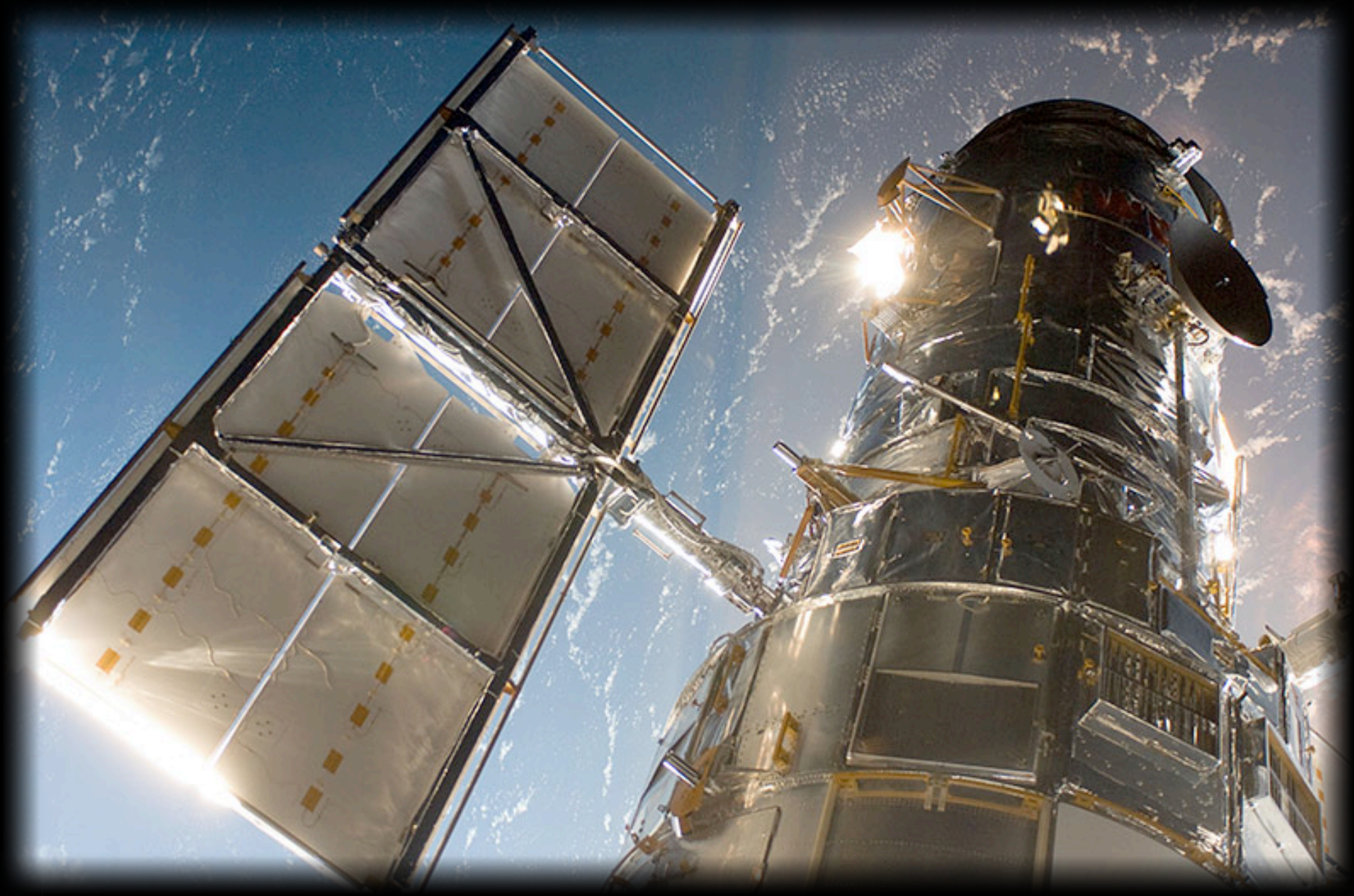
A RESOLVED VIEW ON STELLAR POPULATIONS AT COSMIC NOON



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Reinhard Genzel (MPE)
Arjen van der Wel (MPIA)
Dieter Lutz (MPE)
Yicheng Guo (UMass)
Guillermo Barro (UCSC)
Eric Bell (UMichigan)
Avishai Dekel (Hebrew University)
Sandra Faber (UCSC)
Henry Ferguson (STScI)
Mauro Giavalisco (UMass)
Norman Grogin (STScI)
Nimish Hathi (Carnegie)
Kuang-Han Huang (Johns Hopkins)
Dale Kocevski (UCSC)
Anton Koekemoer (STScI)
David Koo (UCSC)
Benjamin Magnelli (MPE)
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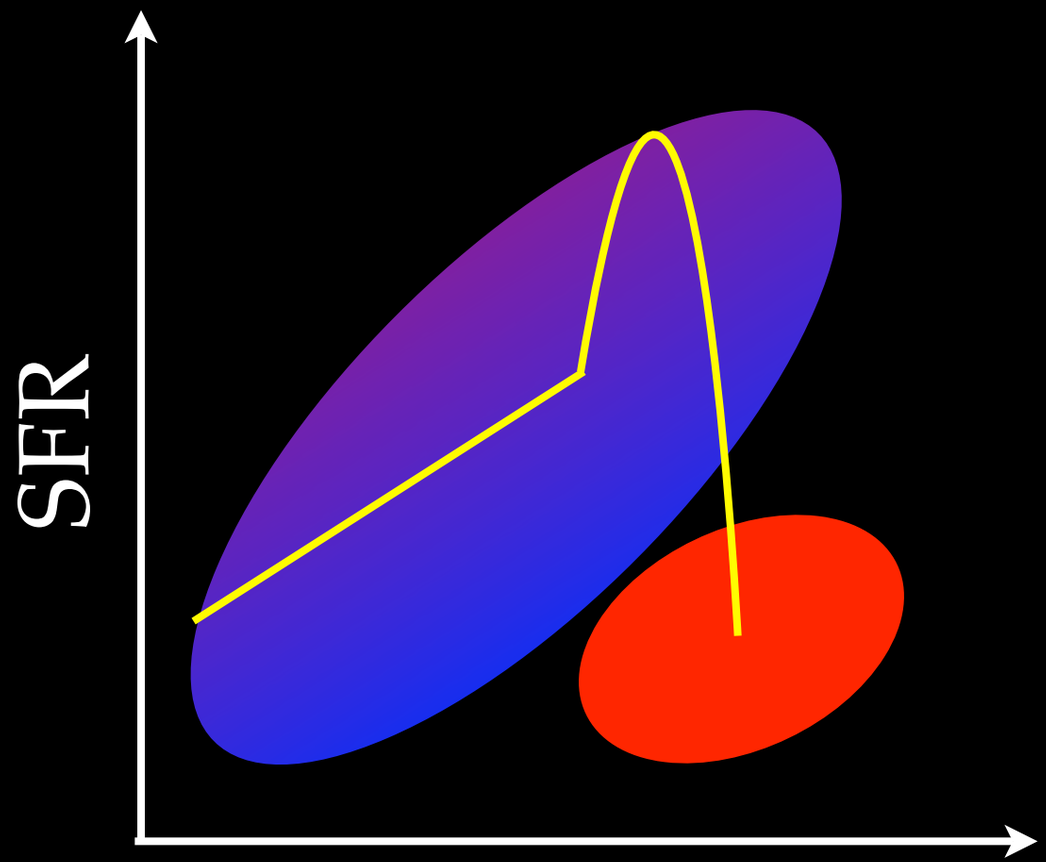
Jennifer Lotz (STScI)
Elizabeth McGrath (UCSC)
Jeffrey Newman (UPittsburgh)
David Rosario (MPE)
Amelie Saintonge (MPE)
Linda Tacconi (MPE)
Benjamin Weiner (UArizona)
Antonio Cava (Madrid)
Paola Popesso (MPE)
Francesca Pozzi (Bologna)
Laurie Riguccini (Bologna)
Giulia Rodighiero (Padova)

CANDELS & PEP

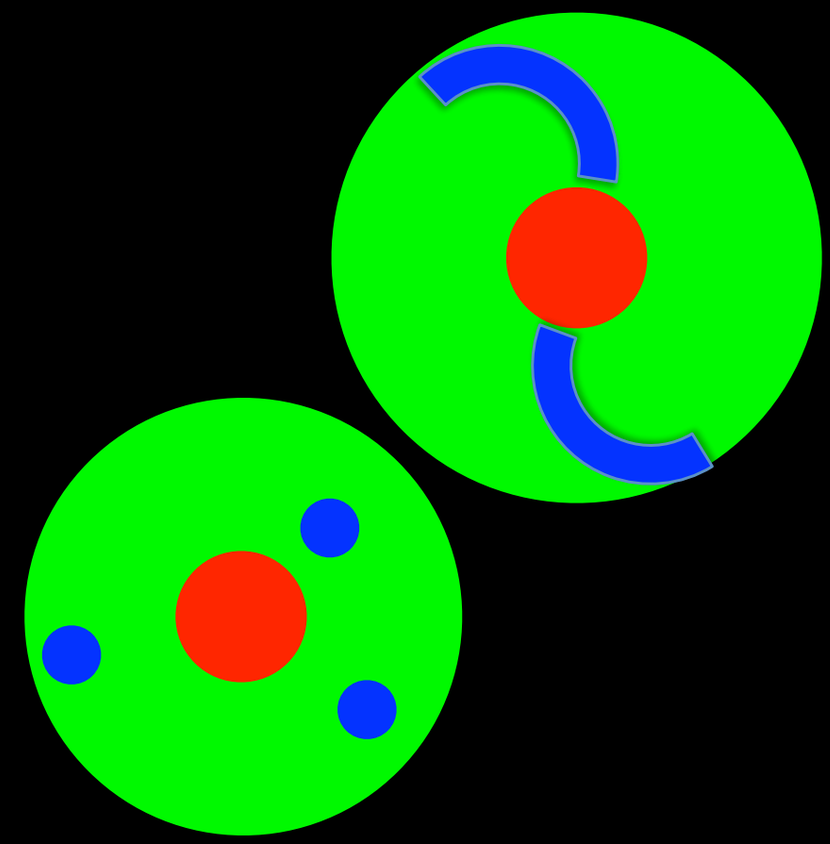
THE RELATION BETWEEN STRUCTURE AND STELLAR POPULATIONS: GLOBALLY & LOCALLY



Galaxy properties across the SFR-Mass diagram:

- normal SFing galaxies
- high-SFR outliers
- quenched galaxies

Wuyts et al. 2011, ApJ, 742, 96



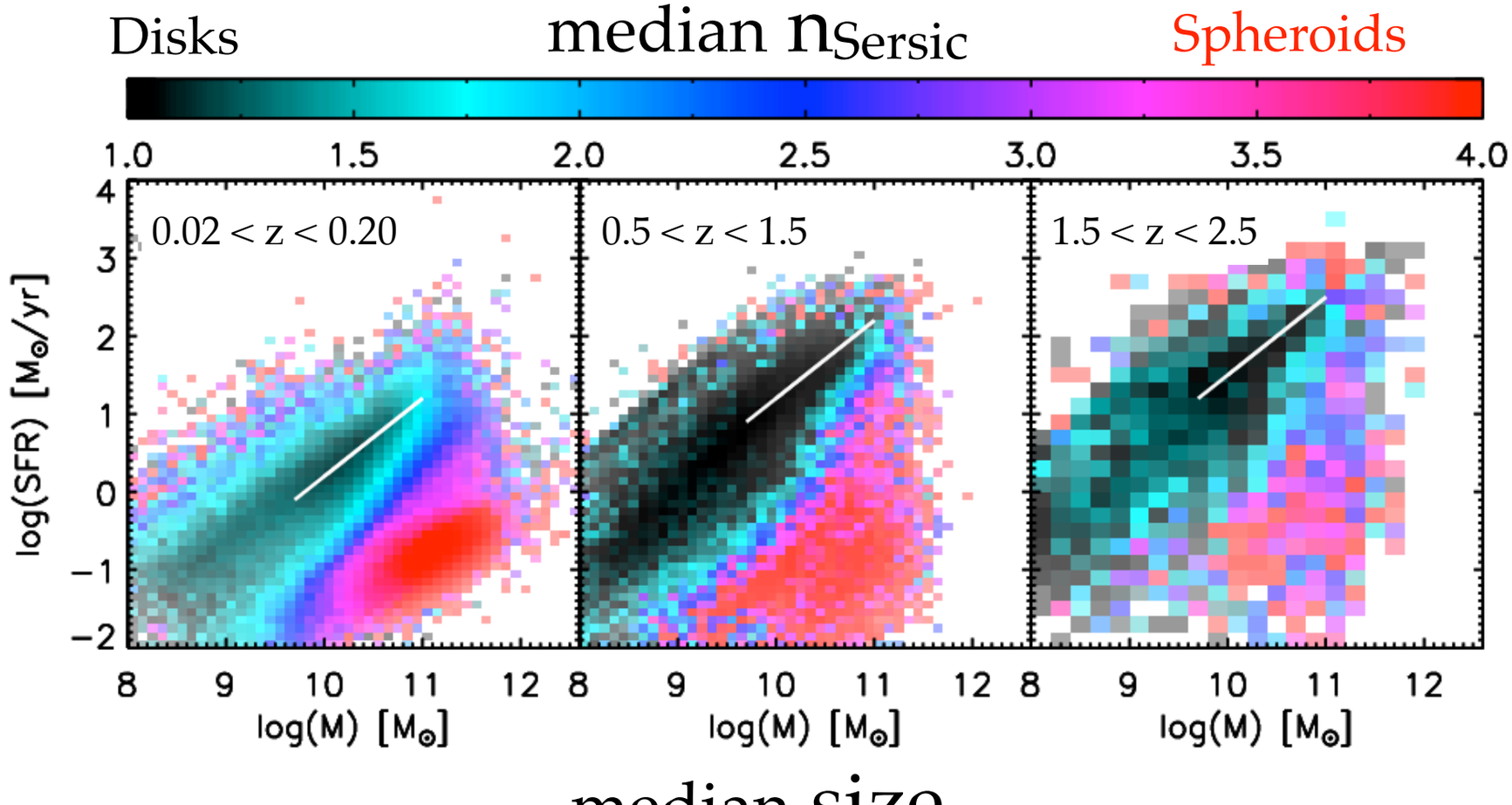
Light ≠ Mass

Smoother stellar mass maps

Short-lived SFing clumps

Wuyts et al. 2012, ApJ, 753, 114

- Departure from main sequence goes hand in hand with morphological transition

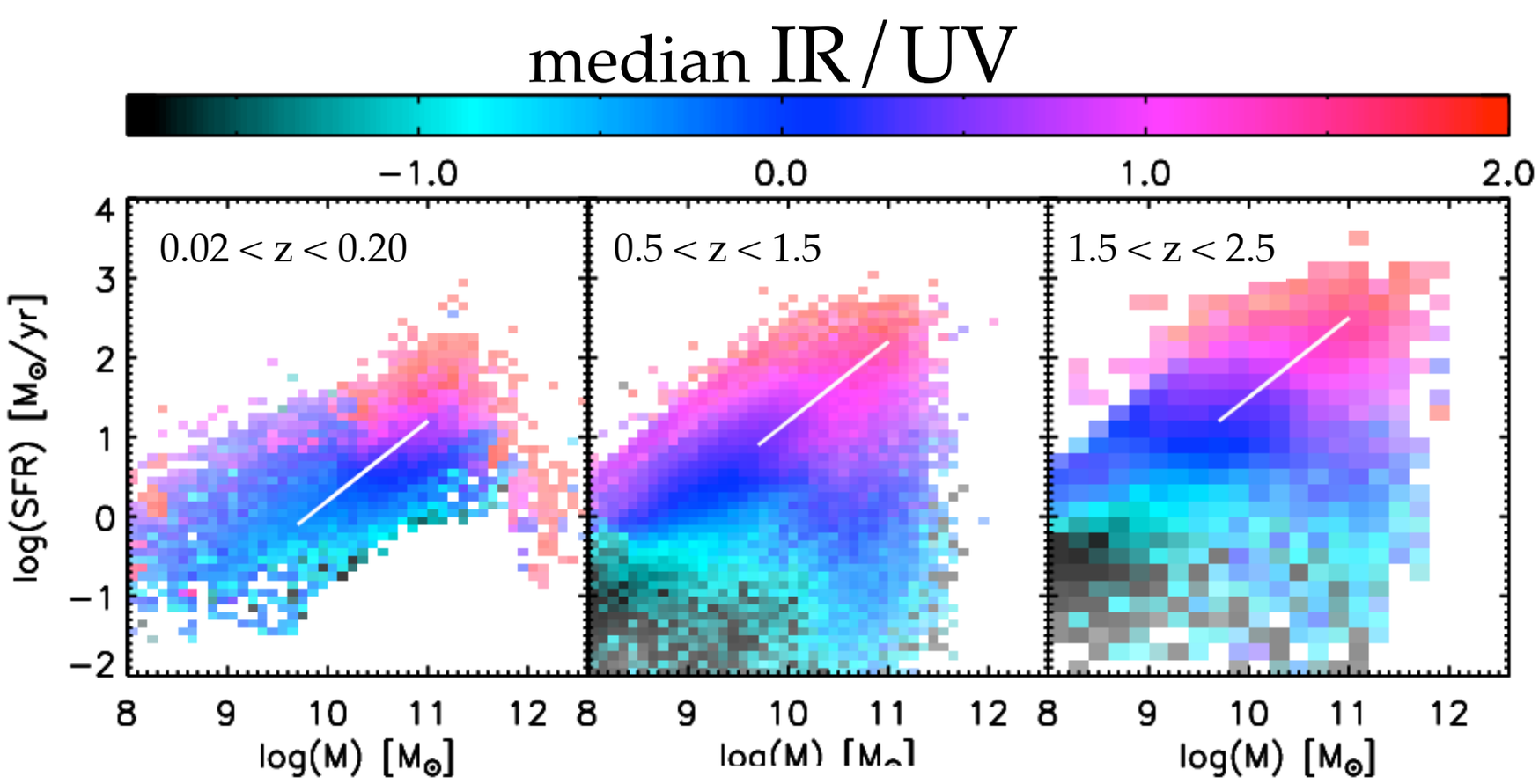


- Main sequence galaxies are the largest at a given mass

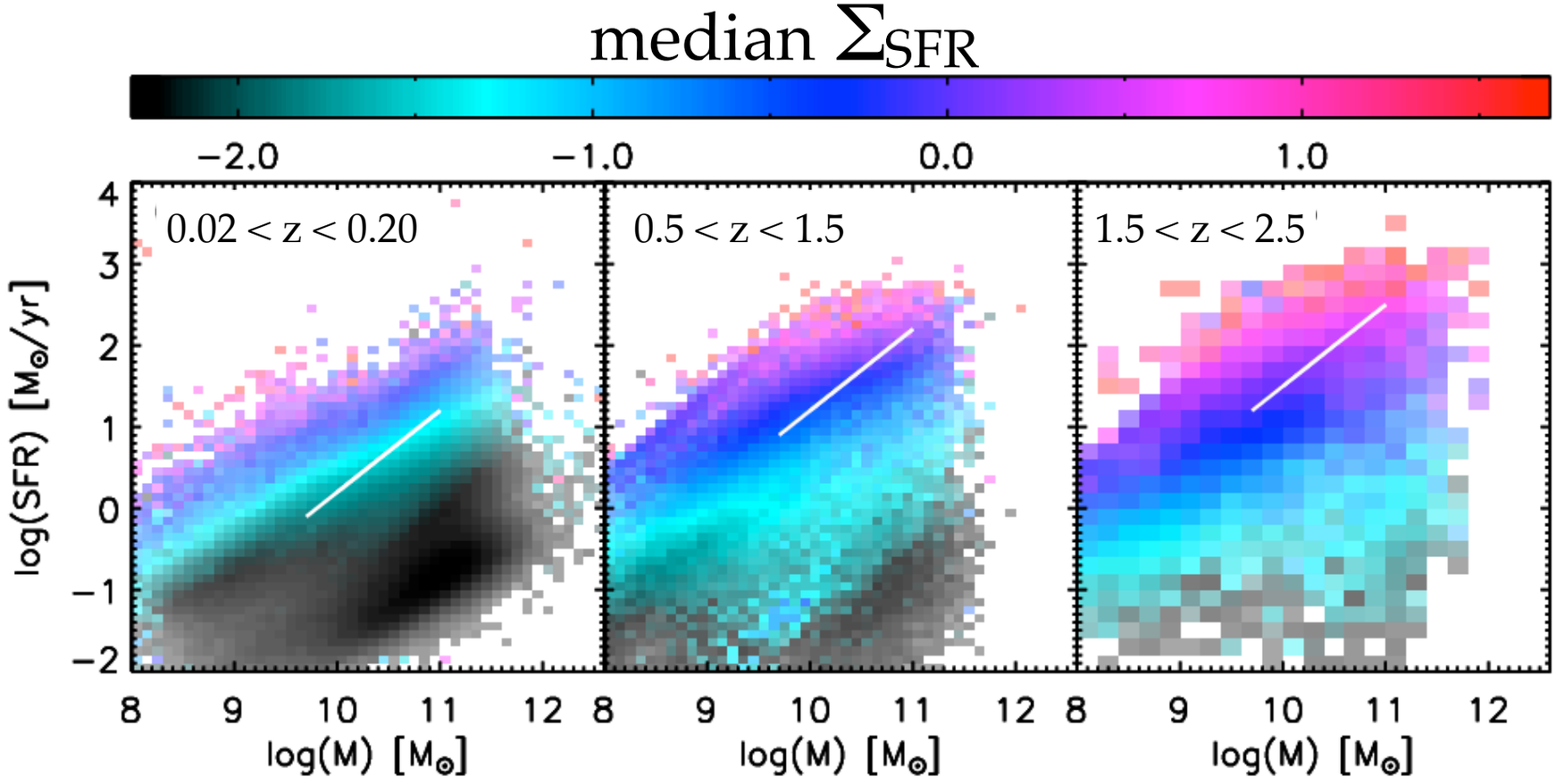
Wuyts et al. 2011b

see also Kauffmann et al. 2003; Brinchmann et al. 2004; Schiminovich et al. 2007; Wake et al. 2012 @ z ~ 0.1
Toft et al. 2009; Williams et al. 2009; Szomoru et al. 2011; Bell et al. 2011; Elbaz et al. 2011 @ intermediate & high z

- Obscuration increases along MS, and at a given mass across MS



- High-SFR outliers not just upscaled MS galaxies; more SFR per unit area
  → intenser radiation field, higher ionization parameter, ...



Wuyts et al. 2011b

see also Kauffmann et al. 2003; Brinchmann et al. 2004; Schiminovich et al. 2007; Wake et al. 2012 @ z ~ 0.1
Toft et al. 2009; Williams et al. 2009; Elbaz et al. 2011; Bell et al. 2012; Whitaker et al. 2012 @ intermediate & high z

MORE GALAXY PROPERTIES VARYING RELATIVE TO THE MAIN SEQUENCE OF STAR FORMATION

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- Dust conditions:

  PAH strength ($L_{8\mu m}/L_{IR}$)

  Elbaz et al. 2011; Nordon et al. 2012

  Dust temperature

  Magnelli et al. 2012b

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  Daddi et al. 2010; Genzel et al. 2010;
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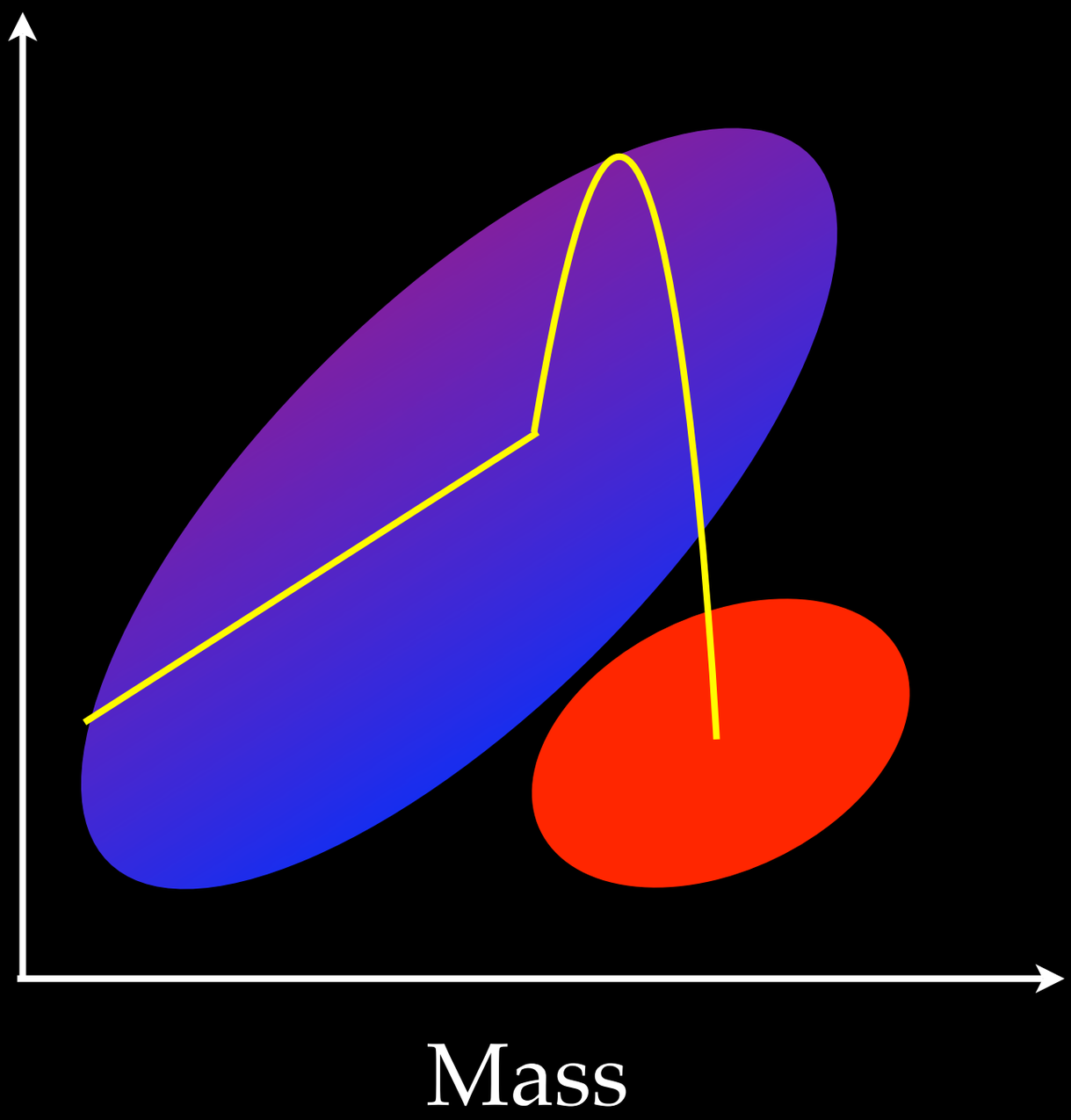
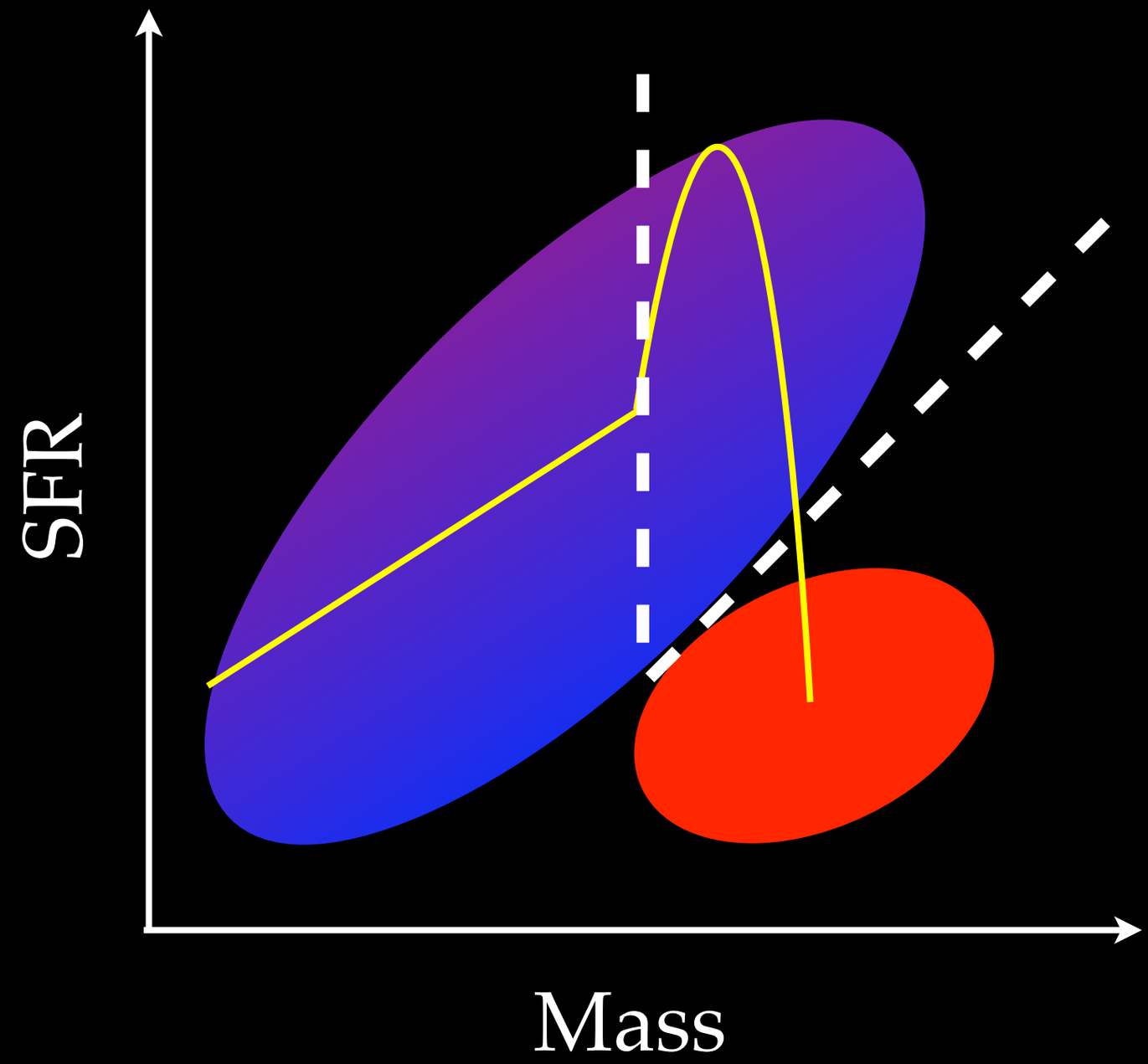
  Daddi et al. 2010; Genzel et al. 2010;
  Saintonge et al. 2012; Magnelli et al. 2012b;
  Martig et al. 2009

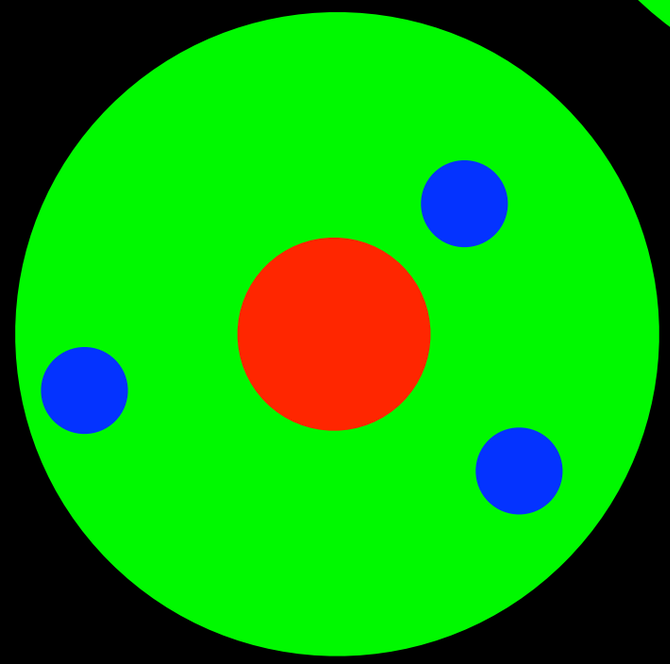
- Visual classifications of (ir)regular morph

  Kartaltepe et al. 2011

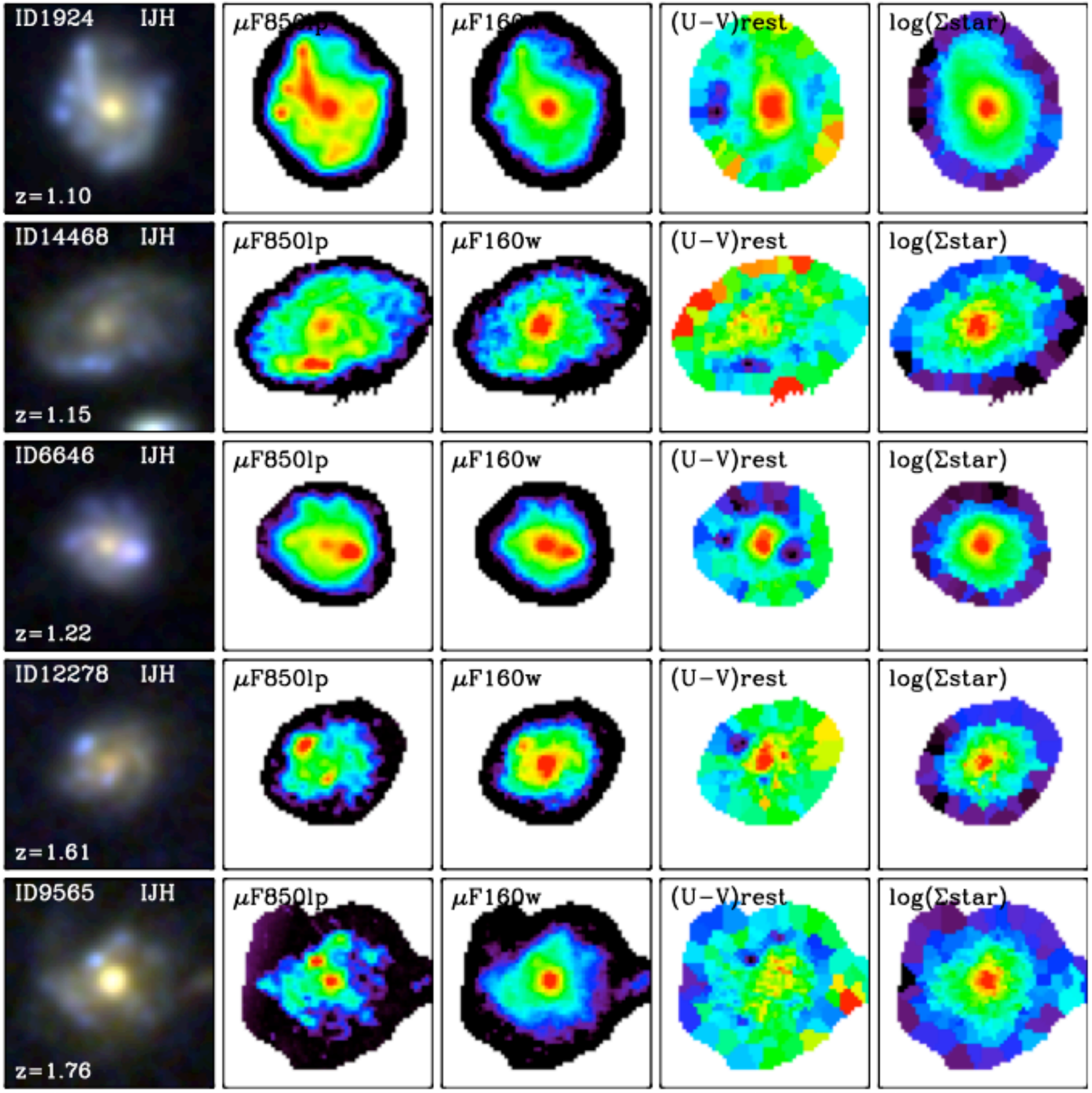

SFR
Mass



- $\log(M) > 10$ & $\log(SFR/M) > \log(1/t_H)$
- 323 SFGs @ $0.5 < z < 1.5$
  326 SFGs @ $1.5 < z < 2.5$



- ERS + CANDELS-Deep in GOODS-S
  Resolved SED modeling accounting for integrated photometric constraints
  UBVizYJHK$_s$[3.6][4.5][5.8][8.0]


ID1924 IJH
z=1.10
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID14468 IJH
z=1.15
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID6646 IJH
z=1.22
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID12278 IJH
z=1.61
μF850lp
μF160w
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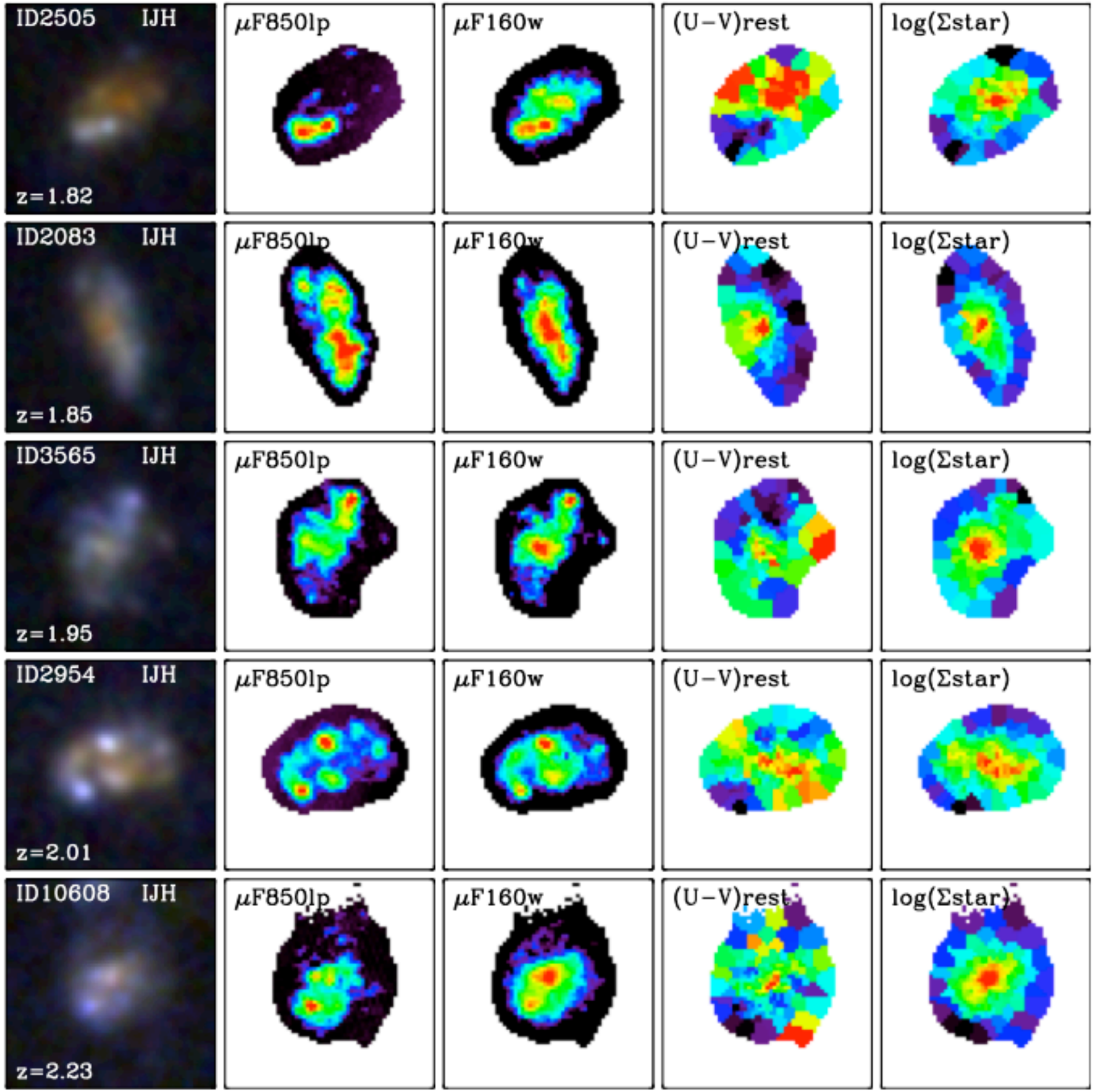
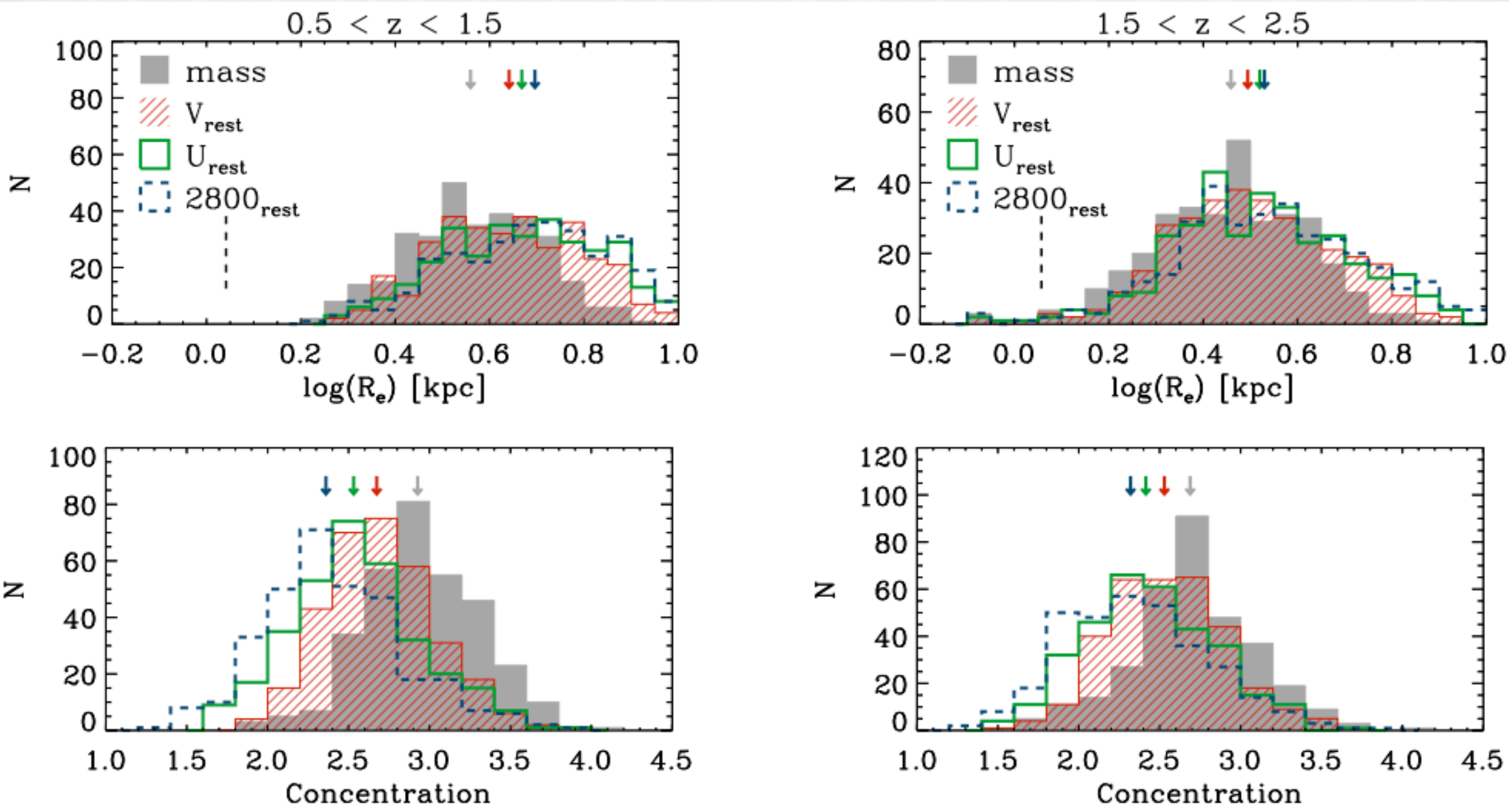
log(Σstar)
ID9565 IJH
z=1.76
μF850lp
μF160w
(U−V)rest
log(Σstar)


ID2505 IJH
z=1.82
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID2083 IJH
z=1.85
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID3565 IJH
z=1.95
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID2954 IJH
z=2.01
μF850lp
μF160w
(U−V)rest
log(Σstar)
ID10608 IJH
z=2.23
μF850lp
μF160w
(U−V)rest
log(Σstar)

GALAXY STRUCTURE IN LIGHT AND MASS

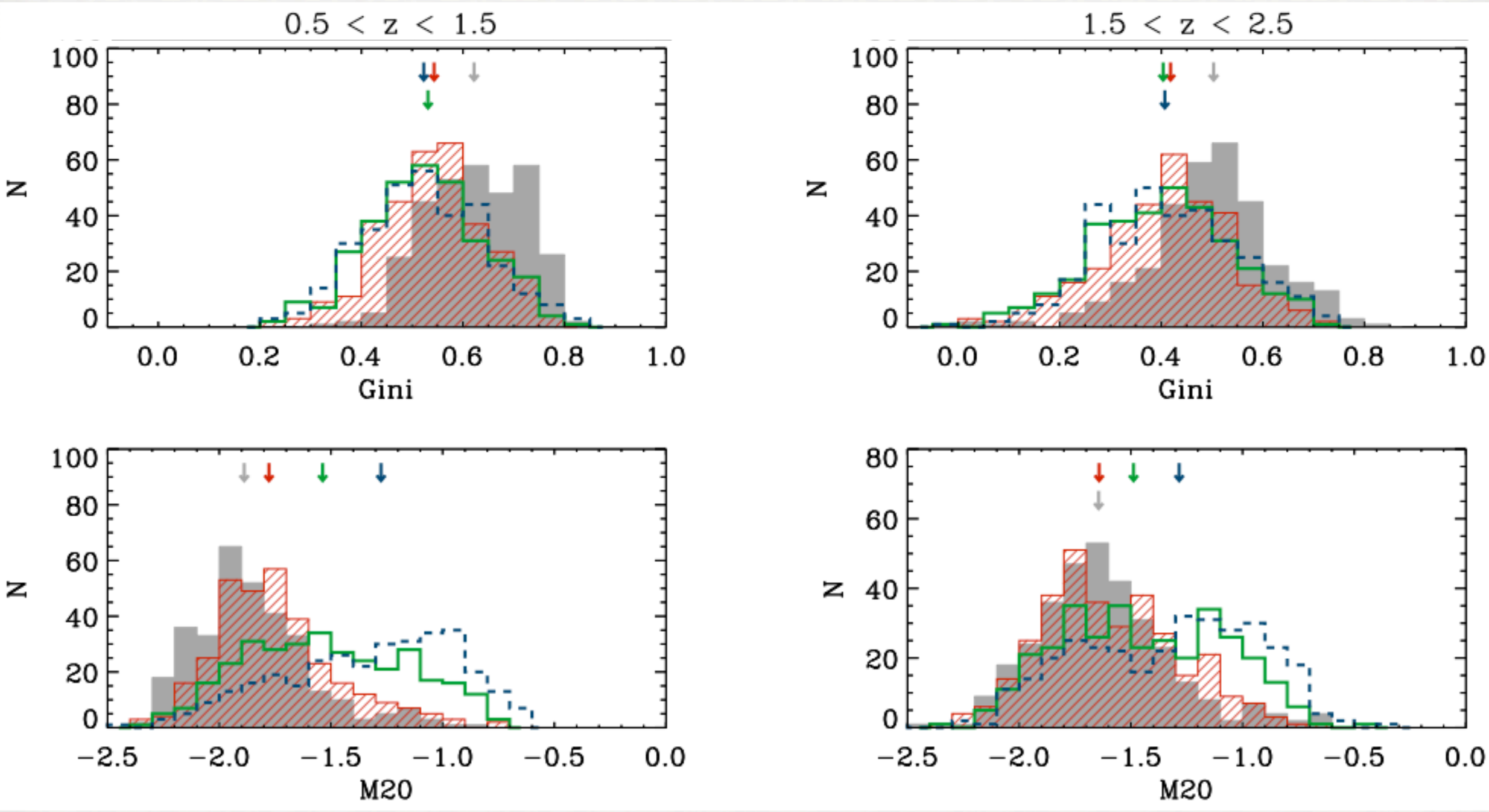
Star-forming galaxies, at low and high z, are smaller and more concentrated in mass than in light.



Wuyts et al. 2012

GALAXY STRUCTURE IN LIGHT AND MASS

Star-forming galaxies, at low and high z, are more concentrated and smoother in mass than in light.

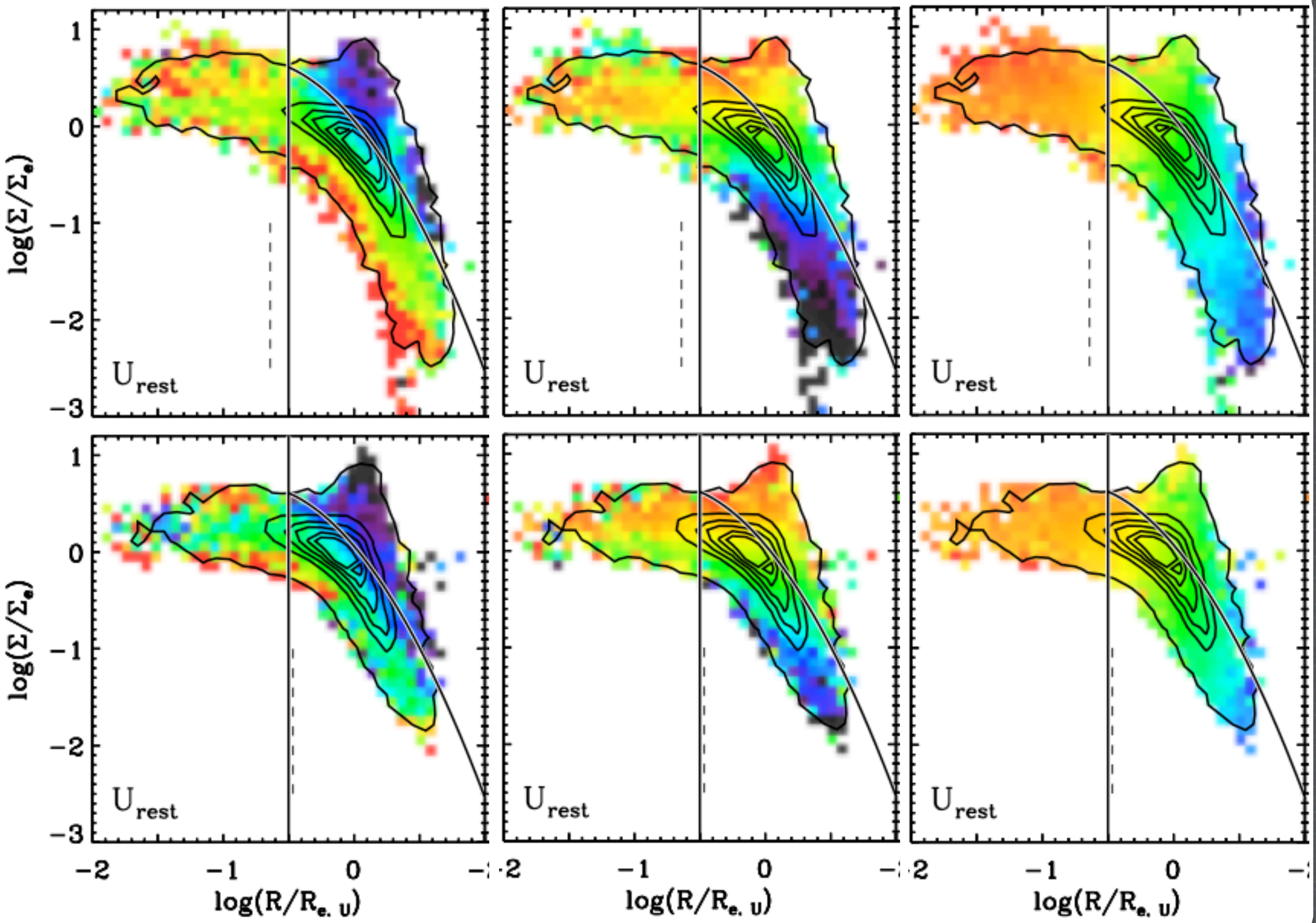


Wuyts et al. 2012

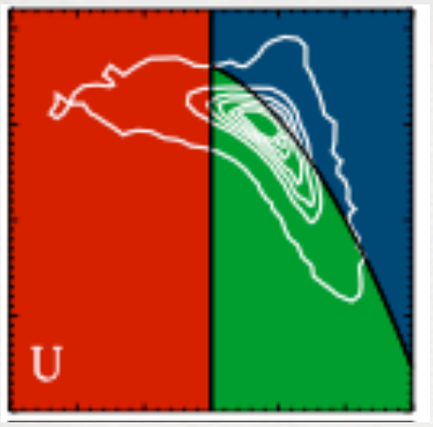
Color-coding: (U-V)rest Σ_{SFR} $\Sigma_{stellar\ mass}$

z ~ 1

z ~ 2



Wuyts et al. 2012 (see also Förster Schreiber et al. 2011; Guo et al. 2011)



CONTRIBUTION OF CLUMPS TO THE TOTAL MASS, SFR, AND LUMINOSITY IN HIGH-REDSHIFT STAR-FORMING GALAXIES

Property used for clump identification[a]	$f_{\rm clumpy}$[b]	$\Sigma_{\rm clumps}/\Sigma_{\rm all\ SFGs}$[c]					$\Sigma_{\rm clumps}/\Sigma_{\rm clumpy\ SFGs}$[d]				
		L_{2800}	L_U	L_V	mass	SFR	L_{2800}	L_U	L_V	mass	SFR
$0.5 < z < 1.5$											
$2800_{\rm rest}$	0.79	0.17	0.14	0.10	0.05	0.15	0.20	0.16	0.12	0.06	0.17
$U_{\rm rest}$	0.57	0.12	0.09	0.07	0.03	0.09	0.19	0.15	0.11	0.06	0.14
$V_{\rm rest}$	0.27	0.05	0.04	0.03	0.02	0.04	0.16	0.14	0.12	0.07	0.12
mass	0.15	0.01	0.01	0.01	0.02	0.01	0.08	0.08	0.09	0.15	0.05
$1.5 < z < 2.5$											
$2800_{\rm rest}$	0.74	0.19	0.17	0.13	0.07	0.18	0.25	0.22	0.17	0.09	0.22
$U_{\rm rest}$	0.60	0.16	0.13	0.10	0.05	0.13	0.24	0.21	0.16	0.09	0.19
$V_{\rm rest}$	0.42	0.11	0.09	0.07	0.04	0.09	0.22	0.20	0.17	0.12	0.19
mass	0.41	0.04	0.04	0.04	0.07	0.04	0.10	0.10	0.11	0.16	0.09

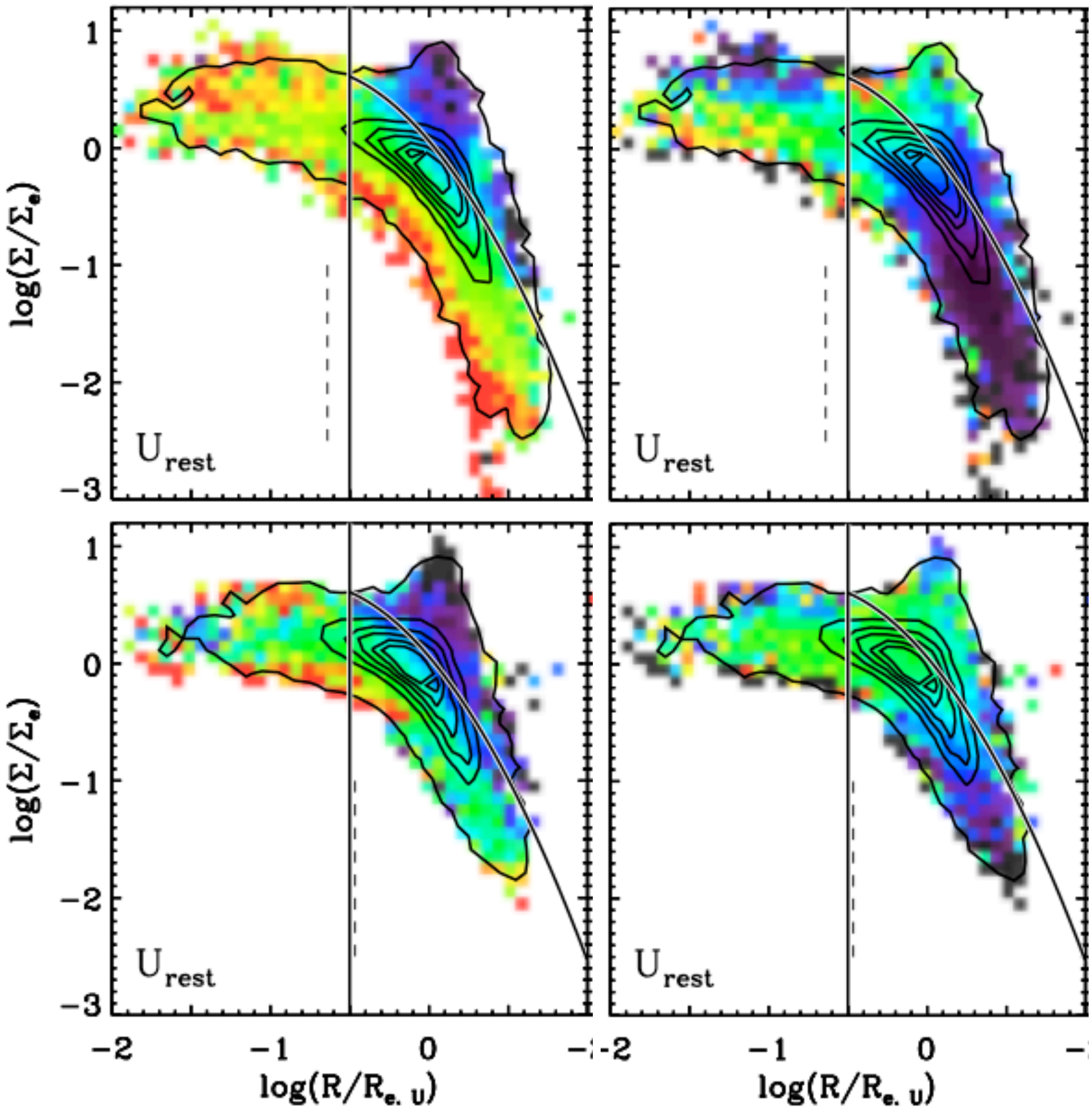
Fraction of SFGs that are ‘clumpy’ is a decreasing function of wavelength.

Off-center ‘clumps’ contribute up to ~20% of the total SFR in distant SFGs, but only 2-7% to the integrated stellar mass.

Color-coding: (U-V)rest A_V

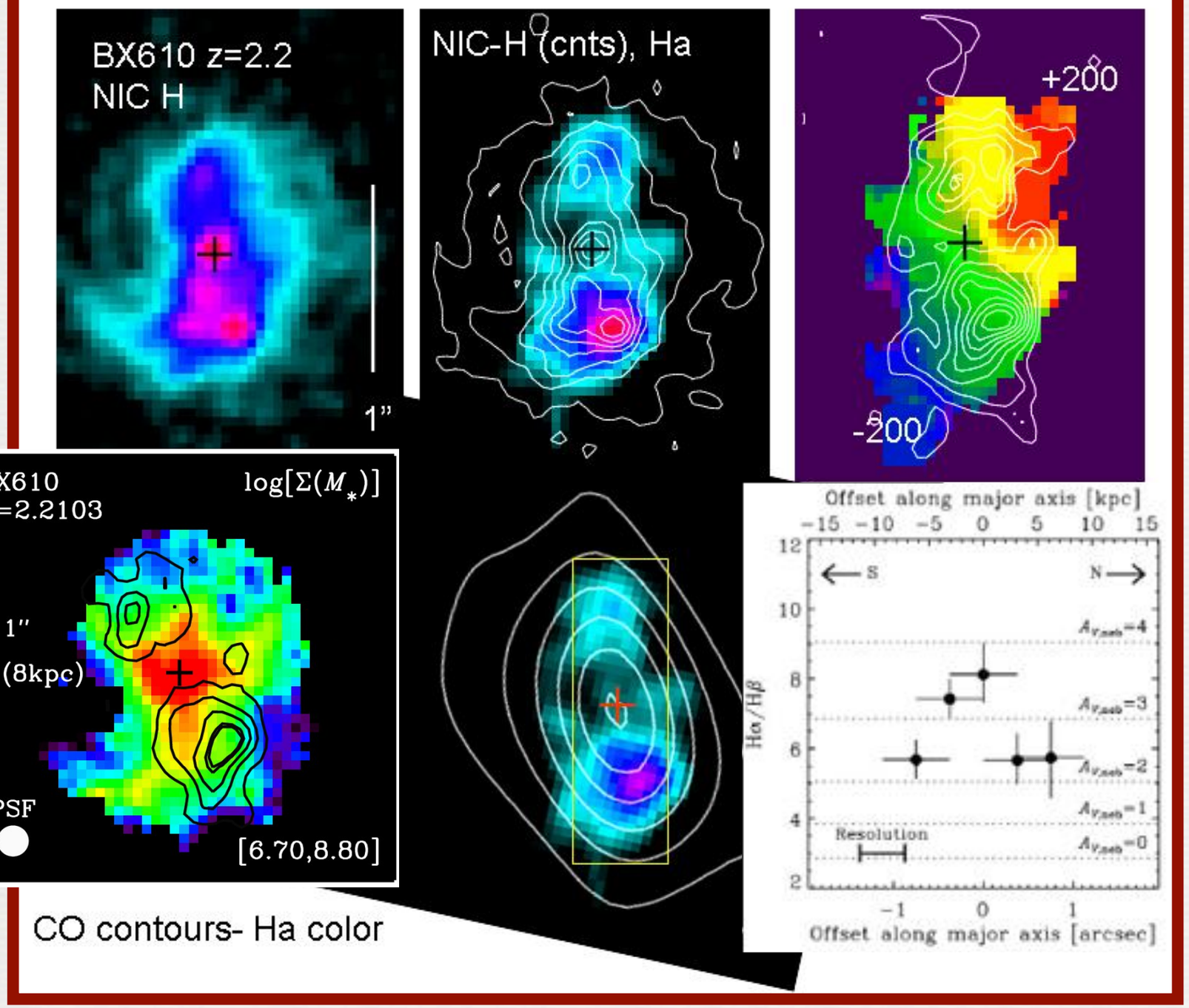
z ~ 1

z ~ 2



Wuyts et al. 2012 (see also Förster Schreiber et al. 2011; Guo et al. 2011)

RADIAL EXTINCTION GRADIENTS: BX610 @ Z=2.2 AS CASE EXAMPLE

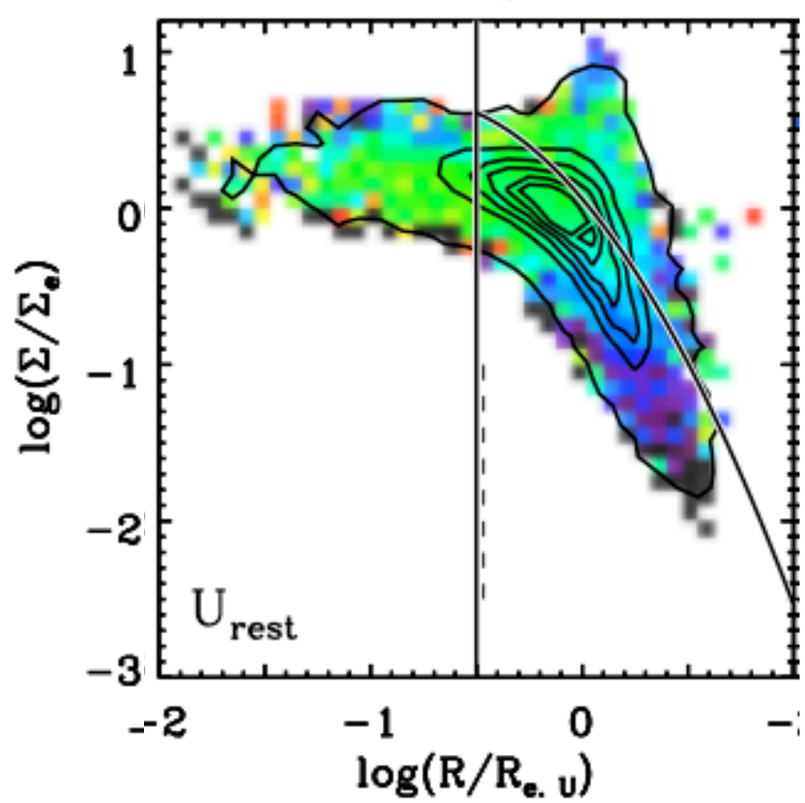


NMFS et al. (2006/20009/2011a,b); Tacconi et al. (2010; in prep); Genzel et al. (2008/2011b)

Case example

Co-added profile

Av



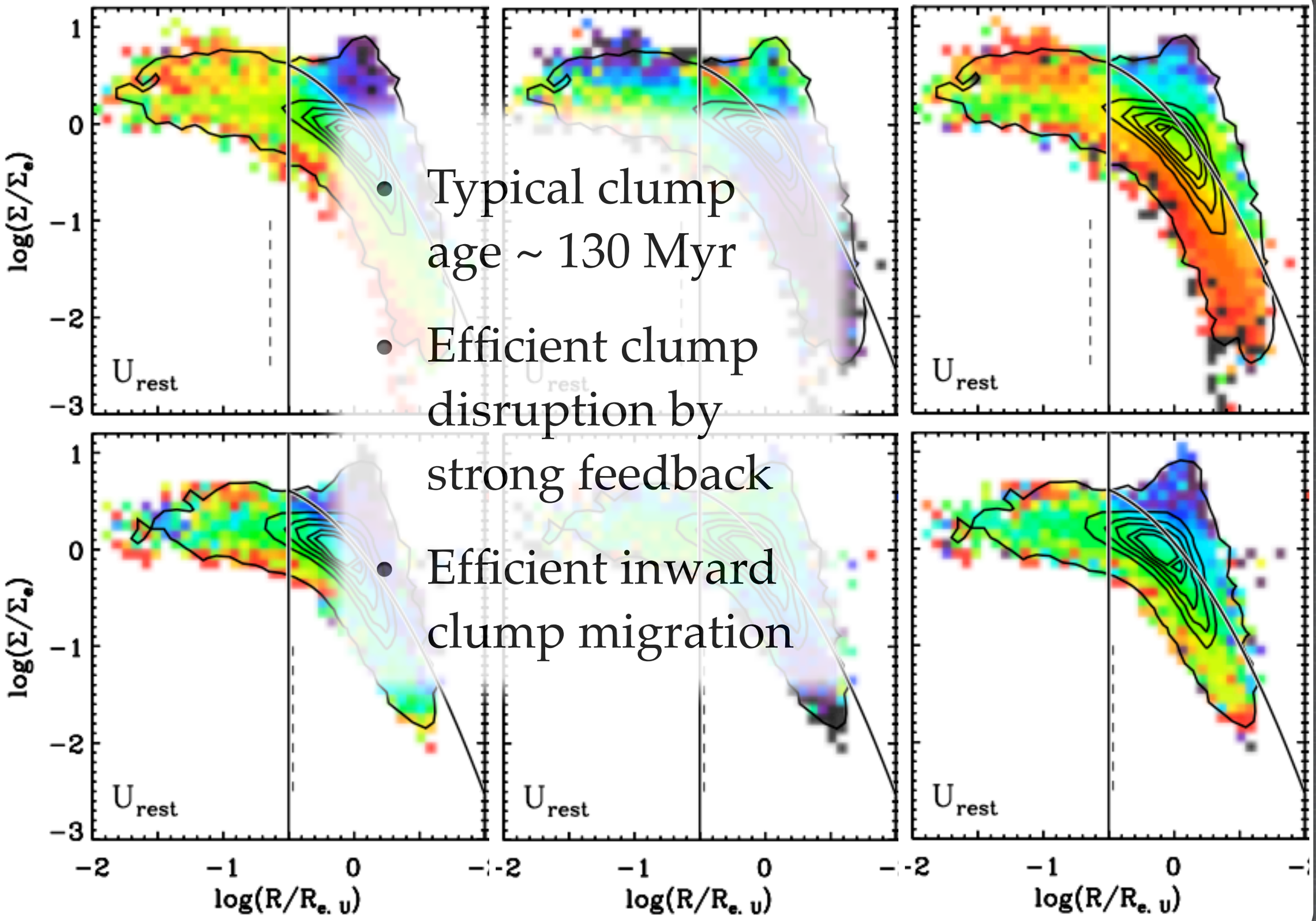
Wuyts et al. 2012

Color-coding: (U-V)rest A_V Age

z ~ 1

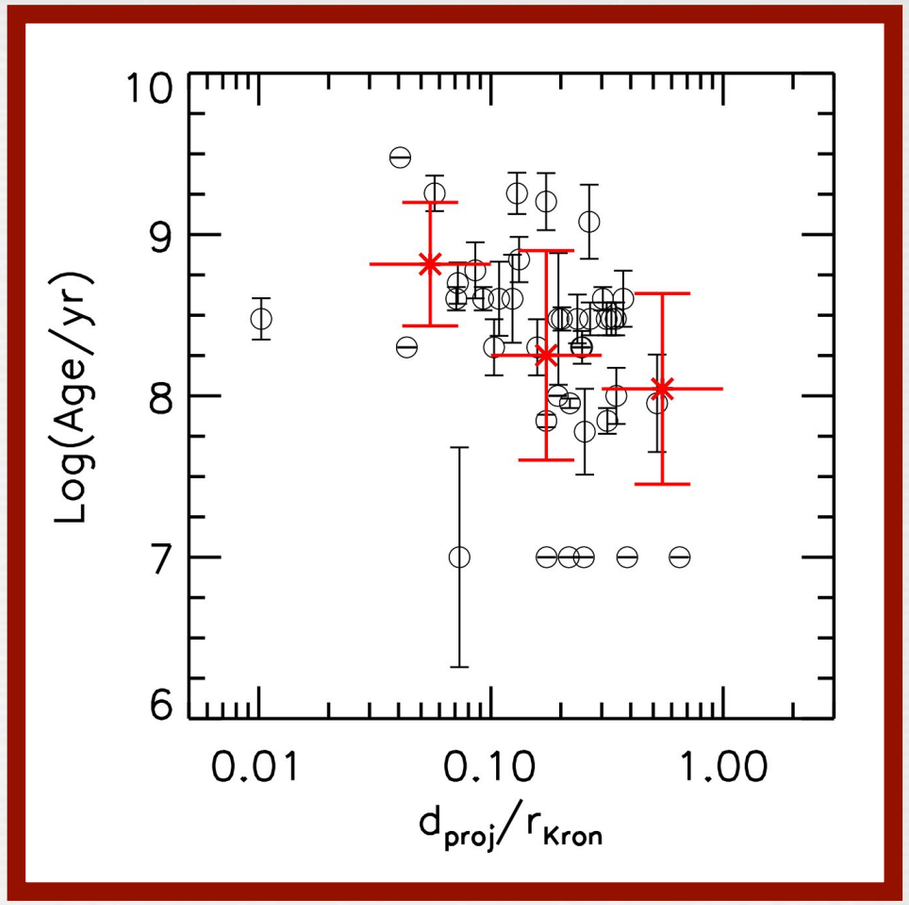
z ~ 2

- Typical clump age ~ 130 Myr
- Efficient clump disruption by strong feedback
- Efficient inward clump migration

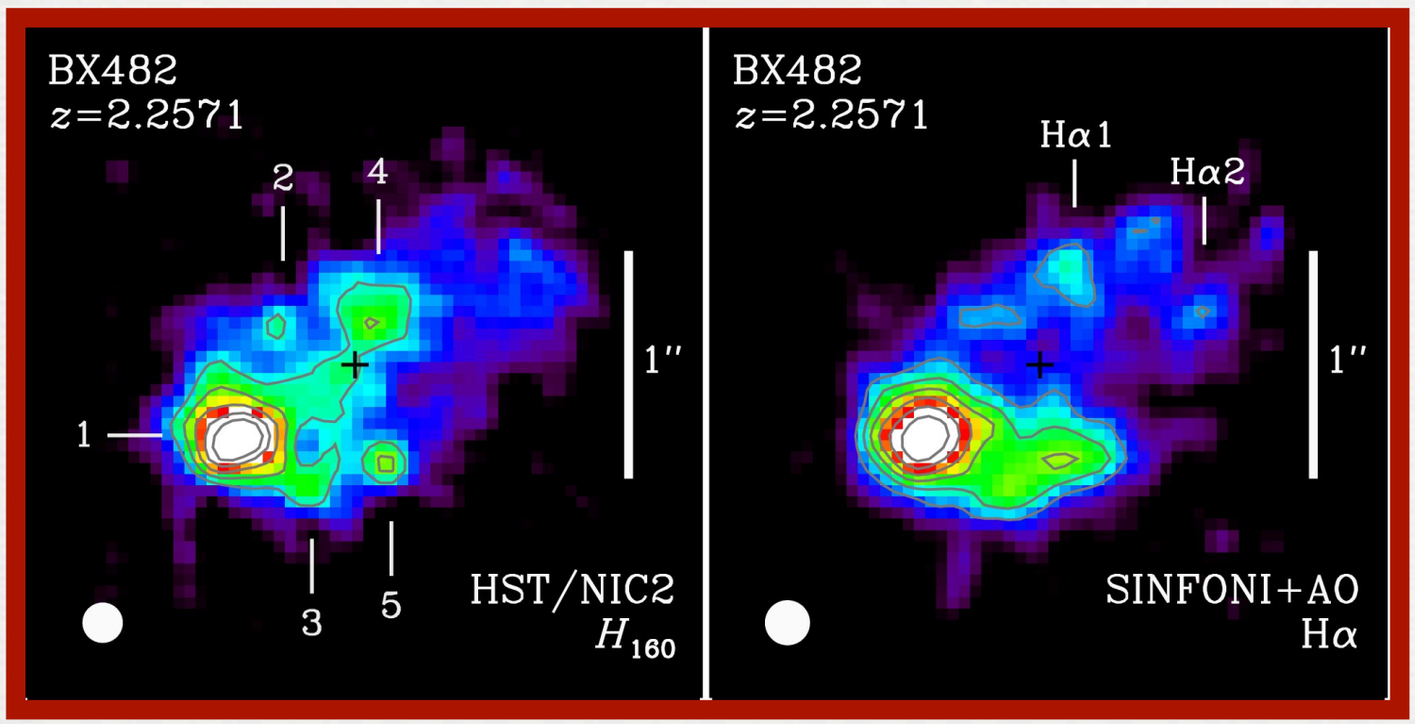


Wuyts et al. 2012 (see also Förster Schreiber et al. 2011; Guo et al. 2011)

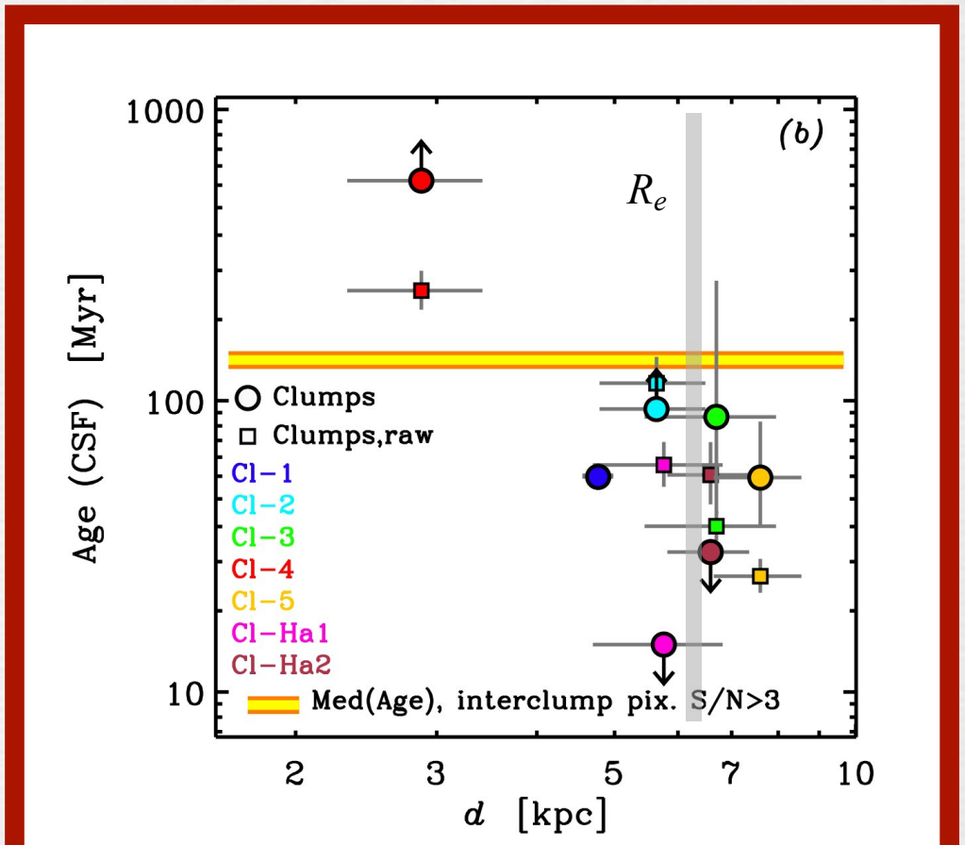
RADIAL TRENDS IN CLUMP EVOLUTIONARY STAGE



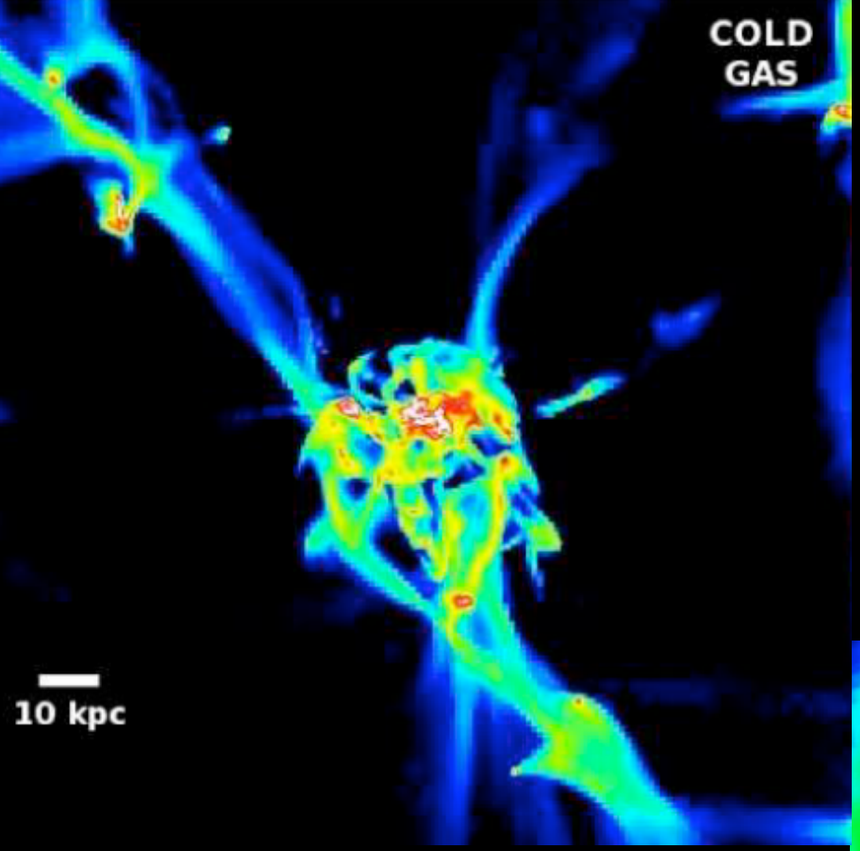
Guo et al. 2011



Förster Schreiber et al. 2011



SIMULATIONS OF CLUMPY DISKS

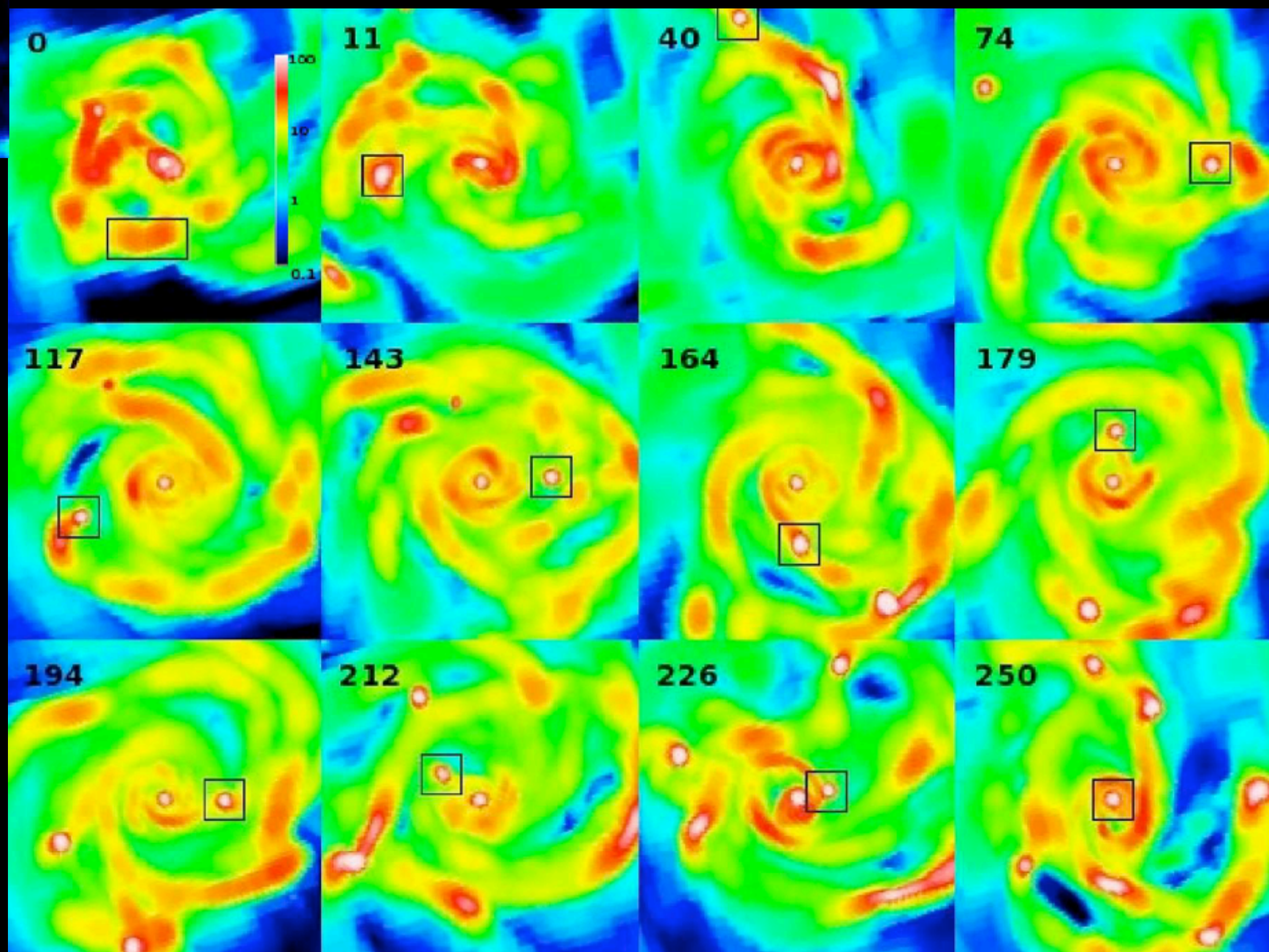


- Typical ages of clumps 100 - 200 Myr, consistent with Wuyts et al. 2012

- 36-76% more stars in bulge than in disk component

- $f_{gas,\ simulated} \sim 0.04 - 0.18$ ↔ observed $f_{gas} \sim 0.45$ by Tacconi et al. 2010

Ceverino et al. 2010, 2012



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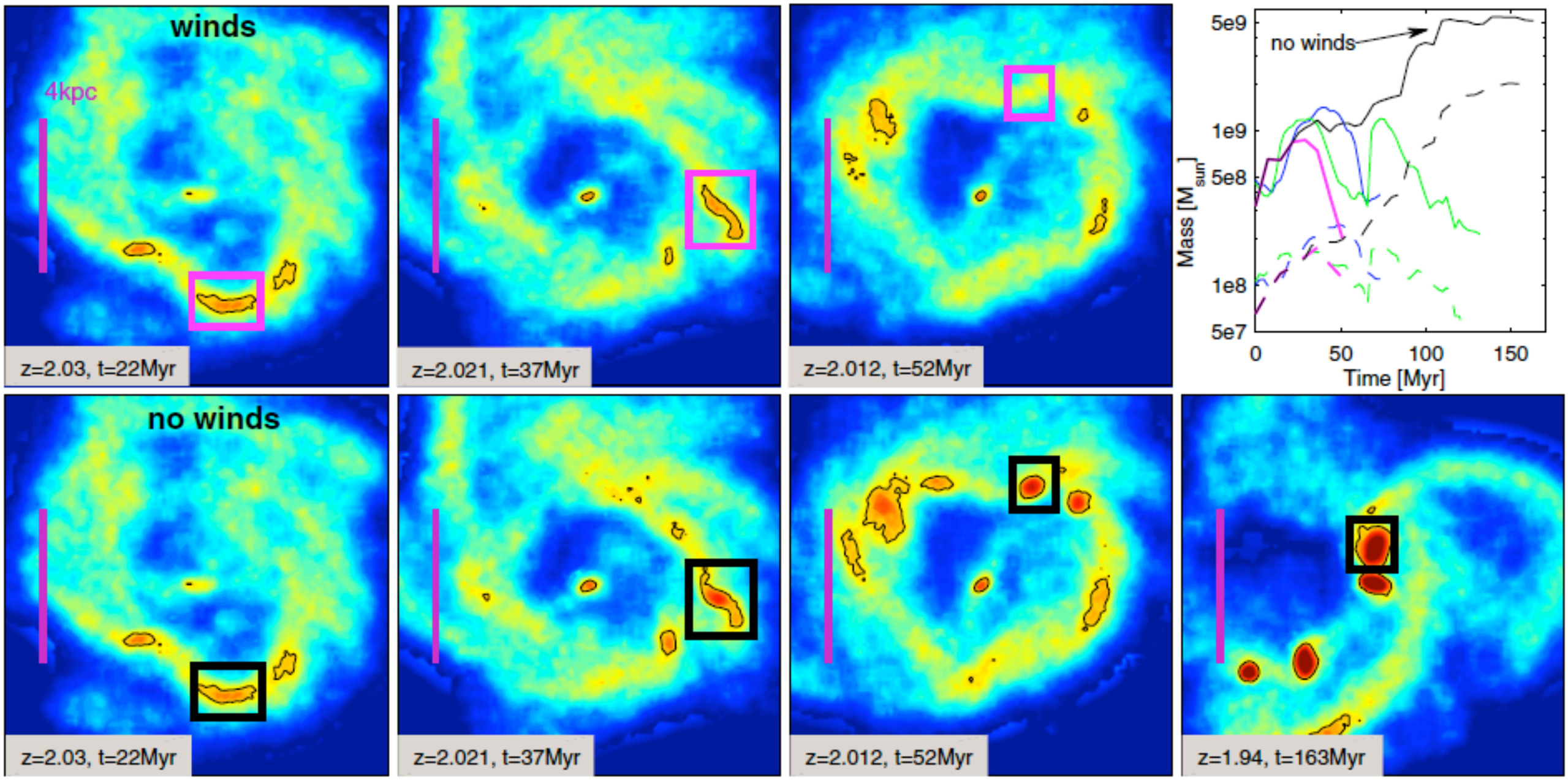


Clump lifetimes 10 - 100 Myr

Typical f_{gas} ~ 0.43

Genel et al. 2012

Standard/All Feedback

Stars

Observed Resolution

No Radiation Pressure

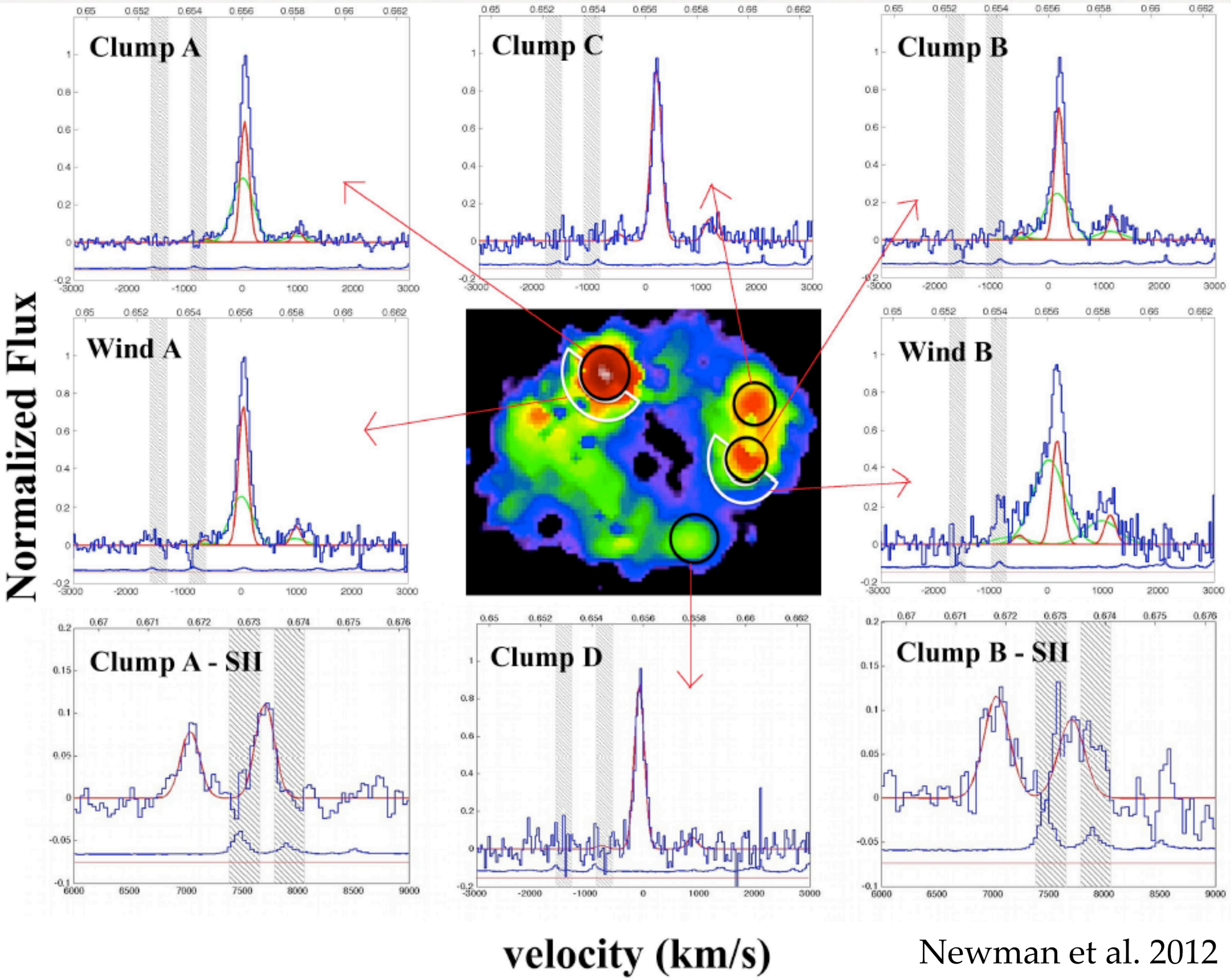
Observed Resolution

Gas

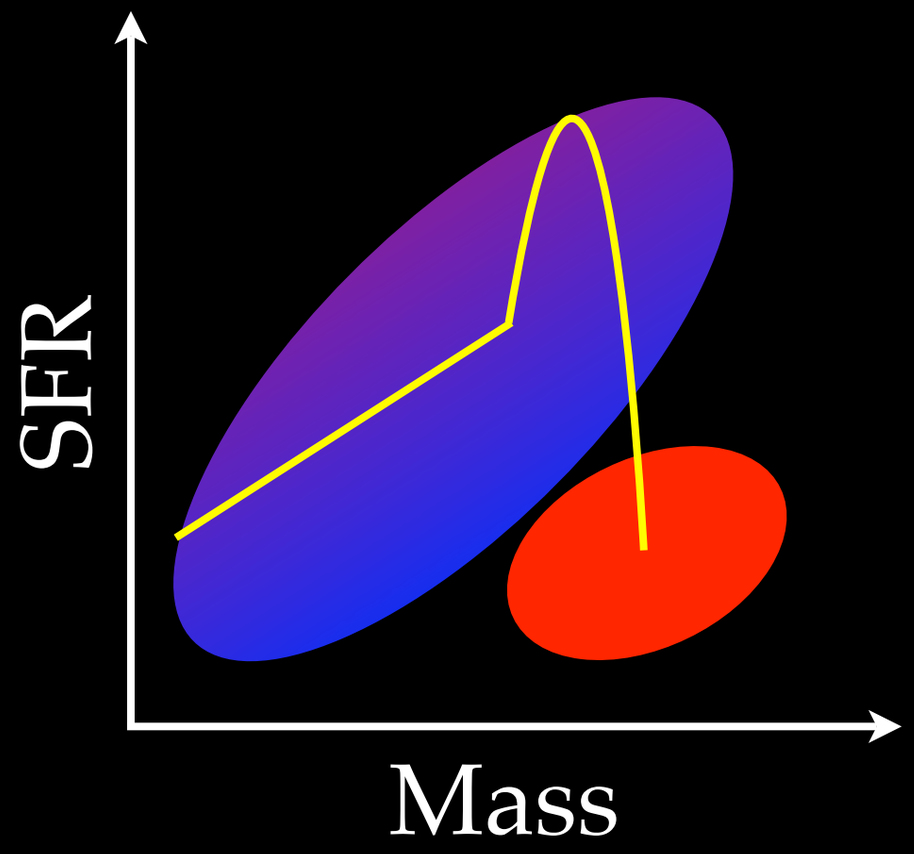
3 kpc

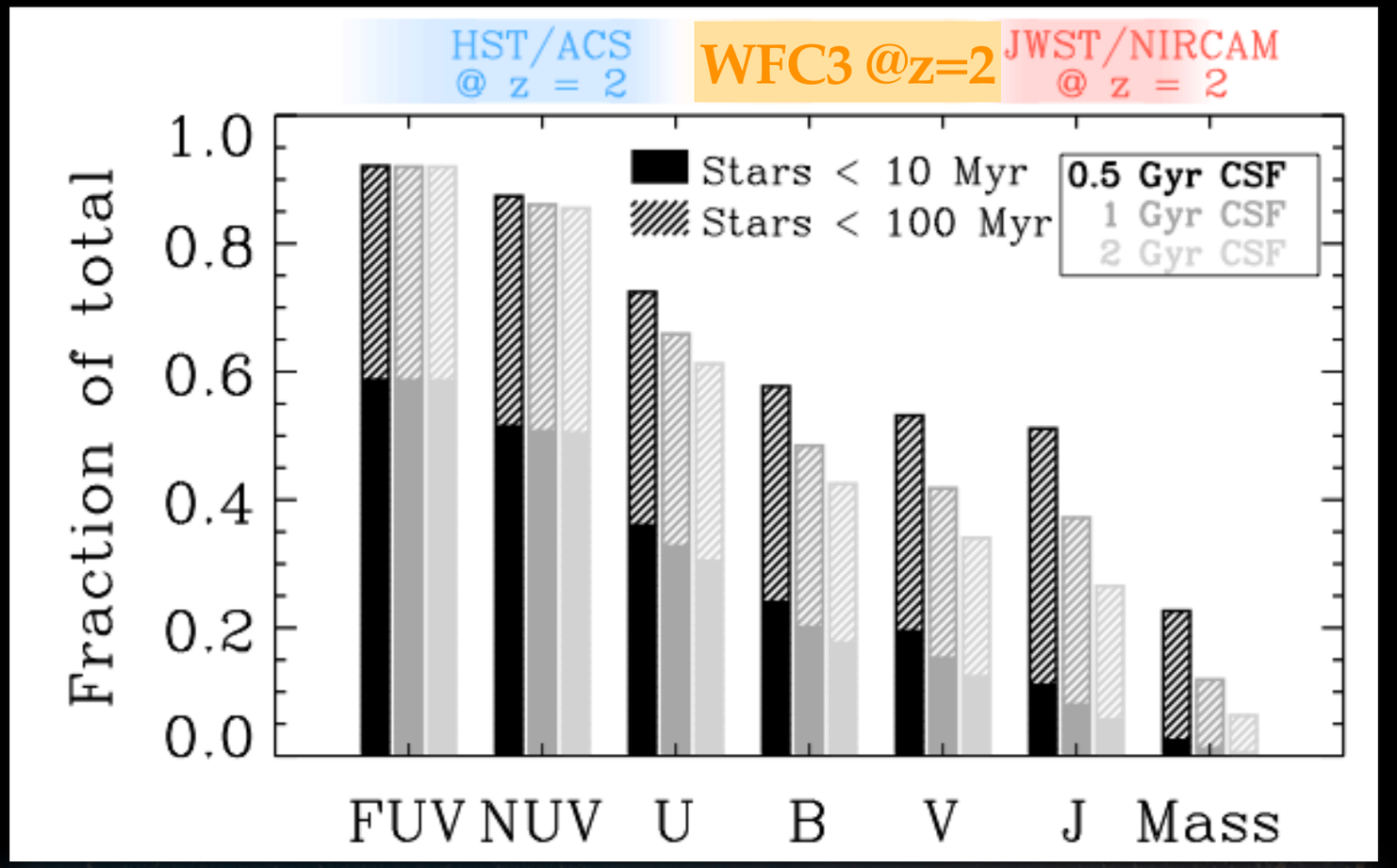
Hopkins et al. 2011

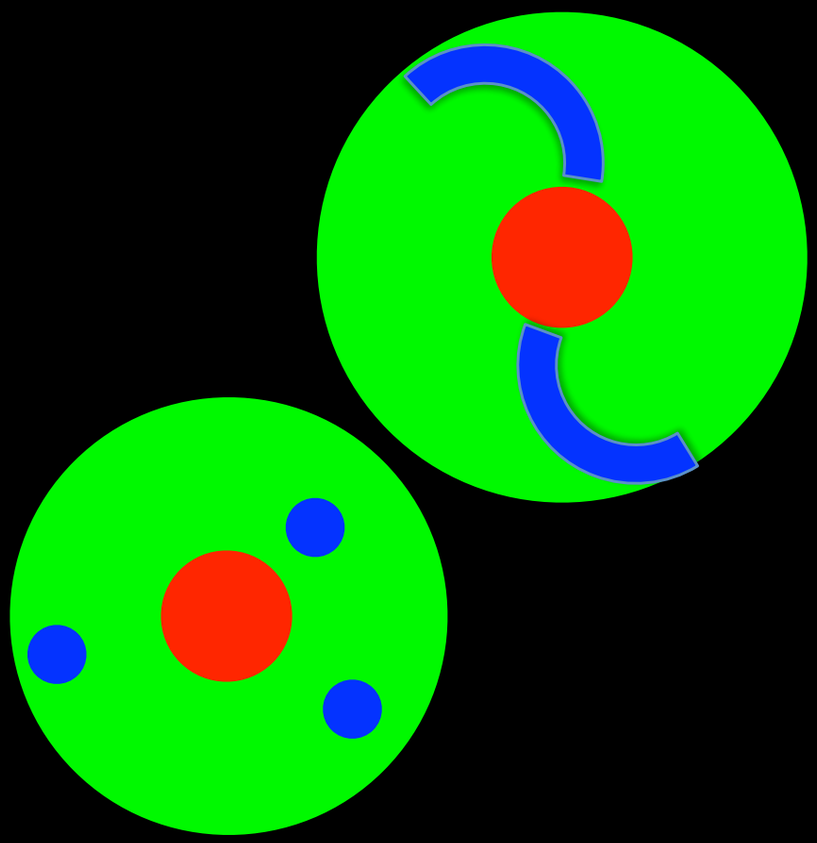
STRONG OUTFLOWS FROM INDIVIDUAL SF-ING CLUMPS



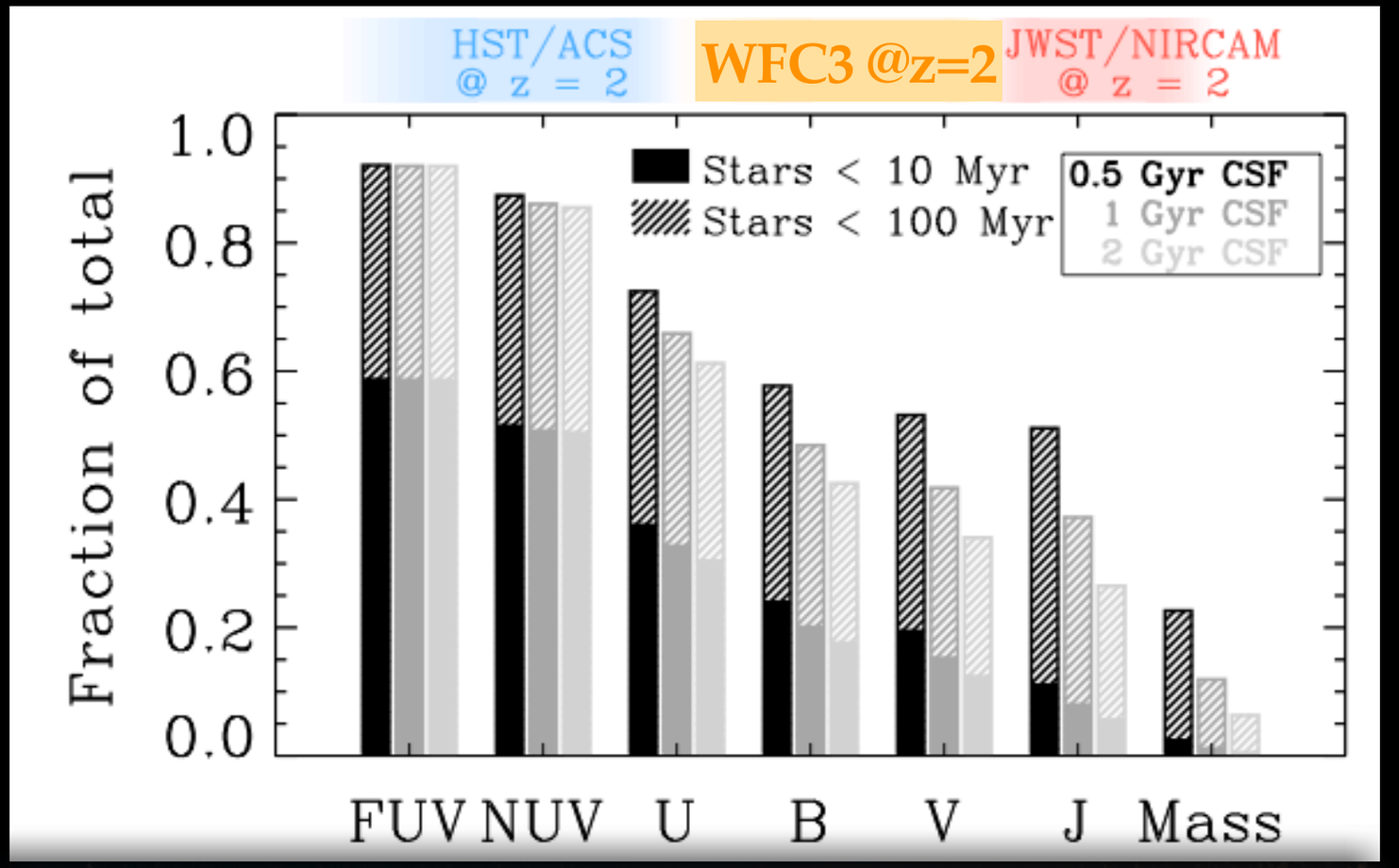
Newman et al. 2012


SFR
Mass


HST/ACS
@ z = 2
WFC3 @z=2
JWST/NIRCAM
@ z = 2
Fraction of total
1.0
0.8
0.6
0.4
0.2
0.0
Stars < 10 Myr
Stars < 100 Myr
0.5 Gyr CSF
1 Gyr CSF
2 Gyr CSF
FUV
NUV
U
B
V
J
Mass



- Redder, dustier & older centers
- Smaller, smoother & more concentrated mass profiles



- Lack of off-center red clumps suggests short lifetimes (e.g. disruption by SF feedback, see Genzel et al. 2011; Newman et al. 2012) or inward migration before they age
- Red centers, green disks + blue SFing clumps superposed consistent with inside-out disk growth + short-term spatial fluctuations of the SFH which is uniform over longer timescales