ISO and the Cosmic Infrared Background

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Outline

- Extragalactic Background Light
- MIR Surveys
  - Source Counts
  - Galaxy Population
- FIR Surveys
  - Source Counts
  - Galaxy Population
  - Fluctuation Analysis
- Models
- Potential of ISO data
- Next Step: SIRTF

The Extragalactic Background Light

Extragalactic Background Light

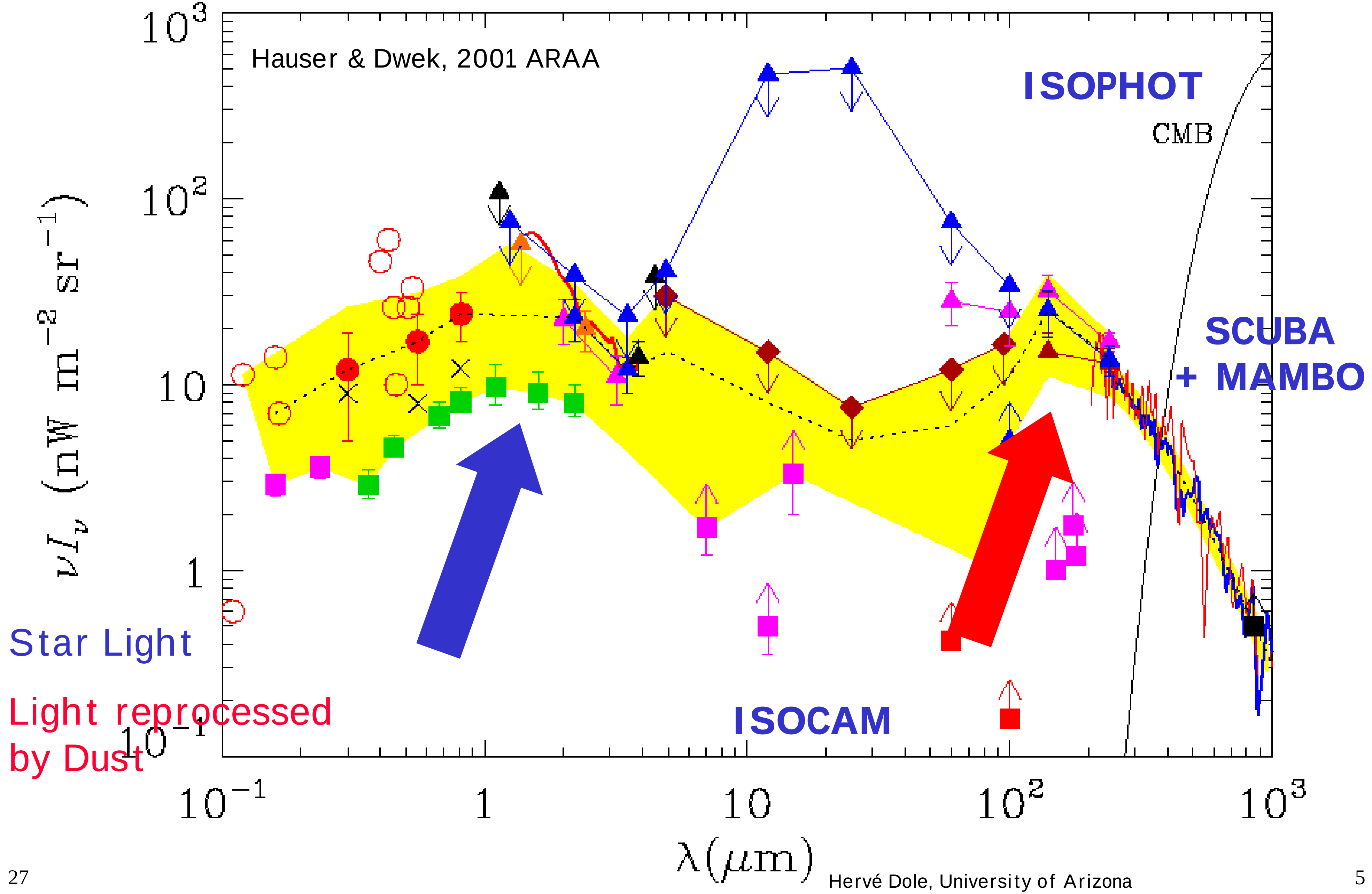
Nature

- Integrated Emission of
  - all galaxies
  - at every redshift
- Isotropic
- Integrate the history of galaxy formation and evolution
- Different from CMB !

Questions

- How and when galaxies form ? How do they evolve ?
- How do evolve the Luminosity Function (w/ z & λ)?
- What is the nature of the galaxies w/ z ?
- Which population contributes at what level to the Extragalactic Background Light ?
- What is the global star formation rate (SFR) history ?

Extragalactic Background

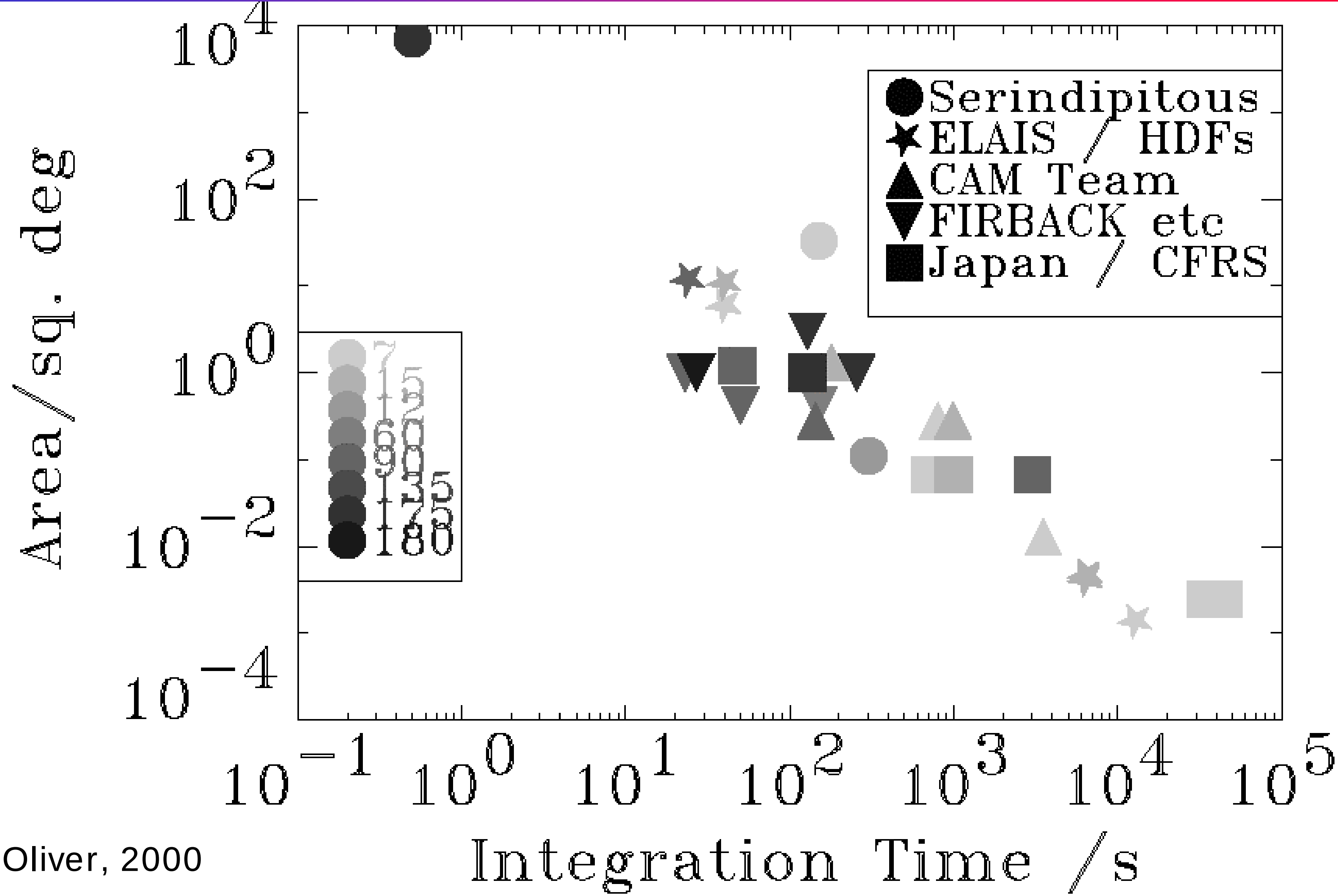


Why Deep Infrared Surveys ?

- Local Universe
  - 30% of the total energy output of galaxies emerges in the Mid- to Far- Infrared
  - Optical/UV observations relevant
- Cosmic Infrared Background
  - More (or equal) energy output in the IR than in the optical/UV it tells us that the dust plays an important role in the processes of galaxy formation/evolution

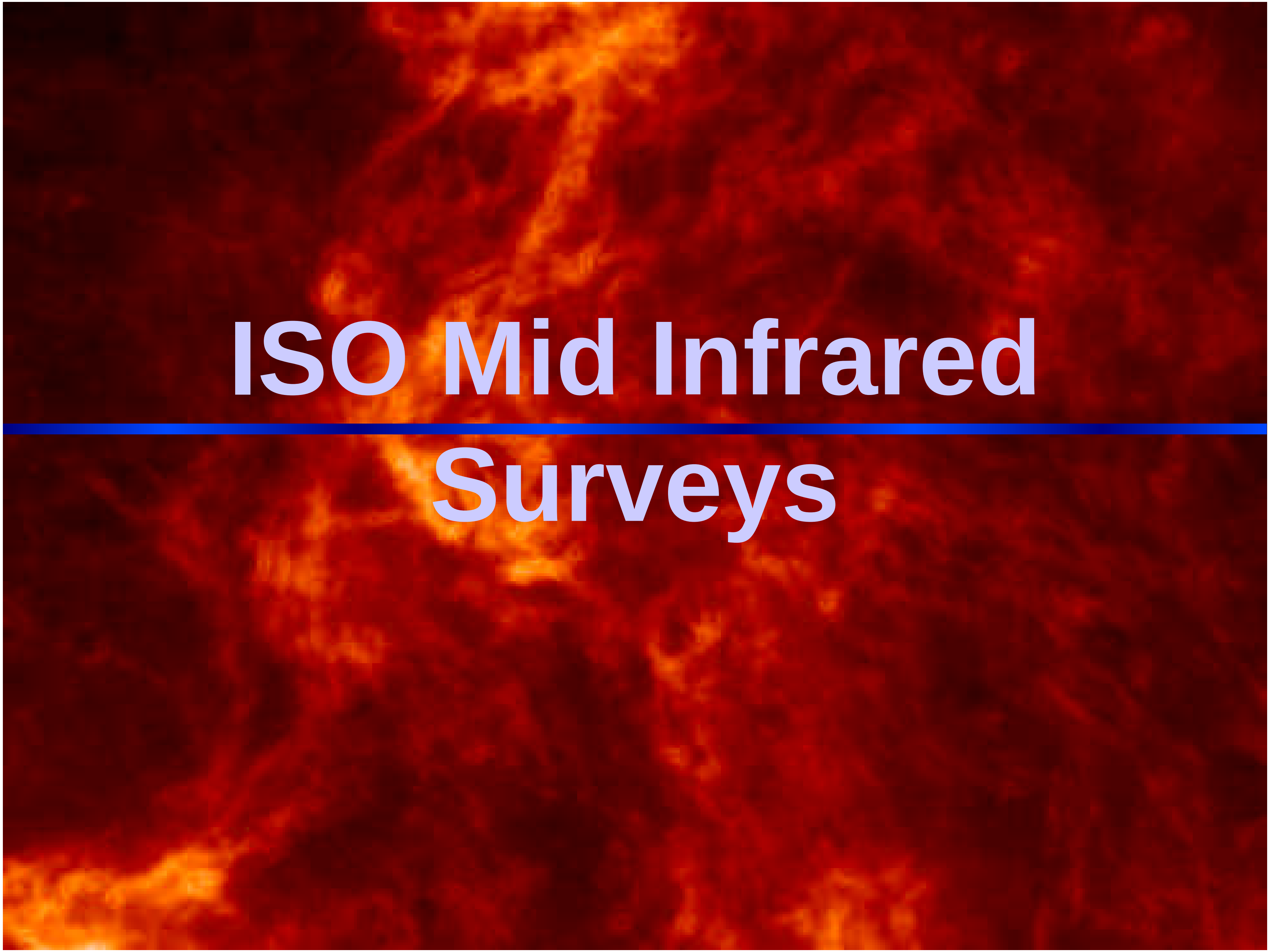
  - **IR observations: a key to understand these processes**

ISO Cosmological Surveys



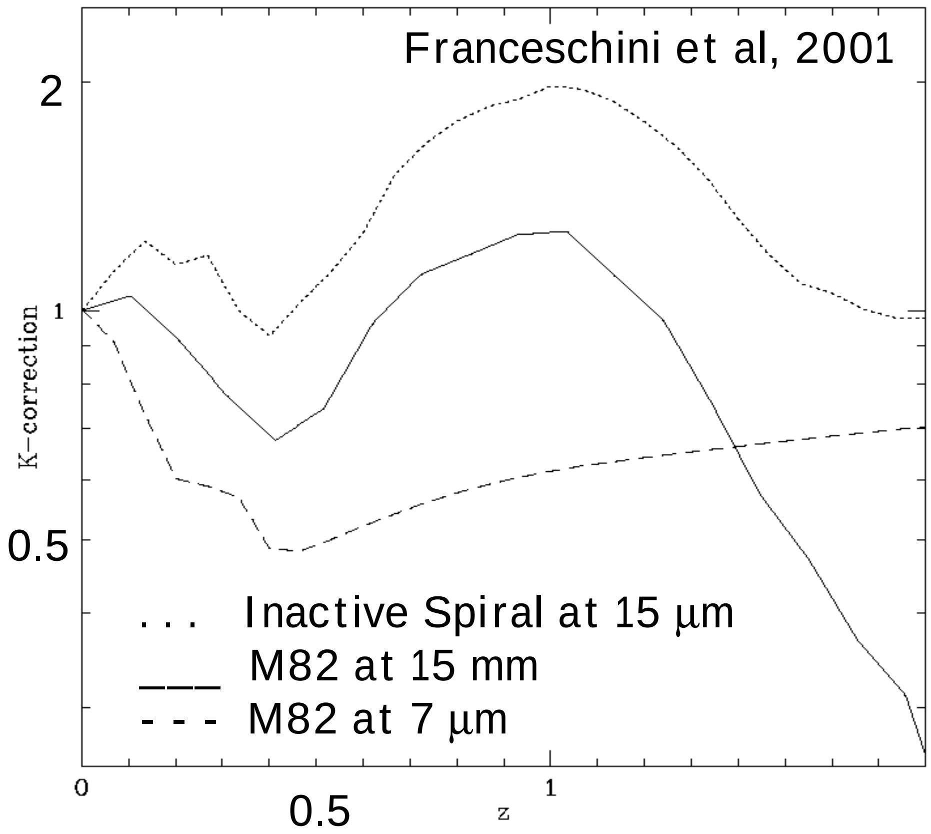
Oliver, 2000

ISO Mid Infrared Surveys



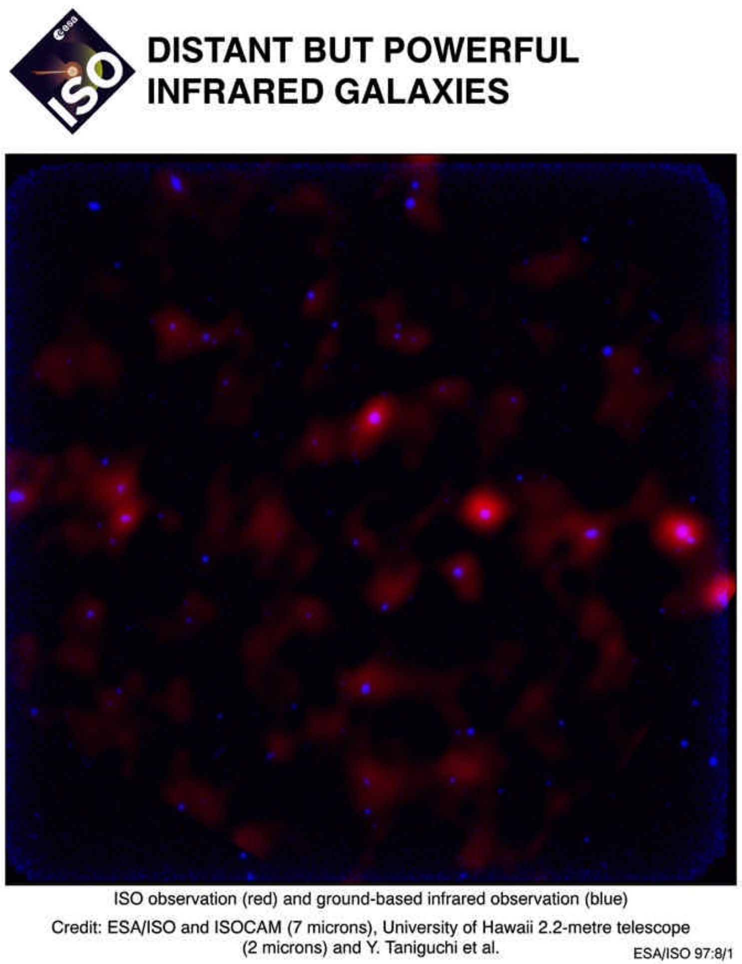
Mid Infrared Surveys

- 15 µm
  - More relevant for cosmological studies
  - Favorable K-Correction
- 7 µm
  - More stellar contamination
  - Less favorable K-correction



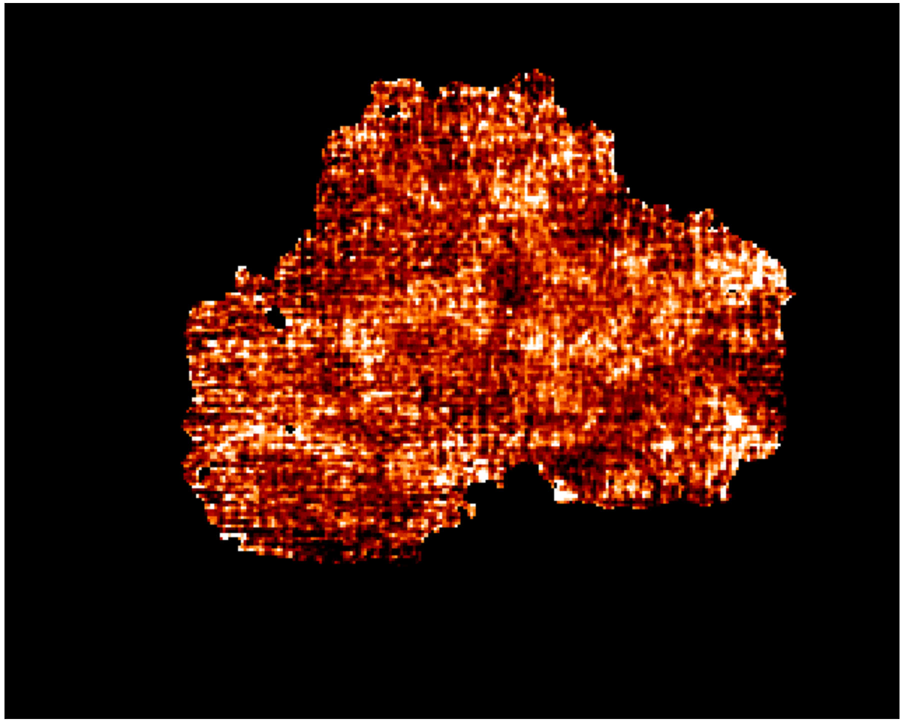
ISOCAM 7 mm

Lockman Hole
0.0025^{o2}



Taniguchi et al, 97

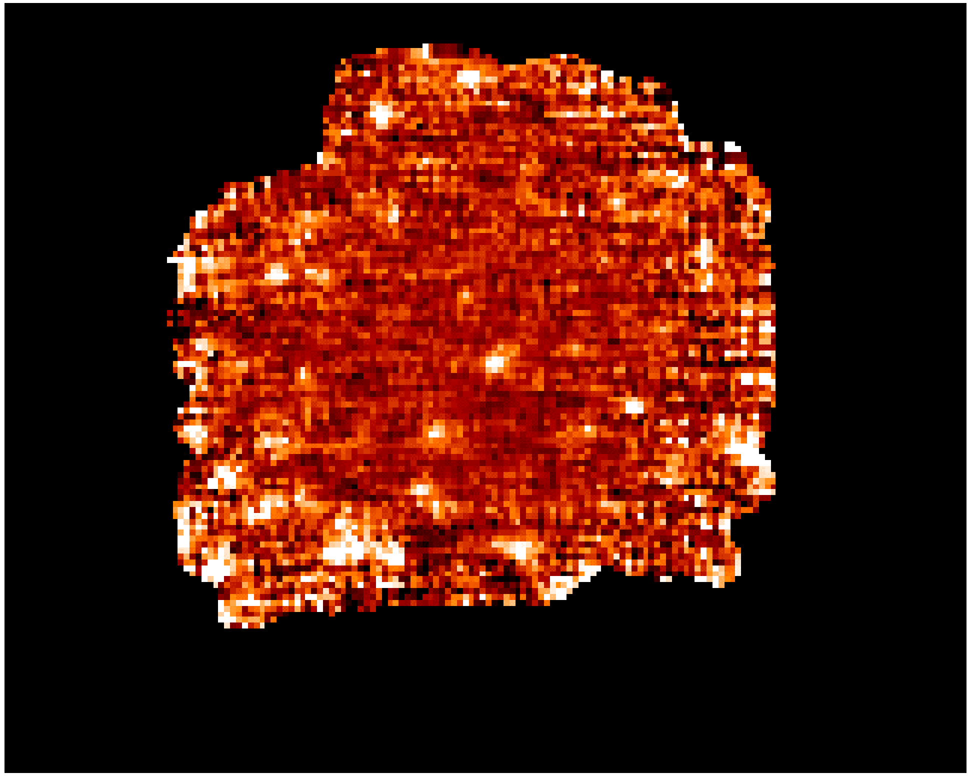
HDF-S
0.005^{o2}



Oliver et al, 2002

ISOCAM 15 mm

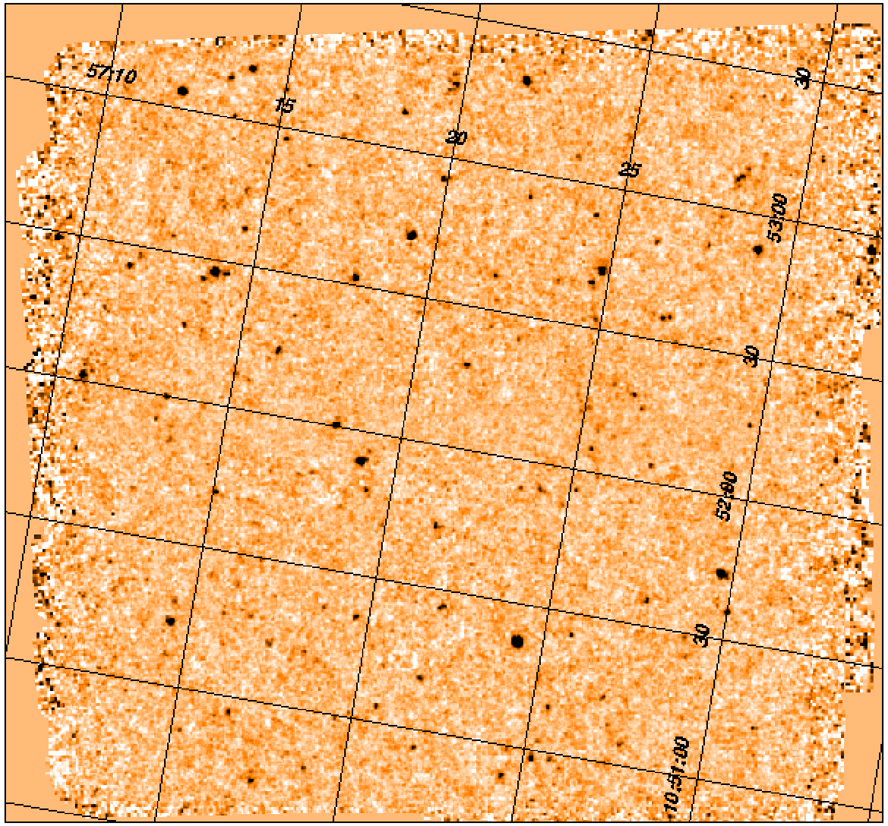
HDF-S



0.005^{o2}

Oliver et al, 2002

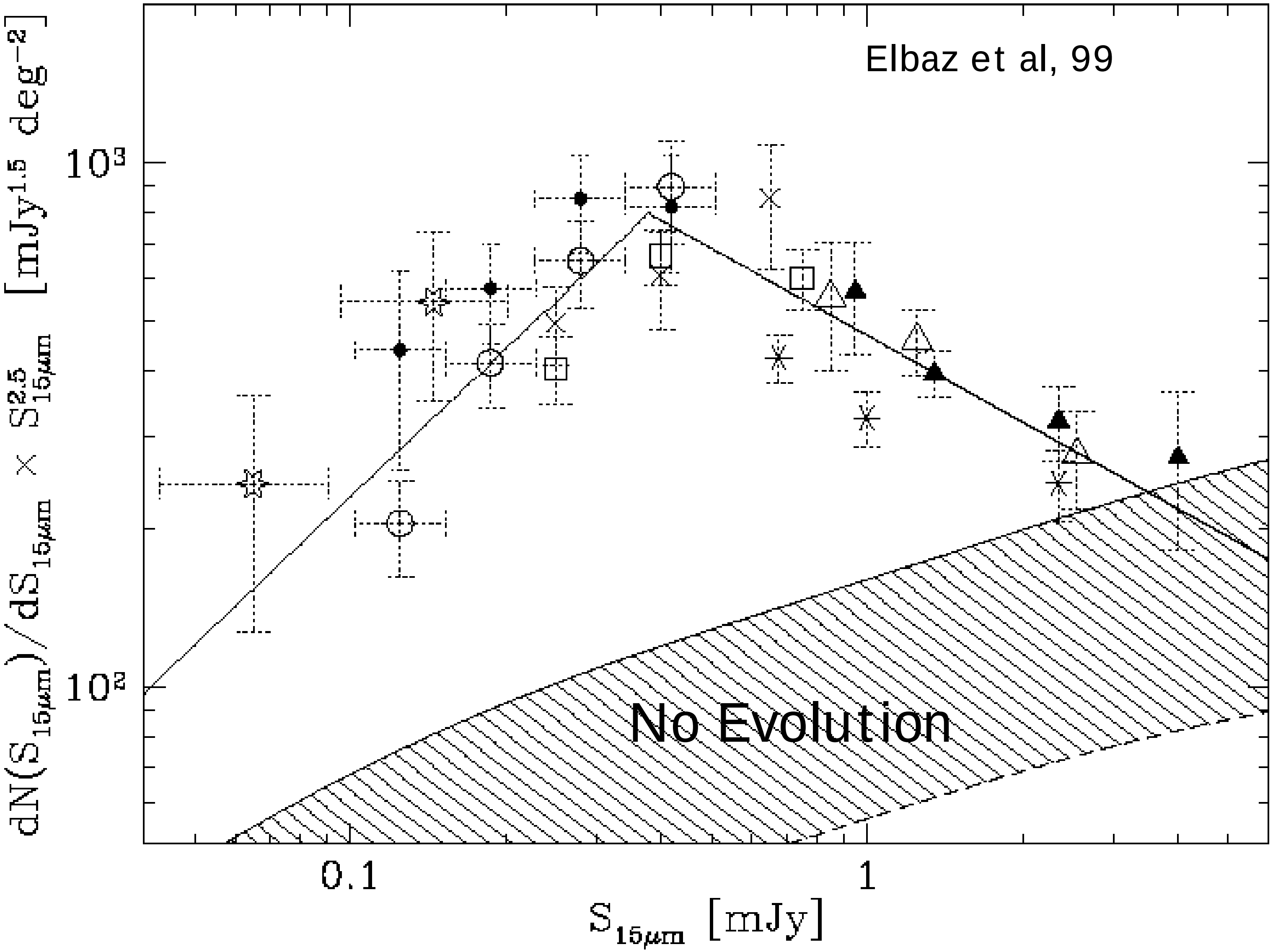
Lockman Hole



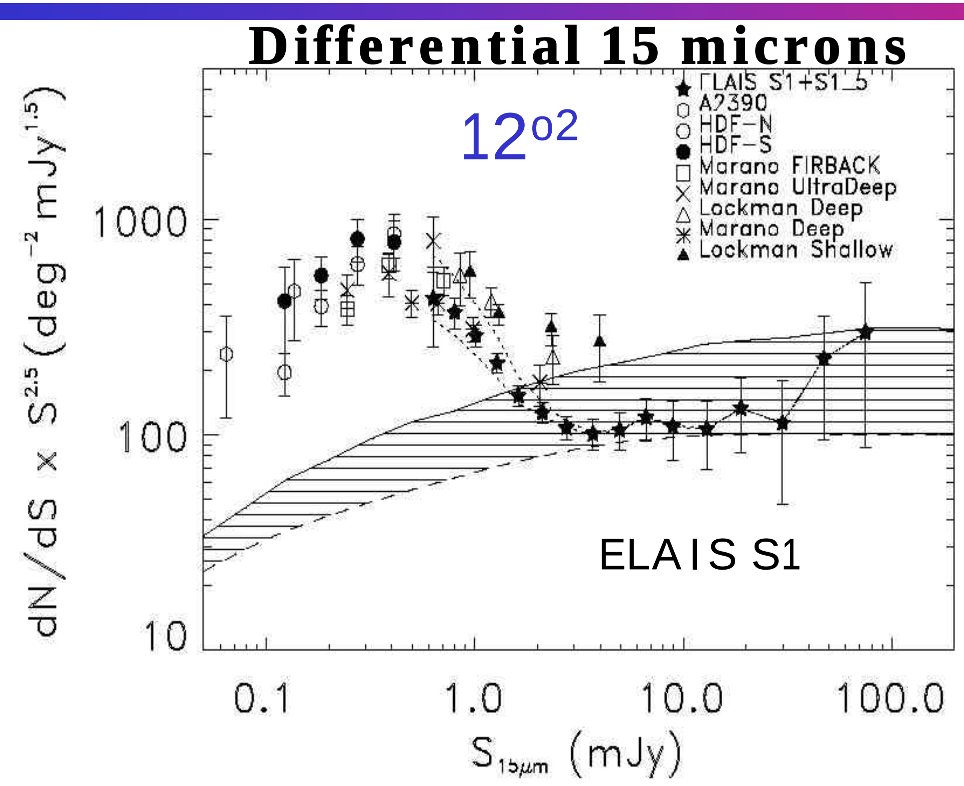
0.15^{o2}

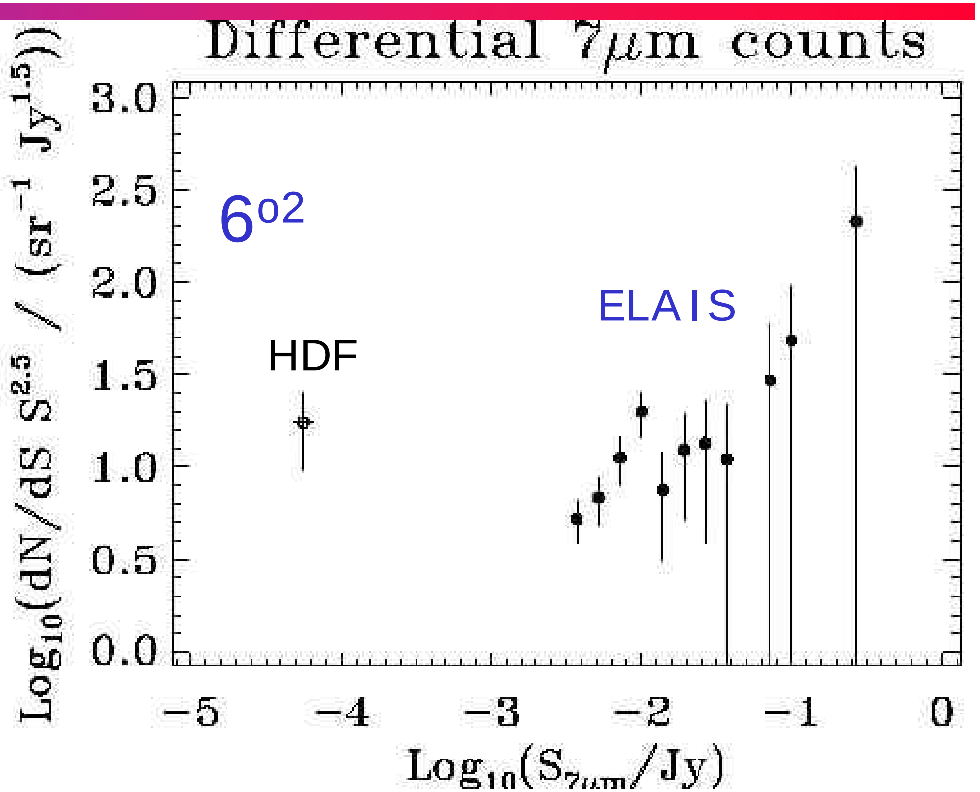
Fadda et al, in prep

15 mm Source Counts



ELAIS MIR Source Counts





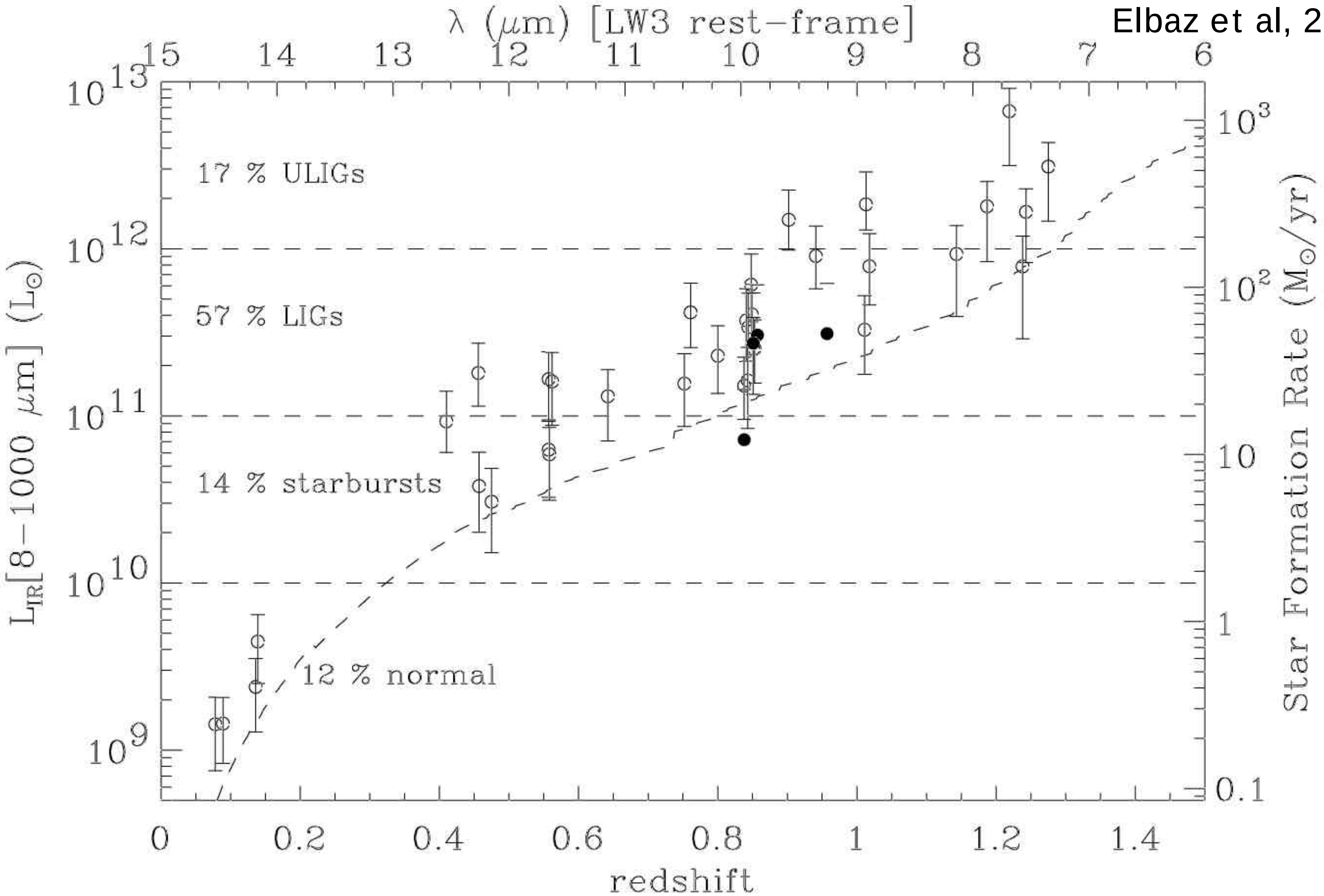
Gruppioni et al, 2002

(see also Oliver et al, 2002)

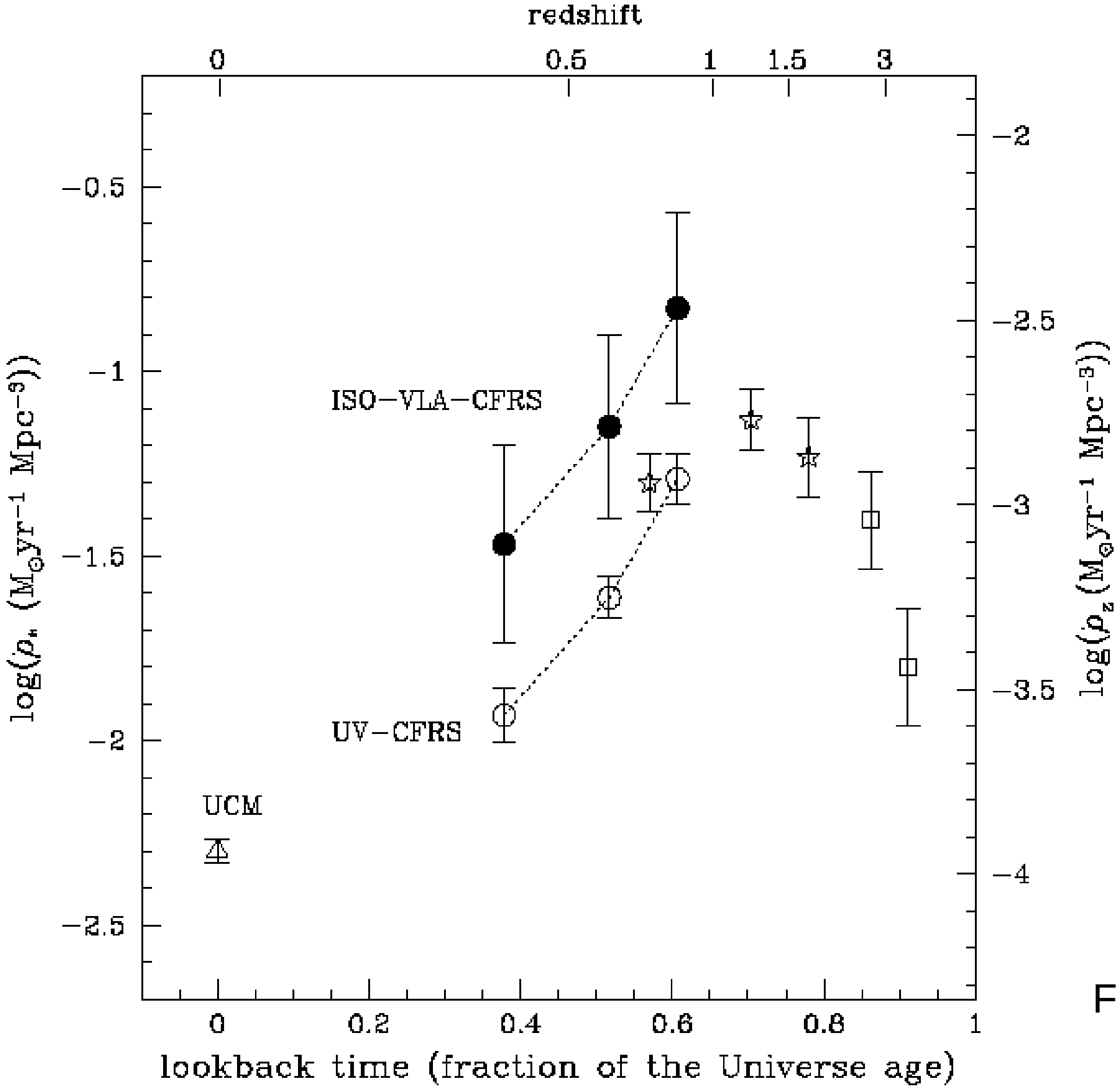
Serjeant et al, 2000

15 mm Sources

Elbaz et al, 2002



Star Formation Rate



Flores et al, 99

15 μm Universe

Source Counts

- Strong Evolution below 1 mJy

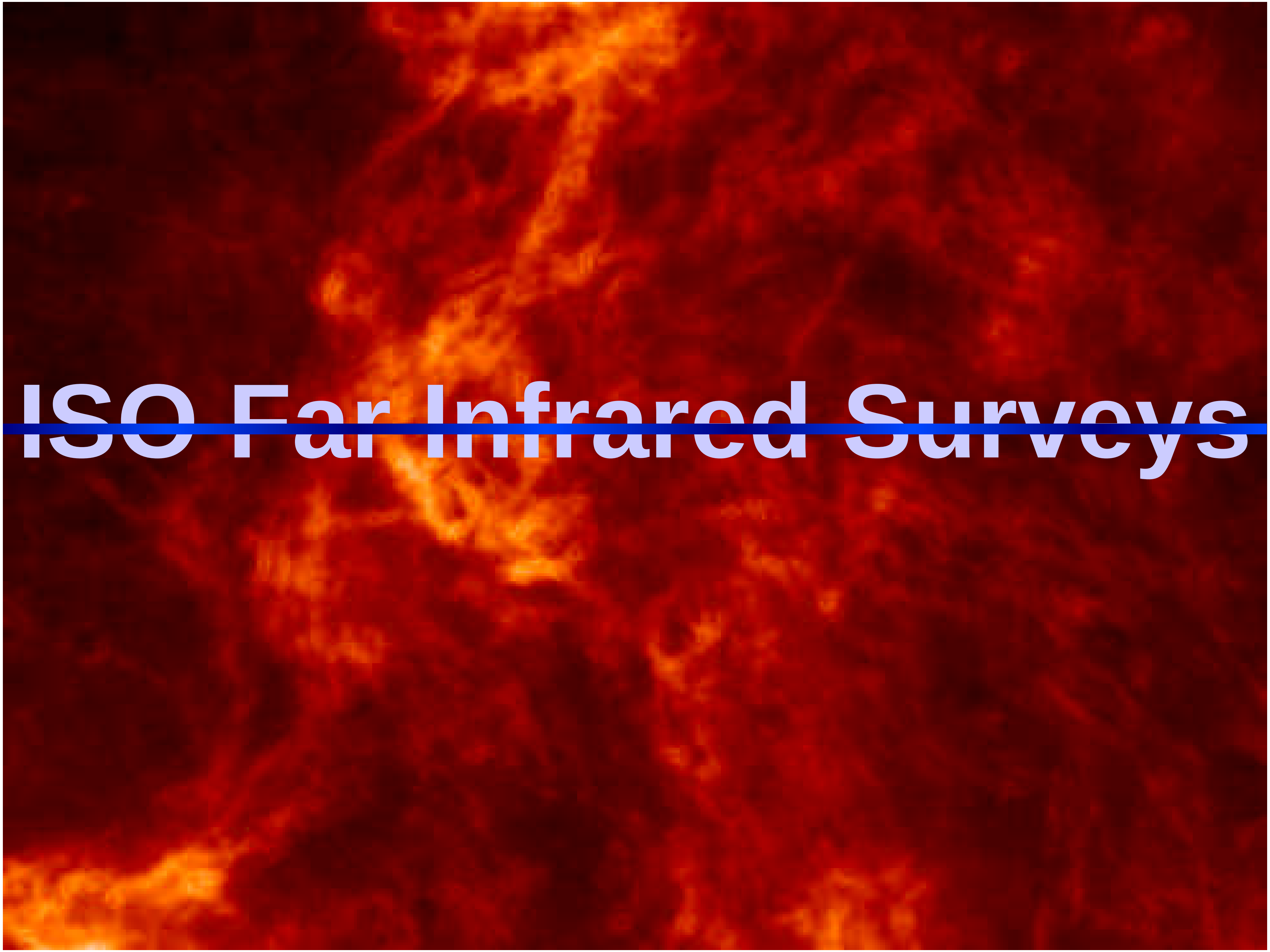
Sources and Evolution

- z distribution: between 0.5 and 1.2; z median = 0.8
- < 20% AGNs
- 75% LIRG, SFR ~ 100 $M_\odot$/yr
- Comoving light density increased by 70 ±35 from z=0 to z=1
  - At z=0, LIRGs represent only 2% of bolometric luminosity density
  - At z=1, LIRGs represent a major contributor

CIB

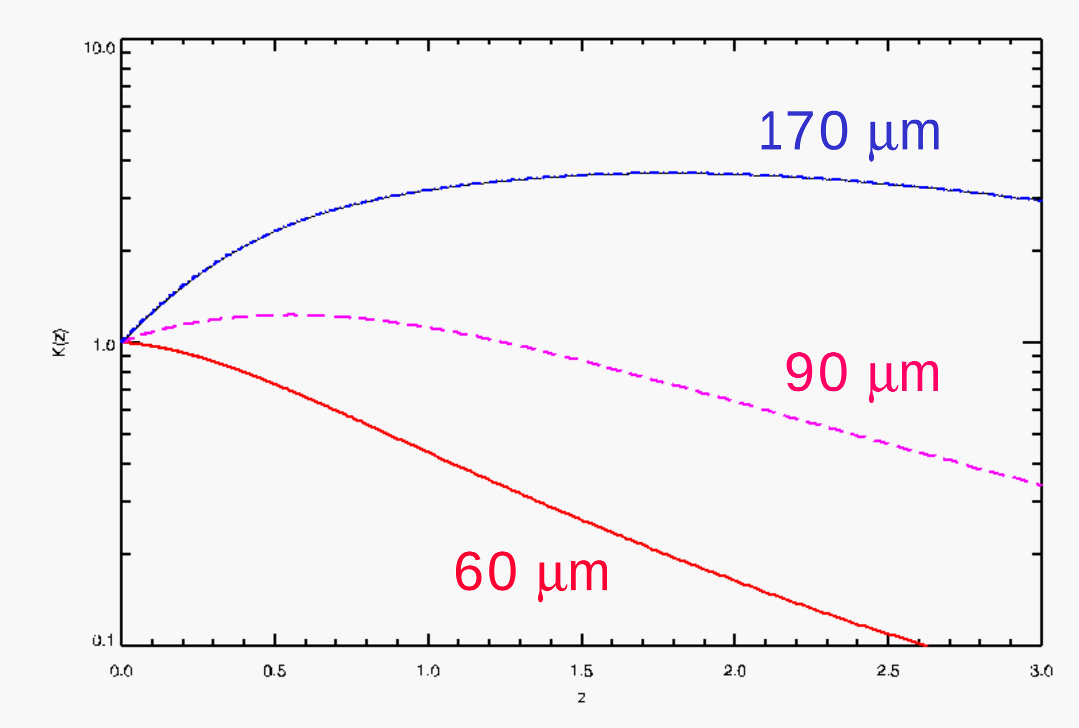
- ~ 70% CIB resolved at 15 μm
- 15 μm sources contribute to ~ 70±30% CIB at 140 μm

ISO Far Infrared Surveys

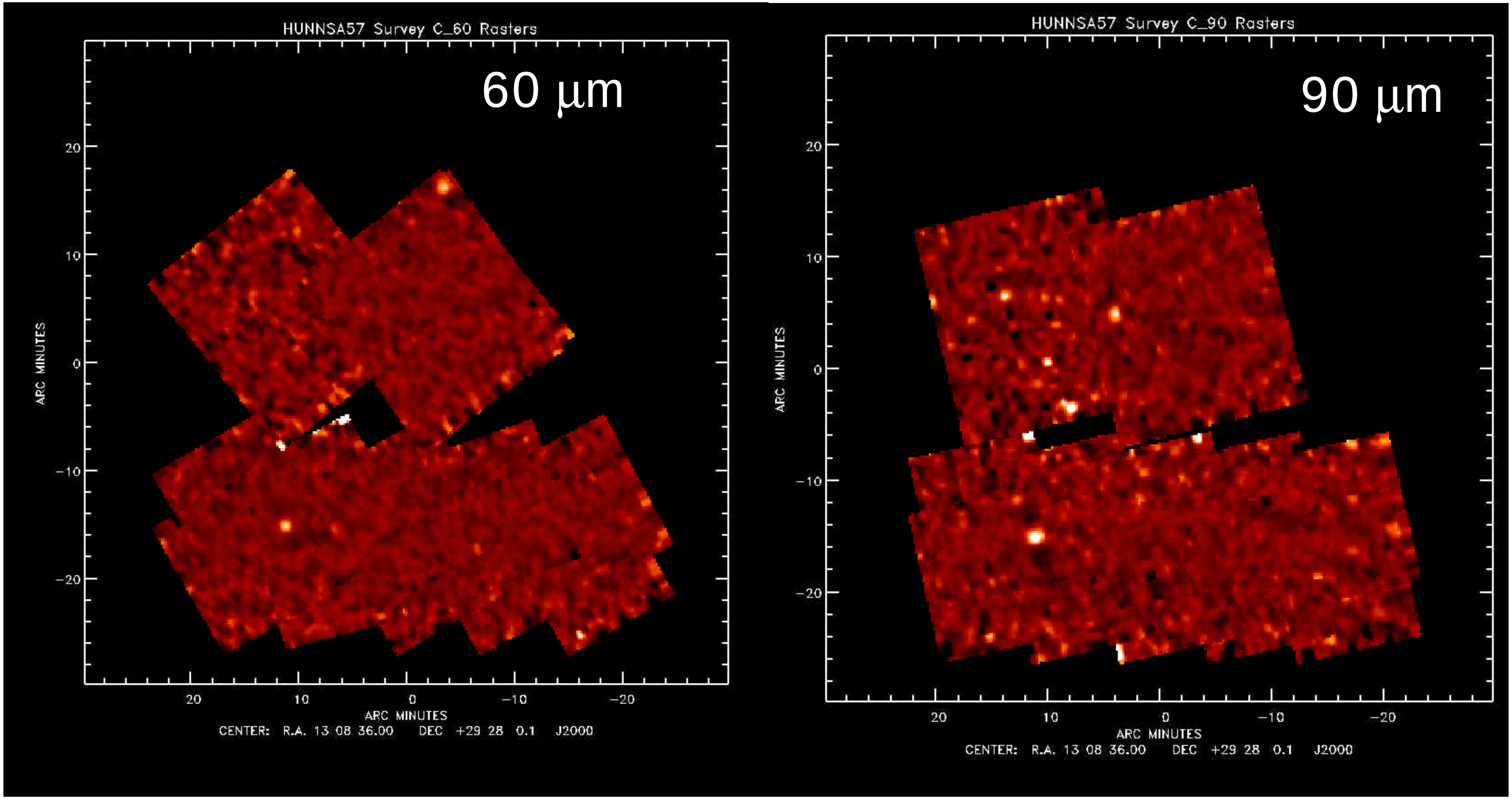


Far Infrared Surveys

- 50-100 μm
  - Peak of rest-frame emission from obscured SF ~60-80 μm
- 100-200 μm
  - Advantageous K-correction
  - Cool galaxies
    - Local cool galaxies
    - Redshifted SB
- FIR
  - Total Bolometric Luminosity: Unbiased Measurement



SA57 at 60 and 90 mm



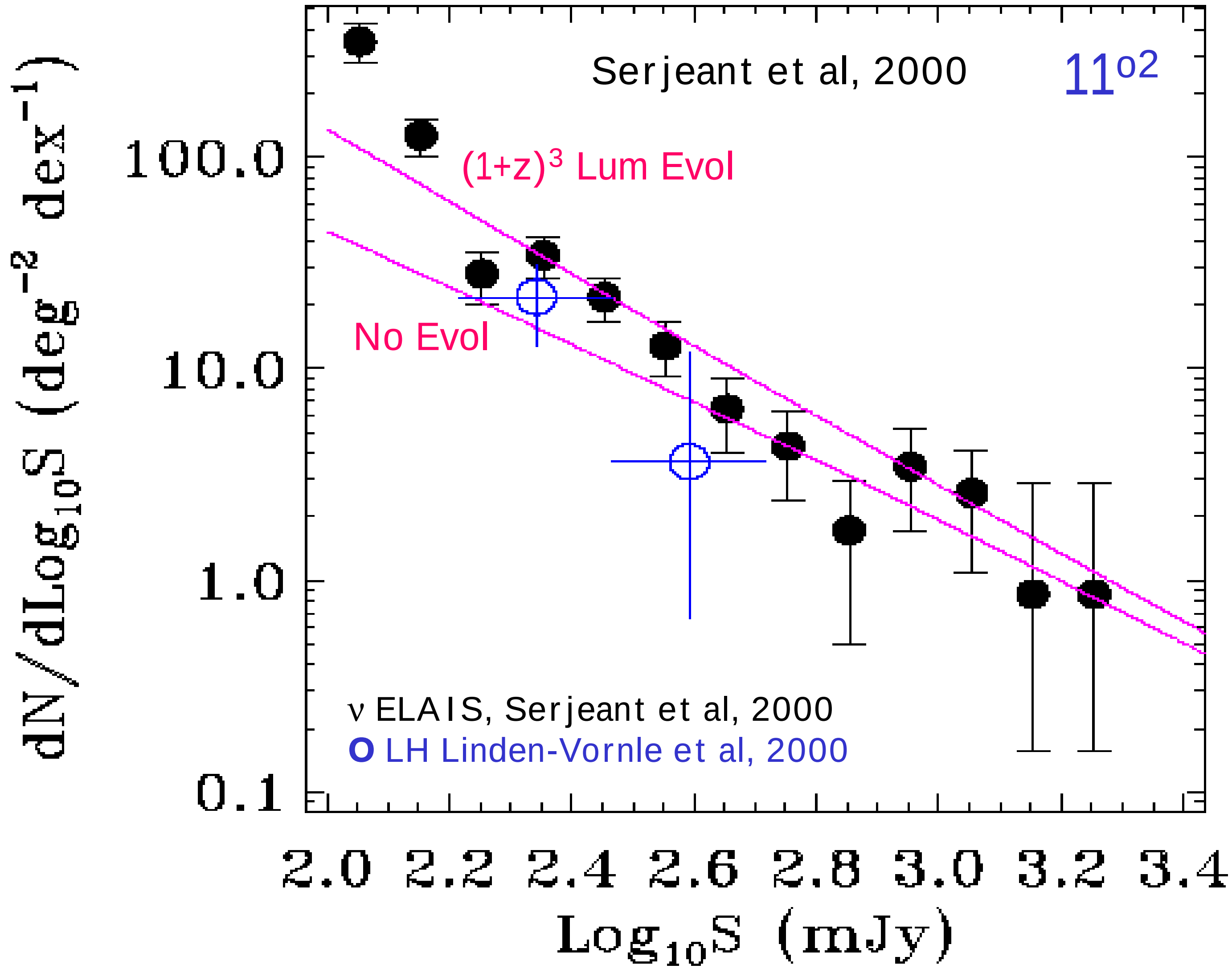
Linden-Vornle et al, 2000

0.4^{o2}

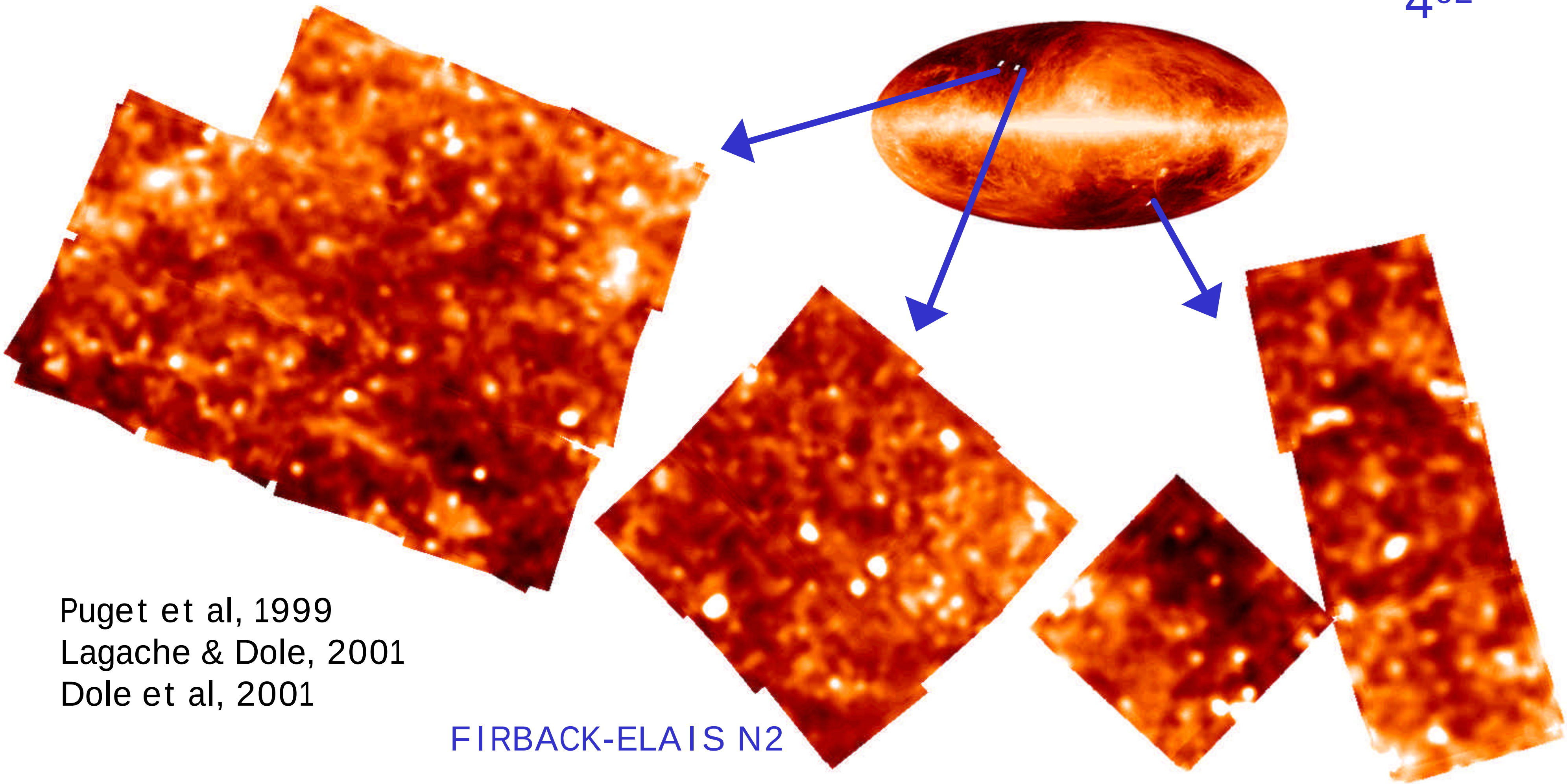
ELAIS 90 mm Source Counts

60 and/or 90 µm Source Counts:

Kawara et al, 1998
Efstathiou et al, 2000
Juvela et al, 2000
Linden-Vornle et al, 2000
Serjeant et al, 2000
Matsuhara et al, 2000



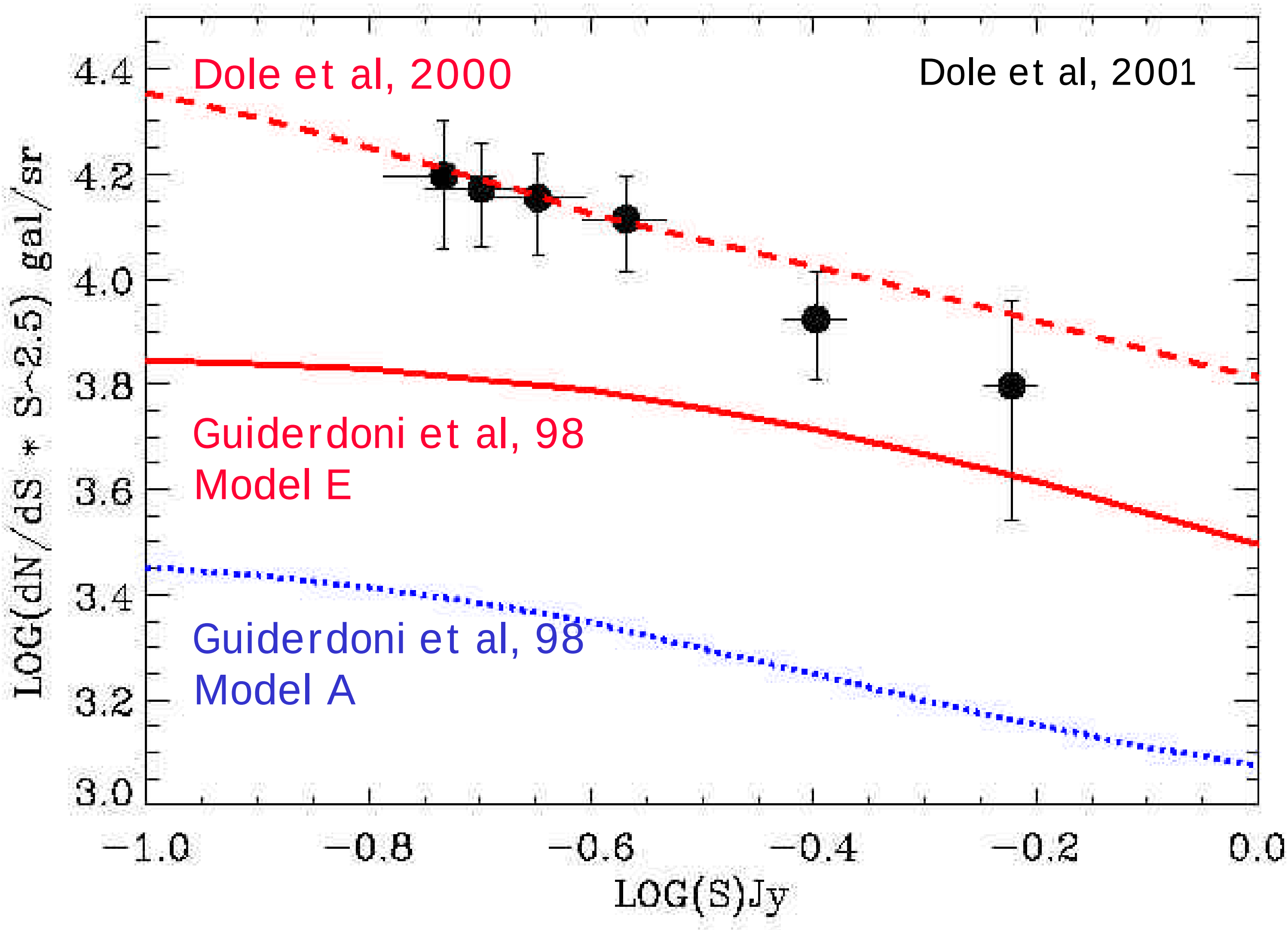
FIRBACK at 170 μm



Puget et al, 1999
Lagache & Dole, 2001
Dole et al, 2001

170 mm Source Counts

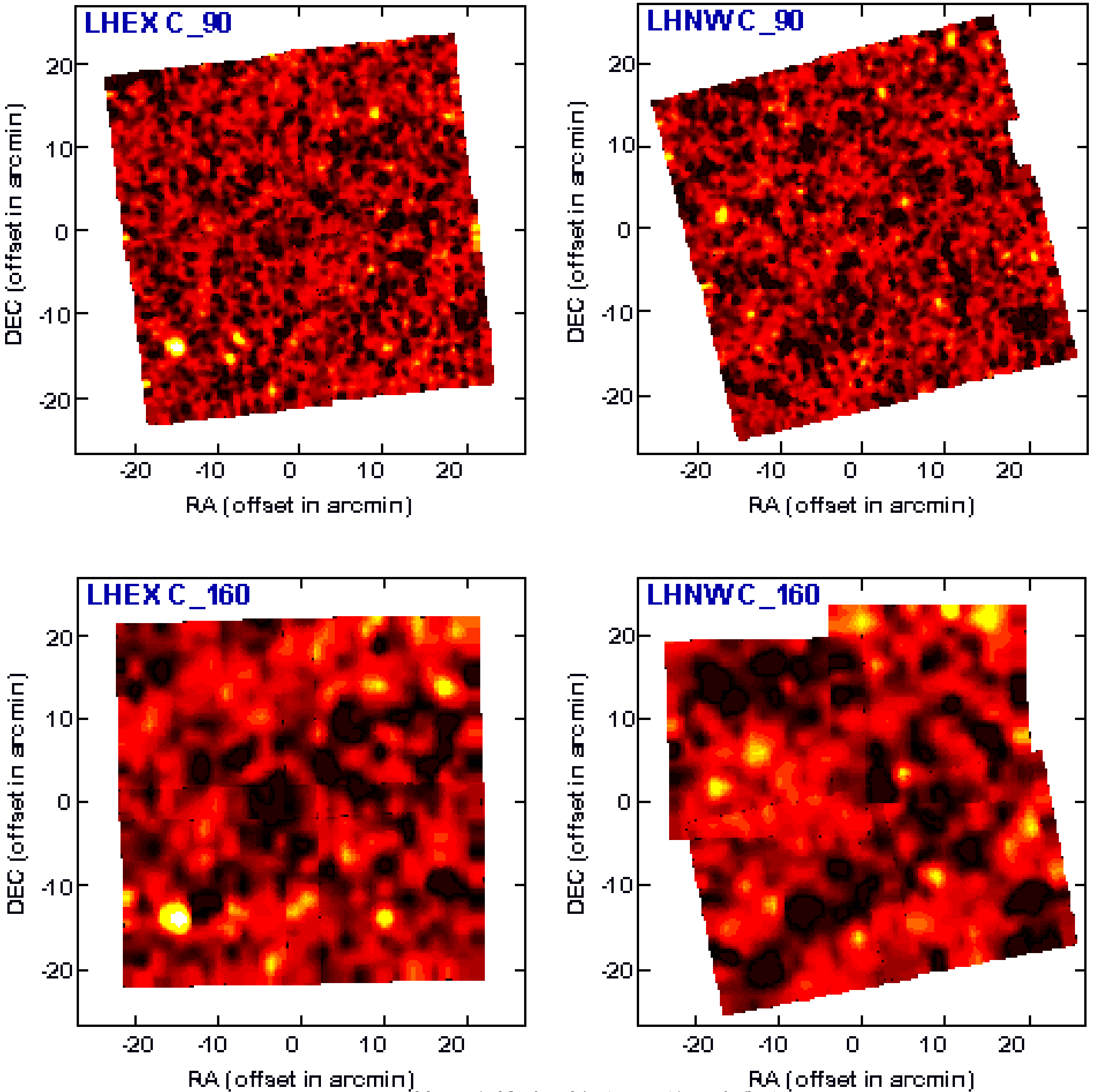
~ 5% CIB resolved at 170 µm
Predicted bulk: 2-10 mJy



170 µm Source Counts:

Kawara et al, 1998
Puget et al, 1999
Juvela et al, 2000
Matsuhara et al, 2000
Dole et al, 2001

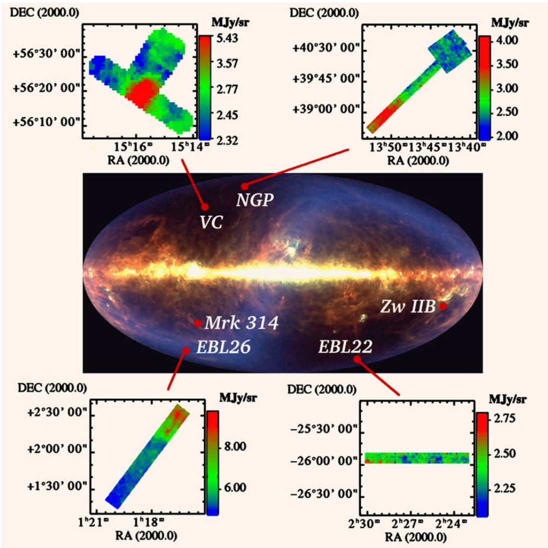
Lockman Hole at 90 and 170 mm



1o2

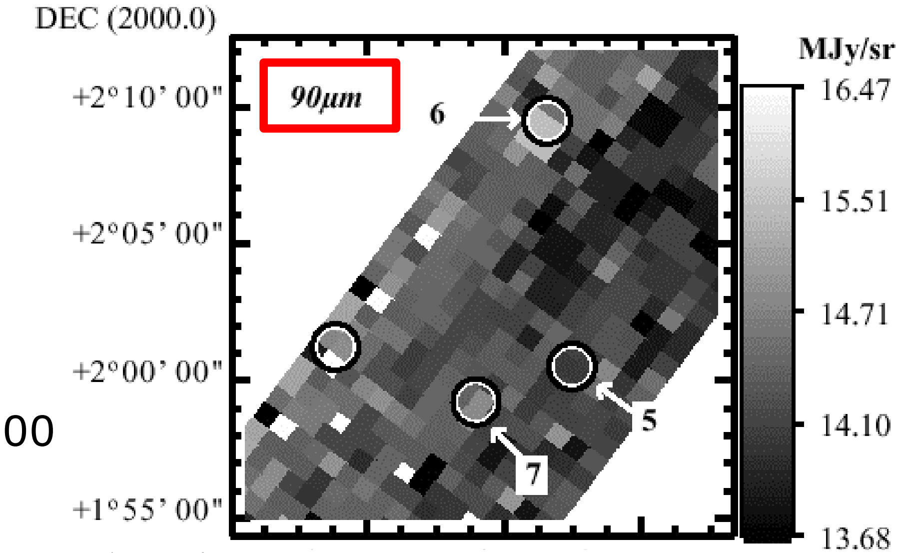
Kawara et al, 98
Matsuhara et al, 2000

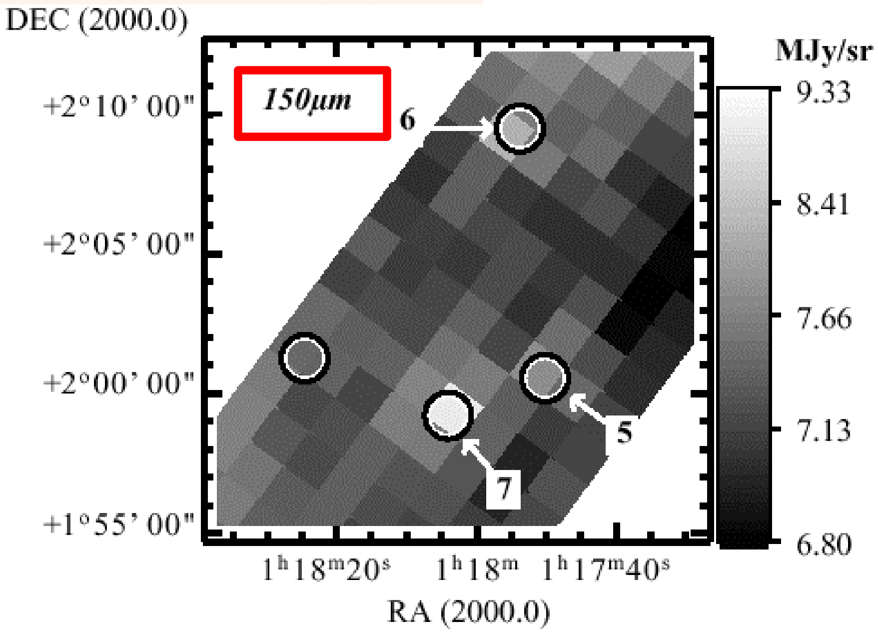
Multi l maps in the FIR

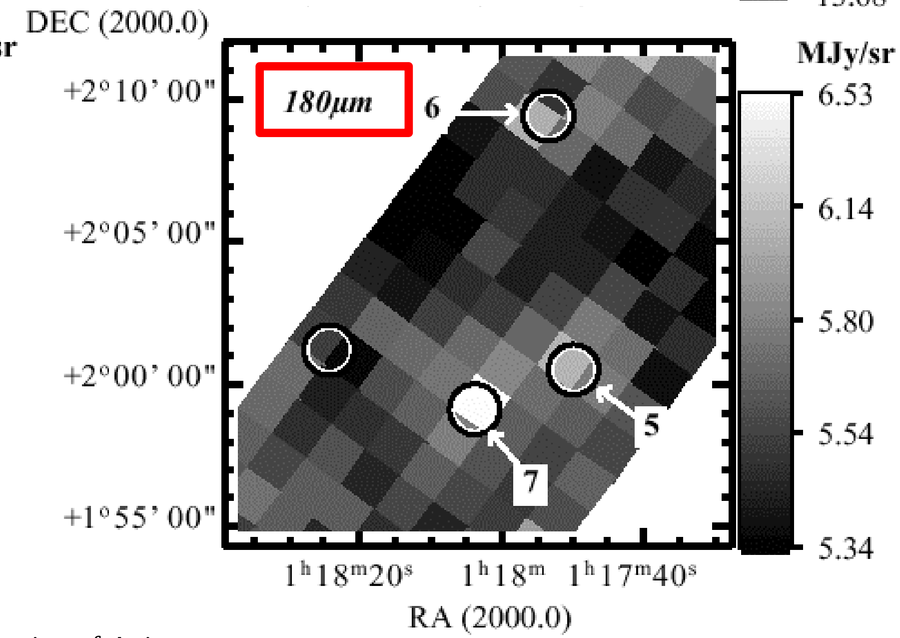


1.5^{o2}

Juvela et al, 2000







Cirrus/Source SEDs

■ Average Source SED
□ Cirrus SED

Multi-λ approach: useful for component separation

■ Source SED

Juvela et al, 2000

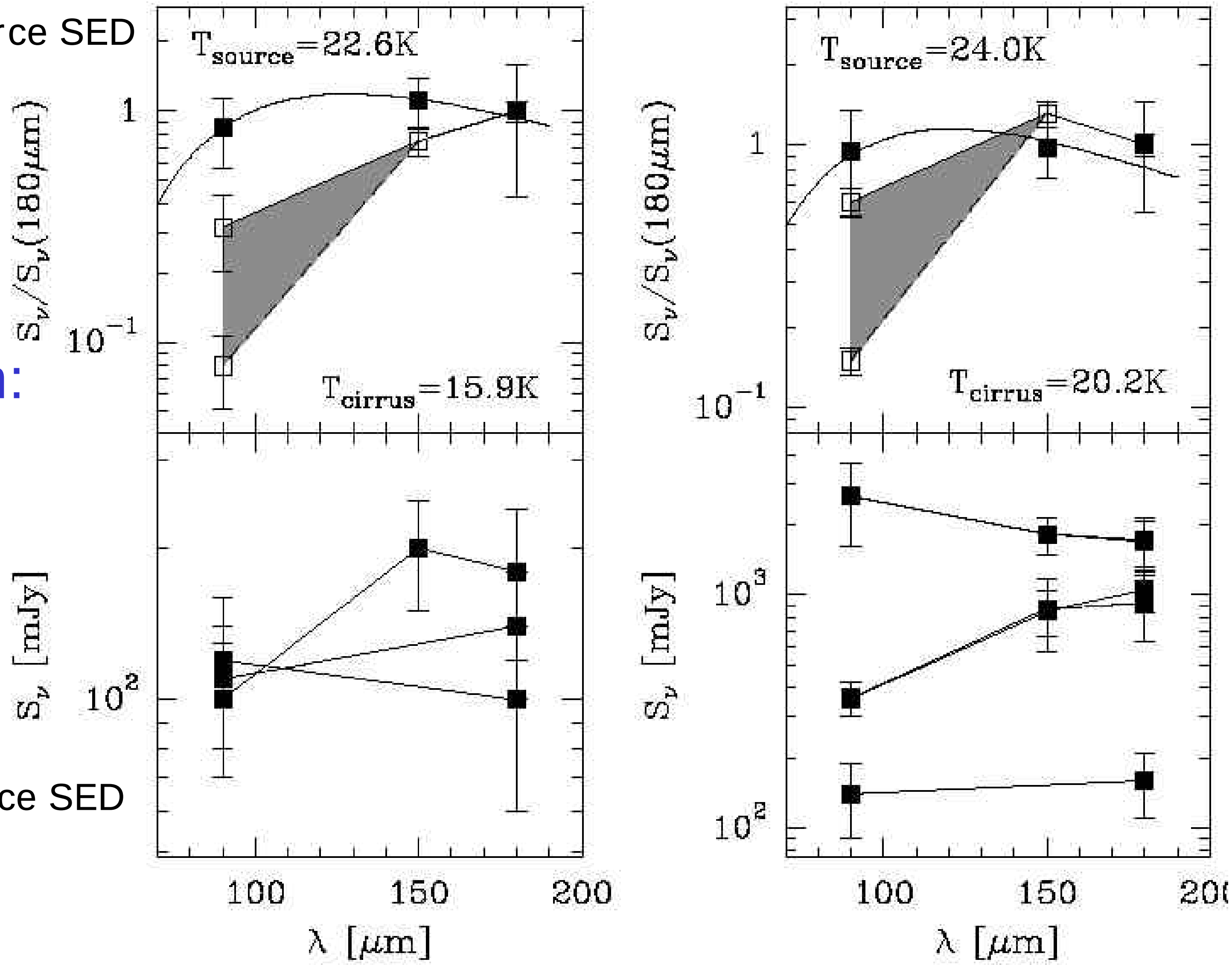
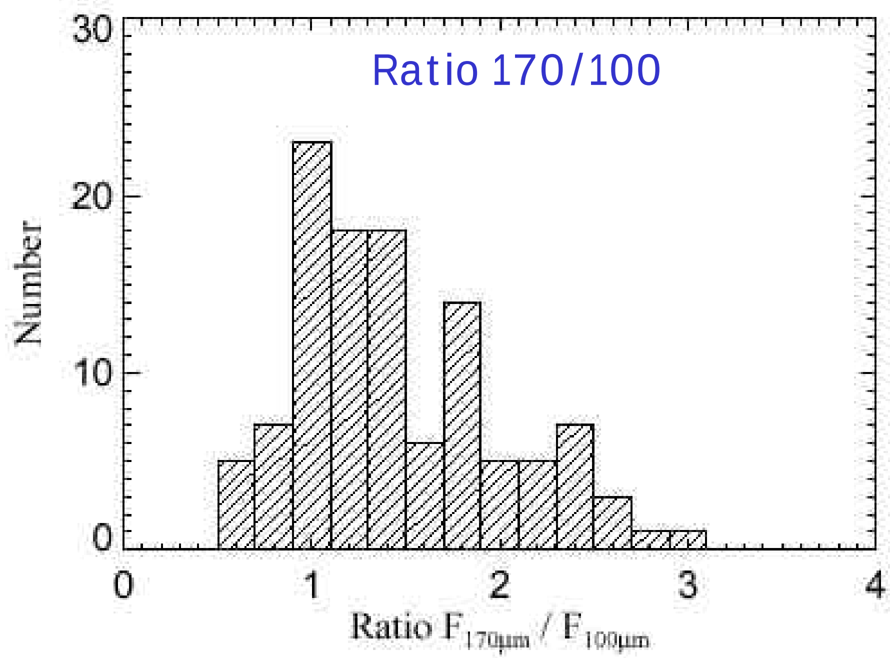
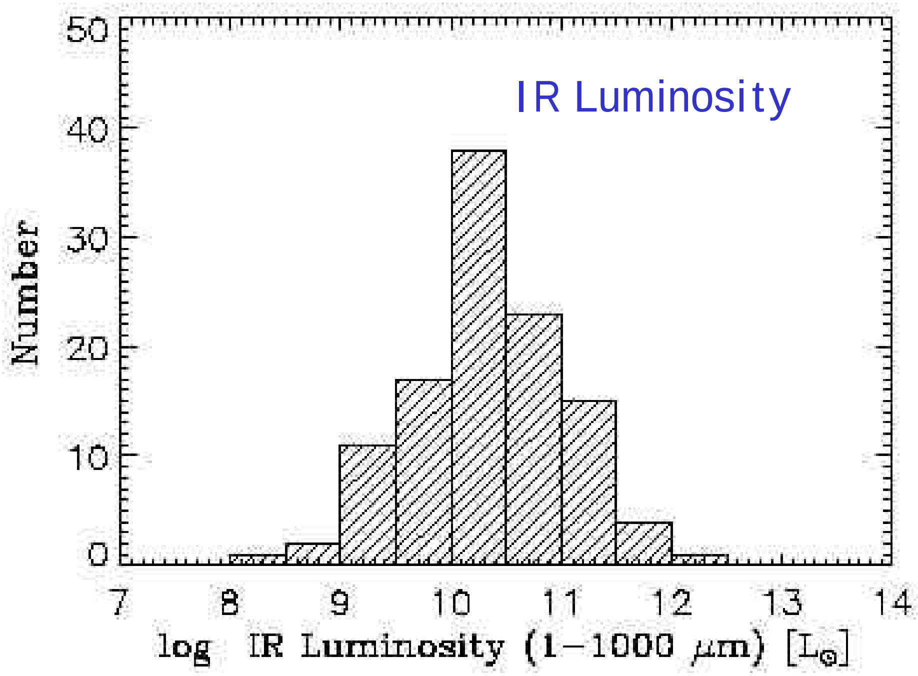


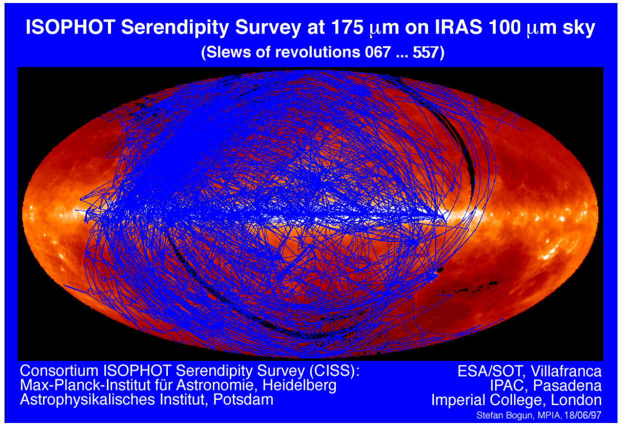
Fig. 5. Cirrus spectrum and source spectra in the field EBL22 **Fig. 6.** Cirrus spectrum and source spectra in the field EBL2

Serendipity Sources: Cold, Low L

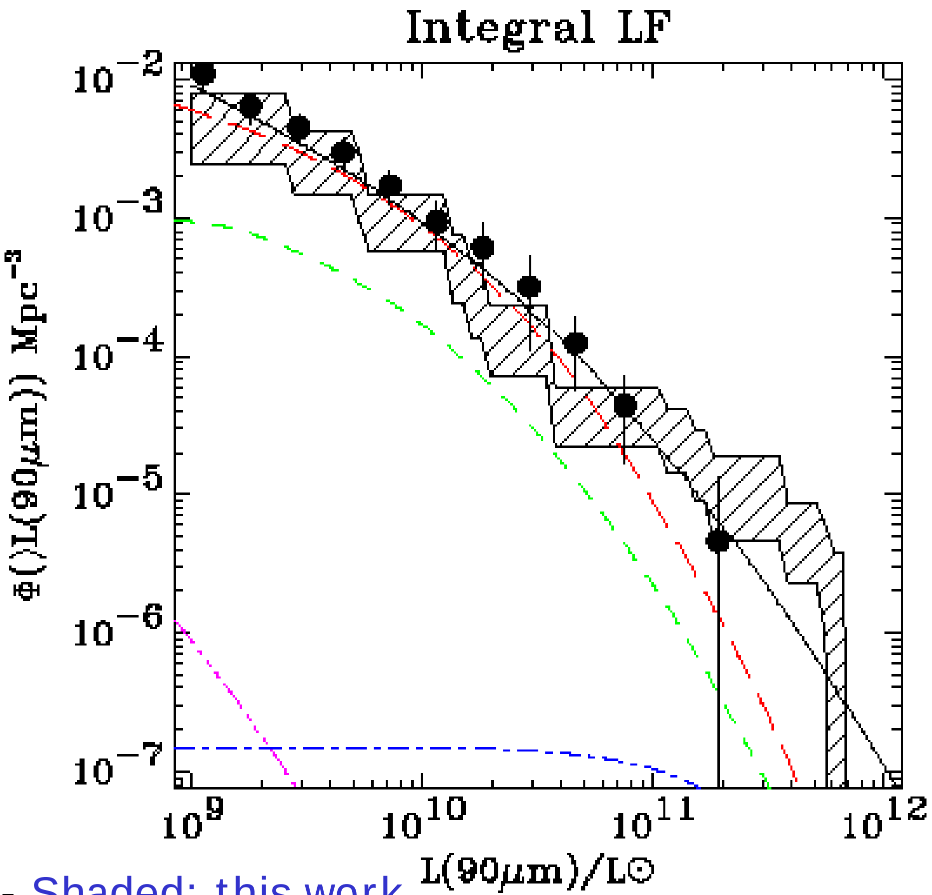


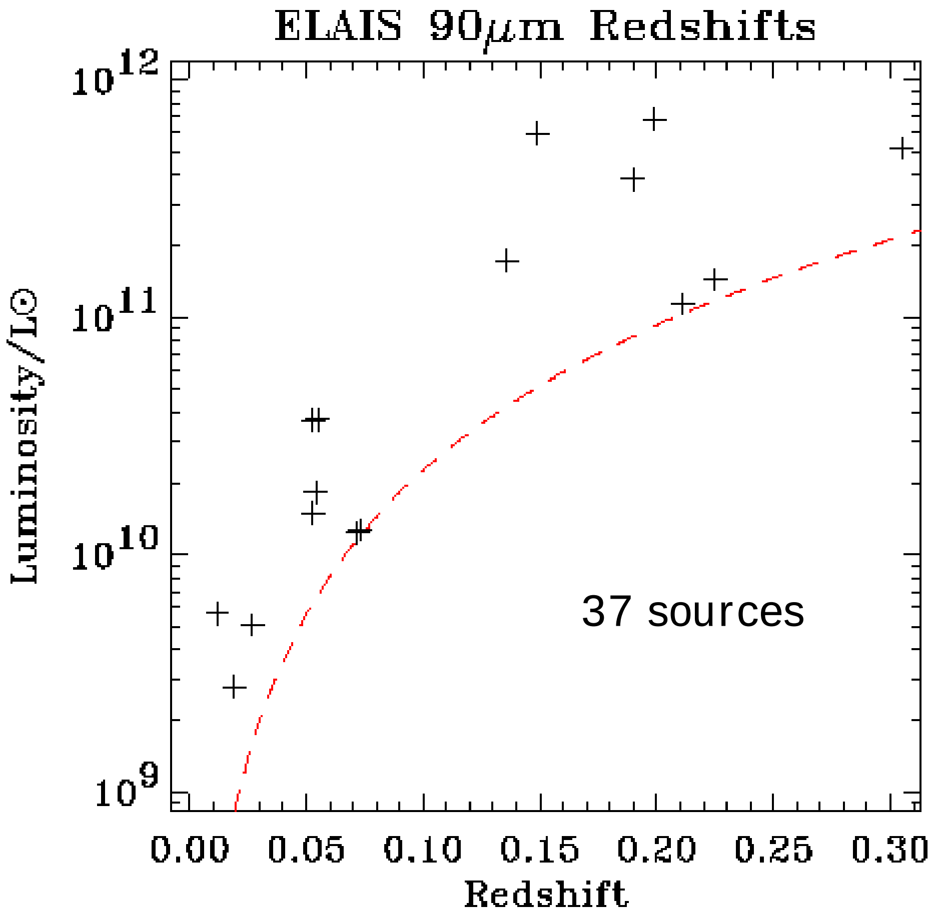


Stickel et al, 2000



90 mm LF



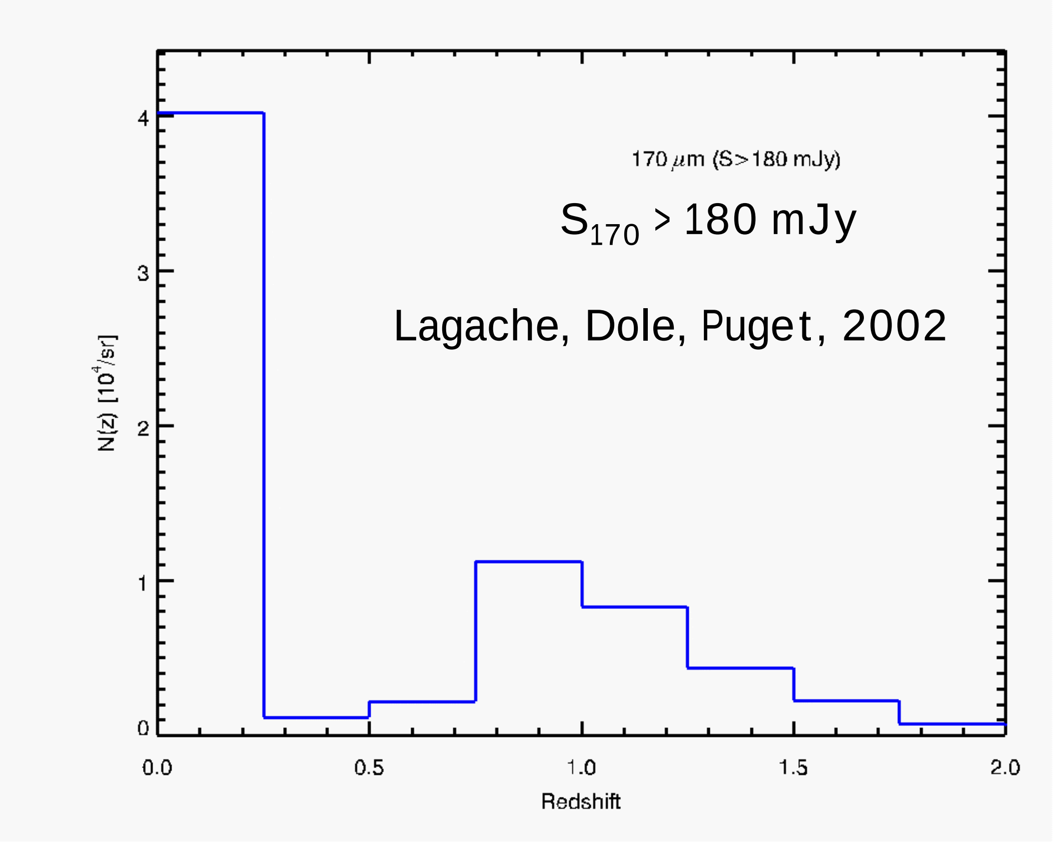


- Shaded: this work
- Dots: Local 100 μm LF (Rowan-Robinson et al, 87)
- Black Line: Fit
- Red dash: "cirrus" population (RR, 2000)
- Green dash: Starburst (RR, 2000)
- Blue Dash-Dot: Arp220 (RR, 2000)
- Purple: AGN (RR, 2000)

Serjeant et al, 2000

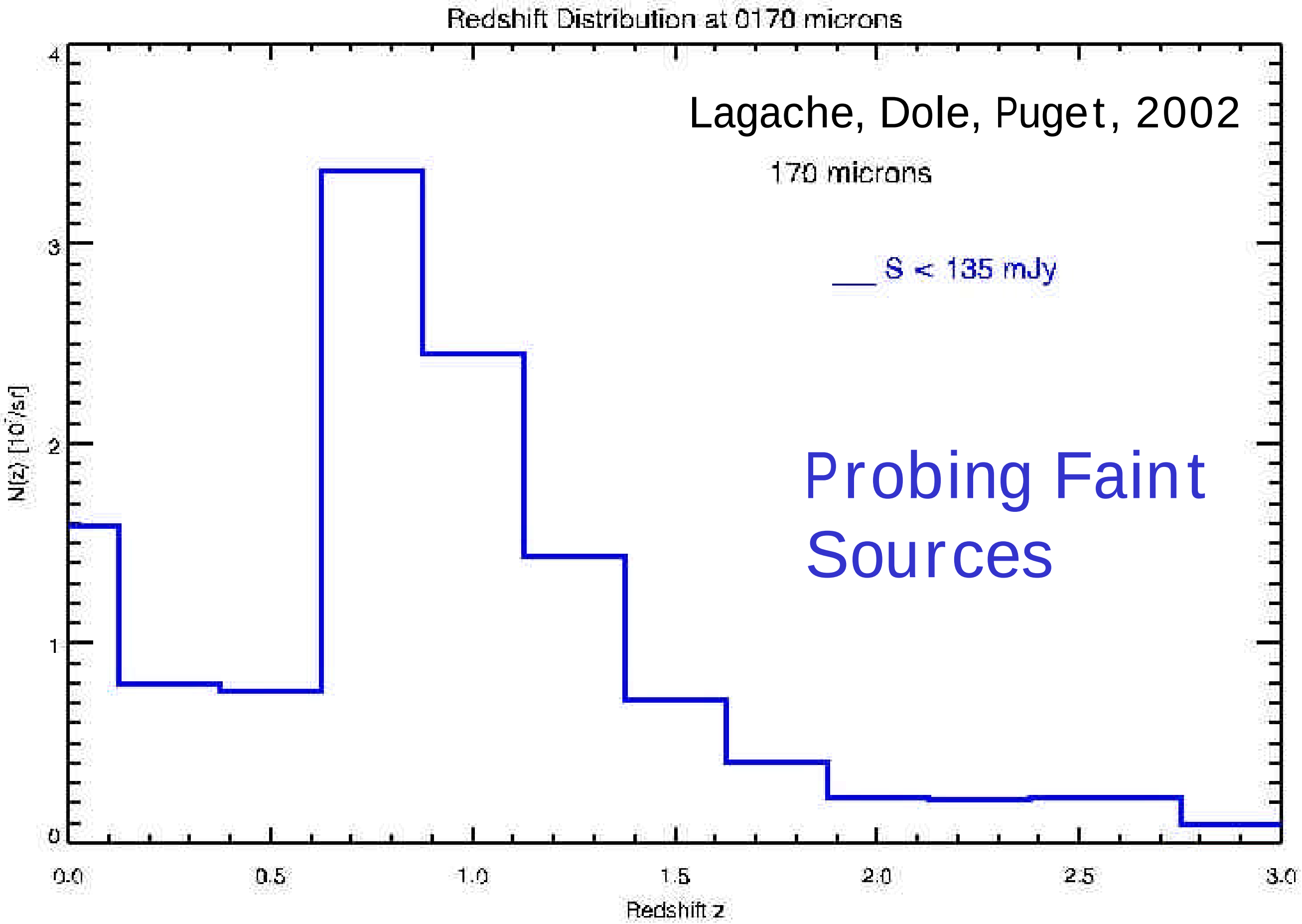
170 mm Sources

- **Redshift**
  - Most z < 0.3
  - Some 0.3 < z <1
  - A Few z > 1
    - Kakazu et al, 2002
    - Sajina et al, 2002
    - Chapman et al, 2002
- **Luminosity**
  - Local: L < $10^{11}L_\odot$
  - Higher-z: L > $10^{11}L_\odot$
  - A few HyLIGs
    - Serjeant et al, 2000
    - Kakazu et al, 2002



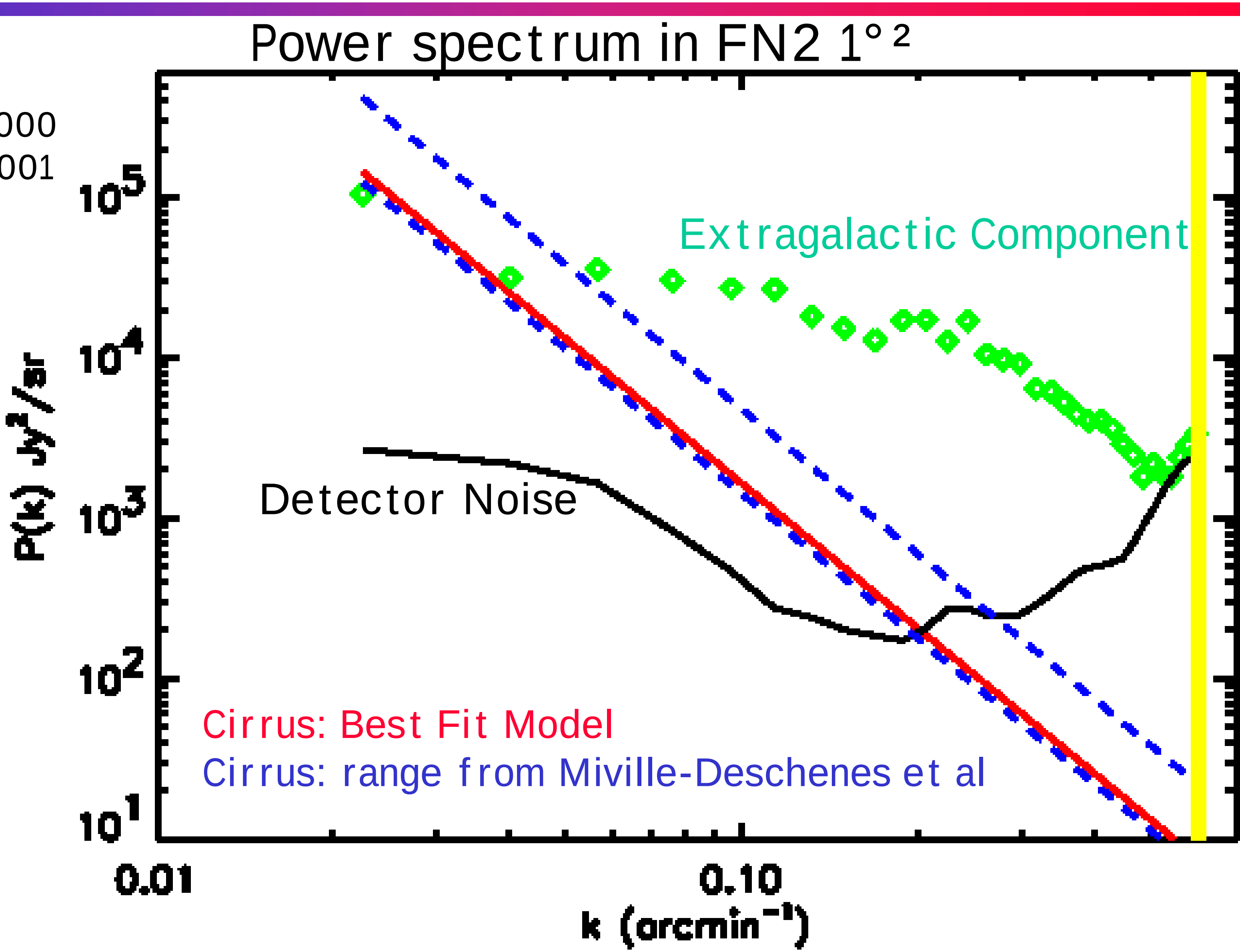
Fluctuations: Why Bother ?

Predicted Redshift Distribution of Sources
Creating the Fluctuations at 170 μm

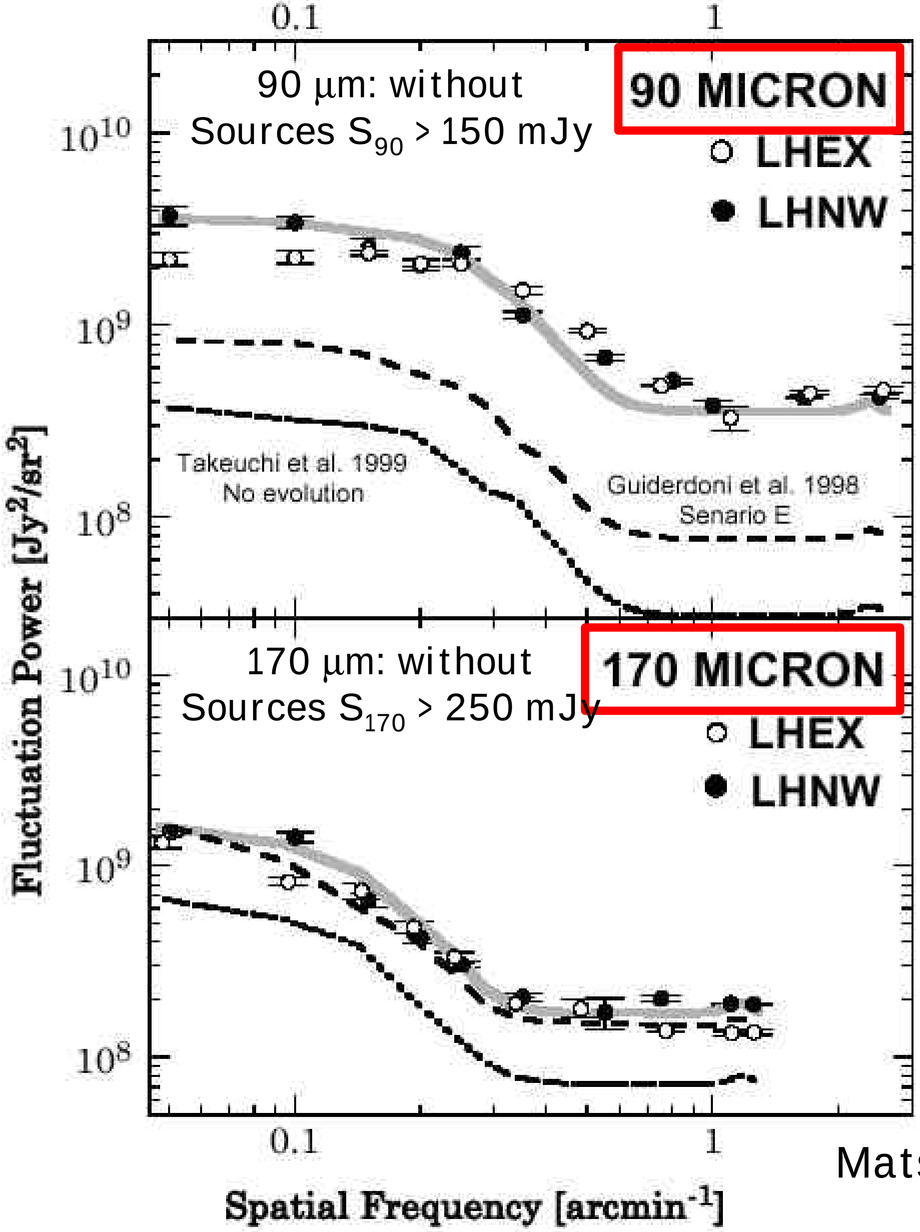


CIB Fluctuations at 170 mm

Lagache & Puget, 2000
Puget & Lagache, 2001

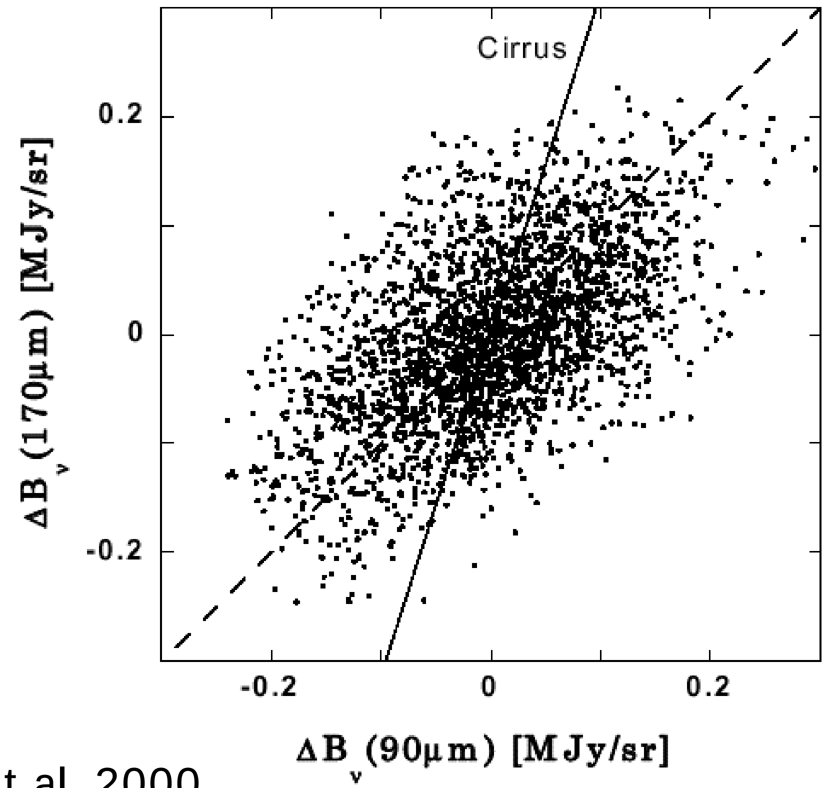


Fluctuations at 90 and 170 mm



Power Spectra

Color of the Fluctuations

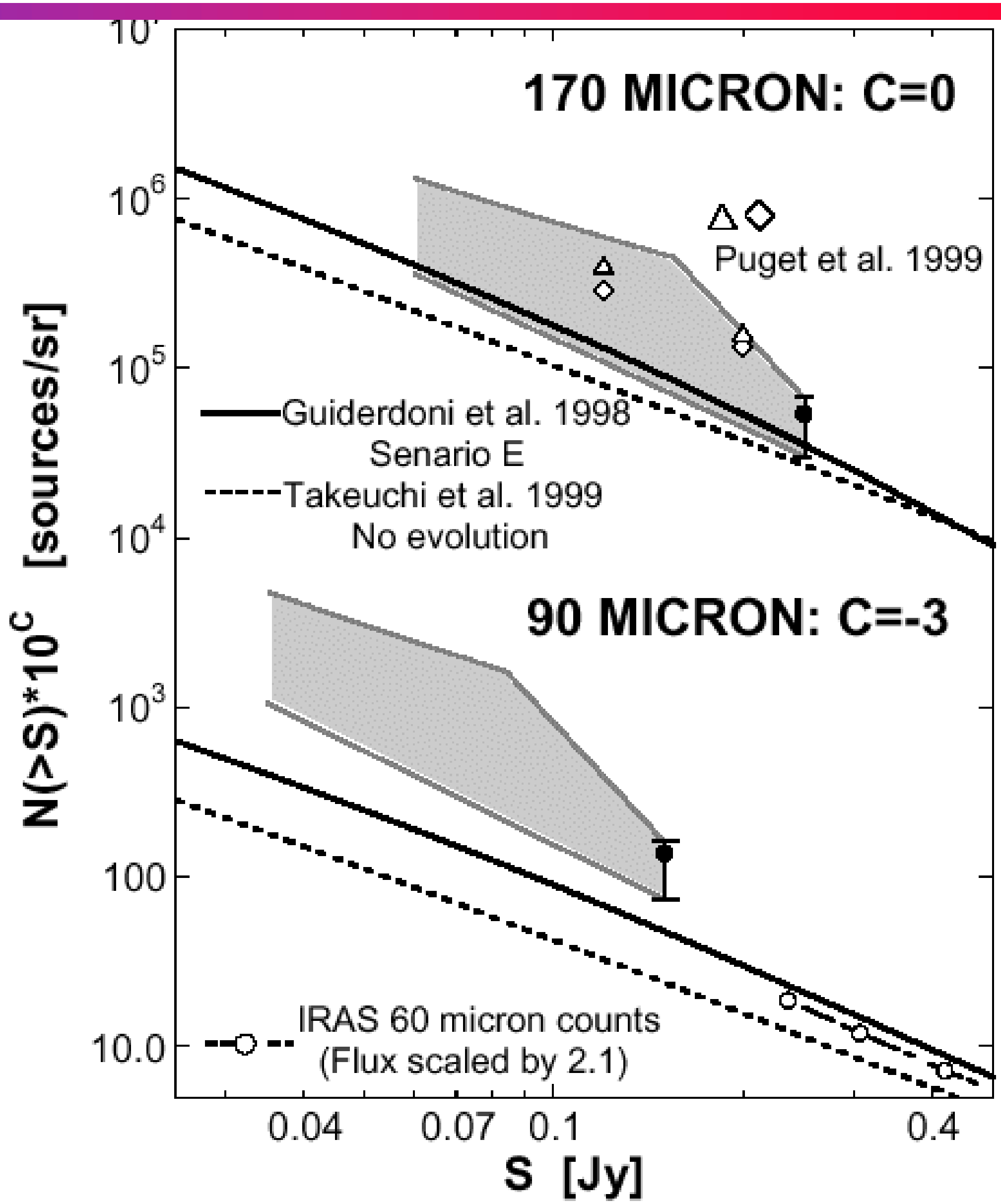


Matsuhara et al, 2000

Fluctuation Analysis at 170 mm

Constraints of the source counts' faint end at 170 µm in the Lockman Hole using simulations to fit the observed fluctuations

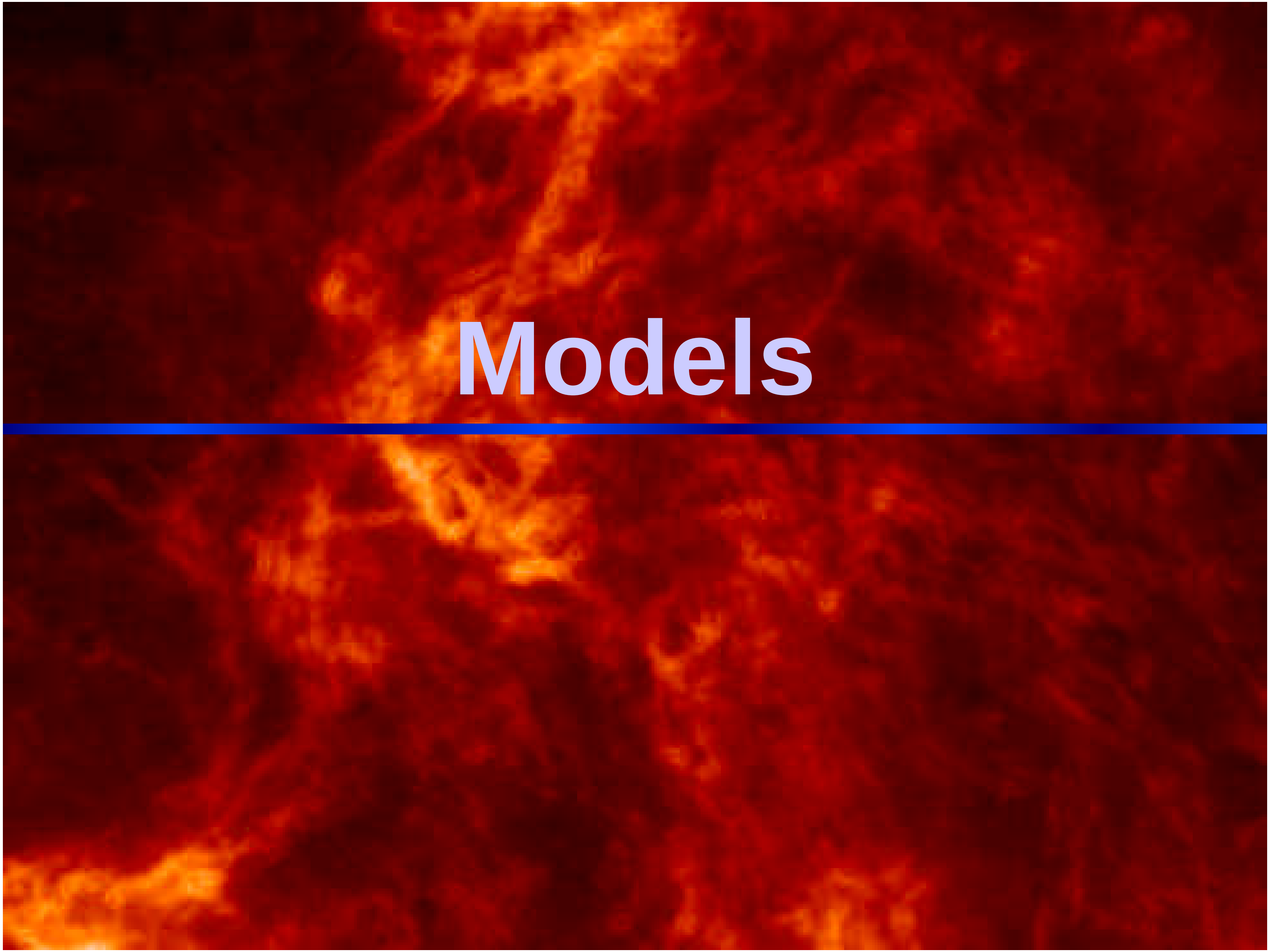
Matsuhara et al, 2000



Fluctuations of CIB

- 90 and 170 μm
  - Fluctuations Detected w/ High S/N
  - Extension of Source Counts to Lower Fluxes
  - Color of CIB Fluctuations
- 170 μm
  - Clustering Detected in FIRBACK N1/N2
- All Cases
  - Foreground Removal limits Larger Scales
  - FIR Observations limited by Sky Fluctuations
    - e.g Herbstmeier et al, 98; Kiss et al, 2001

Models



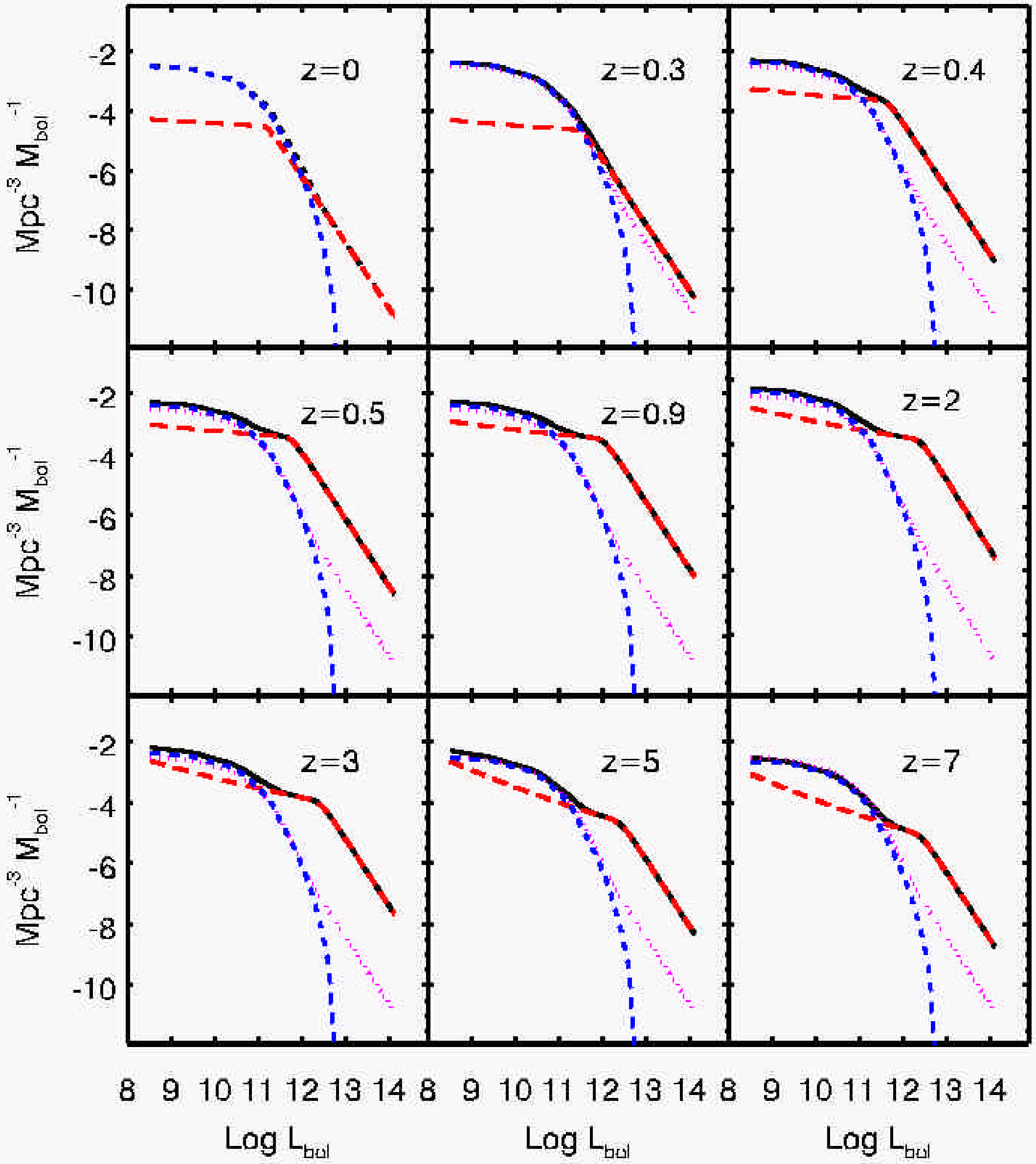
Models

- ISO Data strongly constraint models
  - Counts at 15, 170 μm
    - Also counts at 7, 60 & 90 μm
  - Redshift Distributions at 15 & 170 μm
  - Fluctuations of the CIB at 90 & 170 μm
- CIB SED
- Models
    - (1^{st} auth) Chary, Devriendt, Dole, Franceschini, Guiderdoni, Malkan, Pearson, Takeuchi, Totani, Roche, Rowan-Robinson, Tan, Wang, Xu
  - Lagache, Dole, Puget 2002 (submitted)
  - Franceschini et al, 2001
  - Chary & Elbaz, 2001

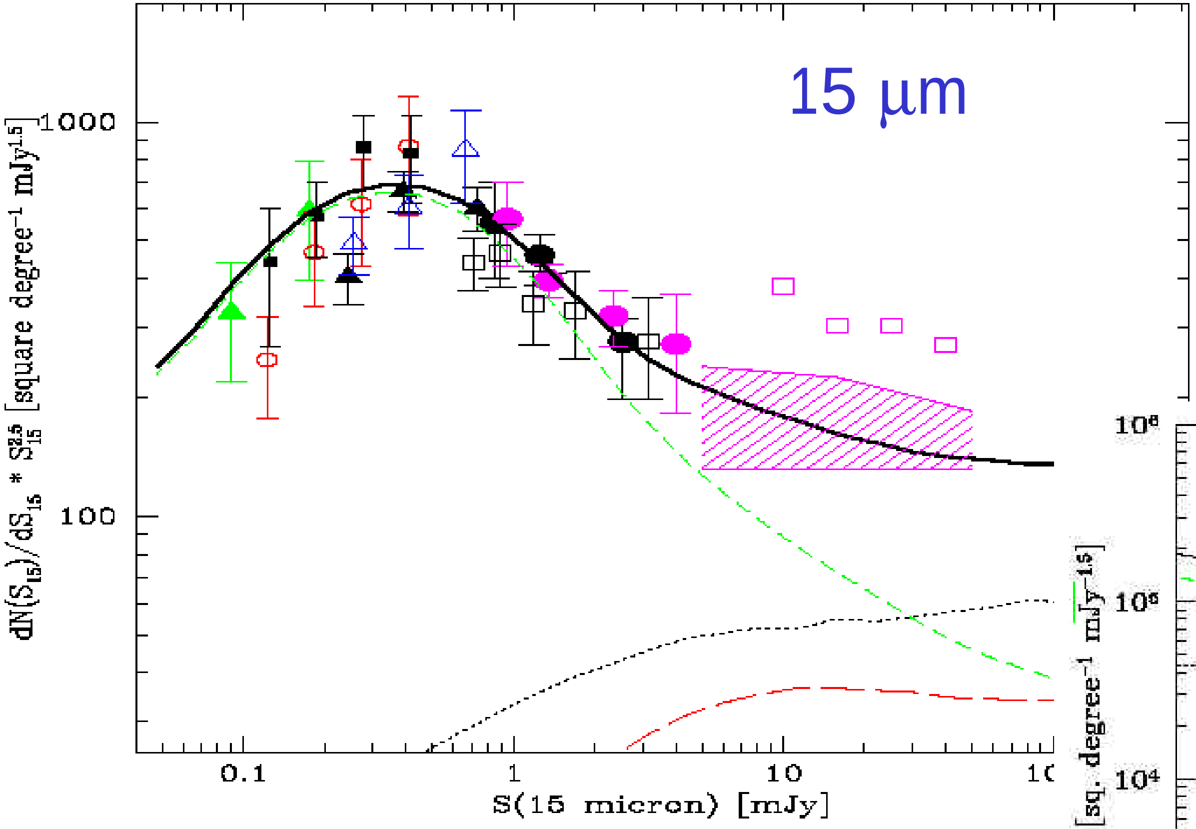
Evolving LF to Fit ISO Data

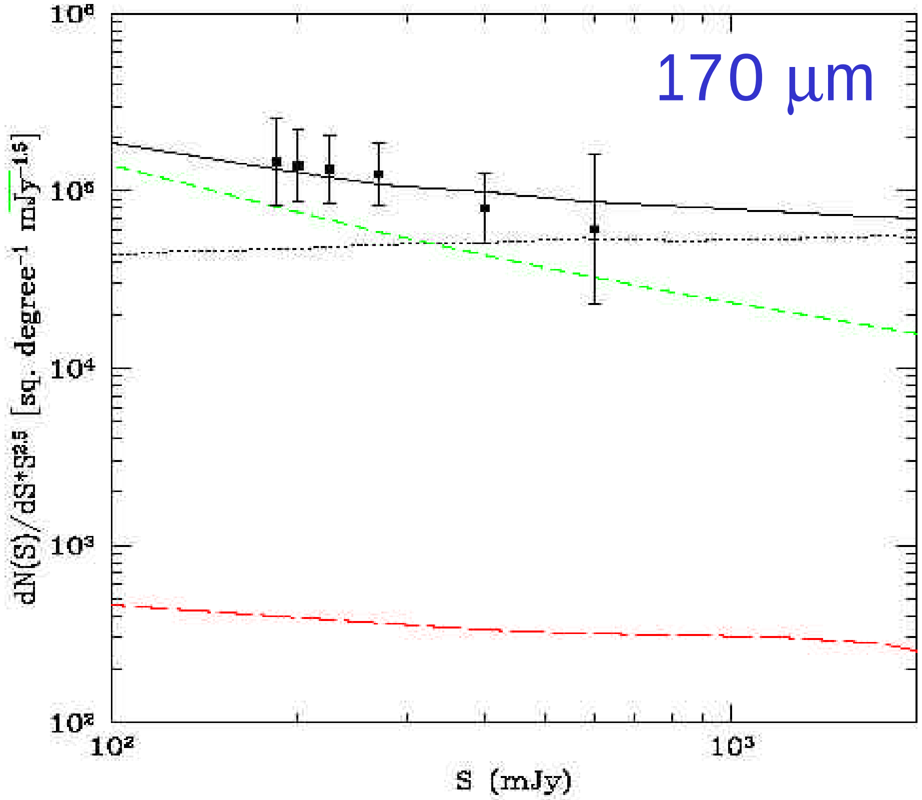
Lagache, Dole, Puget, 2002 (sub)

Fit of:
- 15, 60, 90, 170, 850 μm and 1.2 mm Source Counts
- Redshift Distributions at 15 and 170 μm
- CIB SED
- CIB Fluctuations



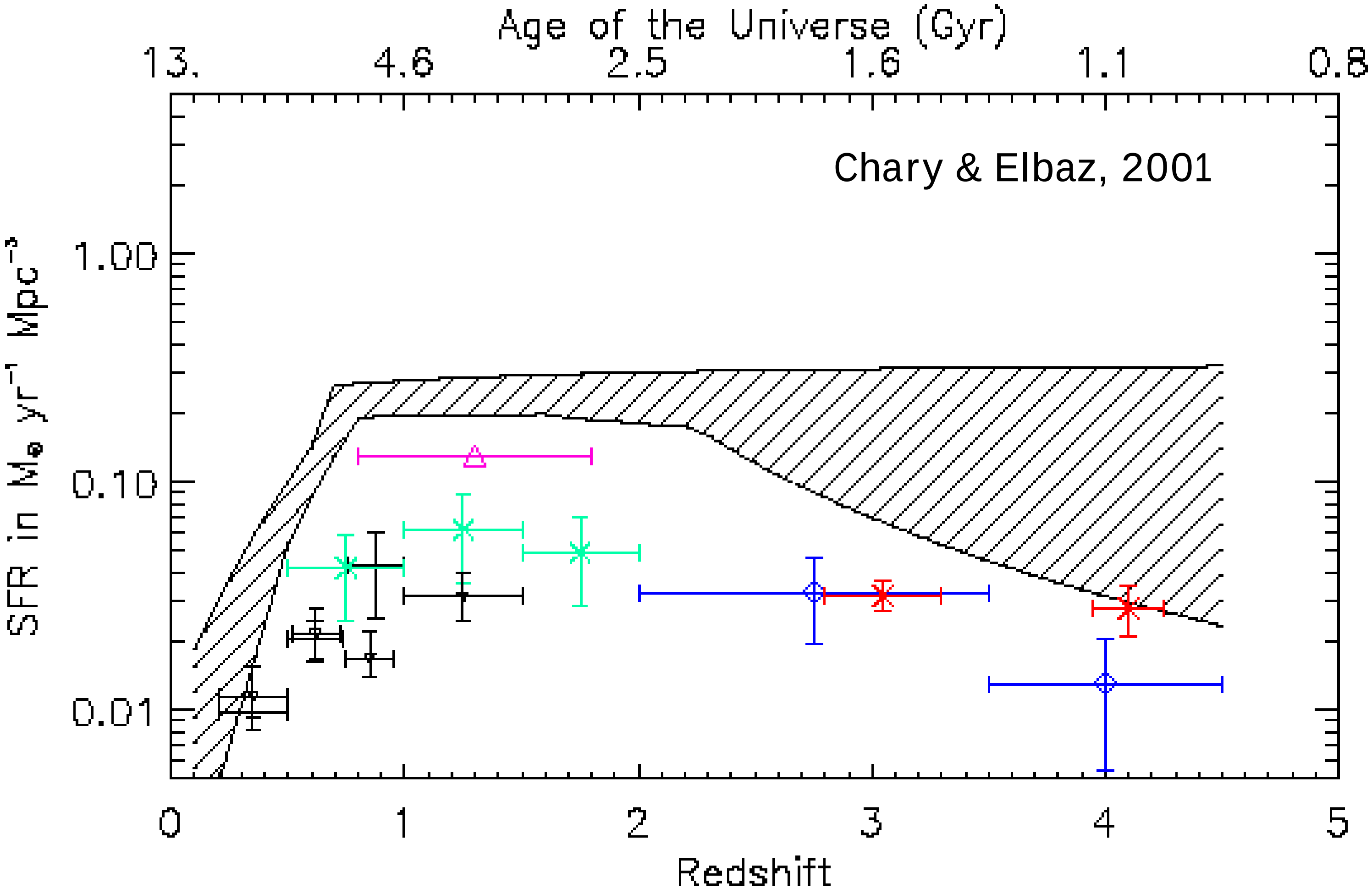
Source Counts





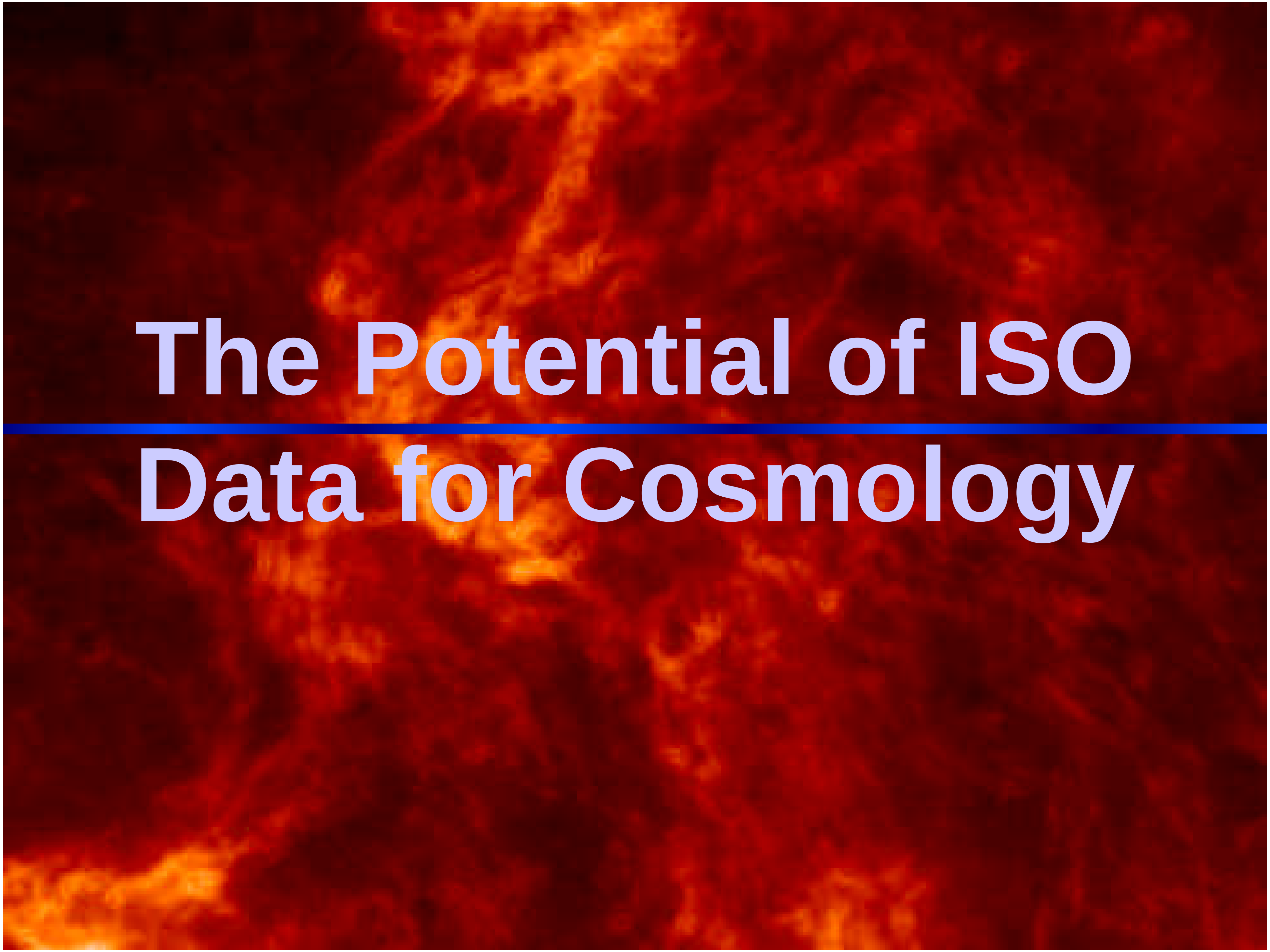
Franceschini et al, 2001

Star Formation Rate



See Also
Gispert, Lagache, Puget, 2000

The Potential of ISO Data for Cosmology

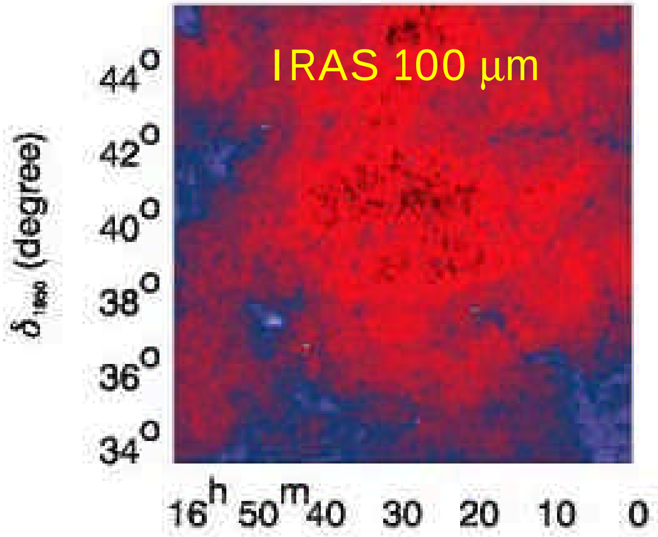


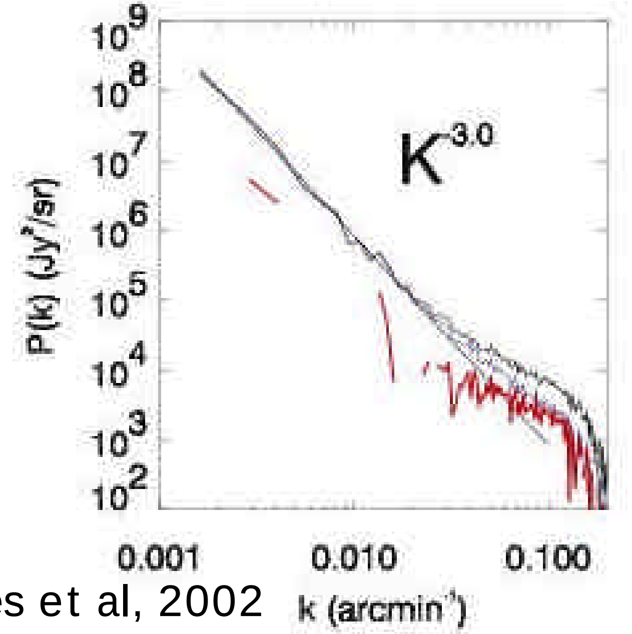
Published Data

- Re-Analysis of Published Data
  - Better understanding of ISO detectors
    - e.g. Lari Method, SLICE
  - HDF-S ISOCAM
    - Oliver et al, 97 – Oliver et al, 2002
  - Lockman Hole ISOPHOT
    - Kawara et al, 98
    - Matsuhara et al, 2000
    - Rodighiero et al

Reexplore / Correlate Data

- Influence of Foregrounds
  - Herbstmeier et al, 98
  - Kiss et al, 2001
- Nature of the Sources
  - LIRGs
- Extragalactic Background
  - Multi λ approach
    - Matsuhara et al, 2000, Juvela et al, 2000
  - Knowledge of CIB properties in ISO data allows discovery in IRAS data
    - Miville-Deschênes et al, 2002





Miville-Deschênes et al, 2002

Unpublished Results

- Galaxy Clusters
  - Stellar Populations, SZ, Arclets, intermediate and high-z Clusters, search for Early Clusters
- Quasars
  - Dust Mass, z>4, radio-quiet, low L radio, photometry
- ULIRGs, FSS-IRAS
  - SED, Identification, Power Source
- Galaxies
  - Ellipticals, Reds, Young, Faint Blue μJy radio sources

Preparation - Comparison

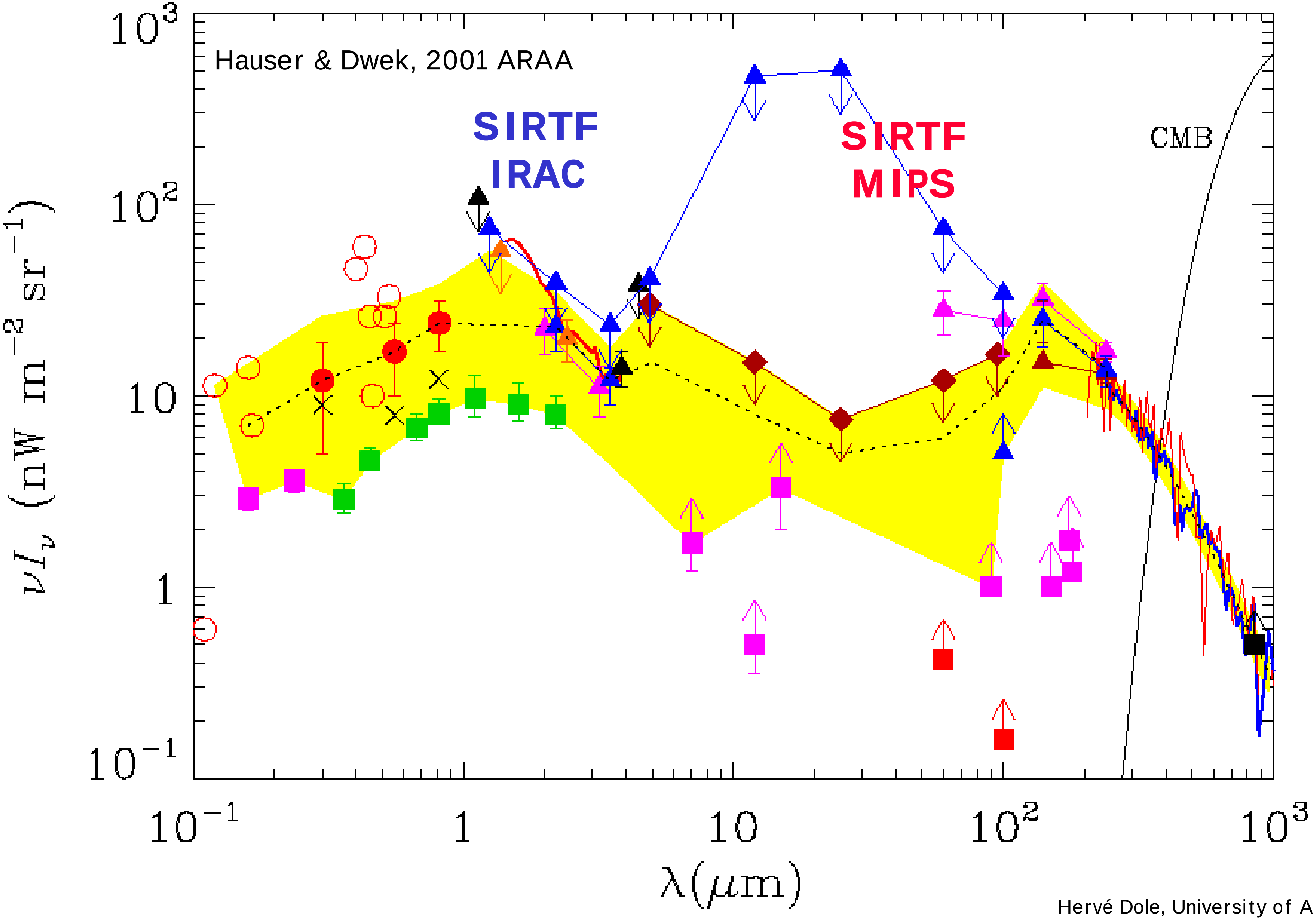
- SIRTF
  - Launch: Next January
- Herschel
  - Launch: March 2007
- Preparation / Comparison - Intercalibration
  - Like ISO/COBE/IRAS
    - e.g. Lagache & Dole, 2001

The Next Step:

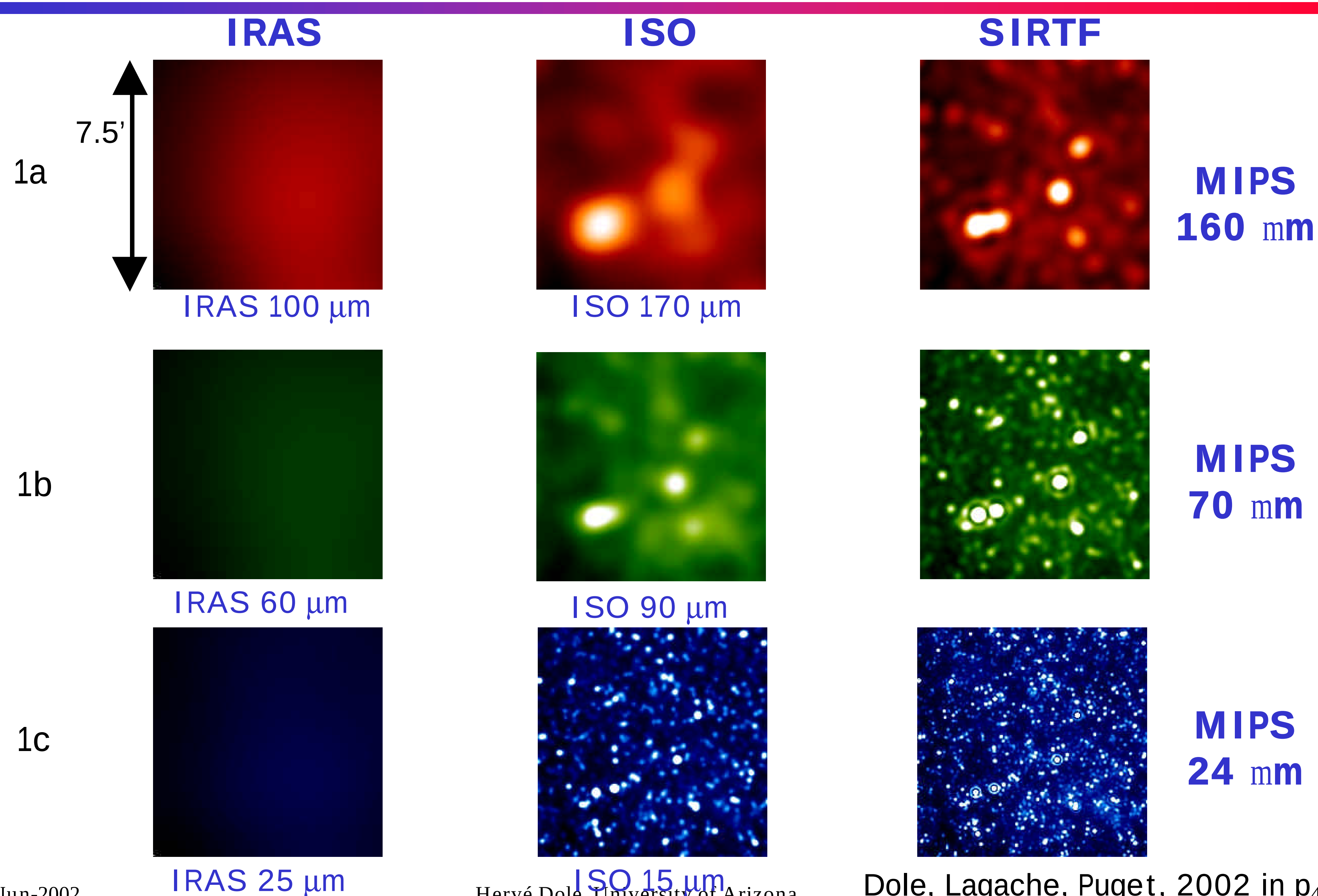
SIRTF

SIRTF

Extragalactic Background



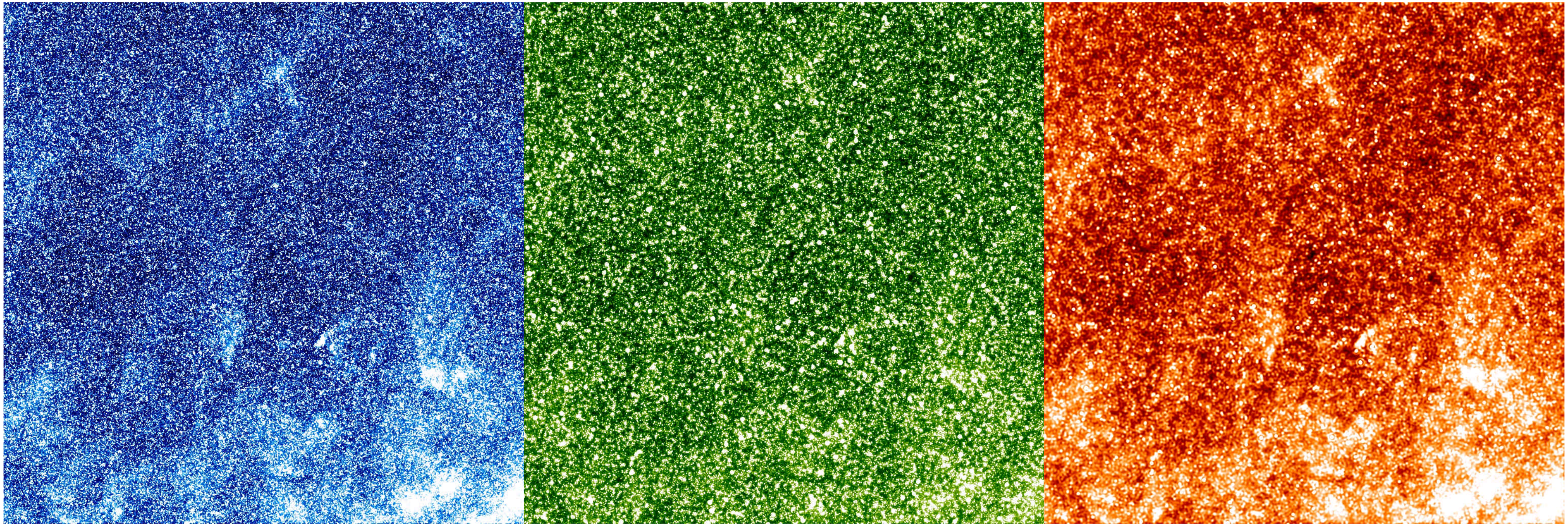
IRAS, ISO, SIRTF



Dole, Lagache, Puget, 2002 in p

Panchromatic IR Sky

Simulated sky: 5 squares degrees

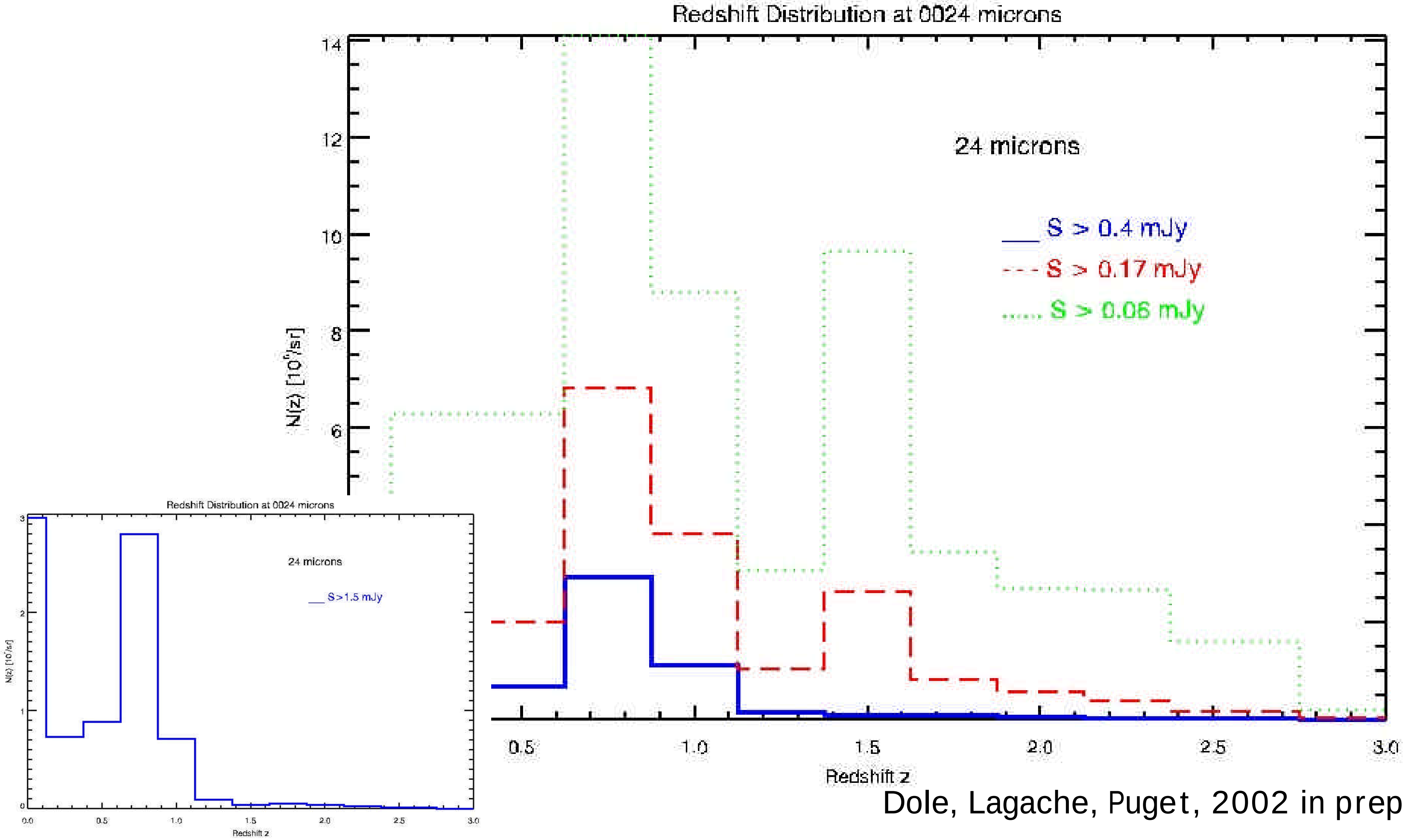


MIPS 24 μm **MIPS 70 μm** **MIPS 160 μm**

+ IRAC: 4 filters

Dole, Lagache, Puget, 2002 in prep

Redshift Distributions @ 24 μm



Dole, Lagache, Puget, 2002 in prep

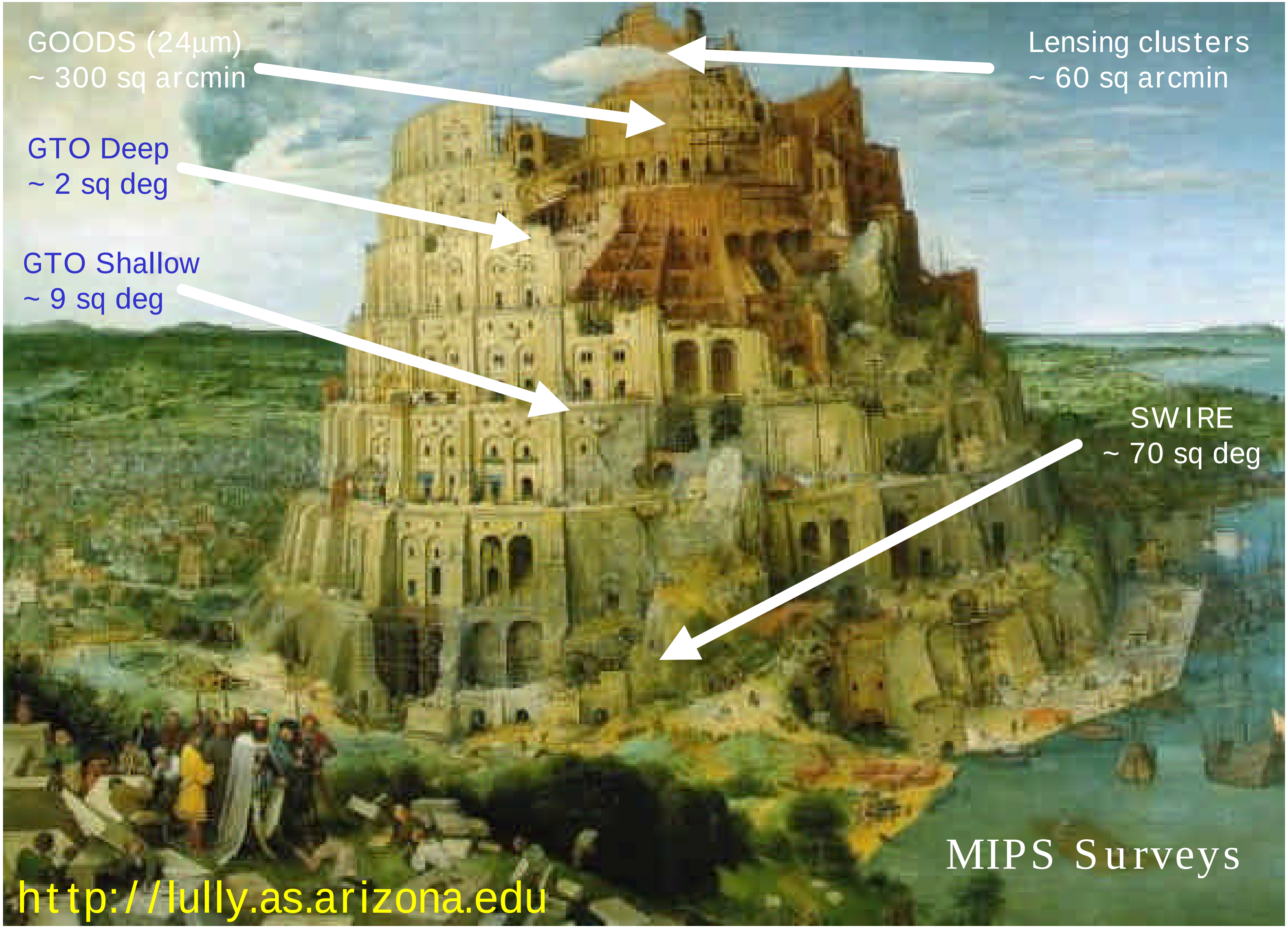
Resolution of the CIB

- Predictions

	24 μm	70 μm	160 μm
%	62%	47%	19%

Lagache, Dole, Puget, 2002 (sub)
Dole, Lagache, Puget, 2002 in prep

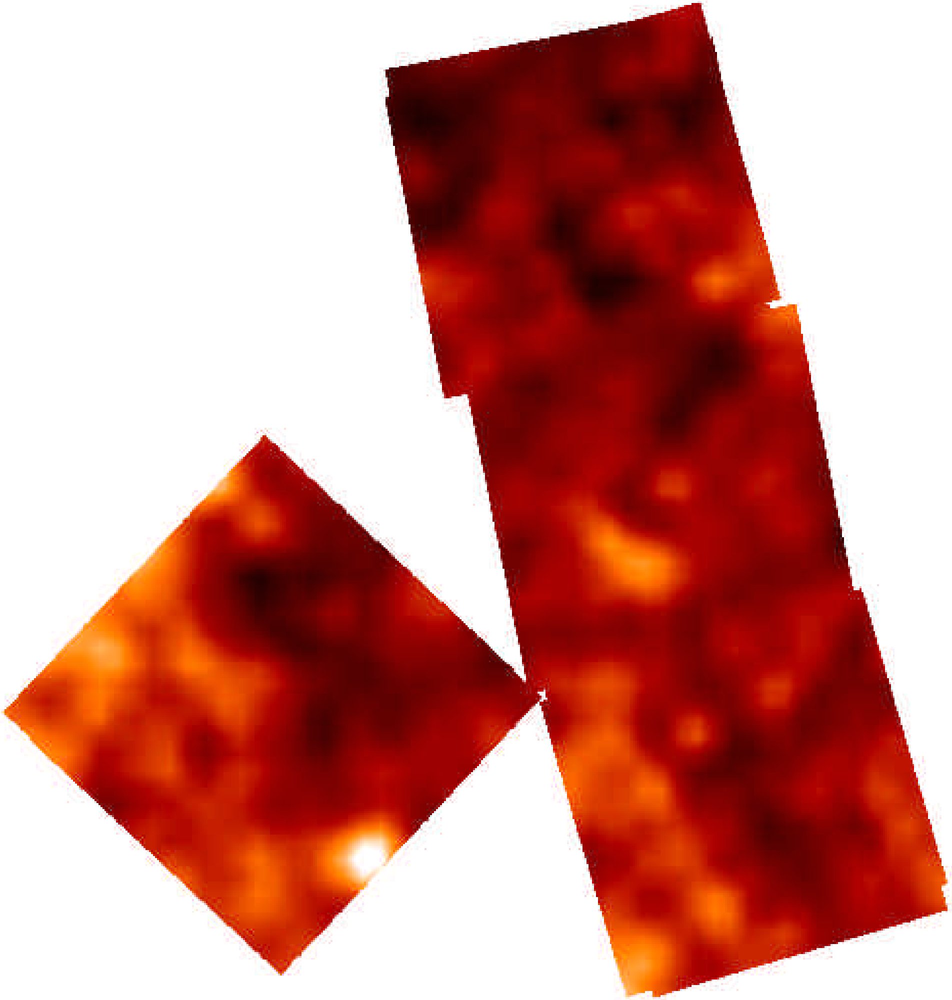
- 15 μm
  - 70% w/ ISOCAM at 15 μm (Chary & Elbaz, 2001)
- 170 μm
  - 4-8% w/ ISOPHOT at 170 μm (Dole et al, 2001)



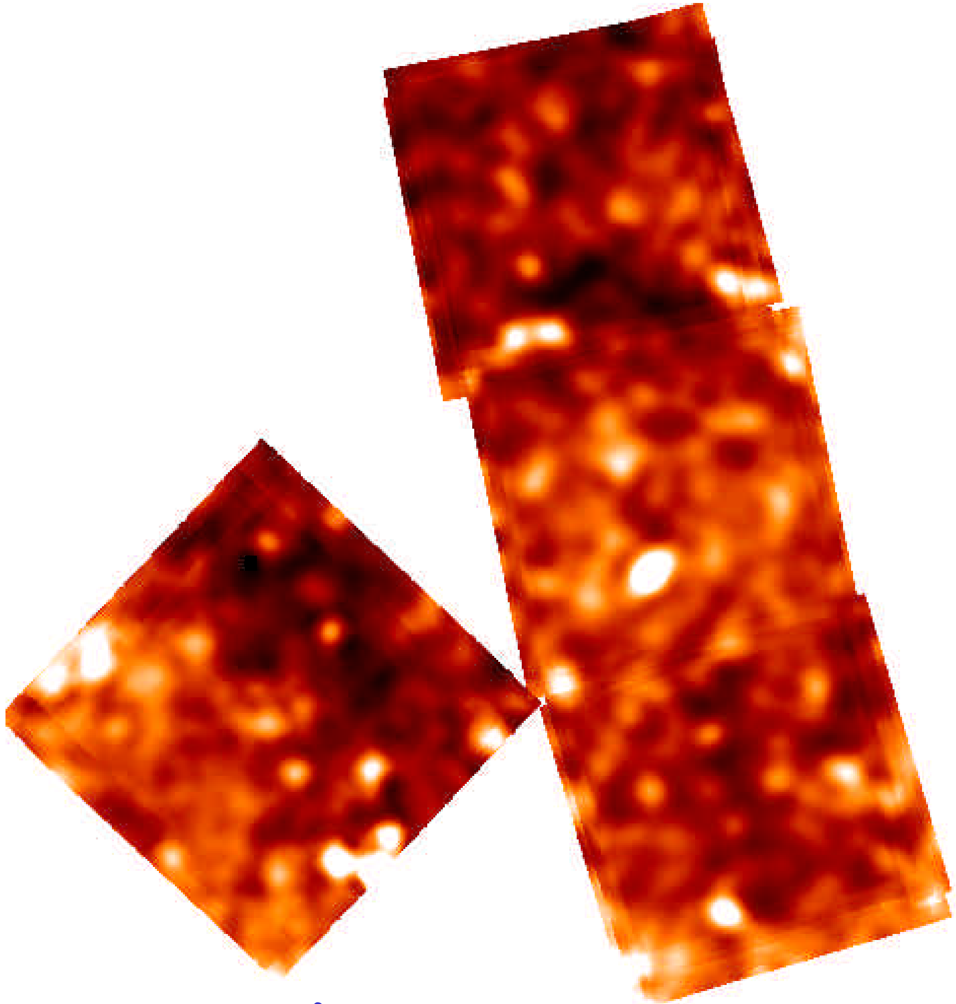
The Tower of Babel by Pieter Breughel the Elder

Courtesy G. Rieke

IRAS 1984 vs ISO 2000



λ = 100 μm
t = few s/sky pix
r = < 4.5 arcmin



λ = 170 μm
t = 256 s/sky pix
r = < 92 arcsec