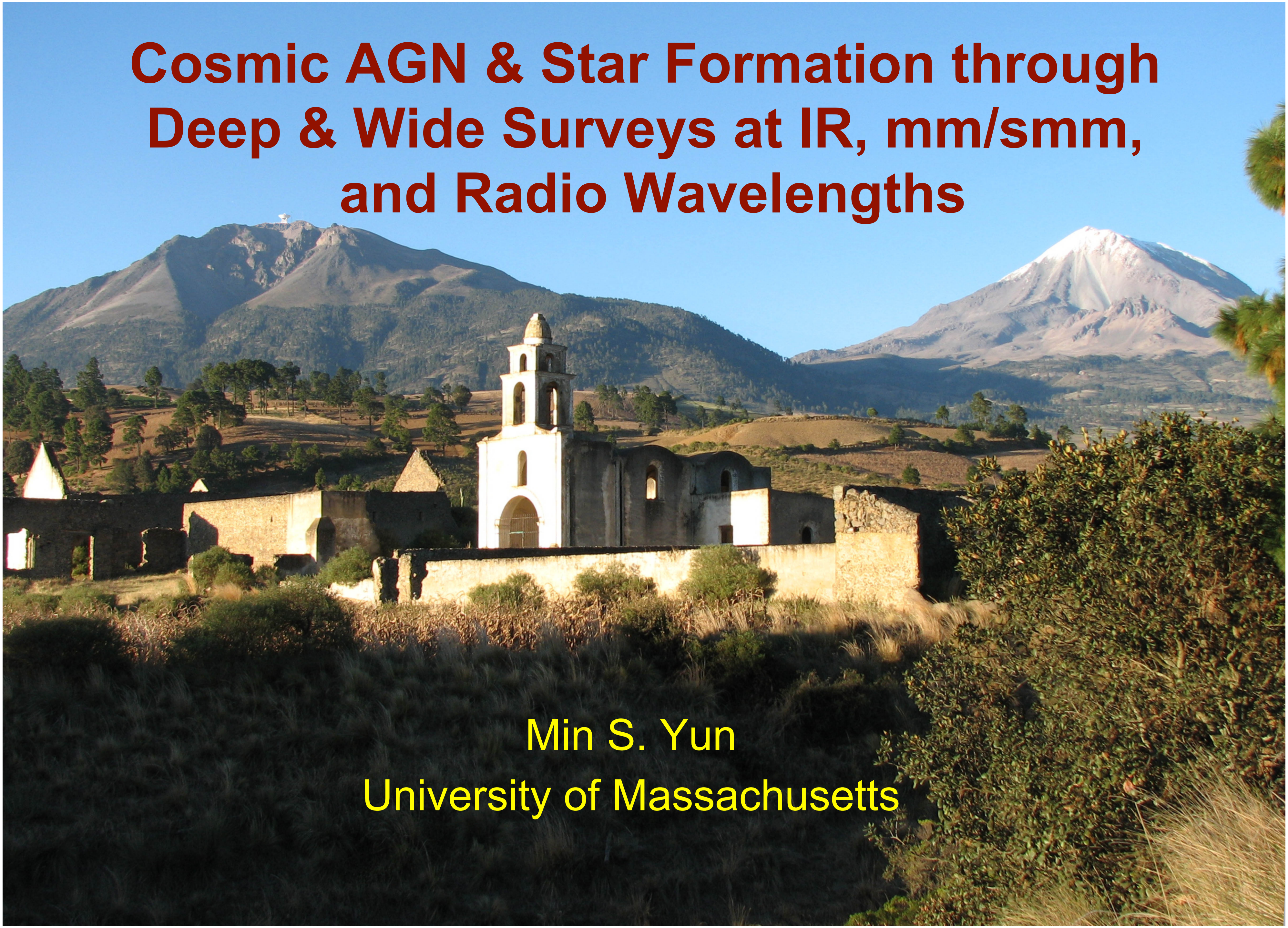
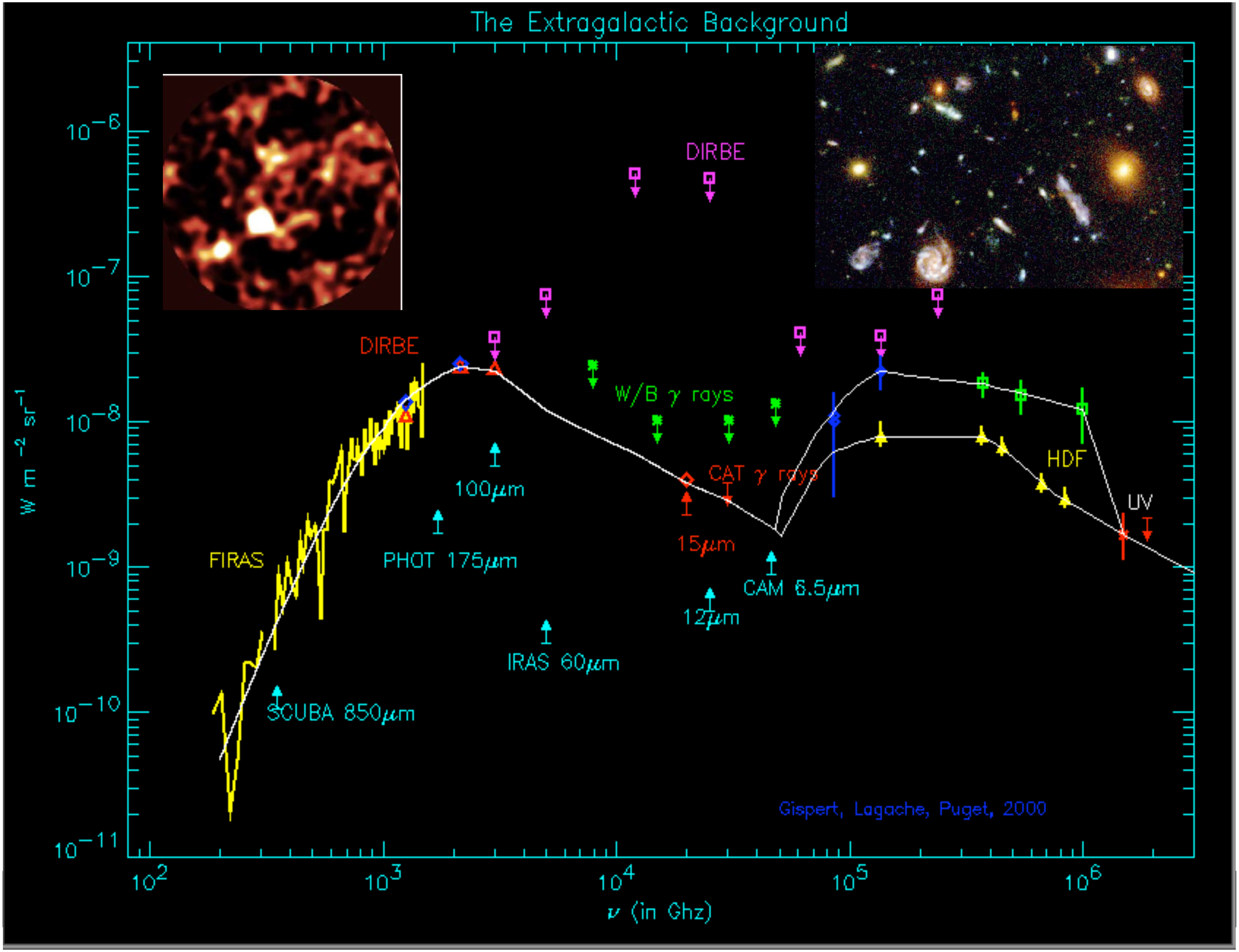


Cosmic AGN & Star Formation through Deep & Wide Surveys at IR, mm/smm, and Radio Wavelengths

Min S. Yun
University of Massachusetts

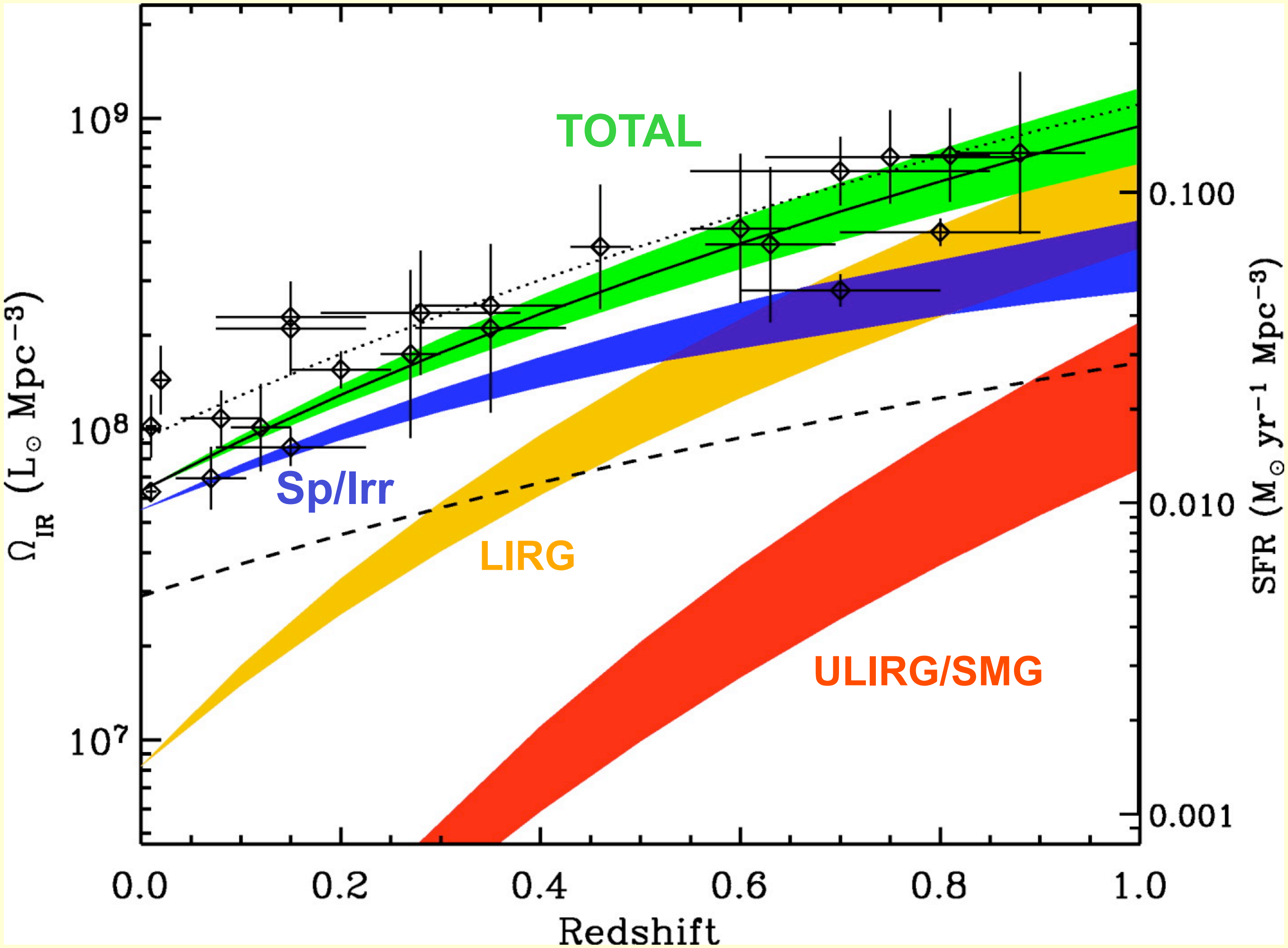
OUTLINE

1. Motivations
2. Finding high-z dusty starbursts/AGNs
3. Measuring redshifts and mass assembly history
4. Role of the EVLA



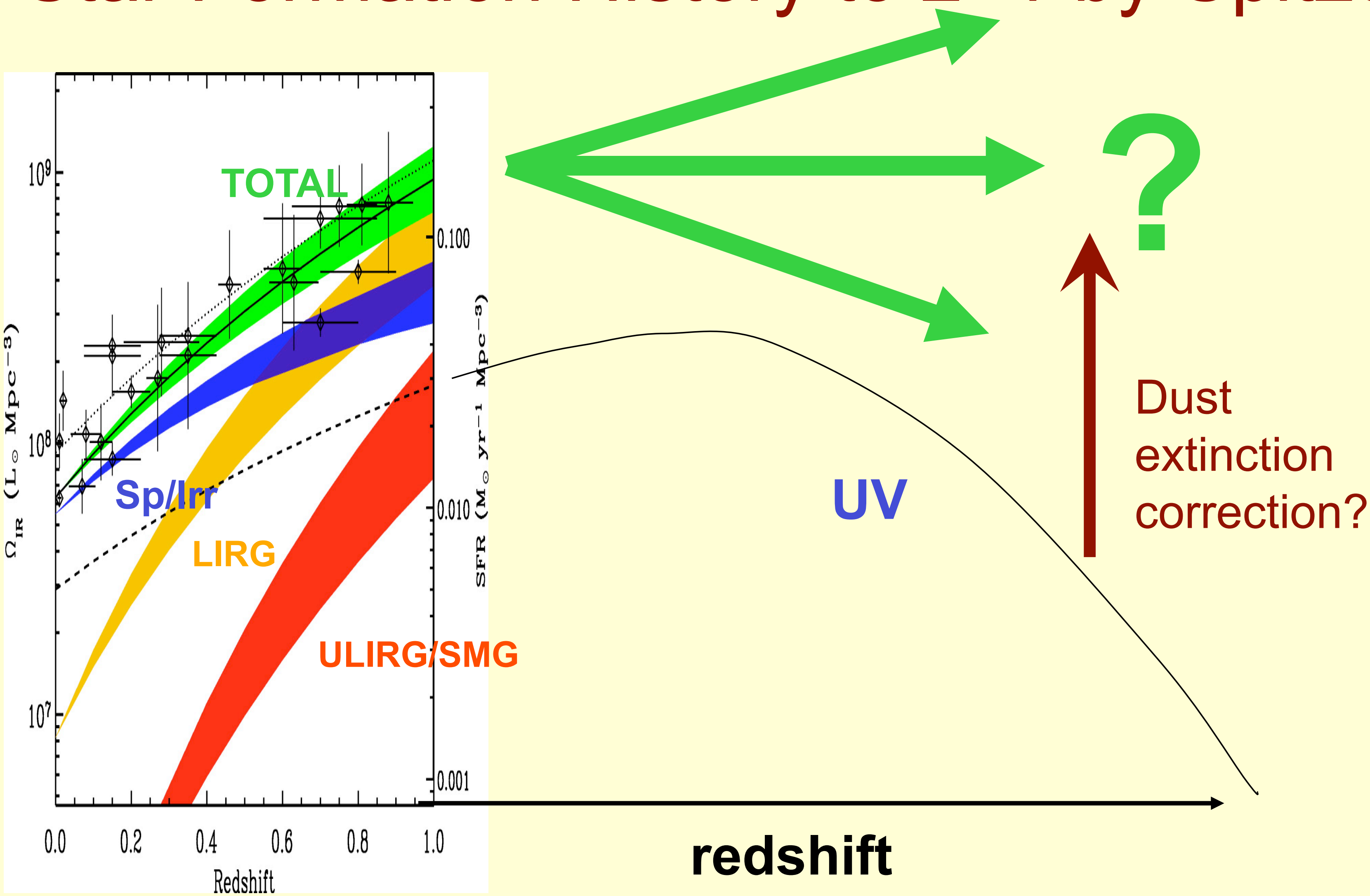
The Extragalactic Background
DIRBE
DIRBE
W/B γ rays
CAT γ rays
HDF
UV
100μm
PHOT 175μm
FIRAS
15μm
CAM 6.5μm
12μm
IRAS 60μm
SCUBA 850μm
Gispert, Lagache, Puget, 2000
W m⁻² sr⁻¹
ν (in Ghz)

Star Formation History to z=1 by Spitzer

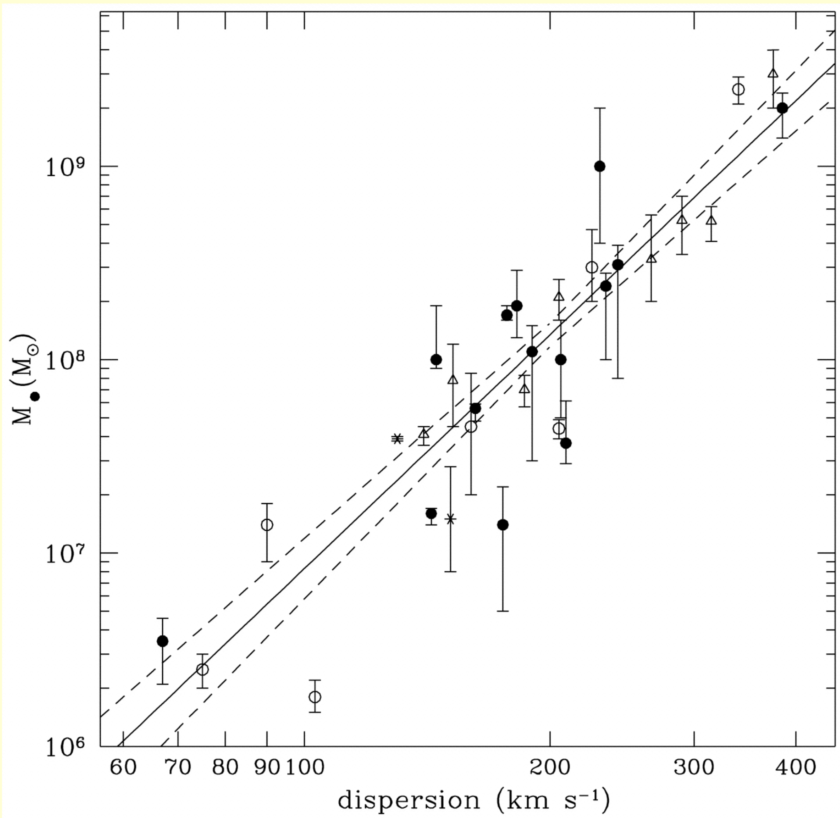


Le Floc'h et al. (2005)

Star Formation History to z=1 by Spitzer



M_{BH} and Host Mass Relation



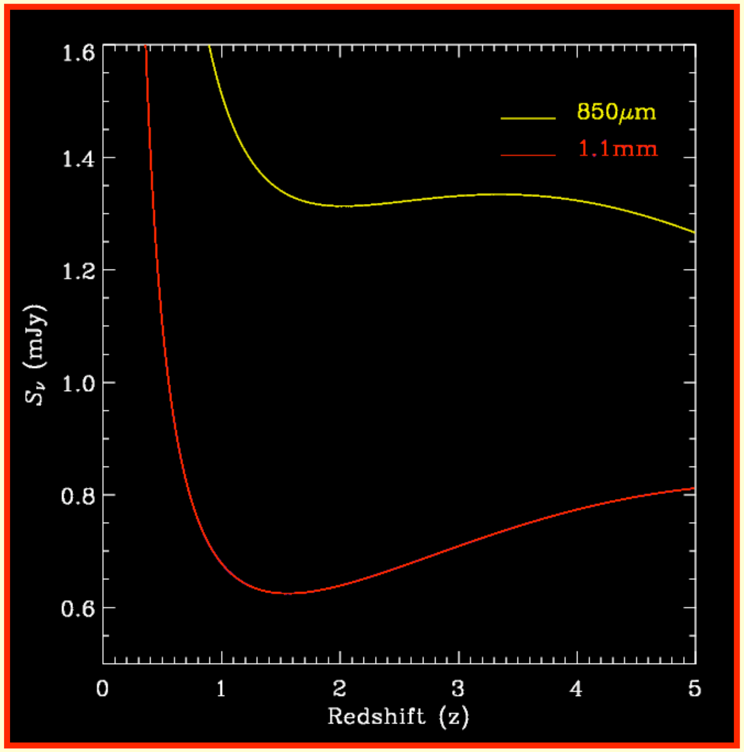
- Apparent correlation between M_{BH} and σ_*
- Growth of SMBH and mass build-up of the host linked

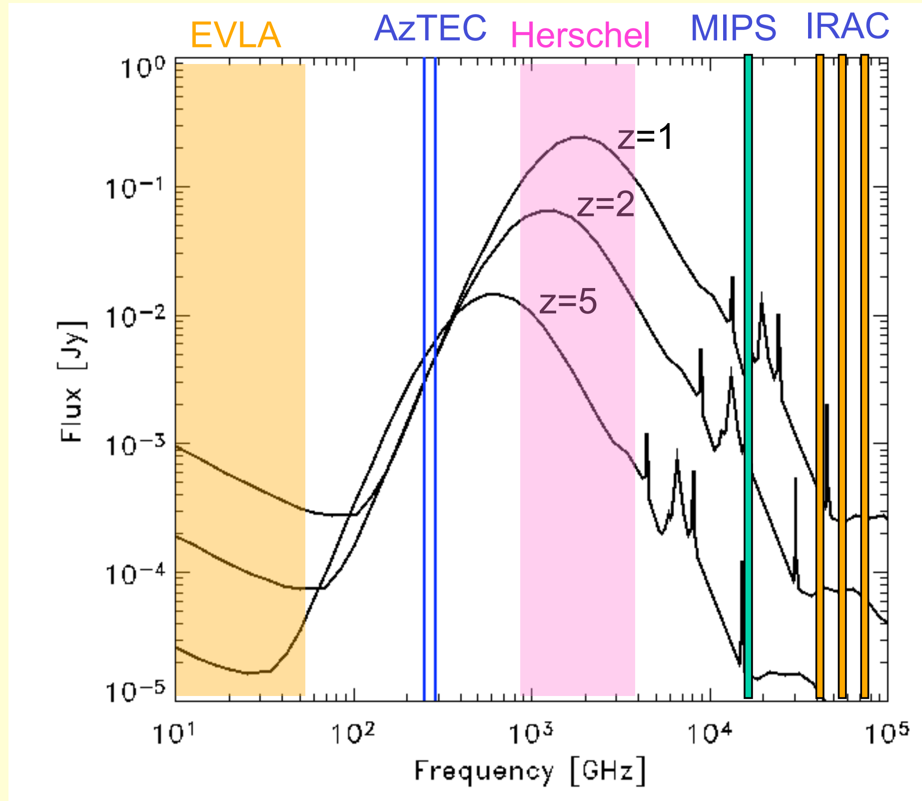
Clues to the BH growth in the galaxy assembly history?

Gebhardt et al. 2001; Ferrarese & Merritt 2001, Tremaine et al. 2002

Finding High-z Starbursts

Dust-obscured star formation via IR/mm/submm wavelength surveys



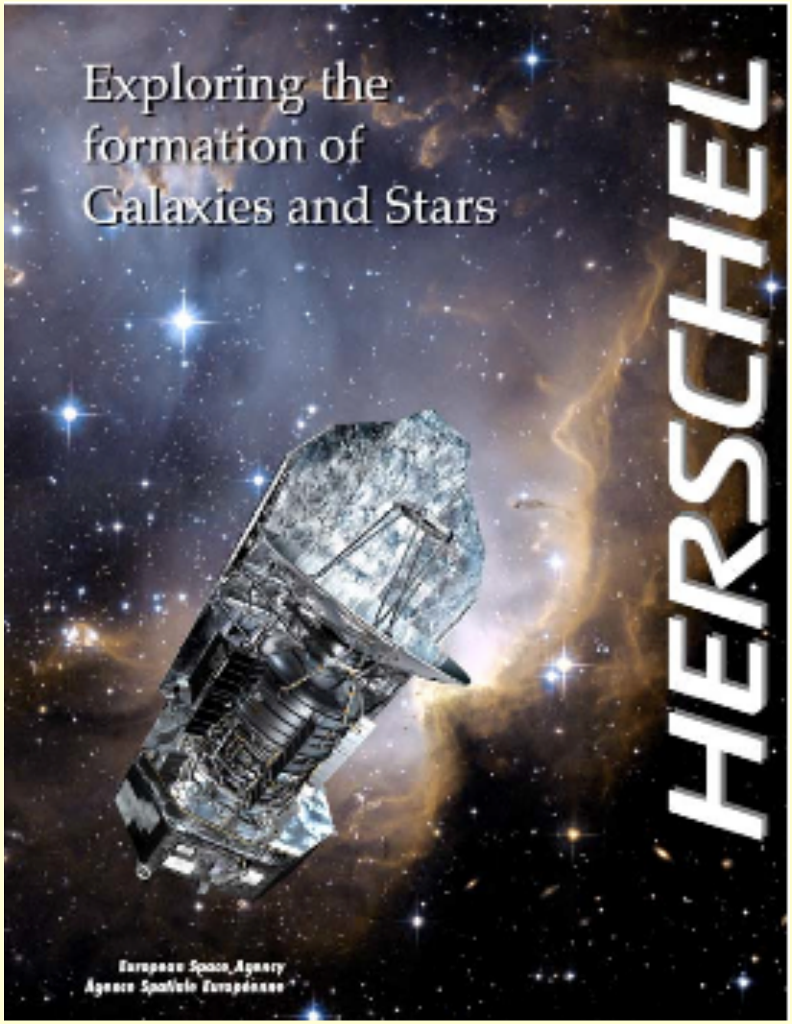


(model SMG spectrum by
Efstathiou, Rowan-Robinson and Siebenmorgen, 2000)

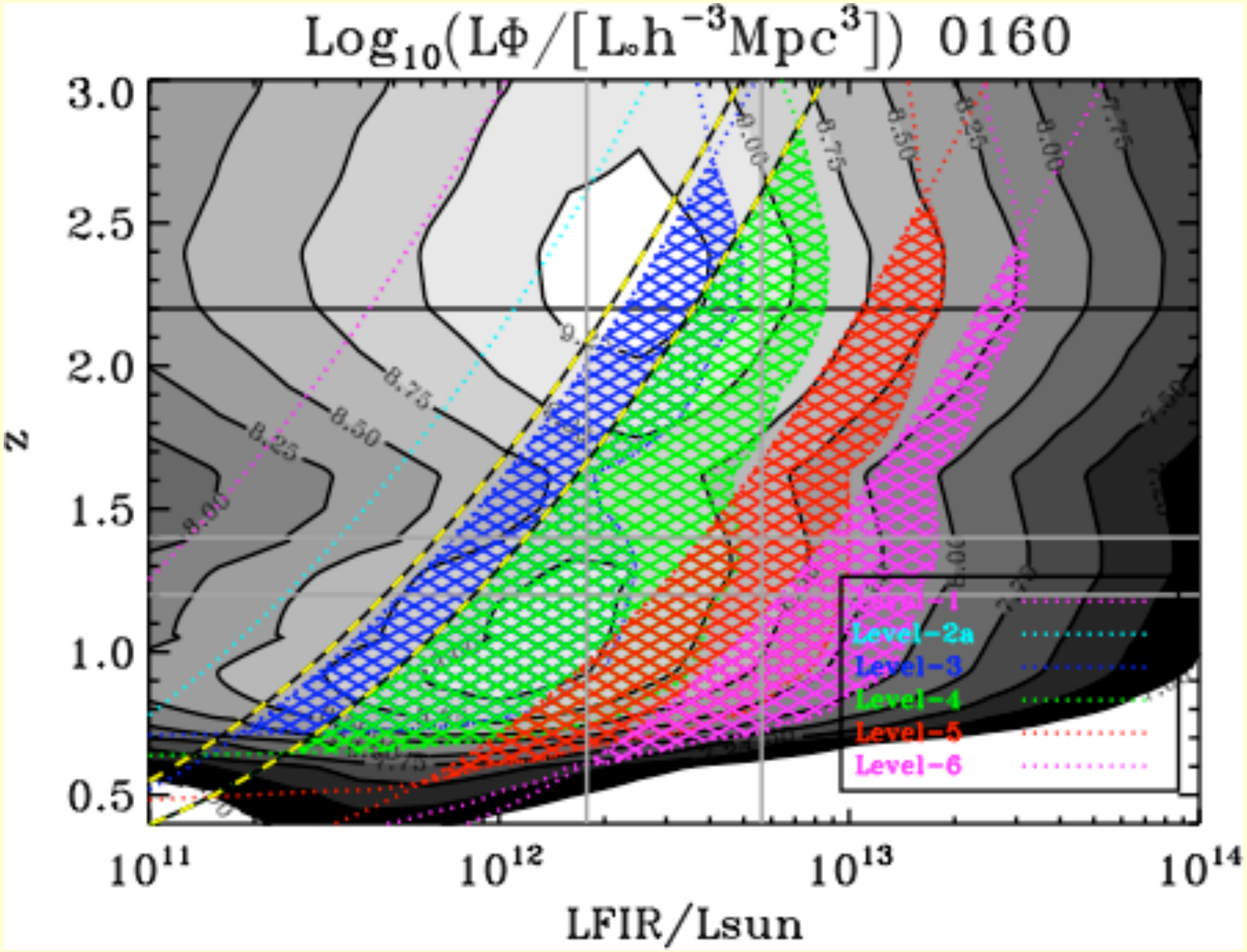
mm/submm wavelength observations provide a (roughly) redshift independent tracer of star formation in dusty galaxies with z>1.

Herschel Space Observatory

- Instruments
  - PACS (70/110/160 μm)
  - SPIRE (250/350/500 μm)
  - HIFI (150-625 μm)
- Key Cosmology Programs:
  - Herschel Multi-tiered Extra-galactic Survey (HerMES)
  - PACS Evolutionary Probe (PEP)
  - Herschel 1000 Degree Survey
  - GOODS-Herschel
  - Broad area and depth coverage through multiple nested/tiered projects
- Launch planned in 2009

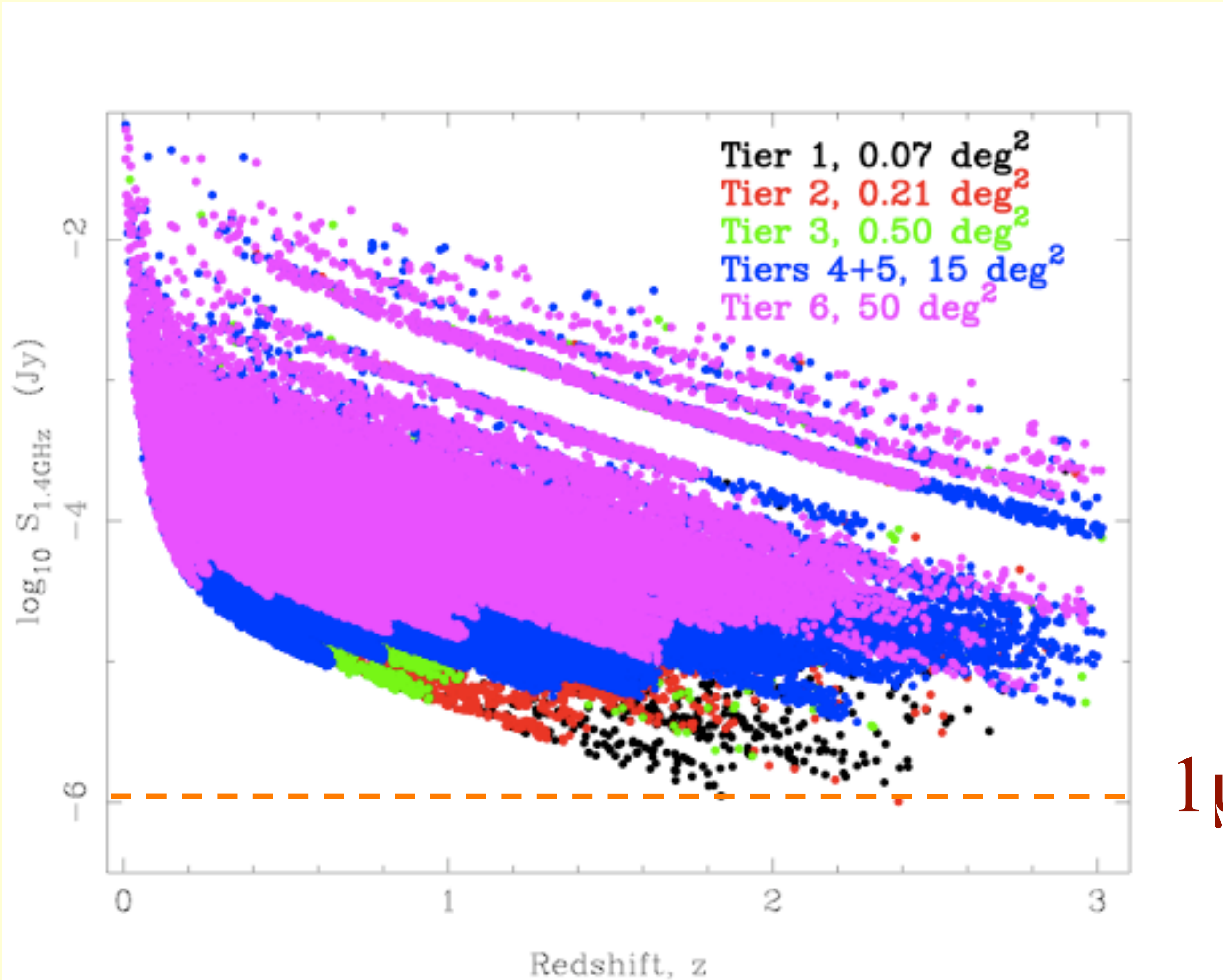


HerMES/PEP/GOODS-H



HerMES GT team

HerMES/PEP/GOODS-H

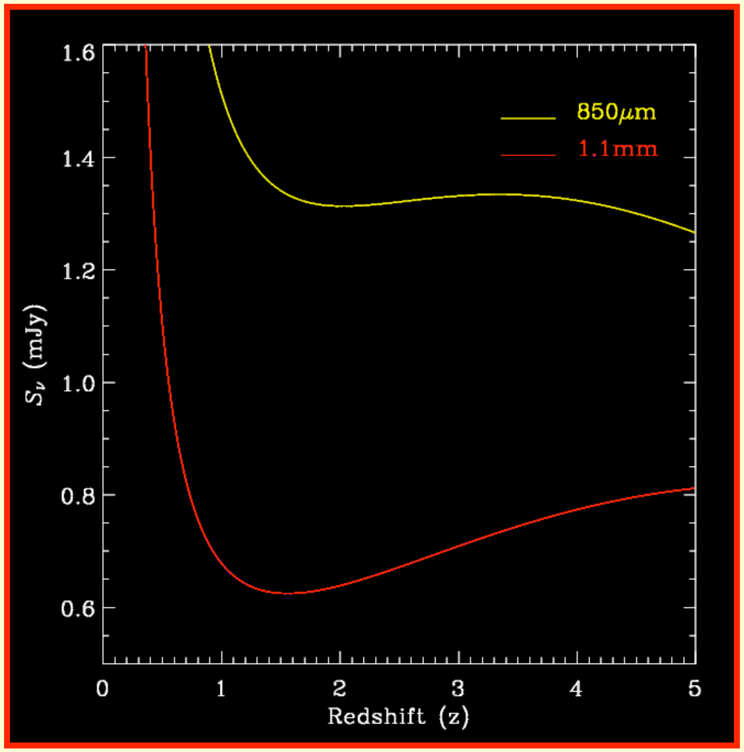


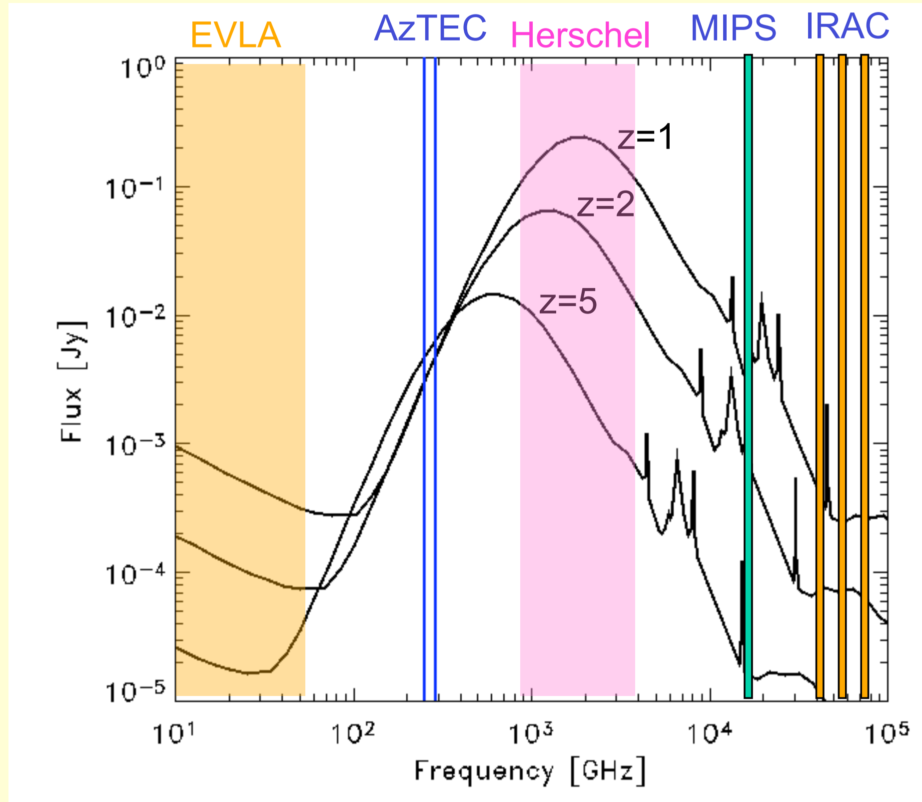
1μJy

R. Ivison and HerMES GT team

UMassAmherst

Dust-obscured star formation via IR/mm/submm wavelength surveys





(model SMG spectrum by
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mm/submm wavelength observations provide a (roughly) redshift independent tracer of star formation in dusty galaxies with z>1.

mm-galaxy Surveys circa 2007

	AzTEC JCMT 2005	AzTEC ASTE 2007	SCUBA JCMT 1997-2005	MAMBO IRAM 30-m 1998-2007	BOLOCAM CSO 2005-2007
Area (arcmin^2)	**4000**	**3969**	**1200**	**1500**	**1200**
1$\sigma_{1.1mm}$ r.m.s. (mJy)	**0.9-1.5**	**0.5-1.0**	**0.5-1.2**	**0.7-1.5**	**1.4-1.9**
N	**389**	**595**	**~300**	**~60**	**~23**
N ($S_{1.1mm}$ > 5 mJy)	**90**	**34**	**~10**	**~20**	**21**
Total Area (arcmin^2)		**7969**			**3900**
Total N		**984**			**~383**

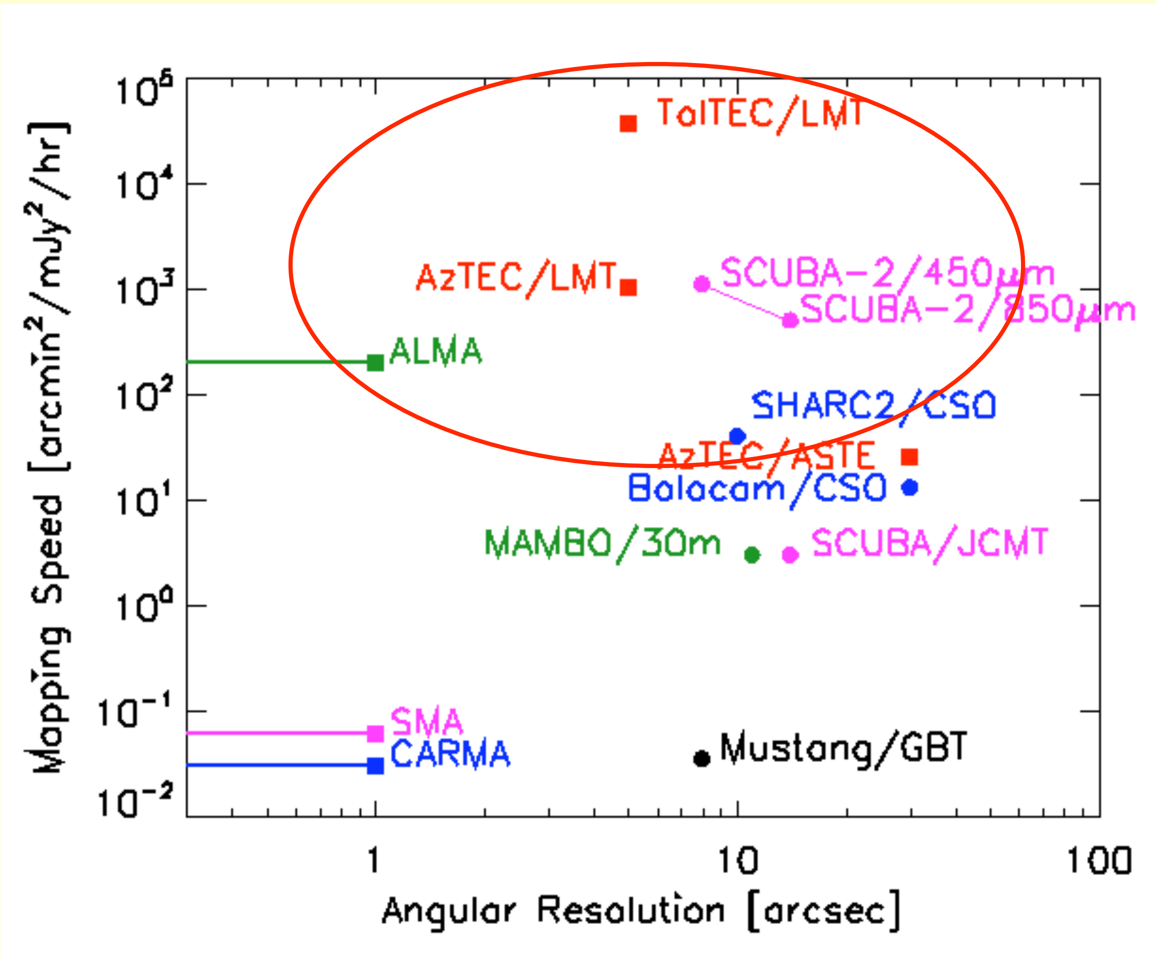
- What do we know about these sources?
  - radio selected sample peaks at z~2.3 (Chapman et al. 2005)
  - incredibly massive
    - $M_{halo} > 10^{12} M_\odot$ (Blain et al. 2004)
    - $M_{stars} > 10^{11} M_\odot$ (Chapman et al. 2008, Lonsdale et al. 2008)
  - SFR > several 100s $M_\odot$ /yr
  - Luminous: $L_{bol} \sim 10^{12}$-$10^{14}\ L_\odot$

Large Millimeter Telescope (LMT)

- 50m mm-wave Antenna
  - Operation: 4mm-0.85mm
  - Active Primary Surface
    75 microns rms.
  - 1/3 of ALMA collecting area
- Located in Mexico
  - Excellent mm-wave site
  - High Altitude (15,000 ft)
  - +19 deg. Latitude
- State-of-the-art instrumentation:

  array cameras

Mapping Speeds of Next Generation mm/smm Instruments



- AzTEC:
  1000 arcmin^2/mJy^2/hr
- TolTEC:
  10 deg^2/mJy^2/hr
- Resolution: 5” FWHM
- Confusion Limit:
  < 0.1 mJy
- Positional accuracy:
  < 1”

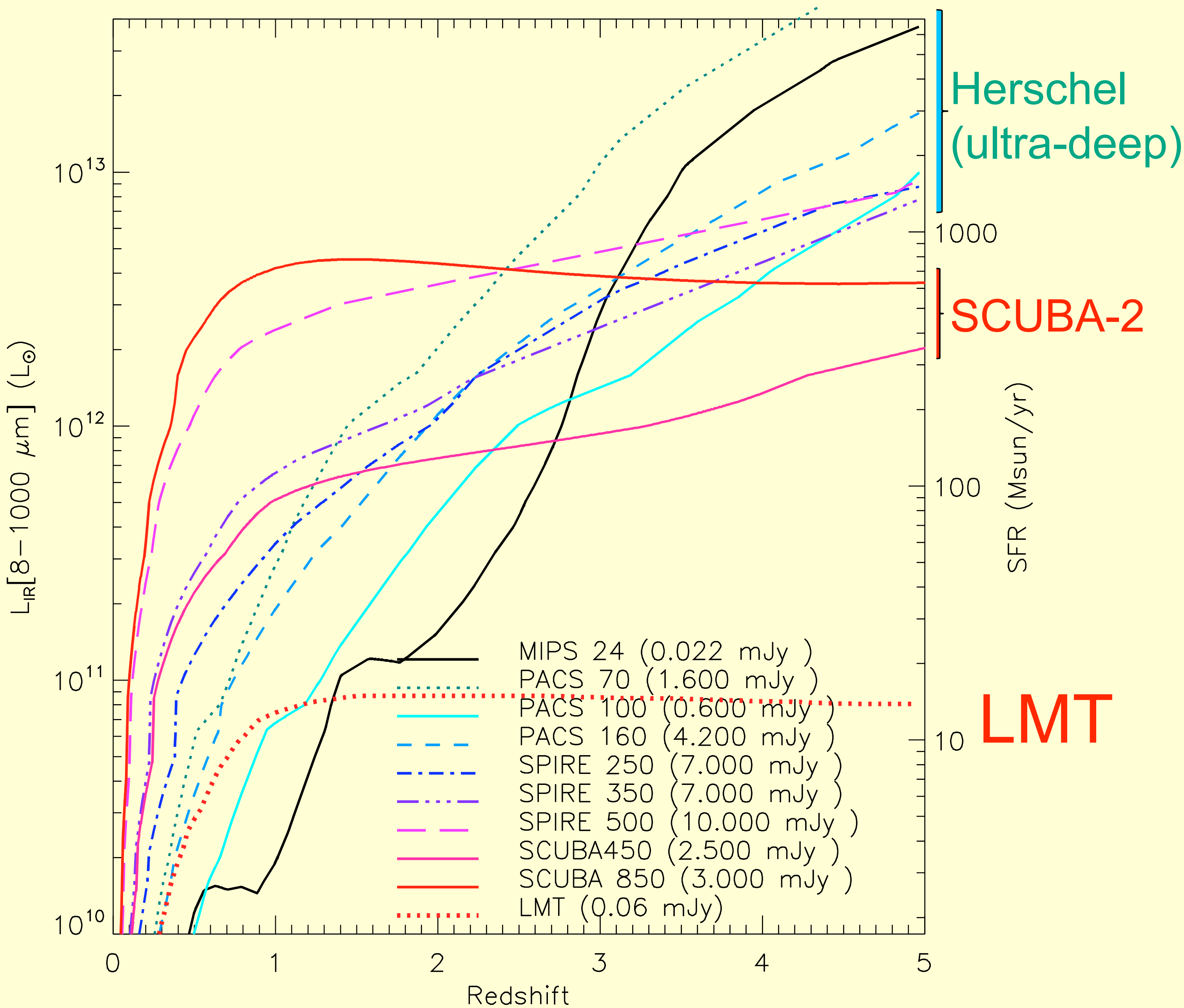
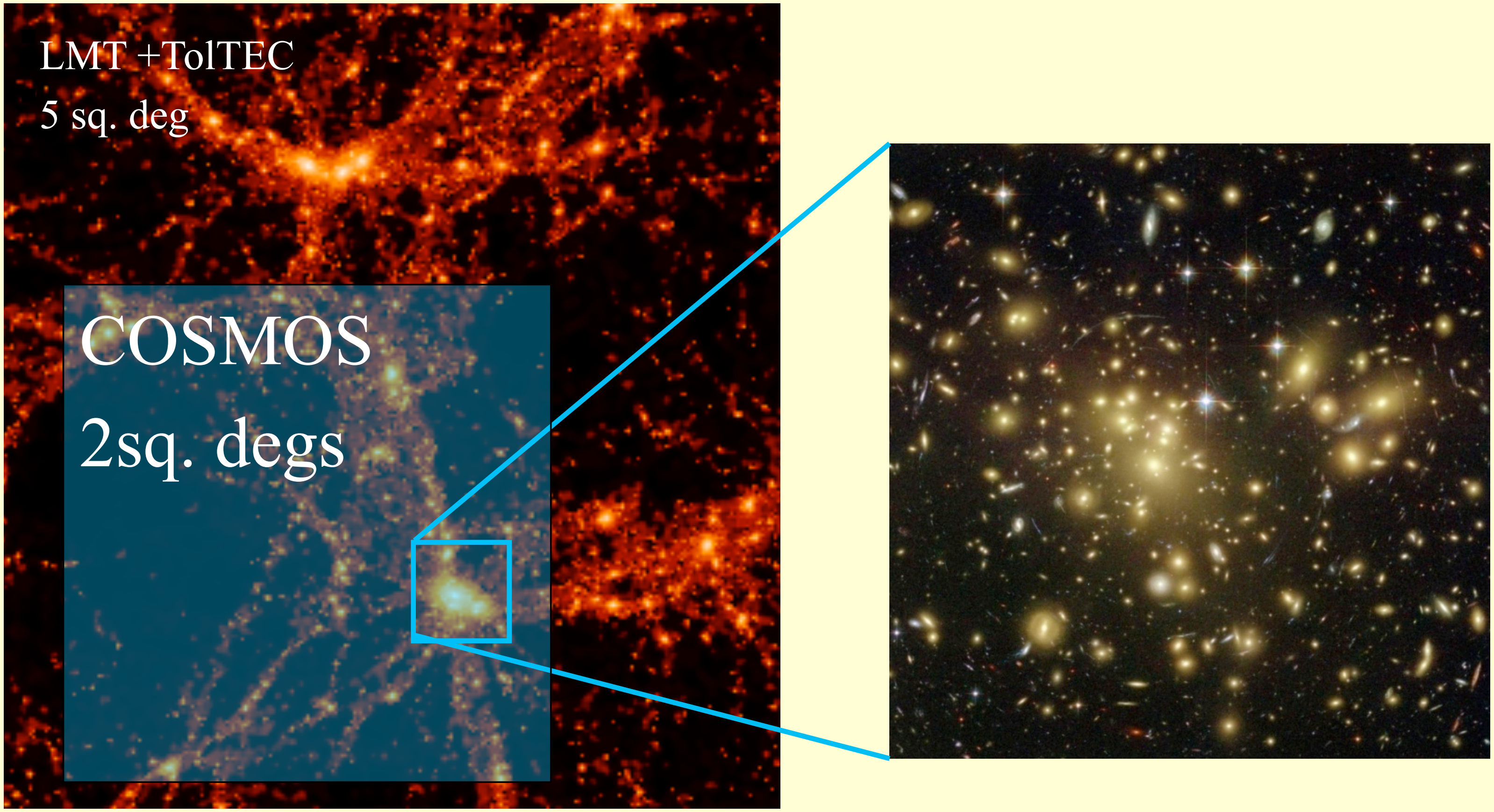


Figure courtesy D. Elbaz & M. Dickinson

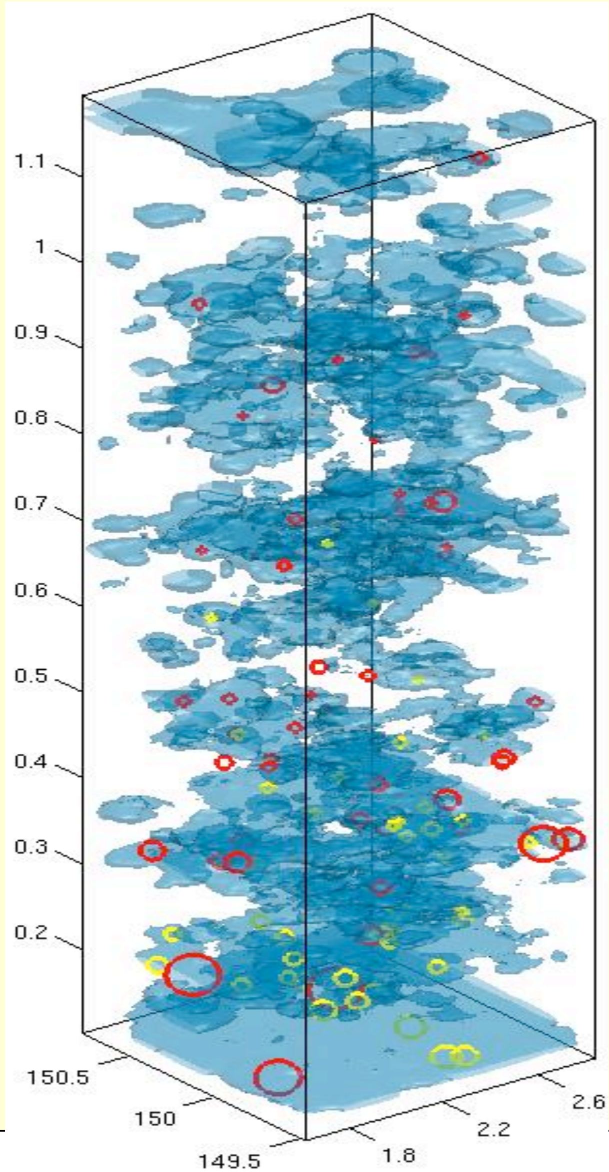
Near-term LMT Continuum Surveys



- **Key Project:** 5 sq. degs sample - wide variety of LSS environments
- **> 100, 000 galaxies in 100 hr survey** (>0.4mJy; **SFR >40 M ס /yr ;**
  or resolving 100% of the extragalactic mm-background or 60% of FIR background)

Measuring Redshifts and Mass Assembly History

LSS in the COSMOS Survey



Scoville et al. (2007)

- Mapped LSS to z~1 using 10^5 photo-z
- Spec-z are difficult to obtain – 10^4 spectra from VLT, Kecks, Subaru, Gemini, Magellans, etc. combined over 3-4 yrs, mostly at *z*<2

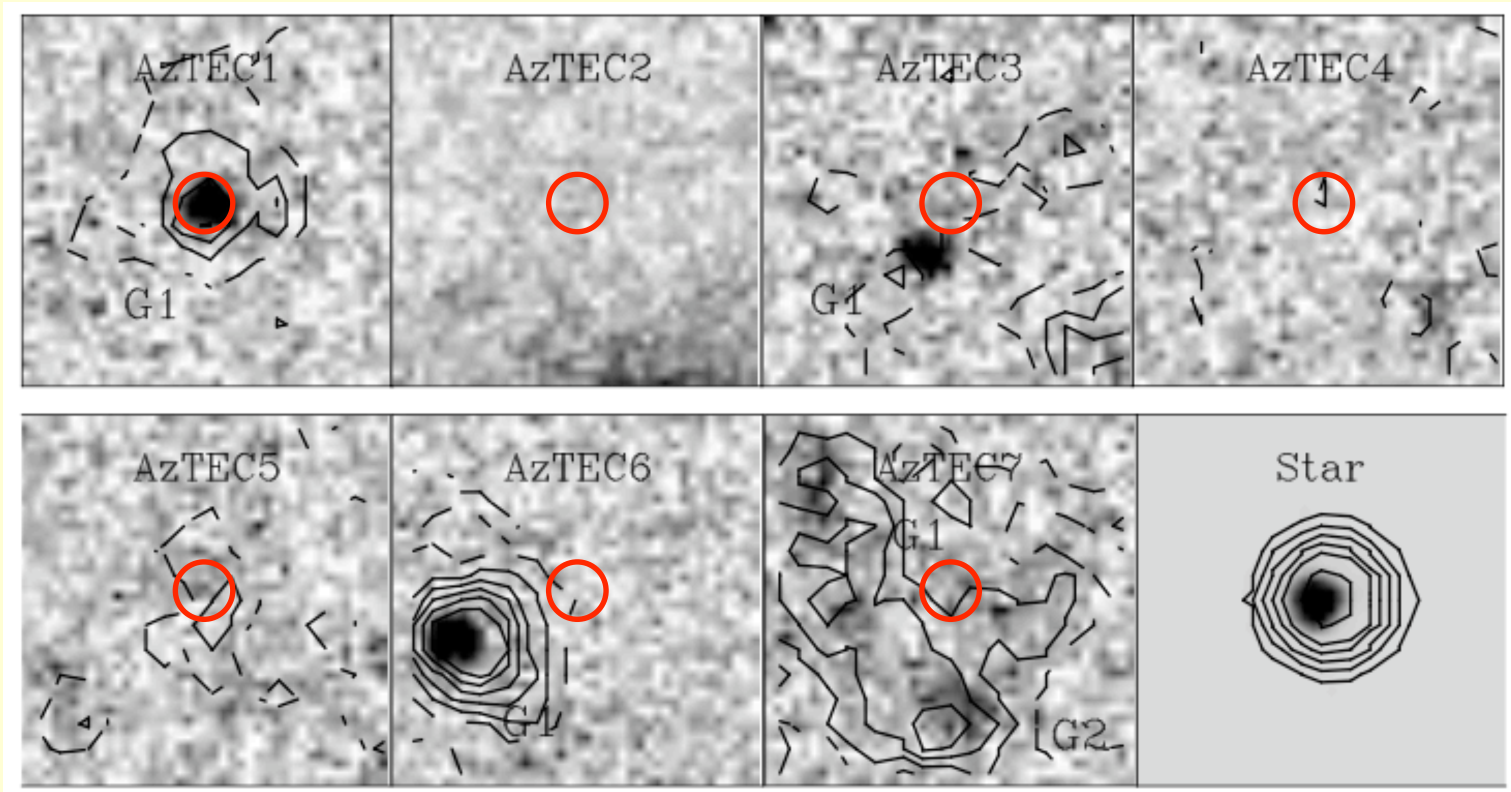
K.Kovac

zCOSMOS (PI:Lilly)

10k IAB<22.5

How do we push this to z=4-5 and beyond?

Young Massive SBs at high-z are Dark



SMA Greyscale: HST *i*-band, Contours: Subaru *r*-band

Many are exceedingly faint with *i > 25 and r > 27*

Younger et al. (2007)

LMT Ultra Wideband Redshift Search Receiver

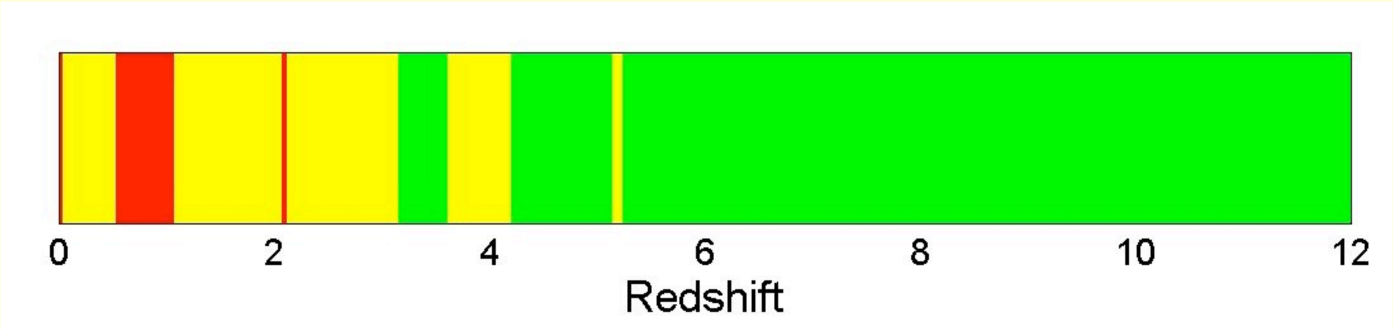
- A new generation of spectrometer is needed for this problem.
- Science goal is to measure galaxy redshifts where *z* is unknown.
- 74-110.5 GHz covered simultaneously with a receiver/spectrometer having 30 MHz resolution (R~3000).
- Wide bandwidth with very low noise is practical with InP MMIC amps operated at 20 K.
- Full receiver has 4 pixels - two dual polarization feeds with ortho-mode transitions.
- 1 KHz ferrite beam switch on input for very flat baselines.
- Each receiver has 2 IF outputs 1.5-20 GHz x 4 receivers

  → 146 GHz total IF bandwidth!

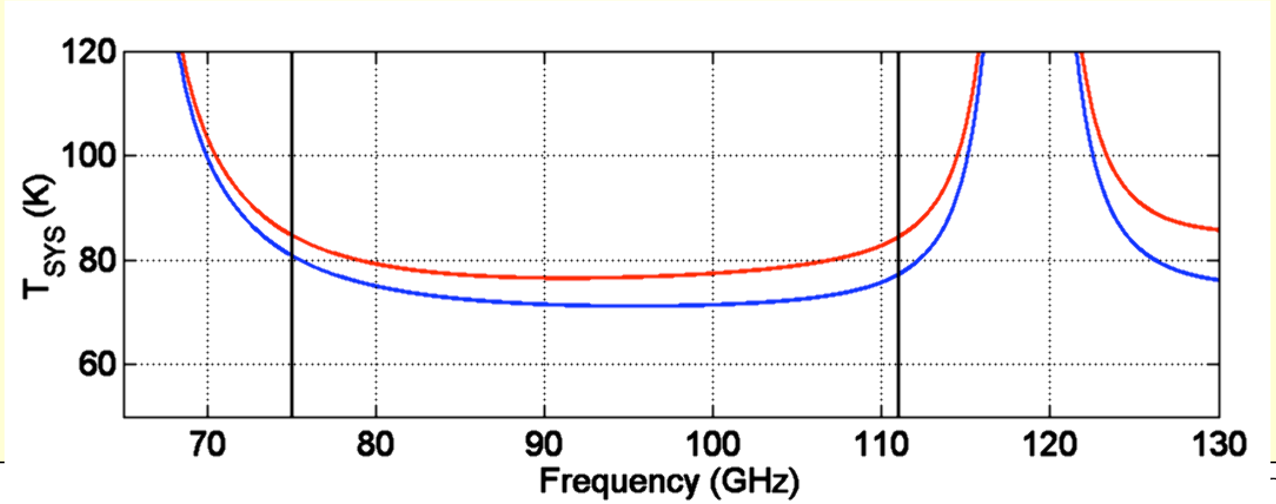
Frequency Range

• Strongest spectral lines from CO and C (492, 810 GHz). More than one line needed; search the maximum possible bandwidth.

• Lines are expected to be quite weak, search in best 3 mm window.

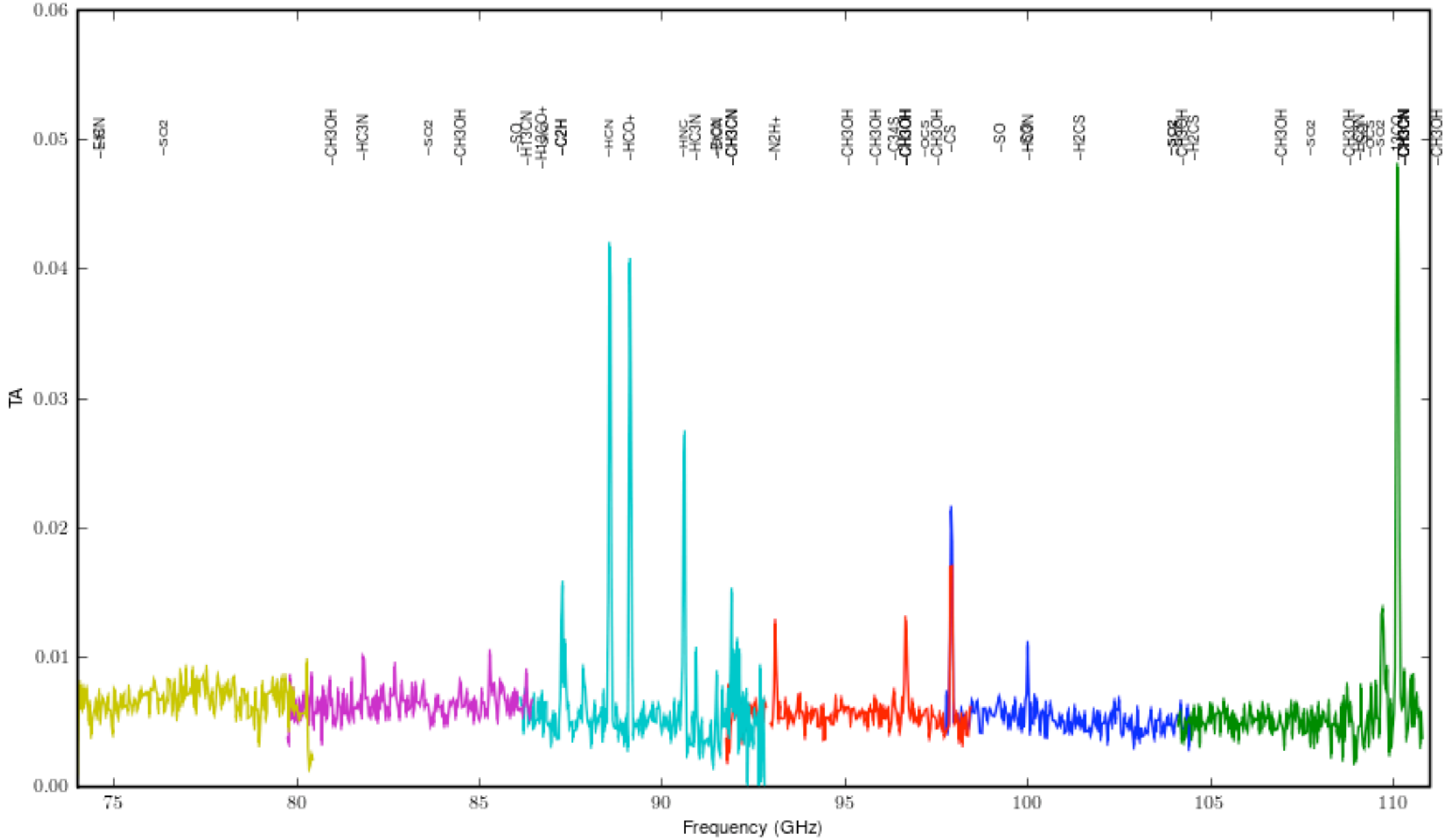


Redshift coverage in 74-110.5 GHz band, red no CO line, yellow; one line, green; two lines.

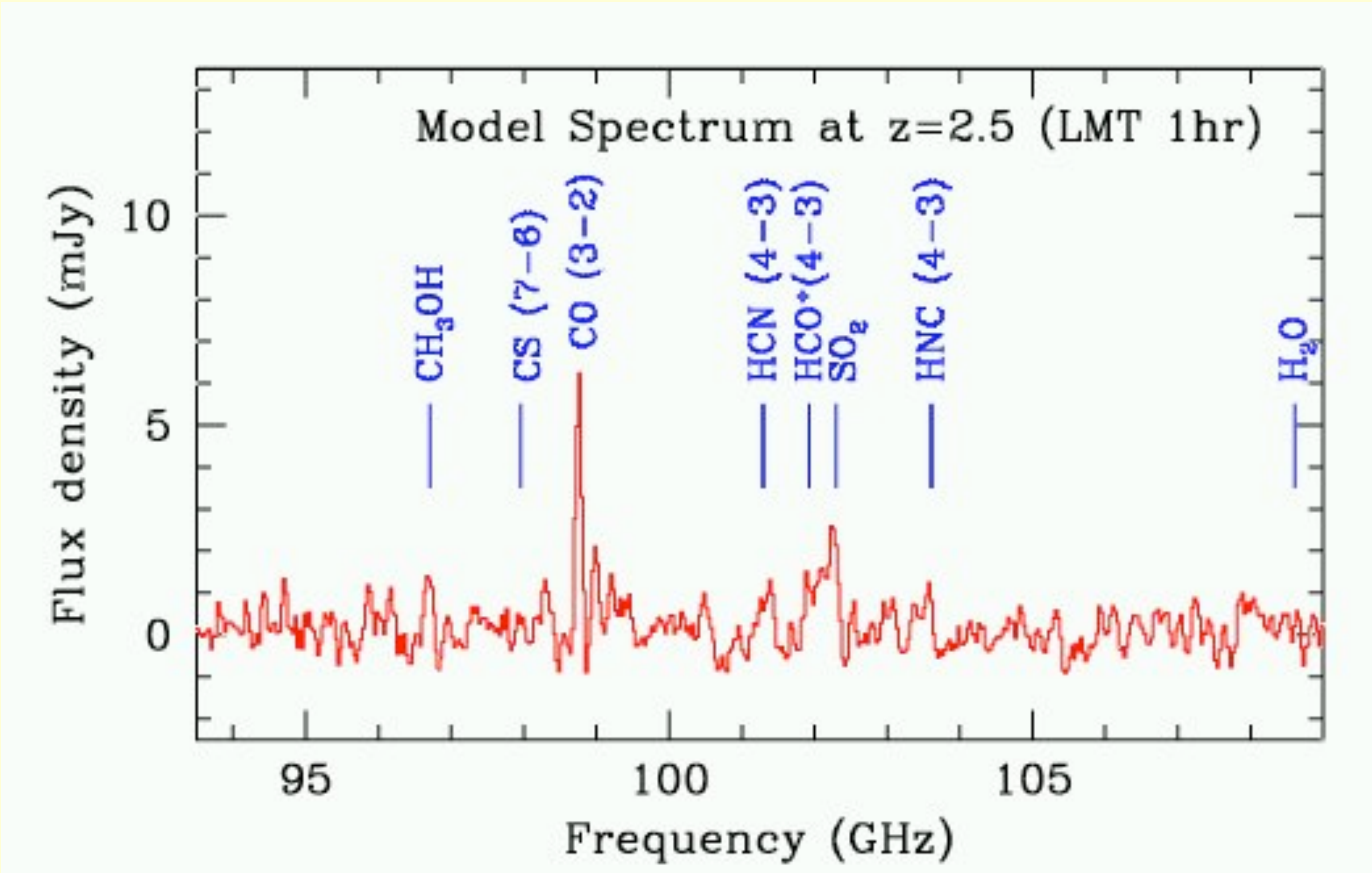


System noise temp with T_{rx} = 60 K and 2 and 5 mm PWV.

NGC 253 (Nucleus)

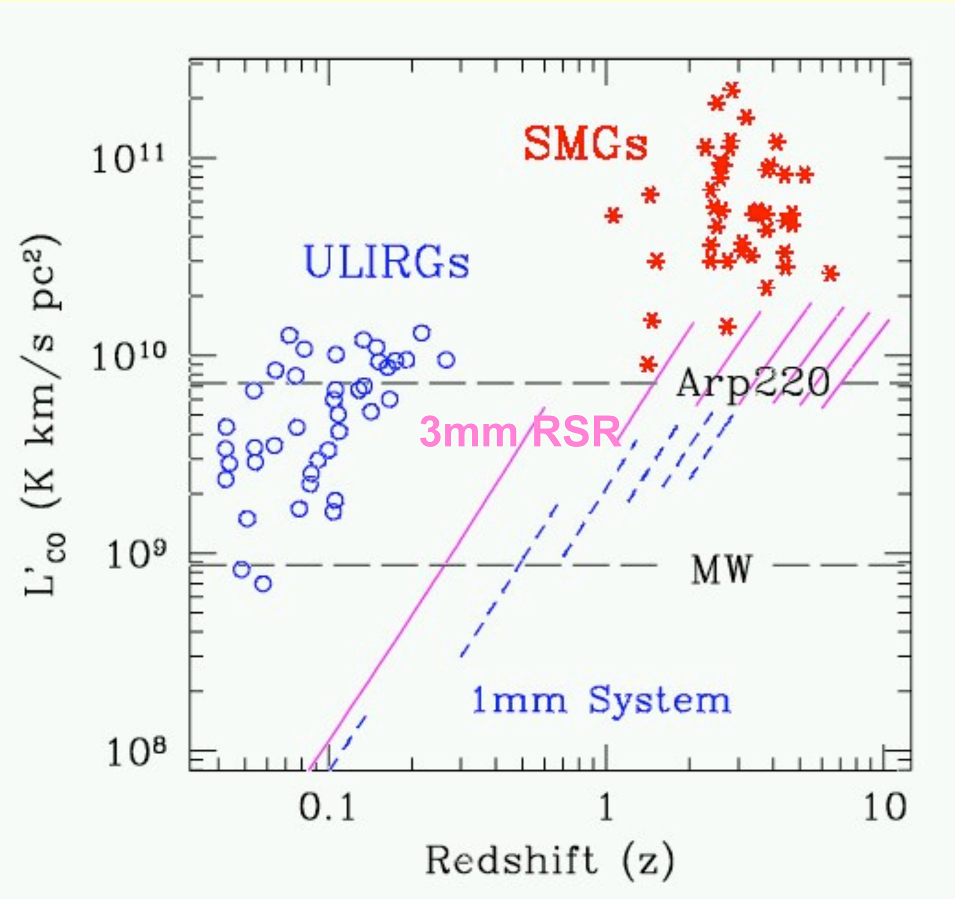


RSR is 40 times Faster on LMT



- Model RSR spectrum of a z=2.5 SMG with LMT in 1 hr
- Template analysis for z, ΔV, chemistry, multiplicity, etc.

RSR Sensitivity on LMT



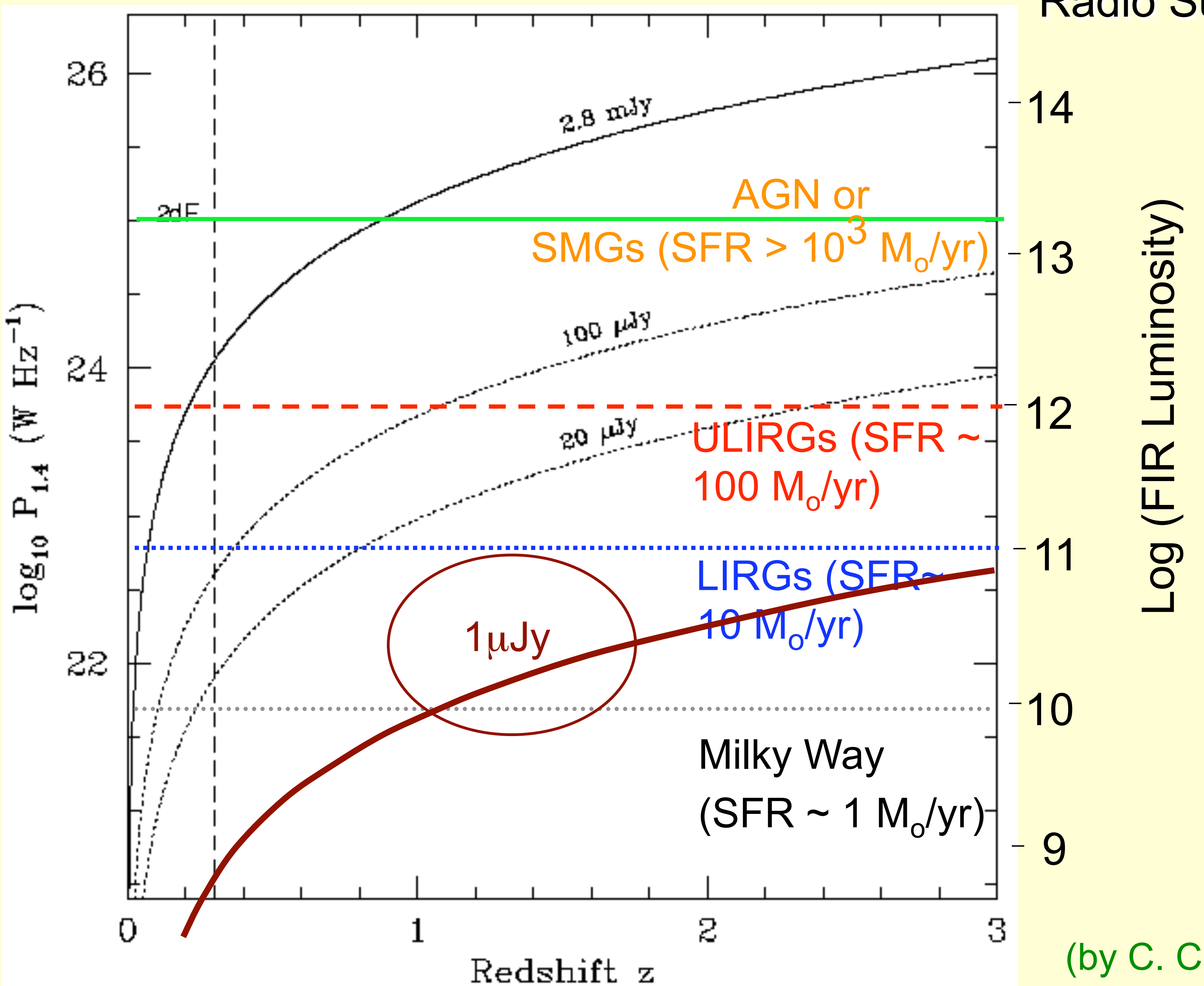
- **In 1 hr, we can detect and obtain unambiguous reds hifts of:**
  - each known SMGs (S_{850m}> 5mJy) with S/N>10
  - each ULIRGs at all redshifts with S/N>5
  - MW-like galaxies to z=0.2
- 1mm Rx with RSR backen d would be 3-4 times more s ensitive if CO line is fully ther malized.

Large RSR Surveys

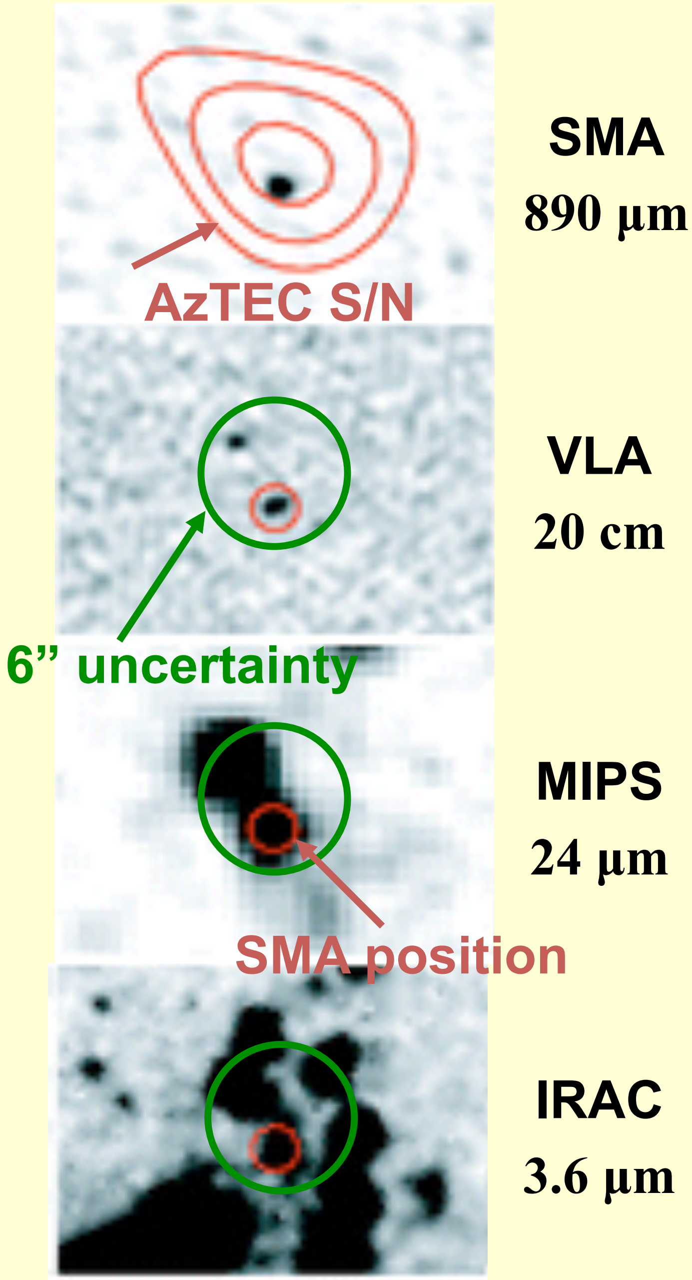
- Short term: 10^4 redshifts
  - Coarse mapping of LSS at $z > 1$
  - SMG LF and H_2 MF and their evolution
  - cosmic SF history and stellar mass build-up
  - Dynamical and chemical evolution of galaxies
  - BH-galaxy co-evolution?
- Long term: 10^6 redshifts
  - Detailed 3D tomography of LSS to z~10? – probe connection between LSS and galaxy bias
  - Acoustic peak at z>2
  - Requires a new instrument

Role of the EVLA

Radio Surveys



(by C. Carilli)

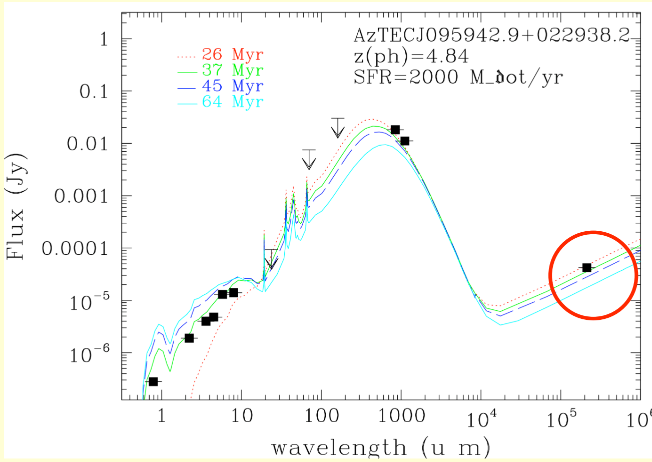


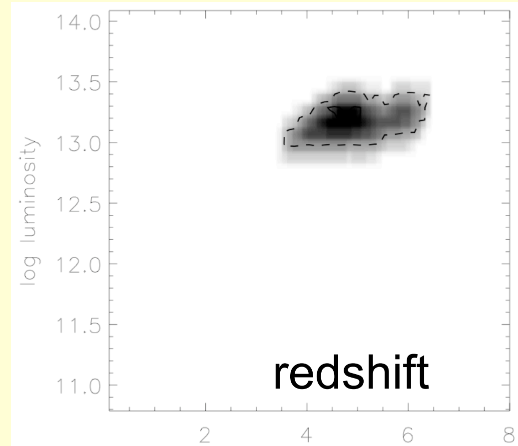
Nature of High-z SBs

- arcsec resolution required for correct counterpart ID
  - Follow-up spectroscopy
  - SED analysis and photo-z
  - Spatially resolved structure and gas kinematics

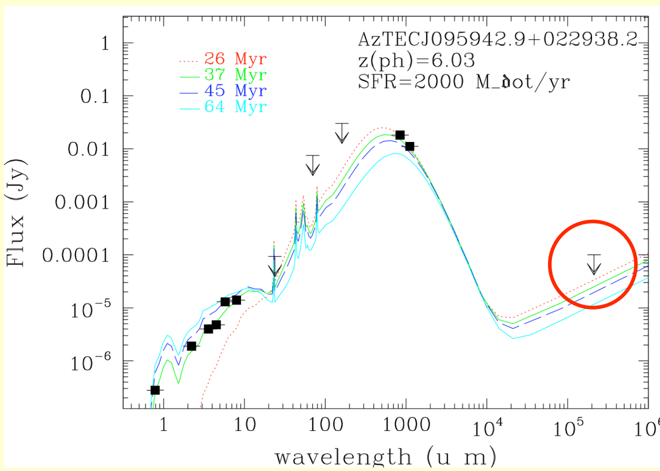
(also J. Younger talk)

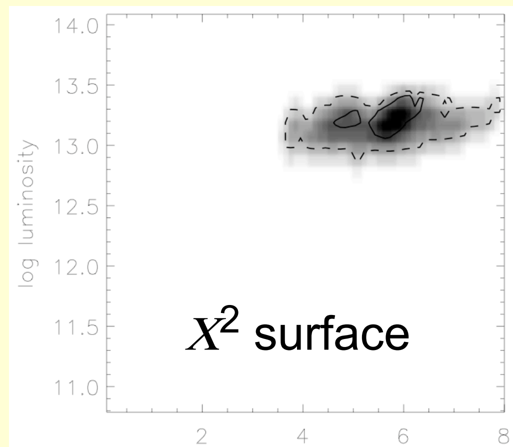
Panchromatic Photometric Redshifts





with radio detection



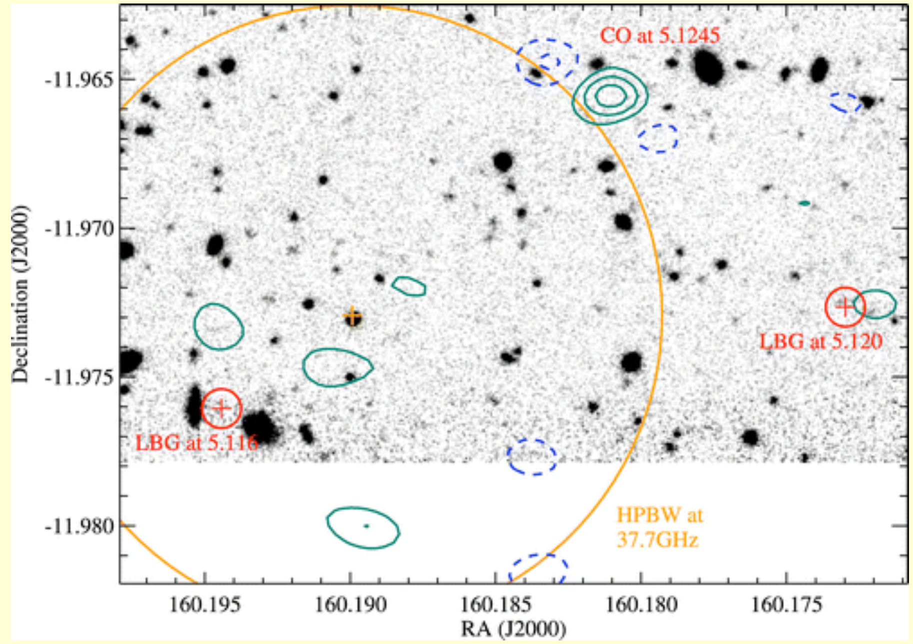


with radio upper limit

- Photometry at radio wavelengths critically important
- A large statistical sample (~10^6 redshifts) is needed for the study of LSS, clustering (halo mass), etc

CO Spectroscopy

Like ALMA:



Stanway et al. (2008)

- Excellent angular and spectral resolution
  - Details of gas distribution and kinematics
  - Link between gas and activities
  - Large scale structure and clustering at small scales
- Not well suited for blind redshift surveys

(talks by E. Daddi, D. Reichers)

Summary Remarks

- $10^{5\text{-}6}$ dusty SBs will be known from the Herschel, AzTEC, SCUBA-2, and other surveys by the time EVLA comes on line, entering the phase of deeper understanding, rather than just discovery.
- EVLA will be critical for understanding detailed properties (SEDs, distribution and kinematics of gas and other activities) and statistical studies (photo-z's, clustering).
- Deep HI survey for mapping the cold gas content evolution is indeed a "no-brainer."