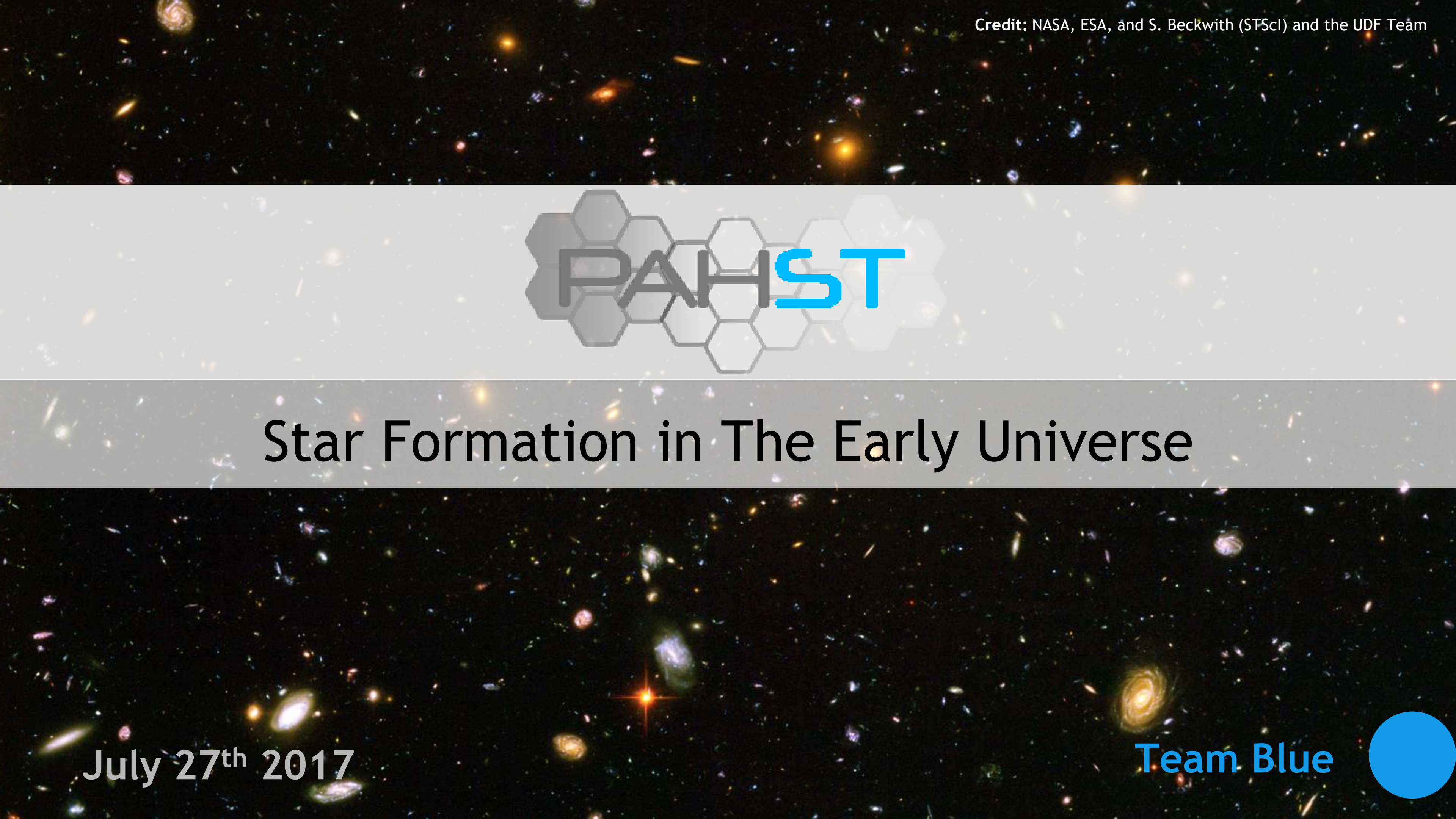


Credit: NASA, ESA, and S. Beckwith (STScI) and the UDF Team

PAHST

Star Formation in The Early Universe

July 27th 2017

Team Blue

SCIENCE CASE

SCIENCE CASES

TOPICS

Primary science topic:

Towards a complete view of star formation in the early Universe at z~5 and beyond

Secondary science topic:

Inner structure of “ridges” (dense filaments) in the Galactic ISM

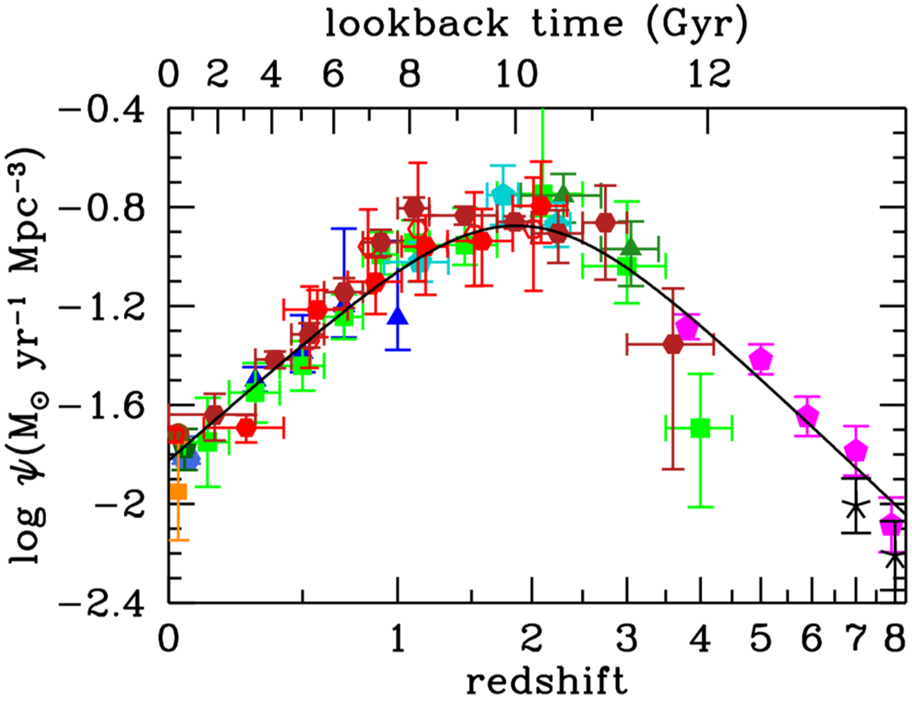
Tertiary science topic:

Y-class Brown Dwarfs Observations

COSMIC STAR FORMATION HISTORY

MOTIVATION

Star formation rate density

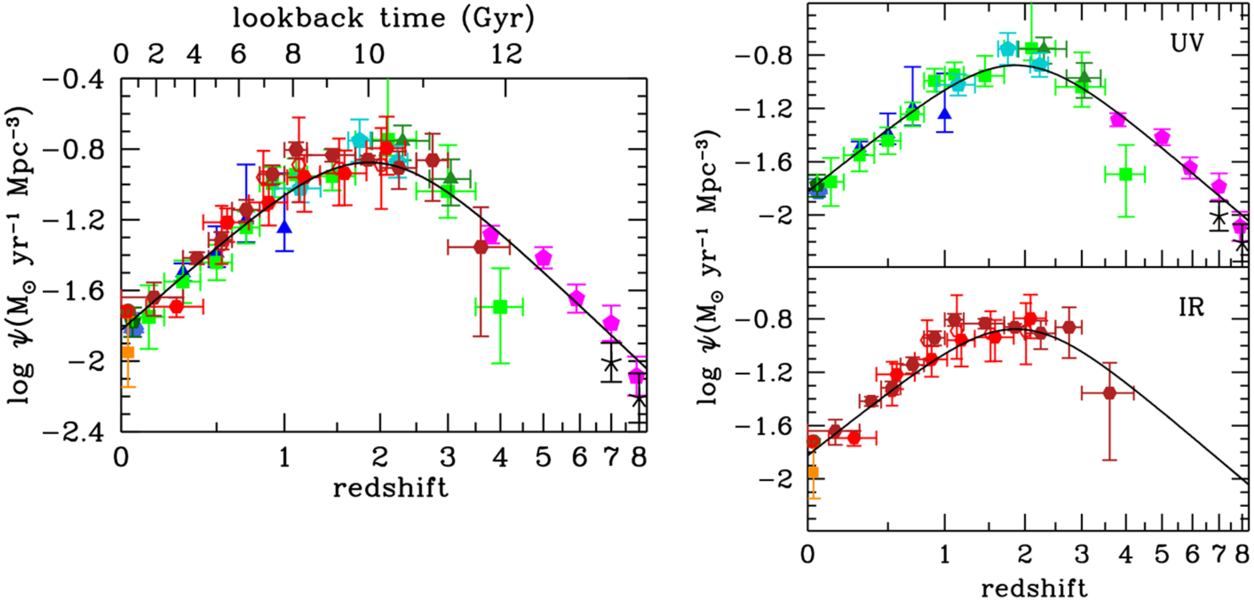


Madau et al. (2014)

COSMIC STAR FORMATION HISTORY

MOTIVATION

Star formation rate density

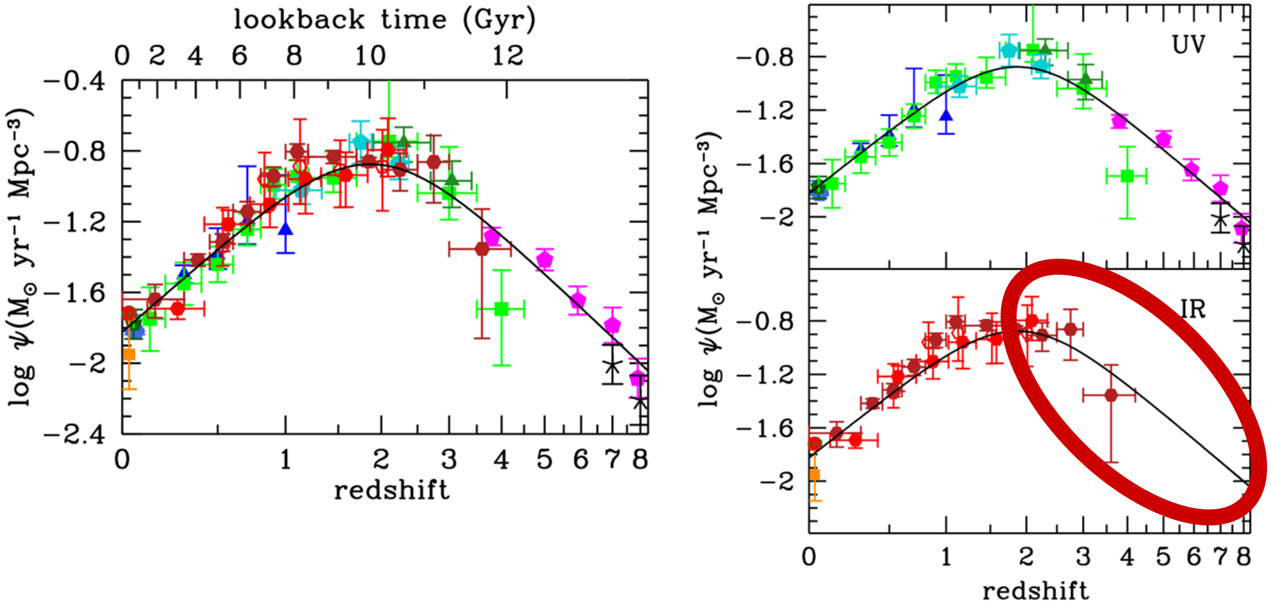


Madau et al. (2014)

COSMIC STAR FORMATION HISTORY

MOTIVATION

Star formation rate density

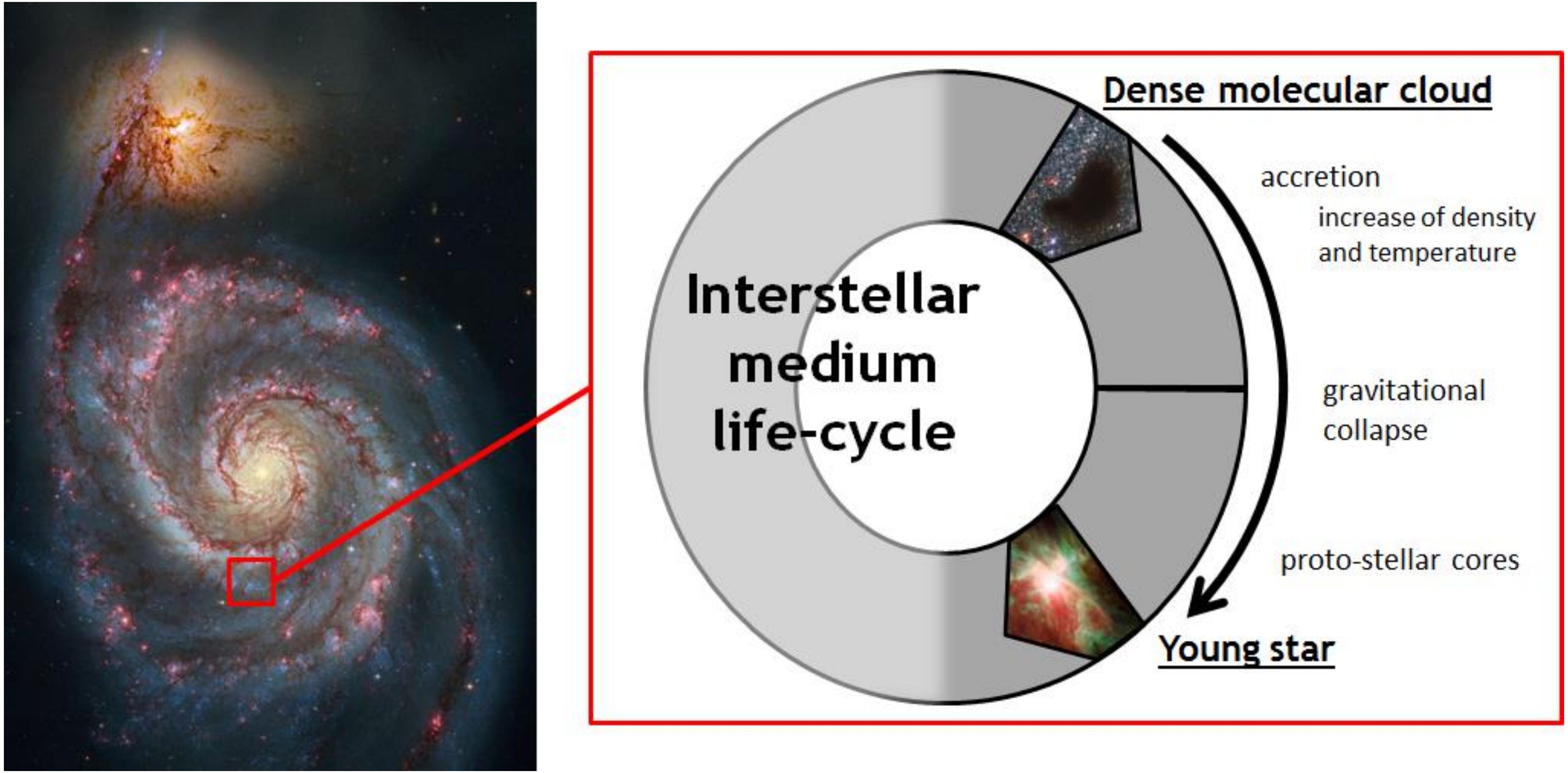


Madau et al. (2014)

HOW DO STARS FORM?

(in the local universe…)

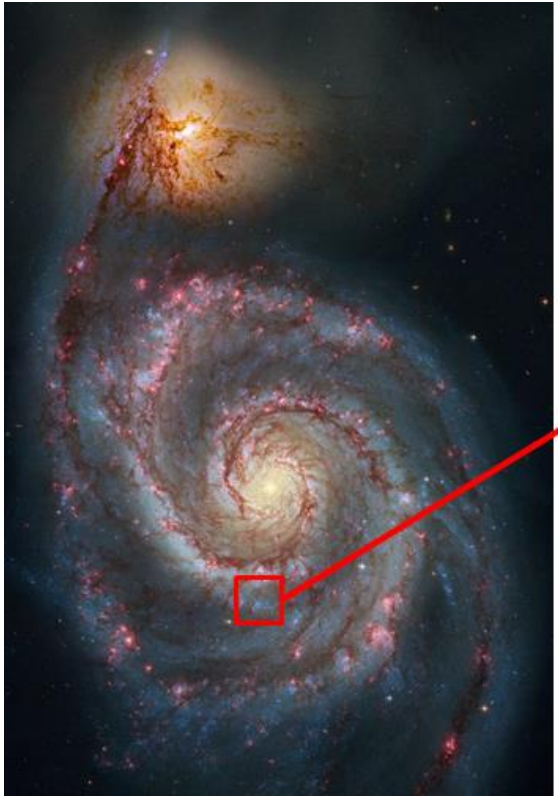
INTRODUCTION

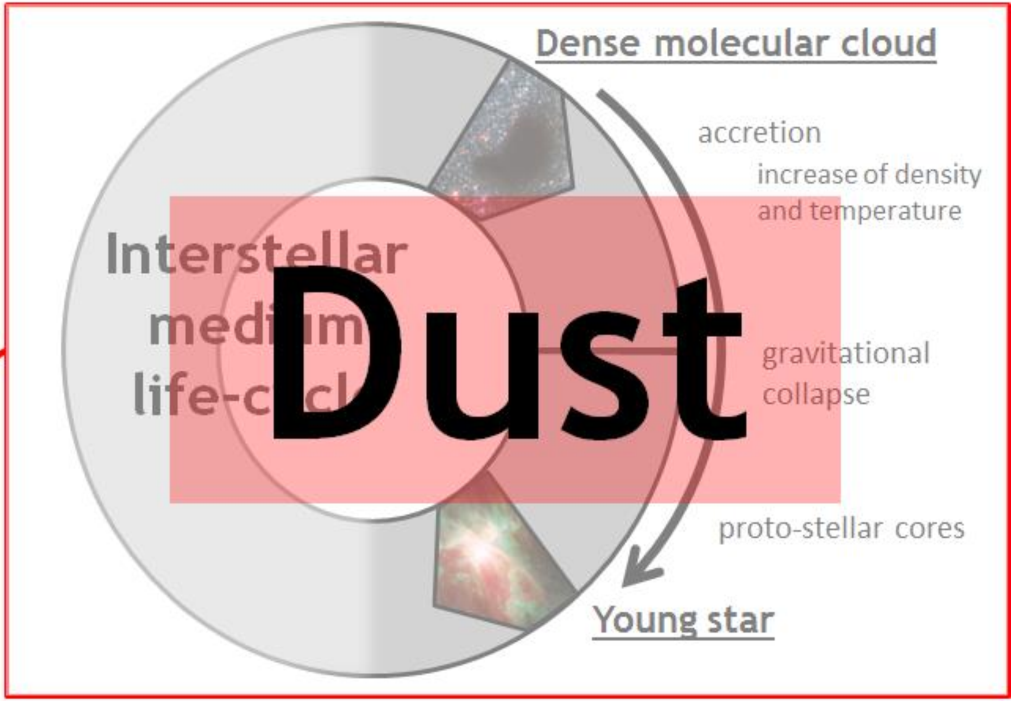


Credit: NASA, Hubble Heritage Team, ESA, S. Beckwith
Credit: FORS Team, 8.2-meter VLT Antu, ESO
Credit: NASA, JPL-Caltech, T. Megeath

STAR FORMATION IN GALAXIES

INTRODUCTION

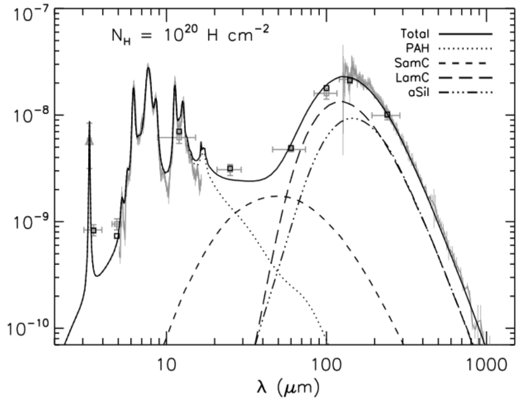




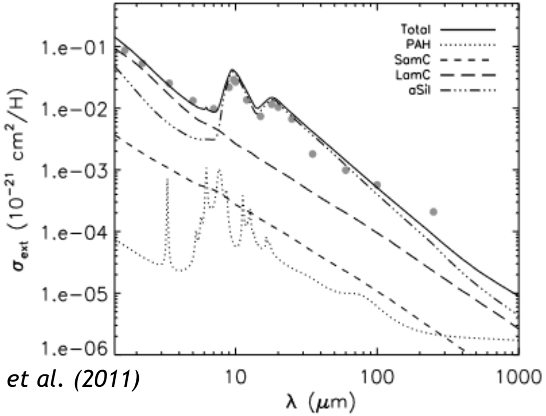
Credit: NASA, Hubble Heritage Team, ESA, S. Beckwith
Credit: FORS Team, 8.2-meter VLT Antu, ESO
Credit: NASA, JPL-Caltech, T. Megeath

DUST - BASICS

Emission



Extinction



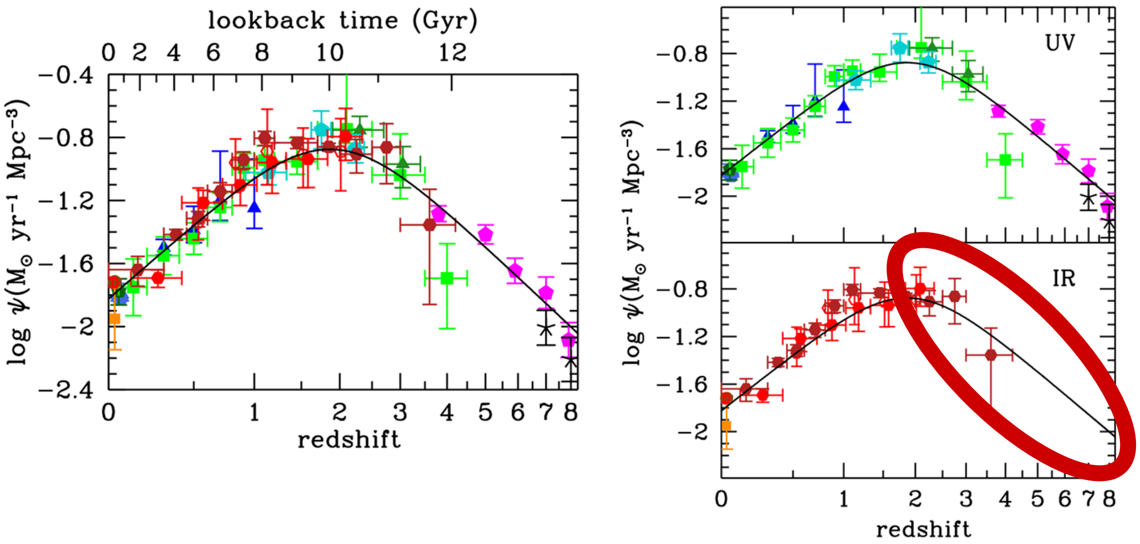
Compiègne et al. (2011)

- “Dust” describes small solid particles
- It absorbs the UV light from young stars
- It re-emits this energy in the IR

COSMIC STAR FORMATION HISTORY

MOTIVATION

Star formation rate density

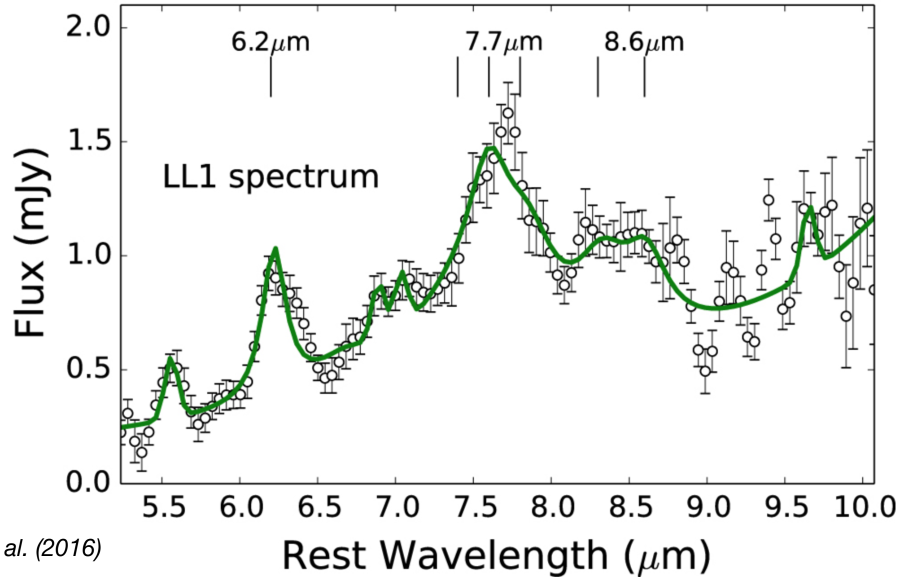


Madau et al. (2014)

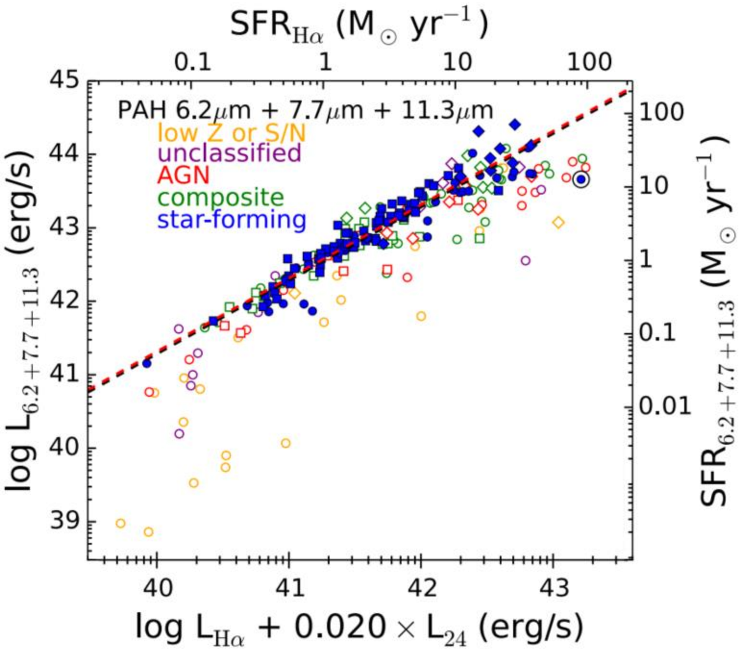
Obtain direct measurements of the IR tracers of obscured star formation in distant galaxies

POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

PAHs PROBE STAR FORMATION IN GALAXIES



Shipley et al. (2016)

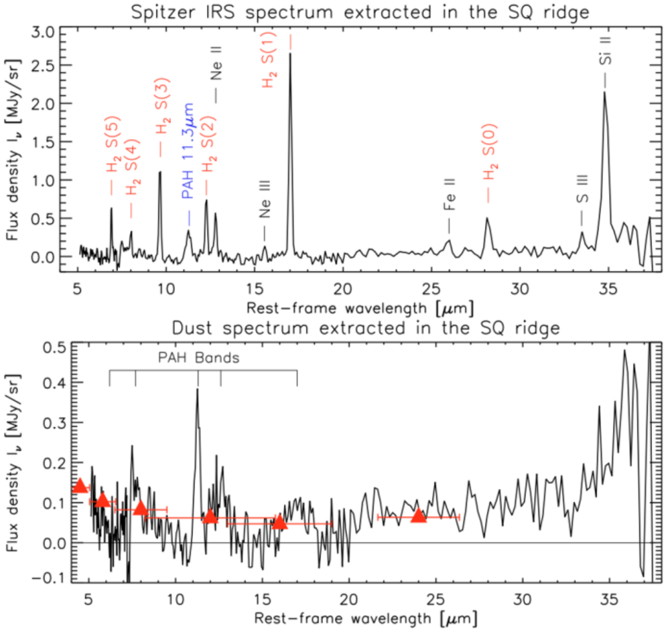


PAH features at 6.2, 7.7, 8.6, 11.3, 17 μm projected at z~5 ⇒ Spectral range: Δλ = 30 to 100 μm

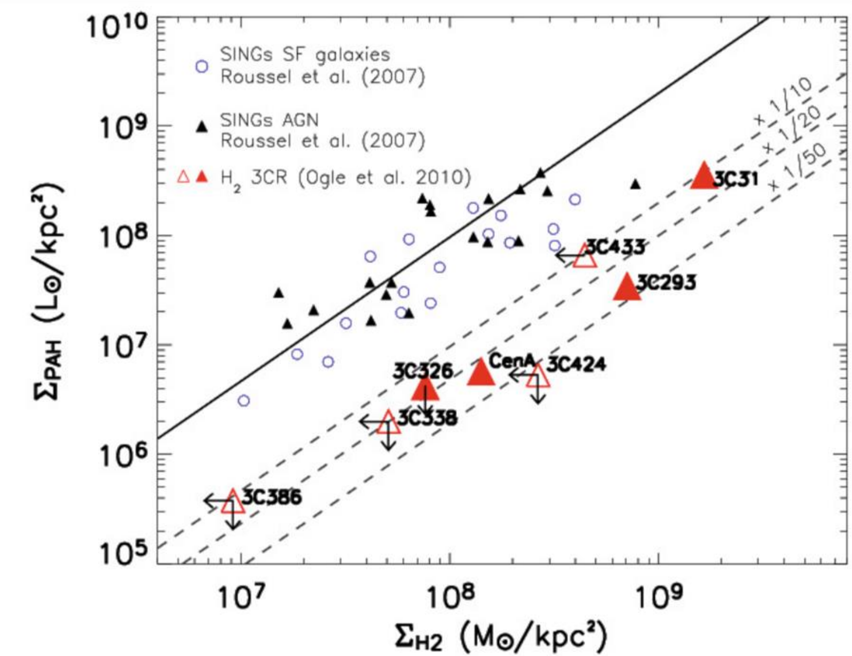
⇒ R~200

LINKING PAHS WITH MOLECULAR GAS

IONIZATION STATES AND POSSIBLE AGN SOURCE



Guillard et al. (2010)



Nesvadba et al. (2010)

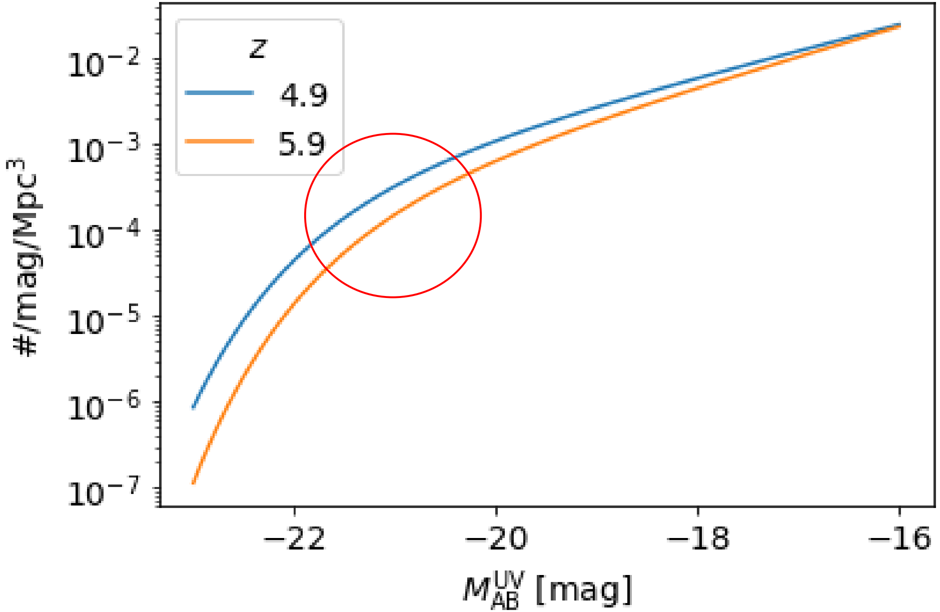
Ne II and Ne V emission lines at 15.6, 14.3 µm
H2 emission line at 17.1, 28.2 µm

} ⇒ Spectral range: Δλ = 90 to 200 µm
⇒ Spectral resolution R~1000

SCIENCE CASE

FLUX DENSITY ESTIMATION

UV luminosity functions (brightness distribution of galaxies):

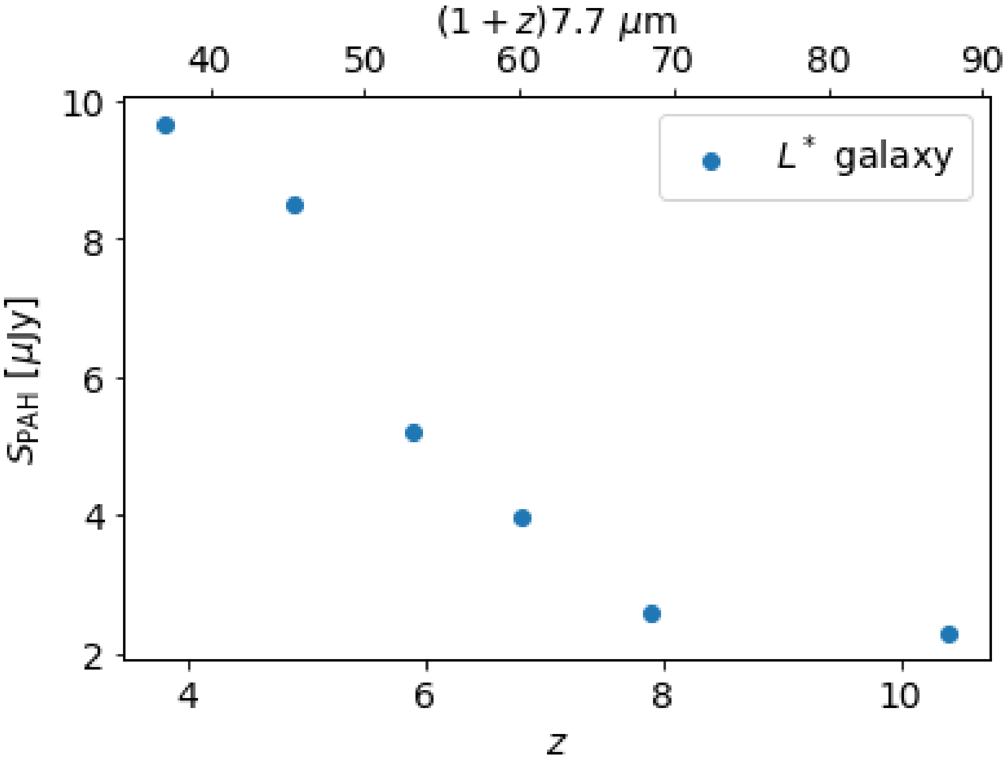


Bouwens et al. 2015

- No FIR luminosity functions at high z, therefore estimate from UV
- Need detection down to “knee” (L* galaxies) to constrain SFR

FLUX DENSITY ESTIMATION

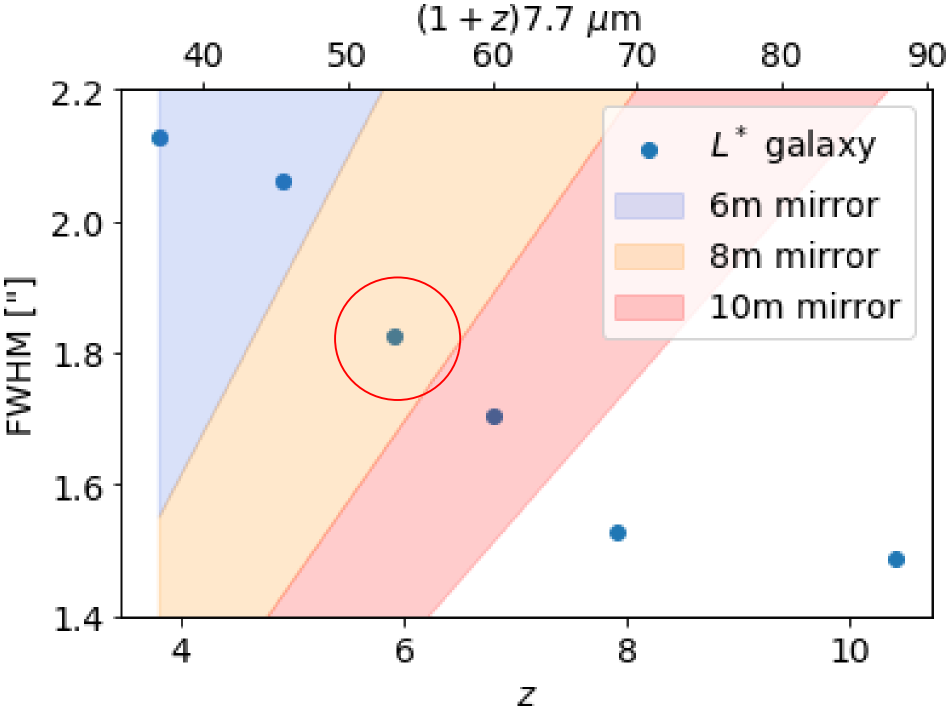
Use SEDs of normal galaxies up to z~2 (Elbaz et al. 2011) to obtain expected flux density at 7.7 µm (rest frame)



SCIENCE CASE

BEATING CONFUSION

- Need high resolution to detect faint FIR sources against background
- Number of FIR sources per solid angle brighter than targets taken from *Herschel* (Berta et al. 2011)



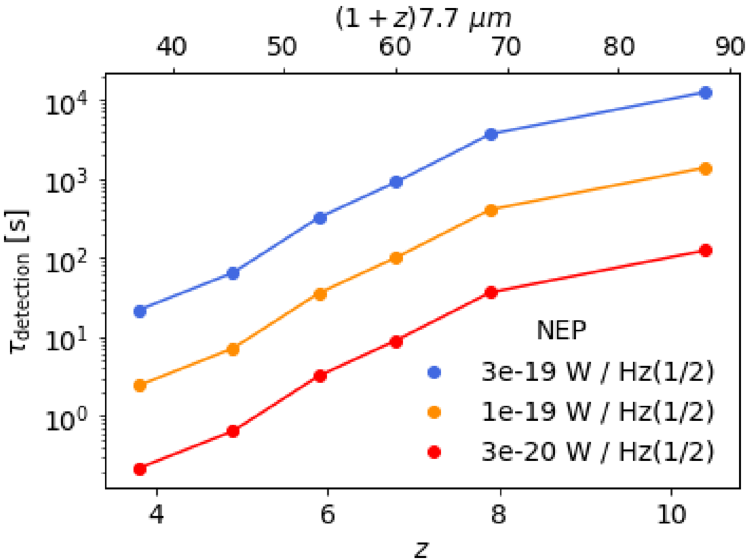
⇒ **Mirror diameter d = 8 m**

SCIENCE CASE

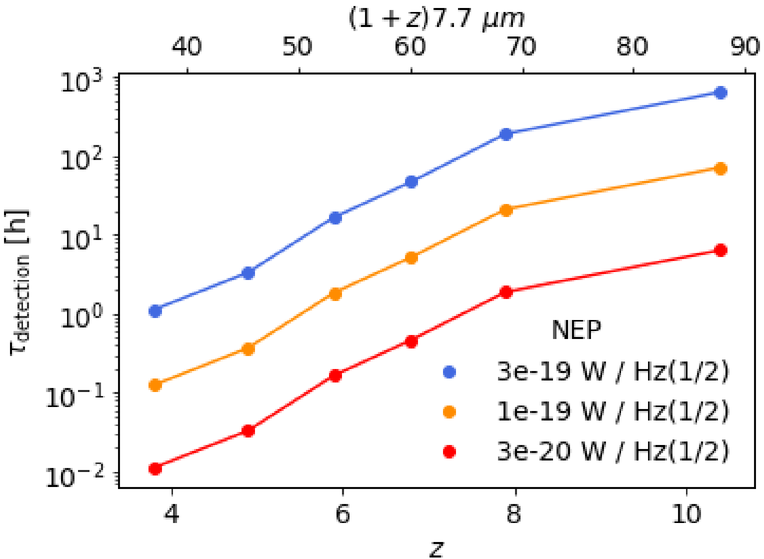
REQUIRED DETECTOR SENSITIVITY

Estimate integration time for S/N = 10 with S_{PAH} as before, d = 8 m, instrument transmission of 50% and splitting the incoming power across four pixels:

Photometry



Spectroscopy

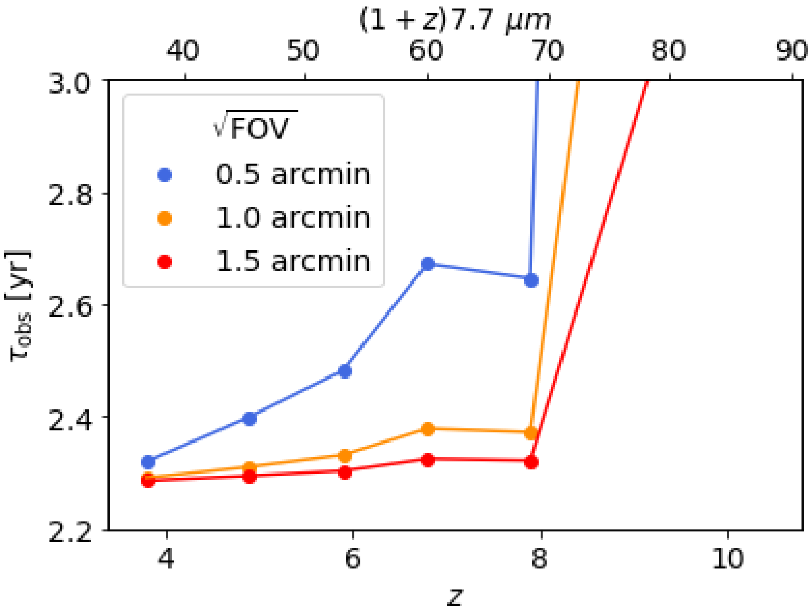


⇒ Required NEP 3e-19 W Hz^(-½)

SCIENCE CASE

REQUIRED FOV

- Statistical sample at z = 6: 1000 photometric detections (cf. Bouwens et al. 2015)
- Do spectroscopic follow-up observations on 1000 targets from all redshift bins
- Constrain FOV via total necessary observation time assuming ~5 min photo integration time, ~20 hr spectral integration time and estimating target density from UV LFs (Bouwens et al. 2015)



⇒ **Required FOV 0.5 ’ x 0.5 ’**

REQUIREMENTS - TRACEABILITY MATRIX

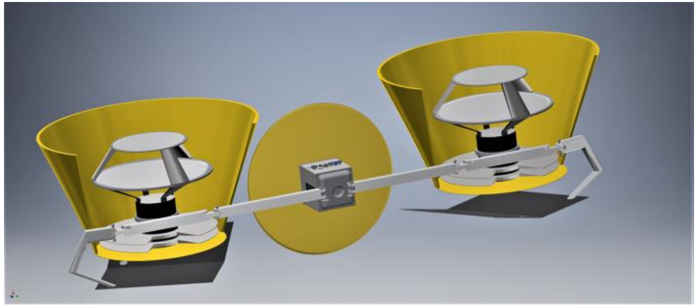
Topic	Question / Driver	Code	Requirement level 1	Param	Code	Requirement level 2	Parameter values
Star formation at high redshift	What does obscured star formation look like at high redshift?	ST1SR1	Resolve an L* galaxy at high redshift	6>z>4	ST1SR1SR1	Angular resolution	1.6' at 50 μm
					ST1SR1SR2	Mirror size	d = 8 m
	What is the relation between PAHs, H_2 and AGN?	ST1SR2	Detect PAH features and emission lines		ST1SR2SR1	Spectral resolution	R = 200-1000
					ST1SR2SR2	Spectral range	λ = 30-200 μm
	What is the IR galaxy population at high redshift?	ST1SR3	Statistical sample up to z=6		ST1SR3SR1	Photometric detection time	t_{phot} ~ 5 min
					ST1SR3SR2	Spectroscopic detection time	t_{spec} ~ 10 hours
					ST1SR3SR3	Field of view	fov = 0.5' x 0.5' @ 50 μm
					ST1SR3SR4	Total observation time	t_{tot} ~ 2.5 yr

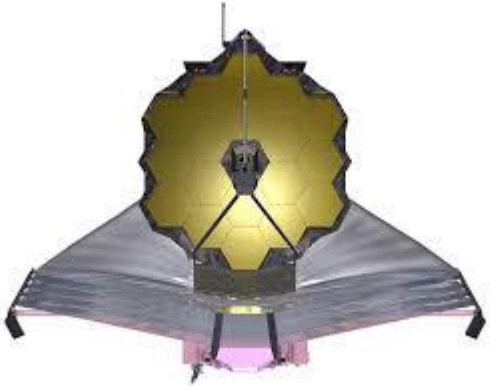
MISSION CONCEPT

MISSION CONCEPT

INTERFEROMETER AND SINGLE-DISH TRADE-OFF

- **Interferometer offers increased angular resolution** in situations where single telescope is not feasible (i.e. space launch with limited fairing volume)
- **Equivalent size single dish offers much better sensitivity** than an interferometer.
- Interferometer with folded mirrors and boom structure is very complicated.
- For high z, the brightness of sources is very low (Flux: ~10^{-21} W/m^2)
- **Single dish telescope was selected to achieve required sensitivity.**





Credits: NASA

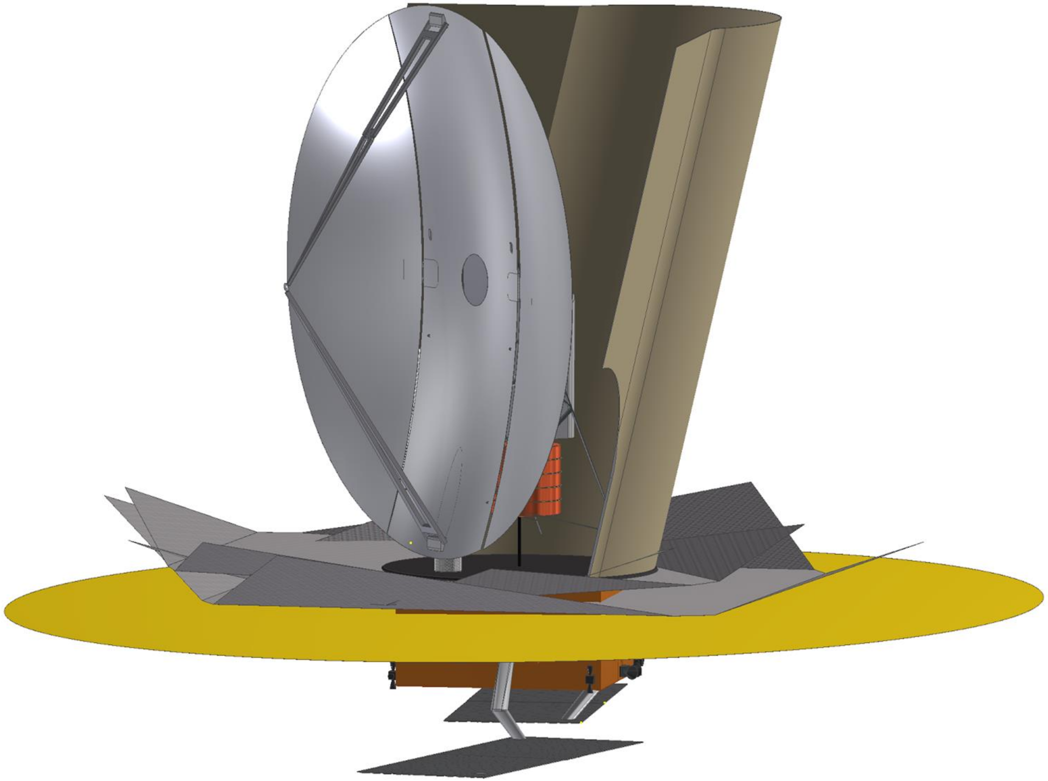
MISSION CONCEPT

TELESCOPE AND SENSOR REQUIREMENTS

- Angular resolution: 1.6’’ @ 50 μm
    - Sensitivity requires large collecting area: 8 m
    - On-axis designs for better angular resolution, mirror size is limited by fairing
    - Limited fairing diameter requires novel mirror folding techniques
- Required antenna temperature: 4 K
    - Sunshield combined with passive and active cooling
- S/N of 5 required for detection
- NEP ~3 x 10^{-19} W/$Hz^{1/2}$

MISSION CONCEPT

SATELLITE CONCEPT

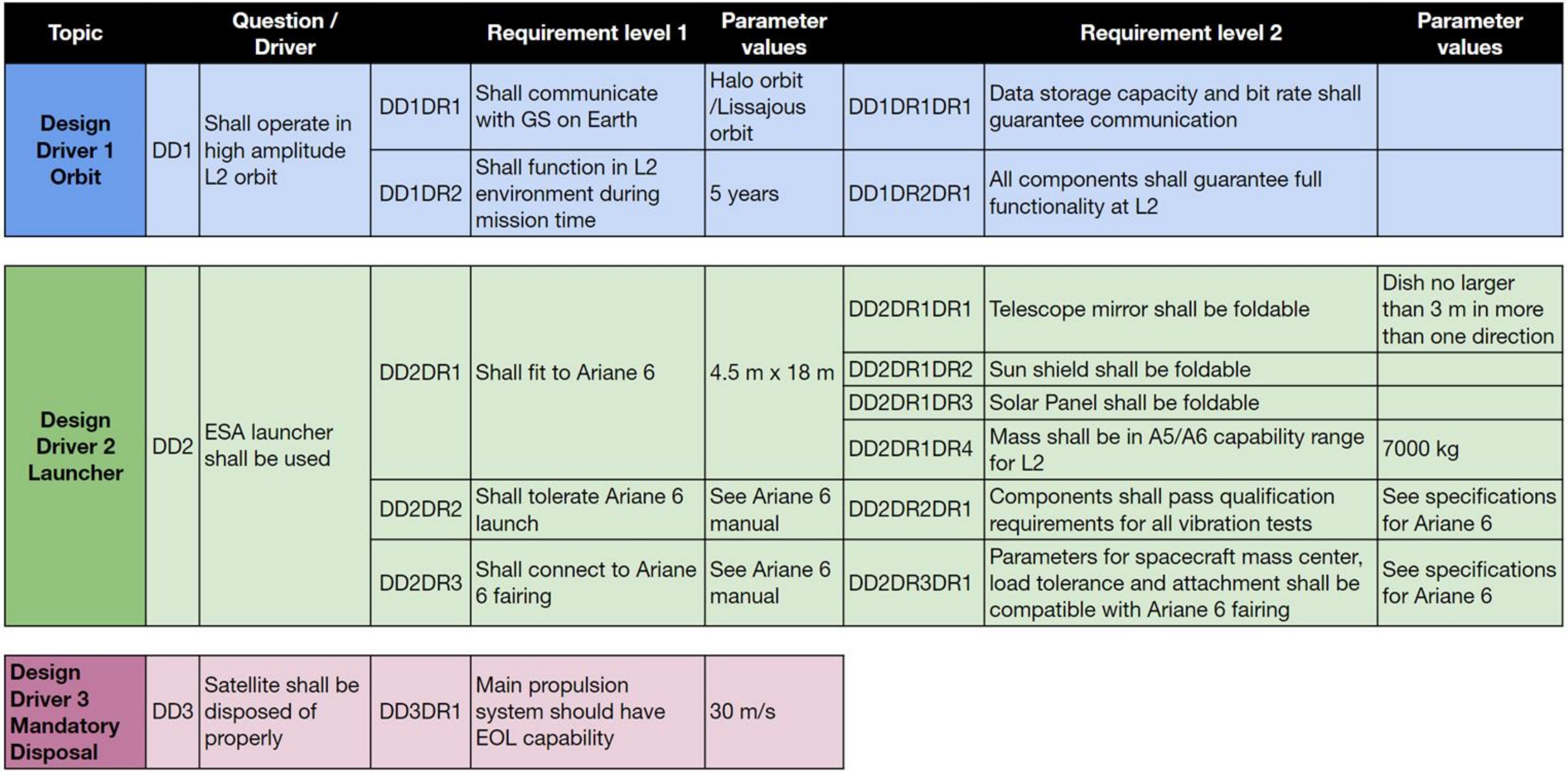


MISSION CONCEPT

PAHST MIRROR

MISSION CONCEPT

DESIGN DRIVERS - TRACEABILITY MATRIX



Topic	Question / Driver		Requirement level 1		Parameter values	Requirement level 2		Parameter values
Design Driver 1 Orbit	DD1	Shall operate in high amplitude L2 orbit	DD1DR1	Shall communicate with GS on Earth	Halo orbit /Lissajous orbit	DD1DR1DR1	Data storage capacity and bit rate shall guarantee communication	
			DD1DR2	Shall function in L2 environment during mission time	5 years	DD1DR2DR1	All components shall guarantee full functionality at L2	
Design Driver 2 Launcher	DD2	ESA launcher shall be used	DD2DR1	Shall fit to Ariane 6	4.5 m x 18 m	DD2DR1DR1	Telescope mirror shall be foldable	Dish no larger than 3 m in more than one direction
						DD2DR1DR2	Sun shield shall be foldable	
						DD2DR1DR3	Solar Panel shall be foldable	
						DD2DR1DR4	Mass shall be in A5/A6 capability range for L2	7000 kg
			DD2DR2	Shall tolerate Ariane 6 launch	See Ariane 6 manual	DD2DR2DR1	Components shall pass qualification requirements for all vibration tests	See specifications for Ariane 6
			DD2DR3	Shall connect to Ariane 6 fairing	See Ariane 6 manual	DD2DR3DR1	Parameters for spacecraft mass center, load tolerance and attachment shall be compatible with Ariane 6 fairing	See specifications for Ariane 6
Design Driver 3 Mandatory Disposal	DD3	Satellite shall be disposed of properly	DD3DR1	Main propulsion system should have EOL capability	30 m/s			

MISSION CONCEPT

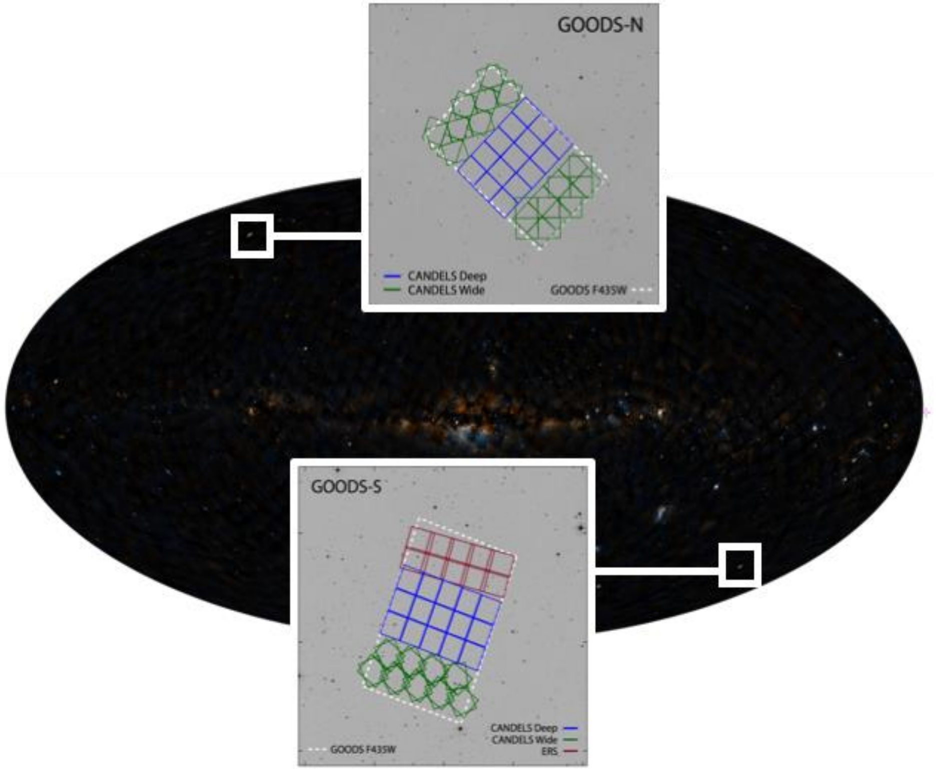
OBSERVATION STRATEGY

Detected sources

- HST Deep Field UV observations
- N > 1000 sources in each redshift bin at z > 4
- Available magnitude and photometric redshifts
- Photometric mapping, OTF mode

Blind surveys

- Depends on FoV



SECONDARY SCIENCE BACKGROUND

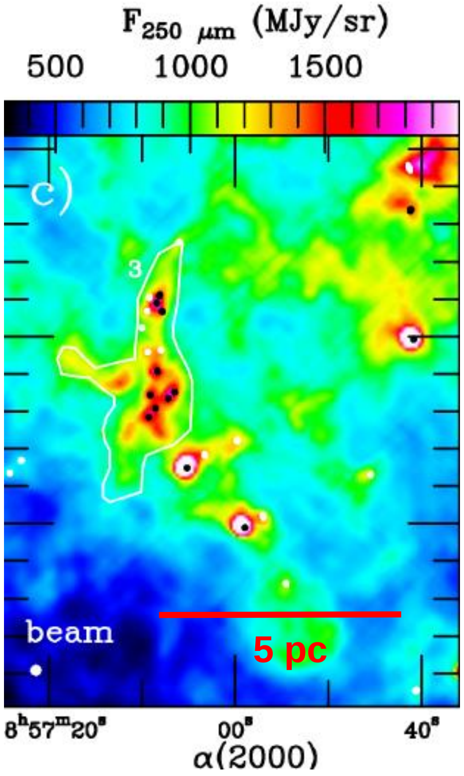
RIDGES/FILAMENTS IN THE GALACTIC ISM

Dusty filaments in the Galactic ISM up to ~1.7 kpc have ~0.1 pc inner width (Arzoumanian et al. 2011).

“Ridges”:

- Filamentary structures with high column density ($>10^{23}$ cm^{-2}, Hill et al. 2011).
- Forming high-mass stars through converging flows.

Are ridges merged individual filaments ?

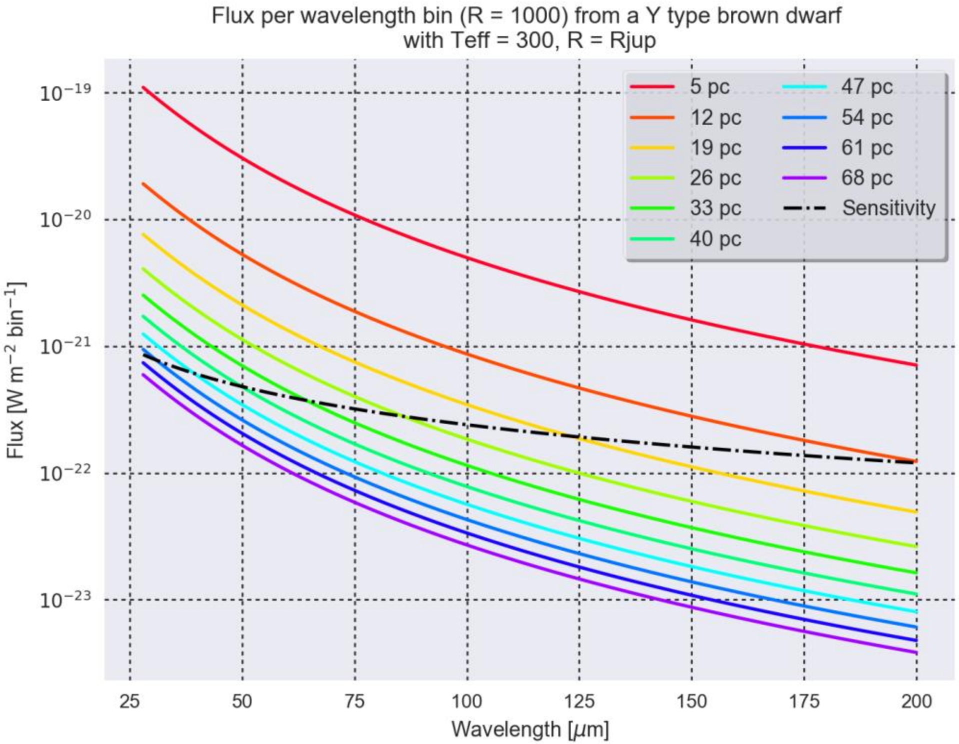


G035.39–00.33 ridge in the W48 SF molec. complex at ~3 kpc (Nguyen-Luong et al. 2011).

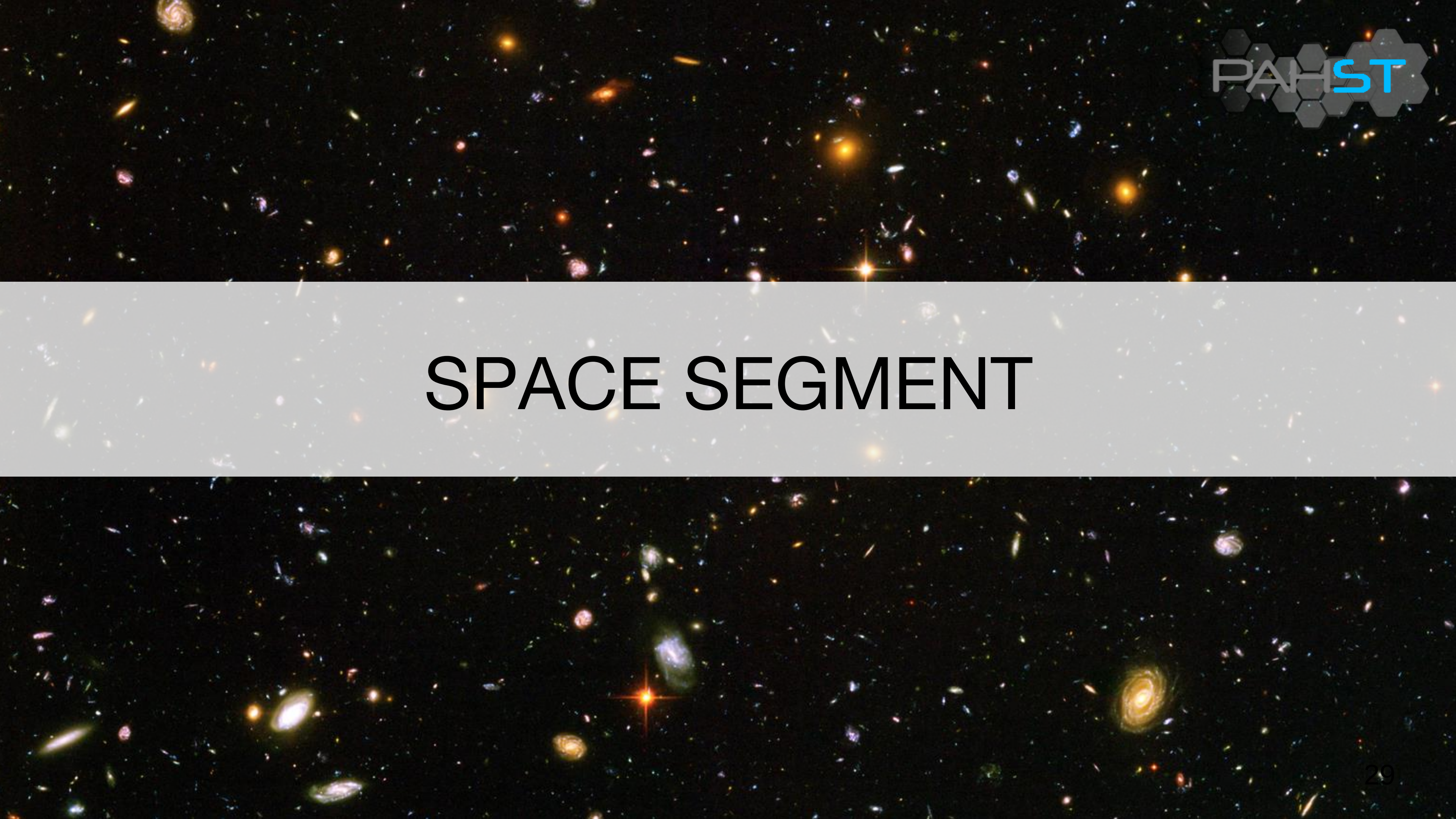
TERTIARY SCIENCE BACKGROUND

BROWN DWARFS: DUSTY RINGS & THE ELUSIVE Y CLASS

- Detect their disks (Zakhozhay et al. 2016)
- Class Y:
  - Extremely cold (250 < T < 400 K)
  - Existence confirmed only very recently (Cushing et al. 2011)
  - Not yet observed in the MIR/FIR
  - 24 currently known (Leggett et al. 2017)
  - WISE detects up to 6 pc away



Theoretical blackbody spectra of Y Class brown dwarves in the vicinity of the Sun.



SPACE SEGMENT

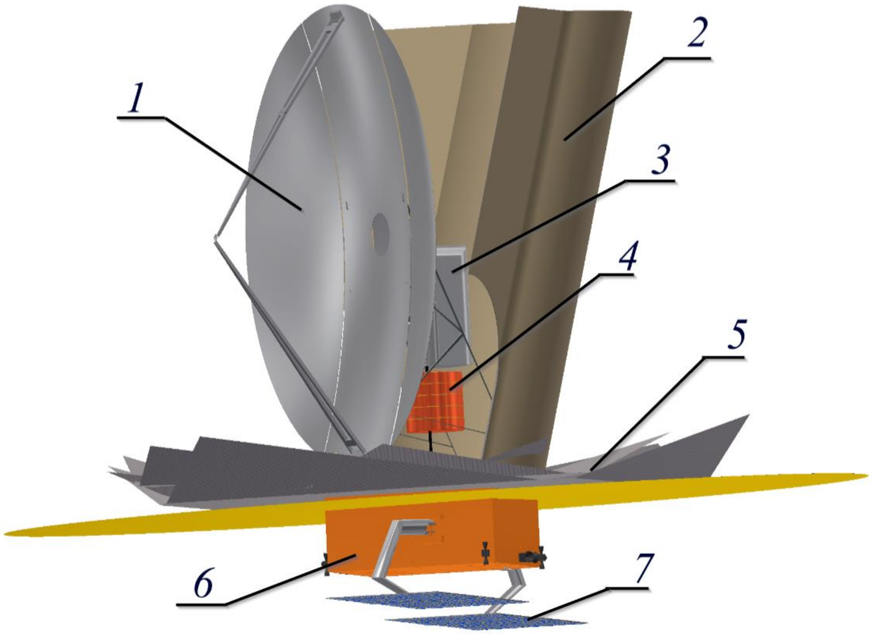
SPACE SEGMENT

INITIAL DESIGN PROPOSAL

- Foldable primary mirror
  (adaptation of JWST design)
- Foldable sun shield combined with V-Grooves
- Passive + active cooling
- Solar panel at the bottom

Predicted used volume:

- 11.18 m height
- 4.57 m diameter

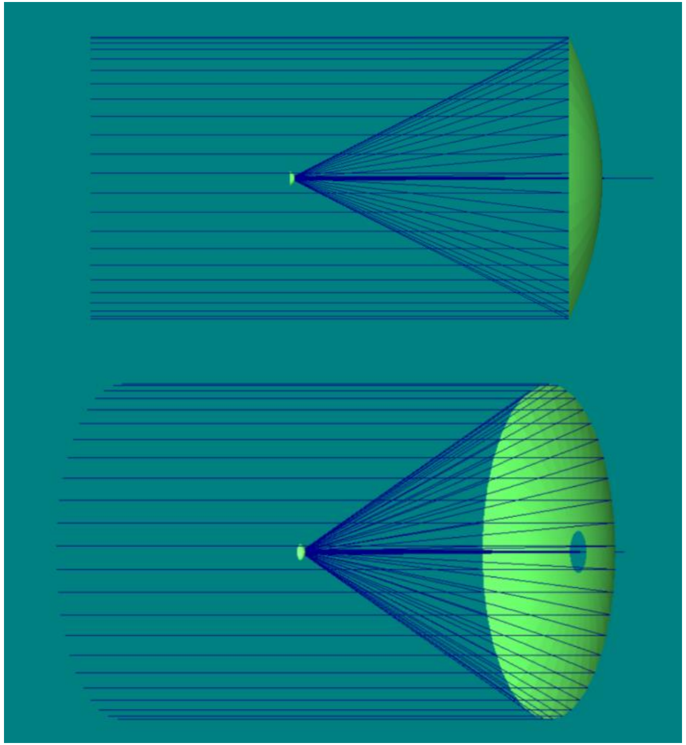


PAHST spacecraft. Main mirror (1),Al thermal shield (2), detectors (3), cryogenic systems (4), V-groove passive cooler (5), service module SVR (6), solar panels (7).

SPACE SEGMENT

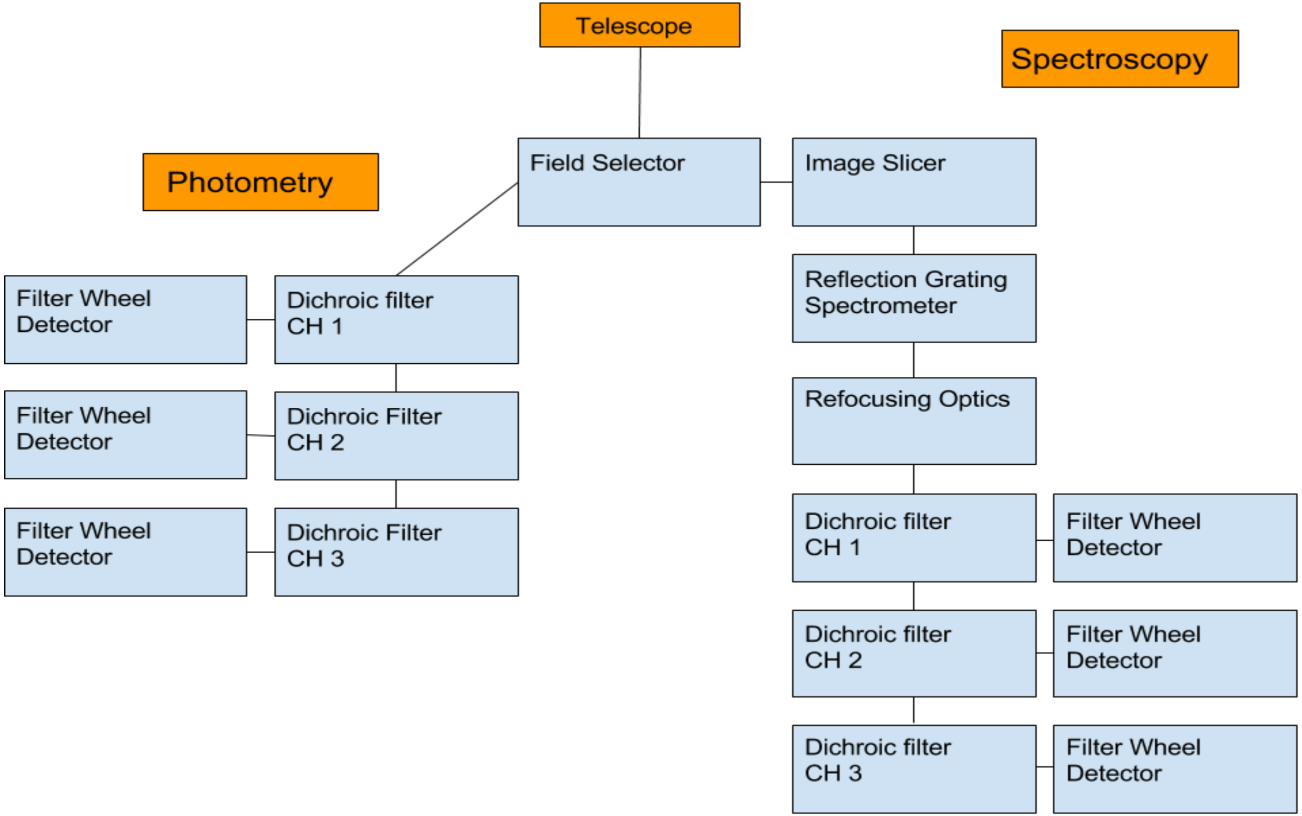
SELECTED MIRROR DESIGN

- 8 m Cassegrain design
- System focus located 1 m below primary mirror
- 1.6’’ resolution at 50 μm
- Dish surface tolerance is on the order of 1 μm (compared to nm precision for optical mirror surfaces)
- SiC is the standard material for the IR (Herschel, SPICA)
- Al coating (Herschel: ~1 μm)



SPACE SEGMENT

INSTRUMENT SCHEME



Telescope

Spectroscopy

Photometry

Field Selector

Image Slicer

Reflection Grating Spectrometer

Refocusing Optics

Dichroic filter CH 1

Filter Wheel Detector

Dichroic Filter CH 2

Filter Wheel Detector

Dichroic Filter CH 3

Filter Wheel Detector

Dichroic filter CH 1

Filter Wheel Detector

Dichroic filter CH 2

Filter Wheel Detector

Dichroic filter CH 3

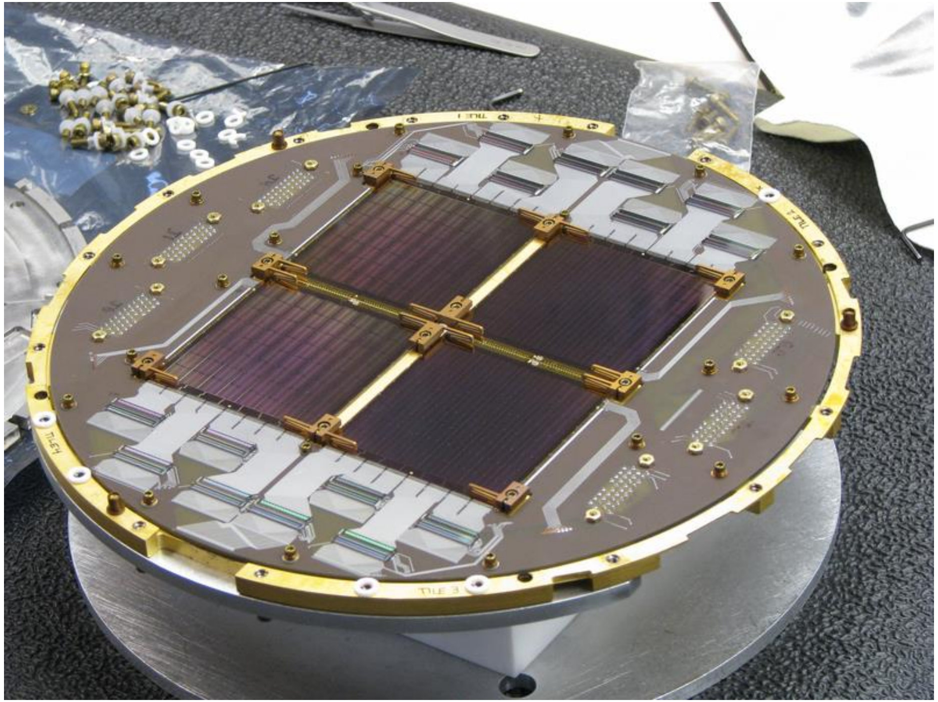
Filter Wheel Detector

INSTRUMENT REQUIREMENTS

- Spectroscopy and Photometry
- 30 - 200 μm [3 channels]
- Detectors must be highly sensitive - NEP = 3×10^{-19} W/Hz$^{1/2}$
- FoV slightly larger than HSTDF: ~30 ’’ x 30 ’’
- Pointing accuracy: 0.5 ’’
- Pointing knowledge: 0.1 ’’

PHOTOMETRY MODE

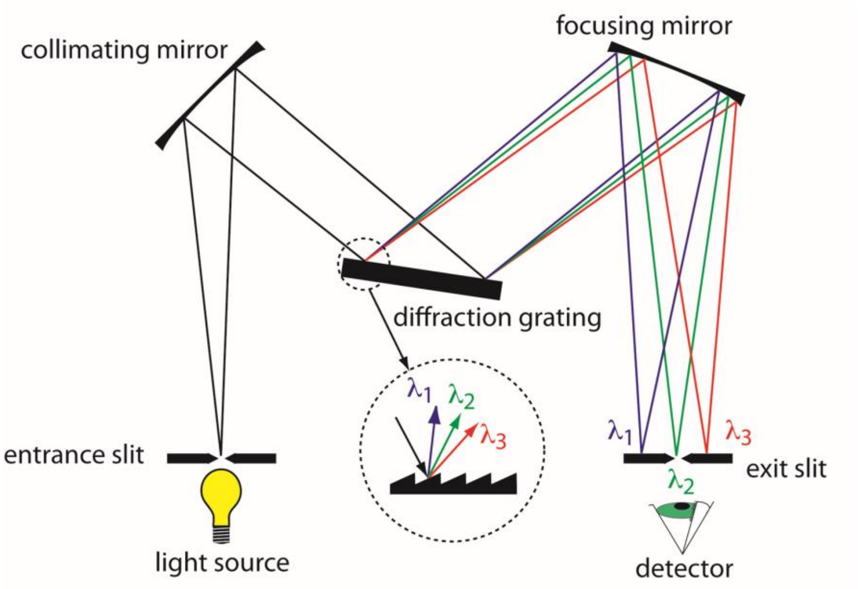
- Will operate between 30 - 200 μm in three channels
- Dichroic filter will separate three channels and direct them to detectors via parabolic mirror
- Filter wheels will be present after channel selection
- Detectors will be TES (50 mK) for channels 1, 2 & 3



Ogburn, R.W., IV *et al.*

SPECTROSCOPY MODE

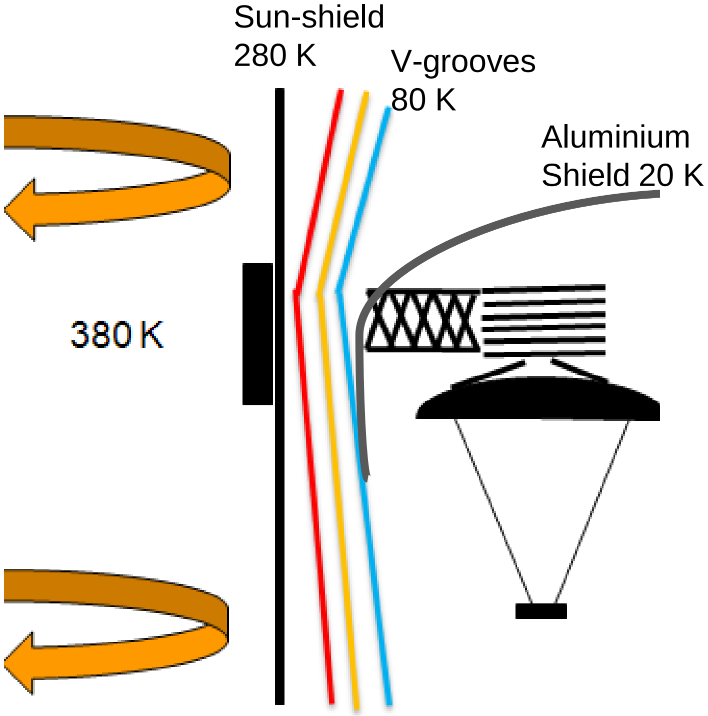
- Spectrometer: Reflection Grating Spectrometer
- Will operate between 30 - 200 µm in three channels
- Image slicer will flatten image
- Dichroic filters will separate the channels
- Detectors will be TES (50 mK) for channels 1, 2 & 3

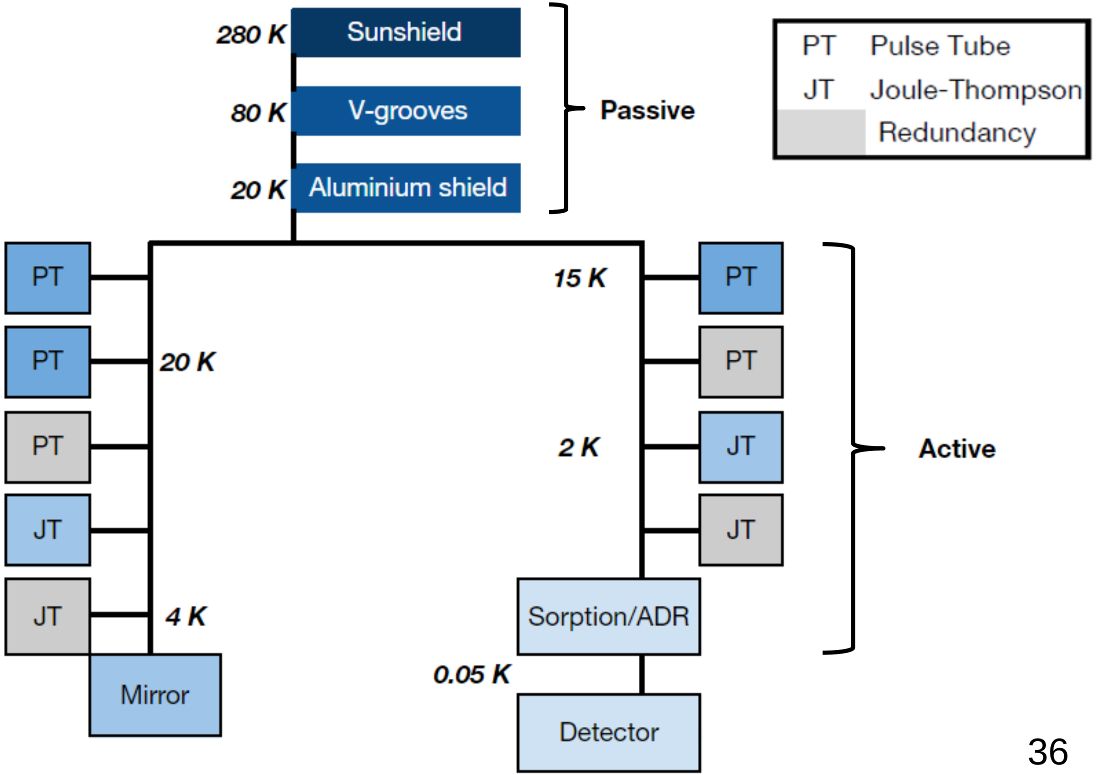


Credits: chem.libretexts.org/

SPACE SEGMENT

CRYOGENIC SYSTEM





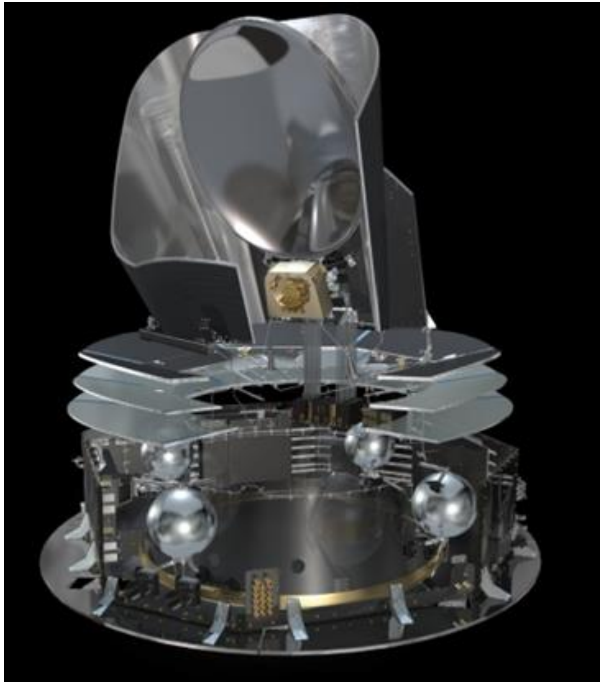
CRYOGENIC SYSTEM: PASSIVE COOLING

Passive Cooling:

Sunshield	280	K
V-grooves	80	K
Aluminium Shield	20	K

Passive cooling TRL: 6

No electrical power needed



Planck spacecraft, credits: ESA

SPACE SEGMENT

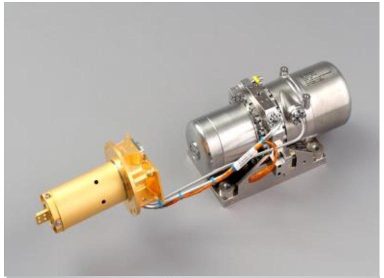
CRYOGENIC SYSTEM: ACTIVE COOLING

Active Cooling (telescope + detectors):

Pulse-Tube x5 (3+2)		20/15 K
Joule-Thompson x2 (Telescope)	[Planck]	4 K
Joule-Thompson x2 (Detectors)		2 K
Hybrid Sorption/ADR(Detectors)	[SPICA]	0.05 K

Pulse-Tube	TRL level	~**6**
Joule-Thompson 2 K	TRL level	~**6**
Hybrid Sorption/ADR	TRL level	~**6**

Pulse-Tube

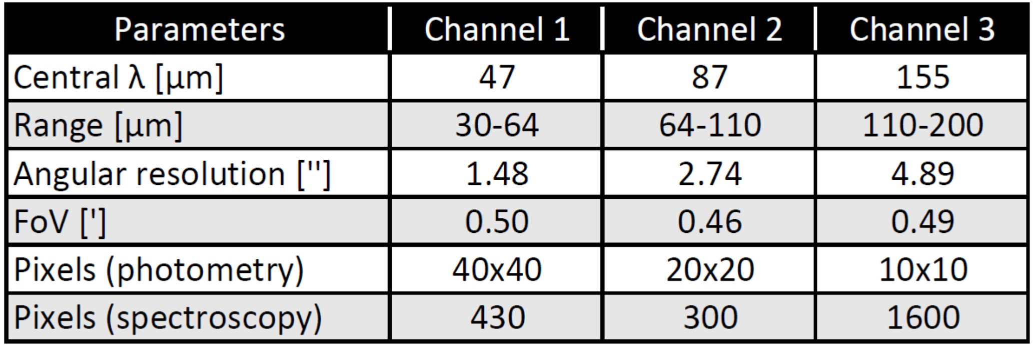


Sorption - ADR

Credits: ESA/CEA/Néel

SPACE SEGMENT

DETECTORS



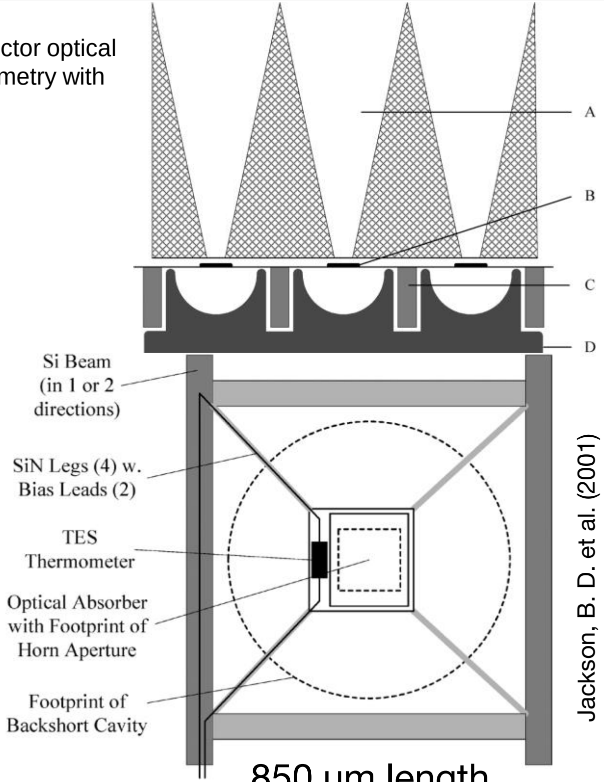
Parameters	Channel 1	Channel 2	Channel 3
Central λ [µm]	47	87	155
Range [µm]	30-64	64-110	110-200
Angular resolution ['']	1.48	2.74	4.89
FoV [']	0.50	0.46	0.49
Pixels (photometry)	40x40	20x20	10x10
Pixels (spectroscopy)	430	300	1600

Transition Edge Sensors [SPICA, SRON] 0.05 K

Readout: SQUIDs

Micro-Lamps for calibration [Spitzer/IRAC]

SAFARI detector optical coupling geometry with horns



Jackson, B. D. et al. (2001)

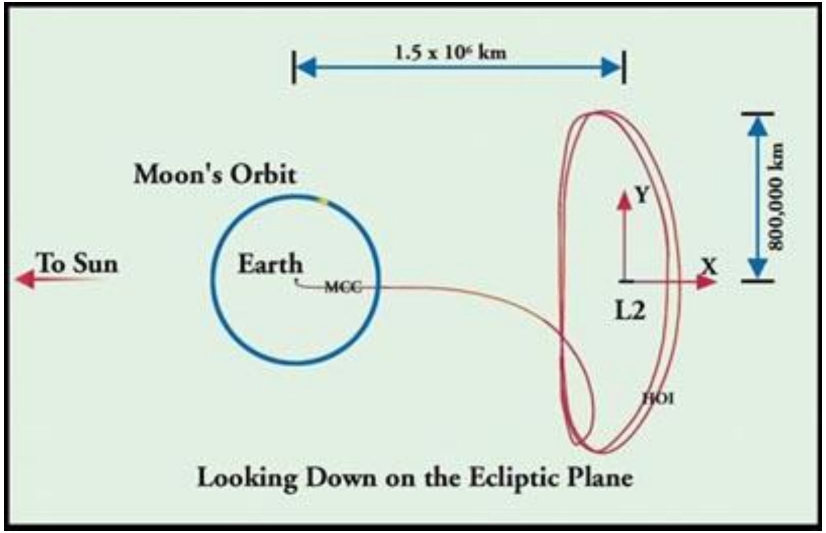
850 µm length

TES [SPICA]

MISSION CONCEPT

ORBITAL ENVIRONMENT AT L2

- Solar constant: 1340 ± 10 W/m^2
- Distance: 1.5x10^6 km from Earth
- Orbit: Halo



Credits http://www.stsci.edu/jwst/overview/design/orbit

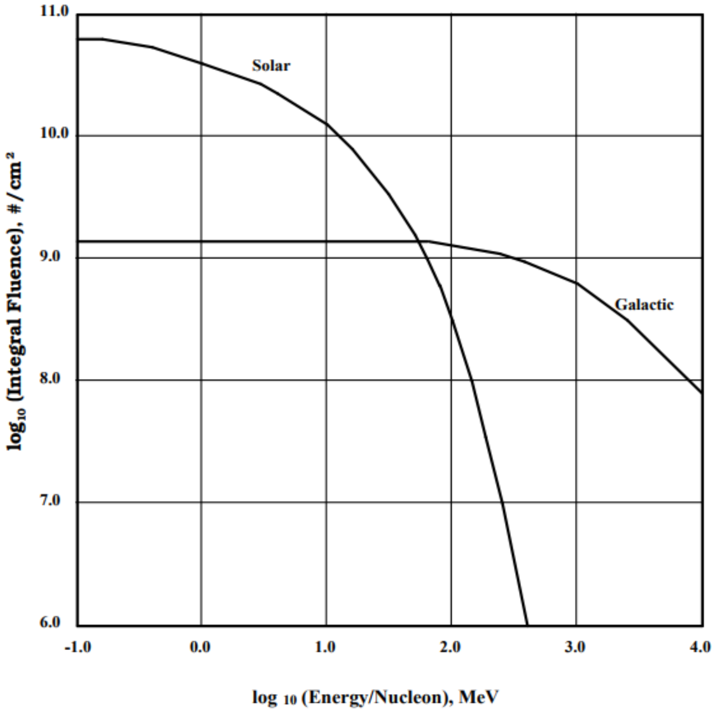


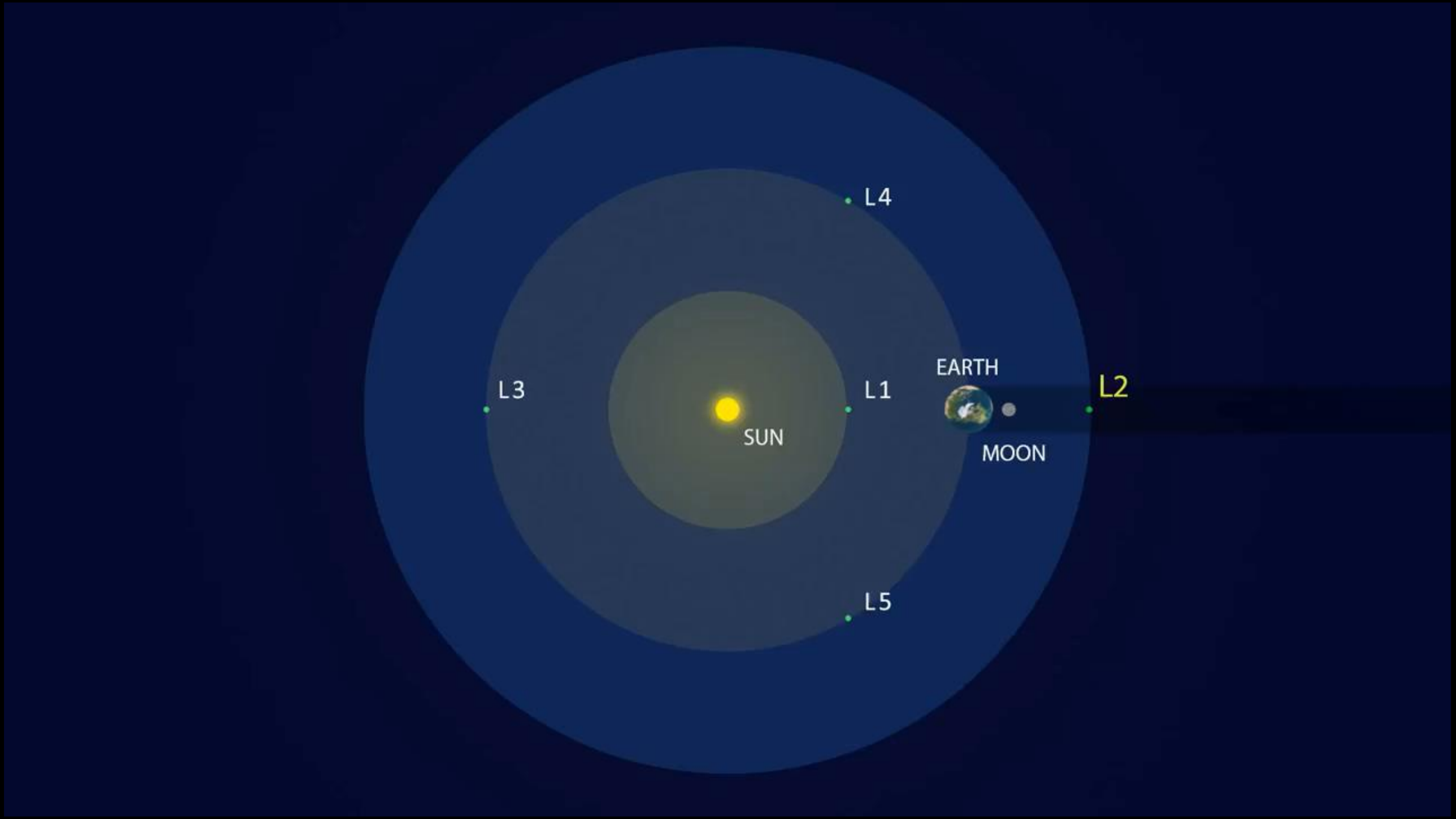
Figure 5.2 Ion spectra for 10 years at L2 for solar and galactic sources.

Credits http://www.dept.aoe.vt.edu

MISSION CONCEPT

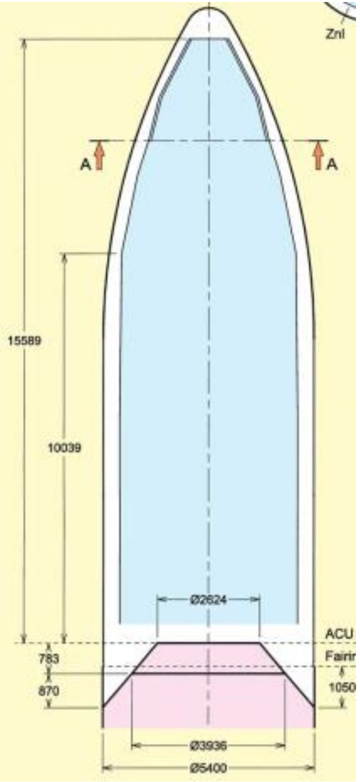
LAUNCHER & ORBIT INJECTION

Ariane 64



MISSION CONCEPT

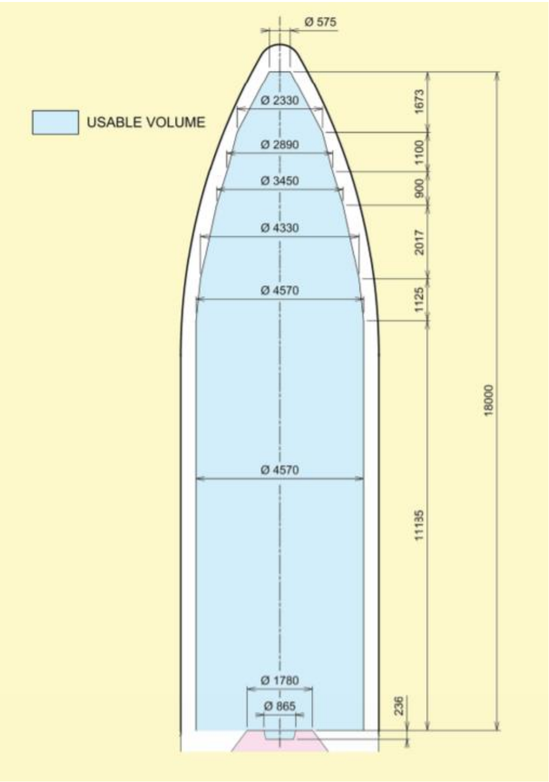
ENVELOPE FOR LAUNCH



Ariane 5

10 m x 4.57 m

Total mass of load under 6,600 kg



Ariane 6

11.18 m x 4.57 m

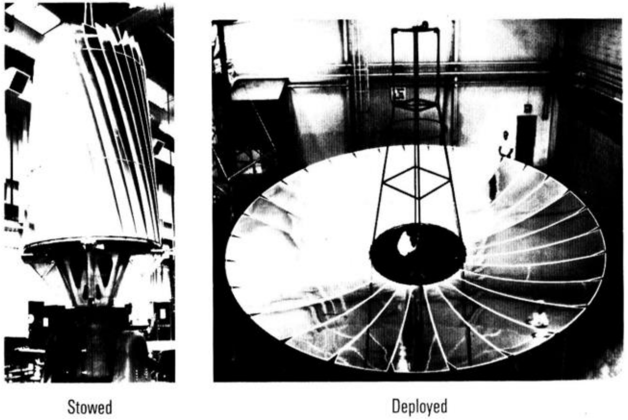
Total mass of load under 7,000 kg

MISSION CONCEPT

MAIN MIRROR FOLDING OPTIONS

Option 1

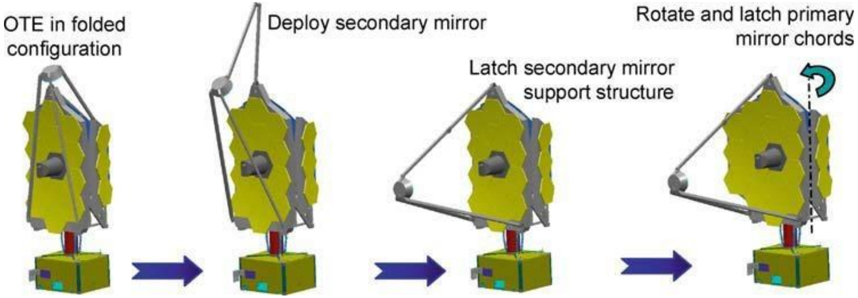
- Mechanism: TRL 7-8
  (Due to size: TRL 4-5)
- Outer 2 m annulus will be segmented into 32 slices (15 kg)
- Mirror horizontally in fairing



Lillie, C. F. 2005

Option 2

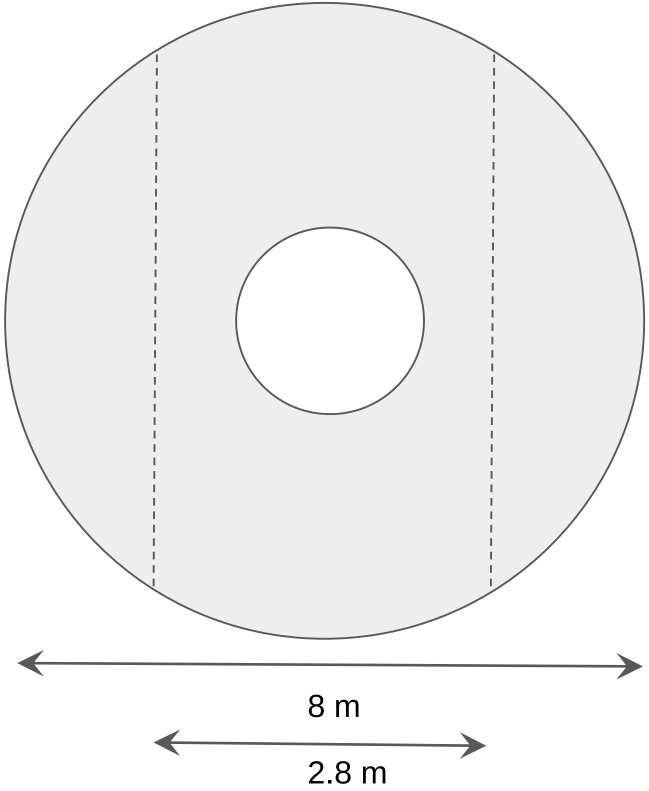
- JWST-like folding
- Side parts of the main mirror folded to the sides
- Mirror vertically in fairing



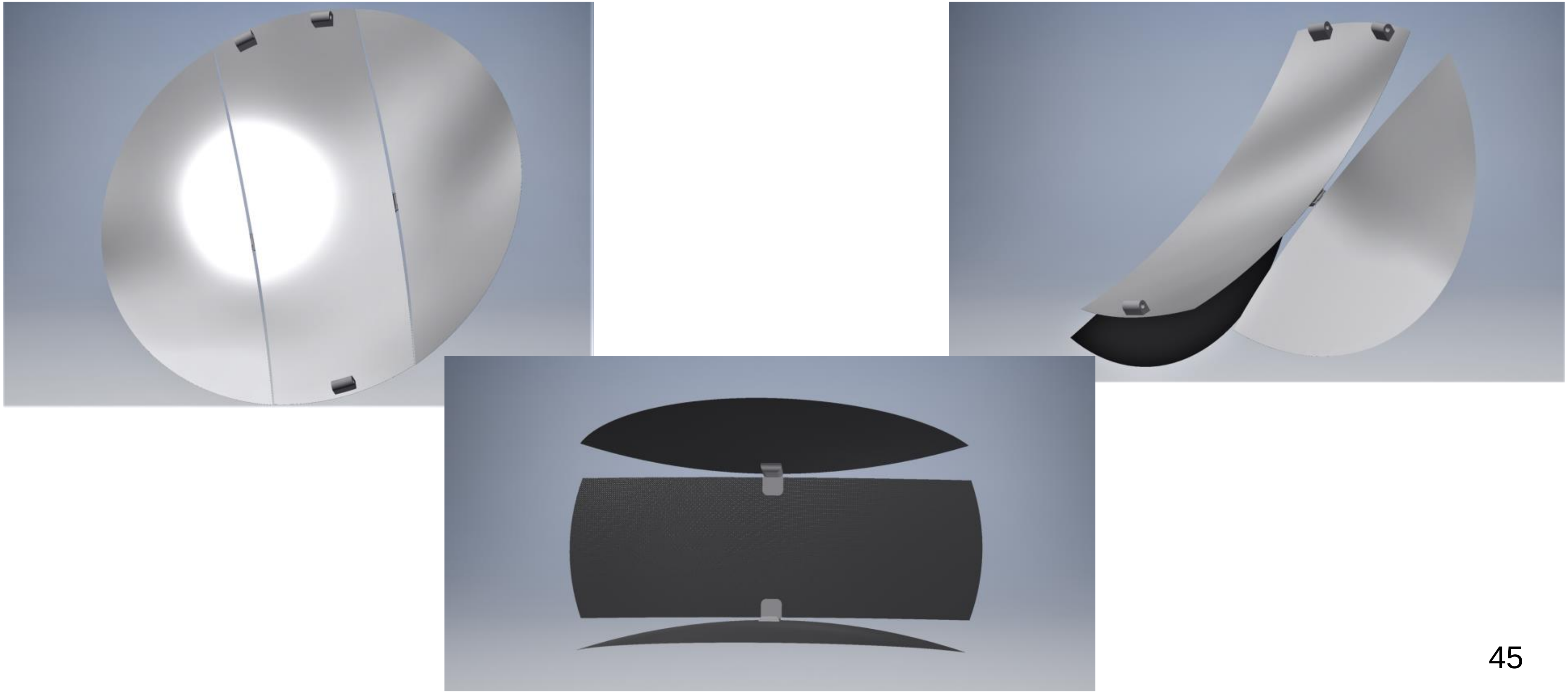
Credits: NASA

SELECTED MAIN MIRROR FOLDING CONCEPT

- Secondary mirror and supports are stowed behind the mirror
- Then sides of the mirror are folded backwards
- This method would make better use of the fairing volume
- Single central piece allows higher accuracy and cheaper production



MIRROR PRELIMINARY DESIGN



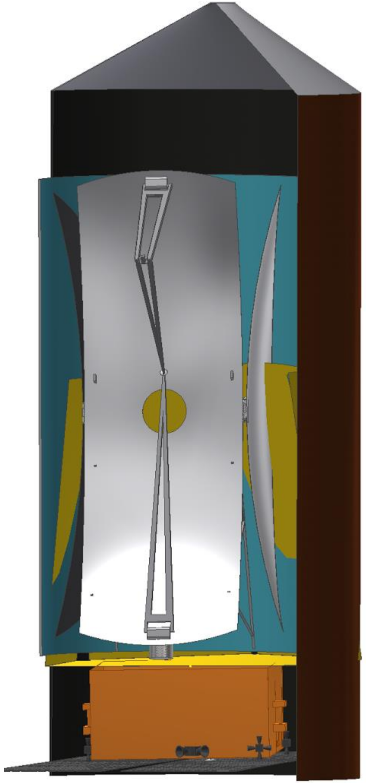
MISSION CONCEPT

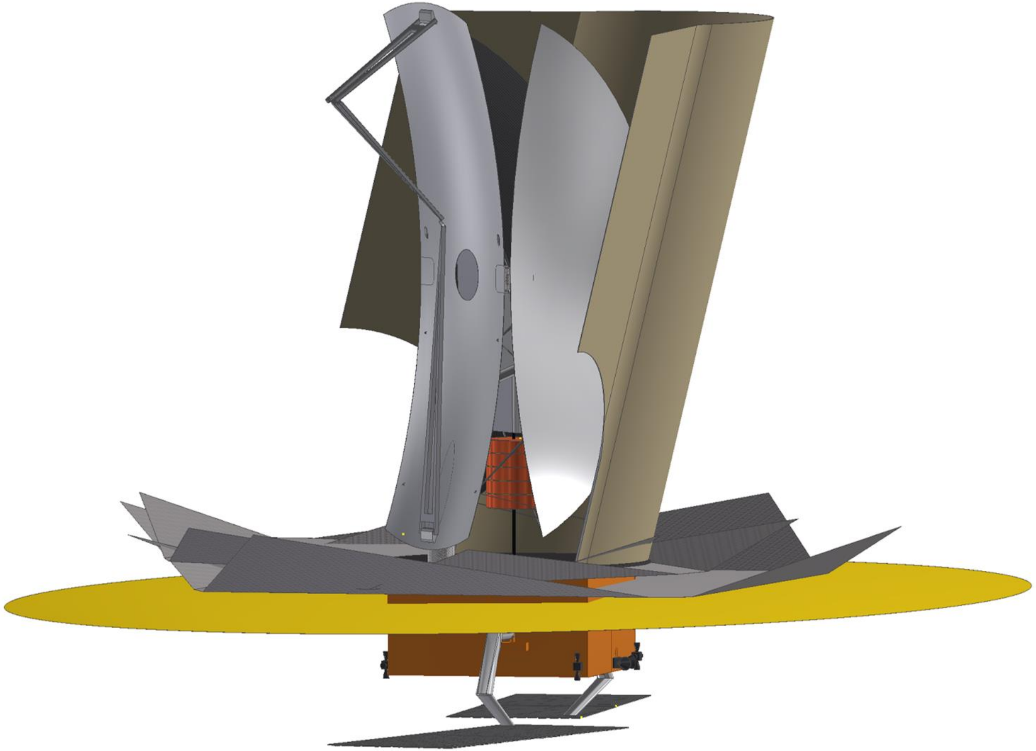
DEPLOYMENT

MISSION CONCEPT

PAHST

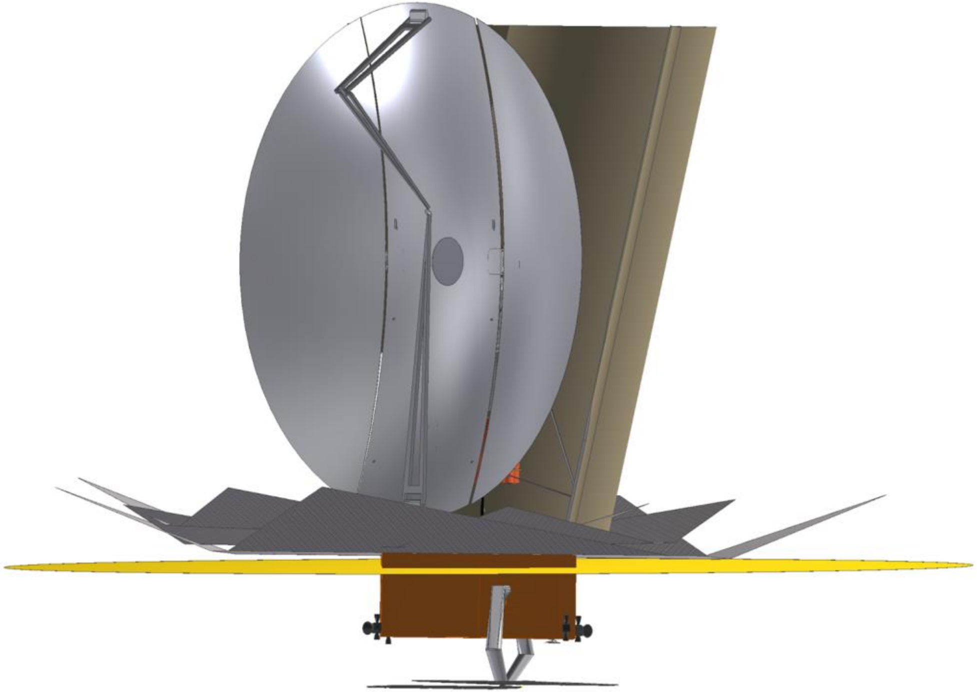
PAHST DEPLOYMENT - ENVELOPE AND MIRROR

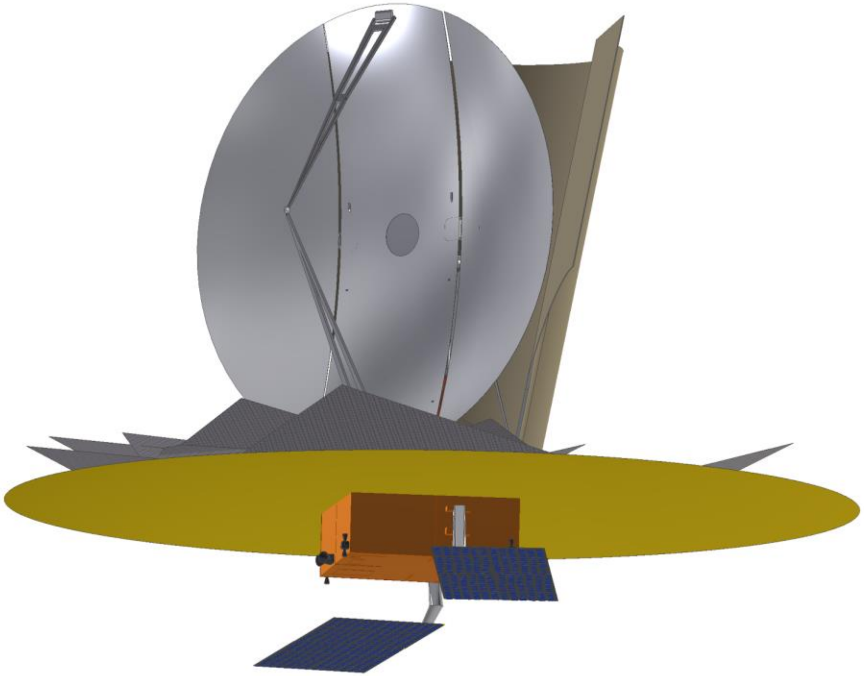




MISSION CONCEPT

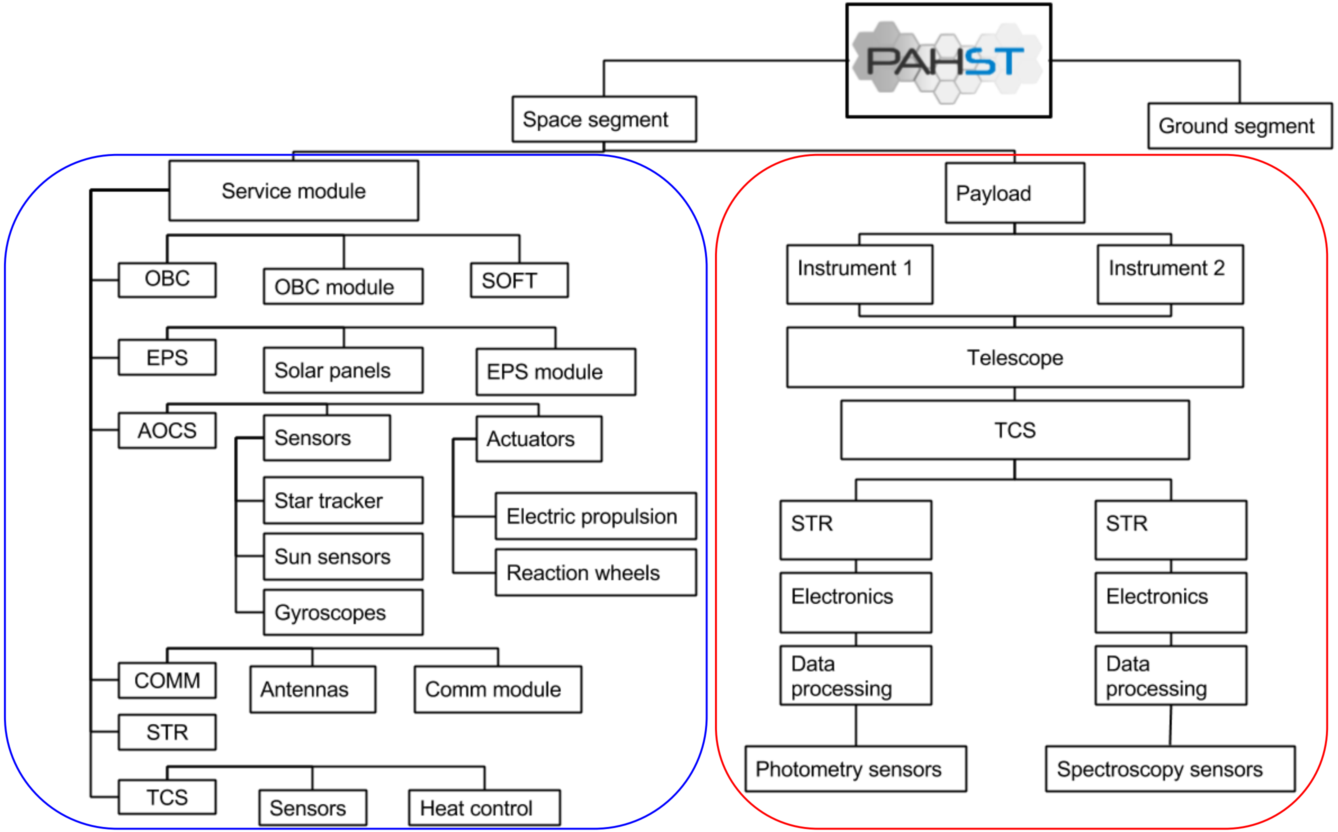
PAHST DEPLOYMENT - FINAL ASSEMBLY





SPACE SEGMENT

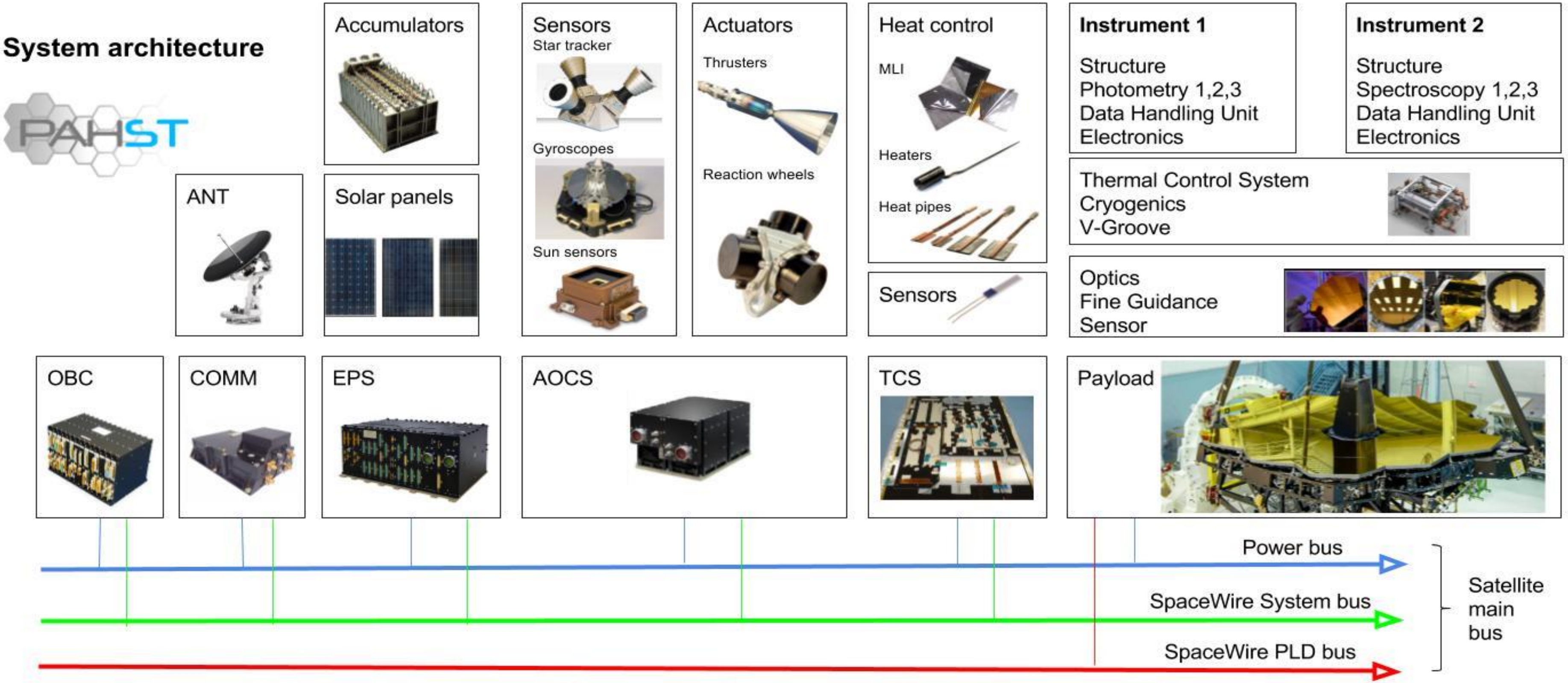
PRODUCT TREE



SPACE SEGMENT

SYSTEM ARCHITECTURE

System architecture



Accumulators

Sensors
Star tracker
Gyroscopes
Sun sensors

Actuators
Thrusters
Reaction wheels

Heat control
MLI
Heaters
Heat pipes

Sensors

Instrument 1
Structure
Photometry 1,2,3
Data Handling Unit
Electronics

Instrument 2
Structure
Spectroscopy 1,2,3
Data Handling Unit
Electronics

Thermal Control System
Cryogenics
V-Groove

Optics
Fine Guidance
Sensor

ANT

Solar panels

OBC

COMM

EPS

AOCS

TCS

Payload

Power bus

SpaceWire System bus

SpaceWire PLD bus

Satellite
main
bus

SPACE SEGMENT

TRL LEVELS

	Component	TRL level
Service Module	Structure	**4**
	Sunshield	**4**

Payload	Optics and Structure	**4**
	Detectors	**5**
	Structure	**4**

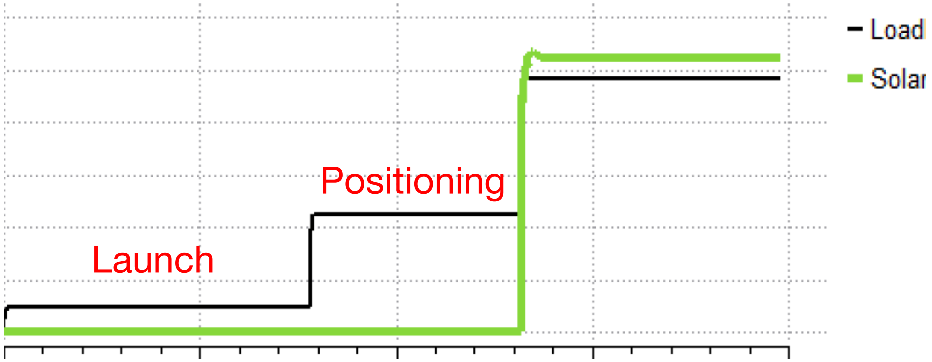
- System drivers: TRL < 6 are most critical
- Projects have to be initiated to increase the TRL level

POWER SUB-SYSTEM: BATTERIES

Battery required during LEOP:

Launch: 245 W x 130 minutes	530 Wh
Initialisation: 550 W x 90 minutes	800 Wh

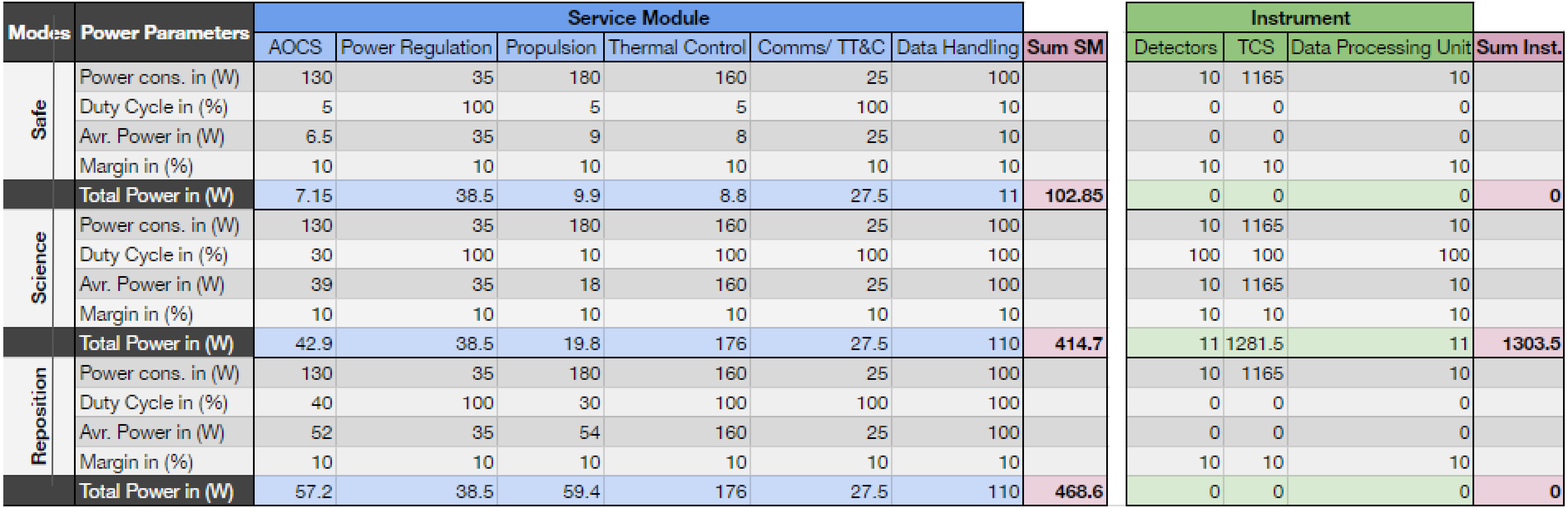
Estimation: 200 Wh/kg - 4 kg



Credits: SPICA mission

SPACE SEGMENT

POWER BUDGET

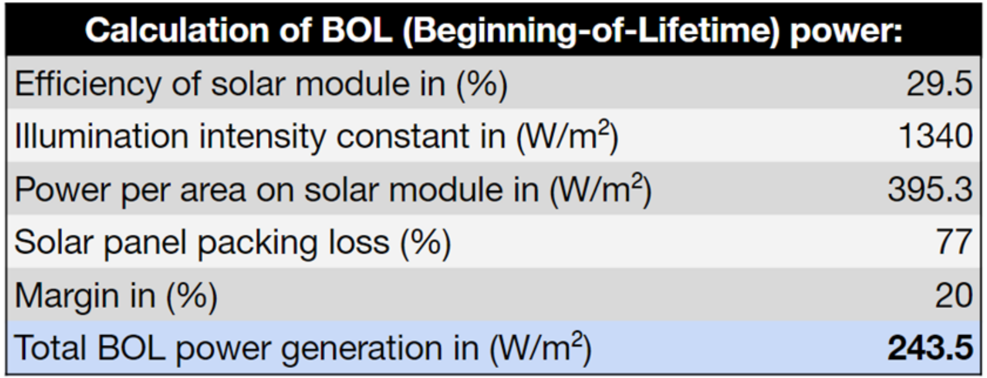


Modes	Power Parameters	Service Module							Instrument			
		AOCS	Power Regulation	Propulsion	Thermal Control	Comms/ TT&C	Data Handling	Sum SM	Detectors	TCS	Data Processing Unit	Sum Inst.
Safe	Power cons. in (W)	130	35	180	160	25	100		10	1165	10	
	Duty Cycle in (%)	5	100	5	5	100	10		0	0	0	
	Avr. Power in (W)	6.5	35	9	8	25	10		0	0	0	
	Margin in (%)	10	10	10	10	10	10		10	10	10	
	Total Power in (W)	7.15	38.5	9.9	8.8	27.5	11	**102.85**	0	0	0	**0**
Science	Power cons. in (W)	130	35	180	160	25	100		10	1165	10	
	Duty Cycle in (%)	30	100	10	100	100	100		100	100	100	
	Avr. Power in (W)	39	35	18	160	25	100		10	1165	10	
	Margin in (%)	10	10	10	10	10	10		10	10	10	
	Total Power in (W)	42.9	38.5	19.8	176	27.5	110	**414.7**	11	1281.5	11	**1303.5**
Reposition	Power cons. in (W)	130	35	180	160	25	100		10	1165	10	
	Duty Cycle in (%)	40	100	30	100	100	100		0	0	0	
	Avr. Power in (W)	52	35	54	160	25	100		0	0	0	
	Margin in (%)	10	10	10	10	10	10		10	10	10	
	Total Power in (W)	57.2	38.5	59.4	176	27.5	110	**468.6**	0	0	0	**0**

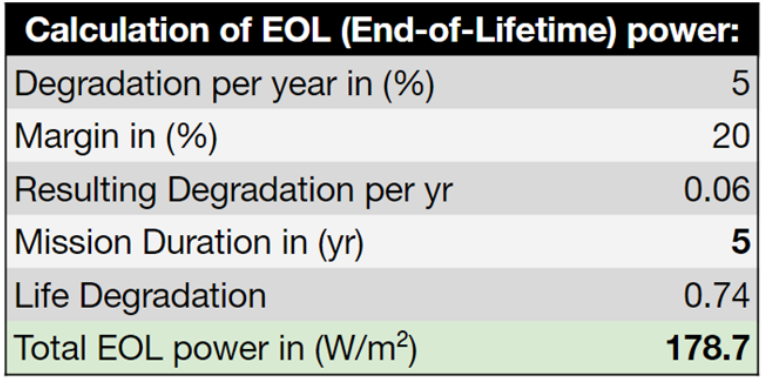
- Maximum power demand at ‘**Science Mode**’: 1718.2 W
- Including 20% system margin: **2061.84 W**

SPACE SEGMENT

POWER GENERATION

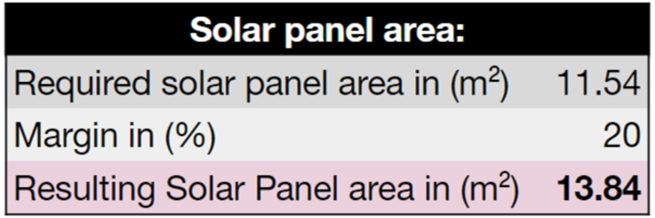


Calculation of BOL (Beginning-of-Lifetime) power:	
Efficiency of solar module in (%)	29.5
Illumination intensity constant in (W/m²)	1340
Power per area on solar module in (W/m²)	395.3
Solar panel packing loss (%)	77
Margin in (%)	20
Total BOL power generation in (W/m²)	**243.5**



Calculation of EOL (End-of-Lifetime) power:	
Degradation per year in (%)	5
Margin in (%)	20
Resulting Degradation per yr	0.06
Mission Duration in (yr)	**5**
Life Degradation	0.74
Total EOL power in (W/m²)	**178.7**

- Solar Cells: Triple-Junction InGaP/InGaAs/Ge
- Power at BOL: 243.5 W/m^2
- Power at EOL: 178.7 W/m^2
- Resulting Solar panel area: **13.84 m^2** w.r.t. 2061.84 W power demand



Solar panel area:	
Required solar panel area in (m²)	11.54
Margin in (%)	20
Resulting Solar Panel area in (m²)	**13.84**

ON-BOARD COMPUTER & DATA HANDLING

Data Handling

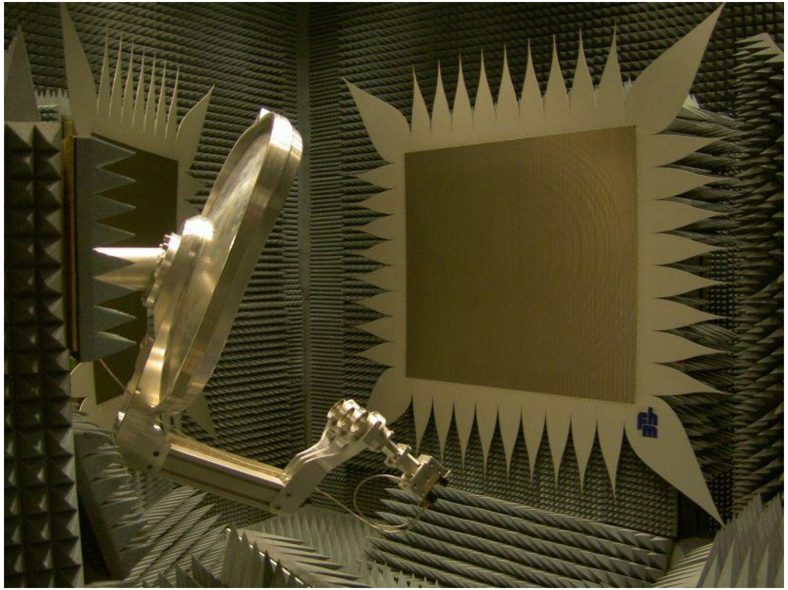
- Memory Unit: Buffer of measurement data
    - Data production of 4 MB/s in “Science Mode”
        - Observation of max. 38 hrs
        - Reference to SPICA
        - 38 h observation: ~600 GB
    - Usage of SpaceWire
        - Space proven: *Gaia* uses SpaceWire
    - Transmit data as soon as ground station is reachable

OBC of Herschel/Planck

Credits: ESA

COMMUNICATION SUBSYSTEM

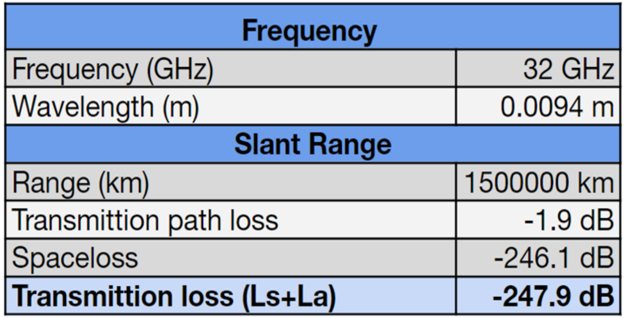
- Amount of Data
  - Standard: 5 h - 72 GByte
  - Maximum: 38h - 600 GByte
- Ka-Band is used as downlink
  - Maximum downlink bit rate: 75 Mbit/s
  - Fast transmission due to high frequency
- X-Band is used as uplink
  - Maximum uplink bit rate: 9.5 Mbit/s
  - More reliable than high frequency bands



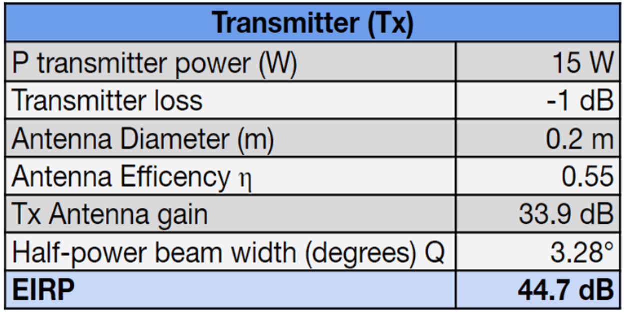
Credit: ESA

SPACE SEGMENT

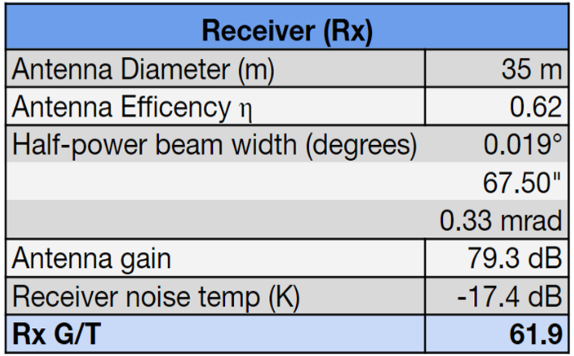
LINK BUDGET: Ka-BAND (Downlink)



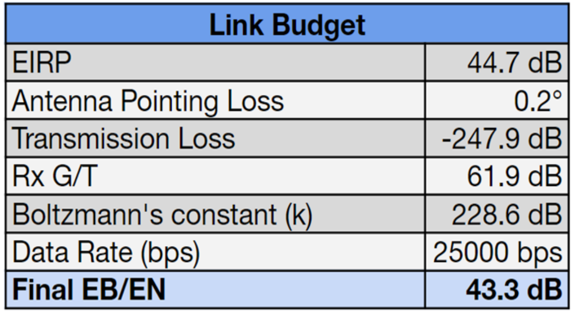
Frequency	
Frequency (GHz)	32 GHz
Wavelength (m)	0.0094 m
Slant Range	
Range (km)	1500000 km
Transmittion path loss	-1.9 dB
Spaceloss	-246.1 dB
Transmittion loss (Ls+La)	**-247.9 dB**



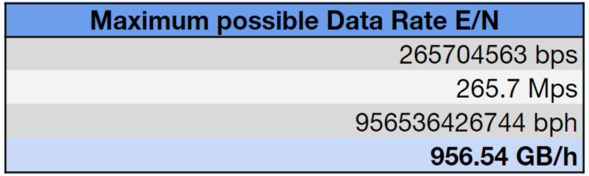
Transmitter (Tx)	
P transmitter power (W)	15 W
Transmitter loss	-1 dB
Antenna Diameter (m)	0.2 m
Antenna Efficency η	0.55
Tx Antenna gain	33.9 dB
Half-power beam width (degrees) Q	3.28°
EIRP	**44.7 dB**



Receiver (Rx)	
Antenna Diameter (m)	35 m
Antenna Efficency η	0.62
Half-power beam width (degrees)	0.019°
	67.50"
	0.33 mrad
Antenna gain	79.3 dB
Receiver noise temp (K)	-17.4 dB
Rx G/T	**61.9**



Link Budget	
EIRP	44.7 dB
Antenna Pointing Loss	0.2°
Transmission Loss	-247.9 dB
Rx G/T	61.9 dB
Boltzmann's constant (k)	228.6 dB
Data Rate (bps)	25000 bps
Final EB/EN	**43.3 dB**



Maximum possible Data Rate E/N
265704563 bps
265.7 Mps
956536426744 bph
956.54 GB/h

- Frequency **32 GHz**
- Transmitter power **15 W**
- Transmitter diameter **0.2 m**
- Receiver diameter **35 m**

- Final EB/EN **43.3 dB**

- Maximum possible data rate: **957 GB/h**

SPACE SEGMENT

LINK BUDGET: X-Band (Uplink)

Frequency	
Frequency (GHz)	8.4 GHz
Wavelength (m)	0.04 m
Slant Range	
Range (km)	1500000 km
Transmittion path loss	-1.9 dB
Spaceloss	-234.4 dB
Transmittion loss (Ls+La)	**-236.3 dB**

Transmitter (Tx)	
P transmitter power (W)	15 W
Transmitter loss	-1 dB
Antenna Diameter (m)	0.2 m
Antenna Efficency η	0.55
Tx Antenna gain	22.3 dB
Half-power beam width (degrees) Q	12.5°
EIRP	**33.1 dB**

Receiver (Rx)	
Antenna Diameter (m)	35 m
Antenna Efficency η	0.62
Half-power beam width (degrees)	0.07°
	257''
	1.25 mrad
Antenna gain	67.7 dB
Receiver noise temp (K)	55 K
Rx G/T	**50.3 dB**

Link Budget	
EIRP	33.1 dB
Antenna Pointing Loss	0.2°
Transmission Loss	-236.3 dB
Rx G/T	50.3 dB
Boltzmann's constant (k)	228.6 dB
Data Rate (bps)	25000 bps
Final EB/EN	**31.7 dB**

Maximum possible Data Rate E/N
18484541 bps
18.484541 Mps
66544345856.64 bph
66.54 GB/h

- Frequency **8.4 GHz**
- Transmitter power **15 W**
- Transmitter diameter **0.2 m**
- Receiver diameter **35 m**

- Final EB/EN **31.7 dB**

- Maximum possible data rate: **67 GB/h**

ΔV ANALYSIS (1)

Manoeuvre	ΔV (m/s)	Margin (%)	Total ΔV (m/s)
Launcher Dispersions	45	50	67.5
Station Keeping	3	50	4.5
RW Desaturations	5	100	10
EOL Disposal	10	50	15

Dry Mass of Spacecraft: 5699 kg

Launcher Dispersions → St. Keep. & RW Des. (5 yr) → EOL Disposal

$M_{tot,0}$ = 6046 kg

$M_{tot,1}$ = 5859 kg

$M_{tot,2}$ = 5799 kg

$M_{tot,end}$ = 5699 kg

Launcher Dispersions → St. Keep. & RW Des. (**10** yr) → EOL Disposal

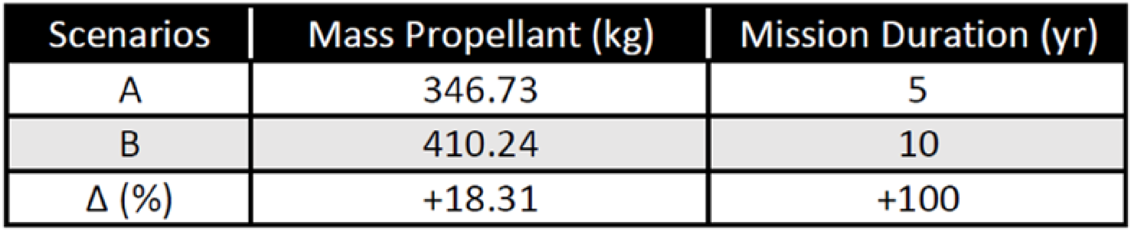
$M_{tot,0}$ = 6110 kg

$M_{tot,1}$ = 5921 kg

$M_{tot,2}$ = 5860 kg

$M_{tot,end}$ = 5699 kg

ΔV ANALYSIS (2)



Scenarios	Mass Propellant (kg)	Mission Duration (yr)
A	346.73	5
B	410.24	10
Δ (%)	+18.31	+100

- Increasing propellant mass by **18%** → Increase of mission duration by **100%**
- Only station keeping costs are affected by the mission duration
- Propellant mass for **10** years was considered for the mission

SPACE SEGMENT

MASS BUDGET

		Mass [Kg]	Maturity	Margin in (%)	Total (kg)
Service Module	Solar Arrays	80	Minor Modified	10	88
	Power Control	32	Minor Modified	10	35
	Harness	83	Minor Modified	20	100
	AOCS	66	Space Proven	5	69
	Structure	350	New	20	420
	Thermal Control	300	Minor Modified	10	330
	Data Handling	30	Space Proven	5	32
	Communication	21	Minor Modified	10	23
	Sunshield	600	New	20	720
				Mass SM	**1817**

Payload	Optics and Structure	1800	New	20	2160
	Detectors	46	Minor Modified	10	51
	TCS	210	Minor Modified	20	252
	Structure	300	New	20	360
	Harness	100	Minor Modified	10	110
				Mass Payload	**2933**

Total	Dry Mass	4749
	Sys. Margin (%)	20
	Total Dry Mass (kg)	5699
	Propellant Mass (kg)	410
	Total Mass (kg)	**6110**

- Dry Mass: **5699 kg**
- Propellant Mass: **410 kg**
- Total Mass: **6110 kg**

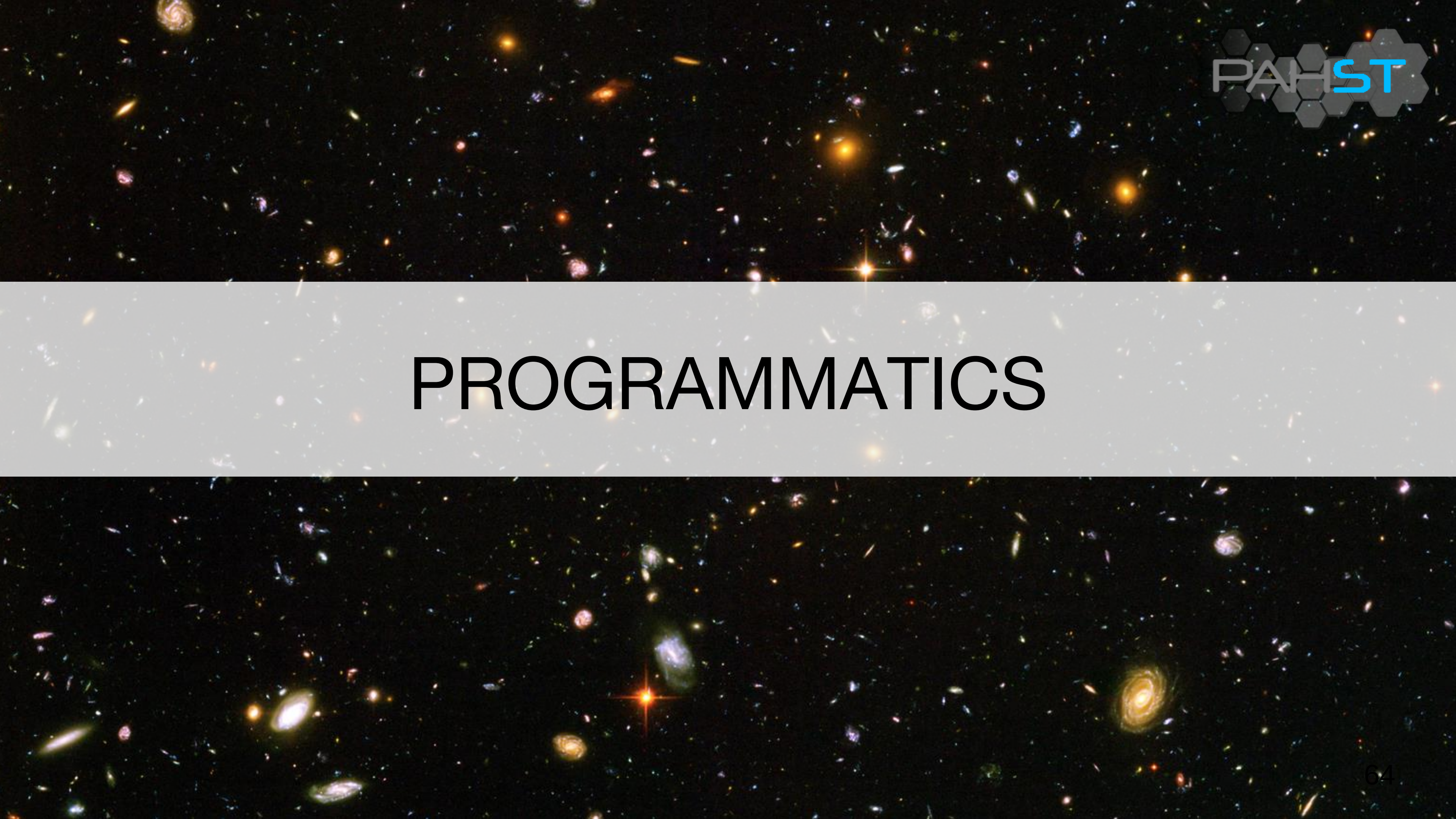
GROUND SEGMENT

GROUND SEGMENT OVERVIEW

- Communication window for 3hrs each day
    - **Prime:** Cebreros (Spain)
        - X-Band and Ka-Band available
    - **Secondary:** Malargüe station (Argentina)
        - X-Band and Ka-Band available

Specification from Herschel/JWST, credits: ESA

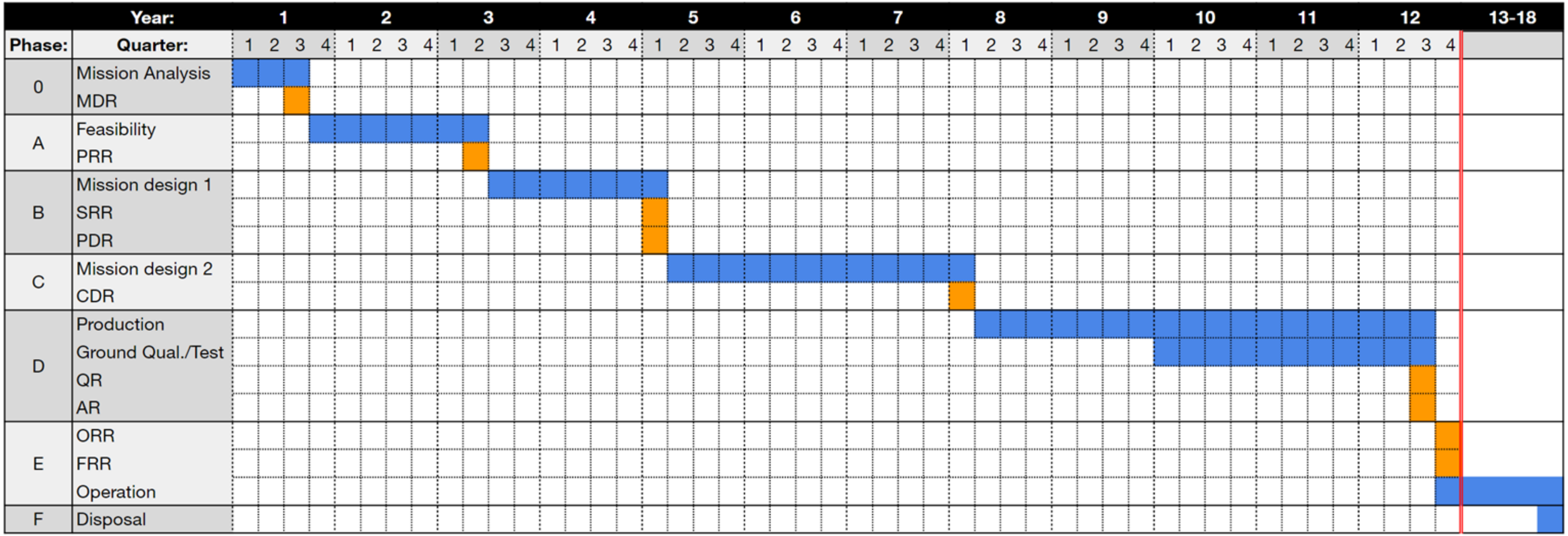
Credits: ESA



PROGRAMMATICS

PROGRAMMATICS

MISSION TIMELINE



	Year:	1				2				3				4				5				6				7				8				9				10				11				12				13-18
Phase:	**Quarter:**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
0	Mission Analysis	■	■	■																																														
	MDR			■																																														
A	Feasibility				■	■	■	■	■	■	■																																							
	PRR										■																																							
B	Mission design 1											■	■	■	■	■	■	■																																
	SRR																	■																																
	PDR																	■																																
C	Mission design 2																		■	■	■	■	■	■	■	■	■	■	■	■																				
	CDR																													■																				
D	Production																														■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Ground Qual./Test																																					■	■	■	■	■	■	■	■	■	■	■		
	QR																																															■		
	AR																																															■		
E	ORR																																																■	
	FRR																																																■	
	Operation																																																■	■
F	Disposal																																																	■

MDR → Mission Definition Review,
PRR → Preliminary Requirements Review,
SRR → System Requirements Review,

PDR → Preliminary Design Review,
CDR → Critical Design Review,
QR → Qualification Review,

AR → Acceptance Review,
ORR → Operation Readiness Review,
FRR → Flight Readiness Review

Mission design 1 = preliminary design
Mission design 2 = detailed design

* 20 % margin is included in every phase

PROGRAMMATICS

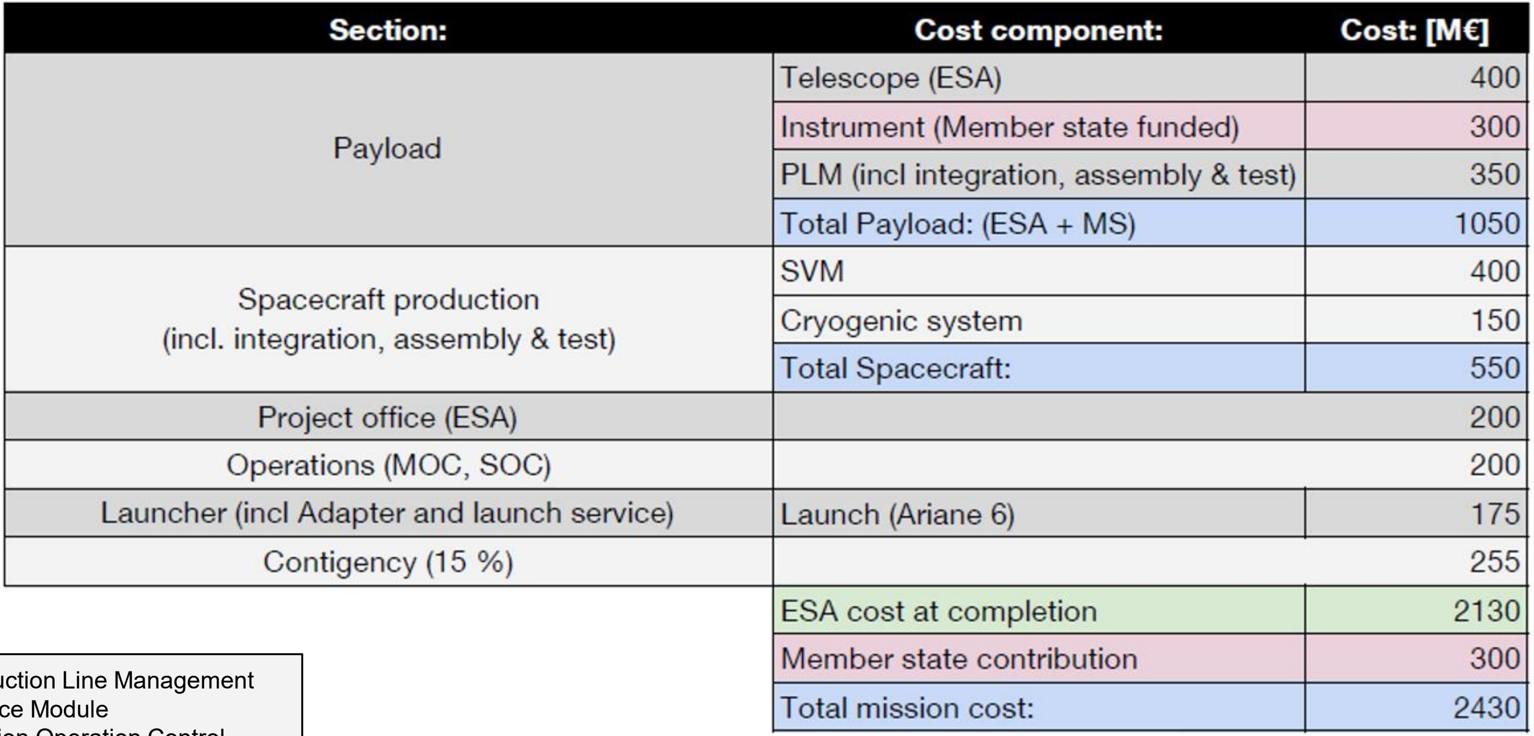
RISK ASSESSMENT

Risk:	Impact:	Severity:	Likelihood:	Total:	Mitigation act:
Ariane 6 not available for launch	S/C	3	A	A3	Use other launcher
Delays in folding mirror development	S/C/P	3	C	C3	Delays accepted
Delays in sensor development	S/C/P	2	C	C2	Delays accepted
Sensor is not space proven	S/C/P	4	B	B4	Alternative sensor technology
Simpler folding mirror not feasible	C/P	4	B	B4	Using the JWST folding technology
Mirror opening malfunction	P	3	B	B3	Structure design, materials selection, test campaign
Sunshade deployment malfunction	P/M	4	B	B4	Structure design, materials selection, test campaign

S → Schedule, M → Mission, C → Cost, P → Performance

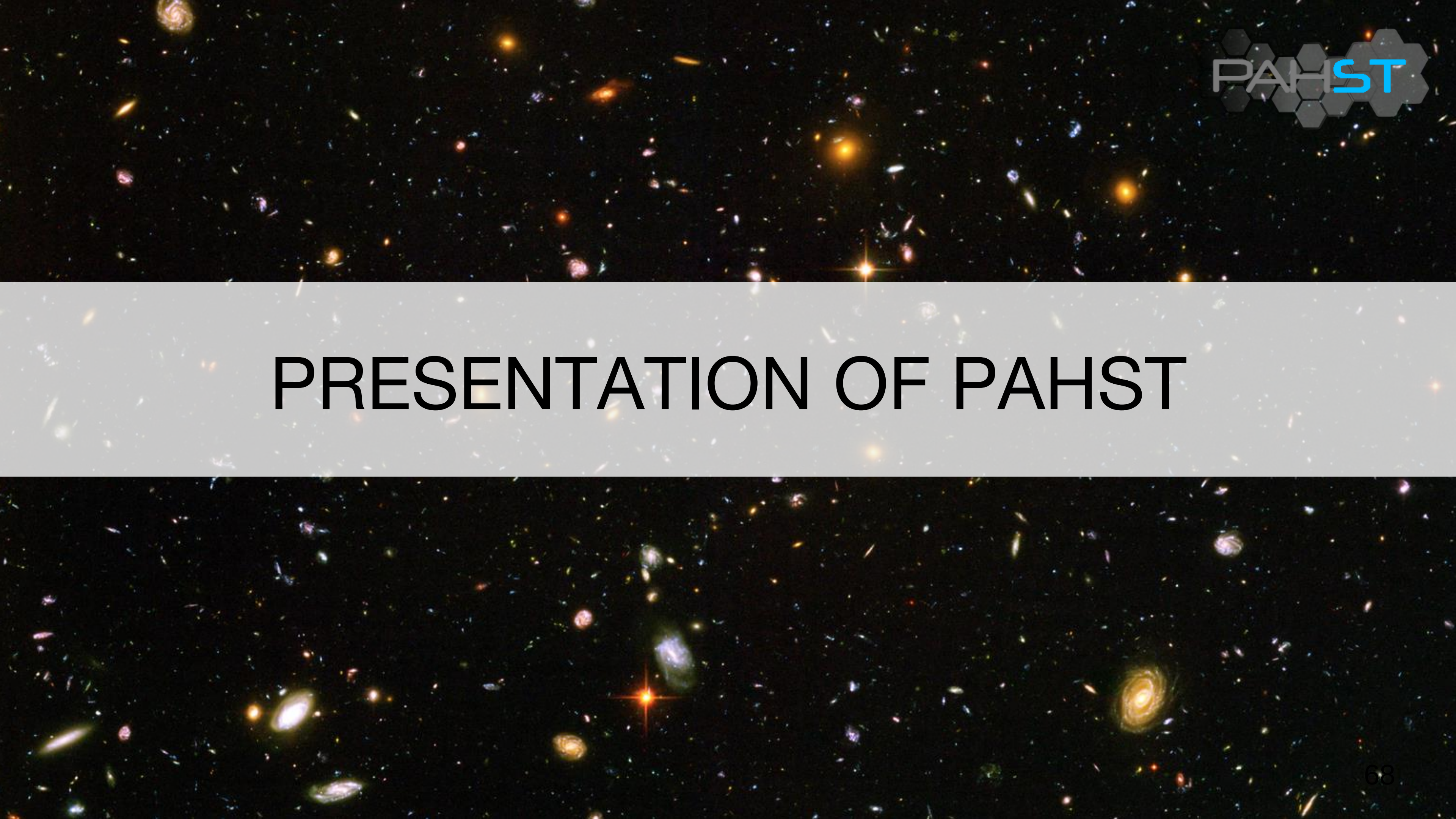
PROGRAMMATICS

COST ESTIMATION



Section:	Cost component:	Cost: [M€]
Payload	Telescope (ESA)	400
	Instrument (Member state funded)	300
	PLM (incl integration, assembly & test)	350
	Total Payload: (ESA + MS)	1050
Spacecraft production (incl. integration, assembly & test)	SVM	400
	Cryogenic system	150
	Total Spacecraft:	550
Project office (ESA)		200
Operations (MOC, SOC)		200
Launcher (incl Adapter and launch service)	Launch (Ariane 6)	175
Contigency (15 %)		255
	ESA cost at completion	2130
	Member state contribution	300
	Total mission cost:	2430

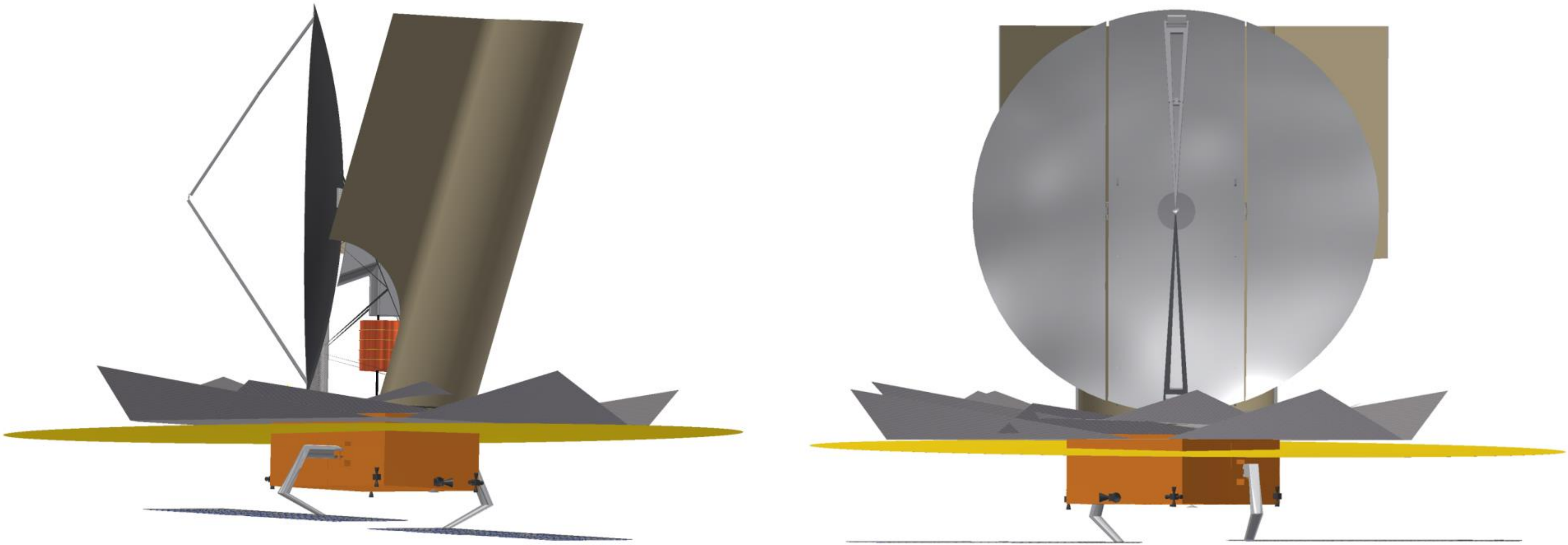
PLM → Production Line Management
SVM → Service Module
MOC → Mission Operation Control
SOC → Science Operation Control



PRESENTATION OF PAHST

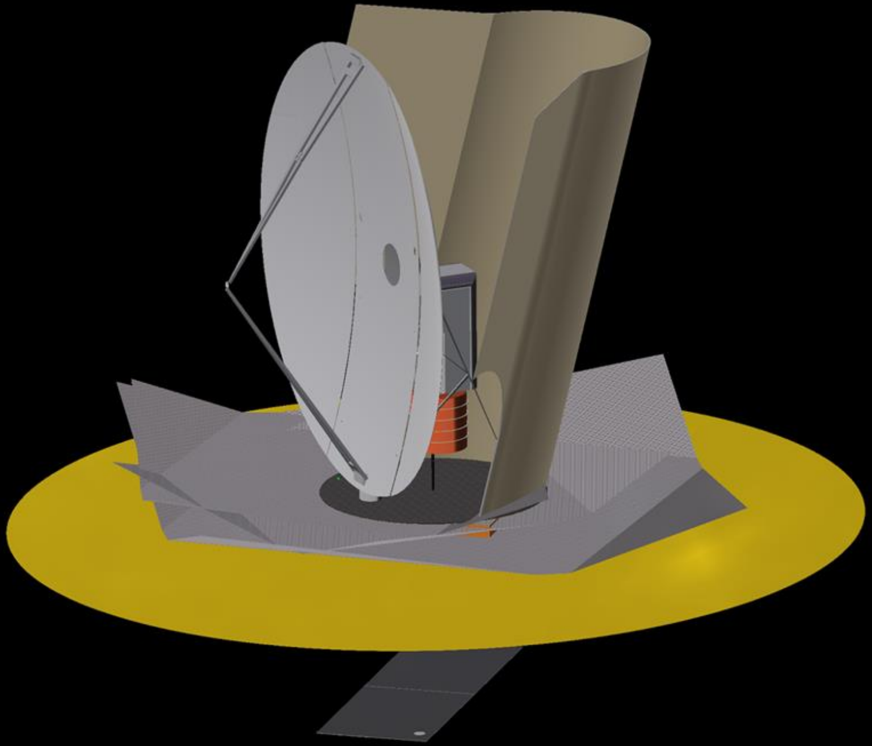
PRESENTATION OF PAHST

DEMONSTRATION



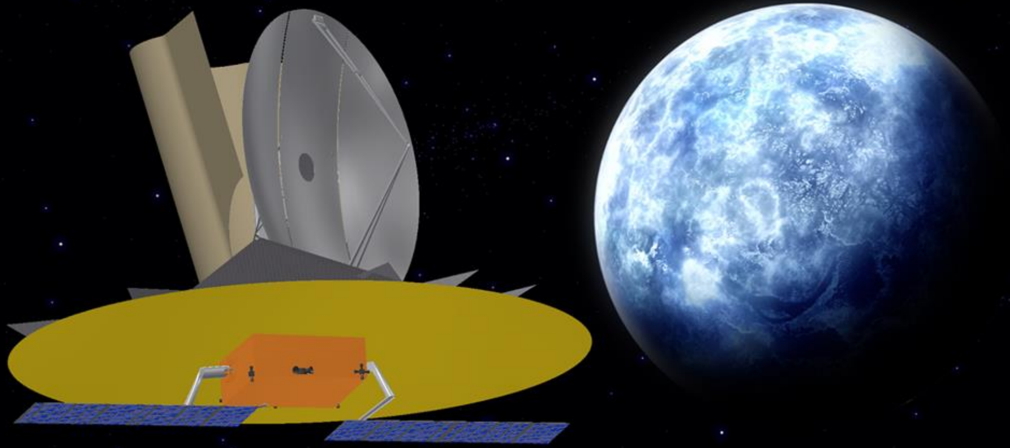
PRESENTATION OF PAHST

DEMONSTRATION



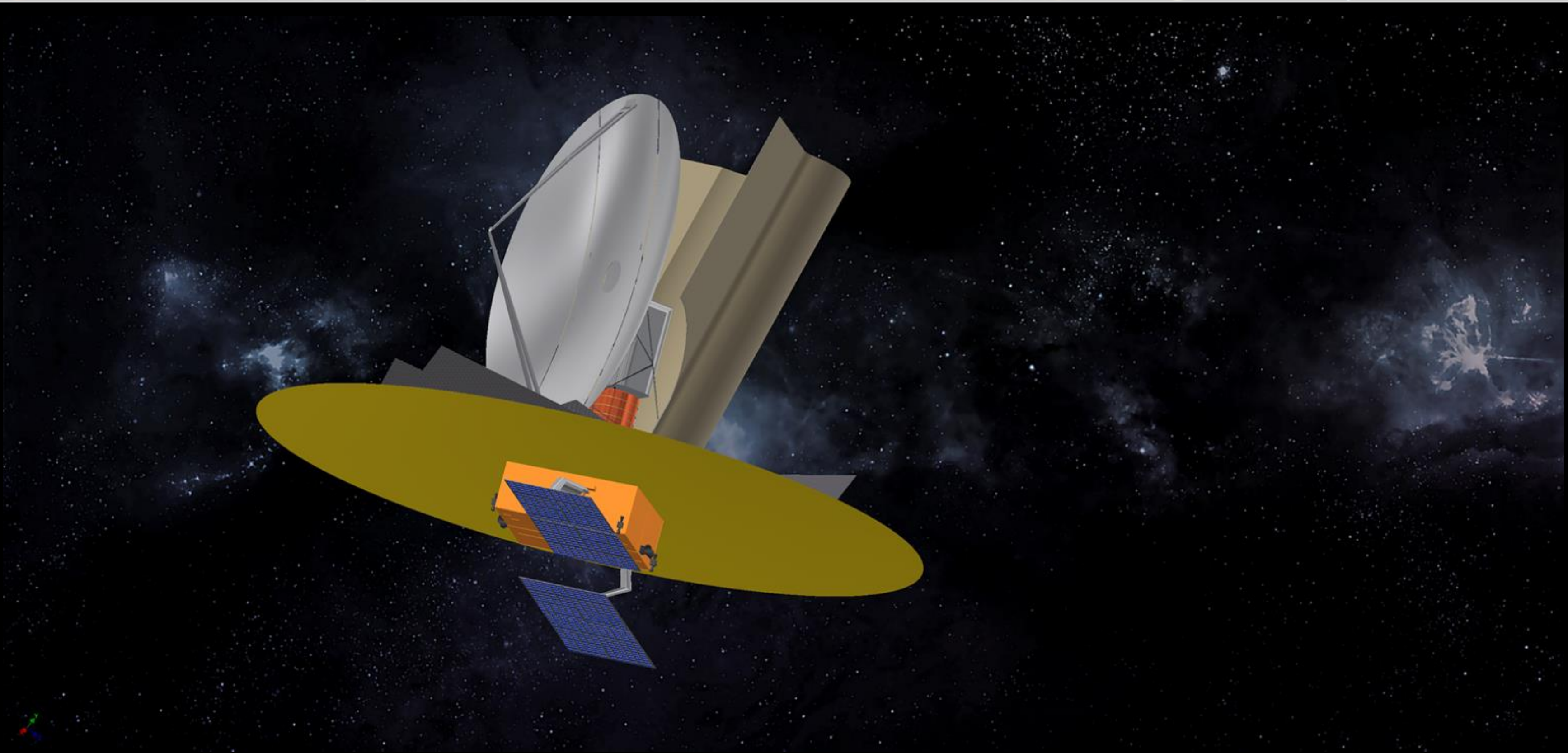
PRESENTATION OF PAHST

DEMONSTRATION IN SPACE



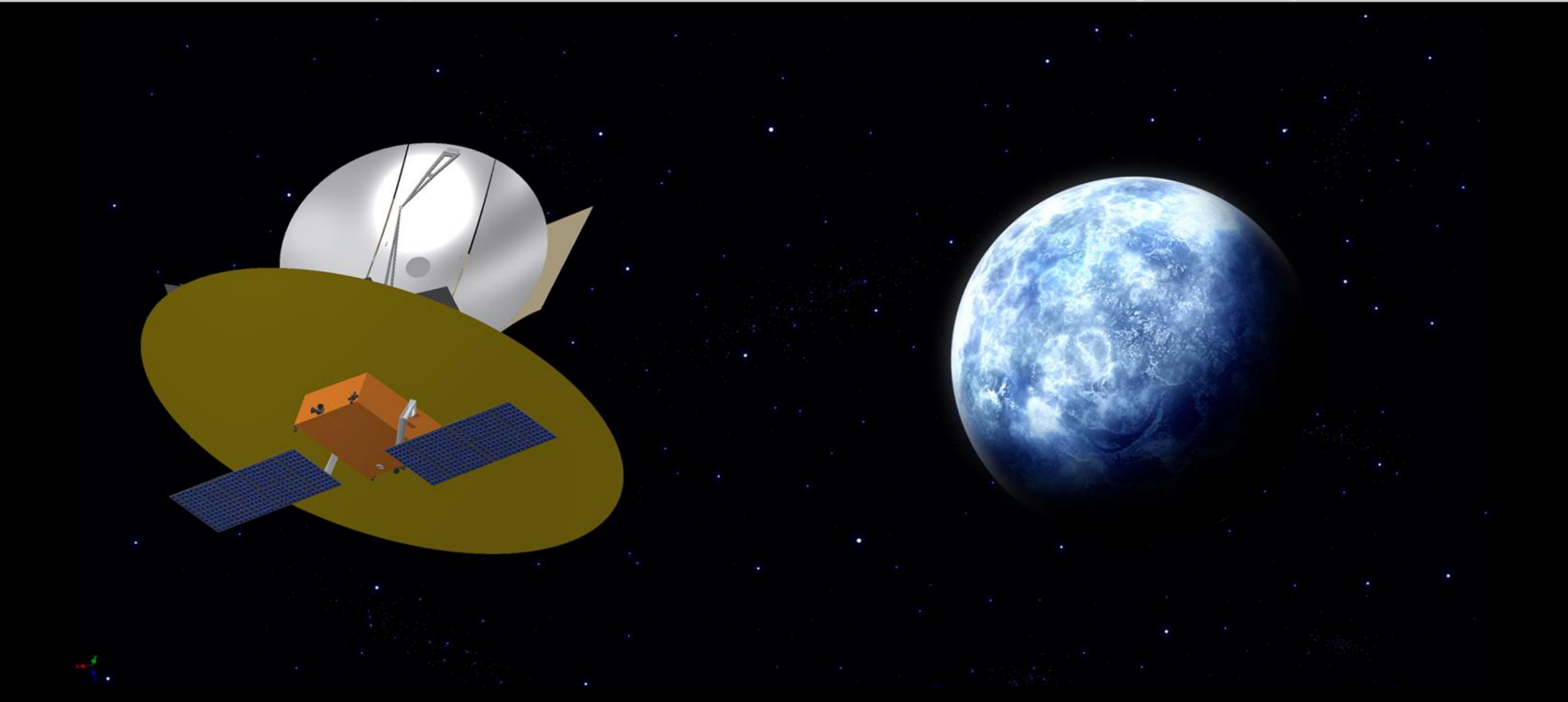
PRESENTATION OF PAHST

DEMONSTRATION IN SPACE



PRESENTATION OF PAHST

DEMONSTRATION IN SPACE



OUTREACH

GENERAL PUBLIC APPEAL

AlpbachSpace - PAHST
@Alpbach_PAHST

Updates and news about the PAHST mission of Alpbach Space, the (fictional) space agency of the Austrian village of Alpbach.

Alpbach, Österreich
summerschoolalpbach.at

AlpbachSpace - PAHST @Alpbach_PAHST · 1h
To detect the light from the PAHs in far away galaxies, we need a large mirror. PAHST's mirror will be bigger than JWST's! #PAHST #JWST #ESA

→PAHST: SHEDDING LIGHT ON ANCIENT GALAXIES

→In December 1995, the Hubble Space Telescope observed an “empty” patch of sky in the constellation Ursa Maior for ten consecutive days. Although the angular size of this area was extremely small, being equal to the size of a tennis ball at 100 meters, it revealed thousands of galaxies.
The faintest galaxies in this Hubble Deep Field all have a reddish colour, which is due to the waves of light emitted by their stars being stretched by the expansion of the Universe. From this, one can determine that the dimmest are roughly 13.3 billion years old, emitting the light captured by Hubble only 470 million years after the Big Bang.

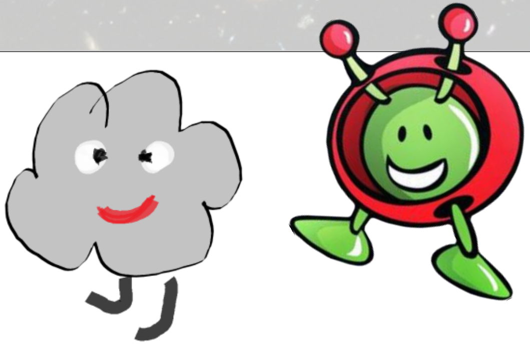
With PAHST, the Polycyclic Aromatic Hydrocarbon (PAH) Space Telescope, a joint mission between the Alpbach Space Agency and the European Space Agency, astronomers hope to image these galaxies in infrared light with unprecented sensitivity. By looking at light emitted by PAHs, molecules similar to those in soot here on Earth, one can determine the amount of star being formed in these galaxies. This will provide an unparalleled view on the evolution of the early Universe.

Image courtesy: ESA/Hubble

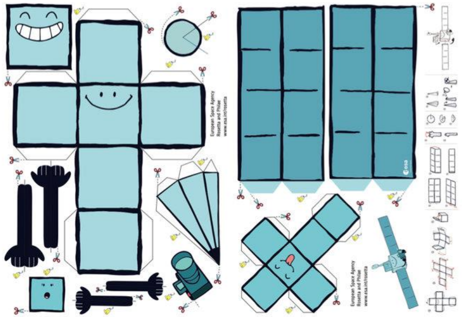
OUTREACH

EDUCATION ACTIVITIES

Dusty friend of Paxi



PAHST model

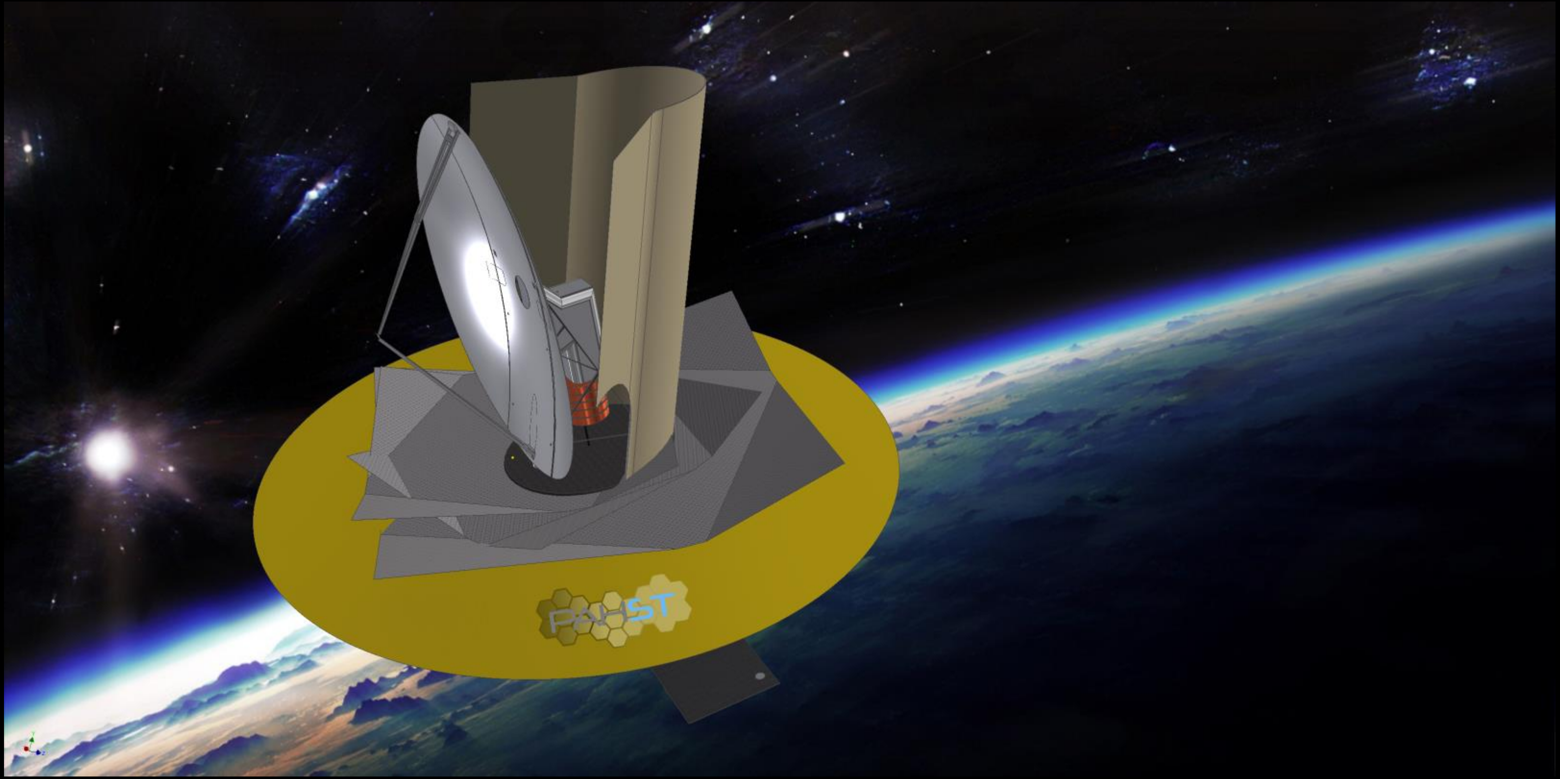


Dust in the Universe lecture scenarios

Extension of Cesar programme

PRESENTATION OF PAHST

DEMONSTRATION IN SPACE



PAHST

Thank you for your attention!

FFG ESA Team Blue

PAHST

Polycyclic Aromatic Hydrocarbons Space Telescope

FFG/Summer School Alpbach 2017 / © M.A. Jakob AT 1180

BACKUP

Backup Slides

DRAFT for content

Science Case

1. Science statement

2. Science background
3. Science Questions
4. Requirements (Traceability matrix)
5. Instruments
6. Observation strategy

Mission analysis

1. Orbit
2. Orbital Environment
3. Mission timeline
4. Disposal

Ground Segment

1. Ground segment overview
2. Communication windows

Space Segment

1. Interferometer & Single dish tradeoff
2. Main mirror folding concept
3. Spacecraft concept and fairing configuration (solar+shade)
4. Product tree
5. System architecture
6. Thermal control
7. Attitude control
8. Communication subsystem
9. Mass budget
10. Power budget
11. Delta V budget
12. OBDH

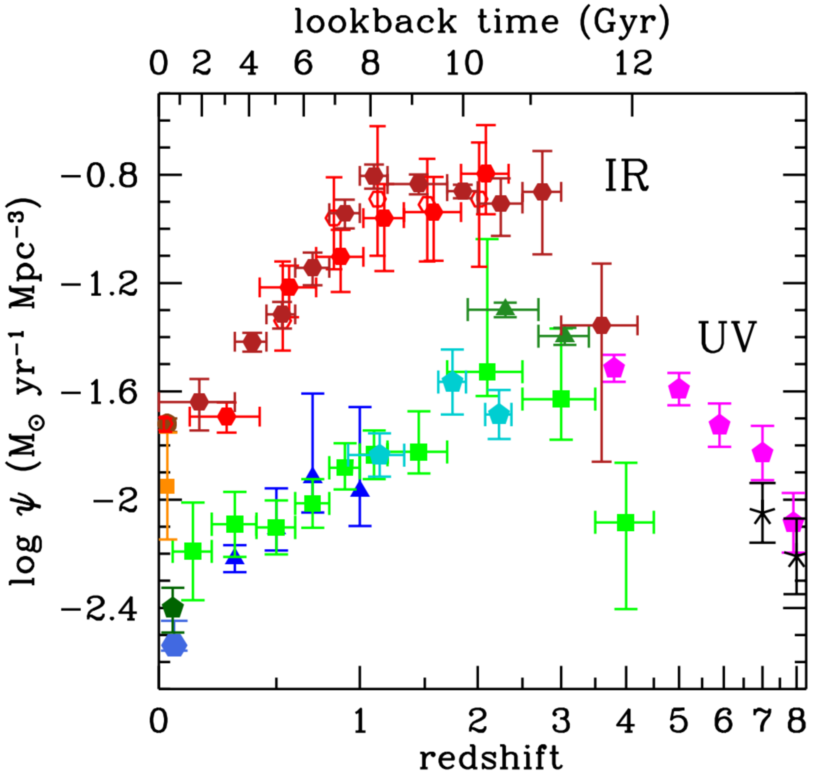
Programmatics

1. Cost
2. Risks analysis
3. Project timeline

COSMIC STAR FORMATION HISTORY

MOTIVATION

Star formation rate density



Madau et al. (2014)

SCIENCE CASE

Science Questions

What does obscured star formation look like at high redshift?

How does the PAH spectra compare at low and high redshift?

Can **Polycyclic Aromatic Hydrocarbons** be used to trace **Star Formation** in the **Early Universe**?

SCIENCE CASES

TOPICS

Primary science topic:

Star formation in the early Universe at z~5

Secondary science topic:

Inner structure of “ridges” (dense filaments) in the Galactic ISM

Tertiary science topic:

Y-classification Brown Dwarfs Observations

[Tertiary science topic:]

[Follow-up of GRB afterglows]