The Herschel Mission

Herschel Calibration Workshop

Leiden, 1 December 2004

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Research and Scientific Support Department

HERSCHEL SPACE OBSERVATORY

Beginnings to … the present

HERSCHEL SPACE OBSERVATORY

Herschel mission

- **ESA cornerstone observatory**
  - instruments ‘nationally’ funded, int’l - NASA, CSA, Poland – collaboration
  - ~1/3 guaranteed time, ~2/3 open time
- **FIR (57 - 670 μm) space facility**
  - large (3.5 m), low emissivity (< 4%), passively cooled (< 90 K) telescope
  - 3 focal plane science instruments
  - 3 years routine operational lifetime
  - full spectral access
  - low and stable background
- **Unique and complementary**
  - for λ < 200 μm larger aperture than cryogenically cooled telescopes (IRAS, ISO, SIRTF, Astro-F,…)
  - more observing time than balloon- and/or air-borne instruments (~1000 SOFIA flights per year)
  - larger field of view than interferometers
- **Launch in 2007**

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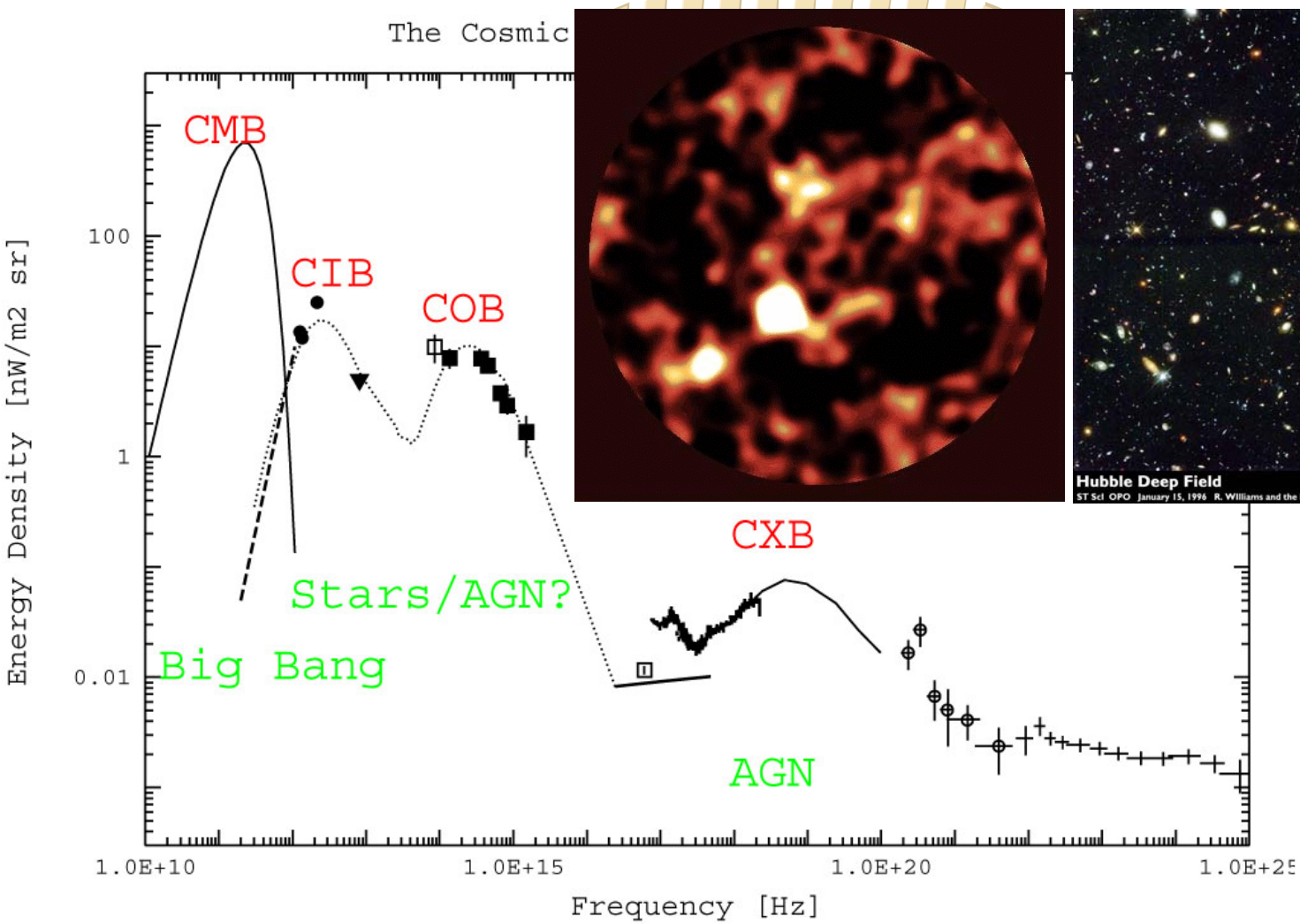
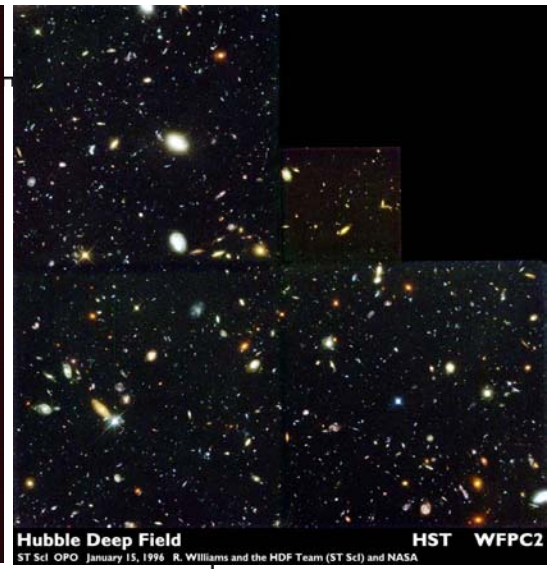
Galaxy formation & evolution





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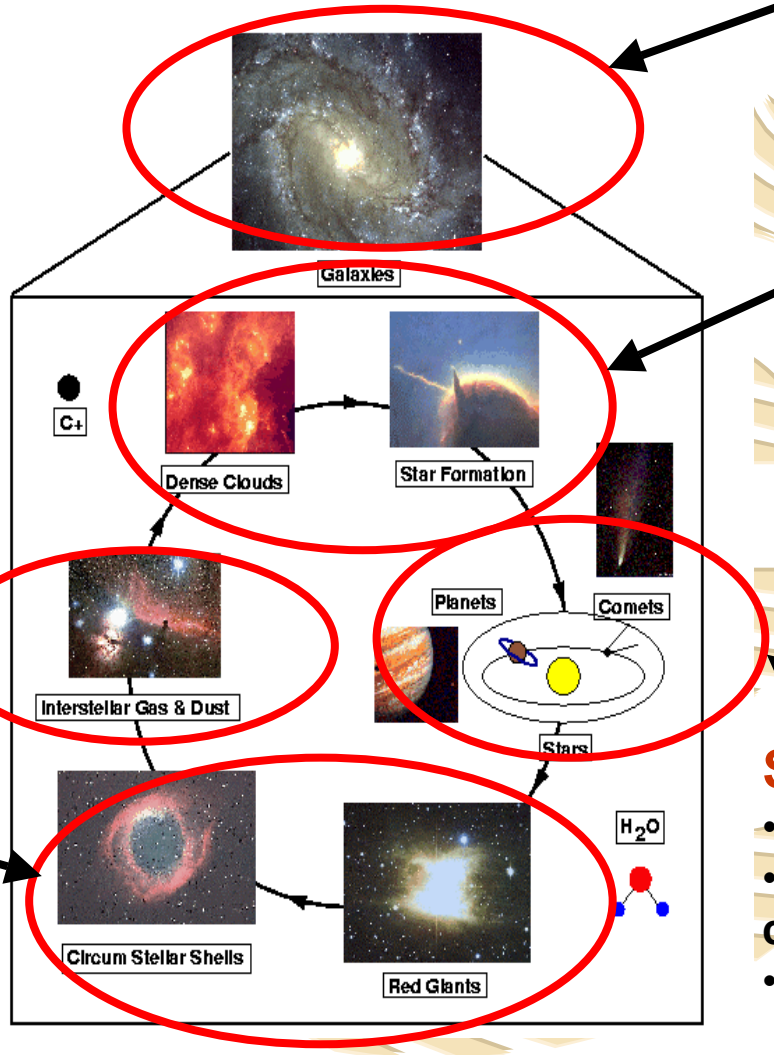
Star formation & evolution

ISM in Galaxies:
- Normal galaxies
- Physical properties of star-forming ISM

ISM in the Milky Way:
- Structure
- Dynamics (pressure)
- Composition (gradients)



Dense cores and star-formation:
- Temperature, density structure
- Dust properties
- Stellar IMF

Late stages of stellar evolution:
- Winds
- Shells
- Asymmetries
- Composition

Solar System:
- Water in Giant Planets
- Atmospheric chemistry
- Water activity and composition of comets

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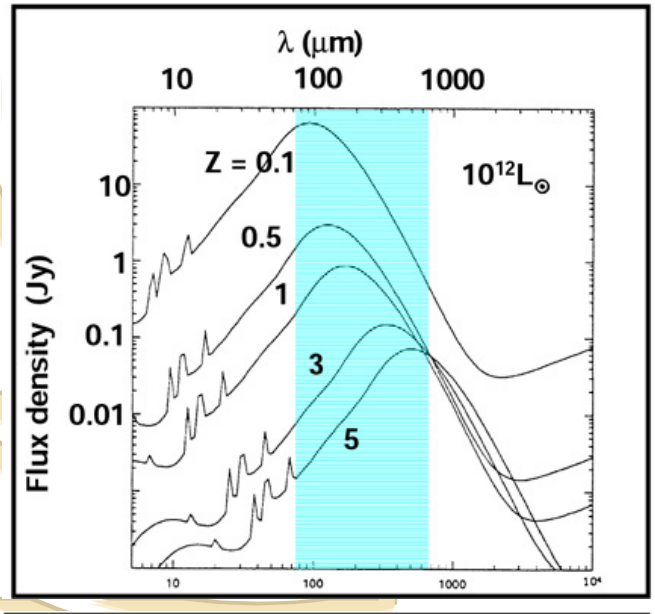
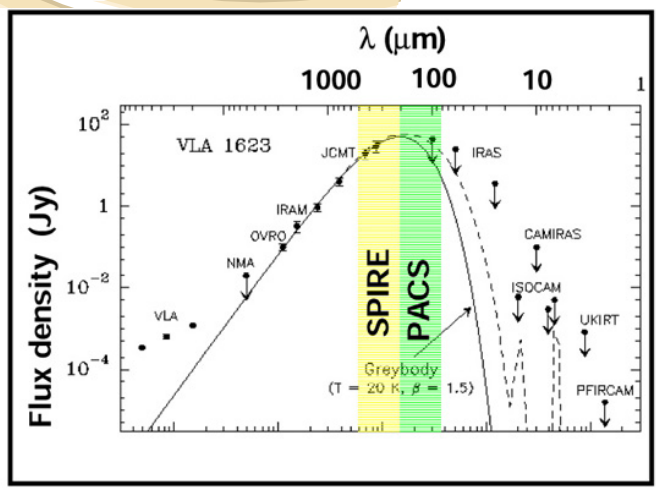
The Cool Universe

- **Herschel spectral coverage**
  - black-bodies 5-50 K
    - continuum radiation
    - dust grains (re-)radiating
  - gases 10-few100 K
    - brightest atomic/molecular lines
- **Herschel emphasis**
  - formation and evolution of galaxies & stars
  - ISM physics & chemistry
  - solar system bodies
- **Herschel strengths**
  - covers ISM SED peaks
  - wide area mapping
  - spectral scans, water lines





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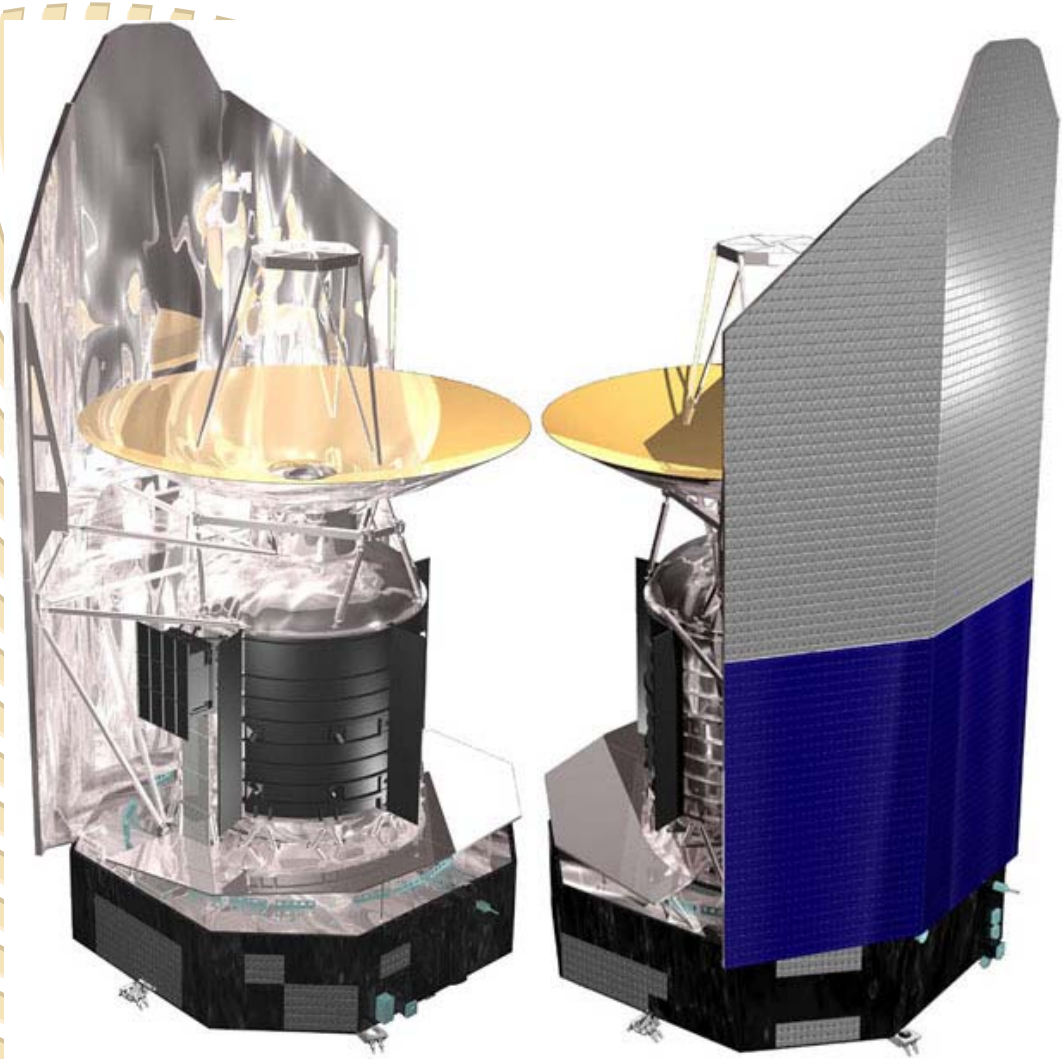
Herschel spacecraft

- telescope diameter 3.5 m
- telescope WFE < 6 μm
- telescope temp < 90 K
- telescope emissivity < 4%
- abs/rel pointg (68%) < 3.7” / 0.3”
- science instruments 3
- science data rate 130 kbps
- cryostat lifetime 4.0±0.4 years
- height / width ~ 7.5 / 4 m
- launch mass ~ 3200 kg
- power ~ 1500 W
- orbit ‘large’ Lissajous around L2
- **solar aspect angle 60-120 deg**
- launcher (w Planck) Ariane 5 ECA



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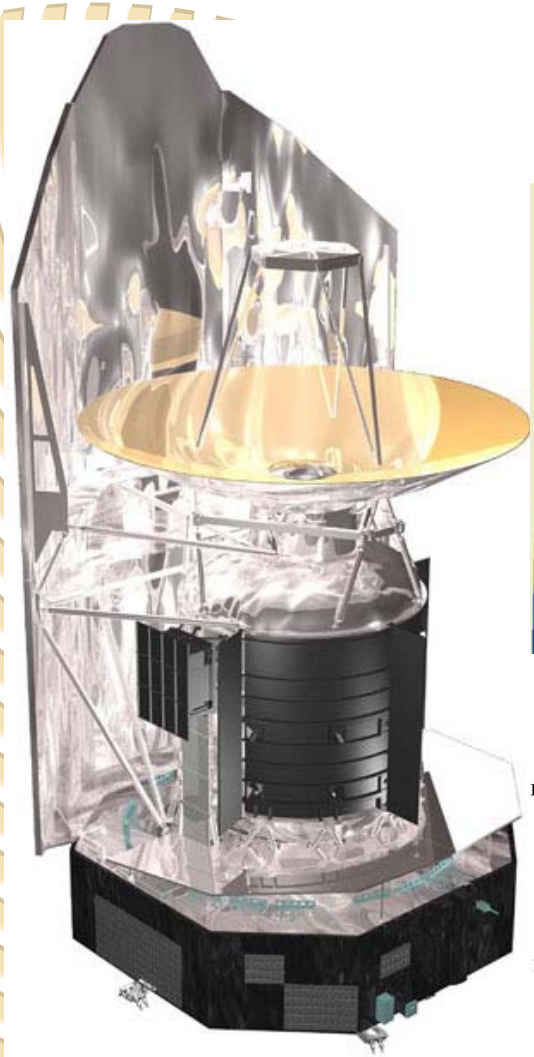
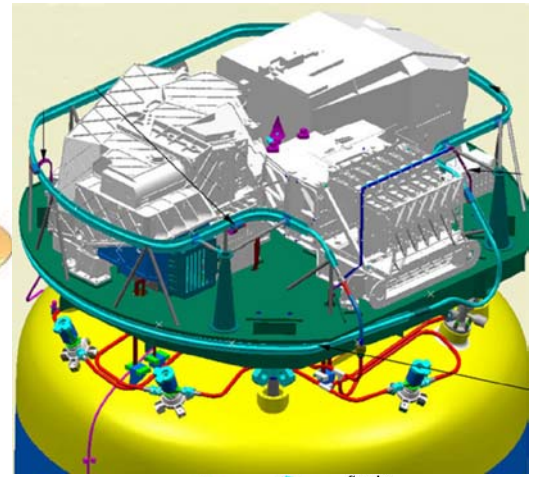
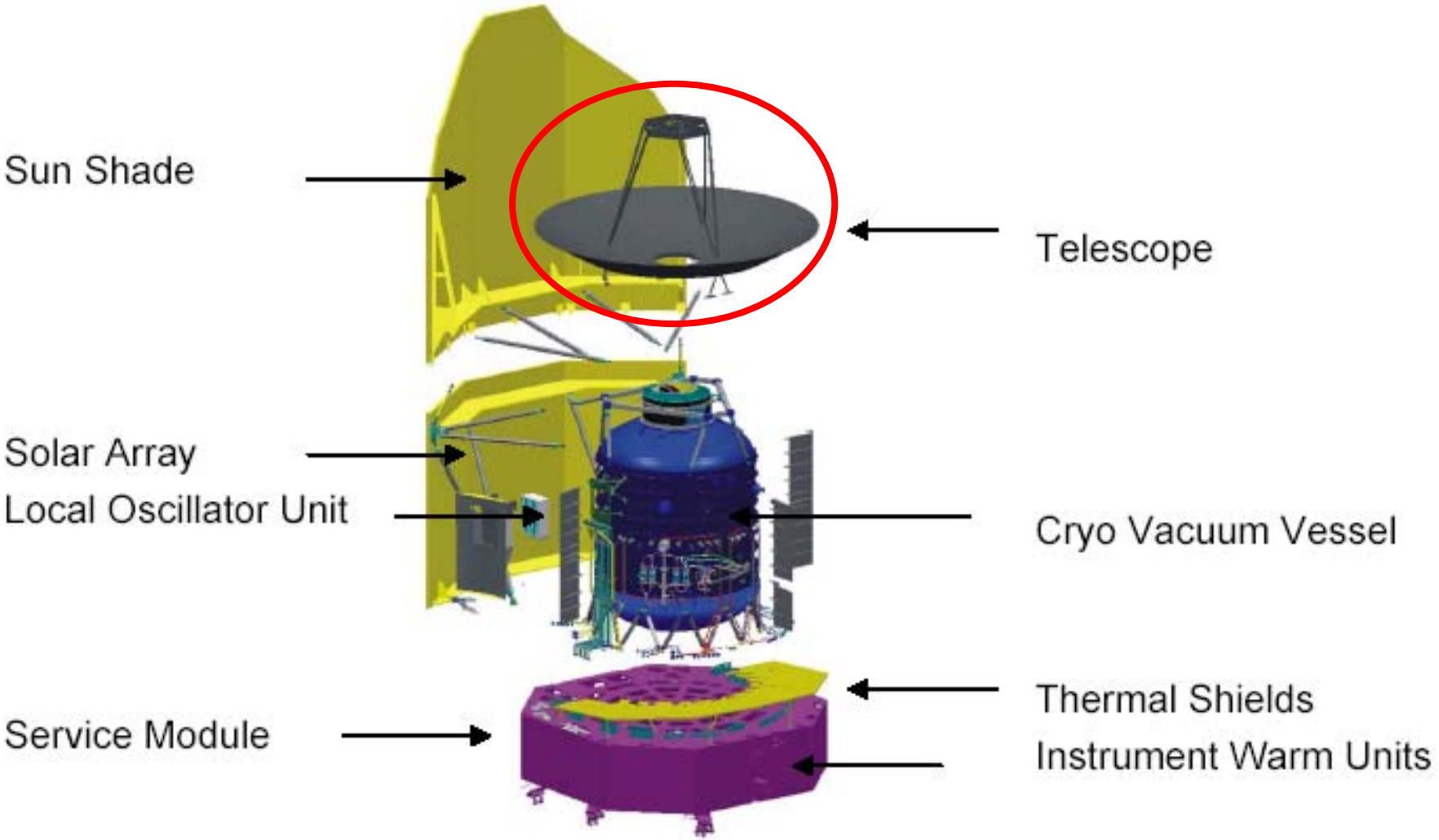
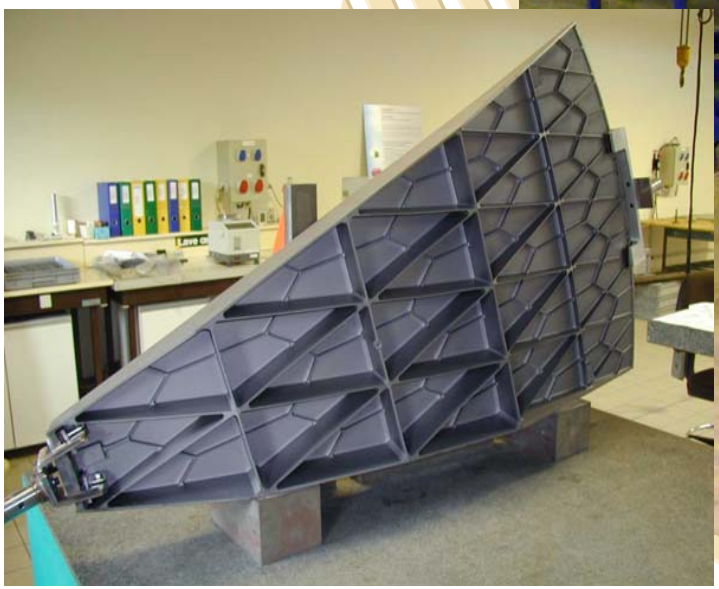




Herschel spacecraft



Petals ready for brazing



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Brazing of primary mirror ‘blank’

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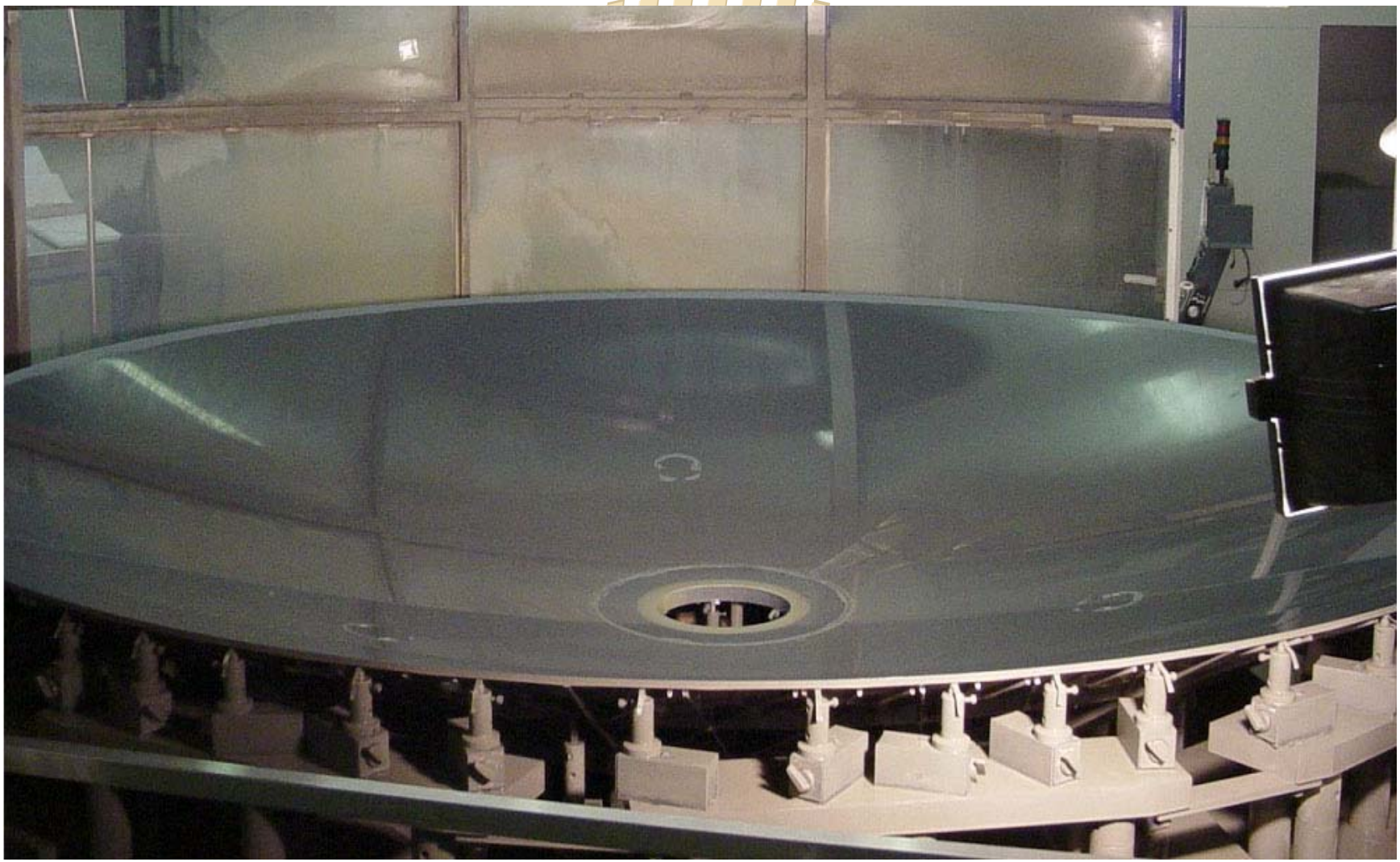
Grinding of primary mirror



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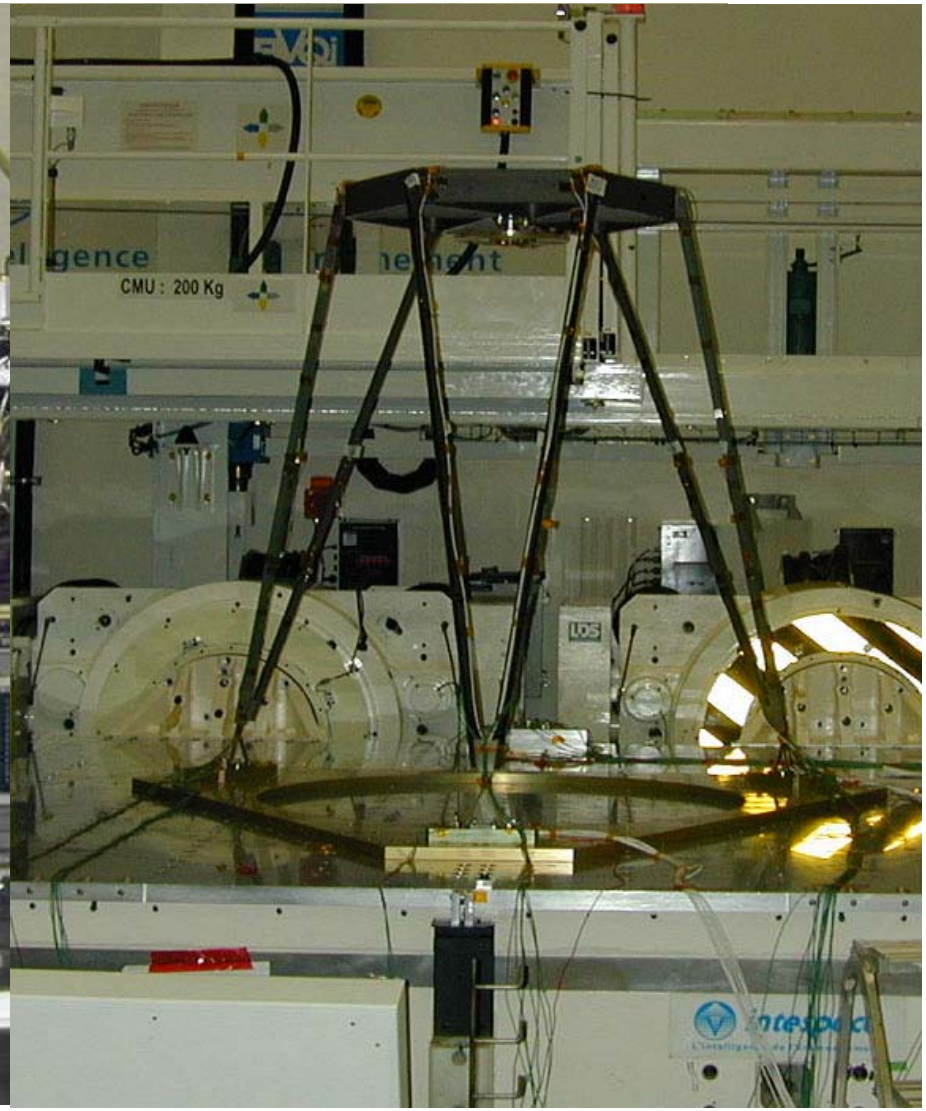
Warm vibration



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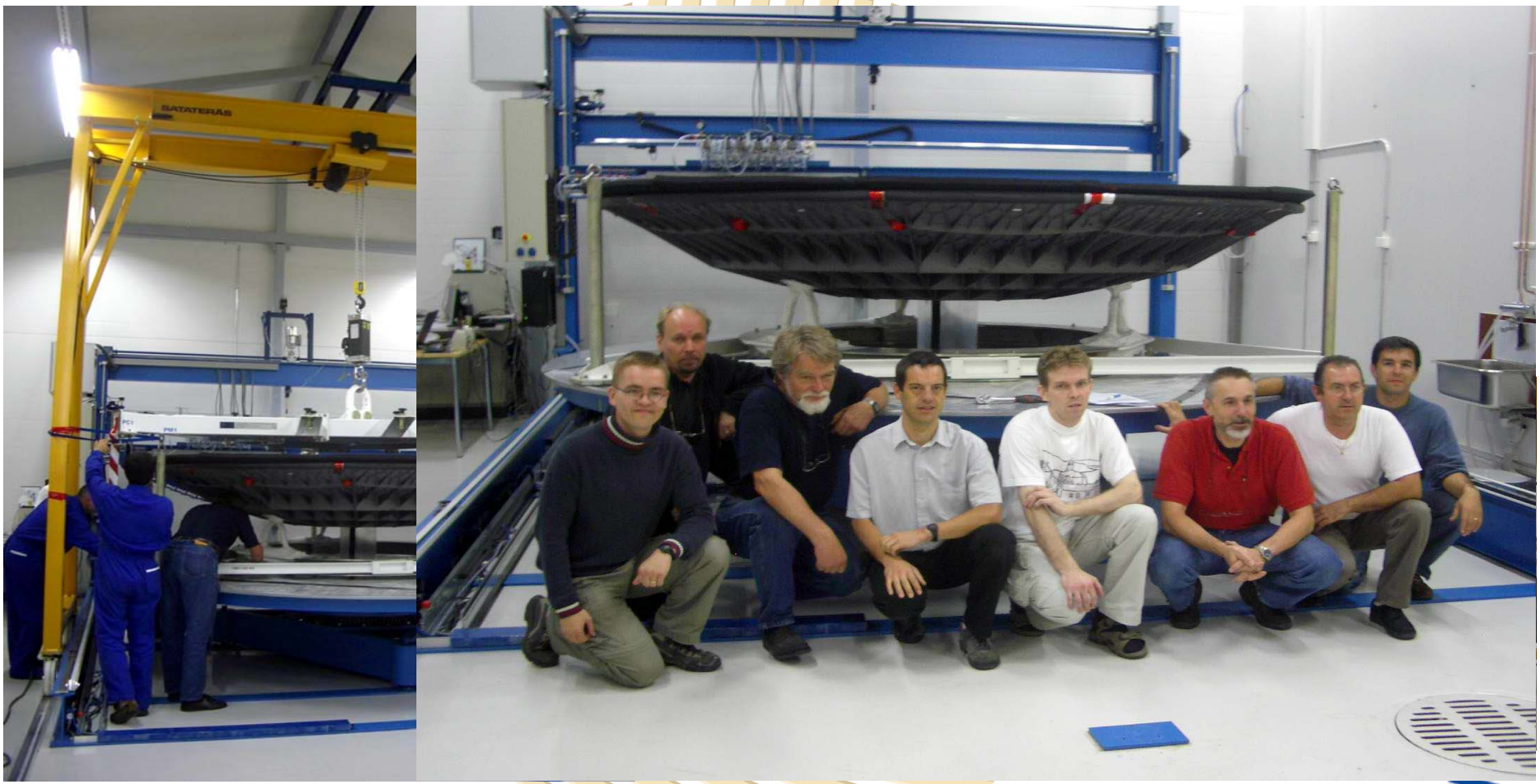
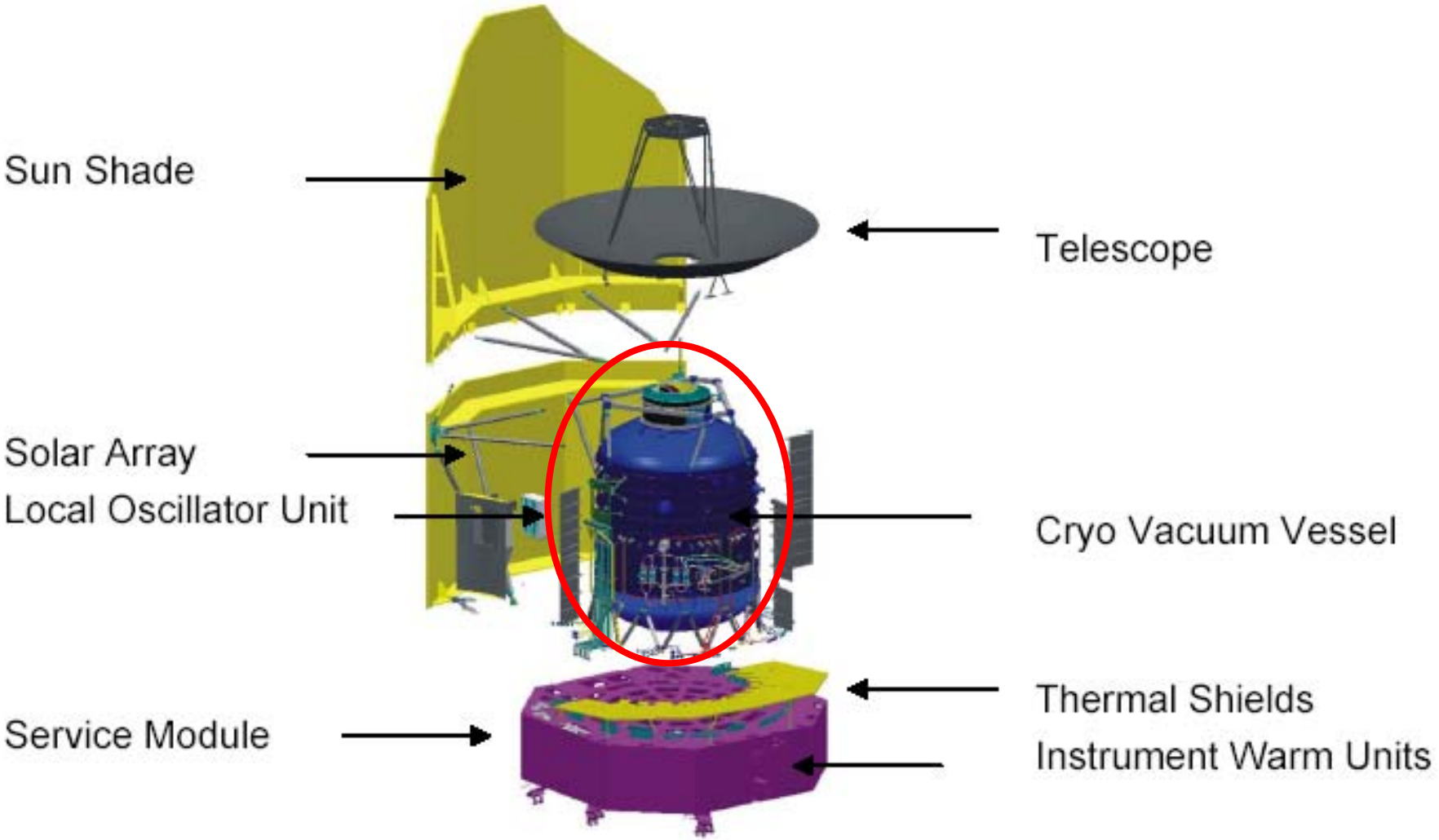
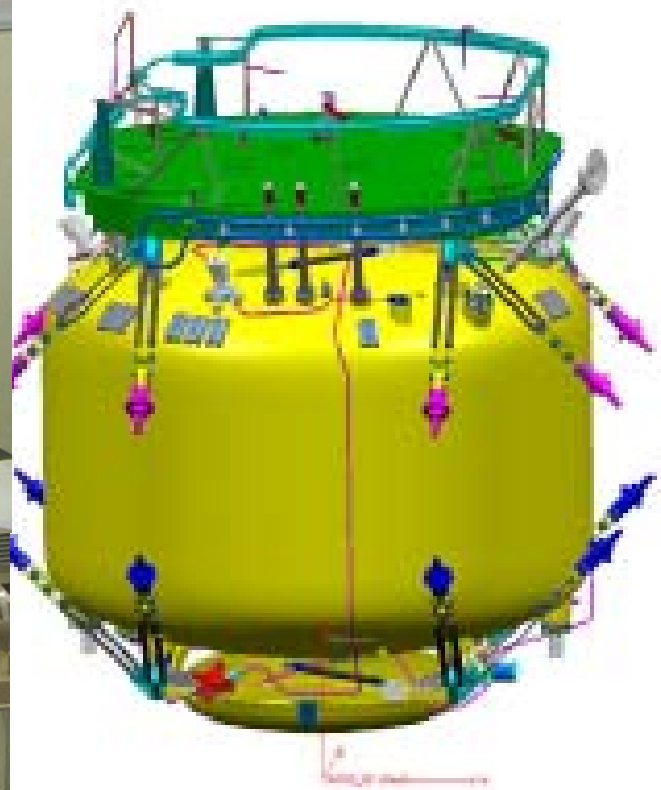
Polishing



Herschel spacecraft



Herschel payload module

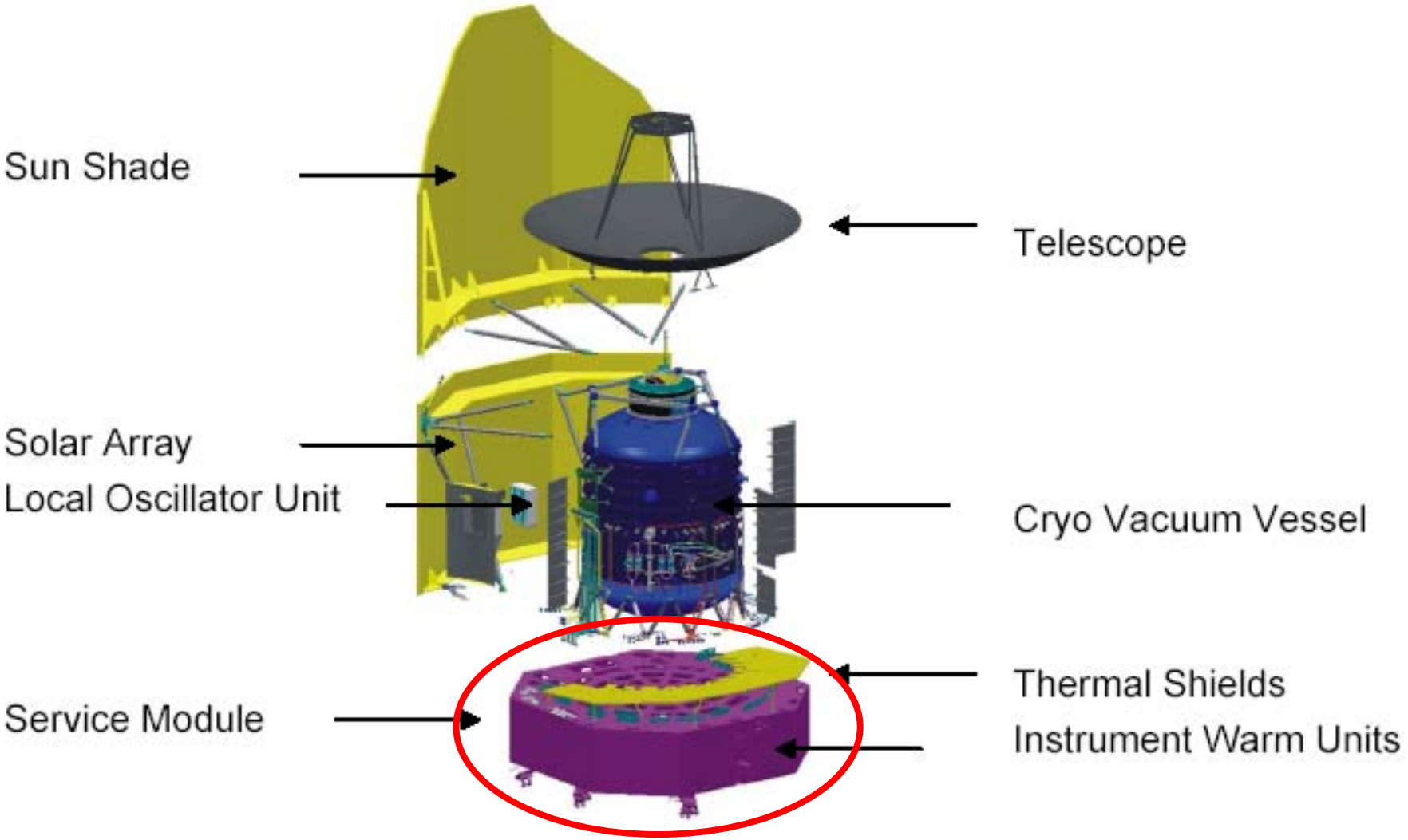


HERSCHEL SPACE OBSERVATORY

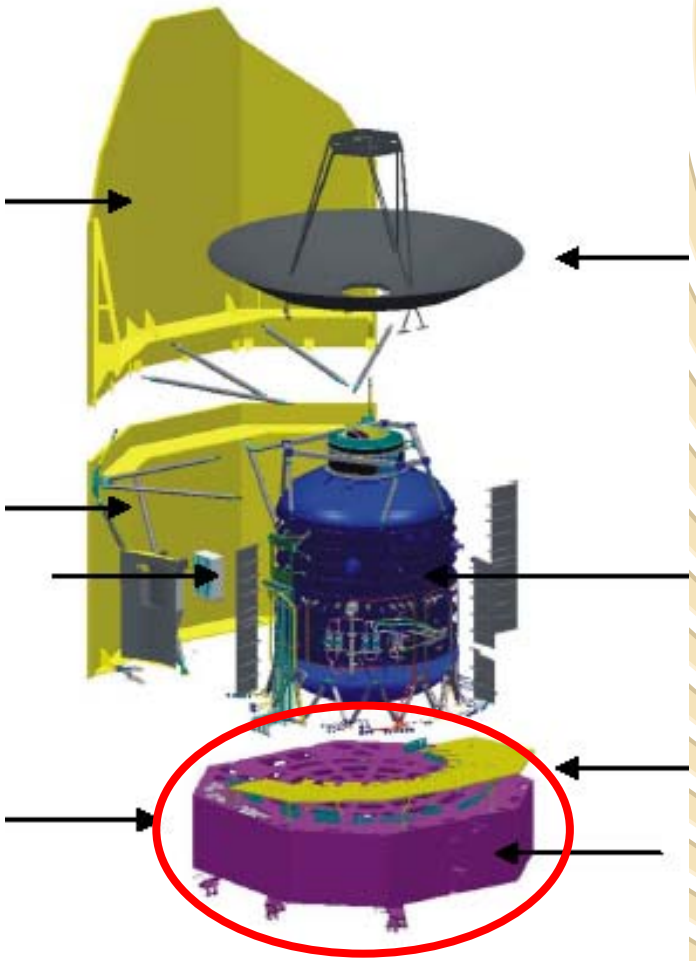
Herschel payload module

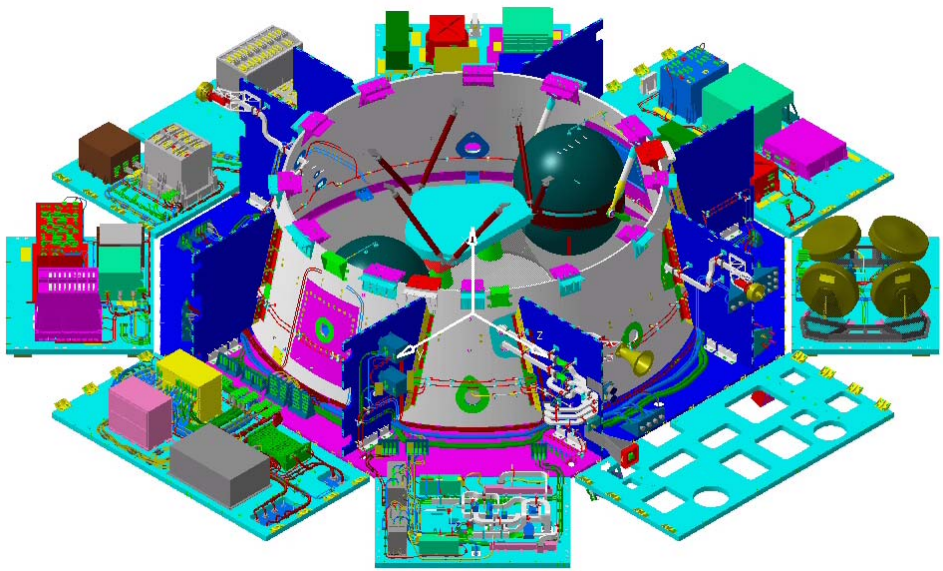
HERSCHEL SPACE OBSERVATORY

Herschel spacecraft



Herschel service module





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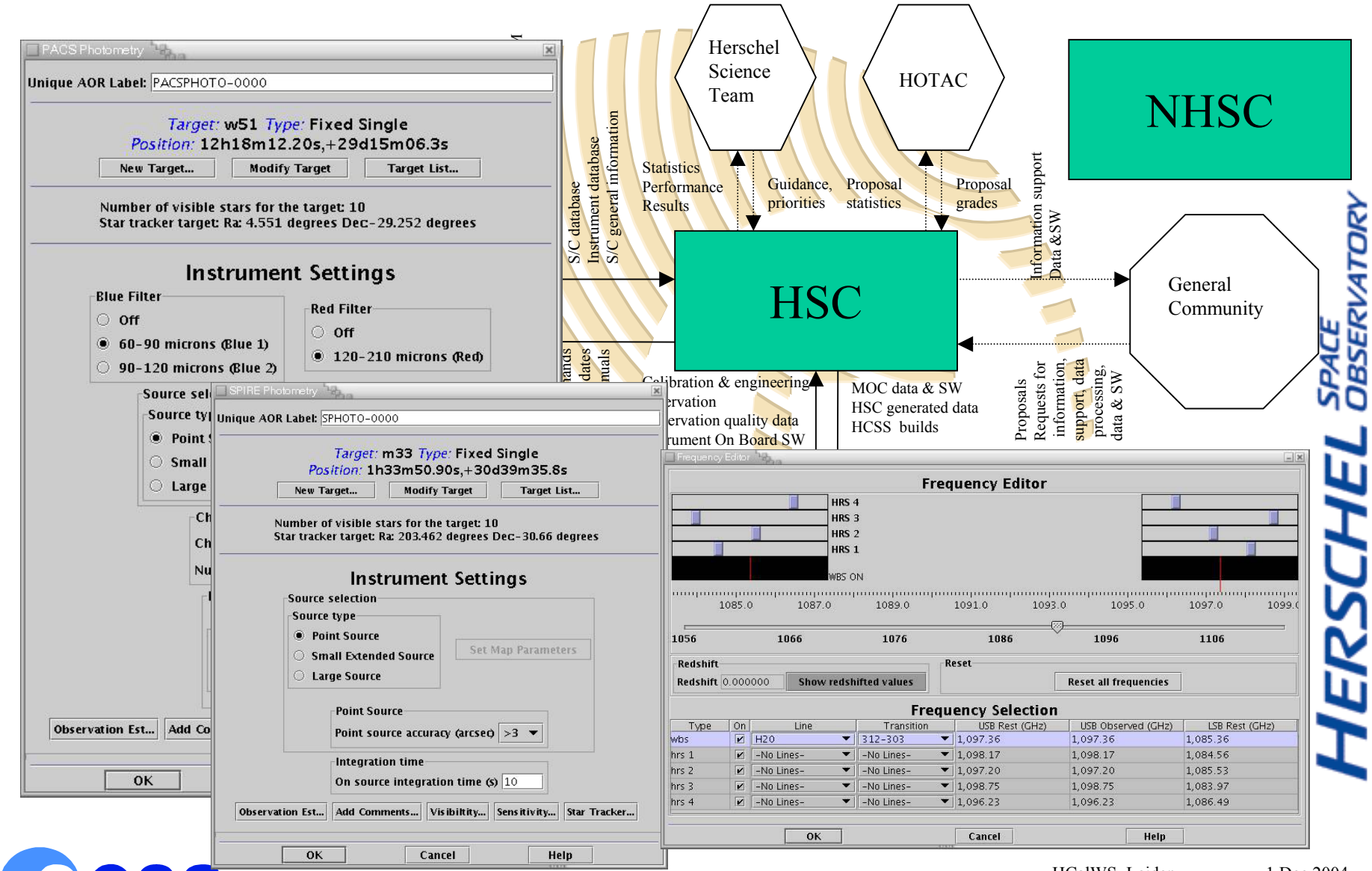
Ground segment



Status & schedule

• Science Payload AO	September 1997
• Invitation to Tender issue	September 2000
• Kick-off of industry	April 2001
• System Requirements Review	June - October 2001
• PDR Satellite	October - December 2002
• Mission level PDR	February 2003
• CDR Herschel Payload Module	May - July 2004
• CDR Satellite	August - October 2004
• Mission level CDR	January - March 2005
• Launch	3 August 2007

'Best working schedule' constructed by industry – based on ESA inputs for telescope and instruments – for Satellite CDR, to be technically and contractually formalized to become 'nominal schedule' by Xmas 2004.

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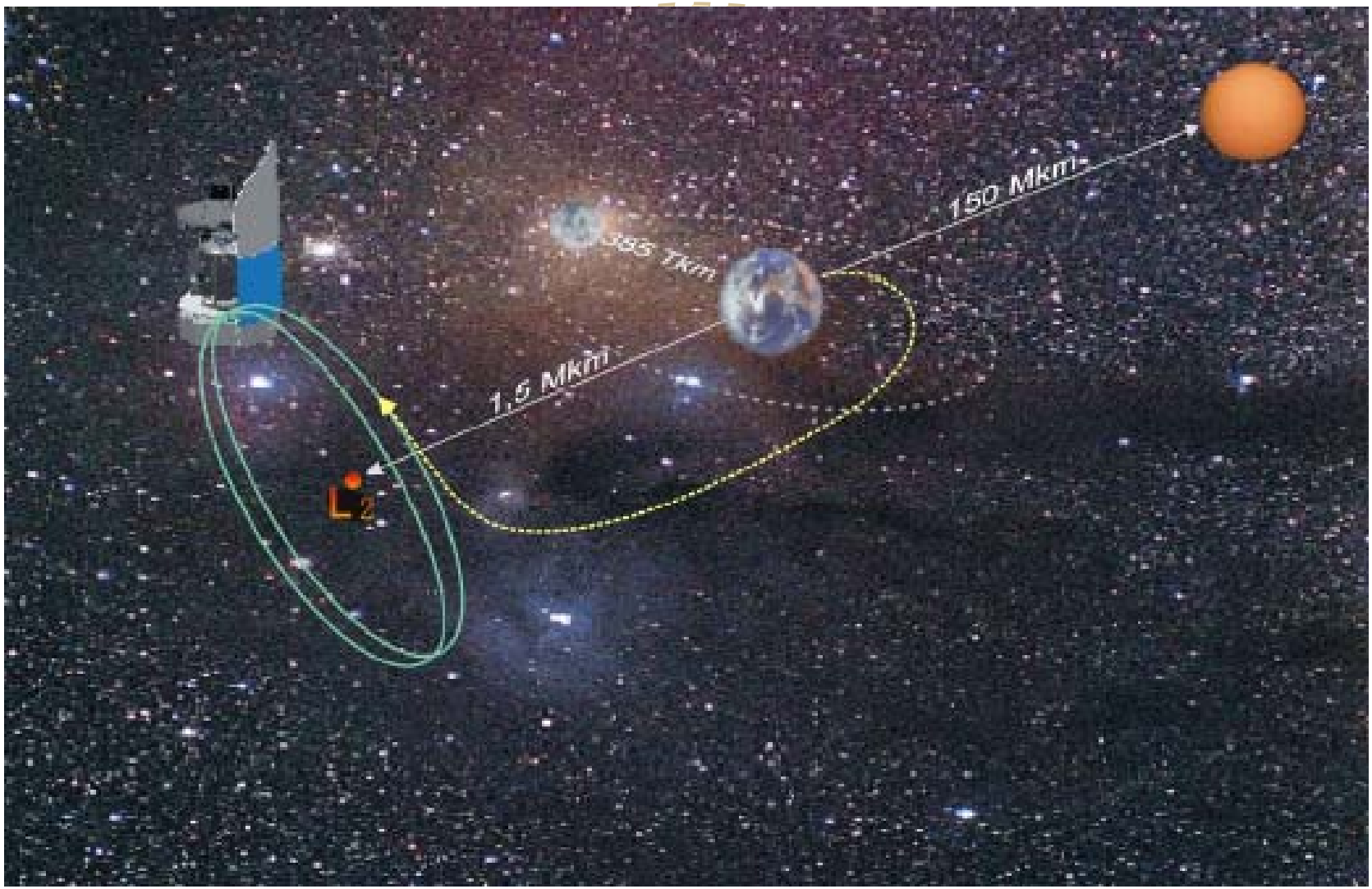
Launch and orbit



HERSCHEL SPACE OBSERVATORY

Herschel mission phases

- **Launch and early operations (LEOP)**
- **Commissioning and performance verification (SC + payload)**
- **Science demonstration phase**
- **Routine science operations phase (36 months)**
  - **Guaranteed time programmes – GT (32%)**
    - open for GT holders only
  - **Open time programmes – OT (68%)**
    - including discretionary time and targets of opportunity
    - open for all – including GT holders
- **Three 'Call for proposals' (AO) cycles are foreseen**
  - one Call for 'Key Projects' programmes only (GT and OT)
  - two Calls for regular programmes (GT and OT)
- **Each AO will be divided in two parts**
  - GT awarded first
  - OT awarded after GT in same cycle

HERSCHEL SPACE OBSERVATORY

Herschel observing - generalities

- **Top level considerations**
  - overall goal is to maximise science return and impact
  - Herschel is a strictly consumables limited mission
- **Herschel to a certain degree its own pathfinder**
  - follow-up observations must be feasible (data reduction, scheduling)
  - concept of 'Key Project' programmes upfront
- **Three years of 'routine science operations' available**
  - LEOP, commissioning, PV, science demonstration, initial 6 months
  - followed by 3 years of 'routine science operations'
  - approx 1000 days / 20000 hours schedulable time available
- **Data rights**
  - first year of routine science operations 12 months - then 6 months
  - non-routine phase observations - none (but overlap mechanism)
- **All observing proposals – including for GT programmes – will be assessed by the Herschel Observing Time Allocation Committee for scientific merit**

HERSCHEL SPACE OBSERVATORY

Herschel 'Key Projects'

- **Foreseen to be important upfront (SMP/instrument AO)**
  - introduced to ensure that 'unusually large' observing programmes can be proposed, selected, and observed
  - need 'pre-identified' due to the nature of the foreseen science objectives and the lack of 'precursor' (IRAS-type) mission
- **Definition of a 'Key Project' programme - it must**
  - exploit unique Herschel capabilities address (an) important scientific issue(s) in a comprehensive manner
  - require a large amount of observing time to be used in a uniform and coherent fashion
  - produce a resulting well characterised dataset of high archival value
- **Data reduction**
  - it is recognised that there is a legitimate science return interest that
    - the data generated by the observations are timely reduced, and
    - the data products and tools are made public
  - therefore 'Key Project' consortia must demonstrate commitment and ability to perform data reduction, and must make data products and tools publicly available at the end of the proprietary time period

HERSCHEL SPACE OBSERVATORY

‘Rules of the road’

- **SMP**
  - issued 1997
  - SPC approved
  - basis for AO
- **Observation Programmes document**
  - elaborating on SMP
  - AWG approved
  - issued 2004
- **Available on web**
  - ‘community info’
- **Basis for updated SMP**
  - to come

Timeline exercise – (1)

- **Logic: Issue 'Call for Proposals' (AOs) as late as possible**
  - for pure scientific reasons
  - and for performance knowledge reasons
  - but early enough for observers to prepare
  - and to have observations available for scheduling
  - and enable community support staff 'training on the job'

- **AO + 0 mths: Issue AO for 'Cycle KP' proposals**
- AO + 3 mths: Submission deadline for GT KP proposals
- AO + 6 mths: Selection & announcement of GT KP programmes
- AO + 9 mths: Submission deadline for OT KP proposals
- AO + 12 mths: Selection & announcement of OT KP programmes

- **AO + 12 mths: Issue AO for 'Cycle 1 GT' proposals**
- AO + 15 mths: Submission deadline for GT1 proposals
- AO + 18 mths: Selection & announcement of GT1 programmes

- **L: Launch followed by in-orbit operations**

Timeline exercise – (2)

- **L:** **Launch followed by and in-orbit operations**
- **L + 5 mths:** **Science demonstration workshop & optimisation of observing programmes**
- **L + 6 mths:** **Issue AO for 'OT1' proposals**
- L + 9 mths: Submission deadline for OT1 proposals
- L + 12 mths: Selection & announcement of OT1 programmes
- **L + 18 mths:** **Issue AO for 'Cycle 2' proposals**
- L + 21 mths: Submission deadline for GT2proposals
- L + 24 mths: Selection & announcement of GT2 programmes
- L + 27 mths: Submission deadline for OT2 proposals
- L + 30 mths: Selection & announcement of OT2 programmes
- **L + 42 mths:** **End of nominal mission**

- **Initial AO foreseen 'early 2006'**
- **Subject to optimisation!**

HERSCHEL SPACE OBSERVATORY

Herschel observatory capabilities

- **Photometry - imaging, 6 broad bands in 75-500 μm range**
  - **PACS** - simultaneous 2 colour fully-sampled (0.5Fλ) imaging with FOV 1.75x3.5 arcmin with R~2.5 centred at 75/110 and 170 μm
  - **SPIRE** - simultaneous 3 colour 2Fλ imaging with FOV 4x8 arcmin with R~3 centred at 250, 363, and 517 μm
  - for larger fields 'on-the-fly' mapping, mosaicing
  - sensitivity is somewhat wavelength and observing mode dependant, very roughly for point sources 1mJy - 1σ - 1 hour; for mapping confusion limit is important

- **Spectroscopy - in 57-670 um range, varying R in 20-10^7 range**
  - **PACS** - 5x5 spatial x 16 spectral pixels, FOV 0.8 arcmin, R~1500, λ ~57-210 μm
  - **SPIRE** - FTS spectrometer, R ~20-100+, FOV 2.6 arcmin, λ ~200-670 μm
  - **HIFI** - heterodyne spectroscopy with R up to 10^7, λ ~157-212 and 240-625 μm, 2 orthogonal polarisations, 4000 spectral channels per polarisation, single pixel on the sky, mapping by 'on-the-fly' or mosaicing observations

- **Very different instrument technologies and performance limitations!**

Other talks !!

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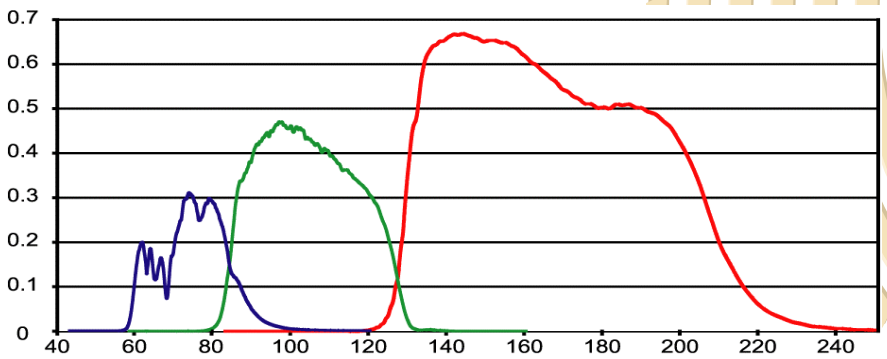
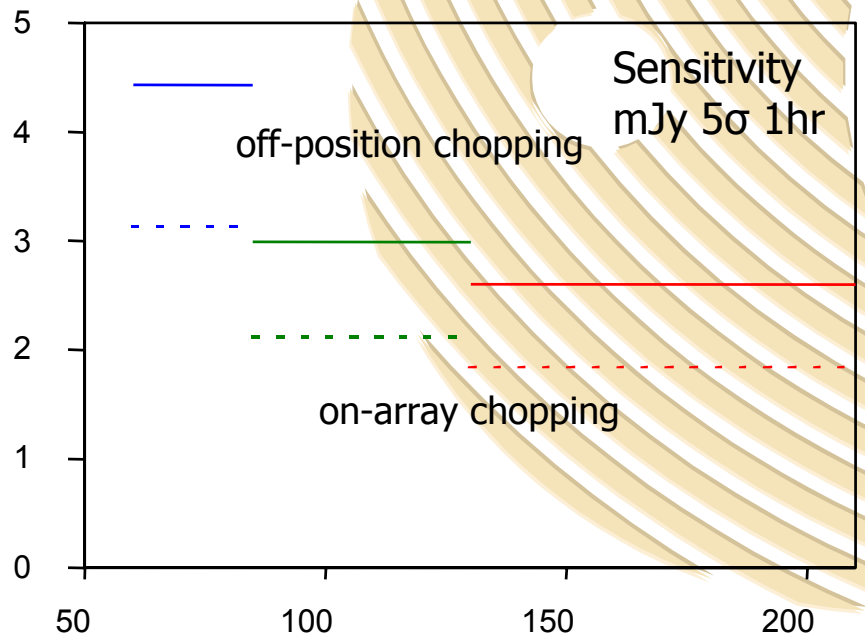
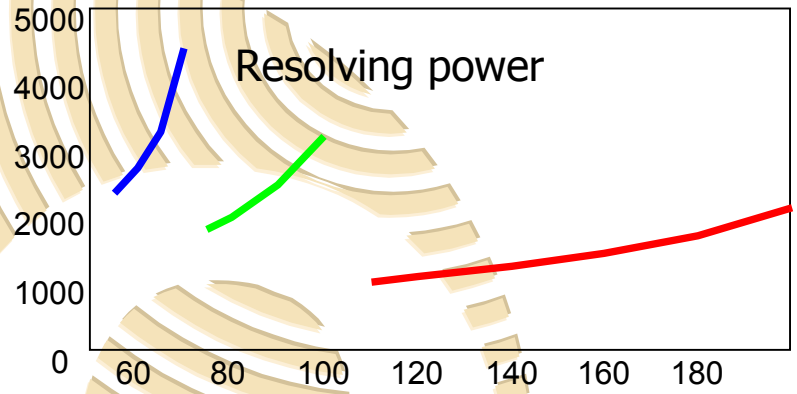
PACS predicted performance

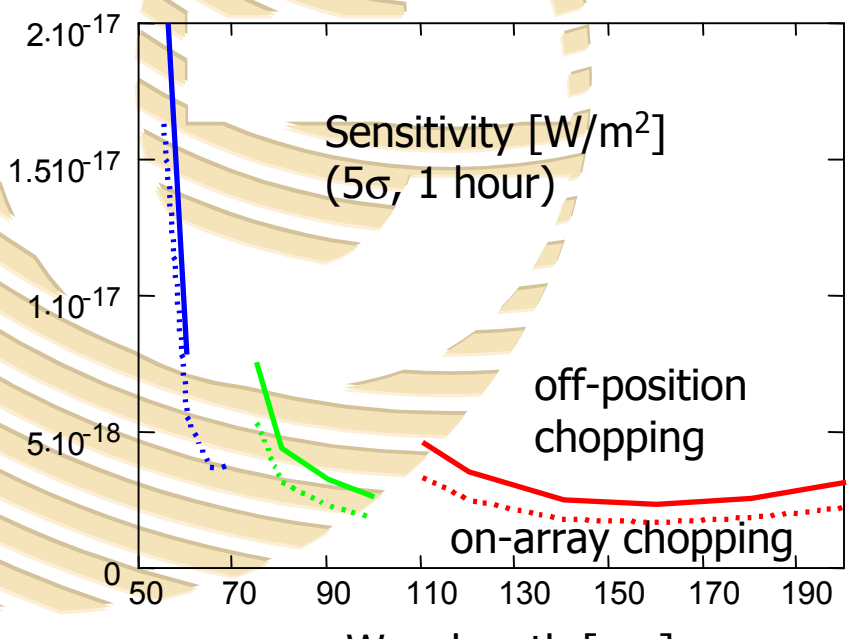
Photometry





Spectroscopy





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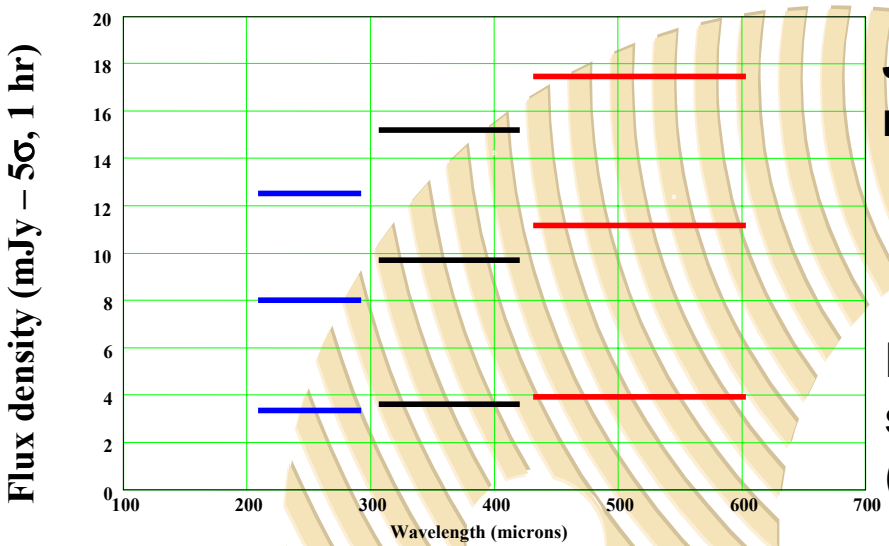
SPIRE predicted performance

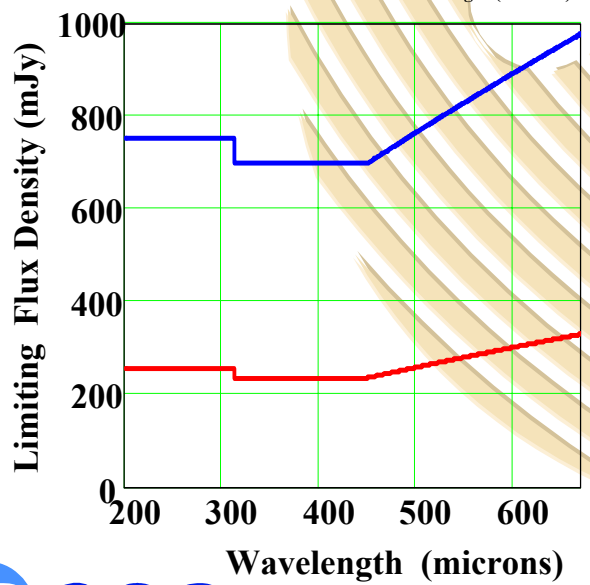


Jiggle map

Scan map

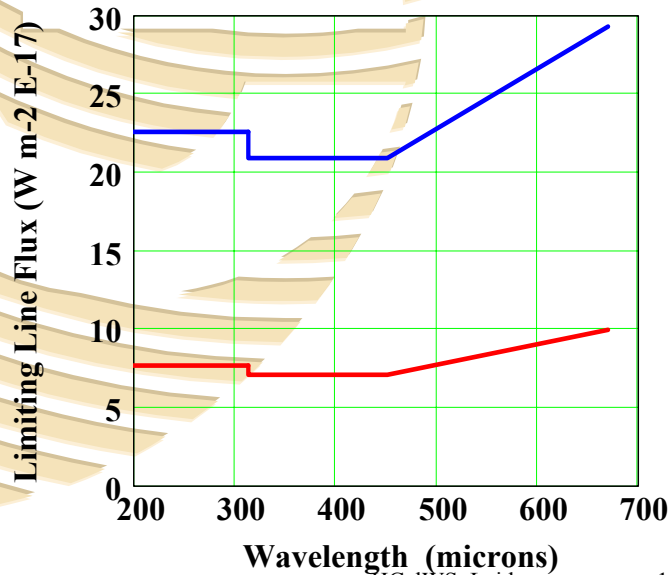
Point source (7-point)

- Photometry
- Spectrophotometry
- Line spectroscopy
- at 5σ, 1 hr



Fully-sampled map

Point source/ sparse map



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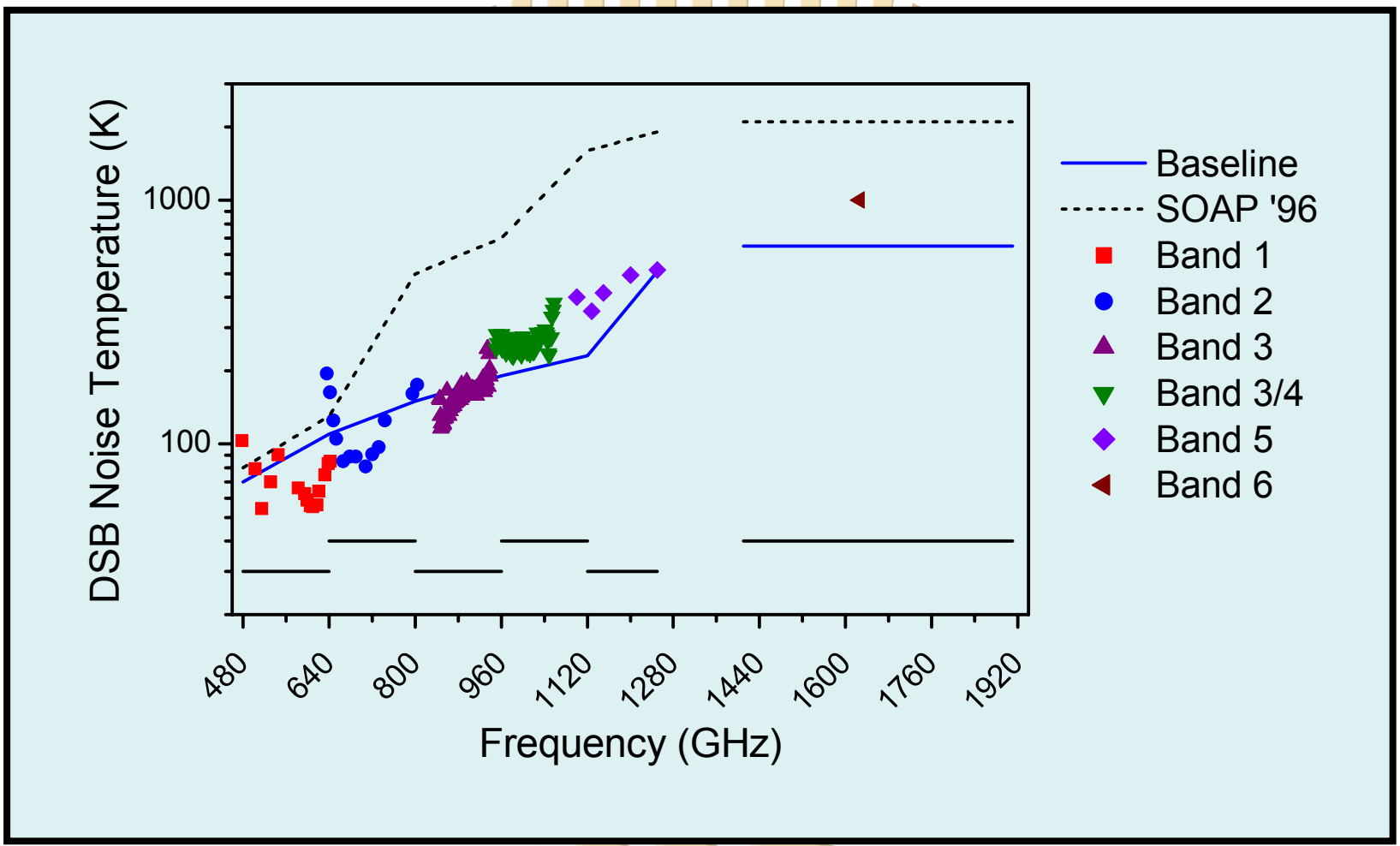
HIFI mixer performance



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Early mission phases

- **Launch and early operations (LEOP)**
  - nominally ~few weeks, but
  - telescope kept warm during s/c cooldown
  - cryo-cover opening (first light!) ~4-6 weeks after launch
- **Commissioning and performance verification (SC + payload)**
  - nominally ~2 months, but
  - PV plans not yet in place
- **Science demonstration phase**
  - convince us we know how to operate the observatory
  - demonstrate the capabilities of the observatory
  - convince ourselves we can achieve expected objectives
  - generate 'pretty pictures' – and 'pretty spectra'!?
  - **need to have calibration & data processing in place!**
- **Begin routine science operations phase (36 months)**
  - not later than 6 months after launch
  - initially Key Progs (GT & OT) and 'regular' GT progs

HERSCHEL SPACE OBSERVATORY

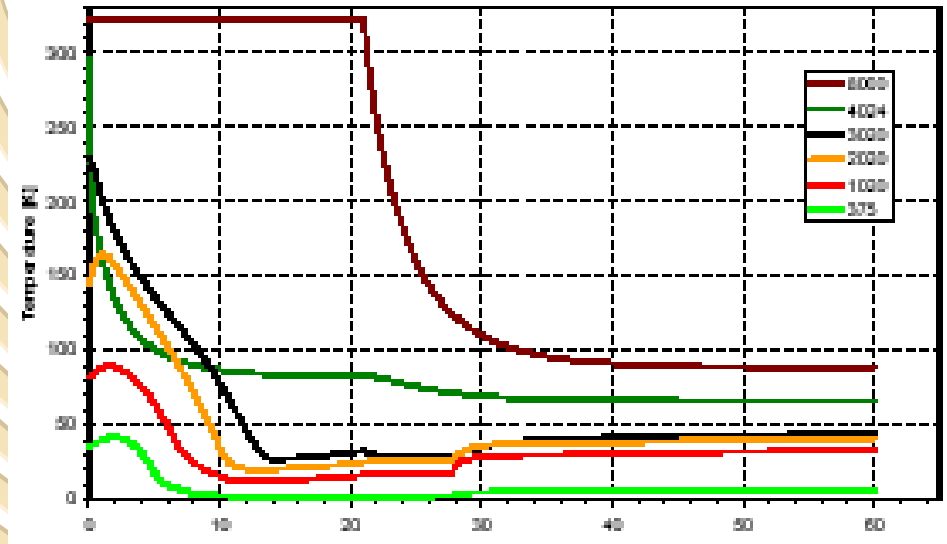
Calibration issues

- **Calibration is continuous activity**
  - ILT leading into PV and future improvement
    - by nature ‘only instrument’ measurements at ILT
    - adding ‘observatory’ and ‘environment’ in PV
  - both ground and in-orbit calibration time is limited
    - ground activities resource and schedule limited
    - in-orbit calibration time allocation helium limited
  - in particular the PV phase will be crucial
    - need good preparations – and ability to react
    - need ‘instrument model’ for interpretation – starting now!
- **Calibration ‘physical’ constraints**
  - SAA => [sky visibility limitations](t)
    - but never within 60 deg away from the sun
  - cryo-cover opening (first light!) ~4-6 weeks after launch
  - telescope still slowly cooling down
    - towards unknown operating temperature

Telescope initial cooldown

from HCalSG mtg#3, 7 March 2003

- **Telescope launched warm**
- **Kept at 313 K for 2-3 weeks**
- **Avoid trapping outgassed contaminants**
- **Cooling down is slow(ish)**
  - long(ish) time constant
  - four e-folding times > 98%
  - not completely consistent picture here => sort out!
- **Cryocover opening**
  - 4-8 weeks post launch (TBC)
- **Start observing!**



ASED spacecraft PDR doc
=> time const ~ 5 days

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- **Telescope launched warm**
- **Kept at 313 K for 2-3 weeks**
- **Avoid trapping outgassed contaminants**
- **Cooling down is slow(ish)**
  - long(ish) time constant
  - four e-folding times > 98%
  - time const temperature dependent
- **Cryocover opening**
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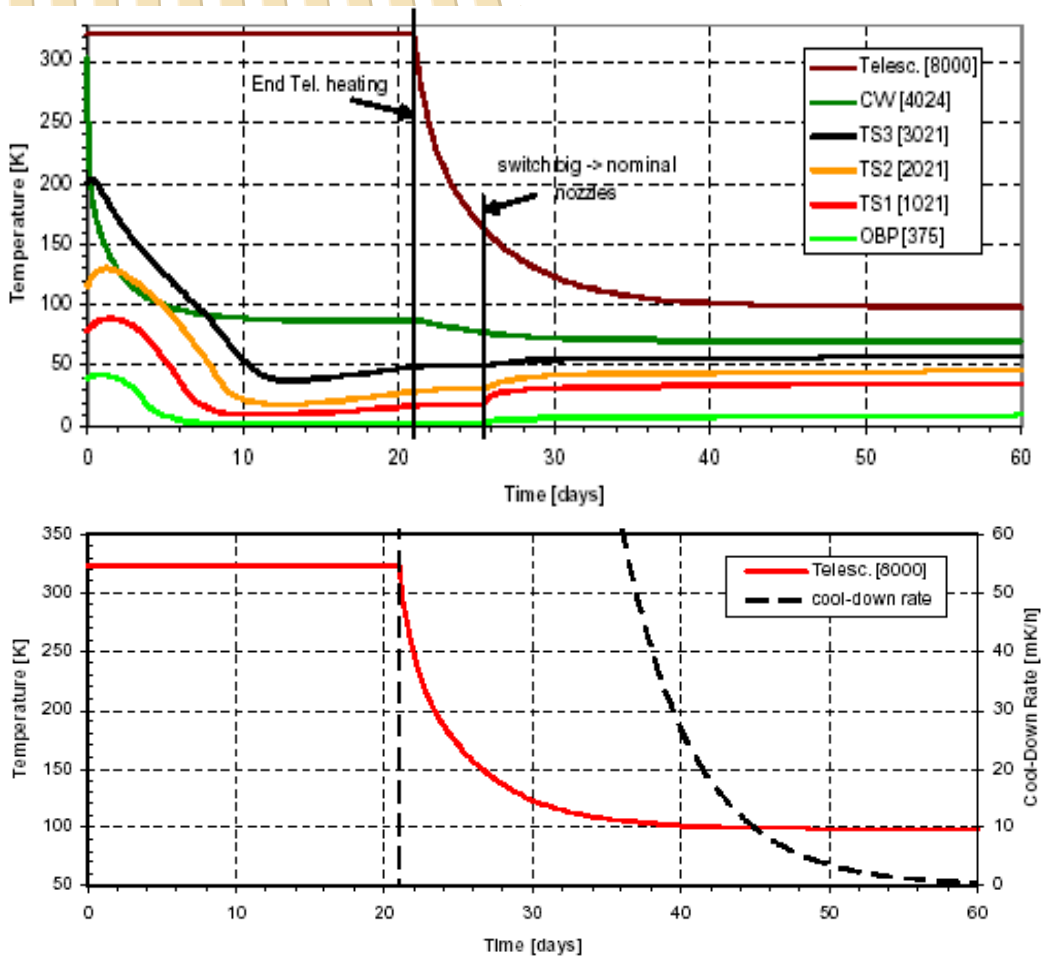
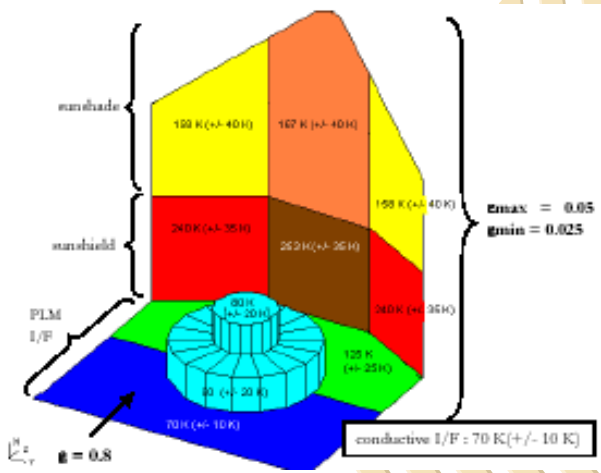
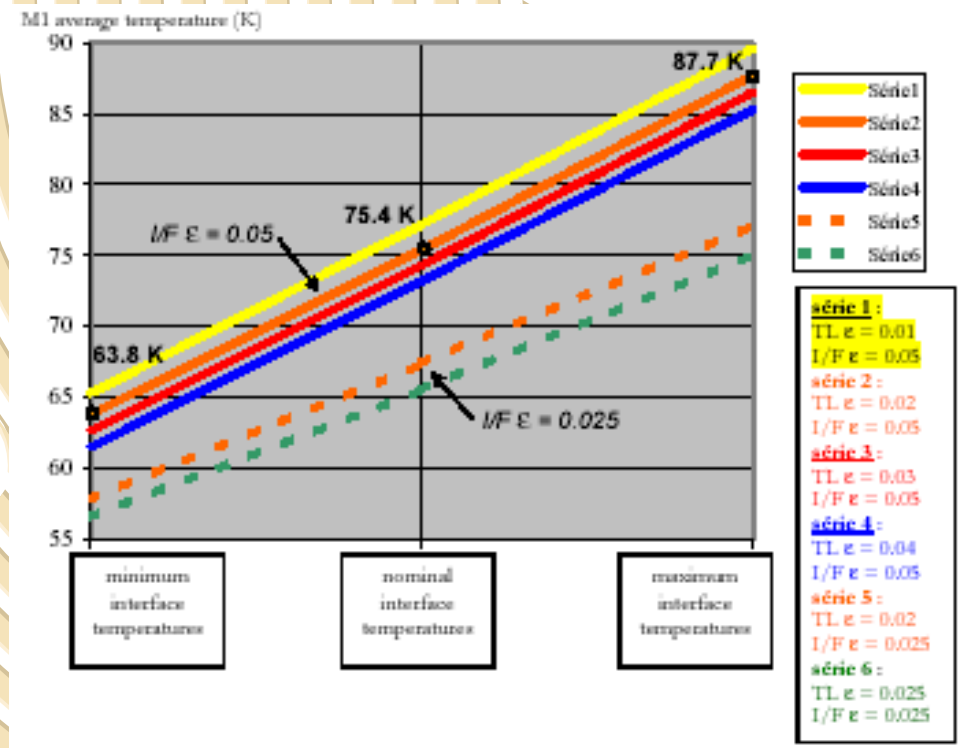


HERSCHEL SPACE OBSERVATORY

Predicted M1 average temperature

from HCalSG mtg#3, 7 March 2003





The telescope temperature depends critically on the temperatures and emissivities of the thermal interfaces; the sunshade/shield and CVV topside

=> Accurate knowledge before in-orbit operation questionable!

HERSCHEL SPACE OBSERVATORY

Predicted M1 average temperature

- and gradients

"specified interface", as specified in AD1

"system" interfaces, as a realistic case, coming from the last S/L predictions.

		M1			M2	Gradient M1	Grad. M1/M2	*average IF cond. Temp.*
		Min	**Average**	Max	**Average**			
SPEC I/F	Hot case	89.6 K	**89.8 K**	90.0 K	**87.9 K**	0.43 K	1.9 K	*80 K*
	Cold case	61.4 K	**61.5 K**	61.5 K	**61.1 K**	0.08 K	0.4 K	*60 K*
SYSTEM I/F	Max hot case	91.0 K	**91.2 K**	91.4 K	**89.0 K**	0.44 K	1.2 K	*92.3 K*
	Hot case	87.6 K	**87.9 K**	88.1 K	**86.0 K**	0.44 K	1.9 K	*85.3 K*
	Cold case	71.7 K	**71.8 K**	71.9 K	**70.8 K**	0.14 K	1.0 K	*77 K*
	Min cold case	67.2 K	**67.3 K**	67.3 K	**66.5 K**	0.12 K	0.8 K	*70 K*

The telescope temperature depends critically on the temperatures and emissivities of the thermal interfaces; the sunshade/shield and CVV topside

=> Accurate knowledge before in-orbit operation questionable!

HERSCHEL SPACE OBSERVATORY


• Herschel is happening now!
• ‘Key Progs’ AO foreseen early 2006!
• We are making it happen!
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