ASTRONOMY & ASTROPHYSICS

Exploring Intense, Low Metallicity Star Formation with JWST

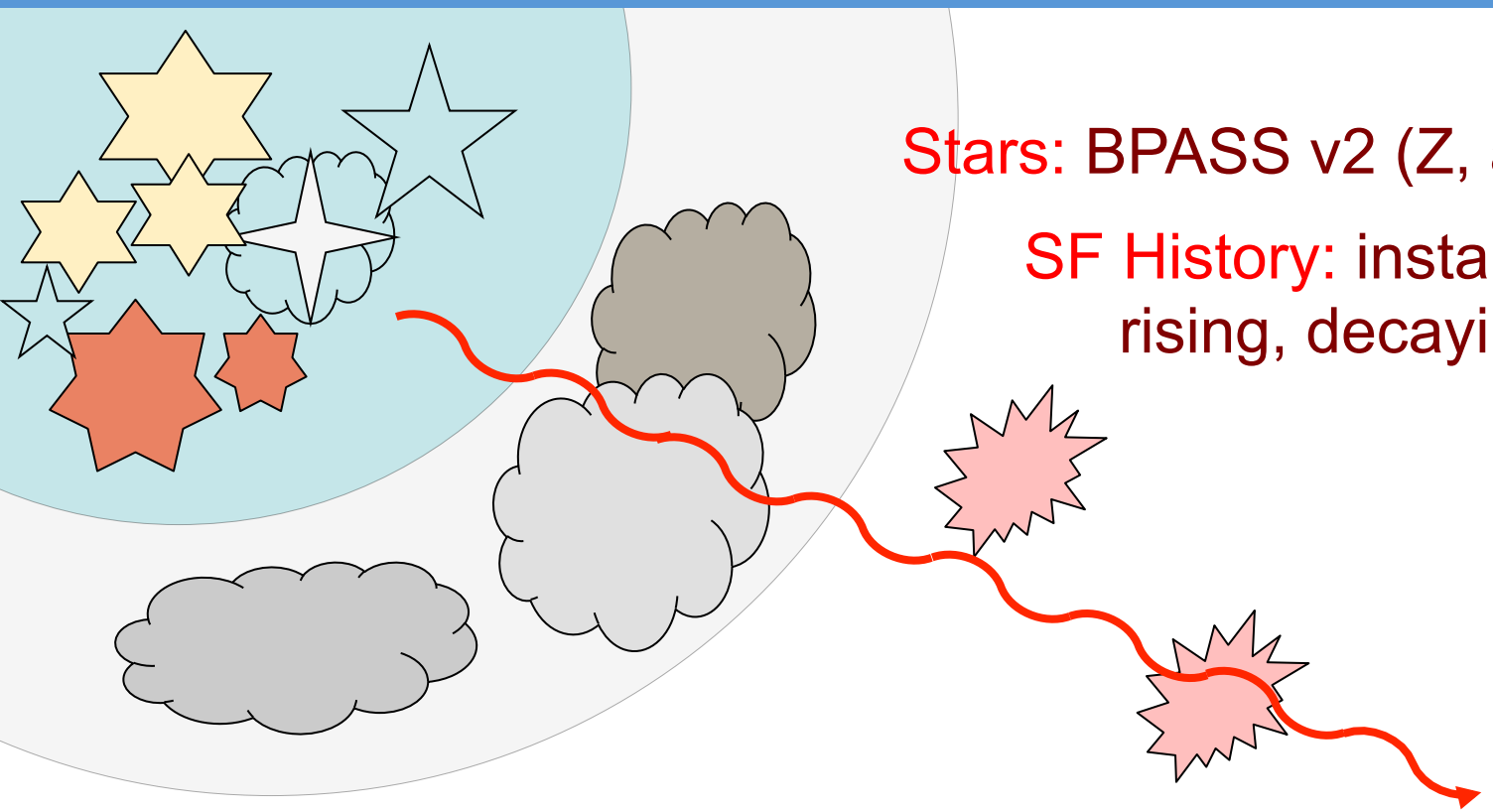
Elizabeth Stanway University of Warwick, UK

with

J J Eldridge University of Auckland, NZ

and many others

Components of SPS Codes



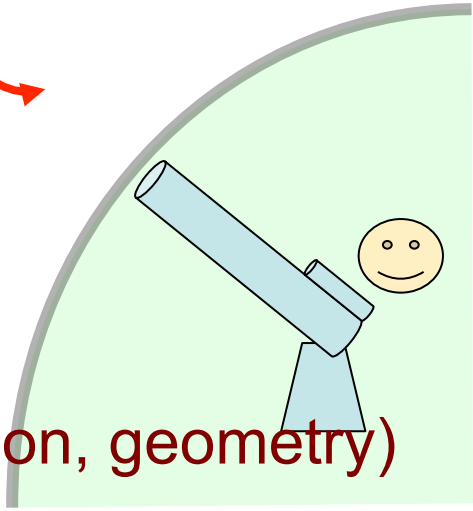
Stars: BPASS v2 (Z, age, sin/bin)

SF History: instant, constant, rising, decaying, delayed, multi-burst

Intergalactic Gas Clouds: Madau 1998

Dust: Calzetti extinction & Energy balance

Gas : CLOUDY v13.03 (Z, density, covering fraction, geometry)



binary population & spectral synthesis

THE UNIVERSITY OF AUCKLAND
FACULTY OF SCIENCE

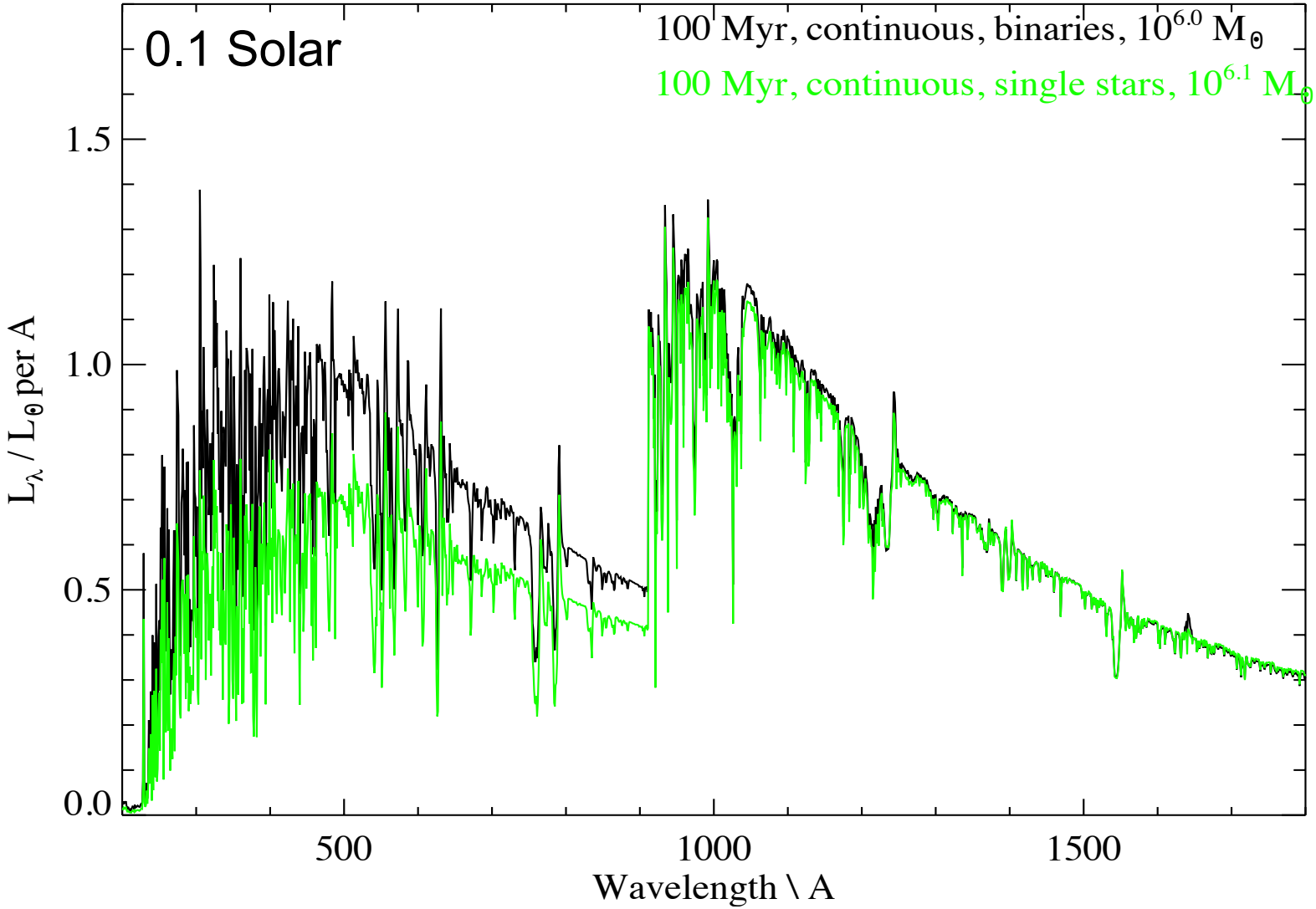
- Binary Population And Spectral Synthesis
- **~200,000 detailed** stellar evolution models in v2.0.
- Can be used to study a broad range of astrophysical systems: stars, supernovae, GW sources, stellar clusters and galaxies.
- **WARWICK.AC.UK/BPASS**

  (also bpass.auckland.ac.nz or bpass.org.uk)
- Work in progress includes more models, more masses, lower metallicities, compact binaries, rotation?, varied abundance ratios, more on dust and non-thermal emission

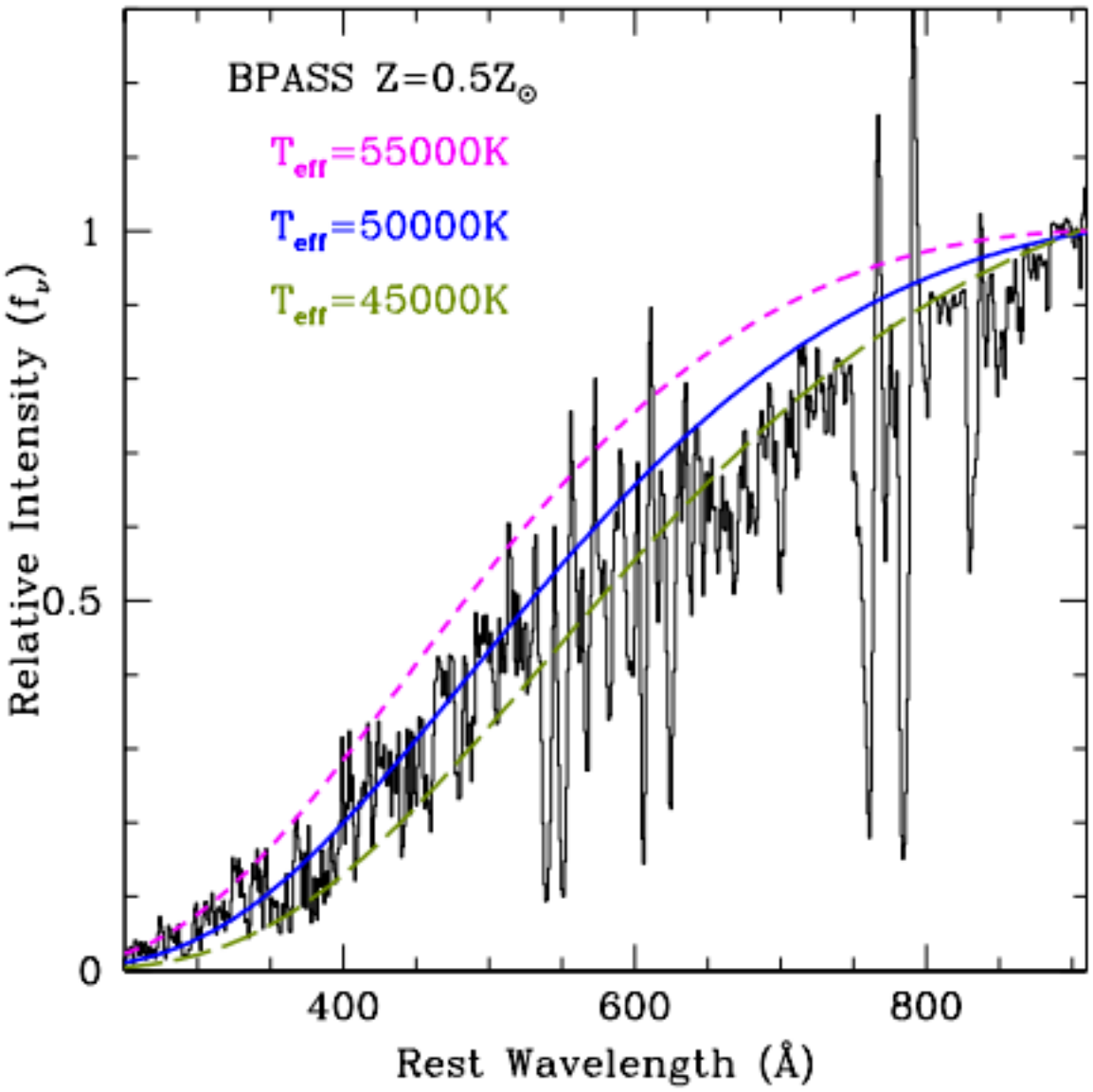
(Eldridge & Stanway 2009, 2012; Stanway et al 2016; Eldridge et al in prep)

The Effect of Binary Evolution

Binary evolution produces stronger Lyman continuum flux:



Ionising Spectra

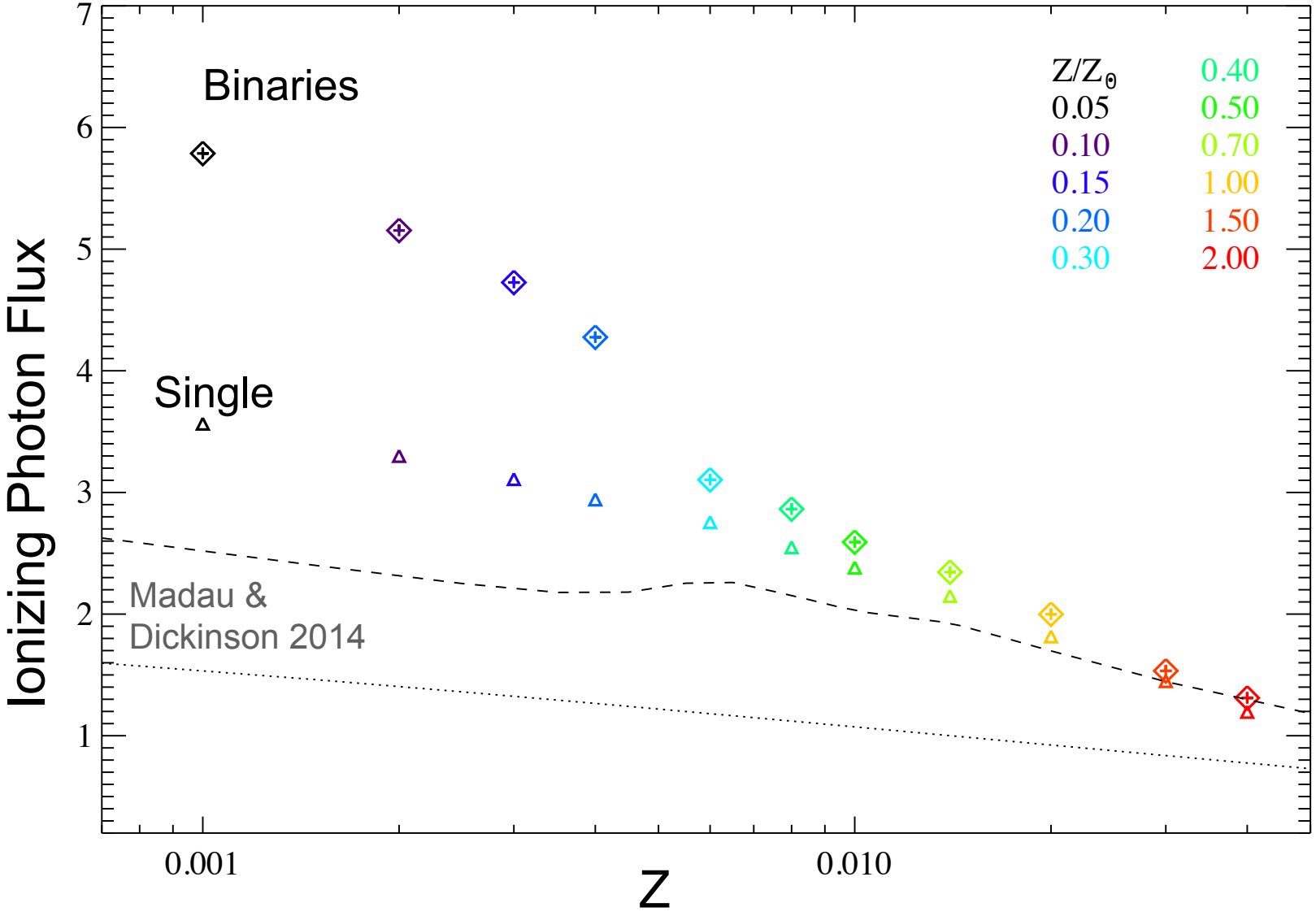


Binary pathways lead to more hot, massive and WR stars in a stellar population at late times

The resulting spectrum is 'hotter' with a bluer ultraviolet spectrum

Plot from Steidel et al 2014

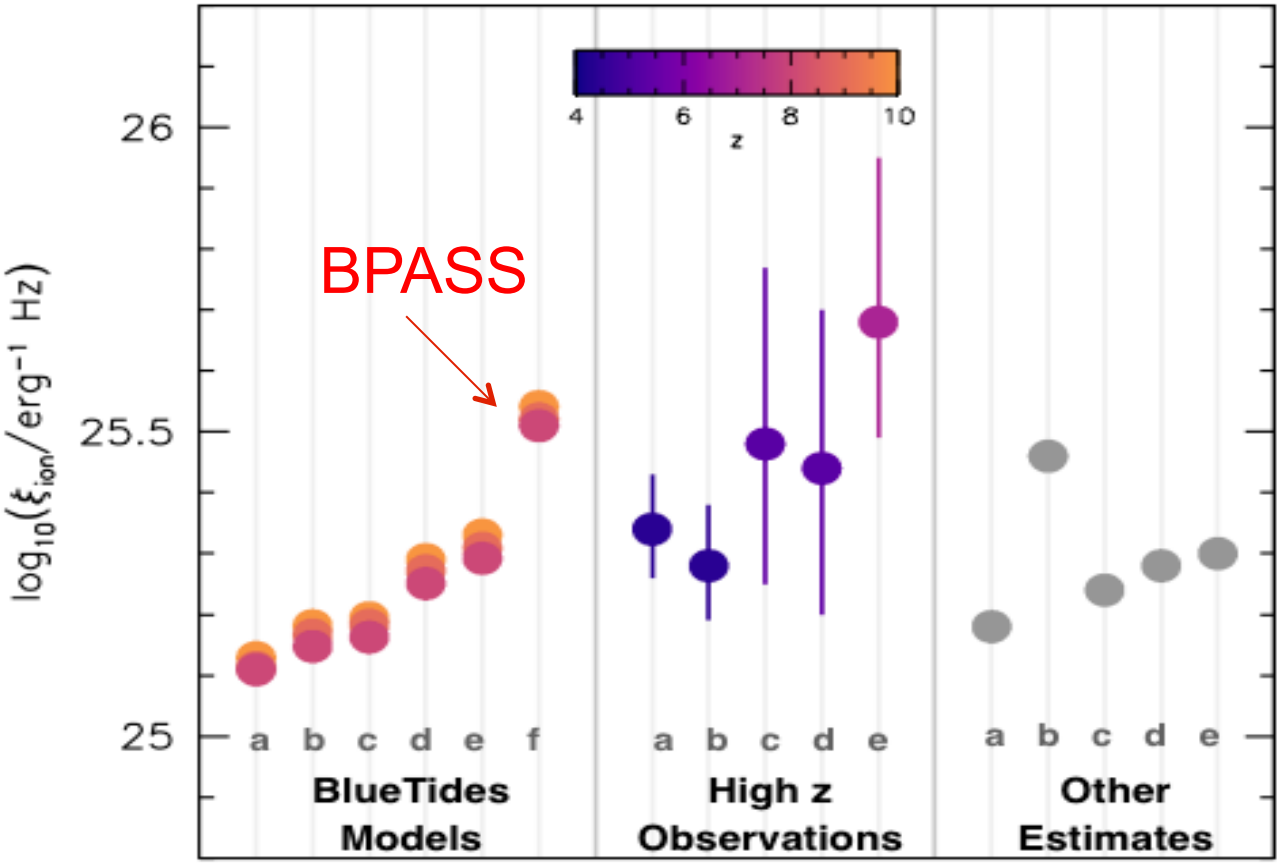
Difference in Ionizing Flux



BPASS v2,
Stanway et al (2016), Eldridge et al (in prep)

Difference in Ionizing Flux

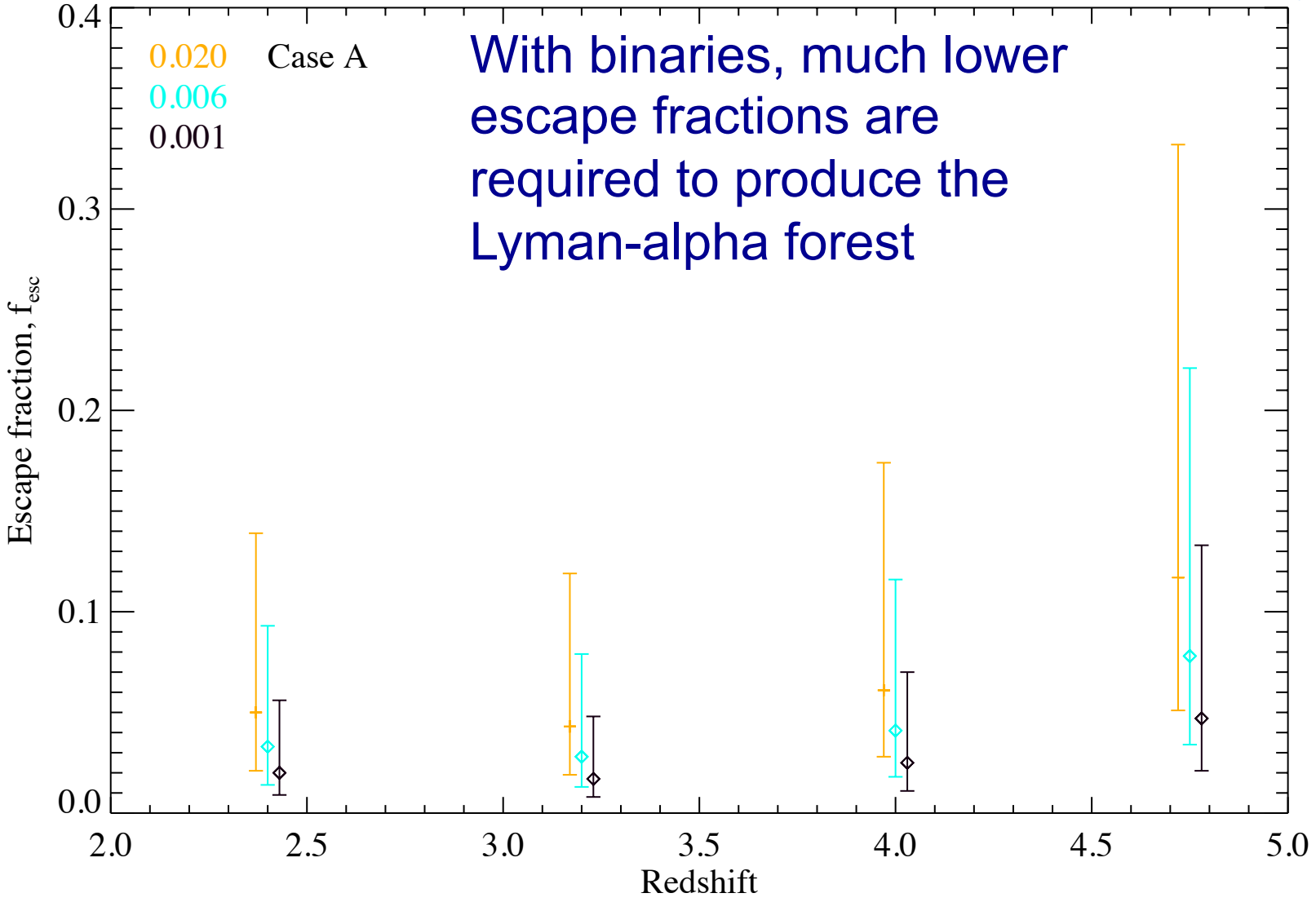
Observations of high redshift ionizing flux, in combination with galaxy evolution models, suggest this kind of photon flux is needed to explain reionization.



Wilkins et al 2016

See also
Ma et al 2016;
Steidel et al 2016

Escape Fractions



Stanway et al, 2016

Reionization with JWST

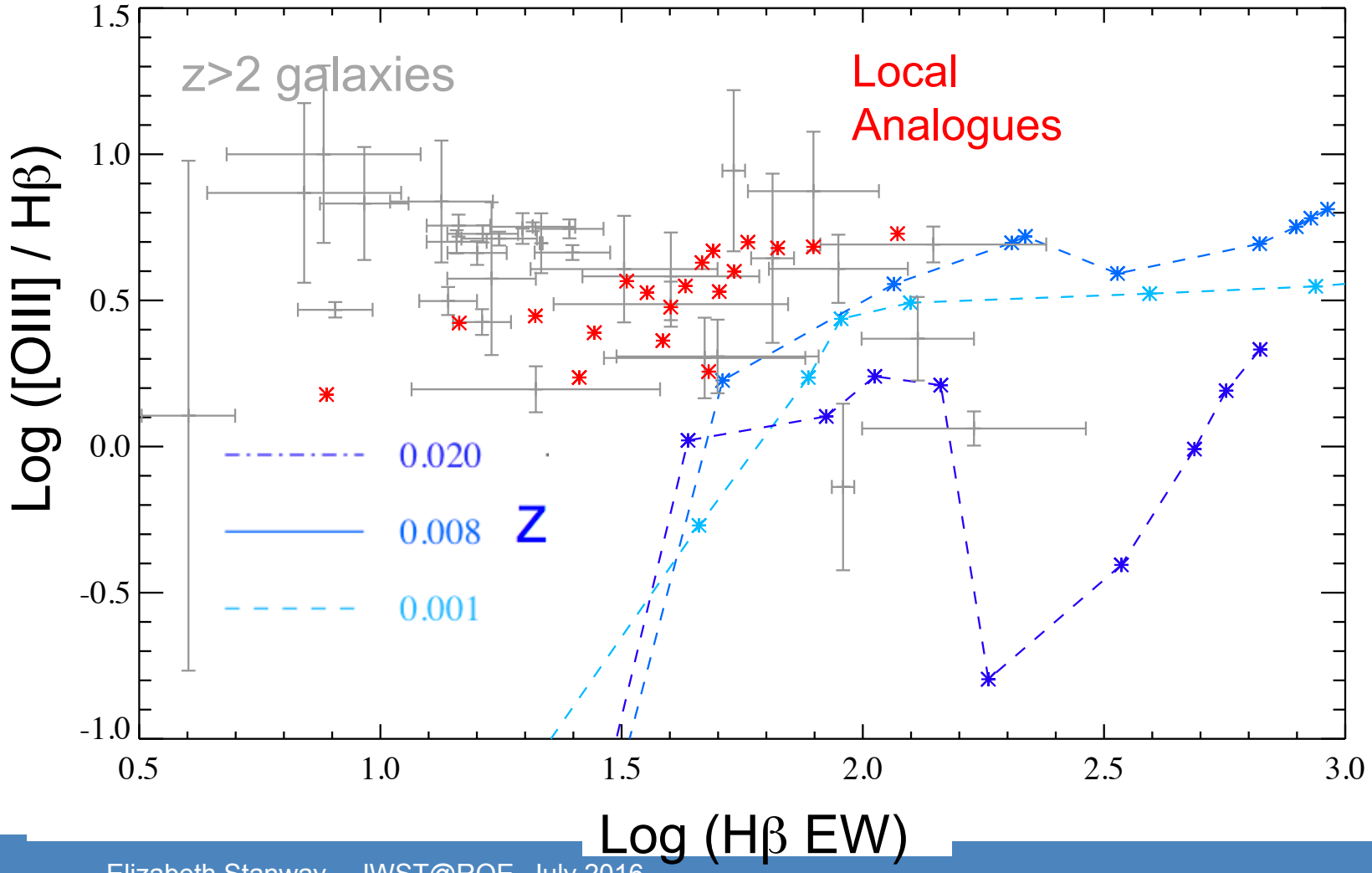
- Binary effects are strongest in young stellar pops and at low metallicities.
- It might be over-optimistic (and unnecessary) to expect very high escape fractions in the early Universe.
- The 1500A continuum flux from ionizing sources may be low compared to previous predictions.
- Relatively small galaxies can ionize large regions – we might not see these in the continuum.

Emission Lines

- BPASS models stellar continuum emission.
- This should be reprocessed by dust and nebular gas before comparison with data.
- We recommend the use of a radiative transfer code such as CLOUDY or MAPPINGS.
- We have been wary of providing a processed data set: it is important to distinguish between uncertainties in the stellar models and those in their later reprocessing.
- Feel free to talk to us about this if you want to use line emission models.

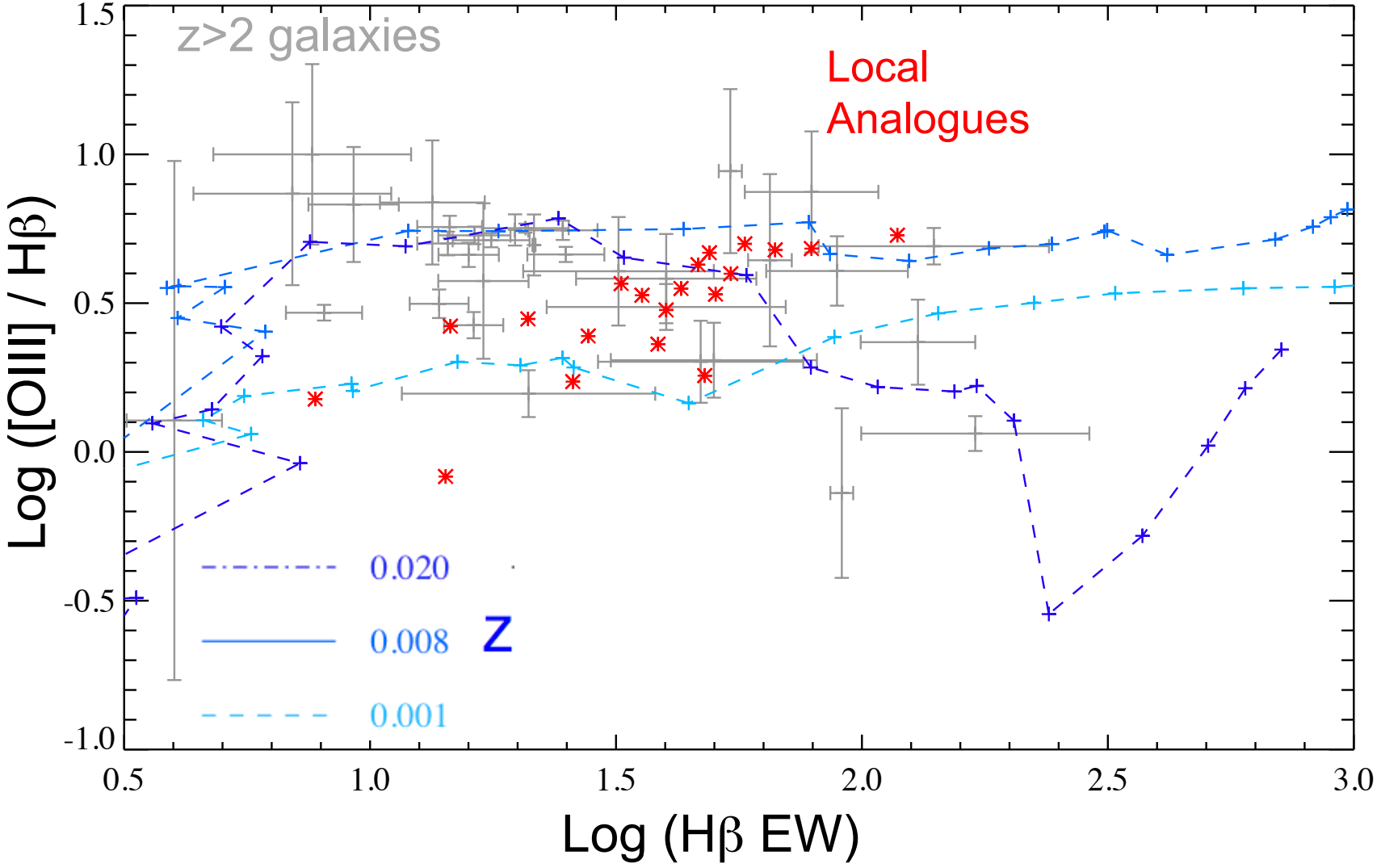
Emission Line Diagnostics

The ratio of optical emission line strengths provides information on the hardness of the ionizing radiation field



Stanway et al, 2014, MNRAS 444 3466
For LBAs see Stanway & Davies 2014; Greis et al 2016

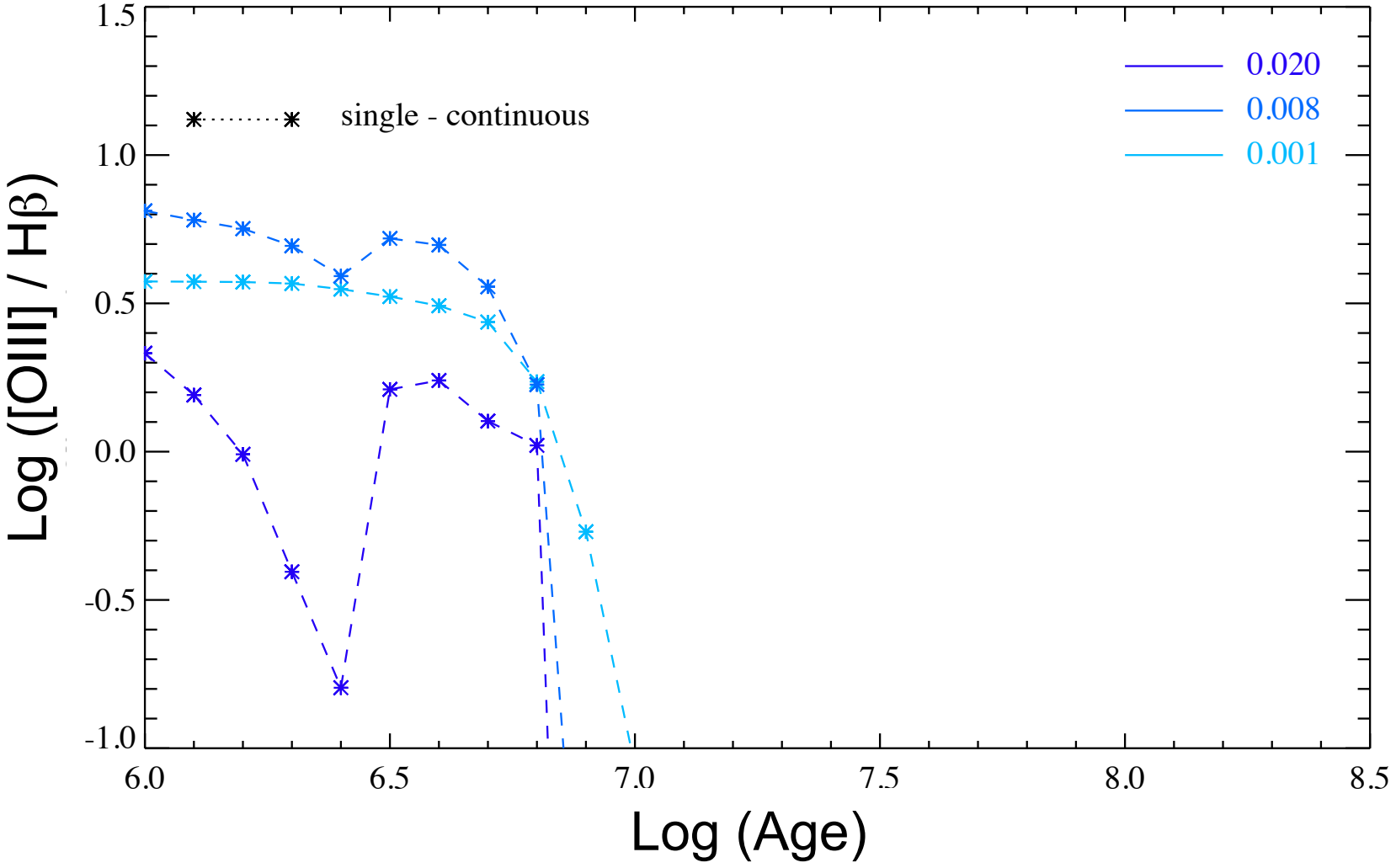
Emission Line Diagnostics



Stanway et al, 2014, MNRAS 444 3466

Timescales for high [OIII]/Hb

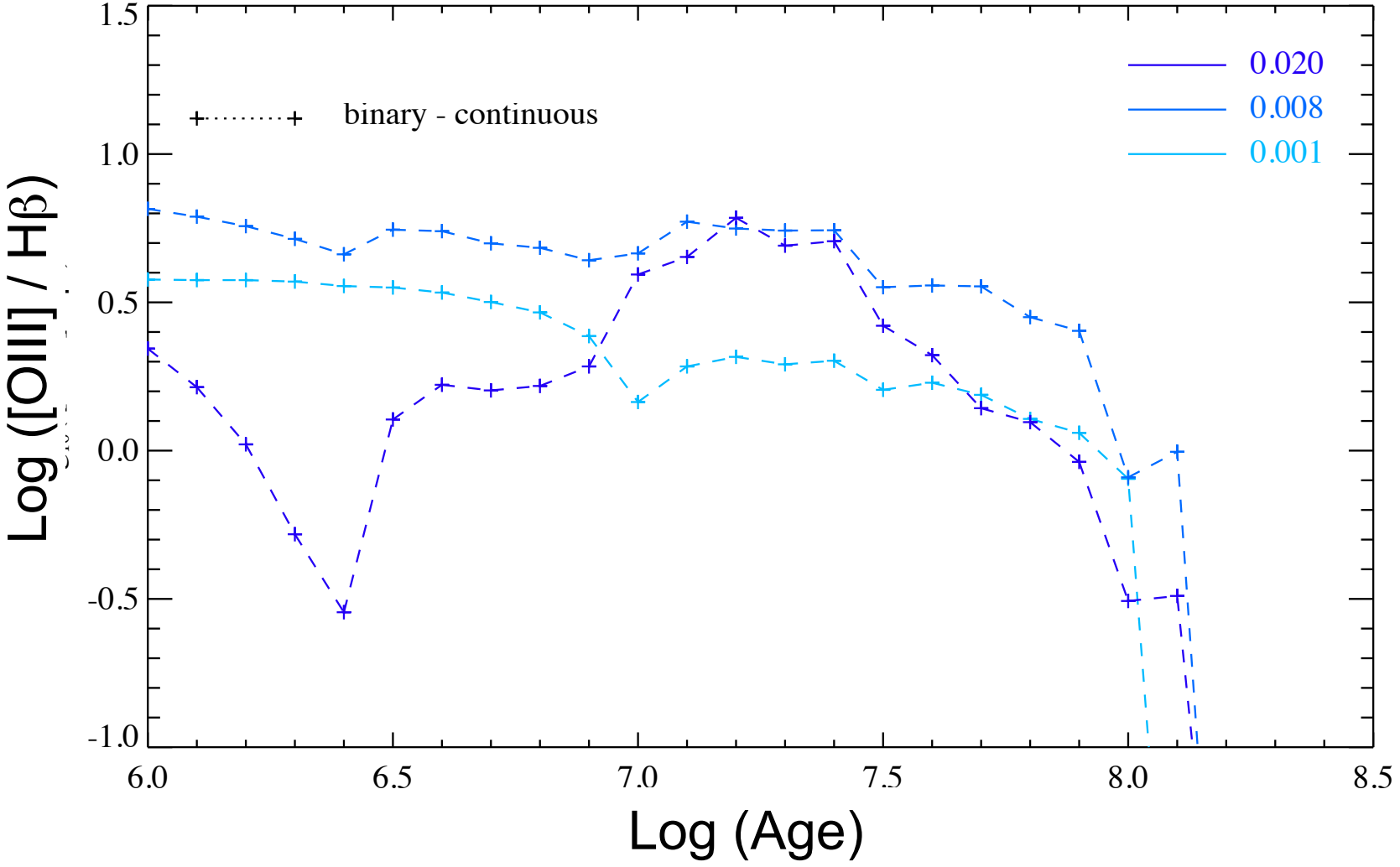
This is primarily an effect of timescales – massive stars contribute flux for longer in a binary population.



Stanway et al, 2014, MNRAS 444 3466

Timescales for high [OIII]/Hb

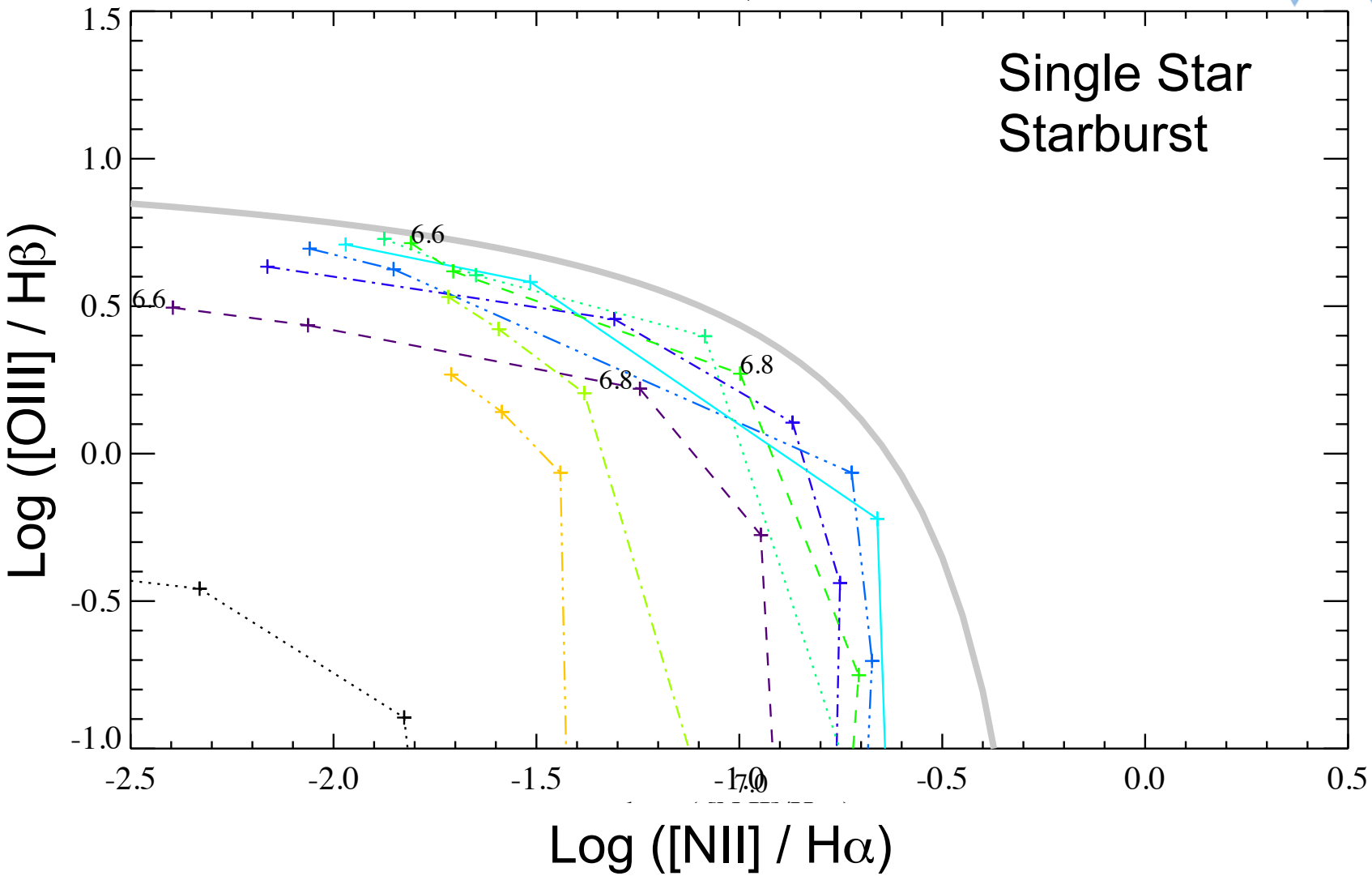
This is primarily an effect of timescales – massive stars contribute flux for longer in a binary population.



Stanway et al, 2014, MNRAS 444 3466

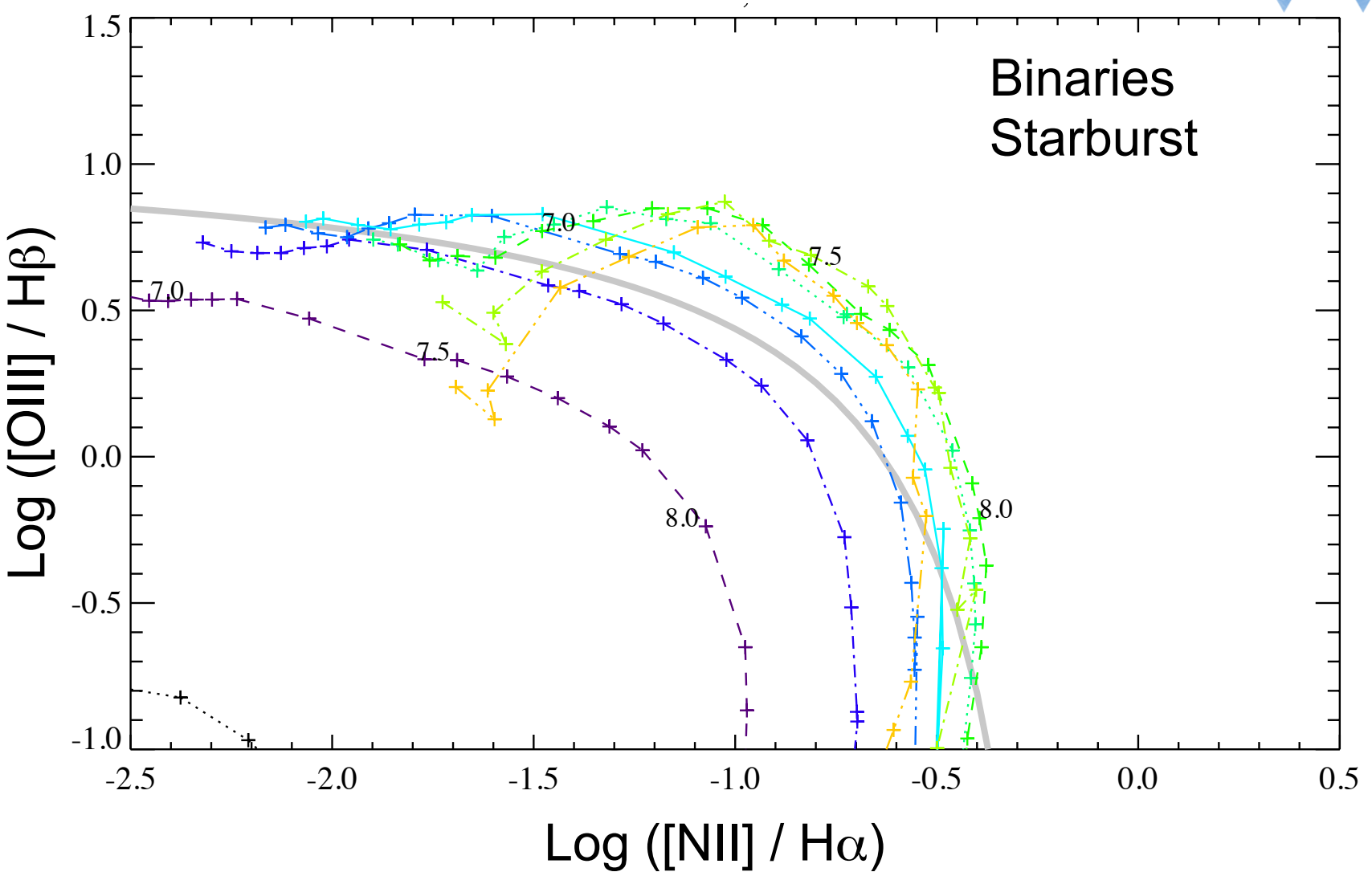
The BPT diagram

JWST/NIRSPEC will allow rest-optical spectroscopy...



The BPT Diagram

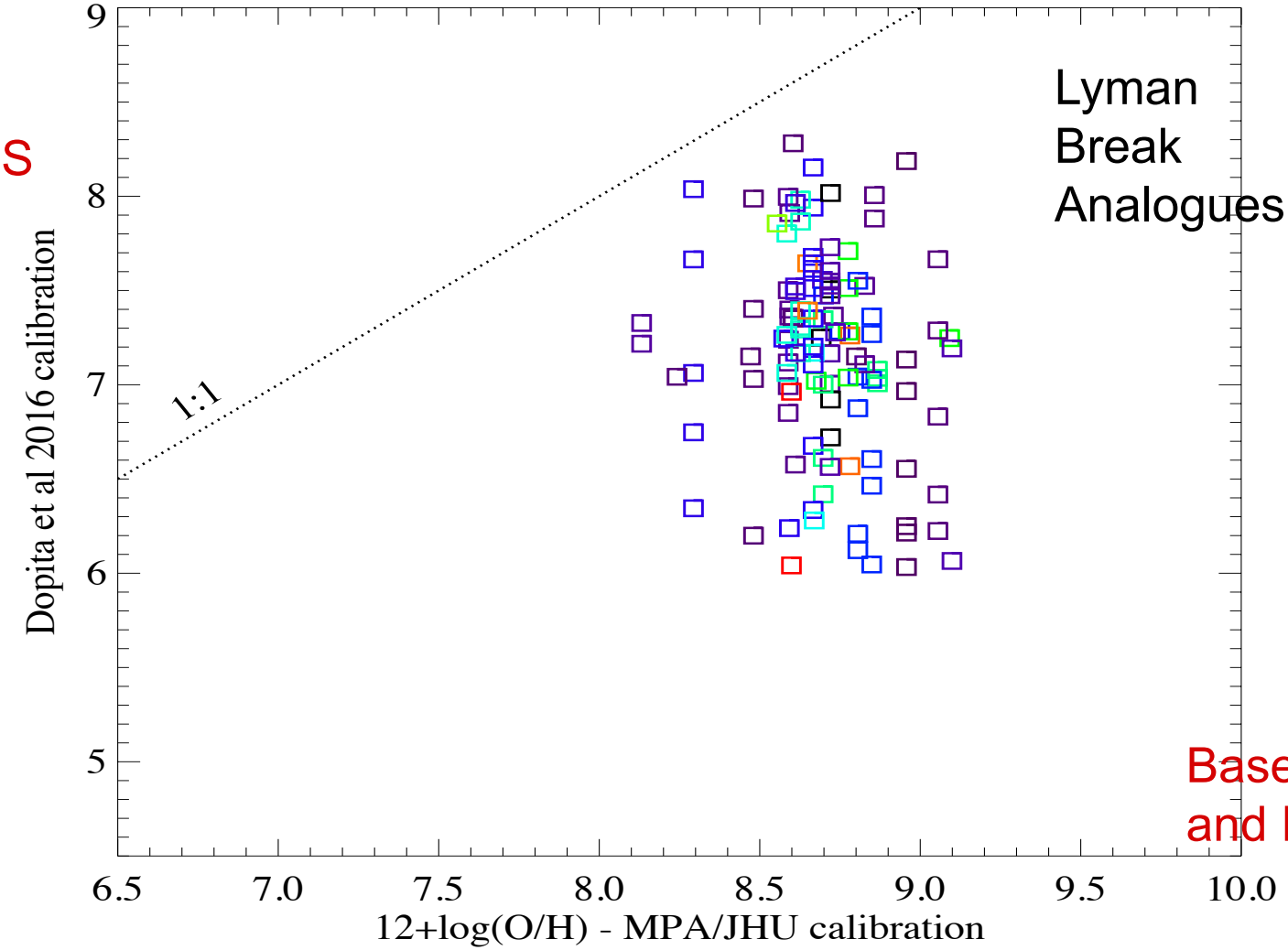
…caution may be required when interpreting it!



Metallicity from Line Ratios

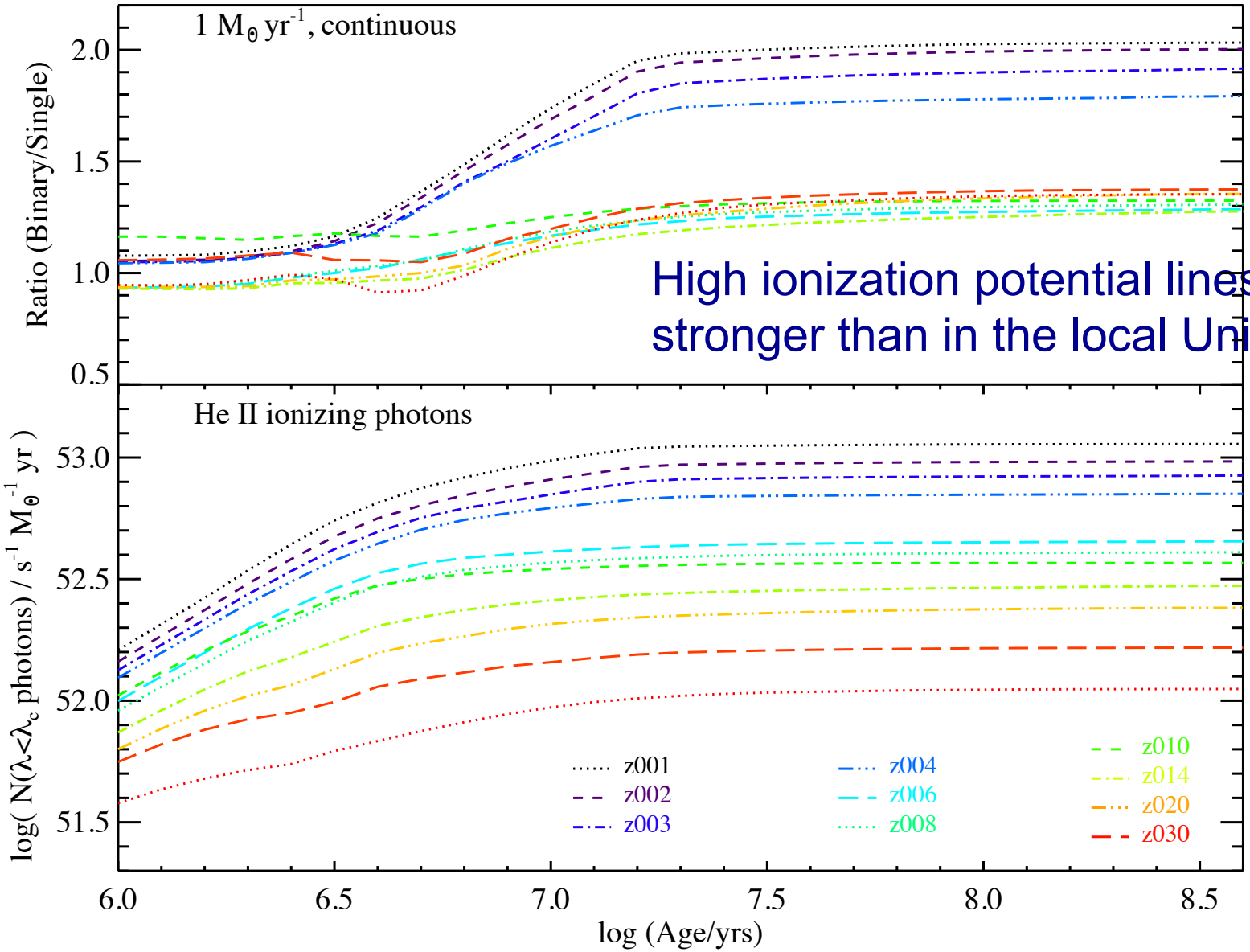
Local metallicity calibrations need to be applied carefully:

Based on N, H and S lines



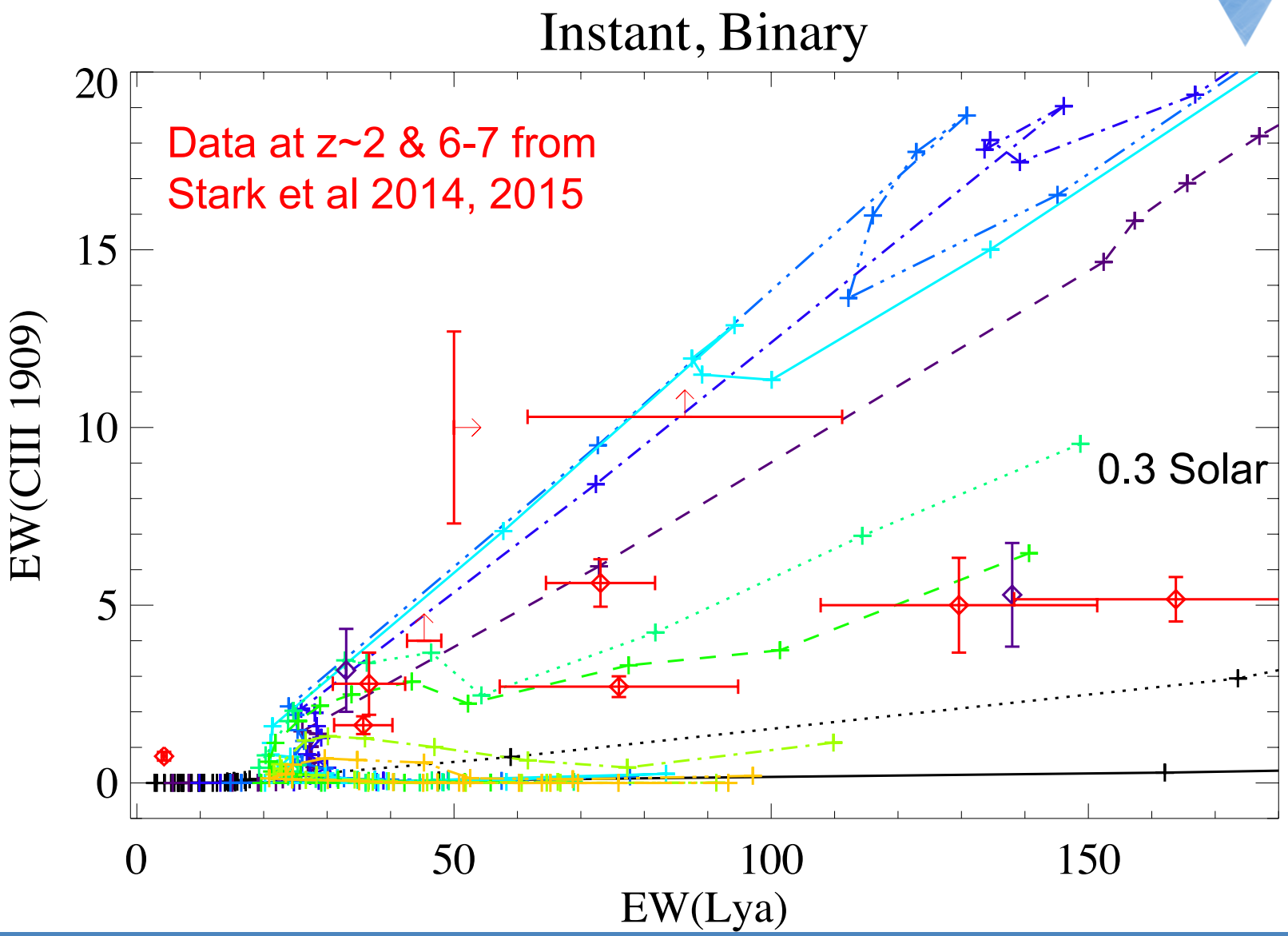
Based on O and H lines

Helium Ionizing Photons



High ionization potential lines may be stronger than in the local Universe

CIII] 1909 in High z spectra



Emission Lines with JWST

- JWST will be spectacular for measuring line diagnostics from galaxies across a broad range of redshifts.
- We should expect strong emission lines from young, low metallicity stellar pops.
- These will need careful modelling for accurate interpretation – local analogues may be useful for calibration.
- Local calibrations, e.g. for the BPT diagram or metallicity, may need adjusting.

Conclusions

- Binary evolution pathways are particularly important for massive stars and young starbursts, and for low metallicities
- Incorporating these in stellar pop synth models can match (some) observed properties of galaxy populations
- Our BPASS models include detailed binary models – bpass.auckland.ac.nz
- These can be used to make predictions for JWST – they suggest applying caution when extrapolating from the local Universe.