLARNET SPRING Workshop

Freiburg, April 29 & 30, 2018

Leibniz-Institut für Sonnenphysik (KIS)

Conference profile | Conference programme | Important dates | Registration and payment | Venue, hotel, travel | Conference contributions

Solarnet/SPRING Workshops

Register for conference

SPRING 2019 Workshop

CID: spring2019

Website hosted by: SOLARNET - High Resolution Solar Physics Network
Affiliation: Leibniz-Institut für Sonnenphysik

Organizing institutions: Leibniz-Institut für Sonnenphysik

Main category: Natural Sciences (Astronomy)

Conference/Workshop objectives:
The main objective of the workshop is to organize the tasks of Solarnet Workpackage WP8.

Location:
Freiburg, Germany
Date: 29.04.2019 - 30.04.2019

Conference poster: Download poster here.

Local organizing committee:
Markus Roth

Tirtha Som

Views: 156 | Tweet | Share 0 | Share | Empfehlen 0 | Teilen

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WP8.1 Design of telescopes and instrument platform

One (50cm) telescope is required for precise magnetic field measurements of the full-disk, optimized for wavelengths between 0.38 to 1.56 microns

In addition full-disk imaging telescopes in parallel to provide data in white light and in several wavelength ranges in the blue (3933 – 5434 Angstroms), red (5890 – 6768 Angstroms) and infrared (8542 – 15648 Angstroms)

1. Revisiting the technical feasibility document

   In this context science requirements were discussed at

   - workshop in Freiburg April 29 & 30, 2019
   - videoconference with US partners, May 15, 2019
   - workshop in Boulder with participants from NSO, HAO, NOAA, Airforce on September 26 & 27, 2019 at HAO and NSO

2. Updating the design for the front-end telescopes
   - ZEMAX model for small telescopes done at KIS and in consultation with NSO and HAO
   - Meeting with AMOS on December 18, 2019 to start elaborating details.

3. First thoughts on the pointing strategy were made

WP8.2 Post-focus instrumentation

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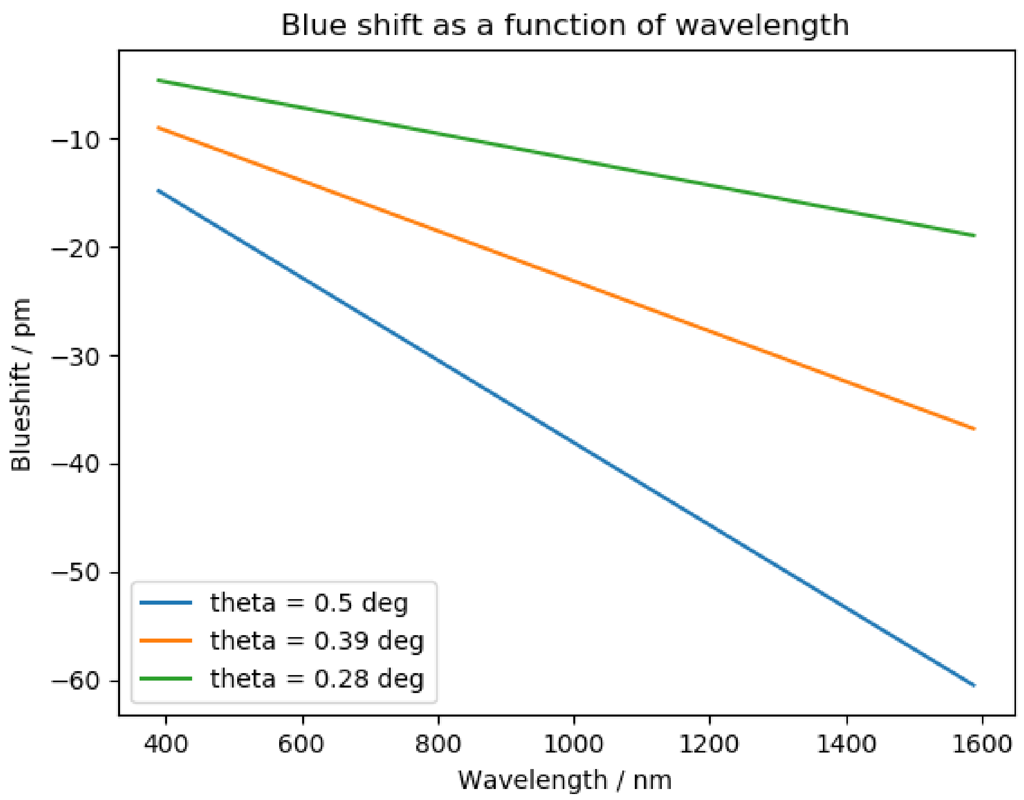
- Creating ZEMAX models for Fabry-Perot system
  - Instruments and detector define the telescope
  - Meeting with ICOS to discuss possible size & environment of Etalons

- Prototype of SPRINGRIDE (FPI-based 2D filtergraph instrument) is ready
  - Setup of Fabry-Perot at the VTT for full-disk observations / various options discussed
    - Collimated mode leads to strong blueshift, which affects cadence
    - Experience with IBIS to be discussed with colleagues at INAF and UTORV
  - Work on concepts for inclusion of polarimeter started
  - Programming the control system for SPRINGRIDE completed
    - First setup was done on Tenerife in June at VTT.
    - Observation campaign scheduled for October 2019. But VTT affected by power failure.



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Science Requirements

		Reference in D80.2
Total wavelength region	400 to 1500 nm	Page 40
Number of spectral lines	10 – 12	Page 40,
Cadence	30 s to several minutes per line	Page 22, 25
SNR per pixel	1400 for CaK and He10830	Page 26
SNRper pixel	320 for Fe6173	Page 27
FWHM of the scan profile	8 pm (corresponding to a spectral resolution between 50000 (@ 400 nm) to 200000 (@ 1600 nm)	Page 26
Image sampling	0.5 arcsec	Page 24
FOV	± 0.28 deg = ± 1000 arcsec	

Signal-to-noise calculations

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Wavelength	$W/m^2/nm$	Photons/px/s D = 250 mm	SNR (50 ms) D = 250 mm	Photons/pix/ s D = 150 mm	SNR (50 ms) D = 150 mm
Ca line center	0.65	9×10^6	700	5.1×10^6	500
Fe 617.3 continuum	1.64	3.5×10^7	1300	2.0×10^7	1000
Fe 630,2 continuum	1.67	3.5×10^7	1300	2.0×10^7	1000
He 1083 continuum	0.61	2.2×10^7	1000	1.2×10^7	800
Fe 15648 continuum	0.27	1.4×10^7	800	7.8×10^6	600

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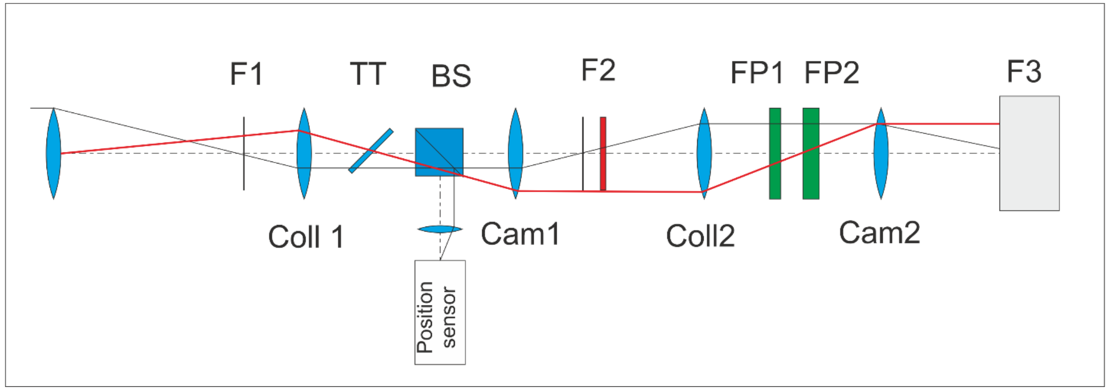
Telescope Parameters

Feature	Remark
Detector: (Andor Balor sCMOS, 4096 x 4096)	Diagonal 70 mm
Diameter = 250 mm	• Up to 50 W heat power enter the telescope. Heat management is an issue • Diameter is determined by SNR and blueshift considerations
Final focal length = 5156 mm	Determined by the detector, here a 50 x 50 mm detector is assumed. Negative Tolerance
Fast tip tilt correction	100 Hz closed loop bandwidth (0dB)
Pupil imaging with D_{Pupil} = 180 mm	Pupil in a collimated beam
Two Etalons in a collimated beam close to a pupil position	The precise dimensions of the air gaps are TBD
Etalons are used horizontally, e.g. light propagates verticall through the etalons	Etalons of this size (180 mm) must be used in a non-movable position and with gravity in the direction of light in order to avoid deformation and loss of parallelism.
Mounting: Alt-Az	We need a vertical light path to illuminate the etalons.



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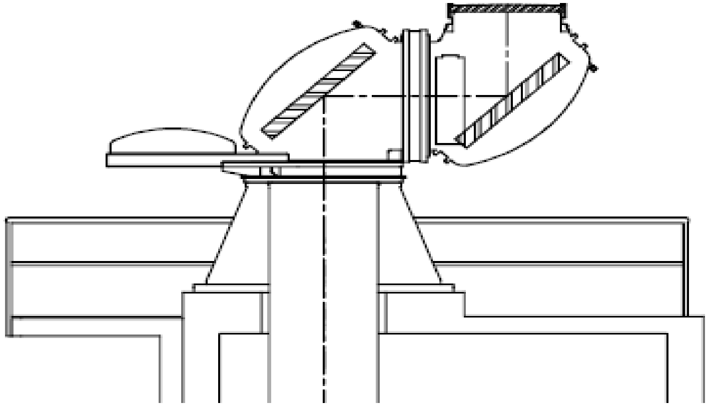
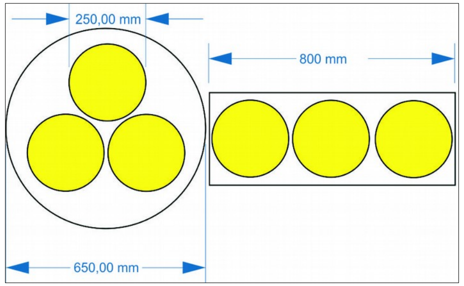
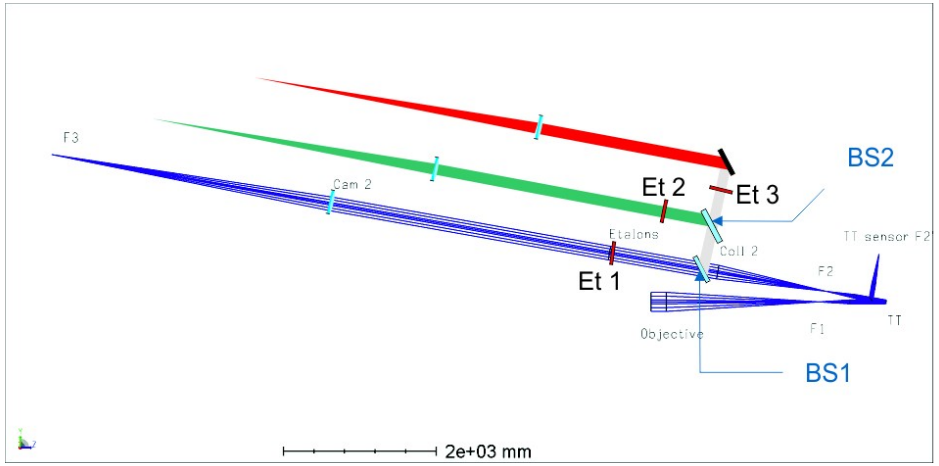
Telescope Mount & Feed

- Original thought:
  Telescope and instruments on common mount

- Now:
  a stationary (vertical) instrument table is suggested, e.g.
  large etalons better be on a stationary platform
  light-feed needed that could feed three telesopes at a time.







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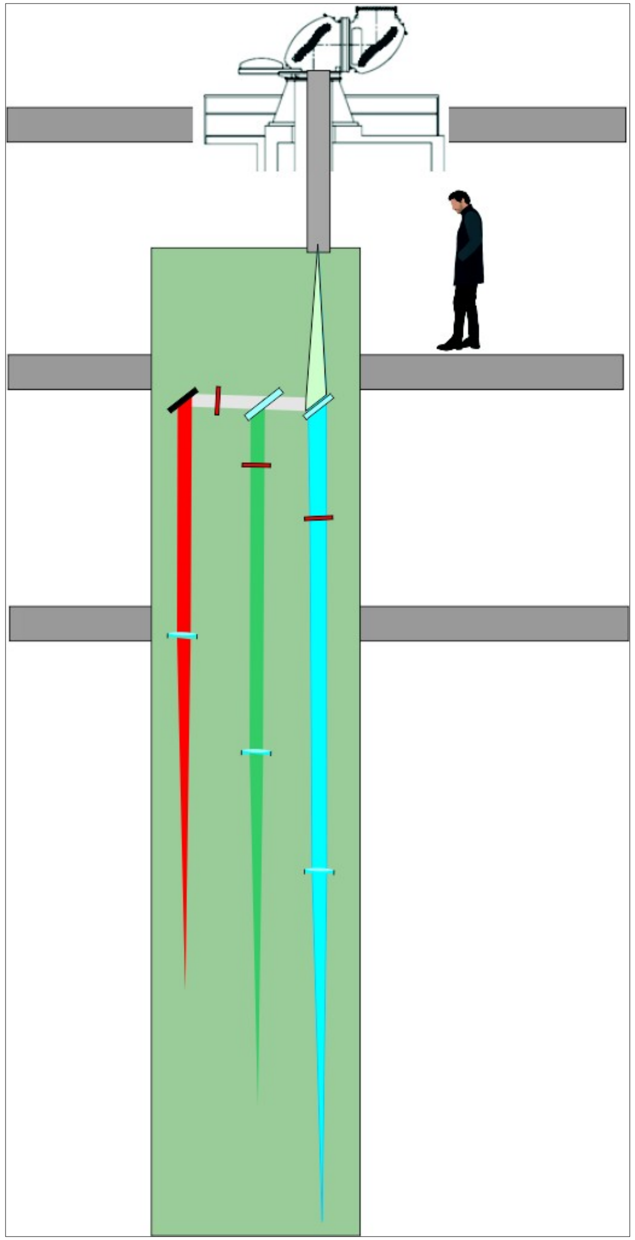
New consideration

- Vertical setup
- Advantage of moving telescope above ground layer seeing (~6 m)

- Extendable observatory
  - 50 cm telescope to be designed
    - Multi-plexed spectrograph
    - Further instruments



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WP 8.3 Data Processing

D8.4 Technical feasibility report on rationale and results of the quasi real-time Lucky-Imaging data-reduction pipeline at ORB (Month 42)

D8.5 Report on Demonstration Platform and results of Lucky-Imaging using multi-instrument data (Month 42)

- Acquisition of a **joined data set** from **KSO** and **ORB** (Obs. campaign)
- Investigation of **Image Stacking** with **Deep Learning**

D8.8 Software for data calibration, data merging (Month 48)

- Acquisition of a **joined data set** from existing **European infrastructure** (campaign & archive)
- Development of **cloud detection** algorithm (ongoing)
- **Solar image enhancement** with Deep Learning (ongoing)
- Programs for data reduction of CLV and global Inhomogeneities (ongoing)

D8.9 Report on rationale and results of the data homogenization and multi-instrument flare detection developed and tested on archival data (Month 30)

- **Flare detection** with **Deep Learning** based on H-α images (started)

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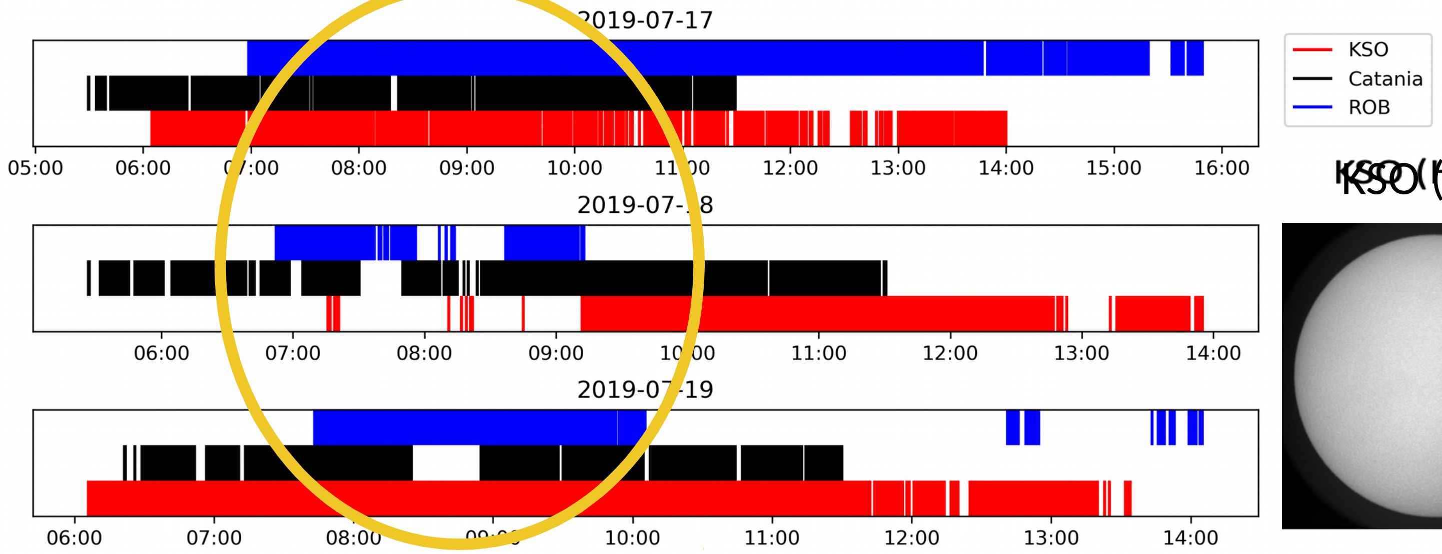
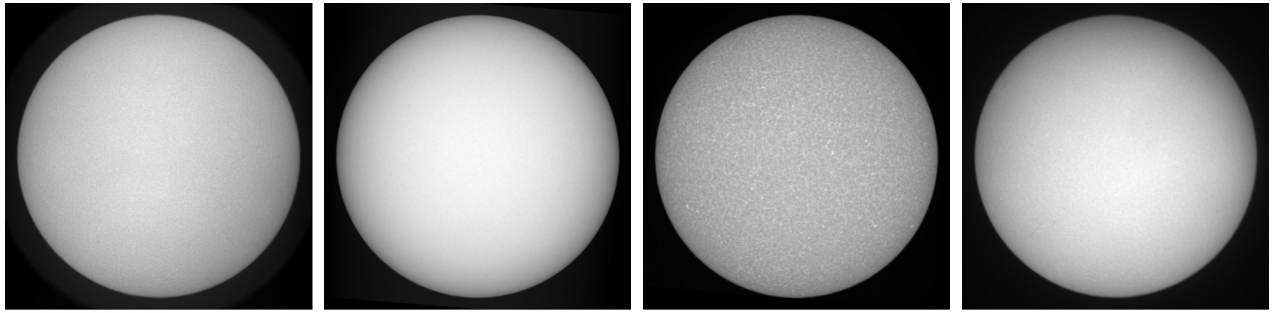
Joined Observation Campaigns (D8.8)

- For the development and testing of advanced algorithms to work with multi-site data a joined dataset with observations from the existing European infrastructure was acquired.
  - Wavelengths: H-α, Ca-II, Whitelight
  - Overlapping observations of 4 observatories between 08/07/2019 – 23/07/2019
  - Publicly accessible data set: http://kanzelhohe.uni-graz.at/download.php



Selected days of the H-α observations from the joined observation campaign

KSO (H-α) | ROB (WL) | INAF (Ca-II) | OACT (H-α)



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Joined Observation Campaign **(D8.8 + D8.9)**

- Preparation of archival data of the existing European infrastructure.
  - Simultaneous high-quality full-disc observations from KSO and ROB.
  - Publicly accessible data set: http://kanzelhohe.uni-graz.at/download.php
- Acquisition of a multi-instrument data set for testing the Lucky-Imaging algorithm:
  - Simultaneous observation from KSO and ROB
  - High cadence mode with up to 4 frames per second

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The joined campaigns

- Summary of past homogenization and Lucky imaging campaigns
  - For homogenization ,
    - Date : 8 – 19 July 2019
    - Participants: USET, Kanzelhohe (KSO), Rome and Catania
    - Three wavelengths (White-light, Calcium, H-alpha)
    - Cadence: 10 s
  - For Lucky Imaging
    - Date : 29 July – 9 August 2019
    - Participants: USET and KSO
    - Three wavelengths (White-light, Calcium, H-alpha)
    - Cadence: up to 4 images per second
- The overlap between observations was relatively small. This emphasizes the need for a network of stations in order to have a good temporal coverage for synoptic ground-based observations.
- There are tentative plans for another joined campaign the last week of January and in the summer of 2020.
- We also plan to further develop the image homogenization in 2020.

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Plans for Lucky imaging

- Development plan for the lucky imaging software:
  1. Build semi-automated prototype of lucky imaging pipeline (e.g., from a directory of fits files, extract 10s intervals and process the images in those intervals.) Parts of the pipeline already exist but need to joined together.
  2. Tune parameters such that both ROB data and KSO data (and data from additional stations in the future) are processed with near-optimal parameters (under different seeing conditions, etc.
  3. Build post-processing pipeline on the lucky-imaging results (restoring image resolution, e.g., via blind-deconvolution techniques)
  4. Define and test algorithm to select 'best' image for a particular time given that multiple stations created data at that time.
  5. Go back to the step 1 and re-iterate.
- We're confident we'll deliver deliverable D8.4 on time.

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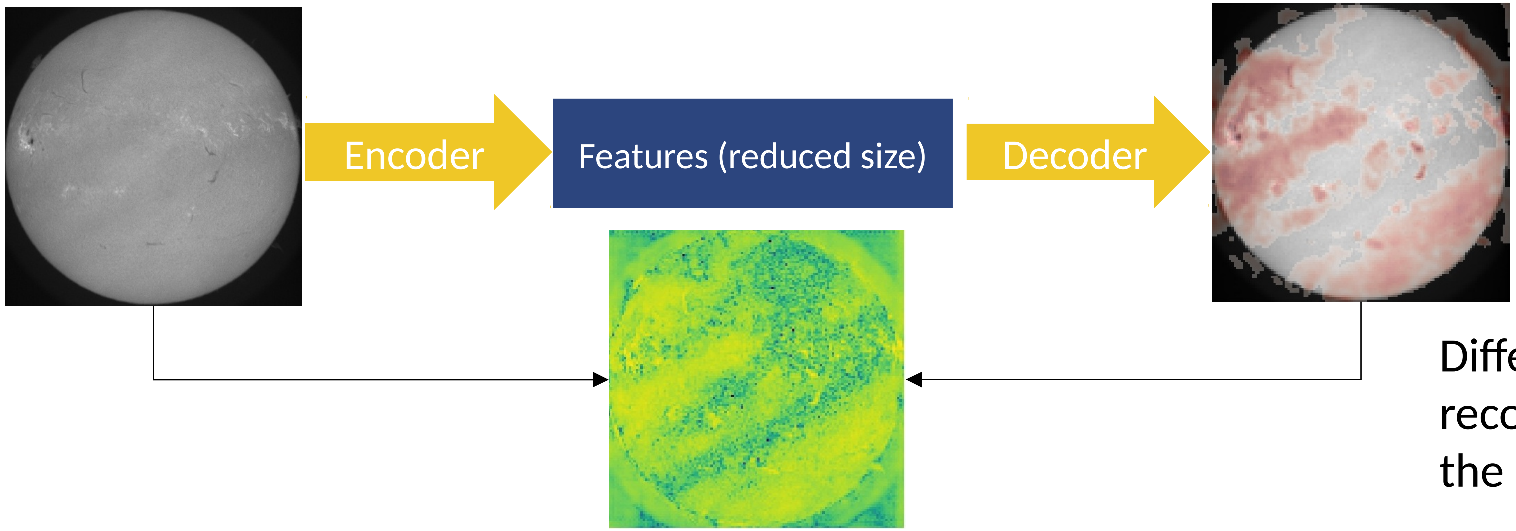
Cloud Detection **(D8.8 + D8.9)**

- For the fully-automated observation with a high cadence, an efficient data post-processing is needed to sustain the quality of the data series.
    - Weak filtering leads to low-quality observations in the data set.
    - Strong filtering reduces the amount of information obtained.
    - The automated detection of large-scale distortions is crucial.
- We optimize existing approaches by a deep learning based anomaly detection.
- The method can be applied analogous across all observation sites.



Difference between the input and reconstructed Image corresponds to the distortion of the observation

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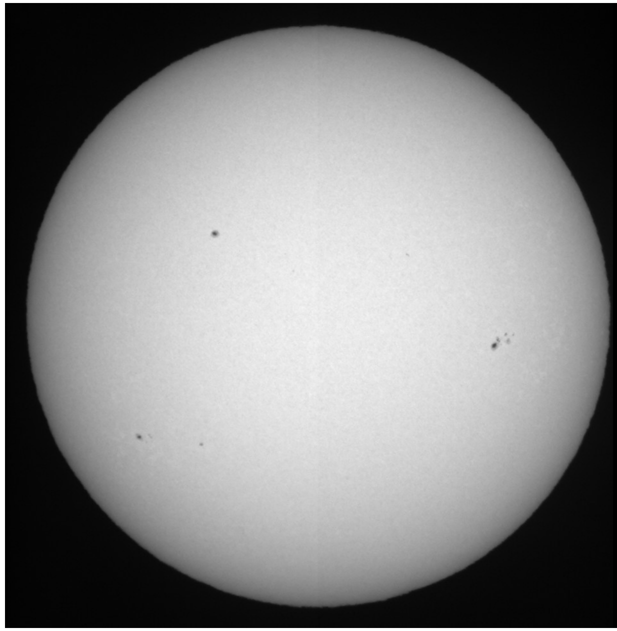
Data Homogenization (D8.8)

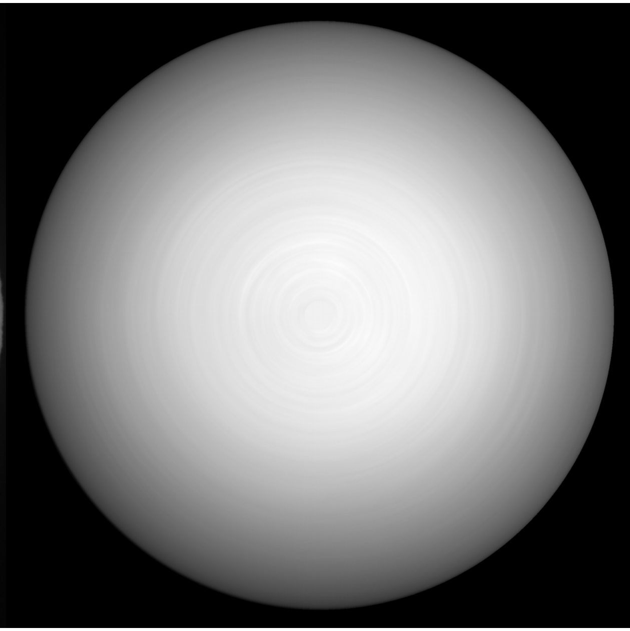
Center Limb Variations (CLV)

December 26, 2014 at 08:19 white light

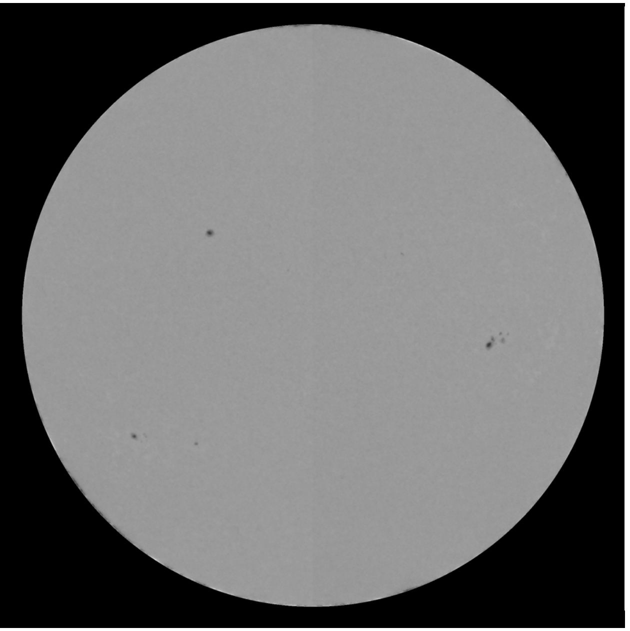
Original image



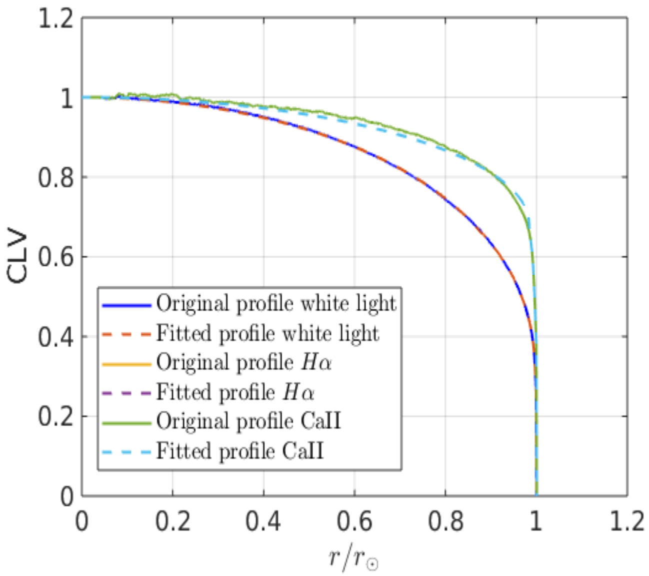
Median filter image



Corrected image



CLV profile



Circle fit using Levenberg-Marquardt nonlinear regression

Fitted CLV profile

$$y = \frac{1 + b \cdot \cos(\mathrm{asin}(a \cdot x))}{1 + b}$$

Data Homogenization **(D8.8)**

Center Limb Variations (CLV) - September 05, 2017

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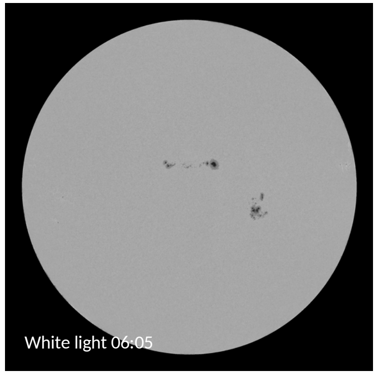
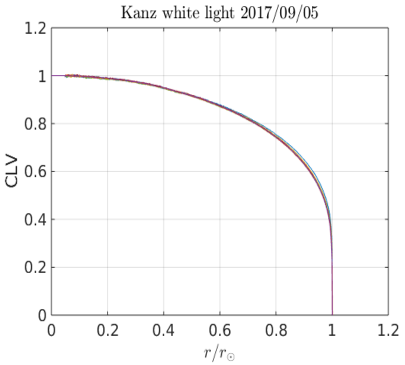
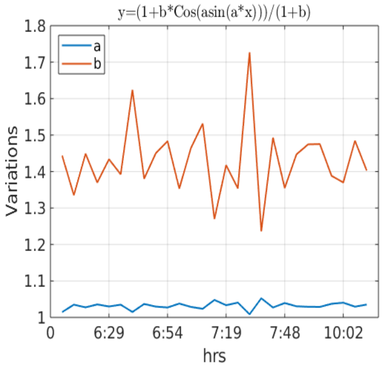
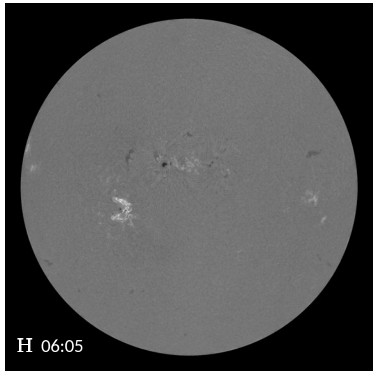
White light

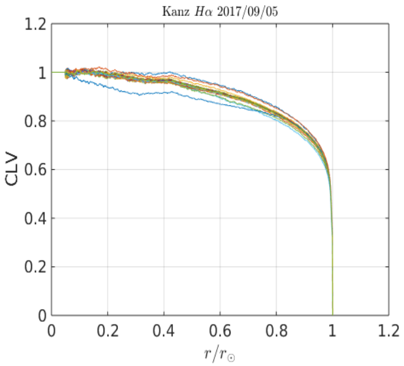


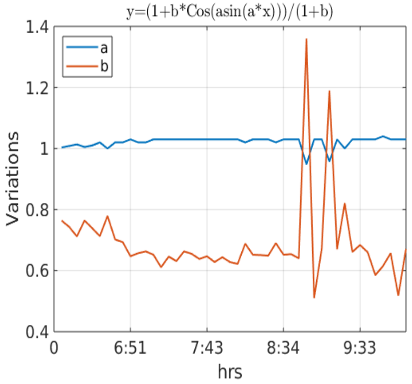




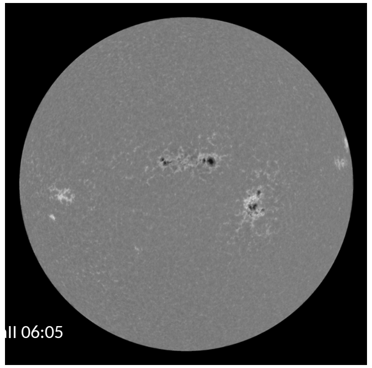
Hα

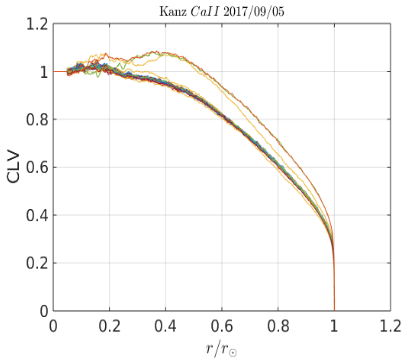






Ca II





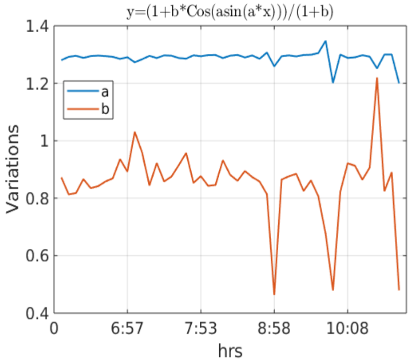


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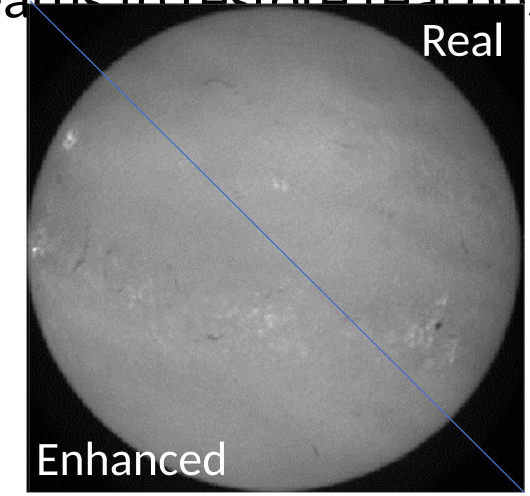
Image Enhancement **(D8.8 + D8.5)**

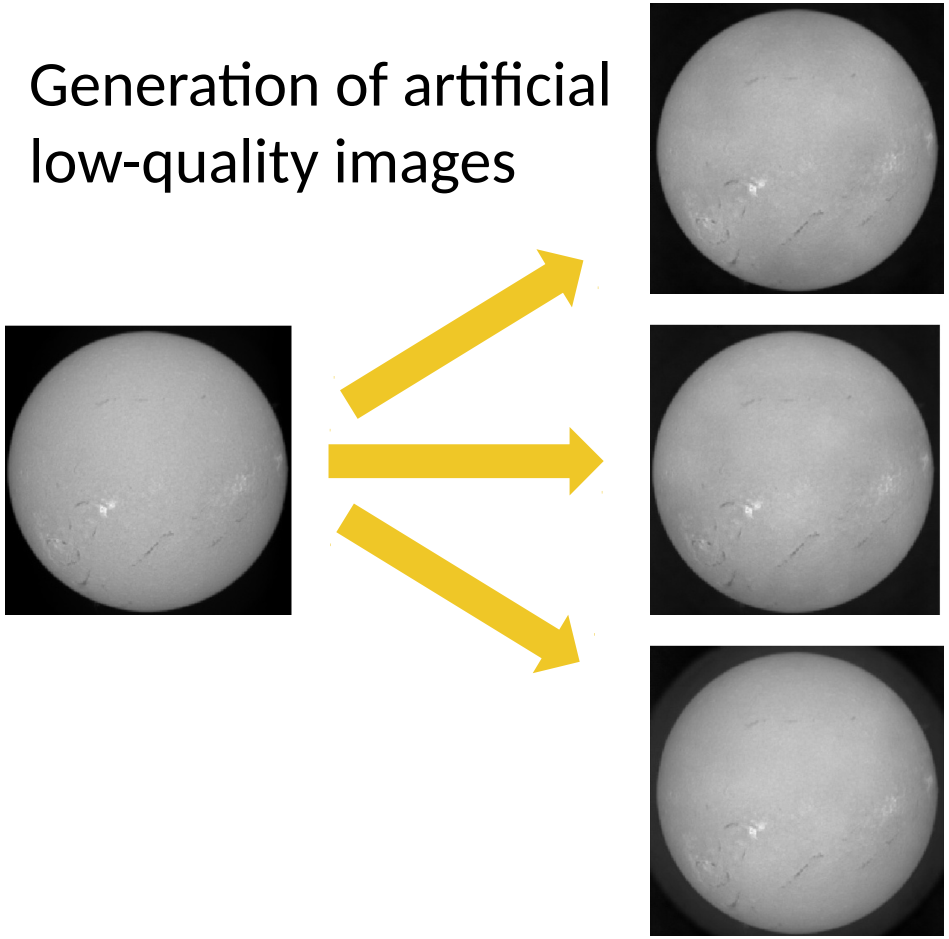
- To preserver the high quality of the data series, deep learning methods are used to recover low-quality images which could otherwise lead to gaps in the series.
- The fundamental problem of image enhancement is the absence of the original high-quality image, Therefore, a neural network is trained to generate artificial low-quality images from high-quality observations. By reverting this process the network learns to restore real observations.



Example of cloud compensation of H-α observations from KSO

Example of cloud compensation of H- observations from KSO

Generation of artificial low-quality images



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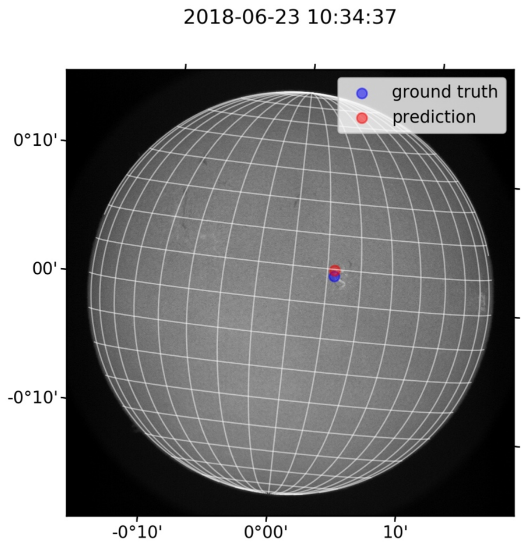
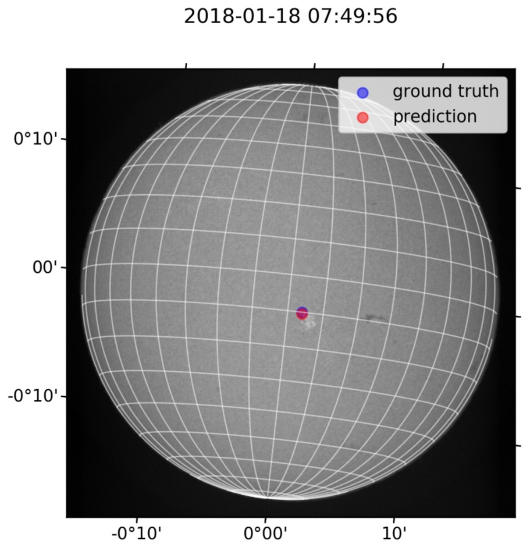
Flare Detection **(D8.9)**

- For SPRING the flare detection algorithm is required to operate in real-time across multiple instruments to provide important context data.
- The existing KSO flare detection algorithm will be reimplemented with a deep learning approach for a more stable detection. A first pilot project has been already established.
- The neural network will be extended by:
  - Learning from a multi-instrument data set
  - Detection based on multiple wavelengths





Results of a first deep learning approach to automatically detect flares

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Acknowledgment

- The authors acknowledge the usage of the Skoltech CDISE HPC cluster (Arkuda) for obtaining the results presented here.
- The computational results presented have been achieved using the Vienna Scientific Cluster (VSC).

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WP8.3.2 Data calibration, Merging and Inversions

- Tasks T4, T5 and T6 accomplished
- C-MILOS: Stokes inversion code developed and tested
  - Based on 1-component ME atmosphere
  - Instrumental PSF taken into account
  - Written in C
  - FITS files for I/O, following SOLARNET standard
  - SIR-like control files, to facilitate use
  - Sequential and parallel versions
  - Parallel code based on MPI
- Publicly available on github
  https://github.com/IAA-InvCodes/C-MILOS

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Inversion speed

Sequential version, one image

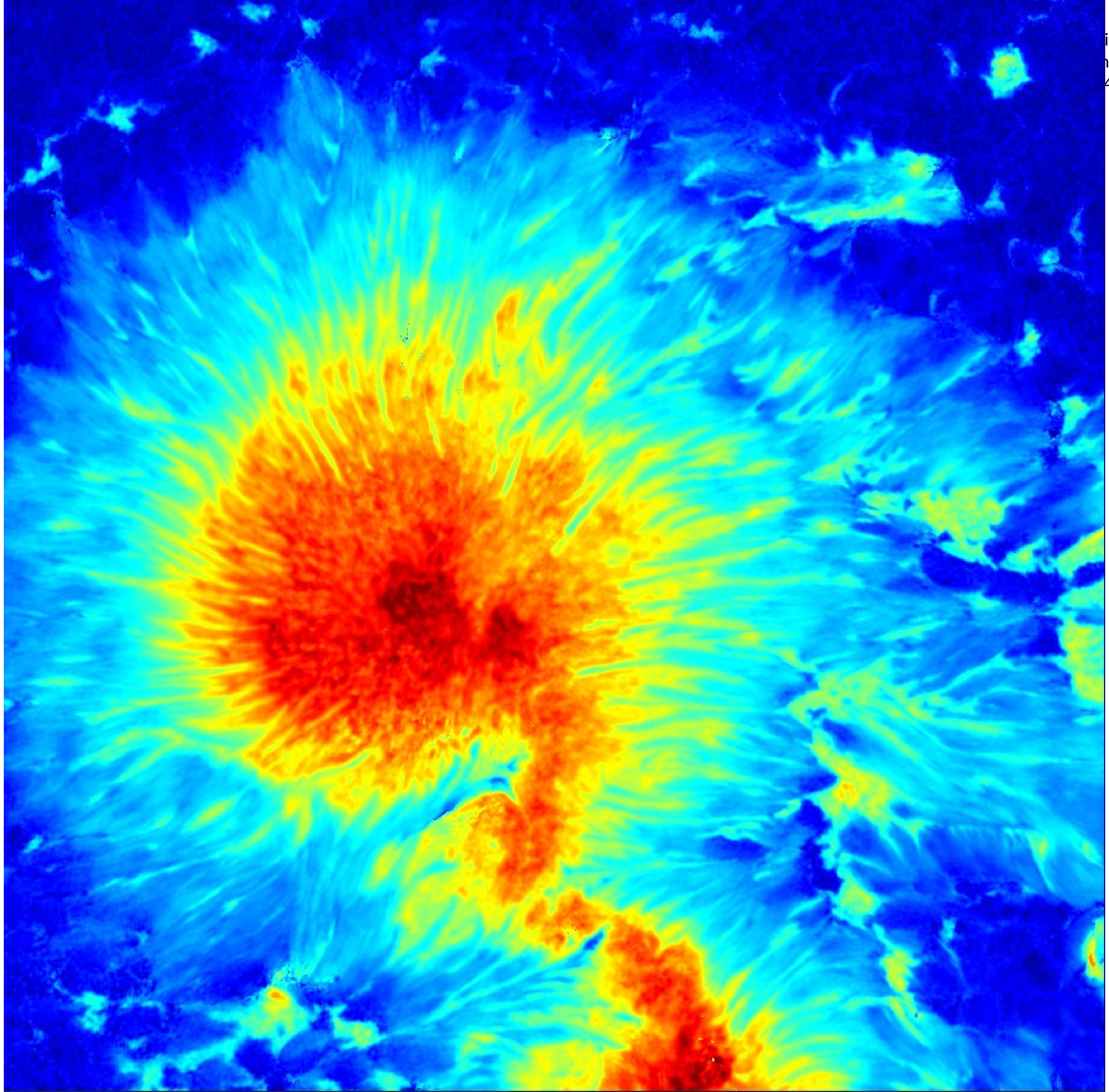
- CPU user time
  - 2526 s
- 312 pixels per second per core

Parallel version, time series of 99 images

- CPU user time per image
  - 2578 s
- 306 pixels per second per core
- Parallelization strategy
  - If #processors > #images one image per processor. For remaining images, each image divided between all processors
- Inversion of 1 image takes 42 s in 64-core server

Time calculated for data cube of dimensions: 894x883x30x4 (x , y, wavelengths, stokes)
Spectral line: Fe 6173 A
PSF: 49,2 mA
Max Iterations: 100

Magnetic field strength (Gauss)



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and innovation programme
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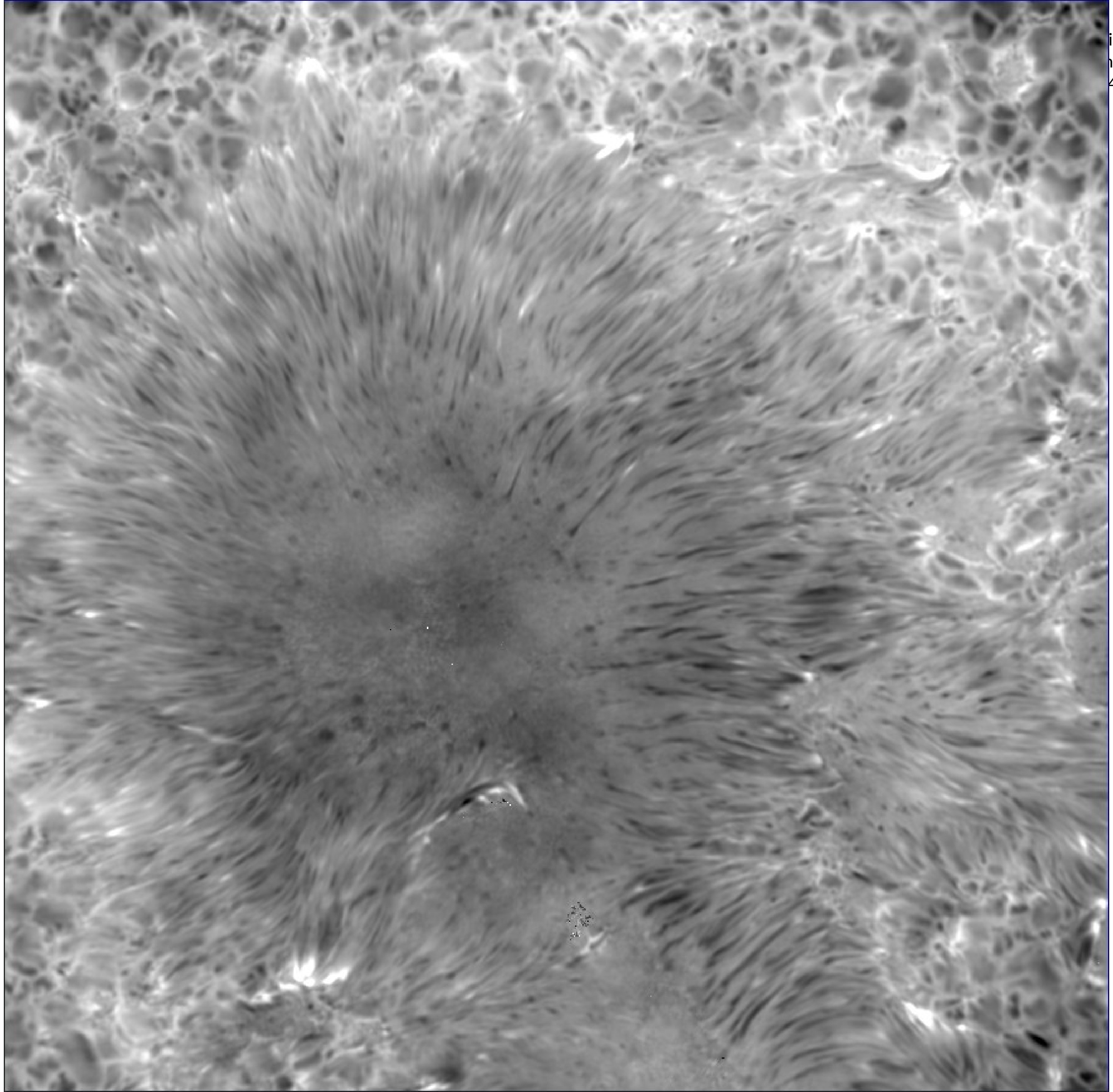
Line of sight velocity (km/s)



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Future work

- Currently, writing documentation for D8.5 (due date M24)

- Continue optimization of parallel code
- Implement and test new parallelization strategies
- Design GPU implementation

SOLARNET

Coordination of International E

- NSO & HAO submitted proposal to NSF in March 2019
  - Asking for a funding of 10 M€ to contribute to the development of SPRING
  - Rejected

- White Paper submitted
  - “Synoptic Studies of the Sun as a Key to Understanding Stellar Astrospheres”
  - in preparation of the Astro2020 decadal survey on Astronomy and Astrophysics by the US National Academy of Sciences

- Further European inititative for a new ground-based network is SAMNet

- US partners would like to have a new network (ngGONG) with coronographic capabilities

Merging all initiatives

-> New proposals to EU (November 2019) & NSF (March 2020)

Astro2020 Science White Paper

Synoptic Studies of the Sun as a Key to Understanding Stellar Astrospheres

Thematic Areas ☒Stars and Stellar Evolution ☒Multi-Messenger A&A

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Abstract (optional):
Ground-based solar observations provide key contextual data (i.e., the “big picture”) to produce a complete description of the only astrosphere we can study *in situ*: our Sun’s heliosphere. The next decade will see the beginning of operations of the Daniel K. Inouye Solar Telescope (DKIST). DKIST will join NASA’s Parker Solar Probe and the NASA/ESA Solar Orbital mission, which together will study our Sun’s atmosphere with unprecedented detail. This white paper outlines the current paradigm for ground-based solar synoptic observations, and indicates those areas that will benefit from focused attention.

SOLARNET

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Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.1	Report on optical and mechanical design of telescope and mounting	35 - AMOS	Report	Public	24
D8.2	Preliminary design for front-end telescope and mounting including schematics	35 - AMOS	Report	Public	42
D8.3	Design for post-focus instrumentation (Dopplergraph and magnetograph)	1 - KIS	Report	Public	42
D8.4	Technical feasibility report on rationale and results of the quasi real-time Lucky-Imaging data-reduction pipeline at ROB	17 - ORB	Report	Public	24
D8.5	Report on Demonstration Platform and results of Lucky-Imaging using multi-instrument data	17 - ORB	Report	Public	42
D8.6	Software for Stokes inversion	9 - CSIC	Demonstrator	Public	24
D8.7	Report on preliminary design of GPU implementation of inversion code	9 - CSIC	Report	Public	30
D8.8	Software for data calibration, data merging	1 - KIS	Other	Public	48
D8.9	Report on rationale and results of the data homogenization and multi-instrument flare detection developed and tested on archival data	21 - UNI GRAZ	Report	Public	30
D8.10	Report on data homogenization of SPRING prototype data and feedback to calibration sub-WP	21 - UNI GRAZ	Report	Public	42

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Thank you!