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A SPICA far-IR instrument SAFARI

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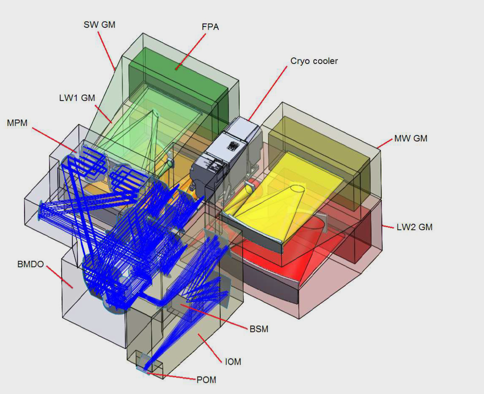
Abstract

SAFARI (SpicA FAR-infrared Instrument) consists of two main functions, namely SAFARI/SPEC and SAFARI/POL. SAFARI/SPEC is a powerful spectrum mapping machine that covers 34–230μm, 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^{-2}], 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 $R = 11000$ (34μm) to $R = 1500$ (230μm) with a comparable sensitivity of 1×10^{-19} [Wm^{-2}] 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 100μm, 200μm and 350μm. The prime science driver for SAFARI/POL is the polarimetric mapping of Galactic filamentary structures. Polarisation-sensitive Si bolometer-array detectors with 3×10^{-18} [W/$\sqrt{\text{Hz}}$] gives us a confusion-limited sensitivity with a high dynamic range that is required for observations of Galactic extended emissions. We present the details of the instrument specifications and expected scientific outcomes.

SAFARI SPEC & POL

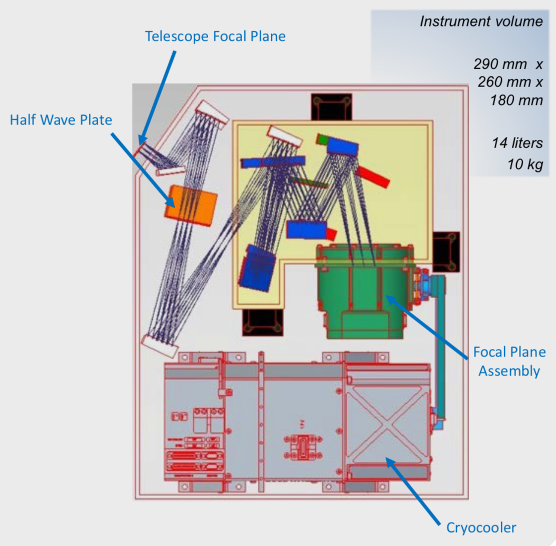
SAFARI/SPEC – high sensitivity grating spectrometer

- Basic $R \simeq 300$ mode $\rightarrow 7 \sim 8 \times 10^{-20}$ [W m^{-2}] (1hour, 5σ)
  – [OIV] 25.9 μm $\simeq 1 \sim 2 \times 10^{-20}$ [W m^{-2}] ($L \simeq 10^{11.5} \sim 10^{12} L_\odot$ @ z=3)
- Martin Puplett Interferometer to provide High-R mode
  – $R \simeq 1500 \sim 11000 \leftrightarrow \Delta V \simeq 200 \sim 30$ [km s^{-1}]
- 4 bands instantaneously covering $35 \sim 230$ μm
  – 230 μm $\leftrightarrow$ [NIII] 57 μm @ z=3
- Spatial Resolution: $3'' - 21''$



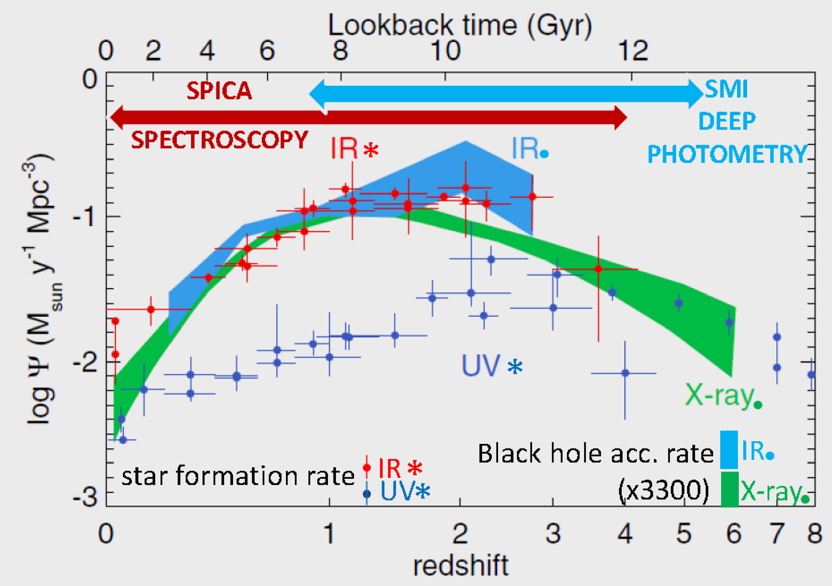
SAFARI/POL – imager polarimeter

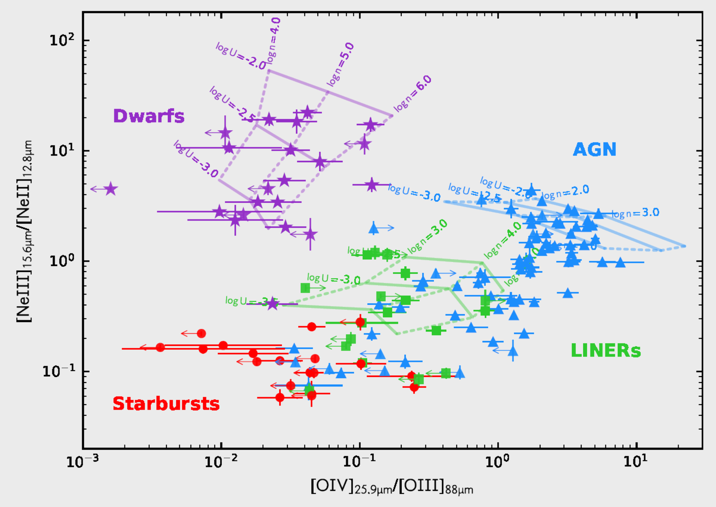
- Polarization sensitive bolometers at 100, 200, and 350 μm
- > 8000 detector dynamic range
- Confusion-limited photometric sensitivity
- $1° \times 1°$ mapping in a few $\sim$ 10 hours



Galaxy Evolution at z$\sim 1-4$ to the Present

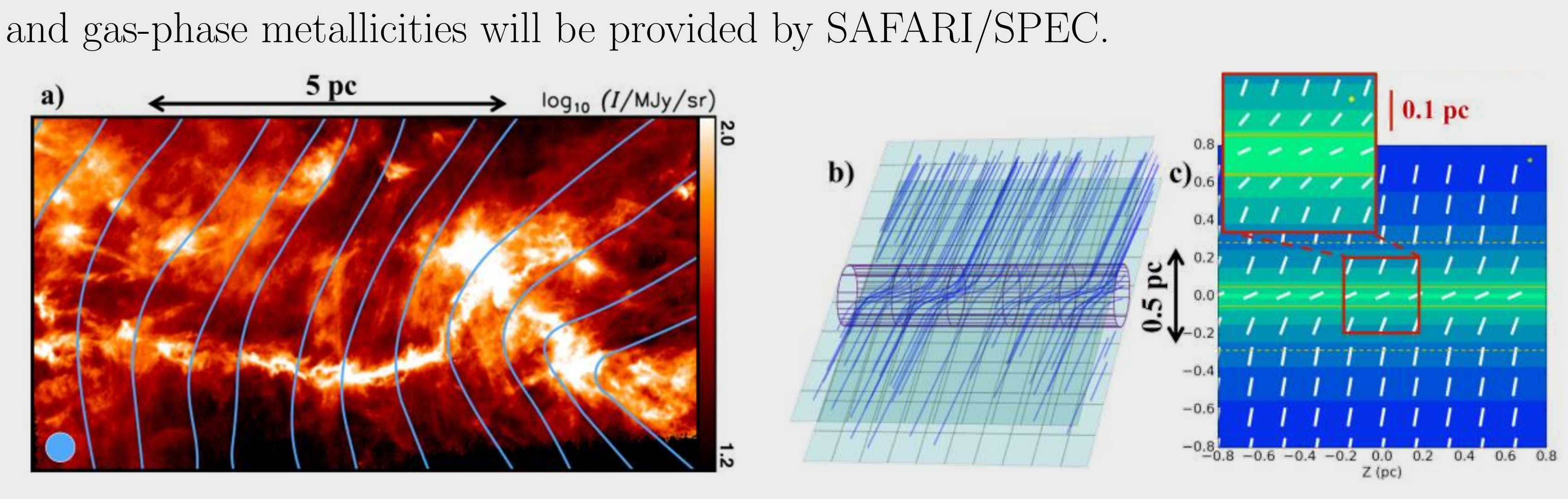
SPICA's large-area deep spectrophotometric surveys will provide large samples of the star-formation rate and black hole accretion rate histories of galaxies, reaching lookback times of 12 Gyr. Densities, temperatures, radiation fields and gas-phase metallicities will be measured in galaxies with a large range of mass and luminosity from faint local dwarf galaxies to luminous quasars in the distant Universe, to uncover AGN and starburst feedback and their feeding mechanisms (Spinoglio *et al.*, 2017).





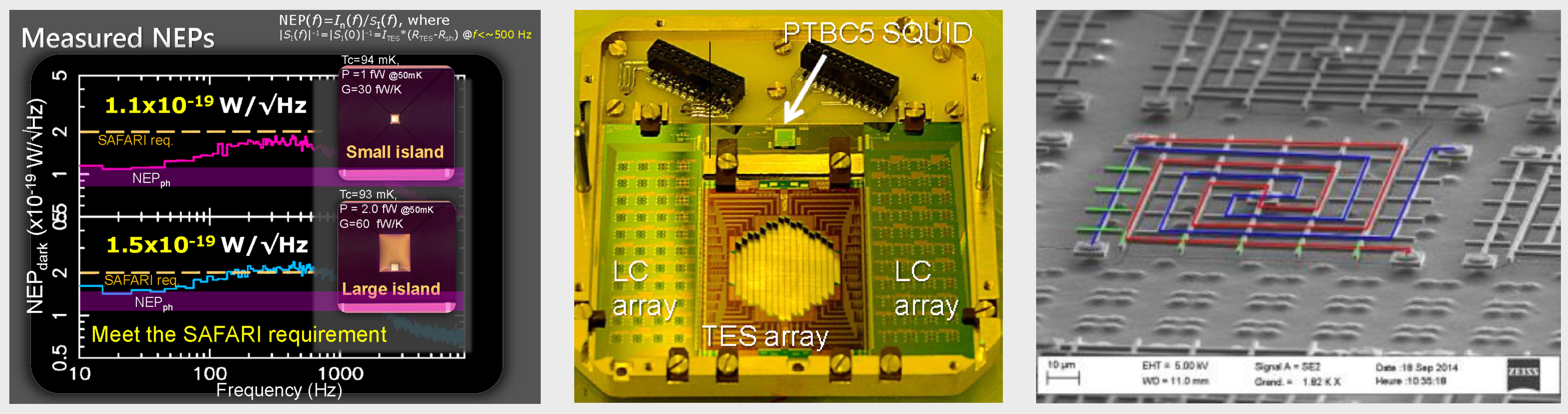
Magnetic Field in Star-Formation Regions

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 a confusion-limited sensitivity and 30 times better spatial resolution comparing to Planck. Critical information of interstellar media such as densities, temperatures, radiation fields and gas-phase metallicities will be provided by SAFARI/SPEC.



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.

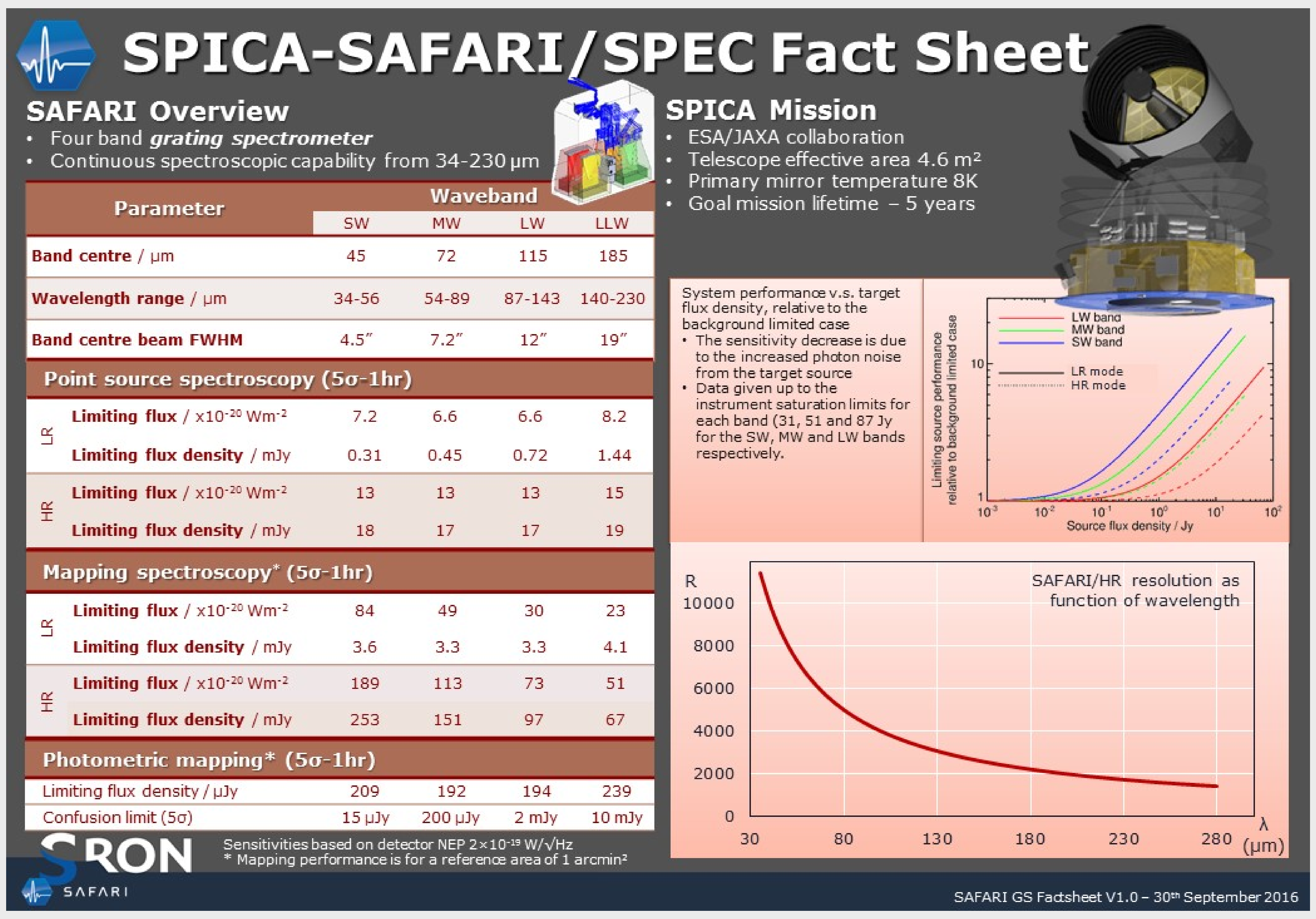
Cutting-edge Detector Technologies



Recent TES detector developments:

- $NEP_{det} = 1 \times 10^{-19}$ W Hz$^{-1/2}$ for single pixels
- successful demonstration of $\times 176$ pixel FDM readout

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



SPICA-SAFARI/SPEC Fact Sheet

SAFARI Overview
- Four band ***grating spectrometer***
- Continuous spectroscopic capability from 34-230 μm

SPICA Mission
- ESA/JAXA collaboration
- Telescope effective area 4.6 m²
- Primary mirror temperature 8K
- Goal mission lifetime – 5 years

Parameter		Waveband SW	MW	LW	LLW
Band centre / μm		45	72	115	185
Wavelength range / μm		34-56	54-89	87-143	140-230
Band centre beam FWHM		4.5″	7.2″	12″	19″
Point source spectroscopy (5σ-1hr)					
LR	Limiting flux / x10⁻²⁰ Wm⁻²	7.2	6.6	6.6	8.2
LR	Limiting flux density / mJy	0.31	0.45	0.72	1.44
HR	Limiting flux / x10⁻²⁰ Wm⁻²	13	13	13	15
HR	Limiting flux density / mJy	18	17	17	19
Mapping spectroscopy* (5σ-1hr)					
LR	Limiting flux / x10⁻²⁰ Wm⁻²	84	49	30	23
LR	Limiting flux density / mJy	3.6	3.3	3.3	4.1
HR	Limiting flux / x10⁻²⁰ Wm⁻²	189	113	73	51
HR	Limiting flux density / mJy	253	151	97	67
Photometric mapping* (5σ-1hr)					
Limiting flux density / μJy		209	192	194	239
Confusion limit (5σ)		15 μJy	200 μJy	2 mJy	10 mJy

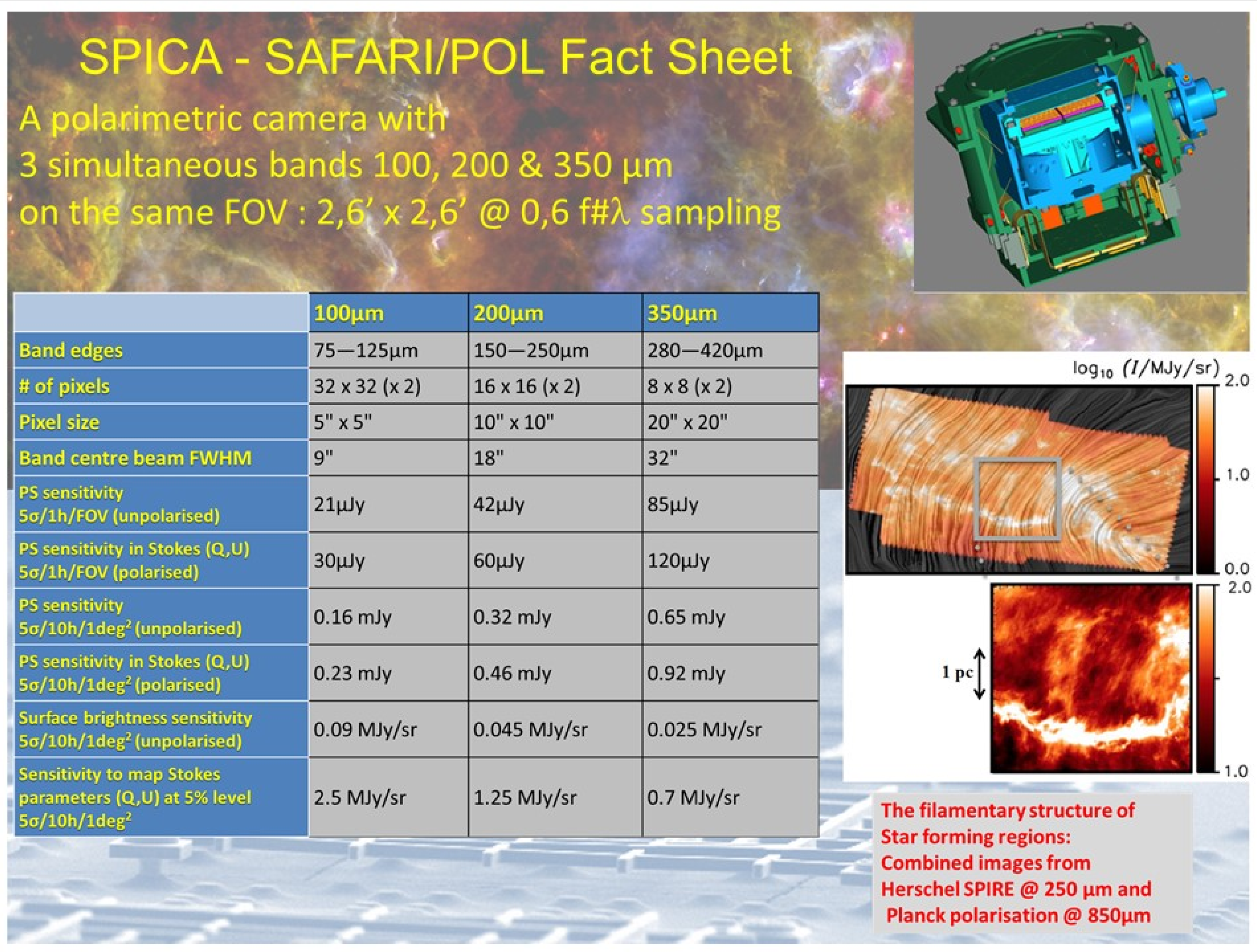
System performance v.s. target flux density, relative to the background limited case
- The sensitivity decrease is due to the increased photon noise from the target source
- Data given up to the instrument saturation limits for each band (31, 51 and 87 Jy for the SW, MW and LW bands respectively.

SAFARI/HR resolution as function of wavelength

Sensitivities based on detector NEP 2×10⁻¹⁹ W/√Hz
* Mapping performance is for a reference area of 1 arcmin²

SRON SAFARI

SAFARI GS Factsheet V1.0 – 30th September 2016



SPICA - SAFARI/POL Fact Sheet

A polarimetric camera with
3 simultaneous bands 100, 200 & 350 μm
on the same FOV : 2,6′ x 2,6′ @ 0,6 f#λ sampling

	100μm	200μm	350μm
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)
Pixel size	5" x 5"	10" x 10"	20" x 20"
Band centre beam FWHM	9"	18"	32"
PS sensitivity 5σ/1h/FOV (unpolarised)	21μJy	42μJy	85μJy
PS sensitivity in Stokes (Q,U) 5σ/1h/FOV (polarised)	30μJy	60μJy	120μJy
PS sensitivity 5σ/10h/1deg² (unpolarised)	0.16 mJy	0.32 mJy	0.65 mJy
PS sensitivity in Stokes (Q,U) 5σ/10h/1deg² (polarised)	0.23 mJy	0.46 mJy	0.92 mJy
Surface brightness sensitivity 5σ/10h/1deg² (unpolarised)	0.09 MJy/sr	0.045 MJy/sr	0.025 MJy/sr
Sensitivity to map Stokes parameters (Q,U) at 5% level 5σ/10h/1deg²	2.5 MJy/sr	1.25 MJy/sr	0.7 MJy/sr

The filamentary structure of Star forming regions: Combined images from Herschel SPIRE @ 250 μm and Planck polarisation @ 850μm

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