New Illuminating Highlights on Galaxies and AGNs from CANDELS

David Koo &
CANDELS Team
13 August 2013

Santa Cruz Galaxy Workshop 2013

OUTLINE

- Overview CANDELS survey:
  Observations Done!
  - Overall science goals, strategy, and status
- Highlights:
  - Morphologies of Galaxies at z ~ 2:
    - Bulge growth
    - Properties of clumps in galaxies
  - Morphologies of AGN Host Galaxies at z ~ 2:
    - Obscured AGN hosts are more disturbed
    - Compactness & Colors of AGN hosts suggest
      2 modes of BH growth
- Summary:

CANDELS

Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey

~175 team members

~45 institutions

12 countries

Builders:

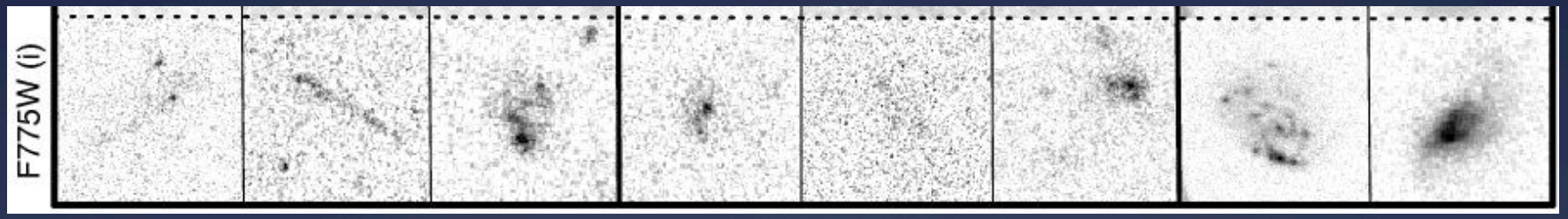
PIs: Sandra Faber & Harry Ferguson
Adam Riess, Steve Rodney
Norman Grogin, Dale Kocevski
Anton Koekemoer, Kamson Lai

candels.ucolick.org

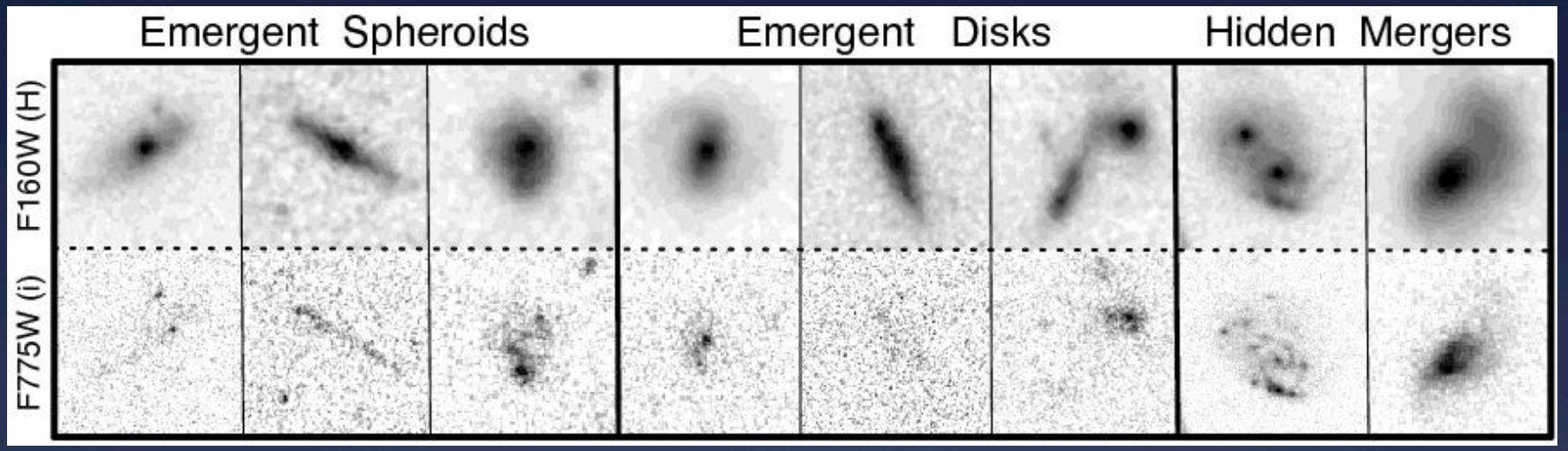
CANDELS in a nutshell

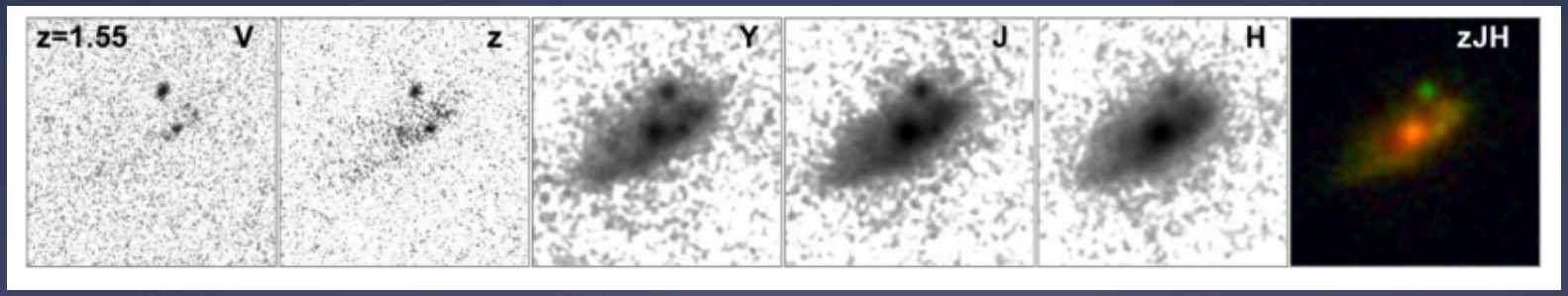
- HST O/IR imaging survey of 0.24 sq deg area in 5 slices representative of the universe.
  - These slices include Hubble's 2 deep fields and also cover 3 more areas less deeply
  - These are among **the best** reference fields for studies of the distant universe
- Near-infrared images provide crucial insight into galaxy assembly
- CANDELS works in concert with other surveys to provide as much multiband and multispectral information as possible on each galaxy.
- Also searches for distant SN and gets some UV

What The *Hubble* WFC3 Can Do



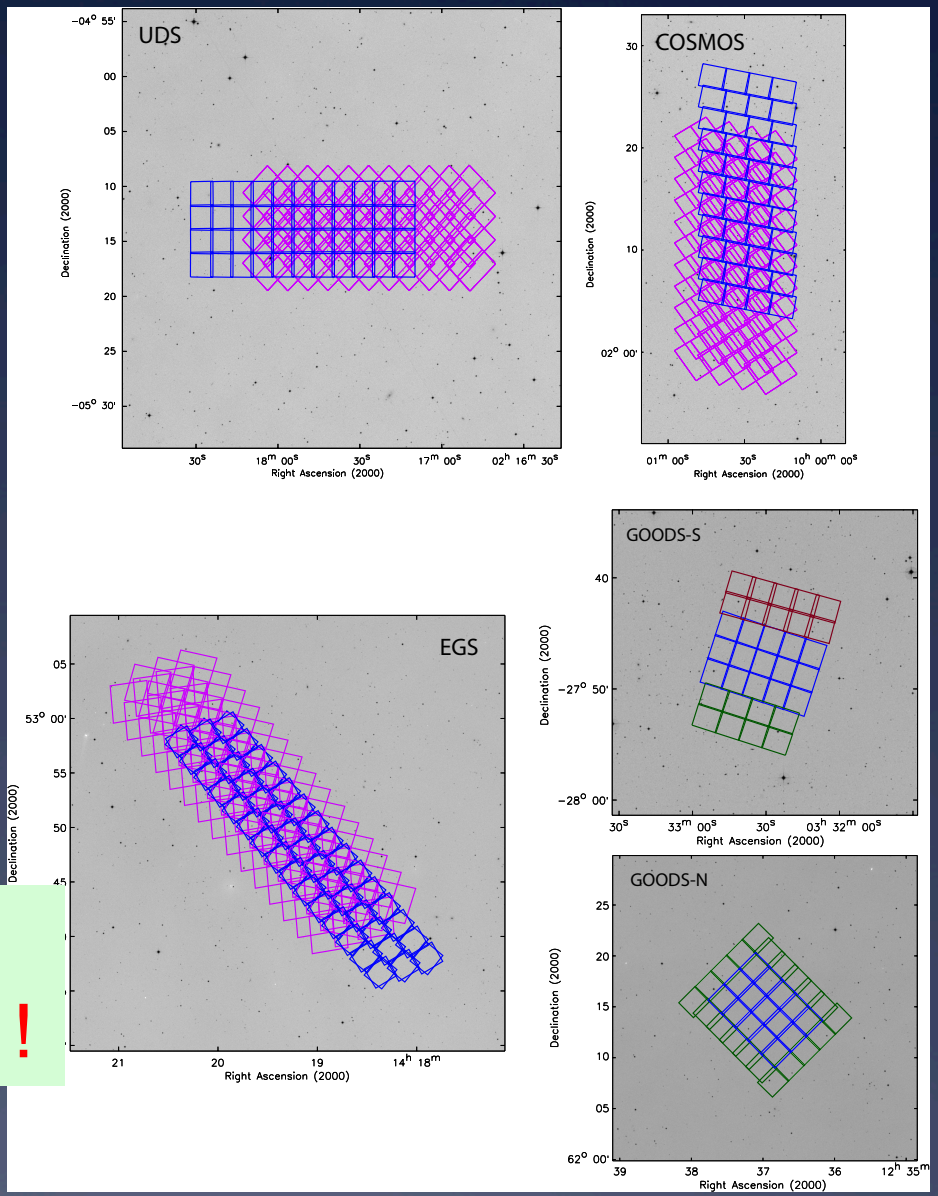
What WFC3 Can Do





CANDELS Fields

- Reference fields for studies of the distant universe:
  - Densest, deepest redshift surveys
  - ~250,000 galaxies
  - ~2x10^6 Mpc^3 per unit z for redshifts z > 1.5
  - Raw and processed data are public when available

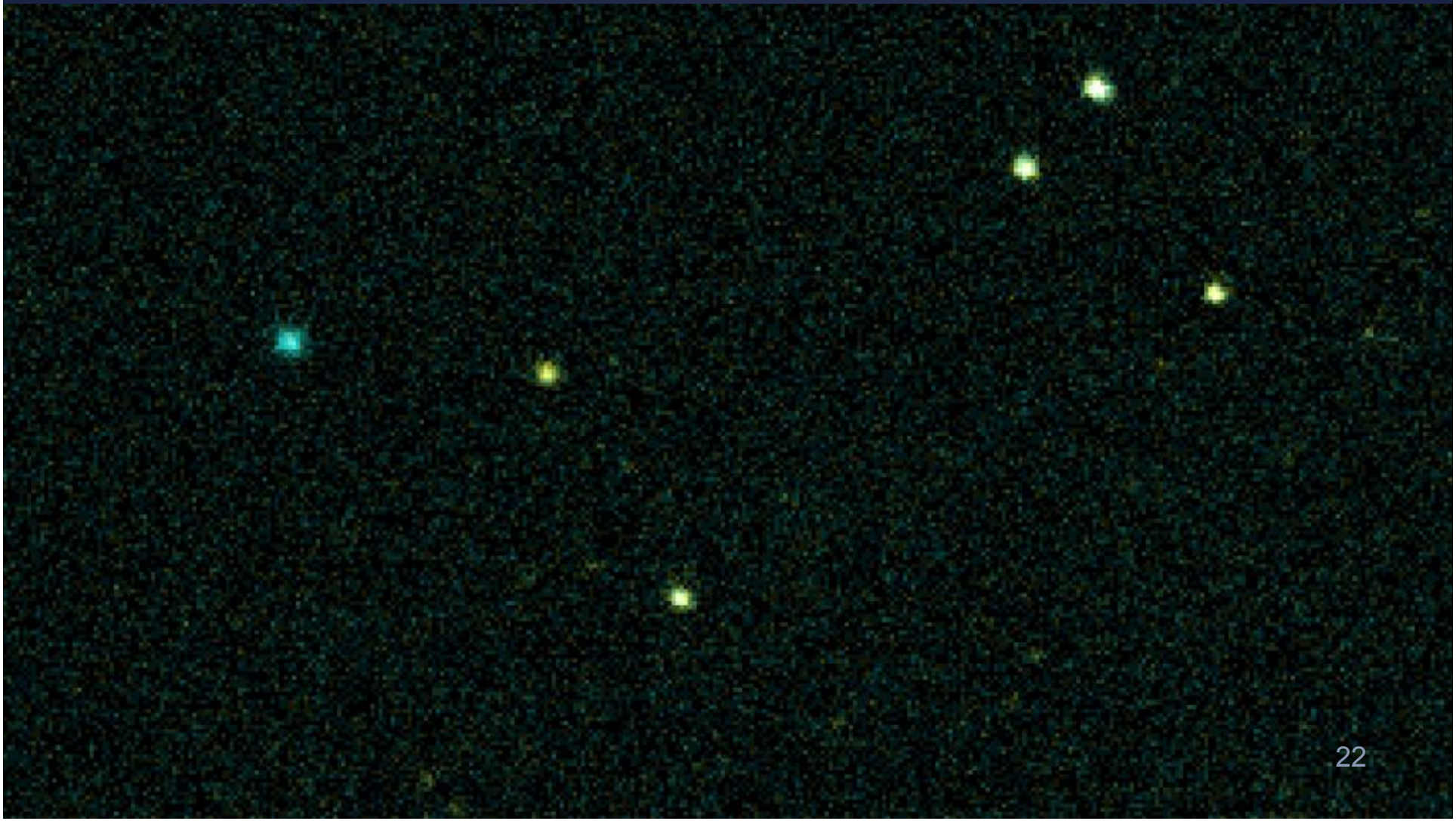


CANDELS Observations were completed last week !

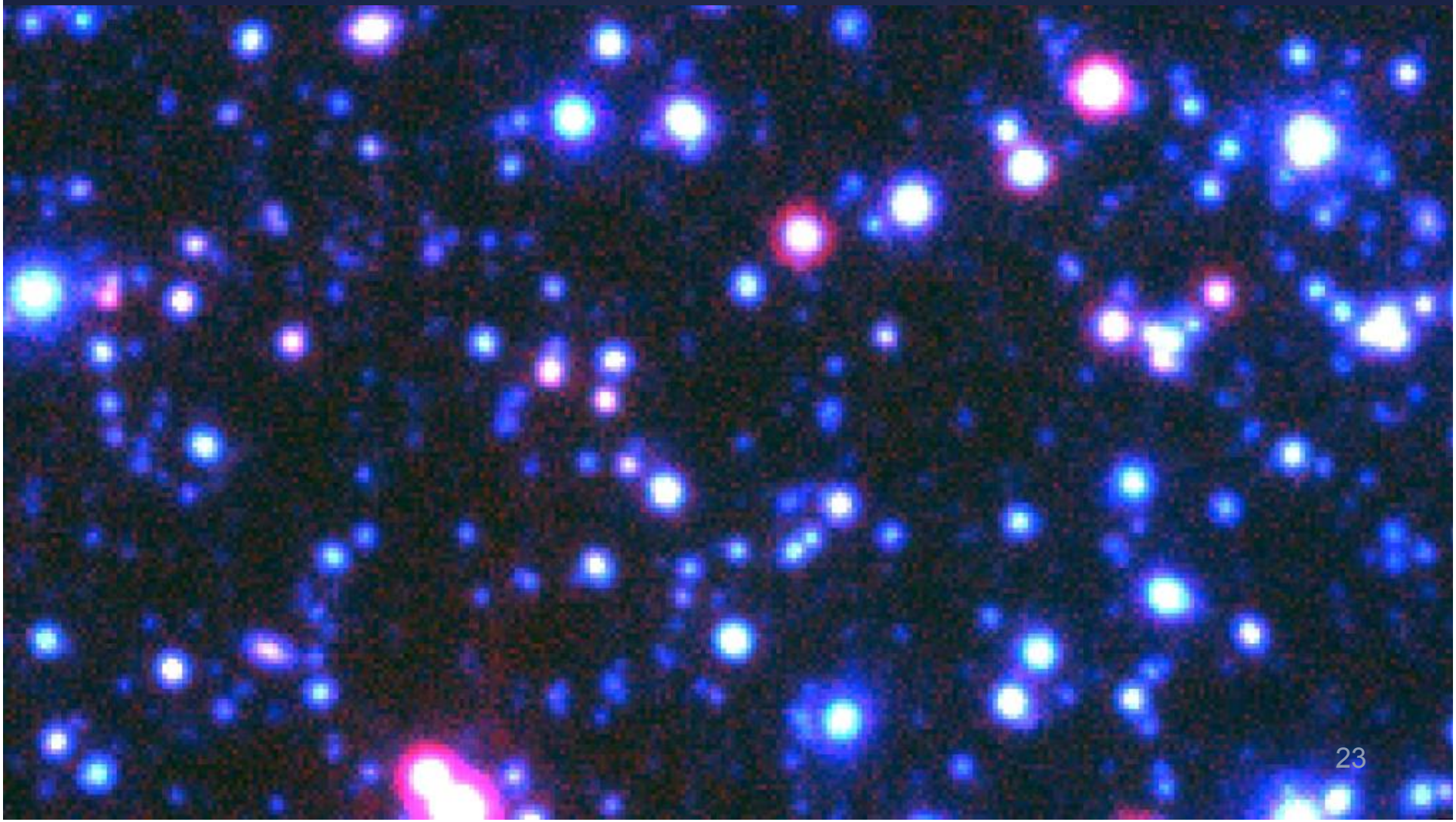
Multi-wavelength slices of the universe…

Hubble
0.6, 1.25, 1.6 microns

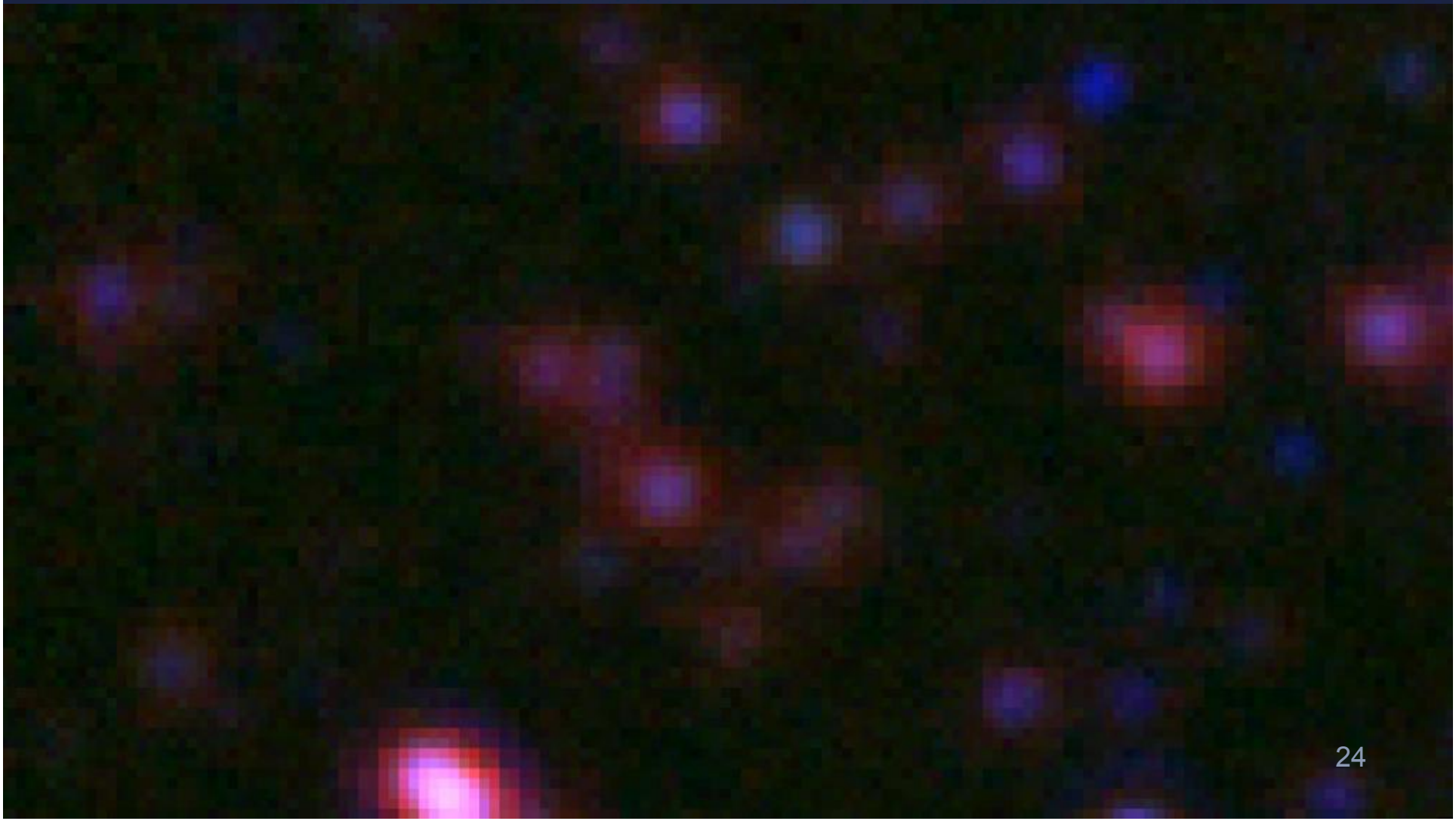
Chandra X-ray observatory
0.5-2, 2-8, 5-8 keV (0.0002-0.002 microns)



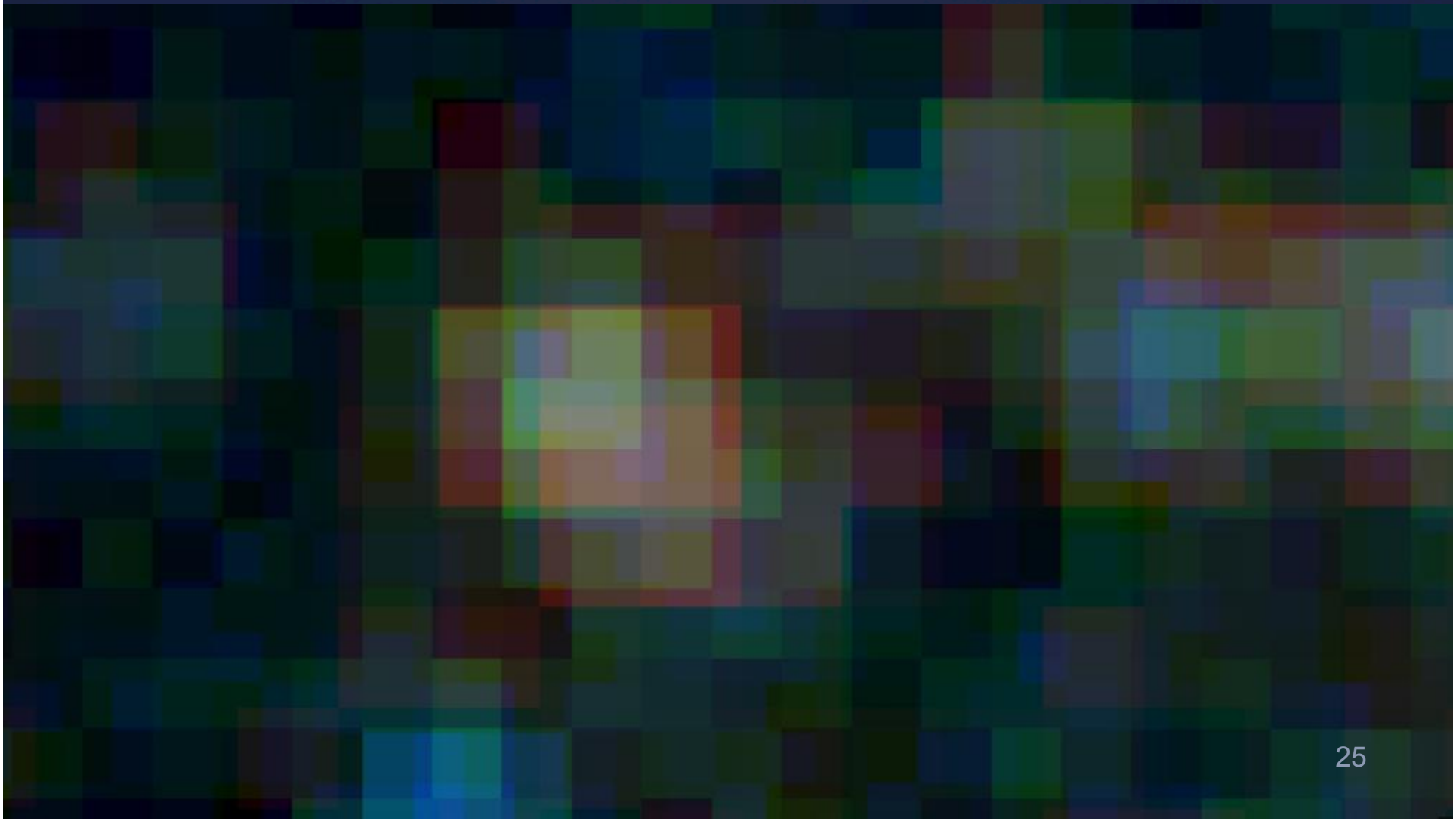
Spitzer observatory
3.6+4.5, 5.6, 8 microns



Spitzer and Herschel observatories 24, 100, 160 microns



Herschel Observatory
250, 350, 500 microns



Survey Infrastructure

- Morphology
  - CAS/GINI/M20, Galfit, GIM2D
  - Visual classifications
  - Galaxy Zoo
- SED fitting, photometric redshifts
  - 13 different groups with different codes
- Theory:
  - Multiple semi-analytic models
  - Hydrodynamic models, cosmologically embedded, with dusty radiative transfer
- Outreach:
  - 101 blog posts so far
    - candels-collaboration.blogspot.com
  - Teacher workshop, iphone app

Major Science Goals of CANDELS Team

1. Cosmic Dawn at redshifts z > 4 (P. Oesch talk Monday)

2. Distant Supernovae as probes of Dark Energy (skip)

3. Deep UV studies of z > 1 dwarfs, LBG, and Ly-continuum escape fraction in one field (GOODS-N) – (skip)

4. Cosmic Noon at redshifts z ~ 1 to 4: key transition epoch for both galaxies and AGNs

   (a) census of, mass-size-clustering of galaxies at 1.5 < z <4.
   (b) study of bulge & disk growth at 1 < z < 3
   (c) detect and study galaxy subclumps
   (d) study envelope growth and color gradients of these galaxies
   (e) test models of co-evolution of SMBH and bulges
   (f) study the structure of AGN hosts at z ~ 2.
   (g) identify and study Compton-thick, obscured AGN at z ~ 2.

33 CANDELS submitted papers

Lead Author	Paper Title
Yicheng Guo	CANDELS Multi-Wavlength Catalogs: Source Detection and Photometry in the GOODS-South Field
David O. Jones	Discovery of the Most Distant Type Ia Supernova at Redshift 1.914
A. Galametz	The CANDELS UDS Multiwavelength catalog
A. Cooray	CANDELS: Strong Lensing Galaxies In HST/WFC3 Imaging Data Of UDS AND GOODS-S
J. Lotz	The Assembly of Massive Cluster Galaxies at z=1.62
R. Bassett	CANDELS Observations of the Color-Morphology Relation at z = 1.6 and its Dependence on Mass and Environment
V. Tilvi	LBGs at z~7 from the zFourGE Survey
J. Herrington	No Significant Evolution of the Bar Fraction in Large Disk Galaxies from z=1.8 to z=0.6
T. Targett	The properties of (sub)millimetre selected galaxies as revealed by CANDELS WFC3/IR imaging in GOODS-South
G. Barro	The progenitors of red nuggets at z>2 as seen by CANDELS
E. Curtis-Lake	The stellar populations of spectroscopically confirmed z~6 galaxies in the CANDELS UDS/GOODS-S field
D. Rosario	X-ray selected AGN Hosts are Similar to Inactive Galaxies out to z=3: Results from CANDELS/CDF-S
V. Bruce	Morphologies of Massive Galaxies at 1<z<3 in the CANDELS-UDS Field: The Rise and Fall of Massive Disks
H. Yan	Luminous and High Stellar Mass Candidate Galaxies at z~8 Discovered in CANDELS

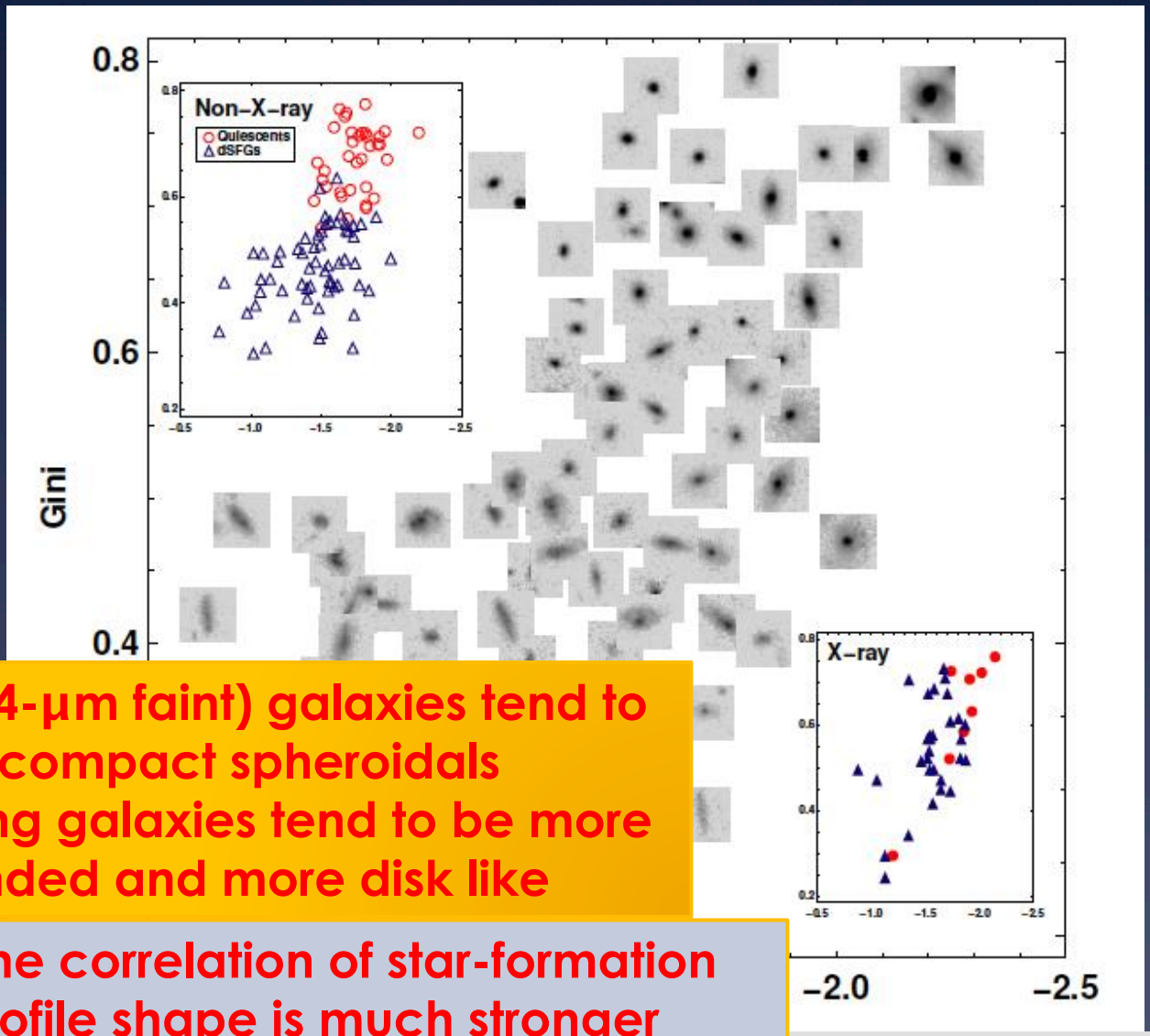
CANDELS submitted papers

Lead Author	Paper Title
A. van der Wel	Galfit Structural Parameters of Galaxies from CANDELS
S. Finkelstein	CANDELS: The Contribution of the Observed Galaxy Population to Cosmic Reionization
A. Grazian	The size-luminosity relation at z=7 in CANDELS and its implication on reionization
K. I. Caputi	The nature of H-[4.5]>4 galaxies revealed with SEDS and CANDELS
J. S. Kartaltepe	Morphology of Herschel Selected ULIRGs at z~1-3
S. Wuyts	Smooth(er) Stellar Mass Maps in CANDELS: Constraints on the Longevity of Clumps in High-redshift Star-forming Galaxies
S. Rodney	A Type Ia Supernova at Redshift 1.55 in Hubble Space Telescope Infrared Observations from CANDELS
E. Bell	What turns galaxies off? The morphologies of intermediate-mass and massive quiescent galaxies during the last ten billion years using the CANDELS Survey
T. Wang	CANDELS: Correlations of SEDs and Morphologies with Star-formation Status for Massive Galaxies at z ~ 2
S. Wuyts	Galaxy Structure and Mode of Star Formation in the SFR-Mass Plane from z~2.5 to z~0.1
E. Vanzella	On The Detection Of Ionizing Radiation From Star-Forming Galaxies At Redshift z~3-4
C. Papovich	The Structural Properties and Evolution of Galaxies in a Cluster at z=1.62
S. Finkelstein	Evolution of UV Spectral Slope from z=4-8
D. Kocevski	CANDELS: Investigating the AGN-Merger Connection at z~2
J.R. Trump	A CANDELS WFC3 Grism Study of Emission Line Galaxies at z~2: A Mix of Nuclear Activity and Low-Metallicity Star Formation
A. van der Wel	Extreme Emission Line Galaxies in CANDELS
N. A. Grogin	CANDELS: The Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey
A. M. Koekemoer	CANDELS: HST Imaging Data Products and Mosaics

Highlights from "Cosmic high noon"

- Morphologies of Quiescent vs. star-forming galaxies (Wang+12, Bell+12)
- The emergence of bulges within galaxy disks (Bruce+13, Mortlock+13)
- Clumpy star formation (Wuyts+12, Ravindranath+13 in prep)
- AGN host galaxies (Donley+13, Kocevski +13, Rangel+13)

Massive z~2 galaxies: morphology vs. SFR



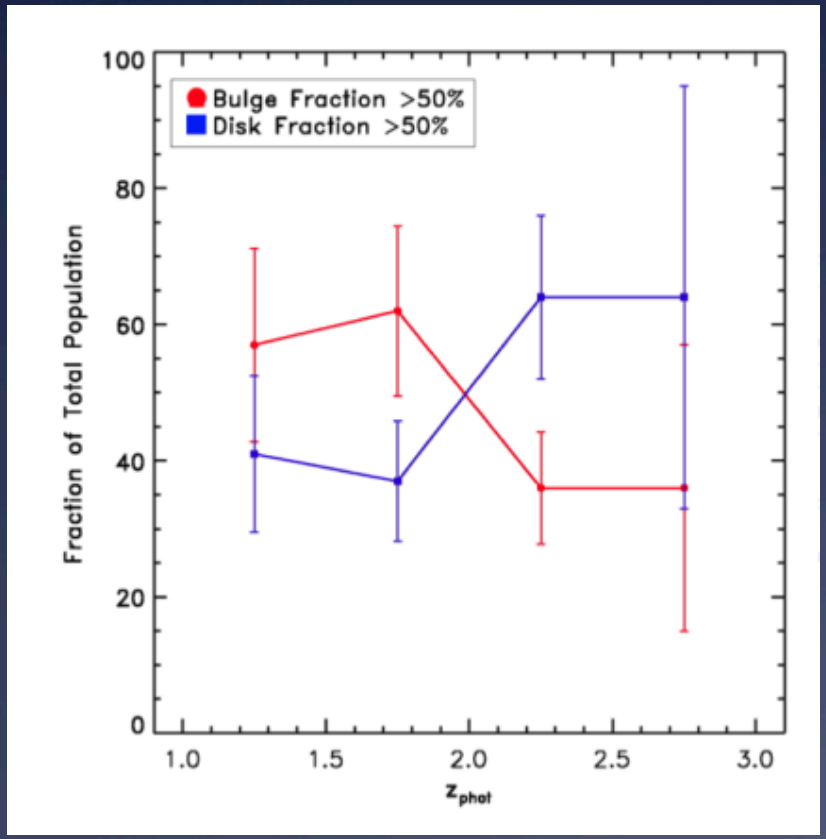
Passive (24-μm faint) galaxies tend to be compact spheroidals
Star-forming galaxies tend to be more extended and more disk like

Also, the correlation of star-formation with profile shape is much stronger than with stellar mass. (Bell+ 2012)

Wang+ 2012

The Hubble Sequence at z~2

Bulge fractions



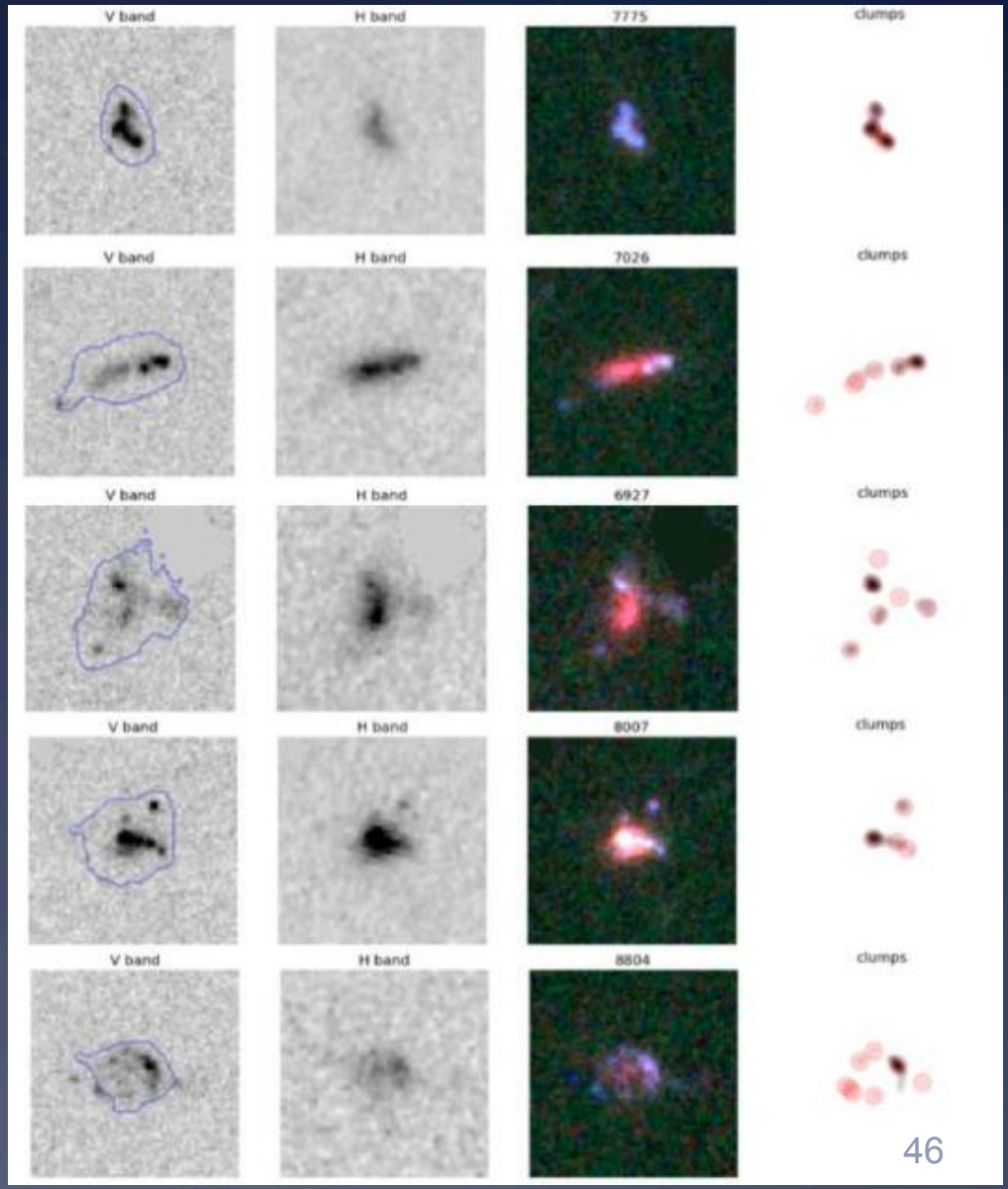
Bruce+13
Mortlock+13

Massive galaxies $M^*>10^{11}\,M_\odot$

- Bulges become dominant in massive galaxies at z~2
- Bulges are smaller at fixed mass at z~2 than today.
- While most passive galaxies are bulge dominated, a few passive galaxies appear to be pure disks.
  - Implications for quenching models?
- *Era of massive disks* at 2<z<3

Emergence of clumpy disks

- Gas instabilities in gas-rich disks?
- Mergers?
- The seeds of bulges?



Guo et al. 2011
Ravindranath et al. 2013 in prep.
Mozena et al. 2013 in prep

Star-formation histories pixel by pixel

Sample: ~650 $z \sim 2$ galaxies at $1.5 < z < 2.5$ with $M^* > 10^{10} M_o$

Off-center clumps account for ~20% of the star formation but 7% of the mass

Sizes are smaller in mass than light imply inside-out disk growth

Clumps bluer than disk and not seen in mass imply brief (100 – 200 My) SF episodes

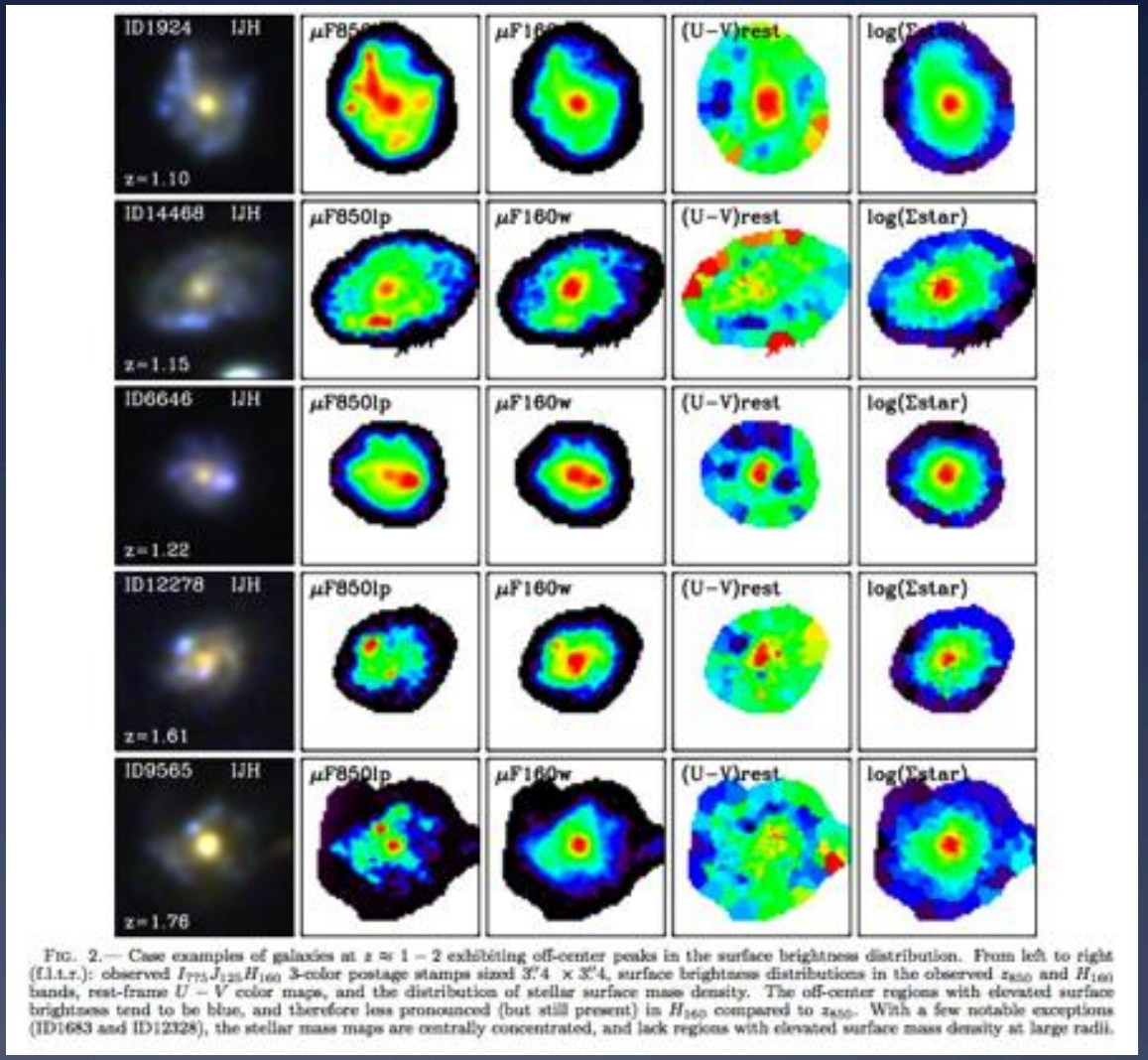
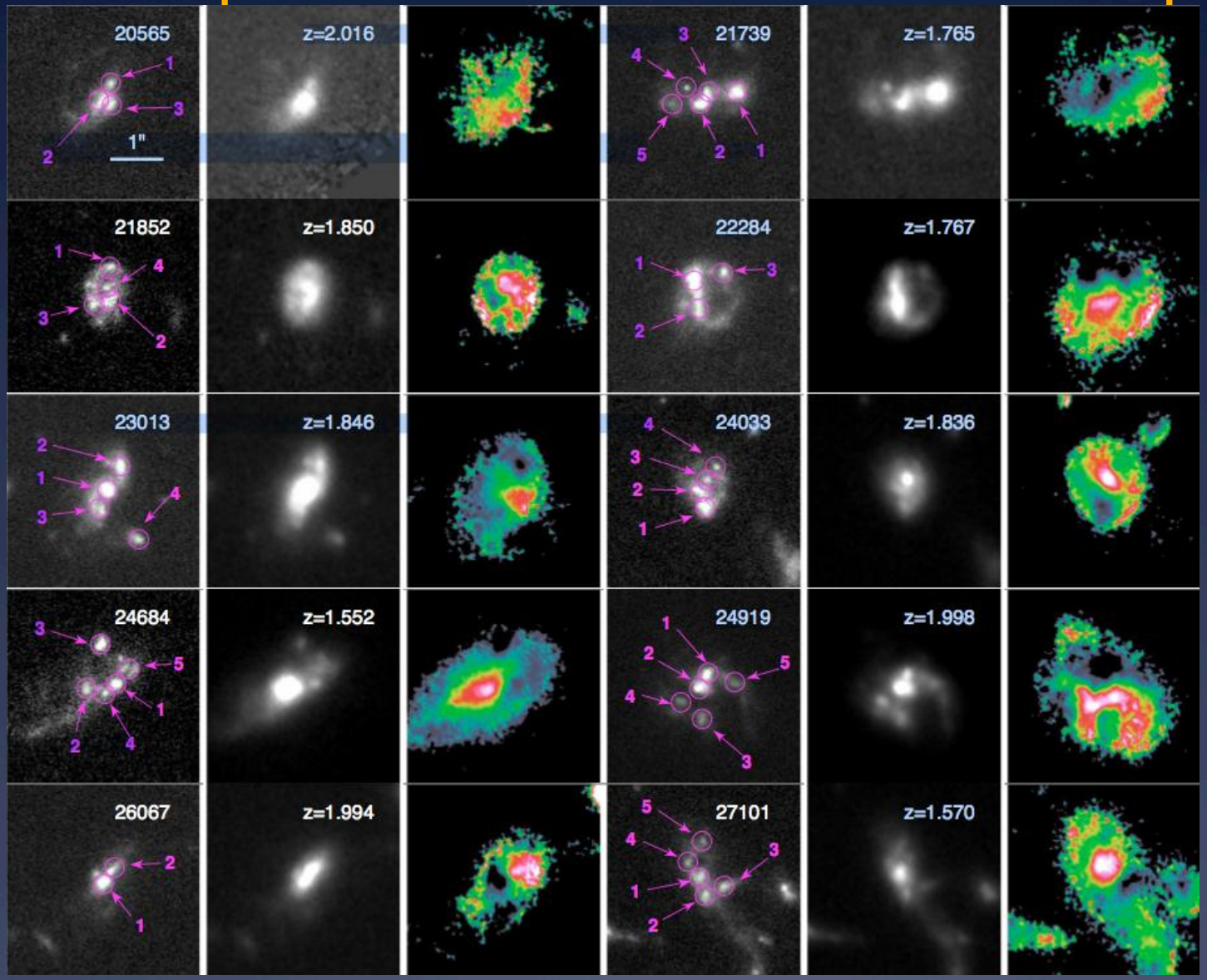


FIG. 2.— Case examples of galaxies at $z \approx 1-2$ exhibiting off-center peaks in the surface brightness distribution. From left to right (l.t.r.): observed $I_{775}J_{125}H_{160}$ 3-color postage stamps sized 3".4 × 3".4, surface brightness distributions in the observed z_{850} and H_{160} bands, rest-frame $U-V$ color maps, and the distribution of stellar surface mass density. The off-center regions with elevated surface brightness tend to be blue, and therefore less pronounced (but still present) in H_{160} compared to z_{850}. With a few notable exceptions (ID1683 and ID12328), the stellar mass maps are centrally concentrated, and lack regions with elevated surface mass density at large radii.

Wuyts+13

Examples of identified clumps



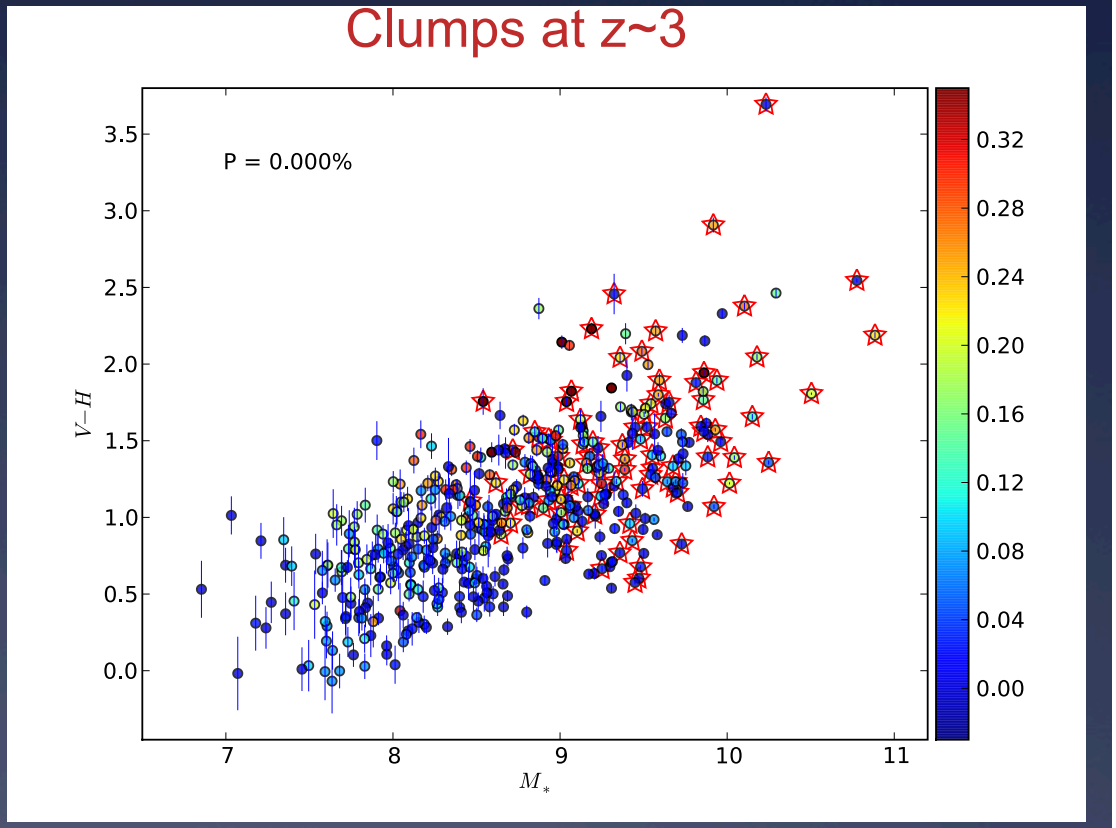
Ravindranath+13 in prep.

More massive clumps are redder

- Mass-metallicity relation for clumps ?
  - Imply winds only partially effective in removing metals

Cooler stars

Hotter stars

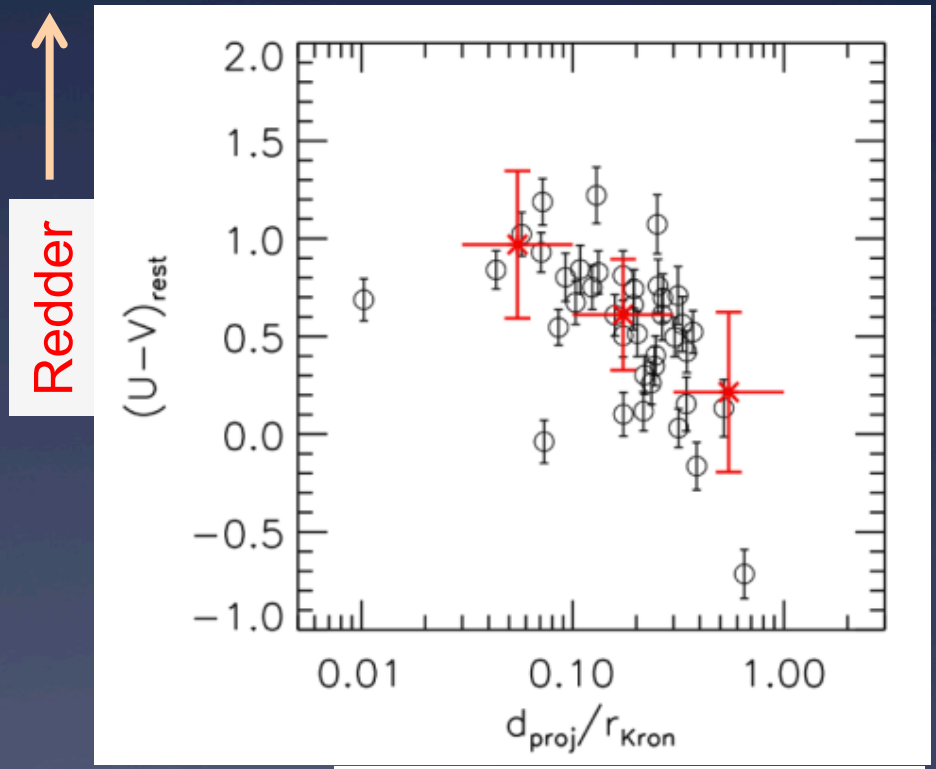


More massive clumps →

Ravindranath+13 in prep.

Radial Trends

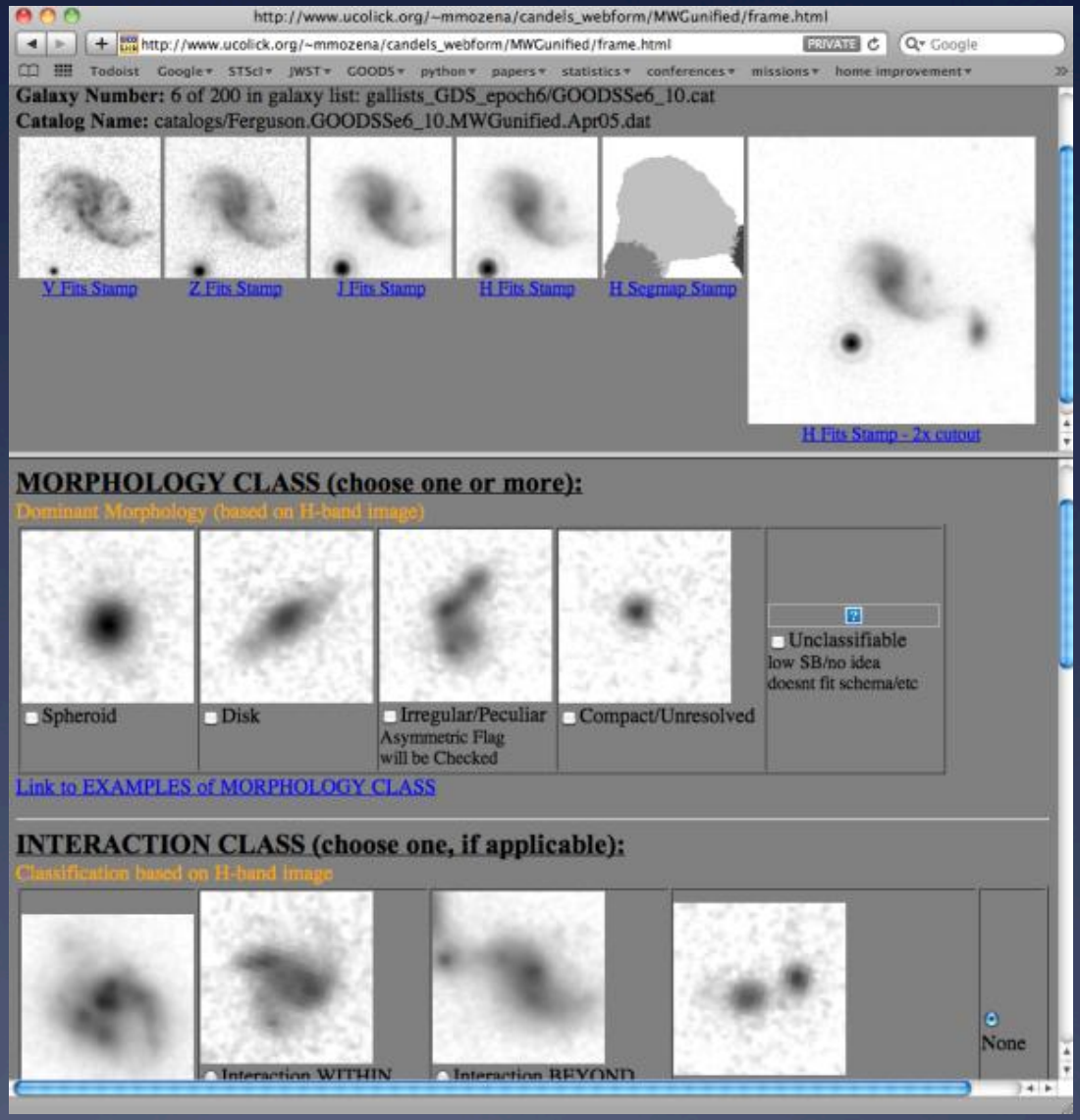
- Clumps near the center tend to be redder and higher mass.
  - Preference for more massive clumps to form near the center?
  - Migration coupled with aging of the clumps?
- Trends roughly agree with predictions



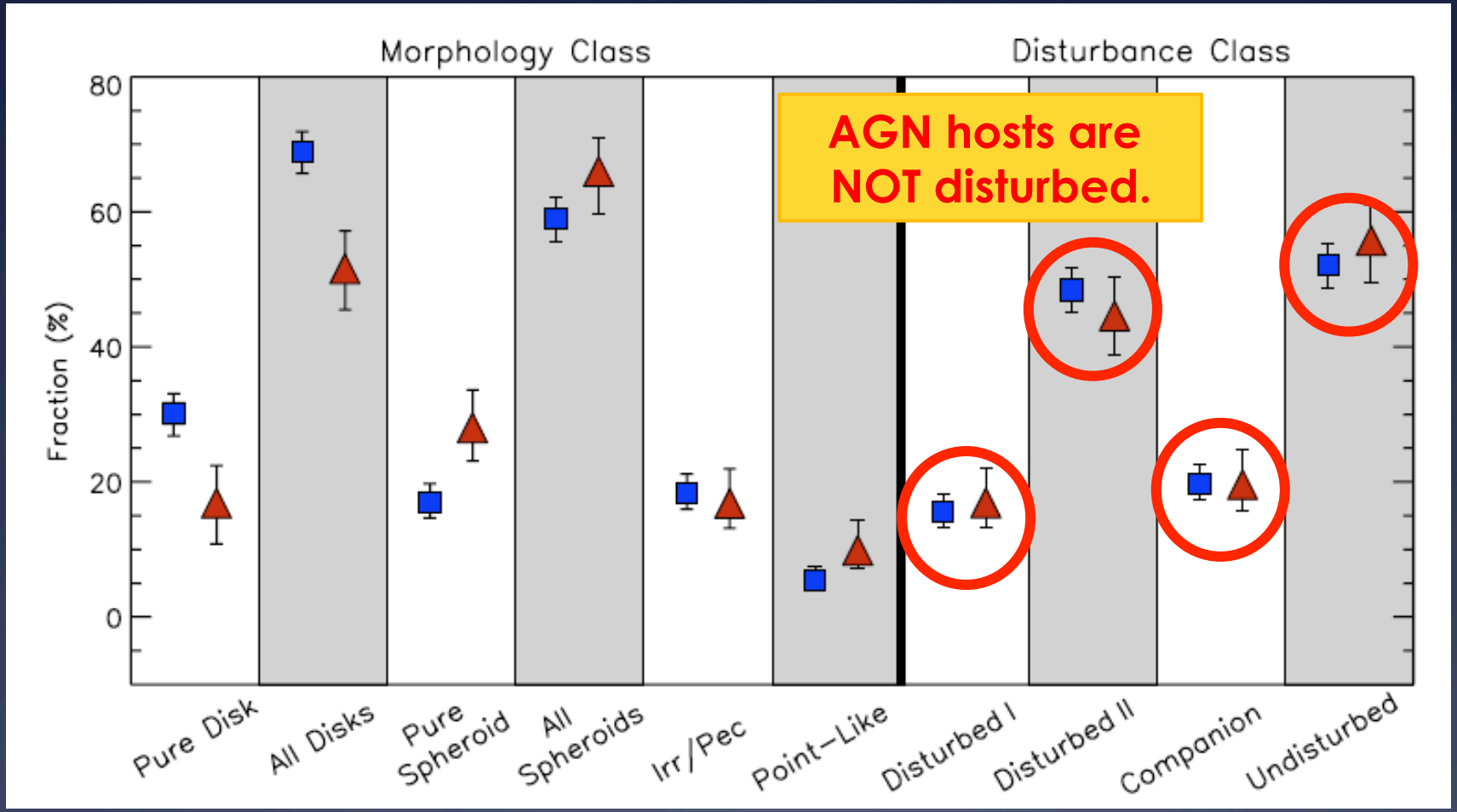
Guo+12
Ravindranath+13 in prep.

Visual classifications

- Inspection of thousands of galaxies by eye
- Help from Galaxy Zoo: 40 million classifications!

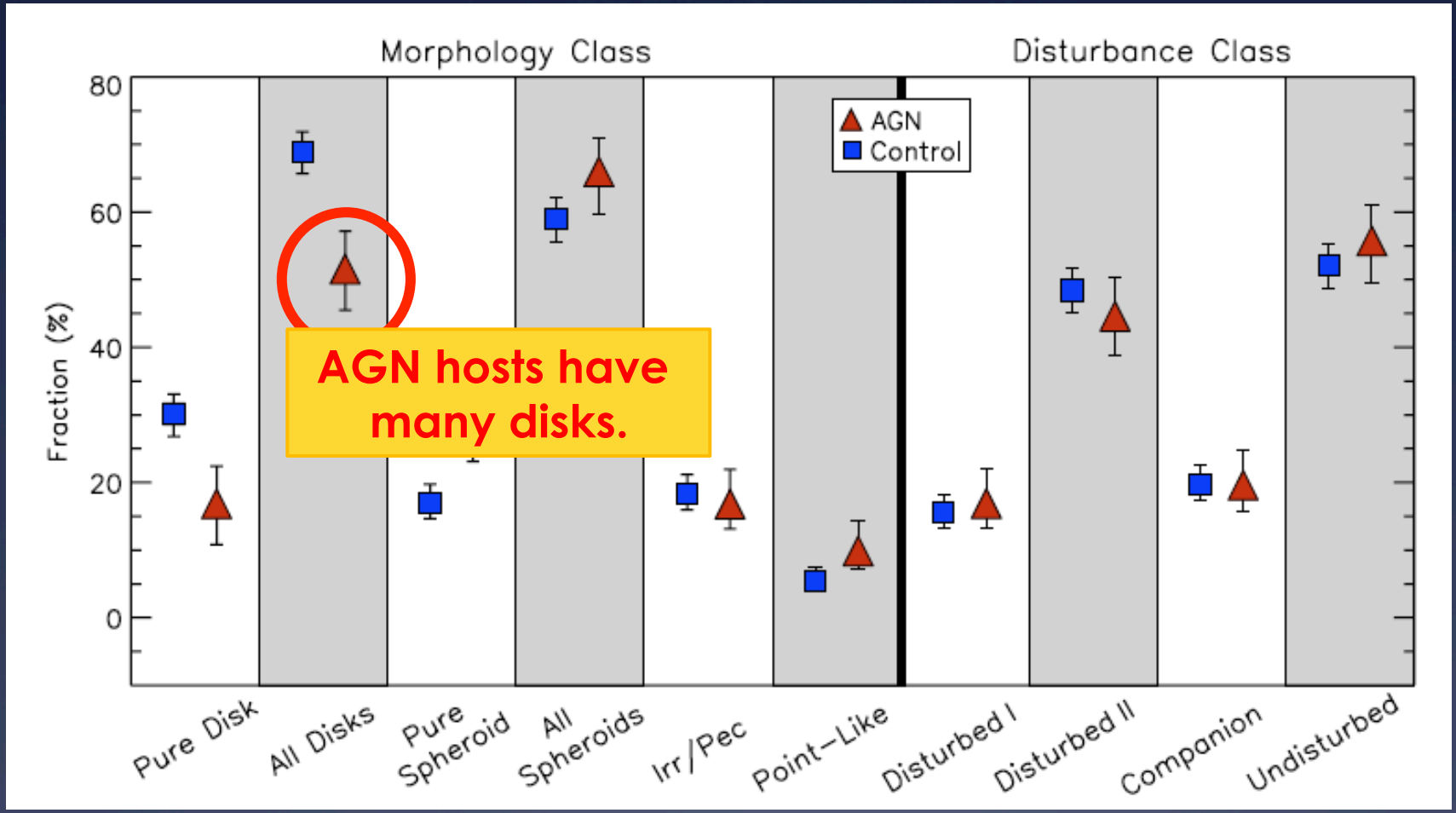


Morphologies of X-ray AGN hosts at z~2



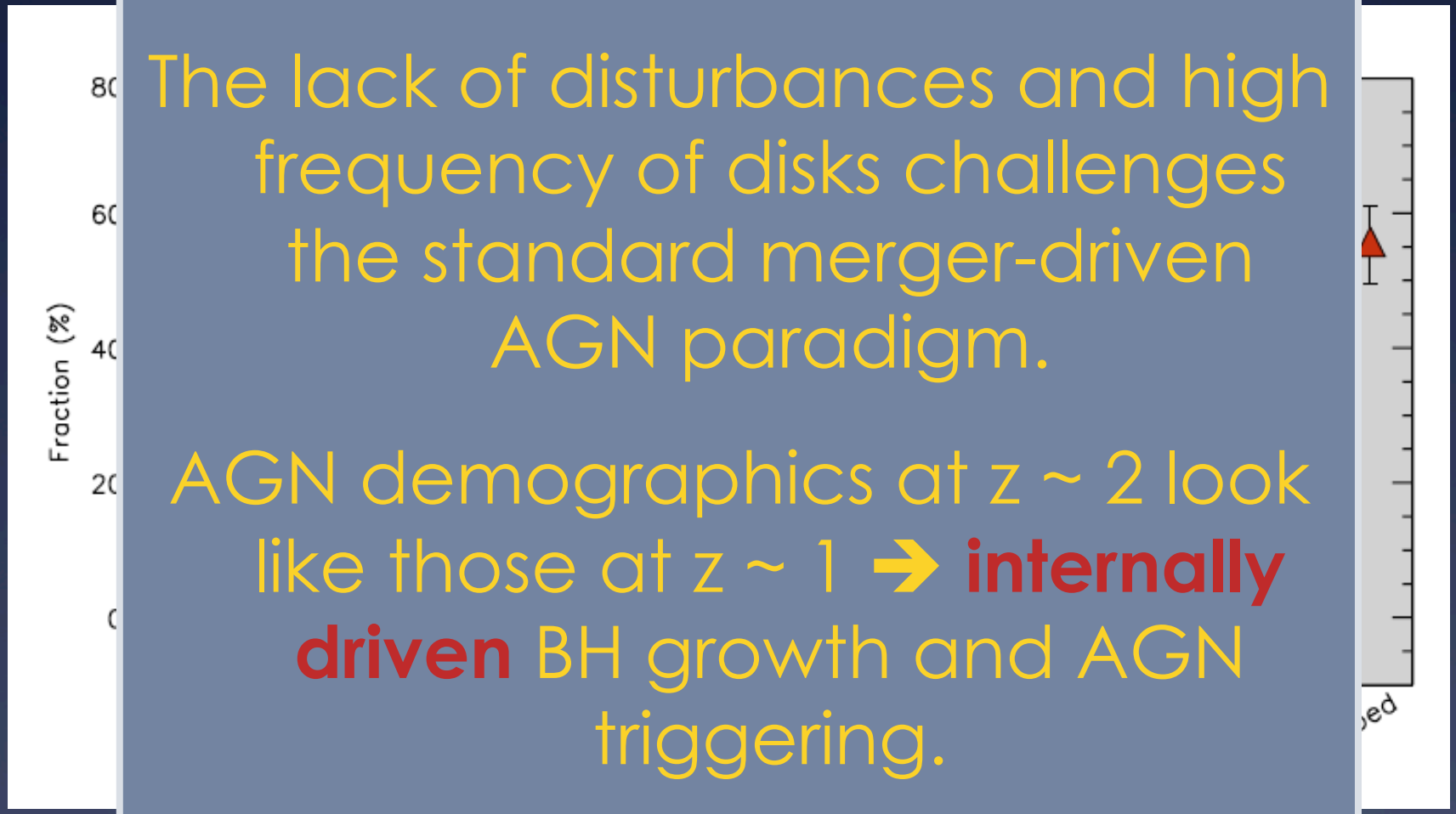
Kocevski+12

Morphologies of X-ray AGN hosts



Kocevski+12

Morphologies of X-ray AGN hosts

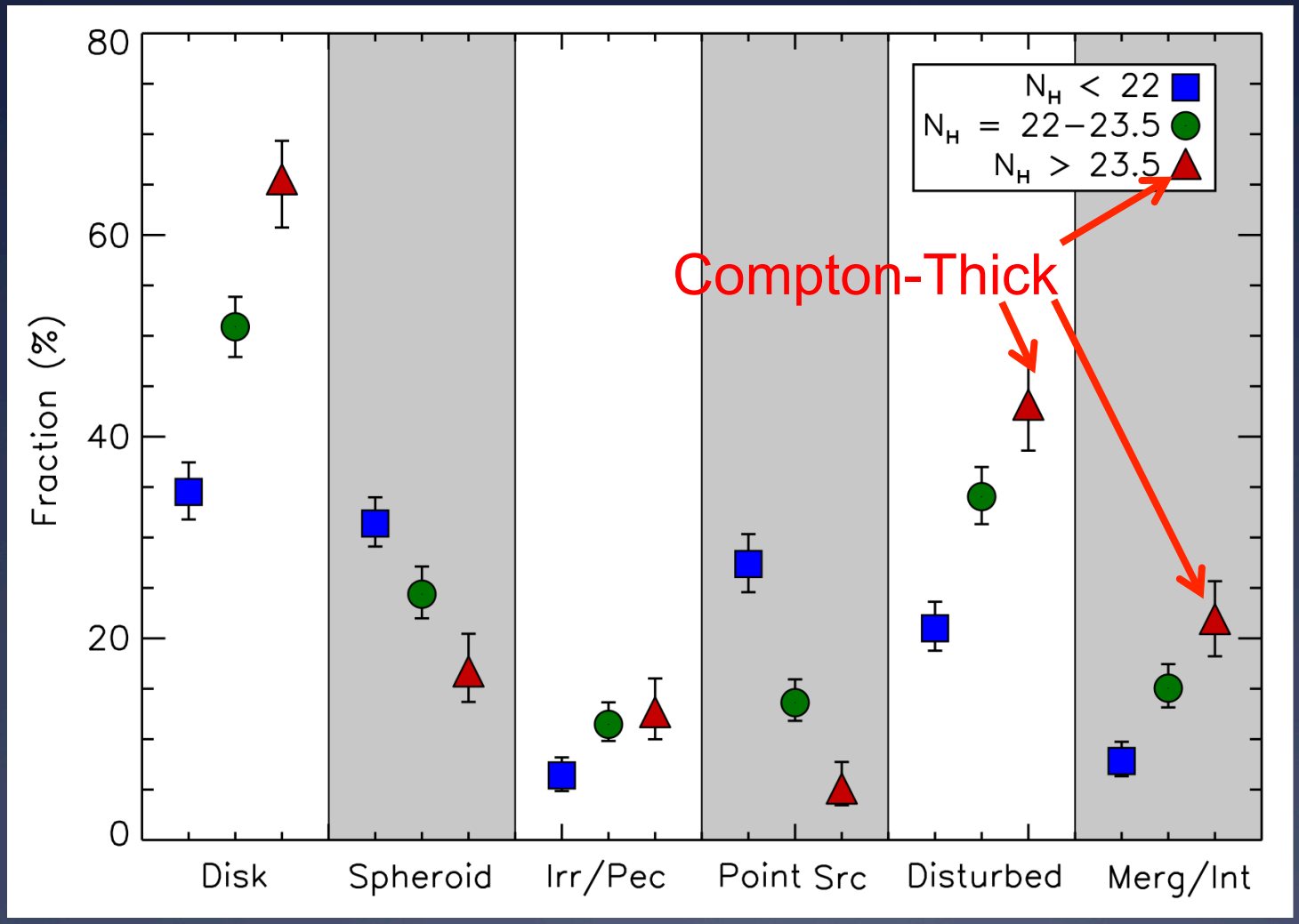


The lack of disturbances and high frequency of disks challenges the standard merger-driven AGN paradigm.

AGN demographics at z ~ 2 look like those at z ~ 1 ➔ **internally driven** BH growth and AGN triggering.

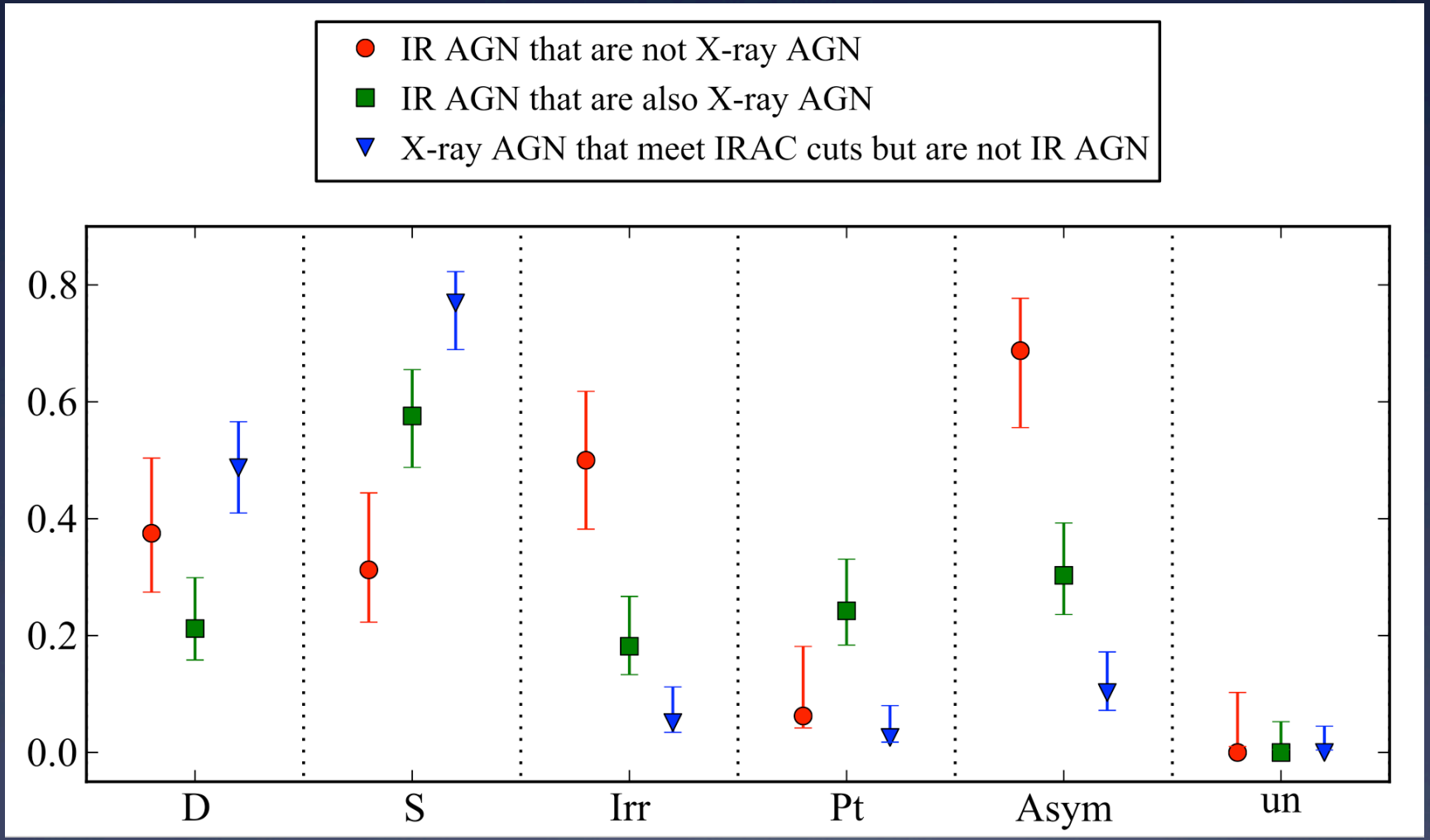
Kocevski+ 2012

More Obscured AGNs Appear More Frequently Disturbed or Merger-Like



Kocevski+13, in prep.

IR Bright Sources without X-rays (more obscured & more luminous) are more Irregular or Asymmetric



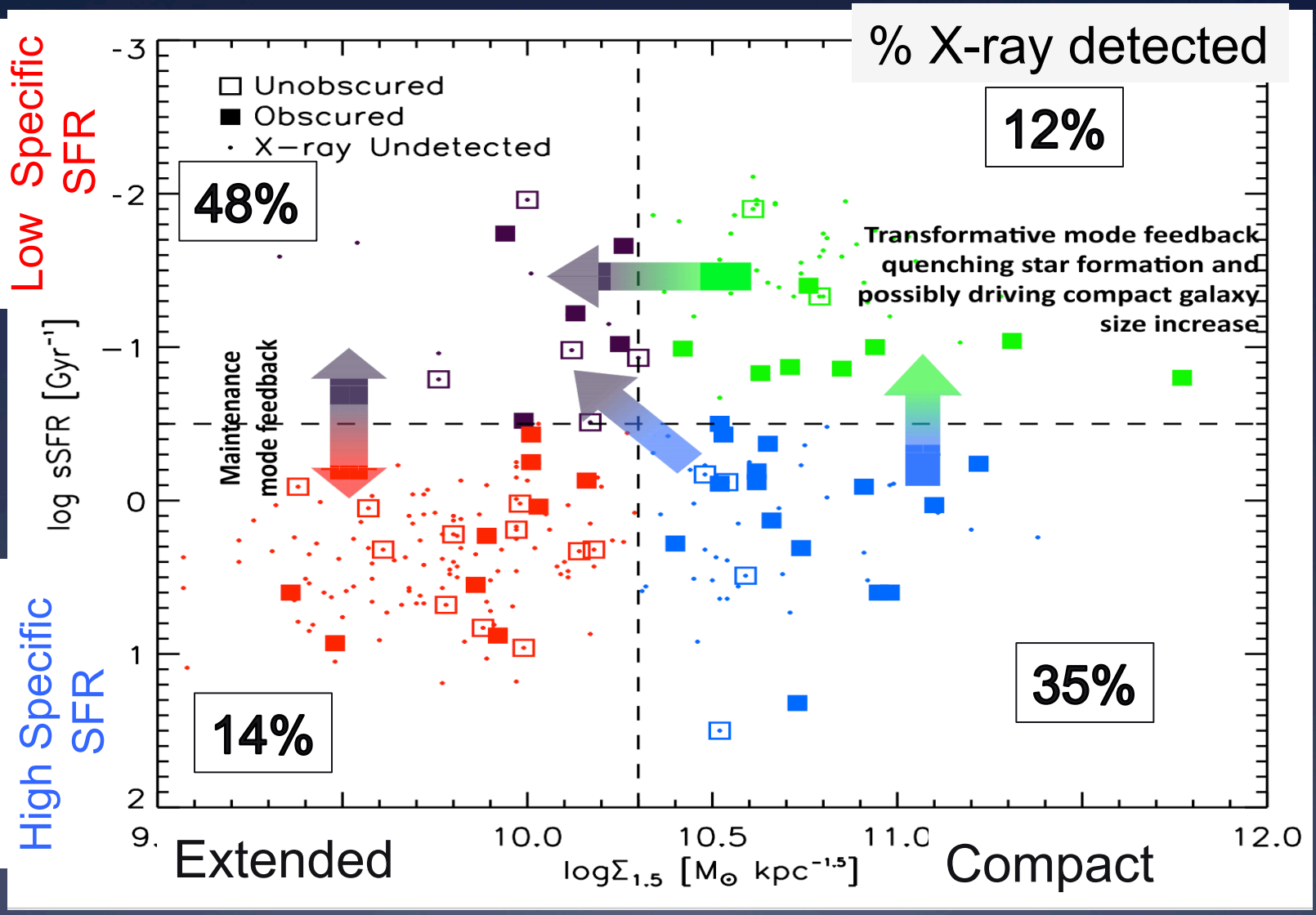
Donley+13, in prep.

Two Modes of Black Hole Accretion in Massive Galaxies at z ~ 2

Sample:

280 galaxies

$>10^{10.5}M_o$



Rangel +13, just submitted

Results & Implications

1. AGN luminosities and X-ray obscuration differ in the 4 quadrants with different specific SFR and compactness

2. Compact galaxies are more AGN luminous and obscured than more extended galaxies

3. The differences suggest two modes of BH growth: obscured luminous AGN are in the “transformative” mode with ~10x BH growth of “maintenance” mode for low AGN luminosity unobscured extended galaxies.

4. The fractions of AGN detected in each quadrant reflects their duty cycle: e.g., compacts with high sSFR and high X-ray detection fractions (35%) have long duty cycles.

Summary for CANDELS

- Last HST observations of 3 year survey were completed last week !
- Range of CANDELS science is incredibly rich and diverse due also to the enormous amount of complementary survey data from X-ray to radio, from imaging to spectra, and from theory models to new analysis tools.
- Mentioned highlights show:
  - Switchover of bulge to disk domination around z ~ 1.5
  - Clumps are redder if more massive or nearer the center; clumps are bluer than disk suggesting episodic SFH
  - More luminous & obscured AGN hosts are more disturbed
  - BH growth may have two modes, one associated with compact galaxies and higher AGN luminosity and obscuration and the other with extended galaxies with lower AGN luminosity and obscuration

Stay tuned to continued results from CANDELS for years to come!

Check the CANDELS website for more information or data:

candels.ucolick.org