Stratospheric Balloons
A potential platform for the next large FIR observatory

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1. Introduction: The ESBO DS Project
2. The Challenge – Science
3. The Challenge – Technology
4. Balloons as an Answer
5. How good would it get?
6. How do we get there? – ESBO Vision
1 - The ESBO DS Project

• Who?
  o University of Stuttgart, Institute of Space Systems (DE)
  o Swedish Space Corporation (SSC, SE)
  o Universität Tübingen (DE)
  o Max Planck Institute for extraterrestrial Physics (MPE, DE)
  o Instituto de Astrofísica de Andalucía (IAA, ES)

• What?
  o Design study for a balloon-based research infrastructure
  o Focus on regular, observatory type operations & easy access
  o Construction of a prototype UV/vis flight system
  o Conceptual design of a FIR balloon observatory

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 777516.
1 – The ESBO DS Project

Sunrise
- Solar Telescope
- UV/vis
- 0.1 arcsec resolution
- 1 m aperture
- Mass: 2 t

BLAST
- Submm telescope
- 205, 350, 500 µm
- 2 m aperture
- Mass: 1.8 t

PoGO+
- X-Ray telescope
- 600 kg telescope
- Mass: ~1.5 t

Sounding Balloons
- Visible camera
- 7 cm aperture
- Mass: 3 kg
A short reminder:
Selected upcoming science areas

Survey needs
- FIR continuum maps after IRAS
  - IRAS: 1.5 arcmin resolution
  - -> high spatial resolution
- FIR line maps (Galactic / extragalactic)
  - [CII], [OI], CO,…
  - -> high spectral & spatial resolution

Discrete sources
- FIR ice features
  - Determine structure & phase transitions
  - -> medium spectral resolution
- Spectroscopy of light hydrides
  - -> high spectral resolution

Cosmic Vision Themes

1) What are the Conditions for Planet Formation and the Emergence of Life?
Formalhaut: ESA/Herschel/PACS/ Bram Acke

4) How Did the Universe Originate and What is it Made of?
Andromeda: ESA/Herschel/PACS/ SPIRE/O. Krause, HSC, H. Linz
Main requirements for future FIR missions (the old mantra):

- **Higher sensitivity**
  - Larger telescopes, cooled telescopes -> SPICA

- **Higher angular resolution**
  (also: to overcome confusion limit)
  - Larger telescope or interferometry

- **Higher spectral resolution**
  - Heterodyne instruments

- **Longer observation times**
  More survey coverage (e.g. FIR cooling lines)

- **More detectors**
  More survey coverage

- **Unmanned**
  (wrt SOFIA -> less safety issues)
4 – Balloons as an Answer?

Why balloons?

- **Observation conditions „between ground & space“**
  - Above 99 % of atmospheric mass
  - Above 99.99 % of water vapour

- **Flight altitude:**
  - 30 to 40 km

- **Flight duration:**
  - Up tp ~40 days (zero pressure balloons)

- **Suspended mass:**
  - Up to 3,600 kg

- **5 m x 2.5 m telescope:**
  - 2x SOFIA spatial resolution, increase of Herschel's confusion limit
  - Similar collecting area as Herschel
  - Gregorian Off-Axis design

- **Practical implications:**
  - Exchange of instruments
  - Update & repair of instruments
  - Refill of cryogens
5 – How good would it get?

Performance for science applications

- **FIR line maps** (Galactic / extragalactic)
  - [CII], [OI], CO, ...
  - Mapping of M32 in ca. 1 year (~40 observation days)

- **FIR continuum maps after IRAS**
  - IRAS: 1.5 arcmin resolution @100 µm
  - ESBO 5 m: 5 arcsec @100 µm

- **FIR ice features**

- **Spectroscopy of light hydrides**
  - See table on the right

Potential Sensitivities
(900 s exposure time, 4 σ, ca. 44 kHz, i.e. 0.003 to 0.01 km/s resolution)

Selected lines of light hydrides
(900 s exposure time, 4 σ, ca. 44 kHz, i.e. 0.003 to 0.01 km/s resolution)

<table>
<thead>
<tr>
<th>Species</th>
<th>Wavelength</th>
<th>Line sensitivity [W/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 km</td>
<td>30 km</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>181.05 µm</td>
<td>8.95·10⁻¹⁶</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>100.87 µm</td>
<td>1.59·10⁻¹⁶</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>100.58 µm</td>
<td>5.82·10⁻¹⁶</td>
</tr>
<tr>
<td>CH⁺</td>
<td>179.62 µm</td>
<td>-</td>
</tr>
<tr>
<td>CH⁺</td>
<td>90.03 µm</td>
<td>-</td>
</tr>
<tr>
<td>CH⁺</td>
<td>72.14 µm</td>
<td>5.59·10⁻¹⁶</td>
</tr>
<tr>
<td>HF</td>
<td>121.70 µm</td>
<td>-</td>
</tr>
<tr>
<td>HF</td>
<td>81.22 µm</td>
<td>-</td>
</tr>
</tbody>
</table>

10x
6 – How to get there

Potential ESBO Timeline

<table>
<thead>
<tr>
<th>Idea</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations &amp; Governance</td>
<td>ESBO organisation founded</td>
</tr>
<tr>
<td>„FIR“ flight system</td>
<td>Science flights of „FIR“ System</td>
</tr>
<tr>
<td>Intermediate extension</td>
<td>Science flights with new instruments</td>
</tr>
<tr>
<td>„UV“ flight system</td>
<td>Possibly with NIR capabilities</td>
</tr>
</tbody>
</table>

2016 2018 2021 2023 2025 2033
Thank you for your attention!

Your input is welcome!
We welcome scientific & experimental collaboration
Safe landing & recovery
Safe Landing
Backup II

UV/vis Prototype Mission
UV/vis prototype (0.5 m)

Flight-ready Prototype

Telescope/Platform

- 0.5 m UV-NIR Telescope
- 400-500 kg Gondola
- Coarse telescope stabilization in azimuth & elevation
- Exchangeable instruments
- Space for add-on instruments

Instruments

- Highly sensitive imaging UV-camera (180 - 330 nm)
- Andor-camera for the visible range (330 – 1000 nm)
- Image stabilization within the optical path (goal: ~ 0.5 arcsec)

PoGO+ gondola, built by SSC. Credit: SSC.
## Main Telescope Parameters

<table>
<thead>
<tr>
<th><strong>Scientific Application / Main Instrument</strong></th>
<th><strong>Secondary Instrument</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument</td>
<td>Custom MCP*</td>
</tr>
<tr>
<td>Main application</td>
<td>UV Photometry</td>
</tr>
<tr>
<td>Main wavelength range</td>
<td>180 – 330 nm</td>
</tr>
<tr>
<td>Sensor size</td>
<td>40 mm Ø</td>
</tr>
<tr>
<td>Pixel size</td>
<td>20 µm x 20 µm</td>
</tr>
<tr>
<td>Preferred FOV</td>
<td>Ca. 32 arcmin Ø</td>
</tr>
<tr>
<td>Instrument</td>
<td>Andor iXon</td>
</tr>
<tr>
<td>Main application</td>
<td>Image stabilisation</td>
</tr>
<tr>
<td>Wavelength range</td>
<td>Ca. 330 – 1000 nm</td>
</tr>
<tr>
<td>Sensor size</td>
<td>13.3 mm x 13.3 mm</td>
</tr>
<tr>
<td>Pixel size</td>
<td>13 µm x 13 µm</td>
</tr>
</tbody>
</table>

### Current Telescope configuration

<table>
<thead>
<tr>
<th><strong>Configuration</strong></th>
<th><strong>Cassegrain</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture</td>
<td>500 mm</td>
</tr>
<tr>
<td>Focal ratio</td>
<td>f/8</td>
</tr>
</tbody>
</table>

*MCP = Micro Channel Plate*
Flight option Prototype Flight

“Turnaround Conditions” over Esrange / Kiruna

Environmental Conditions

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight duration:</td>
<td>10-40 h</td>
</tr>
<tr>
<td>Flight altitude:</td>
<td>Ca. 40 km</td>
</tr>
<tr>
<td>Season of flight:</td>
<td>2nd half of August 2021</td>
</tr>
<tr>
<td>Ambient pressure:</td>
<td>&gt; 3 mbar</td>
</tr>
<tr>
<td>External air temperature (flight):</td>
<td>-70 deg C</td>
</tr>
<tr>
<td>Air temperatures (ground):</td>
<td>-15 deg C</td>
</tr>
</tbody>
</table>