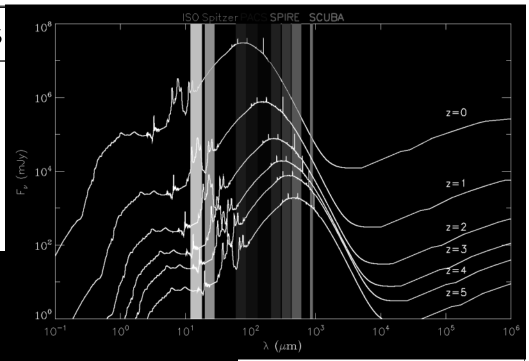
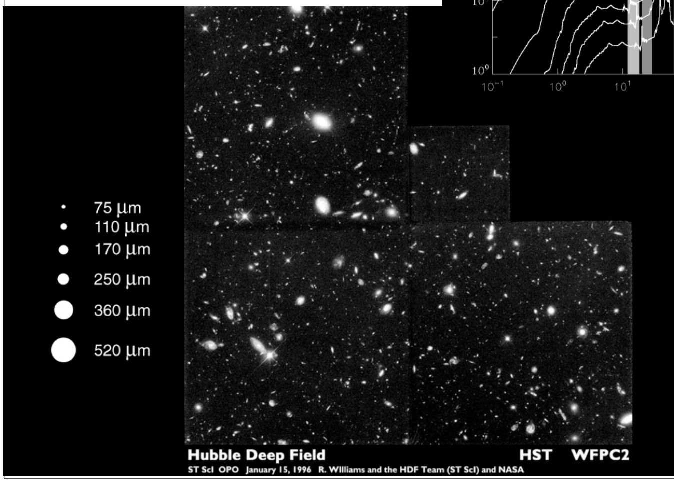
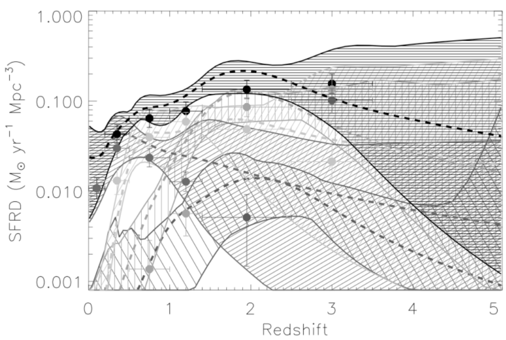
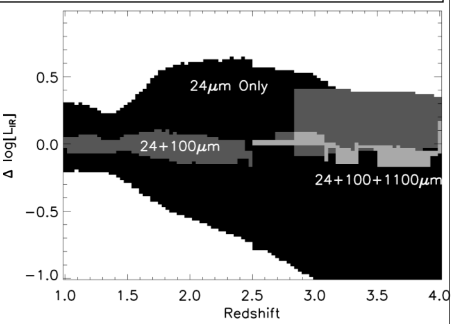
Herschel extragalactic surveys





Cosmic SFR history vs extrapolations





Name	70	100	160	250	350	500
PSF FWHm(")	5.4	8	12	18	25	36
S(mJy) conf°	1 (0.1)	0.6	5	11	15	15
logL(IR)@z~1	11.2 (10.4)	10.8	11.3	11.8	12.2	12.6
logL(IR)@z~2	12.2 (11.2)	11.7	12.1	12.3	12.5	12.8
logL(IR)@z~3	12.8 (11.9)	12.1	12.5	12.7	12.8	12.9

Confusion limit:
<30% blended sources
S/N>4 (noise from sources below S_{lim})

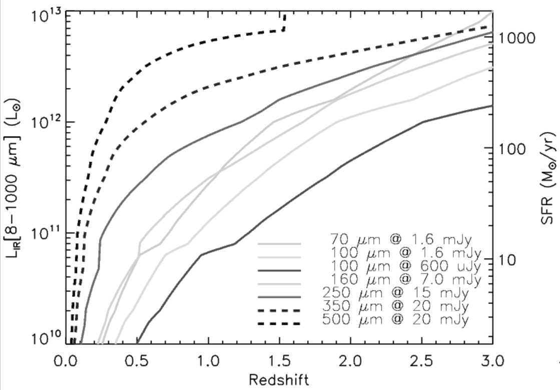
Herschel Key Programmes

- GT= 1/3rd, OT= 2/3rd of total observing time (KP + normal call)
- nominal mission= 3 years= 20 000 hours
- 57% of Herschel science time dedicated to Key Programmes (11258 h) :
  - 52% of Guaranteed Time KP (5878.9 hours)= 93% of all GT
  - 48% of Open Time KP (5378.8 hours)= 40% of all OT
- 22% of all KP time for extragalactic surveys :
  - 26% of all GT KP (1555h, 62% of extragal.surveys) :
    - ***HERMES (SPIRE GT, 900h) coordinated by S.Oliver & J.Bock***
    - ***PEP (PACS GT, 654.9h) coordinated by D.Lutz***
  - 18% of all OT KP (962.6h, 38% of E.S.): complementary at both extremes
    - ***H1K (PI S.Eales, 600h): very wide (0.8sq.deg), very shallow***
    - ***GOODS-Herschel (PI D.Elbaz, 362.6h): ultradeep, pencil beam***

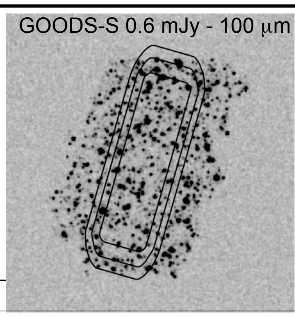
Key Project consortia must make data products and tools publicly available at the end of the proprietary time period (1 year for 1st year data, 6 months after)

Herschel extragalactic surveys: PEP - PACS Extragalactic Probe (650 h) HERMES - the Herschel Multitiered Extragalactic Survey (900 h)

Name	70	100	160	250	350	500
PSF FWHm(")	5.4	8	12	18	25	36
S(mJy) conf°	1 (0.1)	0.6	5	11	15	15
logL(IR)@z~1	11.2 (10.4)	10.8	11.3	11.8	12.2	12.6
logL(IR)@z~2	12.2 (11.2)	11.7	12.1	12.3	12.5	12.8
logL(IR)@z~3	12.8 (11.9)	12.1	12.5	12.7	12.8	12.9



Confusion limit:
<30% blended sources
S/N>4 (noise from sources below S_{lim})

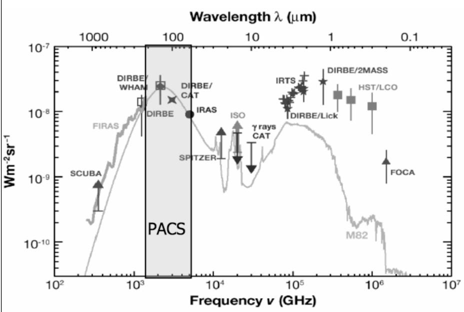


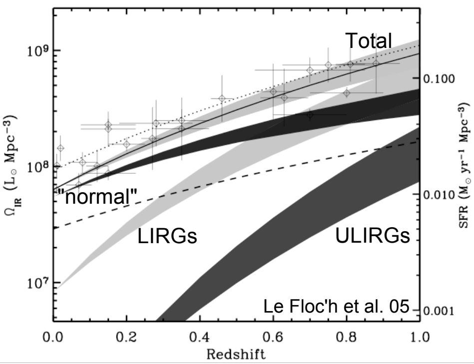
Herschel extragalactic surveys:
GOODS-Herchel (364.5 h) + PEP (650 h) + HERMES (900 h)

Name	**70**	**100**	**160**	**250**	**350**	**500**	**PEP time**	**PEP size**	**HERMES (h)**	**HERMES (°2)**
PSF FWHm(")	5.4	8	12	18	25	36				
S(mJy) conf°	1 (0.1)	0.6	5	11	15	15				
logL(IR)@z~1	11.2 (10.4)	10.8	11.3	11.8	12.2	12.6				
logL(IR)@z~2	12.2 (11.2)	11.7	12.1	12.3	12.5	12.8				
logL(IR)@z~3	12.8 (11.9)	12.1	12.5	12.7	12.8	12.9				
Level 1:							***227.4 h***		***22.9 h***	***250.3 h***
GOODSS		1.72	2.43	4.2	5.7	4.9	113.71h	10'x15'	22.9 h	0.11 sq.deg.
GOODSS	1.61		2.43				113.71h	10'x15'		
Level 2:							***65 h***		***12.3 h***	***77.3 h***
GOODSN		3.33	4.70	8.8	12.0	10.2	30.46h	10'x15'	3.8 h	0.11 sq.deg.
ECDFS		5.88	8.25	8.7	11.9	10.1	34.51 h	30'x30'	8.5 h	30'x30'
Level 3 *(4 fields)*							***69.4 h***		***16.7****+61.5* ***h***	***147.6 h***
Lockman Hole		4.9	6.8	11.1	15.2	12.9	34.9h	24'x24'	3.15 h	30'x30'
EGS		5.44	7.75	11.1	15.2	12.9	34.53 h	10'x67'	3.75 h	10'x90'
Level 4 *(4 fields)*							***212.75 h***		***61.1****+85.3* ***h***	***359.1 h***
COSMOS		6.13	8.63	10.8	14.7	12.5	212.75h	85'x85'	44.15 h	1.4°x1.4°
Bootes-SCUBA2		20.4	29.3	14.0	19.3	16.3	No			2 sq deg
NDWFS/Bootes		38.2	54.8	26.2	36.1	30.4	No			8 sq deg
Level 5 *(6 fields)*	***18***	***31.3***	***35.7***	***10.9***	***15.2***	***12.8***	***No***		***328.1 h***	***18.3 sq deg***
Level 6 *(7 fields)*	***18***	***70***	***80***	***24.4***	***33.9***	***28.6***	***No***		***165.8 h***	***50.3 sq deg***
Clusters							***74.6 h***		***147 h***	***221.6 h***
Lensing clusters		2.6	4.0	3.4	4.7	4.0			147 h	0.01 sq.deg
GOODS-Herschel										
GOODSS (ultradeep)		0.6	0.9				206.7h	42'2		
GOODSN (superdeep)		1.5	2.0	4.2	5.7	4.9	124.7h	10'x15'	31.1 h	10'x15'

Science Goals

- *What are the constituents of the Cosmic Infrared Background (CIB)?*
- *How does the star formation rate density and galaxy luminosity function evolve?*
- *What is the relation of far-infrared emission and environment at intermediate redshift? What are the clustering properties of infrared galaxies?*
- *What is the role of AGNs and how do they co-evolve with galaxies?*
- *What is the infrared emission and total energetics of known galaxy populations? What is the role of extinction?*





Issues

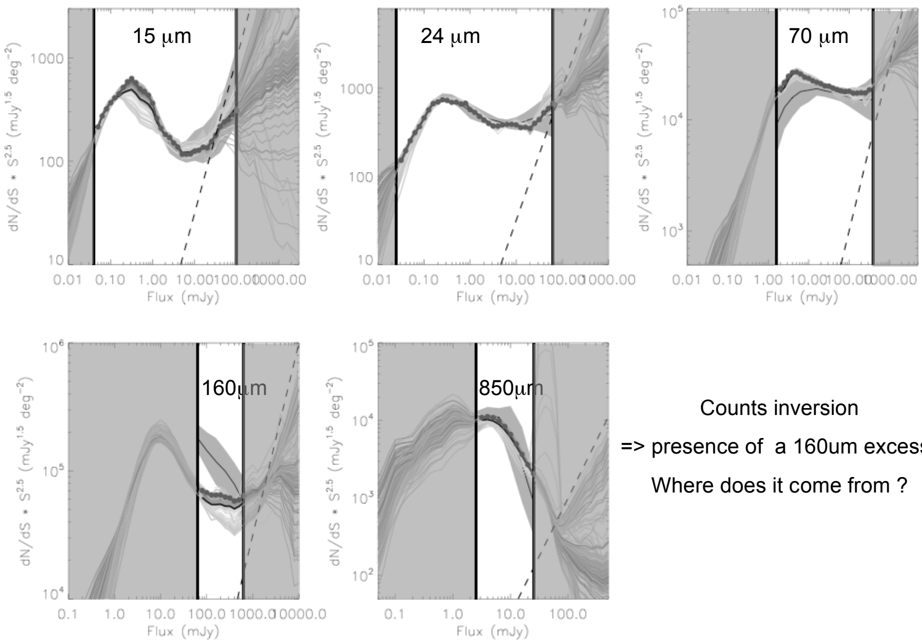
1. Big grains temperature uncertain => large error on Lir, hence SFR…

2. Existing constraints on cosmic SFR history rely on strong extrapolations from both sides of the peak emission : either mid-IR or sub-mm…

3. Mid-infrared overestimates Lir at z>1.5

4. Excess MIR emission = f(M*)
   + role of Compton Thick AGNs

Inversion des comptages (Le Borgne, Elbaz, Ocvirk, Pichon 08)



Counts inversion

=> presence of a 160um excess.

Where does it come from ?

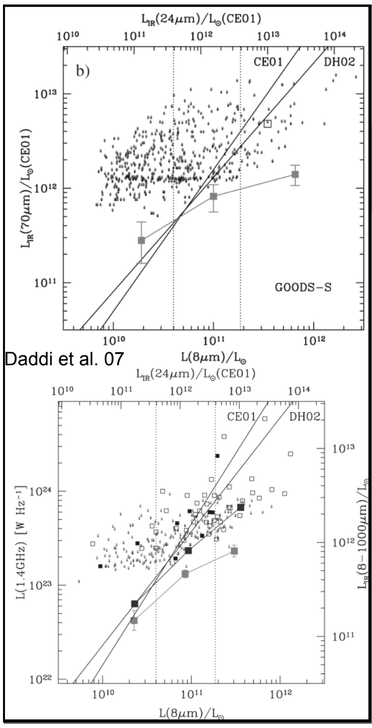
Issues

1. Big grains temperature uncertain => large error on Lir, hence SFR…

2. Existing constraints on cosmic SFR history rely on strong extrapolations from both sides of the peak emission : either mid-IR or sub-mm…

3. redshift evolution of IR SEDs: mid-infrared overestimates Lir at z>1.5

4. Excess MIR emission = f(M*)
   + role of Compton Thick AGNs

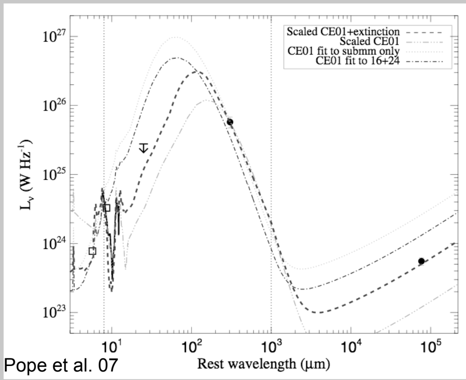


Daddi et al. 07

L'incertitude des extrapolations: évolution des SEDs

L'infrarouge moyen sur-prédit la luminosité IR par rapport au 70μm à z~2 dans le domaine des ULIRGs.
Les extrapolations sont donc très incertaines dans ce régime

La température des gros grains dans le FIR est plus froide qu'attendu à partir des SEDs locaux



Pope et al. 07

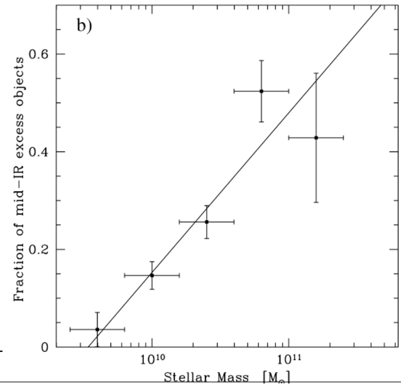
Issues

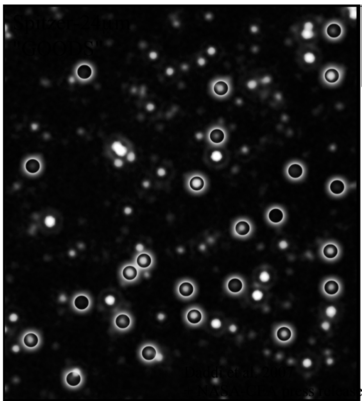
1. Big grains temperature uncertain => large error on Lir, hence SFR…

2. Existing constraints on cosmic SFR history rely on strong extrapolations from both sides of the peak emission : either mid-IR or sub-mm…

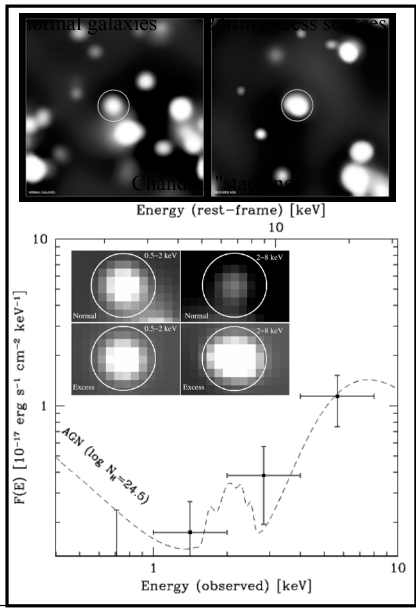
3. Mid-infrared overestimates Lir at z>1.5

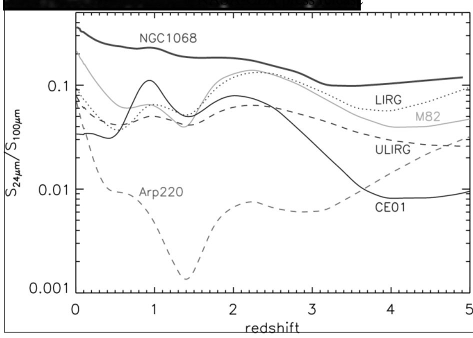
4. Excess MIR emission = f(M*)
   + role of Compton Thick AGNs





Compton Thick AGNs revealed by 24μm excess@z~2: 20-40% galaxies with $M^*>5x10^{10}M_\odot$ (Daddi et al 07)





GOODS-Herschel

The Great Observatories Origins Deep Survey : far infrared imaging with Herschel

David Elbaz (CEA Saclay) + many others…

Dave Alexander, Durham University, UK
Bruno Altieri, ESAC, ESA
Herve Aussel, CEA / Saclay
Mark Brodwin, NOAO
Veronique Buat, OAMP, Marseille, France
Denis Burgarella, OAMP, Marseille, France
Daniela Calzetti, University of Massachussetts, USA
Catherine Cesarsky, ESO
Stephane Charlot, IAP, Paris, France
Vassilis Charmandaris, Dept. of Physics, Univ. of Crete
Ranga–Ram Chary, Spitzer Science Center, USA
Emanuele Daddi, SAp, CEA/Saclay, France
Mark Dickinson, NOAO, USA
Herve Dole, IAS, Orsay, France
Peter Eisenhardt, JPL/Caltech, USA
Henry C. Ferguson, STSci, USA
Natascha Forster Schreiber, MPE, Garching, Germany
Dave Frayer, IPAC, Caltech, USA
Rene Gastaud, CEA / Saclay
Mauro Giavalisco, University of Massachussetts, USA
Roberto Gilli, INAF, Bologna, Italy
Minh Huynh, Spitzer Science Center, USA
Rob Ivison, ROE, UK
Damien Le Borgne, SAp, CEA/Saclay, France ← Mock catalogs, model predictions
Emeric Le Floc'h, University of Hawaii, USA
Dieter Lutz, MPE, Garching, Germany
Benjamin Magnelli, SAp, CEA/Saclay, France ← Simulations
Glenn Morrison, U. Hawaii/IfA, USA
Eric J. Murphy, IPAC, CalTech, USA
Casey Papovich, Texas, A&M University
Alexandra Pope, NOAA, USA
Paola Popesso, MPE, Garching, Germany
Naveen Reddy, NOAO, USA
Douglas Scott, University of British Columbia, Canada
Christian Surace, LAM, Marseille, France
Harry Teplitz, Spitzer Science Centre, USA
Ivan Valtchanov, ESAC, ESA
Min S. Yun, University of Massachussetts, USA
Grant Wilson, University of Massachussetts, USA

Collaborators (39):
France (10), USA, Germany, UK, Greece, Italy, Canada
ESO, ESA

362.6 hours (100μm & 160μm PACS, including 31 h SPIRE)

Major goals of GOODS-Herschel

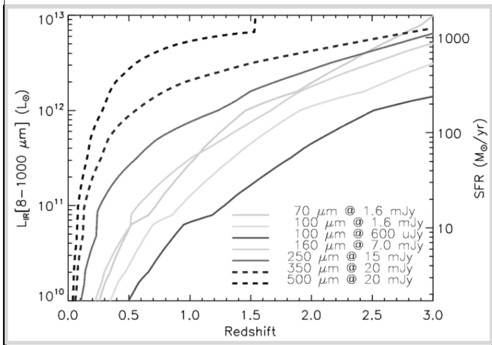
1. to resolve most of the cosmic SFR density up to z ~ 4, by detecting ~ 2000 galaxies in the unexplored regimes of normal galaxies up to z ~ 1, LIRGs up to z~ 2, ULIRGs to z~4
2. to bridge IR and UV selected galaxies down to the level where both SFR agree up to z ~ 1.5 and potentially up to z ~ 4 as discussed below.
3. to identify and study the buried Compton Thick AGNs responsible for the still unresolved 30% fraction of the cosmic X-ray background (CXB), which peaks at 30 keV.

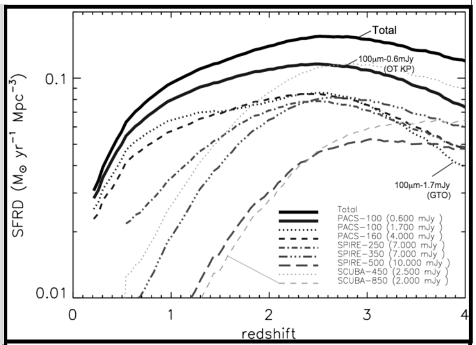
An ultradeep survey at 100μm (0.6 mJy) + superdeep (1.5mJy)

- Trade-off between k-correction, which favors the longest wavelengths, and source confusion, increasing with beam size:

PACS-70μm requires 9x longer integrations to reach same SFR than PACS-100μm

Longer wavelengths are limited to >8x shallower depths than PACS-100μm due to their larger beam sizes and steeper source counts.

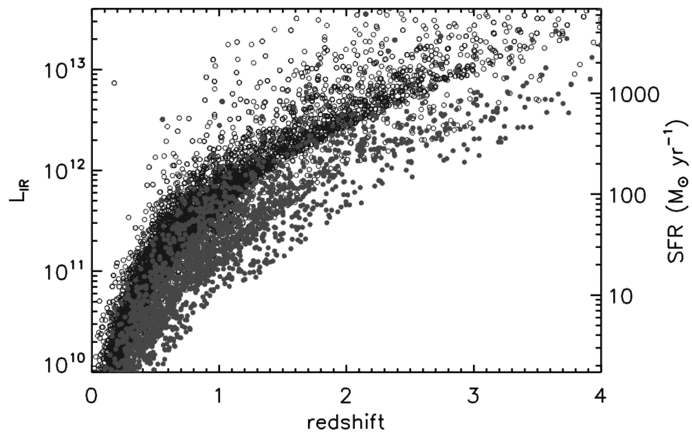




L_{IR}>6x10^{10}L$_\odot$ up to z~1
L_{IR}>4x10^{11}L$_\odot$ up to z~2
L_{IR}>10^{12}L$_\odot$ up to z~3 ; L_{IR}>3x10^{12}L$_\odot$ up to z~4

Resolve 75% of global SF density out to z~4 by measuring 20-50μm rest-frame at 1<z<4 model Le Borgne et al. (2008)

Comparison between GOODS-Herschel (red) and GTO KP (blue)

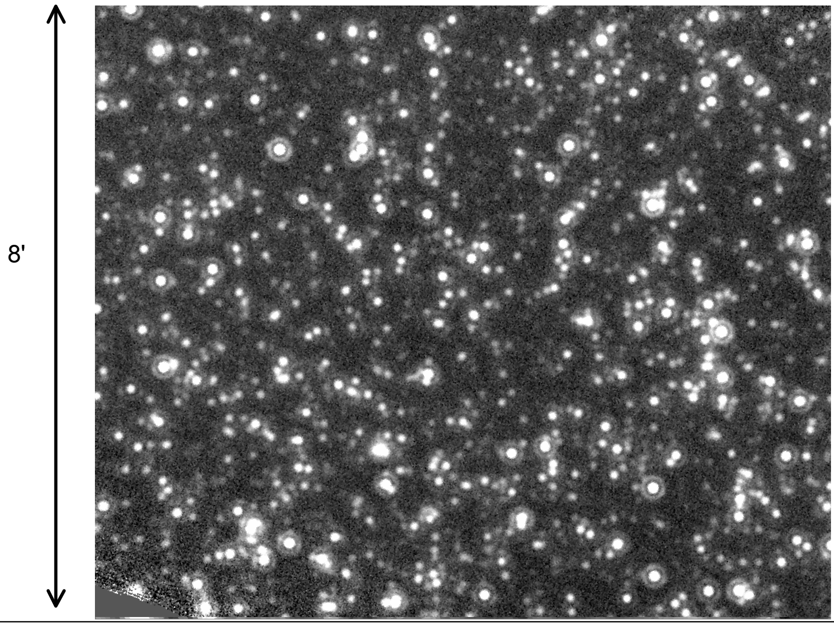


from mock Herschel catalogs

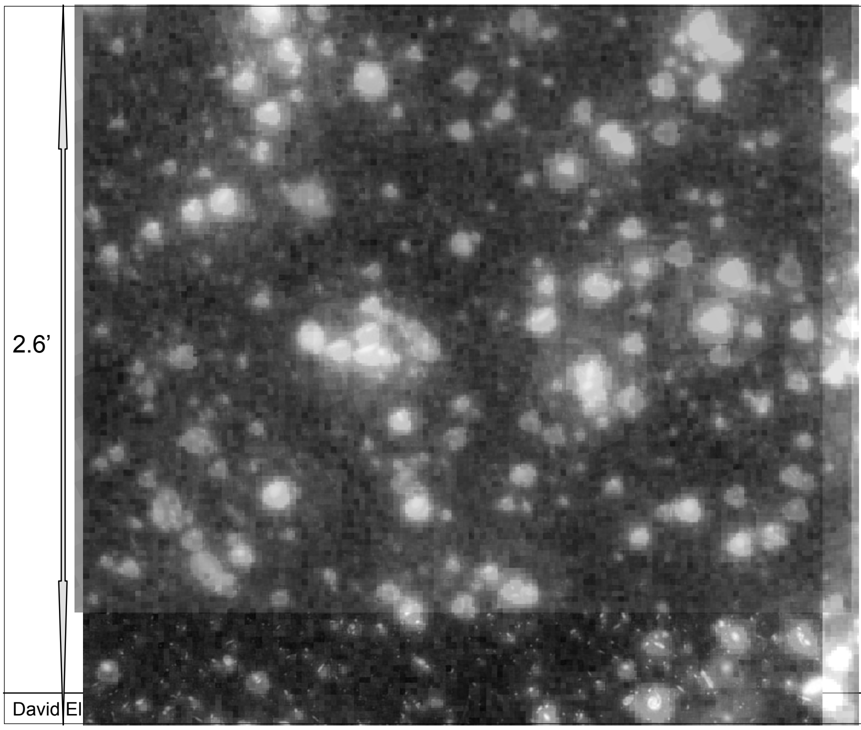
generated by Damien Le Borgne

# gals	z_{min}	z_{max}	<Lir>	<SFR>
1148	0	1	10.63	7
551	1	2	11.59	66
149	2	3	12.31	354
52	3	4	12.70	861
10	4	5	13.19	2692
1910	**0**	**5**	**11.11**	**22**

Spitzer MIPS 24 versus 70 µm (GOODSN + Frayer et al. 06)



David Elbaz Herschel extragalactic surveys 17

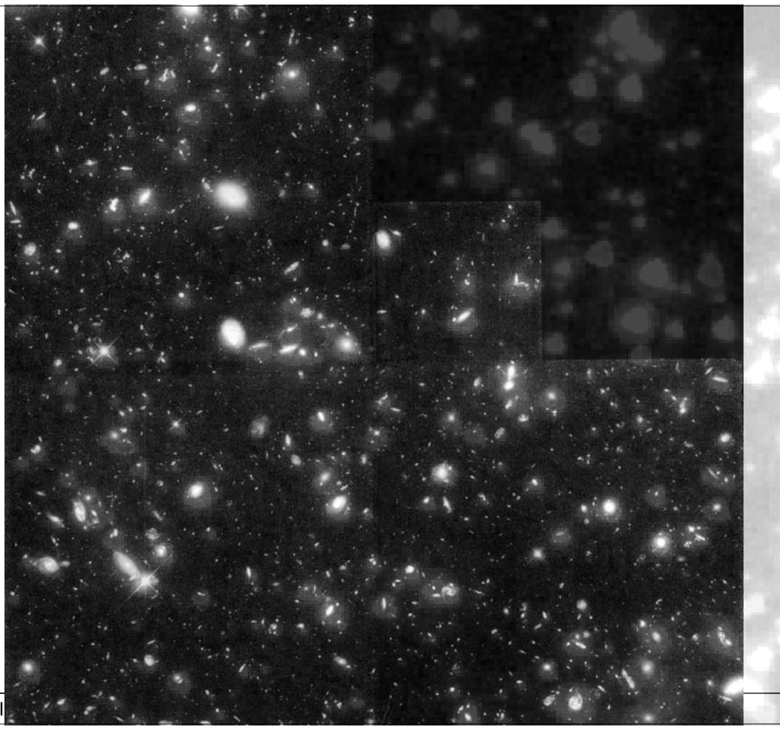


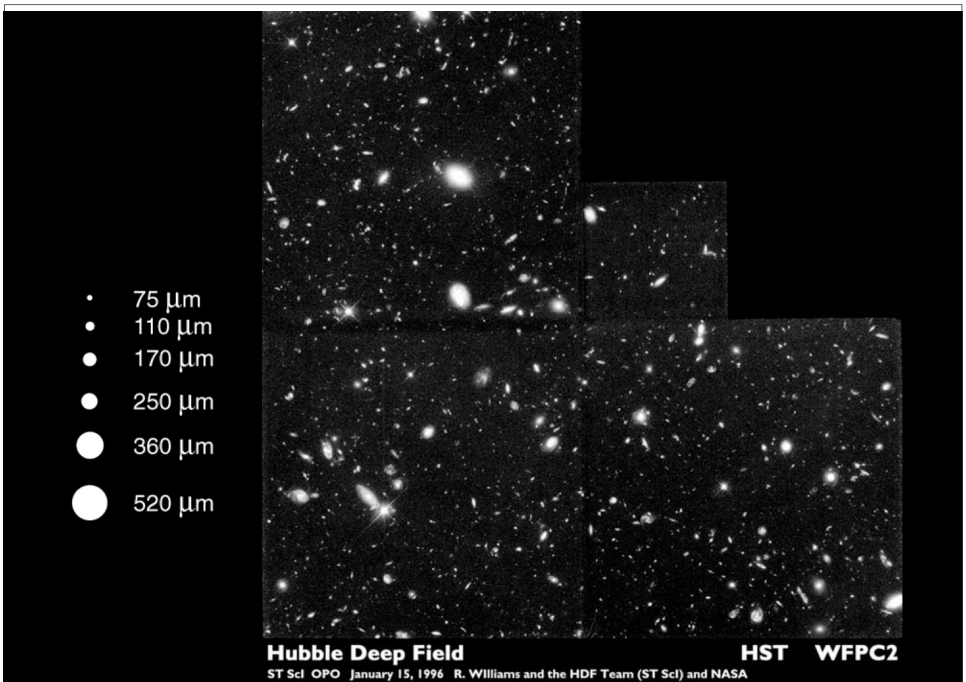
3.6µm
25 hrs
0.8"

24µm
10.9 hrs
5.6"

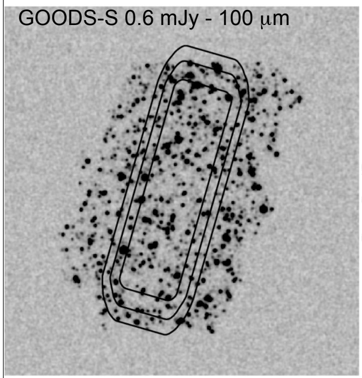
70µm
2.9 hrs
16"

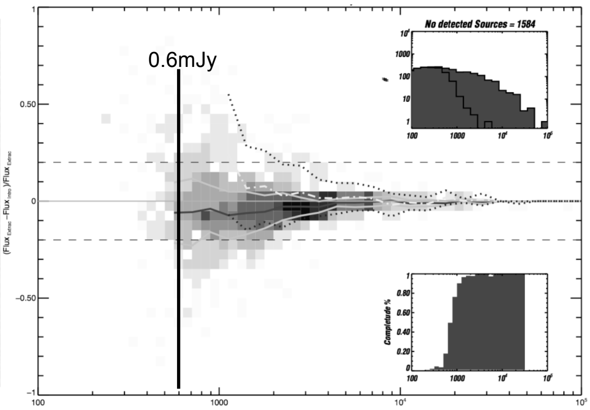
David El 18

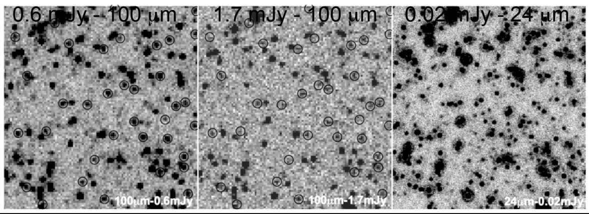



75 µm
110 µm
170 µm
250 µm
360 µm
520 µm
Hubble Deep Field
HST WFPC2
ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

Simulations & confusion limit (by Benjamin Magnelli)

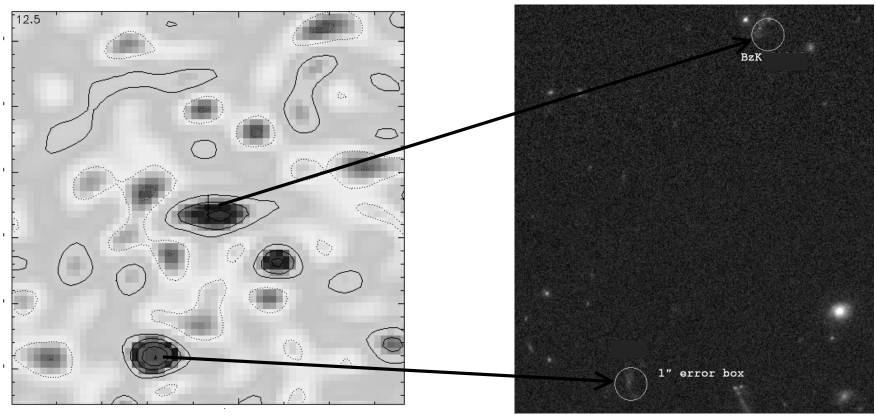






Identifying high-z starbursts: by chance…

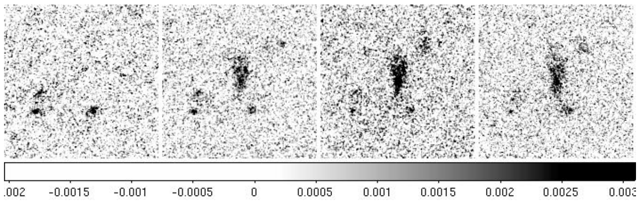
E. Daddi, H. Dannerbauer, D. Elbaz, M. Dickinson, G. Morrison
(paper in preparation)



3000km/s averaged PdBI map

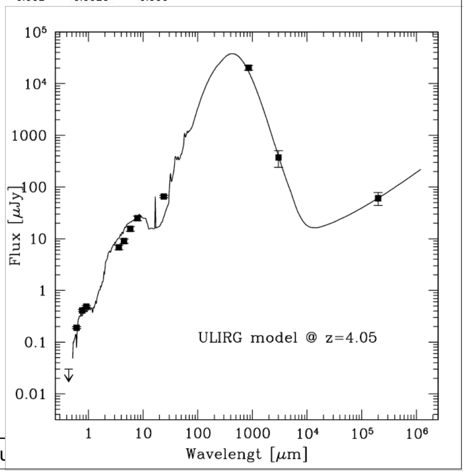
ACS image
New object: >20mJy@850um

F435W F606W F775W F850LP



Clear B-drop
→z>3-4
UV z-phot: z=4.05

Band [um]	Flux [mJy]
70	1-1.5 Nope
100	3-4.5 --> GOODS
160	10-15 --> COSMOS
250	25-30 easy
350	35-40 easy
520	40-45 easy



Finding rare distant objects…

~ 70 similar galaxies detectable in COSMOS, ECDF, EGS, LH
Most efficient PACS band is 160um

Similar sources will have ~30-40mJy in SPIRE bands over 70 square degrees !!!!
→~1000-2000 similar galaxies should be detected
→ how to recognize them ? (20"- 40" PSF)
→ ARTEMIS will detect 50 of them @~400μm in 500 h over 2.5 sq.deg. with PSF=9"