Why (and how to) do astronomy from balloons?


$^1$Institute of Space Systems, University of Stuttgart, Germany, $^2$Swedish Space Corporation, Sweden, $^3$Institut für Astronomie und Astrophysik, Universität Tübingen, Germany, $^4$Instituto de Astrofísica de Andalucía (CSIC), Spain, $^5$Max-Planck-Institut für extraterrestrische Physik, Germany
The ESBO DS Project

• What?
  - Design study for European Stratospheric Balloon Observatory
  - 3-year H2020 project (Mar 2018 – Feb 2021)

• Goals:
  - Regularly flying balloon observatory, long-term: 5 m FIR telescope (5-15 years perspective, feasibility study)
  - 0.5 m UV prototype (launch foreseen for Sept. 2021)

• Who?

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 777516.
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• Who?

See poster by S. Bougueroua & talk by L. Hanke
1. Why do Astronomy from Balloons – Opportunities and limitations
2. Current Capabilities
3. Achievements and capabilities ahead
4. Observational Conditions
5. What is Missing? – The idea behind ESBO
1. Why balloon-borne astronomy?

Historically: because there was nothing else.

- 1912: Experimental confirmation of cosmic rays by V.F. Hess on a manned balloon (few kg?)
- 1957: Stratoscope I, a 0.3 m aperture solar telescope (USA, 0.8 t)
- 1963: Stratoscope II, a 0.9 m aperture telescope (USA, 3.6 t)
- Early development in Germany as well:
  - 1973: THISBE (UV-FIR; MPIA)
  - 1975: Spektro-Stratoskop (KIS)
  - 1977: MPE Compton Teleskop
  - 1978: IAAT/MPE X-ray experiment
  - 1980: Golden Dragon (FIR; MPE)
  - 1980: HEXE (X-rays; MPE & IAAT)
1. Why balloon-borne astronomy?

And today? – Observational Conditions

FIR Atmospheric Transmission

Vis/NIR Atmospheric Transmission
1. Why balloon-borne astronomy?

**Day-/nighttime differences**

Visible

Near-infrared

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**Sky Brightness [kR/nm]**

**Wavelength [nm]**

- 30 km
- 40 km
- Nighttime Ground
- Daytime ground (Ivanov 1970)

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**Sky Brightness [kR/nm]**

**Wavelength [nm]**

- 39 km
- Mauna Kea
- Nighttime 41 km
Content

1. Why do Astronomy from Balloons – Opportunities and limitations
2. Current Capabilities
3. Achievements and capabilities ahead
4. What is Missing? – The idea behind ESBO
# 2. Current capabilities

## Operational conditions compared to space

<table>
<thead>
<tr>
<th></th>
<th>Balloon</th>
<th>Space</th>
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<tbody>
<tr>
<td>Launch costs</td>
<td>0.4 – 3 MEUR</td>
<td>&gt; 70 MEUR</td>
</tr>
<tr>
<td>Shape and size restrictions:</td>
<td>Flexible</td>
<td>Launcher payload fairing</td>
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<tr>
<td>Available data retrieval rates:</td>
<td>&gt; 100 GB/day avg.</td>
<td>2 GB/day (Herschel)</td>
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<tr>
<td>Pointing restrictions</td>
<td>Southern/Northern hemisphere 24-h cycle wrt ecliptic for mid-latitudes</td>
<td>None / 90-min cycles, depending on orbit</td>
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![PoGO+ (2013, 2016)]
- PI: KTH (SE)
- X-ray telescope

![Sunrise (2009, 2013, ...)]
- PI: MPS (D)
- 1 m UV solar telescope

![OLIMPO (2014, 2018)]
- PI: Univ. La Sapienza (IT)
- 2.6 m CMB telescope
And today?

Launch Sites:

- **Short-duration flights**  ca. 30 h  
  (3 h to ~ 40 h, April & Aug/Sept)
- **Mid-duration flights**  ca. 130 h  
  (~ 7 days, May-Aug)
- **Long-duration flights**  ca. 1000 h  
  (up to 55 days, Nov-Jan)
- **Inactive**

Generally:

- 30 to 40 km altitude (above 99.9 % of atm. Mass)
- Up to 3.6 t payload
- Image stabilisation: < 0.1”
2. Current Capabilities

**And today?**

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1. History of BBA
2. Current Capabilities in stratospheric ballooning
3. Achievements and capabilities ahead
4. A regular observatory – the ESBO vision
3. Achievements and Capabilities ahead

Ultra Long Duration flights

- Based on Super Pressure balloons
- Flight durations of 100 days and more
- 1000 – 2000 h of observation per flight
- Launch sites: McMurdo (AQ), Wanaka (NZ)

Trajectory of ULDB Flight 2016 (COSI): Wanaka (NZ) -> Peru 46 days afloat
Reliable landing technology

Current situation:
• Unsteered parachutes
• No opening shock damping

Future improvements: soft landings
• Automated steered parafoils
• Opening shock damping
• Subject to work under ESBO DS
1. History of BBA
2. Current Capabilities in stratospheric ballooning
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4. What is missing?– The idea behind ESBO
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Challenges

- Experiment vs. observatory
- Resources for instrument + telescope + platform
- Too much effort on technology + platform -> smaller percentage of focus on science return
- Reliability of flight opportunities (part. Antarctica)
- „Something always breaks“
**Goal:** Establish an accessible balloon-borne astronomical observatory

- Instrument flight opportunities
- Observation time access
- Exchange, upgrade, refill of instr.
- Regular flights, regular operation
- Fast turnaround times
- Maximum re-use of hardware

**Enablers:**
- Modern balloon systems & long flight trajectories
- Soft landing technologies
- Autonomous systems
4. What is missing? – The idea behind ESBO

Observatory elements under ESBO DS / STUDIO Prototype

- Safe landing technologies
- Modular gondola
- Modular / expandable ADCS
- Flexible Mission Control SW
- Instrument-independent image stabilisation
- Qualification procedures
Other observatory facility proposals

Gondola for High Altitude Planetary Science (GHAPS)

FIR Astronomy Stratospheric Balloon Facility
(see talk by J. Pineda)
4. What is missing?

Other observatory facility proposals

Gondola for High Altitude Planetary Science (GHAPS)

FIR Astronomy Stratospheric Balloon Facility
*(see talk by J. Pineda)*

- Plumes in Icy Worlds
- Minimal terrestrial absorption
- H$_2$O and CO$_2$ in comets
- KBO, NEO Asteroid Binaries
- 100-day flights
- Diffraction-limited performance
- UV-Vis-IR spectroscopy and imaging

**Proposed instrument suite & science capabilities**

A cost-effective state-of-the-art 2.5-m class balloon borne facility observatory to accommodate next-generation instruments for infrared astronomy

- Easy access to the sky for science teams and instrument developers with no capabilities to run a complete balloon or space mission
- Up to 4,000 hrs. of observing time per year
- Medium resolution Fabry-Perot interferometers or Fourier Transformation Spectrometers
The other way around: questions to you

• What has to change to increase the attractiveness of balloon platforms / the science return?
• How do you see the roles of space/balloon-/air-borne platforms?