Quasar Variability and Star Formation in Mergers

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Outline

- Quasar Variability
  - Selecting quasars using time-domain information
- Quasar *Color* Variability
  - Probing the physics of quasar using time-domain information
- 3D-HST
  - Star Formation in redshift 1.5 mergers
- Work @ UCSB...

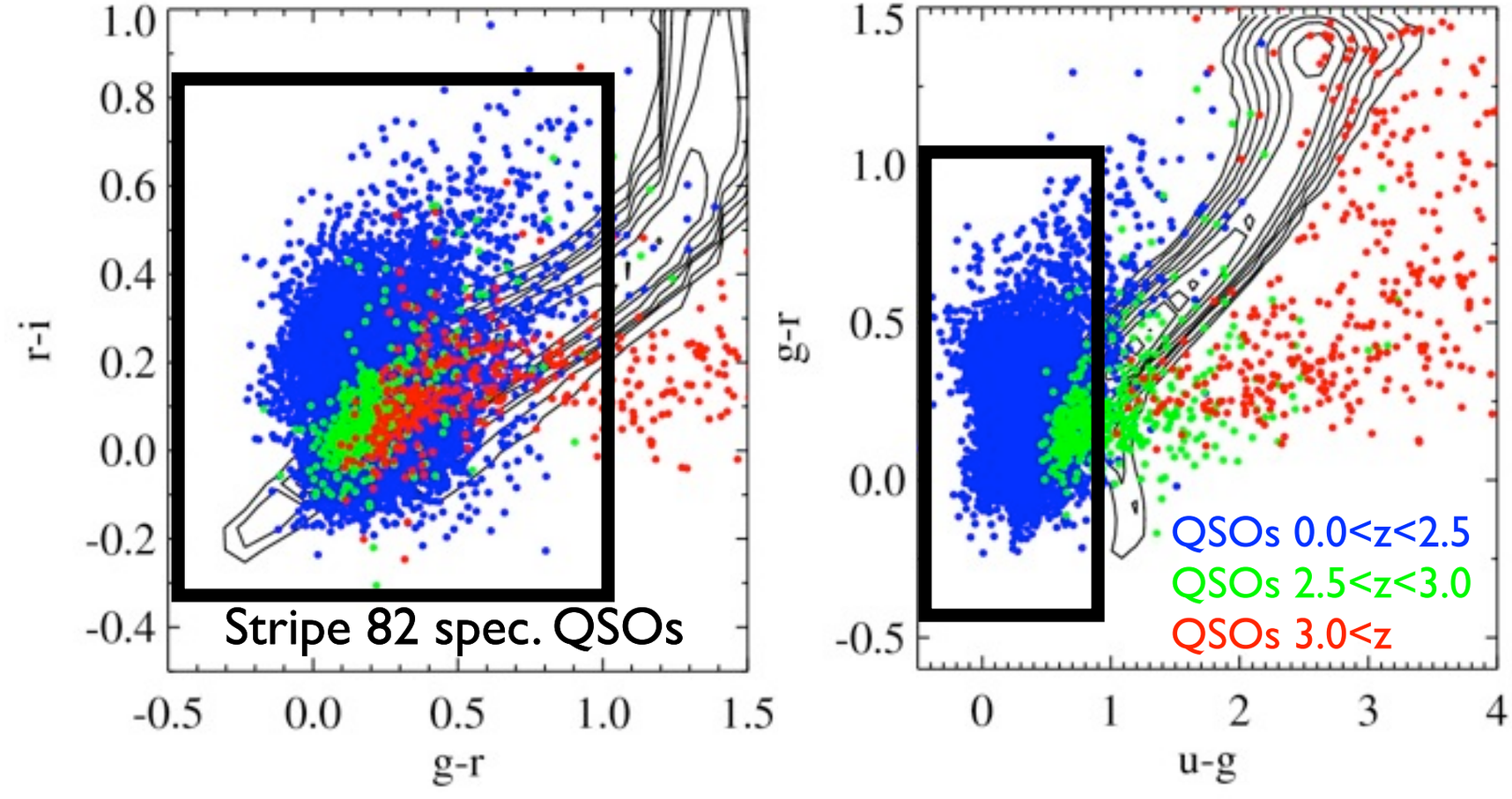
Why Variability Selection?

1. Works at all redshifts
2. Works **without** u-band (UV excess) information
3. Enables identification of unusual (QSO) variability objects

Standard QSO Color Selection

Has provided candidate samples of $>10^6$

Fails with:
- no UV excess info
- for 2.5<z<3



SDSS Stripe 82 as a Testbed

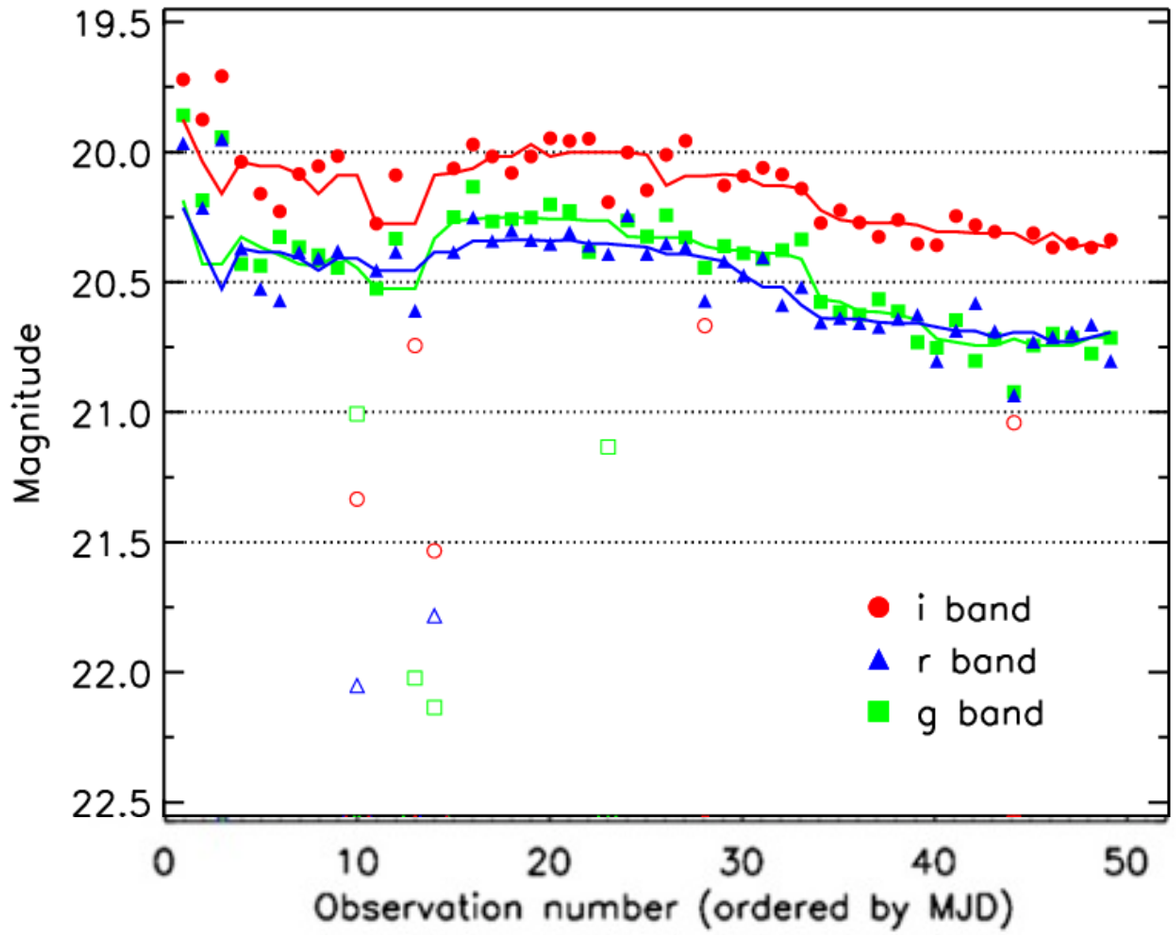
Data: Structure function

$$V_{i,j}(\Delta t_{i,j}) = |\Delta m_{i,j}| - \sqrt{\sigma_i^2 + \sigma_j^2}$$

Model: Power-Law

$$V_{\rm mod}(\Delta t_{i,j}|A,\gamma) = A\left(\frac{\Delta t_{i,j}}{1{\rm yr}}\right)^{\gamma}$$

SDSS Stripe 82: ~60 epochs over 8 years



Other recent variability selections: Kelly et al. 2009, MacLeod et al. 2010, 2011, Butler & Bloom 2011, N Palanque-Delabrouille et al. 2011, Kim et al. 2011

SDSS

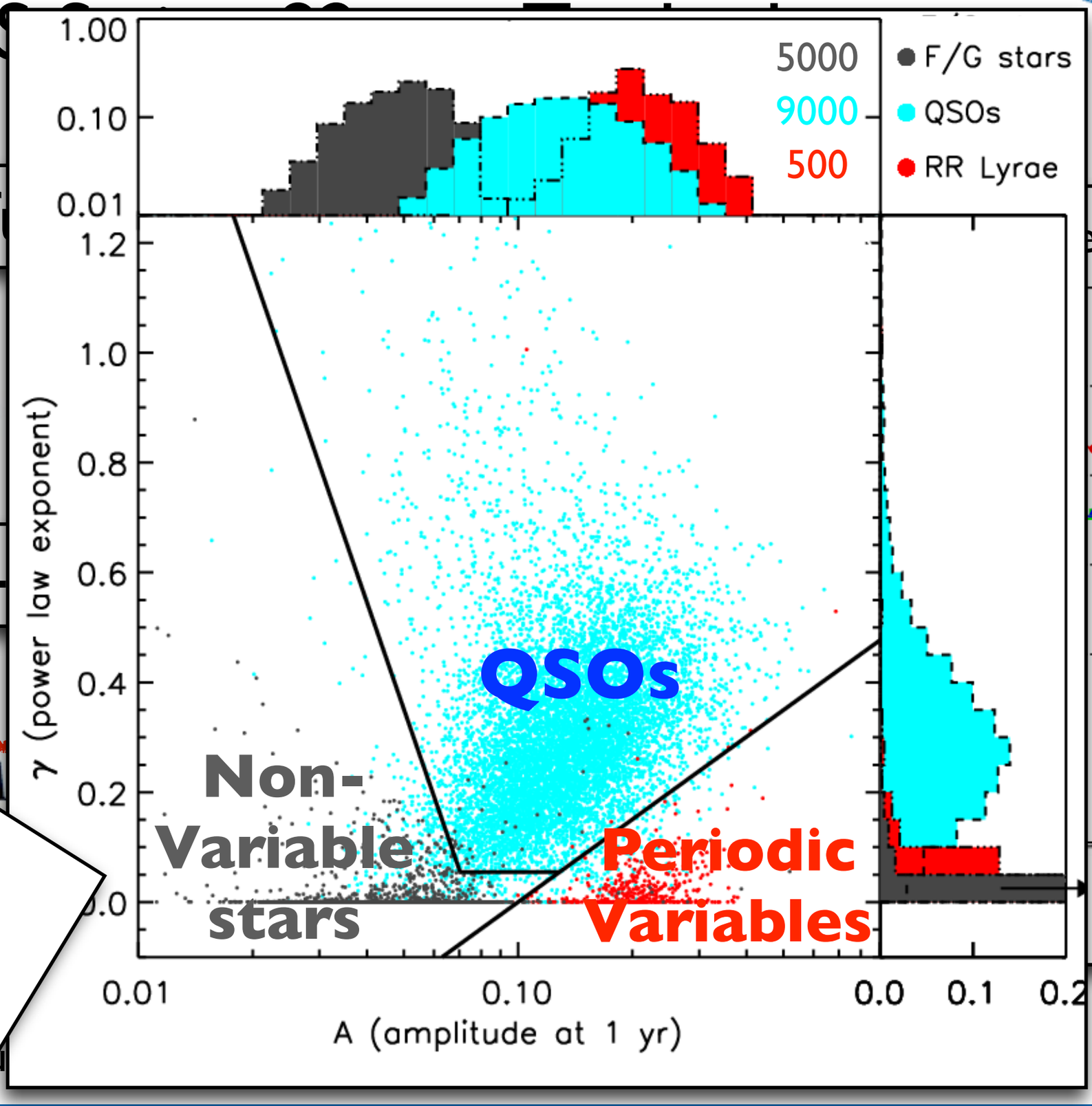
Data: Structure f

Model: Power-

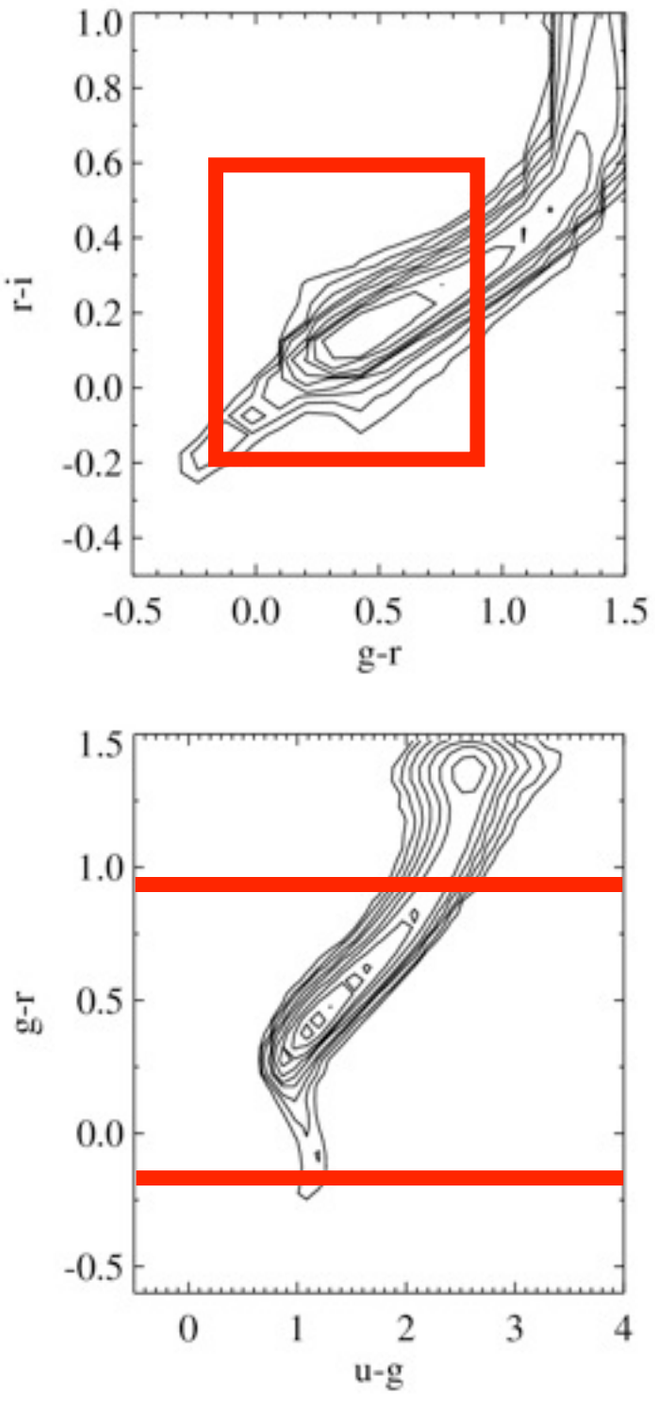
$$V_{i,j}(\Delta t_{i,j}) = |\Delta m_{i,j}| -$$

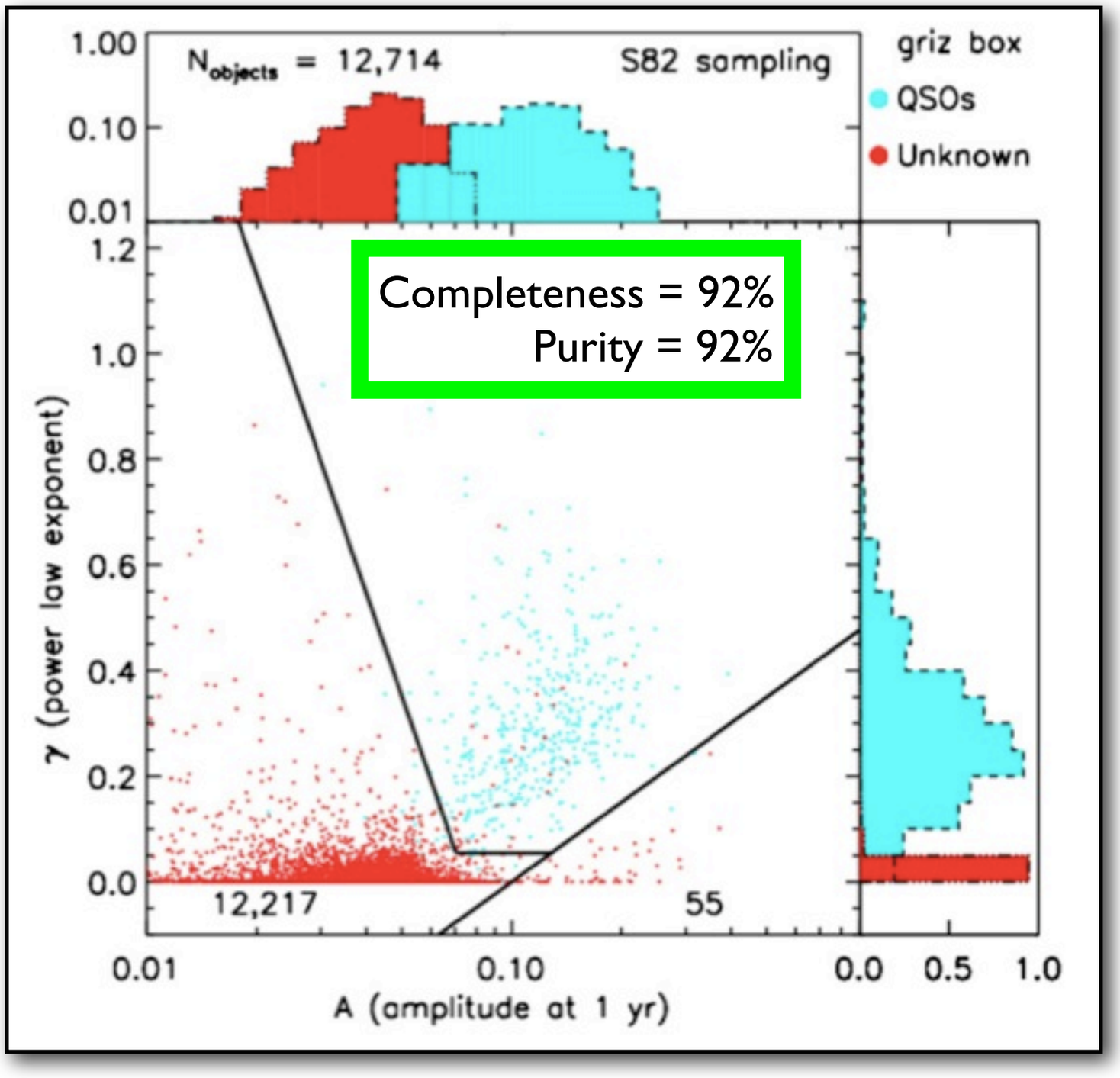
$$V_{\rm mod}(\Delta t_{i,j}|A,\gamma) \quad A$$

Structure function power-law fitting

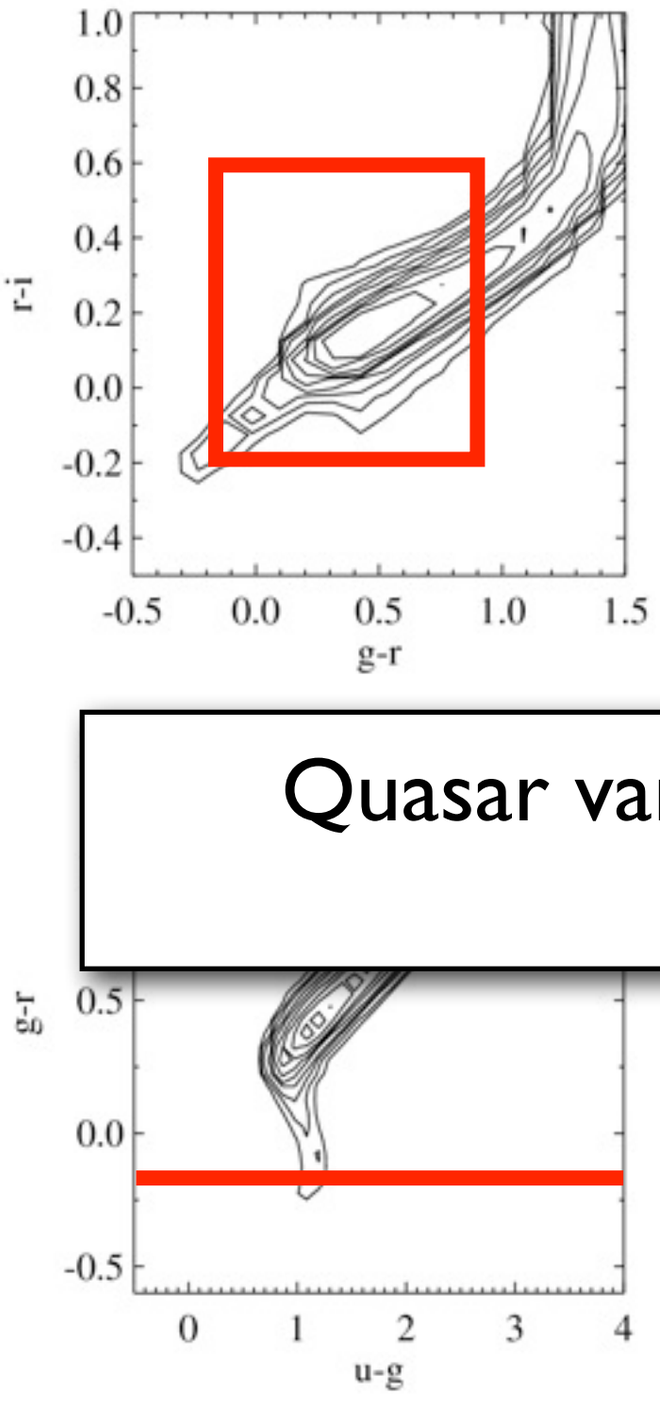


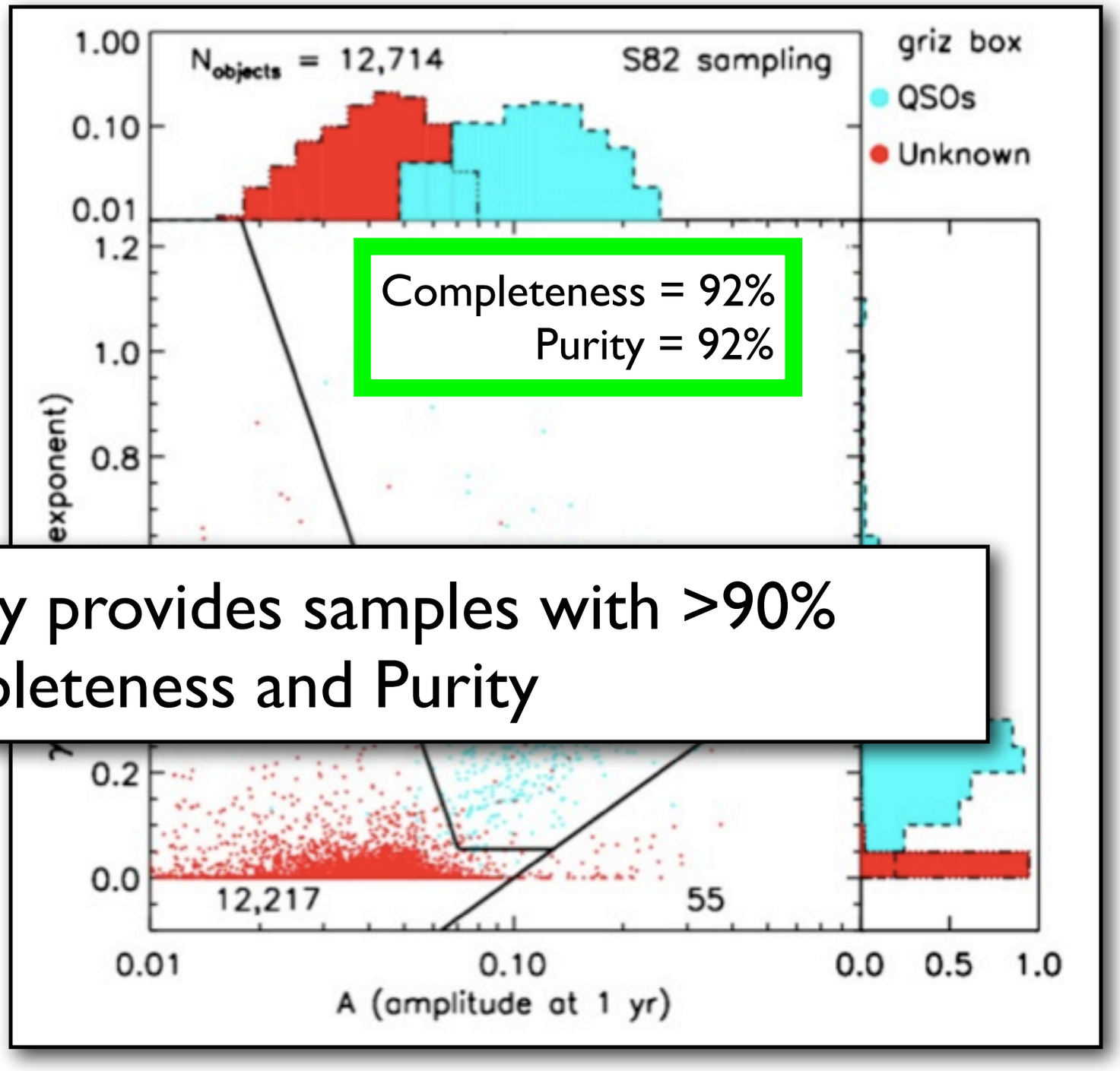
Variability Selection w/o UV excess info





Variability Selection w/o UV excess info





Quasar variability provides samples with >90% Completeness and Purity

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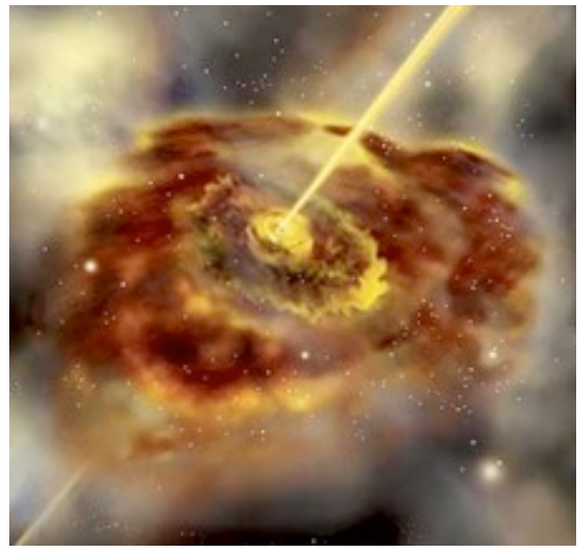
Color Variability

Change of quasar color as brightness changes on year timescales

- We know that quasars vary on time-scales of years
- Physics of this variability unclear
- Change in accretion rate has been proposed
  - e.g. Pereyra et al. 2006 Li & Cao 2008, MacLeod et al. 2010
- Color changes used to probe the underlying physics



NASA E/PO, Sonoma State University, Aurore Simonnet

Brighter = Bluer ?

- Previous studies have found a connection in Color-mag space
  - e.g. Giveon et al. 1999; Trevese et al. 2001; Trevese & Vagnetti 2002; Geha et al. 2003; Vanden Berk et al. 2004; Wilhite et al. 2005

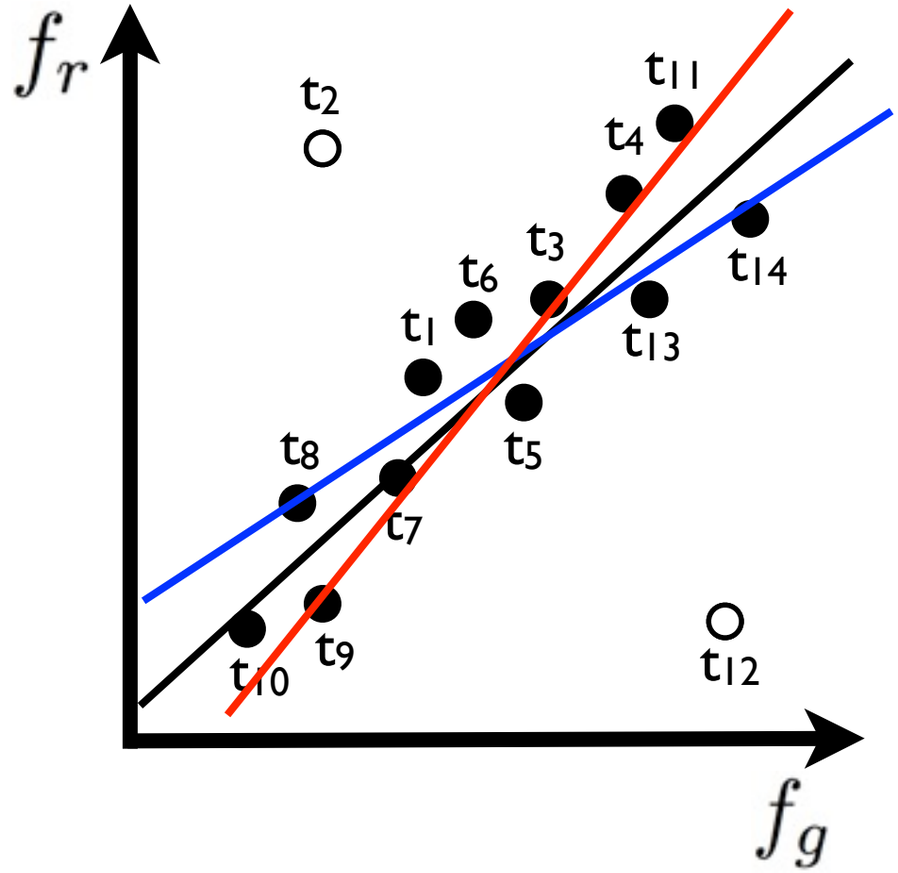
- 9000 Spectroscopic Quasars from SDSS Stripe 82

- Change in color estimated on *gr* space
- Color Variability: $s_{gr} \equiv \frac{\partial f_r}{\partial f_g} - 1$

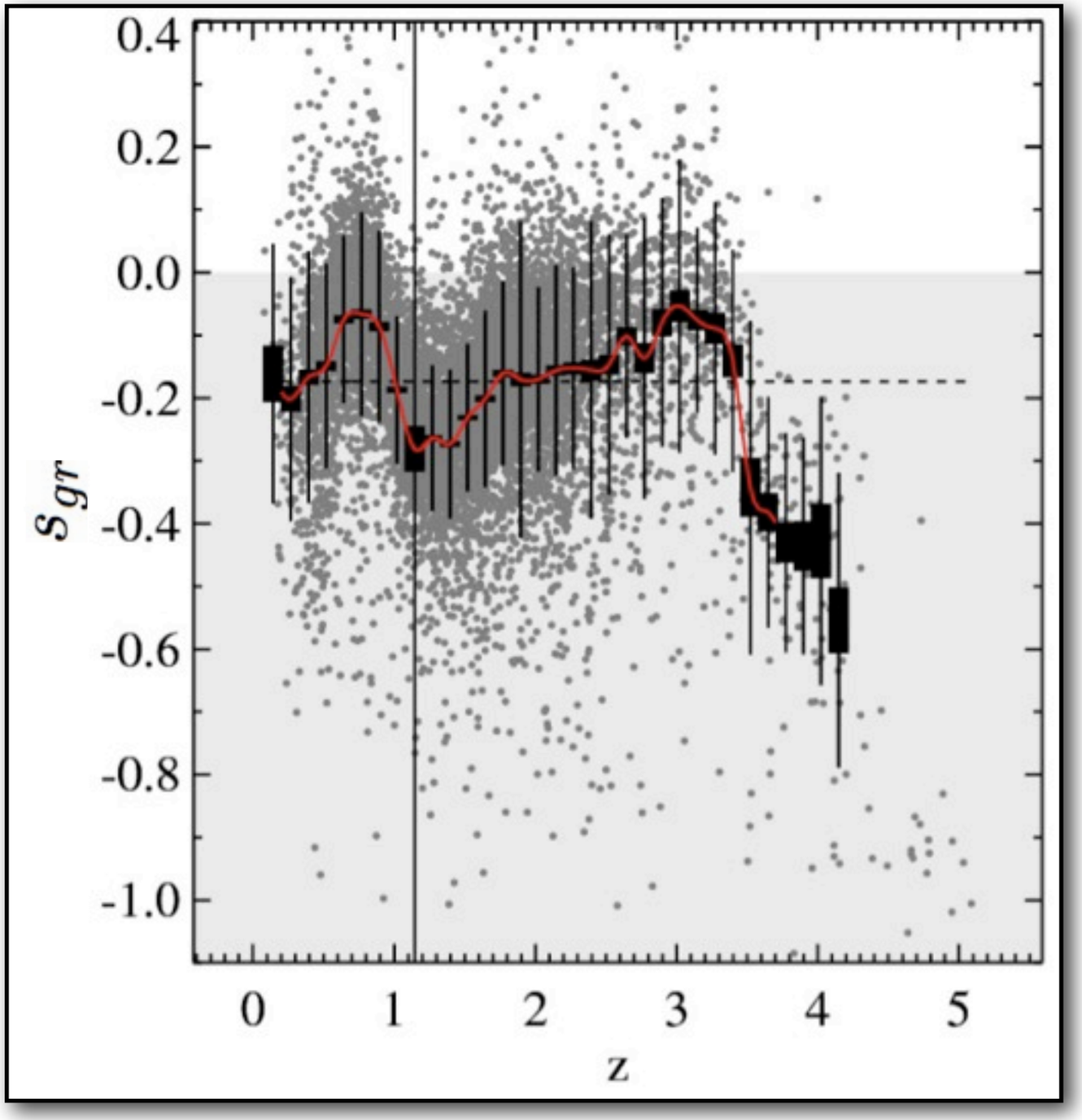
s_{gr} < 0: Brighter = Bluer

s_{gr} > 0: Brighter = Redder

s_{gr} = 0: No Color Change



Brighter = Bluer ?



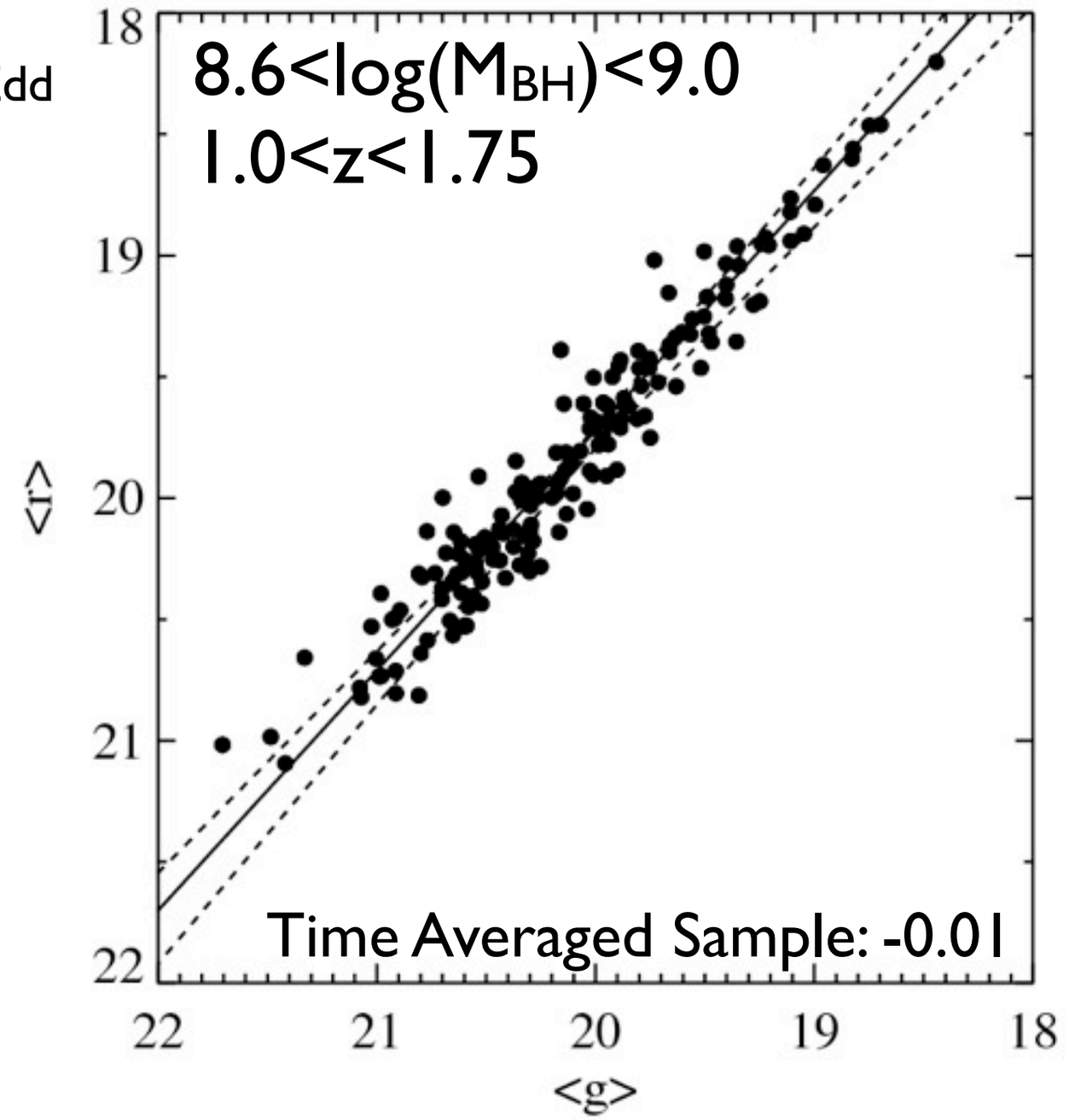
Yes;

Brighter ➡ Bluer

...at all redshifts

Color Variability = Mean Accretion Rate Change?

Sequence in L/L_{Edd} with fixed M_{BH}



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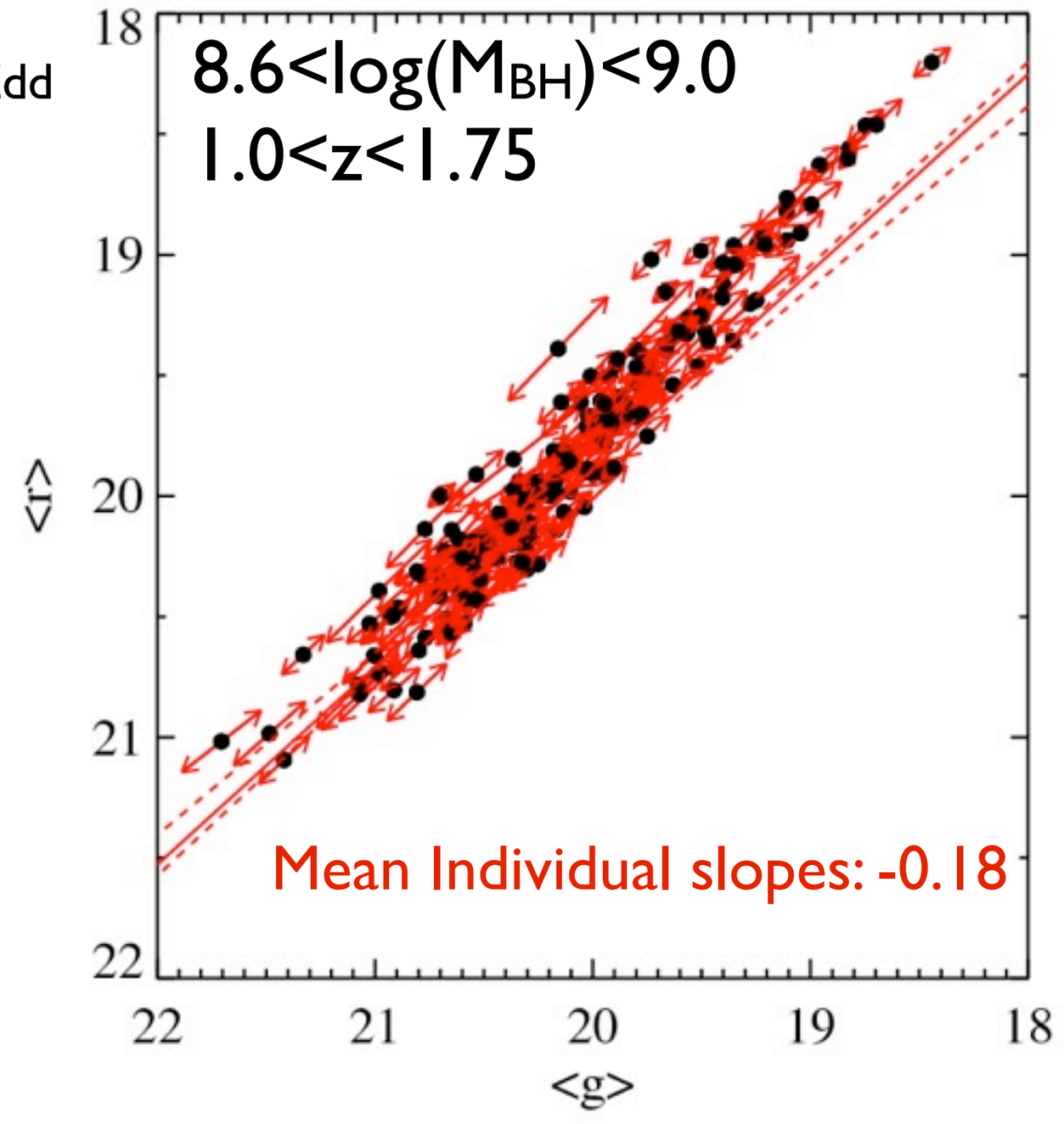
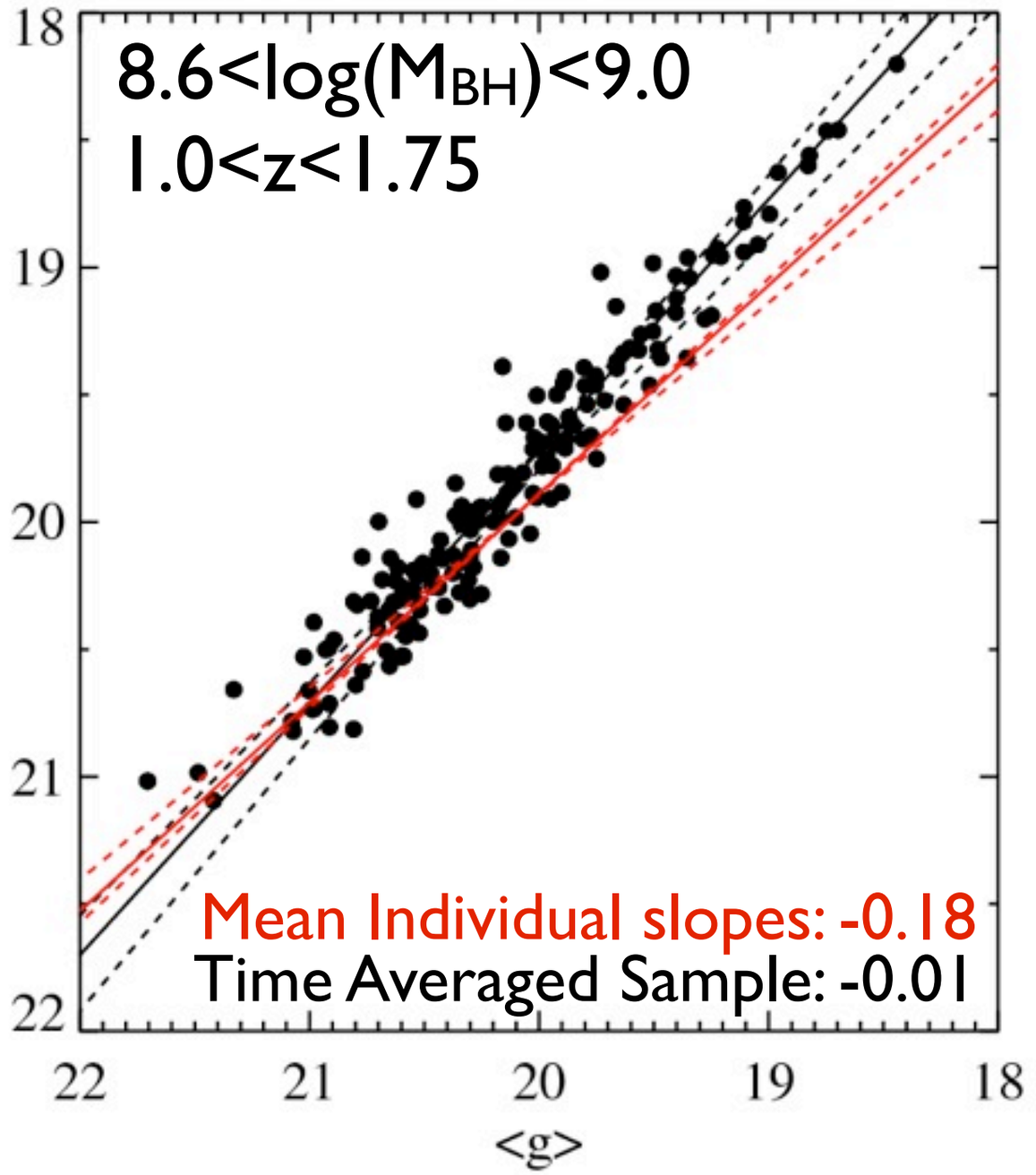


Color Variability = Mean Accretion Rate Change?

Sequence in L/L_{Edd} with fixed M_{BH}



Color Variability = Mean Accretion Rate Change?

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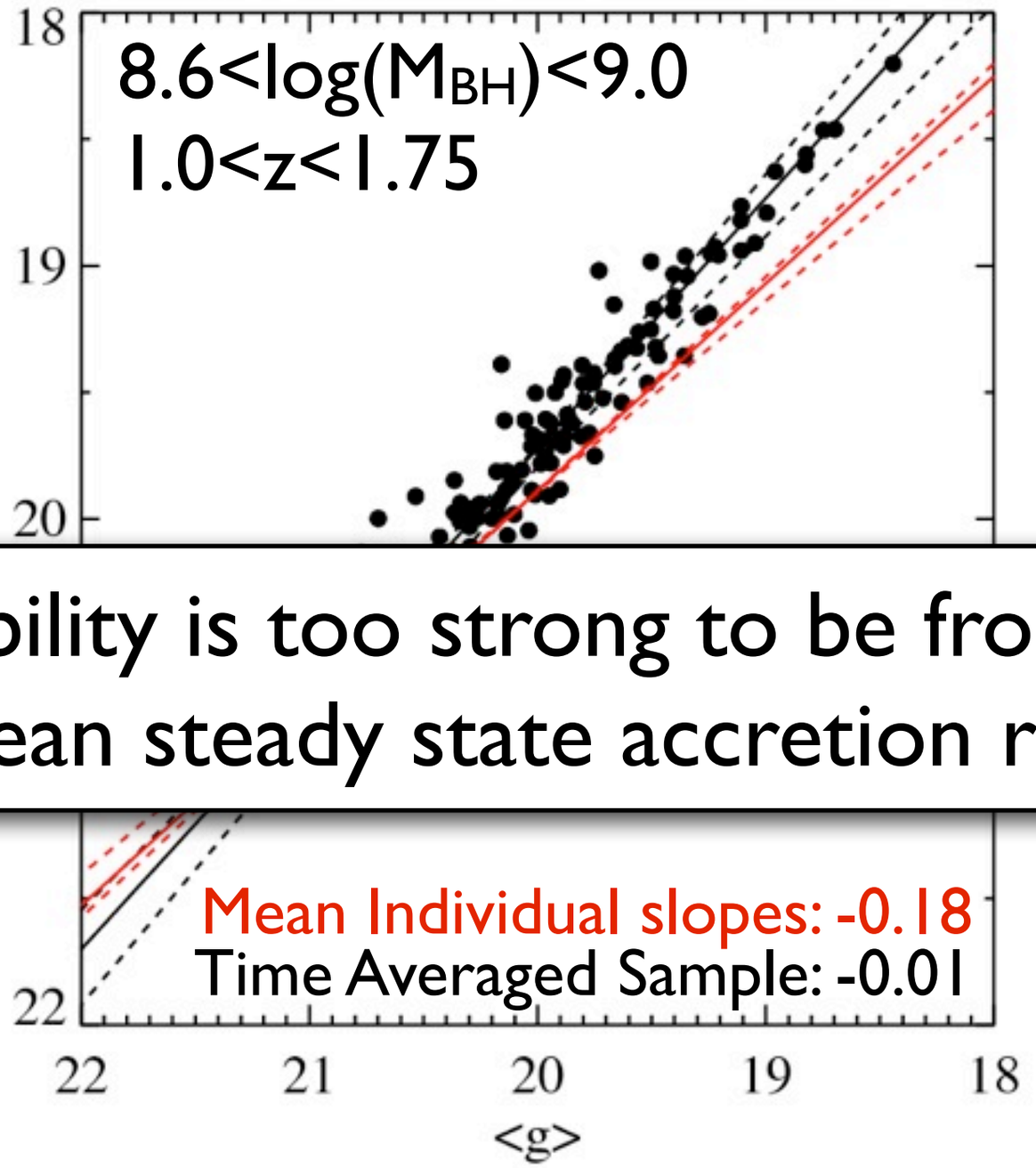

Color variability is too strong to be from changes in mean steady state accretion rate

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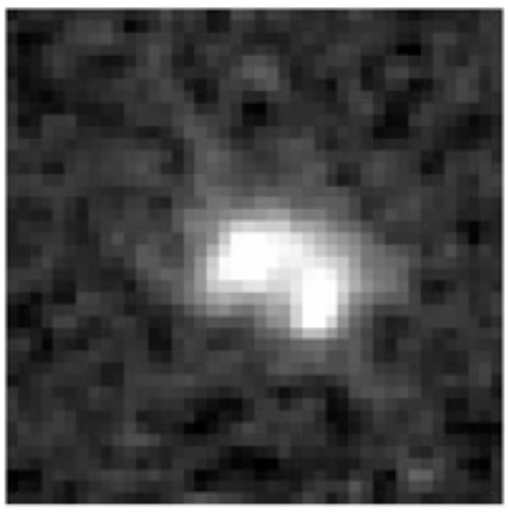
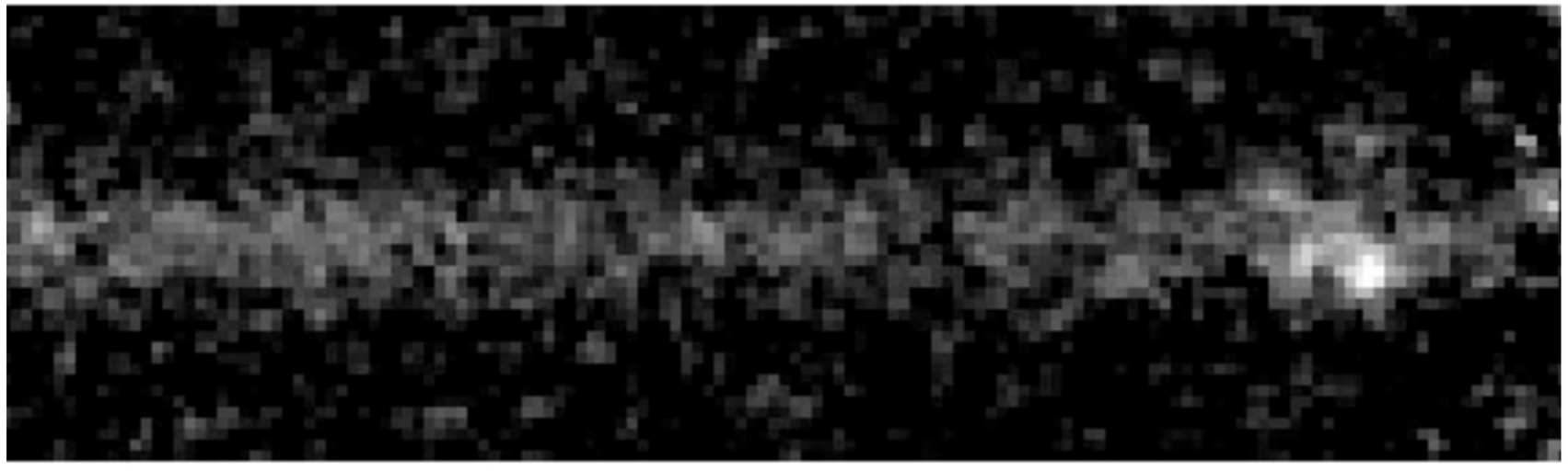
Star Formation in Mergers at z~1.5

- Where does star formation happen?
  - Tidal tails, nuclear burst, in all components, etc.?
- No well defined merger samples of spectra with spatial information
- Best sample so far: SINS IFU mergers (Förster-Schreiber et al. 2009)
  - but only very few mergers
- This has changed with the 3D-HST survey

The 3D-HST Survey (PI: van Dokkum)

- 248 orbit NIR HST legacy survey
- High-res. NIR imaging
- Grism (3D) spectroscopy



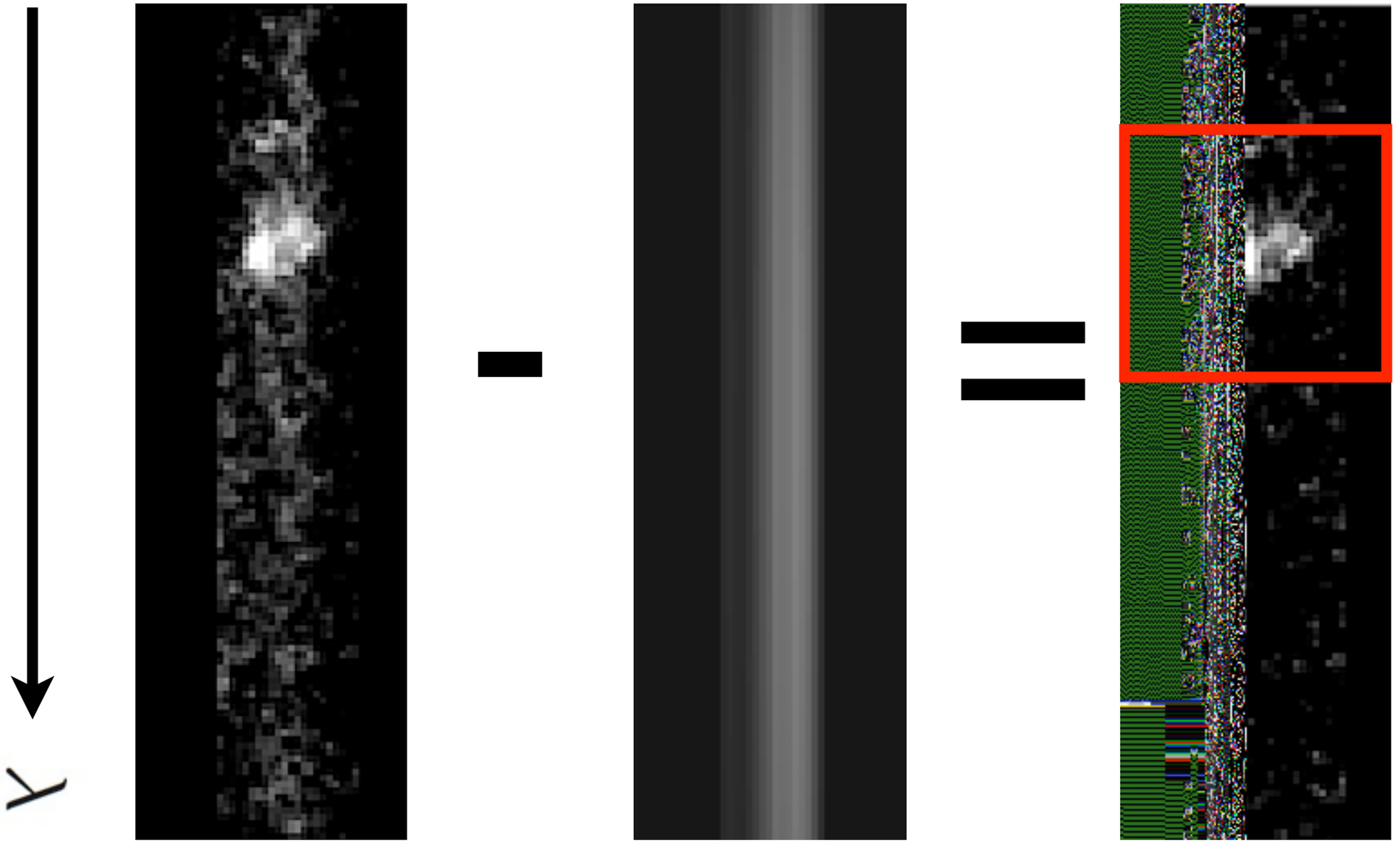


Emission Line (Star Formation) Mapping

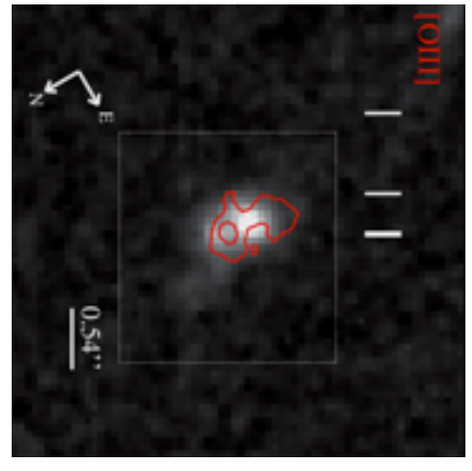
Observed Spectrum

2D Continuum Model

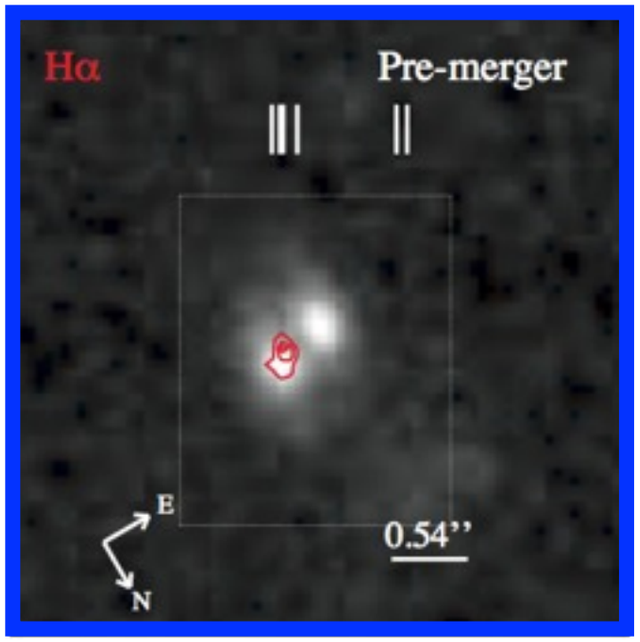
Continuum-Subtracted Spectrum



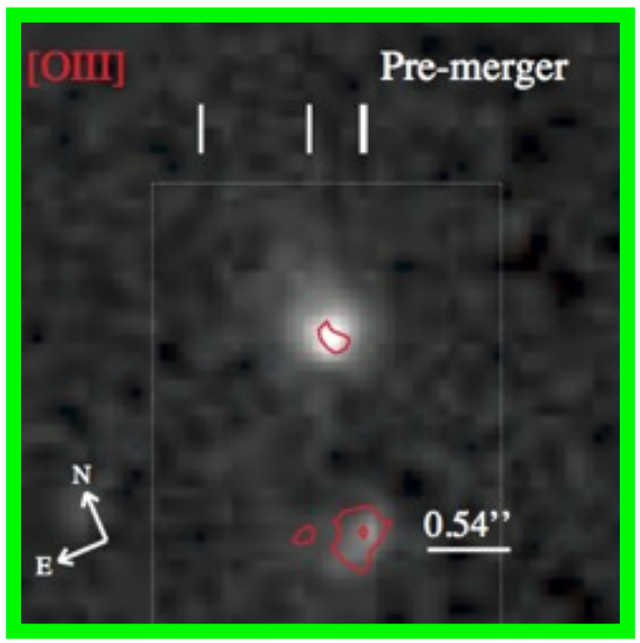
Emission Line Map



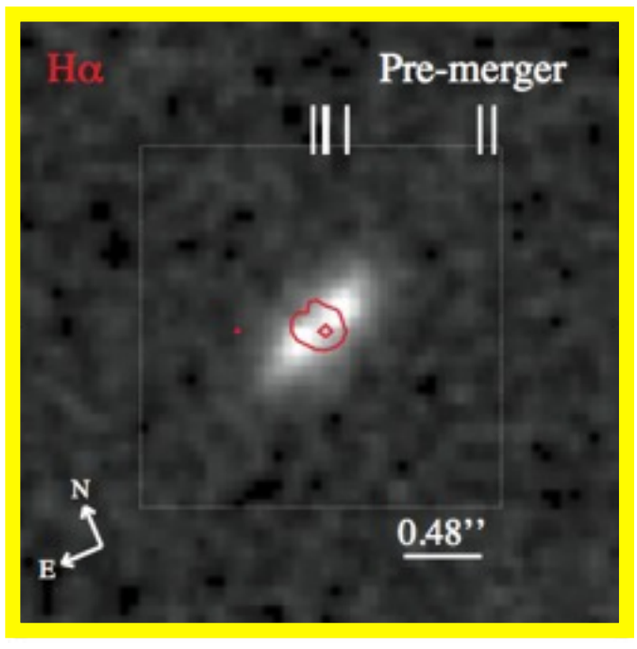
Categorizing Spatial Extent of Star Formation



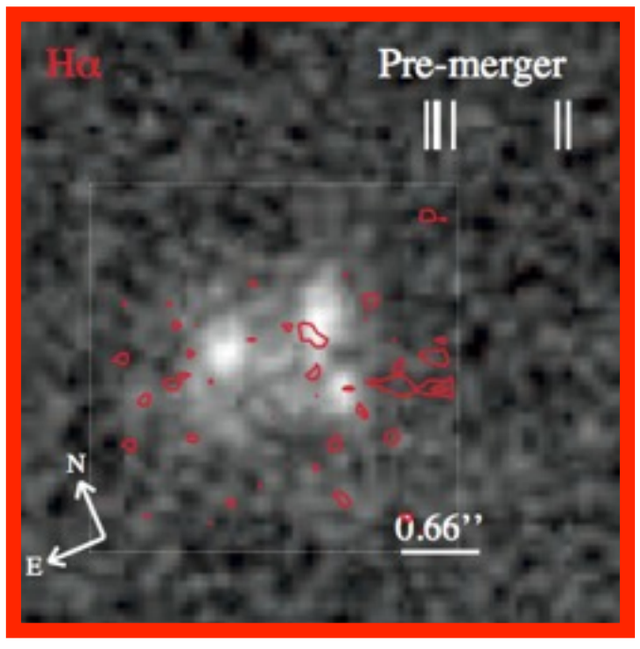
SF Type 1:
One Comp.
58%



SF Type 2:
All Comp.
32%



SF Type 3:
In-Between
3%



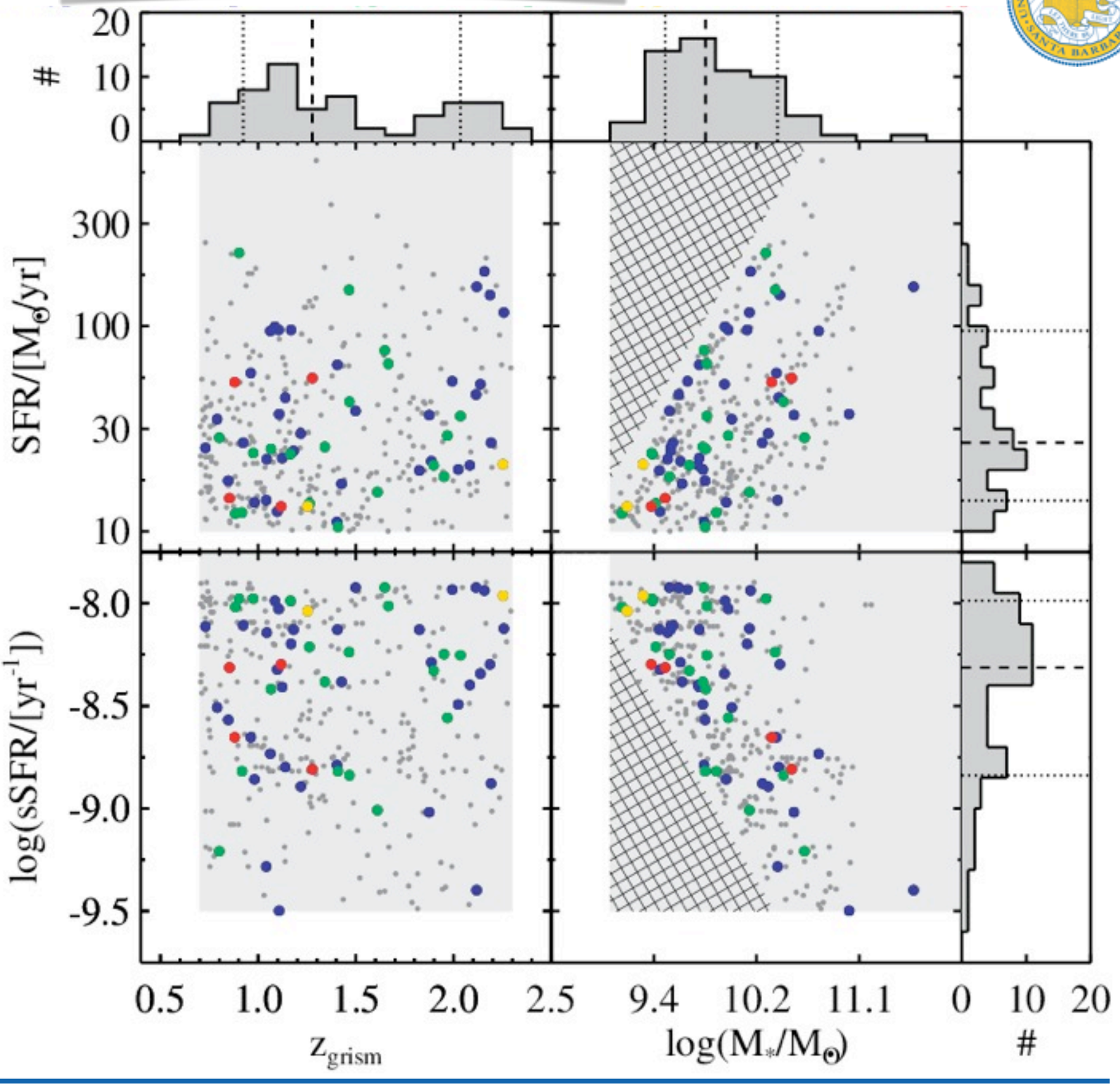
SF Type 3:
Low S/N
7%

SF Type 1:
One Comp.
58%

SF Type 2:
All Comp.
32%

SF Type 3:
In-Between
3%

SF Type 3:
Low S/N
7%



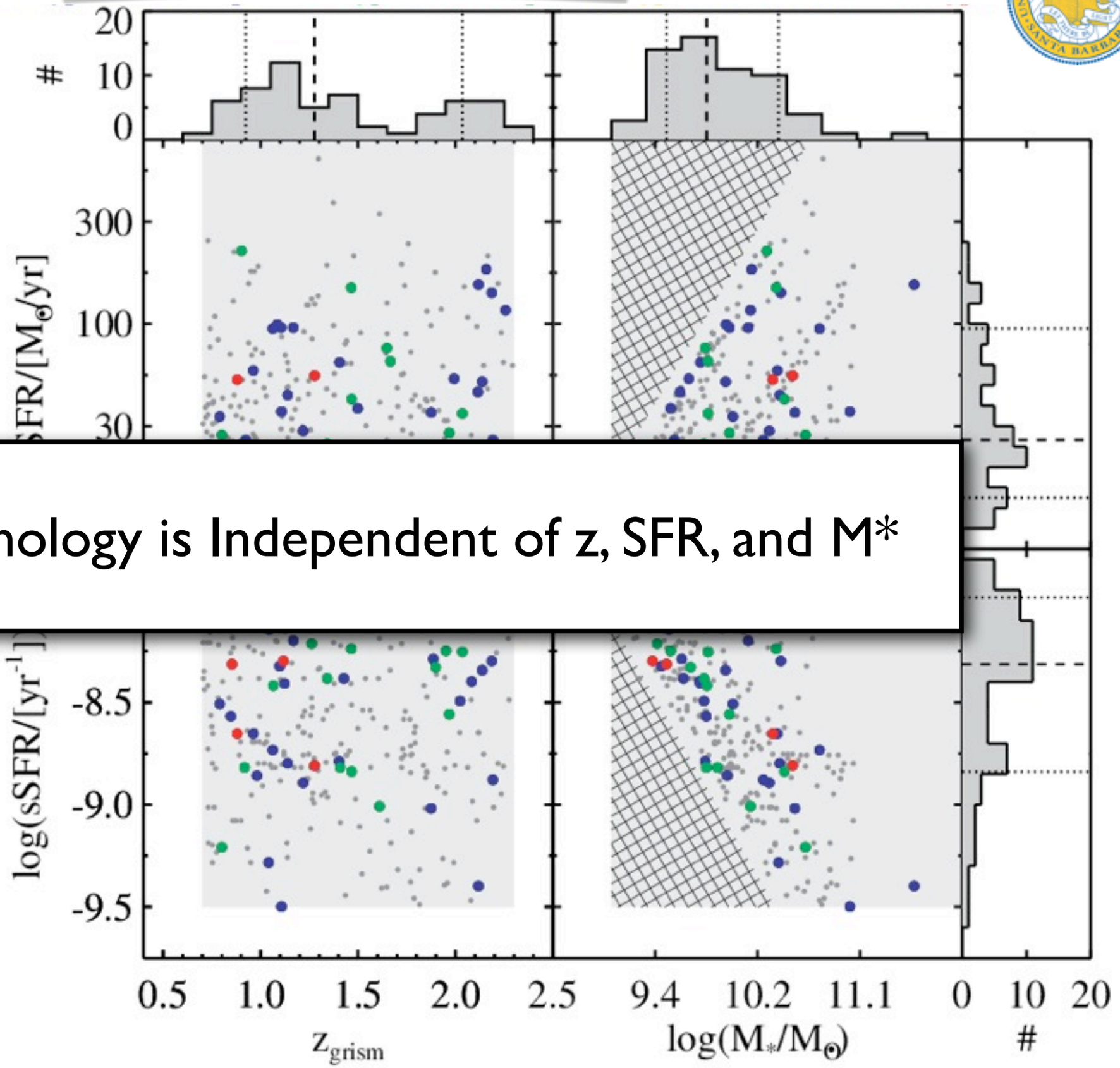
SF Type 1:
One Comp.
58%

SF Type 2:
All Comp
32

SF Ty
In-Between
3%

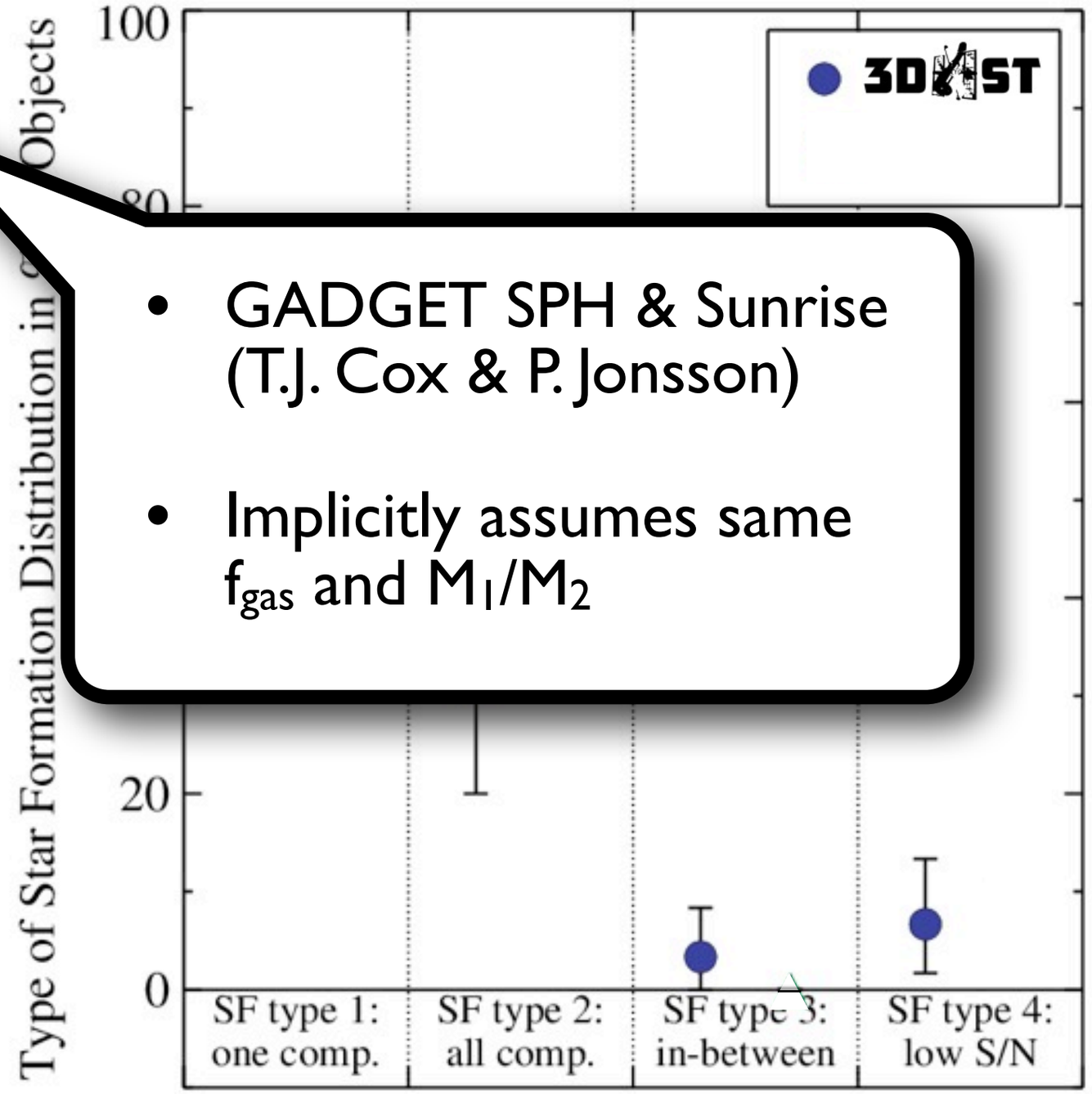
SF Type 3:
Low S/N
7%

SF Morphology is Independent of z, SFR, and M*



The Spatial Extent of Star Formation in 3D-HST Mergers at z~1.5

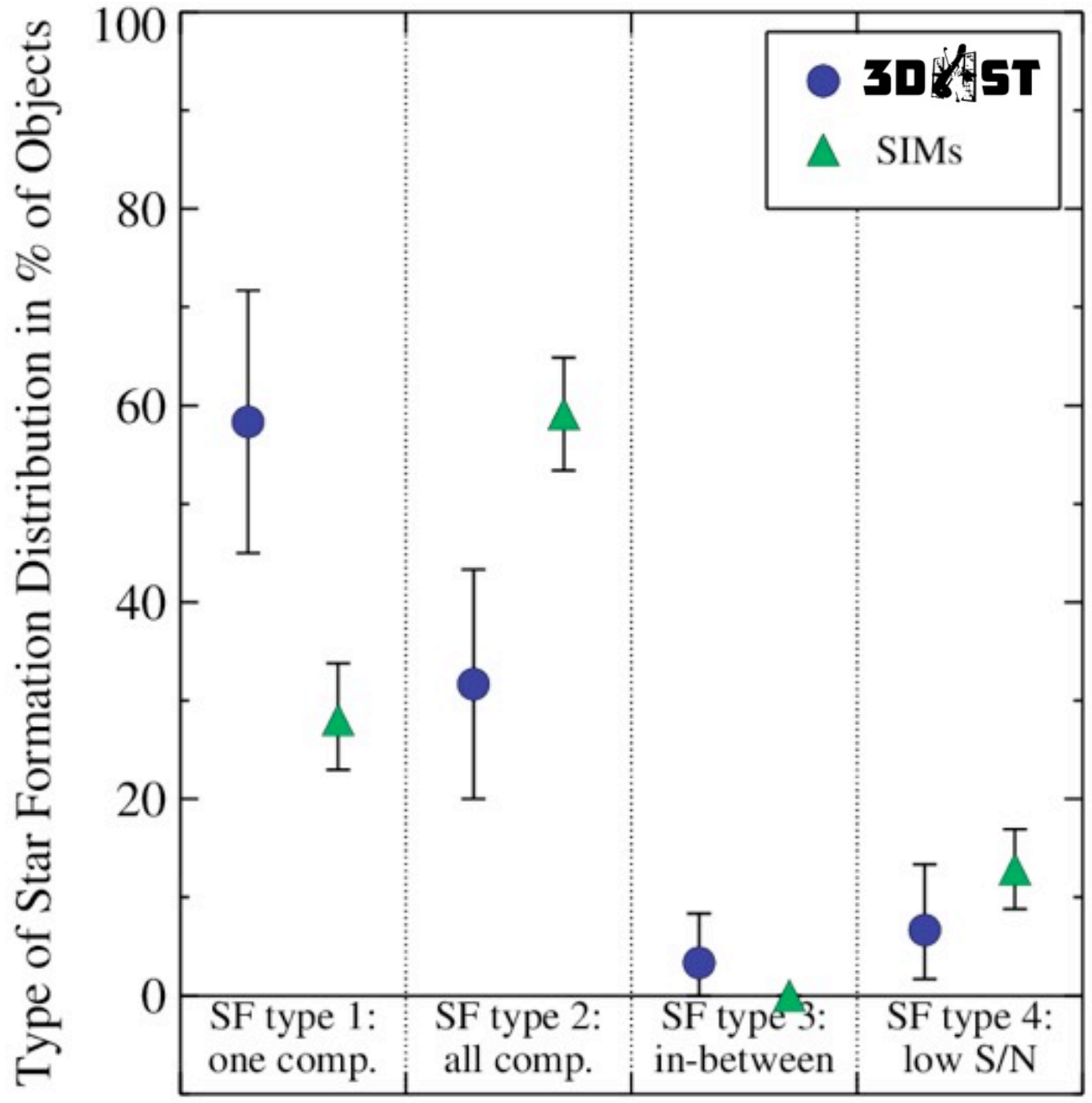
	3D-HST	Sims
SF Type 1	58%	
SF Type 2	32%	
SF Type 3	3%	
SF Type 4	7%	



- GADGET SPH & Sunrise (T.J. Cox & P. Jonsson)
- Implicitly assumes same f_{gas} and M_1/M_2

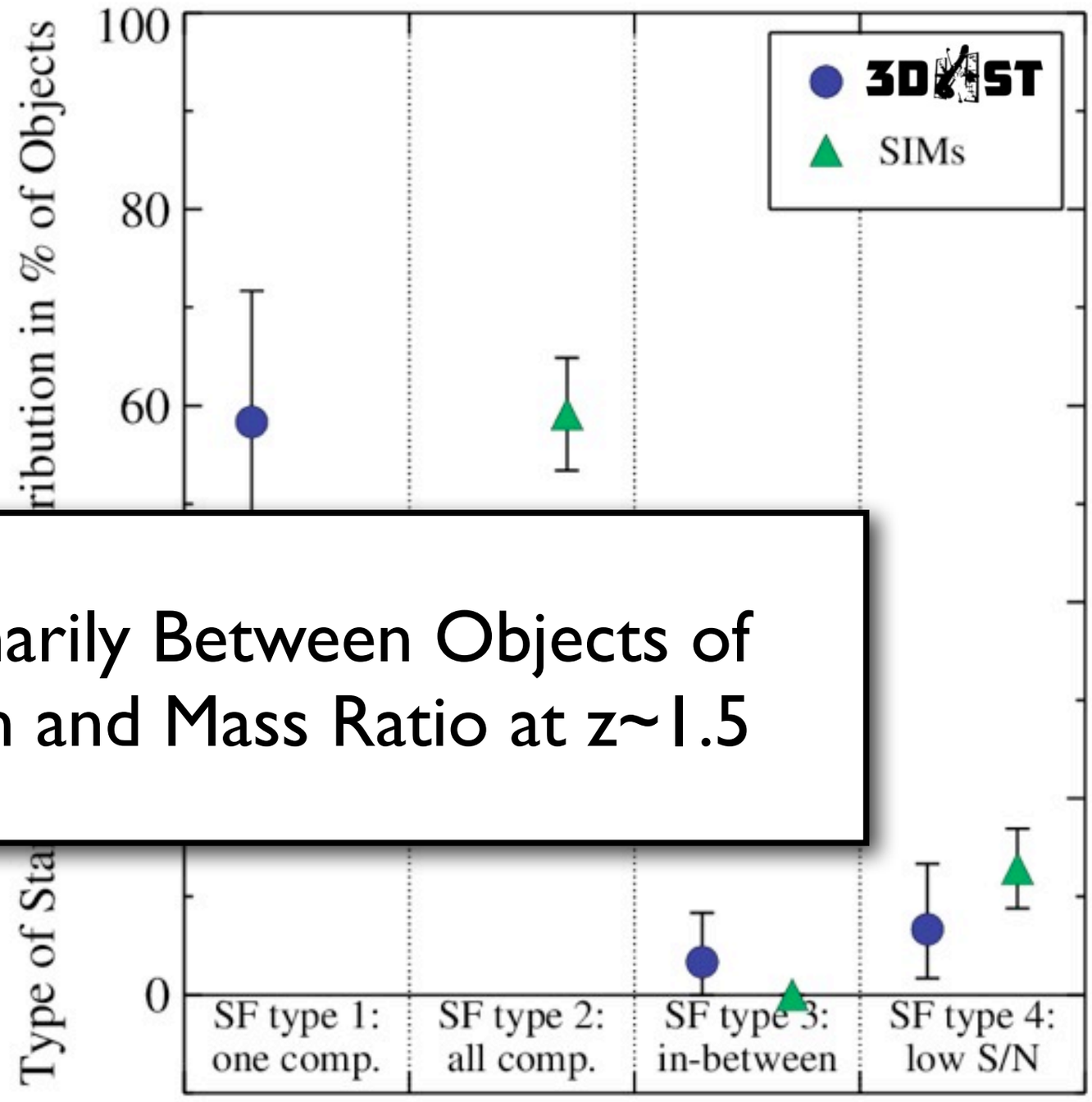
The Spatial Extent of Star Formation in 3D-HST Mergers at z~1.5

	3D-HST	Sims
SF Type 1	58%	28%
SF Type 2	32%	59%
SF Type 3	3%	0%
SF Type 4	7%	13%



The Spatial Extent of Star Formation in 3D-HST Mergers at z~1.5

	3D-HST	Sims
SF Type 1	58%	28%
SF Type 2	32%	59%
SF Typ		
SF Typ		



Mergers Happen Primarily Between Objects of Different Gas Fraction and Mass Ratio at z~1.5

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Future work at UCSB w. Treu et al.

- The **B**rightest **o**f **R**eionization **G**alaxies Survey (PI: Trenti)

- 274 arcmin^2 of pure parallel HST observations

- V_{606}, Y_{098}, J_{125} ($\leq$ 27.4), and H_{160} band data to look for z~8 Y-band dropouts
(Trenti et al. 2011 & 2012)

- Updating Bright-end luminosity function
(Bradley et al. 2012)

Future work at UCSB w. Treu et al.

- Part of data-team incl. reduction and analysis
- NIR Spectroscopic follow-up and confirmation of z~8 candidates with MOSFIRE on Keck
- Statistical assessment of line-of-sight lensing magnification of high redshift objects in general and BoRG objects in particular

Not been working alone...

Hans-Walter Rix, Philip J. Marshall,

Jo Bovy, Gabriel B. Brammer, Thomas J. Cox, Elisabete da Cunha, Gregory Dobler, Pieter van Dokkum, Marijn Franx, Natascha M. Förster Schreiber, Mattia Fumagalli , Joseph F. Hennawi, David W. Hogg, Sebastian Jester, Patrik Jonsson, Matthias Knecht, Britt Lundgren, Dan Maoz, Michael V. Maseda, Ivelina Momcheva, Erica J. Nelson, Joseph C. Shields, Rosalind E. Skelton, Arjen van der Wel, and Katherine E. Whitaker