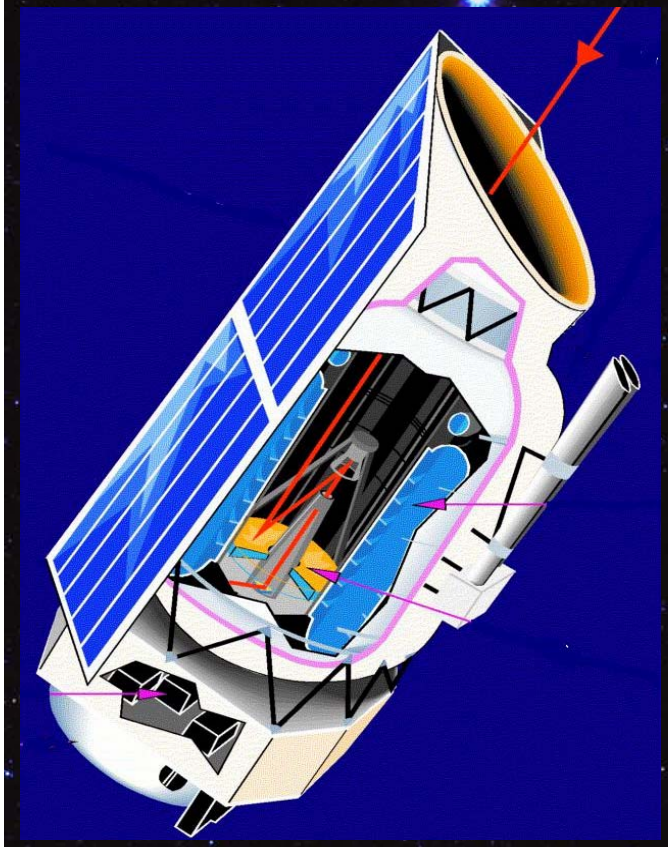
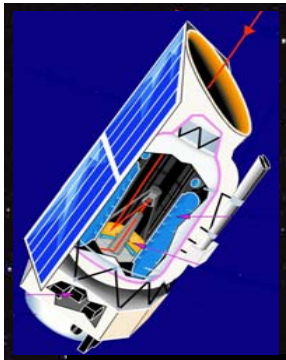
COSMOLOGICAL SURVEYS WITH THE INFRARED SPACE OBSERVATORY



Alberto Franceschini
Padua University



GTO Survey Team and Associates

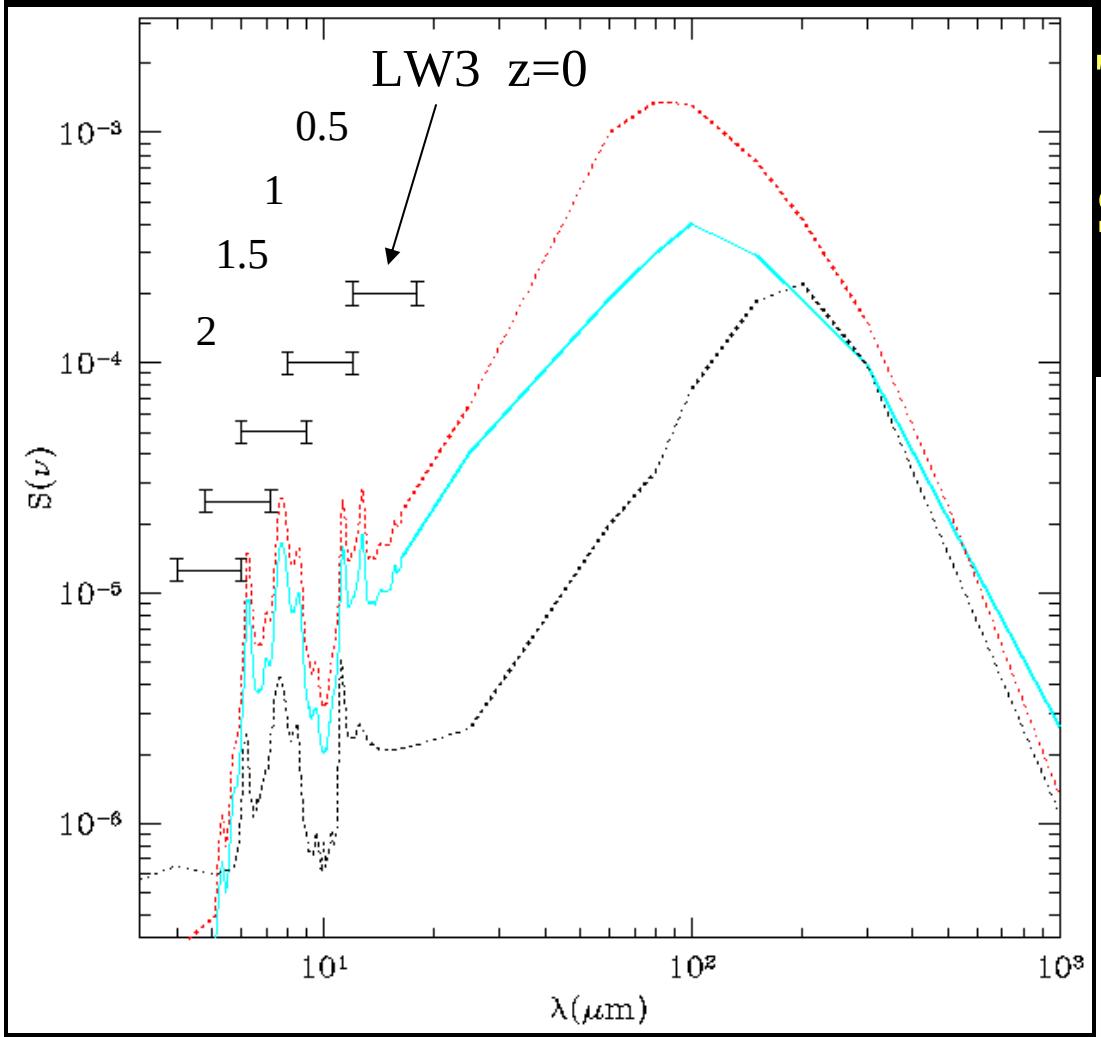
The ISO Guaranteed Time Extagalactic Surveys (IGTES)

Catherine Cesarsky	PI	CEA, Saclay	Herve' Aussel
David Elbaz	Ass	CEA, Saclay	Dario Fadda
			Dave Clements
Alberto Franceschini	Co-I	Padua University	Giulia Rodighiero, Stefano Berta, Mattia Vaccari
Martin Harwit	Miss. Scientist	Washington	J.L. Stark, Reno Mandolesi, L. Danese
Jean-Loup Puget	Co-I	Orsay	

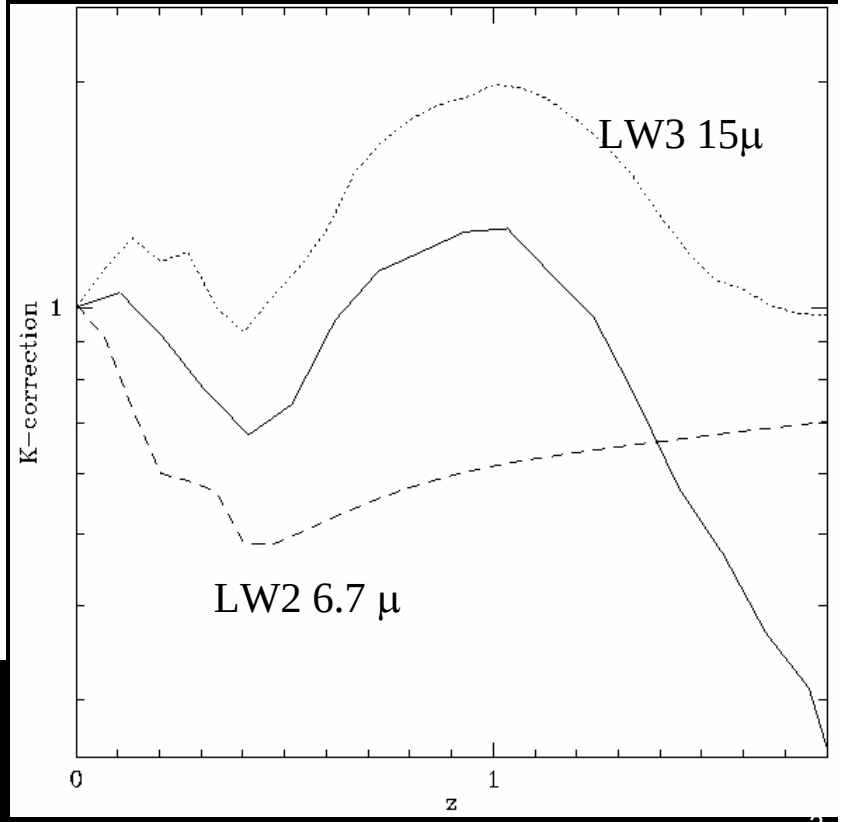
The Canada-France Redshift Survey (CFRS)

Francois Hammer	PI	Meudon
Hector Flores	Assoiate	Hawaii
Francois Bouchet	Associate	IAP Paris
Bruno Guiderdoni	Simulation/Models	SSC/IPAC
Catherine Cesarsky		CEA Saclay

Mid-Infrared Surveys with ISO



Typical source spectra



K-corrections

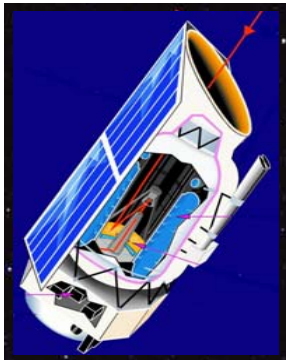
The ISOCAM 15μ Surveys

Field Name	Area (□')	Depth (mJy)	Nr.
A2390	5.3	.05	31
HDF-N	24	.1	44
HDF-S	28	.1	63
UD1	90	.14	137
UD2	90	.14	142
CFRS03+00	100	.3	57
CFRS14+52	100	.4	41
Firback	900	.4	144
Lockman Deep	510	.6	70
Lockman Shallow	1944	.7	80
ELAIS	40000	3	1600

P.I.: Metcalfe Rowan-Robinson

Cesarsky Hammer

... the *wedding cake* approach...



GTO Survey Team and Associates (cnt.)

The Japanese Guaranteed Time Survey

Yoshii Taniguchi	PI	Tokio
Lennox Cowie	Assoiate	Hawaii
Dave Sanders	Associate	Hawaii

The Lensing Cluster Survey

Leo Metcalfe	PI	ESTEC
Bruno Altieri	Associate	
Daniela Coia	Data Analysis	
Andrea Biviano	Ass.	

The ISOPHOT SA57 Survey

Kalevi Mattila	PI	Finland
Chris Lehnert	"	Germany
Iuvela	Associate	

The Lockman Deep ISOPHOT Survey

K. Kawara et al.	PI	Japan

Data Reduction

- Pattern REcognition Technique for Isocam data (Starck et al., 1999)

  multi-resolution technique to find and remove glitches,

  we remove also bumps after big dippers

- Rejection of noisy data

  bad illuminated pixels, initial transients

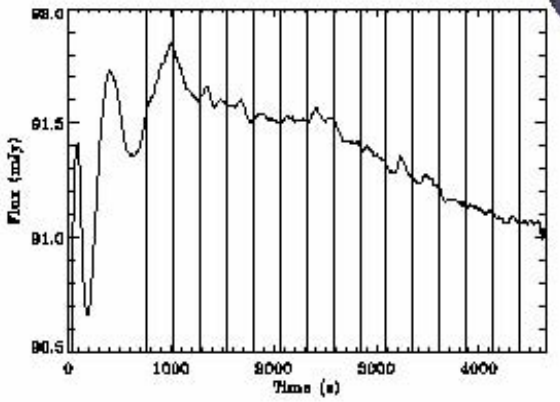
- Coaddition of several rasters

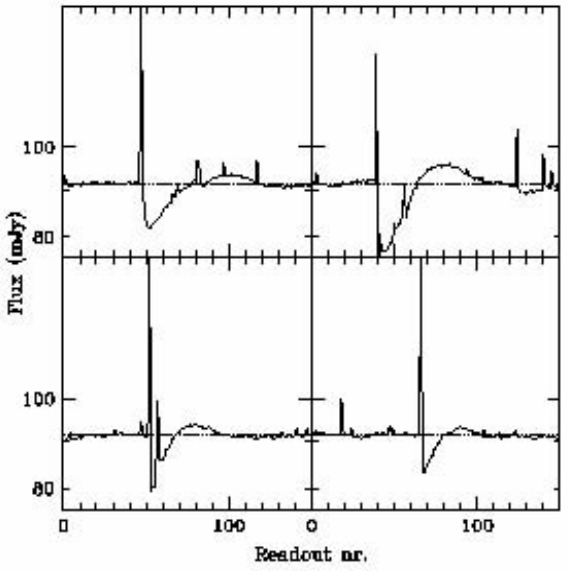
  after astrometry corrections and using distortion coefficents

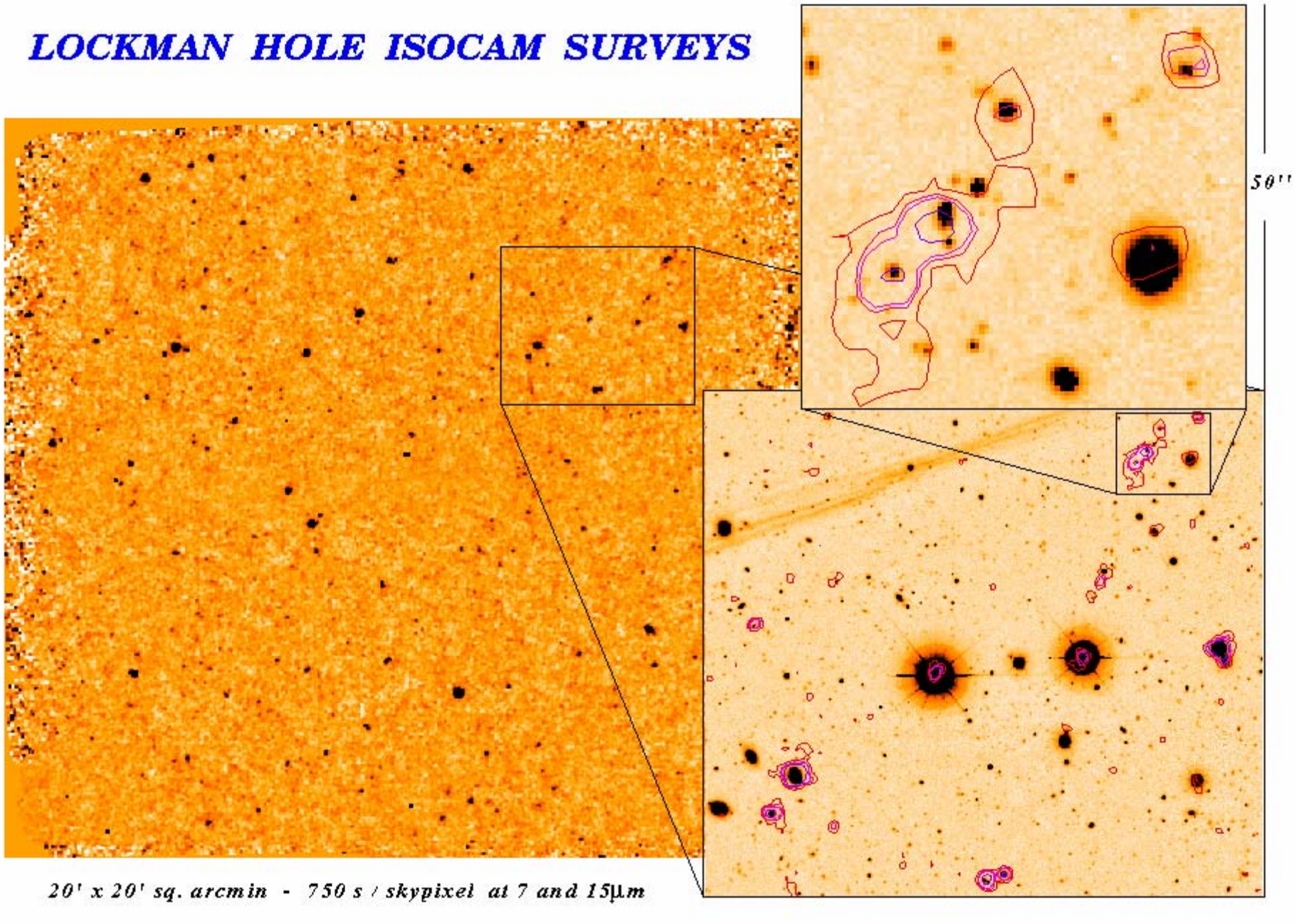
- Calibration and Photometry

  aperture photometry (deblending with the ISOCAM PSF),

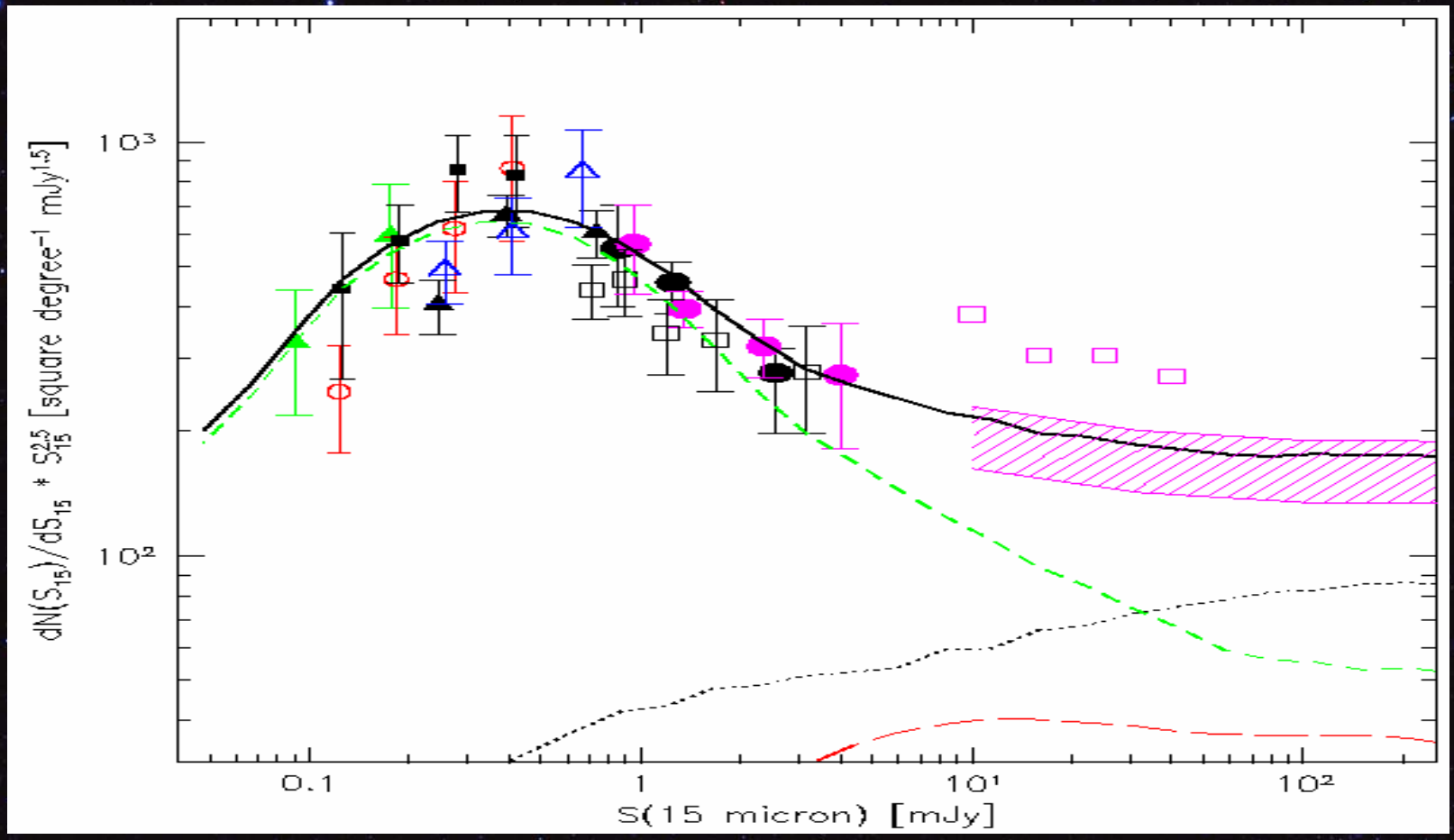
  calibration by adding simulated sources to real data.





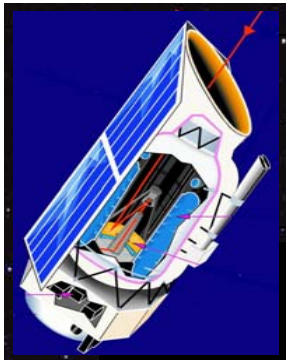


(Fadda et al. 2000)



(~ 1000 sources altogether)

15 μ differential counts (Euclidean normalized)
(Elbaz et al. 1999; Franceschini et al. 2001)



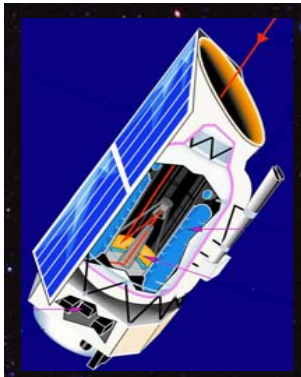
Open Time Survey Teams and Associates

ISO Far-Infrared Background Survey (FIRBACK)

Jean-Loup Puget	PI	Orsay	
Xavier Desert	Assoiate	Orsay	
Herve' Dole	Data analysis	Orsay	
Francois Bouchet	Associate	IAP Paris	H. Aussel, W. Reach, Alan Moorwood
Bruno Guiderdoni	Simulation/Models	IAP Paris	
Catherine Cesarsky	PI	CEA Saclay	
Alberto Franceschini	Spheroids/AGN	Padua	

The European Large-Area Extragalactic Survey (ELAIS)

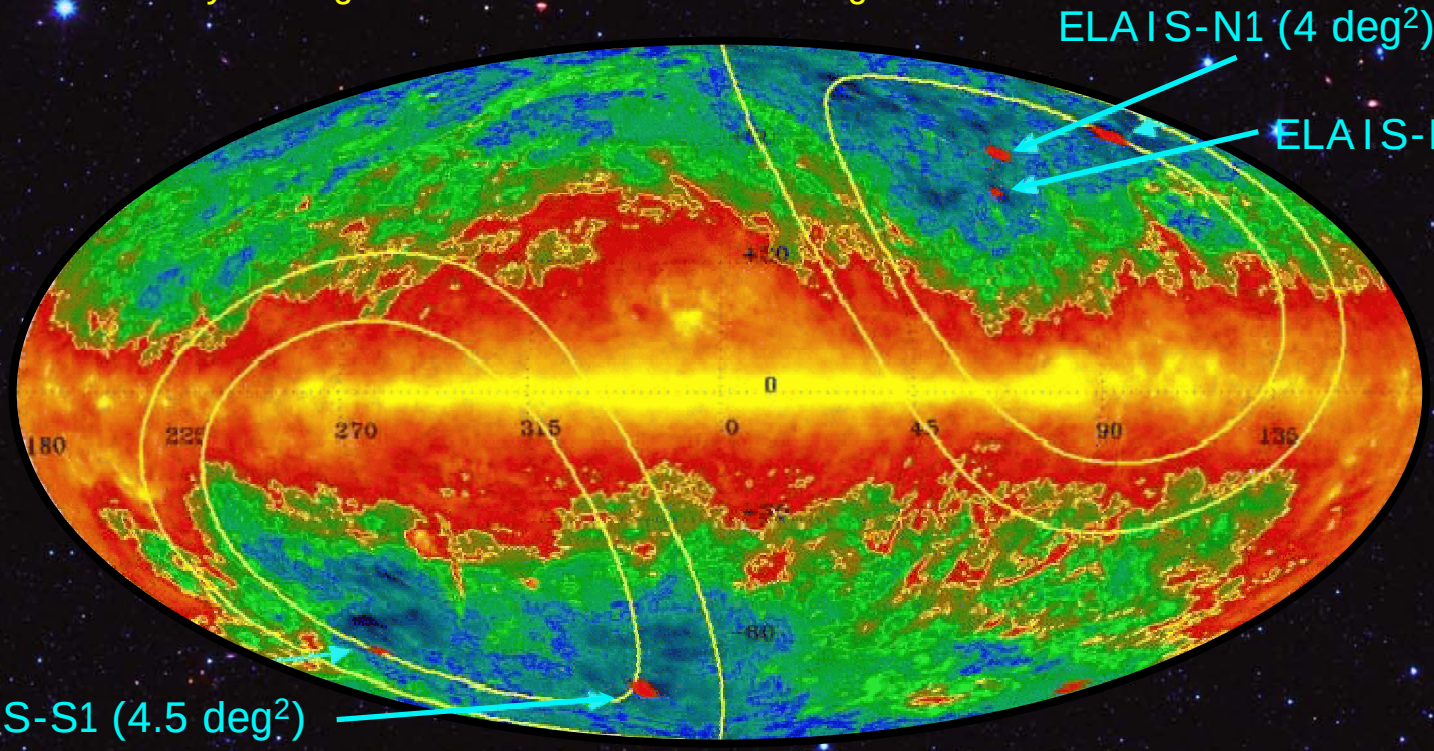
Michael Rowan-Robinson	PI	IC, London	Duncan Farrah, Dave Clements,
Seb Oliver	Co-I	IC, London	
Bo Mann	Ass	IC	Tom Babbedge, Dave Clements
Steve Serjeant	Ass	IC	
Alberto Franceschini	Spheroids/AGN	Padua	Stefano Berta, Giulia Rodighiero,
David Elbaz	Ass	CEA, Saclay	Mattia Vaccari
Catherine Cesarsky	Ass	CEA Saclay	
Jean Loup Puget	M.S.	Orsay	
Alan Moorwood	M.S.	ESO	

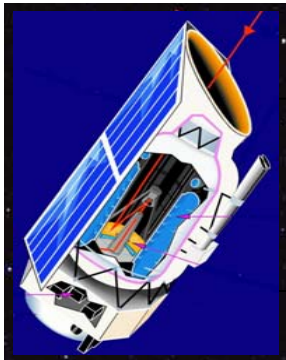


THE EUROPEAN LARGE_AREA ISO SURVEY (ELAIS) including among the largest lowest infrared background regions in the sky

Field Selection Strategy:

- Low galactic extinction and cirrus emission ($I_{100\mu m}$ < 0.5 MJy/sr) ⇨ less confusion and noise.
- High galactic latitude fields ⇨ low zodiacal background.
- Large contiguous area ⇨ large scale structure studies.
- Minimum contamination by bright stars, galaxies, radio sources, and galaxy clusters.
- Availability of large data sets at other wavelengths

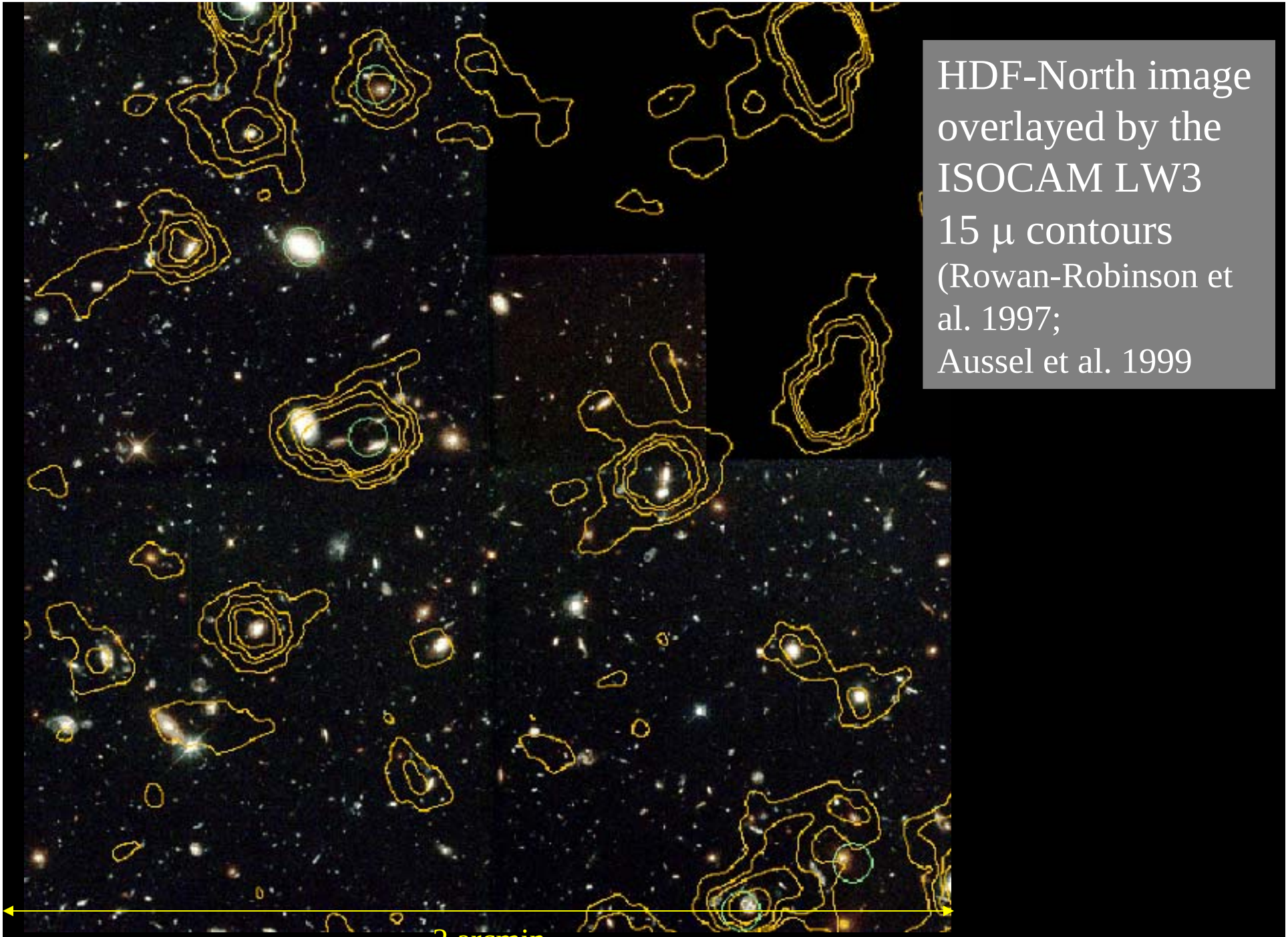




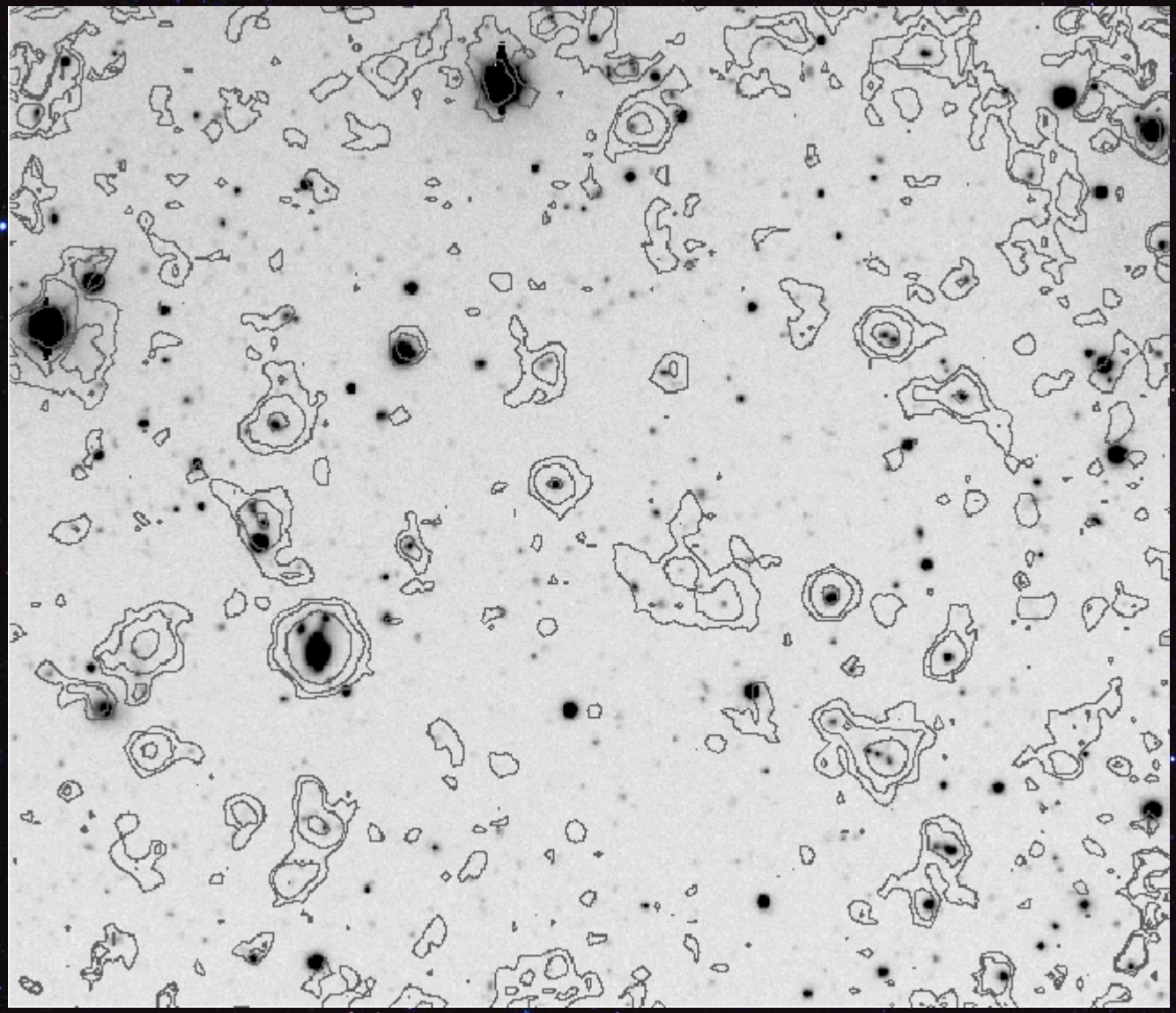
Open Time Survey Teams and Associates (cnt.)

- **The ISOCAM-HDF observation HDF North & South Fields**

•	**Michael Rowan-Robinson**	PI	**IC, London**	**Duncan Farrah, Dave Clements,**
•	**Seb Oliver**	Co-I	**IC, London**	
•	**Bo Mann**	Ass	**IC**	**Tom Babbedge, Dave Clements**
•	**Steve Serjeant**	Ass	**IC**	
•	**Alberto Franceschini**	Spheroids/AGN	**Padua**	**Stefano Berta, Giulia Rodighiero,**
•	**David Elbaz**	Ass	**CEA, Saclay**	**Mattia Vaccari**
•	**Catherine Cesarsky**	Ass	**CEA Saclay**	
•	**Jean Loup Puget**	M.S.	**Orsay**	
•	**Alan Moorwood**	M.S.	**ESO**	

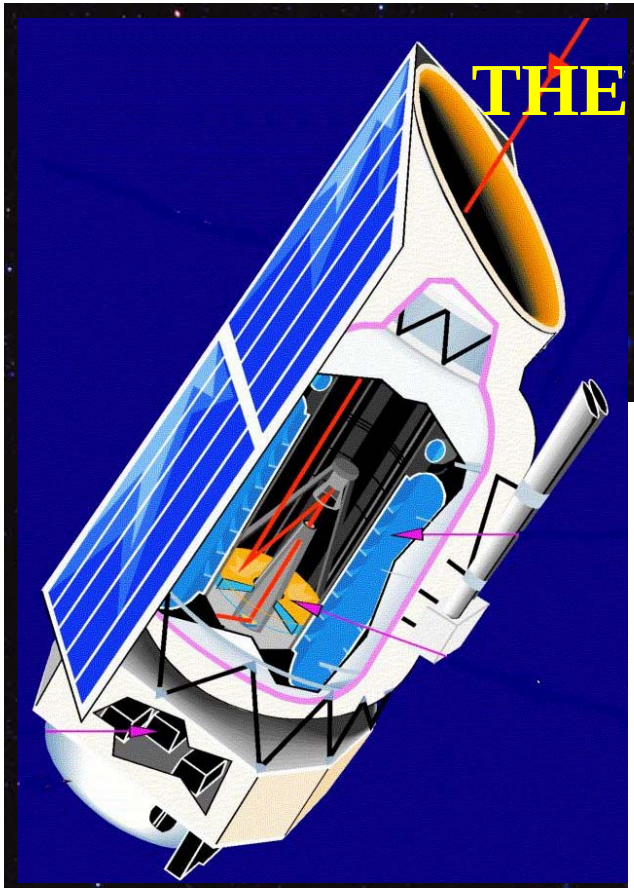

HDF-North image overlayed by the ISOCAM LW3 15 μ contours (Rowan-Robinson et al. 1997; Aussel et al. 1999
2 arcmin

The HDF-S observed with ISO



ISO LW3 15 μ contours ovelayed on the NTT EIS I-band image (Aussel et al.)

THE INFRARED SPACE OBSERVATORY

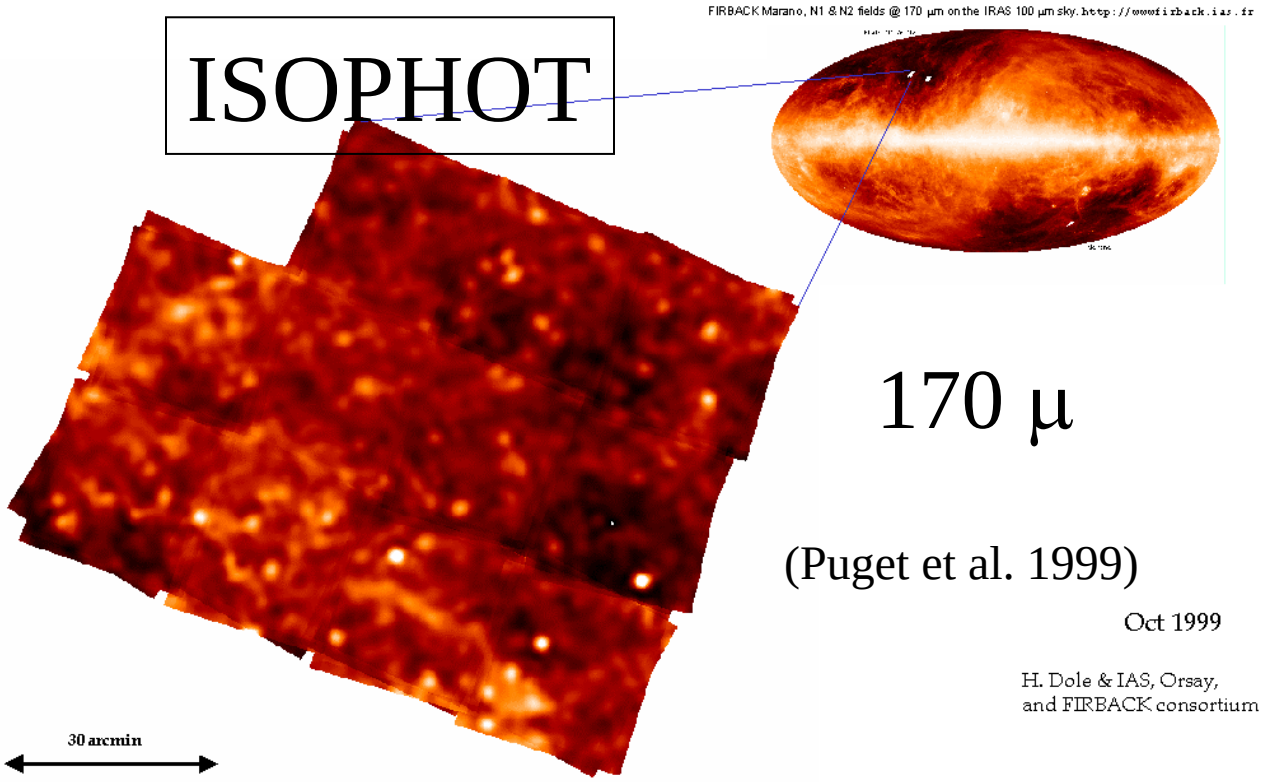


To access wavebands unreachable from ground (λ~10 to 200 μm)

THE FIRBACK SURVEY: N1 FIELD

http://wwwfirback.ias.fr

ISOPHOT



170 μ

(Puget et al. 1999)

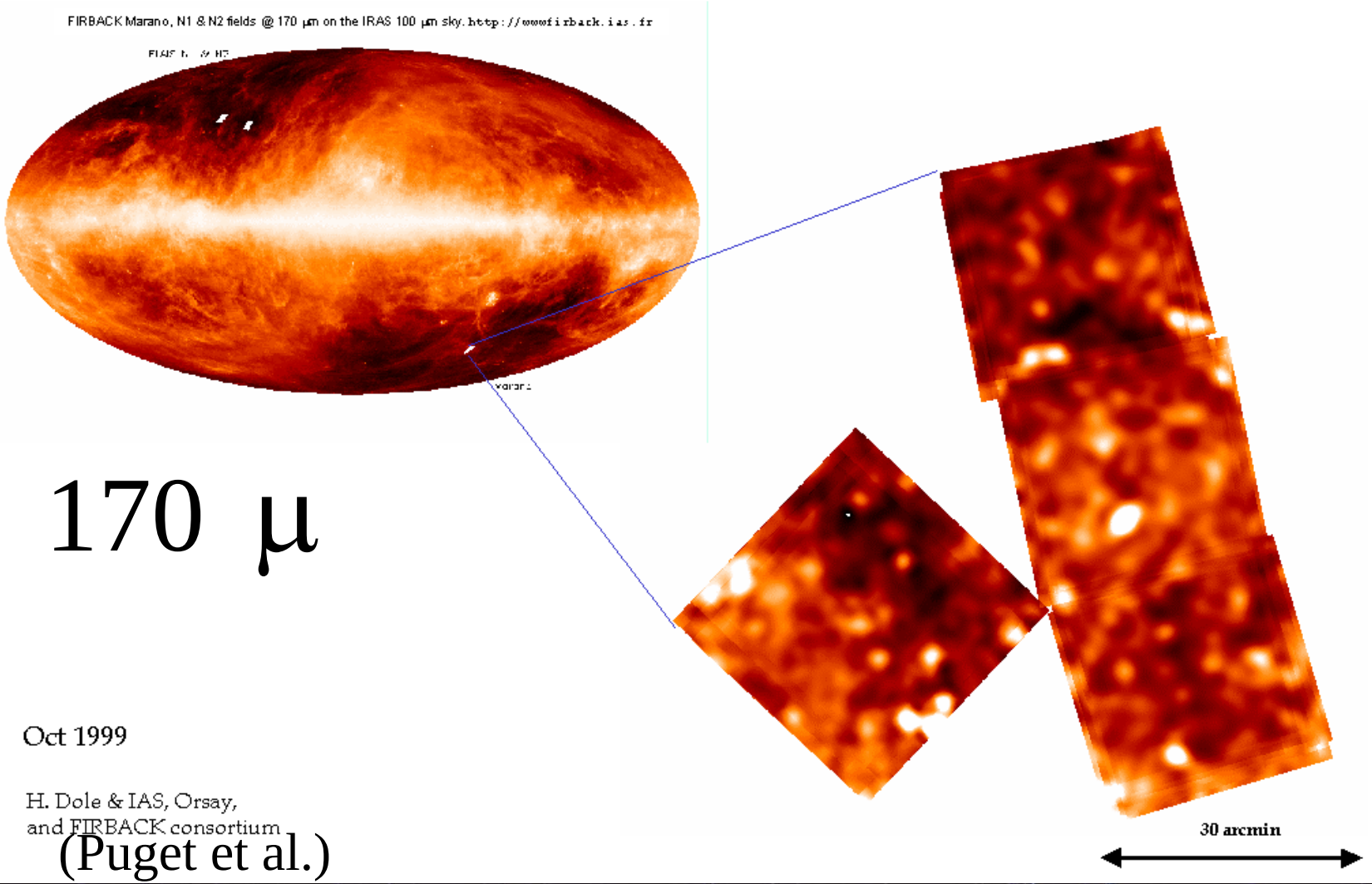
Oct 1999

H. Dole & IAS, Orsay,
and FIRBACK consortium

Jean-Loup Puget
Xavier Desert
Herve' Dole
Francois Bouchet
Bruno Guiderdoni
Catherine Cesarsky
Alberto Franceschini
H. Aussel
W. Reach
Alan Moorwood

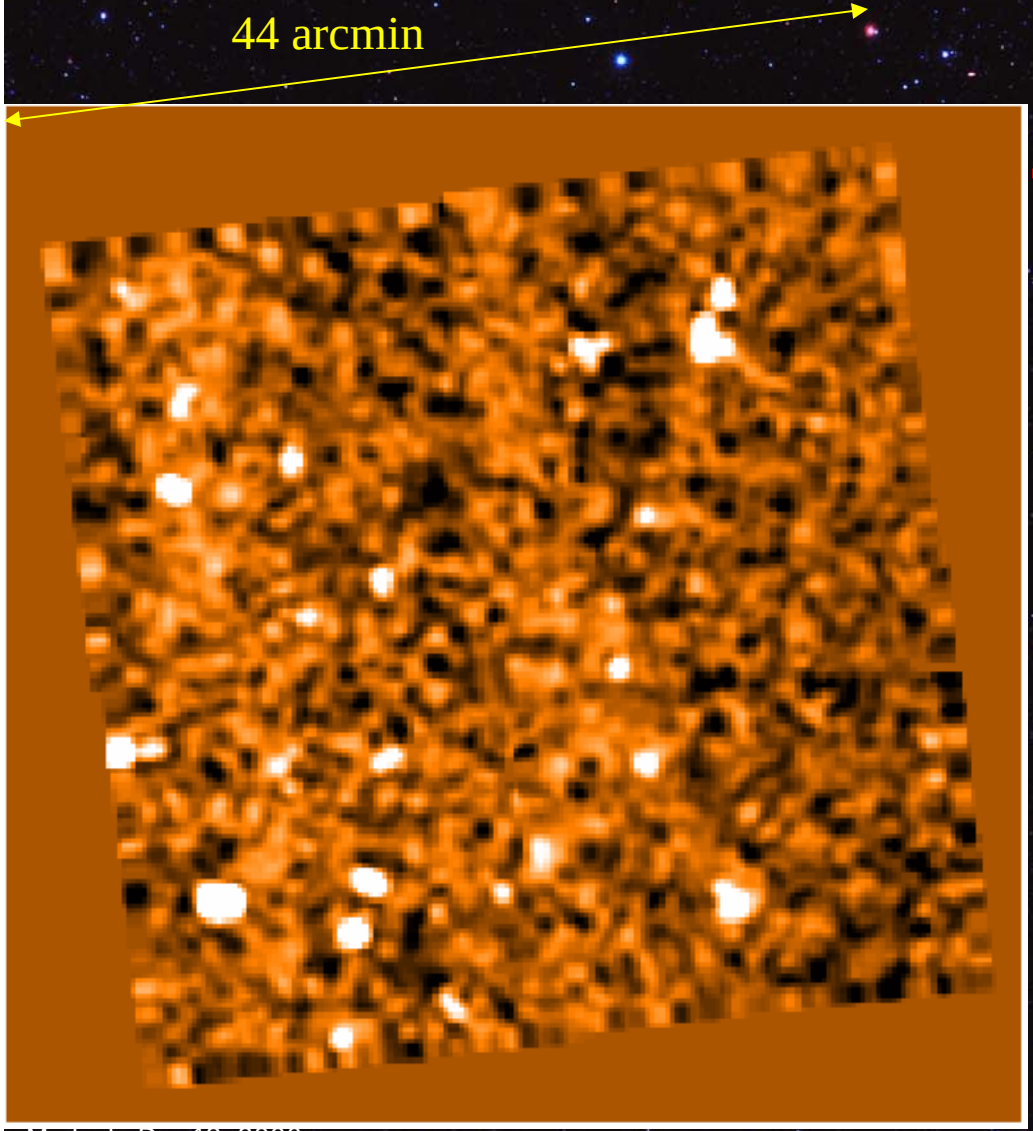
The FIRBACK Survey: Marano Field

http://wwwfirback.ias.fr



(Puget et al.)

The LOCKMAN HOLE as seen by ISOPHOT at 95 *μm*

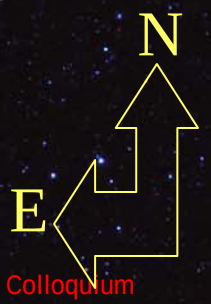


THE SURVEY

area : ~40´ x 40´

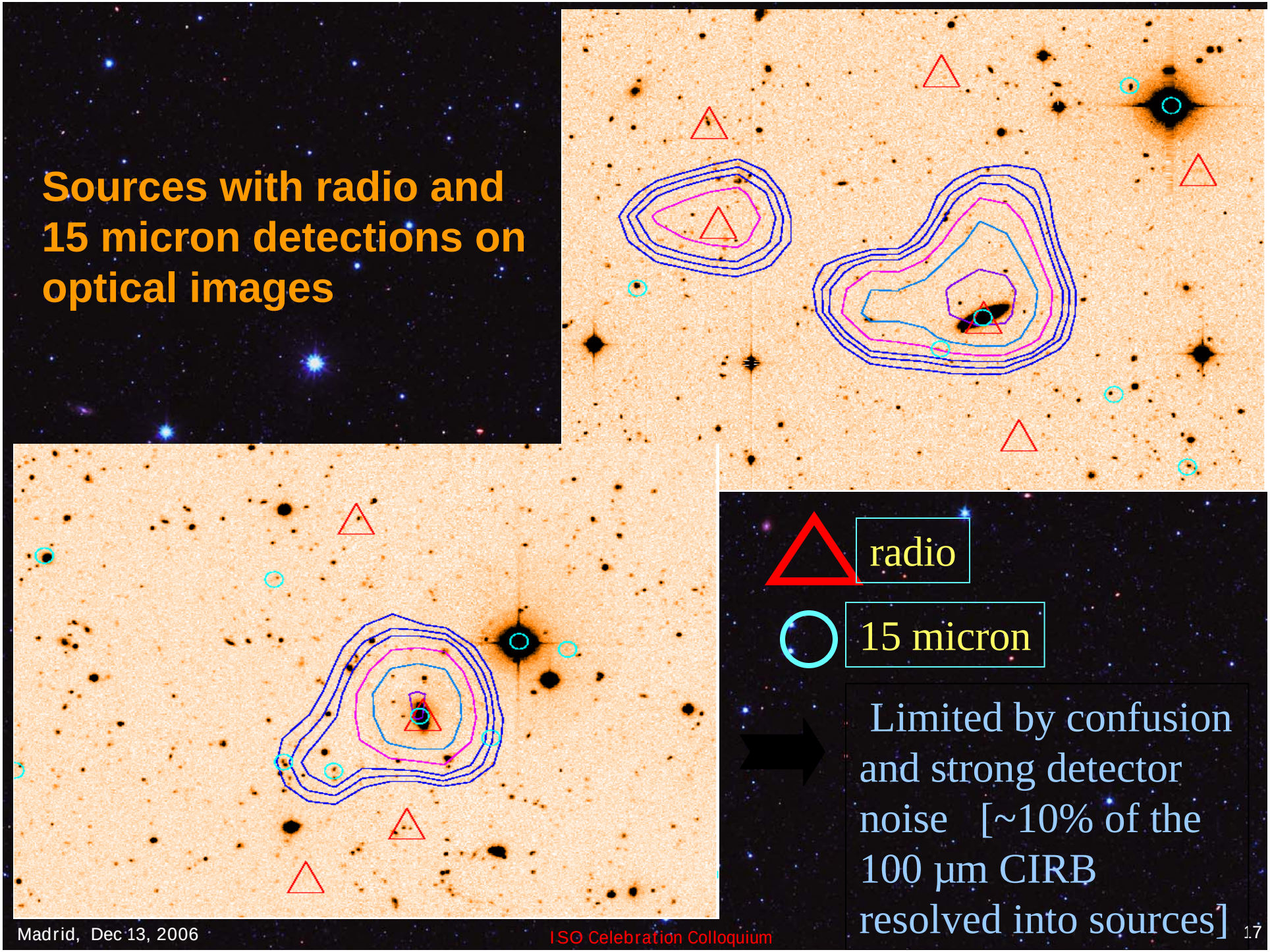
number of sources detected:36 (above 4 sigma). 10 sources present both CAM and RADIO counterparts.

minimum flux level: ~30 mJy



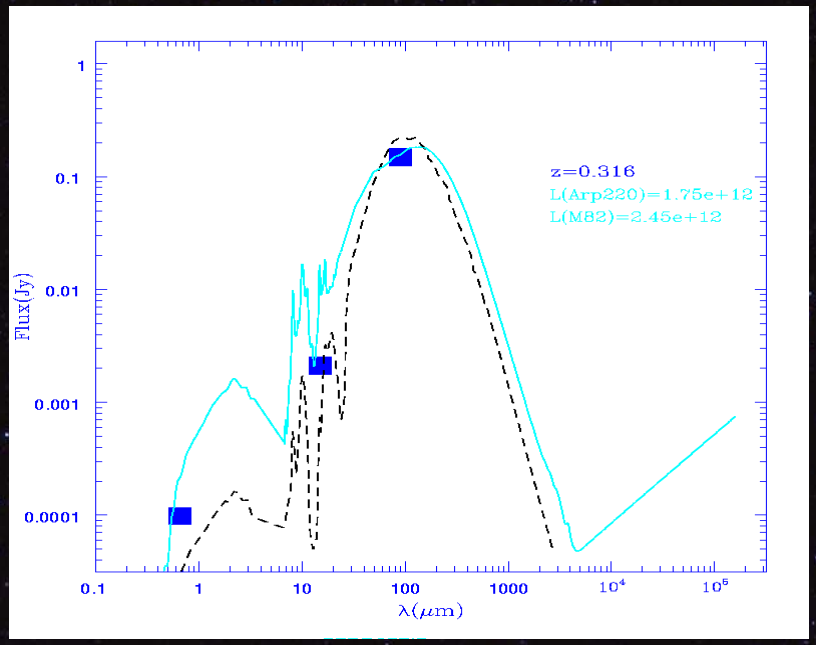
(Rodighiero et al. 2002)

Sources with radio and 15 micron detections on optical images

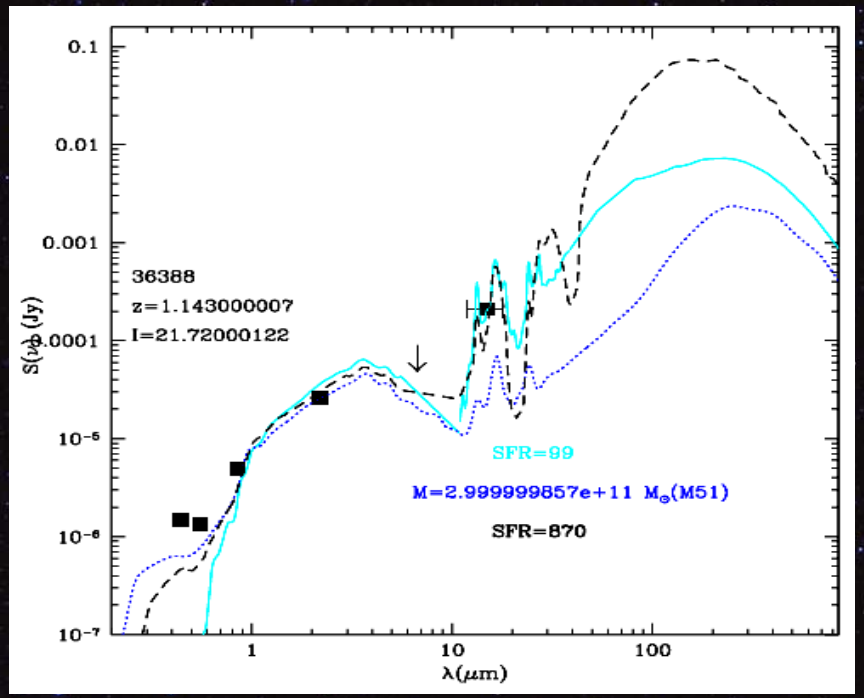


SED consistent with that of luminous and ultraluminous IR galaxies

LIRG $L = 4\ 10^{11}\ L_{\odot}$

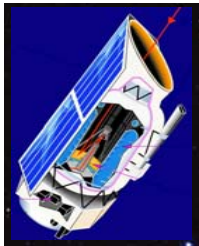


ULIRG $L = 4\ 10^{12}\ L_{\odot}$



ISO discovered that such luminous galaxies were extremely more numerous during the past history of the Universe than they are now

→ a new pathway for galaxy formation



Conclusions

- A large fraction (≈15%) of the ISO observing time dedicated to deep extragalalactic surveys
- Such large, well coordinated effort provided us for the first time with crucial data on obscured star formation (in galaxies) and gravitational accretion (AGNs) at high redshifts
- These results, together with concomitant (SCUBA) observations at the mm, had a profound impact on cosmology and galaxy formation [Spitzer Space Observatory later confirmed them]
- The ISO mission heralded a very innovative approach to sky exploration:
  - **not only providing sensitive instrumentation in an almost completely uncharted waveband domain (λ=3 to 200 μm),** but also...
  - establishing a completely new strategy for cosmological surveys, combining wide-area shallow observations with progressively deeper observations on smaller regions, in a well coordinated way [an approach later adopted by all space observatories, Spitzer, ASTRO-F, HST, Herschel, etc.]

Tab. 1 - ISOCAM surveys

Name	λ (μm)	Area ($'^2$)	depth (mJy)	# objs	Ref.	coord.(2000)
CAM parallel	7,15	1.2e5	5	>10000	(1)	–
ELAIS	7,15	4e4	1,3	~1000	(2)	(a)
Marano2 FIRBACK	15	2700	1.4	29	(3)	03 13 10 –55 03 49
Lockman Shallow	15	1944	0.72	180	(4)	10 52 05 +57 21 04
Comet Fields	12	360	0.5	37	(5)	03 05 30 –09 35 00
Lockman Deep	7,15	500	0.3	166	(6)	10 52 05 +57 21 04
CFRS 14+52	7,15	100	0.3	23,41	(7)	14 17 54 +52 30 31
CFRS 03+00	7,15	100	0.4		(8)	03 02 40 +00 10 21
Marano2 Deep	7,15	900	0.19,0.32	180	(9)	03 13 10 –55 03 49
A370	7,15	31.3	0.26	18	(10)	02 39 50 -01 36 45
Marano Ultradeep	7,15	90	0.14		(11)	03 14 44 –55 19 35
Marano2 Ultradeep	7,15	90	0.1	~120	(12)	03 13 10 –55 03 49
A2218	7,15	16	0.12	23	(10)	16 35 54 +66 13 00
ISOHDF South	7,15	25	0.1	66	(13)	22 32 55 –60 33 18
ISOHDF North	7,15	24	0.05,0.1	7;44	(14)	12 36 49 +62 12 58
Deep SSA13	7	9			(15)	13 12 26 +42 44 24
Lockman DEEPPGPQ	7	9	0.034	15	(16)	10 33 55 +57 46 18
A2390	7,15	5.3	0.030	32,31	(17)	21 53 34 +17 40 11

References: (4) Désert, F.-X., *et al.*, to be submitted (tbs); (6) Fadda, D., *et al.*, tbs; (8) P.I.: F.Hammer; (9) Désert, F.X., *et al.*, tbs; (11) Elbaz, D., *et al.*, tbs; (12) Aussel, H., *et al.*, tbs; (13) Oliver, S.J., *et al.*, tbs; (16) P.I. Y.Taniguchi;

Tab. 2 - ISOPHOT surveys

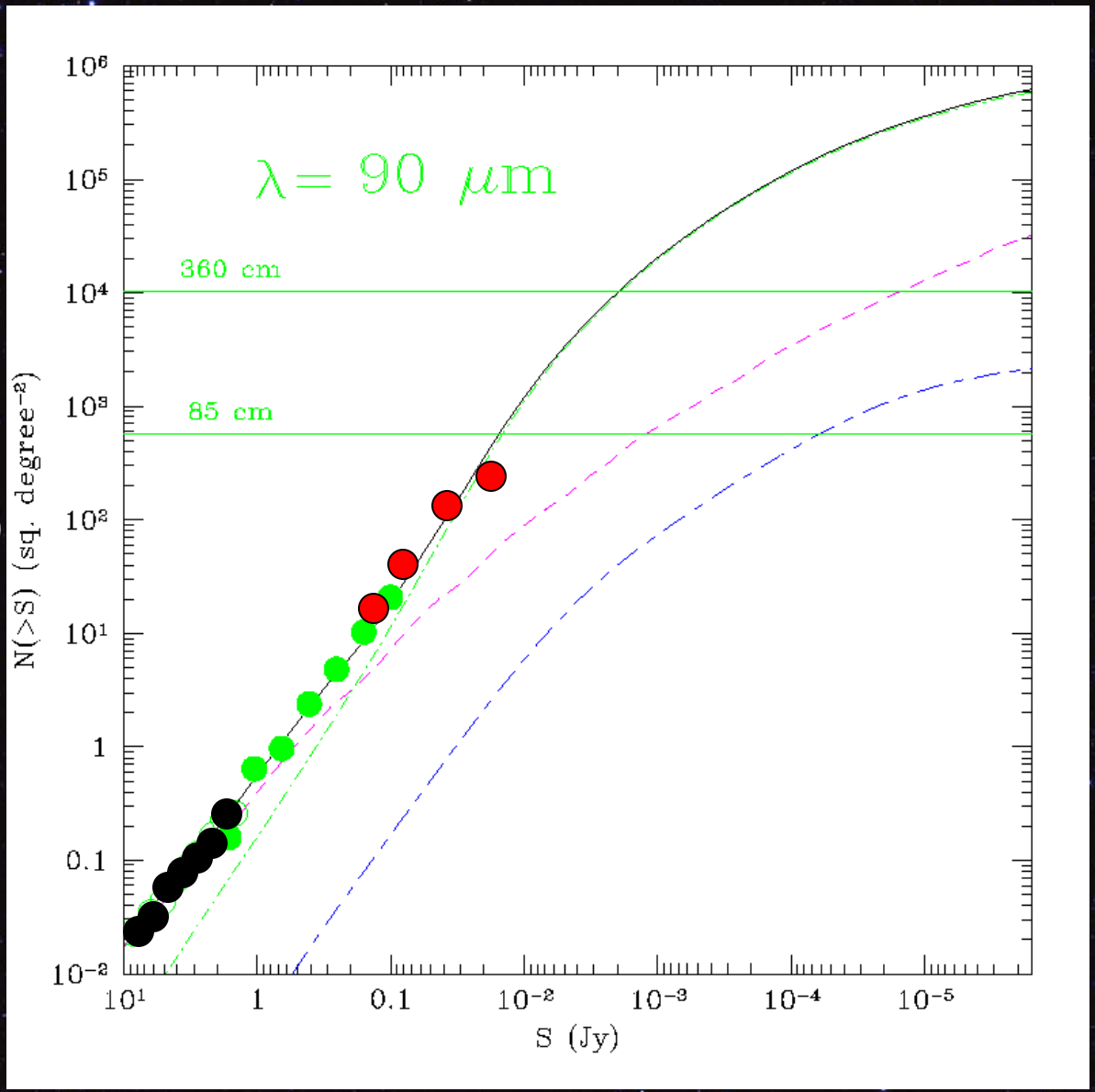
Name	λ (μm)	Area (sq.deg.)	depth (Jy)	# objs	Ref.	coord.(2000)
PHOT Serendipitous	170	7000	1.5	4000	(1)	–
ELAIS	90,170	12,2	0.05,0.1	~500	(2)	16 11 00 +54 25 00
FIRBACK	170	3	0.1	200	(3)	03 13 10 –55 03 49
Lockman DEEPPGPQ	90,170	1.1	0.1,0.1	–	(4)	10 34 00 +57 46 00
SA 57	60,90	0.42	–	–	(5)	

References: (1) Stickel M., et al. (1998); (2) Oliver S., et al. (1999); (3) Puget J.L., et al. (1999); (4) Kawara K, et al. (1998); (5) Mattila K, et al. (1999, in prep.); Noorgaard-Nielsen H.H., et al. (1999, in prep.);

90 micron counts

- LOCKMAN
- ELAIS (Efstathiou et al 2000)
- IRAS

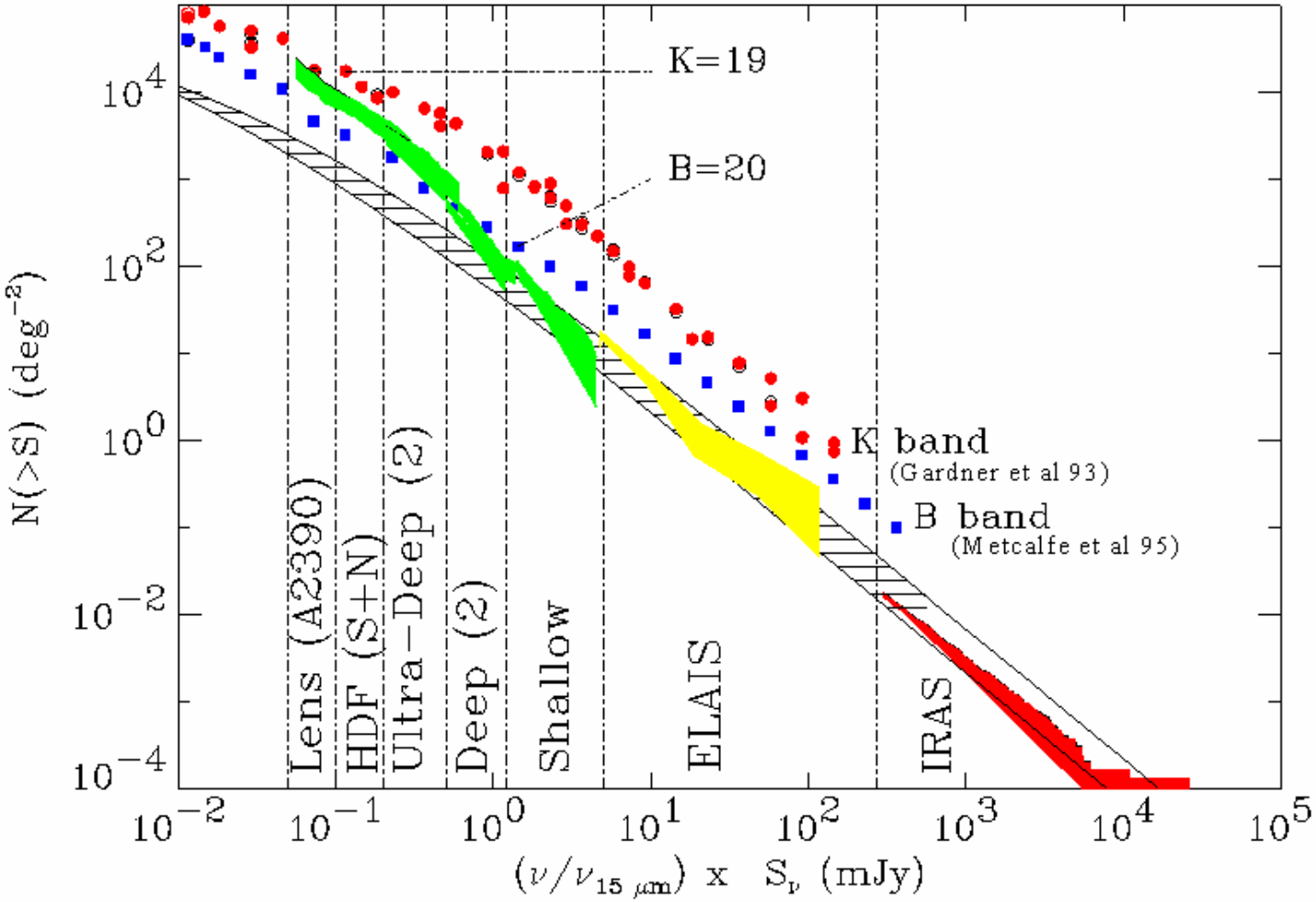
Our sample resolves only 10 % of the CIRB



Rodighiero et al. (2001)

The Counts

The Lockman Deep Survey sees a rapid increase in the LW3 counts



(Elbaz, Cesarsky, Fadda et al., 1999, A&A)

Integral 15 microns counts