Exploitation of Space Data for Innovative Helio- and Asteroseismology – SpaceInn

Markus Roth & SpaceInn Board
Kiepenheuer-Institut für Sonnenphysik

Tenerife, March 13, 2014

The Coordination Action "HELAS"

European Helio- and Asteroseismology Network (HELAS)

- Currently 24 participating institutions
  22 European + 2 US

- Co-ordinate activities among European institutions and organizations in helio- and asteroseismology

- Enable transfer of knowledge, data, and data analysis techniques

- In order to
  – ensure European competence and competiveness in this research area by spreading expertise
  – increase in volume and quality the European scientific output in helio- and asteroseismology
  – enhance the synergy between helio- and asteroseismology
  – prepare European research community for important future opportunities
    (CoRoT, Kepler, Picard, SDO, Solar Orbiter)
  – improve the public understanding and interest in solar and stellar physics

Research Infrastructures Action
FP6 – 2004 – Infrastructures - 5

HELAS

European Helio- and
Asteroseismology Network
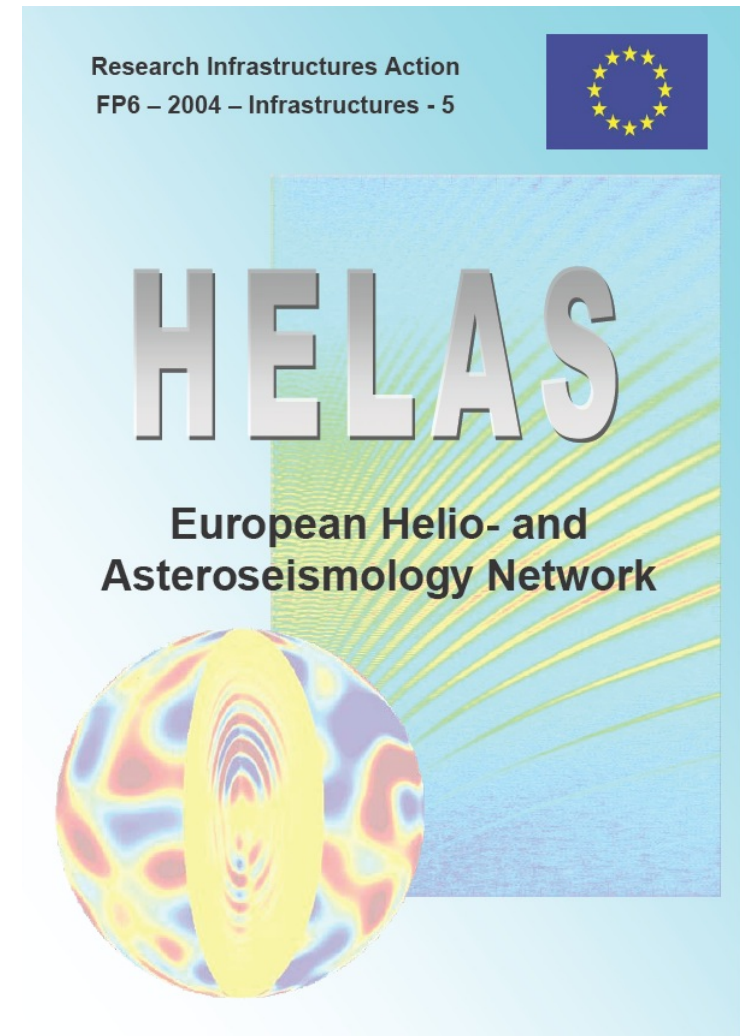
HELAS Funding lines

- EU FP6 Capacities
  Coordination Action
  04/2006 – 03/2010   -> 2.265 M€

- ESF *Research Conference*
  05/2012   -> 40 k€

- **EU FP7 Cooperation Theme 9: Space**
  Collaborative Project SpaceInn
  since 01/2013   -> ~2M€

- EU FP7 Capacities
  Collaborative Project & Support Action
  Solarnet -> **SPRING, Conferences, Mobility Program, and Schools**
  since 04/2013   -> ~600k€ out of 6 M€

What is SpaceInn?

Collaborative Project

by the European research groups active in helio- & asteroseismology

initiated by the European Helio- and Asteroseismology Network – HELAS

Objectives:

to make full use of data collected in space and complementary on ground for the physics of solar and stellar interiors.

Coordinator:

Oskar von der Lühe, Kiepenheuer-Institut für Sonnenphysik, Freiburg

Scientist in Charge / PI:

Markus Roth, Kiepenheuer-Institut für Sonnenphysik, Freiburg

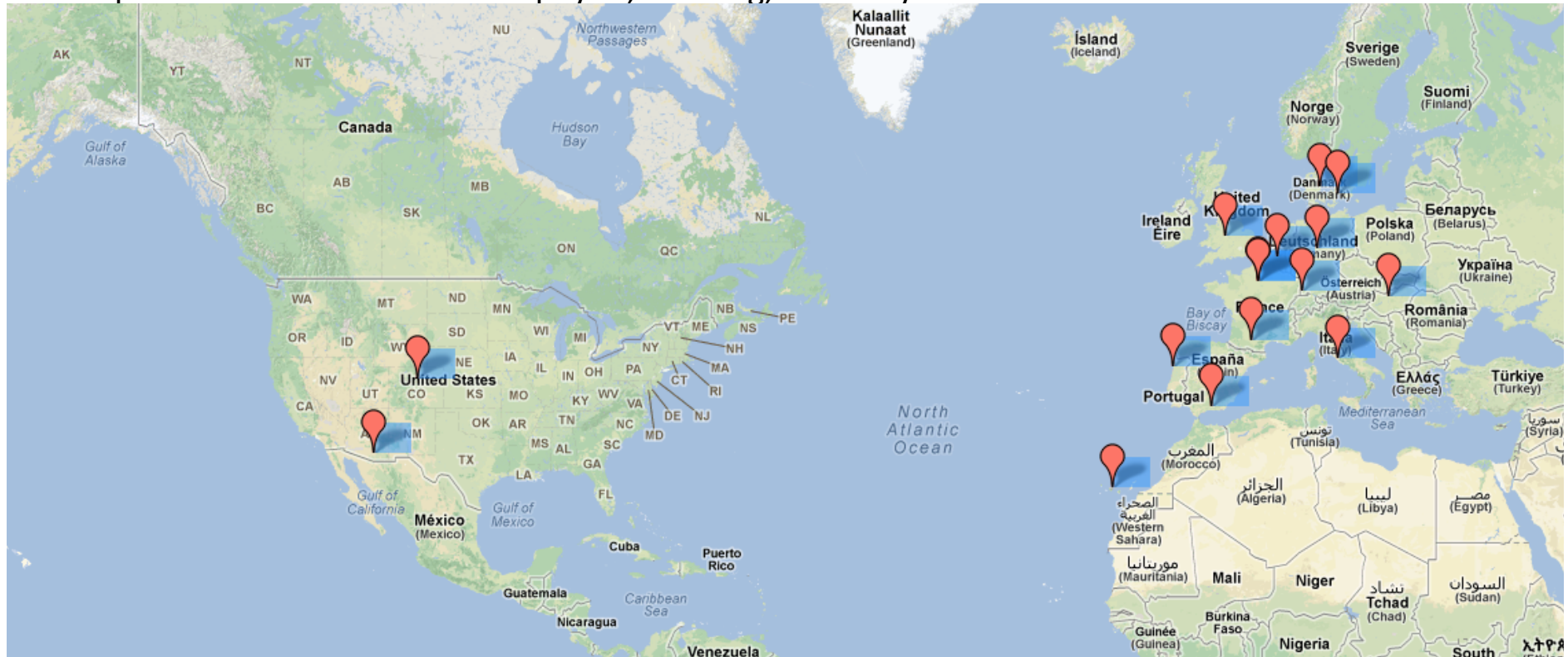**Project Duration:** January 1, 2013 – December 31, 2016

Funding: 1.994.615,00 €

The SpaceInn Consortium

Full Project Partners:

1   Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany   KIS

14   Royal Library Copenhagen, Denmark   RB

15   National Solar Observatory, Tucson, USA   AURA

16   High Altitude Observatory, Boulder, USA   UCAR

17   Konkoly Observatory of the Hungarian Academy of Sciences, Hungary   MTA-CSFK

Data Bases in Europe

- BiSON
  - Birming Solar Oscillation Network

- CoRoT
  - Data processing: Paris Observatory and Laboratoire d'Astrophysique de Marseille.
  - Scientific data is made available through the project archive located at IAS (Space Astrophysics Institute), Orsay, France

- SDO
  - Centre for the distribution and analysis of data at the Max-Planck Institute for Solar-system Research, Germany.

- KEPLER
  - Use of asteroseismic data is led by Aarhus University, Denmark, through the establishment of the Kepler Asteroseismic Science Operations Centre (KASOC) and the leadership of the Kepler Asteroseismic Science Consortium (KASC)

Data Bases in USA

- GONG
  - Freely available helioseismic data recorded from the GONG instruments hosted by the National Solar Observatory in Tucson, USA

- SOHO
  - Freely available helioseismic data recorded by the the instruments aboard SOHO are available through the data bases at Stanford University, USA
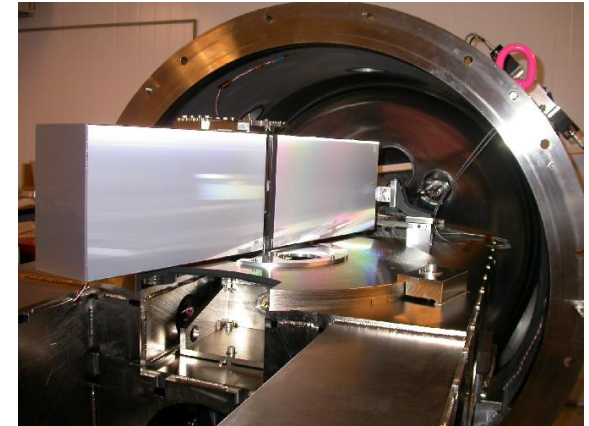
European Investments on Ground

Europe has made large investments in ultra-precise modern instrumentation suitable for asteroseismology:

- **UVES** spectrograph at the Very Large Telescope

- **HARPS** spectrograph at the 3.6m Telescope of the European Southern Observatory

- Danish-led asteroseismic **SONG** network is under development

+ many more

Important for follow-up studies of space-based observations

SpaceInn will enable:

Extension and efficient exploitation of these asteroseismology data by

- Spreading the data

- Combining data from ground and space

Work Programme

- **Coordinated archives** of space- and ground-based data & results of the analyses.
  - Tools for efficient data access
  - Organization in a Virtual Observatory environment

- Secured **long-term preservation** of these often unique data
  - Expertise by the National Library of Denmark in Copenhagen

- **Coordinated utilization** of the data
  - Improved understanding of solar structure, dynamics and activity, as well as of stellar structure and evolution

- An **increased awareness** of the field
  - Amongst the general public
  - At all levels of the educational system, throughout Europe

Project Overview
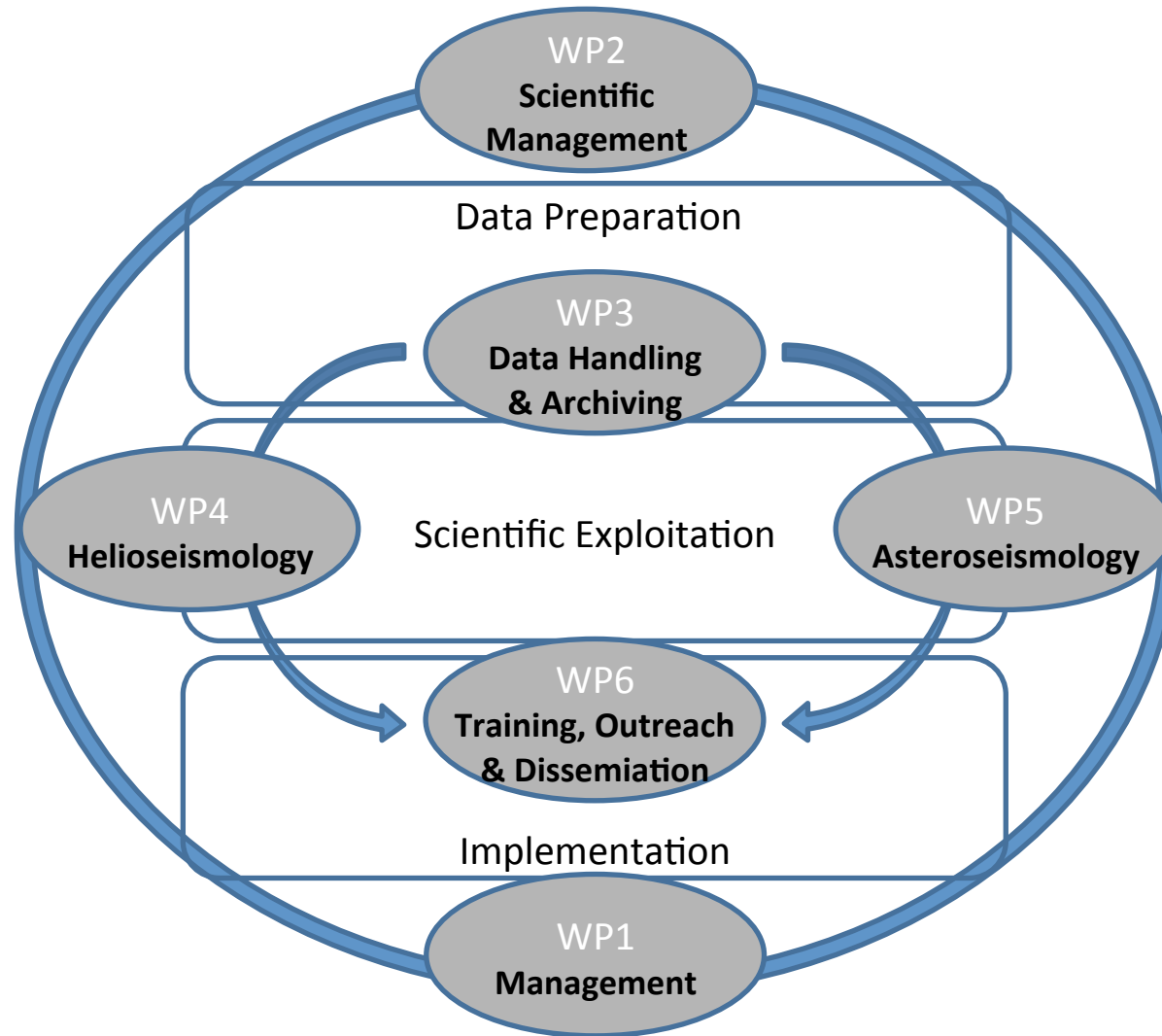
WP3: Data Handling & Archiving

- Coordinated access to the large variety of data sources available
  - space, ground, stellar, solar, photometry, velocity
- Provide tools to handle and combine data for a broad scientific community
  - Seismo community and beyond (exoplanets, galactic populations,…)

WP3 is the SpaceInn work package with the biggest work load

Chair: E. Michel, OBSPARIS

WP3: Data Handling & Archiving

- 'The Seismic Plus': a global public portal
- Seismic indices data base
- Ground-based CoRoT complementary archive
- KASOC, Kepler archive
- Ground-based Kepler complementary archive
- HMI/SDO European data centre
- "Mark-I" solar spectrophotometer data base
- Stellar/Solar Models
- …

WP4: Helioseismology

Two sub-WPs:

4.1 Global Helioseismology (*R. Garcia, CEA*)

– Study the changing Sun as it evolves in many different time scales (new magnetic activity index)

– New techniques to extract low-amplitude signals (p and g) modes by combining information provided by all the instruments.

– Tools to combine Sun-as-a-star observations (e.g. GOLF, BISON and VIRGO) with the imaged ones (e.g. GONG, MDI or HMI)

– Improve the realism of solar 3D models in which the convective envelope is non-linearly coupled to the deep solar radiative interior

WP4: Helioseismology

4.2 Local Helioseismology (*L. Gizon, MPG*)

– Explore systematic effects present in the analysis of space observations

– Make available and exploit numerical simulations of seismic waves and their interactions with internal heterogeneities and magnetic regions.

– Preparation of the Solar Orbiter mission to be launched in 2017

– Implement Fourier-Hankel/Legendre analysis (FH) to study structures like sunspots

– Develop fast, automated data processing by implementing efficient workflows to process historical data sets (MDI and GONG) and for the continued analysis of SDO-HMI data

WP5: Asteroseismology

Two major components:

- WP5-1: Solar-like oscillators (*W. Chaplin, UoB*)
- WP5-2: Heat-driven oscillators (*C. Aerts, KULeuven*)

Objectives:

- Reduce uncertainties in our understanding of stellar interiors physics
- Improvements to stellar properties estimation
- Leverage high-quality data from space missions, ground-based observations
- Linkages/synergies:
  - evolution & characterisation of stellar systems (inc. stellar activity)
  - stellar populations studies

Solar-like oscillators

- Solar-like oscillations: constraints on stellar interiors physics, non-standard processes
- Development, testing and verification of tools to fully exploit data:
  - Robust, accurate inference
  - Reliable knowledge of intrinsic limitations, biases

- **Tasks:**
  - End-to-end hare-and-hounds
  - Comparison of stellar evolution codes
  - Dealing with near-surface effects
  - Stellar activity cycles studies
  - Automated peak-bagging

Massive star asteroseismology: heat-driven oscillators

Why: details of the internal mixing processes determine the amounts of heavy-element production ➜ contribute significantly to the understanding of the chemical enrichment of the Galaxy.

Challenge

- Mode identification is difficult

But

- Uncertainties on evolution far larger
- Successful modeling will have large impact on stellar evolution theory

WP5-2: Heat-driven oscillators

To make progress in forward modelling ➔ identification of modes is need

Challenge: Frequencies do not follow oscillation patterns as for stars with stochastically excited modes

Solution: focus on stars for which fundamental stellar parameters can be deduced by other means than asteroseismology

Eclipsing Binaries

tuning of physical processes such as diffusion, convective mixing and differential rotation

WP6: Training, Outreach & Dissemination

- Dissemination of results of SpaceInn

- Strong involvement of the research groups active in this research area in the efforts of the SpaceInn project and usage of its developments
  - sharing and training on the use of data and innovative tools to combine data sets from different origins

- Reference publications on available data and guides/training materials

- Dissemination through publications and communication of results
  - establishing an archive of documentation
  - support material that facilitates the access to data

- Generating interest in the scientific community and related space agencies, and industry for the scientific exploitation based on the developed products or services

Chair: Mario Monteiro, CAUP

SpaceInn Workshops

- **Workshops/Tutorials**:

  - Dynamics of solar-like stars: current theoretical and observational challenges
    (3 days; to be organised by CEA until 09/2013)

  - Peak-Bagging Techniques, Data Inversion and Modelling
    (3 days; organised by IAC, this workshop)

  - Massive Asteroseismic Data Analysis in the XXIth century
    (5 days; organised by UPS until 09/2014)

  - Exploiting Seismic Data of Fast Rotating Stars
    (4 days; organised by UPST, until 03/2015)

  - Frequency Analysis of Pulsating Stars in Eclipsing Binaries
    (3 days; organised by KUL, until 09/2015)

  - Photometric and Spectroscopic Mode Identification
    (3 days; organised by KUL, until 03/2016)

Peak-Bagging Workshop/Tutorial

Excerpt from the SpaceInn Description of Work:

- The goal is to review and apply methodologies in the peak-bagging techniques, data inversion and modelling to identify causes of potential contamination of the outcomes that affect the resulting physics of the radiative and lower convection zones.

  In the detailed sounding of the radiative and lower convective zone in the Sun, at present, we still have not reached consistent precisions and resolutions of the order of nHz for helioseismic data.

  In terms of consistency, the various peak-bagging techniques applied to different instrument's data, must give similar results below a certain limit or precision.

  This topic should regain attention of the helio-seismic community, since the standard peak-bagging techniques that have been applied till now to existing data sets are more than a decade old and they contain some well-known bugs and errors.

  Without this effort, little improvement in the understanding of the deeper layers of the Sun (and hence of solar and stellar evolution) will be gained. The tutorials will address the need to upgrade existing tools in order to fully exploit the precision of the existing space data for the Sun available in the archives.

- Contribution: CEA, OBSPARIS, INAF, UOB, AU, UPS

SOLARNET Conferences

2013:

Synergies between ground- and space-based solar research, Norway

2014:

Solar and stellar magnetic activity, Italy

2015:

Helio- and asteroseismology, Germany

2016:

The physics of the Sun from the interior to the outer atmosphere, Spain

SOLARNET Schools & Workshops

- School: Introduction to solar physics
  Workshop: Radiative processes in the Sun and the stars
  Wroclaw, Poland, March – April 2014

- School: Ground- and space- based instruments
  Workshop: Methods in high resolution and synoptic solar physics
  Tatranska Lomnica, Slovakia, September 2014

- School: Solar magnetic fields: modeling and measuring techniques
  Workshop: Polarization as a tool to study the Sun, the Solar System, and beyond, Spain

- School: MHD waves and oscillations in the solar atmosphere
  Workshop: Heating mechanisms in the solar atmosphere, UK

- School: Solar MHD and magnetic reconnection theory
  Workshop: Solar eruptive events: observations and modelling, UK

Next HELAS Conferences

- 2014/15 HELAS-VI, Göttingen, Germany
  "Seismology of planet-hosting stars"
  September 1 – 5, 2014

- 2015 HELAS-VII / SOLARNET-III, Freiburg, Germany
  "Helio- and Asteroseismology"
  provisional August 31 – September 4, 2015

- 2016 HELAS-VIII / SpaceInn, Porto, Portugal
  "Exploitation of Space Data for Innovative Helio- and Asteroseismology"

Website