Escape of Lyman radiation from galactic labyrinths
18th April 2023

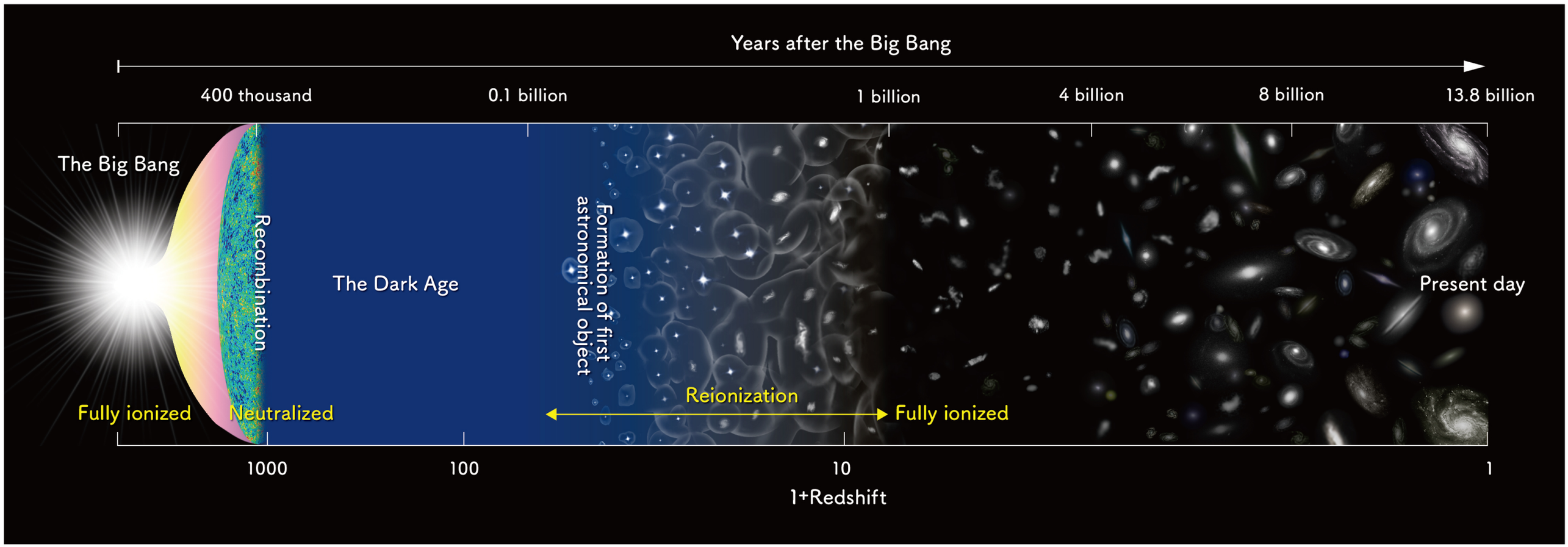
Absorption lines as diagnostics of the escape of ionising photons from simulated galaxies

Valentin Mauerhofer

Context of Reionisation

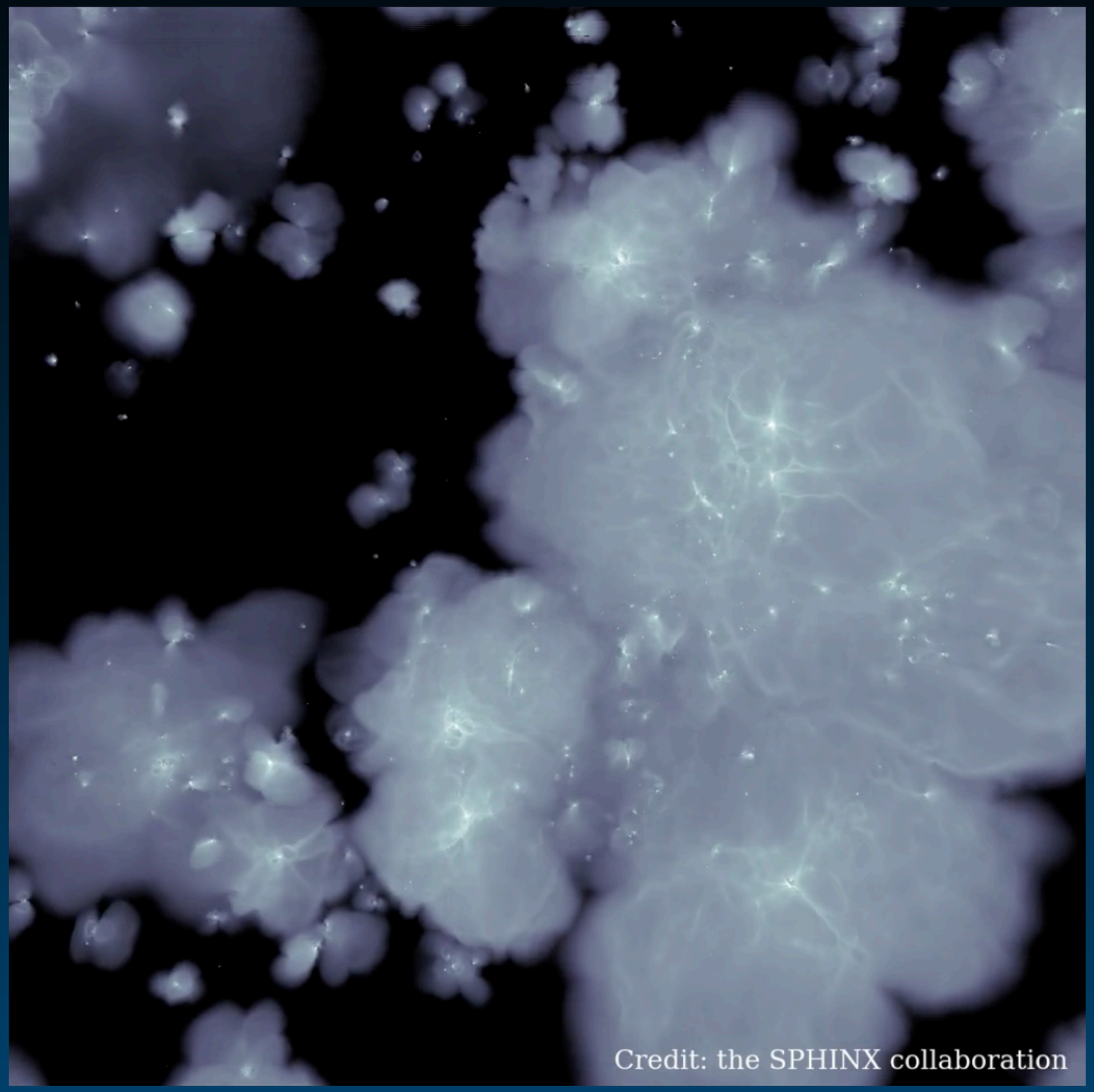
Growth of galaxies until present times

Credit: NAOJ



Reionisation

Reionisation: who is responsible?



Which type of galaxies emit the most ionising photons?

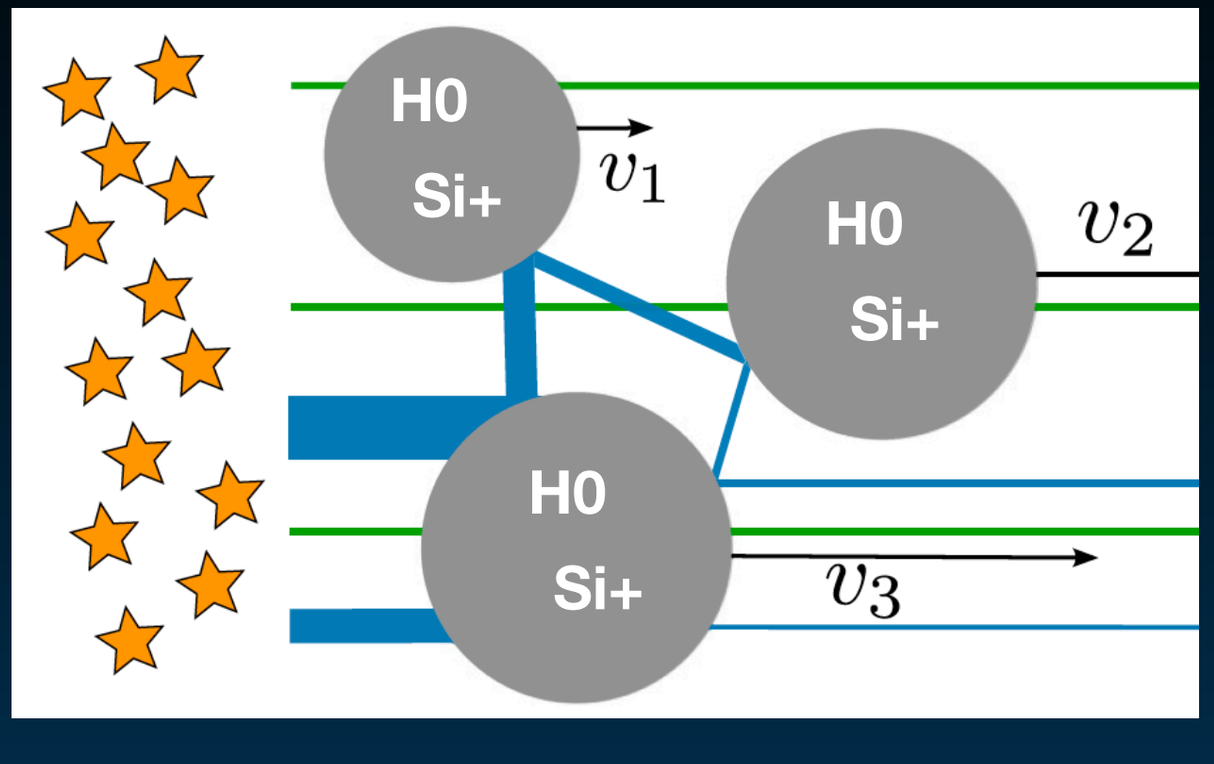
$$\text{Ionising emissivity} = \text{SFR} \times \xi_{\text{ion}} \times f_{\text{esc}}$$

Escape fraction of ionising photons: Important to identify the sources of Reionisation

Lyman continuum escape and metallic UV absorption lines

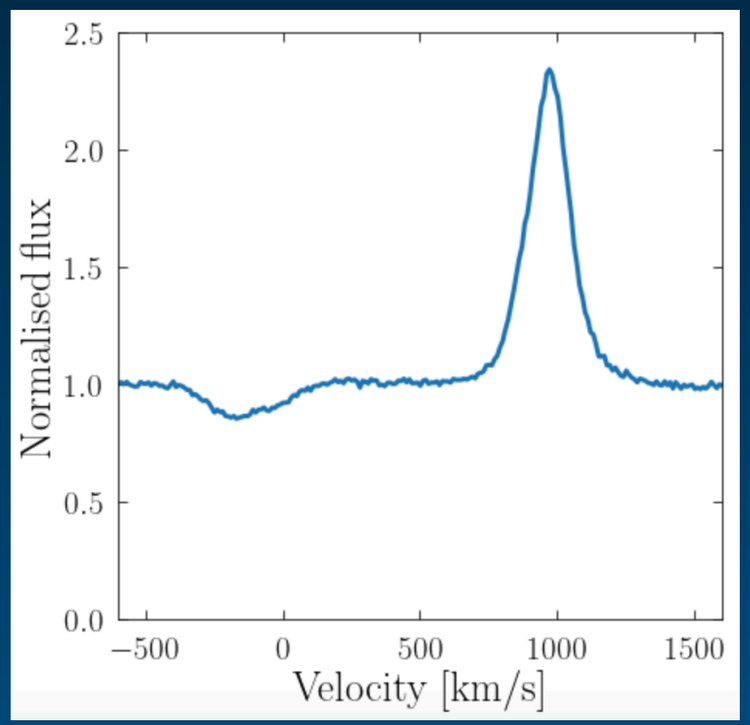
Rivera-Thorsen+15

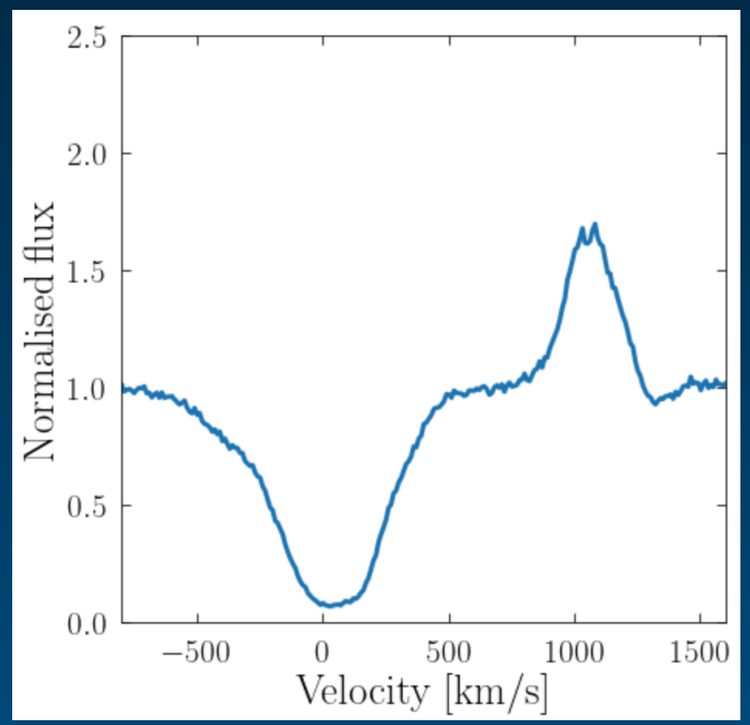
or



SiII 1260

weak line
~
rather high fesc



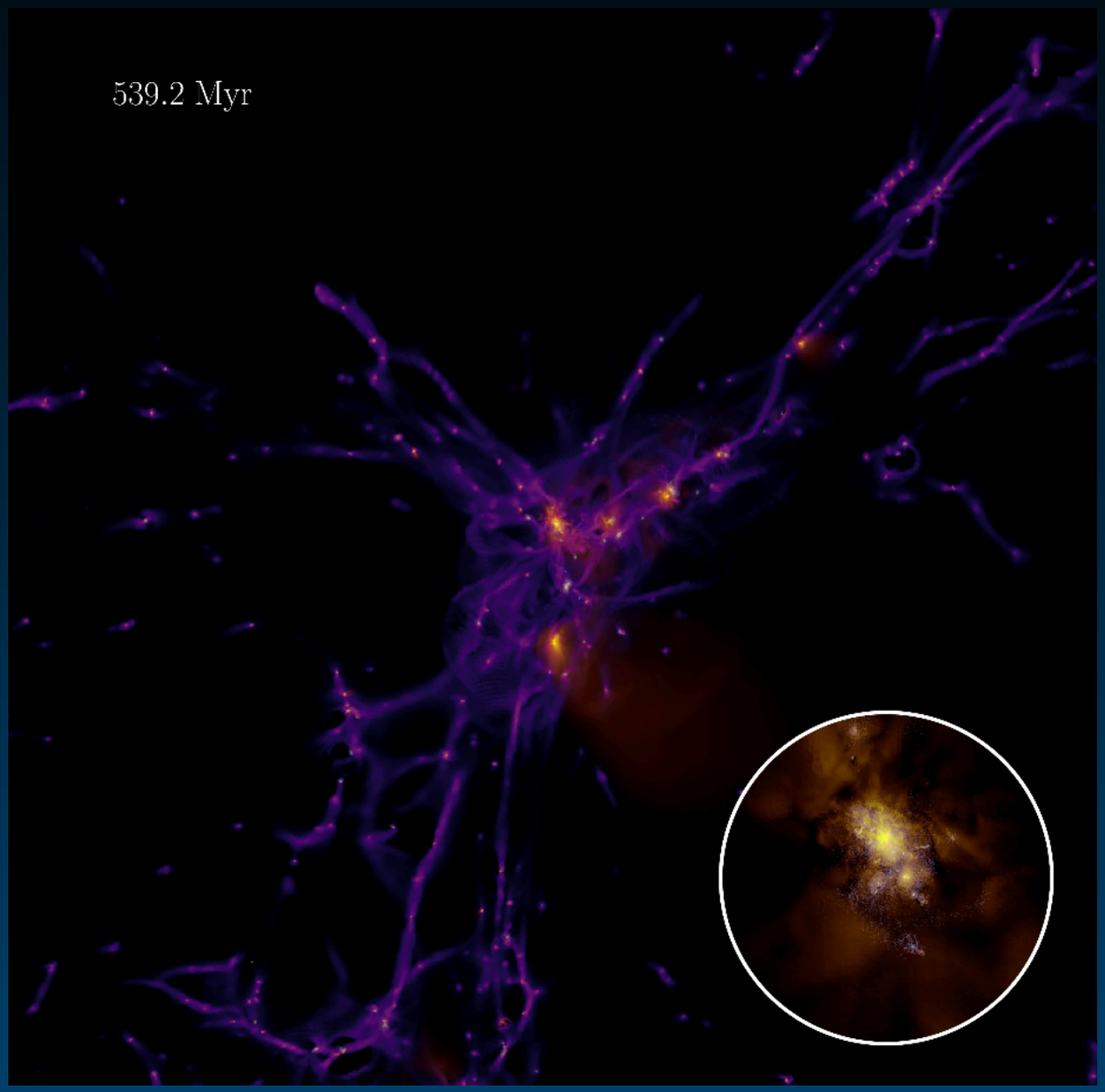


SiII 1260

strong line
~
rather low fesc

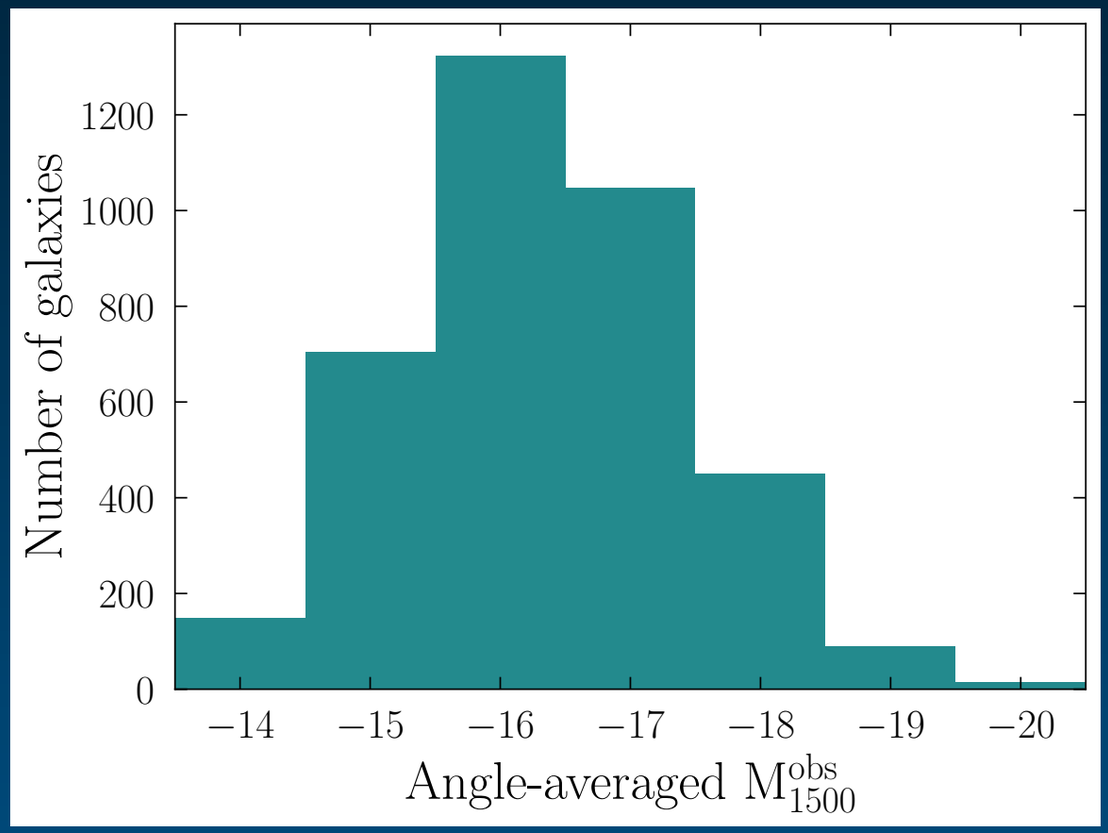
Simulation used in this project

Sphinx20, Rosdahl et al. 2022



- Radiative transfer of ionising photons
- Cosmological initial conditions
- Evolving down to z=4.7
- Adaptive resolution, down to 10 pc
- Box of 20 cMpc

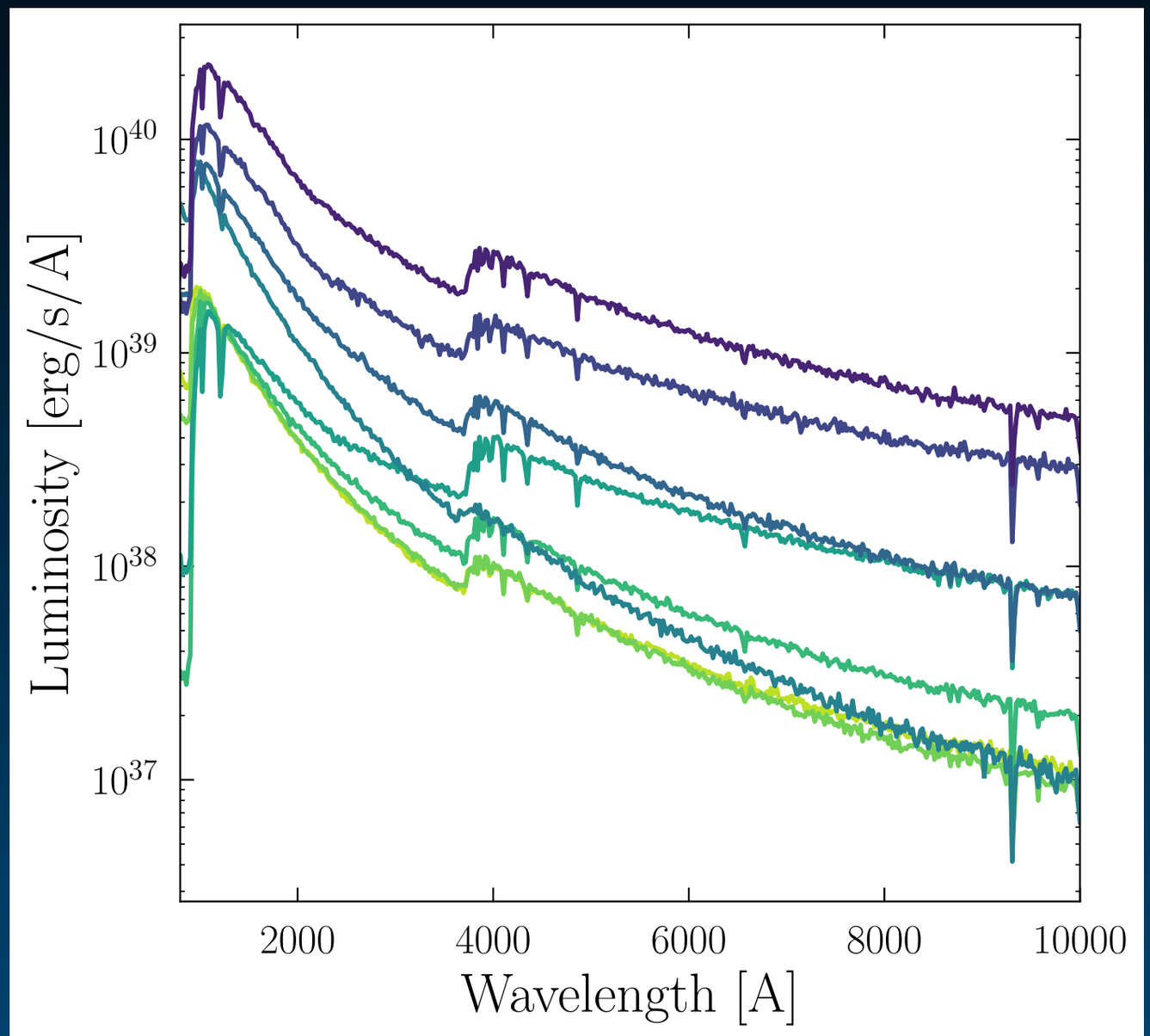
Sample of ~4000 galaxies at 5<z<10



Mock observations with RASCAS Michel-Dansac+20

~4000 galaxies in 108 directions of observation

1) Stellar continuum



Using the dust model implemented by Katz+22b, following observations of Remy-Ruyer+14

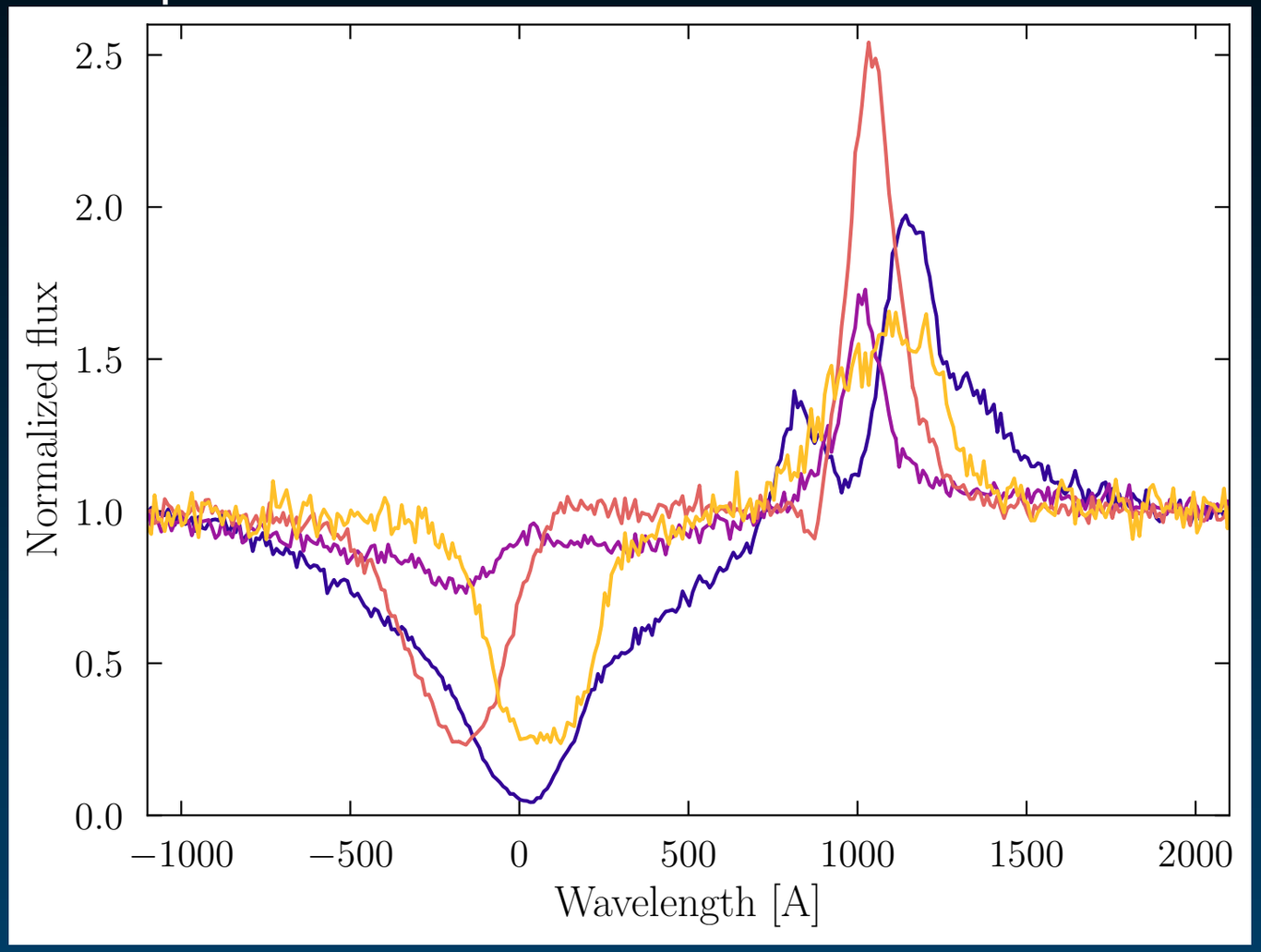
~4 cpu-hours per galaxy

Mock observations with RASCAS Michel-Dansac+20, Mauerhofer+21

~4000 galaxies in 108 directions of observation

2) Absorption lines

examples of SiII 1260A



- Using the BARE-GR-S dust model, Katz+22b
- Dust depletion following Konstantopoulou+22
- Ionisation fractions computed with Krome
- Turbulent velocity computed in every cell.
  Density average of 25 km/s
  Volume average of 100 km/s
- ~15 cpu-hours per galaxy

Happy to share my >400’000 mock spectra!

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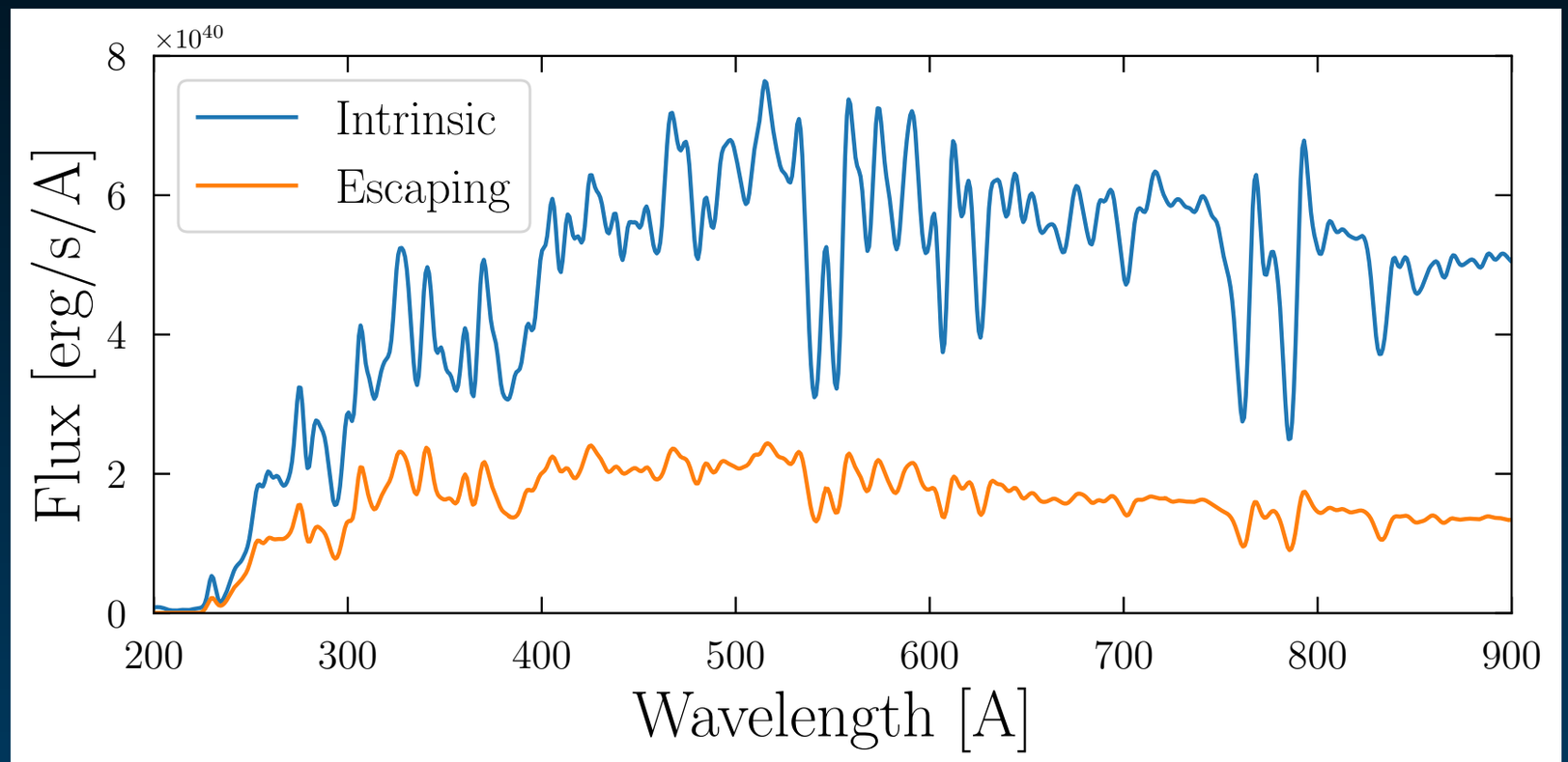
Mock observations with RASCAS Michel-Dansac+20

~4000 galaxies in 108 directions of observation

3) Lyman continuum spectra, to compute the escape fractions



Including absorption by H0, He0, He+ and dust

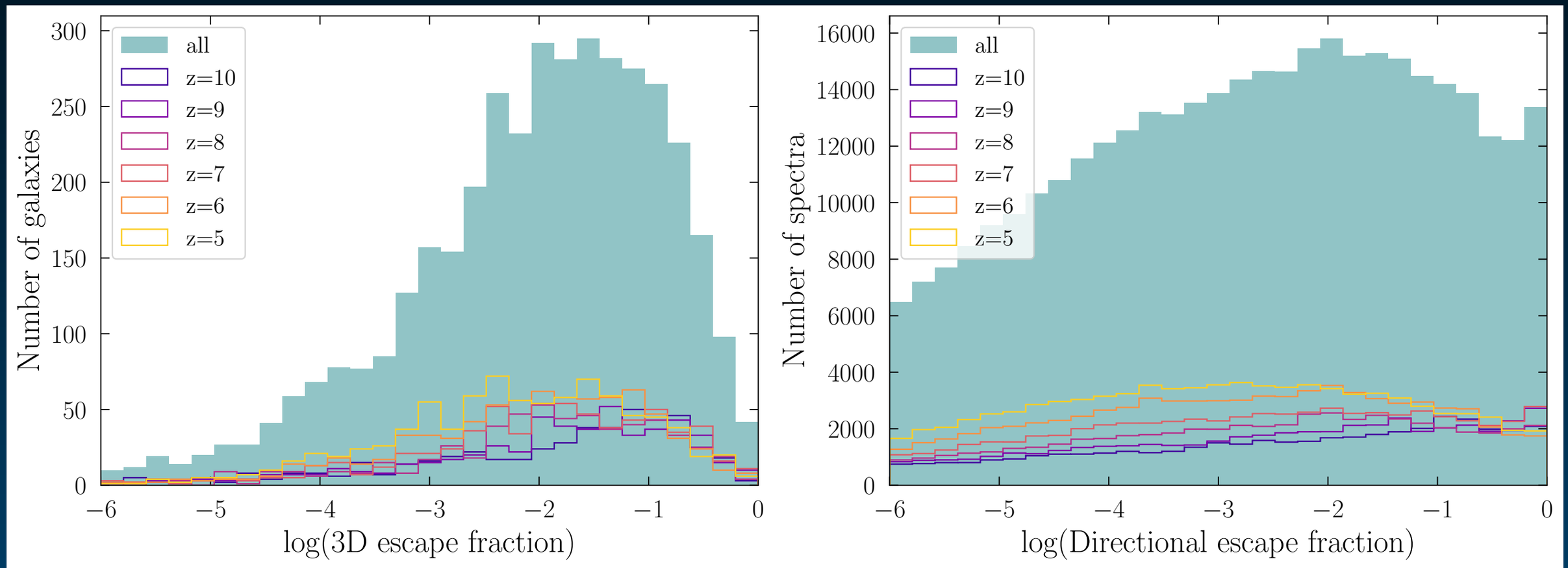
~4 cpu-hours per galaxy

Mock observations with RASCAS Michel-Dansac+20

~4000 galaxies in 108 directions of observation

3) Lyman continuum spectra, to compute the escape fractions

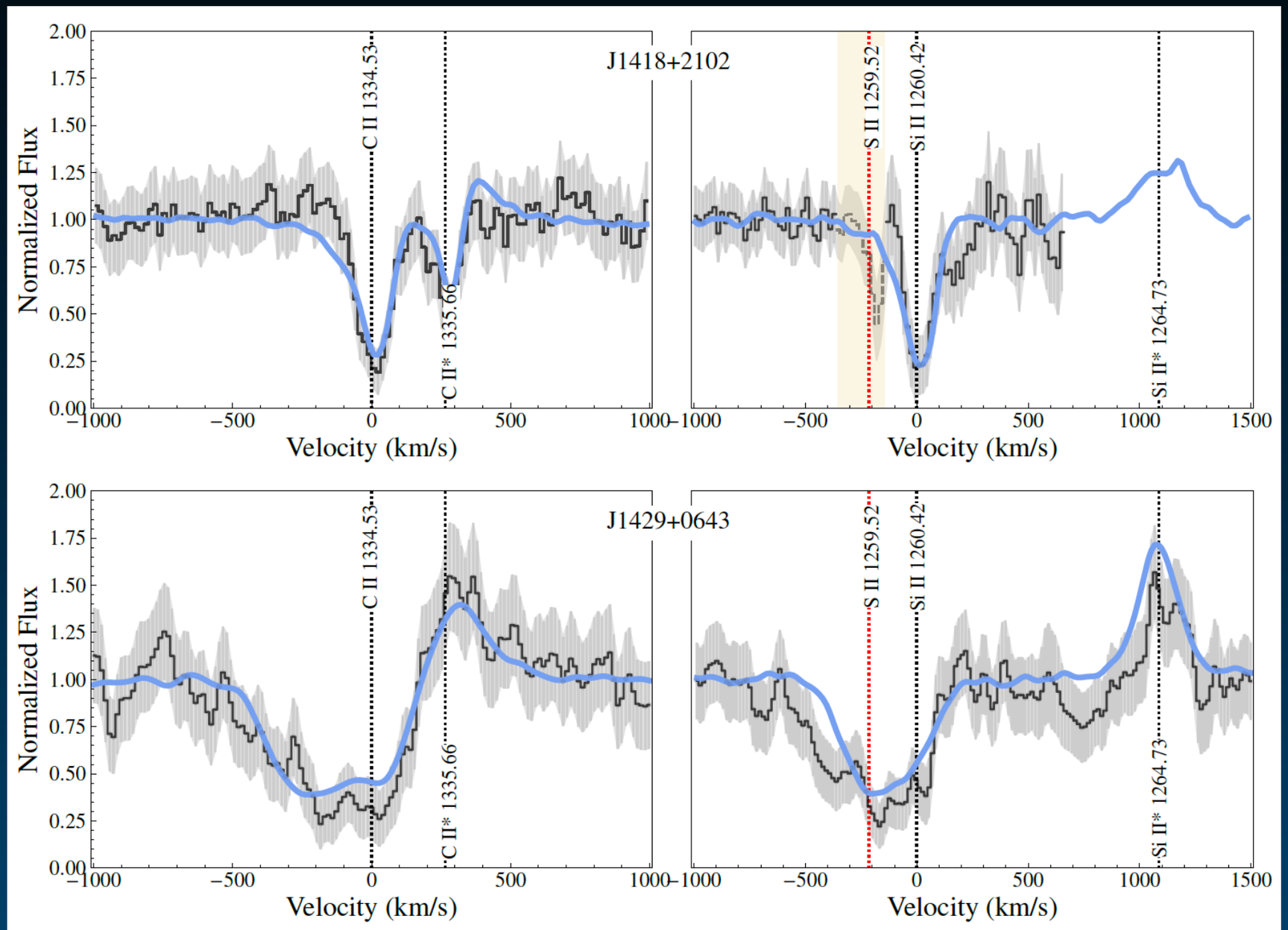
The distribution of angle-averaged f_esc differs from the one of directional f_esc



~20% of directional f_esc > 0.05, while ~35% of angle-averaged f_esc > 0.05

Are our mock absorption lines realistic?

Gazagnes et al. submitted



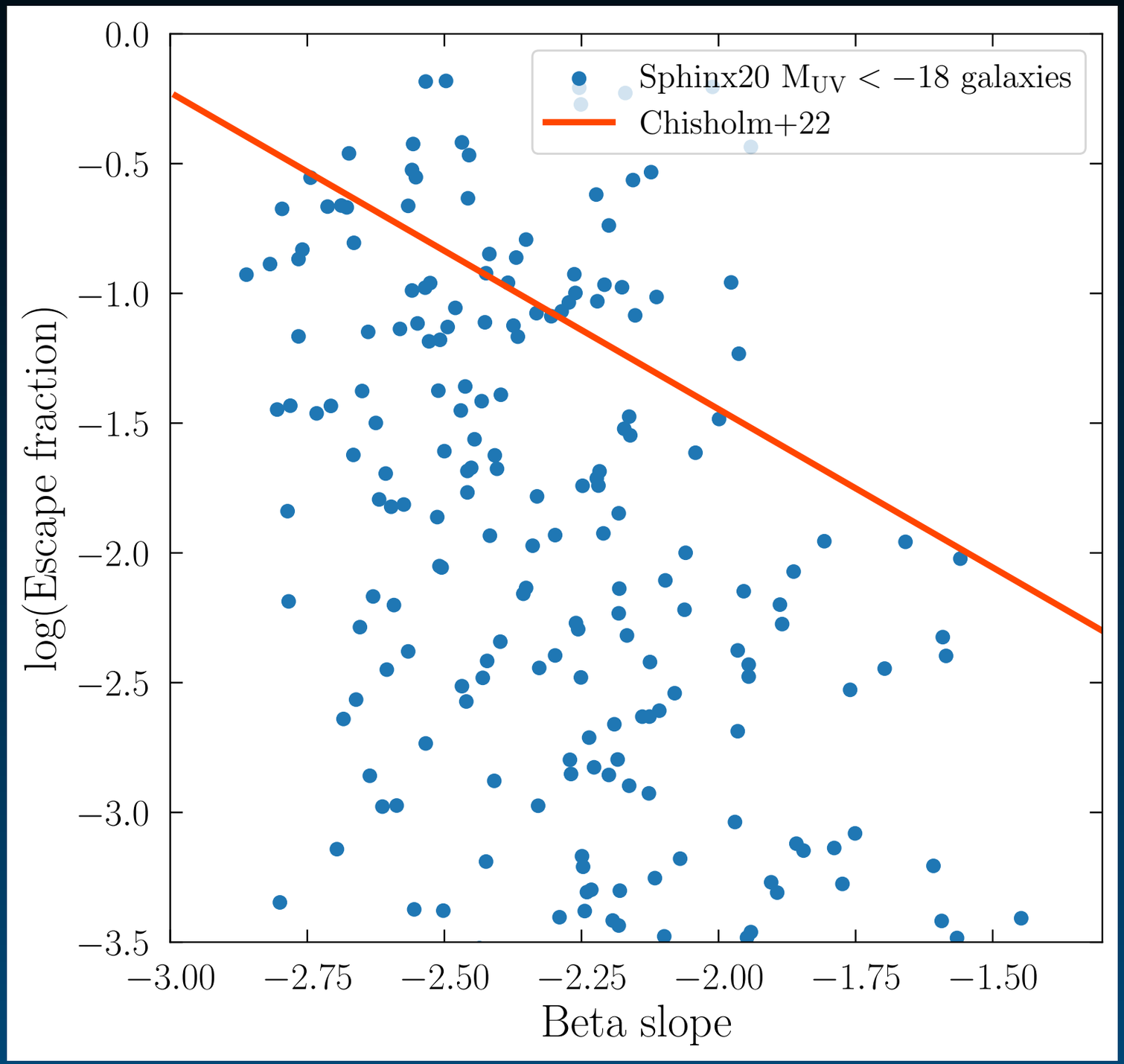
Comparison with low-z analogs of high-z galaxies: the CLASSY sample (Berg+22). Compact, low metallicity star-forming galaxies

~90% of CLASSY galaxy absorption lines are well reproduced by a single z~3 simulated galaxy with Mstar ~ 10^9

Can we infer escape fractions of ionising photons from absorption lines?

1) No one-to-one correlations

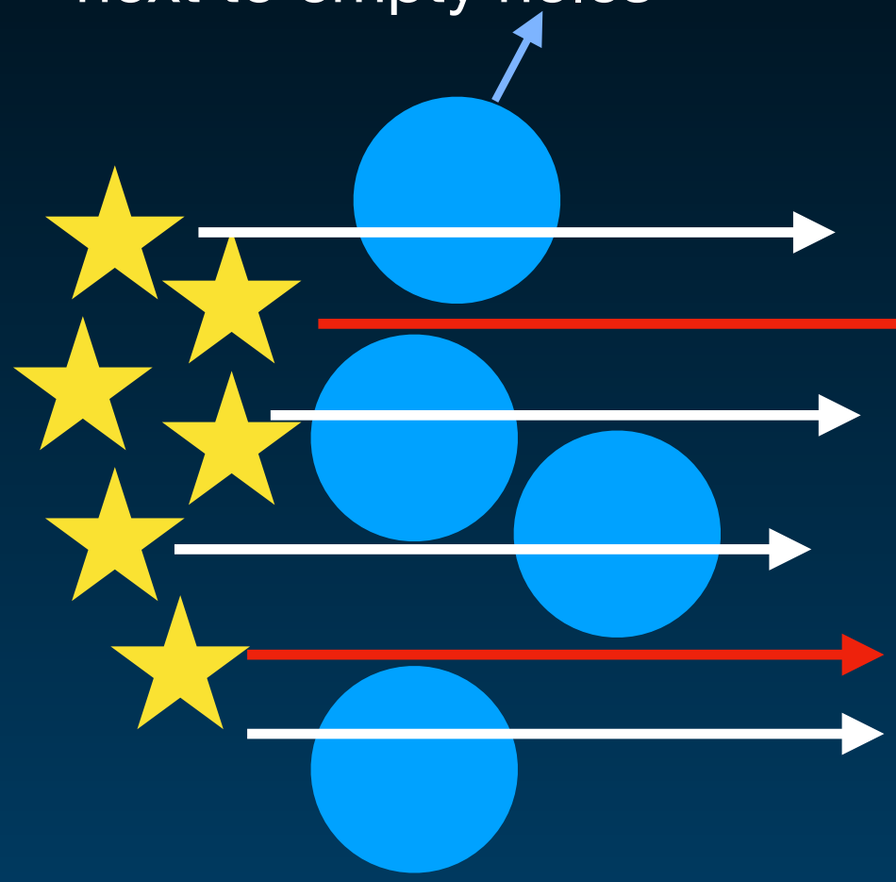
For example with the beta slope

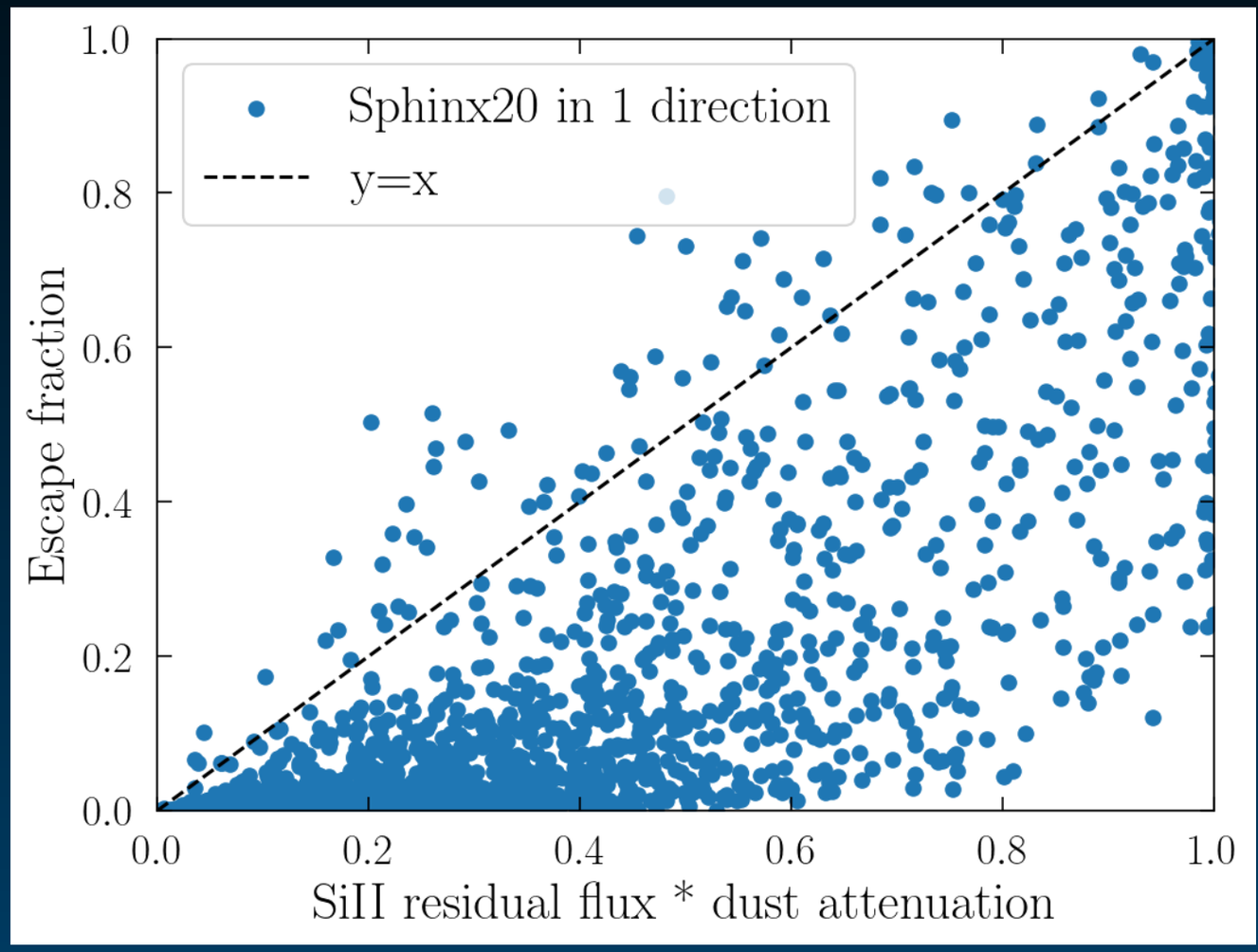


2) Using the picket-fence model

e.g.
Reddy+16
Steidel+18
Chisholm+18
Saldaña-Lopez+22

High column density of C+, H0, dust next to empty holes





In this configuration,

$f_{\rm esc}$ = residual flux × dust attenuation

However, this model does not reproduce the complexity of star-forming galaxies. More details in Mauerhofer+21

3) Using multivariate statistics

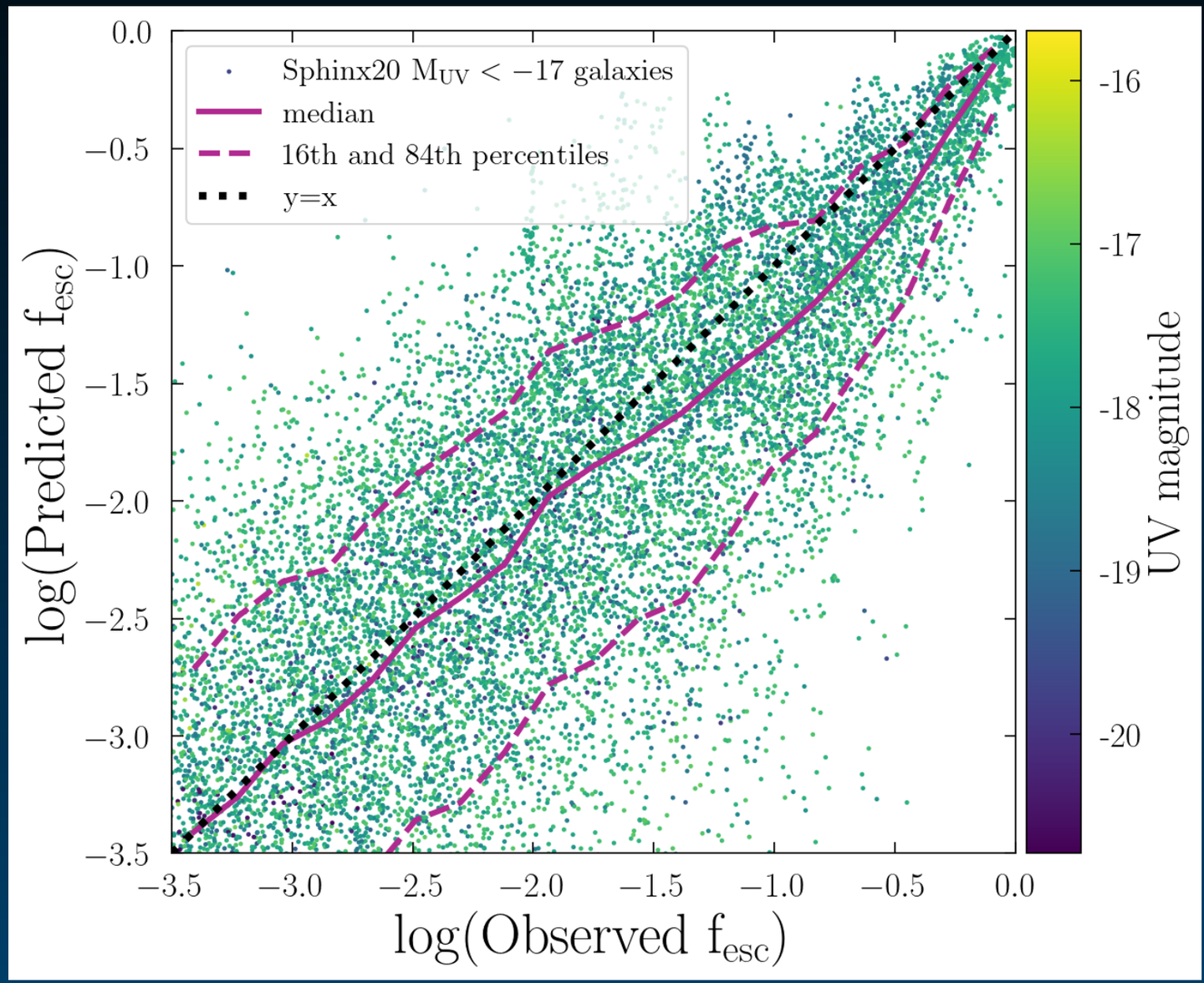
from sklearn.ensemble import RandomForestRegressor

List of input features:

- 1500A luminosity
- UV beta slope

  SiII 1260A properties:
- residual flux
- equivalent width
- centroid velocity

After applying a magnitude cut, training on 80% on the galaxies and testing on the remaining 20%.

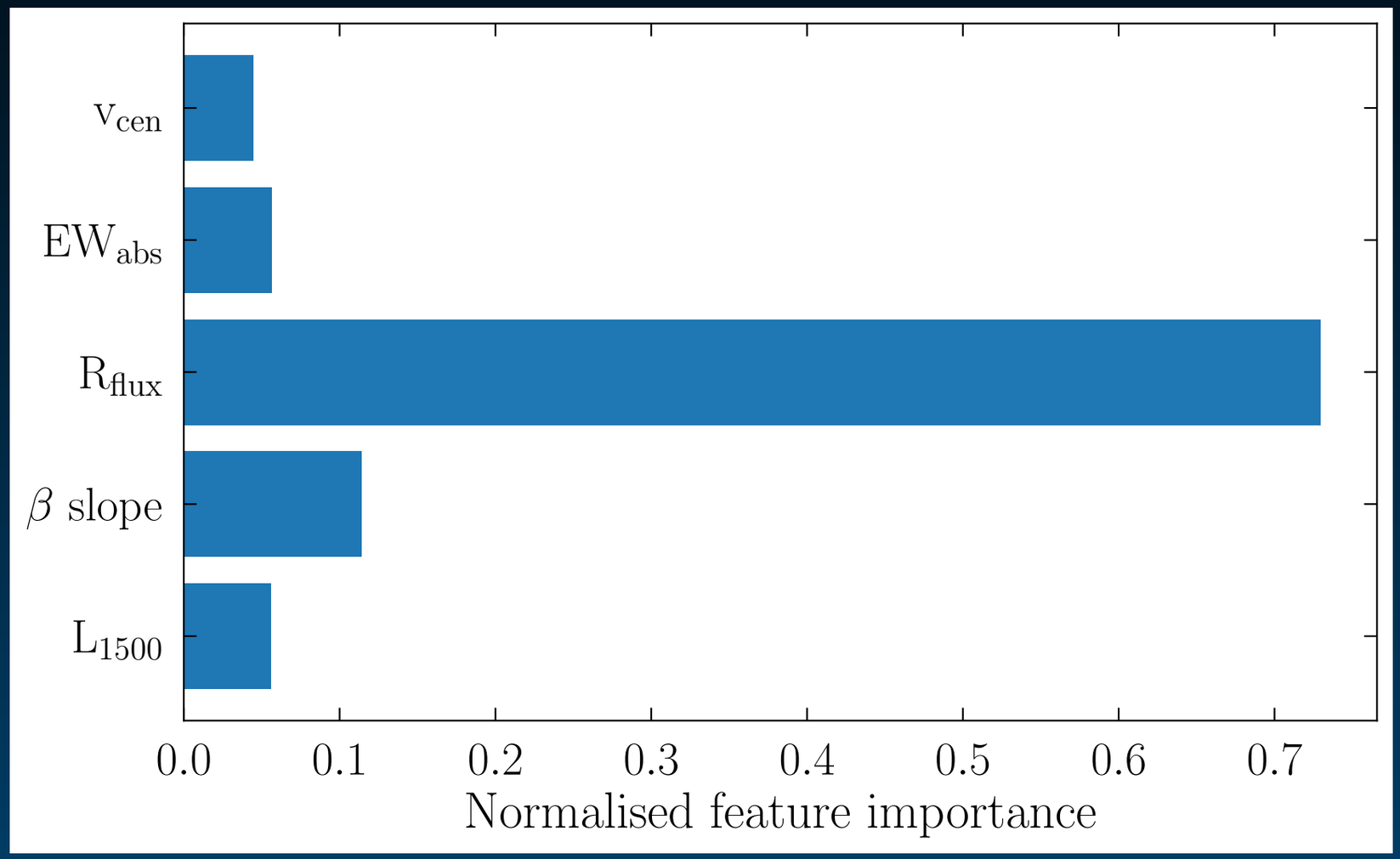


$R^2 = 0.76$

Statistical analysis in progress

3) Using multivariate statistics

from sklearn.ensemble import RandomForestRegressor.feature_importances



The residual flux is the most important input feature,
but it is not sufficient.

Summary

- Using the SPHINX20 simulation, I produce mock observations of the stellar continuum and absorption lines using RASCAS

- The simulated galaxies yield realistic absorption profiles

- Multivariate regression algorithms using Random Forests can relatively accurately predict the escape fraction of ionising photons based on low-ionisation state absorption lines

Thank you! And please contact me if you want mock spectra

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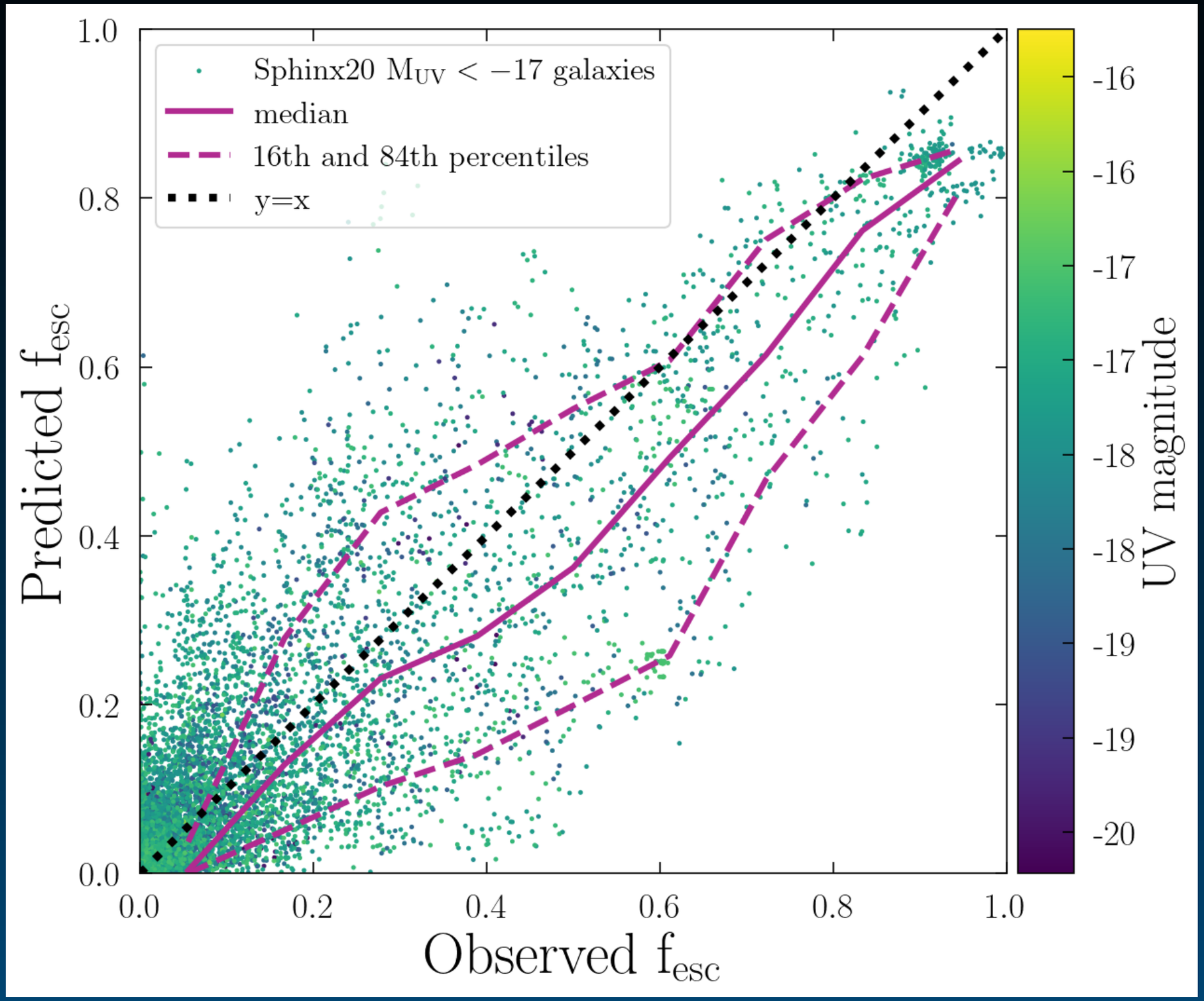
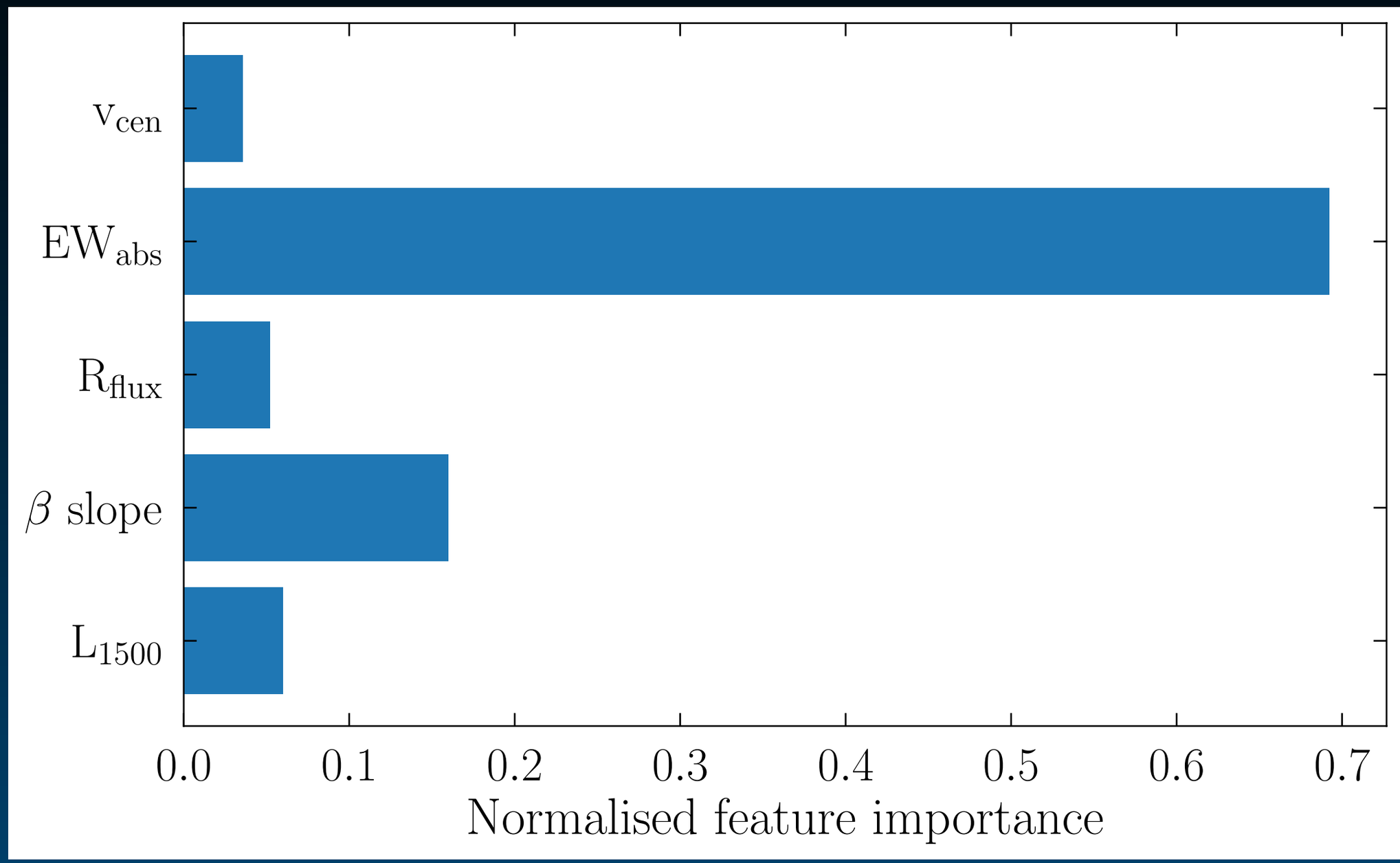

Sphinx20 $M_{UV} < -17$ galaxies
median
16th and 84th percentiles
y=x
Predicted f_{esc}
Observed f_{esc}
UV magnitude
0.0
0.2
0.4
0.6
0.8
1.0
-16
-16
-17
-17
-18
-18
-19
-19
-20


v_{cen}
EW_{abs}
R_{flux}
β slope
L_{1500}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Normalised feature importance