The SAFARI Imaging Spectrometer for the SPICA space observatory

From planets to galaxies, revealing the origins of the universe.

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The Japanese *SPace Infrared telescope for Cosmology and Astrophysics*, **SPICA**, will provide astronomers with a long awaited new window on the universe. Having a large cold telescope cooled to only 6K above absolute zero, SPICA will provide a unique environment where instruments are limited only by the cosmic background itself. A consortium of European and Canadian institutes has been established to design and implement the *SpicA FAR infrared Instrument* **SAFARI**, an imaging spectrometer designed to fully exploit this extremely low far infrared background environment provided by the SPICA observatory.

SAFARI's large instantaneous field of view combined with the extremely sensitive Transition Edge Sensing detectors will allow astronomers to very efficiently map large areas of the sky in the far infrared – in a square degree survey of a 1000 hours many thousands of faint sources will be detected. A large fraction of these sources will be fully spectroscopically characterised by the instrument. Efficiently obtaining such a large number of complete spectra will be essential to address several fundamental questions in current astrophysics: how do galaxies form and evolve over cosmic time?, what is the true nature of our own Milky Way?, and why and where do planets like those in our own solar system come into being?

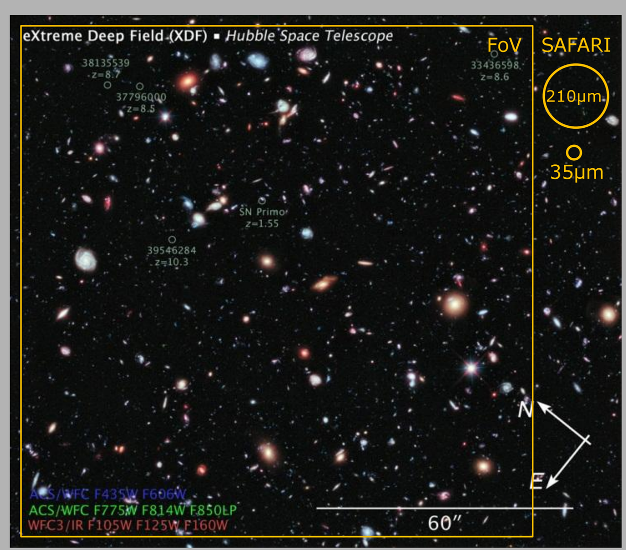
SAFARI science – the multi-colored universe

The key science drivers for SAFARI

How do stars and galaxies form and evolve over cosmic ages?
SAFARI will be used to observe thousands of obscured, far away galaxies and determine what processes govern their evolution

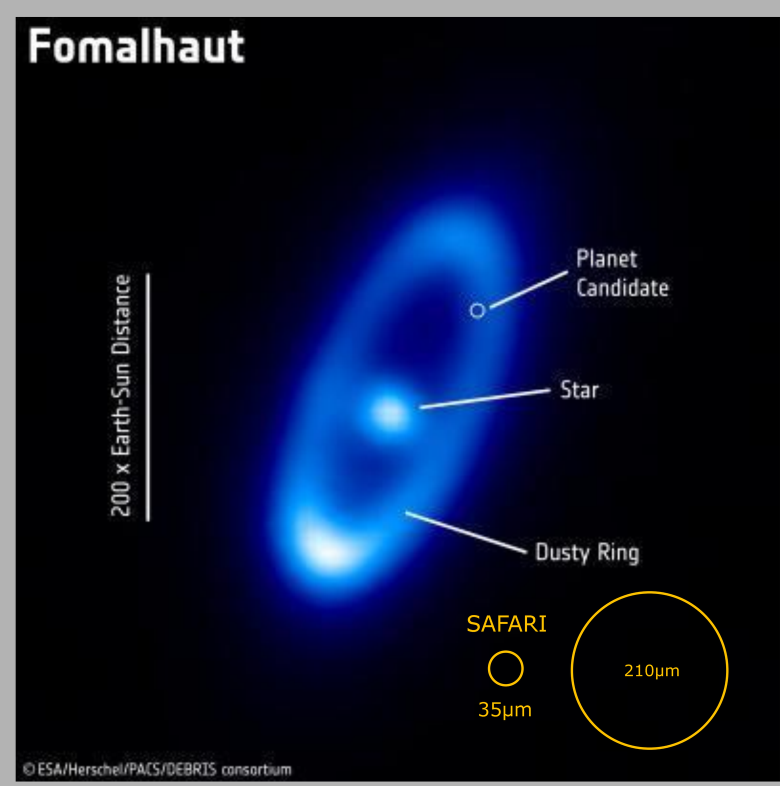
How does our solar system relate to other planetary systems and could life evolve elsewhere?
SAFARI will characterize oxygen, water, ice and rock in young planet forming systems and study their relation to the rocks and ice in our own Solar System

Herschel-PACS (left) and Hubble images of the colliding galaxy pair "the Antennae". Regions that are obscured in the Hubble image appear bright in the far-infrared. These are likely sites of massive star formation triggered by the collision. SAFARI will provide a full 34-210 μm spectrum at every pixel. (credit ESA / PACS / SHINING / U. Klaas & M. Nielbock, MPIA).

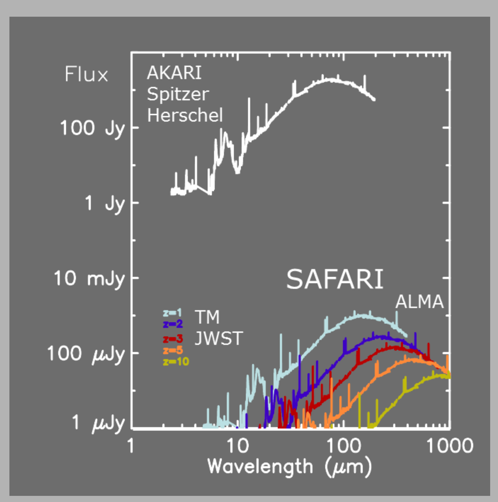


The Hubble eXtreme Deep Field (or XDF), assembled by combining 10 years of NASA Hubble Space Telescope photographs taken of a patch of sky in the constellation Fornax. XDF reveals about 5,500 galaxies, both nearby and very distant, making it the deepest image of the universe. The faintest galaxies are one ten-billionth the brightness of what the human eye can see.

Herschel-PACS image of the debris ring surrounding the nearby star Fomalhaut. The ring is caused by colliding rocky bodies, probably similar to those in the solar system Kuiper belt. A planet is believed to be responsible for stirring the debris ring. SAFARI will be used to obtain spectroscopic maps of these kinds of sources, allowing detailed studies of the mineral, molecular and atomic constituents across such a disk.

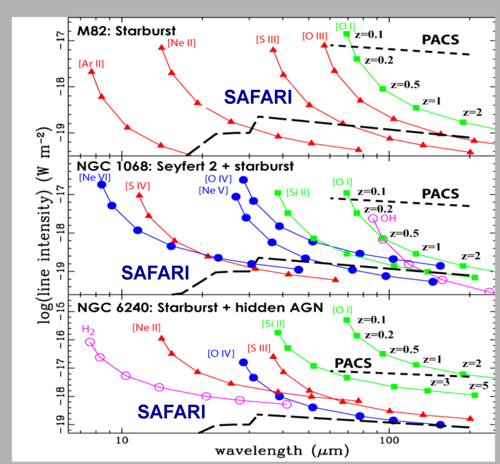


Tracing the evolution of galaxies over cosmic time



The spectra of high redshift, i.e. far away and old galaxies, become weaker and shift to the far infrared. These weak, 'red' sources are best studied in the domain of SAFARI.

By taking spectra of *thousands* of galaxies out to high redshift, the evolution of these objects over cosmic timescales can be followed. SAFARI will readily detect atomic and molecular lines, and possibly even PAHs out to redshifts of 3 to 4. This will allow us to determine which of the different formation and evolution processes is the dominant one; star formation or black hole matter accretion.

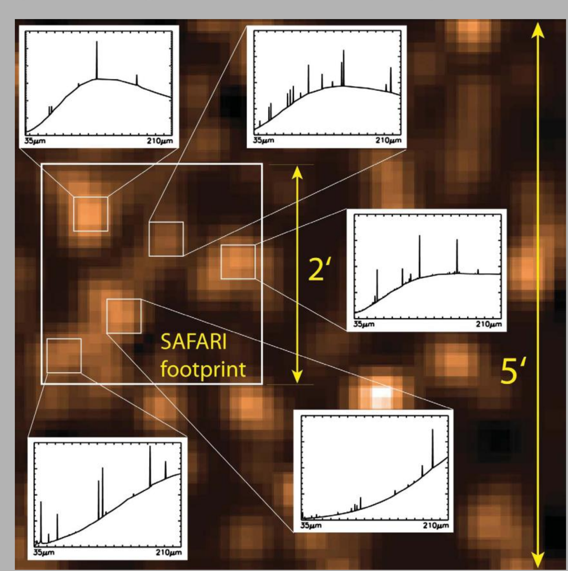


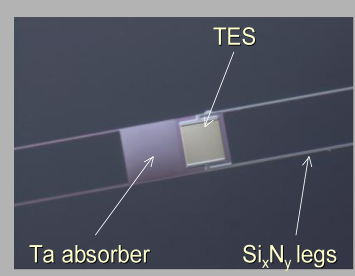
With SAFARI the ionic lines – fundamental tracers of star formation – can be detected for many galaxies out to much higher redshift than is possible today.

The SAFARI instrument

The SAFARI instrument is an imaging Fourier Transform Spectrometer. It operates simultaneously in three wavelength bands to cover the 34-310μm range over the full field of view. Within one hour in a single field SAFARI will typically observe spectra for 5-7 individual sources, thus allowing large area surveys yielding data for many thousands of objects.

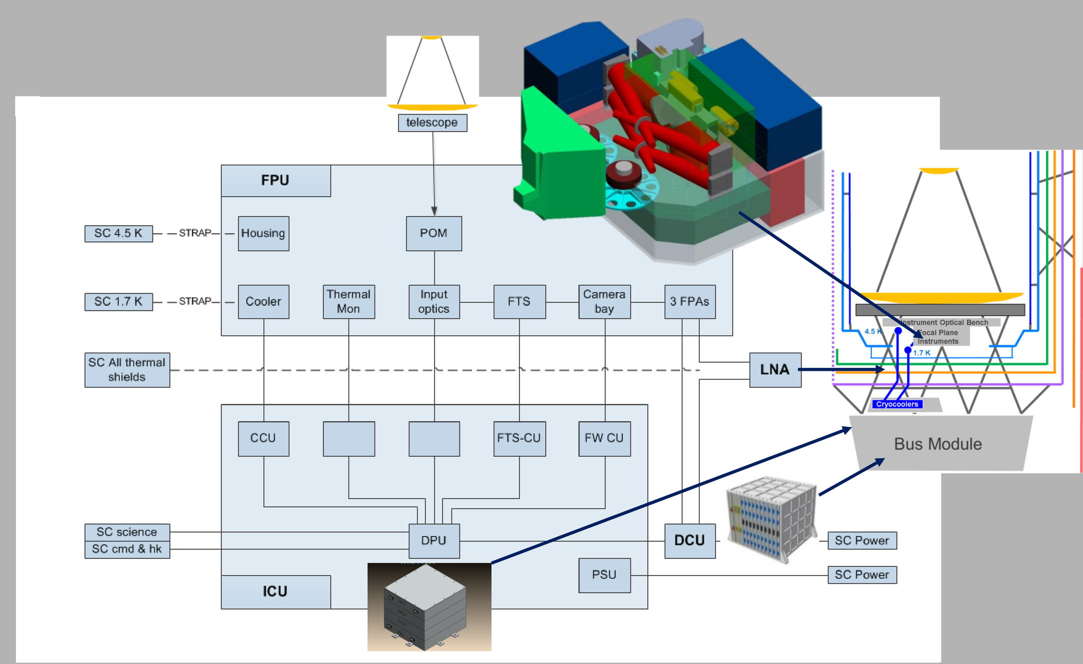
SAFARI top-level specifications	
Field of view	2' x 2' ~Nyquist sampled
modes:	
photometry	$\lambda/\Delta\lambda \sim 3$
SED mode	$\lambda/\Delta\lambda \sim 150 - 200$
spectroscopy	$\lambda/\Delta\lambda \sim 2000$
line sensitivity	few x 10^{-19} W/√Hz (5σ-1h)
continuum sens.	<20 μJy (5σ-1hr)
bright sources	up to 1 Jy without ND filter
3 bands:	
SW, 34-60 μm	43x43
MW, 60-110 μm	34x34
LW, 110-210 μm	18x18





To reach the extreme sensitivity needed to fully profit from the unique low background condition provided by the SPICA satellite, SAFARI uses Transition Edge Sensors operated at 50mK in the three detector arrays.

SAFARI is split in two major components – the optics and the detectors in the cold 4.5K focal plane unit, and the control and readout electronics in the SPICA service module.



From gas and dust to planets

SAFARI's study of protoplanetary disks; from ices to oceans. With SAFARI we can trace the presence dusty disks similar to our Kuiper Belt out to ~150 pc and provide a comprehensive inventory of stars with circumstellar disks for future planet imaging facilities. We will be able to study the transition from protoplanetary to debris disks which is of prime importance to understand the process of planet formation. We will resolve the *"snow line*" in nearby "Vega" disks and follow the main gas coolants and key chemical species (e.g. water, oxygen, organics) in proto-planetary disks.

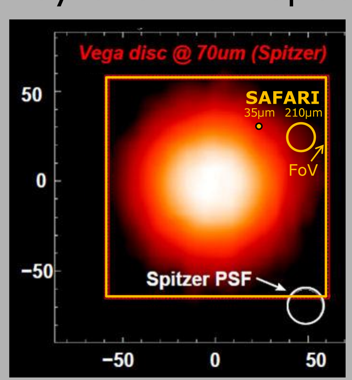
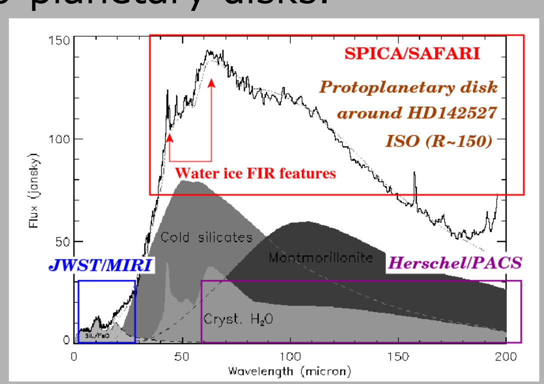


Image of Vega debris disk at 70um with Spitzer (Su et al. 2005). Spatial resolution equivalent to ~23 AU will be enough to detect the expected "snow-line" region at 42 AU with SPICA.



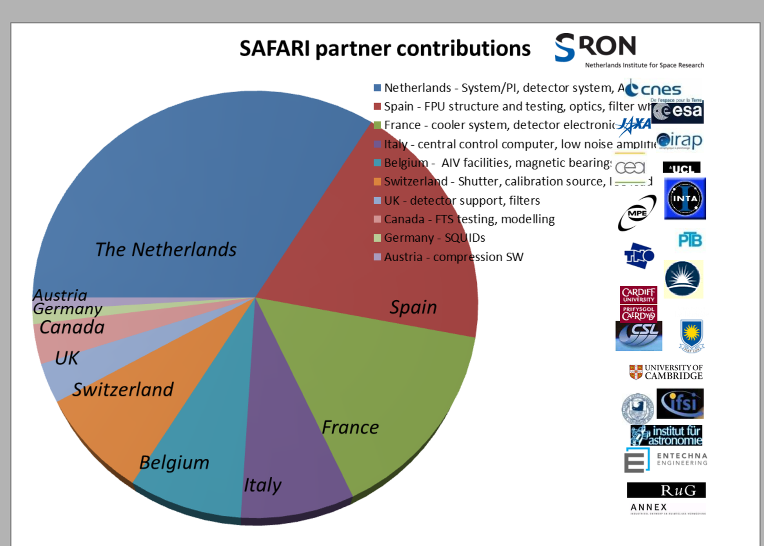
The ISO spectrum towards the young star HD142527 (Malfait et al. 1999) showing the components of the MIR/FIR disk emission. Water ices can be detected through the 43/62μm emission features.

The SAFARI Consortium

Partners from Europe and around the world have formed an international consortium, led by SRON, to jointly design and build the SAFARI instrument.

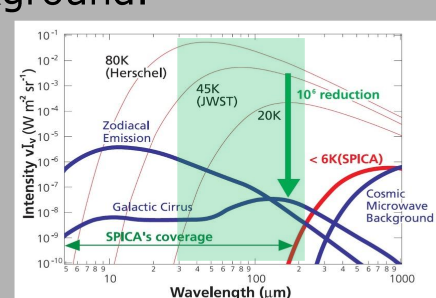
The Dutch participation in SAFARI funded in part through grant 184.032.209 from the NWO Roadmap for large scale research infrastructure.

www.sron.nl/safari



The SPICA satellite

The Japanese SPICA satellite, to be launched in 2022, will provide a 3 meter class 6K cold telescope. This will allow astronomers for the first time to also in the far infrared observe sources as weak as the celestial background.



www.ir.isas.jaxa.jp/SPICA/SPICA_HP