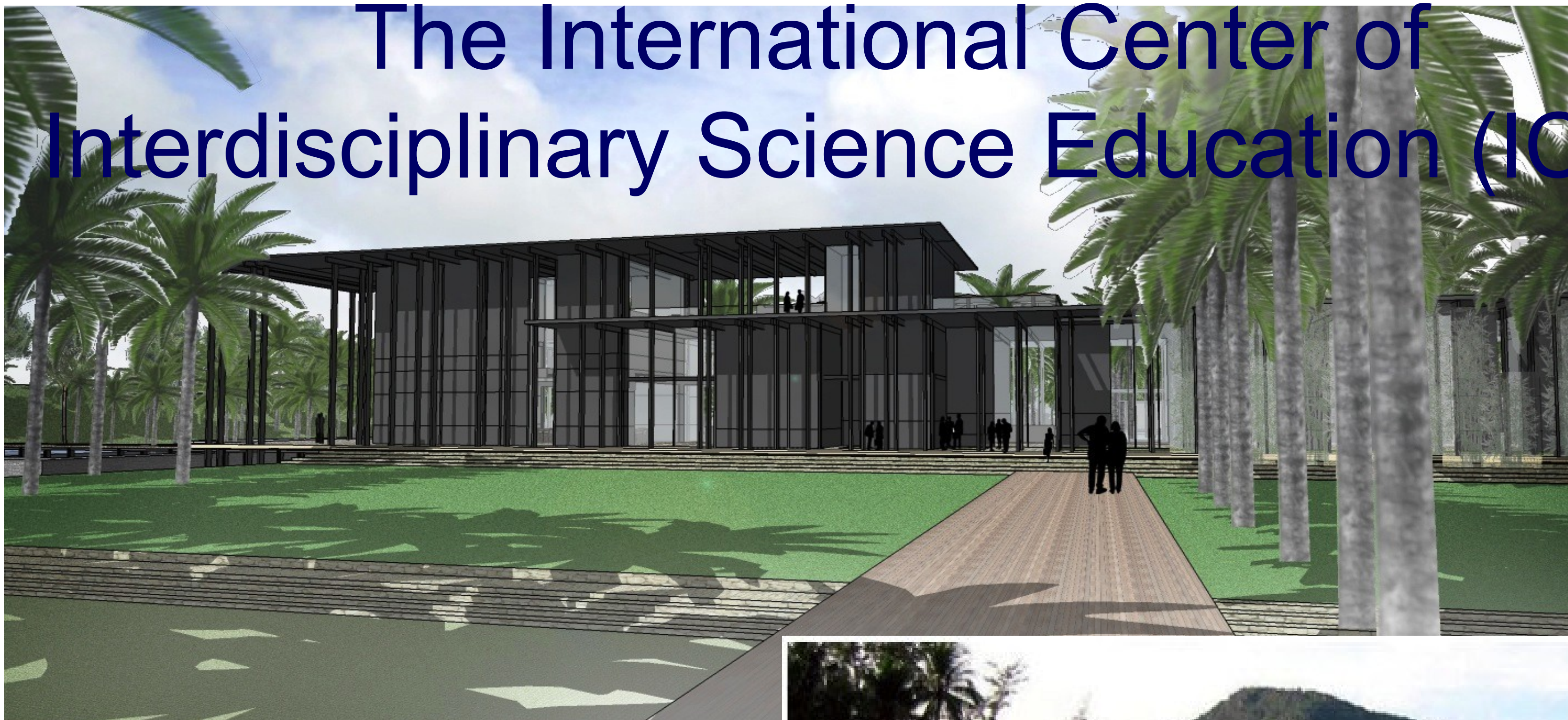
The International Center of Interdisciplinary Science Education (ICISE)



Trại phong Quy Hòa

lived and died Hàn Mạc Tử - prolific poet

Sub-arcsecond far-infrared space observatory: a new step to the understanding of the universe

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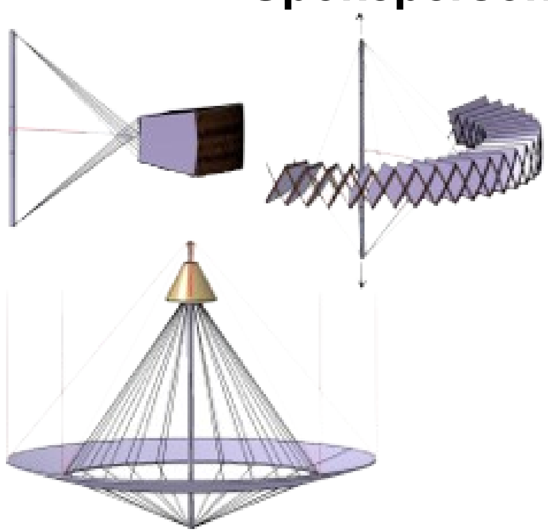
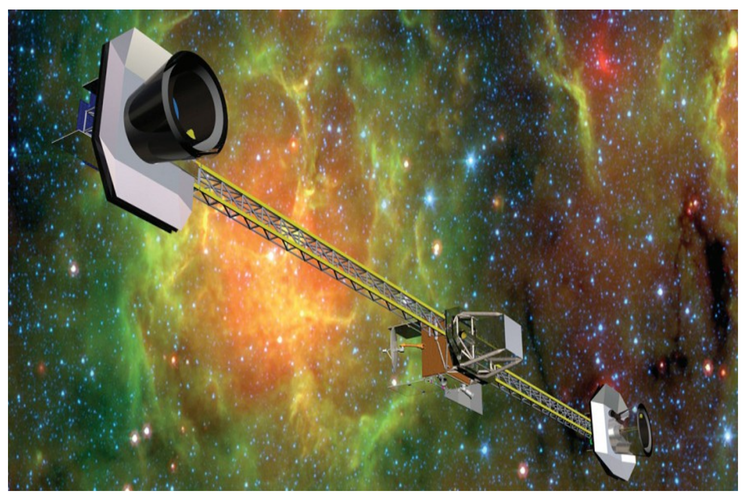
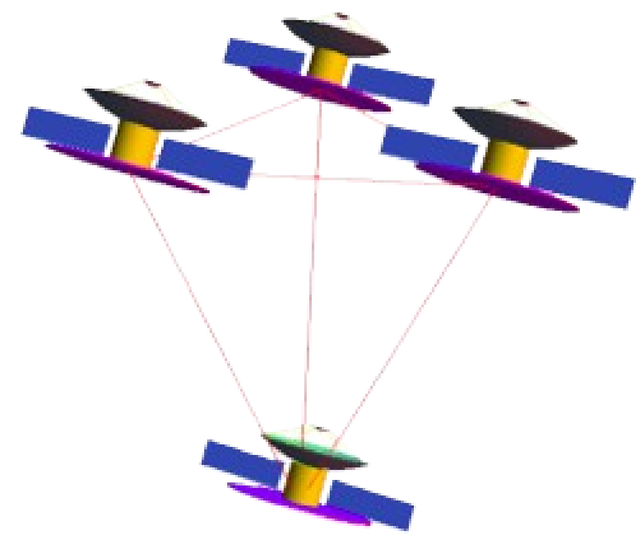
Canadian Institute for Theoretical Astrophysics
Toronto - Canada

FIRI project **www.firi.eu**
Spokeperson: Marc Sauvage (Service d'astrophysique, CEA Saclay, FR)







Windows on the Universe, Quy Nhơn, Việt Nam - 12-17 August 2013

Success of Herschel Space Observatory

Launched: 14 May, 2009
Ended: 29 April 2013
1446 ODs
3.5 m telescope, 3 instruments

Imaging instruments:
PACS: 70 or 100 and 160 μm
SPIRE: 250, 350, 500 μm
Resolutions: 5-36''

Spectroscopic instruments:
PACS: 60-210 μm (line imaging)
SPIRE: 194-672 μm (low spectral resolution)
HIFI: 212-625 μm (high spectral resolution)

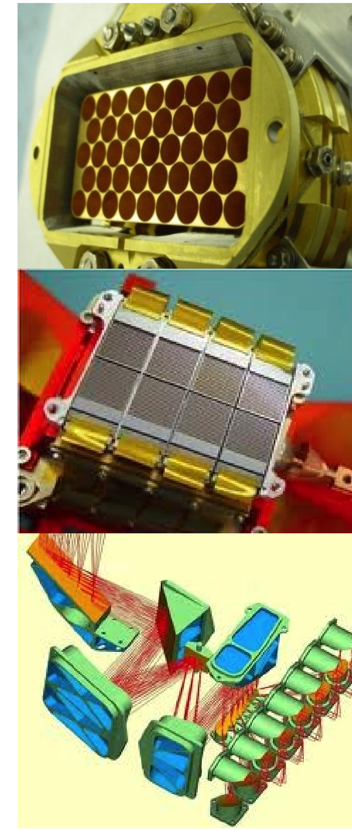
SPIRE

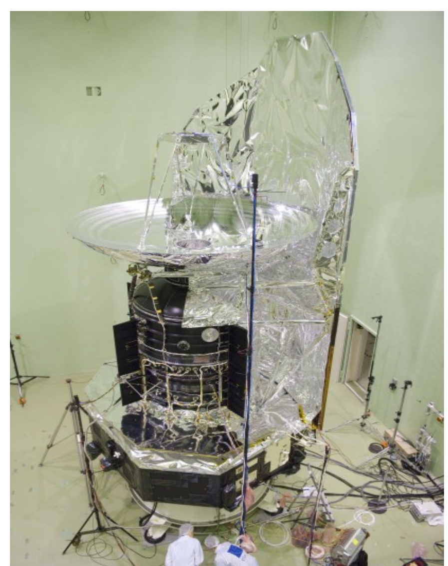
Spectral & Photometric Imaging REceiver

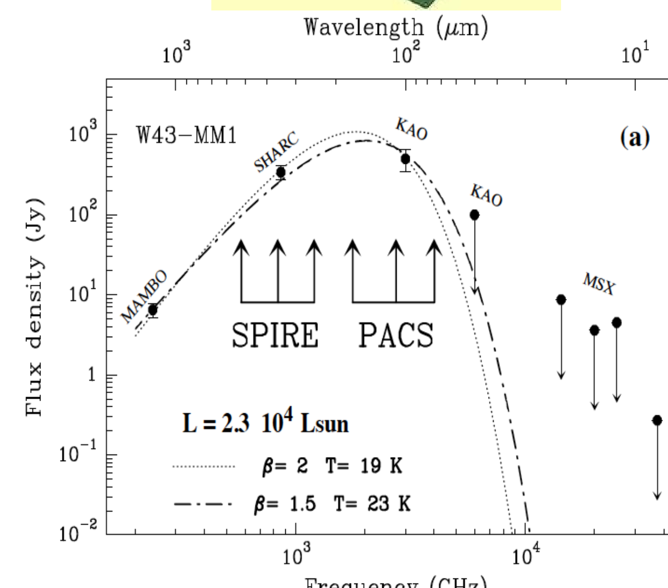
Photodetector Array Camera & Spectrometer

HiFi

Heterodyne Instrument for the Far-Infrared

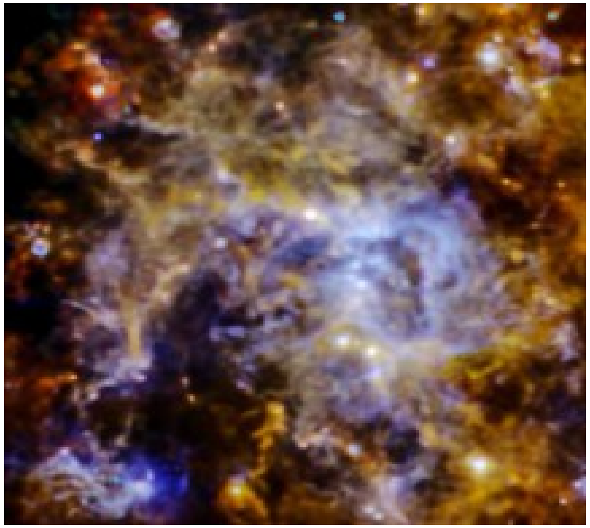




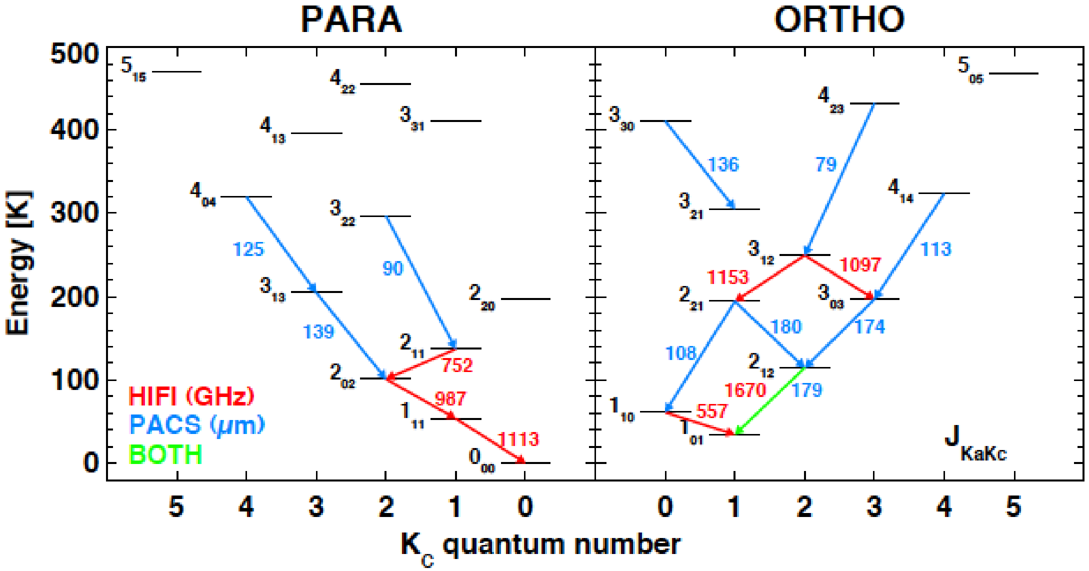


Success of Herschel Space Observatory: only in star formation

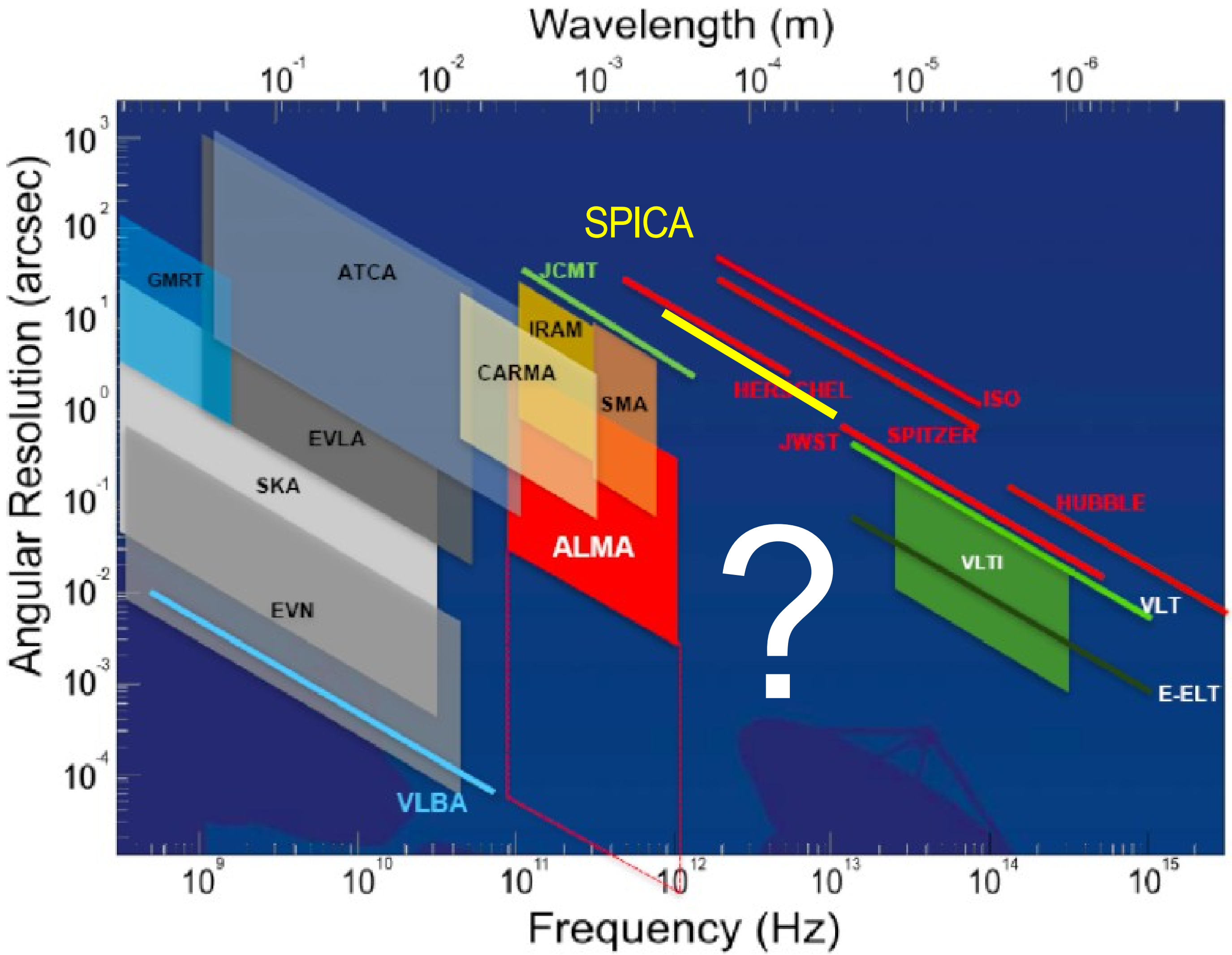
- Star formation:
  - Roles of filaments and ridges in star formation
  - CMF --> IMF
  - Nature of prestellar cores
  - Complete the evolutionary scenario of star formation from filaments to cores and to stars



- Chemistry in the ISM:
  - Roles of waters in protoplanetary disk/outflows, star formation
  - Discovery of the high abundance of CII in the galaxy
  - Discovery of SH, O_2, ND, HD,OH^+ and H_2O^+......



The need for a sub-arcsecond FIR observatory

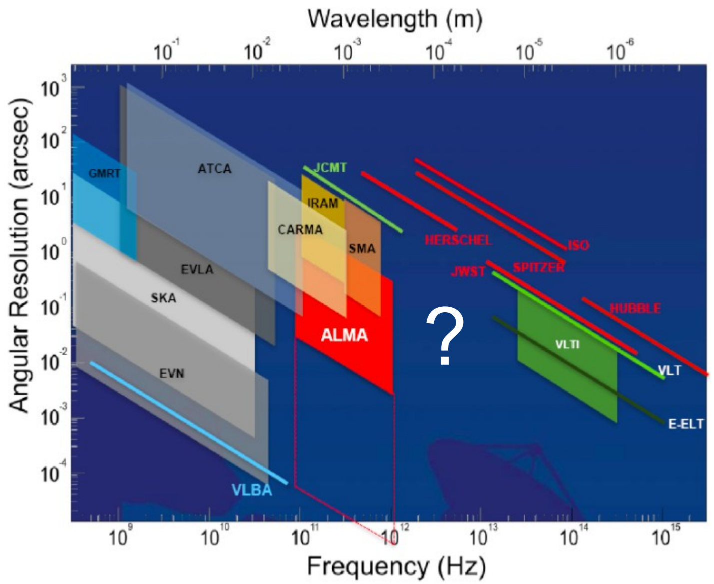


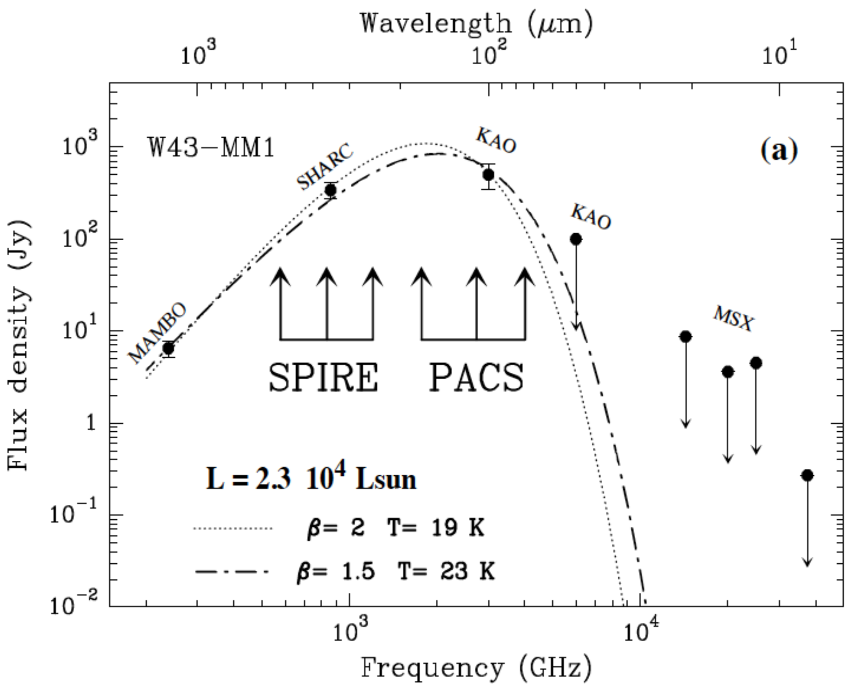
Future SPICA (PI: Japan): 30-200 μm, 1 or 2 order of magnitude more sensitive than Herschel but resolution is not much better

- Exploratory territory for a high-resolution FIR observatory:
  - Wavelength: 20 – 500 μm
  - Angular resolution: 0.1 – 1" at 100 μm
  - Launch time: end of 2020s, 2030s

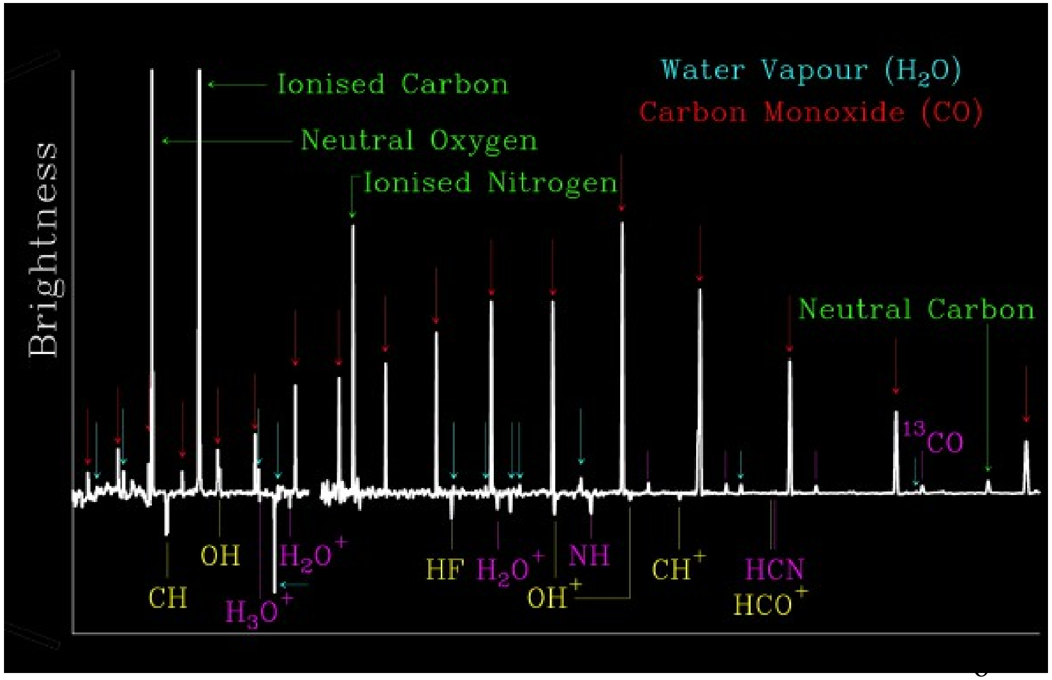
The need for a sub-arcsecond FIR observatory

- The FIR domain will present a severe gap in resolution and sensitivity between ALMA and JWST/E-ELT.
- The band maps on key tracers:
  - dust continuum peak, and features tracing composition and formation.
  - wide variety of molecular tracers including water, HD, and O_2.





Motte et al. (2010)



Goicoechea et al. (2012)

The need for a sub-arcsecond FIR observatory

Spectral resolution:

heterodyne: R = 10^{6-7}

medium:R = 1000 – 5000

SED: broadband

Science case	Resolution
Gas mass in disks	heterodyne
Water transport	heterodyne
Protoplanetary systems	SED, medium
Feedback	SED
Massive star formation	SED
Highlighting activity with water	heterodyne
Magnetic field	SED
Dust budget	SED, medium
Thermal balance	medium
Massive star formation	SED, medium
AGN/host relationship	medium
Galaxy and AGN co-evolution	medium
H_2 for galaxy evolution	medium
First stars	medium

Angular resolution: 0.1-1"

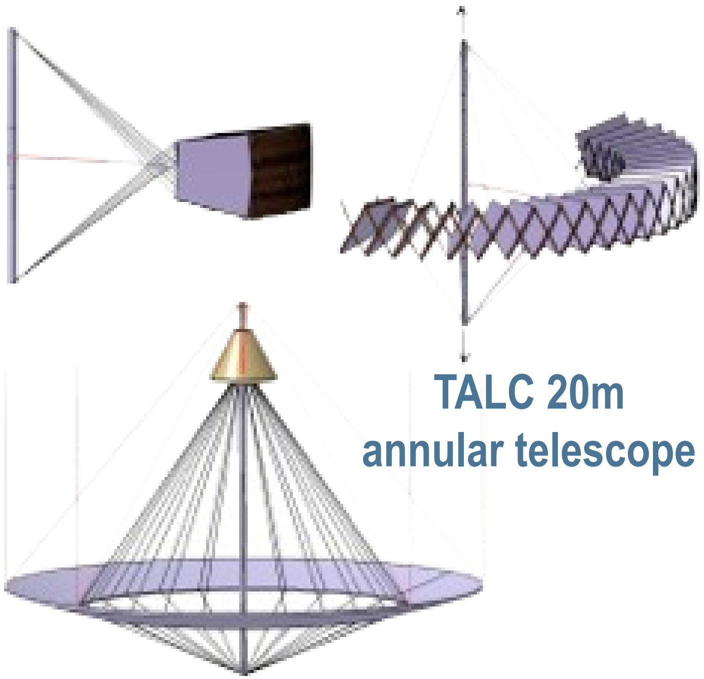
planet: 100 AU @ 1 kpc

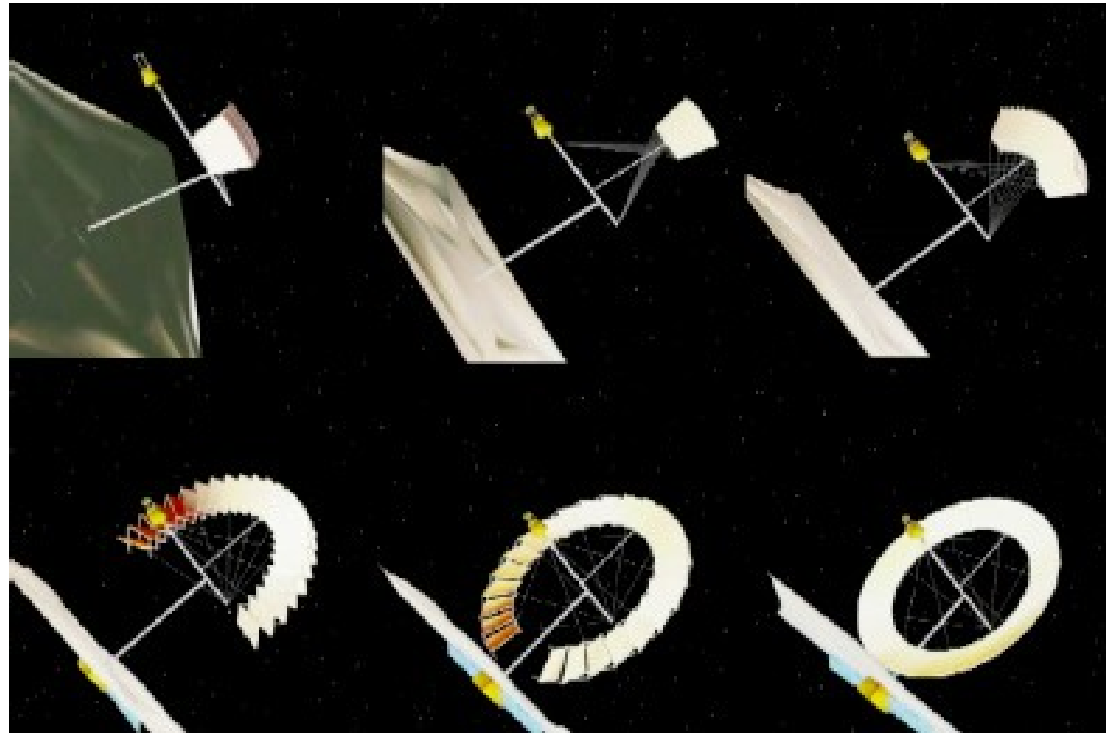
protostar: 0.1 pc @ 200 kpc

galaxy: 1 kpc @ 200 Mpc

- Addressing that angular resolution gaps accessing science cases such as:
  - Protoplanetary disks (gas mass available for planet formation, structure, composition including water content).
  - Star formation (structure formation, feedback processes, IMF at the high mass end, massive star formation scenario).
  - Nearby universe (dust formation, thermal balance in the ISM, IMF in external galaxies, AGN/host relationship including star formation quenching).
  - The evolving universe (co-evolution of galaxies and their central black holes, H_2 as a tracer for galaxy mass accretion and first stars).

Sub-arcsecond FIR observatory: telescope concepts

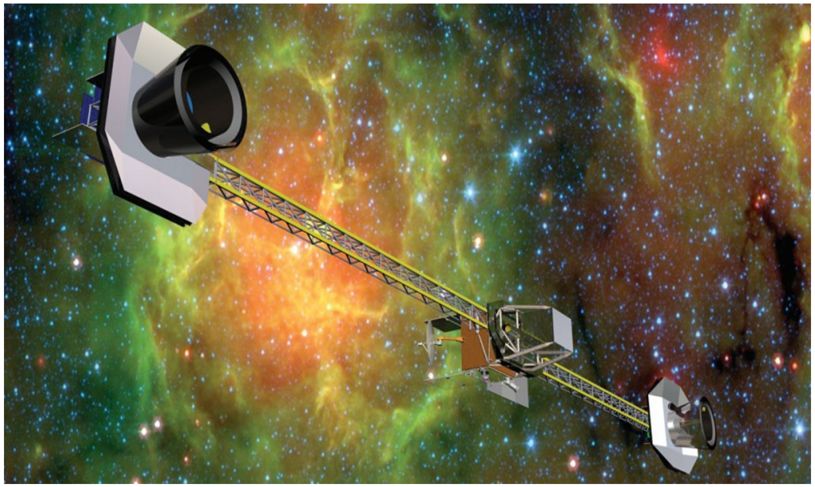


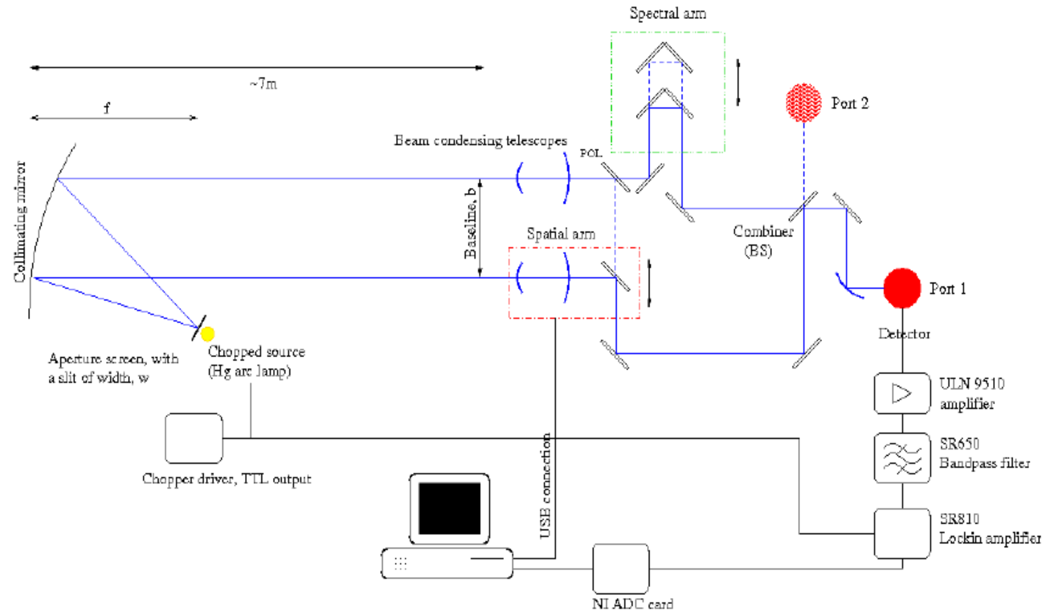


- **Thinned Aperture Light Collector (TALC):**
  - 20m diameter, 3m width annulus telescope
  - Optics & data reduction challenge
  - Mechanical challenge
  - Unfilled main beam --> 30% of the total energy
  - Sensitivity 5σ = 0.1 mJy @ 1hr compare to 5σ = 5.5 mJy @ 1hr of Herschel

Sub-arcsecond FIR observatory: telescope concepts

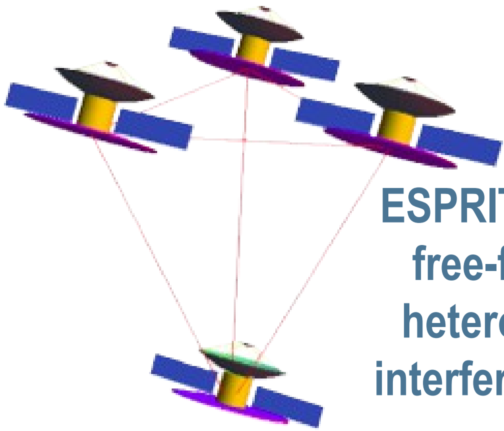
FIRIT 36m direct imaging interferometer



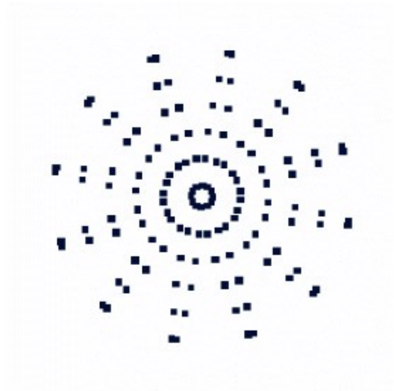


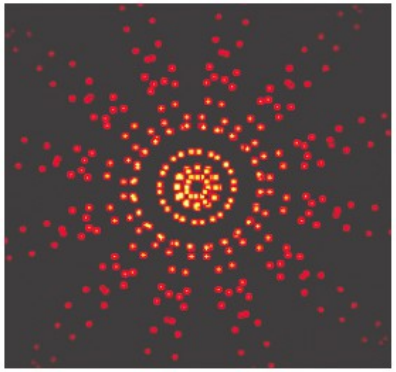
- **Far-InfraRed Interferometer (FIRIT):**
  - 36m baseline, two or three 1m diameter telescopes
  - Double Fourier modulation technique --> spatial & spectral interferometry
  - Resolution: 2.8" @ 400 μm, 0.18" @ 25 μm
  - Fuel efficiency

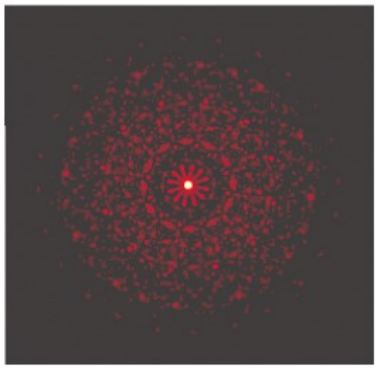
Sub-arcsecond FIR observatory: telescope concepts



ESPRIT ~50m
free-flying
heterodyne
interferometer



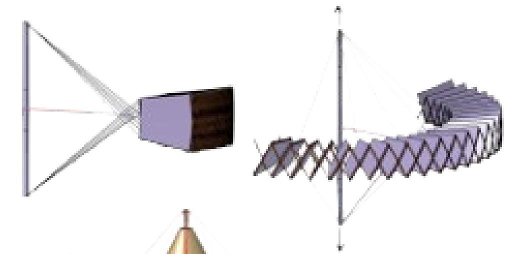




- **Exploratory Submm Space Radio-Interferometric Telescope (ESPRIT) (Wild et al. 2008):**
  - Four - Six 3.5m diameter telescopes
  - Baseline up to 50m
  - Free flying configuration to fill uv plane
  - Heterodyne interferometer as HERSCHEL/HIFI or ALMA --> Great spectral resolution
  - Sub components: high sensitivity, large bandwidth, sensitive heterodyne mixer: Local Oscillator, correlation system & colling system (4K is OK)
  - Baseline change --> consume fuel --> trade-off between good u-v coverage & operating lifetime

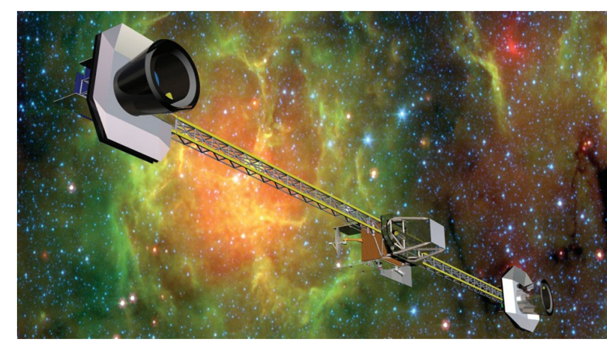
Conclusion

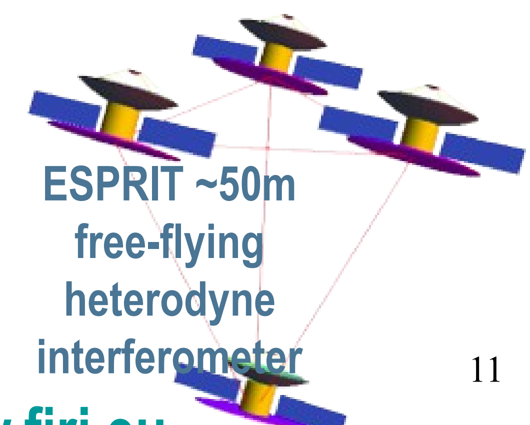
- In the L2/L3 era, the FIR domain will present a severe gap in resolution and sensitivity between ALMA and JWST/E-ELT.
- The band maps on key tracers:
  - dust continuum peak, and features tracing composition and formation.
  - wide variety of molecular tracers including water, and HD.
  - fine structure lines from various ISM phases.
- Addressing that angular resolution gaps accessing science cases such as:
  - Protoplanetary disks (gas mass available for planet formation, structure, composition including water content).
  - Star formation (structure formation, feedback processes, IMF at the high mass end, massive star formation scenario).
  - Nearby universe (dust formation, thermal balance in the ISM, IMF in external galaxies, AGN/host relationship including star formation quenching).
  - The evolving universe (co-evolution of galaxies and their central black holes, H_2 as a tracer for galaxy mass accretion and first stars).B=b



TALC 20m annular telescope

FIRIT 36m direct imaging interferometer





ESPRIT ~50m free-flying heterodyne interferometer

Download the white paper and Express your support at www.firi.eu

Thank you.

Thank you.

Thank you.

Cold Telescope – New Capability

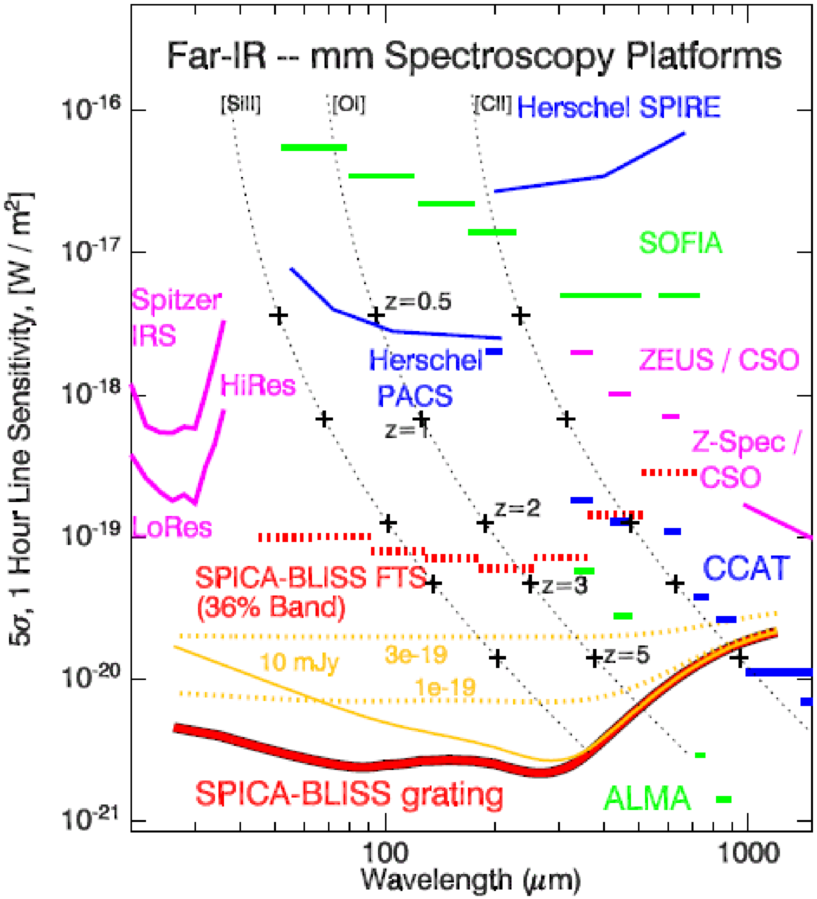
A 3 m class cold telescope offers dramatic improvement in far IR/submm sensitivity

1. Mm instruments need bigger telescopes for better sensitivity

2. Far IR/Submm spectrometers need cold space telescope (cold is more important than big)

one year of integration time on Herschel can be done in < 10 sec on a SPICA/BLISS system.

A Golden Opportunity!



C.M. Bradford