SOLARNET

5. Nationaler Weltraumwetterworkshop

The Solar Physics Research Integrated Network Group – SPRING

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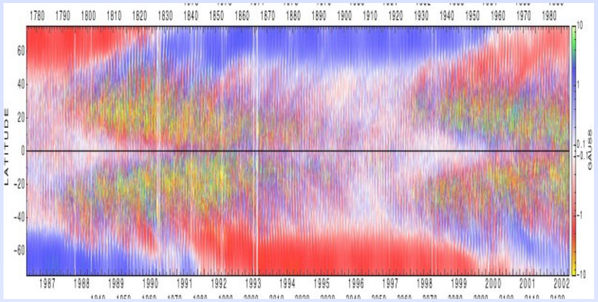
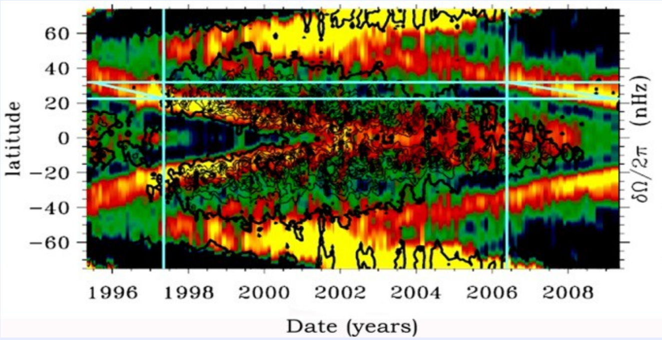
The Need for Synoptic Observations of the Sun

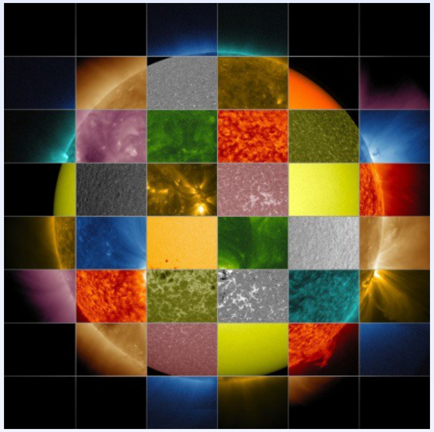
- **Long term monitoring of the solar magnetic fields**
  - to understand solar dynamo
  - evolution with solar cycle (polar and active region fields)
  - Active region evolution for space weather studies
  - surface flows via feature tracking



- **Long term monitoring of velocity fields**
  - Sub-surface 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 a fulldisk image could support the pointing system



Current synoptic facilities cannot serve all these new demands!

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Science Drivers for Solar Physics – Purposes of Synoptic Observations

- **How is the solar magnetic field generated, maintained and dissipated?**
  - **Discriminate solar dynamo models**
  - **Determine the characteristics of angular momentum transport inside the Sun**
  - Observe, identify and characterize magnetic reconnection
  - Determine the role of induction effects near the surface for the global field

- **How are the solar corona and the solar wind maintained and what determines their properties?**
  - Observe, identify and characterize acoustic and magneto-acoustic waves in the upper atmosphere

- **What triggers transient energetic events?**
  - **Determine the role of the interaction of interior flow and magnetic fields**
  - Establish reliable space weather prediction

- **How does solar magnetism influence the internal structure and the luminosity of the Sun?**
  - **Compare the Sun with stars with differ in magnetic activity through asteroseismology**
  - **Determine impact on exoplanet detection and characterization**

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The Many Facettes of Solar Activity

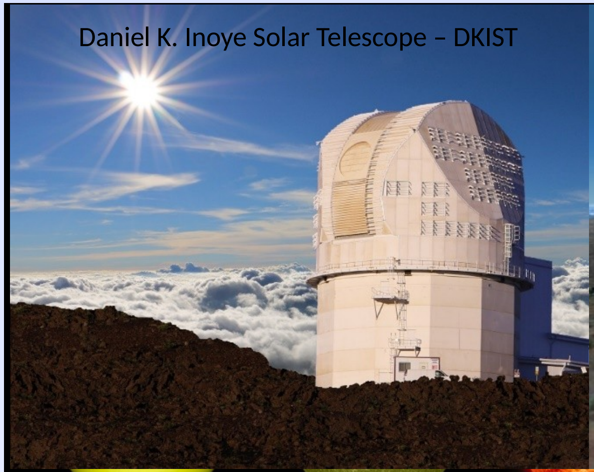
Solar activity can only be understood by

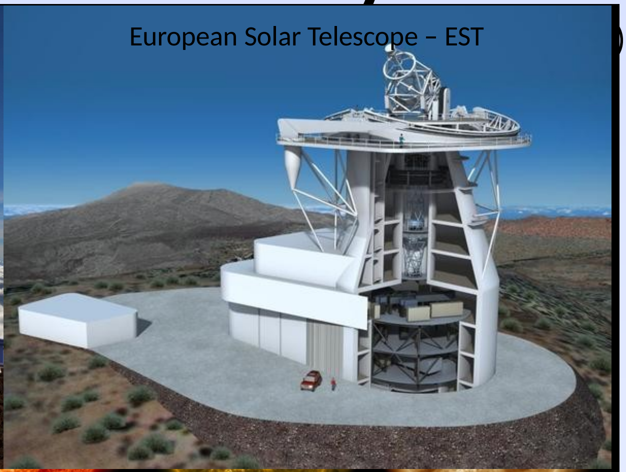
- Obtaining height information
  - multi-line observations
- Small-scale induction effects
- Large-scale interdependencies

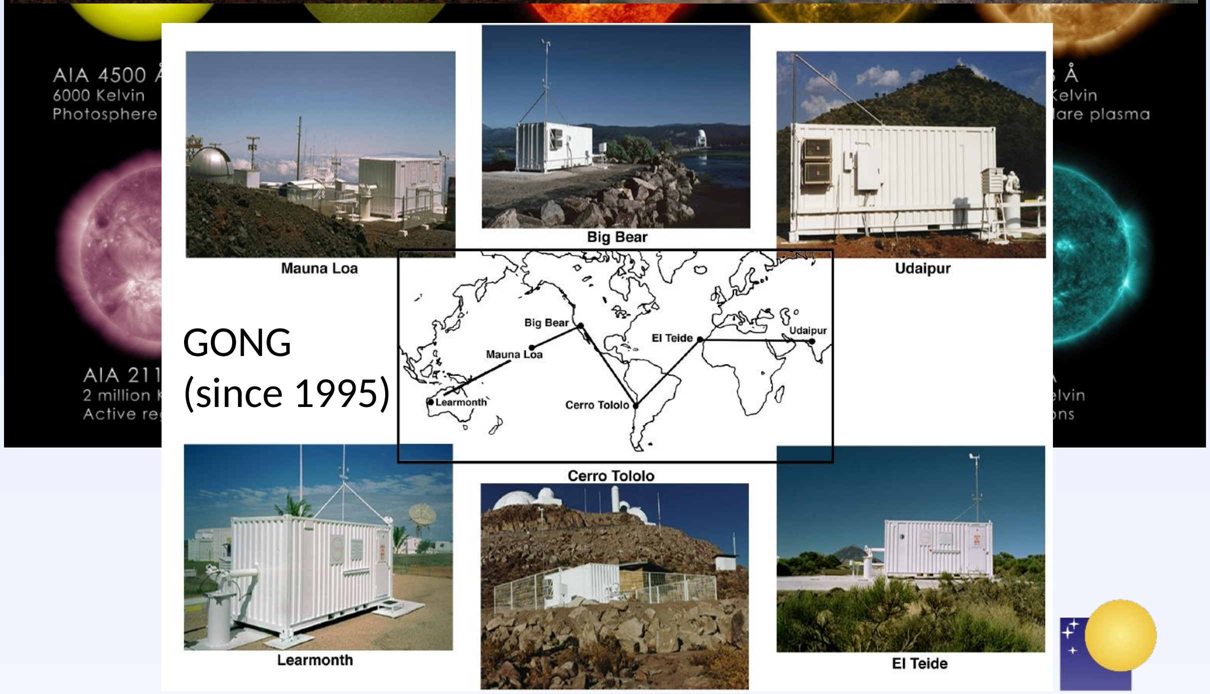
New instruments on the ground:

DKIST – high-resolution (commissioning)
EST – high-resolution (planning phase)
SPRING – full-disk (design phase)
worldwide effort to replace GONG

In Europe:
Joint instrument development under
H2020 Project SOLARNET (PI: M. Roth); 10 M€
35 partners
(31 EU incl. Univ. Graz + USA, RUS, JP, CH)







Future synoptic observations: Solar Physics Research Integrated Network Group (SPRING)

Work Package of the ***High-resolution Solar Physics Network (SOLARNET)***
funded by EU under FP7 (2013-2017) and now under H2020 (2019-2023)

Objective: Development of instrumentation for

- *large field-of-view observations of the Sun*
- *with a ground-based network* of solar telescopes

Technical Requirements / Future synoptic telescopes should provide

- Doppler velocity images
- vector magnetic field images
- intensity images

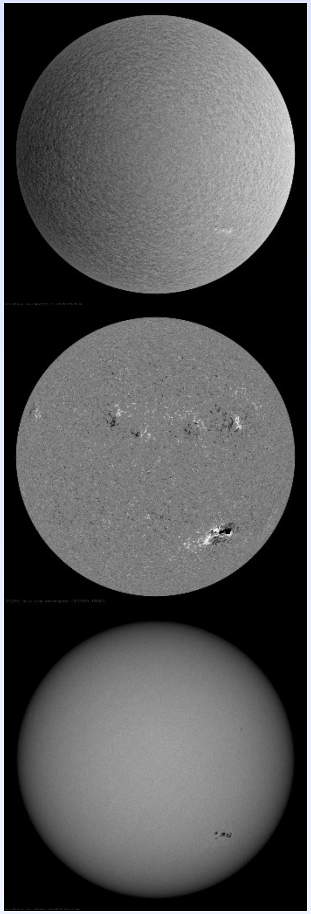
of the full solar disk

Provide the above data products

- in a variety of wavelengths
- at a high cadence (≤ 60 seconds)
- at a spatial resolution of 1” (0.5” pixels)
- at least 90% of the time
- for at least 25 years

Large International Collaboration (EU, UK, USA, Russia, India)

SDO/HMI
August 30, 2021



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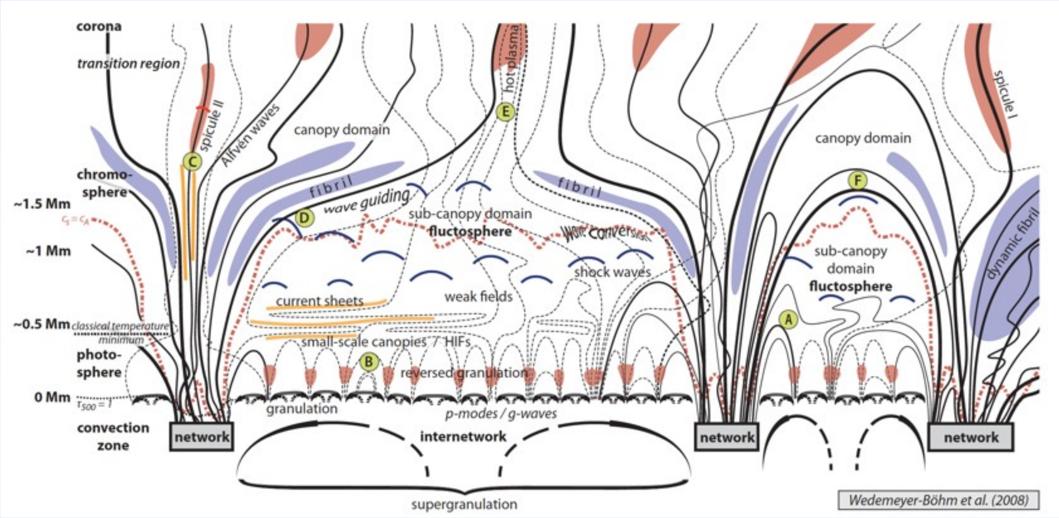
Expected Improvements: Magnetometry

Multi-line high-resolution magnetic observations of the Sun

Several Advantages:

- 3-D magnetic topology of active region magnetic fields

- Improved coronal field extrapolations
  First ground based continuous vector magnetometry for near real time space weather predictions



- Flare related changes in magnetic fields and electric currents in the chromosphere

- Long-term magnetic field records with improved spatio-temporal resolution

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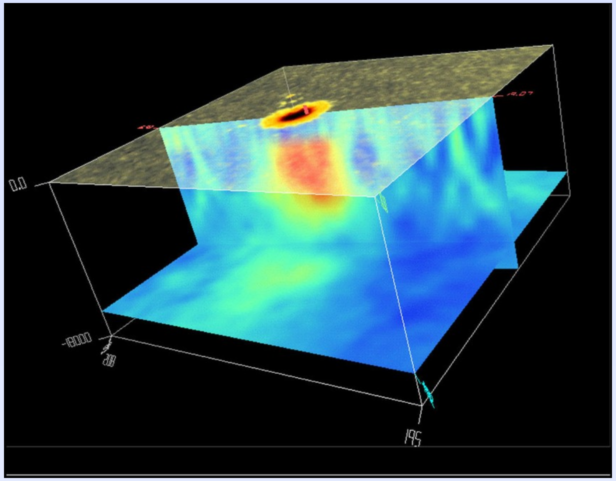
Expected Improvements: Helioseismology

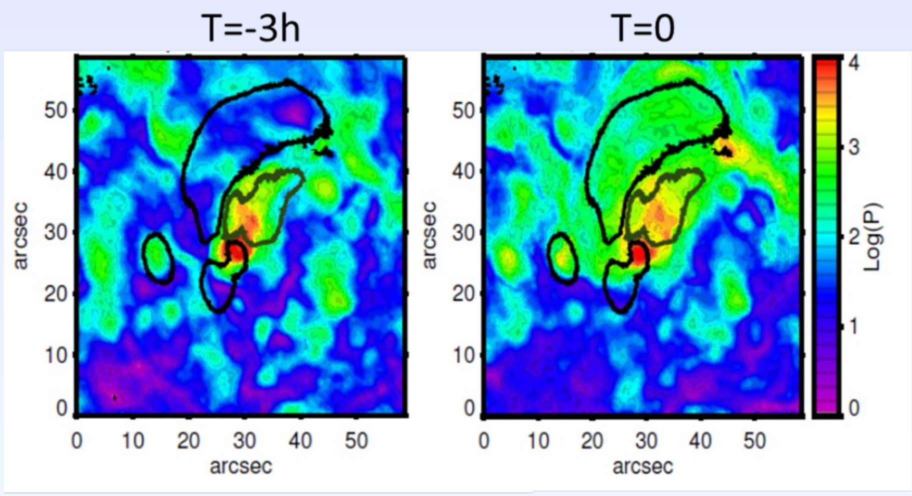
Multi-line high-resolution Doppler observations of the Sun



(ESA/NASA)

Several Advantages:

- Improved accuracy of helioseismic mapping in vicinity of active regions (Hill 2009).
- Reduction in systematic errors (Baldner & Schou 2012)
- Seismic mapping of solar atmosphere (Wisniewska et al. 2016, Finsterle et al. 2014, Nagashima et al. 2009).
- Transportation of convective energy through solar atmosphere (Jefferies et al. 2006).



(Wisniewska et al. 2019)

See review by
Elsworth et al., 2015, Space Sci. Review, 193, 137

Development Steps

Science Working Groups

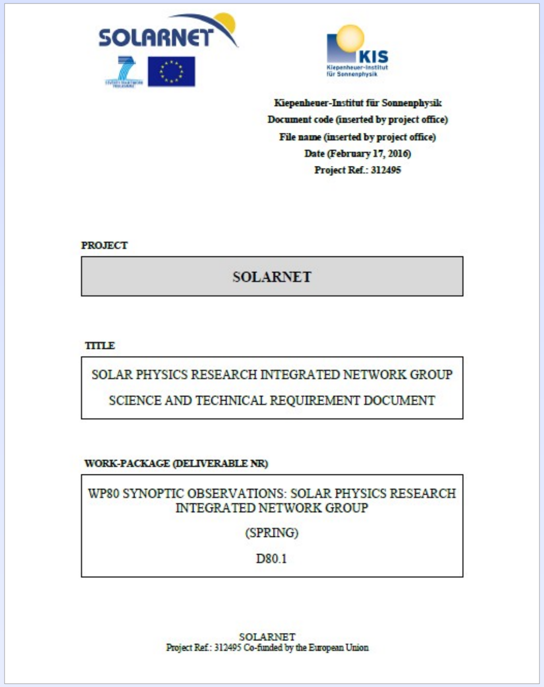
- Synoptic Magnetic Fields
- Solar Seismology
- Transient Events
- Solar Awarness

Science Requirement Document

Feasibility Study

- Front-end telescopes
- Post-focus instrumentation
- Data volumes and processing
- Seeing analysis at GONG sites

Technical Requirement Document



Kiepenheuer-Institut für Sonnenphysik
Document code (inserted by project office)
File name (inserted by project office)
Date (February 17, 2016)
Project Ref.: 312495

PROJECT

SOLARNET

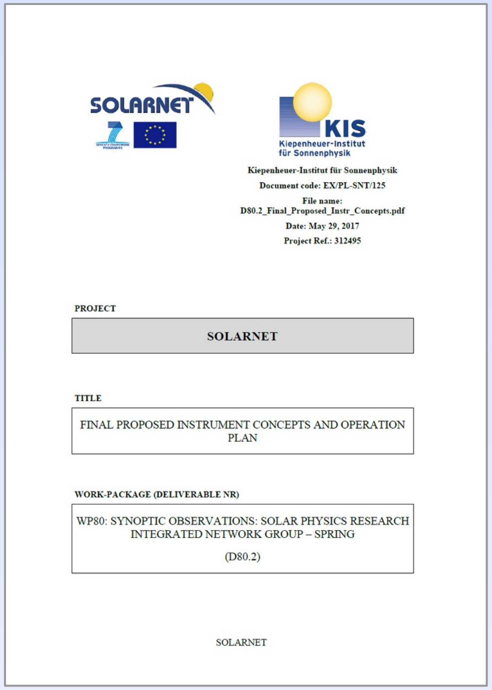
TITLE

SOLAR PHYSICS RESEARCH INTEGRATED NETWORK GROUP
SCIENCE AND TECHNICAL REQUIREMENT DOCUMENT

WORK-PACKAGE (DELIVERABLE NR)

WP80 SYNOPTIC OBSERVATIONS: SOLAR PHYSICS RESEARCH INTEGRATED NETWORK GROUP
(SPRING)
D80.1

SOLARNET
Project Ref.: 312495 Co-funded by the European Union



Kiepenheuer-Institut für Sonnenphysik
Document code: EX/PL-SNT/125
File name: D80.2_Final_Proposed_Instr_Concepts.pdf
Date: May 29, 2017
Project Ref.: 312495

PROJECT

SOLARNET

TITLE

FINAL PROPOSED INSTRUMENT CONCEPTS AND OPERATION PLAN

WORK-PACKAGE (DELIVERABLE NR)

WP80: SYNOPTIC OBSERVATIONS: SOLAR PHYSICS RESEARCH INTEGRATED NETWORK GROUP – SPRING
(D80.2)

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Key Idea: *Simplicity*

- SINGLE instrument can not do the job
  complexity would lead to higher costs and low mean time between failures
- MULTIPLE **instruments on a single platform is the way to go.**

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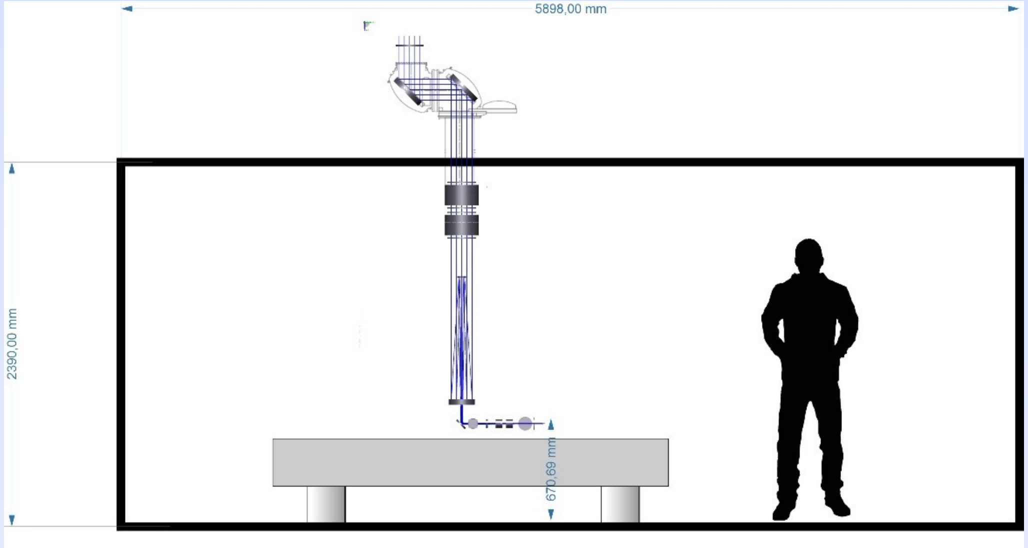
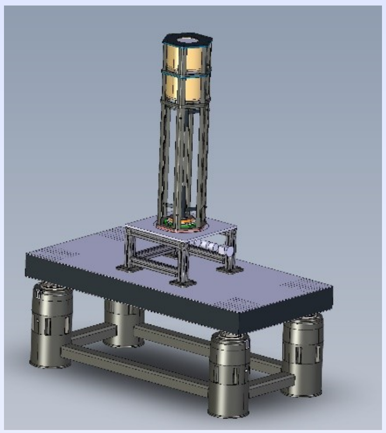
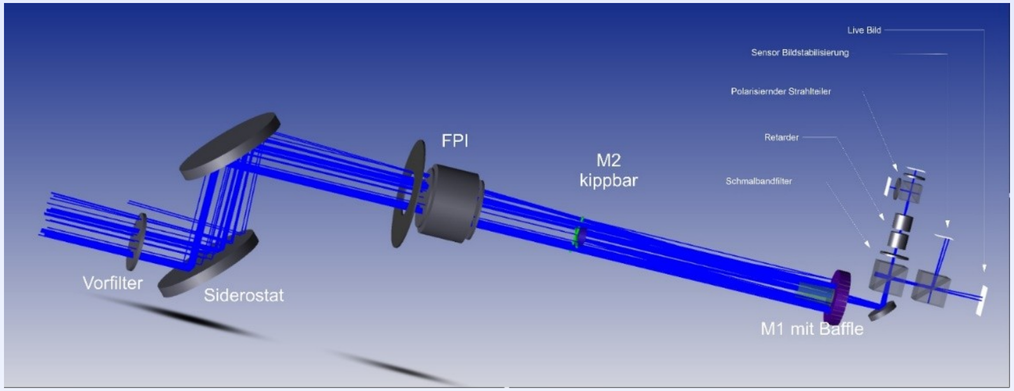
Preliminary Design

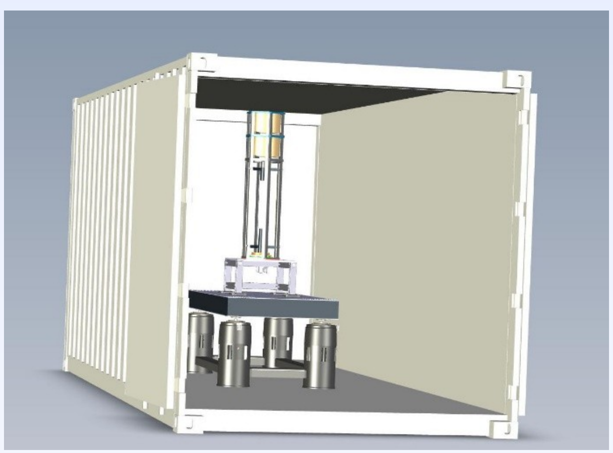
Full-Disk Telescopes + Dopplergraph

- 12 cm aperature
- Multi-line Doppler & spectro-polarimetry measurements
- Filtergraph: Fabry-Perot system









Design developed with industrial partner AMOS

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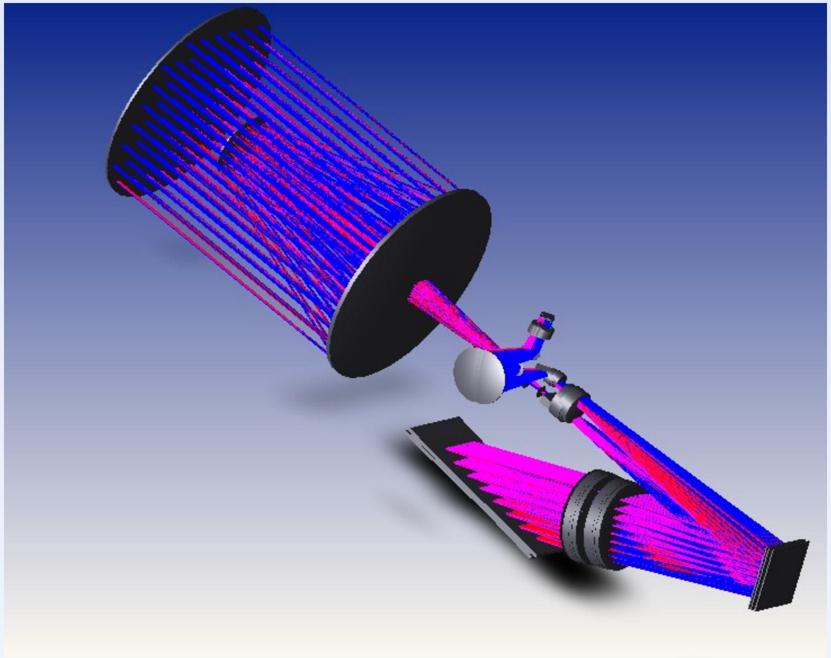
Second Instrument on the Platform

50 cm Ritchey-Chrétien telescope + magnetograph

- Post-focus instrument: Multi-slit configuration
- NSO SOLIS telescope as the model
  - Larger detector



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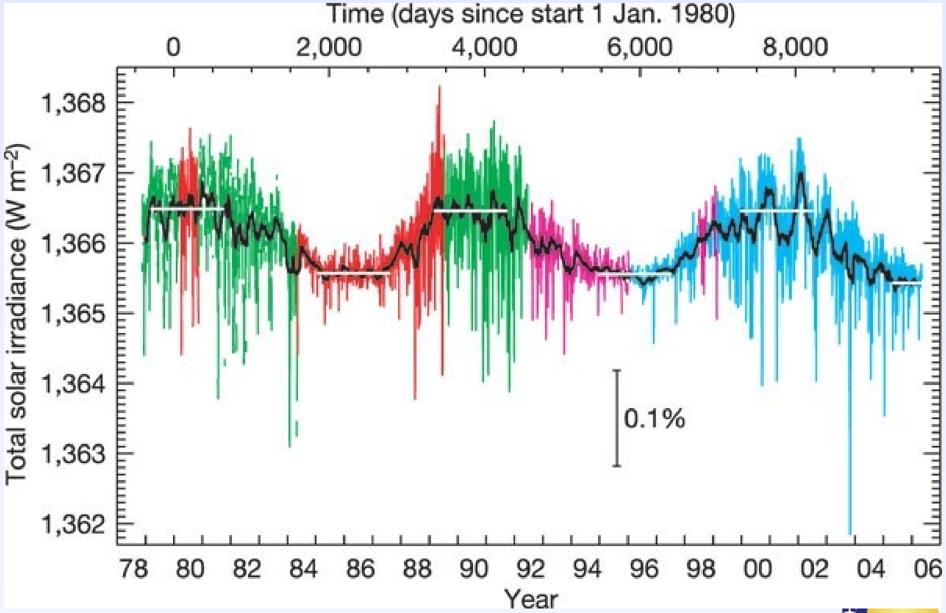
Further Instruments

- **Coronagraph**
  - Investigating outer layers of the Sun

  -> Coronal Mass Ejections

- **Device for Irradiance Measurements**
  - Total solar irradiance
  - Spectral solar irradiance
  - Measurements in the near-infrared required at:
    - 855 nm
    - 1055 nm
    - 1083 nm
    - 1241 nm
    - …

  -> Driver of Earth‘s climate



(Foukal et al. 2006)

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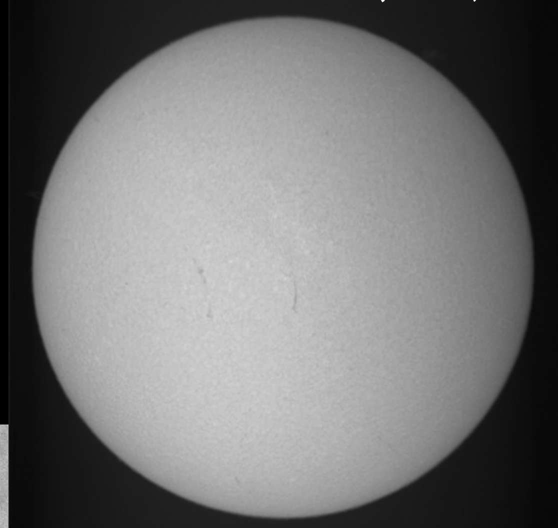
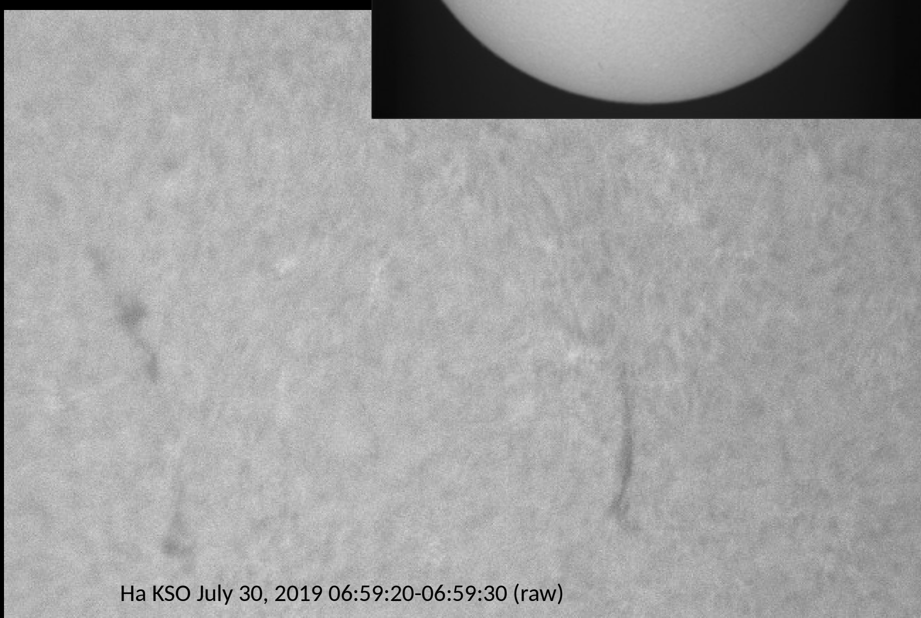
Data Recording – Lucky Imaging

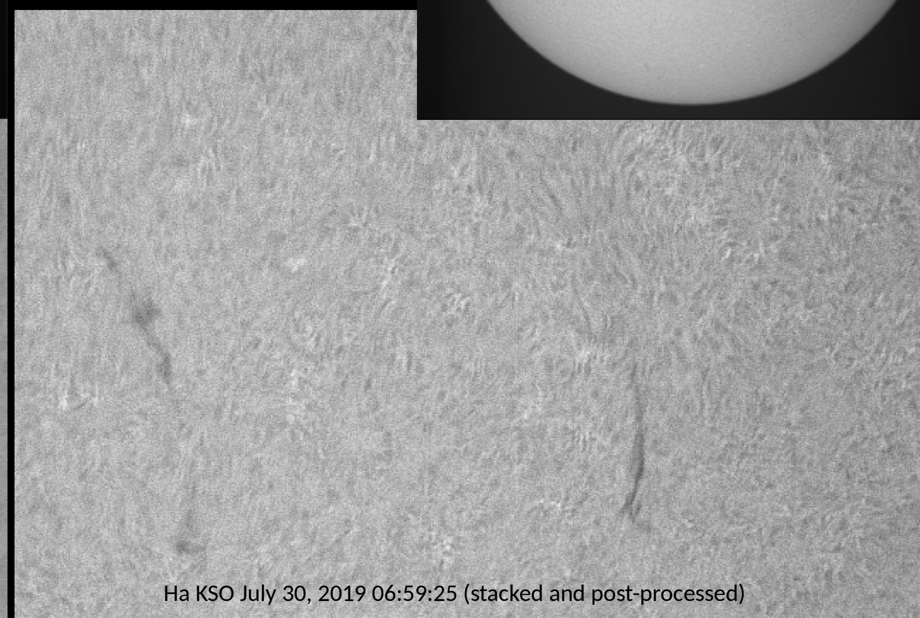
Testing with data from Kanzelhöhe (ROB, Uni Graz)

Raw sequence





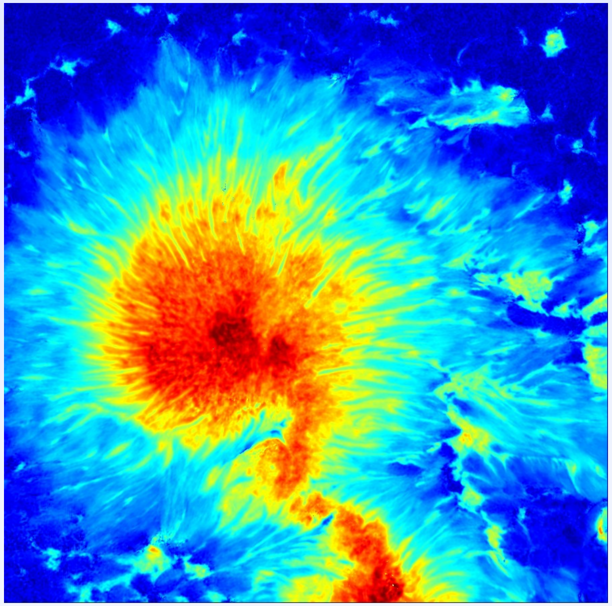
After lucky-imaging



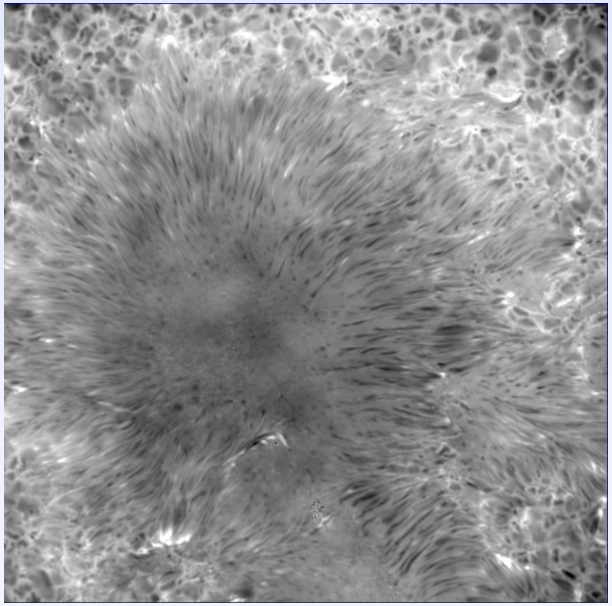
Stokes Inversions (IAA)

- Code development for real-time analysis of SPRING observations completed
- **P-MILOS:** very fast Stokes inversion code developed and validated
- Code publicly available (with proper funding acknowledgment) at

https://github.com/IAA-InvCodes/P-MILOS



Magnetic Field



Line-of-sight velocity

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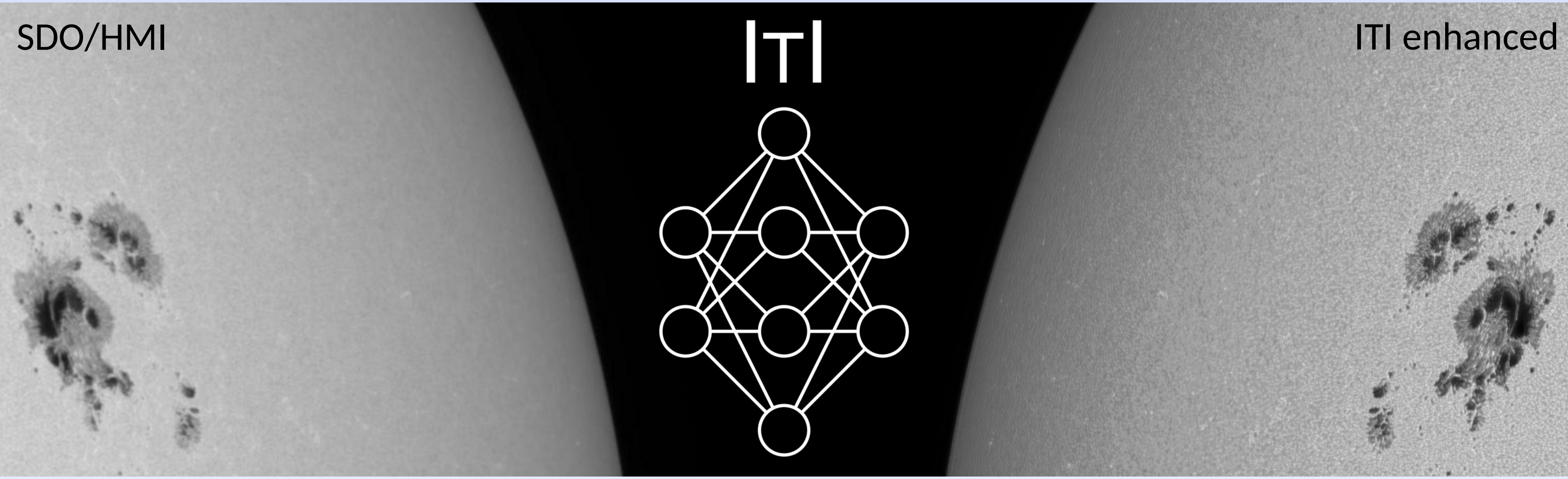
Data Homogenization (Uni Graz)



Instrument-to-Instrument translation:
Solar image enhancement and data set homogenization with deep learning

- Informed image enhancement
  - Use most recent observations as reference
- General framework based on deep learning
  - Image enhancement
  - Data set homogenization

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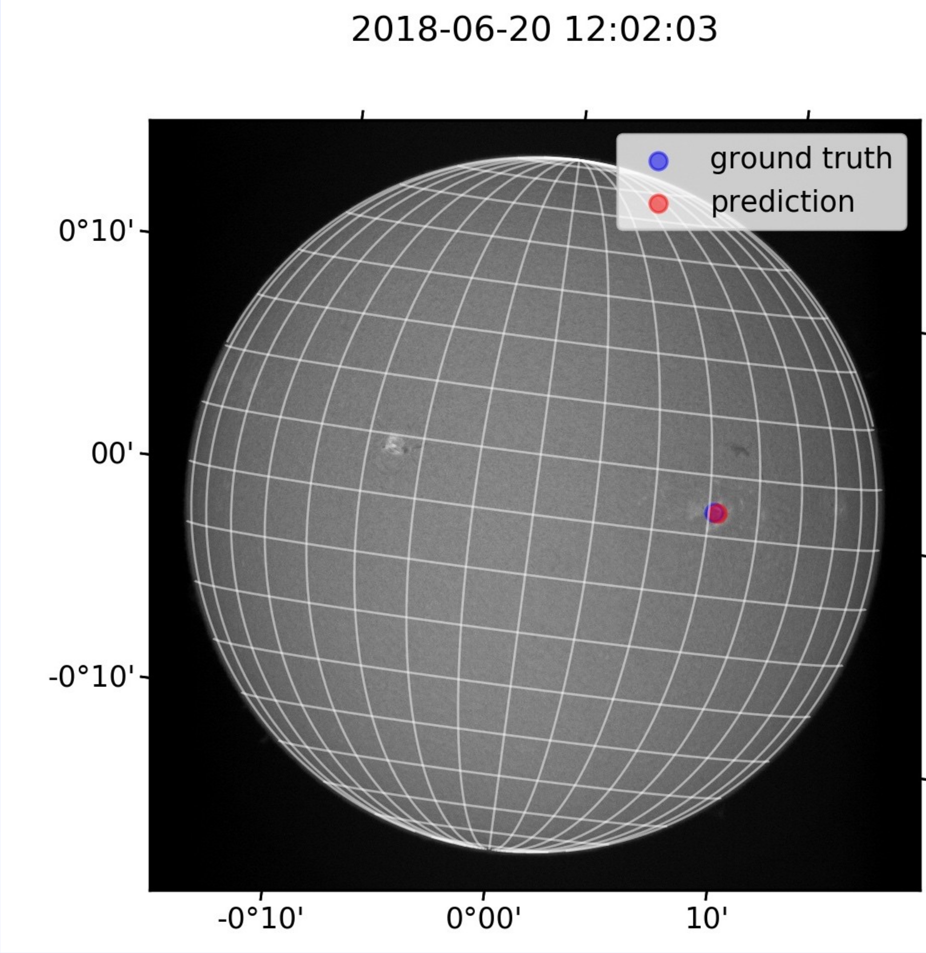
Flare Detection (Uni Graz, SKOLTECH, Obs Catania)

- Automatic detection of solar flares
- *Ongoing work:*
  1. Neural network to improve existing flare detection algorithm
  2. Combination of various indicators
- Currently working on single-site data
  Next step: multi-site data set



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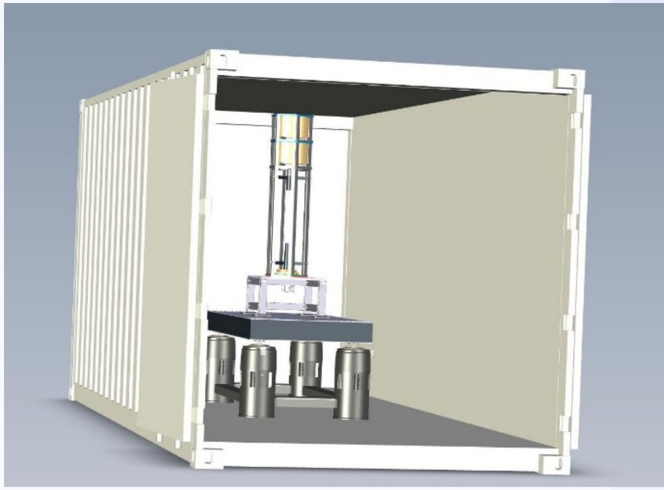
Summary

- Several science questions in solar physics including helioseismology require **new instrumentation**

- **Suggested concept for SPRING = ngGONG**
  - Platform carrying several new instruments
  - Large telescope (>0.5m) for magnetic field measurements
  - Smaller telescope (~0.2m) for Doppler velocities
  - Coronagraph for linking lower and higher atmospheric layers

- **Instruments**
  - Development of technical design on the way
  - Completion by 2022

- **Next steps:**
  - Completion of preliminary design (2022)
  - Work on prototype instruments and detectors (2022-25)
  - Detailed site analysis (2023/2024)
  - Completion of design (2025-2027)
  - Construction of network (by 2028)



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