HERSCHEL Mission: Overview and Observing Opportunities

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ESTRELA workshop IRA 20 January 2009

Mission Name

Herschel, originally named **FIRST (Far Infrared and Sub-millimetre Telescope)**, was renamed in honour of the pioneering astronomers William and Caroline Herschel.

Spacecraft

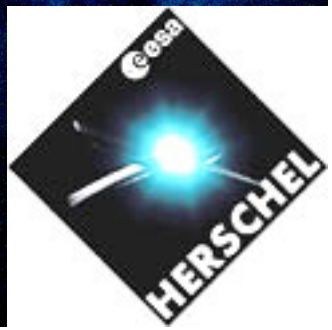
Launcher - Ariane-5 from Guiana Space Centre

Orbit - L2 **(1.5 million kilometres from the Earth)**

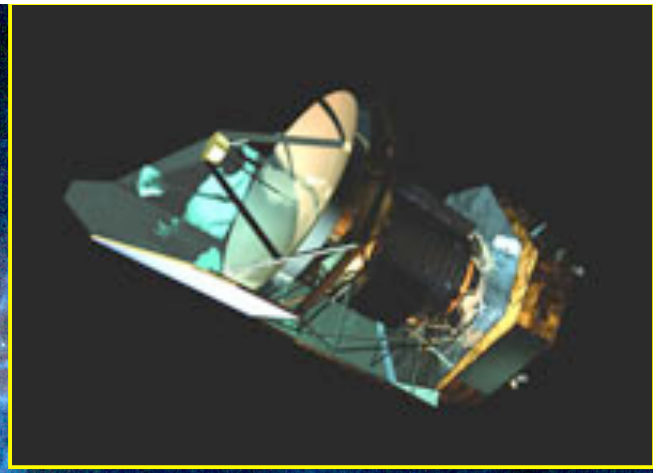
Launch Date - **April 2009?**

Mission Lifetime - 3 years nominal, 4 years extended

Wavelength - Infrared: **60 to 670 μm**



Hershel in a nutshell



- ESA cornerstone observatory
  - ~1/3 guaranteed time, ~2/3 open time
- FIR (57 - 670 μm) space facility
  - large (3.5 m) monolithic low emissivity passively cooled telescope
  - 3 focal plane science instruments
  - 3 years routine operational lifetime
  - full spectral access
  - low and stable background
- Unique and complementary
  - for $\lambda < 200$ μm larger aperture than cryogenically cooled telescopes (IRAS, ISO, Spitzer, Akari,...)
  - more observing time than balloon- and/or air-borne instruments
  - larger field of view than interferometers
- Launch in 2009

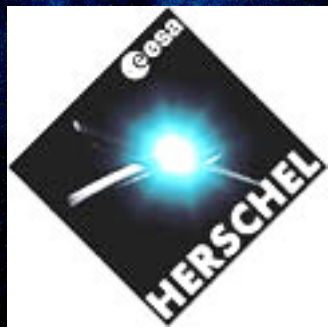
MISSION OVERVIEW

Herschel is the only space facility dedicated to the **sub-millimetre and far-infrared part of the spectrum**.

Herschel has the potential of **discovering the earliest epoch proto-galaxies, revealing the cosmologically evolving AGN-starburst symbiosis, and unraveling the mechanisms involved in the formation of stars and planetary system bodies**.

key science objectives:

★ formation of stars and galaxies,
★ interrelation between the two,
★ physics of the interstellar medium,
★ astrochemistry,
★ solar system studies.



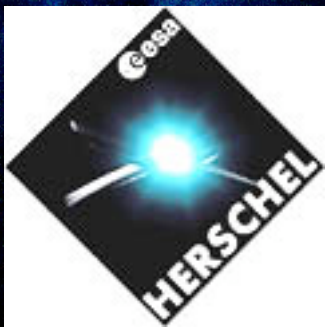
Instruments in Brief

The Herschel scientific instrument complement comprises three instruments:

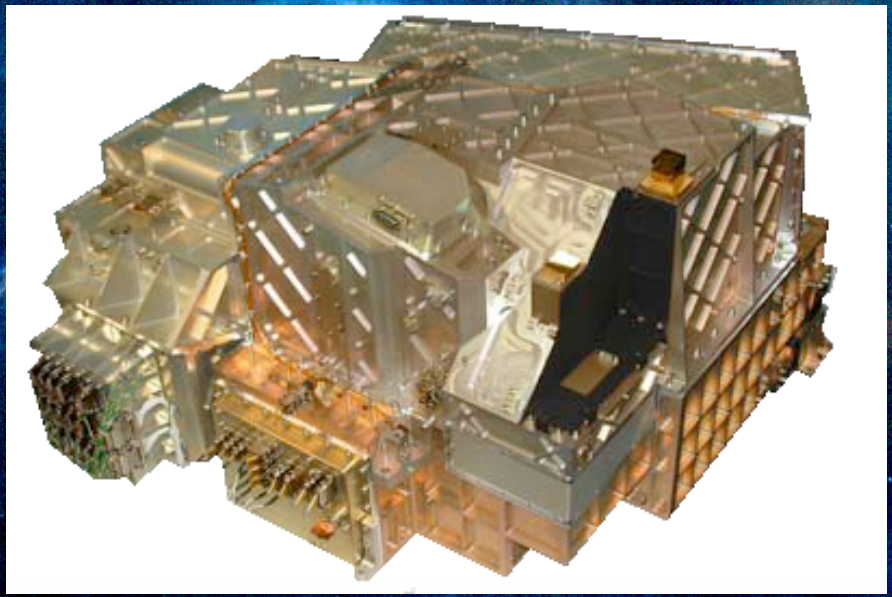
➔ **PACS** (PI: Albrecht Poglitsch, MPE, Garching, Germany) : imaging photometer and integral field line spectrometer for wavelengths between 60 and 210 μm

➔ **SPIRE** (PI: Matt Griffin, University of Wales, Cardiff, UK) : three band imaging photometer and and imaging Fourier transform
Spectrometer for wavelengths between 200 and 670 μm

➔ **HIFI** (PI: Thijs de Graauw, SRON, Groningen, The Netherlands) :
very high-resolution heterodyne Spectrometer from 480 to 1910 Ghz



Photodetector Array Camera and Spectrometer (PACS)



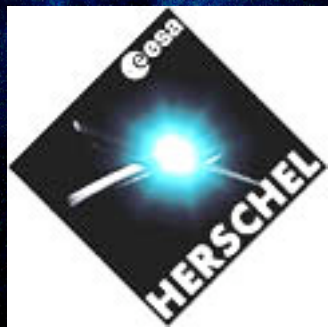
PACS is an imaging photometer and integral field line spectrometer for wavelengths between **60 and 210 μm**.

It employs two bolometer arrays for imaging photometry and two germanium/gallium photoconductor arrays to perform imaging line spectroscopy.

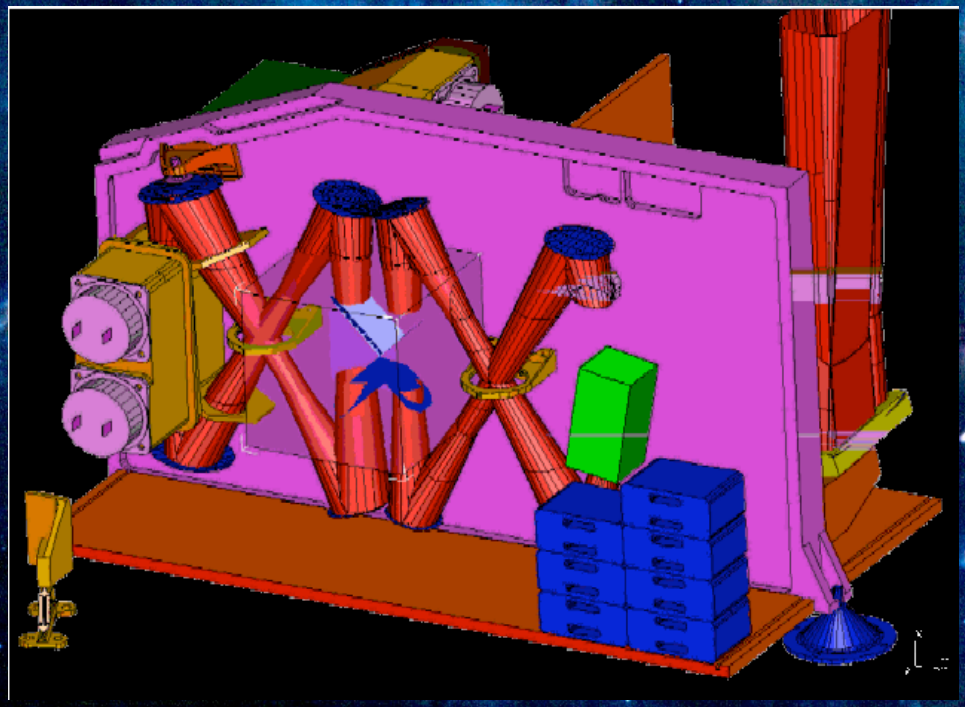
Photodetector Array Camera and Spectrometer (PACS)

★ In **photometry mode**, PACS will simultaneously image in **two bands**, one of either **60 - 90 μm** or **90 - 130 μm** together with **130 - 210 μm**, over fields of view of **1.75 x 3.5 arcmin** point source detection limit **~3 mJy (5σ, 1h)**, resolution: **6.6"** or **3.3"**

★ In **spectroscopy mode**, PACS will image a field of about **50 x 50 arcseconds**, resolved into 5 x 5 pixels, with an instantaneous velocity coverage of about **1500 km s^{-1}** and a velocity resolution of between **150** and **200 km s^{-1}**.



Spectral and Photometric Imaging Receiver (SPIRE)



SPIRE comprises a three band imaging photometer and an imaging Fourier transform spectrometer. SPIRE employs arrays of spider-web bolometers with neutron transmutation doped (NTD) germanium

The photometer images a 4x8 arcminute field of view on sky in three bands simultaneously: 250 360 520 μm

Diffraction limited beams 18" 25" 36"

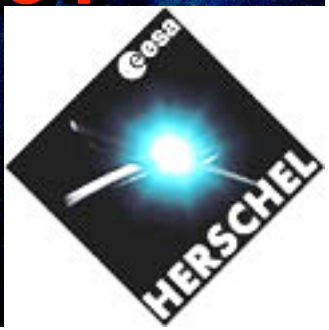
Point source detection limit: 2.4 2.8 3.1 mJy (5σ, 1h)

Spectral and Photometric Imaging Receiver (SPIRE)

The photometer has three observing modes:

* Point source photometry
* Field mapping, with a maximum field size of 4 x 4 arcminutes
* Scan mapping, with a field of view of 4 x 8 arcminutes

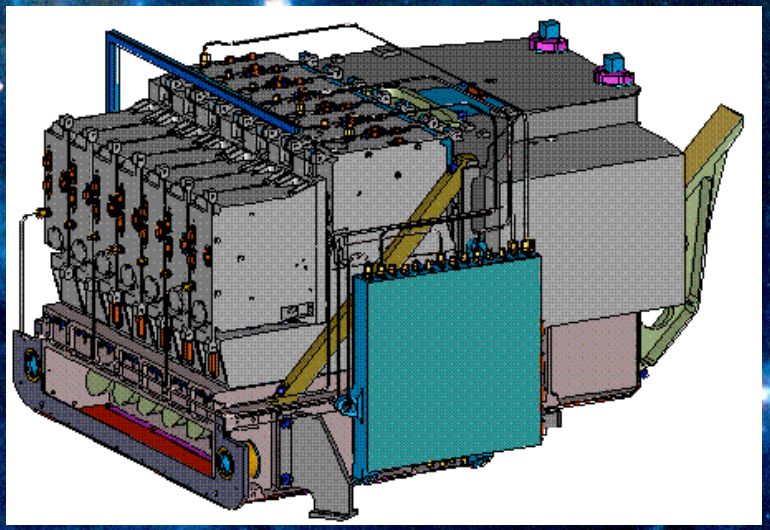
The spectral resolution of the SPIRE spectrometer can be adjusted between 0.04 and 2 cm^{-1} ($\lambda/\Delta\lambda$: 20 - 1000 at 250 μm). Circular field of view of 2.6 arcmin.



Heterodyne Instrument for the Far Infrared (HIFI)

HIFI is a **very high-resolution heterodyne spectrometer**

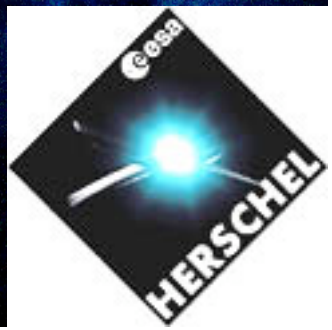
* 480 – 1250 GHz and 1410 – 1910 GHz
* 134 kHz – 1 MHz frequency resolutions **(R = 10^3 - 10^7 (300 - 0.03 km/s)**
* 4 GHz IF bandwidth
* 2 – 40" beam
* dual polarization ® sensitivity & redundancy



Two spectrometers: a **Wide Band** and a **High Resolution**: each capable of processing signals of both polarisations simultaneously.

Herschel mission phases

- Launch and early operations (2009?)
- Performance verification
- Routine science operations (36 months)
  - GT (32%) [open for GT holders only]
  - OT (68%) [open for all (incl GT hold)]
- Three Call for Proposals (AO) cycles
  - one Call for Key-projects [GT + OT]
  - two Calls for regular programmes
- Each AO divided in two parts
  - GT awarded first
  - OT awarded after GT in same cycle



Guaranteed Time (GT) Key-Projects

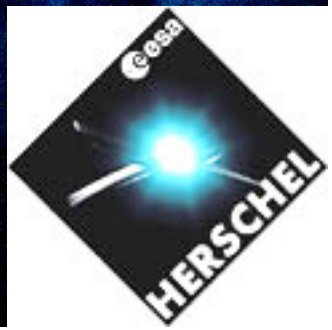
19 programmes for a total of 5878.9 hours

Solar System (1)

ISM/Star formation (10)

Galaxies/AGNs (5)

Cosmology (3)



Guaranteed Time (GT) Key-Projects

Cosmology Projects

"The Herschel Multi-tiered Extragalactic Survey (HerMES): Measuring the Infrared Galaxy Formation History of the Universe"
(PI: Seb Oliver, 900.0 hours allocated)

"The Dusty Young Universe: Photometry and Spectroscopy of Quasars at z>2"
(PI: Klaus Meisenheimer, 164.5 hours allocated)

"PACS Evolutionary Probe - A guaranteed time key programme survey of the extragalactic sky"
(PI: Dieter Lutz, 654.9 hours allocated)

PEP Italian Cols:
P. Andreani, A. Cimatti, R. Maiolino,
C. Gruppioni, F. Pozzi, G. Rodighiero

Open Time Key-Projects

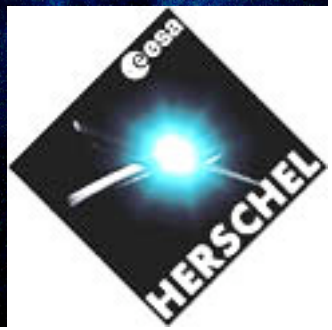
21 Programmes for a total of 5378.8 hours

Solar System (1)

ISM/Star formation (10)

Galaxies/AGNs (8)

Cosmology (2)



Open Time Key-Projects

21 Programmes for a total of 5378.8 hours

Cosmology Projects

"The Herschel Thousand Degree Survey"
(PI: Stephen Eales, 600.0 hours allocated)

"The Great Observatories Origins Deep Survey : far-infrared imaging with Herschel"
(PI: David Elbaz, 362.6 hours allocated)

PEP: PACS Evolutionary Probe

PI Dieter Lutz (Max Planck Institut fuer E. Physik)

PEP is a Herschel guaranteed time key programme survey of the extragalactic sky, aimed at studying the restframe far-infrared emission of galaxies up to redshift ~3, as a function of environment.

PEP is a comprehensive far-infrared photometric survey of the extragalactic sky. Blank field surveys using PACS at 170, 110 and 75 μm are supplemented with targeted observations of massive z~1 clusters and lensing clusters.

The PEP Fields

Blank fields

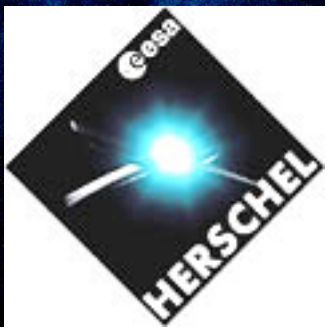
Field	100um image [2.5x2.5]	Center RA Dec	Area	P.A.of map on sky [deg]	Total Exp. [hours]	5 sigma (70) [mJy]	5 sigma (100) [mJy]	5 sigma(160) [mJy]
COSMOS		00:00:28.6 +02:12:21	85'x85'	0.0	213	--	6.13	8.63
Lockman Hole		10:52:43.0 +57:28:48	24'x24'	0.0	35	--	4.90	6.84
E-CDFS		03:32:25.0 -27:48:50	30'x30'	0.0	35	--	5.90	8.25
Groth Strip		14:19:17.4 +52:49:34	67'x10'	40	35	--	5.44	7.75
GOODS-S		03:32:30.4 -27:48:17	10'x15'	-10	113 113	1.61 --	-- 1.72	2.43 2.43
GOODS-N		12:36:54.9 +62:14:19	10'x15'	40	30	--	3.33	4.70

HerMES: The Herschel Multi-tiered Extragalactic Survey

PI Seb Oliver (University of Sussex)

HeMES is a 900 hr Guaranteed Time Key Project to study the evolution of galaxies at high redshift using ESA's Herschel Observatory. The project is carried out by the The SPIRE high-z Specialist Astronomy Group.

HerMES consists of a nested set of fields that will bring unprecedented depth and breadth to the study of infrared galaxies. Its main aim is to chart the formation and evolution of infrared galaxies throughout cosmic history.



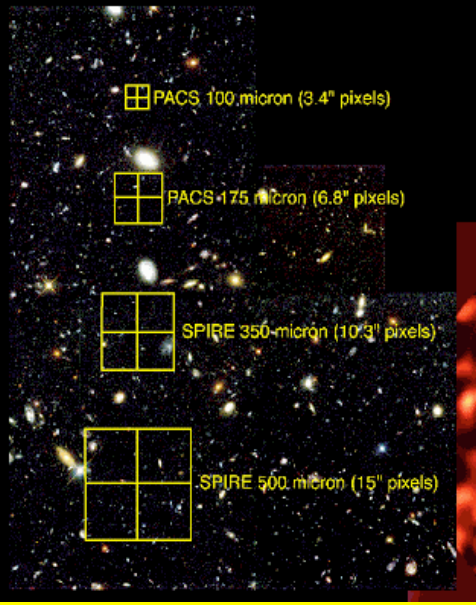
The HerMES Fields

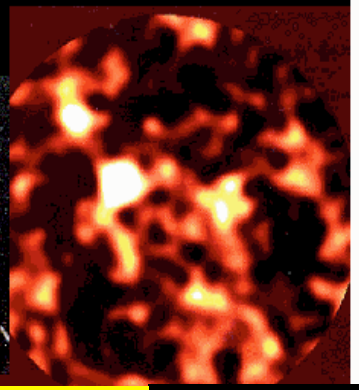
Level	Fields	Area	RA	Dec	Number of SCANs in each mode						5-sigma sensitivity (ignoring confusion)					Donut Area
					PACS-MED	PACS-SLOW 25"	PACS-SLOW 50"	PARALLEL	SPIRE-FAST	SPIRE-NOM	110	160	250	350	500	
Clusters Deep	Various	0.01	Various	Various		72				400	2.0	3.0	3.4	4.7	4.0	0.01
Cluster Shallow	Various	0.04	Various	Various		30				240	3.1	4.7	4.4	6.0	5.1	0.04
Level-1	GOODS-S	0.11	03h32m30s	-27d48m17s		112		4	20	240	1.6	1.7	4.2	5.7	4.9	0.11
Clusters Highz	Various	0.03	Various	Various		24				120	3.5	5.2	6.2	8.5	7.2	0.03
Level-2	GOODS-N	0.11	12h36m55s	+62d14m19s		30				60	3.1	4.7	8.8	12.0	10.2	0.11
	ECDFS	0.25	03h32m25s	-27d48m50s			16	4	20	38	5.9	8.3	8.7	11.9	10.1	0.14
Level 3	Lockman-ROSAT	0.25	10h52m43s	+57d28m48s			24	4	20	14	4.8	6.8	11.1	15.2	12.9	0.25
	UDS	0.25	02h17m48s	-05d05m45s			21	7		14	5.1	7.2	11.1	15.2	12.9	0.25
	Groth	0.25	14h19m17s	+52d49m34s			20	7		14	5.2	7.4	11.1	15.2	12.9	0.25
	Lockman-OWEN	0.25	10h46m00s	+59d01m00s			18	4	20	14	5.5	7.8	11.1	15.2	12.9	0.25
	HDFN	0.25	12h36m49s	+62d12m58s						30			12.4	17.0	14.4	0.14
Level-4	COSMOS	2	10h00m28s	+02d12m21s	52					40	6.2	8.7	10.8	14.7	12.5	2.0
	UDS	0.7	02h17m48s	-05d05m45s			7	7		14	8.3	11.8	11.1	15.2	12.9	0.5
	VVDS	0.7	02h26m00s	-04d30m00s			7	7		14	8.3	11.8	11.1	15.2	12.9	0.7
Level-5	XMM	5	02h21m36s	-04d39m00s				7			20.4	29.3	14.0	19.3	16.3	3.6
	ELAIS-N1-SCUBA	2	16h10m00s	+54d30m00s				7			20.4	29.3	14.0	19.3	16.3	2.0
	Bootes-SCUBA2	2	14h32m06s	+34d16m48s				7			20.4	29.3	14.0	19.3	16.3	2.0
	EGS-SCUBA2	1.3	14h19m12s	+52d48m00s				7			20.4	29.3	14.0	19.3	16.3	1.1
	CDFS	8	03h32m00s	-28d16m00s				4	20		27.0	38.8	14.0	19.3	16.3	7.8
	Lockman	11	10h45m00s	+58d00m00s				4	20		27.0	38.8	14.0	19.3	16.3	10.5
Level-6	XMM	9.3	02h21m20s	-04d30m00s				2			38.2	54.8	26.2	36.1	30.4	4.3
	ELAIS S1 SWIRE	7	00h38m30s	-44d00m00s				2			38.2	54.8	26.2	36.1	30.4	7.0
	ELAIS N1 SWIRE	9.3	16h11m00s	+55d00m00s				2			38.2	54.8	26.2	36.1	30.4	7.3
	ELAIS N2 SWIRE	4.8	16h36m48s	+41d01m45s				2			38.2	54.8	26.2	36.1	30.4	4.8
	NDWFS/Bootes	8	14h32m06s	+34d16m48s				2			38.2	54.8	26.2	36.1	30.4	6.0
	FLS	4.7	17h18m00s	+59d30m00s				2			38.2	54.8	26.2	36.1	30.4	4.7
	0444 Akari	7	04h41m24s	-53d22m12s				2			38.2	54.8	26.2	36.1	30.4	7.0

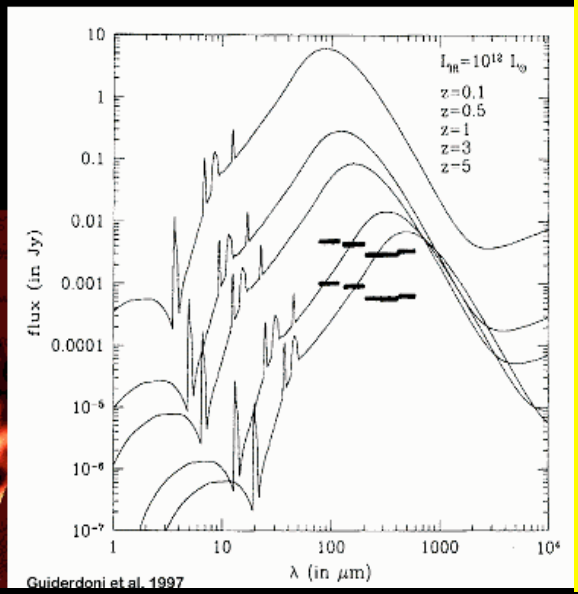
Notes:

1 Number of scans include the observations from overlapping but shallower AORS
2 "Area" is the area in this field at this depth
"Donut Area" is the area excluding deeper cores
"Cumulative Area" is the total area in the survey above deeper than this
3 PEP team observations

HERSCHEL and Cosmology

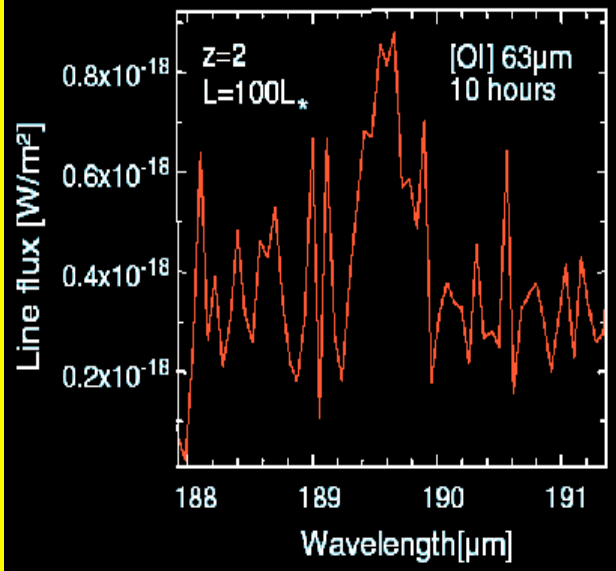


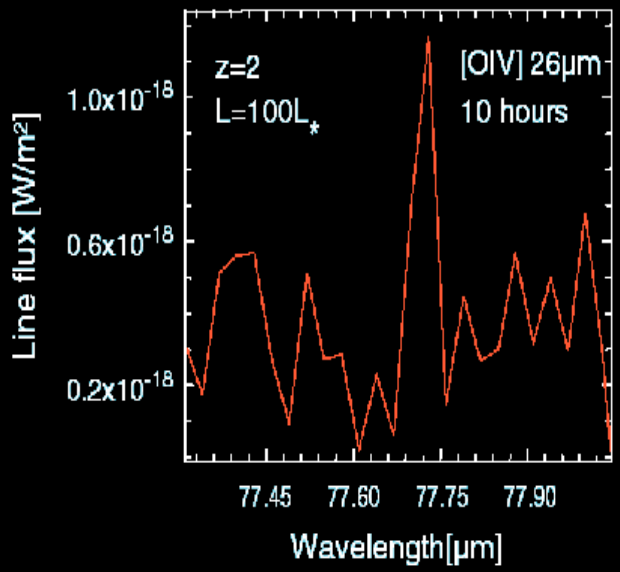


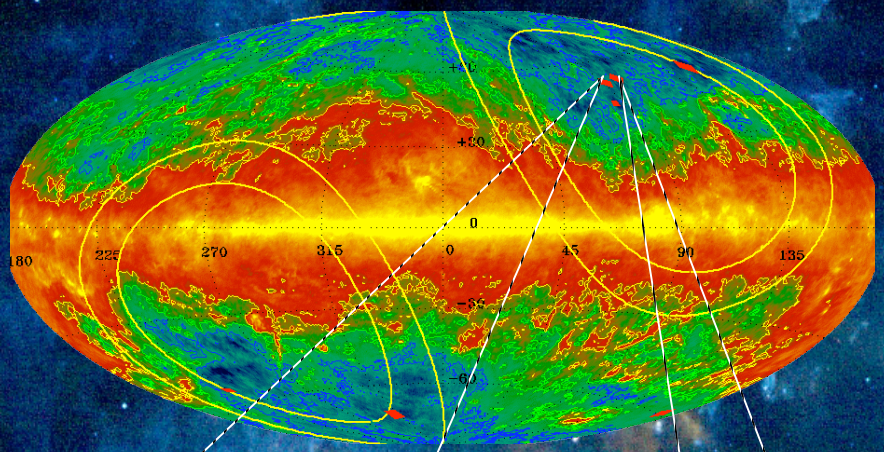


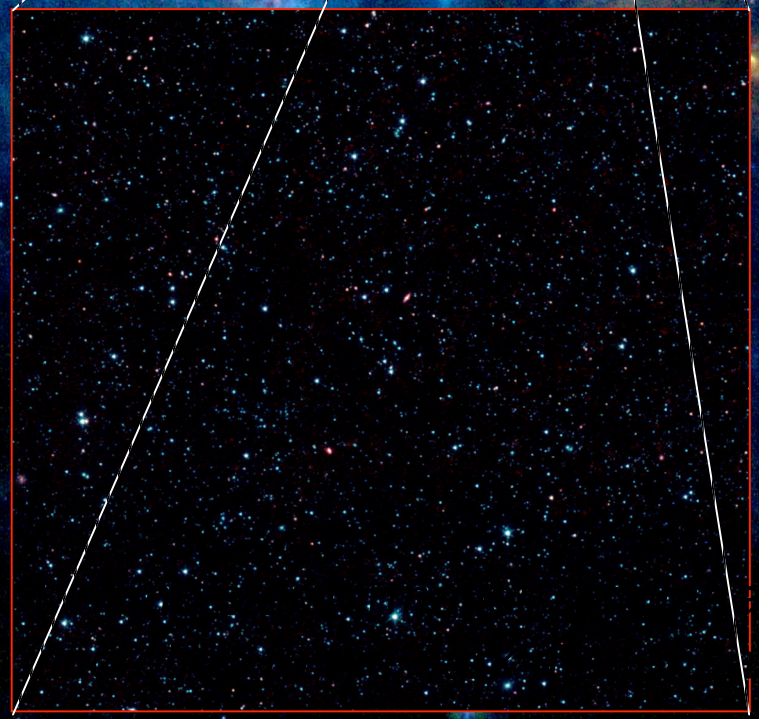
Deep multi-band potometric survey (PACS+SPIRE): search for FIR luminous galaxies at high z

Follow-up spectroscopy: what power sources (AGN/starburst) and how do they evolve?



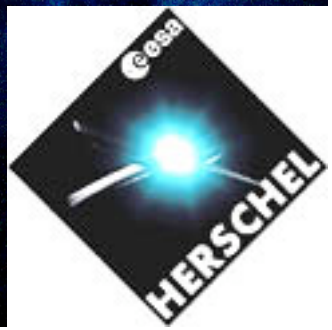






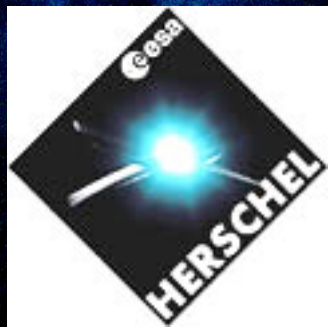
Census of the Universe

- Best Survey fields
- Photometric Coverage
  - X-ray --- XMM
  - UV --- Galex
  - Optical --- Various
  - Mid-IR --- Spitzer
  - Near-IR --- UKIDSS/VISTA
  - Far-IR -- Herschel
  - Sub-mm --- SCUBA-2/Apex
  - Radio -- -Various
- Redshift surveys...
  - Magellan 100k redshifts
  - AAT AAOmega
  - ESO-VLT VIMOS
  - Subaru FMOS
  - Hectospect AGES



Surveys for galaxy evolution

- Physics of galaxy evolution is very poorly understood
- Observationally constrained by photometric, imaging and spectroscopic surveys
- Survey requirements for are becoming achievable
  - Fair sample volume
  - Sample populations at significant luminosities
  - Sample all significant emission processes

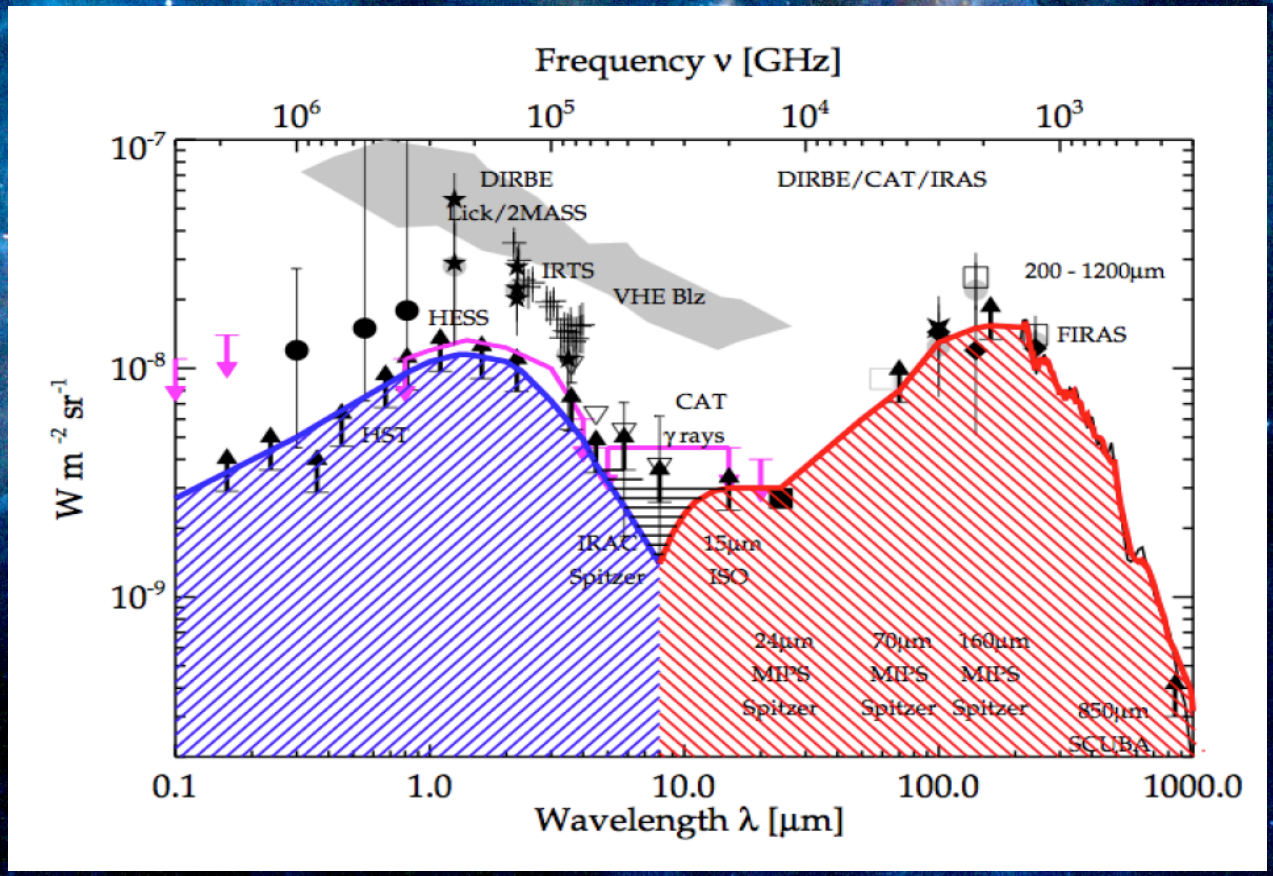


Surveys for galaxy evolution

- the usual strategy for cosmological surveys in terms of a wedding cake -
- a small area on the sky surveyed very deep,
- a larger area pretty deep, and
- finally a very large area to shallow limits.

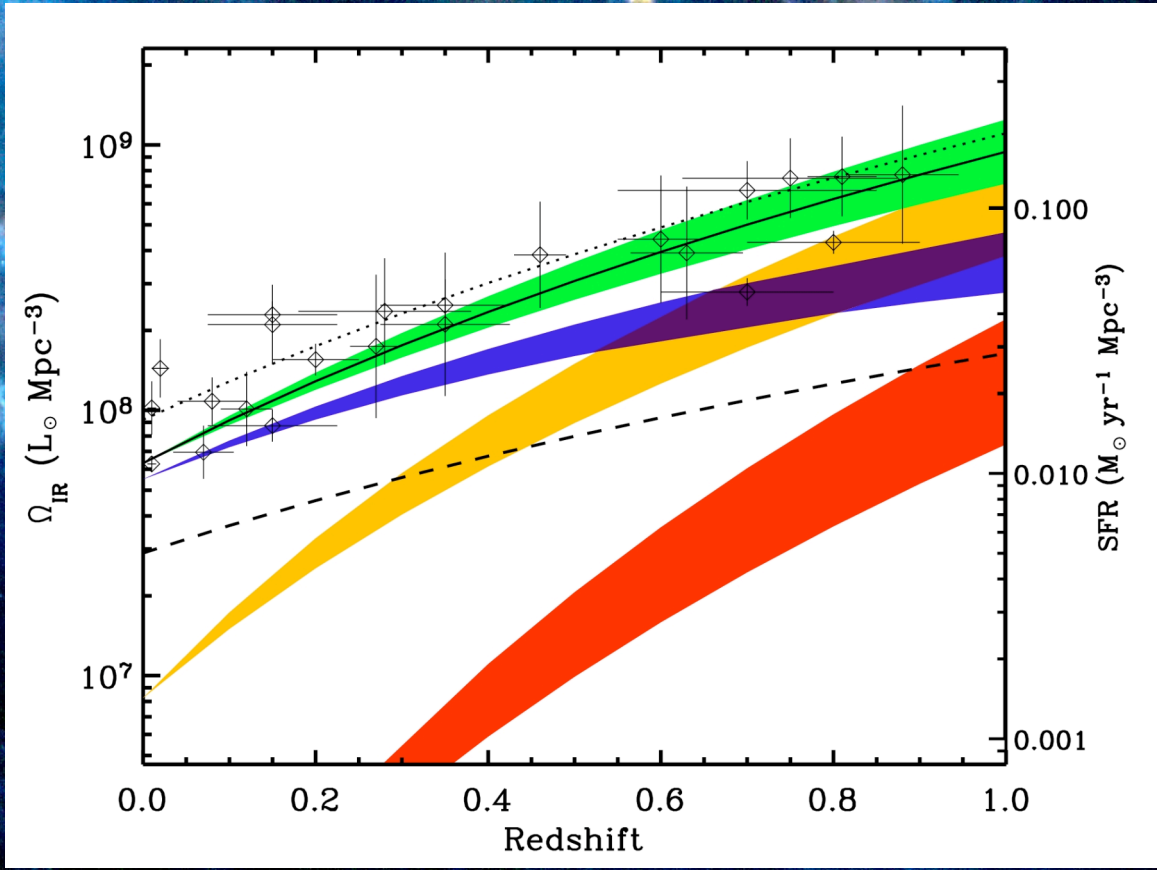
HERSCHEL

The Cosmic Far-Infrared Background Radiation



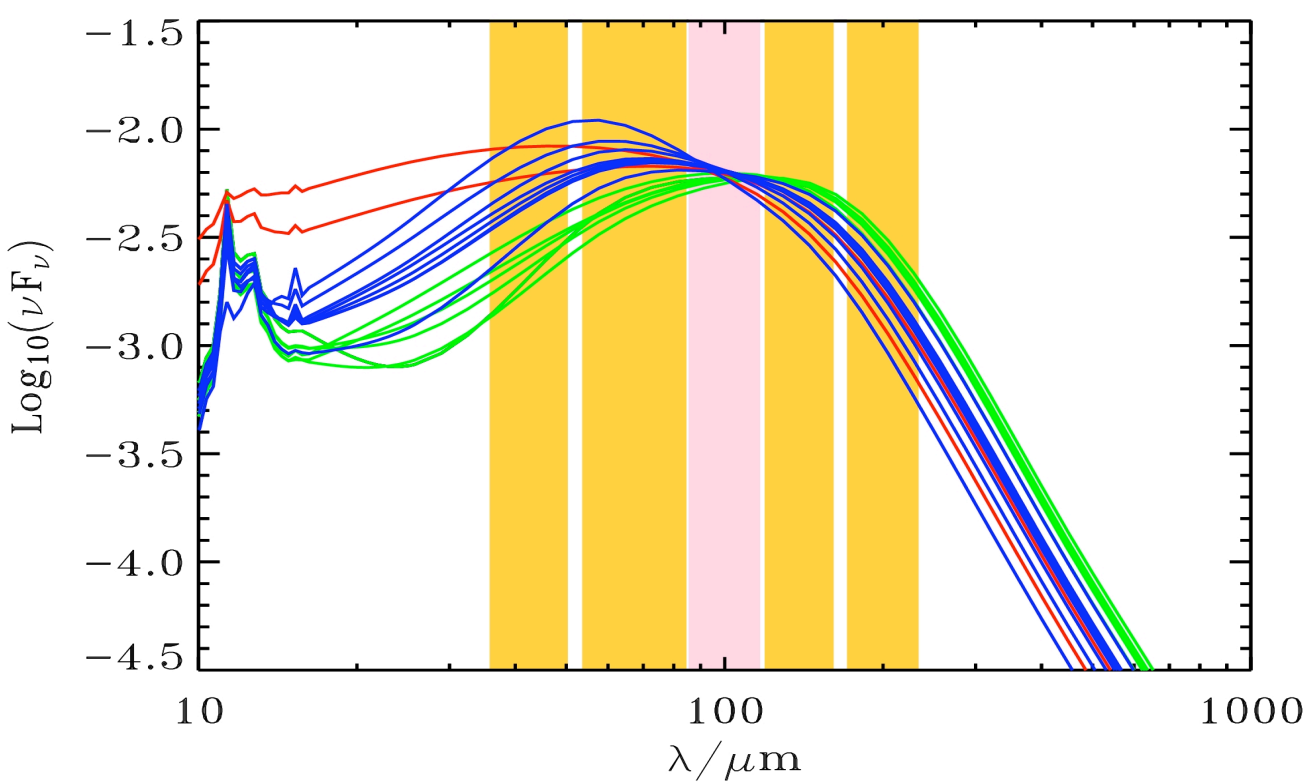
The integrated extragalactic background light in the far-infrared and submillimeter region of the spectrum is approximately equal to the integrated background light in the optical and UV part of the spectrum. To develop a complete understanding of galaxy formation, this background light must be resolved into galaxies and their properties must be characterized.

The Importance of the Luminous Galaxies



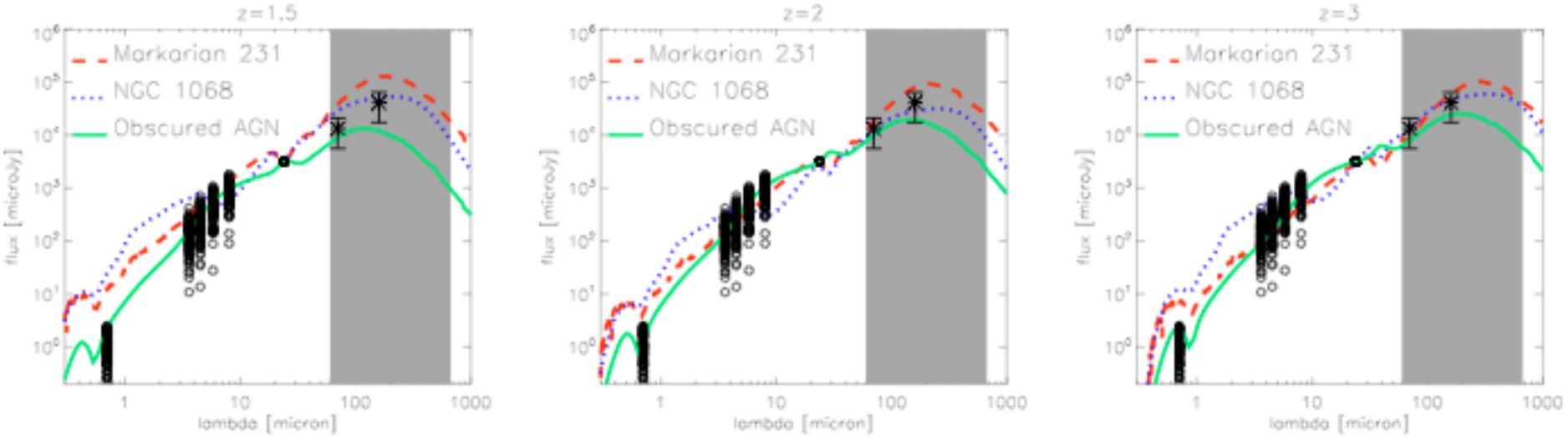
Previous observations from Spitzer and SCUBA have shown that Luminous galaxies make an increasingly significant contribution to the luminosity density of the Universe (E.g. from LeFloch et al. 2005)

Constraining Bolometric Luminosity



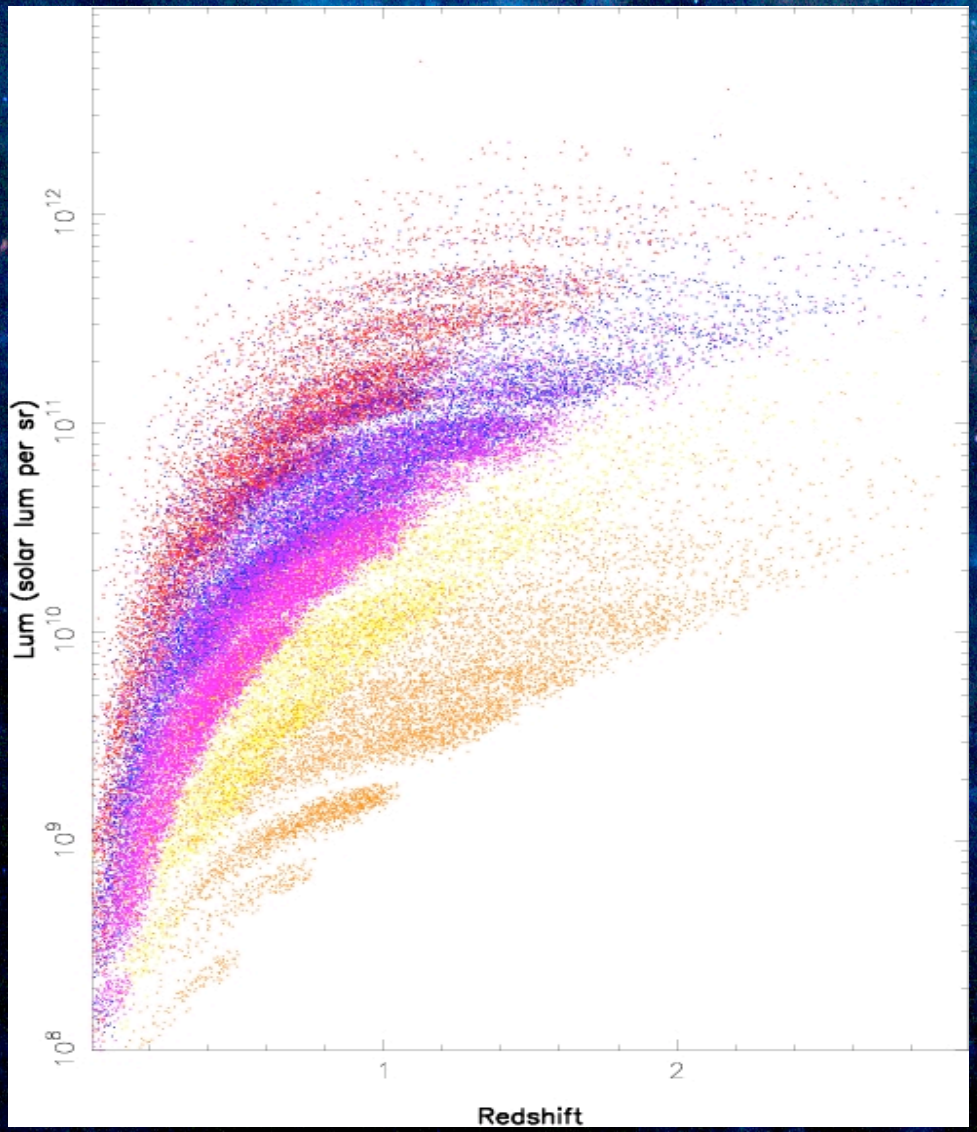
Herschel bands will be crucial in constraining the bolometric luminosity of galaxies. This will help untangle the contribution of AGN and star-formation cool/warm dust and thus constrain the star-formation history. Various model spectra shown here normalized at rest-frame 100micron.

High-z Galaxy and AGN SEDs

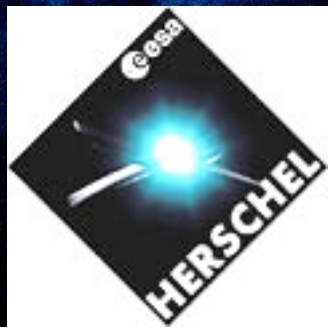


The peak of dust emission at high redshift will fall just in the Herschel bands, a still unexplored range but crucial to fully characterise the galaxy and AGN SEDs and measure their bolometric Luminosities.

Redshift-Luminosity Space Probed by the Herschel Surveys



Redshift-luminosity space probed in a 4-tier wedding cake survey. Orange and yellow: **0.25 square degrees, with 1.7 and 3.3 mJy 5σ threshold at 120 μm (PACS);** magenta, blue, and red: **0.9, 9, and 90 square degrees, with 5σ thresholds of 10, 31, and 100 mJy at 250 μm (SPIRE).** The PACS and first SPIRE surveys would be confusion-limited.



What are we doing in Bologna?

Deep involvement in the PEP:

PEOPLE (members of the PEP Consortium):

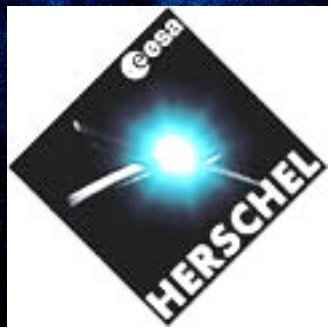
C. Gruppioni (INAF-OABo), F. Pozzi and A. Cimatti (UniBo)

MAIN TOPICS:

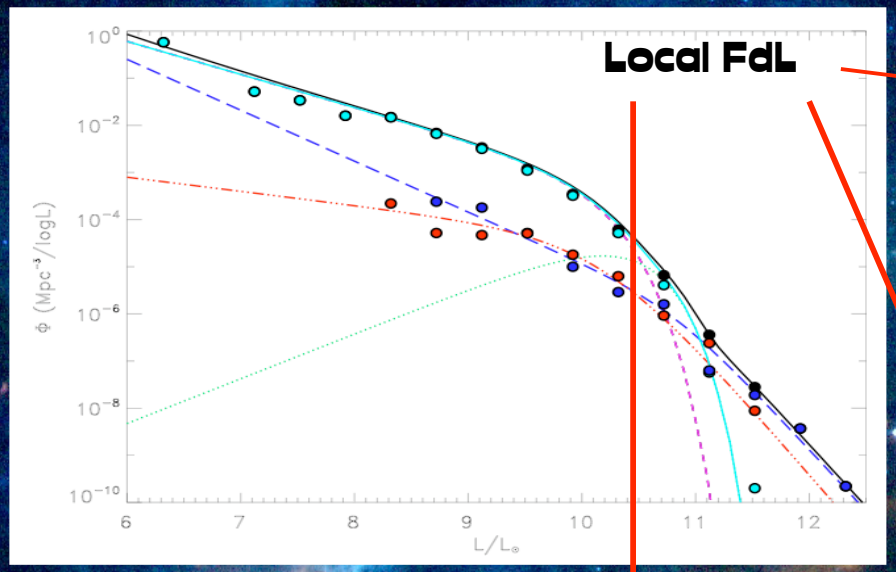
* * The FIR Luminosity Function and its Evolution as a Function of Redshift *(PhD Student: H. Dominguez-Sanchez)*

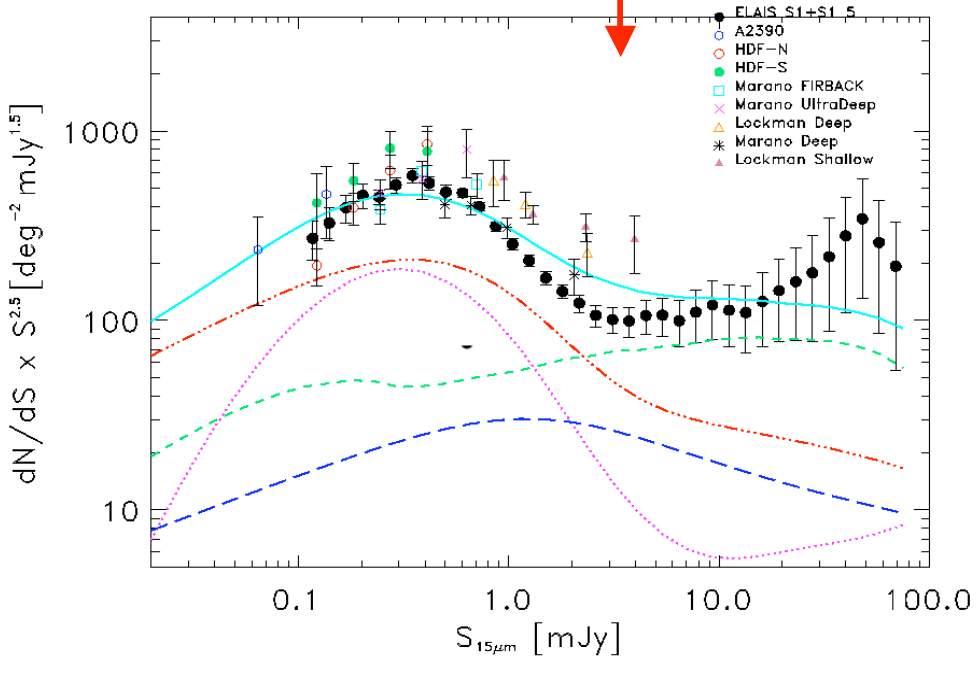
* * Mass Assembly and Specific Star-Formation Rate

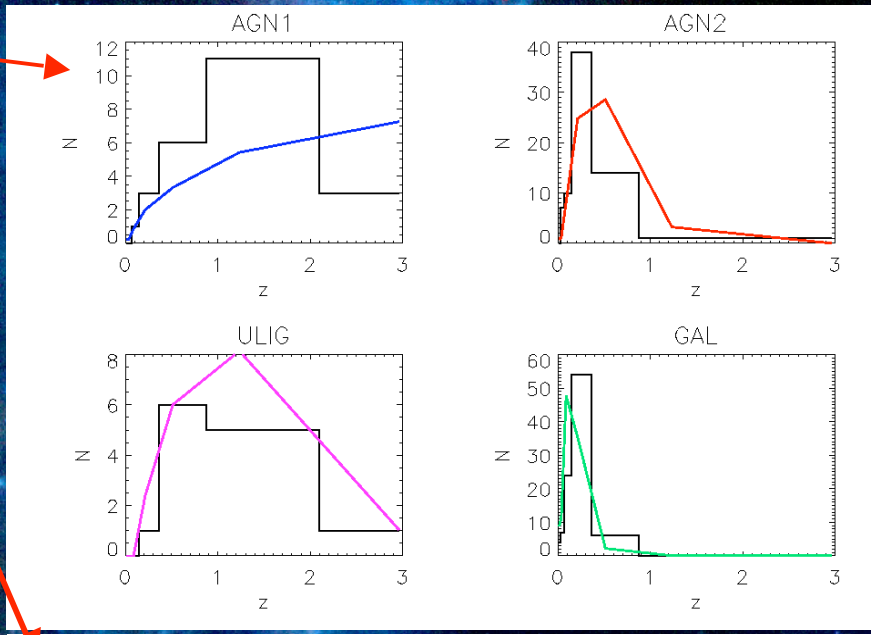
* Search for and Characterization of Heavily Obscured AGN at High Redshift

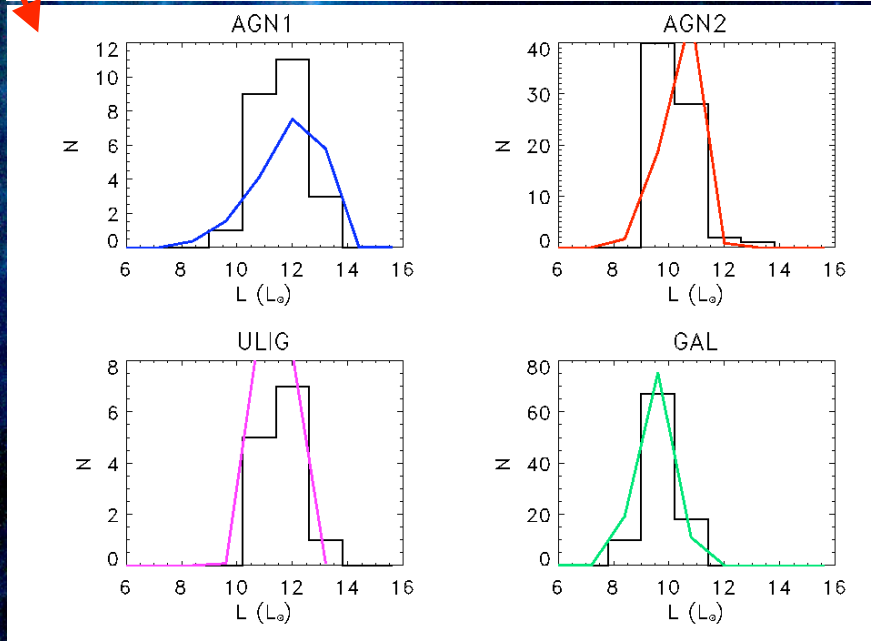


Evolution of the FIR Luminosity Function

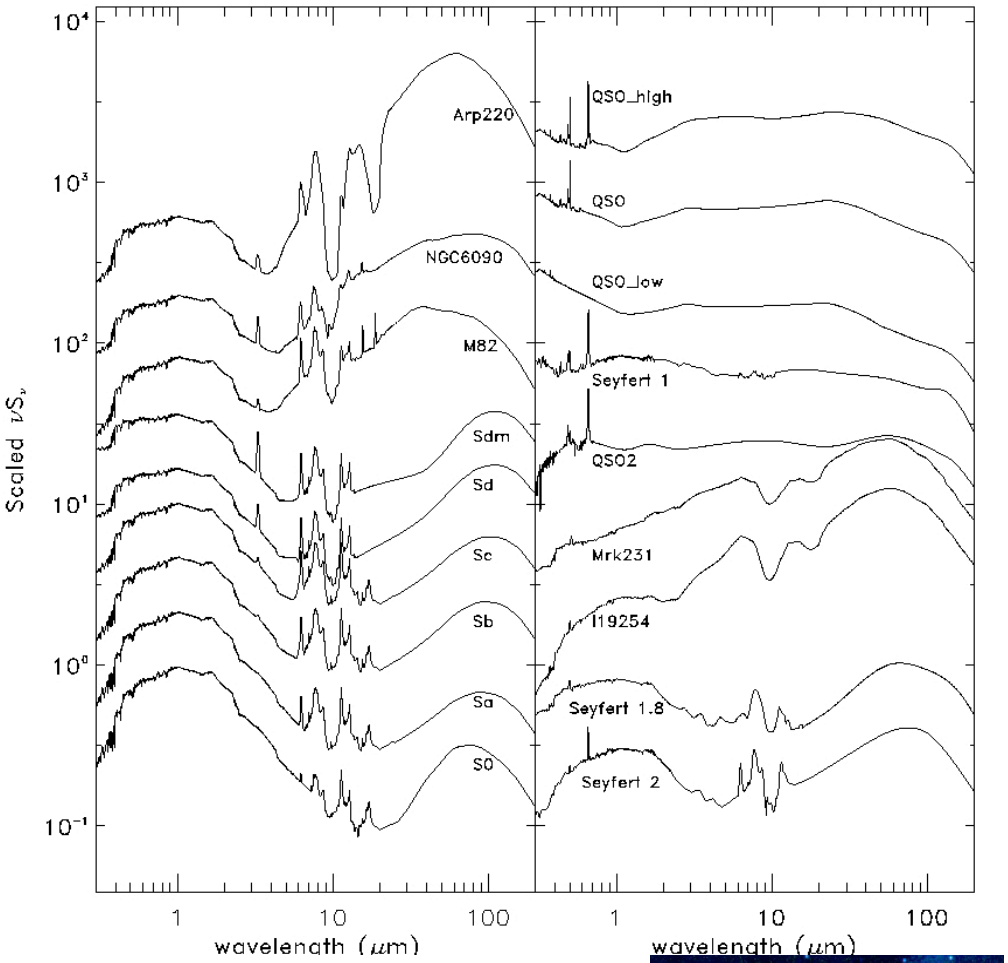








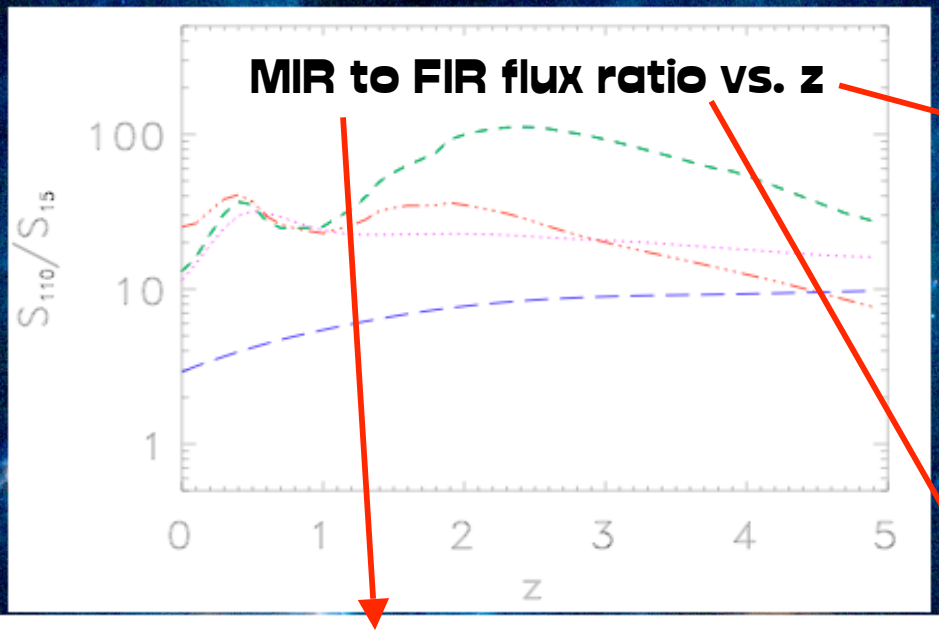
Evolution of the FIR

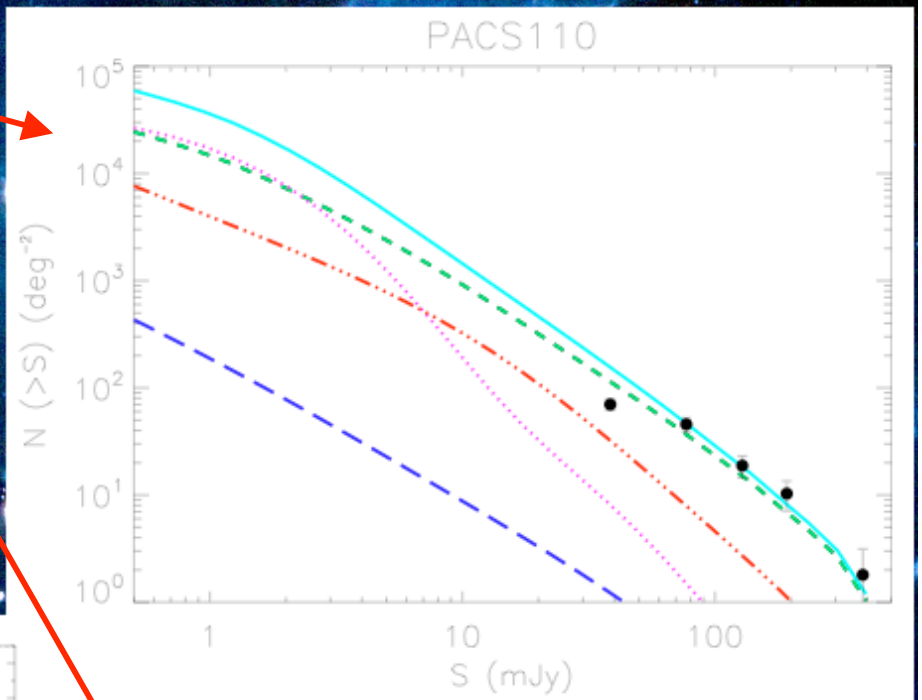


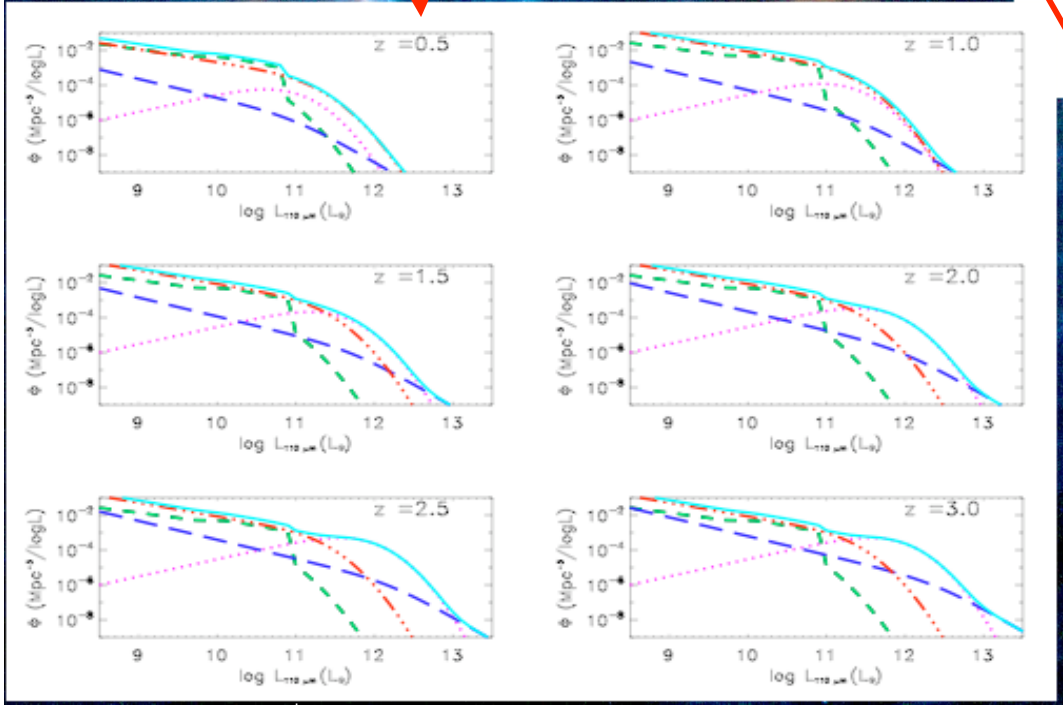
Four different population evolve separately:

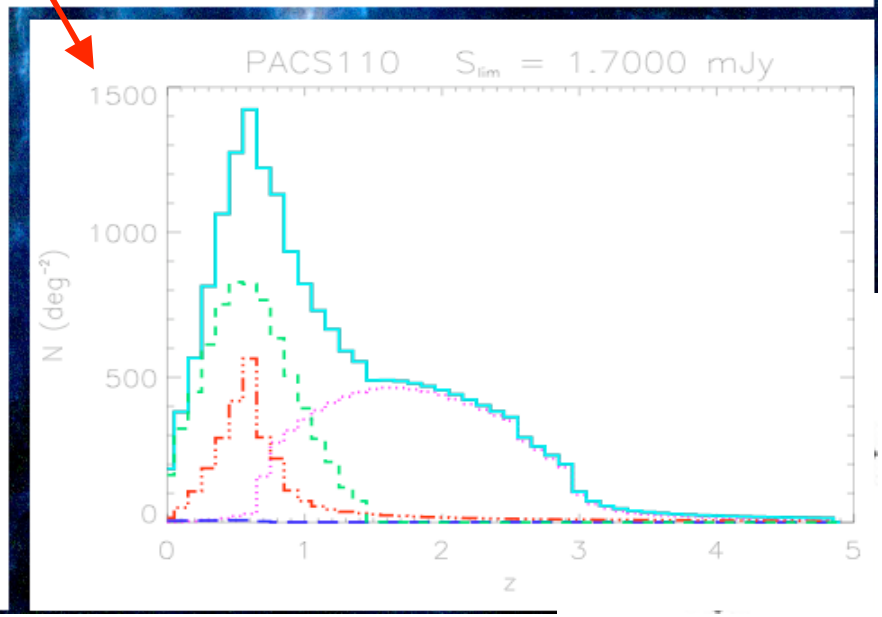
- **Galaxies (SEDs vary with L from Sb to starburst)**
- **ULIGs (composite agn+starburst SED: Mrk231)**
- **Type 2 AGN (Seyfert2 SED)**
- **Type 1 AGN (Qso)**

Evolution of the FIR Luminosity Function



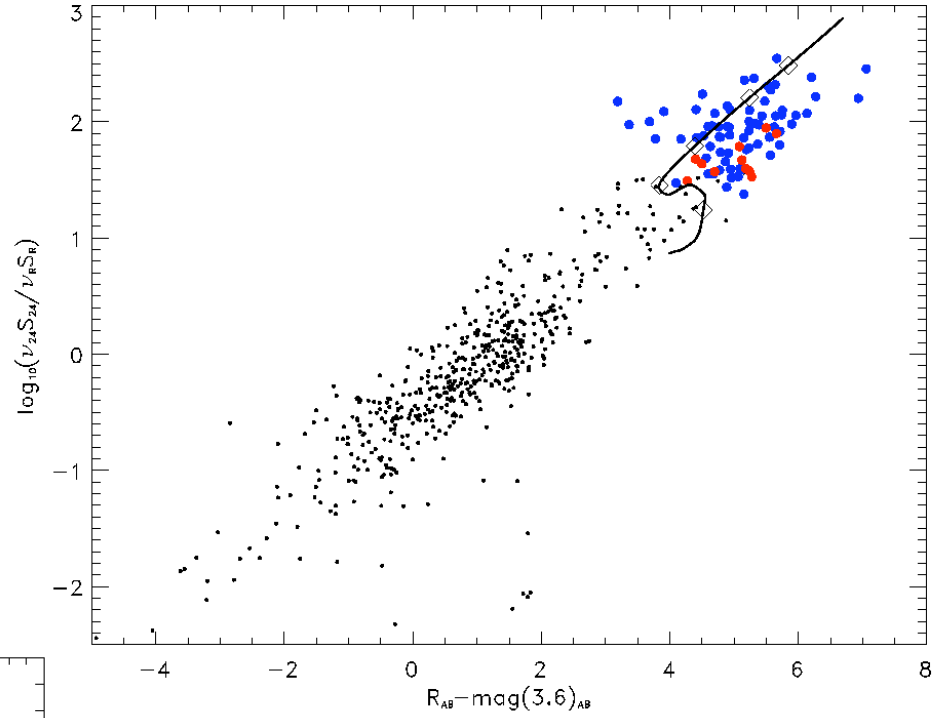


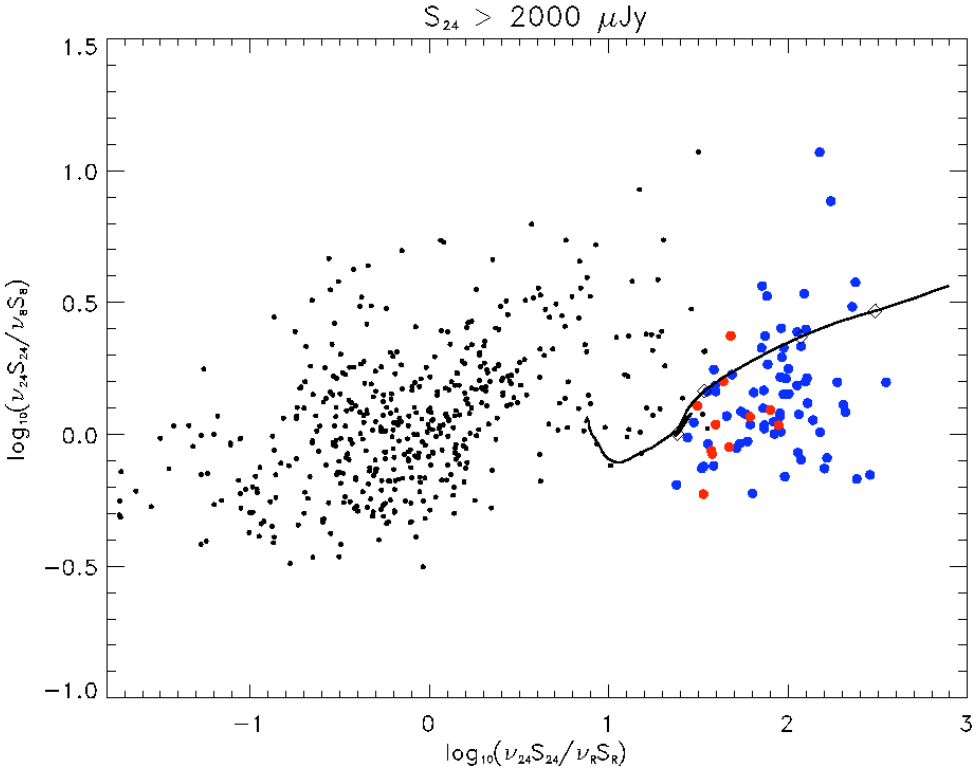




SELECTION OF OBSCURED AGN CANDIDATES

(for a HERSCHEL OT PROJECT TO BE SUBMITTED at next OT AO)





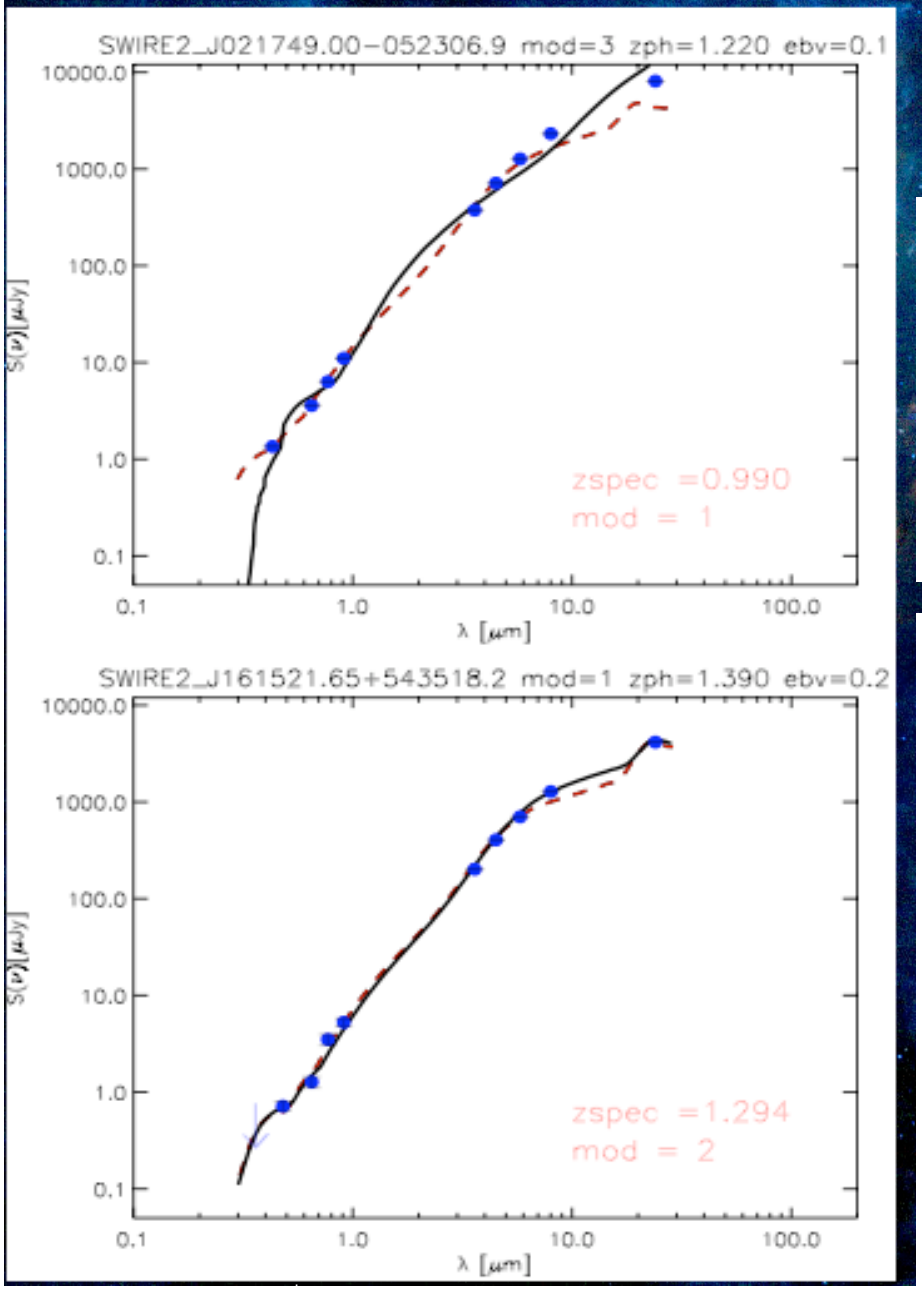
Optical/IR colour Selection:

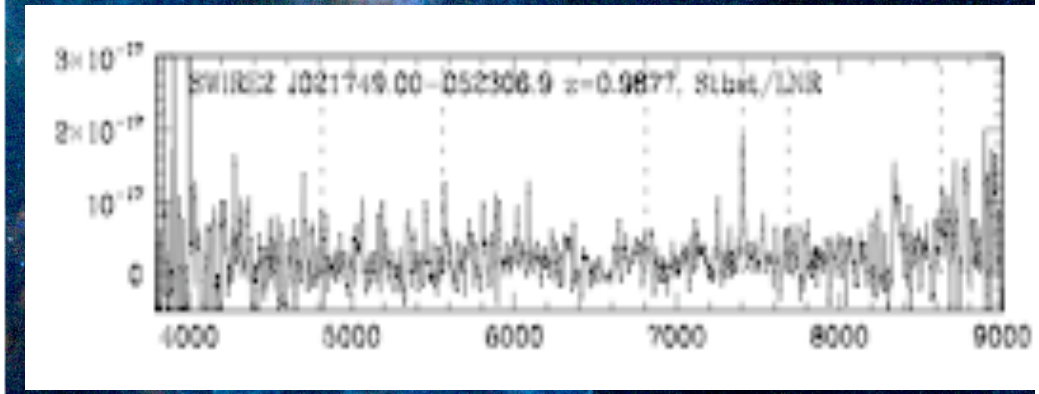
$F_{24} > 2$ mJy

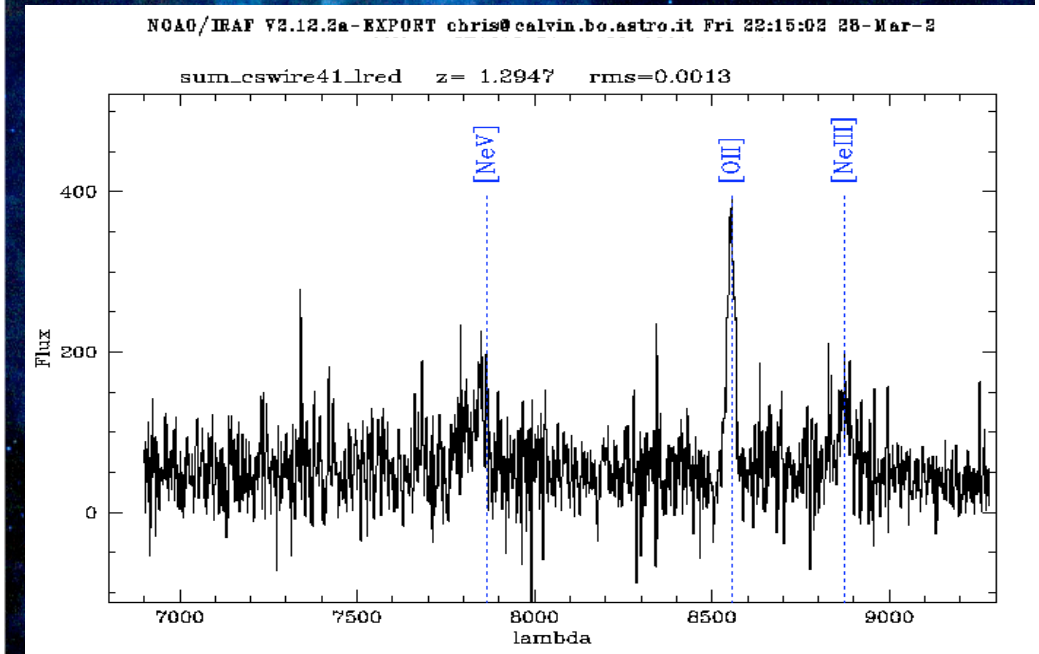
R_{AB}-mag$(3.6)_{AB} > 4.5$

$F_{24}/F_R > 1250$

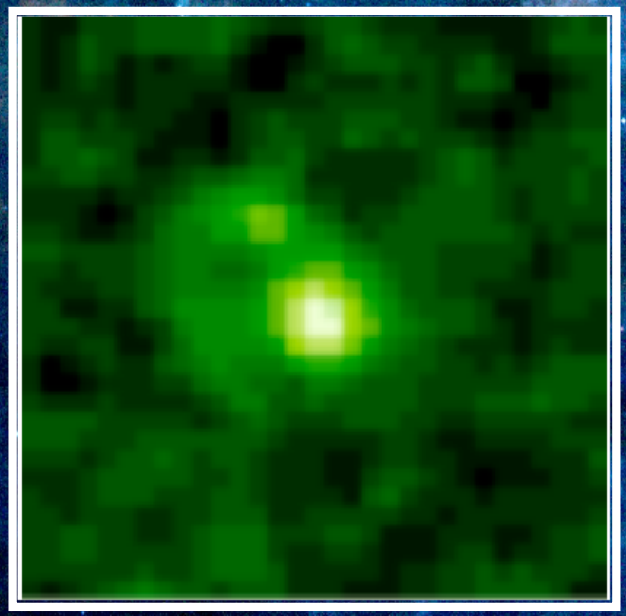
Photo-z vs. Spec-z

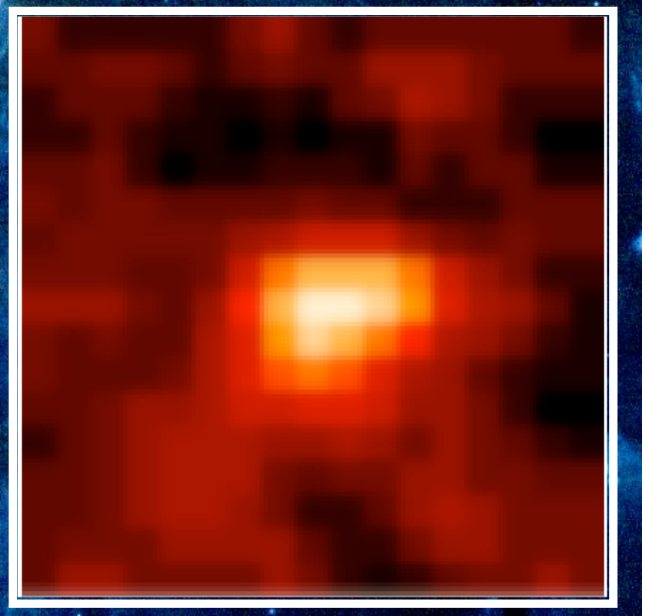






Stacking at 24 micron positions in 70 & 160 μm MIPS images





F_{24} = 2.9 mJy
(<F_{24}> = 3.0 mJy!!)

F_{70} = 12.1 mJy

F_{160} = 37.4 mJy

Many sources below the catalogue limit but visible on images

CONCLUSIONS

★ Herschel will be the largest space telescope of its kind (3.5-m) when launched (April 2009)

★ Two instruments for Cosmological Studies: PACS & SPIRE covering the wavelength range 60 - 670 μm

★ Cosmological K-Projects: 3 GT + 2 OT

★ Large involvement of Bologna Observatory + University in the PEP K-project:

- FIR Luminosity Function and its Evolution with z
- Heavily Obscured AGN Search for and Characterization
- Mass Assembly