Hunting down the galaxies that reionized the Universe

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Fingerprints

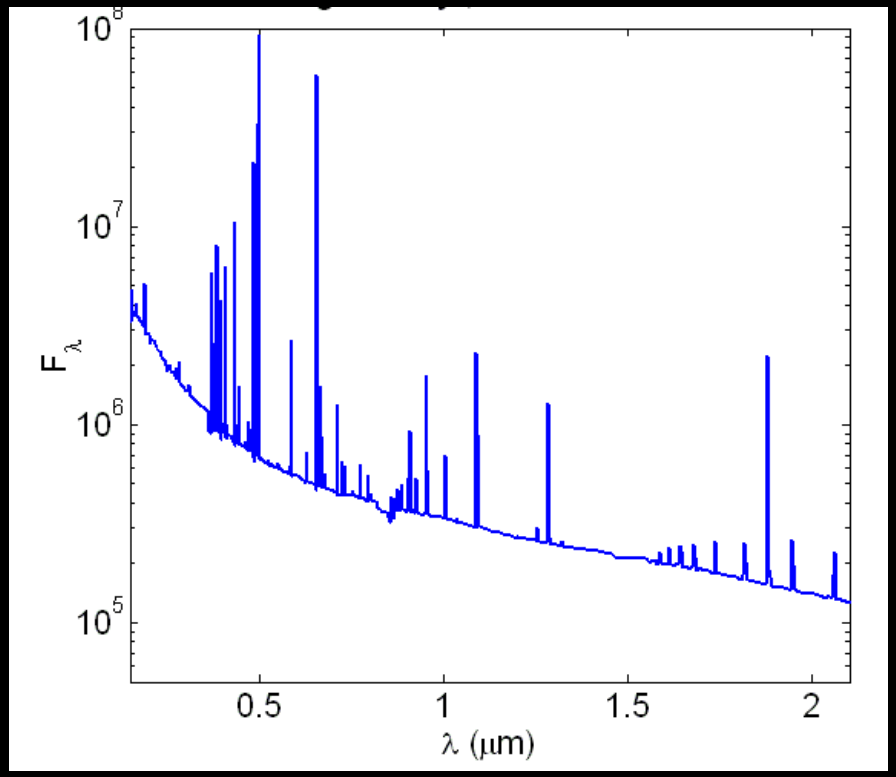
Classical use:

- Whorls, arches, loops in fingerprint pattern → Identification

The next frontier:

- Chemical analysis of fingerprint → Drug habits, medication

Galaxy Spectra



Classical use:

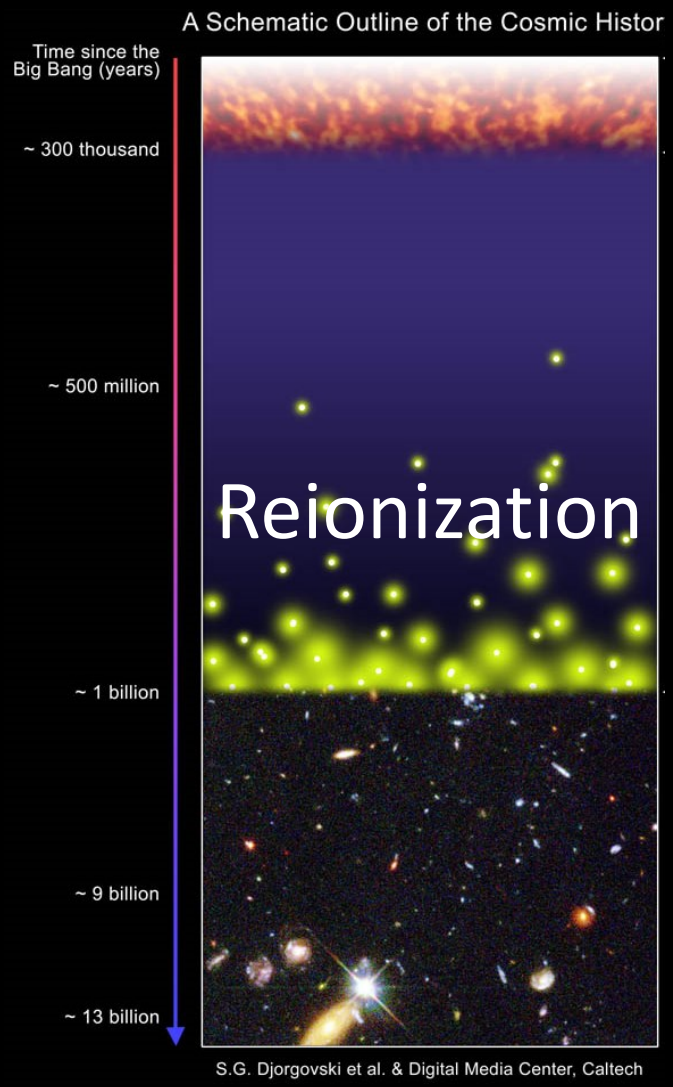
- Template fitting → Galaxy type, redshift
- SED modelling → SFR, Z, E(B-V), M_{stars}, SF history, IMF

The next frontier:

- SED modelling → Escape Fraction (f_{esc}) of ionizing photons from galaxies @ z>6

Ono+ 10, Pirzkal+ 12, Zackrisson+ 13

Did Galaxies Reionize the Universe?



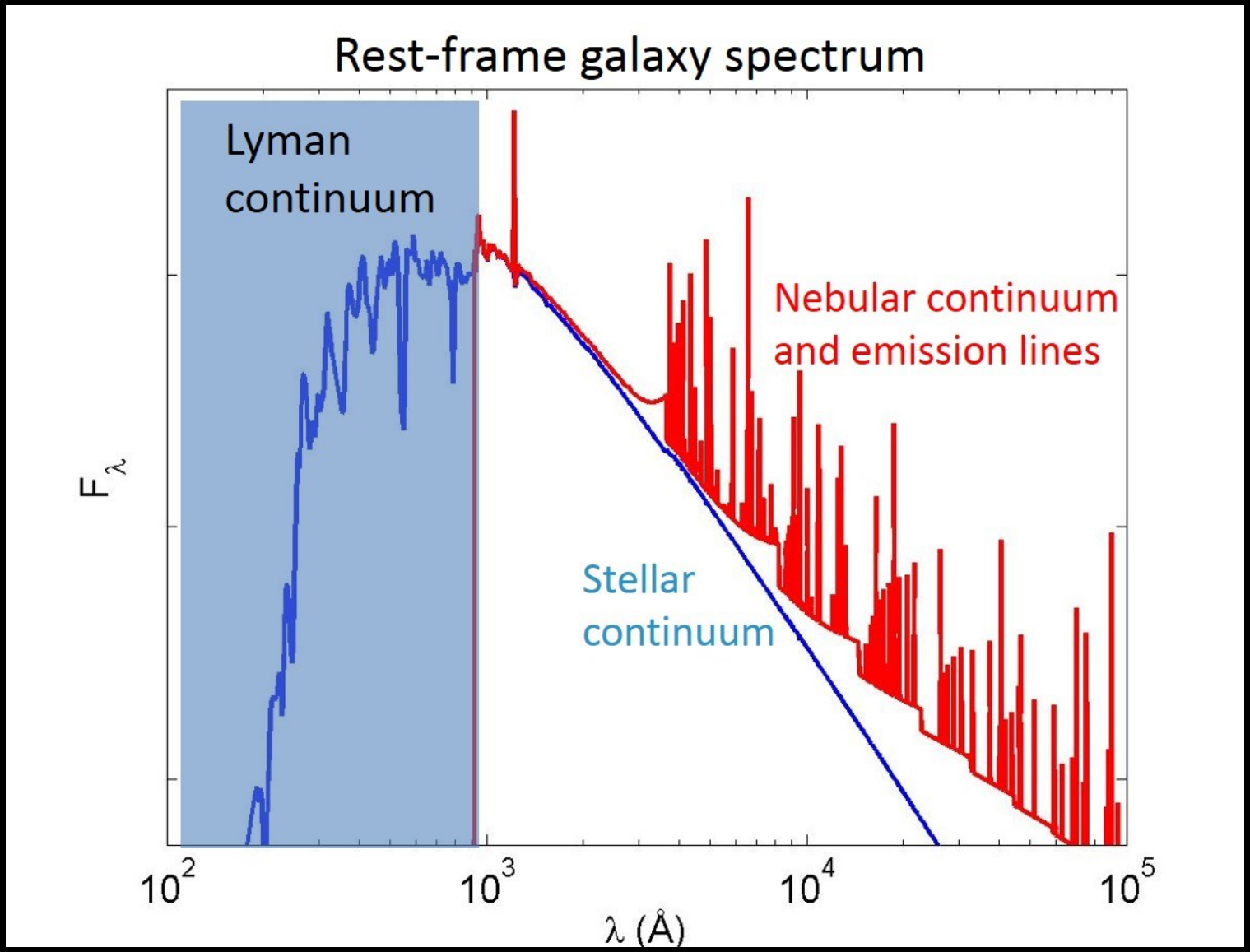
Ionizing photon budget relevant for reionization:

$$\dot{N}_{\mathrm{ion}} \propto \rho_{\mathrm{UV}} f_{\mathrm{esc}}$$

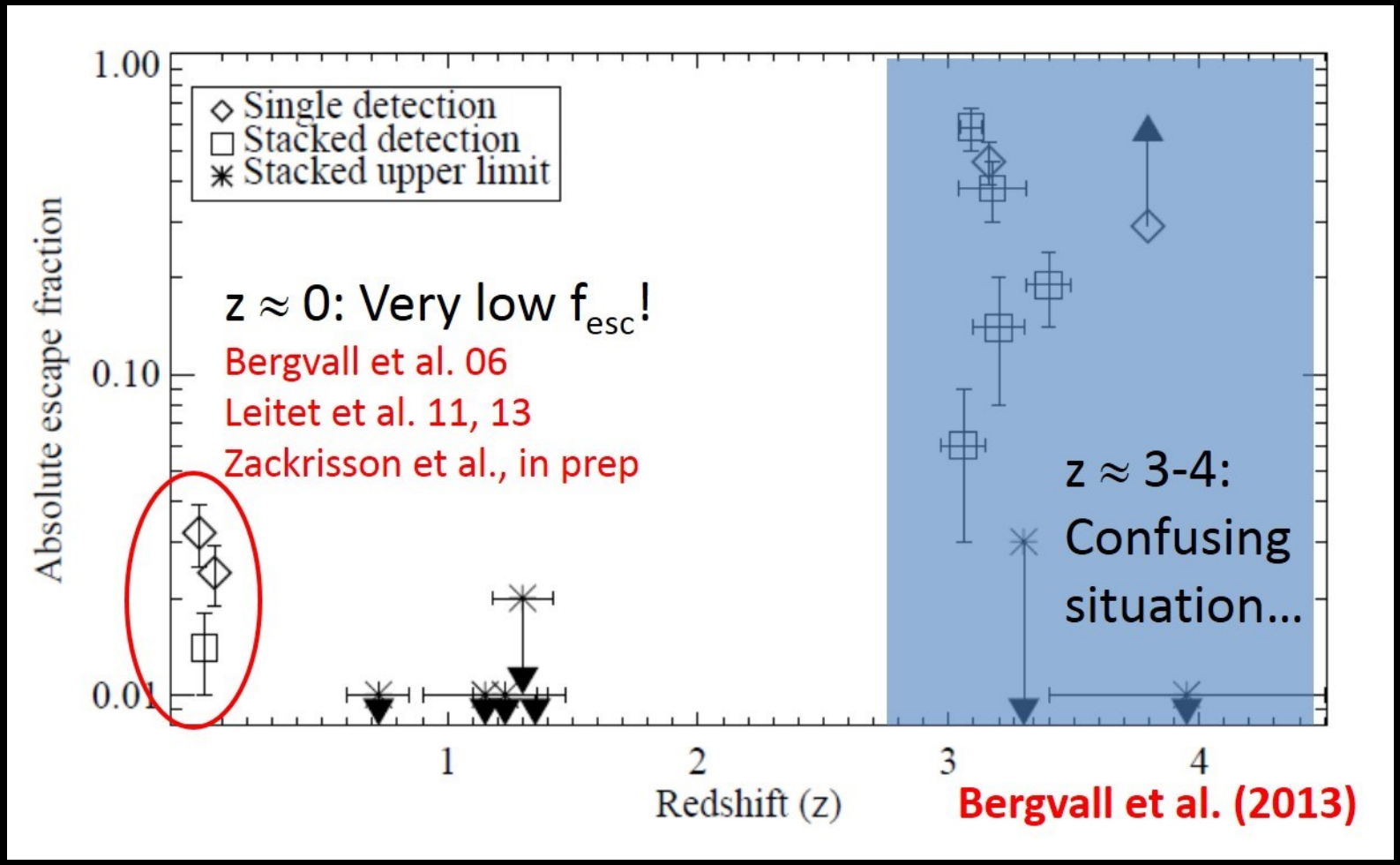
From observed galaxy luminosity function at z>6

Escape fraction of ionizing photons (Lyman continuum)

Lyman Continuum Radiation



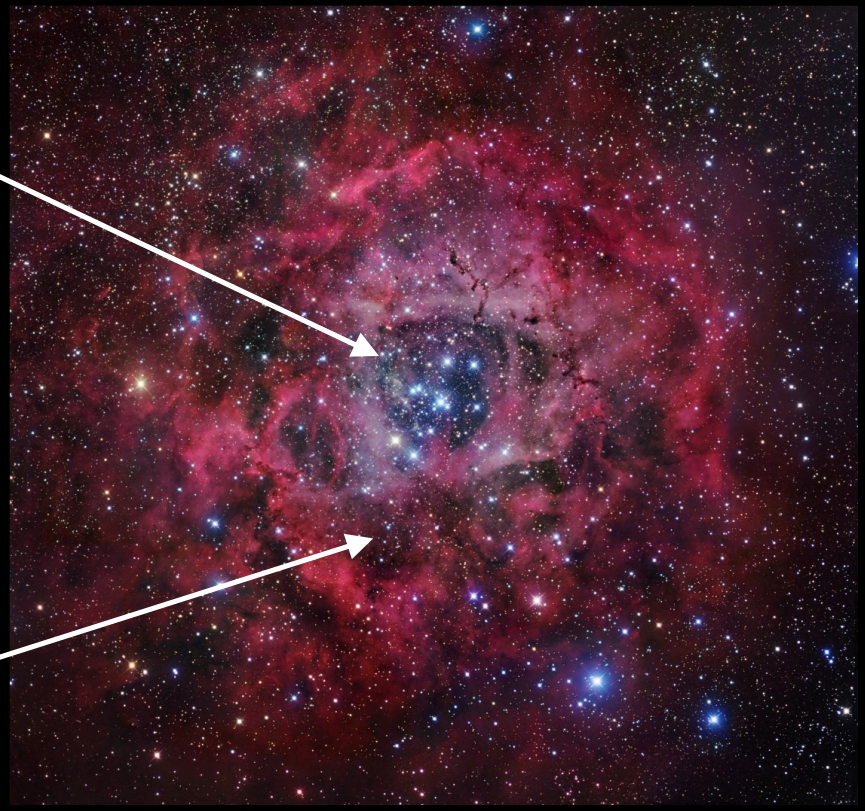
The Lyman Continuum Escape Fraction



At z > 4-5, the IGM opacity prevents direct detections of escaping Lyman continuum (Inoue & Iwata 2008) – Indirect methods needed!

How Lyman Continuum Leakage Affects the Spectra of Galaxies

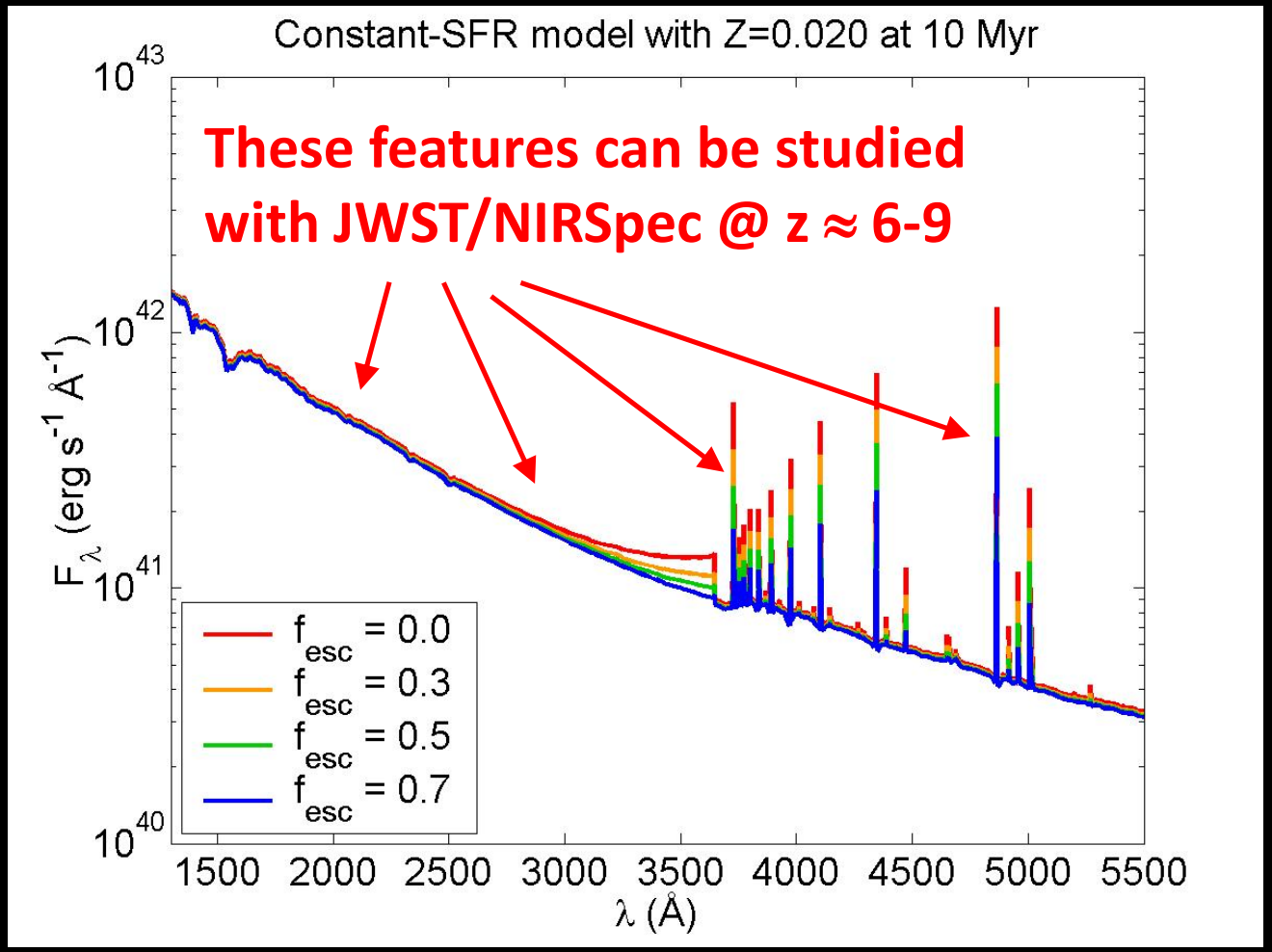
Young stars



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

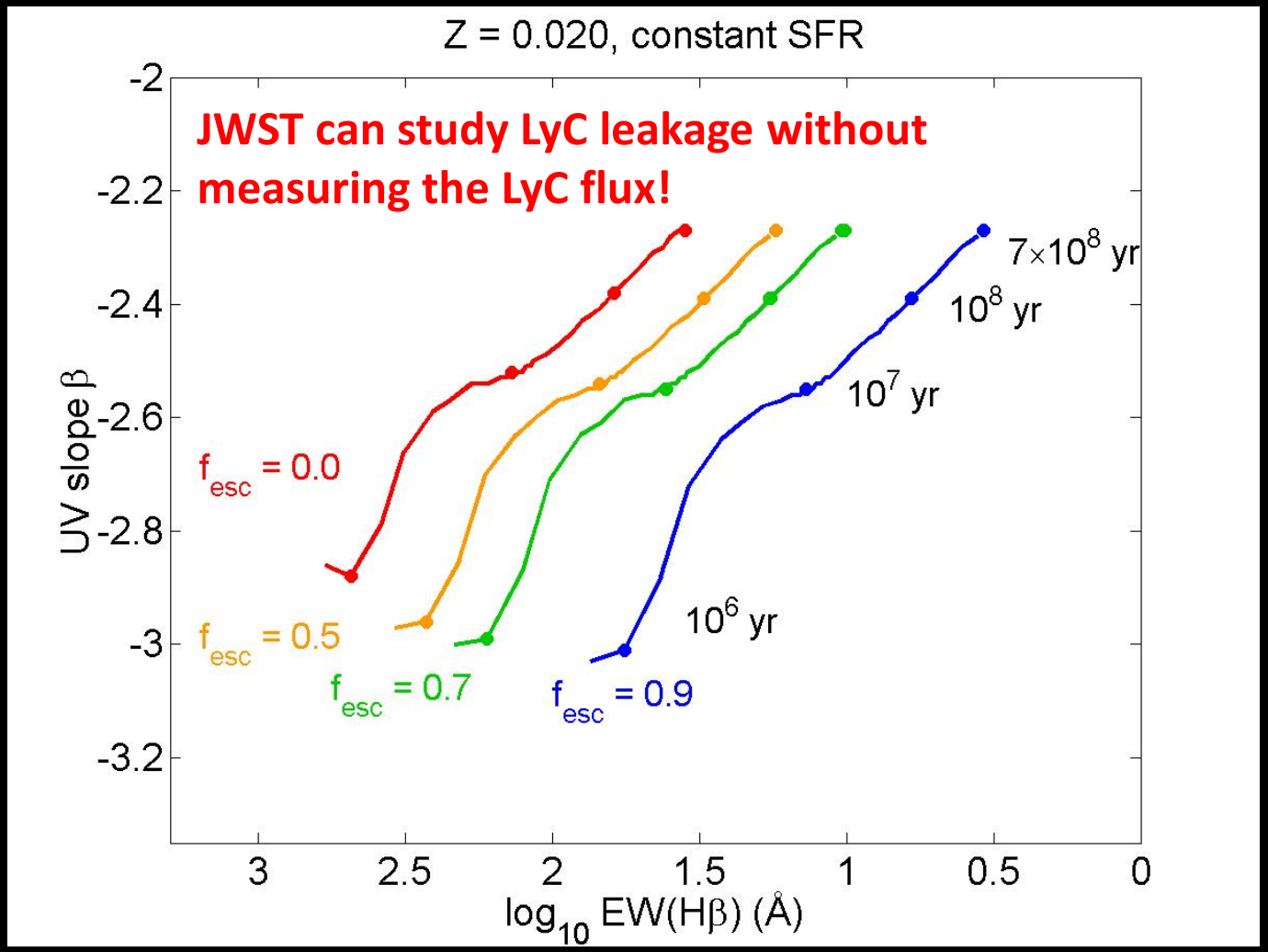
If some of the LyC photons escape without ionzing the ISM → *Less nebular emission!*

Studying Lyman Continuum Leakage in the Reionization Epoch



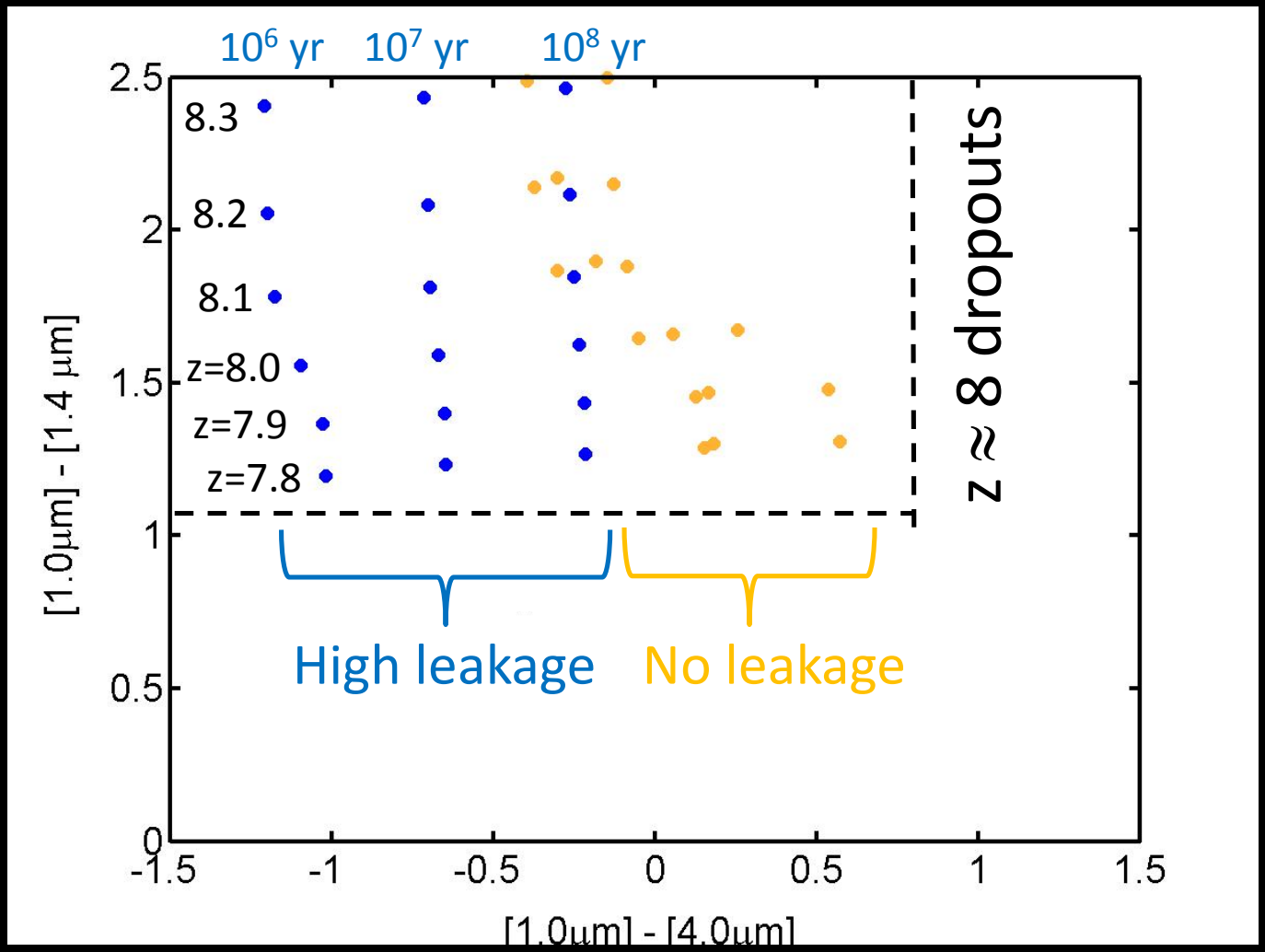
Zackrisson, Inoue & Jensen 2013, ApJ, 777, 39

Indirect Constraints on f_{esc} for Galaxies at z ≈ 6-9

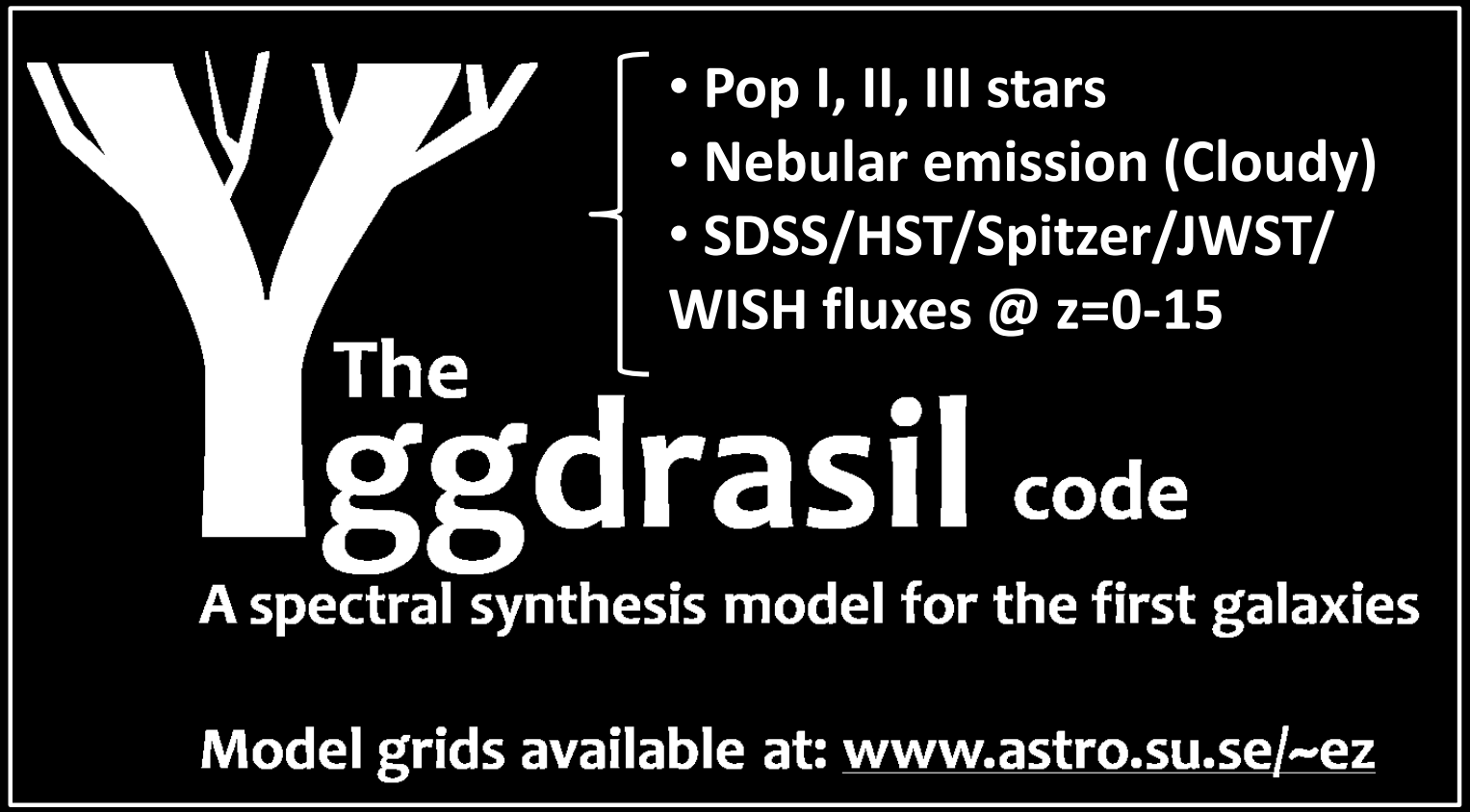


Zackrisson, Inoue & Jensen 2013, ApJ, 777, 39

LyC leakage candidates in WISH surveys

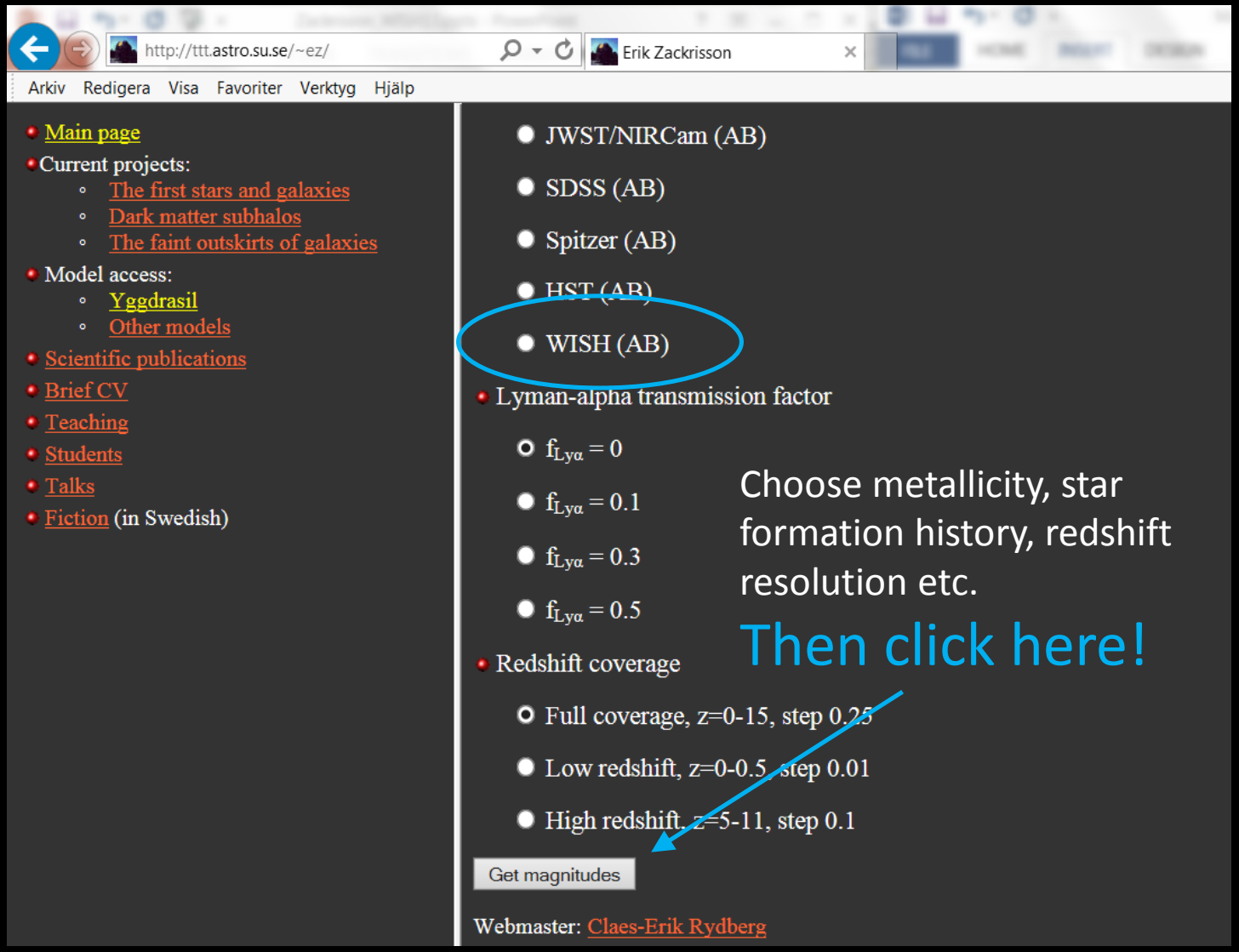


LyC leakage candidates found through WISH imaging can then be followed up with JWST/ELT spectroscopy



Zackrisson et al. 2011, ApJ, 740, 13

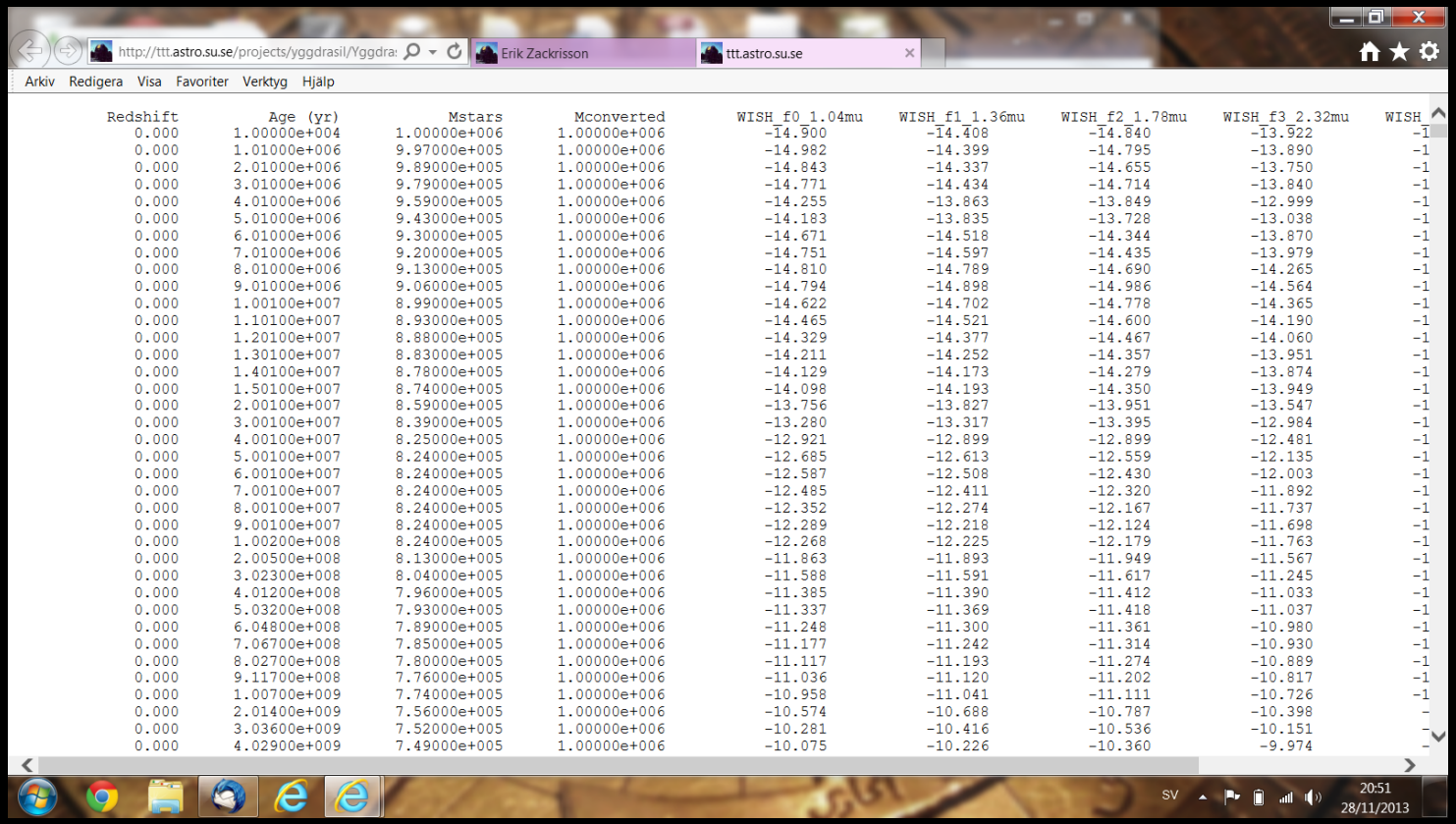
Galaxy models for WISH



Yggdrasil models: www.astro.su.se/~ez

Galaxy models for WISH

… and you immediately get AB magnitudes in WISH filters as a function of galaxy age and redshift!



Redshift	Age (yr)	Mstars	Mconverted	WISH_f0_1.04mu	WISH_f1_1.36mu	WISH_f2_1.78mu	WISH_f3_2.32mu	WISH_
0.000	1.00000e+004	1.00000e+006	1.00000e+006	-14.900	-14.408	-14.840	-13.922	-1
0.000	1.01000e+006	9.97000e+005	1.00000e+006	-14.982	-14.399	-14.795	-13.890	-1
0.000	2.01000e+006	9.89000e+005	1.00000e+006	-14.843	-14.337	-14.655	-13.750	-1
0.000	3.01000e+006	9.79000e+005	1.00000e+006	-14.771	-14.434	-14.714	-13.840	-1
0.000	4.01000e+006	9.59000e+005	1.00000e+006	-14.255	-13.863	-13.849	-12.999	-1
0.000	5.01000e+006	9.43000e+005	1.00000e+006	-14.183	-13.835	-13.728	-13.038	-1
0.000	6.01000e+006	9.30000e+005	1.00000e+006	-14.671	-14.518	-14.344	-13.870	-1
0.000	7.01000e+006	9.20000e+005	1.00000e+006	-14.751	-14.597	-14.435	-13.979	-1
0.000	8.01000e+006	9.13000e+005	1.00000e+006	-14.810	-14.789	-14.690	-14.265	-1
0.000	9.01000e+006	9.06000e+005	1.00000e+006	-14.794	-14.898	-14.986	-14.564	-1
0.000	1.00100e+007	8.99000e+005	1.00000e+006	-14.622	-14.702	-14.778	-14.365	-1
0.000	1.10100e+007	8.93000e+005	1.00000e+006	-14.465	-14.521	-14.600	-14.190	-1
0.000	1.20100e+007	8.88000e+005	1.00000e+006	-14.329	-14.377	-14.467	-14.060	-1
0.000	1.30100e+007	8.83000e+005	1.00000e+006	-14.211	-14.252	-14.357	-13.951	-1
0.000	1.40100e+007	8.78000e+005	1.00000e+006	-14.129	-14.173	-14.279	-13.874	-1
0.000	1.50100e+007	8.74000e+005	1.00000e+006	-14.098	-14.193	-14.350	-13.949	-1
0.000	2.00100e+007	8.59000e+005	1.00000e+006	-13.756	-13.827	-13.951	-13.547	-1
0.000	3.00100e+007	8.39000e+005	1.00000e+006	-13.280	-13.317	-13.395	-12.984	-1
0.000	4.00100e+007	8.25000e+005	1.00000e+006	-12.921	-12.899	-12.899	-12.481	-1
0.000	5.00100e+007	8.24000e+005	1.00000e+006	-12.685	-12.613	-12.559	-12.135	-1
0.000	6.00100e+007	8.24000e+005	1.00000e+006	-12.587	-12.508	-12.430	-12.003	-1
0.000	7.00100e+007	8.24000e+005	1.00000e+006	-12.485	-12.411	-12.320	-11.892	-1
0.000	8.00100e+007	8.24000e+005	1.00000e+006	-12.352	-12.274	-12.167	-11.737	-1
0.000	9.00100e+007	8.24000e+005	1.00000e+006	-12.289	-12.218	-12.124	-11.698	-1
0.000	1.00200e+008	8.24000e+005	1.00000e+006	-12.268	-12.225	-12.179	-11.763	-1
0.000	2.00500e+008	8.13000e+005	1.00000e+006	-11.863	-11.893	-11.949	-11.567	-1
0.000	3.02300e+008	8.04000e+005	1.00000e+006	-11.588	-11.591	-11.617	-11.245	-1
0.000	4.01200e+008	7.96000e+005	1.00000e+006	-11.385	-11.390	-11.412	-11.033	-1
0.000	5.03200e+008	7.93000e+005	1.00000e+006	-11.337	-11.369	-11.418	-11.037	-1
0.000	6.04800e+008	7.89000e+005	1.00000e+006	-11.248	-11.300	-11.361	-10.980	-1
0.000	7.06700e+008	7.85000e+005	1.00000e+006	-11.177	-11.242	-11.314	-10.930	-1
0.000	8.02700e+008	7.80000e+005	1.00000e+006	-11.117	-11.193	-11.274	-10.889	-1
0.000	9.11700e+008	7.76000e+005	1.00000e+006	-11.036	-11.120	-11.202	-10.817	-1
0.000	1.00700e+009	7.74000e+005	1.00000e+006	-10.958	-11.041	-11.111	-10.726	-1
0.000	2.01400e+009	7.56000e+005	1.00000e+006	-10.574	-10.688	-10.787	-10.398	-
0.000	3.03600e+009	7.52000e+005	1.00000e+006	-10.281	-10.416	-10.536	-10.151	-
0.000	4.02900e+009	7.49000e+005	1.00000e+006	-10.075	-10.226	-10.360	-9.974	-

Yggdrasil models: www.astro.su.se/~ez

The LYman Continuum ANalysis Project

Logo: Genoveva Micheva

SPH/RT simulations + Yggdrasil + obs. errors → Mock spectra of high-z galaxies with LyC leakage

Can tackle:

- How well can f_{esc} be retrieved from JWST/ELT spectra?
- How well can high-f_{esc} candidates be selected from WISH imaging data?

Lyman Continuum Leakage and Cosmic Reionization

13-15 August 2014 | **AlbaNova University Center, Stockholm University, Stockholm, Sweden**

Home

The contribution from star-forming galaxies to the reionization of the Universe depends on the galaxy luminosity function *and* on the Lyman continuum (LyC) escape fraction of galaxies at redshifts greater than z~6. While most activity in this field has so far focused on quantifying the luminosity function, this 3-day workshop focuses on current and future efforts to constrain the LyC escape fraction of galaxies at both low and high redshift, and the impact that this is likely to have on our understanding of cosmic reionization.

Topics to be explored include:

- Direct and indirect methods to constrain LyC leakage (from the local to the high-redshift Universe)
- Observations of LyC leakage
- Theoretical perspectives on LyC leakage mechanisms
- Simulations and observational probes of reionization: How can empirical data on LyC escape fractions help? Is it necessary to know the galaxy LyC escape fraction to prove that galaxies reionized the Universe?
- Complications: Anisotropic leakage, IGM clumping factors, gravitational lensing etc.

Stockholm, Sweden, August 13-15, 2014

Summary

- WISH imaging can help us find galaxies leaking ionizing radiation into the IGM at z>6
- Follow-up spectroscopy can constrain the ionizing escape fraction
- WISH fluxes for Yggdrasil model galaxies at redshifts z=0-15: www.astro.su.se/~ez