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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FIRI project  www.firi.eu
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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)
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, O₂, ND, HD, OH⁺ and H₂O⁺......
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 \( \text{O}_2 \).

Goicoechea et al. (2012)

Motte et al. (2010)
The need for a sub-arcsecond FIR observatory

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- Spectral resolution:
  - heterodyne: $R = 10^{6-7}$
  - medium: $R = 1000 – 5000$
  - SED: broadband

- Angular resolution: 0.1-1"
  - planet: 100 AU @ 1 kpc
  - protostar: 0.1 pc @ 200 kpc
  - galaxy: 1 kpc @ 200 Mpc

- Addressing 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, H₂ 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 $5\sigma = 0.1$ mJy @ 1hr compare to $5\sigma = 5.5$ mJy @ 1hr of Herschel
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
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\textsubscript{2} as a tracer for galaxy mass accretion and first stars).

Download the white paper and Express your support at [www.firi.eu](http://www.firi.eu)
Thank you.
Thank you.
Thank you.
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!