U.S. Participation in the JAXA-led SPICA Mission: The Background-Limited Infrared-Submillimeter Spectrograph (BLISS)

Responses to Astro2010 PPP Questions*

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Overview

We address the questions posed by the Astro 2010 Program Prioritization Panel:

1. How much time will be allotted for US scientists on the SPICA mission?
2. What is the main goal for the Japanese program on SPICA?
3. What is the timeline for a decision on SPICA?
4. What is SPICA's proposed organizational structure? What is the proposed US/Japanese interface for SPICA?
5. How much observing time is required to achieve the BLISS science goals? How will this be allocated within the SPICA mission?
6. How much access, if any, will US astronomers be provided to the other SPICA instruments?
7. How much access, if any, will Japanese astronomers be provided to BLISS?

Most of these questions are best answered directly by the SPICA leadership, and have been forwarded to them. Much of what follows comes directly from the SPICA PI Takao Nakagawa and focal-plane scientist Hideo Matsuhara with only minor editing for english translation purposes.

*original submission available at `http://www.submm.caltech.edu/BLISS/decadal/BLISS_decadal_final.pdf`

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1 How much time will be allocated for US scientists on SPICA?

The answer will depend of course on whether the US is a member country or not. The time allocations are now being negotiated as the mission is being defined. We *(Japanese team)* are now preparing the "SPICA research concept" for the JAXA System Requirement Review, and are presenting a tentative time allocation plan of:

- Engineering time: perhaps $\sim 10\%$
- Director's discrectionary time (including target-of-opportunity observations): perhaps $\sim$5%
- Guaranteed time for SPICA mission team: $\sim$25%, to be allocated to partners based on of level of contribution. This will include instrument teams, science working group, and mission scientists.
- Open time for member countries: $\sim$40%
  - including Legacy Programs
  - only one TAC, but each member country should have its own allocated time
- Open time for general international community: $\sim$20%.

We emphasize that the above numbers are tentative, and will be updated pending further discussion among the member countries. We *(US team)* envision that a contribution of an instrument such as BLISS plus other supporting activities could represent 10–20% of the total SPICA effort.

2 What is the main goal for the Japanese program on SPICA?

We *(Japanese team)* are not partitioning the science programs and their goals to the member countries, although some of the objectives come from the Japanese-led instrument teams. All member countries will have opportunities to conduct arbitrary science programs with any focal-plane instrument. We intend for SPICA will be a great-observatory-style mission. Our vision is that the international SPICA partnership will use the observatory to study fundamental processes on all scales in our Universe: from our Solar system to our Galaxy to distant galaxies and their large-scale structure. We categorize the scientific objectives into three major themes:

1. The Birth and Evolution of Galaxies.
2. The Formation and Evolution of Dust in the Universe.
3. A Thorough Understanding of Planetary System Formation.

The details of the above scientific objectives, targets, the success criteria, and the mission requirements are described in the SPICA Mission Requirement Document (MRD). The draft MRD is open to the public* (although the success criteria / mission requirements are only

*see `http://home.hiroshima-u.ac.jp/hasc/koutenren/stf/MRD_objective_090520.pdf` written in Japanese). For the purposes of the Astro2010 survey, we outline our goals in these main themes in Appendix A at the end of this document. Accomplishing these goals requires a large cryogenic telescope with imaging and spectroscopy throughout the mid- and far-IR with sensitivity approaching the natural background limits.

3 What is the timeline for a decision on SPICA?

(*paraphrased from correspondence with Takao Nakagawa*)
The schedule for SPICA is shown in Figure 1. The go / no-go reviews for SPICA in Japan are the System Definition Review (SDR—the technical review) scheduled for early CY 2011, and the Project Approval Review (for management / cost) will occur at most 6 months later. After these reviews, all technical specifications and budgetary responsibilities should be fixed. Of course, the major contributors will need to be working together closely in advance of this as the project evolves. Specifically there are two key decision points. First, the system requirements review (SRR) at JAXA is this fall (Fall, 2009) in which the observatory system-level resources and requirements are to be fixed (for example, the total mass and power for the complete focal-plane instrument suite in aggregate). For this SRR, input is requested from each potential instrument provider describing the instrument concept and indicating the prospect for commitment from the funding agency. The focal-plane instrument (FPI) selection will occur very shortly thereafter, in late 2009 to early 2010. While we are exited with the prospect of sensitive spectroscopy with BLISS, the resources (mass, power, cooling capability) for the focal-plane instruments are limited, so some optimization is required. The FPI selection will be made based on scientific merits, technical feasibility, compatibility with the other instruments and the system requirements, and the programmatic / funding situation.

We *(US team)* have been working with the Japanese team to specify the interfaces for BLISS, and are refining our design so that it will fit within the resource availability (especially cryogenic mass). NASA electing to participate in SPICA in a manner consistent with the JAXA schedule is important, and it is our hope that a positive recommendation from Astro2010 will enable NASA to initiate steps for formal US participation as soon as possible.

4 What is SPICA's proposed organizational structure? What is the proposed US/Japanese interface for SPICA?

We *(Japanese team)* envision three principal bodies which will govern the mission:

- **The SPICA Steering Committee** will be in charge of all final decisions concerning the SPICA project. It will consist of members from the space agencies and PIs of the instruments. The SPICA project manager will be the committee chair. This committee will likely include sub-committees to address specific aspects.

- **The Science Advisory Committee** will review activities and provide advice to the SPICA project from a scientific standpoint. It will consist of a broad range of international scientists representing key disciplines in astronomy. The SPICA project scientist will chair this committee.

- **The Joint Systems Engineering Team** will ensure clear and cogent interface definitions and anticipate system-level problems which will might arise. It will be made up of flight engineers with various backgrounds and representing the various member countries.

The organizational structure is represented graphically in Figure 2.

Regarding the interfaces, observatory-level systems engineering will be the responsibility of JAXA, and they will produce interface documents which will govern the interfaces. The details would be worked out through negotiations involving NASA and JAXA should NASA elect to participate in the mission. We *(US team)* have worked to design an instrument with straightforward interfaces which fit within the allocations for SPICA. The key technical interfaces for an instrument like BLISS will be:

- Mechanical and optical interfaces for the BLISS optical bench and the foreoptics in the 4 K instrument enclosure.
- Thermal interface with the facility 2 K cooler.
- Mechanical, electrical, and data interfaces for the warm electronics.
- Thermal and electrical interfaces along the facility cooling chain from the warm electronics box to the 2K thermal interface, to carefully heat sink and to eliminate electromagnetic interference (EMI), for the BLISS signal and magnetic cooler wiring harnesses.

5 How much observing time is required for the BLISS science goals? How will this be allocated within the SPICA mission?

Should NASA elect to participate in SPICA it would solicit instrument proposals. It would then be the responsibility of the selected PI along with his/her team to work with JAXA and NASA to develop the details related to observing time and its allocation. In the case of BLISS, we envision it as a facility instrument that would be open to anyone. The BLISS science case as written in the Astro2010 submission is meant to illustrate the capabilities of an optimized instrument on the cold telescope. Science goals are not quantified in terms of a detailed observing program, but we expect that over the lifetime of the mission, a wide variety of programs will be carried out with BLISS by guaranteed-time teams (both mission and instrument), as well as open-time programs (both legacy and general observer).

We do note that the extragalactic spectroscopy described in the BLISS Astro2010 submission could easily be accomplished in an instrument guaranteed time program. As Figure 3 shows, BLISS will obtain spectra of galaxies at cosmological distances (even to z$\sim$5) at a typical rate of 1 per hour, and much faster for low-redshift sources. A (strawman example) 1000-hour BLISS GTO program could thus easily obtain 500 complete far-IR spectra of galaxies spanning a wide range in redshift and luminosity. We remind the panel that very few if any of these z>1 galaxies observable with SPICA-BLISS in an hour will be accessible to the Herschel spectrometers given the sensitivity limitation of the warm telescope.

Again, since a NASA instrument such as BLISS would be available to all observers, it is likely that over the full mission, the majority of the total time used with the instrument would be via a wide range of other guaranteed and open time programs.

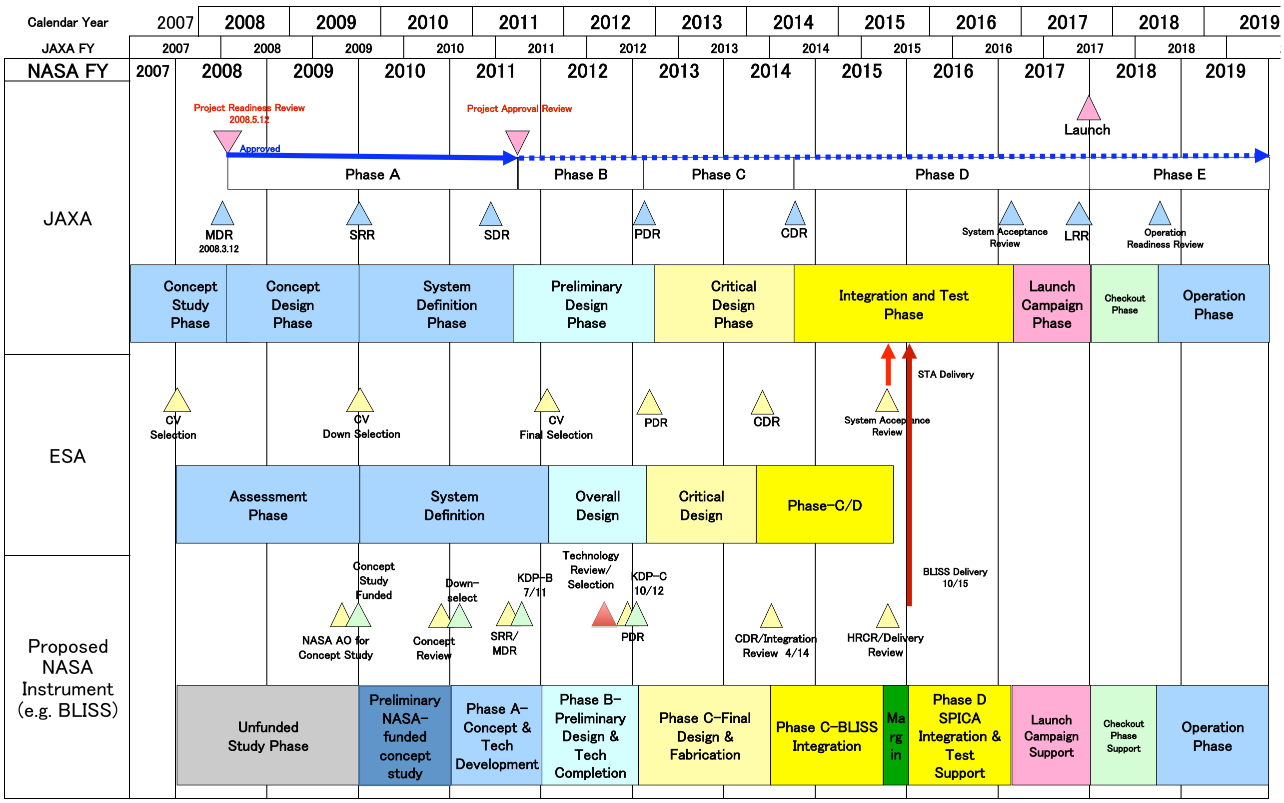

Figure 1: SPICA schedule (provided by mission PI Takao Nakagawa), showing key dates for JAXA and ESA. We have added our proposed schedule for BLISS. Note that the JAXA fiscal year is 6 months out of phase with the NASA fiscal year. Phase E extends for 5 years, to 2023.

6 How much, if any, will US astronomers be provided access to the other SPICA instruments?

US astronomers have full access to use any of other SPICA instruments for their research activities with SPICA. The fraction of total observing time available to the US depends on the level of participation in the SPICA project, as discussed in Question 1.

7 How much, if any, will Japanese astronomers be provided access to BLISS?

The vision is that any NASA-provided instrument will be one of the facility instruments for the mission, used in a manner similar to one of the Spitzer or Herschel instruments. There would be no limitations to its use—any scientist using SPICA would be welcome to use a NASA instrument as needed for their program.

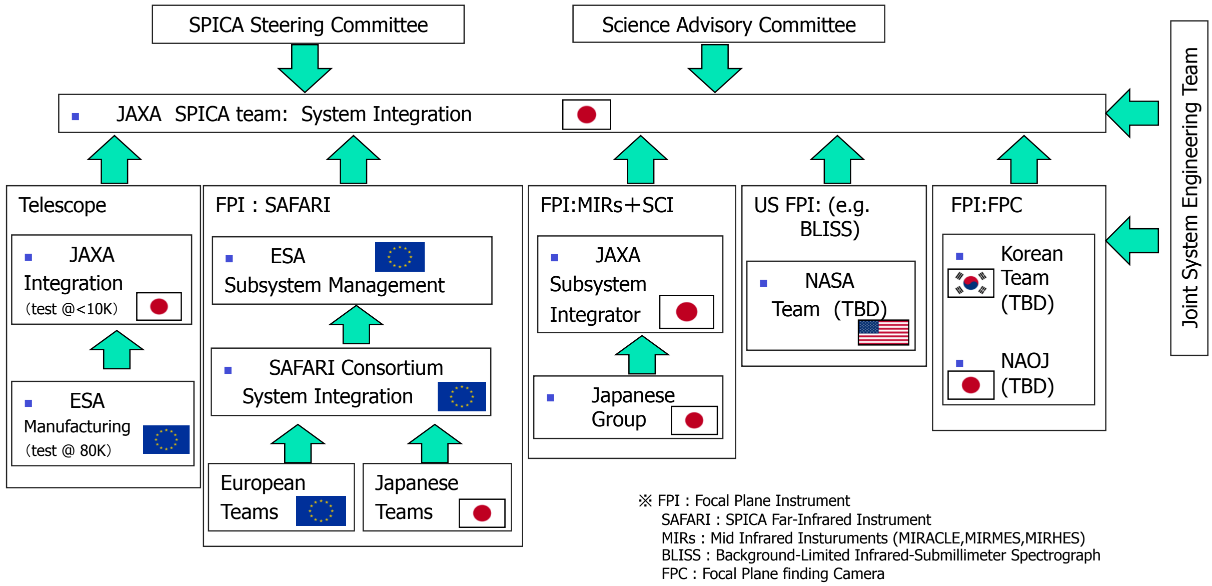

Figure 2: SPICA organizational structure, provided by mission PI Takao Nakagawa.

A Science Goals for the Japanese SPICA Program

A.1 The Birth and Evolution of Galaxies

1. We will search for redshifted (z>7) recombination transitions from low-metallicity objects ($Z < 10^{-4}$ solar) with mid-IR spectroscopy. We hope to discover and/or confirm the existence of population III objects through this technique. We will also investigate the formation of population III objects at later times (z>3) through their molecular hydrogen emission lines—the key cooling lines of primeval molecular clouds—using far-infrared spectroscopy.

2. We will resolve the cosmic far-infrared background light into individual far-infrared galaxies with spatial resolution at least 3 times greater than AKARI and sensitivity at least 2 orders of magnitude better than Herschel. After the removal of these individual galaxies, we will then study the far-infrared background fluctuations in an effort to reveal their origin through detailed analyses such as SED fitting to multi-wavelength images.

3. We will reveal the interstellar environments and dust emission characteristics of high-redshift galaxies out to z∼3 (z∼6 with BLISS) through their PAH features and atomic and molecular emission lines using broad-band mid- and far-IR spectroscopy. These observations will reveal the physical and chemical conditions of galaxies in the early universe (back to the first BY) with probes which are immune to dust attenuation.

4. We will study a large number of super-massive black holes (SMBHs) at epochs ranging from the early universe to the present day with infrared imaging and spectroscopy. Many SMBHs cannot be easily observed with other methods due to their dust obscuration. By combining these results with the galaxy evolution studies, we hope to understand the role of SMBHs in galaxy evolution.

5. We will undertake wide-area imaging survey to observe the galaxy clusters and large scale structures in the era when star forming activity peaked (z=1–3) using the in the mid-infrared. The large survey area (∼300 Mpc) complements the excellent follow-up capability of JWST, and we will probe large scale structure, the mass assembly history, and their impact on galaxy evolution.

A.2 The Formation and Evolution of Dust in the Universe

1. We will observe several ($>\sim 5$) dust-forming supernovae in nearby (d<25 Mpc) galaxies several times within 1–2 years after their explosions. Changes in the mid-infrared spectra as the dust condenses in the ejecta gas and then cools to the temperature of circumstellar pre-existing dust (∼a few hundred K) will reveal the dust composition, particle size distribution, and total mass.

2. We will study faint dust shells around ∼30 low- to intermediate-mass evolved stars (e.g., AGB stars, planetary nebulae, novae etc) in the Milky Way and Magellanic clouds with mid-IR imaging and spectroscopy. The imaging will probe the mass-loss histories and the dust-formation processes, while the spectroscopy will constrain the composition and the particle size distribution of the dust condensing in the mass-loss winds.

3. We will study grain growth and the relationships between the Glass with Embedded Metals and Sulfides (GEMS), the Interplanetary Dust Particles (IDPs) and the interstellar dust grains. We will use mid- and far-IR spectroscopy of cold dense molecular clouds housing embedded young stellar objects (YSOs); in particular, we will study infrared bands of iron sulphide.

4. We will undertake a program of mid- and far-IR imaging spectroscopy targeting about 30 infrared-detected SNRs. With these data we will investigate the composition and quantity formed dust, the role of shocks, and the aggregate effects on the ISM.

5. We will conduct mid- and far-IR imaging spectroscopy to provide spatially-resolved studies of the interstellar media in 50 nearby galaxies of our AKARI sample, tracking galaxy-scale material circulation from sources to sinks.

A.3 The Complete Process of Planetary System Formation

1. With a planet/star contrast ratio of 10^{-6} or better, we will directly detect gas-giant exoplanets, and obtain spectra to reveal their atmospheric compositions. Comparison with our solar-system planets will help us to understand the diversity in the nearby planetary systems.

2. Using sensitive infrared spectroscopy, we will measure gas transitions in proto-planetary disks, especially those of molecular hydrogen, to study the relationship of gas mass with age of the primary star.

3. We will study the geometric, physical and chemical structure of proto-planetary disks by measuring the gas velocities with high-resolution mid-infrared spectroscopy.

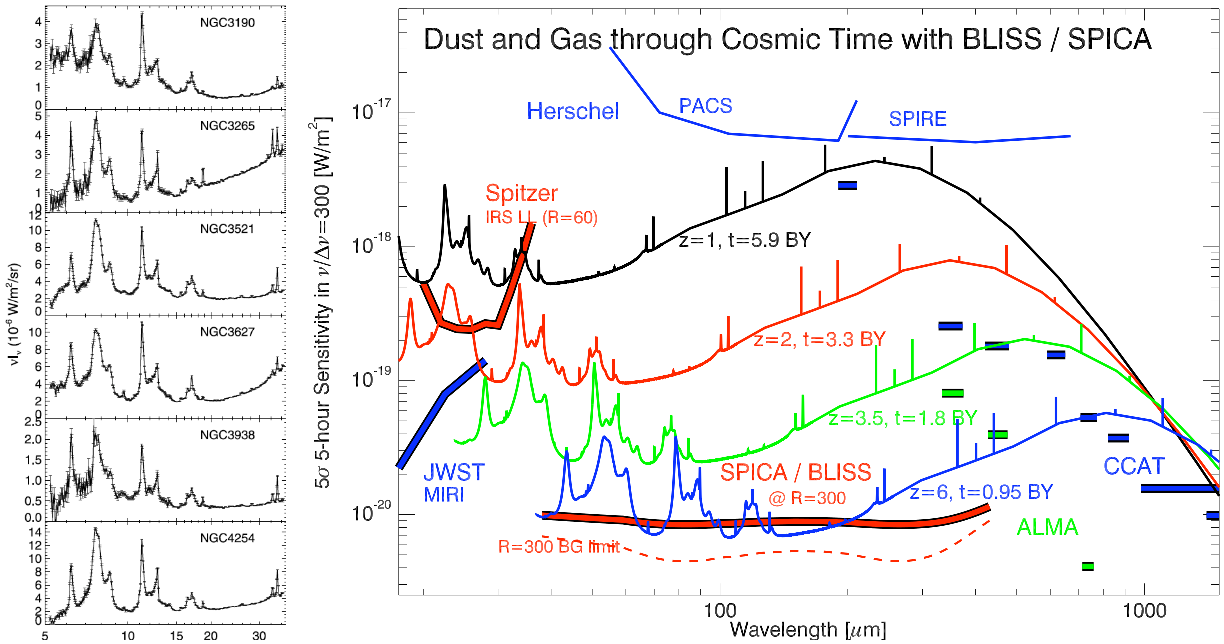

Figure 3: LEFT: Spitzer SINGS mid-IR spectra of nearby galaxies showing the powerful emission features from polycylic aromatic hydrocarbons (PAHs). RIGHT: Sensitivity of BLISS, a proposed NASA instrument on SPICA, along with redshifted galaxy spectra using the local-universe template and assuming $L = 10^{12}\ L_{\odot}$. With a sensitive grating spectrometer such as BLISS, SPICA can be 2–3 orders of magnitude more sensitive than Herschel, which is limited by the thermal emission from its ambient temperature telescope. Observation speed scales as the square of this sensitivity. With BLISS / SPICA, the mid-IR PAH features and the bright fine-structure lines are accessible for galaxies as early as 1 GY after the Big Bang.

4. We will search for infrared excesses around nearby stars and expect to find many disks. SPICA will be sensitive to dust emission as low as 1 zodi.

5. We will apply high-contrast IR coronagraphy to protoplanetary disks and debris disks, to reveal their structures and understand their relationship to disk evolution. Further infrared spectroscopy will reveal the distribution and physical state of solid materials, particularly ice, in proto-planetary disks and dust disks around main-sequence stars.

6. Using SPICA's outstanding sensitivity to mid- and far-IR thermal emission, we will undertake a survey of primitive solar-system bodies (e.g. Kuiper Belt Objects), to reveal to albedos, sizes, thermal intertias, and surface compositions.