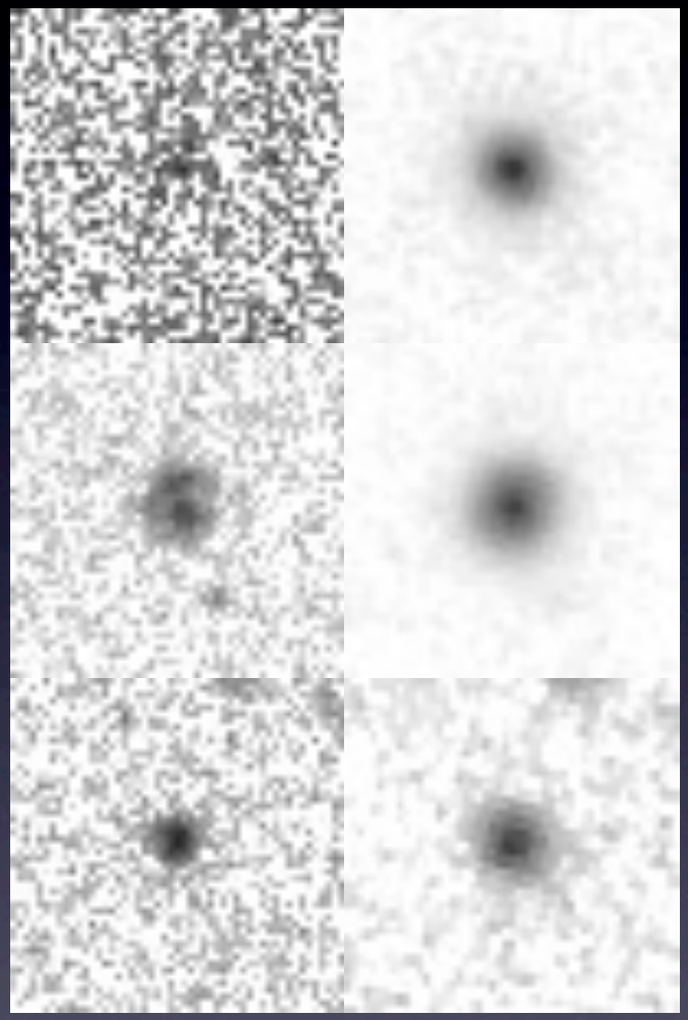
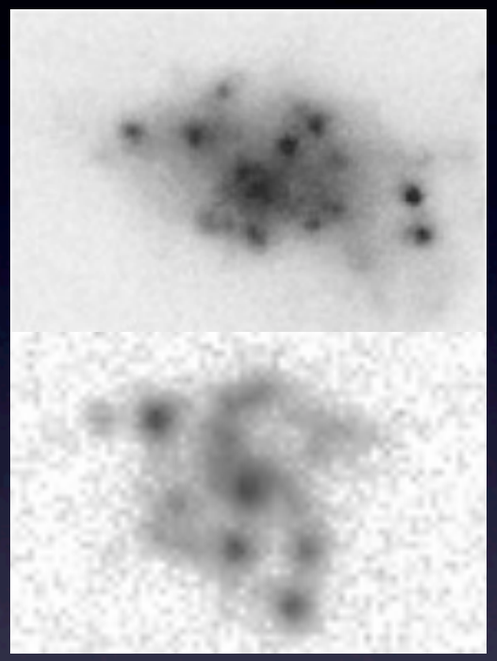
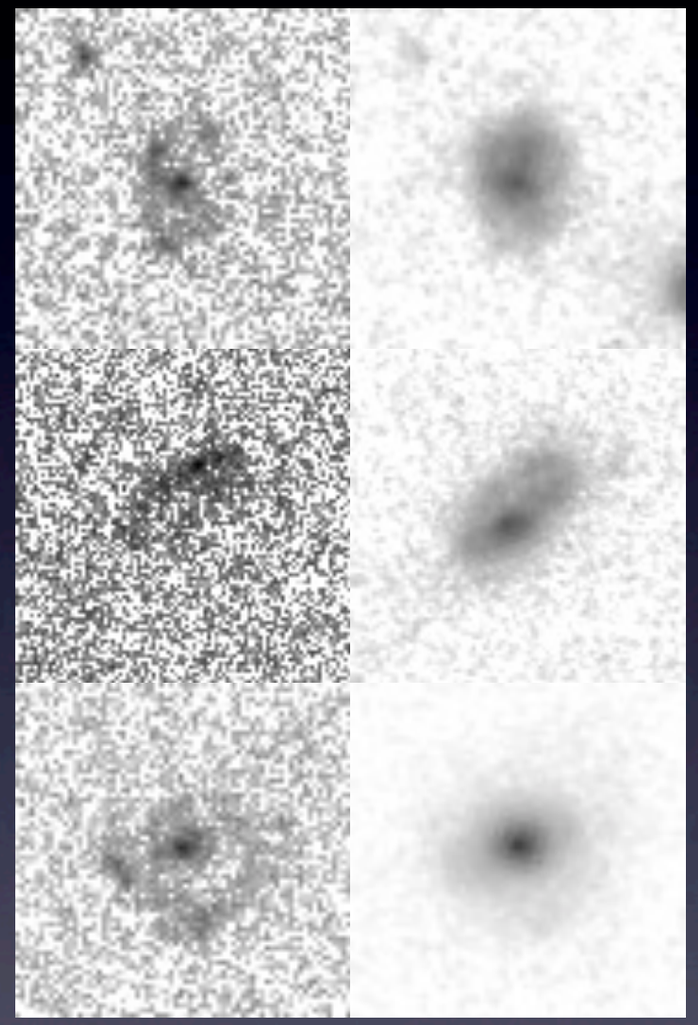
Galaxy Morphologies in the z ~ 2 Universe







Mark Mozena

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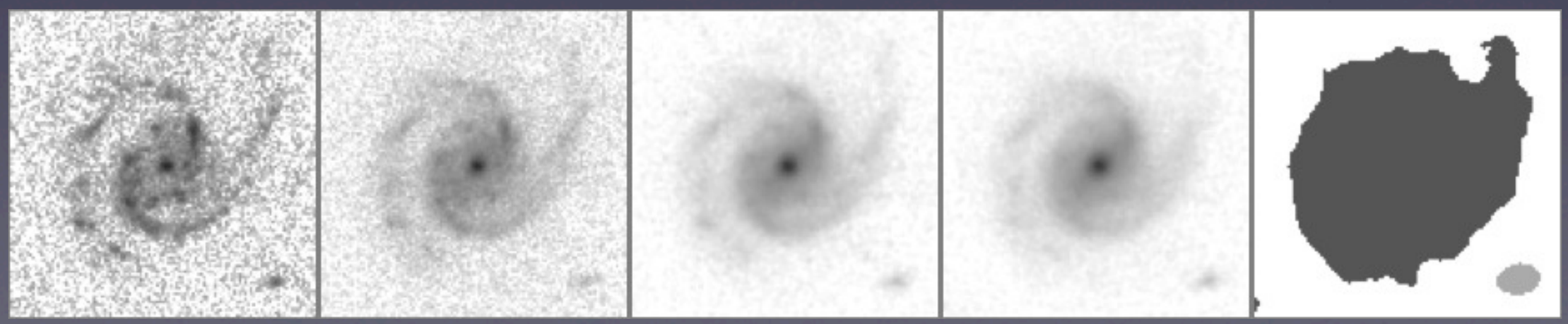
CANDELS Morphology

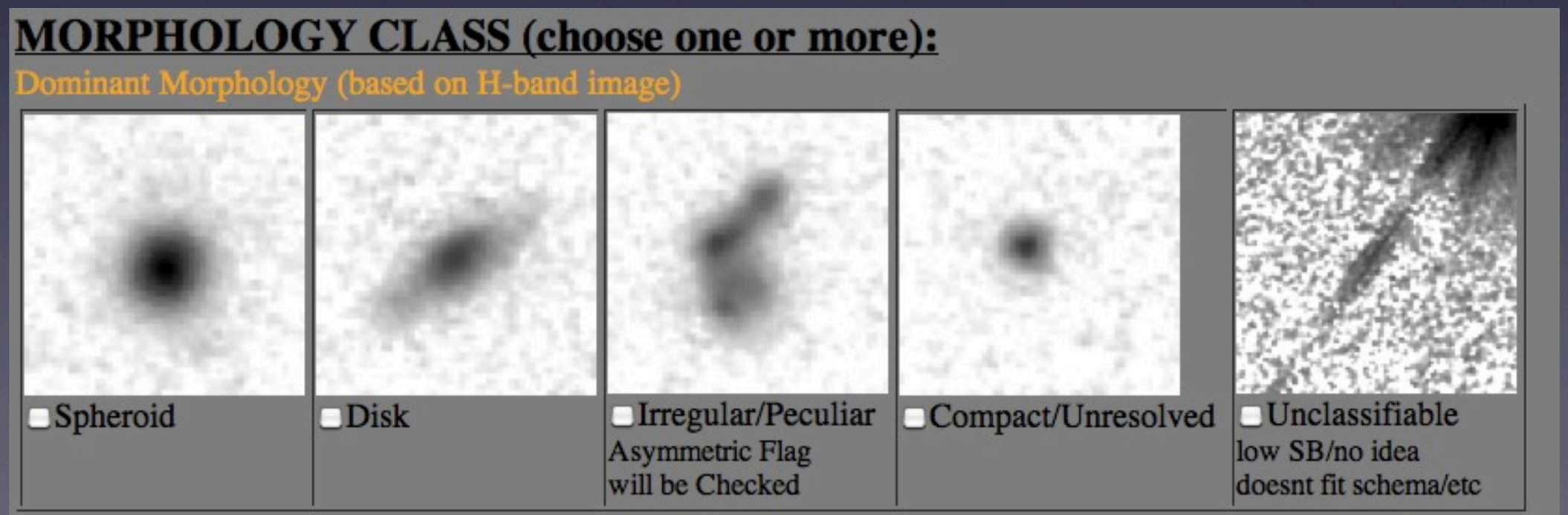
- Visually classify every galaxy in the CANDELS fields with H_{mag}<24.5
- nearly 45,000 galaxies
  - ERS~2,800
  - GOODS-S~5,400 (1/2 at deep depths as well)
  - GOODS-N~5,400 (1/2 at deep depths as well)
  - UDS~10,000
  - EGS~10,000
  - COSMOS~10,000

- GOODS-S morphology catalog will be released around October 1st along with a paper describing the morphology classification scheme



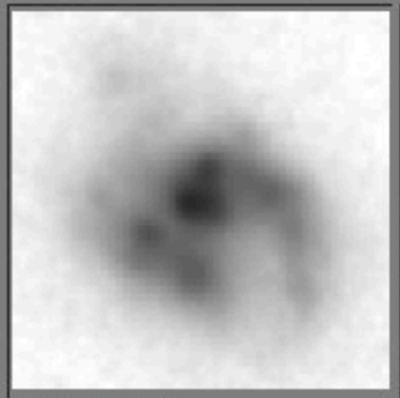
CANDELS Visual Classification Scheme

- developed a classification scheme to capture the morphologies of both local galaxies and the more peculiar ones seen at higher redshift
- includes Hubble-type classifiers as well as visible interaction types and a focus on clumps



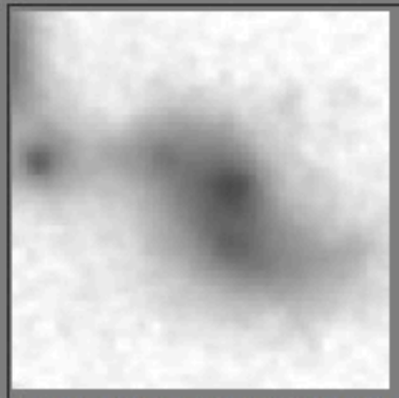
INTERACTION CLASS (choose one, if applicable):

Classification based on H-band image

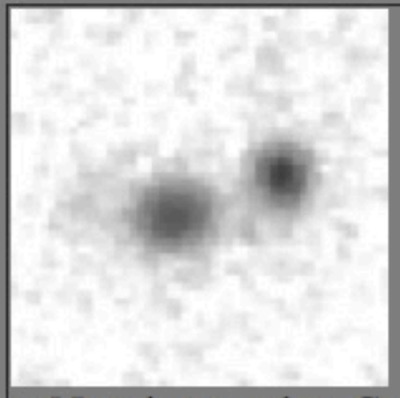


○ Merger
(Train Wreck)

○ Interaction WITHIN segmap
(2+ distinct gals with distortions)



○ Interaction BEYOND segmap
(2+ distinct gals with distortions)



○ Non-interacting Companion
(WITHIN or BEYOND segmap)
close nearby neighbor(s) but morph undisturbed

◉ None

FLAGS:

Flags based on entire cutout

Quality Flags

- ☐ Bad Deblend
  (includes over and under deblended objects in segmap)
- ☐ Image Quality Problem
  (includes: nearby bright object, near edge, diffraction spikes)
- ☐ Uncertain
  (Image quality is fine but classification is uncertain)

K-Correction

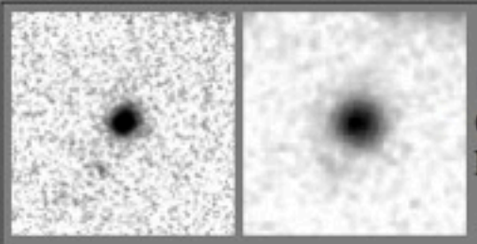
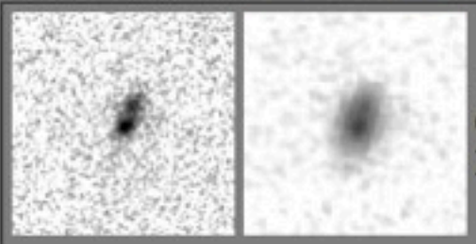
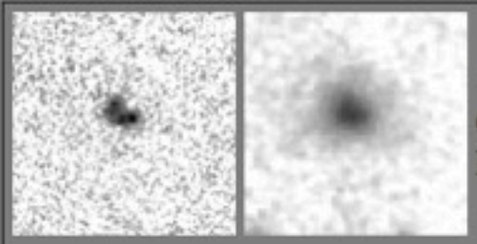
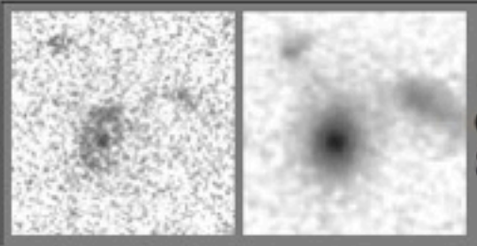
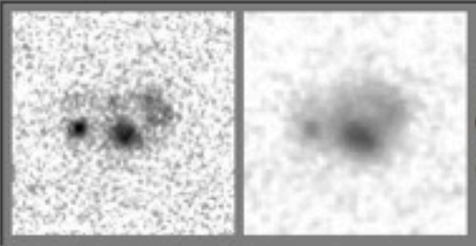
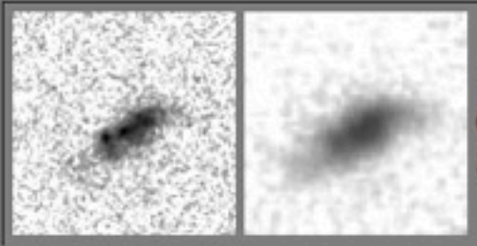
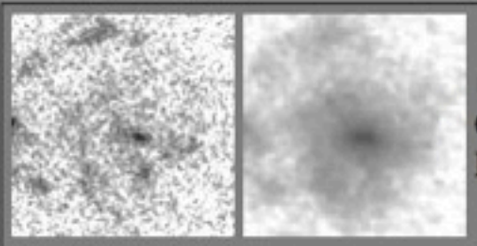
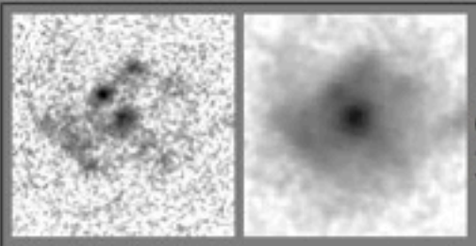
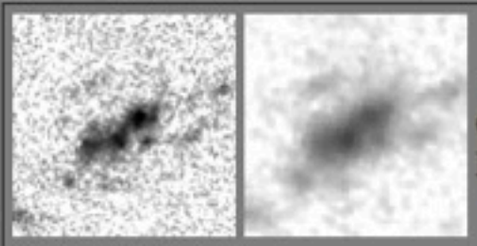
- ☐ V-band Different Morphological Classification
- ☐ z-band Different Morphological Classification
- ☐ J-band Different Morphological Classficiation

Structure Flags

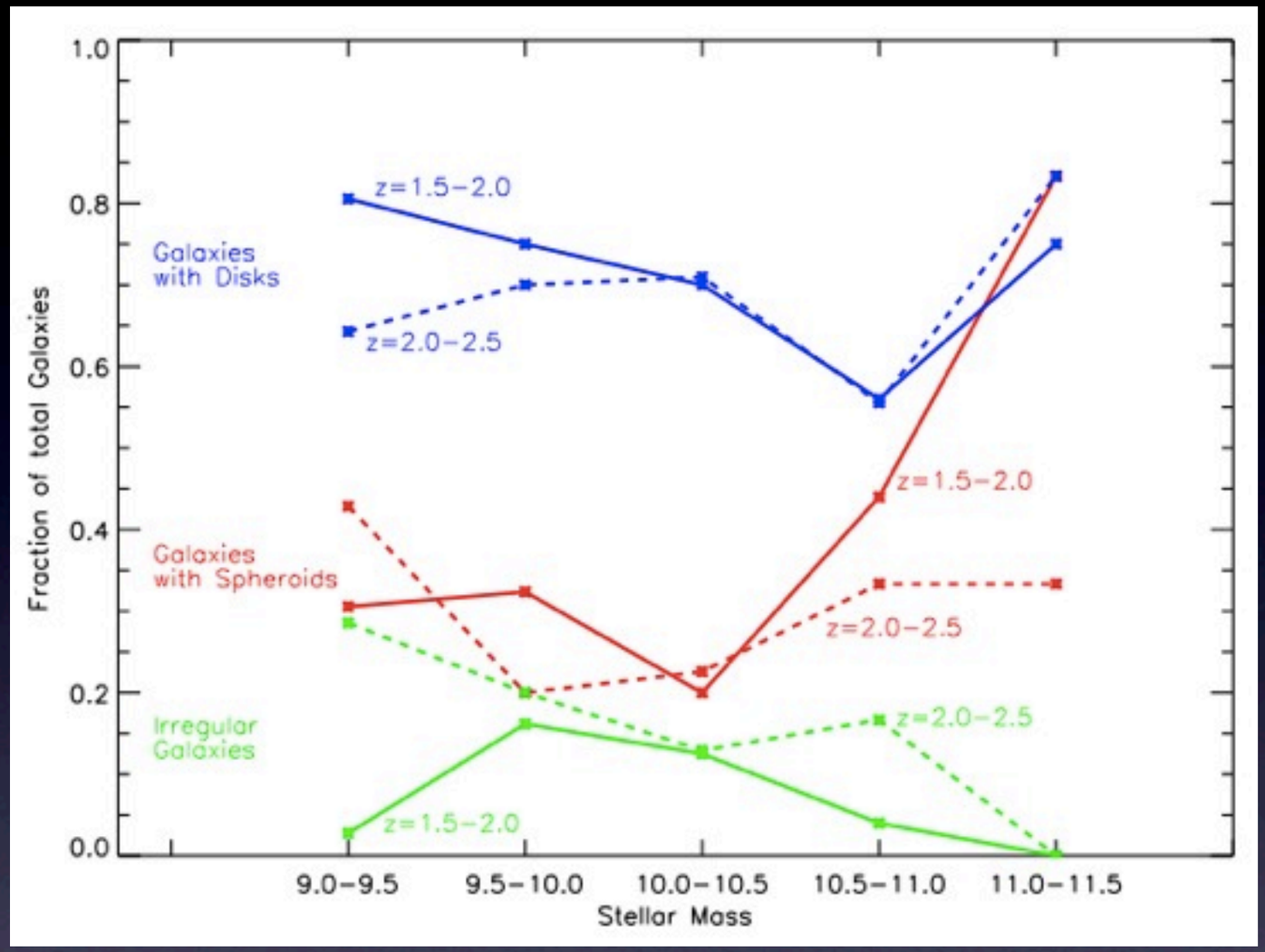
- ☐ Tidal Arms
- ☐ Double Nuclei (in Hband)
- ☐ Asymmetric (in Hband)
- ☐ Spiral Arms/Arc/Ring
- ☐ Bar
- ☐ Pt Source Contamination
  (galaxy with contaminant)
- ☐ Edge-on Disk
- ☐ Face-on Disk
- ☐ Tadpole (2:1)
- ☐ Chain (3:1 with clumps)
- ☐ Disk Dominated (in Hband)
- ☐ Bulge Dominated (in Hband)

CLUMPS (choose one or more):

Classification of dominant target galaxy (based strongly on V-band)

	Major Clumpiness		
Blue Patchiness	 ☐ **No Major Clumps No Patchiness**	 ☐ 1-2 Major Clumps No Patchiness	 ☐ 3+ Major Clumps No Patchiness
	 ☐ No Major Clumps Some Patchiness	 ☐ 1-2 Major Clumps Some Patchiness	 ☐ 3+ Major Clumps Some Patchiness
	 ☐ No Major Clumps Lots of Patchiness	 ☐ 1-2 Major Clumps Lots of Patchiness	 ☐ 3+ Major Clumps Lots of Patchiness

Morphology Fractions

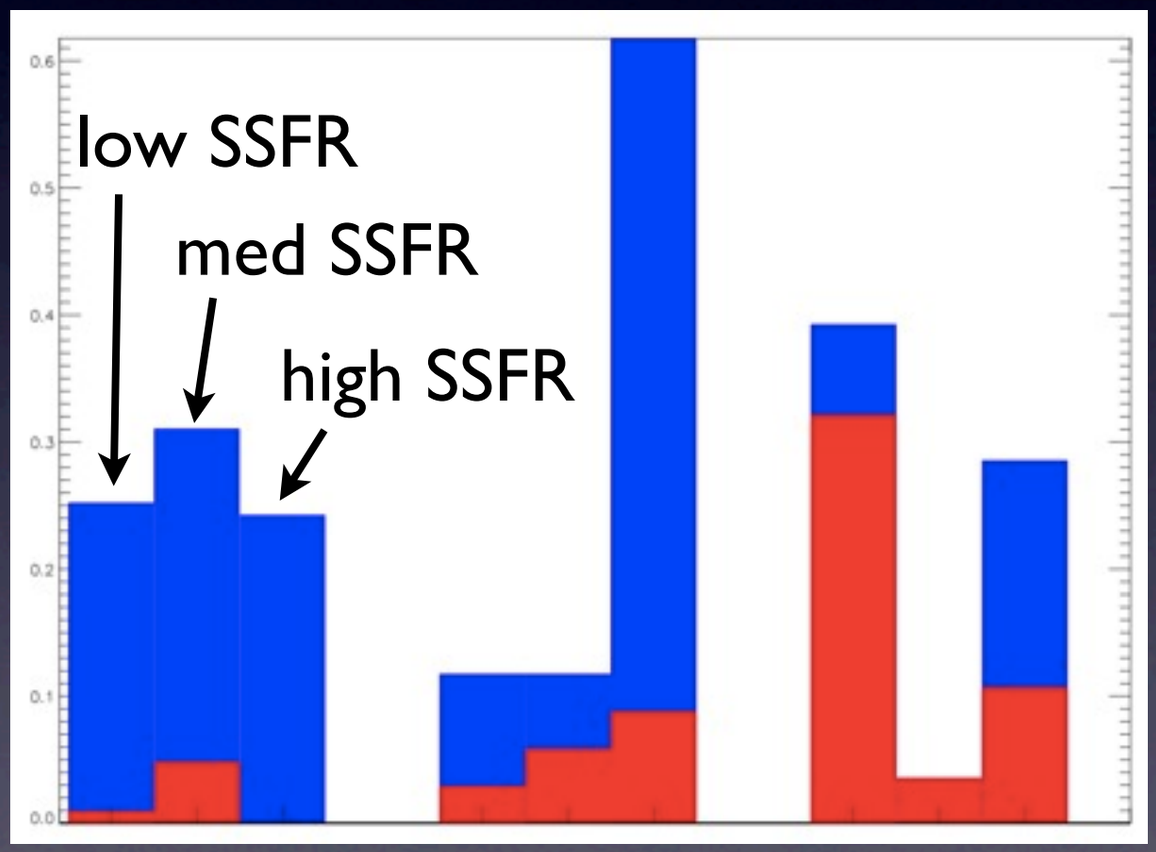


- High mass spheroids emerge by z =1.5-2.0
- More irregulars at lower masses and higher redshift
- **<u>Clumpy and irregular galaxies are rare and do not dominate at z~2</u>**
- Clumpy galaxies tend to be lower mass and at higher redshifts
- Large fraction of galaxies are classified as disks (much more than in Cameron et al., 2010)

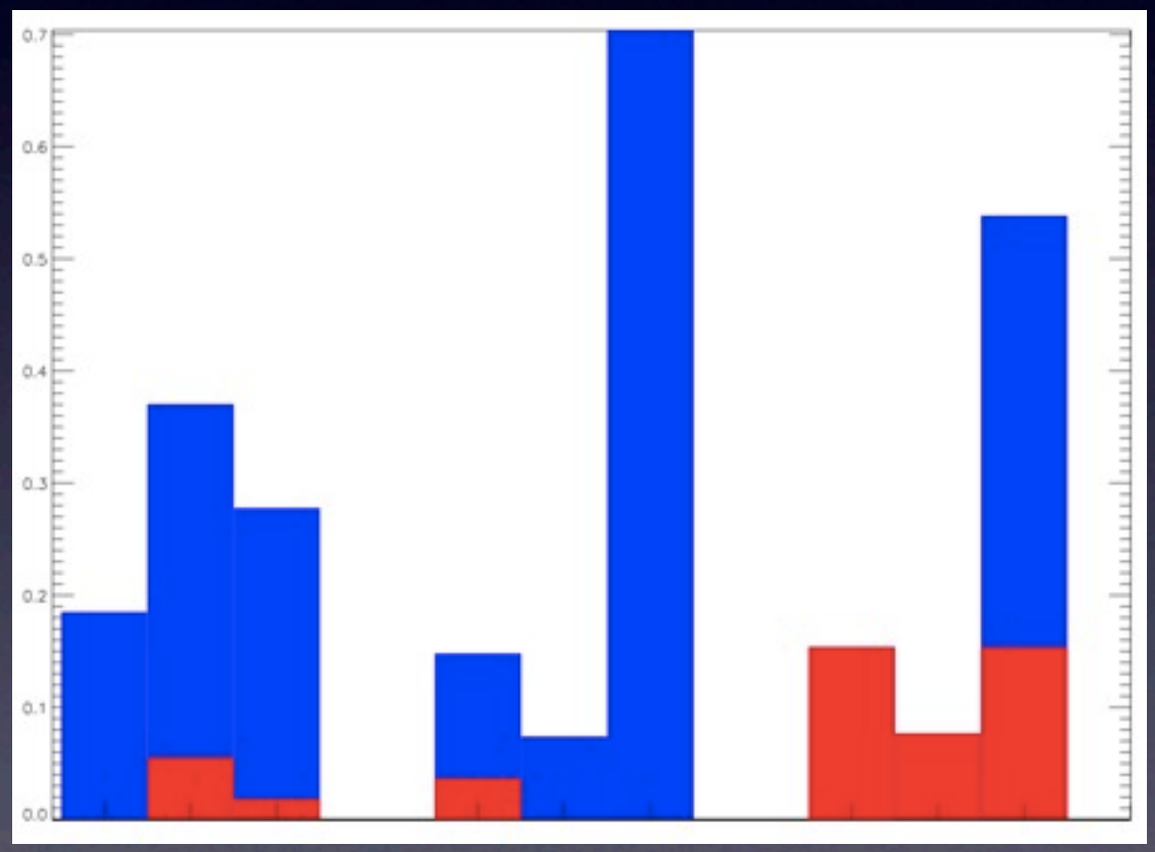
Emergence of Massive Spheroids at z~2

Blue: Disk Dominated (n<1.5)
Red: Spheroid Dominated (n>2.5)

1.5 < z < 2.0



2.0 < z < 2.5



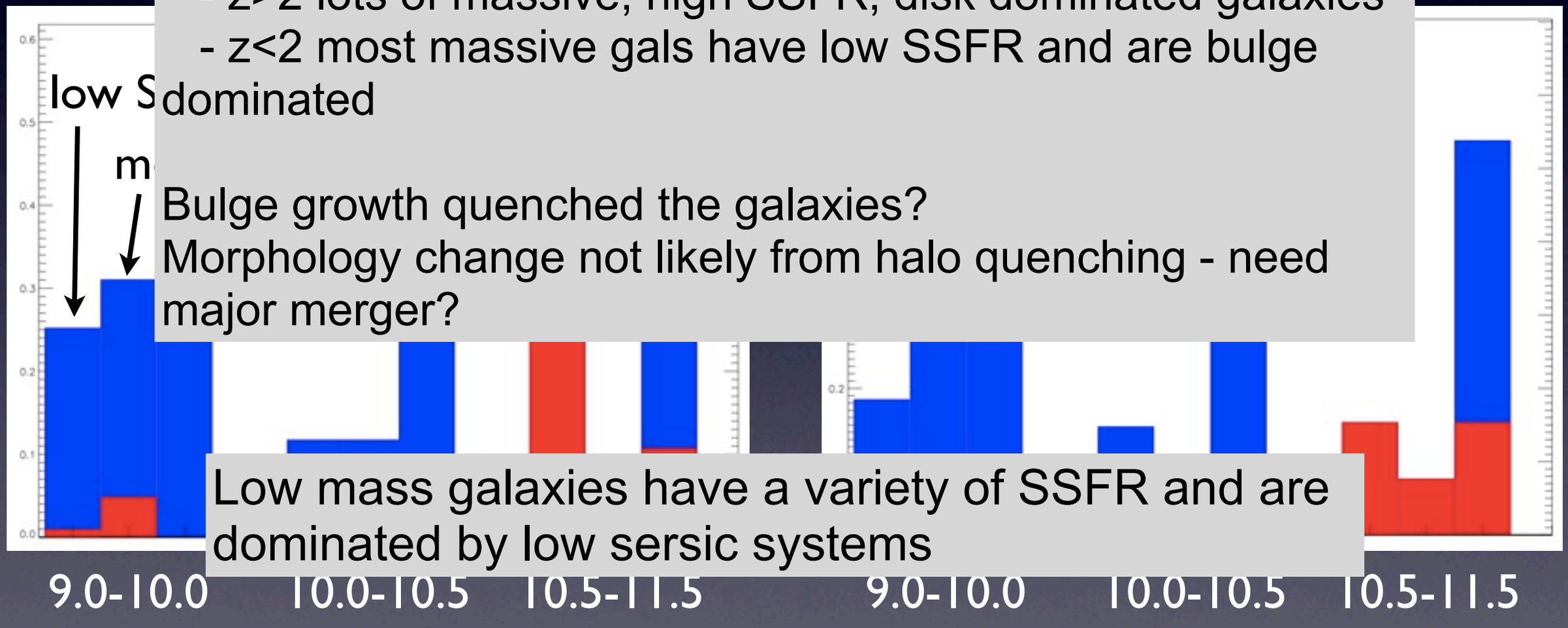
Stellar Mass

Emergence of Massive Spheroids at z~2

Blue: Disk Dominated (n<1.5)
Red: Spheroid Dominated (n>2.5)

Massive galaxies are quenched at z~2
- z>2 lots of massive, high SSFR, disk dominated galaxies
- z<2 most massive gals have low SSFR and are bulge dominated

Bulge growth quenched the galaxies?
Morphology change not likely from halo quenching - need major merger?

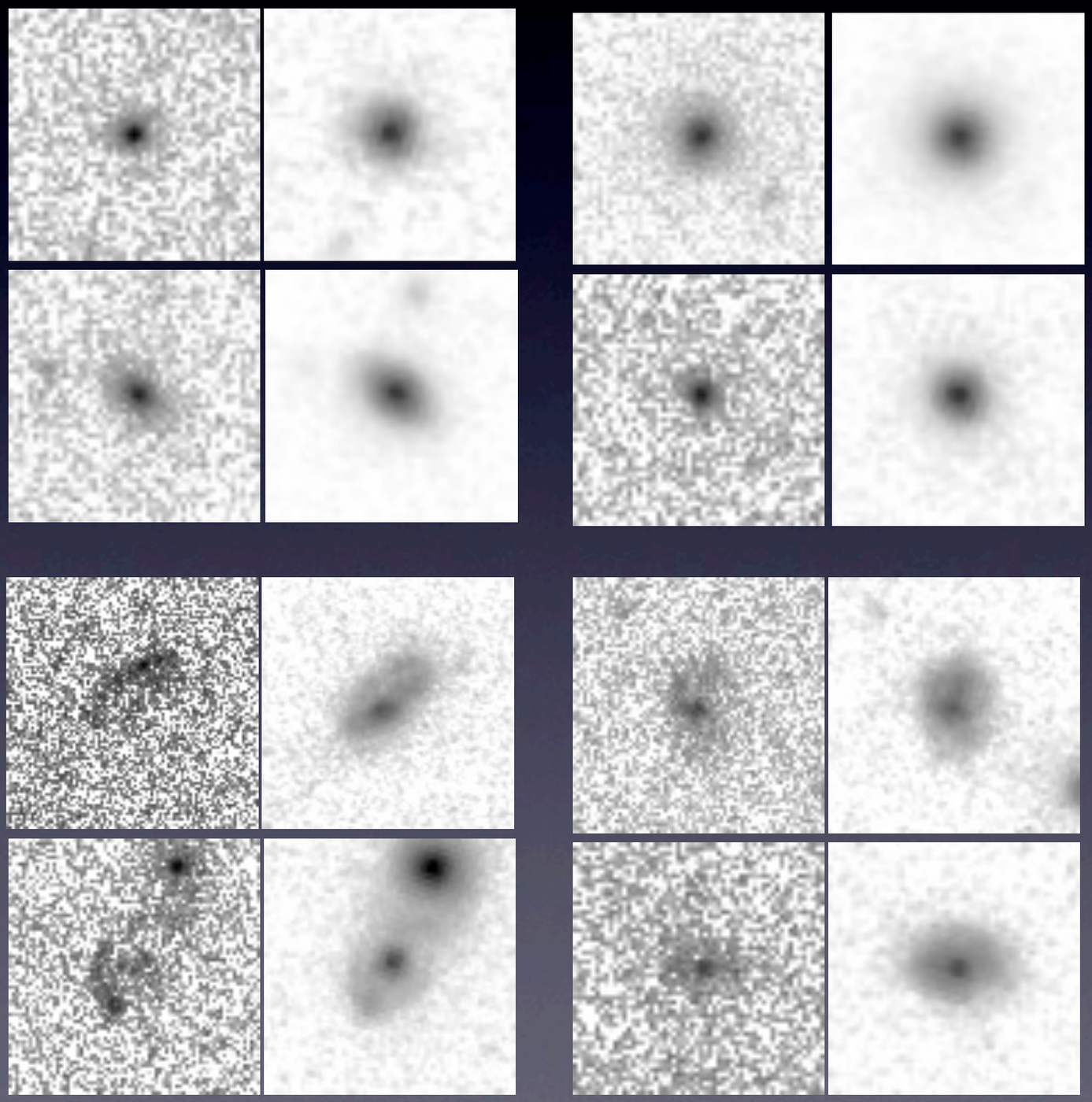


Low mass galaxies have a variety of SSFR and are dominated by low sersic systems

Stellar Mass

Massive Red Galaxies

The most massive z~2 galaxies (>10^{11} M_{star})



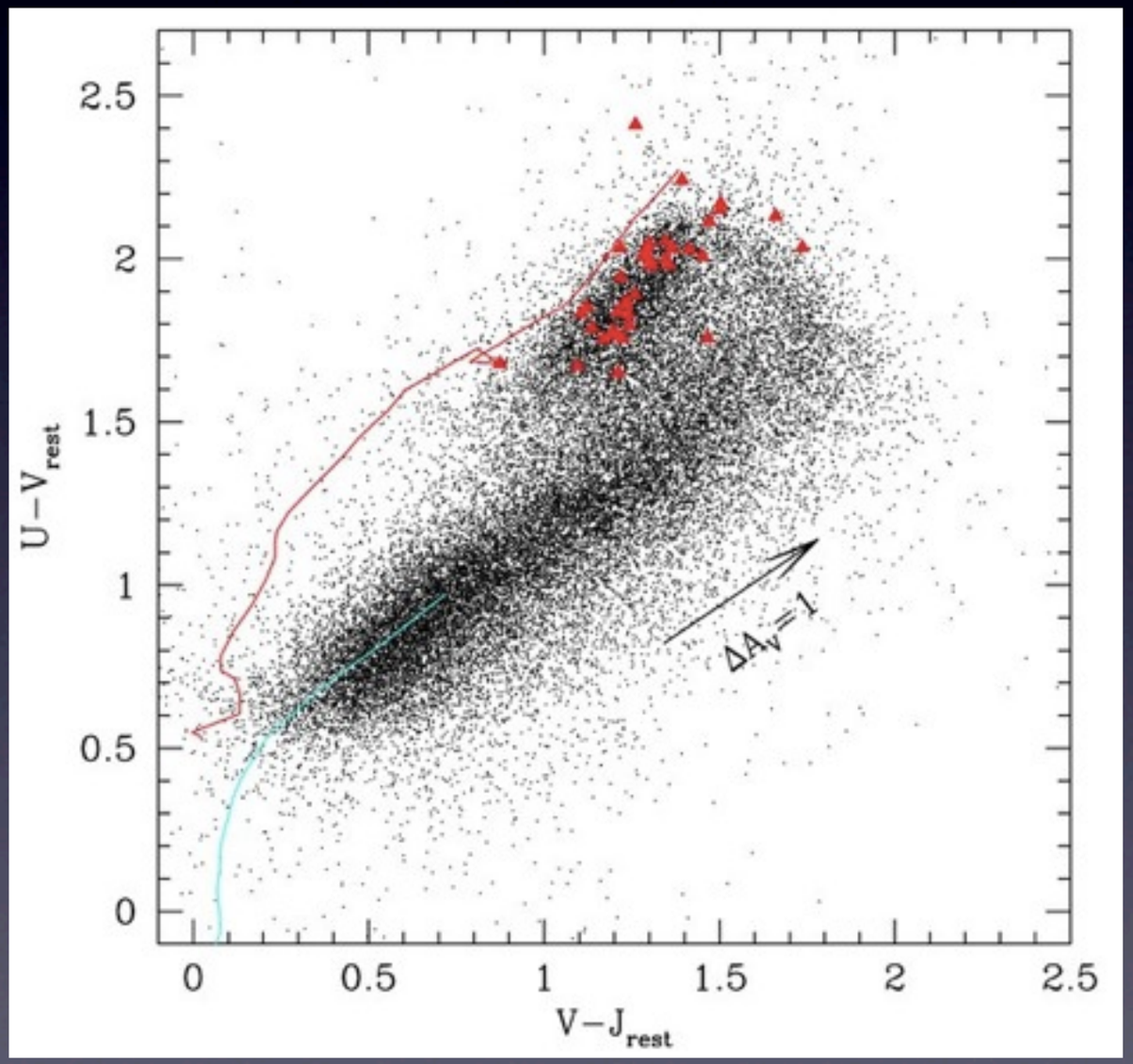
Most are smooth, spheroid dominated, red galaxies

A second "class" of galaxies is also seen

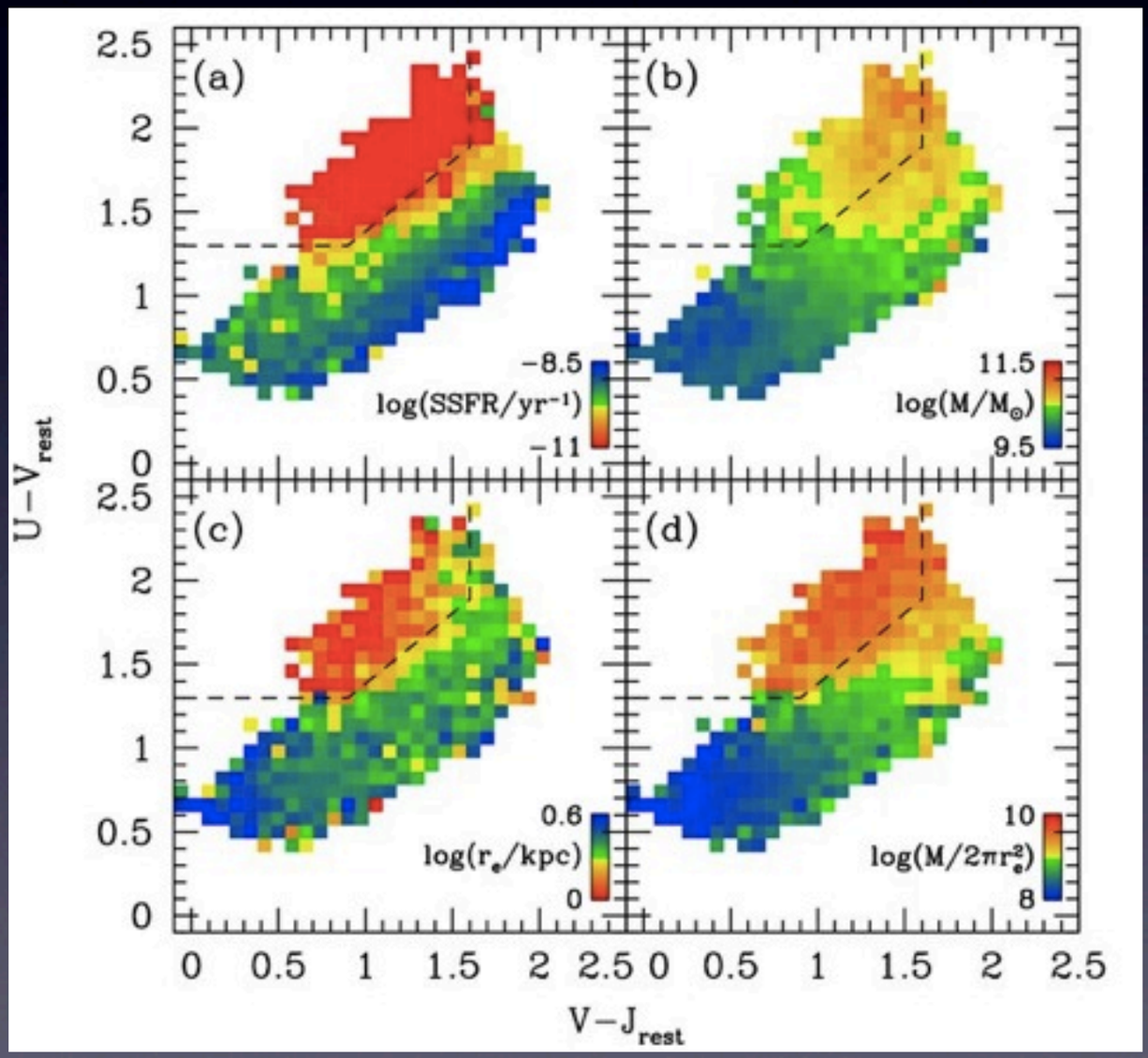
- -patchy in UV
- -low Sersic values
- -weak or absent bulge in Hband

Are these patchy massive disks caused by dust or are they quiescent bulgeless galaxies?

UVJ diagram - separate dusty from quiescent

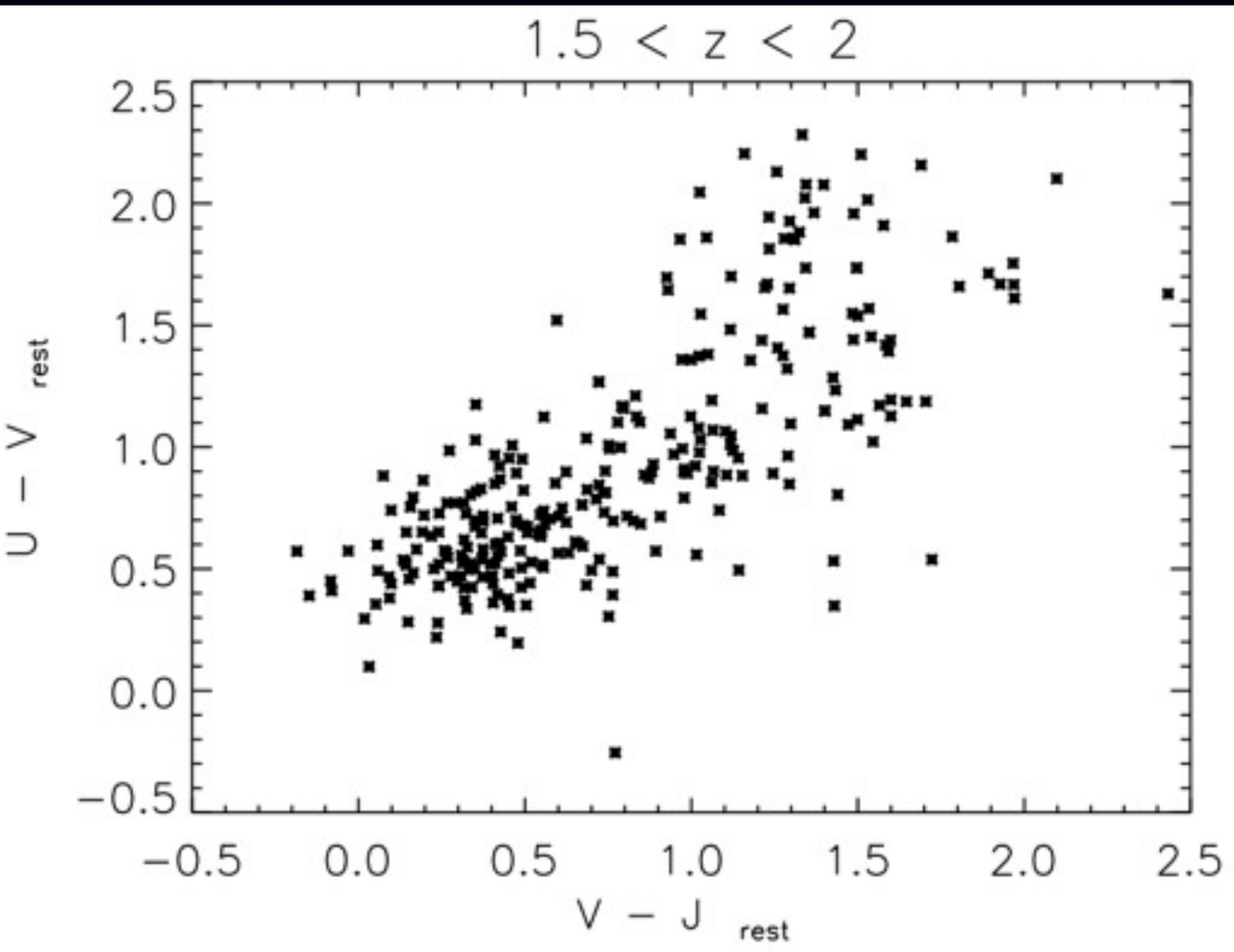


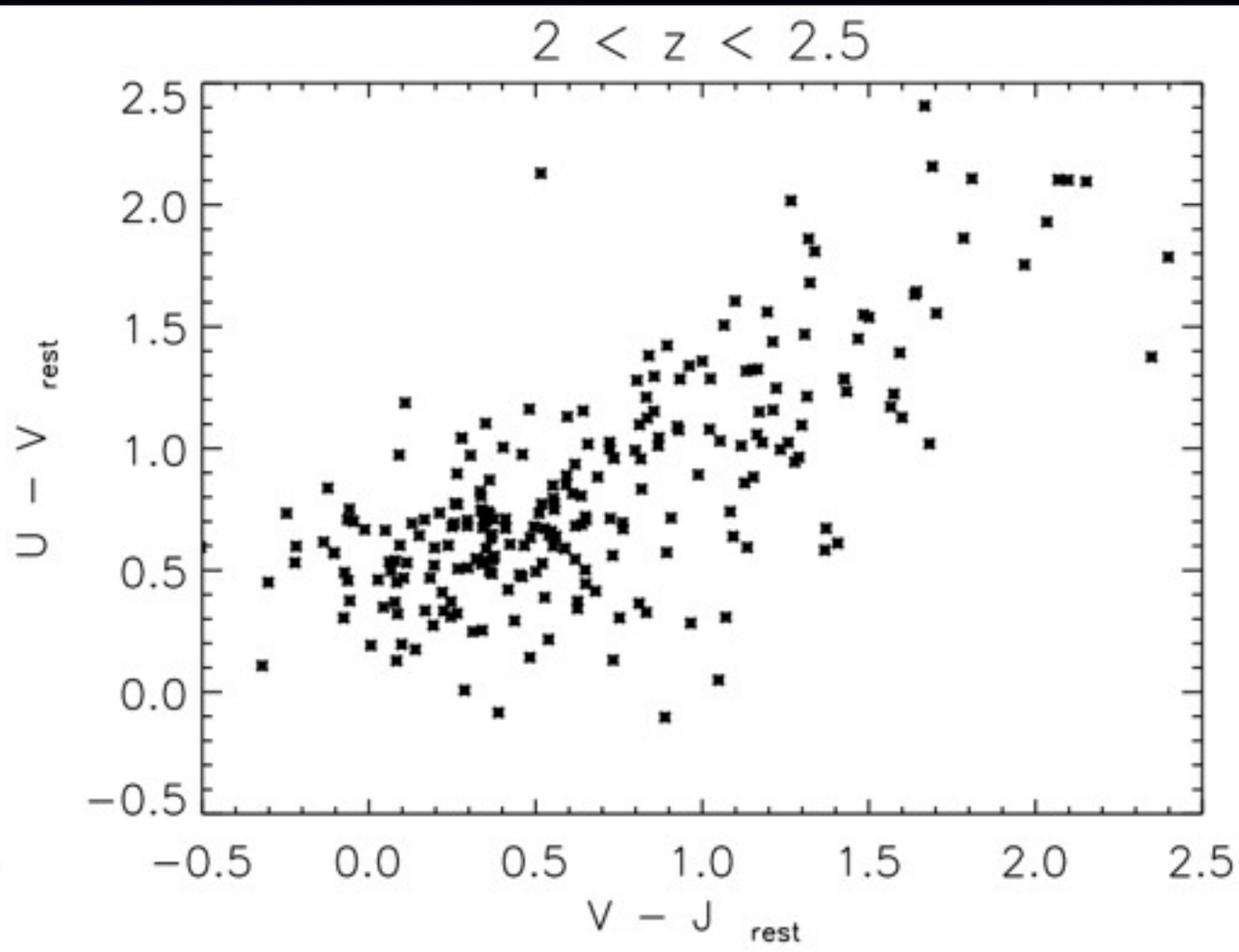
Rik J. Williams 2009 ApJ



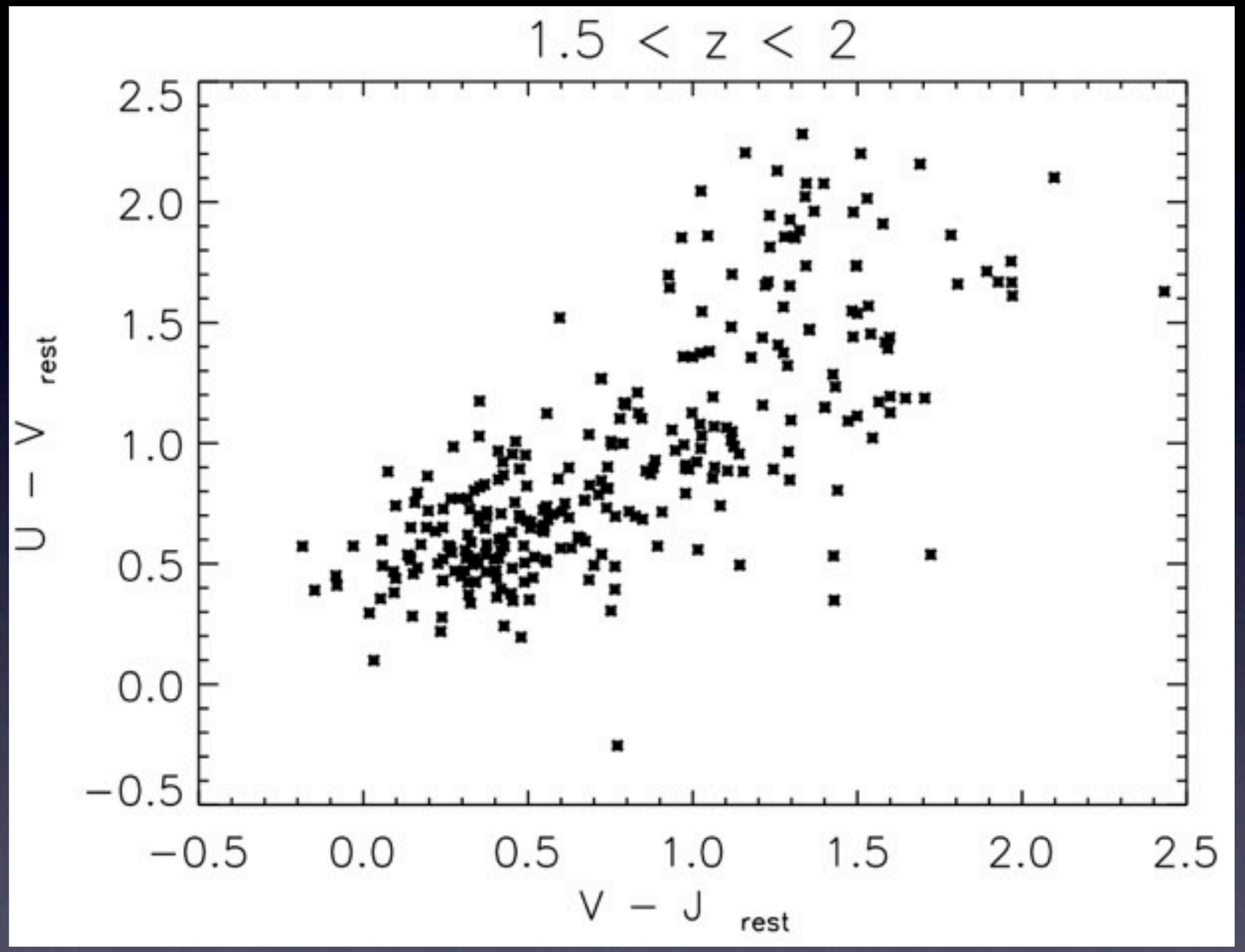
Rik J. Williams 2010 ApJ

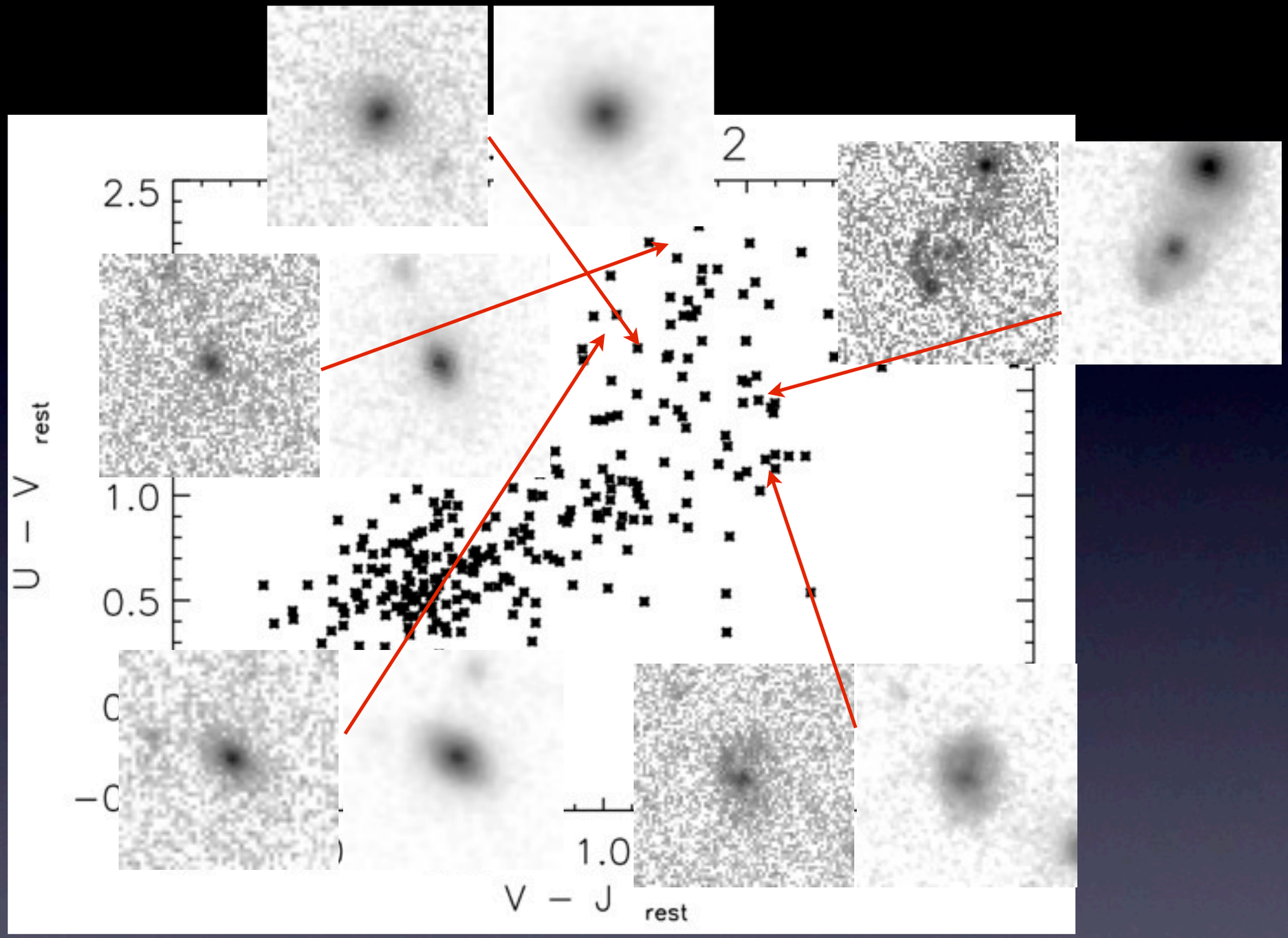
UVJ Diagram





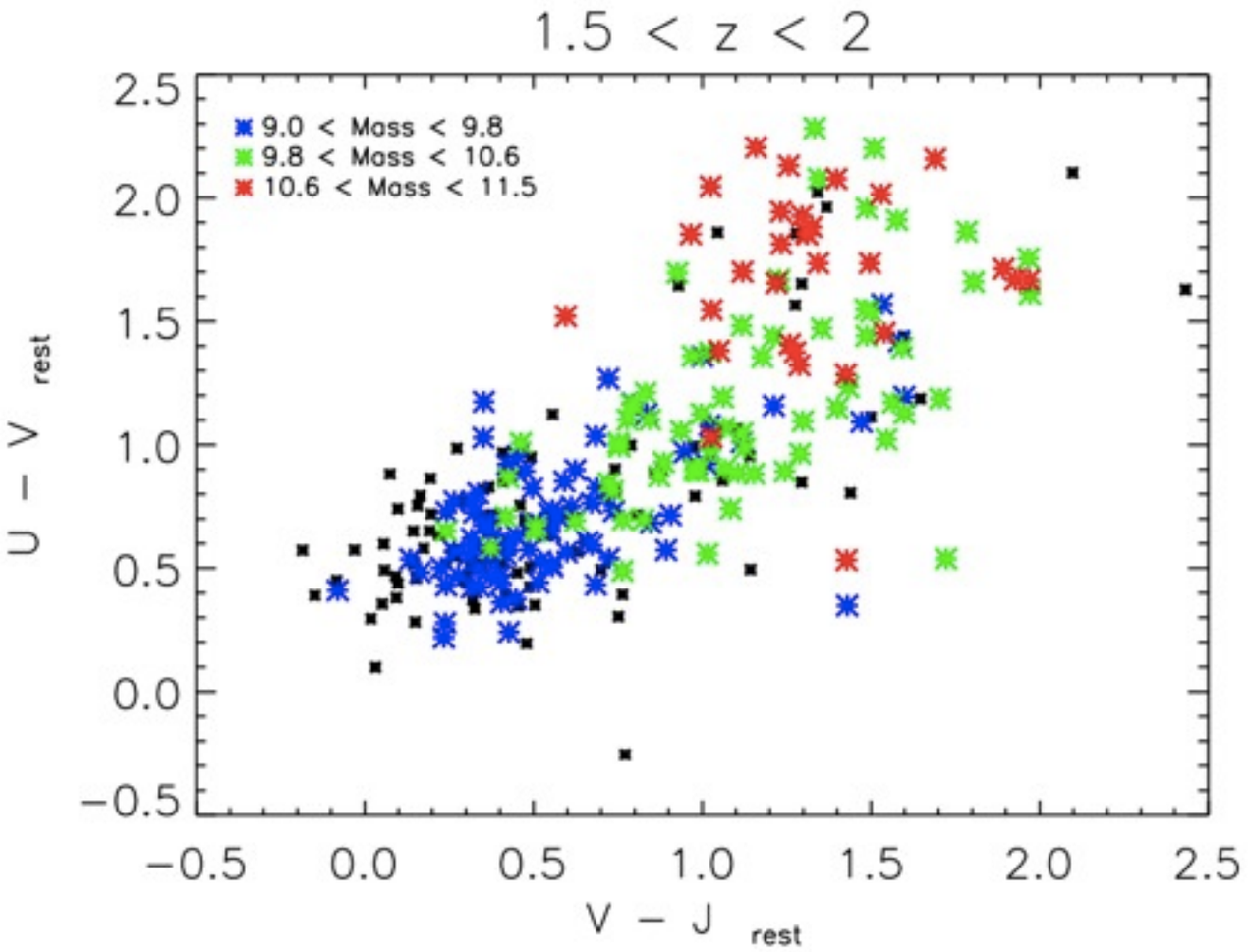
Higher redshifts seem to have a reduced quiescent red spheroid cluster


1.5 < z < 2
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
U − V rest
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
V − J rest

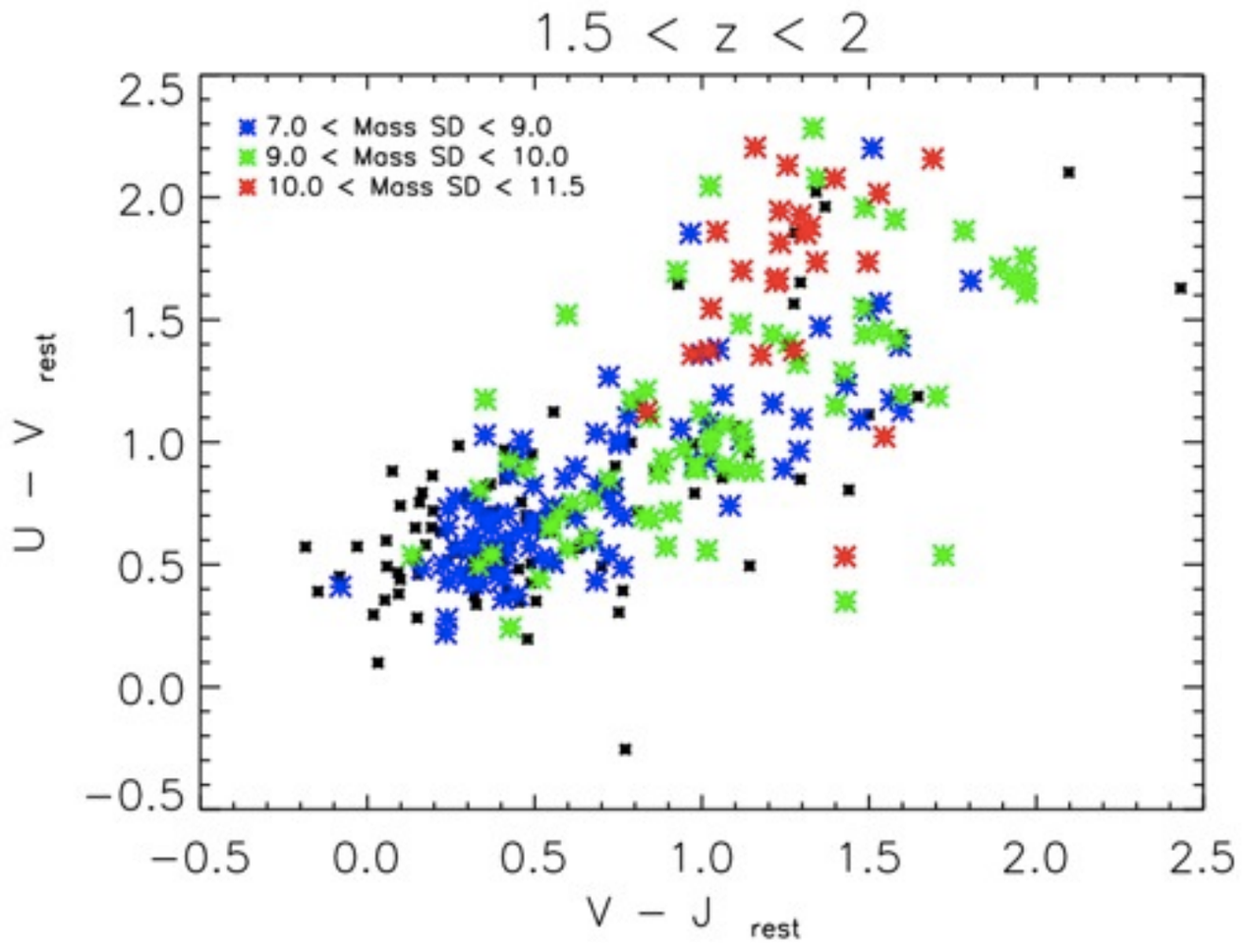

2
2.5
1.0
0.5
U − V rest
1.0
V − J rest

UVJ Diagram

Mass



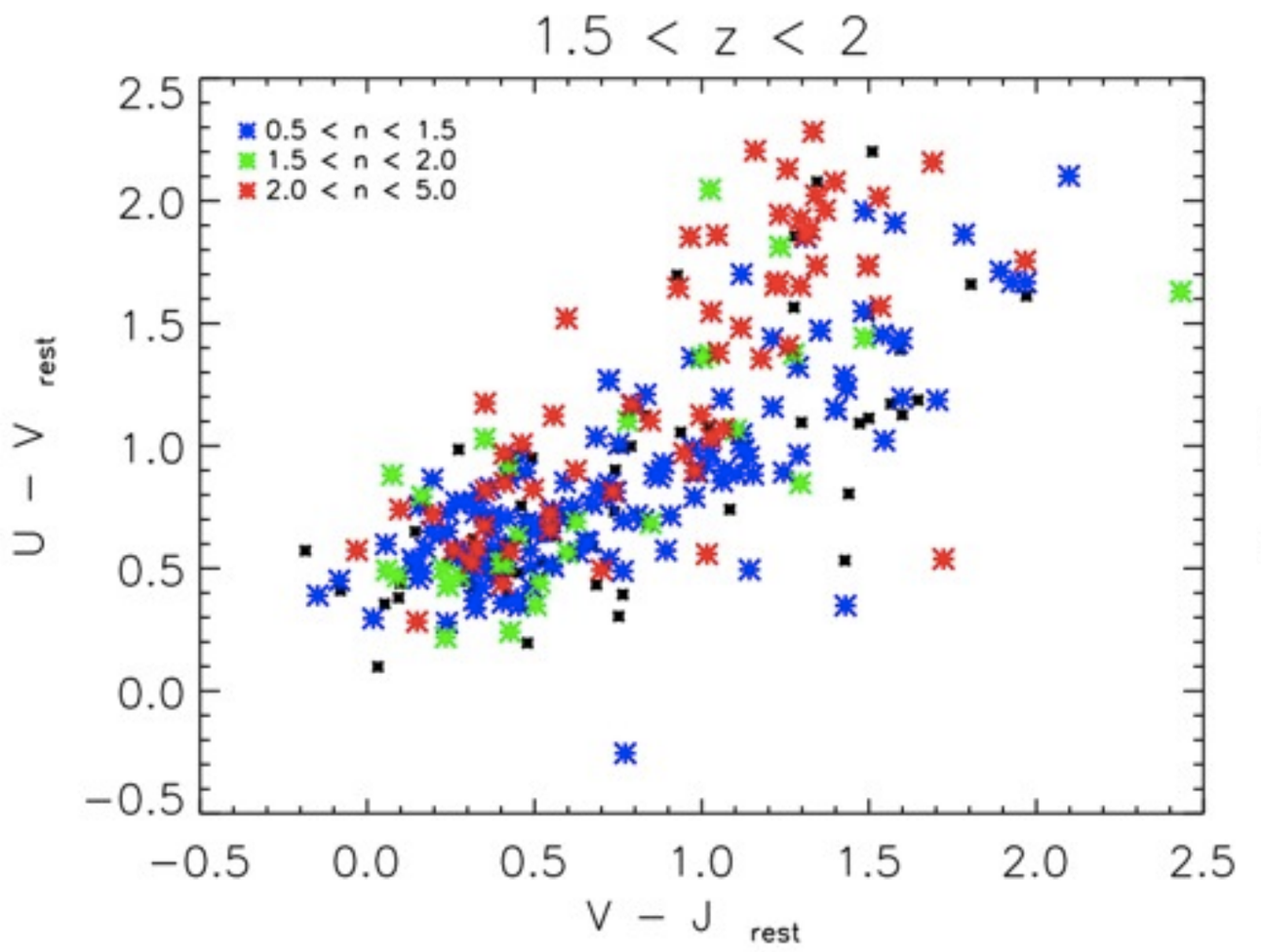
Mass Surface Density



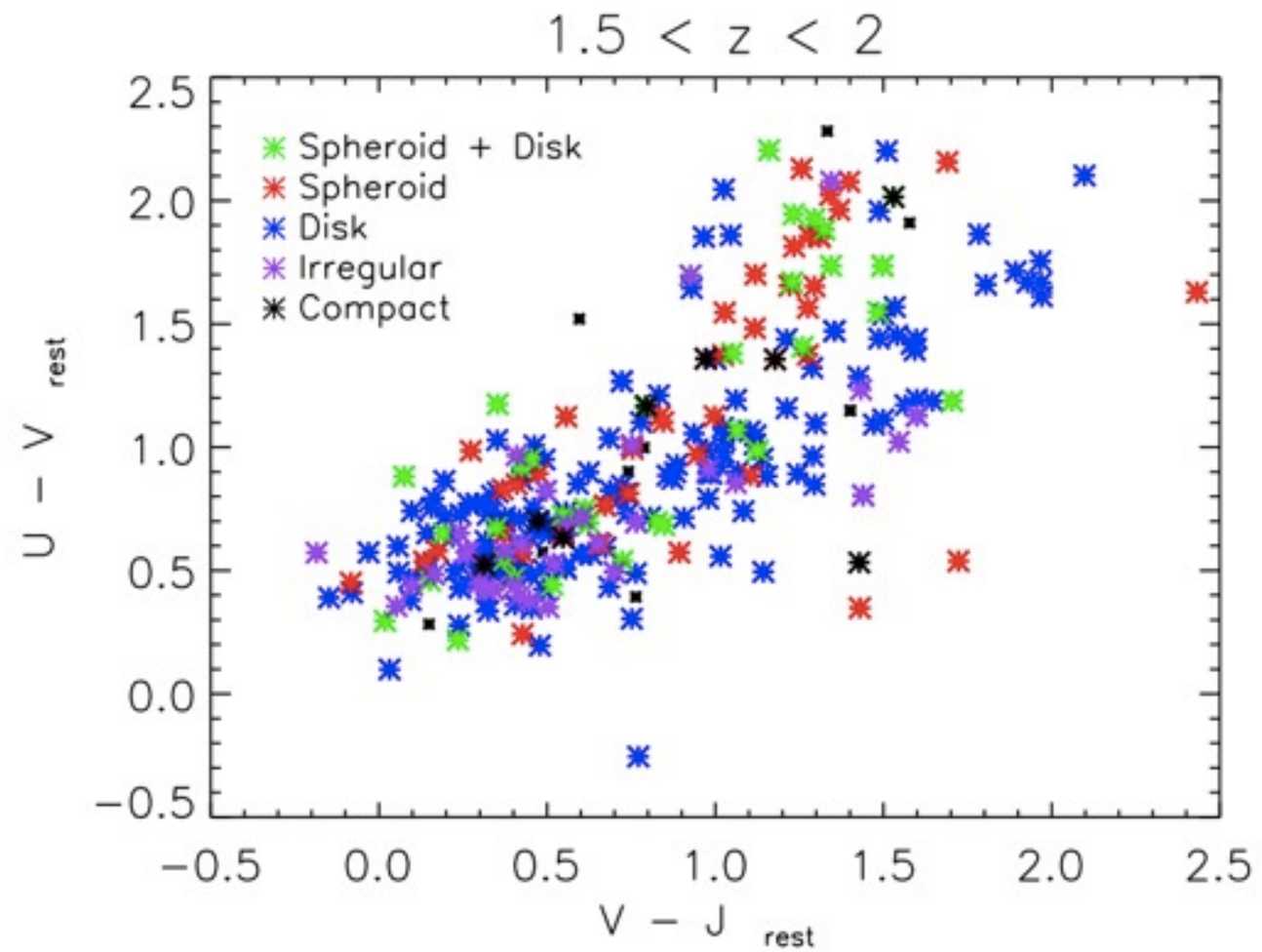
Mass from FIREWORKS - Stijn Wuyts

UVJ Diagram

Sersic



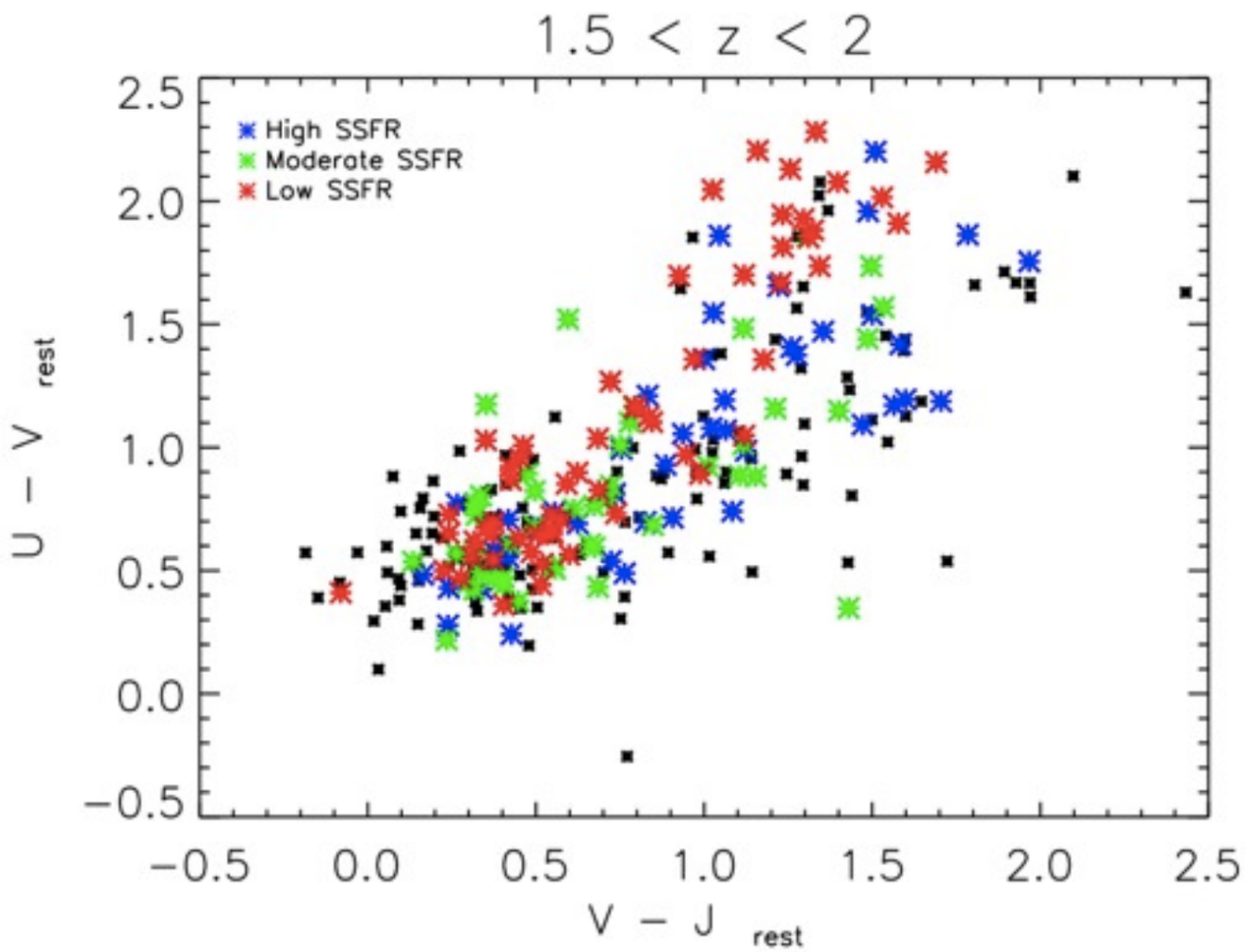
Visual Classifications



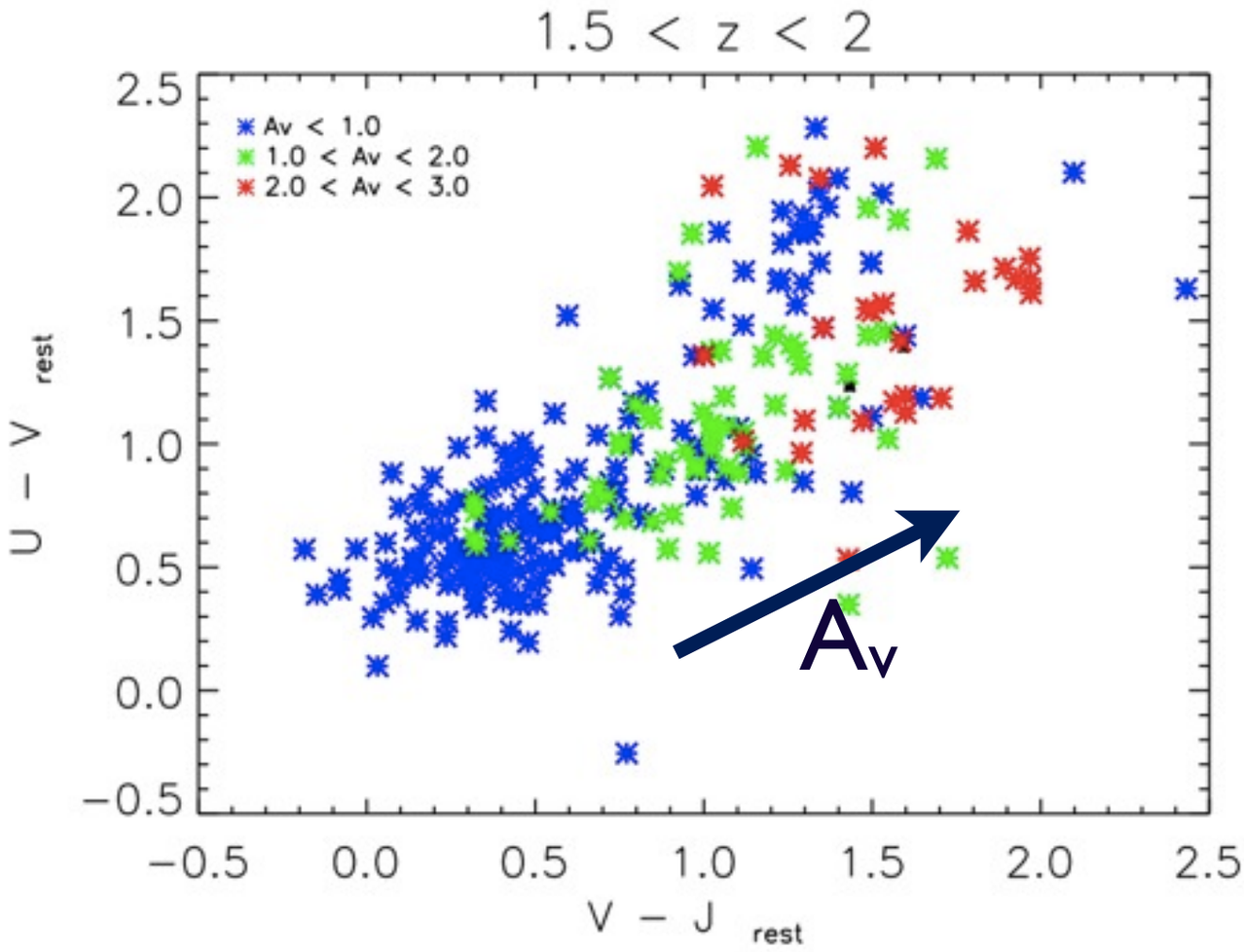
Sersic from Galapagos - Arjen van der Wal

UVJ Diagram

SSFR



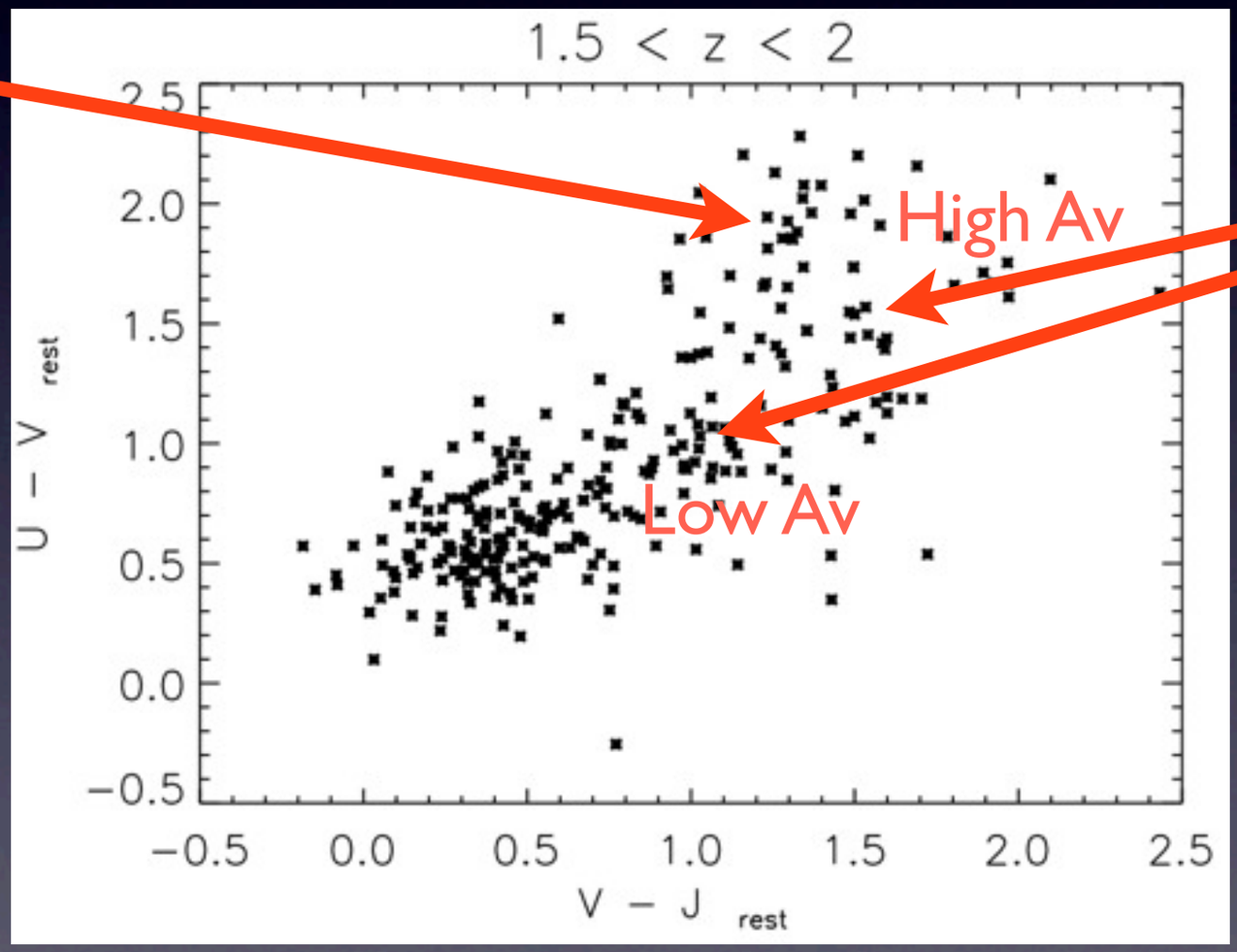
A_v



SFR and A_v from FIREWORKS - Stijn Wuyts

Massive Red Galaxies

Spheroidal
High Stellar Mass (> 10.6)
High Mass SD
High Sersic
Low SSFR
Low Av

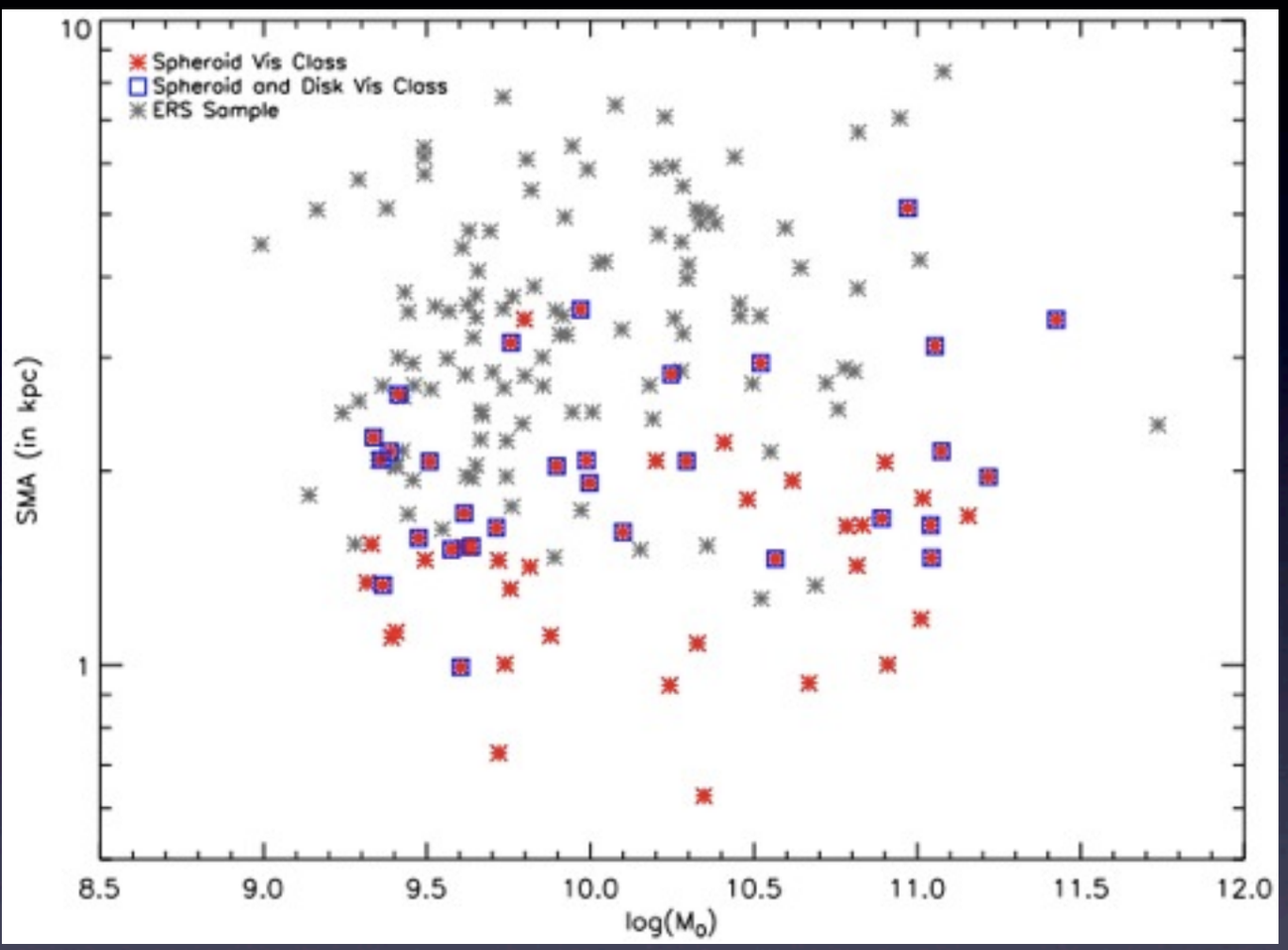


Disky
Moderate Stellar Mass (9.8-10.6)
Moderate Mass SD
Low Sersic
Moderate - High SSFR

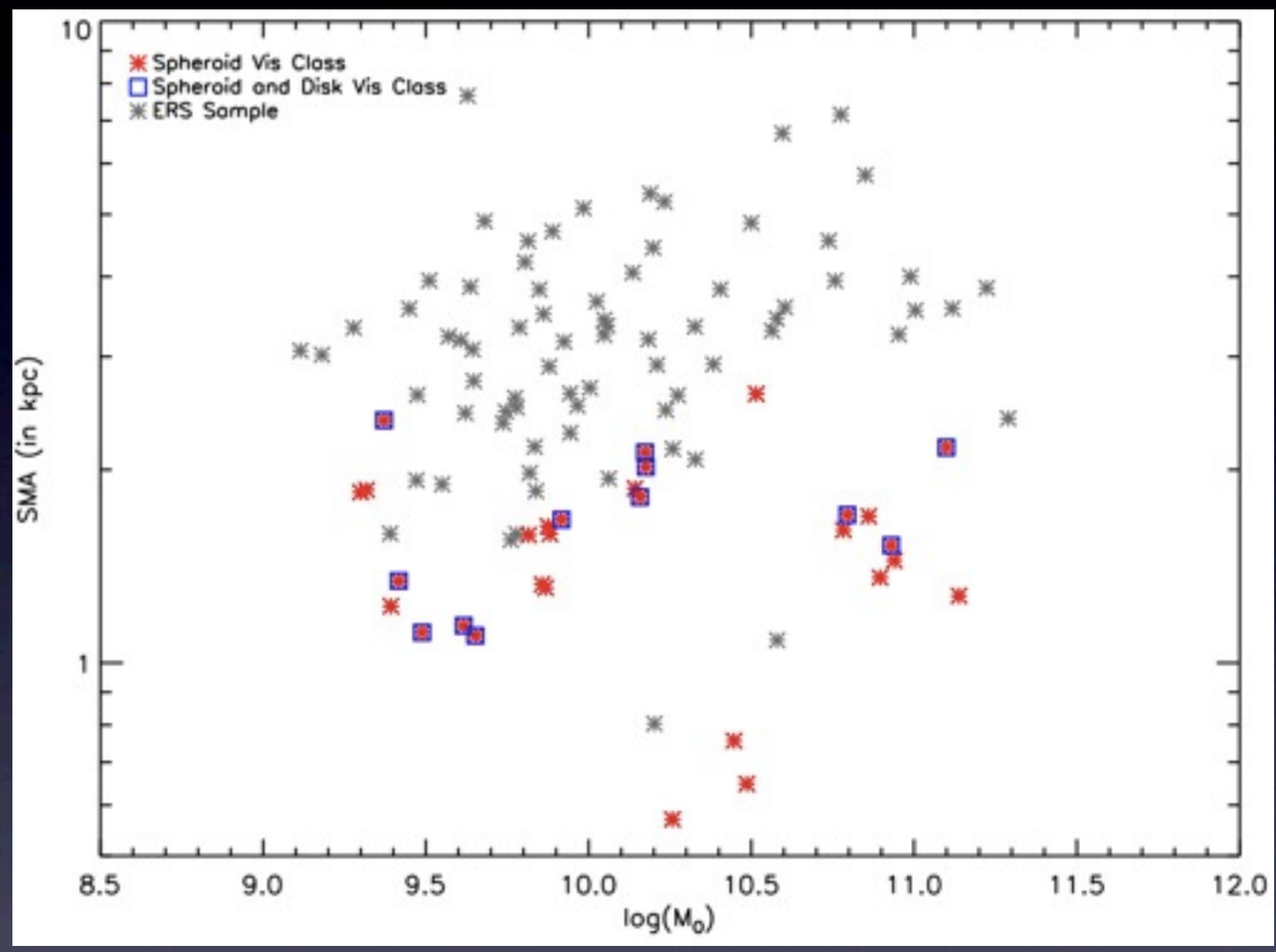
Not actually red bulgeless disks
Dusty disks that have been reddened

No Clear Size-Mass Trend

1.5 < z < 2.0



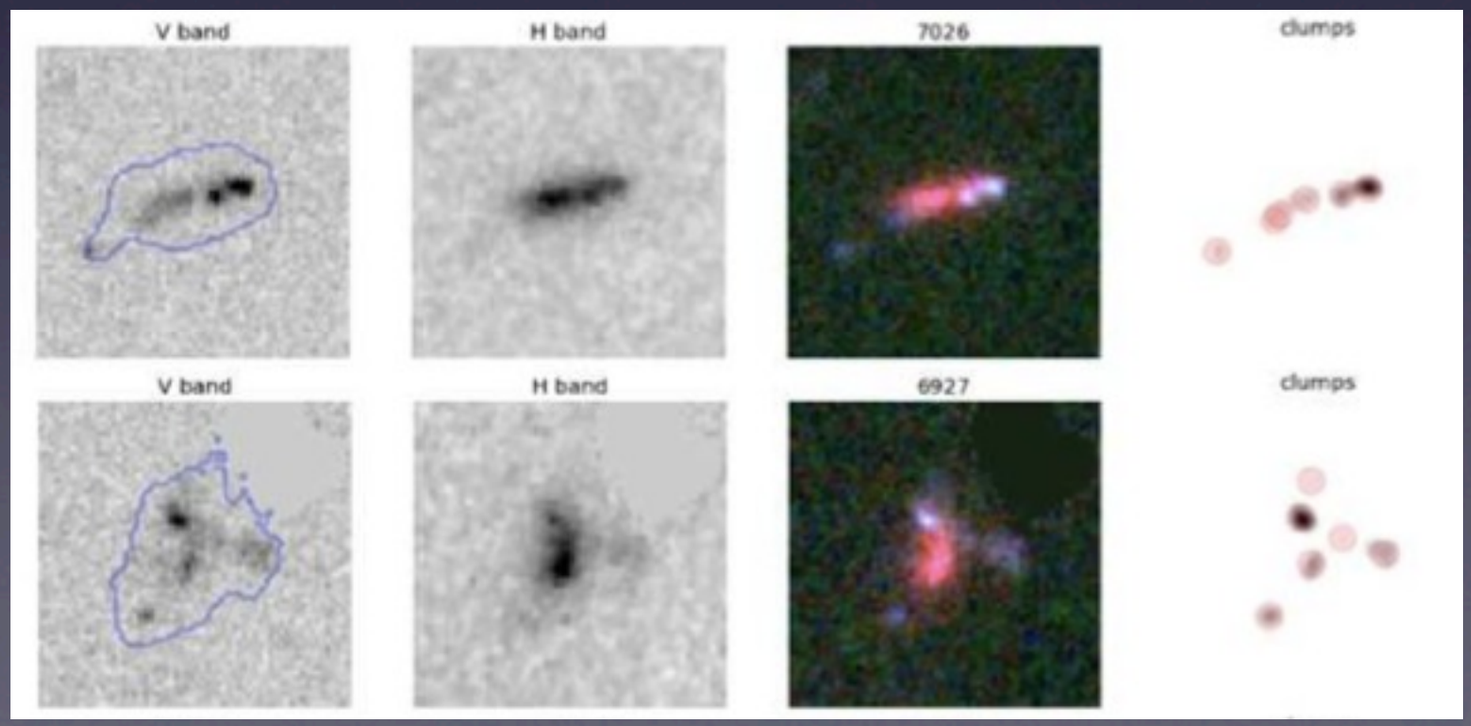
2.0 < z < 2.5

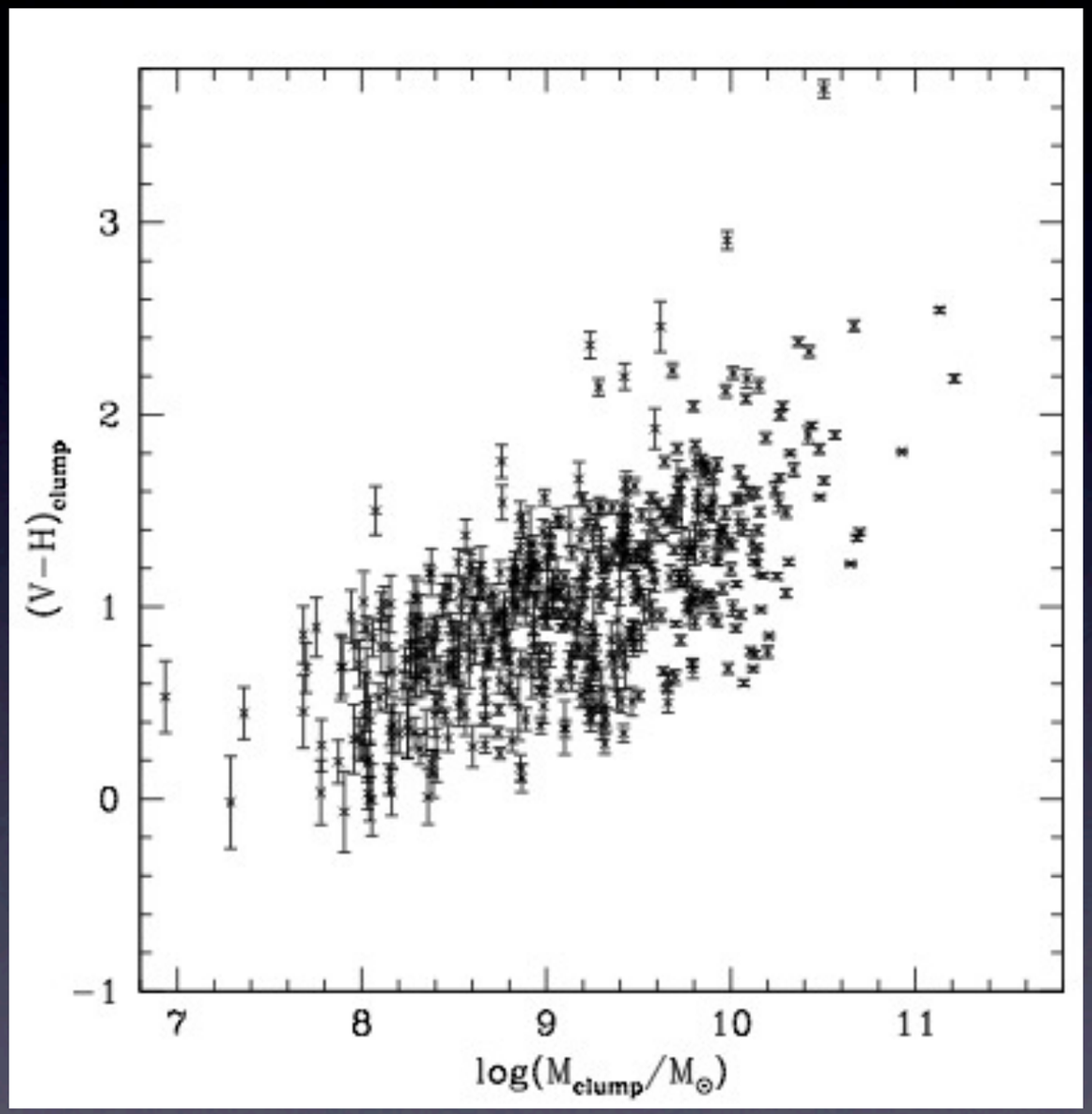


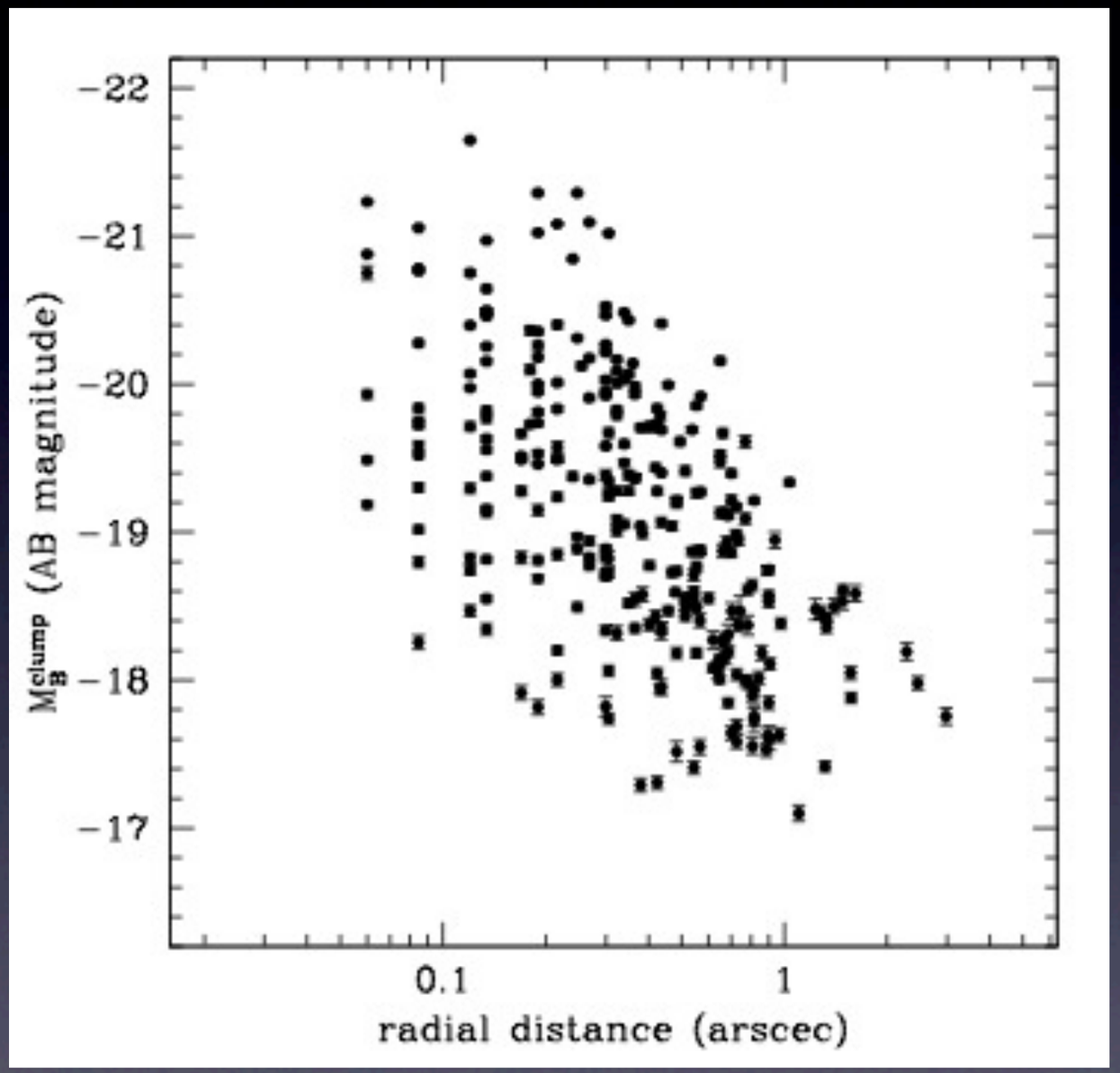
No major trend between the radius and mass of a galaxy at z~2
-mass is going up but radius is not (particularly at z=1.5-2.0)
-creates a trend in Surface Mass Density
-break down of size-mass relationship

Clump Properties

- Swara Ravindranath et al. (in prep) The Rest-Frame UV-Optical Properties of Kiloparsec-Scale Clumps in Galaxies at Z~3
- Program to identify clumps and compare properties as a function of mass and distance from galaxy center



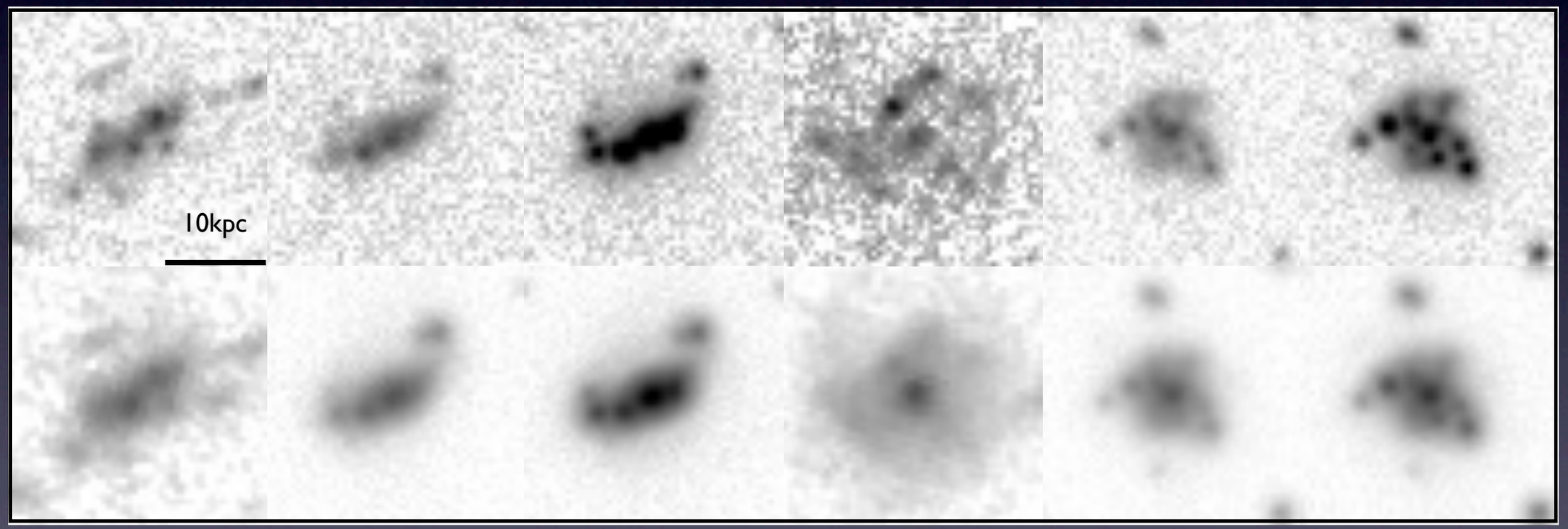

3
2
1
0
−1
7
8
9
10
11
$(V-H)_{clump}$
$\log(M_{clump}/M_{\odot})$


−22
−21
−20
−19
−18
−17
0.1
1
M_B^{clump} (AB magnitude)
radial distance (arscec)

Simulations

- "Observe" hydro simulations of galaxies and compare to observations
  - Ceverino, Dekel, and Primack
  - Guedes and Madau
- Focus on basic structural properties and clumps (number, color, size, radius, etc.)
- Repeat Swara's analysis on simulations - can we use clump properties to distinguish between in-falling clumps from mergers and clumps formed from gas in-falling onto galaxy
  - Form clumps in cold flows or form within the disk?

Importance of Dust



Thank You