KICC WORKSHOP 2017: Emission Line Galaxies with MOS: from cosmic noon to the re-ionisation era

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Cosmic evolution of synthetic nebular emission of massive galaxies

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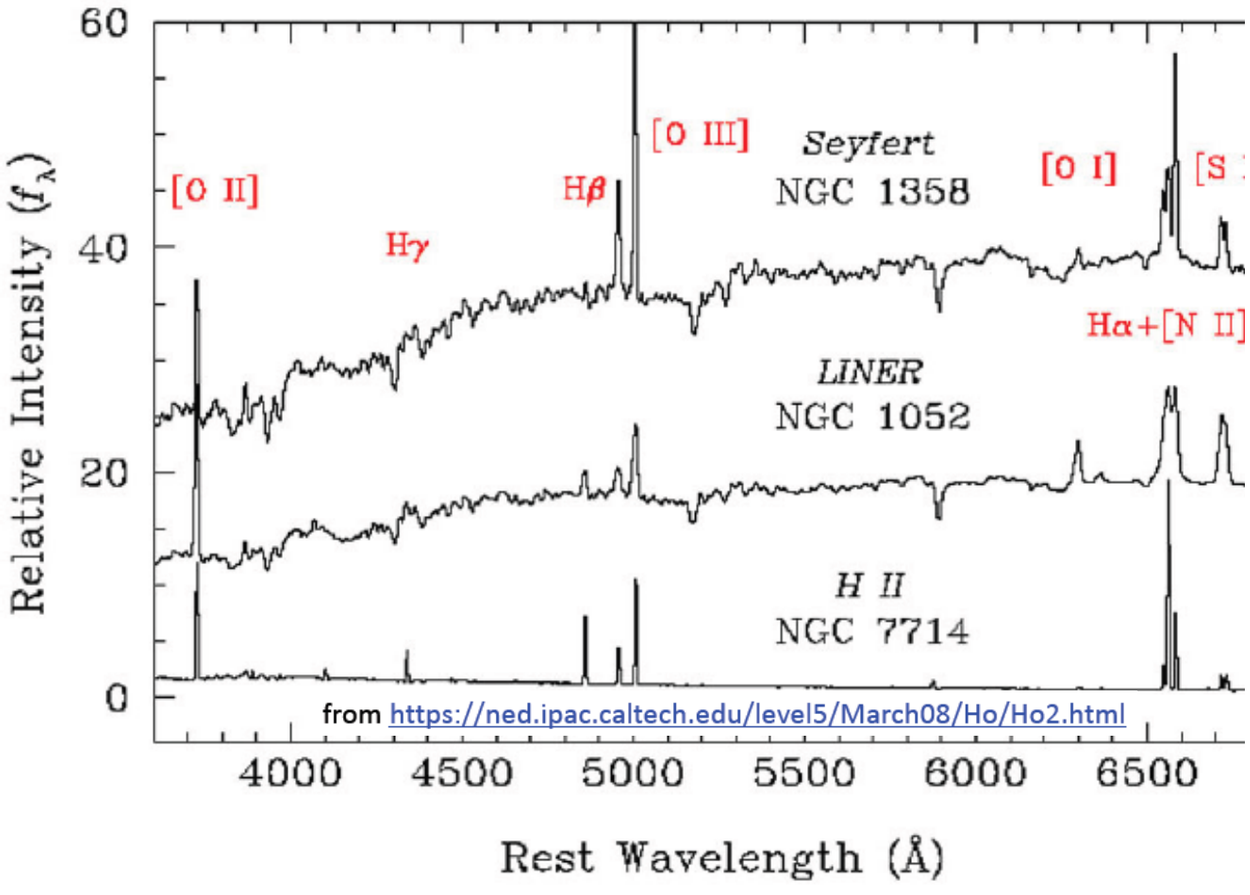
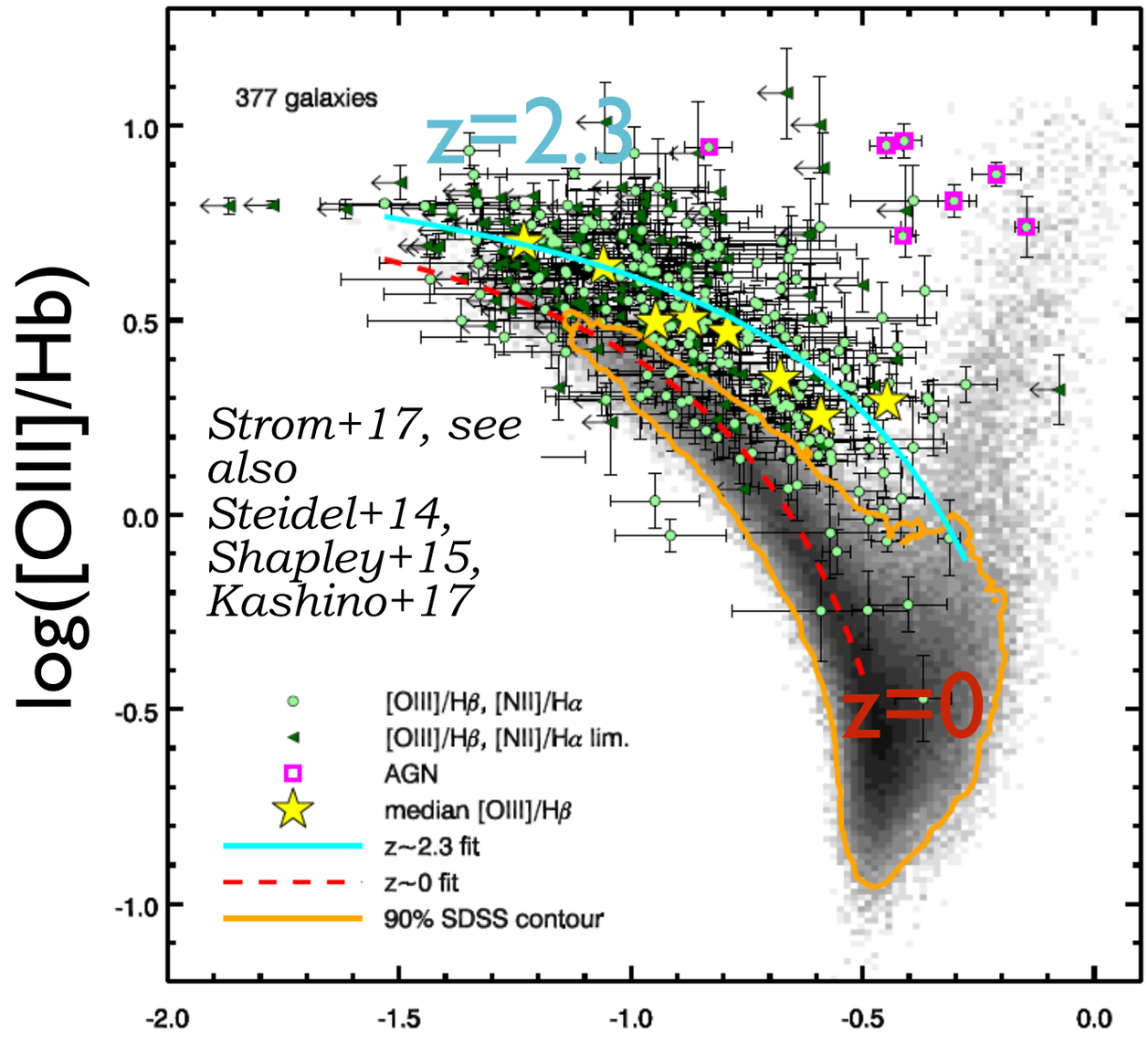
With S. Charlot, A. Feltre, T. Naab, R. Somerville, J. Ostriker, E. Choi

Emission lines in local & distant gal's

Optical nebular emission lines





- …used to observationally distinguish between types in the *local* Universe,
- Optical selection criteria still applicable at z~>2?!
- [OIII]/Hβ found to *evolve* over cosmic time

Why *synthetic* nebular emission?

Exploration of synthetic spectra with nebular emission lines of galaxies in a full cosmological context

- *How can we distinguish the main ionising sources of a galaxy, incl. composites, at high redshift?*
  - Anna's talk: difficult with optical lines
  - What about *UV diagnostic diagrams*? — Distinct regions for SF, AGN and *composites*?

- *Which is the physical origin of evolving optical emission line ratios?*

- *Can we identify directly observable signatures in nebular emission for specific physical processes* governing galaxy evolution, e.g. AGN feedback?

Cosmological zoom-in simulations

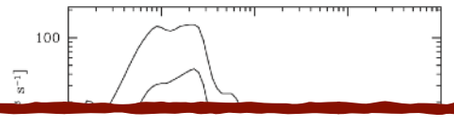
Set of 30 cosmological zoom-in simulations of massive galaxies

Choi,…,Hirschmann+17, Hirschmann+17

$3e12\ M_\odot < M_{halo} < 3e13\ M_\odot$, $x_{spatial}$ = 200pc, m_{gas}=1.4e5 $M_\odot$

Initial conditions of *Oser+10*, *Hirschmann+12*

"Modern" SPH-code Gadget-3 *(Hu+14)*



Predictions of realistic massive galaxies

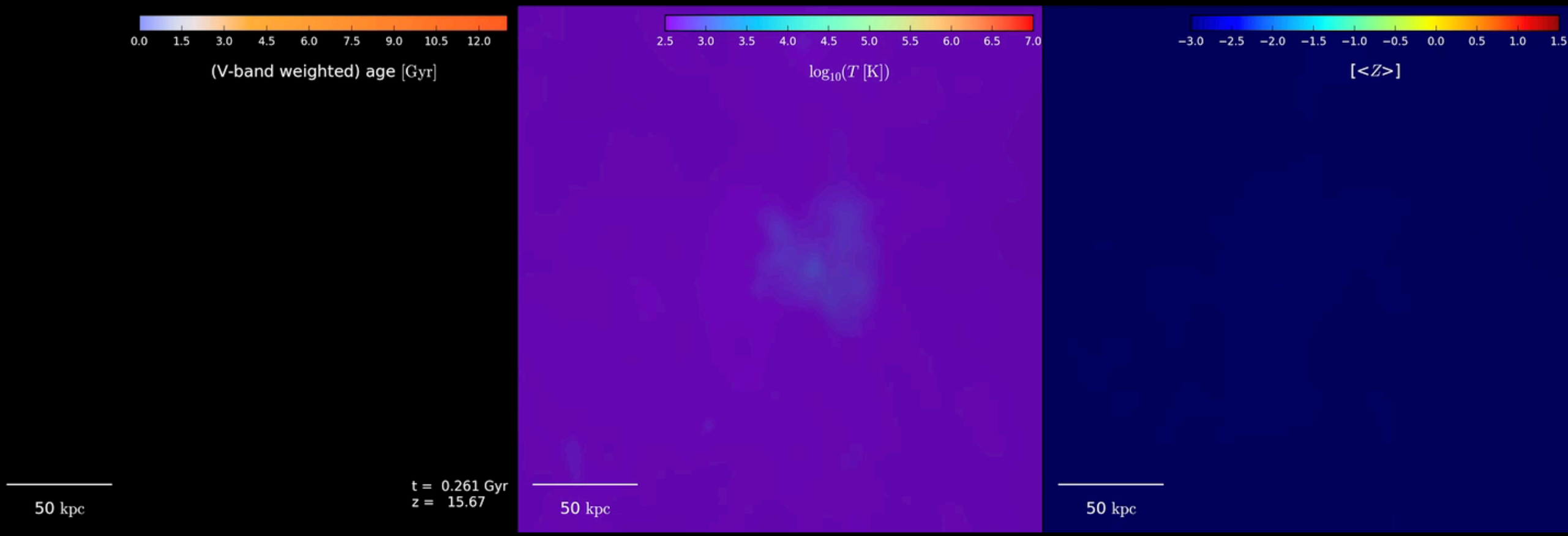
with reasonable SFR and metal enrichment histories

- ✓ *Choi, Ostriker, Naab, Hirschmann+17 — Simulation overview and general galaxy properties: Low X-ray luminosities, low stellar content,…*
- ✓ *Hirschmann, Charlot+17 — Evolution of optical synthetic nebular emission lines*
- ✓ *Brennan,…,Hirschmann+17, subm. — Baryon cycle due to AGN-driven outflows*
- ✓ *Hirschmann, Zibetti, Gallazzi+17, in prep., — Stellar populations*
- ✓ *Frigo, Naab, Hirschmann+17 in prep — Stellar kinematics*
- ✓ *Choi,…,Hirschmann+17, in prep — Size evolution*
- ✓ *Choi,…,Hirschmann+17, in prep — Metal enrichment of the circum-galactic medium*

BH growth & mass, momentum & energy conserving *AGN feedback* *(Ostriker+10, Choi+12/ 13)*

Visualization of a zoom-in sim.

M_{halo} = 1e13 $M_\odot$, $x_{spatial}$ = 200pc, m_{gas}=1.4e5 $M_\odot$



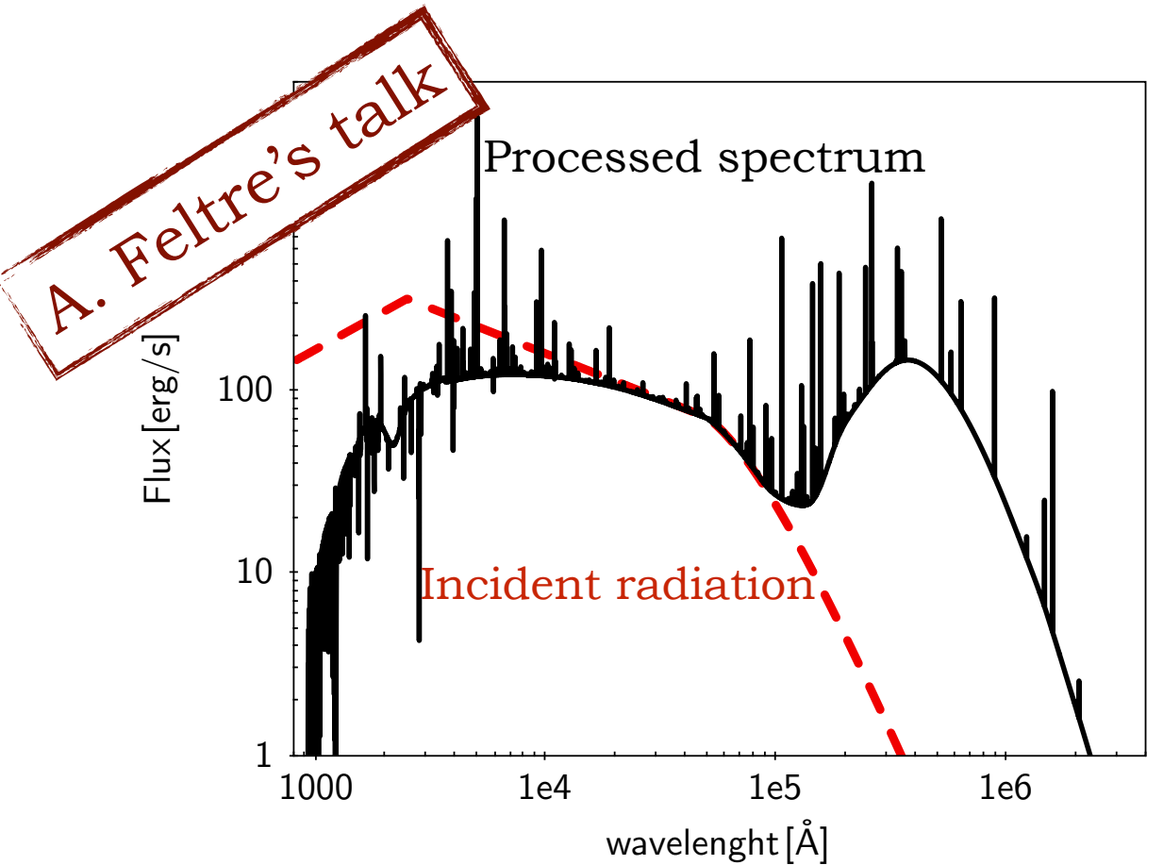
Nebular emission over cosmic time

Cosmic evolution of nebular emission lines of simulated of galaxies

Newly developed spectral evolution models (Cloudy)

Cosmological hydrodynamic simulations

Fixed dust-to-metal mass ratio, fixed $\rho_{ionized}$ ← *Select one of the modelled spectra* → *Z_{gas}, $(C/O)_{gas}$, $<\rho_{gas}>$, SFR, L_{AGN}, M_{PAGB}, Age_{PAGB}*



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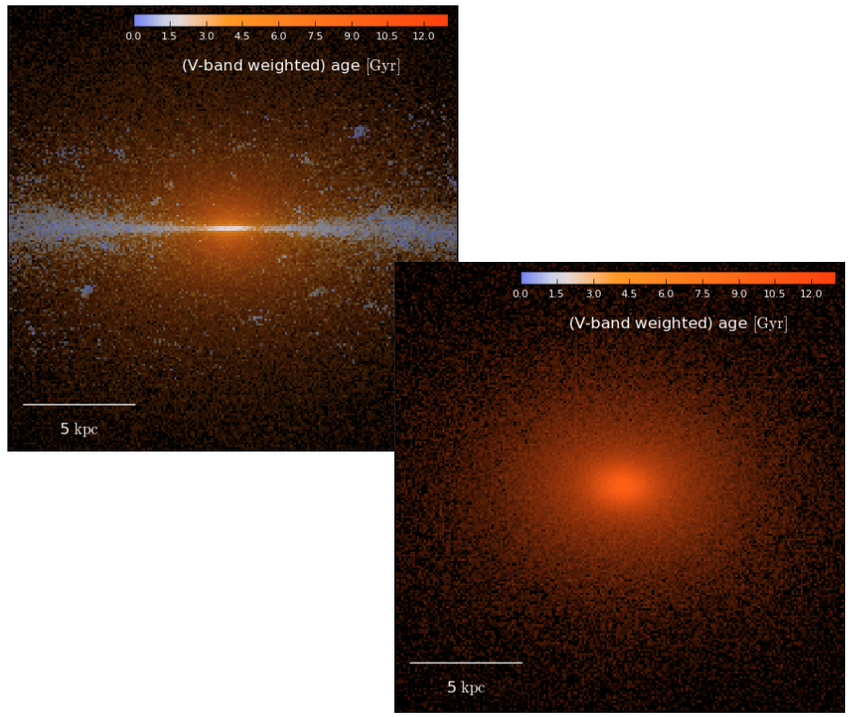


Nebular emission from young stars, AGN and post-AGB stellar populations
(Feltre+16, Gutkin+16, Hirschmann+17)

Sets of zooms of massive halos with and w/o AGN feedback
(Choi+16, Hirschmann+17)

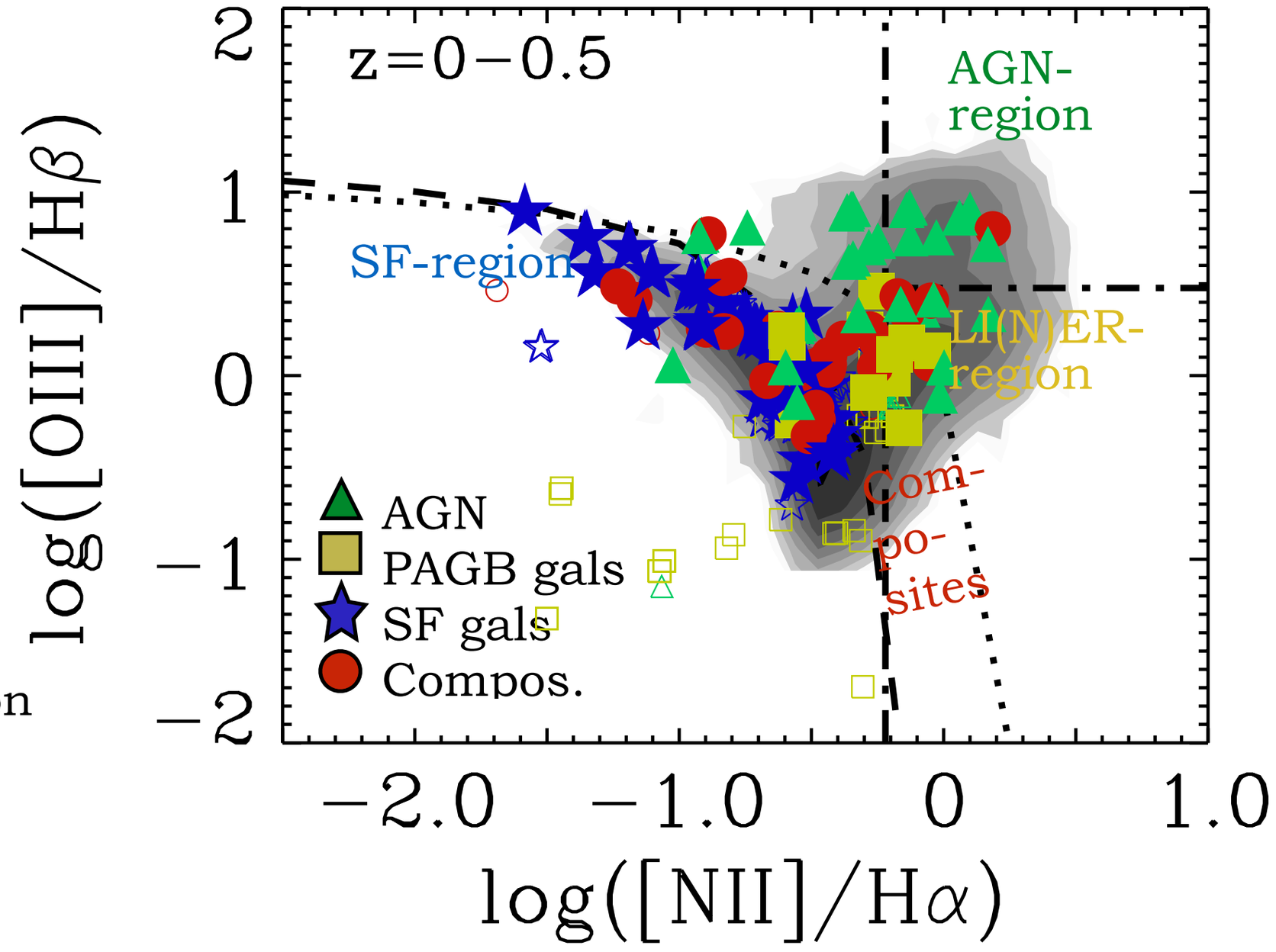
I. Are synthetic emission lines consistent with observations of the local Universe?

Optical line-ratios in local galaxies

Hirschmann+17: arXiv:1706.00010

- Observational flux limits applied
- AGN: log(BHAR/SFR) > -2
- Composites: -4 < log(BHAR/SFR) < -2
- SF: log(BHAR/SFR) < -4

Black lines: observational selection criteria of Kauffmann+03, Kewley+01

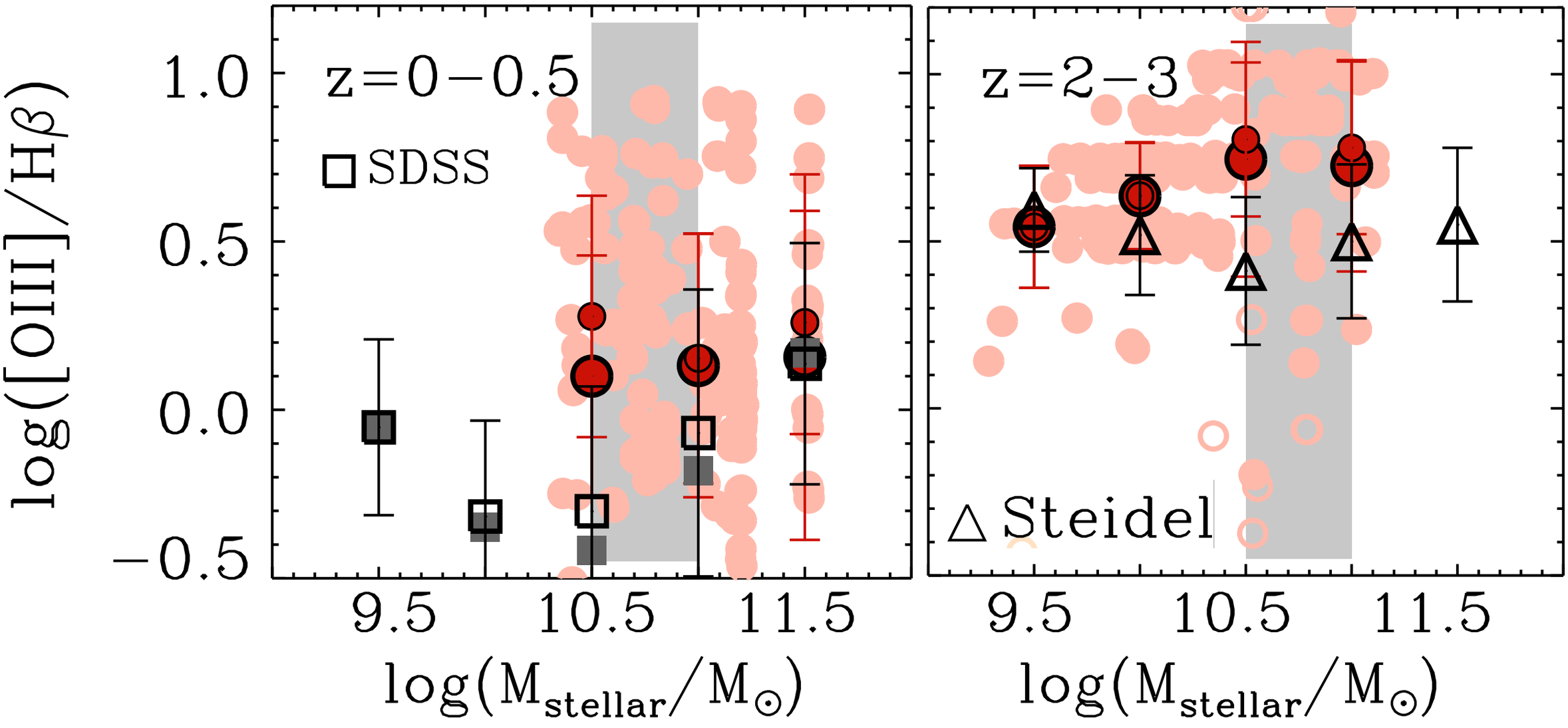


Reasonably reproducing the observed SDSS results
Widely confirming optical selection criteria

II. How do optical emission-line ratios evolve with redshift?

Evolution of optical line-ratios

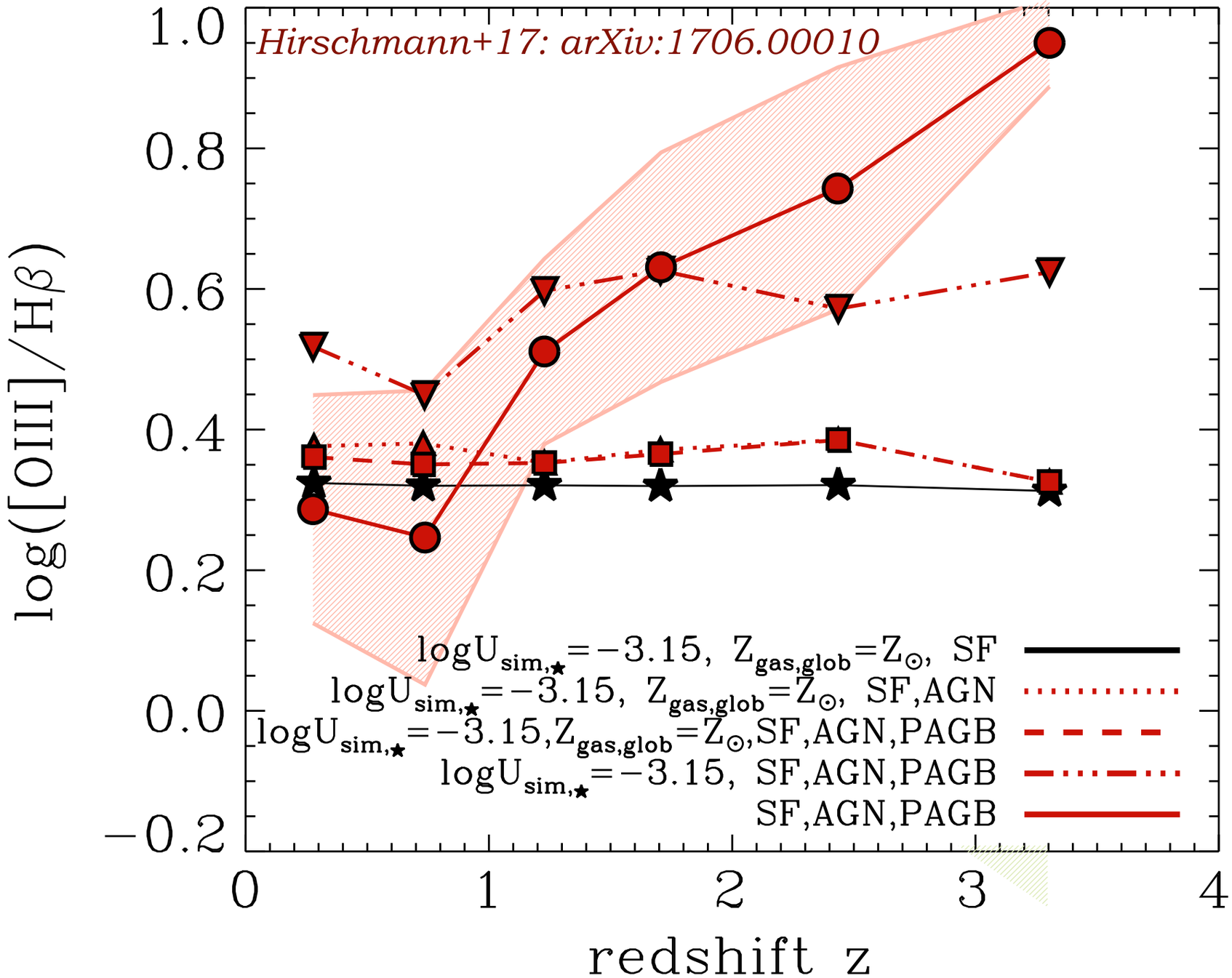
Hirschmann+17: arXiv:1706.00010



- [OIII]/Hβ increases towards z=2-3 at a given stellar mass
- What is the physical origin, extreme ISM conditions ($\rho_{ionized}$, Z_{gas}), SFR, ionisation parameter, AGN, elevated N/O or harder ionising radiation?

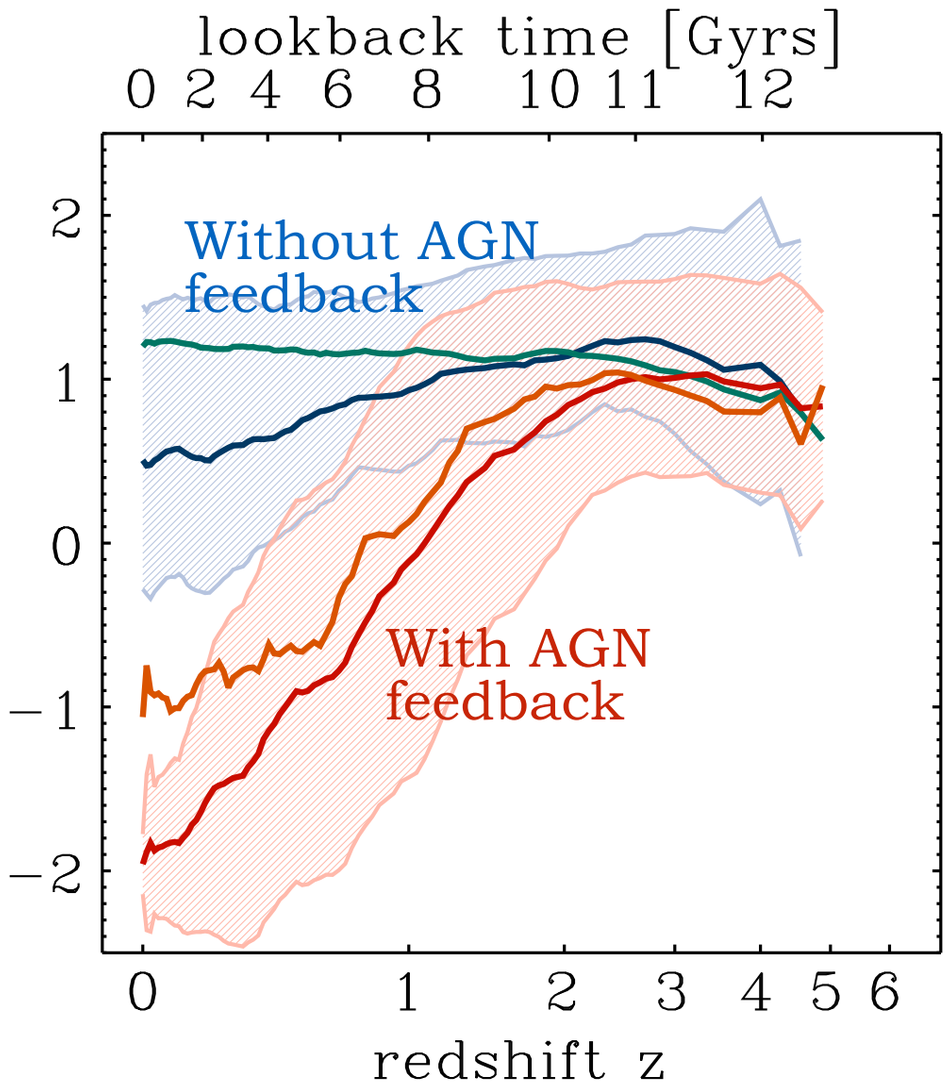
Origin of the evolving [OIII]/Hβ

Progenitors at fixed stellar mass bin $10.5 < \log(M_{\rm stellar}/{\rm M}_\odot) < 11.0$



- Ionisation parameter, governed by SFR, is driving the evolution of [OIII]/Hβ, other parameters (dust-to-metal mass ratio - N/O, $Z_{\rm stars}$, $n_{\rm H}$ have no dominant effect)

Origin of the evolving [OIII]/Hβ



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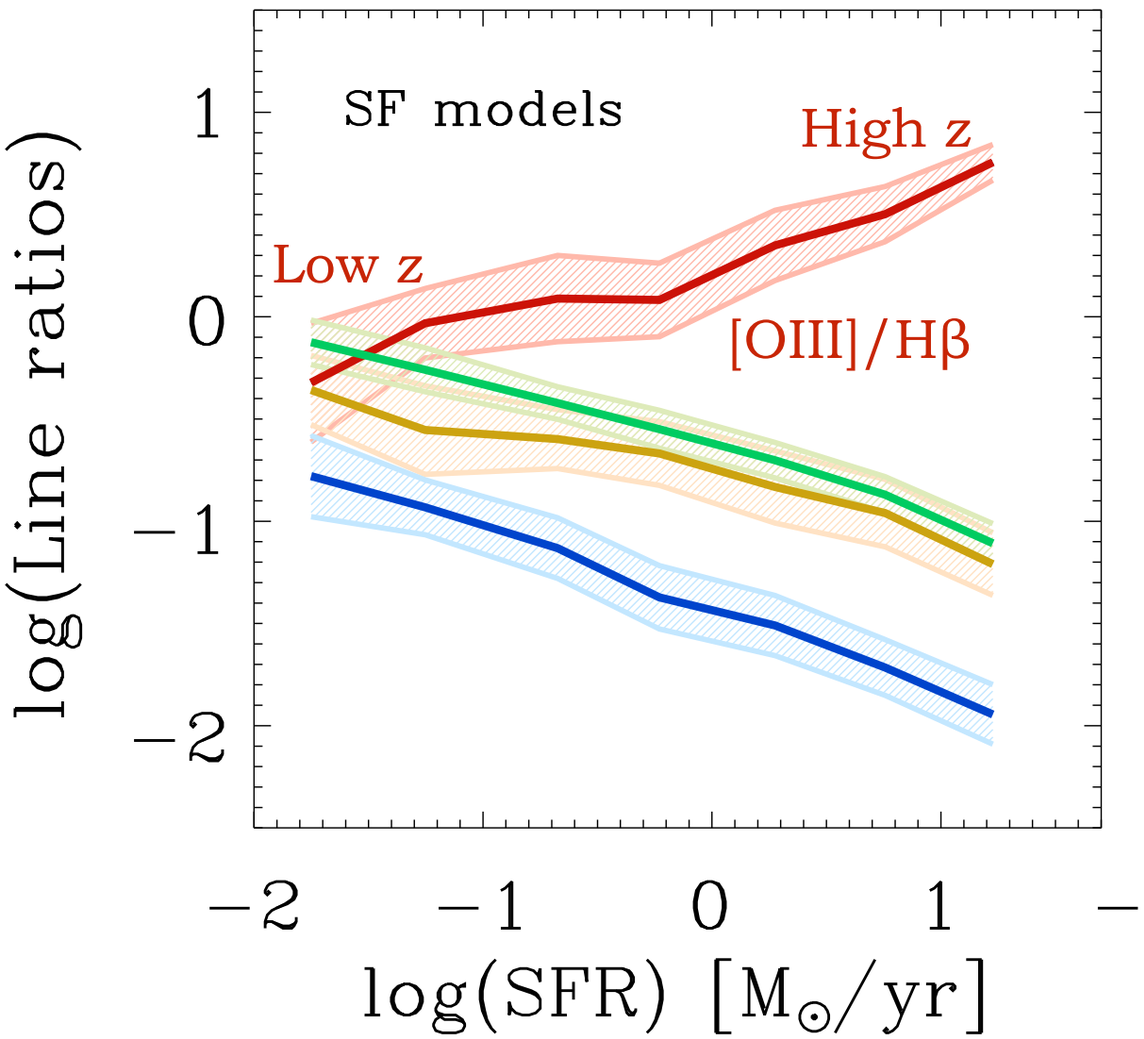
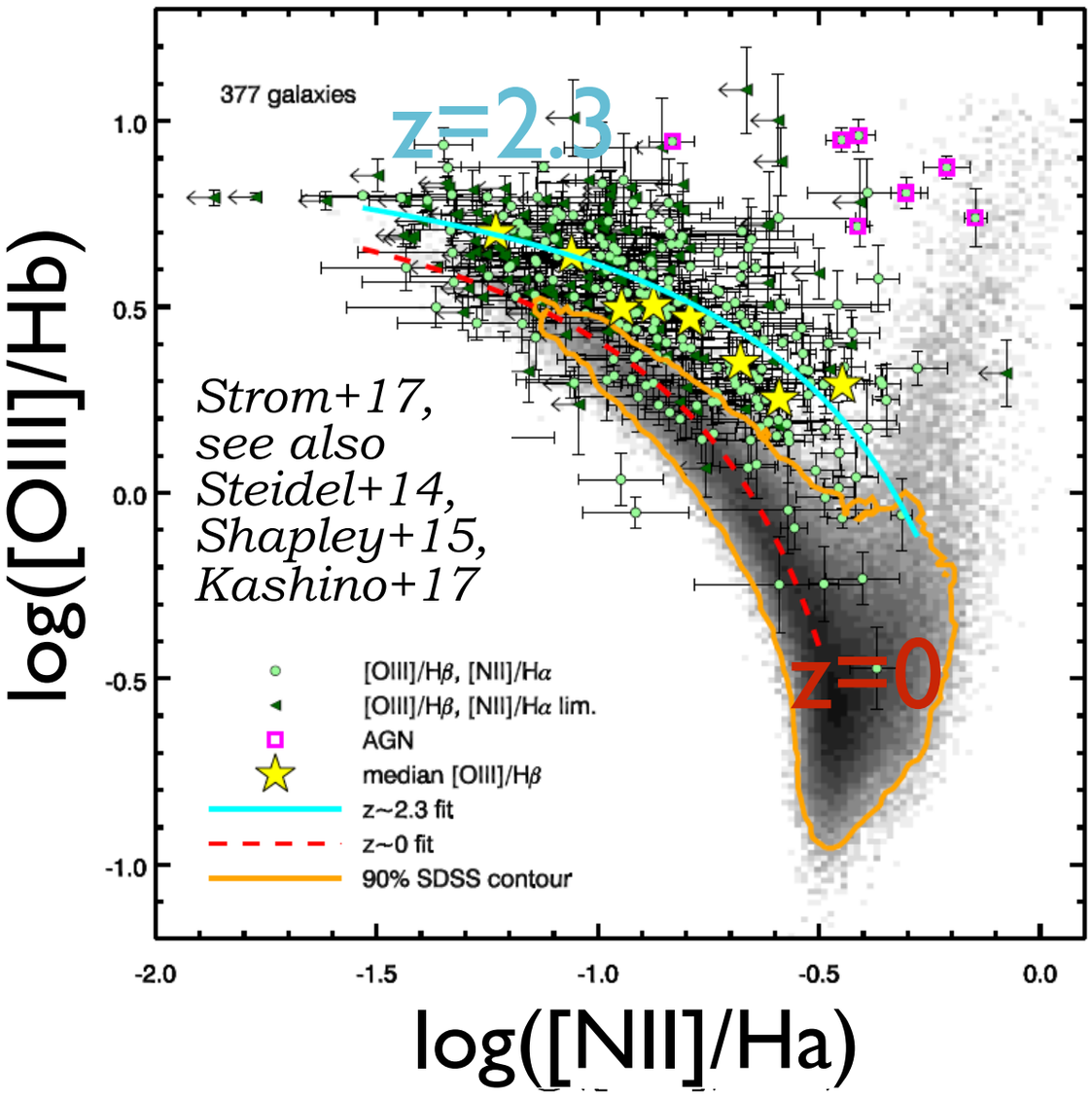


- Why can SFRs lead to an evolution in [OIII]/Hβ *at fixed stellar mass?*
- [OIII]/Hβ is increasing with increasing SFR
- AGN-driven winds cause a strong decrease in SFR, and thus, the decrease of [OIII]/Hβ

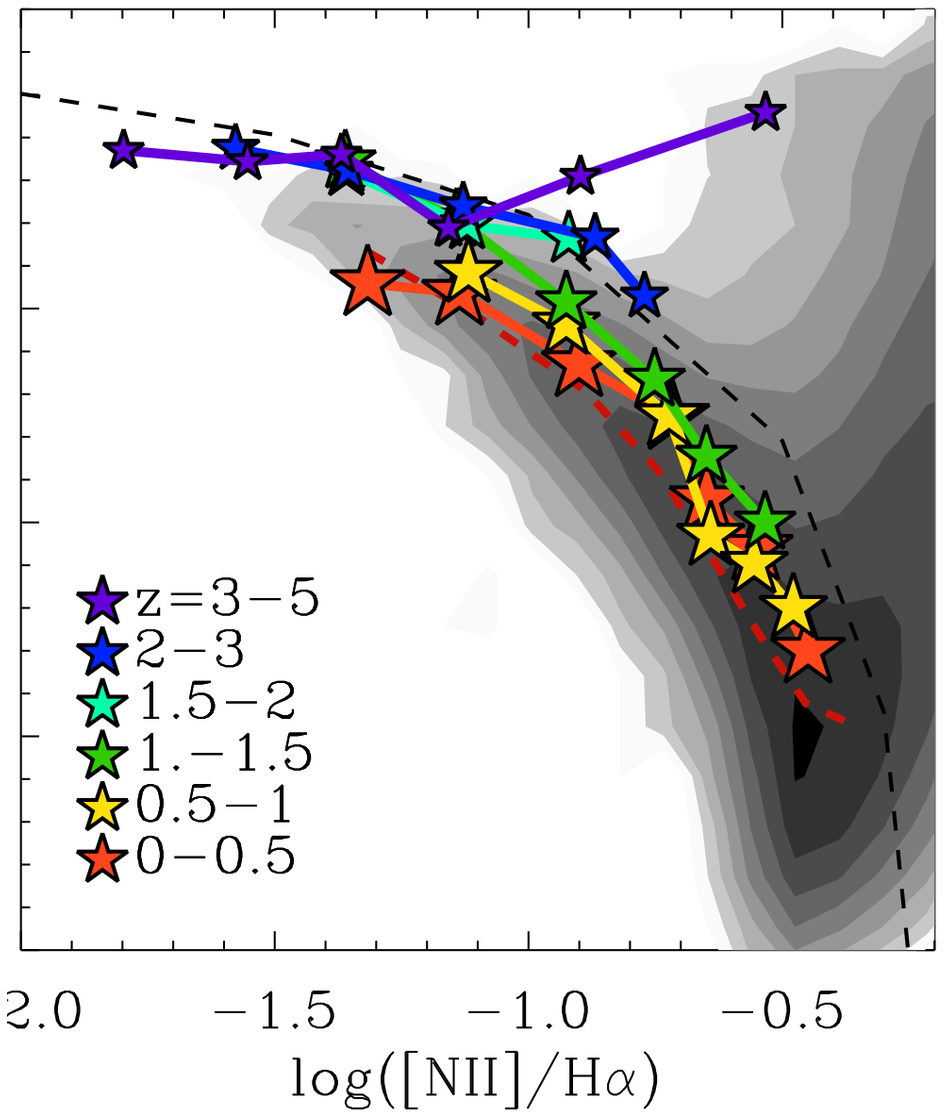
Evolution of the SF branch

Focus on SF-dominated galaxies with log(BHAR/SFR) < -4

Observations



With AGN fb



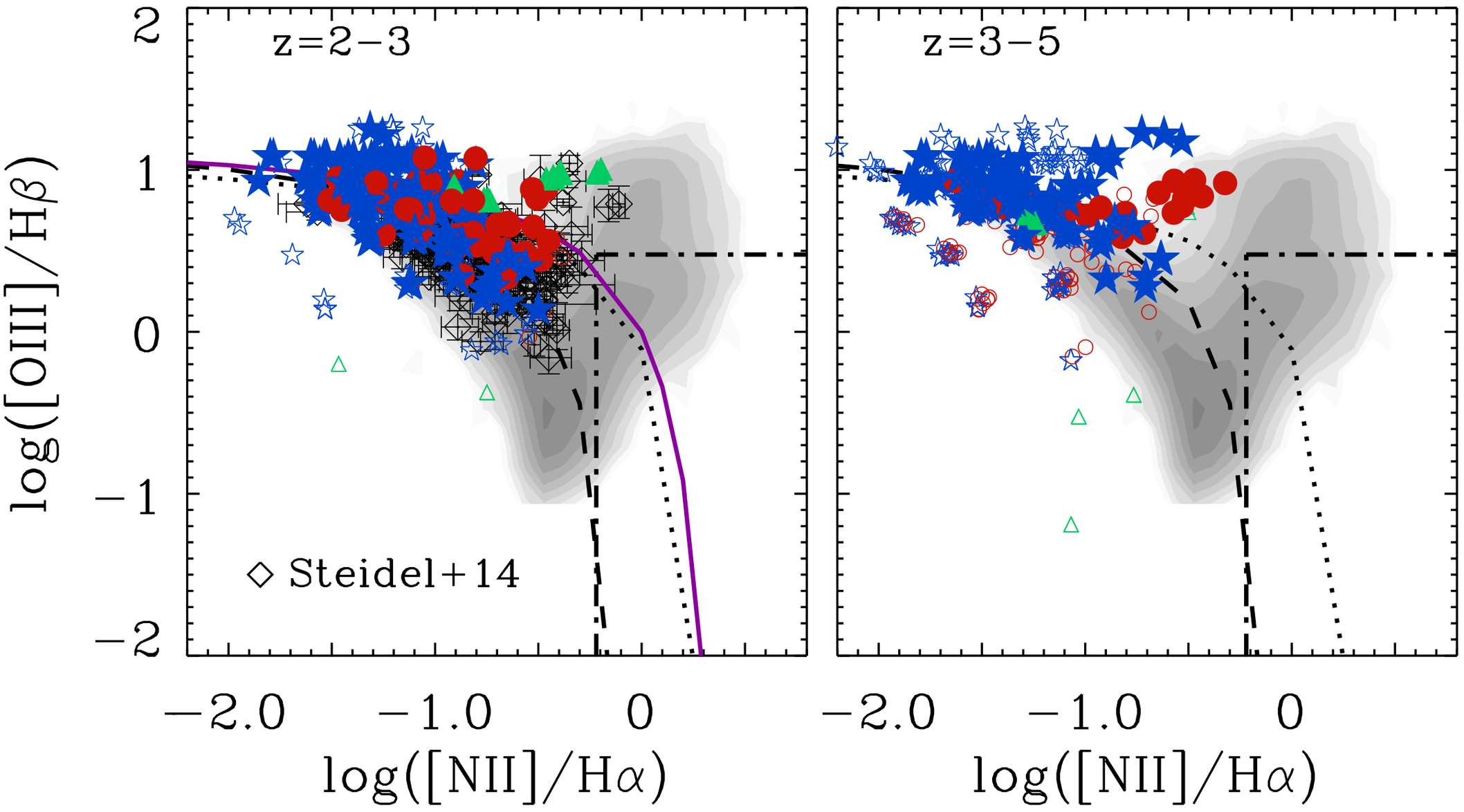
Hirschmann+17: arXiv:1706.00010

- Evolving [OIII]/Hβ ratios are consistent with observed trends
- Offset in [OIII]/Hβ is observational signature for AGN fb?!

III. How to best distinguish ionising sources in high-z galaxies?

Optical line-ratios of distant galaxies

Hirschmann+17, in prep.



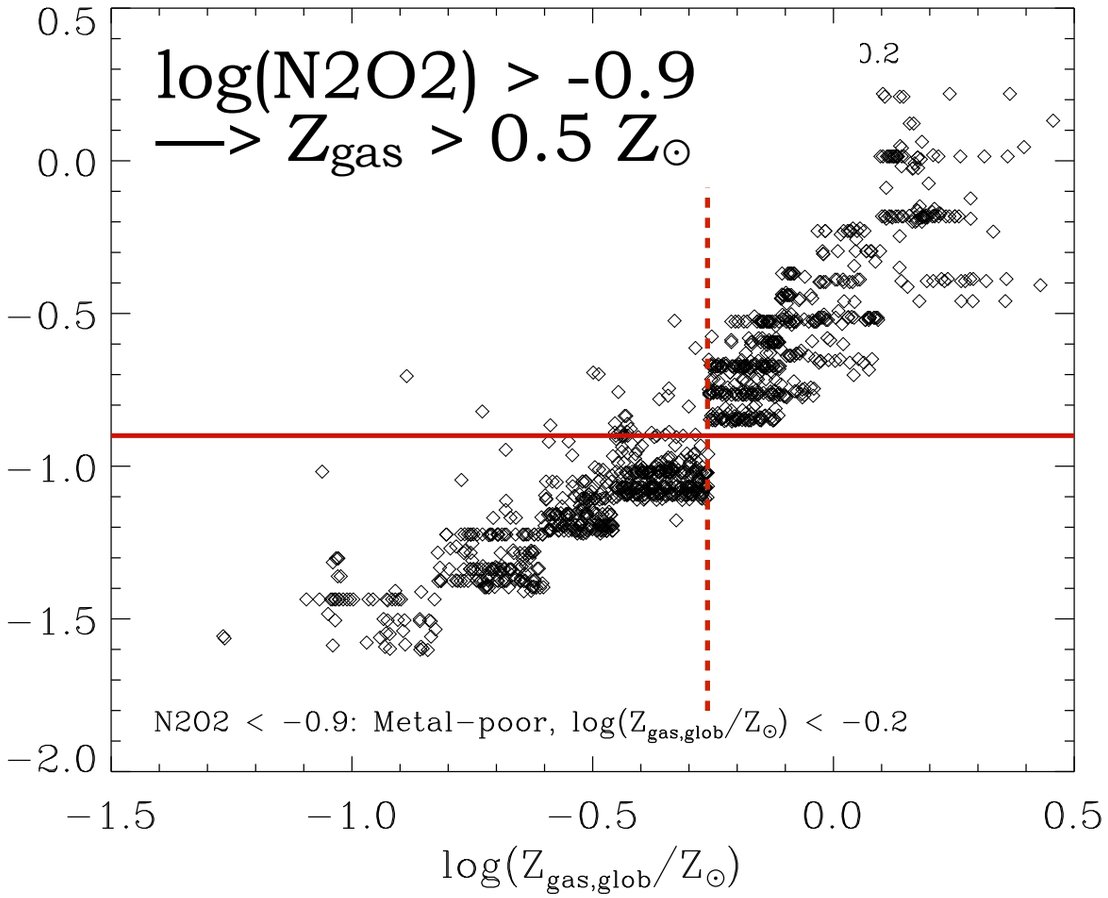
Toward high z, different galaxy types tend to occupy the same region

➡ *Optical selection criteria break down*

➡ Due to more metal-poor galaxies at high z *(Gutkin+16, Feltre+16, see also Kewley+13)*

Optical line-ratios of metal-rich galaxies

log([NII]/[OII]) scales tightly with Z_{gas}

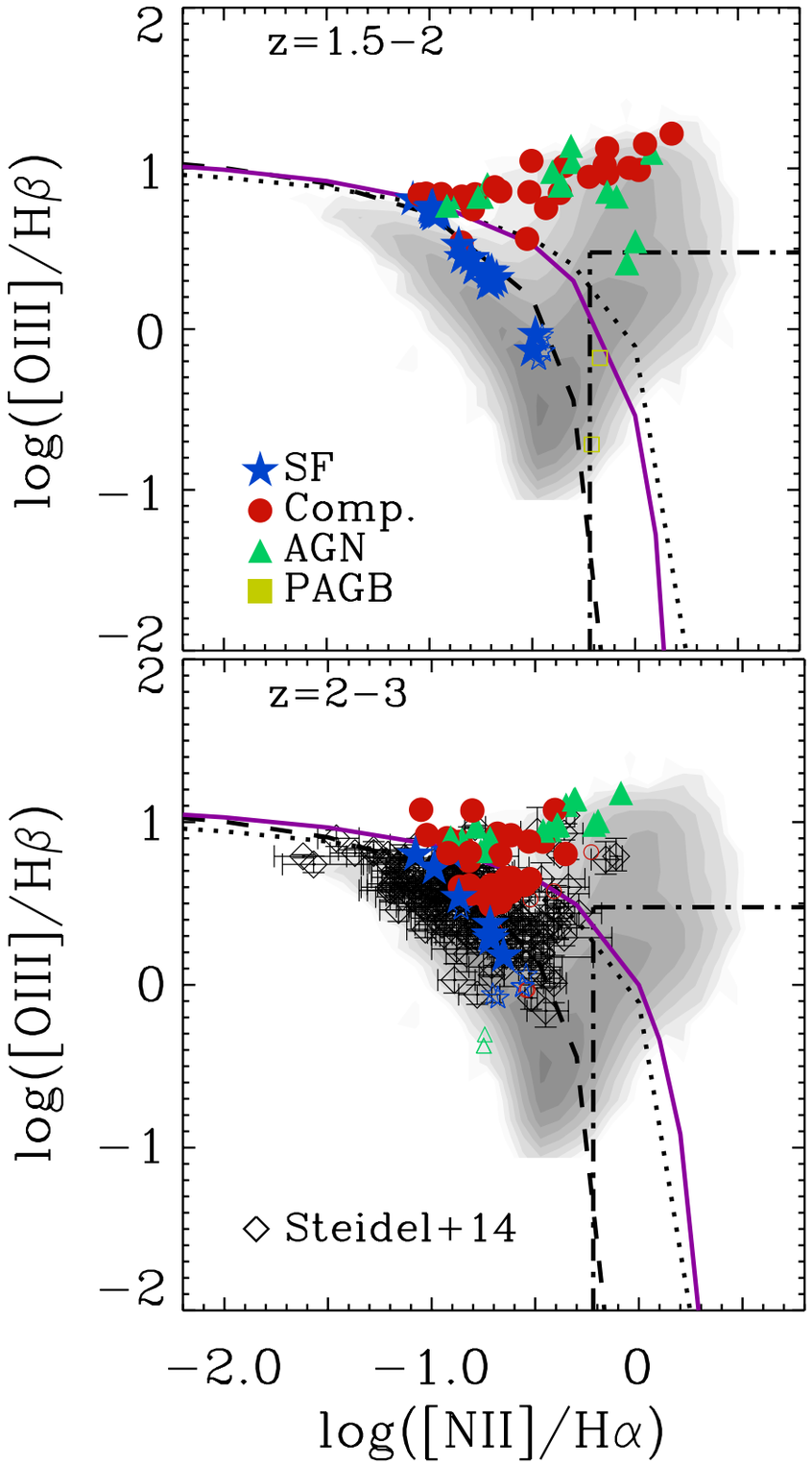


Hirschmann+17, in prep.

➡ *For metal-rich galaxies "modified" optical selection criteria reasonable also at higher z*

What about metal-poor galaxies, particularly at high redshifts?

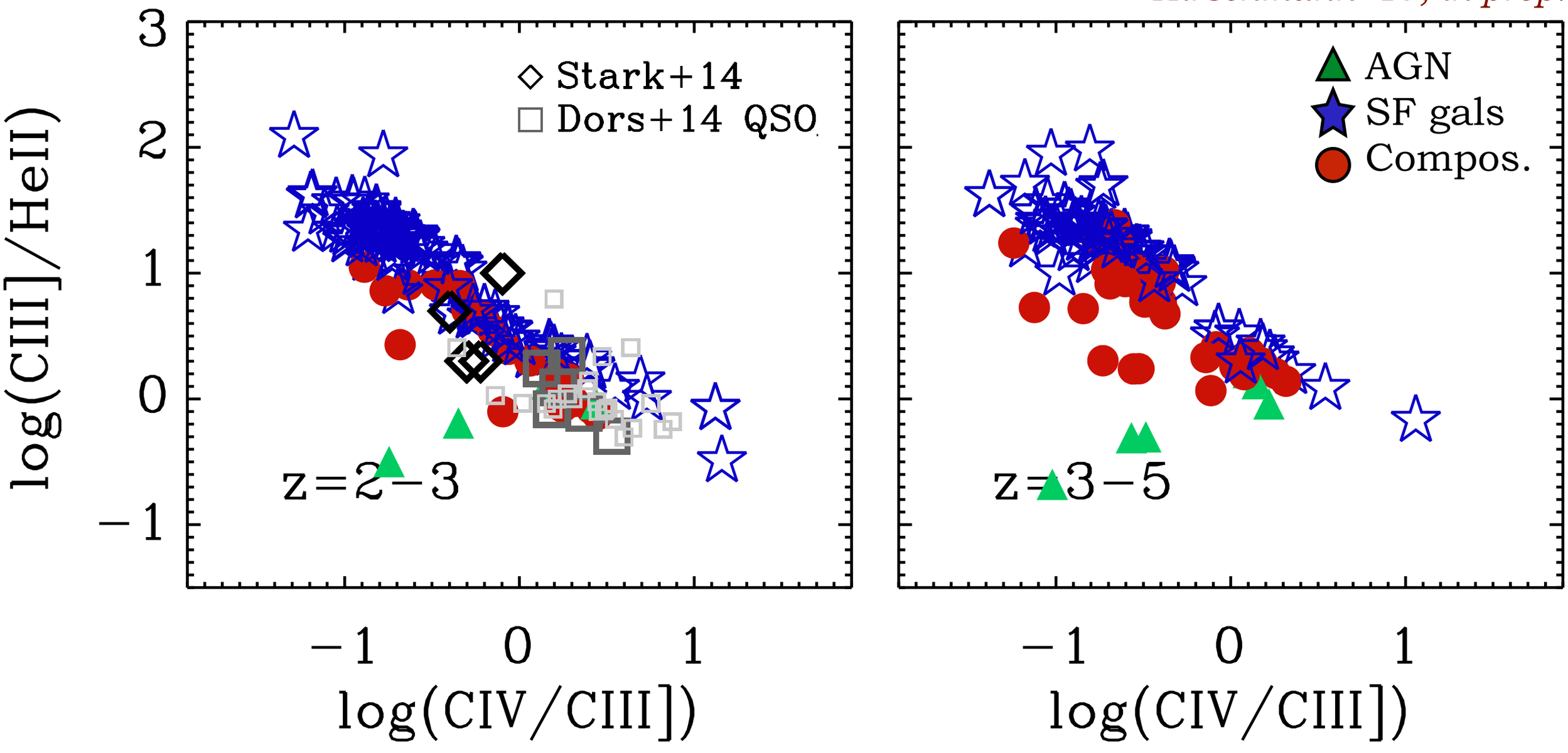
Select metal-rich galaxies with log([NII]/[OII]) > -0.9:



UV line-ratios of distant galaxies

Galaxies of ALL metallicities in a given redshift interval

Hirschmann+17, in prep.

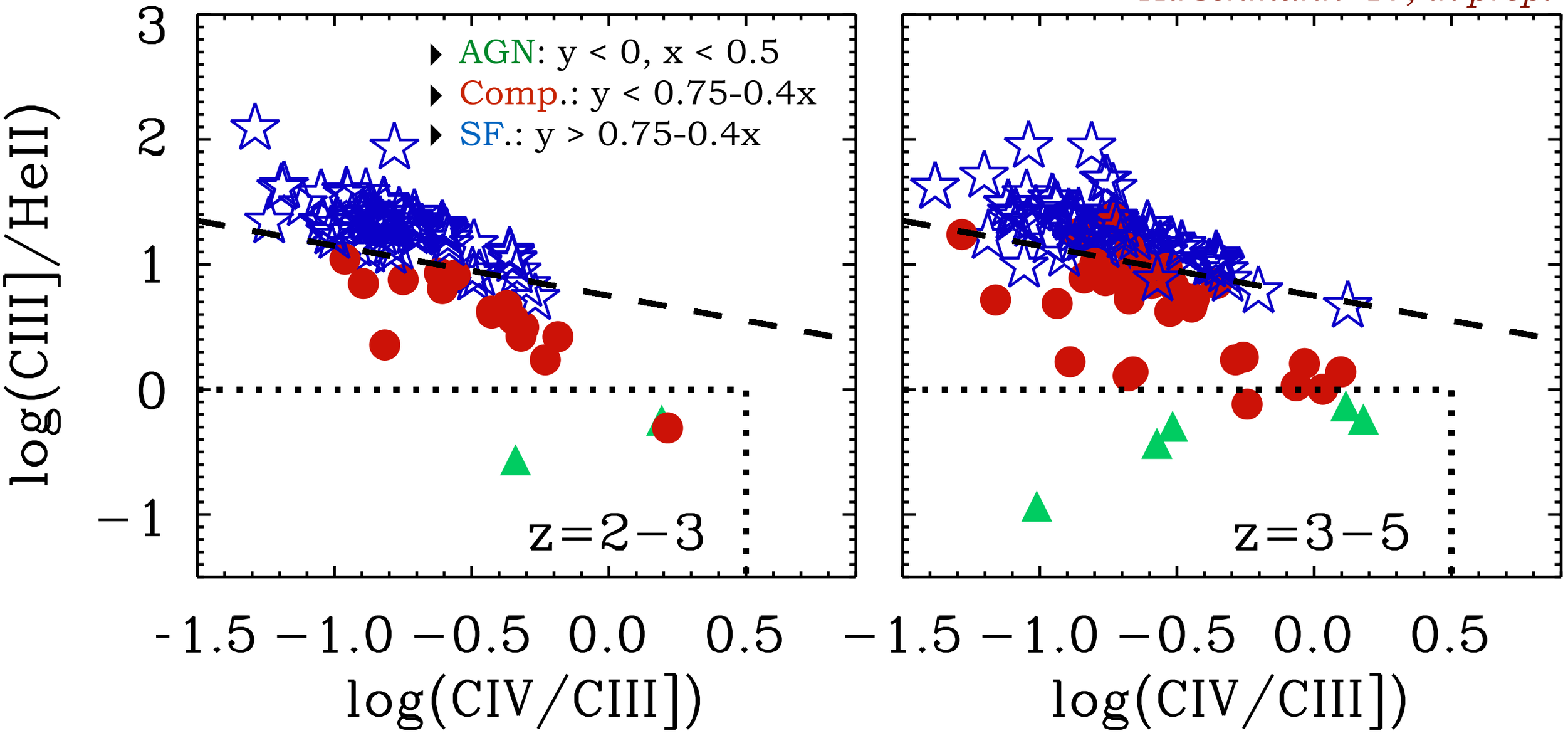


- Consistent with sparse observations, but no good distinction of galaxy types

UV line-ratios of metal-poor gal's

Select metal-poor galaxies with log([NII]/[OII]) < -0.9:

Hirschmann+17, in prep.



- For metal-poor gals, UV diagnostics can provide reasonable selection criteria for different galaxy types, at least out to z~5

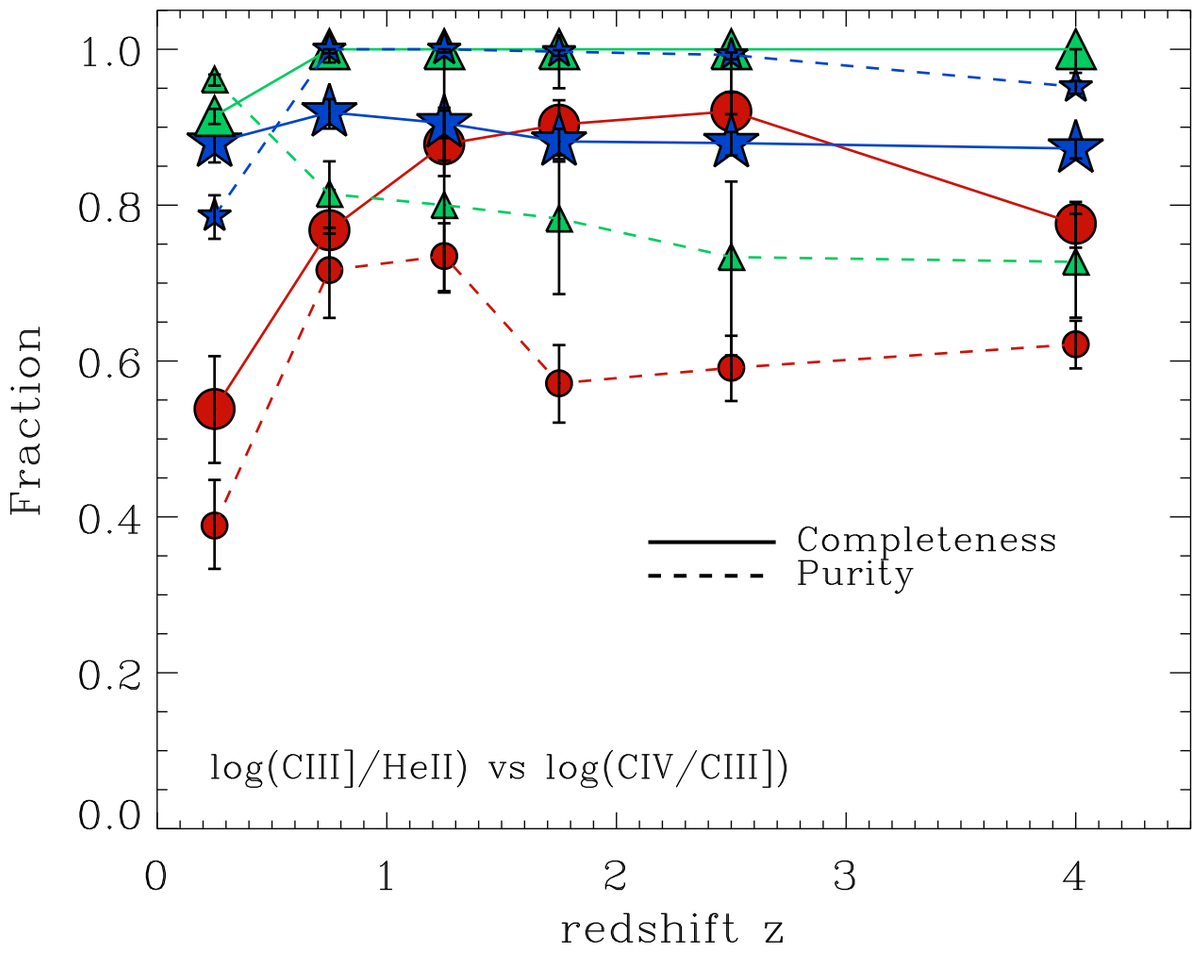
Completeness and purity

…for UV selection criteria for galaxies with log([NII]/[OII]) < -0.9

Completeness: based on the theoretical galaxy type definition, fraction of galaxies which would be identified as the same type with UV criteria

Purity: vice versa

CIII]/HeII vs CIV/CIII]:



- High purity and completeness fractions
- Similarly good diagnostics:
  - CIII]/HeII vs OIII/HeII
  - CIII]/HeII vs SiIII/HeII,
  - CIII]/HeII vs (CIII]+CIV)/HeII or
  - CIII]/HeII vs NIII/HeII

Hirschmann+17, in prep.

Summary

COSMIC EVOLUTION OF SYNTHETIC NEBULAR EMISSION:
Nebular emission models + Cosmological simulations

- Synthetic line-ratios consistent with observations in the local and distant Universe (optical+UV)

PHYSICAL ORIGIN OF EVOLVING OPTICAL LINE-RATIO [OIII]/ Hβ:

- Decreasing SFR towards z=0 (due to AGN feedback)
- Observational signature for AGN feedback in massive galaxies

DIAGNOSTICS TO DISTTINGUISH GALAXY TYPES AT HIGH Z:

- Metal-rich galaxies: optical selection criteria as traditionally used
- *Metal-poor galaxies: UV diagnostic diagrams out to z~6*
- *UV selection criteria can be helpful for the interpretation of large samples of high-quality high-z data from future facilities, e.g. NIRSpec on board JWST…*

FUTURE

- Adding shocks
- Adding absorption line models from Alba (Vidal-Garcia+17)
- Spatially resolved emission/absorption line maps, gradients etc. confronting with current and future IFU data