3DHST:

A Slitless Spectroscopic Survey of Distant Galaxies with *HST*

Gabriel Brammer (ESA/AURA @ STScI)

Sexten / January 26, 2015

http://3dhst.research.yale.edu

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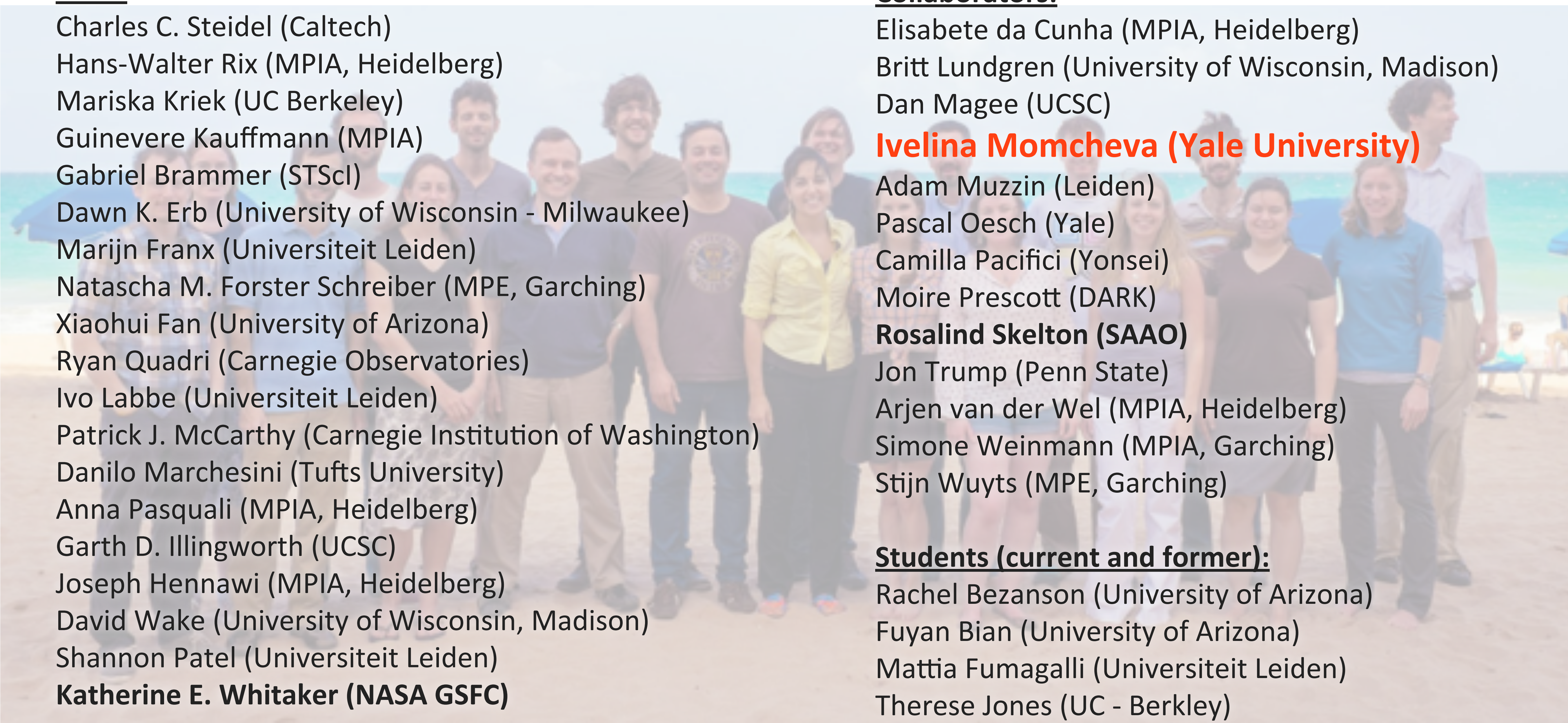

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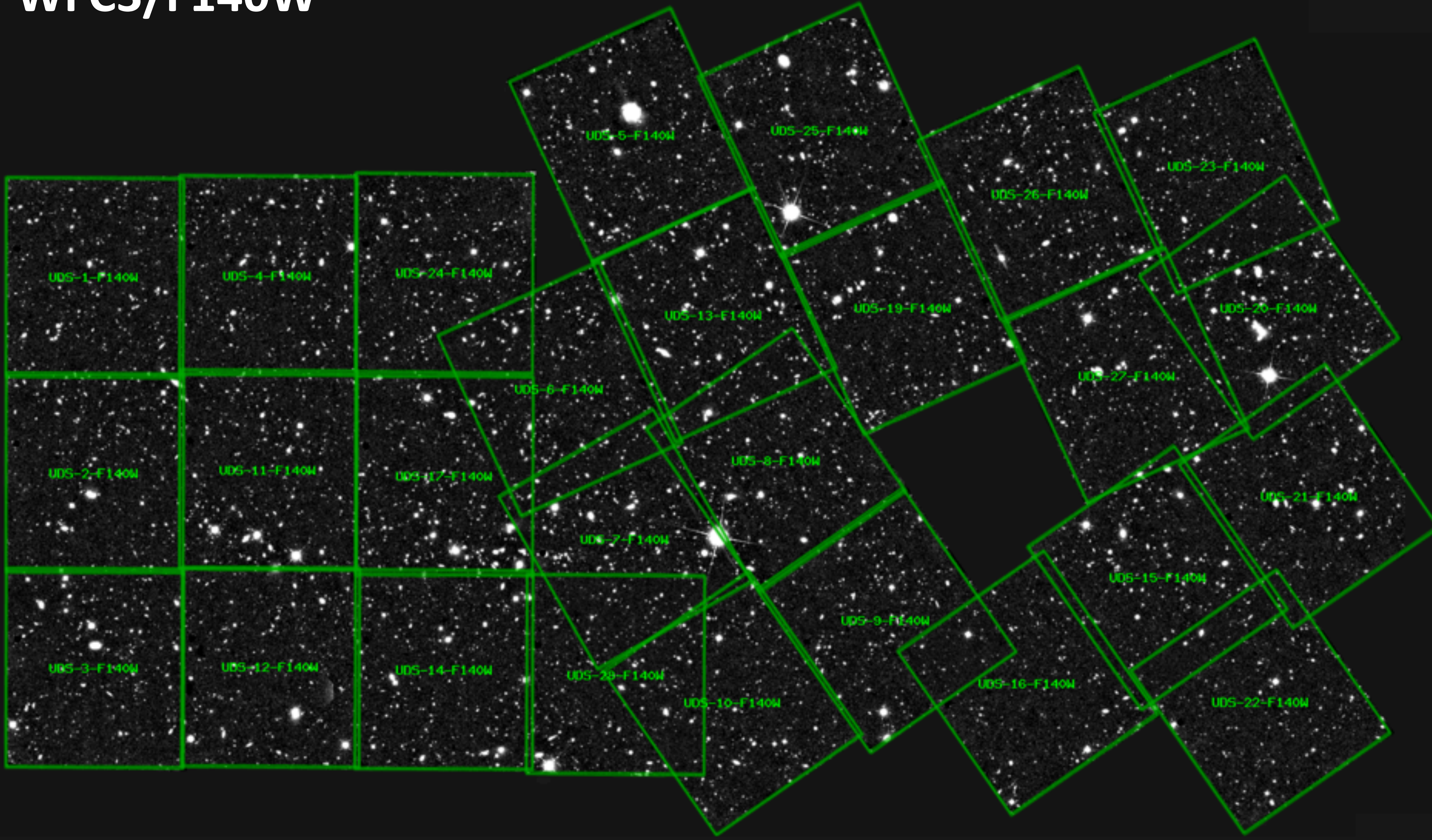
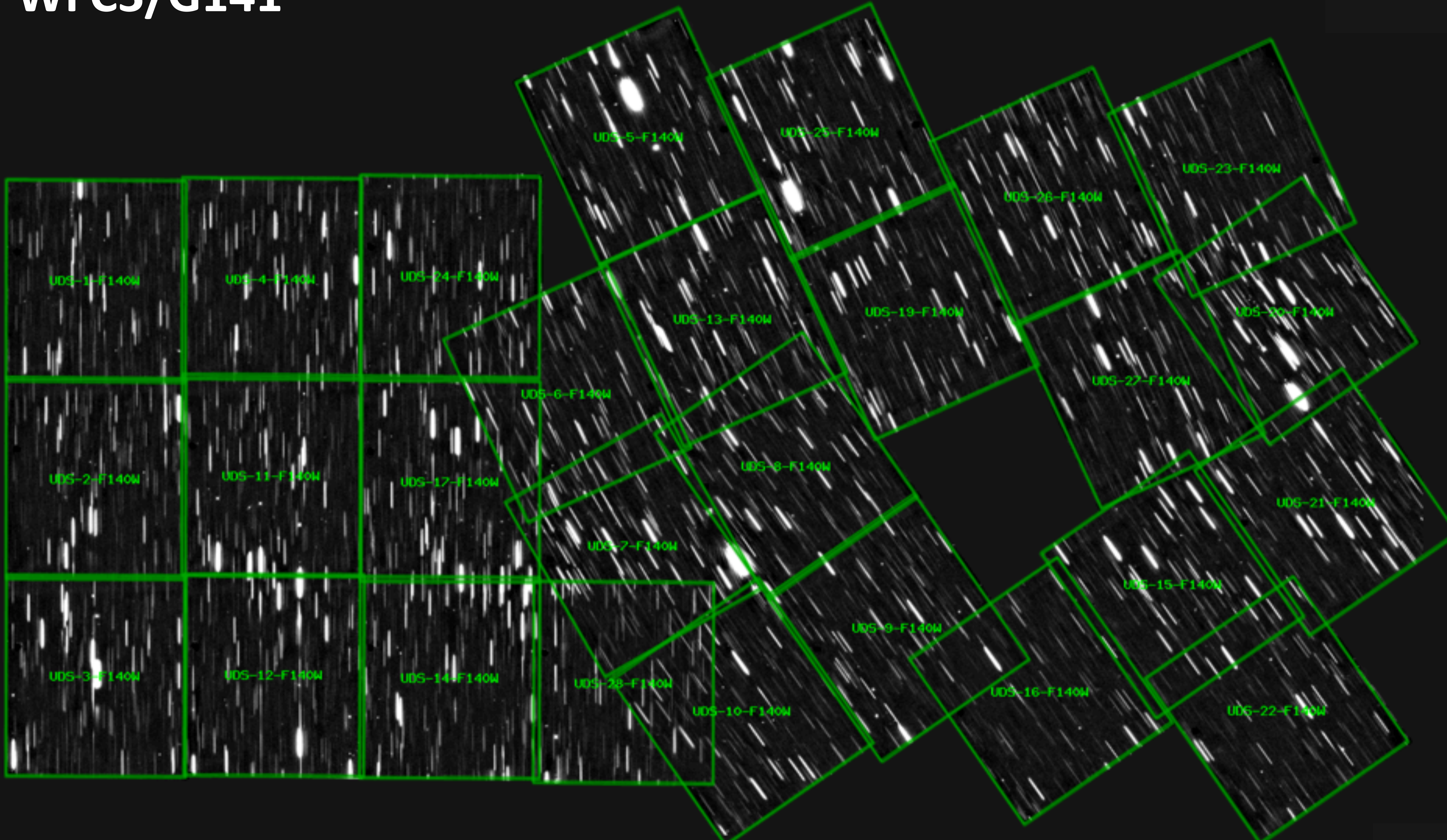
CANDELS UDS
WFC3/F140W



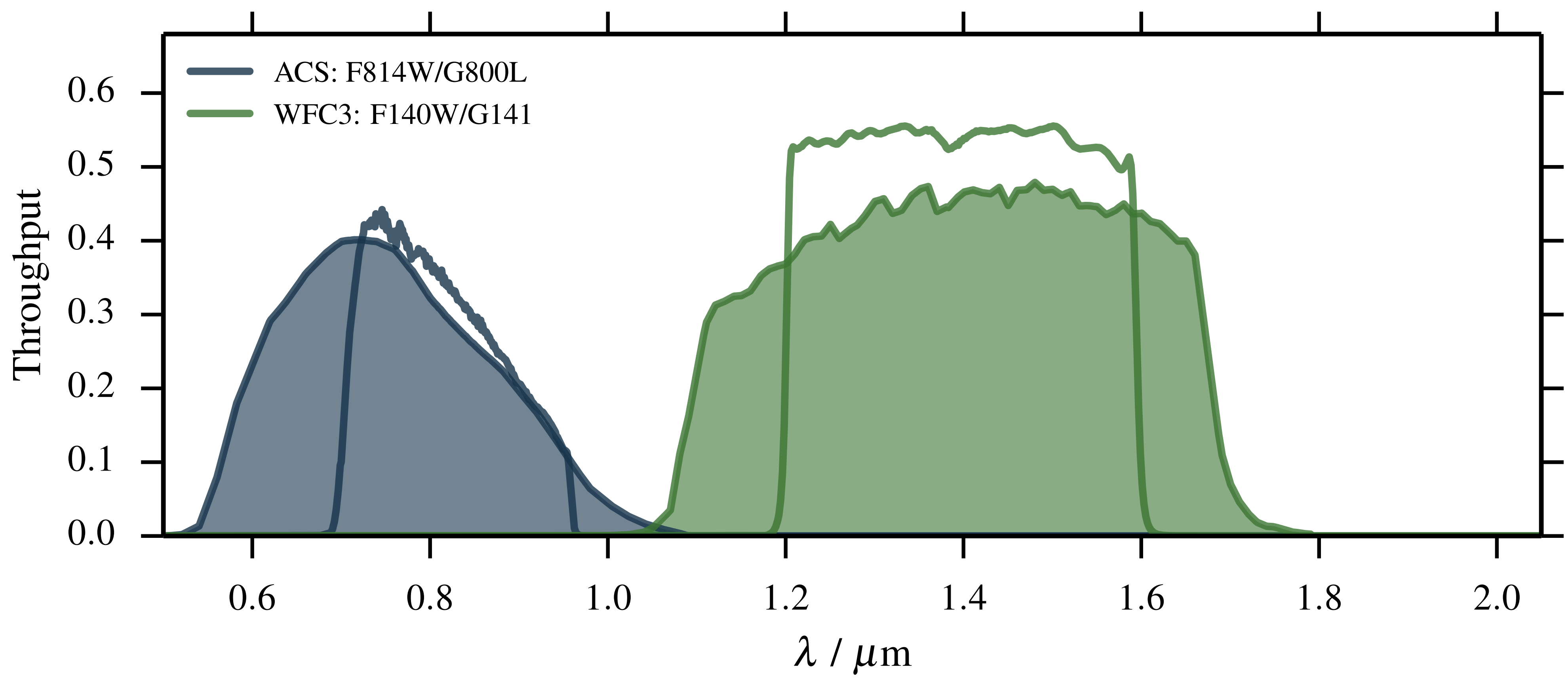
CANDELS UDS
WFC3/G141

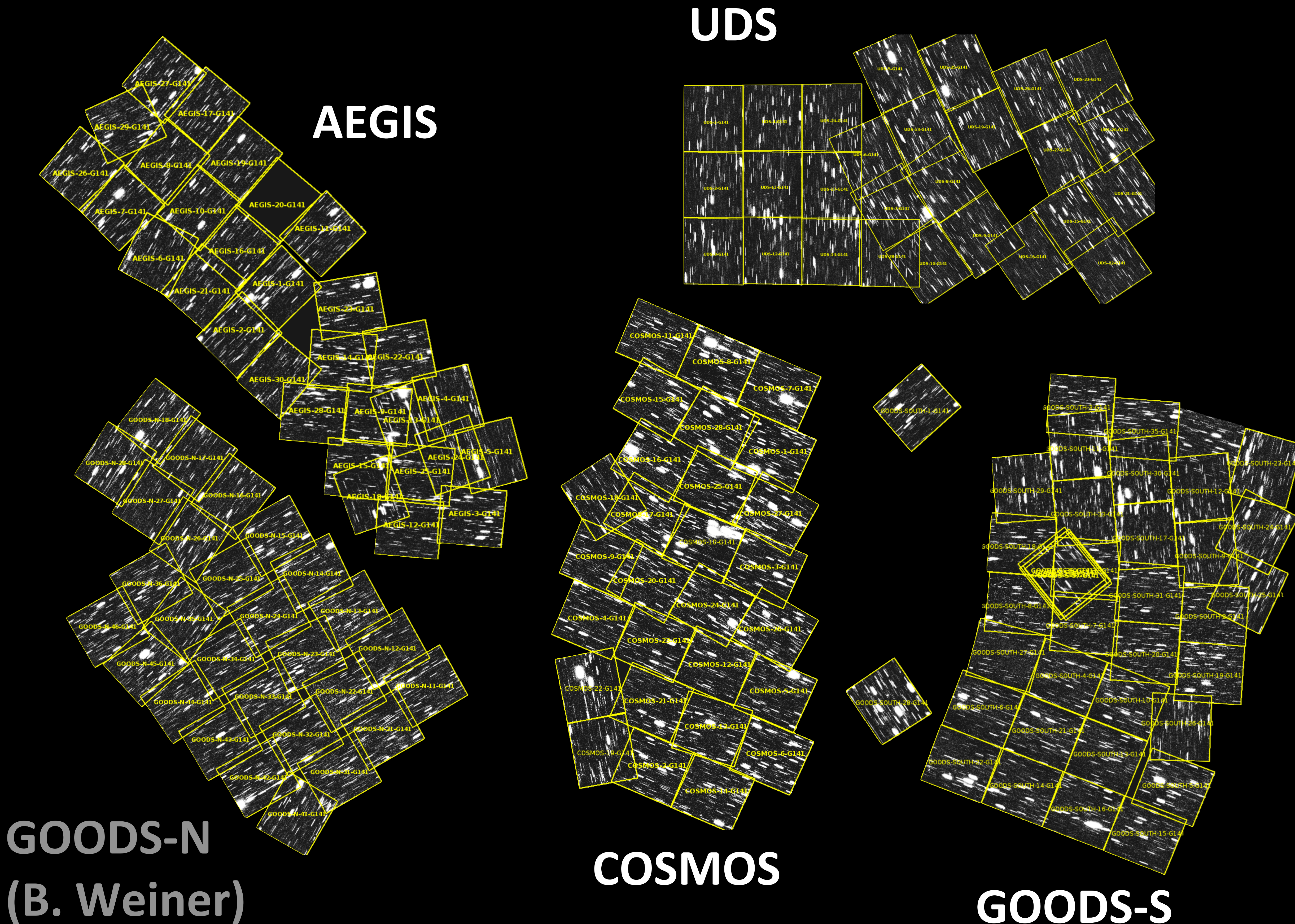


Survey Overview

(Brammer+2012, Skelton+2014)

- **Two-orbit visits** 4× [140W (800s) + G141 (4700s)] exposures
- **124 + 28** (GOODS-N, B. Weiner) pointings covering 625 arcmin^2
- ACS F814W + G800L parallels



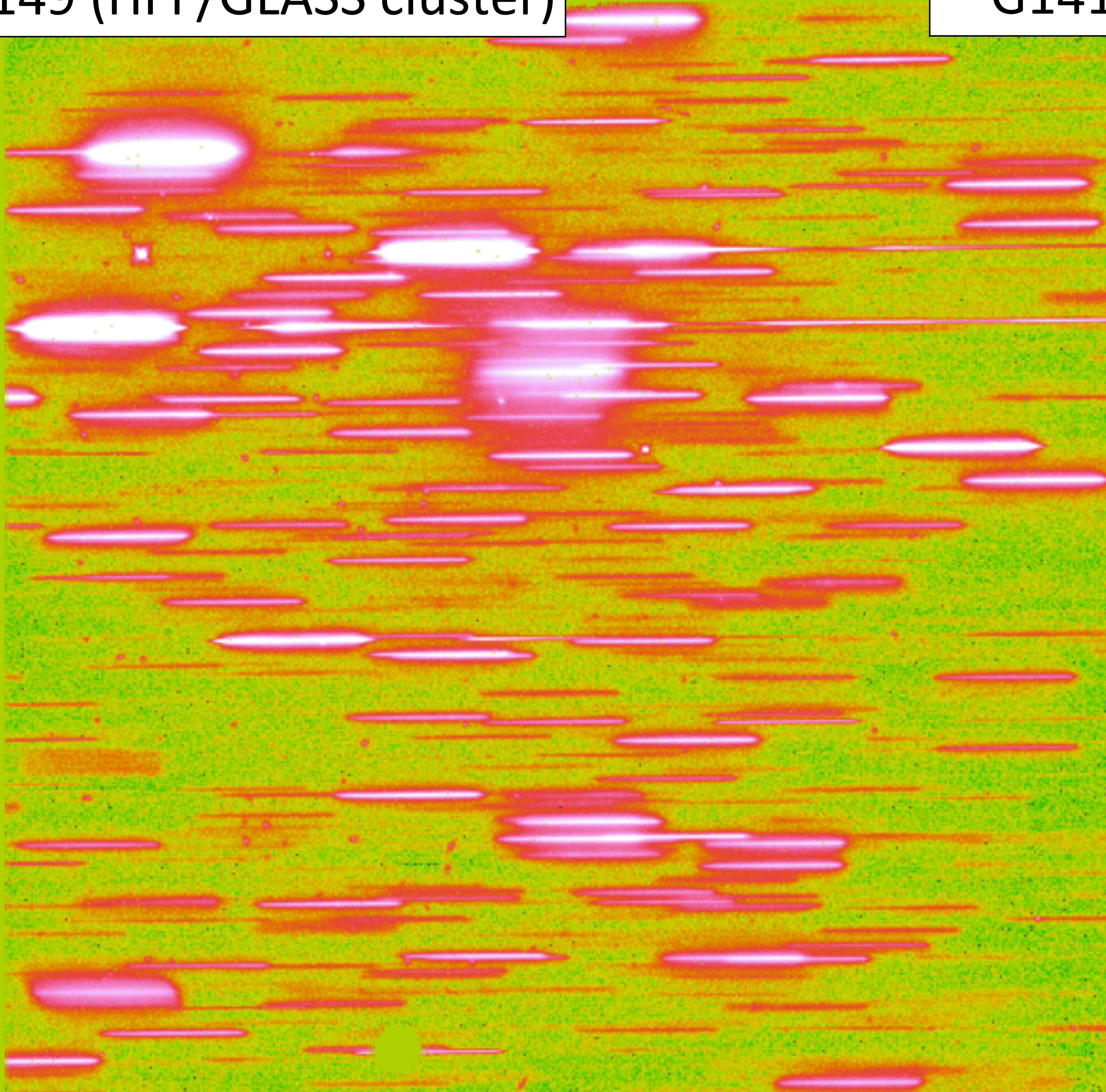

UDS
AEGIS
GOODS-N
(B. Weiner)
COSMOS
GOODS-S

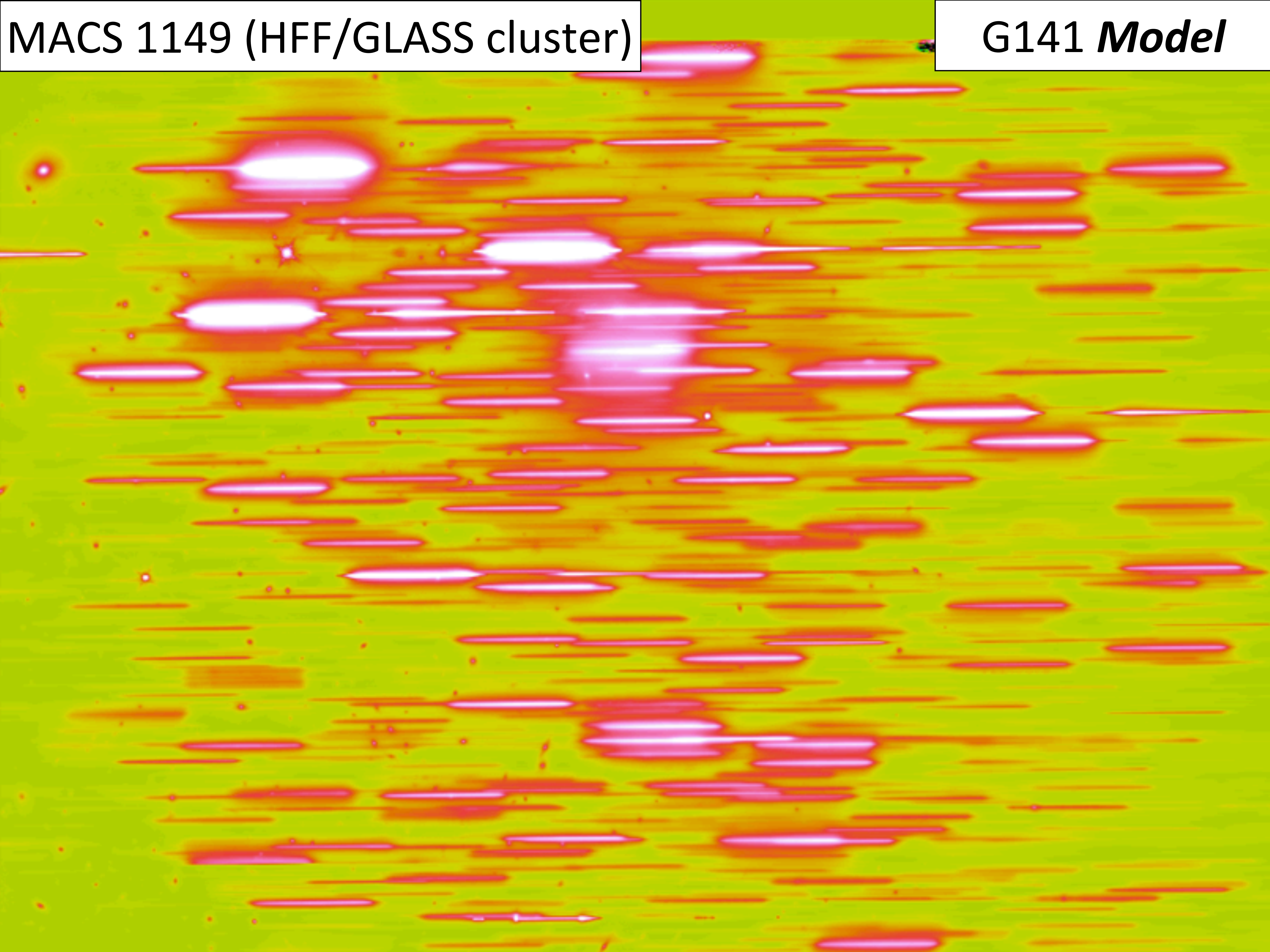
MACS 1149 (HFF/GLASS cluster)

Direct imaging

MACS 1149 (HFF/GLASS cluster)

G141 grism

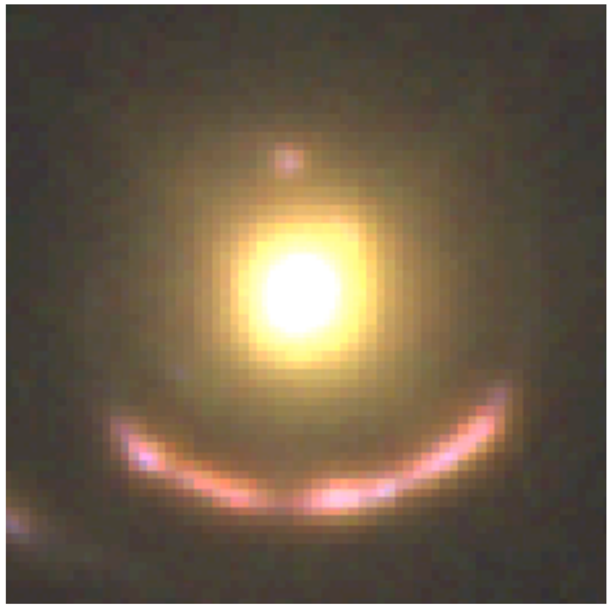


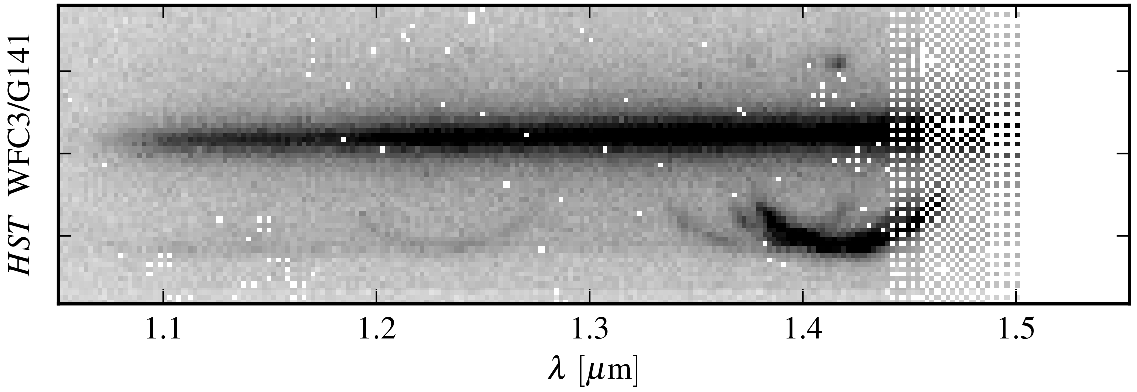

MACS 1149 (HFF/GLASS cluster)
G141 ***Model***

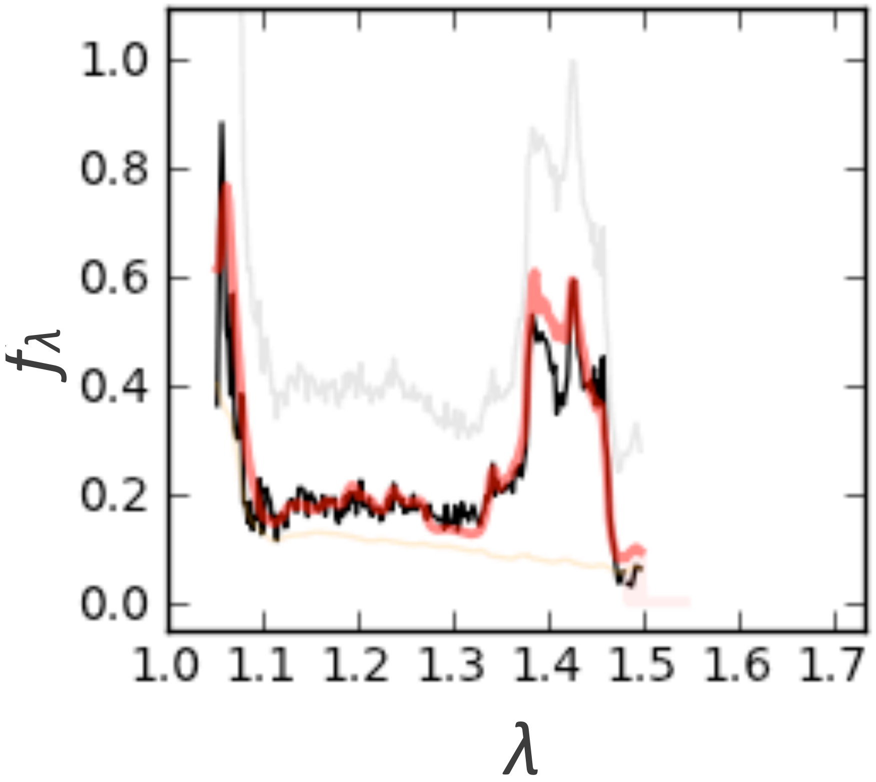
Extracting & Fitting Spectra

- The slitless configuration typically requires modeling galaxy spectra in **2D**, both for the **morphology** of the objects themselves and for **contamination** from nearby objects.

Brammer+2013







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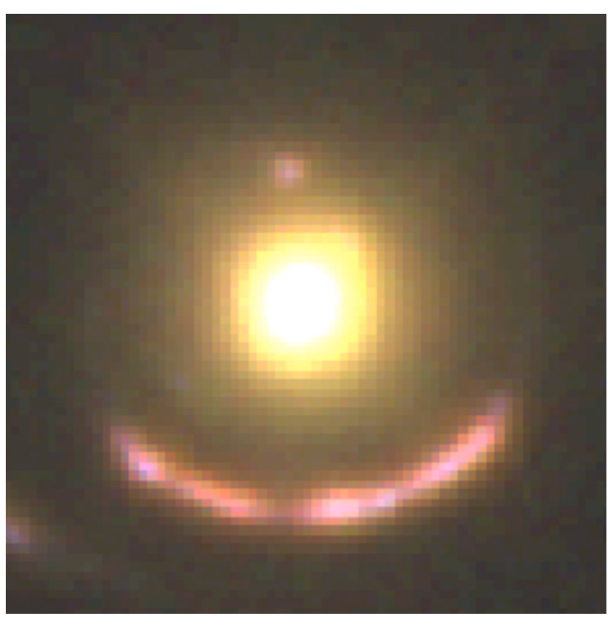
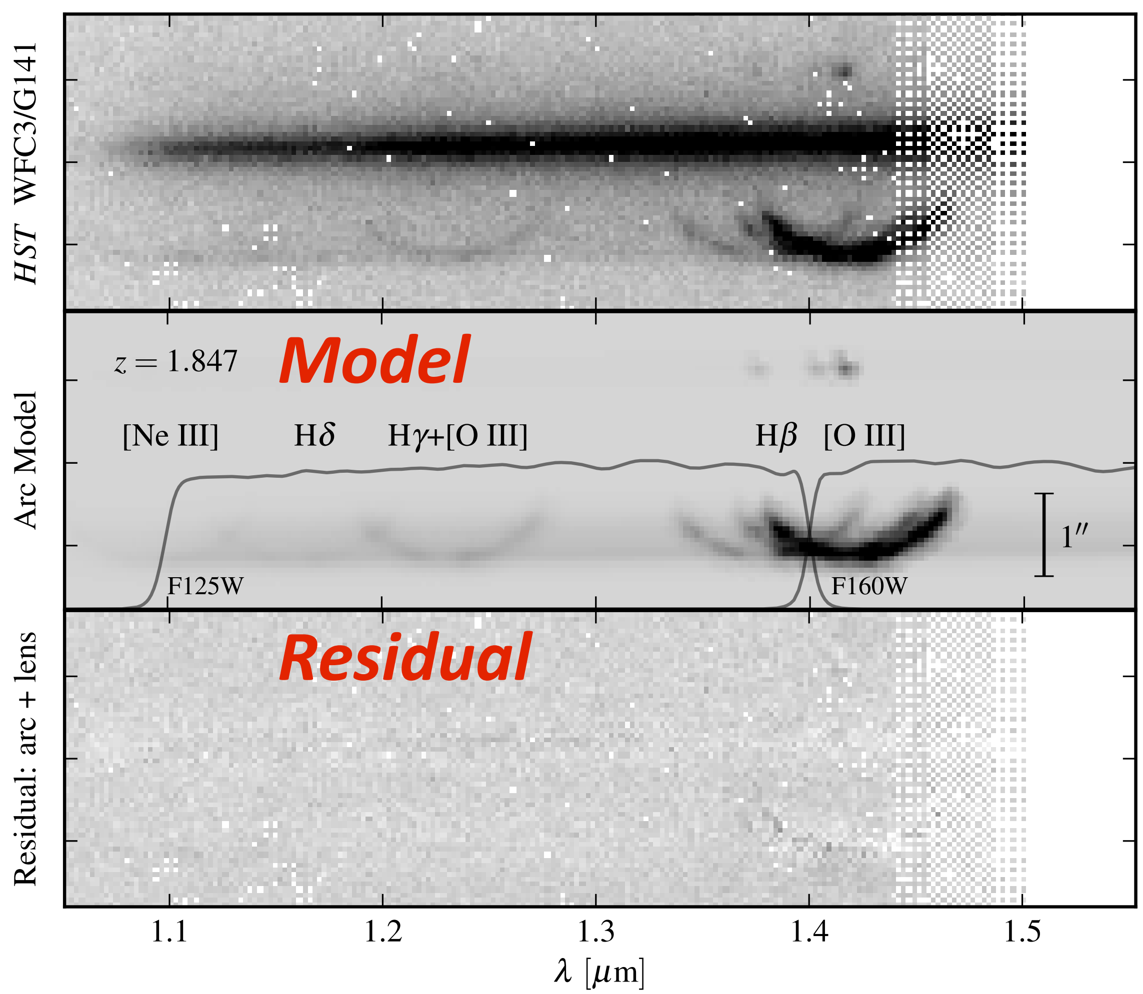
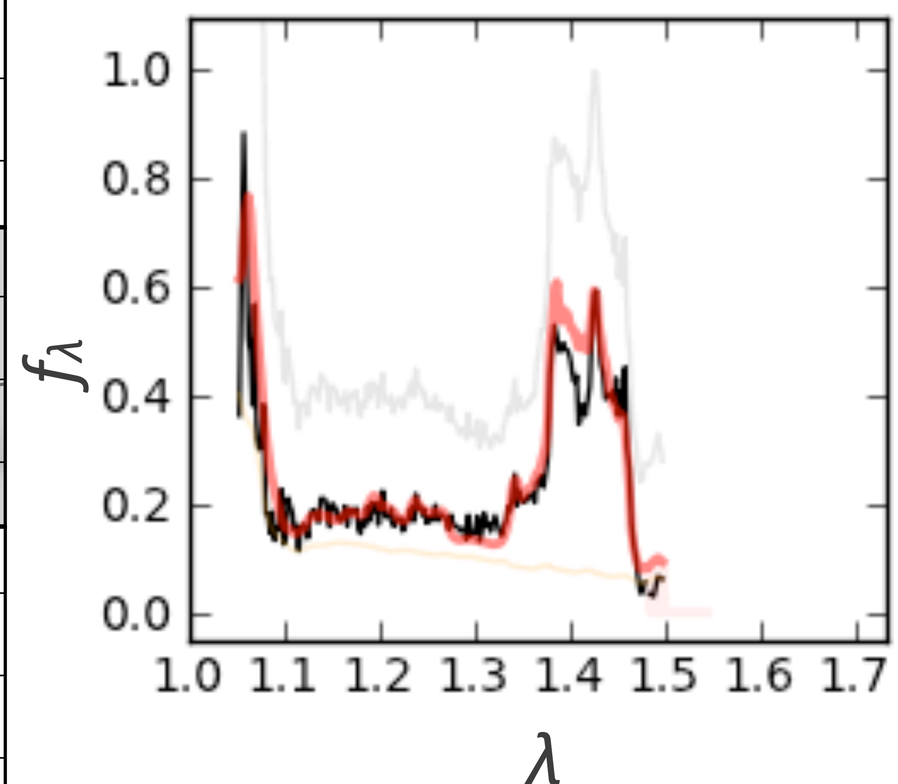


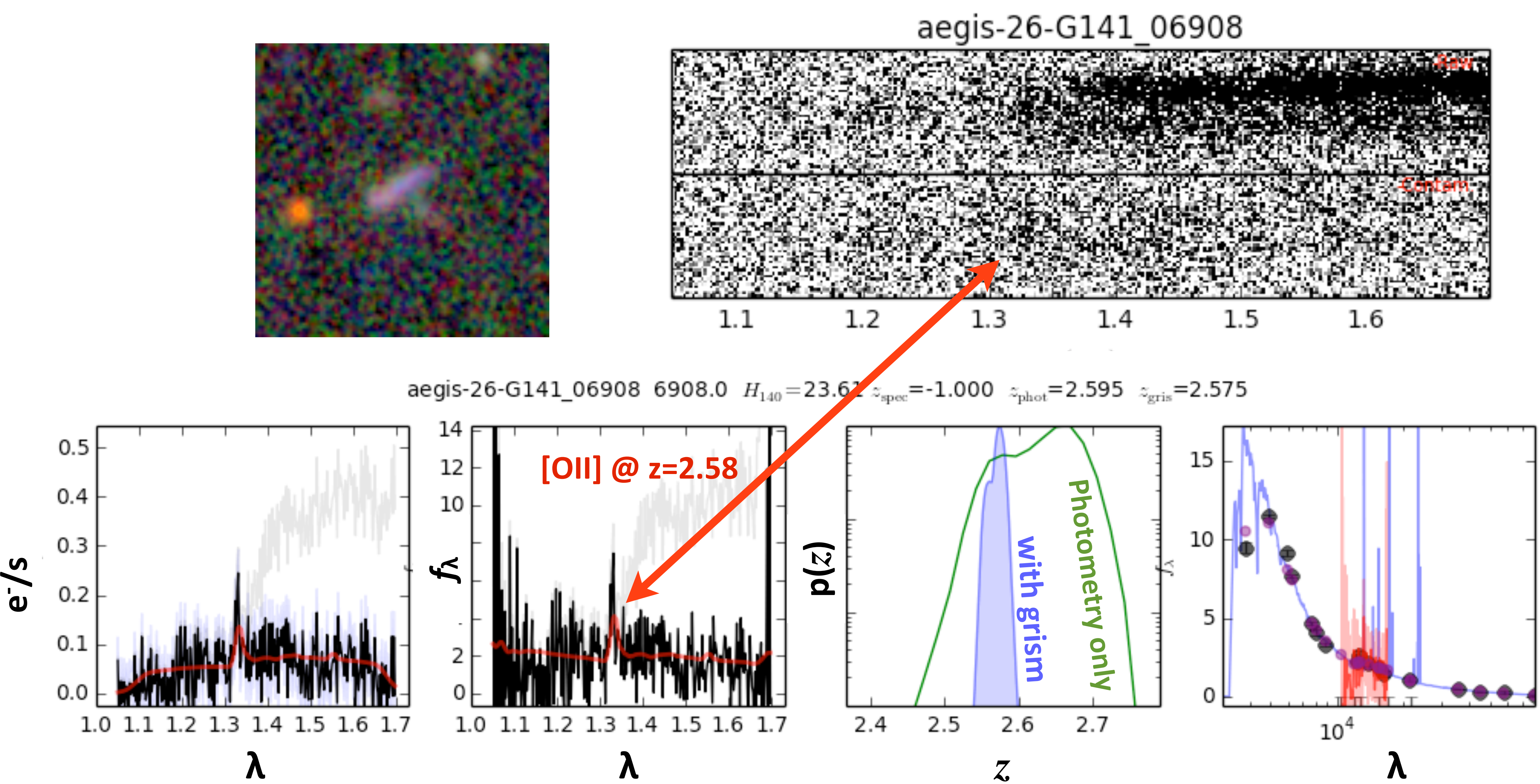
F814W F125W F160W

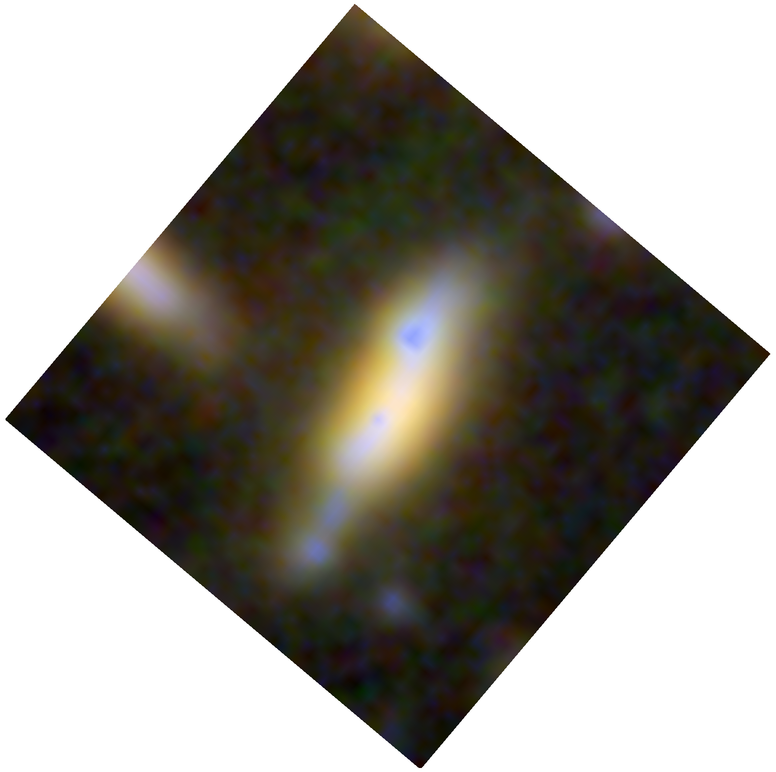


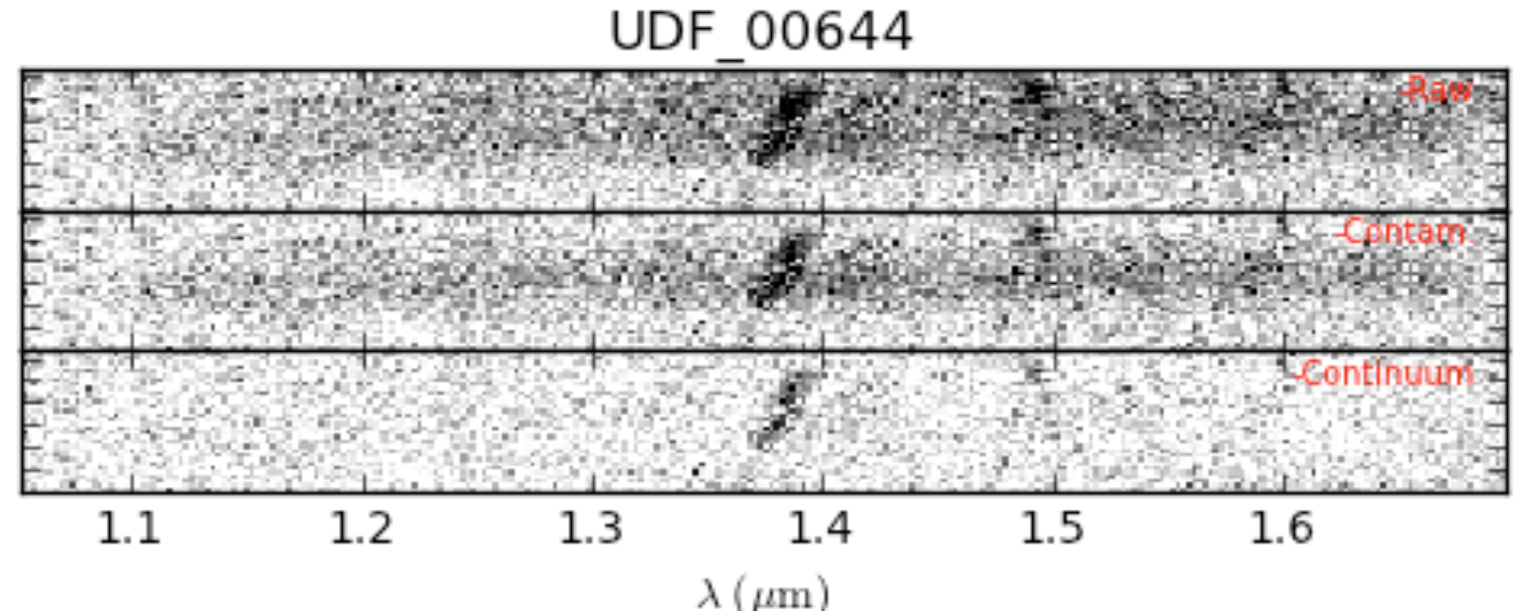


Extracting & Fitting Spectra

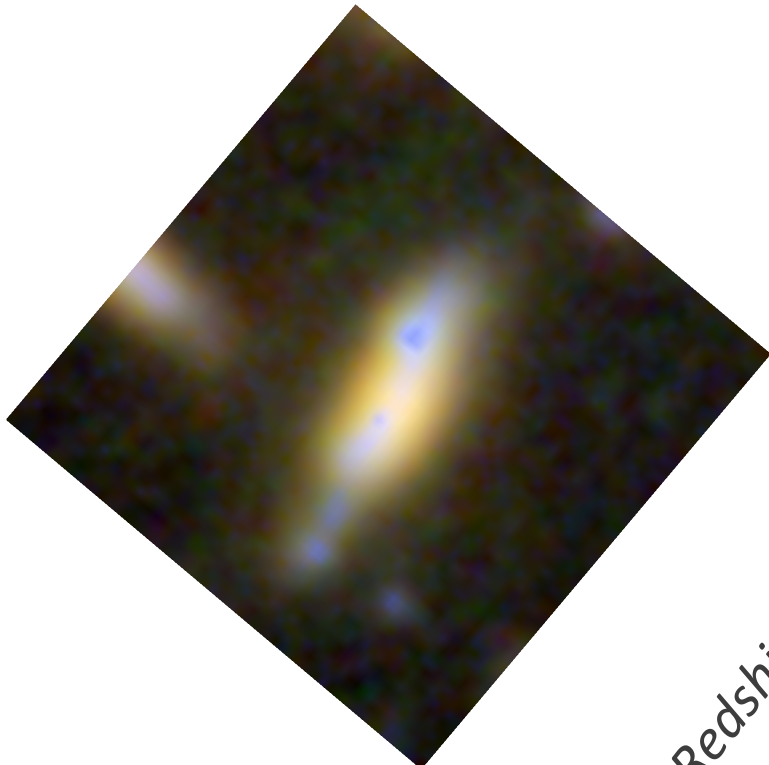
- Finding and identifying faint lines greatly aided by constraints from **ancillary photometry** (e.g., CANDELS: **Skelton+2014**)

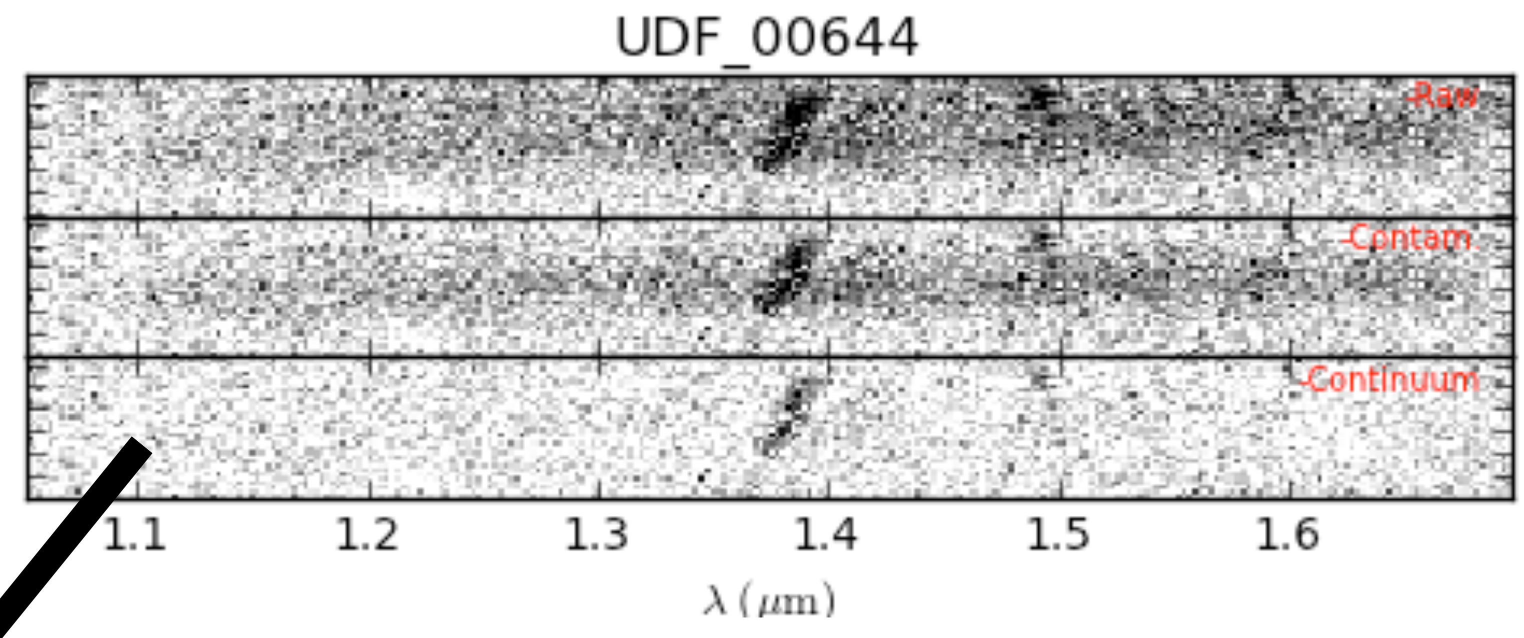




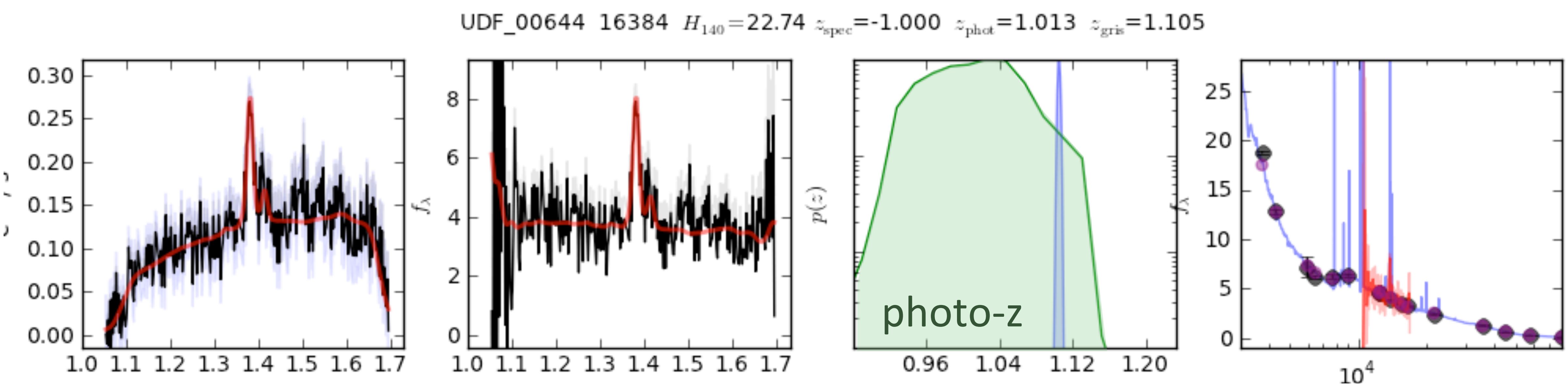


Model all objects and extract 2D spectra.
*All **fits** are done on the 2D specdtra.*





Redshift fits

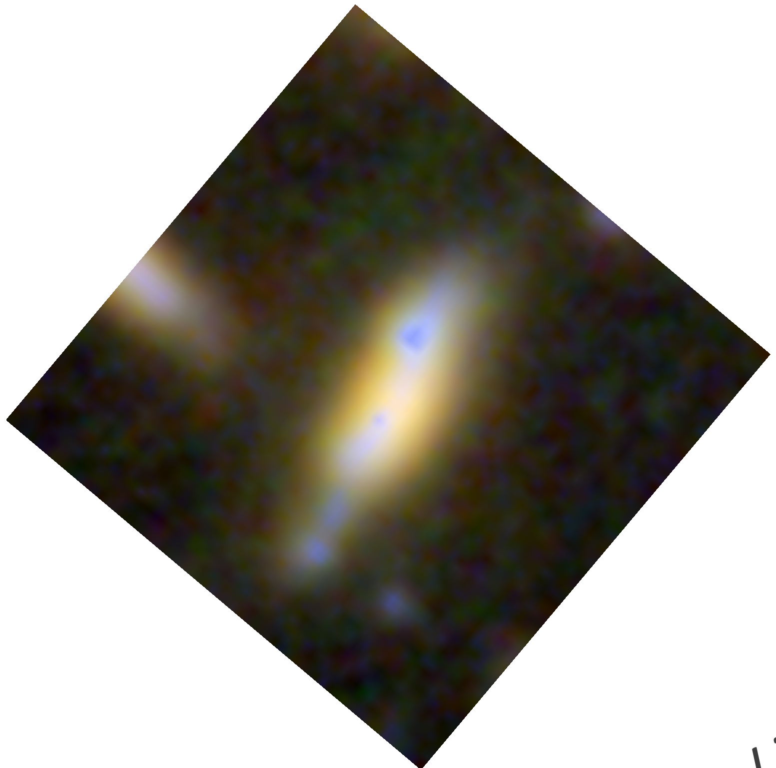


(electrons / s)

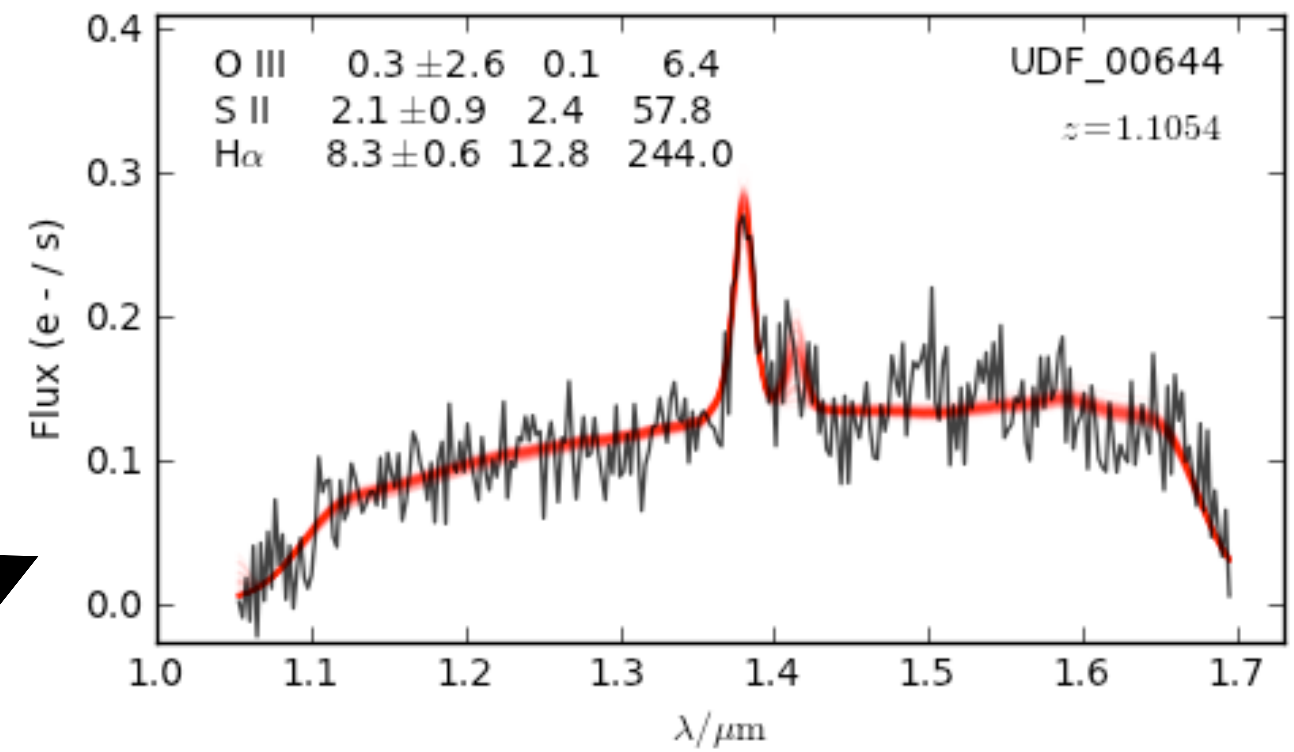
(flux calibrated)

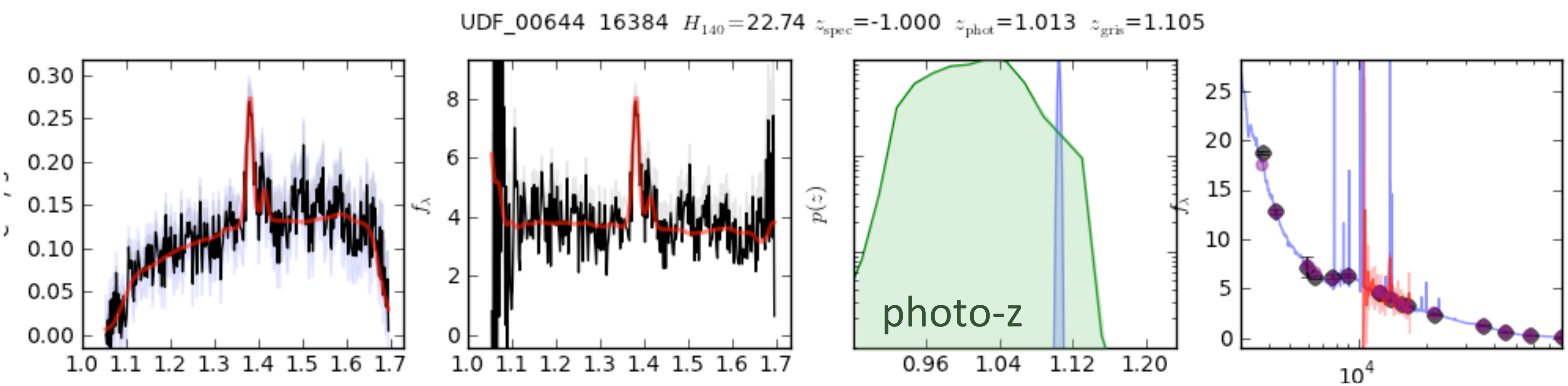
p(z)

(with broadband photometry) Skelton+2014

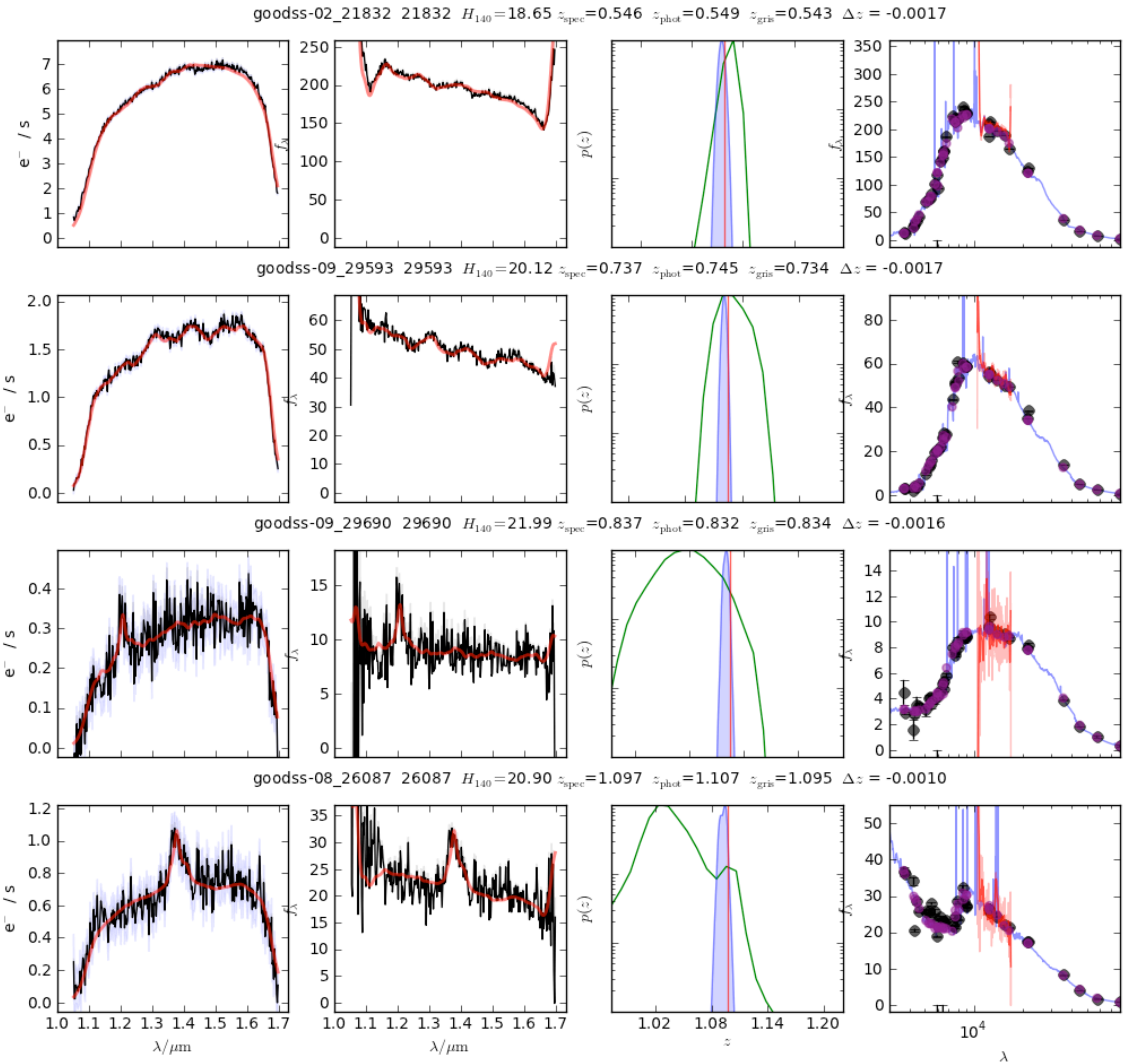


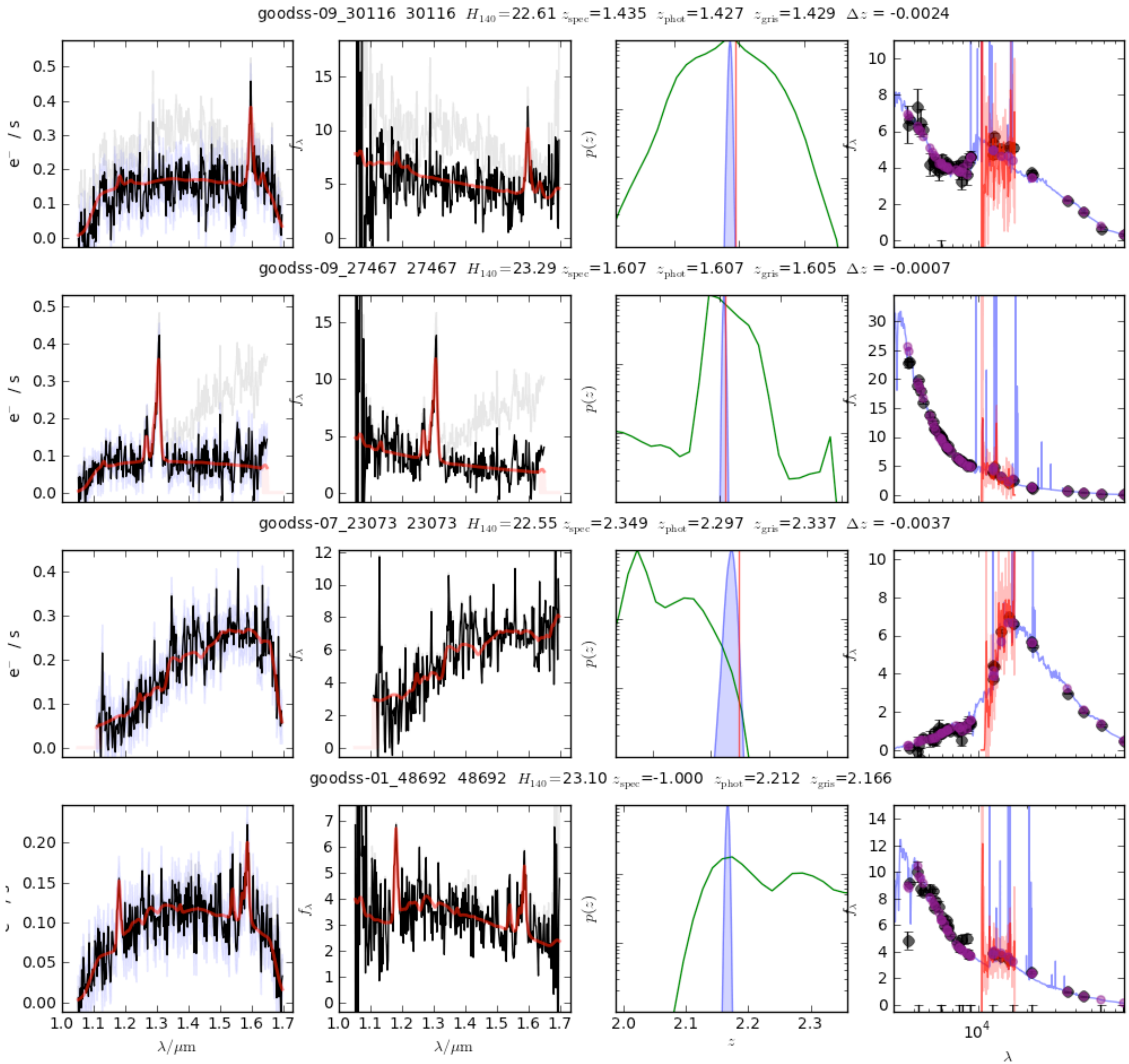
Line fits





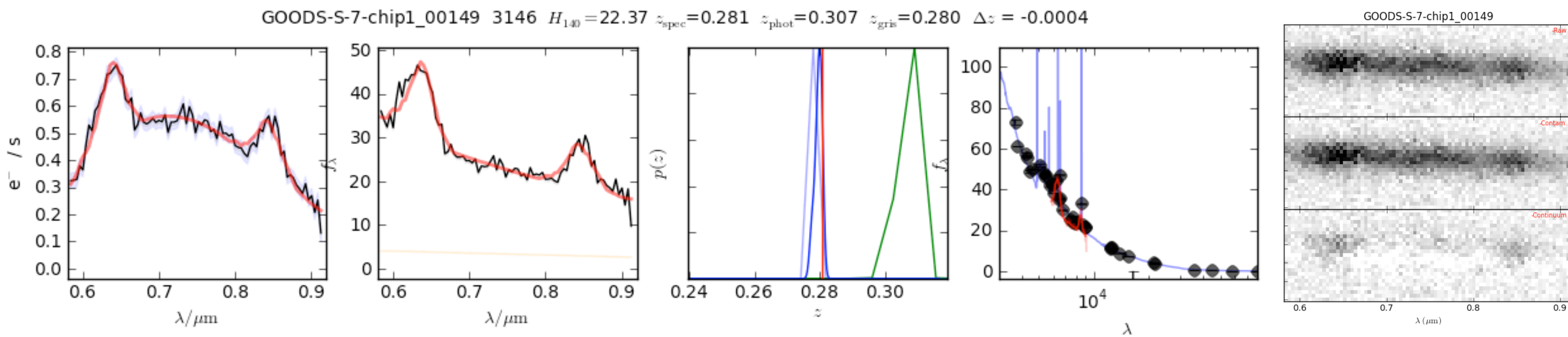
(electrons / s) **(flux calibrated)** **p(z)** ***(with broadband photometry) Skelton+2014***

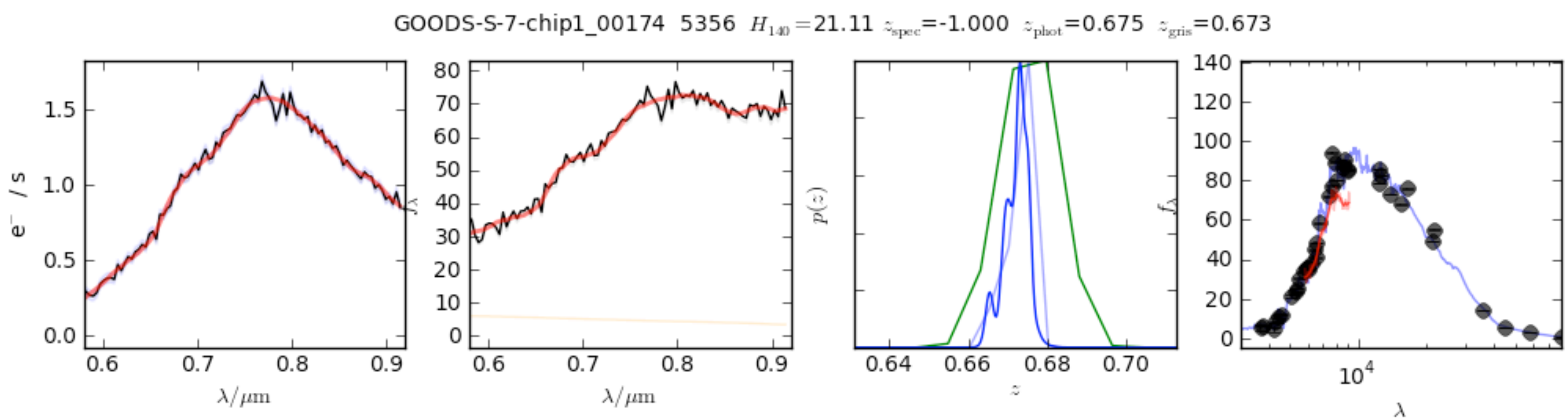

goodss-02_21832 21832 H_{140}=18.65 $z_{\rm spec}$=0.546 $z_{\rm phot}$=0.549 $z_{\rm gris}$=0.543 Δz = -0.0017
goodss-09_29593 29593 H_{140}=20.12 $z_{\rm spec}$=0.737 $z_{\rm phot}$=0.745 $z_{\rm gris}$=0.734 Δz = -0.0017
goodss-09_29690 29690 H_{140}=21.99 $z_{\rm spec}$=0.837 $z_{\rm phot}$=0.832 $z_{\rm gris}$=0.834 Δz = -0.0016
goodss-08_26087 26087 H_{140}=20.90 $z_{\rm spec}$=1.097 $z_{\rm phot}$=1.107 $z_{\rm gris}$=1.095 Δz = -0.0010
e⁻ / s
f_λ
$p(z)$
λ/μm
z
λ
10^4



goodss-09_30116 30116 H_{140}=22.61 $z_{\rm spec}$=1.435 $z_{\rm phot}$=1.427 $z_{\rm gris}$=1.429 Δz = -0.0024
goodss-09_27467 27467 H_{140}=23.29 $z_{\rm spec}$=1.607 $z_{\rm phot}$=1.607 $z_{\rm gris}$=1.605 Δz = -0.0007
goodss-07_23073 23073 H_{140}=22.55 $z_{\rm spec}$=2.349 $z_{\rm phot}$=2.297 $z_{\rm gris}$=2.337 Δz = -0.0037
goodss-01_48692 48692 H_{140}=23.10 $z_{\rm spec}$=-1.000 $z_{\rm phot}$=2.212 $z_{\rm gris}$=2.166
e⁻ / s
f_λ
$p(z)$
λ/μm
z
λ
10^4

ACS G800L parallels

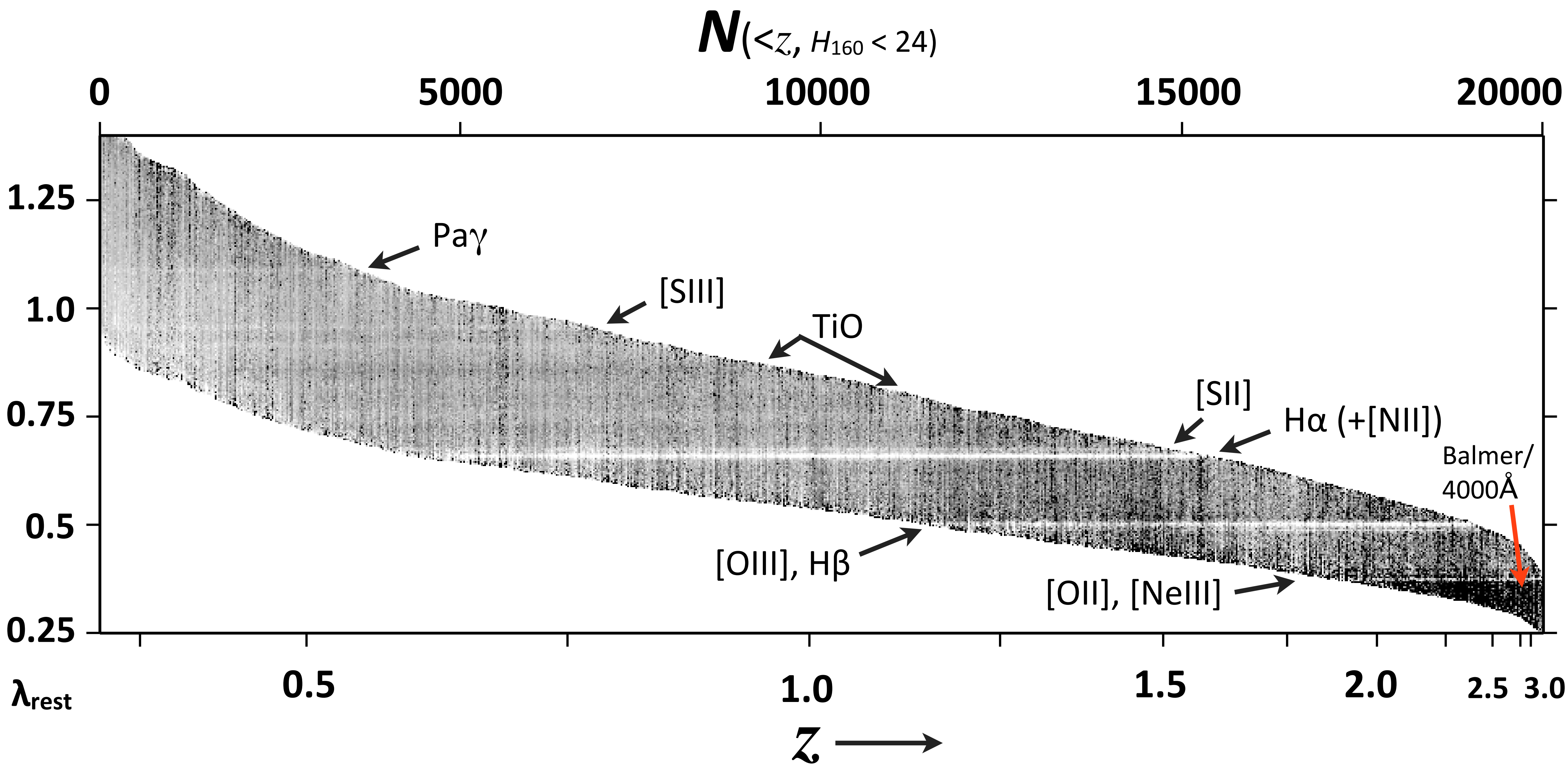




- The 3D-HST reduction pipeline works for ACS/G800L spectra as well, but we have currently focused primarily on IR/G141.

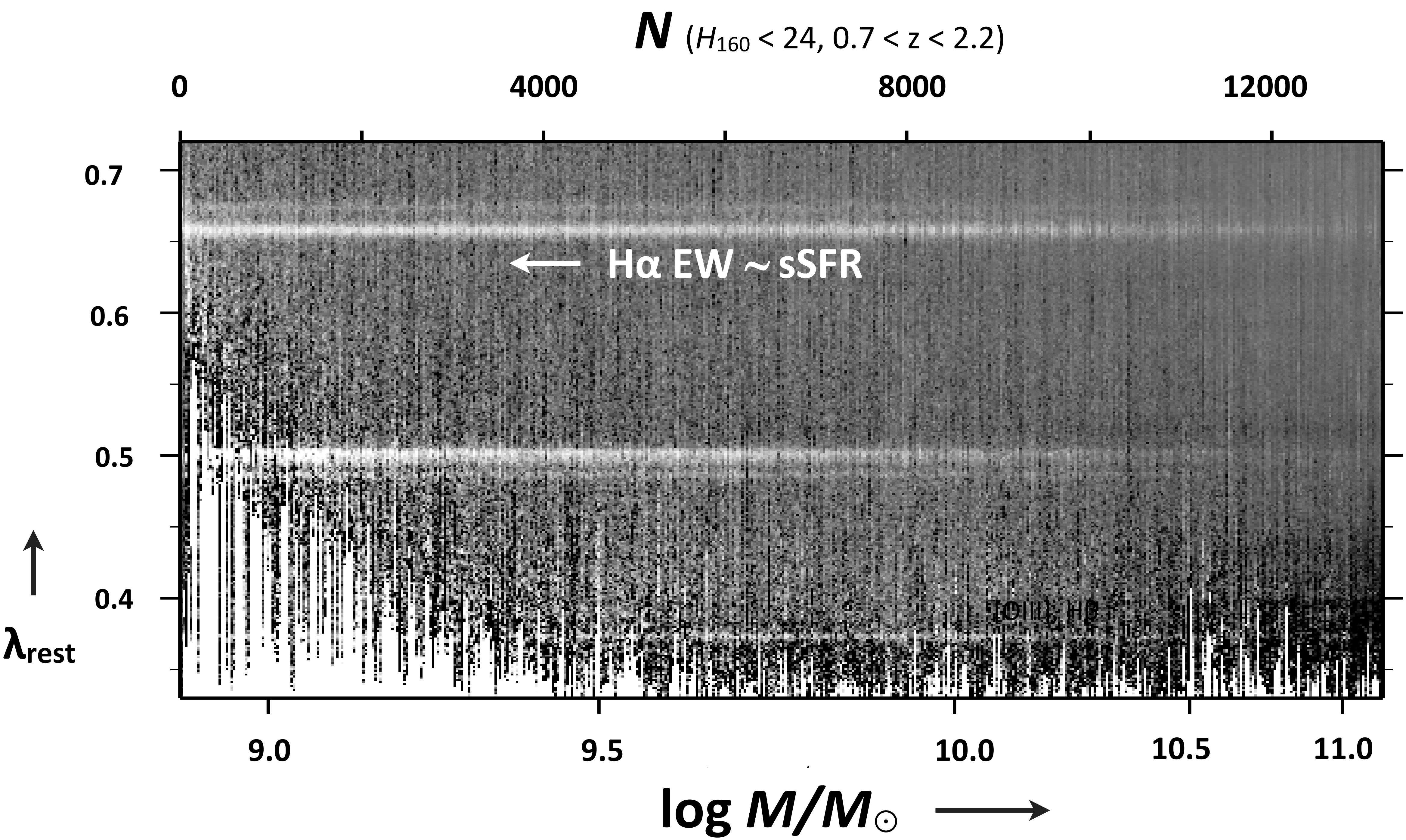
A (mini) "Sloan in Space"

- Slitless spectra provide a **spectrum of everything** in the field. The challenge is *extracting, fitting and cataloging* spectra of everything.



A (mini) "Sloan in Space"

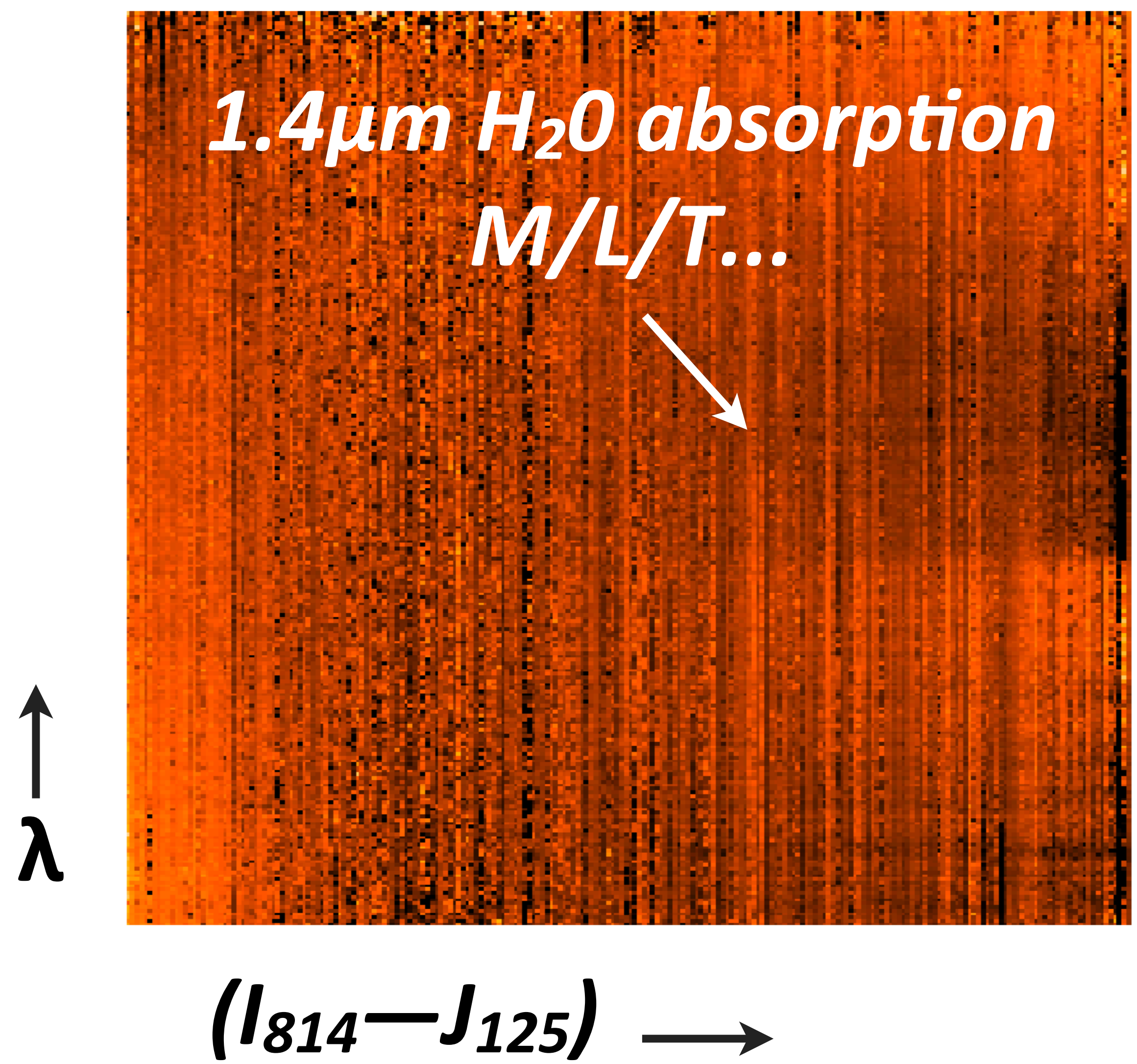
- **Highly complete** spectroscopic coverage allows detailed study of correlation and evolution of galaxy properties



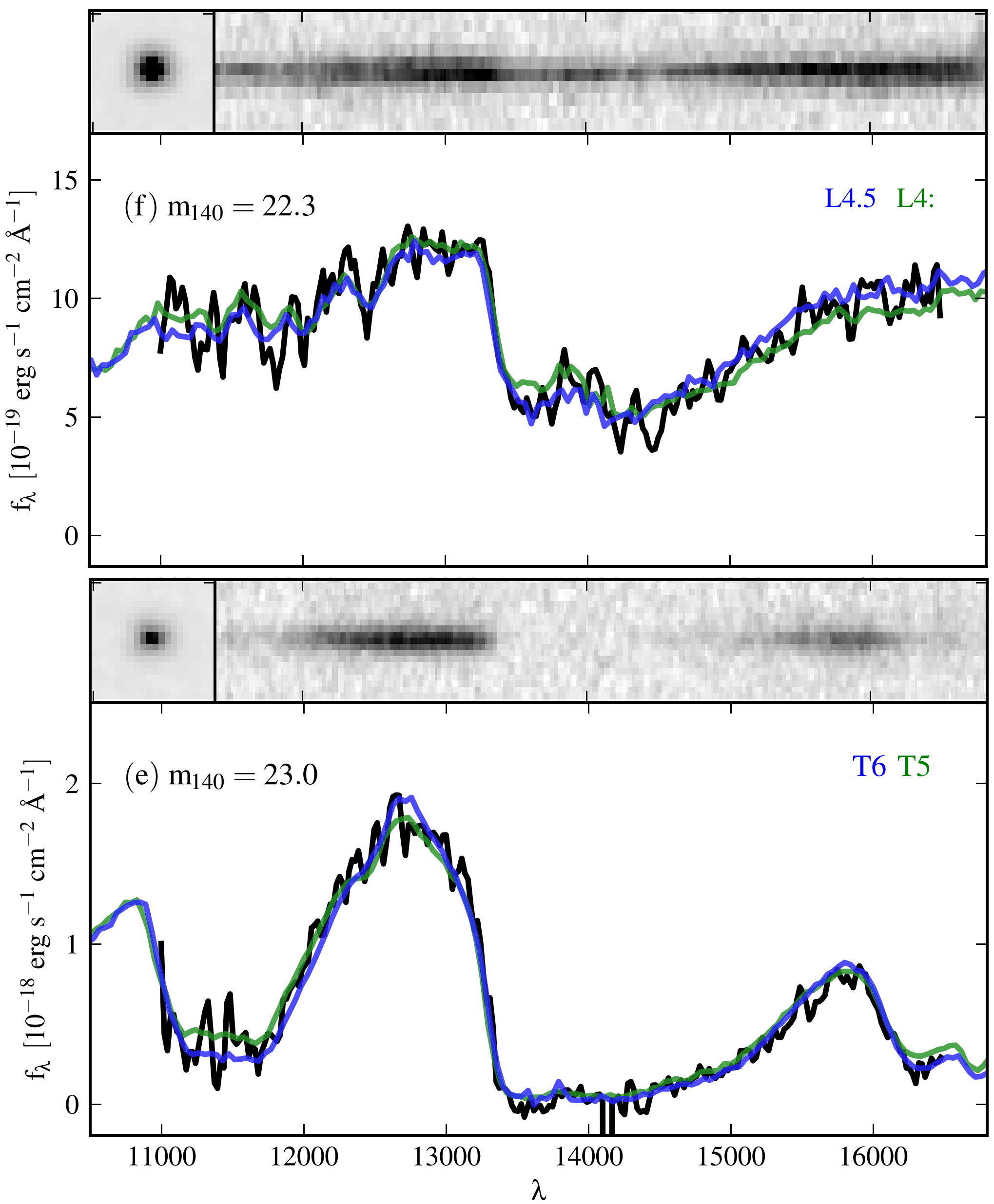
A (mini) "Sloan in Space"

- **Highly complete** spectroscopic coverage allows detailed study of correlation and evolution of galaxy properties

(Stars, too)

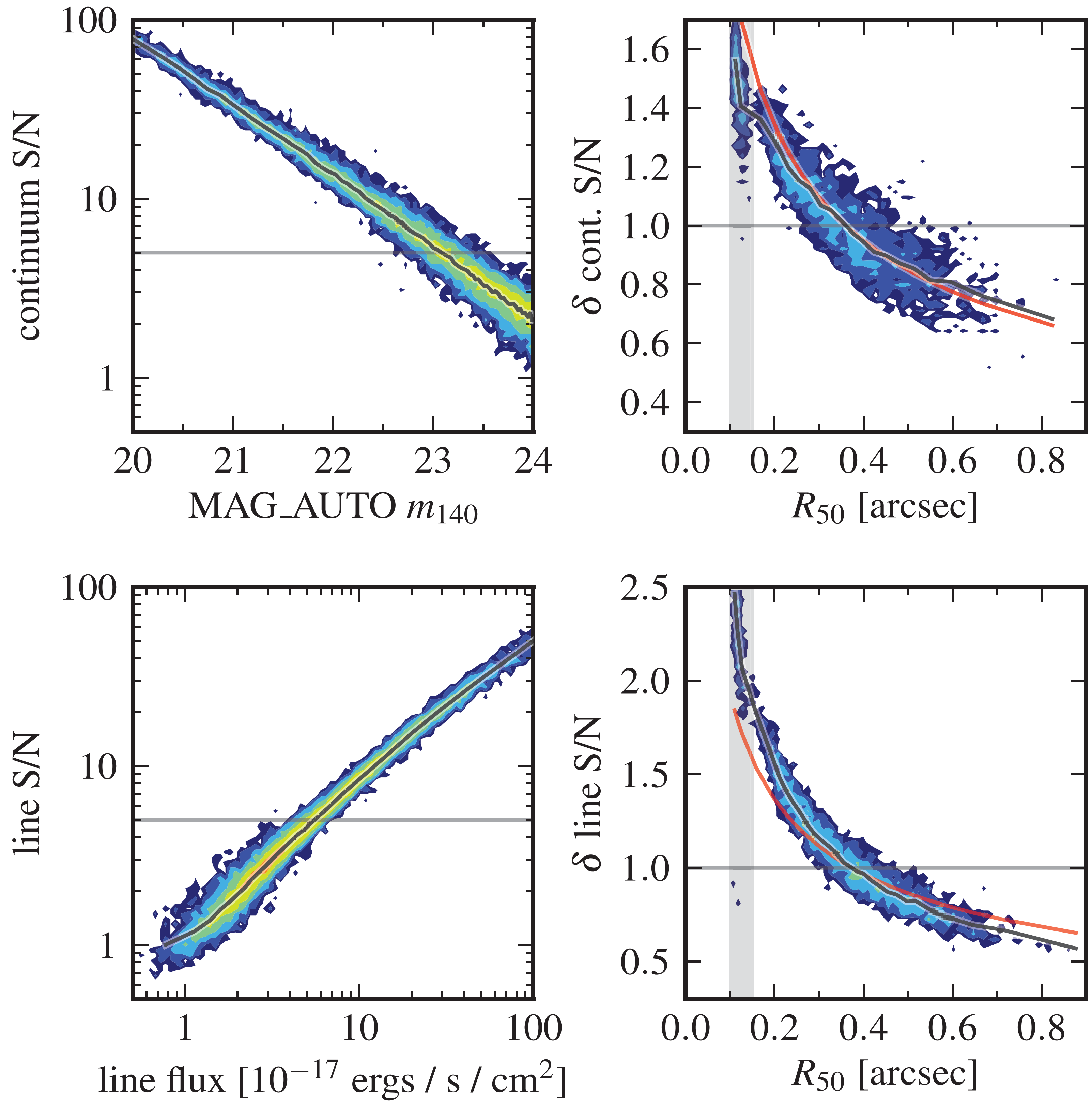


Brammer+2012, Masters+2012



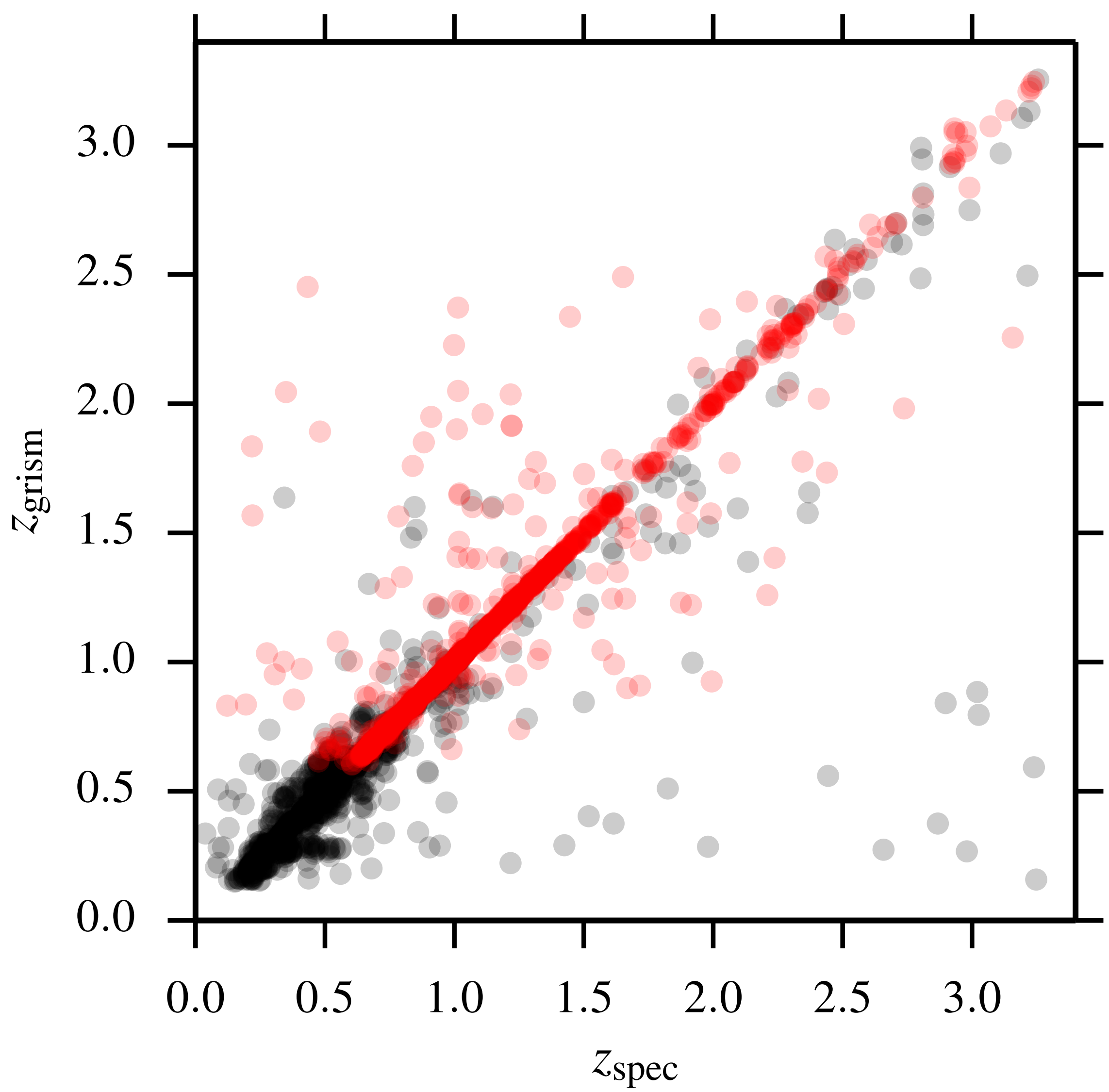
Sensitivity

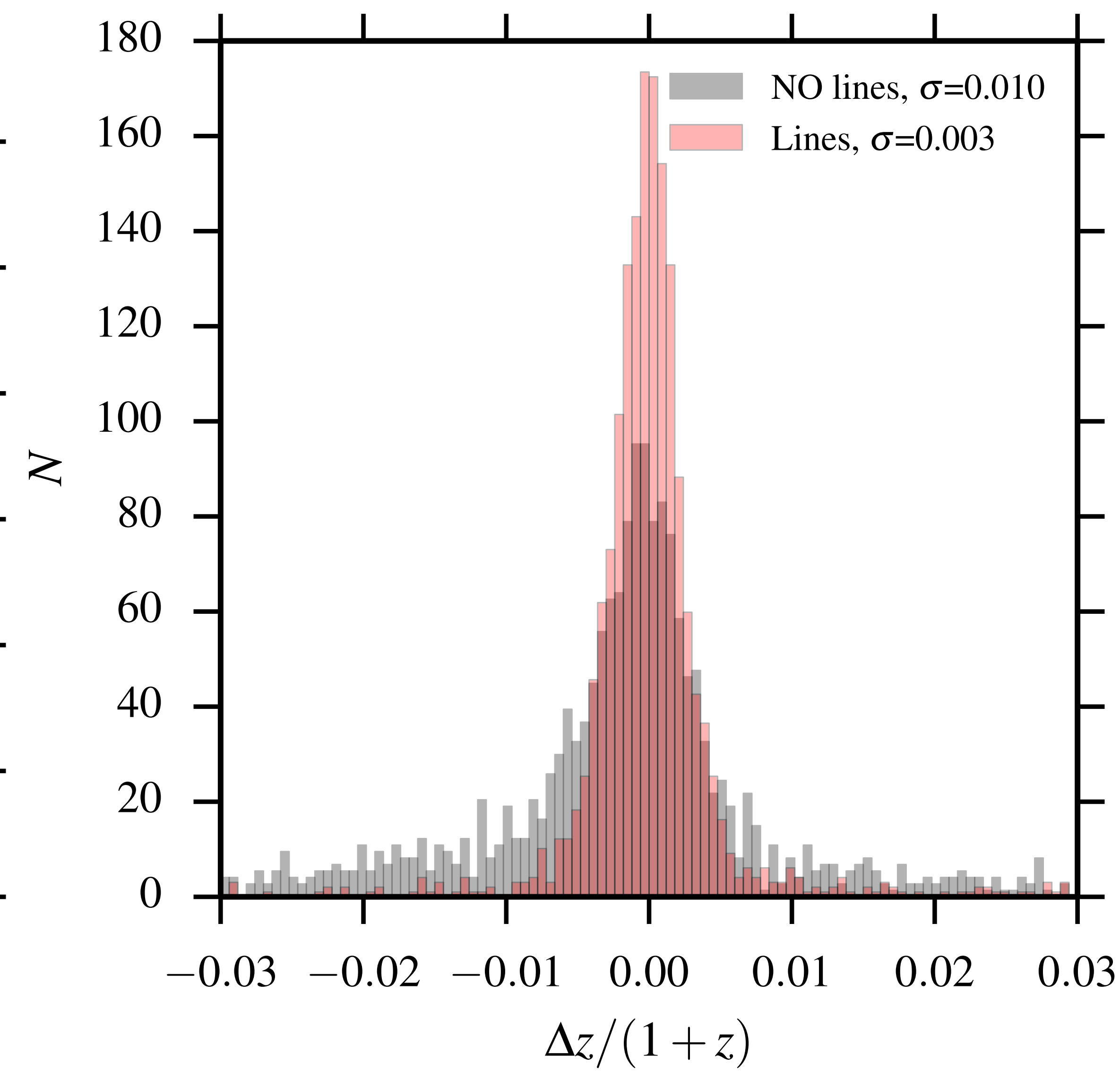
- **Continuum** sensitivity
  - 5σ @ H_{140}=23.2
- **Line** sensitivity
  - 5σ @ 5×10^{-17} erg/s/cm^2
- Both depend on object size (and background)



Redshift precision

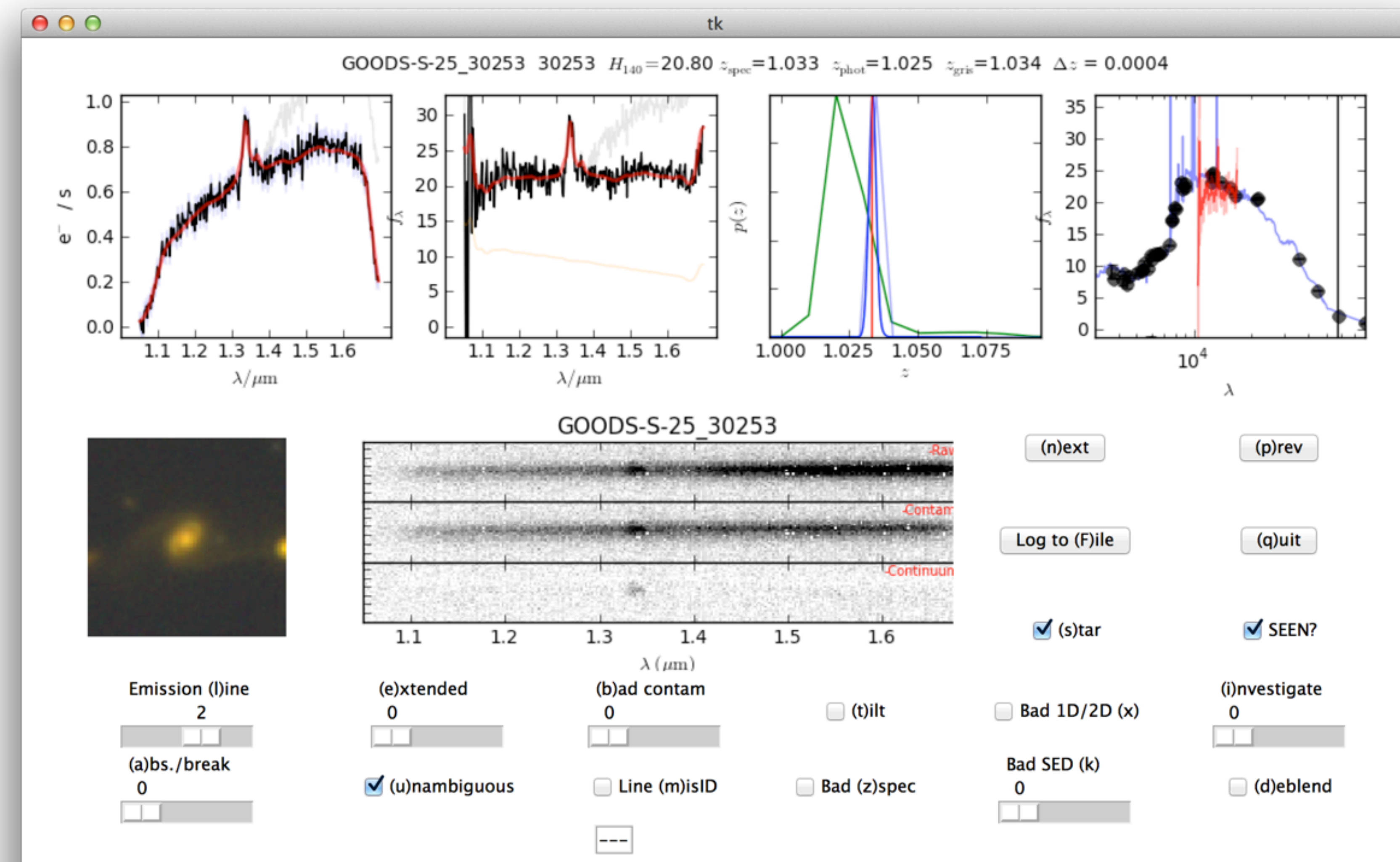
- For objects with detected lines, δz/(1+z), σ=0.3% ~ 1000 km/s
- 1% for objects without lines, depends on availability of good photometry + photo-zs.





Outstanding issues

- Some remaining minor bugs with the pipeline + improvements in SED fitting
- All spectra must be **inspected visually** by one or more people for gross data-quality failures



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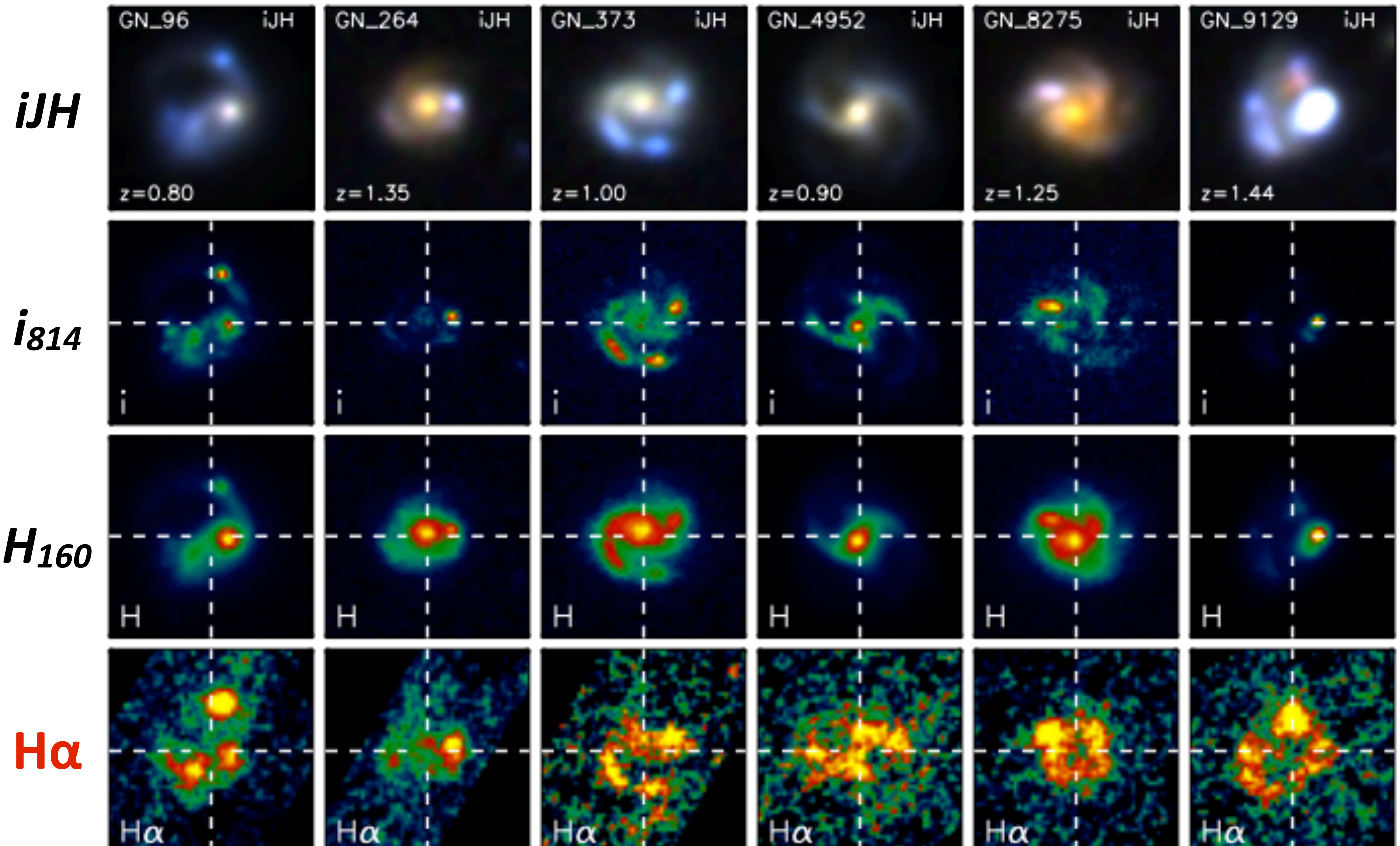
Catalog release

- **We're planning for a full spectroscopic release in March 2015**
  - *Redshifts, emission line fluxes, quality flags, 1D+2D spectra, tools*
- Certainly ~20K sample at H_{160}<24, likely to also have extracted spectra, if not full fits, to fainter magnitudes
  - Low S/N in continuum, but many emission lines at 24 < H < 26

Science: Hα maps at *HST* spatial resolution

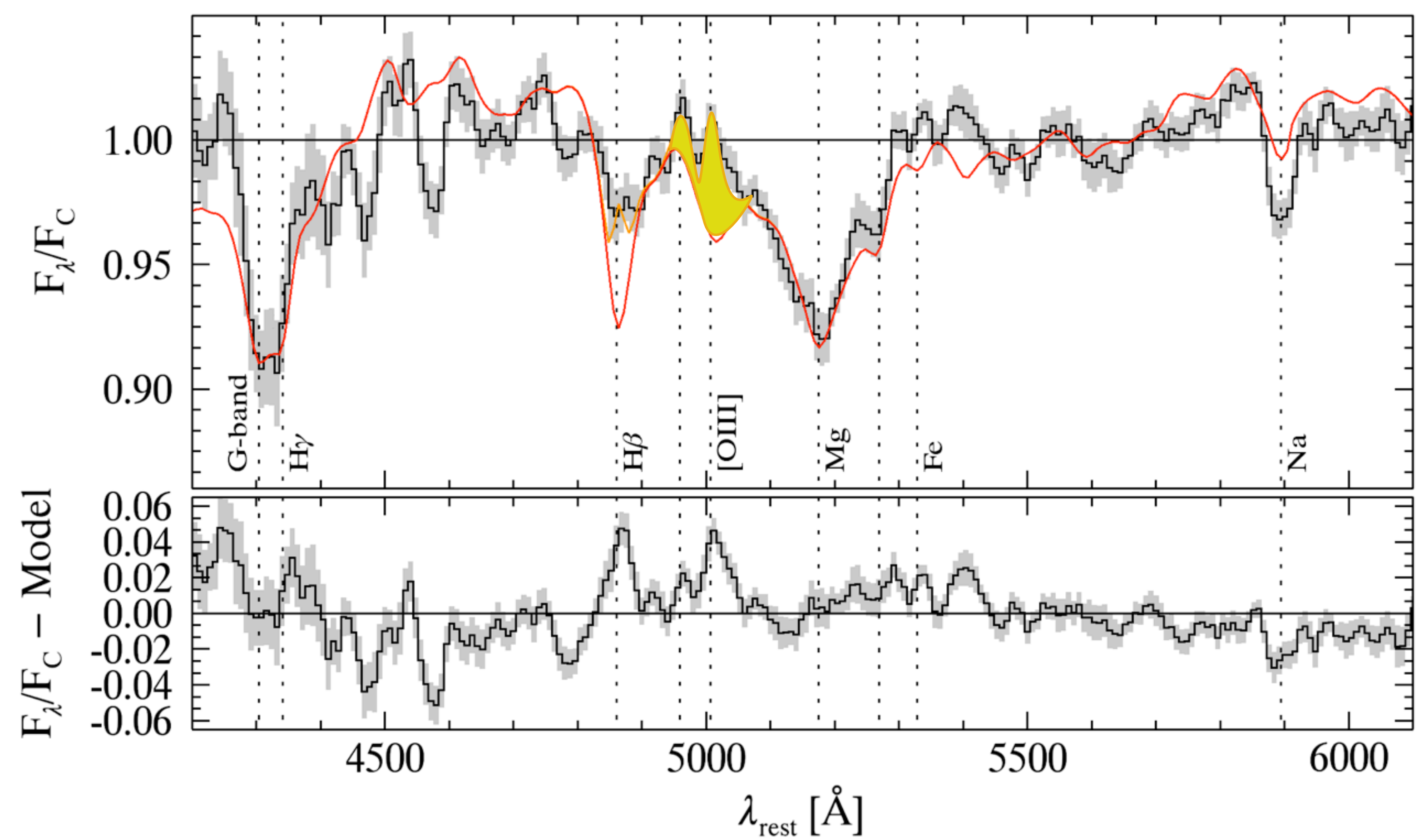
Wuyts+2013, see also Nelson+2012,2013

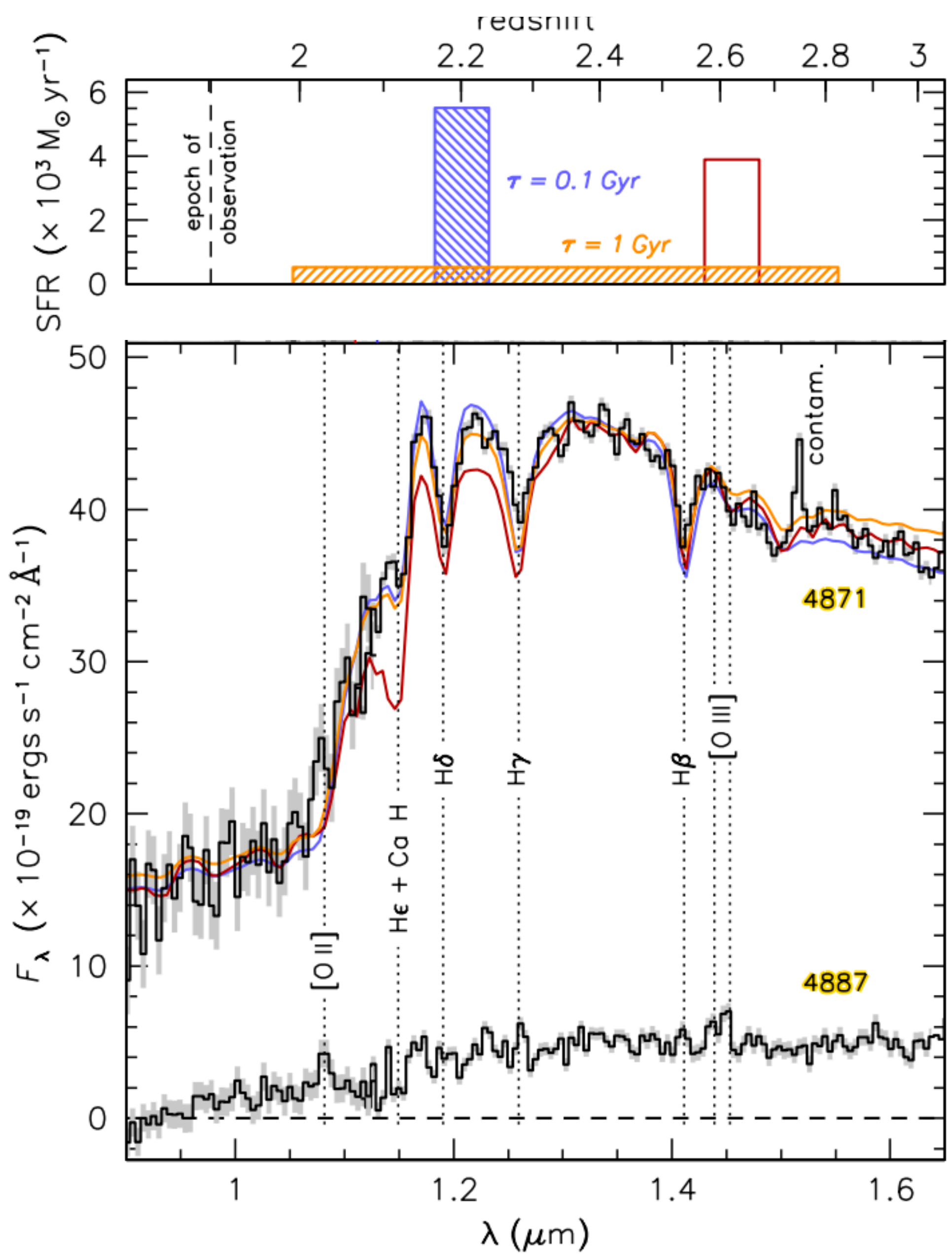


Science: Absorption line spectra

- Near-IR Continuum sensitivity difficult/impossible to achieve from the ground for N > few samples

Stack: Whitaker+2013





Individual:
van Dokkum & Brammer (2010)

Science: Absorption line spectra

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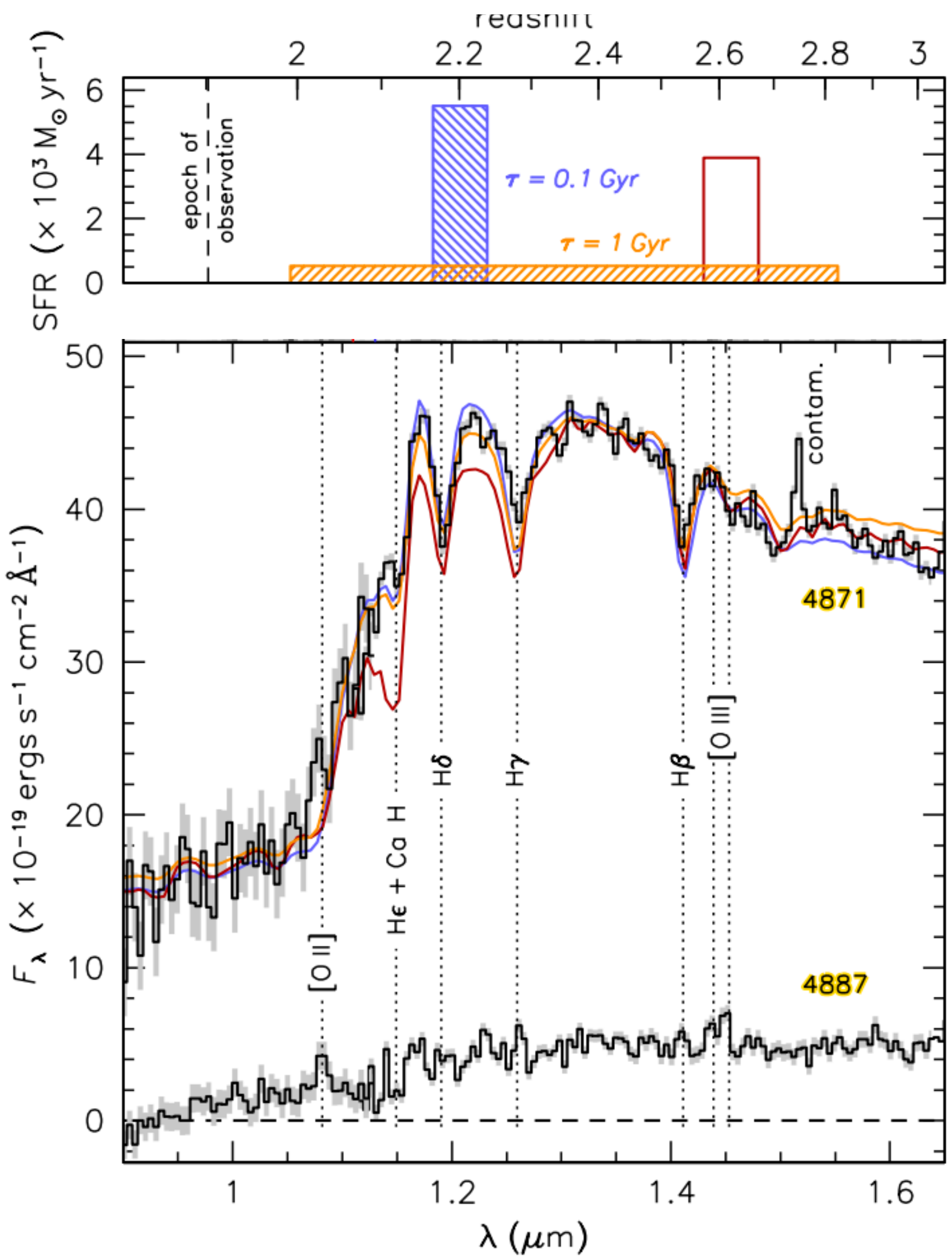

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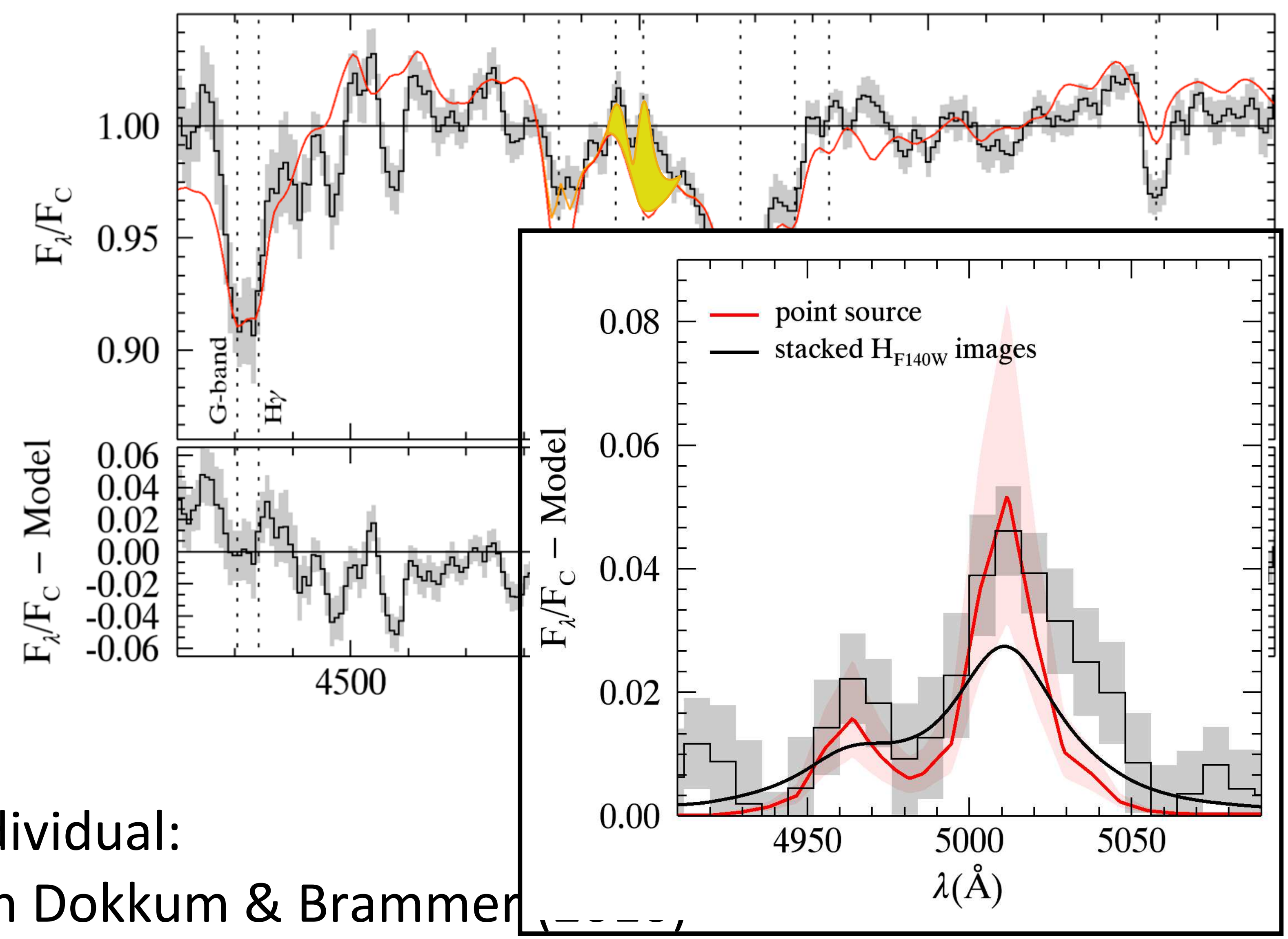


Individual:
van Dokkum & Brammer

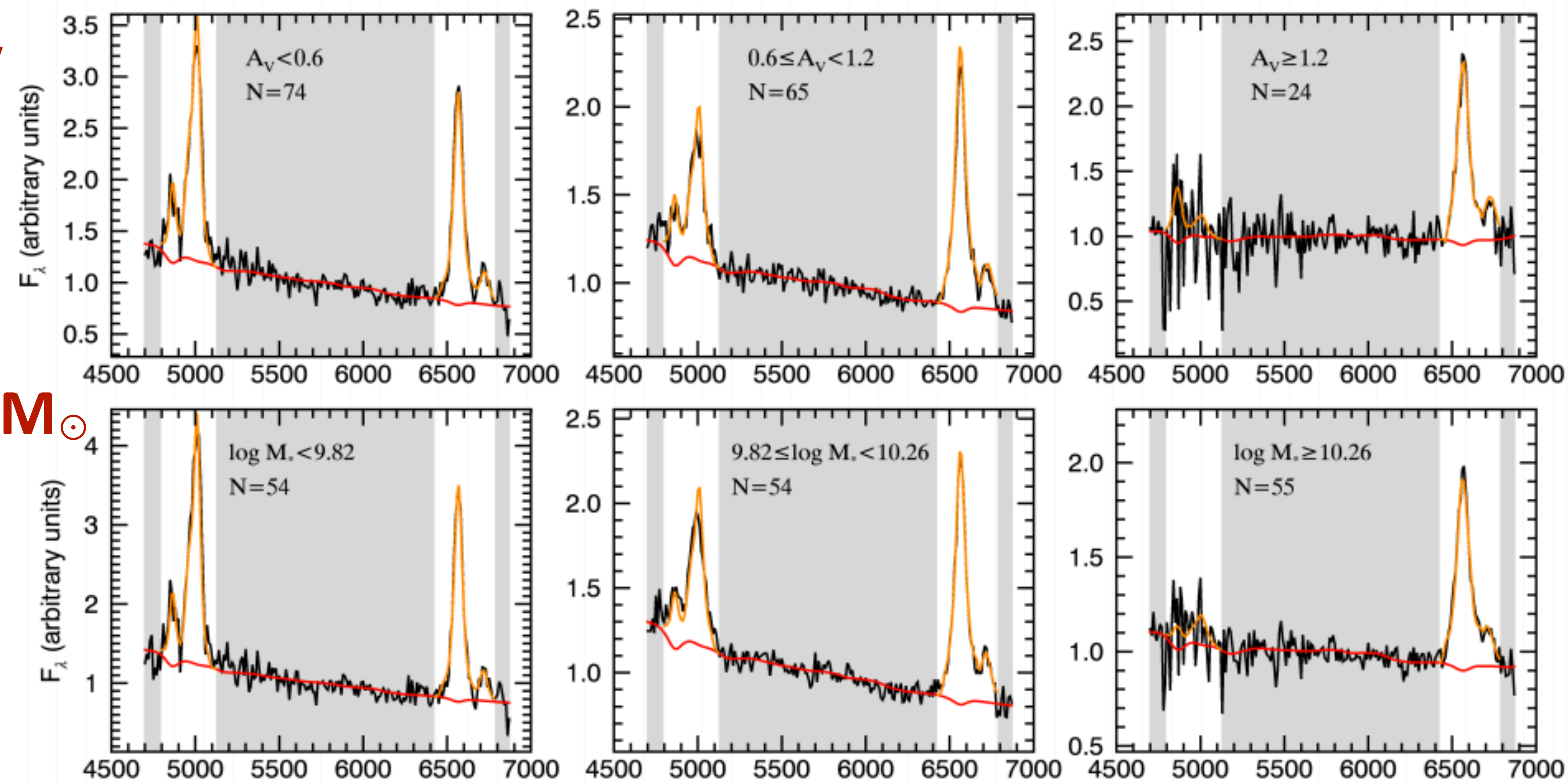
Science: Balmer decrements

- Hα + [OIII]/Hβ at z~1.3

Bins of A_V

Price+2014

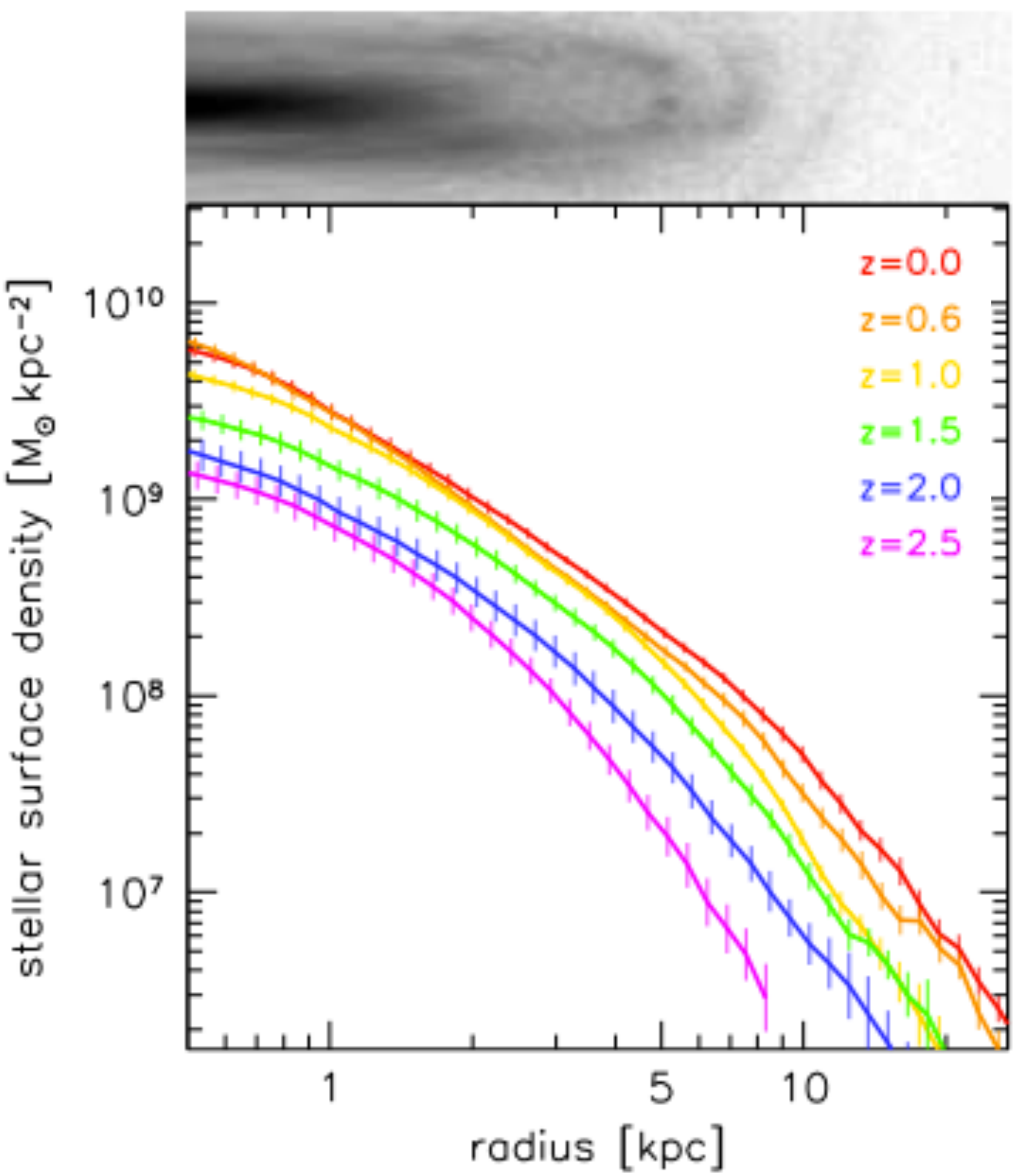
$M/M_\odot$

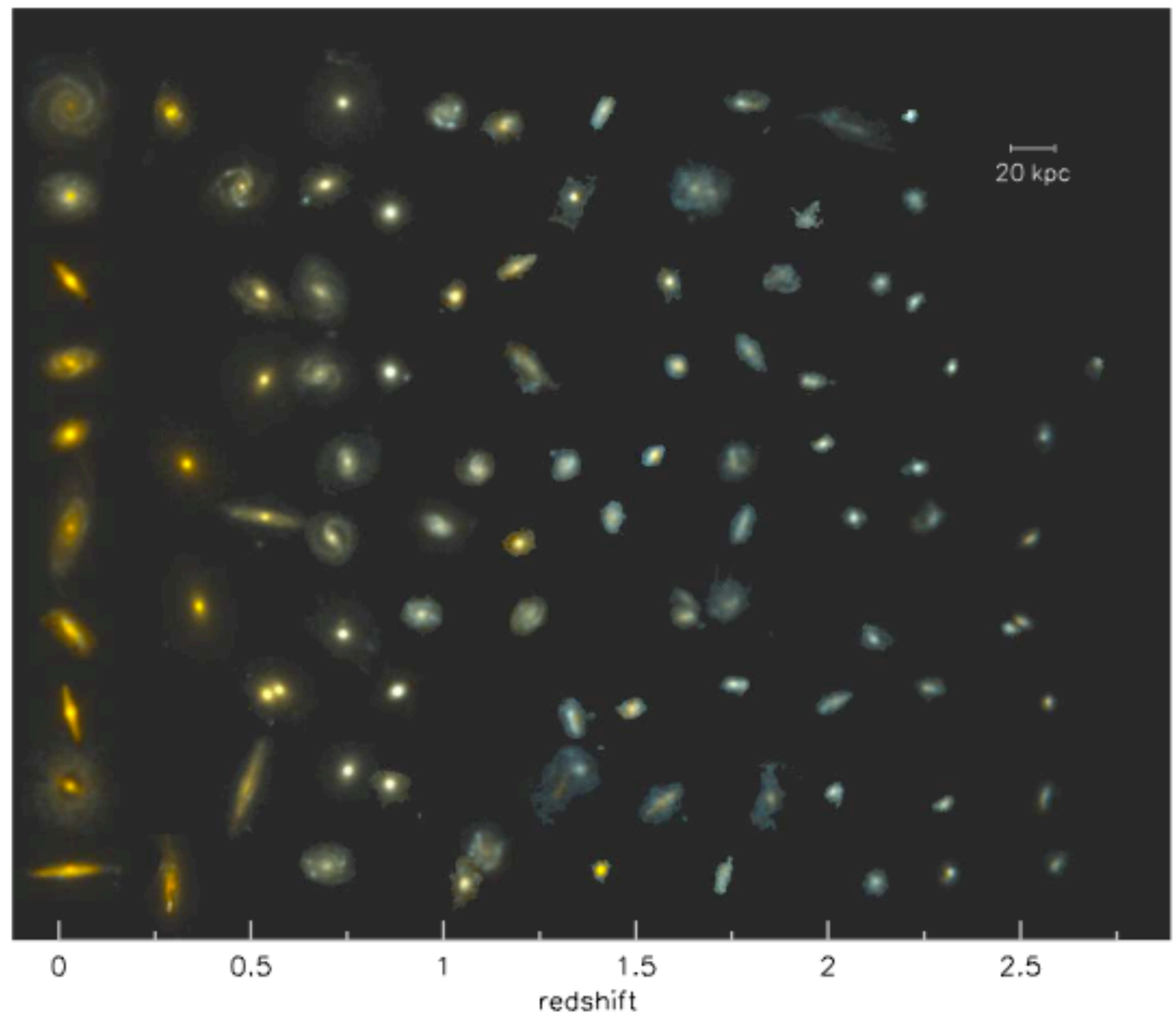


Science: Population studies

- E.g., evolution of Milky Way progenitors (number-density selected)

van Dokkum+2013, Patel+2013

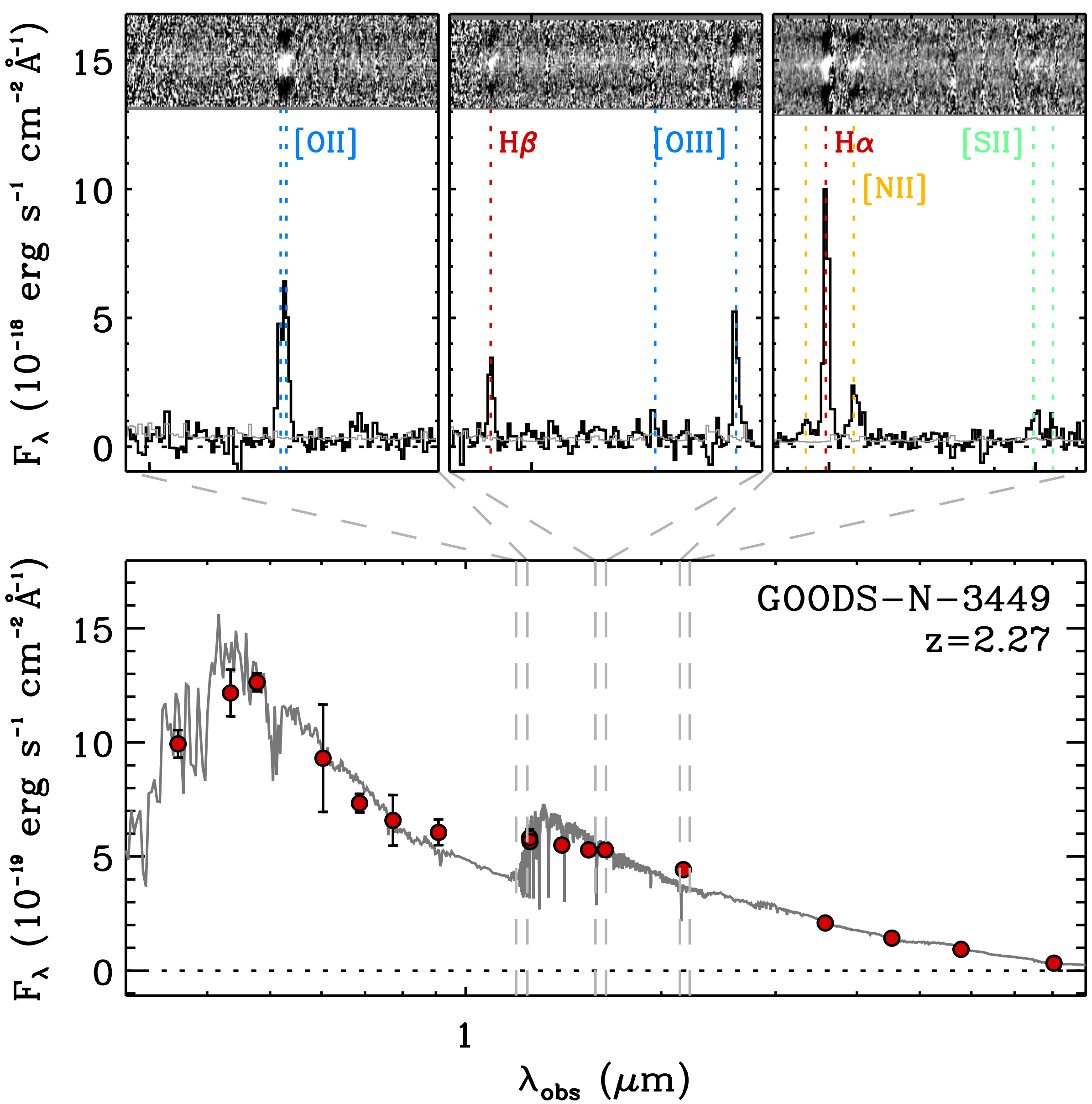




Science: Ground-based followup

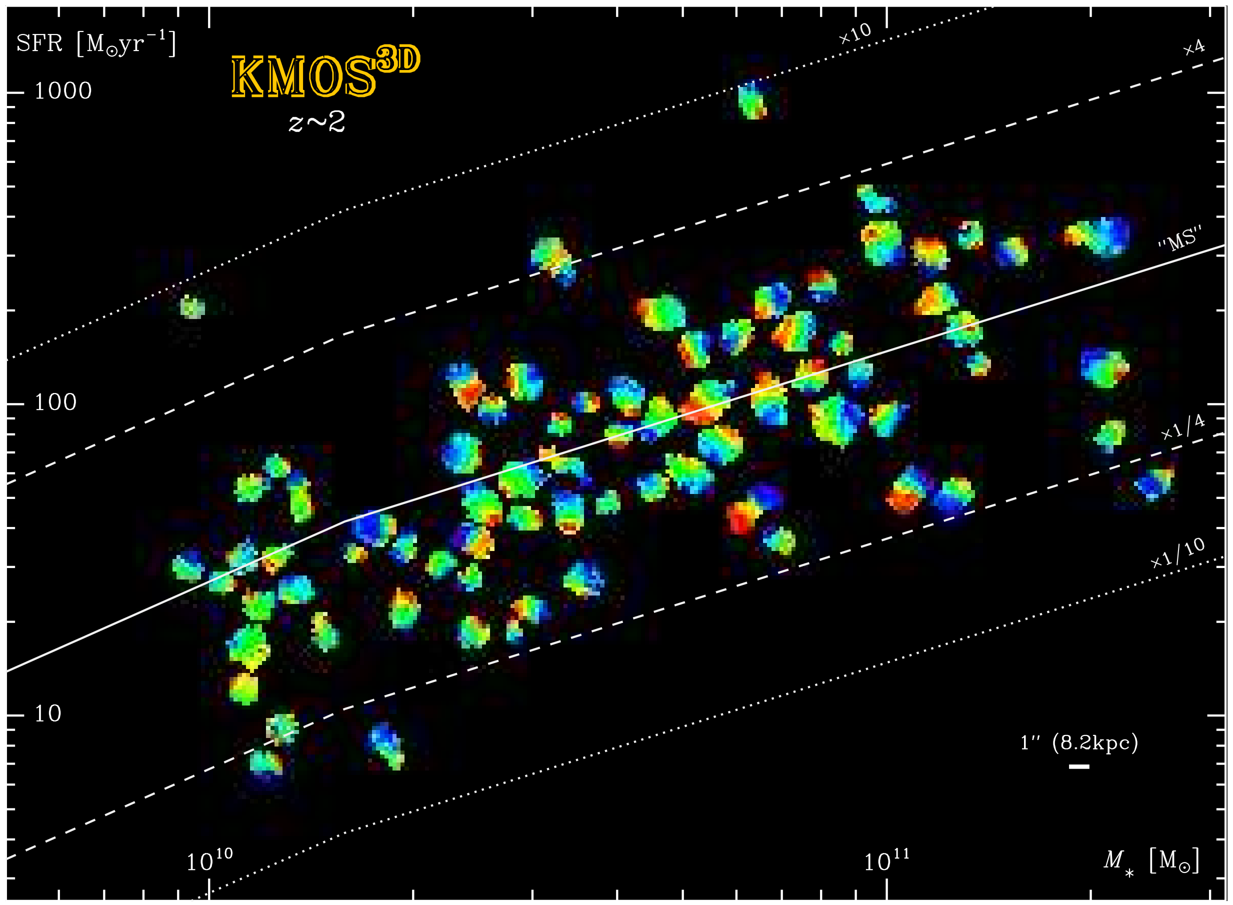
MOSDEF (Keck)

Kriek+2014



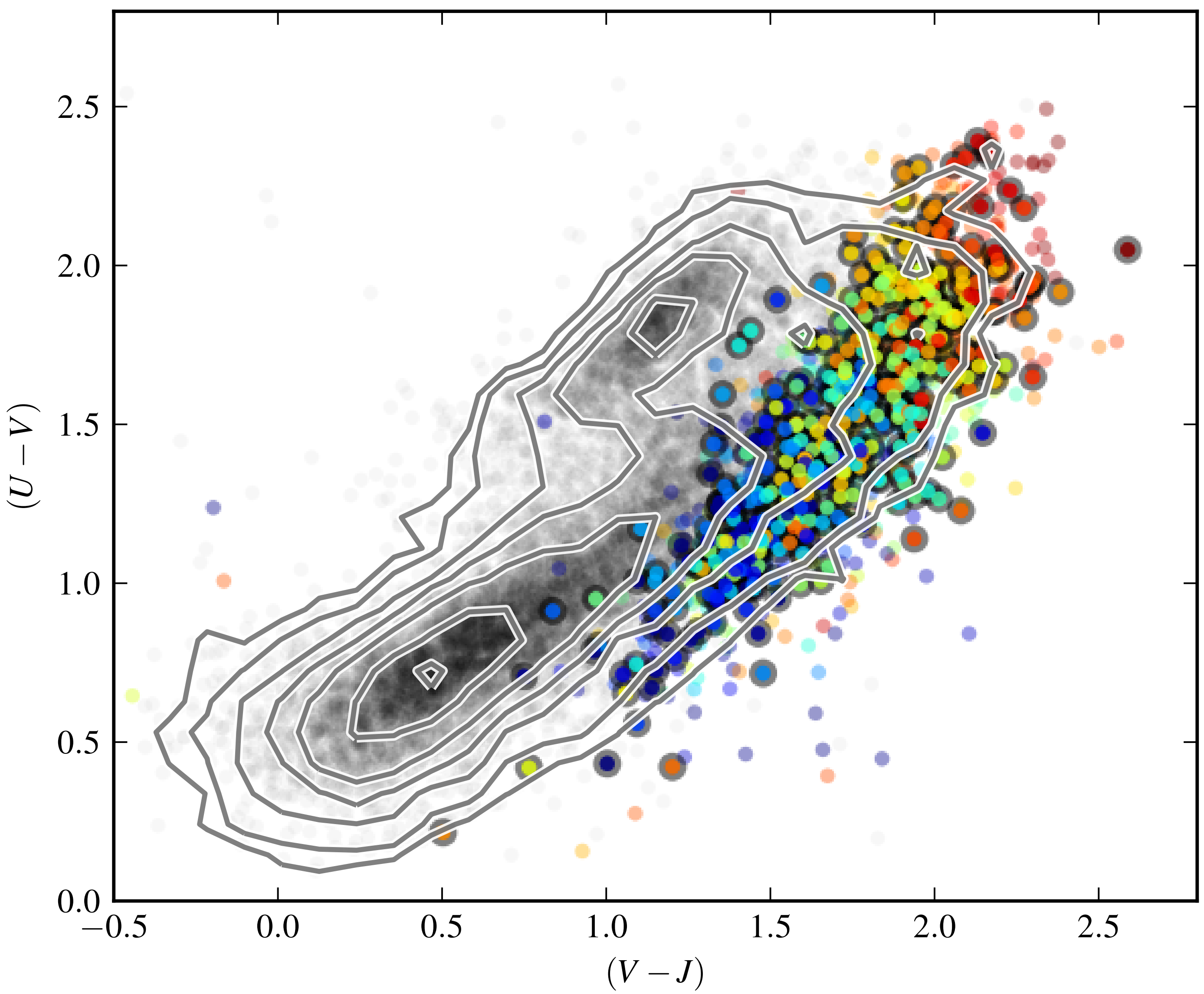
KMOS^{3D} (VLT)

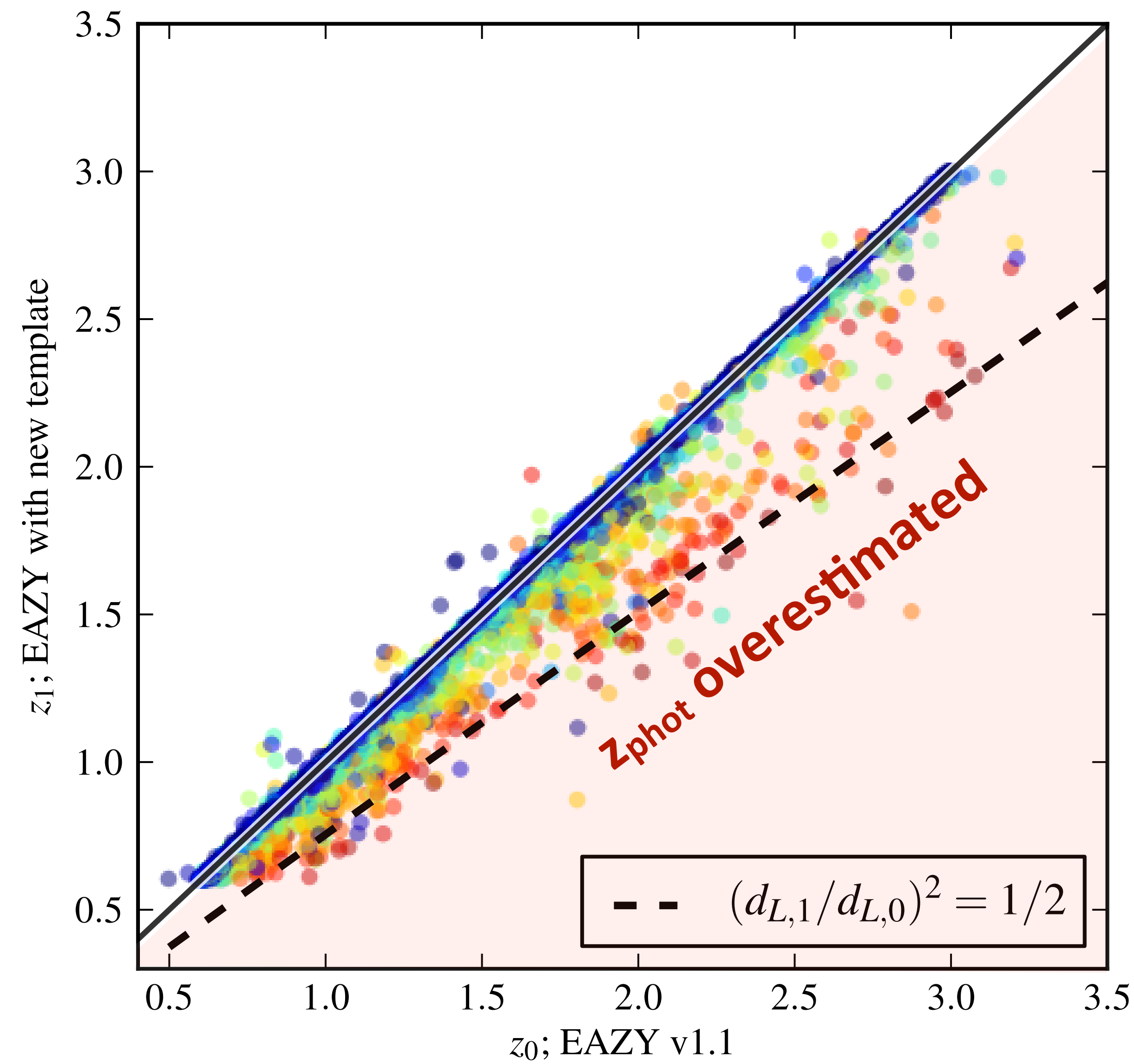
Wisnioski+2014

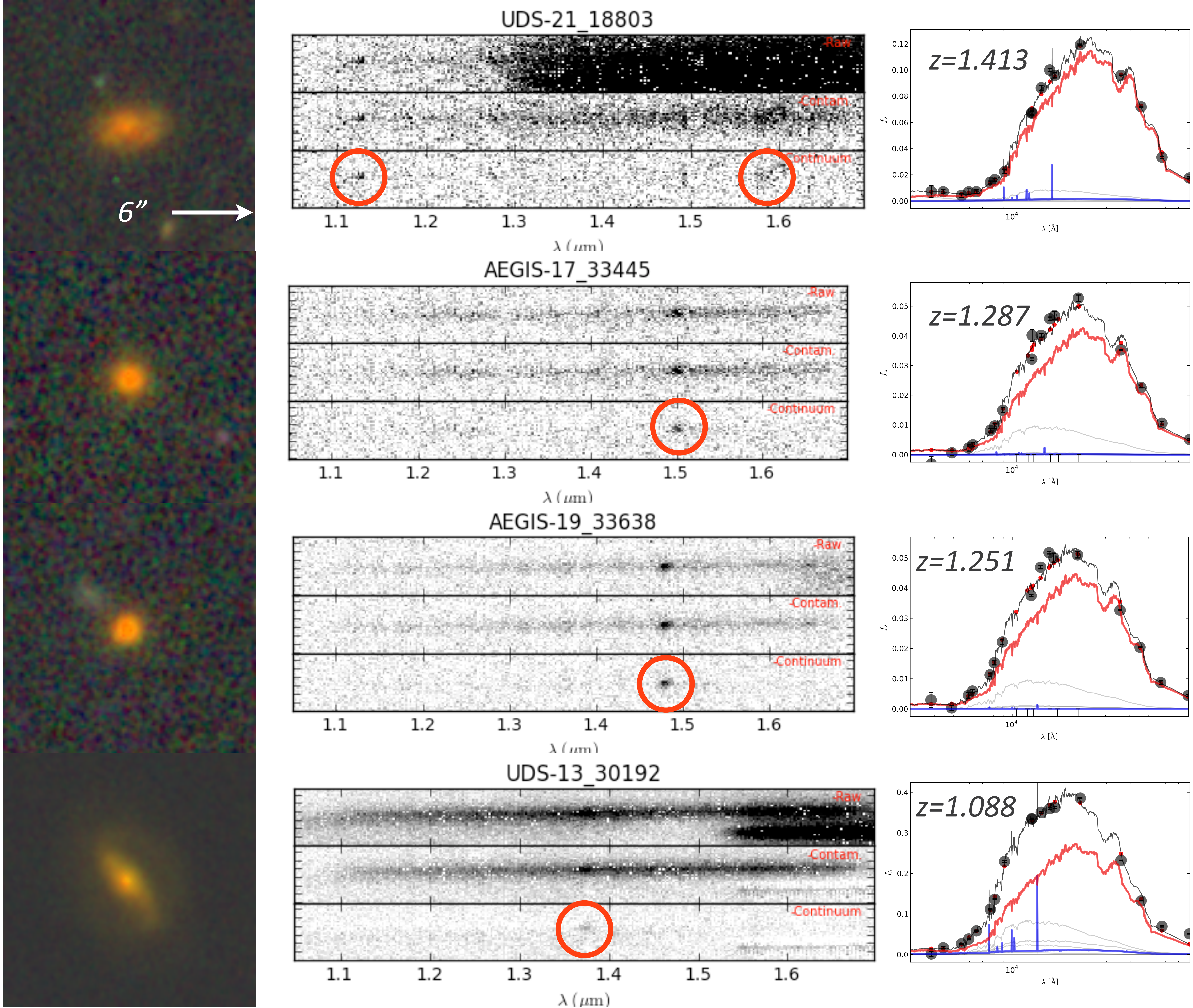


Science: *Multiwavelength SEDs*

- 3D-HST breaks redshift vs. age/dust degeneracy for a population of the **reddest *UVJ*** galaxies, which have always been difficult to model (Brammer+in prep)
- (EAZY) photo-zs too high without a red enough (**dusty *and* old**) template






6″
UDS-21_18803
Raw
Contam
Continuum
1.1 1.2 1.3 1.4 1.5 1.6
λ (μm)
z=1.413
AEGIS-17_33445
Raw
Contam
Continuum
1.1 1.2 1.3 1.4 1.5 1.6
λ (μm)
z=1.287
AEGIS-19_33638
Raw
Contam
Continuum
1.1 1.2 1.3 1.4 1.5 1.6
λ (μm)
z=1.251
UDS-13_30192
Raw
Contam
Continuum
1.1 1.2 1.3 1.4 1.5 1.6
λ (μm)
z=1.088
10^4
λ [Å]

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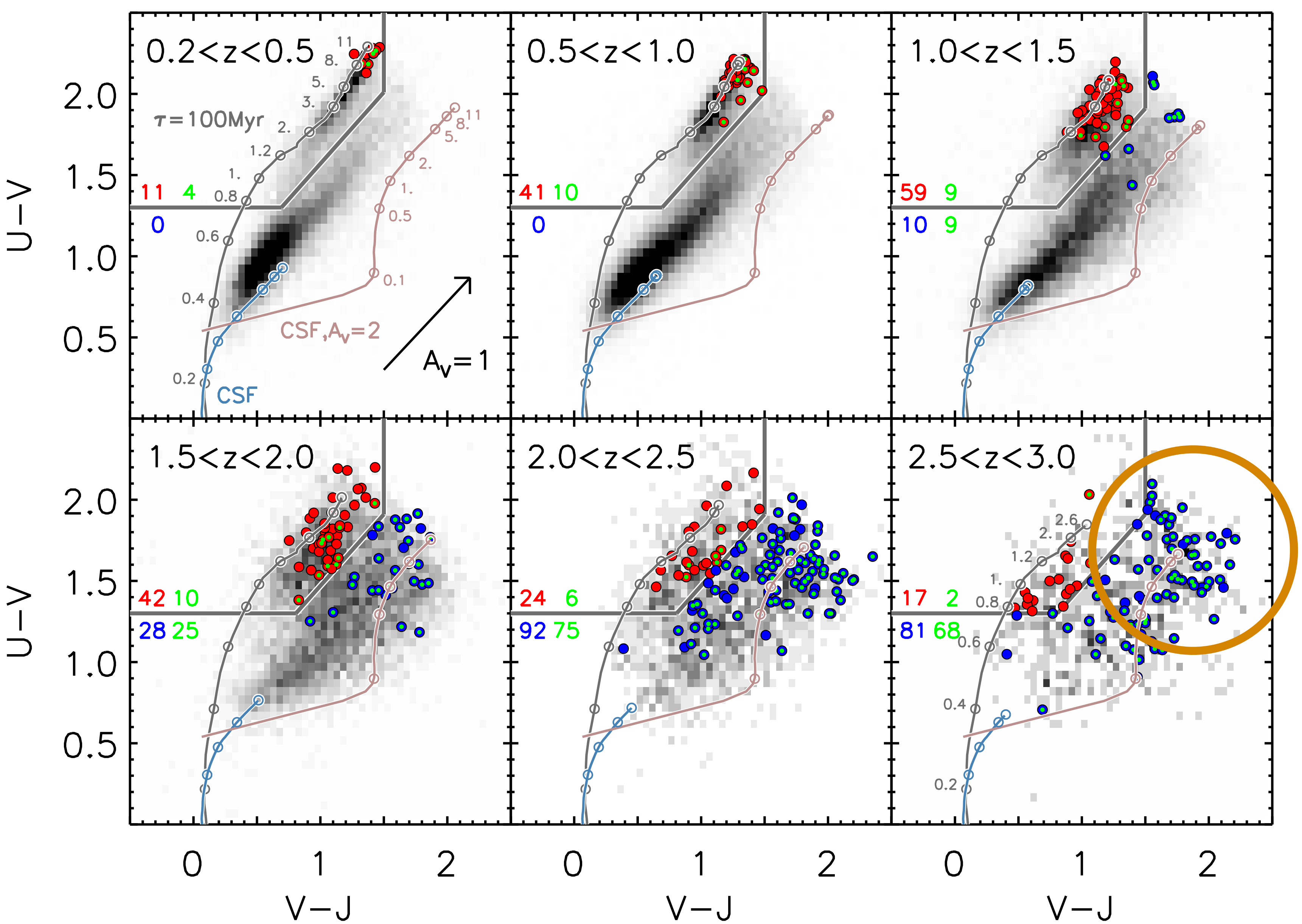


UVJ Quiescent

UVJ Star-forming

Number-density-selected progenitors of local BCGs

Marchesini+2012, 2014

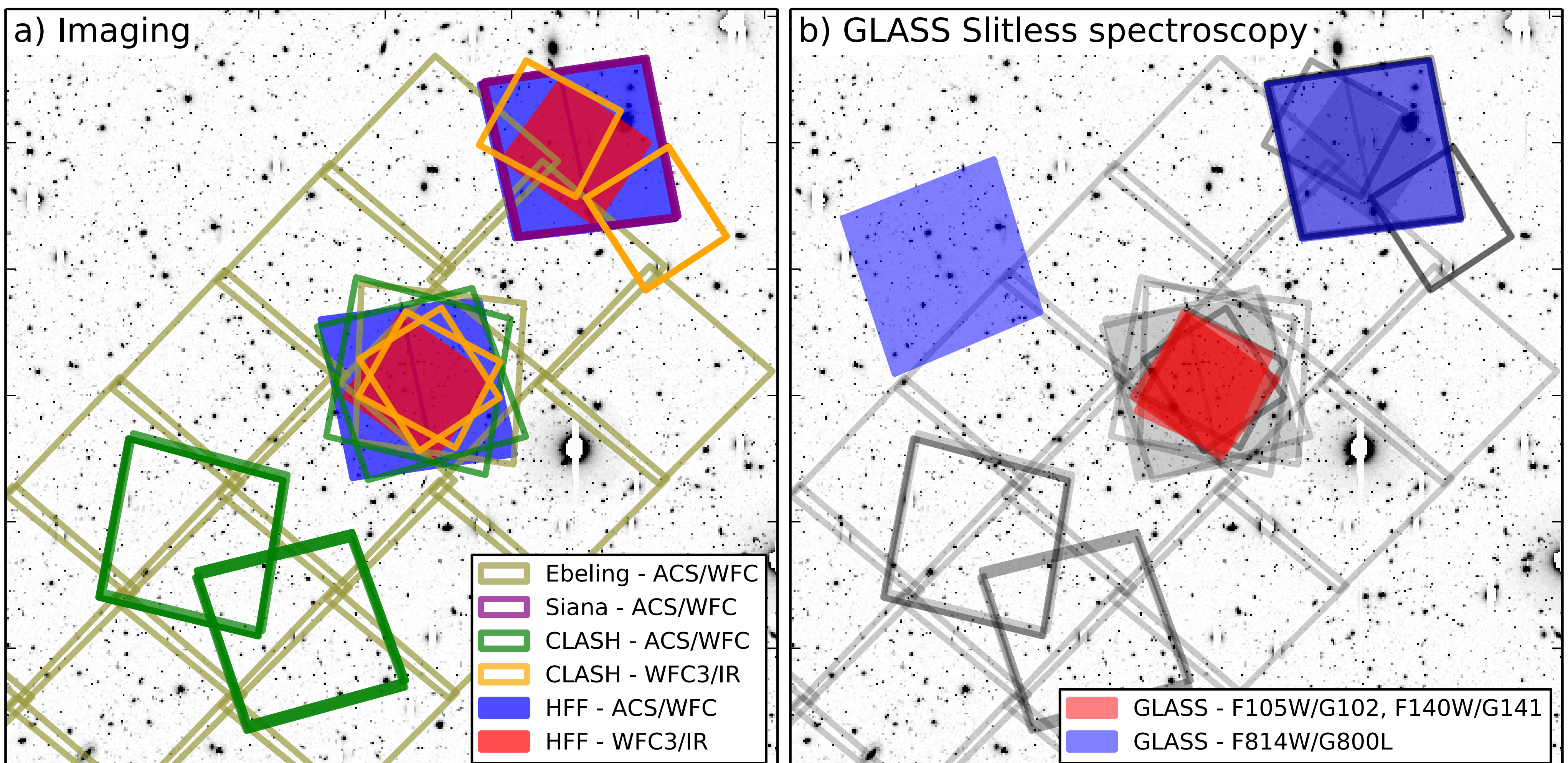
An increasing fraction of the reddest dusty galaxies with redshift at highest masses

Current & Future prospects

- **GLASS** (T. Treu) 10 CLASH/HFF clusters, **G102**(10)+**G141**(4 orbits) Upcoming data release for MACS 0717, others to follow. Reductions with 3D-HST pipeline, similar data products

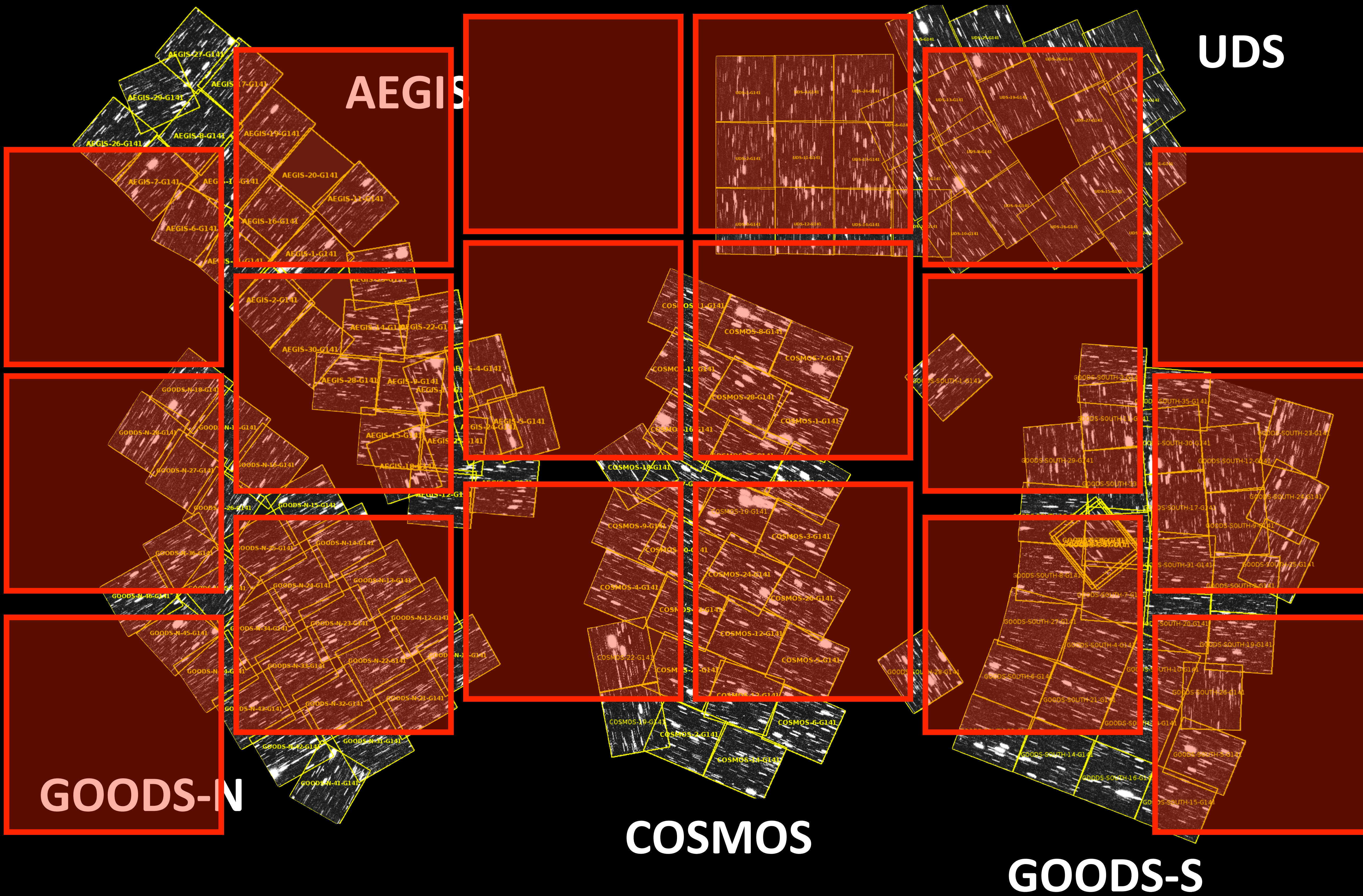
- **30-orbit** G141 DD (SN Refsdal, z=1.49) program covering MACS 1149

MACS 0717, Treu+in prep

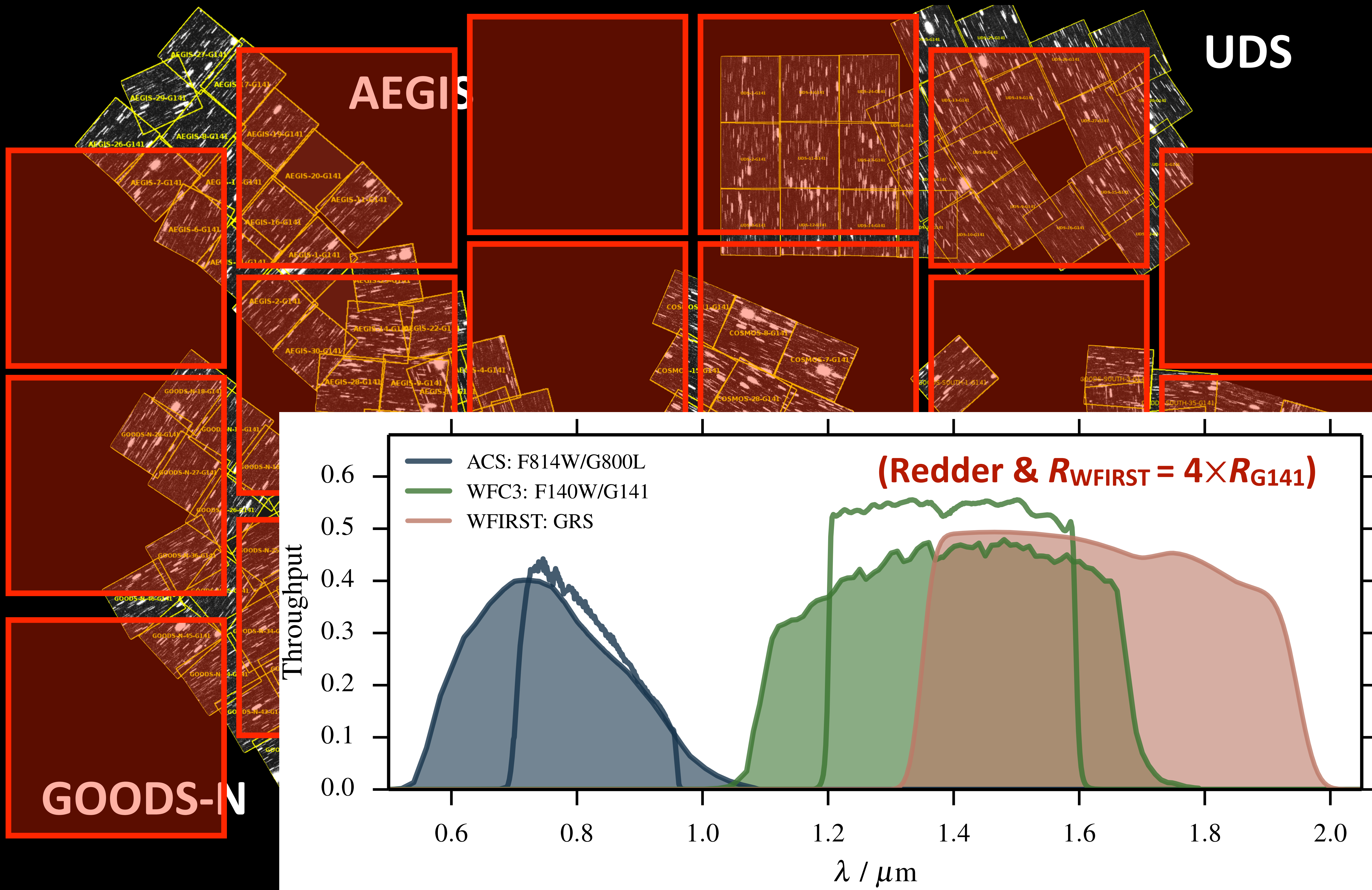


Kelly+2014

WFIRST: 0.28 deg^2 / pointing, 2400 deg^2 total



WFIRST: 0.28 deg² / pointing, 2400 deg² total



Summary

- Grism surveys like 3D-HST offer highly complete spectroscopic resource for galaxy evolution studies
- Slitless nature of the spectra presents formidable data analysis challenges, but with significant benefits
(e.g., continuum depth, completeness, spatial resolution)
- **Upcoming 3D-HST spectroscopic data release Spring 2015**
- Lessons **and science** from current *HST* grism programs will help pave the way for upcoming space missions (JWST, EUCLID, WFIRST-AFTA)

3D-HST

GLASS
The Grism Lens-Amplified Survey from Space