HST and Spitzer views of luminous compact blue galaxies

z≈0: NGC 7673

James Lowenthal

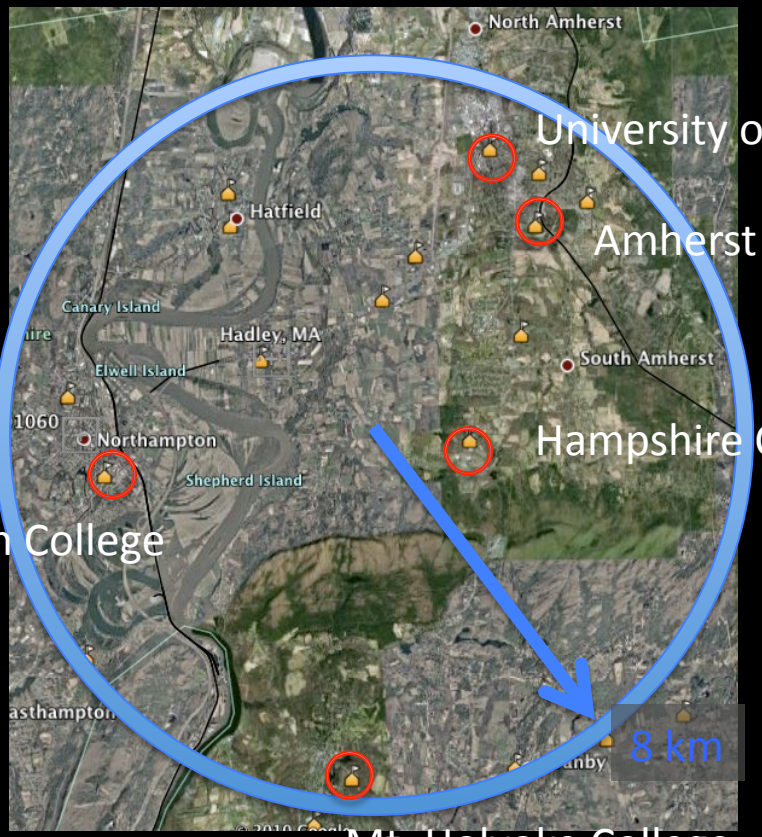
Smith College

Northampton, Massachusetts, USA

SMITH COLLEGE

Santa Cruz 8 August 2011

Smith College/Five College Astronomy Department



University of Massachusetts

Amherst College

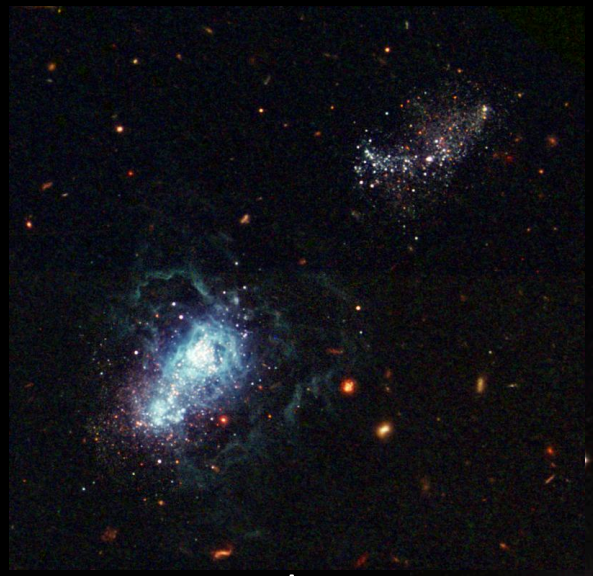
Hampshire College

Smith College

Mt. Holyoke College

- 20 faculty, including D. Calzetti, S. Edwards, M. Giavalisco, N. Katz, H. Mo, A. Pope, T. Tripp, D. Wang, M. Weinberg, G. Wilson, M. Yun
- Home of now-retired FCRAO 14-m telescope
- Home of 2MASS
- Co-leading (with Mexico) the 50-m Large Millimeter Telescope/Gran Telescopio Milimetrico (LMT/GTM)

What is a Starburst Galaxy?

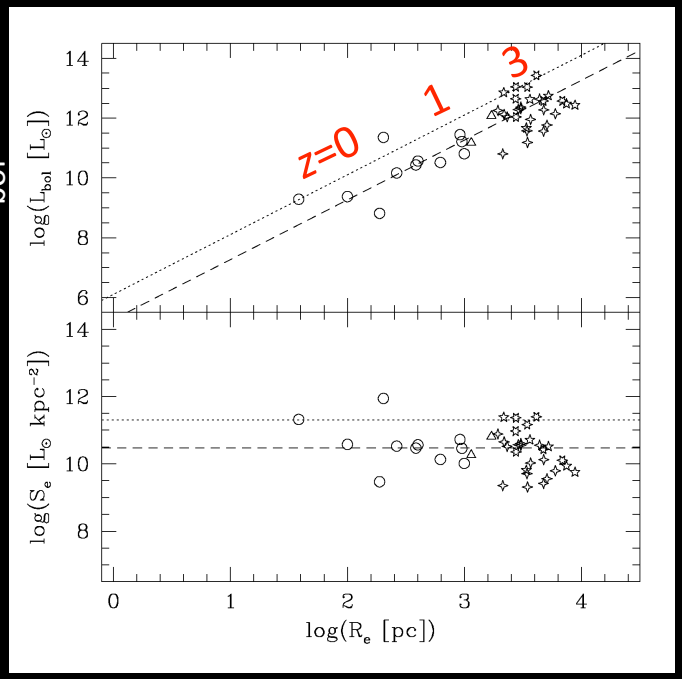


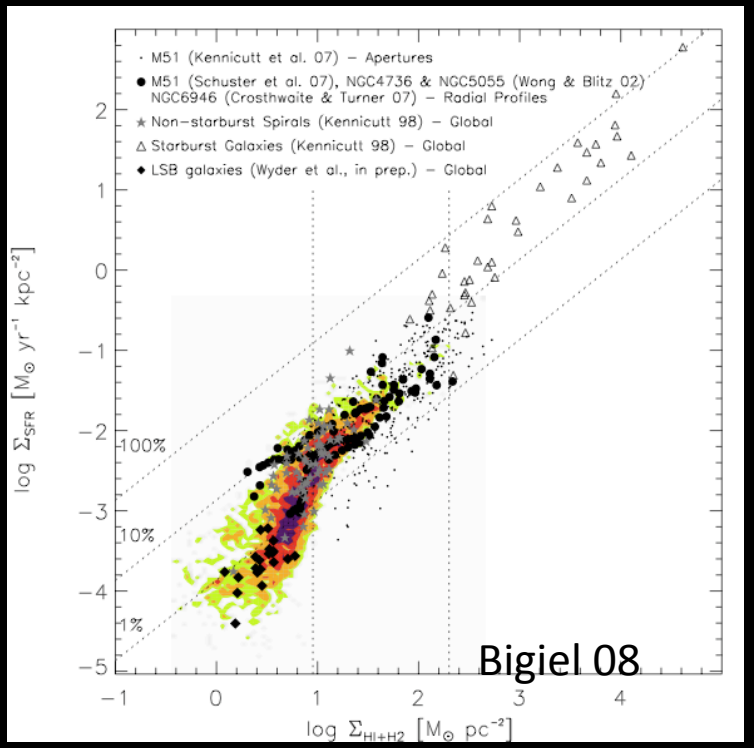
- M82, HII galaxies, ultraluminous inf galaxies (ULIRGs), break galaxies (LE

- Note huge range mass, luminosity, morphology, phys conditions, envirc

90 kpc ULIRG; Borne

Star formation in starbursts



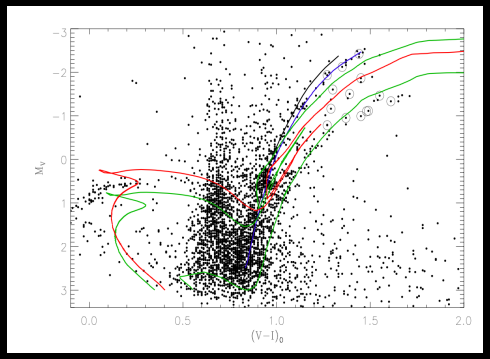


- SBs have extreme
  - specific star formation rate (SSFR) = SFR/M
  - star formation efficiency = SFR/M_{gas}
  - surface brightness
- SB's obey Schmidt-Kennicutt, but with different mode (low SF, high SFE) of SF than in non-SB galaxies? (BzK's: Daddi…)

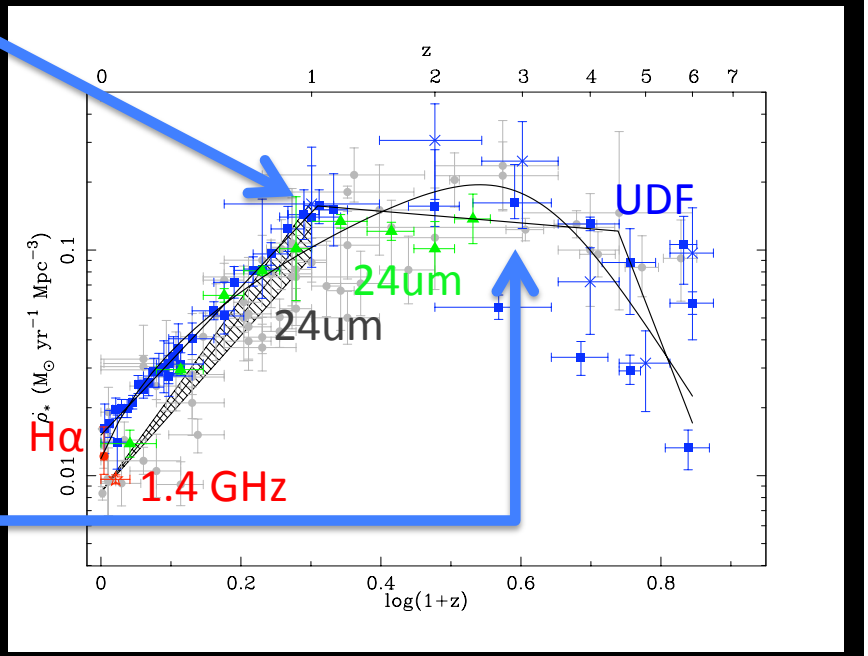
Role of starbursts in galaxy formation and evolution?

Some hints:

- optical z<1:
  - Multiple SF episodes in stellar pops
  - 10x rise in SF to z=1: 40% due to low-mass SBs ("downsizing")
- optical z>1: LBG, sBzK: SFR~10-100 $M_\odot$/year; LF provides enough for >10% of current stars in galaxies (esp. if dust correction is large)



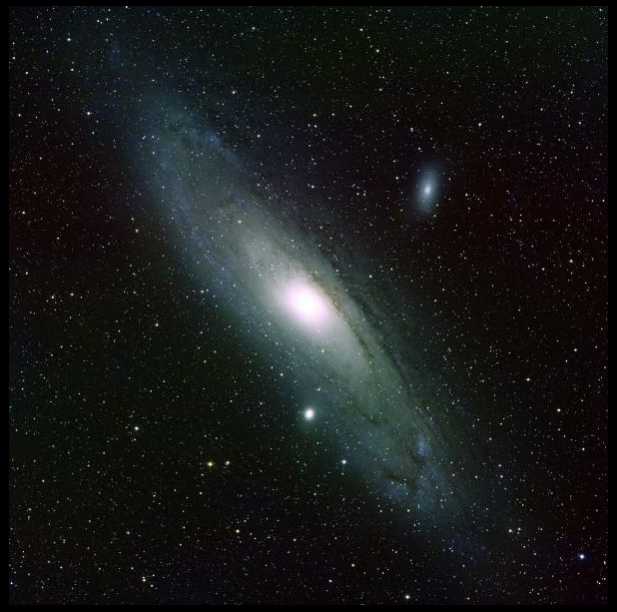
Smecker-Hane



Hopkins & Beacom 2006

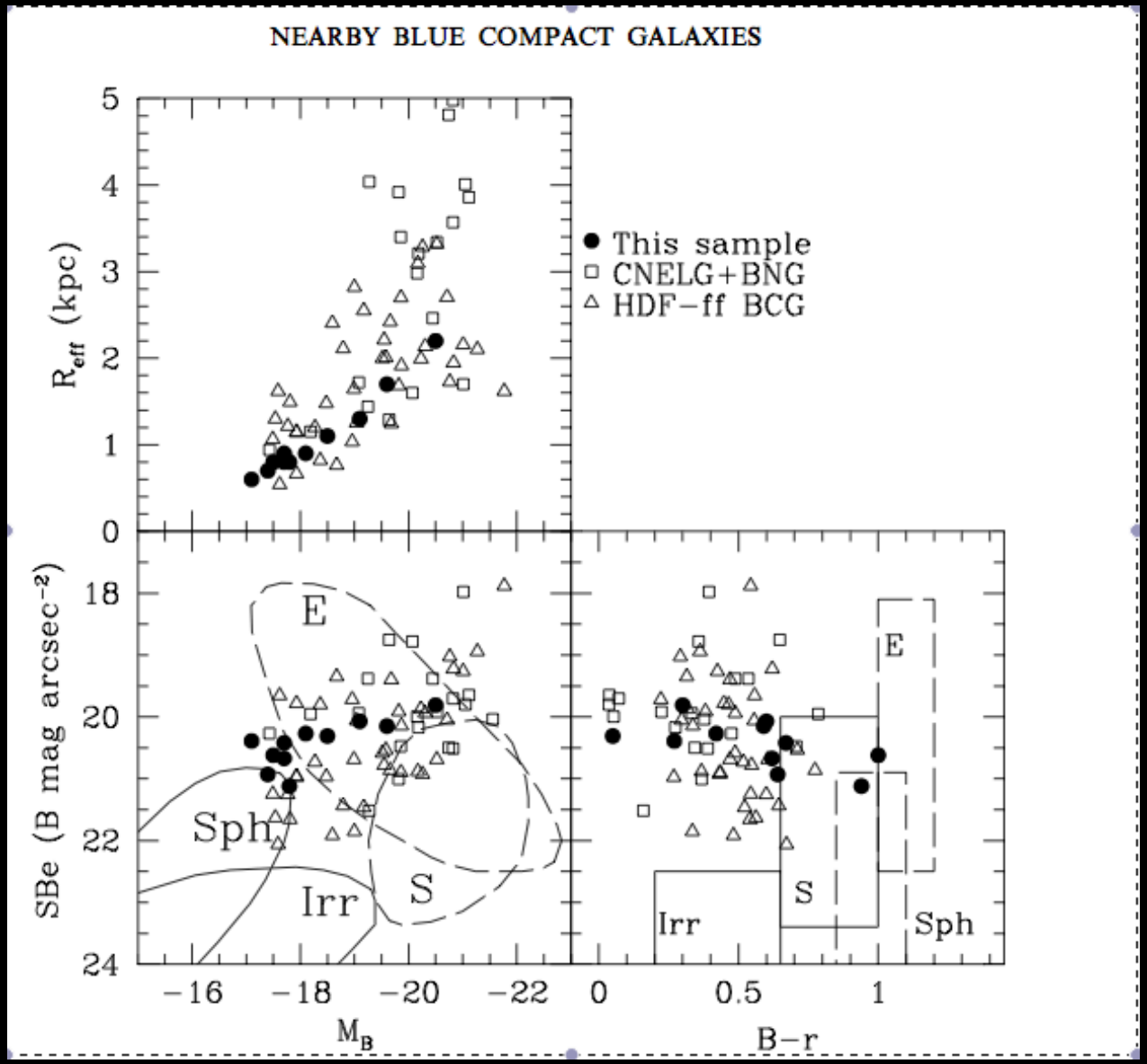
Luminous Blue Compact Galaxies = LCBGs

- L ~ L* but tiny, r_e ~ 2 kpc (L_{M31}, r_{N205})
- Extreme starbursts
  10-20 $M_\odot$/yr
- High surface brightness
  μ_B<21 mag/arcsec^2
- Narrow emission lines
  30-120 km/s
- Low masses < $10^{10}M_\odot$
- M_{burst}/M_{tot}>10% (from O/IR SEDs)
- Strong evolution: 40% of SF↑ to z=1
- Similar to UVLGs (GALEX: Heckman, Overzier) and Small Green Peas (SDSS: Cardamone 09)
- Top candidates for local LBGs analog: HII galaxies and luminous blue compact galaxies = LCBGs
  (*not* BCG or BCD)



Cf. Pérez-Gallego 09; Melbourne 07; Noeske 07; Werk 04; Ferguson 04; Pisano 01; Lilly 98; Phillips 97; Guzmán '97, '98, '03; Koo '94, 95; Bershady '00

LCBGs vs. normal galaxies



Pisano 2001

LCBGs at z<1

Project:

- compare LCBGs and LBGs in rest-UV and MIR with *HST* and *Spitzer*
- Search for additional SF hidden in dust

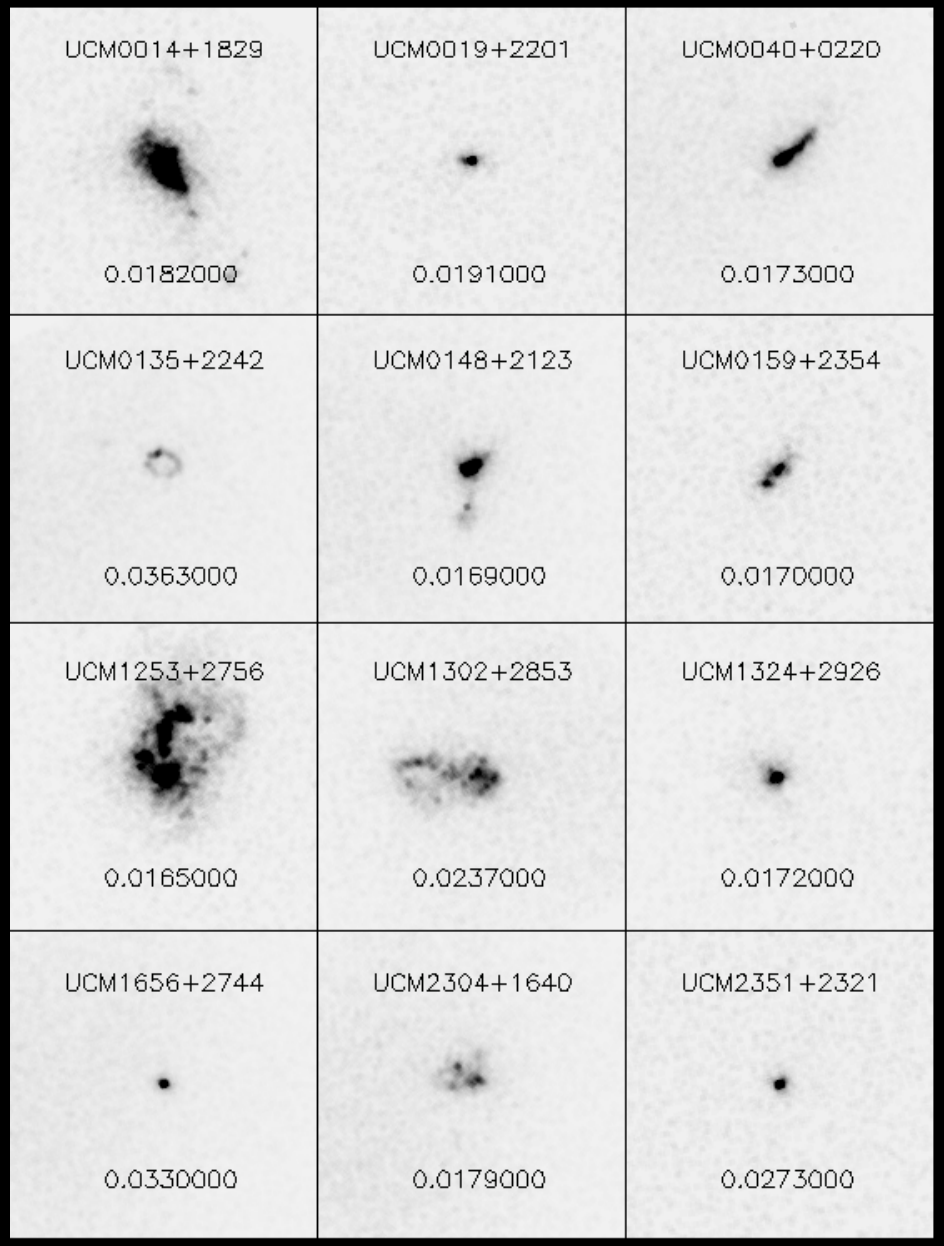
- Sample:
  - 12 HII gals at z=0 from UCM survey
  - 14 LCBGs at z<1 from LBDS/KPGRS
- Data:
  - *HST*/STIS FUV and NUV images = rest-UV
  - *Spitzer*/IRAC+MIPS photometry

With Bershady, Gallego, Guzmàn, Koo, Hameed, Macie, Finn



STIS FUV images of *z*~0 sample

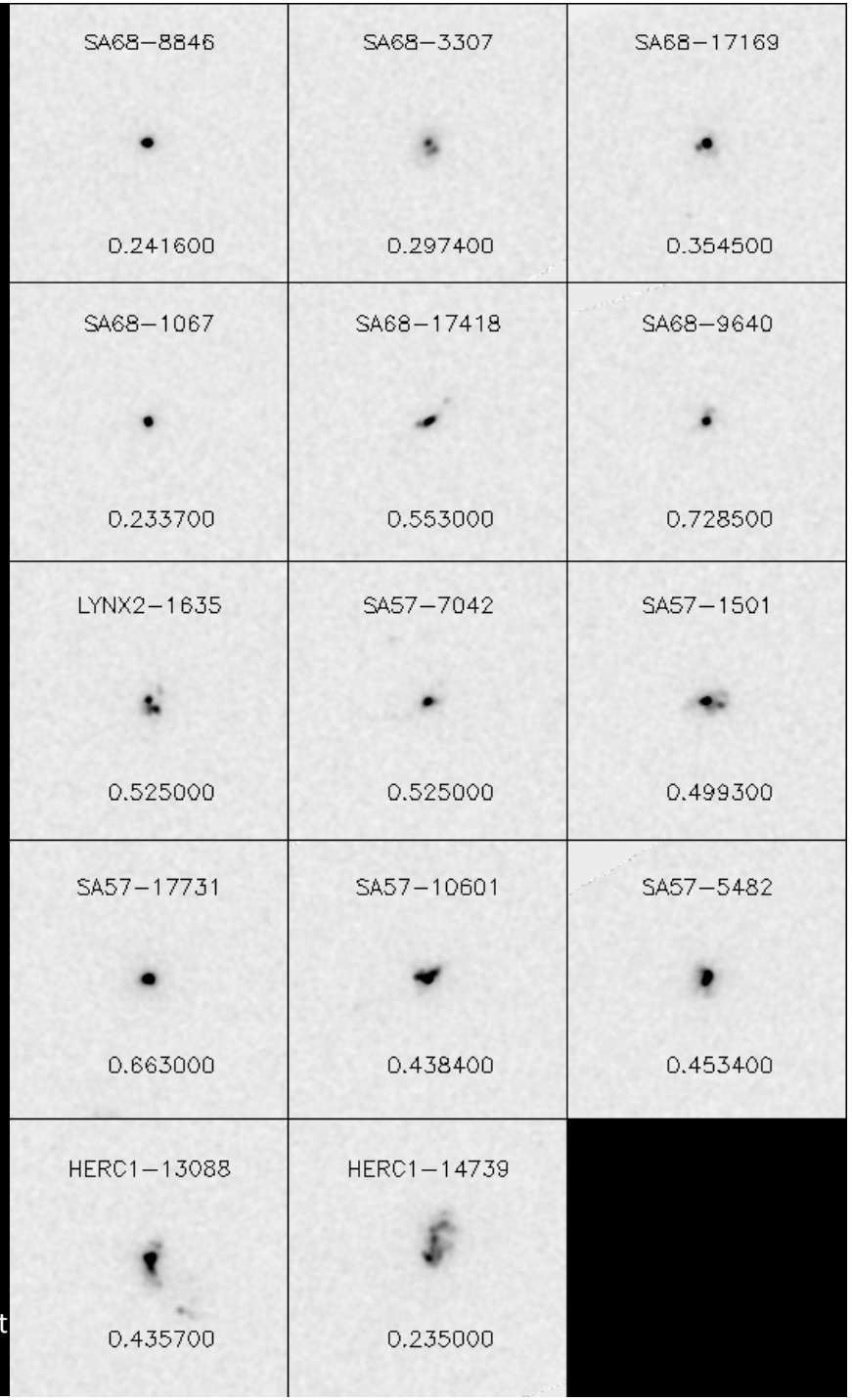
- Morphologies: VERY diverse, disturbed, multiple knots, rings, etc.
- No definitive merger signature (vs. Overzier 08, 09, 10), but several could be mergers



STIS NUV images of *z*<1 sample

9” ~ 31-66 kpc

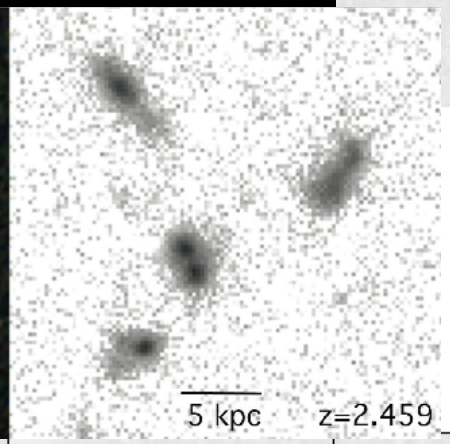
Morphologies: again, disturbed, multiple knot systems, but some nearly unresolved

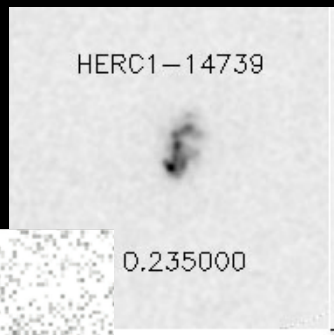


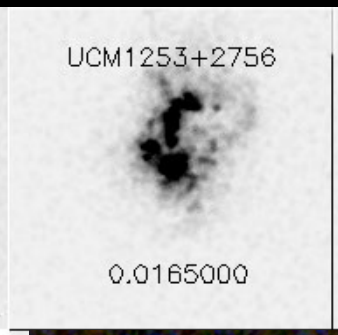
FUV morphologies

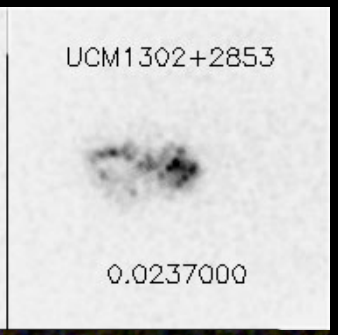
extended

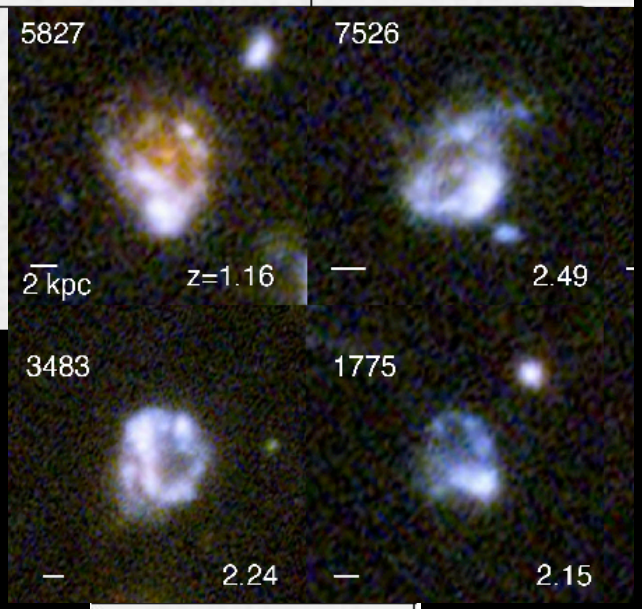
Elmegreens' high-z "clumps"

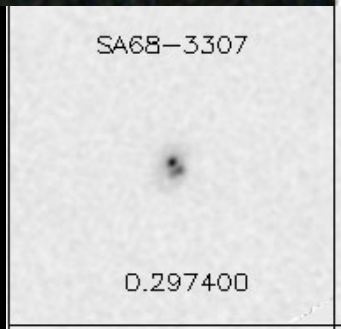


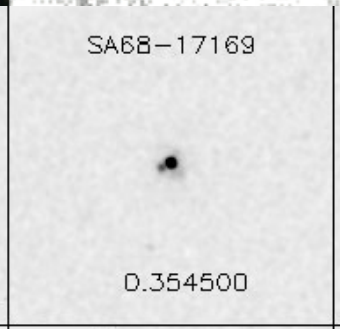


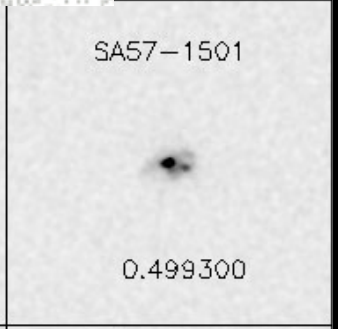


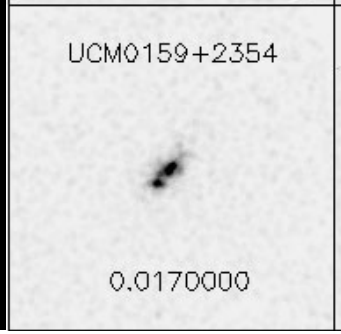


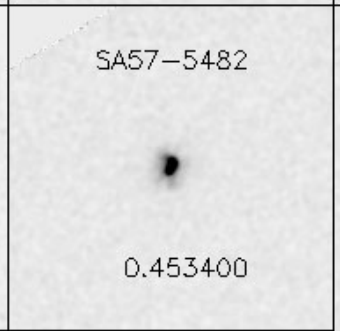


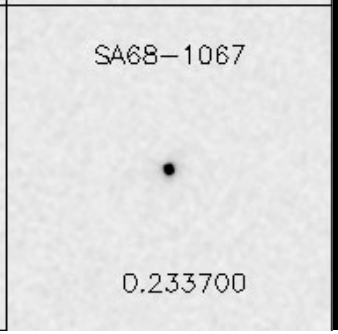


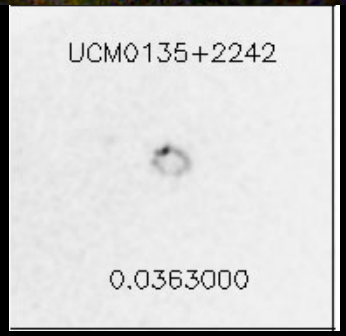








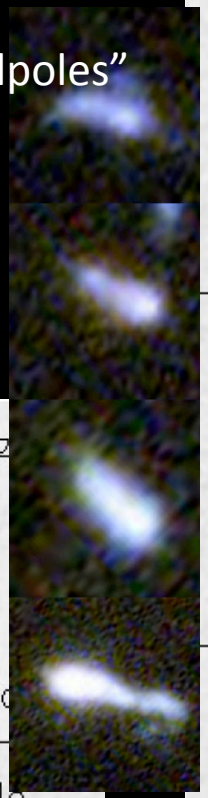




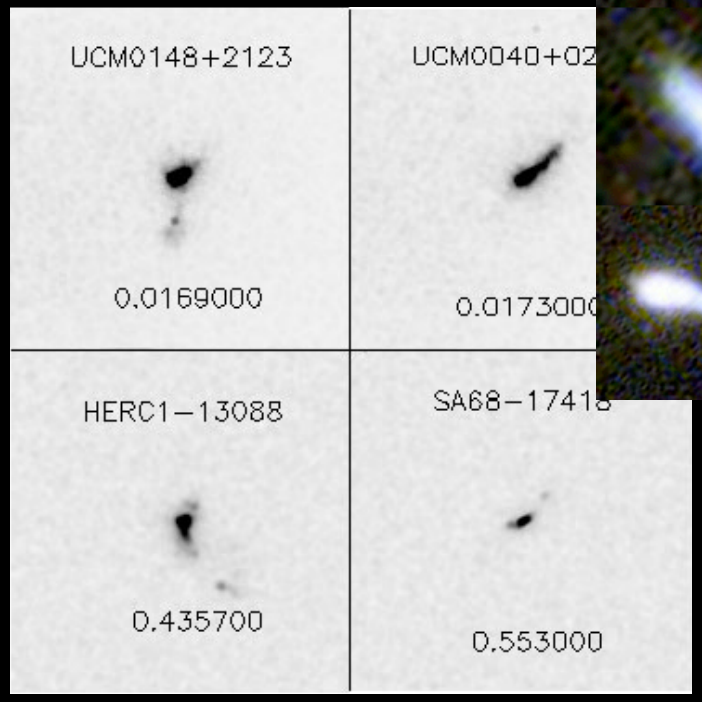
FUV morphologies

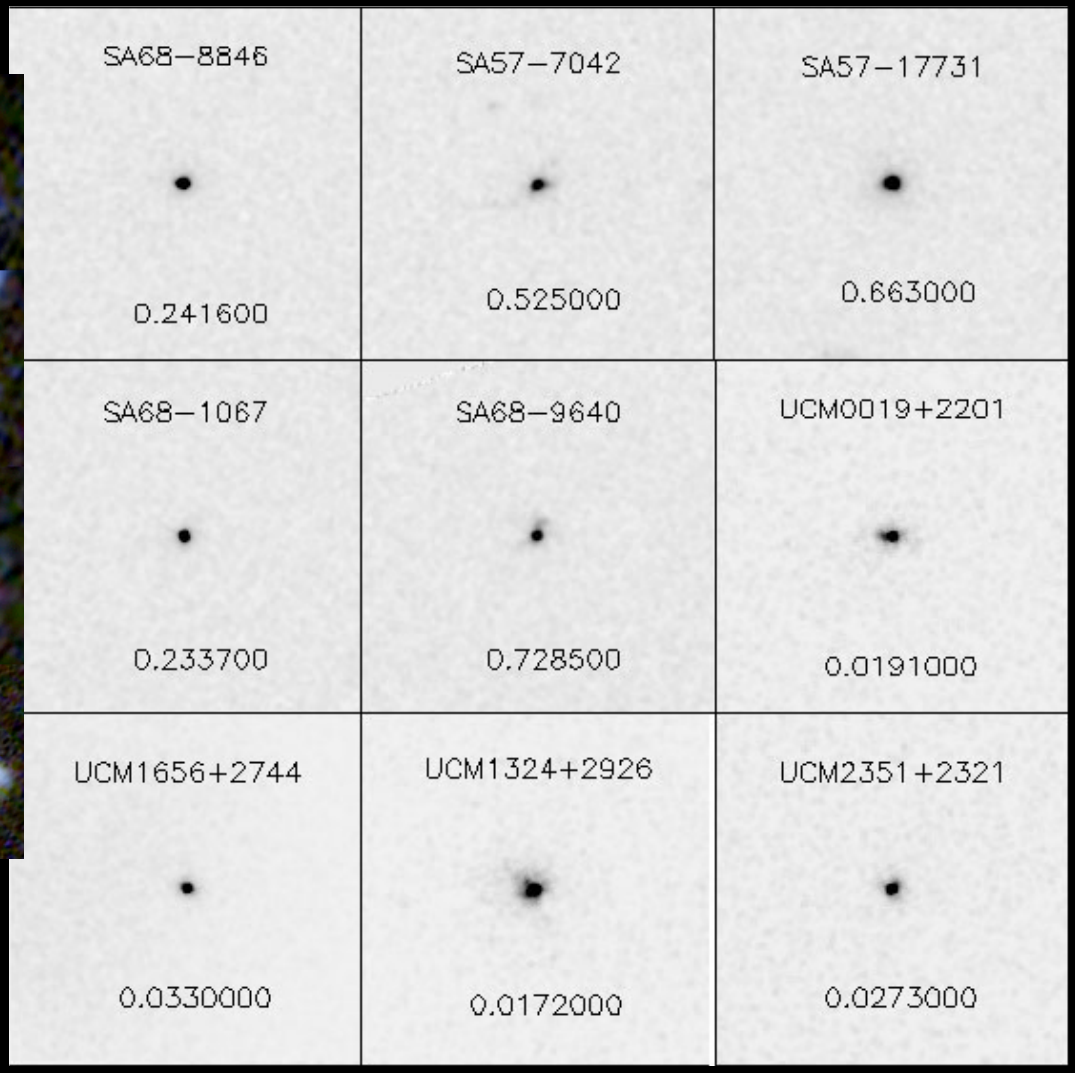
compact

Elmegreens' high-z "tadpoles"



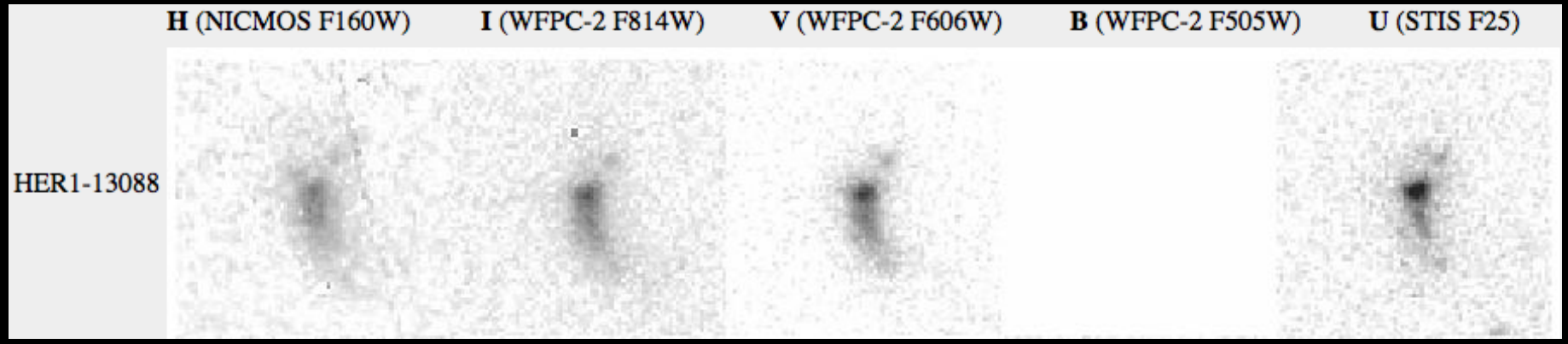
linear



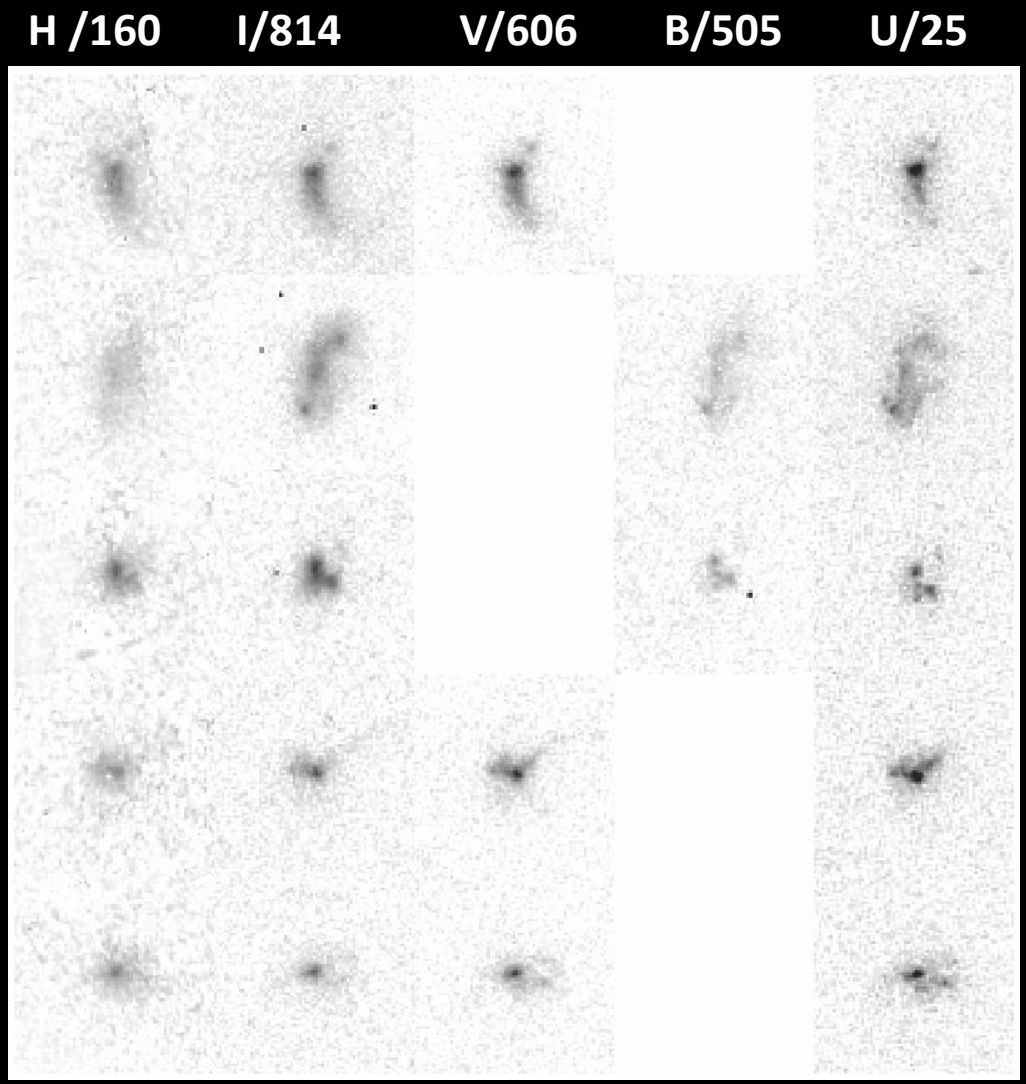


Santa Cruz 8 August 2011

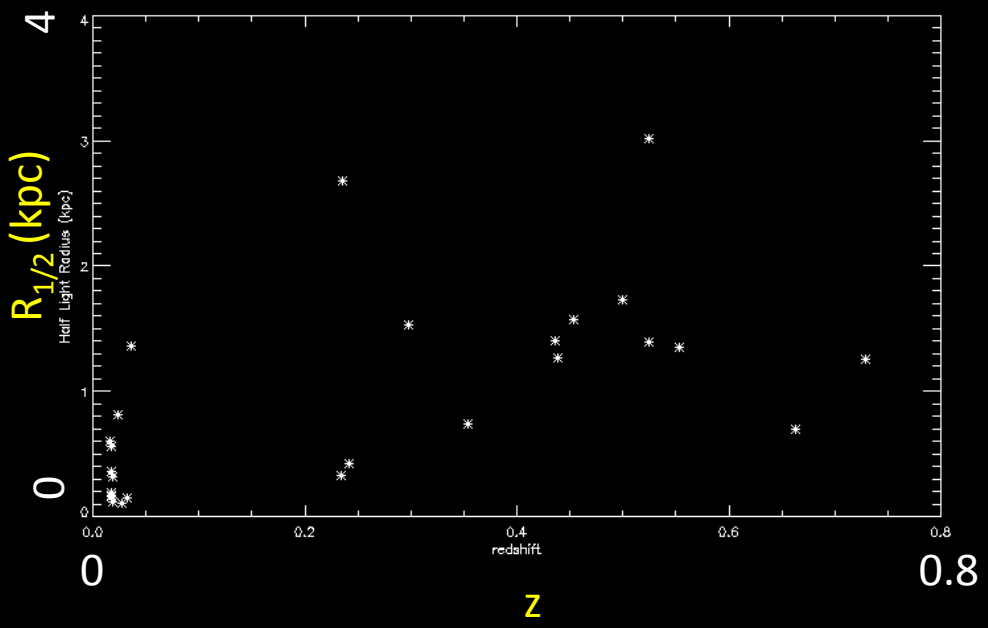
Morphologies similar NIR-Opt-UV

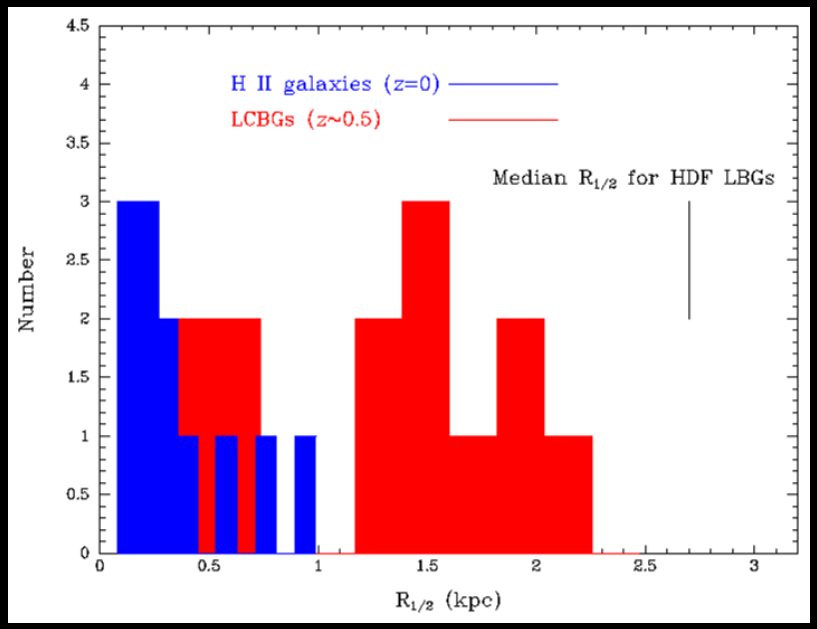


HST Morphologies similar NIR-Opt-UV

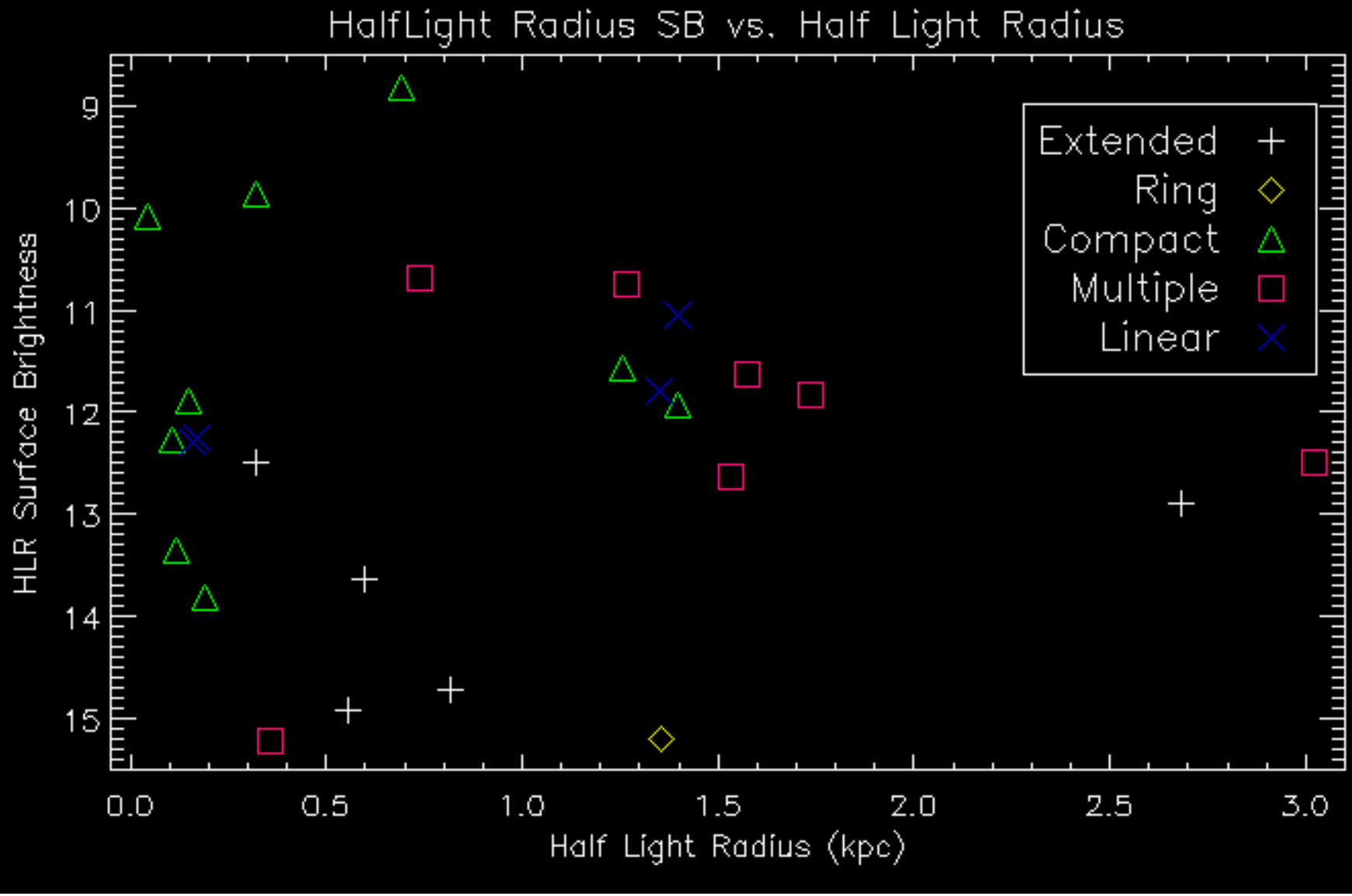


LBGs are small; LCBGs are smaller



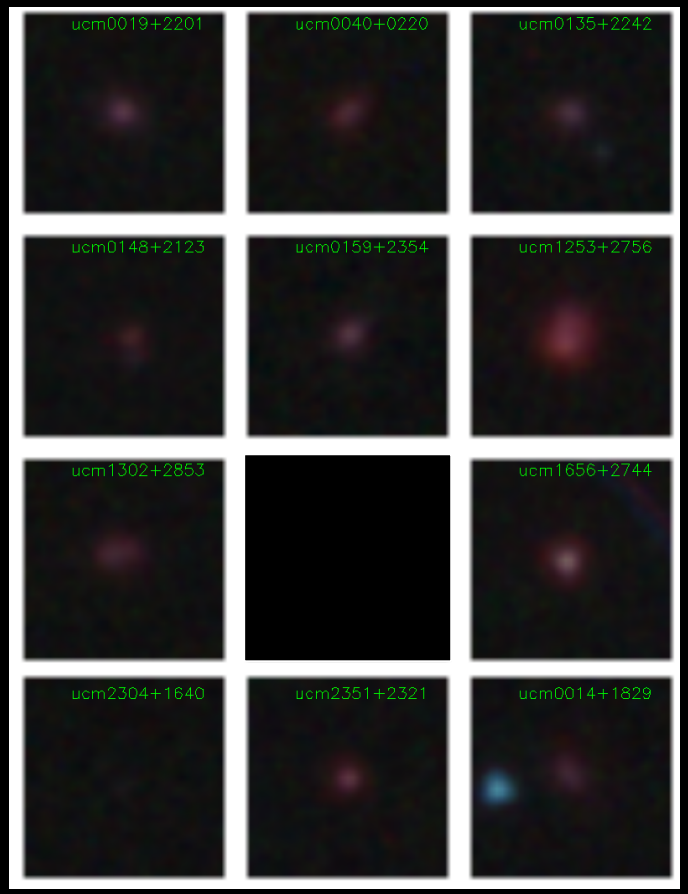


FUV Morphology correlates loosely with size, SB



Spitzer/IRAC+MIPS photometry

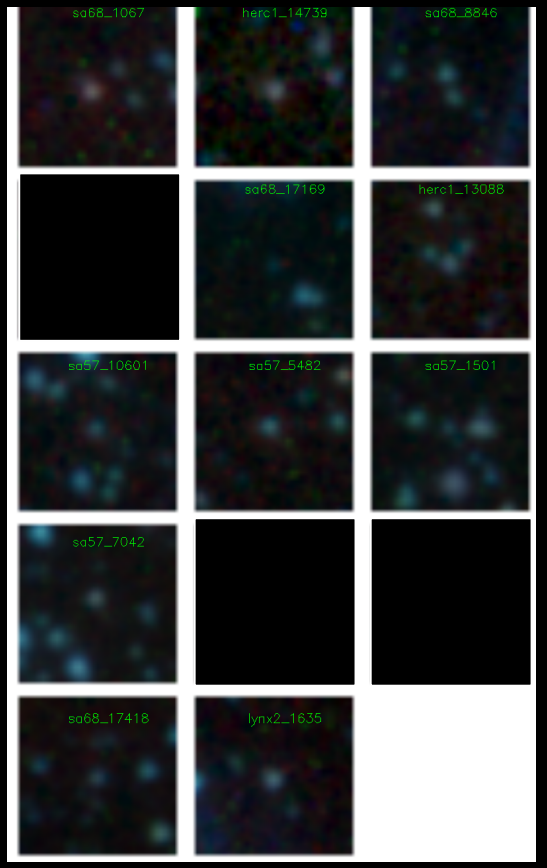
z~0 UCM galaxies



30”~12 kpc

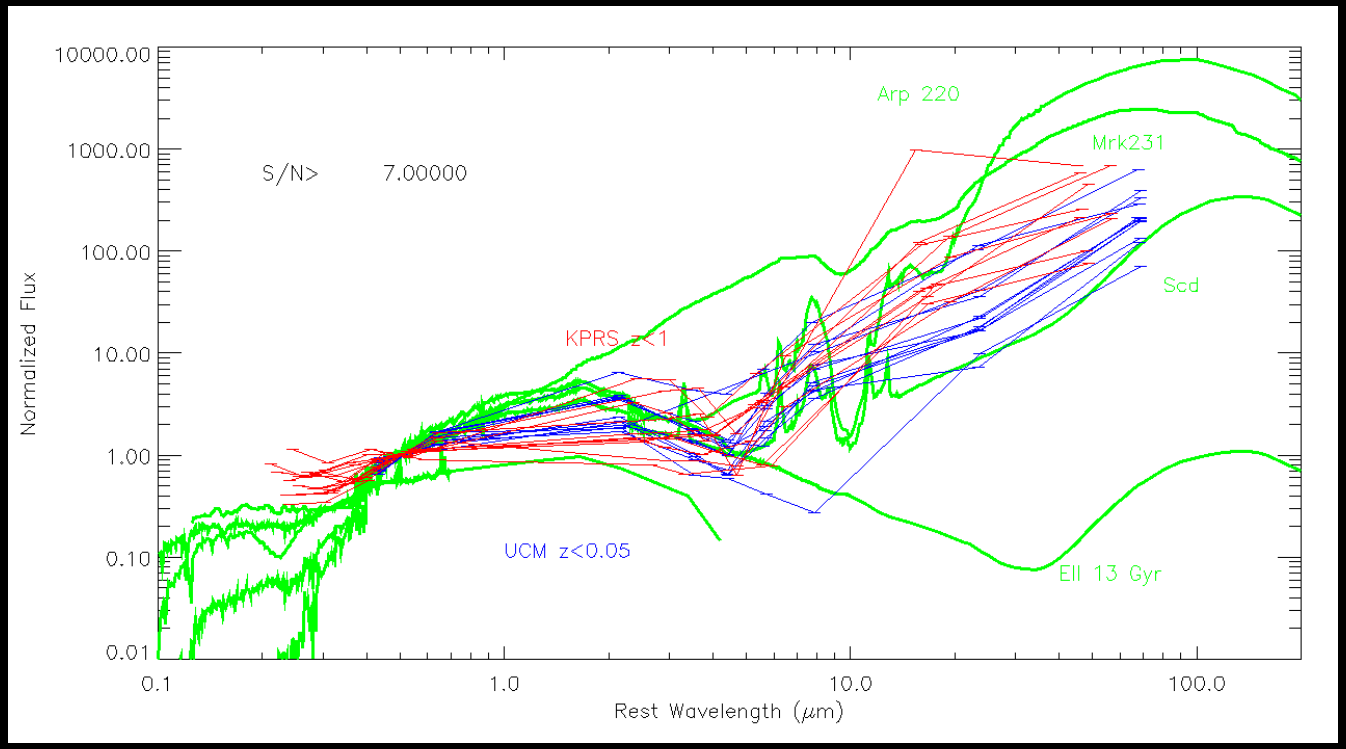
IRAC
ch 1,2,3

z<1 LCBGs



30” ~ 170 kpc

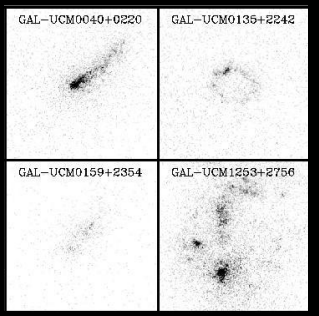
Spectral Energy Distributions



Strong 24, 70um detections…

…but little/no evidence for hidden dusty SFR

Conclusions on LCBGs at $z<1$

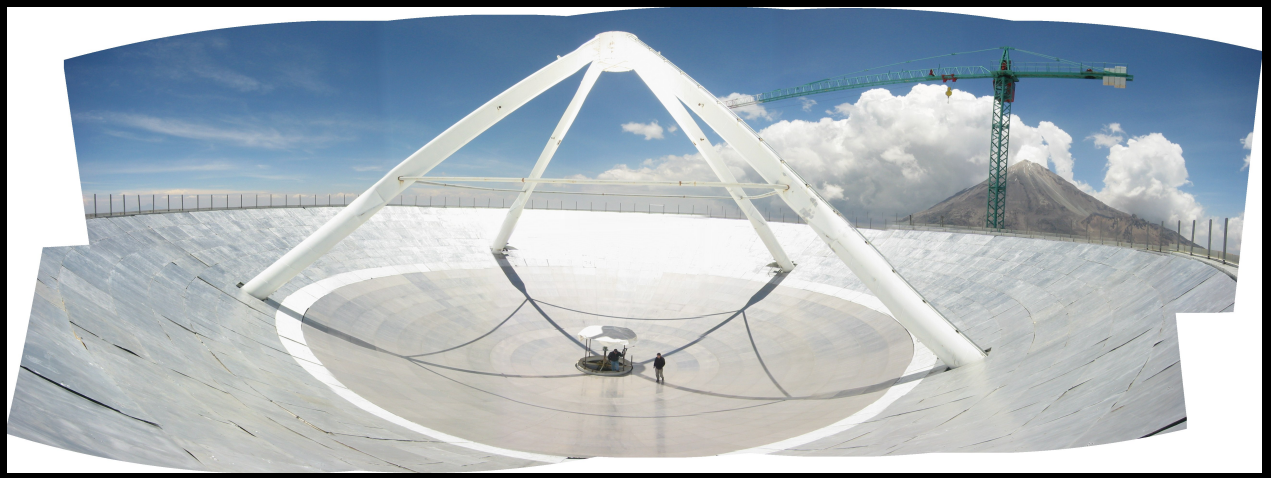


- LCBGs and HII galaxies are excellent local analogs of LBGs: FUV morphologies, sizes, colors, SF props, masses all in continuum with LBGs.
- rest-UV images show star formation in wide range of morphologies, from rings to compact nuclei. Almost all within 2 kpc radius, but not "nuclear" starbursts.
- Morphologies not dramatically different UV-Opt-NIR
- No obvious merger signatures (some mergers possible)
- Cold flows, clumpy disks plausible
- Spitzer: little or no excess SFR_{IR} compared to SFR_{UV} – what you see is what you get

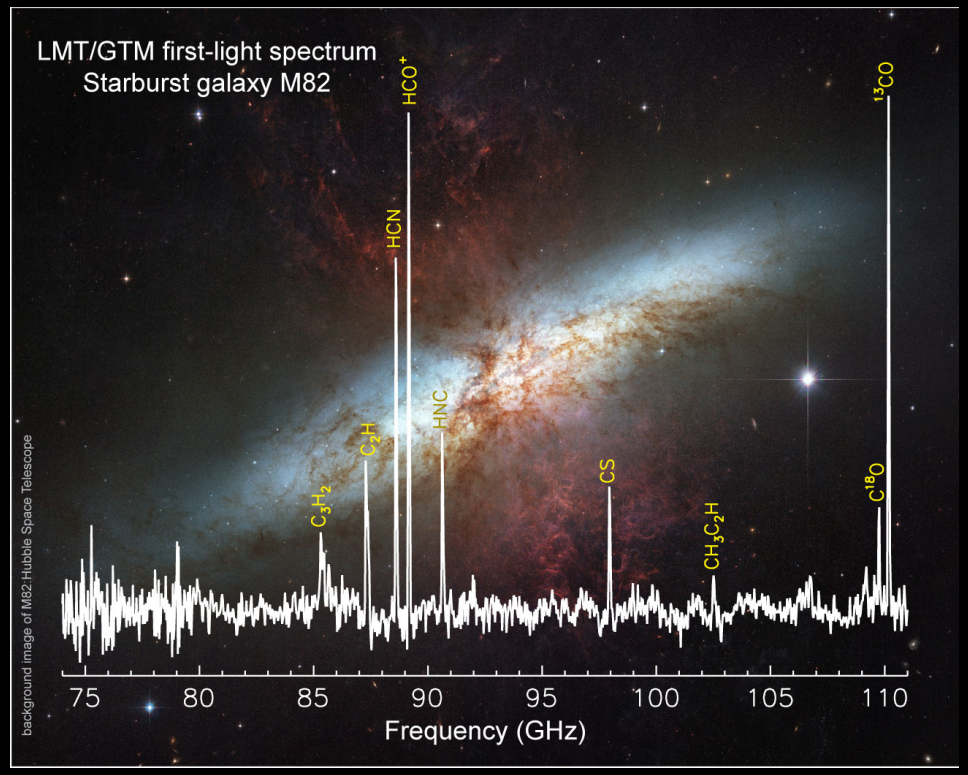
Santa Cruz 8 August 2011

50-m Large Millimeter Telescope/Gran Telescopio Millimetrico

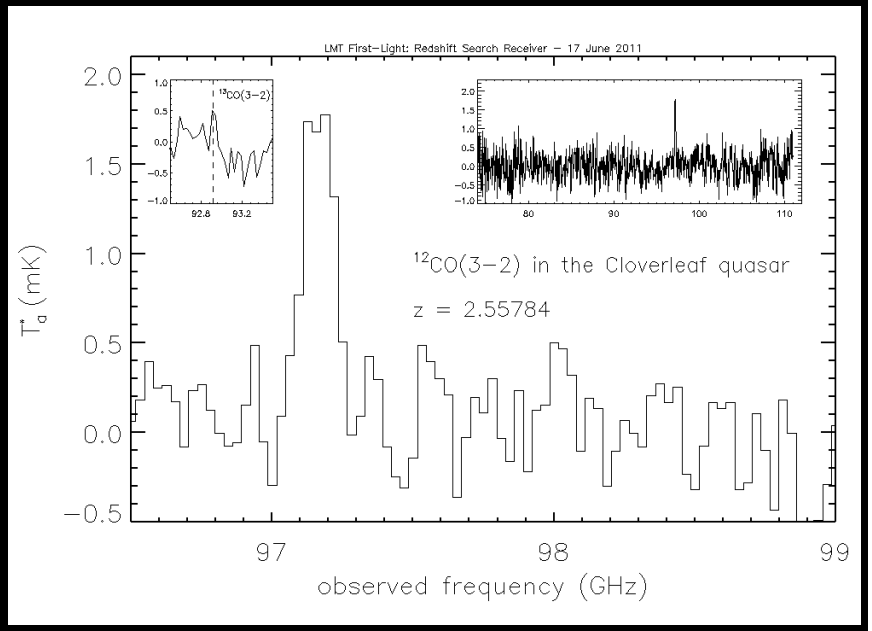
- UMass + Mexico
- $140M; largest science project ever for Mexico
- Cierra la Negra (5000m)
- 65 µm (rms) active surface
- 6” FWHM beam at 1 mm
- Pointing to 1”
- AzTEC, Redshift, SEQUOIA, SPEED
- 1000’s of SMGs/night; pathfinder for ALMA



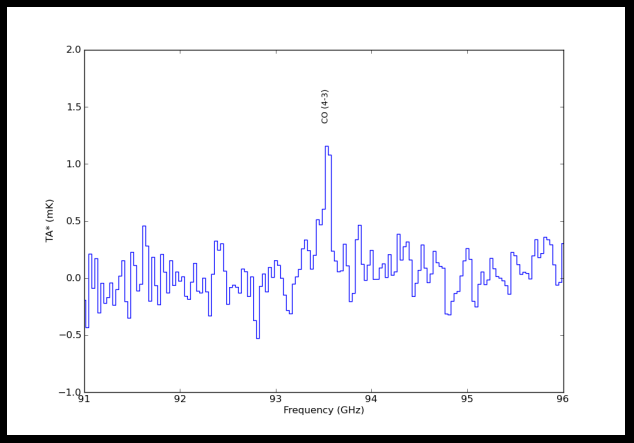
June 2011: LMT sees First Light!



Redshift Search Receiver delivers 38GHz bandwidth

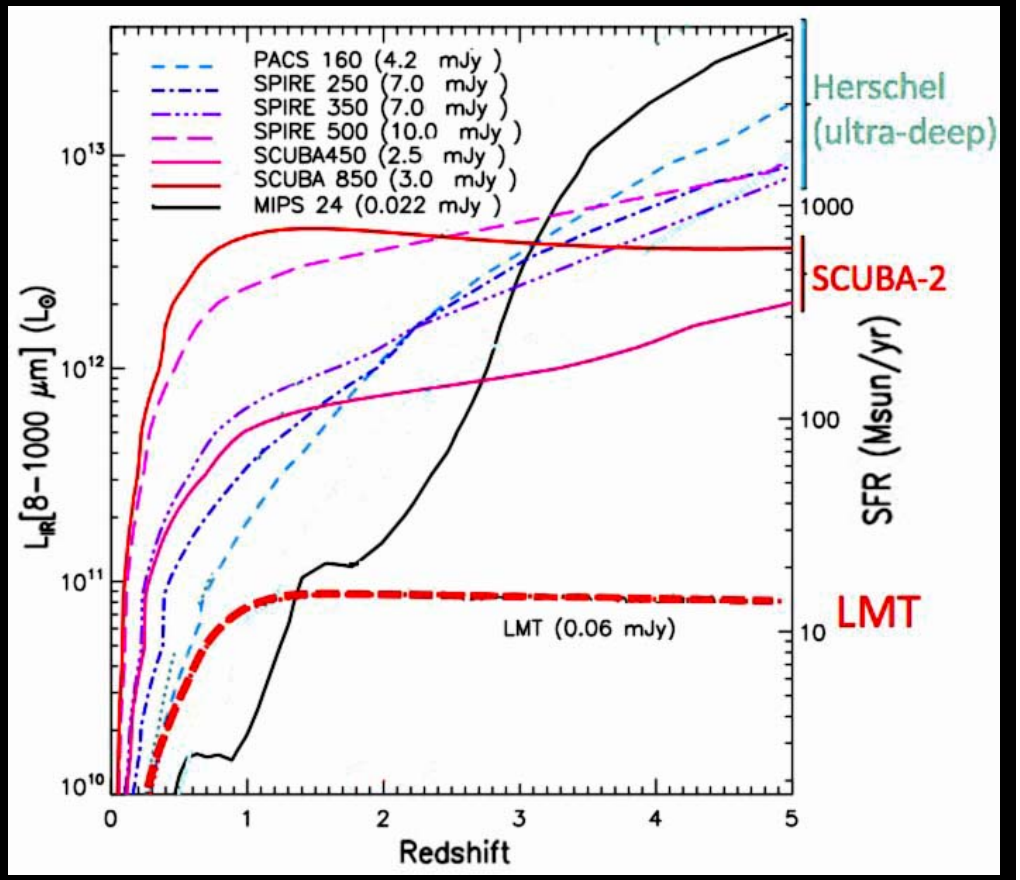


Cloverleaf (z=2.558)



SMG MMJ18423+5938 (z=3.930)

Santa Cruz 8 August 2011



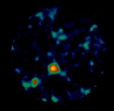
(figure courtesy M. Dickinson/D. Elbaz)

Instrument	Resolution	Mapping Speed [arcmin2/mJy2/hr]	Confusion Limit [mJy]
MAMBO/IRAM-30	11”	3	0.5
LABoCa/APEX	20”-30”	9	2
Bolocam/CSO	30”	10-13	2
AzTEC/JCMT	18”	20-30	1.5
AzTEC/ASTE	28”	20	2

Perspective on 32m dish operation:

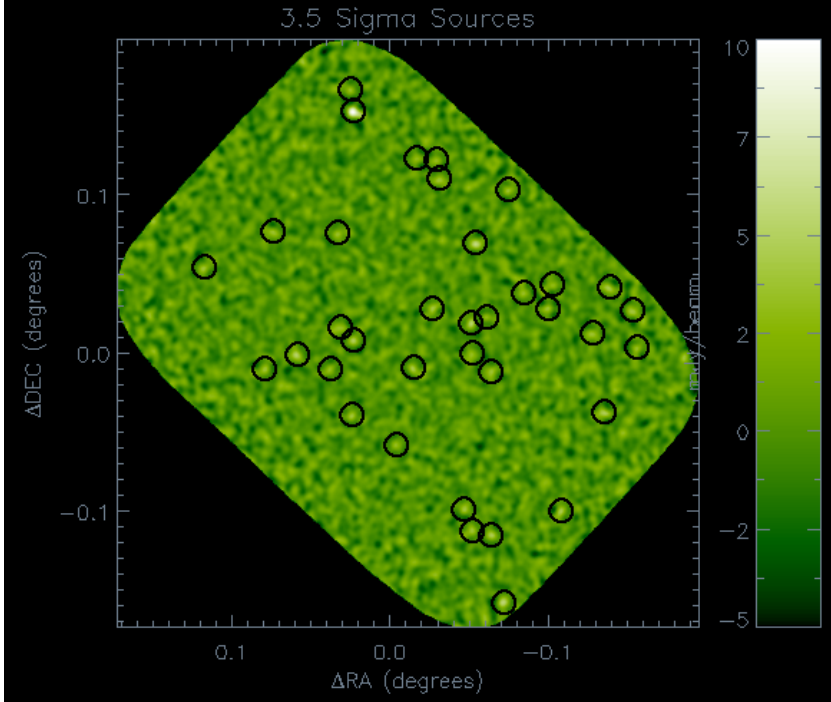
- repeating all deep SMG surveys to date takes 24 hours (8” resolution)
- imaging 2sq deg COSMOS field to 0.1mJy rms takes 1200 hrs (key project size)
- 100 sq. deg. at 10mJy rms (SPT-bright sources) takes 6 hours

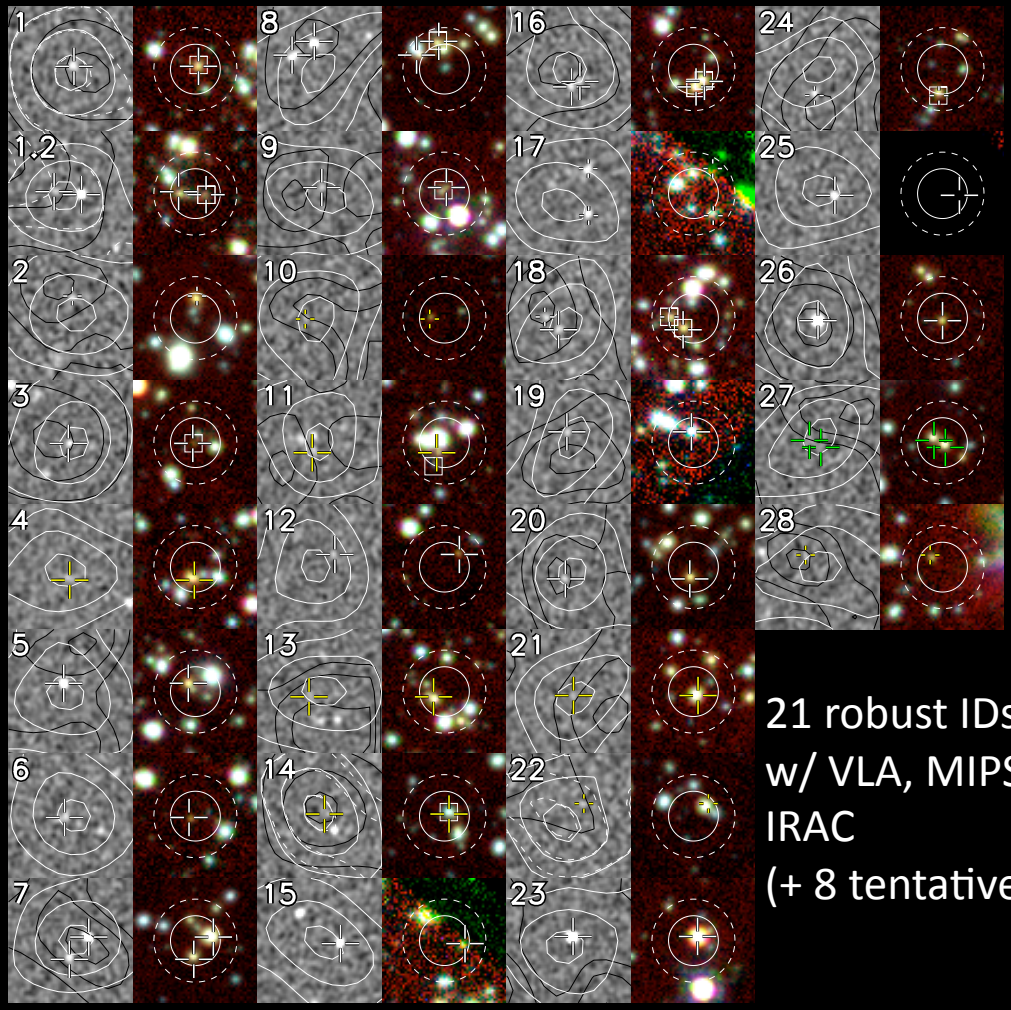
SMG Surveys with AzTEC



50 hours w/SCUBA:
5 sources (Hughes 98)

AzTEC/GOODS-N
245 arcmin^2



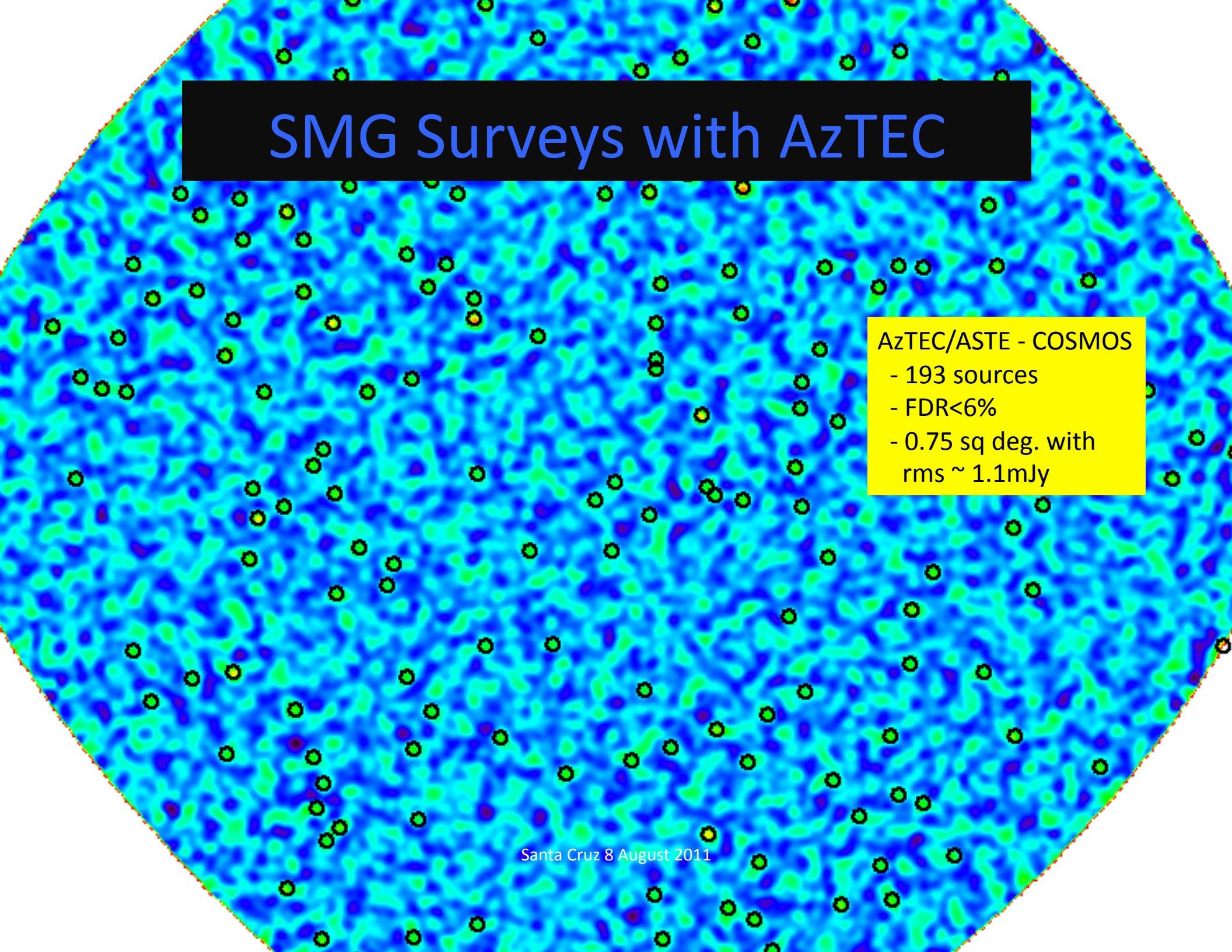


21 robust IDs
w/ VLA, MIPS, IRAC
(+ 8 tentative)

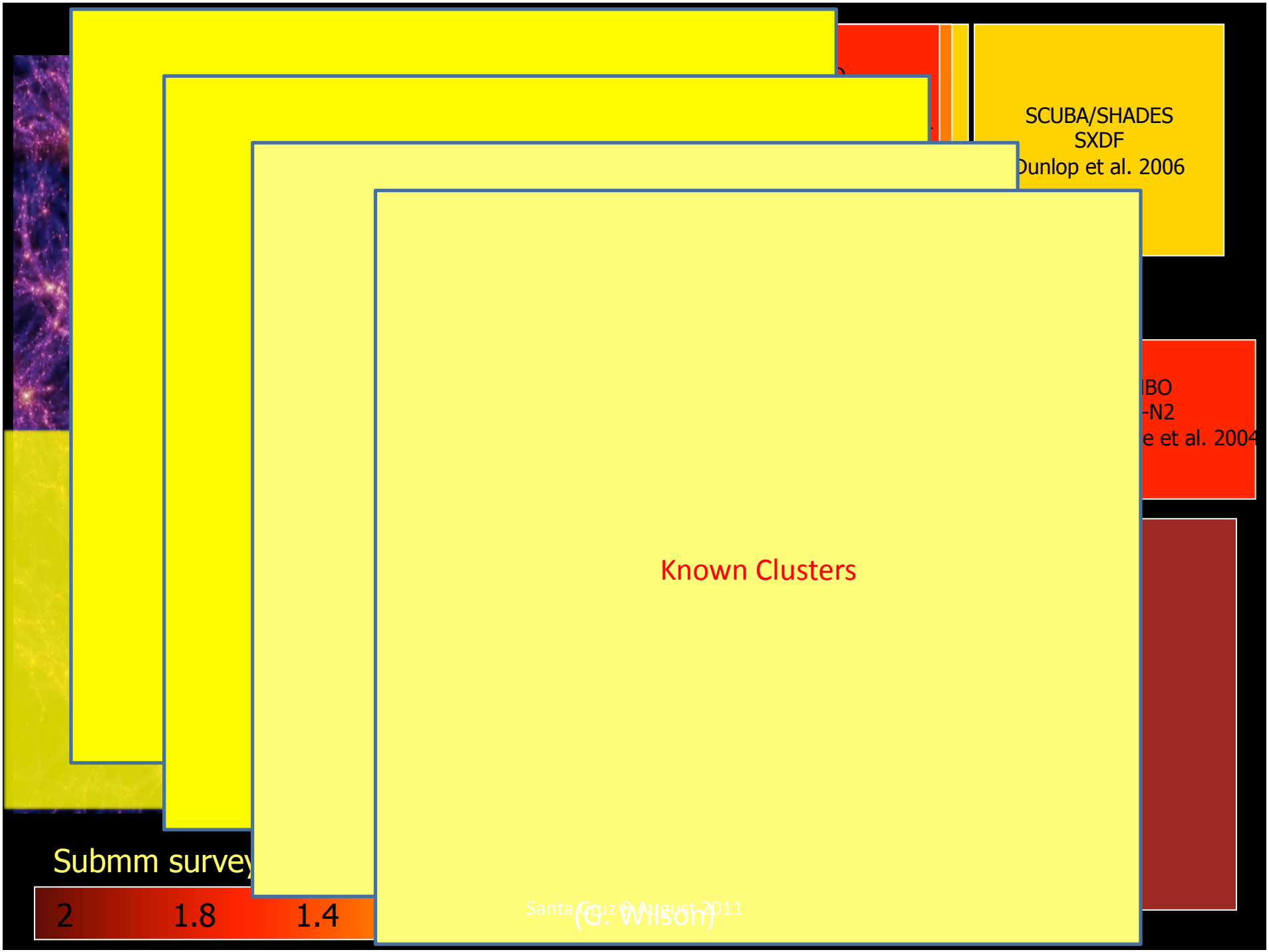
30 hours w/AzTEC: 29 sources (Perera 08)

Chapin 09

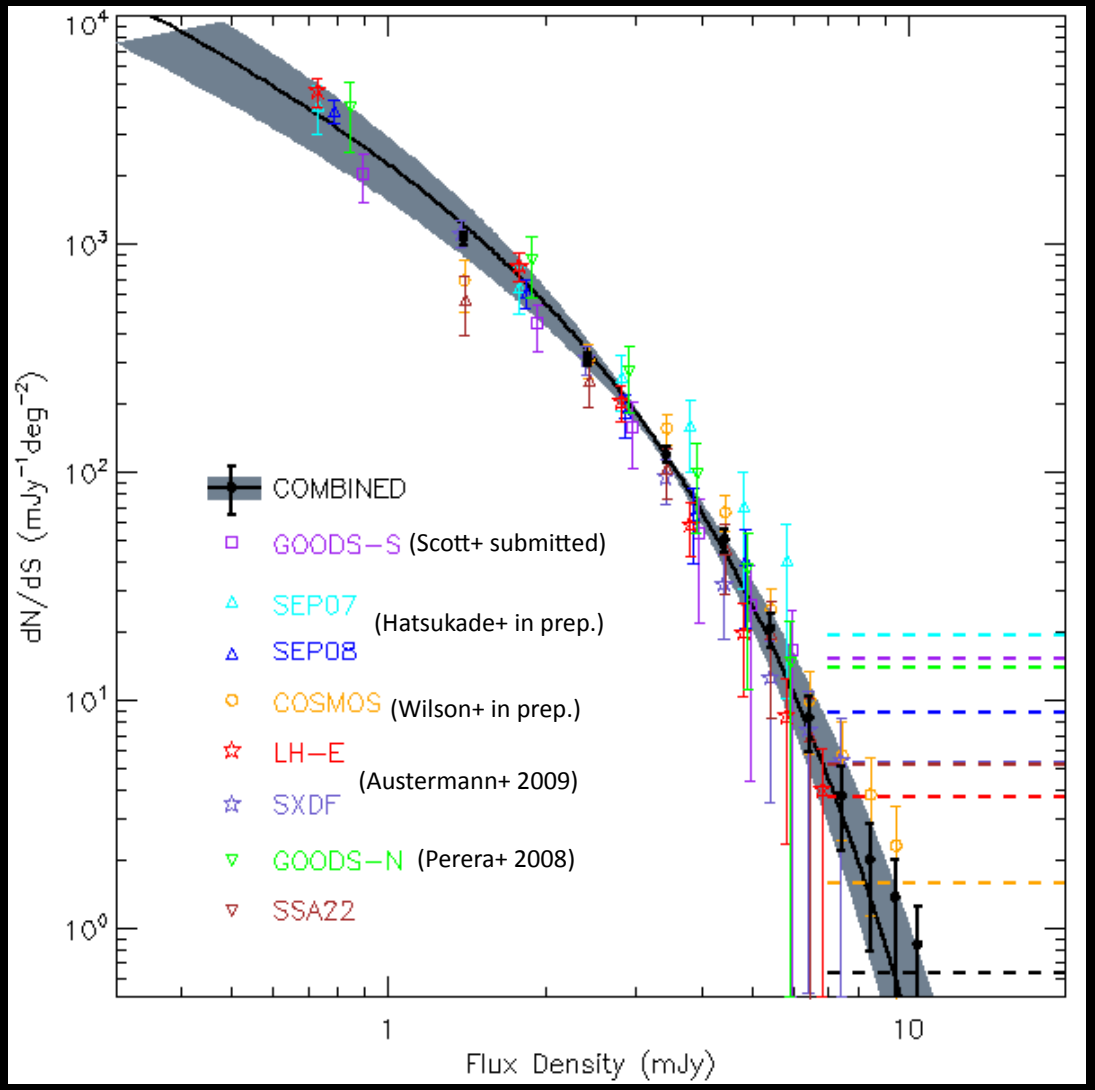
SMG Surveys with AzTEC



AzTEC/ASTE - COSMOS
- 193 sources
- FDR<6%
- 0.75 sq deg. with rms ~ 1.1mJy


SCUBA/SHADES
SXDF
Dunlop et al. 2006
IBO
-N2
e et al. 2004
Known Clusters
Submm survey
2
1.8
1.4
Santa Cruz 8 August 2011
(G. Wilson)

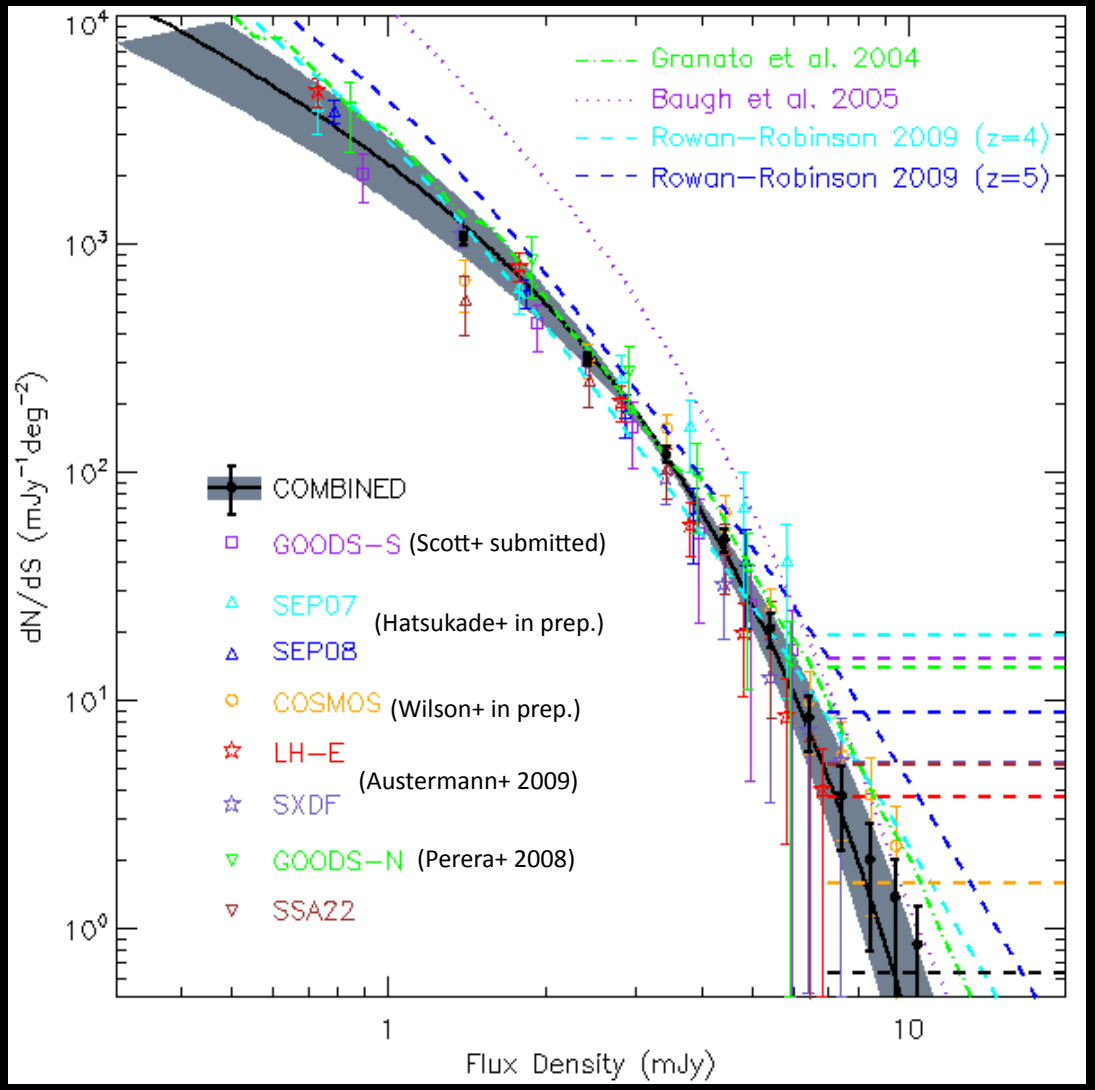
“Blank-Field” SMG Number Counts



Scott et al. in prep

- 838 sources
- 1.74 sq deg.
- New constraints on counts at both bright and faint end

“Blank-Field” SMG Number Counts



Scott et al. in prep

- 838 sources
- 1.74 sq deg.
- New constraints on counts at both bright and faint end
- Models stressed at both ends

Planned Future LMT Continuum Inst.

TolTEC

- 1.1mm imager filling 4' diameter field of view
- ~5000 detectors
- ~36,000 arcmin^2/mJy^2/hr mapping speed

Imaging the entire
2 sq. deg. COSMOS field
to 0.1mJy rms
(SFR~20-30 M_{sun}/yr)
will require only 20 hours.