COMBINED COSMOLOGY PROGRAMS WITH SPIRE AND PLANCK HFI

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Abstract

The early-release Planck sub-millimeter all-sky survey will detect galaxies at significant cosmological distances, including a fraction that may be gravitationally lensed. Follow-up spectral line surveys with SPIRE will determine the redshift and will probe the interstellar medium in these extremely far-infrared luminous galaxies. Spectral and imaging observations of clusters of galaxies, detected by Planck via the Sunyaev-Zel'dovich effect, may assess relativistic corrections to the S-Z distortion, and probe the contribution from thermal dust emission. Finally, the evolution and clustering of galaxies at high redshift may be probed by fluctuations in the extra-galactic far-infrared background. A P(D) analysis with a deep SPIRE survey will probe the far-infrared background at higher sensitivity and angular resolution over a smaller region of sky, complementing proposed studies of the far-infrared background with Planck.

Key words: Cosmology: galaxy clusters, star formation– Missions: FIRST, Planck

1. Introduction

While the FIRST Spectral and Photometric Imaging Receiver will have the largest arrays of space-borne bolometers Planck-HFI will have the most sensitive bolometers flown in space. We envision a joint cosmology program with SPIRE that exploits the rich data set provided by the first Planck/HFI all-sky surveys.

2. Cluster science

2.1. Sunyaev-Zel'dovich effect

Compton-scattering of CMB-photons with hot electrons in clusters of galaxies causes an intensity change of the CMB. The combination of measurements of this Sunyaev-Zel'dovich (SZ) effect at mm-wavelengths with x-ray data is an important tool for cosmology. The SZ effect provides the capability to determine the Hubble-constant, the large-scale velocity field of the universe and the formation of structure. A follow-up of SZ-sources with SPIRE may be used to:

- determine the temperature of the cluster through the relativistic SZ effect;
- search for lensed FIR galaxies;
- search for intercluster dust;
- map nearby clusters with high resolution;
- separate the emission from galactic dust and galaxies.

2.2. Properties of clusters at high z

In contrast to the x-ray signal that vanishes $\sim (1+z)^{-4}$ the SZ effect is independent of redshift. Planck-HFI hence might detect a number of rich clusters at high z without x-ray counterparts. At electron temperatures $T_e > 5$ keV relativistic effects give the spectrum a unique shape. Consequently, measuring the spectrum gives a method to determine T_e.

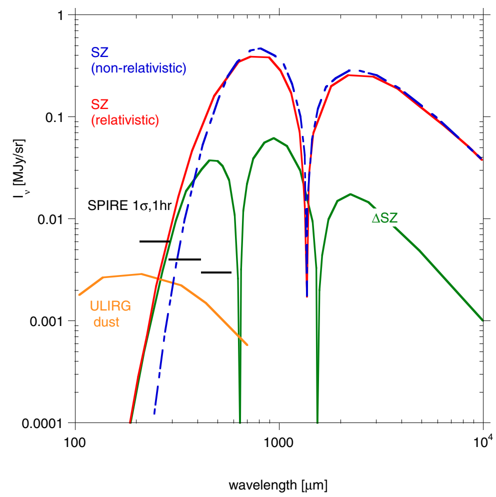

Figure 1. Spectra of the relativistic (red) and the non-relativistic (blue) thermal SZ effect in a cluster of galaxies.

Figure 1 shows the relativistic (red) and the non-relativistic (blue) spectrum of the thermal SZ effect in a cluster of galaxies with $T_e = 8$ keV and comptonization parameter $Y_{center} = 3 \cdot 10^{-4}$. The green curve shows the difference due to relativistic SZ effect. The black bars show the SPIRE sensitivity for a 4" beam obtained by summation of adjacent pixels. Observations with SPIRE may determine the electron temperature to a precision of 4 keV for clusters at z = 1 (Pointecouteau 1998).

2.3. Intercluster dust

Observations with ISOPHOT at 170 μm (Stickel et al. 1997) suggest the presence of cold intercluster dust emission at FIR wavelength in clusters of galaxies. However, these observations suffer confusion by cirrus emission thus SPIRE's multiband photometer is required.

3. Follow-up of Planck ERCSC galaxies

The early-release Planck HFI all-sky survey will detect on order of 10000 infrared galaxies. Some of them will be at significant cosmological distances including a fraction that may be gravitationally lensed. We envision follow-up spectral line surveys of the high-redshift candidates with SPIRE. This will determine their positions more accurately, measure their redshifts and probe the inter-stellar medium providing a powerful method of distinguishing between different models of galaxy evolution and star formation history.

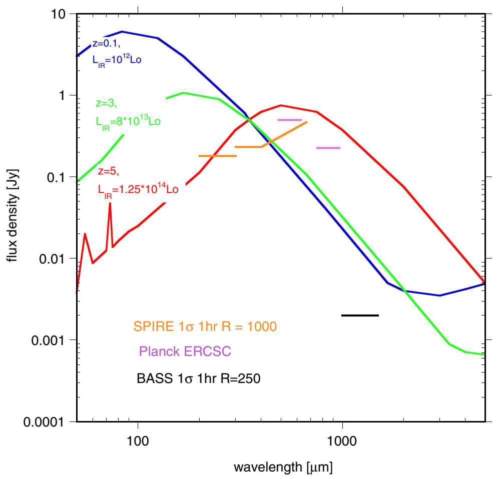

Figure 2. Spectra of a starburst galaxy at different redshifts.

A starburst galaxy detected by Planck (figure 2) with a flux density of 500 mJy at 350 μm may be at low redshift and of high luminosity (blue) or at high redshift and extremely luminous (red). Horizontal bars represent the noise of the Planck ERCSC and the 1s noise of SPIRE at resolution of R = 1000 after 1 hr of integration. Note that if the continuum emission is detected, lines with a ratio of line flux to continuum emission of 10^{-3} can be observed. The black bar indicates the sensitivity of BASS, a millimeter spectrometer with a resolution of 250 currently built at Caltech / JPL and U Colorado.

4. FIR background fluctuations

Far-infrared background (FIRB) fluctuations depend on the clustering, number counts, and star-formation history of far-infrared bright galaxies. A measurement of the fluctuations may be the best way to constrain the formation of far-infrared galaxies if systematic redshift determination of individual sources is prohibitively difficult. Shallow FIRST surveys will be able to measure brightness fluctuations from undetected individual sources and probe correlations in dust-free regions. Planck will provide large areal coverage.

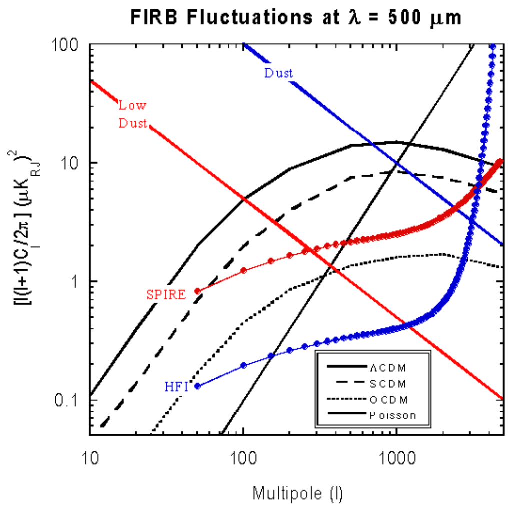

Figure 3. Angular power spectra from FIRB fluctuations.

Figure 3 shows the angular power spectra from FIRB fluctuations computed by Haiman & Knox 2000 with z-dependent bias for ΛCDM, OCDM, and SCDM cosmologies. The faint solid line is the shot noise contribution from point sources. Estimated errors for a survey with Planck HFI covering 10 % of the sky are shown in blue; errors for a large 100 sq. degree survey with FIRST / SPIRE are shown in red. Both surveys are sample variance limited for $l < 2000$. Estimated confusion from Galactic dust is indicated for 10 % of the sky at the SGP (blue) and for the cleanest 400 sq. degree regions (red).

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