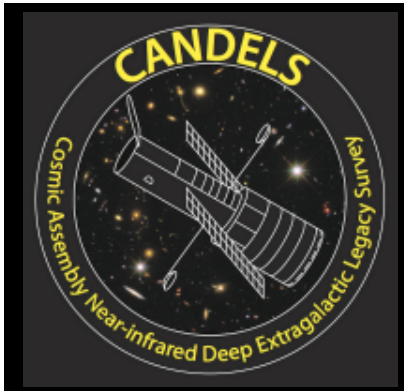


@CANDELS_team
http://candels-collaboration.blogspot.com

Morphological Classification of Galaxies in CANDELS

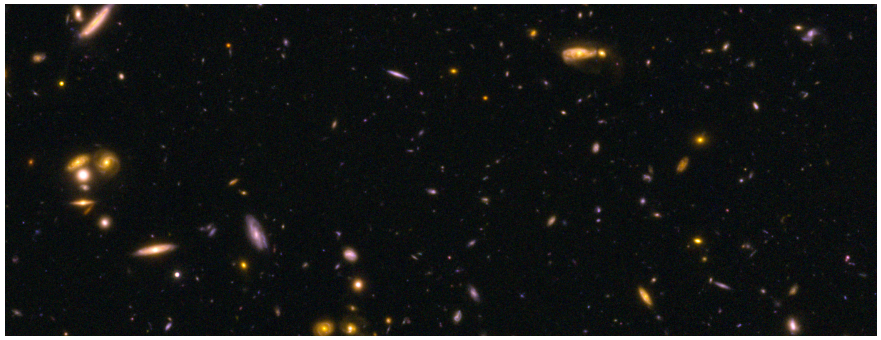
Jeyhan Kartaltepe, Hubble Fellow, NOAO
+ the CANDELS Collaboration

jeyhan@noao.edu, @jeyhan

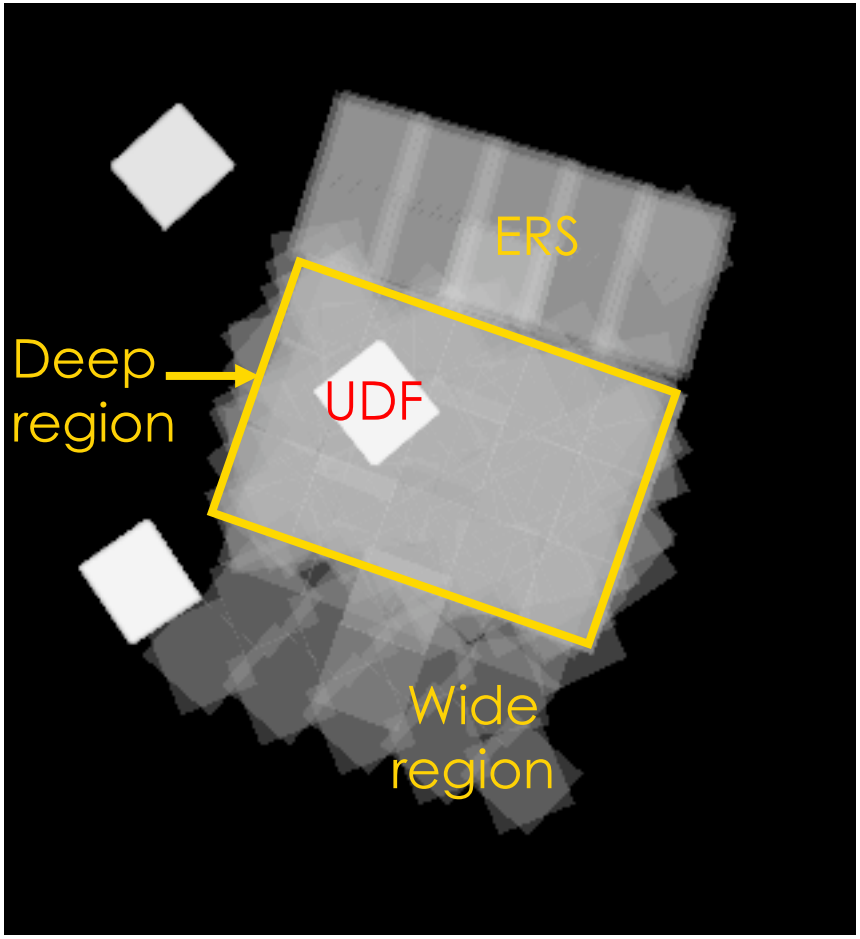
2013 September 25
Galaxy Zoo: Evolutionary Paths in Galaxy Morphology

CANDELS

- Largest HST Survey (PIs: S. Faber & H. Ferguson)
- NIR imaging of 5 of the most commonly studied deep fields
- Deep and wide areas
- Imaging is now complete!
- Work is ongoing



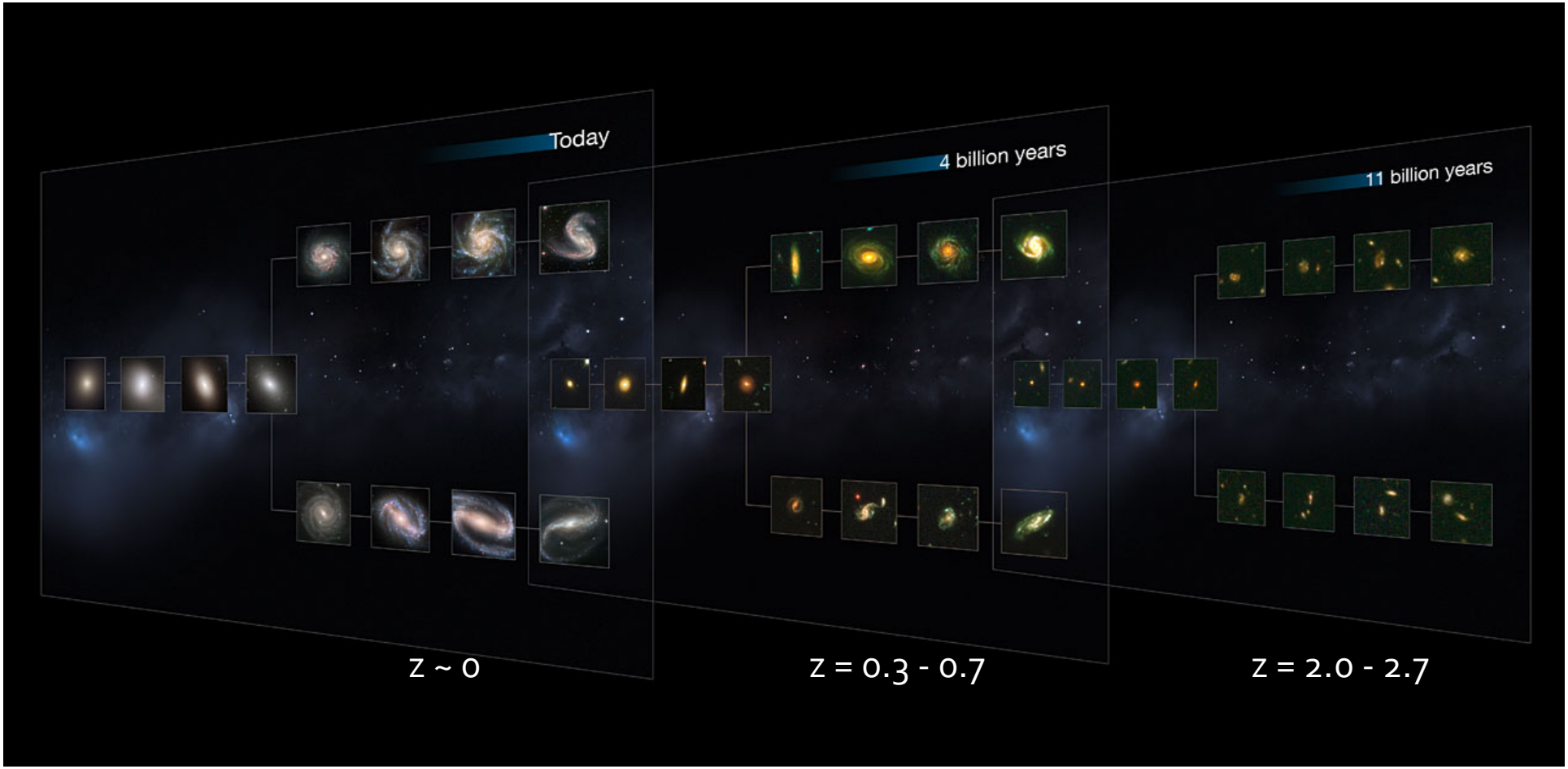
J and H band Coverage of GOODS-S



Galaxy Morphology at High-z

- For galaxies at z~2, deep NIR imaging provides rest-frame optical structure
- With CANDELS WFC3, can look at structure for large samples at z~2 for the first time
- Visual Morphology
- Quantitative Morphology (see talk by Jen Lotz)
  - GALFIT: Sersic index, B/D, size, etc.
  - Non-parametric measures: Gini, M20, CAS, MID, etc.
  - Use Visual Morphology to calibrate these at high-z

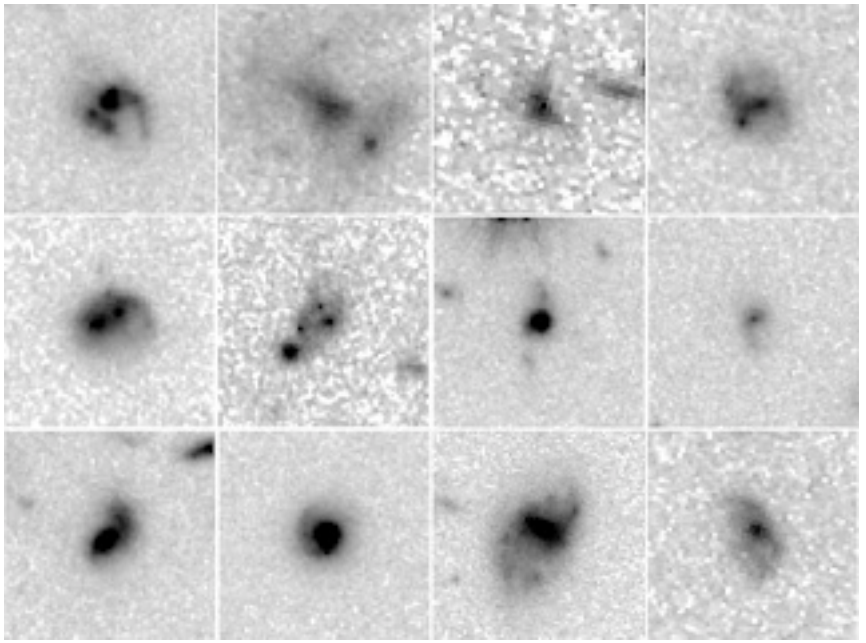
When did the Hubble Sequence Form?



ESA Press Release on Lee et al. 2013

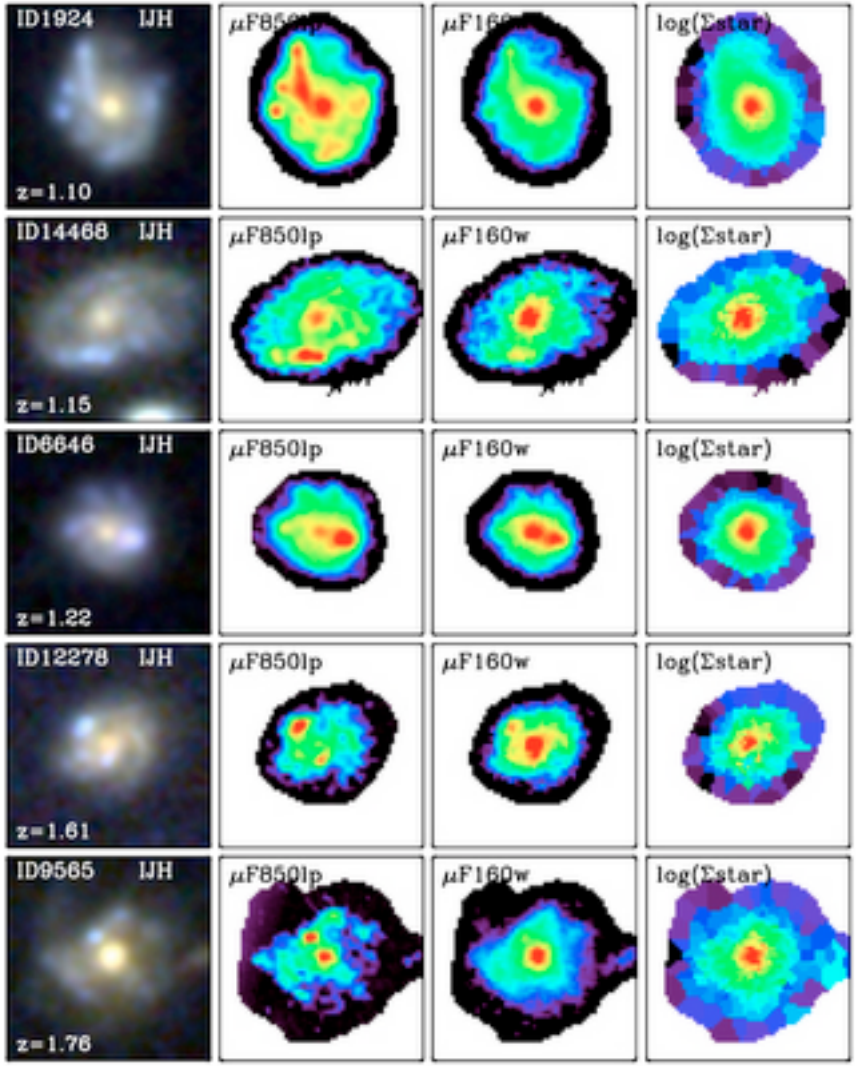
What is the Role of Galaxy Mergers?

- In increasing a galaxy's SFR
- In contributing to the cosmic star formation history
- In fueling AGN
- In the morphological transformation of galaxies
  - Forming spheroids
- Hints at the changing role of mergers in the recent literature but many open questions remain!



How Important are Clumps?

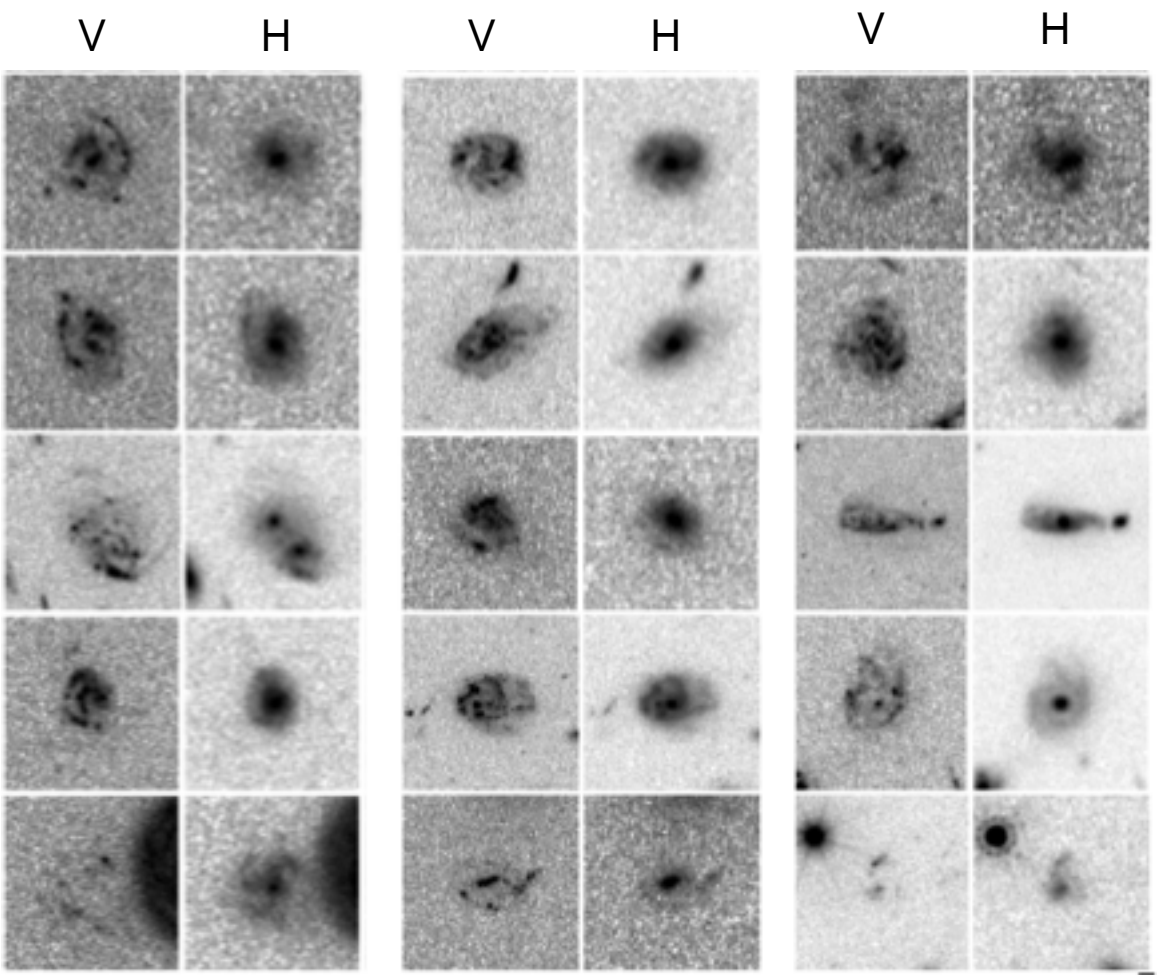
- Disk instabilities?
- Signatures of mergers?
- More frequent in higher gas fraction systems?
- Do these clumps become part of the bulge?



Wuyts et al. 2012

Morphological K-Corrections

- Some objects are very different in the optical and NIR
- Many clumpy irregular systems look regular in the IR
- Bulges are more prominent in the IR



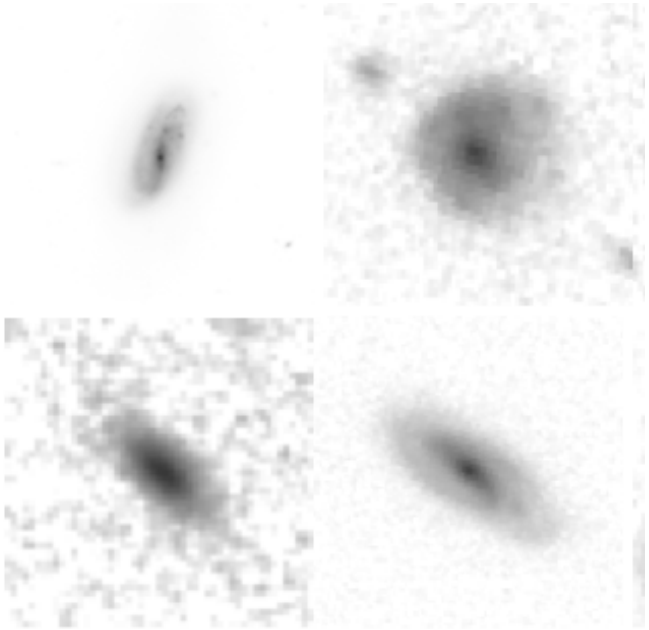
CANDELS Visual Classification Effort

- Classifying all CANDELS Galaxies to H<24.5
  - 3 fields complete (GOODS-S, UDS, COSMOS)
  - 2 remaining (GOODS-N underway)
  - Total of ~50,000 galaxies by the end of survey
  - Classifications at multiple depths in deep area
  - Primarily in H-band, use other bands to inform
- Multiple classifiers for comparison and statistical analysis
  - ~3-5 people per object
  - ~65 classifiers in total
- Catalogs to be made public (GOODS-S with Kartaltepe et al., in prep)

Classification Scheme

- Two levels
  - Main Morphological Class
    - NOT mutually exclusive! – can choose more than one

Disks



Classification Scheme

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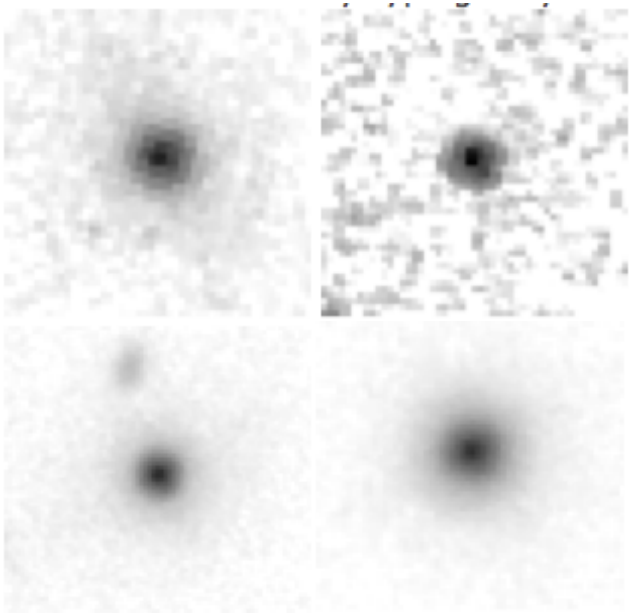
    - NOT mutually exclusive! – can choose more than one

Spheroids



Classification Scheme

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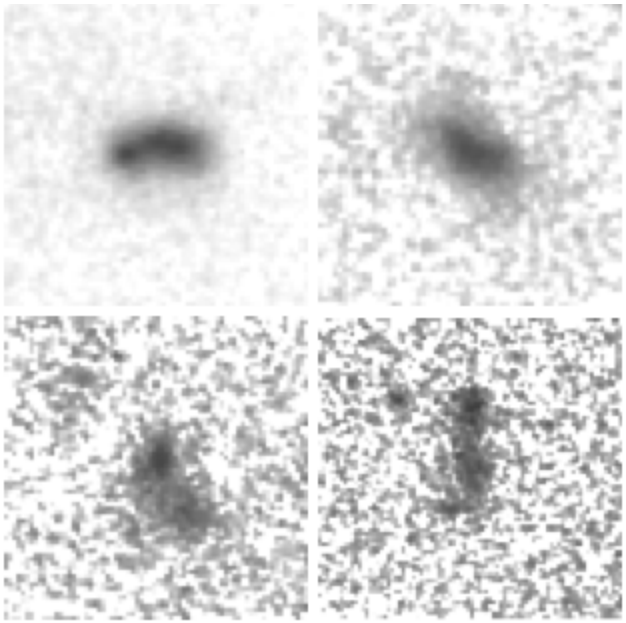
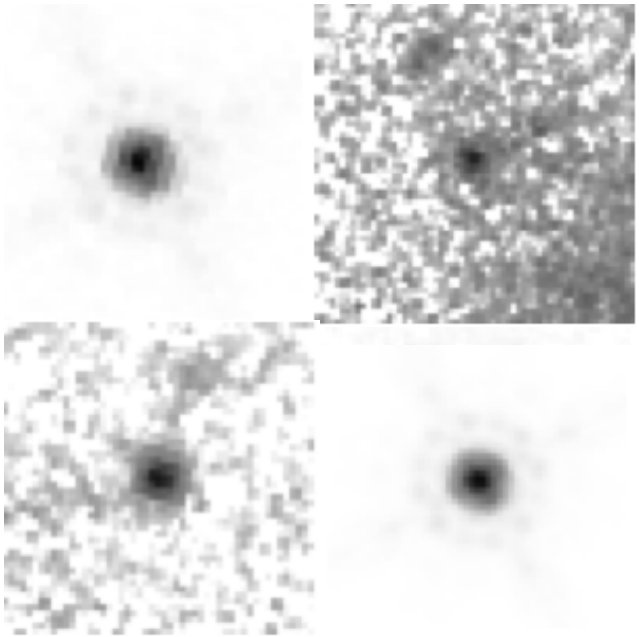
Irregular



Classification Scheme

- Two levels
  - Main Morphological Class
    - NOT mutually exclusive! – can choose more than one

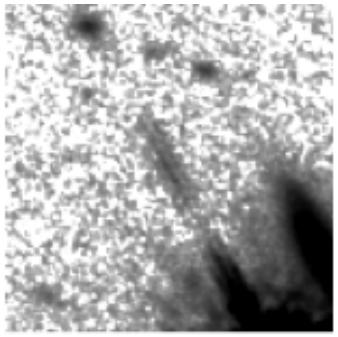
Compact/
Unresolved



Classification Scheme

- Two levels
  - Main Morphological Class
    - NOT mutually exclusive! – can choose more than one

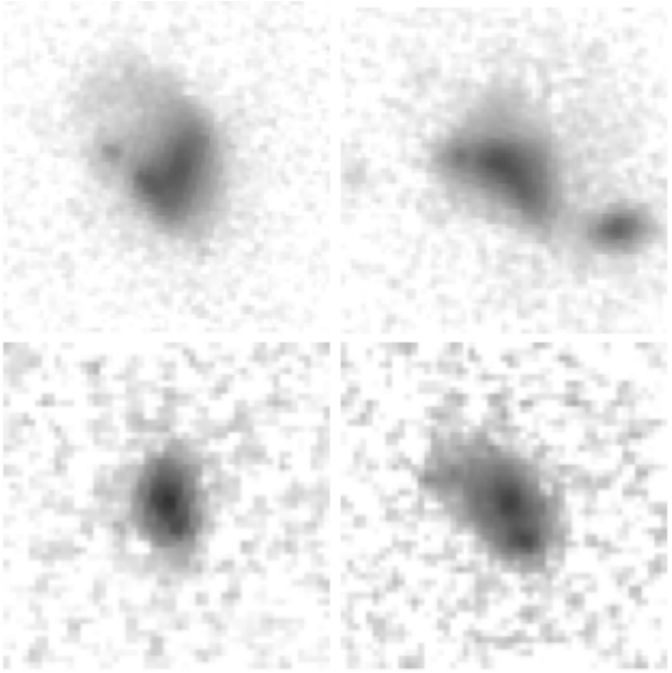
Unclassifiable



Classification Scheme

- Two levels
  - Main Morphological Class (disk, spheroid, irregular, point source, unclassifiable)
    - NOT mutually exclusive! – can
  - Interaction Class
    - Only one choice (or none)

Mergers



Classification Scheme

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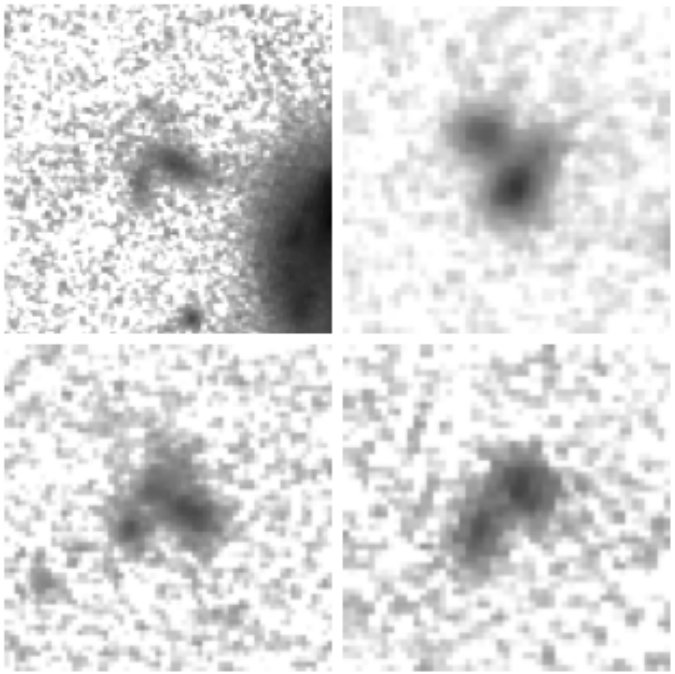
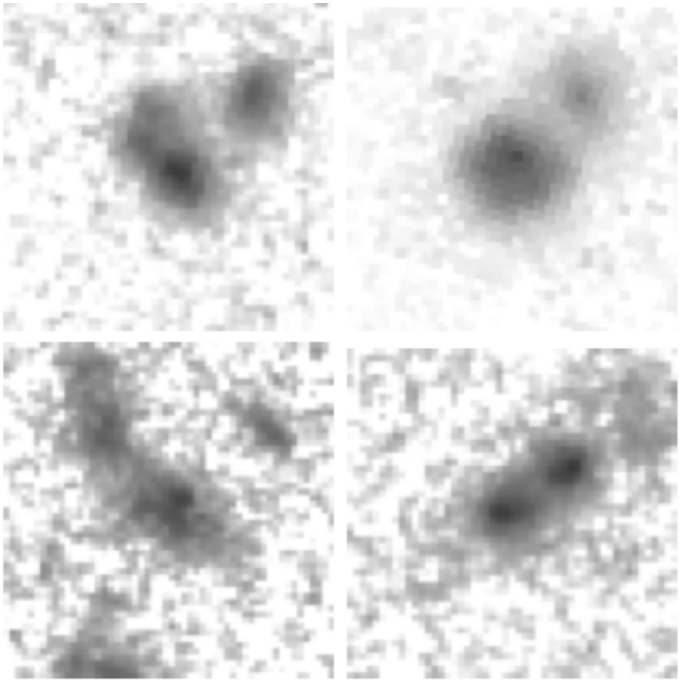


Interaction within Segmentation Map

Classification Scheme

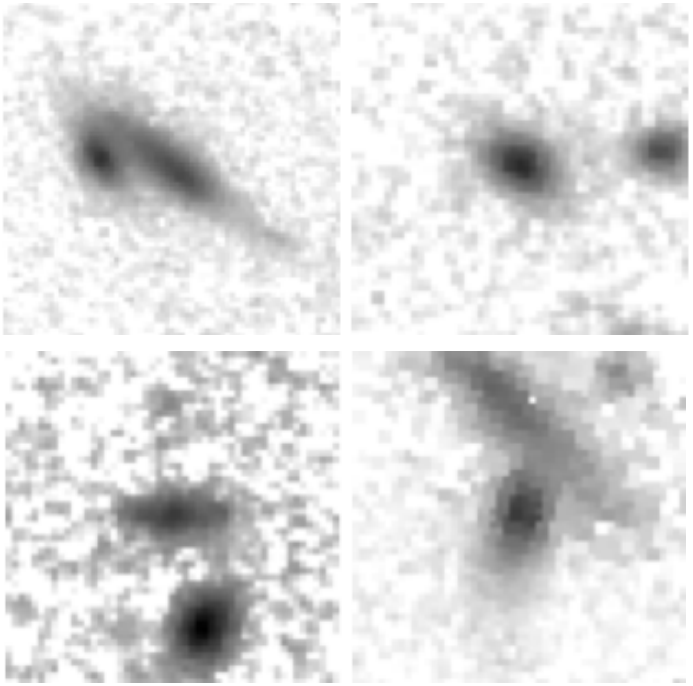
- Two levels
  - Main Morphological Class (disk, spheroid, irregular, point source, unclassifiable)
    - NOT mutually exclusive! – can
  - Interaction Class
    - Only one choice (or none)

Interaction Beyond Segmentation Map



Classification Scheme

- Two levels
  - Main Morphological Class (disk, spheroid, irregular, point source, unclassifiable)
    - NOT mutually exclusive! – can
  - Interaction Class
    - Only one choice (or none)



Non-interacting Companion

Classification Scheme

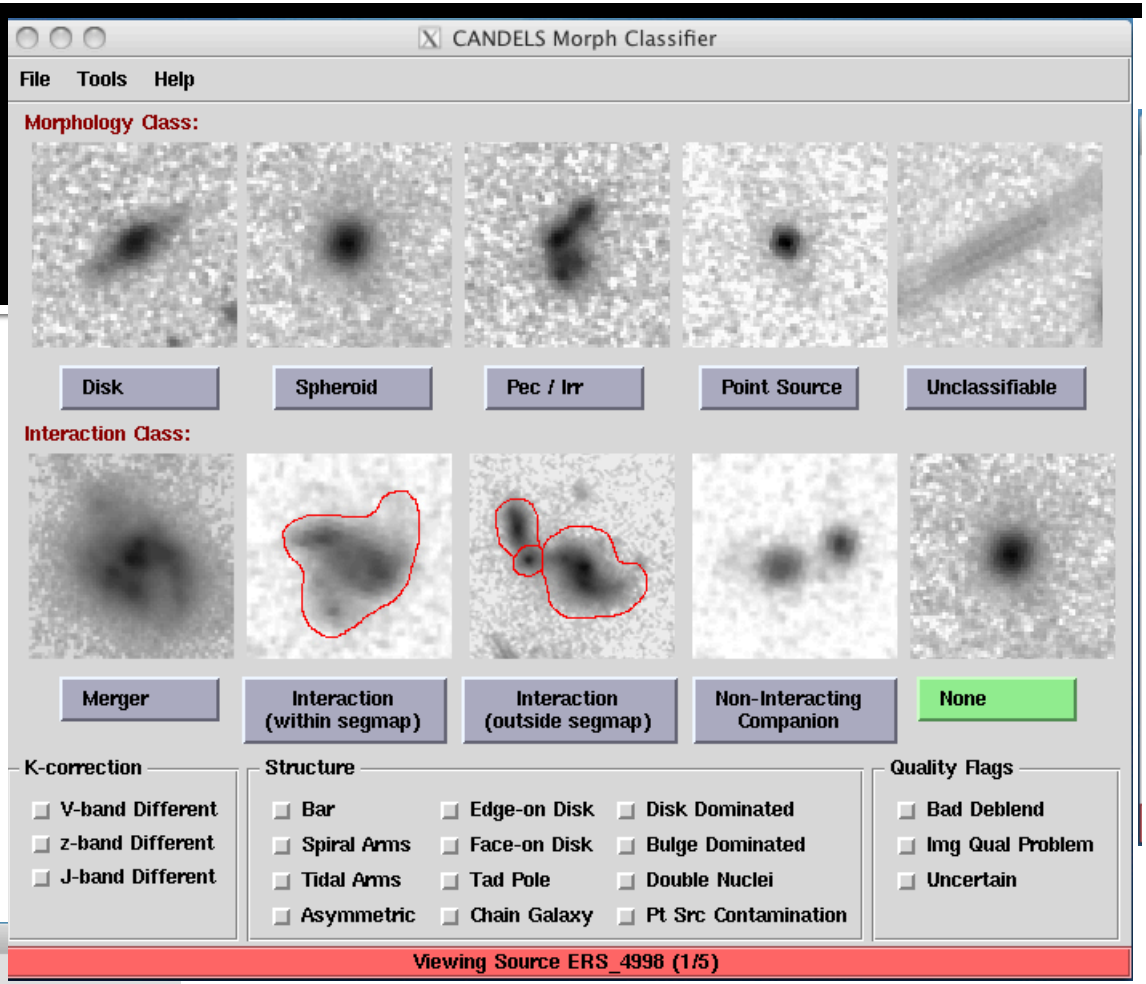
- Two levels
  - Main Morphological Class (disk, spheroid, irregular, point source, unclassifiable)
    - NOT mutually exclusive! – can choose more than one
  - Interaction Class
    - Only one choice (or none)
- Structure flags
  - Tidal arms, double nuclei, asymmetric, spiral arms, bar, point source contamination, edge-on/ face-on disk, bulge/disk dominated, tadpole, chain

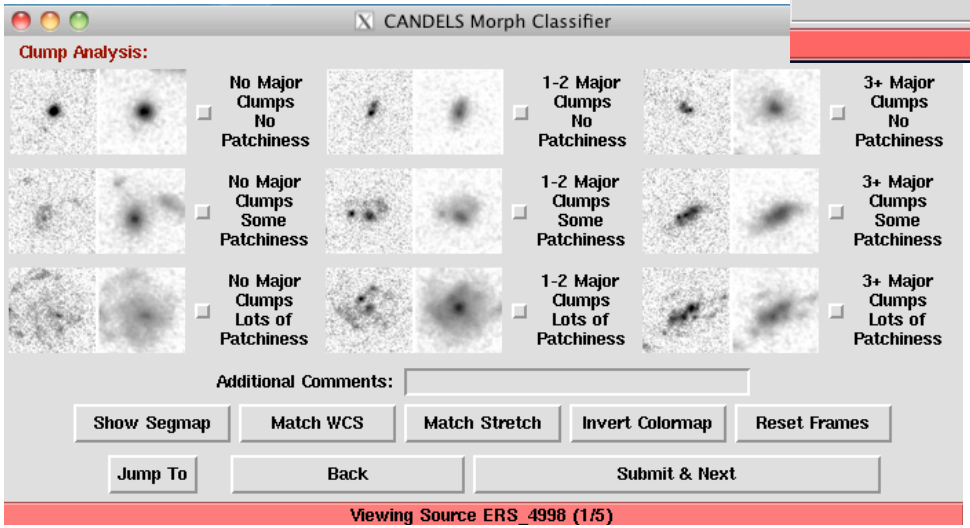
Classification Scheme

- Two levels
  - Main Morphological Class (disk, spheroid, irregular, point source, unclassifiable)
    - NOT mutually exclusive! – can choose more than one
  - Interaction Class
    - Only one choice (or none)
- Structure flags
- K-correction flags
- Quality flags
- Clumpiness flags

GUIs

- Web GUI
  - Designed by Mark Mozena
- ds9/Perl GUI
  - Designed by Dale Kocevski

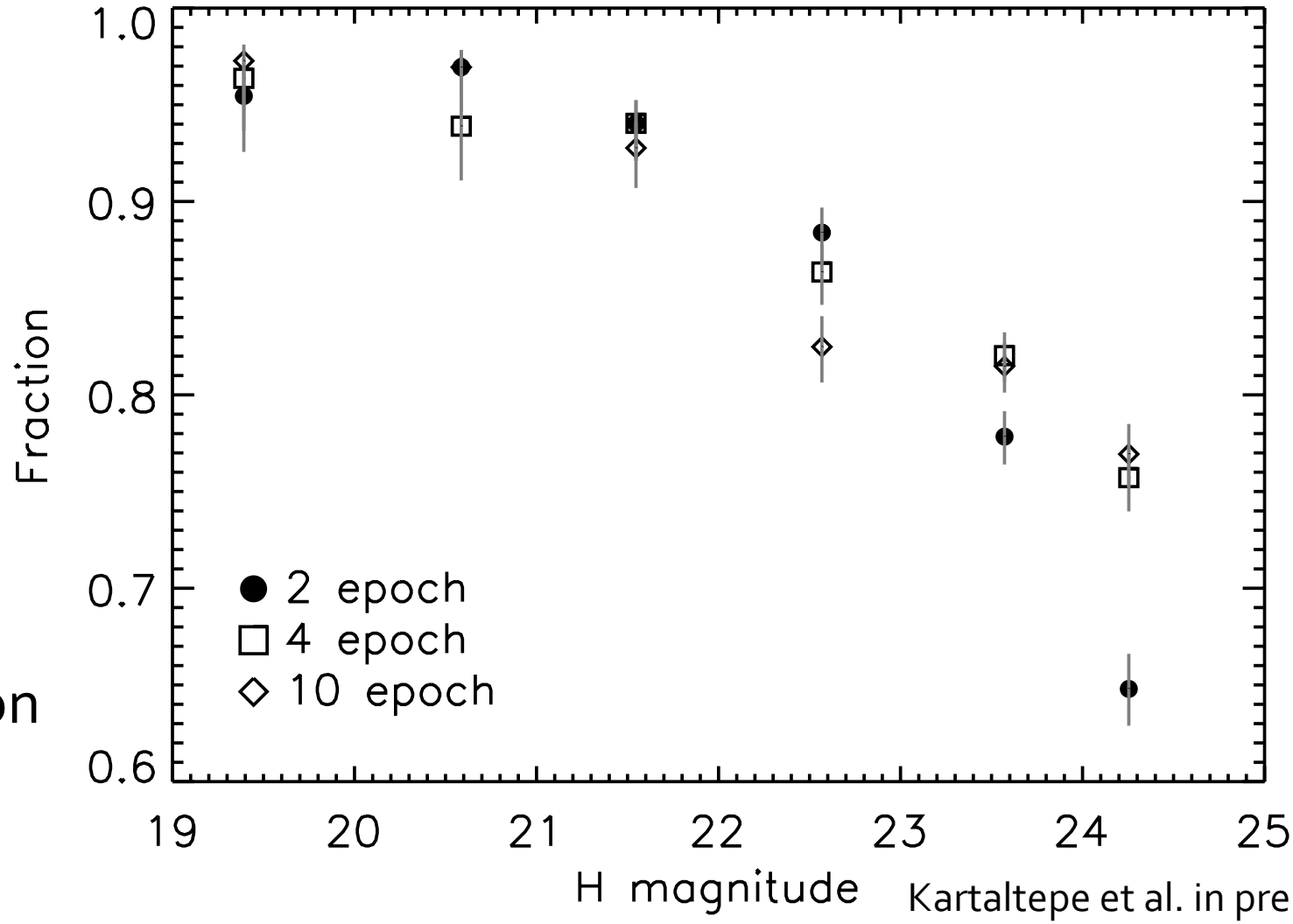




Agreement as a fn of Magnitude

Fraction of galaxies where > 3/5 classifiers agree

This is also dependent on the classification itself

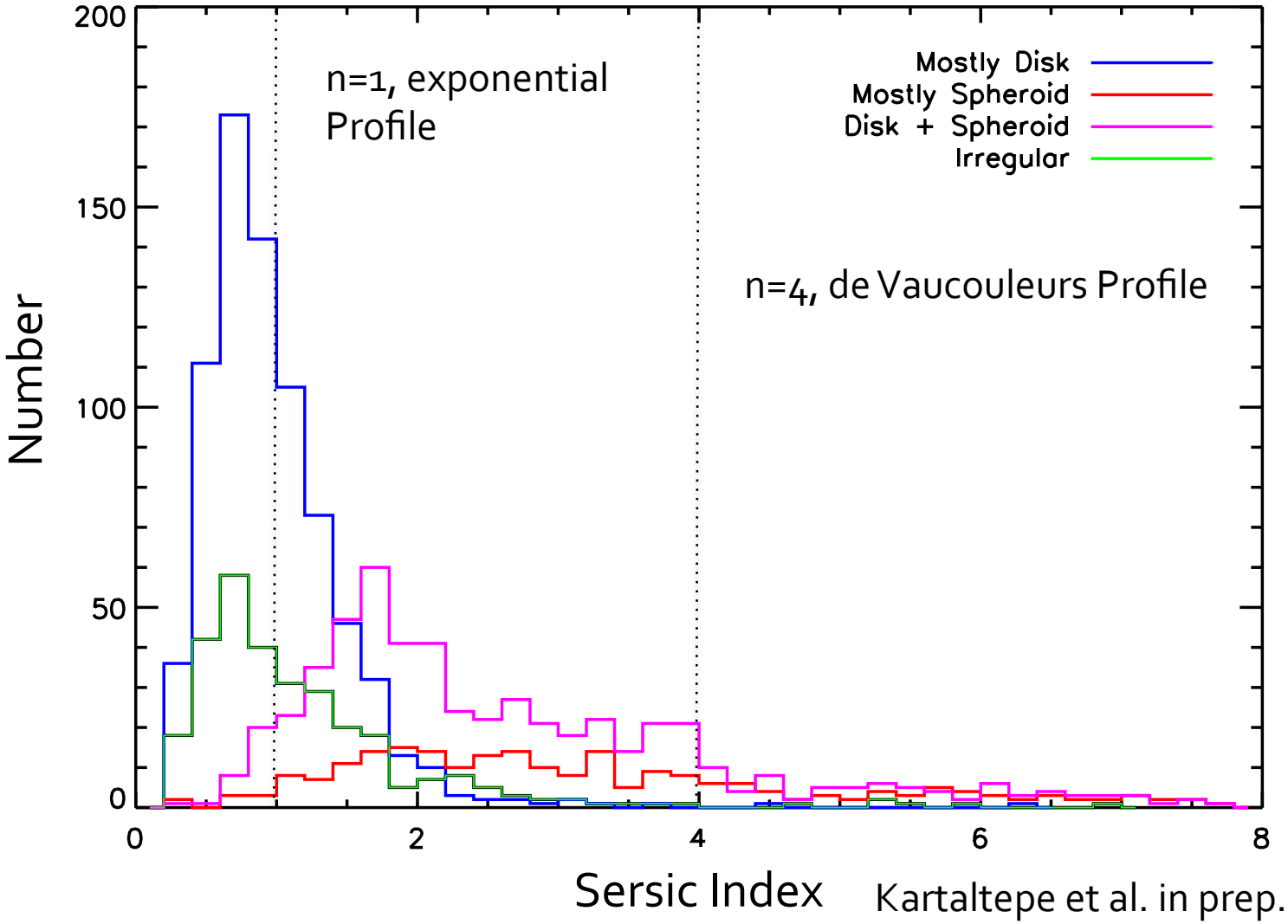


Kartaltepe et al. in prep.

Lessons Learned So Far

- Different depths
  - Agreement between classifications at 2, 4, and 10 epoch depth is magnitude dependent
  - Small difference at H>24 for disks, H>23 for spheroids
- Relative agreement
  - Agreement among classifiers depends on magnitude
  - Highest agreement for disks and spheroids
  - Lowest agreement for irregulars
    - Generally more complex morphologies
- Most difficult cases

Comparison to Sersic Index

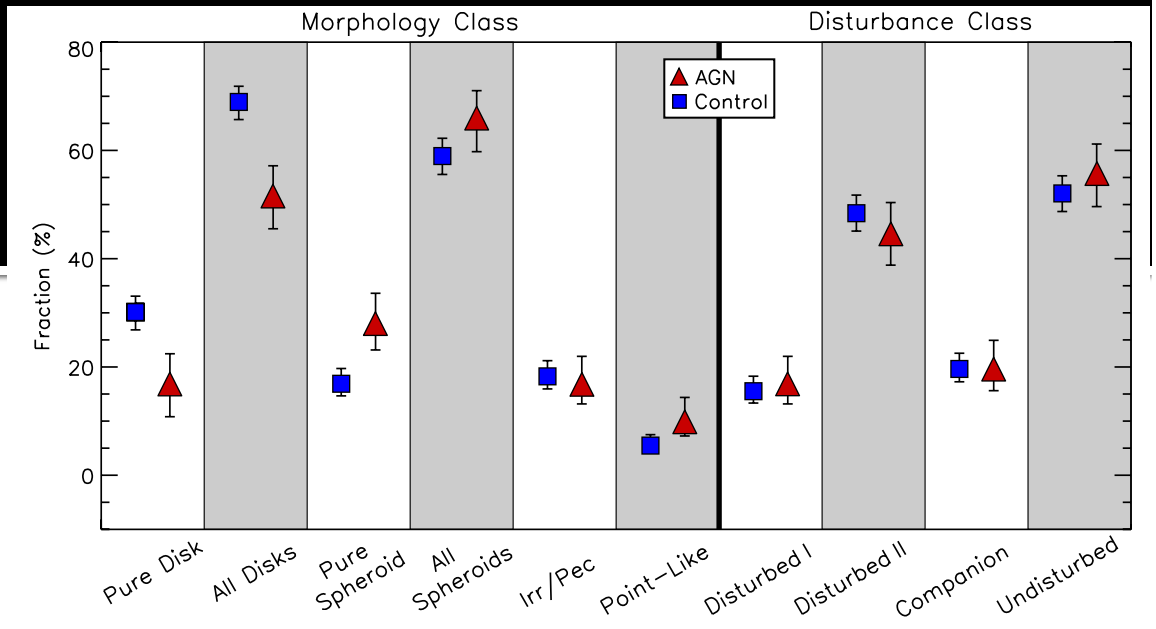


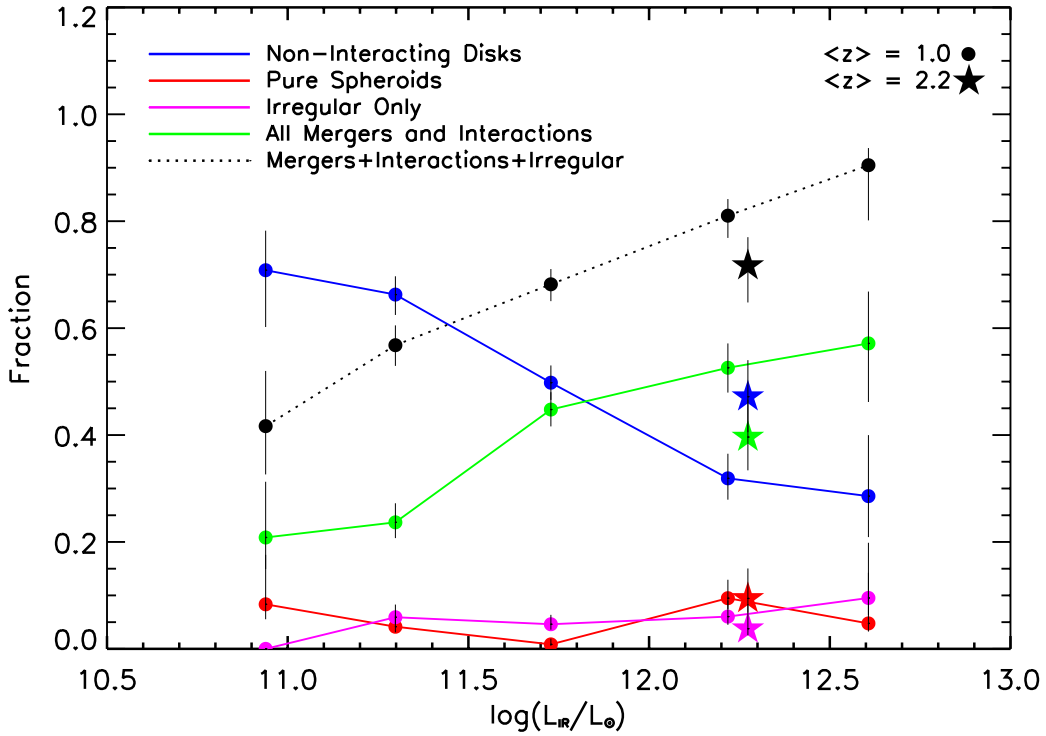
Kartaltepe et al. in prep.

Science Results

- **Kocevski et al. 2012**

Morphology of z~2
Moderate Luminosity
X-ray AGN



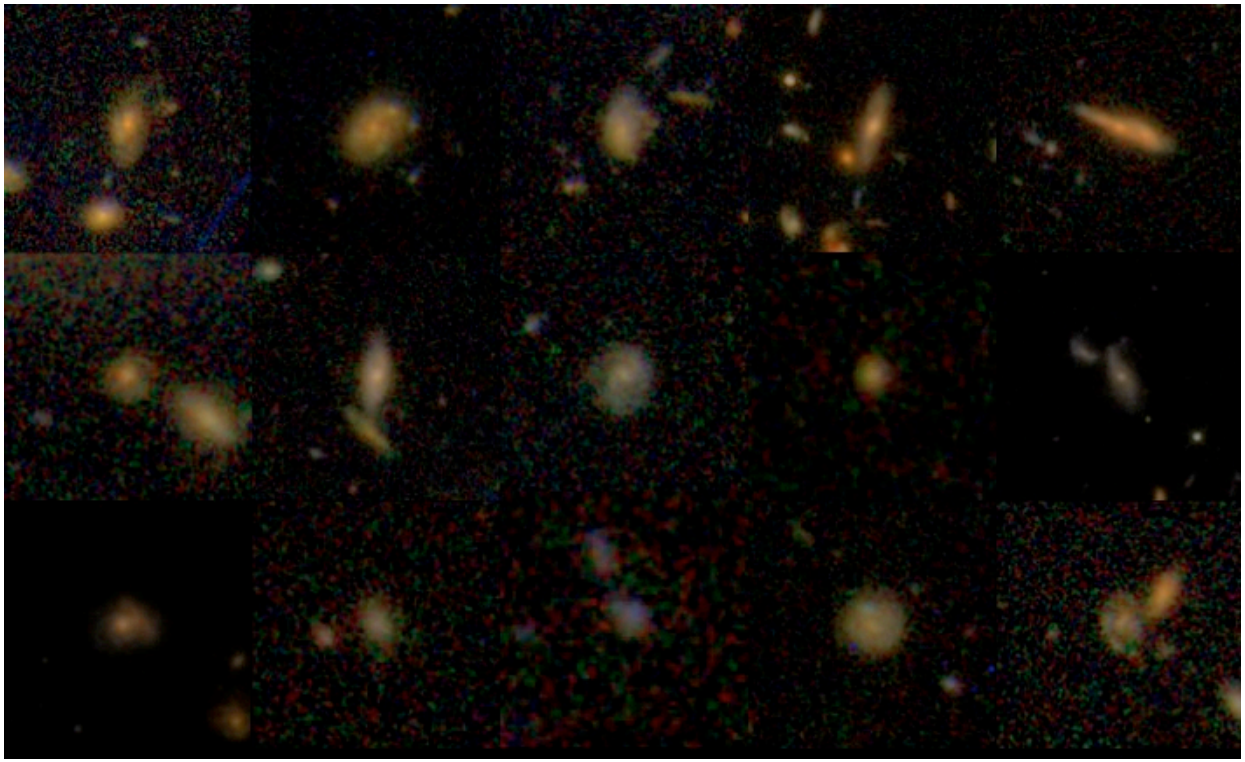


- **Kartaltepe et al. 2012**

Morphology of z~2
ULIRGs

CANDELS and Galaxy Zoo

- Postage stamps for all galaxies with H<25.5
  - Color jpegs (IJH – consistent for all fields)
- GOODS-S, UDS, COSMOS
  - Two depths in deep area for comparison
  - Classifications completed
  - Other fields to be added soon
- Plans to add CANDELized simulated galaxies



Summary

- Large Visual Classification effort within the team
  - 3.5/5 fields have been classified so far
  - 50,000 galaxies by the end
  - To be made public, GOODS-S imminently (Kartaltepe et al., in prep)
  - Lots of science based on these in progress!
- CANDELS and Galaxy Zoo – stay tuned!
- For more information about CANDELS, check out our blog at: http://candels-collaboration.blogspot.com
- Twitter: @CANDELS_team