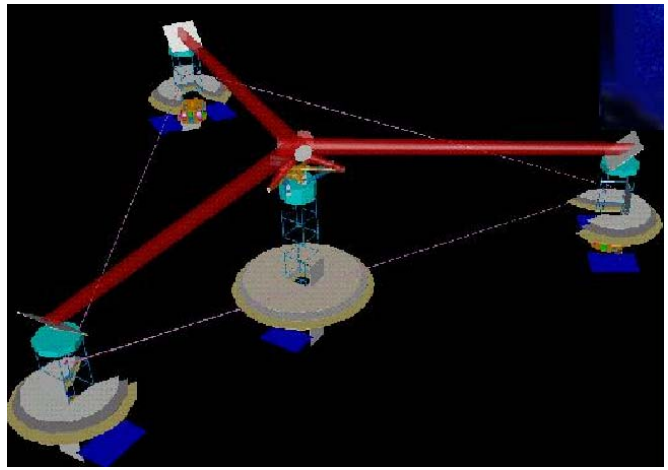
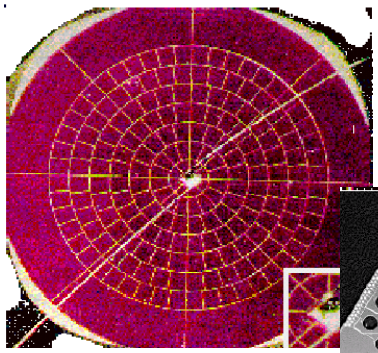


Extragalactic science drivers for FIR/submm detectors in the next decade

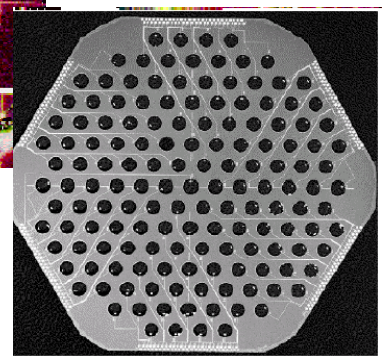
Reinhard Genzel
MPE Garching, FRG and Dept.of Physics, UCB

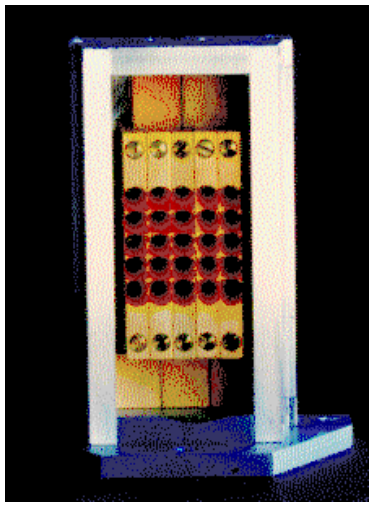
See also the reports by G.Rieke, J.Mather and D.Leisawitz

Progress in incoherent FIR detectors



SCUBA/SHARC
MAMBO/BOLOCAM
1996-2000: 10^2 pixels

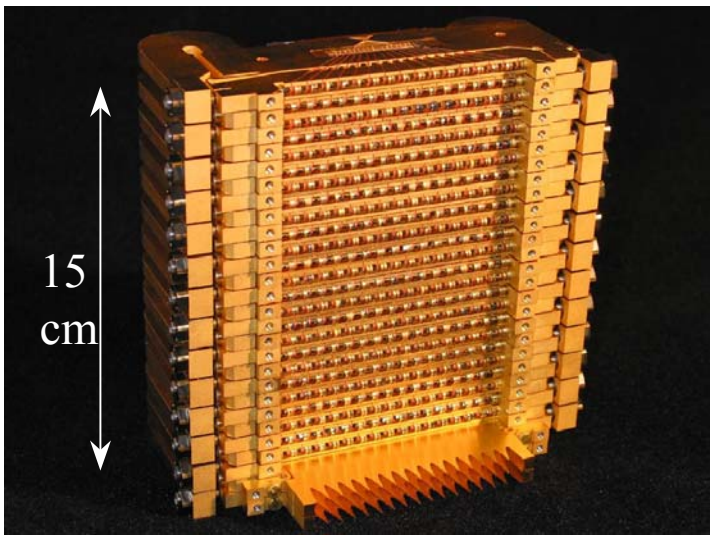


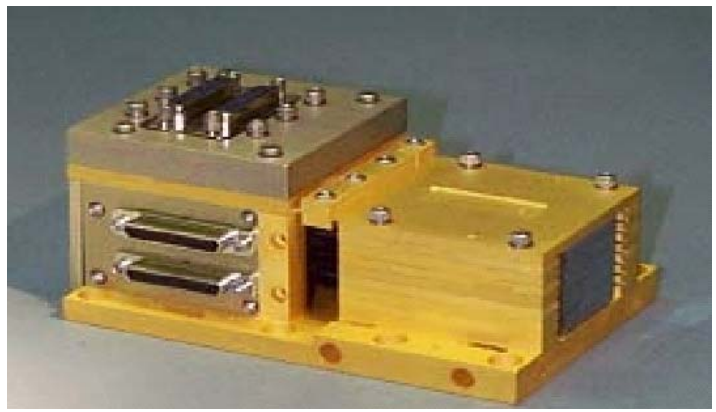


2005: 64^2 pixel bolometers and photoconductors

2010: 128^2-256^2 arrays

FIFI 1989
5x5 pixels
Ge:Ga
stressed





SIRTF MIPS 2000: 32^2 Ge:Ga

PACS/SOFIA FIFI-LS 2001:
25x16 (x2) Ge:Ga (stressed/unstressed)

Detectors are crucial!

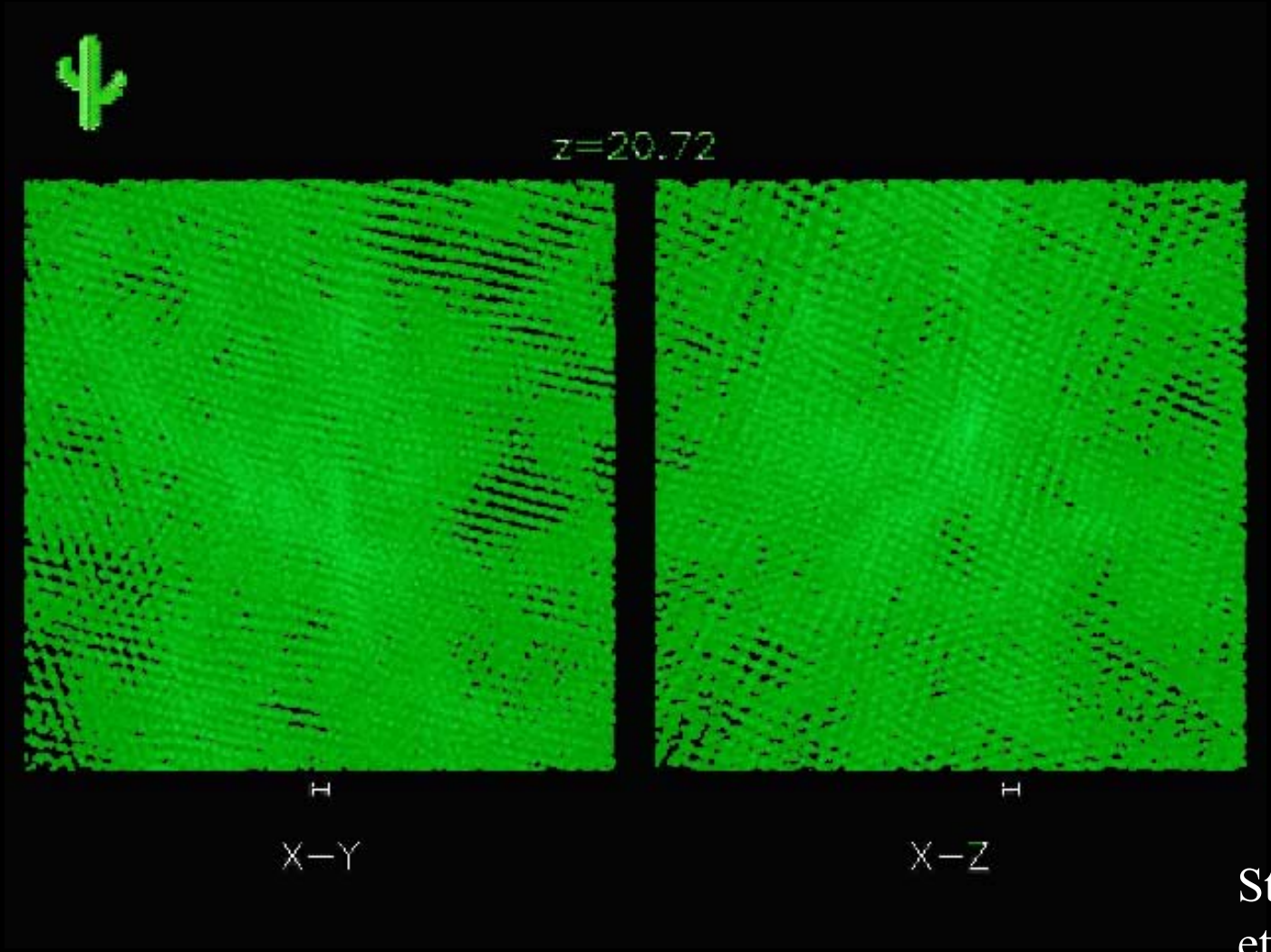
• of the dramatic improvements during the last decade in optical/ near-IR capabilities on 10m class telescopes, progress in instrumentation and detectors have outweighed the benefit from the large telescopes themselves!

• the 30-500μm region has enormous potential (several orders in magnitude in observing speed) for improvement through new detectors, and especially detector arrays.

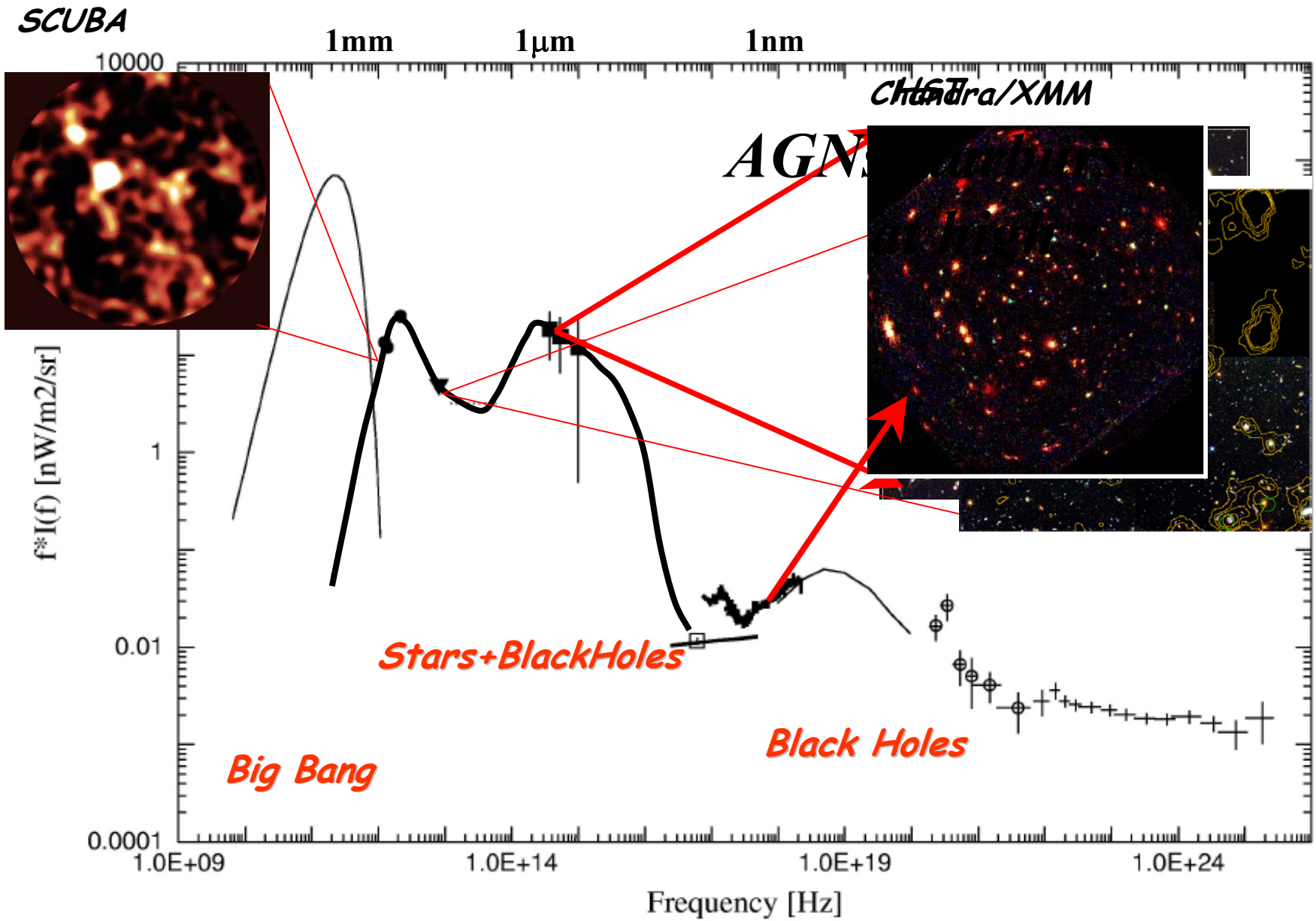
• we are now entering a phase where FIR detectors cannot be built anymore in 'university style'. We need 'industrial' style manufacture, relying on professional systems engineering, with the appropriate funding. Unfortunately, military developments are generally not available to pave the road.

• no single technology can be presently identified that will fulfill all the needs. We need to invest in several directions.

Galaxy formation: the theoretical prediction



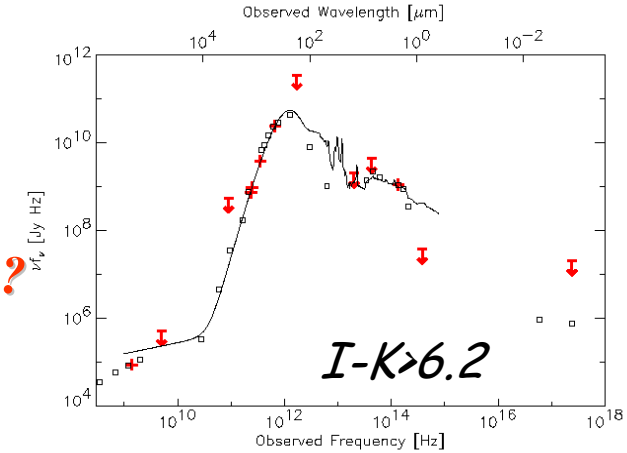
Steinmetz et al.2001

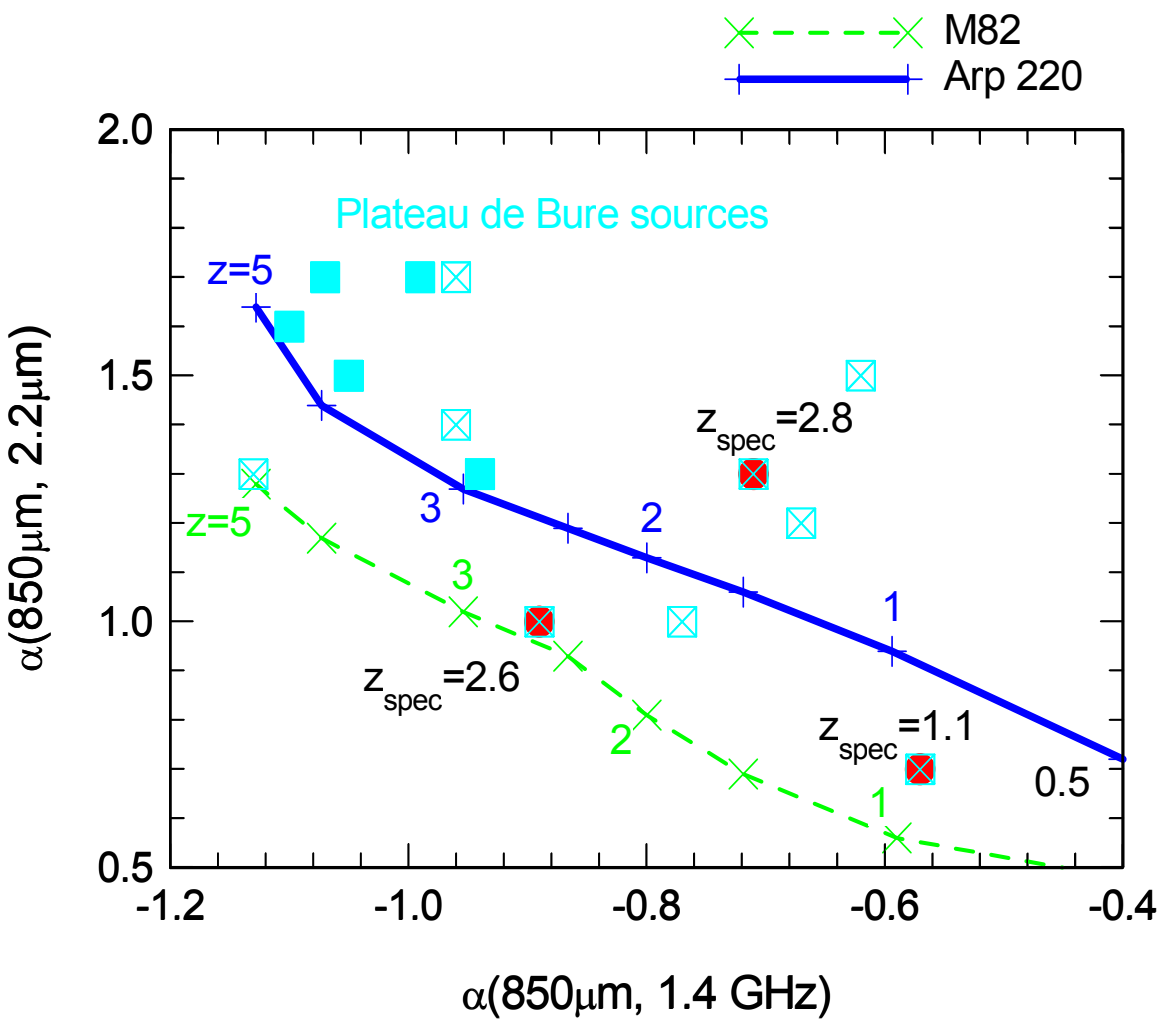


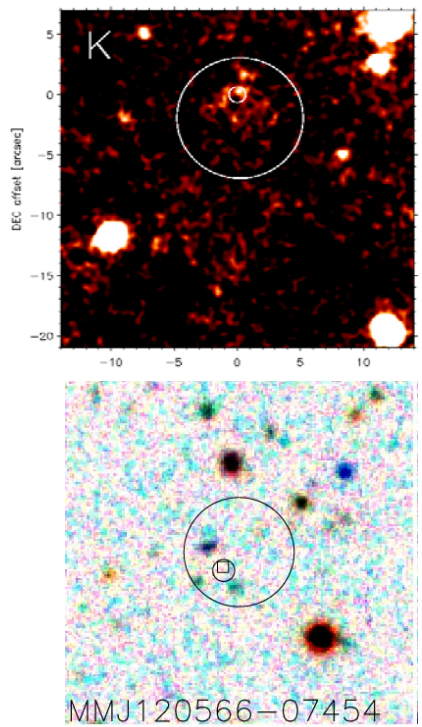
Aussel, Barger, Blain, Cowie, Cesarsky, Elbaz, Giacconi, Hasinger, Hughes, Ivison, Madau, Mushotzky, Pettini, Steidel, Williams et al. 1996-2001

Nature of submm population

A population of colder galaxies (Chapman, Fardha) ?







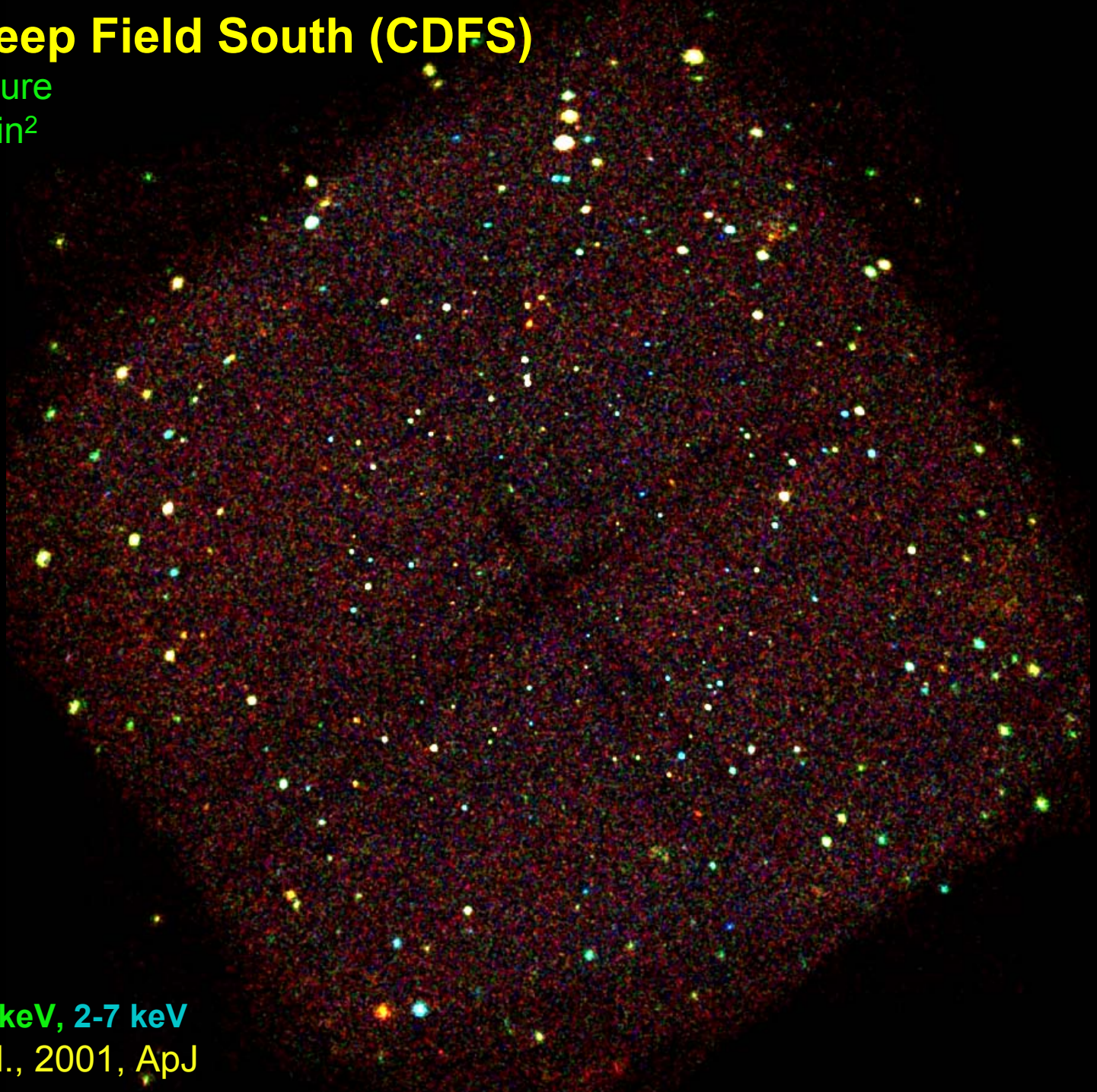
Lutz et al. 2001,
Dannerbauer et al. 2002

Chandra Deep Field South (CDFS)

940 ksec exposure

ACIS-I 64 arcmin^2

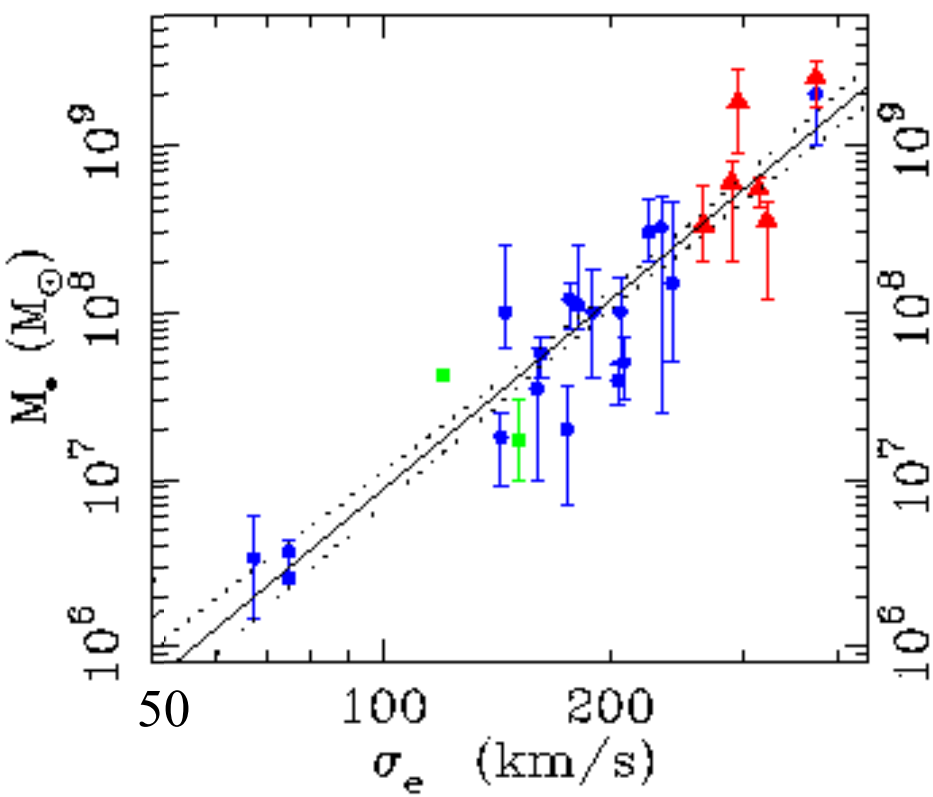
$S_{min} = 6*10^{-17}$

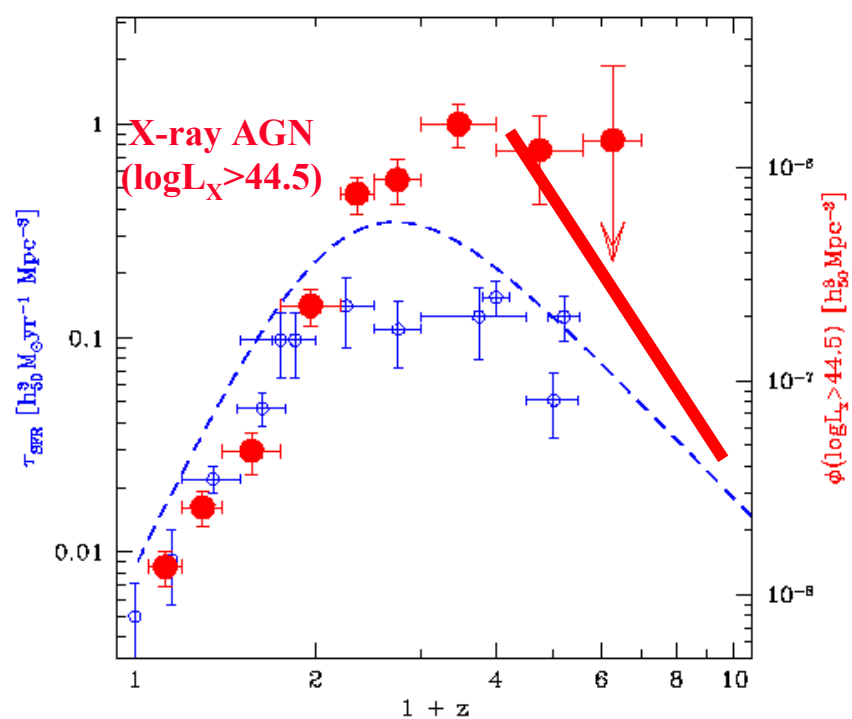


0.3-1 keV, 1-2 keV, 2-7 keV

Giacconi et al., 2001, ApJ

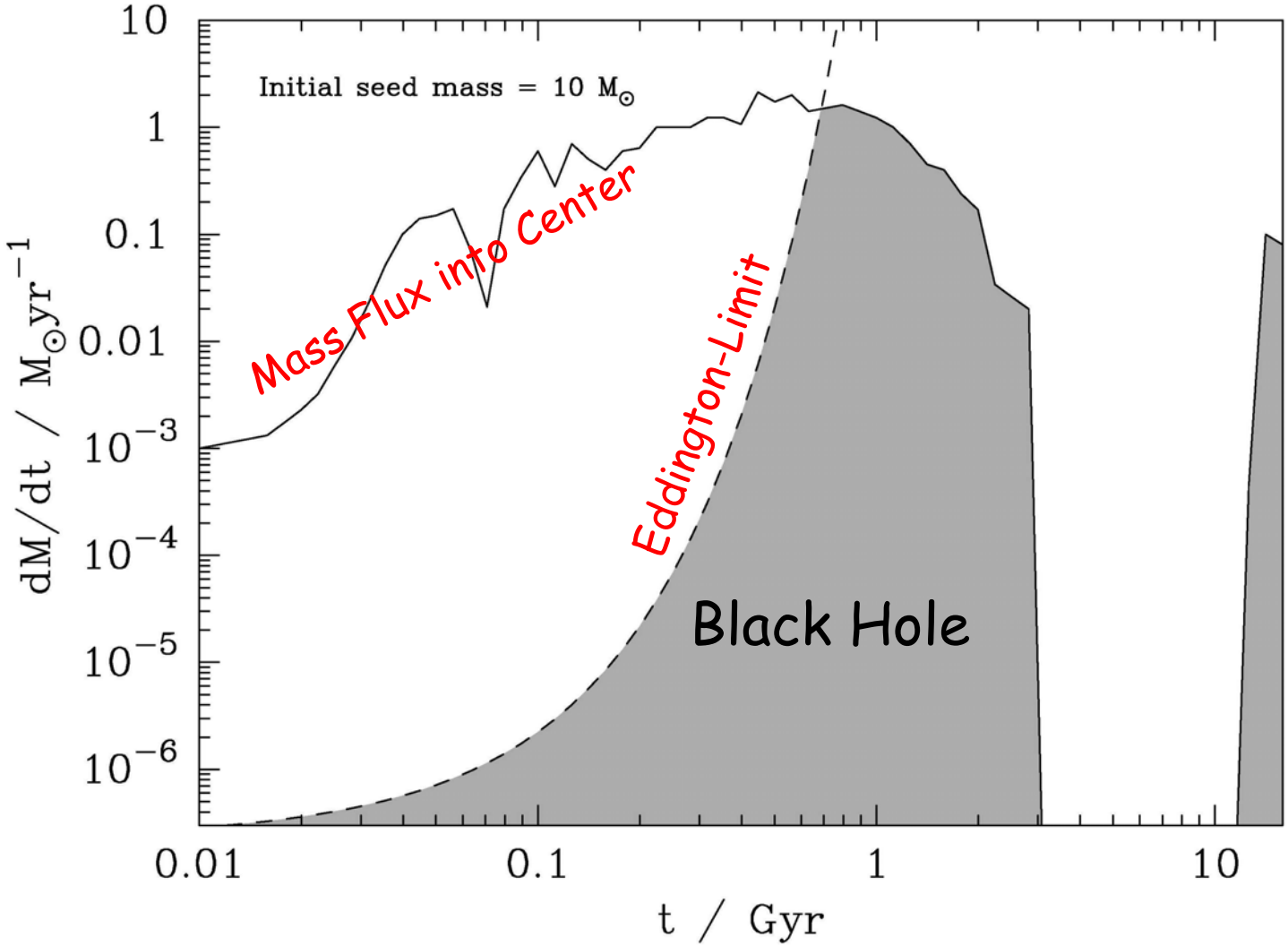
Black holes and galaxy formation





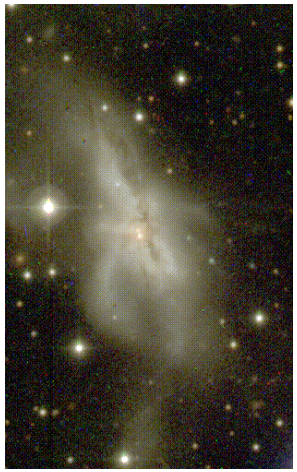
Magorrian et al. 1998, Kormendy and Ho 2000, Gebhardt et al. 2000, Hasinger et al. 1999, 2002, Steidel et al. 1999

Formation of Quasars

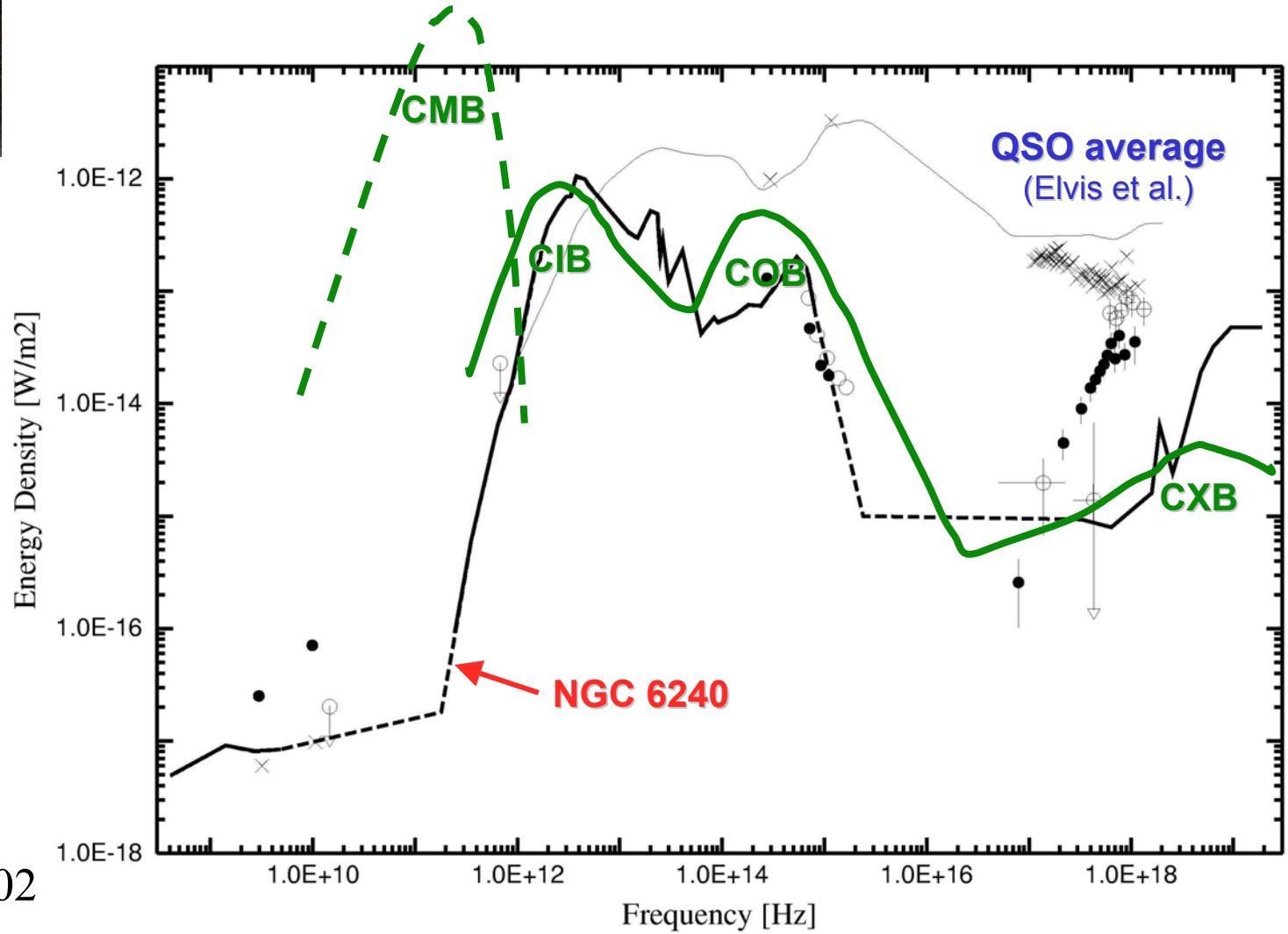


Archibald et al., 2001

Absorbed AGN



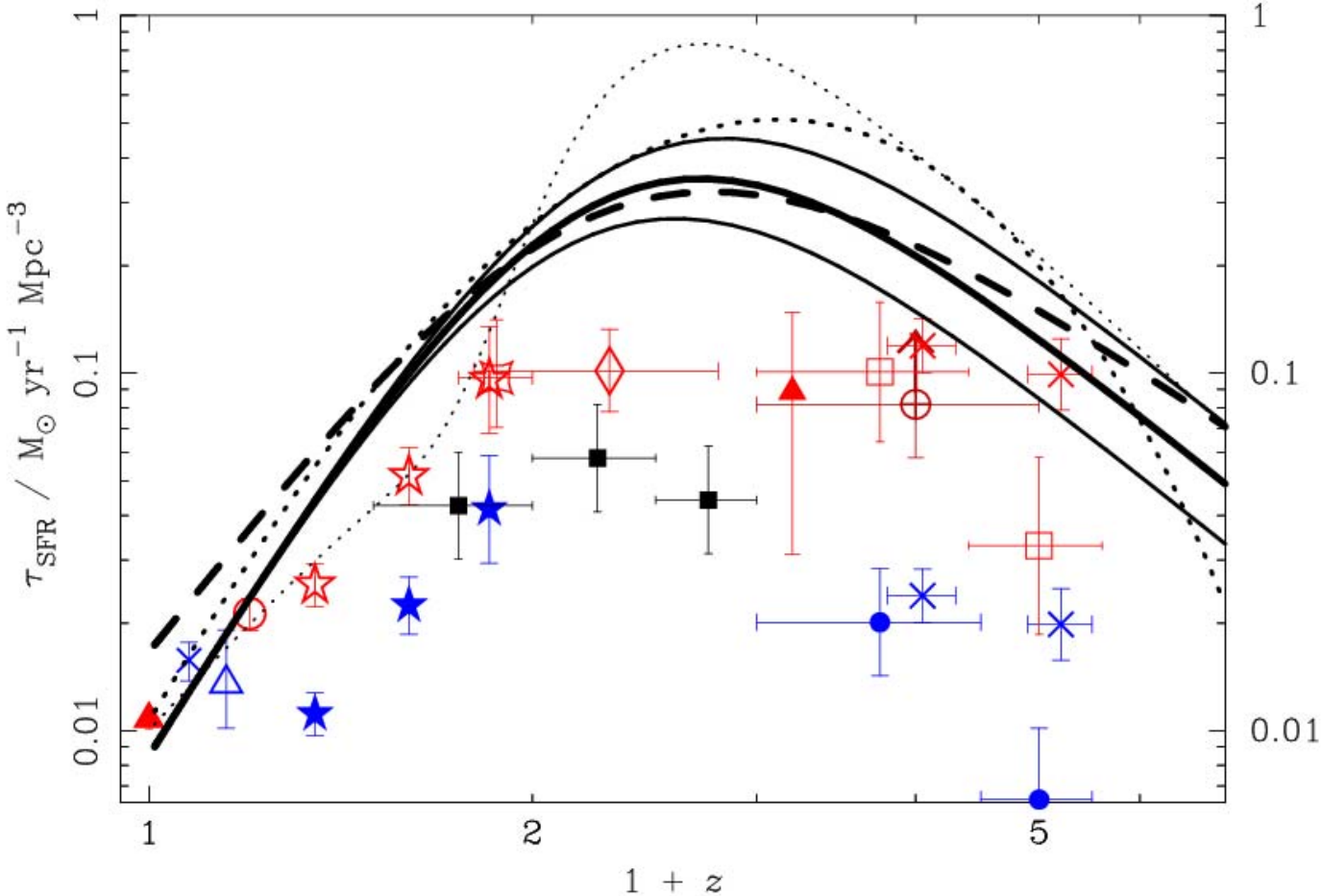
NGC 6240
D=97 Mpc



Hasinger 2002

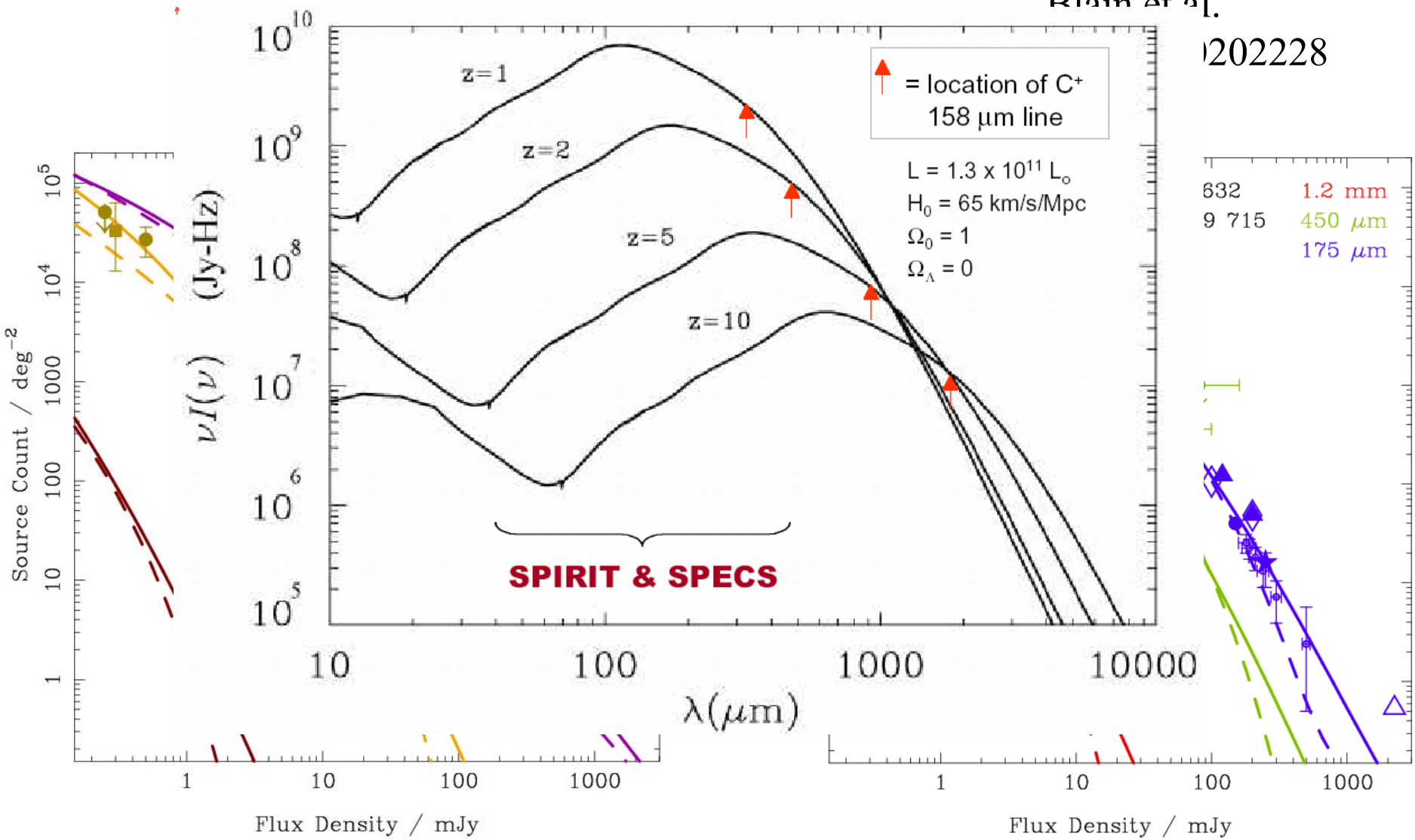
Models of evolution of cosmic star formation

Blain et al. 2002 astro-ph 0202228, Steidel et al. 1999…….



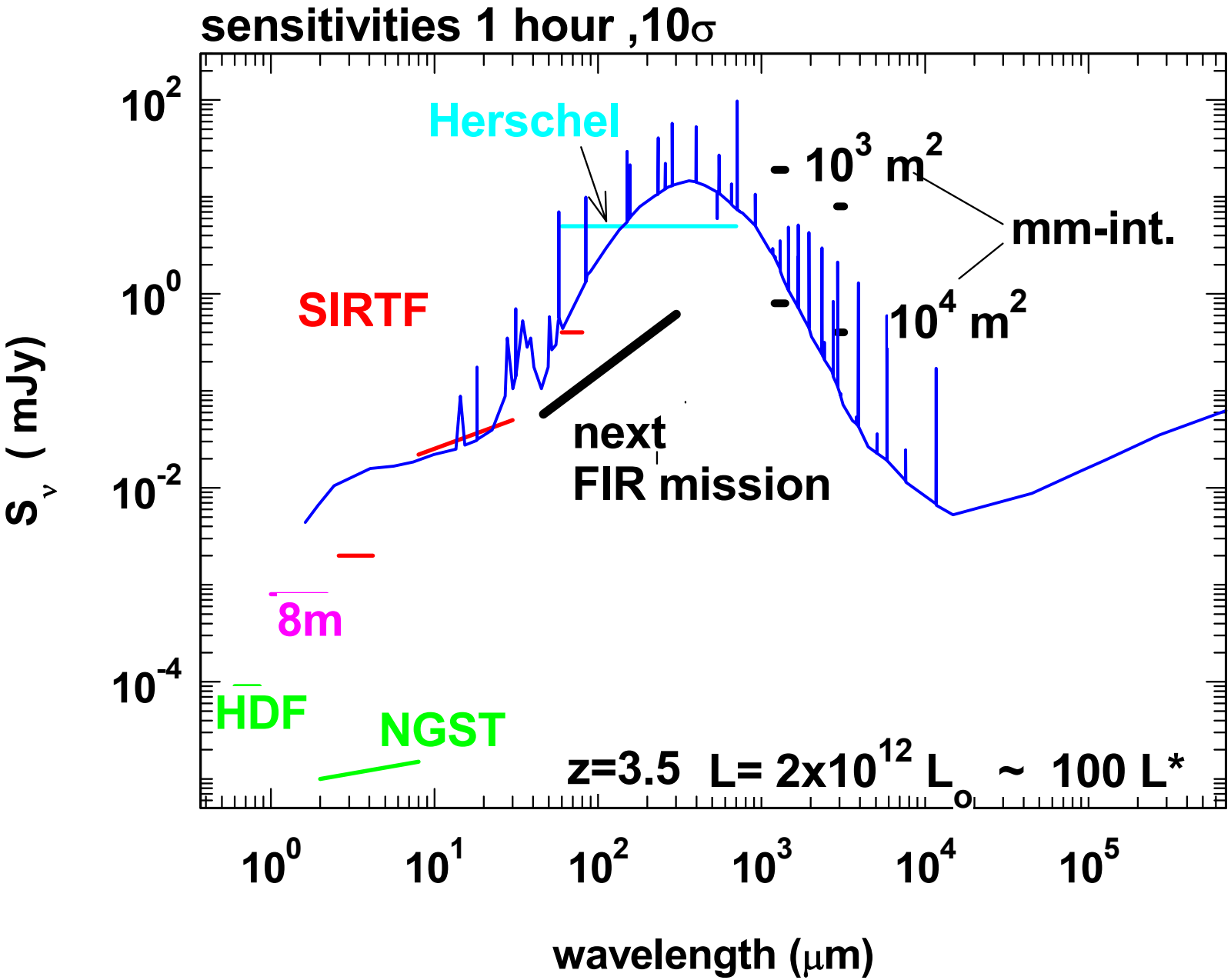
Source counts

Blain et al.
0202228



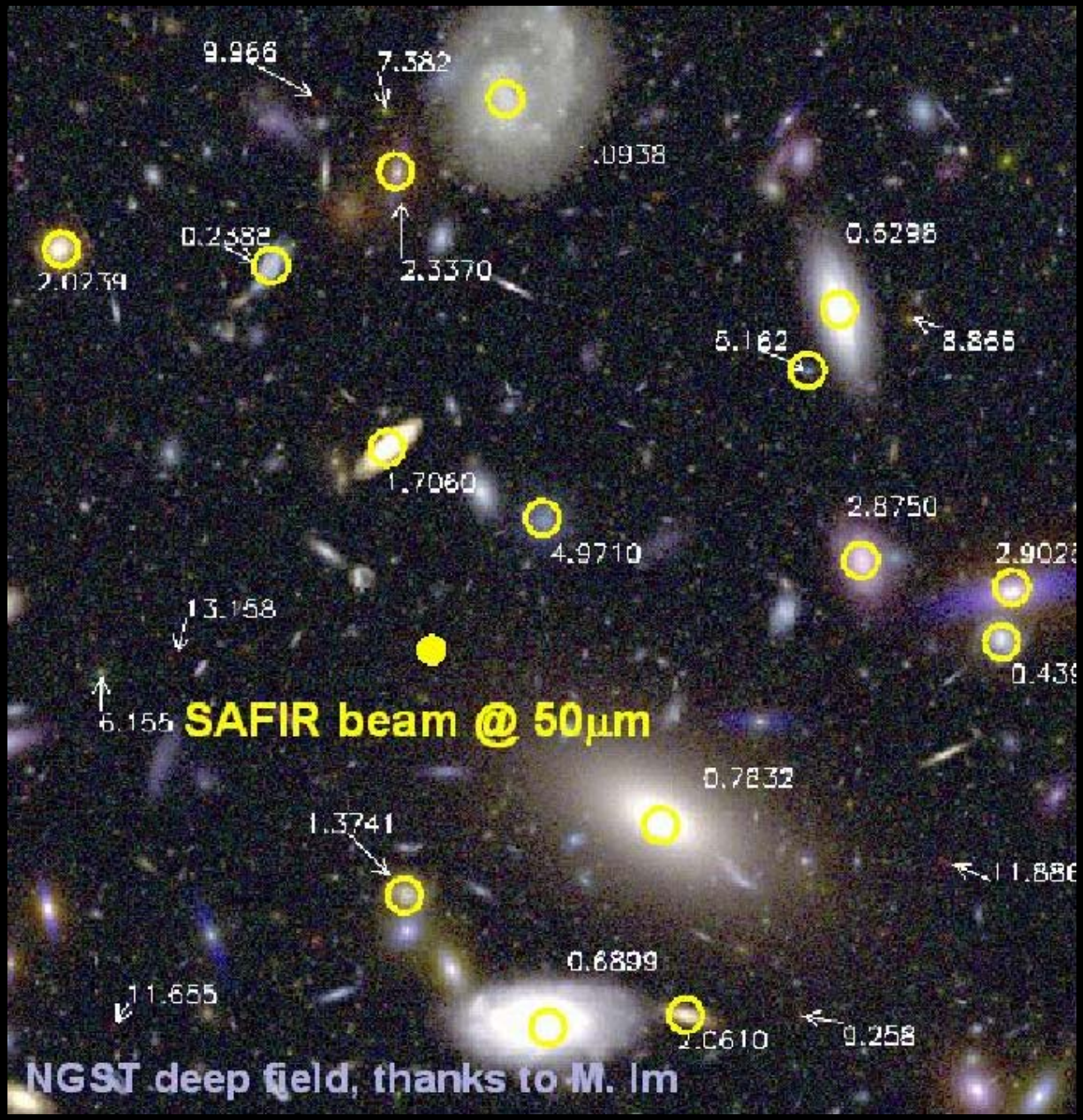
What will be needed to clinch the problem?

- ***large surveys to fully resolve the FIRB***
- ***complete SEDs to disentangle z_{phot}, T, $\beta(\lambda)$***
- ***spectroscopic redshifts***
- ***physical properties of galaxies (detailed multi-line spectroscopy)***
- ***luminosity functions as a function of z: $\Phi(L,z)$***

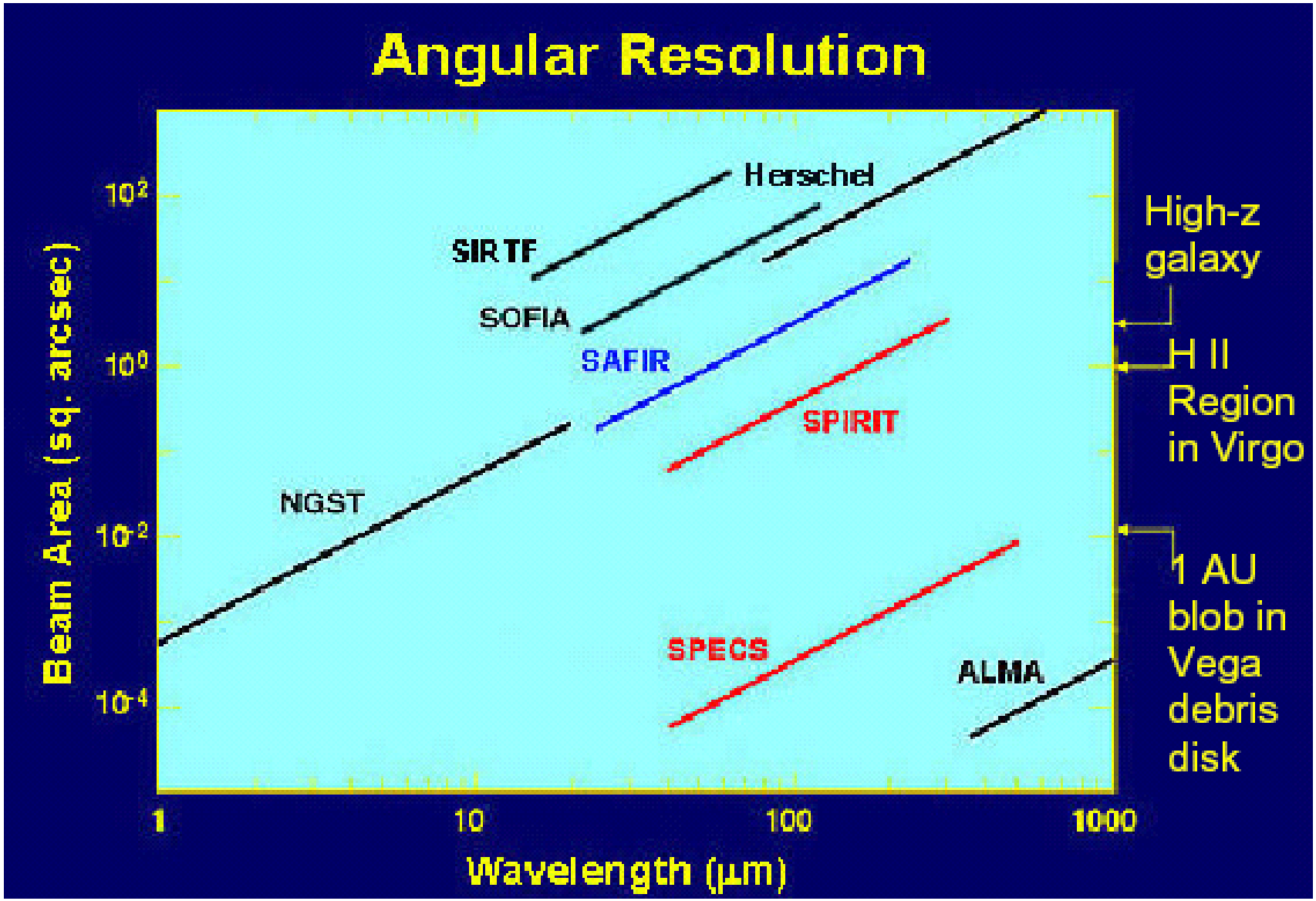

sensitivities 1 hour ,10σ
Herschel
- 10^3 m^2
mm-int.
SIRTF
10^4 m^2
next
FIR mission
8m
HDF
NGST
z=3.5 L= 2x10^12 L_o ~ 100 L*
S_ν (mJy)
wavelength (μm)
10^2
10^0
10^-2
10^-4
10^0
10^1
10^2
10^3
10^4
10^5

The need for large format arrays

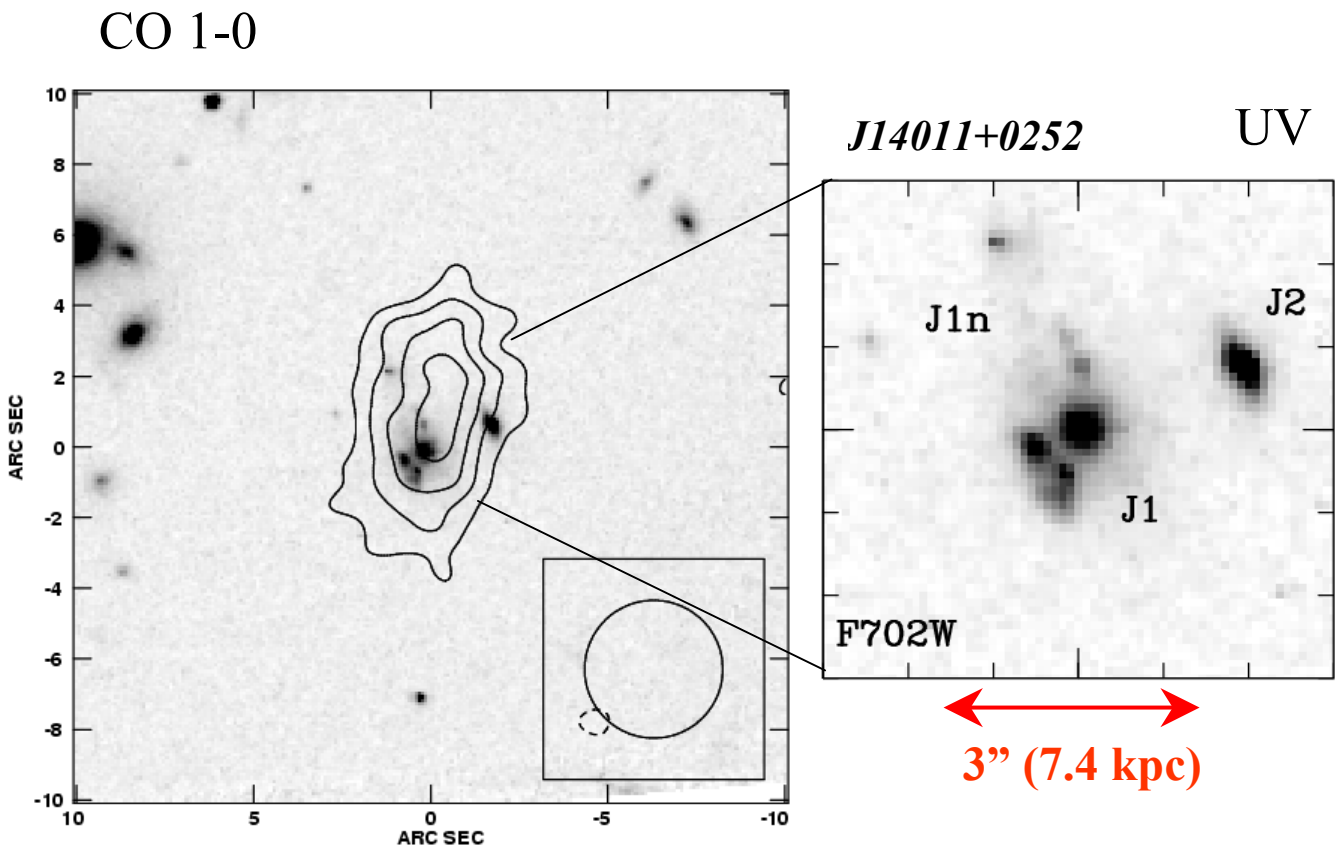
a few arcmin (~1Mpc)



NGST simulation


Angular Resolution
Herschel
SIRTF
SOFIA
SAFIR
SPIRIT
NGST
SPECS
ALMA
High-z galaxy
H II Region in Virgo
1 AU blob in Vega debris disk
Beam Area (sq. arcsec)
10^2
10^0
10^{-2}
10^{-4}
1
10
100
1000
Wavelength (μm)

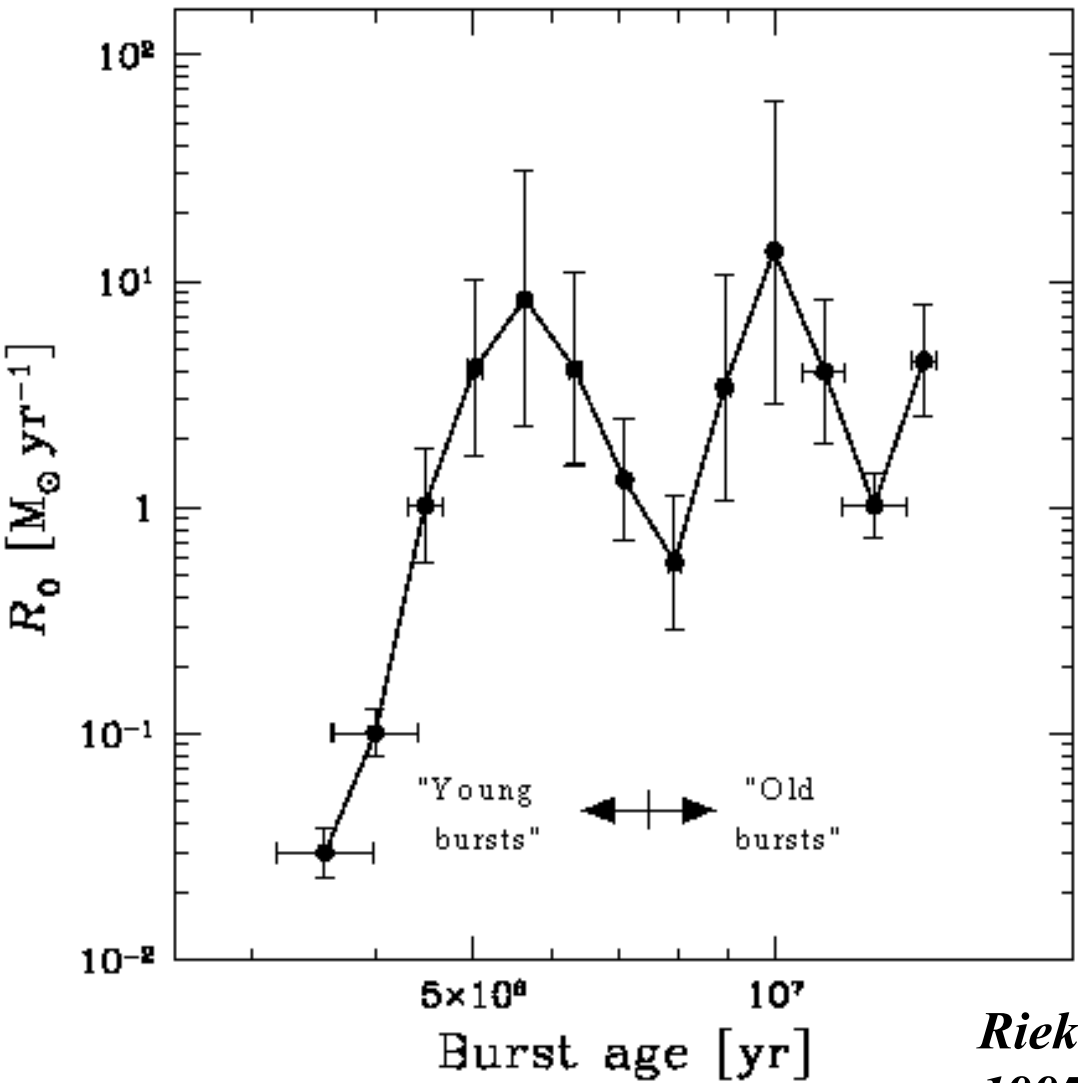
The need for high resolution

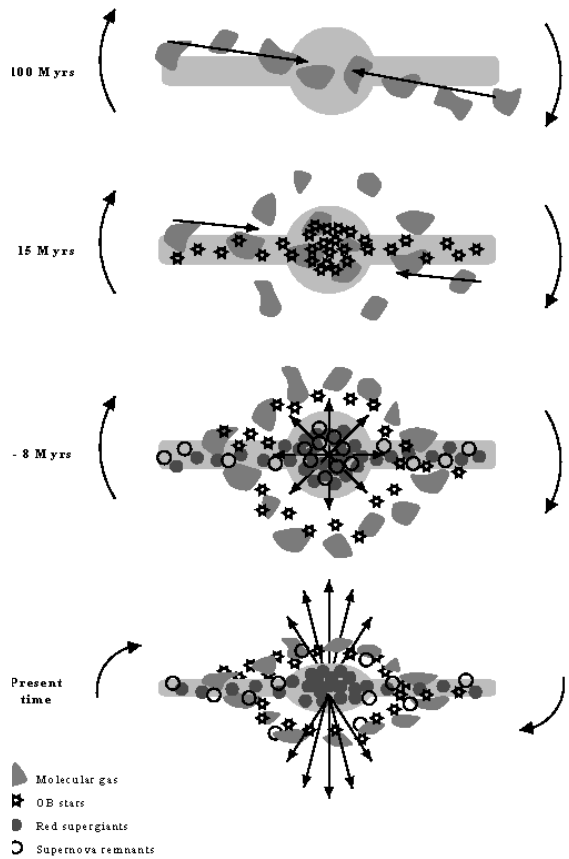


Ivison al. 2001

Detailed studies of nearby star-forming galaxies

M82 Star Formation history





Rieke et al. 1993, Satyapal et al. 1997, Boeker et al. 98, Foerster-Schreiber et al. 98, 01-02

Broad band imaging requirements

for broad band deep imaging:

large format (10^3-10^4 pixel) bolometer cameras with NEP<$10^{-17\ldots-18}$ W $Hz^{-1/2}$ for the wavelength range 30-500 μm, with Nyquist sampling of diffraction limited beam (1" λ_{100}/D_{10}): 128^2 pixels for 2^2 $arcmin^2$.

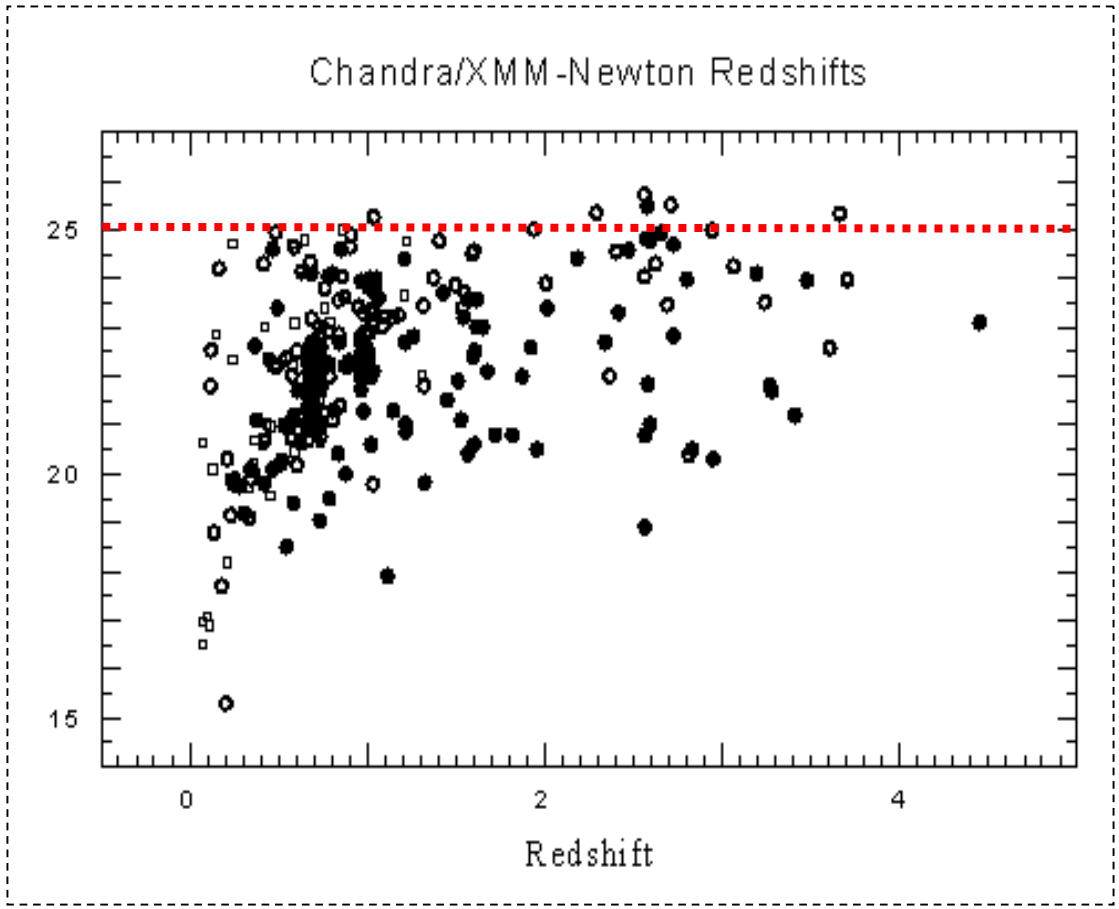
at 90% of FIRB (~ 1mJy) the source density (of O(10^{11} $L_\odot$ gals)) is ~25 sources/$arcmin^2$. For surveying 10^4 sources or more, need O(1 square degree) surveys.

It will be highly desirable to have some energy resolution for photometric redshifts (e.g. multi-band detectors working simultaneously)

for interferometry:

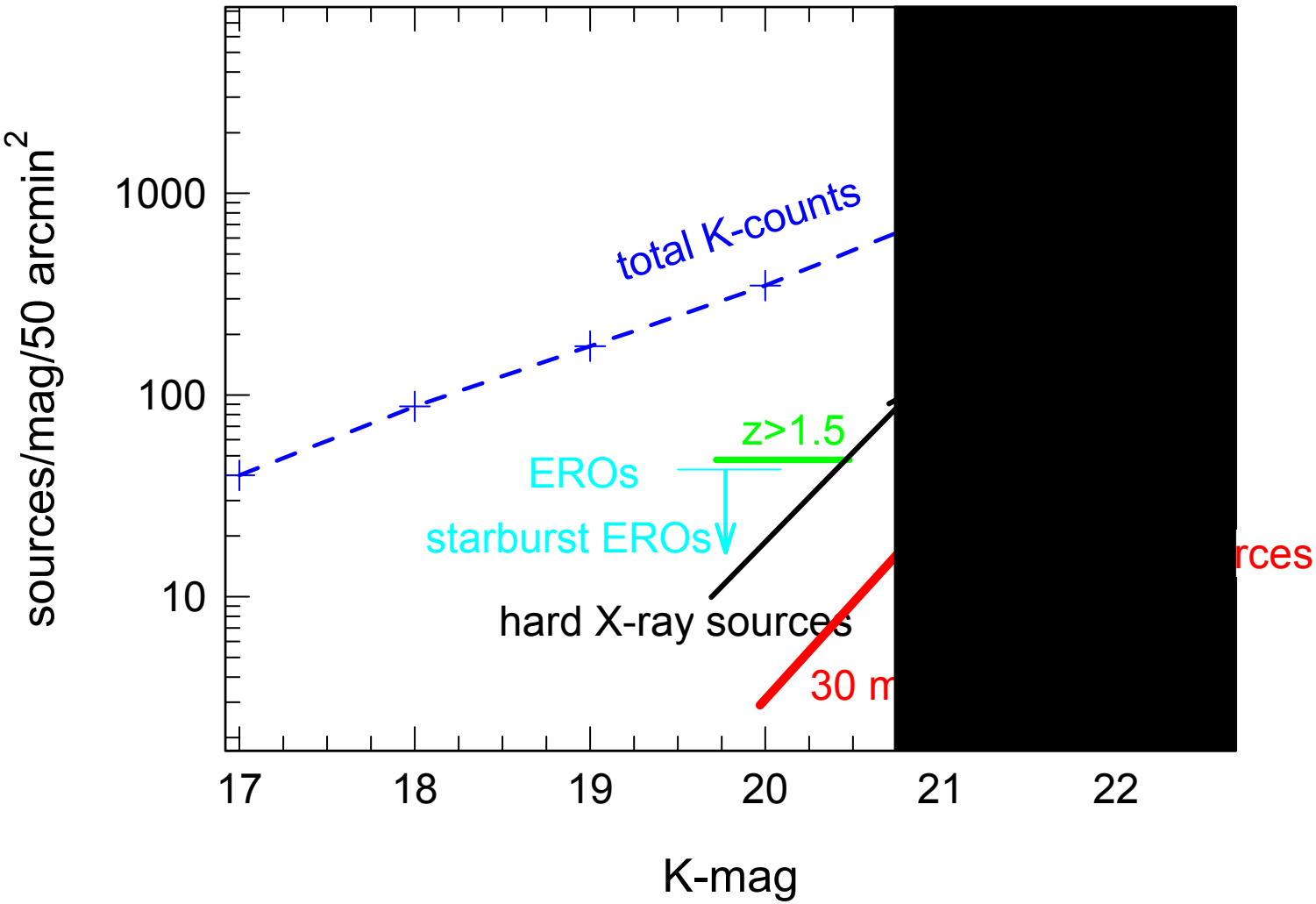
ultra-sensitive bolometer detectors (10^{-20} W $Hz^{-1/2}$, modest number initially)

Redshifts: limits to optical spectroscopy

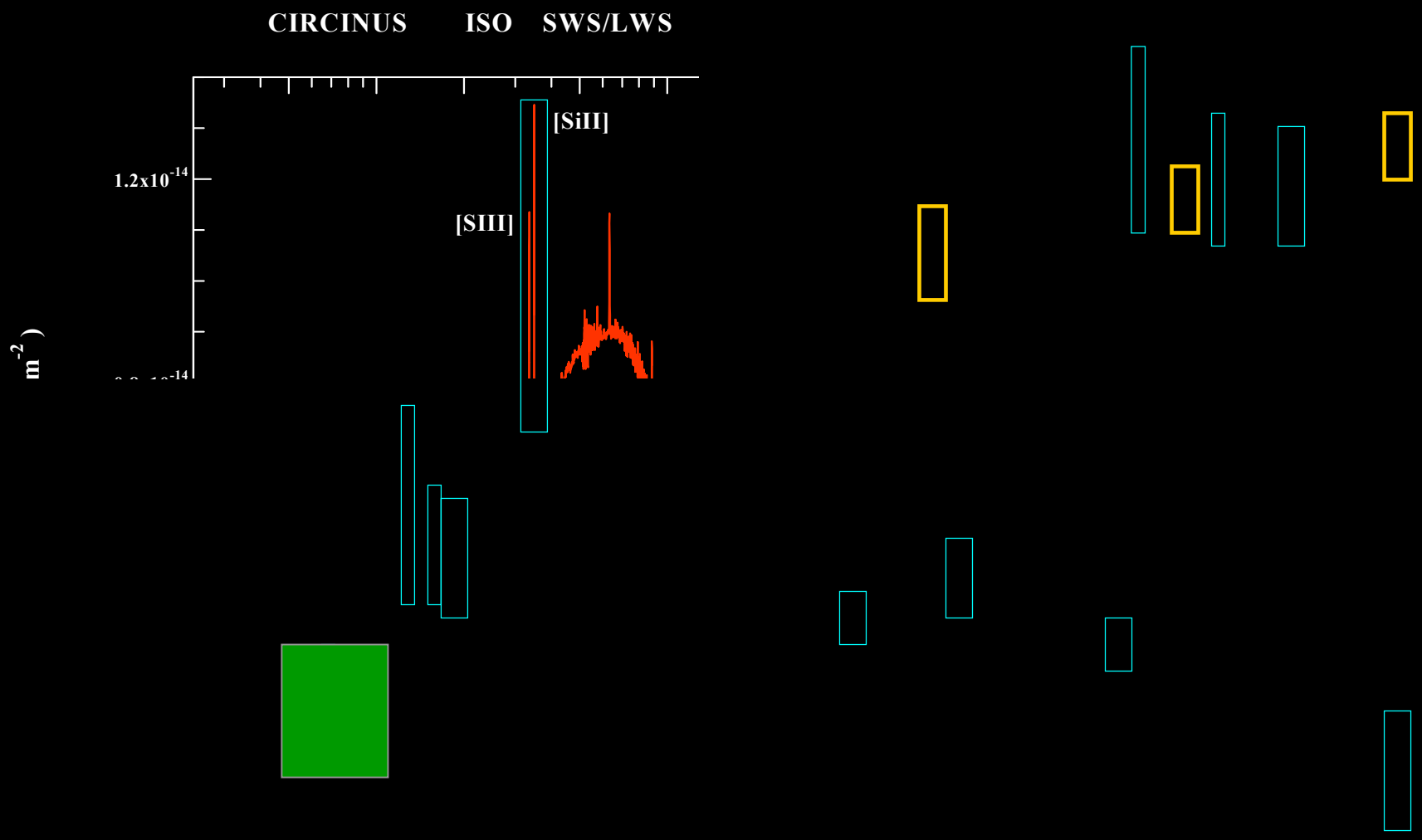


CDFS: Manieri et al. 2002

Limits of near-IR spectroscopy

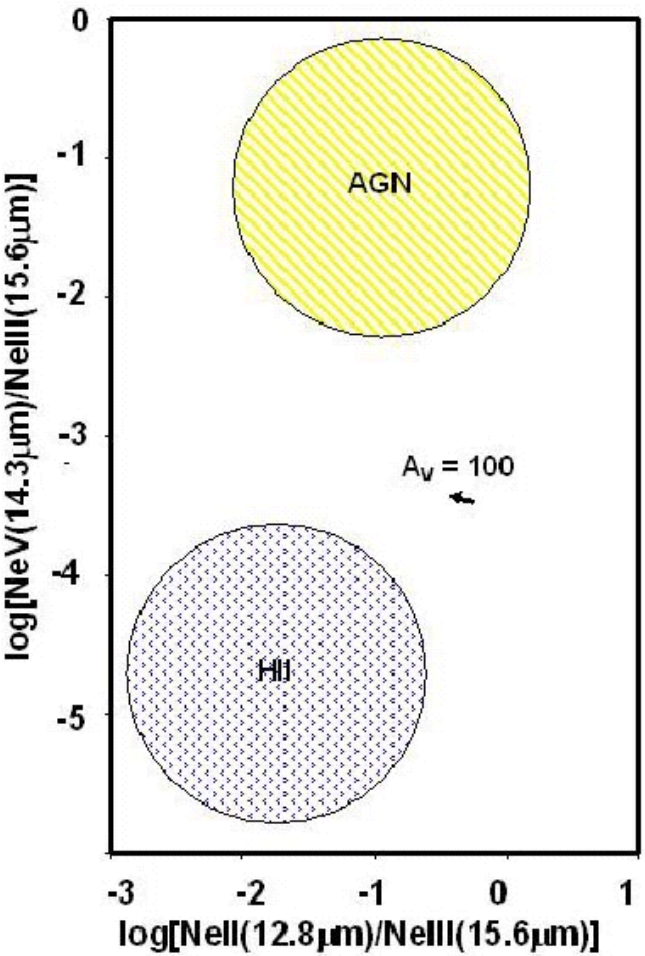


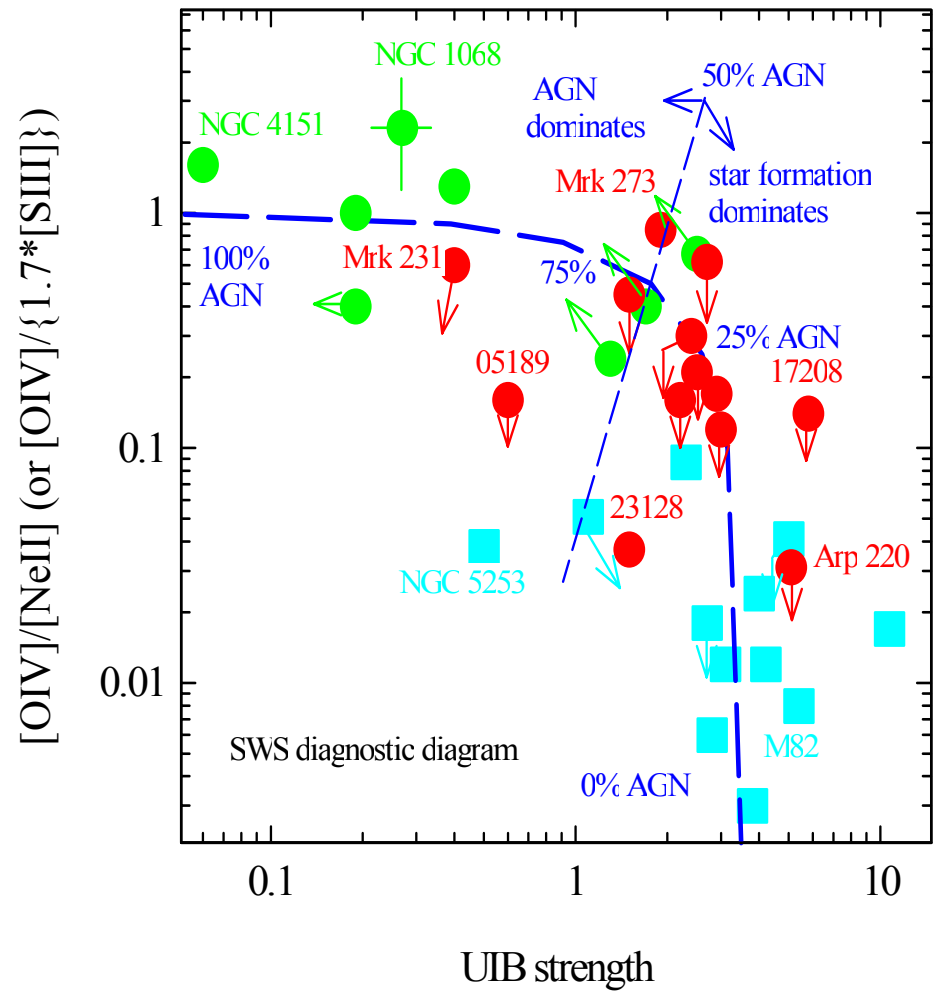
AGNs and starbursts in the mid- and far-IR



Moorwood, Sturm et al.1999

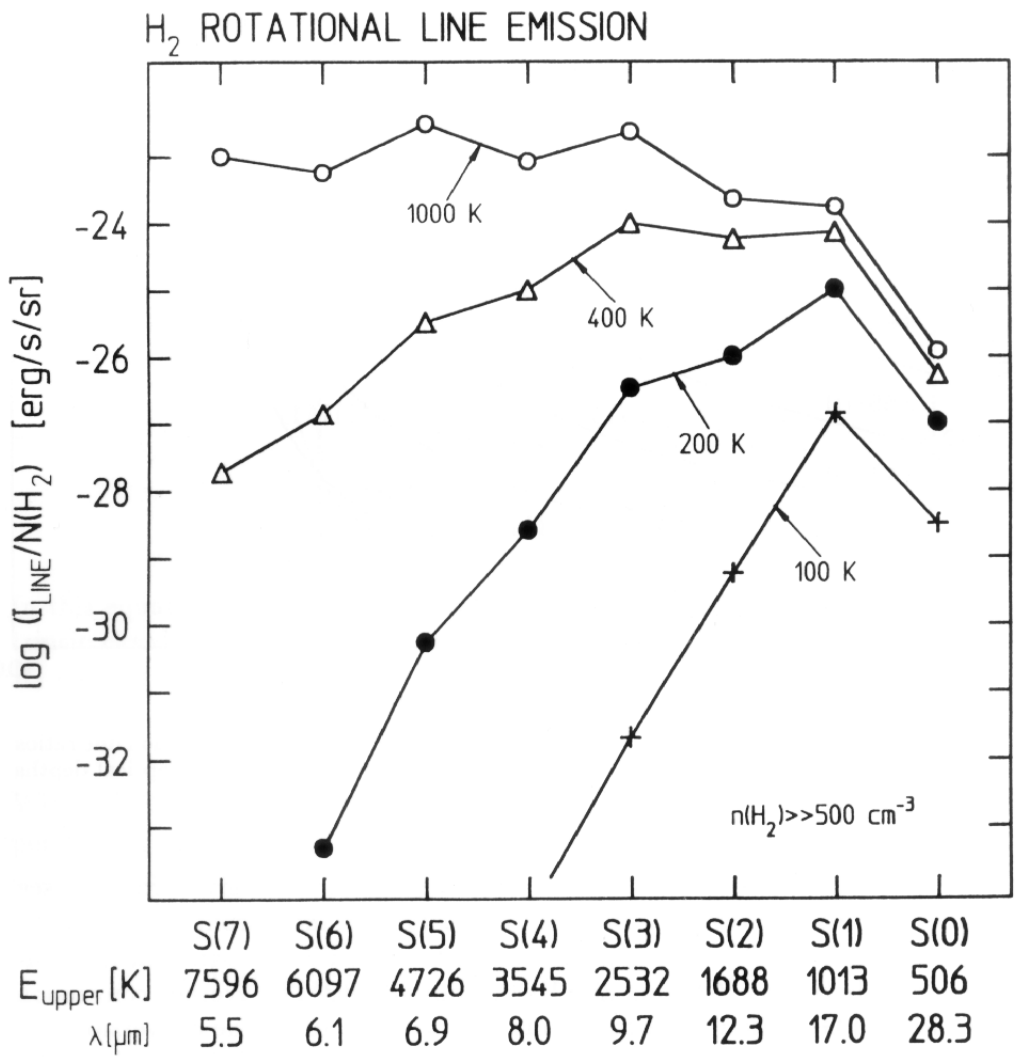
What powers obscured galaxies: mid-IR diagnostics





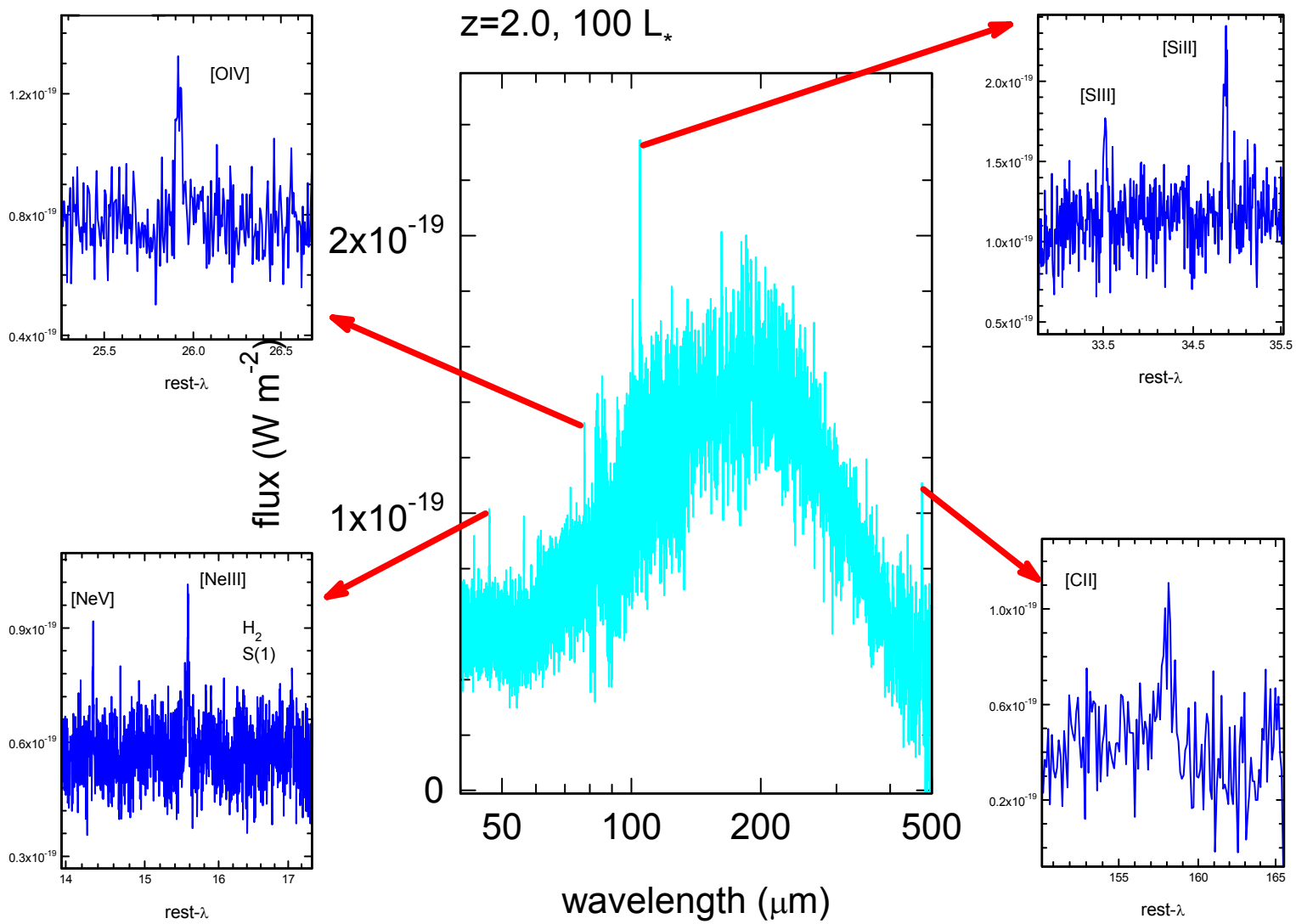
Genzel et al.1998, Lutz et al.1998, 99, Rigopoulou et al. 1999, Laurent et al. 01, Rieke SAFIR white paper

molecular hydrogen



FIR spectroscopy of distant galaxies

Simulation :10m, 40K, NEP=1e-18, R=2000 wide band spec., diffraction limited, 3 hr



Spectroscopic requirements

for 'in-band' diagnostic spectroscopy and red-shift searches

large format photoconductor arrays (128^2-256^2) in 30-350μm band, or alternatively, very sensitive bolometer arrays, for cross-dispersed, wide-band spectroscopy, at NEP<10^{-18} W $Hz^{-1/2}$.

for detailed physical and chemical studies of star formation and ISM in nearby galaxies

moderate size (10x10), fully spectrally multiplexed heterodyne mixer arrays for 1-3 THz region (hot electron bolo and SIS)

General detector issues

- *efficient fabrication of large format arrays*
- *low noise cryogenic readouts*

- *cooling requirements for ultra-sensitive bolometer arrays*
- *dynamic range of bolometers*

- *non-ideal time behavior in photoconductors*
- *quantum efficiency in monolithic photoconductor arrays*
- *extension of wavelength response beyond 120(200)μm*

- *manufacture and LO requirements of heterodyne detector arrays*