Astrophysics with Infrared Surveys: A Prelude to SIRTF
ASP Conference Series, Vol. 177, 1999
M. D. Bicay, C. A. Beichman, R. M. Cutri, and B. F. Madore, eds.

The FIRBACK 175μm Survey

David L. Clements, J-L Puget, G. Lagache, H. Dole, P. Cox, R. Gispert

Institut d'Astrophysique Spatiale, Univ. Paris XI, F-91405 ORSAY Cedex, France

W.T. Reach

IPAC, Caltech, MS 100-22, Pasadena, CA 91125, USA

C. Cesarsky, D. Elbaz, H. Aussel

Service d'Astrophysique, Orme des Merisiers, Bat. 709, CEA/Saclay, F91191 Gif-sur-Yvette CEDEX, France

F. Bouchet, B. Guiderdoni, A. Omont

IAP, Boulevard d'Arago, Paris

F-X. Desert

Laboratoire d'Astrophysique, Observatoire de Grenoble, BP 53, 414 rue de la piscine, 38041 Grenoble CEDEX 9, France

A. Franceschini

Dipartimento di Astronomia, Universita' di Padova, Padova, Italy

A. Moorwood

European Southern Observatory, Garching, Germany

D. Lemke

Max Planck Instiute for Astronomy, Königstuhl, Heidelberg, Germany

Abstract. The FIRBACK project is a collaboration of eight institutes aimed at using long wavelength surveys with ISO to uncover the nature of the Cosmic Far-Infrared Background. We have surveyed nearly 4 sq. deg. in three regions in the northern and southern hemispheres with the ISOPHOT instrument on ISO, using the 175μm filter. As reported by Puget et al. (1998) and Reach et al. (these proceedings), the first 0.25 sq. deg. region studied in this programme contains many more 175μm sources than expected. Initial reduction of the remaining survey areas appears to confirm this result. The area surveyed by FIRBACK represents the largest and deepest long wavelength far-IR survey available before the launch of SIRTF.

1. Introduction

There has been considerable suspicion for some time that dust obscuration may bias the optical view of the early universe. UV and optical radiation from dusty objects would be reprocessed into thermal emission from dust, and shifted from the optical into the far-IR, and thus inaccessible from the ground. This effect becomes more significant at higher redshifts where the observed-frame optical corresponds to the near and far-UV in the emitted-frame. The IRAS all-sky survey unveiled the local population of infrared galaxies ranging from normal spirals to the spectacular luminous and ultraluminous infrared galaxies, but only a handful of these sources had a significant redshift. Our knowledge of the far-IR 'dark-side' of galaxy formation is thus limited to the local universe. We do, however, know that there are individual objects at high redshift that contain substantial amounts of dust. The gravitationally lensed IRAS source 10214+4724 (Rowan-Robinson et al 1991, Serjeant et al 1995) is perhaps the best-known high redshift IRAS galaxy, but dust has also been detected in submillimetre observations of several quasars and radio galaxies (Hughes et al 1997 and references therein). Information on the dust properties of the bulk of galaxies at high redshift has so far relied on measurements of the integrated cosmic far-IR background (CIRB). Clear detection of this background has now been achieved (eg. Guiderdoni et al 1997) using data from the COBE satellite. The level of this background is substantially higher than was expected on the basis of models that do not include a substantial amount of dust-obscured star formation. Models of the CIRB (Guiderdoni et al. 1997) suggest that a significant fraction ($\sim$ 10%) of the objects contributing to the CIRB might be detectable by the ISO satellite by observations using its longest wavelength cosmological filter - the PHOT 175μm channel. The FIRBACK survey was devised to make these observations. A separate survey in a small area at these wavelengths by a Japanese team (Kawara et al. 1998) has also been attempted. Their results are compatible with those of FIRBACK.

2. The FIRBACK Survey

The FIRBACK Survey was conducted in two regions selected for low cirrus contamination and low galactic foreground. The two areas selected were the Marano Field (Marano et al. 1988) and the ELAIS N1 survey region (Oliver et al. in preparation). Roughly one sq. deg. was observed in the Marano Field, while about two sq. deg. were observed in ELAIS N1. Additionally, a further $\sim$one sq. deg. was observed in the ELAIS N2 region in collaboration with the ELAIS survey programme. The final survey area will thus be about 4 sq. dgrees. The rest of this paper will concentrate only on the Marano and ELAIS N1 surveys since we have so far not processed the ELAIS N2 data. All the FIRBACK surveys were conducted with the PHOT instrument aboard ISO using the C200 2x2 array detector and the C160 (175μm effective wavelength) filter. Three different strategies were used for the observations. The first Marano Field area covered, a 0.25 sq. deg. region dubbed Marano 1, is discussed extensively by W.T. Reach in the present volume and Puget et al. (1998). Four 19x19 rasters were obtained in this area. Each raster scan stepped by one pixel in both scan and cross-scan directions so that each point on the sky was observed by each of the four C200 pixels for an integration time of 16s. This sequence was then repeated four times with an offset of 92", the size of one pixel. We thus obtain either four completely independent maps each with a 64s integration time, or a combined map with a 256s integration time. See Reach et al. and Puget et al. (1998) for further discussion. For the remaining 0.75 sq. deg. in the Marano region, termed Marano 2 to 4, we used a similar technique, except that the four independent rasters are offset by $\sim$ 46" (ie. half a pixel) rather than 92". This yields significantly better sampling of the PSF. The ELAIS N1 survey uses a similar idea, but uses just two independent rasters offset by 46". We expect to reach detection limits of $\sim$100mJy in all survey regions. Based on number counts obtained in Marano 1, this should provide over 200 175μm sources in the final 4 sq. deg. studied. Other ISO data is also available for some of these areas. The ELAIS N1 region has been surveyed by the ELAIS team at 15 and 90 μm, while the Marano 1 area coincides with the ISOCAM DEEP and ULTRADEEP surveys at 7 and 15 μm. The Marano 2 and 3 regions ($\sim$ 0.5 sq. deg.) were also surveyed at 15μm during the course of the FIRBACK observations, so that only one 0.25 sq. deg. area, Marano 4, has no corresponding survey in the mid-IR. We use a combination of standard PIA techniques and custom-written software to reduce the FIRBACK data and to extract sources and fluxes. To date only the initial Marano 1 area has been fully reduced and had a final catalogue extracted. Preliminary analysis of the rest of the FIRBACK data however supports the initial conclusions in Reach et al. and Puget et al. (1998), namely that we find many more 175μm sources than would be expected on the basis of what we currently know of the local infrared galaxy population.

3. The Next Steps

Once the ELAIS N1 and Marano 2–4 regions are fully reduced, we must obtain identifications for our far-IR sources and obtain redshift spectra for them. This will not be an easy process since the PHOT angular resolution is very poor. The locations of our 175μm sources will be uncertain by over an arcminute, especially in the Marano 1 region where the PSF is poorly sampled. We must thus rely on observations at other wavelengths to provide identifications. The two most useful wavelengths for this are likely to be the mid-IR, which is why most of the FIRBACK survey regions have also been studied at 15μm, and the radio. The mid-IR data will be able to detect hot dust associated with the same processes that power the far-IR luminosity. In a typical nearby starburst the mid-to-far-IR flux ratio is $\sim$4%, though with a large scatter, suggesting that a typical 100mJy far-IR source should have a 15μm flux of a few mJy. However, there are substantial variations in the mid-to-far-IR ratio from object-to-object, while the complex spectral features in the mid-IR mean that this ratio will strongly vary with redshift. Nevertheless initial results suggest that a substantial number of Marano 1 175μm sources have 15μm counterparts. The ISOCAM data will provide source positions to $\sim$ 6" accuracy. The well-known radio-far-IR relation (Helou et al. 1987) implies a radio to 175 μm flux ratio of about 0.5%, though with a large scatter. Several hundred mJy 175μm sources might thus be expected to correspond to radio sources of a few hundred μJy. These fluxes are readily detectable in long integrations with modern radio interferometers and are thus be capable of identifying the 175μm survey objects. Much of the ELAIS N1 area has been surveyed by the ELAIS team using the VLA, while we have conducted ATCA observations of the Marano regions. This will provide source positions with an accuracy of ~1" or better. With better positions from radio or mid-IR associations, we will be able to determine an optical identification and then obtain a redshift. For objects lacking a mid-IR or radio association, obtaining an optical identification will be much more difficult and we may have to rely on optical and infrared multicolour techniques to select likely targets. For example, the FIRBACK sources are likely to contain substantial masses of dust and may thus be redder than more normal galaxies. Red objects within the positional error circle for a FIRBACK source will thus be strong candidate identifications. The results of the radio and mid-IR identifications will guide the techniques applied at other wavelengths.

4. Conclusions

The FIRBACK 175μm survey will provide the first information on the nature and origin of the newly-discovered cosmic far-IR background. The early indications are that the background is the integrated emission of a large number of point sources, of which FIRBACK is detecting about 10%. We must await the completion of the followup programme before the nature of these sources is understood. As far as surveys with the SIRTF instruments are concerned, FIRBACK is the deepest far-IR large-area survey that will be completed before the launch of SIRTF and provides a useful preview of what the 160μm channel of MIPS will be capable of. With sensitive instruments, better PSF sampling and a larger mirror, MIPS and SIRTF may well be able to resolve most of the objects contributing to the far-IR background. Once this has been achieved, we will have determined the role of dust in the early universe, and have unveiled the "dark-side" of galaxy formation.

Acknowledgments. DLC is supported by the EC TMR Network programme, FMRX-CT96-0068. This work is based on observations with ISO, an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdon) and with the participation of ISAS and NASA

References

Guiderdoni et al., 1997, Nature, 390, 20-11-97

Helou, G., Soifer, B.T., Rowan-Robinsion, M., 1985, APJ., 298, L7

Hughes, D.H., Dunlop, J.S., Rawlings, S., 1997, astro-ph/9705094

Kawara, K., et al., 1998, A&A, in press

Marano, B., et al., 1988, MNRAS, 232, 111

Puget et al., 1998, A&A, submitted

Rowan–Robinson, et al., 1991a, Nature, 351, 719

S. Serjeant, et al., 1995, MNRAS, 276, L31.