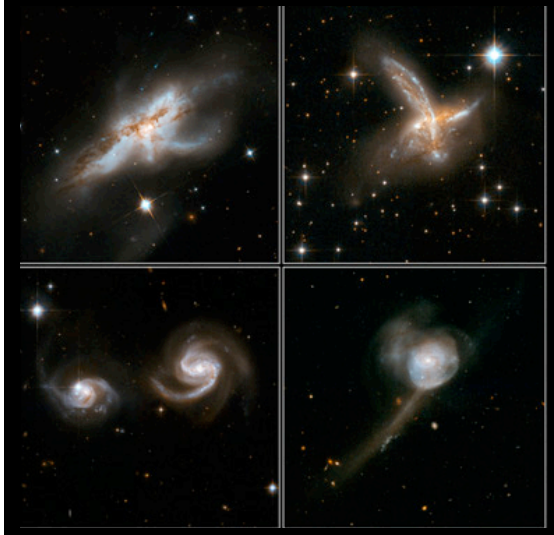
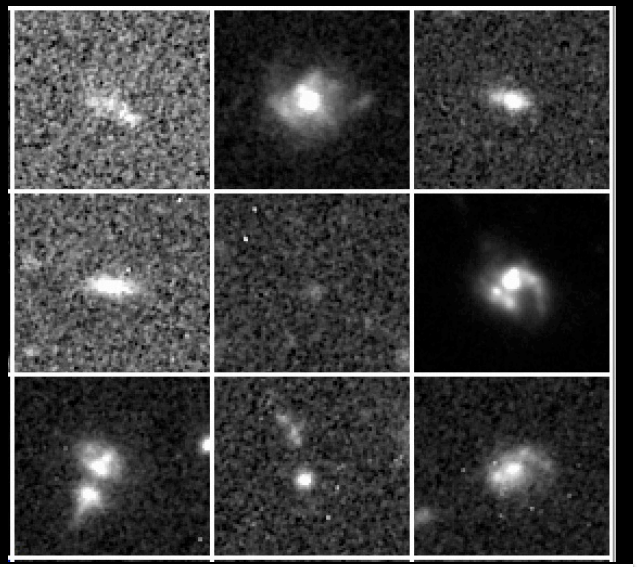
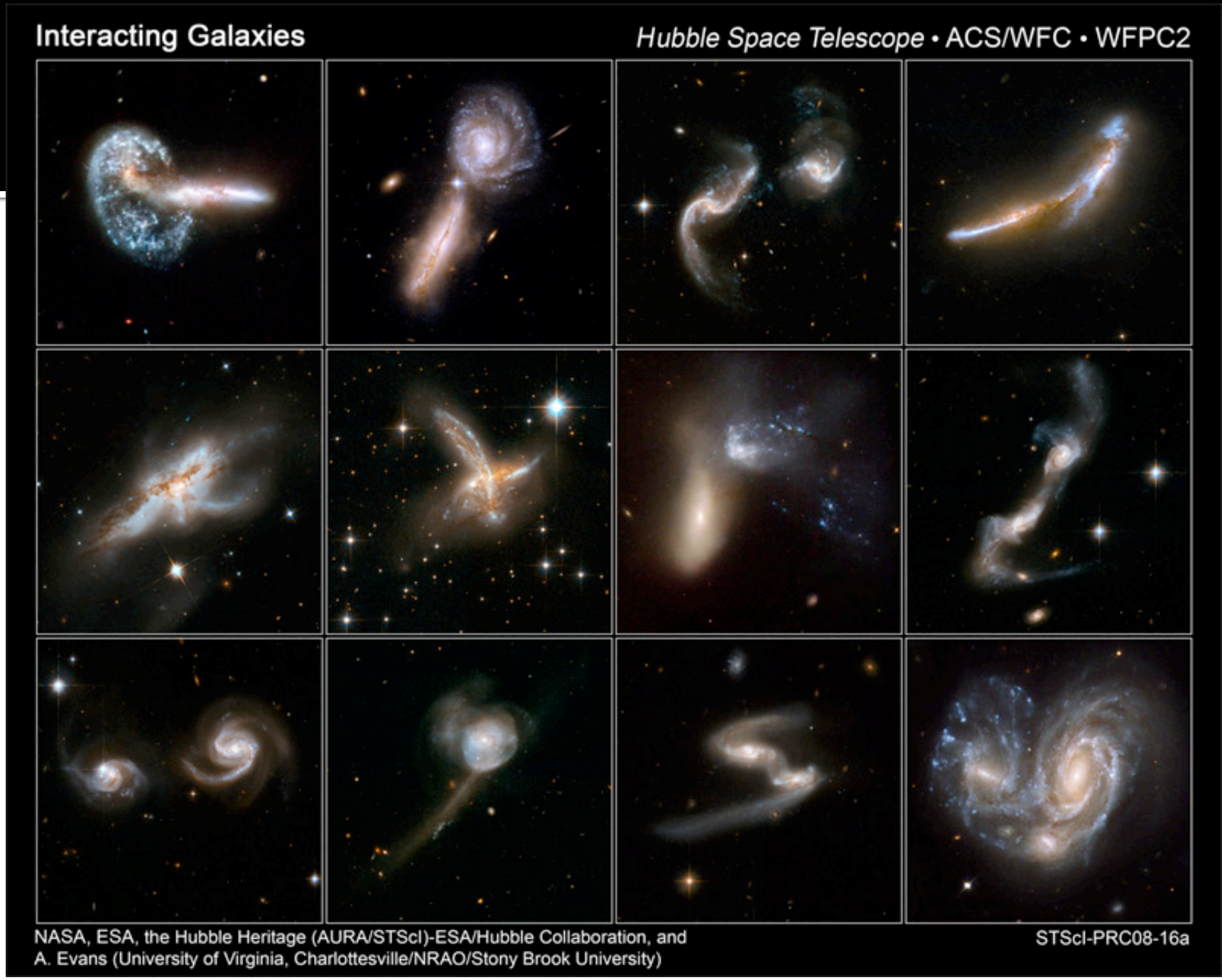
The Role of Galaxy Mergers Among High Redshift (z~2) ULIRGs





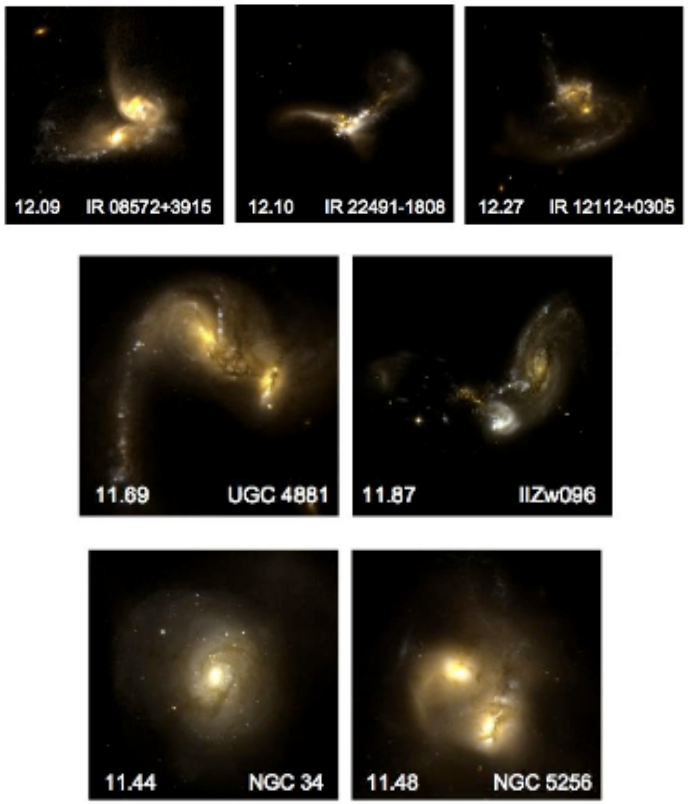
Jeyhan Kartaltepe
Hubble Fellow, NOAO
GOODS-Herschel & CANDELS Teams

Through the Infrared Looking Glass: A Dusty View of Galaxy and AGN Evolution
2011 October 4


Interacting Galaxies
Hubble Space Telescope • ACS/WFC • WFPC2
NASA, ESA, the Hubble Heritage (AURA/STScI)-ESA/Hubble Collaboration, and
A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
STScI-PRC08-16a

Properties of Local (U)LIRGs

- ULIRGs: IRAS 1 Jy Sample, med(z) = 0.145 (Veilleux, Kim, & Sanders 2002)
  - > 99% are major mergers of gas rich spirals
- LIRGs: RBGS, med(z) =0.0082
  (Sanders et al 2003, Ishida 2004)
  - $\log(L_{IR}) > 11.5$
    - strongly interacting major mergers (65%)
    - doubles (18%)
    - minor interactions (18%)
  - $\log(L_{IR}) < 11.5$
    - strongly interacting major mergers (36%)
    - doubles (23%),
    - minor interactions (15%)
    - high luminosity end of normal star forming disks (26%)

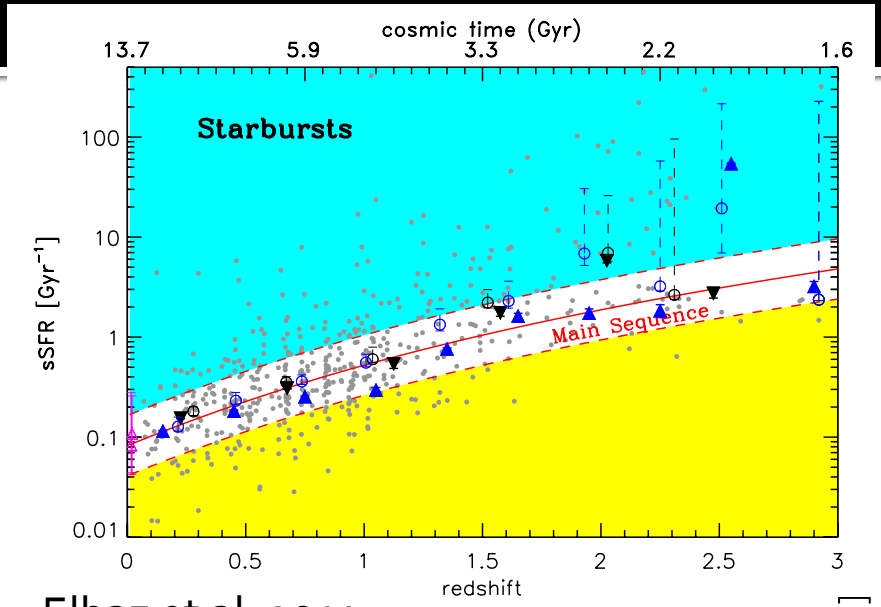


Fraction of mergers increases systematically with L_{IR}!

High Redshift (z~2) ULIRGs

- Are mergers necessary to produce these extreme luminosities?
- Studies at high redshift have been limited so far
  - Small samples
  - Uncertain luminosities
  - Lack of rest-frame optical imaging
- Most previous studies have been based on Spitzer 24 μm selection
  - Pre-Herschel, longer wavelength data has only been available for small numbers of objects (e.g., Spitzer 70/160 μm, Submillimeter)
- We can do much better with GOODS-*Herschel*!

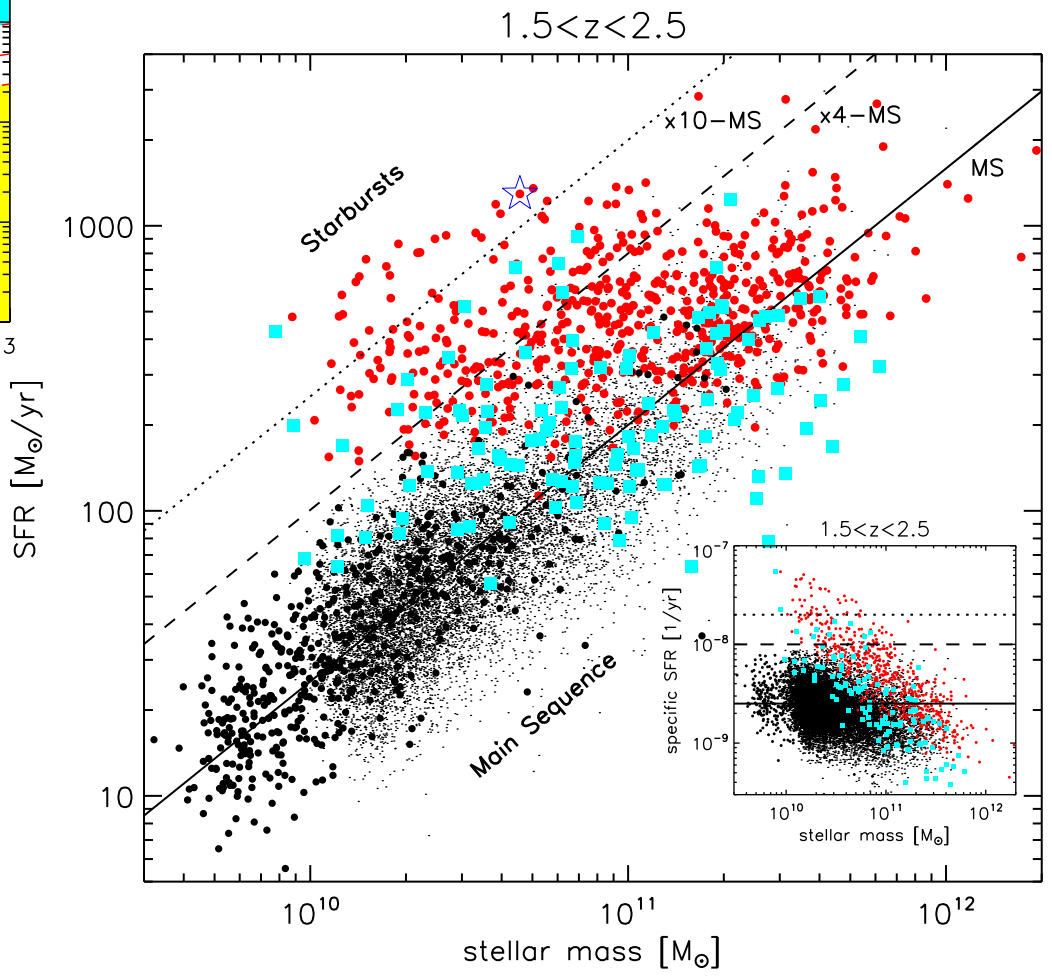
"Main Sequence" and Starburst Galaxies



Elbaz et al. 2011

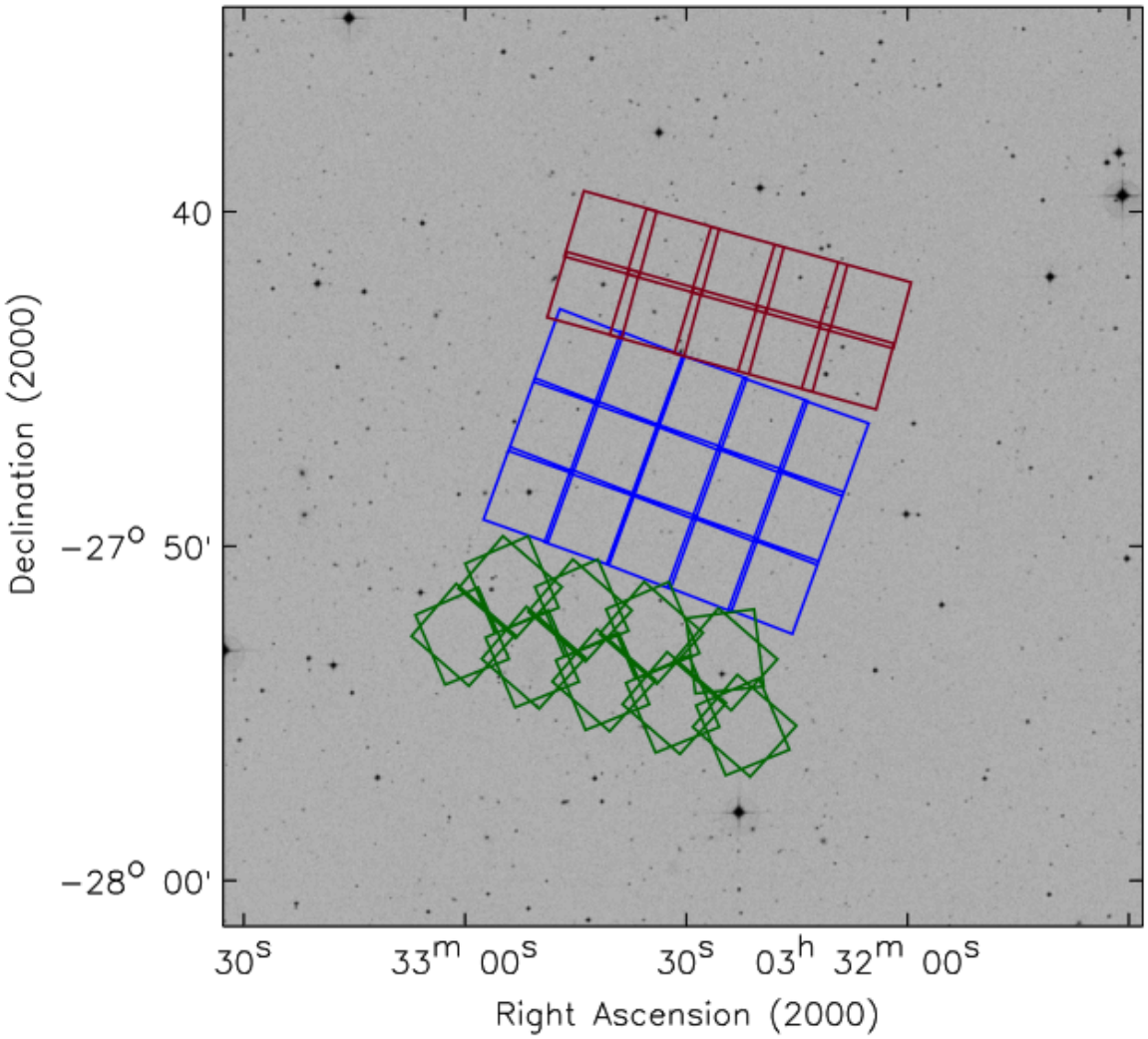
What is the role of mergers among starbursts and "main sequence" galaxies at z~2?

Rodighiero et al. 2011

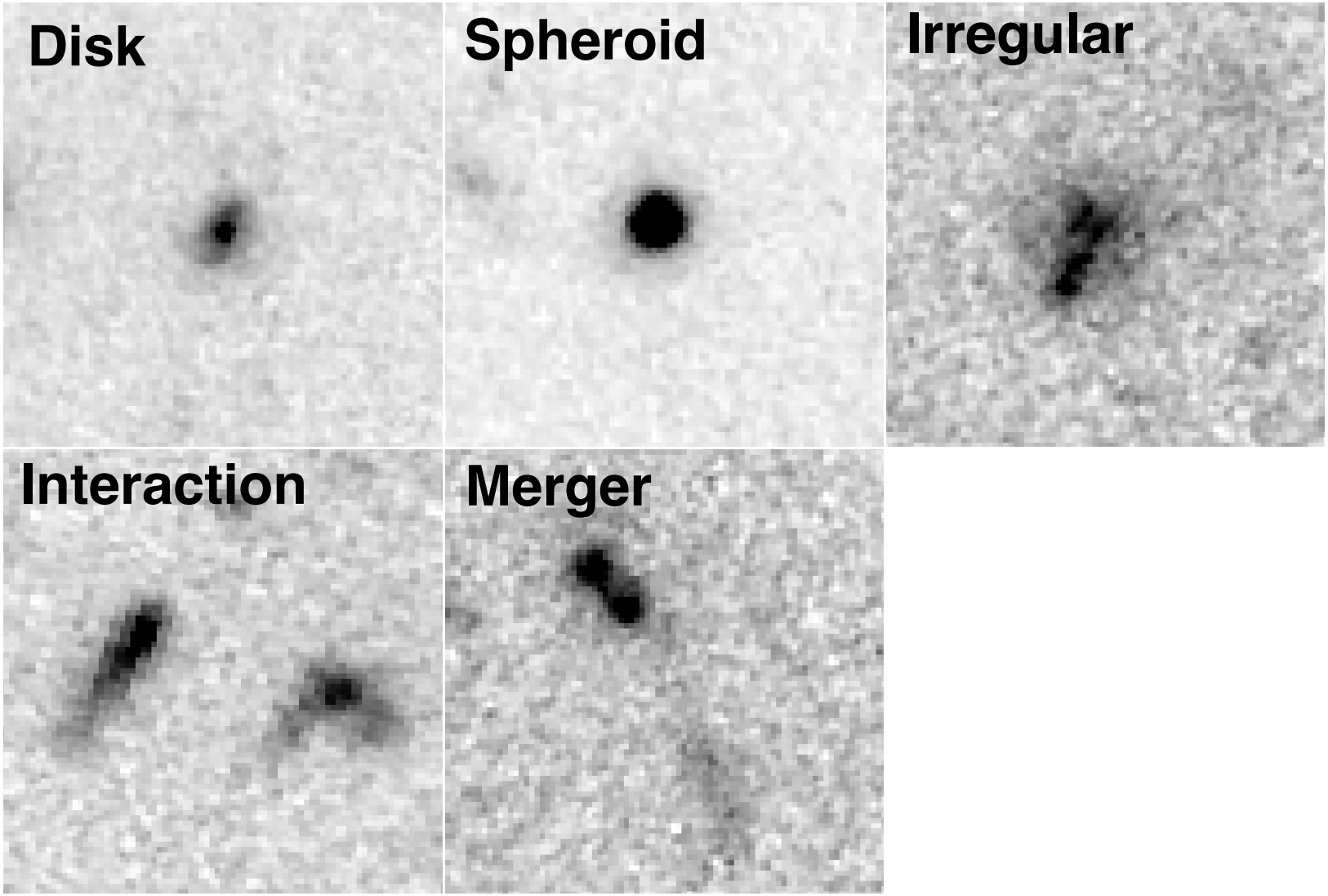


GOODS-*Herschel* & CANDELS

- A match made in heaven!
- Rest-frame optical imaging for z~2 galaxies
- Ideal for probing structure of high-z ULIRGs

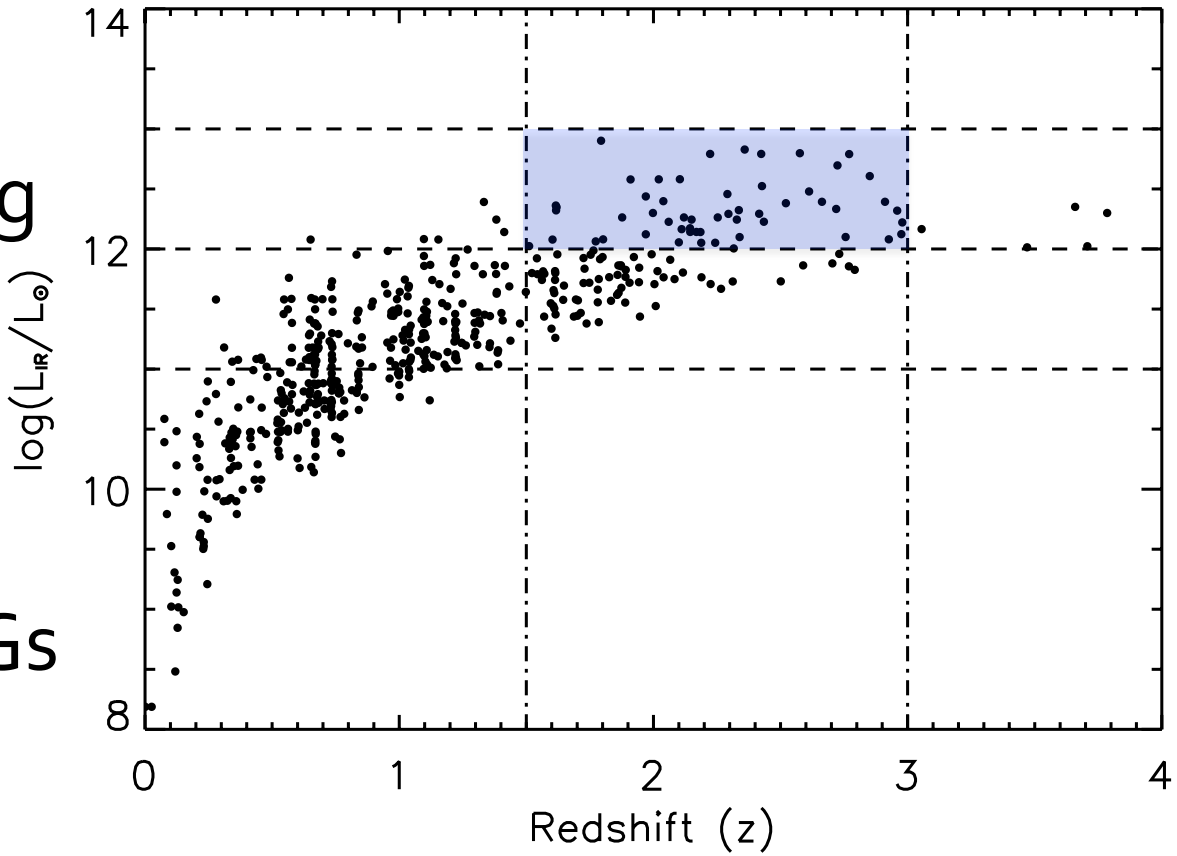


Visual Classification Scheme



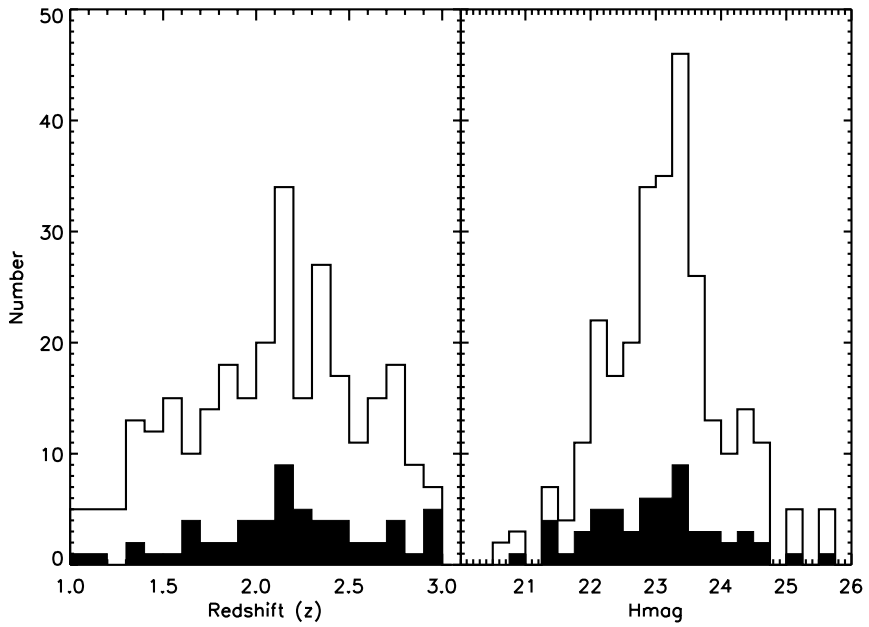
GOODS-*Herschel* ULIRG Sample

- Focus on all ULIRGs with z=1.5-3 in GOODS-S
- 51 ULIRGs with CANDELS imaging
- $\langle \log(L_{IR}) \rangle \sim 12.26$
- $\langle z \rangle \sim 2.2$
- Additional 74 LIRGs over this z range

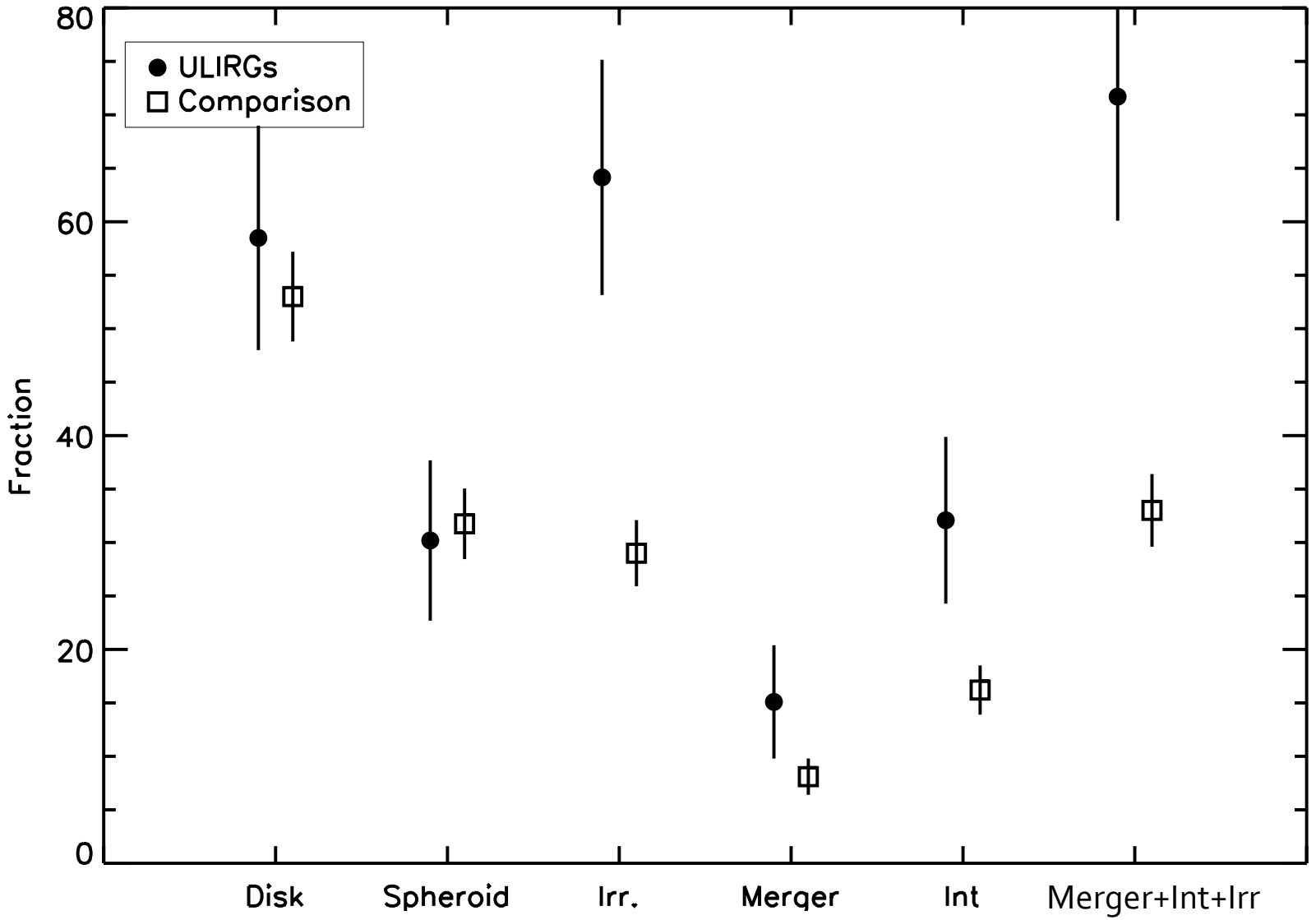


Comparison Sample

- Selected ~ 300 comparison galaxies
- Roughly matched to redshift and H magnitude
  - Slightly fainter
- Randomized and classified ULIRGs + comparison
  - Visual classification scheme
  - Classified by me + 3-5 other classifiers
  - Analyzed agreement

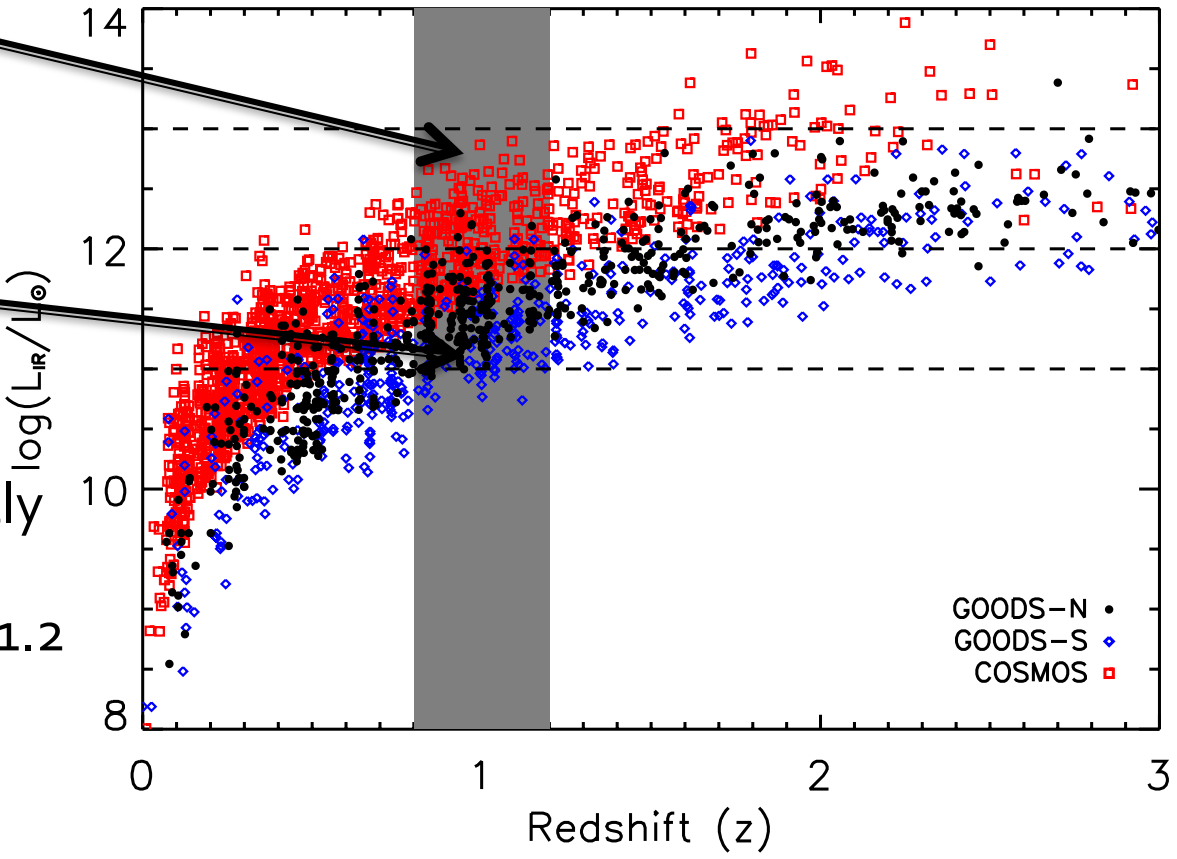


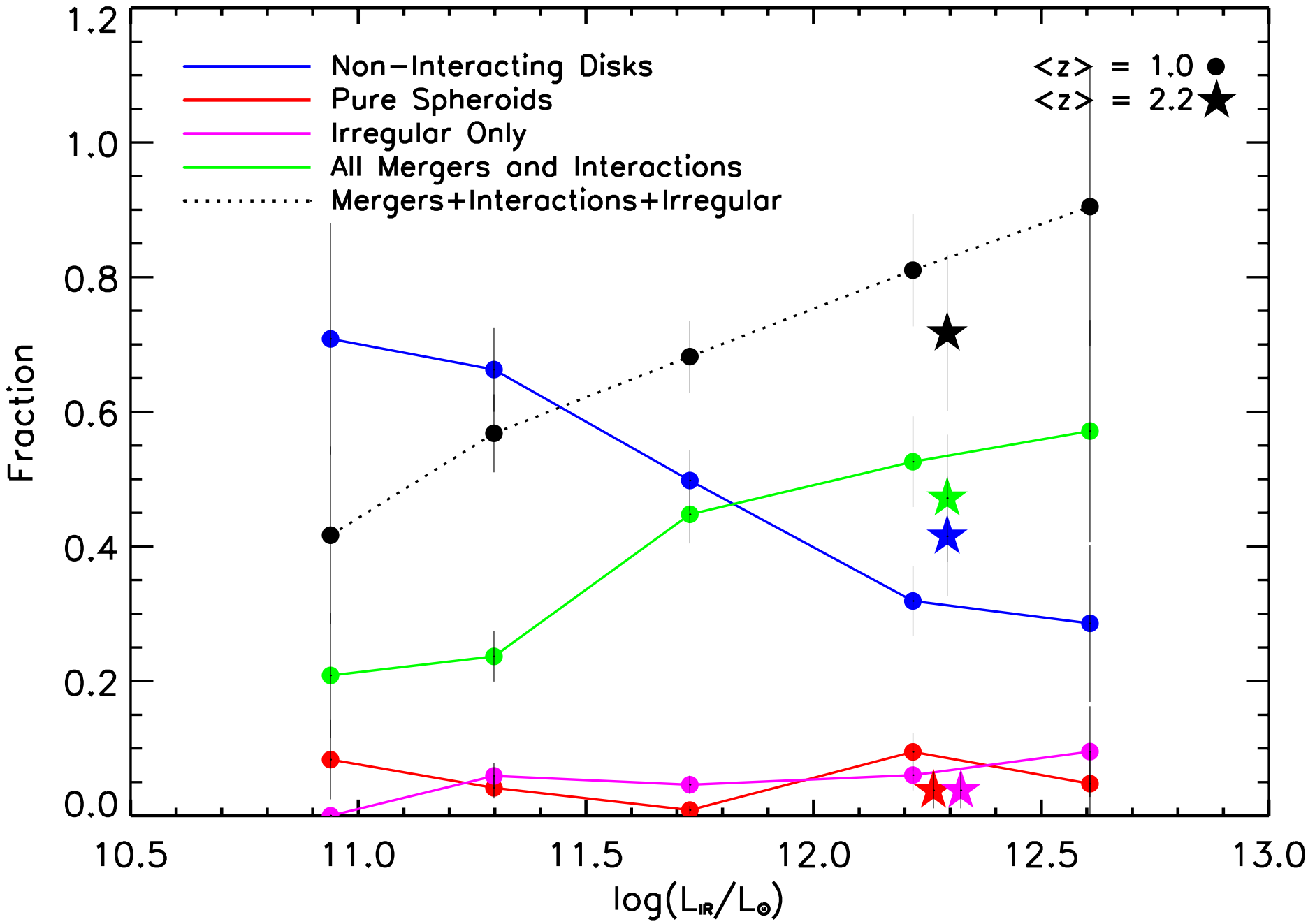
Results


ULIRGs
Comparison
Fraction
80
60
40
20
0
Disk
Spheroid
Irr.
Merger
Int
Merger+Int+Irr

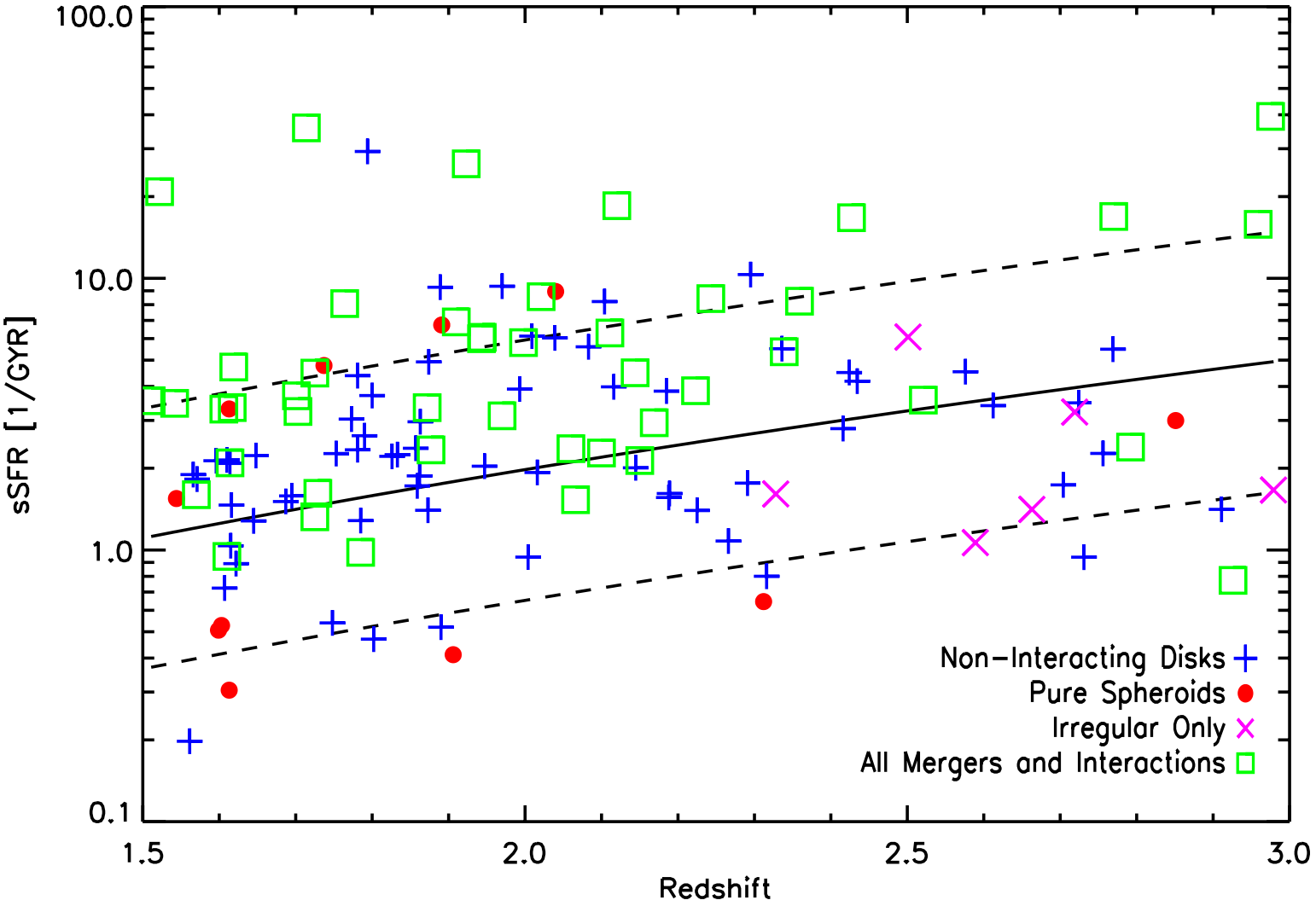
Comparison with z ~ 1

- COSMOS 70 μm
  - 277 sources 0.8 < z < 1.2
  - Log(L_{IR}) = 11.3 - 12.9
- GOODS-Herschel
  - North+South
  - 100/160 μm
  - Smaller area, significantly deeper
  - 293 sources w/ 0.8 < z < 1.2
  - Log(L_{IR}) = 10.6 – 12.4
- Classified using ACS imaging




Non−Interacting Disks
Pure Spheroids
Irregular Only
All Mergers and Interactions
Mergers+Interactions+Irregular
<z> = 1.0
<z> = 2.2
Fraction
log(L_IR/L_⊙)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
10.5
11.0
11.5
12.0
12.5
13.0

Are z~2 ULIRGs Starbursts?



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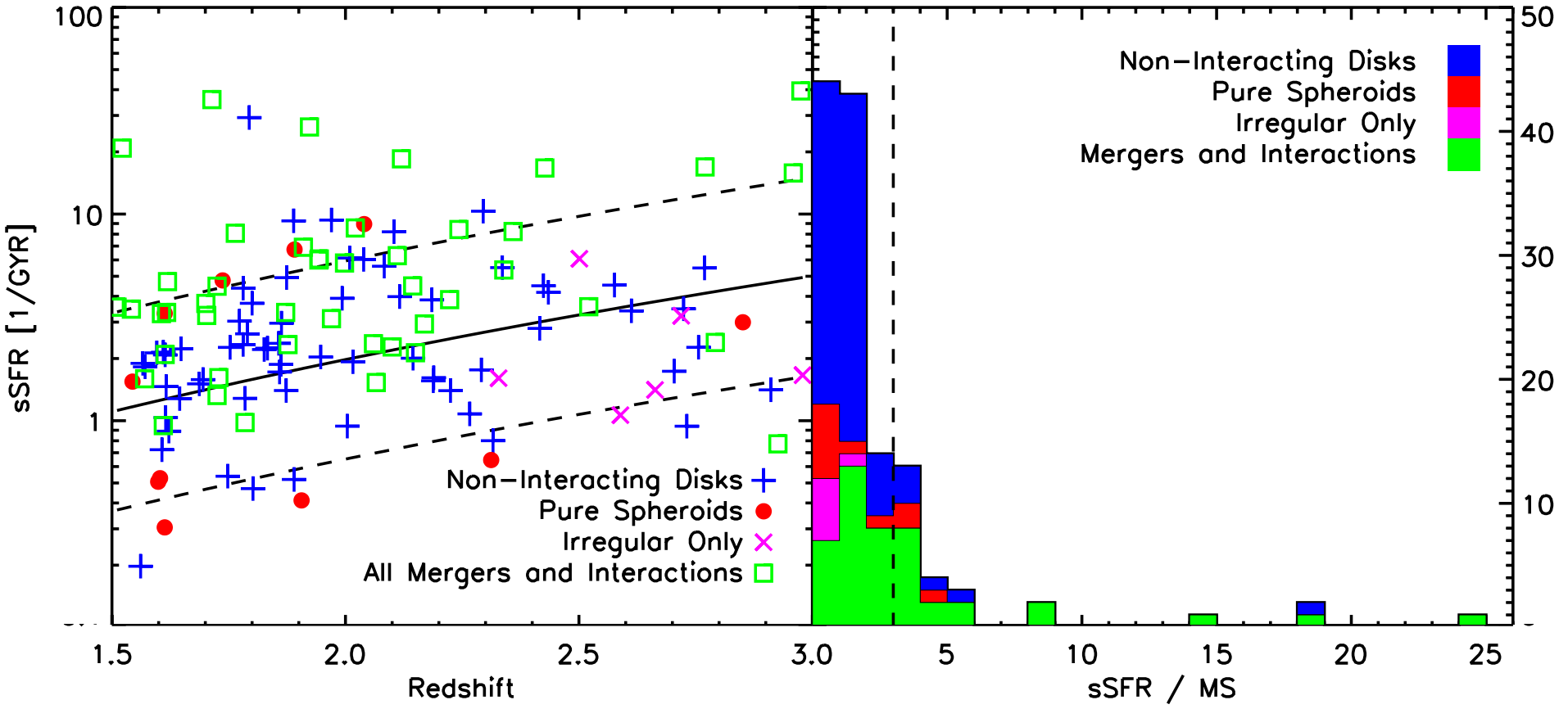

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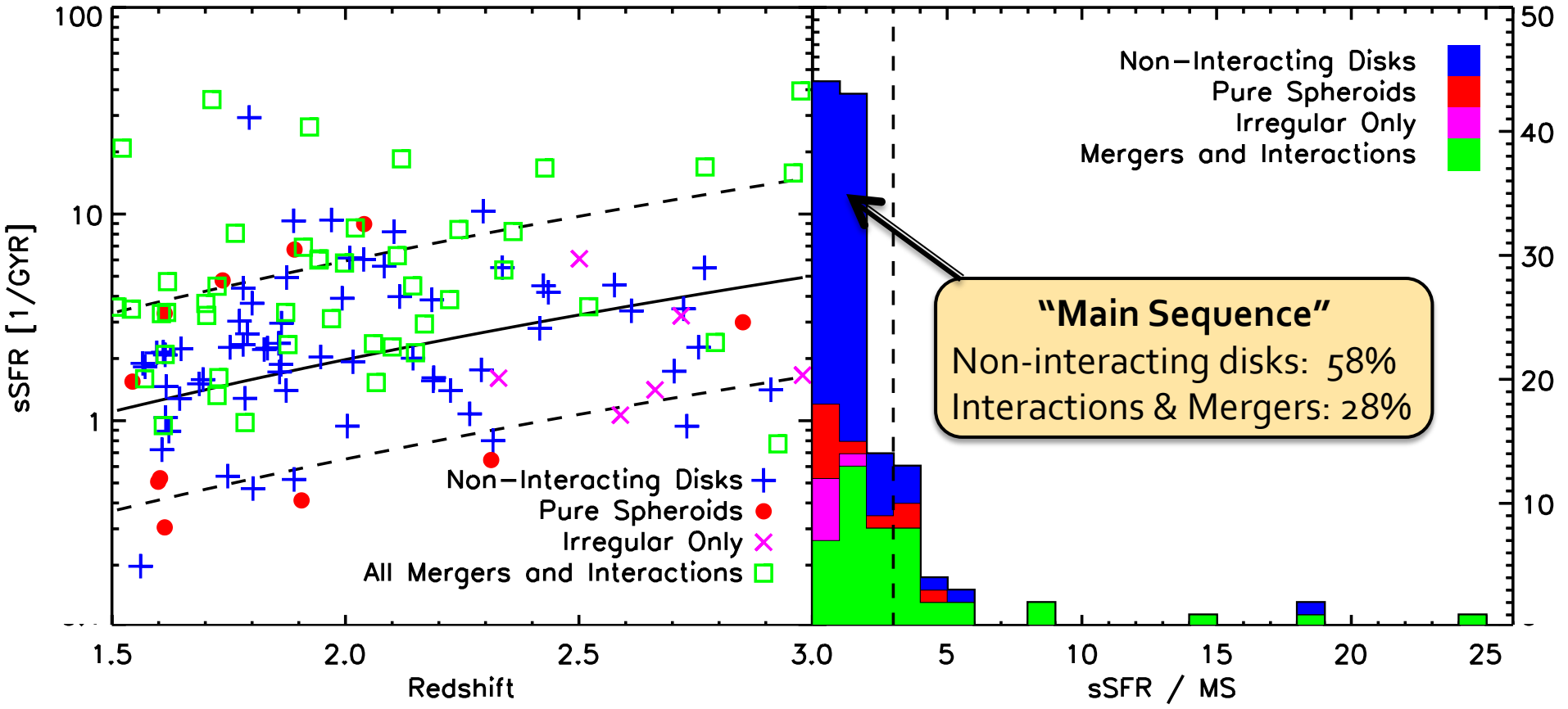
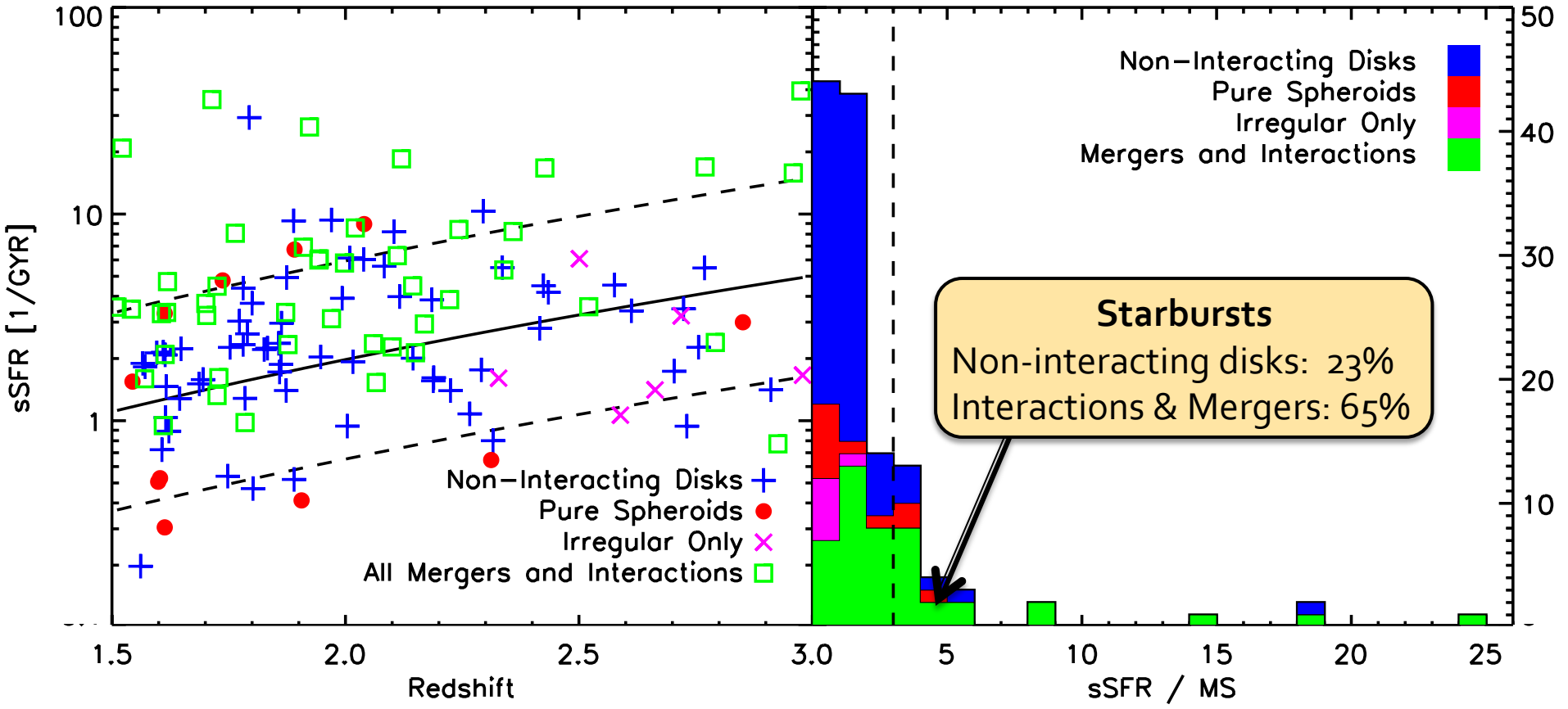
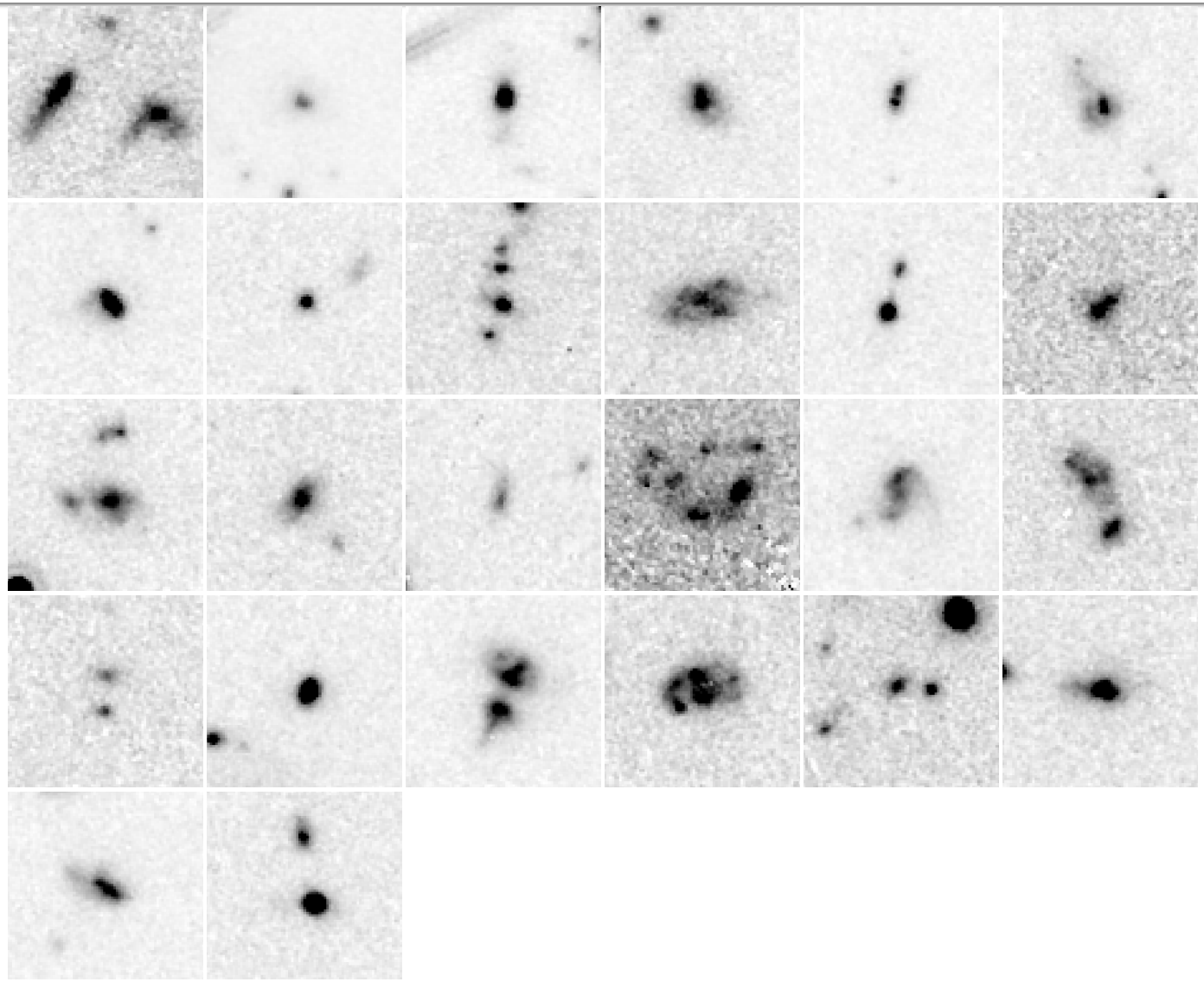


Are z~2 ULIRGs Starbursts?



Starbursts

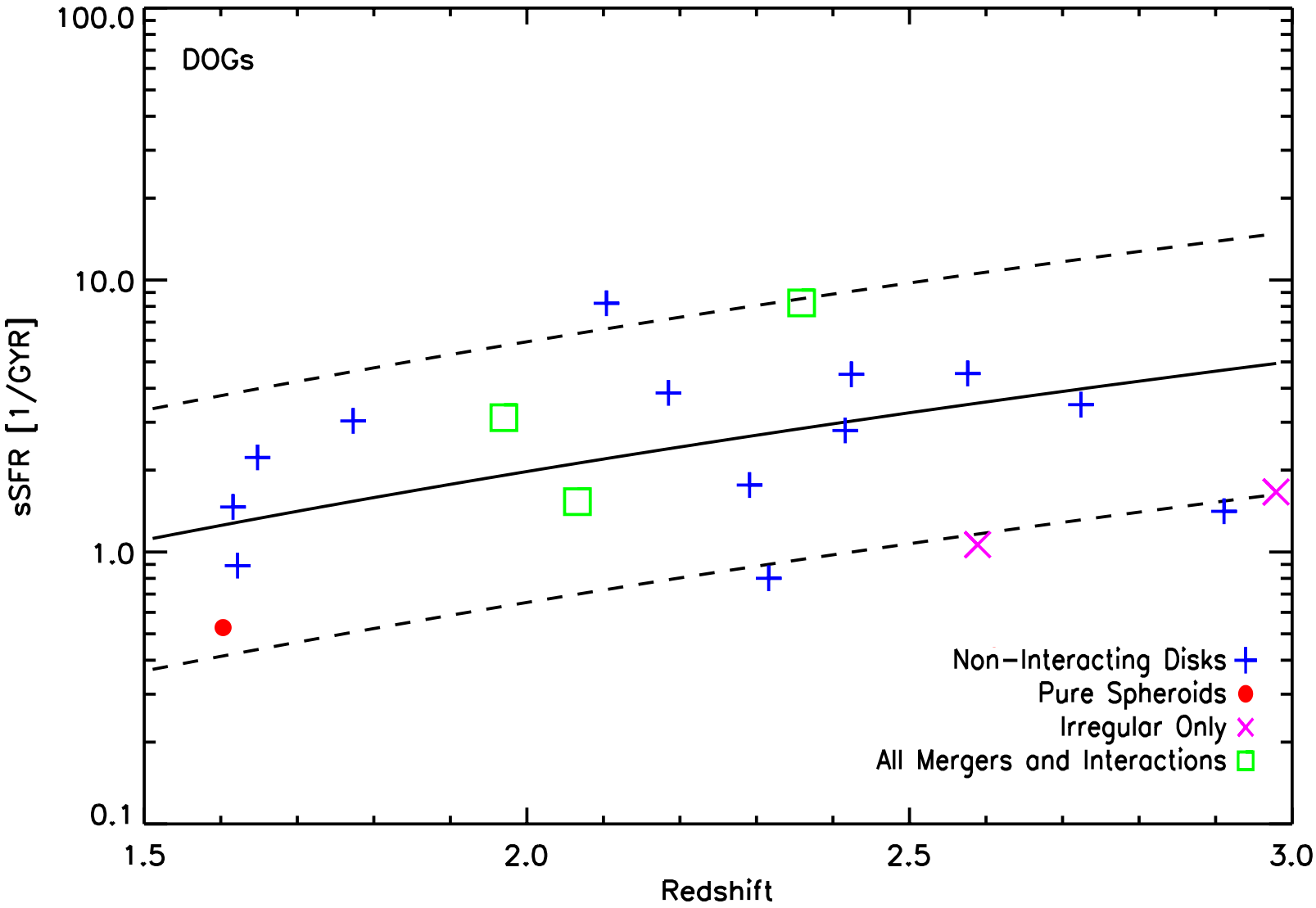


Conclusions

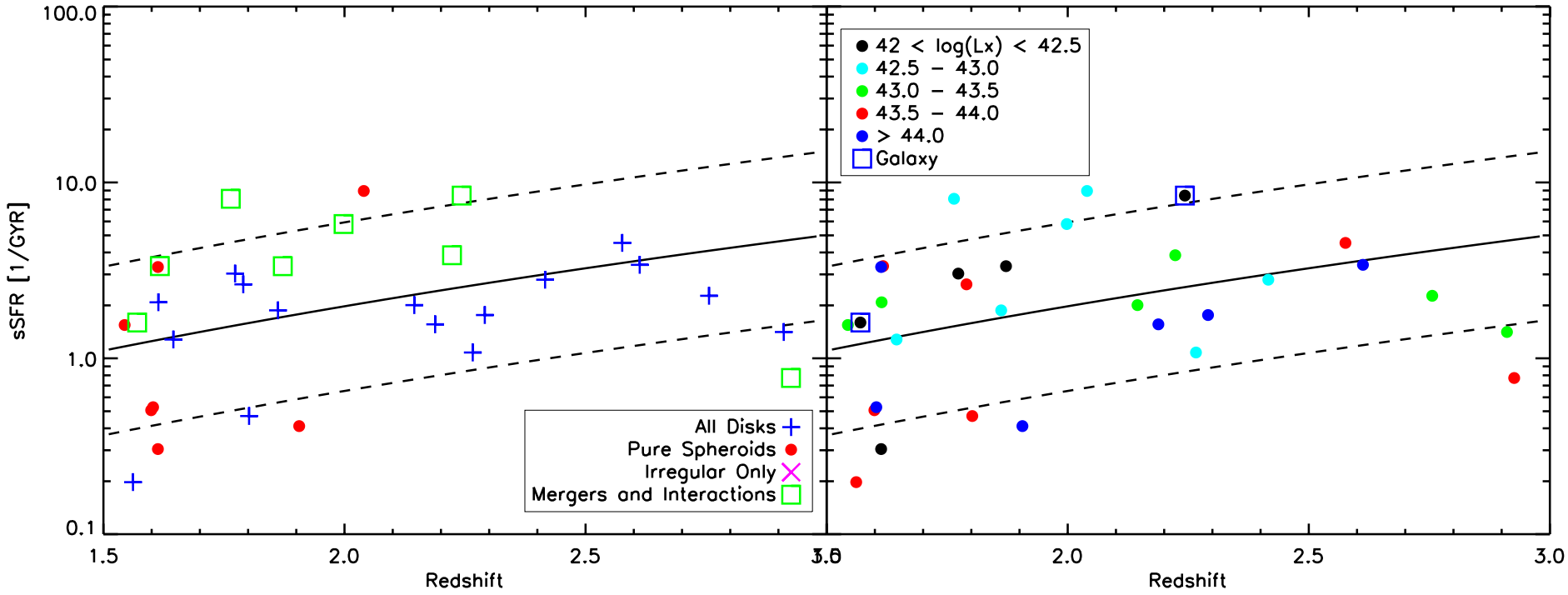
- Morphologies of z~2 ULIRGs span a wide range
  - 'Disks' make up a significant fraction (many irregular)
    - 40% non-interacting, 60% total
  - ~45% are mergers or interactions
  - Additional ~25% are irregular (minor mergers?)
  - Comparable to fractions at z~1, slightly lower
  - More likely to be interacting pairs than advanced mergers

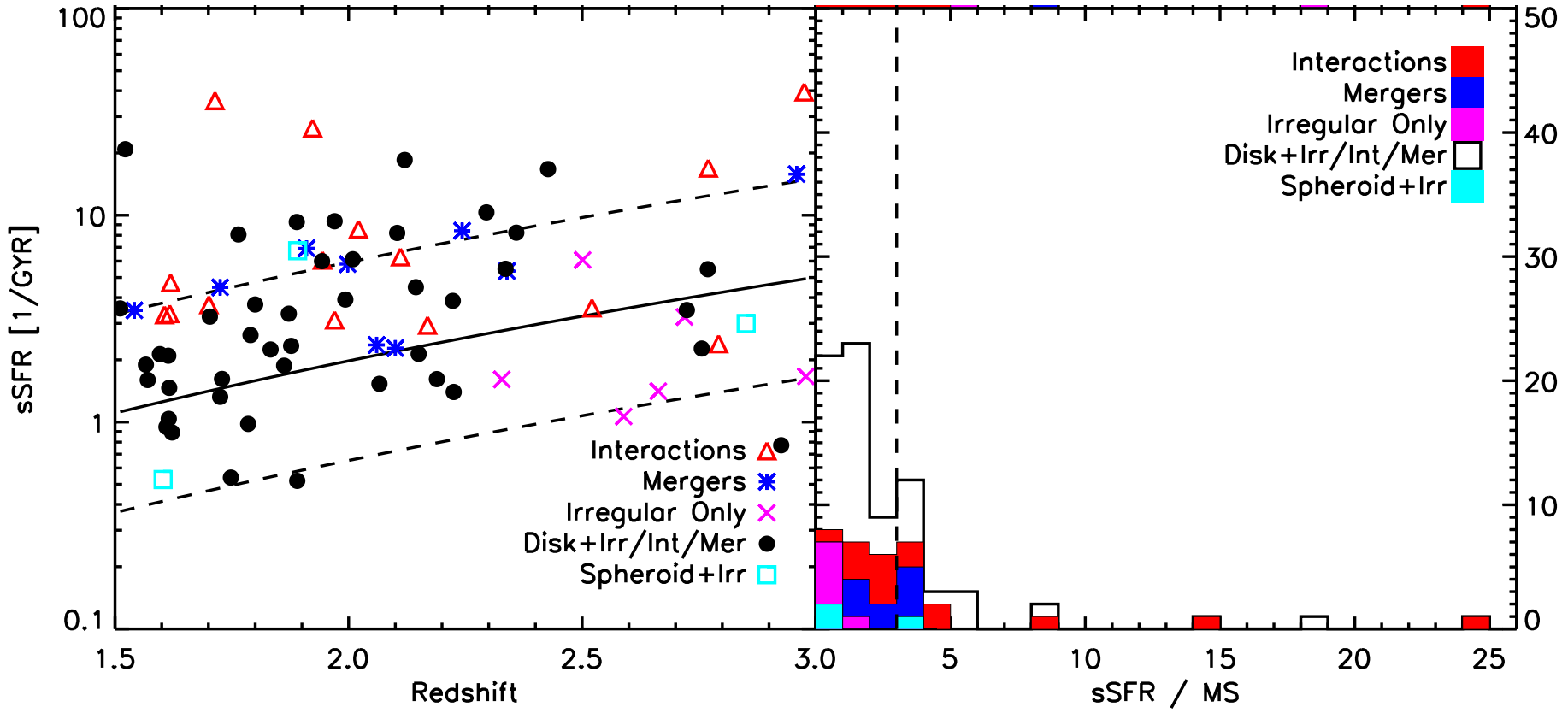
  → z~2 ULIRGs more like z~0 LIRGs
- Most (U)LIRGs on the main sequence are disks (58%)
  - BUT significant (28%) number are mergers
- Most starbursts are mergers/interactions (65%)
- Enhanced role of minor mergers?

Where do DOGs live?



Where are X-ray AGN?

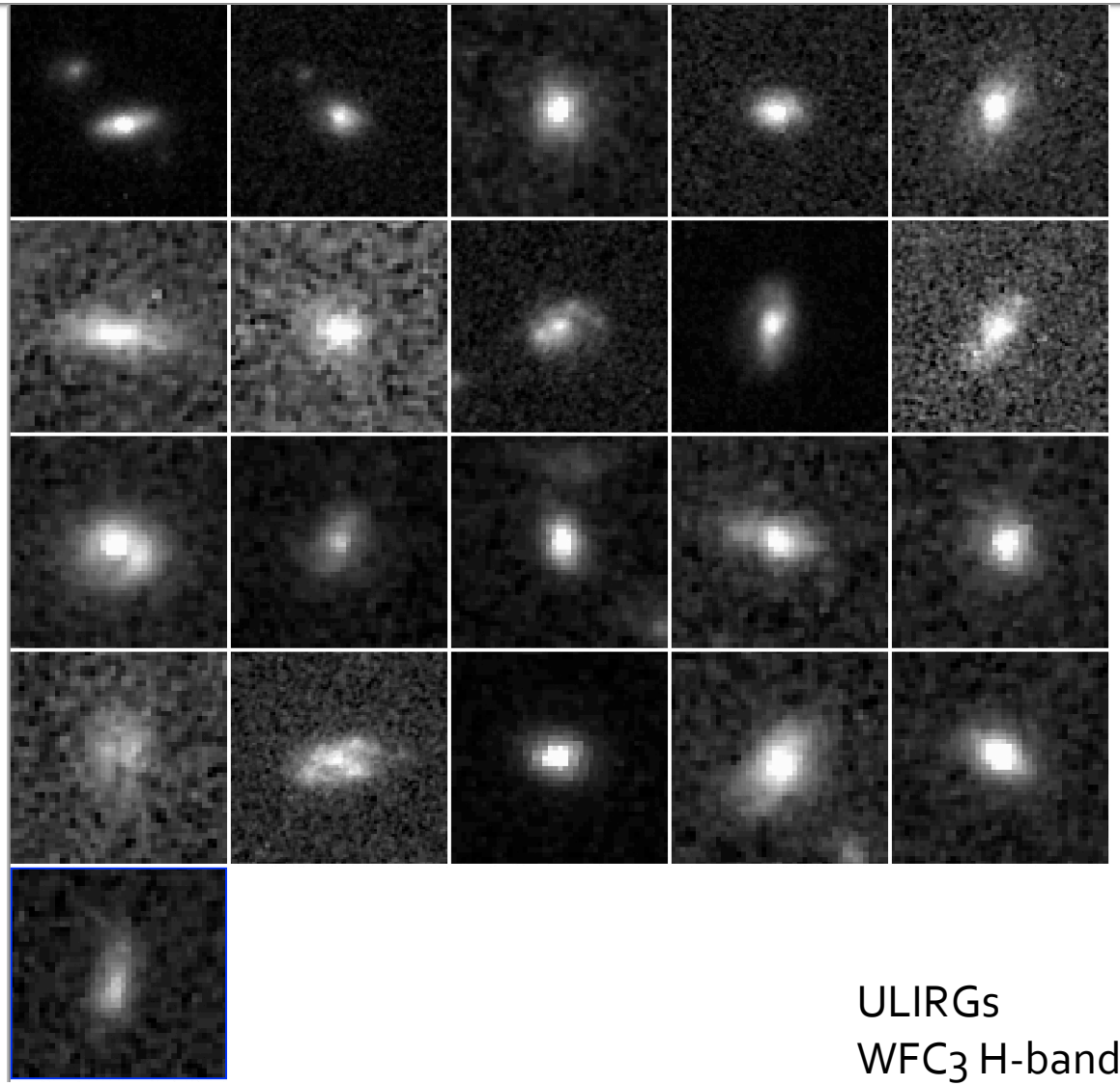



100
10
1
0.1
sSFR [1/GYR]
1.5
2.0
2.5
3.0
Redshift
Interactions
Mergers
Irregular Only
Disk+Irr/Int/Mer
Spheroid+Irr
50
40
30
20
10
0
5
10
15
20
25
sSFR / MS
Interactions
Mergers
Irregular Only
Disk+Irr/Int/Mer
Spheroid+Irr

CANDELS Morphology: Visual Classifications

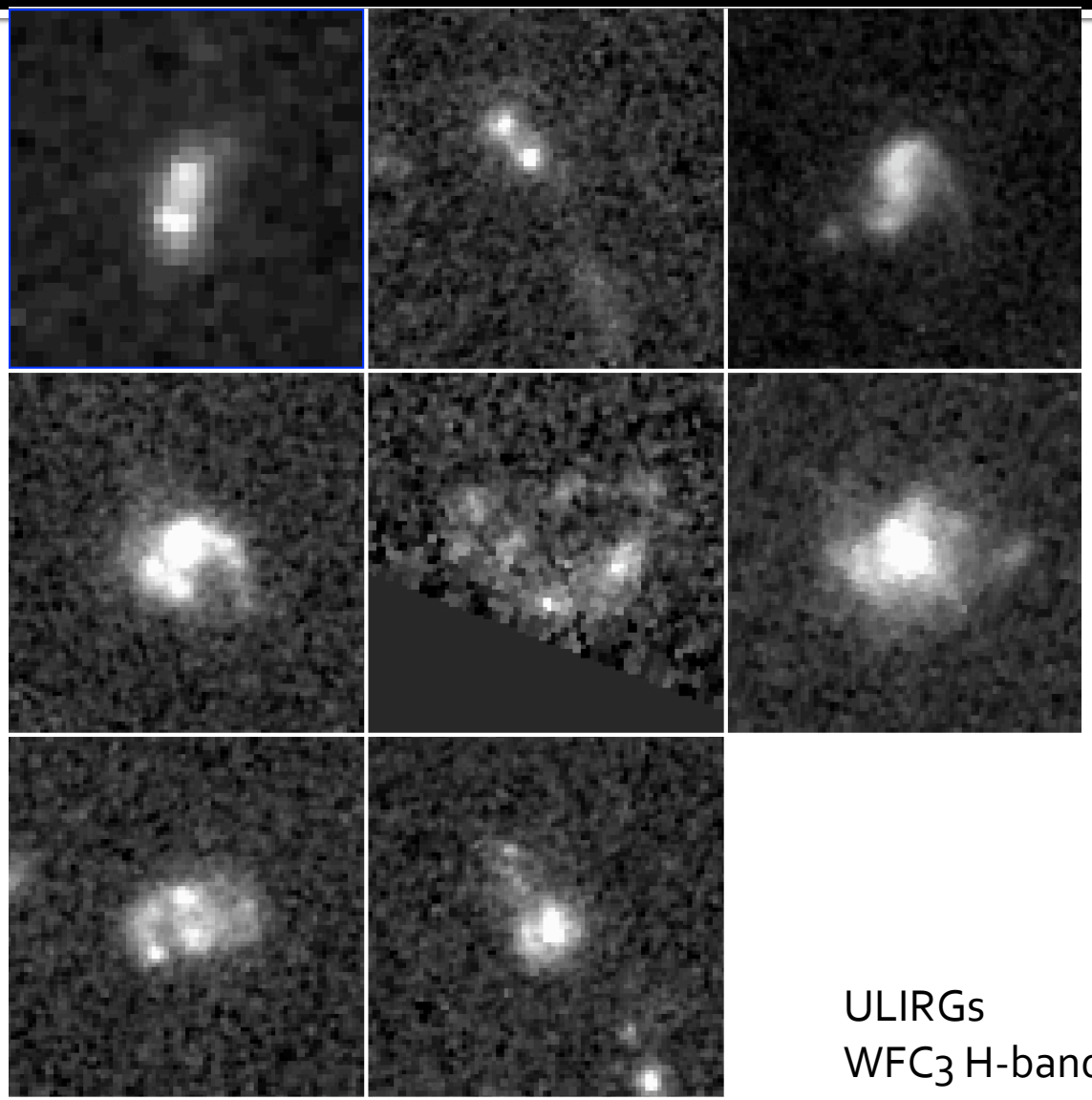
- Aim to classify all galaxies in CANDELS down to H<24.5
  - All redshifts
  - Primarily based on H but including J and ACS bands
  - Thousands of galaxies!
- Detailed classification scheme
- 42 classifiers so far!
  - Goal of 3-5 classifiers per object

Disks



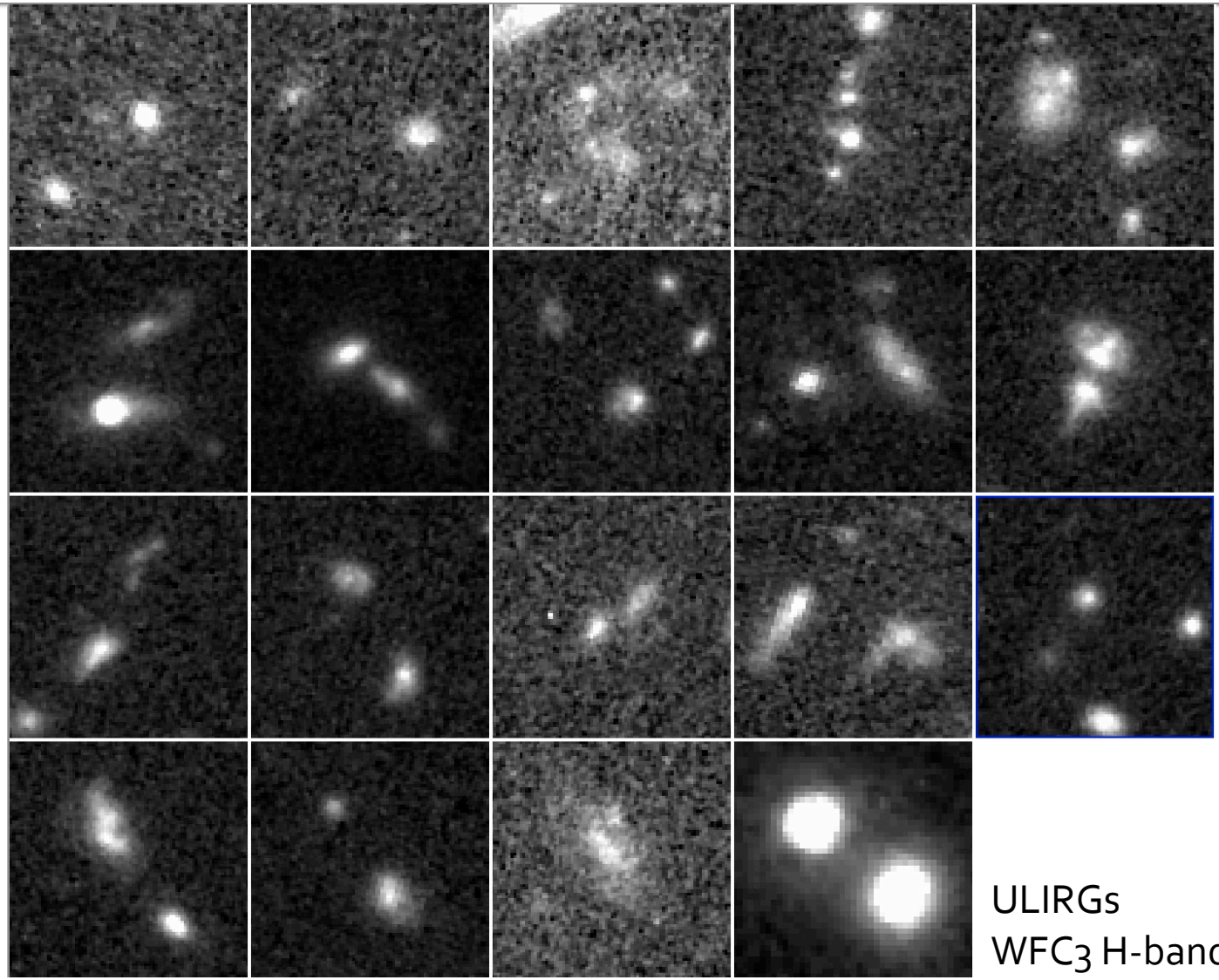
ULIRGs
WFC3 H-band

Mergers



ULIRGs
WFC3 H-band

Interactions



ULIRGs
WFC3 H-band