PANEL A3: DEEP SURVEYS, SOURCE COUNTS, AND COSMOLOGY

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Abstract

Among the rich variety of projects and space missions devoted during the present decade to the exploration of the distant universe at long wavelengths, FIRST maintains unique capabilities of surveying in the far-IR large sky areas with imaging performances comparable to those of optical telescopes on ground. Strategies for deep multi-wavelenght cosmological surveys – which clearly remain among the top priorities of the FIRST mission – have been anticipated and debated during dedicated panel sessions.

Key words: Galaxies: formation, spectral energy distribution – Active Galactic Nuclei – Missions: Herschel-FIRST

1. The worldwide search for the "Origins"

Thanks to new powerful facilities for photon collection, particularly in the optical/NIR, the most remote regions of the universe have recently become accessible for the first time. The remarkable findings from these observations have triggered enormous interest in the so-called *Search for the Origin* of the cosmic structures which are observed in the present day universe. This would be intended to identify and describe the processes through which the universe has evolved from its primordial undifferentiated status to the current highly structured phase.

In parallel with this *search* for the origins in a cosmological sense, fast growing interest is receiving the *search* for the origins of life, which means searching for planets and proto-planetary disks in the solar vicinity, as a model for what happened on the Earth and a tracer of the existence of closeby environments similarly favourable to the live.

Obviously, the two investigations exploit the same or similar astrophysical tools. Mostly to address these fascinating themes, efforts have then been undertaken to develop the most sophisticated and powerful facilities through a set of worldwide collaborations and consortia, with an attempt of best coordination on all aspects of funding, technology development and scientific strategies. Numerous examples can be listed, among which the ALMA and NGST projects are probably the most remarkable.

We feel that the ESA Cornerstone FIRST should be viewed in the context of this global long-term program for astronomy. Indeed, although the mission has been conceived many years ago, some still unique capabilities are provided by the FIRST's large photon collector and spectral coverage. ALMA (and associated mm survey telescopes, like the Atacama Sub-mm Telescope) will sample the long-wavelength tail of the dust emission spectrum in high-z sources, while NGST, in its present configuration, will observe the short-wavelength part at 5-28 μm, where hot grains and PAH molecules dominate the spectrum.

Remarkably enough, the bulk of the dust emission spectrum from high-redshift sources will only be detectable by FIRST with good spatial resolution and sensitivity among the space missions of this decade (according to the NSF Decadal Review, only later than 2010 SAFIR is foreseen to do it better). As explained in detail by other contributions to these Proceedings (see those by S. Oliver and A. Franceschini), the critical limiting factor for observations at such long wavelengths is in the spatial resolution, determined by photon diffraction on the primary mirror. The first large observatory in space, with a mirror diameter 5 times larger than any other working at these wavelengths (ISO, SIRTF and ASTRO-F), will be able to beat the source confusion down to a flux limit where the bulk of the Cosmic IR Background can be resolved into sources, which will be detectable over a very large redshift interval.

Only these direct observations with FIRST of the redshifted peak of dust emission will enable us to *measure* the bolometric luminosity of cosmological sources (starburst and AGNs), otherwise impossible even with the most powerful instruments (ALMA, NGST) because of the large and unpredictable variations in the IR spectral shapes of galaxies. A measure of the bolometric luminosity is essential to quantify the physical and evolutionary state of the sources (the rate of ongoing star-formation, the quasar versus starburst contributions to the emission). This selection by total energy flux of cosmic sources in the FIRST SPIRE and PACS wavebands will identify the active phases in galaxy evolution over large volumes as a function of cosmic time, whereas more quiescent phases dominated by direct stellar radiation are better traced by optical and near-infrared observations.

2. FIRST cosmological surveys

Because of these unique capabilities, deep cosmological surveys with the FIRST's imagers (SPIRE and PACS)

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have been identified as the most important programs for the observatory.

Concepts and strategies for deep surveys with FIRST have been discussed in two public dedicated meetings. In addition, the issue has been addressed by various contributions during the general and parallel sessions, as well as during meetings of the instrument consortia.

During these meetings, some held in common with the other sections of 'A' (extragalactic) Panels, two complementary approaches have been discussed: a) deep unbiassed surveys of empty sky fields; b) deep integrations on pre-selected targets at high-z (like quasars, Lyman-break galaxies and more generally color-selected high-z galaxies). While point (b) is addressed in the summaries by Barthel and Lutz and by Encrenaz, Fisher and Van der Werf in these Proceedings, we expand here on the unbiassed surveys of point (a).

Although both PACS and SPIRE instruments appear well suited to survey large areas of sky, the detailed survey performances for the two instrument (including models of the sky, based on available data from ISO and mm-telescopes, and of the instrumental responses) are presently being simulated by the consortia teams. This will provide more precise indications of the (mostly extragalactic) confusion levels as a function of wavelength and survey modes. From these, the integration time per pixel field-of-view (FOV), redundancy, and the overall mapping speed will be quantified.

2.1. Surveys with SPIRE

Preliminary evaluations of the confusion indicate that it will set in around 10-20 mJy for SPIRE (independent of wavelength from 200 to 500 μm), and from around 1 mJy to several mJy in the PACS bands. Essentially two basic survey strategies for SPIRE have been considered.

- A set of deep surveys simultaneously covering the three SPIRE channels at 250, 350, and 500 μm, down to the estimated confusion limit (10 mJy), over sky areas totalling from 50 to 100 square degrees. According to the predicted SPIRE mapping performances, this deep survey is expected to require from 60 to 120 days of observations.
- A shallower survey to $\sim$ 50 mJy over a much larger area of $\sim$ 1000 square degrees. This would take of order of 5 months of observation with SPIRE. The basic motivation for this important time investment would be to allow detection of rare populations of sources.

The deep survey is obviously of highest priority, since it will allow the deepest sampling of the luminosity funtion of cosmic sources over the largest redshift interval, and over sky areas large enough to allow spatial correlation studies of statistically rich samples of sources (many tens of thousands objects), at moderate cost. The wide area survey would be more time-expensive, while its science could be partly covered by the all-sky surveys of PLANCK HFI. This second was then found to be of lower priority.

2.2. Surveys with PACS

Surveying with PACS the same sky areas covered by SPIRE would be highly desirable for two independent reasons: to reduce the size of the errorbox for faint survey sources to a limit (few arcseconds) where a straightforward identification becomes possible; and to obtain a good characterization of the SED of the sources, needed for physical insights into the nature of the sources and to attempt photometric redshift estimates based on the far-IR SEDs.

Unfortunately, this simultaneous coverage of the same areas with both instruments will be possible only over a limited fraction of the SPIRE areal coverage, due to the lower mapping speed of PACS. The latter is an obvious consequence of the fact that the FIRST confusion flux limit decreases very fast with wavelength, requiring much longer integration times to reach it, while, at the same time, the much better spatial resolution achievable with PACS requires a much smaller pixel FOV and altogther a smaller field.

PACS will provide the sharper vision and allow the deepest probes of the far-IR sky, but on limited sky areas. The wide-field surveys with SPIRE will then require substantial follow-up with ALMA (or other mm interferometers) to achive the positional accuracy required for reliable identifications.

3. Survey fields

The choice of the fields where to focus the FIRST deep surveys has been also subject of some debate. The standard choices are to avoid regions of high Galactic "cirrus" noise and high Zodiacal background, and to prefer regions of good observational visibility by the observatory and containing useful complementary data at other (optical, radio, X-ray, IR) wavelengths.

High priority regions appeared to be those where important datasets from space observatories could be available. One case is the field target of a wide-area survey with XMM (the XMM-LSS, see *astra.astro.ulg.ac.be/themes/spatial/xmm/LSS/*), the other are fields that will be observed by the SIRTF Wide-area Infrared Extragalactic Survey (SWIRE), the largest survey program for SIRTF. SWIRE will observe close to or below the SIRTF confusion at 24, 70 and 170 μm and at 3.6, 4.5, 5.8 and 8 μm a total area of 70 square degrees splitted in 7 high Galactic latitude fields (one is a 10 sq.deg. area in XMM-LSS), for a total of 851 hours of observations (see *www.ipac.caltech.edu/SWIRE/swire_v2.html*).
Similar sky coverage and wavelength complementarity (particularly at 24 μm and at 3 to 9 μm) make the SWIRE areas very attractive for the FIRST cosmological surveys.