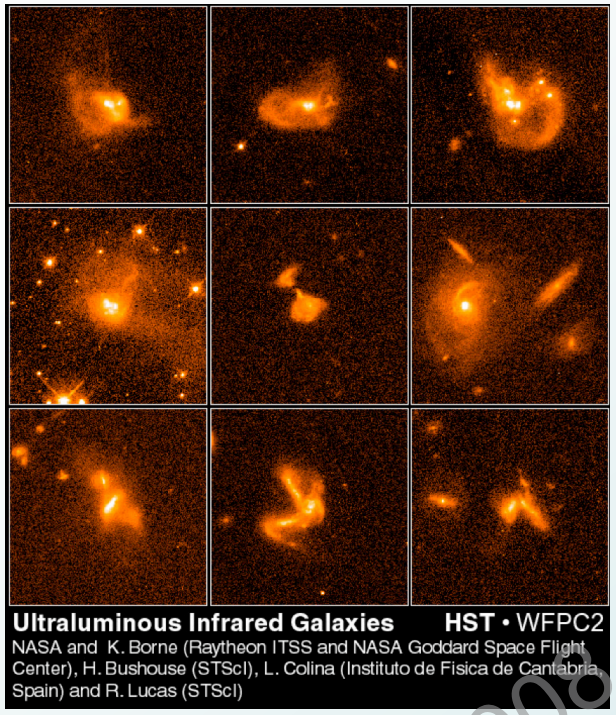
Living fossils: New Clues on Distant Starburst Galaxies based on local Analogs of Lyman break galaxies

Roderik Overzier (MPA)
Tim Heckman (JHU) - Guinevere Kauffmann (MPA)
& The GALEX ScienceTeam

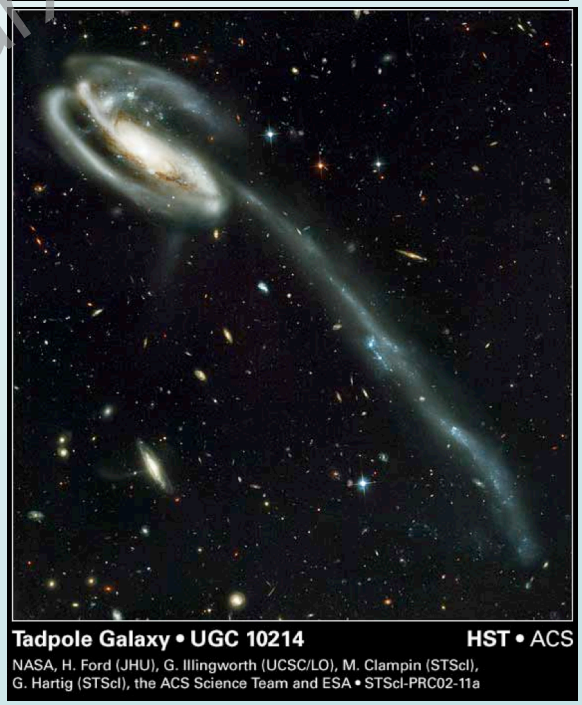
It is well established that galaxy interactions and mergers lead to enhanced star formation (starbursts)



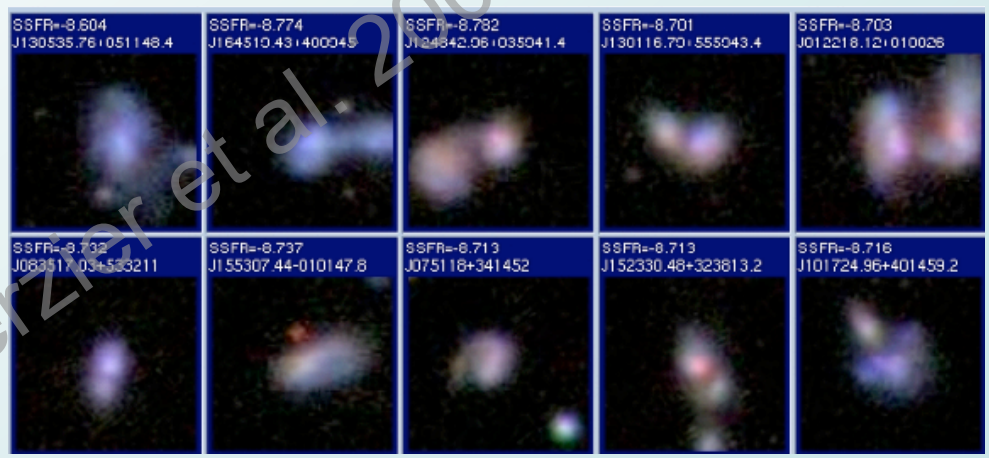
Ultraluminous Infrared Galaxies **HST** • WFPC2
NASA and K. Borne (Raytheon ITSS and NASA Goddard Space Flight Center), H. Bushouse (STScI), L. Colina (Instituto de Fisica de Cantabria, Spain) and R. Lucas (STScI)

Colliding Galaxies NGC 4038 and NGC 4039 HST • WFPC2
PRC97-34a • ST ScI OPO • October 21, 1997 • B. Whitmore (ST ScI) and NASA

The Mice • Interacting Galaxies NGC 4676 **HST** • ACS
NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), the ACS Science Team and ESA • STScI-PRC02-11d

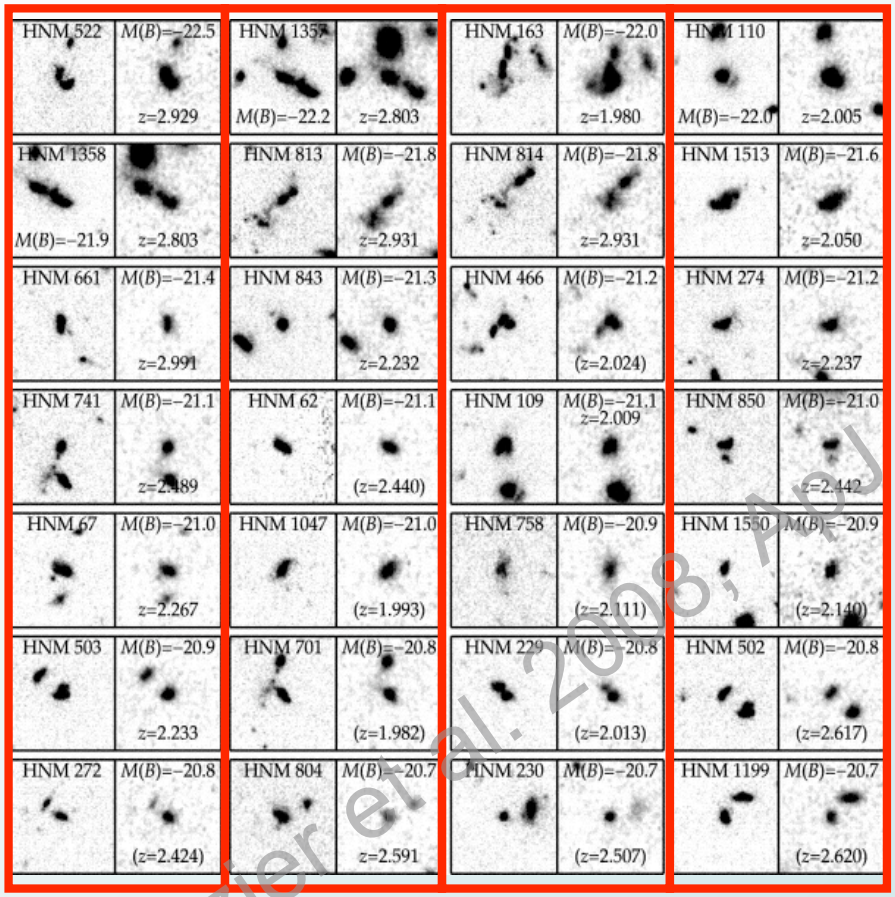


Tadpole Galaxy • UGC 10214 **HST** • ACS
NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), the ACS Science Team and ESA • STScI-PRC02-11a



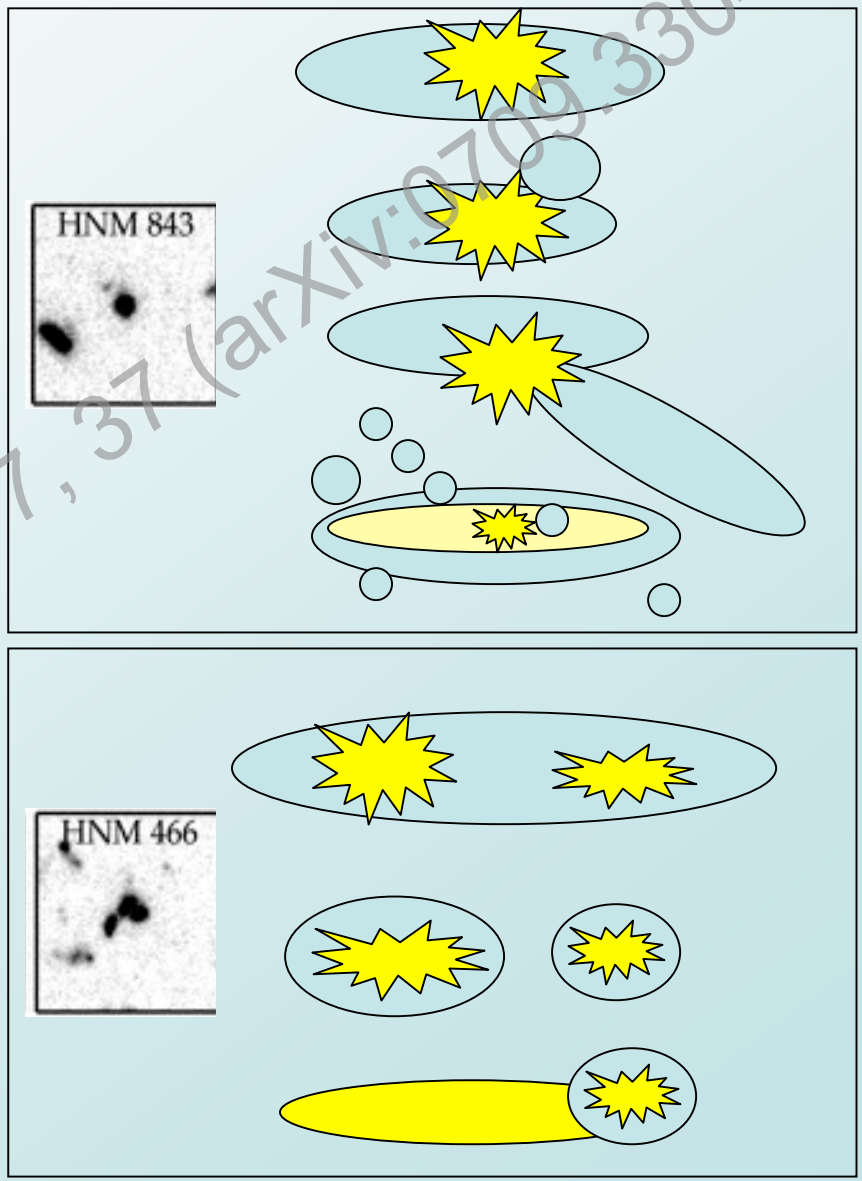
Cheng Li et al. 2008a

LBGs at z=3-6 are compact with very similar morphologies in the rest-frame UV and optical:



Papovich et al. (2005)

But the morphologies do not tell us all that much:



Finding Local Analogs to Lyman break galaxies

Why study LBGs?

- LBGs are the dominant star forming population at high redshift (2<z<10)
- mostly young & little dust (Lya?), low to moderate mass / but some are quite old
- represent major, early phase in galaxy formation (proto-galaxies that may merge to form massive red galaxies by z=0-2)
- what are the mechanisms that form them (merging, accretion, etc)?
- what is the evidence that BH are forming/accreting (AGN fraction only 1-3%)

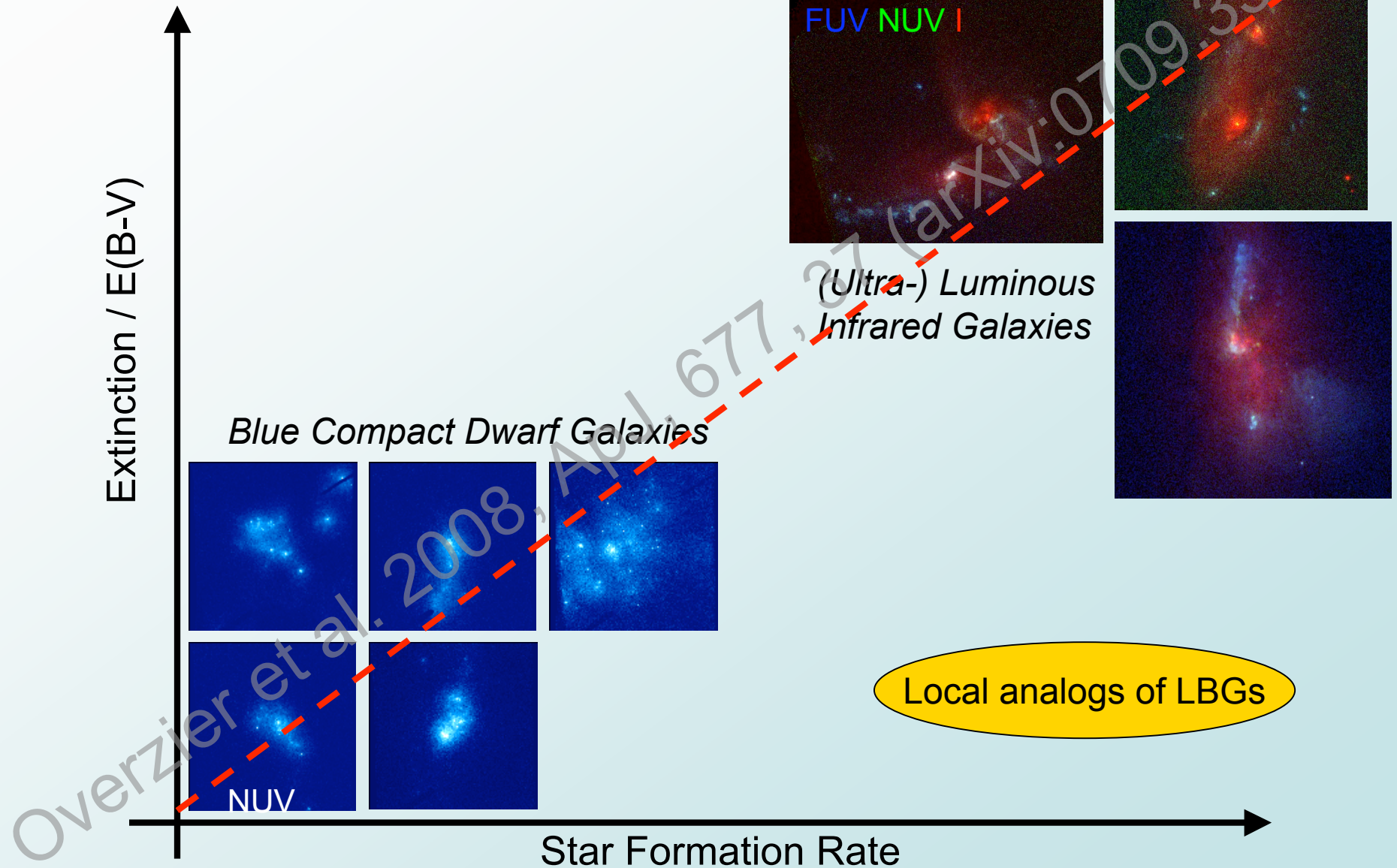
Advantages of having a local sample of LBG analogs:

- not affected by cosmological surface brightness dimming (~10-250x for z=1-3)
- spatial resolution up to ~5 times better (~1 kpc at z=1-3 to ~200 pc at z=0.1)
- all important spectral line diagnostics are in the rest-frame optical

Local starbursts have been used to study LBG properties, but this is problematic:

- Ordinary late-type galaxies (too large, too low SFR)
- Blue compact dwarf galaxies (right metallicity and dust, but too low SFR)
- Luminous infrared galaxies (right SFR, but too much dust, metals and mass)

Strong Correlation between SFR and extinction in Starbursts in the local Universe:



Discovery of a significant GALEX/SDSS sample of local LBG analogs

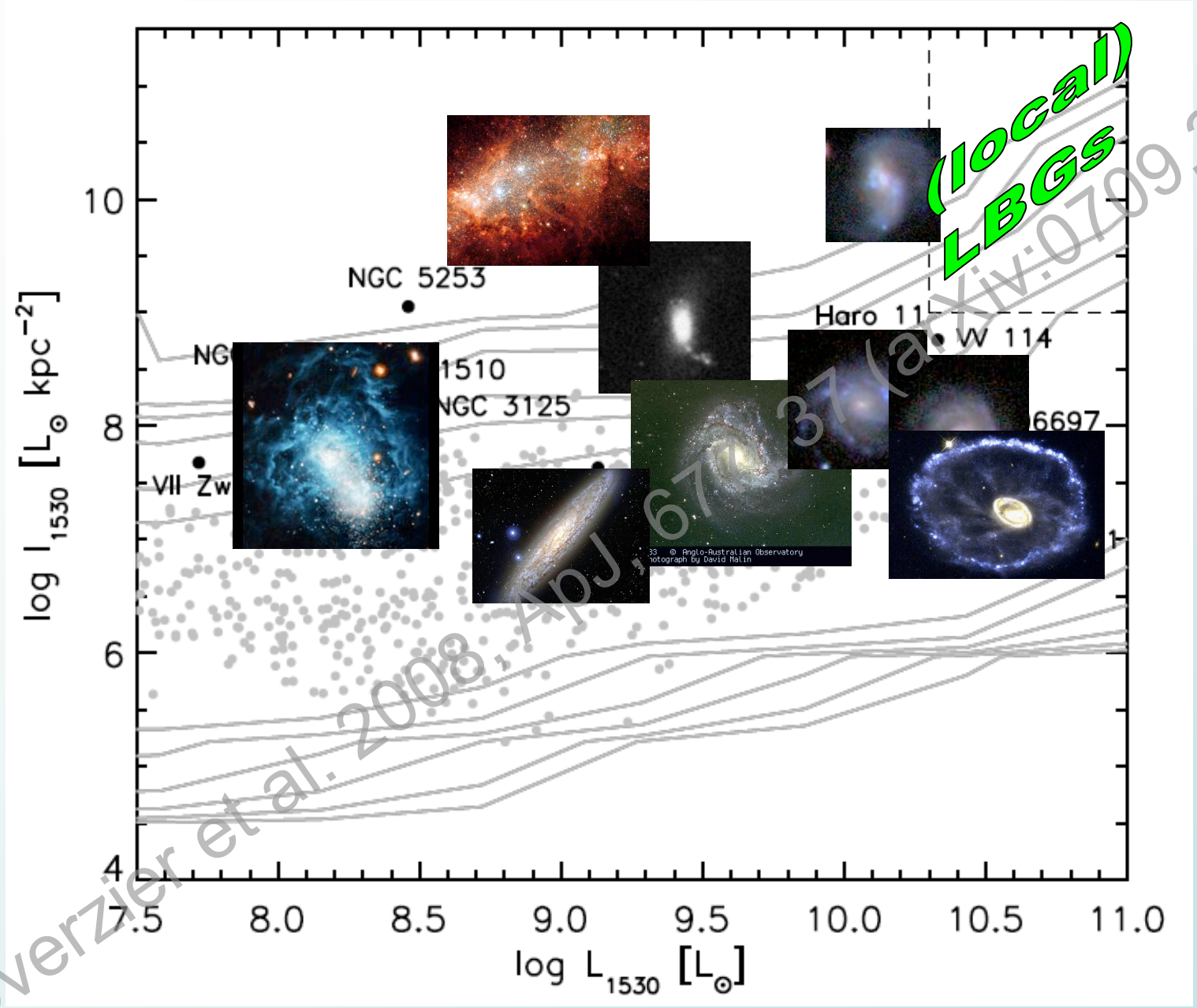
GALEX (PI: Chris Martin)

- NASA small explorer
- UV satellite with 40 cm mirror
- Capable of imaging in the Far- (1500A) and near-UV (2300A)
- PSF ~4-5 arcsec
- Survey telescope probing local (z=0-1) star formation history

Heckman et al. (2005) made a crossmatch between SDSS and the GALEX All-sky Imaging Survey

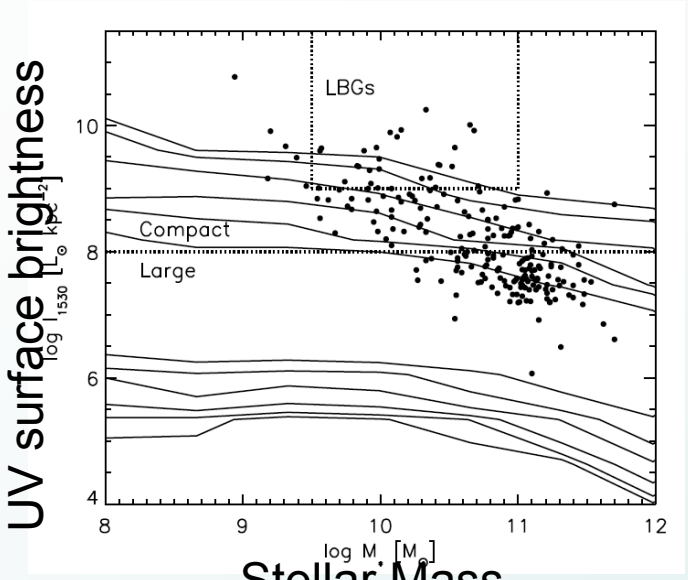
To match typical selection criteria of LBGs at high redshift:

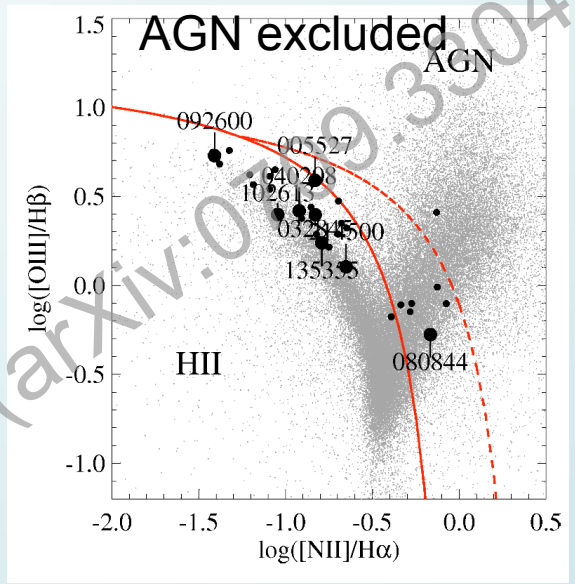
search for objects having both a large L_{FUV} (SFR) and a large FUV surface brightness (compact in size), like this:

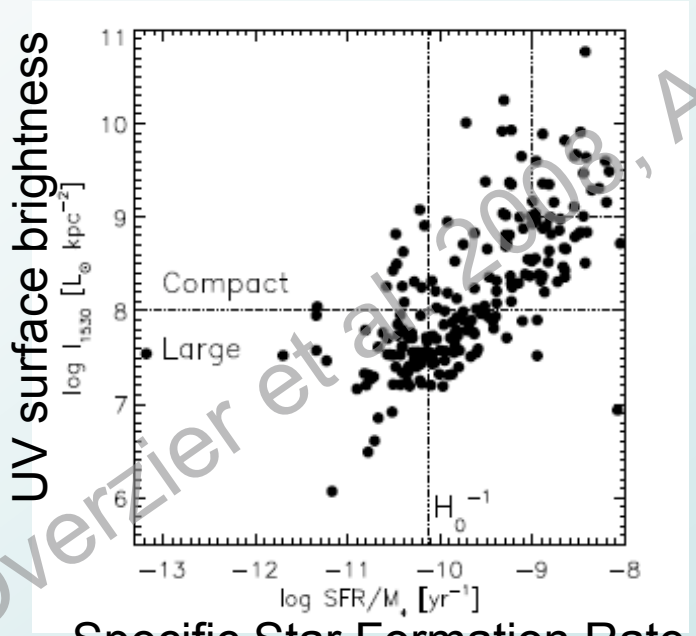


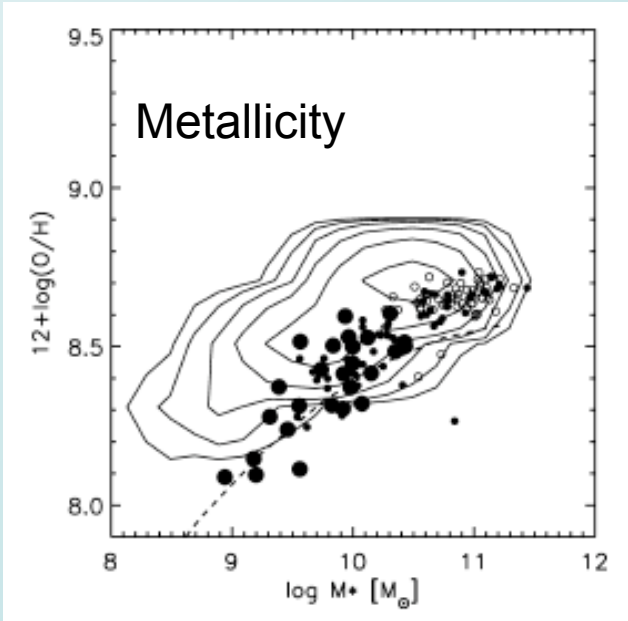
Far-UV Luminosity

Typical *physical* properties of candidate “local LBGs”:









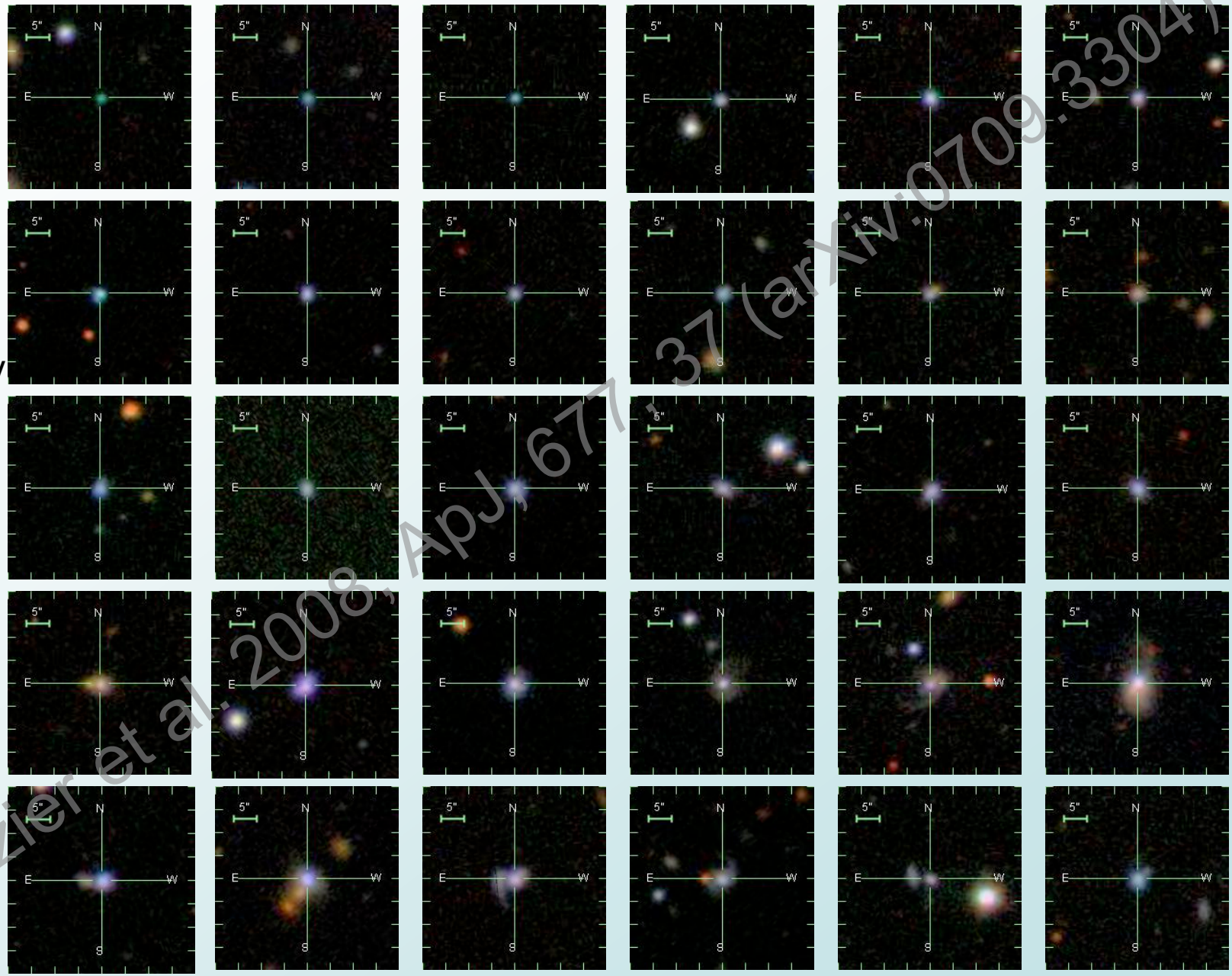
Summary of properties

- Starburst galaxies at $0.1<z<0.3$
- SDSS u' half-light radius of 1-2 kpc ($<r_{hl}>$ of LBGs at z=3-5; Ferguson et al. 2004)
- UV-optical colors $0<FUV-R<2$ (similar to $(R-K)_{AB}$ of LBGs; Shapley et al. 2003)
- metallicity $0.2Z_o$-Z_o(Shapley et al. 2004, Pettini et al. 2001)
- steep UV slopes, E(B-V)=0-0.2 (see Shapley et al. 2003, Bouwens et al. 2006)
- stellar masses of 10^{10} M_o ⟶ *Specific SFR* 10^{-9}-10^{-8} yr
- SFRs of 10-100 M_o yr^{-1}
- emission line velocity disp. of 60-130 km s^{-1} (Pettini et al. 2001, Erb et al. 2006)
- morphologically similar to LBGs (e.g. G, M20, CAS) when simulated at high-z (Overzier et al. 2008)

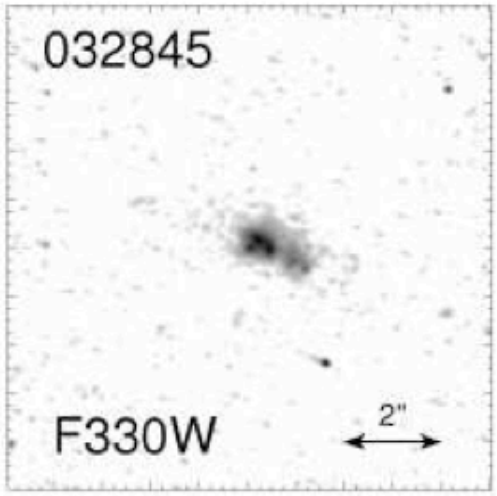
Every physical property we could measure is similar to that of high-z LBGs

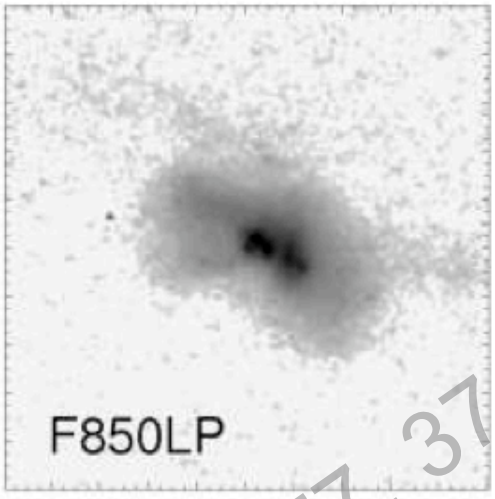
What are they?

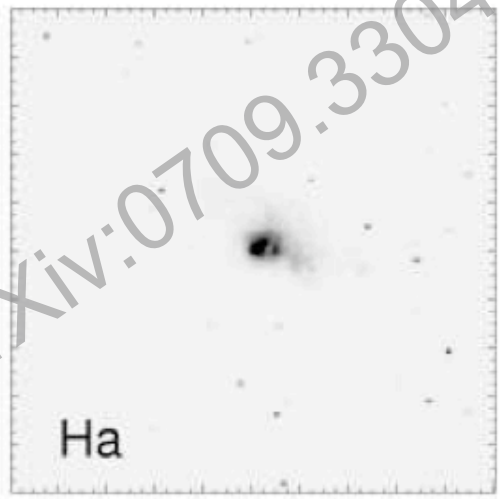
SDSS Images of Compact UVLGs show… compact-ness mostly

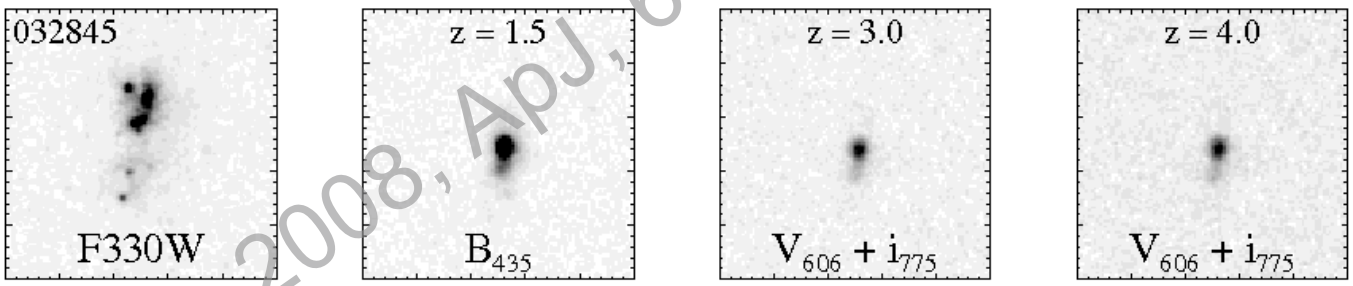


HST imaging follow-up of 31 nearest/brightest (~100 orbits)





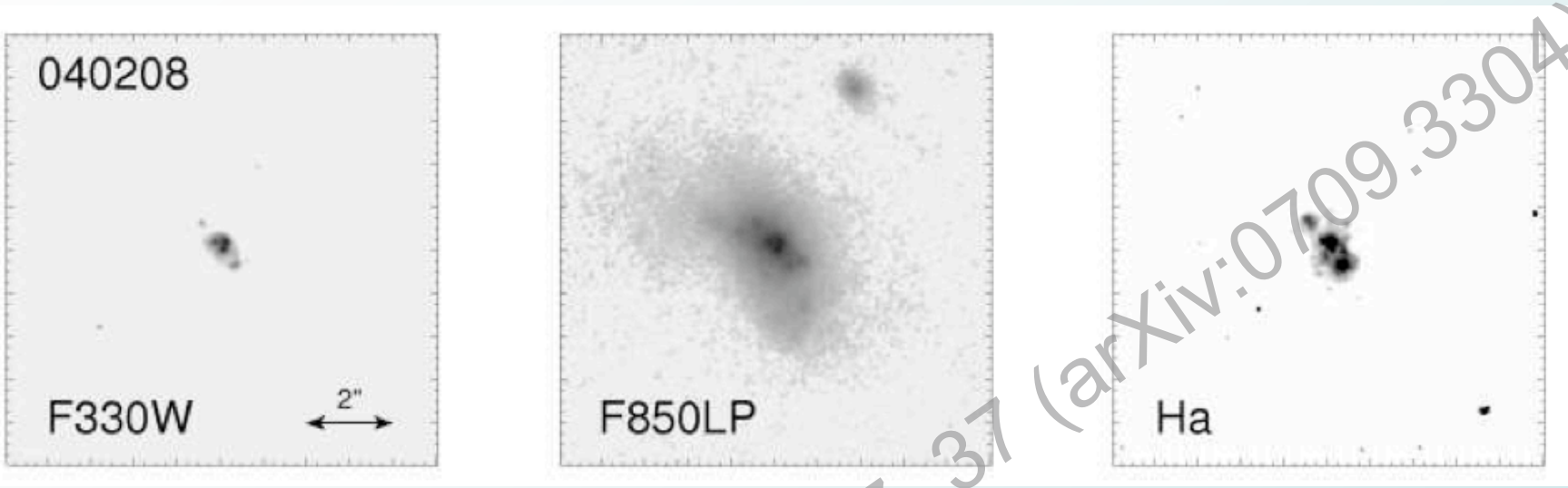


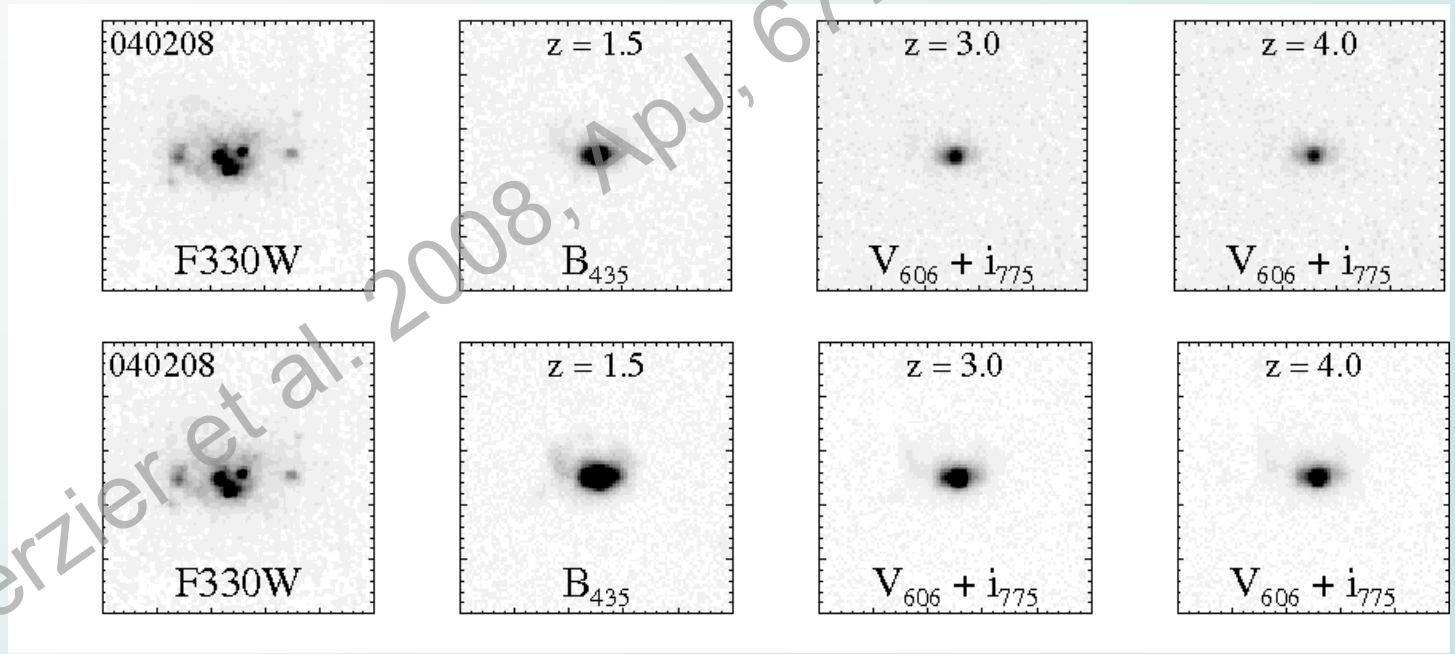


GOODS simulation

UDF simulation

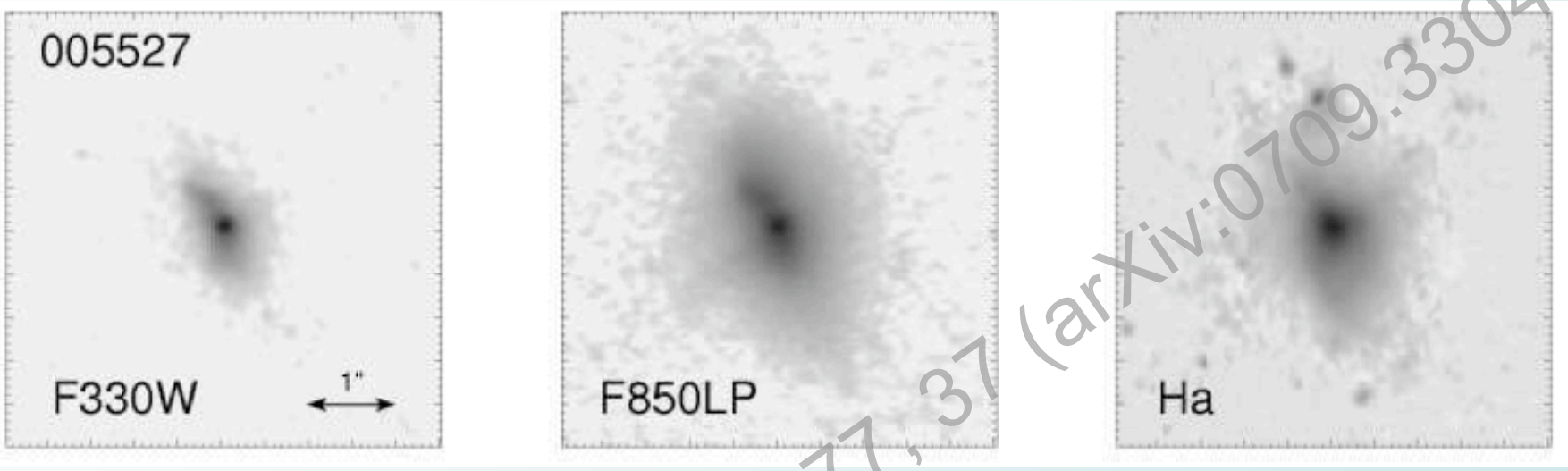
Overzier et al. 2008, ApJ, 677, 37 (arXiv:0709.3304)

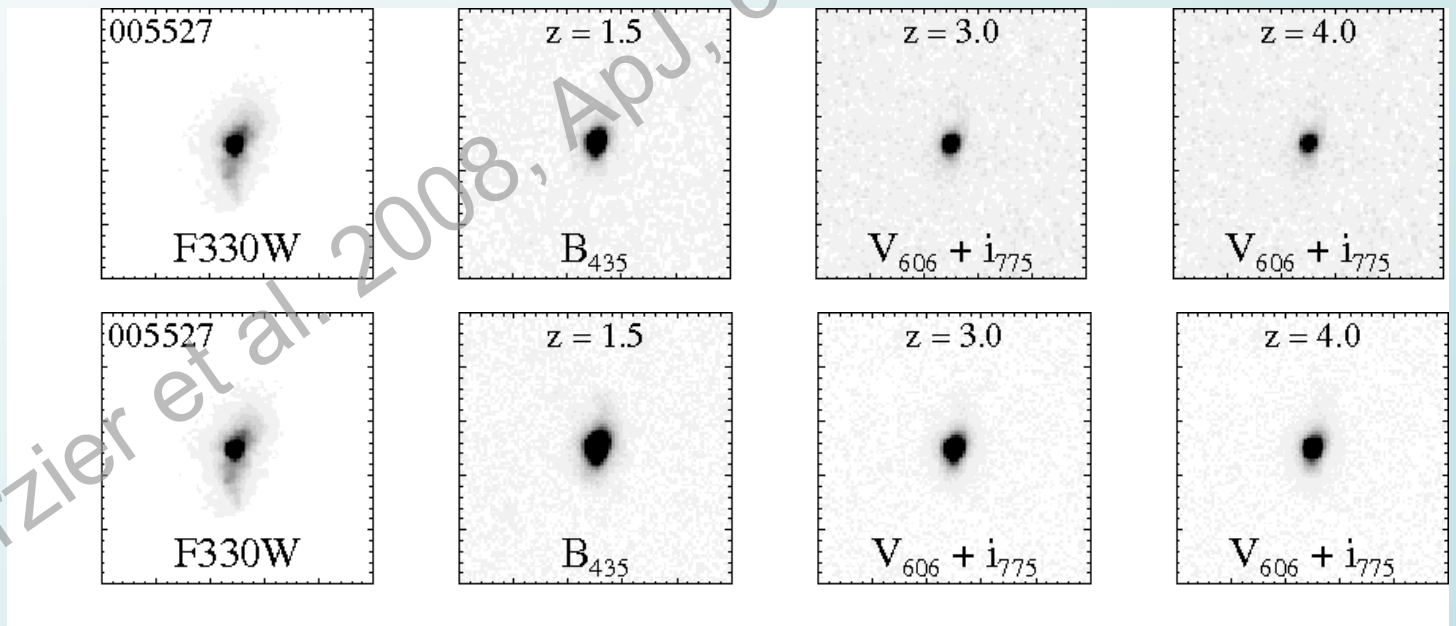




GOODS simulation

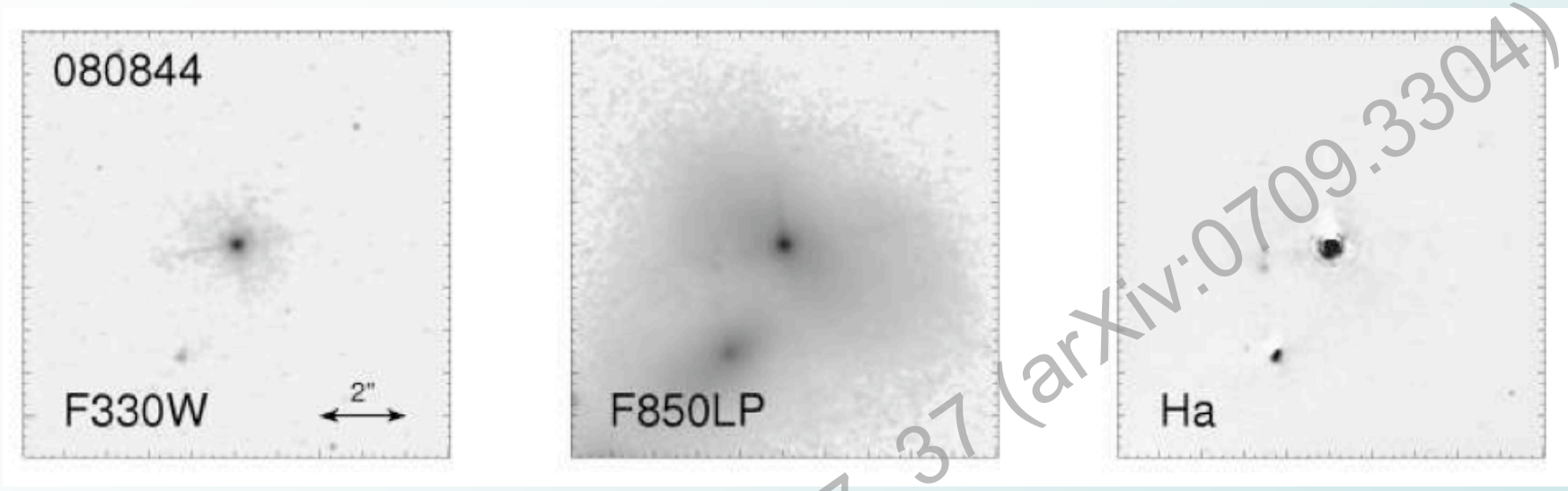
UDF simulation

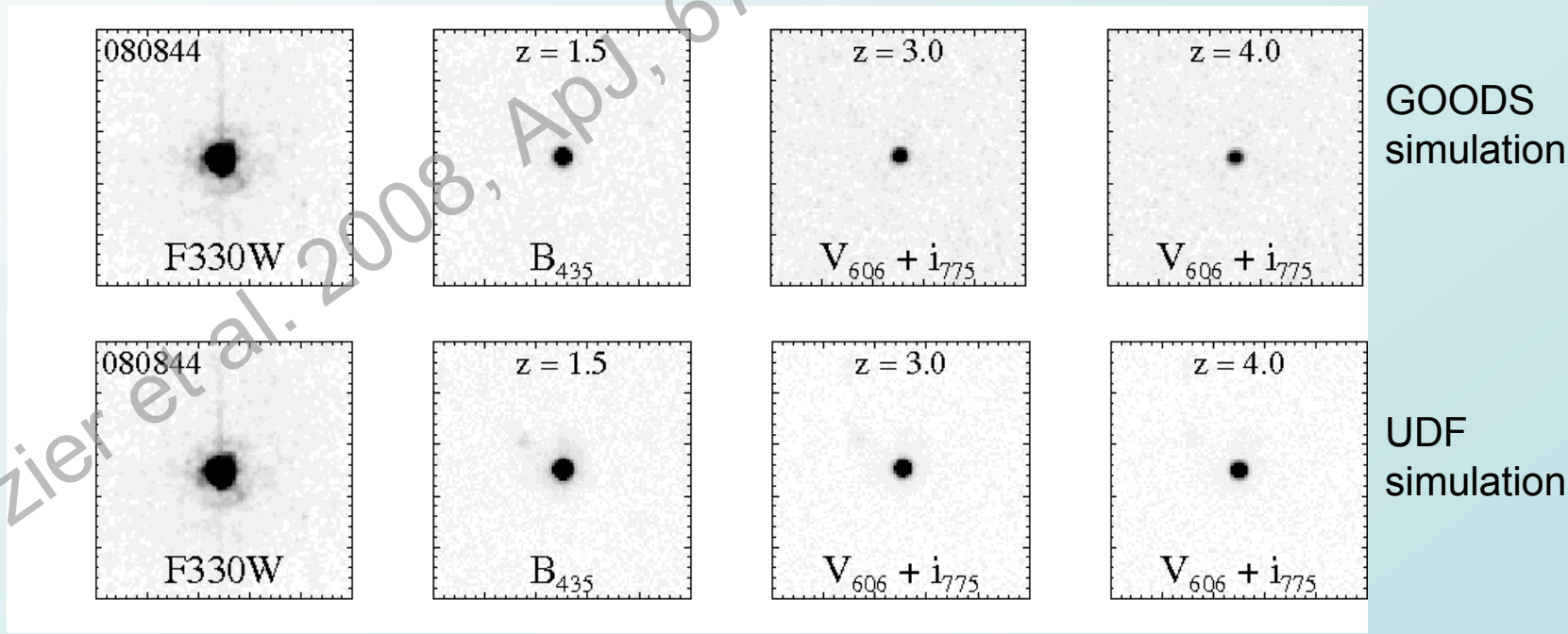


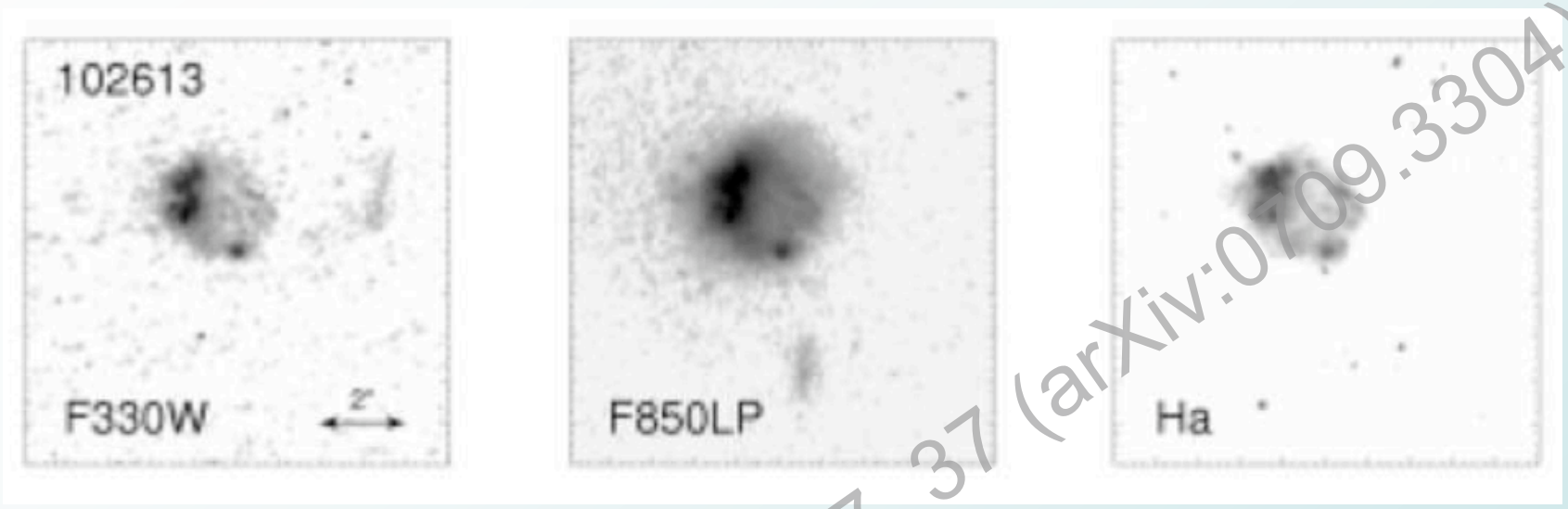


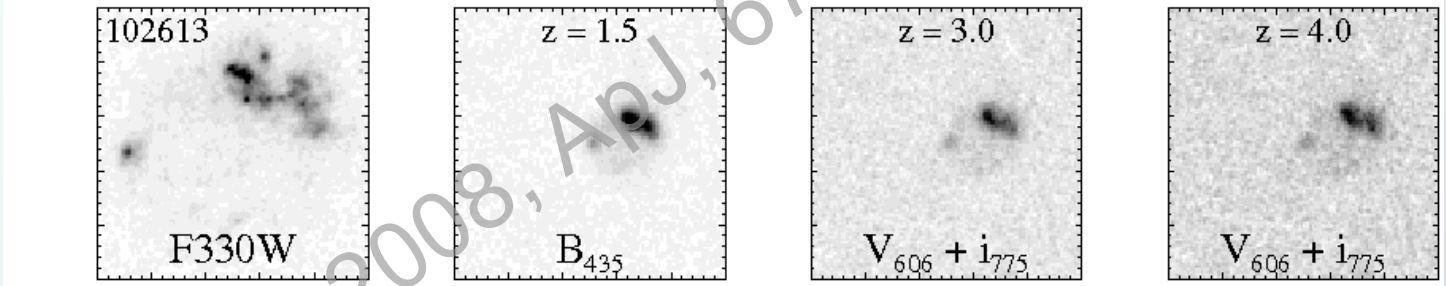
GOODS simulation

UDF simulation

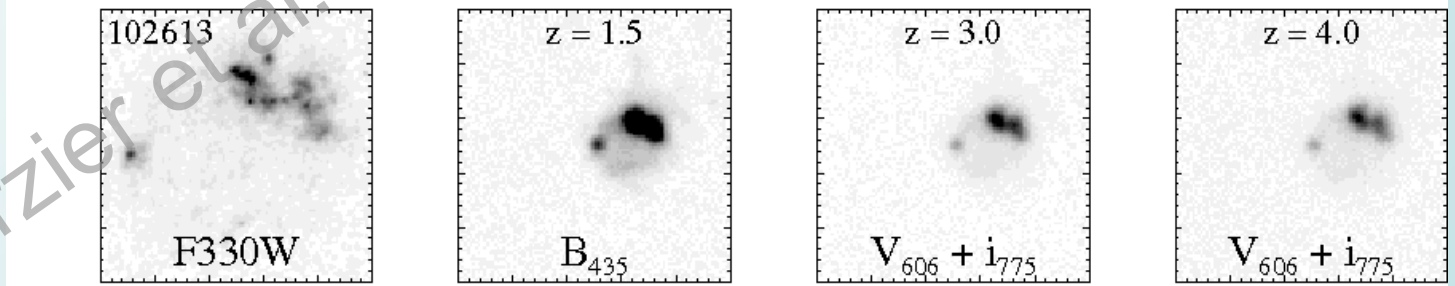




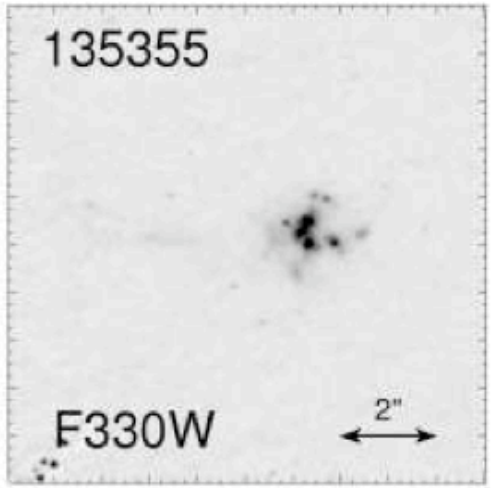


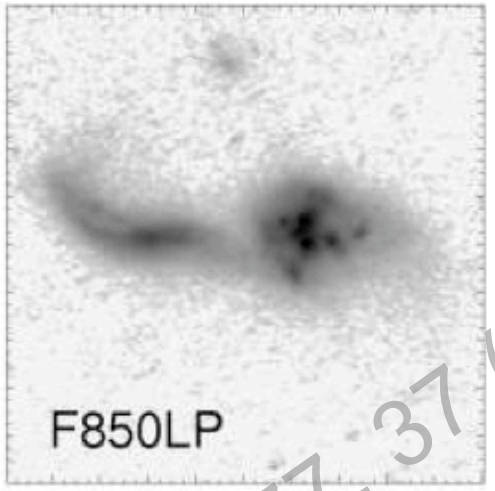


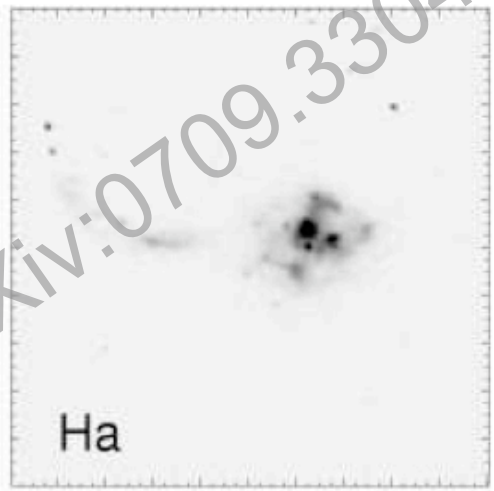
GOODS simulation

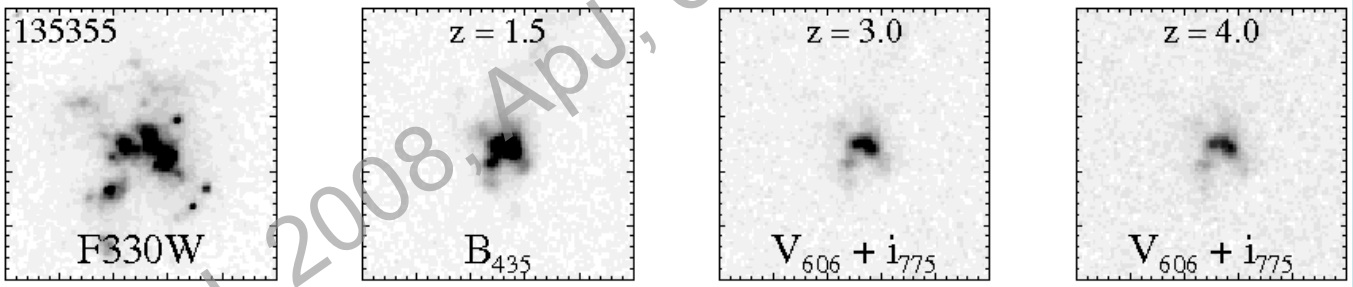


UDF simulation

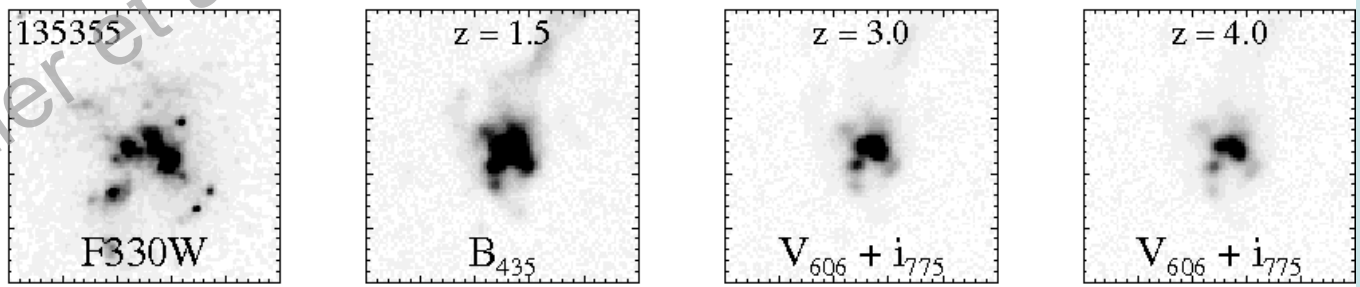






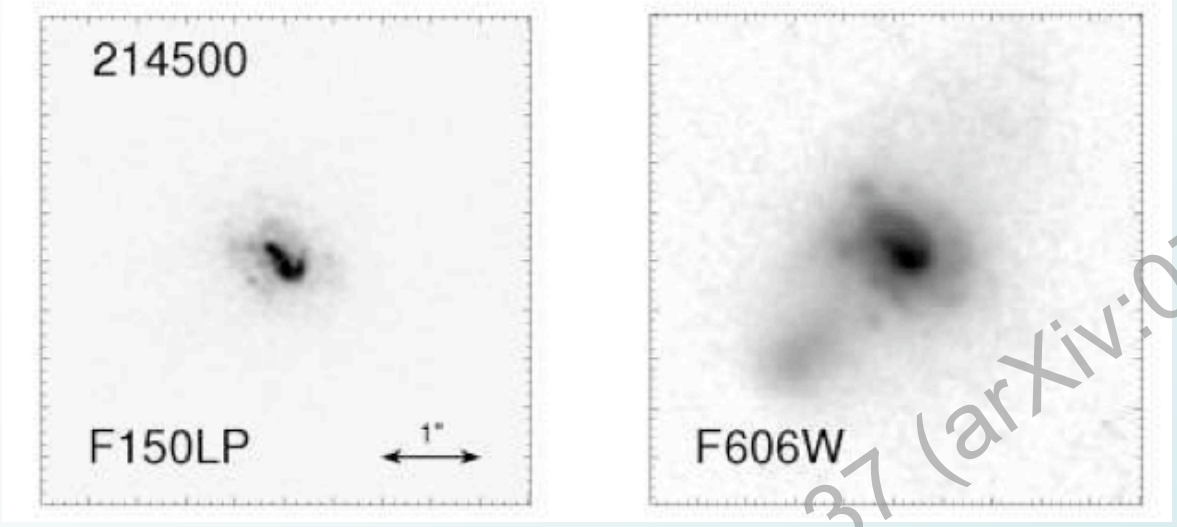


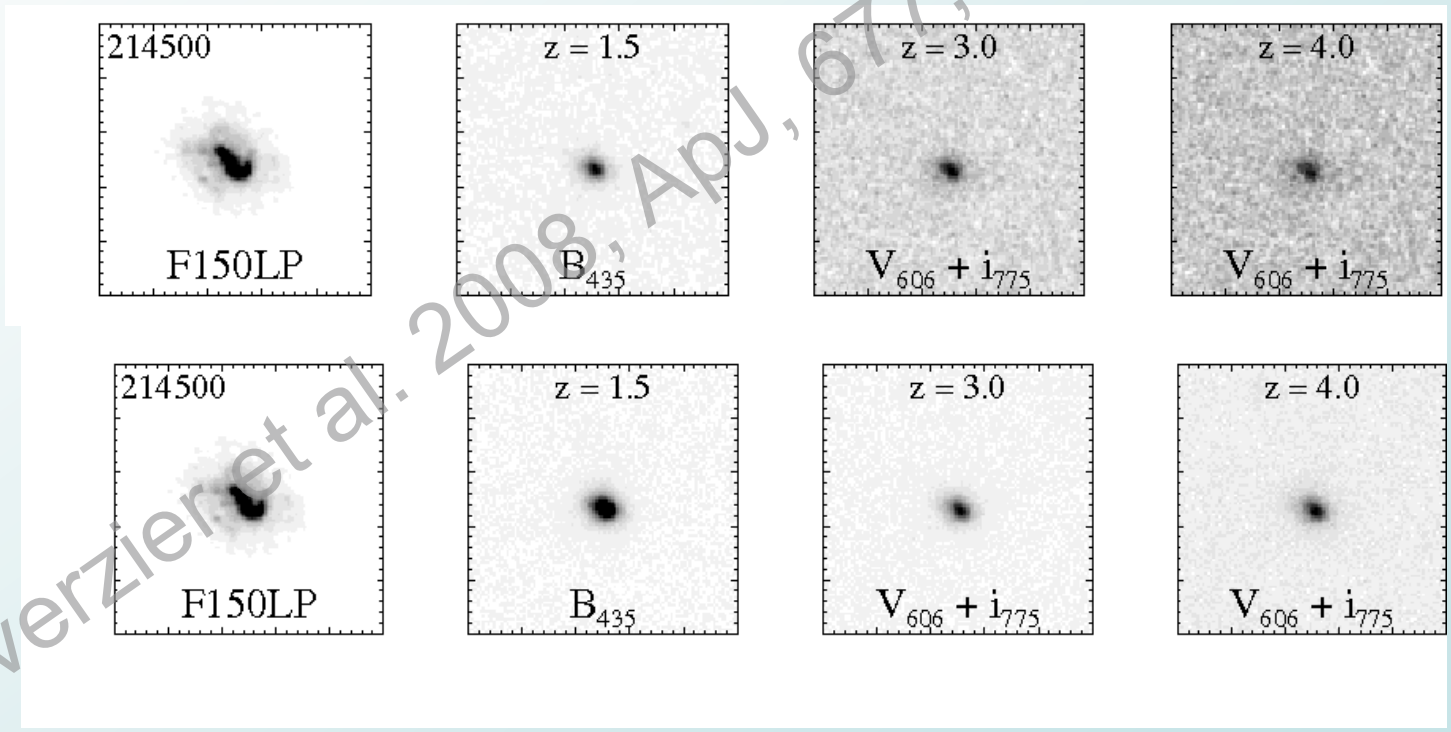
GOODS simulation



UDF simulation

Overzier et al. 2008, ApJ, 677, 37 (arXiv:0709.3304)



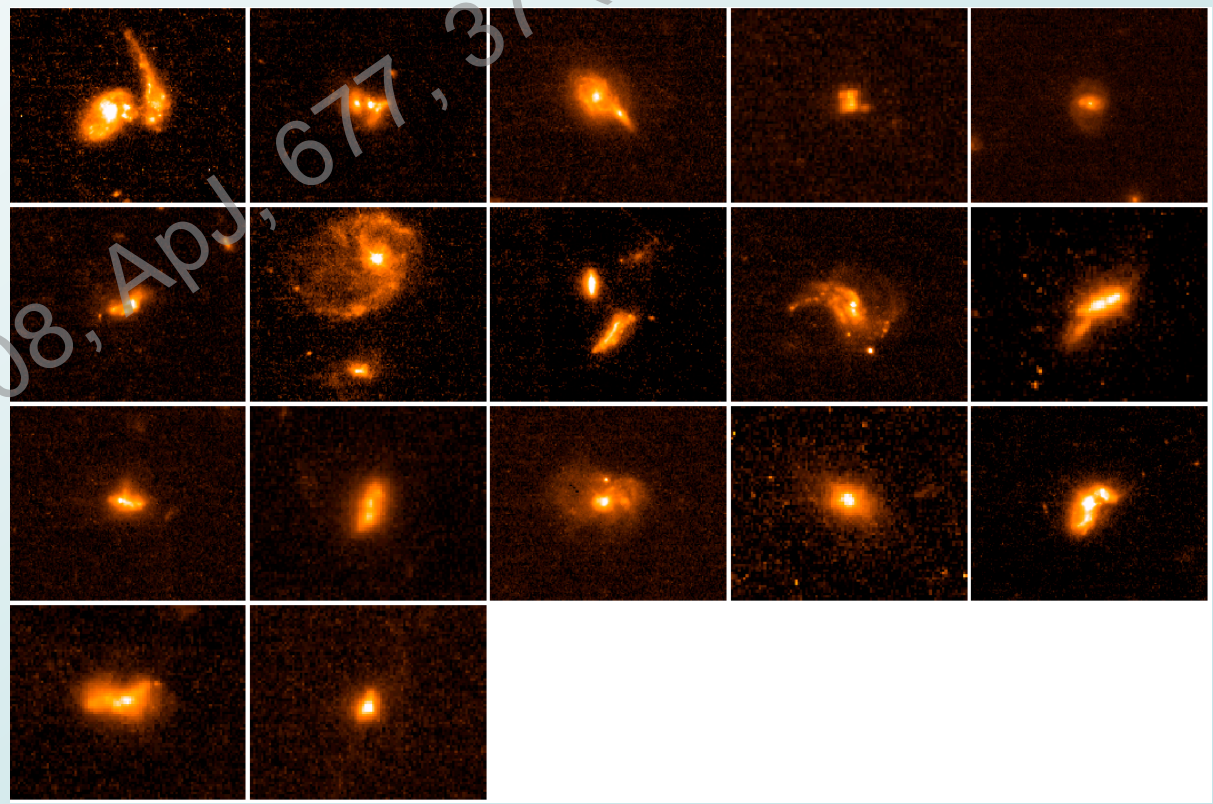


GOODS simulation

UDF simulation

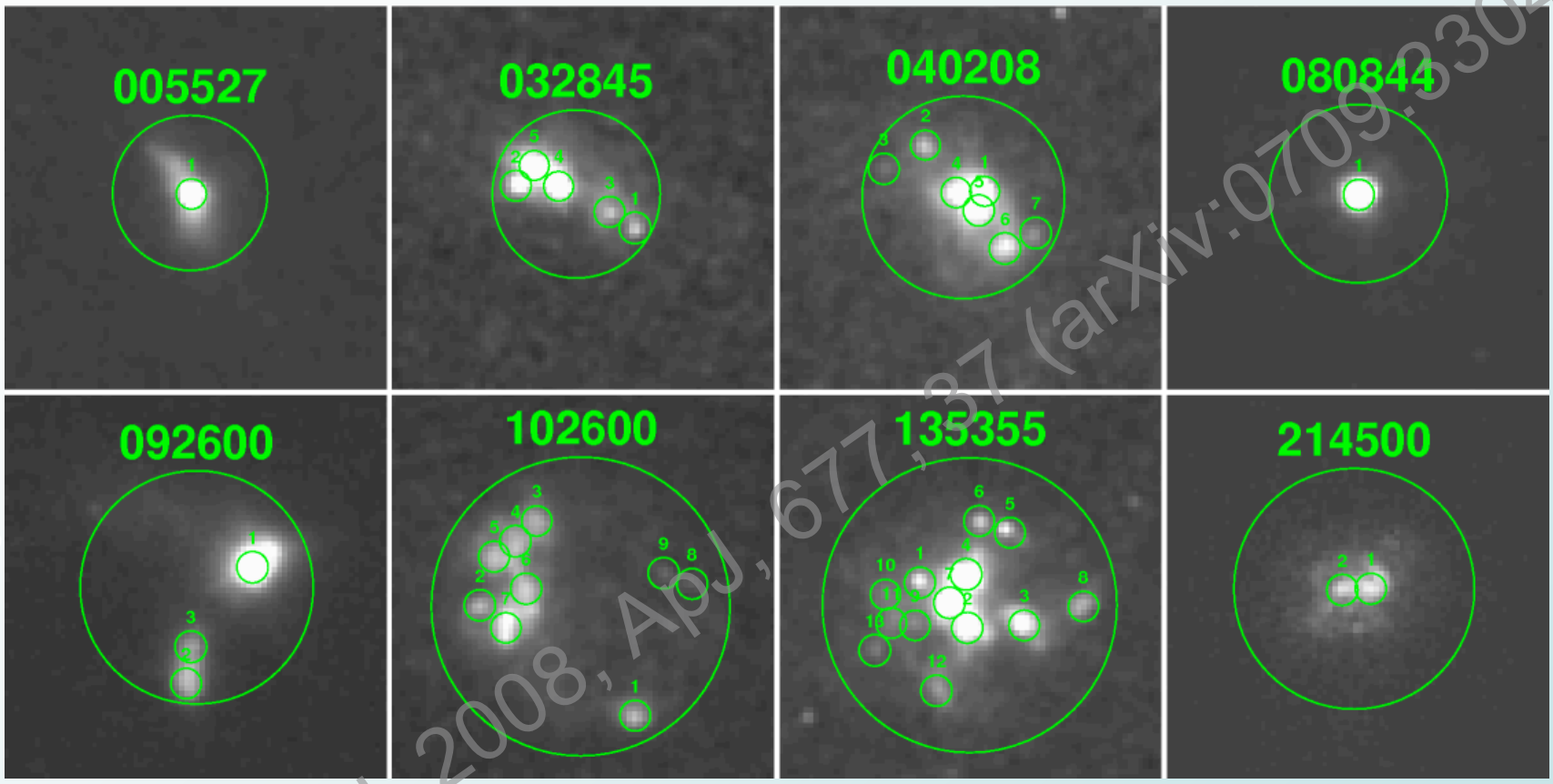
Summary of local LBG morphologies

- Evidence for merger/interaction in each case
- Evidence for merger only seen in optical, not in UV!
- Starbursts concentrated in very small regions



Overzier et al. 2008, ApJ, 677, 37 (arXiv:0709.3304)

Star formation dominated by Super Starburst Regions (SSBs)

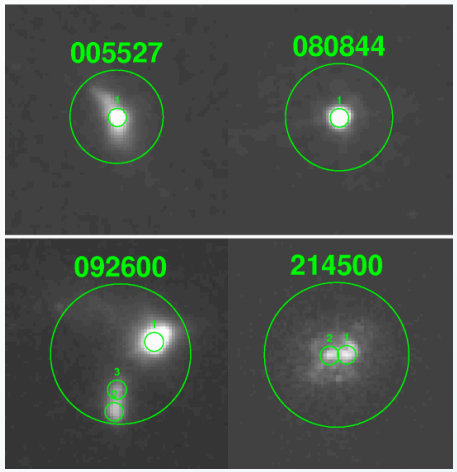


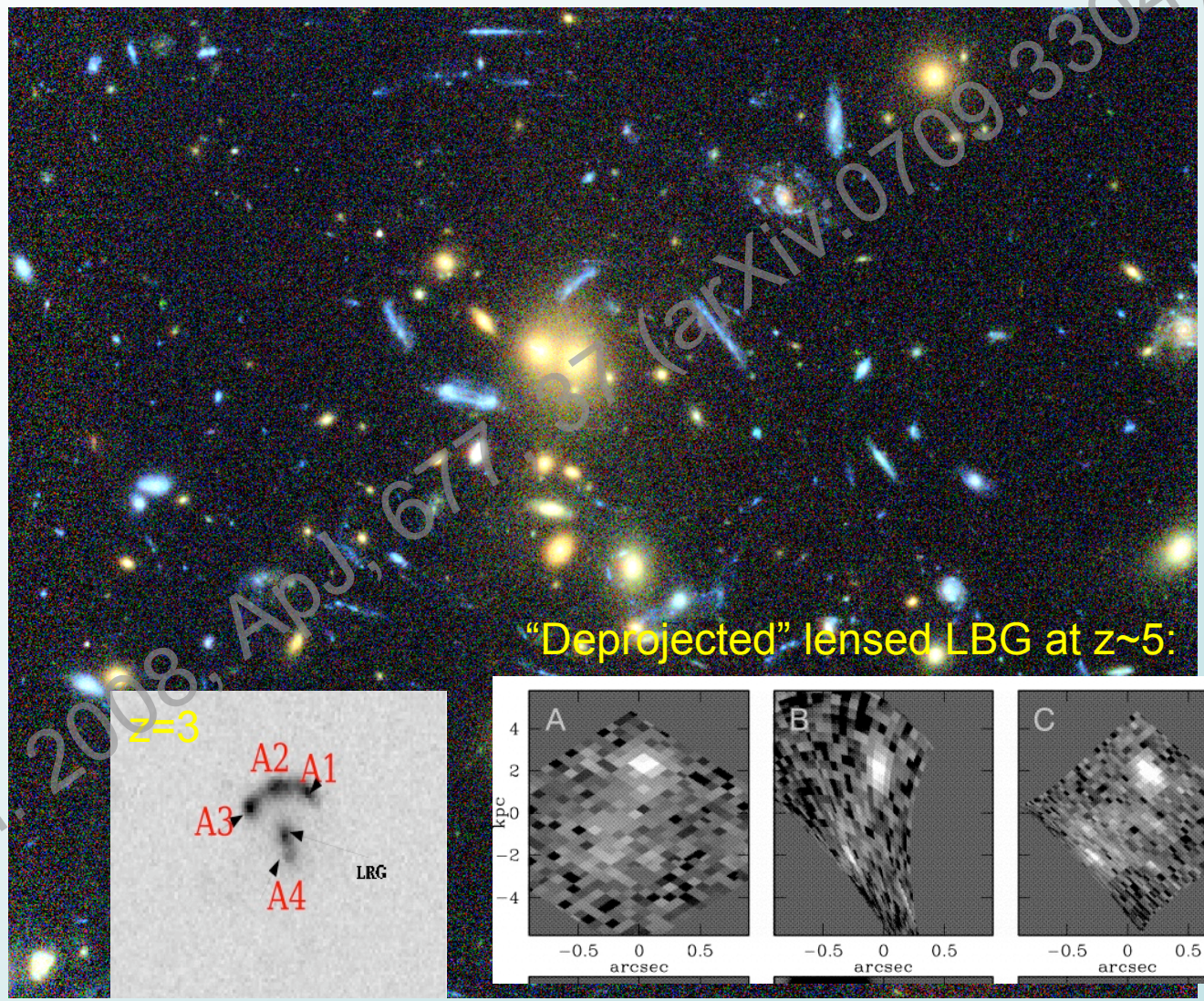
- Contain typically 30-80% of the UV light
- 1 to several per galaxy
- unresolved even with HST
  at z=0.1-0.2 (~100-200 pc)

- stellar masses ~ 10^7 to 10^8 M_o,
- ages ~ 6 Myr to few 100 Myr,
- SFRs ~ 0.1 to 10 M_o/yr,
- may host (forming) globular clusters

for a cluster formation efficiency of ~1%

Is there any evidence to suggest that the substructure of high-z LBGs is similar to the local LBG analogs? Compare with LBGs that are gravitationally lensed:



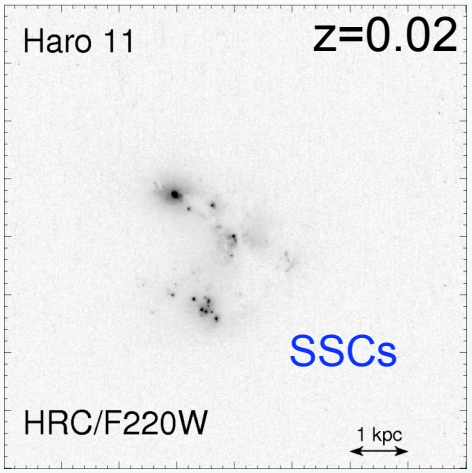


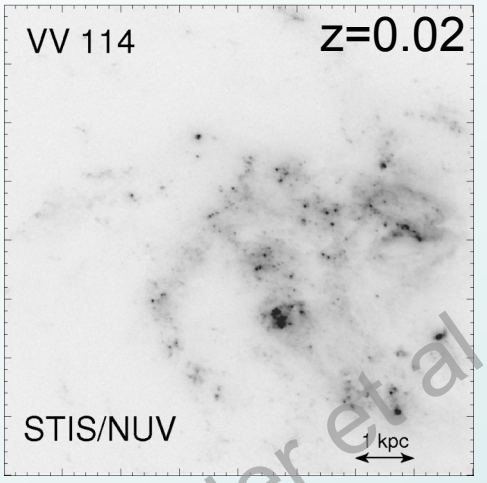
Overzier et al. 2008, ApJ, 677, 37 (arXiv:0709.3304)

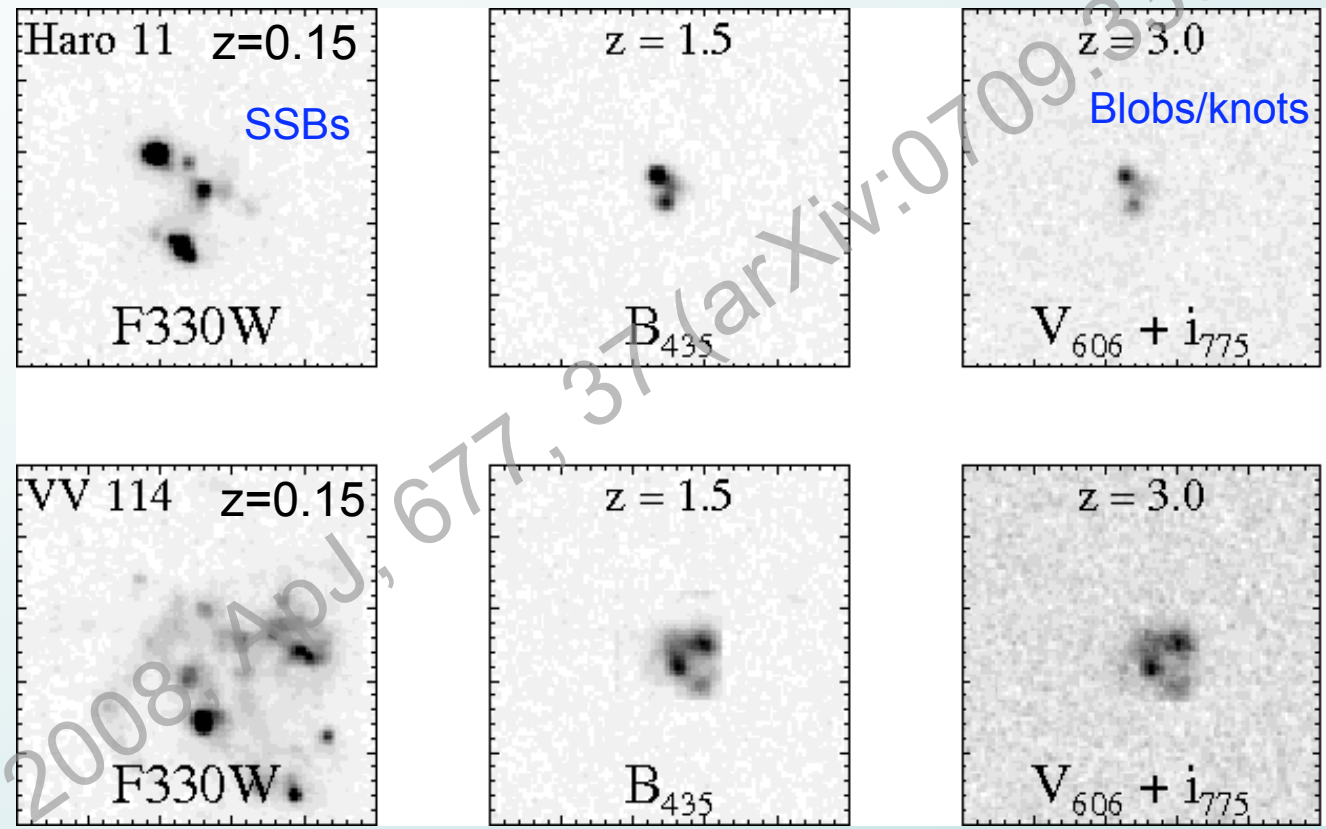
Substructure of lensed LBGs VERY SIMILAR in luminosity (=SFR/mass) and size

(e.g.Franx et al. 1997, Ellis et al. 2003, Allam et al.)

What do the “super starburst regions’’ and LBG ‘”knots’’ consist of



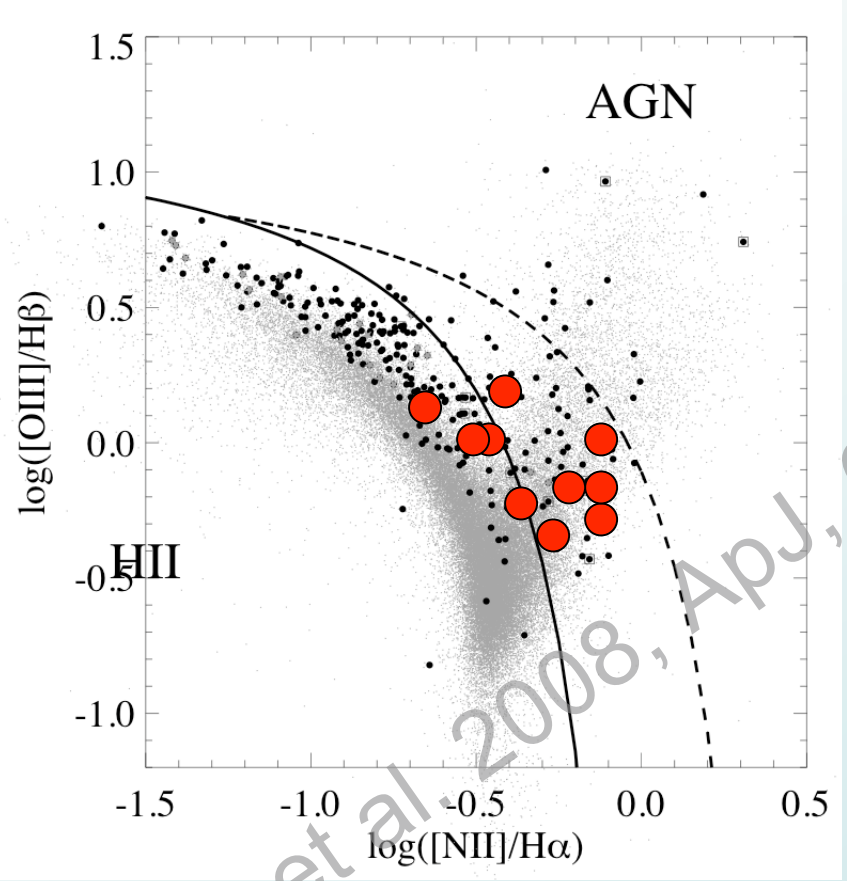




Overzier et al. 2008, ApJ, 677, 37 (arXiv:0709.3304)

- LBG “knots” (~1 kpc) are blends of SSBs (~0.1-0.2 kpc)
- SSBs are blends of bright star clusters ($10^{4\text{-}6} M_o$, <10 pc)
- but also single, compact, supermassive star clusters
- implications for faint-end of high-z LF???

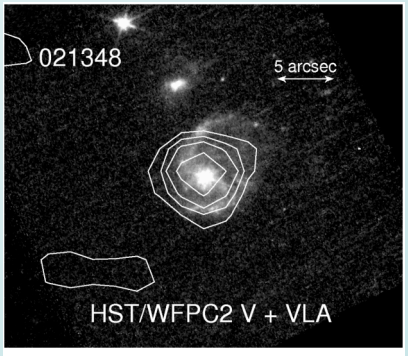
Evidence for accreting black holes in local LBG analogs ?

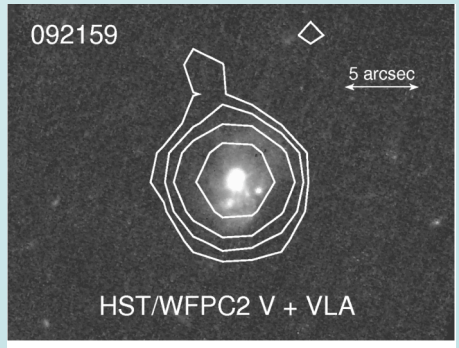


Very weak FIRST radio detection

- LBGs at z~3: only ~3% AGN, but this is likely a (weak) lower limit as X-ray surveys used may miss many optically bright AGN (other AGN diagnostics not available: hard X-rays, [NeV], [NII]/Ha,…)

- Local analogs: ~25% possibly AGN, but this needs to be confirmed (XMM X-ray and VLBI radio observations planned)





Summary

- the GALEX/SDSS sample of compact UVLGs are LBG analogs in every measurable physical property
- the high resolution HST imaging offers a rare view of the relationship between morphology and the main driver of star formation
- results indicate that local LBG analogs are all associated with highly dissipational major/minor mergers turning gas-rich galaxies into stars
- consistent with collisional starburst predictions for high redshift galaxies
- rest-frame UV images not sufficient for establishing that they are mergers! (need faint features in rest-frame optical images)
- predominance of unresolved SSBs are key to the correct interpretation of LBG properties (e.g. sizes, morphologies, star clusters, LF and evolution)
- local LBG analogs may have a considerable AGN fraction, which could be important for BH/bulge growth when extrapolated to high redshift LBGs

Overzier et al. 2008, ApJ, 677, 37 (arXiv:0709.3304)

Thanks!