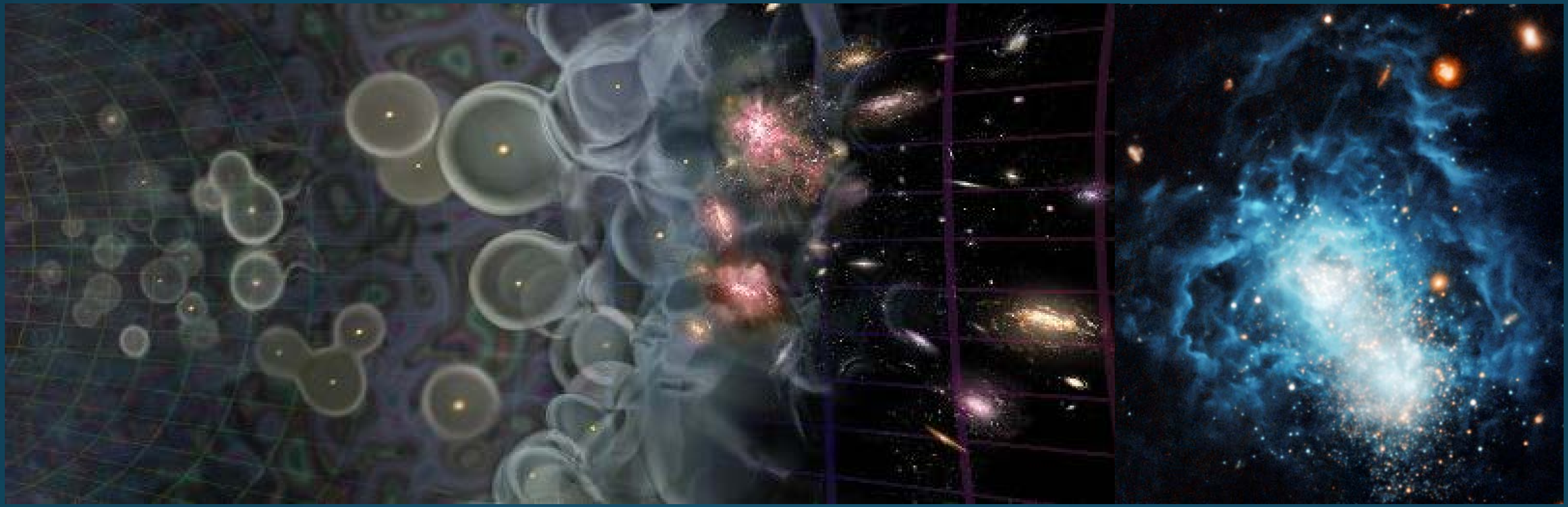
Constraining the escape of ionizing photons from $z > 6$ galaxies with JWST



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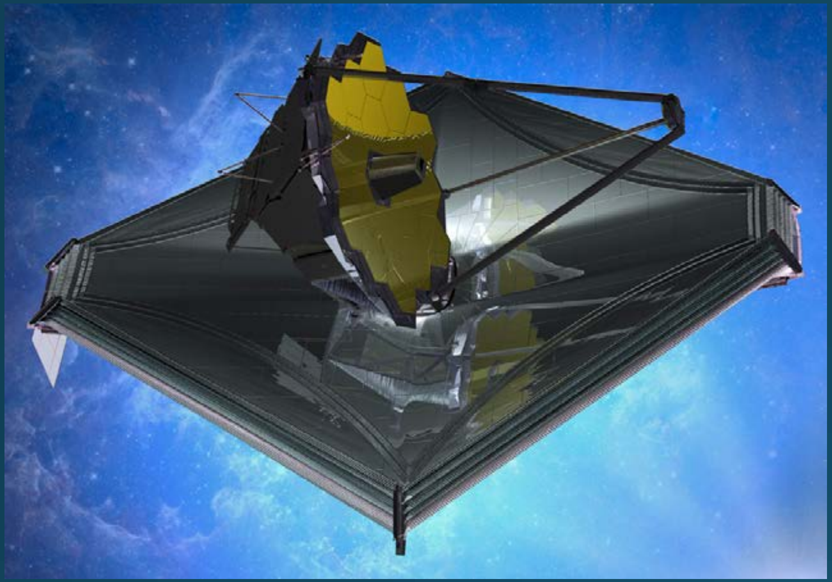
Punchline



New way to study the role of galaxies in the reionization of the Universe:

JWST/NIRSpec measurements of the escape of ionizing radiation from galaxies at redshift $z \approx 6$-9

Zackrisson et al. 2013, ApJ, 777, 39

What caused cosmic reionization?

Studies of the intergalactic medium (e.g. Lyα, CMBR) can reveal *when* reionization happened, but where did the ionizing photons come from?

Star-forming galaxies at $z > 6$ are the prime suspects, but how do we prove that they did it?

S.G. Djorgovski et al. & Digital Media Center, Caltech

CMBR

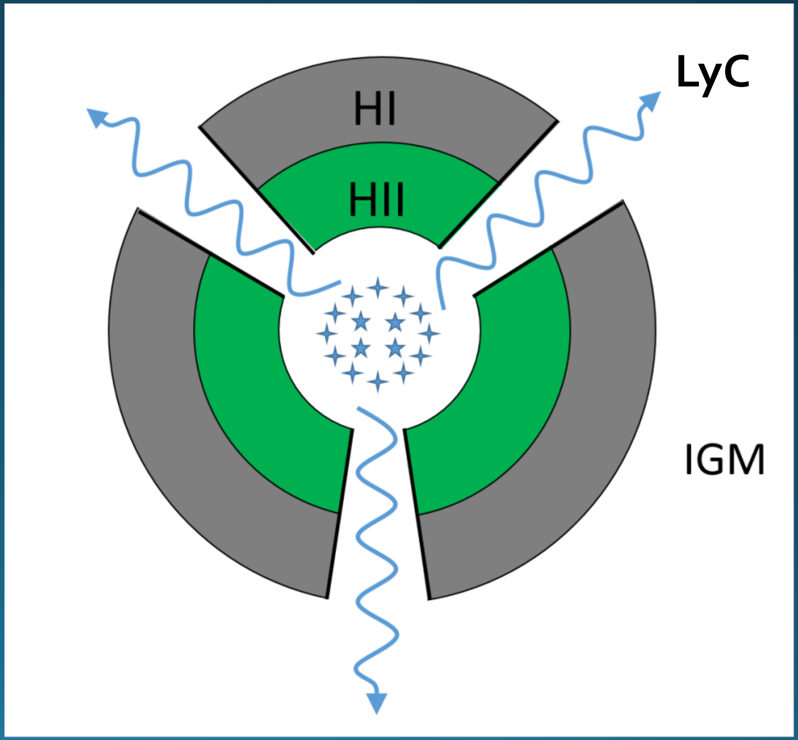
Reionization ($z \approx 6\text{-}14$)

Today

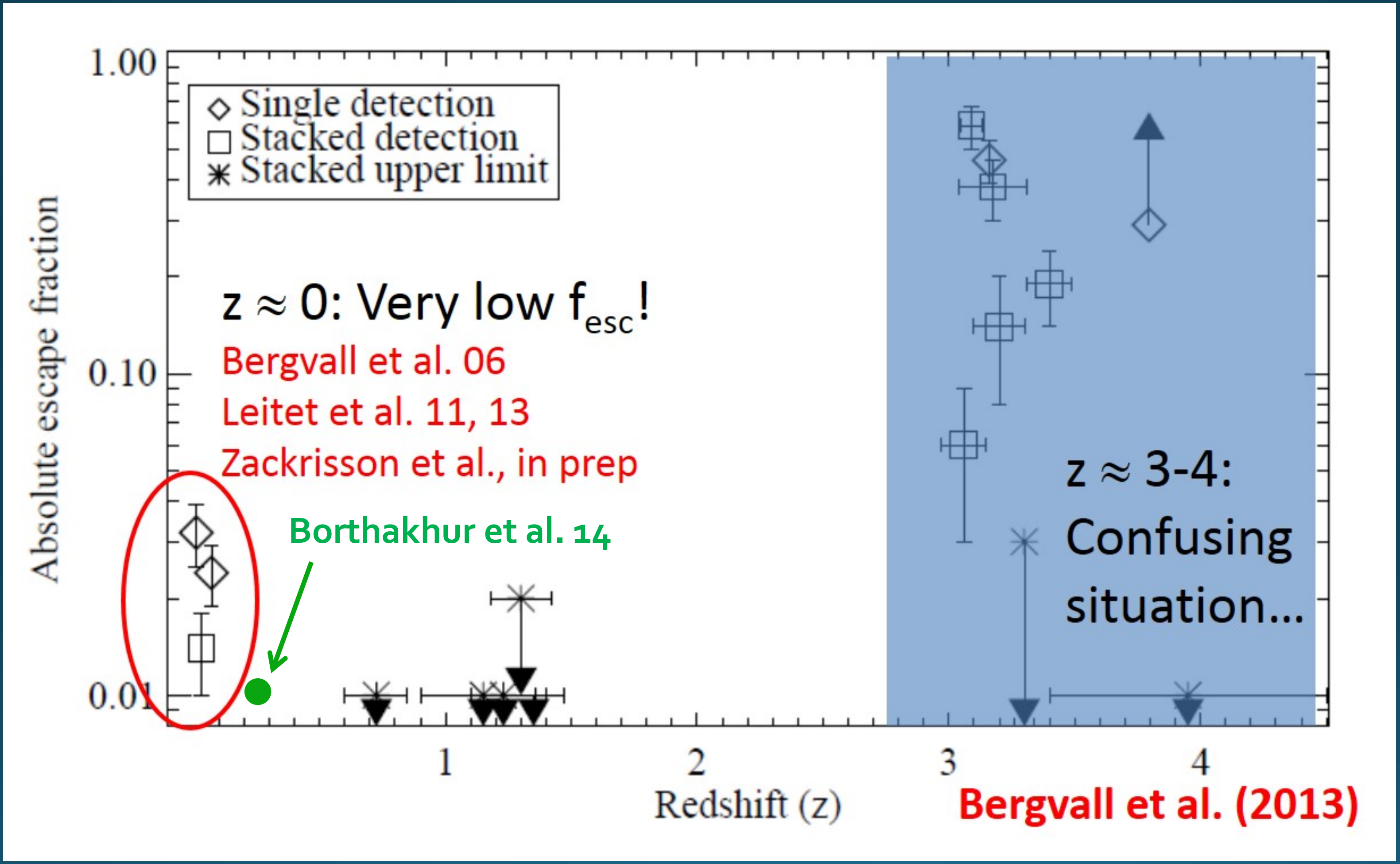
Requirements for galaxy-dominated reionization

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

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

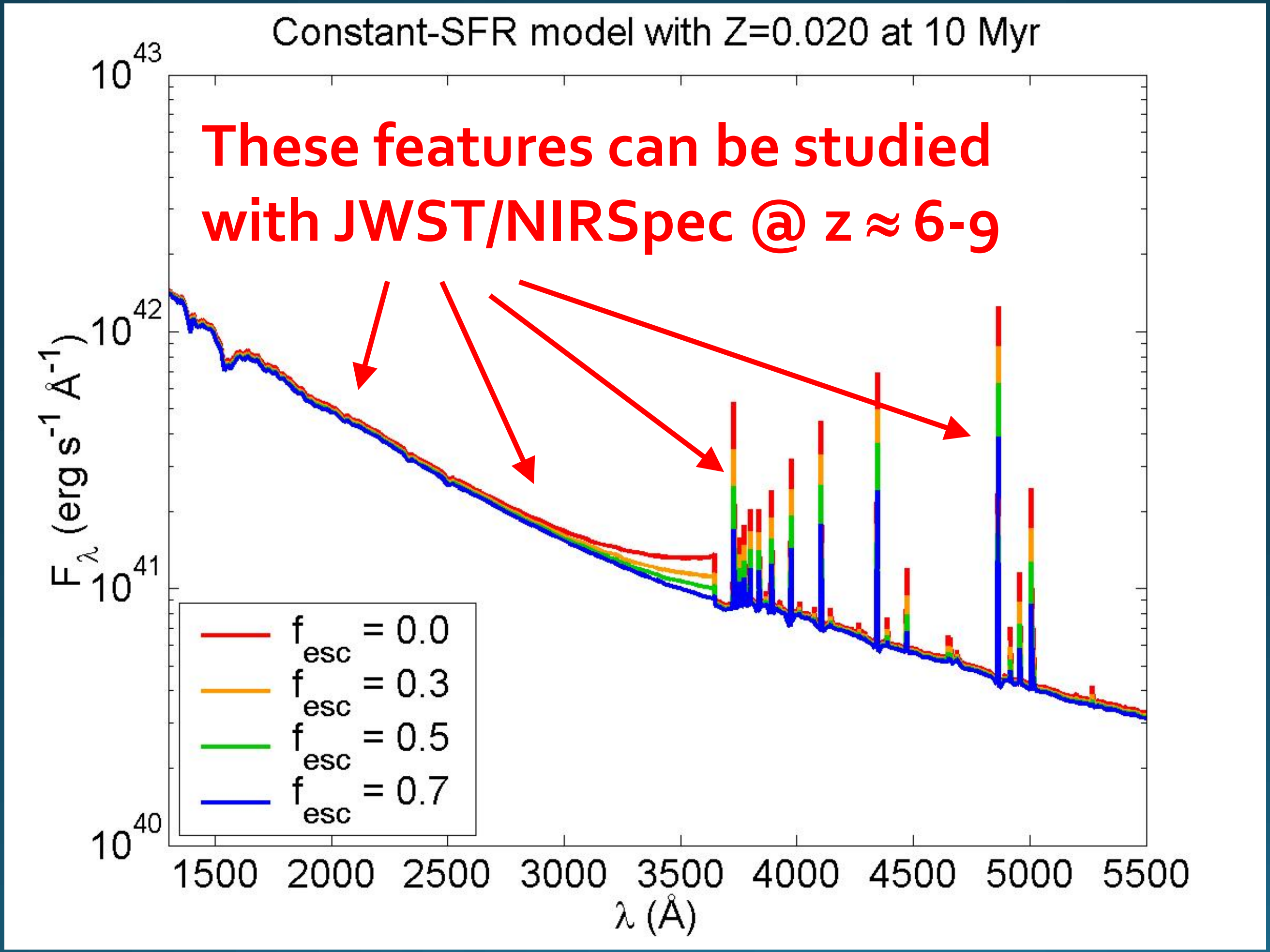


LyC leakage – direct detections



Serious problem: At z > 4-5, the IGM opacity prevents direct detection of escaping Lyman continuum (Inoue & Iwata 2008, Inoue+14)

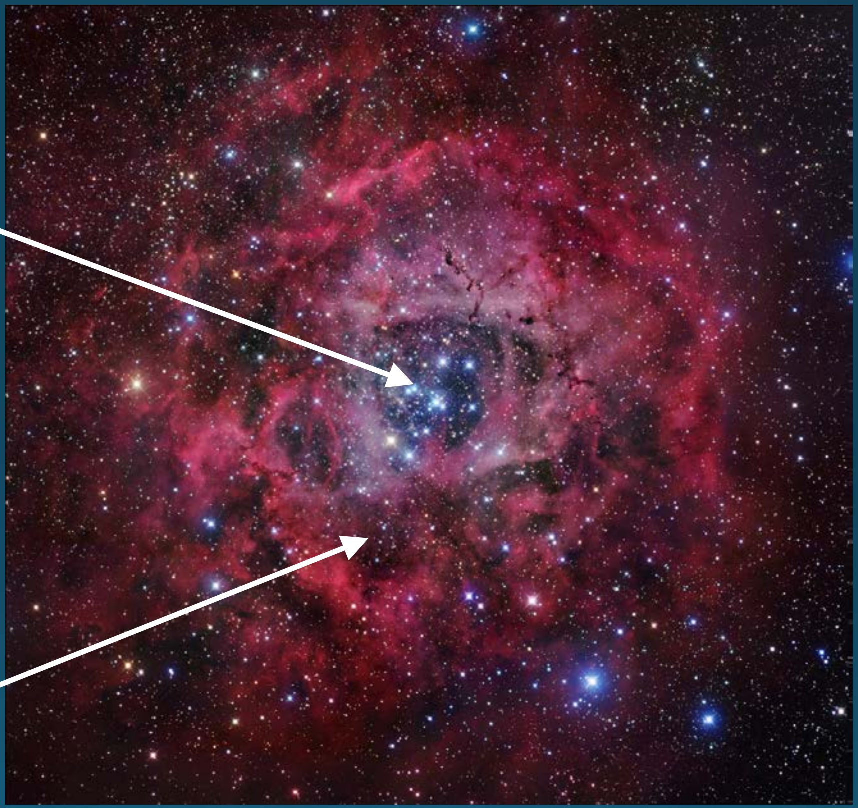
Indirect signatures of LyC leakage



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

How does this work?

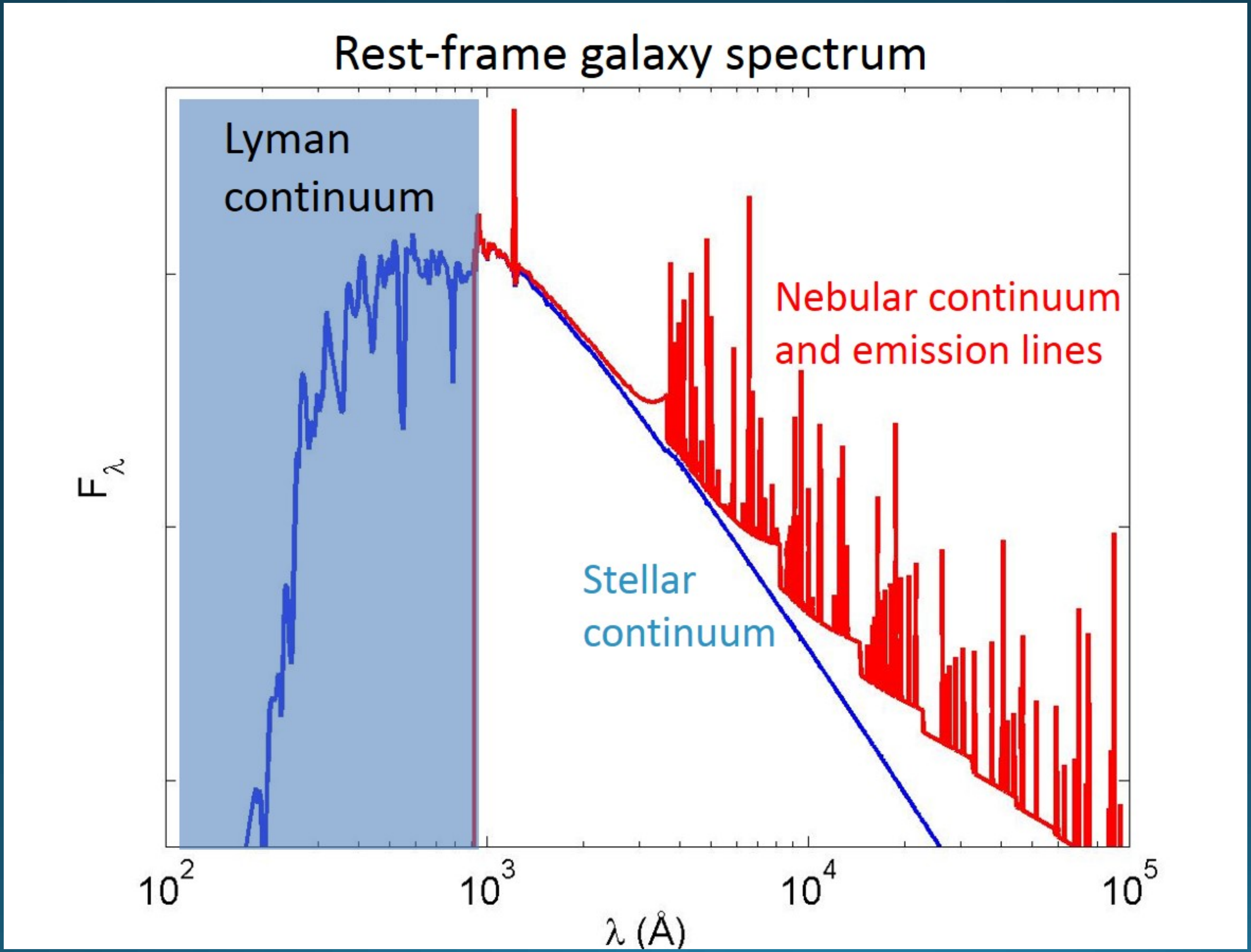
Young stars



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!

Stellar and nebular SEDs



- Pop I, II, III stars + EMP stars
- Nebular emission (Cloudy) + dust
- Rest-frame SEDs (far-UV to near-IR)
- HST/Spitzer/JWST fluxes @ z=0-15

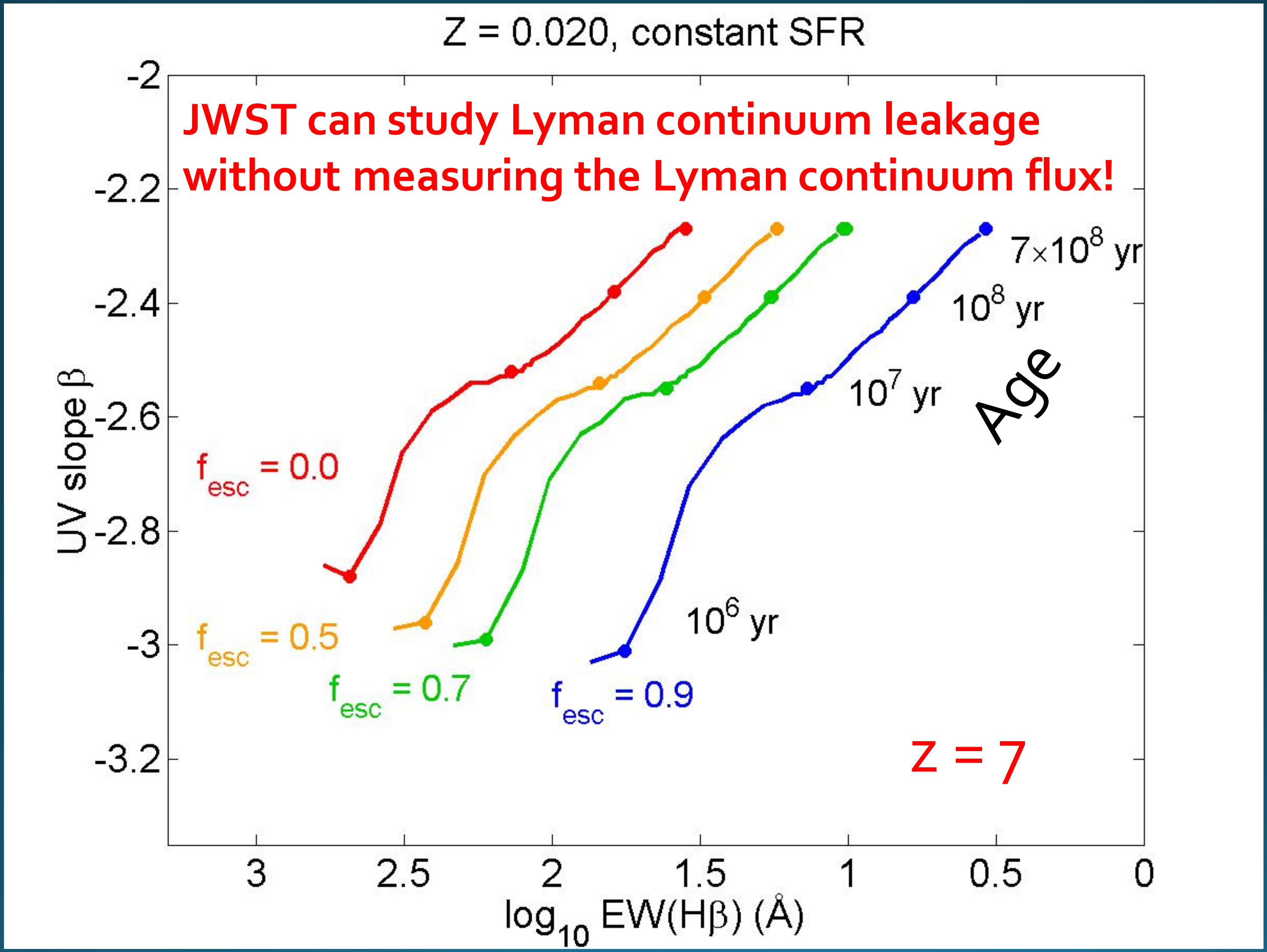
The Yggdrasil code

A spectral synthesis model for the first galaxies

Model grids available at: www.astro.uu.se/~ez

Zackrisson et al. 2011, ApJ, 740, 13

Simple diagnostics: UV slope & Hβ



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

How well can we measure f_{esc}?

LYman Continuum ANalysis project:

Galaxy simulations + Yggdrasil + observational errors $\rightarrow$

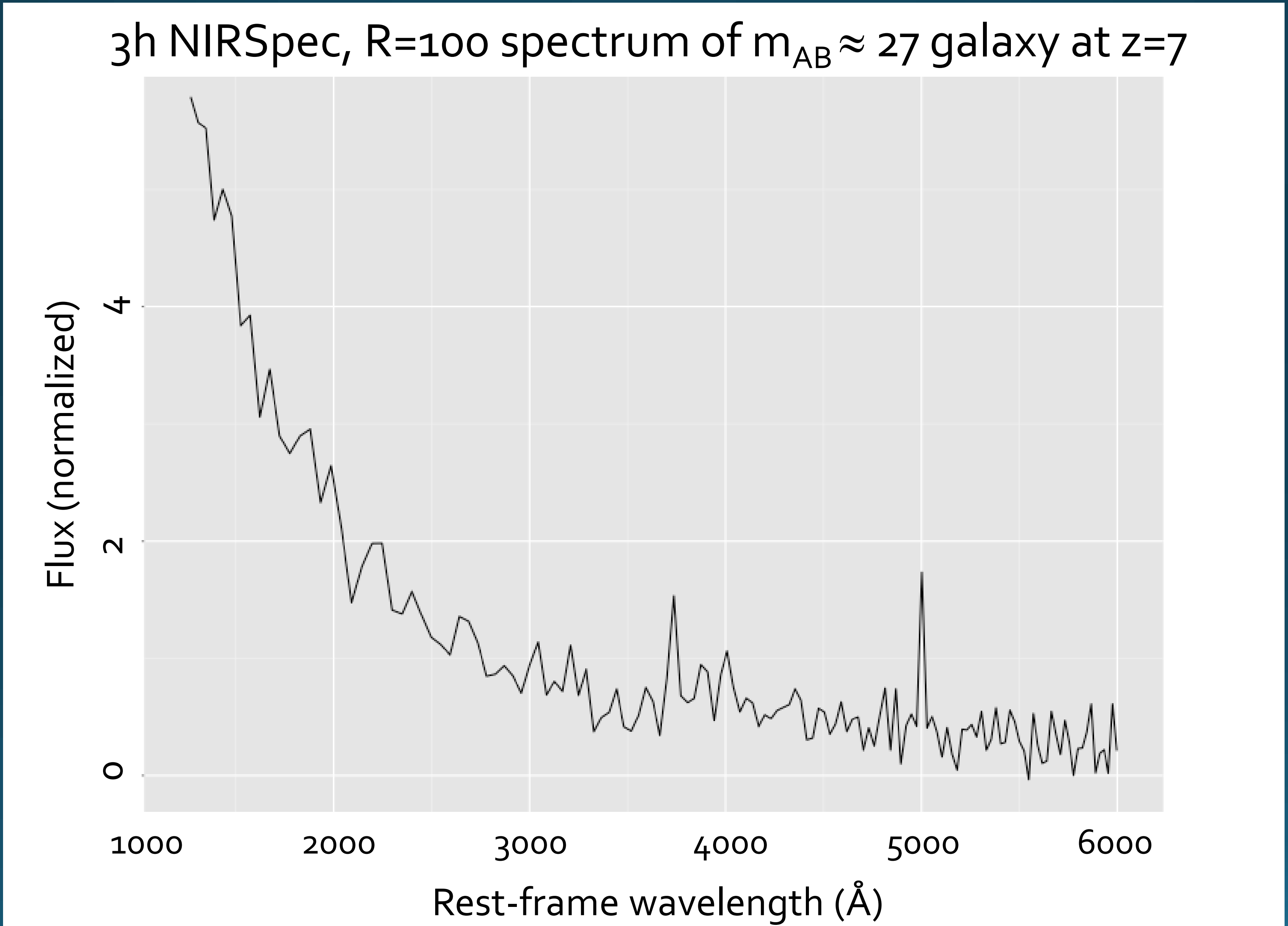
Mock spectra of high-z galaxies with Lyman continuum leakage

Simulations suites:

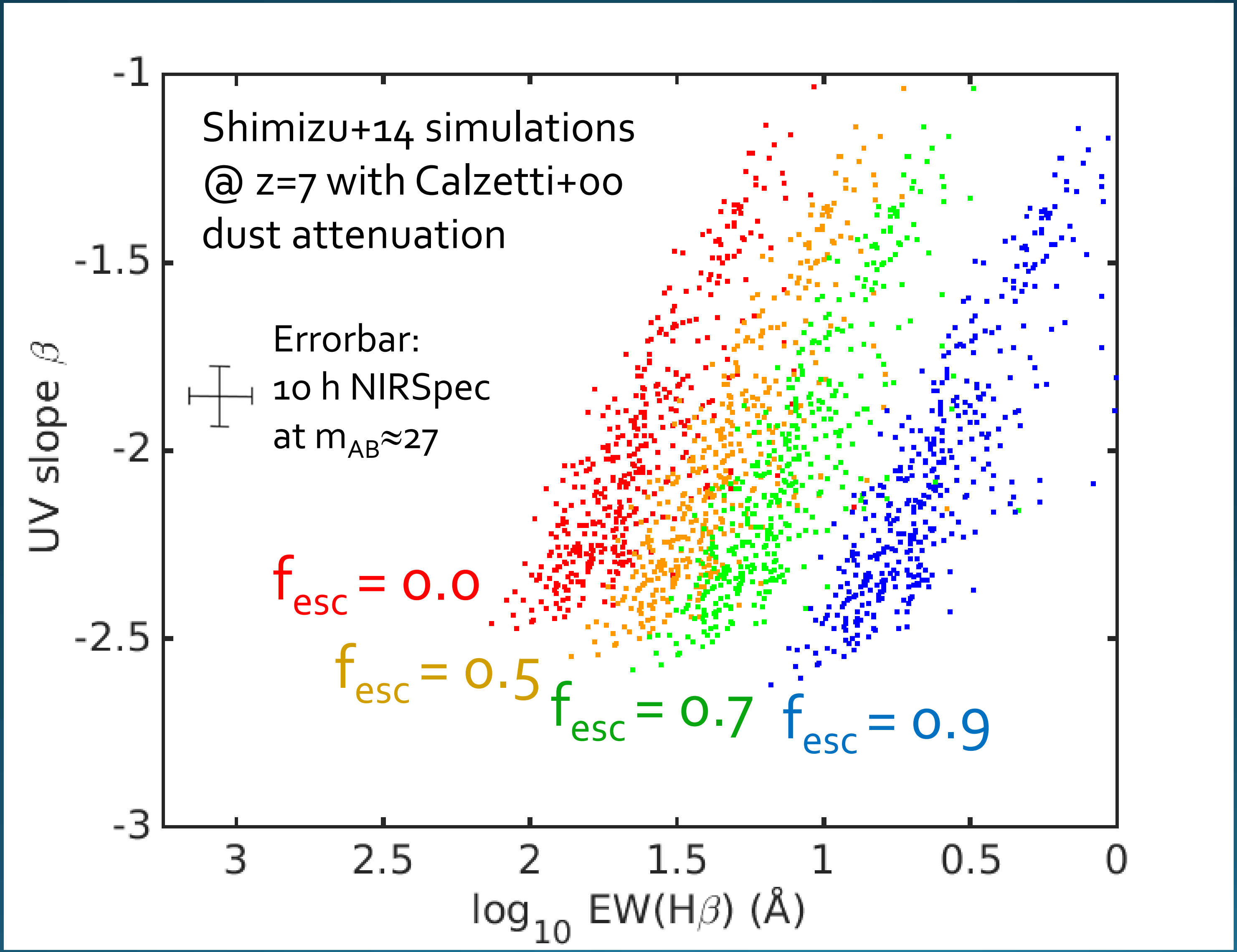
CROC (Gnedin 2014)
FiBY (Paardekooper et al. 2015)
Finlator et al. (2013)
Shimizu et al. (2014)

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

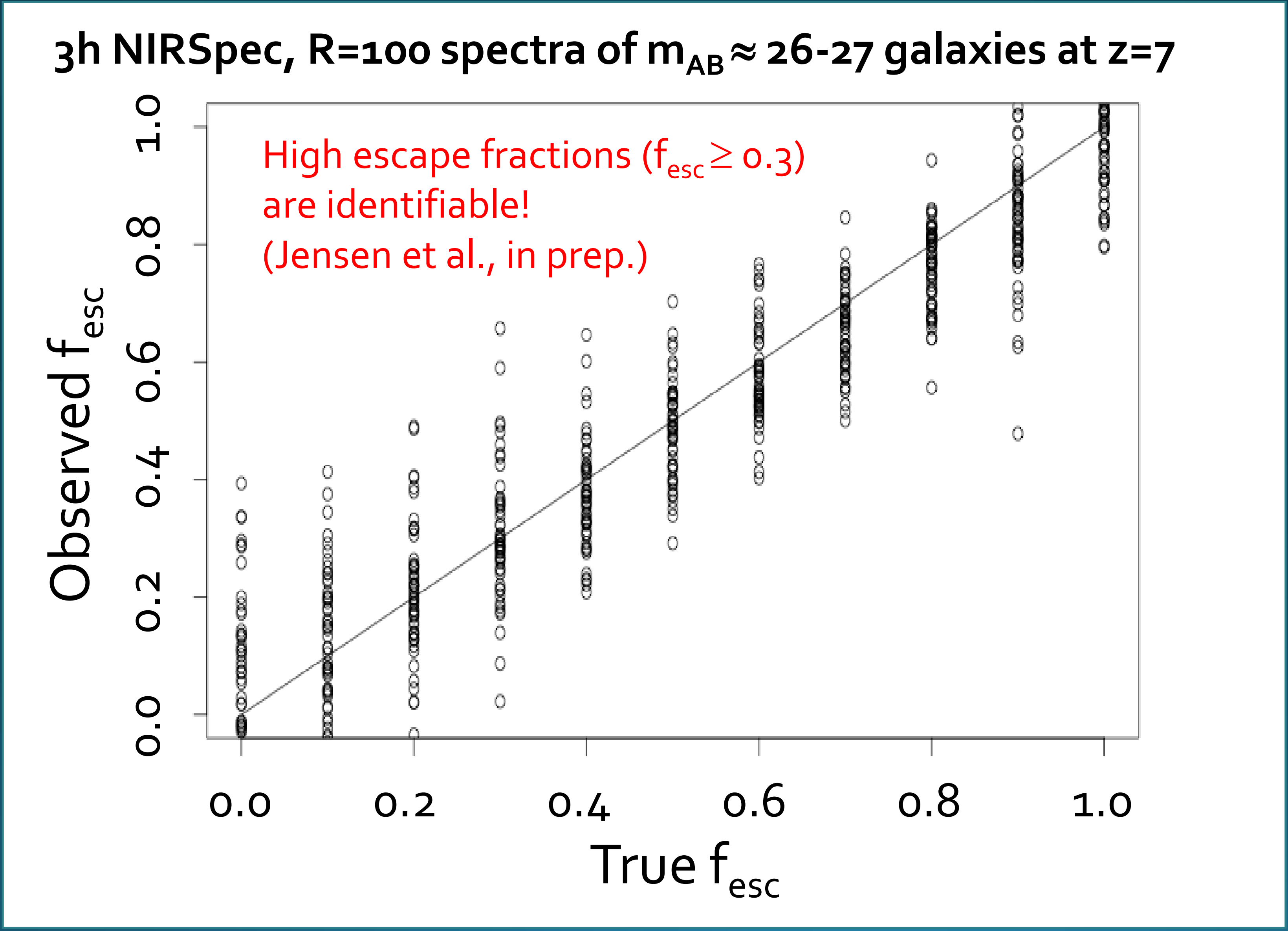
Example of mock SED from LYCAN



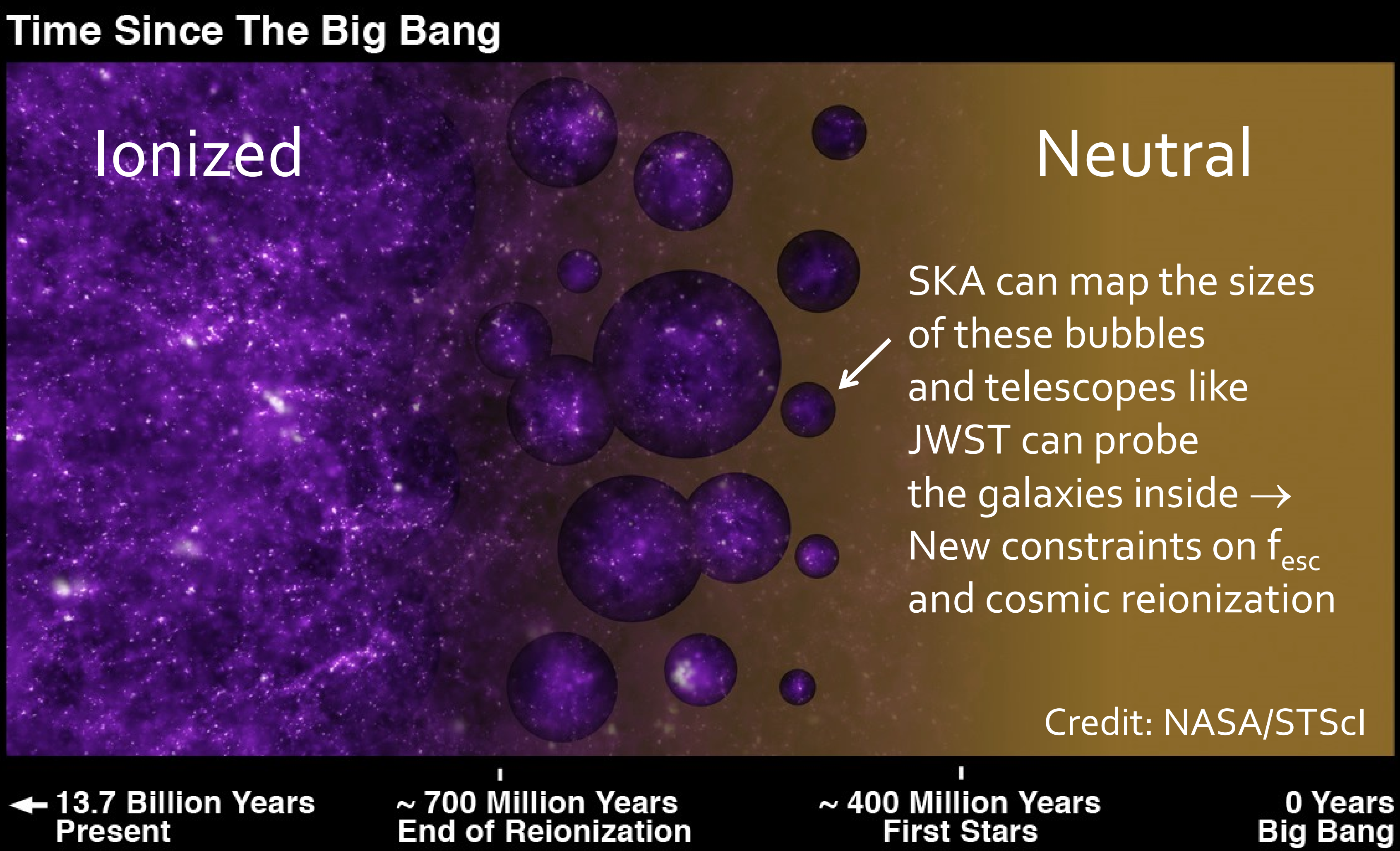
Diagnostics based on realistic SEDs



SED analysis using machine learning algorithms

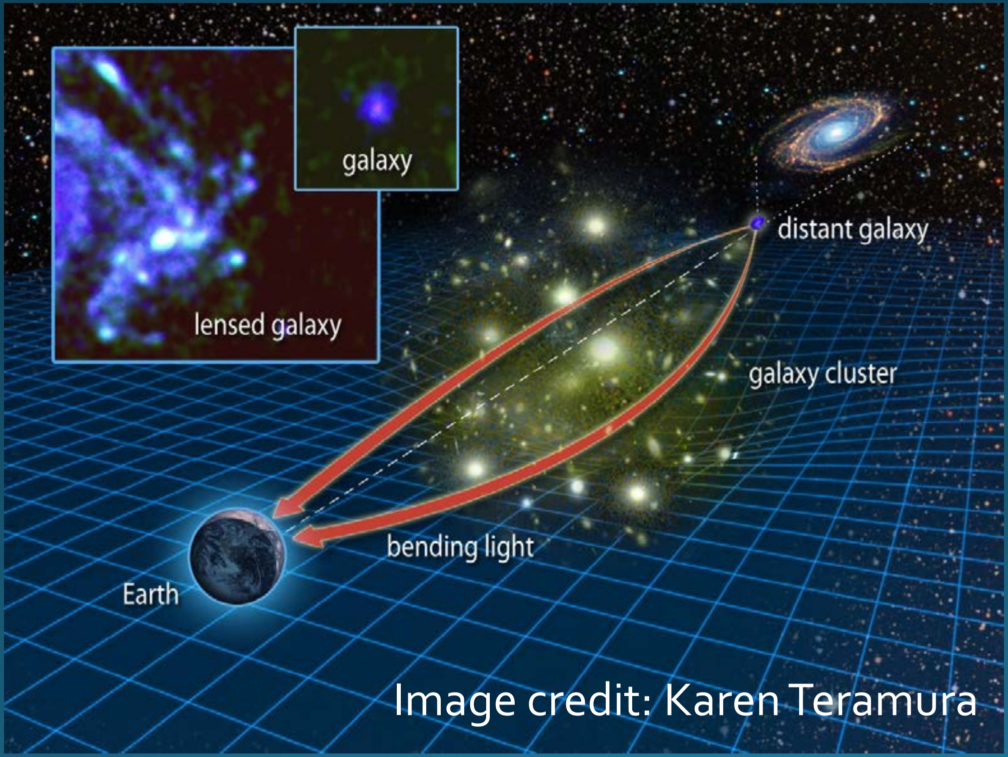


Ongoing work: Synergies with the Square Kilometer Array



Lensed galaxies make the best targets

In <10 h, NIRSpec can get a sufficiently good spectrum for a $z \approx 7$ galaxy with stellar mass ~10^7 Msolar ($M_{1500} \approx -16$) if the gravitational magnification is $\mu \approx 30$



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 $z \approx 9$
- Project can go piggy-back on any NIRSpec survey of $z>6$ galaxies, but lensed galaxies make the best targets
- Publicly available model SEDs for high-z galaxies: www.astro.uu.se/~ez/lycan/lycan.html