A Search for the Light of First Stars with *SPICA*

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ABSTRACT

FPC-S is a back up of the fine guidance camera, but is usable for the scientific observation. FPC-S is optimized to observe the spectrum and fluctuation of near-infrared background. One of main scientific targets is to search for the light of first stars of the universe and to delineate the star formation history and structure evolution during the dark age of the universe. The expected performance and its scientific significance is presented.

1. INTRODUCTION

First star of the universe is crucially important to understand the evolution of the universe after the recombination era. It has been believed UV radiation of first stars re-ionized the universe. Detection of individual first star is extremely difficult, however, light of first star could be detected as a part of near-infrared extragalactic background light. Recent observations indicate there exists significant excess sky brightness over the known background that has a blue stellar spectrum (Matsumoto et al. 2005). Large excess fluctuation of sky brightness was also detected at large angular scale (Matsumoto et al. 2011; Kashlinsky et al. 2005, 2012). Origin of excess brightness and fluctuation could be attributed to the first stars, however, observed level is too high to be explained by the standard theory based on high-z galaxies (Cooray et al. 2012). To solve the controversial situation, more observational evidences are needed, and FPC-S on *SPICA* is an ultimate instrument for the observation of near-infrared background. Compared to *JWST*, FPC has much higher sensitivity owing to a large throughput and a capability of efficient low resolution spectroscopy. FPC-S will provide firm observational evidences on the near-infrared extragalactic background light and delineate the formation and evolution of first stars.

2. FPC-S

FPC-S is a camera with refractive optics which covers wavelength region from 0.7 μm to 5.2 μm. Filter wheel is provided in front of the detector array. One characteristic feature of FPC-S is the observation with linear variable filters (LVF). LVF is a square shaped and transmitting wavelength linearly changes along one direction. Spectroscopic observation with LVF needs scanning mode for *SPICA* telescope but makes low resolution spectroscopy for extended source very efficient. Specification of FPC-S is summarized in Table 1. $5\,\sigma$ detection limit for $R{\sim}5$ with 100 sec integration is ~25.5 AB magnitude. Details of the FPC is presented in this proceedings by D-H Lee.

3. PERFORMANCE OF FPC-S

3.1. Observation of the spectrum of the sky

Figure 1 shows the summary of observations of extra-galactic background light (EBL). Recent observations at optical region show fairly low level EBL (Matsuoka et al. 2011; Mattila et al. 2011) comparable to integrated light of galaxies (solid line), while *COBE* and *IRTS* results indicate fairly high EBL (Matsumoto et al. 2005).

Spectrum of the sky can be observed with LVF by pointed observation. In this observation mode, each pixel observes different field on the sky with a different wavelength. Since fluctuation of the sky is fairly low, co-adding of the pixels

Table 1. Specification of FPC-S.

Detector	InSb 1k×1k array
Field of view	5 arcmin
Pixel scale	0.3 arcsec
Wide band filter: $R = 5$	J, H, K, L and M (tentative)
LVF: $R = 20$	(0.7–1.4 μm) (1.4–2.8 μm) (2.6–5.2 μm)

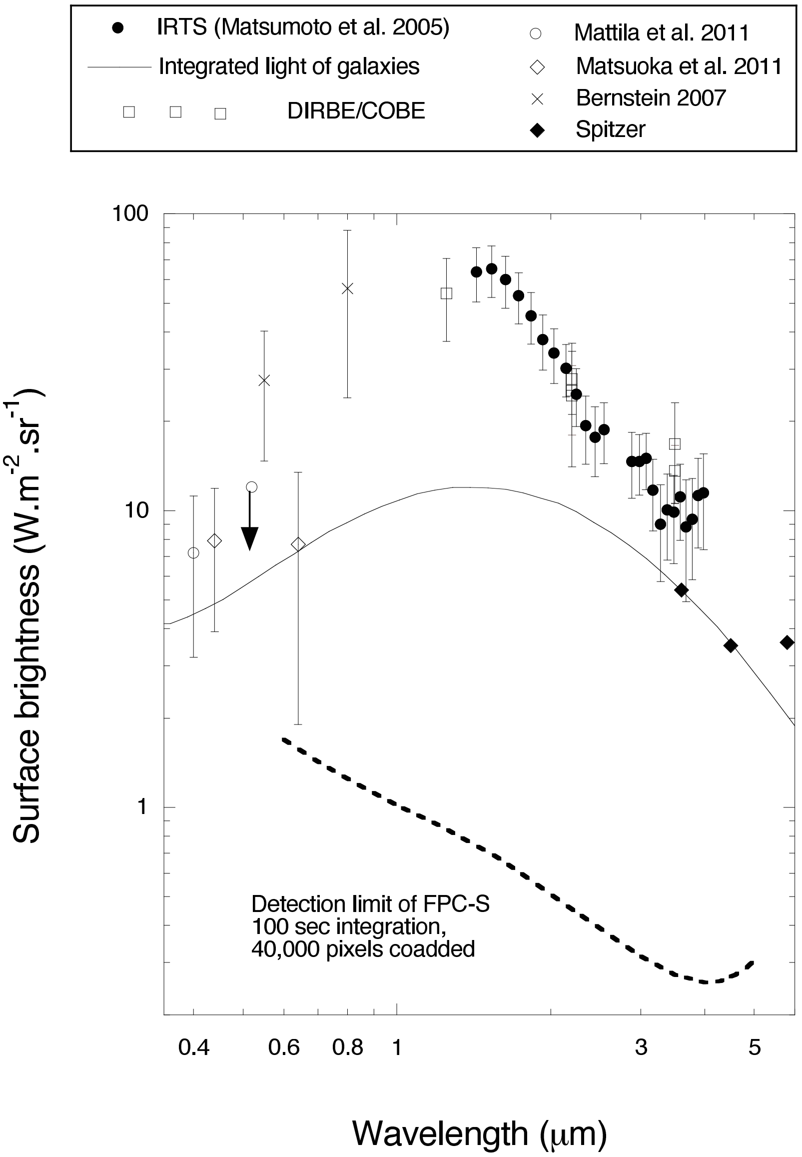

Figure 1. Summary of observations (*symbols*) and detection limit of FPC-S for 100 sec integration with LVF mode (*dashed line*). Thin solid line indicate the integrated light of galaxies.

with same wavelength band after removing point sources makes significant improvement of signal to noise ration possible. Dotted line in Figure 1 indicates the detection limit for 100 sec integration with LVF.

One of the key issue to observe EBL is how to subtract foreground emission components, which are zodiacal light (ZL), integrated star light (ISL) and diffuse galactic light (DGL).

As for the ZL, we propose to perform LVF observations at different ecliptic latitudes and at different epoch of the year. By making use of annual time variation of ZL, we will be able to construct the much more reliable model of the zodiacal light than that of *COBE*/DIRBE (Kelsall et al. 1998), since ISL is negligible for FPC-S owing to high sensitivity of FPC-S.

Another foreground emission source, DGL can also be detected by taking systematic correlation study with far infrared emission. Coordinated observation with SAFARI is crucially important for the study of DGL.

Owing to precise measurement of the foreground emission, accurate and reliable spectrum of EBL will be obtained. Furthermore, it could be possible to detect features of redshifted Lyα and other lines/bands.

3.2. **Observation of the fluctuation of the sky**

Fluctuation of the sky provides another important observational evidence which is independent from foreground emission, since ZL is fairly isotropic (Pyo et al. 2012). Figure 2 shows the result of *AKARI* observation towards NEP at 2.4 μm (Matsumoto et al. 2011) and the preliminary result of *AKARI* NEP wide field. Excess fluctuation is clearly detected at the angle larger than 100 arcsec which extends to degree scale. *Spitzer* detected a similar fluctuation at 3.6 and 4.1 μm (Kashlinsky et al. 2005, 2012).

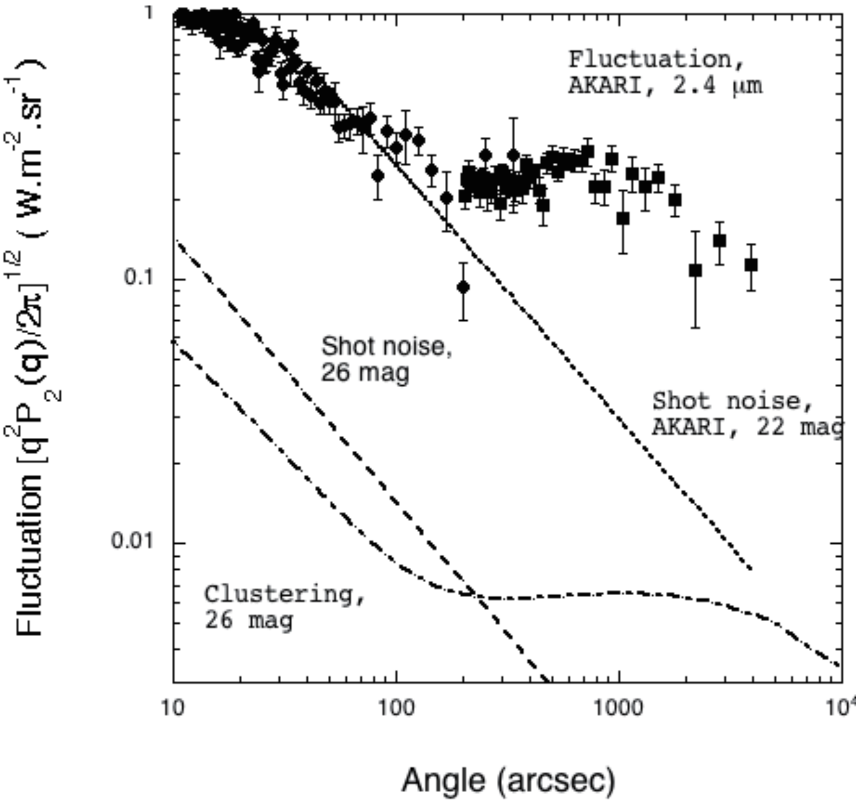

Figure 2. Detection limit of FPC-S for the observation of the fluctuation of the sky is shown by dashed line. Closed circles and squares indicate detected fluctuation with *AKARI* at 2.4 μm. Fluctuations due shot noise are also shown.

Detection limits of fluctuation measurement depend on how faint point sources (galaxies) can be removed, since shot noise of the unidentified faint galaxies is dominant at small angular scale. FPC-S has an excellent performance owing to much higher sensitivity than *AKARI* and *Spitzer*. Figure 2 shows excess fluctuation can be detected at the angular scale down to 10 arcsec. In this scale, clustering effect of first stars could be detected which is crucially important for the study of structure evolution at first star era. Detection limit of 26 mag can be achieved easily for wide band filters with 100 sec integration. With longer integration time, we can detect excess fluctuation down to a few arcsec. LVF observation of the fluctuation is also important. Since the spectra of first stars and Lyα from nebulae appear at the different wavelengths depending on the redshift, correlation study between wavelength bands could delineate the evolution of the large scale structure. Observation for 5 arcmin square with 26 mag detection limit requires 3.3 hours plus maneuvering time.

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