Stratospheric Balloons
A potential platform for the next large FIR observatory

ESBODS
Stratospheric Observatory

P. Maier[1], J. Wolf[1], T. Keilig[1], A. Pahler[1], S. Bougueroua[1], A. Krabbe[1], R. Duffard[4], J. L. Ortiz[4], S. Klinkner[1], M. Lengowski[1], T. Müller[5], C. Lockowandt[2], C. Krockstedt[2], N. Kappelmann[3], B. Stelzer[3], K. Werner[3], S. Geier[3,6], C. Kalkuhl[3], T. Rauch[3], T. Schanz[3], J. Barnstedt[3], L. Conti[3], L. Hanke[3], M. Kaźmierczak-Barthel[1]

[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, [6]Institut für Physik und Astronomie, Universität Potsdam, Germany

Presented by P. Maier
International Astronautical Congress 2018
Bremen, Germany
04.10.2018

Content

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

ESBO DS
Stratospheric Observatory

1 - The ESBO *DS* Project

ESBO DS
Stratospheric Observatory

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

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

European Commission

HORIZON 2020

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

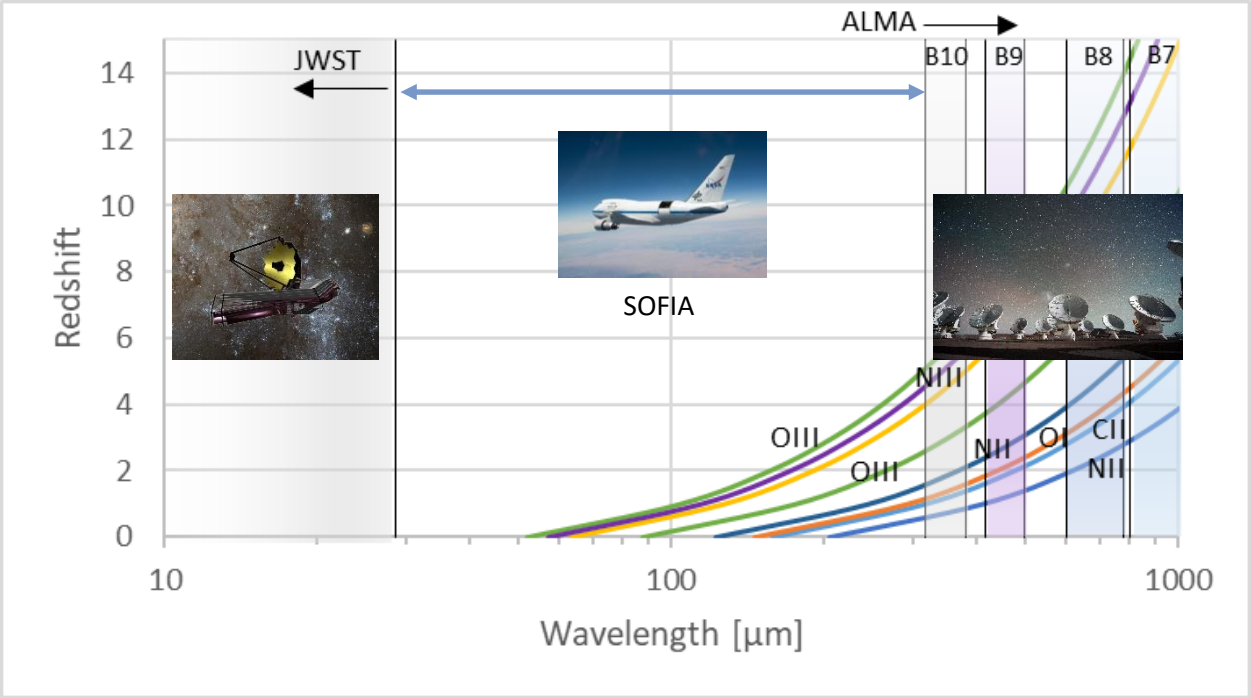
Sounding Balloons

- Visible camera
- 7 cm aperture
- Mass: 3 kg

ESBO

2 – The Challenge (Science)

A short reminder:



Selected upcoming science areas

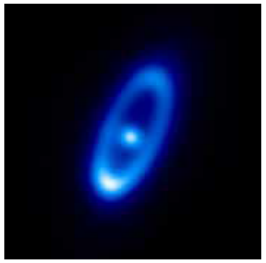
<u>Survey needs</u>

- 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**

<u>Discrete sources</u>

- 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?

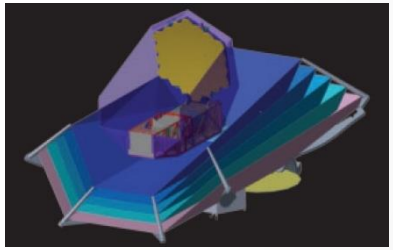
Andromeda: ESA/Herschel/PACS/SPIRE/O. Krause, HSC, H. Linz

2 – The Challenge (Technology)

Main requirements for future FIR missions (the old mantra):

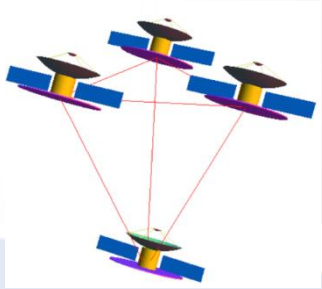
- Higher sensitivity
  -> Larger telescopes, cooled telescopes -> SPICA

- 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)



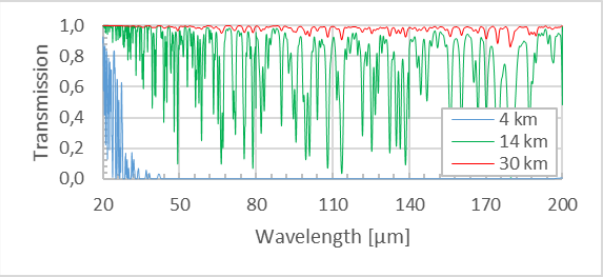
- More detectors
  More survey coverage

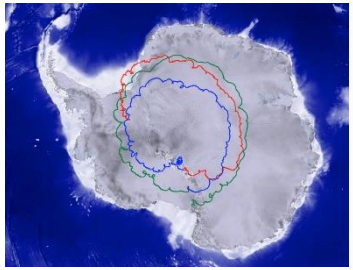
- Unmanned
  (wrt SOFIA -> less safety issues)

4 – Balloons as an Answer?

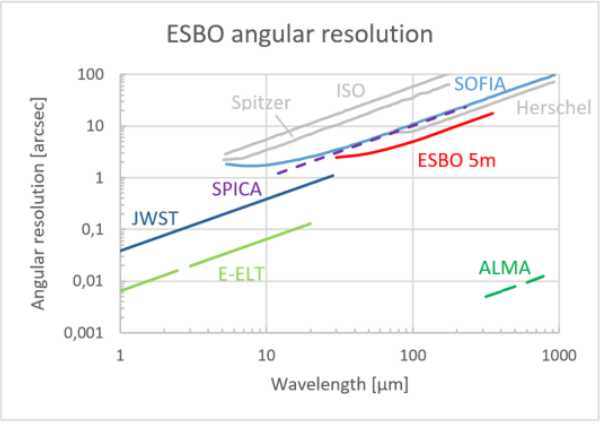
Why balloons?

- 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





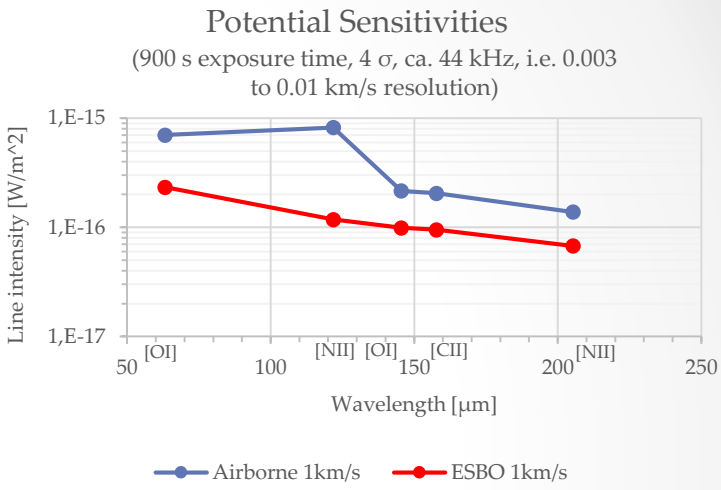
Long-duration flights (5 days / 55 days)



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

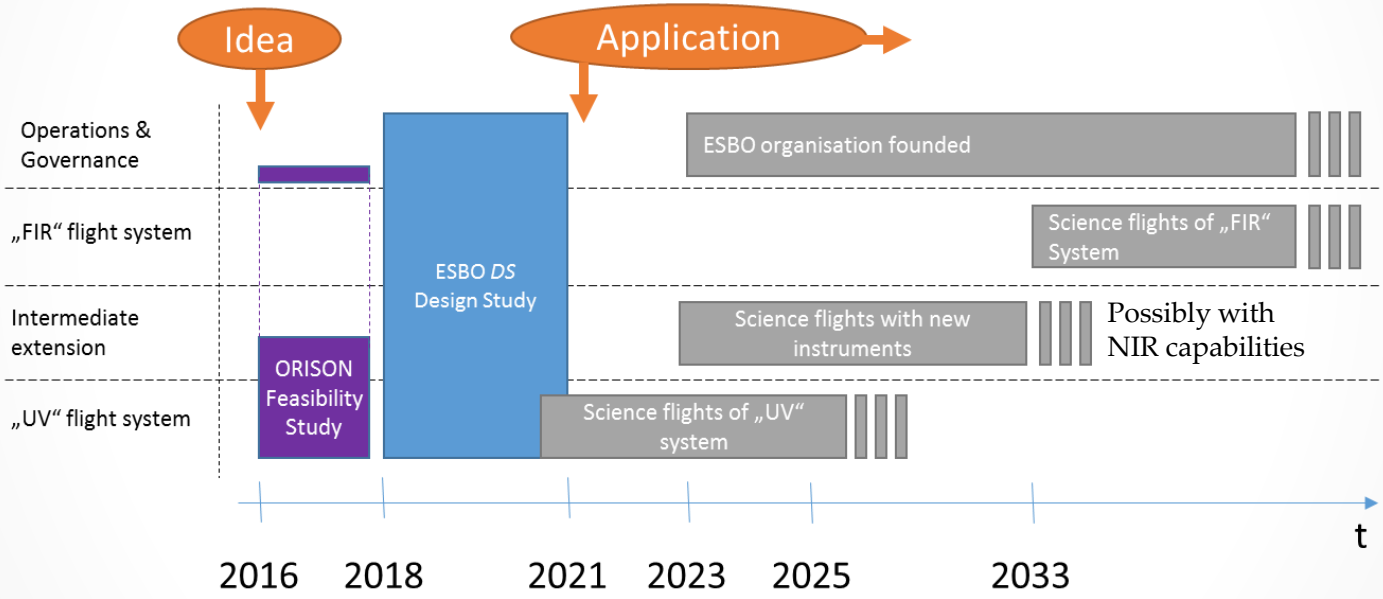


Selected lines of light hydrides
(900 s exposure time, 4 σ, ca. 44 kHz, i.e. 0.003 to 0.01 km/s resolution)

Species	Wavelength	Line sensitivity [W/m²] 14 km	30 km
H_3O^+	181.05 µm	$8.95 \cdot 10^{-16}$	$9.36 \cdot 10^{-17}$
H_3O^+	100.87 µm	-	$1.59 \cdot 10^{-16}$
H_3O^+	100.58 µm	$5.82 \cdot 10^{-16}$	$1.52 \cdot 10^{-16}$
CH^+	179.62 µm	-	$9.81 \cdot 10^{-17}$
CH^+	90.03 µm	-	$1.68 \cdot 10^{-16}$
CH^+	72.14 µm	$5.59 \cdot 10^{-16}$	$2.06 \cdot 10^{-16}$
HF	121.70 µm	-	$1.63 \cdot 10^{-16}$
HF	81.22 µm	-	$7.76 \cdot 10^{-16}$

10x

Potential ESBO Timeline



Thank you for your attention!

Your input is welcome!

We welcome scientific & experimental collaboration

Backup I

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)

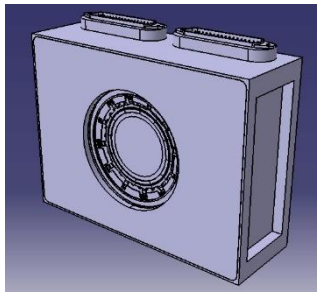
PoGO+ gondola, built by SSC. Credit: SSC.

Main Telescope Parameters

Scientific Application / Main Instrument	
Instrument	Custom MCP*
Main application	UV Photometry
Main wavelength range	180 – 330 nm
Sensor size	40 mm Ø
Pixel size	20 µm x 20 µm
Preferred FOV	Ca. 32 arcmin Ø

Secondary Instrument	
Instrument	Andor iXon
Main application	Image stabilisation
Wavelength range	Ca. 330 – 1000 nm
Sensor size	13.3 mm x 13.3 mm
Pixel size	13 µm x 13 µm

Current Telescope configuration	
Configuration	Cassegrain
Aperture	500 mm
Focal ratio	f/8



UV MCP detector

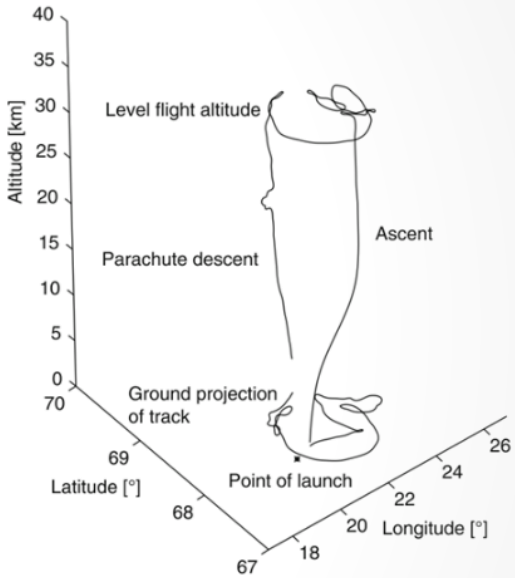
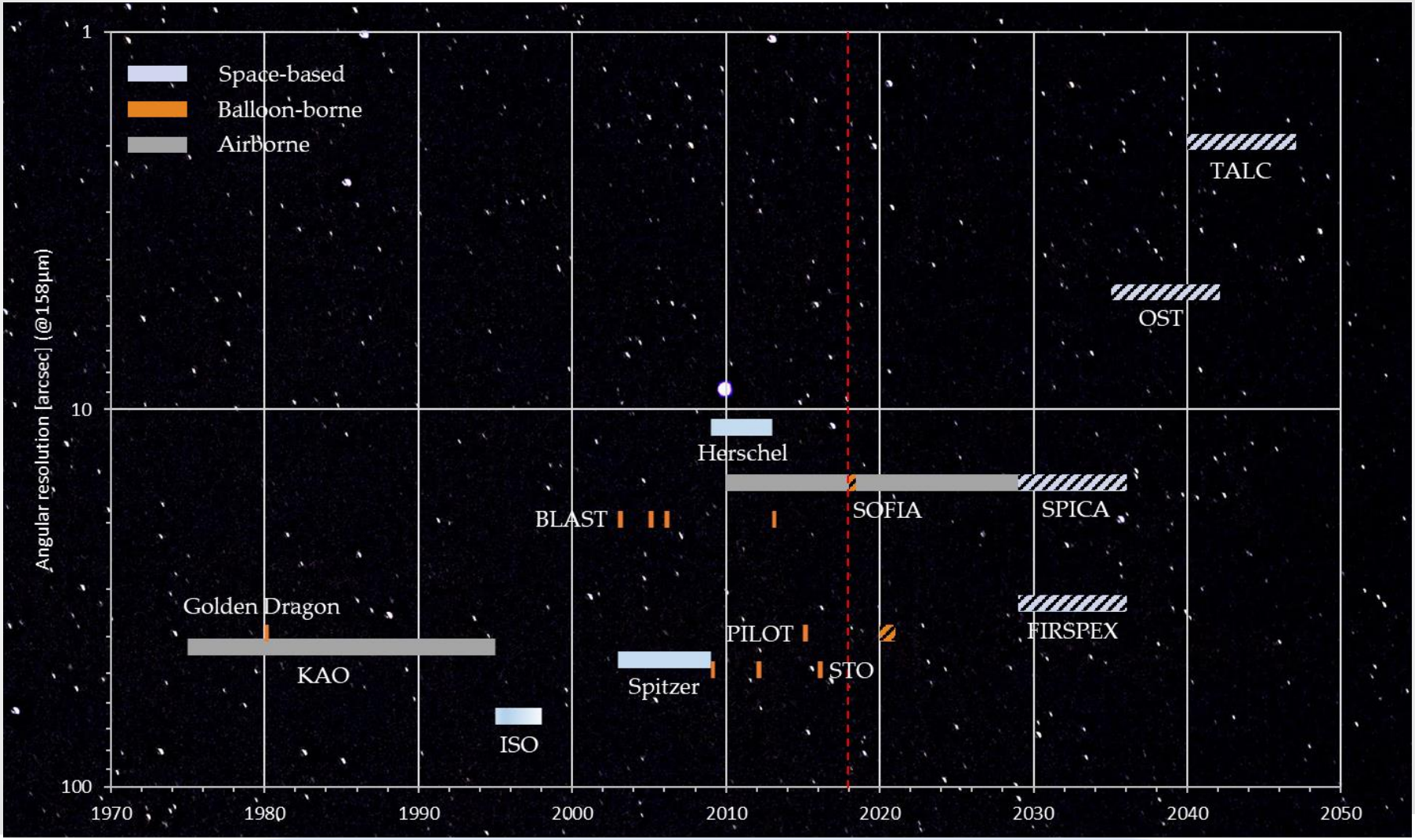
Andor iXon 888

*MCP = Micro Channel Plate

Flight option Prototype Flight

“Turnaround Conditions” over Esrange / Kiruna

Environmental Conditions	
Flight duration:	10-40 h
Flight altitude:	Ca. 40 km
Season of flight:	2nd half of August 2021
Ambient pressure:	> 3 mbar
External air temperature (flight):	-70 deg C
Air temperatures (ground):	-15 deg C



2 – The Challenge (Technology)