Evolution of Herschel science objectives from initial ideas to the launch

Göran Pilbratt, Herschel Project Scientist Herschel 10 years after launch: science and celebration ESA/ESAC, Madrid 13-14 May 2019



<u>111</u> + |

Emergence of IR astronomy



Exp Astron (2009) 25:125–141 DOI 10.1007/s10686-009-9148-7

HISTORICAL REVIEW

History of infrared telescopes and astronomy

G. H. Rieke

Received: 18 November 2008 / Accepted: 21 January 2009 / Published online: 20 February 2009 © Springer Science + Business Media B.V. 2009

Abstract The first attempts to measure the infrared outputs of stars preceded by nearly a century the permanent establishment of infrared astronomy as an important aspect of the field. There were a number of false starts in that century, significant efforts that had little impact on the astronomical community at large. Why did these efforts fizzle out? What was different in the start that did not fizzle, in the 1960s? I suggest that the most important advances were the success of radio astronomy in demonstrating interesting phenomena outside of the optical regime, and the establishment virtually simultaneously in the United States of a number of research groups that could support each other and compete against one another in their approach to infrared astronomy.

Keywords Infrared astronomy · History of astronomy

'In the decade from the early 1960s to early 1970s, virtually the entire foundation for infrared astronomy was put in place' (Rieke 2009)

- Establishment of the photometric system
- Completion of an all-sky survey disproving there is nothing to be seen
- Detection of the internal energy of the giant planets
- Identification of O- and C-rich interstellar dust
- Discovery of prototypical dust-embedded very young star
- Finding the huge and ubiquitous far-infrared outputs of regions where young and massive stars are forming
- Discovery of the center of the Milky Way, both in stellar emission in thermal re-emission by interstellar dust
- Detection of the strong infrared outputs of star-forming galaxies, and discovery of LIRGs and ULIRGs
- Infrared excesses associated with active galactic nuclei

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 3





- 1971: Origin of the 'Shuttle Infrared Telescope Facility' (SIRTF)
- 1972: Greenstein decadal report: 100 um all-sky balloon survey top priority
- 1973: NASA/NAS Woods Hole summer workshop: several IR-related recommendations
- 1974: First planning of what eventually became IRAS
- 1977: Later documents refer to proposals by both Ames and JPL:
 - JPL: 10 m submm space telescope
 - Ames: 30 m infrared space telescope
 - JPL: The Submillimeter Space Telescope WG

Europe/ESRO/ESA

1974-75: Two (of 12) IR mission definition studies (LIRTS & CIRES) ongoing in ESRO 1974: Proposal to the Dutch government for an 'infrared survey satellite', basis for NL study in 1975 1975: Joint NL-US-UK study team, eventually becoming IRAS, launched & operated in 1983 1978: New ESA planning cycle leading to a call for mission proposals, one of them ISO

• ISO one of five studies in 1981-82, selected by ESA in 1983

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 4



JPL submm study group in 1977



SUBMILLIMETER WAVELENGTH ASTRONOMY FROM SPACE :

REPORT OF THE SUBMILLIMETER SPACE TELESCOPE WORKING GROUP

EXECUTIVE SUMMARY

February 10, 1978

Jet Propulsion Laboratory California Institute of Technology Pasadena, California The submillimeter spectral band 100 μ m to 1 mm is uniquely valuable for the investigation of a wide range of astronomical subjects, including:

- the cosmic microwave background,
- emission mechanisms and physical conditions in quasars and other extragalactic radio sources,
- the structure and evolution of galaxies,
- the composition and evolution of interstellar clouds,
- the investigation of both early and late stages of stellar evolution, and
- the composition of comets and planetary atmospheres.

Also the band is largely unexplored

high probability for serendipitous discoveries

Recommends 10 m ambient temperature space telescope

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 5



JPL submm study group in 1977



SUBMILLIMETER WAVELENGTH ASTRONOMY FROM SPACE :

REPORT OF THE SUBMILLIMETER SPACE TELESCOPE WORKING GROUP

EXECUTIVE SUMMARY

February 10, 1978

Thijs de Graauw was a member of this WG

Jet Propulsion Laboratory California Institute of Technology Pasadena, California The submillimeter spectral band 100 μ m to 1 mm is uniquely valuable for the investigation of a wide range of astronomical subjects, including:

- the cosmic microwave background,
- emission mechanisms and physical conditions in quasars and other extragalactic radio sources,
- the structure and evolution of galaxies,
- the composition and evolution of interstellar clouds,
- the investigation of both early and late stages of stellar evolution, and
- the composition of comets and planetary atmospheres.

Also the band is largely unexplored

high probability for serendipitous discoveries

Recommends 10 m ambient temperature space telescope

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 6









Introducing the selling points

- Last major spectral window to be opened
- Priorities: Cosmology, the interstellar medium, the outer parts of the solar system

Science objectives

- Cosmology
 - SZ-effect for clusters, CMB f(angular scales)
- Active galaxies
- ISM & star formation
- Stellar mass loss
- Nearby galaxies
- Solar system studies
 - H_2 /He ratios outer planets, org & prebiotic mols
 - No mention of water!

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 8



FIRST assessment rep't – September 1983 eSa



Introducing the selling points

- Last major spectral window to be opened
- Directly probe the cool universe
- Large variety of astrophysical problems: Star formation, formation of molecular clouds, evolution of galaxies, molecular outflows in YSOs, formation of planetary systems, crucial areas of cosmology

Science objectives

- Molecular cloud astrophysics (incl SF)
- Nearby galaxies (incl active galaxies)
- Cosmology (incl SZ, but not CMB)
- Solar system studies (atmospheres & comets)

Different order (and amount of space) for similar science, but *no* CMB observations

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 9

By Horizon 2000 plan – formed 1983-85





Horizon 2000 plan

- Roger Bonnet D/SCI in May 1983
- Initiated by D/SCI in September 1983
- Call for mission concepts in November 1983
- Venice meeting in June 1984
- Report dated December 1984
- Adopted in Rome in January 1985

Mission concepts

- 77 received
- 2 in submillimetre area (FIRST & SMIT)
 - FIRST (G. Winnewisser)
 - SMIT (R. Gispert)
- Does anyone have these proposals?

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 10





esa sp-1070 Space science Horizon 2000



1+1

By Horizon 2000 plan – formed 1983-85





Horizon 2000 plan

- Roger Bonnet D/SCI in May 1983
- Initiated by D/SCI in September 1983
- Call for mission concepts in November 1983
- Venice meeting June 1984
- Report dated December 1984
- Adopted in Rome January 1995

Mission concepts

- 77 received
- 2 in submillimetre area (FIRST & SMIT)

High Throughput Heterodyne Spectr Mission

- Selected as CS3 or CS4
- Order to be decided on later

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 12



esa sp-260



Proceedings of an ESA Workshop on a Space-Borne Sub-Millimetre Astronomy Mission A cornerstone of the ESA long-term space science programme

Segovia, Spain



Cornerstone meetings

- Community to elaborate on science objectives,
- and formulate a concept for the cornerstone

Science objectives

- Very similar to FIRST assessment rept
- CMB fluct (~10' to ~few deg) obs recogn infeasible

Concept

- 8 m diameter telescope
- Heterodyne spectr to C+ line (1.9 THz /157 um)
- Direct det spectr & imaging phot 50-350 um
- Photometry 350 um to 1 mm

Due to similarity with the FIRST proposal, the cornerstone came to be referred to as FIRST

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 13





1987: Space station connection

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 14

+



Post Segovia meeting – 1986-92



1987: Space station connection

• Discarded due to thermal considerations (~6000 litres of SLHe per year)

1987: Science Advisory Group (SAG) established

- Defining a mission concept compatible with the overall scientific performance of a cornerstone project following the prime objectives as identified at the Segovia workshop,
- but, remaining within the allowable financial envelope

1990: Popular ESA brochure BR-69

1990: 29th Liège meeting: From ground to space-borne submm astronomy

• Both in line with Segovia output, thus with the FIRST assessment report

1990-91: System Definition Study (SDS) by industry

- 8 & 4.5 m diameter telescopes, and multiple payloads
- Baseline: 4.5 m telescope, four instruments (FIP, FIS, STR, THR), SLHe cryostat

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 16

SDS 1992 costing => Rider Study





FIRST in 1992

- Competing with Rosetta for CS3 slot
- FIRST is costed too expensive

Rider Study (aka 'Tiger Team' exercise)

- ESA proposes FIRST/HOM mission
- Rejected, 'not a cornerstone'

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 17

· = ■ ► = = + ■ ■ = = = = ■ ■ ■ = = = ■ ■ ■ ■ = = = ₩ = ■

SDS 1992 costing => Rider Study



 Becketh, J. Coradina, E. van Dubowa, P. Encenaa, E. Contes, M. Contes, A. Barrin, R. Hills, T. & Jang, E. Kollborg, F. Royna, J.-M. Linnerst, R. Luboch, Bartin Pintado, V. Bulan, G. Fillmatt, A. Faglinch, J.-L. Tapat, V. Bartan, Ericanon, J. Suptaki, S. Voloviti, V. Waybory

FIRST in 1992

- Competing with Rosetta for CS3 slot
- FIRST is costed too expensive

Rider Study (aka 'Tiger Team' exercise)

- ESA proposes FIRST/HOM mission
- Rejected, 'not a cornerstone'

New concept

- 3 m diameter telescope
- Heterodyne spectr to 1 THz / 300 um
- Other instruments must not drive concept
- Mechanical coolers instead of SLHe cryostat

Selected as CS4 by SPC in November 1993

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 18









 Beckwith, J. Corasima, E. van Dubowit, P. Encreman, E. Coratti, M. Weller, A. Harrin, R. Hills, T. & Jong, E. Kollburg, F. Rayna, J.-M. Linnarov, E. Lablands, Massin Pintado, V. Natala, G. Pilleratt, A. Foglinch, J.-J. Paper, W. Estward Robinson, J. Stattaki, S. Volesni, W. Wayhara

Science objectives in 'Red Report'

- Stars and interstellar medium
- Nearby galaxies
- Distant galaxies and quasars
- The early universe
- Planets, their atmospheres and satellites
- Comets

Rider Study (aka 'Tiger Team' exercise)

- ESA proposed FIRST/HOM mission
- Rejected, *'not a cornerstone':*
- *interesting but fairly specific mission ... that* unfortunately does not have the breadth and scientific capabilities to tackle a number of the most important goals ... identified for FIRST.'

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 19

· _ II 🛌 :: = + II = 🔚 드 II II = _ :: :: = II II = X: := |+|

NGST Loss of Ariane 501/Cluster Loss of Mars 96

Christopher Simpson

Science/Expert Hearing' – Sep 1996



'Science/Expert hearing' organized by the SAG in ESTEC

- In response to a request from the SSAC to
- 'review the science priorities of the FIRST cornerstone mission in view of recent developments'. (incl budget cuts

'Report on FIRST-SAG hearing' by R. Genzel, 23 October 1996:

- 150-500 um deep broadband (extragalactic) surveys and related research
 - formation of and evolution of galaxy bulges and elliptical galaxies in early universe
 - possibilities of new classes of objects
- physics and chemistry of the interstellar medium in galaxies
 - in our Galaxy, external galaxies, including high redshift galaxies
- detailed high resolution spectroscopy of comets, cool outer planets, Kuiper-belt
- Sunyaev-Zeldovich effect in clusters low priority
- 'bright source' science goals expected to be done by SOFIA

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 21

Grenoble meeting, 15-17 April 1997





European Space Agency

Third ESA FIRST meeting (after Segovia & Liège)

- Baseline FIRST mission:
- 3 m (3.5 m TBC) diameter aluminium telescope
- HET, PHOC, and BOL instruments

Top level science objectives (from Hearing)

- Deep broadband extragal surveys 150-500 um
- Follow-up spectroscopy of interesting objects
- Physics and chemistry of ISM (Galactic and extragalactic, including high redshift)
- Astrochemistry (ISM lifecycle incl star formation)
- Spectroscopy of comets and outer planets, searches for KBOs

Support of the community dispelled FIRST vs NGST questions => ESA go-ahead for FIRST

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 22





ESA/SPC(97)22 20 August 1997

FIRST

Far Infra-Red and Submillimetre Telescope



Science Management Plan



Science Management Plan

- Presented in spring 1997, approved autumn 1997
- Concept of Key Projects call upfront
- FIRST must both survey and follow-up

Instrument / ICCs & Mission Scientists AO

- Issued on 3 October 1997
- Payload (HIFI, PACS, SPIRE) provisionally selected in 1998, and
- Confirmed by the SPC in 1999
- Elaborated on the science objectives in place

Industrial / financial background

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 23

· = ■ ► = = + ■ + ■ = = = ■ ■ ■ ■ ■ ■ ■ ■ ₩ ► ► •

FIRST/Planck merger!



ESA/SPC(97)22 20 August 1997

FIRST

Far Infra-Red and Submillimetre Telescope



Science Management Plan



Science Management Plan

- Presented in spring 1997, approved autumn 1997
- Concept of Key Projects call upfront
- FIRST must both survey and follow-up

Instrument / ICCs & Mission Scientists AO

- Issued on 3 October 1997
- Payload (HIFI, PACS, SPIRE) provisionally selected in 1998, and
- Confirmed by the SPC in 1999
- Elaborated on the science objectives in place

Industrial / financial background

- FIRST/Planck one budget line
- ITT issued in September 2000
- Industrial implementation started on 2 April 2001

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 25

Toledo meeting, 12-15 December 2000





Confirmed speakers, discussing the FIRST mission, its science challenges and capabilities:

> Philippe André Michael Barlow Dominique Bockelée-Morvan José Cernicharo Ewine van Dishoeck **Jacqueline** Fischer Asunción Fuente **Beinhard Genzel** Maryyonne Gerin Thiis de Graauw Matt Griffin Michel Guêlin Martin Kessler Andrew Lawrence Emmanuel Lellouch Dieter Lutz Max Pettini Tom Phillips Göran Pilbratt Albrecht Poglitsch Michael Rowan-Robinson **Rens Waters** Edward Wright

Symposium Website:

http://astro.estec.esa.nl/FIRST/Toledo/toledo.html

Registration deadline: 1 October 2000



The Symposium is co-sponsored by Caja de Ahonse de Castlia la Manchi Consejo Superior de Investigaciones Científica Consejo Superior de Investigaciones Científica Marta de Comunidades de Castlia La Manchi Hostino Gacgation Mancoa Ministerio de Ciencia y Tencelogii Sociedad Española de Antonomi Universida de Castlia la Manchi Universida de Castlia la Manchi Constancia de Castlia la Manchi Castlia de Castlia de Castlia la Manchi Castlia de Castlia la Manchi Castlia de Castlia la Manchi Castlia de Castlia de Castlia la Manchi Castlia de Castlia de Castlia la Manchi Castlia de Castlia

Local Organising Committee: J. Cernicharo (CSIC, chair), J. Martin-Pintado (OAN, co-chair), Asunción Diez (CSIC, secretary), J.R. Goiceachea (CSIC), E. Gonzalez-Atlonao (CSIC), F. Langa (U. Castilla la Mancha), F. Najarro (CSIC), M.J. Sempere (CSIC)

The Promise of FIRST

• Presenting FIRST to the community

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 26







The Promise of Herschel

- Presenting Herschel to the community
- In particular the concept of Key Programmes

'Standard' top level science objectives

- Deep unbiased extragalactic photometric surveys
- Photometric surveys of active and quiescent molecular clouds
- Follow-up spectroscopy of specially interesting galactic and extragalactic survey sources
- Spectral surveys of different types of objects, including early epoch starburst and active galaxies
- Studies of 'individual' sources in detail
- Studies of comets and other solar system objects

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 27

Science objectives 1982 onwards



The Core

- Last major spectral window to be opened
- Directly probe the the cool universe; e.g.:
 - Molecular clouds & star formation
 - ISM & astrochemistry
 - Evolution of galaxies
 - Solar system studies

Added

Water observations (not in proposal)

Removed

CMB and SZ observations (originally top priority)

Post 'The Promise of Herschel' meeting

• The science objectives in the hands of the community

Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 28





Refereed papers for ESA space observatories

Cumulative number of papers vs calendar year after launch



Herschel 10 years after launch: science and celebration | ESAC | GLP | 13/05/2019 | Slide 29



