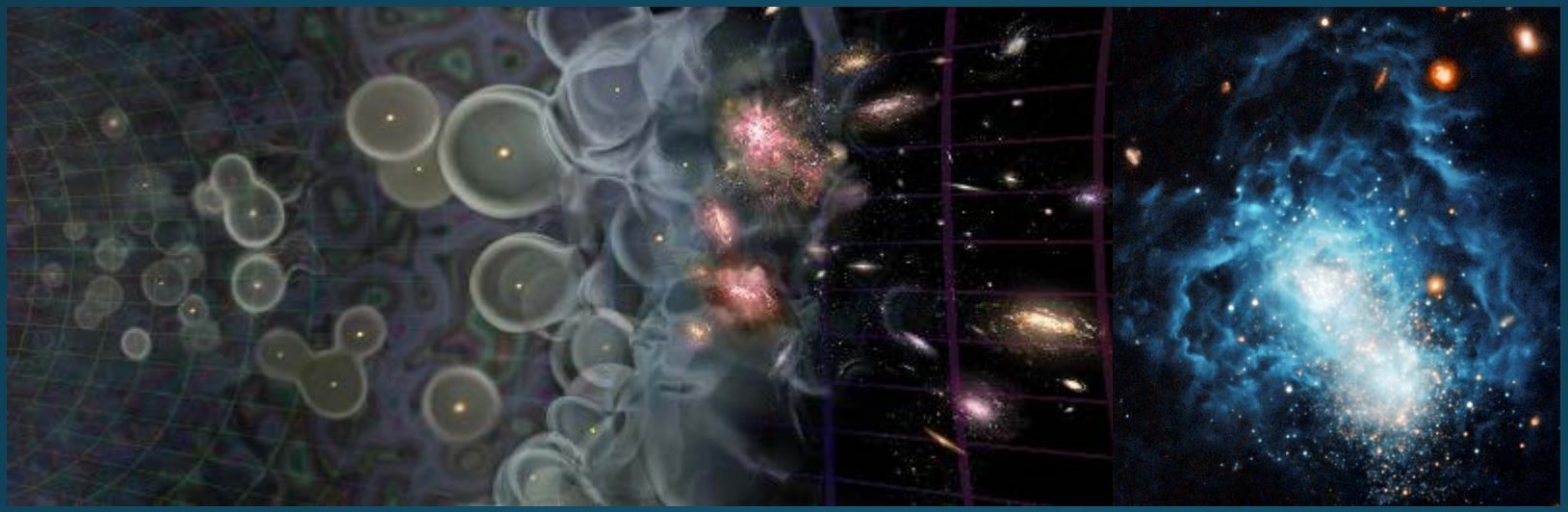
Constraining the escape of ionizing photons from galaxies at z > 6 with JWST



Erik Zackrisson

Uppsala University, Sweden

Christian Binggeli, Kristian Finlator, Nick Gnedin, Jan-Pieter Paardekooper, Ikkoh Shimizu , Akio Inoue, Hannes Jensen, Genoveva Micheva, Kristiaan Pelckmans

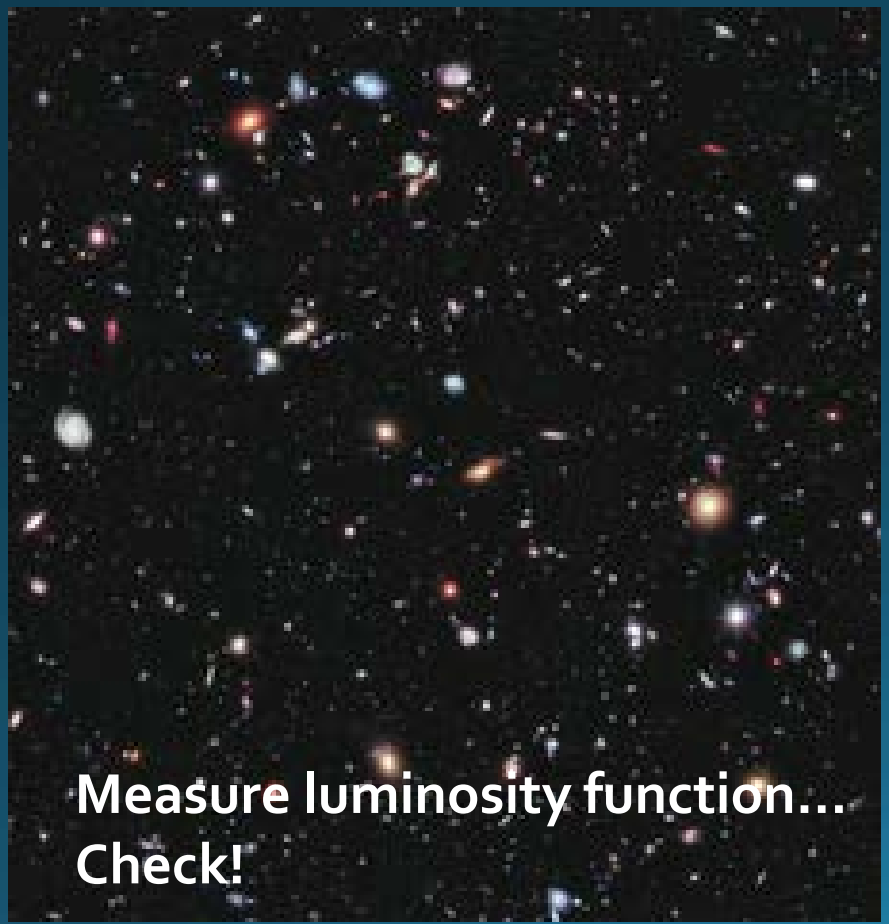
Take-home message

JWST/NIRSpec will be able to measure the escape of ionizing radiation from galaxies at redshift $z \approx 6\text{-}9$ – and this project can go piggy-back on other NIRSpec surveys!

Zackrisson et al. 2013, ApJ, 777, 39
Jensen et al. 2016, ApJ, in press (arXiv1603.09610)

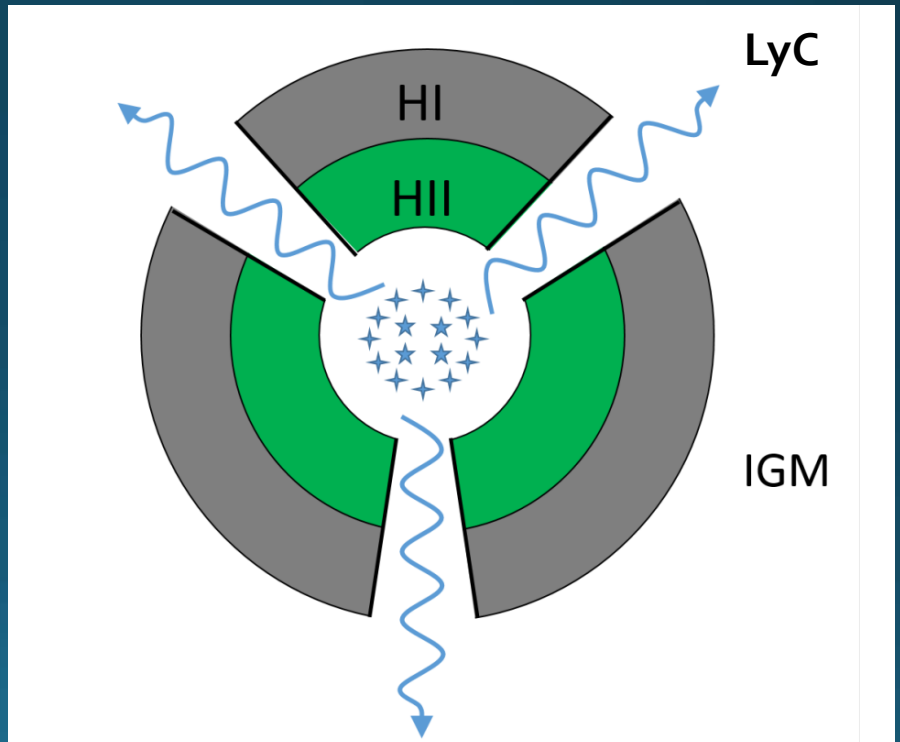
So, you want galaxies to reionize the Universe? Then you need…

1) Lots of star-forming galaxies at redshifts z > 6



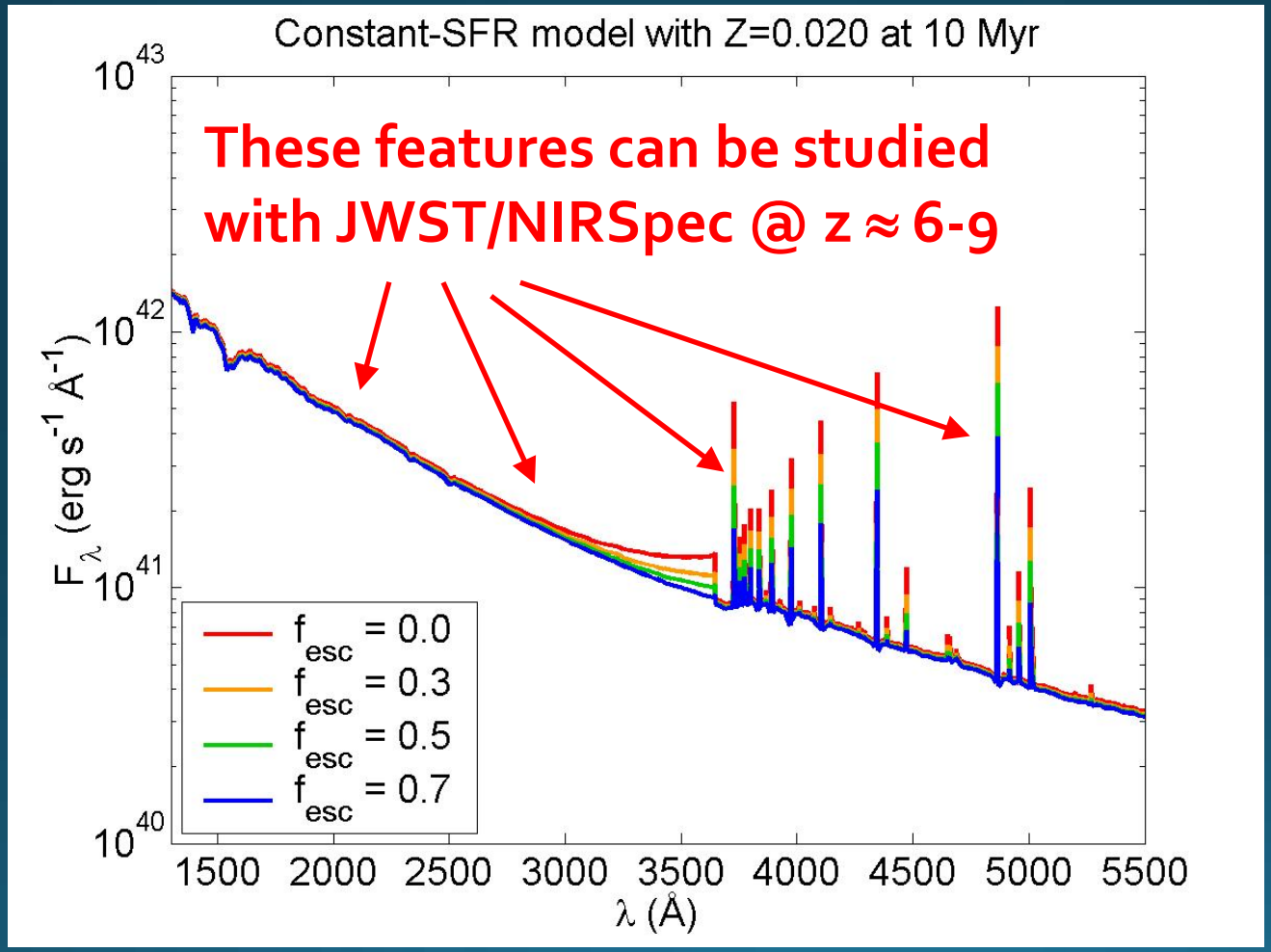
Measure luminosity function… Check!

2) Escape of ionizing photons (Lyman continuum) from galaxies into the IGM



How do you measure this at z>5 ???

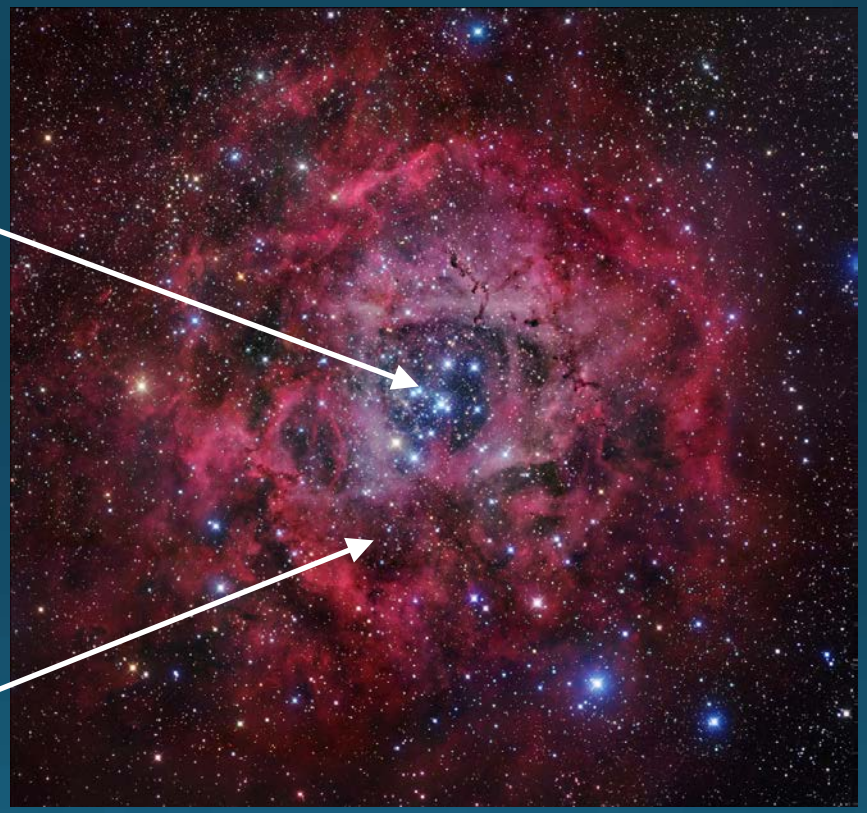
Indirect signatures of LyC leakage



Zackrisson, Inoue & Jensen 2013, ApJ, 777, 39

How does this work?

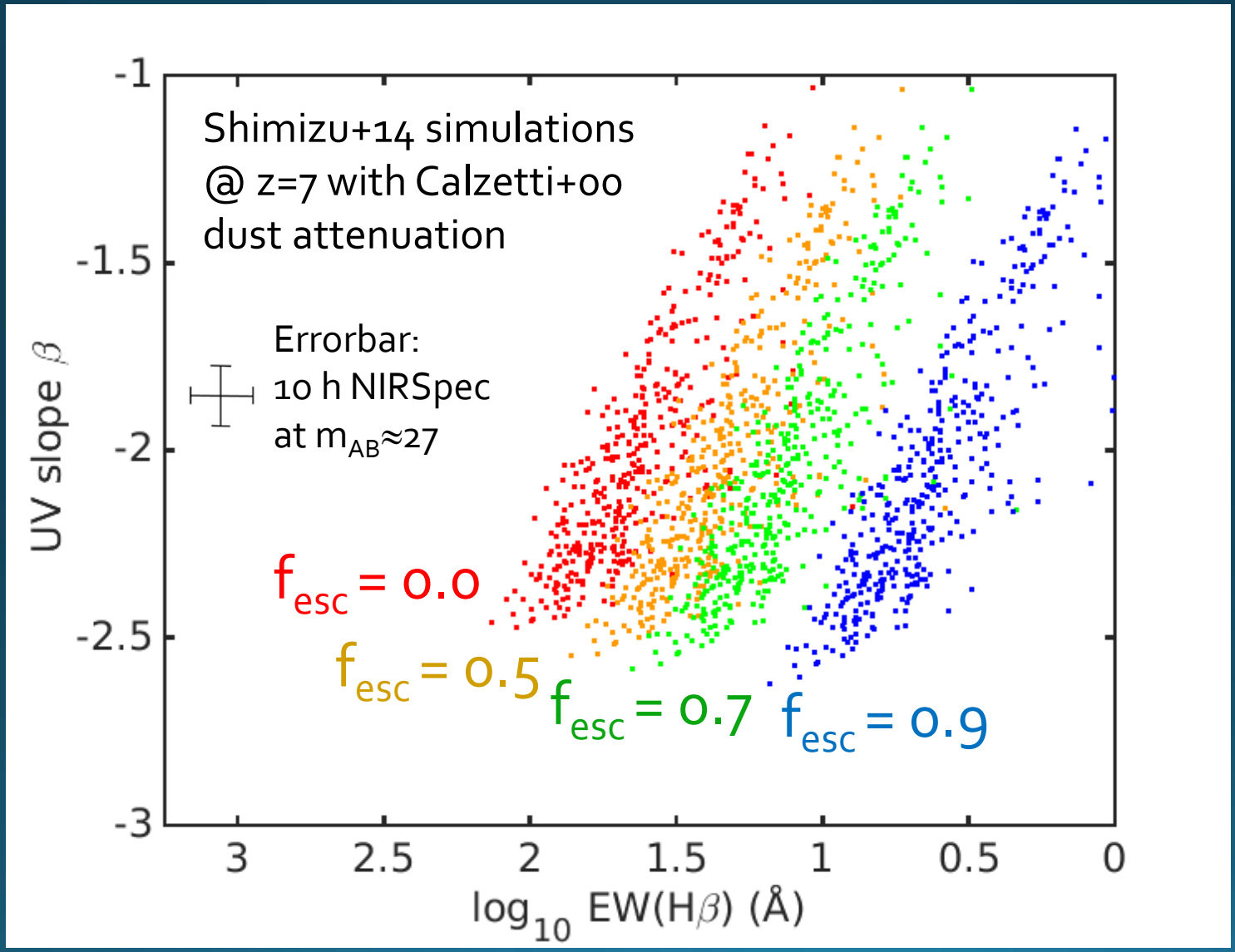
Young stars



Lyman continuum photons from young stars captured by gas → Nebular emission

If some of the LyC photons escape without ionzing the ISM → Less nebular emission!

Simple diagnostics: UV slope & Hβ



How well can we measure f_{esc}?

LYman Continuum ANalysis project:

Galaxy simulations + Yggdrasil SED models (stars, gas, dust; Zackrisson et al. 2011) + observational errors →

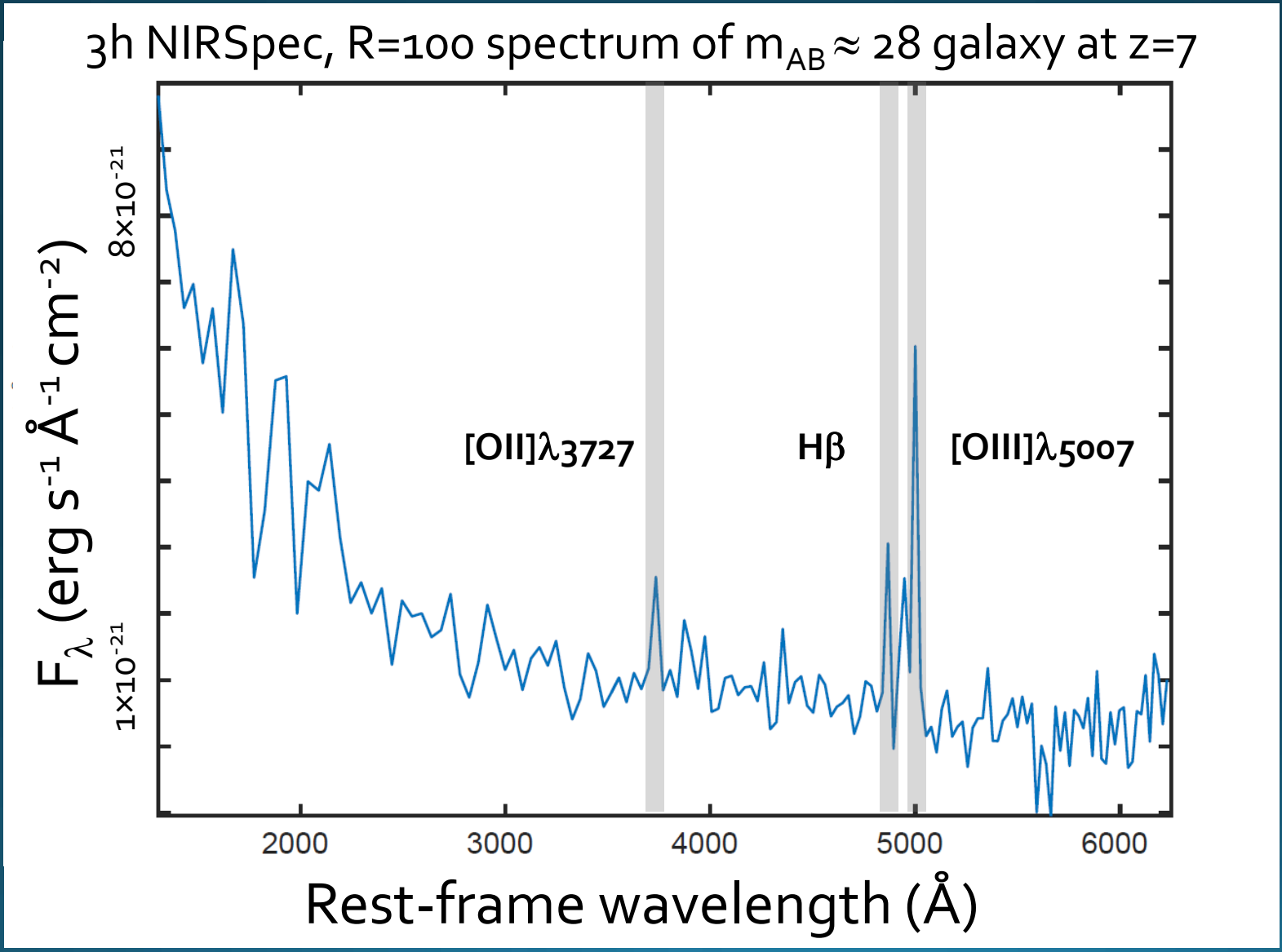
Mock spectra of high-z galaxies with Lyman continuum leakage

Simulations suites:

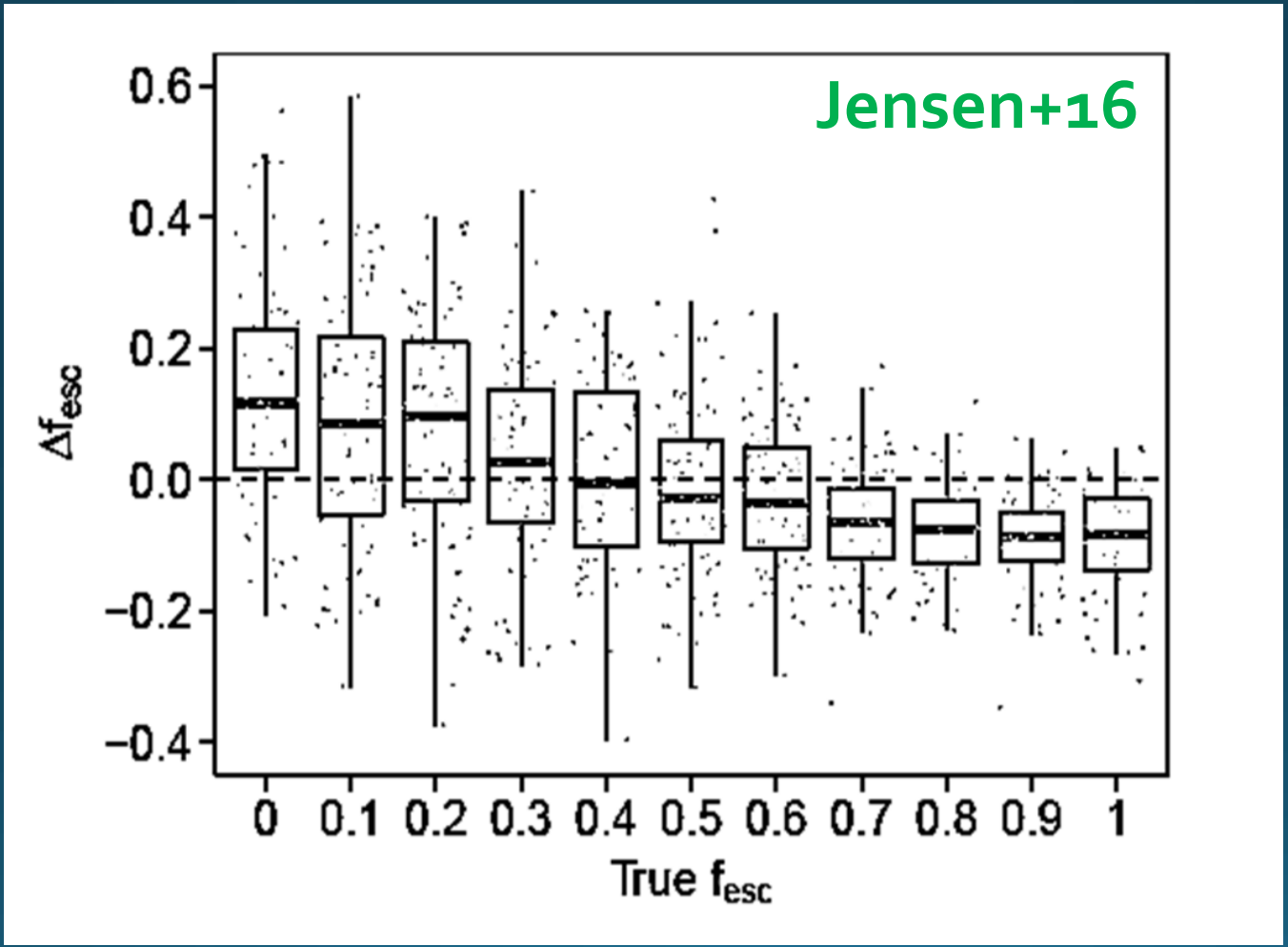
CROC (Gnedin 2014)
FiBY (Paardekooper et al. 2015)
Finlator et al. (2013)
Shimizu et al. (2014)

Highly realistic SEDs for high-redshift galaxies publicly available:
www.astro.uu.se/~ez/lycan/lycan.html

Example of LYCAN mock spectrum

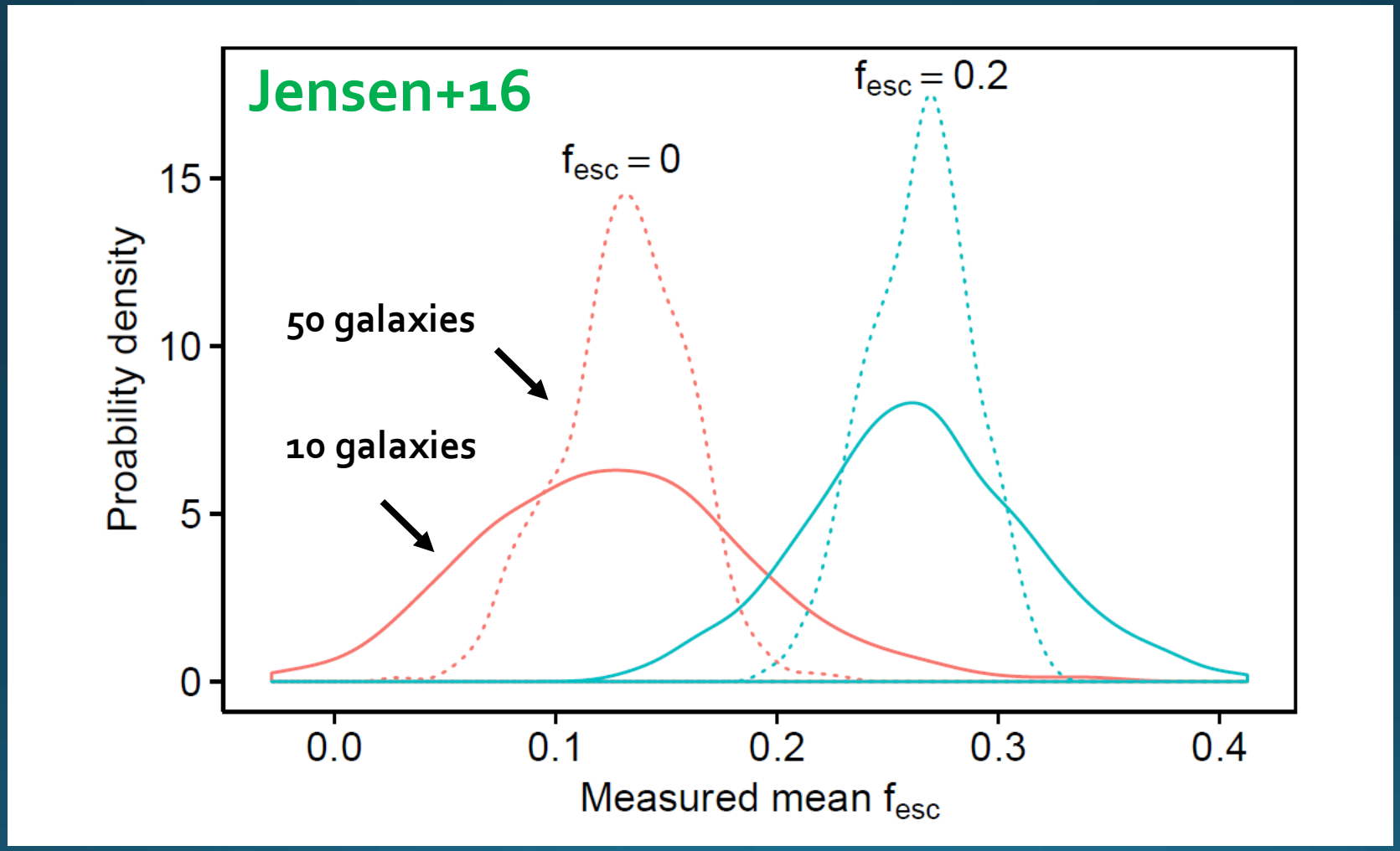


SED analysis using machine learning algorithms



3 h NIRSpec, R=100 spectra of $m_{AB}\approx28$ galaxies at z=7

SED analysis using machine learning algorithms



What you can (and cannot) hope to get

No problem:

- Identification of individual galaxies with extreme LyC leakage (f_{esc}>0.5)
- Typical LyC escape fraction from sample of ≈50 galaxies (to within Δf_{esc}≈0.1)

Problematic:

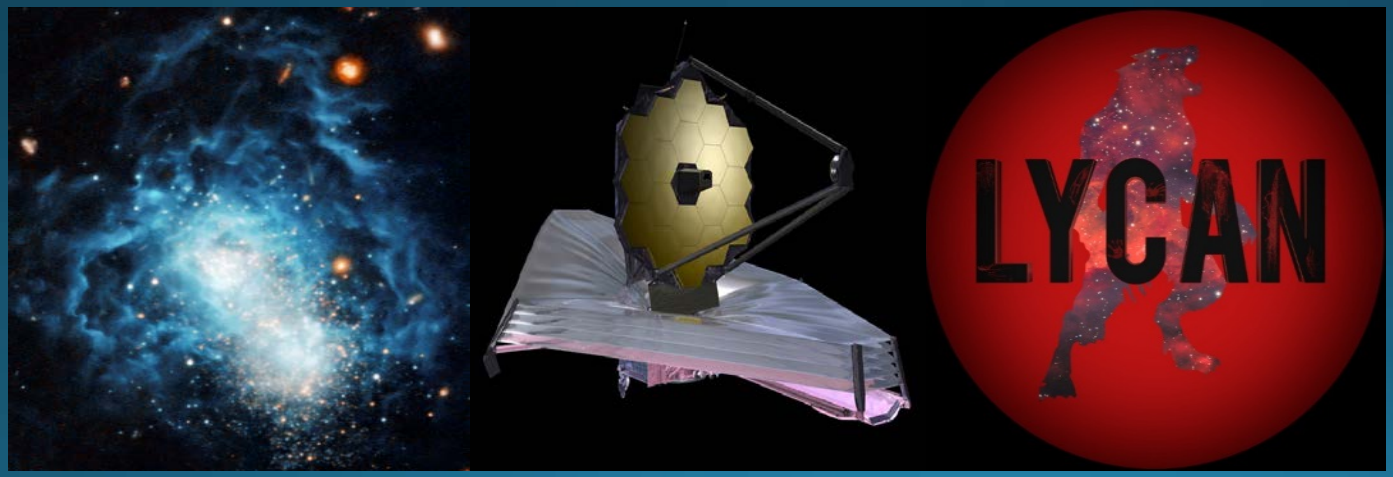
- Reliable estimates of f_{esc} for individual galaxies with f_{esc} < 0.3

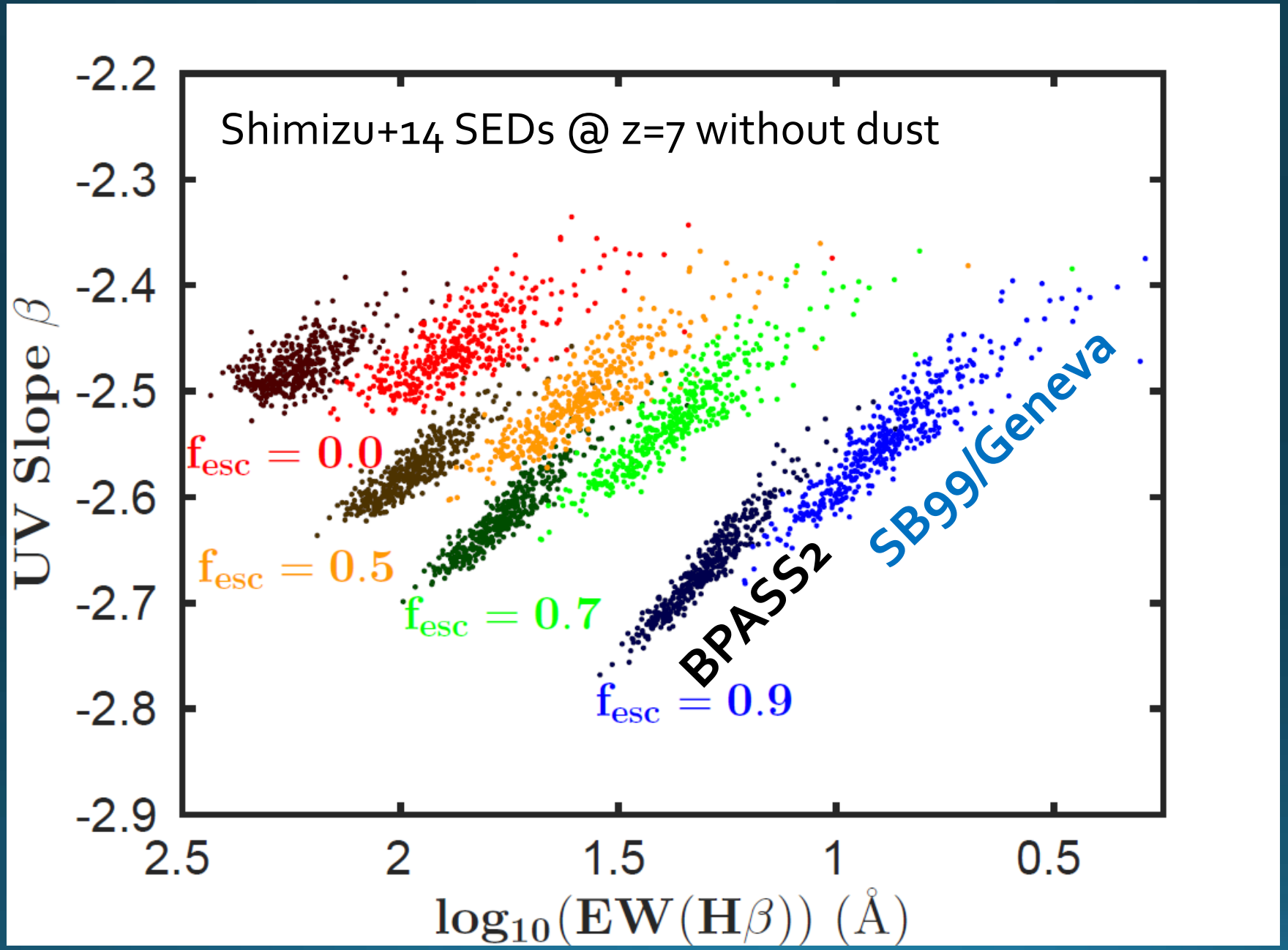
Ongoing work

- Handle on LyC leakage mechanisms: Radiation-bounded nebulae with holes vs. density-bounded nebulae
- Constraints on LyC production efficiency times the escape fraction ($\xi_{ion} f_{esc}$)
- What if you combine NIRSpec data with MIRI photometry?
- Calibration/test of technique using galaxies with direct LyC detections at $z \approx 3$

Summary

- The escape of ionizing photons from galaxies at z>6 is crucial for galaxy-dominated reionization
- JWST/NIRSpec can constrain the escape of ionizing radiation from galaxies up to z ≈ 9
- Project can go piggy-back on any NIRSpec survey of high-redshift galaxies
- Publicly available JWST mock spectra for high-z galaxies: www.astro.uu.se/~ez/lycan/lycan.html




Shimizu+14 SEDs @ z=7 without dust
UV Slope β
-2.2
-2.3
-2.4
-2.5
-2.6
-2.7
-2.8
-2.9
2.5
2
1.5
1
0.5
$\log_{10}(\mathrm{EW}(\mathrm{H}\beta))$ (Å)
$f_{esc} = 0.0$
$f_{esc} = 0.5$
$f_{esc} = 0.7$
$f_{esc} = 0.9$
BPASS2
SB99/Geneva