

HST and Spitzer views of luminous compact blue galaxies



$z \approx 0$: NGC 7673

James Lowenthal

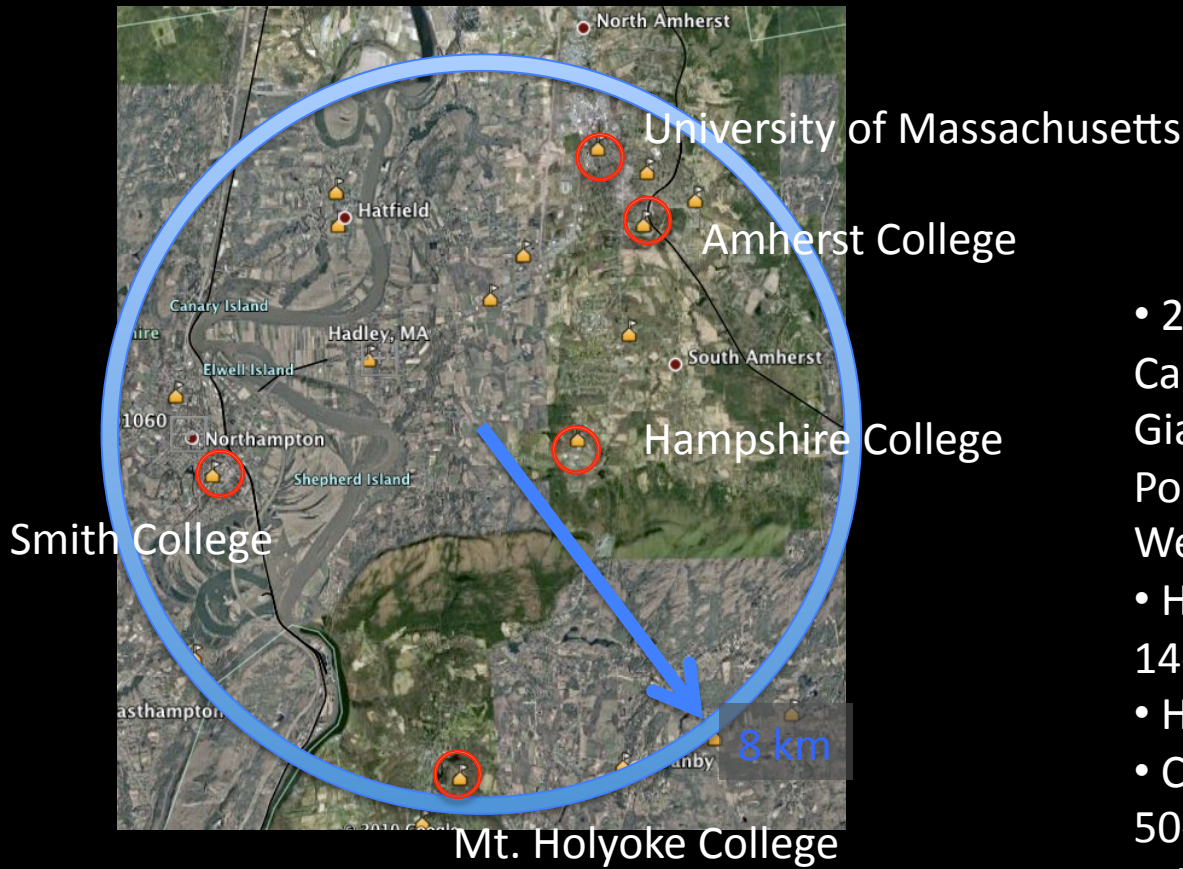
Smith College

Northampton, Massachusetts, USA



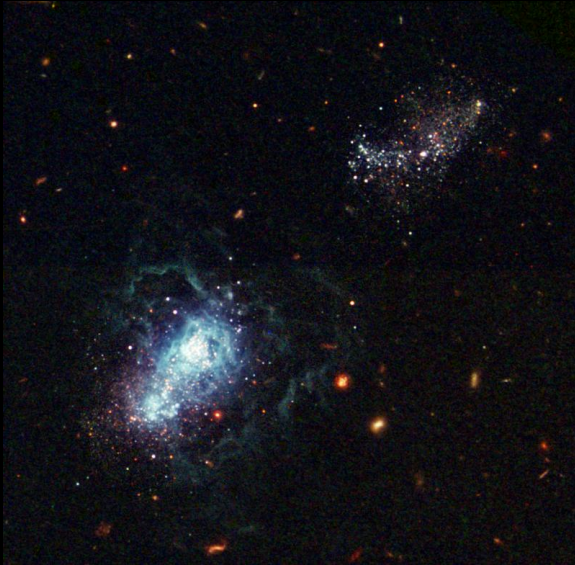
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Smith College/Five College Astronomy Department



- 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?



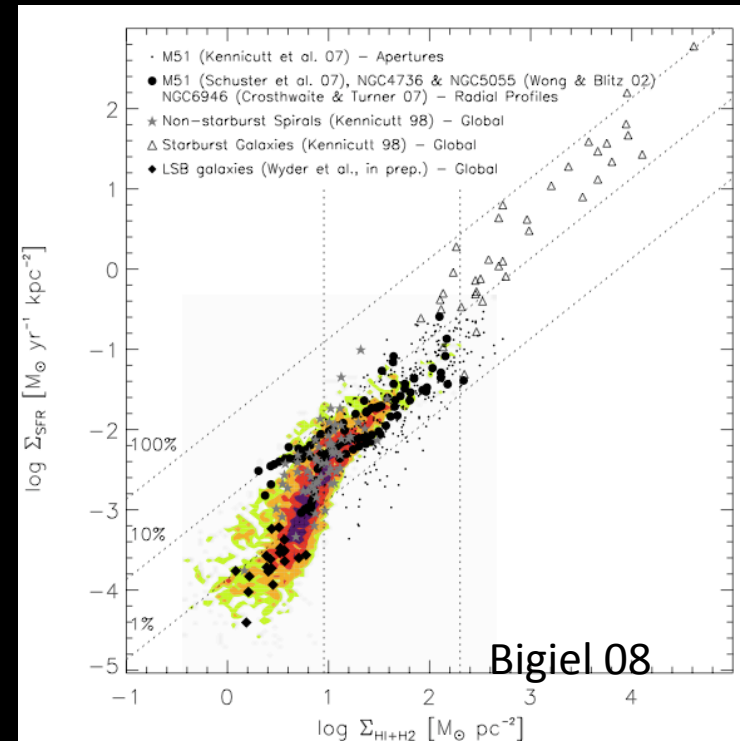
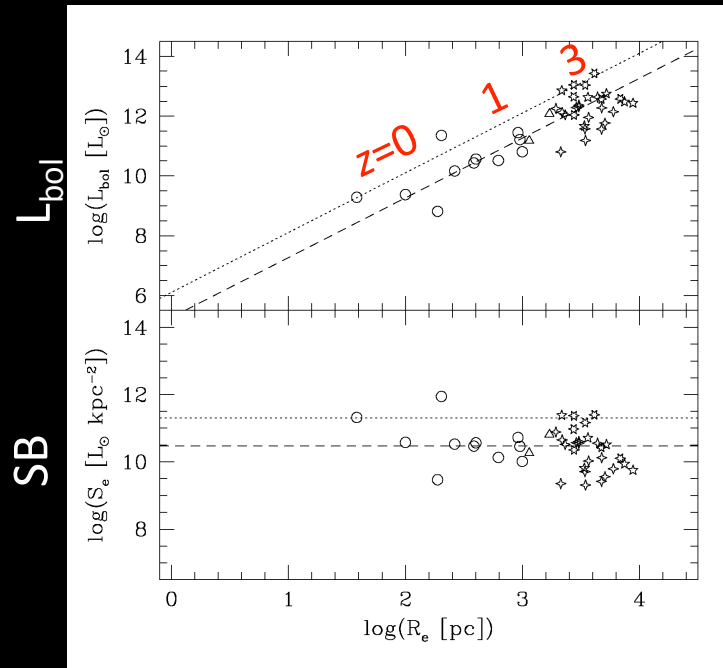
- M82, HII galaxies, ultraluminous infrared galaxies (ULIRGs), break galaxies (LE)
- Note huge range mass, luminosity, morphology, physical conditions, environment



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← 90 kpc ULIRG; Borne →

Star formation in starbursts

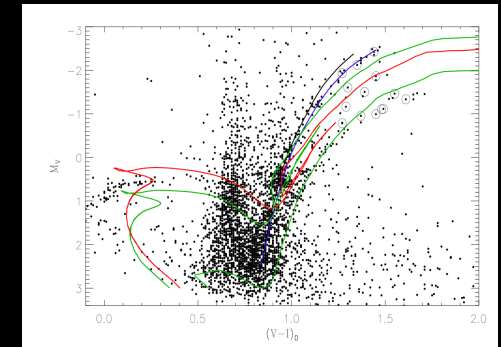


- SBs have extreme
 - specific star formation rate (SSFR) = SFR/M
 - star formation efficiency = SFR/M_{gas}
 - surface brightness
- SB's obey Schmidt-Kennicutt, but with different mode (low SF, high SFE) of SF than in non-SB galaxies? (BzK's: Daddi...)

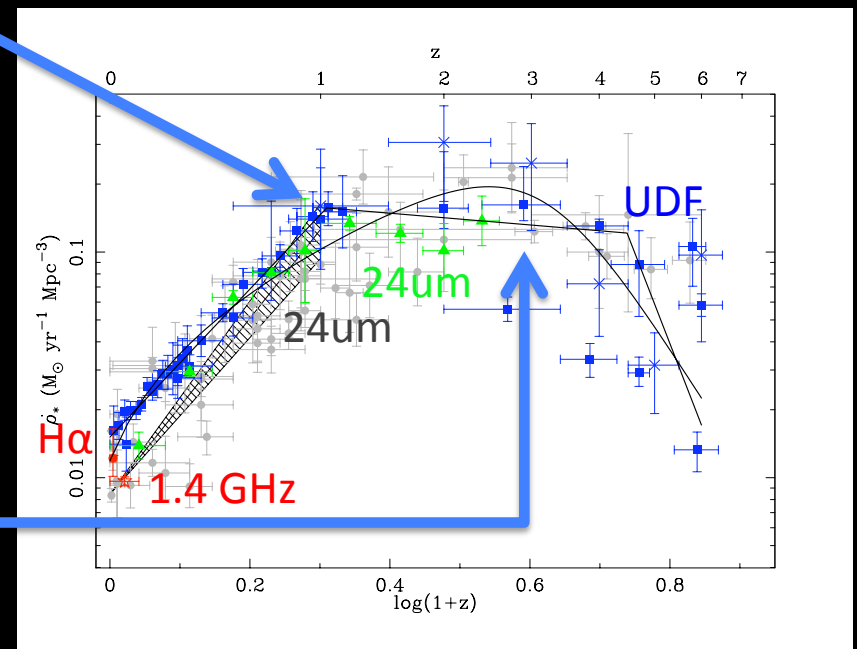
Role of starbursts in galaxy formation and evolution?

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 $\sim 10\text{-}100 M_{\odot}/\text{year}$; LF provides enough for $>10\%$ of current stars in galaxies (esp. if dust correction is large)



Smecker-Hane



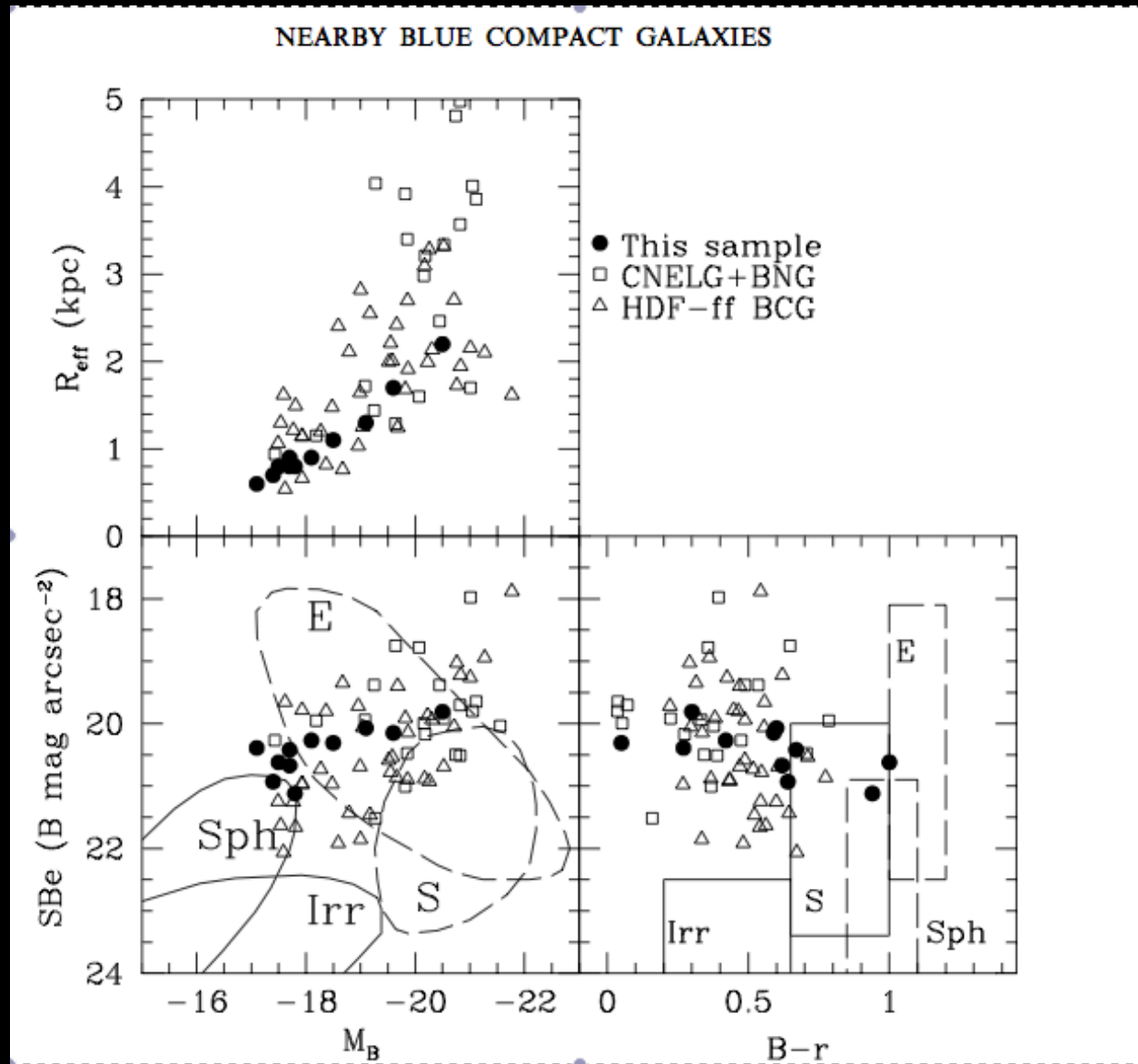
Luminous Blue Compact Galaxies = LCBGs

- $L \sim L^*$ but tiny, $r_e \sim 2 \text{ kpc}$ (L_{M31} , r_{N205})
- Extreme starbursts
 $10\text{-}20 M_{\odot}/\text{yr}$
- High surface brightness
 $\mu_B < 21 \text{ mag/arcsec}^2$
- Narrow emission lines
 $30\text{-}120 \text{ km/s}$
- Low masses $< 10^{10} M_{\odot}$
- $M_{\text{burst}}/M_{\text{tot}} > 10\%$ (from O/IR SEDs)
- Strong evolution: 40% of SF \uparrow 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



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**



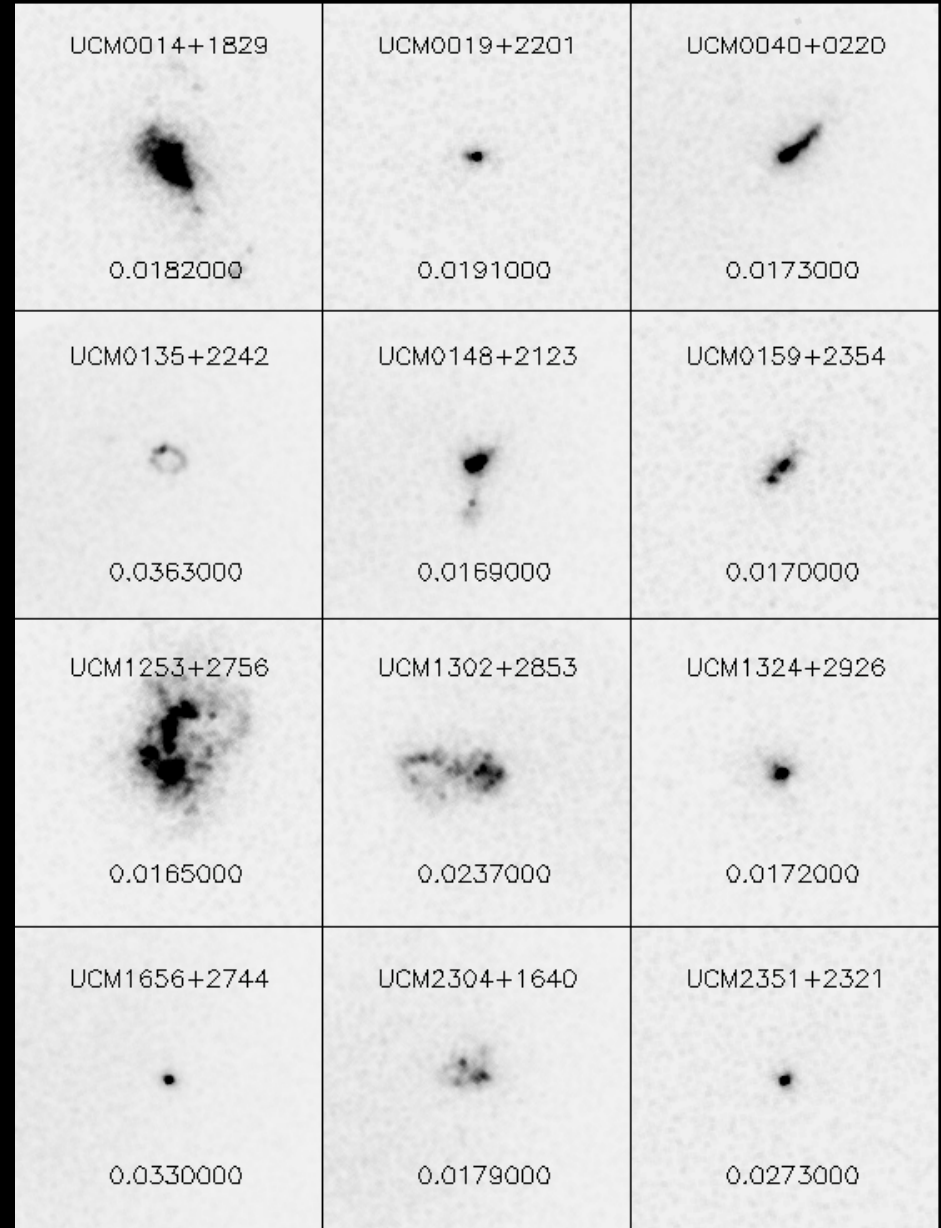
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STIS FUV images of $z \sim 0$ sample

Morphologies: VERY diverse, disturbed, multiple knots, rings, etc.

No definitive merger signature (vs. Overzier 08, 09, 10), but several could be mergers

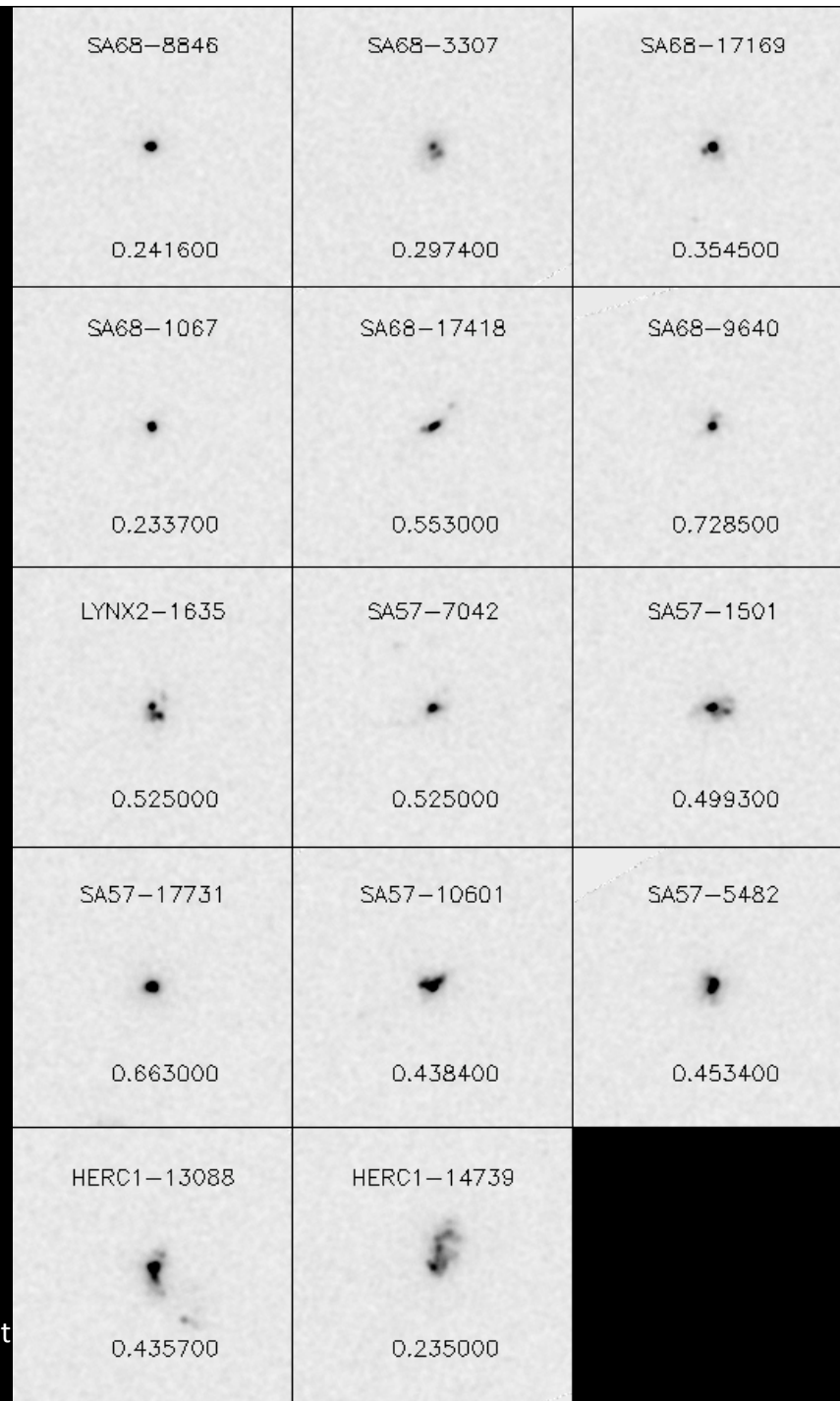
18" = 6 kpc



STIS NUV images of $z < 1$ sample

9" ~ 31-66 kpc

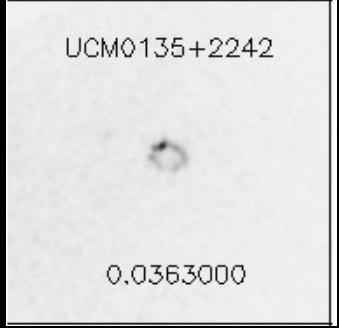
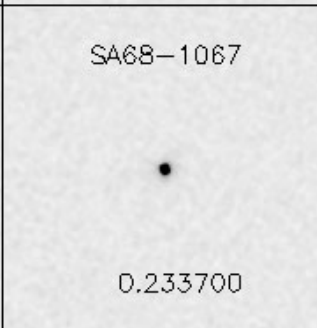
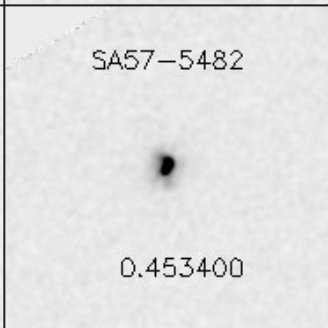
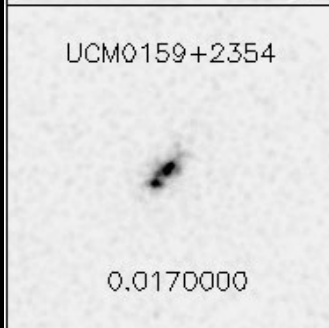
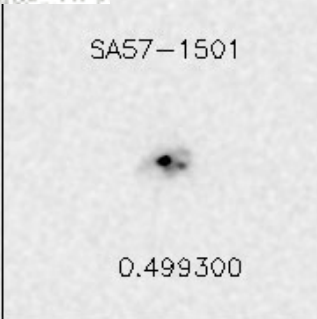
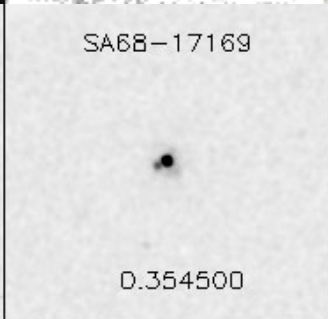
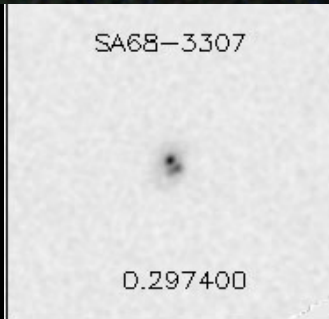
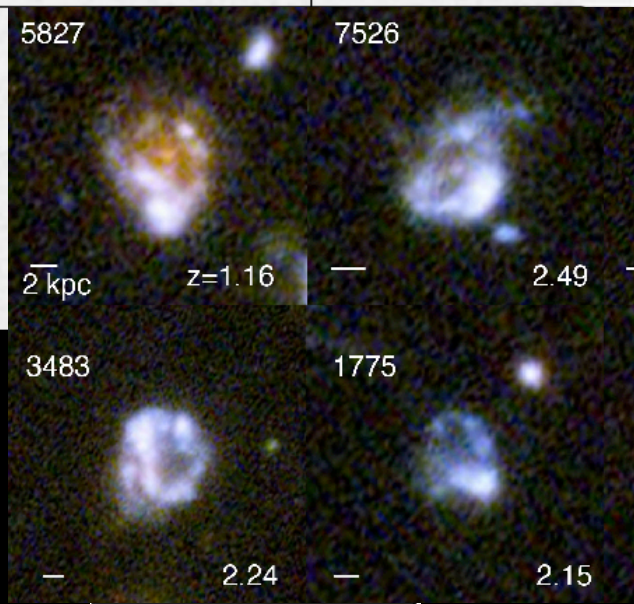
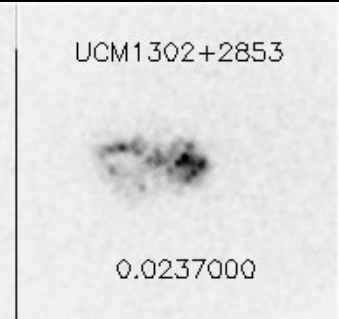
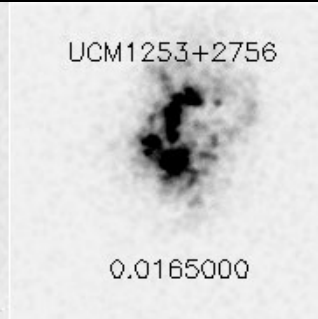
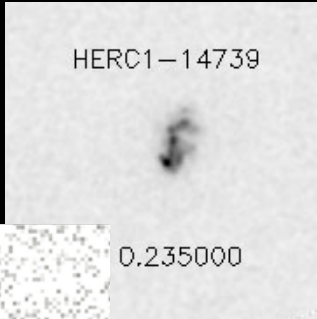
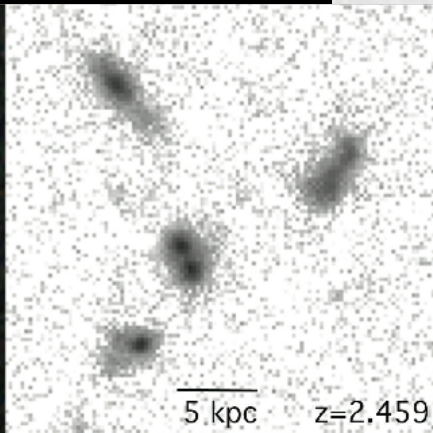
Morphologies: again, disturbed, multiple knot systems, but some nearly unresolved



FUV morphologies

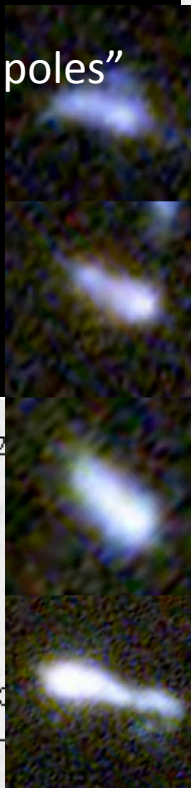
extended

Elmegreens' high-z "clumps"



FUV morphologies

Elmegreens' high-z "tadpoles"



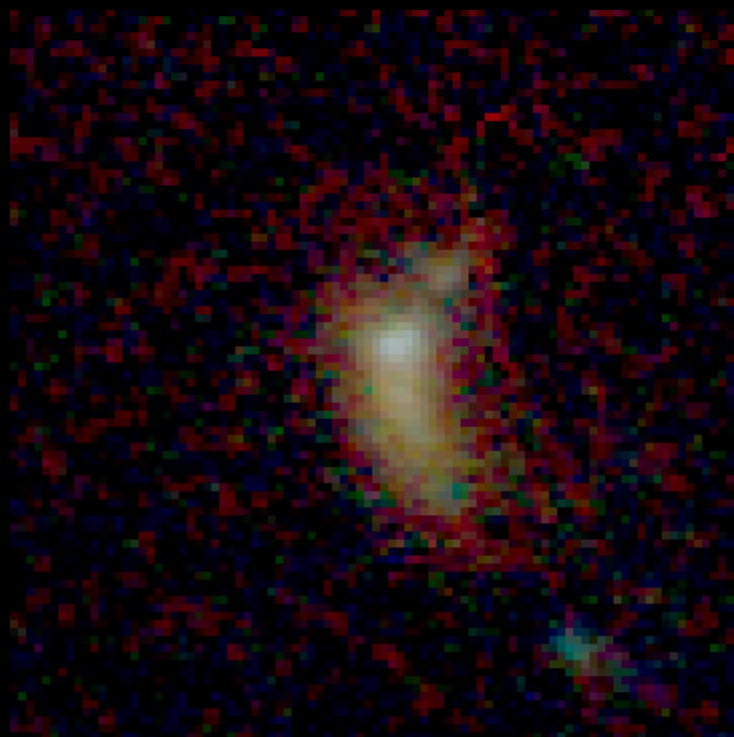
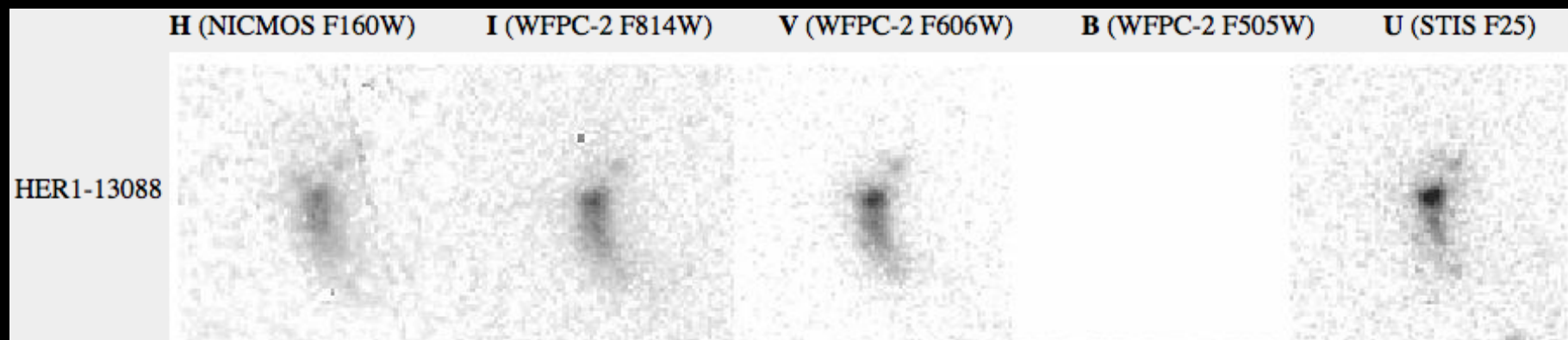
linear

compact

UCM0148+2123 0.0169000	UCM0040+02 0.0173000
HERC1-13088 0.435700	SA68-17418 0.553000

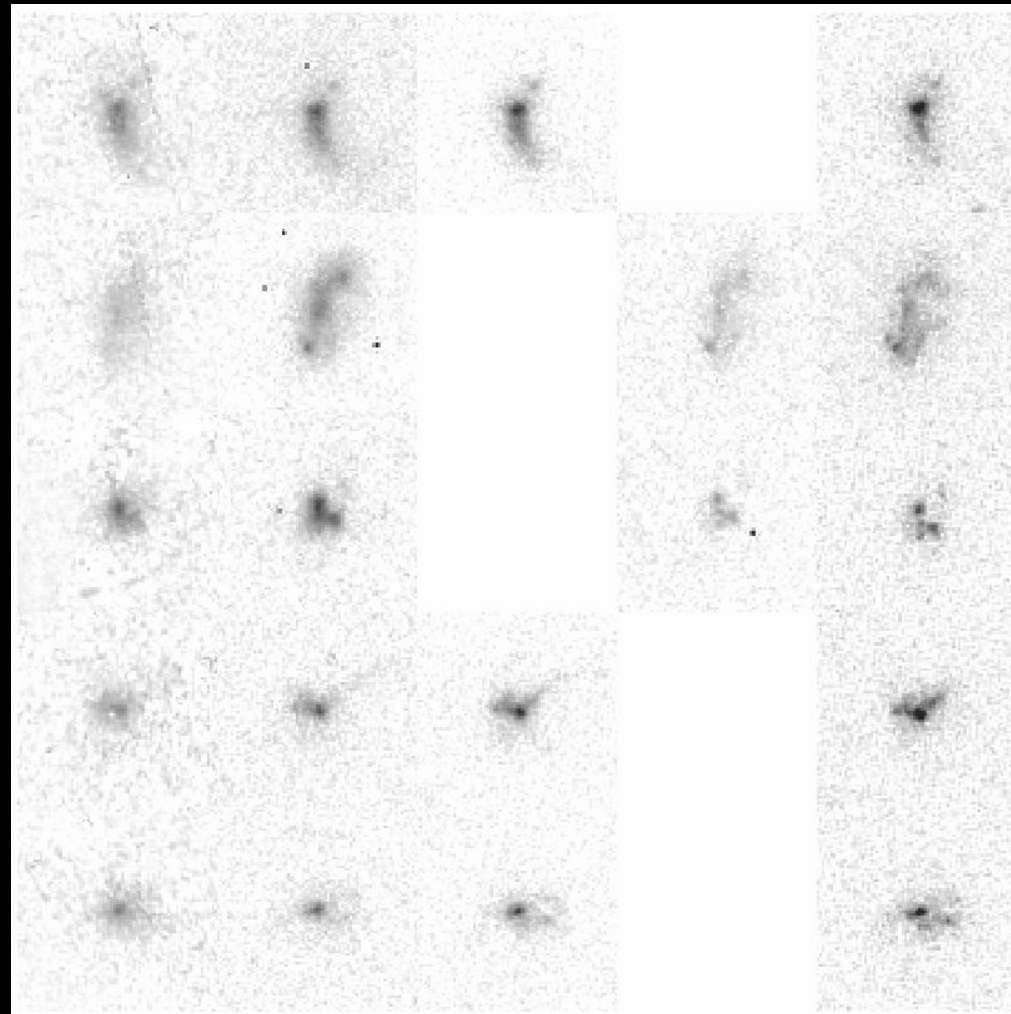
SA68-8846 0.241600	SA57-7042 0.525000	SA57-17731 0.663000
SA68-1067 0.233700	SA68-9640 0.728500	UCM0019+2201 0.0191000
UCM1656+2744 0.0330000	UCM1324+2926 0.0172000	UCM2351+2321 0.0273000

Morphologies similar NIR-Opt-UV

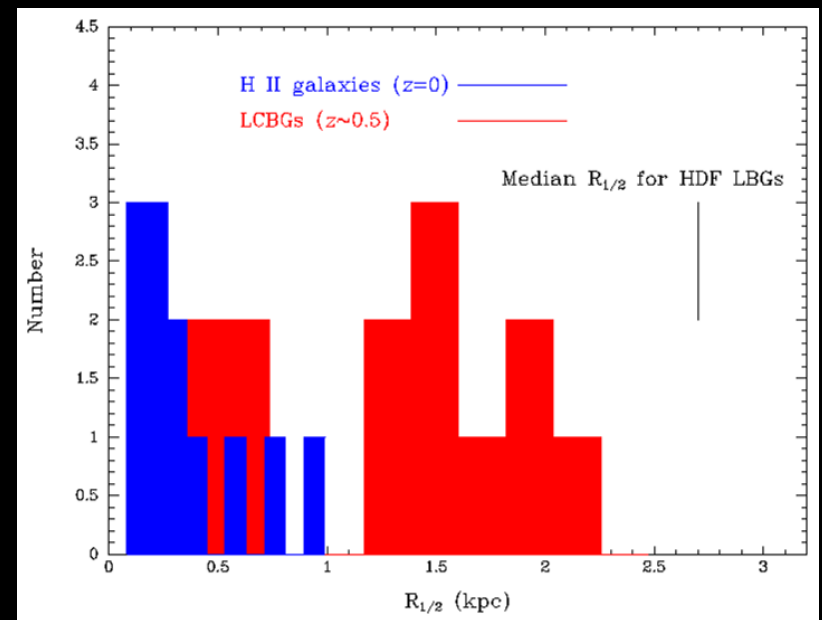
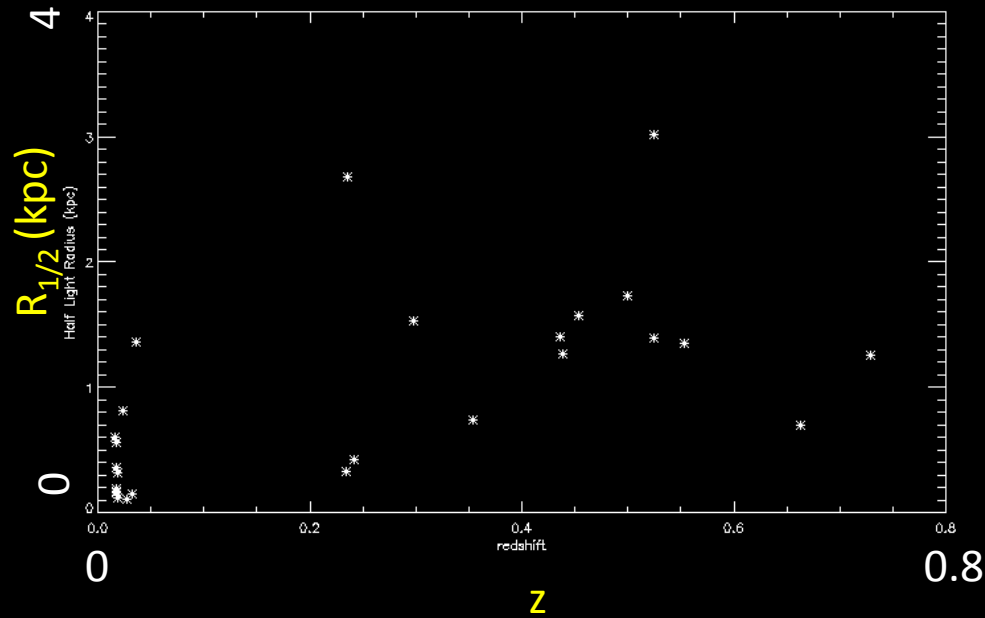


HST Morphologies similar NIR-Opt-UV

H /160 I/814 V/606 B/505 U/25

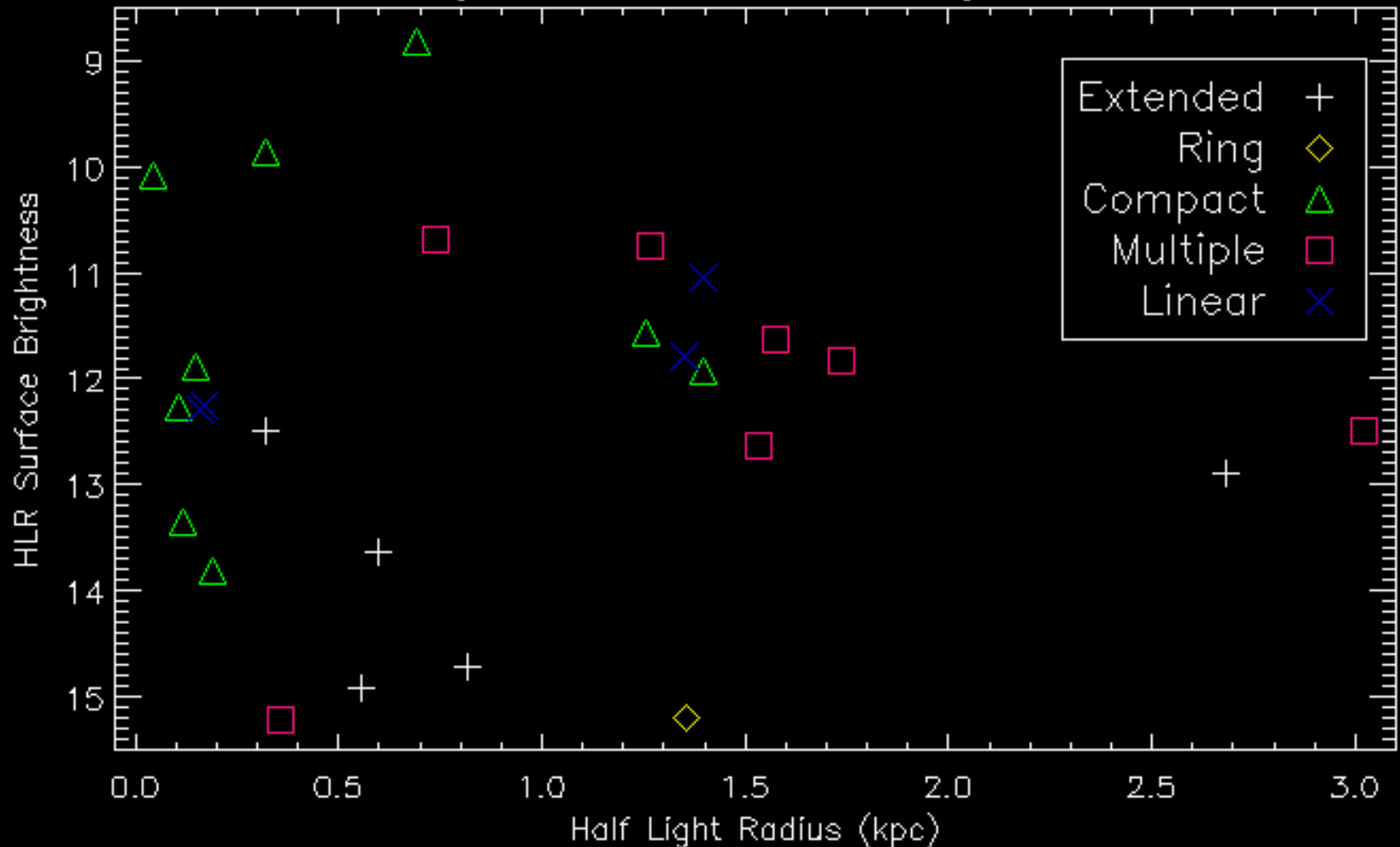


LBGs are small; LCBGs are smaller



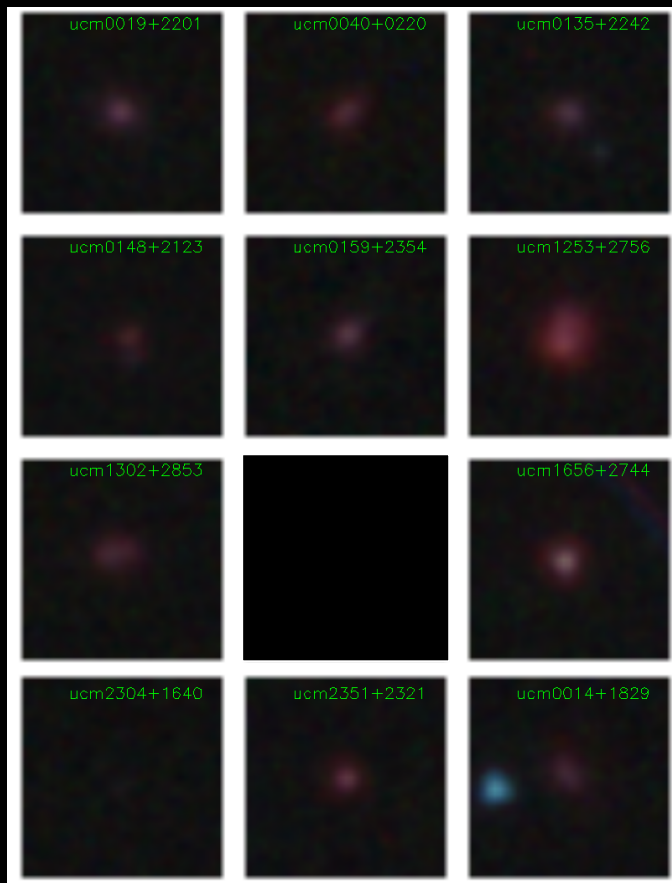
FUV Morphology correlates loosely with size, SB

HalfLight Radius SB vs. Half Light Radius



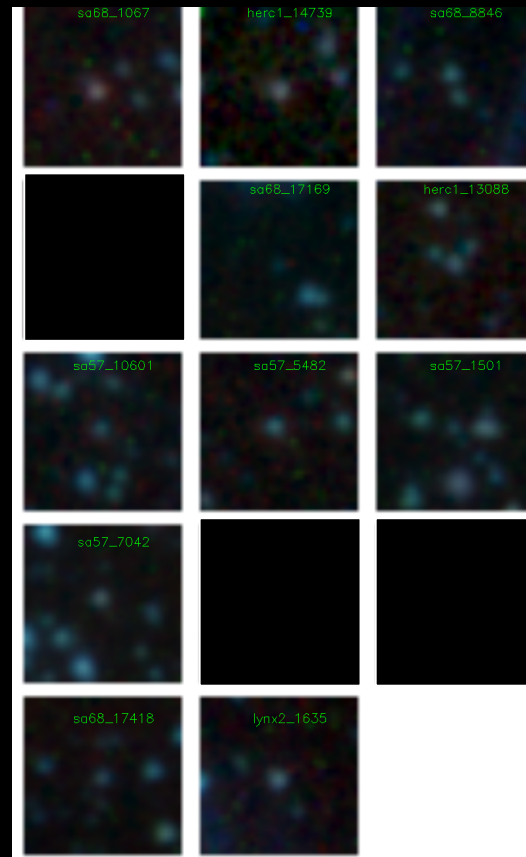
Spitzer/IRAC+MIPS photometry

$z \sim 0$ UCM galaxies



30" ~ 12 kpc

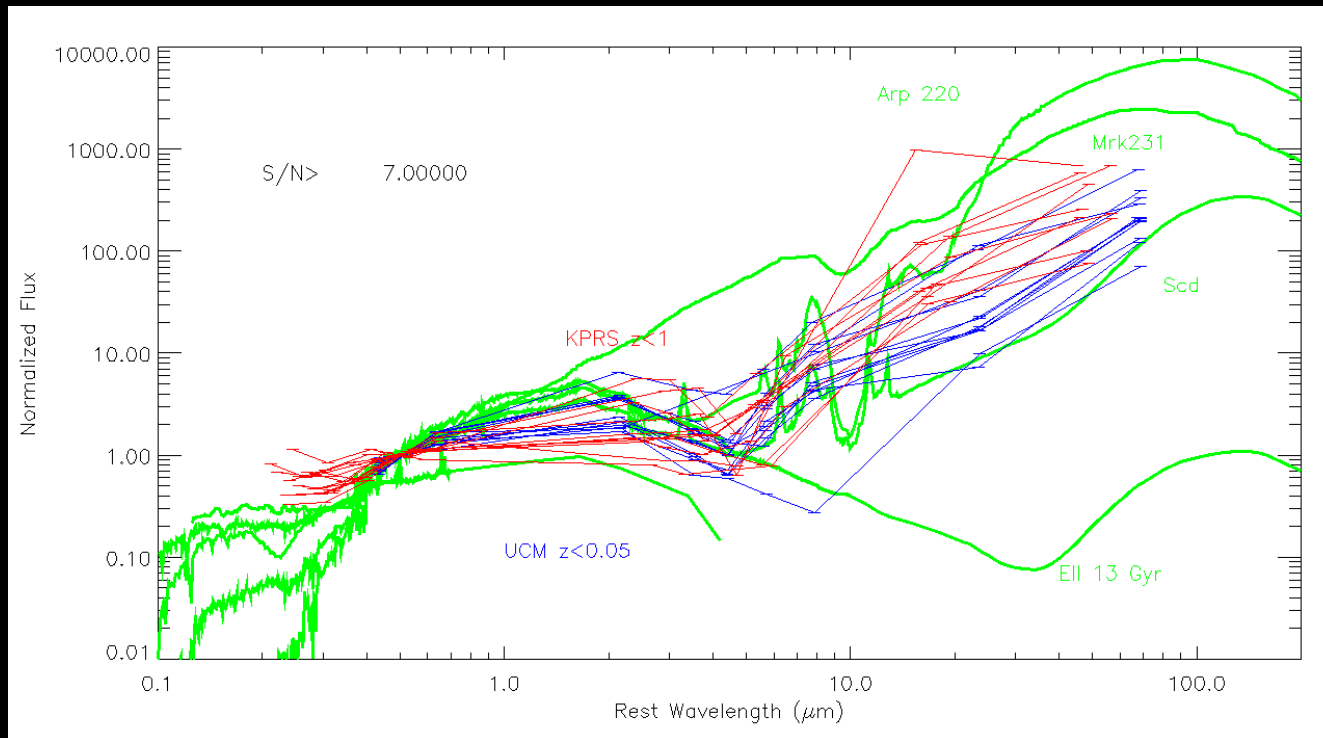
$z < 1$ LCBGs



30" ~ 170 kpc

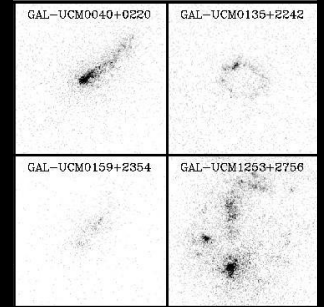
IRAC
ch 1,2,3

Spectral Energy Distributions



Strong 24, 70 μm detections...
...but little/no evidence for hidden dusty SFR

Conclusions on LCBGs at $z < 1$

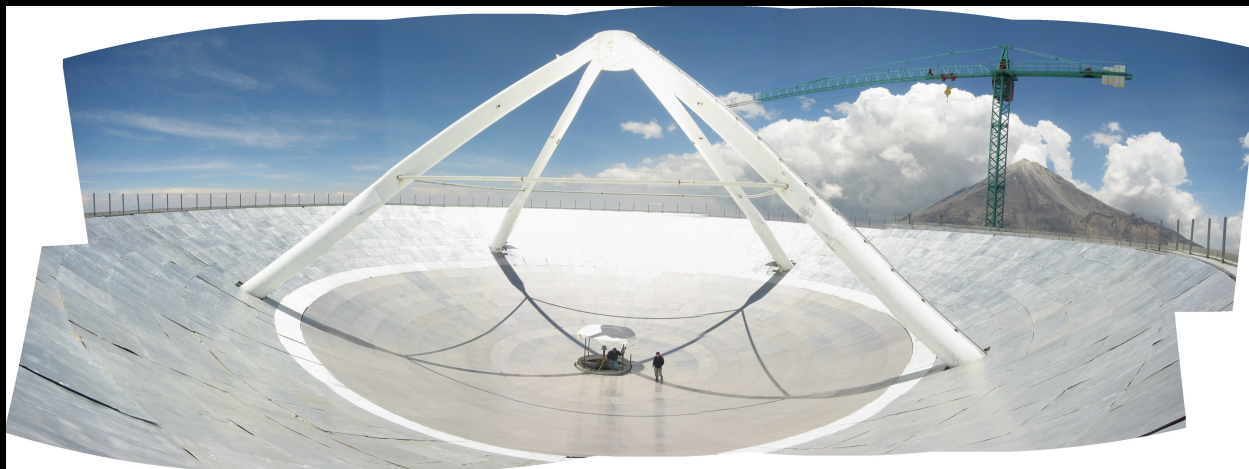


- LCBGs and HII galaxies are excellent local analogs of LBGs: FUV morphologies, sizes, colors, SF props, masses all in continuum with LBGs.
- rest-UV images show star formation in wide range of morphologies, from rings to compact nuclei. Almost all within 2 kpc radius, but not “nuclear” starbursts.
- 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

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50-m Large Millimeter Telescope/Gran Telescopio Millimetrico

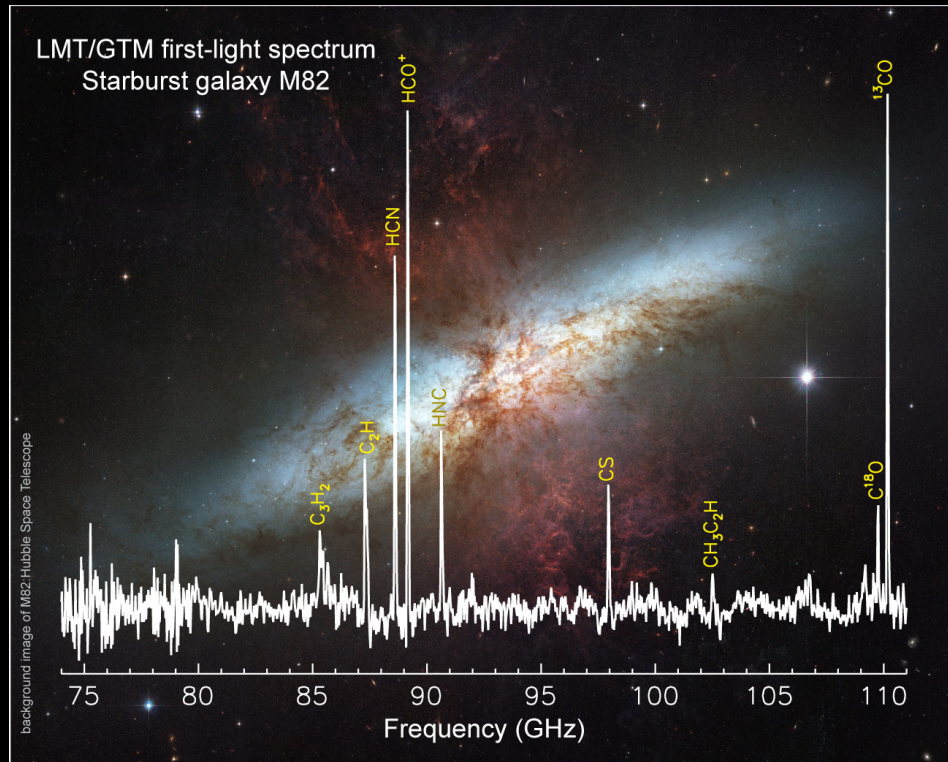
- UMass + Mexico
- \$140M; largest science project ever for Mexico
- Cierra la Negra (5000m)
- 65 μm (rms) active surface
- 6" FWHM beam at 1 mm
- Pointing to 1"
- AzTEC, Redshift, SEQUOIA, SPEED
- 1000's of SMGs/night; pathfinder for ALMA



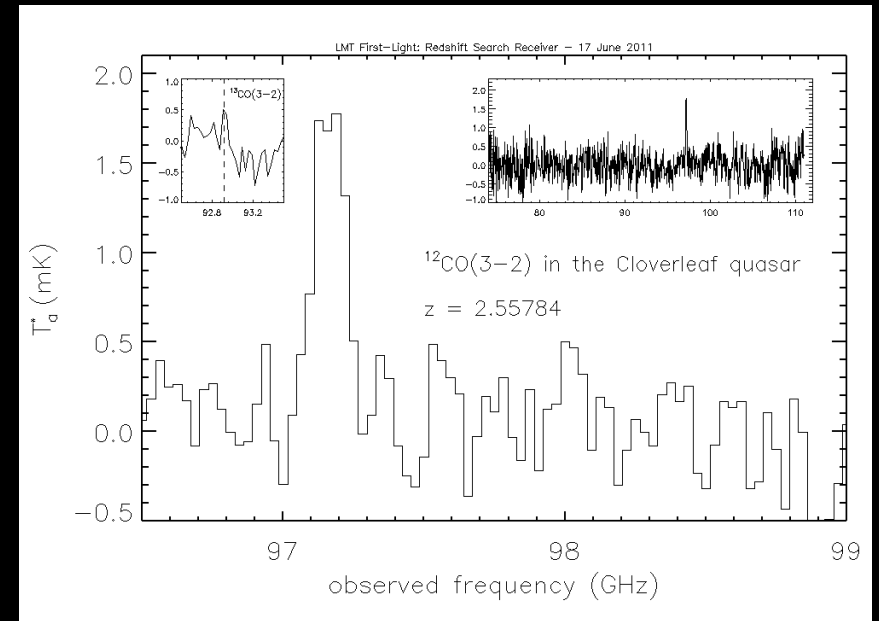
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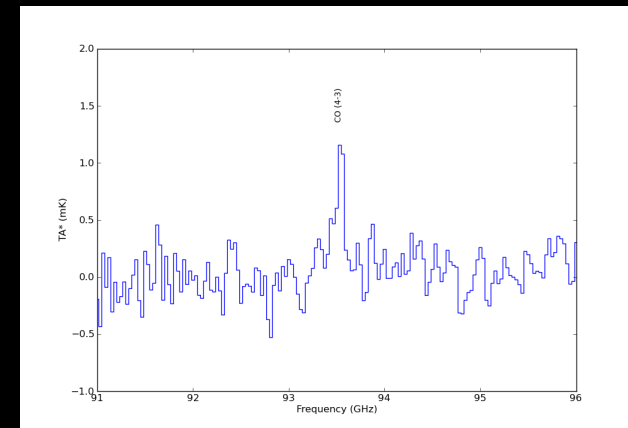
June 2011: LMT sees First Light!



Redshift Search Receiver delivers 38GHz bandwidth

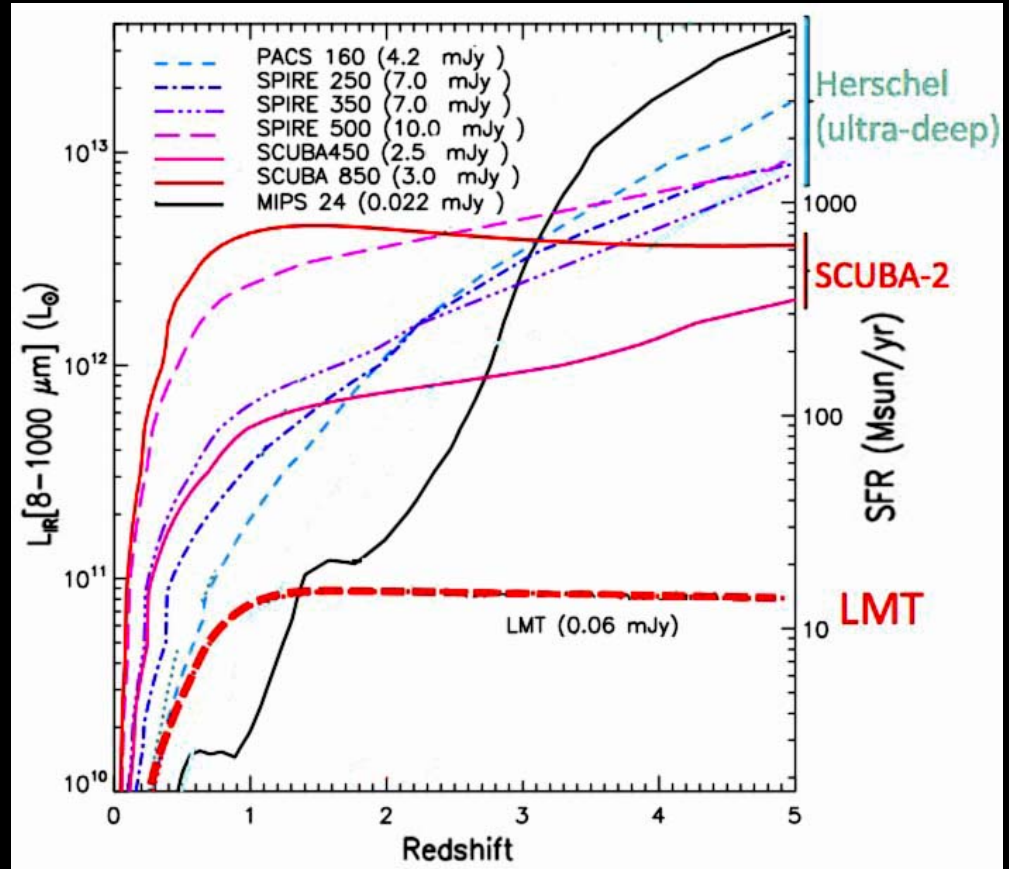


Cloverleaf ($z=2.558$)



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SMG MMJ18423+5938 ($z=3.930$)



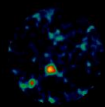
(figure courtesy M. Dickinson/D. Elbaz)

Instrument	Resolution	Mapping Speed [arcmin ² /mJy ² /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

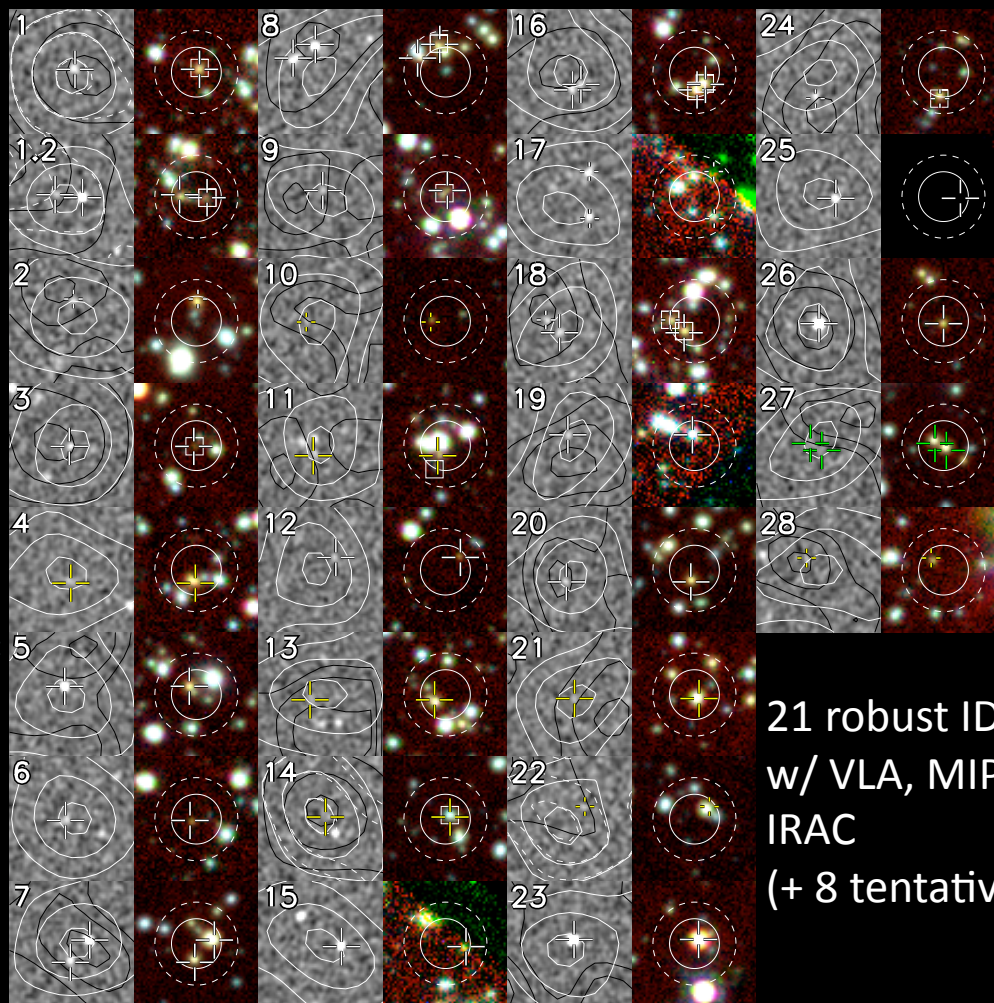
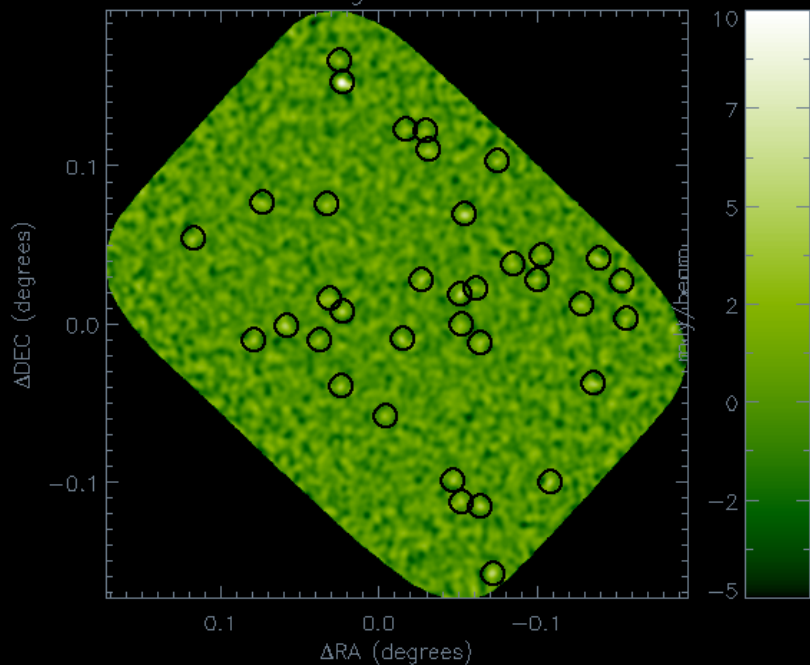
SMG Surveys with AzTEC



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

AzTEC/GOODS-N
245 arcmin²

3.5 Sigma Sources



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

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

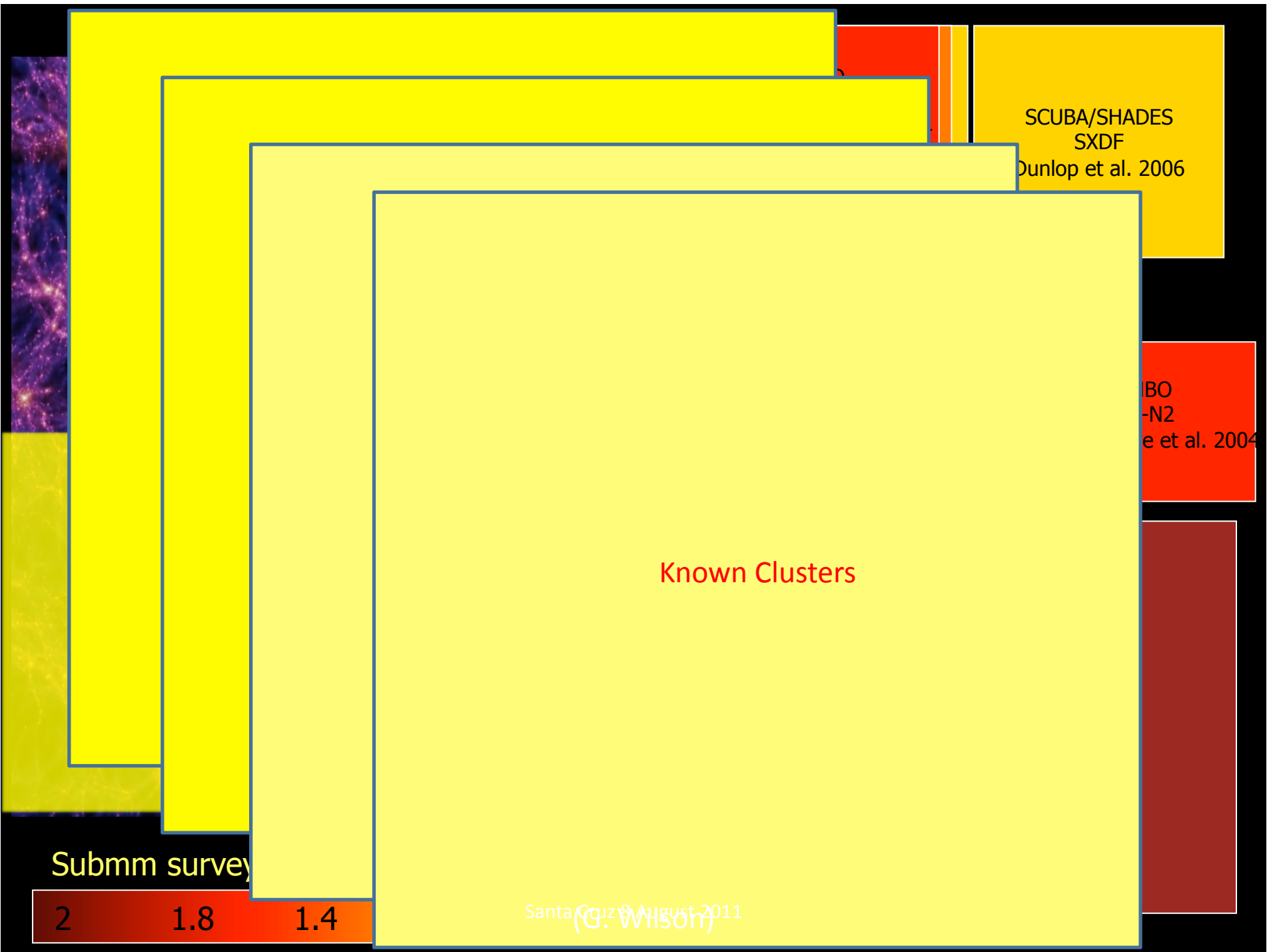
Chapin 09

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SMG Surveys with AzTEC

The background of the slide is a circular field of view filled with a noisy, multi-colored pattern representing a submillimeter galaxy survey. The colors range from dark blue to bright yellow, indicating different intensity levels. Numerous small green circles are scattered across the field, representing individual detected sources.

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



SCUBA/SHADES
SXDF
Dunlop et al. 2006

BO
-N2
e et al. 2004

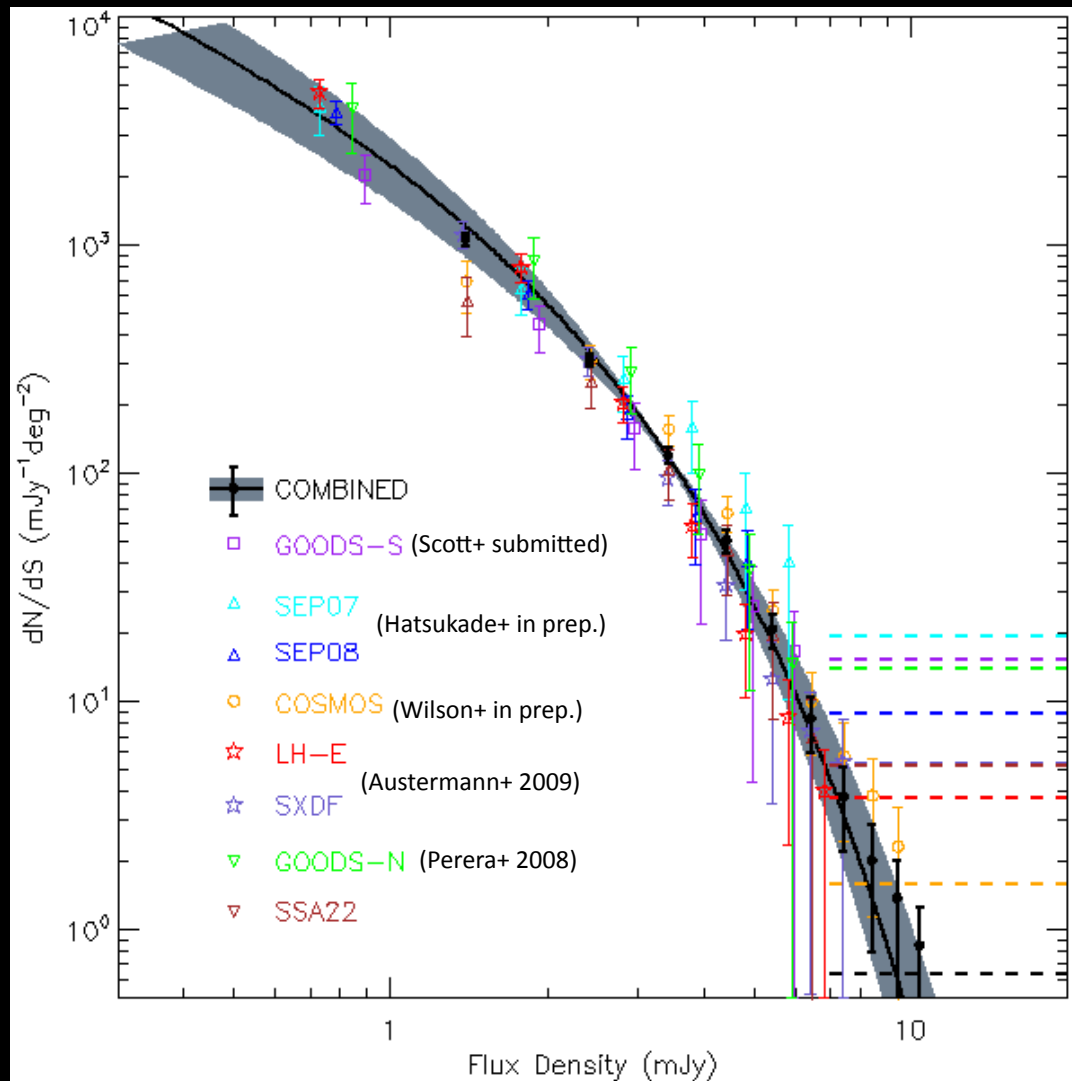
Known Clusters

Submm survey

2 1.8 1.4

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(G. Wilson)

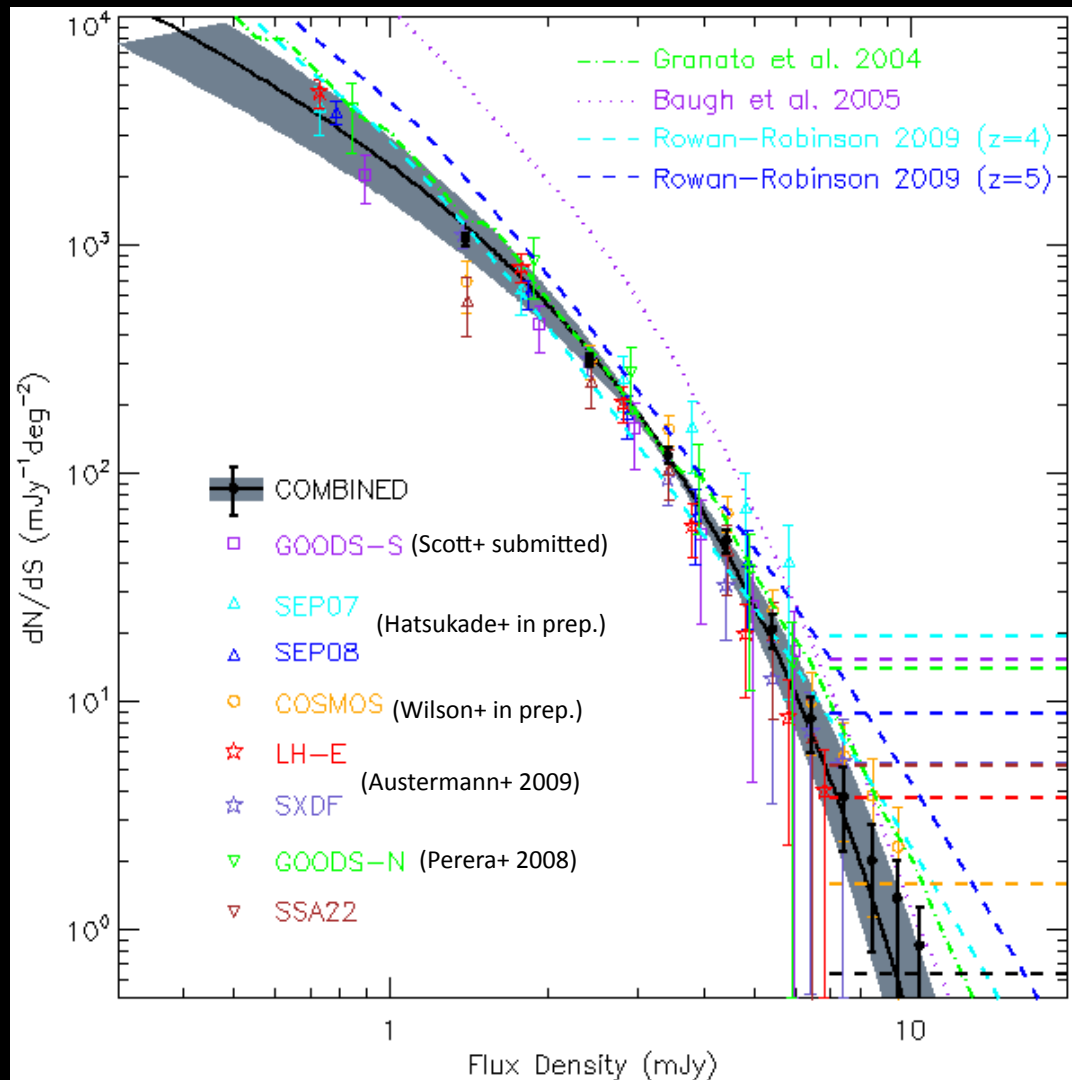
“Blank-Field” SMG Number Counts



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.

ToITEC

- 1.1mm imager filling 4' diameter field of view
- ~5000 detectors
- ~36,000 arcmin²/mJy²/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.

