

The Herschel Space Telescope
Project:
The mission, the science and YOU!

Phil Appleton

*NASA Herschel Science Center
Project Scientist and Task Lead*

3.5-m IR/Sub-mm Herschel Space Observatory

- Fourth “Cornerstone” mission of European Space Agency’s “Horizon 2000” Program and launched in May 2009. It finished observing in April 2013
- Many countries, including the USA, have participated in its design and implementation
- ESA’s European Space and Astronomy Center (ESAC) in Madrid, Spain, hosts the Herschel Science Center (HSC). Caltech hosts the NASA Herschel Science Center (NHSC)
- Both HSC and NHSC will continue to support observers and archive users for the next few years during a Post-ops phase.

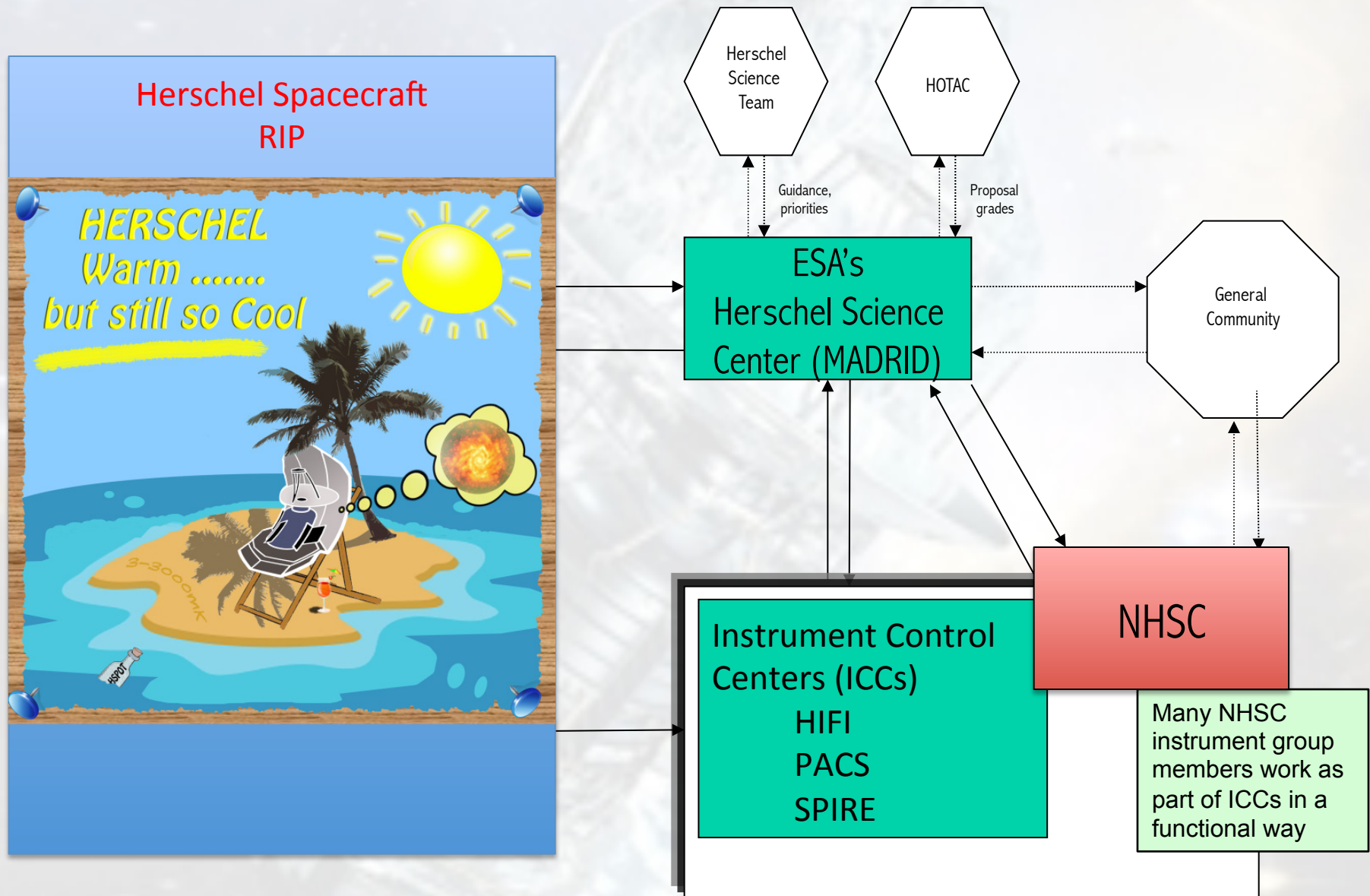
Objective and Scope of the NASA Herschel Science Center

The NHSC has been established at the Infrared Processing and Analysis Center (IPAC) at the California Institute of Technology under support from NASA.

NHSC began operations in 2001 and will continue to operate throughout the lifetime of the Herschel Mission, including the post-cryogen archival phase.

The primary mission of the NHSC is to support the US-based astronomical community in exploiting the Herschel science opportunity, at a level equivalent to that provided to the European Community by ESA's Herschel Science Centre.

Relationship between NHSC and Herschel Project



A satellite is shown in space, oriented diagonally from the bottom-left towards the top-right. The satellite has a complex structure with various panels and antennas. The background is a vast field of stars, with a bright, glowing nebula or star cluster on the right side, creating a sense of depth and cosmic scale. The overall color palette is cool, dominated by blues, greys, and whites, with some warmer tones from the nebula.

HOW TO FIND US ON THE WEB

How to find us on the web

Public Web Site

<http://herschel.caltech.edu>

The image shows two overlapping browser windows. The top window displays the Herschel Space Observatory website, featuring a large image of the telescope and navigation links for 'For Public', 'For Researchers', and 'ESA Herschel Home'. The bottom window shows the NHSC Astronomer's Web Site, which includes a navigation menu on the left, a main header, and a central announcement for a 'Data Processing Workshop: Exploiting the Herschel Archive'. The announcement text provides details about the workshop's location, dates, and registration process.

Science Wiki Page for Astronomers

<http://nhscsci.ipac.caltech.edu>

What the NHSC Does for US Astronomers?

- ✓ Provide resources and tools to help US Community exploit Herschel science (Inc. FREE ACCESS TO REMOTE COMPUTERS)
- ✓ Provide support and documentation for Herschel-specific software (HIPE, HSPOT + others)
- ✓ Advocate US user needs within Herschel Project
- ✓ Engage US community in Herschel Science
- ✓ Help develop the best possible Herschel Science Archive
- ✓ Administration of data analysis grants for US-based observers

A large satellite is shown in space, oriented diagonally from the bottom left towards the top right. The satellite has a complex structure with various panels and instruments. The background is a vast field of stars, with some brighter stars showing lens flare effects. The overall scene is set in a dark, starry space environment.

RESOURCES AND TOOLS
of the NHSC

NHSC Resources	New User	Expert User	Comments
NHSC Helpdesk	Y	Y	nhsc.ipac.caltech.edu/helpdesk
NHSC Wiki Pages	Y	Y	nhscsci.ipac.caltech.edu
NHSC Newsletter	Y	Y	nhscsci.ipac.caltech.edu/sc/index.php/NewsLetters
Intro Workshops	Y	N	Best for beginner users or new archival users
Data School/Advanced DP workshop	N	Y	Users bring their own data to reduce using big machines
Webinars	Y	Y	On-line topical discussion groups
On-line Video and other web- tutorials	Y	Y	Step by Step guides
NHSC In-person visits	N	Y	Staff Availability
Free Remote Access Computer Resources	N	Y	Requested through HELPDESK

NHSC Helpdesk

**FIRST STOP FOR US OBSERVERS
IN NEED OF HERSCHEL HELP:**

<http://nhsc.ipac.caltech.edu/helpdesk>

The screenshot shows the NHSC Help Desk website. At the top left is the NHSC logo and the text "Help Desk". The date "26 Feb 2010" is displayed in the top right. The main content area is divided into several sections: "Support Center" with links for "Register" and "Knowledgebase"; "News" with a link to "View Herschel news and announcements"; "Popular Knowledgebase Articles" with a table of articles and their view counts; "Latest Knowledgebase Articles" with a table of articles and their dates; "Login" with fields for email and password; "Search" with a search box and a dropdown menu; and "Latest News" with a list of recent news items. The footer contains navigation links and the text "Help Desk Software By Kayako eSupport v3.10.02".

Popular Knowledgebase Articles	Views
Where to go for additional information	57469

Latest Knowledgebase Articles	Date Added
Importing SDP data into HIPE	06 Dec 2009 09:01 PM
Using hcss v1.0 with Java 1.6.13	29 Jun 2009 10:43 AM
Are Point Spread Functions (PSFs) available for PACS?	29 May 2009 05:39 PM
Mac requirements for HiPe	13 Nov 2008 10:57 AM

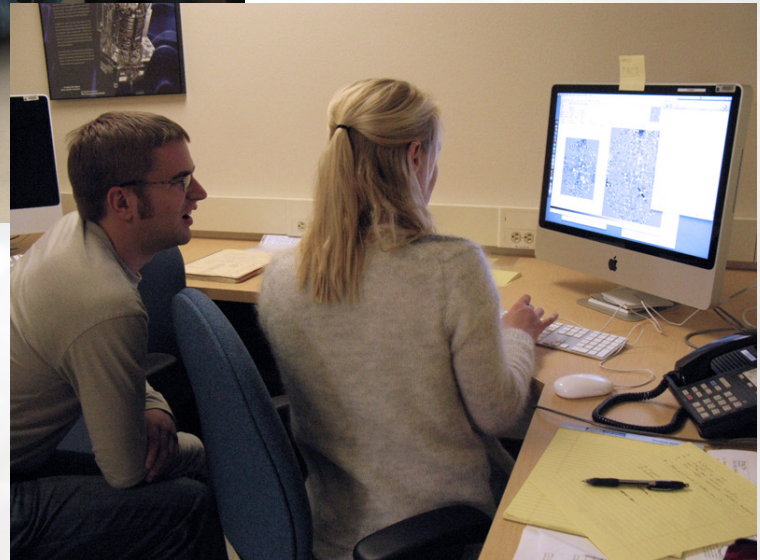
Latest News
September 22: OTKP wiki's unavailable, 23 Sep 09, 13:00-17:00, PDT
July 08: TALKS ONLINE for NHSC OTKP Mini-Workshop - Aug 22, 2008
January 23: The NASA Herschel Science Center
January 23: What is the Herschel Space Observatory

- Has been fully operational since Jan 2007
- NHSC Response:
 - Provide initial OST acknowledgement
 - Ticket forwarded immediately to expert who responds directly within 2 business days
 - In rare case that we are unable to assist, we open and follow-up with European help desk ticket.
- Average response time < 1 business day (often ~ 2-5 hrs)



Our first NHSC Data Processing Workshop in 2009

Visitors to NHSC were common during early operations and still provide a channel for help and advice with DP



NHSC Remote Computing Resources for US-based Observers



- FREE large-memory (64-128 GB) fast machines by remote access
- LATEST HIPE VERSION FULLY INSTALLED
- Large disk space to store and transfer to home institution
- Access to variety of different Herschel mappers for comparison of different mapping methods (currently available MADmap, Scanamorphos and Unimap, SANIPIC + more coming

REQUEST MACHINE VIA NHSC HELPDESK

Outreach Activities

AAS and Other Meeting Support

Help with Publicizing Exciting Results

- *Image or Press Release—coordinated with ESA
if appropriate*

Organizing Conferences and Science Workshops

Team Wiki Pages

The NASA HERSCHEL SCIENCE CENTER ALSO SUPPORTS AAS MEETINGS



Herschel images were presented on the giant electronic “Hyper-board” by Robert Hurt (IPAC) as part of a demo on astronomical images in the IR

In Post-Operations NHSC has a strong emphasis on multiplying the value of the Herschel Science Archive —we have developed interfaces with the NASA InfraRed Science Archive (IRSA) at IPAC

The image shows two overlapping screenshots of the NASA/IPAC Infrared Science Archive (IRSA) website. The left screenshot displays the 'Herschel Space Observatory' mission characteristics page, and the right screenshot shows the 'Herschel Data Search' interface.

NASA/IPAC Infrared Science Archive

for NASA's Infrared and Submillimeter Data

Herschel Space Observatory

Mission Characteristics

Description:	The Herschel Space Observatory is a space-based observatory observing the Far-Infrared and Submillimeter regions of the electromagnetic spectrum.
Lifetime:	May 2009 - February 2013 (estimated)
Wavelength:	51 μm - 670 μm
Area Coverage:	Targeted
Instruments:	<ul style="list-style-type: none"> Photodetector Array Camera and Spectrometer: 60-85, 85-130, and 130-200 μm Spectrometer: 51-220 μm Spectral and Photometric Imaging Spectrometer: 250, 350, 500 μm Spectrometer: 200-670 μm Heterodyne Instrument for the Far Infrared: 1.9-0.49THz (157 - 615 μm), with 600-1000 μm Spectrometer
Science Products Generated:	<ul style="list-style-type: none"> Raw, calibrated, and post-calibration data SPIRE, and HIFI Herschel Key Project data
Funding Agency:	Herschel is an ESA mission with participation from NASA, DLR, CNRS, and ASI.

Herschel Data Search

Home About Holdings Missions Documentation Help Desk

esa

Herschel Metadata HSA4.3.1 was updated on August 2013

This web interface allows users to find data in the *Herschel Science Archive (HSA)* maintained by ESA at the European Space Astronomy Centre, and provides links to the data retrieval through the HSA's Virtual Observatory interface. The archive can also be accessed from ESA's [Herschel Science Archive interface](#). An observation log of all Herschel science observations is also available. Additional information about the mission and the instruments can be found at the [NASA Herschel Science Center](#) webpages as well as the ESA's [Herschel Science Centre](#) webpages.

Cone Search
 Box Search
 Multi-Position Search
 All Sky

Coordinate/Object **Radius** arcmin

 Examples: 0 0 gal | M42

Instrument & Observation Mode

HIFI
 Single Point
 Mapping
 Spectral Scan

PACS
 Photometry
 Line Spectroscopy
 Range Spectroscopy
 SPIRE PACS Parallel

SPIRE
 Photometry
 Spectroscopy
 SPIRE PACS Parallel

Proposer (case sensitive)
 Proposal ID (case sensitive)

The image shows the Herschel Space Observatory in space, set against a backdrop of a starry galaxy. The observatory is a large, complex structure with a prominent central telescope and various instruments. The background is a vast field of stars, with a bright, glowing region on the right side, possibly a star-forming area or a nebula. The overall scene is illuminated by the light of the stars, creating a sense of depth and scale.

HERSCHEL THE OBSERVATORY

What is special about Herschel Data?

- **Herschel is a large telescope**
 - 3.5 m diameter
 - collecting area and resolution
- **Exploring new spectral window**
 - 55-672 μm – bridging the far infrared & submillimetre – the ‘cool’ universe
- **Novel instruments**
 - wide area mapping in 6 ‘colours’
 - imaging spectroscopy
 - very high resolution heterodyne spectroscopy
- **Herschel archive is:**
 - designed to capture the most interesting far-IR/sub-mm astrophysics:
 - galaxy evolution over cosmic time
 - star formation near and far
 - ISM physics/chemistry
 - birth of solar systems
 - many things yet to be discovered in archive!

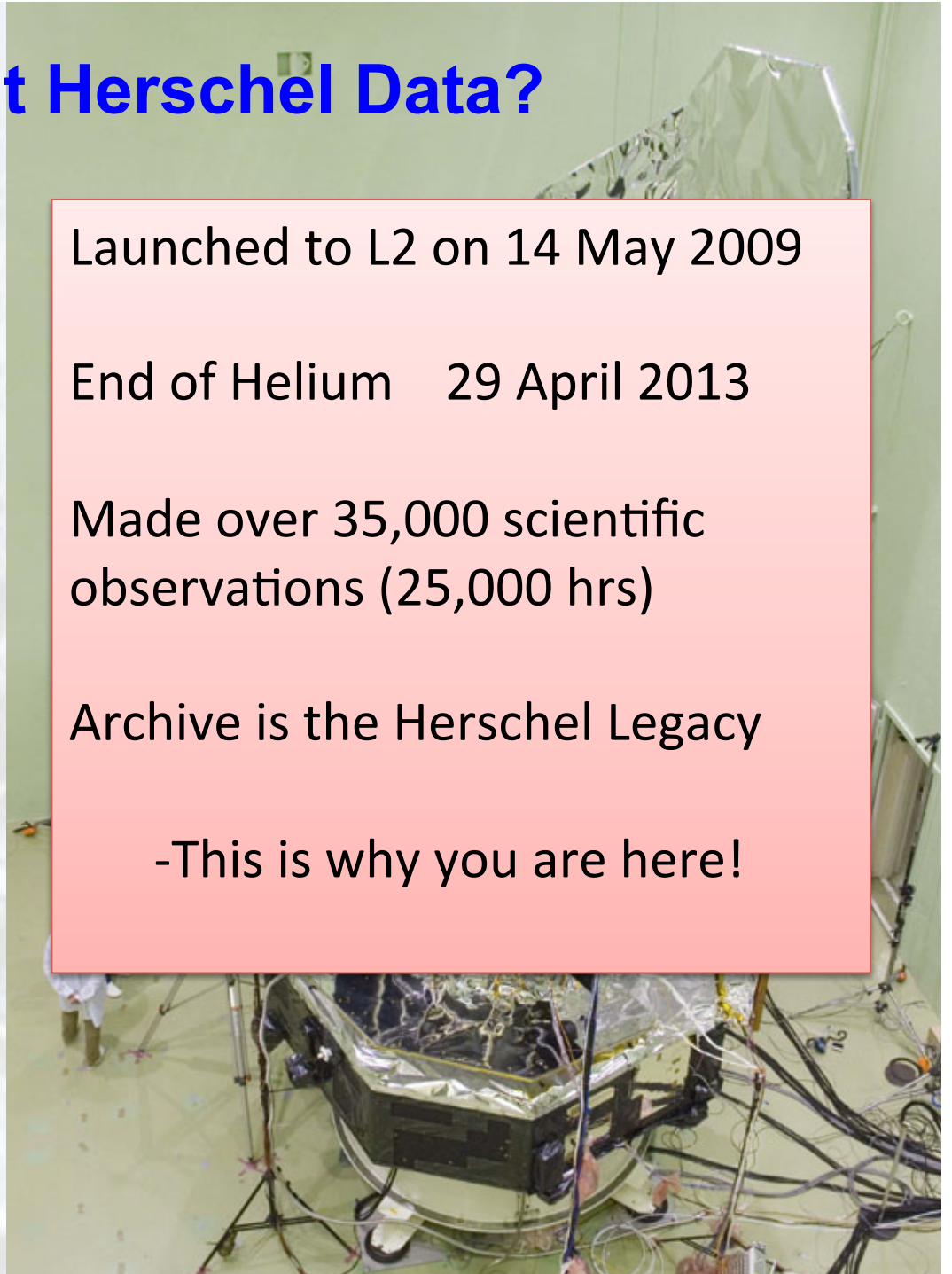
Launched to L2 on 14 May 2009

End of Helium 29 April 2013

Made over 35,000 scientific observations (25,000 hrs)

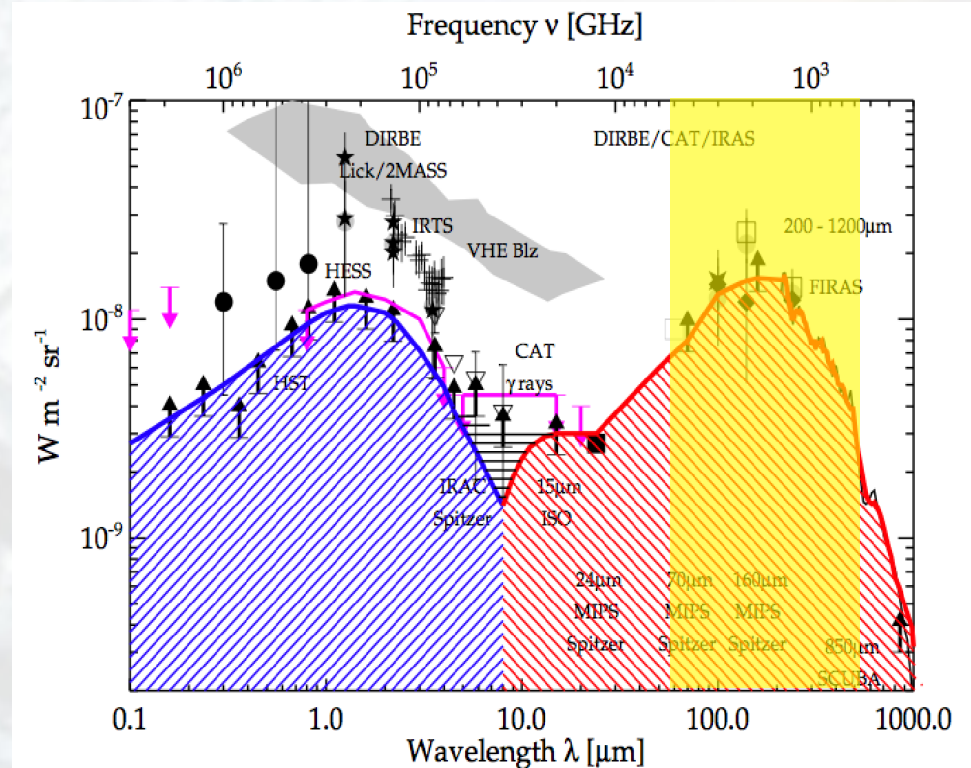
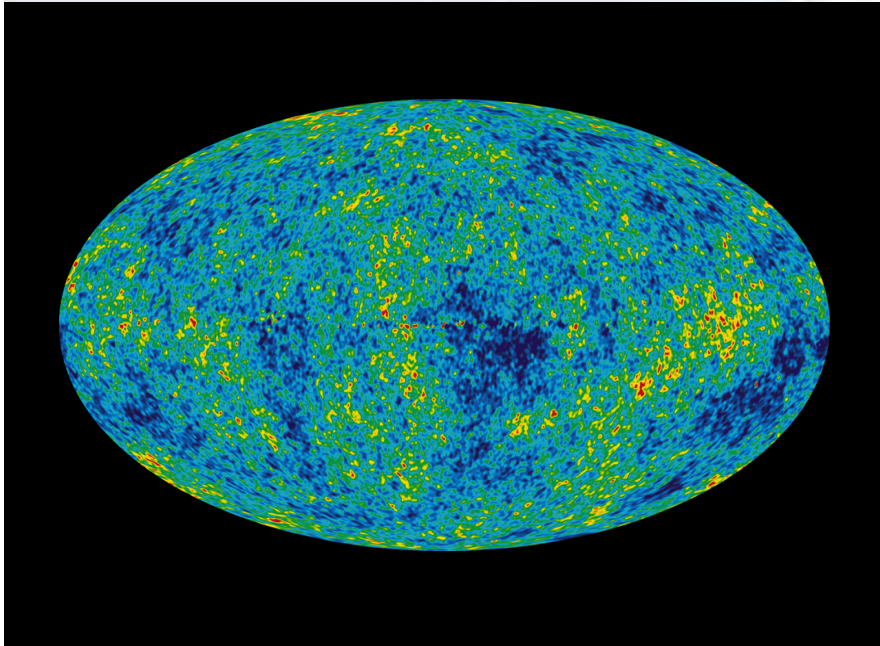
Archive is the Herschel Legacy

-This is why you are here!



Science Background-I

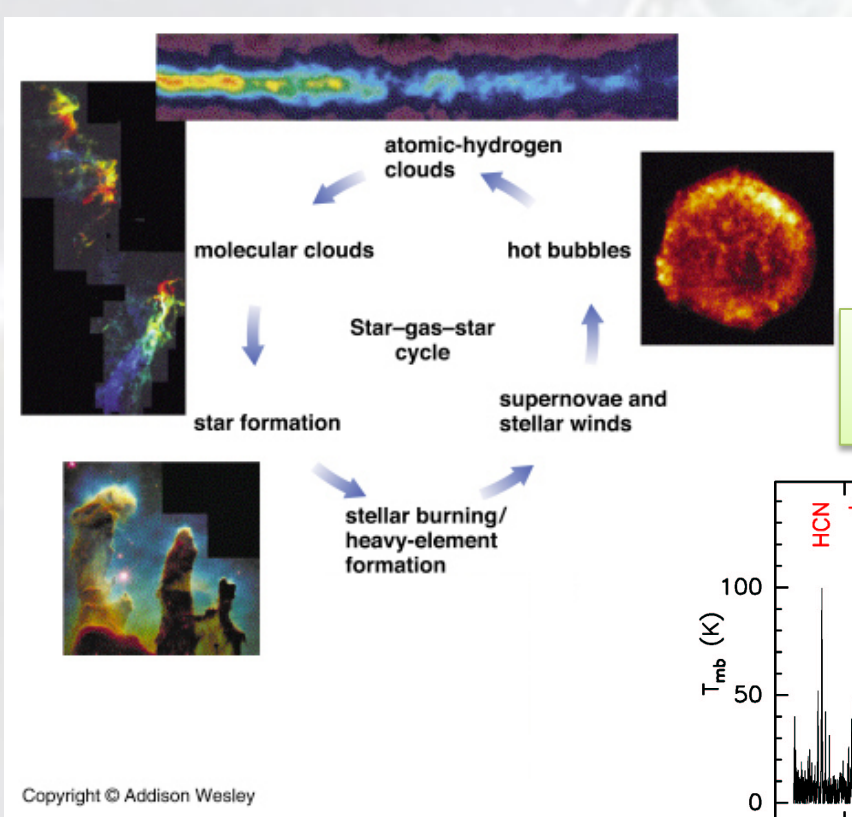
(Galaxies SEDs across cosmic time)



- Half of the energy created in the Universe since the CMB has been reprocessed into the IR
- Herschel covers the IR peak and pushes into the submillimetre
- Herschel is able to resolve a large fraction of galaxies contributing to IR peak

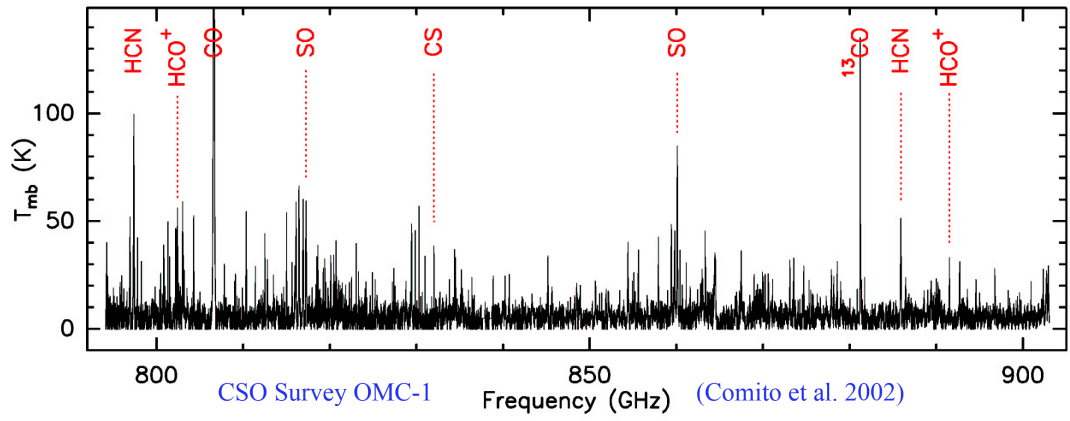
Science Background –II The Molecular Trail to the formation of Life

Herschel is helping to uncover the inter-relationship between the life-cycle of grains and chemistry that created life

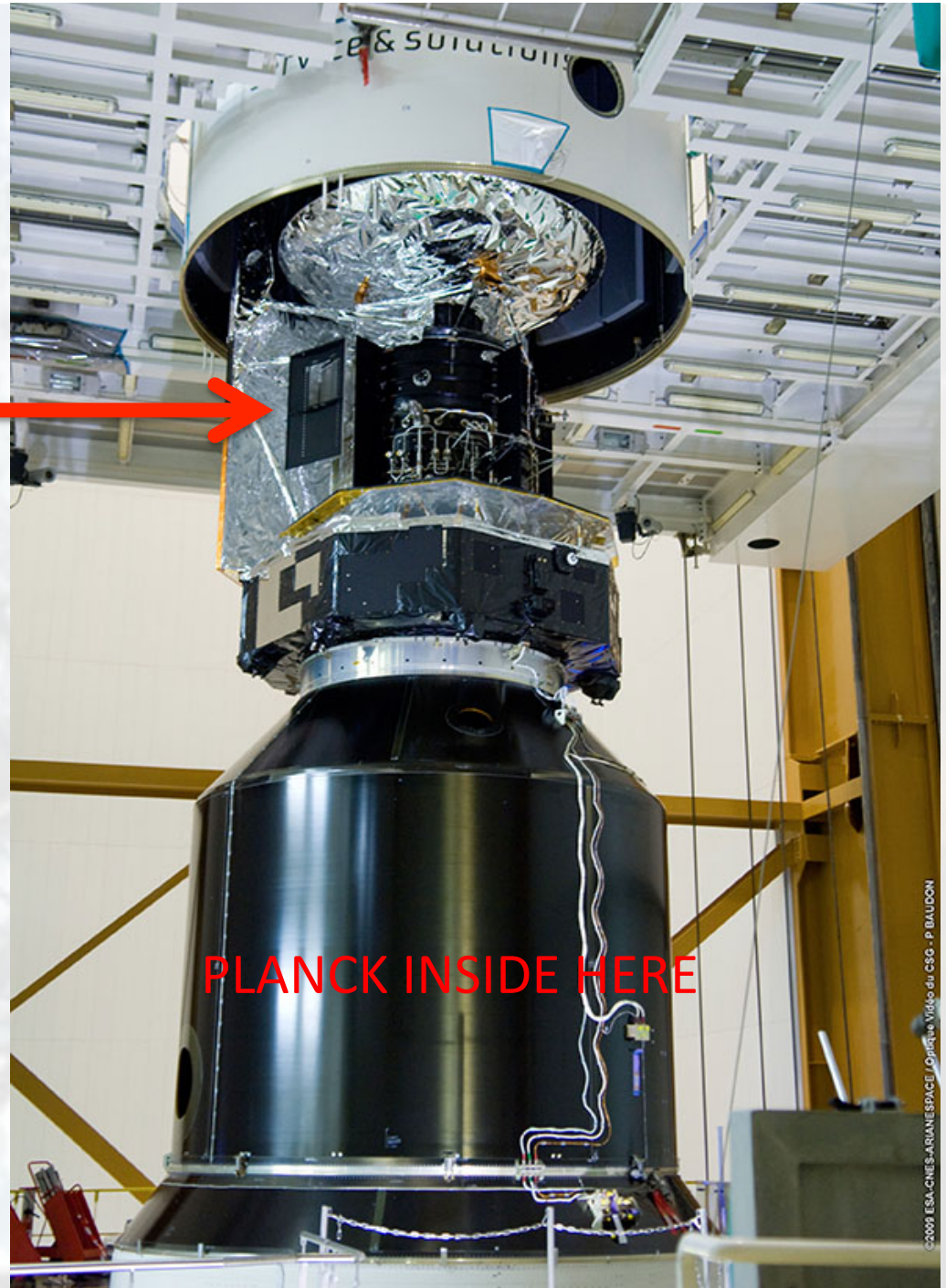


Hydrogen and water chemistry and the relationship to dust and dust recycling in the life of stars.

It is exploring the properties of multi-phase gas and reprocessing in star formation regions



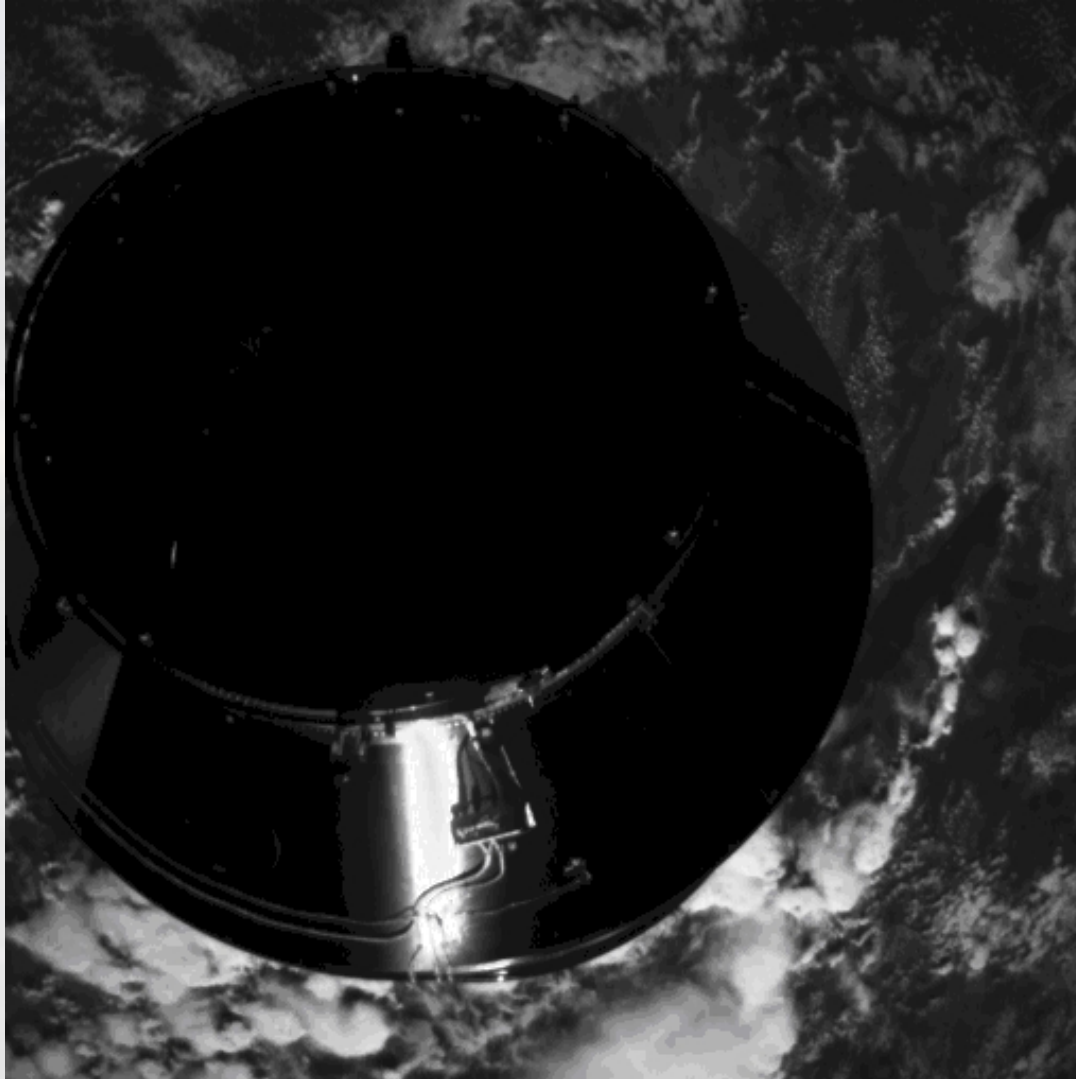
Herschel and Planck
on the launch-pad!
Last view of Herschel
on ground before
launch!



V188 launch on 14 May 2009



Herschel's view of Planck-Sylda above Africa en route for L2

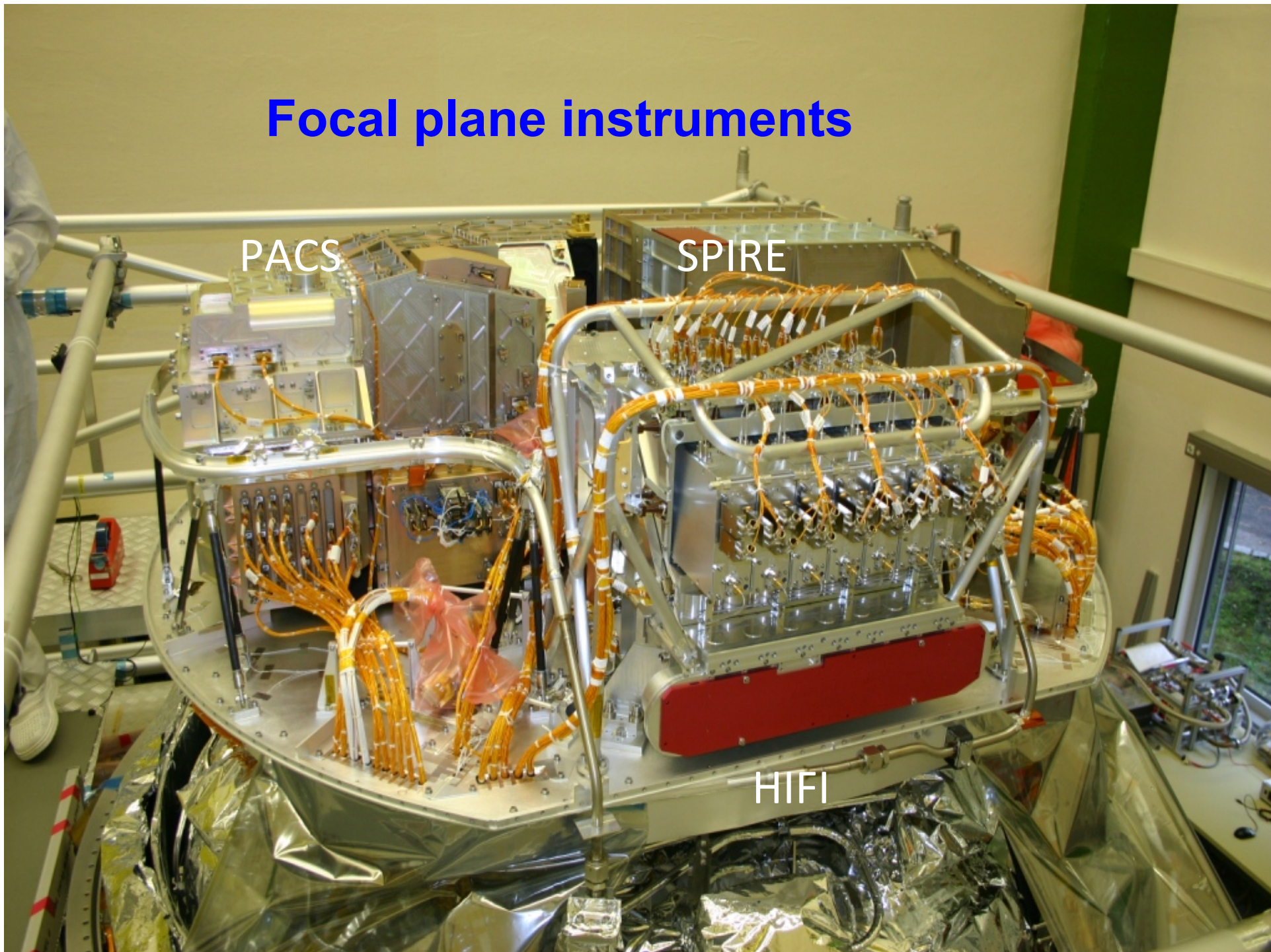


Focal plane instruments

PACS

SPIRE

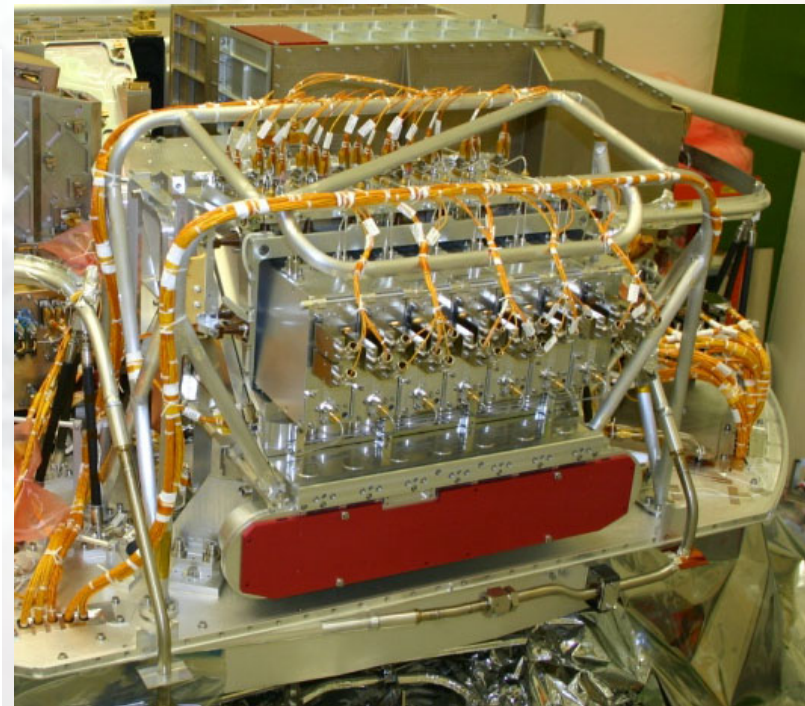
HIFI



HIFI

HIFI – Heterodyne Instrument for the Far Infrared

- PI: Frank Helmich, SRON, Groningen, The Netherlands
- Co-PIs: Tom Phillips, Caltech, USA; Jürgen Stutzki, U Köln, Germany; Emmanuel Caux, CESR, France; and Thijs de Graauw, ALMA
- Very high resolution spectroscopy over 480-1250 and 1410-1910 GHz
- SIS and HEB mixers, auto-correlator and AOS spectrometers



SPIRE

SPIRE – Spectral and Photometric Imaging Receiver

- PI: Matt Griffin, U Cardiff, Cardiff, United Kingdom
- Co-PI: Laurent Vigroux, CEA, Saclay, France
- Imaging photometry and spectro-photometry/-scopy over 194-672 μm
- 3 bolometer arrays for photometry, 2 bolometer arrays for spectroscopy

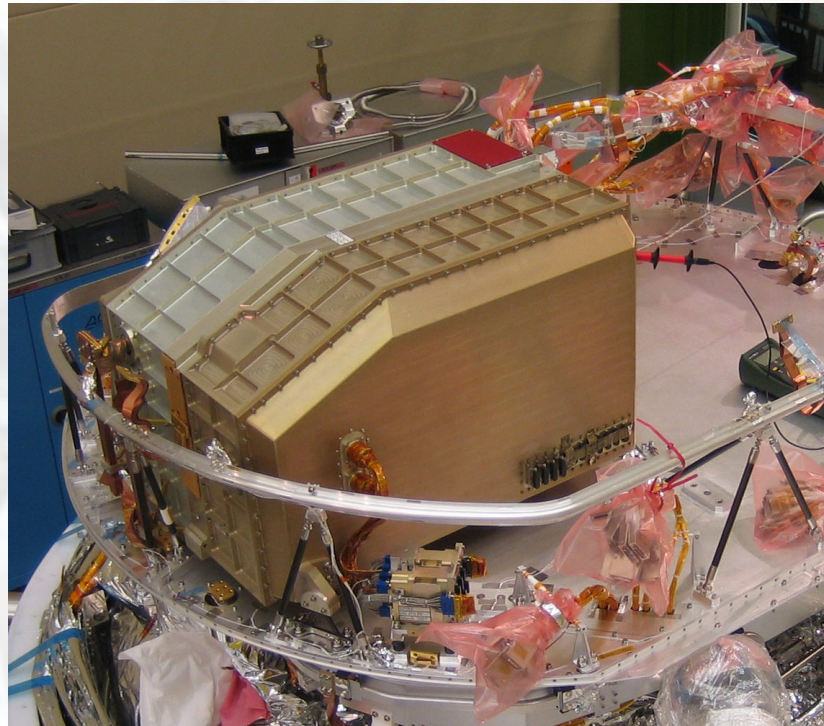


3-band imaging photometer

- 250, 350, 500 μm (simultaneous)
- $\lambda/\Delta\lambda \sim 3$
- 4 x 8 arcminute field of view
- Diffraction limited beams
(17, 24, 35")

Imaging Fourier Transf Spectrom

- 194 - 324, 316 - 672 μm
- 2.6 arcminute field of view
- $\Delta\sigma = 0.04 - 2 \text{ cm}^{-1}$
($\lambda/\Delta\lambda \sim 20 - 1000$ at 250 μm)



PACS

PACS – Photodetector Array Camera and Spectrometer

- PI: Albrecht Poglitsch, MPE, Garching, Germany
- Co-PI: Christoffel Waelkens, KU Leuven, Belgium
- Imaging photometry and spectroscopy over 55-210 μm
- 2 bolometer arrays for photometry, 2 Ge:Ga arrays for spectroscopy



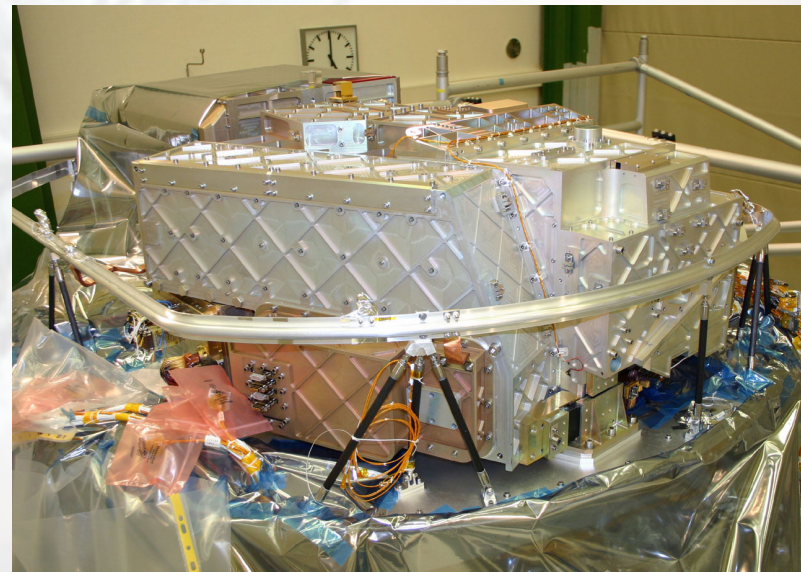
3-band imaging photometer

λ (μm)	70	100	160
FWHM (arcsec)	6	8	12
$\lambda/\Delta\lambda$	2.5	2.8	2.1

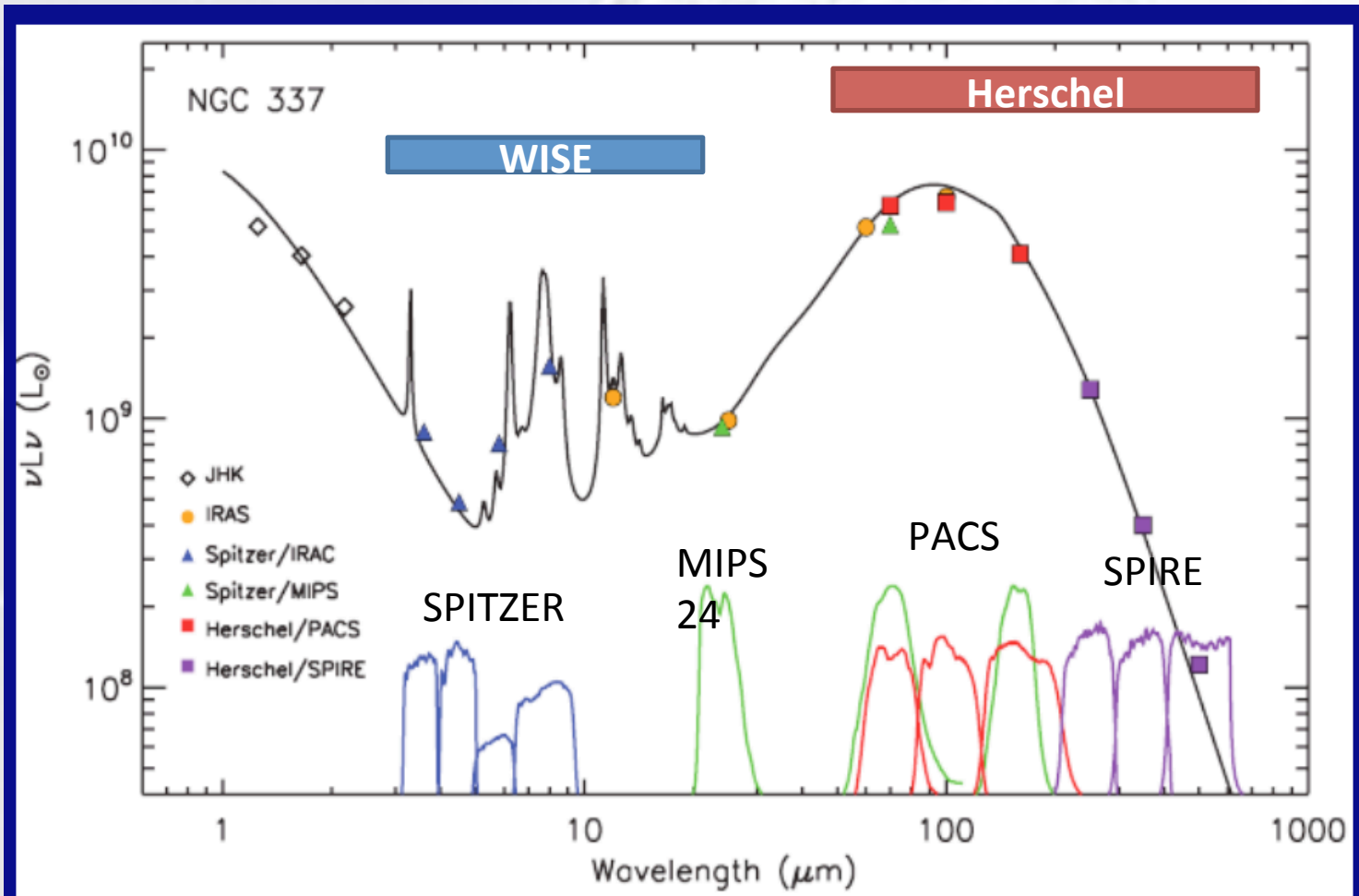
- Simultaneous obs at 70/100 & 160 μm
- 3.5 x 1.75 arcmin fully sampled FOV

Imaging line grating spectrometer

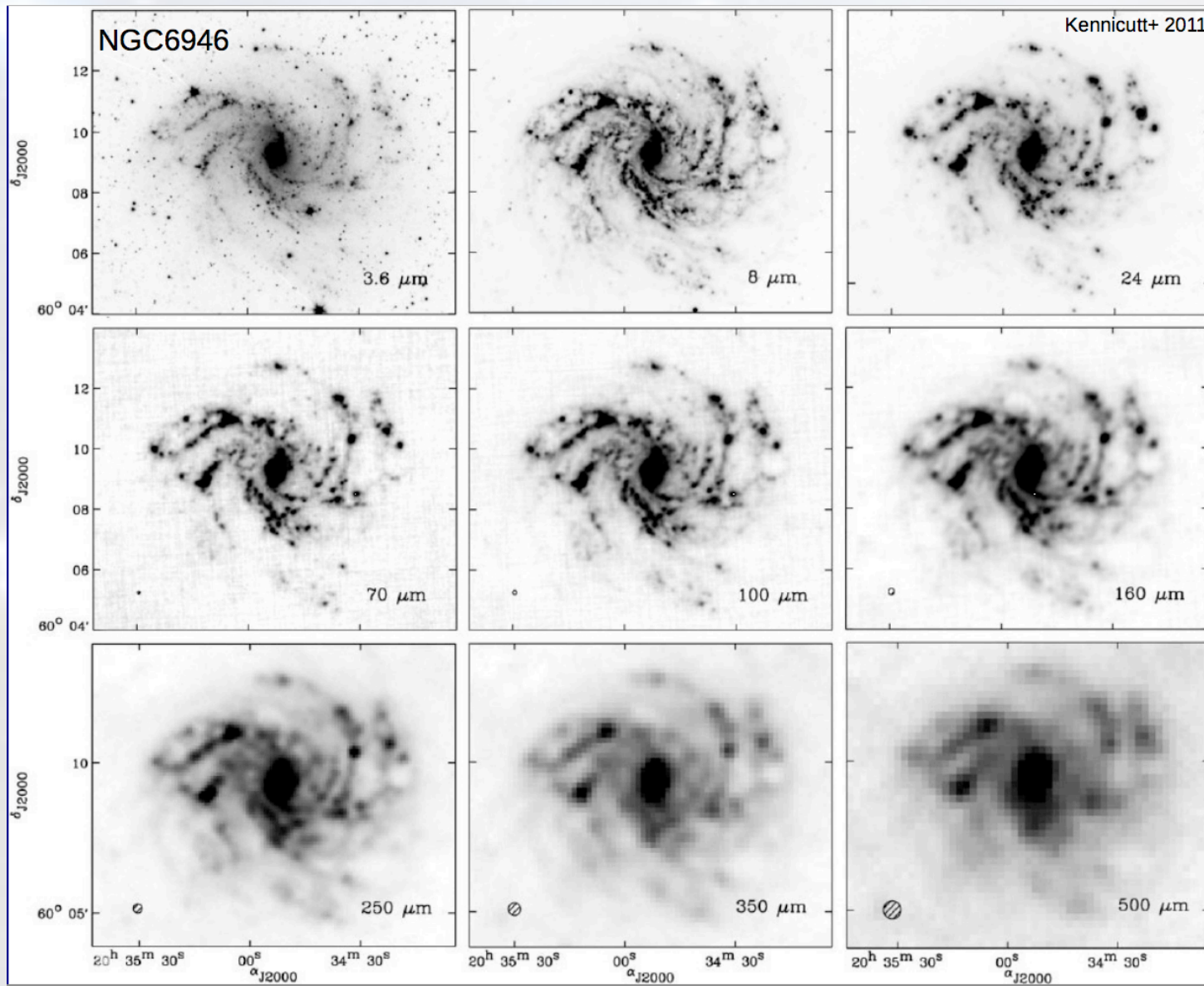
- FOV (arcmin) fully sampled 0.8 x 0.8
- λ order 1,2,3 102-210, 71-98, 55-73 μm
- $\lambda/\Delta\lambda = 1500-4000$



Complementarity of Herschel and WISE/Spitzer Photometry

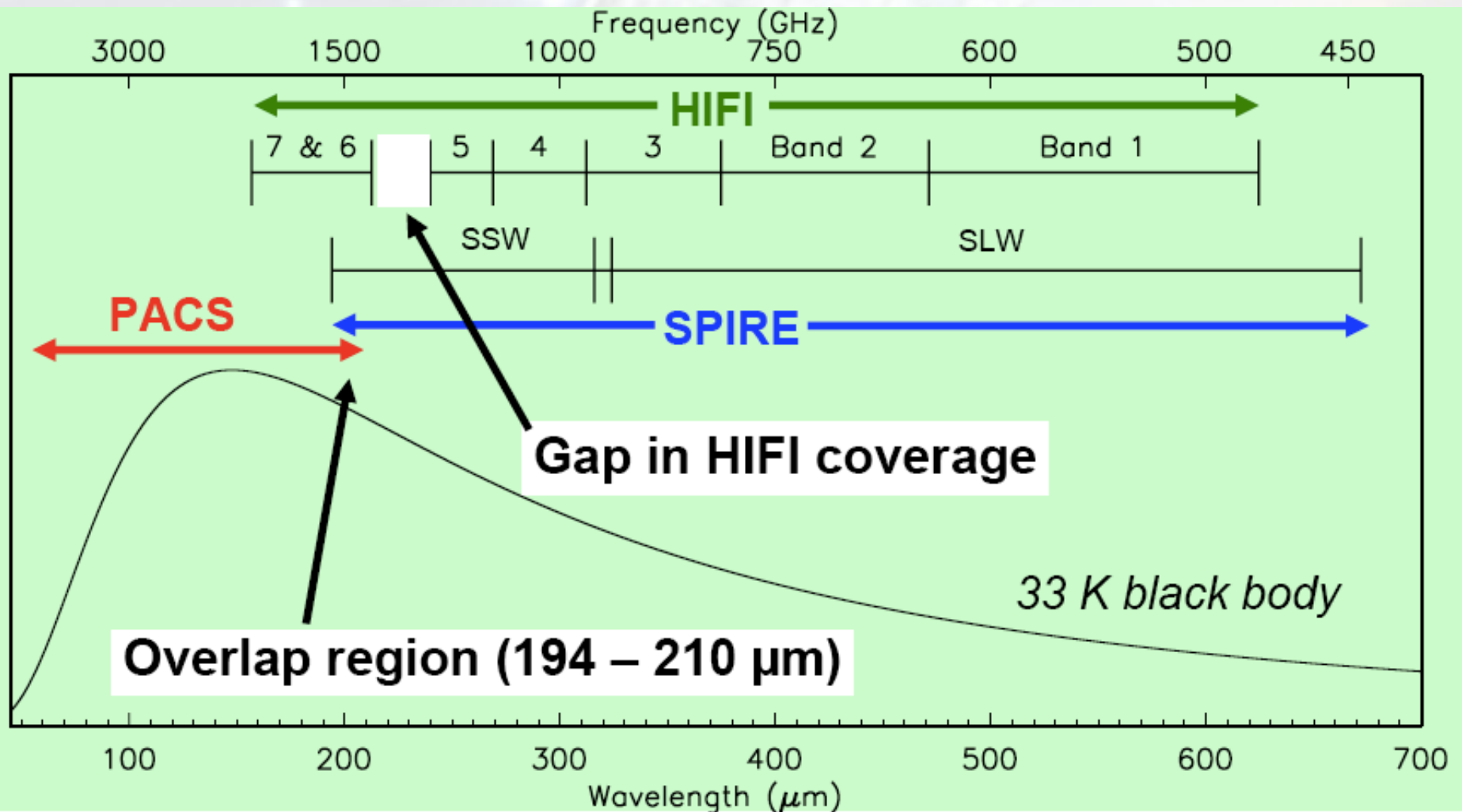


From talk by D. Dale (for KINGFISH)



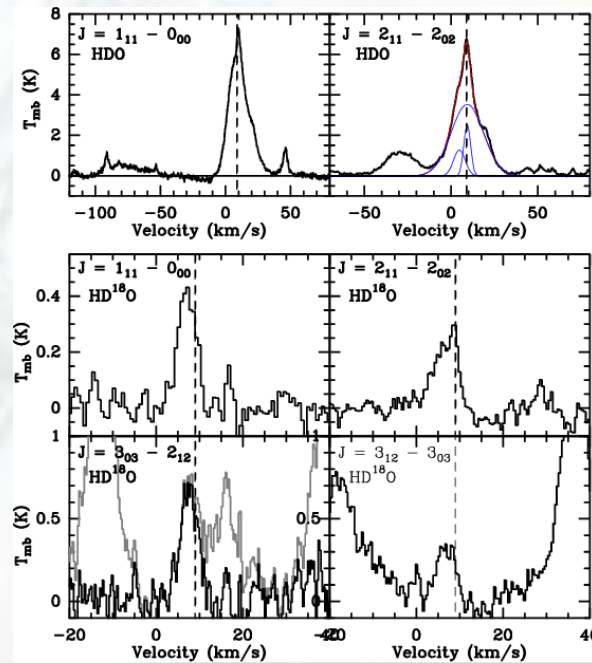
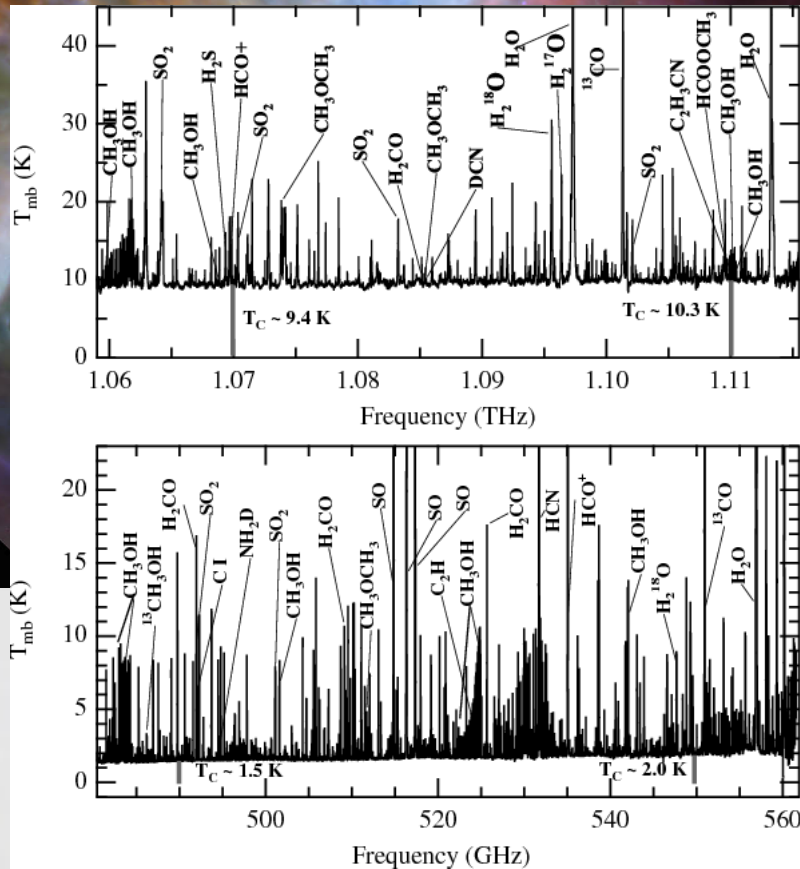
KINGFISH OPEN TIME KEY PROGRAM –From talk by Danny Dale (2012)

Herschel's Three Spectrometers



Example of Power of HIFI
 (from HEXOS Project; Bergin
 et al. 2010)

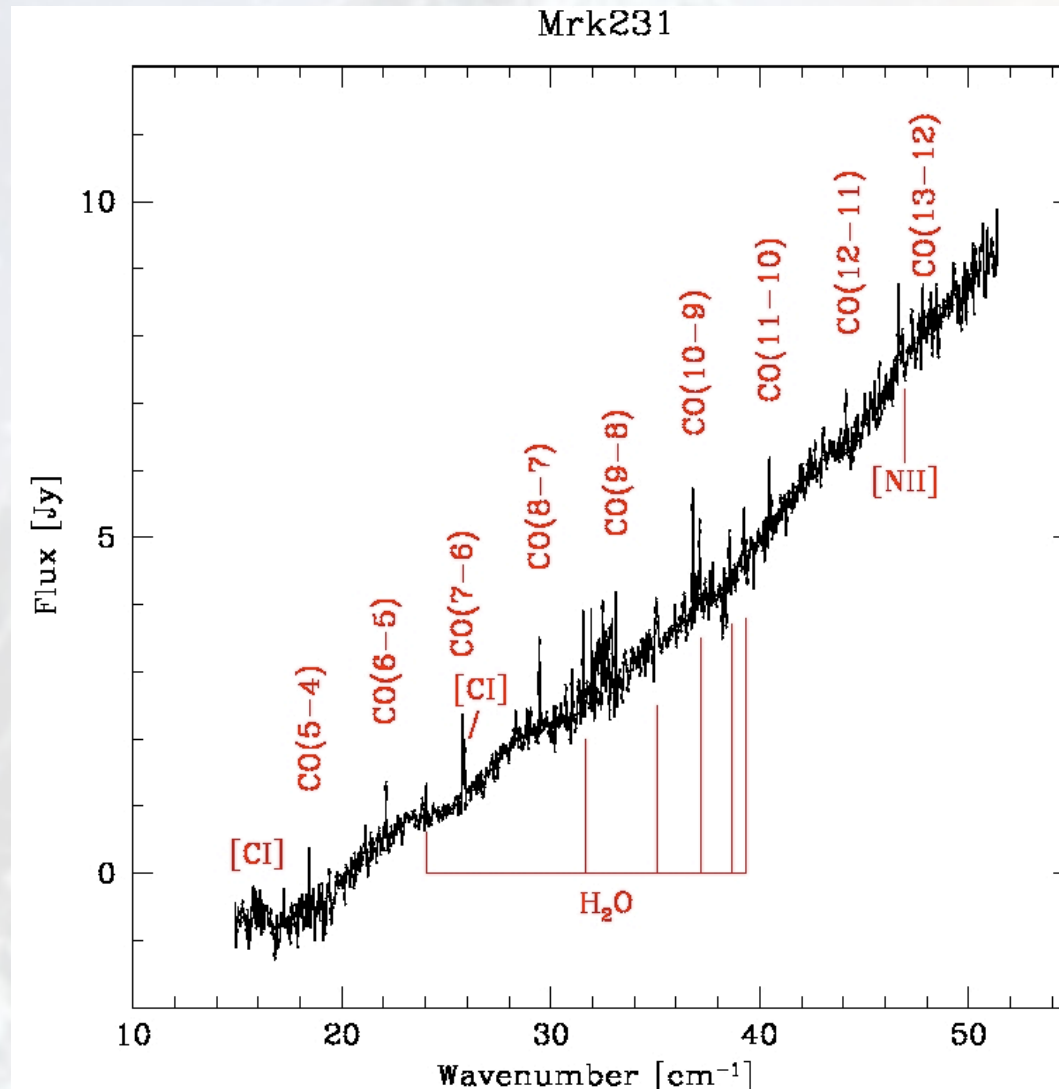
Spectra of Orion KL object



many species!
 many lines!
 fantastic spectral resolution!

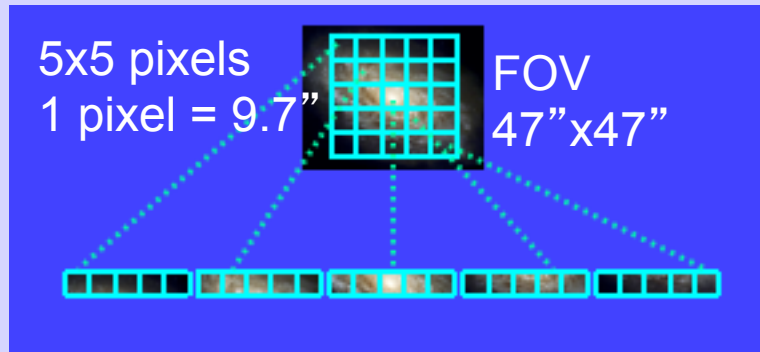
SPIRE FT SPECTROMETER

Mk 231
P. van der Werf
HerCules
project



Entire spectral 194-672 μm coverage is
observed in one go!

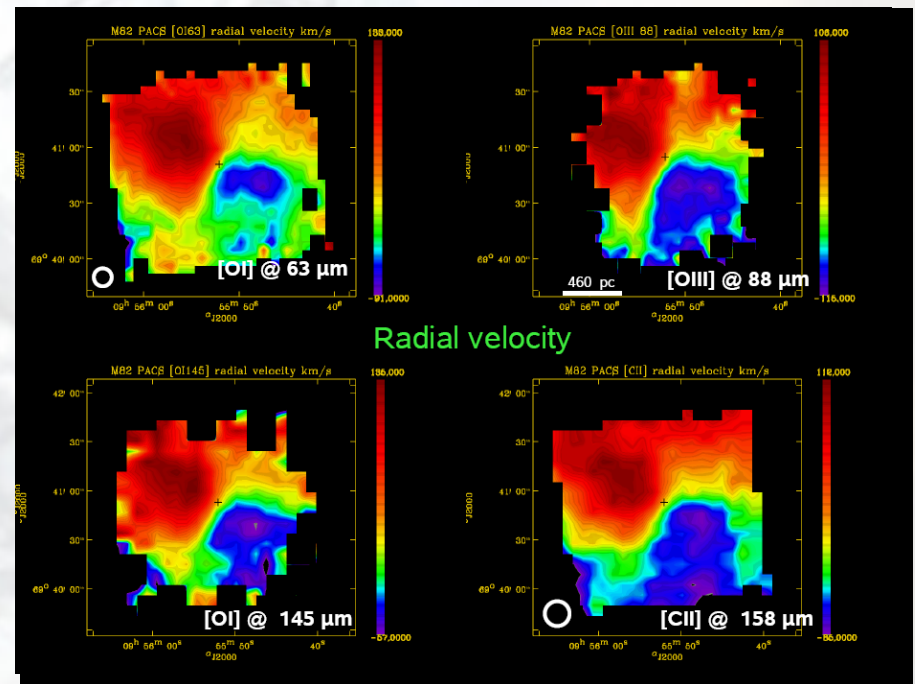
Integral Field Spectrometer



GeGa Two
(25 x 16)
arrays
Stressed
and un-
stressed

PACS Spectrometer

Simultaneous **Blue (55-98 μm)**
Red (102-210 μm) coverage

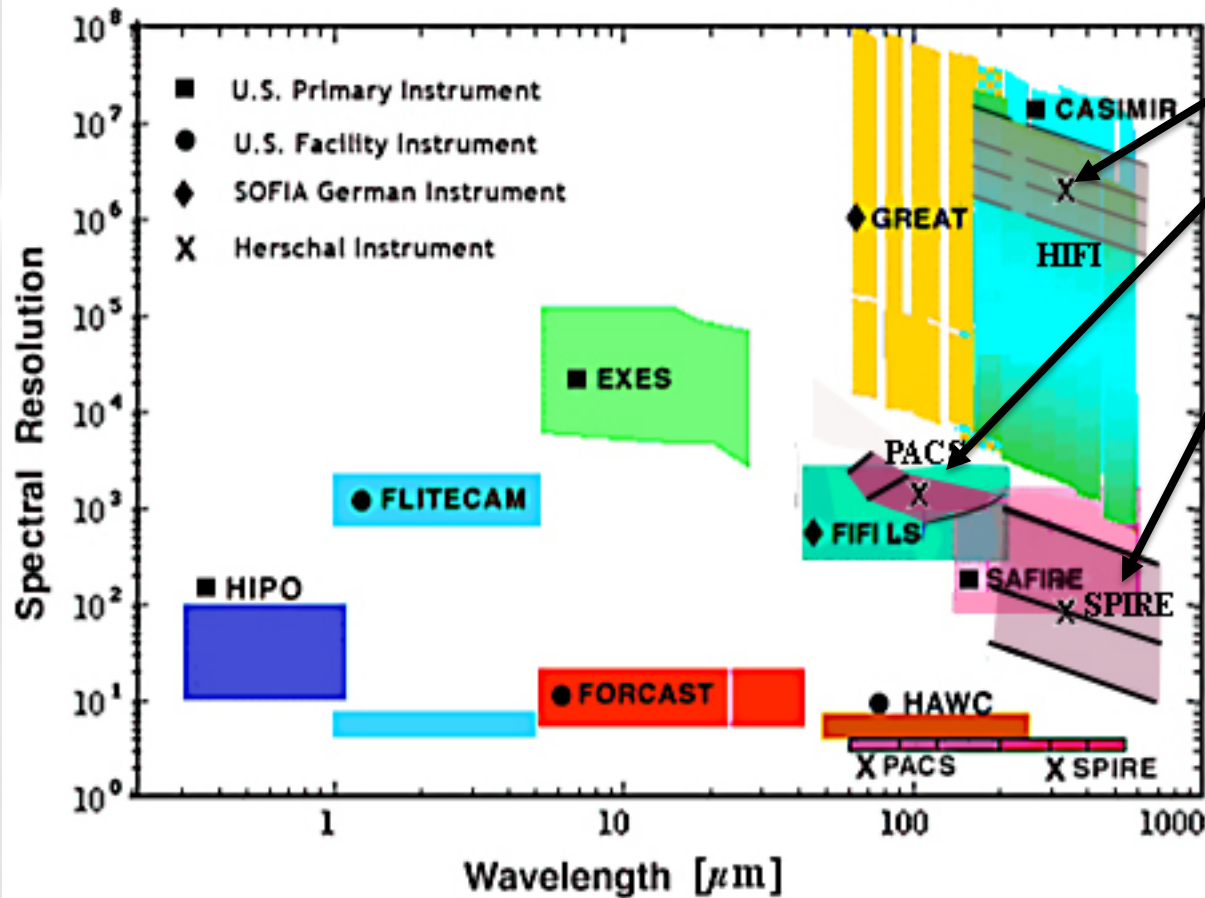


3-D Spectral Mapping of M82 (SHININGS KP)

SOFIA and Herschel



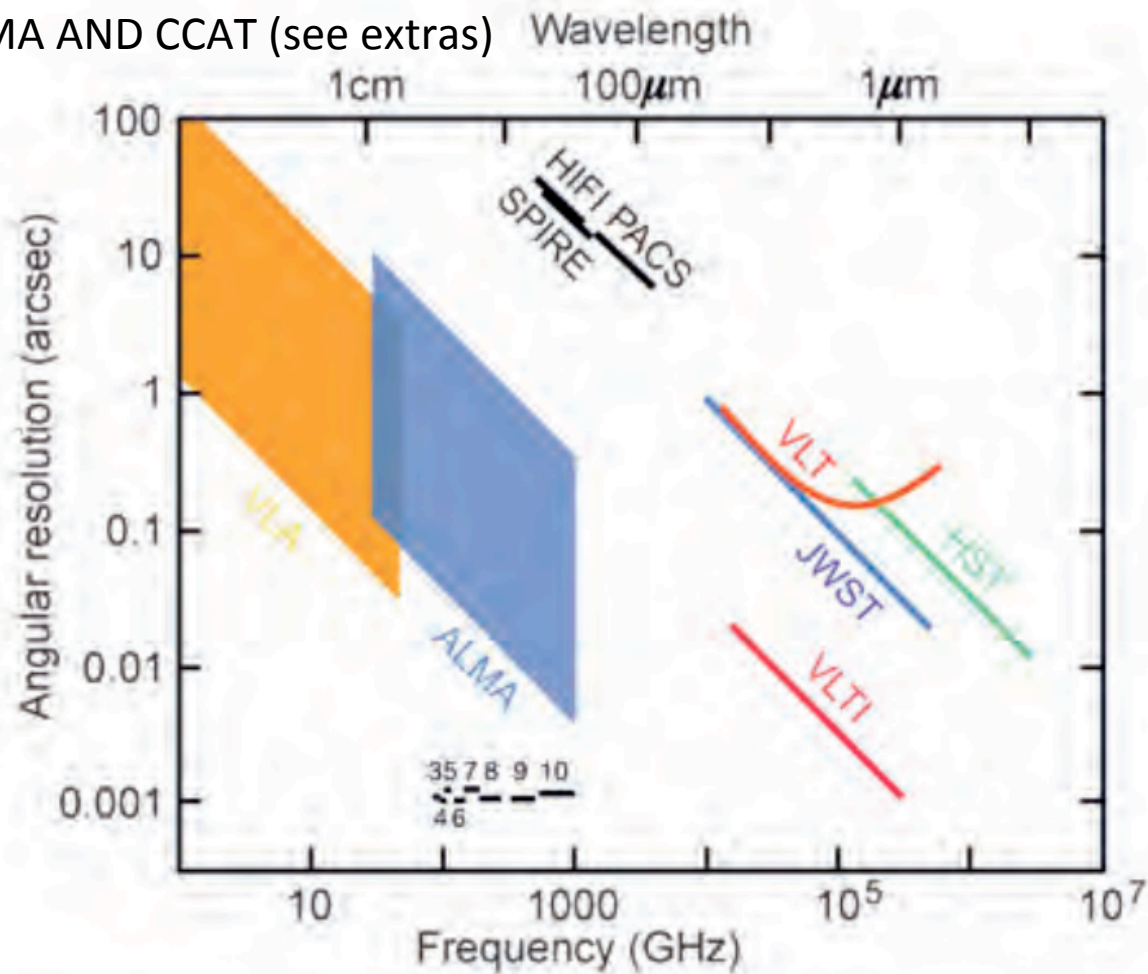
Wavelength Coverage
and Spectral Resolution



Spectrometers

Herschel and ALMA

ALMA AND CCAT (see extras)



GT and Open Time Key Programs

First Year of Operations: Call for Large Projects

LARGE PROJECTS 21 chosen (7 US led)

Projects are providing “User Supplied Data Products”

<http://herschel.esac.esa.int/UserReducedData.shtml>

These are highly processed data created by the OTKP and GTKP projects and are held at the HSC and eventually will reside in the Herschel Science Archive



SOME KEY
HERSCHEL RESULTS

|

Imaging the COOLEST
DUST in the MW:
Crowded Filaments of
proto-stars

The Vela C region

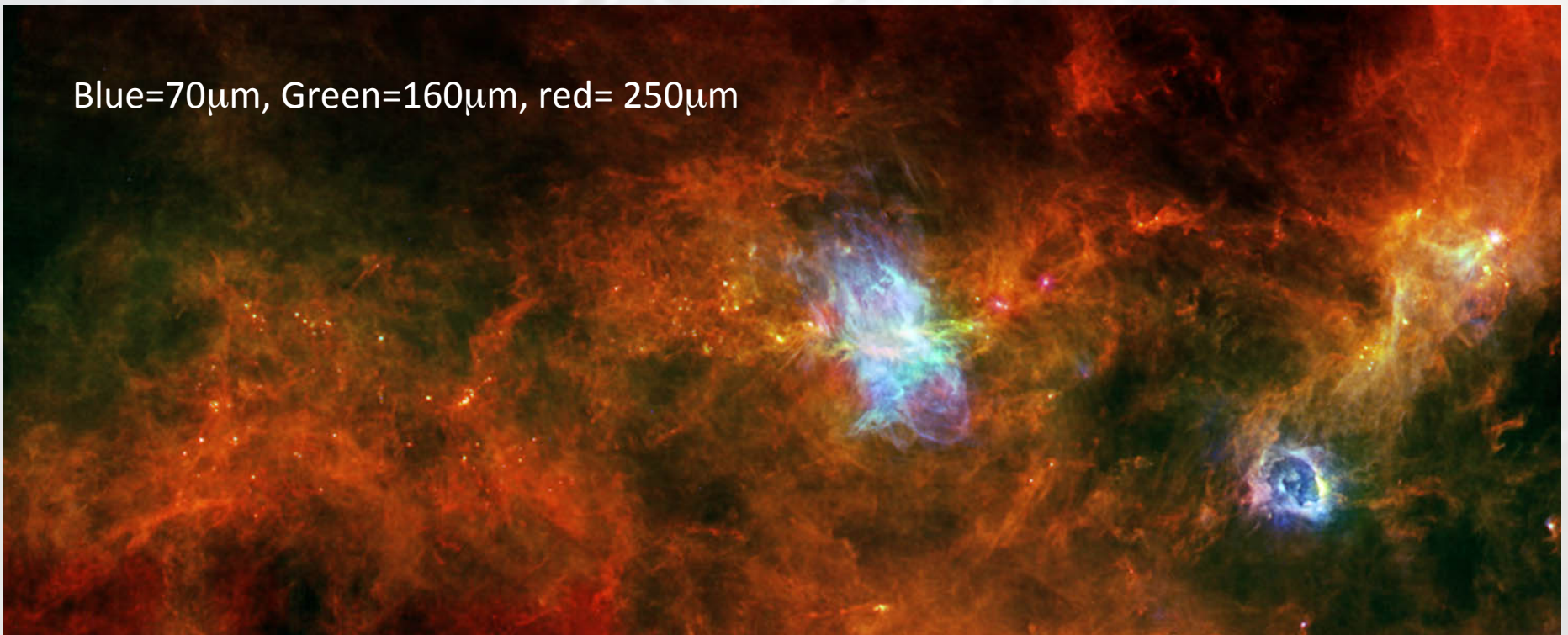
Cool proto-stars and filaments

Part of the Vela complex, by ESA's Herschel space observatory.

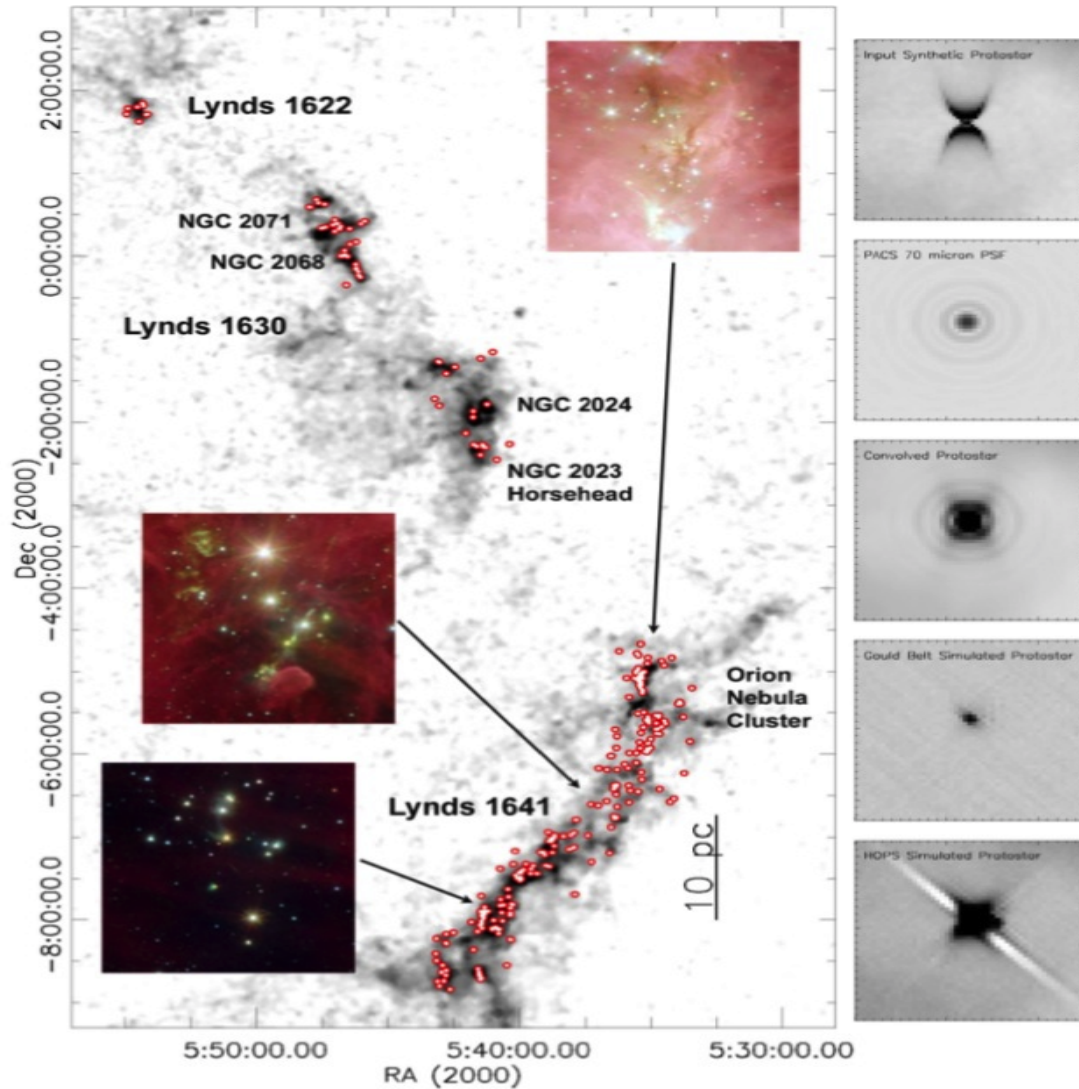
The image demonstrates Herschel's ability to trace both high and low-mass stars at a range of evolutionary stages, from cool filaments, pre-stellar cores and protostars to more evolved regions in which young stars are heating the dust.

Image release: July 9th 2012 HOBYS Key Program/ESA PACS & SPIRE Consortia

Blue=70 μ m, Green=160 μ m, red= 250 μ m



HOPS team discovers extremely young protostars



Observations made by the HOPS team (U. of Toledo) have discovered four Protostars which are so cold they did not show up in previous Spitzer imaging of The Orion region (RHS). The Herschel image (LHS) shows 4 circles which contain very cold protostars. The same circles on the Spitzer Image show no emission.

March 19 2013

Herschel 160 microns (green)
Green (IRAC band 3,4) and

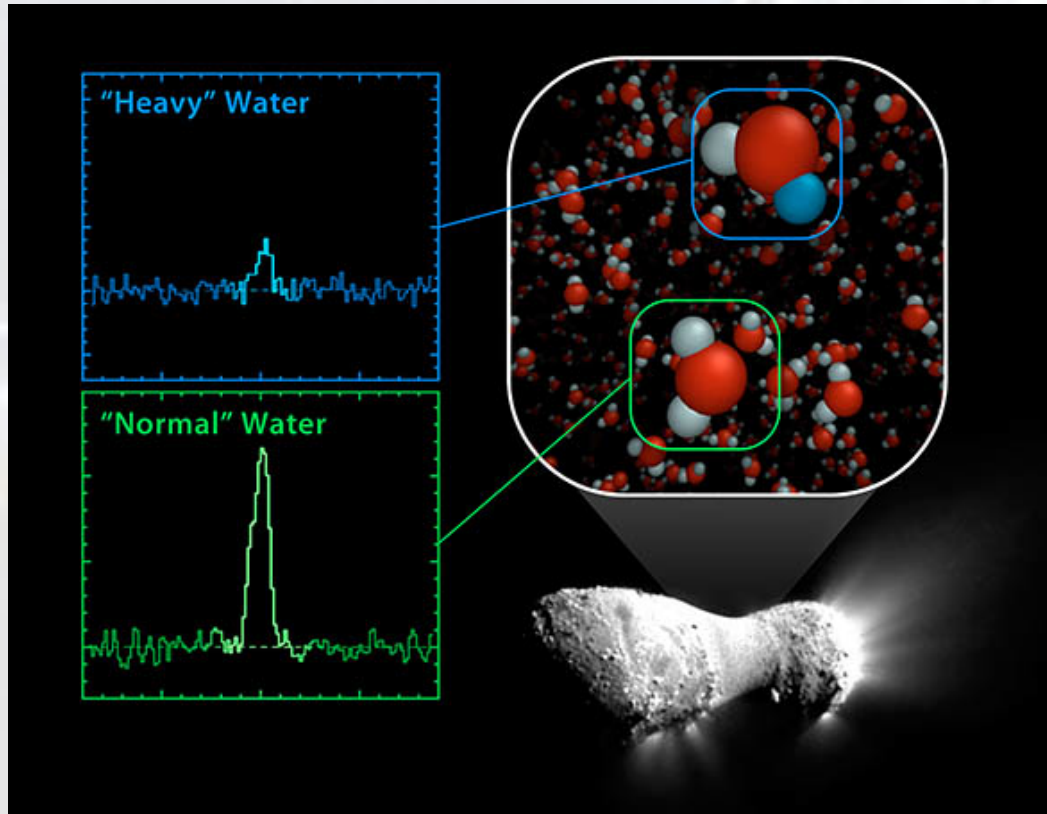
The background of the slide is a photograph of the Herschel Space Observatory in space. The observatory is a large, complex structure with a prominent sunshield, oriented towards the right. The background is a vast field of stars, with a bright, yellowish star on the right side. The overall scene is in shades of blue and white, with some yellow highlights from the stars.

SOME KEY HERSCHEL RESULTS

II

Comets and dust-
disks around stars

Heavy Water found in Comet Hartley 2 in same proportion to that on Earth: Kuiper Belt Origin of Earth's Oceans?



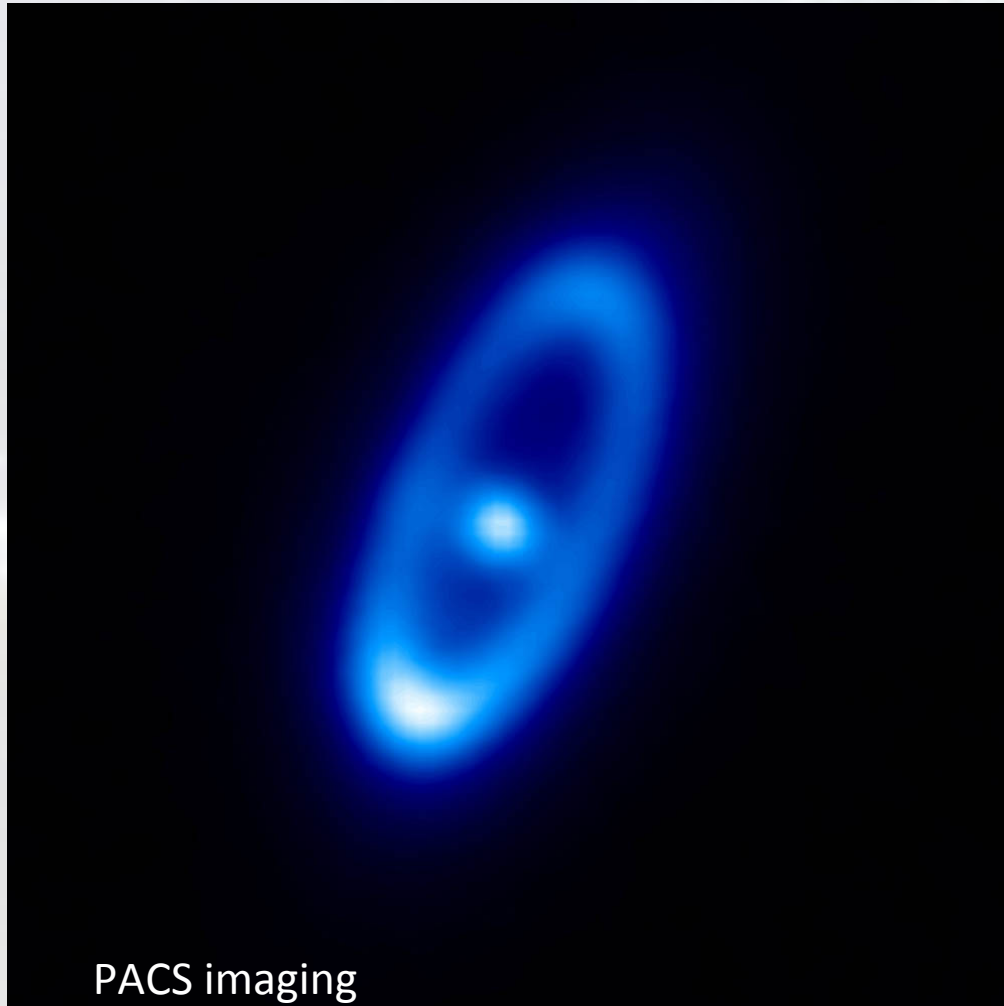
Space Observatory Provides Clues to Creation of Earth's Oceans

Press Release • nhsc2011-017 • Wednesday, October 5th, 2011

PASADENA, Calif. -- Astronomers have found a new cosmic source for the same kind of water that appeared on Earth billions of years ago and created the oceans. The findings may help explain how Earth's surface ended up covered in water.

New measurements from the Herschel Space Observatory show that comet Hartley 2, which comes from the distant Kuiper Belt, contains water with the same chemical signature as Earth's oceans. This remote region of the solar system, some 30 to 50 times as far away as the distance between Earth and the sun, is home to icy, rocky bodies including Pluto, other dwarf planets and innumerable comets.

"Our results with Herschel suggest that comets could have played a major role in bringing vast amounts of water to an early Earth," said Dariusz Lis, senior research associate in physics at the California Institute of Technology in Pasadena and co-author of a new paper in the journal *Nature*, published online today, Oct. 5. "This finding substantially expands the reservoir of Earth ocean-like water in the solar system to now include icy bodies originating in the Kuiper Belt.



Herschel Spots Comet Massacre Around Nearby Star FORMALHAUT

Feature • nhsc2012-006 • Thursday, April 12th, 2012

The Herschel Space Observatory has studied the dusty belt around the nearby star Fomalhaut. Scientists say the dust appears to be coming from collisions that destroy up to thousands of icy comets every day.

Fomalhaut is a young star, just a few hundred million years old, and twice as massive as the sun. Its dust belt was discovered in the 1980s by the Infrared Astronomical Satellite, in which NASA played a key role. Herschel's new images of the belt show it in much more detail at longer infrared wavelengths than ever before.

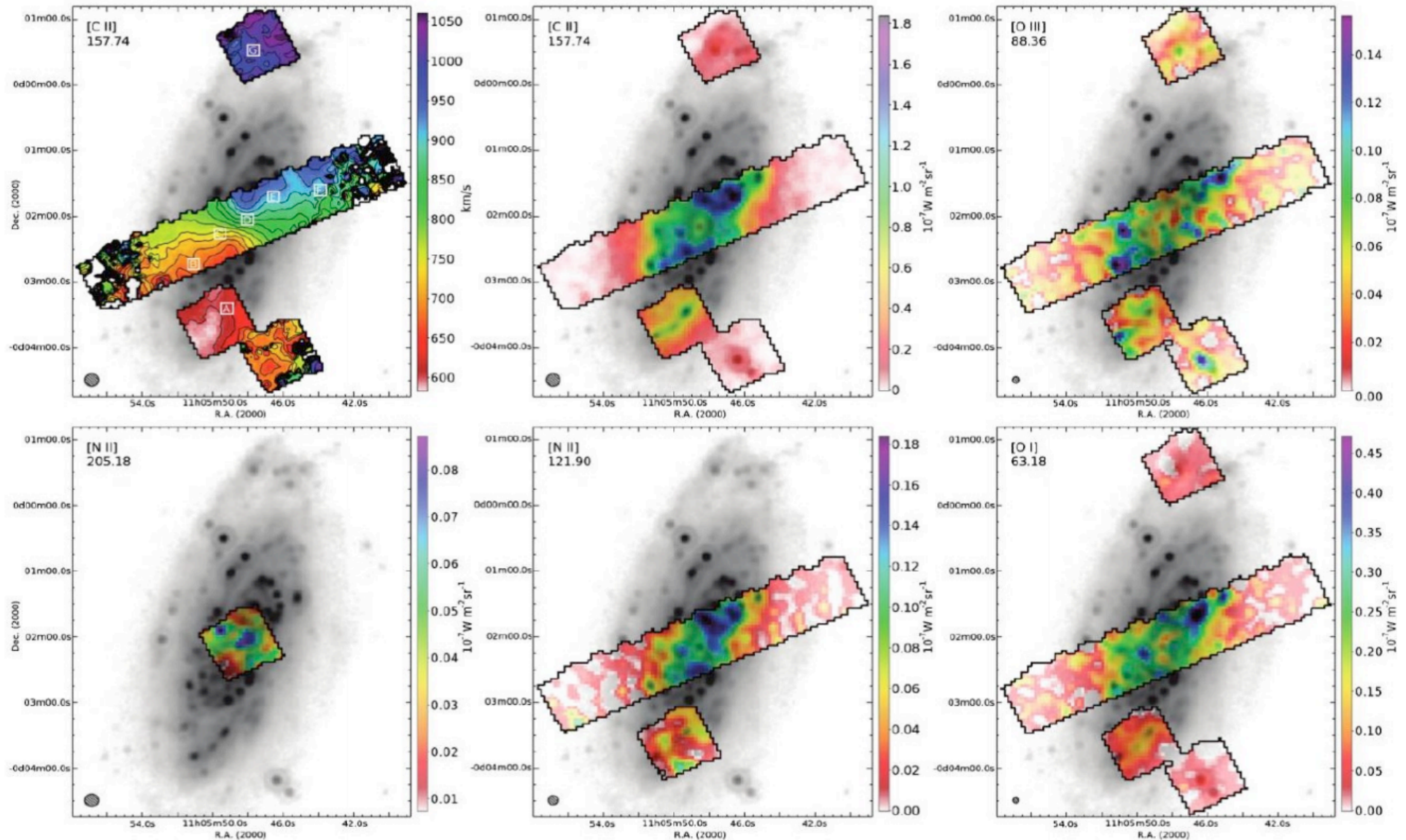
The results indicate the grains in the dust belt are fluffy and tiny, only a few millionths of a meter across (one meter is about 3 feet). They are similar to dust particles released from comets in our own solar system.



SOME KEY
HERSCHEL RESULTS
III

Measuring the Far-IR Cooling lines
in the ISM of Galaxies

Herschel Far-IR Spectroscopy



NGC3521 @ 24 μm

Kennicutt+2011

From Kingfish OTKP (Kennicutt et al. 2011)

The background of the slide is a photograph of the Herschel Space Observatory in space. The observatory is a large, complex structure with multiple solar panels and instruments, oriented diagonally across the frame. It is set against a backdrop of a starry field with some diffuse light clouds. The text is overlaid on this image.

Some Key Herschel Results

IV

Centers of Galaxies and AGN Feedback

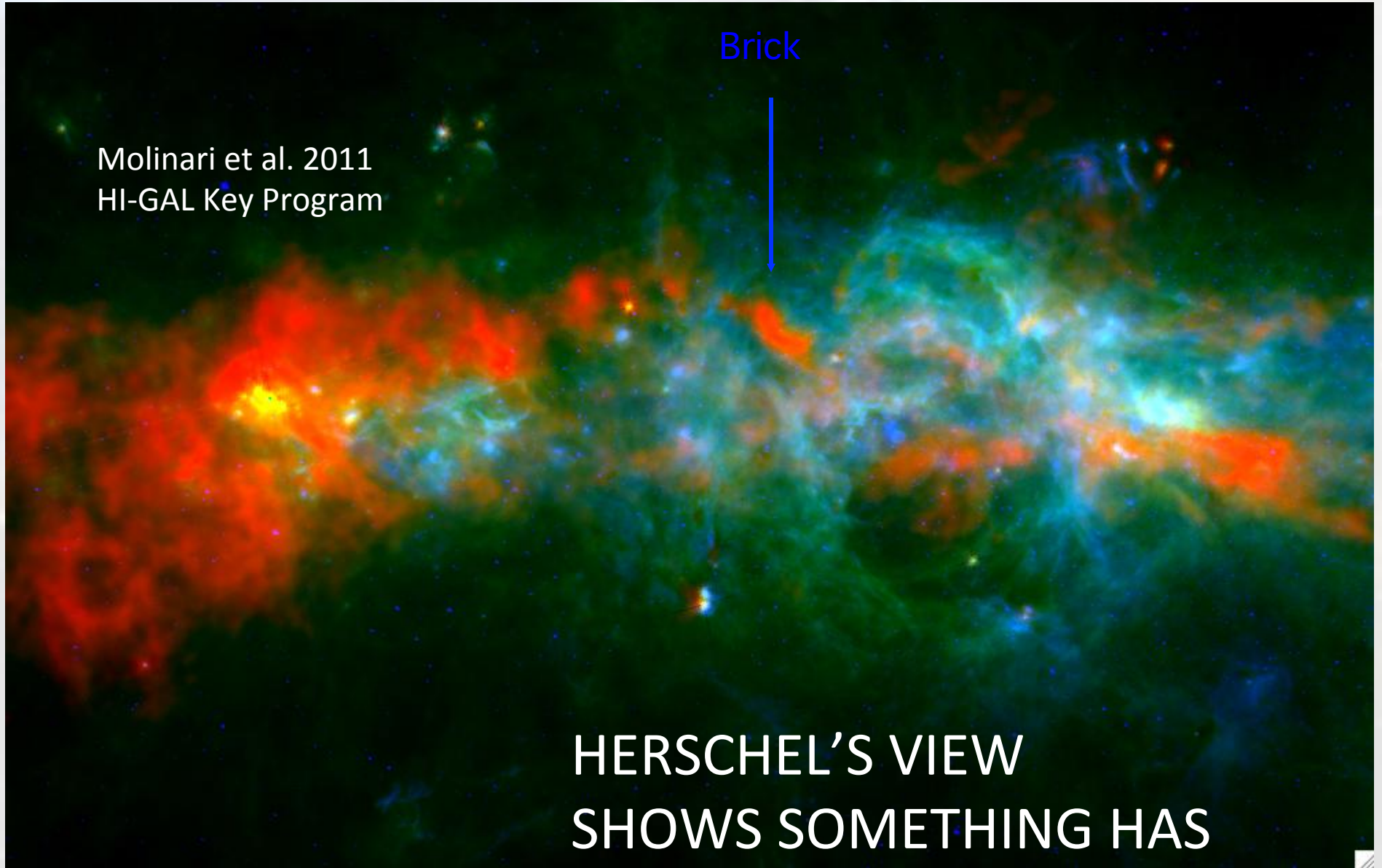
Galactic Center

Brick

Molinari et al. 2011
HI-GAL Key Program

HERSCHEL'S VIEW
SHOWS SOMETHING HAS
EMPTIED CENTER OF COLD GAS

8 μm 70 μm 350 μm



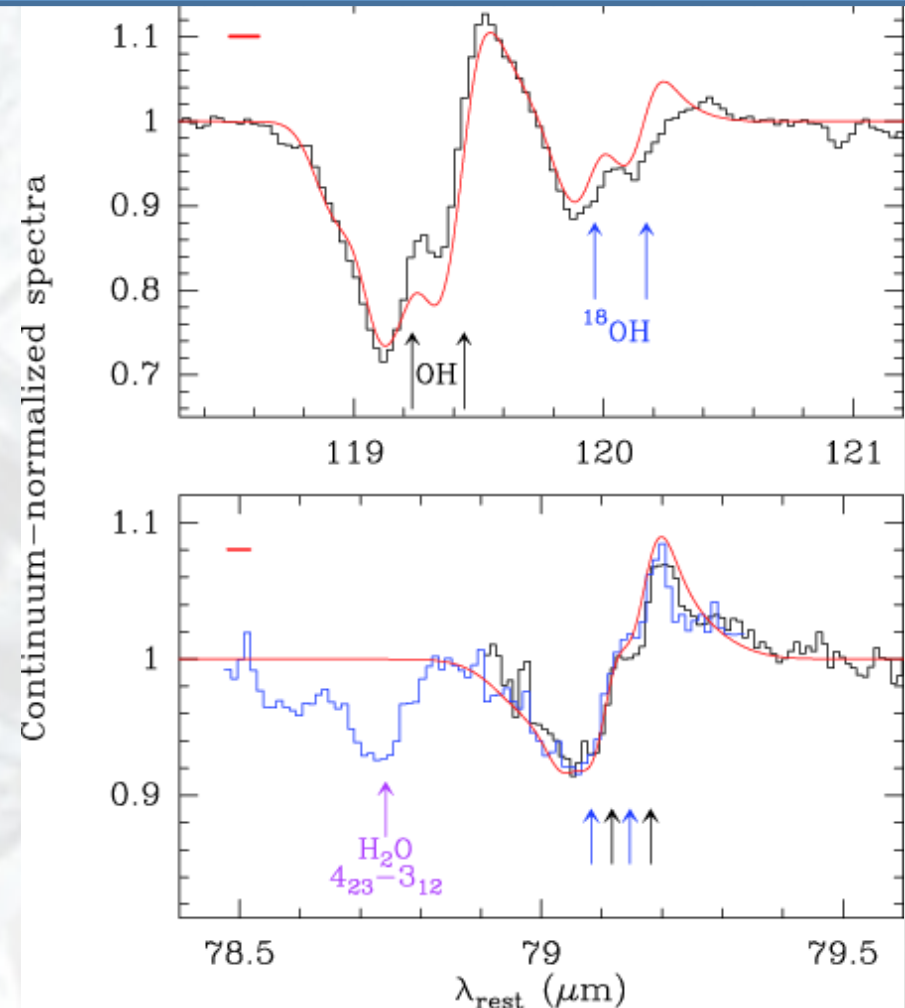
Herschel detects massive molecular outflows in AGN SHINING Key Program (E. Sturm PI)

Massive molecular outflow in Mrk 231



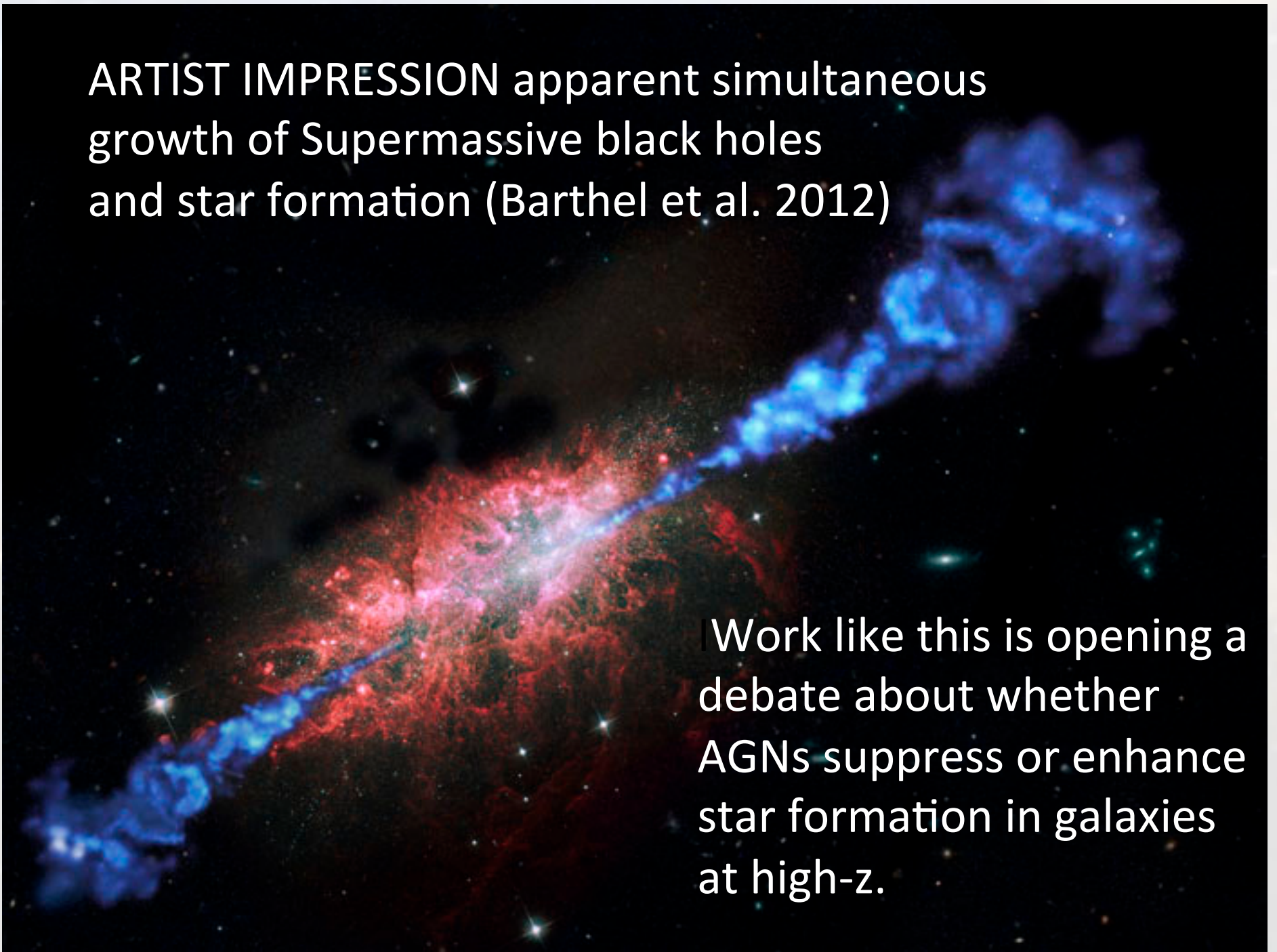
Outflow mass of $7 \times 10^7 M_{\odot}$
Outflow velocities of -1400 km/s
Mechanical energy $\geq 10^{56} \text{ ergs}$

Fischer et
al. 2010



ARTIST IMPRESSION apparent simultaneous growth of Supermassive black holes and star formation (Barthel et al. 2012)

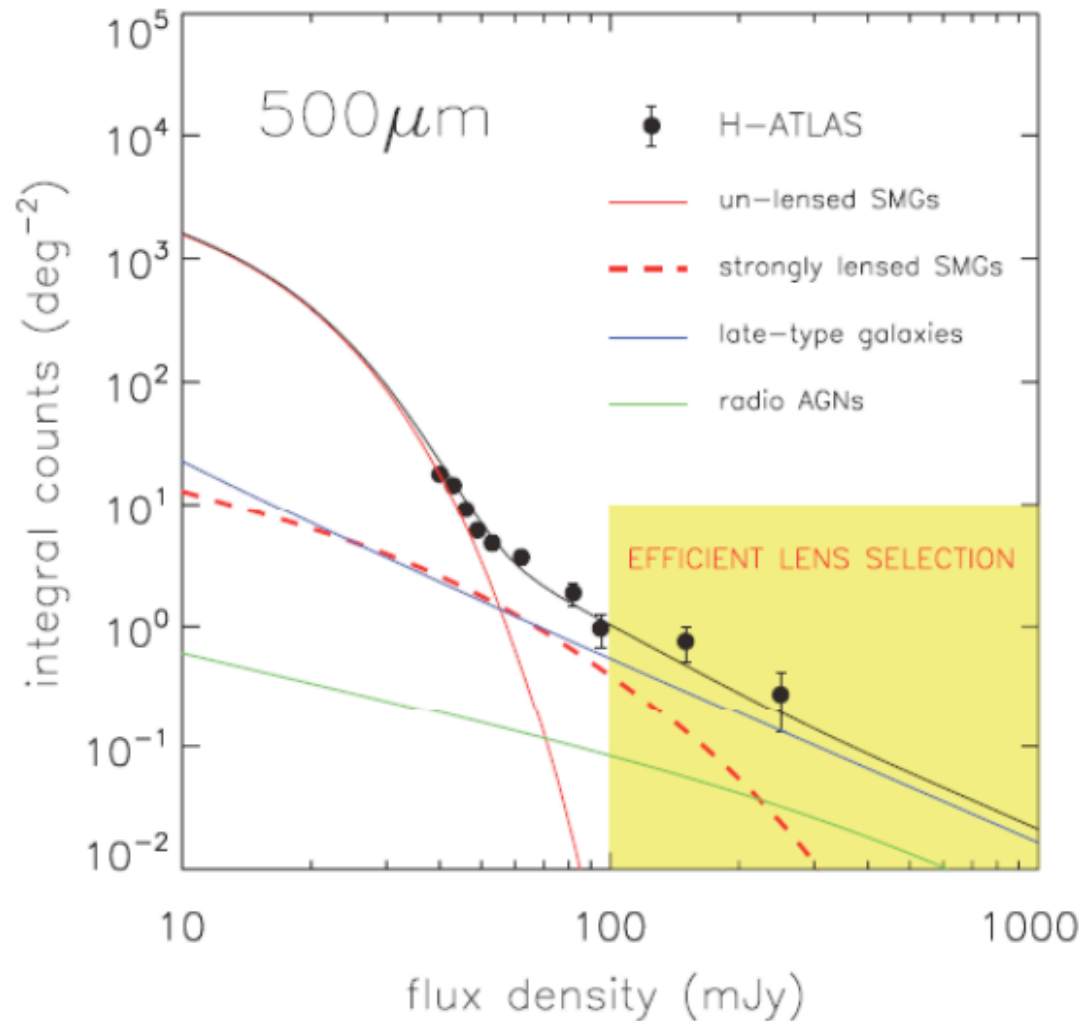
Work like this is opening a debate about whether AGNs suppress or enhance star formation in galaxies at high- z .





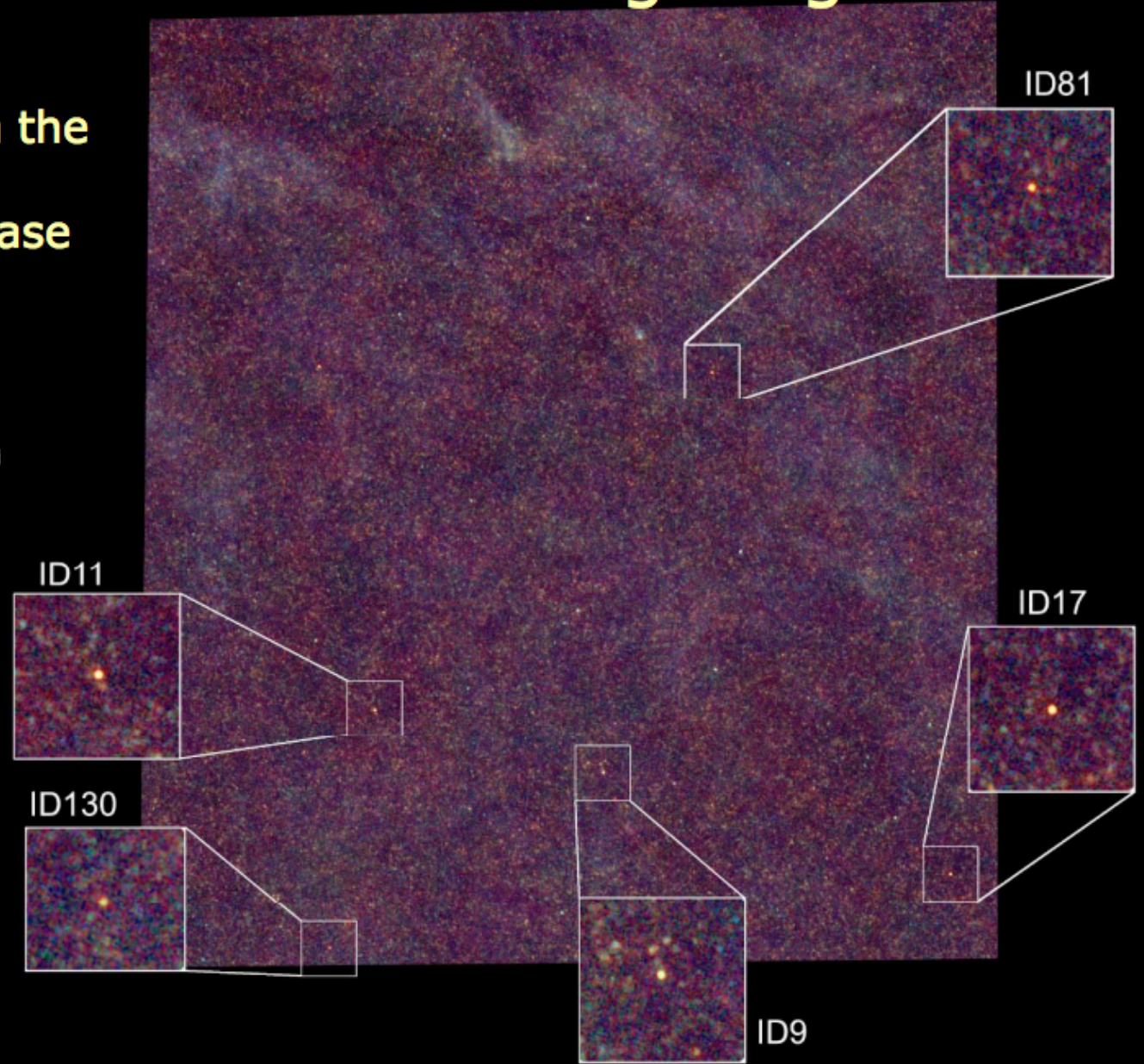
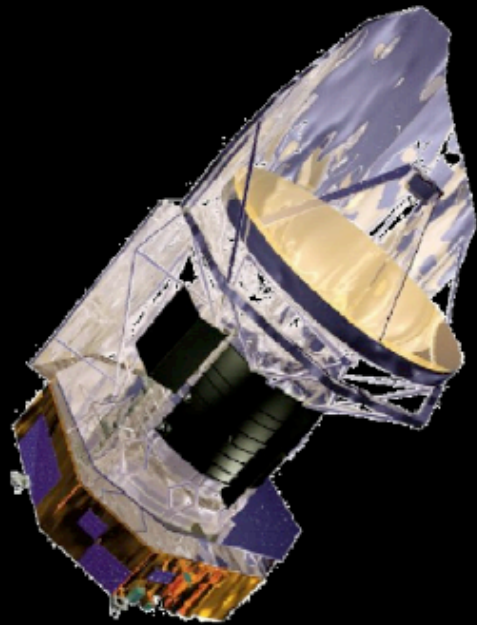
**LENSED GALAXIES ARE
BRIGHT IN SPIRE BANDS**

Galaxy-galaxy gravitational lenses select high-redshift galaxies



Herschel-ATLAS identifies high-z galaxies

SPIRE image from the
Herschel Science
Demonstration Phase





NEXT BIG HERSCHEL
SCIENCE CONFERENCE



→ THE UNIVERSE EXPLORED BY HERSCHEL

15-18 October 2013
ESA/ESTEC, Noordwijk, The Netherlands

HOW TO GET INVOLVED IN HERSCHEL ISSUES?

NHSC and HSC Helpdesks (US users should work with the NHSC Helpdesk)

NHSC User Panel (NUP) : Current Chair : Margaret Meixner STScI
Committee make-up and recent reports—see
<https://nhscsci.ipac.caltech.edu/sc/index.php/Main/NUP>

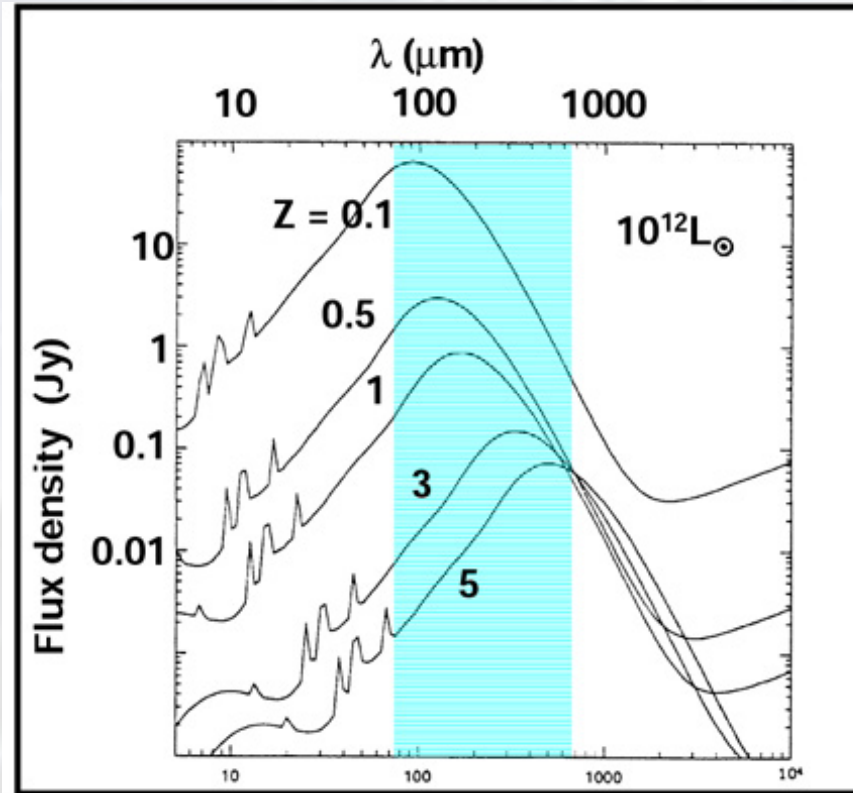
Herschel User Group (HUG): European User Group led by
<http://herschel.esac.esa.int/HUG.shtml>

DPUG DATA Processing User Group: Deals with DP Issues for whole Herschel project. Although historically has contained mainly Herschel experts and developers, the membership is expanding to include users.

A 3D wireframe model of a satellite or space station is shown in a perspective view against a background of a starry space. The model consists of a central cylindrical body with various rectangular panels and protrusions. The word "Extras" is overlaid in the center of the image in a black, sans-serif font.

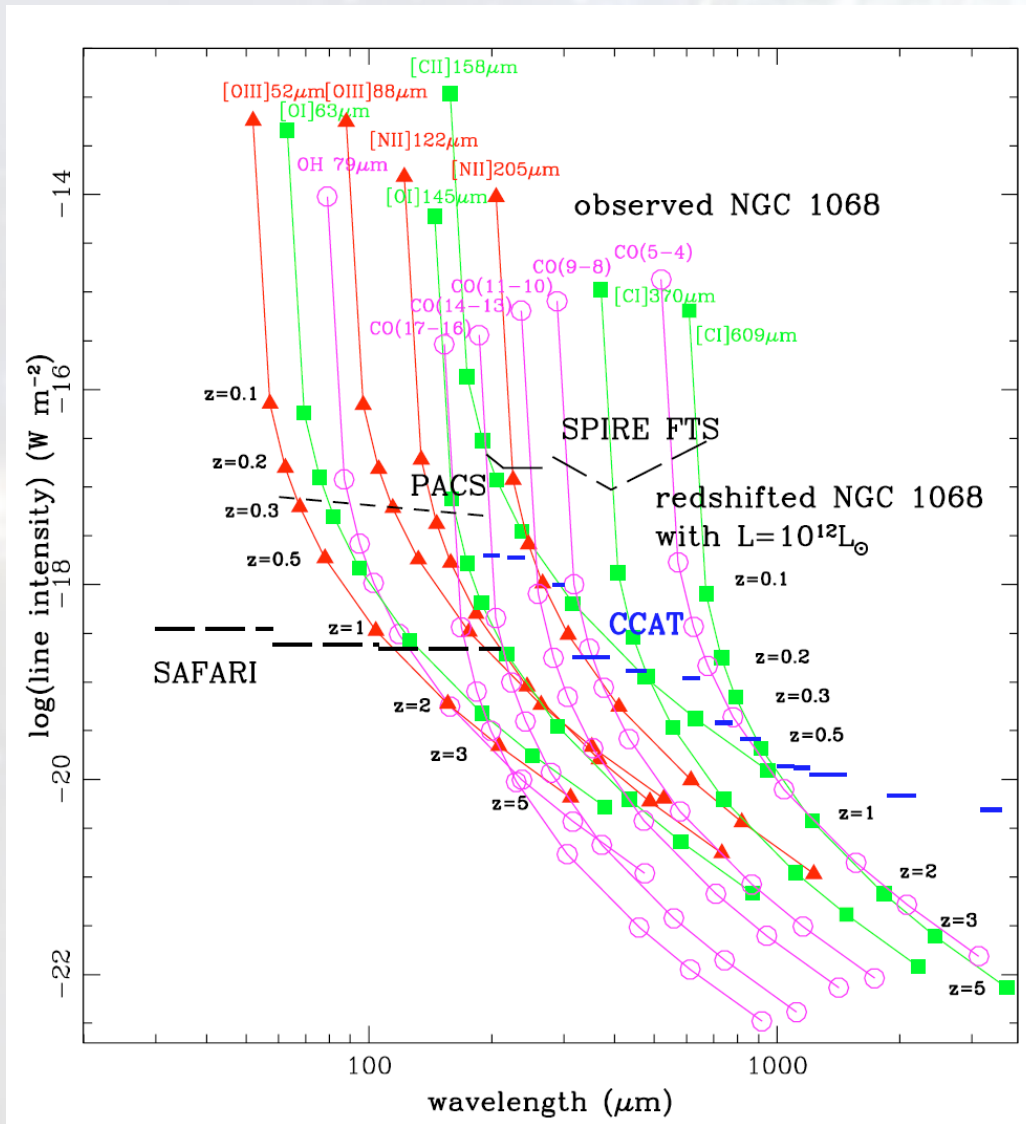
Extras

Importance of the FIR & submm



- Herschel covers the IR peak and pushes into the submillimetre: IR-bright galaxies

Herschel :CCAT and SPICA/SAFARI

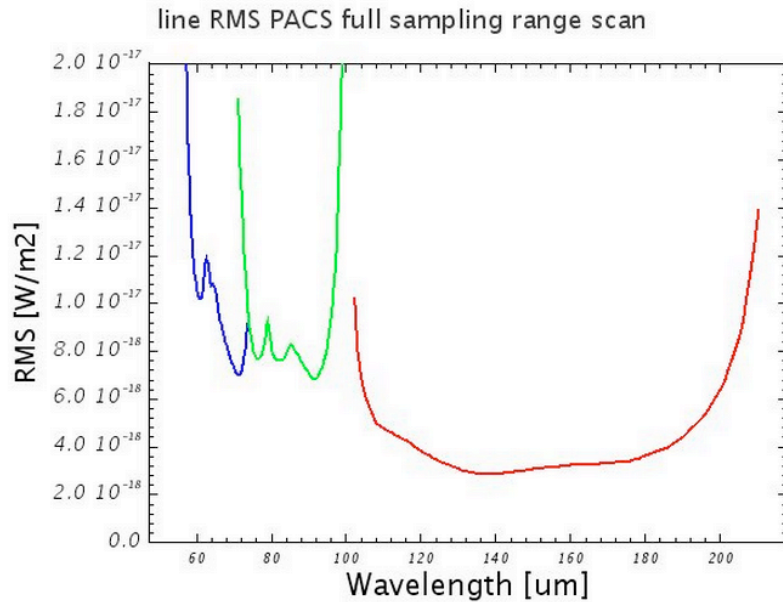


CCAT and SPICA/SAFARI will do for the higher-z what Herschel can do for low-z

Far-IR Spectral Line Diagnostics

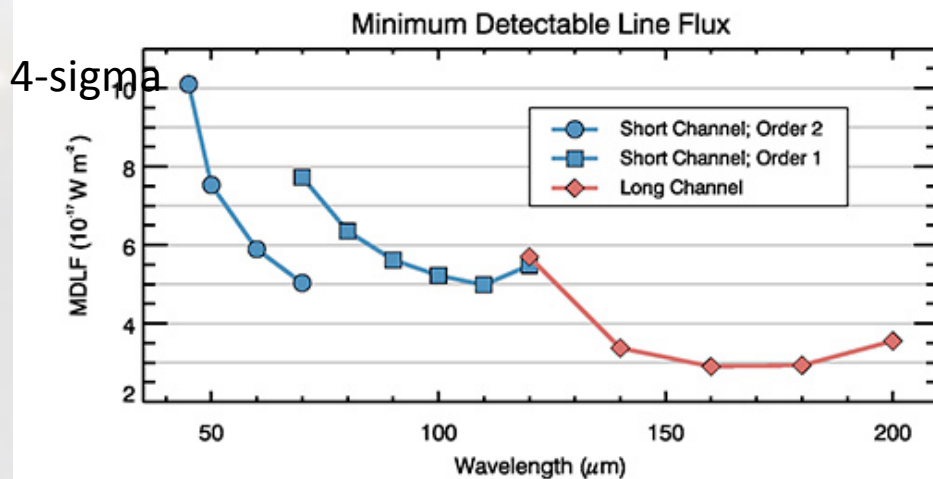
5-sigma 1hr sensitivity in W/m^2

SOFIA FIFI-LS versus HERSCHEL PACS



PACS Spectrometer 450s Integration
rms line flux

Herschel line sensitivity is ~3-5 better than SOFIA over similar range of wavelengths (integrate for 9-16x longer). 6hr SOFIA = 20mins PACS

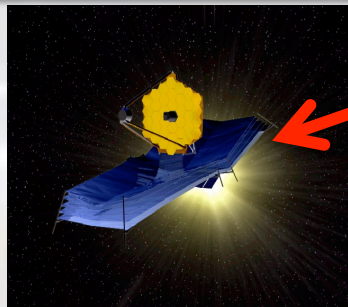


SOFIA : FIFI-LS 900s projected
Minimum detectable line
flux (4x rms)

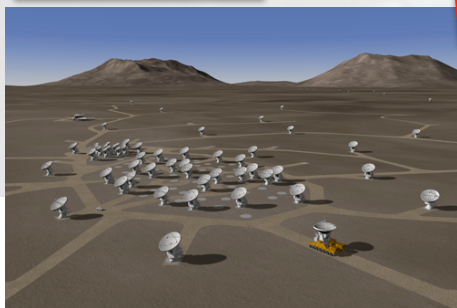
You—as users can help us build synergy with other projects



Spitzer Warm Mission
Deep IR Imaging from Space



JWST Mid-IR from Space



ALMA AND CCAT sub-mm astronomy from ground



HERSCHEL

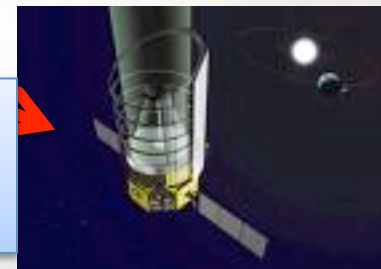


WISE IR Surveys

SOFIA mid/Far IR from aircraft



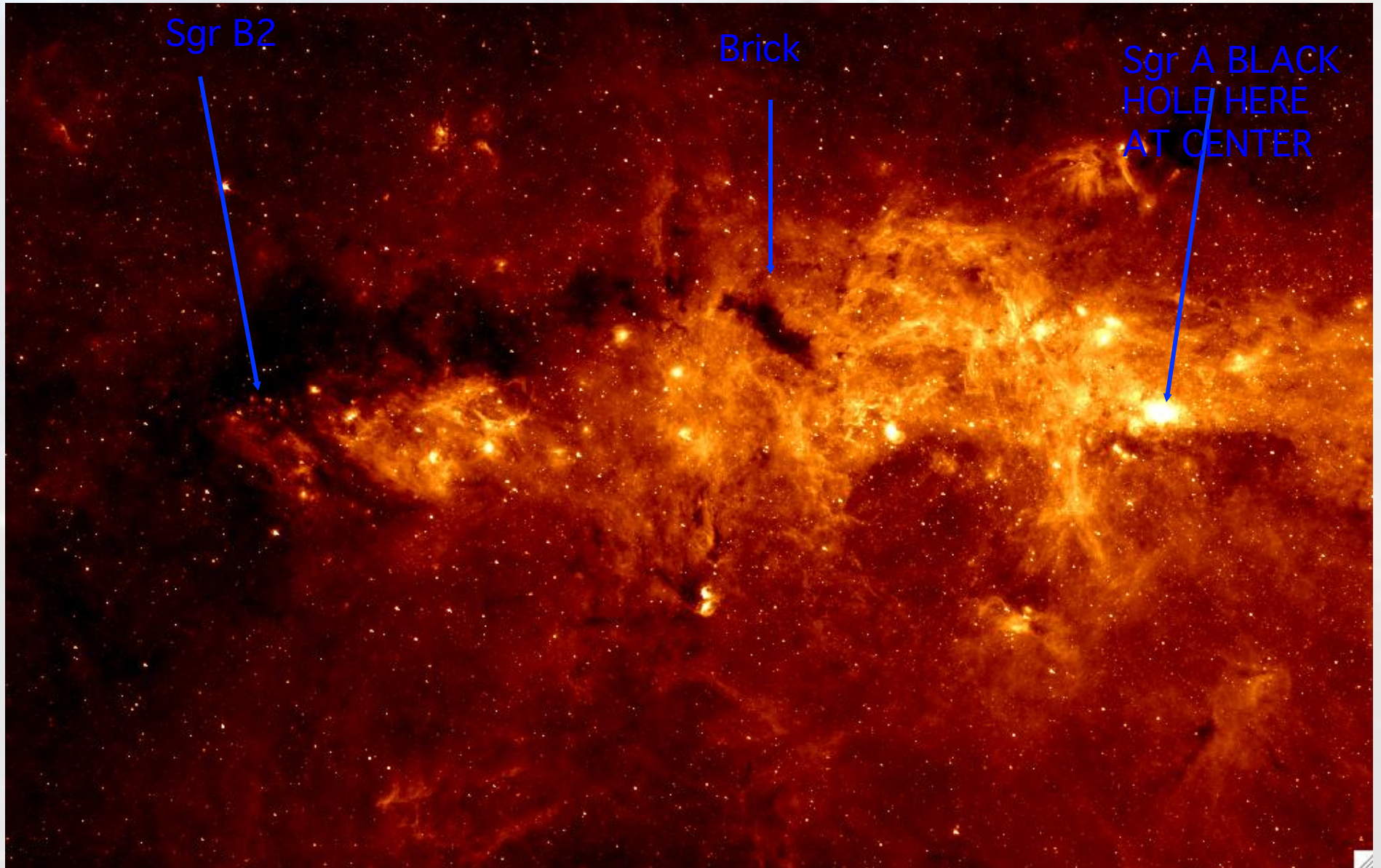
SPICA Far-IR from Space



GBT and eVLA Deep Radio Astronomy



Galactic Center



8 μm NEAR INFRARED FROM SPITZER SPACE TELESCOPE