KIS
Kiepenheuer-Institut
für Sonnenphysik

# SPRING

## Solar Physics Research Integrated Network Group


European Space Weather Week

Markus Roth

November 20, 2014

SOLARNET

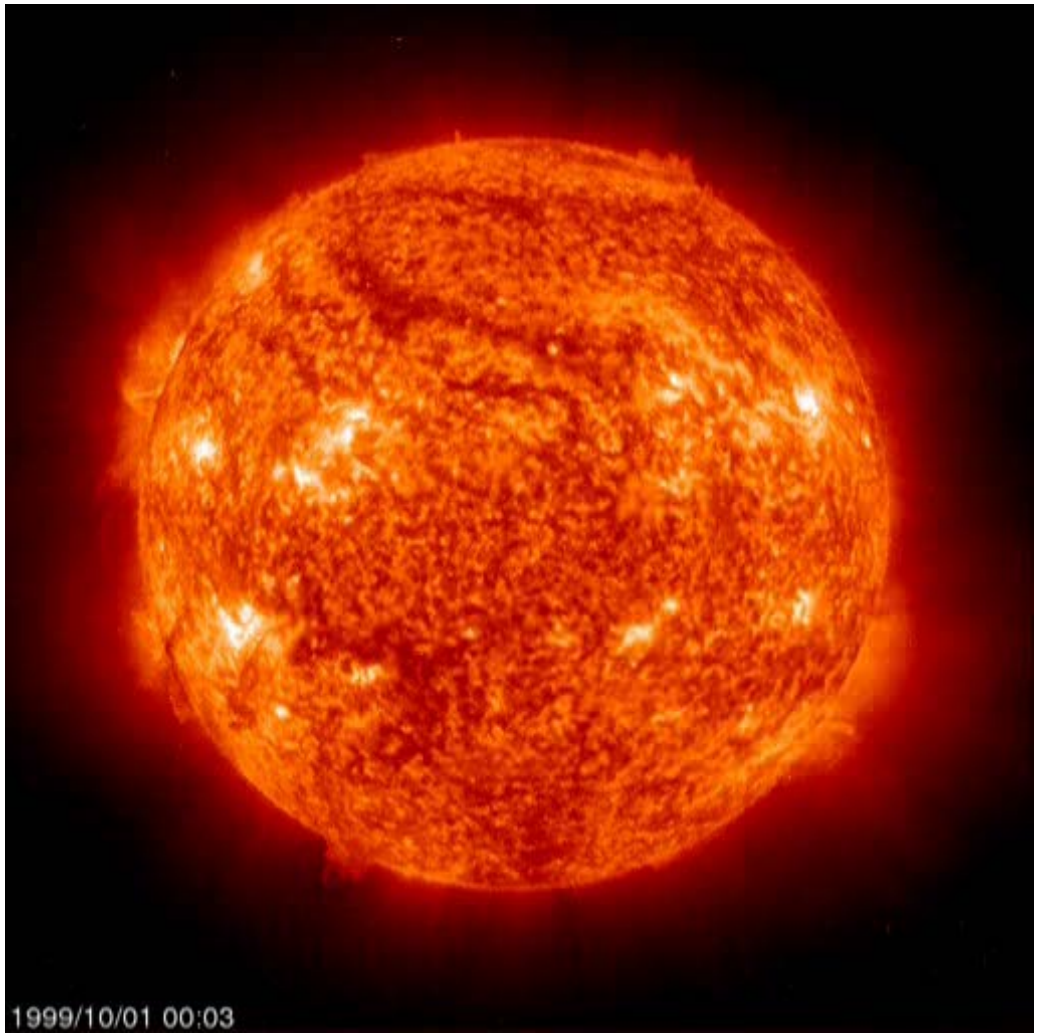
# Understanding the variable Sun



- The Sun is not a constant star
- Level and character of its output change with time
- Long- and short-term variations

***Question:***

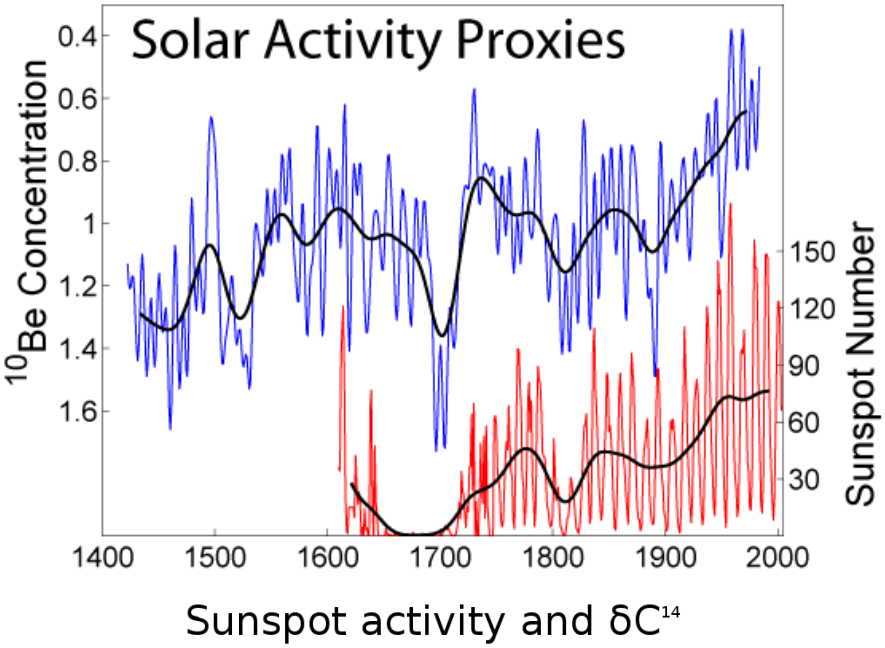
What is the origin of this variability?



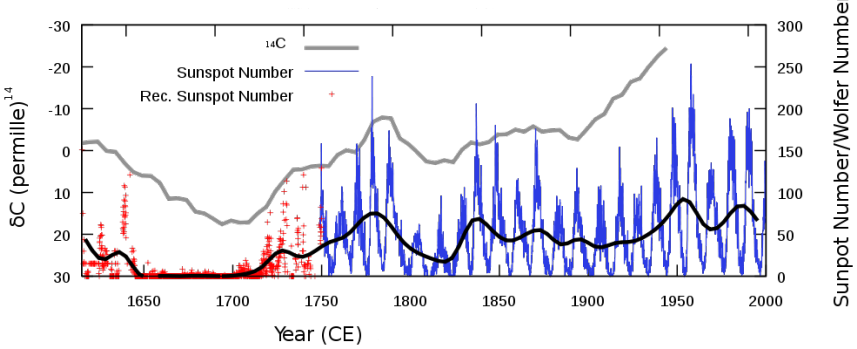
# Understanding the variable Sun

- In order to look at the long-term variations there is a need for continuous observations over many years or decades
  - **Statistics!**

- Once cross-calibration is established, proxies of solar activity can be used to follow behavior over millennia.
  - Example $^{10}$Be or $^{14}$C
  - Proxies are approximate and lack in detail

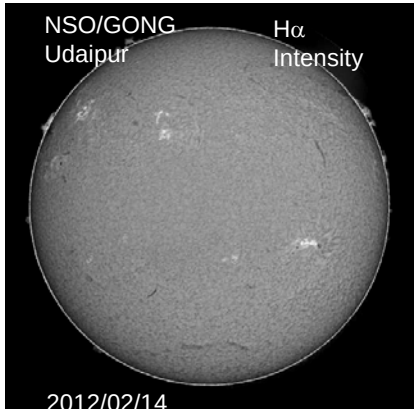


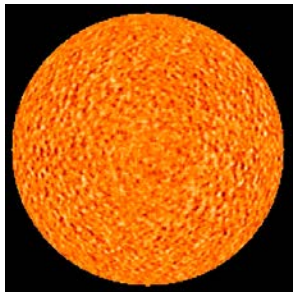

Sunspot activity and $\delta C^{14}$

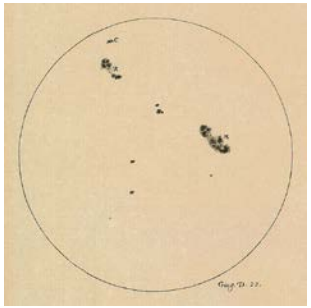


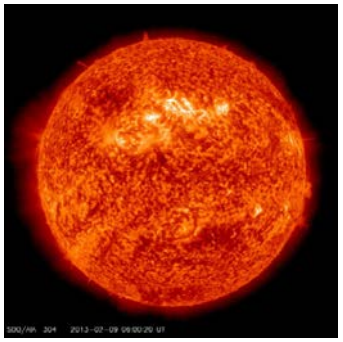
# Examples of Synoptic Observations

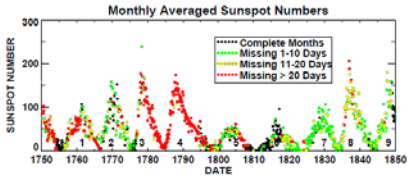
Solarnet
&
SPRING

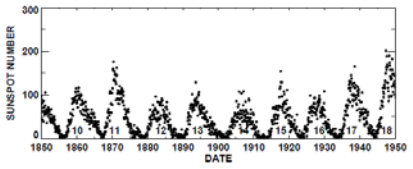


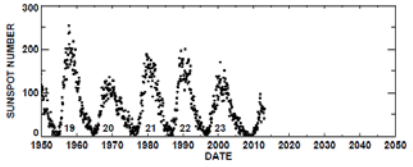



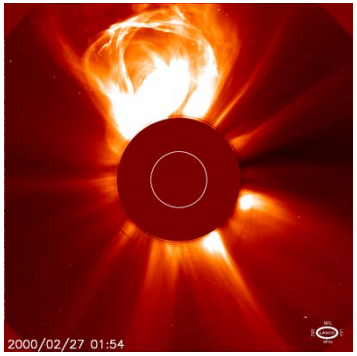


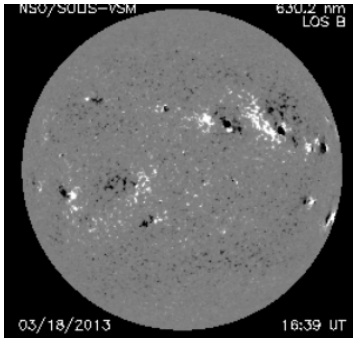


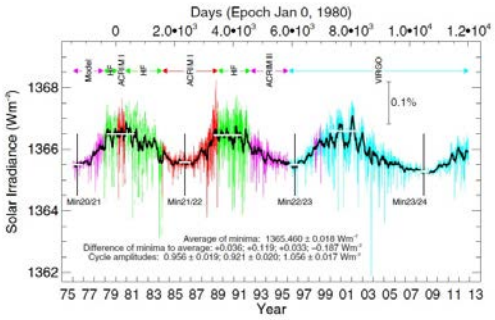


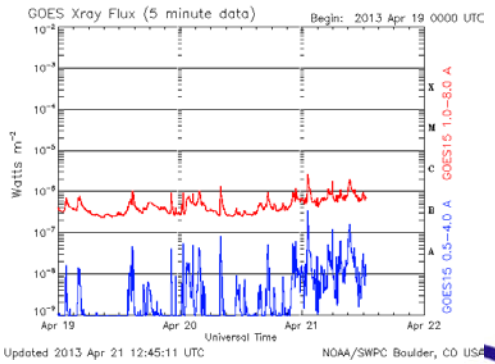




GONG, MDI, AIA,
MSFC, SOLIS,
LASCO, PMOD,
SWPC

# Classical: Synoptic Observations



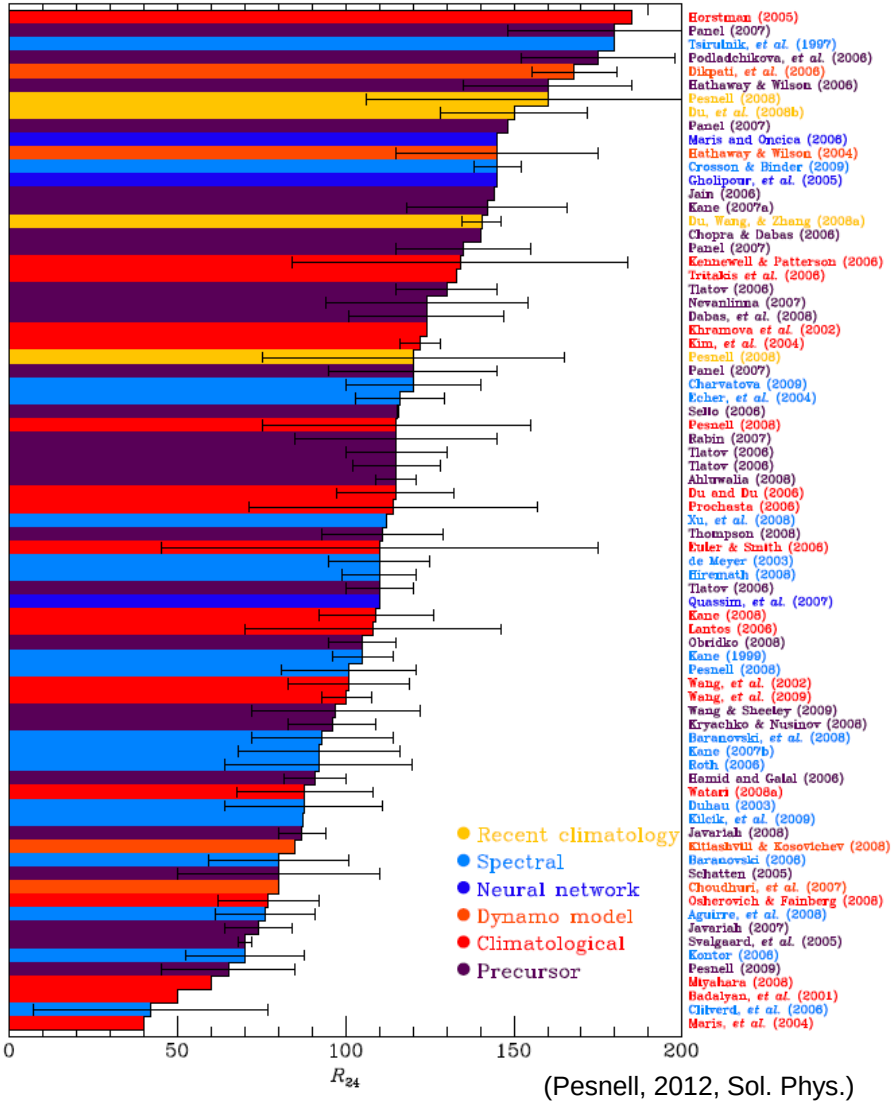
- Sunspot drawings / sunspot number
- Radio Flux 10.7cm
  - Systematically recorded since 1947
- Chromospheric indices
  - Polar fields, flare index, sunspot field strength
- Spectroscopy proxies
  - Core-to-wing ratio in Mg II at 280 nm or the equivalent width of the He II line at 1083 nm
  - Direct measurements of magnetic field
- H$\alpha$
  - Prominences
- Total/Spectral Solar Irradiance
- Helioseismic measurements of internal flow field
- …

# Future Role of Solar Physics



- **Big Challenge:**
  Understanding the solar dynamo and activity
  - Dynamo operates inside the sun
  - Makes sunspots to come and to go on an 11-year cycle
  - What triggers transient events?

- Current understanding of operation mechanism rather poor
  - Predictions on solar cycle do strongly vary
  - Long-term behavior of solar activity needs understanding of
    - Internal dynamics → dynamo
    - Physics that lead to energetic events



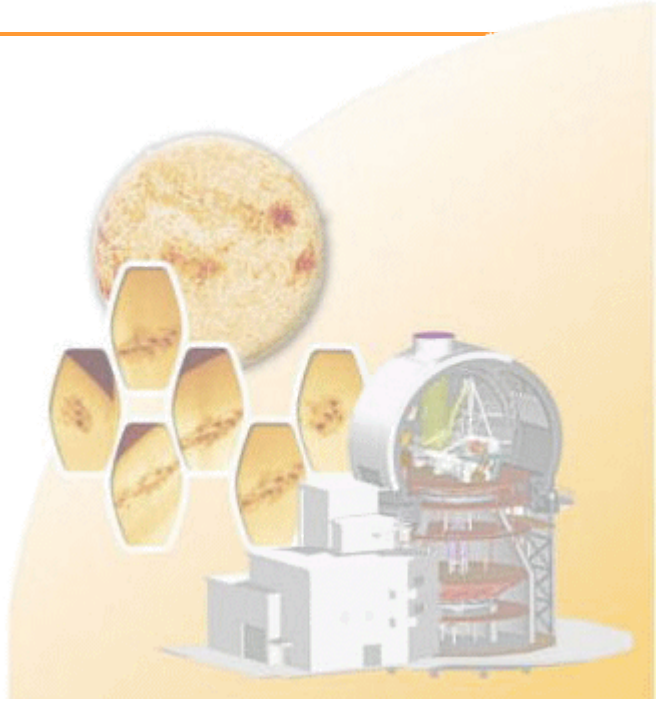

(Pesnell, 2012, Sol. Phys.)

# Need of both: high-res and synoptic observations of the Sun

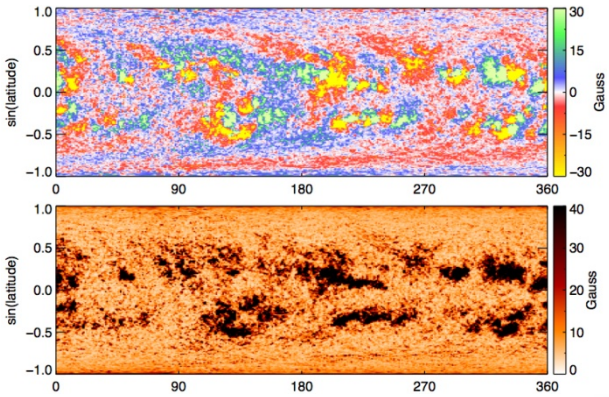


In different wavelengths and polarizations

- High-res observations:
  Details of small scale magnetic fields
  - local dynamo processes
  - flux emergence
  - cancelation and surface diffusion



- Synoptic observations:
  Global properties of solar cycle
  - Magnetic field
  - Sunspots
  - the subsurface dynamics
  - profile of differential rotation
  - meridional flow
  - Temporal variability

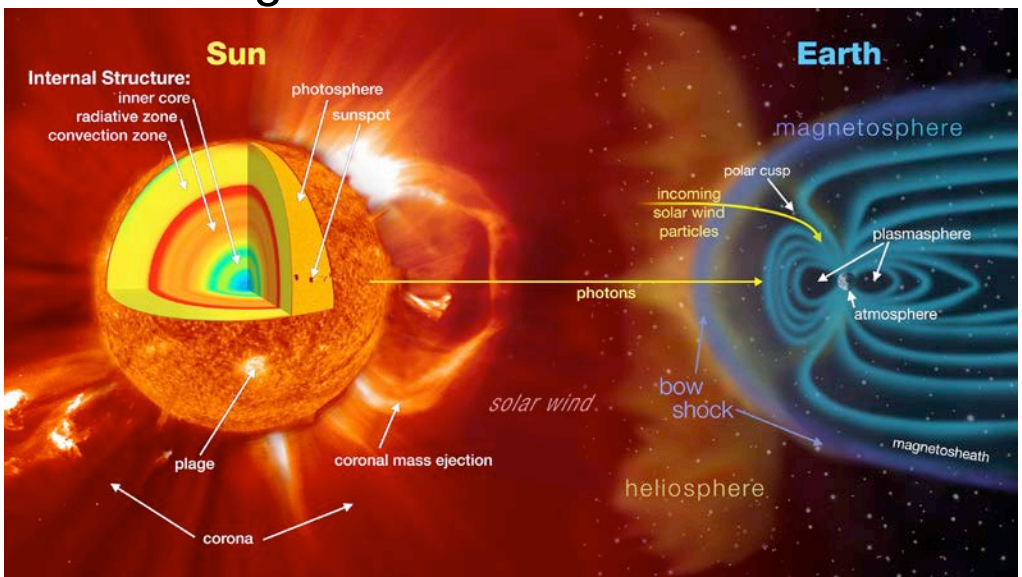


# Space Weather



- Further need for synoptic observations:
  - the topic of space weather is becoming evermore important in our technology dependent world
  - solar community definitely needs a reliable source of continuous real-time information on magnetic field vector of the solar active regions

→ Needed in order to become efficient on flare/CME or space weather forecasting.



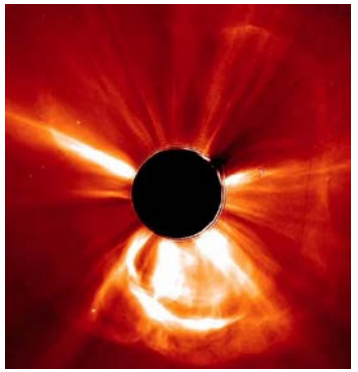
# Role of contemporary solar physics – solar-terrestrial relations



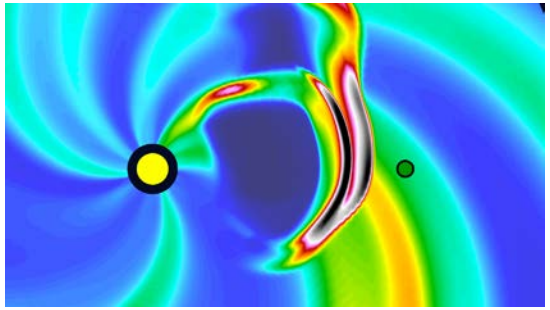
- Monitoring of solar activity and energetic events is essential for spacecraft operations
- Impact of solar activity on the Earth‘s magnetic field may impact large infrastructures

- Predicting solar activity, solar energetic events and their impact on Earth requires intensive solar research

Stereo A



WSA-Enlil (NOAA)



# 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

*Colors:*
Synoptic
High-Res
Both

# EU-Project: High-Resolution Solar Physics Network – SOLARNET

**Solarnet is an Integrated Activity (IA) funded by the European Unions's Capacities Programme under Framework Programme 7:**

**Solarnet's work programme includes:**

- *Networking Activities (NAs)*
  - Workshops & Annual Conferences
  - Mobility Programme
  - Common Time Allocation Committee
  - Definition of Standards for Data Pipelines
  - Coordination among infrastructures
- *Transnational Access and Services (TAS)*
  - Infrastructures on Canary Islands, ROSA, IBIS
  - E-Infrastructures Data Bases of Hinode, IRIS, SDO-AIA, SDO-HMI
- *Joint Research Activities* → ***SPRING***

| | |
|---|---|
| **Coordinator:** | Manolo Collados (IAC) |
| **Technical Manager:** | Markus Roth (KIS) |
| **Project Duration:** | April 2013 – March 2017 |

# Synoptic observations: Solar Physics Research Integrated Network Group (SPRING)

**Objective:** Development of instrumentation for large field-of-view observations of a network of small aperture solar telescopes in support of observations with existing high-resolution solar telescopes (either isolated or in a coordinated way).

**Future synoptic telescopes should provide**

- Full-disk Doppler velocity images
- Full-disk vector magnetic field images
- Full-disk intensity images
- Measurements of quantities relevant for space weather

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

**Participants of Joint Research Activity under Solarnet (EU FP7):**

KIS, IAC, INAF, MPS, QUB, AISAS, AIASCR, IGAM, UoB, NSO, HAO

# SPRING Activity – Three Working Phases

**1. Science requirement study (until early 2015)**

- describe the supporting data required by high-resolution observing programs
- the scientific objectives to be achieved by high-quality synoptic observations
- study of the relation with other existing ground-based solar observation networks

*To be studied:*

- List of small aperture telescopes and other ground-based solar observations networks available
- Develop a strawman document discussing the goals and preliminary support instrumental concepts
- Write a Science Requirement Document (SRD) which shall be consistent, tangible and in accordance with other plans for the next 25 years (commissioning of large-aperture telescopes, space missions, etc.).

# SPRING Activity – Three Working Phases



## 2. Feasibility study (until summer 2016)

### 2.1 Instrument design concepts

Definition of technical requirements for the instrument, based on scientific goals

Definition of alternatives of instruments concepts

***To be studied:***

- Adaptive optics or other image stabilizing/enhancement technology
- Observations in at least the following spectral lines: Ni I 6768, Fe I 6301/2, Na D, H-α, Ca K, Ca H, He10830,Fe I 6173 and Fe I 1.5 micron.
- High-speed image post-processing / High-speed real-time data access
- Location of telescopes for setting up a network mode
- Possible instruments concepts:
  Filtergraph, Spectrograph and Interferometer, each one with different options

### 2.2 Operational concepts

Develop operational ideas (remote operations, data pipelining, delivery of real-time data to operating telescopes)

Develop high-speed image post-processing routines

# SPRING Activity – Three Working Phases



## 3. Development and operation study (until April 2017)

### 3.1 Trade-off analysis

Combination of instruments and cameras

Camera set-up and development, particularly in large format and high cadence

Select less than 3 instrument concepts to be detailed and cost estimated

### 3.2 Network operation and data delivery to high-resolution telescopes

Network operation and performance and on-line data access

Deepening on the studies on data processing and merging, including automated control, data pipelines processing on clusters of CPUs or possible use of Graphical Processing Units and data delivery

# Solarnet/SPRING – Working Groups

***Group 1: Synoptic magnetic fields***

- Sunspots (problems with cool atmospheres)
- Active regions
- Quiet Sun magnetism
- Synoptic Hanle Observations

**Chair: Alexei Pevtsov**

***Group 2: Solar seismology***

- Waves (solar interior)
- MHD waves (magnetoseismology)
- Velocity field inside and on the Sun

**Chair: Rekha Jain**

***Group 3: Transient events***

- Flow of energy through the solar atmosphere (3,2)
- Transient events (flares, prominences, CMEs)

**Chair: Michal Sobotka**

***Group 4: Solar Awareness***

- TSI / SSI
- Space Weather (4,3)
- Space Climate
- Sun-as-a-star

**Chair: Ilaria Ermolli**

# First Draft of the Science Requirement Document

Kiepenheuer-Institut für Sonnenphysik

Current Status:

- Three Workshops were held to discuss science requirements
- Now first draft of Science Requirement Document was created in October 2014
- **Contributions to the Science Requirement Document are still welcome**
- **Contact:**

Markus Roth,
Kiepenheuer-Institut für Sonnenphysik
mroth@kis.uni-freiburg.de

Solar Physics Research Intergrated Network Group – SPRING

Science Requirement Document

V 1.0

October 14, 2014

Authors:

Magnetic Fields: Alexei Pevtsov, Hector Socas-Navarro, Rolf Schlichenmaier, Ilaria Ermolli, Sanjay Gosain, Michal Sobotka, Juan-Manuel Borrero, Siraj Hasan, Wolfgang Schmidt

Solar Seismology: Rekha Jain, Frederic Baudin, Dario Del Moro, Robertus Erdelyi, Wolfgang Finsterle, Siraj Hasan, Frank Hill, Peter Keys, John Leibacher, Markus Roth, Jesper Schou, Michael Thompson, Amel Zaatri

Transient Events: Michal Sobotka, Peter Keys, Francesca Zuccarello, J. Kašparová, J. Štěpán, Dario del Moro, Wolfgang Polanec

Solar Awareness: Ilaria Ermolli, Alexei Pevtsov, Toufik, Dario Del Moro, Fabio Scuderi, Guy Davies, Wolfgang Finsterle, Frank Hill, Michael Thompson, Francesco Berrilli, Francesca Zuccarello, Stangalini

Affiliations:

Logos:

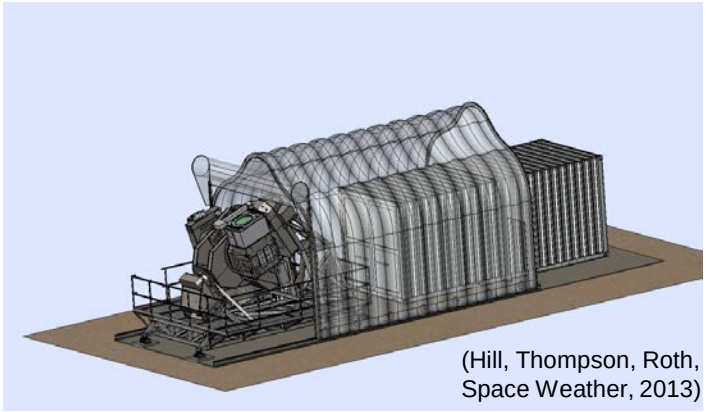
SOLARNET

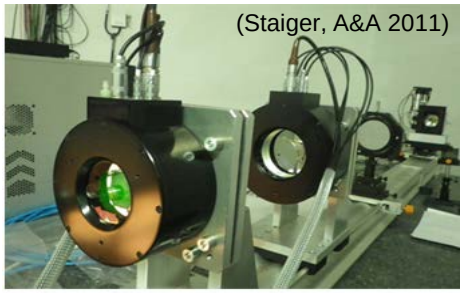
# Next Steps

- ***Work on SPRING Design:***
  *Sanjay Gosain,*
  *joint hiring at KIS and NSO*

- **First Concept:**
  SOLIS-like platform to carry multiple instruments

- **First demonstration instruments:**
  - HELLRIDE at the VTT on Tenerife to perform multi-wavelength observations at high temporal cadence (Joachim Staiger, Freiburg)
  - mxSPEC (Haosheng Lin, Hawaii):
    a Massively Multiplexed Spectroheliograph for Solar Physics Research
    35 slits to obtain full-disk image in 36 seconds


(Hill, Thompson, Roth, Space Weather, 2013)


(Staiger, A&A 2011)