GNIRS observations of massive galaxies in the early universe

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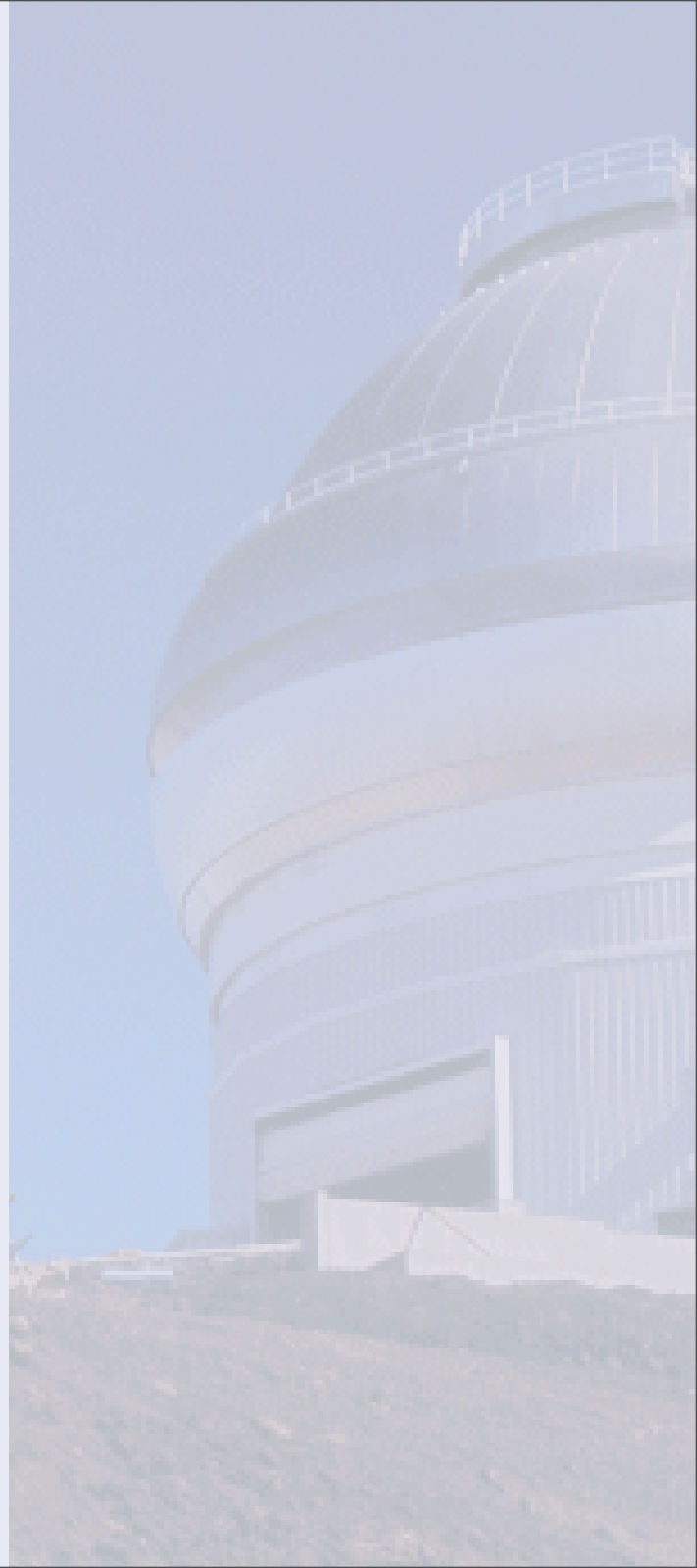
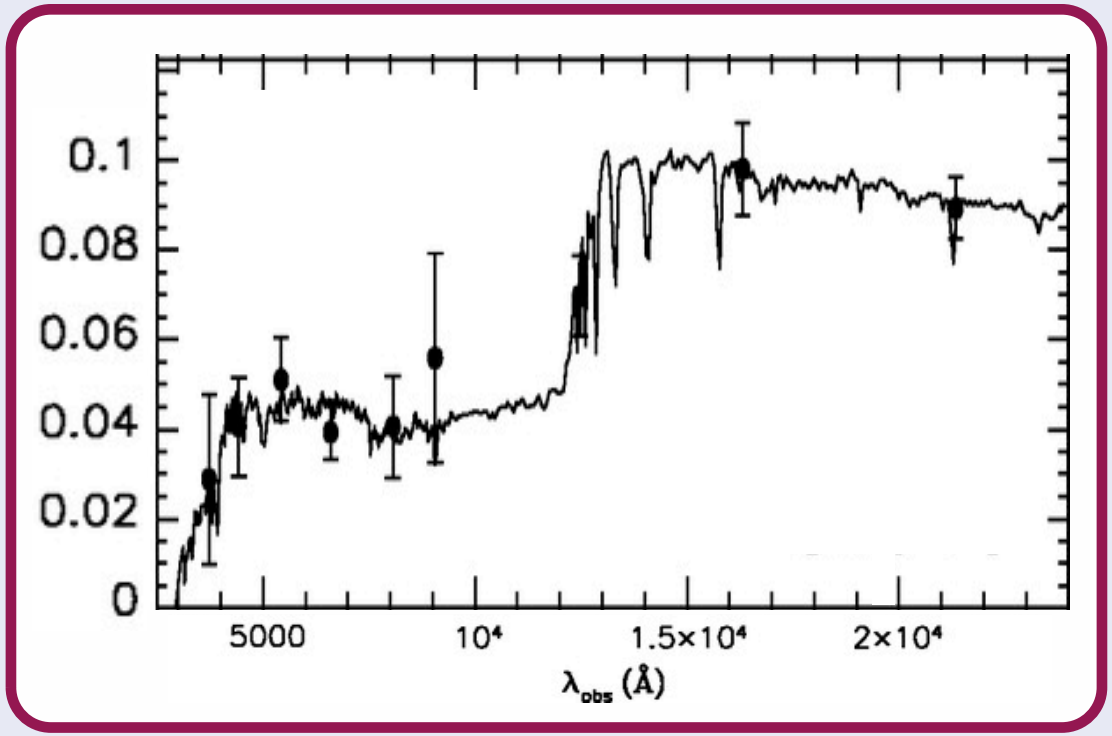


Why use GNIRS to observe massive galaxies in the early universe?

Typical massive galaxy at 2<z<3

- Optically red
  - J-K = 2.48
  - $(U-V)_0$=0.62
- Faint in the observed optical
  - R_{AB} = 25.9



van Dokkum et al. 2006

Beyond the limits of optical spectroscopy

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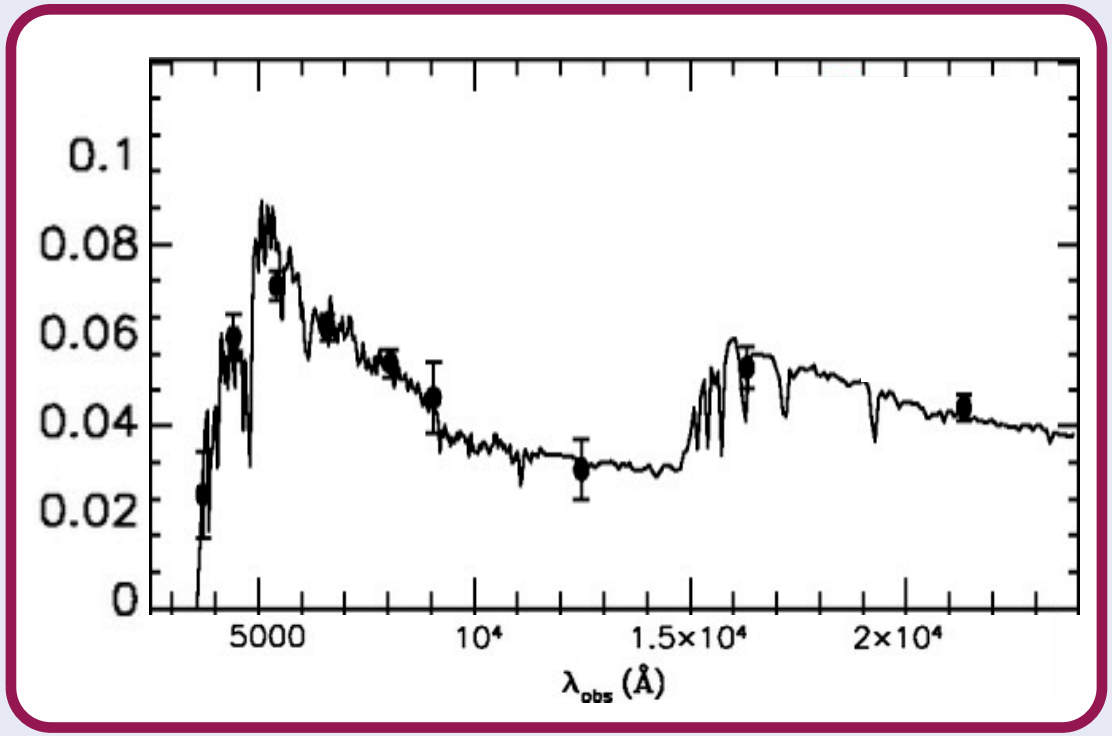

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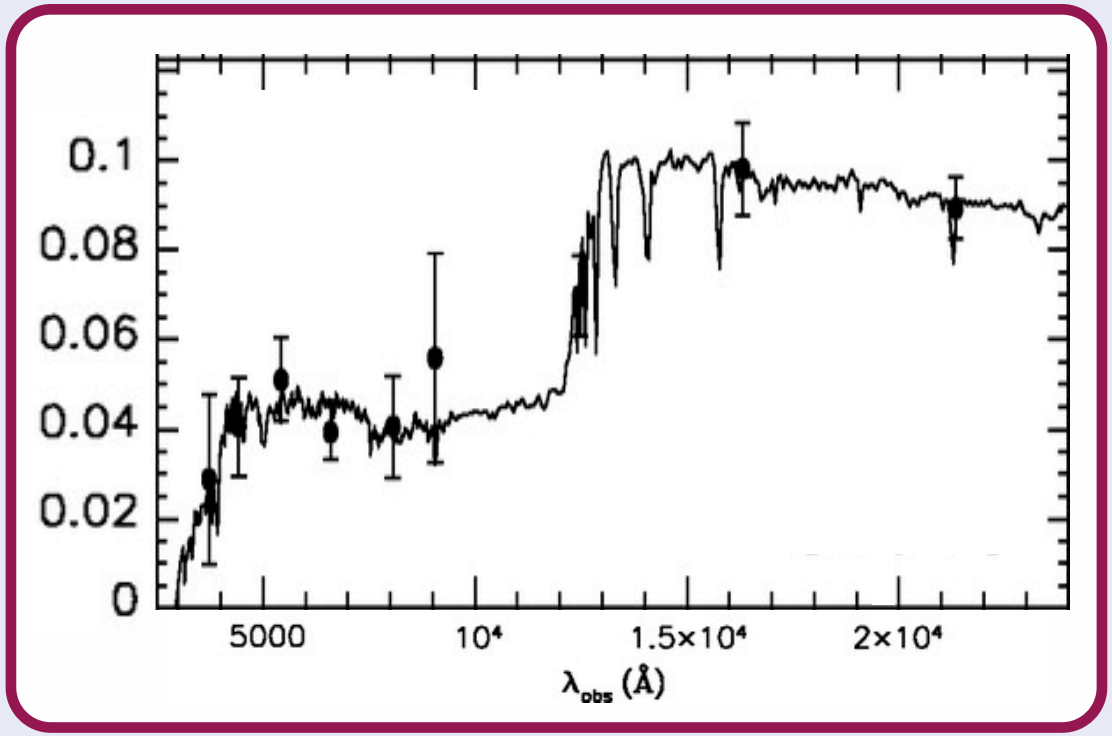

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Beyond the limits of optical spectroscopy

Public GNIRS survey for massive galaxies in the early universe

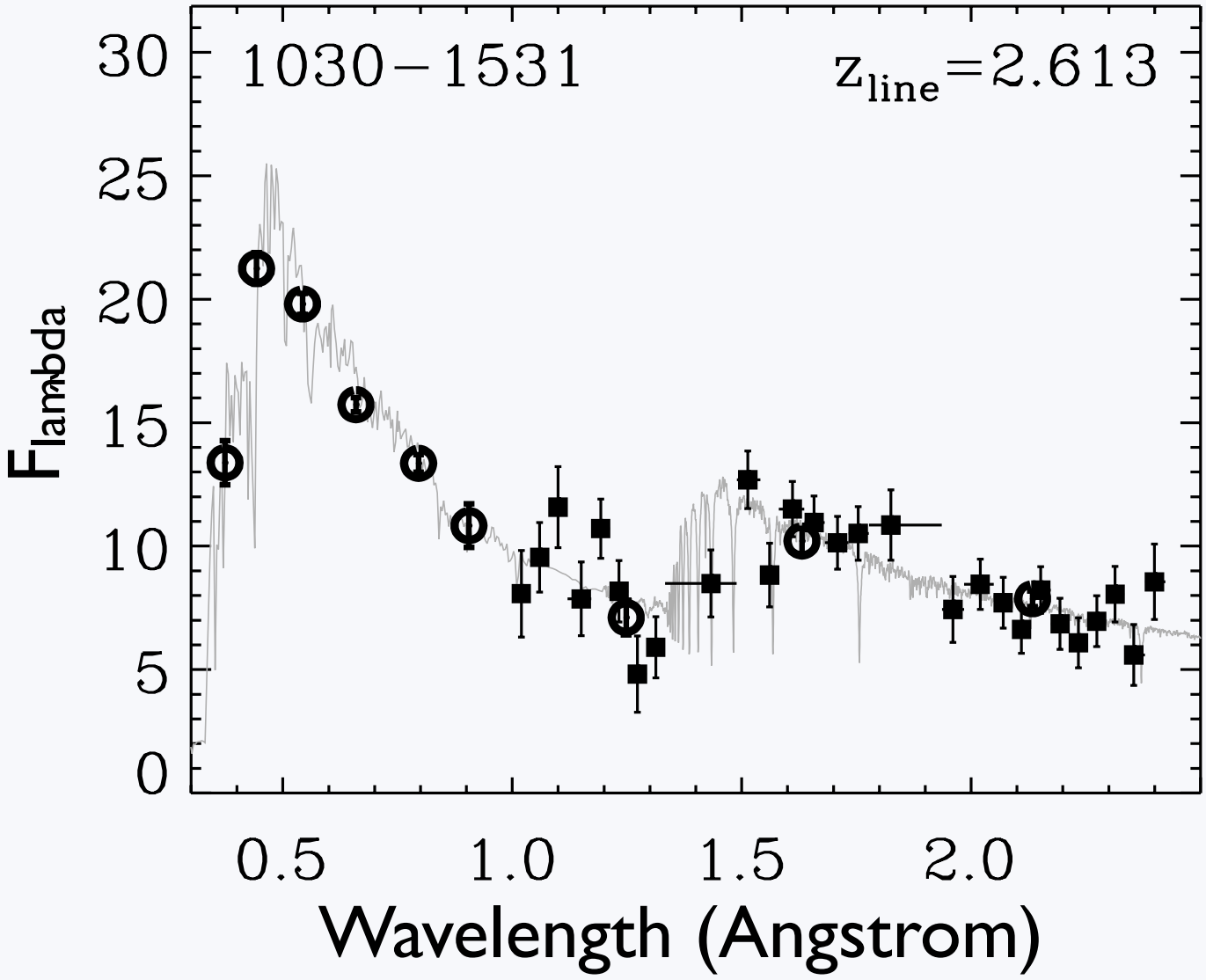
- **Selection:**
  - MUSYC survey: UBVRIzJHK photometry
  - $K < 19.7$
  - $2 < z_{phot} < 3$
- **Total sample: 36 galaxies**
- **Follow-up: SPITZER/IRAC, SPITZER/MIPS, Magellan/LDSS3, HST/NICMOS, Keck/NIRC2-AO**
- **Fully reduced spectra and data products available at:** *www.astro.princeton.edu/~mariska*

Why GNIRS ?

X-disperser: observes 1-2.5 micron simultaneously ⇨ full rest-frame optical for z~2.5 galaxies

- All optical emission lines: [OII], Hβ, [OIII], Hα, [NII], [SII]
- Continuum emission: Balmer / 4000 Angstrom break

Examples of continuum spectra



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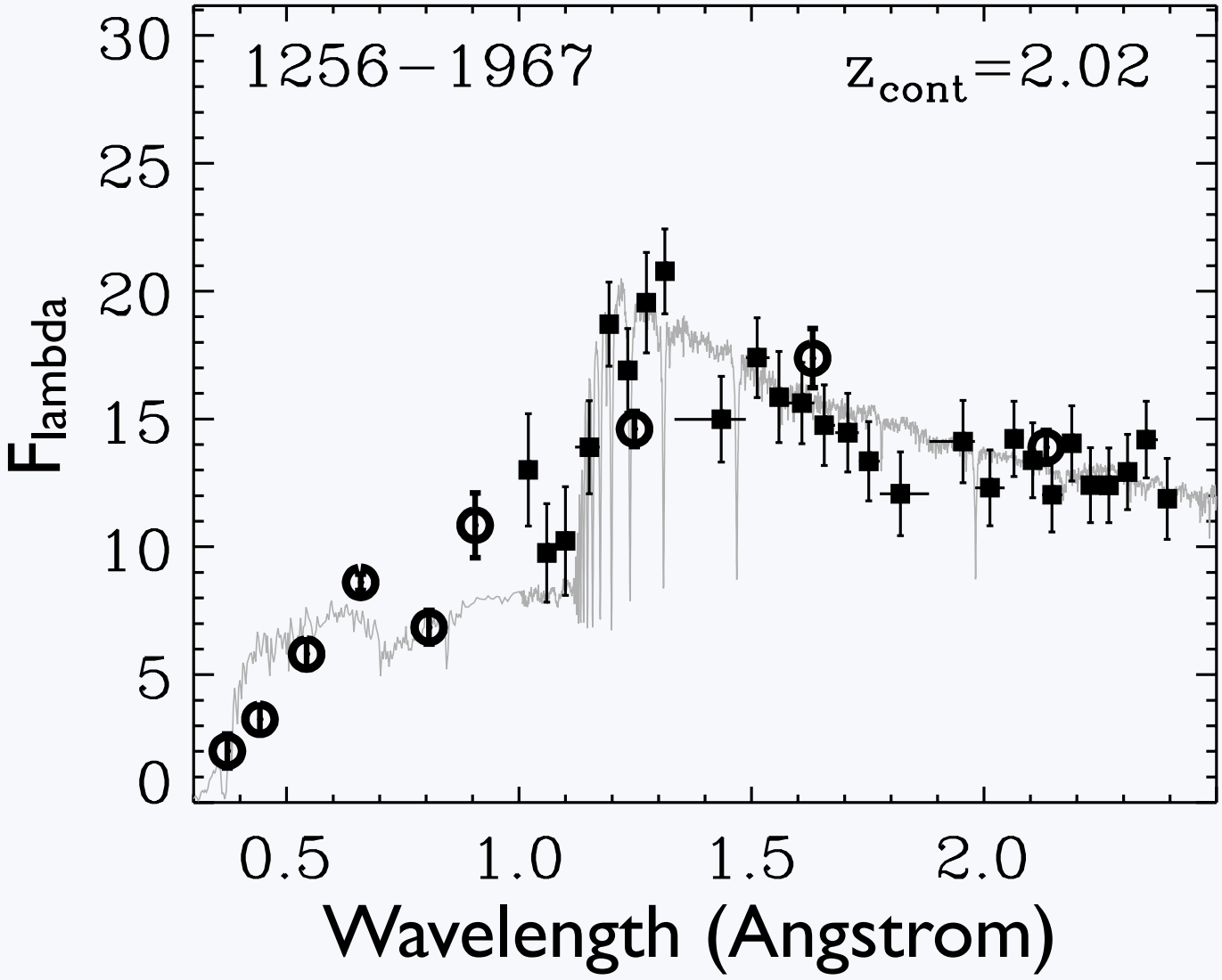

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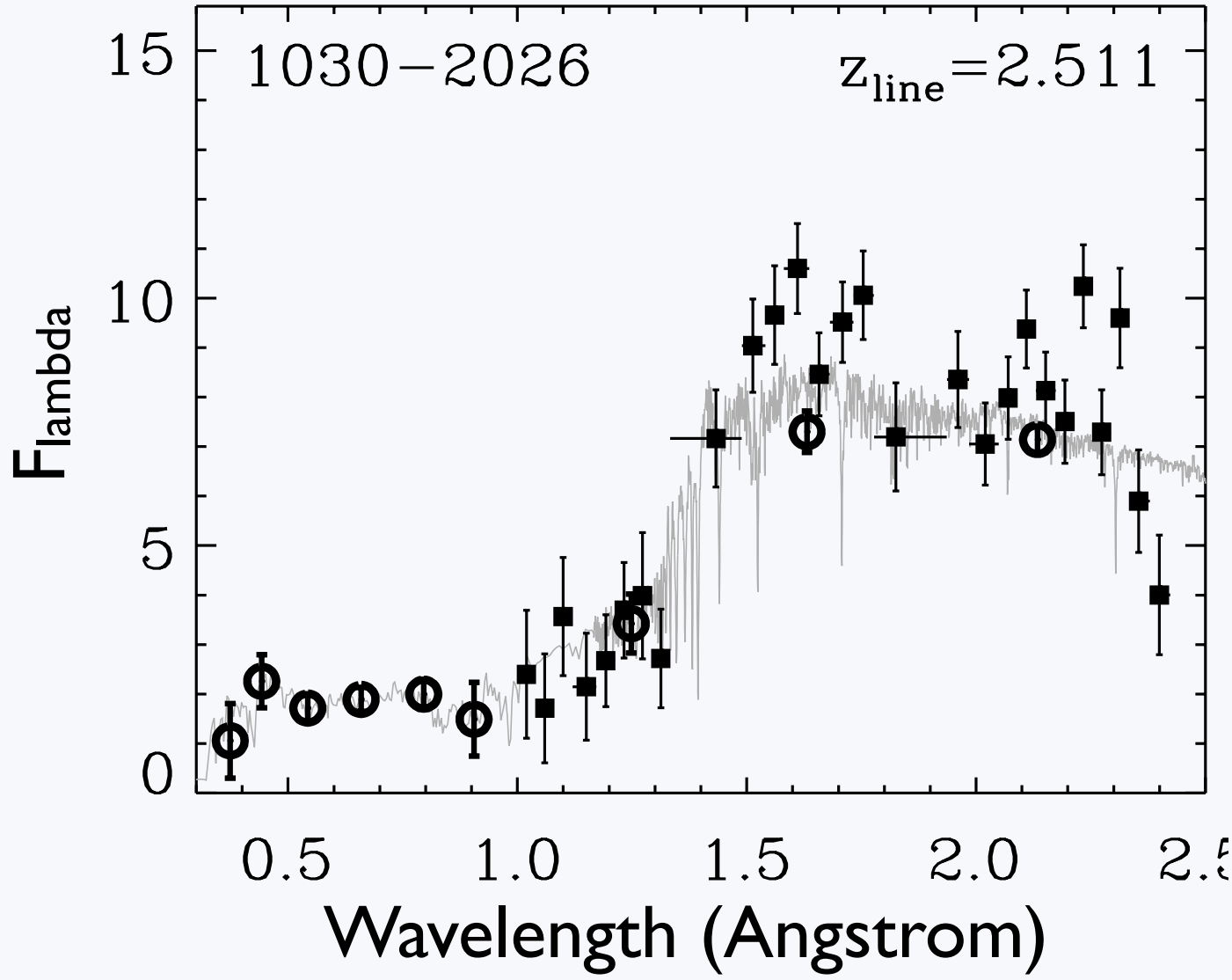

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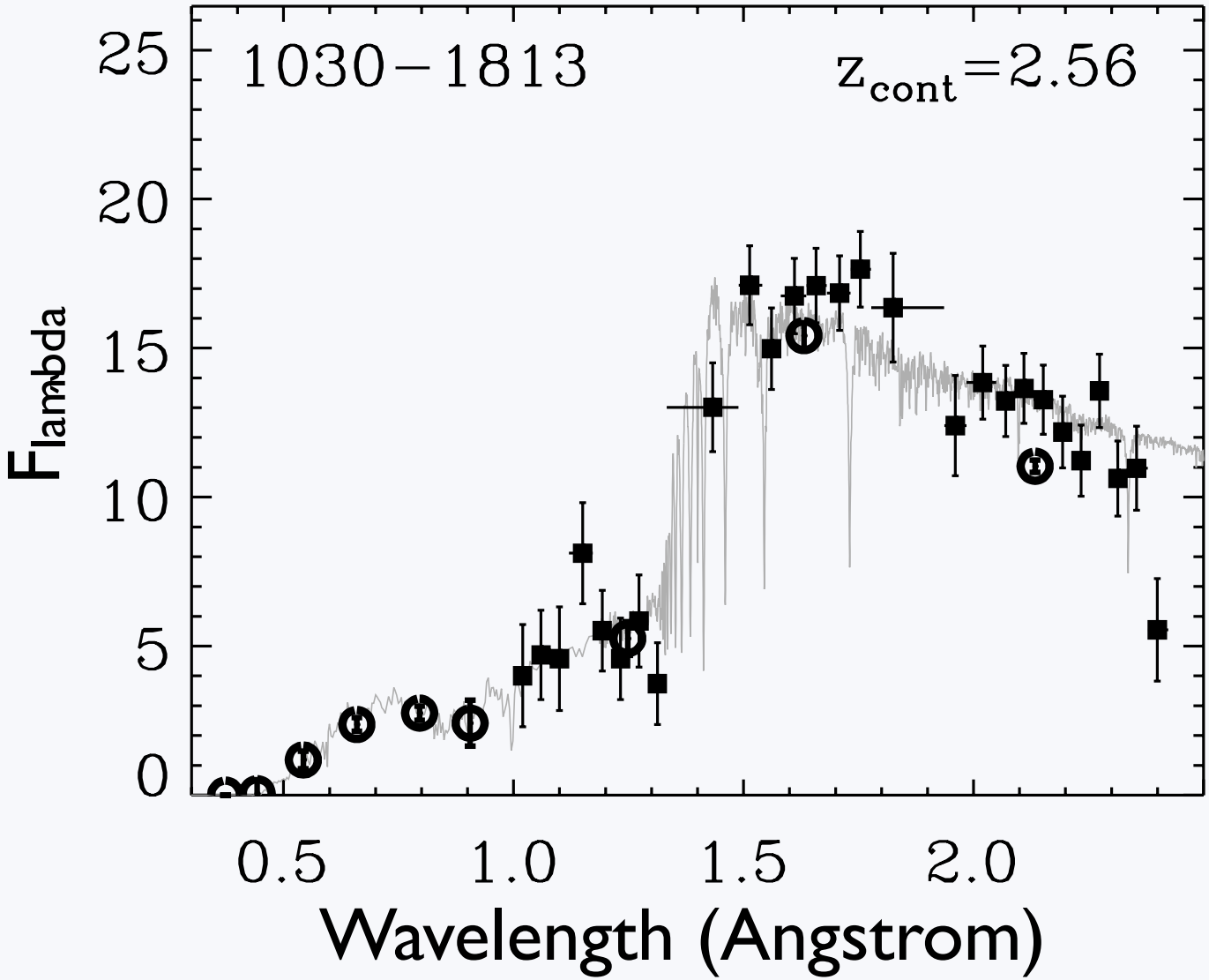

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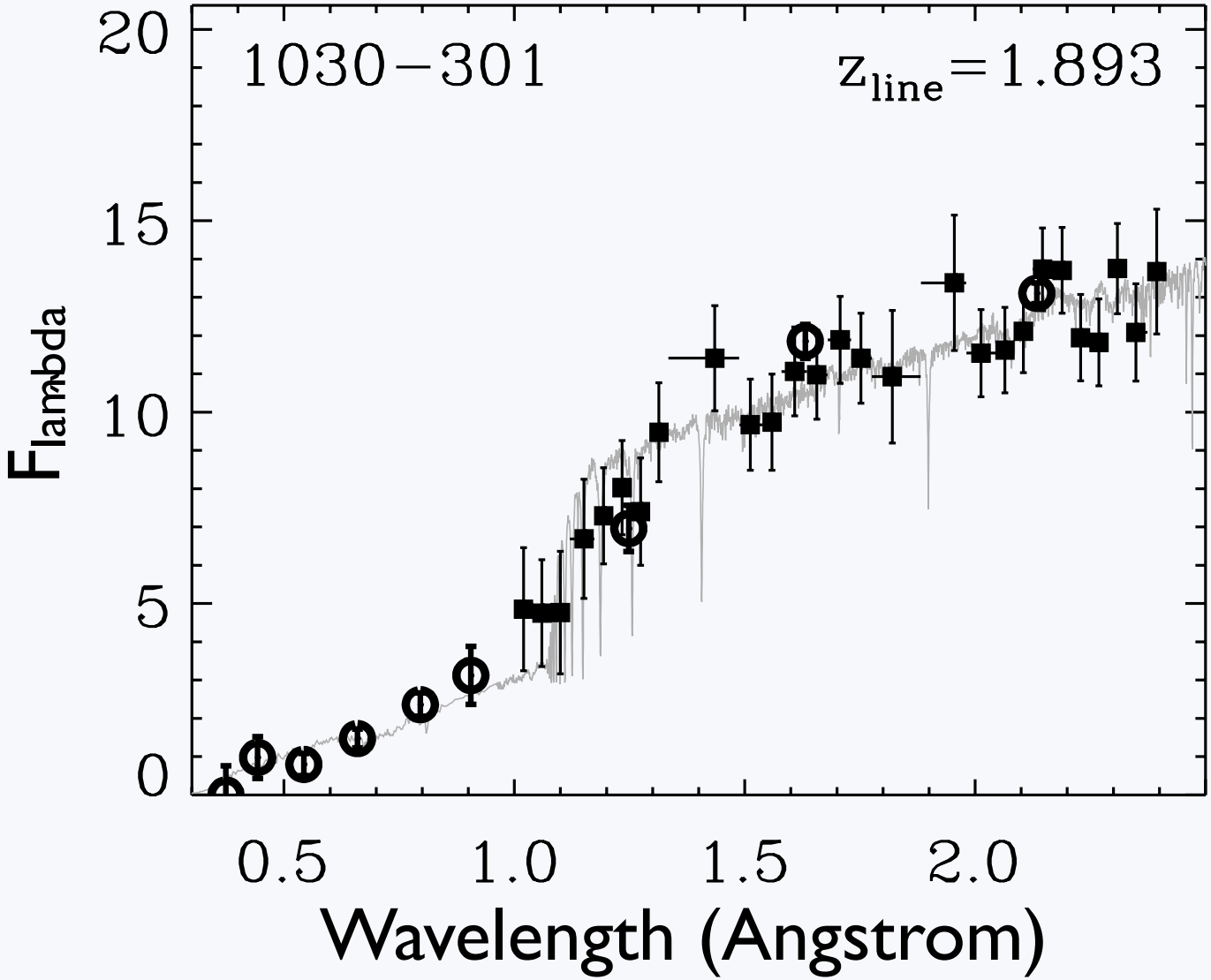
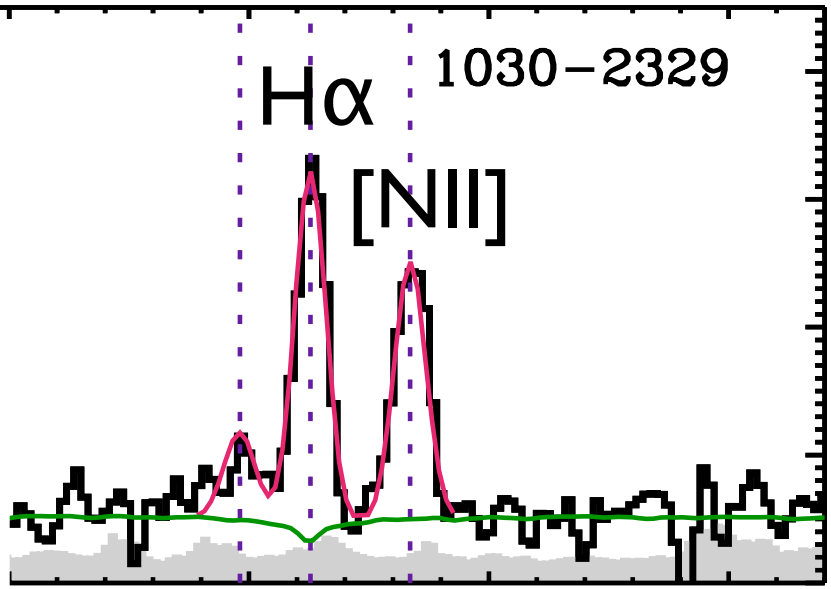
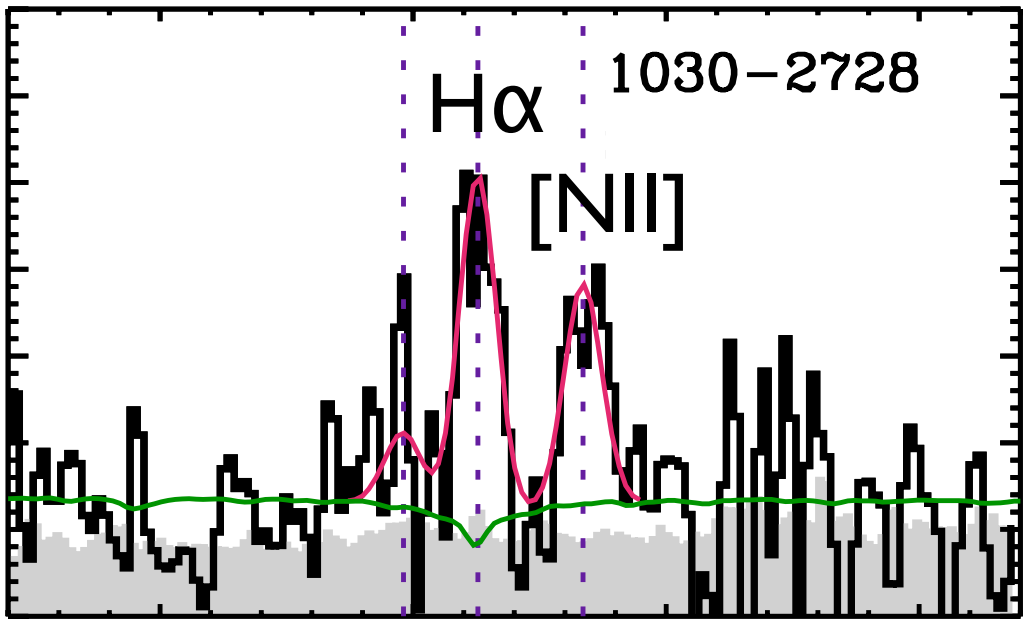


Examples of emission line spectra

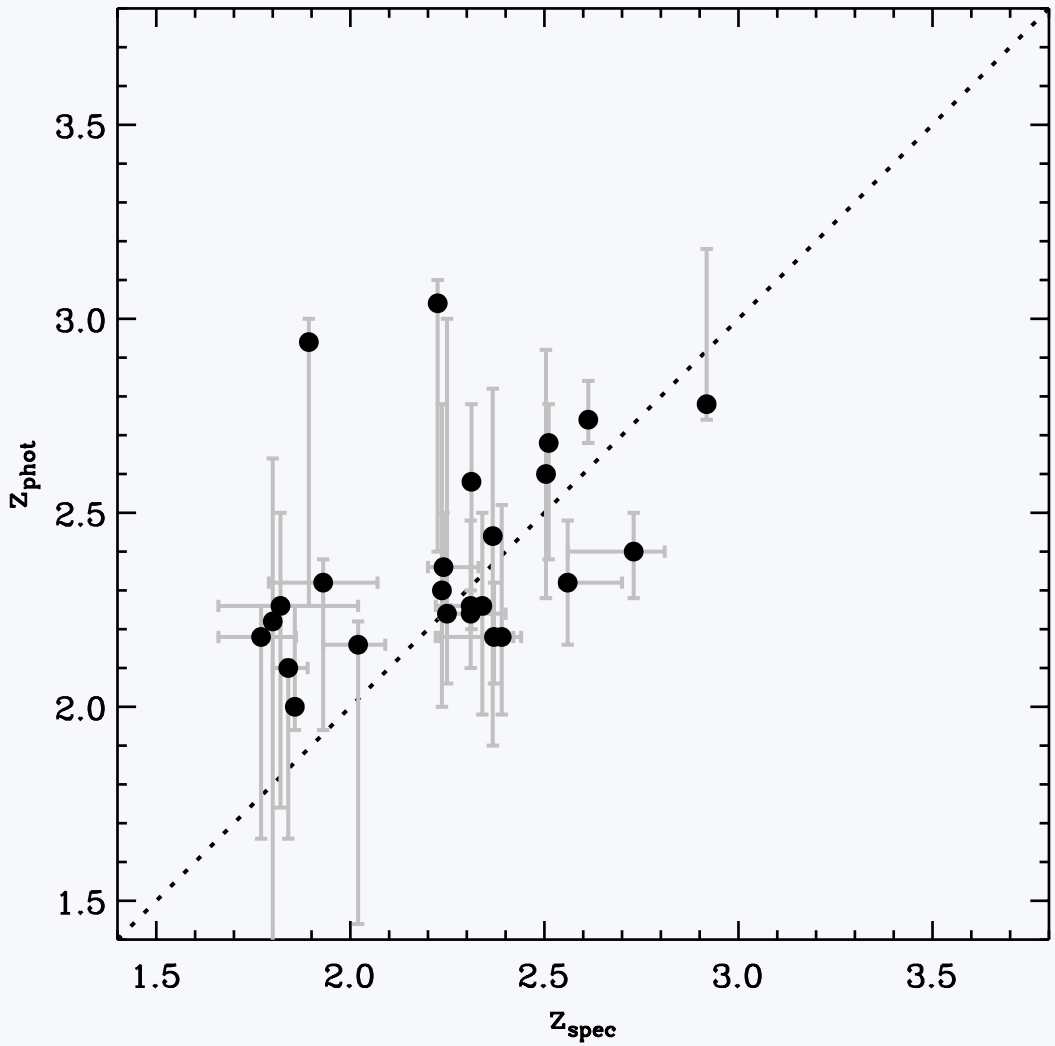




Results

- 8 galaxies at $z < 2$
- 28 galaxies at $2 < z < 3$

Causes for photometric redshift uncertainties



Kriek et al. (2008)

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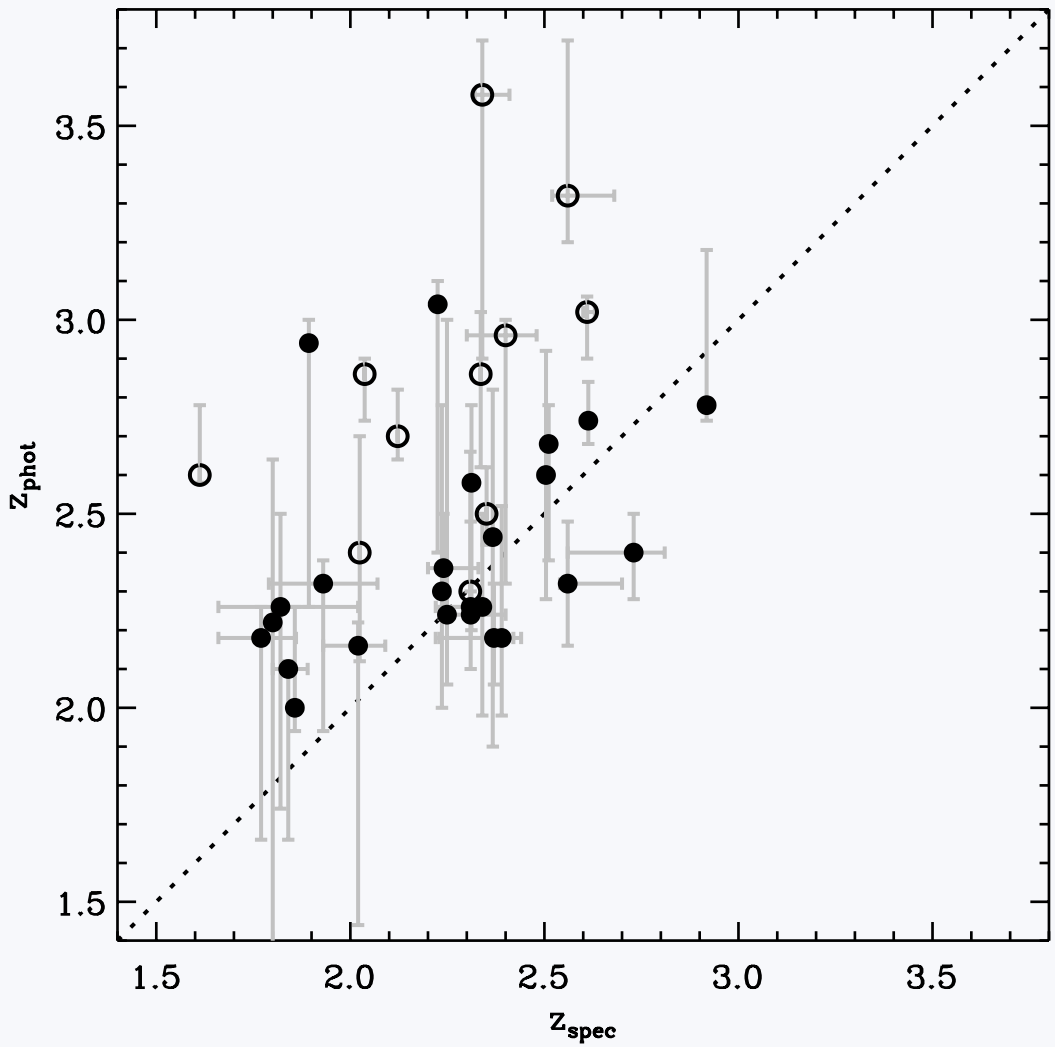

- Shallow NIR photometry

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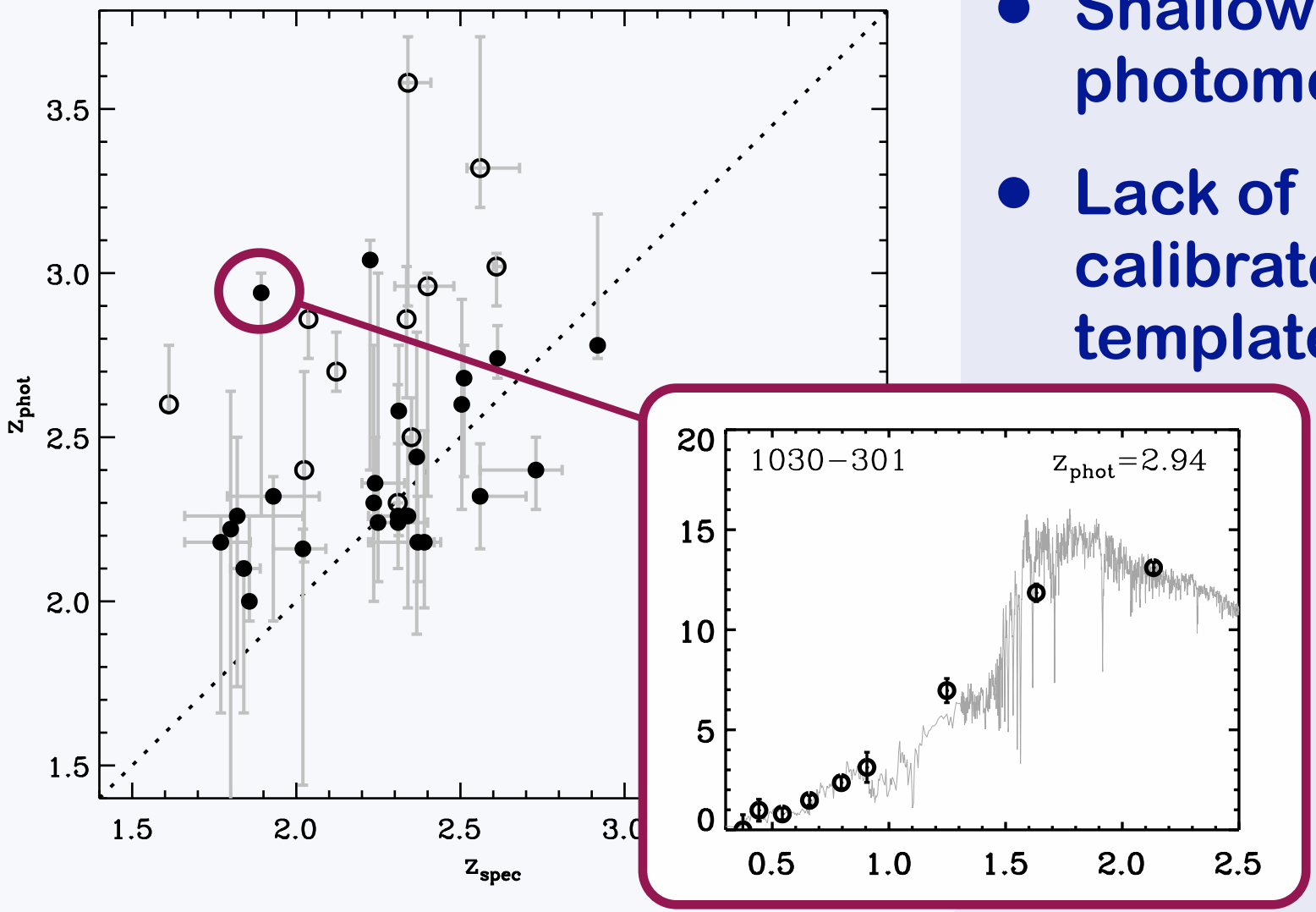

- Shallow NIR photometry
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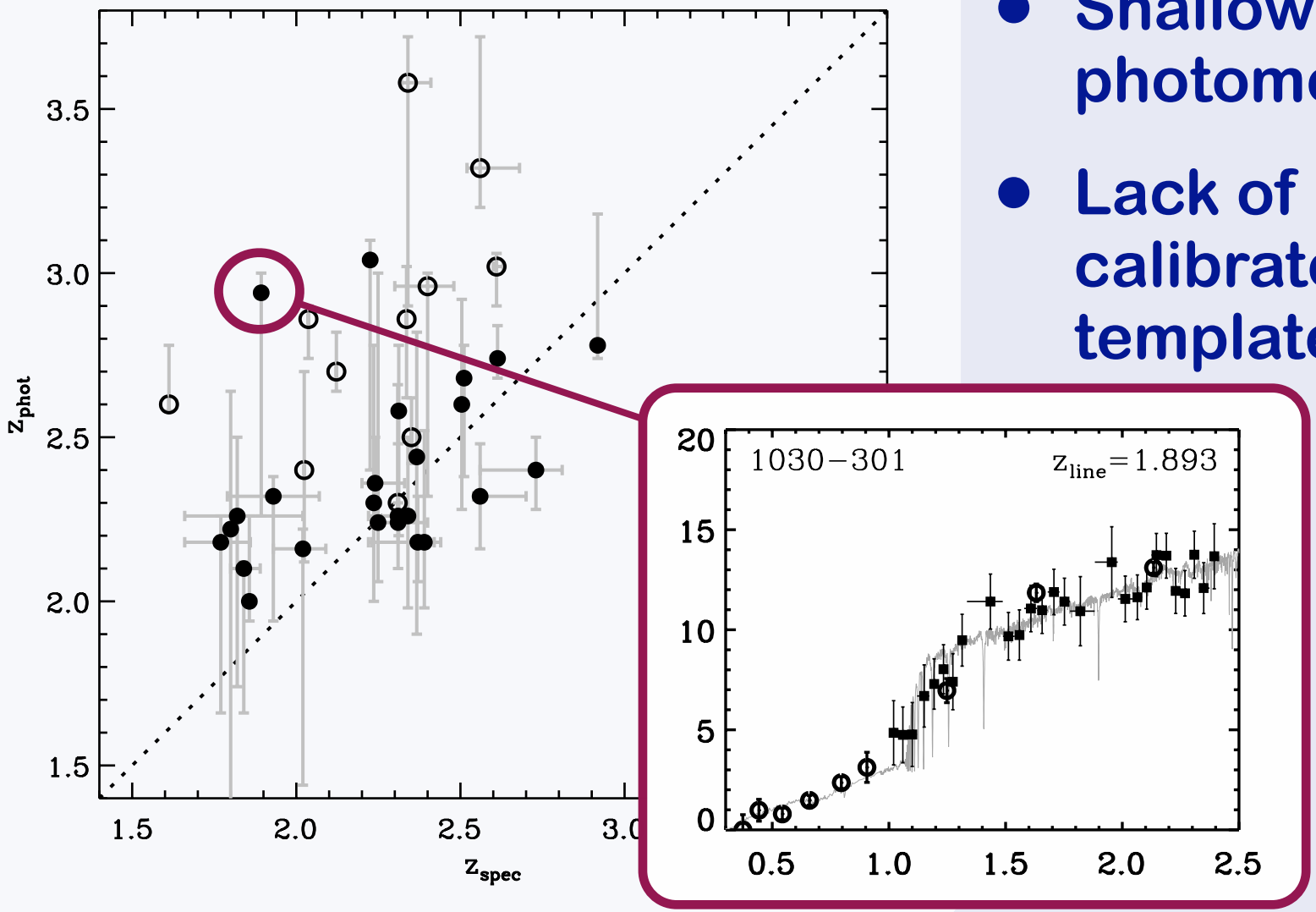

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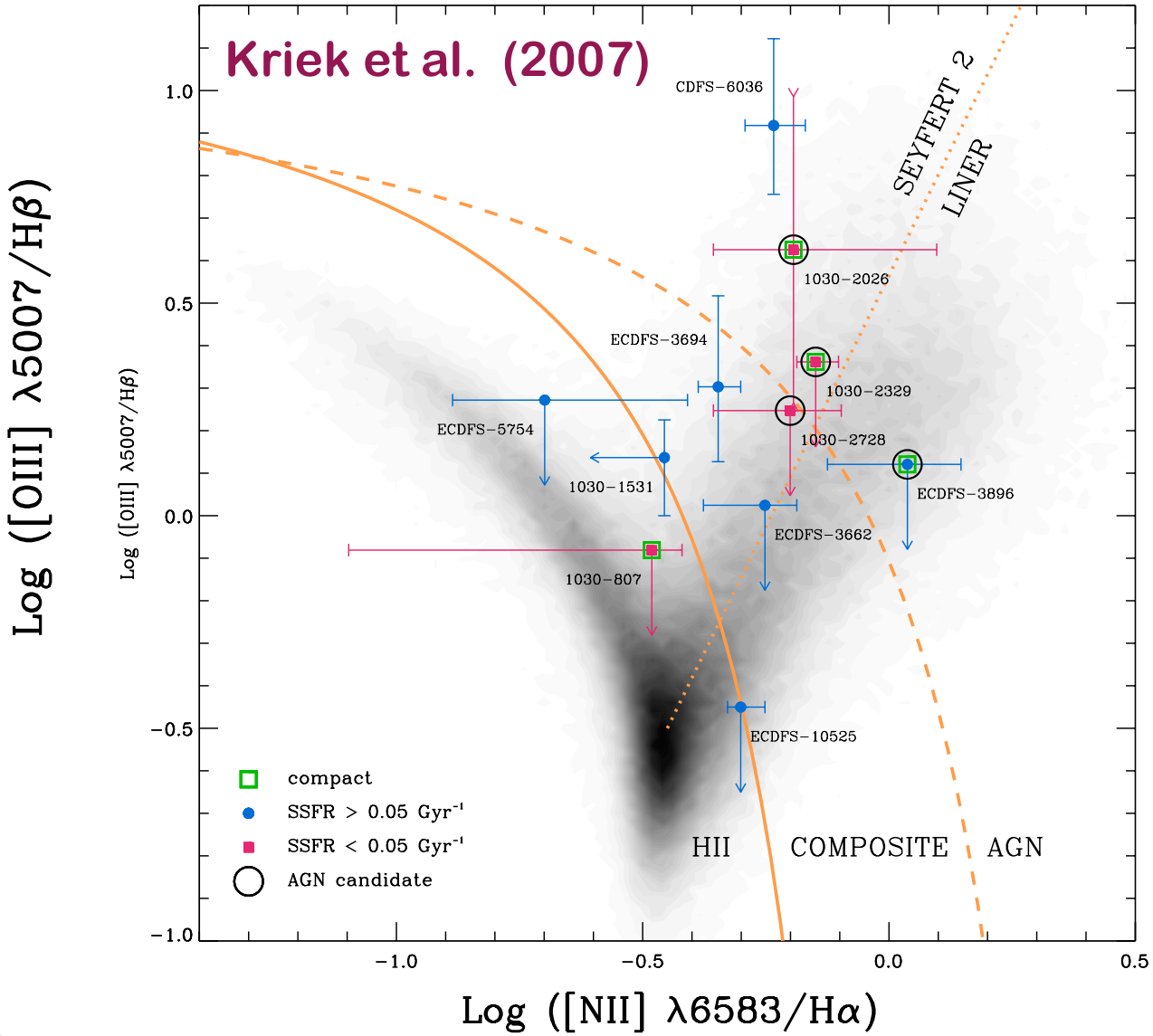
Emission line galaxies: AGN or star formation?



Results

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  - 17 Emission line galaxies (see Kriek et al. 2007)
    - 12 star-forming galaxies
    - 5 AGN host galaxies

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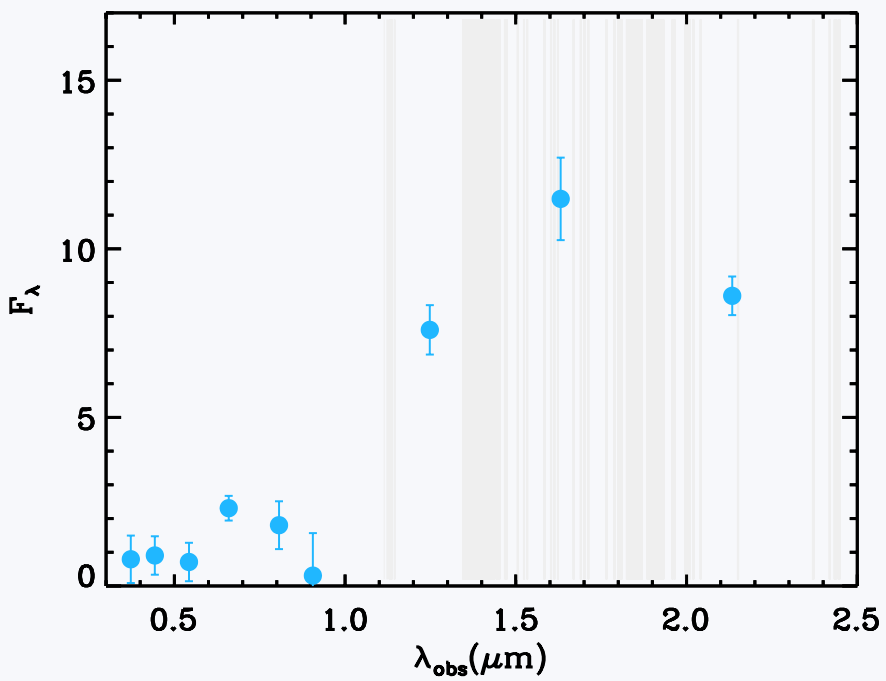
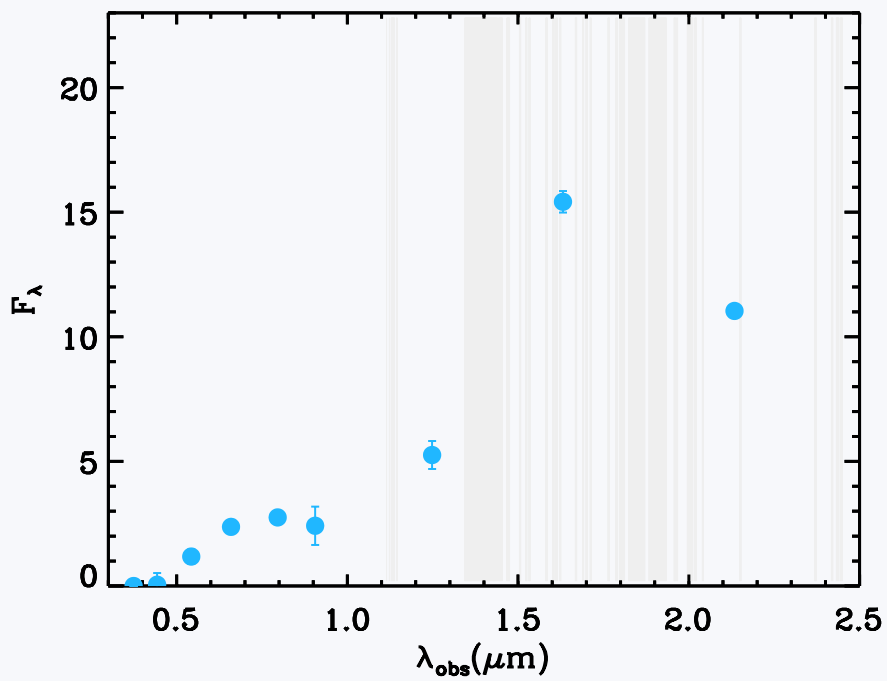
  - 11 Galaxies without detected emission lines

Galaxies without detected Hα emission





Kriek et al. (2006)

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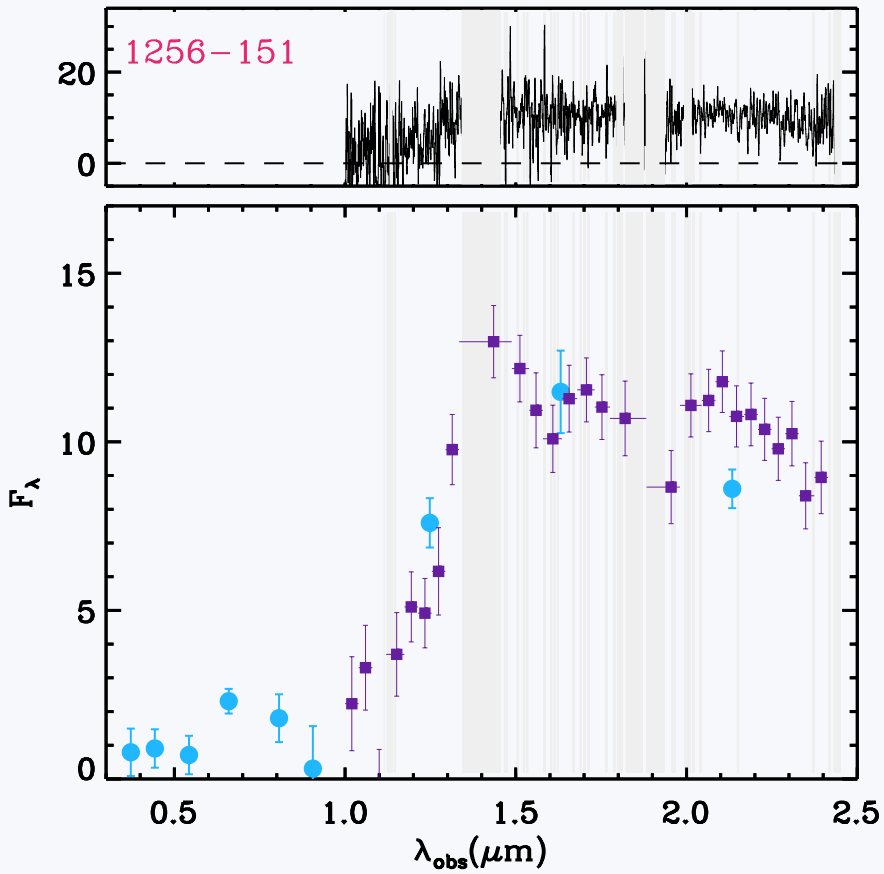

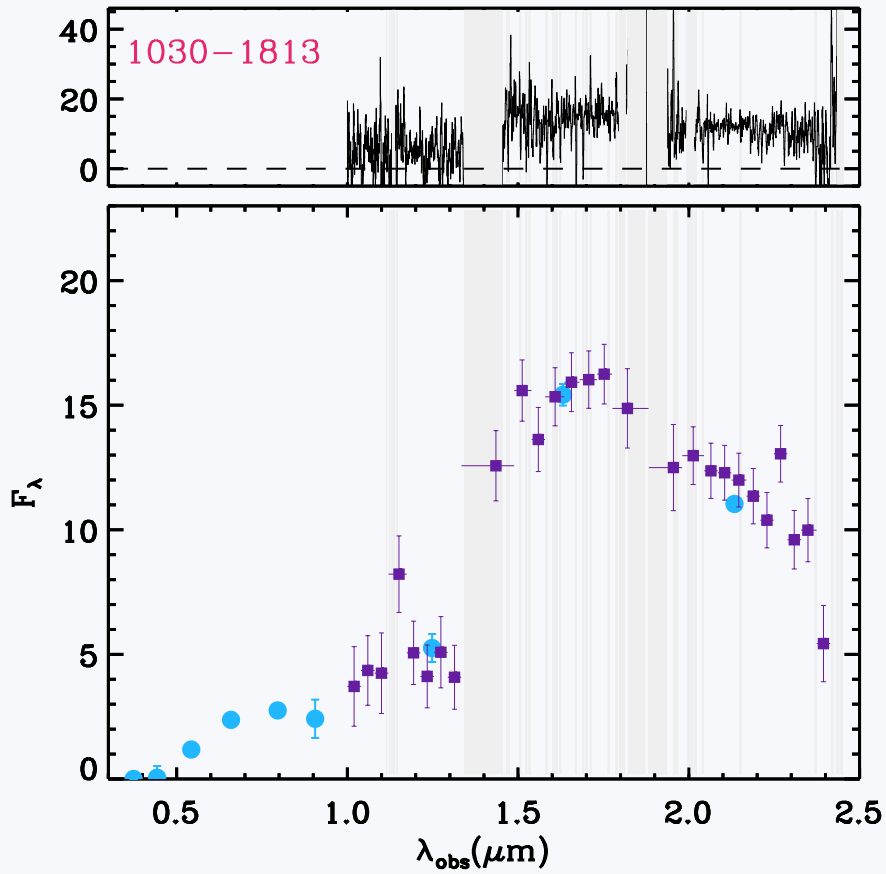

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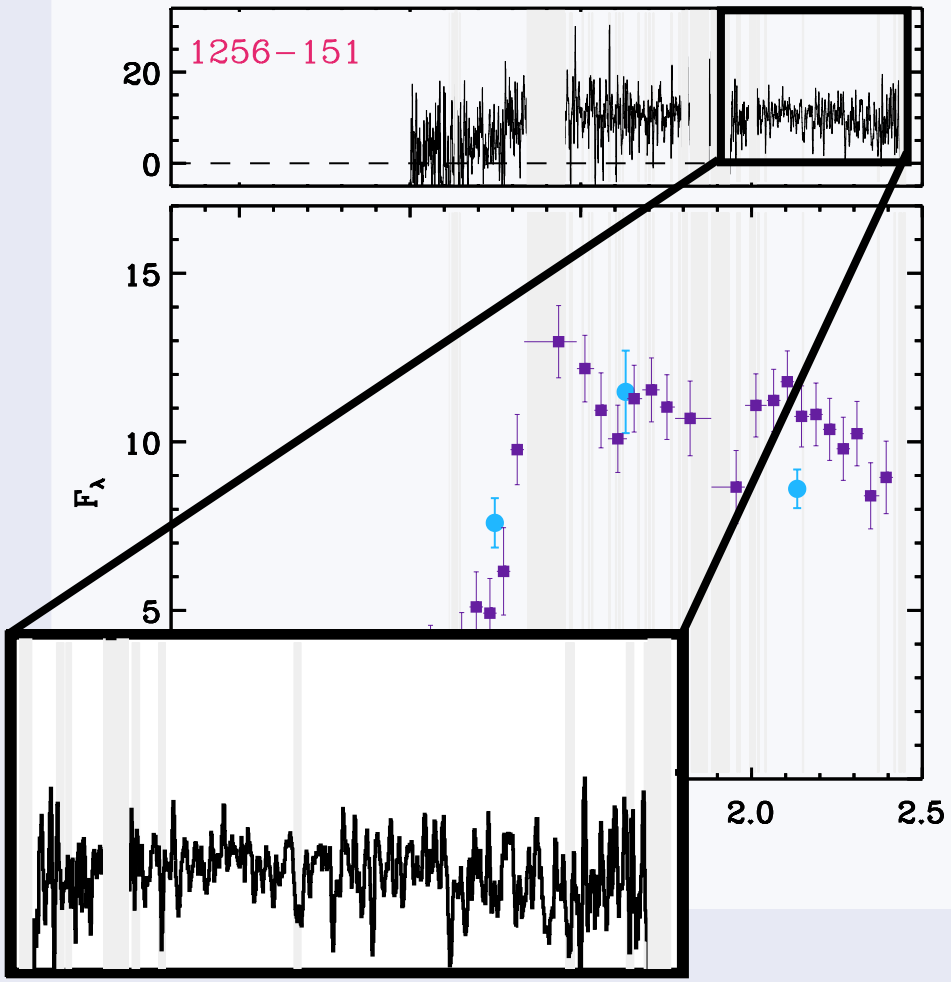

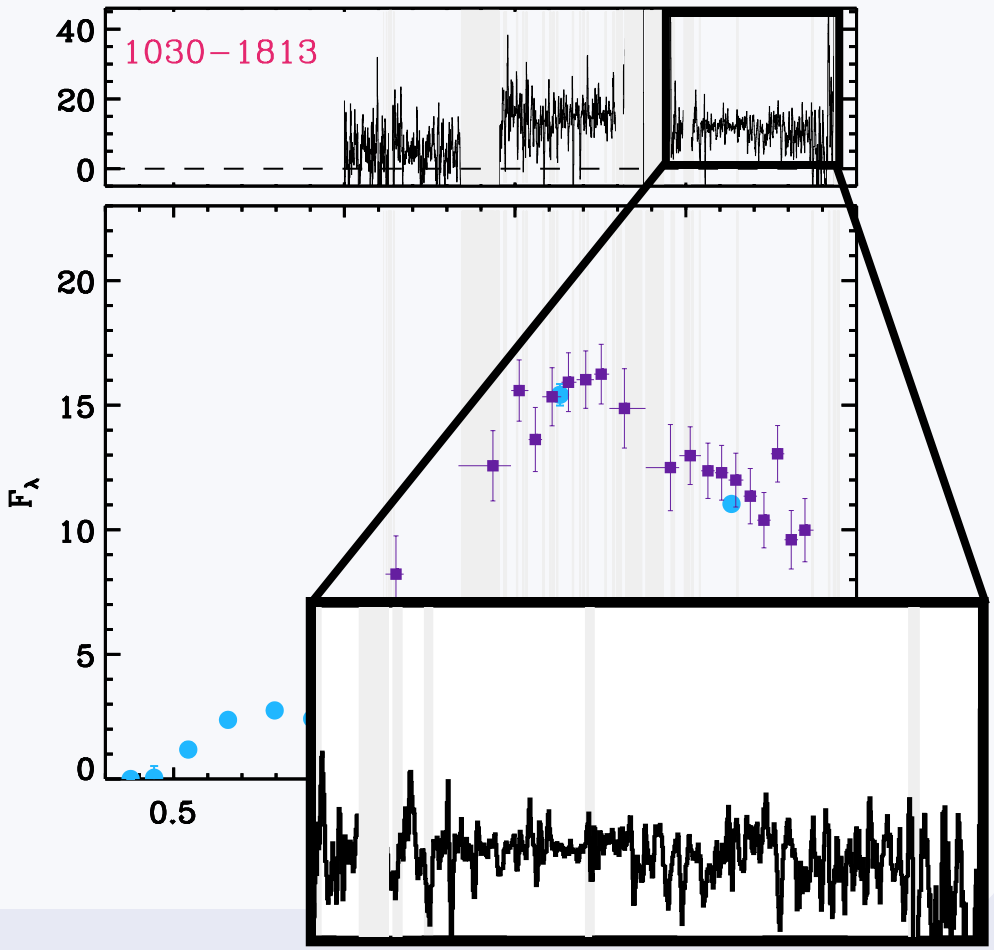

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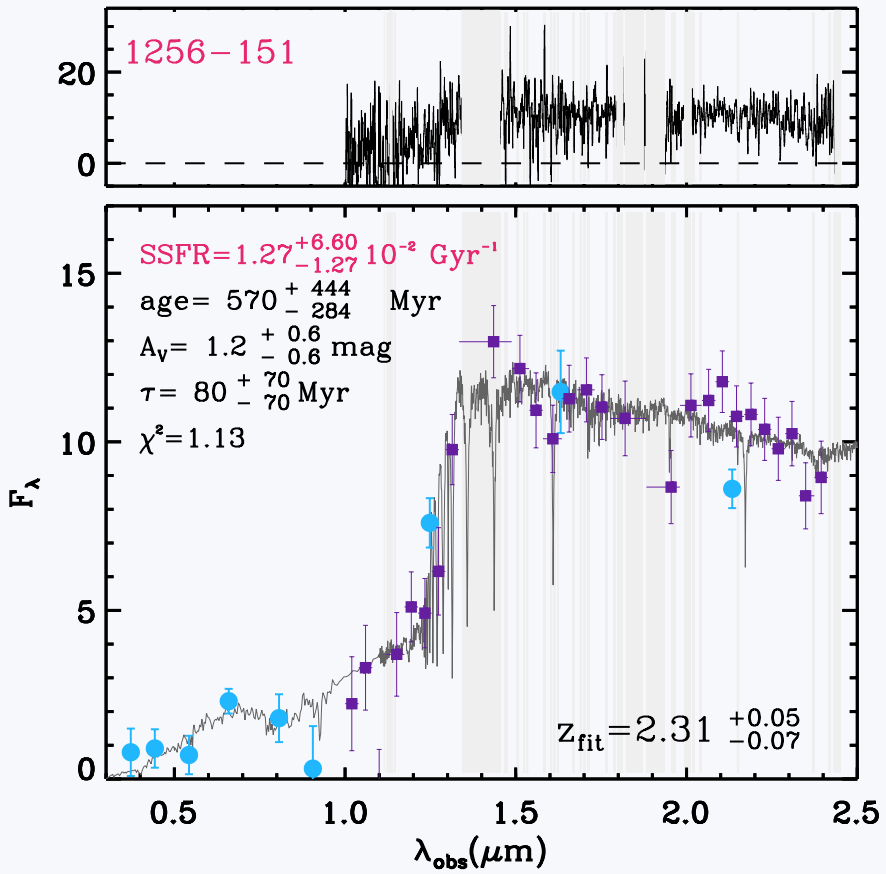
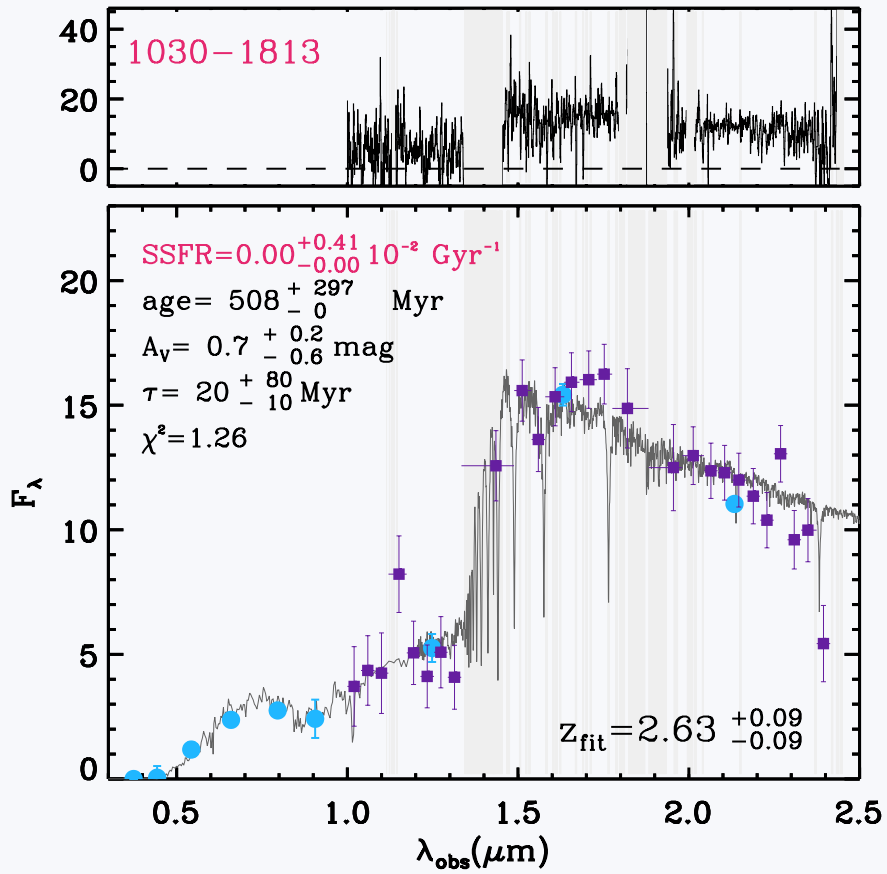
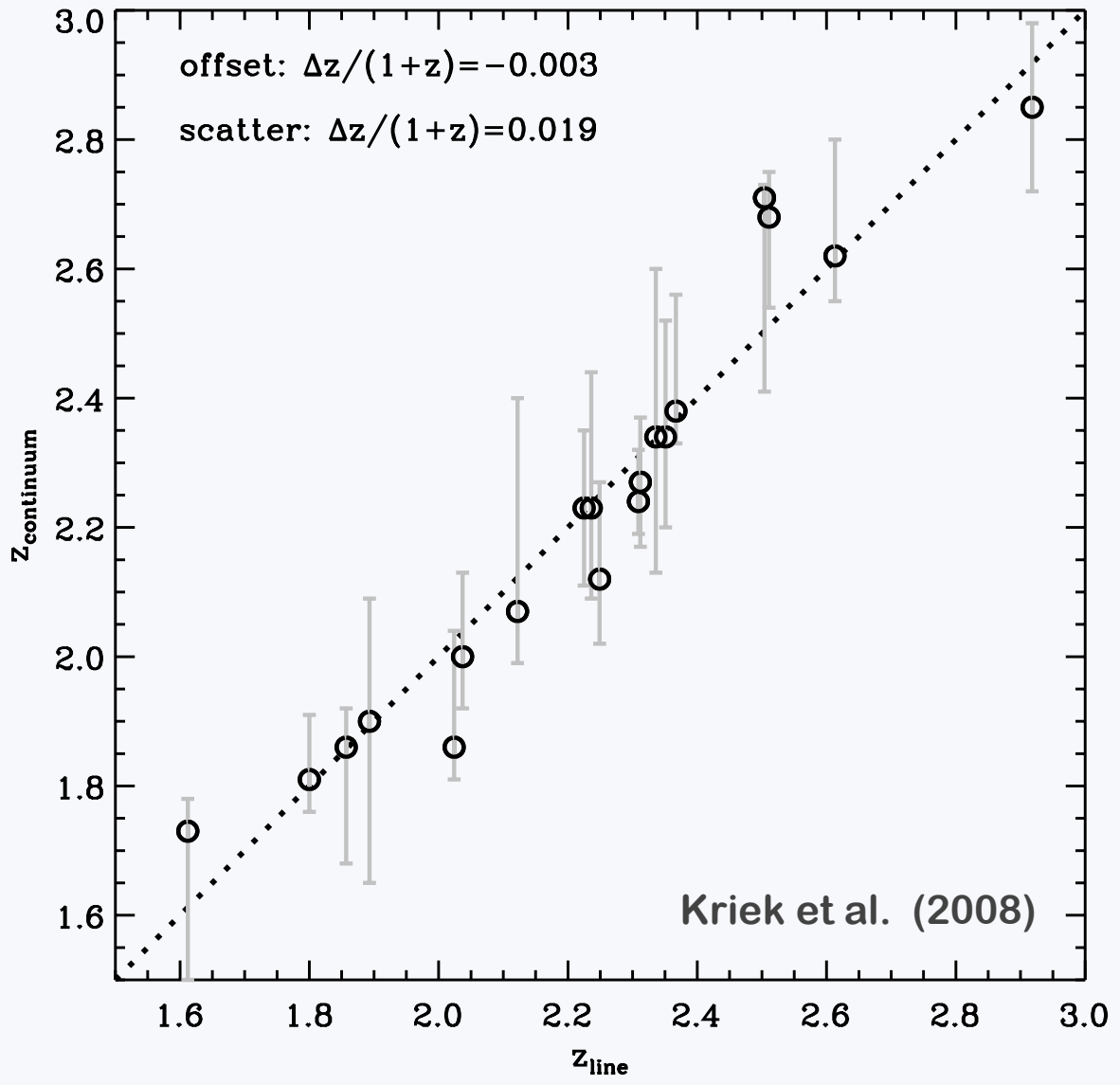




Kriek et al. (2006)

Continuum redshifts



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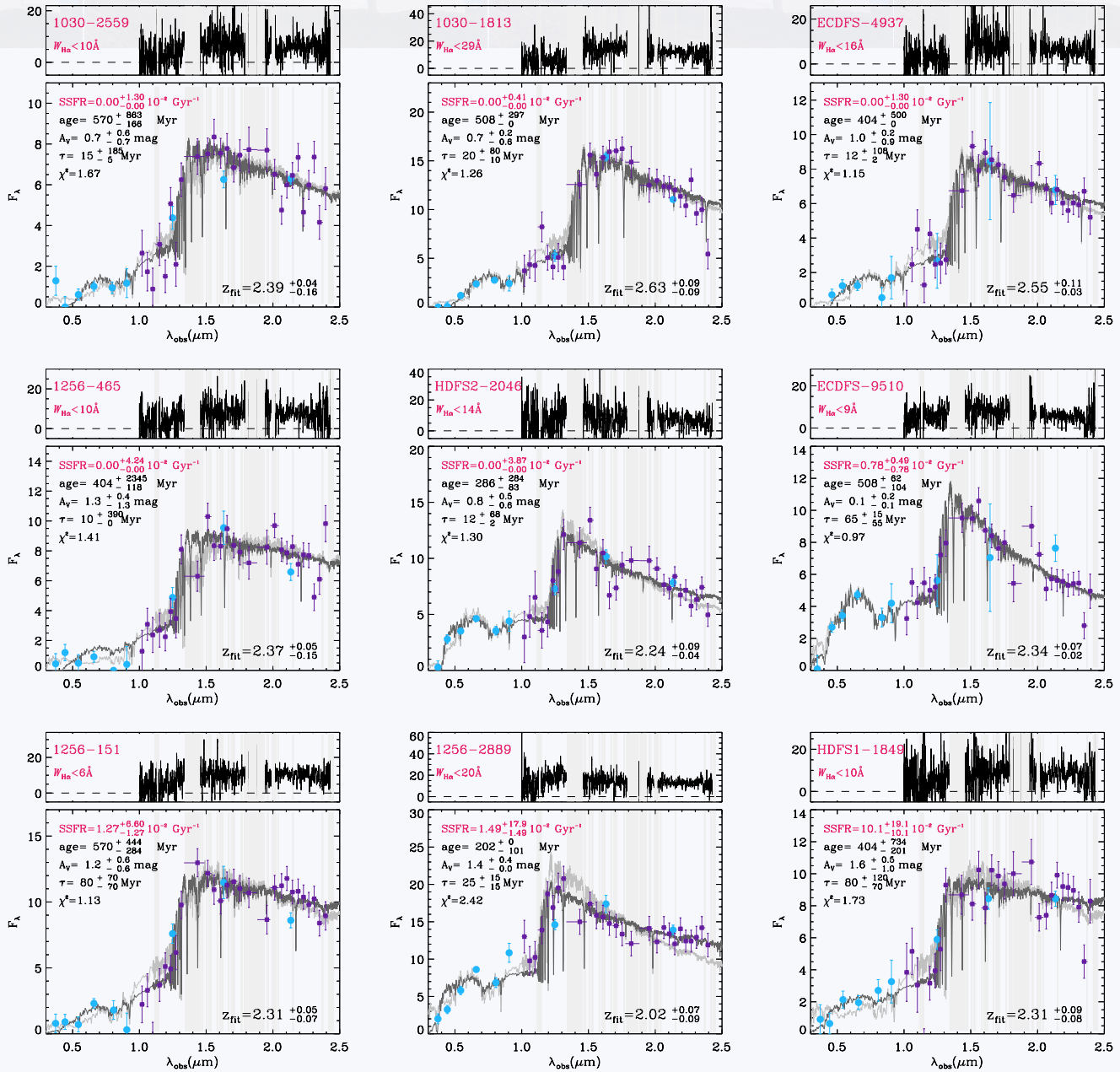
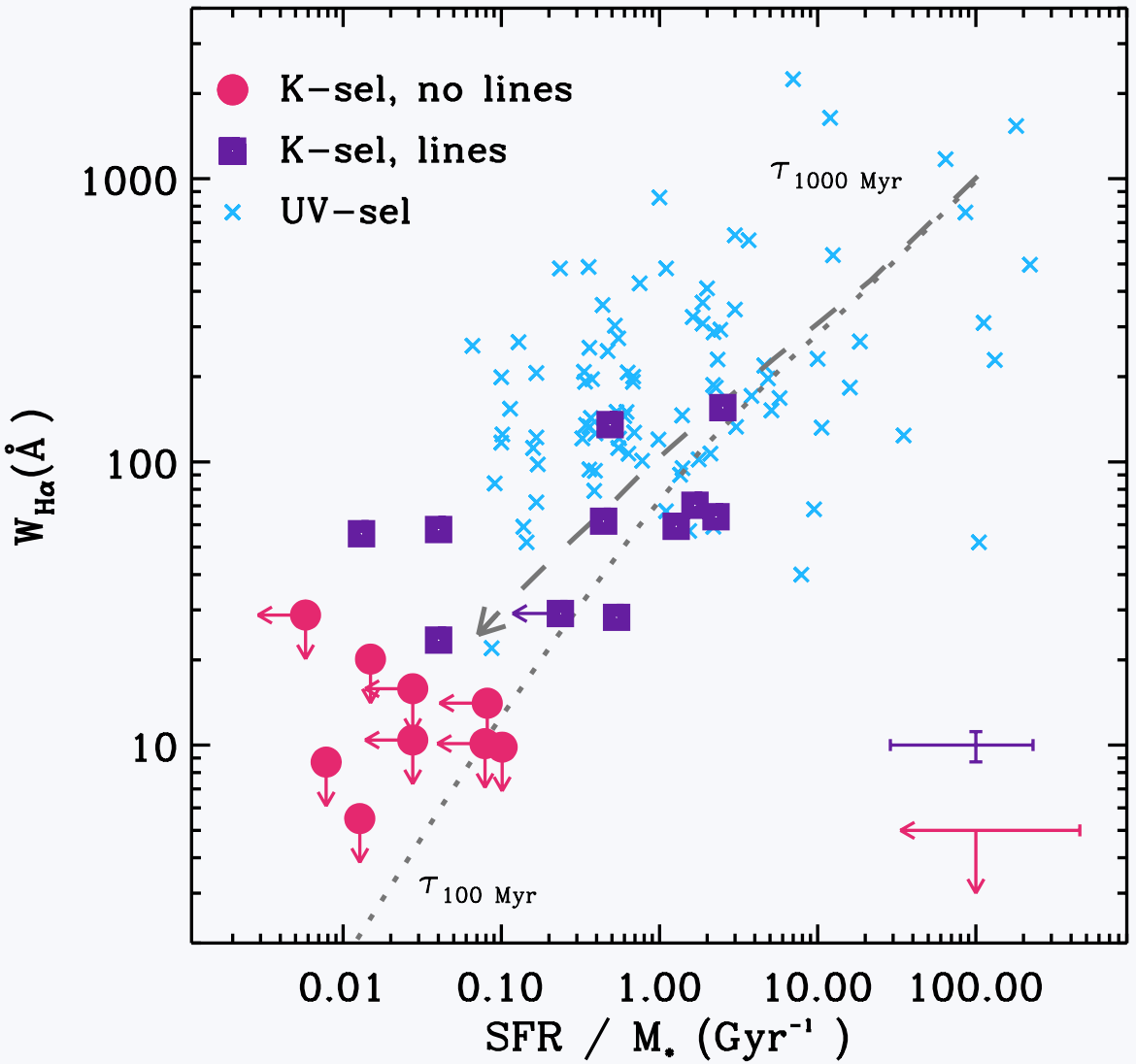


Kriek et al. (2006)

Star formation properties of galaxies at z~2.5



2 independent diagnostics for stellar populations

Erb et al. (2006); Kriek et al. (2006)

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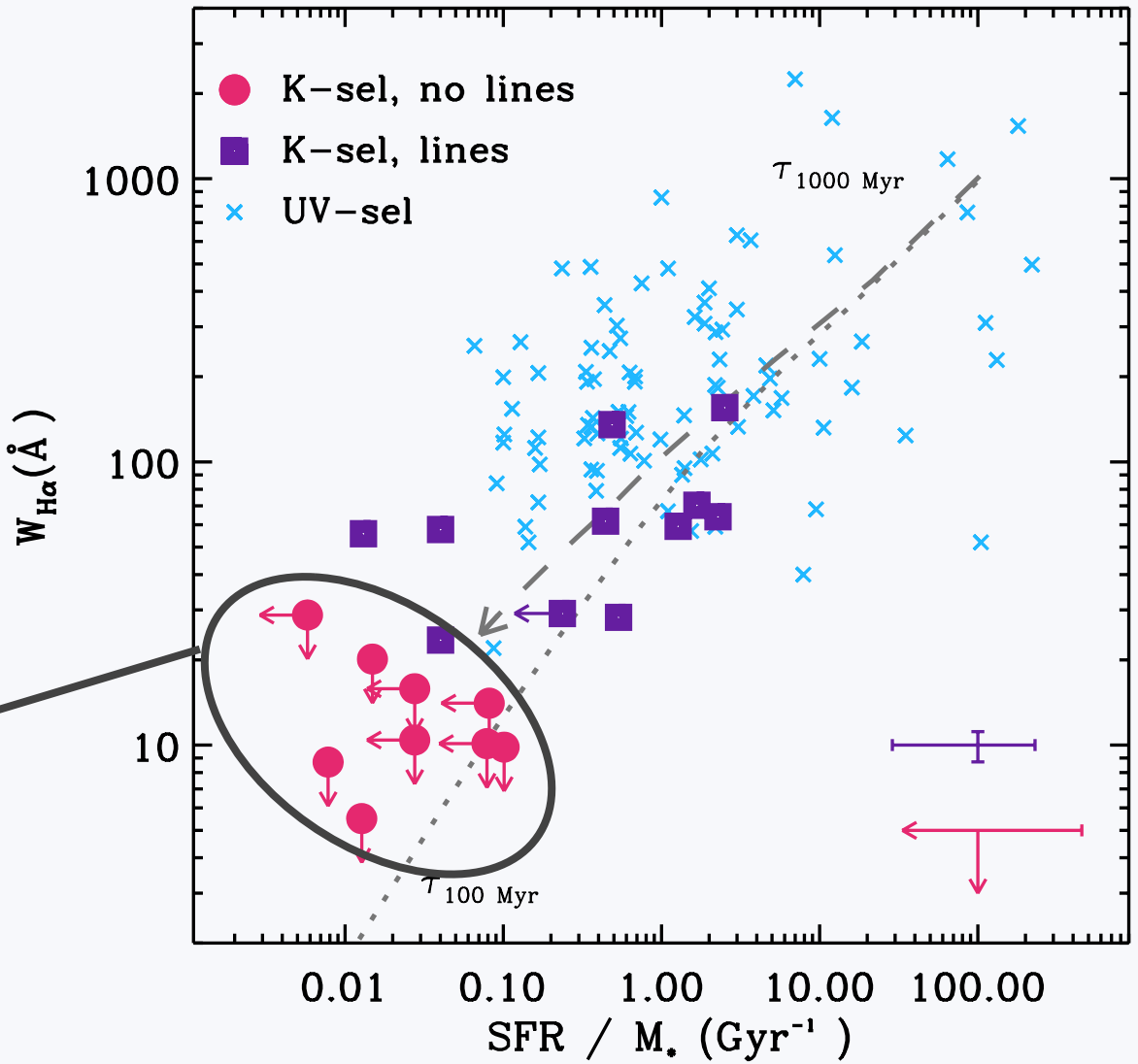

Red Sequence?

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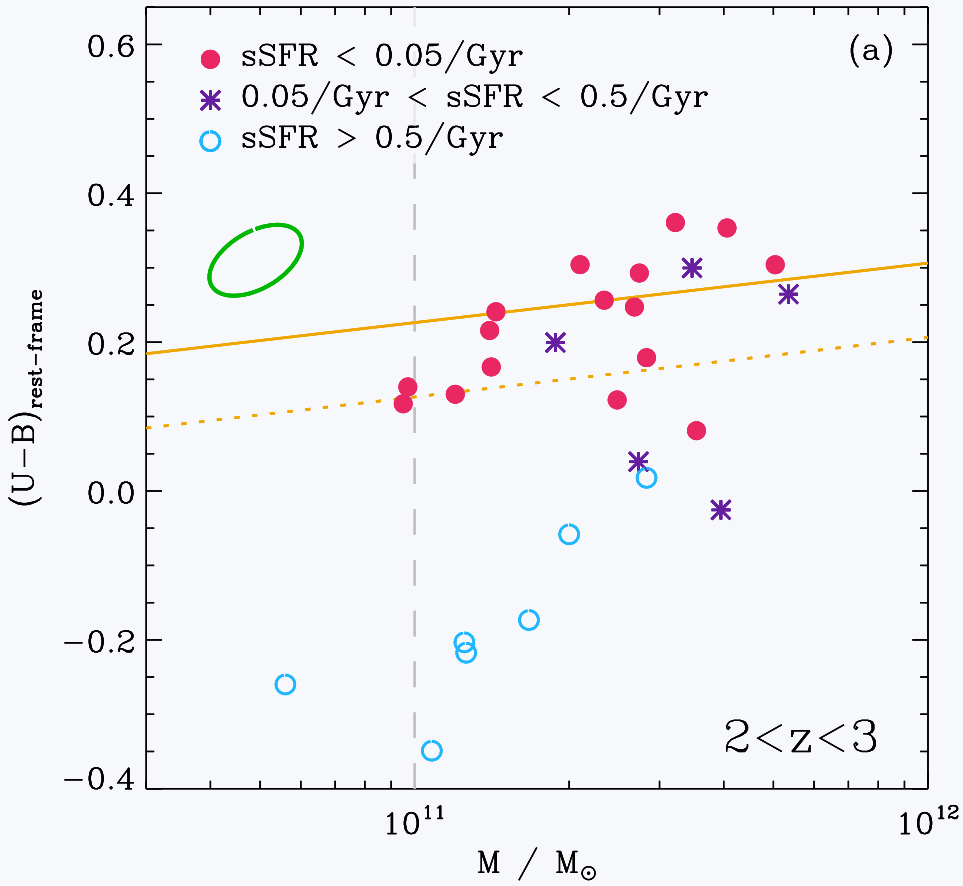
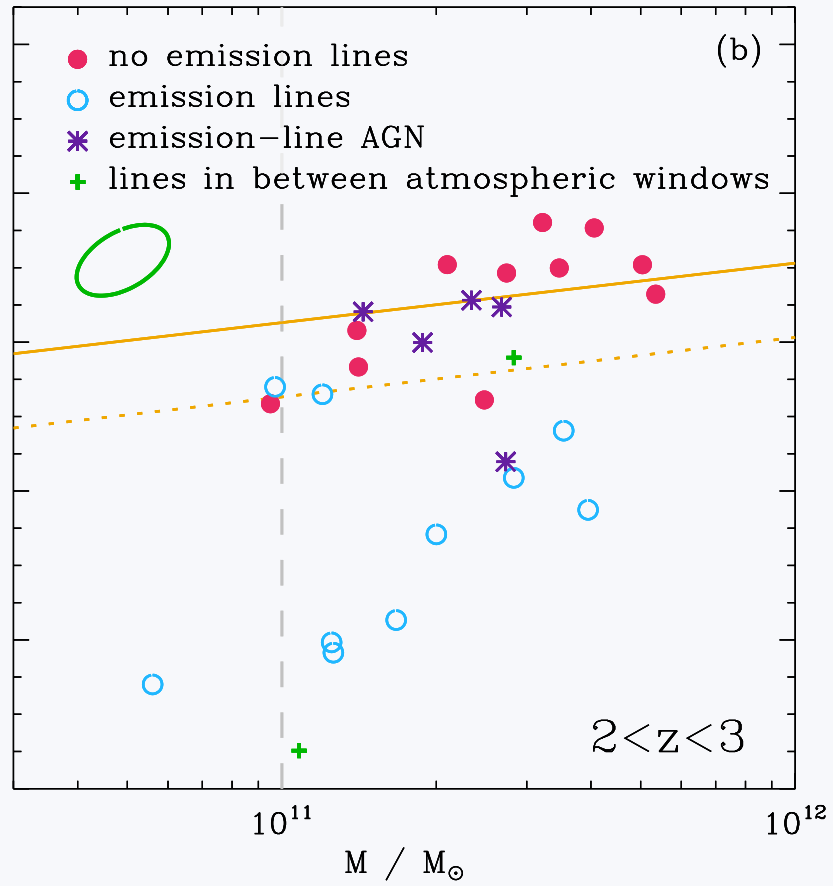
A Red Sequence at z~2.3?





Kriek et al. submitted

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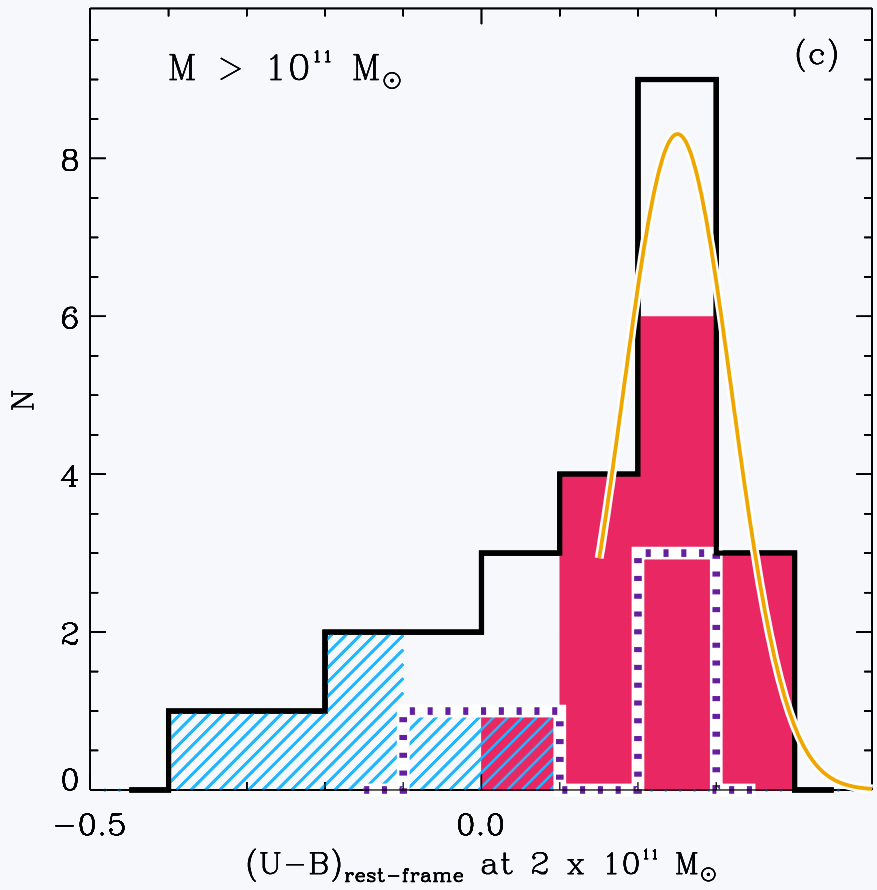
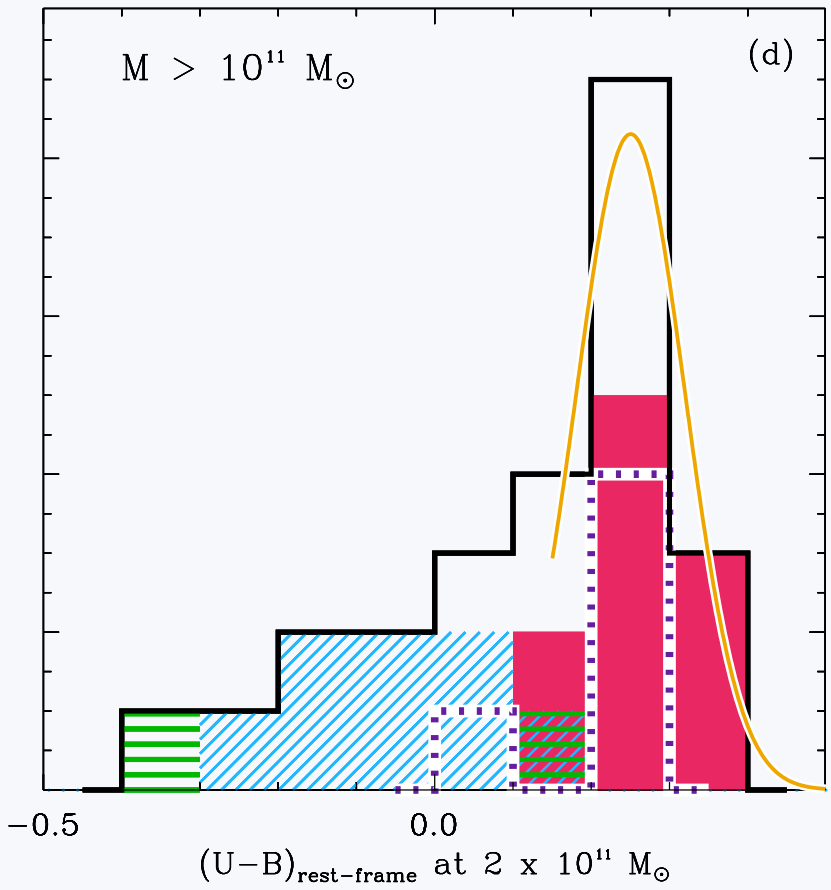
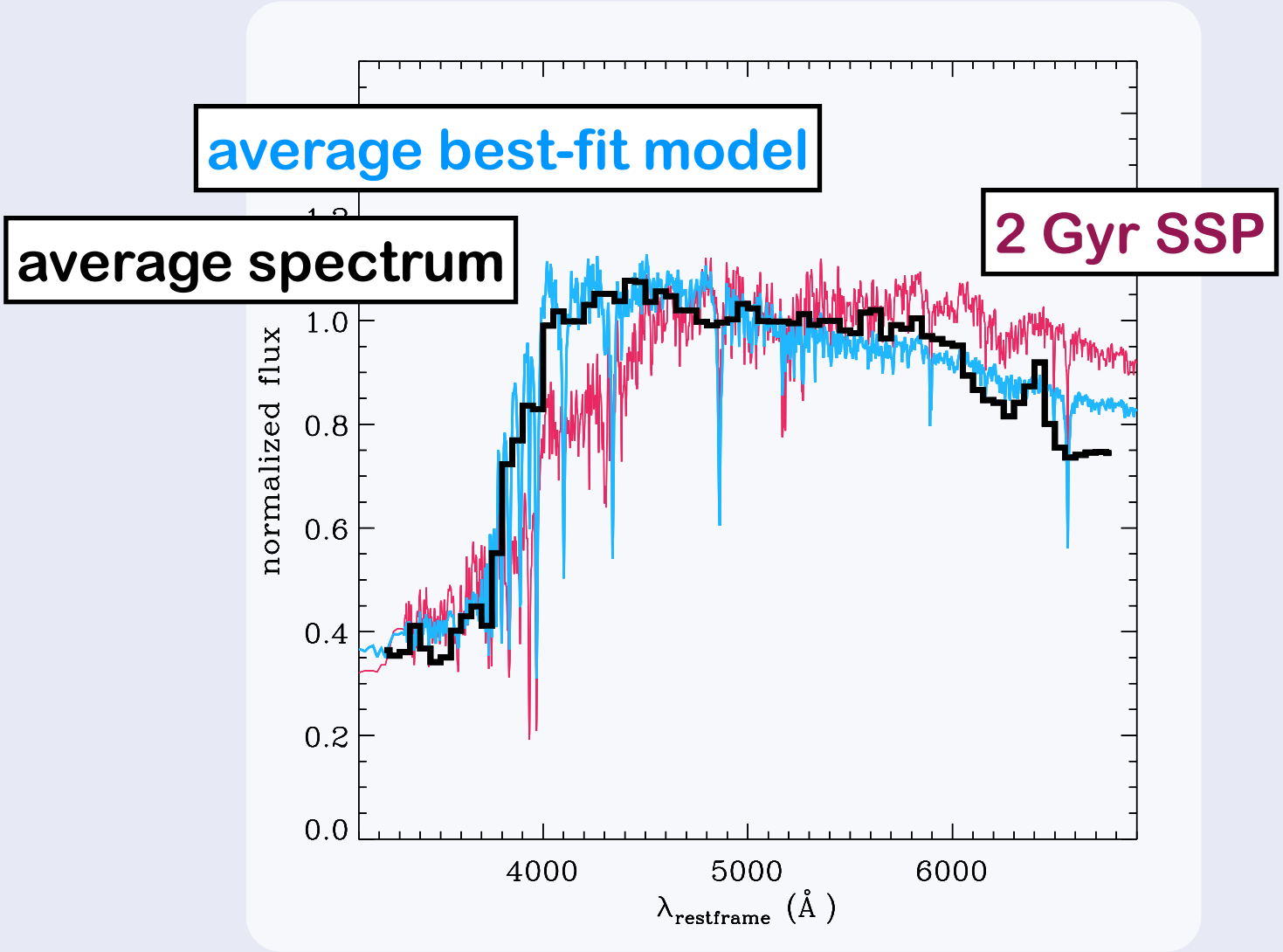




Kriek et al. submitted

Red-Sequence Galaxies at z~2.3



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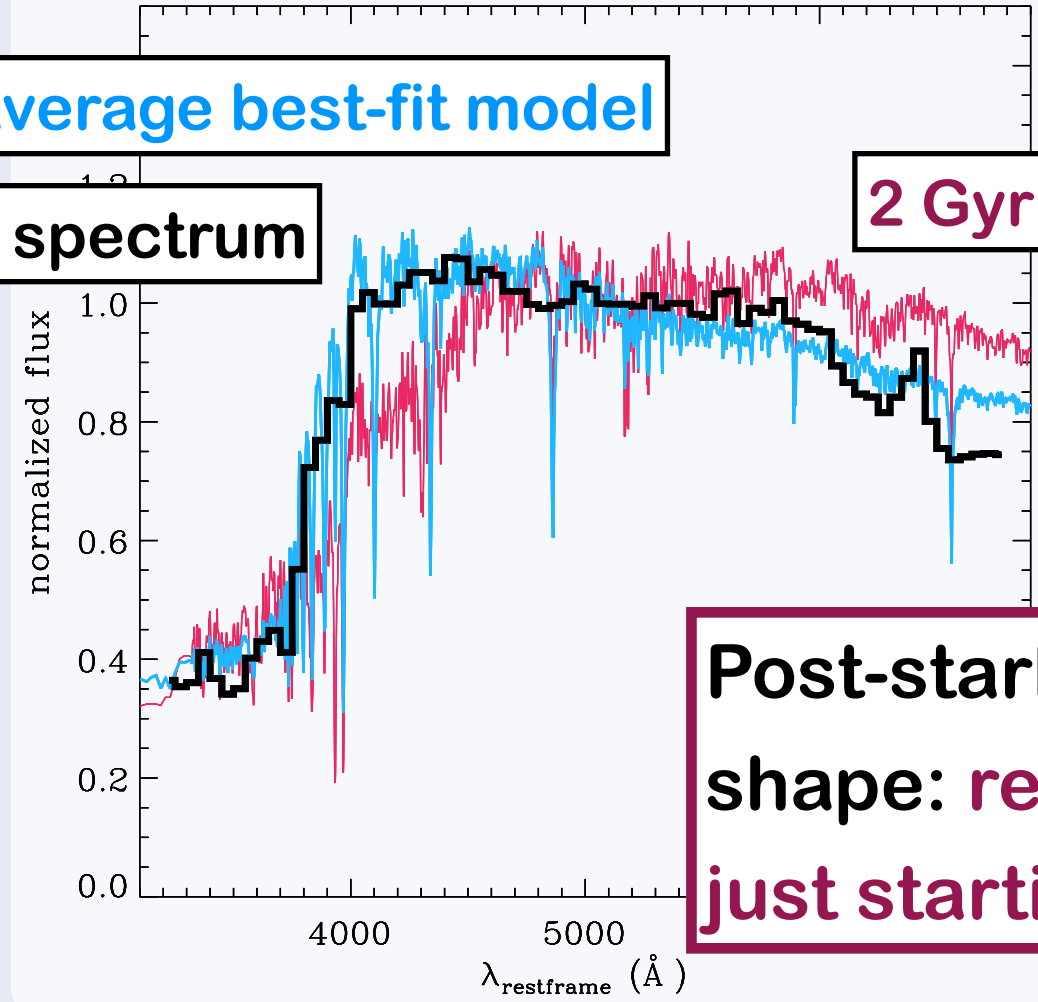

Post-starburst spectral shape: red sequence just starting to build up?

Kriek et al. submitted

Why use GNIRS to observe massive galaxies in the early universe?

Covers the full rest-frame optical for massive galaxies at z~2.5 in one shot: this allows both continuum and emission line studies:

- Redshift for galaxies without detectable emission lines
- Calibrate photometric studies
- Stellar populations properties and stellar masses
- Origin of ionized emission
- Accurate rest-frame color measurements to trace the evolution of the red sequence

~30 hour spectrum!