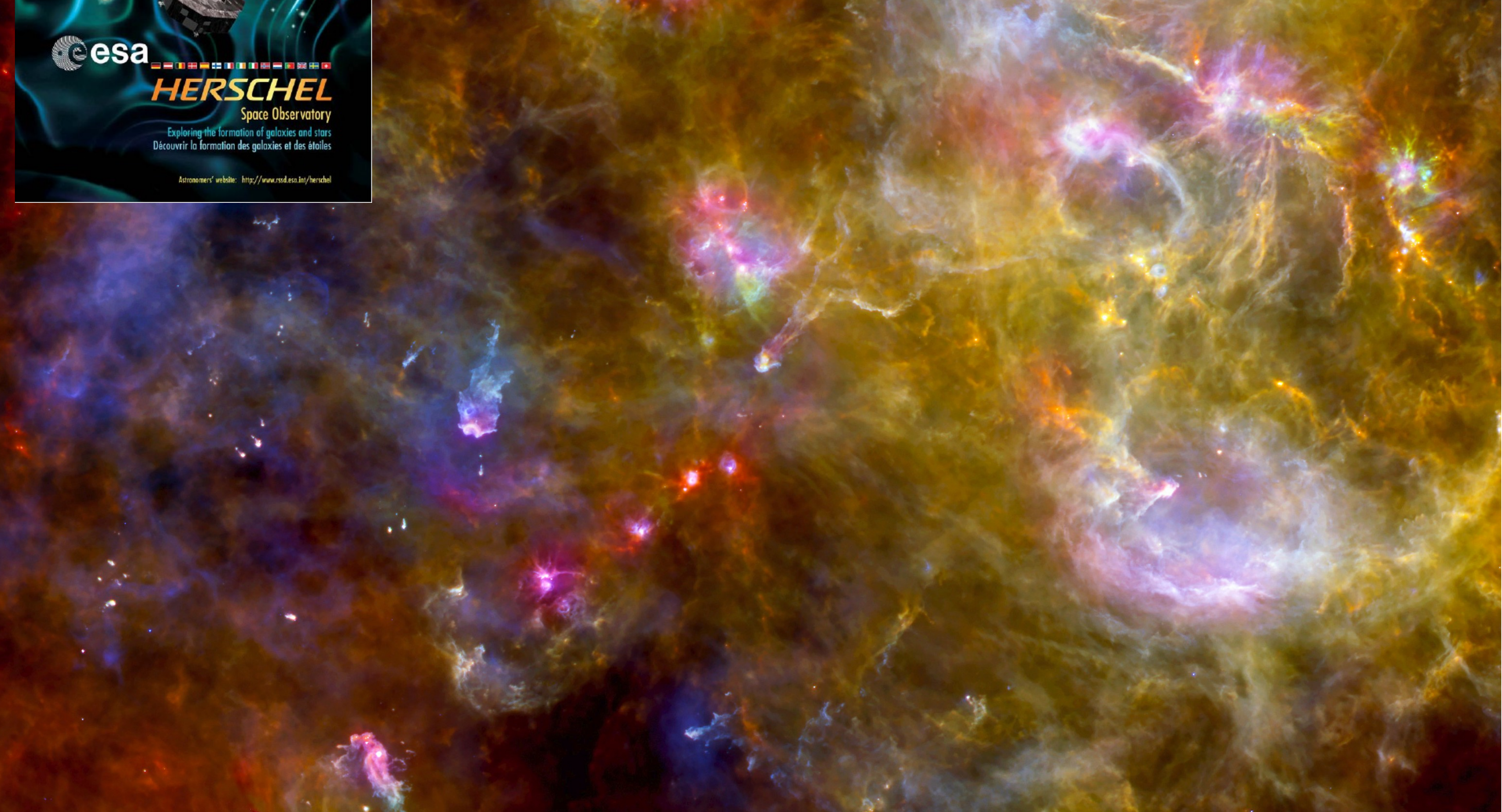
Herschel satellite

Mika Juvela, University of Helsinki

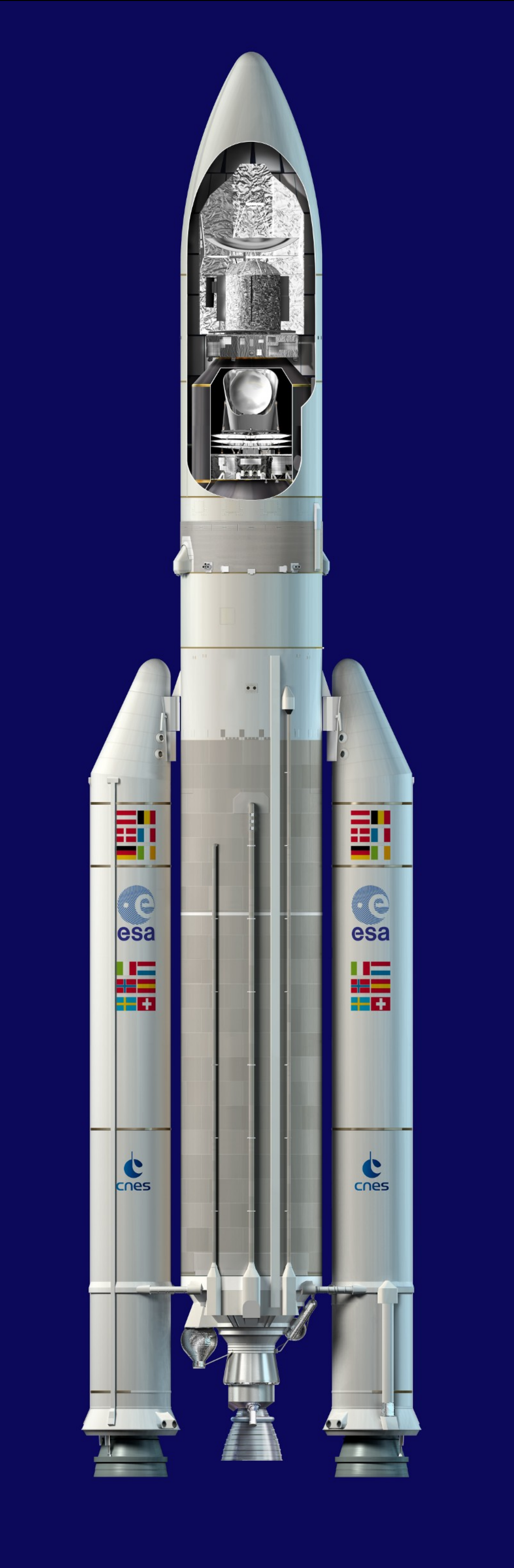


Content

- Satellite and detectors
- Overview of key programmes
- Some highlights

The satellite

- ESA 'cornerstone' mission
  - To study the origin and evolution of stars and galaxies
  - Mass 3.4 tn, height 7.5m
- Main mirror 3.5m
  - Largest space telescope
  - 1.5 times larger than Hubble
- Far-infrared and sub-millimetre observations
  - Wavelengths 55-670μm
  - Photometry and spectroscopy

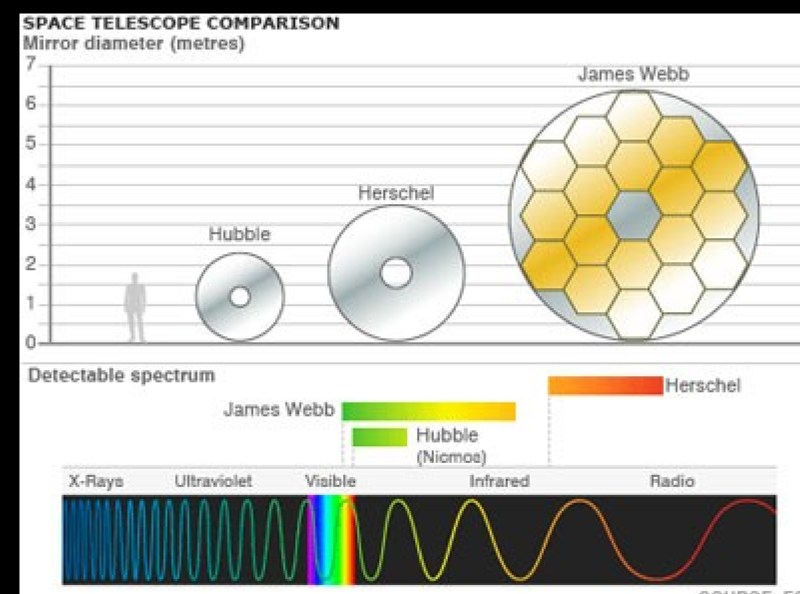


- Launch May 2009 with Planck
- Orbiting L2
- Estimated lifetime 3.5 years

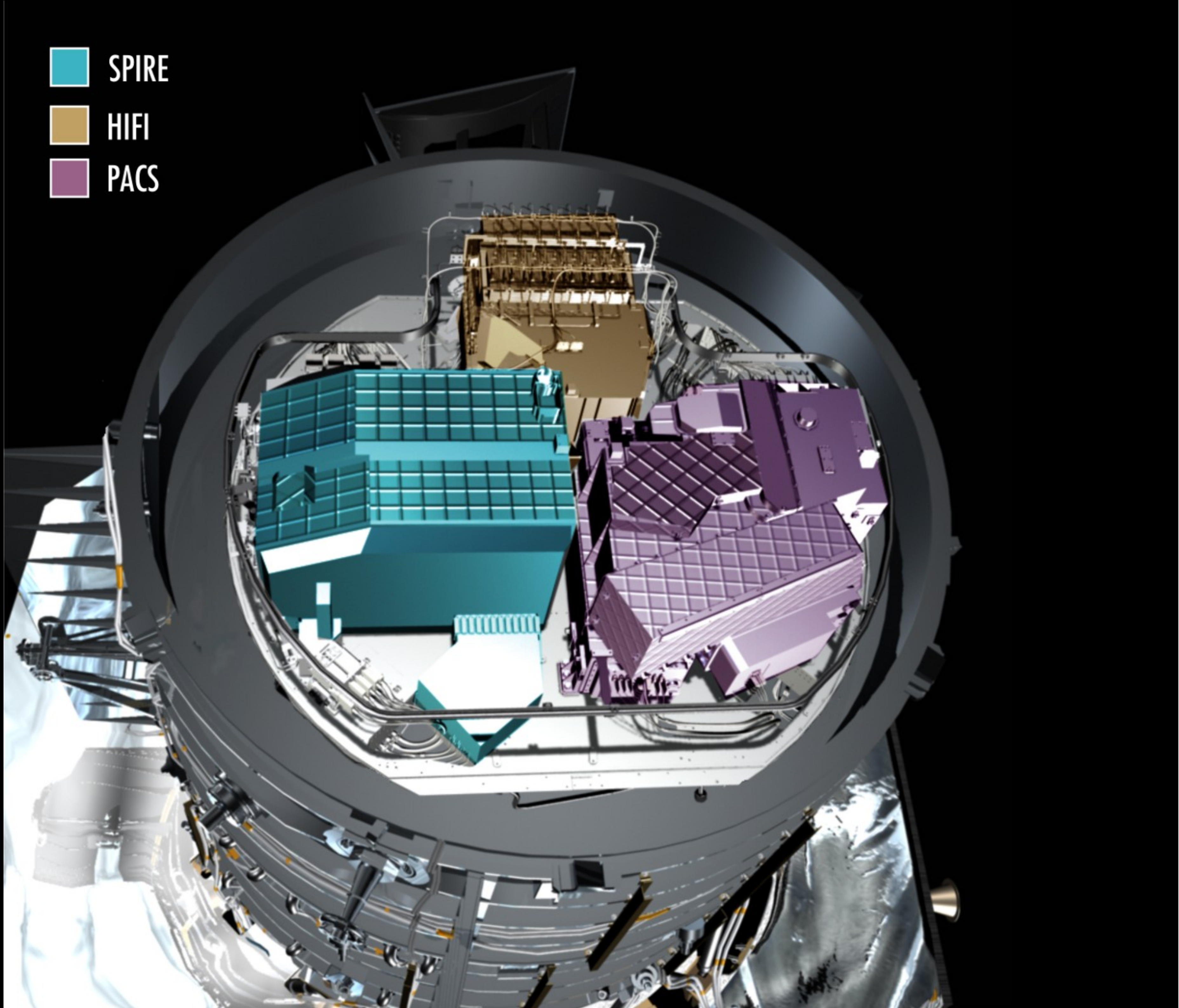
Main mirror

- 3.5m diameter SiC mirror
- Polished in Finland
  - Opteon, Tuorla

Photo: Harry Lehto



BBC/ESA


SPIRE
HIFI
PACS

The detectors

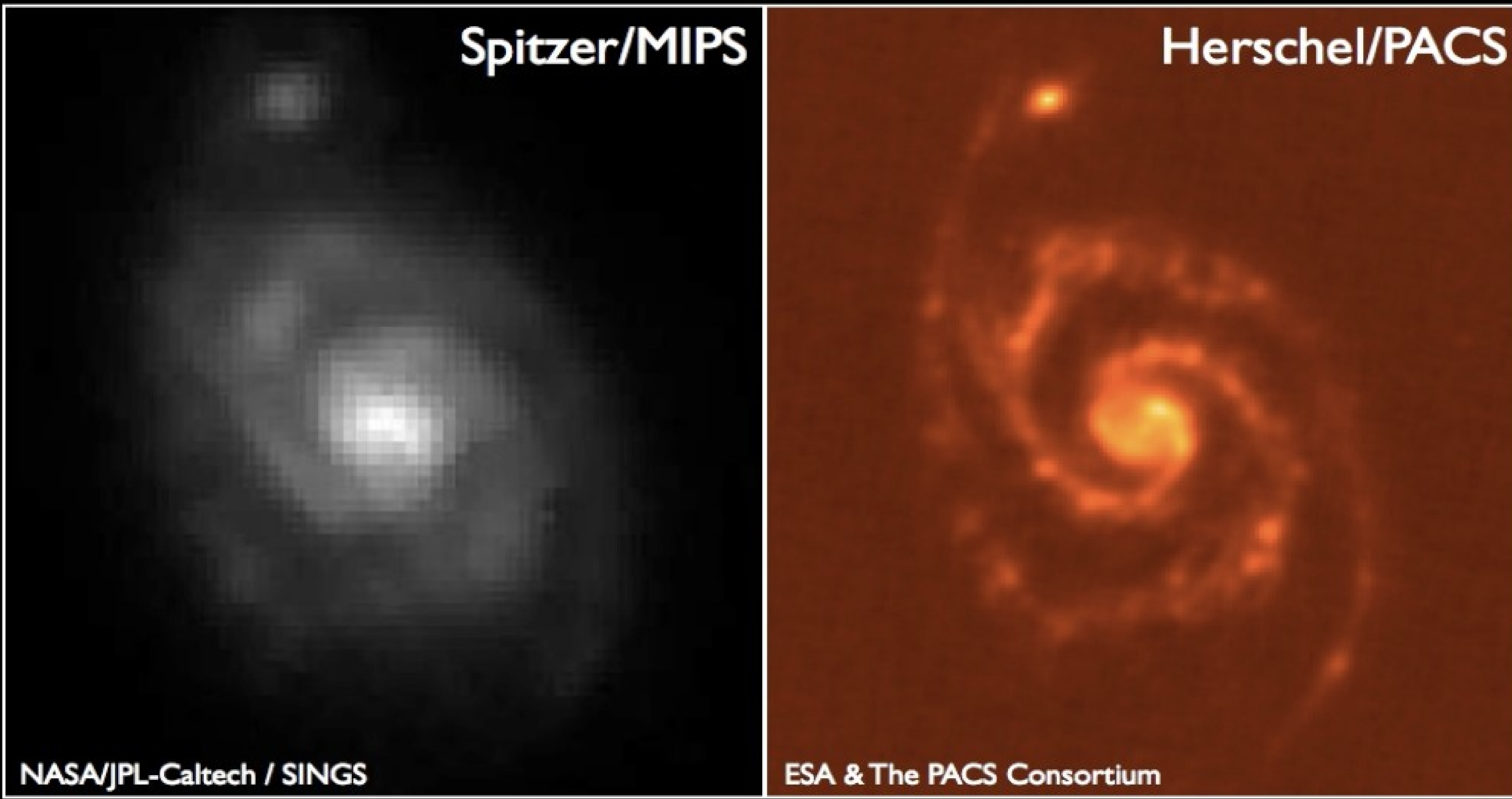
PACS

- *The Photoconductor Array Camera and Spectrometer*
  - consortium lead by MPE, PI Albrecht Poglitsch
- Three photometric bands at 70μm, 100μm, 160μm
- Integral field spectrometer, R ~ 1500
- 47'' × 47'' field of view, resolution 5.5-12''

SPIRE

- *The Spectral and Photometric Imaging REceiver*
  - consortium lead by Cardiff University, PI Matt Griffin
- Three photometric bands at 250μm, 350μm, 500μm
- Imaging FTS, 200-670μm, R ~ 20 - 1000
- resolution 18-38''

Spitzer/MIPS & Herschel/PACS at 160 um



Spiral Galaxy M51 (“Whirlpool Galaxy”) in the Far Infrared (160μm)

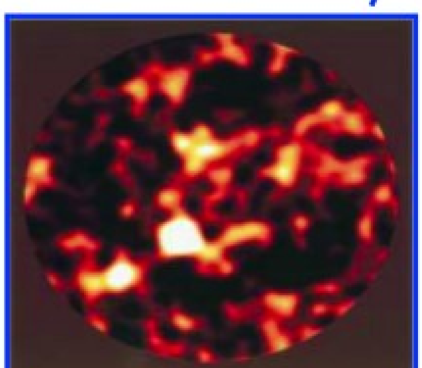
Progress in submm observations

1998

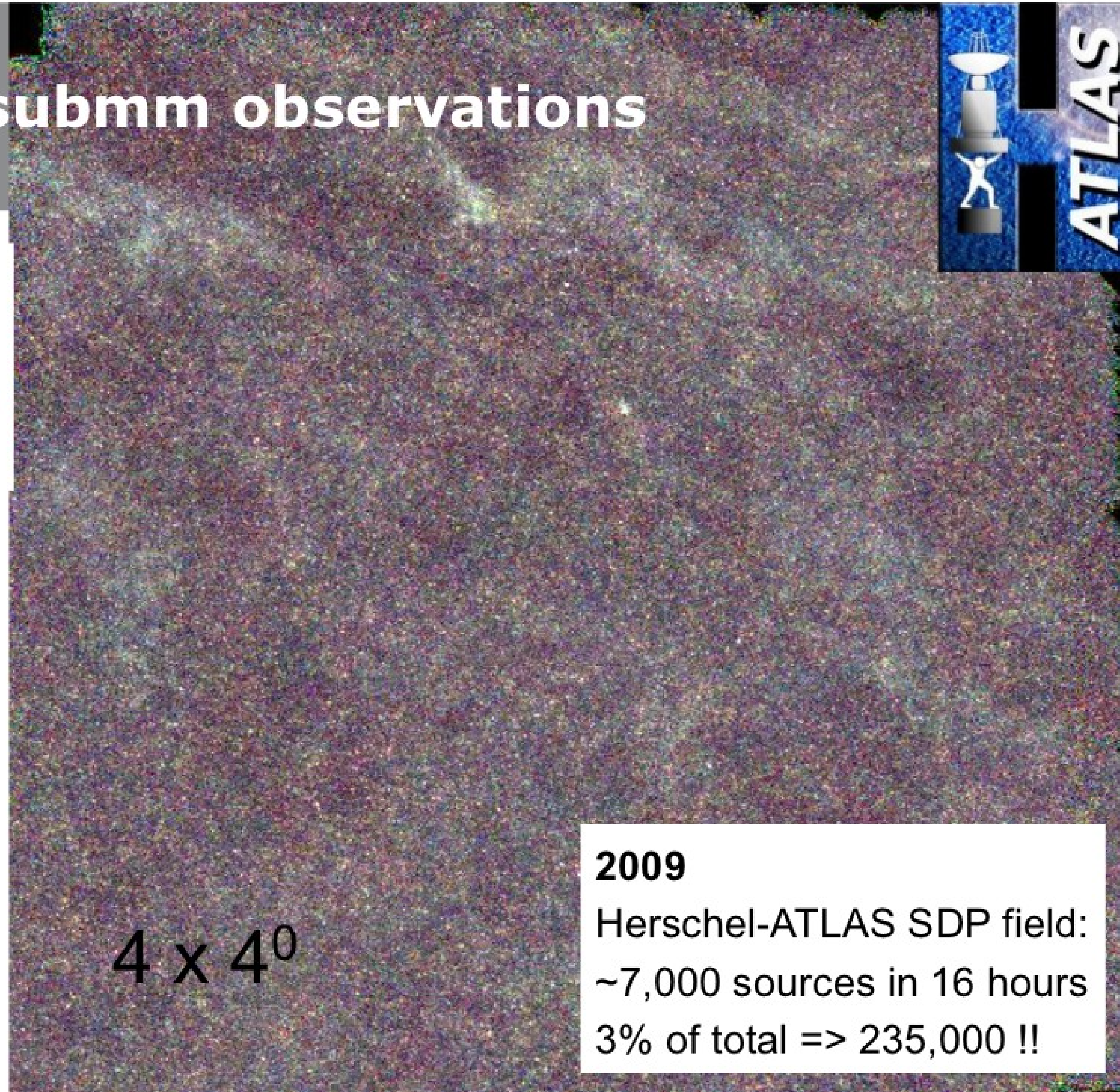
SCUBA HDF:

5 sources after 20 exceptional nights

To scale!



~3 arcmin



2009

Herschel-ATLAS SDP field:

~7,000 sources in 16 hours

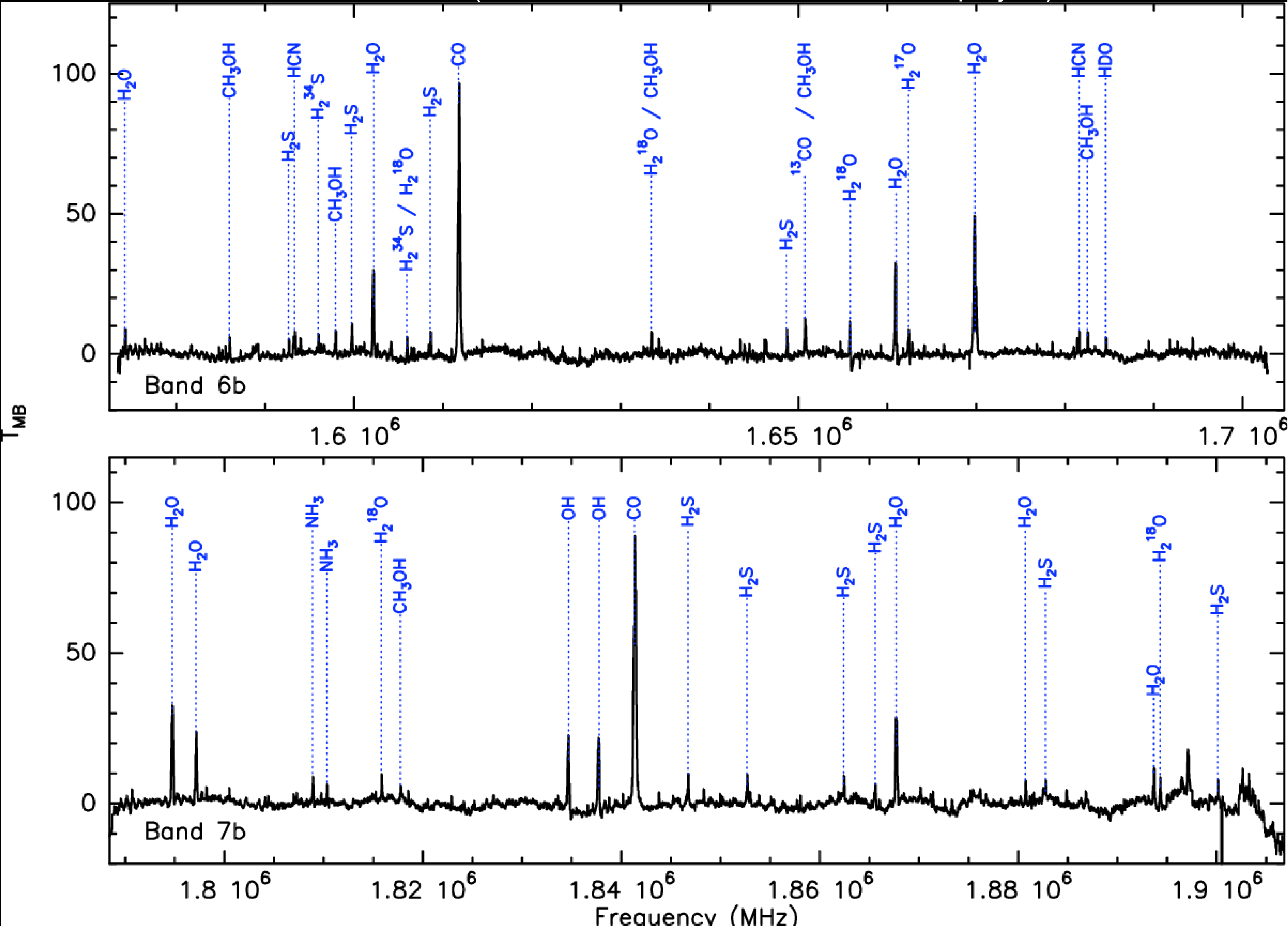
3% of total => 235,000 !!

The detectors

HIFI

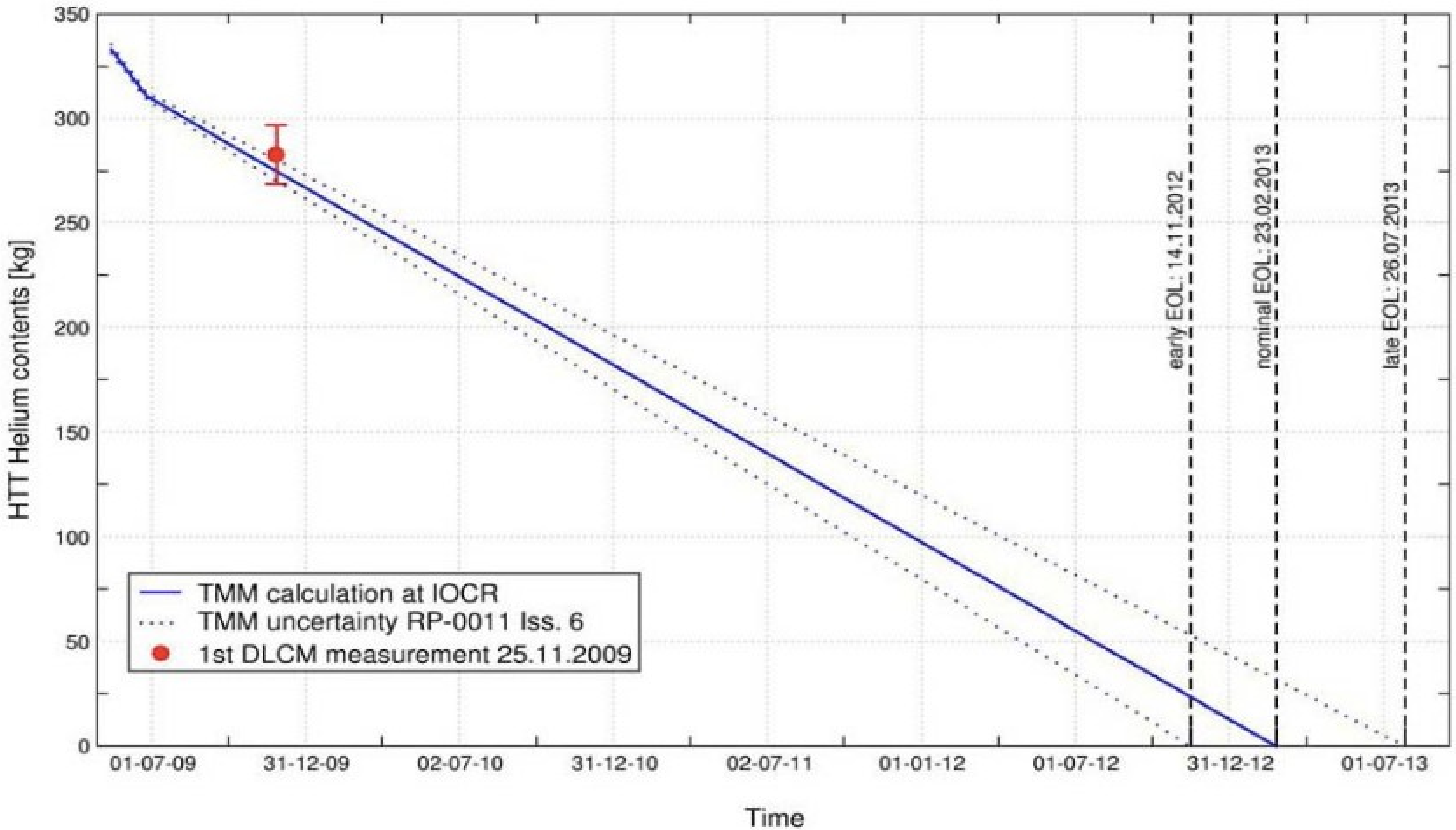
- *Heterodyne Instrument for the Far Infrared*
  - consortium lead by SRON Netherlands Institute for Space Research, PI Thijs de Graauw; Frank Helmich
- High resolution spectroscopy at 625-240µm and 213-157µm
- Four spectrometers (2×AOS, 2×ACS)
- Spectral resolution from 125kHz to 1000MHz
  - velocity resolution down to ~0.1 km/s, R beyond 10^6
- Spectral mapping

Orion KL in HIFI bands 6b and 7b (Crockett et al. 2010 and the HEXOS project)



Mission (cryostat) lifetime

Large uncertainties remain, but confidence in ≥ 3.5 years



HERSCHEL SPACE OBSERVATORY

Observing time

- Divided between guaranteed time programmes, open time key programmes, and normal open time
- Guaranteed time 6000h – GTKP (excluding GT1 and GT2)
  - Solar system (1), ISM/star formation (10), Stars (2), Galaxies/AGN (5), Cosmology (3)
- Open time key programmes 5500h - OTKP
  - Solar system (1), ISM/Star formation (10), Galaxies/AGNs (8), Cosmology (2)
- OT1 (2010) 6600h
  - Solar system (14), ISM/Star formation (110), Stars (31), Galaxies/AGNs (62), Cosmology (24)
- OT2 (2011) 7600h
  - Solar system (9), ISM/Star formation (158), Stars (41), Galaxies/AGNs (**109**), Cosmology (**56**)
- Note: properietary period now 6 months!

Observing time

- some key programmes
  - HerMES, The Herschel Multi-tiered Extragalactic Survey, 900h, Seb Oliver
  - PACS Evolutionary Probe, 655h, Dieter Lutz
  - KINGFISH, Key Insights on Nearby Galaxies: A Far-Infrared Survey with Herschel, 637h, Robert Kennicutt
  - H-ATLAS, The Herschel Thousand Degree Survey, 600h, Stephen Eales
  - WISH, Water in Star-forming regions with Herschel, 499h, Ewine van Dishoeck
  - GBS, Gould Belt Survey, 461h, PI. Philippe Andre
  - GASPS, Gas in Protoplanetary Systems, 400h, Bill Dent
  - ...
  - Cold Cores, 151h, Mika Juvela
  - ...

Scientific output

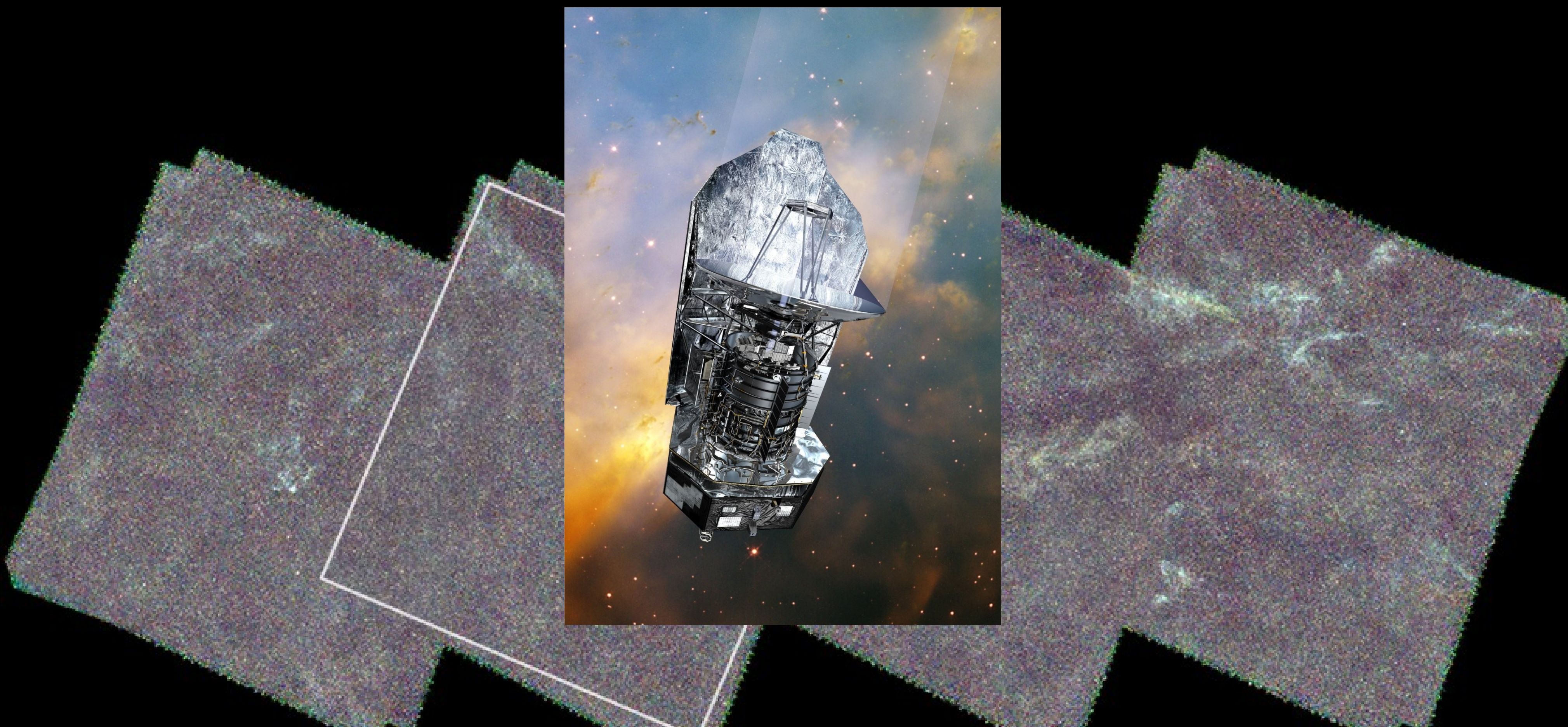
launch May 2009

- Special issue A&A 518, 2010
  - **152** papers on first PACS and SPIRE results
- HIFI first results A&A 521, 2010
  - **67** letters

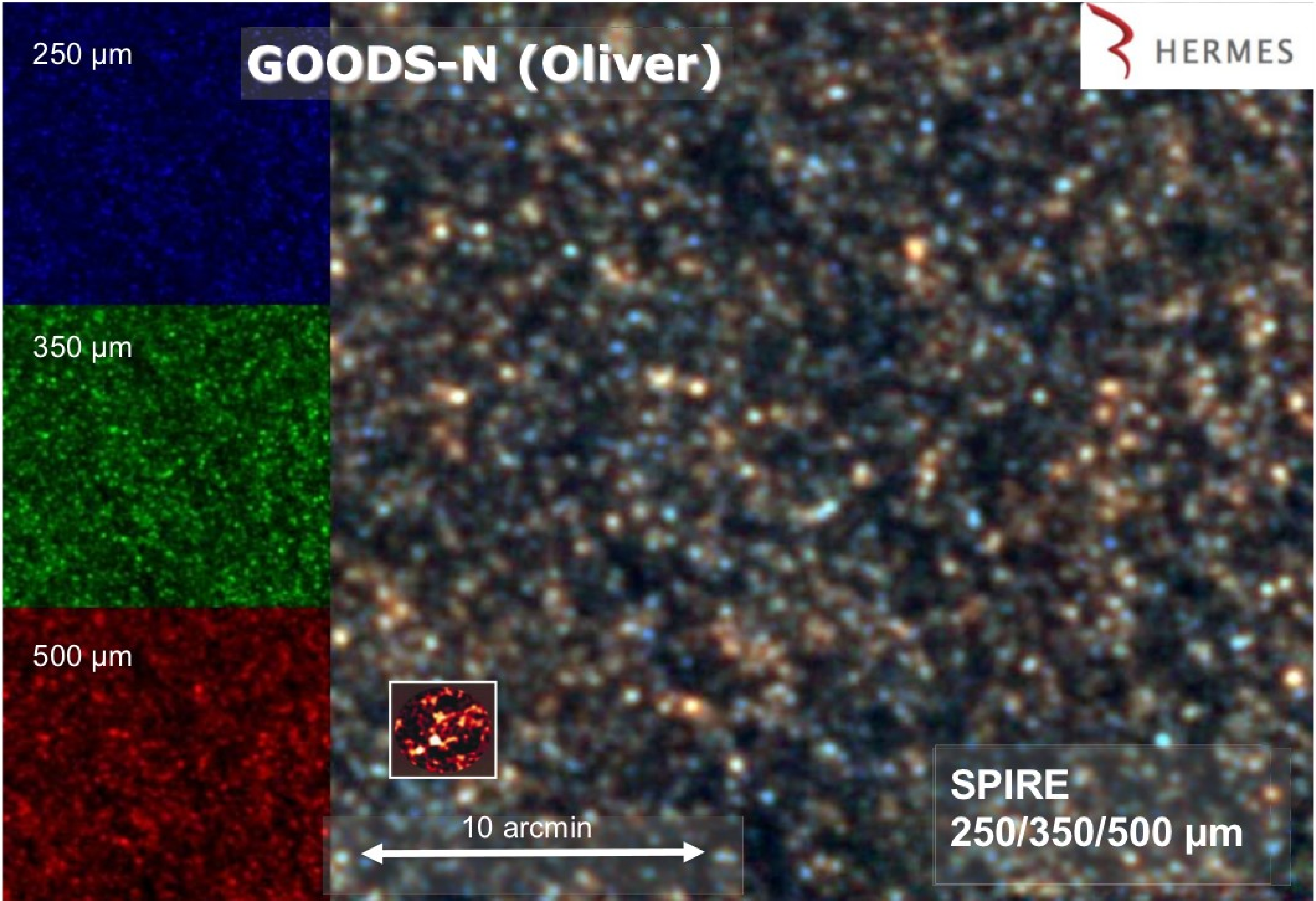
- http://herschel.esac.esa.int/ScientificPublications.shtml
  - **430** papers based on in-flight data
  - updated 25.5., possibly incomplete?

Highlights

- Slides borrowed from presentations by the project scientist Göran Pilbratt and from ESA web releases

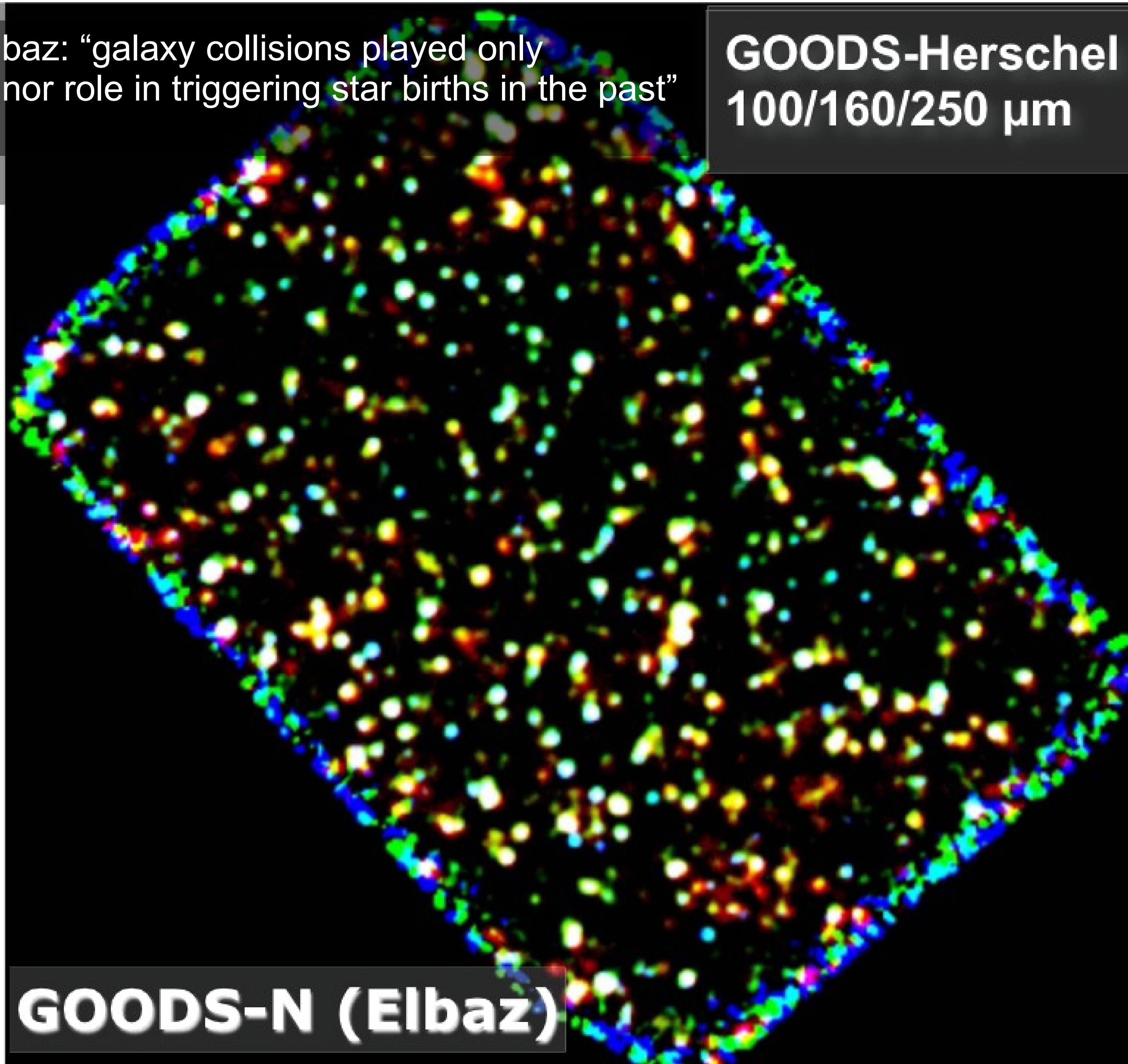


Credit: ESA/Herschel Space Observatory/H-ATLAS Consortium


GOODS-N (Oliver)
HERMES
250 μm
350 μm
500 μm
10 arcmin
SPIRE
250/350/500 μm

D.Elbaz: “galaxy collisions played only a minor role in triggering star births in the past”

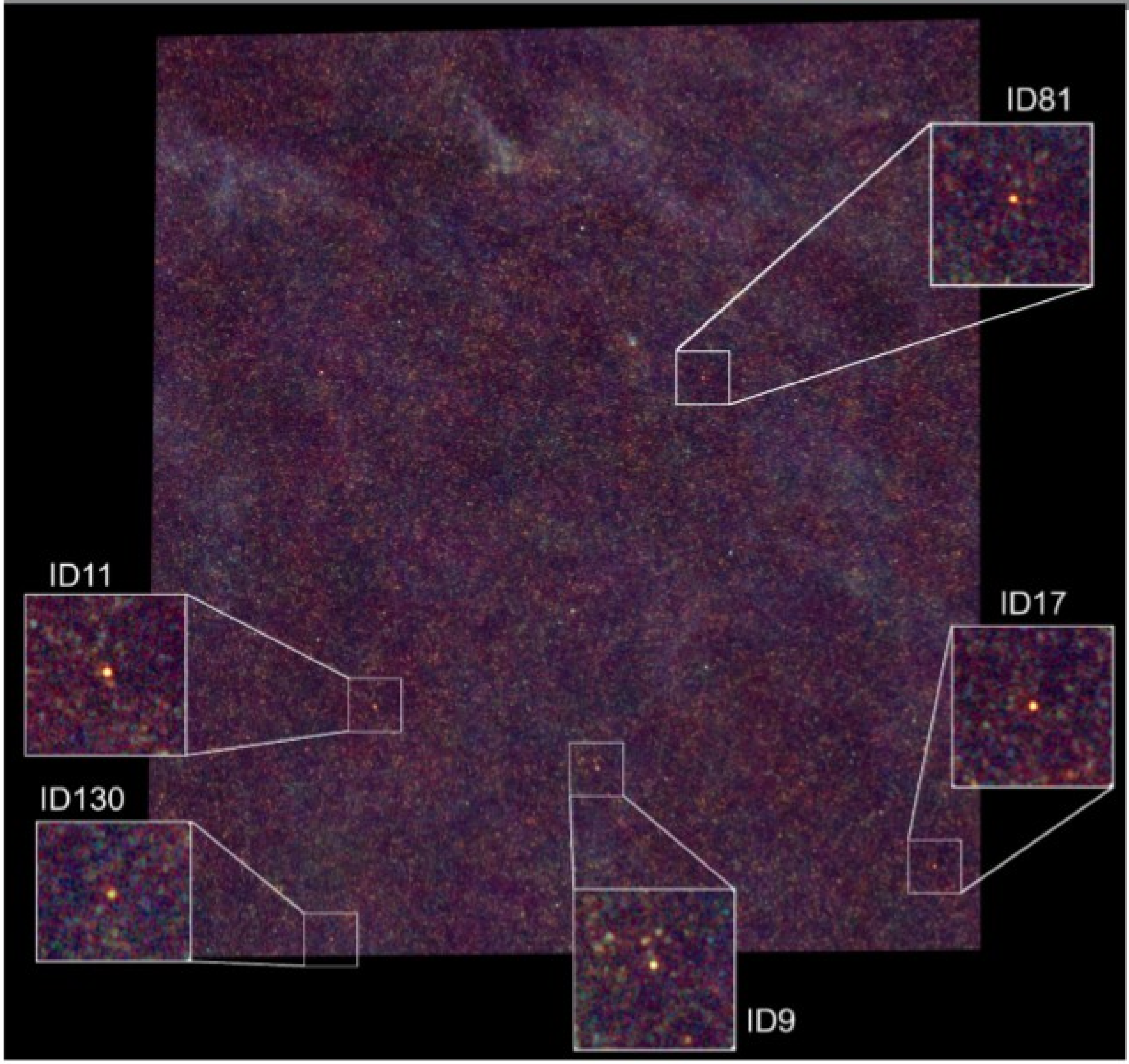
GOODS-Herschel
100/160/250 µm

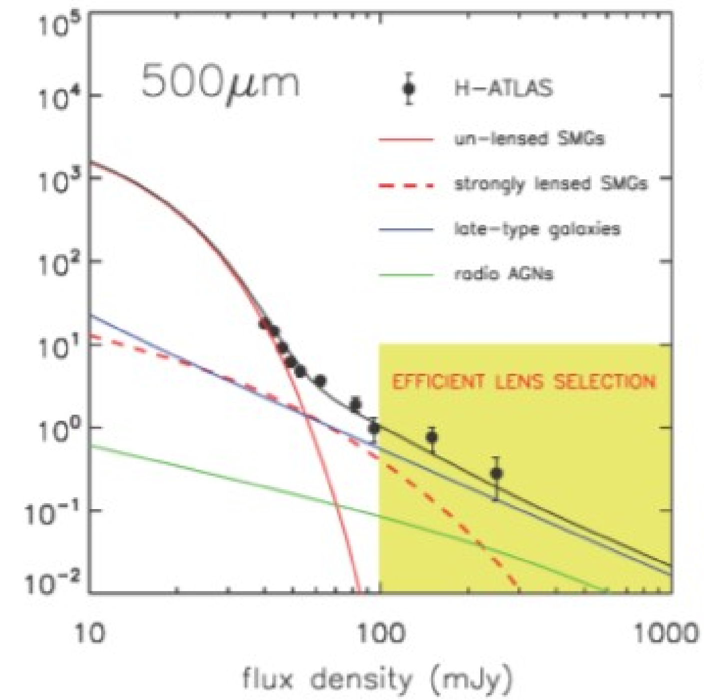


RE
350/500 µm

HERSCHEL SPACE OBSERVATORY

Herschel ATLAS – gravitational lensing





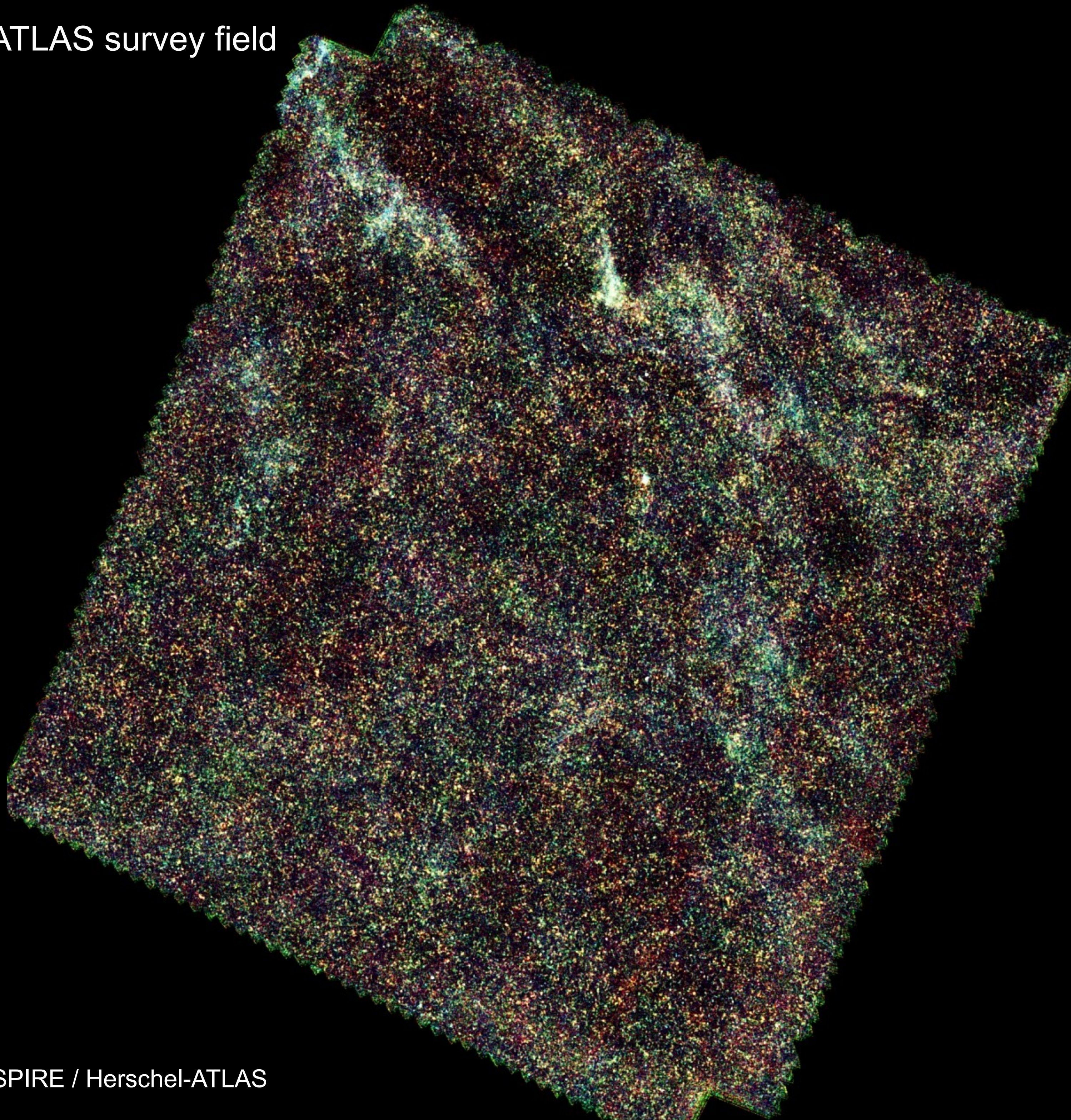
Negrello et al.
Science 330, 800, 2010

HERSCHEL SPACE OBSERVATORY

Negrello et al. (2010)

Gravitational lensing is a powerful astrophysical and cosmological probe and is particularly valuable at submillimeter wavelengths for the study of the statistical and individual properties of dusty star-forming galaxies. However, the identification of gravitational lenses is often time-intensive, involving the sifting of large volumes of imaging or spectroscopic data to find few candidates. We used early data from the Herschel Astrophysical Terahertz Large Area Survey to demonstrate that wide-area submillimeter surveys can simply and easily detect strong gravitational lensing events, with close to 100% efficiency.

Part of the Herschel-ATLAS survey field



Credit: ESA / SPIRE / Herschel-ATLAS

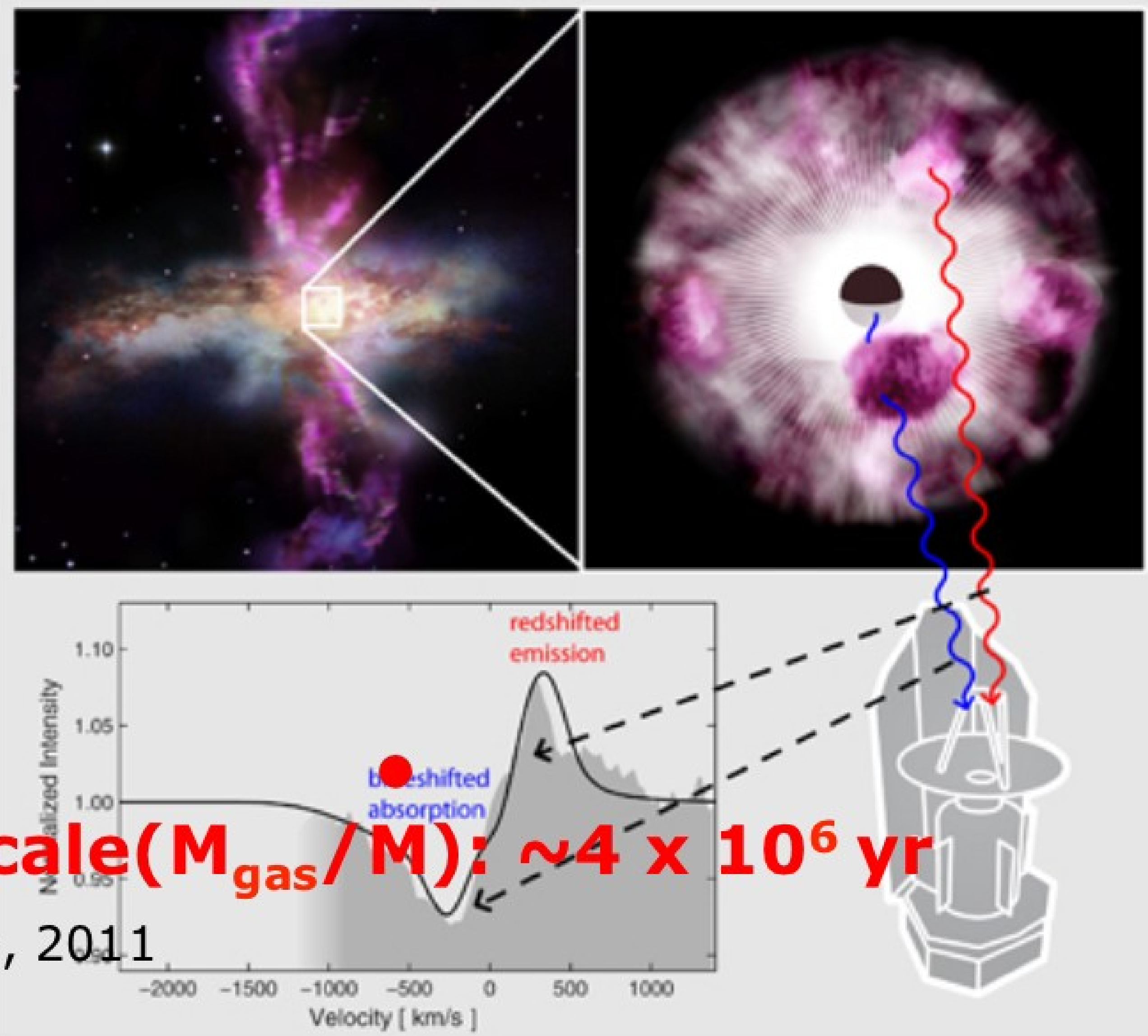
Herschel: SHINING – ULIRG/AGN outflows

Mrk 231:

$L_{IR} = 3.2 \times 10^{12}\ L_\odot$
(70% AGN)

P-Cygni profile with blue-shifted absorption and red-shifted emission =>

$\Delta v \sim 1{,}170$ km/s

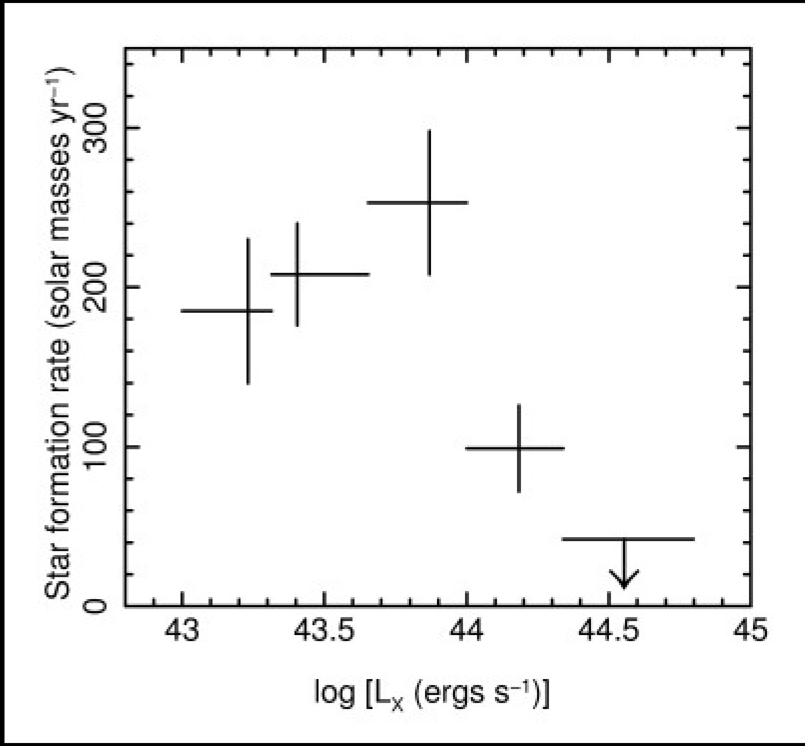


Depletion time scale(M_{gas}/M): ~4 x 10^6 yr

Sturm et al. A&A 733, L16, 2011

Sturn et al. (2011), ApJ 733, 16

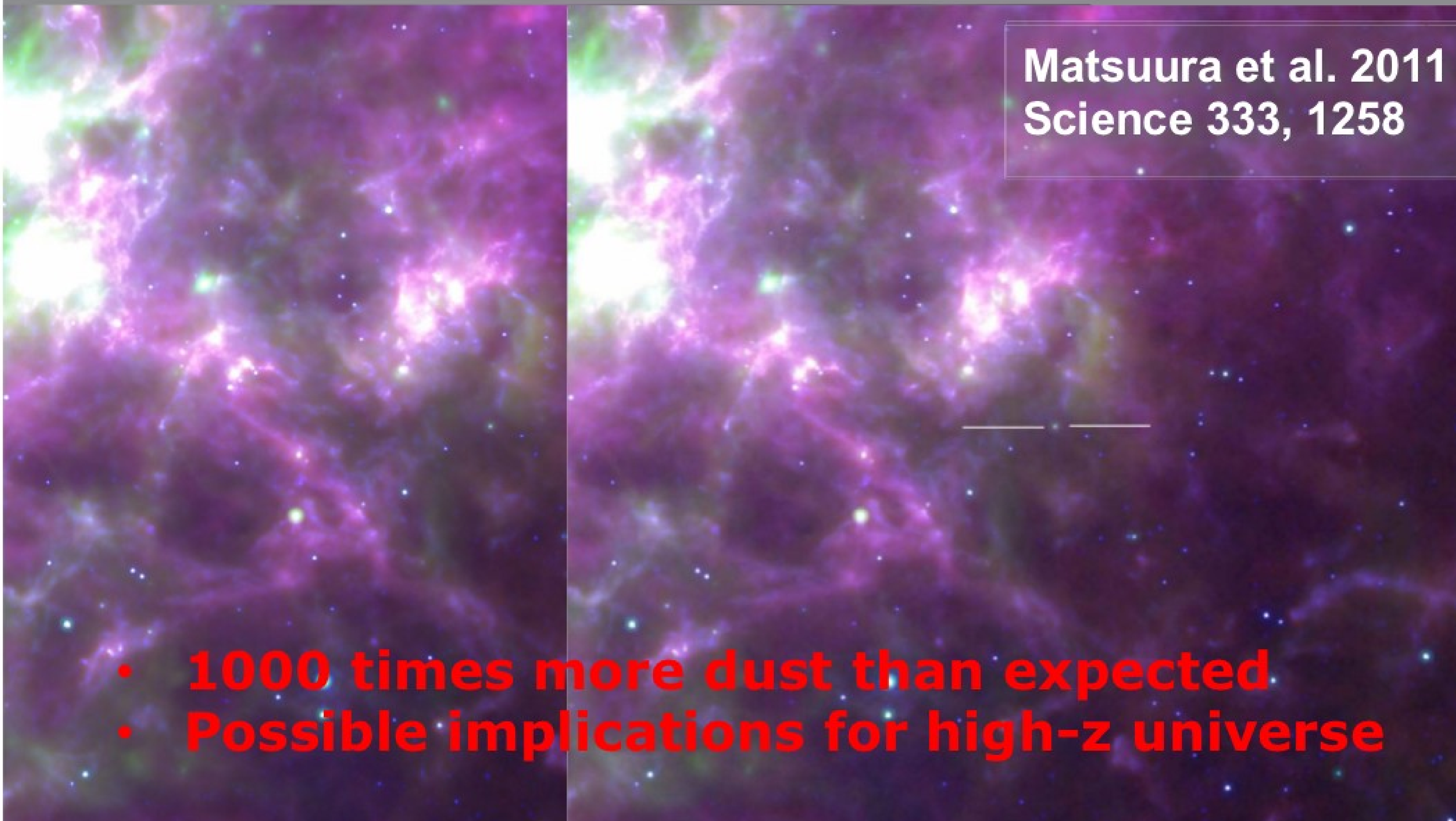
… we report the detection of massive molecular outflows, traced by the hydroxyl molecule (OH), in far-infrared spectra of ULIRGs obtained with Herschel-PACS as part of the SHINING key project. In some of these objects the (terminal) outflow velocities exceed 1000 km s-1, and their outflow rates (up to ~1200 M sun yr-1) are several times larger than their star formation rates. We compare the outflow signatures in different types of ULIRGs and in starburst galaxies to address the issue of the energy source (AGN or starburst) of these outflows. We report preliminary evidence that ULIRGs with a higher AGN luminosity (and higher AGN contribution to L IR) have higher terminal velocities and shorter gas depletion timescales. The outflows in the observed ULIRGs are able to expel the cold gas reservoirs from the centers of these objects within ~10^6-10^8 years.



M. Page
http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=50333

The Whirlpool Galaxy

SN1987A – dust production



Matsuura et al. (2011), Science 333, 1258

We report far-infrared and submillimeter observations of Supernova 1987A, the star that exploded on February 23, 1987 in the Large Magellanic Cloud, a galaxy located 160,000 lightyears away. The observations reveal the presence of a population of cold dust grains radiating with a temperature of ~17-23 K at a rate of about 220 solar luminosity. The intensity and spectral energy distribution of the emission suggests a dust mass of ~0.4-0.7 solar mass. The radiation must originate from the SN ejecta and requires the efficient precipitation of all refractory material into dust. Our observations imply that supernovae can produce the large dust masses detected in young galaxies at very high redshifts.

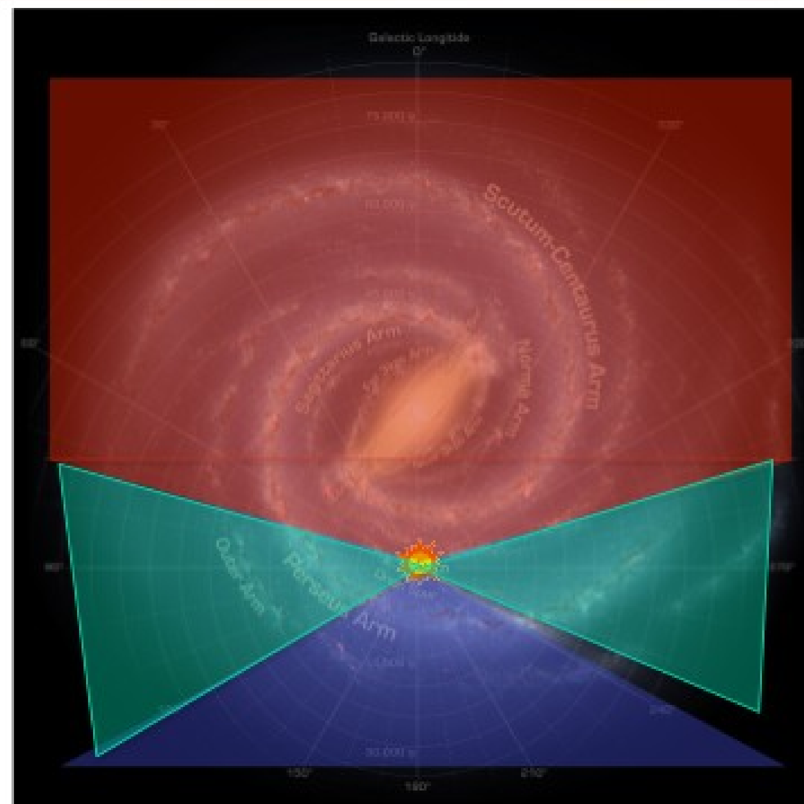
HI-GAL

A Herschel Key-Project to map the Galactic Plane in the Far-IR

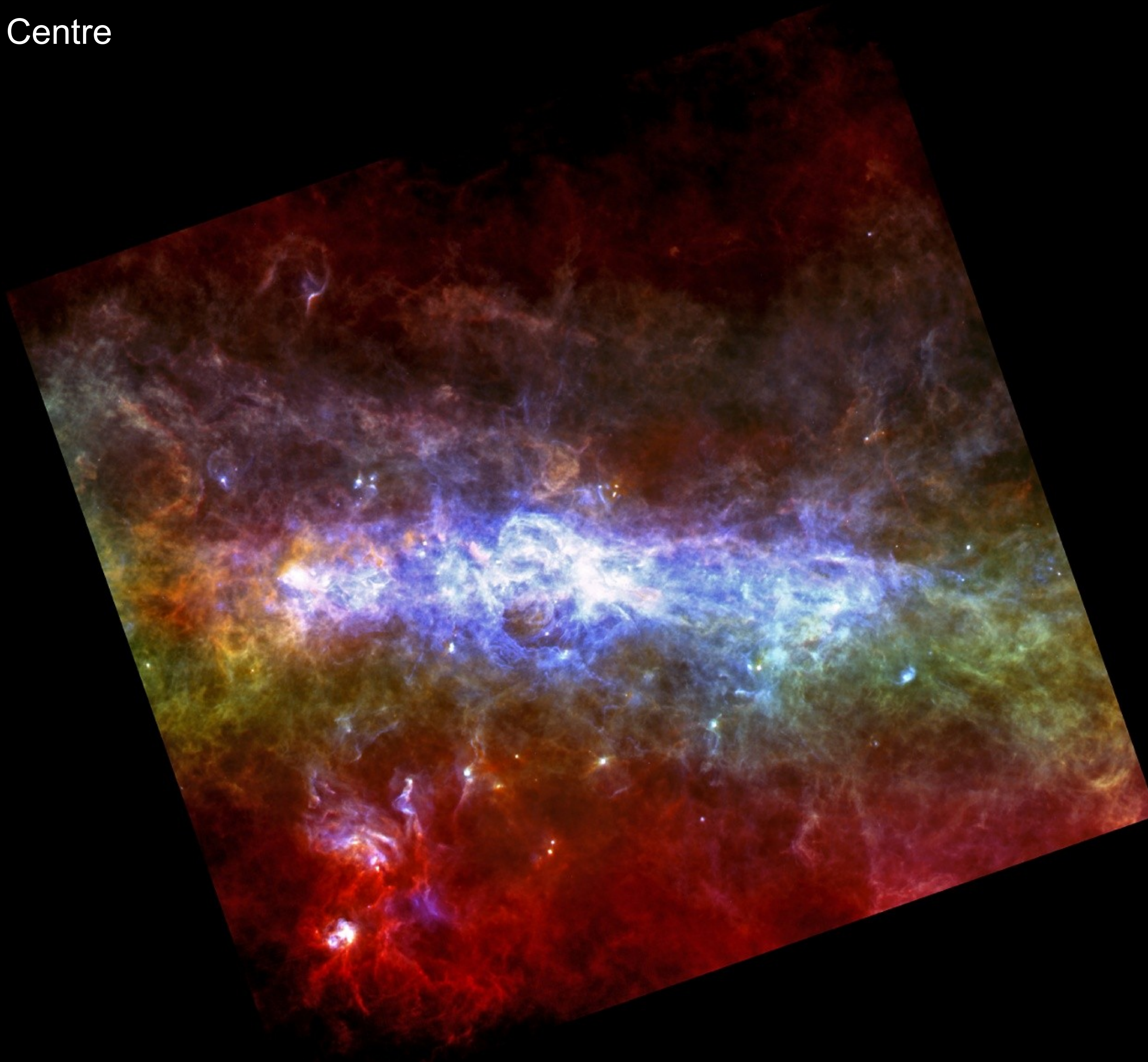
Simultaneous 5-bands (*70-160-250-350-500μm*) continuum mapping of 720 sq. deg. of the Galactic Plane (|*b*|≤1°)

With almost 900 hours observing time is the largest OPEN TIME Herschel KP

Galaxy-wide Census, Luminosity, Mass and SED of dust structures at all scales from massive YSOs to Spiral Arms

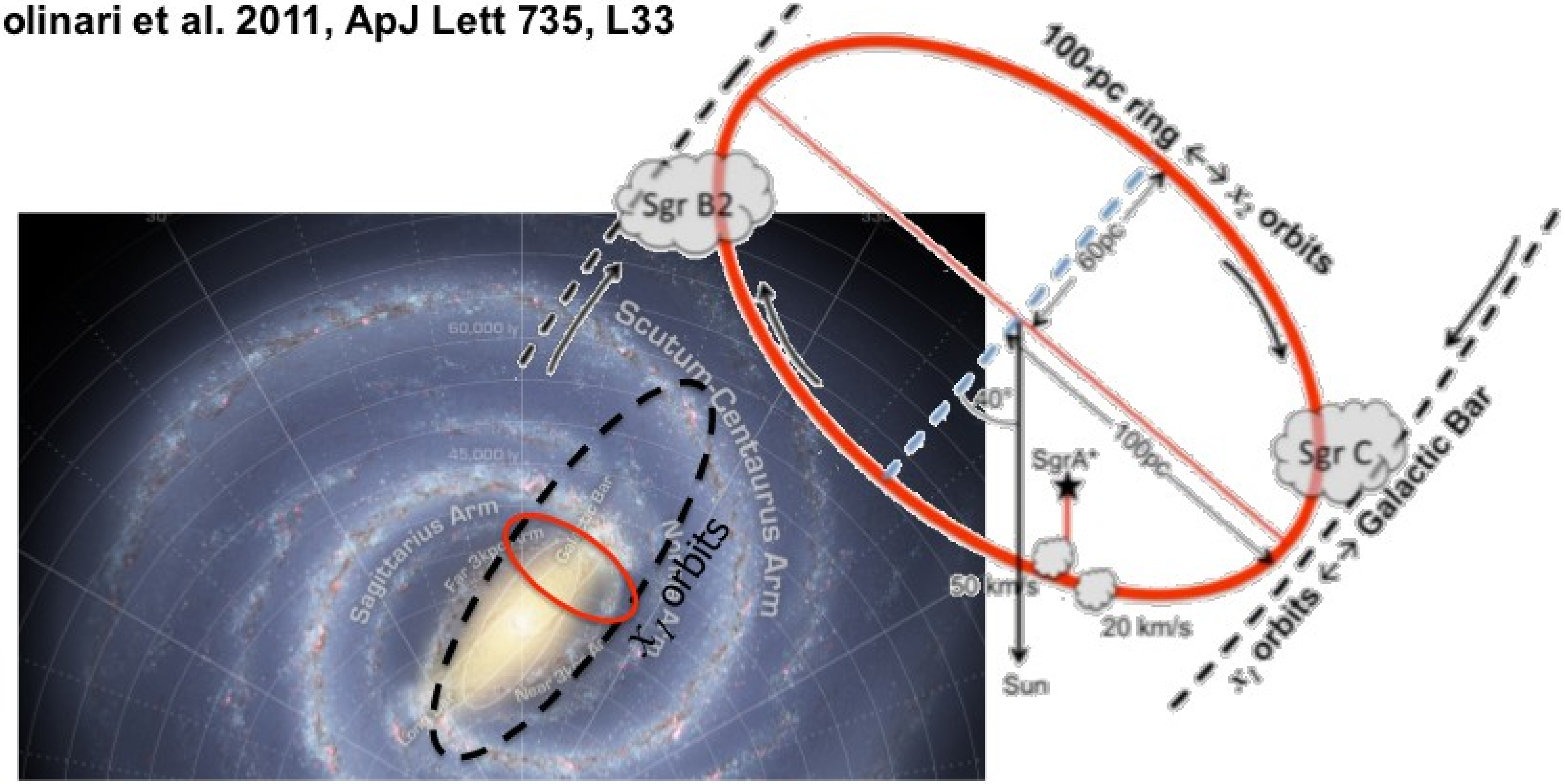


Galactic Centre



ESA/PACS & SPIRE Consortium, Sergio Molinari, Hi-GAL Project

Molinari et al. 2011, ApJ Lett 735, L33



The 100pc ring revealed by Herschel is the counterpart to the x_2 orbits predicted by theory (e.g. Binney et al. 1991)

SgrB2 and SgrC are conveniently located at the converging points between the x_1 and x_2 *orbits*, where shock-focusing mechanism may favour the formation of massive clouds

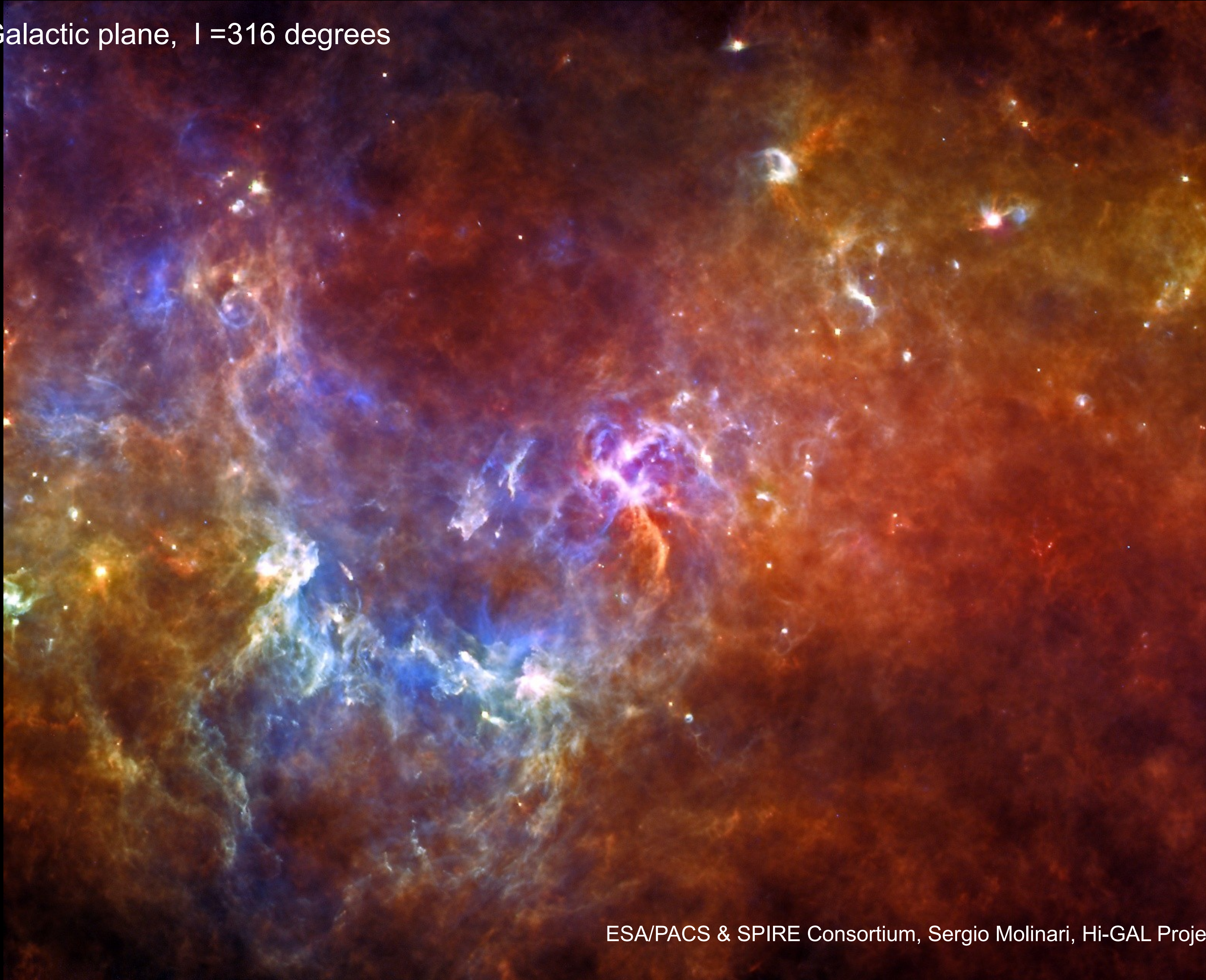
Molinari et al. (2011) ApJ 735, 33

Thermal images of cold dust in the Central Molecular Zone of the Milky Way, obtained with the far-infrared cameras on board the Herschel satellite, reveal a ~3×10^7 Msun ring of dense and cold clouds orbiting the Galactic center. Using a simple toy model, an elliptical shape having semi-major axes of 100 and 60 pc is deduced. The major axis of this 100 pc ring is inclined by about 40° with respect to the plane of the sky and is oriented perpendicular to the major axes of the Galactic Bar. The 100 pc ring appears to trace the system of stable x_2 orbits predicted for the barred Galactic potential. Sgr A* is displaced with respect to the geometrical center of symmetry of the ring. The ring is twisted and its morphology suggests a flattening ratio of 2 for the Galactic potential, which is in good agreement with the bulge flattening ratio derived from the 2MASS data.

Galactic plane, l =319 degrees

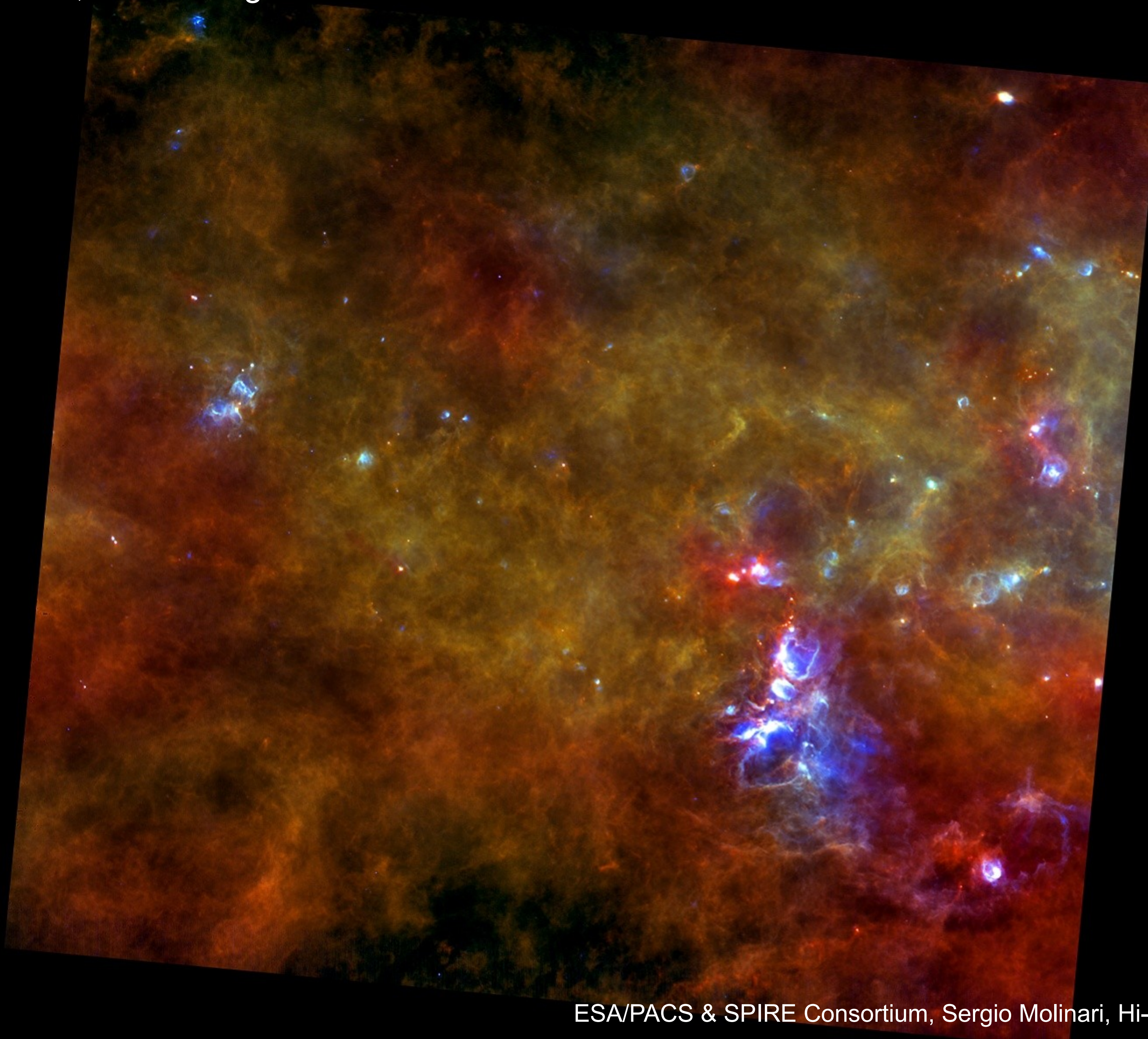
ESA/PACS & SPIRE Consortium, Sergio Molinari, Hi-GAL Project

Galactic plane, l =316 degrees



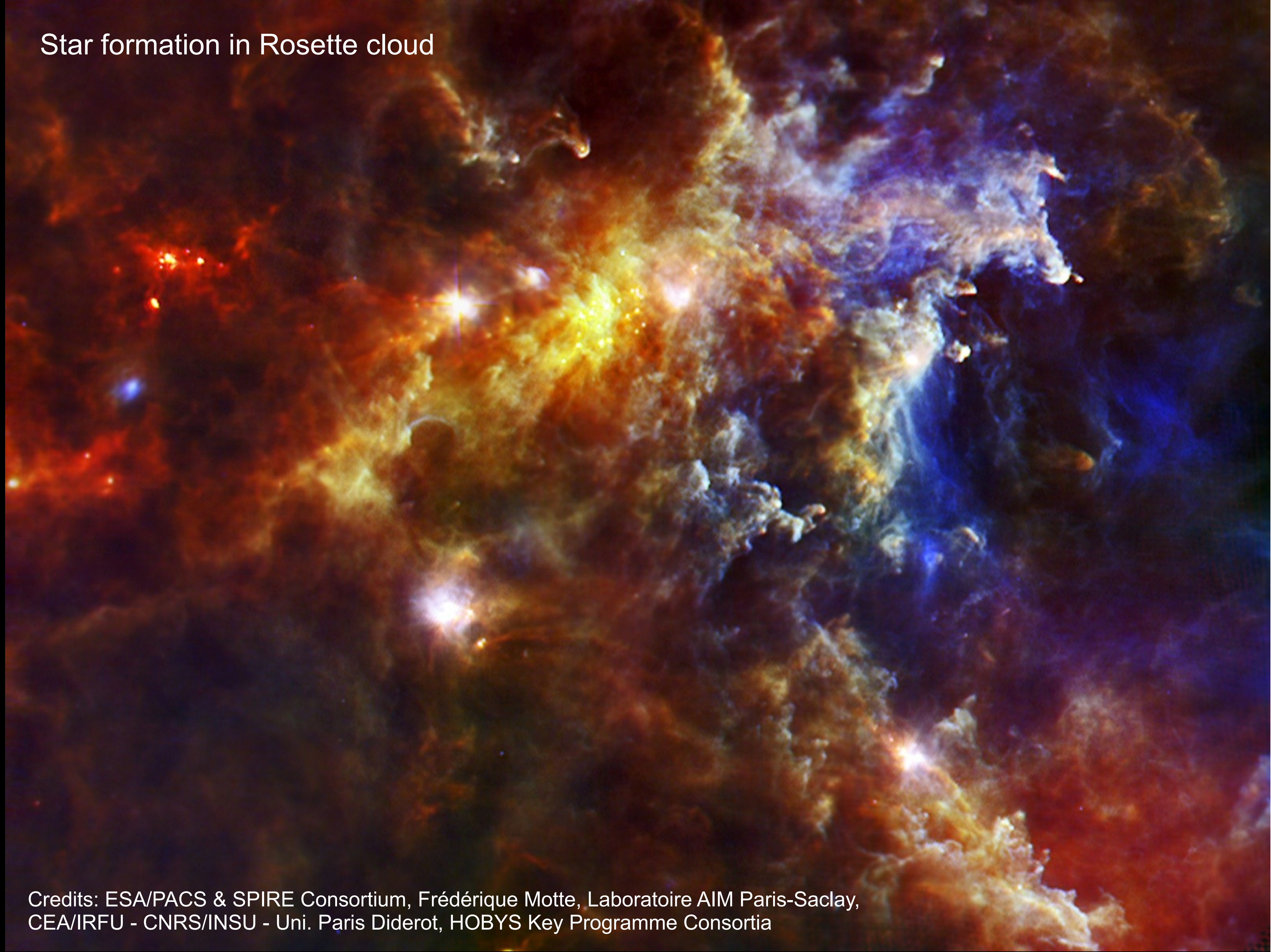
ESA/PACS & SPIRE Consortium, Sergio Molinari, Hi-GAL Project

Galactic plane, l =314 degrees



ESA/PACS & SPIRE Consortium, Sergio Molinari, Hi-GAL Project

Star formation in Rosette cloud

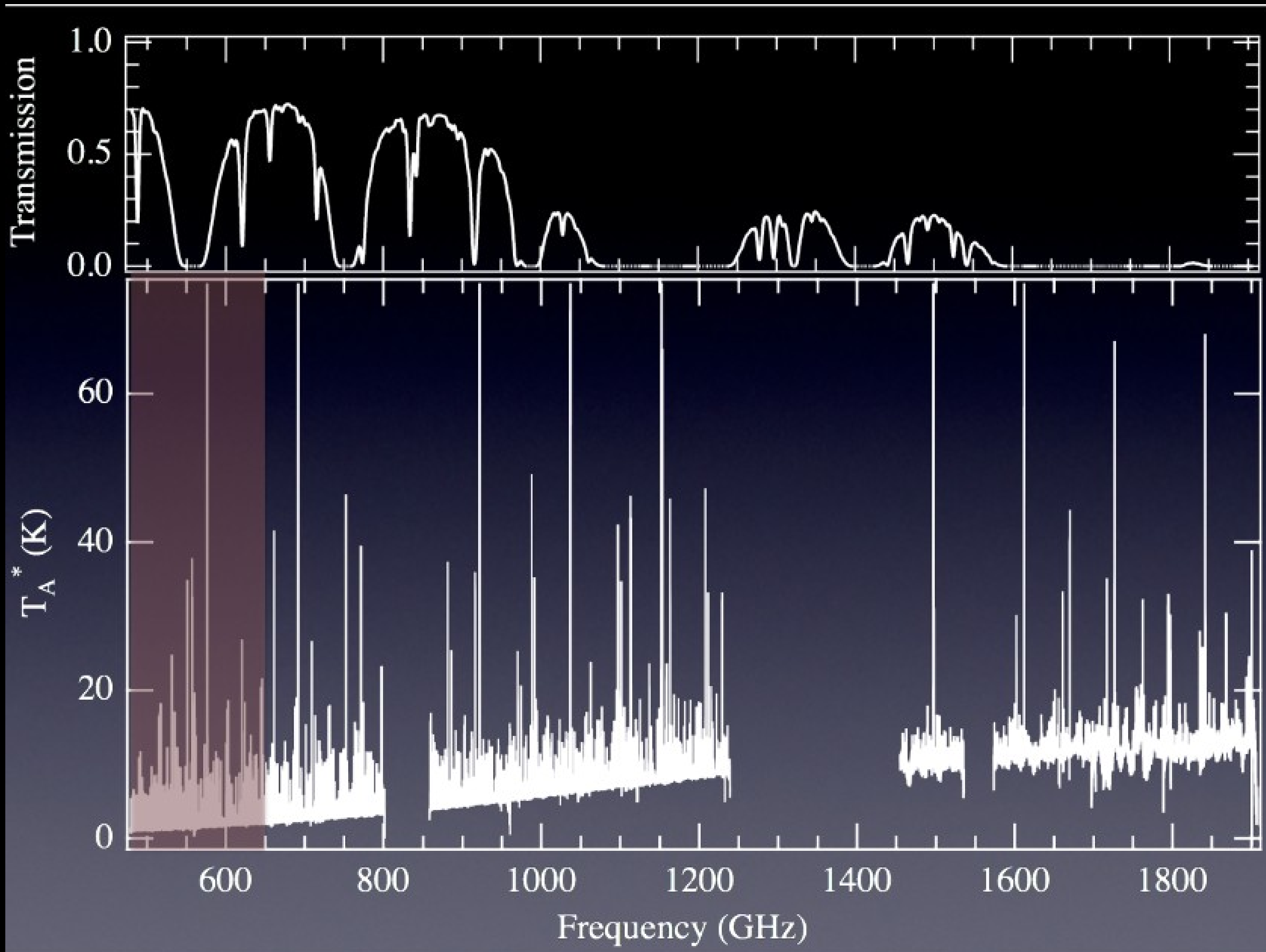


Credits: ESA/PACS & SPIRE Consortium, Frédérique Motte, Laboratoire AIM Paris-Saclay, CEA/IRFU - CNRS/INSU - Uni. Paris Diderot, HOBYS Key Programme Consortia

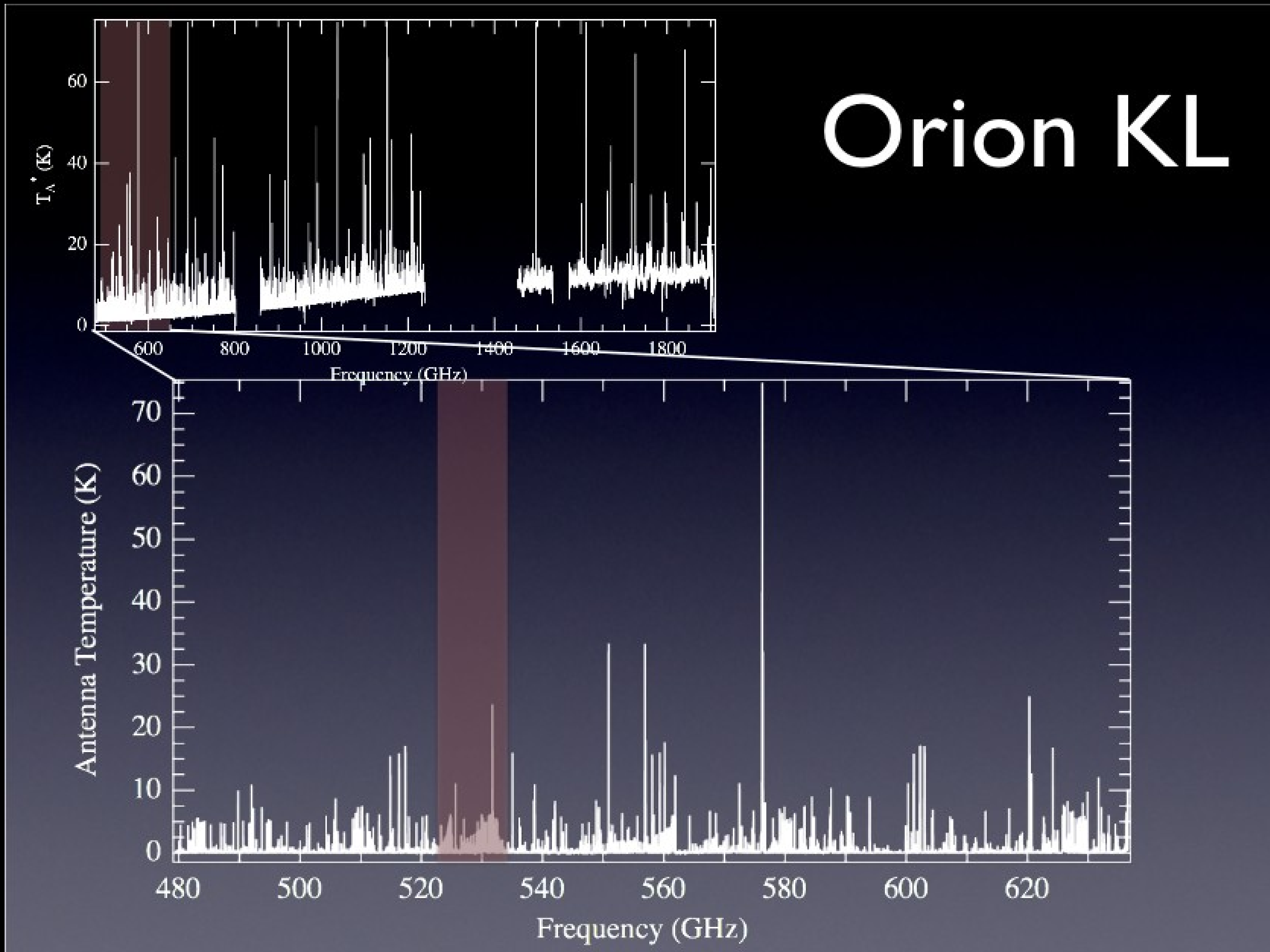
Jets Carve Out Big Hole

ESA / PACS & SPIRE Consortium, Tom Megeath,
NASA/JPL-Caltech/Univ. of Toledo

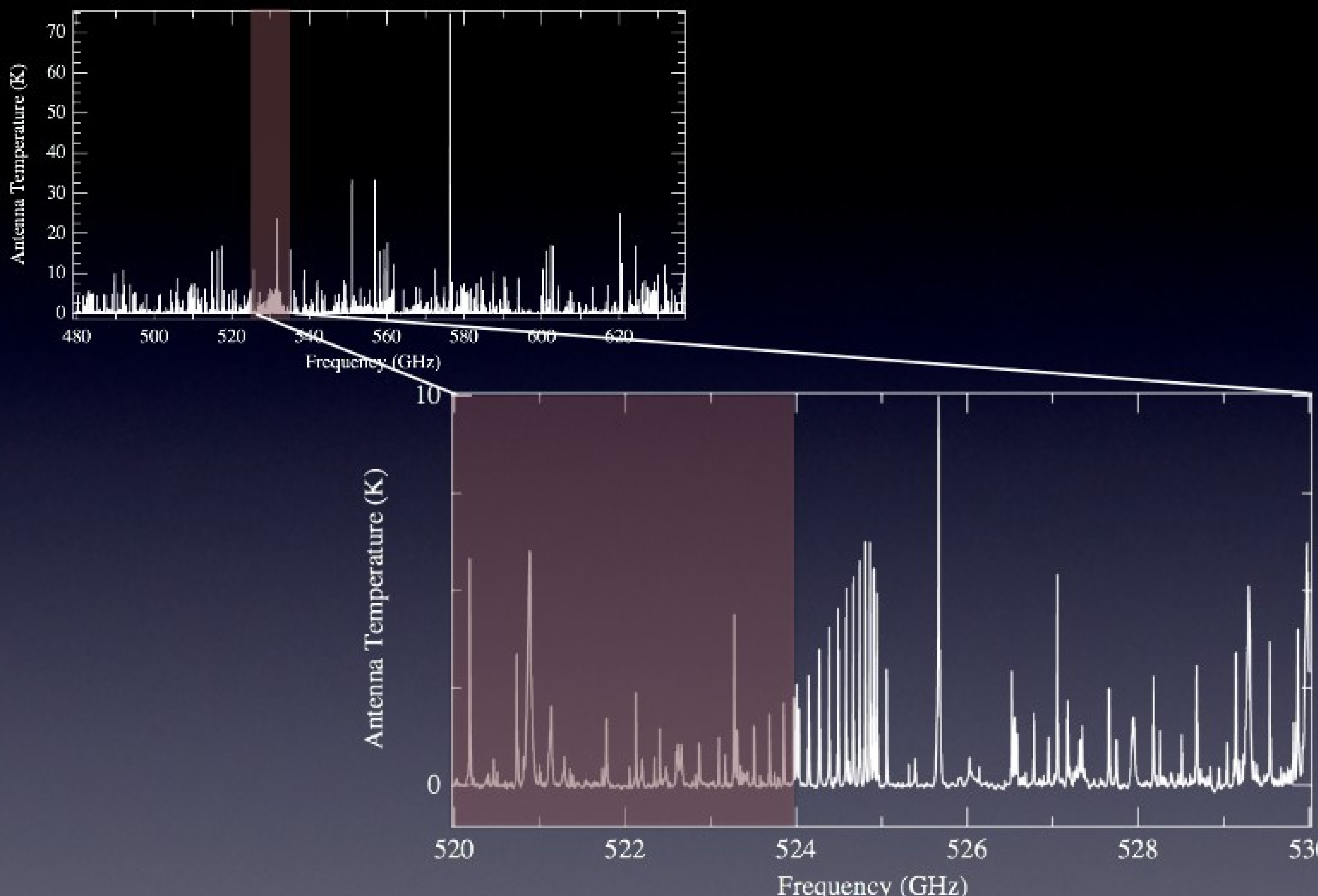
Spectral scans of Orion KL (HEXOS programme, PI E. Bergin)



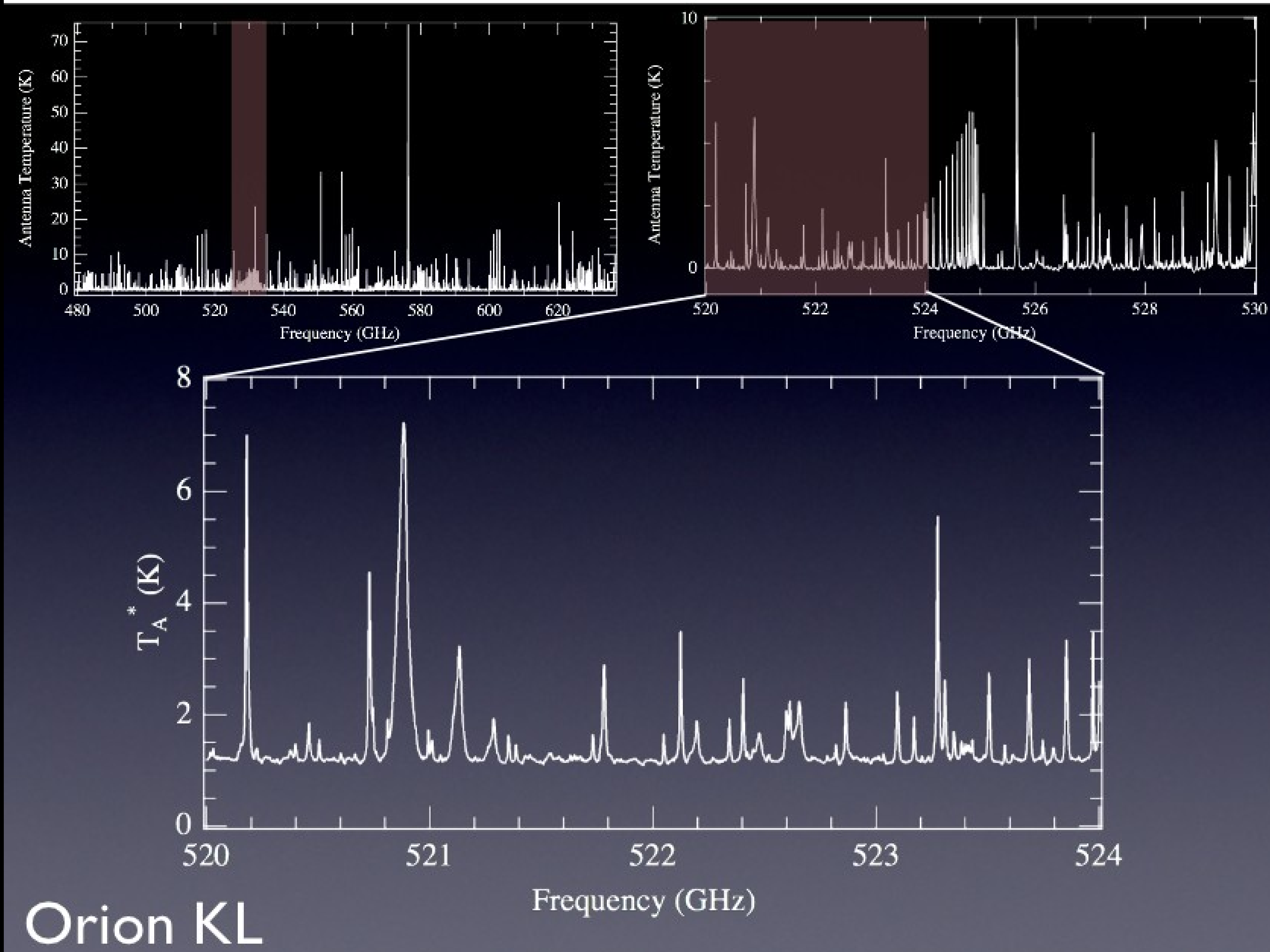
Orion KL

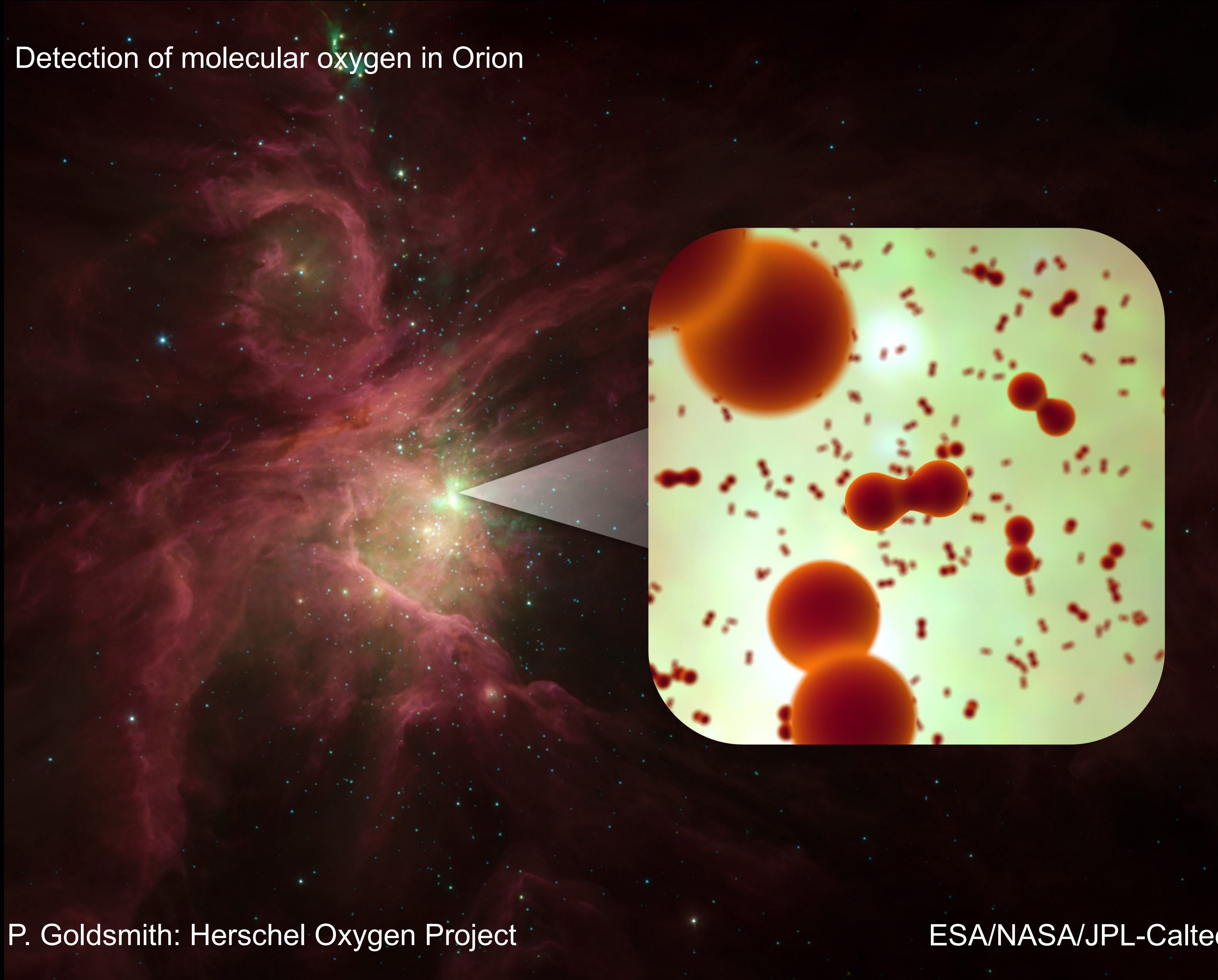


T_A^* (K)
0
20
40
60
600
800
1000
1200
1400
1600
1800
Frequency (GHz)
Antenna Temperature (K)
0
10
20
30
40
50
60
70
480
500
520
540
560
580
600
620
Frequency (GHz)

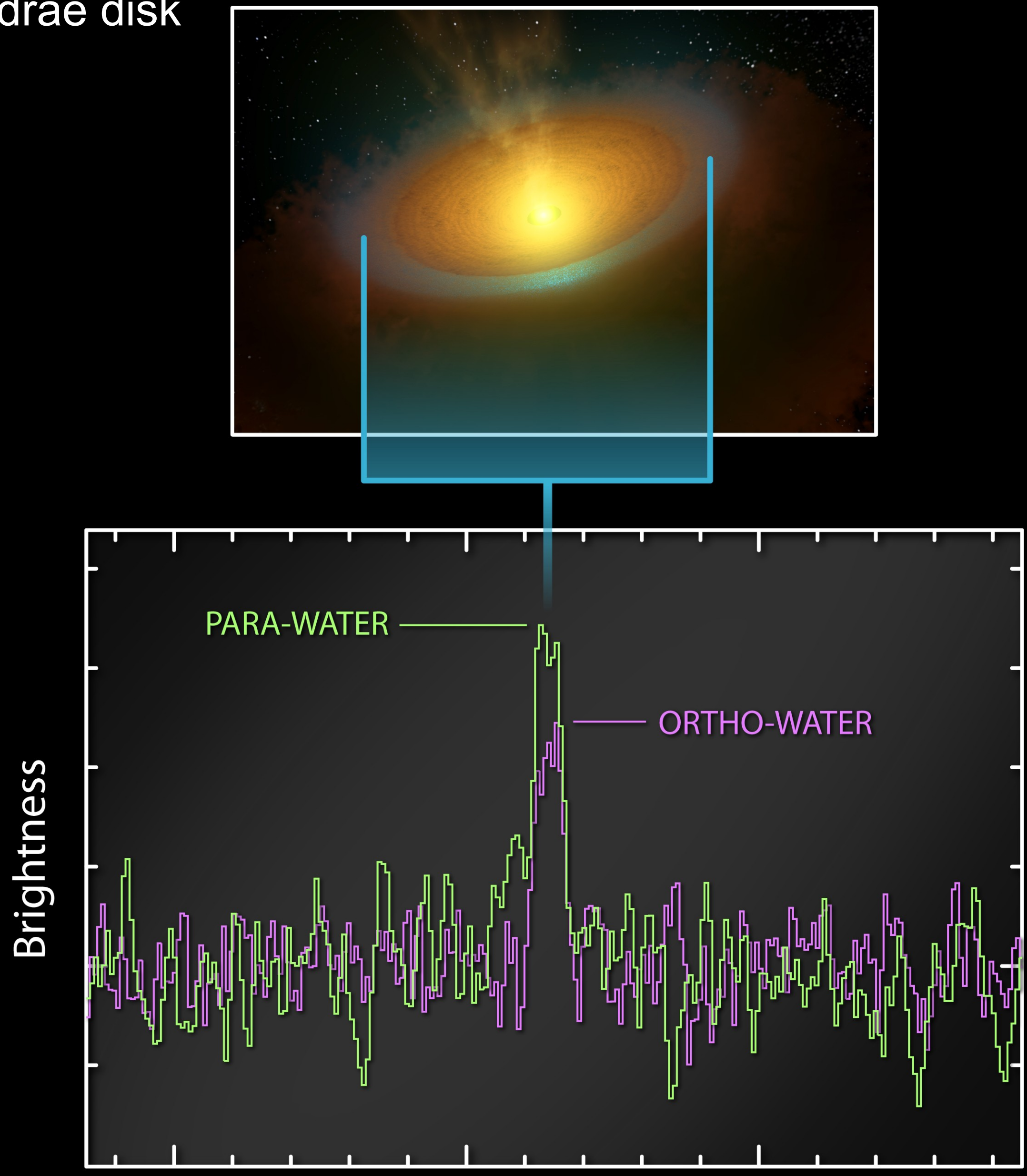


Orion KL - Band I


Antenna Temperature (K)
Frequency (GHz)
Antenna Temperature (K)
Frequency (GHz)
T_A^* (K)
Frequency (GHz)
Orion KL

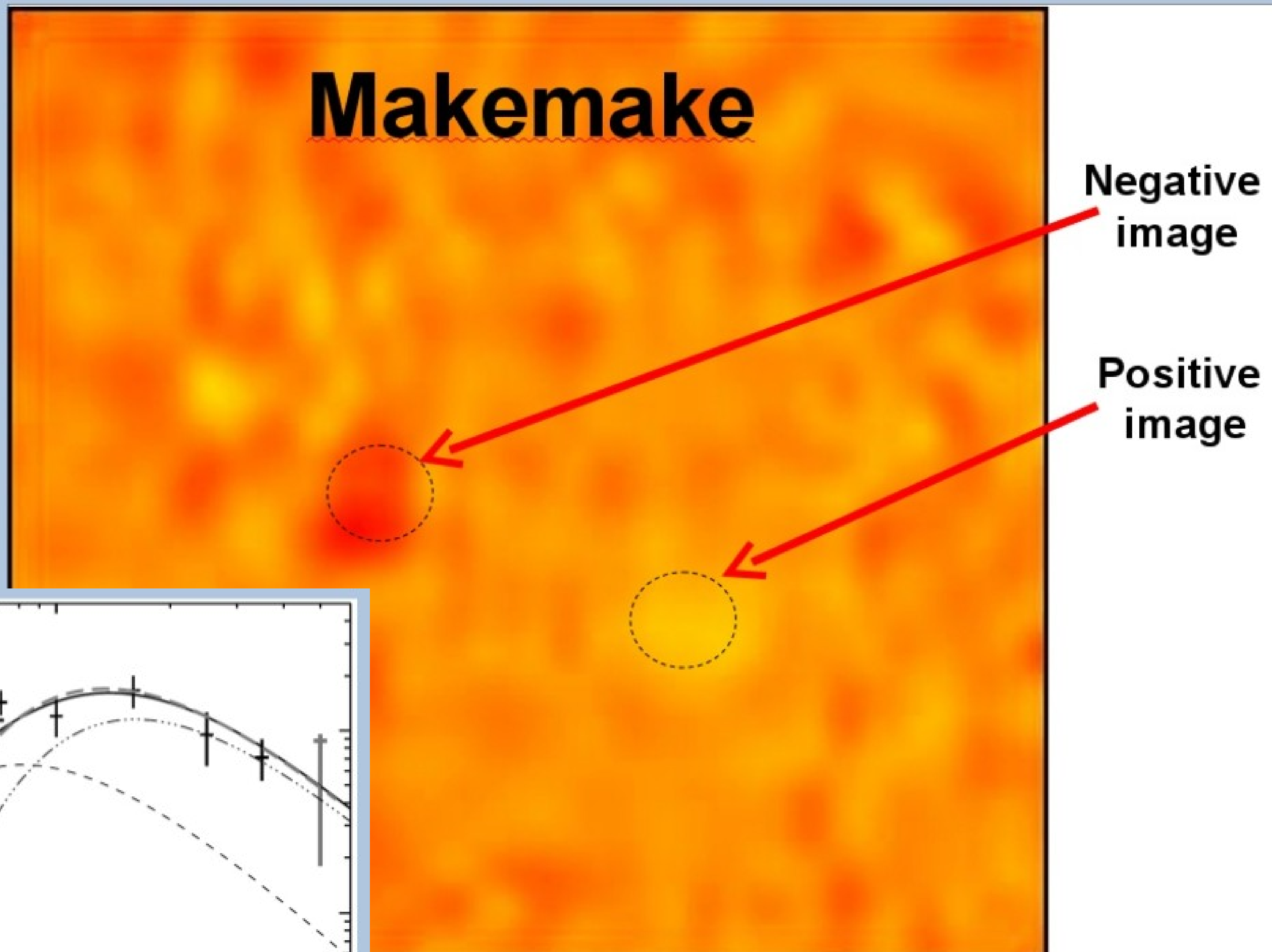

Detection of molecular oxygen in Orion
P. Goldsmith: Herschel Oxygen Project
ESA/NASA/JPL-Caltech

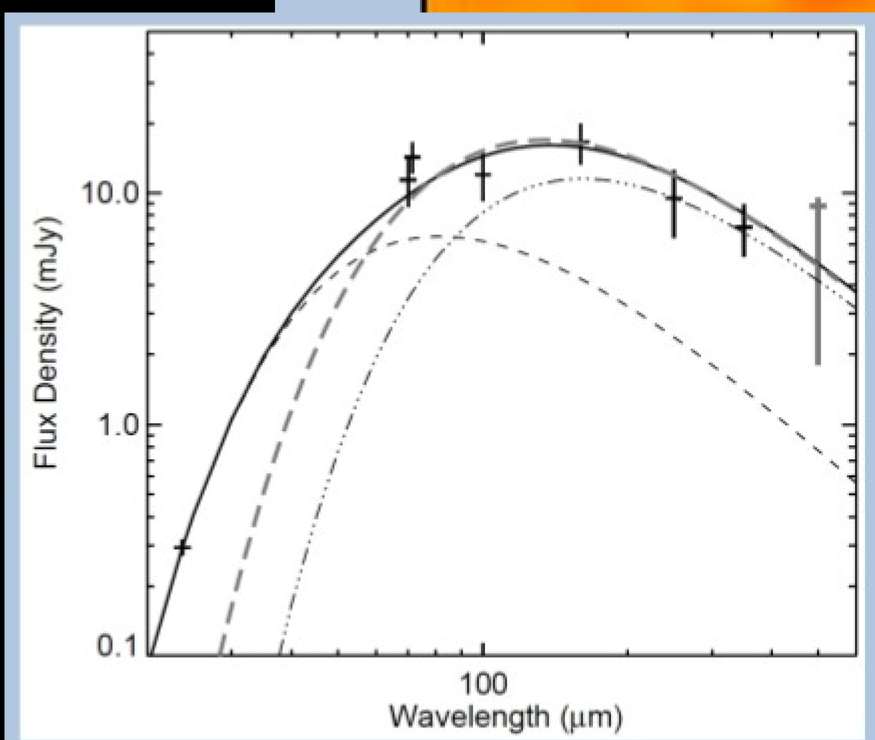
Water in the TW Hydrae disk



HIFI Spectroscopic Signatures of Water Vapor in TW Hydrae Disk

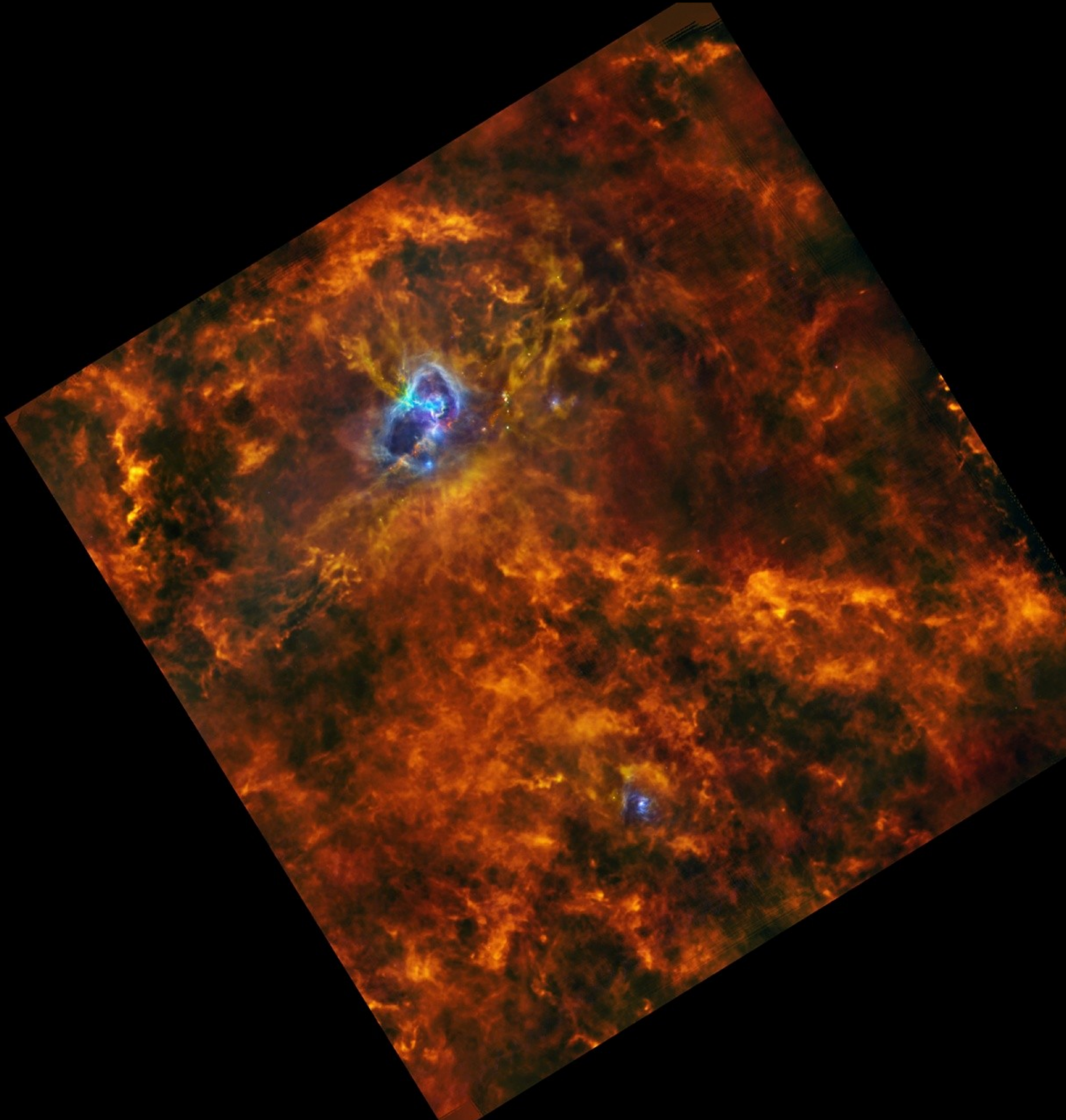
ESA/NASA/JPL-Caltech/M. Hogerheijde (Leiden Observatory)

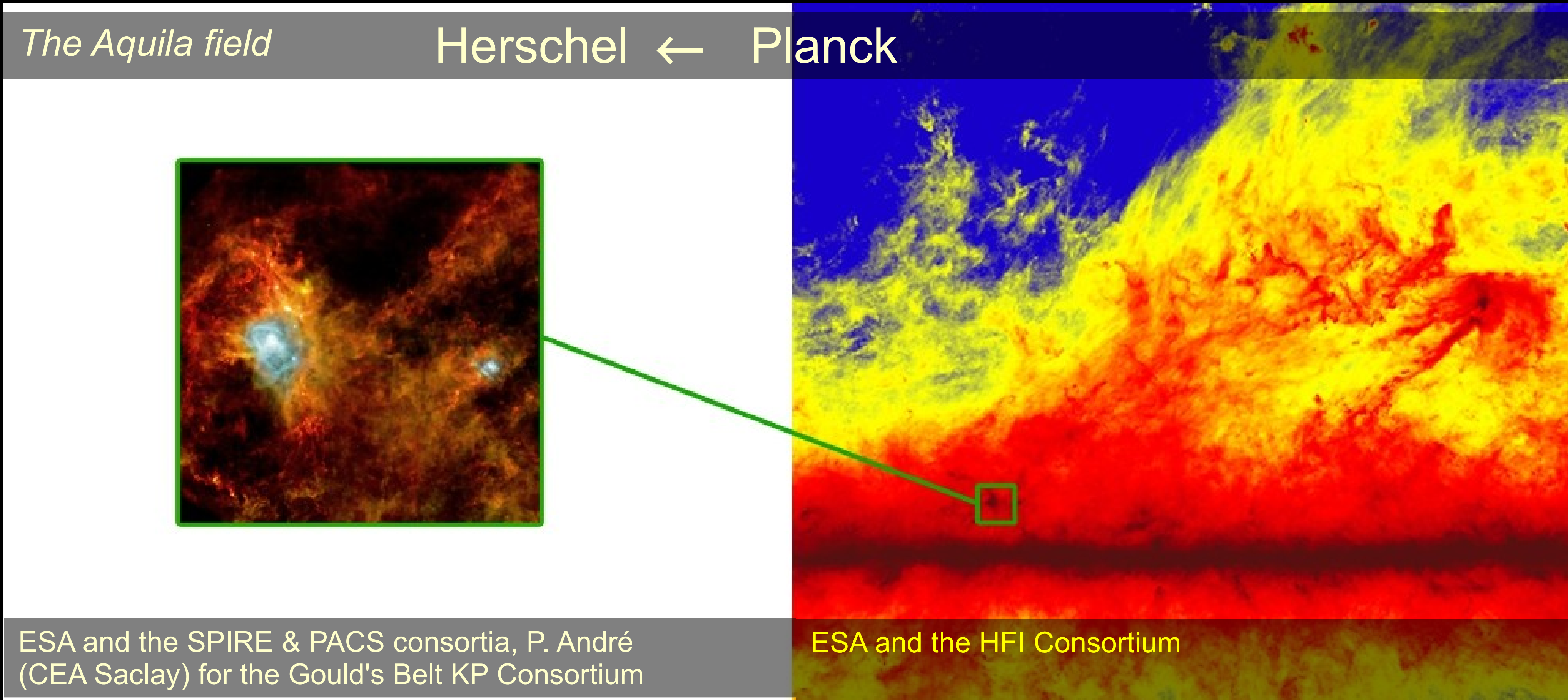

Makemake
Negative image
Positive image

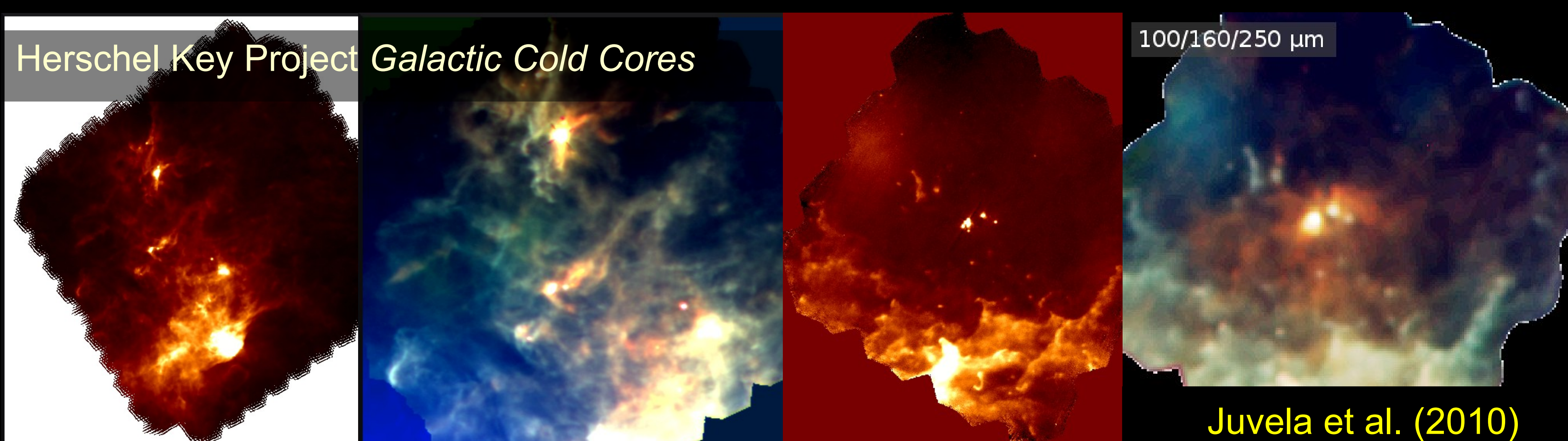

Flux Density (mJy)
10.0
1.0
0.1
100
Wavelength (μm)

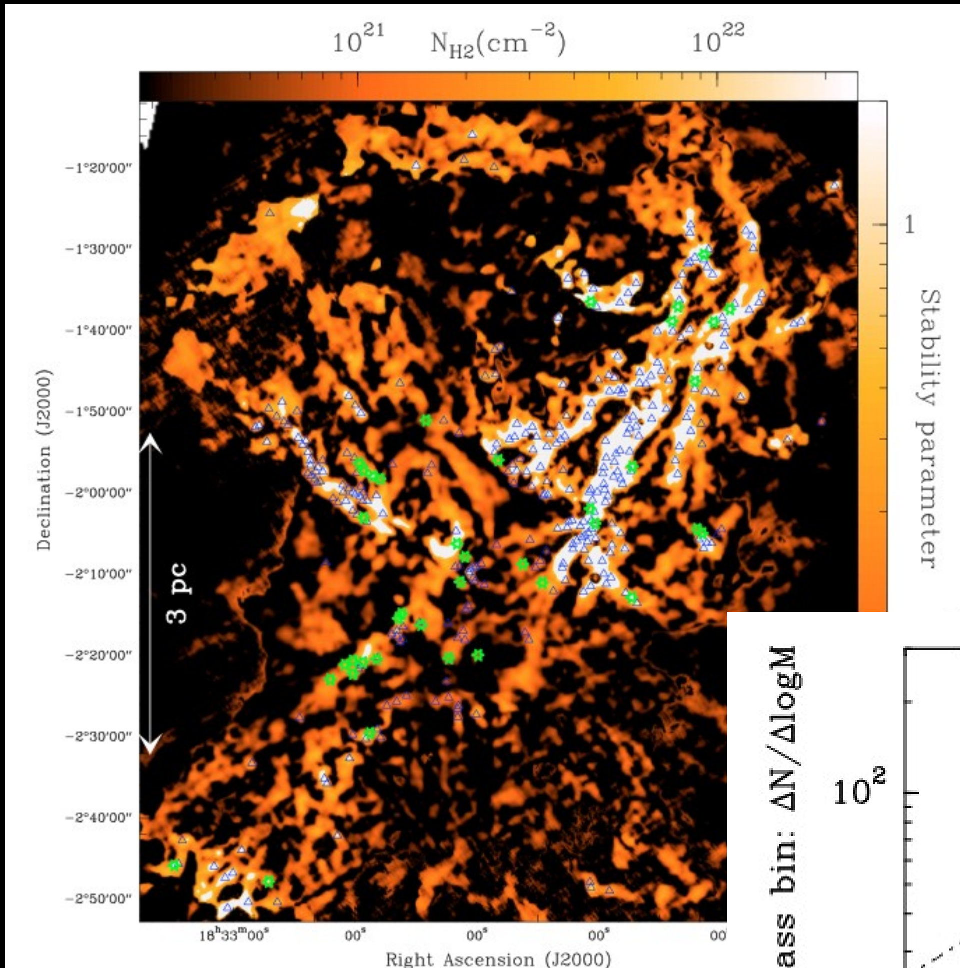
The Milky Way
- in dust emission

Planck – ESA and the HFI Consortium

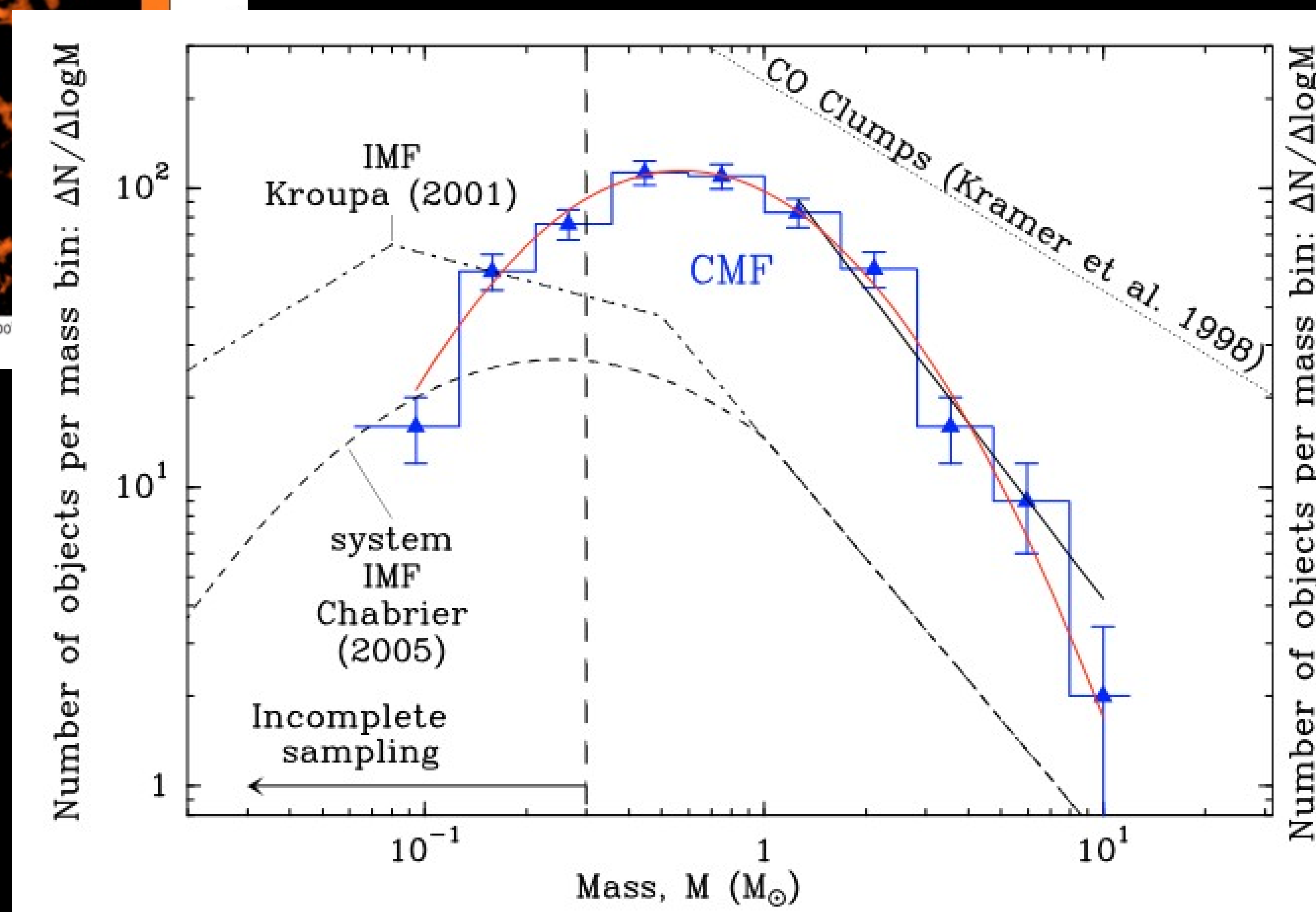



The Aquila field
Herschel ← Planck
ESA and the SPIRE & PACS consortia, P. André
(CEA Saclay) for the Gould's Belt KP Consortium
ESA and the HFI Consortium

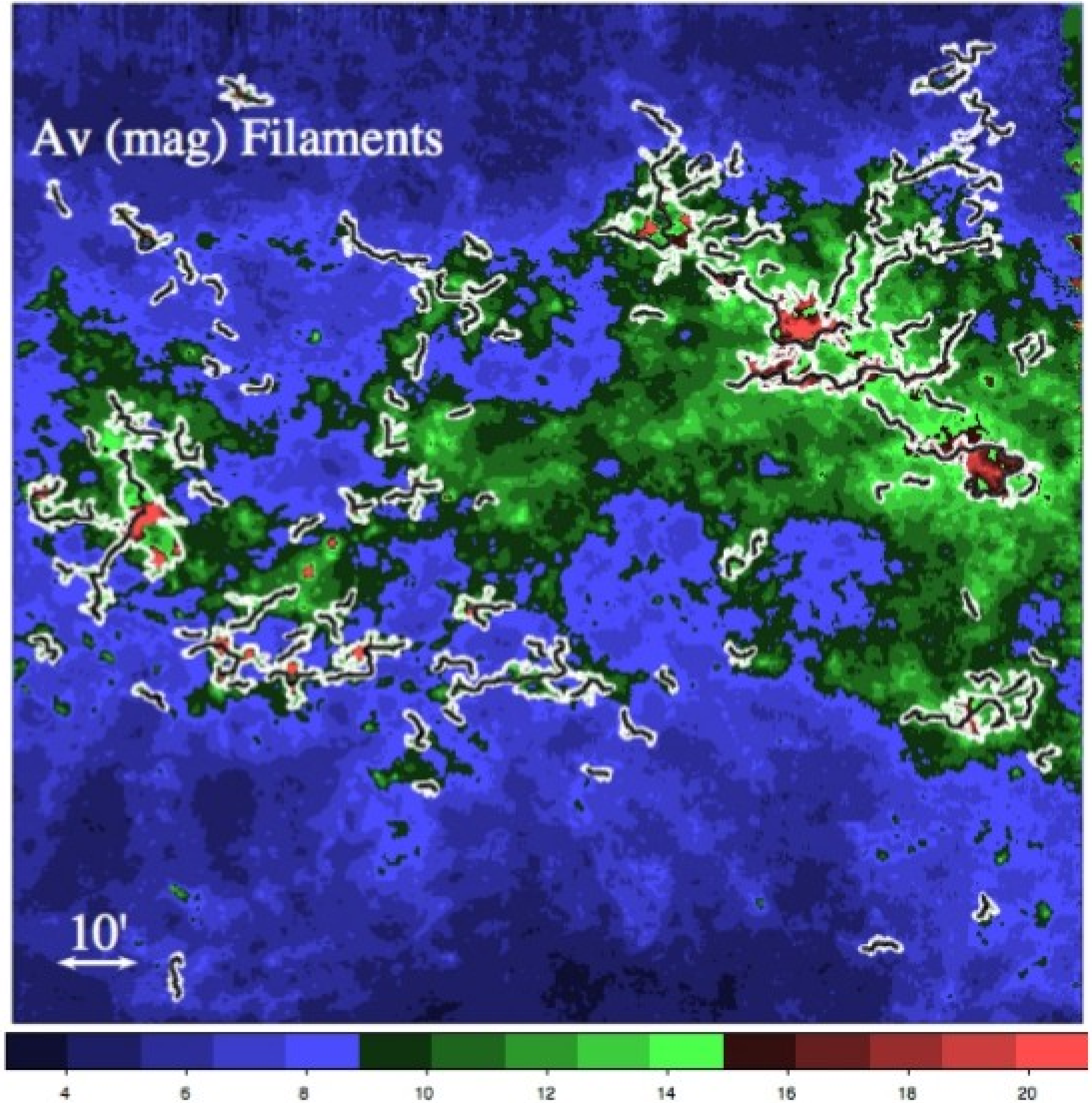

Herschel Key Project *Galactic Cold Cores*
100/160/250 µm
Juvela et al. (2010)



Andre et al. (2010)
Gould Belt Survey



A case of study - L59 region (Schisano et al. 2012, in prep.)

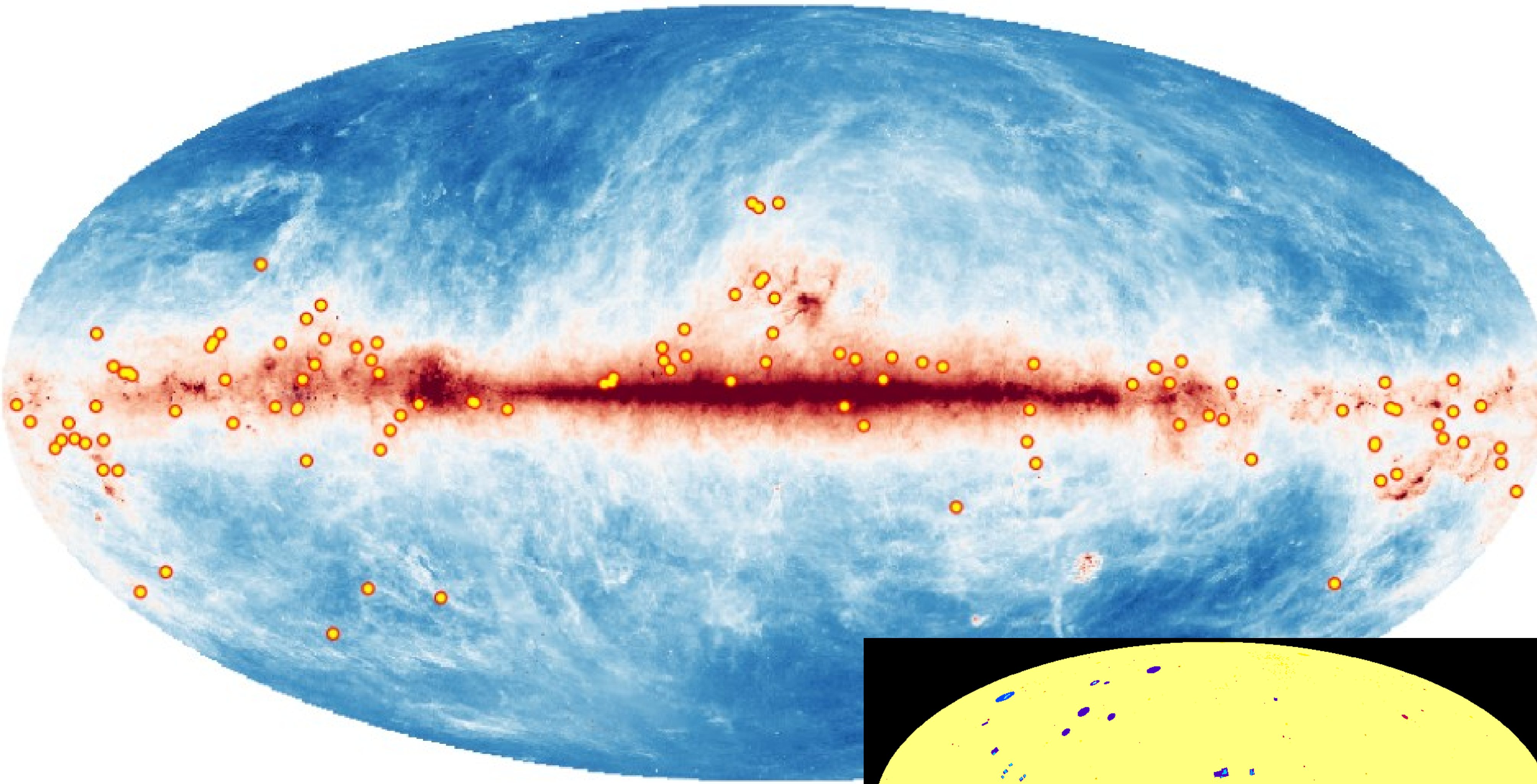


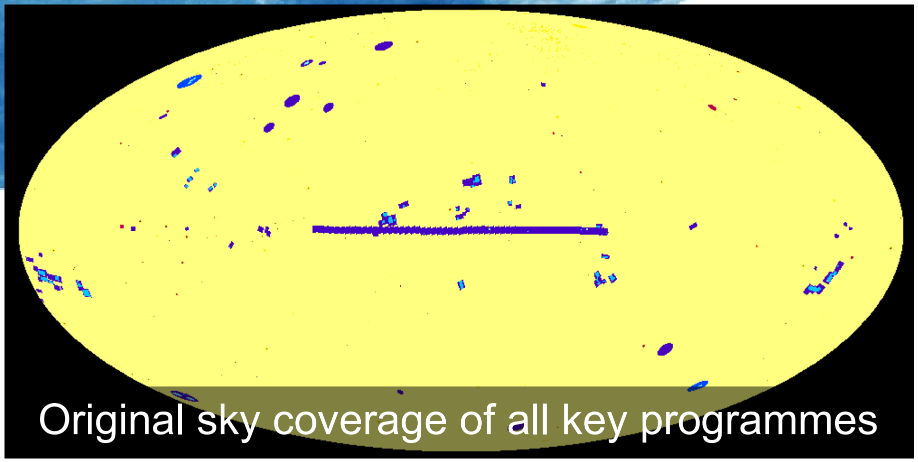
• We identied 100 filaments that have a mean length longer than 200" (> 2 pc @ 2.2 kpc)

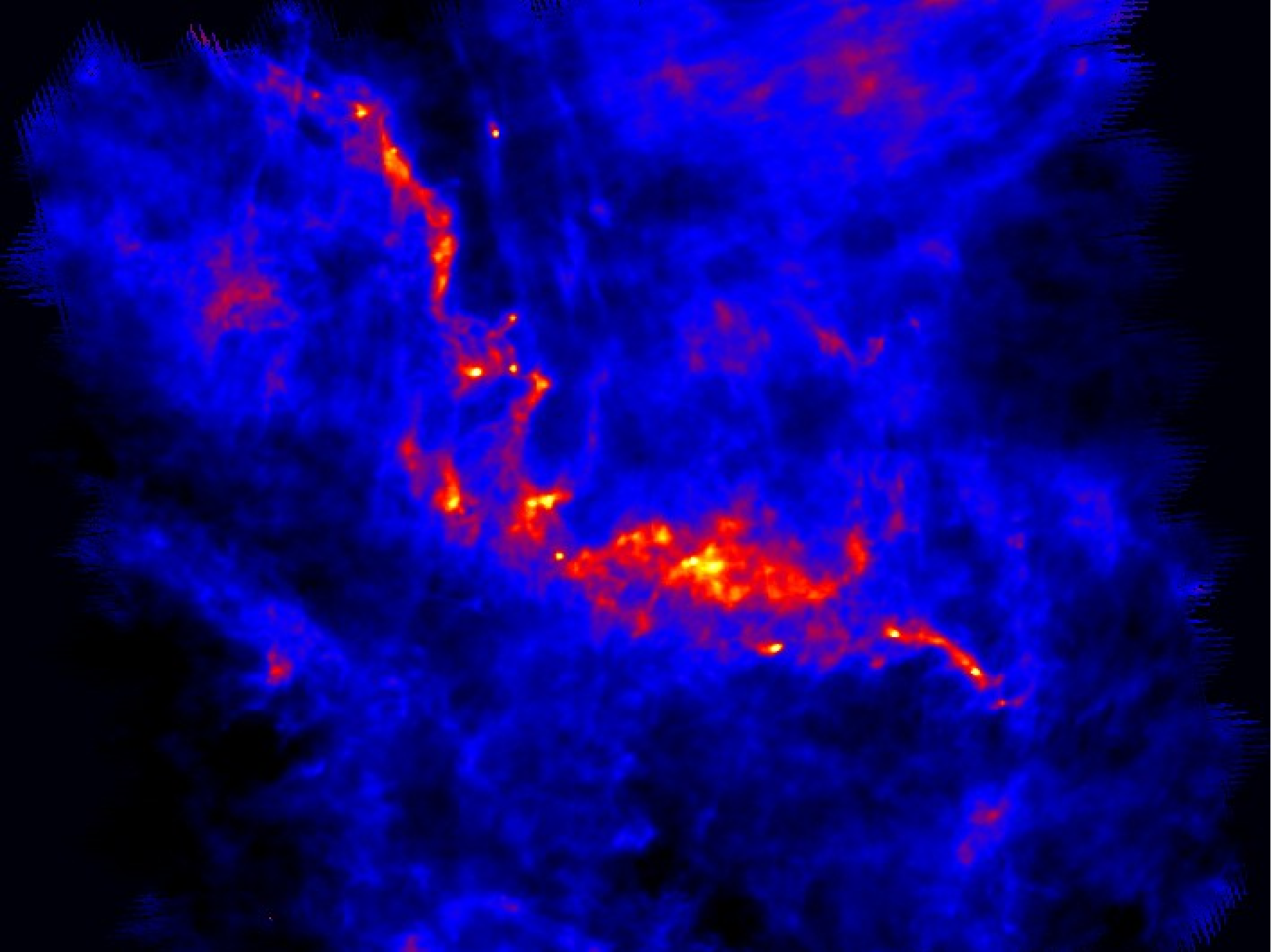
• 60 more structures are identified as candidates coherent structures (i.e. IRDC-like) but are shorter than 200" and we do not call them filaments.

We are automatically detecting what people have been calling IRDCs till now, with the ability to distinguish them from IRDP (Wilcock et al. 2012)

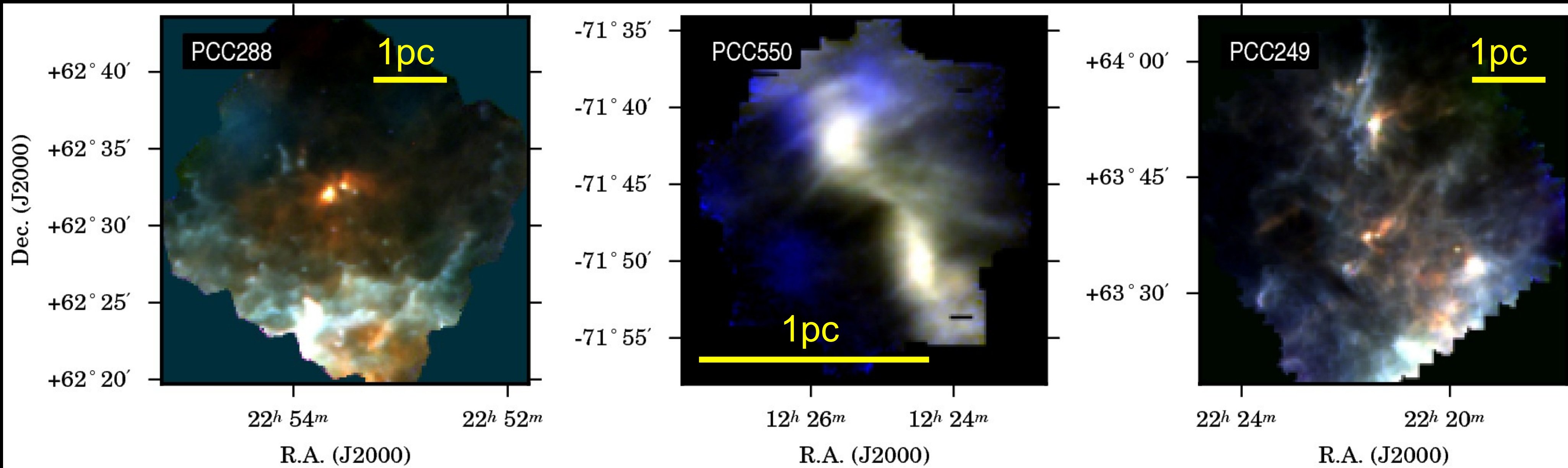
Galactic Cold Cores
Follow-up on over 100 cold dust clouds located by Planck







The first three fields



PCC288 at 800 pc

- ~14K clump in Cepheus with ~140 Msun
- Several compact objects with FIR/submm colour temperatures above 20K
- One Fu Ori type protostar with a molecular outflow
- Between a young stellar group and a molecular cloud – triggered SF?

PCC550 at 225 pc

- Piece of a long filament in Musca
- Two ~11K cores, both about 10 Msun
- Quiescent with density profiles similar to stable Bonnor-Ebert spheres

(Juvela et al. 2010, -11,-12)

PCC249 at 900 pc

- Very active star forming region
- Average temperature high, the Planck detections correspond to ~100 Msun regions at ~17K
- Colder smaller clumps (~13K) between the hot cores – possibly pre-stellar?

Summary

- Many important results published, more to come
- No more observing time calls
  - But check “must-do” at Herschel homepage!
- Most data public, check the Herschel Science Archive!

- http://herschel.esac.esa.int/