



**The Herschel Multi-tiered Extragalactic Survey  
HerMES & Synergies with ALMA  
And Herschel Open Time Key Projects and WISE**

**Andrew Blain** on behalf of **Seb Oliver**  
On behalf of HerMES team

<http://astronomy.sussex.ac.uk/~sjo/Hermes/>

ALMA meeting Charlottesville 23<sup>rd</sup> Sept 2009

SWIRE View of Distant Galaxies

Spitzer Space Telescope • IRAC

Visible (blue): Isaac Newton Telescope

NASA / JPL-Caltech / C. Lonsdale (Caltech/IPAC) and the SWIRE Team

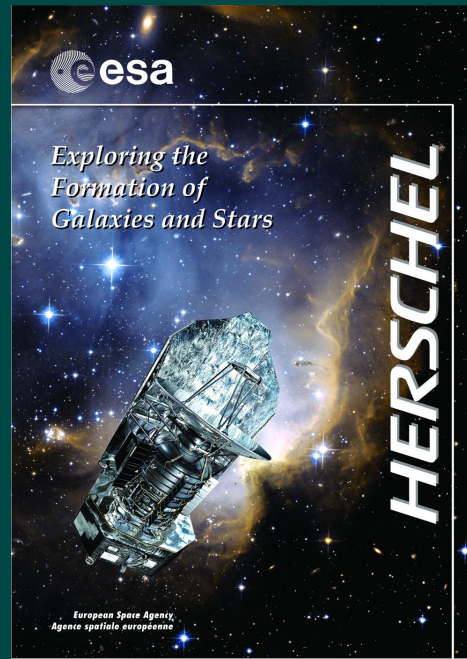
sig05-019



# Herschel Key Programmes

## WISE flight

Herschel and Planck  
flying 18<sup>th</sup> May 2009



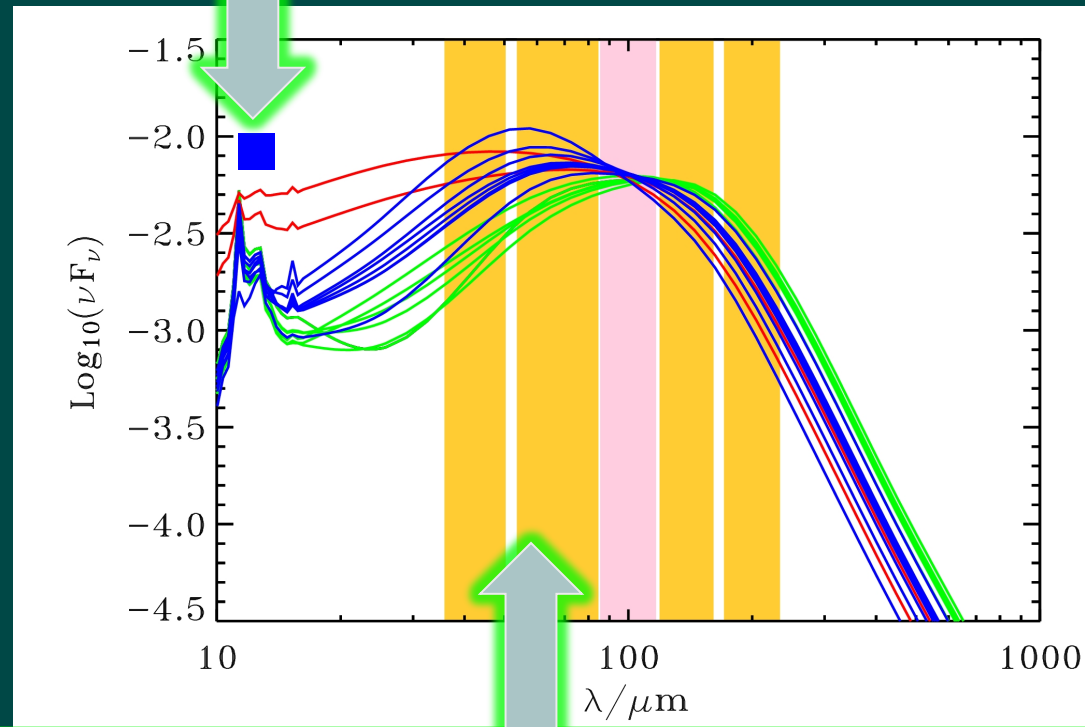
- Herschel Multi-tiered Extragalactic Survey (HerMES, 900hrs)
- PACS Evolutionary Probe (PEP, 650hrs)
- *ATLAS (was Herschel Thousand Degree Survey H1K) (600hrs)*
- *The Great Observatories Origins Deep Survey: far-infrared imaging with Herschel (363hrs)*
- *The Herschel Lensing Survey (292h)*
- 
- Next call Feb/Mar 2010

WISE at Ball Aerospace. Launch Dec 7<sup>th</sup> 2009

- 6-month primary survey
- Data release in mid 2011
- <http://wise.ssl.berkeley.edu/astronomers.html>

# Constraining Bolometric Luminosity

WISE bands 3, 4, 12 & 22  $\mu\text{m}$

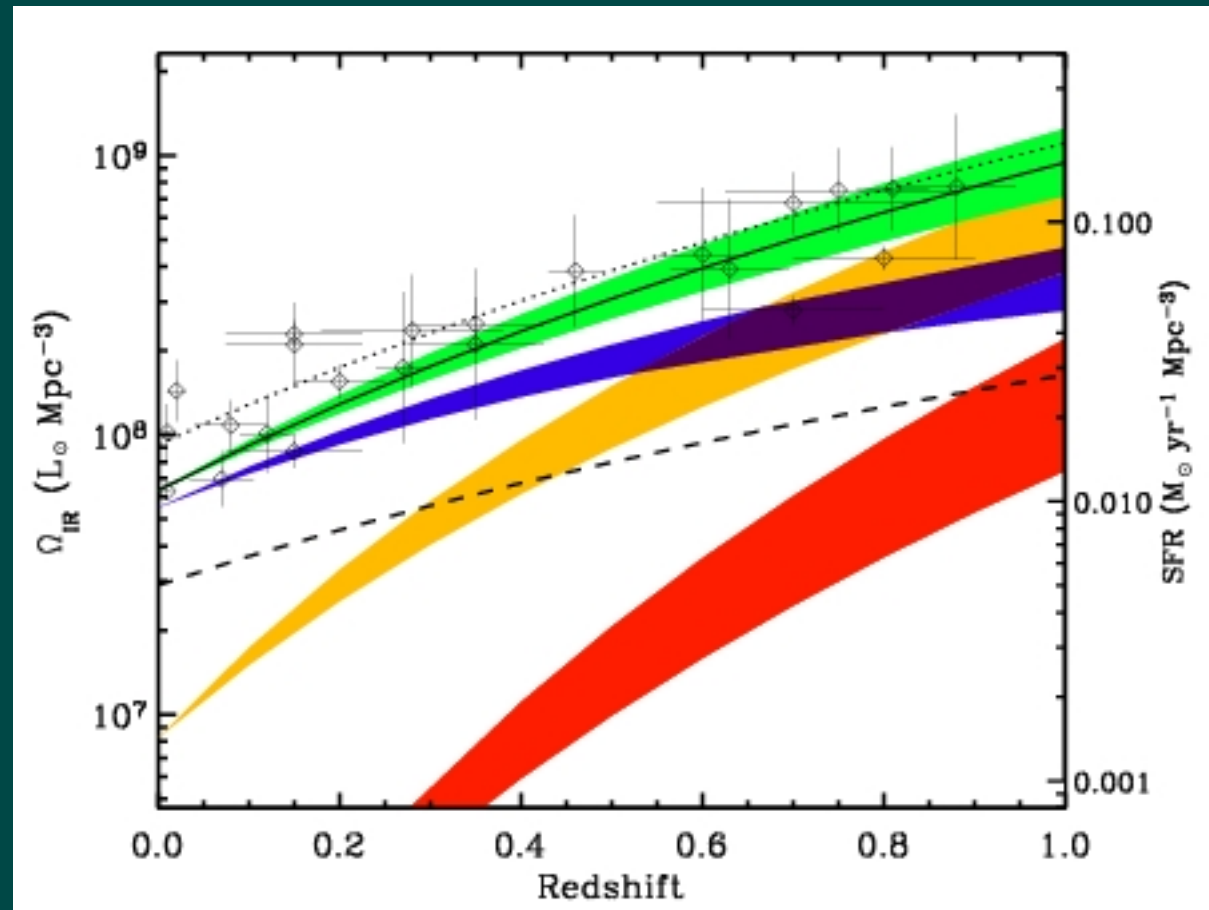


Herschel bands (70, 110, 250, 350 & 500  $\mu\text{m}$ ) crucial in constraining the bolometric luminosity of galaxies. This will help untangle the contribution of AGN and star-formation cool/warm dust and thus constrain the star-formation history. Various model spectra shown here normalized at rest-frame 100  $\mu\text{m}$ .

# Cosmic History of Star formation

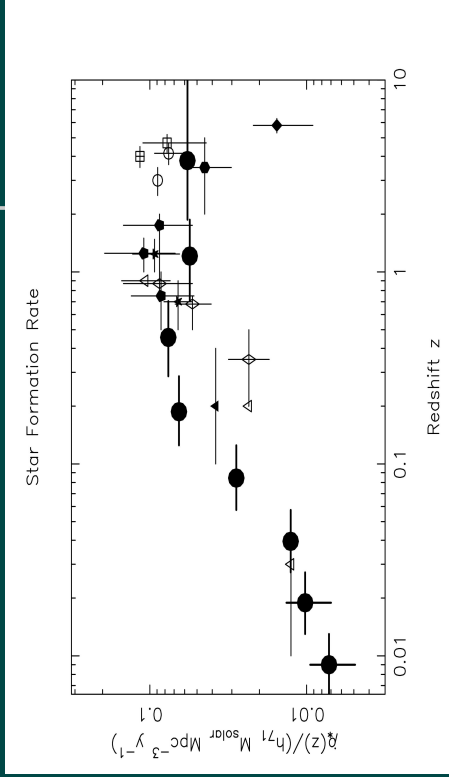
## Down-sizing?

All  
Low luminosity  
LIRGS  
ULIRGS

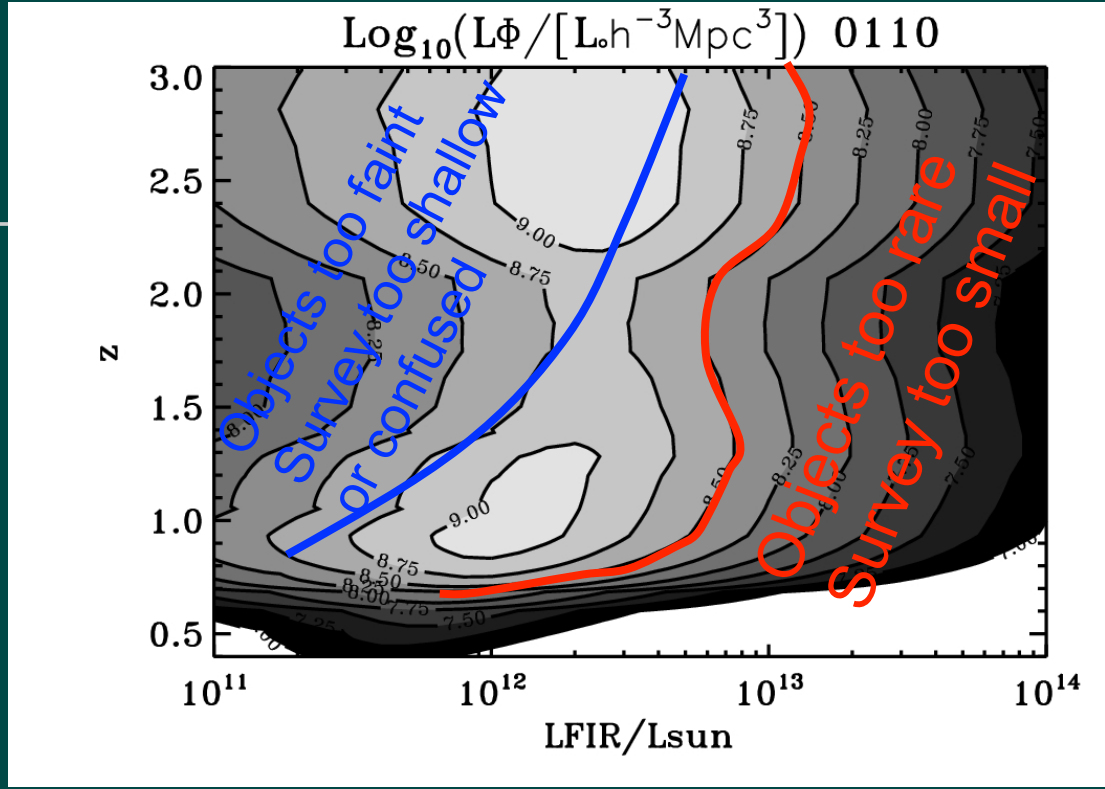
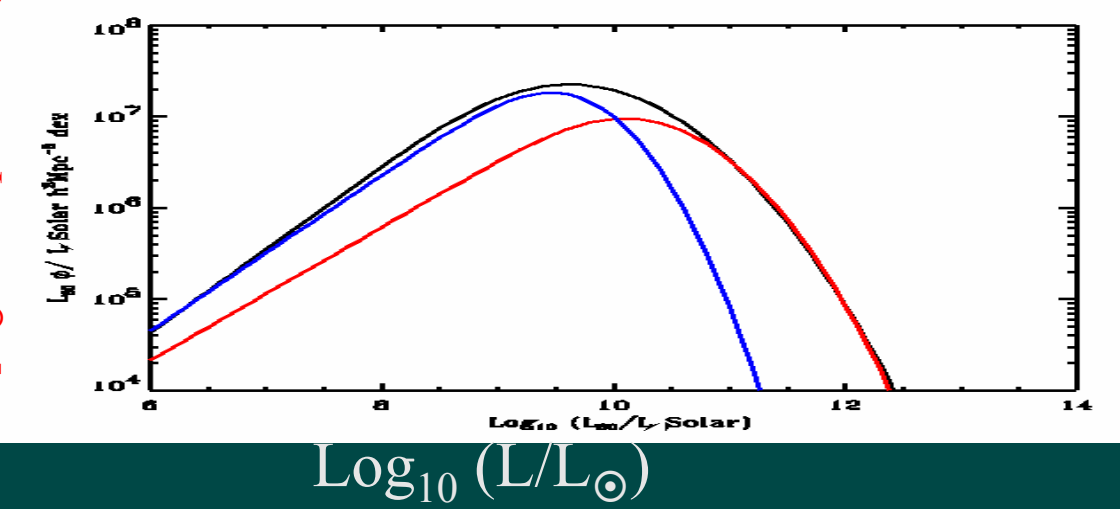


Le Floch et al. 2005

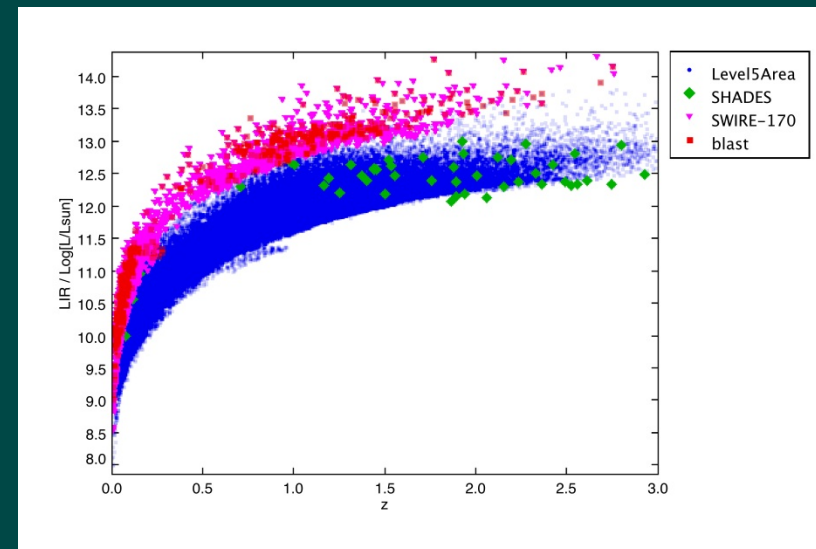
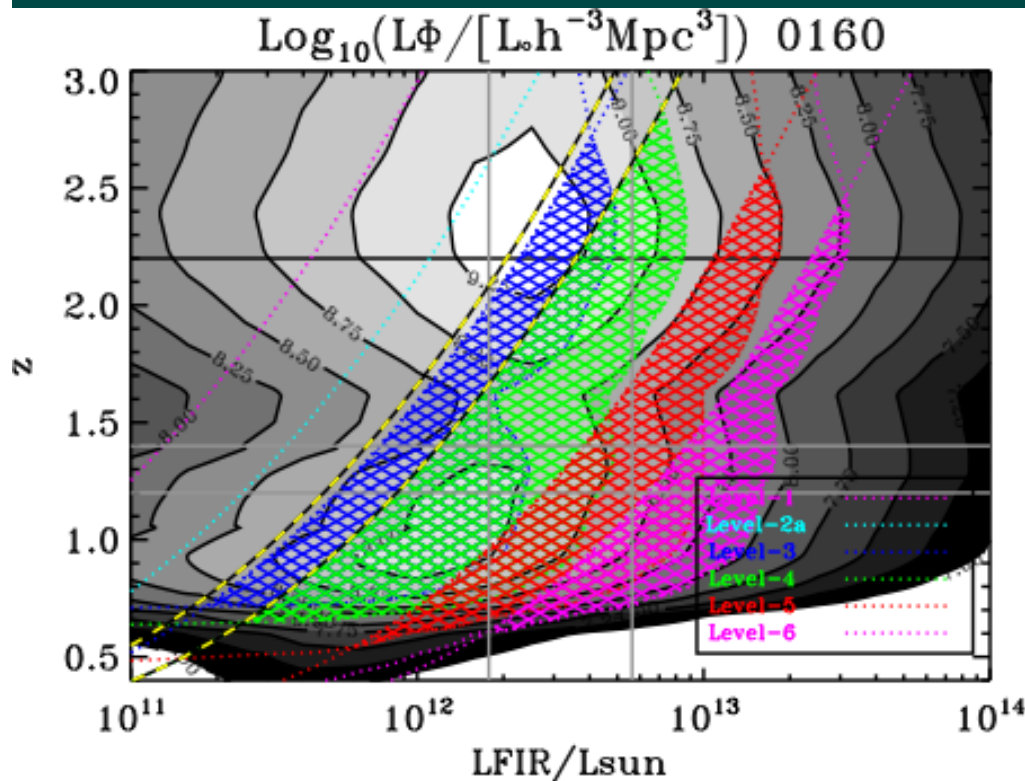
# Madau / Lilly Plot



$L_0 [L_\odot h^{-3} \text{ Mpc}^{-3} \text{ dex}^{-1}]$



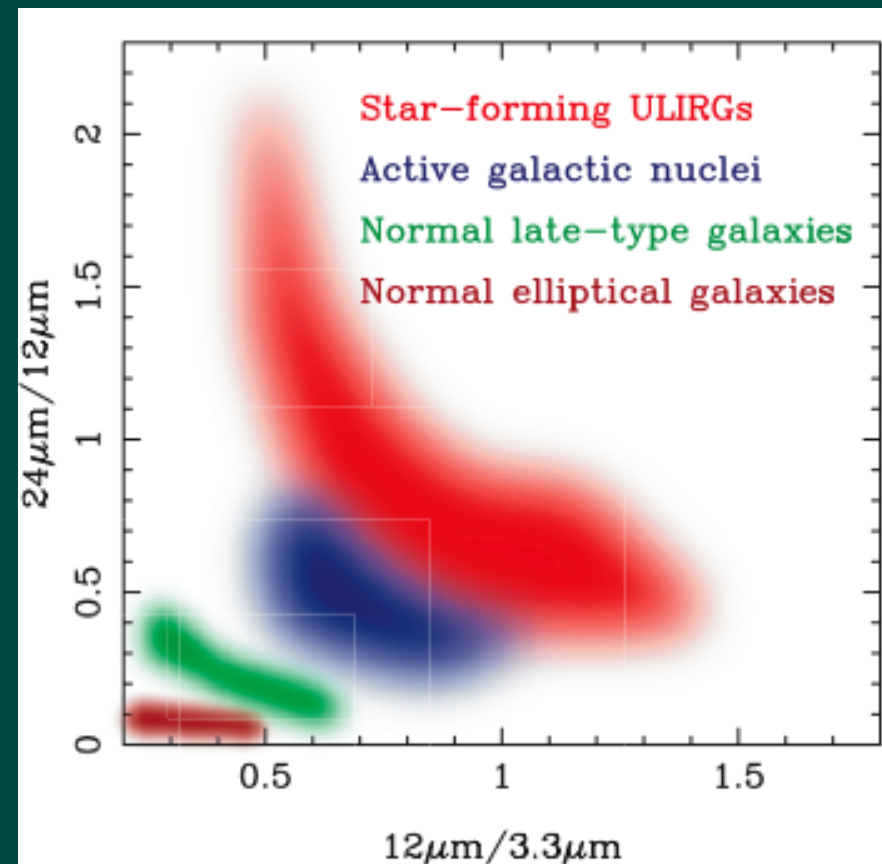
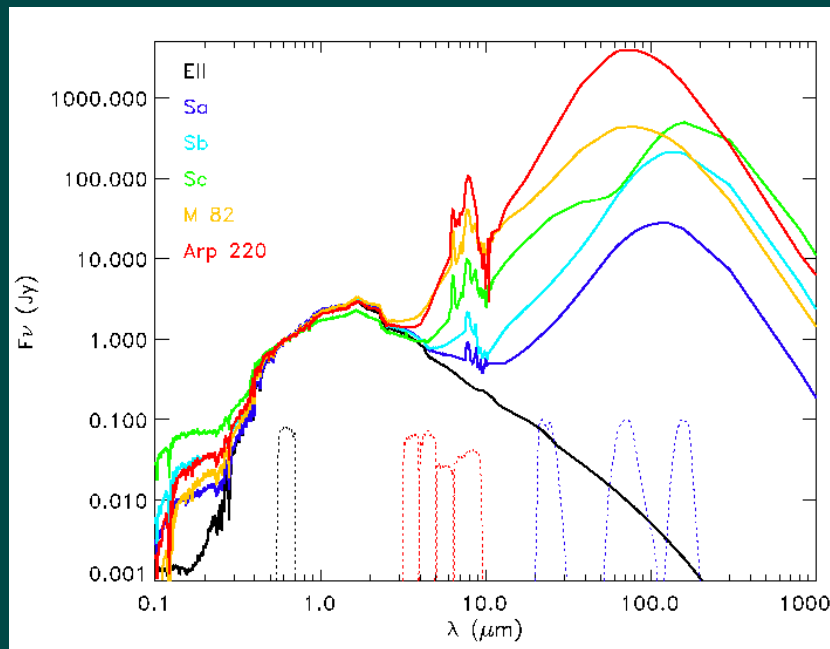
# Herschel Multi-tiered Extra-galactic Survey (HerMES)



Oliver et al. (2008 in prep)

<http://astronomy.sussex.ac.uk/~sjo/Hermes/>

# WISE: selection of ULIRGs/others



Demonstrated for SWIRE  
Degeneracy modest, and help from SDSS  
Millions of objects, follow-up into 2020's



# HerMES & PEP Survey Fields

| Confusion Limits in mJy |     |      |      |      |      |
|-------------------------|-----|------|------|------|------|
| 30 beams/src            | 2.9 | 11.9 | 20.6 | 23.0 | 19.5 |
| +/-                     | 1.0 | 0.9  | 2.2  | 5.3  | 8.4  |
| 4 sigma P(D)            | 1.3 | 8.5  | 20.6 | 25.9 | 24.1 |
| +/-                     | 0.7 | 2.5  | 5.0  | 5.8  | 6.1  |

| Level           | Fields          | RA          | Dec        | Area<br>[sq. deg.] |       |      | Number of SCANS in each mode |                      |                      |              |                | 5-sigma sensitivity (ignoring<br>confusion) |      |      |          |      |      |
|-----------------|-----------------|-------------|------------|--------------------|-------|------|------------------------------|----------------------|----------------------|--------------|----------------|---------------------------------------------|------|------|----------|------|------|
|                 |                 |             |            | Nom.               | Donut | Cum. | PACS-<br>MED                 | PACS-<br>SLOW<br>25" | PACS-<br>SLOW<br>50" | PARA<br>LLEL | SPIRE-<br>FAST | SPIRE-<br>NOM                               | 110  | 160  | 250<br>↓ | 350  | 500  |
|                 |                 |             |            |                    |       |      |                              |                      |                      |              |                |                                             |      |      |          |      |      |
| Clusters Deep   | Various         |             |            | 0.01               | 0.01  | 0.01 |                              | 72                   |                      |              |                | 400                                         | 2.0  | 3.0  | 3.4      | 4.7  | 4.0  |
| Cluster Shallow | Various         |             |            | 0.04               | 0.04  | 0.05 |                              | 30                   |                      |              |                | 240                                         | 3.1  | 4.7  | 4.4      | 6.0  | 5.1  |
| Level-1         | GOODS-S         | 03h32m30.4s | -27d48m17s | 0.11               | 0.11  | 0.16 |                              | 112                  |                      | 4            | 20             | 240                                         | 1.6  | 1.7  | 4.2      | 5.7  | 4.9  |
| Clusters Highz  | Various         |             |            | 0.03               | 0.03  | 0.19 |                              | 24                   |                      |              |                | 120                                         | 3.5  | 5.2  | 6.2      | 8.5  | 7.2  |
| Level-2         | GOODS-N         | 12h36m54.9s | +62d14m19s | 0.11               | 0.11  | 0.30 |                              | 30                   |                      |              |                | 60                                          | 3.1  | 4.7  | 8.8      | 12.0 | 10.2 |
|                 | ECDFS           | 03h32m25s   | -27d48m50s | 0.25               | 0.14  | 0.39 |                              |                      | 16                   | 4            | 20             | 38                                          | 5.9  | 8.3  | 8.7      | 11.9 | 10.1 |
| Level 3         | Lockman-ROSAT   | 10h52m43s   | +57d28m48s | 0.25               | 0.25  | 0.64 |                              |                      | 24                   | 4            | 20             | 14                                          | 4.8  | 6.8  | 11.1     | 15.2 | 12.9 |
|                 | UDS             | 02h17m48s   | -05d05m45s | 0.25               | 0.25  | 0.89 |                              |                      | 21                   | 7            |                | 14                                          | 5.1  | 7.2  | 11.1     | 15.2 | 12.9 |
|                 | Groth           | 14h19m17.4s | +52d49m34s | 0.25               | 0.25  | 1.14 |                              |                      | 20                   | 7            |                | 14                                          | 5.2  | 7.4  | 11.1     | 15.2 | 12.9 |
|                 | Lockman-OWEN    | 10h46m00s   | +59d01m00s | 0.25               | 0.25  | 1.39 |                              |                      | 18                   | 4            | 20             | 14                                          | 5.5  | 7.8  | 11.1     | 15.2 | 12.9 |
|                 | HDFN            | 12h36m49.4s | +62d12m58s | 0.25               | 0.14  | 1.53 |                              |                      |                      |              |                | 30                                          |      |      | 12.4     | 17.0 | 14.4 |
| Level-4         | COSMOS          | 10h00m28.6s | +02d12m21s | 2                  | 2.0   | 3.53 | 52                           |                      |                      |              |                | 40                                          | 6.2  | 8.7  | 10.8     | 14.7 | 12.5 |
|                 | UDS             | 02h17m48s   | -05d05m45s | 0.7                | 0.5   | 3.98 |                              |                      |                      | 7            | 7              | 14                                          | 8.3  | 11.8 | 11.1     | 15.2 | 12.9 |
|                 | VVDS            | 02h26m00s   | -04d30m00s | 0.7                | 0.7   | 4.68 |                              |                      |                      | 7            | 7              | 14                                          | 8.3  | 11.8 | 11.1     | 15.2 | 12.9 |
| Level-5         | XMM             | 02h21m36s   | -04d39m00s | 5                  | 3.6   | 8.3  |                              |                      |                      | 7            |                |                                             | 20.4 | 29.3 | 14.0     | 19.3 | 16.3 |
|                 | ELAIS-N1-SCUBA2 | 16h10m00s   | +54d30m00s | 2                  | 2.0   | 10.3 |                              |                      |                      | 7            |                |                                             | 20.4 | 29.3 | 14.0     | 19.3 | 16.3 |
|                 | Bootes-SCUBA2   | 14h32m06s   | +34d16m48s | 2                  | 2.0   | 12.3 |                              |                      |                      | 7            |                |                                             | 20.4 | 29.3 | 14.0     | 19.3 | 16.3 |
|                 | EGS-SCUBA2      | 14h19m12s   | +52d48m00s | 1.3                | 1.1   | 13.3 |                              |                      |                      | 7            |                |                                             | 20.4 | 29.3 | 14.0     | 19.3 | 16.3 |
|                 | CDFS            | 03h32m00s   | -28d16m00s | 8                  | 7.8   | 21.1 |                              |                      |                      | 4            | 20             |                                             | 27.0 | 38.8 | 14.0     | 19.3 | 16.3 |
|                 | Lockman         | 10h45m00s   | +58d00m00s | 11                 | 10.5  | 31.6 |                              |                      |                      | 4            | 20             |                                             | 27.0 | 38.8 | 14.0     | 19.3 | 16.3 |
| Level-6         | XMM             | 02h21m20s   | -04d30m00s | 9.3                | 4.3   | 35.9 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |
|                 | ELAIS S1 SWIRE  | 00h38m30s   | -44d00m00s | 7                  | 7.0   | 42.9 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |
|                 | ELAIS N1 SWIRE  | 16h11m00s   | +55d00m00s | 9.3                | 7.3   | 50.2 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |
|                 | ELAIS N2 SWIRE  | 16h36m48s   | +41d01m45s | 4.8                | 4.8   | 55.0 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |
|                 | NDWFS/Bootes    | 14h32m06s   | +34d16m48s | 8                  | 6.0   | 61.0 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |
|                 | FLS             | 17h18m00s   | +59d30m00s | 4.7                | 4.7   | 65.7 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |
|                 | 0444 Akari      | 04h41m24s   | -53d22m12s | 7                  | 7.0   | 72.7 |                              |                      |                      | 2            |                |                                             | 38.2 | 54.8 | 26.2     | 36.1 | 30.4 |



Level 1/2 Fields

Level 3 Fields

Level 4 Fields

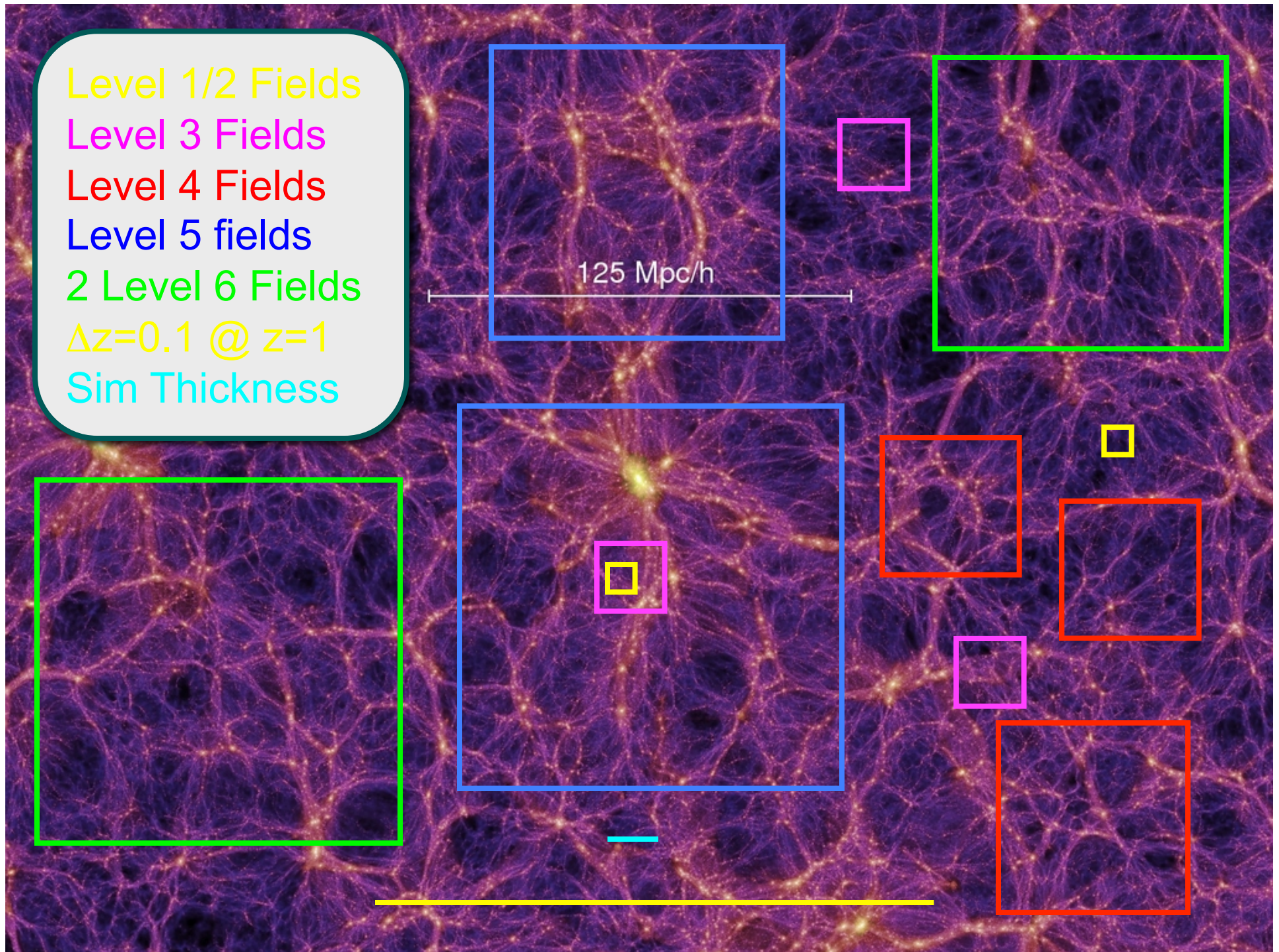
Level 5 fields

2 Level 6 Fields

$\Delta z=0.1$  @  $z=1$

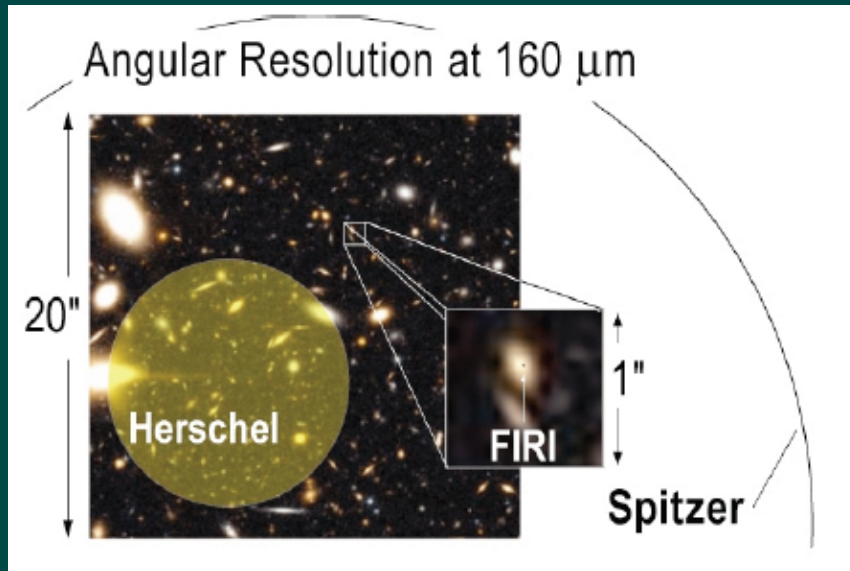
Sim Thickness

125 Mpc/h

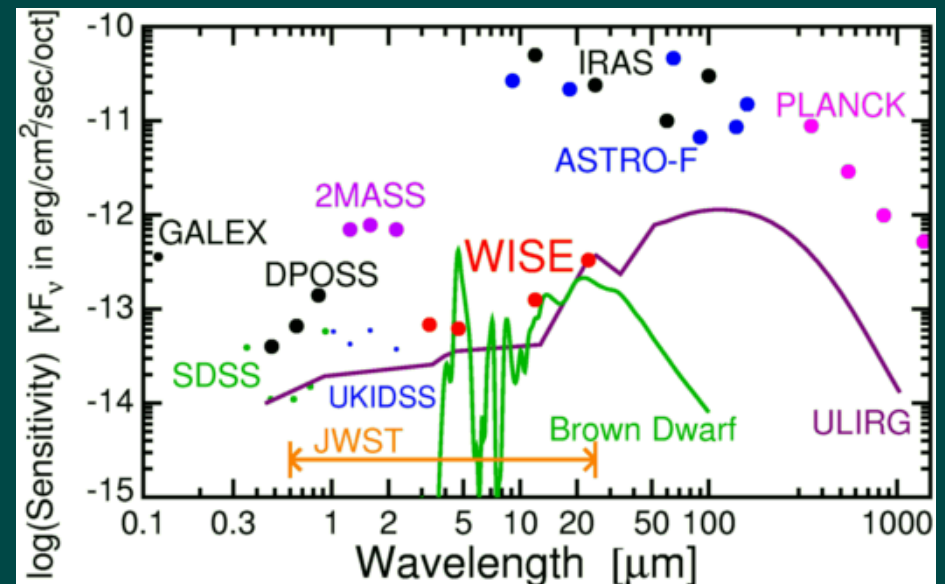




# Probing below nominal Confusion WISE sensitivities



Clusters as lenses  
Source position priors  
Fluctuations  
 $P(D)$   
Stacking







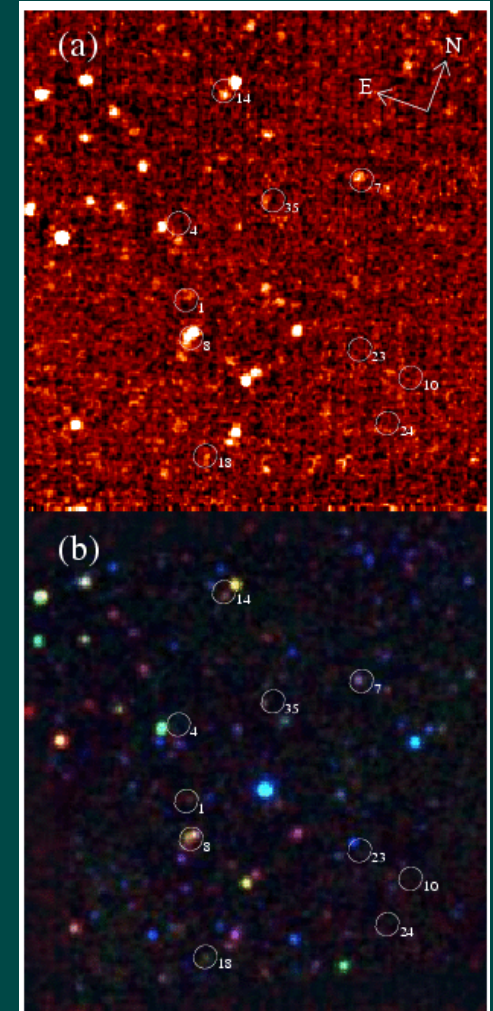
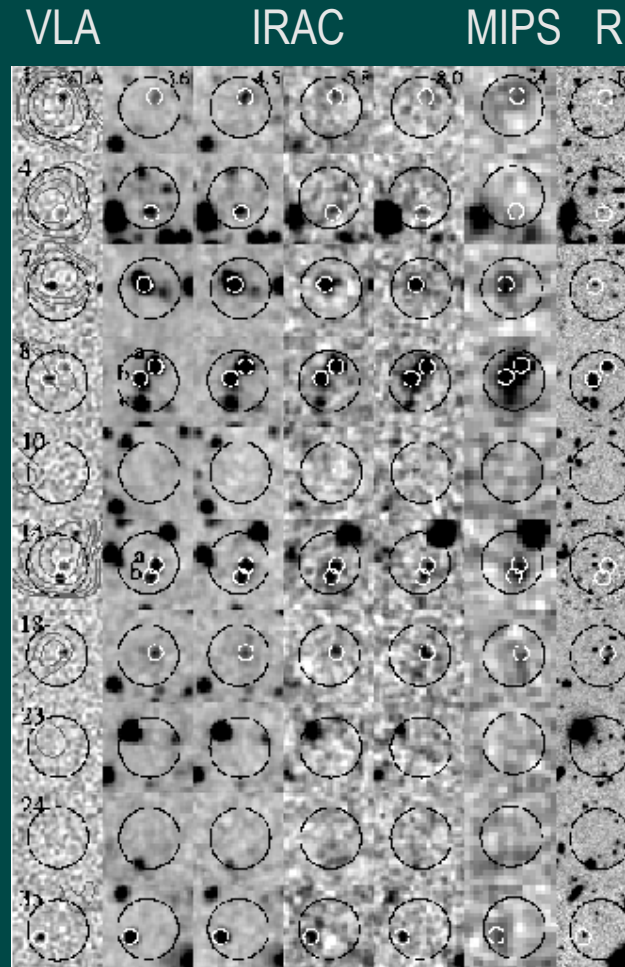
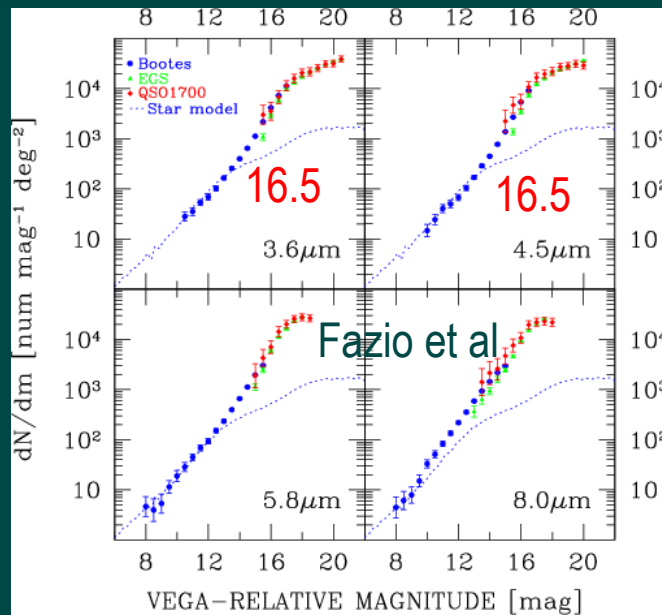
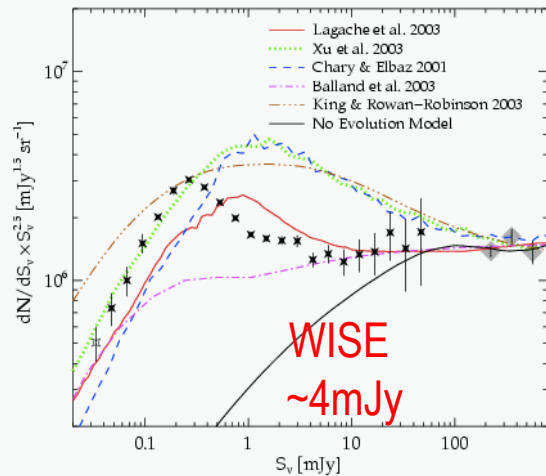
# Spitzer results as taster

US

University of Sussex

5 x 5 arcmin

Papovich et al



Egami et al 4,8,24 microns - about 10x deeper than WISE



- 22k spectroscopic redshifts (NED as of Sep. 2008)
- Spitzer data 3-160micron
  - (SWIRE, SpUDS, Bootes, SERVS etc.)
- NIR data
  - UKIDSS-UDS/DXS
  - VISTA VDF/VIDEO
- SCUBA-2 CLS (CDFS, XMM), LABOCA, etc.
- Radio, GMRT, VLA, ATCA, LOFAR
- Galex, XMM, Chandra, etc.

# Schedule

## Herschel

Launch L = 18 May 2009

L+6mo Science Demonstration SVR

L+6mo Sep-Nov 2009 (Routine Obs. Start) ROS

L+9mo Feb 2010 (Prior to AO2) EDR

L+18mo Nov 2010 (ROS+12) DR1 ALMA ES call

L+42mo Nov 2012 (End of Mission) DR2

## WISE

Launch L = 7 Dec 2009

L+1mo IOC; L+7mo primary survey 2010; L+10mo End of Mission

L+18mo data release

- Confirmation of high-redshift, high star-formation rate (sfr) objects
  - Formation of the most massive galaxies
  - Mapping magnified critical lines in clusters
- Systematic studies of star-formation – selecting on bolometric power
  - gas mass, sfr, stellar mass, environment
  - Disk sizes and gas morphology
  - AGN vs star-formation rings (feedback, bolometric contributions to CIRB)
  - Atomic and molecular gas / dust physics



# Expected Number of HerMES Sources

|          | Area./<br>sq.<br>deg | 110   | 250   | 500  | Any   | All  | S850/<br>mJy | T/Hr |
|----------|----------------------|-------|-------|------|-------|------|--------------|------|
| Clusters | 0.08                 | 772   | 918   | 186  | 1051  | 141  |              |      |
| Level-1  | 0.11                 | 1930  | 1470  | 311  | 2920  | 276  | 0.5          | 3.80 |
| Level-2  | 0.36                 | 2170  | 1747  | 240  | 2690  | 184  | 1.4          | 0.49 |
| Level-3  | 1.25                 | 5360  | 3943  | 485  | 7054  | 390  | 1            | 0.95 |
| Level-4  | 3.4                  | 12520 | 11470 | 1432 | 16020 | 1022 | 1.5          | 0.42 |
| Level-5  | 29.3                 | 20374 | 52590 | 7400 | 42390 | 3279 | 2            | 0.24 |
| Level-6  | 50.1                 | 10000 | 6830  | 3400 | 32100 | 1200 | 3.7          | 0.07 |

> 100k sources

WISE covers all (99.5%) of sky and sees  $10^{7-8}$  galaxies

## At moderate $1 < z < 2$

- Herschel will provide bolometrically selected samples  
(+ with extensive ancillary data)
- Alma will allow us to study the detailed physics of
  - star-formation  $\leftrightarrow$  gas interaction, AGN feedback

## At high $z > 3$

Herschel surveys provide, high- $z$ , high SFR candidates  
Alma can confirm  
pathfinder & complementary to deep Alma surveys