The SPICA Telescope Assembly

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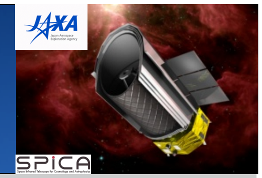


1. BACKGROUND

Understanding the origins and evolution of galaxies, stars and planets are fundamental goals in astronomy. The ISO, Spitzer and AKARI missions have each demonstrated the power of the MIR/FIR in tracing the physical processes that shape galaxies, and drive star and planet formation, all processes which take place in regions typically obscured by dust. Both instruments and telescopes operating in the MIR/FIR need to be cooled, and this has limited aperture sizes in previous missions to <1m.

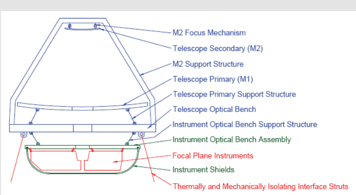
Herschel, the recently launched ESA mission, is already revolutionising our FIR view with a 3m-class telescope at 80K. With its unprecedented sensitivity, the JAXA-led SPICA mission will make the next leap: the combination of a telescope temperature of < 6K and a new generation of very sensitive detectors will enable the 3m-class SPICA to achieve sky-limited sensitivity over the 5-210μm wavelength range for the first time.

Achieving the scientific objectives of the SPICA mission is critically dependent on the specification and performance of the telescope: telescope operating temperature, stray-light levels, image quality as well as the surface cleanliness of the telescope mirrors each have a major impact on the performance of the SPICA instruments.

2. THE SPICA TELESCOPE ASSEMBY (STA)

ESA is a junior partner in the SPICA mission. The major part of the proposed ESA contribution to SPICA is the cryogenic SPICA telescope assembly (STA), to be procured from European Industry. Through its contribution to Herschel, European Industry has significant experience and expertise in the design and manufacture of lightweight, 3m-class cryogenic ceramic telescopes. The STA comprises:

- The primary (M1) and secondary (M2) mirrors
- The M2 support structure and refocusing mechanism
- Internal telescope baffle structures
- The telescope optical bench



A schematic of the SPICA Scientific Instrument Assembly. ESA-provided parts are highlighted in blue

3. STUDIES OF THE STA : 2008-09

The STA was the subject of detailed assessment studies by ESA and by Industry (EADS Astrium and Thales Alenia Space (TAS-F)) during 2008-09. The main objectives of the study were:

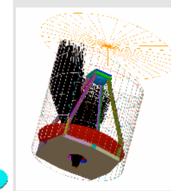
- To define the science requirements for the STA, providing a flow-down to the technical requirements (ESA)
- To consolidate the requirements (Industry)
- To further define the interfaces between the STA and elements of the mission provided by ISAS-JAXA (ESA, Industry, ISAS-JAXA)
- To identify a baseline STA design that meets all requirements and is technically feasible (Industry)
- To determine a development plan including a manufacturing and AIV/AIT schedule (Industry)

Summary of the Original SPICA Telescope Assembly requirements	
Optical design:	Ritchey Chretien, axi-symmetric, Effective Focal length 20m, M1 diameter 3.5m
Operating temperature:	Nominal < 6K, operating range 4.5 – 10K
Wavelength range:	5-210 μm (goal 3.5μm – 210)
Collecting aperture:	Maximum allowed by the HII-B fairing – 3.5m
Total obscuration:	< 12.5% on-axis (goal <10%)
Total transmission:	>90% at 5μm; >95% at 15μm; >99% at 110μm
Image quality:	Diffraction-limited at 5μm over FoV of 5 arcmin (radius)
Field of View (FoV):	>12 arcmin (unvignetted)
Launch Environment:	JAXA launcher H-IIB, warm launch
STA mass allocation:	<700 kg (including margins, excluding mass of instrument optical bench
Stray-light rejection:	Total background from out-of-field stray-light sources (artificial and natural) <20% of in-field background (zodiacal light and self-emission from the telescope).
Lifetime:	>5 yr in orbit (and >5yr on the ground)
Functional requirements:	M2 refocusing at nominal operating temperature In-flight decontamination capability

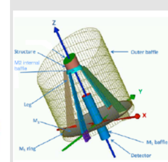
Table 1: Summary of the original top-level requirements of the STA at the start of Industrial study (2008-09)

4. OUTCOME OF STUDIES

- Both industries put forward an all-ceramic, light-weighted design for the STA based on an axi-symmetric, Ritchey Chretien configuration that was compliant with almost all requirements derived from the science goals of the mission. Manufacture from SiC100 and HBCesic was proposed by EADS Astrium and TAS-F respectively
- Placing the aperture stop on M2 was recommended to optimise stray-light rejection. In addition, a cold stop will be required by FIR instrument(s) in order to meet stray-light requirements
- The polishing time for M1 was around 2 years, and this drove the STA delivery schedule
- The thermal behaviour of the STA was dominated by external boundary conditions imposed by spacecraft, in particular by the thermal shields, the cooling power of the 4.5K coolers and heat conduction through the supporting truss. The total heat load exceeded the nominal allocation, but was still within the expected performance of the coolers.



Overviews of the proposed STA designs resulting from the Industrial Studies of 2008-2009: Top: EADS Astrium; Bottom: Thales Alenia Space



5. CURRENT STATUS OF THE STA

In 2010 a decision was taken by ISAS-JAXA to change the SPICA launcher from the H-IIB to the smaller H-IIA, with a change also to the smaller, shorter 5S fairing. The principle implication of this change is a reduction in diameter of M1.

An internal study has been made by ESA to determine the impacts of the rescope on optical design parameters of the STA, and to establish a new baseline model (Section 6). Detailed studies by teams of Japanese and European scientists confirm that the new baseline meets the SPICA mission requirements.

The new baseline is the subject of 6-month studies by EADS Astrium and TAS-F, during which Industry will prepare for formal tendering for the flight telescope procurement. The studies include:

- Optimisation and finalising of the telescope configuration, including its optical, thermal and mechanical design and interfaces with the spacecraft
- Updating of the design and development of AIV/AIT plans in line with the needs of the STA and the spacecraft
- Establishing a detailed schedule for the STA including manufacture, testing and delivery

6. OPTICAL DESIGN PARAMETERS OF THE BASELINE STA (NOV 2010)

Parameter	Value (in mm unless specified)
Design Type	Ritchey-Chretien
Effective focal length	16200
Full FOV radius	+/- 15 arcmin
F number	5.4 (TBC)
M1 Physical Diameter	3200
M1 Clear Aperture Diameter (CAD)	3106 (TBC)
Telescope Entrance Pupil Diameter (EPD) paraxial	3000 (TBC)
M1 to M2 spacing	2511 (TBC)
M1 polishing time [Herschel]	24 [9.5] months
Aperture stop location	On M2
Aperture stop diameter (optical = physical)	< 650 (TBC)
Back Focal Length (BFL)	898
Image Surface radius of Curvature	> 708 (parabolic)
Wave Front Error (WFE) (at 5 arc min)	< 135 nm (TBC)
WFE (full field 15 arcmin)	< 1208 nm (TBC)
Diffraction limit [Herschel]	5 [80] microns

7. SUMMARY

Considerable expertise exists within European Industry in the design, manufacture and testing of light-weight ceramic optics, notably demonstrated through the 3.5m Herschel cryogenic telescope assembly. SPICA will build on this significant heritage.

Assessment by European Industry during the 2008-09 telescope studies concluded that the proposed design for the STA was feasible, and met the requirements. A technical assessment by ESA of the new baseline design imposed by the change of launcher showed a small impact on optical performance, but that the design and manufacture remained feasible. Studies with Industry have been started to optimise and finalise the telescope design and configuration.

A detailed assessment by independent teams of Japanese and European scientists have concluded that the new baseline design (3.2m) meets the SPICA mission requirements:
-- SPICA is a cutting-edge MIR/FIR mission that will answer many key questions in modern astrophysics --