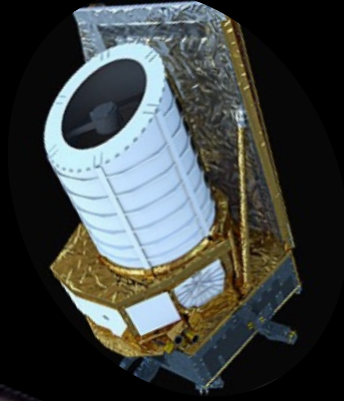# Optical Emission-Line Predictions for the Euclid Wide and Deep Surveys Using Galaxy Populations in GAEA

Lucie Scharré, Michaela Hirschmann, Gabriella de Lucia
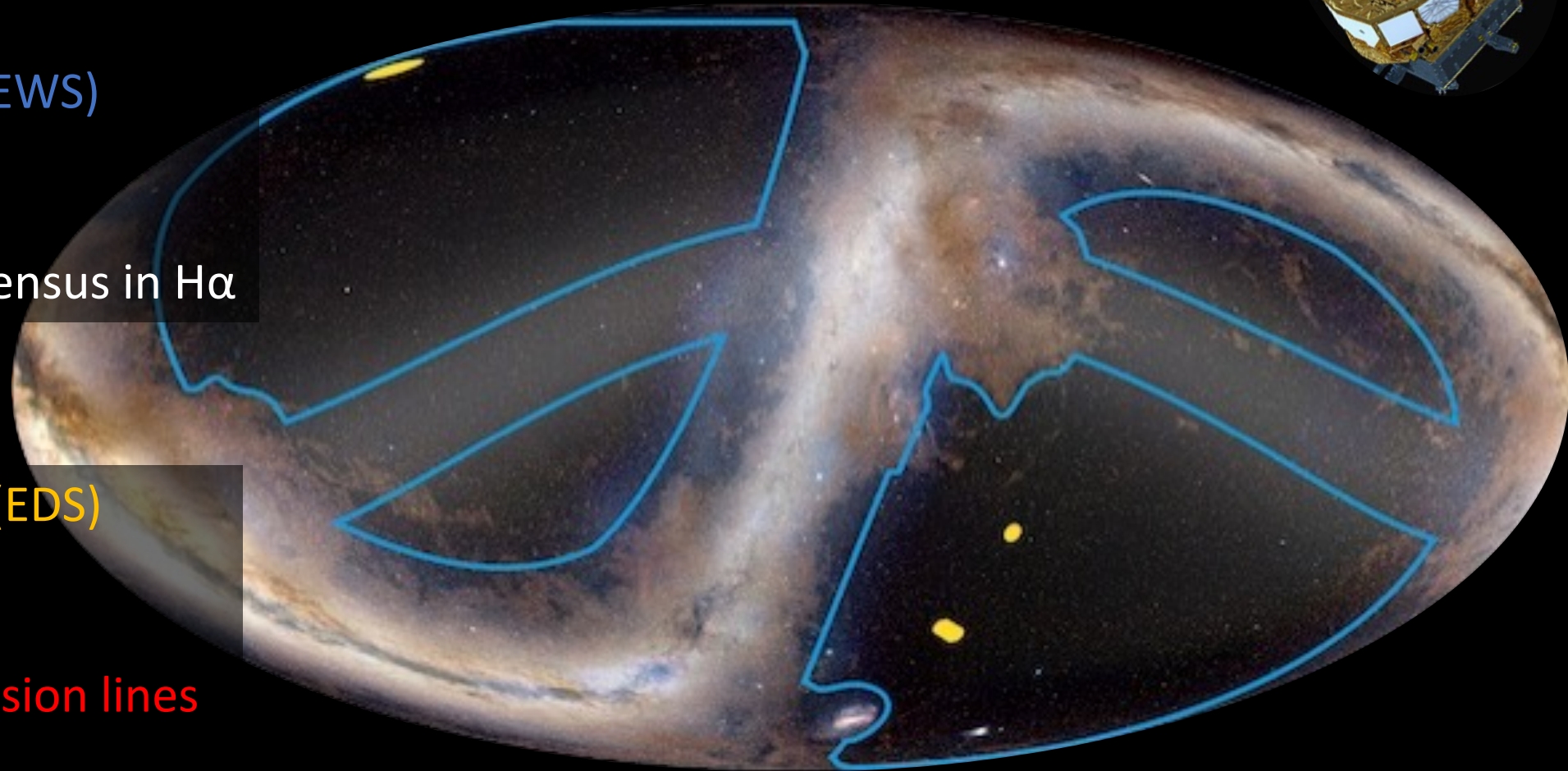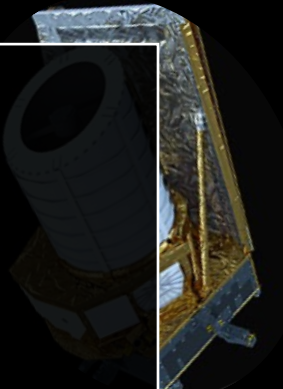
The Euclid Wide and Deep Surveys

Wide Survey (EWS)

- 15 000deg^2
- Mag < 24
- Primiarily census in Hα

Deep Survey (EDS)

- 50 deg^2
- Mag < 26
- Many emission lines

Hundreds of millions of spectra out to z ~ 2.5!

- Very interesting for galaxy evolution

- Optical ELs: Hα, Hβ, [NII]λ4584, [OIII]λ5007,…

$\Rightarrow$ Spectroscopic diagnostics

Spectroscopic Diagnostics

Most are only calibrated for the local Universe

$\Longrightarrow$ Unclear if they can be extended to $z > 0$

BPT diagrams

e.g. **Harikane et al. (2023),** Hirschmann et al. (2019, 2022)

Metallicity calibrations to EL ratios

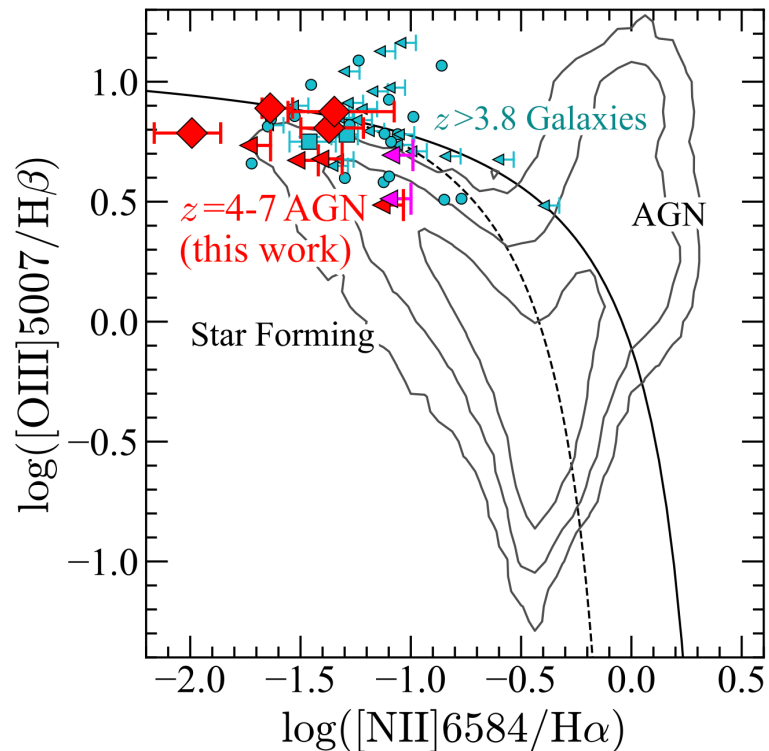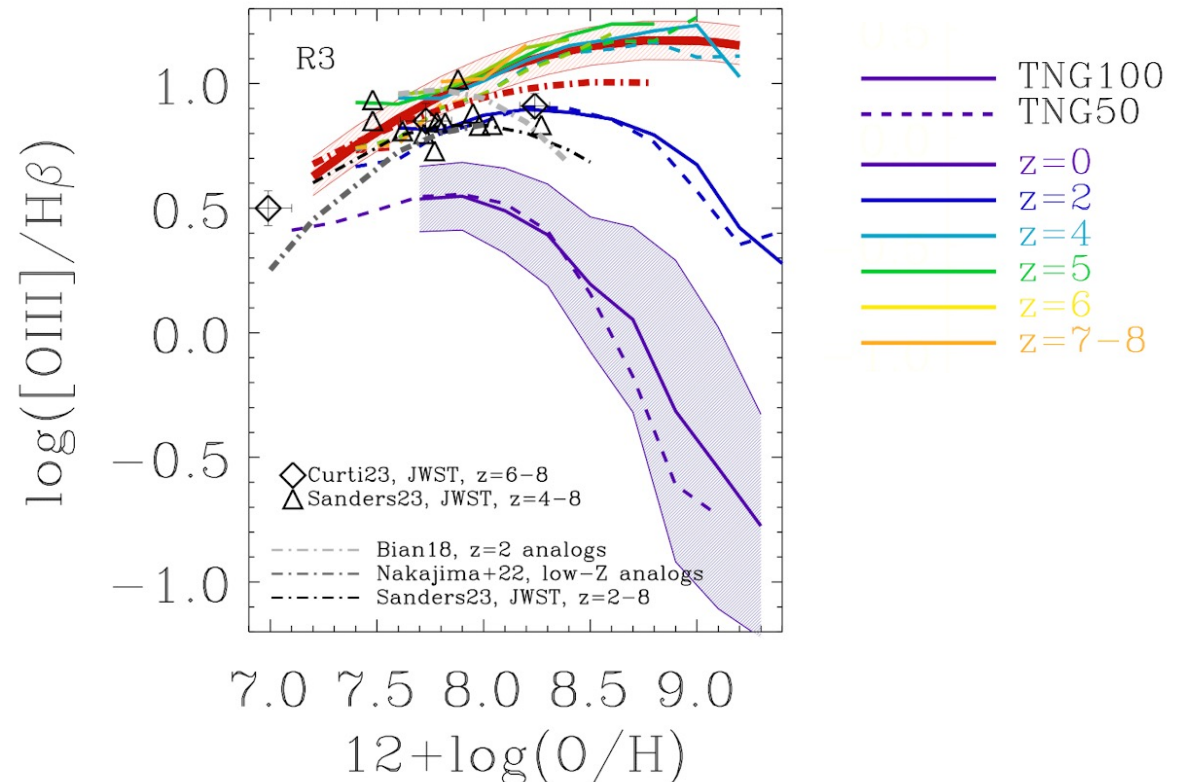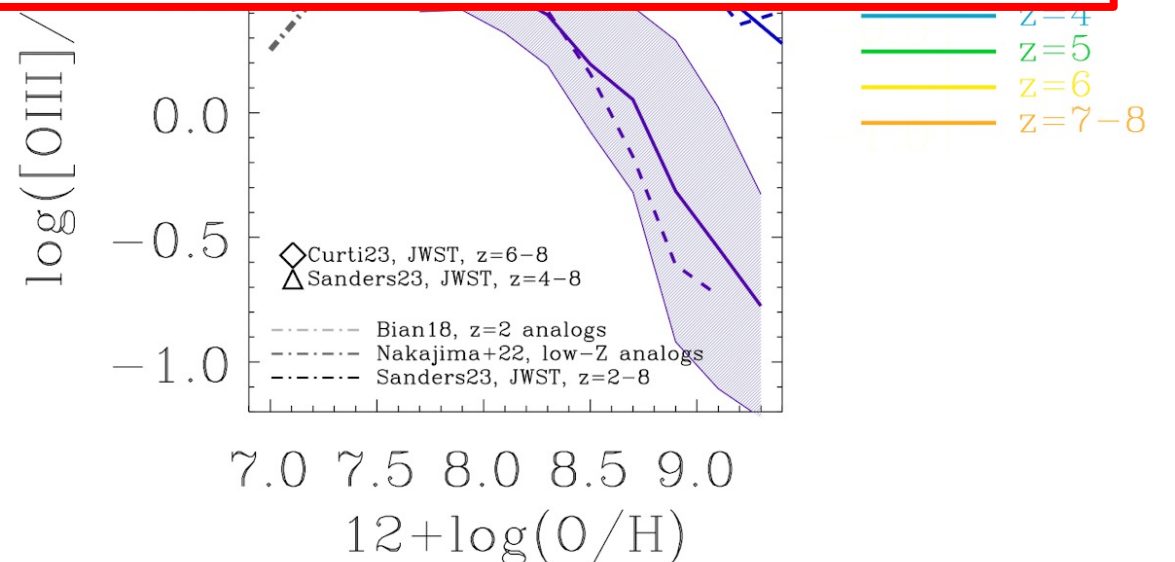e.g. Curti et al. (2022). Sanders et al. (2023). **Hirschmann et al. (2023)**

Spectroscopic Diagnostics
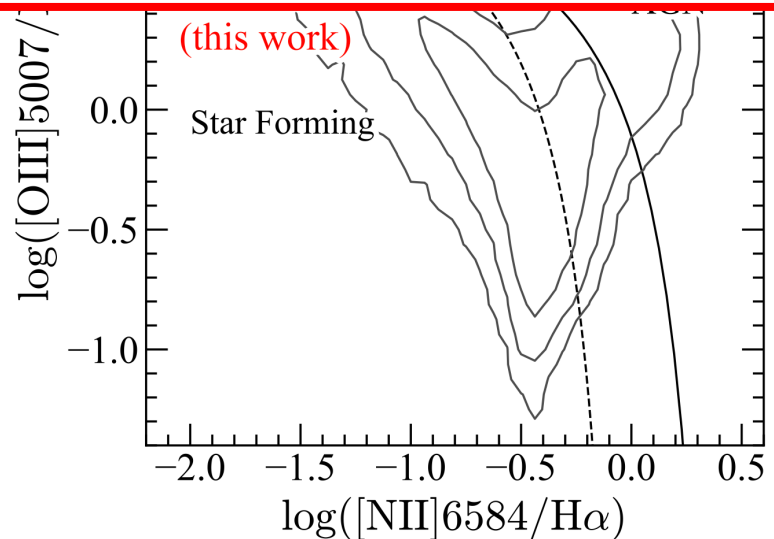
Most are only calibrated for the local Universe

$\Rightarrow$ Unclear if they can be extended to $z > 0$

$\Rightarrow$ Need theoretical guidance to ensure spectral diagnostics can be used to characterise galaxies observed by Euclid!

Theoretical Framework

Euclid-like light cone from GAEA

+

1D CLOUDY photoionisation models

- Young stars (Gutkin et al. 2016)

- AGN (Feltre et al. 2016)

- PAGB stars (Hirschmann et al. 2017)

$\Rightarrow$ Self-consistent prediction of emission lines

Zoldan et al. (2015)
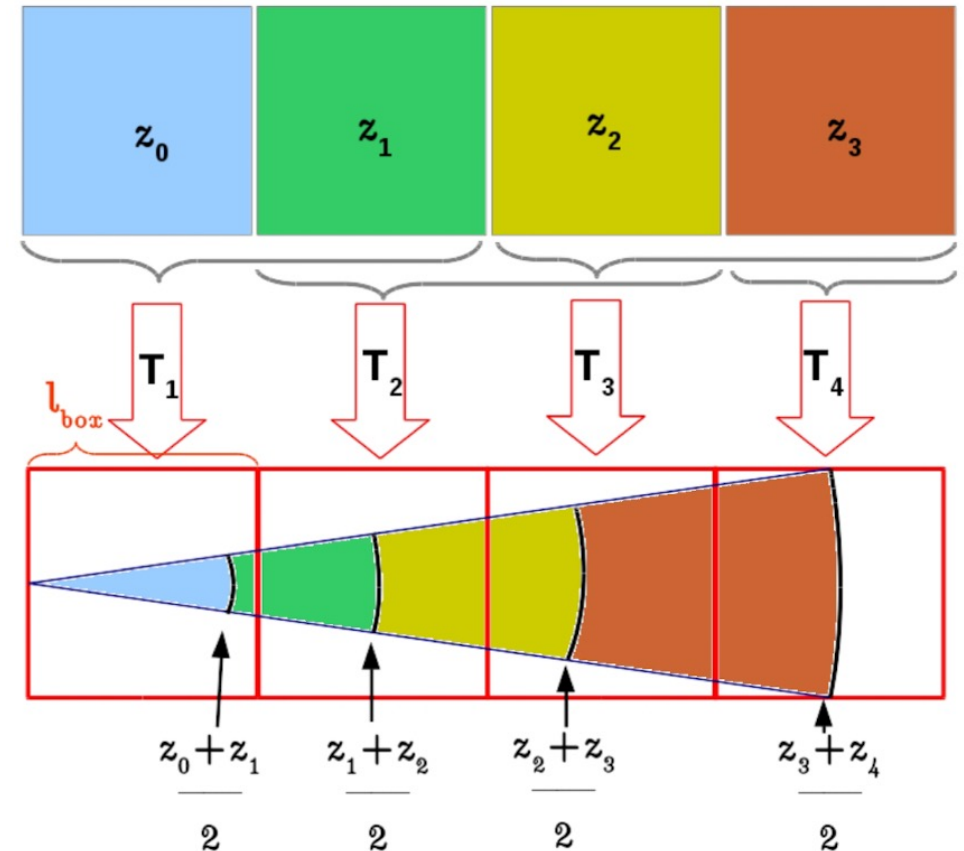
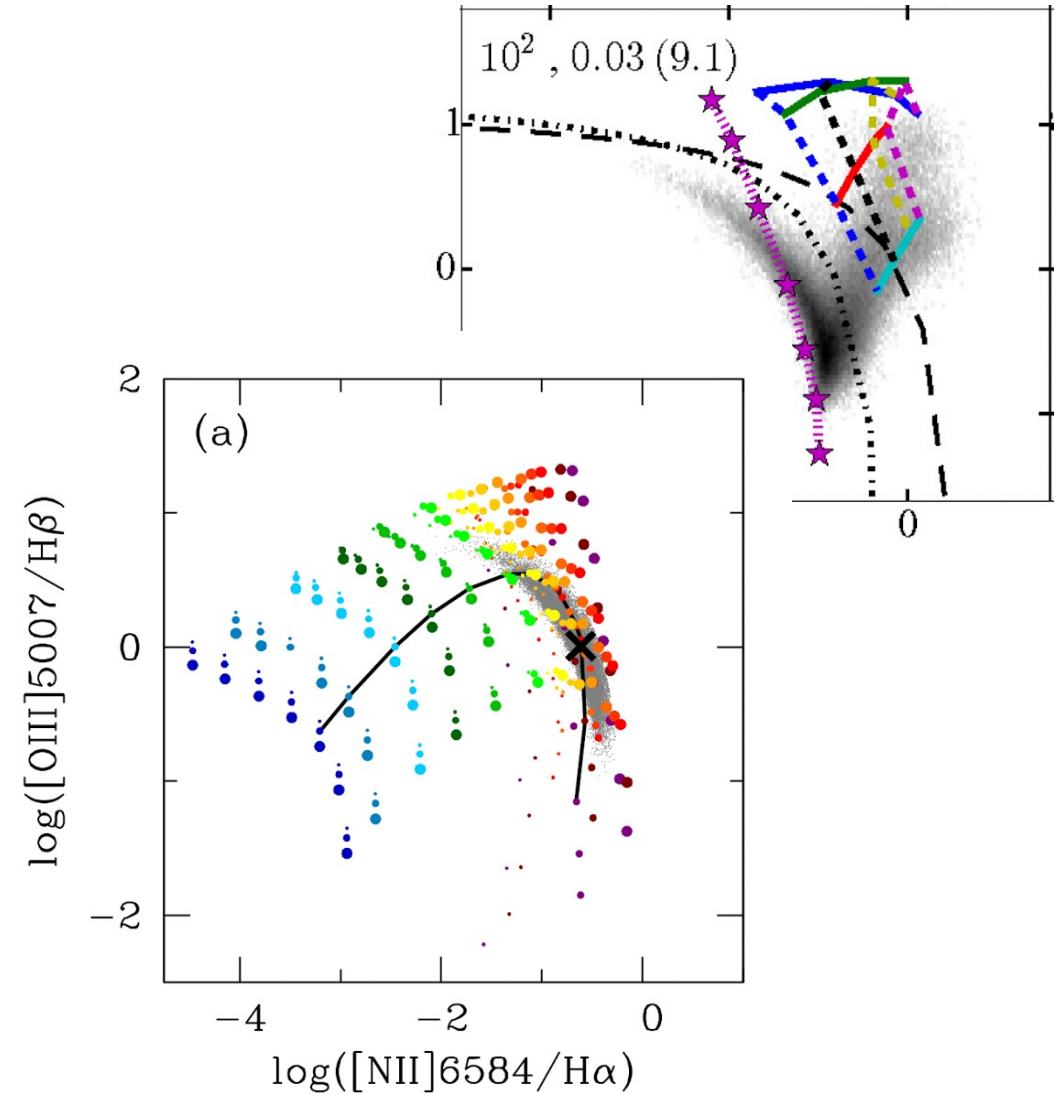# Theoretical Framework

Euclid-like light cone from GAEA

+

1D CLOUDY photoionisation models

- Young stars (Gutkin et al. 2016)

- AGN (Feltre et al. 2016)

- PAGB stars (Hirschmann et al. 2017)

⇒ Self-consistent prediction of emission lines

Key Questions

1. *How are galaxy populations biased when requiring the detectability of emission lines with Euclid?*

2. *Can optical BPT diagrams distinguish between dominant ionising sources in the EDS-observable sample?*

3. *Which EL calibrations can characterise galaxies at intermediate redshifts?*
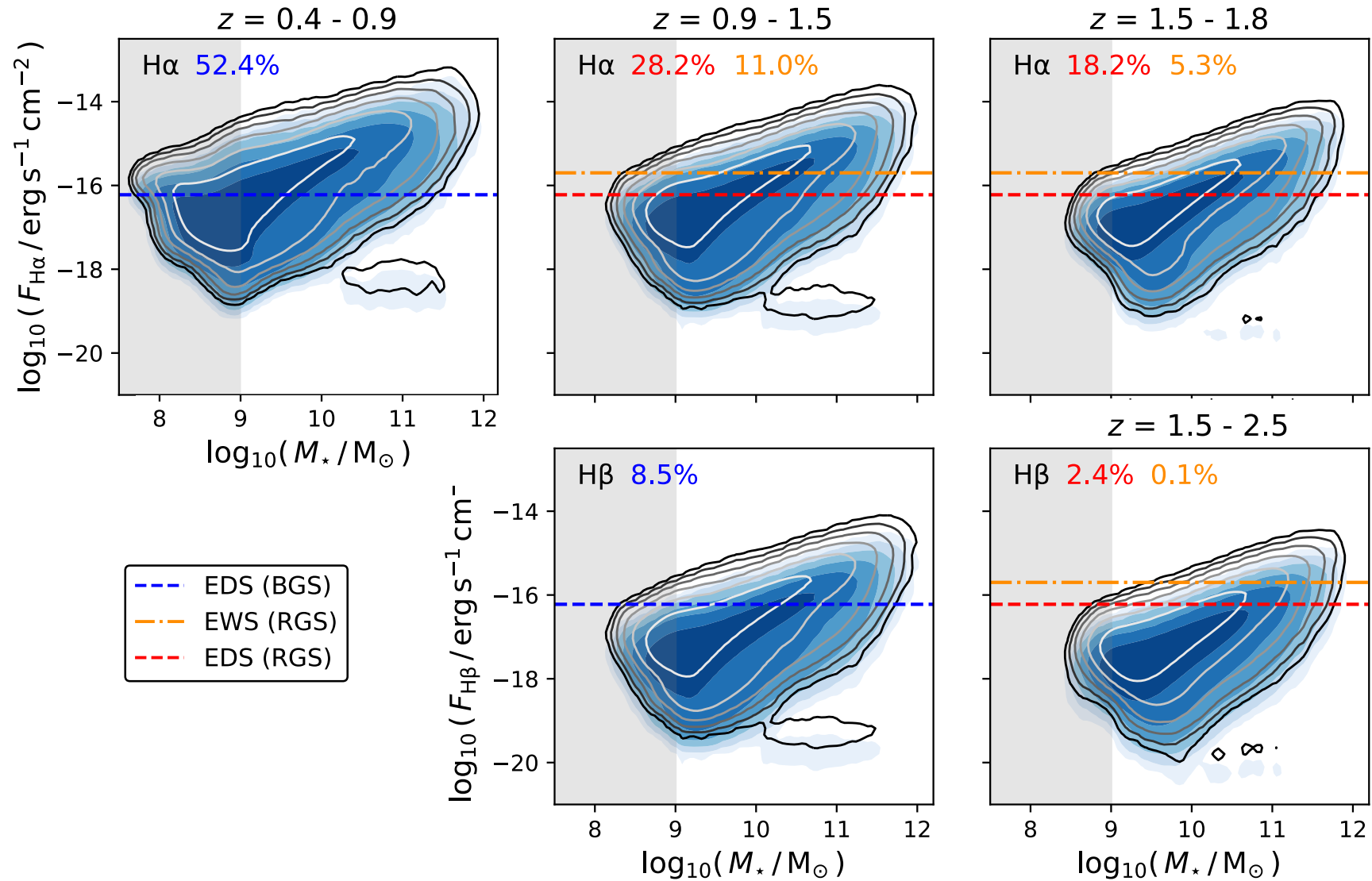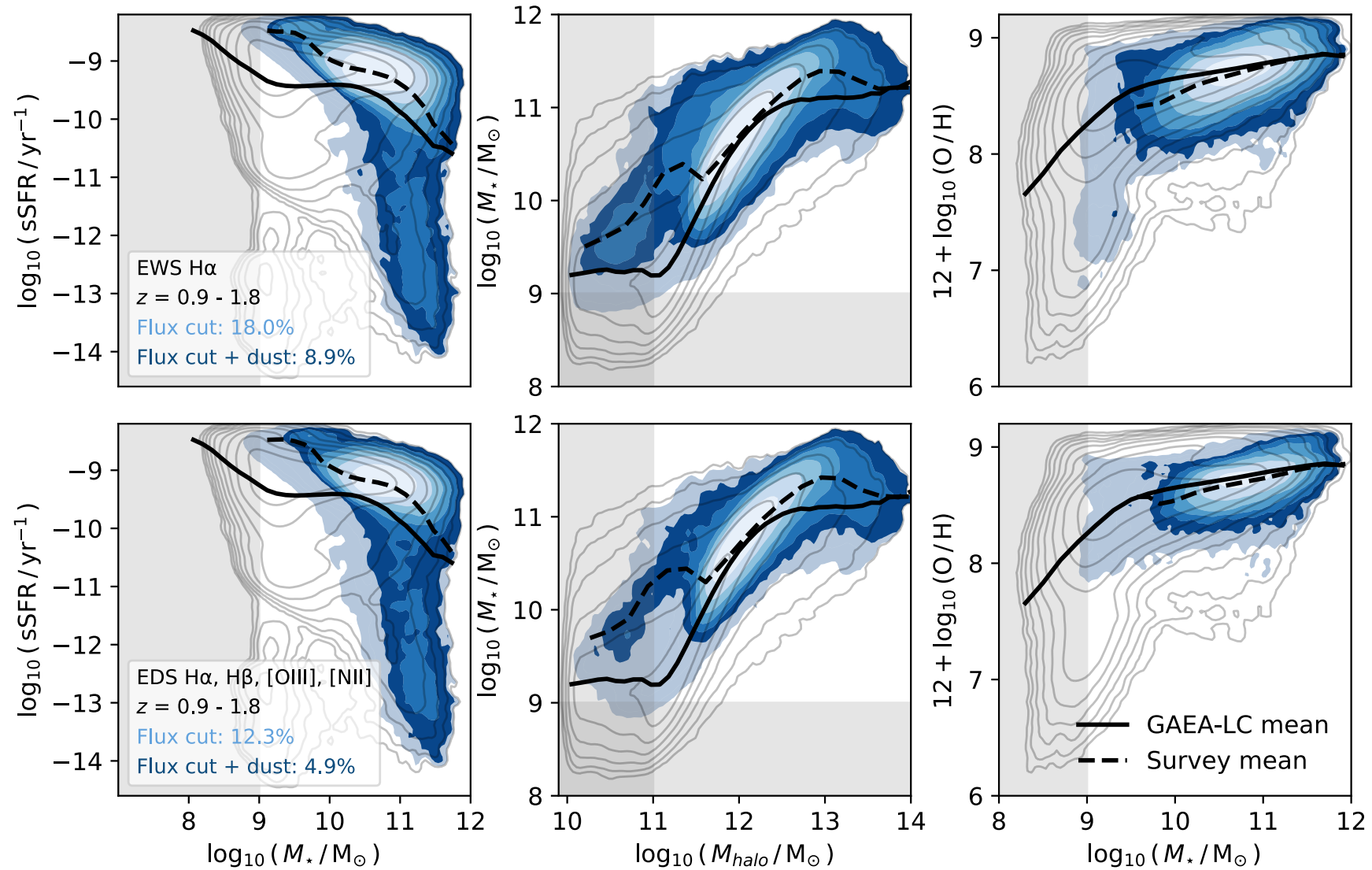
Key Questions

1. *How are galaxy populations biased when requiring the detectability of emission lines with Euclid?*

2. *Can optical BPT diagrams distinguish between dominant ionising sources in the EDS-observable sample?*

3. *Which EL calibrations can characterise galaxies at intermediate redshifts?*

Line and stellar mass plane for Hα and Hβ

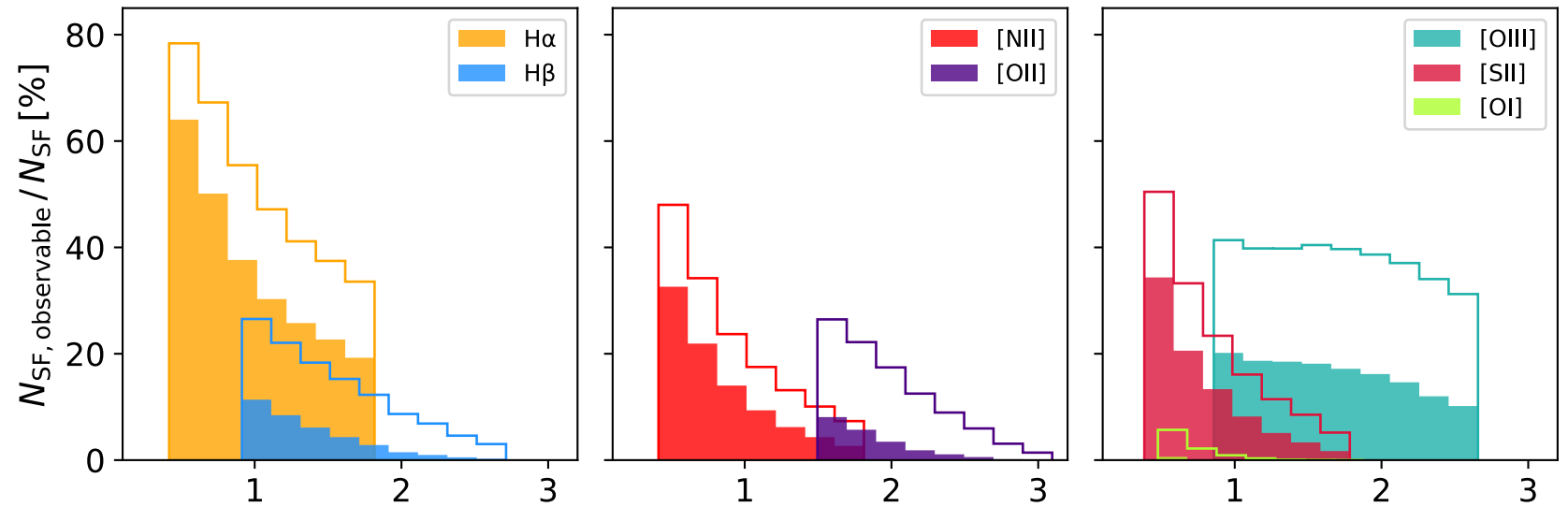$z = 0.4 - 0.9$ $z = 0.9 - 1.5$ $z = 1.5 - 1.8$

Hα 52.4%   Hα 28.2% 11.0%   Hα 18.2% 5.3%

$z = 1.5 - 2.5$

Hβ 8.5%   Hβ 2.4% 0.1%

EDS (BGS)
EWS (RGS)
EDS (RGS)

Standard Scaling Relations Traced by Emission Lines

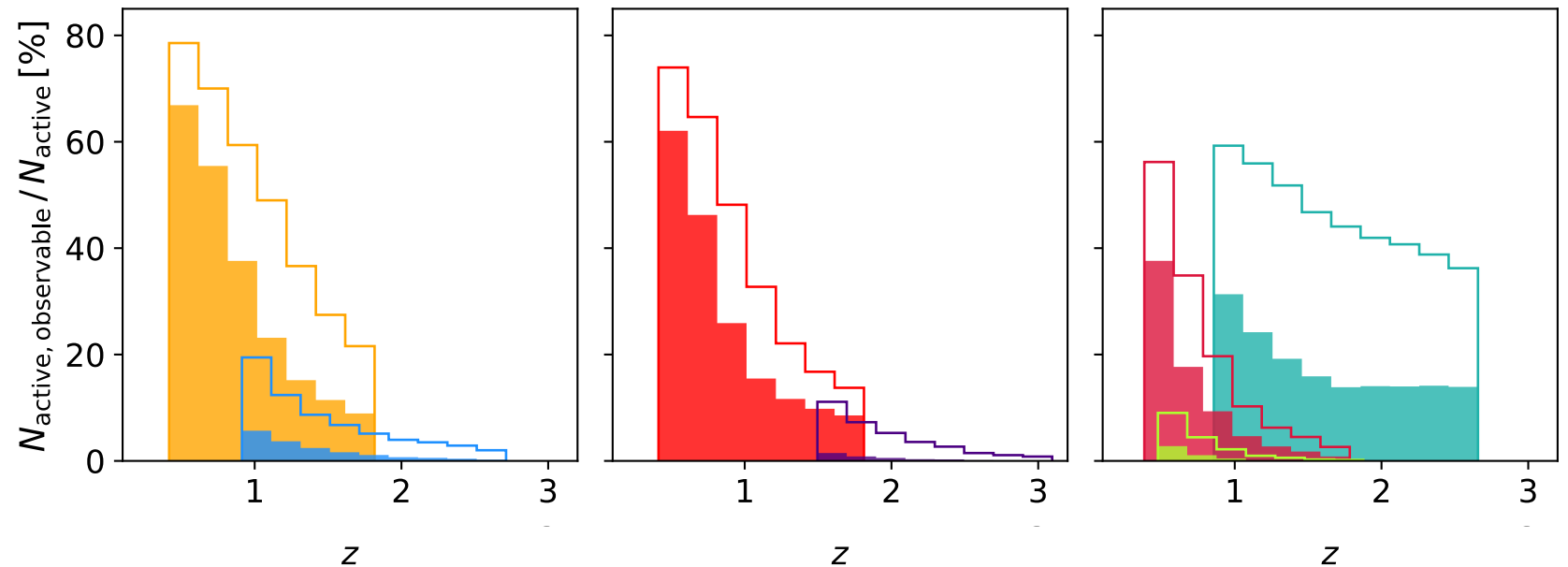# Observable Fractions of Line-Emitting SF and Active Galaxies
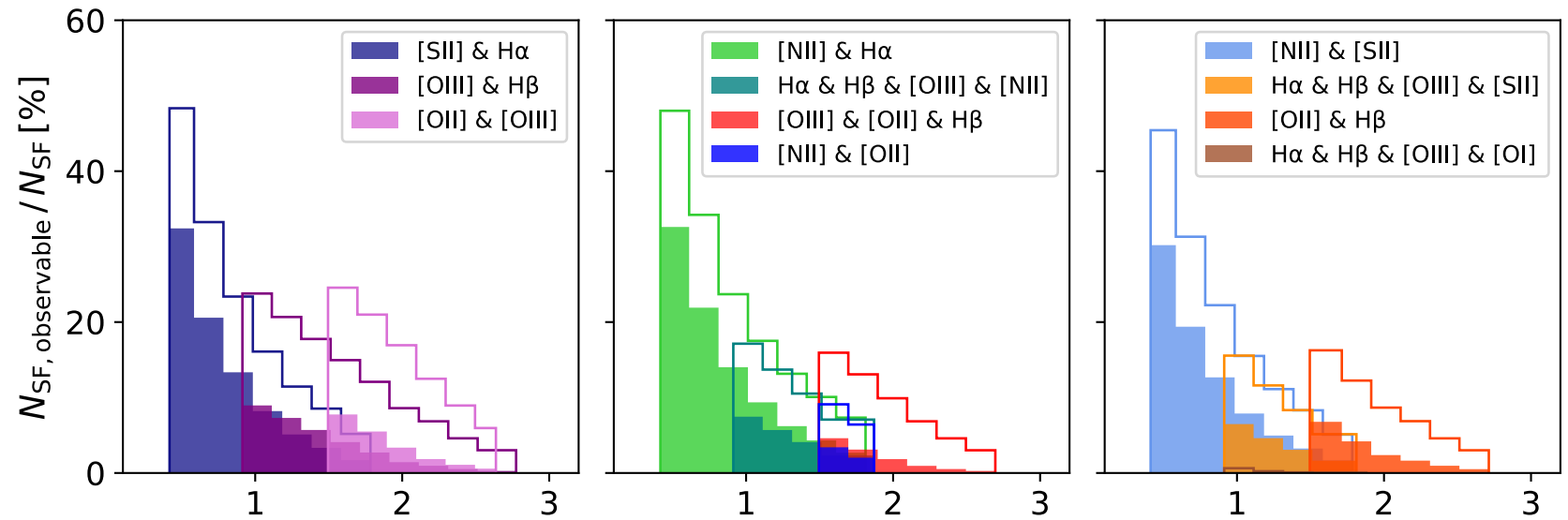
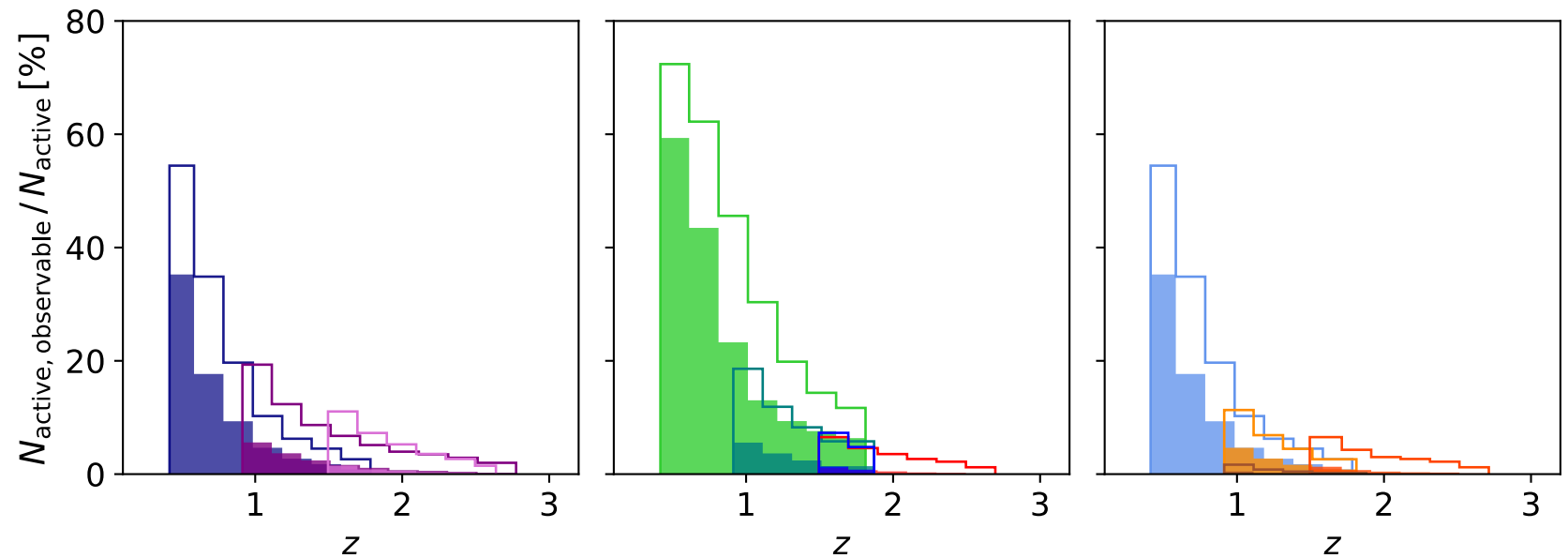# Observable Fractions of Line-Emitting SF and Active Galaxies

Key Questions

1. *How are galaxy populations biased when requiring the detectability of emission lines with Euclid?*

2. **Can optical BPT diagrams distinguish between dominant ionising sources in the EDS-observable sample?**

3. *Which EL calibrations can characterise galaxies at intermediate redshifts?*

[NII]-BPT Diagram Separates Dominant Ionising Sources

$z = 0.9 - 1.2$

$\log_{10}\left([OIII]/H\beta\right)$

$\log_{10}\left([NII]/H\alpha\right)$

SF

Comp

AGN

SF-dominated galaxies
BHAR/SFR < 10^{-3}

Composite galaxies
10^{-3} < BHAR/SFR < $10^{-2.2}$

AGN-dominated galaxies
BHAR/SFR > $10^{-2.2}$
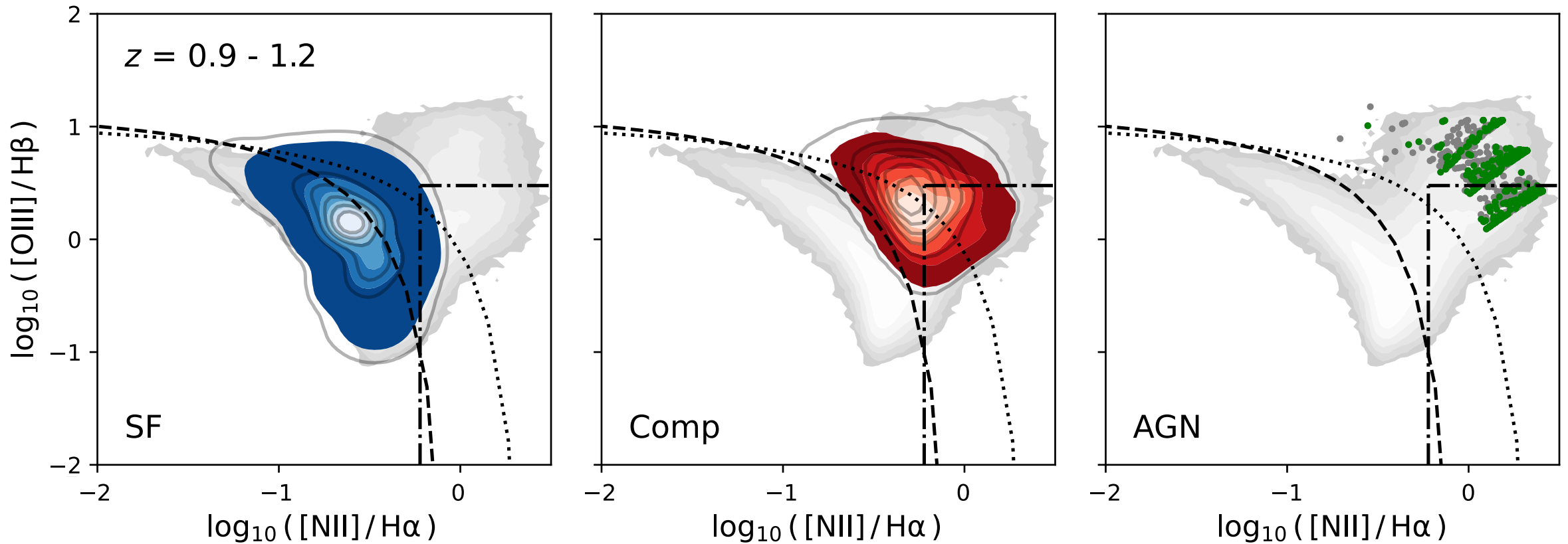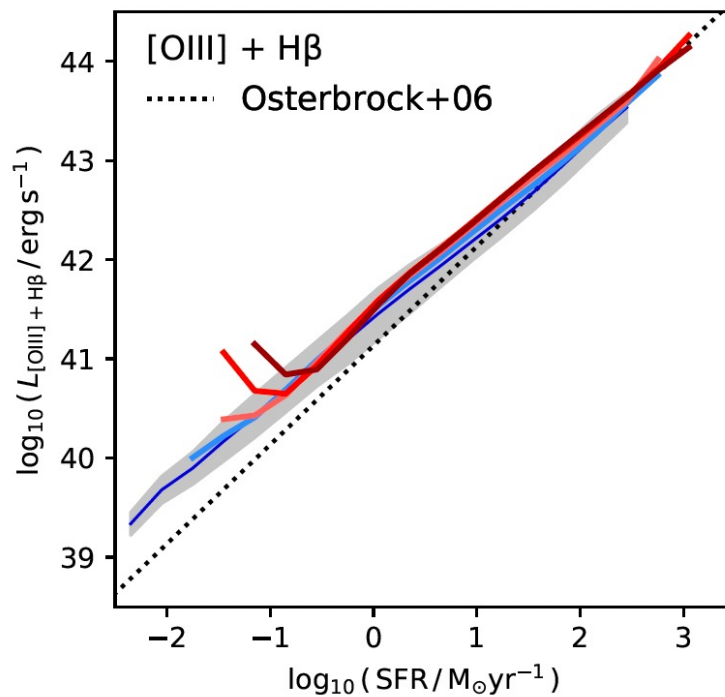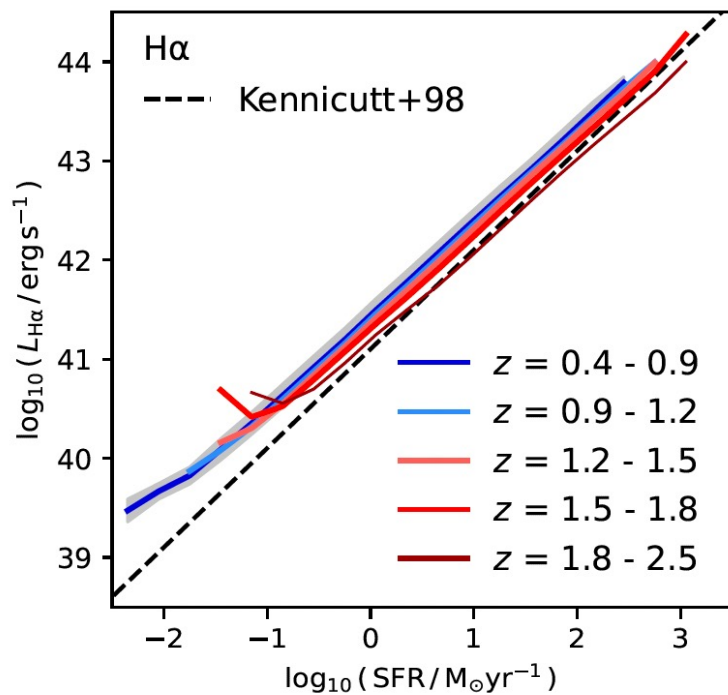
Key Questions
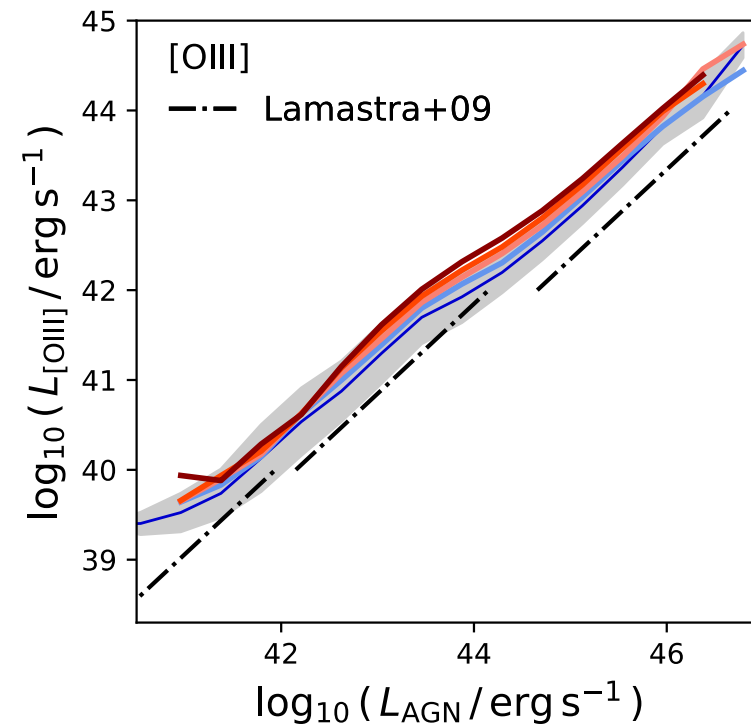
1. *How are galaxy populations biased when requiring the detectability of emission lines with Euclid?*

2. *Can optical BPT diagrams distinguish between dominant ionising sources in the EDS-observable sample?*

3. *Which EL calibrations can characterise galaxies at intermediate redshifts?*

Hα and [OIII]-SFR Relations
for SF Galaxies

[OIII]-LAGN
Relation for Active
Galaxies

[NII]/Hα Depends Strongly on BHAR/SFR!

z = 0 - 2.5

SF

Comp

AGN

$\log_{10}$ ([OIII] / Hβ)

$\log_{10}$ ([NII] / Hα)

$\log_{10}$ ([NII] / Hα)

$\log_{10}$ ([NII] / Hα)
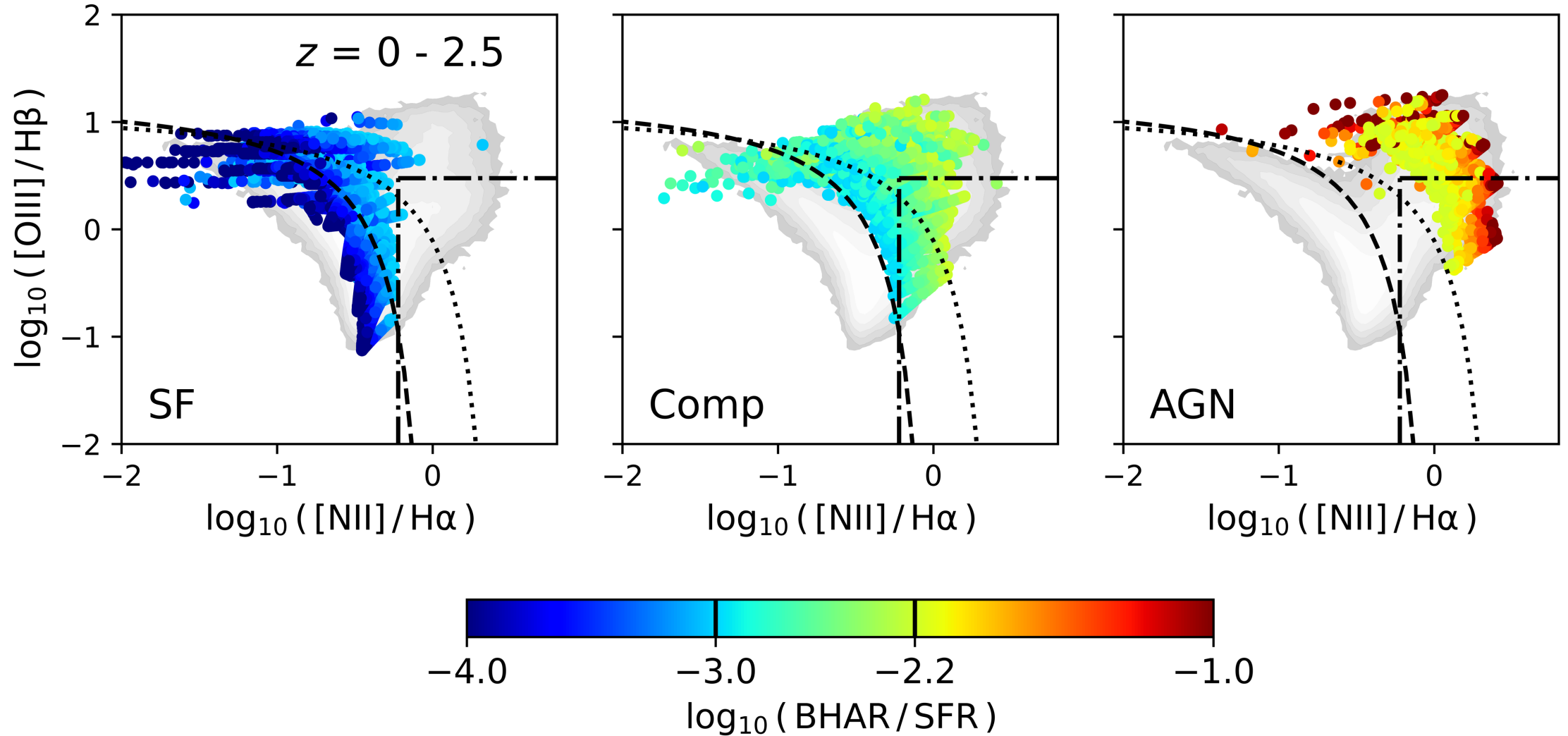
$\log_{10}$ (BHAR / SFR)

New [NII]-Based Line-Ratio Calibrations for BHAR/SFR
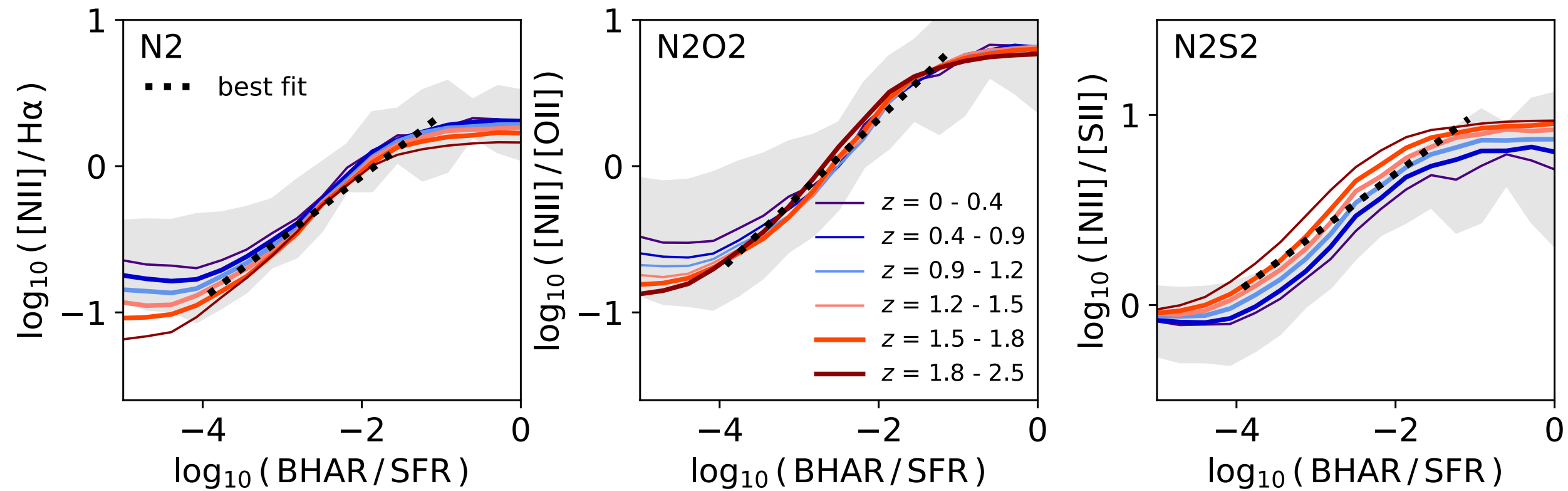
Line-Ratio Calibrations for the Metallicity

Line-Ratio Calibrations for the Metallicity

Summary

Spectral libraries from Euclid will be **biased toward massive, highly star-foming and metal-rich galaxies**.
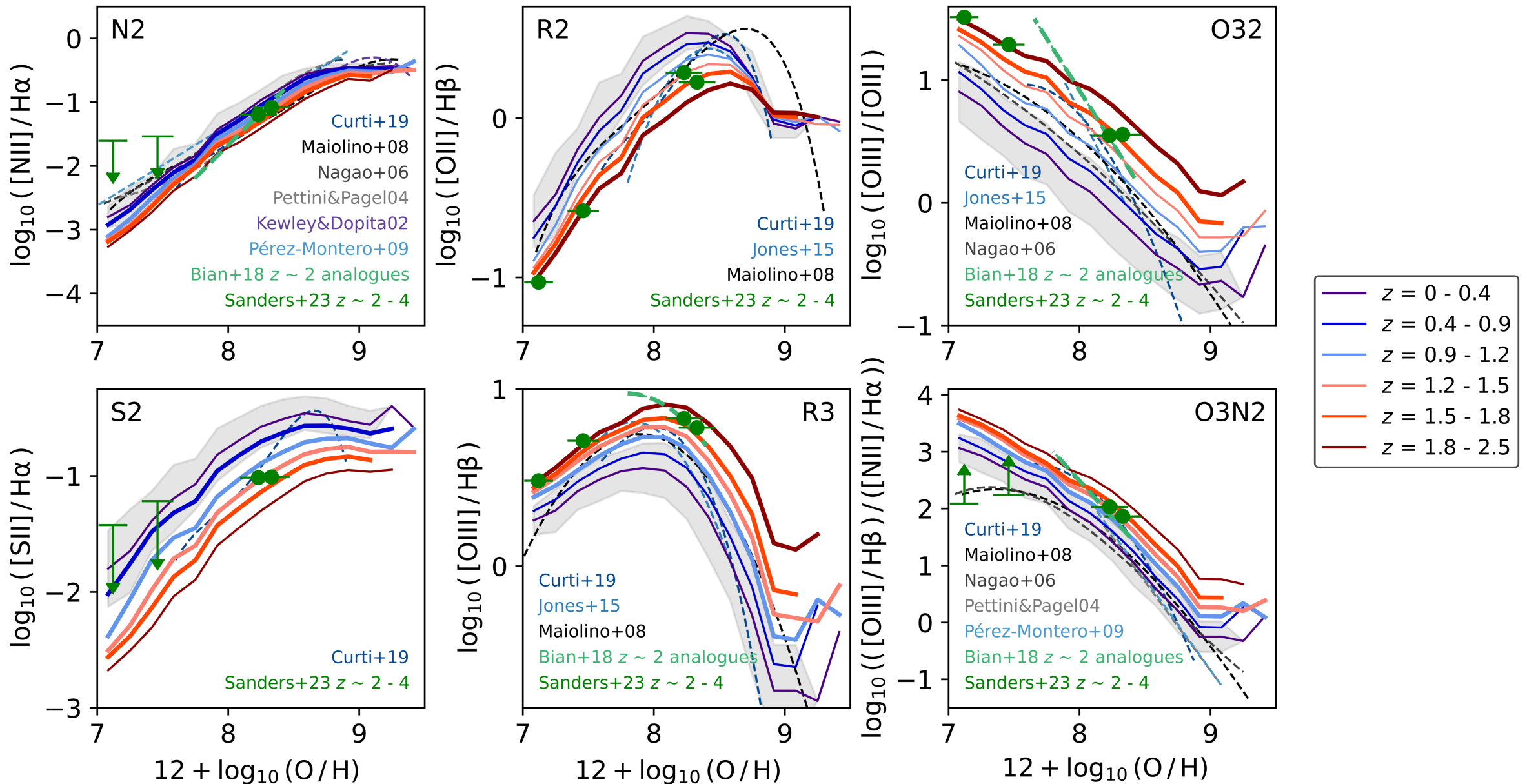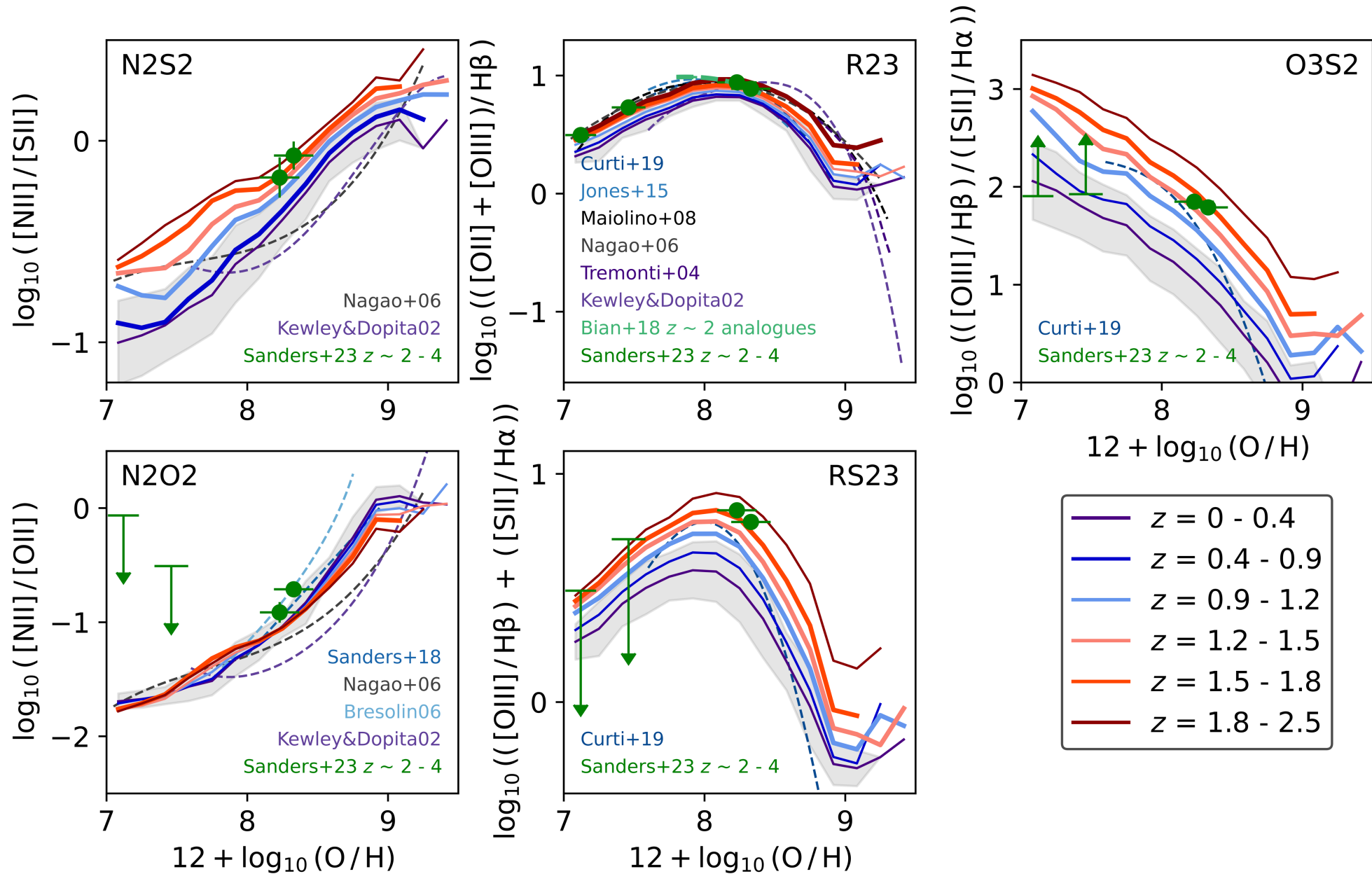
The standard **BPT diagram can successfully identify ionising sources** in EDS-like galaxies.

Hα and [OIII]-based relations for SFR and LAGN are robust with increasing z.

Based on its [NII]-dependence, we derived **novel, *z*-invariant, line-ratio calibrations for the BHAR/SFR**, which are valid for all galaxy types.

Line-ratio calibrations for the gas-phase metallicity undergo shifts in normalisation of up to 1.5 dex in between $z = 0$ and $z = 2.5 \implies$ **agreement with recent JWST results!**

Potential Future Projects

Directly related to GAEA:

- Clustering of EL galaxies (Euclid light cones)

- Origin of extreme EL galaxies found with JWST (GAEA applied to P-Millennium)

- Link between FIR and optical/UV emission lines (ALMA and JWST) via new photo-ionisation models (under construction with A Plat and S Charlot)

Indirectly related to GAEA:

- Improvement of emission-line modelling based on detailed simulations (may lead to reduction of assumptions when modelling line emission for GAEA)

- Impact of LyC photons on EL diagnostics (ionising sources+gas properties) at the reionisation epoch via new coupling and new density-bounded photo-ionisation models (under construction, with A Plat and S Charlot)

- Impact of binary stellar populations on line emission in simulated galaxies (with S Charlot)