The Herschel mission

Paolo Saraceno
IFSI INAF

La Thuile 01- 03 - 2009

Herschel in a nut shell

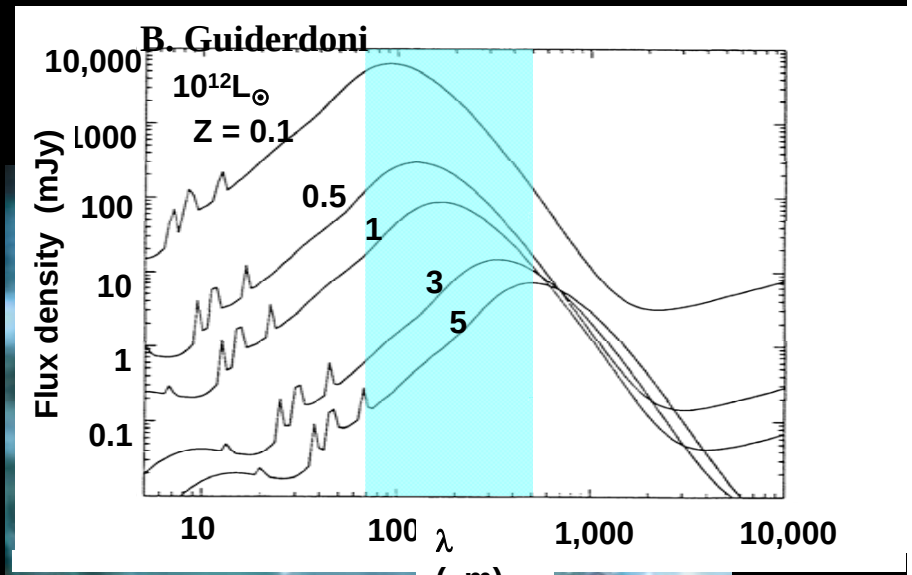
- **ESA cornerstone observatory**
  - 3.5 m monolitic low emissivity passively cooled telescope
  - 3 focal plane instruments nationally funded
  - 1/3 guaranteed time 2/3 open time
- **imaging and spettroscopy** at the difraction limit in the **57 – 670 um** spectral range

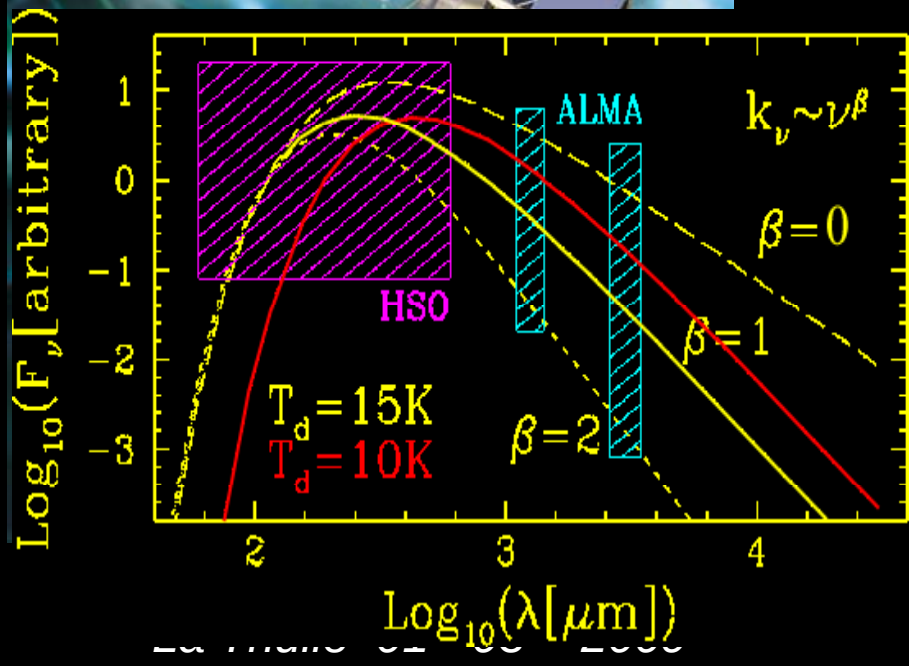
Herschel in a nut shell

- **ESA cornerstone observatory**
  - 3.5 m monolitic low emissivity passively cooled telescope
  - 3 focal plane instrument nationally funded
  - 1/3 guaranteed time 2/3 open time
- **imaging and spectroscopy** at the diffraction limit in the **57 – 670 um** spectral range

Unique to study the

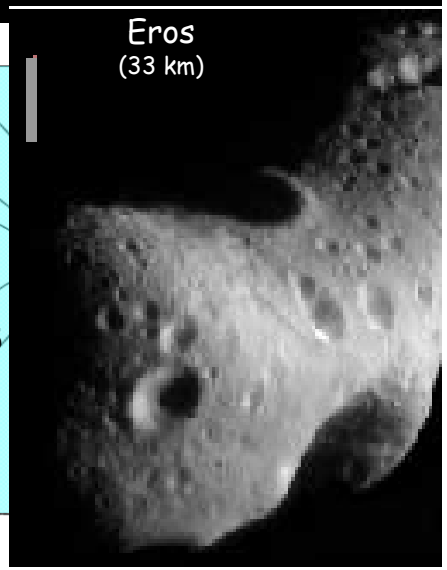
- **the warm embedded universe**
  - high z galaxies
  - star formation





Herschel in a nut shell

•**ESA cornerstone observatory**
-3.5 m monolitic low emissivity passively cooled telescope
- 3 focal plane instrument nationally funded
- 1/3 guaranteed time 2/3 open time
•**imaging and spettroscopy** at the difraction limit in the **57 – 670 um** spectral range



Unique tu study the

- **the warm embedded universe**
  - high z galaxies
  - star formation
- **the cold Universe** (black bodies 5-50k)
  - dust
  - brown dwarf solar system bodies
  - ISM physics and chemistry

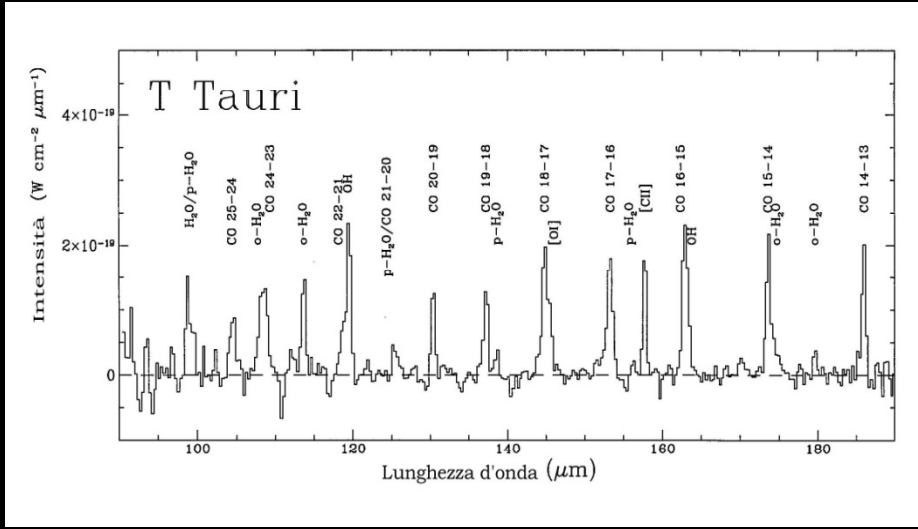
Herschel in a nut shell

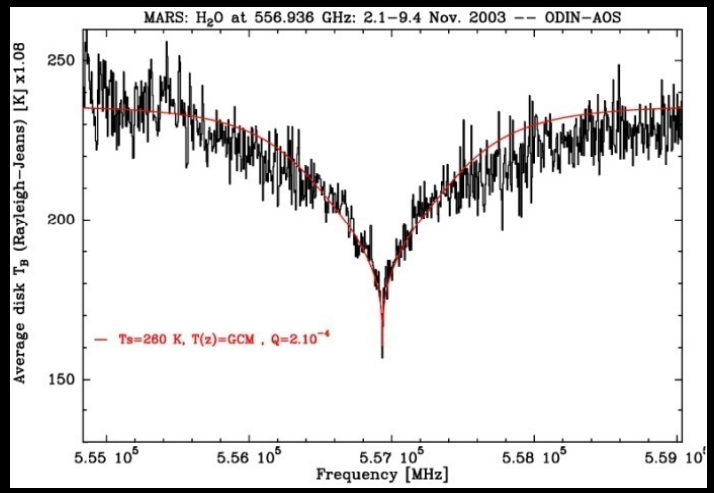
•**ESA cornerstone observatory**
-3.5 m monolitic low emissivity passively cooled telescope
- 3 focal plane instrument nationally funded
- 1/3 guaranteed time 2/3 open time

•**imaging and spettroscopy** at the difraction limit in the **57 – 670 um** spectral range

Unique tu study the

- **the warm embedded universe**
  - high z galaxies
  - star formation
- **the cold Universe (**black bodies 5-50k)
  - dust
  - brown dwarf solar system bodies
  - ISM physics and chemistry
- **ionic and molecular lines** exited in a wide range of physical conditions





The satellite

- height/width 7.5 / 4 m
- launch mass 3300 kg
- power 1500 W "
- science data 130 kb/s

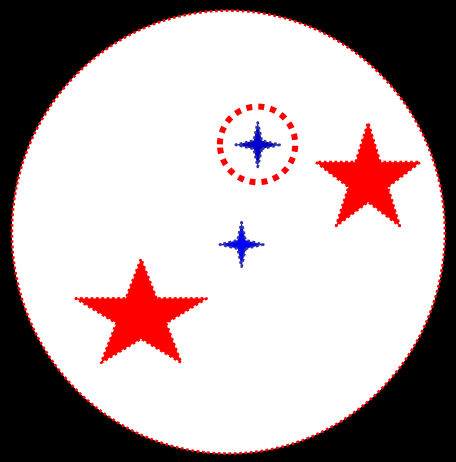
The telescope

- Diameter 3.5 m
- weight ~ 300 kg
- Temperature 80 K
- Emissivity~ < 4 %
- abs. Pointing < 3.7 "

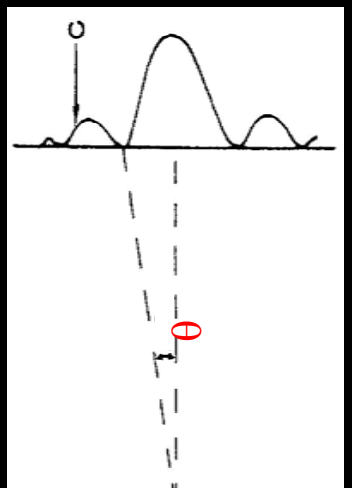
The importance of a large D

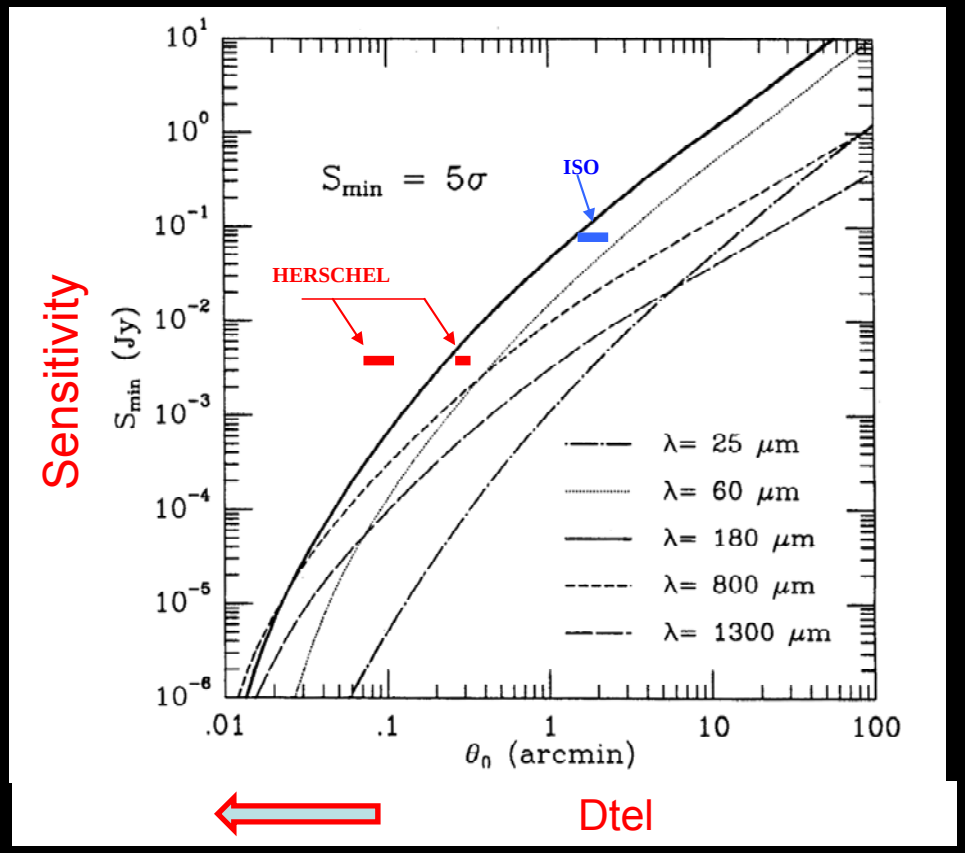
Spectral range 57-670 um

Franceschini et al. (1991) A & A Suppl., 89, 285



$\Theta = 2.4\lambda/D$



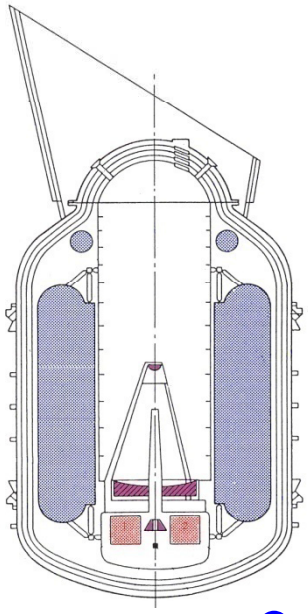


Estimates of confusion noise due to point-like extragalactic sources from 25μm to 1.3 mm. S_{min} is the flux limit below which source counts cannot be directly performed.

The values are lower boundaries because source clustering may locally increase S_{min}.

Confusion noise due to stars is expected to be greater than the one of the figure for |b| < 20° and negligible for b ≥ 50°.

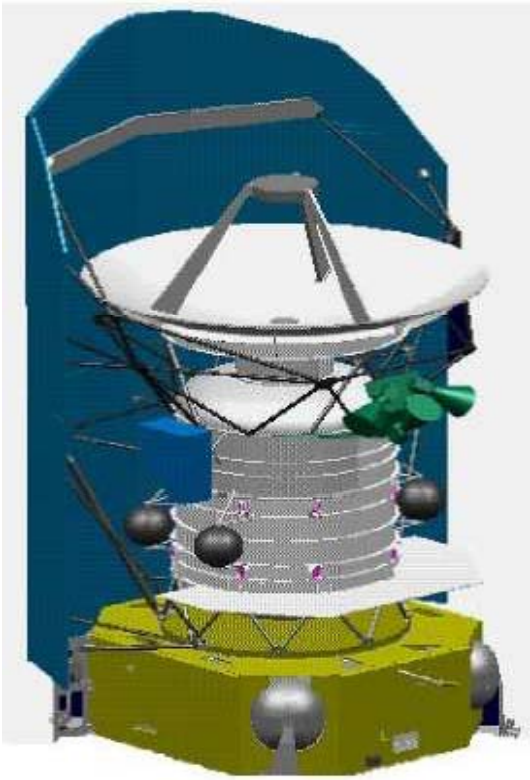
The past:
ISO



2 K

=>

The present:
HERSCHEL



80 K

Small **cryogenically** cooled telescope

=>

Large **radiative** cooled telescope

0.6 => 3.5 m

2.4 => 200 µm

60 => 600 µm

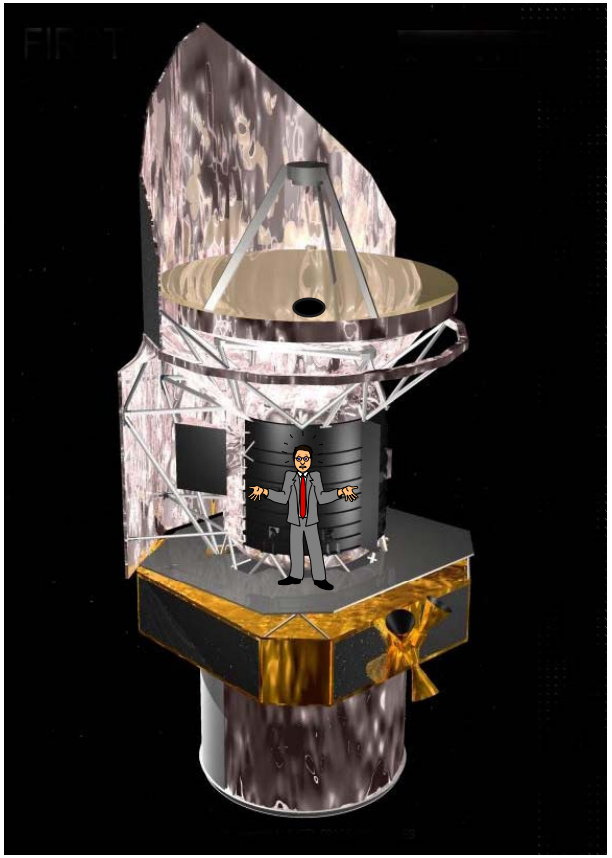
The future

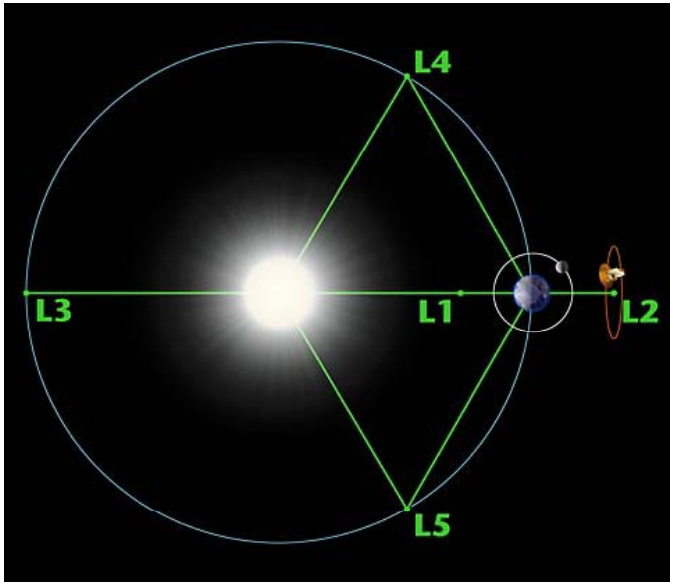
Herschel will remain a unique opportunity for at least 10 years

The Herschel Space Observatory

- Spectral range 57-670 um

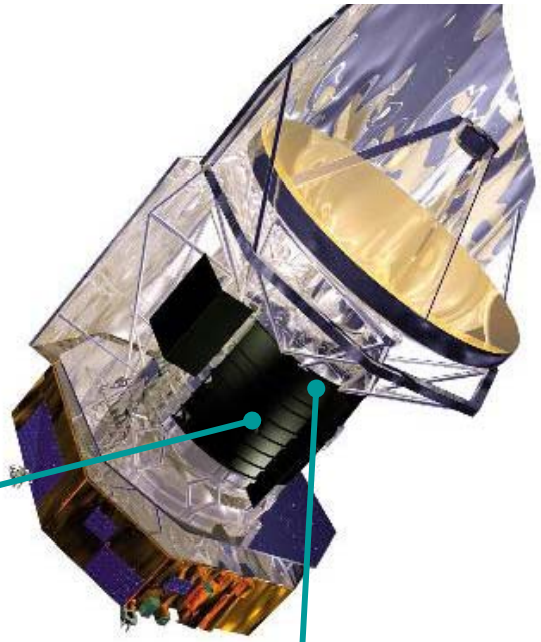
- Telescope
  - Diameter 3.5 m
  - Temperature 80 K
  - Effective emissivity ~ 2% ?



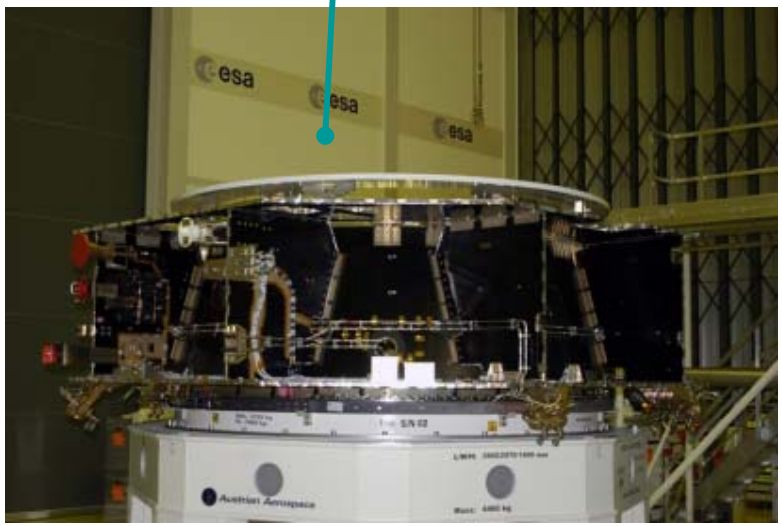


- Lifetime > 3 years
- Orbit L2
- Launch April 2009

Herschel Cryostat



The instruments

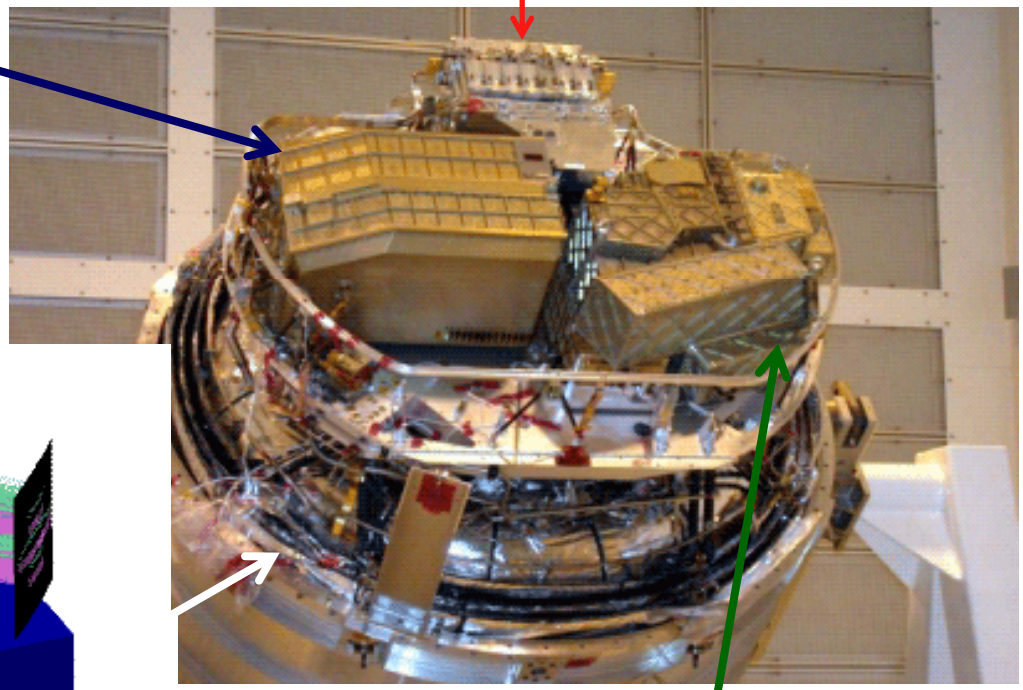


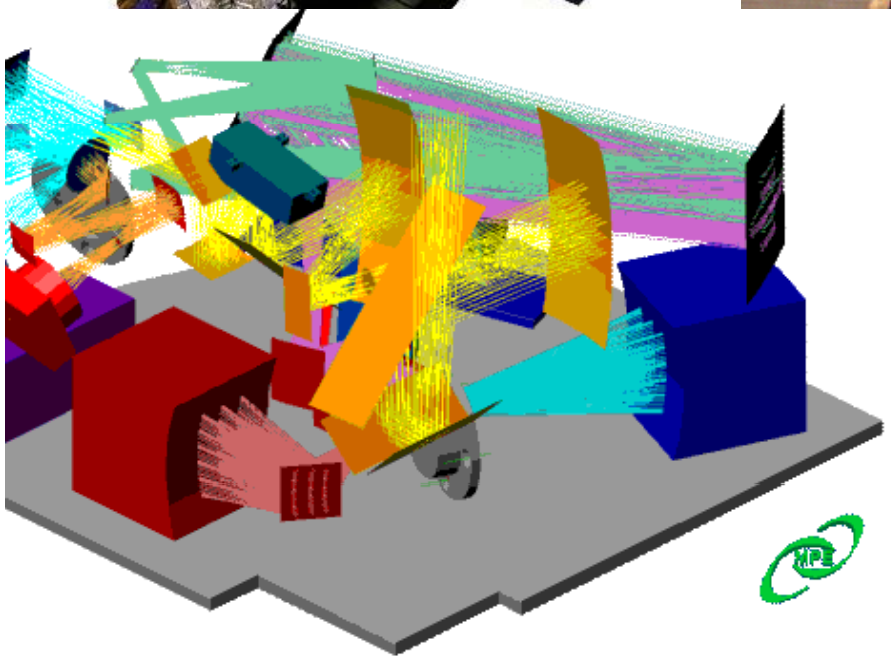
Herschel Instruments

Photometry and Spectroscopy between 57 -670 μm

- SPIRE (200 - 670 μm)
  - Imaging photometer
  - Imaging Fourier transform spectrometer
  - Survey: λ/D λ = 20-1000

- PACS (57 - 210 μm)
  - Imaging photometer
  - Imaging grating spectrometer
  - Lines: λ /D λ ~ 1500





HIFI (157- 212 μm and 240 - 625 μm)
(1.9 THz -→ 480 GHz)

Non-imaging heterodyne receiver
- Lines: λ /D λ = 10^4 - 10^6

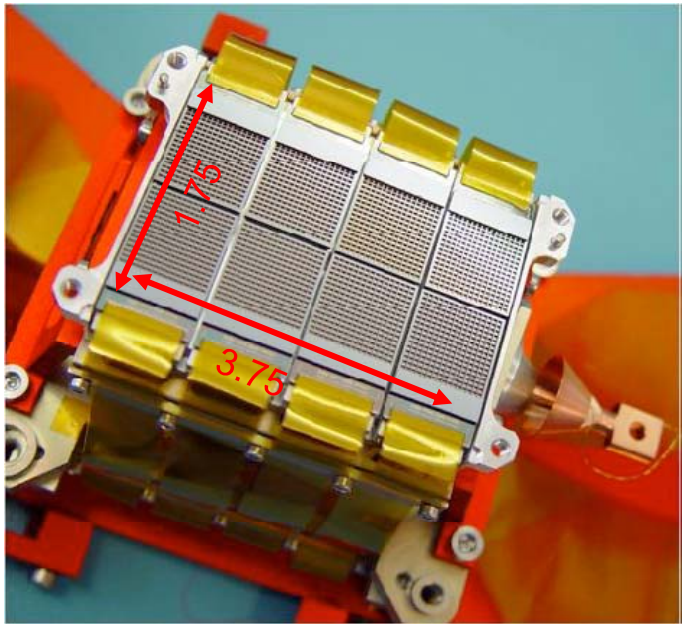
The spider-web bolometers

PACS - Photodetector Array Camera and Spectrometer
– PI: Albrecht Poglitsch, MPE, Garching, Germany

– imaging photometry in 2 bands simultaneously:
  75 or 110 μm (blue) and 170 μm (red)
– 2 filled bolometer arrays (64x32 and 32x16 pixels)

--> full beam sampling over 3.5'x1.75' field of view
– Angular resolution: ~ 5", 8'', 13" (HPBW)

– Expected sensitivity: ~ 3-4 mJy/beam (5σ, 1hr)
– Integral-field line spectroscopy from 57 to 210 μm

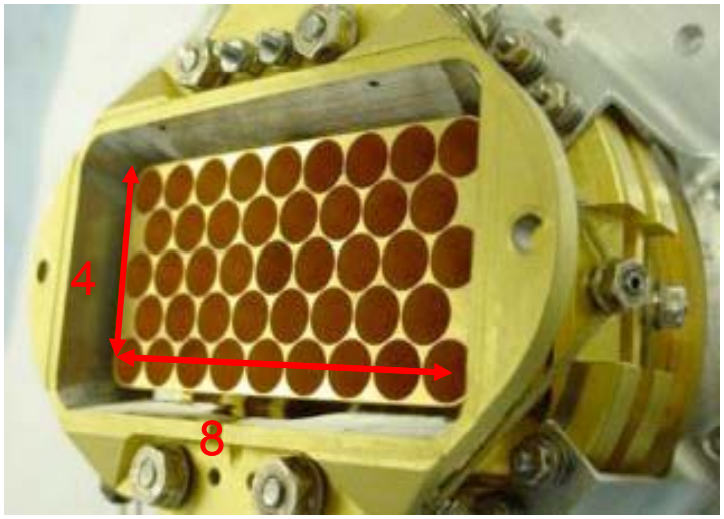


• SPIRE - Spectral and Photometric Imaging Receiver
– PI: Matt Griffin, Cardiff University, UK

– 3-band imaging bolometer array: 250, 350, 500 μm
  (simultaneous)
– 8'x4' field of view (2Fλ feedhorns - cf. SCUBA)

– Angular resolution: 18", 25", 36" (HPBW)

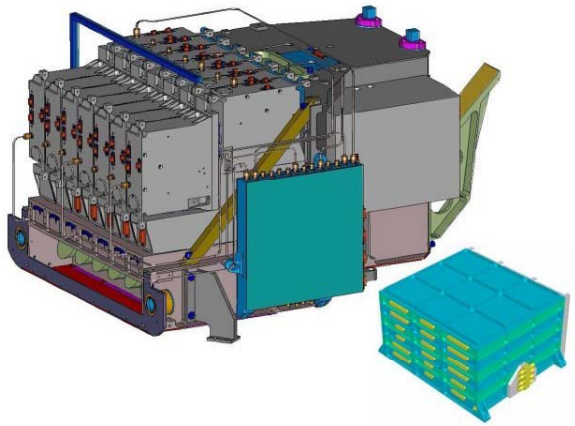
– Expected sensitivity: ~ 2-8 mJy/beam (5σ, 1hr)
– Spectro-imaging FTS from 200 to 670 μm



http://herschel.ifsi-roma.inaf.it/herschel/index.htm

HIFI: Heterodyne Instrument for the Far-Infrared

- Seven-channel heterodyne receiver
- Frequency coverage:
  - 480 - 1250 GHz (625 - 240 μm)
  - 1410 - 1910 GHz (212 - 157 μm)
- Spectral resolution 140 kHz - 1 MHz
- Near-quantum noise limited sensitivity (few mk)
- Instantaneous IF bandwidth: 4 GHz
- FWHM 12 – 40"
- High Resolution Spectrometer (correlator)
- Wideband spectrometer (AOS)



HERSCHEL: unique in detecting pre-stellar condensations

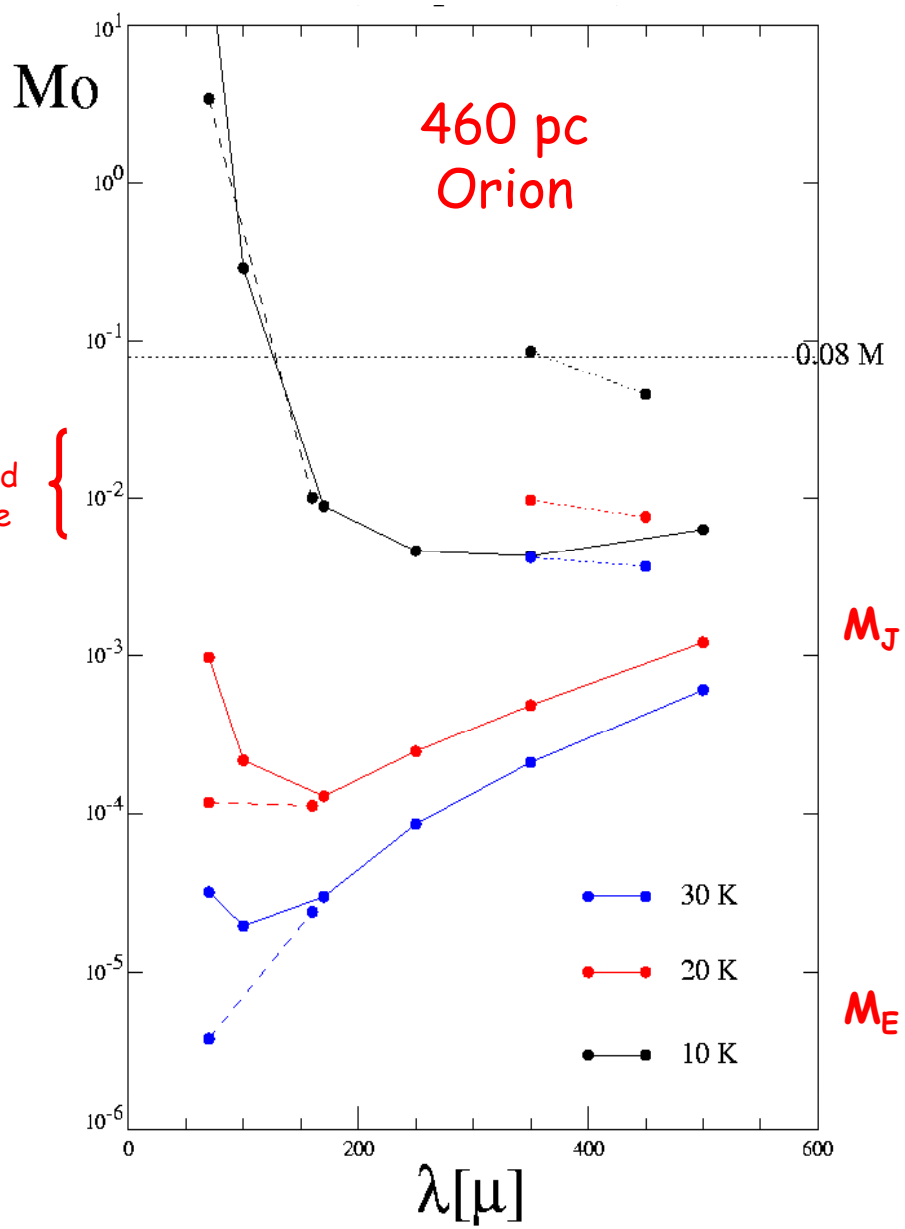
$Mo = F_\lambda \, k \, D^2 / B(\lambda/T)$

$K = 0.1(250/\lambda)$
$[cm^{-2} \, g^{-1}]$

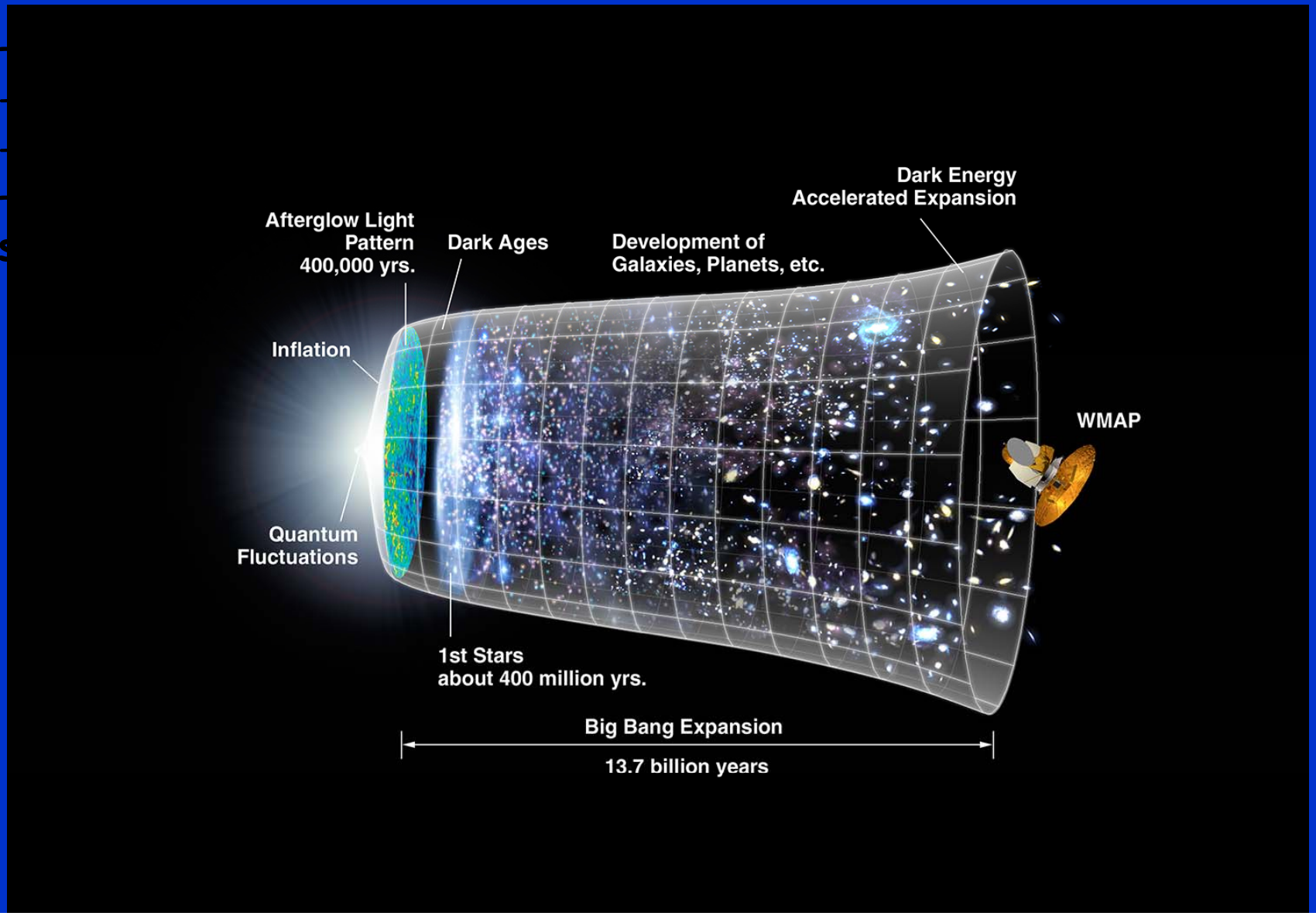
Best use of Herschel :

fast survey of "large" areas of sky

HERSCHEL: dust mass detectable
5σ 1h

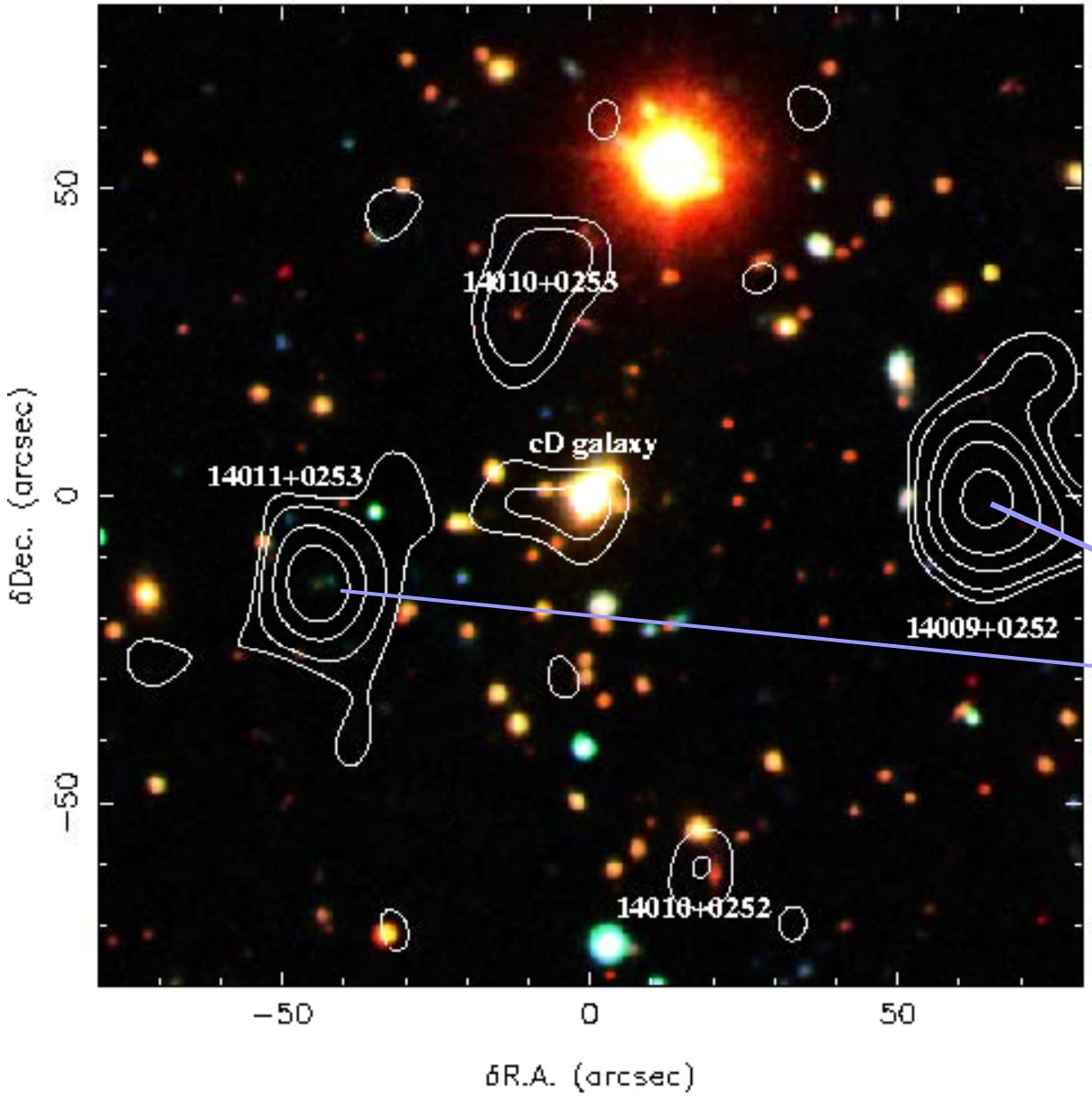


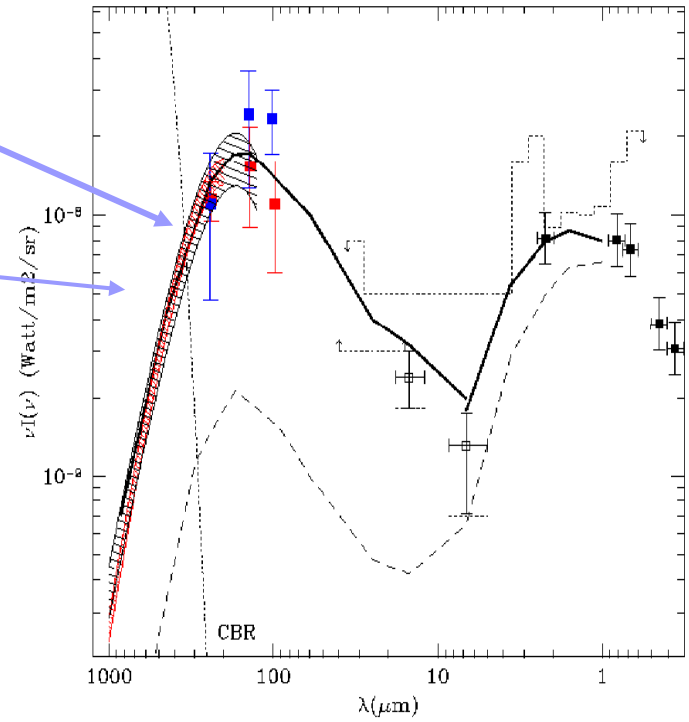
Formation and evolution of galaxies and clusters in the early universe



Palomar 200in
color image in UBI.

Superimposed:
SCUBA image at 850 μm



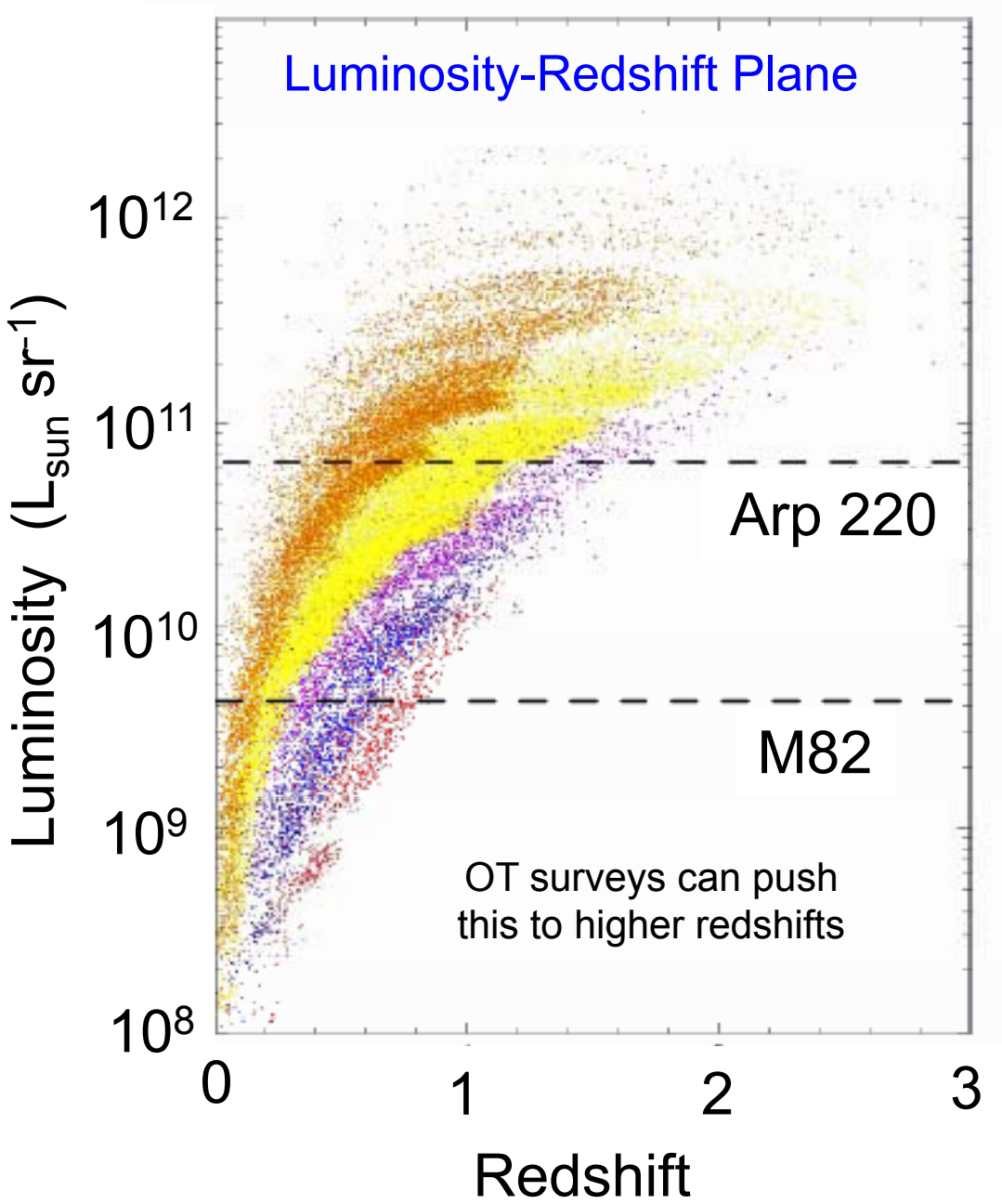


Sources in the cluster A1835

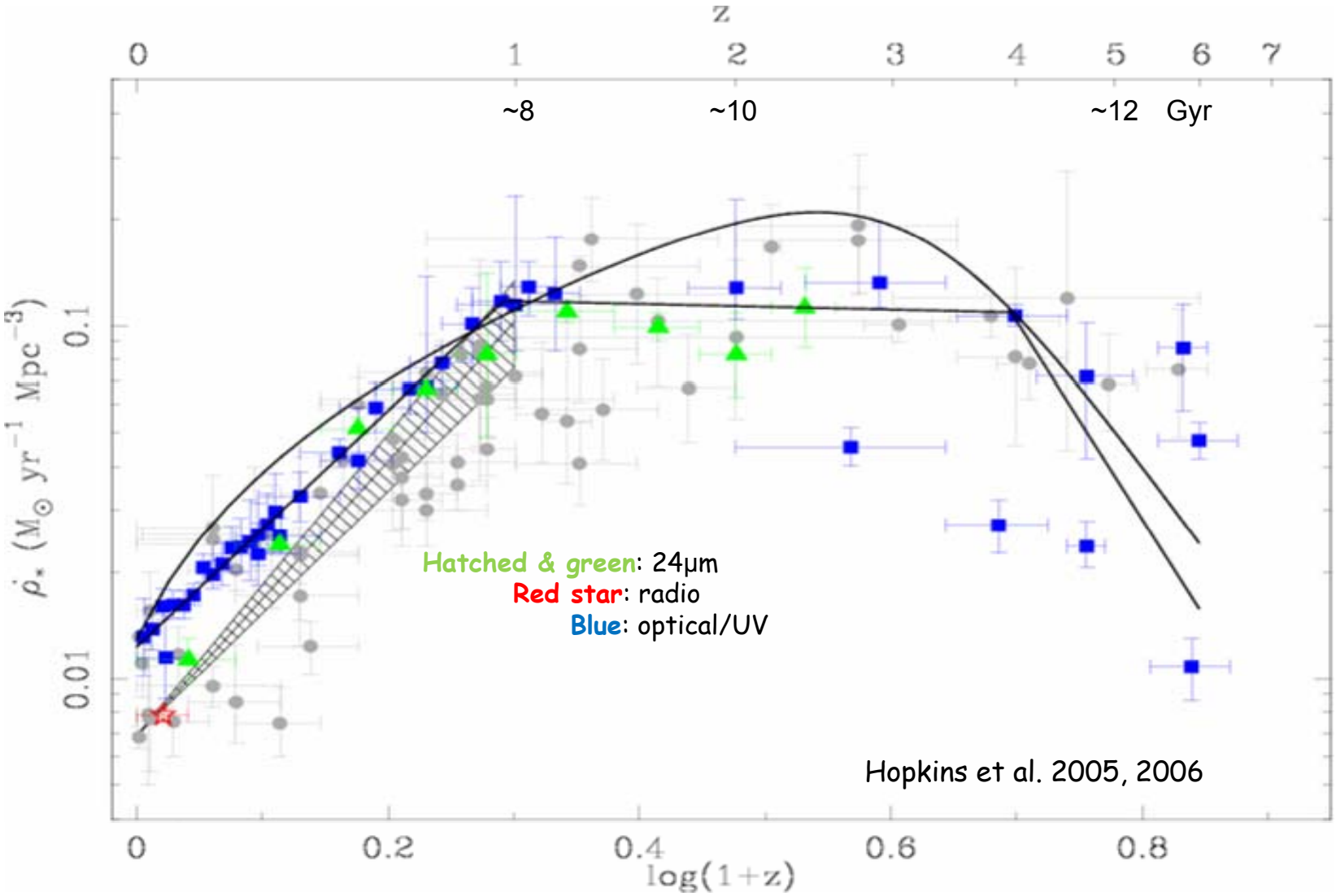
Wedding Cake Survey

smallest areas at the largest depth
to probe L_{Bol} over a wide redshift range

Level	A (Sq. deg.)	Fields	250um Conf.Depth mJy
Level-1	0.04	GOODS-S	11
Level-2	0.04	GOODS-N	11
Level-3	0.25 0.25 0.25	GOODS-S Groth Strip Lockman	11
Level-4	2 2	COSMOS XMM-LSS	21
Level-5	10	Spitzer field(s)[4]	21
Level-6	50	Spitzer fields[6]	61

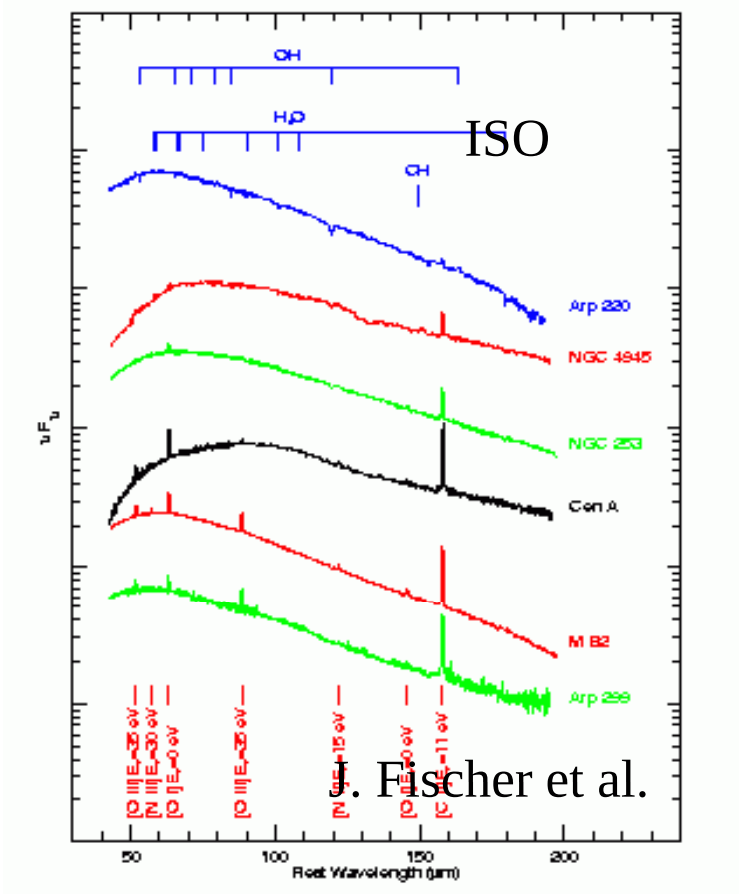


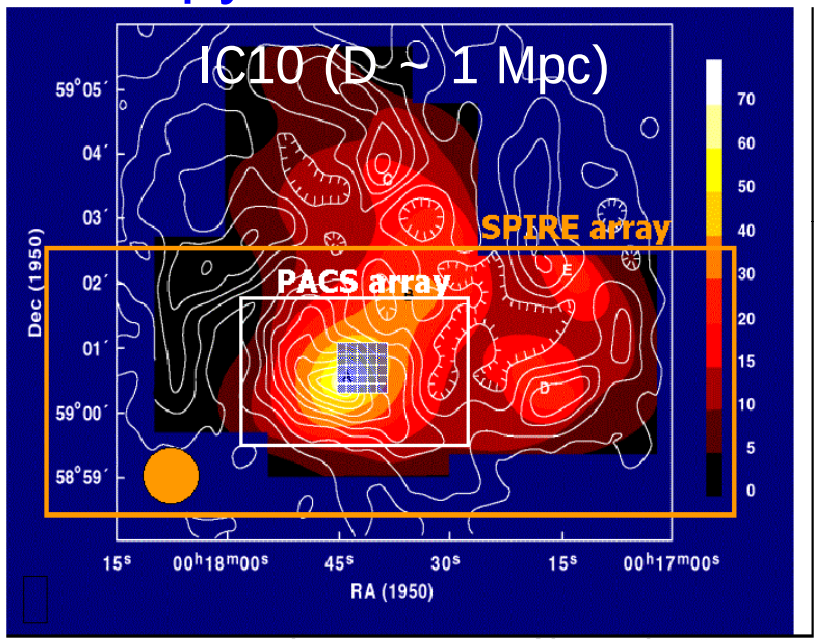
The Lilly – Madau plot
star fomation along the history of the universe

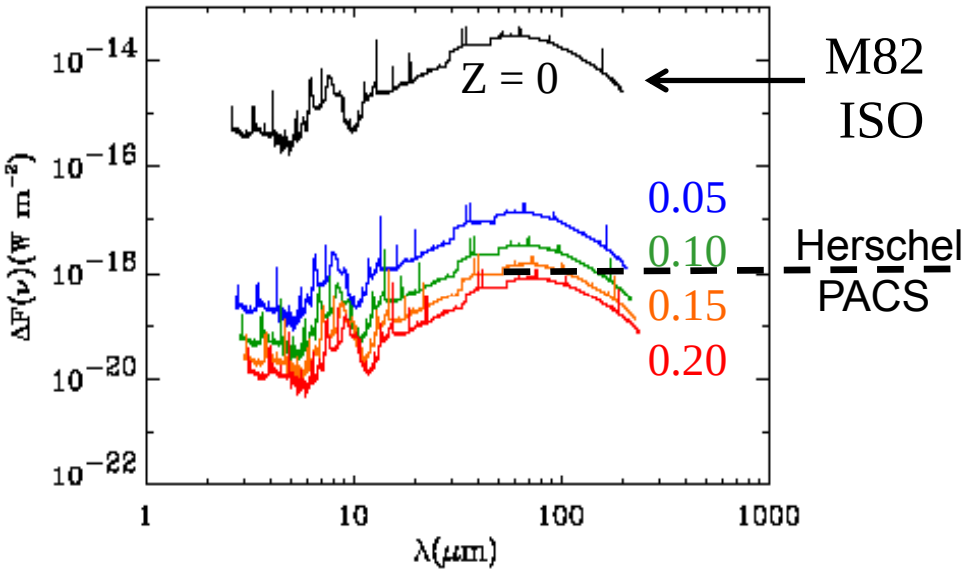


Photometry and Spectroscopy of Galaxies

- Detailed SEDs and dust properties
- Chemistry, metallicity evolution
- AGN vs. starburst
- Testing unified schemes
- Templates for high-redshift studies





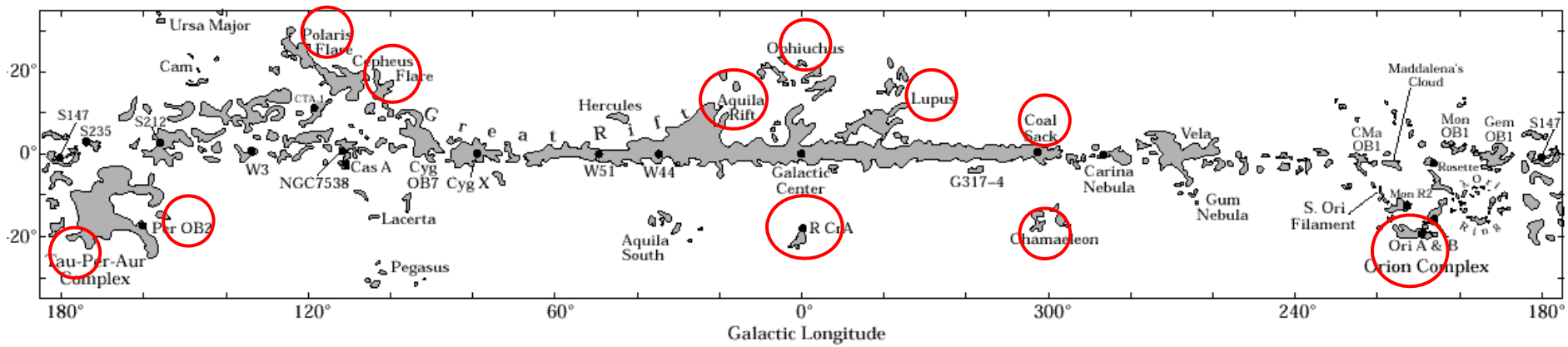


Galactic Astronomy

The photometric study of the nearby star forming regions

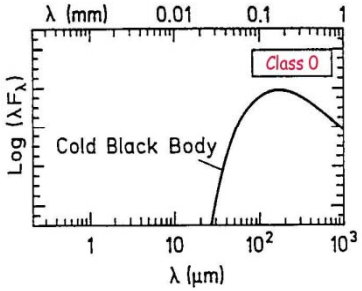
A Key project for the survey of the nearby (<500 pc) star forming regions

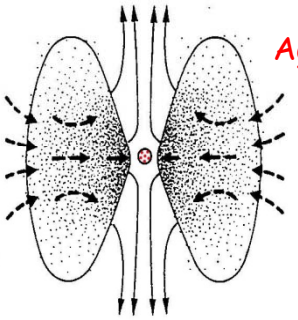
- the origin of IMF
- complete samples of protostars and pre-collapse cores down to ~ 0.03 $M_{\odot}$
- accurate mass, luminosity, temperature, lifetimes
- the evolution of the circumstellar material



LOW MASS STARS EVOLUTION

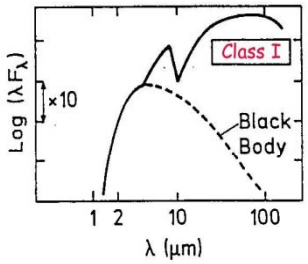
Lada e Wiking 1984
Andrè et al. 1993

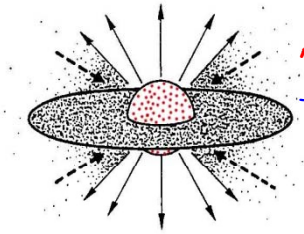




Age =10^3 10^4 yr

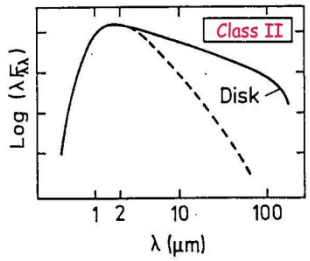
$M_{env} > M_{star}$
FIR → Submm

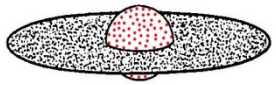




Age ~10^5- 10^6 yr

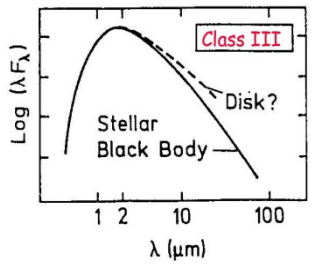
THICK ENVELOPE
IR → Submm





Age ~ 10^6 - 10^7 yr

THICK DISK
$M_{disk} \sim 0.01 M_{\odot}$
V → FIR



Age ~ 10^7 - 10^8 yr

THIN DISK?
$M_{disk} \sim 0.003 M_{\odot}$
V → IR

PLANETS
BUILDING

Herschel is unique to discriminate the different preMain Sequence phases because it is very sensitive to circumstellar material.

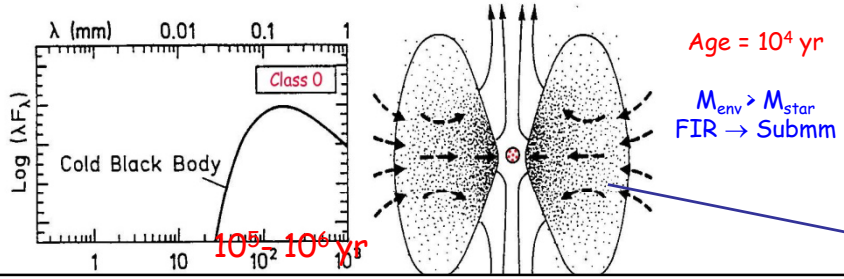
The evolution of a protostar is the evolution of its Circumstellar material

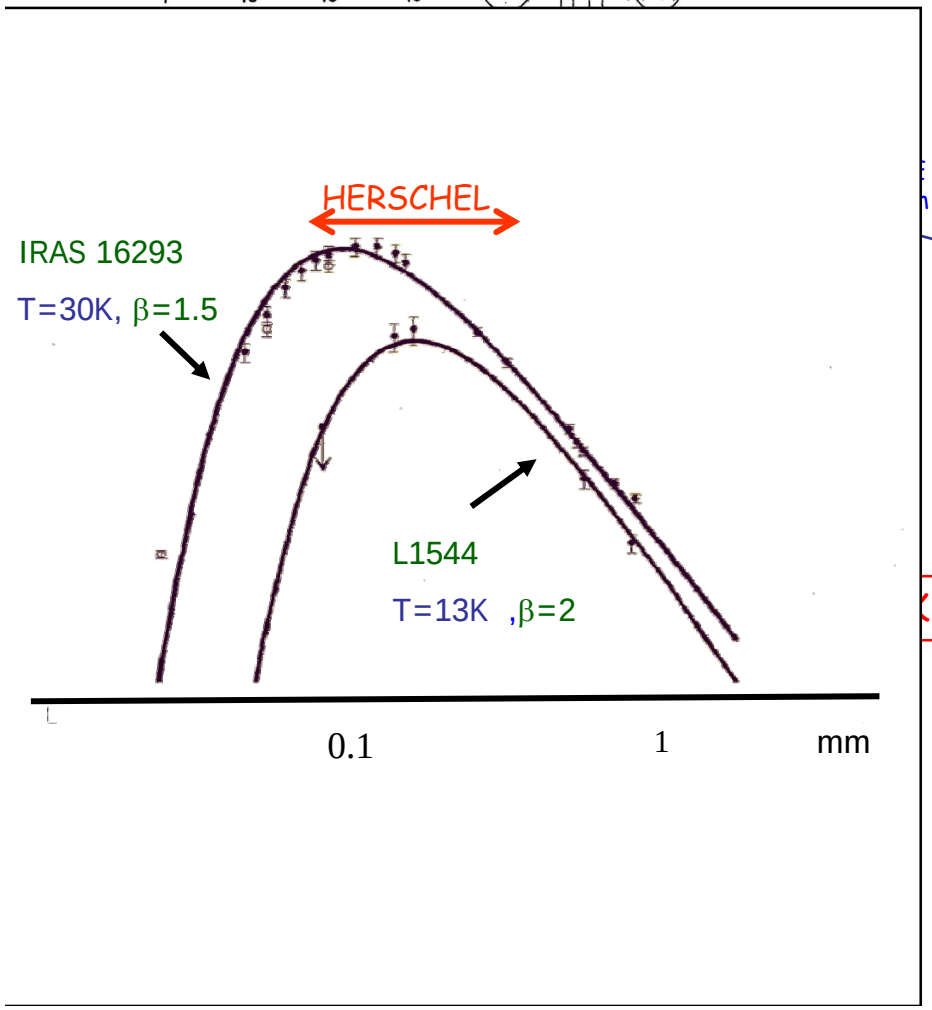
LOW MASS STARS EVOLUTION

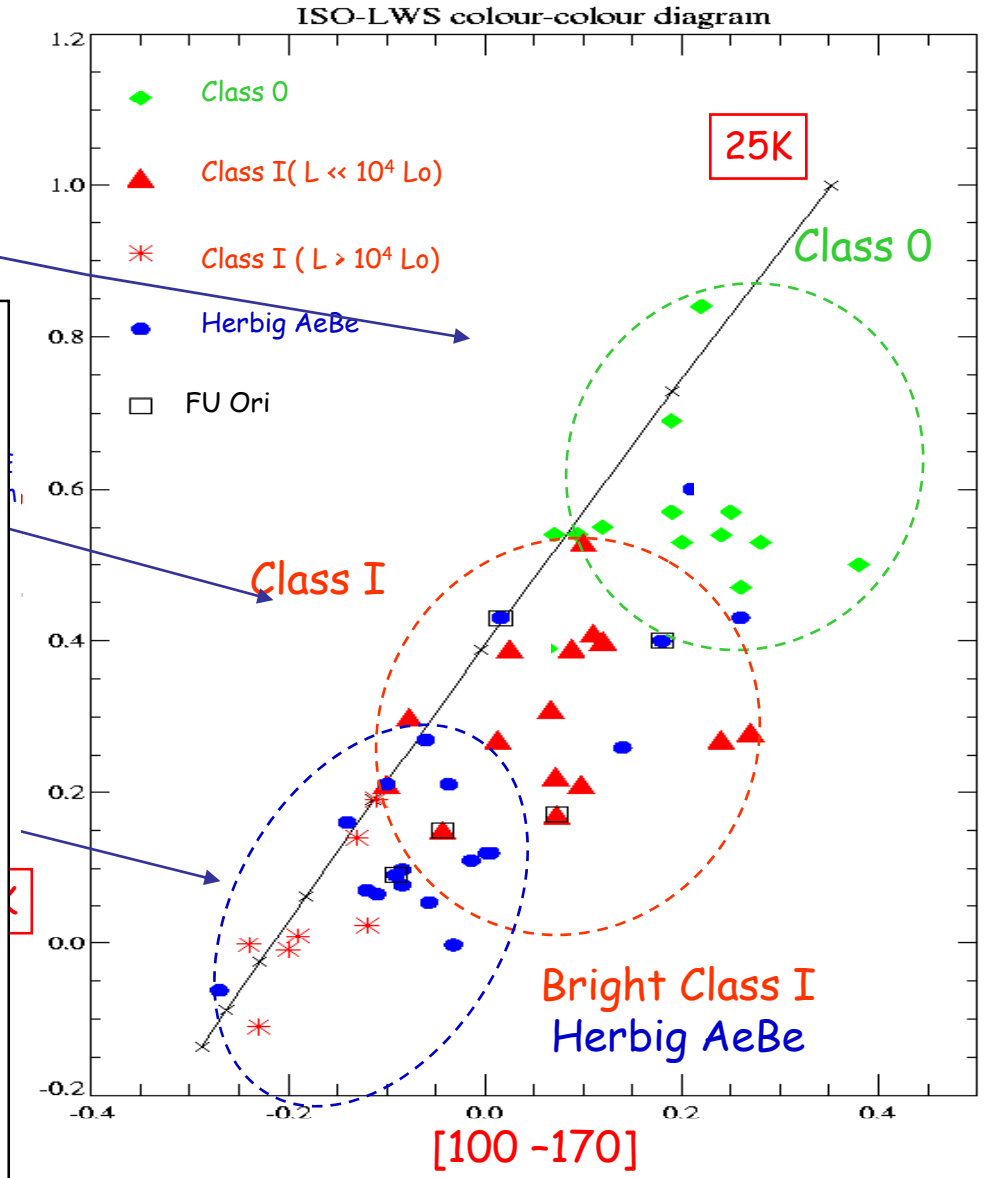
ISO LWS colour colour diagram

(Pezzuto et al. 1998, 2002)

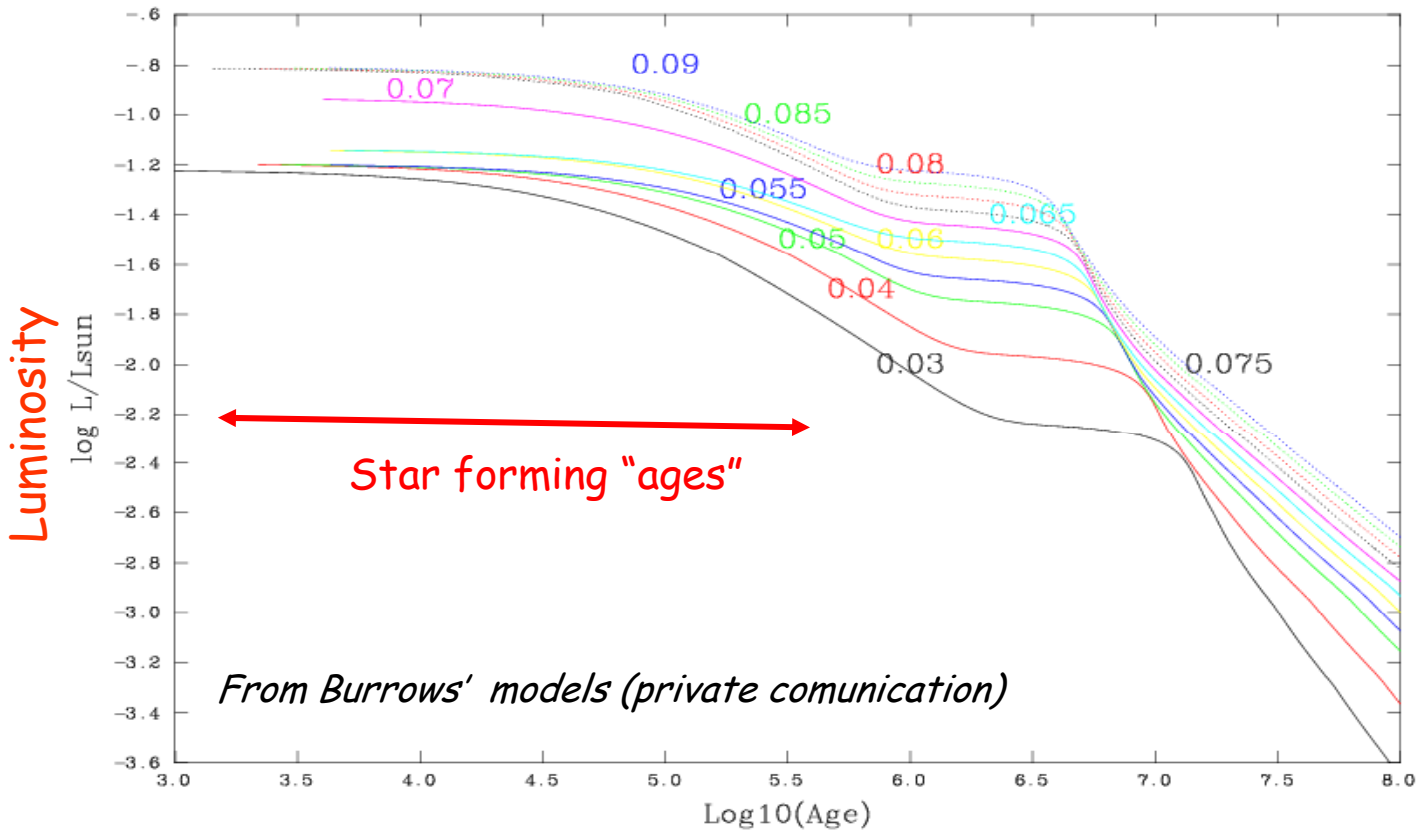
Lada e Wiking 1984
Andrè et al. 1993







In the selected areas we will detect nearly all the Low mass stars and Brown Dwarfs of the selected regions (the limit will be the cirrus noise)

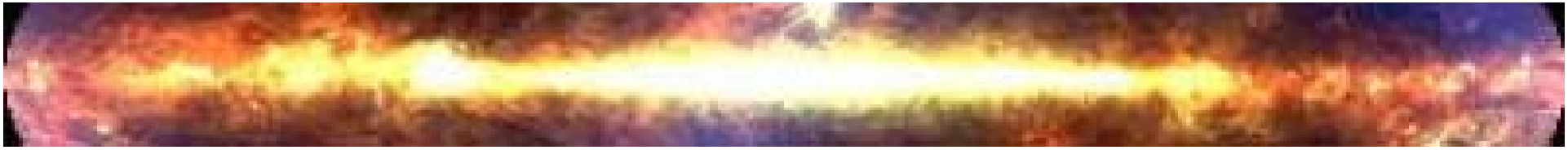


We will understand:

- **how Brown Dwarfs form:** **do they form like planets or like stars (with disks)?**
- **how many can we expect to find in the Universe?**
- **which is their contribution to dark matter?**

Hi-GAL

A Herschel Key-Project for the Far-IR mapping of the inner Galactic Plane

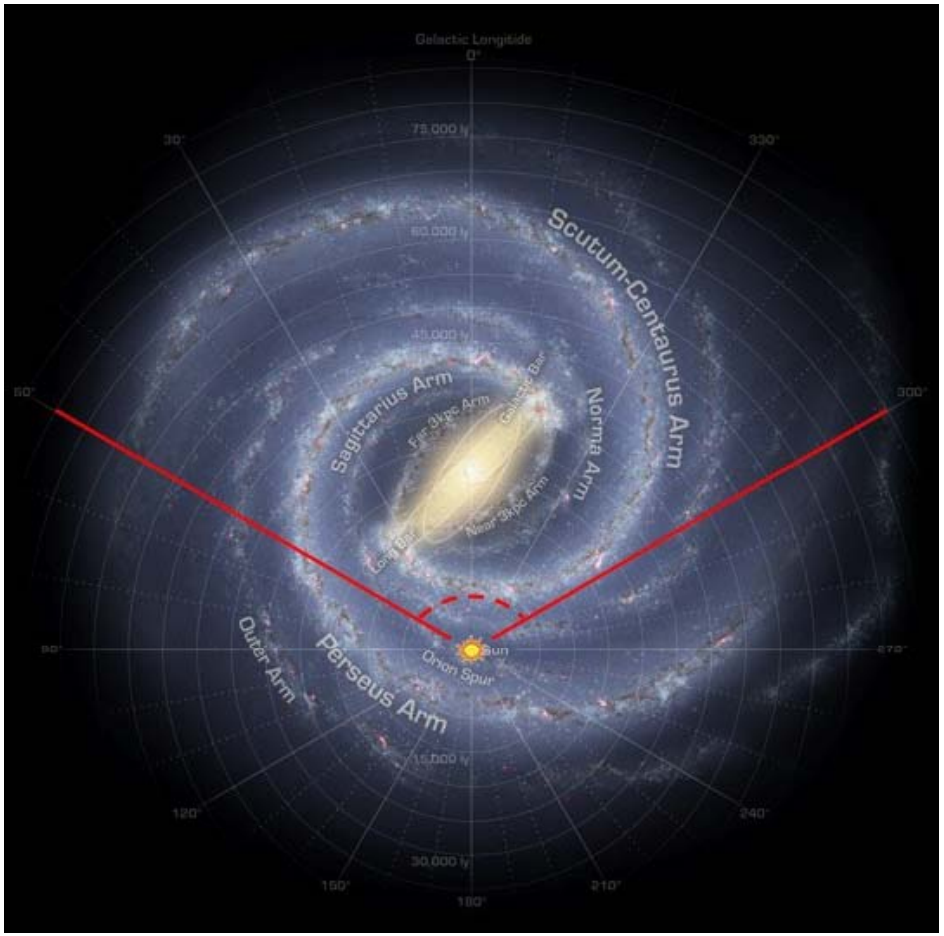


Toward a Predictive Global Model of Galactic Star Formation

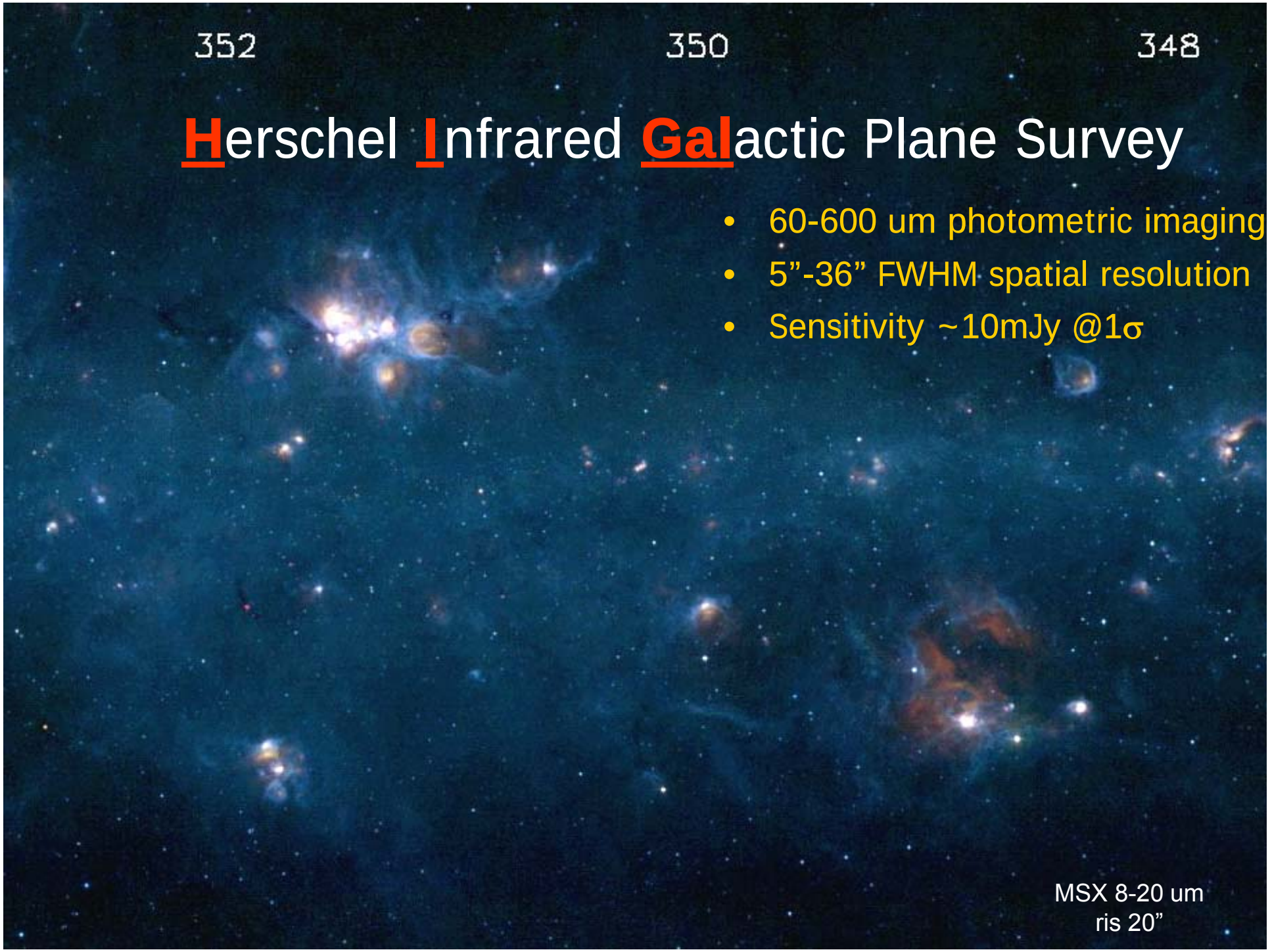
- Measure the star formation rate and history Galaxy-wide
- The High-Mass Star Formation Timeline
- Cold dust in the Galactic Plane and the Formation of Molecular Clouds
- Understanding star formation laws and the nature of thresholds as a function of ISM properties across a full range of galactocentric radii metallicity and environmental conditions
- Determining the relative importance of global *vs* local, spontaneous *vs* triggering, agents that give rise to star formation.
- Build bottom-up recipes and prescriptions useful for Xgal science

Hi-Gal

- 5 bands 70-500μm imaging using PACS and SPIRE in Parallel Mode with crossed-rasters
- 6”-35” resolution across the wavelength range
- 1σ nominal sensitivity ~20mJy, but likely limited by cirrus confusion
- -60°<l<60° - |b|<1°, i.e. the GLIMPSE and MIPSGAL areas



We will use 343 hours (~20 days) of observing time to obtain the Galaxy-wide Census, Luminosity, Mass and SED of dust structures at all scales from massive YSOs to Spiral Arms



Herschel Infrared Galactic Plane Survey

- 60-600 um photometric imaging
- 5”-36” FWHM spatial resolution
- Sensitivity ~10mJy @1σ

The Hi-GAL Team

- **IFSI-Rome**
  - S. Molinari
  - A.M. DiGiorgio
  - S. Pezzuto
  - M. Benedettini
  - F. Faustini
- **Oss. Arcetri**
  - L. Testi
  - R. Cesaroni
  - L. Olmii
- **Univ. Roma 1**
  - P. DeBernardis
  - S. Masi
  - F. Piacentini
- **Univ. Roma 2**
  - P. Natoli
  - G. DeGasperis
- **Univ. Lecce**
  - F. Strafella
  - D. Elia
- **Oss. Catania**
  - G. Umana
- **IRA-Bo**
  - J. Brand
- **IASF-Bo**
  - L. Valenziano

- **IPAC/Caltech**
  - A. Noriega-Crespo
  - B. Ali
  - B. Schulz
  - S. Lord
  - S. Carey
  - W. Reach
- **JPL**
  - H. Yorke
  - P. Goldsmith
- **Berkeley**
  - M. Cohen
- **NRAO**
  - D. Shepherd
- **CfA**
  - H. Smith
  - Q. Zhang

- **Beijing Obs.**
  - M. Huang
  - J. Li

- **Univ. Toronto**
  - P. Martin
- **Univ. Calgary**
  - R. Taylor
  - R. Plume
- **Univ. Laval**
  - G. Joncas
- **Herzberg**
  - J. DiFrancesco

- **MPIfR-Bonn**
  - P. Schilke
  - F. Schuller
  - F. Wyrowsky
- **MPE-Munich**
  - E. Sturm
  - T. Muller

- **Univ. Cardiff**
  - M. Griffin
  - D. Ward-Thompson
- **RAL**
  - B. Swinyard
  - T. Lim
- **Open Univ.**
  - G. White
- **UCL**
  - M. Barlow
- **Univ. Hertsf.**
  - A. Chrysostomou
  - M. Thompson
  - P. Lucas
- **Univ. Leeds**
  - M. Hoare
- **Univ. Liverpool**
  - T. Moore

- **KU Leuven**
  - C. Waelkens
  - J. Blommaert

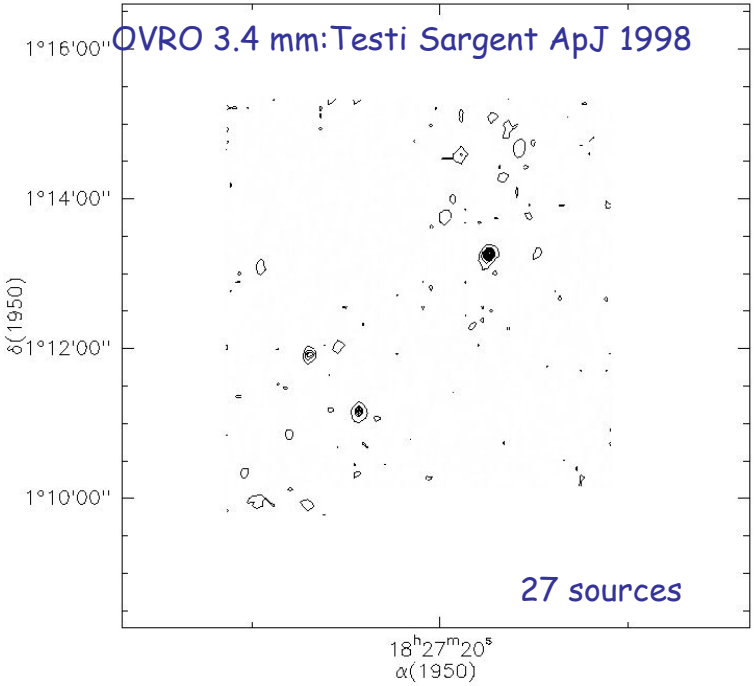
- **CESR-Toulouse**
  - J.P. Bernard
  - M. Giard
  - I. Ristorcelli
  - C. Joblin
- **IAS-Paris**
  - A. Abergel
  - F. Boulanger
  - M-A. Miville-Deschenes
- **LAM-Marseille**
  - A. Zavagno
  - J.P. Baluteau
  - D. Russeil
- **CEA-Saclay**
  - P. Andrè
  - F. Motte
  - V. Minier
- **Obs. Bordeaux**
  - S. Bontemps

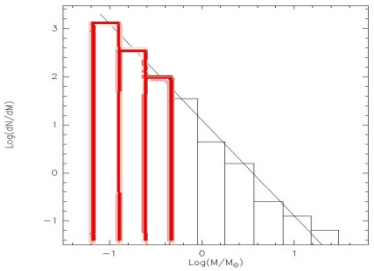
- **Nagoya Univ.**
  - Y. Fukui

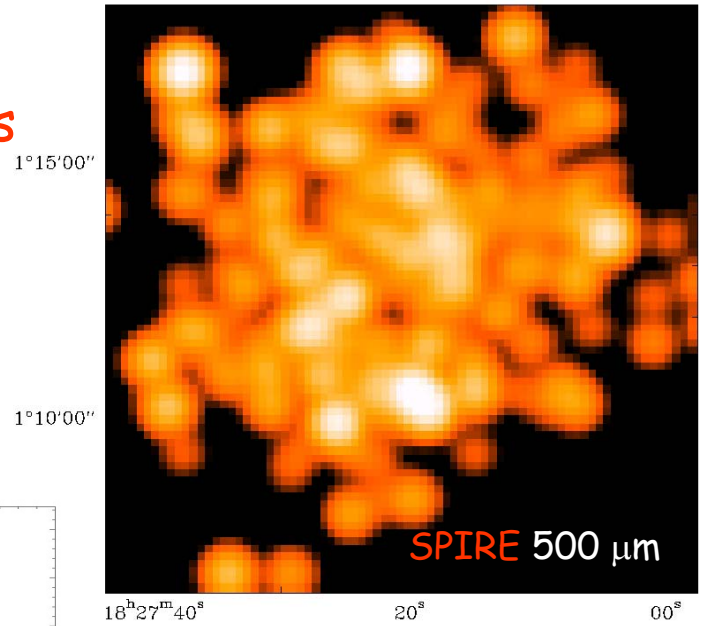
What limits the surveys ?

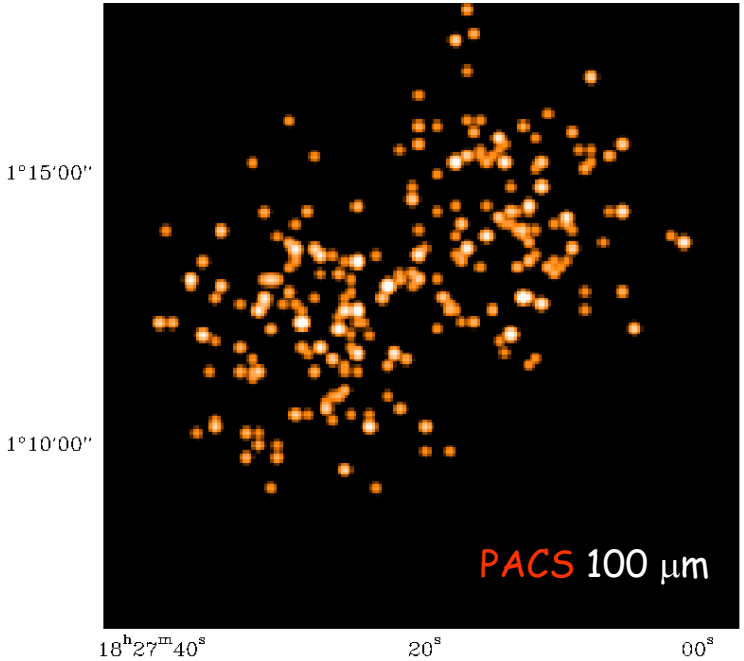
Serpens Core Simulations

50 mJy

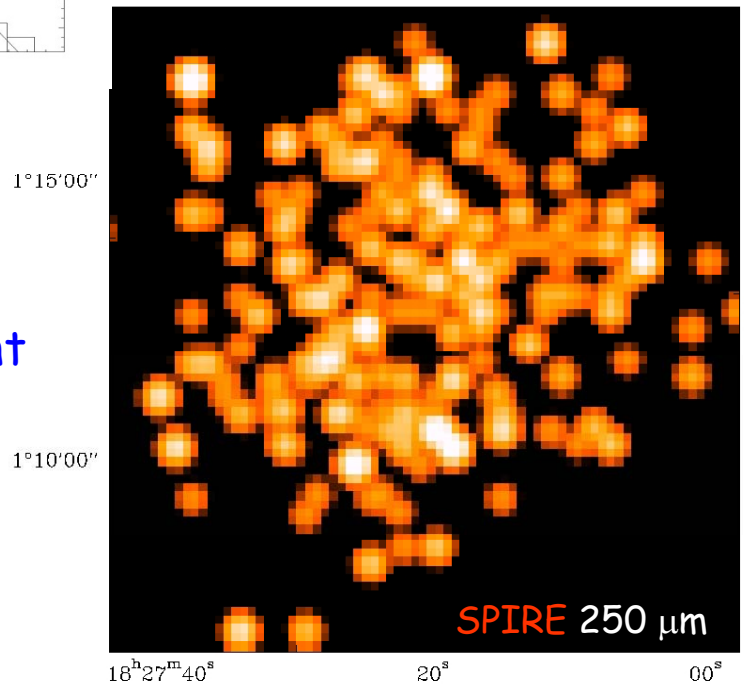






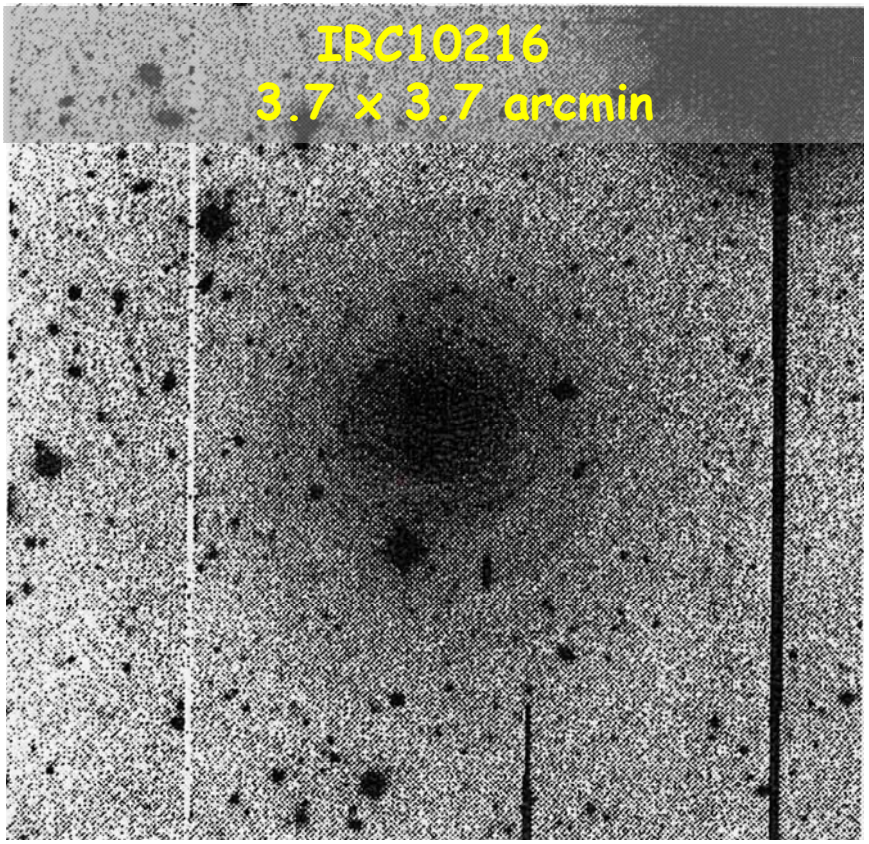


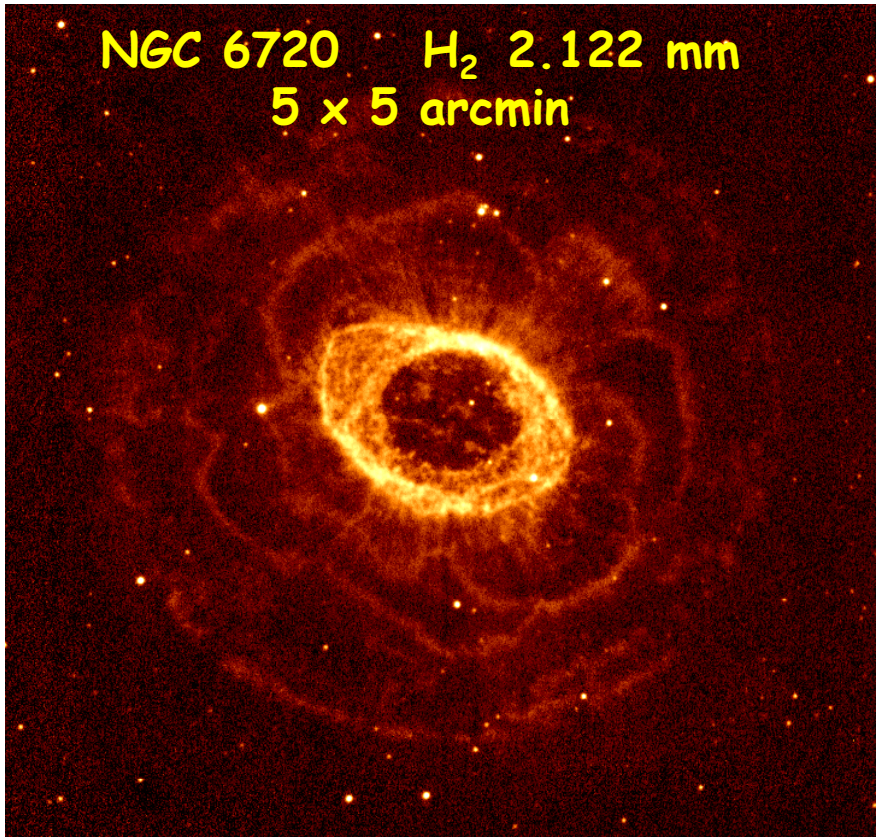
310 pc distant



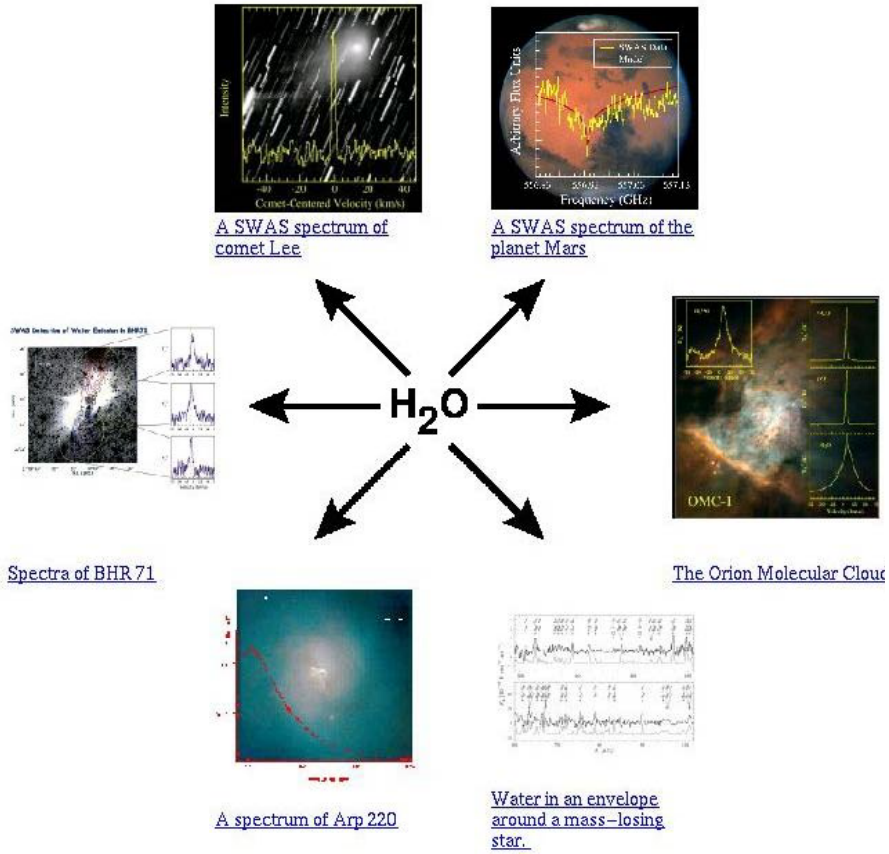
Ejected Dust Shells around Evolved Stars

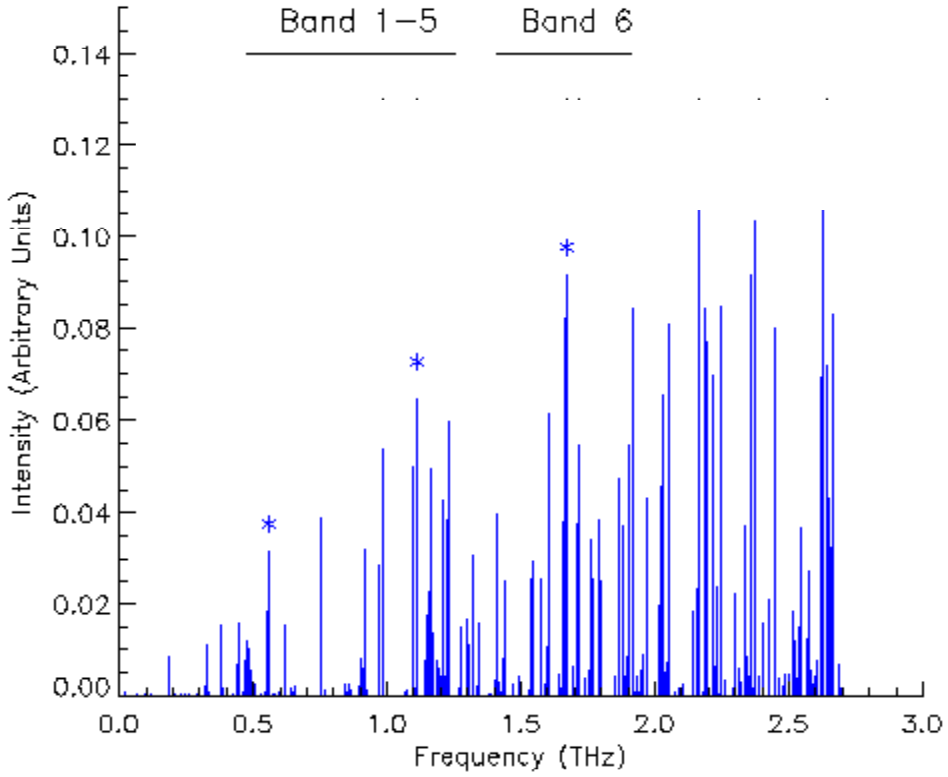
- Multiple shells around post-AGB stars
- Typical white dwarf mass ~ $0.5M_{\odot}$
  $\Rightarrow$ Large amounts of mass lost before white dwarf stage





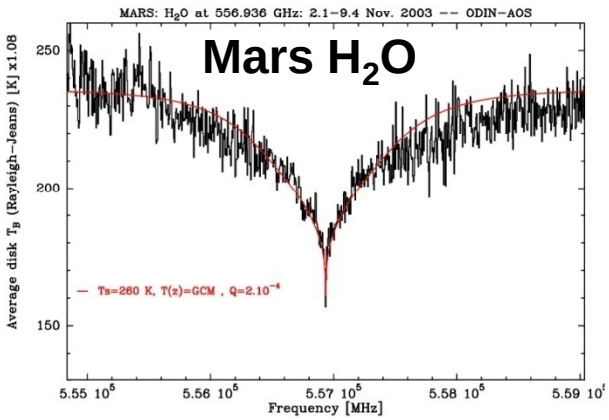
Water


A SWAS spectrum of comet Lee
A SWAS spectrum of the planet Mars
H_2O
Spectra of BHR 71
The Orion Molecular Cloud
A spectrum of Arp 220
Water in an envelope around a mass-losing star.


Band 1–5
Band 6
Intensity (Arbitrary Units)
Frequency (THz)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.0
0.5
1.0
1.5
2.0
2.5
3.0

The Solar System

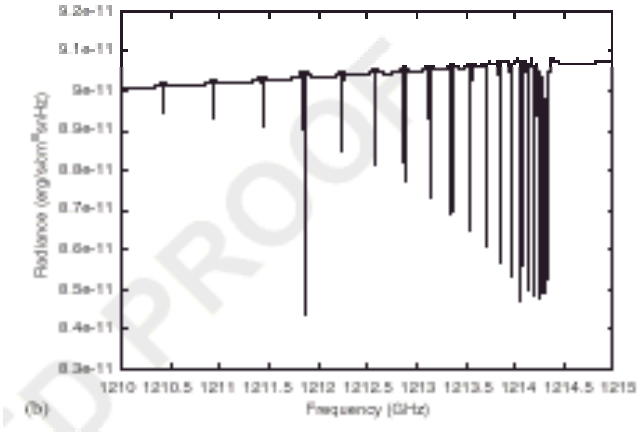
Spectroscopy of Planetary Atmospheres

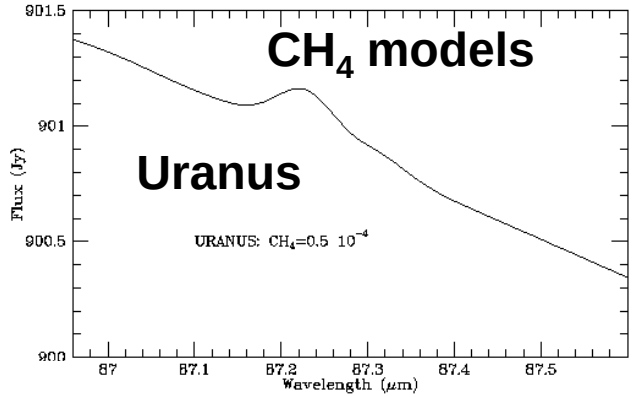


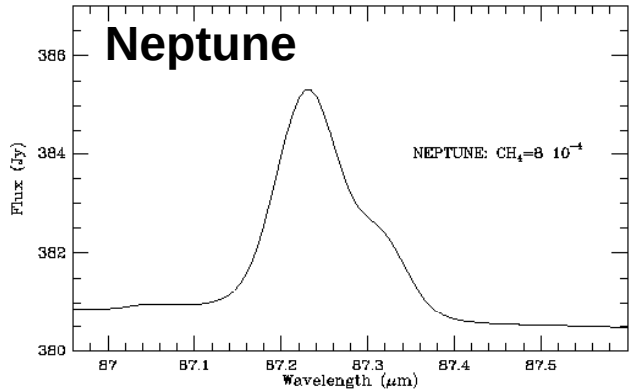
H_2O

- **Abundance, variability - Role of comet impacts**
- **Vertical distribution (HIFI) - Transport models**
- **Low-resolution mapping of J and S (PACS)**
  - Possible trapping in aurorae

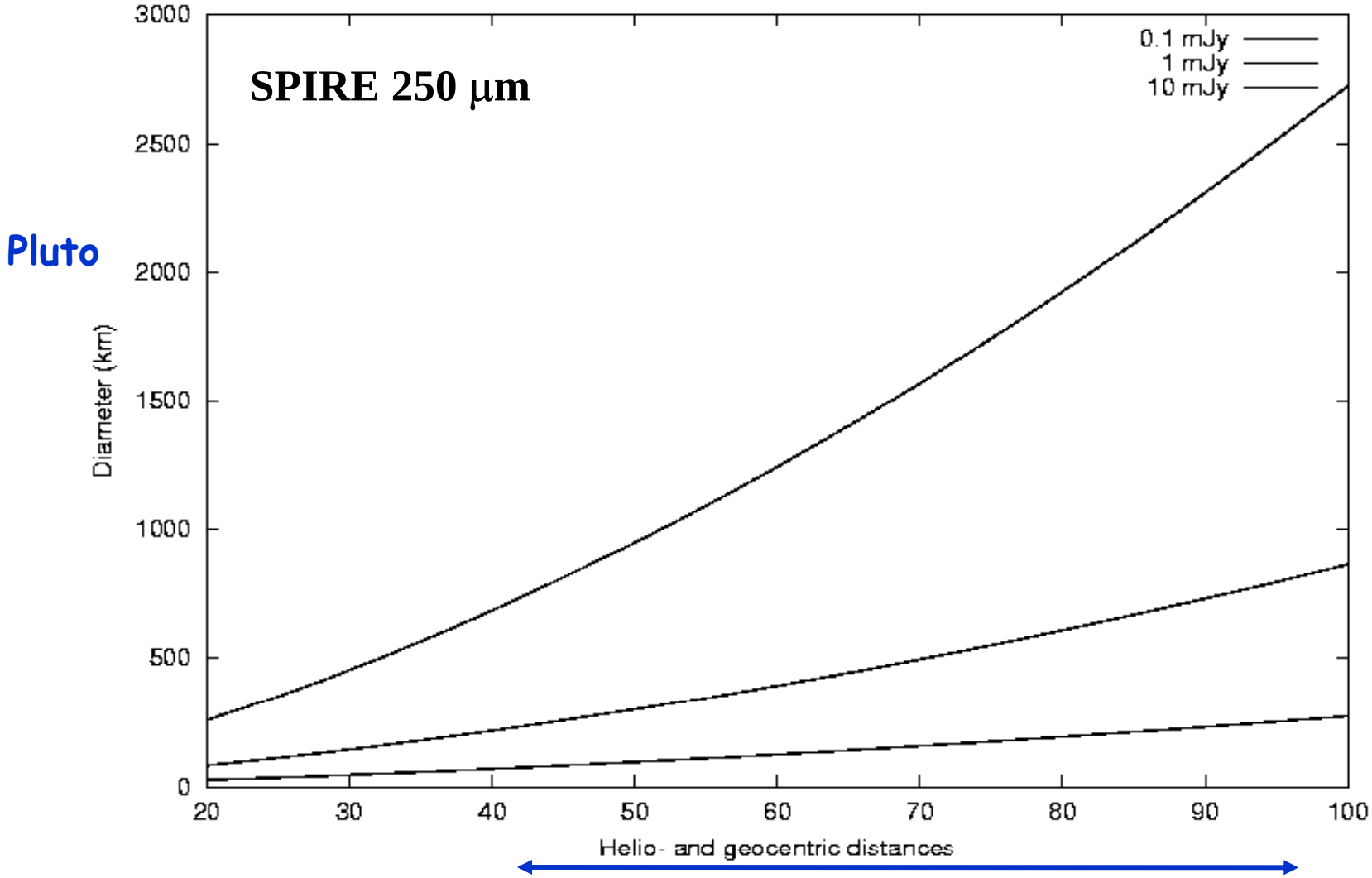
Mars O_3 model







KBOs – Photometry with PACS and SPIRE



Pluto

Kuiper Belt

Conclusions

- Herschel will be the first 3m class space observatory designed for FIR/submm imaging & spectroscopy,
- It will give us the only opportunity for about 1 decade to observe star and galaxy formation at the peak of their emission.
- It will observe the galaxies when they are producing most of their stars
- It will trace the history of star formation and the evolution of galaxies beyond z=2
- It will study the small bodies of the solar system and the planetary atmospheres
- It will carry detailed studies of the ISM of galaxies through spectroscopy (gas) and imaging (dust)