The Herschel Mission and AGN studies

Luca Calzoletti

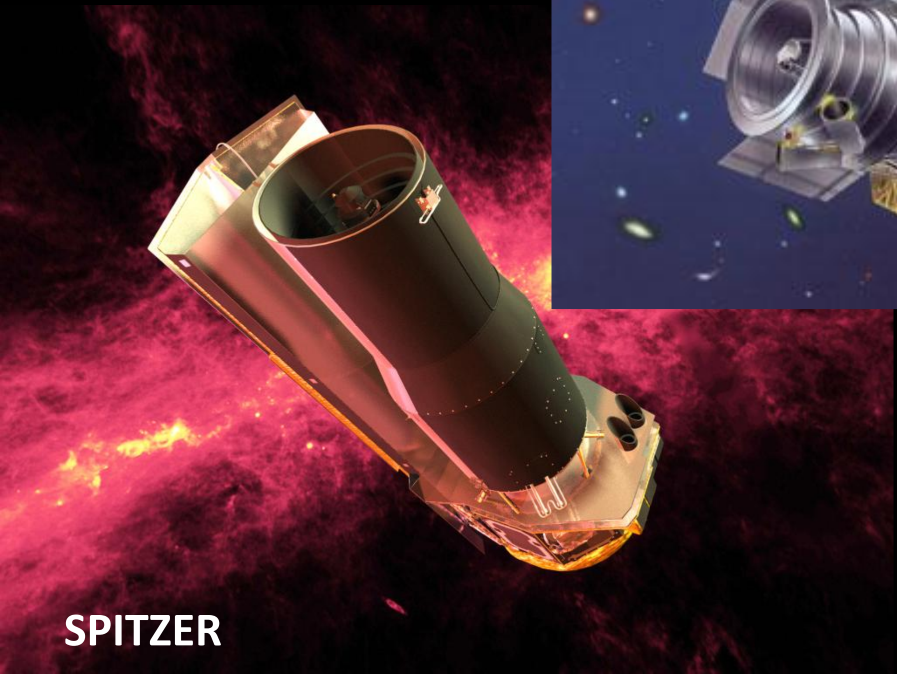
ASI Science Data Center

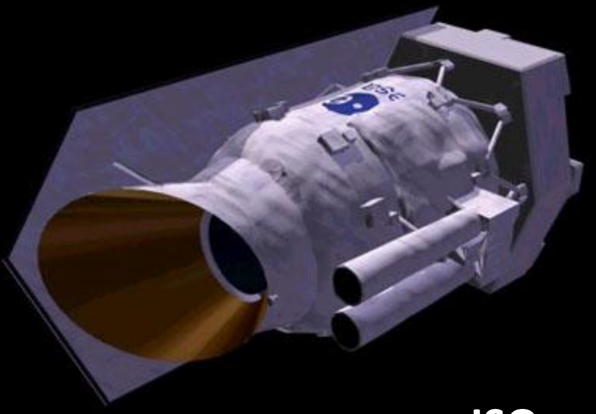
Outline

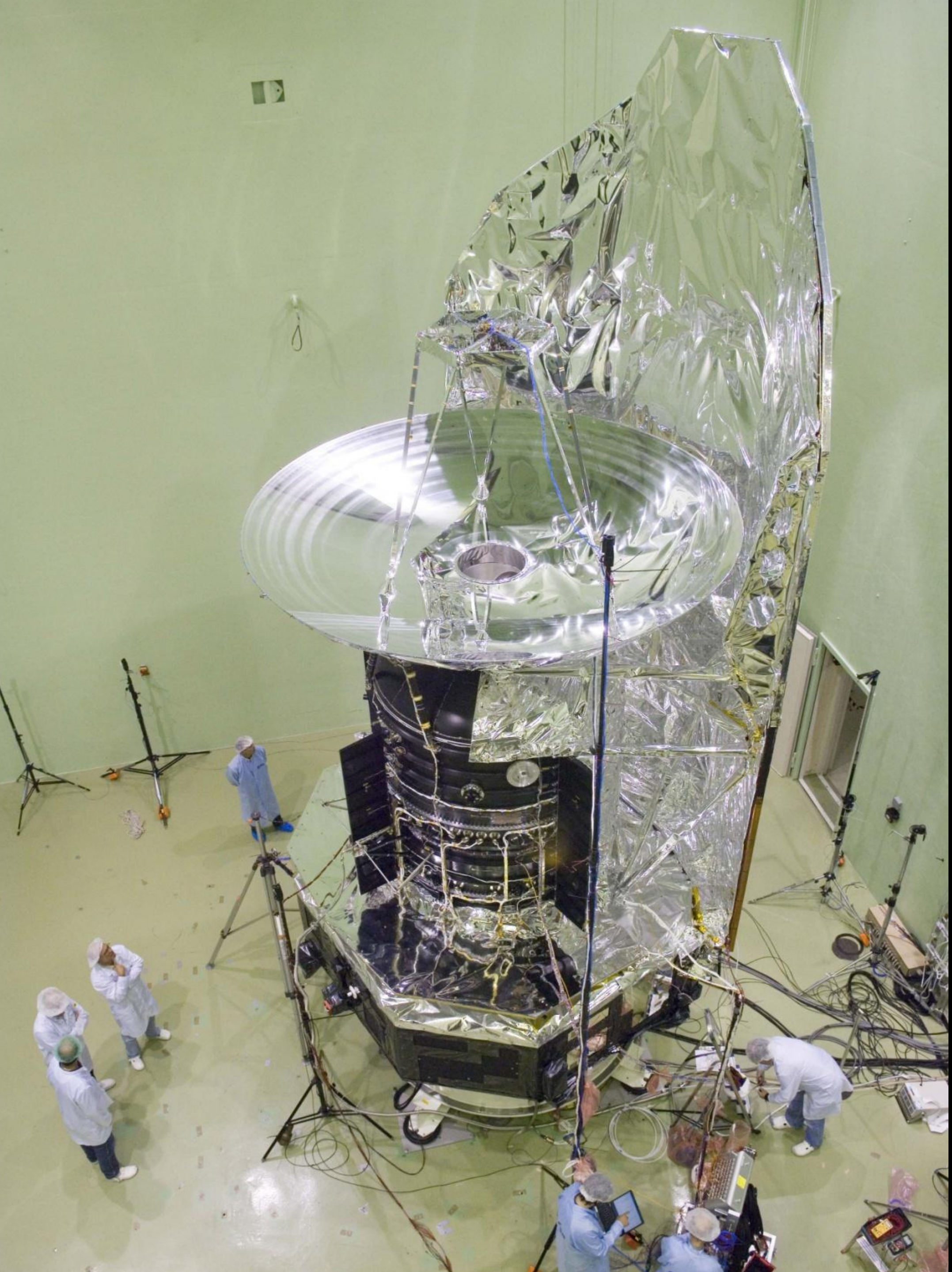
1. Mission overview
2. Science with Herschel
3. Herschel at ASDC
4. AGNs with Herschel
5. A look to the future …

Infrared Space Astronomy
The Heritage

- 1983: IRAS (57 cm, 12-100 μm)
- 1995: ISO (60 cm, 2.4-240 μm)
- 2003: SPITZER (80 cm, 3.6-160 μm)
- 2006: AKARI (67 cm, 1.7-180 μm)







Herschel is a Space Observatory for the infrared and sub-mm astronomy (55-671 μm) It is a cornerstone mission of the of the ESA

3 scientific instruments

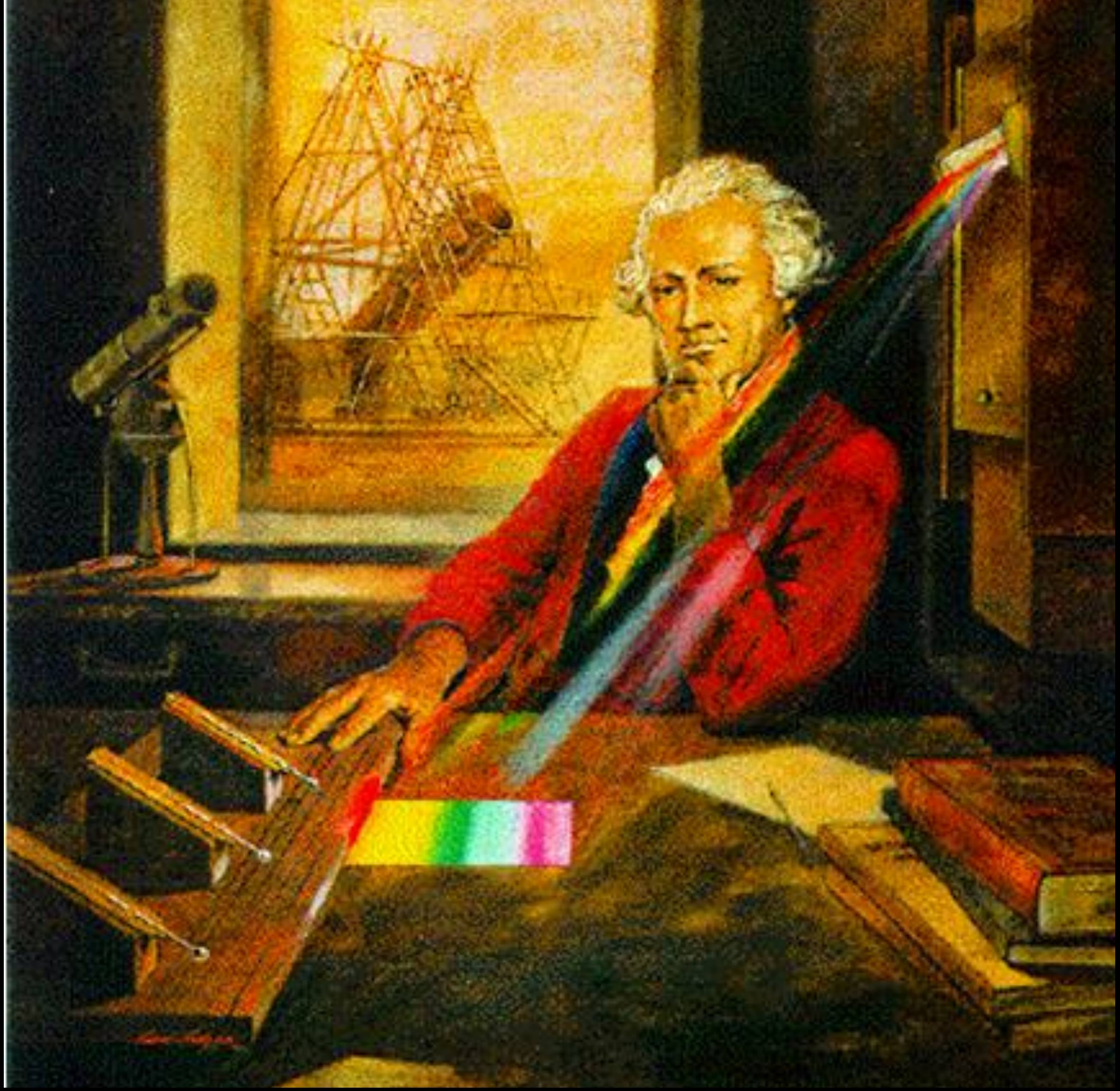
Height: 7.5 m

Width: 4,5 m

Weight: 3,4 ton

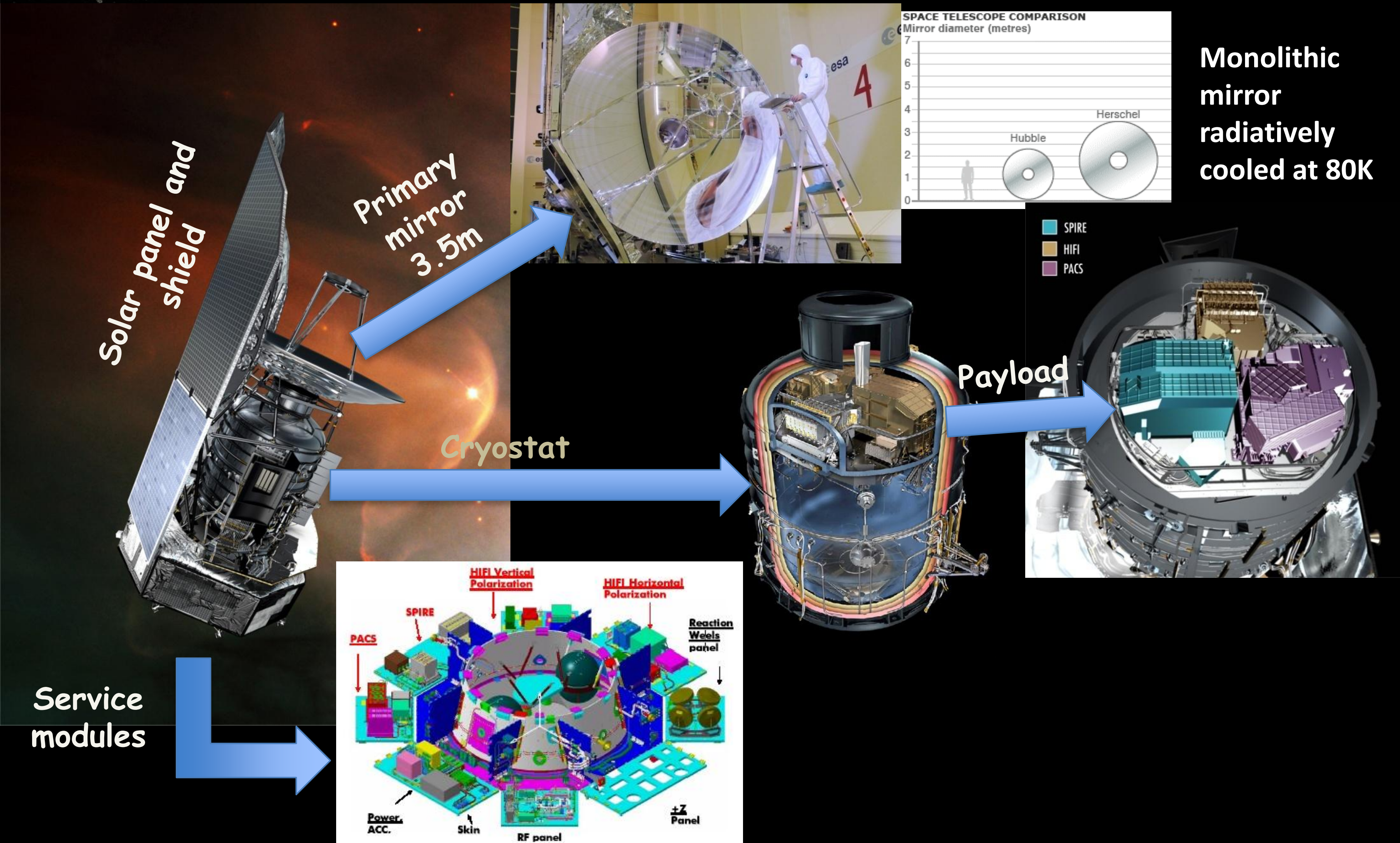
3,5 m telescope primary mirror

!!!!! The largest ever launched into Space !!!!!



Sir William Herschel (1738-1822):
The father of the infrared astronomy

The Herschel Space Observatory



Scientific Instruments

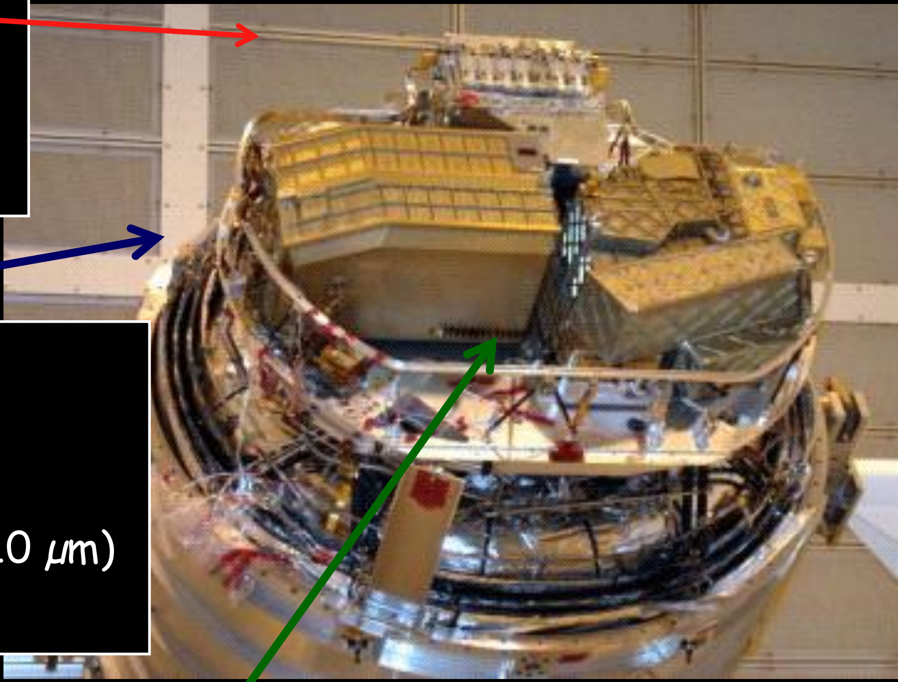
SPIRE

- PI: M. Griffin (RAL, Cardiff, Galles)
- 3-band Imaging photometer (250, 350, 500 μm)
- Fourier transform spectrometer (190-672 μm)

  $\lambda/\Delta\lambda$ = 1300 – 370 (high-res)

  = 60 – 20 (low res)

Photometry and Spectroscopy between 57 -670 μm



PACS

- PI: A. Poglitsch (MPE, Garching, Germany)
- Dual-band Imaging photometer (70/100, 160 μm)
- Integral Field Unit grating Spectrometer (55 – 210 μm)

  $\lambda/\Delta\lambda$ = 1000 – 4000

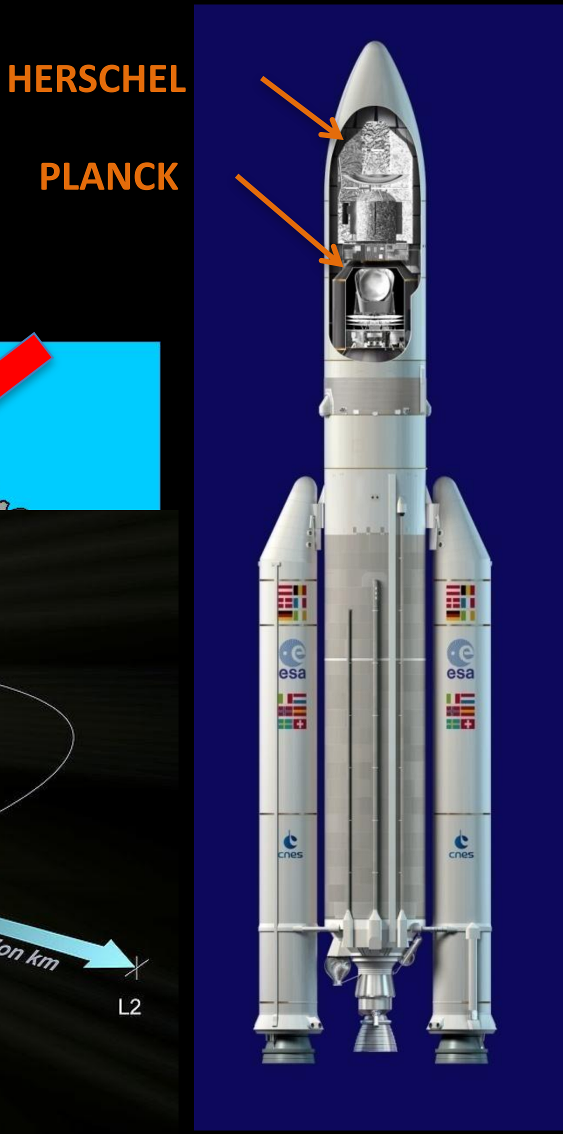
HIFI

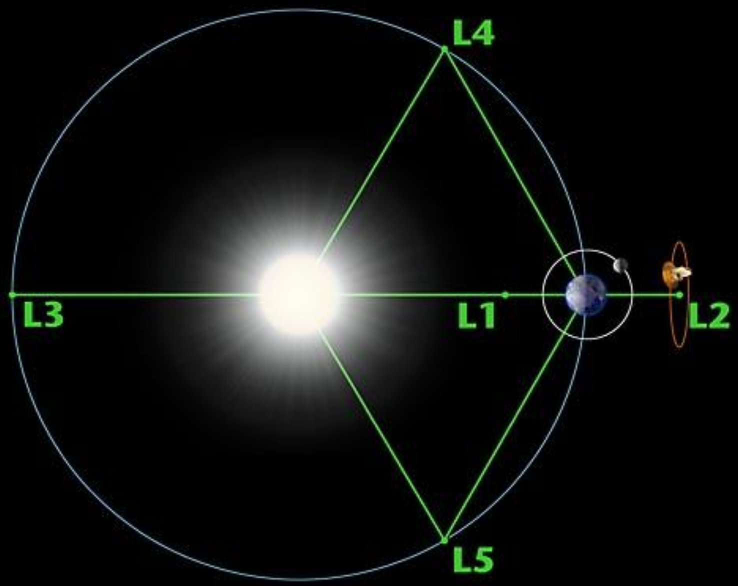
- PI: F. Helmich (SRON, Groningen, Olanda)
- Heterodyne spectrometer (157 – 213 μm e 240 - 625 μm)

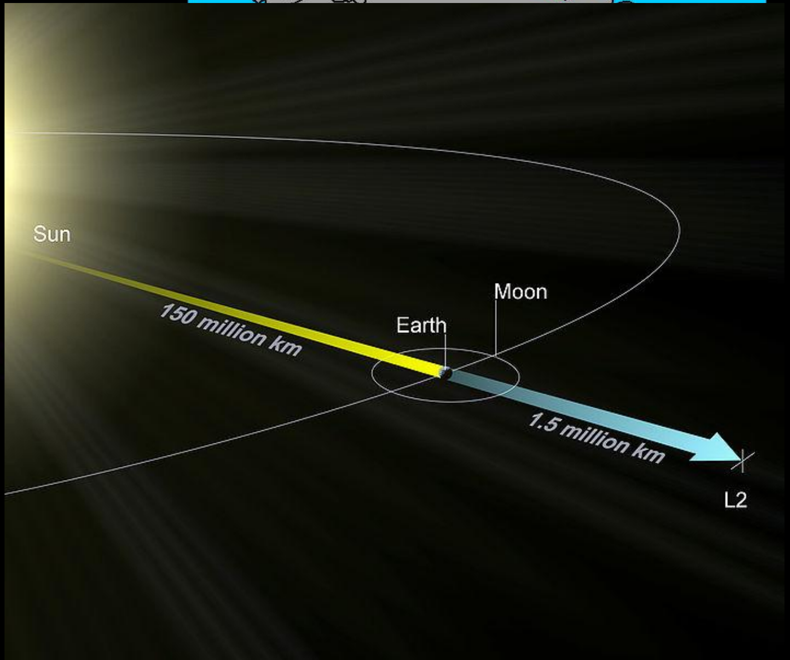
  $\lambda/\Delta\lambda = 10^5 - 10^6$

The Herschel launch

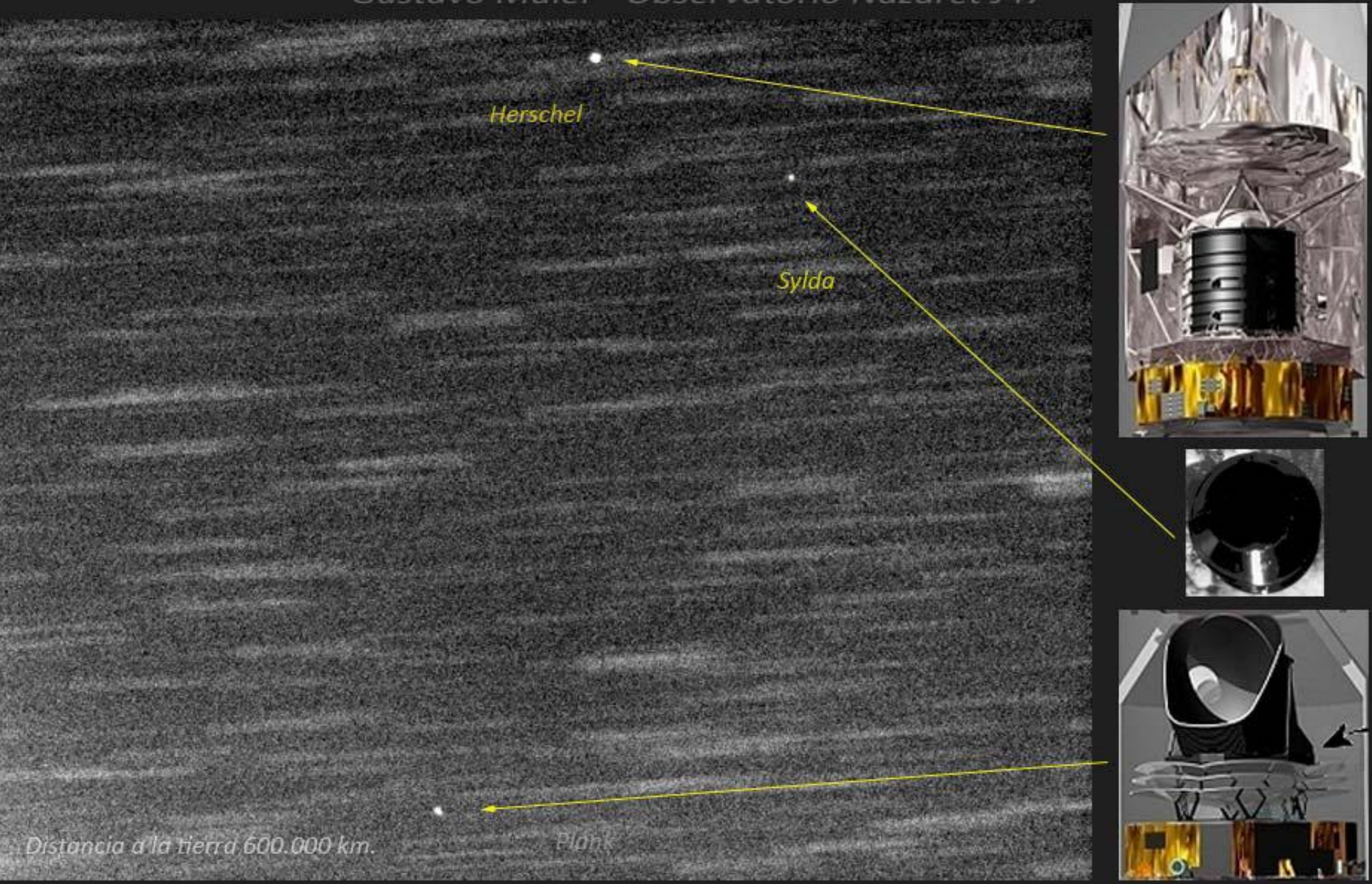
Herschel was launched, together with the Planck satellite, on 14 May 2009, on board an Ariane 5 rocket, from the ESA space harbor of Kourou (French Guiana)





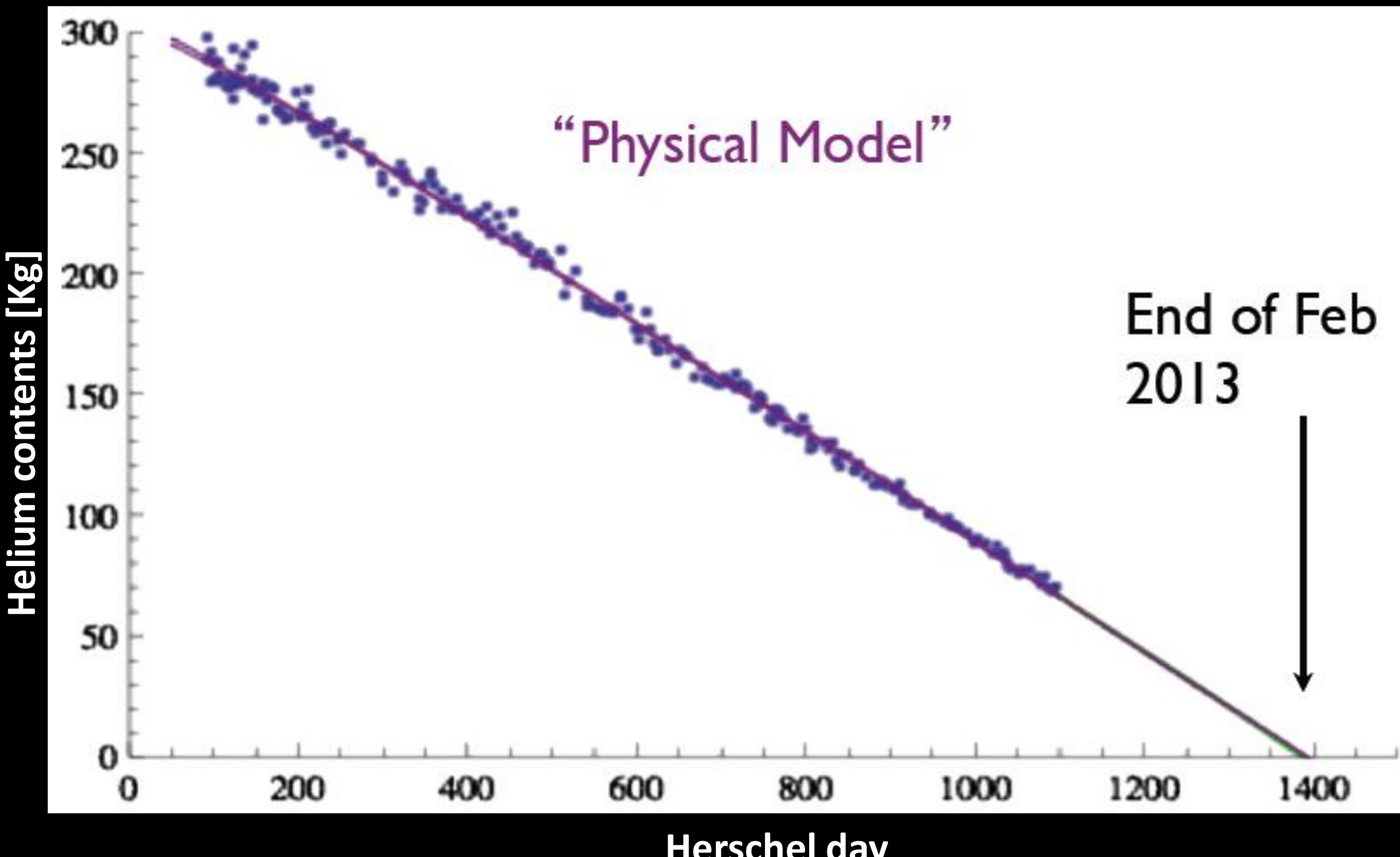


Herschel Plank telescope and sylda - 18 - 05 - 2009 - 80 x 30 seconds
Gustavo Muler - Observatorio Nazaret J47



Cryocooler Analysis

- Data from OD 95 to OD 1095
- Average massflow of 2.7 mg/s



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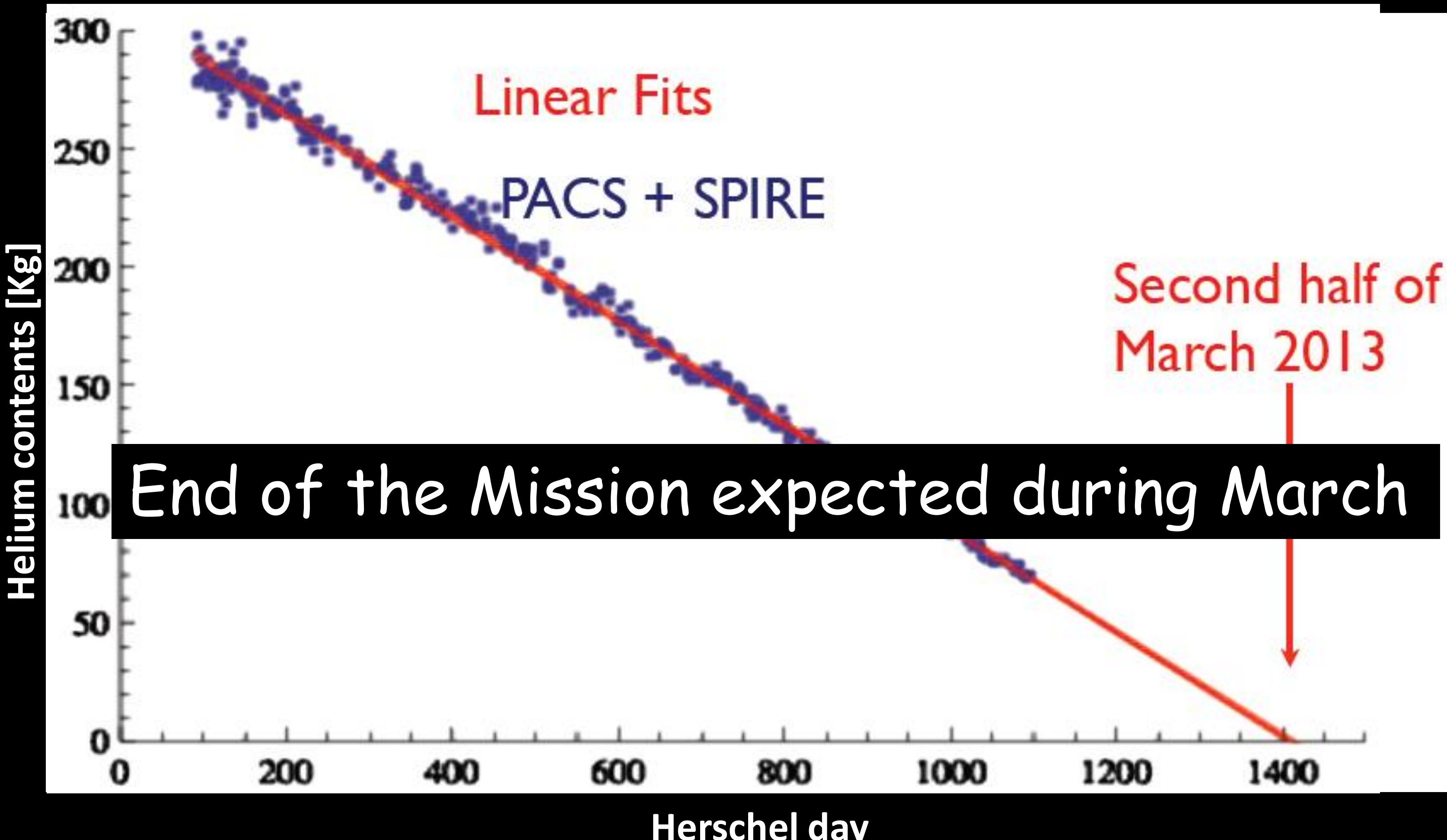
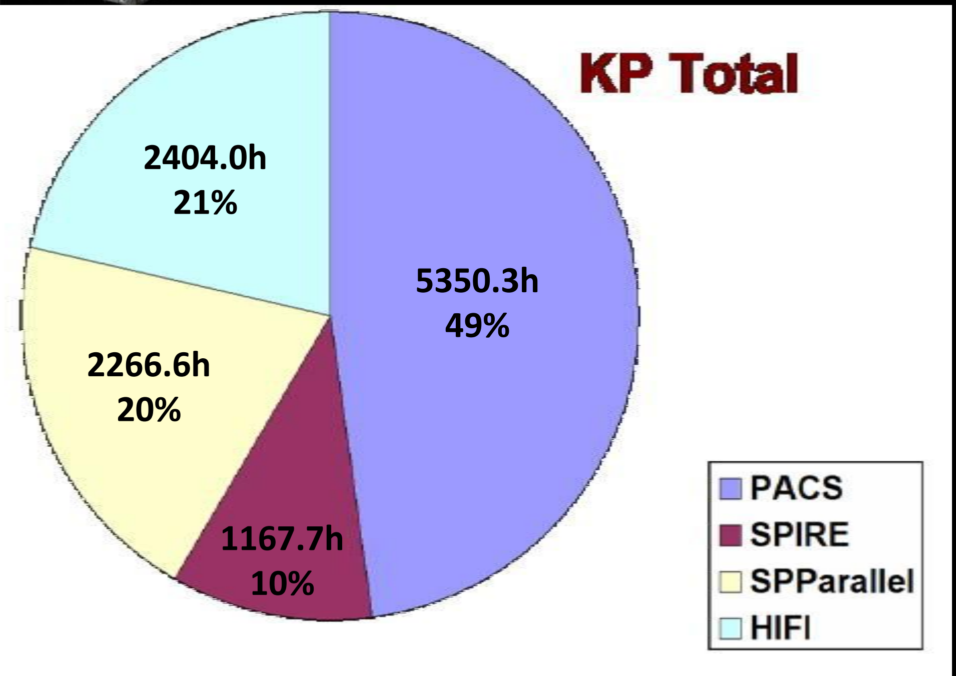


End of the Mission expected during March

Herschel Key Programmes



Scientific arguments	Proposals	Time(ore)
Solar system	2	666.4
Star formation and ISM	20	4450.7
Stars	2	544.6
Galaxies and AGNs	13	2914.0
Cosmology	5	2682.0

About 57% of the Routine Phase was allocated in legacy, long-term programmes (Key Programmes), while the remaining obsarving time was allocated by using 2 Announcement of Opportunities (AOs)

Mail Extragalactic KP:
HeVICS
PEP
HerMES
ATLAS
SHINING
KINGFISHER
……

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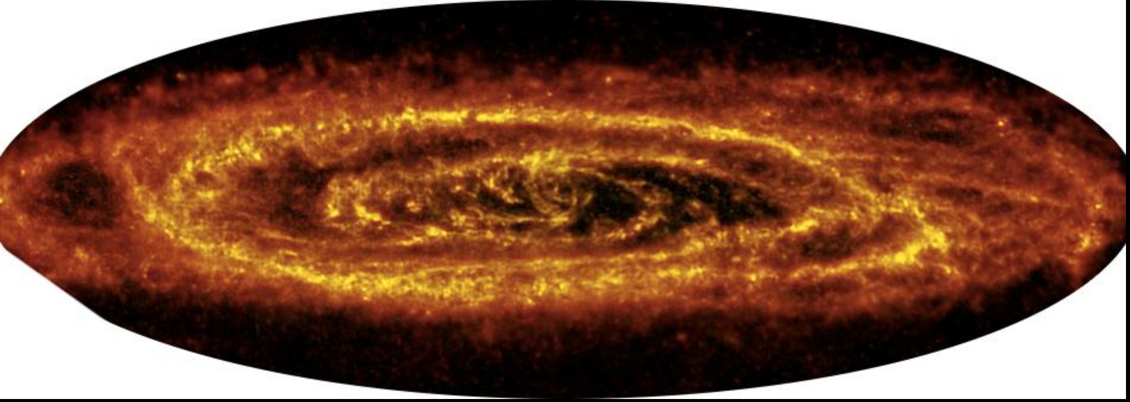
ASI Science Data Center

Herschel objectives

- star formation near and far
- galaxy evolution over cosmic time
- ISM physics/chemistry
- our own solar system

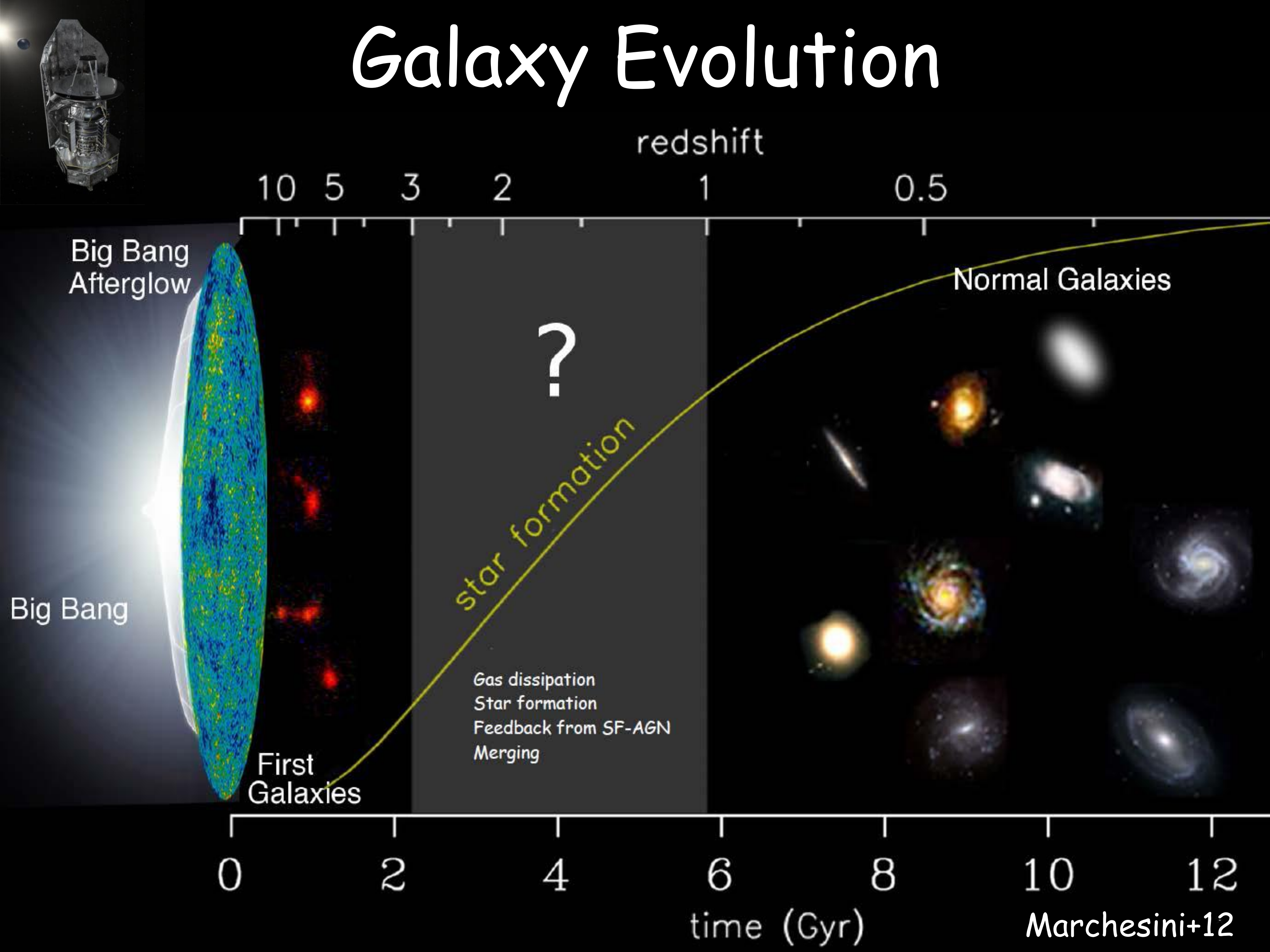


Infrared:
Star formation
(molecular clouds, protostars, protoplanetary systems)

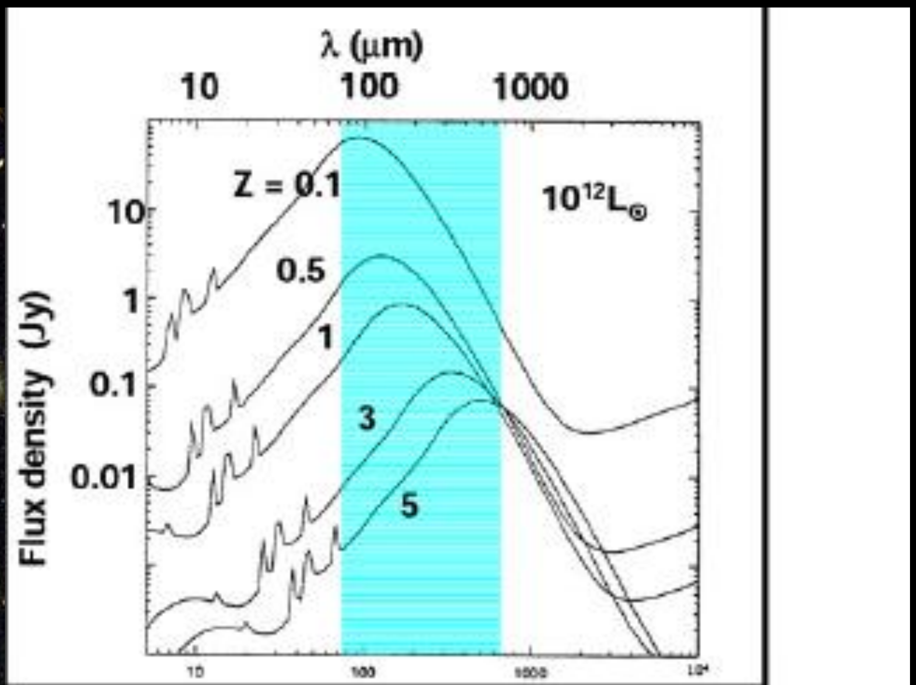
Optical:
Stellar evolution
(main sequence stars, globular clusters, planetary nebula, red giants)

X-ray:
Death of stars
(SN, white dwarfs, neutron stars, BH)

Galaxy Evolution



Infrared Galaxies

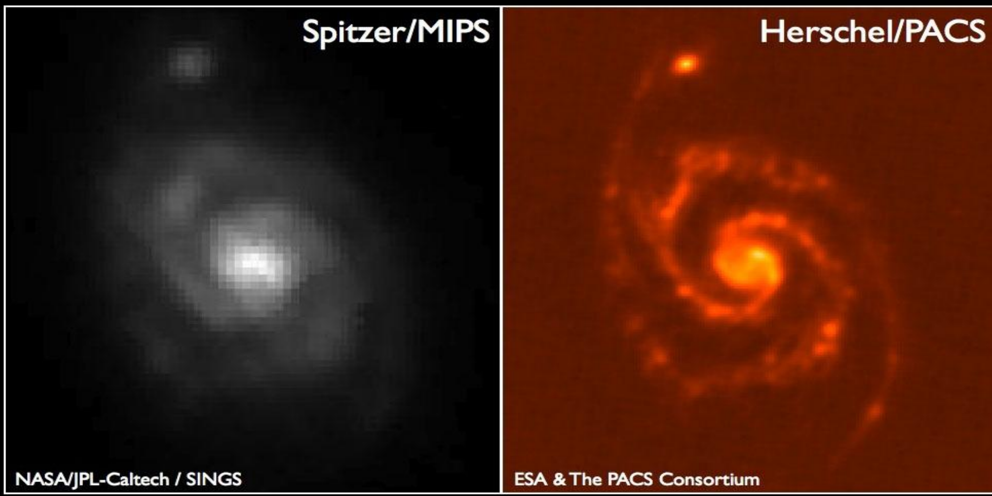


High redshift galaxies are embedded into the dust produced by the first stellar population and have emission peak at FIR wavelengths

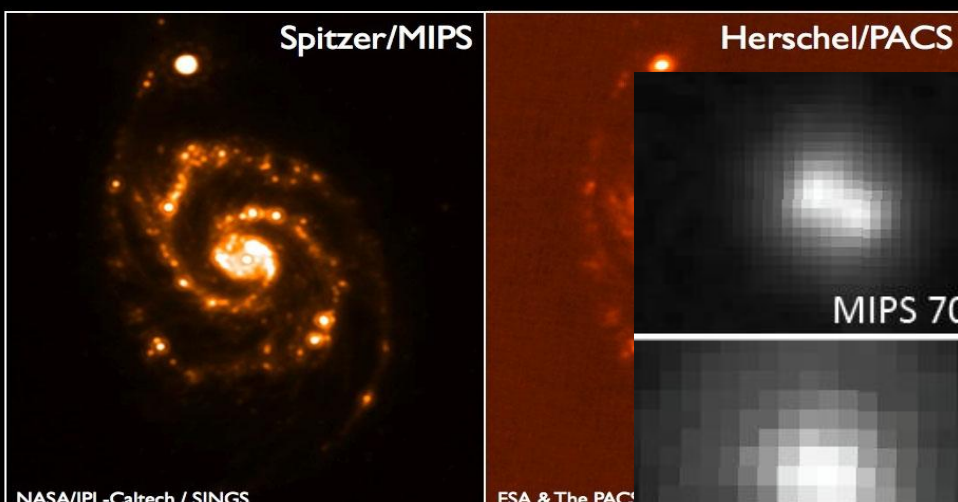
Far galaxies must be resolved in crowed deep fields

$$\Theta \sim \lambda / D$$

PACS vs MIPS

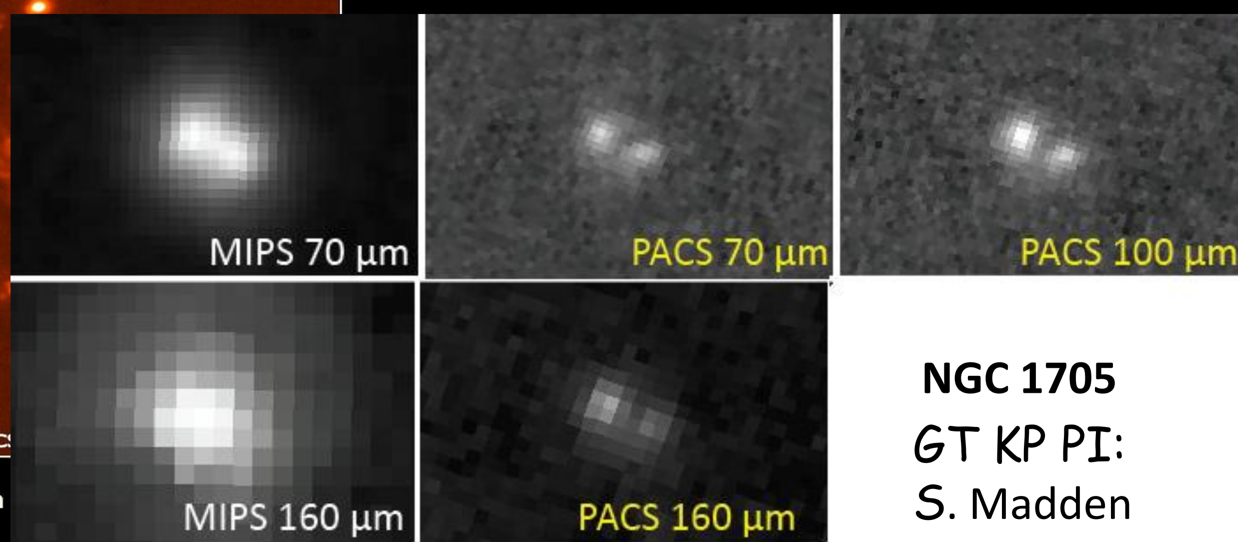


Spiral Galaxy M51 ("Whirlpool Galaxy") in the Far Infrared (160μm)



Spiral Galaxy M51 ("Whirlpool Galaxy") at 24μm

3.5 m vs 0.85 m
Herschel is 4 times better in spatial resolution

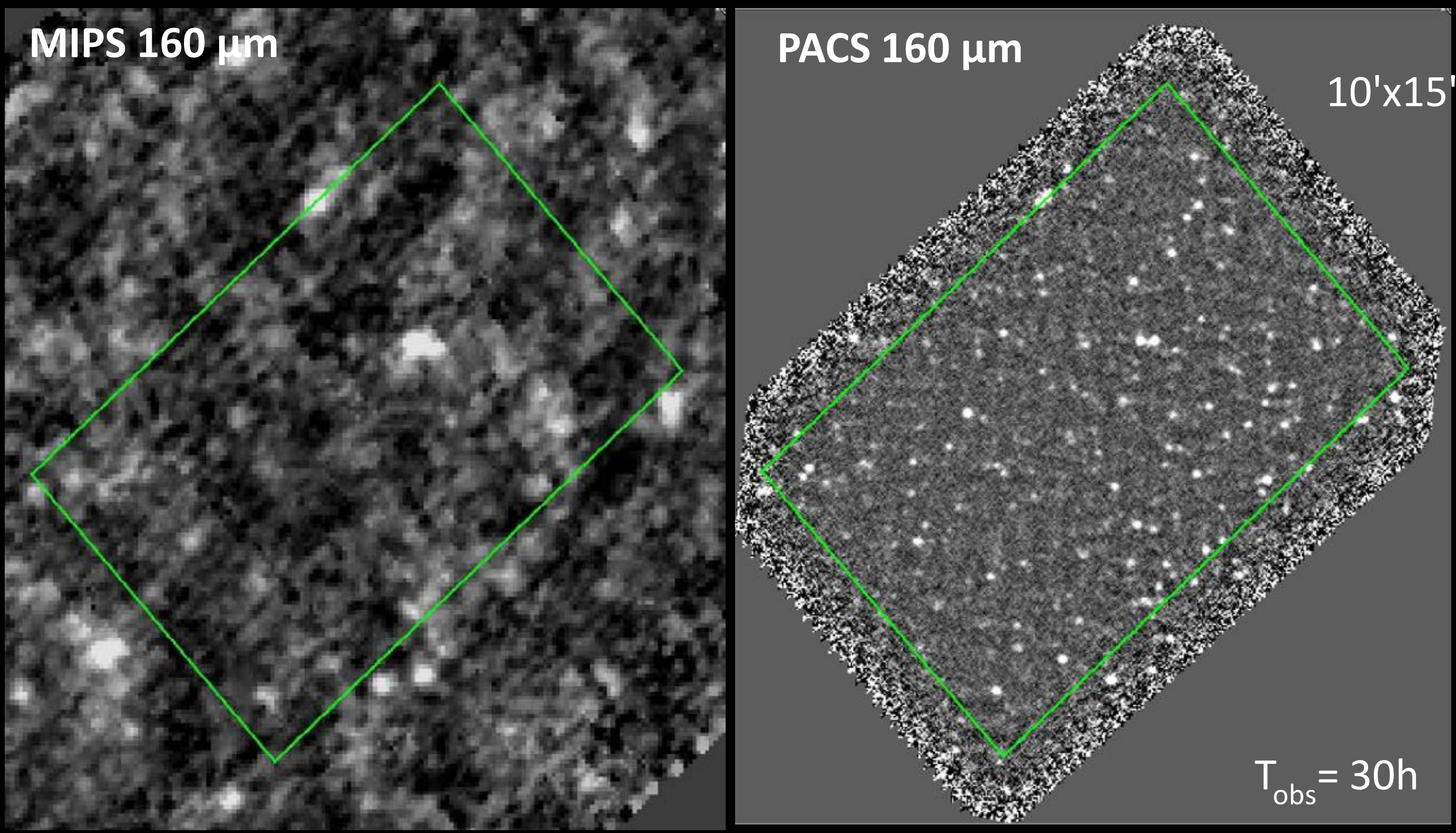


NGC 1705

GT KP PI:
S. Madden

Resolving the CIB

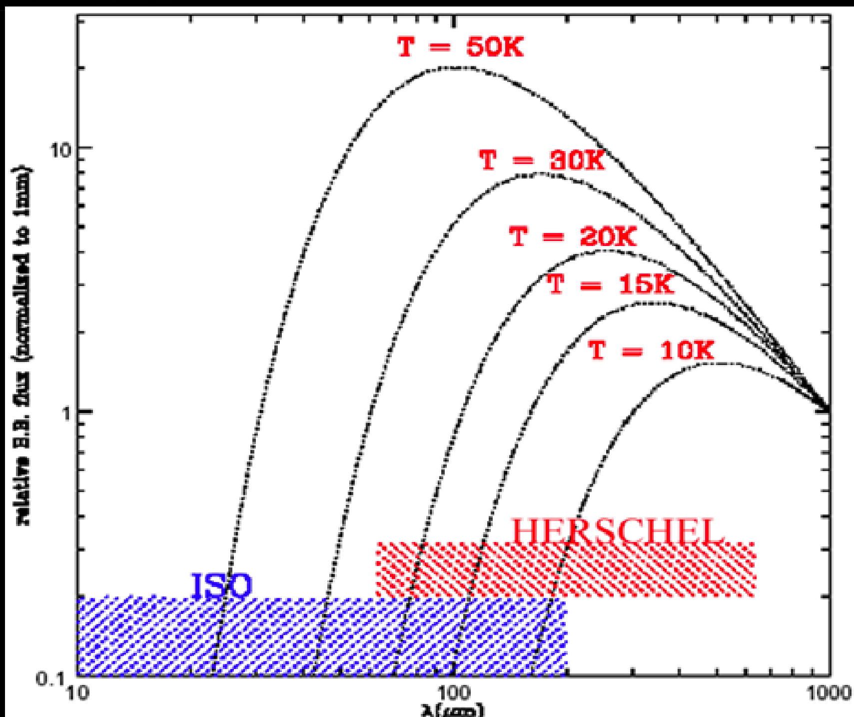
~60% of the Cosmic Infrared Background (CIB) is resolved into individual well detected (5σ) sources at 100 and 160μm

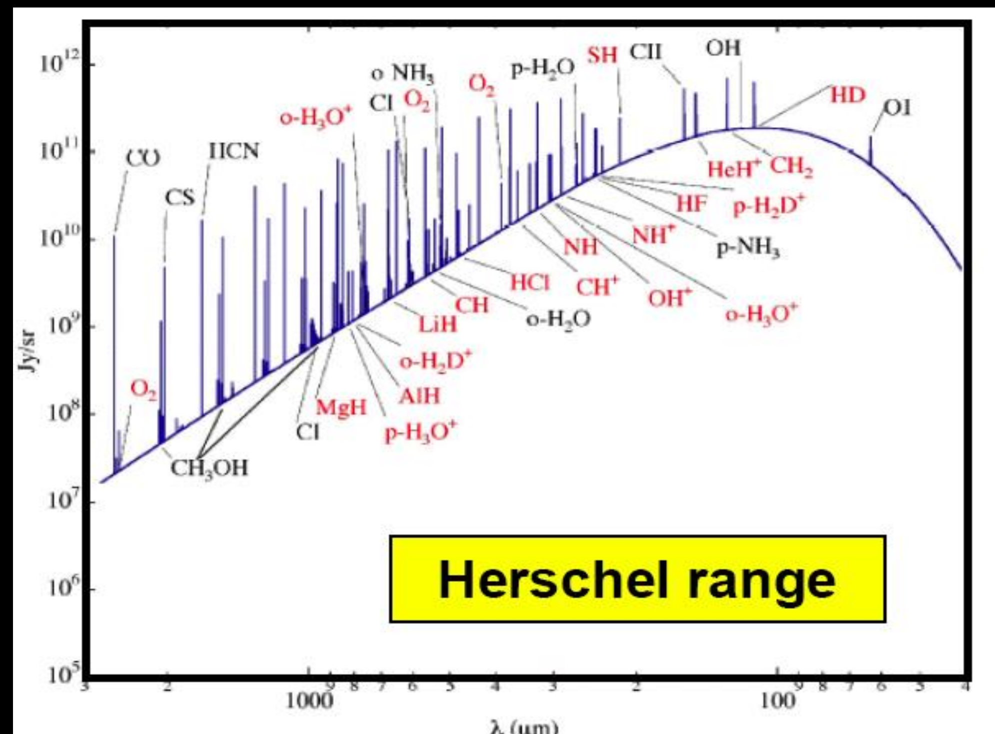


Field GOODS-N (in Hubble Deep Field North)

Great Observatories Origins Deep Survey

The cool and lines rich Universe



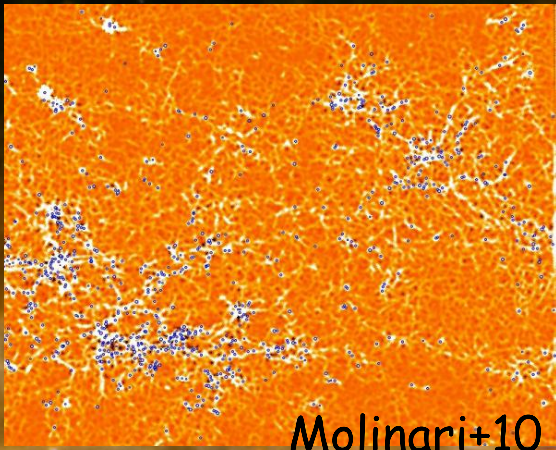


Probe the peak of dust thermal emission at temperature between 5-50 K

Numerous atomic, ionized and molecular lines are in Herschel spectral range

Hi-GAL (P.I.: S. Molinari)

- High dynamical in signal
- High spatial resolution
-ISM structured in a pattern of filaments where the star formation occurs.



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Herschel@ASDC

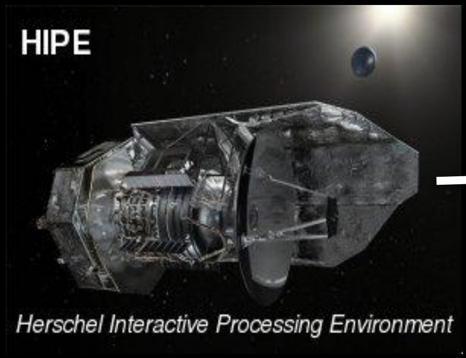
- Herschel Team established in 2009, at Mission launch
  Luca Calzoletti, Fabiana Faustini and Alessandra di Cecco

- Wide-range support for:
  - preparation and submission of proposals during AO-1 (2010) and AO-2 (2011)
  - data handling and data reduction by means standard and non standard recipes

- Archive Herschel data within the ASDC Multi-Mission Interactive Archive

- Develop tools for the data analysis

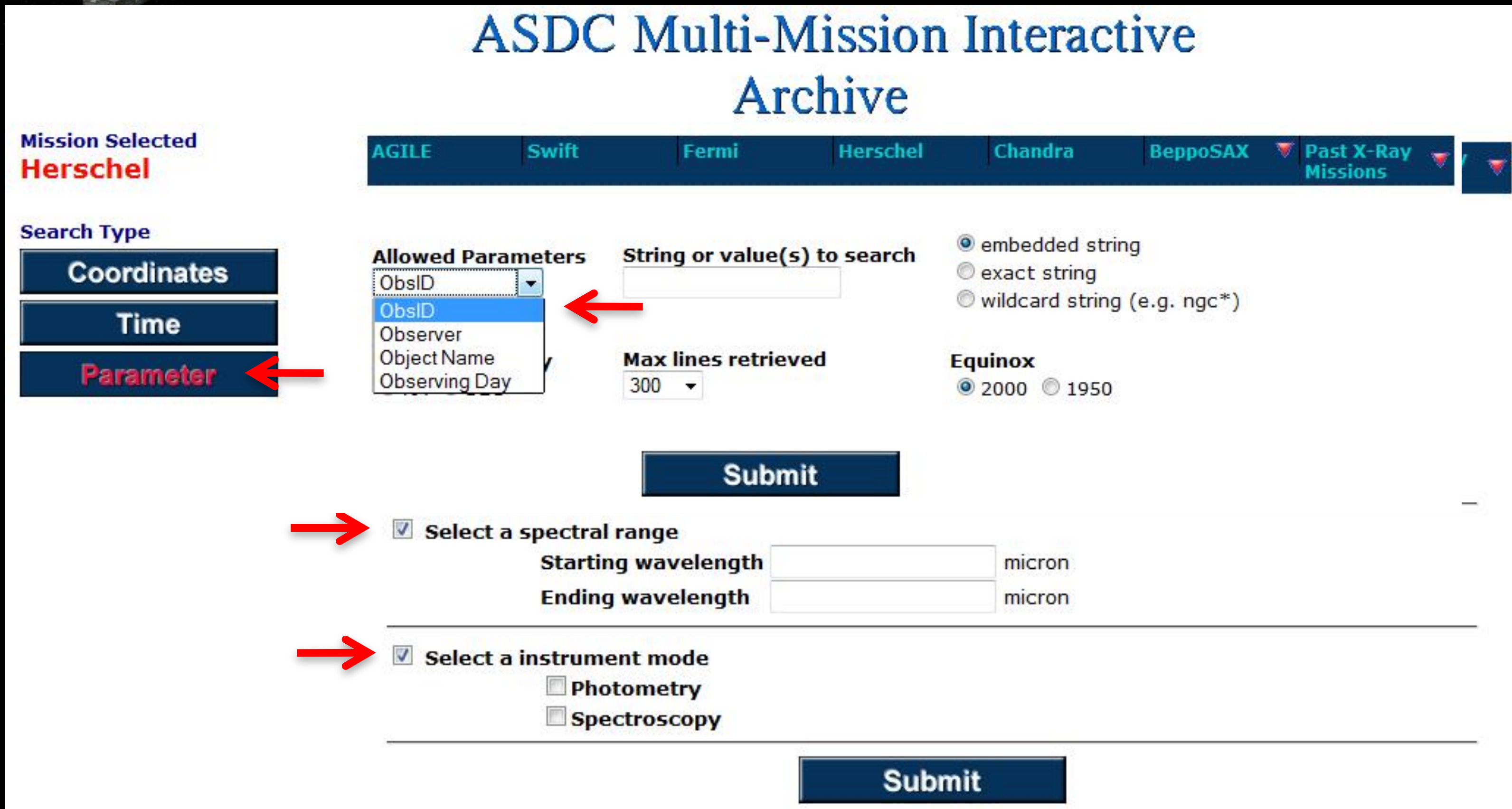
- Collaboration with the Hi-GAL Consortium for:
  - develop dedicated data reduction pipeline (Romagal, Unimap)
  - distribution catalogs and images



HIPE

data retrieval
data explorer
data reduction
data analysis

Herschel @ ASDC Multi-Mission Interactive Archive



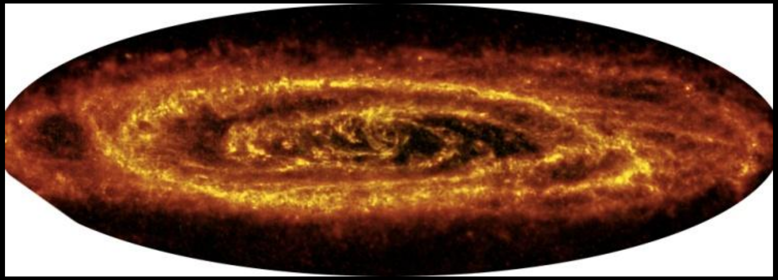
Simple Search types:

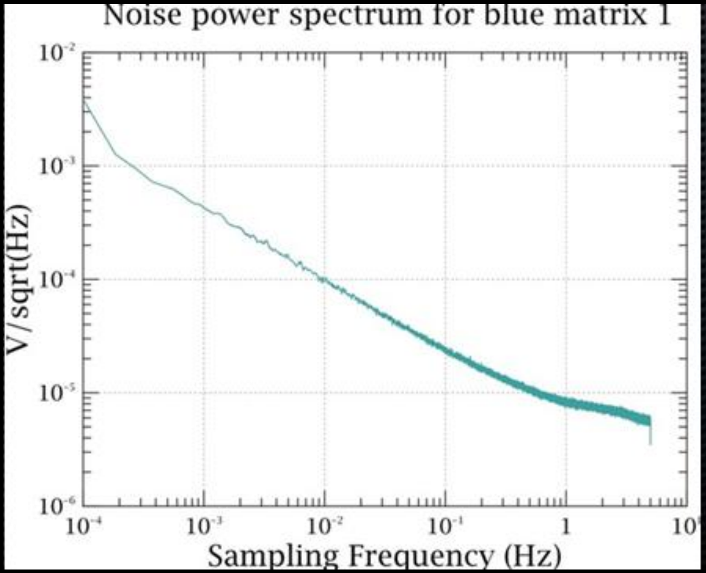
- ✓ Coordinates
- ✓ Parameters
- ✓ Time interval

Query results are in science ready formats (FITS, ASCII)

Map-making (I)

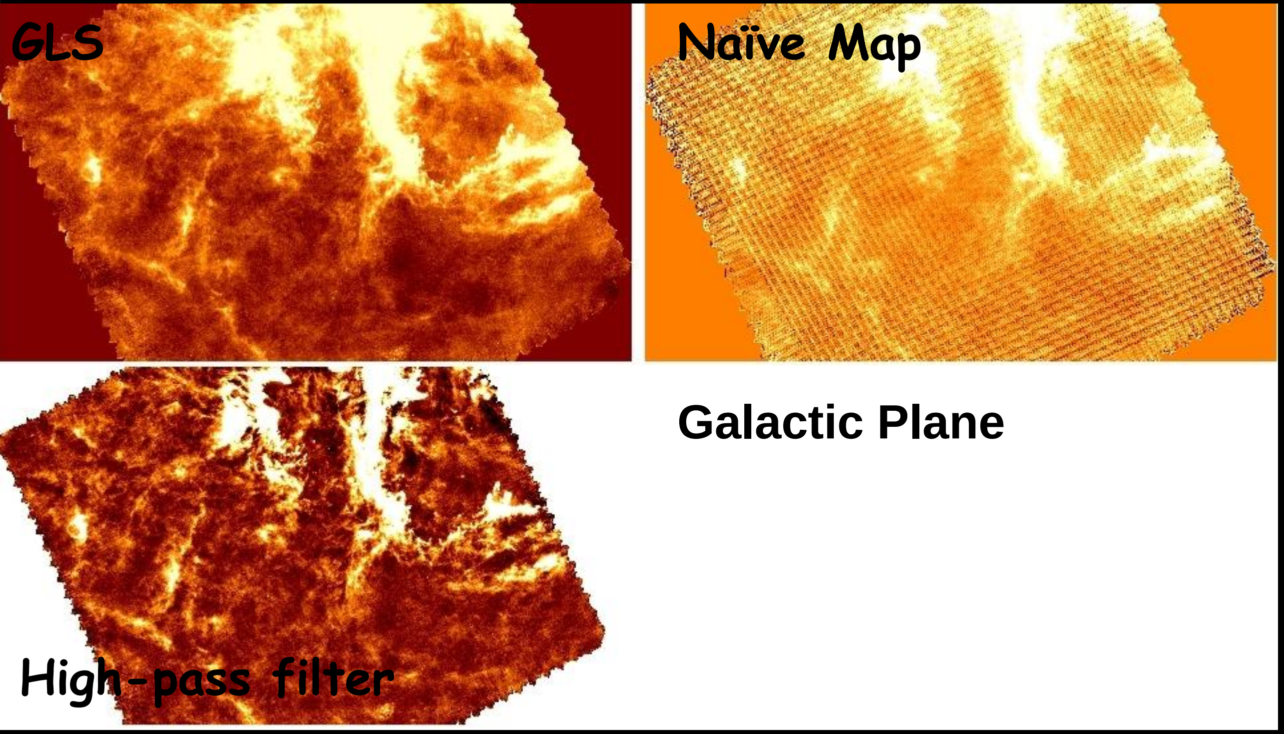
• Herschel photometers observe in mapping mode, often scanning wide sky regions (30% PACS-SPIRE Parallel)
• FIR emission in nearby objects (Galactic Plane, near galaxies) is characterized by point like sources as well extended emissions over large spatial scale
• bolometer are characterized by 1/f noise





Remove the 1/f noise without modifying the sky emission:
• High-pass filtering (masking point-like source)
• Map-making that remove the 1/f noise by using a Generalized Least Square approach, based on a priori knowledge of the noise statistical properties

Map-making (II)



There are several map-makers developed for Herschel data:

MadMap (standard pipeline)
Scanamorphos (Roussel+12)
Romagal(Traficante+11)
Unimap-Unihipe (Piazzo+12)
...

Unihipe is an interface HIPE-Unimap produce Unimap input data.
It is developed by ASDC and can be found at
http://herschel.asdc.asi.it/index.php?page=unimap.html

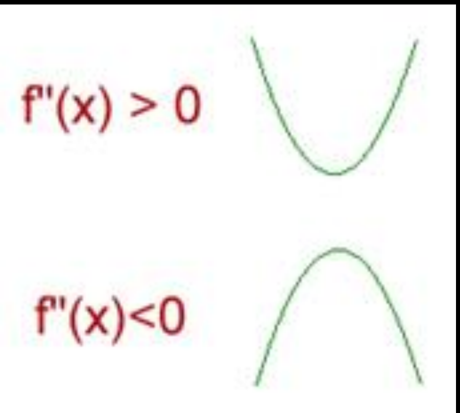
Unimap input is produced starting from Level 1 products by performing a query to the HAS or using downloaded data.

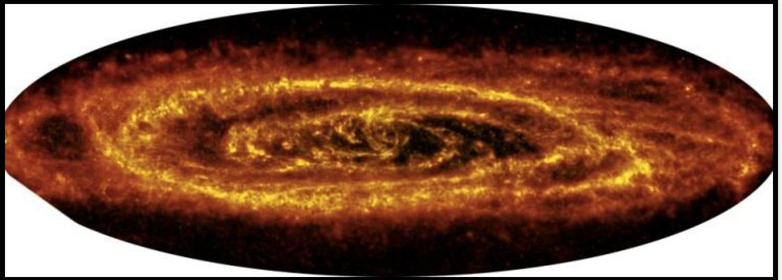
Cutex on-line (I)

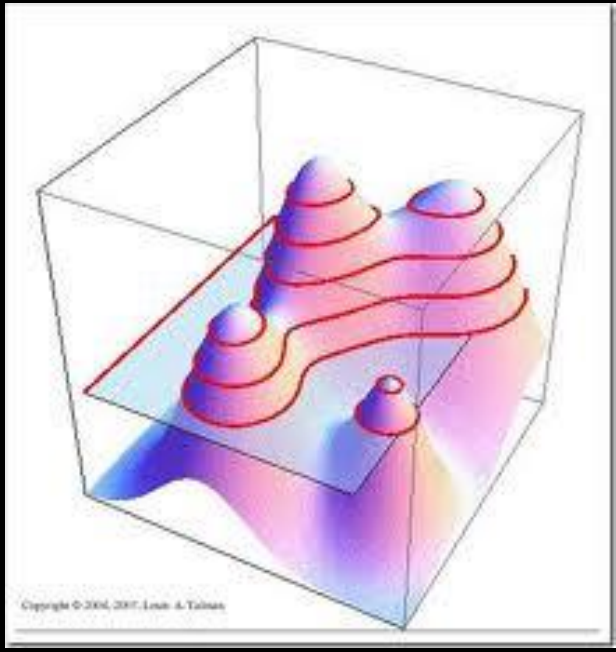
Estimation of background is a challenging task for algorithms dedicated to photometric source extraction, especially in highly variable backgrounds

The Cutex concept (Molinari+11):

- Study of the “curvature” of an image by measuring the 5-points derivatives (first and second) in 4 different directions
- Source size is inferred by using a threshold approach
- Photometry is performed by fitting elliptical 2D Gaussian plus a planar plateau



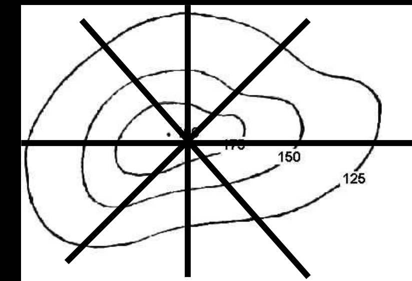




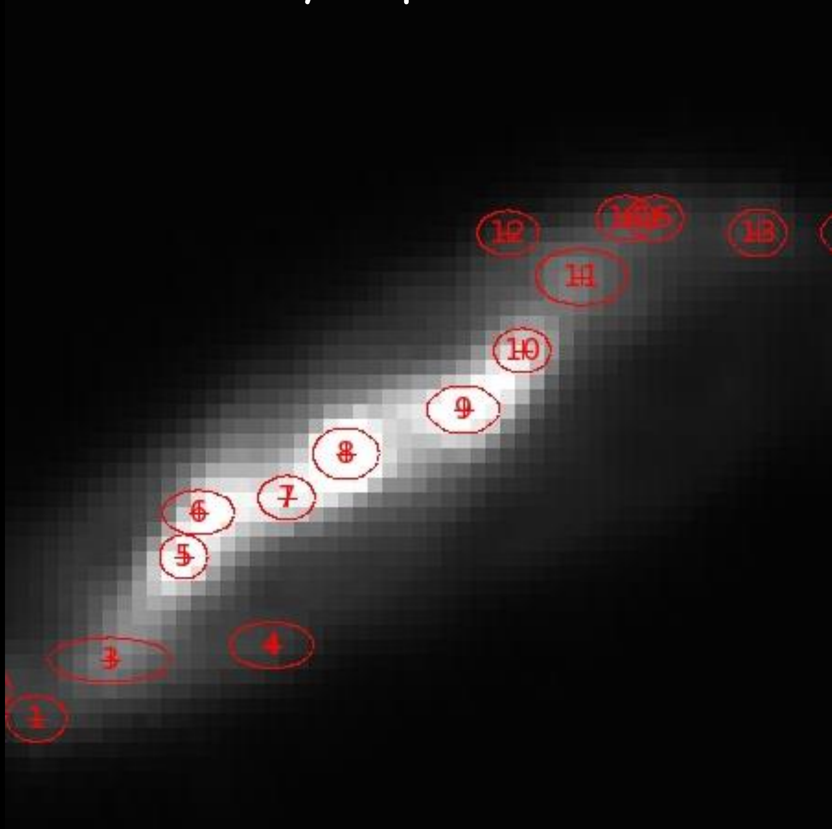
Integration of Cutex in a on-line tool

Cutex on-line (II)

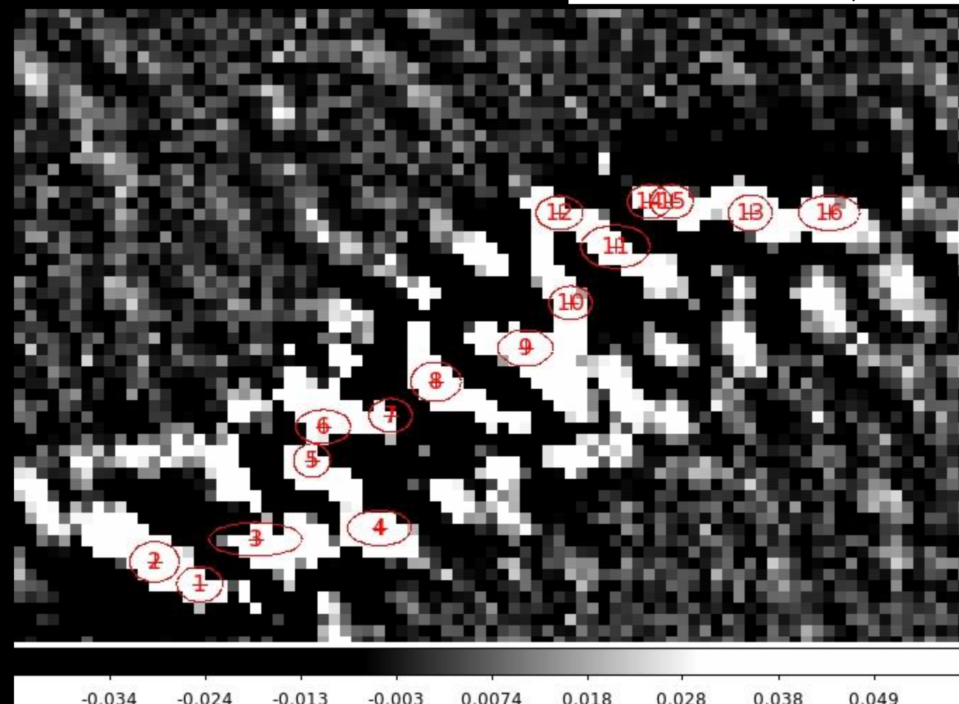
Centaurus A @ 250 μm



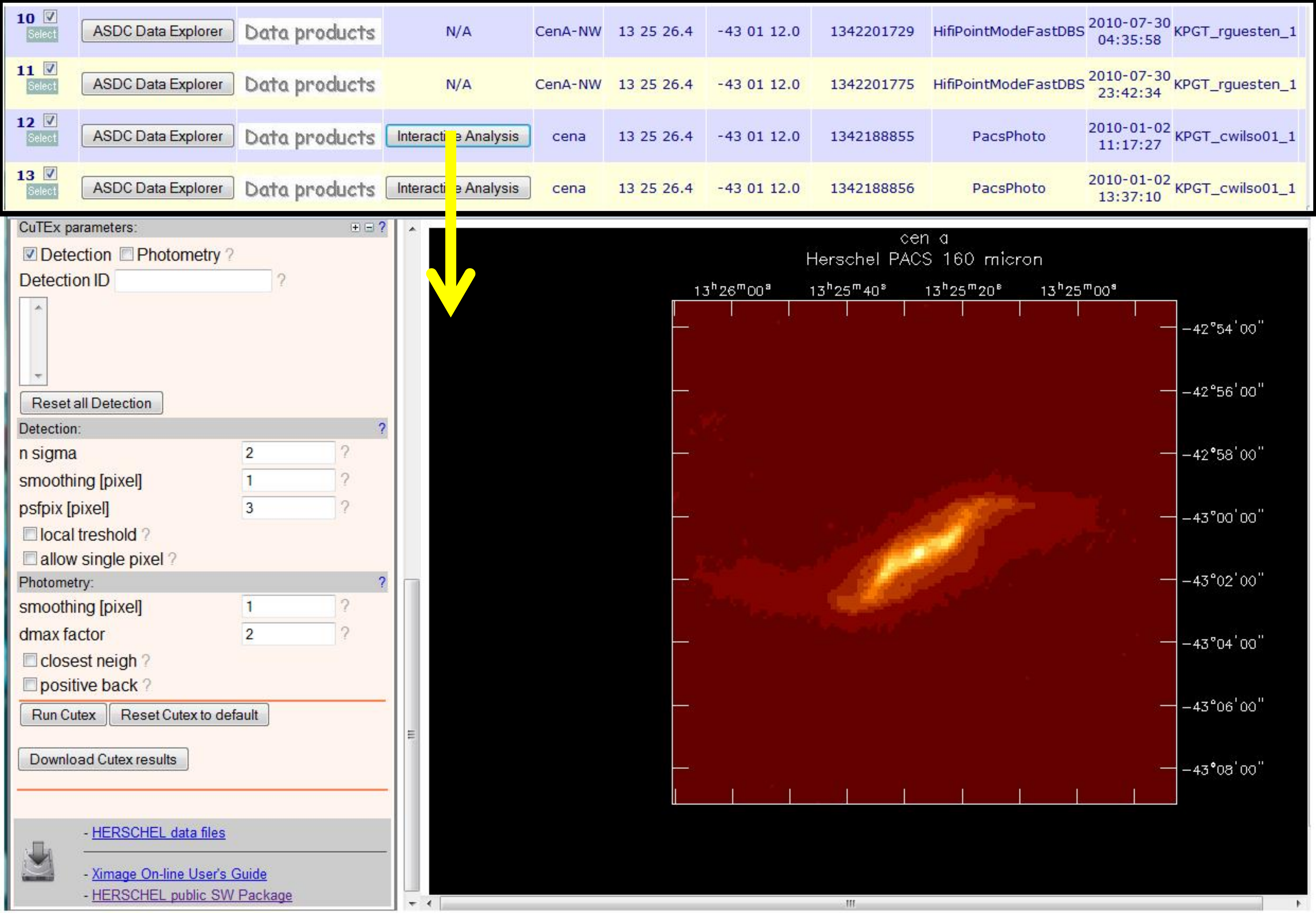
Intensity map



II-derivatives map



- 14 sources detected at 5 σ
- Background locally estimated for every source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11 Select ASDC Data Explorer Data products N/A CenA-NW 13 25 26.4 -43 01 12.0 1342201775 HifiPointModeFastDBS 2010-07-30 23:42:34 KPGT_rguesten_1
12 Select ASDC Data Explorer Data products Interactive Analysis cena 13 25 26.4 -43 01 12.0 1342188855 PacsPhoto 2010-01-02 11:17:27 KPGT_cwilso01_1
13 Select ASDC Data Explorer Data products Interactive Analysis cena 13 25 26.4 -43 01 12.0 1342188856 PacsPhoto 2010-01-02 13:37:10 KPGT_cwilso01_1
CuTEx parameters:
Detection
Photometry
Detection ID
Reset all Detection
Detection:
n sigma 2
smoothing [pixel] 1
psfpix [pixel] 3
local treshold
allow single pixel
Photometry:
smoothing [pixel] 1
dmax factor 2
closest neigh
positive back
Run Cutex
Reset Cutex to default
Download Cutex results
- HERSCHEL data files
- Ximage On-line User's Guide
- HERSCHEL public SW Package
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Herschel PACS 160 micron
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ASI Science Data Center

Galaxy Activity

- nuclear activity (gas accretion into the nucleous)
- stellar activity
- star forming processes

How AGN activity is connected to the host galaxy, in particular with the star formation?

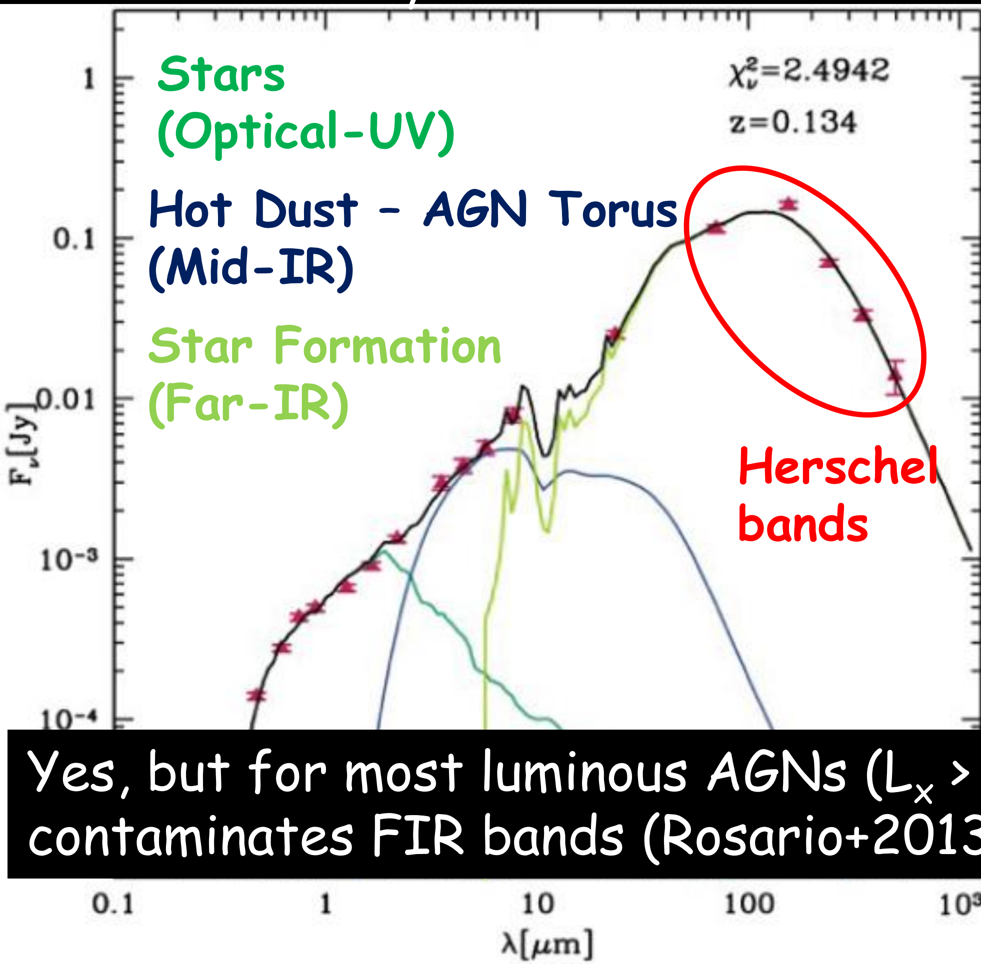
Which are the feedback mechanisms between nuclear activity and star formation?

How these relations regulates star formation and galaxy evolution?

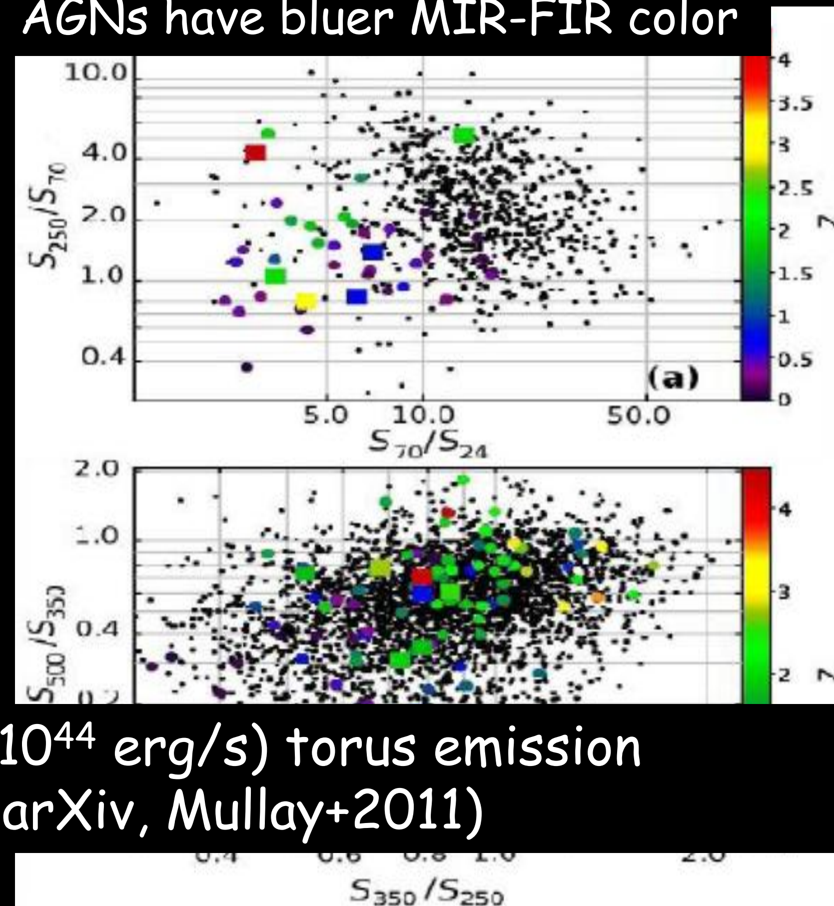
In AGNs, Herschel “looks” at the cold gas involved both in star forming processes and in the accretion into the nucleus

Is the FIR emission in AGNs a tracer of SF?

Far-IR emission is dominated by cold dust emission and it is a probe of the Star Formation activity



AGNs have bluer MIR-FIR color

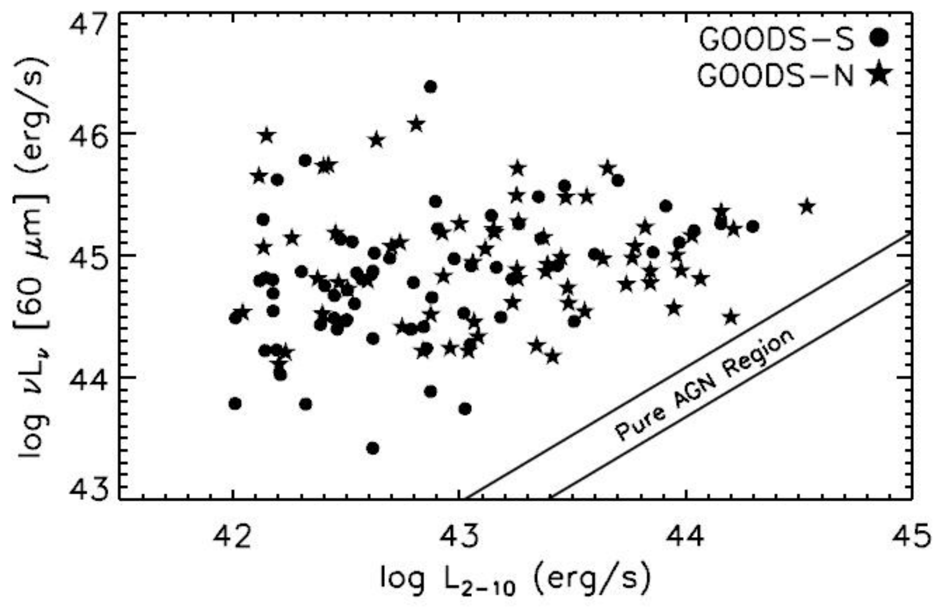


Yes, but for most luminous AGNs ($L_X > 10^{44}$ erg/s) torus emission contaminates FIR bands (Rosario+2013arXiv, Mullay+2011)

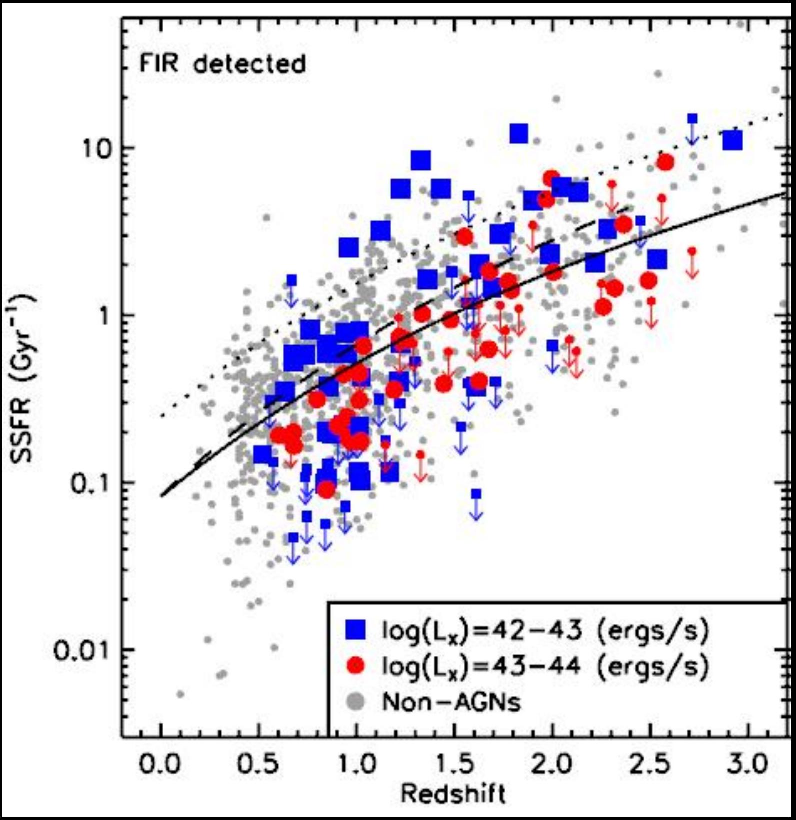
HerMES KP Hatziminaoglou+10

AGNs are confused in SPIRE bands

Relation between AGN and star formation (I)



AGNs luminosities are too low to affect the FIR luminosity (Rosario+2013)

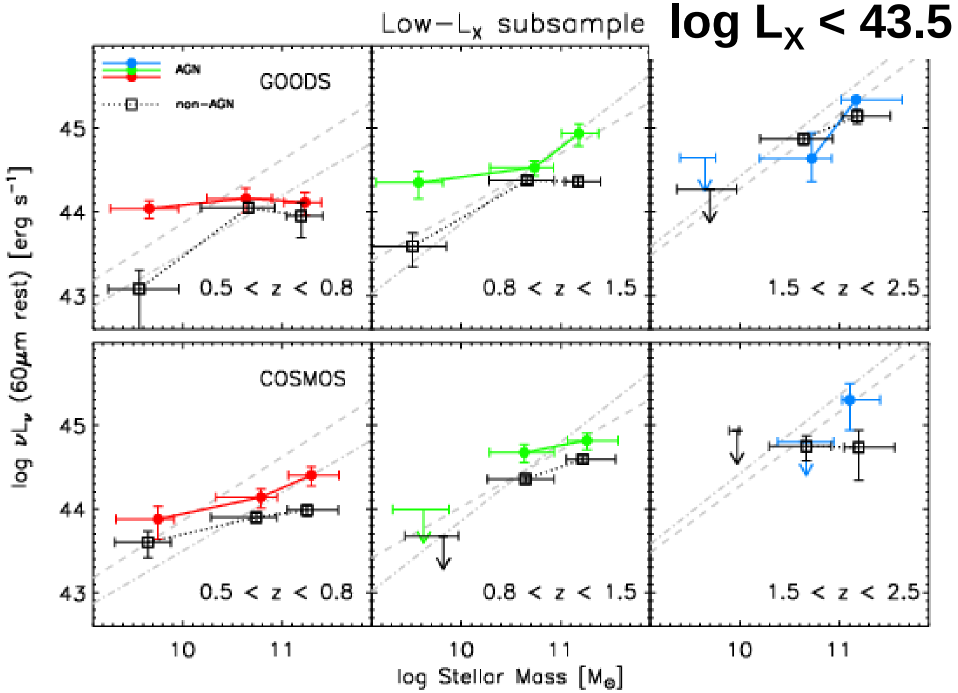


AGNs are main-sequence galaxies (Mullay+2011)

For low and moderate luminosity AGNs there is not correlation between X-ray and FIR luminosities and they normal, star forming galaxies

Relation between AGN and star formation (II)

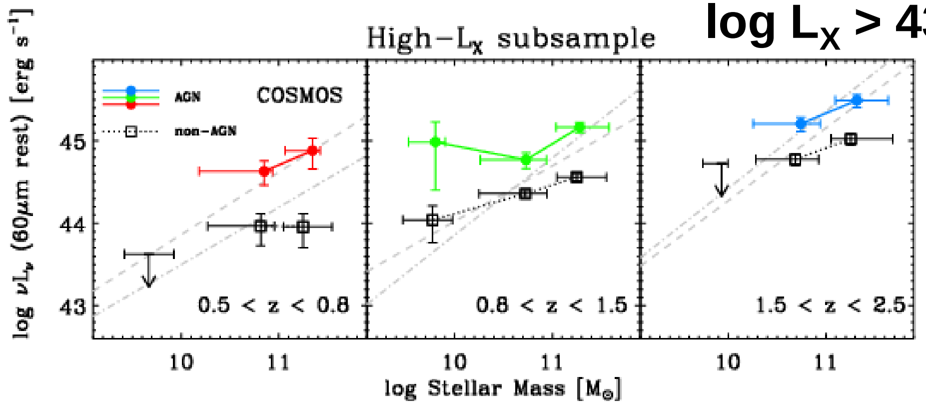
log L_X < 43.5



Low L_x show modest SF enhancement

High L_x show an higher star formation rate with respect to low L_x

log L_X > 43.5



Both nuclear activity and star formation are related to the cold gas reservoir:
Correlation between FIR and AGN should be expected at all scales

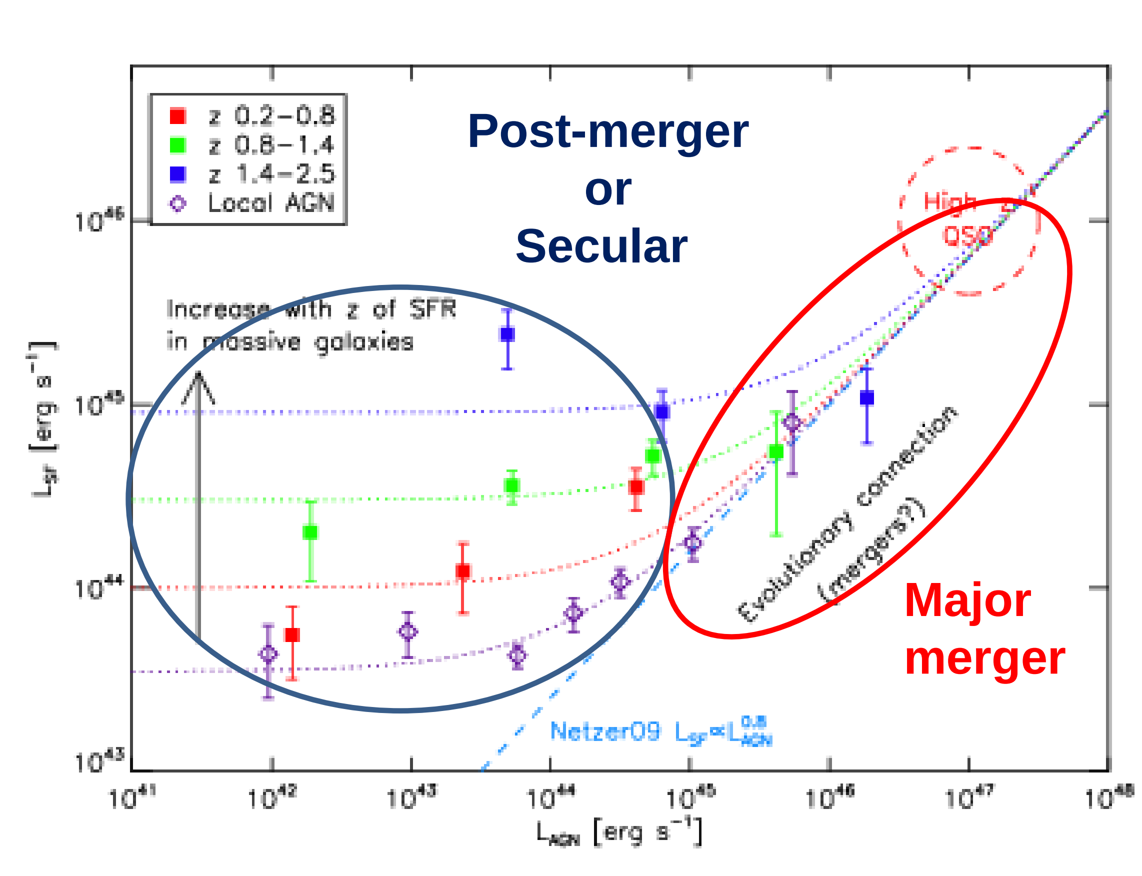
PEP KP
Santini+12

Two models of AGN evolution

L(AGN)>10^{45} erg/s: correlation is observed, i.e. SF and nuclear accretion are tightly coupled

➢ major mergers scenario

L(AGN)<10_{45} erg/s: no correlation between AGN and SF



➢ post-merger accretion:
AGN accretion and SF are not well synchronized, even if casually linked (delayed AGN feeding)

➢ secular accretion:
No major mergers, but local correlation between accretion and star formation (e.g. SF within the inner kpc region)

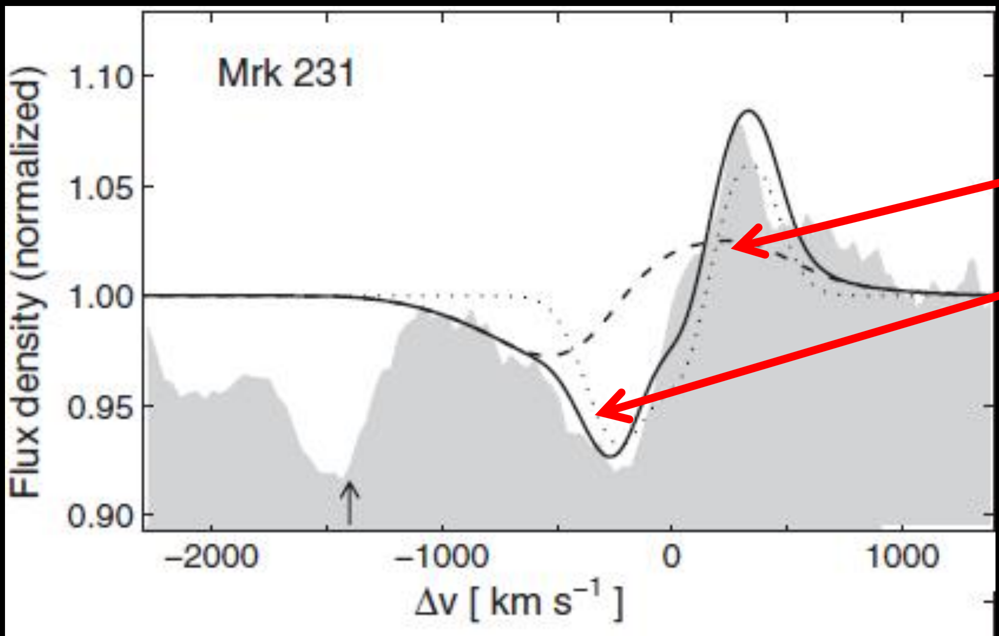
PEP KP Shao+10

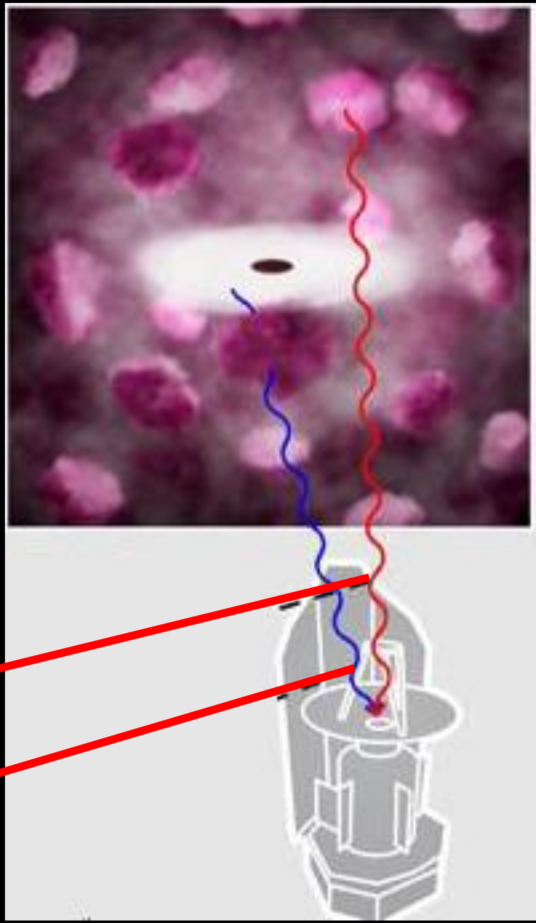
Molecular outflows in ULIRGs (I)

OH@79μm observations in ULIRGs (AGN and Sturburst)

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

Δv ~ 1170 km/s
Depletion time scale:
$M_{gas}/(dM/dt) \sim 4 \times 10^6$ yr

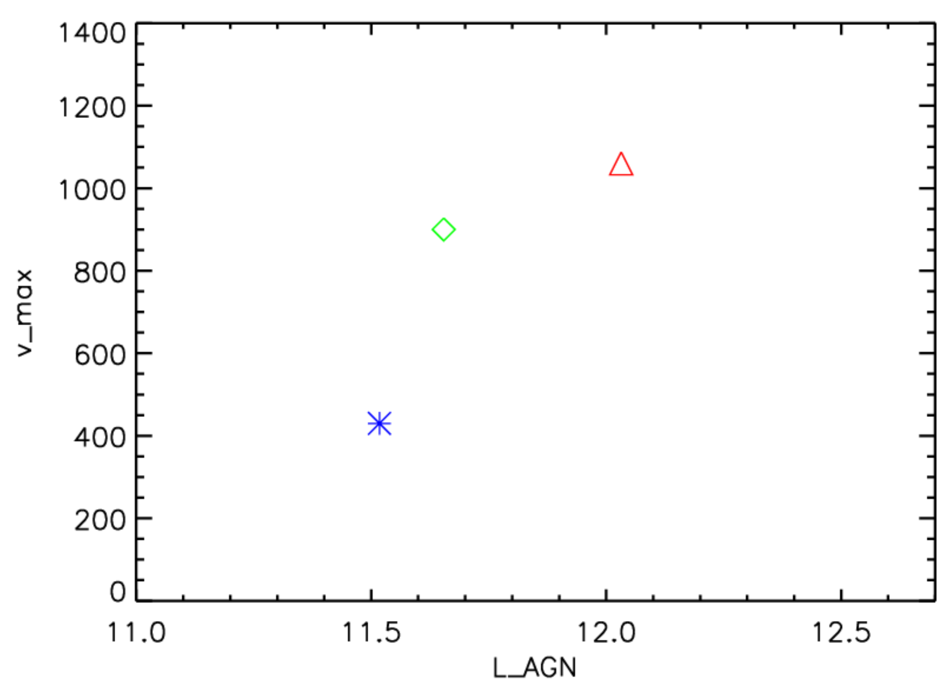


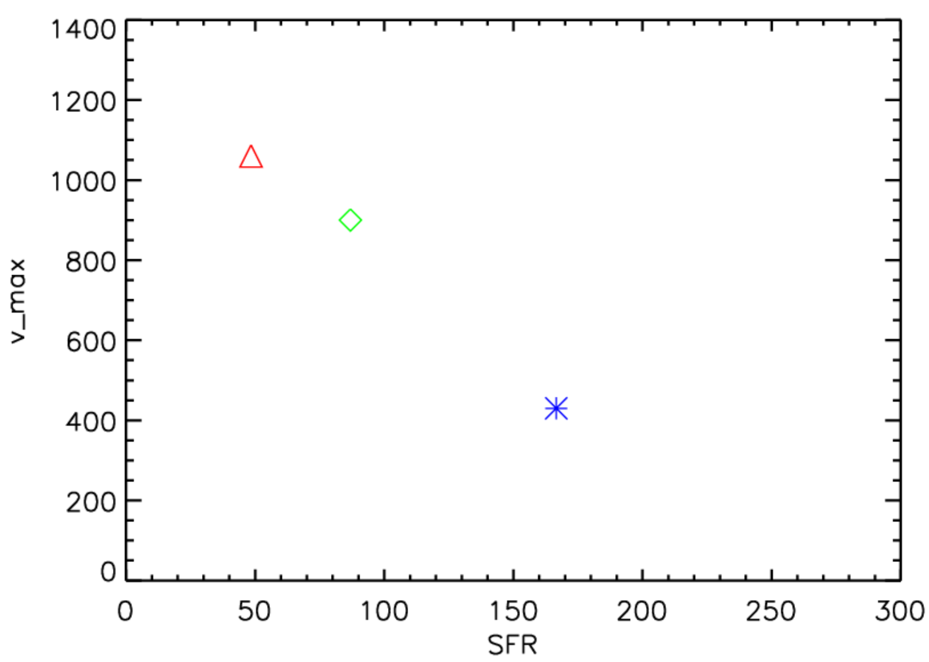


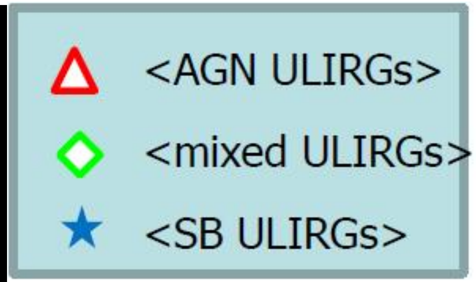
SHINING KP
Strurm+2011

Molecular outflows in ULIRGs (II)

- Are outflows driven by the AGN rather than by the star formation?
- Does the outflow carry sufficient molecular gas to quench the star formation?







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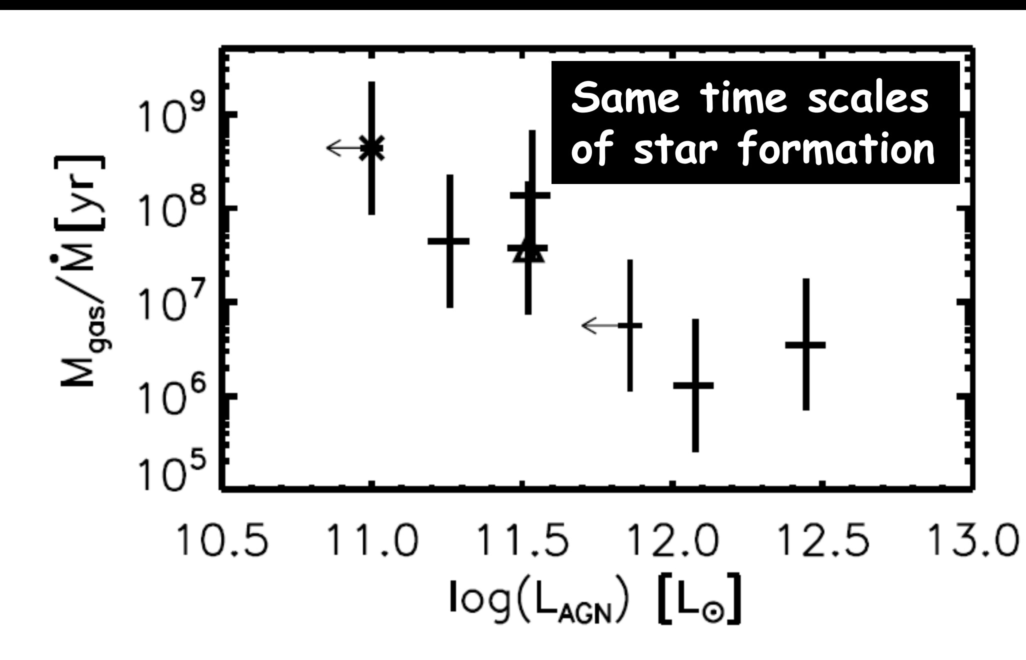
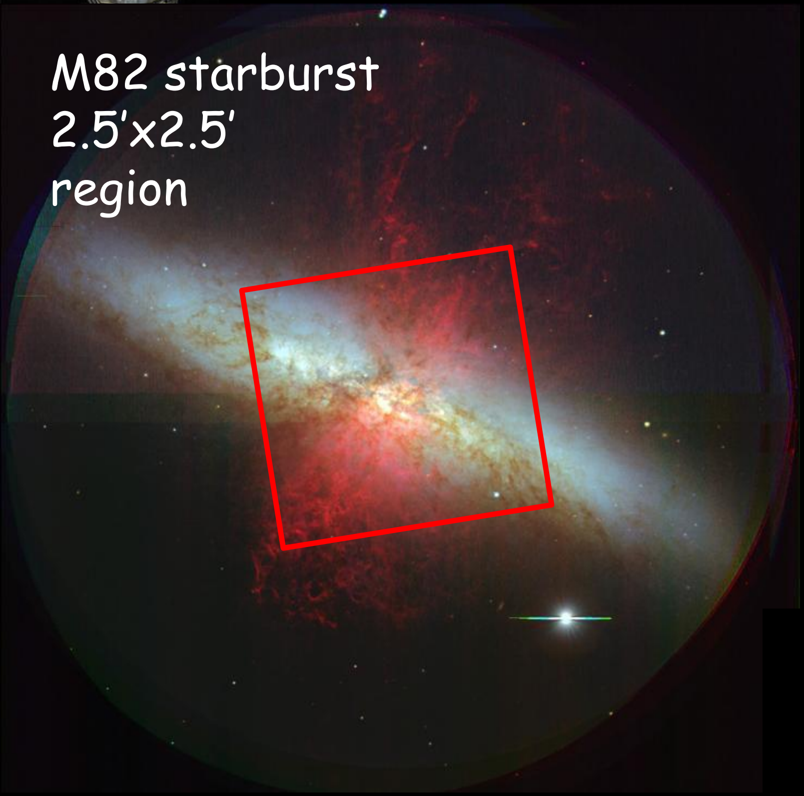
- Are outflows driven by the AGN rather than by the star formation?
- Does the outflow carry sufficient molecular gas to quench the star formation?

Preliminary evidence that ULIRGs with higher AGN luminosity have higher outflow velocity and shorter gas deplation time scales



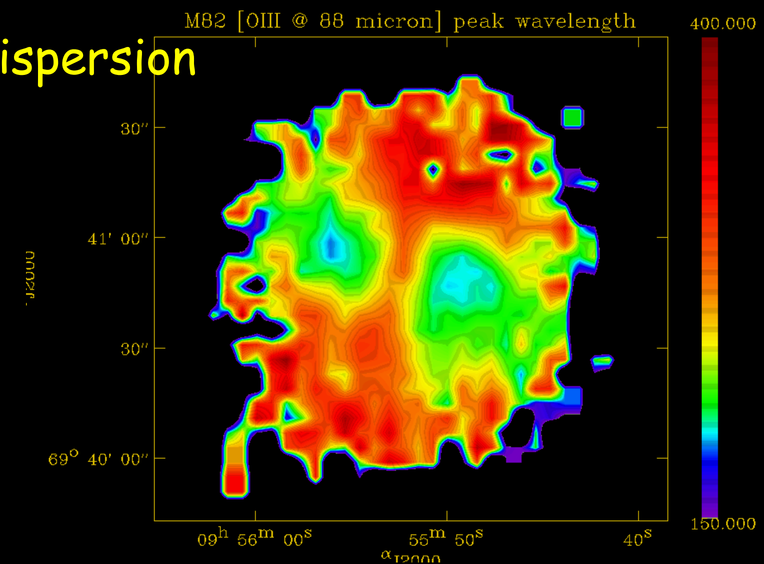
… and remember that PACS is a IFU spectrometer!!

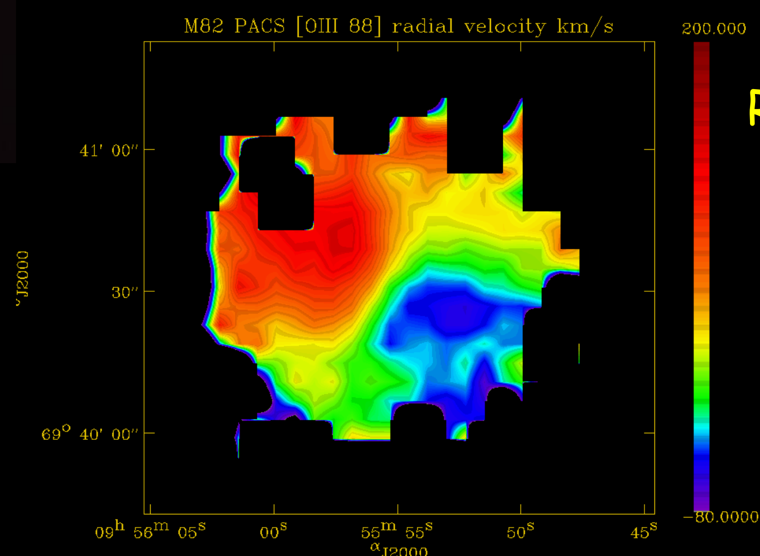


M82 starburst
2.5'x2.5'
region

[OIII] @ 88 µm

Velocity dispersion





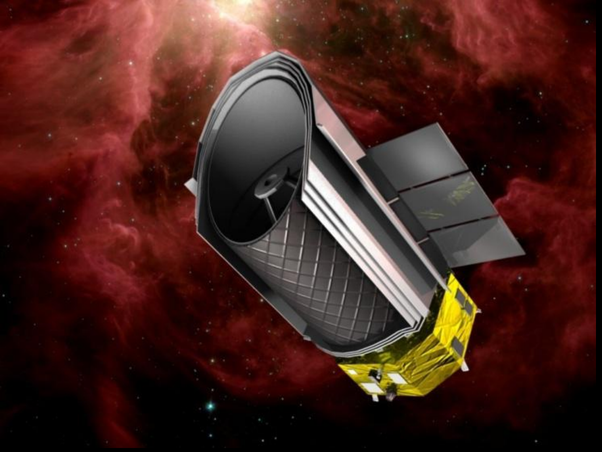
Radial velocity

Line Ratio for obtaining maps of physical parameters:
FUV, n_H, T_{gas}

SHINING KP
Contursi+2012

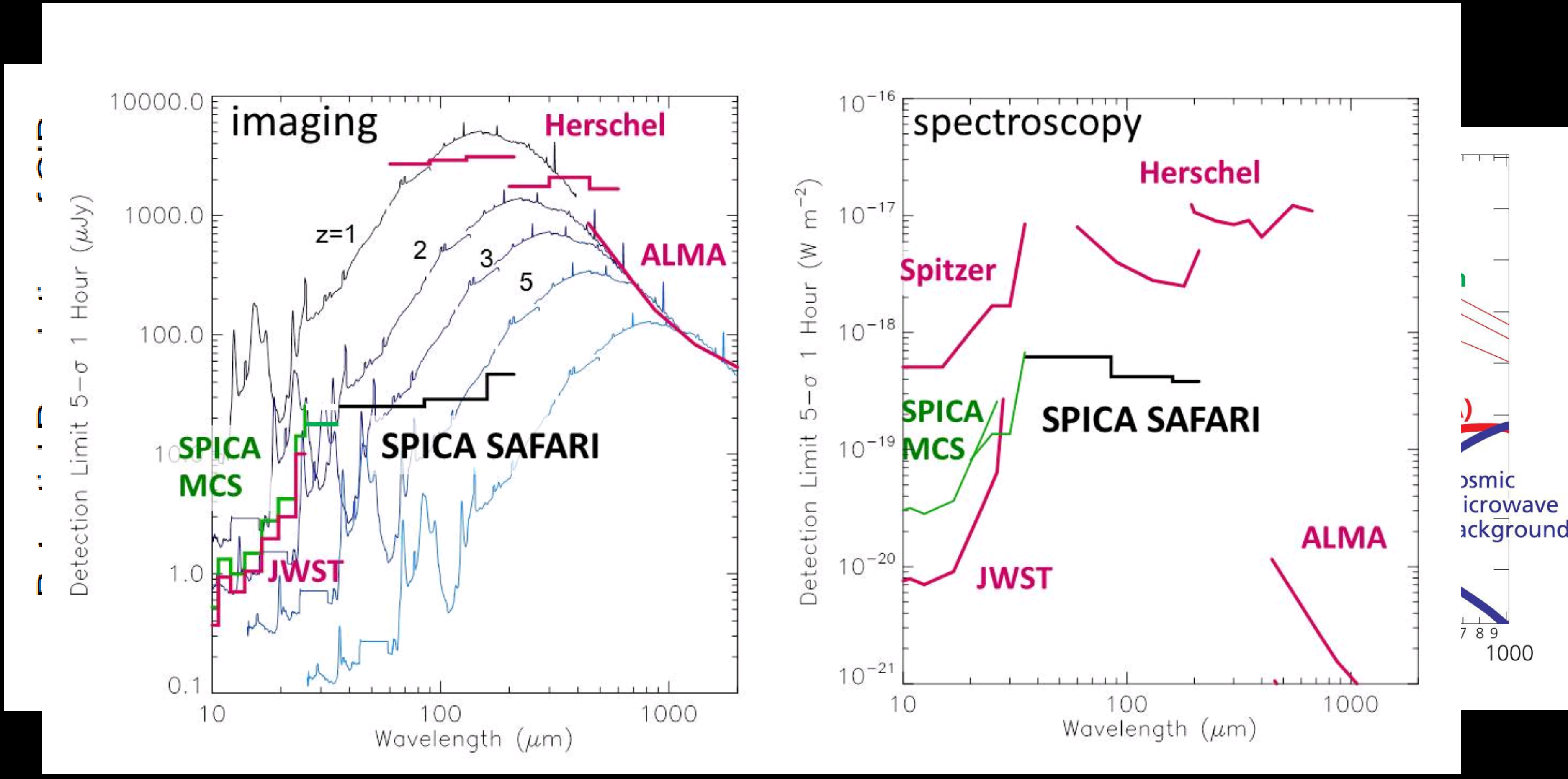
Outline

1. Mission overview
2. Science with Herschel
3. Herschel at ASDC
4. AGNs with Herschel
5. A look to the future …



SPICA

- A mission of the Japanese Space Agency (JAXA) in collaboration with Europe, Korea and Taiwan
- 3.2-meter primary mirror mechanically cooled at 6K
- Photometry and spectroscopy in the 5-210 μm ranfe
- Launch: 2022




Thanks!
Orion A
PACS 70μm
Romagal