1. SWAP and LYRA on PROBA-2 (VUV radiometry with PTB/BESSY)

2. Rapid Imaging Spectrograph Experiment: RAISE

3. Small Explorer for the study of Solar Eruptions: SMESE

4. A Chinese-German space weather mission: KuaFu

5. EUV Imager and Spectrometer on Solar Orbiter: EUI & EUS
1. **SWAP and LYRA on PROBA-2**

**PROBA-2:**

- A technology demonstration mission by ESA
- To be launched **end of 2008**
- Carries two solar instruments: SWAP and LYRA
- SWAP built by Centre Spatiale de Liège (CSL)
- LYRA built by PMOD-Davos (PI at ROB)
- Calibrations led by MPS

- Collaboration of MPS with PTB at BESSY for calibrations at the storage ring beamlines covering spectral range from X-ray to UV
- Calibration of detectors, mirrors, filters, and whole instruments
1. **SWAP and LYRA on PROBA-2**

**SWAP**: Sun Watcher using APS-detector

- A solar EUV filtergraph telescope at 17.5 nm
- innovative design: off-axis Richtey-Chrétien
- multilayer mirrors and CMOS-APS detector
- prototype instrument for Solar Orbiter EUI
1. SWAP and LYRA on PROBA-2

calibration of SWAP

at PTB/ BESSY II:

- for the first time
- full telescope directly at the synchrotron beamline
- on a six-axis goniometer
- first results with APS-Detector
LYRA: Large Yield RAdiometer

- measures the solar EUV irradiance
- with 4 spectral channels (filters!)
- using new diamond detectors (BOLD)
- 3 x 4 detectors, all calibrated at PTB
- at synchrotron beamline at BESSY II
1. **SWAP and LYRA on PROBA-2**

**calibration of LYRA**

at BESSY II using PTB’s normal incidence and grazing incidence beamlines to cover EUV and FUV range:

- characterization of diamond diodes
- pre-calibration at MPS in VUV reflectometer
- at PTB between 10 nm and 240 nm
- calibration of more than 30 diodes after fabrication
- calibration of the whole instrument (12 channels)

Flight data expected in 2009
RAISE is a NASA sounding rocket programme led by D. Hassler (SwRI) for the development of next generation VUV spectrograph (for e.g. Solar Orbiter) using new technology like:

- Toroidal Variable-Line Space grating (TVLS grating)
- intensified Active Pixel cameras (CMOS/APS detectors)

MPS makes development of cameras with intensified APS detectors (in collaboration with SwRI, DLR, Proxitronic Imaging)

startet in 2004 and the flight units will be delivered this month
2. Rapid Imaging Spectrograph Experiment: RAISE
2. Rapid Imaging Spectrograph
Experiment: RAISE

RAISE Overview

- **Shutter Mechanism**: A single electronics chassis contains three identical, modularized PC104 computer modules (one shown) to control each of the RAISE cameras, using a high-speed USB2 interface. Each module also contains 16 GB of solid-state flash memory and its own power supply. A fourth PC104 module controls the mechanisms and TM interfaces.

- **OAP Mirror Mount and PZT Scan Mechanism**: The RAISE OAP has a Bragg coating to enhance short-wavelength reflectance.

- **Aluminum-Coated Graphite Epoxy Composite Optical Bench**: Provides rigid, lightweight support structure for RAISE.

- **Identical Vacuum Camera Receptacles and Mount Mechanisms**: For all MCP intensified APS cameras, simplifies accommodation and testing.

- **RAISE 1k x 1k Active Pixel Sensor (APS)** and custom electronics, with 10 frames/second readout and 13-bit ADC, will be the fastest APS camera to be flown in space.

- **RAISE Slit-Jaw Camera (SJC)** relay optics (below the optical bench) incorporate a simple Cassegrain design to re-image the slit plane.

- **RAISE TVLS Grating**: Mechanically ruled by Tech Research, will be the first TVLS grating to be flown in space.
2. Rapid Imaging Spectrograph
Experiment: RAISE

Solar-blind intensified APS detector

- MCP intensifier
- Fiber optic coupler
- HV supply
- KBr coating
- Photocathode
- window
- Al-filter + Phosphor screen
- APS
- FEE
- STAR 1000 visible CMOS-APS sensor
- HV power supply
Photocathode converts photon to electron

MCP(s) amplify electron by $10^4$ to $10^8$

Rear field accelerates electrons to anode

Patterned anode measures charge centroid, Count stored in digital histogram
2. Rapid Imaging Spectrograph
Experiment: RAISE

Intensified APS

developed with Proxitronic GmbH and DLR Institute for Planetary Research for the NASA RAISE rocket spectrograph
2. Rapid Imaging Spectrograph Experiment

- 3 cameras built for RAISE
- In-house vibration and VUV testing
- To be delivered this month
2. Rapid Imaging Spectrograph
Experiment: RAISE

test images with EUV lamp

grid mask image at 123.6 nm

grid mask image at 58.4 nm
2. Rapid Imaging Spectrograph
Experiment: RAISE

front view of RAISE camera
2. Rapid Imaging Spectrograph
   Experiment: RAISE

Today we have deposited the first KBr photocathode on the third RAISE camera.
3. Small Explorer for the study of Solar Eruptions: SMESE

I. Energy release and initiation of Coronal Mass Ejections (CMEs)

II. The most energetic particles during solar flares

III. Energy transport during solar flares

IV. Large-Scale current sheets in the corona
3. Small Explorer for the study of Solar Eruptions: SMESE

**proposed instrumentation:**

- **LYOT**
  - LYman alpha imaging Orbiting Telescope
    - Lyman-α disk imager (LADI)
    - Lyman-α polarimetric coronagraph (LACI)

- **HEBS-X and HEBS-γ**
  - High Energy Burst Spectrometer

- **DESI R**
  - Detection of Eruptive Solar InfraRed emission
3. Small Explorer for the study of Solar Eruptions: SMESE

Mission Characteristics

- Duration: 2 years minimum; 3 optimum
- Time: scheduled for 2011-2012
- P/L mass: < 70 kg
- Sun-pointed stabilized platform in SS (6-18) orbit
- Roll of the S/C (polarization measurements): ~ twice a week
- Altitude: 650 – 750 km (radiation belts vs. geocorona)
- TM: compatible with continuous imaging at 10 s rate (+ compression)
  : ~ 35 Gbits/day
- Power: 100 W
3. Small Explorer for the study of Solar Eruptions: **SMESE**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Wavelength/Energy</th>
<th>Field of View</th>
<th>Spatial resolution</th>
<th>Cadence (watch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LYOT: Lα imager</td>
<td>121.6 nm</td>
<td>Full Disk</td>
<td>1.1 arcsec</td>
<td>10 s</td>
</tr>
<tr>
<td>LYOT: Lα coronagraph</td>
<td>121.6 nm</td>
<td>5*5 solar radii</td>
<td>2.3 arcsec</td>
<td>20 s</td>
</tr>
</tbody>
</table>
| DESIR: Infra-red Telescope | $35 < \lambda_1 < 80$ microns  
$100 < \lambda_2 < 250$ microns | Full Disk           | 50 arcsec at 35 microns | 100 ms          |
| HEBS                        | 10-500keV  
200keV-10MeV  
10MeV-600MeV | Full Disk           | Full disk           | 1 s, down to 32 ms |
3. Small Explorer for the study of Solar Eruptions: SMESE

The SMESE French-Chinese Team

China:
- PMO : Purple Mountain Observatory, CAS
- NJU : Nanjing University
- CSSAR : Center for Space Science and Applied Research (Beijing)
- NAOC : National Astronomical Observatory, CAS (Beijing)
- CNSA : Chinese National Space Agency

France:
- LESIA/OP : Laboratoire d’Etudes Spatiales et d’Instrumentation en Astrophysique (Paris Observatory)
- IAS : Institut d’Astrophysique Spatiale (Orsay)
- CNES : Centre National d’Etudes Spatiales

+ other institutions (LAM, MPS,...)!
3. design of a Lyman-\(\alpha\) camera for SMESE

Solar-blind intensified APS detector

= MCP intensifier coupled with a CMOS active pixel sensor
3. design of a Lyman-α camera for SMESE

APS sensor with 14 bit electronics built by MPS

MCP intensifier to be coupled with APS sensor
3. design of a Lyman-\(\alpha\) camera for SMESE

- first camera (EM1) delivered to IAS
- future model with new sensor (2k x 2k) to be developed in cooperation with Astrium
- design of photon counting electronics pending due to MPS manpower restructuring
### 4. **KuaFu** - A Chinese-German space weather mission

#### Table 3. List of suggested payloads onboard KuaFu-A

<table>
<thead>
<tr>
<th>Instrument name</th>
<th>Estimated mass (kg)</th>
<th>Countries involved in pre-research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Disk Imaging Package</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EUV/FUV Disk Imager</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi-order Solar EUV Spectrograph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronagraph for the Inner Range</td>
<td></td>
<td>Belgium</td>
</tr>
<tr>
<td>Coronagraph for the Outer Range (*)</td>
<td></td>
<td>Germany, Britain</td>
</tr>
<tr>
<td>Hard X-ray/Gamma-ray Spectrometer (*)</td>
<td>4.5</td>
<td>China</td>
</tr>
<tr>
<td>Radio Burst Instrument</td>
<td>11</td>
<td>France</td>
</tr>
<tr>
<td>Solar Wind Instrument Package</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluxgate Magnetometer</td>
<td>2.5</td>
<td>Britain, Germany</td>
</tr>
<tr>
<td>Plasma Instrument</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Solar Energetic Particle Sensor</td>
<td>6.5</td>
<td>Germany</td>
</tr>
<tr>
<td>Solar High-Energy Proton Detector (*)</td>
<td>4.7</td>
<td>China</td>
</tr>
<tr>
<td>Solar High-Energy Electron Detector (*)</td>
<td></td>
<td>China</td>
</tr>
<tr>
<td>Solar High-Energy Ion Detector (*)</td>
<td></td>
<td>China/Germany</td>
</tr>
<tr>
<td>Solar Irradiance Measurement (*)</td>
<td>13</td>
<td>China/Switzerland</td>
</tr>
<tr>
<td>Total mass</td>
<td>~129.5</td>
<td></td>
</tr>
</tbody>
</table>

There are 11 suggestions with 6 of which marked with (*) are led by China.
4. **KuaFu** - A Chinese-German space weather mission

Possible inclusion of a polarization device in a Lyman-\(\alpha\) telescope

Design solution to be studied:

(presently lacking manpower)
MPS Participations in Solar Orbiter

MPS participates in the Solar Orbiter remote sensing instrumentation:

1. Visible-light Imager and Magnetograph VIM (proposed as PHI)
2. Exteme Ultraviolet Imager EUI with the Lyman-α telescope channel
3. Extreme Ultraviolet Spectrometer EUS with the primary mirror optics
4. Coronagraph COR with the imaging detectors
The EUI instrument suite proposed to ESA is consisting of four telescopes:

- HRI 17.4 nm (Fe IX / X)
- HRI 19.5 nm (Fe XII / XXIV)
- HRI 121.6 nm (H I Lyman-\(\alpha\))
- FSI 17.4 nm / 30.4 nm (Fe IX/X / He II)

The consortium is composed of:

- Royal Observatory of Belgium (ROB)
- Centre Spaciale de Liège (CSL, Belgium)
- Mullard Space Science Laboratories (MSSL, UK)
- Institut d'Astrophysique Spatiale (IAS, France)
- MPI für Sonnensystemforschung (MPS, Germany)
MPS Participations in Solar Orbiter: EUI & EUS

EUI filtergraph design

Each HRI channel is a two-mirror (Ritchey-Chrétien) filtergraph.

two filters + multilayer coated mirrors!

The FSI is a single of-axis mirror (Herschelian) filtergraph
MPS Participations in Solar Orbiter: EUI Lyman-α channel

The Lyman-α detector:
- a solar-blind intensified CMOS/APS camera
- Very high count rate (< 1s cadence)
- spectral purity of >95%
EUI instrument performance summary

FSI simulated 19.5 and 30.4 nm images

HRI Lyman-α image
The EUV Spectrograph SPICE proposed to NASA is a spectrographic raster imager of the solar disk and the solar corona. With a occulting mechanism it can observe on the disk and in the corona (to 3 \( R_{\text{Sun}} \)).

The consortium is composed of:

- Southwest Research Institute (SwRI, USA)
- Goddard Space Flight Center (GSFC, USA)
- Rutherford Appleton Laboratories (RAL, UK)
- Institut d’Astrophysique Spatiale (IAS, France)
- MPI für Sonnensystemforschung (MPS, Germany)
- Institute of Theoretical Astrophysics (ITA, Norway)
Study of a dichroic telescope mirror for EUS

quartz mirror with SiC coating
visible + IR
baffle mirror
transmitted towards a radiator
Study of a dichroic telescope mirror for EUS

The VUV reflectometer chamber...

...being used for testing mirrors, gratings and detectors in the VUV between 58.4 nm and 147.0 nm
VUV reflectometer setup
Study of a dichroic telescope mirror for EUS

mirror coatings: SiC and B₁₄C

(for wavelengths > 50 nm)

Results:
The transmission, reflectance, and absorption of the solar spectral irradiance of the three mirror samples. The spectral curves were generated from the measured photometric properties using a solar irradiance from the „Solar 2000 Model“ spectrum.

⇒ The total power absorbed by the mirror with the 8.9 nm coating is less than 7%!
Study of a dichroic telescope mirror for EUS

- T = 83 %
- A < 7 %
- R = 11 %
- $R_{\text{VUV}} = 20 \text{ to } 40 \%$

- Quartz mirror with SiC coating
- Visible + IR
- Baffle mirror
Study of a dichroic telescope mirror for EUS

- mirror coating for wavelengths 50 nm and up: SiC and B₄C
- a thin coating of ~10 nm provides good VUV reflectivity of 35% to 45%
- longer wavelengths will be transmitted by a transparent substrate
- mirror temperature can be minimised
- detailed thermal study is simple.

→ dichroic telescope mirror can transmit more than 83% of the heat!
4. design of focal plane with intensified APS camera

focal plane design with selective photocathode coating
4. design of focal plane with intensified APS camera

Accommodation of long-wavelength band

More useful dynamic range with selective photocathode distribution
4. design of focal plane with intensified APS camera

BB unit has been built last year...
(in collaboration with SSL, UC Berkeley)
4. design of focal plane with intensified APS camera

...with selective coating of MCP with KBr
5. Radiometric transfer standard source

SUMER calibration source recently recalibrated at PTB/BESSY
5. Radiometric transfer standard source

CDS calibration source recently recalibrated at PTB/BESSY