Study on the Specification of Filters and Grisms for the Wide Field Camera: A Progress Report from the MCS Filter Working Group

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ABSTRACT

We have started the study on the specification of filters and grisms for *SPICA* Mid-Infrared Camera and Spectrometer (MCS; Kataza et al. 2012) Wide Field Camera (WFC) within the framework of MCS Filter Working Group (FWG). The FWG activity aims to obtain the baseline specification of imaging filters and grisms optimized for the maximum science output in any scientific fields of "extragalactic science", "ISM science" and "planetary science" by taking account of the technical constraints. The resultant baseline specifications will be opened to wider science members of *SPICA* project and FWG will get a more effective baseline set of filters and grisms for WFC by reflecting the feedback received. In this article, the latest progress report on the specification of filters and grisms for WFC studied by the MCS FWG is given.

1. THE *VERY BASIC* SPECIFICATION FOR WFC FILTERS REQUESTED FROM THE EXTRAGALACTIC SCIENCE, ISM SCIENCE AND PLANETARY SCIENCE

In order to carry out the SED analyses of any galaxies at different redshift evenly, the extragalactic science cases request that the WFC filters shall have constant spectral resolution power ($R \sim 5$ for WFC-S and $R \sim 10$ for WFC-L) and continuous spectral coverage (4–26 μm for WFC-S and 18–38,μm for WFC-L). Thus, the center wavelength of n^{th} photometric band, $\lambda_c(N)$, is defined as

$$\lambda_c(n) = \lambda_c(1)\left\{\left(1+\frac{1}{2}R^{-1}\right)\left(1-\frac{1}{2}R^{-1}\right)^{-1}\right\}^{n-1}, \quad (1)$$

where R is the spectral resolution power and $\lambda_c(1)$ is the center wavelength of the initial photometric band.

On the other hand, many ISM and planetary science cases focus on emission and/or absorption features arising from various dust species in different physical condition in the spectral range of MCS. While the spectroscopy is required for the detailed identification and physical/chemical diagnoses of those spectral features, multi-band photometry with WFC shall aim to efficiently find objects that have unusual SED in the mid-infrared.

2. THE CANDIDATE SET OF WFC-S PHOTOMETRIC FILTERS

Table 1 shows the candidate set of WFC-S photometric filters selected to measure the emission and/or absorption strengths of astronomical silicate and the UIR bands effectively. $\lambda_c(1) = 4.39\,\mu$m and $R = 4.5$ are adopted for this selection. We confirmed that S5.4, S9.8 and S14.6 bands are almost free from major UIR bands and those bands are used to measure the strength of silicate absorption and to define the hot dust continuum underlying the UIR features. Based on our simulation analyses using *ISO* SWS spectra of various types of Galactic objects (Hony et al. 2001; Sloan et al. 2003), we confirmed that S6.6 and S8.0 bands will efficiently measure the strengths of UIR 6.2 μm and 7.7 μm features, respectively, after subtracting the hot dust continuum emission contribution estimated by S5.4, S9.8 and S14.6 bands. However, we found that the strength of UIR 11.2 μm feature cannot be correctly measured by S12.0 band. Additional U11.2 photometric band with $\lambda_c = 11.20\,\mu$m and $\Delta\lambda = 0.40\,\mu$m is, therefore, strongly requested to discriminate UIR 11.2 μm feature out from the hot dust continuum emission.

3. THE CANDIDATE SET OF WFC-L PHOTOMETRIC FILTERS

Because of the difficulty in measuring the strengths of faint dust features on strong hot dust continuum emission in the spectral range of WFC-L, it is hard to find a superior set of WFC-L photometric filters based on our knowledges on wavelength positions of certain dust species. While the extragalactic science cases generally requires multi-band photometric capability with $R \sim 10$, ISM science cases requires efficient mapping capability using smaller number of imaging filters with $R < 5$. In Table 2 the candidate sets of WFC-L photometric filters are shown. Plan A assumes $\lambda_c(1) = 18.9\,\mu$m and $R = 10.0$ for narrow band filters and $\lambda_c(1) = 27.0\,\mu$m and $R = 4.5$ for wide band filters, while Plan B assumes $\lambda_c(1) = 20.5\,\mu$m and $R = 8.0$ for narrow band filters and $\lambda_c(1) = 23.0\,\mu$m and $R = 4.5$ for wide band filters.

4. GRISMS FOR WFC

WFC plans to have low-resolution slit-less spectroscopic capability using $293'' \times 300''$ FOV and short slit spectroscopic capability using $7''$length slit at FOV edge (Kataza et al. 2012). Table 3 summarizes the list of grisms requested to achieve the extragalactic, ISM and planetary science cases proposed in the *SPICA* mission requirement documents.

SG1, SG2, LG3 and LG4 will provide us successive spectroscopic capability from 5–39 μm with $R = 50$ and are requested, in particular, by extragalactic science cases. Slit-less spectroscopic capability with SG1H and SG2H will have advantages over JWST/MIRI for some science cases such as the investigations of infrared absorption spectra of foreground molecular clouds using background stars. Moreover, some science cases targeting time varying phenomena (e.g., SNe, LVBs, WRs) require wide spectral coverage in 4–38 μm with relatively high spectral resolution. For such purpose, simultaneous data acquisition between WFC-S/SG1H, SG2H (4–13 μm, $R = 200$) and MRS (12.2–37.5 μm, $R = 1100$–3000; see Sakon et al. 2012) are crucial to investigate the signatures of interaction between stellar wind and circumstellar medium and to demonstrate the physical phase transition of matters including gas ejection, formation of molecules and condensation of dust in circumstellar environment.

Table 1. Candidate set of WFC-S photometric filters

Band	λ_c (μm)	$\Delta\lambda$ (μm)	comment
S4.4	4.39	0.88	Continuum (stellar/hot dust), CO
S5.4	5.36	1.07	Continuum (stellar/hot dust)
S6.6	6.56	1.31	PAH C-C stretch (UIR 6.2 μm)
S8.0	8.01	1.60	PAH C-C stretch (UIR 7.7 μm complex, UIR 8.6 μm)
S9.8	9.79	1.96	Silicate abs./emi.
S12.0	11.97	2.39	PAH C-H oop bending (UIR 11.2 μm, 12.7 μm), [Ne II]
S14.6	14.63	2.93	Hot Dust Continuum, [Ar II]
S17.9	17.88	3.58	Silicate abs./emi., PAH C-C-C wagging, C60, [S III]
S21.8	21.85	4.37	Hot Dust Continuum, Crystalline Silicate

Table 2. Candidate sets of WFC-L photometric filters

Plan A			Plan B		
Band	λ_c (μm)	$\Delta\lambda$ (μm)	Band	λ_c (μm)	$\Delta\lambda$ (μm)
L18.9	18.92	1.89	L20.5	20.50	2.56
L20.8	20.81	2.08	L23.0	23.06	2.88
L22.9	22.89	2.29	L26.0	25.95	3.24
L25.2	25.18	2.52	L29.2	29.19	3.65
L27.7	27.70	2.77	L32.8	32.84	4.10
L30.5	30.47	3.05	L36.9	36.94	4.62
L33.5	33.52	3.35	L23W	23.00	5.1
L36.9	36.87	3.69	L28W	28.11	6.3
L27W	27.00	6.0	L34W	34.36	7.6
L34W	33.75	7.5			

Table 3. Candidate sets of grisms for WFC

channel	disperser	wavelength (μm)	spectral resolution
WFC-S	SG1H	4–7.5	R = 200
	SG2H	7–13.0	R = 200
	SG1	5–9	R = 50
	SG2	8–15	R = 50
WFC-L	LG3	14–26	R = 50
	LG4	24–39	R = 50

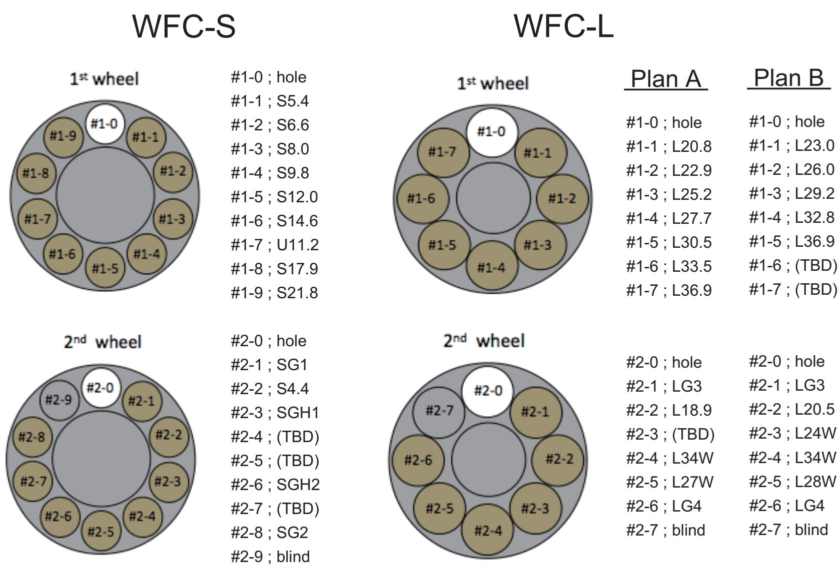

Figure 1. Available slots for filters and grisms for WFC-S and WFC-L.

5. TECHNICAL CONSTRAINTS FOR THE CHOICE OF FILTERS AND GRISMS FOR WFC

Each channel of WFC plans to employ double filter wheels. The number of slots in each filter wheel should be smaller than 10 for WFC-S and 8 for WFC-L from the technical reason. Each filter wheel must have "hole" position and either one of the filter wheel must have a "blind" position. Therefore, at most 17 slots are available for the imaging filters and grisms for WFC-S and 13 slots for WFC-L. Figure 1 shows the available slots for filters and grisms for WFC-S and WFC-L. Besides the baseline filter sets discussed in Sections 2–4, 3 slots in WFC-S and 1–2 slots in WFC-L are available for additional narrow band filters and/or wide band filters. Further discussion is still needed to get the even more useful baseline set of filters and grisms for WFC-S and WFC-L.

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