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A COSMOLOGICAL PAH SURVEY WITH SPICA

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ABSTRACT

We propose a cosmological survey to probe star formation and nuclear activity in galaxies at redshifts of z=2-4 by polycyclic aromatic hydrocarbon (PAH) features using the SPICA mid-infrared instrument (SMI) with a spectral resolution of R=20. We will cover a wavelength range of 20-36 μm that corresponds to z=2-4 for the PAH features (11.3, 7.7, and 6.2 μm). The sensitivity will be 1×10^{-19} W/m^2 (5 σ) in case of a reference survey that covers 4 arcmin^2 field in a one-hour observation. It corresponds to L_{IR}=2×10^{11} $L_\odot$ at z=3 and will give us more than 10000 galaxies in a 450 hour survey.

Key words: galaxy: AGN: PAH

1. INTRODUCTION

The redshift range z=1–3 is the "golden age" of galaxy and active galactic nucleus (AGN) evolution when both cosmic star formation and AGN activity peaks (Burgarella et al., 2013; Ueda et al., 2003). The physical reason why they peak at that age is still unknown because most of the activity is hidden in dust. The polycyclic aromatic hydrocarbon (PAH) features as well as the other MIR/FIR lines are most powerful diagnostics because they are less sensitive to dust extinction than UV/optical and soft-Xray lines. Expected fluxes of these MIR/FIR diagnostics are summarized in table 1.

The PAH features have two advantages compared to the other MIR/FIR lines: firstly, they are more luminous (table 1) and secondly, they are broad so a low-resolution spectroscopic survey is very efficient (figure 1). We plan to conduct a spectro-imaging survey of PAH features with a spectral resolution of R=20 with the SPICA (Nakagawa et al., 2012) mid-infrared instrument (SMI) imager with a set of bandpass filters.

The SMI is a simplified version of the MCS (Kataza

Table 1
Expected flux ($\times 10^{-19}$ W/m^2) of diagnostic lines and PAH features from an ULIRG (L=$10^{12.5}$ $L_\odot$)

z	star-formation		shock		AGN		metallicity	starburst/AGN		
	[O III][a]	[S III][a]	[Fe III][a]	[Si II][a]	[Ne V][b]	[O IV] [b]	[N III][a]	PAH[b]		
	52μm	33μm	26μm	34μm	24μm	26μm	57μm	6.8μm	7.7μm	11.3μm
1.0	33.3	20.6	2.3	23.1	6.5	12.4	12.7	61.4	173	43.5
2.0	5.9	3.7	0.4	4.1	1.2	2.2	2.3	10.9	30.8	7.7
3.0	2.2	1.4	0.2	1.5	0.4	0.8	0.8	4.1	11.4	2.9

Ratio to the total IR luminosity is taken from [a] Bonato et al. (2014), [b] Spinoglio et al. (2012) and [c] Pope et al. (2008).

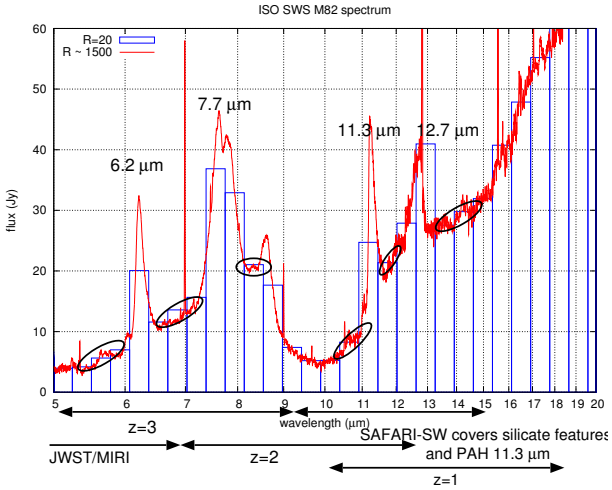

Figure 1. ISO SWS spectrum (R$\sim$ 1500) of M82 and SED (R=20). The locations of PAH features and continuum are superposed.

et al., 2012). The SMI imager is the camera part of the SMI with the following features: wide field of view (5'×5'), diffraction limited imaging capabllity, unique wavelength coverage of 20-36 μm beyond JWST/MIRI, contiguous coverage in the MIR wavelength region with 14 bandpass filters with R=20 (SED mode), and natural background (Zodiacal light) limited sensitivity, 24 μJy or 1×10^{-19} W/m^2 in 2'×2' survey with all the 14 SED mode filters (5σ 1 hour).

In this paper, we describe the PAH survey and examine whether R=20 is enough to use the PAH feature as "spectroscopic" redshift indicator and whether it is enough to determine the PAH/continuum ratio as an indicator of star-formation/AGN (Genzel, 1998).

2. THE PAH SURVEY

We plan a reference survey which covers 0.5 □° in 450 hour observational time (including time for filter change and telescope maneuver). In the survey, all the 14 SED mode filters are used in order to obtain contiguous wavelength coverage at 20-36 μm which corresponds to the 7.7 μm PAH feature at z=1.5-3.5. In this configuration, we obtain a sensitivity of 1×10^{-19} W/m^2 (5 σ) and the main PAH features (6.2, 7.7, and 11.3 μm) of ULIRGs can be detected at the target redshift (table 1). The expected number of galaxies detected by this survey is $\sim$ 3000 (LIRGs) and $\sim$ 400 (ULIRGs) at z=1-3 per Δz=0.5.

Table 2
Result of spectral fit (Ohyama et al.)

z_{in}	$3\times10^{11}L_\odot$ (M82x10)				$3\times10^{12}L_\odot$ (M82x100)			
	z_{fit}	PAH L_{in}/L_{out}			z_{fit}	PAH L_{in}/L_{out}		
		6.2	7.7	11.3		6.2	7.7	11.3
2.00	2.02	–	1.19	0.98	2.01	–	1.24	0.68
3.00	2.99	1.28	1.11	–	3.02	0.75	0.92	–
4.00	–	–	–	–	4.00	0.72	–	–

3. WHAT SPECTRAL RESOLUTION IS REQUIRED?

We have made two independent simulations to test whether R = 20 is sufficient to estimate the source redshift and their flux of PAH feature and continuum.

One is a photometric redshift (phot-z) method followed by a spectral fitting. An M82 spectrum scaled to a set of redshifts with expected background photon noise is fit by SED templates of 6 star-forming galaxies and 6 AGN in the photo-z fitting. The spectral fitting is done using the code developed for the AKARI unbiased slit-less spectroscopic survey program, SPICY (Ohyama et al in preparation). PAHs are fit by Lorentzian profiles. There are 11 free parameters: redshift, the fluxes and widths of the PAH features at 6.6, 7.7, 8.6, and 11.3 microns, and the coefficient and index of the power law continuum. The results are summarized in table 2. The redshift estimation accuracy is $\sim$ 2% and that of PAH flux is $\sim$ 30% for LIRGs at z=2-3 and ULIRGs at z=2-4.

The other is based on PAHFIT (Smith et al., 2007). Model spectra (Draine & Li, 2007) with the expected noise, convolved to R=15 and R=20, and redshifted between z=2 and z=3 are fit by PAHFIT. 50 of them are

prepared with different inter-band ratios. The accuracy of redshift determination is 3% and 1% for S/N=5 and 10. The systematic error in the PAH and continuum flux estimation is approximately 20% and 10% in R=15 and 20.

4. SUMMARY

We propose an unbiased PAH galaxy survey at z=2-4 which is complementary to the MIR/FIR line survey. A field of 0.5 $\square^\circ$ can be surveyed in 450 hours with 1×10^{-19} W/m^2 sensitivity (5 σ) by SPICA/SMI-Imager at 20-36 μm with R=20. More than 1000 ULIRGs and 10000 LIRGs at z=2-4 will be detected. PAHFIT simulations show R=20 is the minimum resolution for 10% accuracy of PAH and continuum flux estimation.

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