Perspective on Extra-Galactic Studies with MCS WFC Slit-less Spectroscopy Survey

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ABSTRACT

The wide field camera of MCS onboard *SPICA* will have an unique capability of slit-less grism spectroscopy survey. It utilizes wide ($5' \times 5'$) field of view (FOV), and spectra of all sources within the FOV would be acquired at once with grisms mounted on filter wheels, covering 5–38 μm in total. We simulate the slit-less spectroscopy images of a realistic deep universe with galaxies populated according to their luminosity function in order to examine detectability of galaxies as a function of their luminosity and redshift while quantitatively assessing source overlapping problem.

1. INTRODUCTION

MCS (Mid-infrared Camera and Spectrograph Kataza et al. 2011) onboard *SPICA* (Nakagawa et al. 2011) is an imaging and spectroscopy instrument to cover 5–38 μm. For imaging, two wide-field cameras (WFC) cover $5' \times 5'$ field of view (FOV) for each -S and -L channel. For spectroscopy, WFC utilizes low-resolution grisms ($R \simeq 50$) mounted on its filter wheels. Four grisms, SG1, SG2 (both in WFC-S channel), LG3, and LG4 (both in WFC-L channel) cover 5–9, 8–15, 14–26, and 24–39 μm, respectively. In addition to (short-)slit spectroscopy, slit-less mode is available to utilize full WFC FOVs. Since its capability/limitation has not been fully explored yet, this paper addresses its scientific capability for extra-galactic survey science cases by conducting realistic simulations of the sky in slit-less survey mode.

The slit-less mode is unique in many aspects, and here we summarize its pros and cons. Pros in generals are: (a) Multi-object spectroscopy is made. (b) Little selection effect is introduced since no a-priori target selection information is needed when compared with targeted slit spectroscopy. Pros specific to extra-galactic science cases are: (c) Spectral typing to identify their activity (normal/star-forming/AGN/stellar) is readily made. (d) Spectroscopic redshift measurement (at $R \sim 50$) is made, and luminosity is readily measured. Cons are: (1) Source overlapping/contamination will damage the information. (2) Sensitivity is shallower than the slit spectroscopy due to higher sky background. We believe it important to quantitatively examine those pros and cons to help designing scientifically attractive and technically feasible survey parameters (e.g., sensitivity, redshift range, area coverage, and required hours). Therefore we performed the slit-less observation simulation, and report the results here.

2. SIMULATION DETAILS

The simulation is made of two parts: observation part and source extraction part. For observation simulation, we adopt the latest specifications of MCS and *SPICA*, including aperture size (3 m), MCS optics (FOV, pixel scale, system throughput, grism wavelength coverage and resolution Kataza et al. 2011) and detector performance (quantum efficiency, readout noise Wada et al. 2011). Galaxies are assumed to follow AKARI rest frame 8 μm luminosity function by Goto et al. (2010) with some extrapolation toward higher redshift, and are randomly distributed on sky. For each galaxy, a representative star-forming galaxy spectral energy distribution (SED), a M82 SWIRE template in which only PAH features around rest 5–15 μm are replaced by M82 *ISO*/SWS high resolution spectrum. Assuming deep extra-galactic survey toward ecliptic pole, the low zodiacal light conditions ($T = 273$ K, 15 MJy/str at 25 μm) are used. For comparison, we simulated for two exposure times: 3600 sec and 600 sec. Source detections are made at redshifted PAH 7.7 μm peak (3 sigma), and spectra are extracted over boxes with wavelength- (point spread function (PSF)-) depending width. Once a source is detected in one grism image, extraction is made over all four grism images. When a part of the wavelength region is overlapped by neighbors, only that part is masked in the extracted spectra while it is counted as overlapped source for overlap statistics.

3. RESULTS

Simulated slit-less spectroscopy images are shown in Figure 1. Redshifted galaxies are very red within MCS wavelength coverage, and they become more evident in longer LG3 and LG4 bands. Overlap fraction increases for redder bands and longer exposure case (Table 1), and the extracted one-dimensional spectra show missing wavelength regions due to the overlap masks (Figure 2). Figure 3 highlights luminosity-redshift parameter space where larger number of sources and

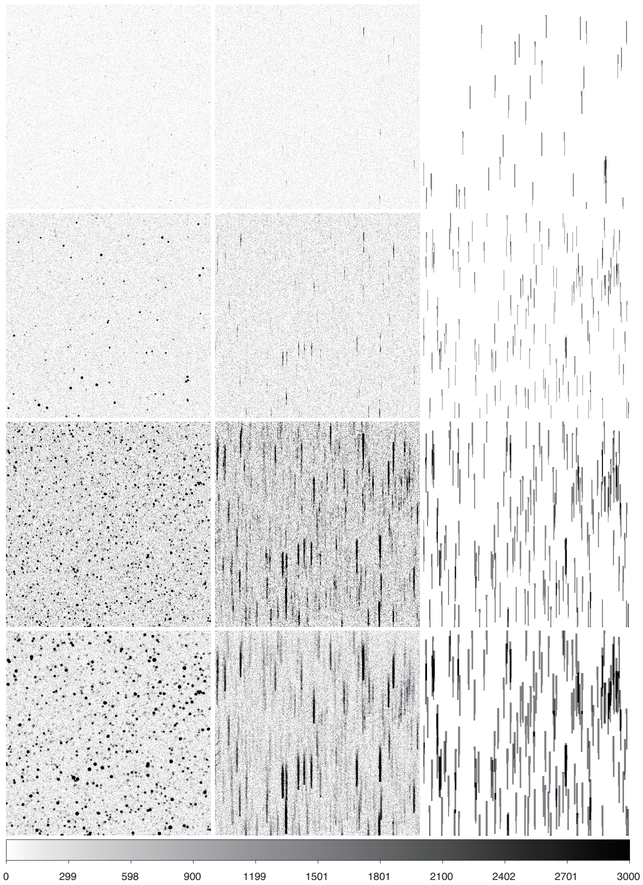

Figure 1. Simulated images over $5' \times 5'$ with 3600 sec exposure. Four vertical panels show the same field in broad-band (*left columns*), slit-less spectroscopy (*center columns*), and overlap images (*right columns*) taken with four grisms (SG1, SG2, LG3, and LG4 from top to bottom). In the central columns, wavelength increases upward.

brighter sources are preferentially detected. Note that results with 600 sec exposure are not shown in figures, but overlap statistics is shown in Table 1 together with the case of 3600 sec exposure.

Table 1. Source overlap fraction

Exposure time	# of detected sources	SG1	SG2	LG3	LG4
3600 sec	154	4%	15%	38%	54%
600 sec	47	0%	0%	13%	28%

4. DISCUSSIONS

With 3600 sec exposure, > 100 galaxies are detected per FOV up to $z = 2$ and beyond. For the redshift range, the most prominent PAH 7.7 μm feature comes at LG3 for $z \lesssim 2$ and SG2 for $z \lesssim 1$, and it can be easily recognized. In such a situation, together with rather low spectral resolution ($R \simeq 50$) and limited S/N quality for most distant/faintest sources, detailed spectral feature fitting analysis would not be possible for most sources. Rather, simple Gaussian/Lorenzian PAH fitting seems to work fine for measuring redshift, PAH flux, and, hence, PAH luminosity. Combined analysis with broad-band photometry may also be helpful (see Wada et al. in this proceedings). Overlapping fraction is as high as 50 % in the worst case, LG4 in 3600 sec exposure, due to larger PSF in pixel unit. However, we note that even a part of the spectrum is damaged by overlapping, it is flagged to be "overlapped" in this statistics, which may be too stringent. In fact half of the overlapped sources still show detectable PAH 7.7 μm feature for redshift measurement, and most of them are in SG2 or LG3 where overlapping is less severe.

We are successful in demonstrating that the slit-less extra-galactic survey with MCS/WFC is feasible though with some overlapping problem, and is still powerful for detecting PAH and, hence, spectral typing. We expect the mode provides an

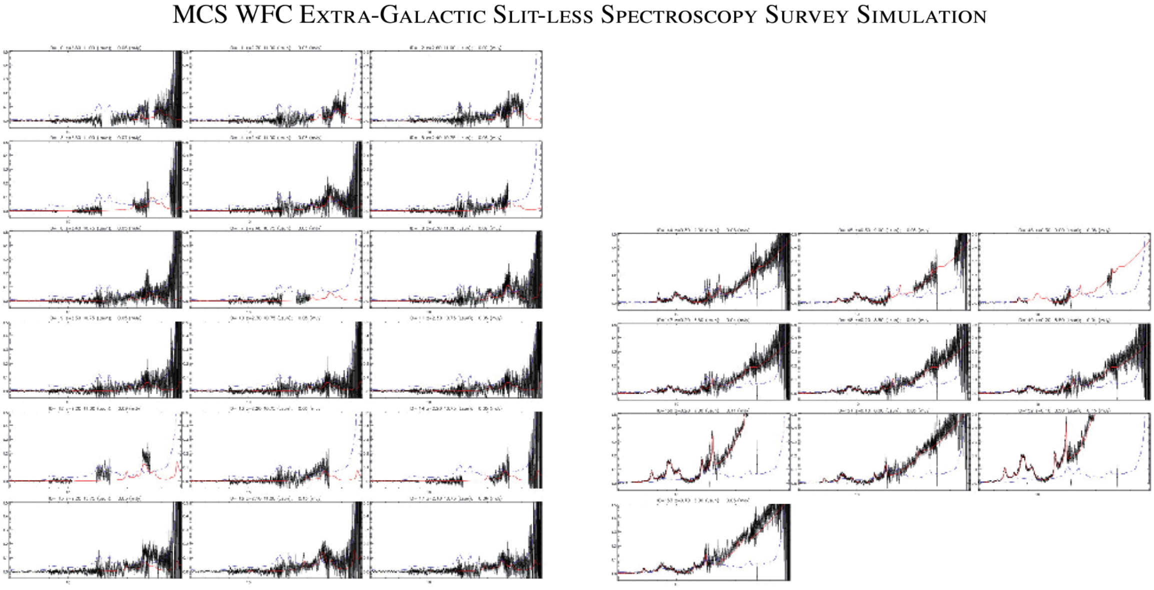

Figure 2. Examples extracted one-dimensional spectra with 3600 sec exposure. Faintest 18 and brightest 10 sources are shown in the left and right panels, respectively. In all sub-panels, black, red, and blue lines show observed spectra, input model spectra, and 5 sigma sensitivity, respectively.

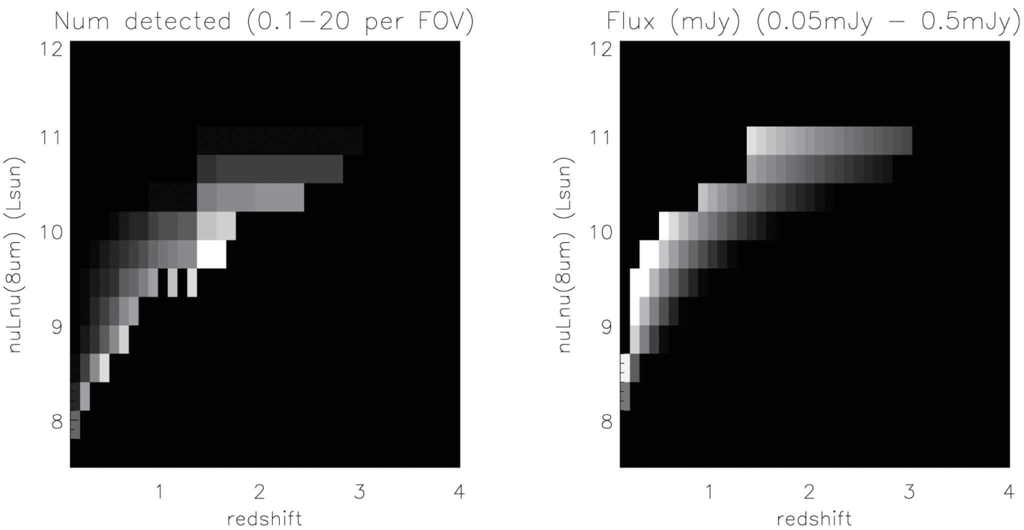

Figure 3. Number (*left*) and flux distribution (*right*) of detected sources over rest 8,μm luminosity vs. redshift plane for 3600 sec exposure. Upper left black regions correspond to the parameter space where number of detected sources are too small within a FOV. Lower right black regions correspond to the parameter space where galaxies are too faint to be detected with 3600 sec exposure.

efficient way to explore galaxy evolution with PAH-related quantities (cosmic evolution of star formation rate (density), AGN fraction, etc.) up to $z \gtrsim 2$. Optimally designing the survey parameters will be our next step.

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