# STELLAR POPULATION SYNTHESIS AND TEMPLATES FOR PHOTOMETRIC REDSHIFTS

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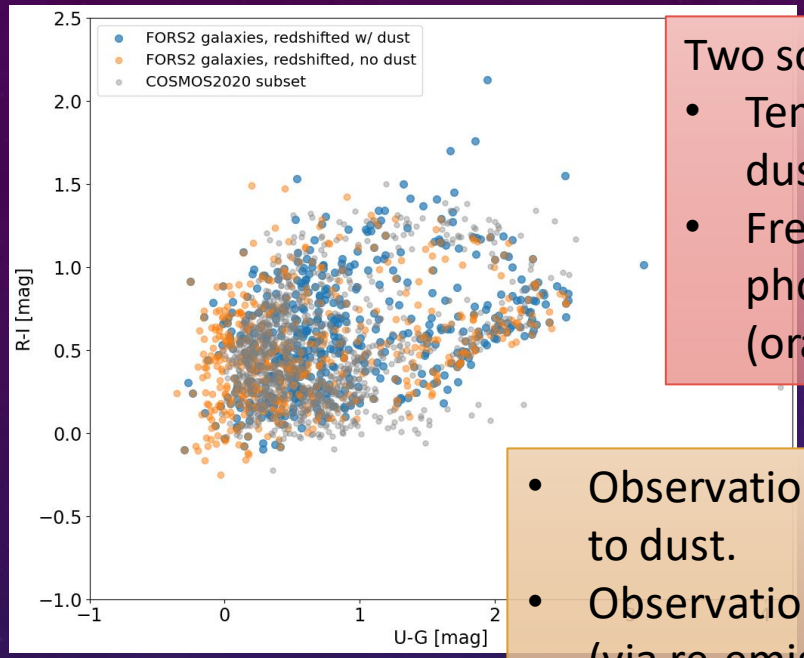
# OUTLINE

1. Introduction : Stellar Population Synthesis, dust and photometric redshifts
2. Spectral Energy Density from Stellar Population Synthesis
3. Lines identification using GELATO
4. Back to SEDs
5. Caveats
6. Takeaway

# INTRO : SPS, DUST AND PHOTO-Z

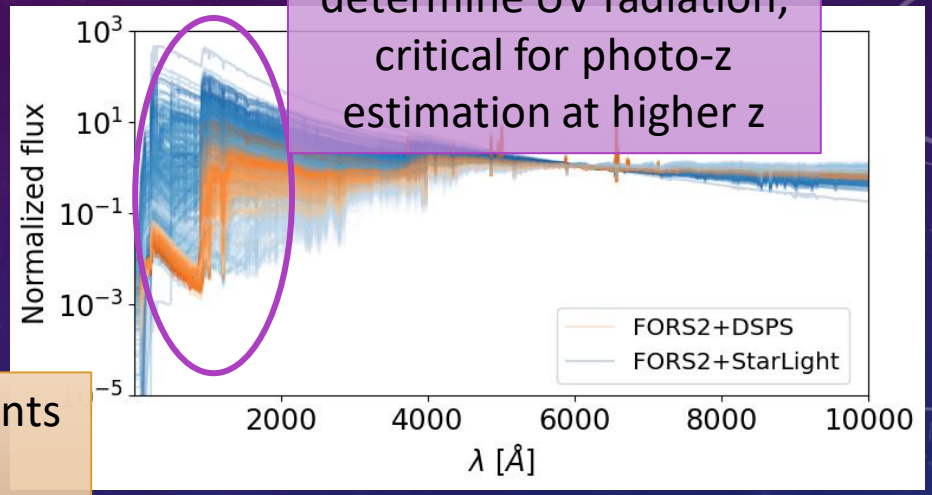




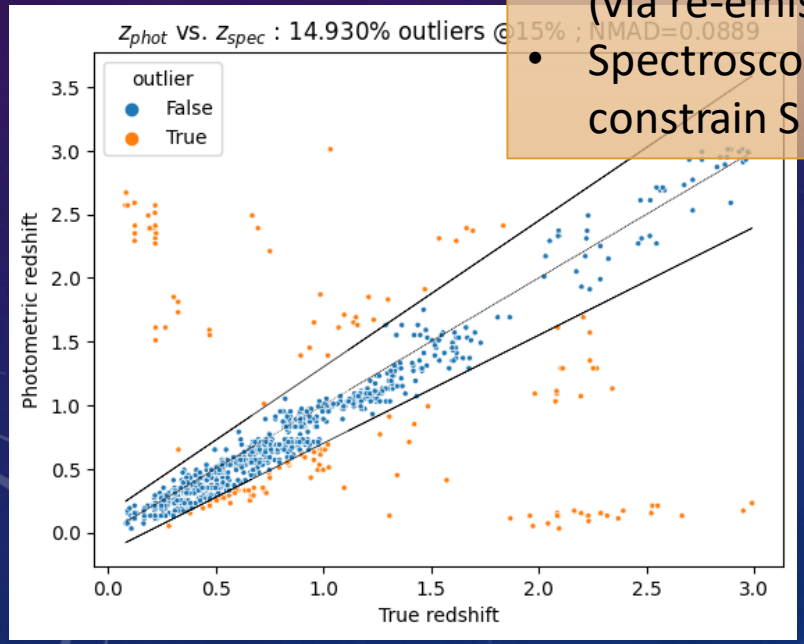

Two solutions for dust :

- Templates that include dust extinction (blue)
- Free parameter during photo-z estimation (orange)

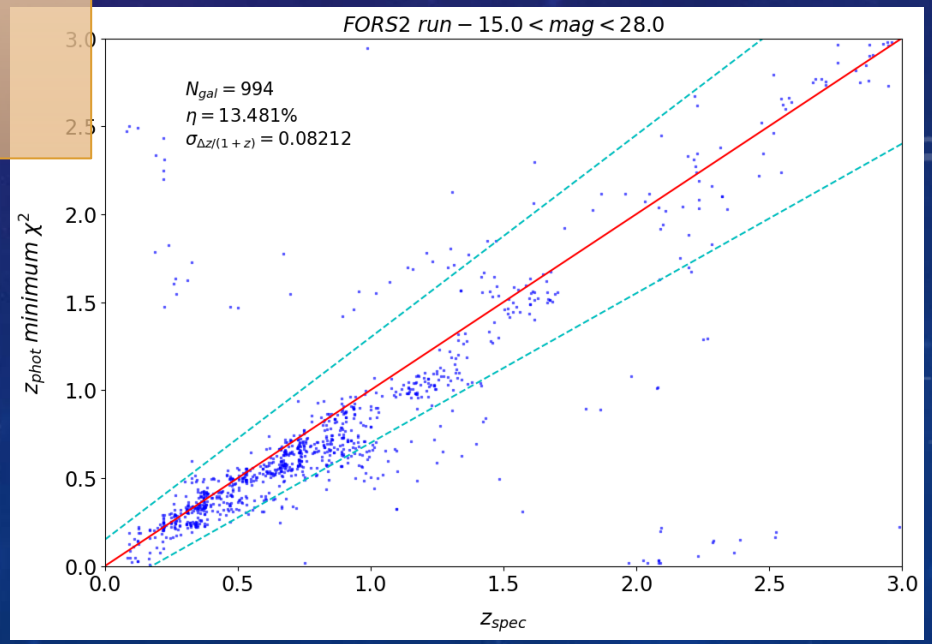
Dust extinction and SFR determine UV radiation, critical for photo-z estimation at higher z




- Observations in UV can yield SFR and hints to dust.
- Observations in infrared can constrain dust (via re-emission).
- Spectroscopy (emission lines) can constrain SFR.




*FORS2 templates with dust, no extinction in photo-z estimation*
← EmuLP | LEPHARE →



# SED TEMPLATES FROM SPS



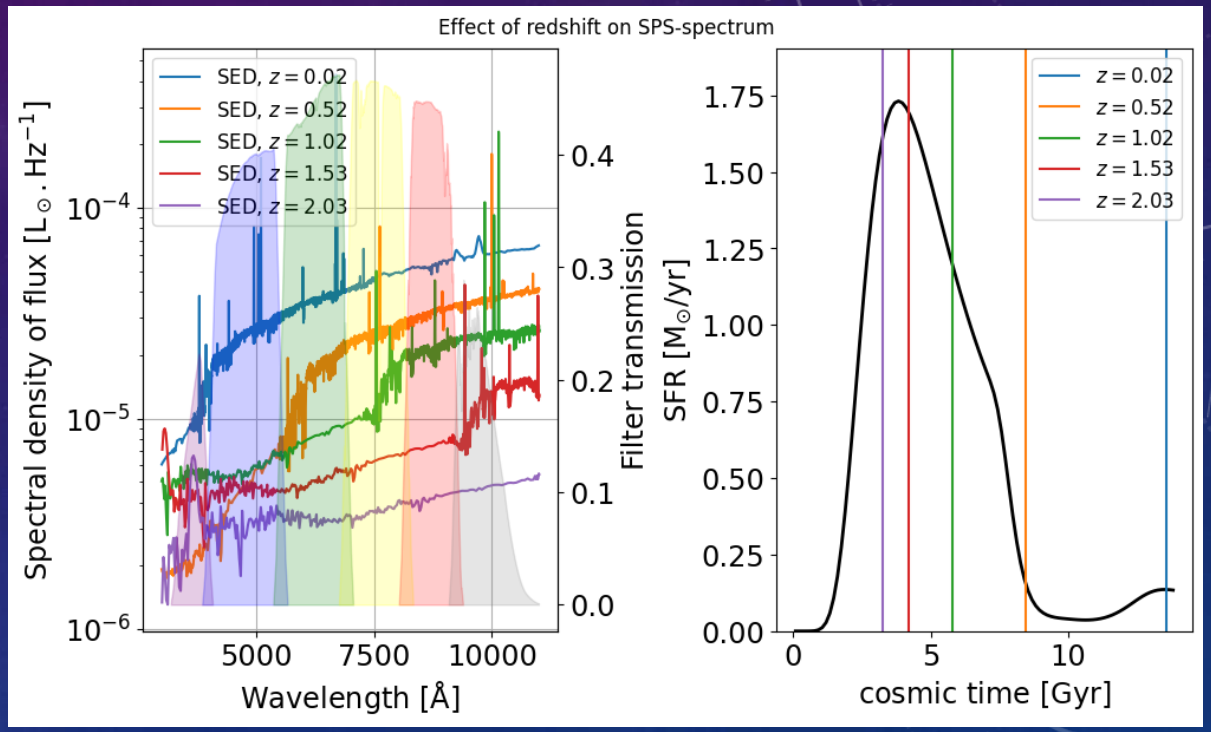
Template spectrum shifted
+ its stellar content adjusted to the epoch of emission.
***Aim : better representativeness of templates at higher z***

**The key :** representativeness.

**The issue :** well-calibrated templates are mostly local, observations will be distant.

**The fix :** use Stellar Population Synthesis (SPS) and Star Formation History (SFH) to improve SED templates.

**The idea :** compare the radiation emitted by "young" galaxies to "younger" versions of the templates, as the stellar content evolves with time.




Galaxies = stars + dark matter + other (dust, gas…)

**Emit the light we observe (~ black body)**

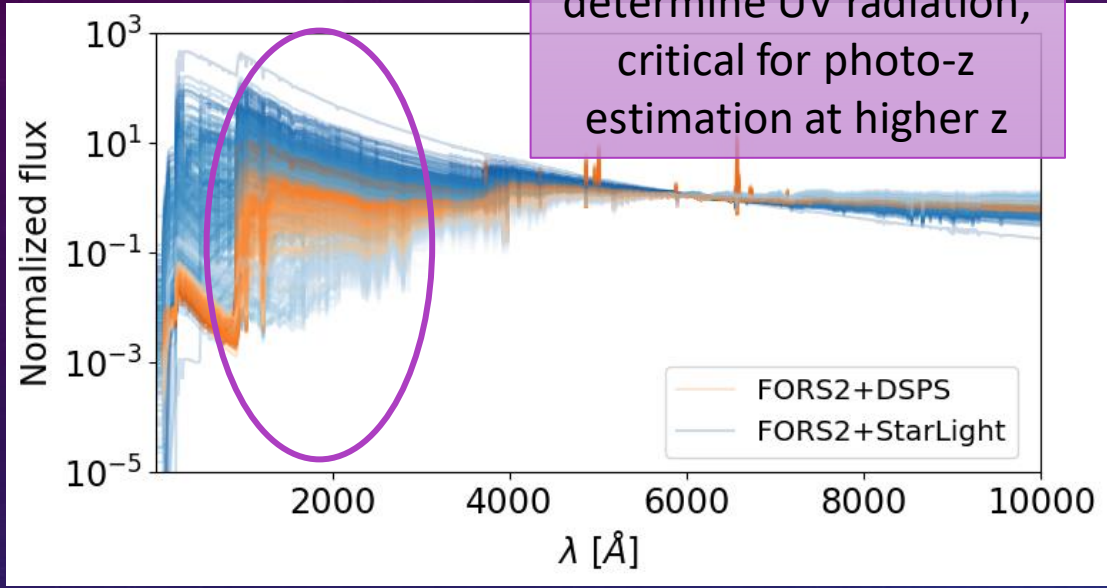
**Alter the signal**

**SPS = fit models of galaxy contents to observations**

**Use the results as (or instead of) SED templates**

# SED TEMPLATES FROM SPS

Dust extinction and SFR determine UV radiation, critical for photo-z estimation at higher z




***Dust :***

✓ necessary for good representativeness

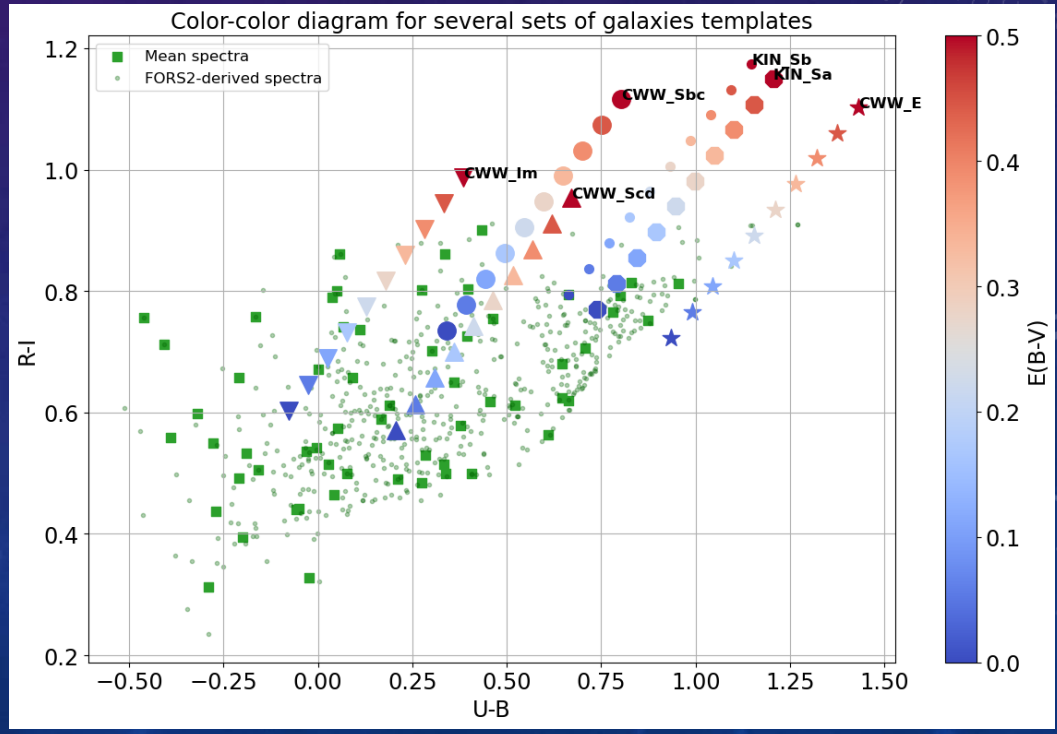
× Yields degeneracies with photo-z

→**Requires careful treatment**

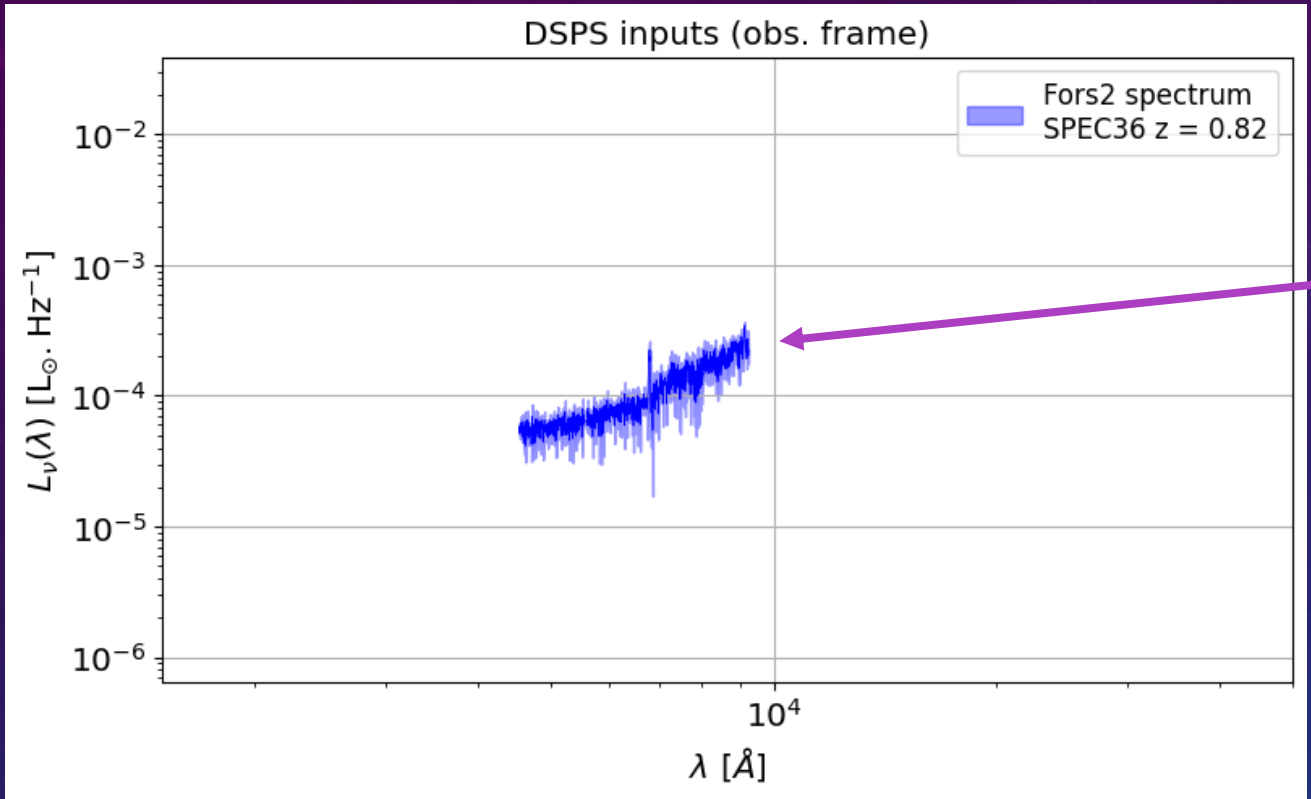
***UV-light :***

- Shifted into visible : key to high z
- Related to star formation
- Attenuated by dust

**Good photo-z = Star formation + dust**



# SED TEMPLATES FROM SPS




Observed spectra from FORS2 at VLT (Giraud *et al.*, 2011)

***Guideline :***

- UV in templates is key to good photo-z
- Observations in UV can yield SFR and hints to dust,
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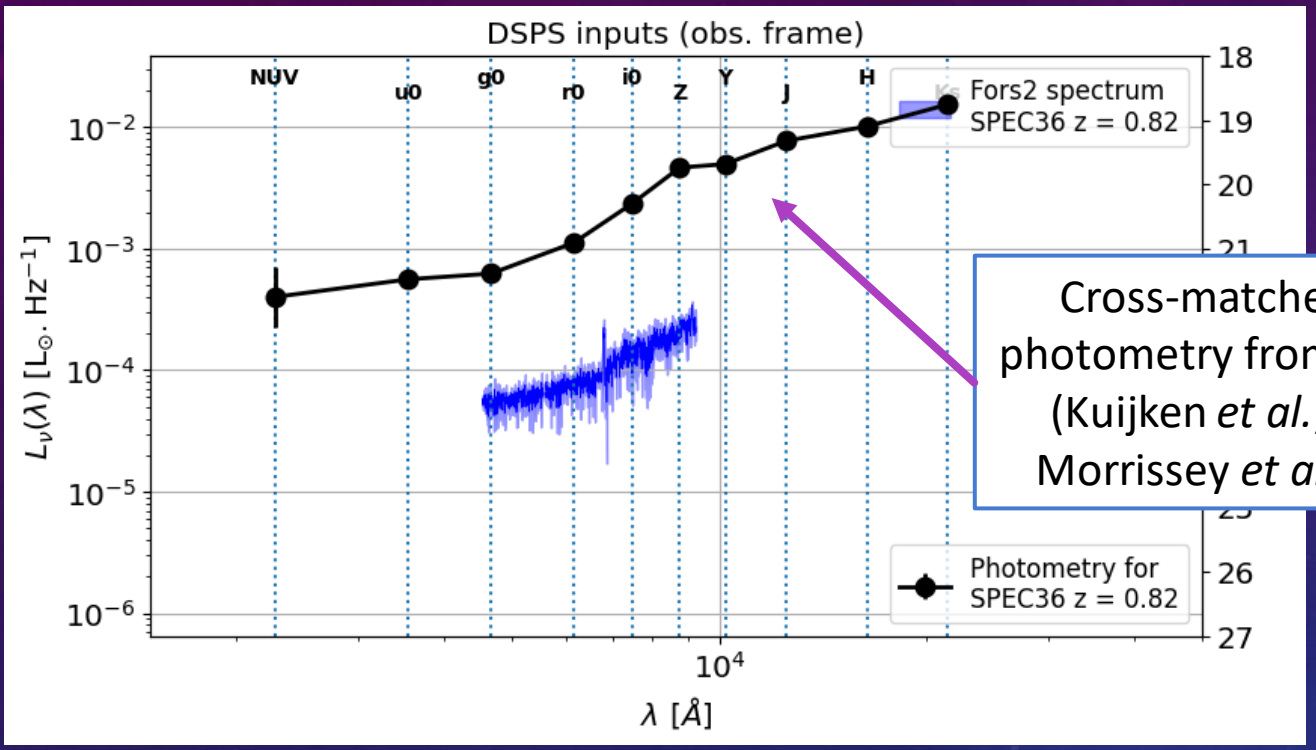
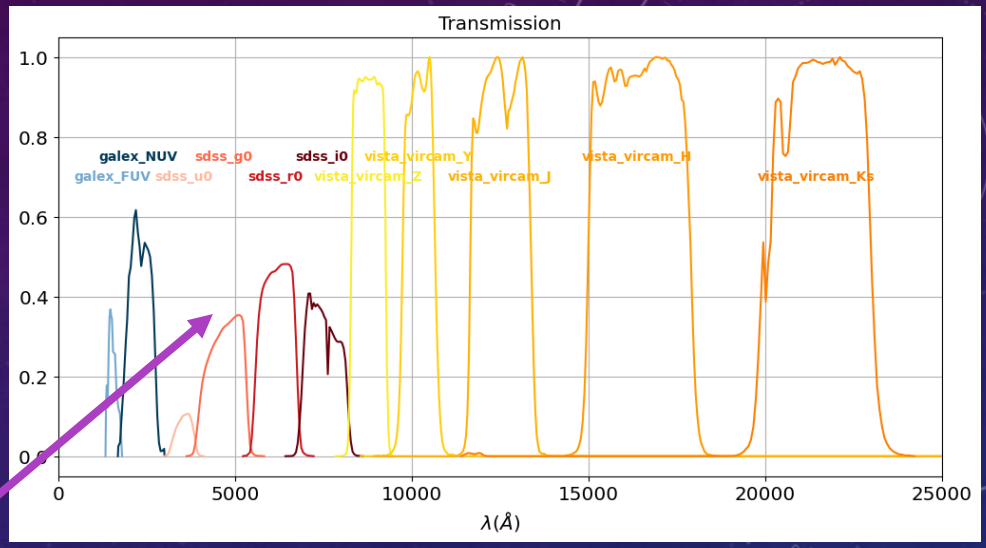
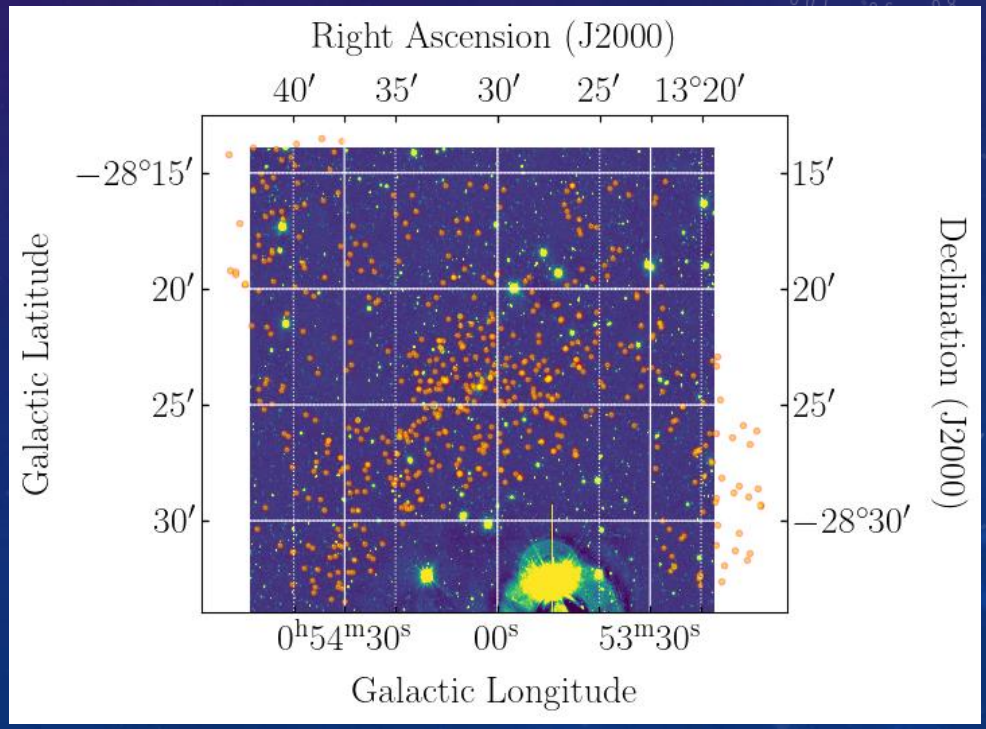
# SED TEMPLATES FROM SPS




Cross-matched with photometry from UV to IR (Kuijken *et al.*, 2019 ; Morrissey *et al.*, 2007)

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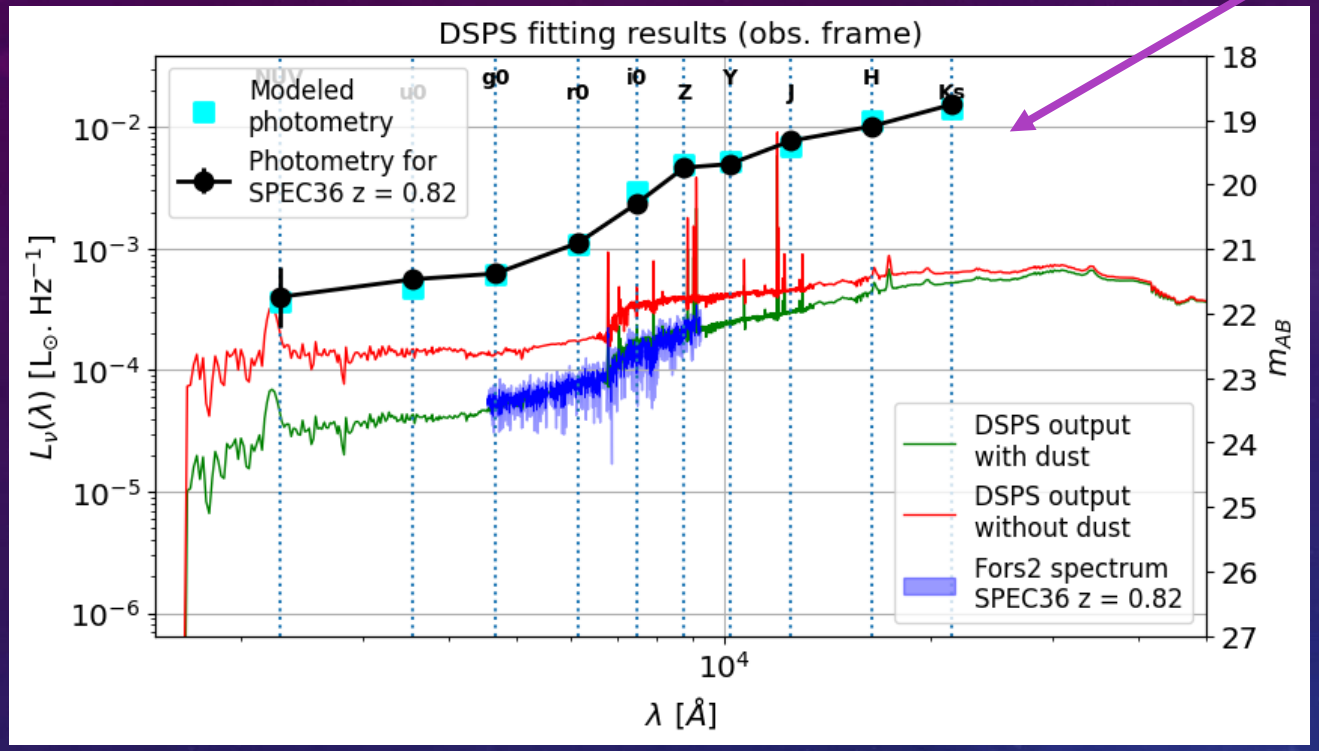
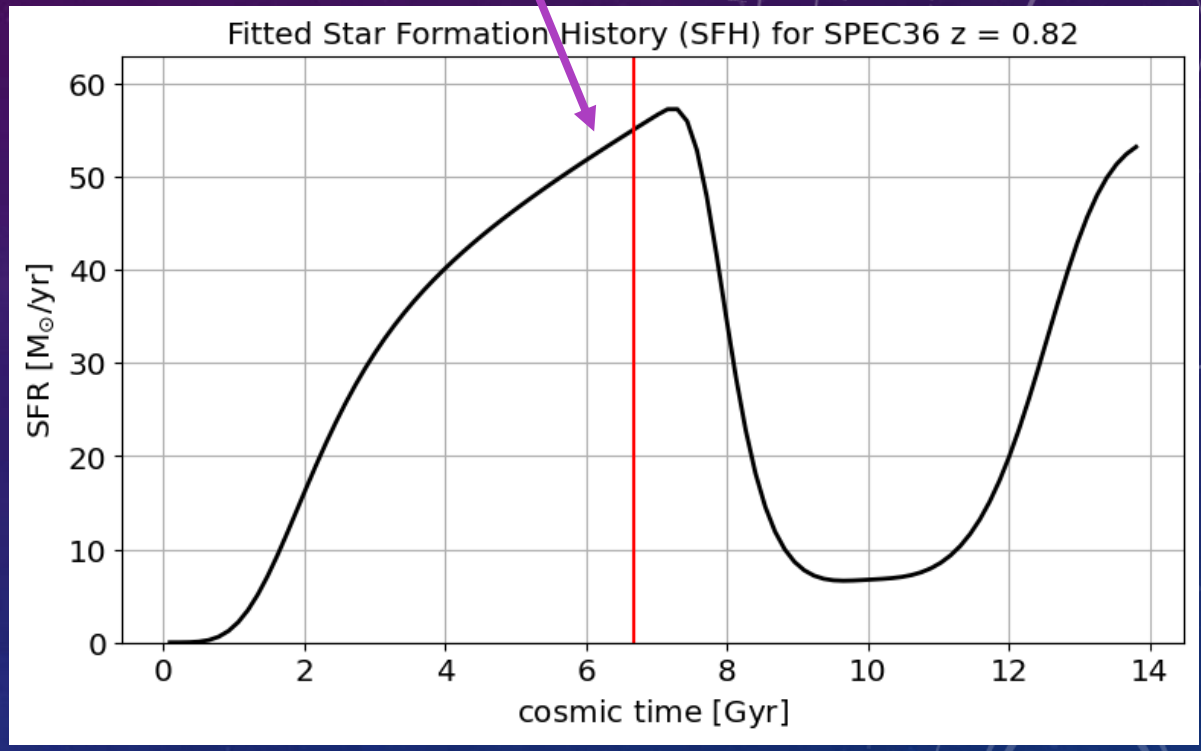
# SED TEMPLATES FROM SPS

Fit with DSPS
(Hearin *et al.*, 2023)



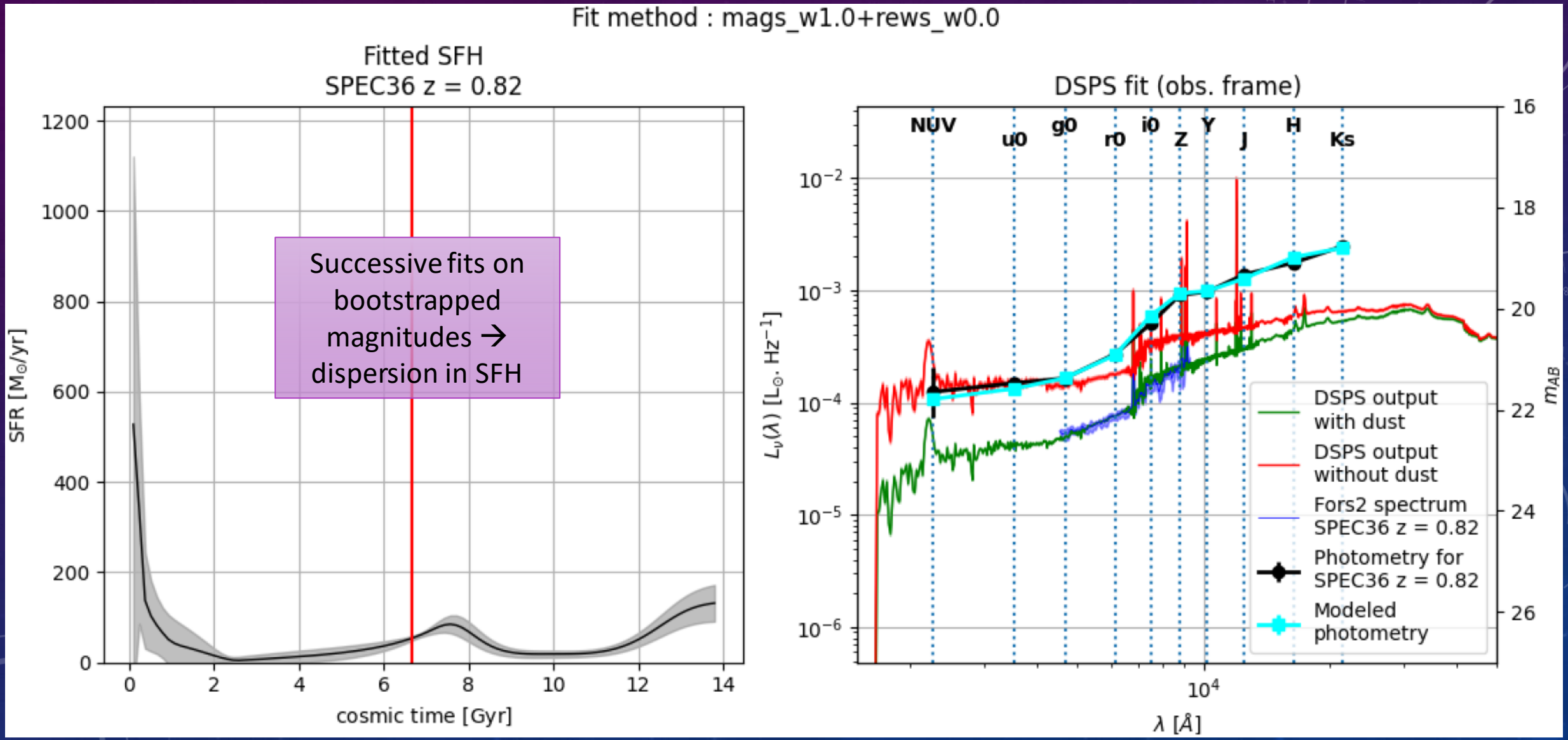

***DSPS :*** <u>16 to 18 parameters to fit *vs* 4 to 11 photometric bands.</u>

- SFH : 5 Parameters for stellar mass, 4 parameters for DM halo, 4 parameters for quenching
- Dust : 3 parameters for attenuation law
- Metallicity : 0 to 2 parameters

***We need to add spectral constraints such as equivalent widths of spectral lines.***

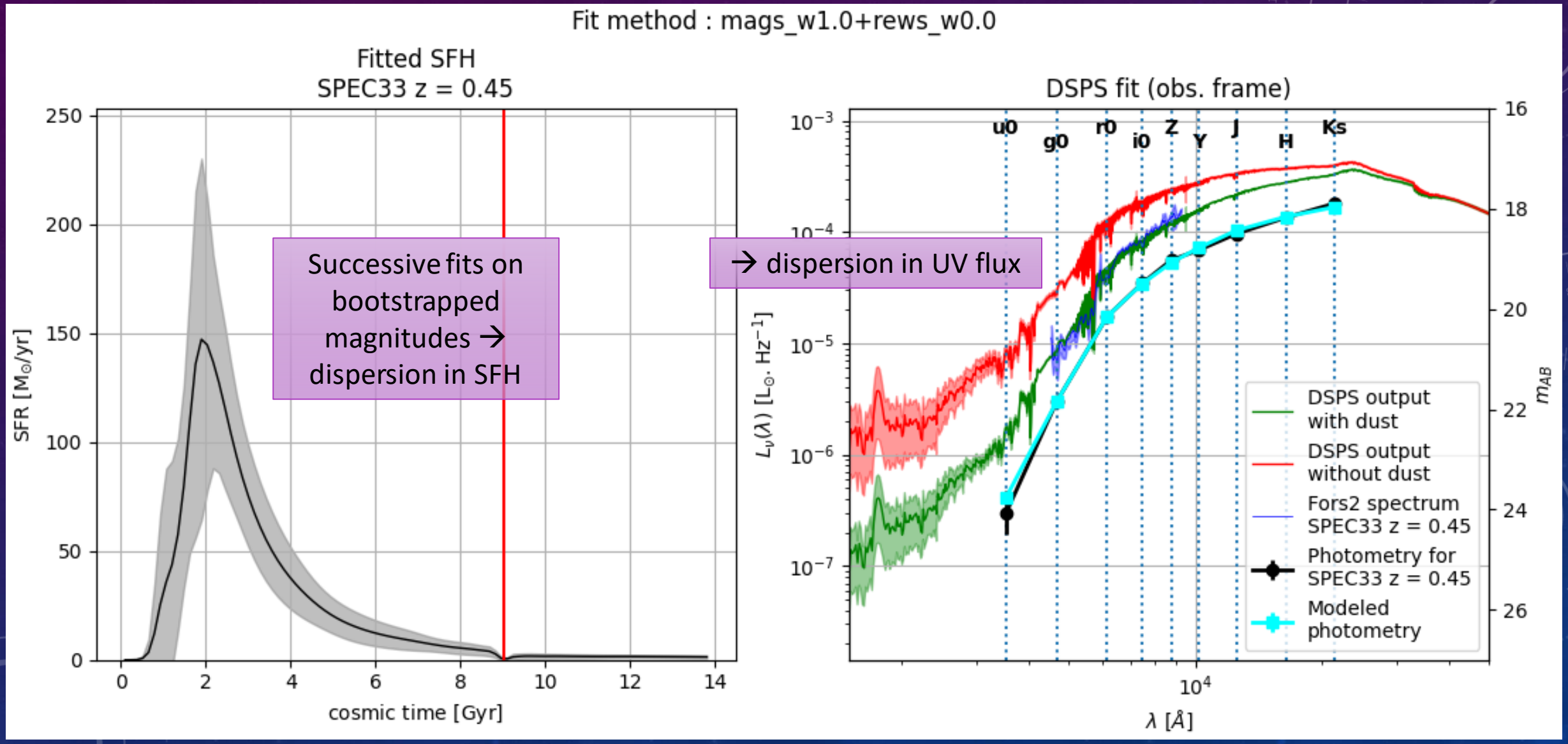
# SED TEMPLATES FROM SPS





# SED TEMPLATES FROM SPS

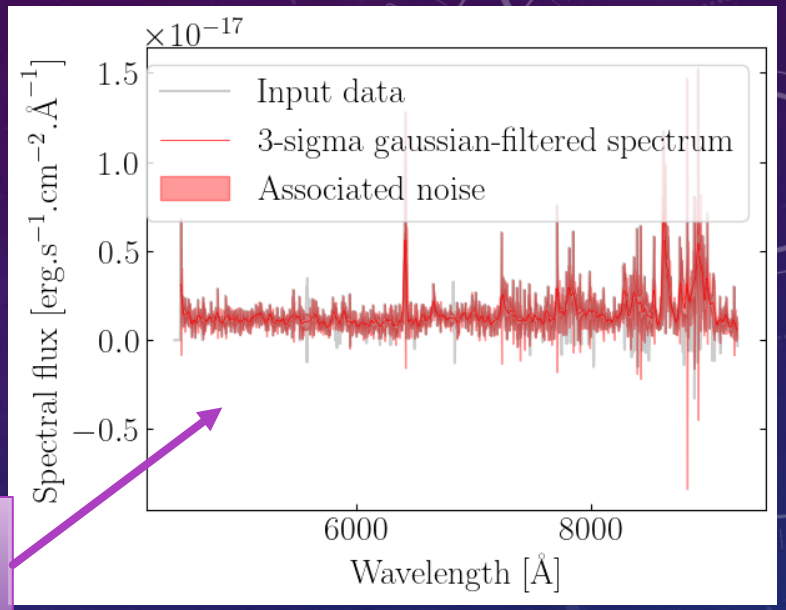




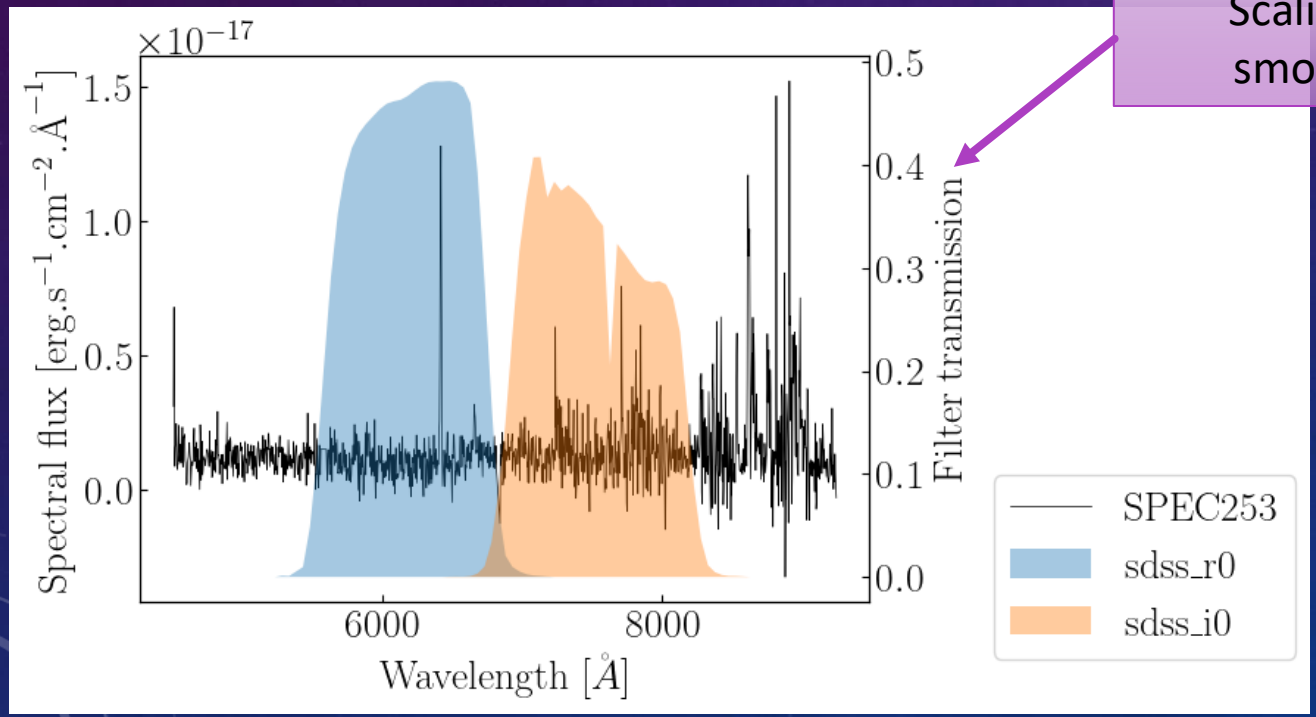
# LINES ID WITH GELATO

***Guideline :***

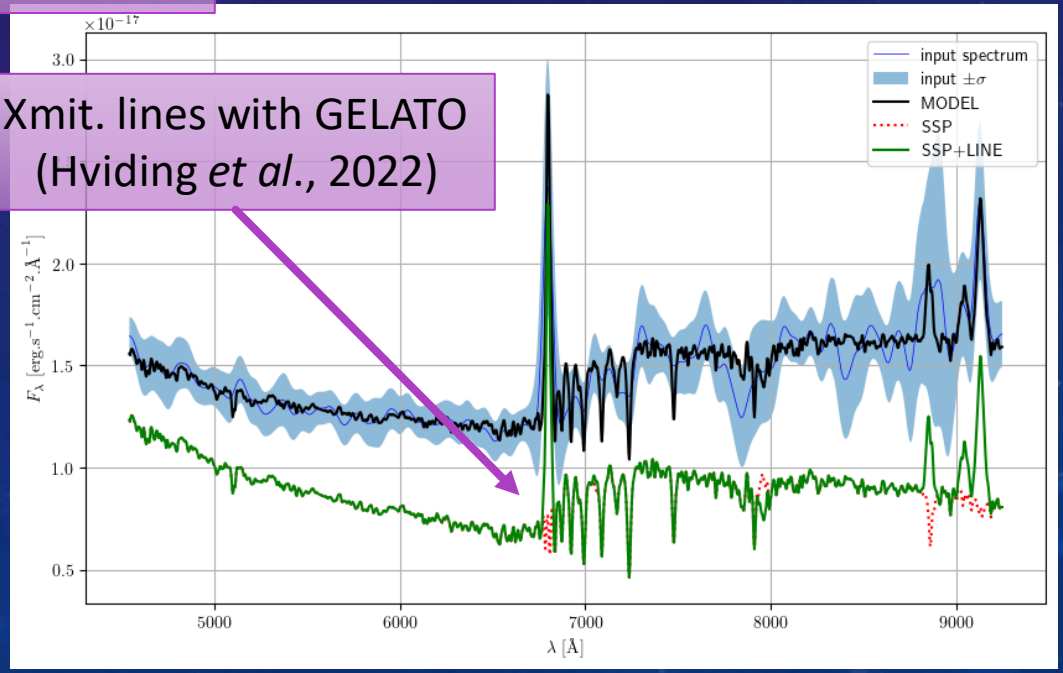
- Raw spectrum from FORS2 observations scaled on KiDS photometry
- Redshift from associated database
- Spectral flux error : smoothing and estimation…




Scaling and smoothing

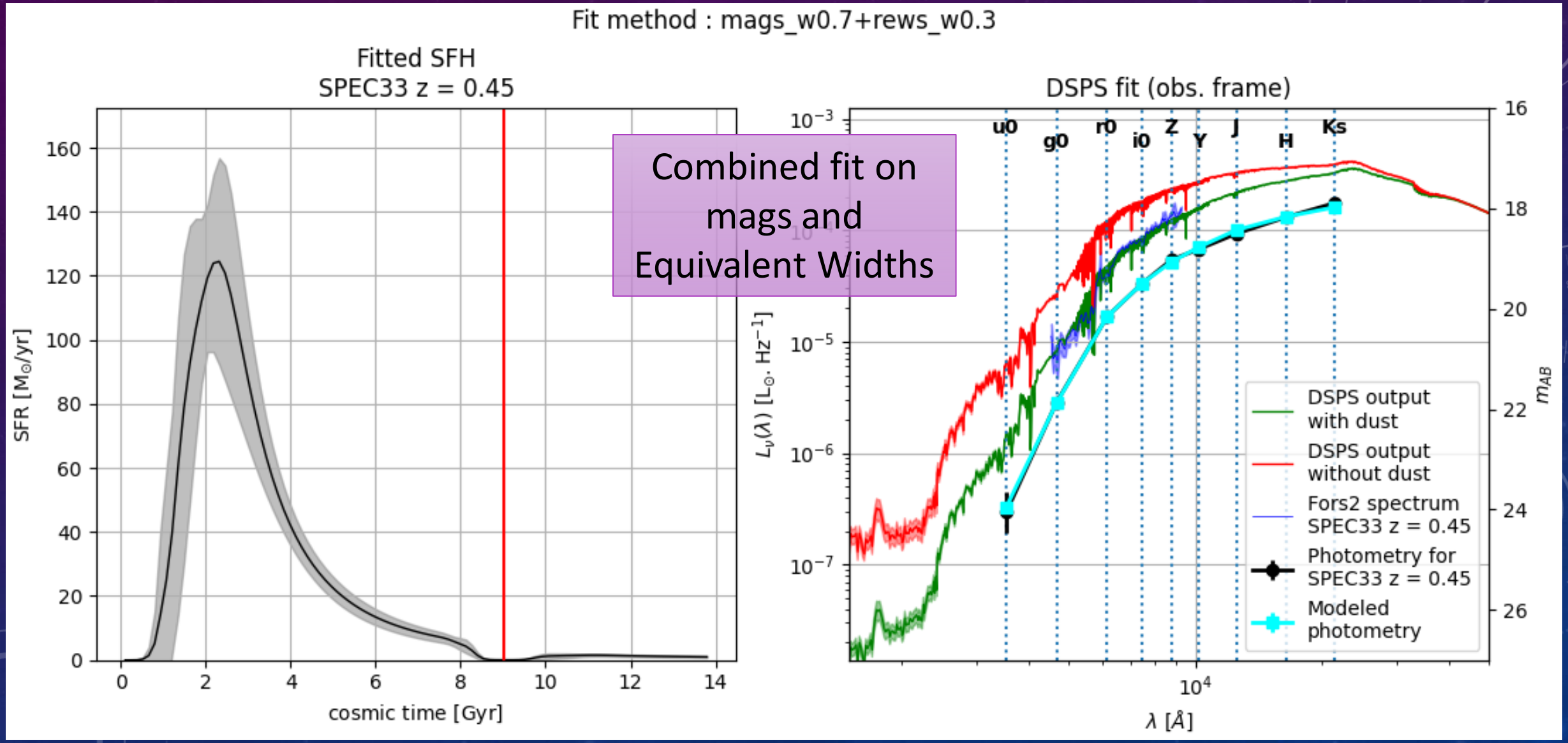



Xmit. lines with GELATO (Hviding *et al.*, 2022)



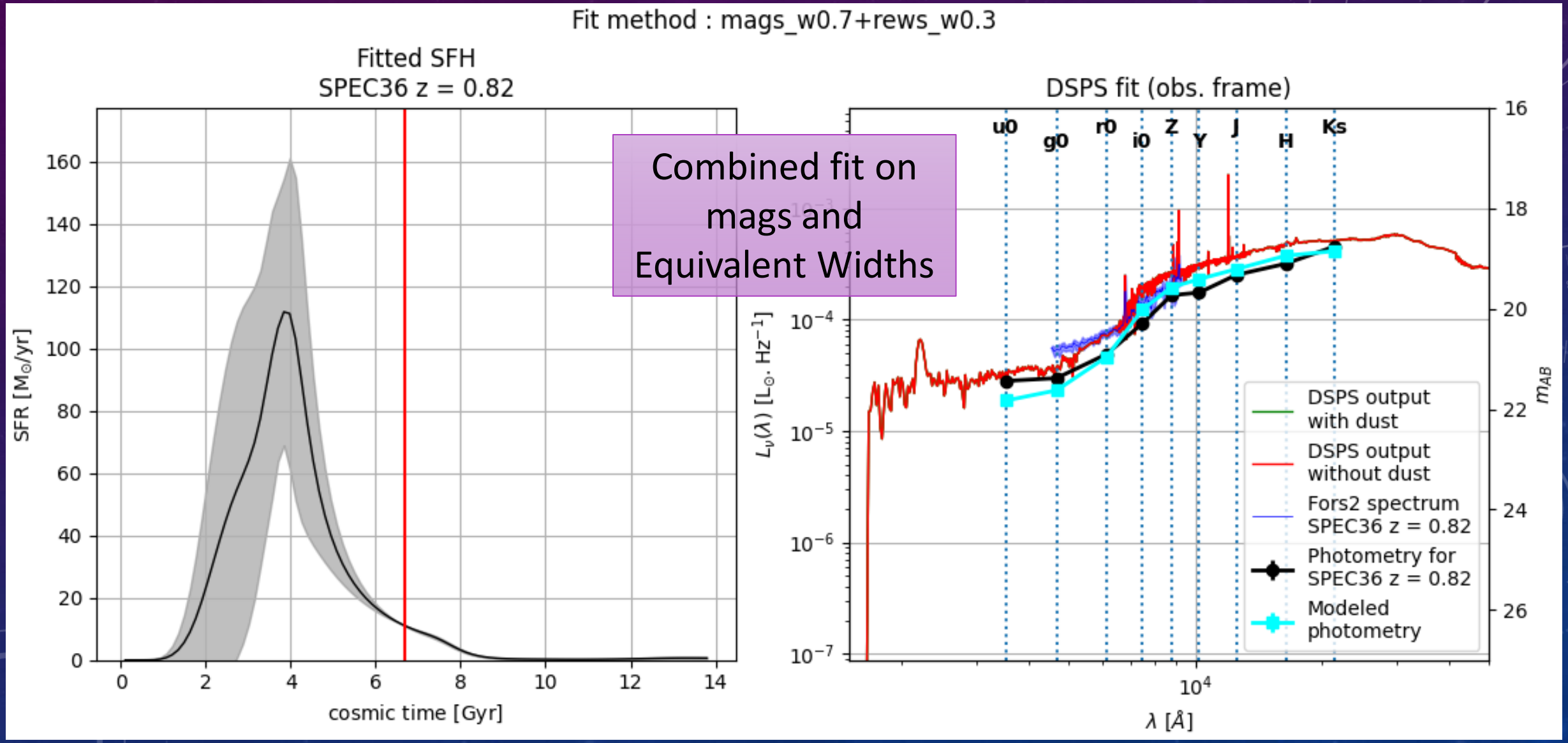
# SED TEMPLATES FROM SPS



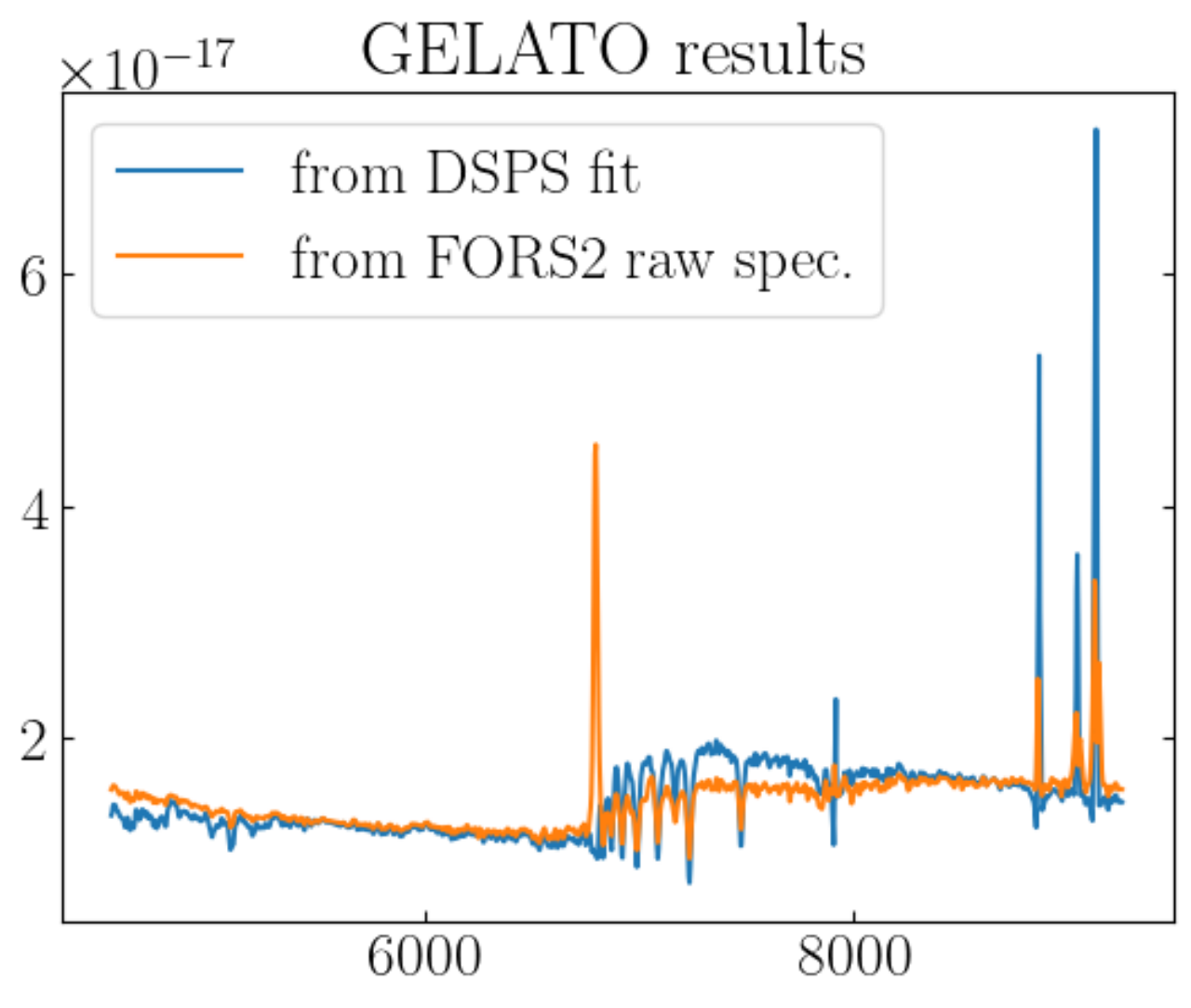


# SED TEMPLATES FROM SPS





# CAVEATS – LINES ID




***Requirements :***

- Calibrated spectra + errors (erg.cm$^{-2}$.s$^{-1}$.ang$^{-1}$)
- Requires accurate redshift value
- Good wavelengths coverage

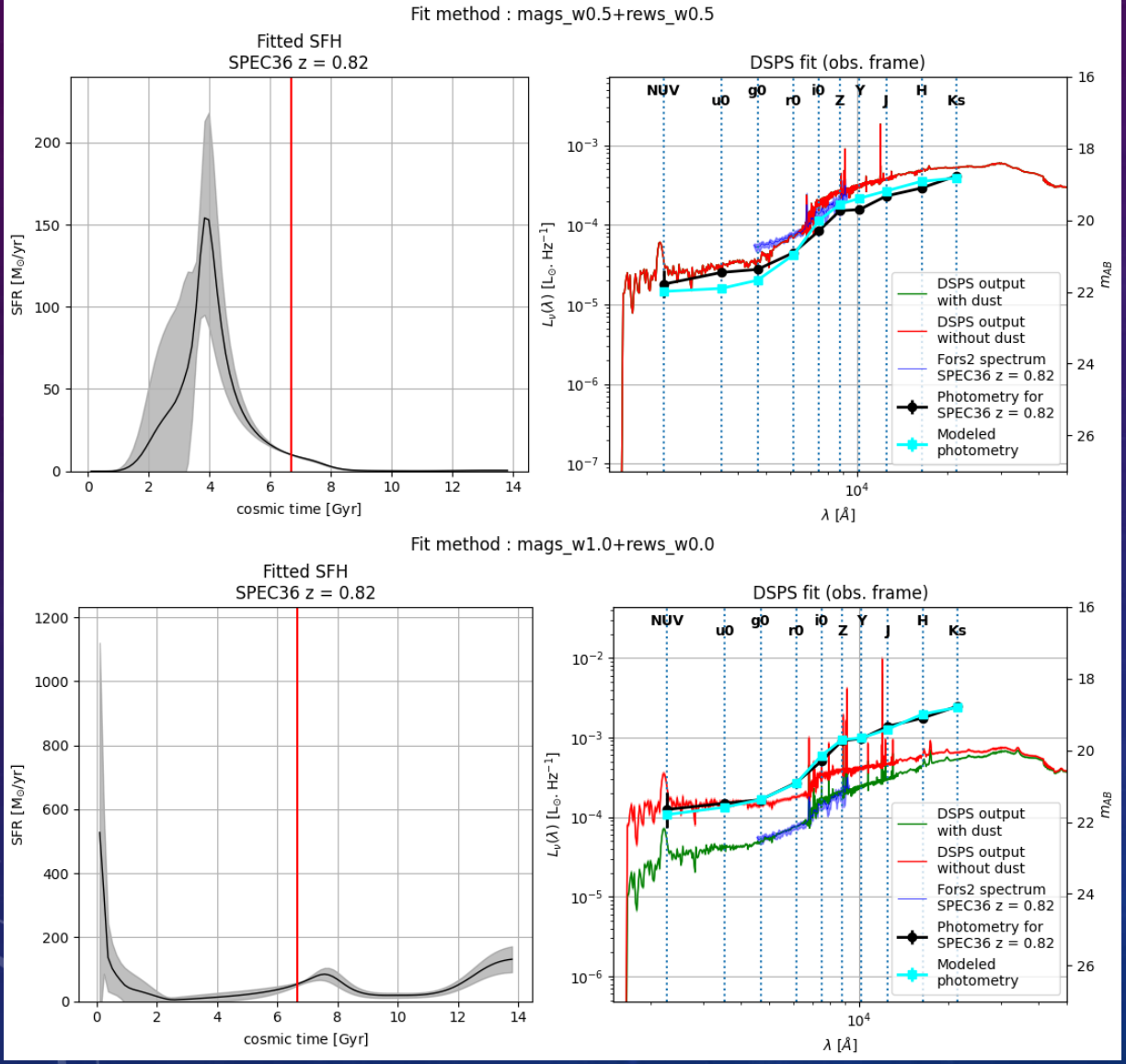
***Issues :***

- We only have raw data in arbitrary units, arbitrary noise estimation
- Spectroscopic redshift, no error estimation
- Narrow wavelength coverage

***Possible solutions :***

- Fit errors to optimize lines ID
- Use other spectra (SDSS, DESI)
- ID lines on SPS-extended spectra + classif. (iterative process)

# CAVEATS – SPS FITTING




***Issues :***

- More parameters to fit than available magnitudes
- Dispersion in resulting SFH and extended spectra

***Possible solutions :***

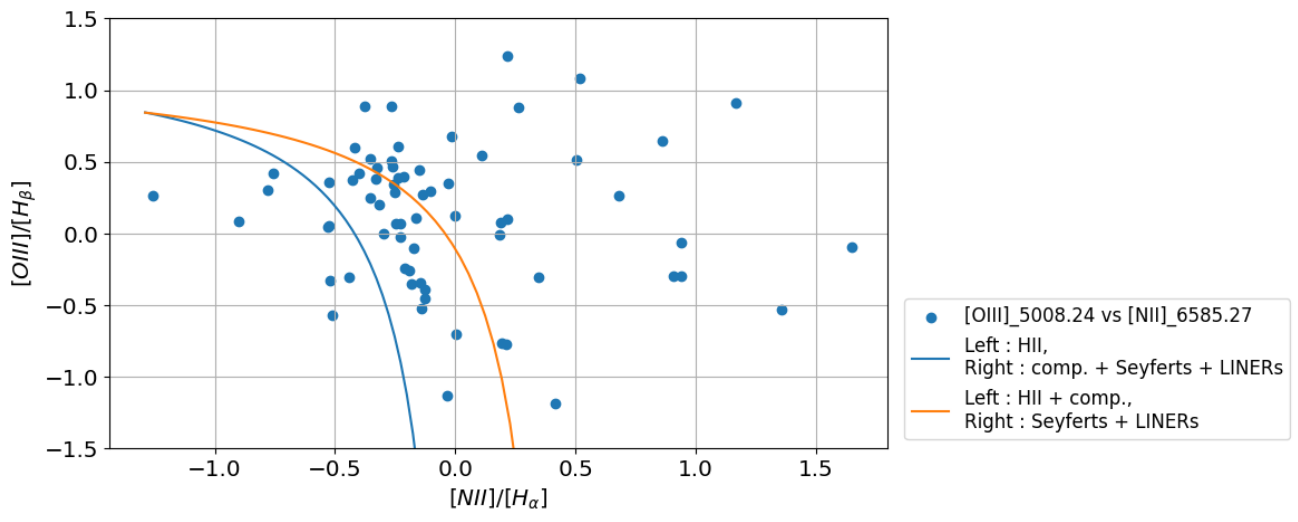
- Add REWs to the process but see previous slide
- Compare several methods (DSPS *vs* CIGALE) and reject bad matches
- Stats/autodiff to quantify the impact of each parameter (heavy computational requirements)

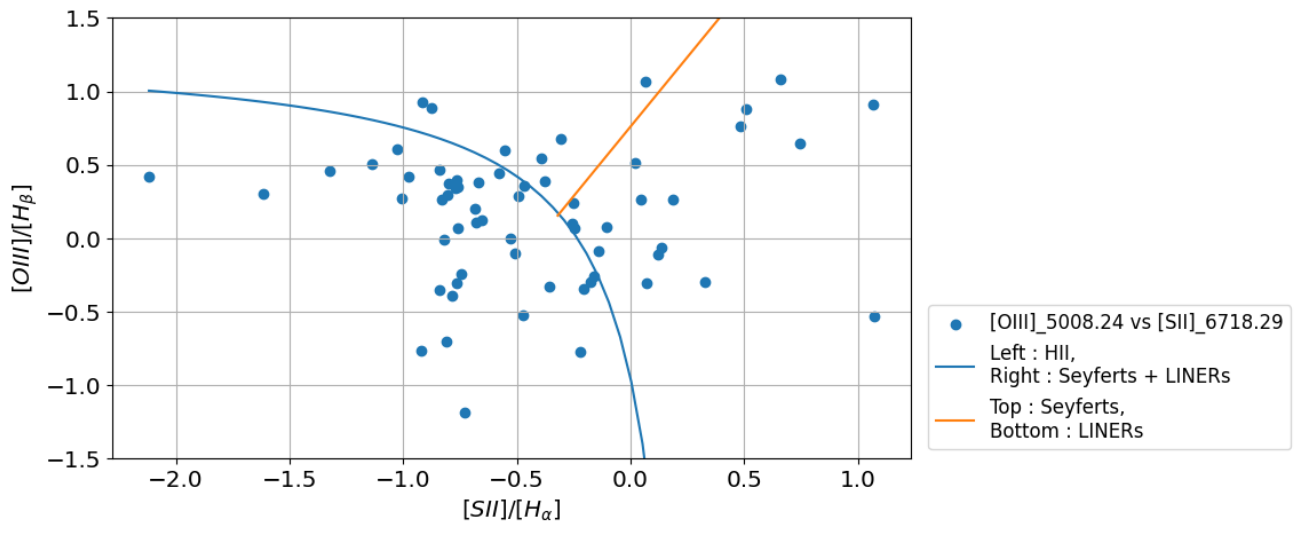
# TAKEAWAYS

- Arbitrary choices due to lack of reliable constraints / generic criteria
- Big dispersion in SFH and UV fluxes between fits on similar data
- Reliable classification of the majority of galaxies is not possible at this stage

+ Methods and tools to combine all sorts of data into SPS
+ Several ways to perform SPS on observed data
+ SED synthesis and selection criteria to use as templates for photo-z
+ Paving the way for future SPS-based photo-z estimator

# LINES ID – BPT CLASSIFICATION




***BPT diagrams (Kewley et al., 2006) :***

- 4 categories (HII regions, LINER, Seyfert, Composite)
- Based on Restframe Equivalent Widths (REW) of spectral lines from GELATO
- Minority of our galaxies due to limited wavelengths coverage
- Several criteria → ambiguous classif.