# A SPICA FAR-IR INSTRUMENT SAFARI Yasuo Doi<sup>1</sup>, Peter R. Roelfsema<sup>2</sup>, and the SAFARI consortium<sup>3</sup>

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#### Abstract

SAFARI (SpicA FAR-infrared Instrument) consists of two main functions, namely SAFARI/SPEC and SAFARI/SPEC is a powerful spectrum mapping machine that covers  $34-230\mu m$ , where we can observe many important gas diagnostic lines of distant galaxies and reveal their evolutional histories. A grating spectroscopy mode with  $R \sim 300$  achieves a high sensitivity of  $6 \sim 8 \times 10^{-20}$  [Wm<sup>-2</sup>], which enables us to study not only exotic bright galaxies but also main-stream galaxies from  $z \simeq 3$  to the present. By adding a Martin-Puplett Fourier spectrometer to its optical path, SAFARI/SPEC achieves higher spectral resolutions of  $R = 11000 (34 \mu \text{m})$  to  $R = 1500 (230 \mu \text{m})$  with a comparable sensitivity of  $1 \times 10^{-19}$  [Wm<sup>-2</sup>] to its base spectroscopy mode. TES detector with ultra-low noise (NEP =  $1 - 2 \times 10^{-19}$  [W/ $\sqrt{\text{Hz}}$ ]) is being fabricated to achieve the ultra-high sensitivity of SAFARI/SPEC. SAFARI/POL is a unique instrument that has a polarimetric/photometric mapping capability at  $100\mu m$ ,  $200\mu m$  and  $350\mu m$ . The prime science driver for SAFARI/POL is the polarimetric mapping of Galactic filamentary structures. Polarisation-sensitive Si bolometer-array detectors with  $3 \times 10^{-18} [W/\sqrt{Hz}]$  gives us a high dynamic range sensitivity that is required for observations of Galactic extended emissions. We present the details of the instrument specifications that is being proposed as the candidate ESA M5 mission.

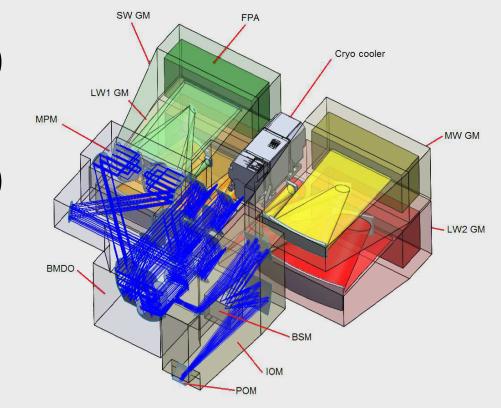
### SAFARI SPEC & POL

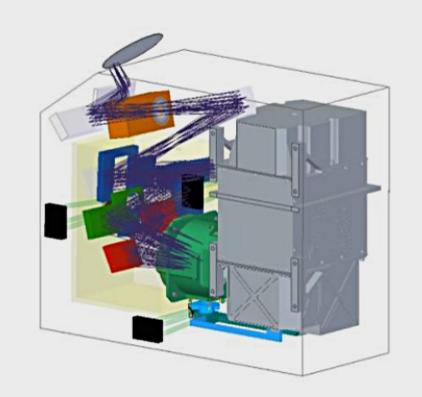
**SAFARI/SPEC** – high sensitivity grating spectrometer • Basic  $R \simeq 300 \mod \rightarrow 5 \sim 7 \times 10^{-20} [\text{W m}^{-2}]$  (1hour,  $5\sigma$ )  $-[\text{OIV}] 25.9 \ \mu\text{m} \simeq 1 \sim 2 \times 10^{-20} \ [\text{W m}^{-2}]$  $(L \simeq 10^{11.5} \sim 10^{12} L_{\odot} @ z=3)$ 

- Martin Puplett Interferometer to provide High-R mode  $-R \simeq 1500 \sim 11000 \leftrightarrow \Delta V \simeq 200 \sim 30 \,[\mathrm{km \, s^{-1}}]$
- 4 bands instantaneously covering  $35 \sim 230 \ \mu m$  $-230 \ \mu \text{m} \leftrightarrow [\text{NII}] 57 \ \mu \text{m} @ \text{z=}3$
- Spatial Resolution: 3'' 21''

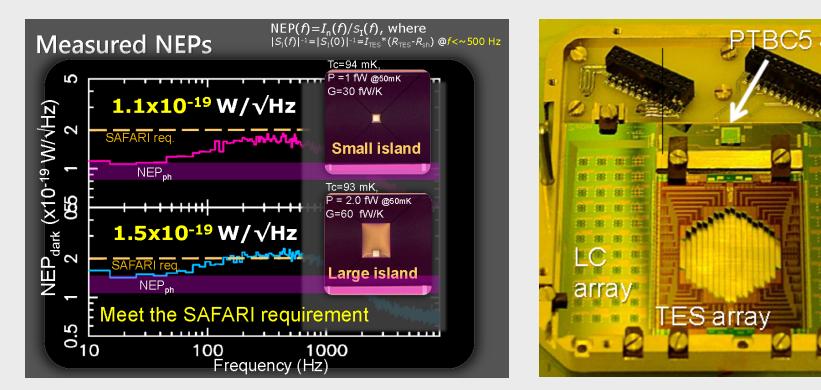
**SAFARI/POL** – imager polarimeter

- Polarization sensitive bolometers
- 3 bands centring at 110, 220, 350  $\mu$ m
- Spatial Resolution: 9'' 32''
- FOV:  $160'' \times 160''$  (for each band / overlapped)

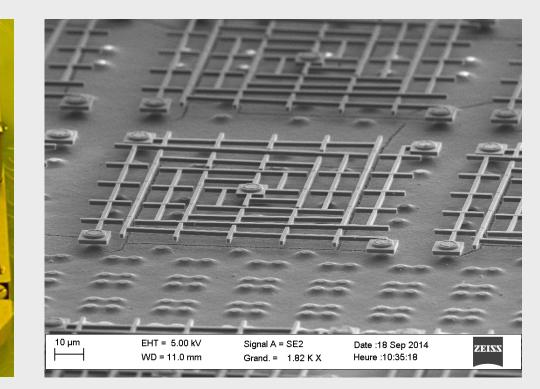




## Cutting-edge Detector Technologies



Recent TES detector developments: •  $NEP_{det} = 1 \times 10^{-19} \text{ W Hz}^{-1/2}$  for single pixels • successful  $\times 132$  FDM readout has been achieved



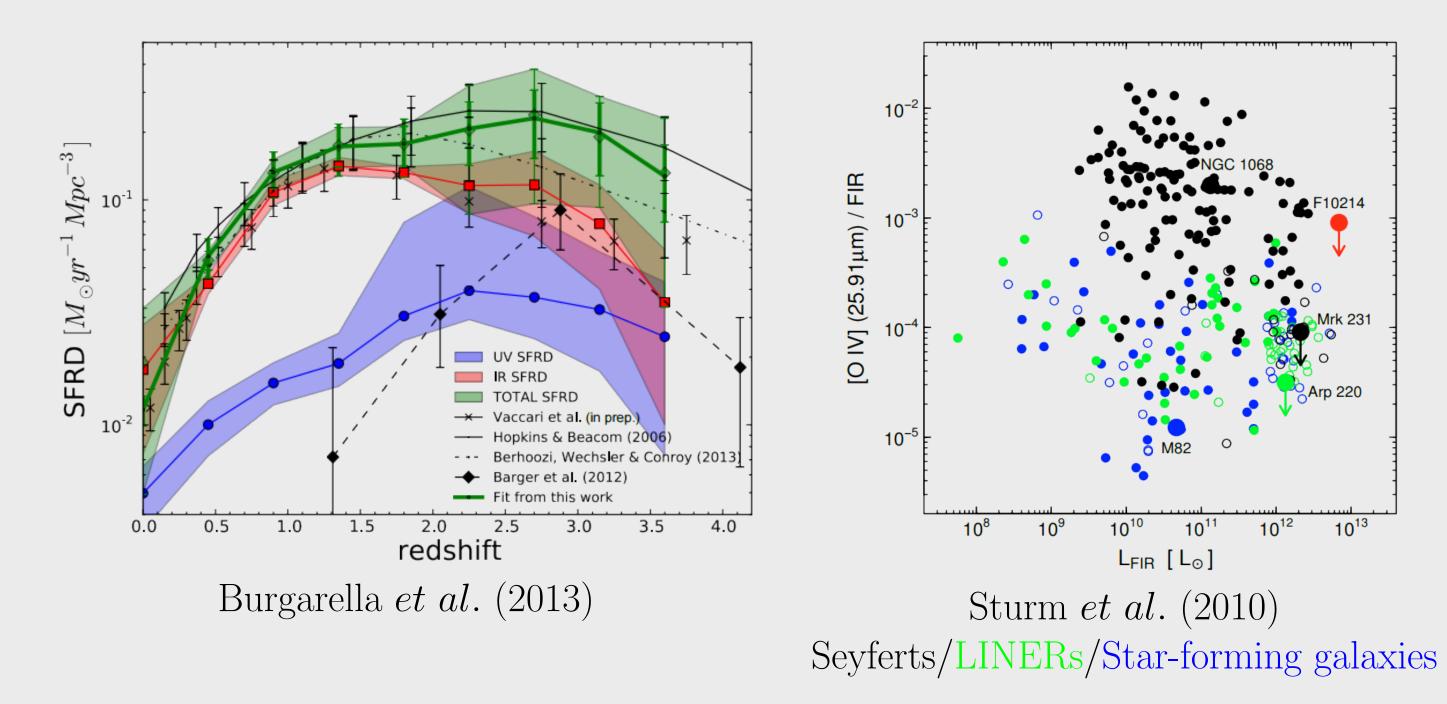
Polarisation-sensitive bolometer array with readout analogous to Herschel/PACS system



array

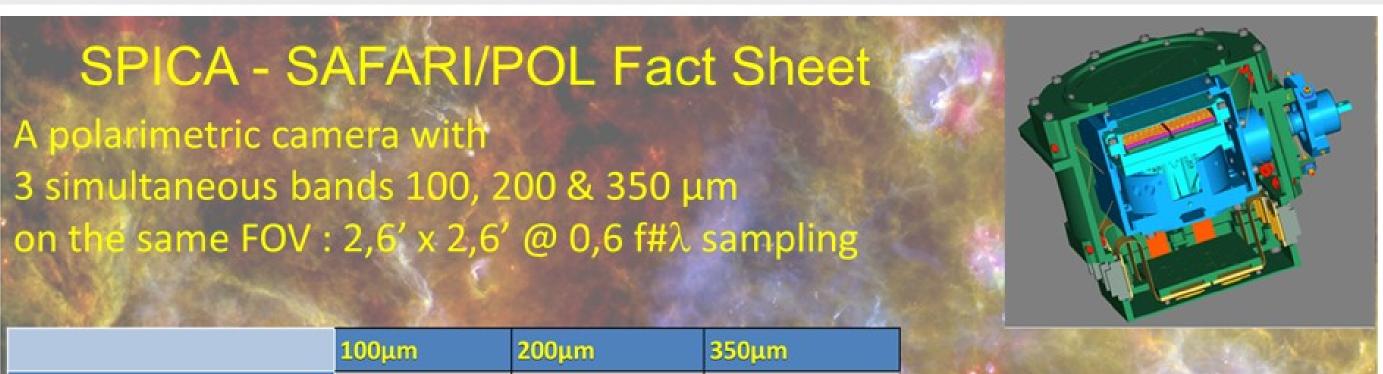
One of the key scientific objectives of the SPICA mission is to reveal the whole process of the galaxy evolution. SAFARI will detect key diagnostic lines and reveal physical conditions of distant galaxies at  $z \sim 1-3$ , where the star formation activities were of their peak, as well as nearby galaxies to reveal the variety of physical conditions at the present epoch.

Galaxy Evolution at  $z \sim 1 - 3$  to the Present

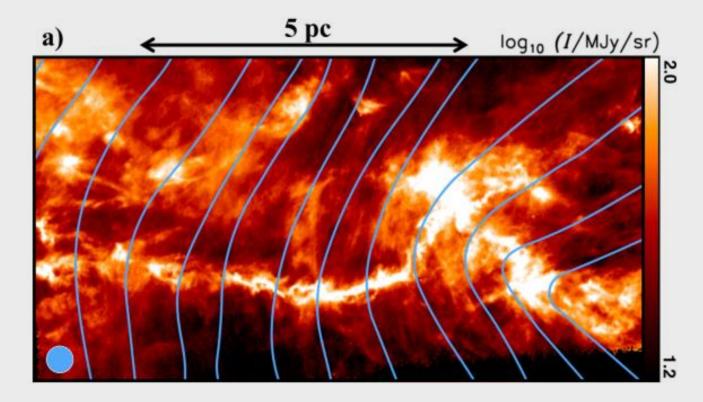


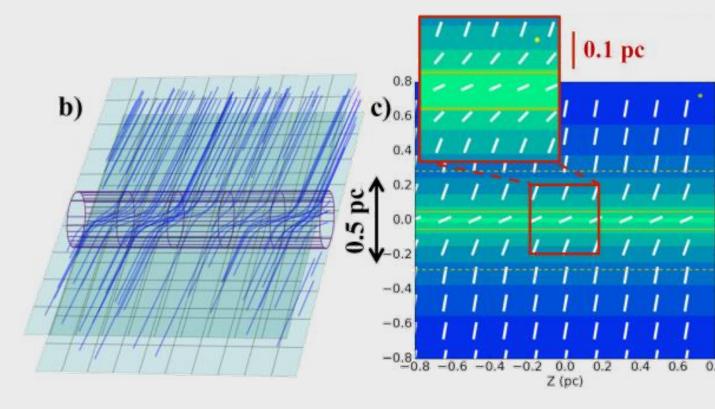
### Magnetic Field in Star-Formation Regions

Wavelength range / µm		34-56	54-89	64-89 87-143	140-230	System performance v.s. target flux density, relative to the
Ban	d centre beam FWHM	4.5″	7.2″	12″	19″	<ul> <li>background limited case</li> <li>The sensitivity decrease is due to the increased photon noise from the target source</li> <li>Data given up to the instrument saturation limits for each band (31, 51 and 87 Jy for the SW, MW and LW bands respectively.</li> </ul>
Po	oint source spectroscopy	(5σ-1hr	)			from the target source • Data given up to the
C.	Limiting flux / x10 <sup>-20</sup> Wm <sup>-2</sup>	7.2	6.6	6.6	8.2	each band (31, 51 and 87 Jy
L	Limiting flux density / mJy	0.31	0.45	0.72	1.44	for the SW, MW and LW bands see the sectively.
œ	Limiting flux / x10 <sup>-20</sup> Wm <sup>-2</sup>	13	13	13	15	
Η̈́	Limiting flux density / mJy	18	17	17	19	10 <sup>-3</sup> 10 <sup>-2</sup> 10 <sup>-1</sup> 10 <sup>0</sup> 10 <sup>1</sup> 10 Source flux density / Jy
Ma	apping spectroscopy* (50	o-1hr)				R SAFARI/HR resolution as
4	Limiting flux / x10 <sup>-20</sup> Wm <sup>-2</sup>	84	49	30	23	10000 function of wavelength
	Limiting flux density / mJy	3.6	3.3	3.3	4.1	8000
œ	Limiting flux / x10 <sup>-20</sup> Wm <sup>-2</sup>	189	113	73	51	6000
Η̈́	Limiting flux density / mJy	253	151	97	67	4000
Ph	notometric mapping* (50	σ-1hr)				2000
Lim	niting flux density / µJy	209	192	194	239	2000
Co	nfusion limit (5σ)	15 µJy	200 µJy	2 mJy	10 mJy	ολ
5	RON Sensitivities * Mapping pe	based on dete erformance is	ector NEP 2× for a referen	10 <sup>-19</sup> W/√H; iœ area of 1	z . arcmin²	30 80 130 180 230 280 (µm
	SAFARI					SAFARI GS Factsheet V1.0 – 30th September 20



SAFARI/POL will unveil the significant role of magnetic fields in the star-formation process by imaging the magnetic field lines in interstellar media of degree-wide areas with 30 times better resolution comparing to Planck.





Interstellar magnetic field observed by Planck superposed on interstellar filaments observed by Herschel (a). Simulated magnetic field in filamentary structure (b) and its synthetic polarisation map on the sky (c). Figures are cited from the SPICA M5 proposal document.

Band edges	75—125µm	150—250µm	280—420µm	
# of pixels	32 x 32 (x 2)	16 x 16 (x 2)	8 x 8 (x 2)	log <sub>10</sub> (1
Pixel size	5" x 5"	10" x 10"	20" x 20"	
Band centre beam FWHM	9"	18"	32"	
PS sensitivity 5σ/1h/FOV (unpolarised)	21µЈу	42μJγ	85µJy	
PS sensitivity in Stokes (Q,U) 5σ/1h/FOV (polarised)	30µЈу	60µJy	120µЈу	Cutton to the formation
PS sensitivity 5σ/10h/1deg² (unpolarised)	0.16 mJy	0.32 mJy	0.65 mJy	All the second
PS sensitivity in Stokes (Q,U) 5σ/10h/1deg <sup>2</sup> (polarised)	0.23 mJy	0.46 mJy	0.92 mJy	1 pc
Surface brightness sensitivity 50/10h/1deg <sup>2</sup> (unpolarised)	0.09 MJy/sr	0.045 MJy/sr	0.025 MJy/sr	and the second sec
Sensitivity to map Stokes parameters (Q,U) at 5% level	2.5 MJy/sr	1.25 MJy/sr	0.7 MJy/sr	The filamentary structure of

