ADAHELI: Investigating the structure of Sun’s lower atmosphere

F. Berrilli, University of Roma, Tor Vergata (IT)
A. Bigazzi, Altran and INAF, Roma (IT)
L. Roselli, University of Perugia, (IT)
M. Velli, University of Florence, (IT)
and
the ADAHELI Team
• **ADAHELI** is an Italian Space Agency (ASI) project, approved for **Phase-A**, feasibility study within ASI’s “Small Missions” call.

• **ADAHELI** is a mini-satellite-class Mission, around 400Kg and a budget of **50 MEuros** + launch

• After Phase A, ASI will select **two Missions**, out of the five competing projects, to proceed on to design, manufacturing and launch, with no further selection.

• The two selected Missions will be launched by **2012 and 2014**, respectively.
ADAHELI's science objectives

1. Photospheric and chromospheric structure and dynamics
2. Emergence and evolution of solar active regions
3. Chromospheric and coronal heating and turbulence

   High-Energy (>1 MeV) particle acceleration in solar flares

Augmented Science Objectives (Optional Instruments):
   – Helioseismology
   – Basic physics: solar gravitational red-shift
   – EUV variability of different solar features on the Sun throughout the descending phase of the solar cycle.
   – Diagnostics of the extended solar corona.
   – Origin of ENA between terrestrial magnetosphere and geocorona
The need for new observations

- Chromospheric and photospheric large dynamical excursions and very short timescales, require fully time-dependent analysis;

- **Fabry-Perot interferometers** are the devices of choice for 2-D spectrometers, as they can provide sufficient spectral resolution (> 100,000) to well resolve the intricate signatures of large motions and changing magnetic fields in the spectral lines, and they can be tuned rapidly to obtain many spectral points in the required timeframe.

- On Earth, typical duration of good-quality observations is limited to about 1 hr while space-based observation may improve on this.

- Improve the statistical and temporal characterization of flare events at millimeter-waves. Verify the existence of fast time structures.
ISODY is a **50 cm** telescope for hi-res, high-cadence spectral imaging in the visible and NIR.
- Spatial res: 0.2“@430nm, 0.4“@830nm
- Spectral res: 230000@850nm

ISODY’s focal plane suite comprises:
- B-B channel for photospheric and chromospheric imaging in G-band, Ca K.
- N-B channel with a spectral imager based upon **Fabry-Perot** interferometers operating in the NIR regions around **845nm** and **1083nm**, for selected photospheric and chromospheric lines.

ISODY’s NB channel will perform high-cadence (5 ms exposure time, < 1fps) high-resolution monochromatic images, within a time frame of 30 s per scan. ISODY shall operate continuously for at least **4 hours** each day, in high-rate sampling mode.
The MIOS mmW radiometer

MIOS, a millimeter-wave (90 GHz) radiometer will measure the flux spectral density variations due to solar flares with high time-on-target (>75%), high temporal resolution (100ms), and good sensitivity (10sfu). MIOS will detect and determine solar flares intensities and temporal evolution.

A space-based solar radio-telescope with a sensitivity of 10sfu in 0.1s and 3sfu in 1s is expected to detect at least one order of magnitude more events than ground-based telescopes:

- makes careful statistical work possible
- will allow a more representative picture of the anomalous events with flat or rising non-thermal spectra at millimeter wavelengths to be obtained.
- The 0.1s resolution is also important to verify that the rapid fluctuations that SST has seen are not atmospheric in origin.
ADAHELI’s Optional Science instruments

Non-baseline, optional instruments:

**DIMMI-2h**: a double channel magneto-optical filter (MOF)-based **full disk imager** operating at 589 and 770 nm, allowing high temporal resolution velocity and magnetic field measurements at two **different heights** in the solar atmosphere.

- **NPA**, a Neutral Particle Analyzer able to detect Energetic Neutral Atoms (ENA) radiating from two different directions.

- **EISR**, an EUV imaging and spectro-radiometry instrument.
**ISODY’s heritage: IBIS (Interferometric Bi-dimensional Spectrometer)**

- **IBIS** is a tunable narrowband filter whose main components are two air-spaced, 50mm diameter Fabry-Perot interferometers.
- IBIS operates in the spectral range 580-860 nm and can provide quasi-monochromatic images at any wavelength in that range by suitably tuning interferometers.

IBIS is currently installed and working at the NSO/Dunn Solar Telescope.
IBIS: Photospheric and chromospheric line sampling

IBIS: FeI 630.2 nm lines: Intensity and longitudinal MF

IBIS: 854.2 nm Ca II Core
ISODY’S Fabry-Perot – Main Characteristics

- A closed-loop capacitive control system to adjust plate alignment and spacing.
- FP in classical mounting with an interferential filter in between.
- Spectral range = 8500 Å – 10900 Å
- Spectral lines: Fe I 8526.7 Å, Ca II 8542.1 Å, Mn I 8741 Å, Si I 10827.1 Å, He I Tripl. (10829.09 Å, 10830.25 Å, 10830.34 Å)
- Spectral resolution = 200,000 (@ 10900 Å) – 230,000 (@ 8500 Å)
- Parasitic ligth = 0.8 % – 1.0 %  Ghost = 0.8 %
- Field of View (FoV) = 105 arcsec
- Image spatial scale = 0.21 arcsec/pixel (2 – 2.6 arcsec/resolved element)
- Field-dependent blue-shift = 10^{-5} \lambda (85 \text{ mÅ} @ 8500 \text{ Å} – 109 \text{ mÅ} @ 10900 \text{ Å})
- Integration time = 3 – 4 ms (continuo solare, S/N = 100)
- Stability in \lambda = \pm 4.5 \text{ ms}^{-1} \text{ for } \Delta T = \pm 0.1 ^\circ \text{K} (\text{Zerodur capacitance supports})
• Ca II infrared triplet, around 854 nm

These lines are the best candidates for chromospheric diagnostics due to their relatively simple formation physics, their long wavelengths and the valuable information they carry on the thermal and magnetic conditions of the higher atmosphere.

• He I multiplet at 1083 nm

Of great interest for chromospheric and coronal studies, this line is seen in emission in prominences and in absorption in filaments, with strong polarization signals arising from both Hanle and Zeeman effect.
Mission Context: Solar Programs

- **Space Missions**
  - STEREO (2006)
  - Solar Dynamics Observatory (2008)
  - Picard (2009)
  - Solar Orbiter (2017?) ~ Sentinels (2017?)

- **Balloon Mission**
  - Sunrise (2009)

- **Ground-based Telescopes and Radiotelescopes**
  - GREGOR Telescope (2008 VIS-1.5m)
  - ALMA (radiotelescope array, 2012)
  - Advanced Technology Solar Telescope (4m USA, first light 2016)
  - **EST European Solar Telescope** (4m EU, first light 2019)
Carlo Gavazzi Space, is a leading Italian satellite manufacturer, providing LEO platforms from 35 to 800 Kg for scientific & commercial missions.

MITA - Microsatellite Italiano a Tecnologia Avanzata

AGILE - Astrorivelatore Gamma ad Immagini Leggero

MIOSAT - Missione Ottica basata su microSATellitite

PRISMA – Missione Ottica per Osservazione terrestre
Adaheli’s Phase-A Industrial Team

Thales Alenia Space – On-board electronics and Payloads Integration. Leading european aerospace industry in the design, development and manufacturing of Space Systems for orbital infrastructures and telecommunication, Earth Observation, meteorological and scientific satellites. Space transport systems and re-entry vehicles.

Telespazio S.p.A. – Ground Segment responsible
Leading european industry in the field of satellite services, ground segments and satellite operations.

Rheinmetall Italia S.p.A. – Support to thermo-mechanical project

Altran: European leading engineering consulting firm

SRS Engineering Design S.r.l. - SME, Telescope’s structure thermo-mechanical project

WIS S.r.l. – SME. mmW Radiometer project
ADAHELI’s Science Team: PI’s and Co-I’s

S.M. White, Co-I
Solar and stellar astrophysics, pre-flare and burst phenomena in microwaves

F. Zuccarello, Co-I
Solar dynamics, Evolution of solar active region

P. Curti, Co-I
Space Flight Dynamics

L. Valdettaro, Co-I
Modeling and Scientific Computing, Fluid Dynamics

S. Orsini, NPA proposer
Heliophysics, Monitoring of Space Storms, Neutral Atom Imaging

M. Romoli, EISR proposer
Solar physics, UV coronal spectroscopy

37th COSPAR Scientific Assembly, Montreal, 2008. Session E21
ADAHELI’s Associate Scientists

Alberto Egidi
Sergio Cantarano
Dario Del Moro
Valentina Penza
Bartolomeo Viticchiè
Marco Stangalini
Serena Criscuoli
Mauro Centrone
Fabrizio Giorgi
Franco Giammaria
Daniela Cardini
Alessandro Chieffi
Federico Alimenti
Valeria Palazzari
Antonio Vecchio
Fabio Lepreti
Luca Sorriso-Valvo
Lidia Contarino
Salvo Guglielmino
Anna Milillo
Alessandro Mura
Elisabetta De Angelis
Valeria Mangano
Gianna Cauzzi
Kevin Reardon
Marco Romoli

Dip. Fisica – Università di Roma Tor Vergata
Dip. Fisica – Università di Roma Tor Vergata
Dip. Fisica – Università di Roma Tor Vergata
Dip. Fisica – Università di Roma Tor Vergata
Dip. Fisica – Università di Roma Tor Vergata
Dip. Fisica – Università di Roma Tor Vergata
INAF - Osservatorio Astronomico di Arcetri
INAF - Osservatorio Astronomico di Arcetri
iNAF - Osservatorio Astronomico di Arcetri
Dip. Fisica – Università degli Studi dell'Aquila
INAF-IASF Roma
INAF-IASF Roma
DIEI - Università degli Studi di Perugia
DIEI - Università degli Studi di Perugia
Dip. Fisica – Università della Calabria
Dip. Fisica – Università della Calabria
INAF – Osservatorio Astrofisico di Catania
Dip. Fisica – Università di Catania
INAF – IFSI Roma
INAF – IFSI Roma
INAF – IFSI Roma
INAF – Osservatorio Astronomico di Arcetri
INAF - Osservatorio Astronomico di Arcetri
DASS – Università degli Studi di Firenze
• ADAHELI is an ASI low-budget, high-performance solar Mission based on a proven Small-Satellite class platform (such as CGS’s AGILE).

• ADAHELI will be the first mission to carry on-board a polarimetric imaging device based on a double Fabry-Perot interferometer, exploiting the same technology at the core of the Visible Imager and Magnetograph (VIM), which has been proposed for the ESA mission Solar Orbiter.

• ADAHELI’s instrument suite integrates and complements - without overlap - the present major objectives of ESA, NASA and the International Living with a Star program, in particular the Solar Dynamics Observatory, STEREO, Solar Orbiter and the Solar Probe missions.
Conclusions/2

Francesco Berrilli, University of Rome, Tor Vergata (IT)
Francesco.Berrilli@roma2.infn.it
Marco Velli, University of Florence (IT)
mvelli@arcetri.astro.it
Luca Roselli, University of Perugia (IT)
roselli@diei.unipg.it

Program Manager:
Paolo Sabatini. Director, Satellite Division, Carlo Gavazzi Space.
psabatini@cgspace.it

Science Program Manager:
Alberto Bigazzi, Altran Italy
Alberto.bigazzi@roma2.infn.it

Contacts: