Characterizing z~2 Galaxies in HYDRO-ART Simulations and Observations

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Background

- z~2 epoch is the most active period of galaxy formation
  - Galaxies are accreting mass from cold gas streams and also undergo halo mergers
  - Leads to SFR~100 $M_\odot$ /yr
- Clumps form through disk instabilities fed by in-falling gas; "clumps" can also be remnants of mergers
  - 10-40% of UV light from z~2 gals is in clumps - significant structures
  - z~2 clumps are much larger than z~0 star forming "clumps"/regions
  - Clumps migrate to centers of galaxies to build up bulge
    - Eventually bulge mass is sufficient to stabilize disk and prevent further clump development
- Clumpy phase around z~2 is thought to last a few Gyrs

Objectives

- Compare the hydro simulations to observations
- Are the simulations recreating the structure we observe?
- Are there features/types of galaxies which the simulations aren't recreating?
- Can we use the simulations to develop structural measures to differentiate between clumps caused by disk instabilities fueled by cold flow gas accreting onto the disk and those clumps that are remnants of halo mergers from in-falling structures (with DM halos)
    - Use this measure on real galaxies to distinguish between the two

Simulations

- Cosmological simulations of high redshift galaxies using AMR (resolution better than 70pc) - resolves fragmentation of disks
- Accretes gas onto disk through cold flows and allows gas to cool below 10^4K to have clump formation
- Initial conditions set by WMAP5 results
- Galaxies in this talk have halos ~1×10^{12} $M_\odot$ at z~1
- See Ceverino et al. 2010 for more details

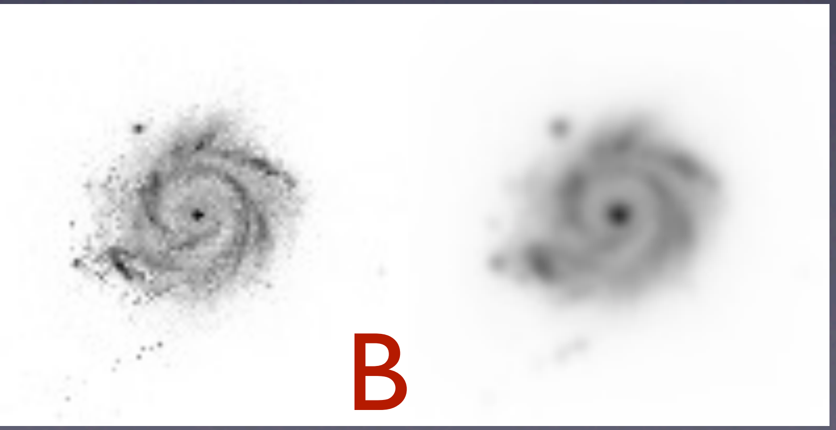
MW3 David Ellsworth

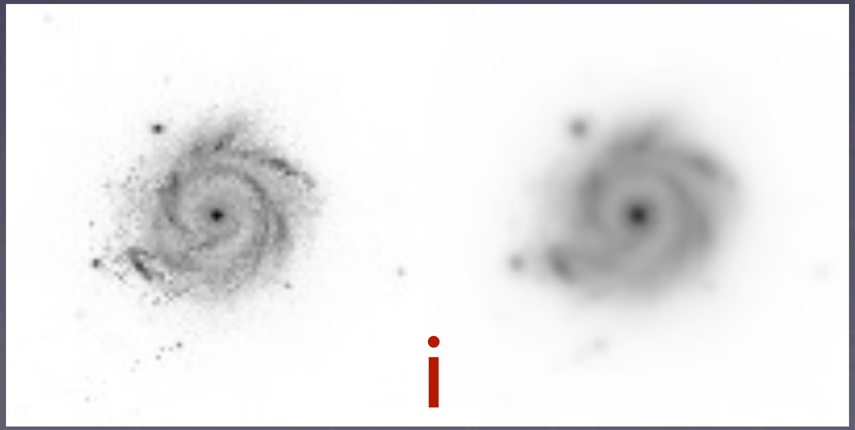
Observations

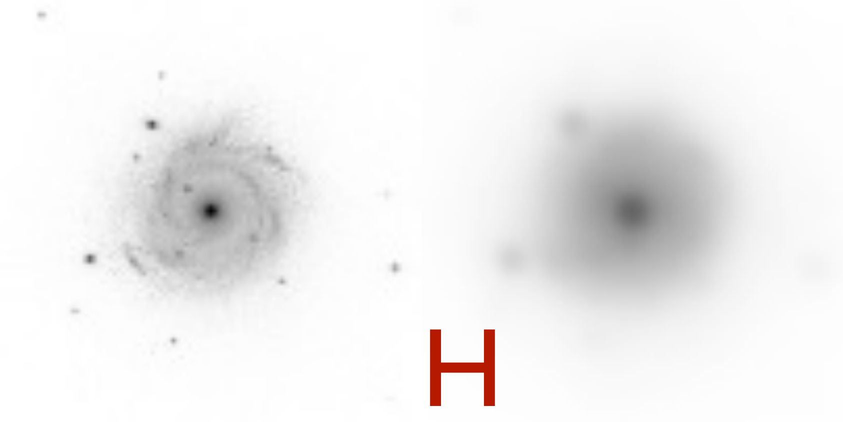
- ACS and WFC3 B,V, i, z, Y, J, H (rest UV - B,V at z~2)
  - Currently have UDF and ERS2
  - MUSIC and Wuyt's FIREWORKS Catalog
    - MUSIC (z + K selected) 65 specz and 938 photoz at 1.5<z<2.5
    - FIREWORKS (K selected) 74 specz and 262 photoz at 1.5<z<2.5
    - Redshift Issues - photometric redshift reliability beyond z~1.5?
  - With CANDELS will have thousands of objects (data starts being taken in October 2010)

Sims --> Obs

- Simulations provide locations, ages, metallicities, and mass for each star forming particle
    - Use Bruzual & Charlot 03 to compute the SED for each star forming particle and then generate the observed luminosities in each HST band
- Pixellate images to match UDF ACS pixel scale (30 mas)
- Convolve with UDF psfs derived from centering and stacking stars across the field

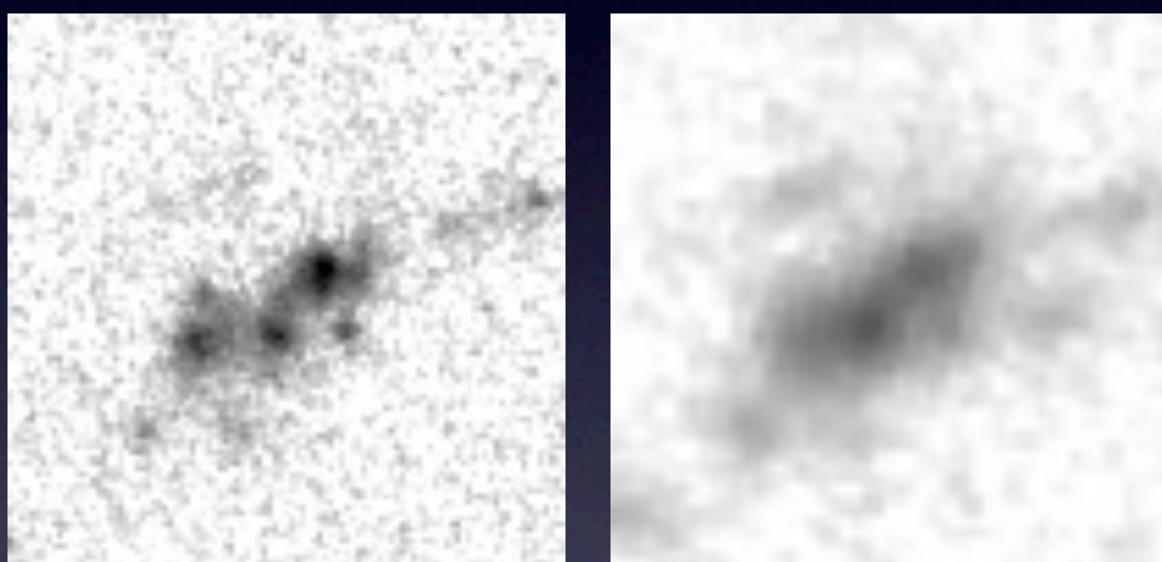






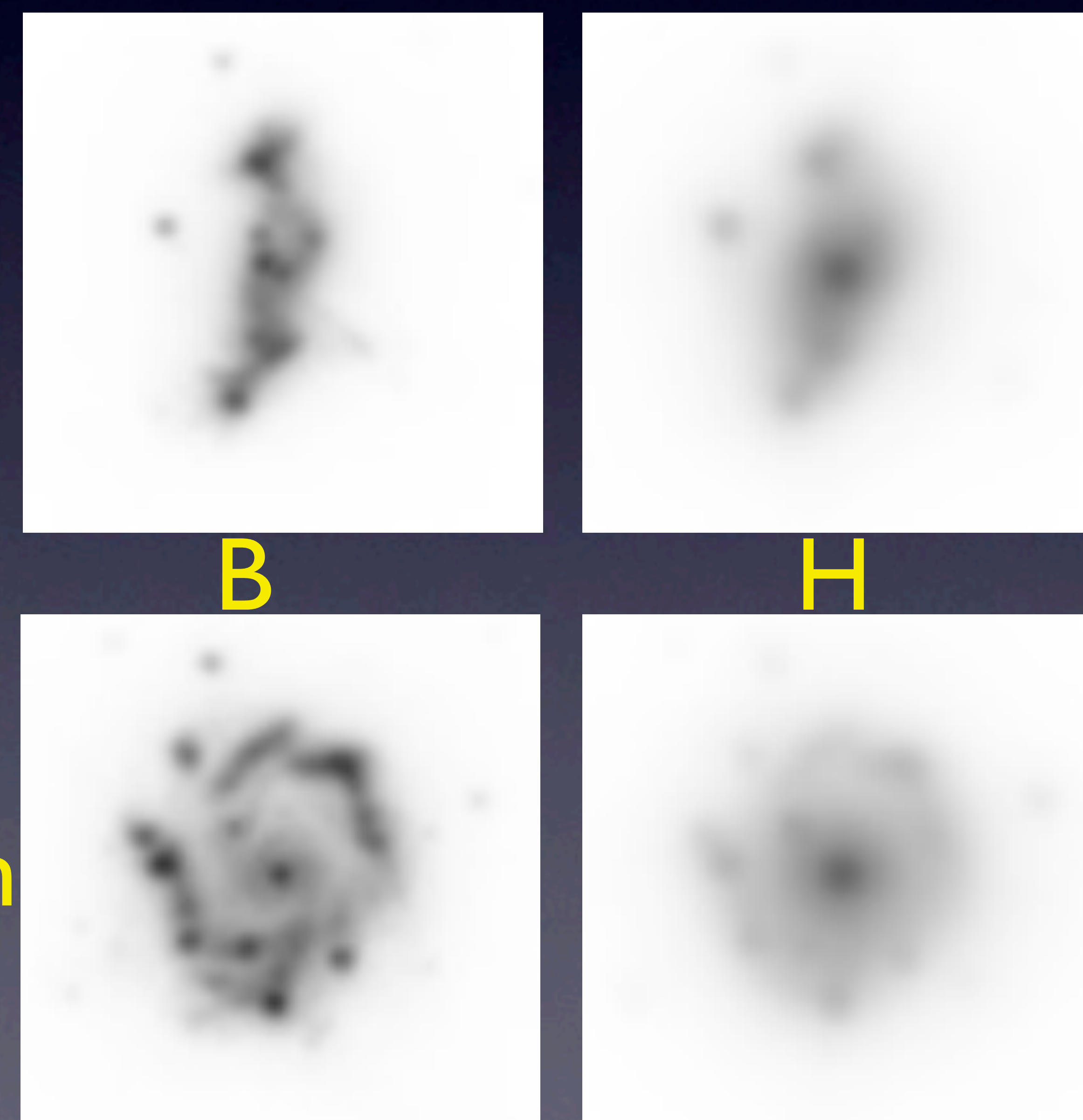
Examples

Fireworks 5201 z~1.96



B H

MW2 z~1.94

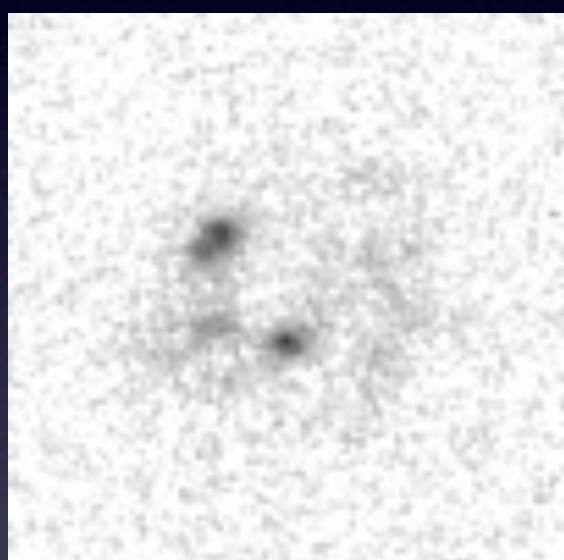


B H

face-on

Examples

Fireworks 4934 z~1.61

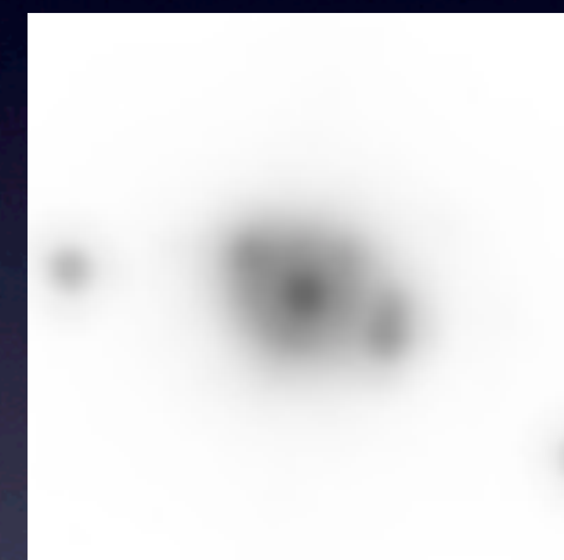


B

H

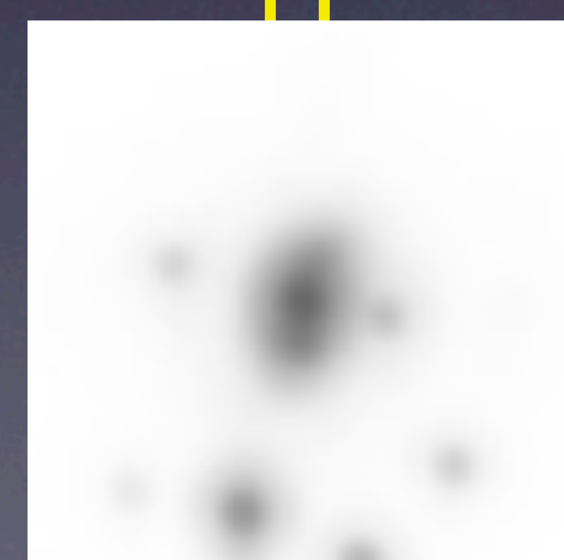
MW1 z~2.33

B



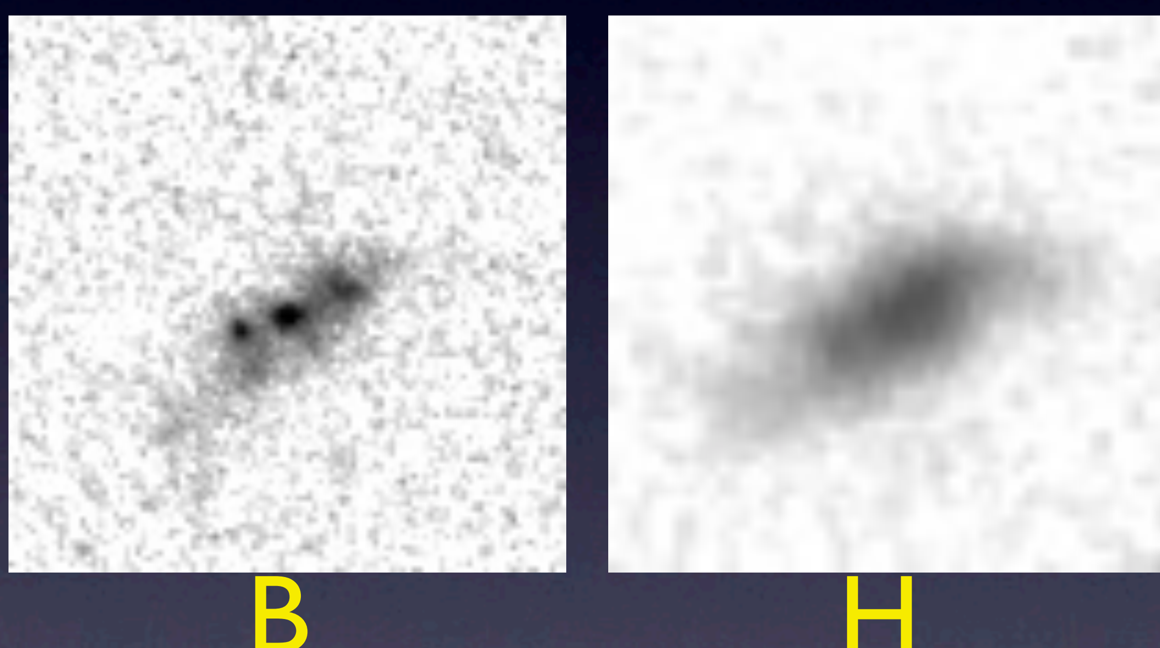
H

edge-on

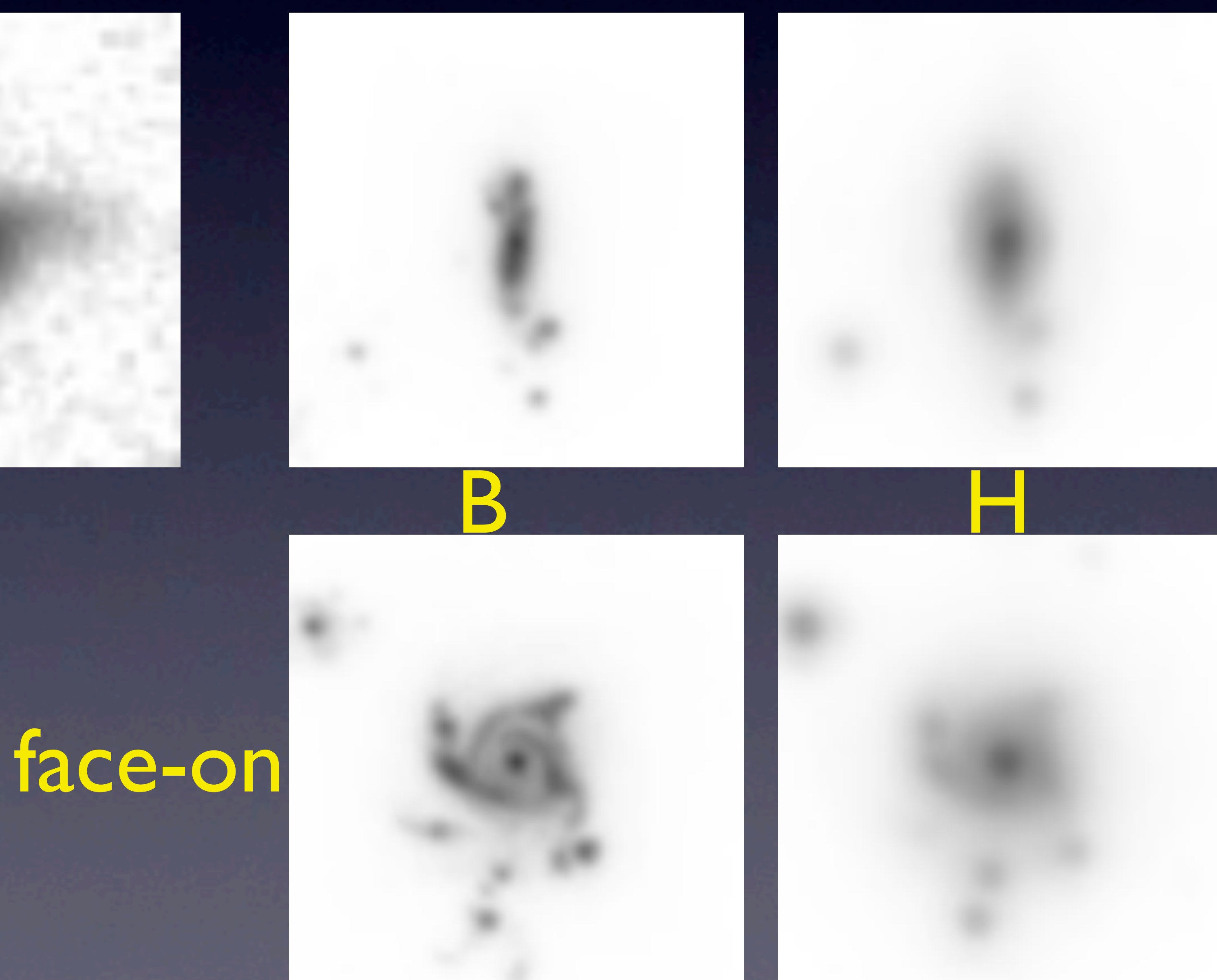


Examples

Fireworks 4404 z~2.04



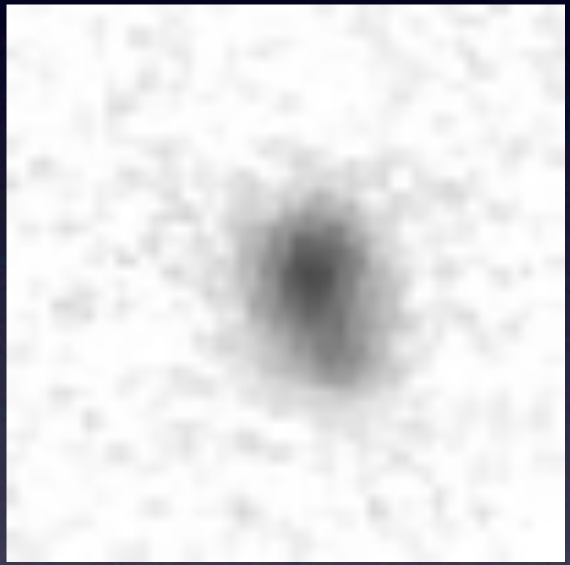
MW3 z~2.12



Examples

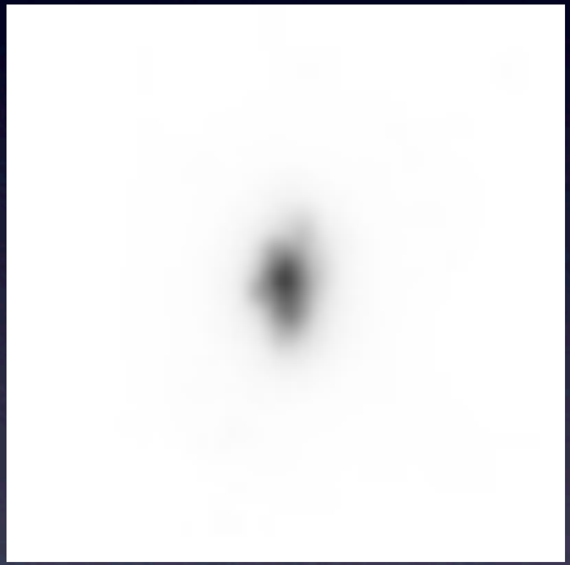
Fireworks 5350 z~1.61

B

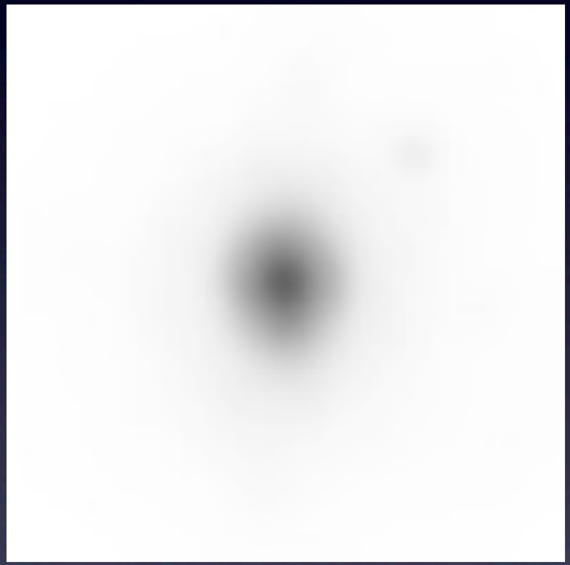


H

MW4 z~1.78

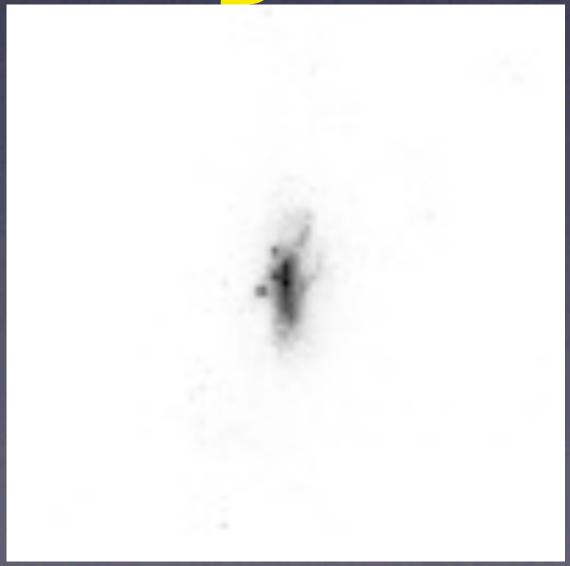


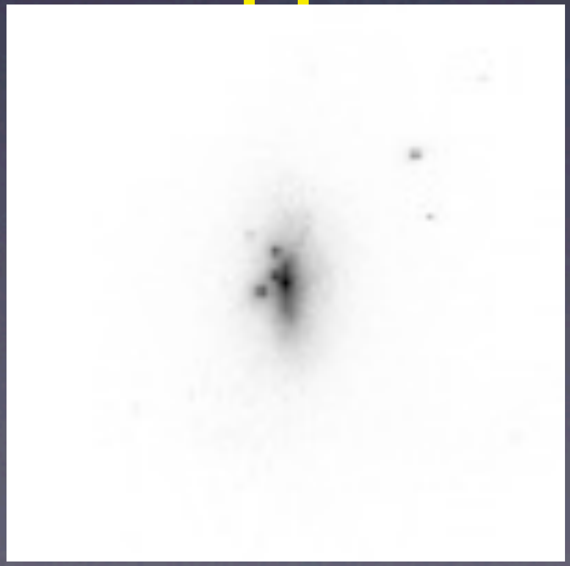
B



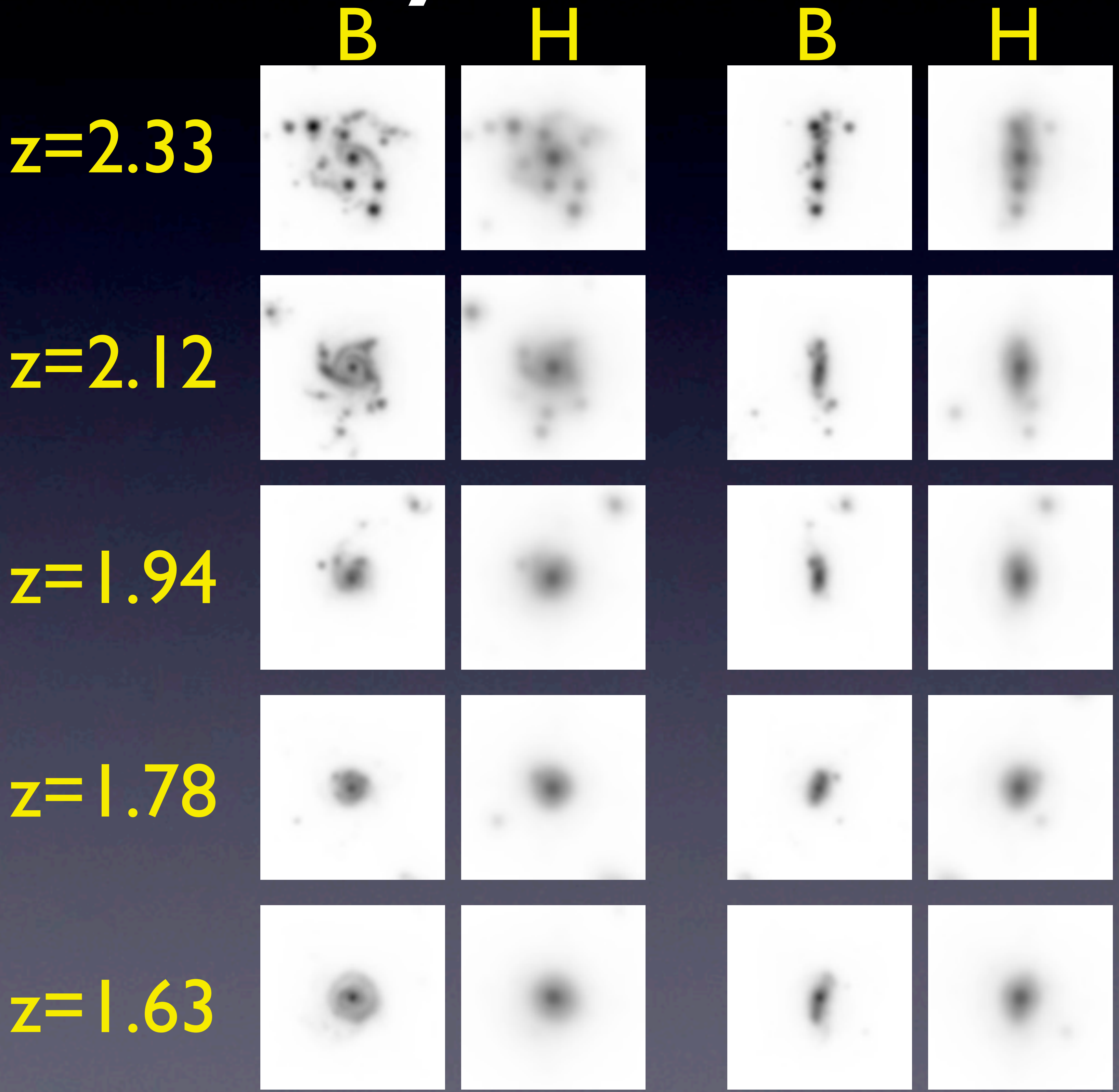
H

no psf





Changing Galaxy Structure



Mergers and in-falling gas leads to frequent changes in galaxy structure

MW3: Stellar mass ~1.6e10 @ z=2.33

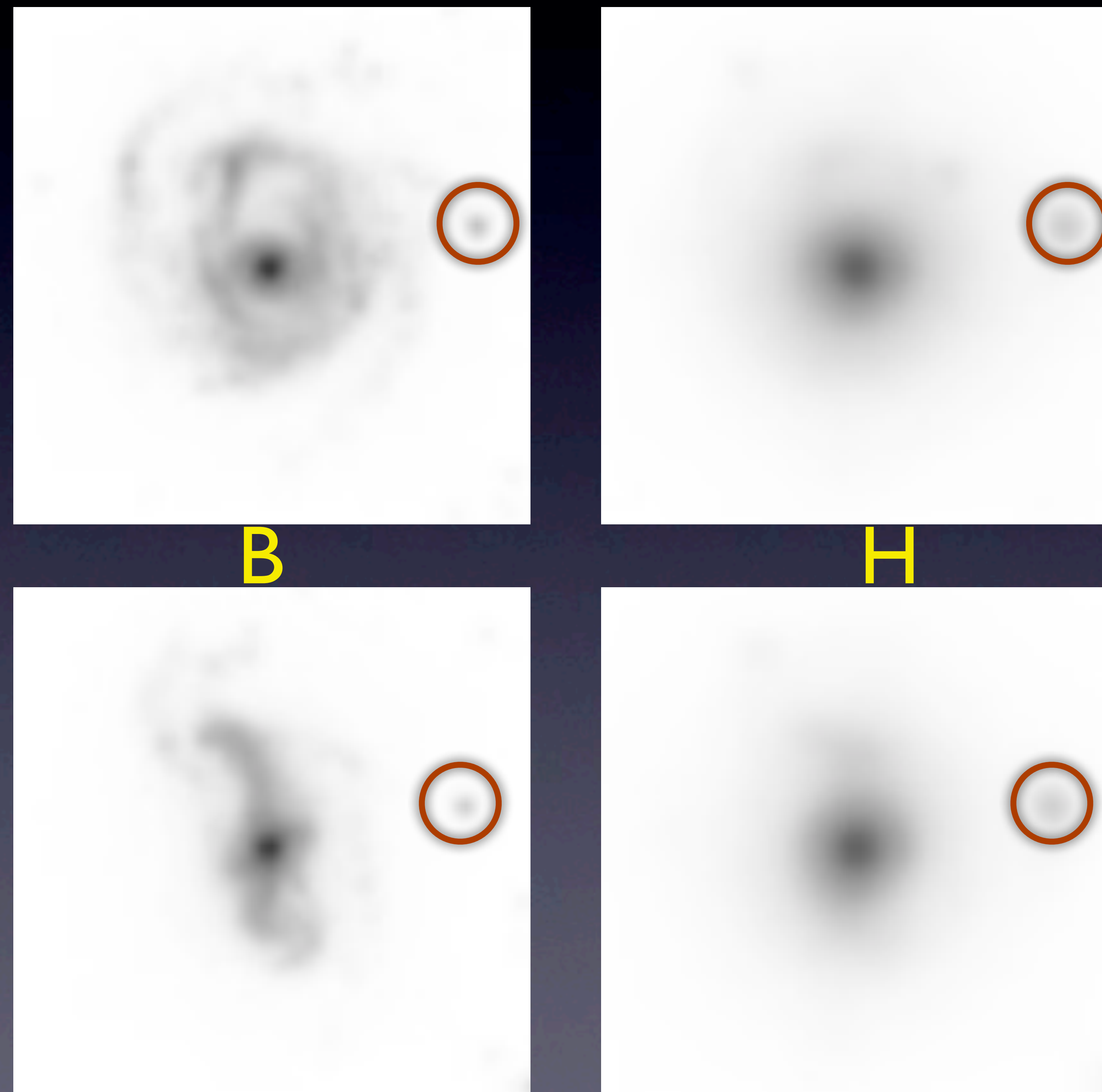
~3.5e10 @ z=1.94

Out-of-Plane Clumps

face-on

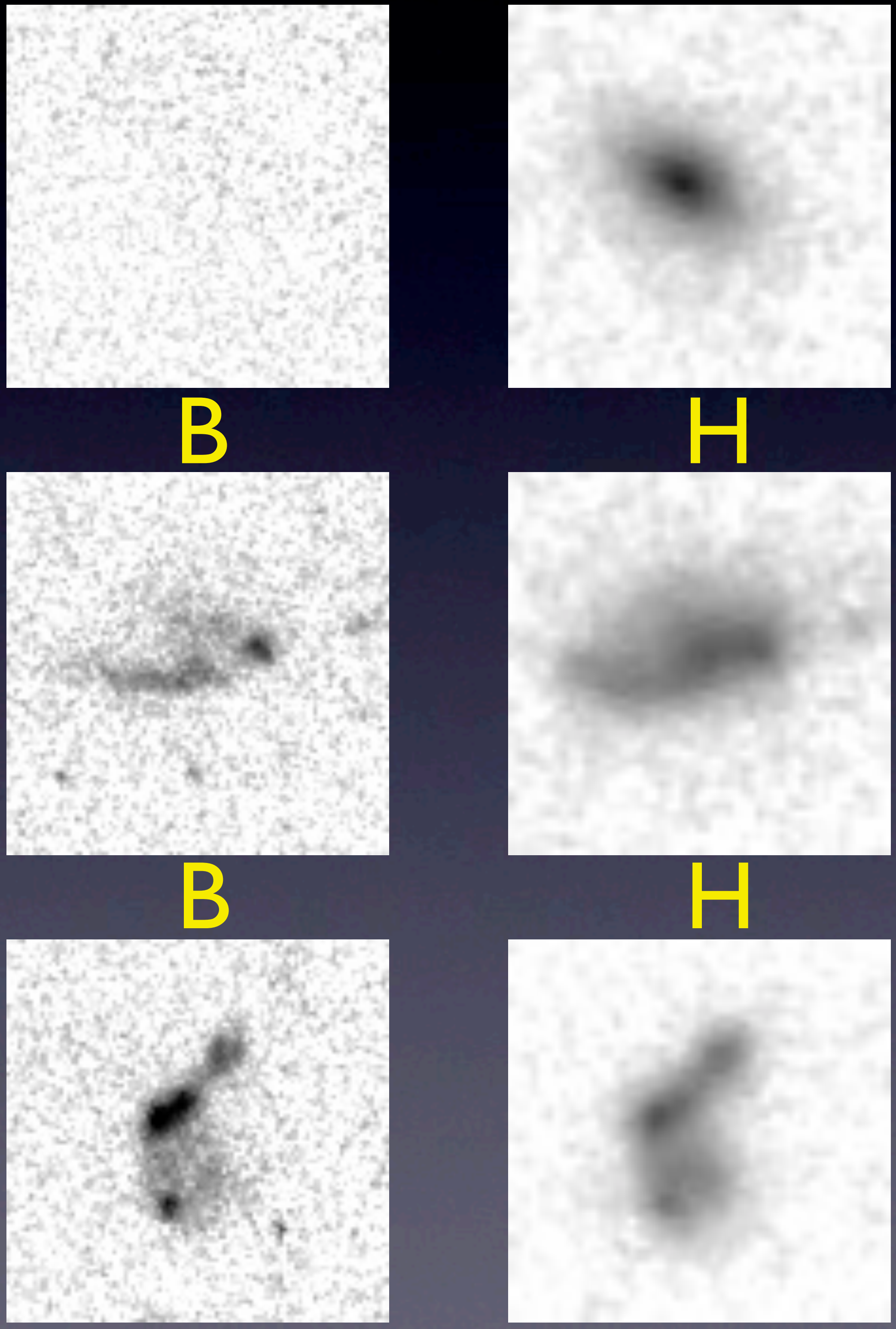
MW4 z~1.63

edge-on



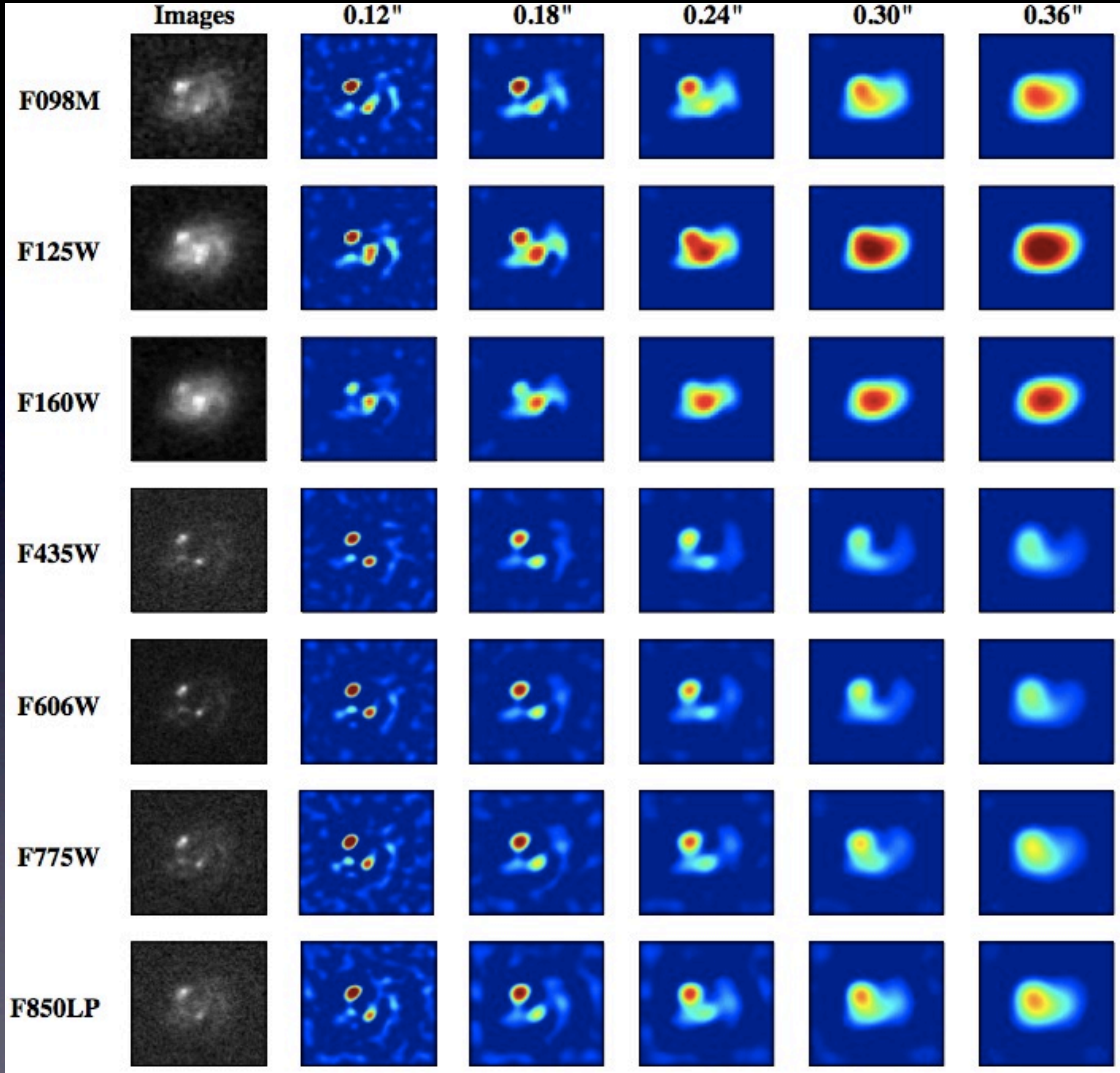
“Missing” Galaxies

- Simulation did not produce galaxies as red as some of those observed - dust?
- Center “bulges” in simulations were fairly well defined - some observed galaxies have off-center “bulges” above disk or to one side
- Observed galaxies appeared more disturbed



Future Analysis

- Clump measurements
  - Measure the mass, light, and colors of each clump
  - Age clumps
    - Are they being destroyed (Genzel - outflows?) or are they surviving to migrate to center?
  - When does a galaxy's clumpy phase begin and end?
  - Numbers and spatial distributions of clumps in disks
- Structure measures of underlying galaxy
  - CAS, Gini-M20, GIM2D/GALFIT, other
- Wavelets/Shapelets
  - To isolate and remove clumps and determine characteristic sizes
- Add dust to models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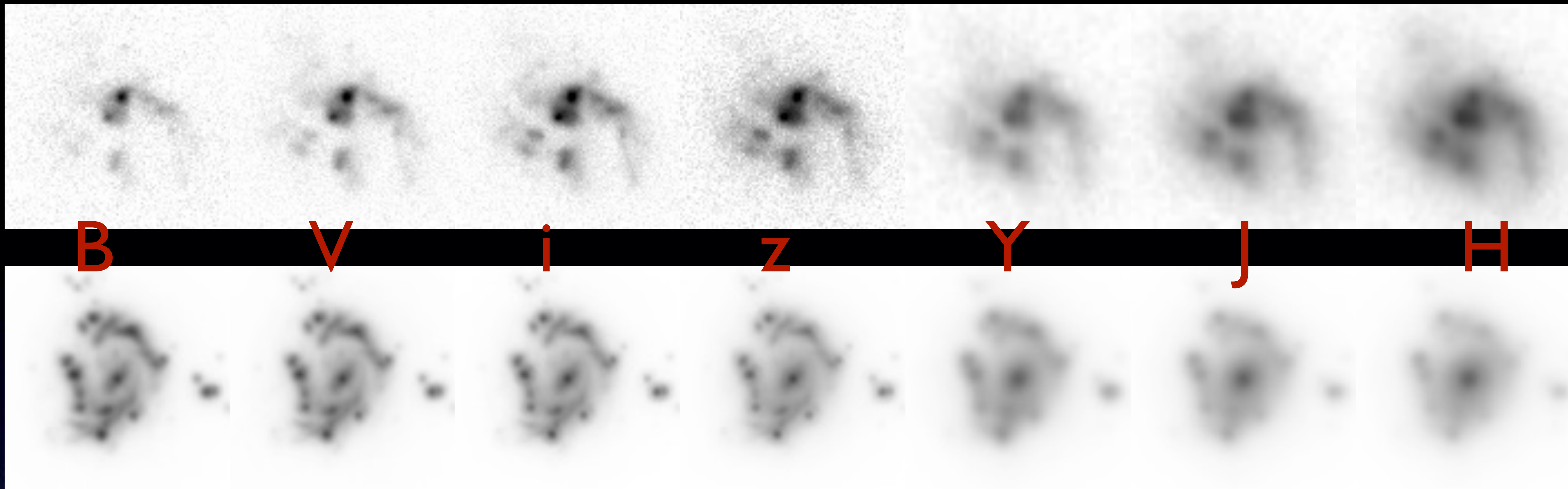
F098M
F125W
F160W
F435W
F606W
F775W
F850LP

Summary

- Ceverino's simulation is able to produce clumps in galaxies fed by cold flows
- Simulated galaxies bear a resemblance to some types of observed galaxies in z~2 epoch
- A galaxy's structure is dynamic and changes frequently in this epoch as it undergoes gas accretion and mergers



Thanks