Participación del Departamento de Astrofísica Molecular e Infrarroja (Inst. Estructura de la Materia) en el COSMIC VISION

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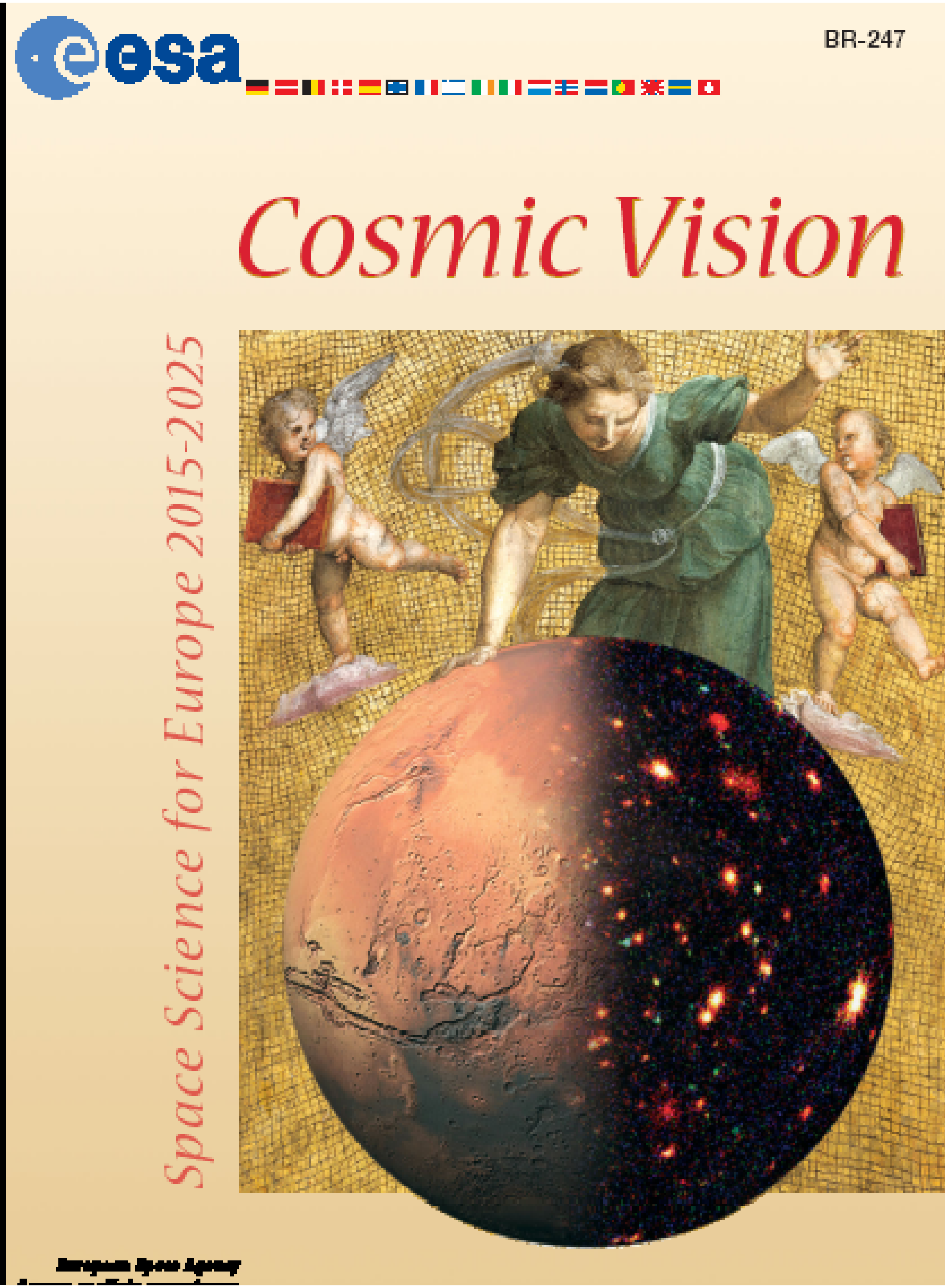
F. Najarro

J. Martín-Pintado

DAMIR

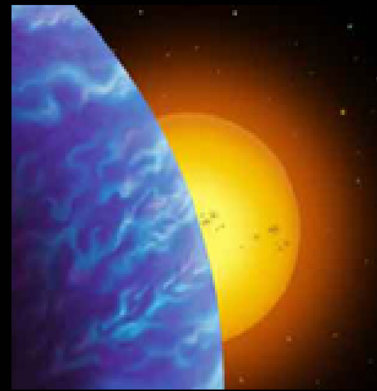
SPICA and Cosmic Vision

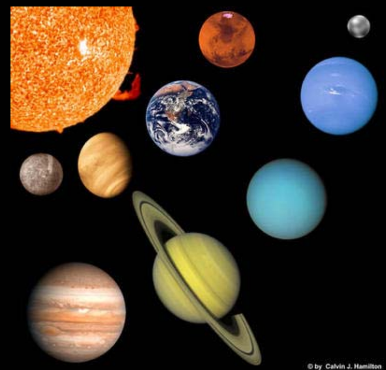
F. Najarro, J. Cernicharo, J. Martín-Pintado, Ismael Pérez Fournon & DAMIR & IAC

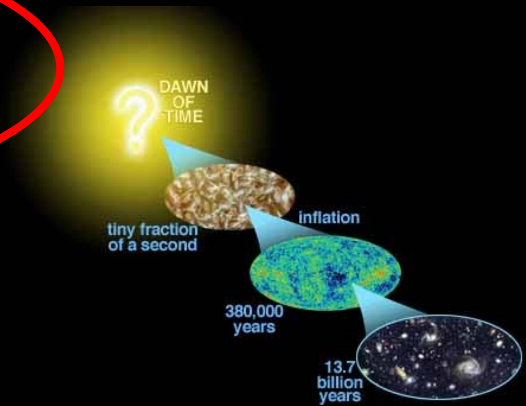


Themes Addressed by SPICA

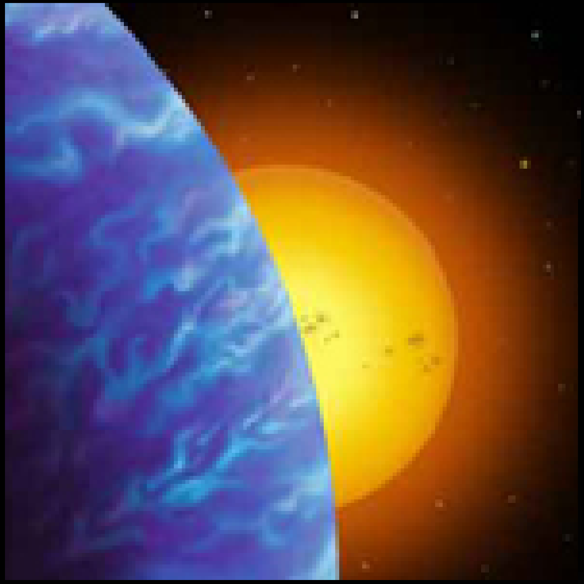
1. **What are the conditions for life and planetary formation?**
2. **How does the Solar System work?**
3. **What are the fundamental laws of the Universe?**
4. **How did the Universe originate and what is it made of?**

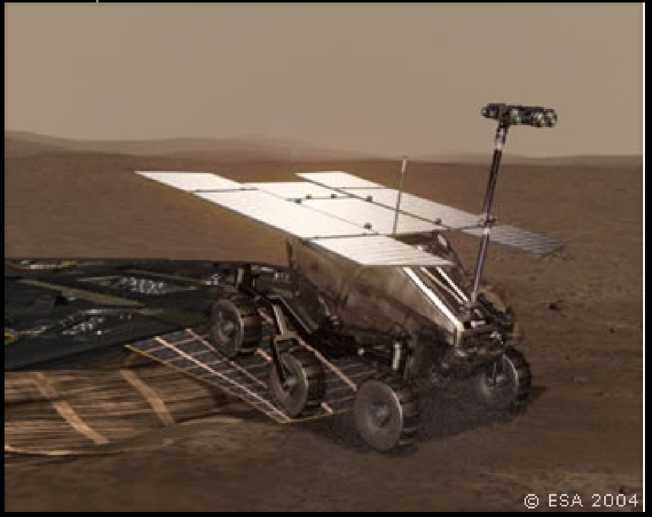






1. Conditions for life and planetary formation





From Gas and Dust to Stars and Planets

Observe the birth and evolution of stars and planetary systems

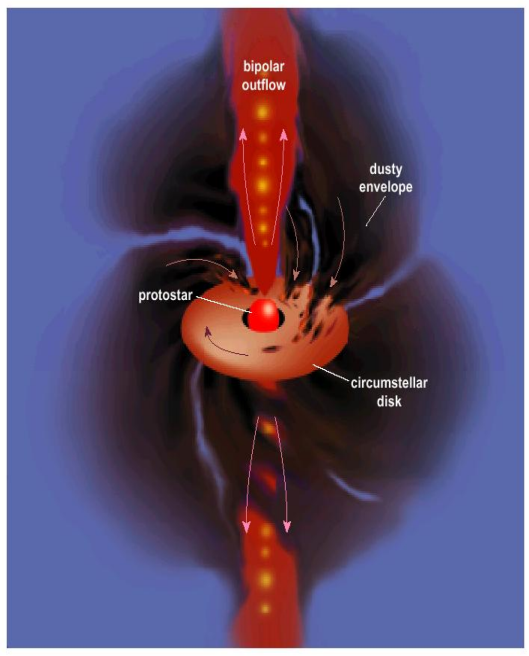
Which properties of the host stars and which locations in the Galaxy are favourable to the formation of planets?

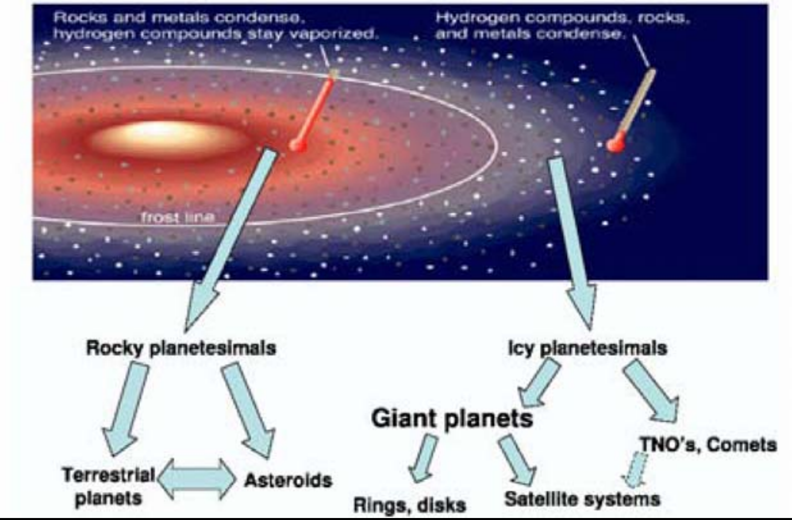
FIR observatory with high spatial resolution - FIRI

SPICA Contribution

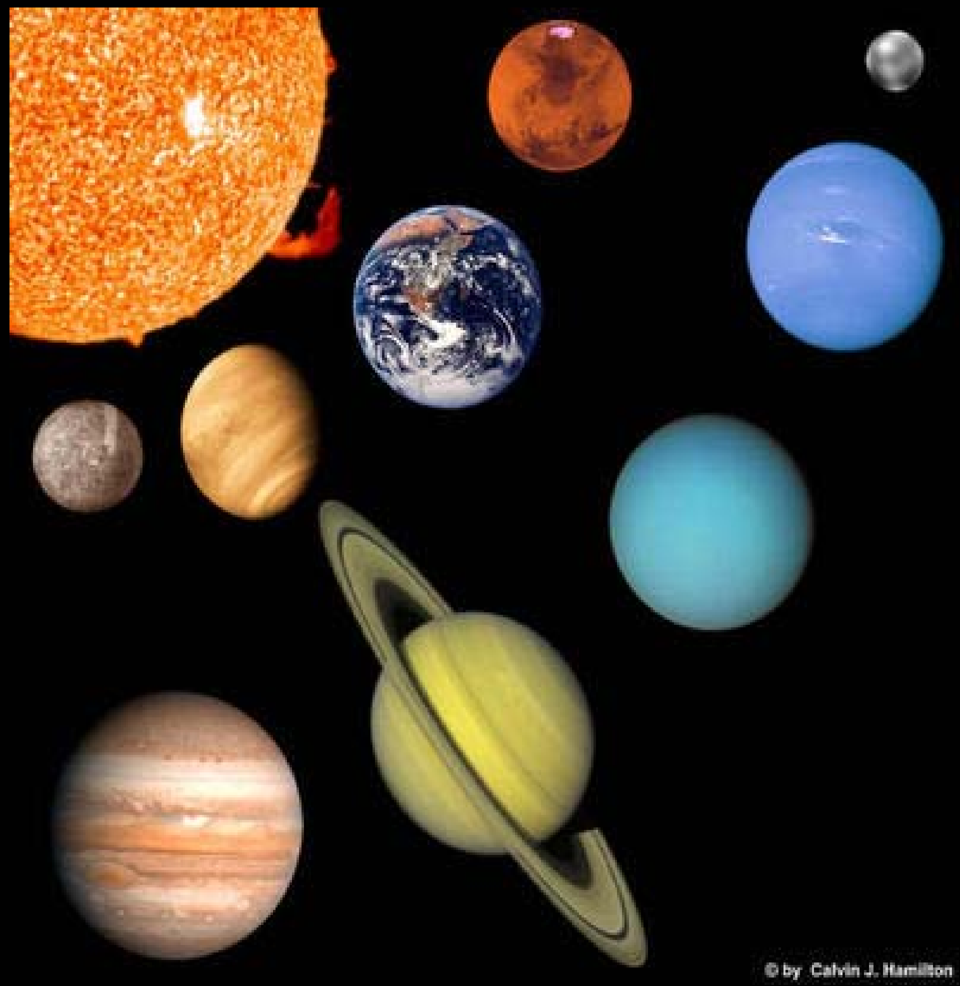
- Planet detection

- Planetary system formation





2. How does the Solar System work ?

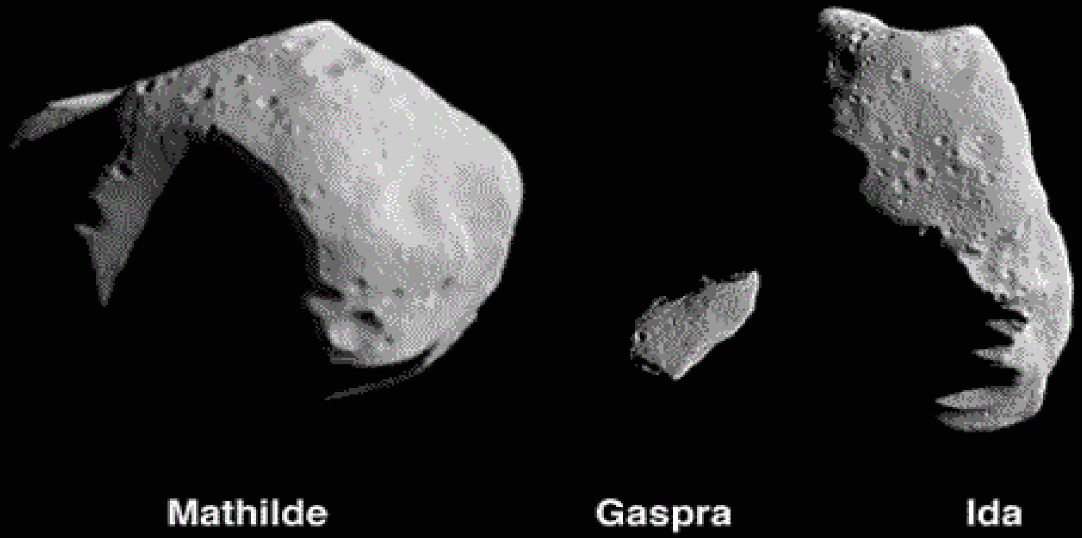


The Building Blocks of the Solar System

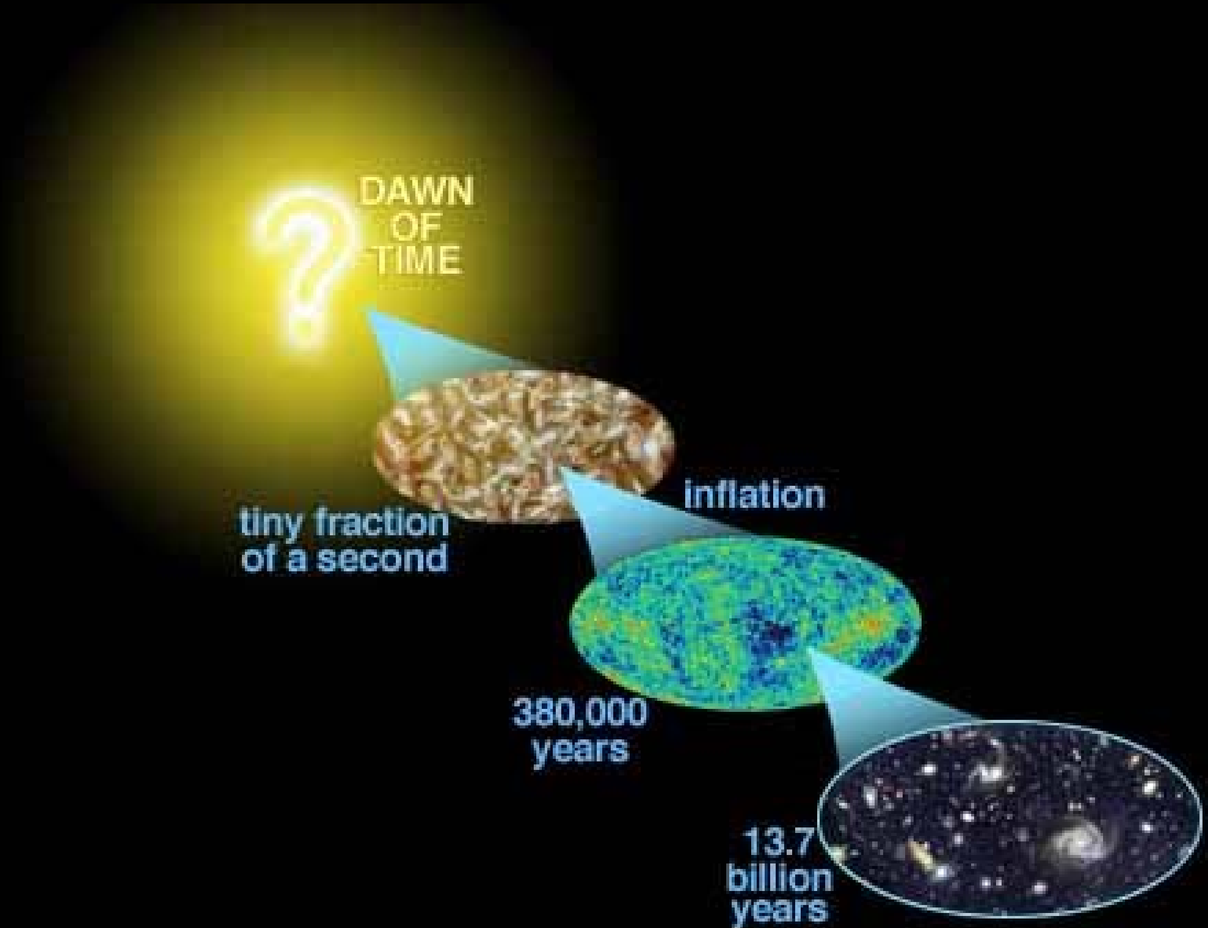
Primitive building blocks of the solar system
Chemical composition and initial conditions in the early solar nebula

NEO sample return
Mars sample return

SPICA Contribution
- KBOs and small bodies
- Cometary spectroscopy



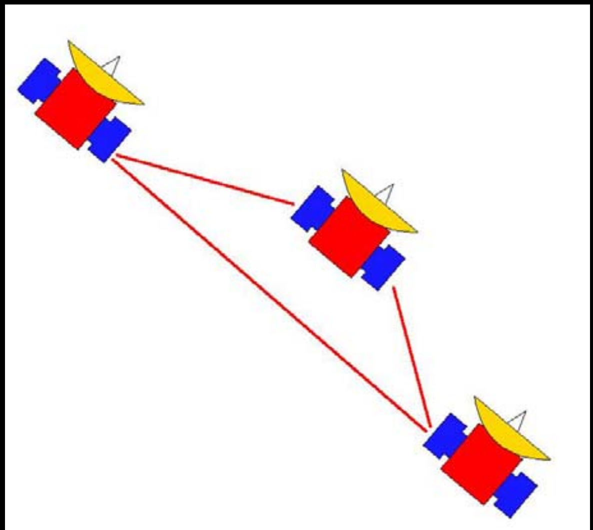
4. How did the Universe originate and what is it made of?

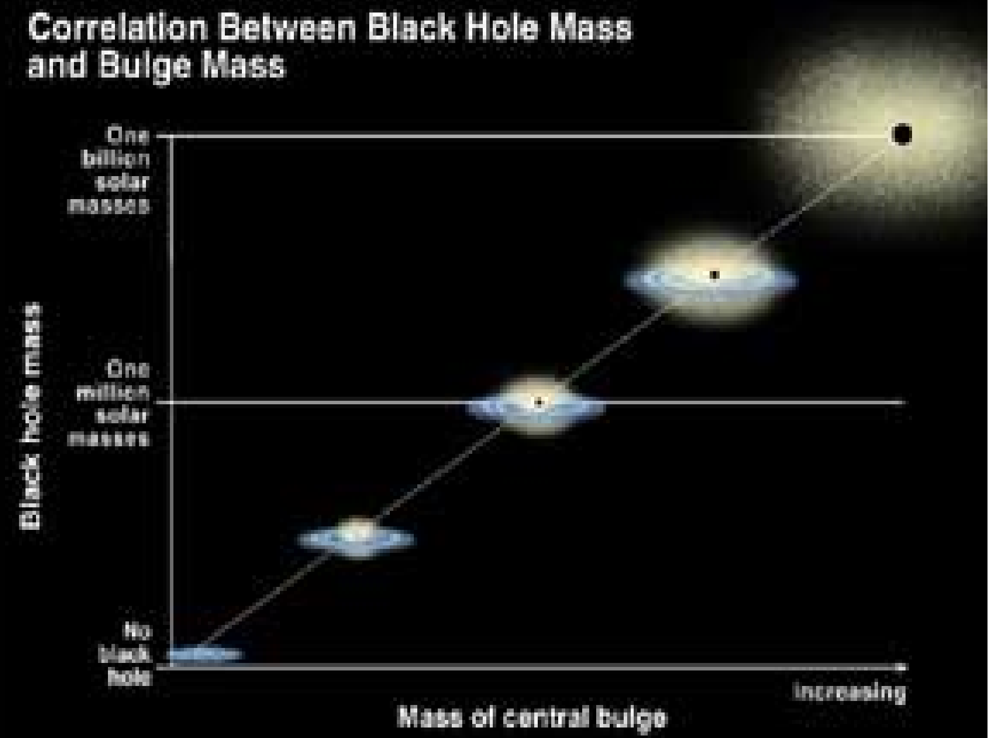


The Universe Taking Shape

Observe the formation and evolution of galaxies

- **History of star formation and heavy element production**
- **Study how a milky-way type galaxies were formed**
- **Far infrared interferometer (FIRI)**





SPICA Contribution

- **FIR spectroscopy**

Major Technology Developments for FIRI

- Actively cooled telescopes:
  - Limited by natural astrophysical backgrounds

- A new generation of cryogenic detectors and instruments:
  - Large-format arrays with sensitivity 10 - 100 times better than the current generation of detectors
  - Ultra-low background instrument design

SPICA Contribution

- Active development and evaluation of these technologies

SPICA and Cosmic Vision

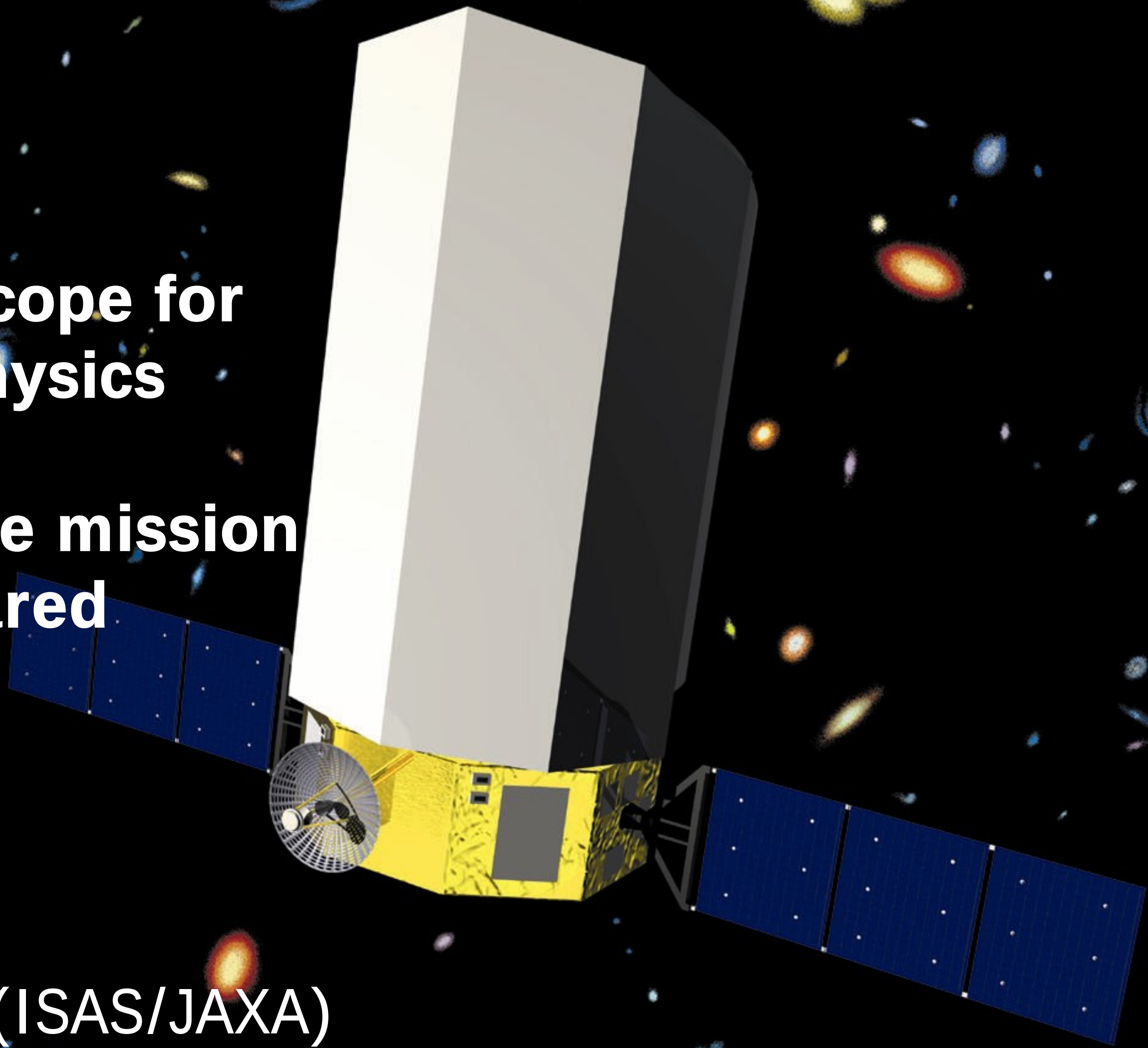
- Advantages of SPICA in the Cosmic Vision competition
  - Strong science case which is very relevant to Cosmic Vision themes
  - Well-developed mission concept
  - Satisfies a large European FIR community for another decade
  - Builds on and extends European industrial capabilities
  - Technological and scientific preparation for FIRI
  - Low cost to ESA – good value for money
  - Major international collaboration

Updates on

SPICA

Space Infrared Telescope for Cosmology & Astrophysics

3.5m cooled telescope mission for mid- and far-infrared astronomy

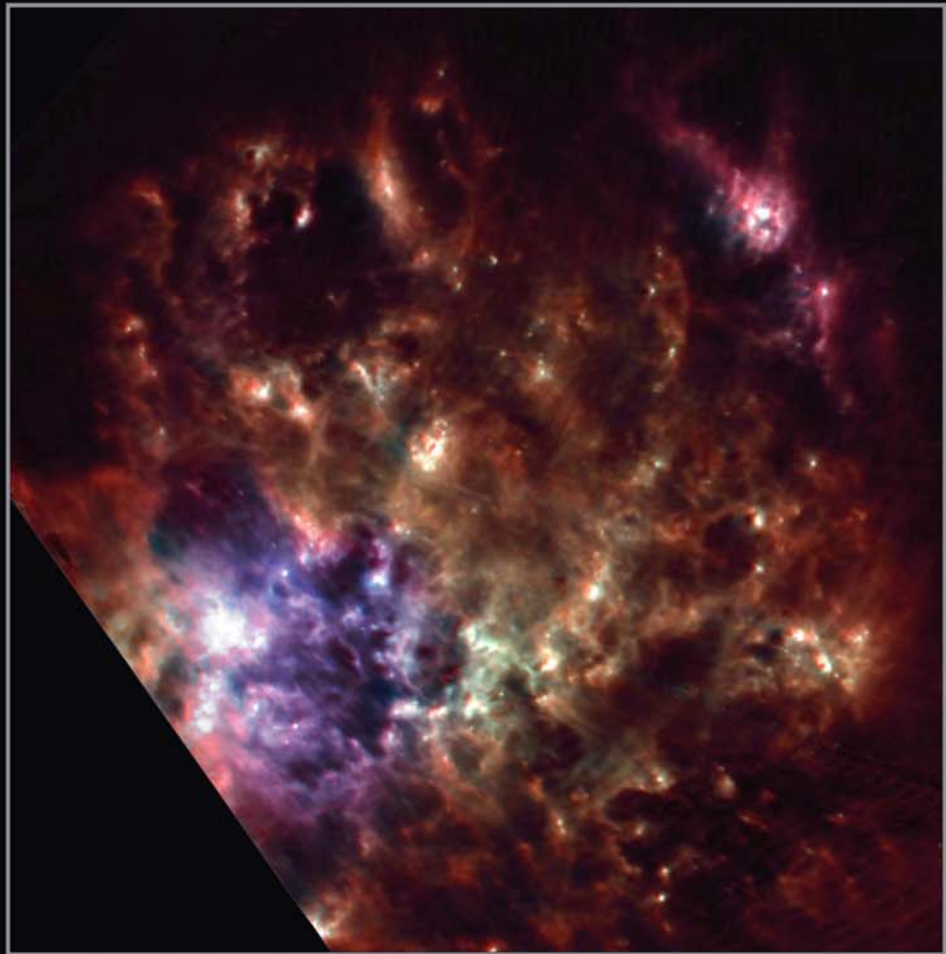


From Takao Nakagawa (ISAS/JAXA)
for SPICA Working Group

ISAS

JAXA
宇宙航空研究開発機構
Japan Aerospace Exploration Agency

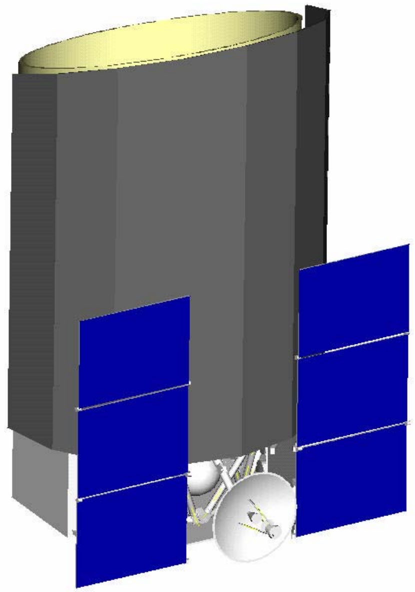
Far-Infrared Image of the Large Magellanic Cloud



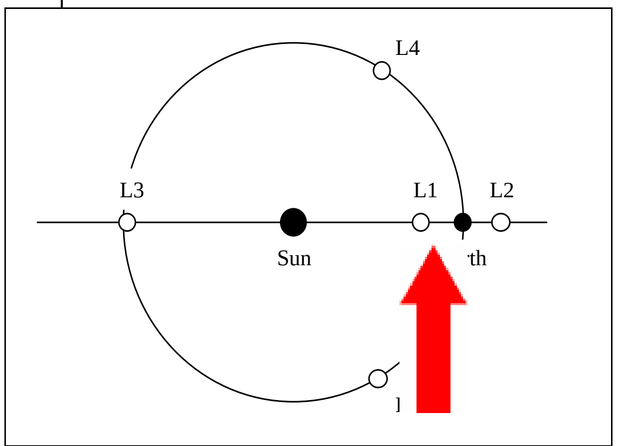
AKARI / Far-Infrared Surveyor
(false color composite from 60μm, 90μm, and 140μm)

1st Nov., 2006

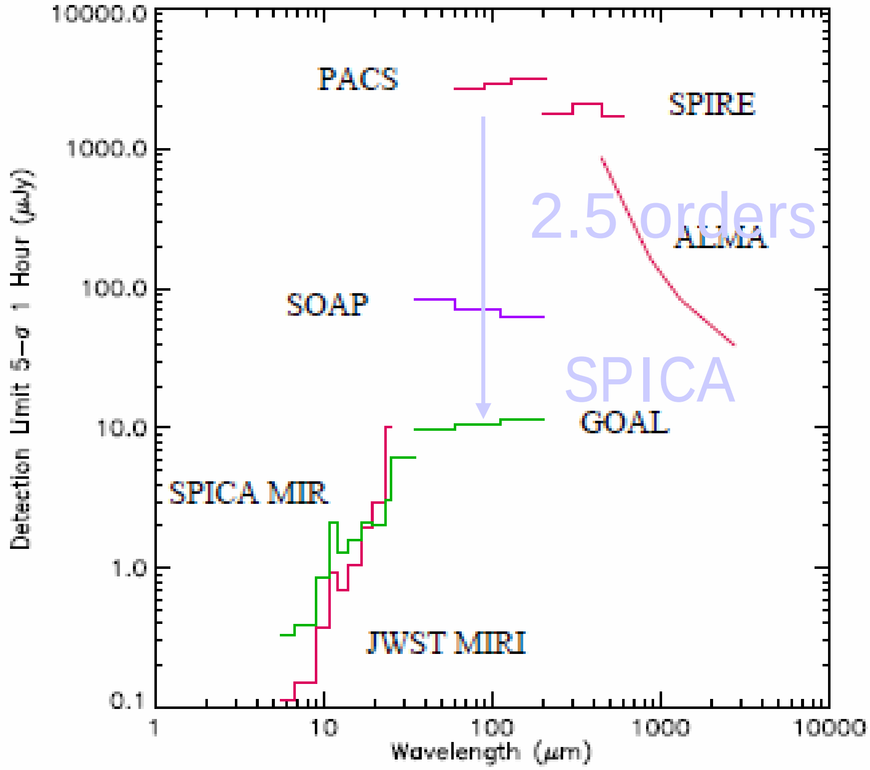
SPICA Mission



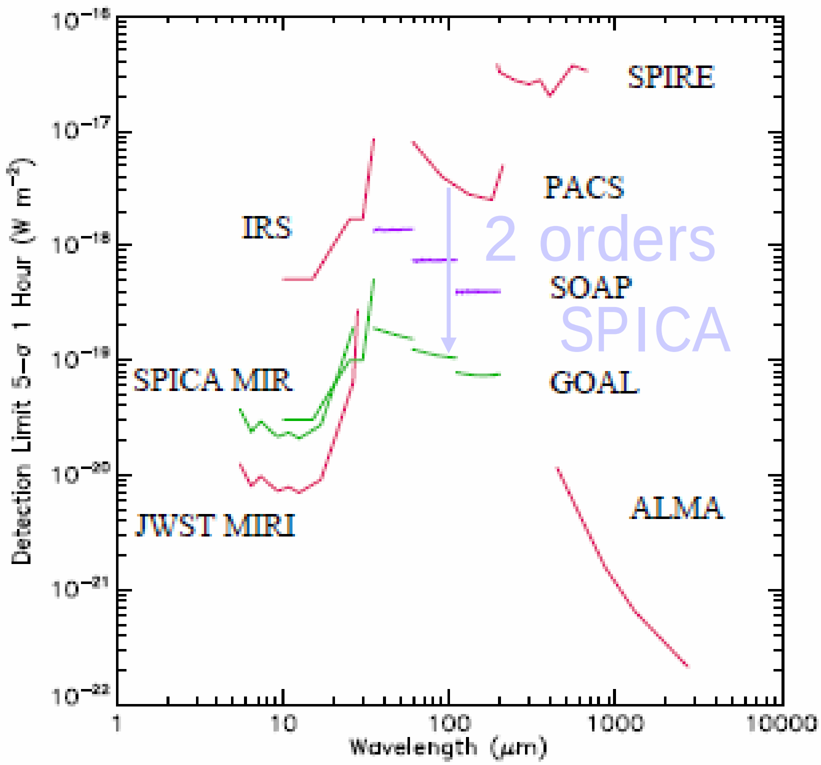
- Scientic Objectives
  - Revealing the history of cosmic evolution
  - Heritage of previous mission
    - AKARI, SPITZER, ISO, Herschel
- Specficiations
  - Telescope: 3.5m, 4.5 K
    - Revolving CIB at its energy peak
    - Direct detection of exoplanets
  - Core wavelength: 5-200 μ m
    - MIR Instrument
      - Including Coronagraph
    - Far-Infrared Instrument (ESI)
  - Orbit: Sun-Earth L2 Halo
  - Weight: 2.6 t
  - Launch: mid 2010s (H-IIA)



Huge Gain of Sensitivity !

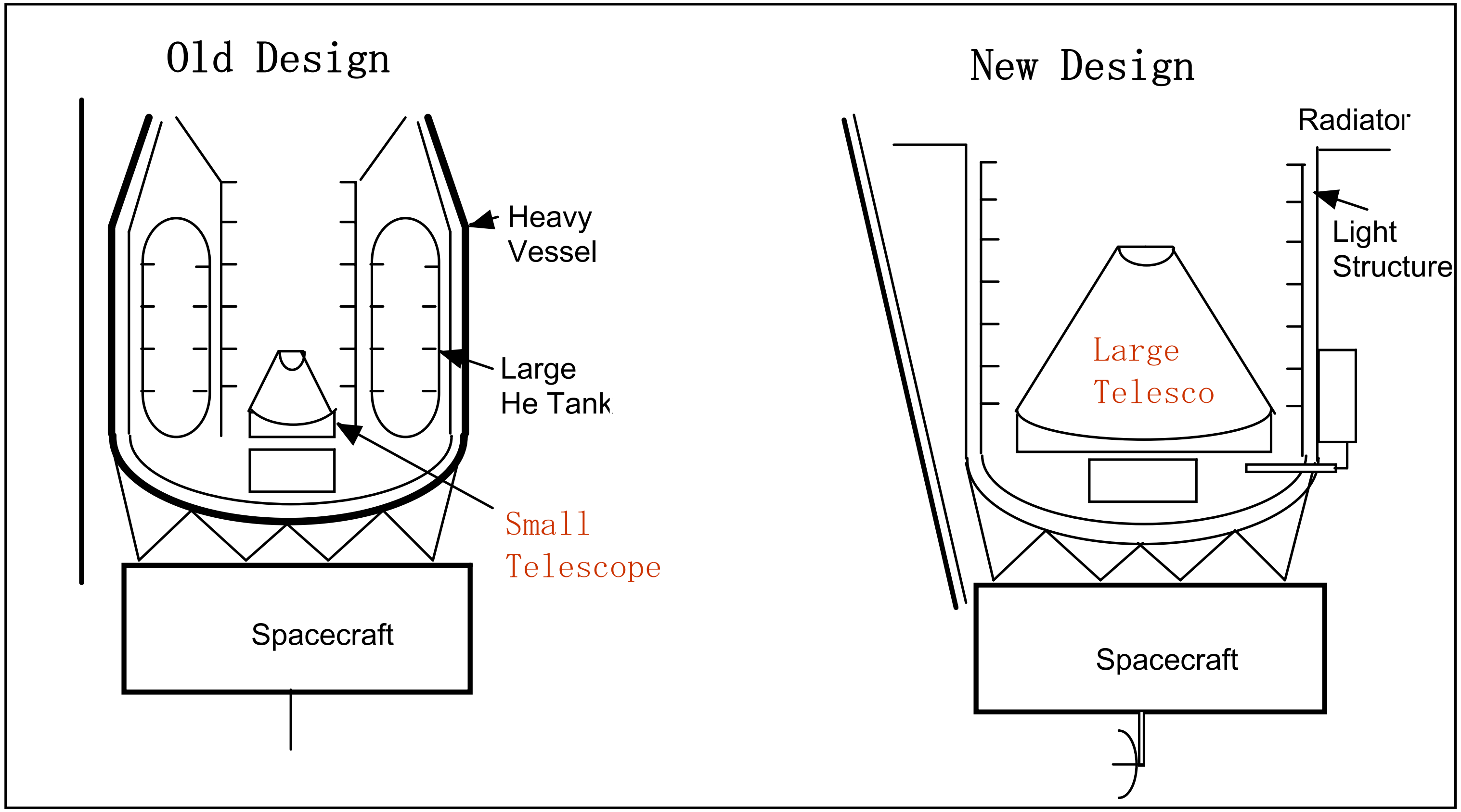


Photometric performance – uJy 5-sig 1 hour



Spectroscopic Performance – W m-2 5-sig 1 hour
ALMA assumes 100 km/s resolution

SPICA COOLED TELESCOPE

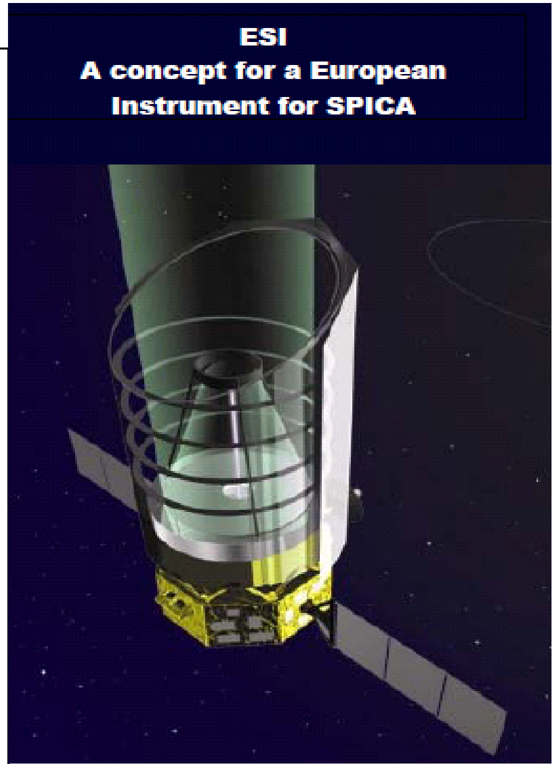


ISO (60cm)
(2000L He、2.6t)

SPICA (3.5 m)
(No Cryogen、2.6t)

SPICA as an International Mission

- Europe (ESA, ESI Consortium)
  - Instrument
    - ESI : European SPICA Instrumentation (P.I: B. Swinyard, RAL, UK)
  - ESA Contribution
    - Telescope, Ground Station
  - Proposal Under Preparation for Cosmic Vision
- Korea (KASI, Seoul National University)
  - MIR Instrument
    - Infrared Working Group (P.I. H. M. Lee, Seoul University)
- USA (NASA/JPL, UA, Caltech..)
  - BLISS: Background Limited Spectroscopy for SPICA
    - P.I. M. Bradford, JPL, USA



Proposed Schedule for SPICA/ESI

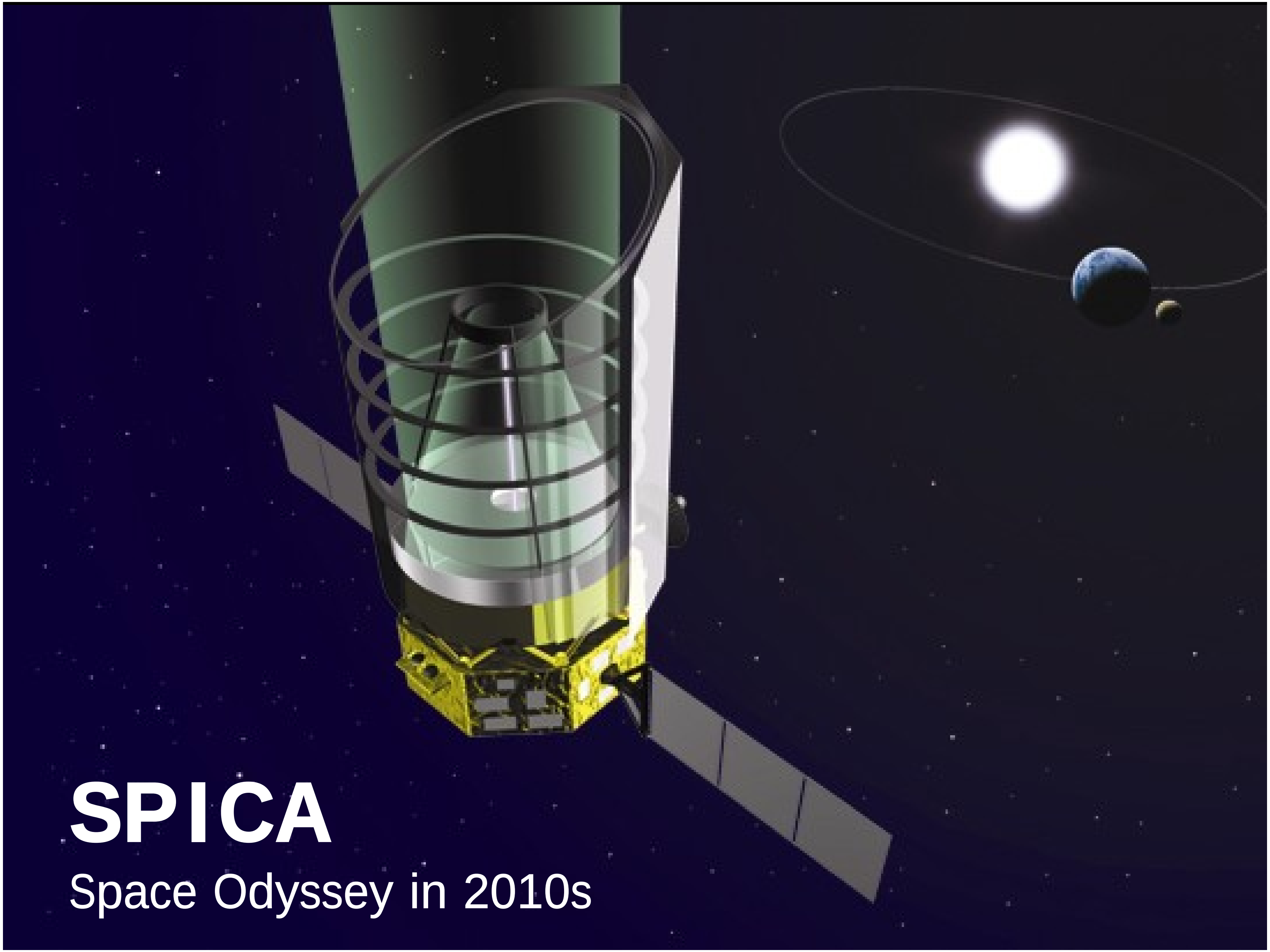
(Tentative, Under Discussion)

JAXA

- Summer-Fall 2007
  - System Requirements Review by Space Science steering Committee and SAC
- FY 2008 – FY 2010
  - Full Phase-A
    - Funding being submitted
- End of FY 2010
  - System Definition Review by Space Science Steering Committee and JAXA HQ
- FY 2011 - FY 2013
  - Phase-B
- FY 2014 – FY 2016
  - Phase-C/D
- 2017 (2016?)
  - Launch

ESA

- June, 2007
  - Mission Proposal due
- Oct. 2007
  - Selection for Assessment Phase
- Nov 2007- May 2008
  - Internal Assessment Phase
- Jun 2008 – Aug 2009
  - Industrial Assessment Phase
- Oct-Nov 2009
  - Selection for Definition Phase
- Apr 2010-Sep 2011
  - Definition Phase
- Nov 2011 – July 2012
  - Selection for Implementation
- Sep 2012-2016
  - Implementation Phase
- 2017 (2016?)
  - Launch


SPICA
Space Odyssey in 2010s

Mid, Far-IR SCIENCE CASE

- The importance of the MIR/FIR
- Heritage
- SPICA, H2-EX, FIRI
- Mid, Far-IR Science science:
  - Extragalactic science case
  - Galactic science case

The MIR/FIR waveband

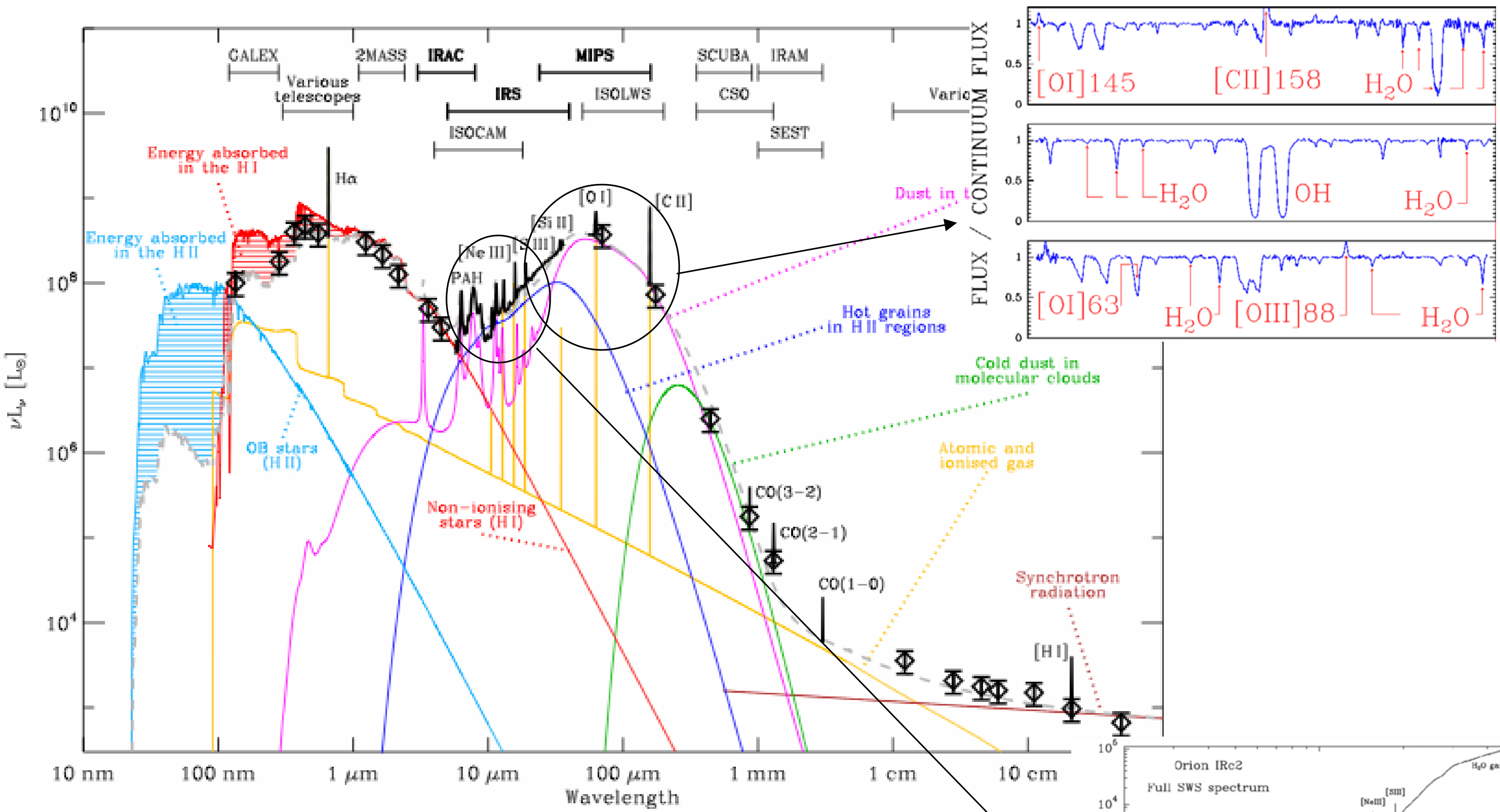
- Waveband host to many diagnostic emission lines:
  - Atomic and ionic fine structure lines:
    - Atomic gas and PDRs: [CII] 158μm; [OI] 63/145 μm
    - Ionized medium: eg. [OIII] 53/88μm; [NII] 122/205μm; [SIII] 33μm; [SiII] 35μm; [NeIII] 36μm
  - Molecular lines: high-J CO ladder, H_2O,OH, HD

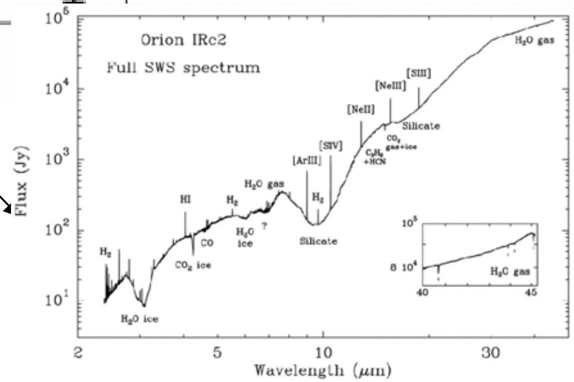
  → Lines trace a wide range of different physical conditions:
  - Density, temperature, UV field, ionization parameter

  →Complementary to what will be traced by ALMA
  →Direct obsevation of H2 (H2-EX)

- Lines largely unaffected by interstellar dust extinction
  - Good probes of heavily obscured regions and young dusty galaxies

- In addition, continuum/broadband features:
  - Broadband SEDs → dust temperatures, mass…
  - PAHs/polycrystalline dust features/mineralogy





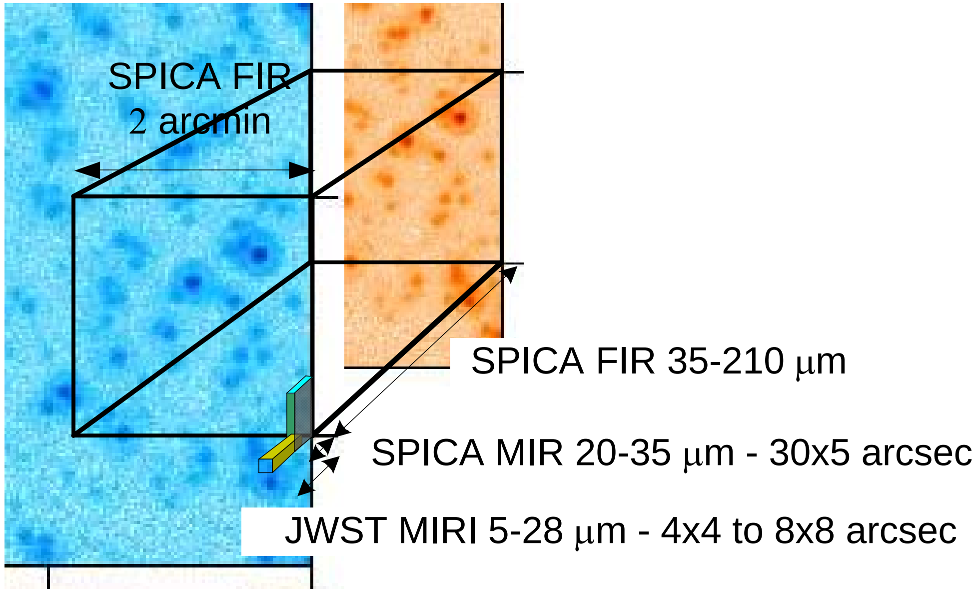
- Narrow-band spectral line features
- Broad-band PAH features + mineralogy
- Underlying SED

Heritage

- IRAS/ISO/AKARI/SPITZER -- all cooled (~5K) but <1m aperture
  - Many groundbreaking discoveries:
    - ULIRGS
    - AGN/starburst diagnostics - lines and PAHs
    - Ices
  - Low background, but limited spatial resolution…

- HERSCHEL/JWST
  - HSO (2008): 3.5 m passively cooled to ~70K
    - 60 to 210 μm
  - JWST (~2013) : 6.5 m passively cooled ~37K
    - 0.6 to 28 μm

SPICA multiplexing capability



SPICA/JWST spectral volumes superposed on deep GOODS 24μm image

SPICA MIR/FIR: warm/cool gas + dust

- JWST:
  - 3 settings/ full waveband
  - 30 hrs to get 10 sources
- SPICA:
  - 30 hrs integration ~ same sensitivity

Multiple sources in field - comparable sensitivity

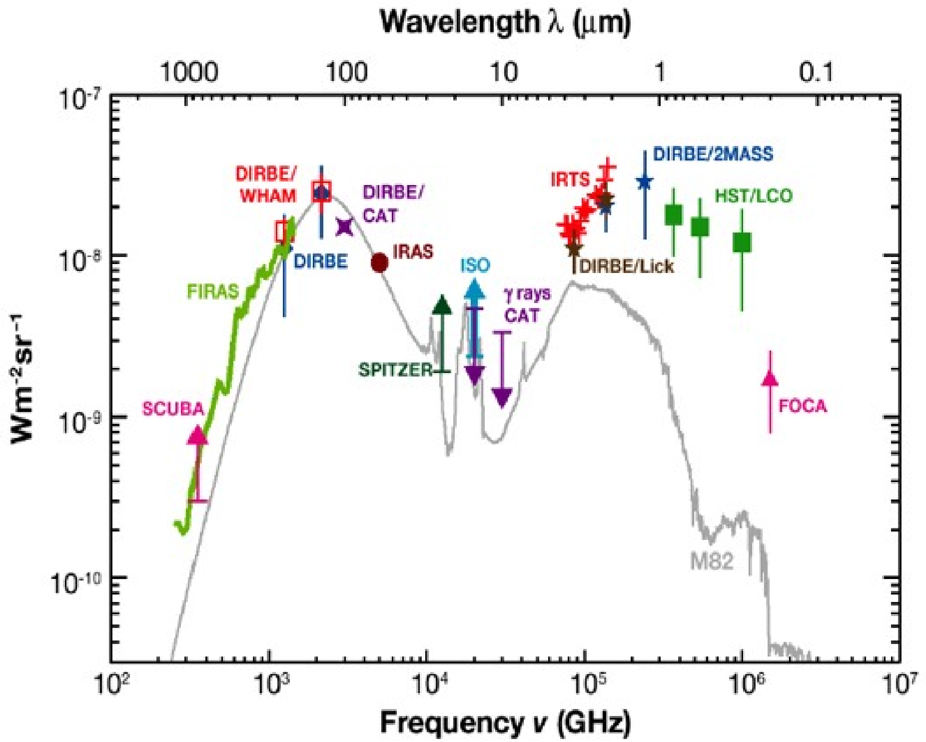
MIR/FIR

- High point source sensitivity (line and continuum)
- Large field of view -- multiplexing
- Large instantaneous spectral coverage (particularly FIR)
- High surface brightness sensitivity
- Access to the 28 - 55μm wavelength desert (SPICA)
- Access to the 28-300 um with high angular resolution (SPICA/FIRI).
- Planets and star formation (FIRI !)
- Mass determination of the Universe (H2-EX)

Extragalactic Science

- Formation and evolution of galaxies
- LIRGs: local/distant
- Feedback - starburst/AGN
- Extrema -- Milky Way
- Local galaxies - laboratories

Sensitivity+spectral coverage+FoV+cold telescope(ref.)



Lagache et al.

Deep continuum surveys – mapping speeds

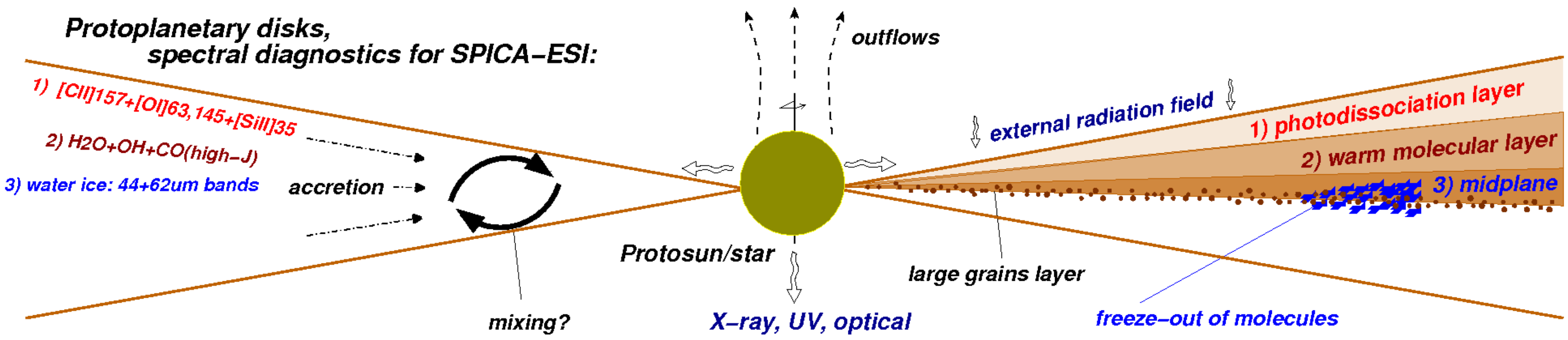
- Spitzer (24μm):
  - 100 sq. arcmin in 37 hours (2mJy 5σ)
- PACS (75μm) :
  - 100 sq. arcmin in 37 hours (2mJy 5σ)
    (detecting 1 source/sq. arcmin)
- H2-EX 20’x20’ field of view in 4 lines of H_2
- SPICA (70μm) - to confusion limit:
  - 100 sq. arcmin in 50hrs (SOAP detectors), expectation of detecting c. 18-20 sources/sq. arcmin
  - Same area/depth in ~ 1 hr for GOAL detectors

Galactic Science

Much of FIR spectroscopy in SF will have been done by PACS+HIFI, ALMA…

- Planetary formation
  - Gas and dust (ices) SPICA/FIRI
- Dust formation and processing
  - Key constituent of galaxies, but, …. (SPICA/FIRI)

Planetary system formation: from dust to rubble, from ices to oceans

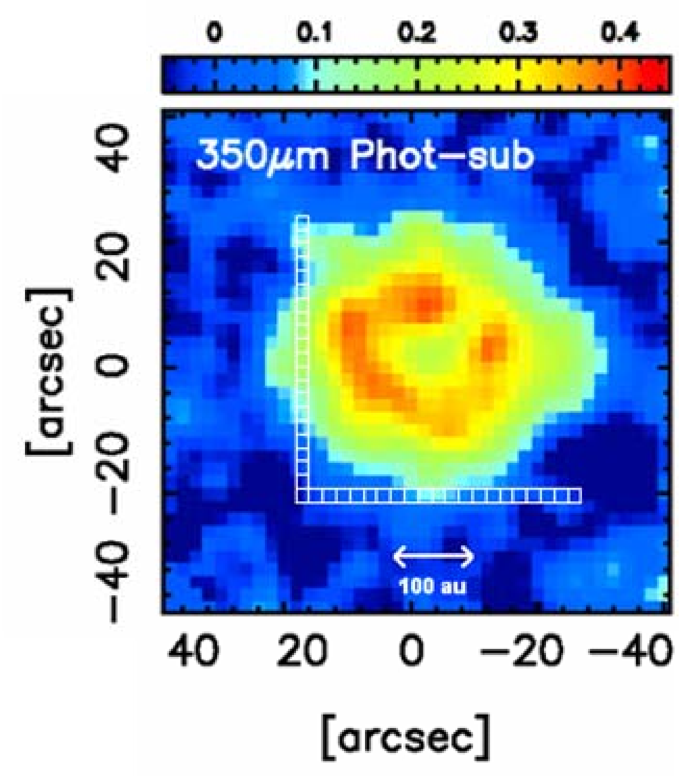


- Tests of theories of planet formation - planetary disks
- MIR/FIR: dust + gas lines - strong coolants cf. CO
- Young stars - accretion disks - reservoirs

Planetary system formation: dust to rubble; ices to oceans

- Protoplanetary disks:
  - Mapping of the Vega disk
    - Dust processing/ mineraology/Ices
    - Snowline - water
  - Disks around main sequence stars:. (P.Najarro, DAMIR)
    - MIR -stellar photospheres
    - FIR - dust excess
    - Full inventory of open clusters
    - Coeval
  - Molecular hydrogen/FeII - Keplarian disks (R~30,000)

  (J.R. Goicoechea, DAMIR)

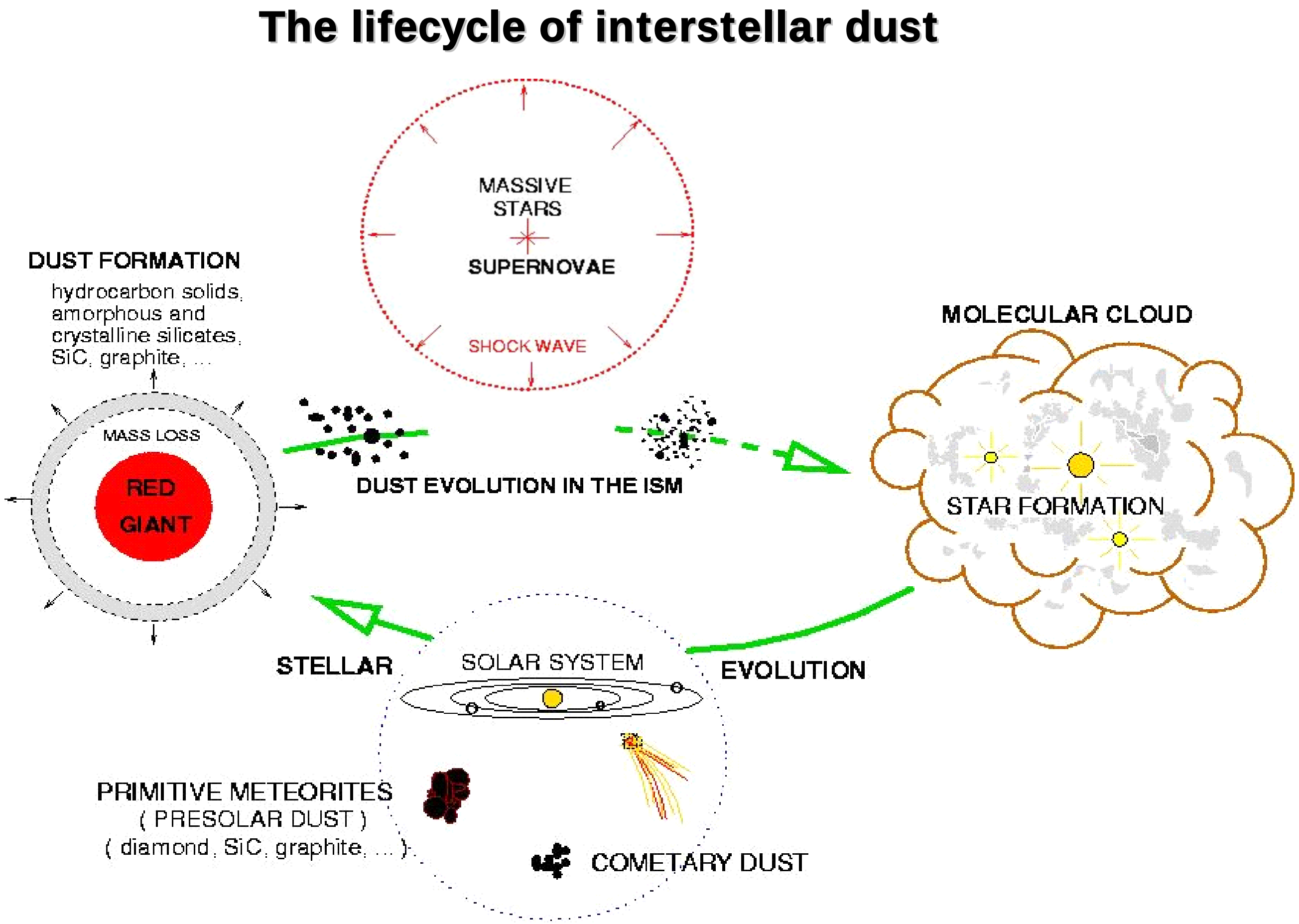


Planet formation

- Planet formation/Exo-planets
  - Habitable planets require interferometry, however….
  - Coronograph:
    - Unsegmented, high optical quality of mirror
    - Directly image MIR spectra of Jupiter-like planets
    - Prebiotic/biotic tracers eg. methane, water, ammonia
    - Can probe to 9AU (Saturn's orbit) at 5μm at 10pc
      - Younger planets

FIRI + SPICA

A Dust inventory: formation, destruction and processing



- MIR/FIR spectroscopy
- FIR-submm SED – grain size

OBJETIVOS CIENTÍFICOS EN EL MARCO DE DAMIR/ASTROCAM

- Astrofísica Galáctica (DAMIR, UEM, ESAC, UCM)
- Astrofísica Extragaláctica (UCM, UAM, UEM, DAMIR)
- Cosmología (UAM)
- UPM puede contribuir en la fase de desarrollo y construcción
- Dentro de la Astrofísica Galáctica los miembros del ASTROCAM lideran la preparación científica de las siguientes líneas de investigación :
  - Discos protoplanetarios
  - Física Estelar
  - Astroquímica
- Coordinador español : F. Najarro (DAMIR)
- Proyecto presentado al COSMIC VISION
- Acción especial solicitada (todo ASTROCAM)

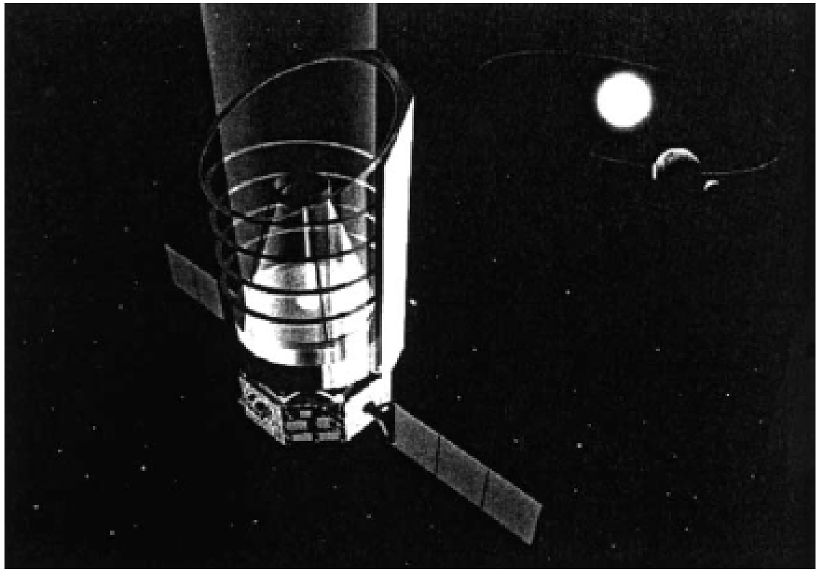


Fig. 1. Artist's impression of SPICA in orbit.

Table 1
Summary of current specifications of SPICA

Parameter	Value
Mirror size	3.5 m
T_{Mirror} in space	4.5 K
T_{Mirror} at launch	300 K
Core wavelength range	5–200 μm (diffraction limit at 5 μm)
Orbit	S–E L_2 Halo
Cooling	Radiative cooling and mechanical coolers
Total mass	2600 kg
Launch vehicle	H-IIA Rocket
Launch year	2010

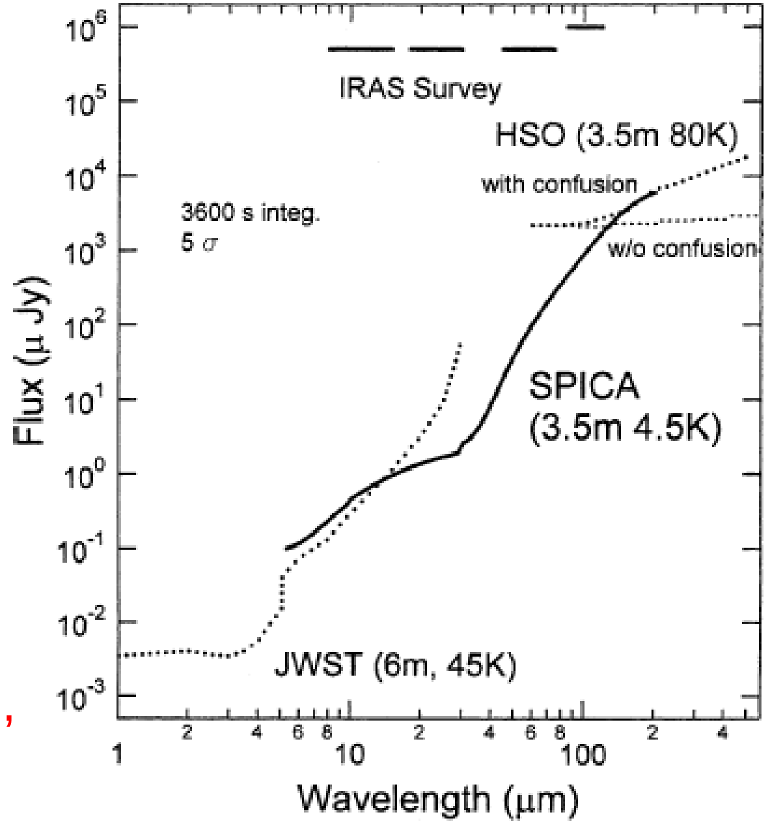


Fig. 4. Comparison of point source sensitivities of "Big Missions" scheduled within a decade.

From Nakawaga 2004

Contribucuión Europea : Instrumento ESI 30-200 micras

Participación Española : Electrónica de control, Segmento de tierra, ICC (4-5 M€)

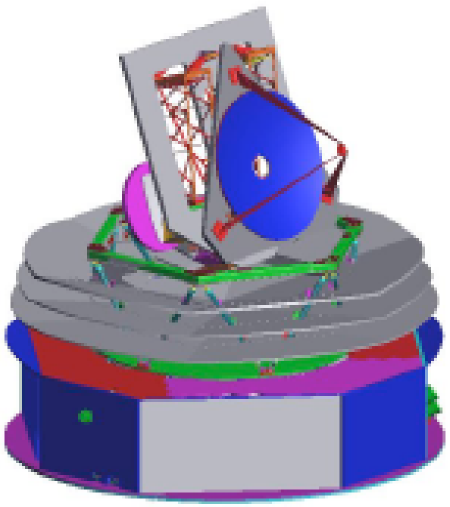
Empresas : DEIMOS, SENER, GMV, INDRA, VEGA, SERCO, INSA, ADS

Misión H_2-EX

- Reutilización de la tecnología desarrollada para el satélite Planck
- Estudio de las líneas rotacionales puras del hidrógeno molecular
- Astroquímica
- Telescopio de 1m refrigerado pasivamente
- Proyecto presentado al programa “COSMIC VISION”
- Acción especial solicitada al MEC para realizar estudios de viabilidad con las empresas.

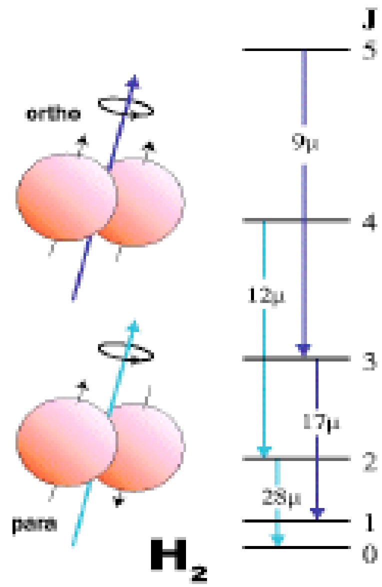
The Molecular Hydrogen Explorer (H2EX)

François Boulanger, Institut d'Astrophysique Spatiale, Orsay, France



H2EX instrument (w.o. baffle) accommodated on Planck SVM

In answer to the ESA Cosmic Vision 2015-2025 Call, we will be submitting a proposal for a medium class astronomy mission to survey for molecular hydrogen across the universe by direct, high resolution, spectroscopy of H_2 utilising its lowest rotational transitions. H2EX will be the first mission dedicated to the observation of the most abundant, but elusive, molecule in space. Its payload will be the first wide field spectro-imager built for the observation of molecular gas. It will open unexplored perspectives on the formation of the luminous universe from galaxies to the genesis of planets.



Participación de DAMIR/ASTROCAM

- Astroquímica (DAMIR, ESAC, UEM)
- Cosmología (UAM)
- Extragaláctico (UCM, UAM, UEM)
- Coordinador español : J. Cernicharo (DAMIR)
- Posibles contribuciones : Electrónica de control (cryocooler), mecánica, ICC, segmento de tierra, software de control (UPM)
- Coste aproximado de la participación española 5-8 M€

PARTICIPACIÓN EN FIRI

- Proyecto tipo “cornerstone”. Posible coste > 1000 M€
- Proyecto de futuro para el infrarrojo lejano
- Un telescopio de 10 metros rodeado de una flotilla de 6 telescopios de 3.5 m
- Interferometría heterodina para Astrofísica galáctica y single dish con arrays de bolometros para cosmología y receptores para astronomía galáctica.
- Presentado al COSMIC VISION (DAMIR)

GÉNESIS DE FIRI

- 2003 : Congreso organizado por el DAMIR en el campus del CSIC : “The future of far-Infrared after Herschel”
- Propuesta por parte del DAMIR de un proyecto ambicioso que abarcase los problemas fundamentales :
  - Formación de las primeras galaxías
  - Formación de planetas

The Science Cases for High angular and High Spectral Resolution in the far-IR and Submillimeter Domains

New Perspectives for Radioastronomy
in the
Submillimeter and Far Infrared Domains

The future of far-Infrared Astronomy after Herschel
Madrid, Sep 2003

José Cernicharo & J. Martín-Pintado

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(DAMIR)
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What is unique in the far-IR that ALMA, Herschel, SOFIA, … will not cover ?

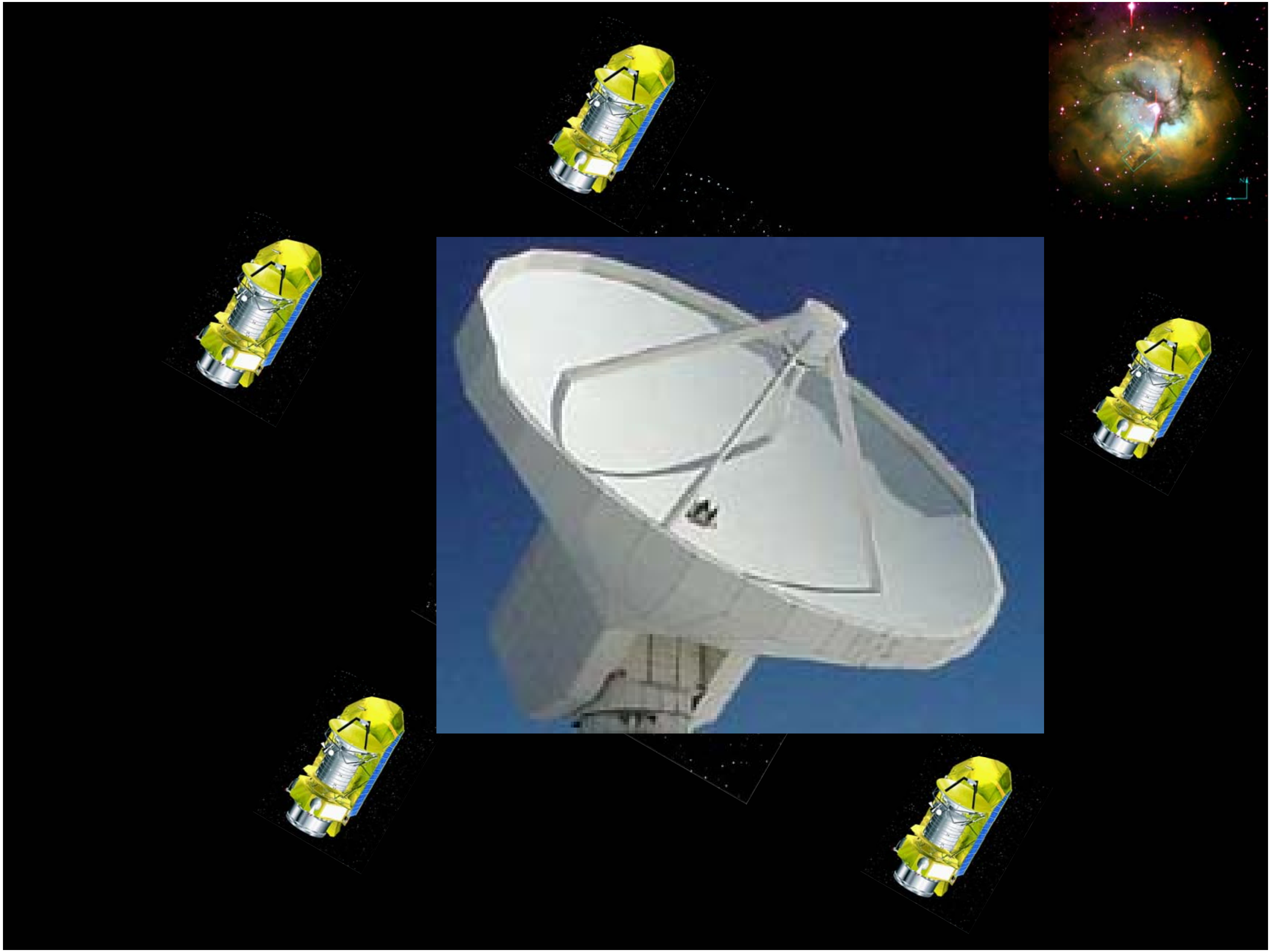
- **First driver : SCIENCE**
  - **If we want to convince committees about the need for new instruments for Astrophysical research we have to be sure that the same science can not be done using existing instrumentation or by selecting different tracers !! IN MANY FIELDS OF ASTROPHYSICS ALMA will produce a lot of exciting science.**

- **Second driver : TECHNOLOGY**
  - **We have to be sure that the science we want to do could be done with the available technology in the next 10-15 years (for a mission within 20 years !!!).**

- **Ground based, airborne or space platform ?**
  - **This is not an obvious question. The science driver has to be selected among many interesting competing projects. Which of them can be done uniquely from the space have to be carefully selected and we have to show that the selected science will really provide outstanding results.**

What kind of interferometer ?

- **A reasonable number of elements (6)**
- **Large off-axis telescopes (3.5 m minimum)**
- **A good frequency coverage (50-250 μm or 1-5 THz, not necessarily complete band -selected frequencies for outstanding science)**
- **Good receivers (Tsys=1000 K)**
- **Good LOs**
- **Good metrology**
- **FOV = 6 ” (in fact related to telescope size and sensitivity, but mosaicing or receiver arrays will be needed; ZERO SPACING MANDATORY)**
- **Velocity resolution 1 km/s (goal 0.1 km/s)**
- **No phase referencing (goal)**
- **A flexible correlator (1.5-2 bits)**
- **4 GHz instantaneous bandwidth (limited for extragalactic research, goal should be 8 GHz or more.)**
- **Digital delay lines**
- **Pointing 0.2” (10 times better than Herschel absolutely required!!!)**
- **Pointing knowledge 0.1”**
- **Possibility to have very short baselines = 5 meters (or just satellite size)**
- **Largest baseline = 1 km ? (0.02” at 100 μm)**
- **3D configuration; random / scalable**



ACTIVIDADES EN FIRI

- Creación de un consorcio, sobre la base de ASTROCAM, pero abierto a toda la comunidad, para preparar la ciencia que podrá realizarse con FIRI
- Estudio de las posibles contribuiciones al desarrollo y construcción del proyecto
- Dependerá de la decisión que tome la ESA sobre la clasificación de FIRI –aceptada o estudios de desarrollo y viabilidad-

Science with FIRI

A far-IR interferometer in space will be able to:

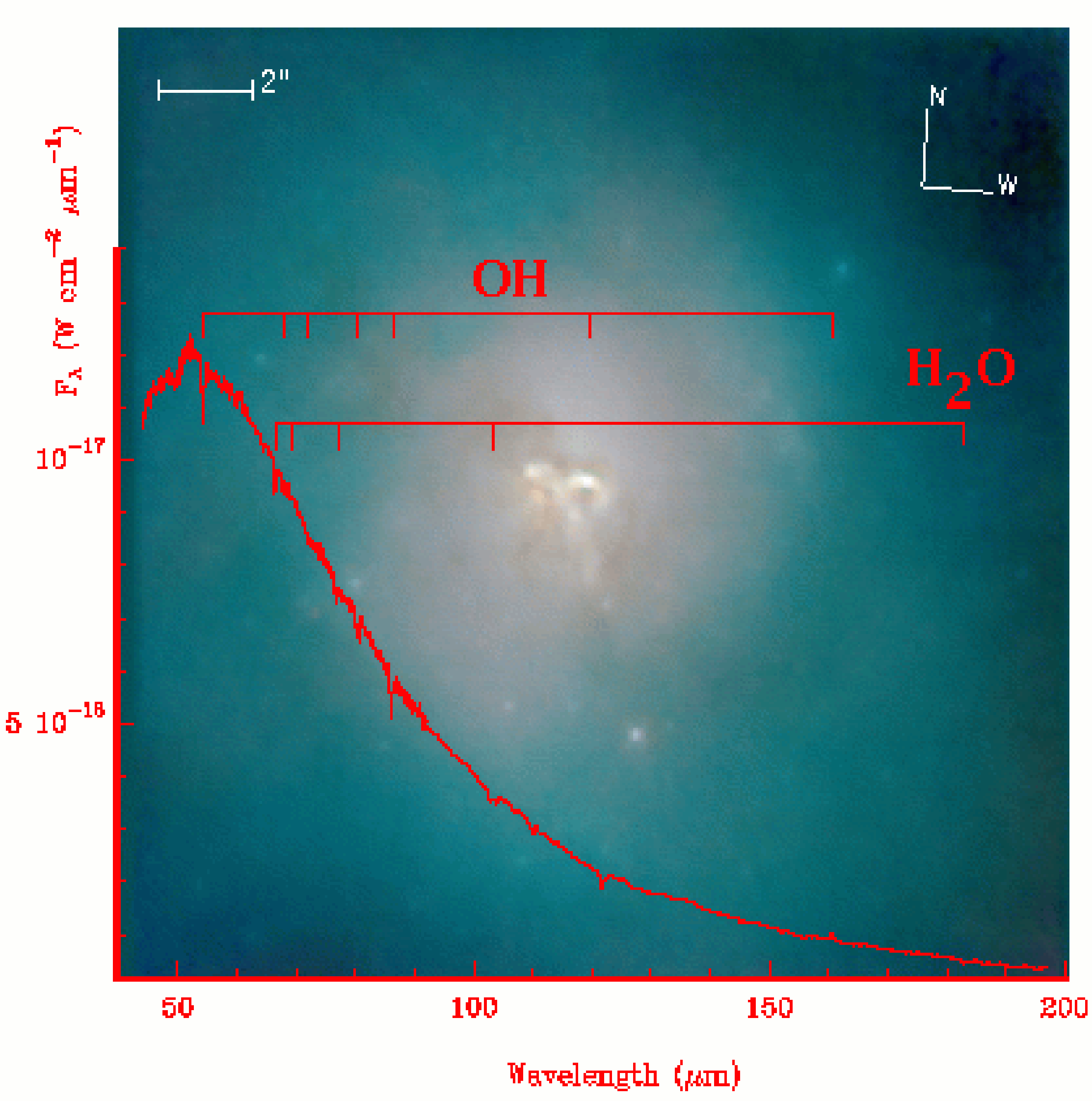
- **Detect the first dusty galaxies and study their formation**
  - View of the obscured central engines inside active galaxies
  - Imaging of the most distant known starburst galaxies
  - Discovery of many new ones beneath the current confusion limit.

Study disks and evolution of stellar/planetary systems
  - Water and ices in proto-planetary disks
  - Conditions that led to life on Earth

- **Directly detect planets and bright extra-solar comets**

- **Others**
  - Star formation
  - ISM studies
  - Late stages of stellar evolution

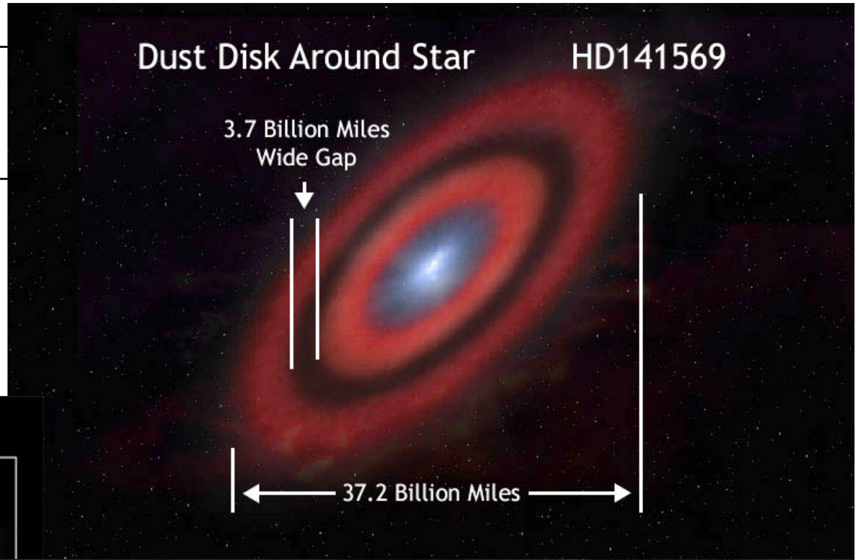
First dusty galaxies and study their formation

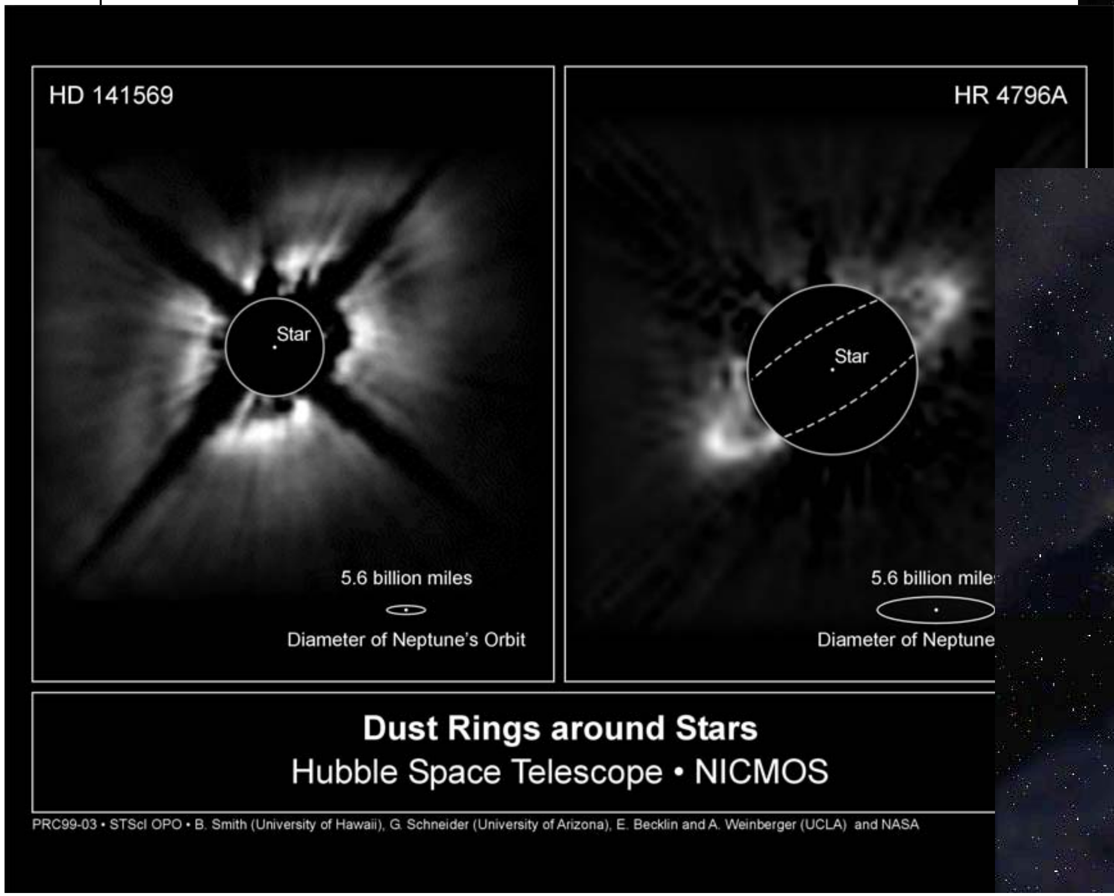


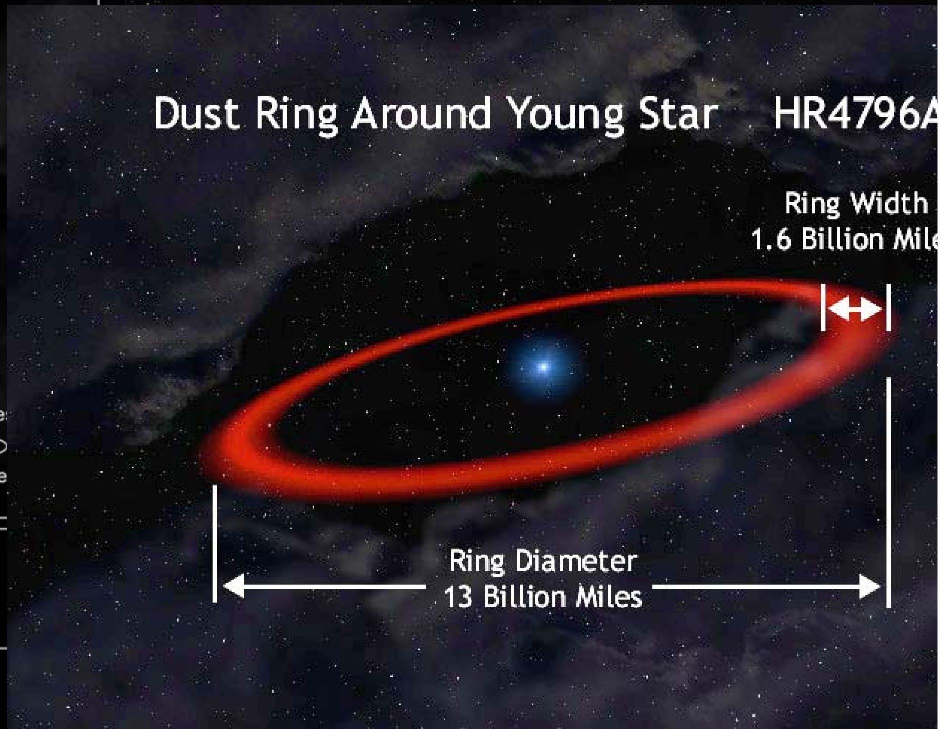
Arp 220

FIRI will image these ULIRGS in lines and continuum at very high z

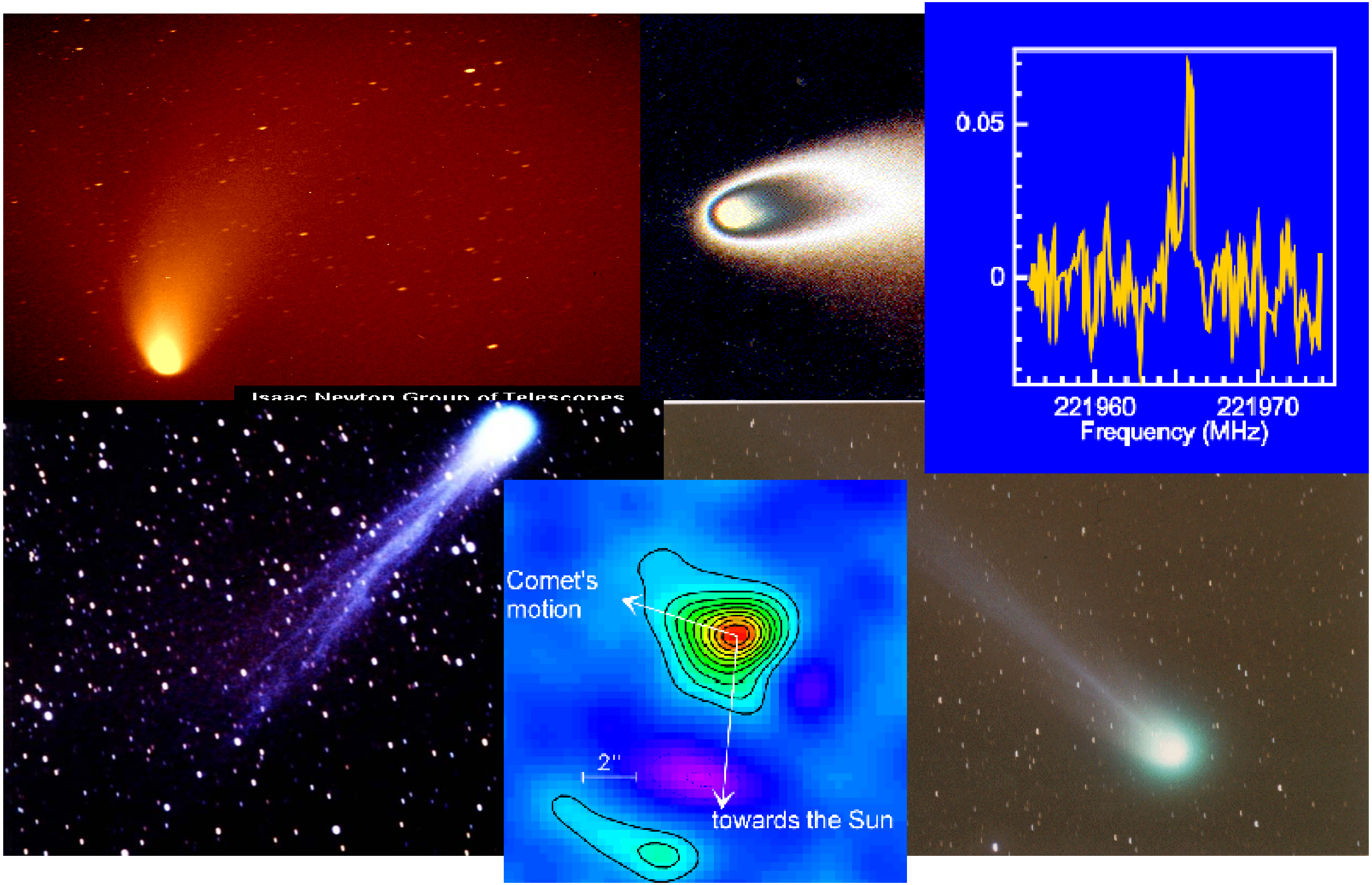
Study disks and evolution of planetary systems







Directly detect planets and bright extra-solar comets



FIRI. Concept

- Continuum and line measurements in the far-infrared
- Observatory-class mission: single dish & interferometer
- Large dish (10-m class) supported by several 3.5-m dishes
- FIRI will be free-flying
- Achieve a spatial resolution of 0.02-0.1 arcsec
- Instrumentation built by nationally-funded consortia

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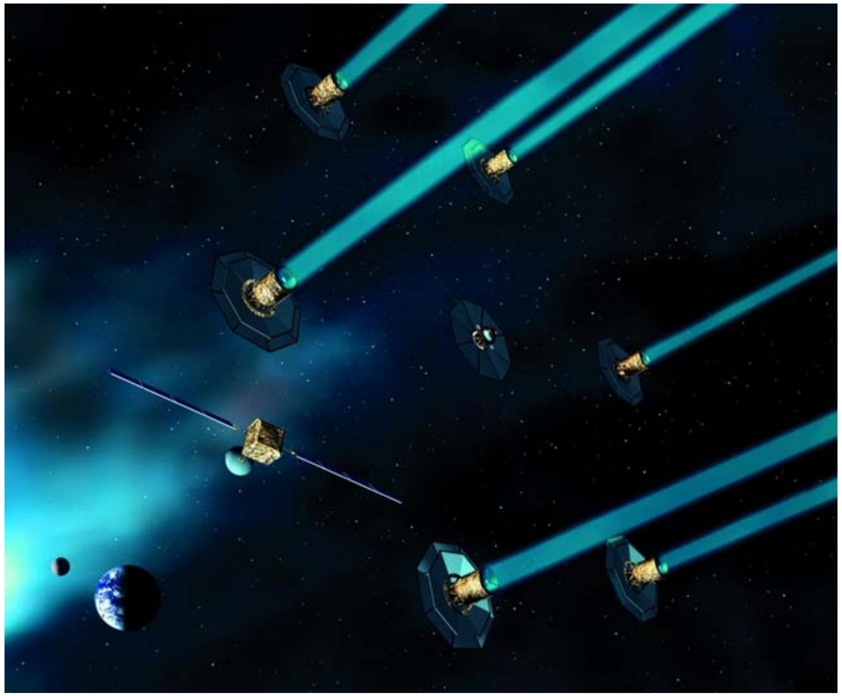

Be located in L2
No cryogens
Unlimited in lifetime

International collaboration

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Durham University, UK
IFSI-INAF, ROMA, Italy
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Manchester University
MPIfR, Bonn, Germany
MSSL, Dorking, UK
Open University, UK
Onsala Space Observatory, Onsala, Sweden
Padova University, Italy
Rutherford Appleton Laboratory (STFC), UK
Rijksuniversiteit Groningen, The Netherlands
SRON, Groningen, The Netherlands
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Universite Bordeaux 1, France
University of Cardiff, UK
University of Innsbruck, Austria
Universiteit Leiden, The Netherlands
University of Oxford, UK
University of Sussex, UK
University of Waterloo, Canada (representing a Canadian consortium)