Relative merits of different types of observations to constrain galaxy physical parameters

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Stephane Charlot, Susan Kassin, Elisabete da Cunha, Sukyoung Yi

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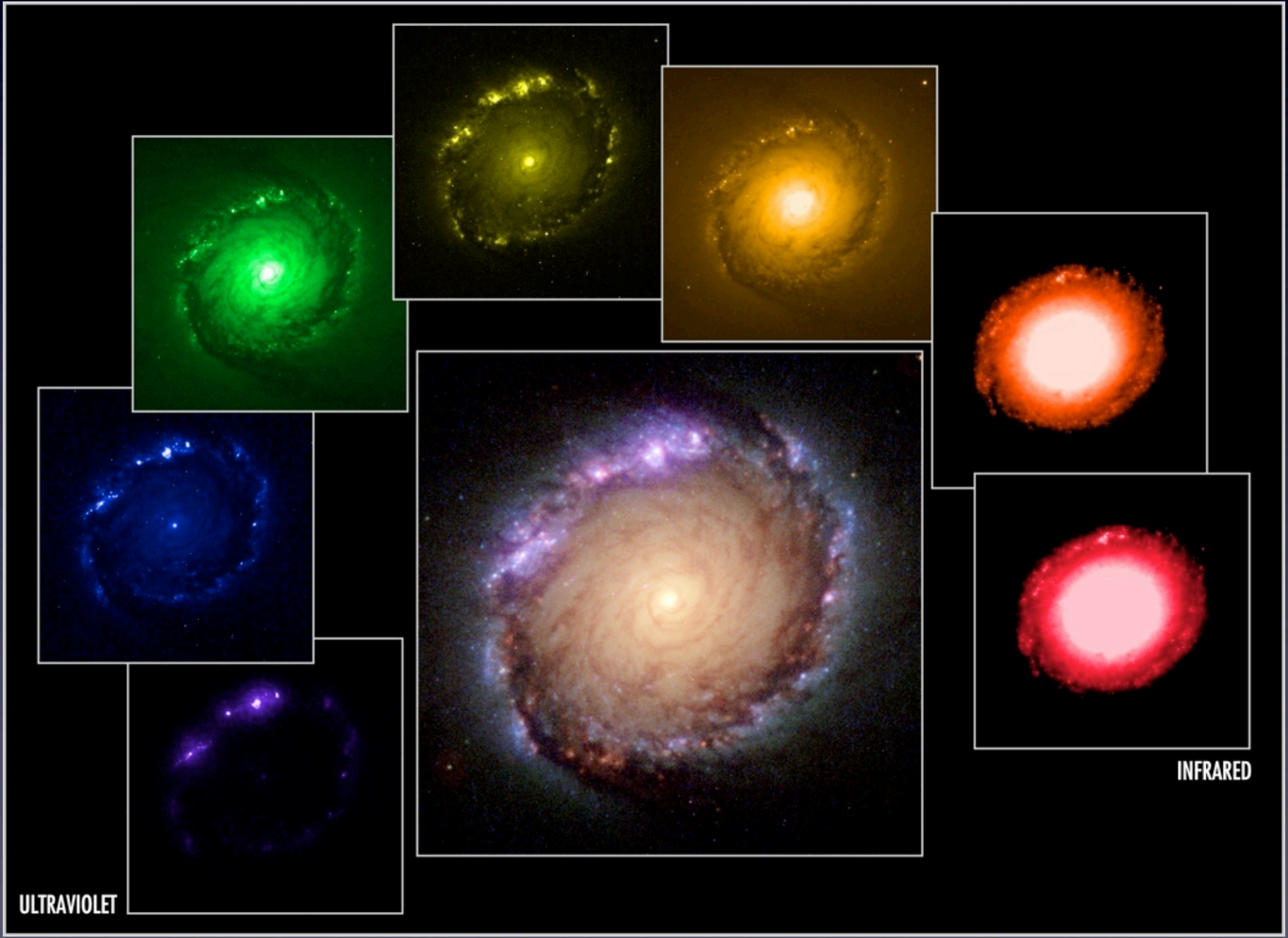
Outline

- Motivation
- Modeling approach
- Assess relative merits of different types of observations to constrain physical parameters
- Current and future applications
    - assessing the star formation histories of DEEP2 galaxies
    - photometry and spectroscopy of 3D-HST galaxies

Motivation

Galaxies...

- how do they form?
- how do they evolve?
- what are they made of?



characterize physical properties of galaxies from their light

Motivation

characterize physical properties of galaxies from their light

- compute the light emitted by stellar populations
- stars are not all of the same age and metallicity
- light from stars excites the gas
  - it re-emits (narrow emission lines)
- light form stars and gas is affected by the dust before it escapes from the galaxy

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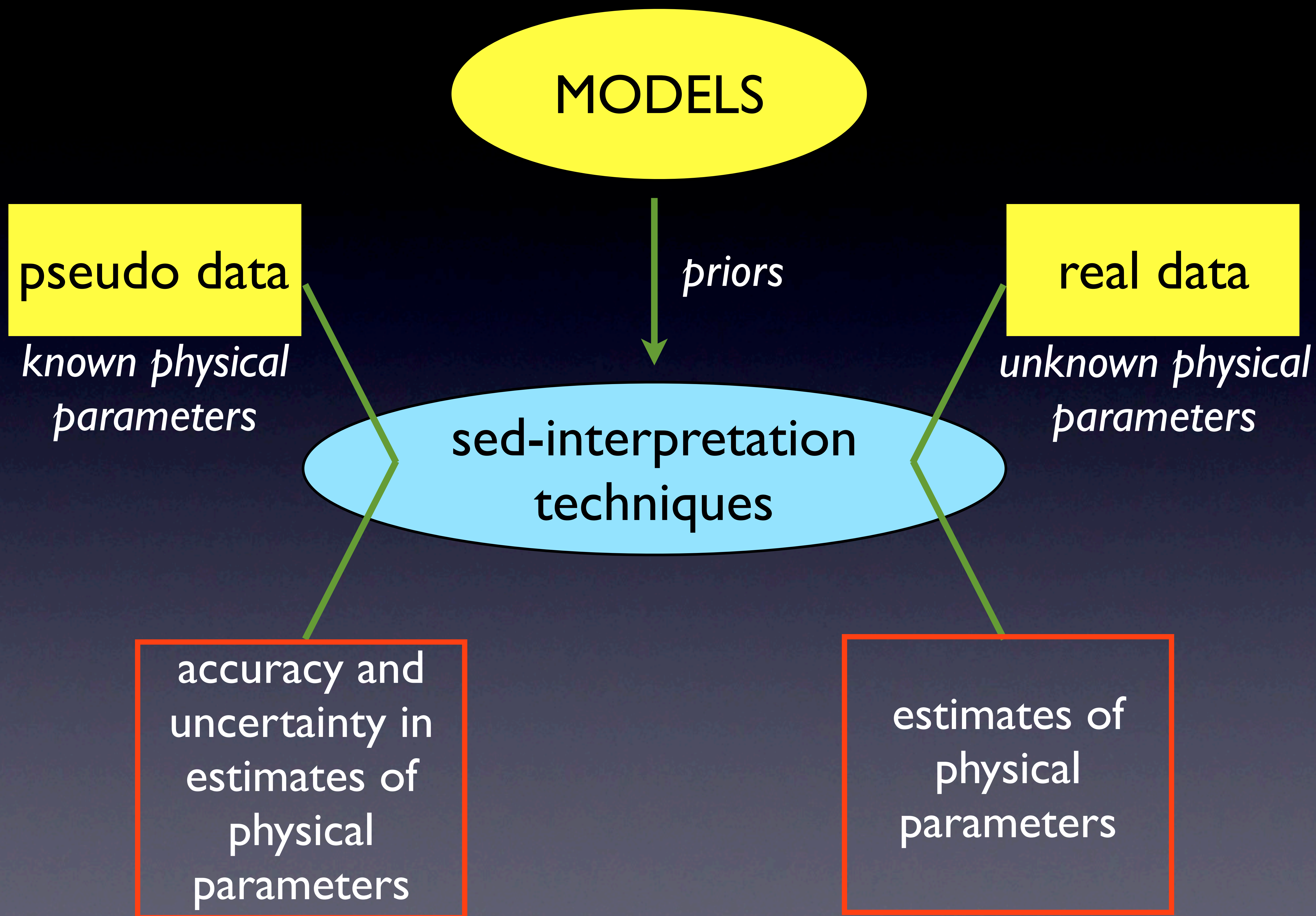
quantify the accuracy to which physical parameters can be extracted from various photometric and spectroscopic observations


MODELS
pseudo data
known physical parameters
priors
real data
unknown physical parameters
sed-interpretation techniques
accuracy and uncertainty in estimates of physical parameters
estimates of physical parameters

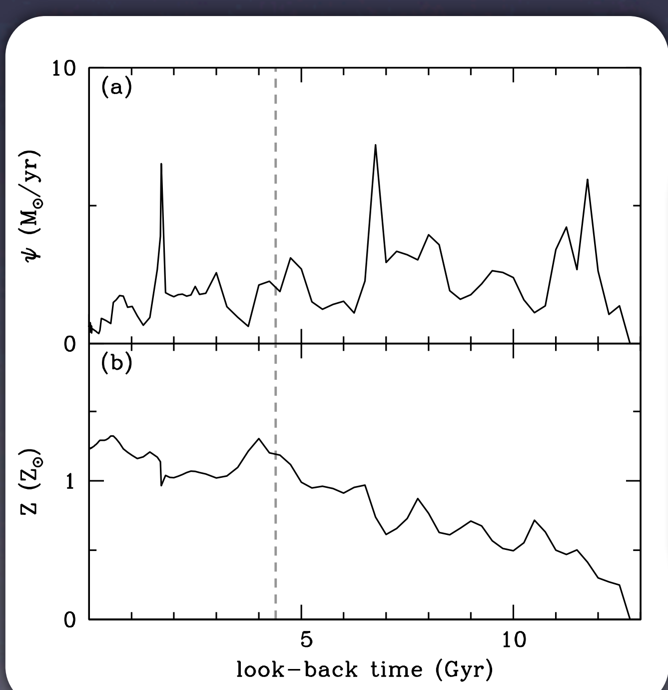
Models

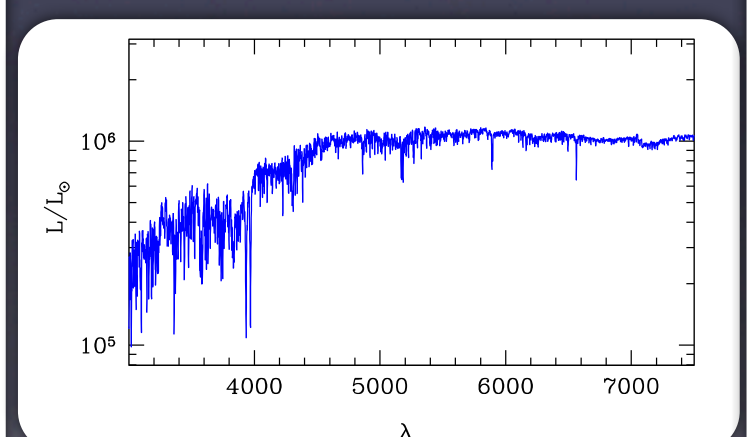
Pacifici et al. (2012), MNRAS

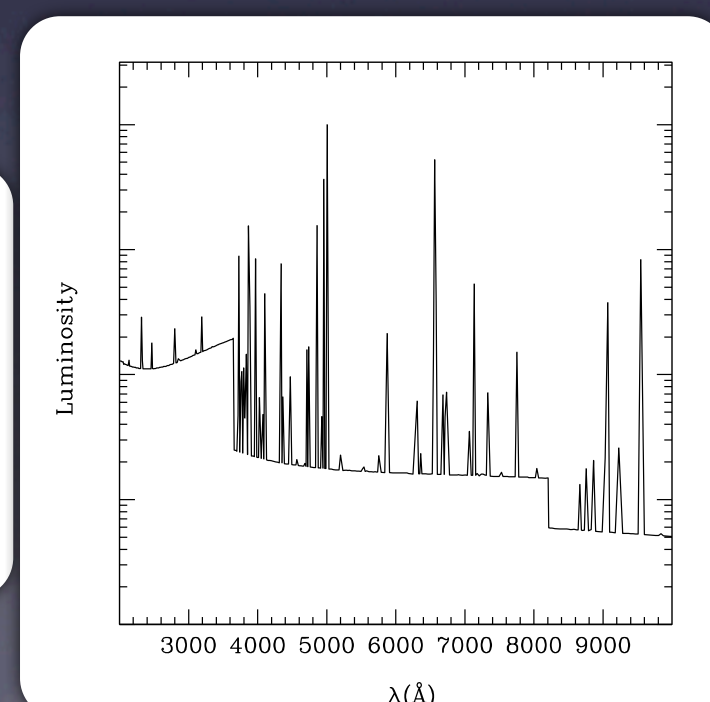
Appeal to state-of-the-art models to include:

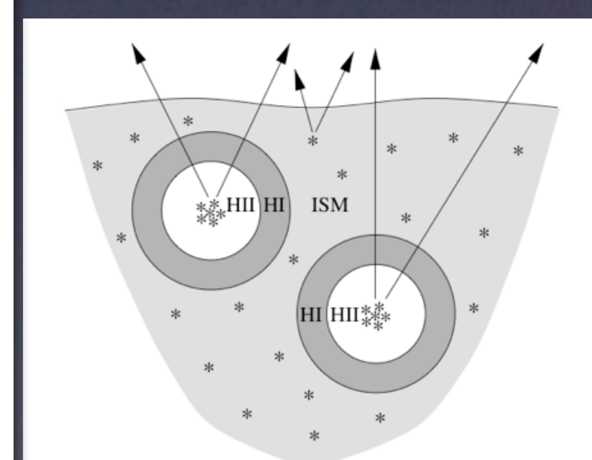
- physically motivated SF and chemical enrichment histories (from simulations)
- latest progress in the spectral modeling of stellar populations
- contamination of stellar emission by nebular emission
- more sophisticated prescriptions for attenuation by dust

(comprehensive range of parameters to account for models uncertainties)









Models

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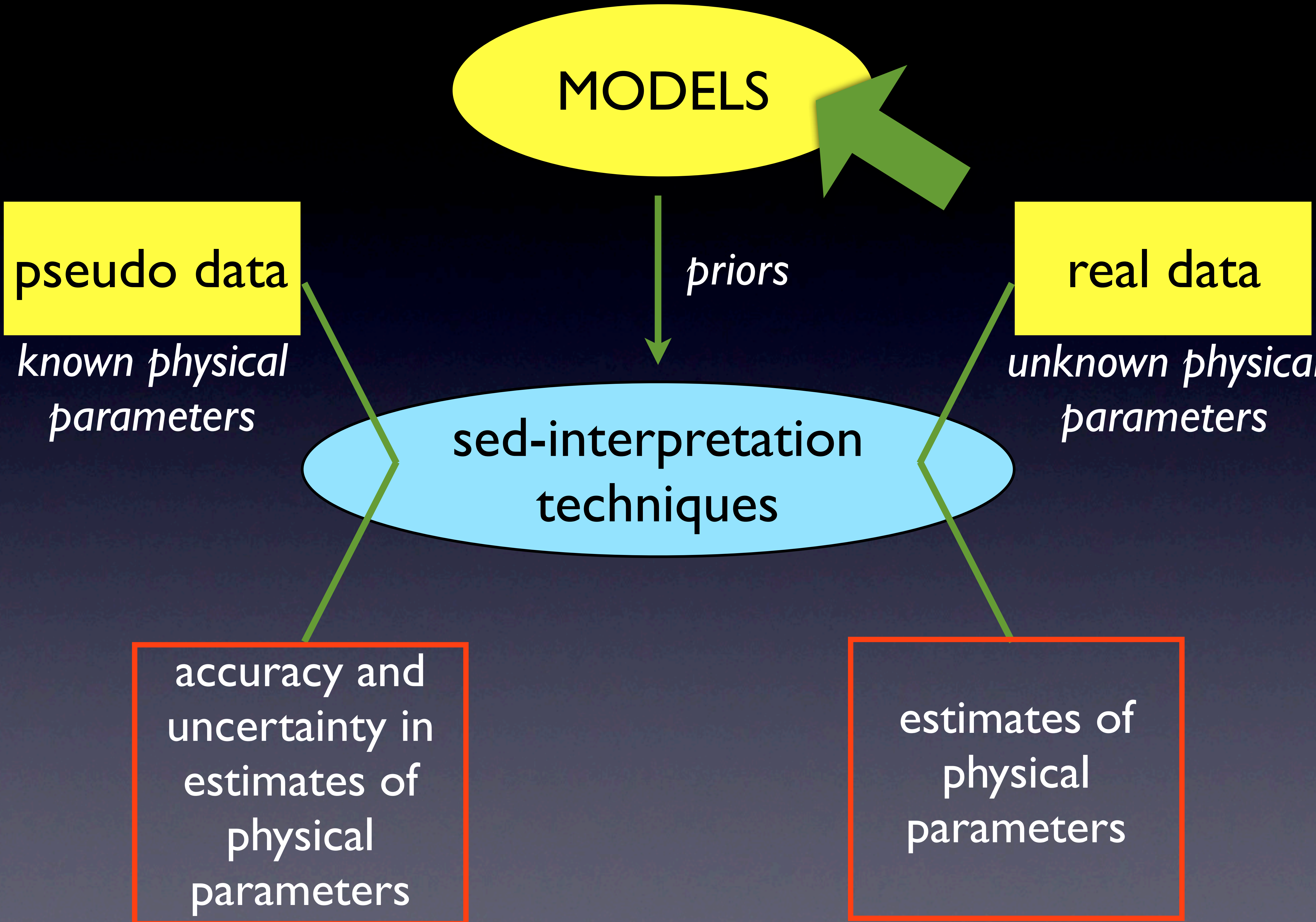
build large library of "as realistic as possible" SEDs to estimate physical parameters from multi-wavelength observations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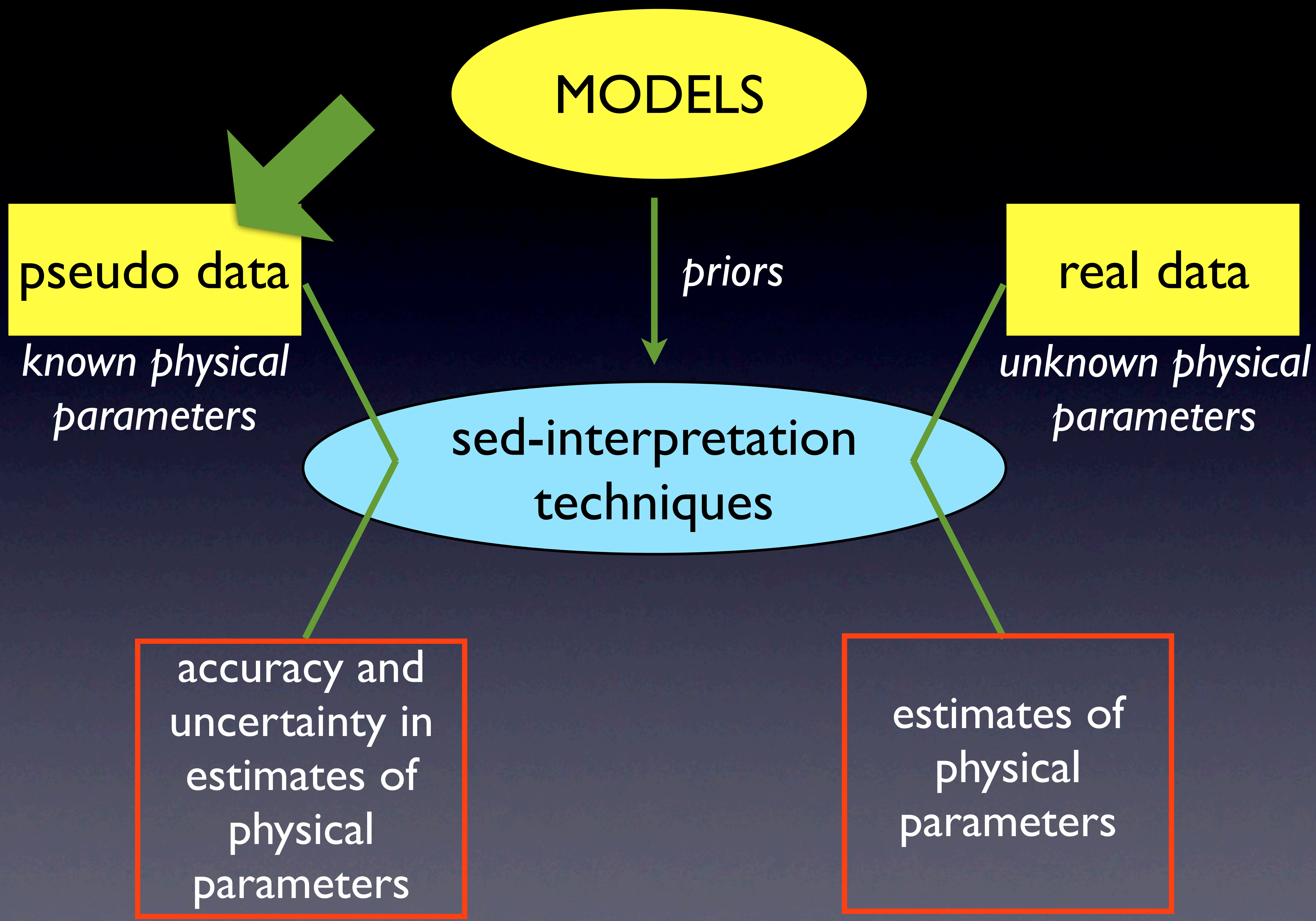

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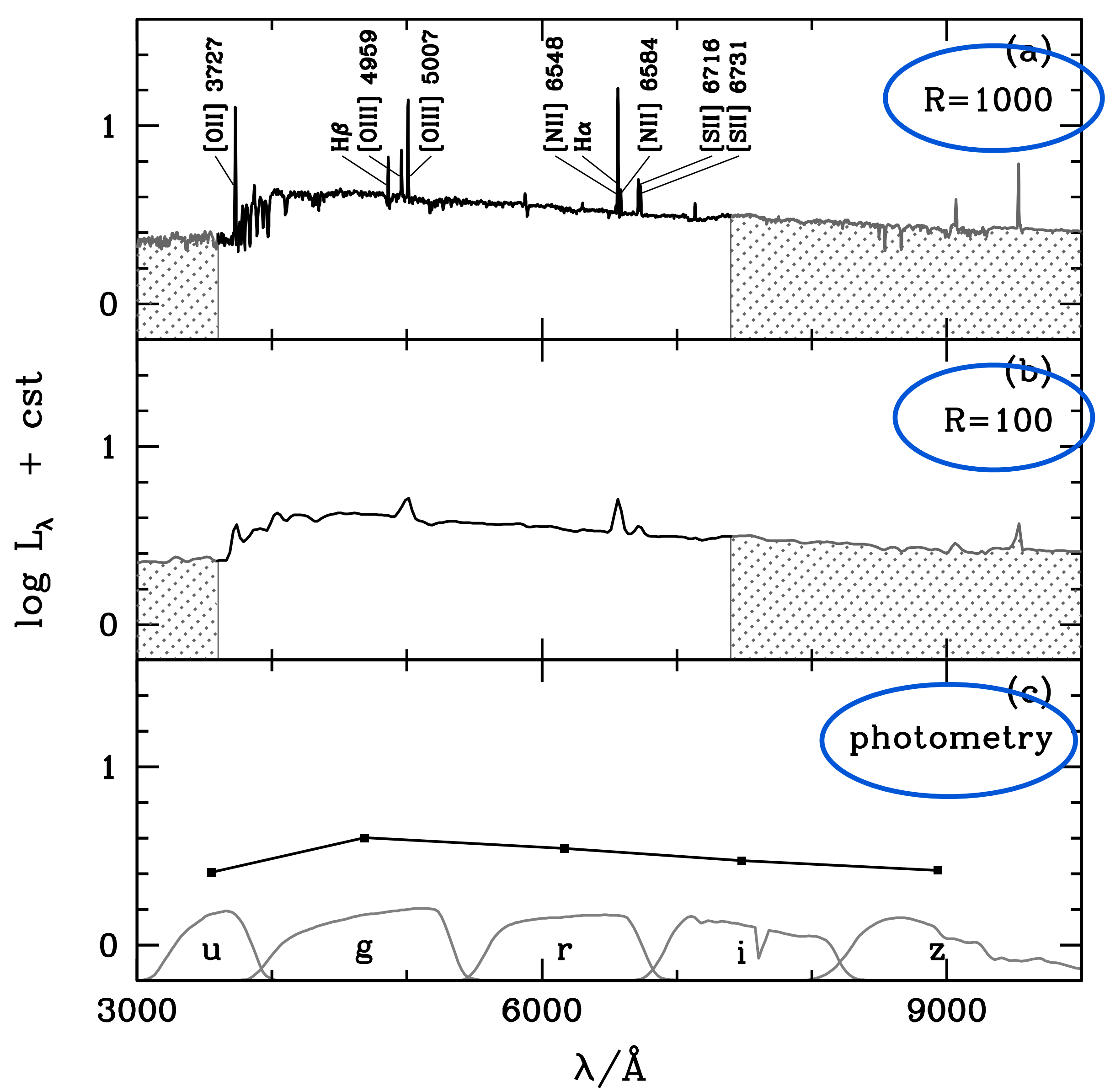
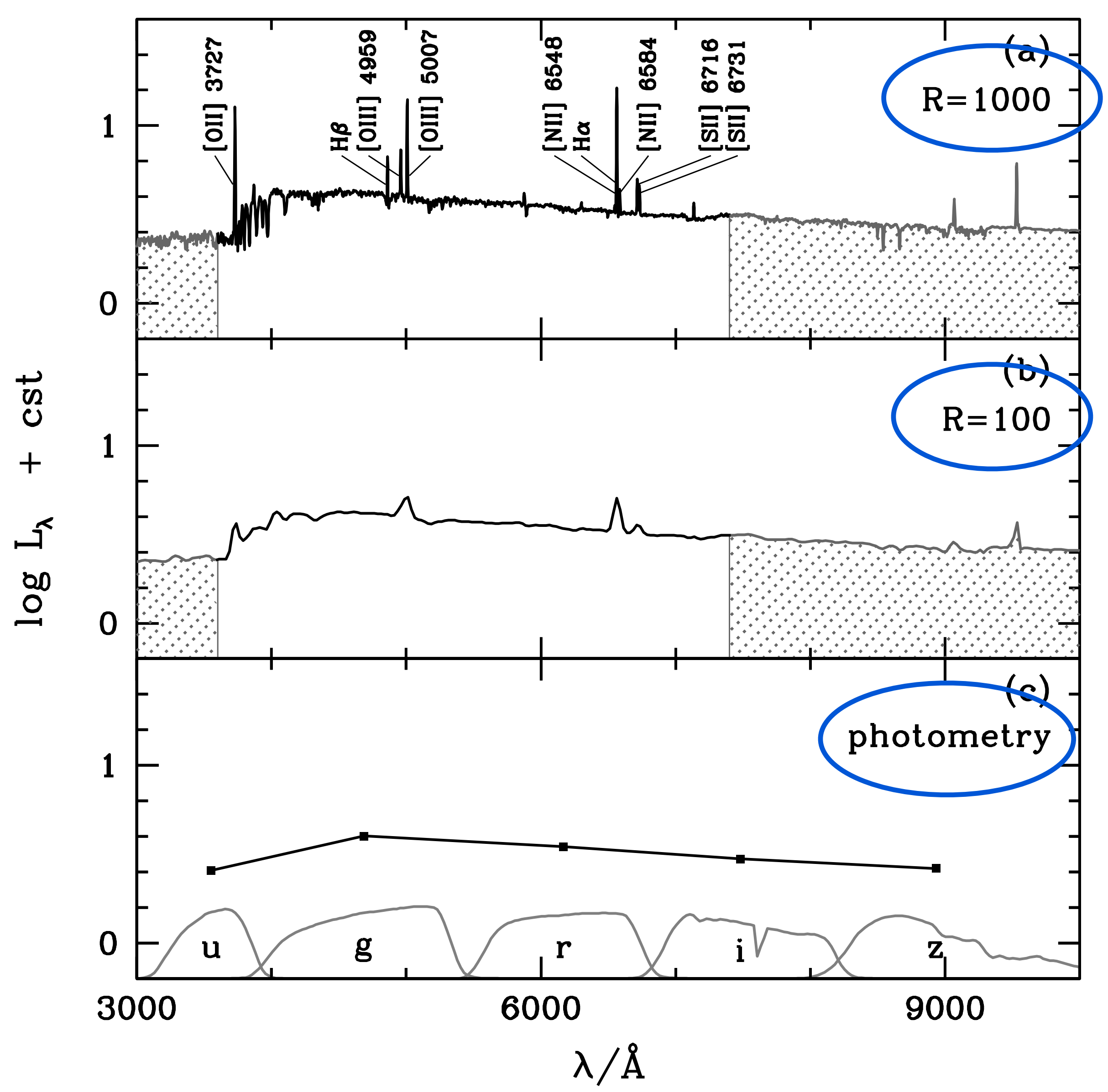
Building pseudo-observations



use these models to generate SEDs of 5 millions galaxies in the library

estimate physical parameters of observed galaxies by comparison with every model in library (Bayesian)

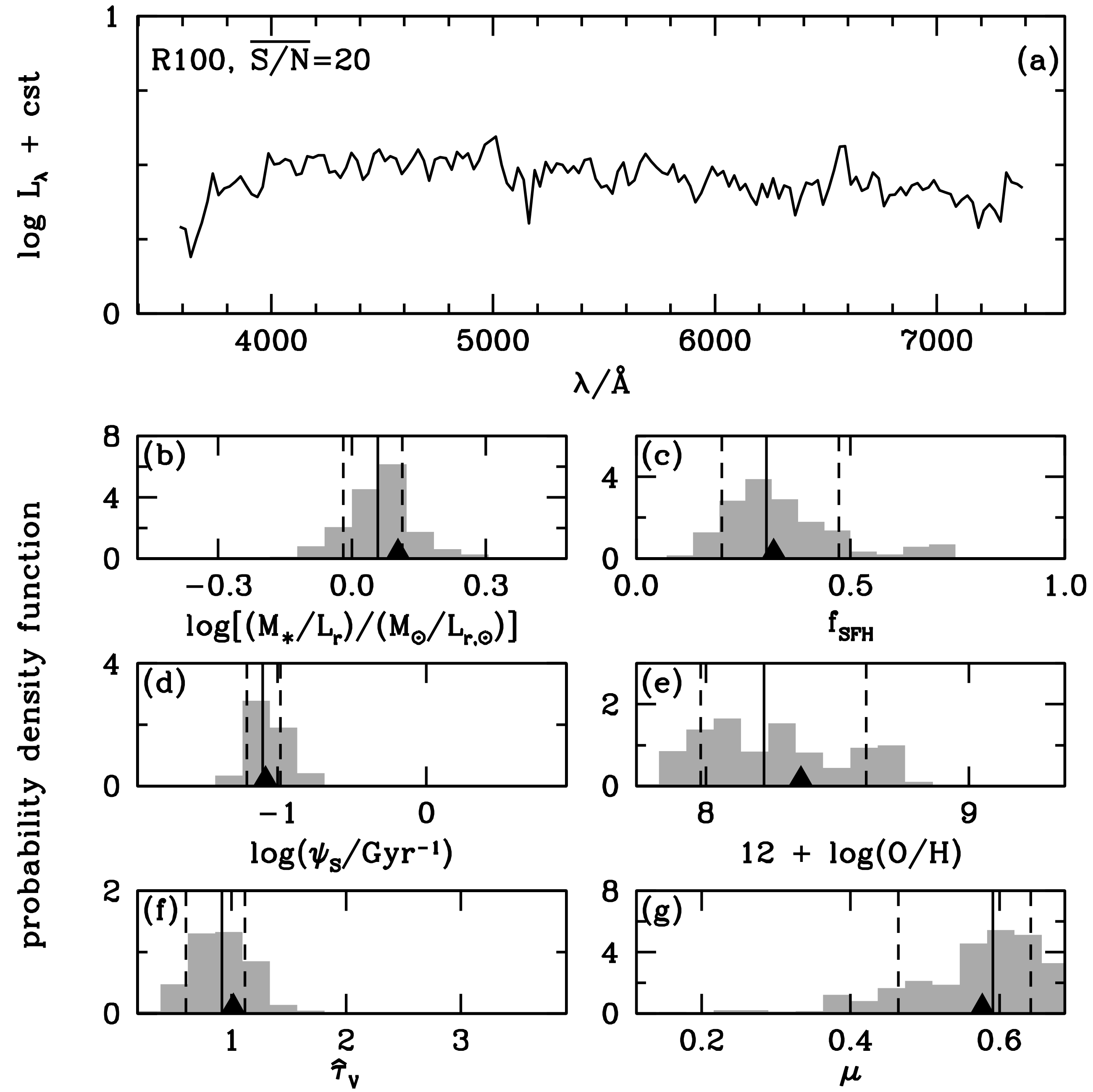
Building pseudo-observations



<u>main feature</u>: stellar continuum and nebular emission fitted simultaneously

estimate physical parameters of observed galaxies by comparison with every model in library (Bayesian)

Example of parameter retrieval



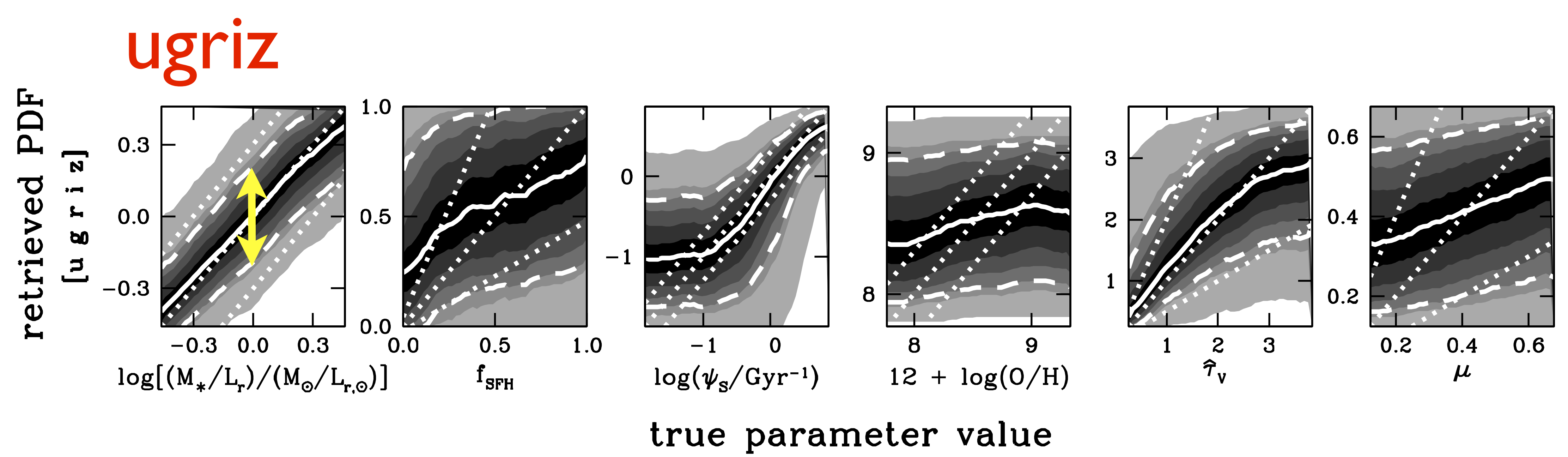
SPECTRAL FIT

rest-frame optical spectrum
S/N~20, R=100

- mass-to-light ratio
- fraction of stellar mass formed in the last 2.5 Gyr
- specific SFR
- gas-phase oxygen abundance
- dust attenuation optical depth
- fraction dust in the ISM

Parameter retrieval from different types of observations

broad-band photometry *ugriz*
S/N=30
5,000,000 models, 10,000 pseudo-observation

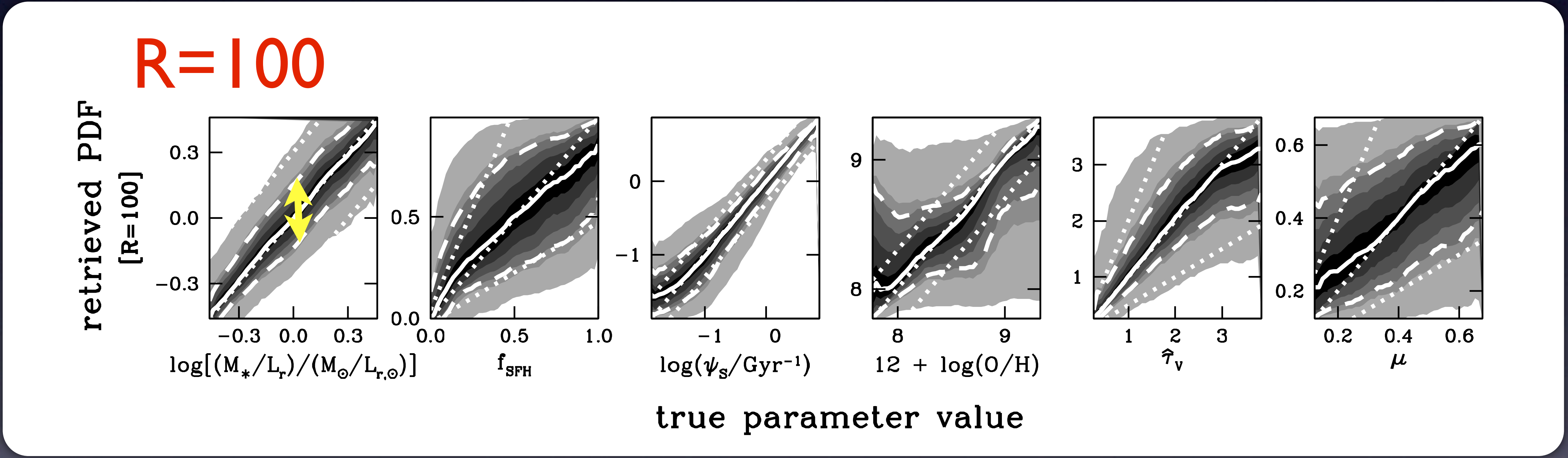


16% - 84% confidence interval

(50% median = best estimate)

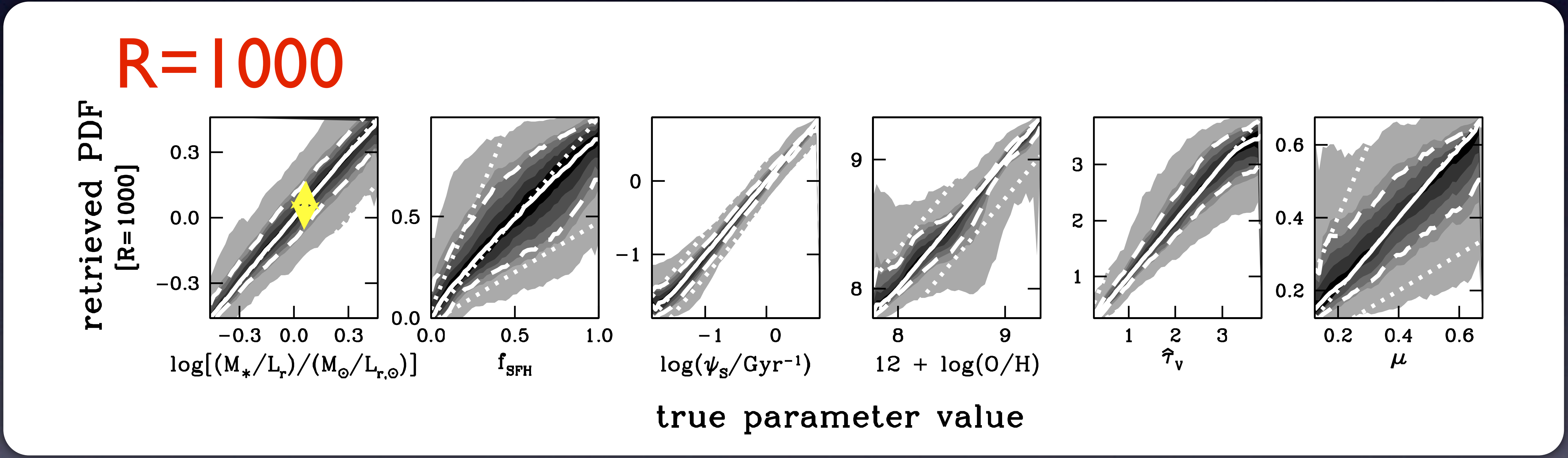
Parameter retrieval from different types of observations

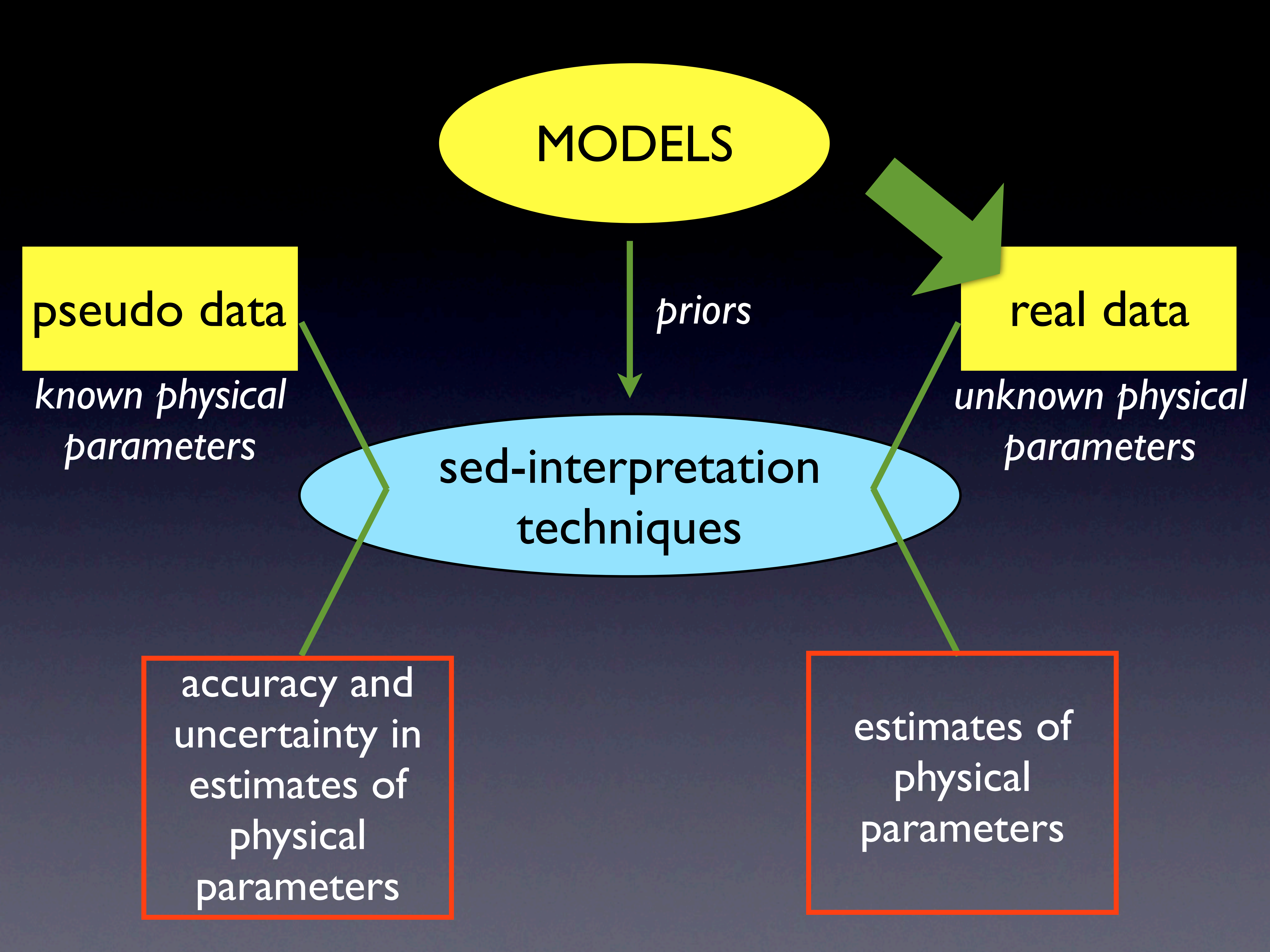
spectral fit low-resolution (R=100, FWHM=50 Å)
S/N=20
5,000,000 models, 10,000 pseudo-observation



Parameter retrieval from different types of observations

spectral fit medium-resolution (R=1000, FWHM=5 Å)
S/N=20
5,000,000 models, 10,000 pseudo-observation

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Current applications

- apply this approach to the analysis of different types of observations across the wavelength range covered by spectral evolution models
    - ★ $0.2 < z < 1.4$ DEEP2 galaxies - photometry & emission lines
    - ★ $0.7 < z < 3.5$ 3D-HST galaxies - photometry & grism spectroscopy

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The SFH of galaxies at z<1.4

DEEP2

combine photometric and spectroscopic observations to assess the "*shape*" of the star formation history for different galaxy stellar masses and redshifts

Pacifici et al. (submitted)

with Susan Kassin, Jonathan Gardner, Ben Weiner

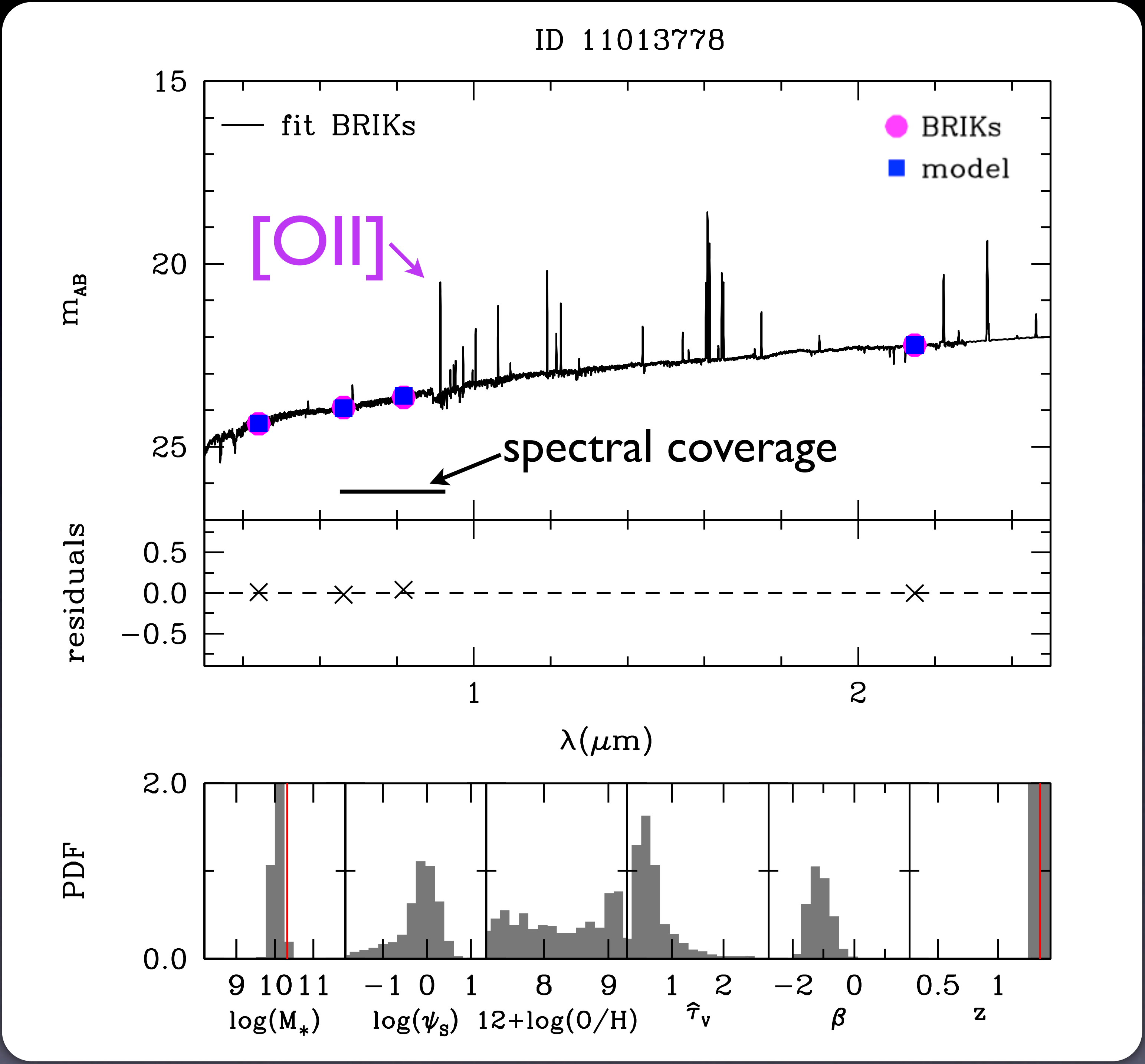
The SFH of galaxies at z<1.4

DEEP2

B R I K_S

emission-line measurements

redshift



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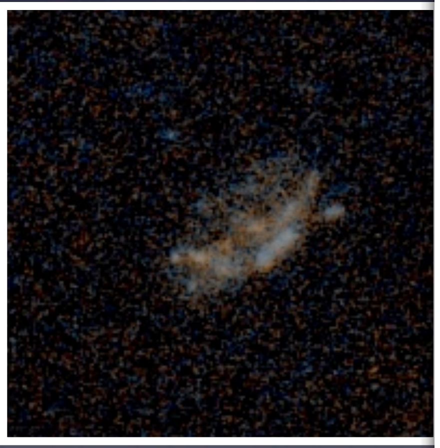
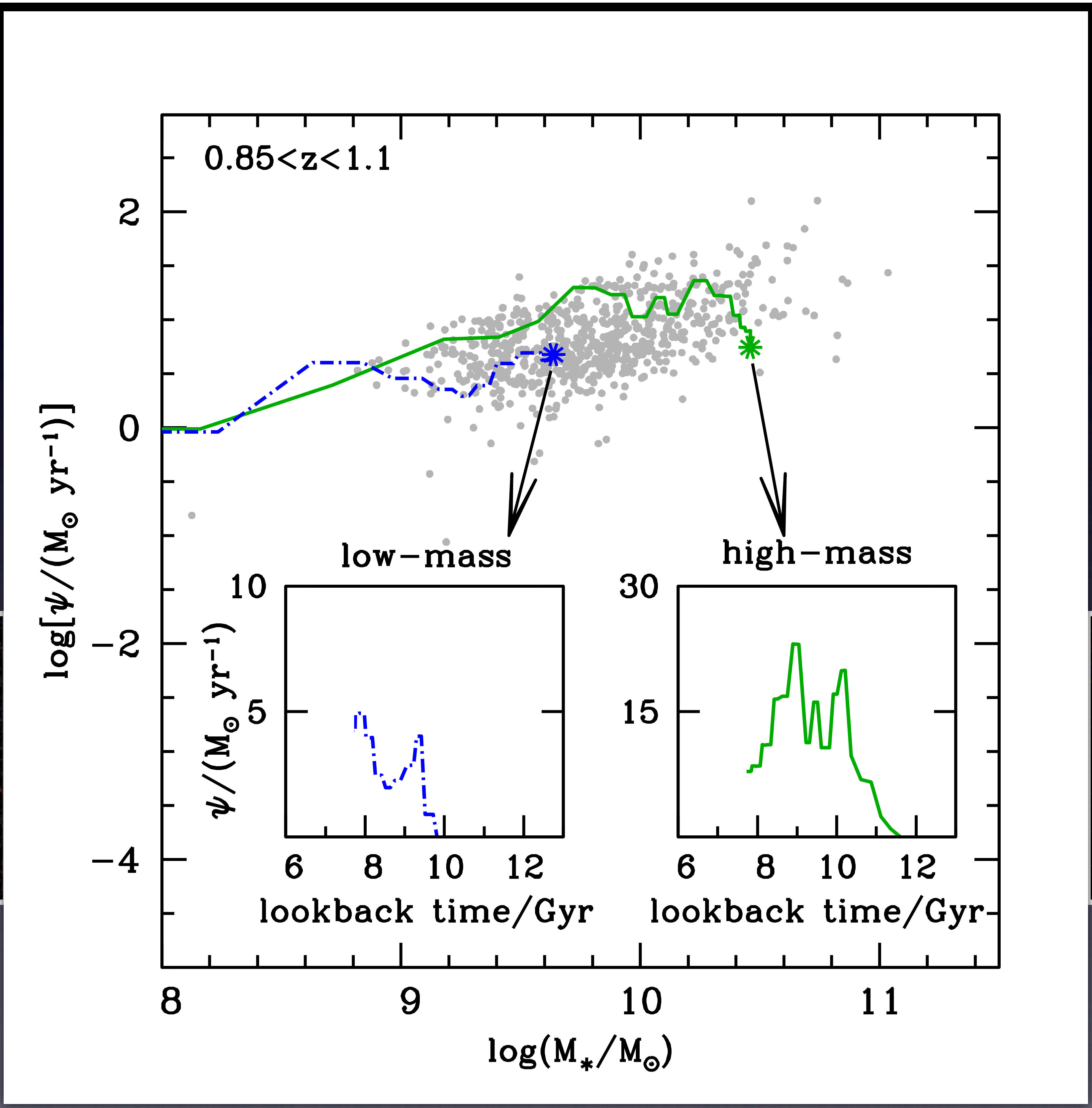
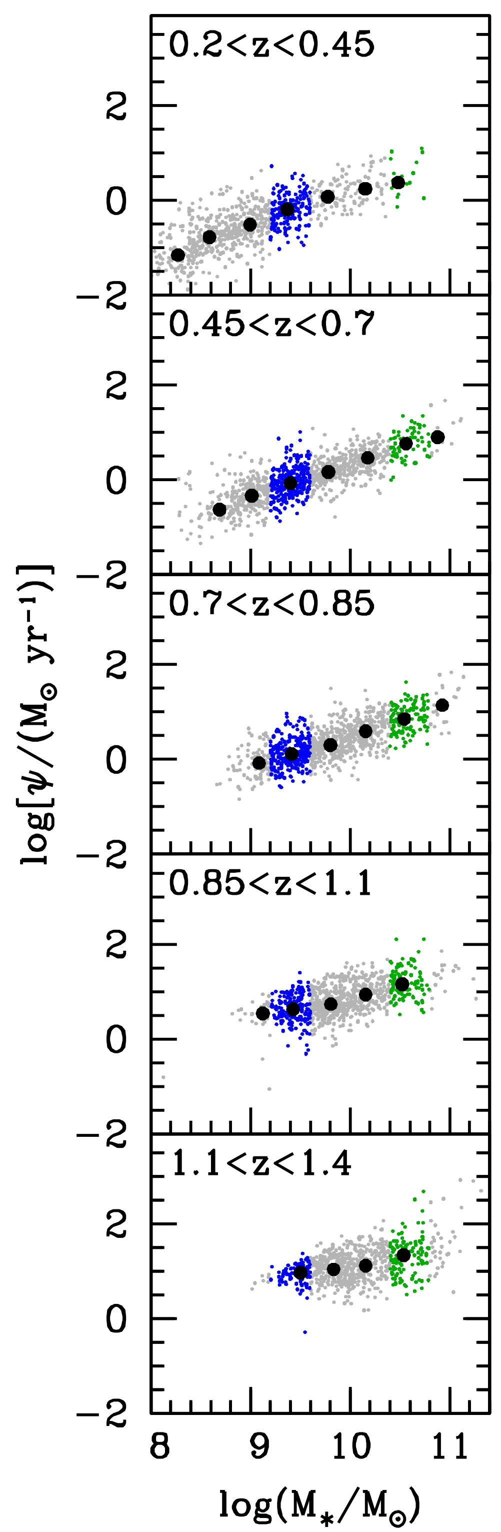


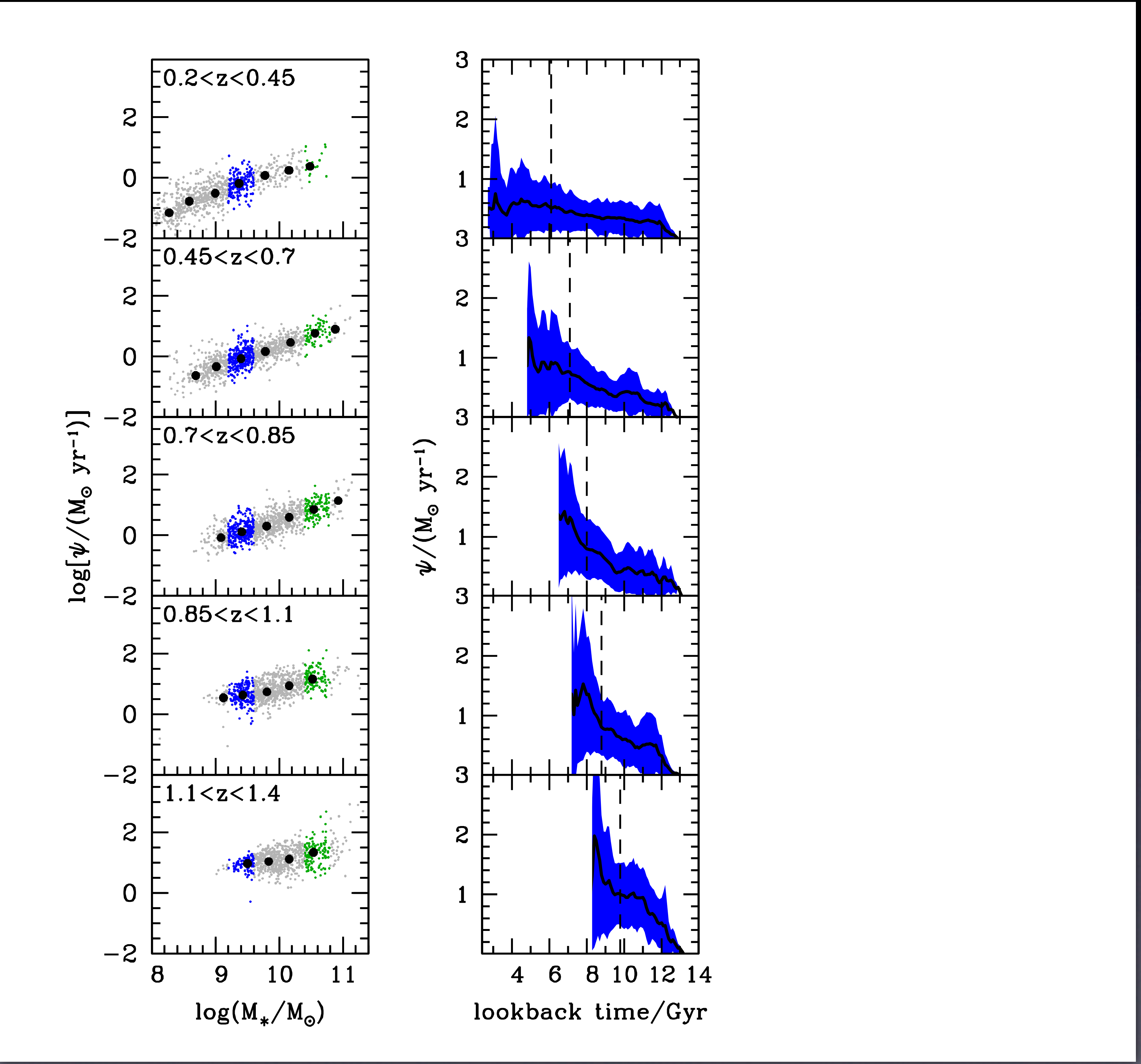


The SFH of galaxies at z<1.4



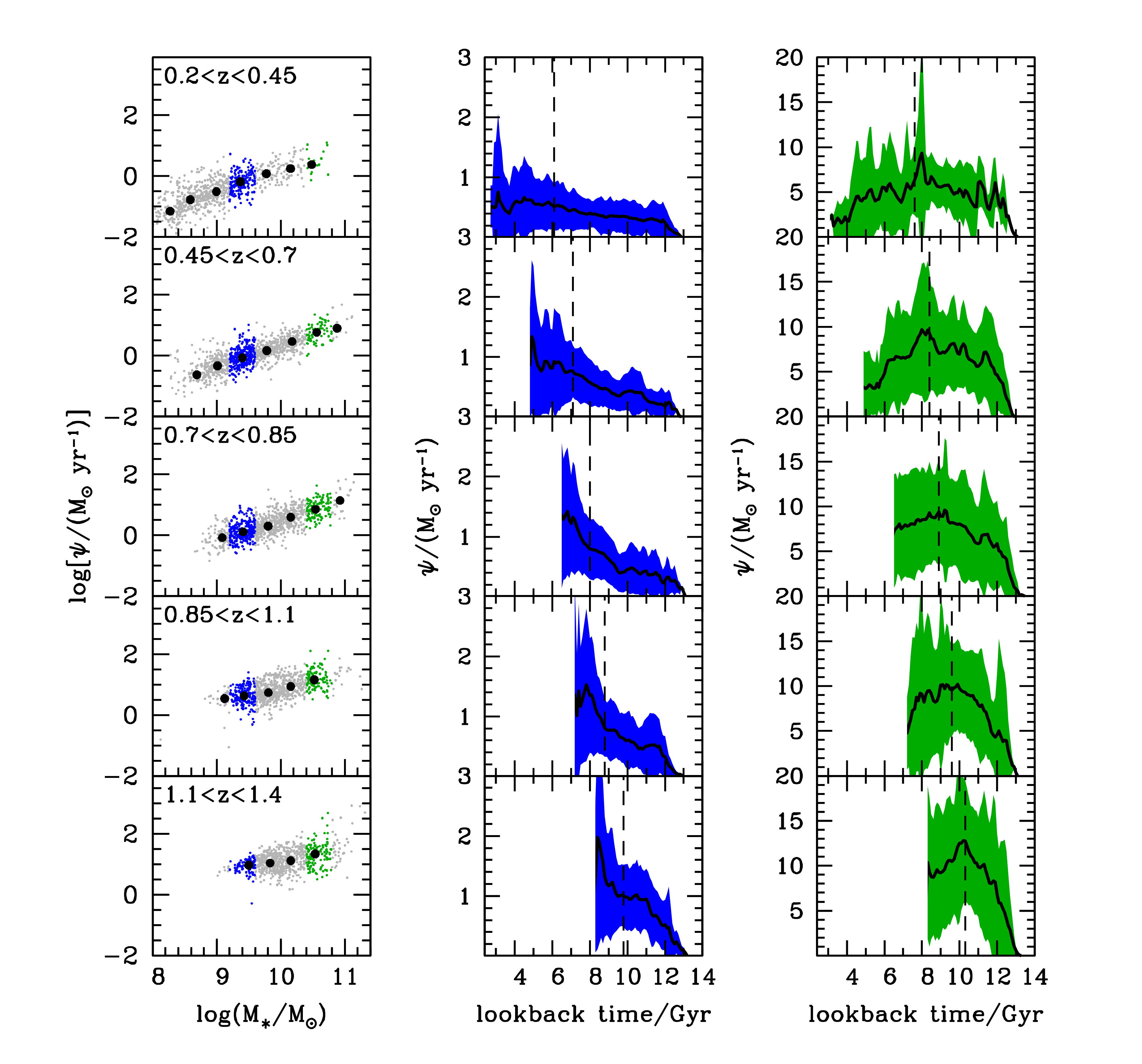
SFR
vs
stellar mass

The SFH of galaxies at z<1.4



low-mass galaxies: rising SFH

The SFH of galaxies at z<1.4



low-mass galaxies: rising SFH

high-mass galaxies: bell-shaped SFH

Current applications

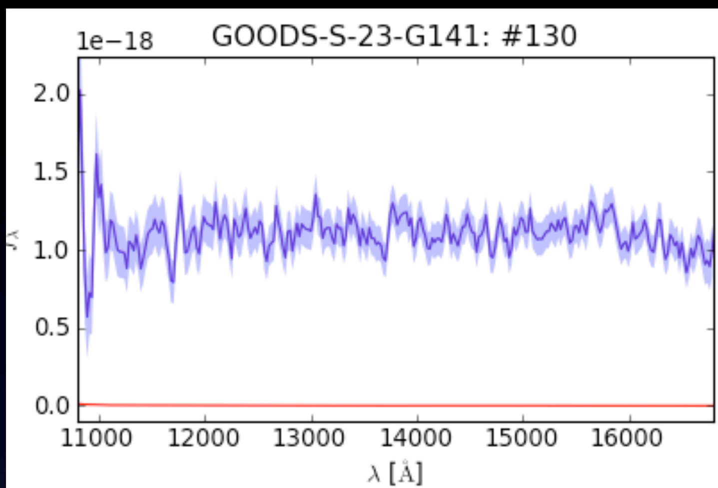
- apply this approach to the analysis of different types of observations across the wavelength range covered by spectral evolution models
    - ★ $0.2 < z < 1.4$ DEEP2 galaxies - photometry & emission lines
    - ★ $0.7 < z < 3.5$ 3D-HST galaxies - photometry & grism spectroscopy

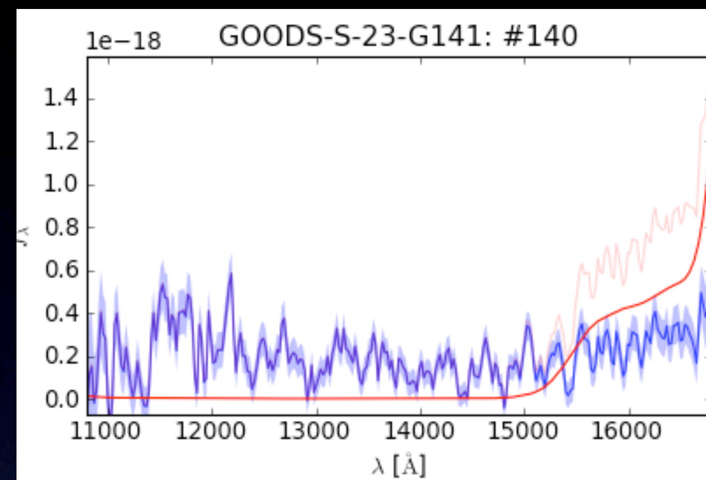
3D-HST galaxies (0.7<z<3.5)

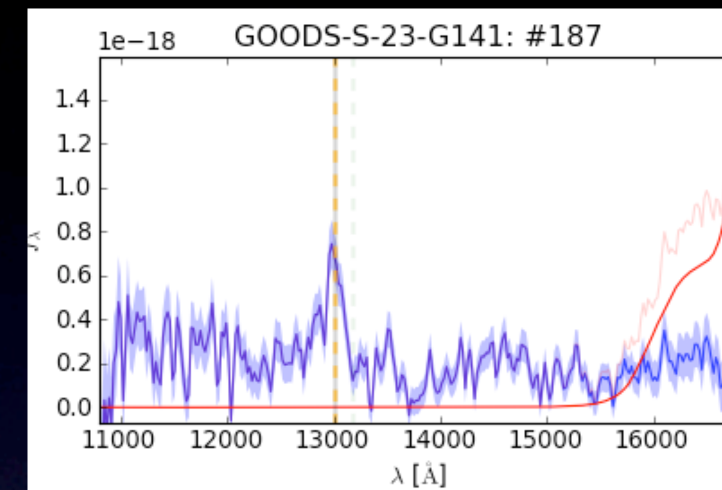
- available UV to FIR photometry and grism spectroscopy in the range 1.1 to 1.6 µm
- combine photometry and spectroscopy to improve constraints on physical parameters: mass, star formation rate, dust optical depth
    - MIR & FIR photometry using da Cunha et al. models (MAGPHYS)

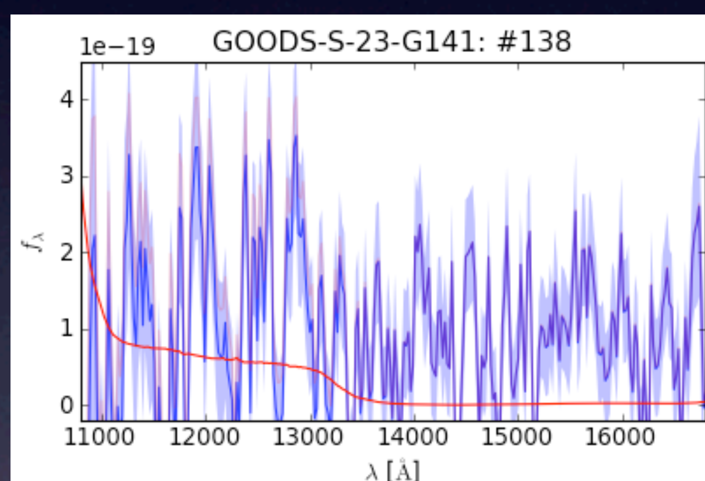
Elisabete da Cunha (MPIA), **Hans-Walter Rix** (MPIA)

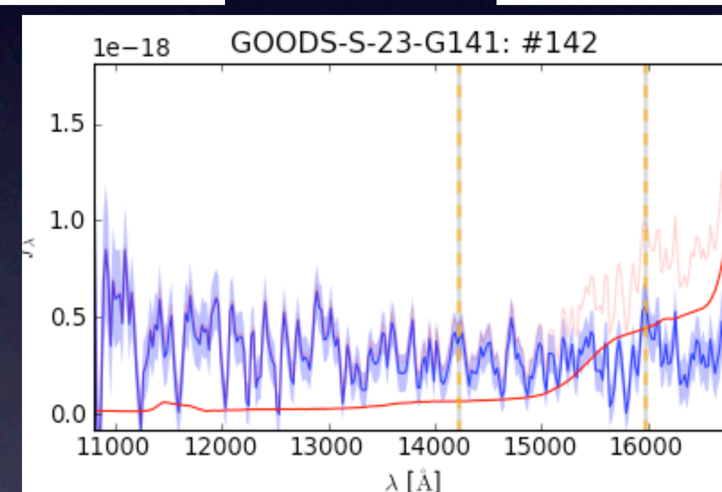
3D-HST galaxies (0.7<z<3.5)

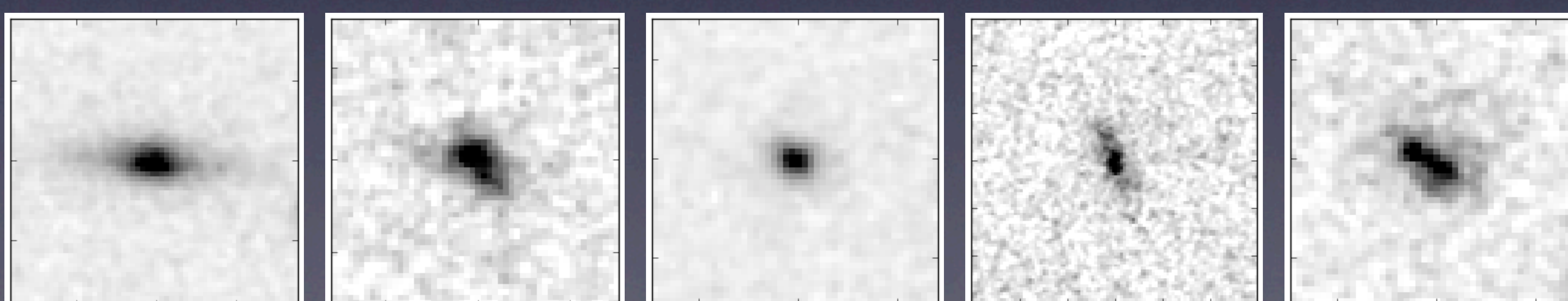








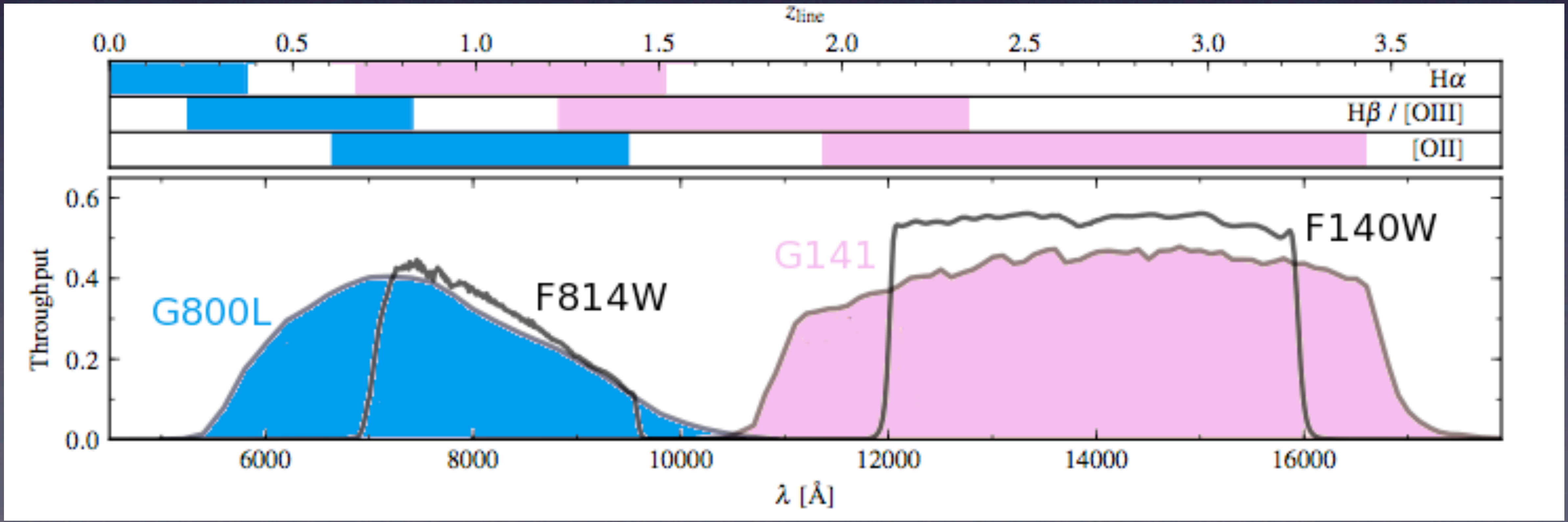




3D-HST galaxies (0.7<z<3.5)

Spectrum calibration is a tricky issue: we can use equivalent width instead of complete spectrum

- ★ build a library which includes consistently nebular emission AND dust emission
- ★ fit photometry + equivalent width of emission lines ([OII], Hβ, [OIII] and Hα)



Brammer et al. 2012

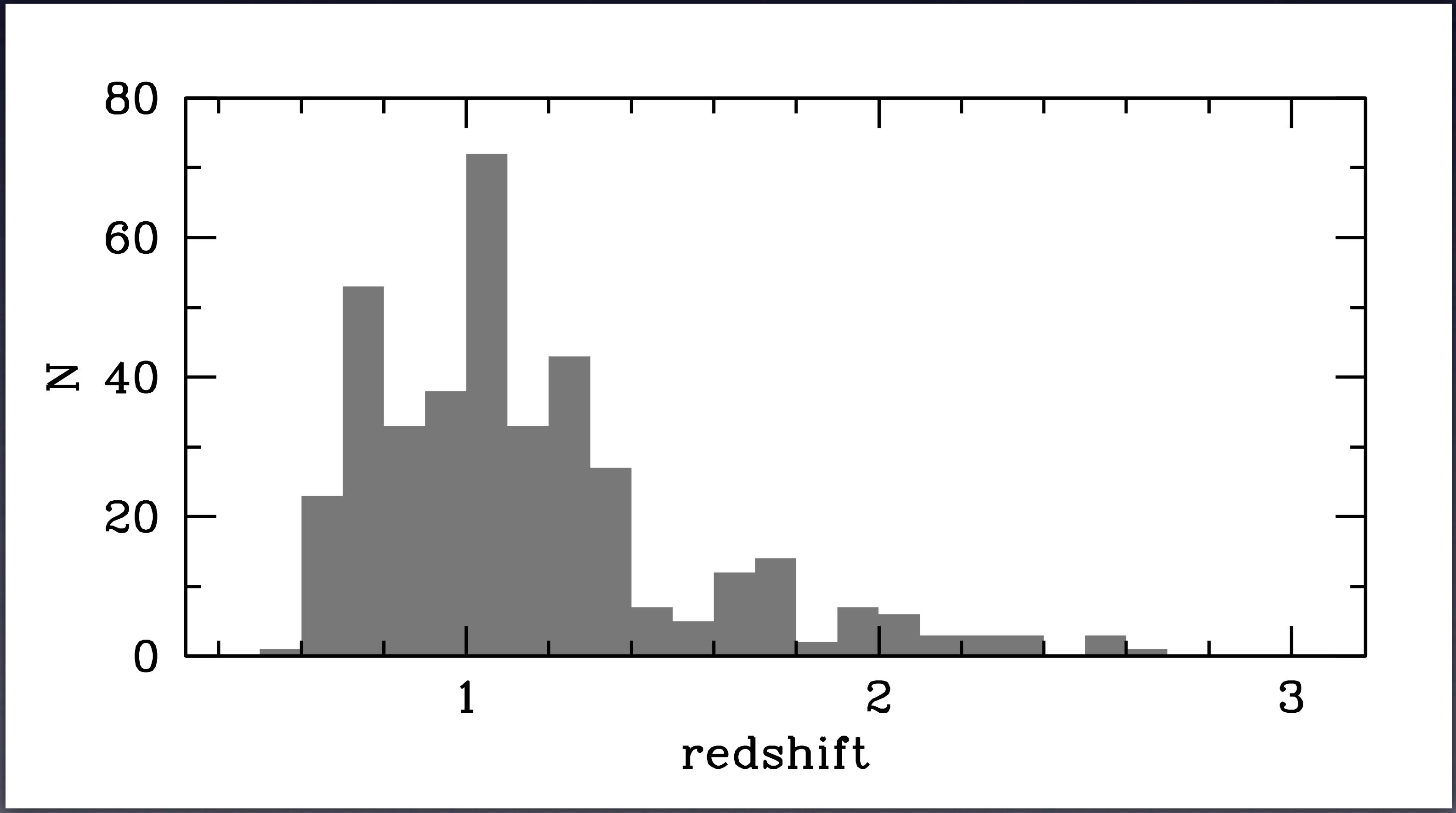
3D-HST galaxies (0.7<z<3.5)

Sample selection: galaxies selected by the quality of the spectra. Required detection of at least one emission line with EW>10 and S/N>2.

398 galaxies in GOODS-South

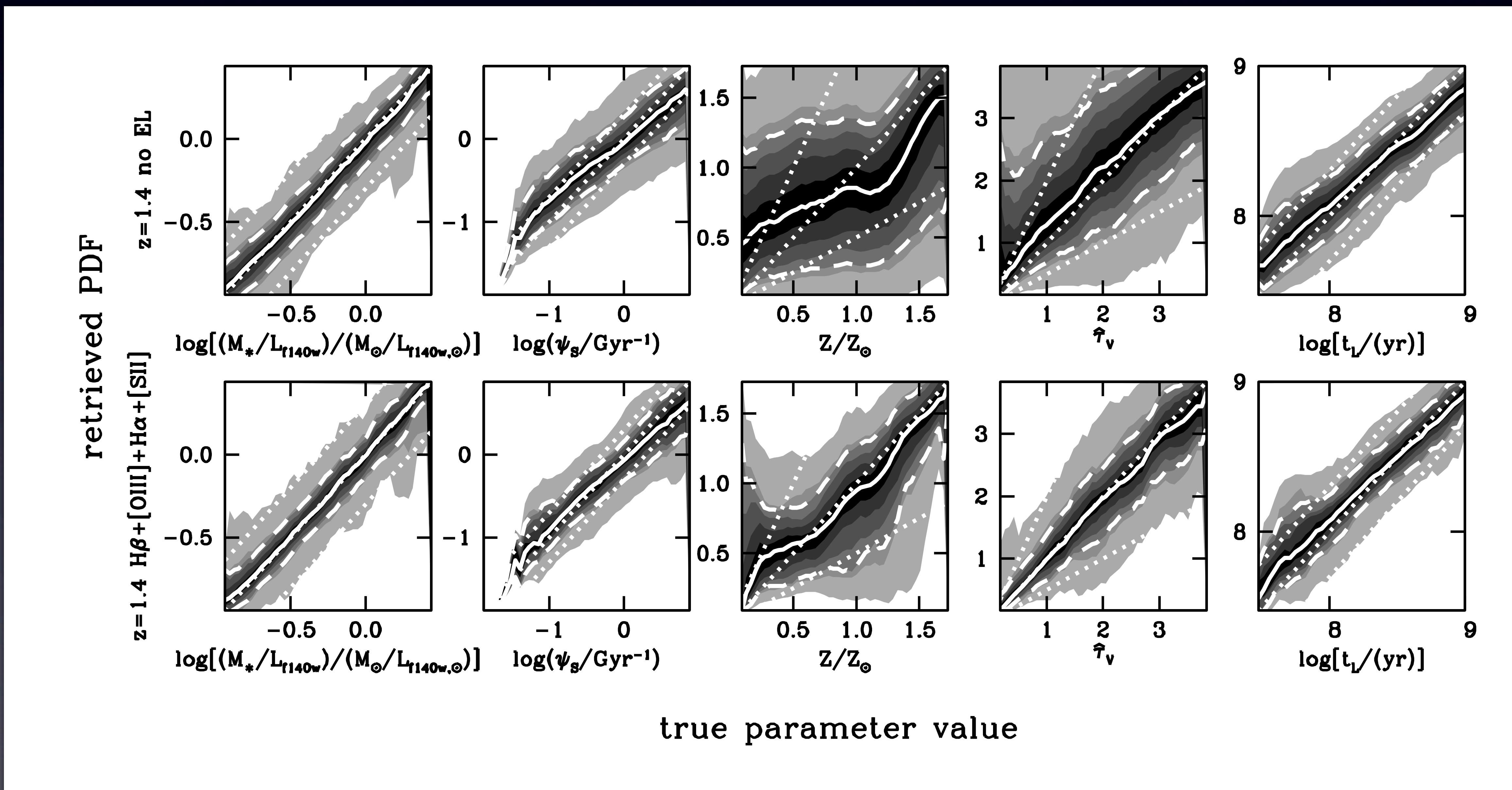
photometry form UV to IRAC 8μm

redshift



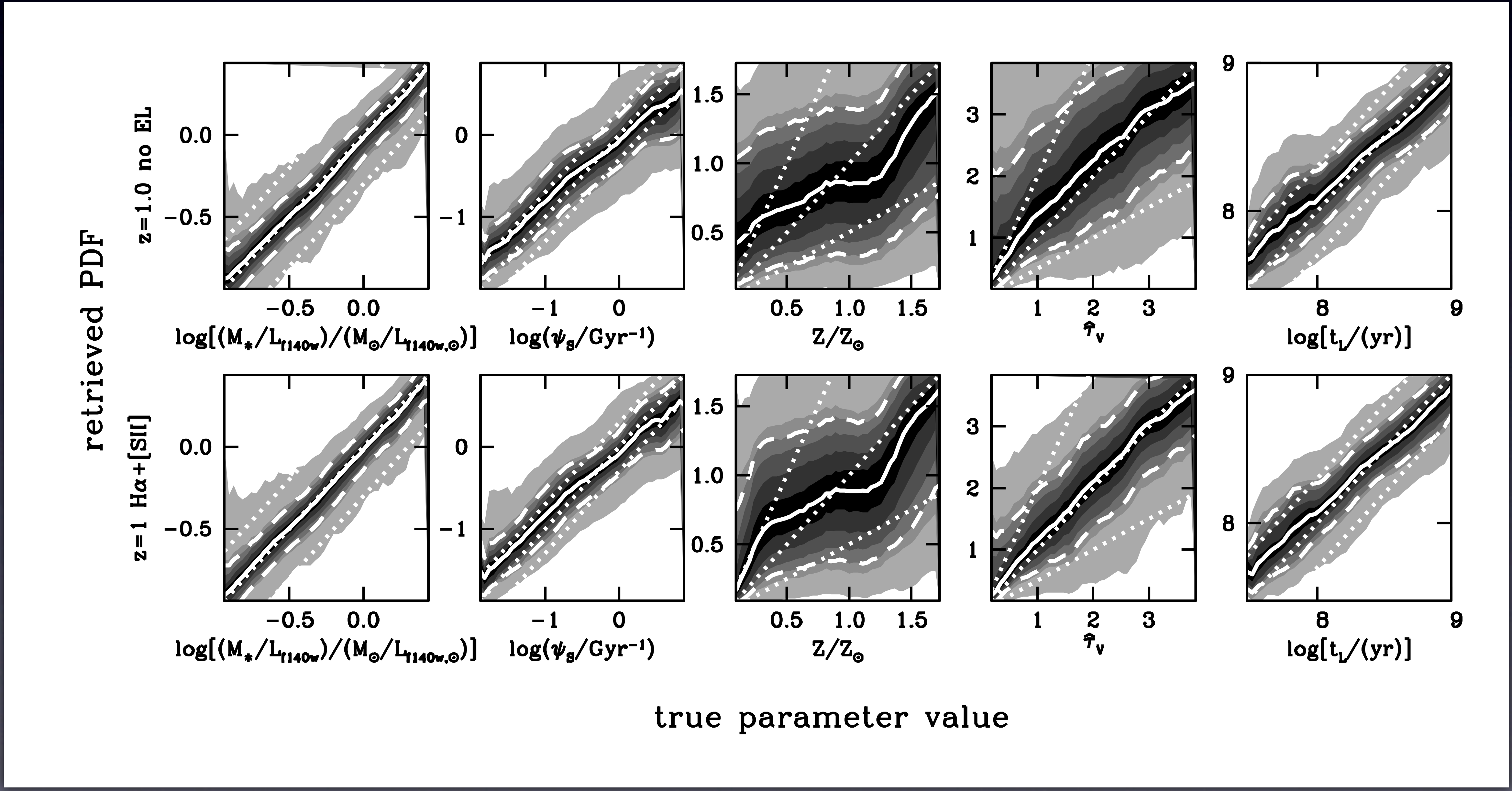
3D-HST galaxies (0.7<z<3.5)

Best case: UV to IRAC photometry
+ 4 emission lines



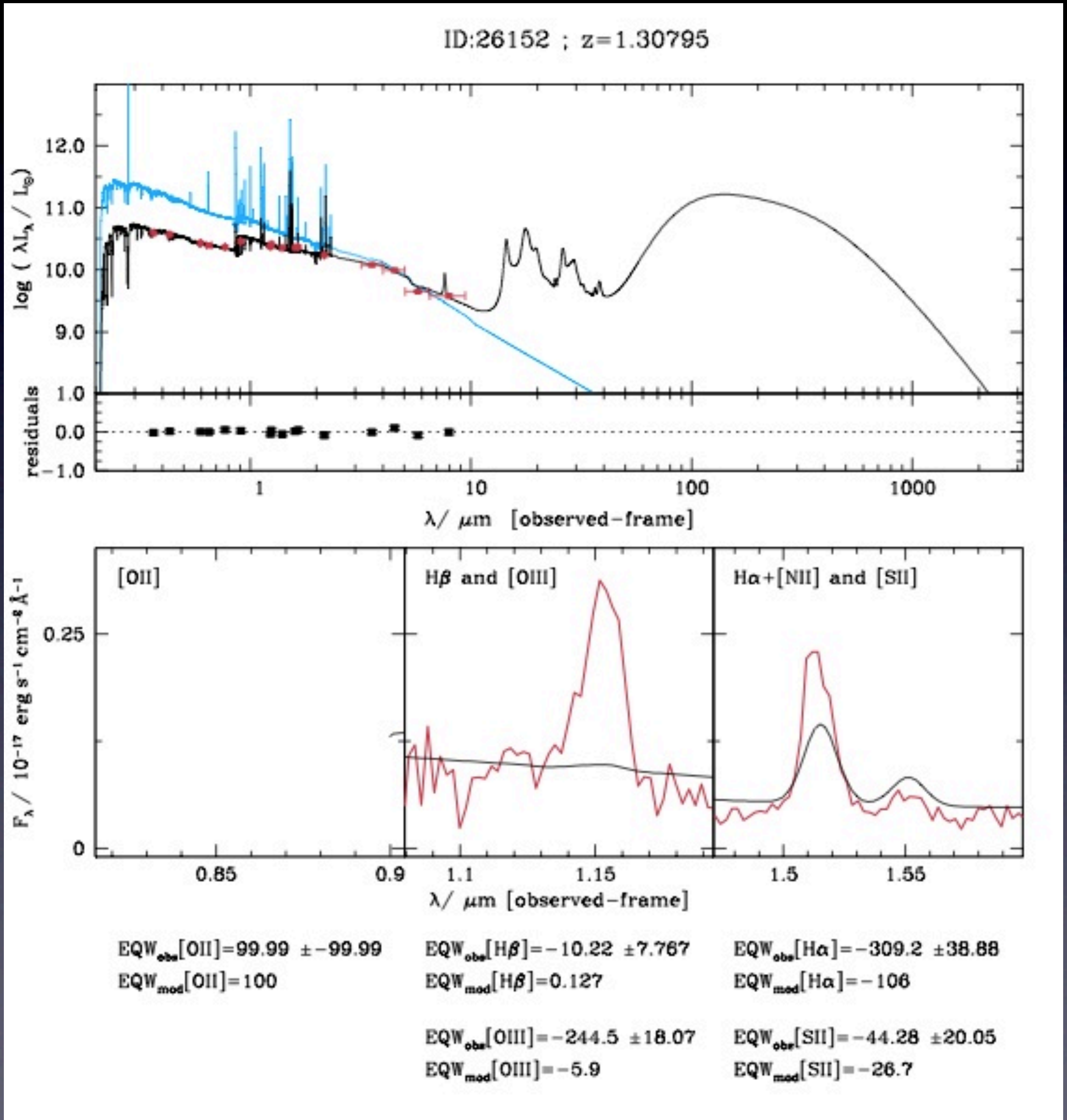
3D-HST galaxies (0.7<z<3.5)

Most common case: UV to IRAC photometry
+ 1 emission line



3D-HST galaxies (0.7<z<3.5)

Example



3D-HST galaxies (0.7<z<3.5)

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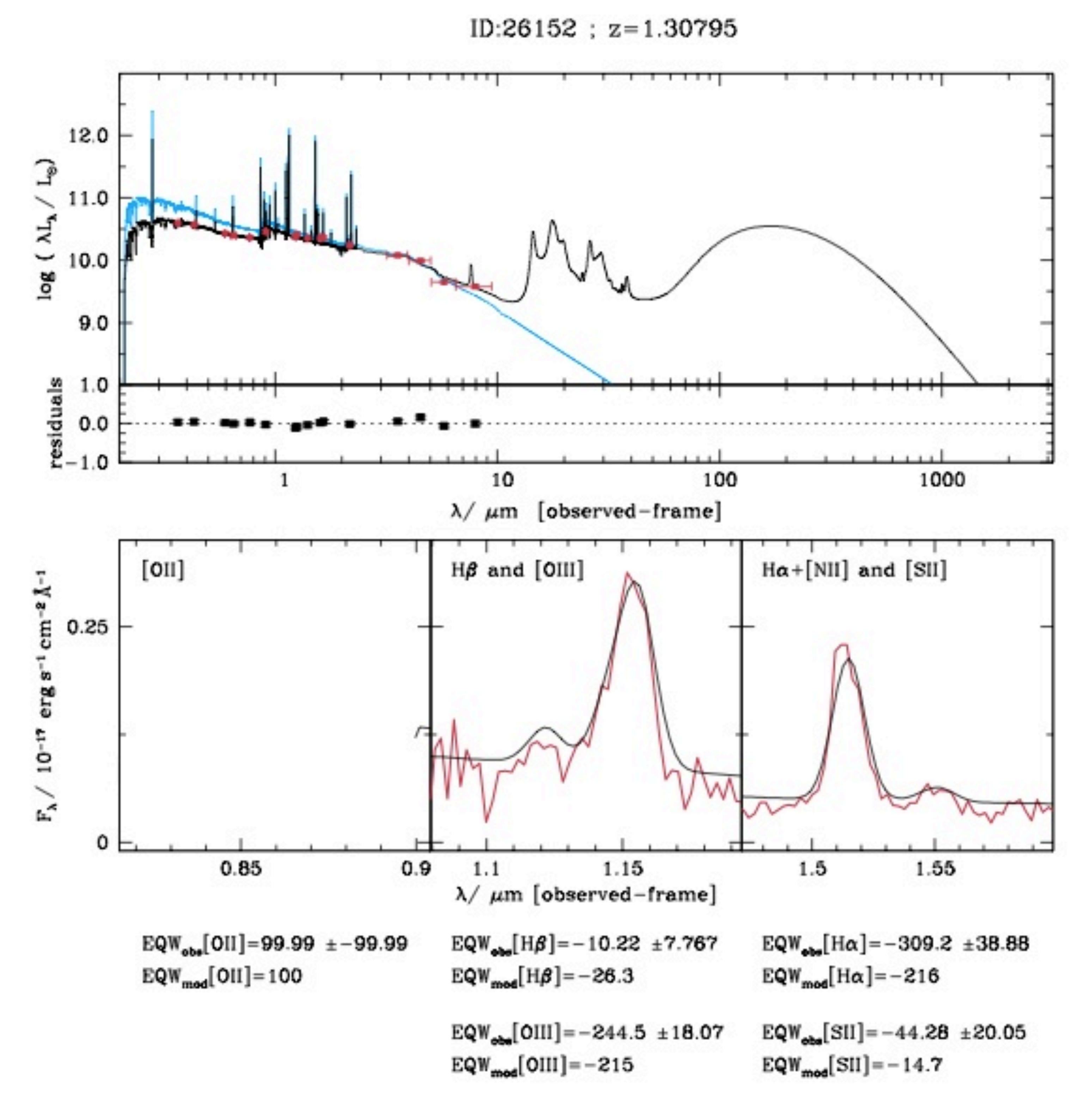

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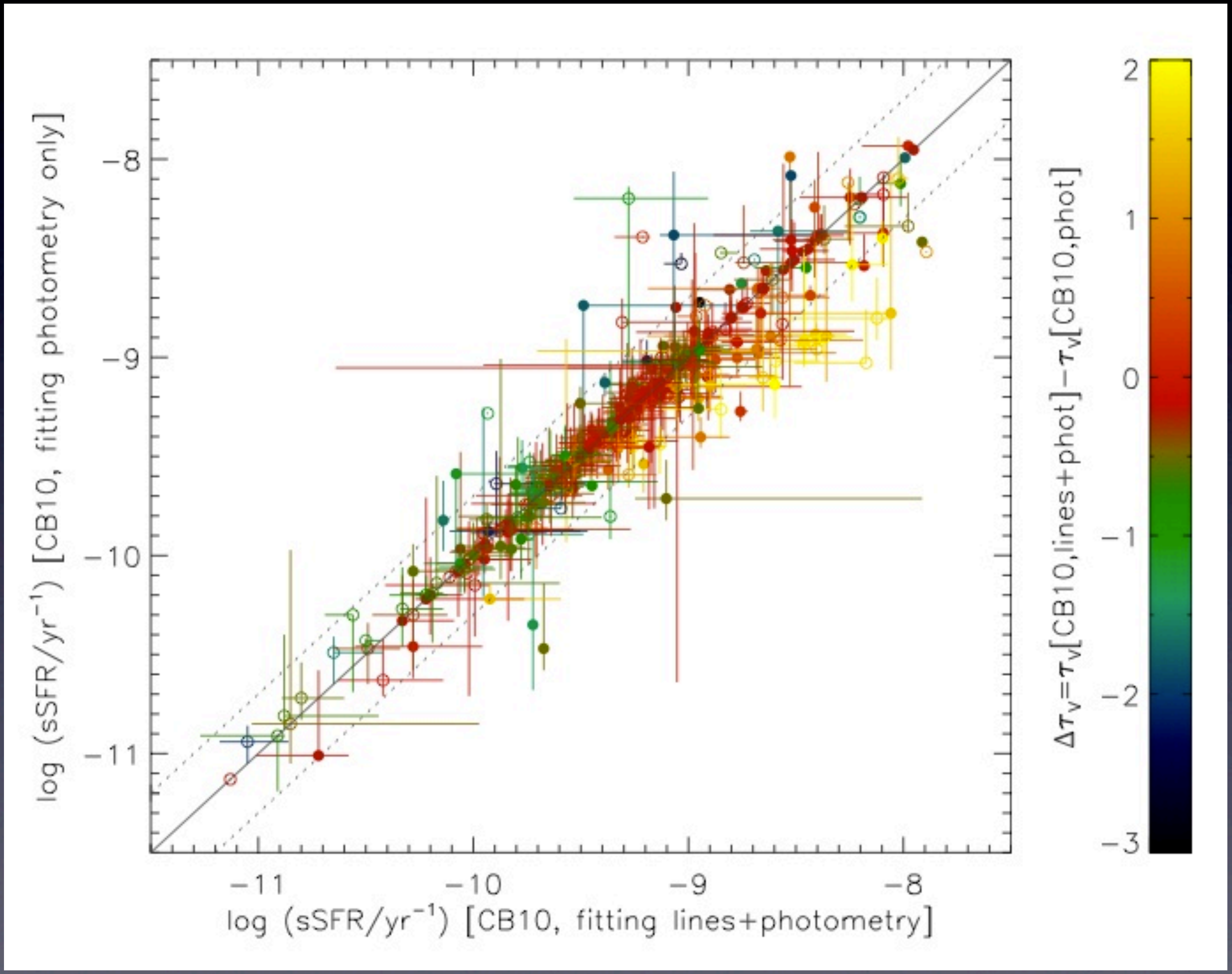

Summary & Conclusion

- Developed new approach to assess the relative merits of different types of observations
  - large library of model galaxies covering broad ranges of parameters
  - *pseudo-observations* at different resolutions and signal-to-noise ratios
  - low-resolution spectroscopy is very promising
- Applicability of the approach to any type of observation to constrain main parameters (DEEP2, 3D-HST)
- Future
  - explore different semi-analytic models
  - extend the models including dust emission and AGNs
  - explore the UV rest frame (absorption features)

Thanks

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