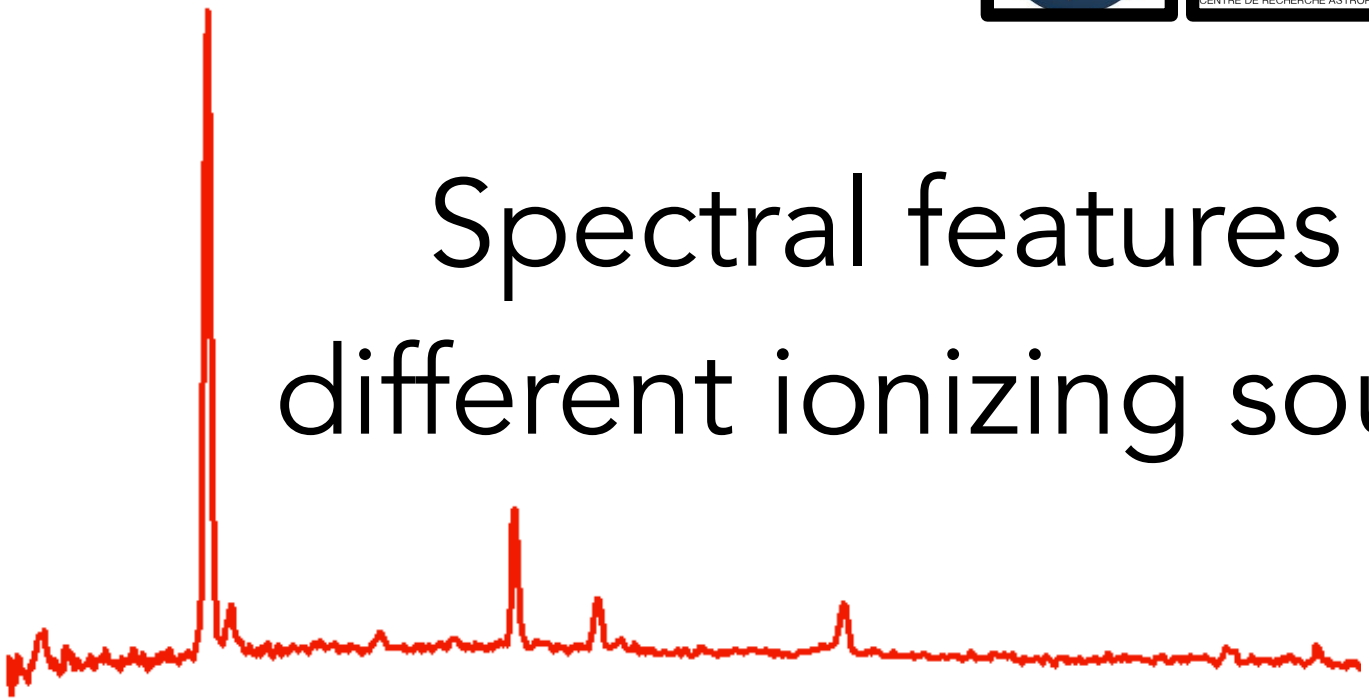


Spectral features of different ionizing sources

A. Feltre

R. Bacon, L. Tresse + MUSE consortium,

S. Charlot, M. Hirschmann, J. Chevallard + NEOGAL team,

M. Mignoli, F. Calura, A. Bongiorno

KICC Workshop 2017 "Emission Line Galaxies with MOS: from cosmic noon to the reionization era"

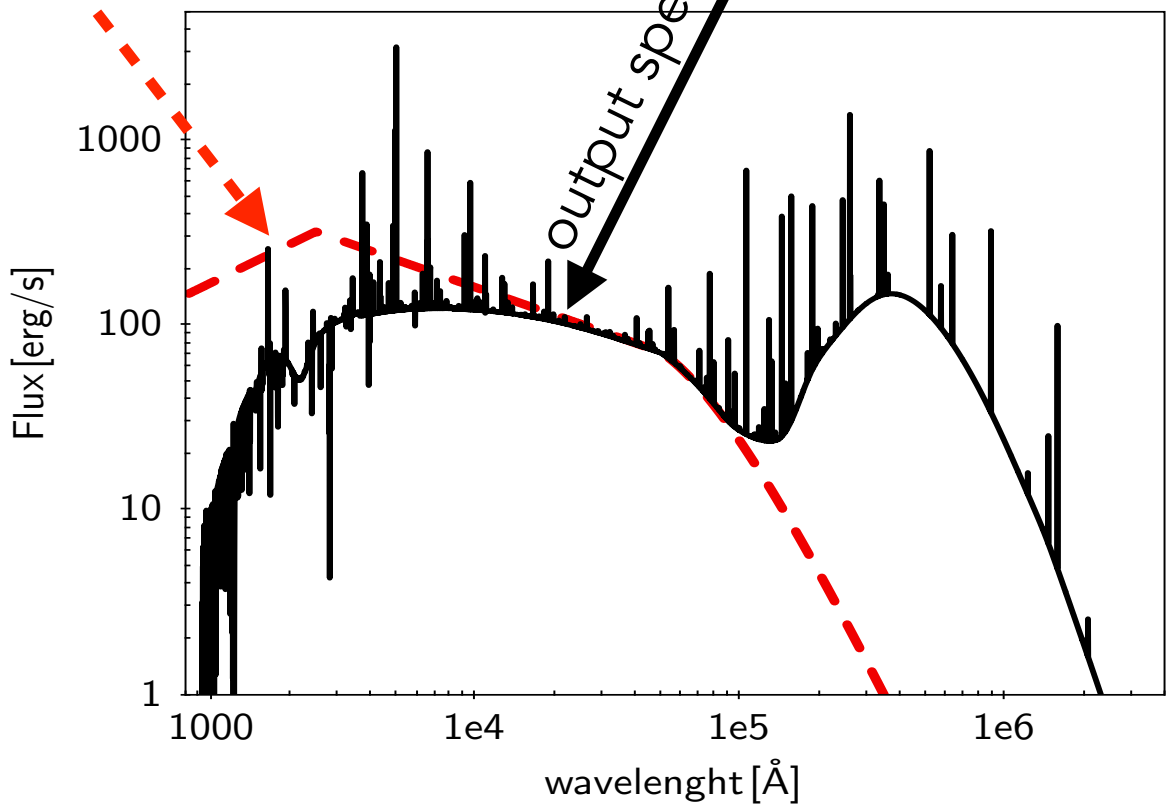
Spectral models

natural link between theory and observations

- diagnostics of the nature of the ionizing sources
- diagnostics of the physical properties of the ionized gas
- combined with SED fitting tools
- combined with cosmological simulations

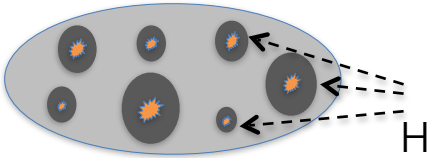
Spectral modelling

ionizing source + **photoionization code** = **CONTINUUM + NEBULAR**



Spectral modelling

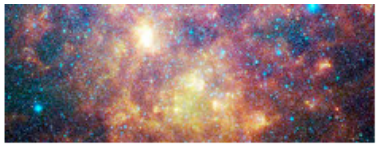
SF GALAXY



Several HII regions

e.g. Charlot & Longhetti 01, Brinchmann+04, Kewley & Dopita 02, Kewley+13, Blanc+14, Gutkin+16, Jaskot & Ravindranath 16, Nakajima+17

PAGB



diffuse gas heated by postAGB stars

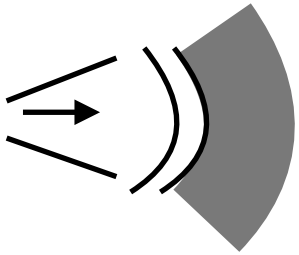
e.g. Binette+92, Flores-Fajardo+11, Hirschmann+17

AGN NLR

AGN accretion luminosity

e.g. Binette+96, Dopita+02, Groves+04, Nagao+06, Feltre+16, Nakajima+17

SHOCKS

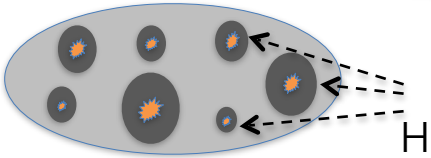


e.g. Allen+98, Allen+08

NB: for studies on the effect of shocks on emission lines see e.g. **Kewley+13, Jaskot & Ravindranath 16**

Spectral modelling

SF GALAXY



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e.g. Charlot & Longhetti 01, Brinchmann+04, Kewley & Dopita 02, Kewley+13, Blanc+14, Gutkin+16, Jaskot & Ravindranath 16, Nakajima+17

PAGB

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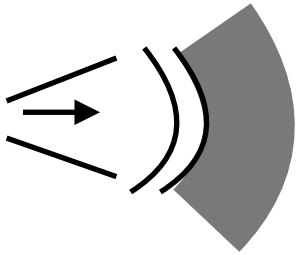
SHOCKS



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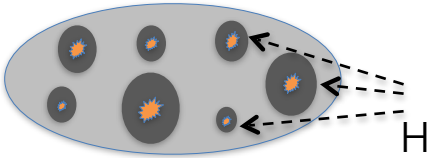
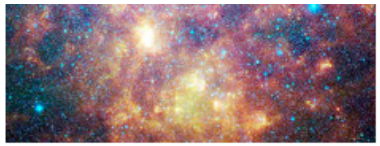
Spectral modelling

SF GALAXY



Several HII regions

PAGB



diffuse gas heated by postAGB stars

AGN NLR

AGN accretion luminosity

✳ **Charlot and Bruzual, in prep**
new tracks for massive (WR) stars

✳ **IMF cutoffs** 100-300 $M_\odot$
✳ **Gutkin+16** updated

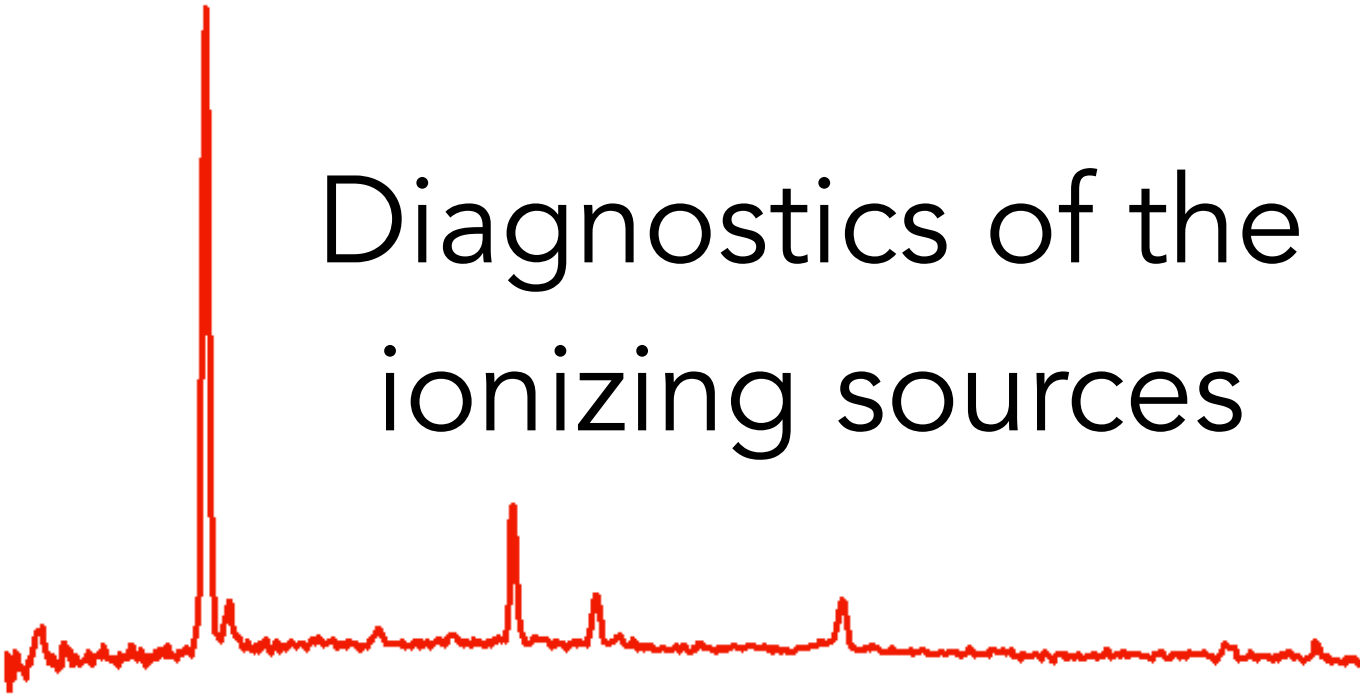
✳ single-**age** (3 to 9 Gyr) stellar population
✳ **Hirschmann+17**

✳ $F_\nu \sim \nu^\alpha$ (**spectral index**)
✳ **Feltre+16** updated (inner radius and micro turbulent velocity as model parameters)

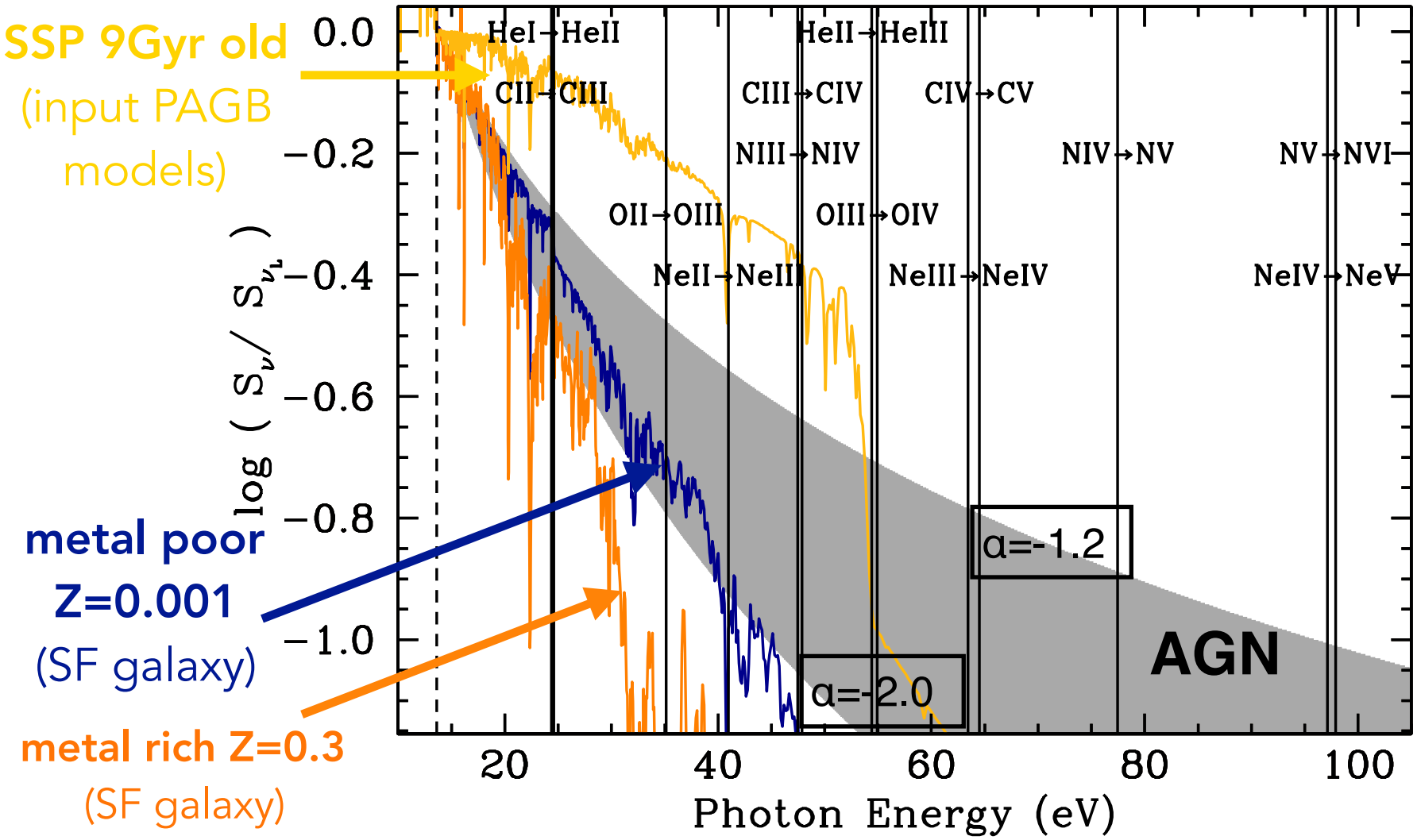
photoionization code **CLOUDY**
Ferland+13

➡ **ionization parameter** $n\gamma/n_H$ log(U)
➡ **hydrogen gas density** $\log(n_H/cm\text{-}3)$
➡ **metallicity** Z (gas+dust phase)
➡ dust-to-metal mass ratio (**depletion**) ξd
➡ **C/O abundance ratio**

Diagnostics of the ionizing sources

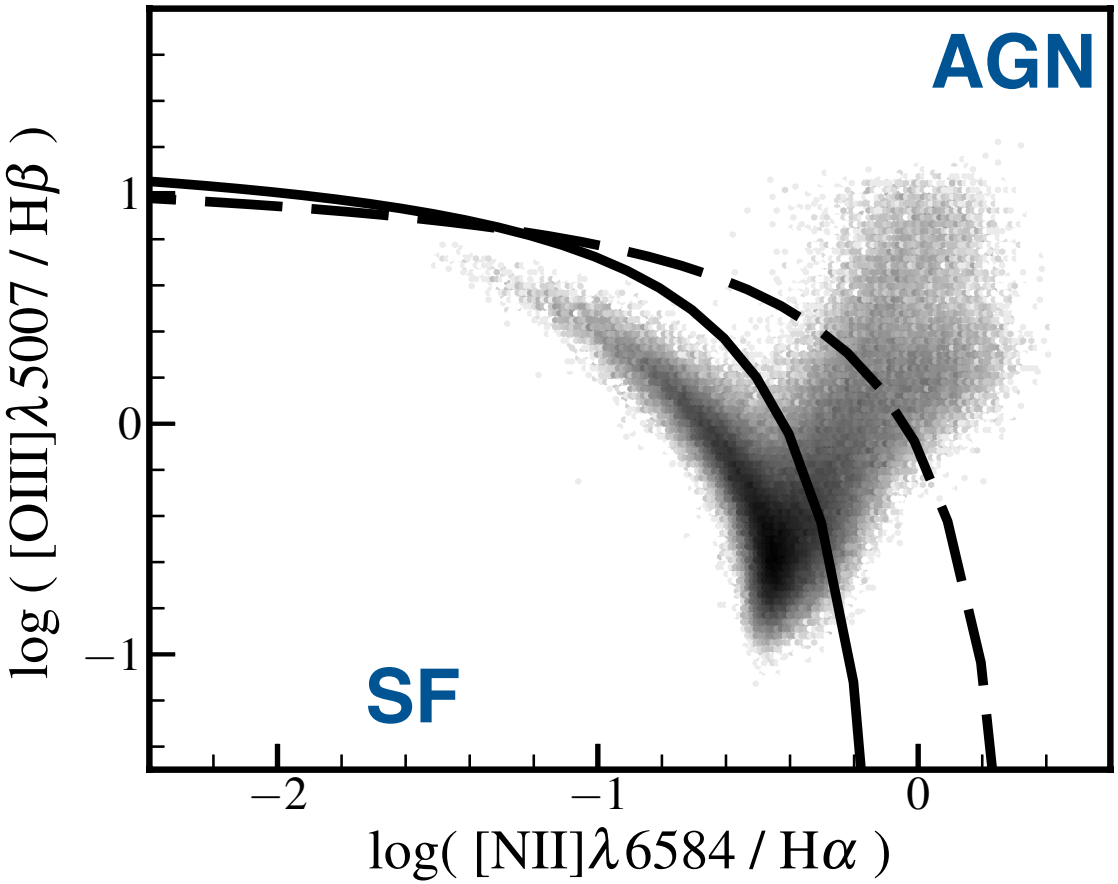


Ionizing spectra



Standard optical diagnostics

Baldwin, Phillips & Terlevich 81 BPT diagram



Kewley+01

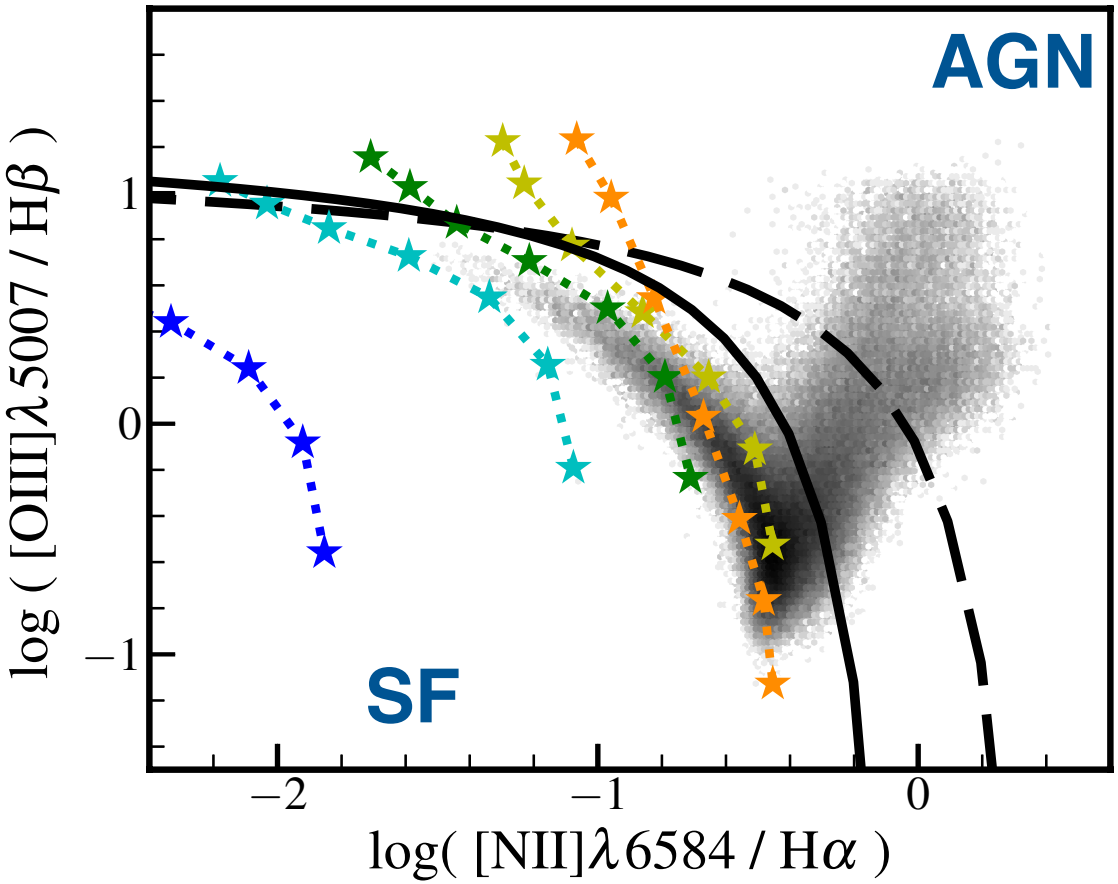
Kauffmann+03

SDSS sources

$0.04 < z < 0.2$

Standard optical diagnostics

Baldwin, Phillips & Terlevich 81 BPT diagram



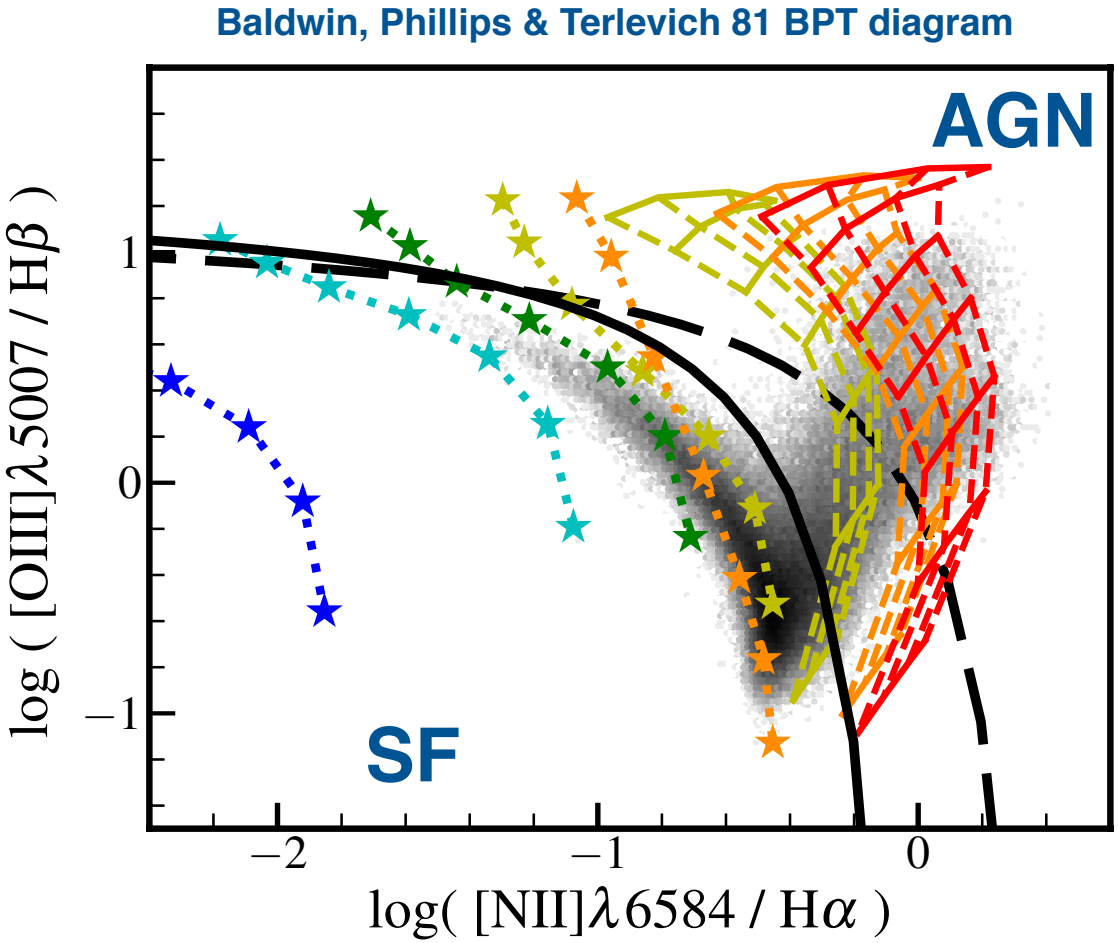
Z=0.001
Z=0.004
Z=0.008
Z=0.017
Z=0.03
Z=0.04

Kewley+01

Kauffmann+03

SDSS sources
$0.04 < z < 0.2$

Standard optical diagnostics



$n_{H\,(AGN)}=10^3\ cm^{-3}$

$n_{H\,(SF)}=10^2\ cm^{-3}$

$\xi_d = 0.3$

Z=0.001
Z=0.004
Z=0.008
Z=0.017
Z=0.03
Z=0.04

Kewley+01

Kauffmann+03

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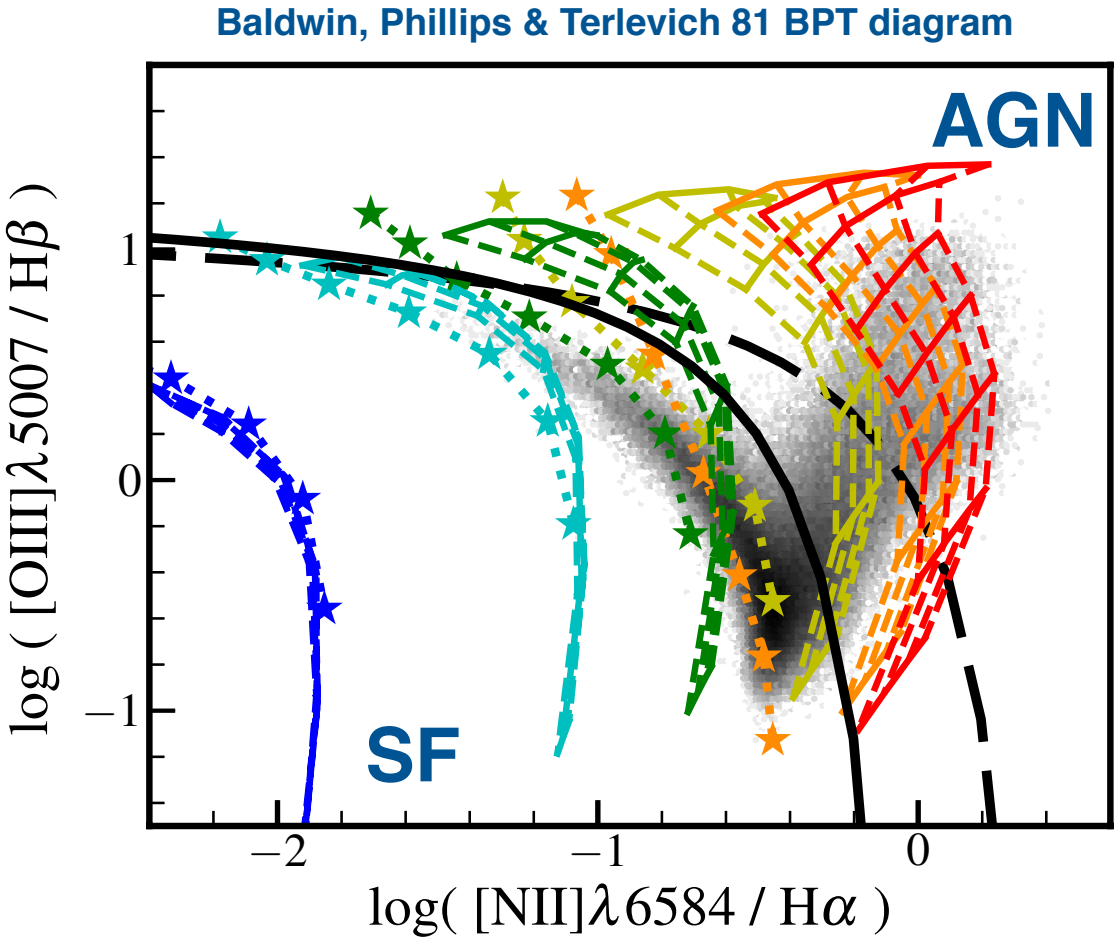

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Kewley+01

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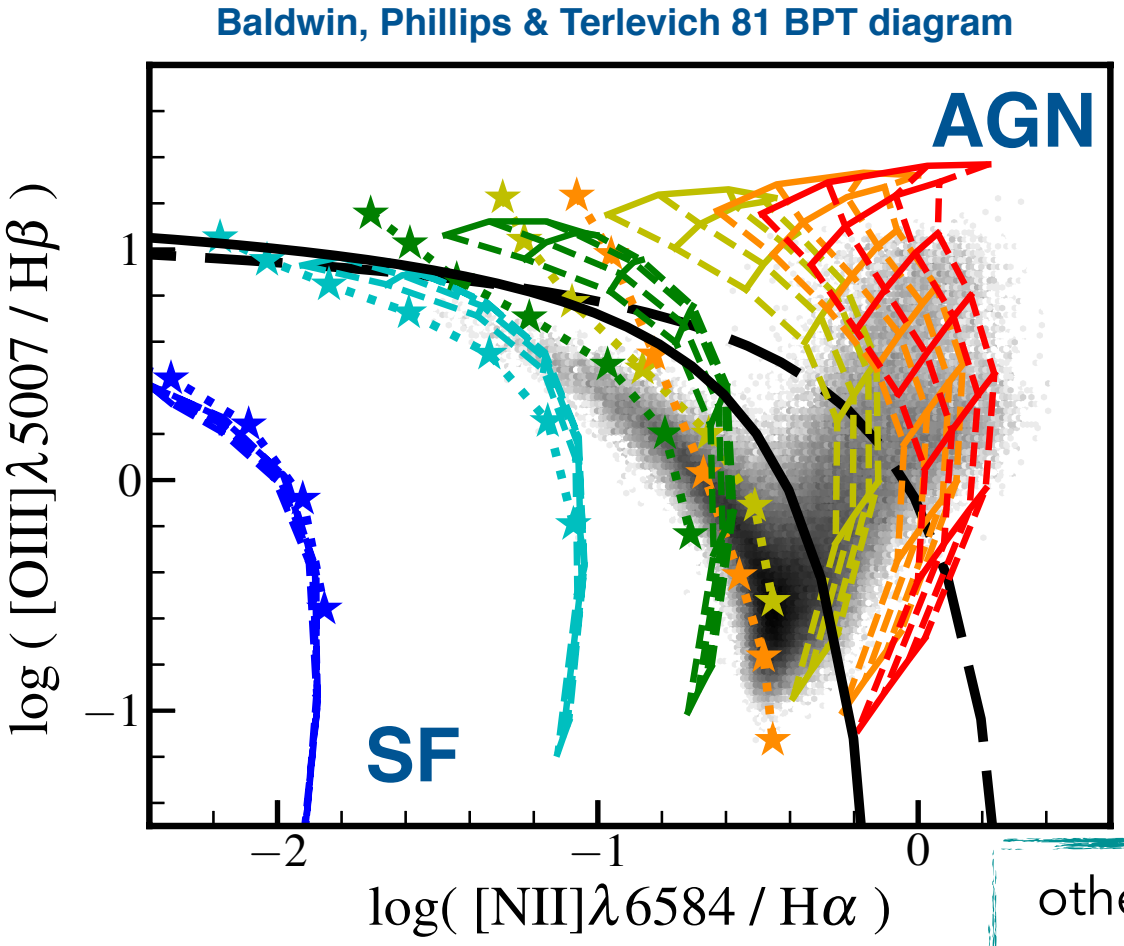

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Z=0.017
Z=0.03
Z=0.04

Kewley+01

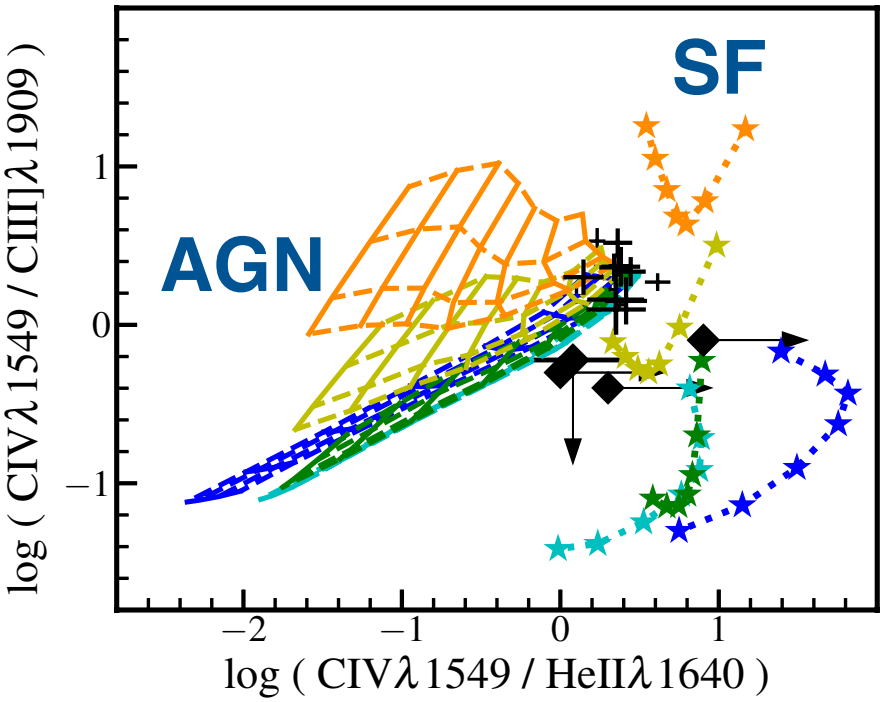
Kauffmann+03

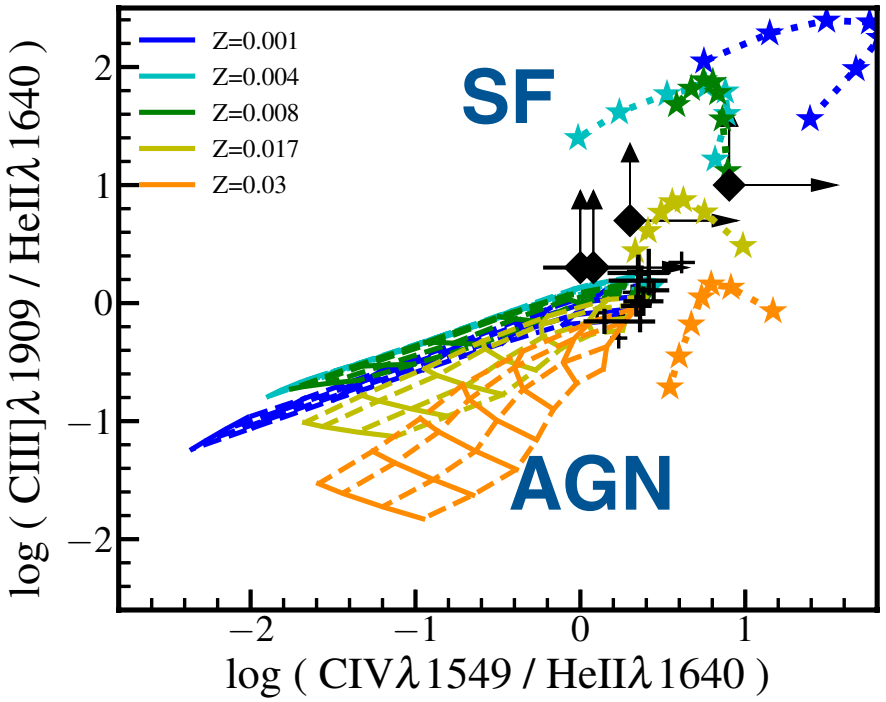
SDSS sources

0.04 < z < 0.2

other (e.g. UV) diagnostics, in addition to the standard optical ones

UV diagnostics



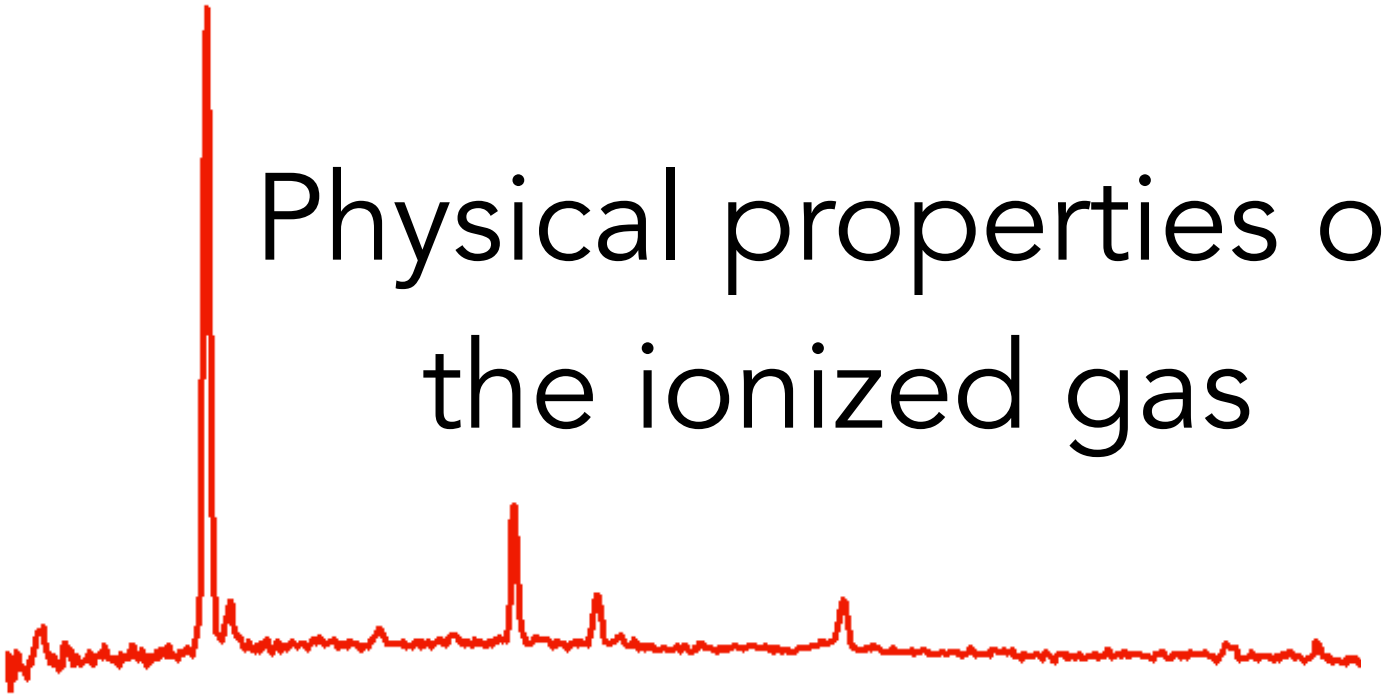


\+ **Dors+14**
Sy2 - low z
QSO2 - z~2

◆ **Stark+14**
dwarf galaxies
z~2

and many others such as CIII]1909/HeII1640 or CIV1550/HeII vs NV1240/HeII, NV1240/CIV1549, NV1240/NIII]1750, OIII]1661,1666/HeII, NIII]1750/HeII **Feltre+16**

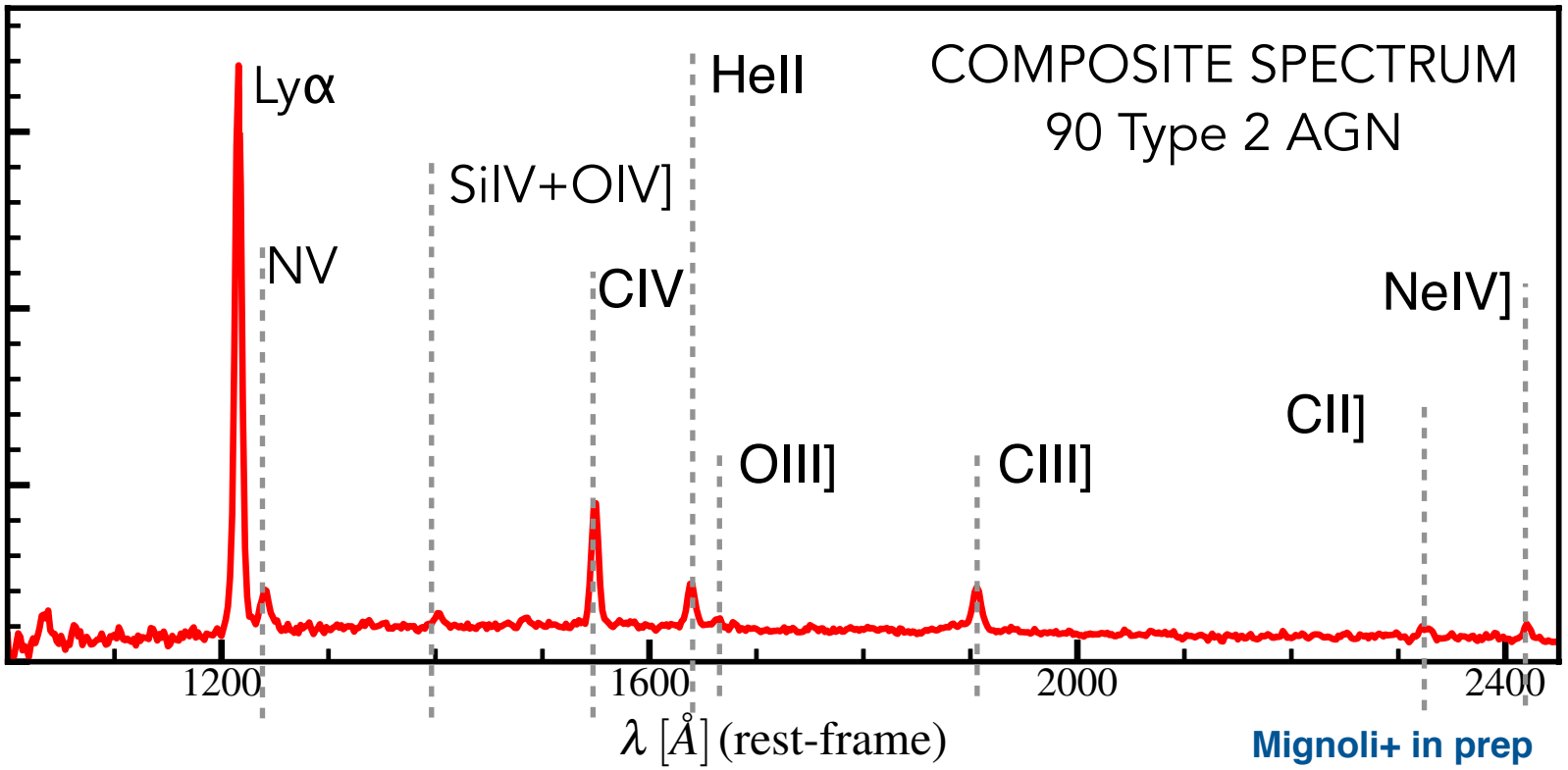
Physical properties of the ionized gas



CIV-selected Type2 AGN

zCOSMOS Deep (PI: S. Lilly)
8k sample (K<23.5 & B<25.5)
VIMOS/VLT (rest-UV)
90 CIV-selected AGN
with 1.5 < z < 3.0

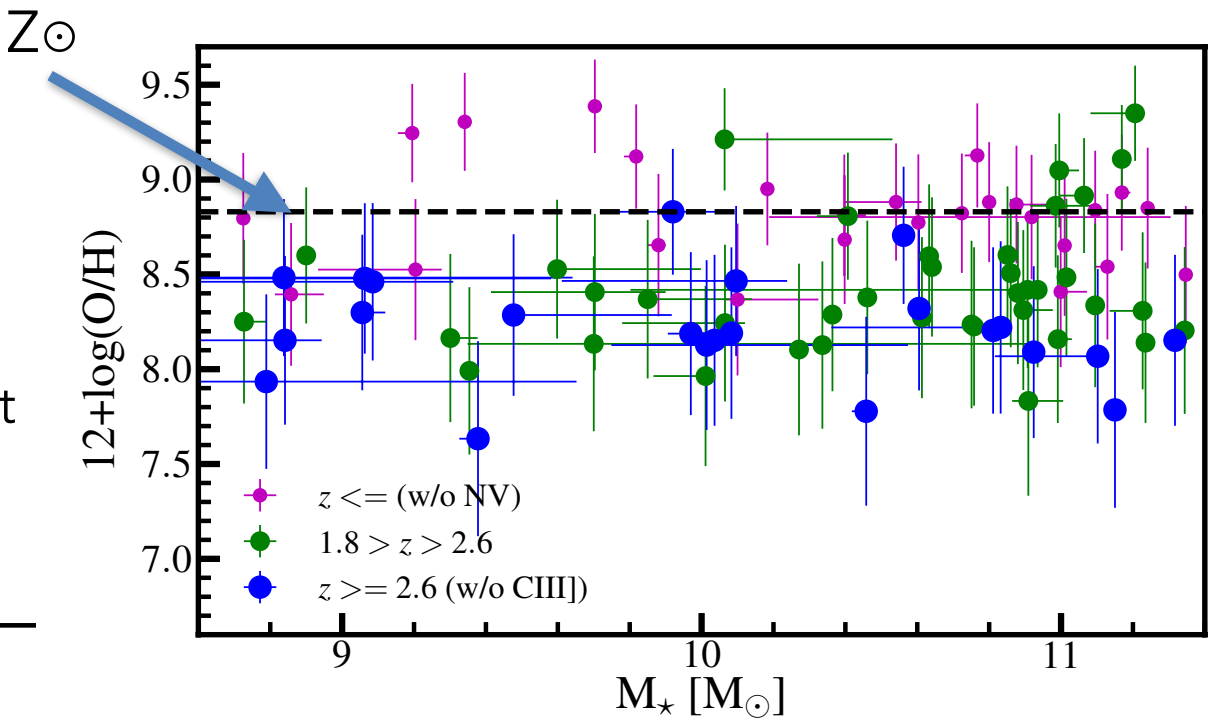
✳ accurate emission line measurements to study the excitation properties of the AGN NLR ionised gas (metallicity, ionisation parameters …)



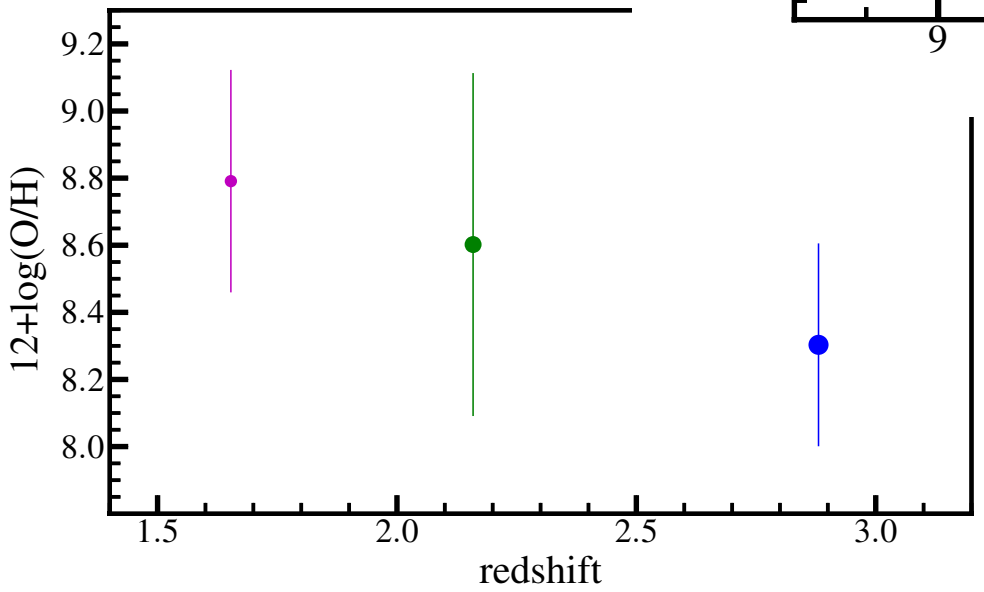
Mignoli+ in prep

CIV-selected Type2 AGN

- no need of models with high metallicity
- flat relation between NLR metallicity and stellar mass of the host

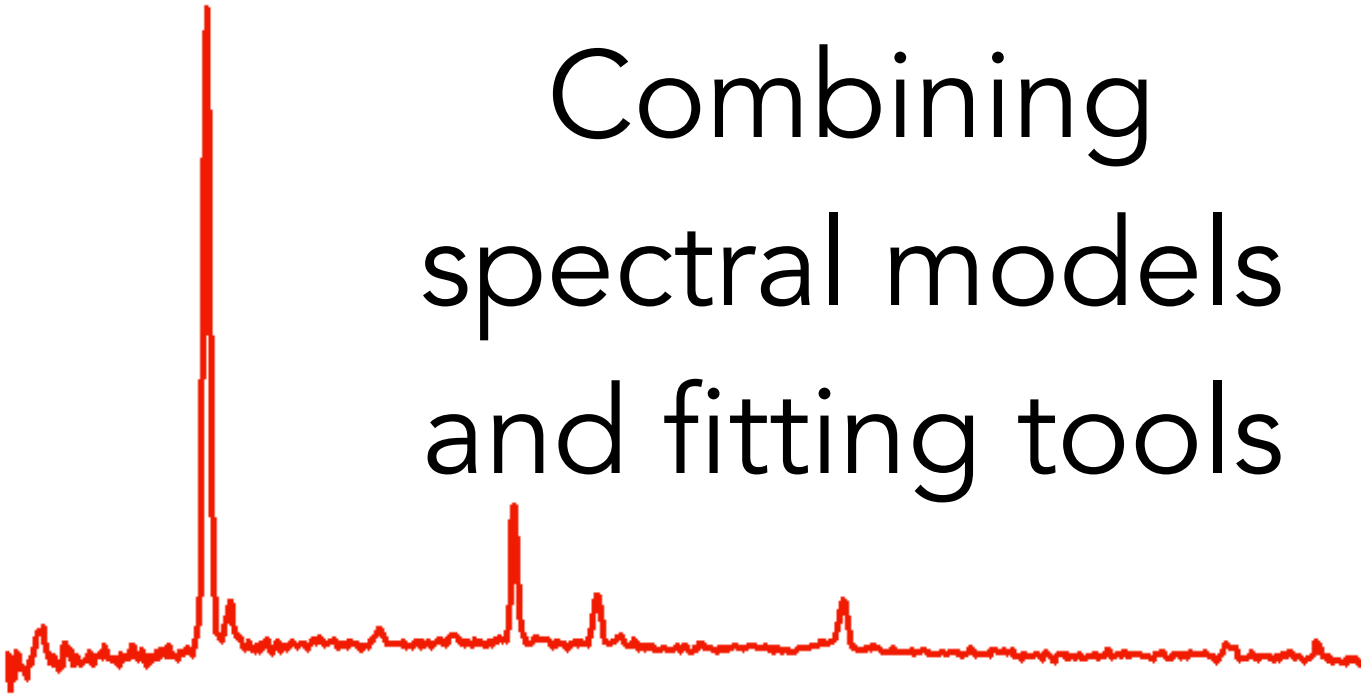


Mignoli+ in prep



- lower metallicity at higher redshift (expected)

NB: improve this study with a simultaneous fit of broad band photometry + spectral lines with a Bayesian approach



Combining spectral models and fitting tools

BayEsian Analysis of GaLaxies sEds

beagle

Chevallard & Charlot 16

MAIN FEATURES

- coherently combines emission from **different components** (stars, gas, dust, AGN)
- adopts **Bayesian approach**
- includes predictions from galaxy formation models

APPLICATIONS

- fit **spectro-photometric data** at UV to IR
- **synthetic catalogues** of galaxy SEDs
- study **retrievability** of galaxy physical **parameters**

OPTIONS

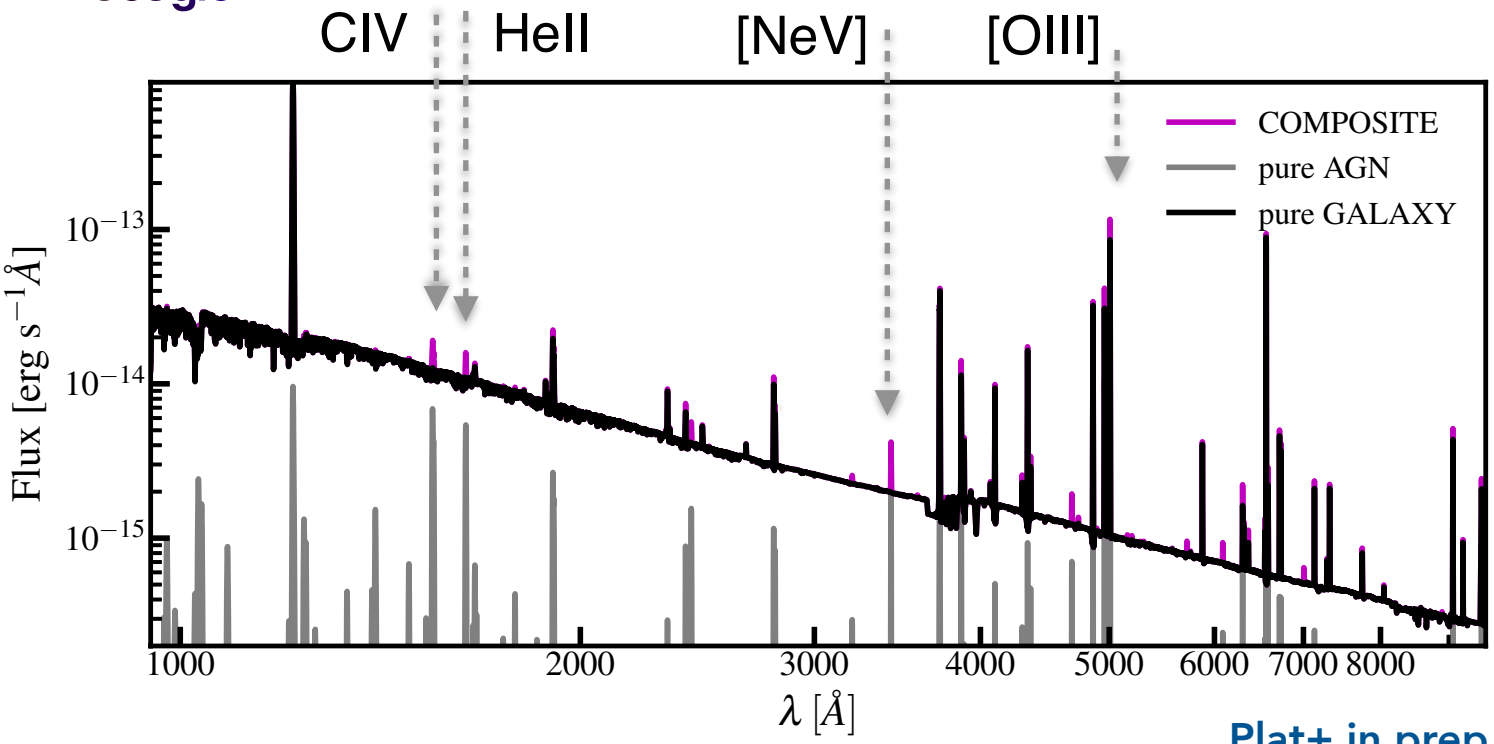
- broad-band **photometry**
- and/or **spectral features** (e.g. line intensities or EW)
- **full spectral** fit

see also
E. Curtis-Lake's talk

NB: a public version of BEAGLE for the estimation of photometric redshifts and galaxy physical parameters is available at https://gazpar.lam.fr/

with AGN

Chevallard + in prep



Plat+ in prep

host galaxy:
10^{10} M⊙
Zgas = 1/2 Z⊙
logU=-3.0

AGN:
Lacc 10^{45} erg/s
Zgas = Z⊙
logU = -2.0

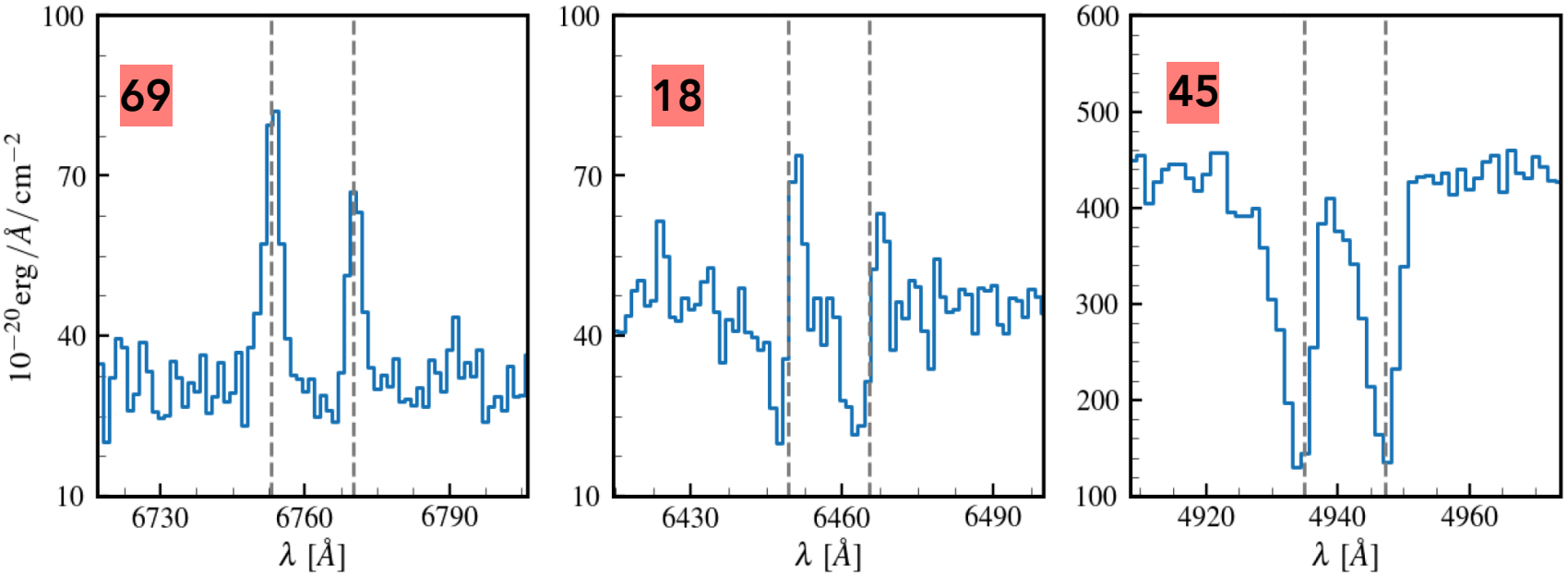
- study the effects of the presence of AGN with different accretion luminosities on the UV/optical spectral features
- produce mock catalogues of UV/optical spectra of AGN2
- fit UV/optical spectra of obscured AGN at any redshift

MgIIλ2800 sample

MUSE Hubble Ultra Deep Field Survey **Bacon+17, in press**

0.7 < z < 2.34 (**404** sources)

MgII emitter | **MgII P-Cygni** | **MgII absorber**

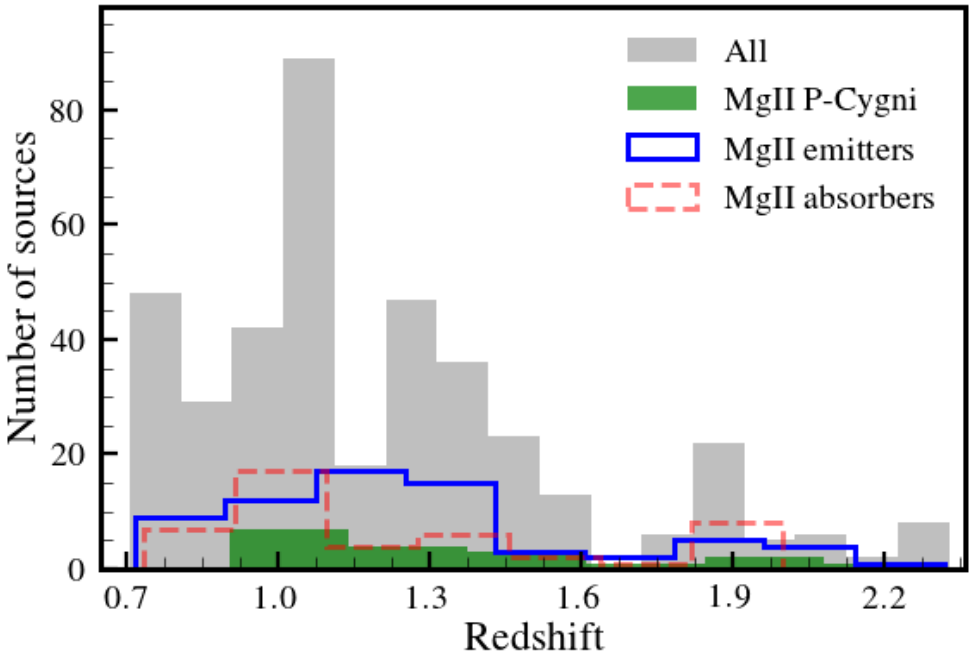


✳ classification based on EW and S/N of emission lines and spectra + visual inspection

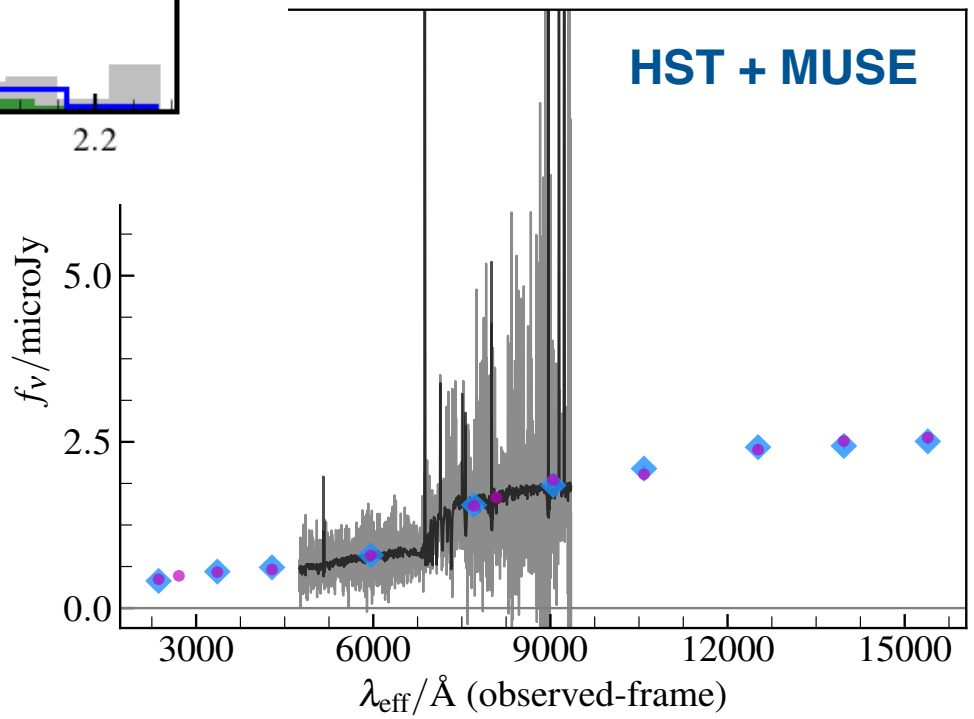
✳ additional emission lines: CIII] 1907/1909, [OII] 3726/3729, [NeIII] 3869, [OIII] 4959/5007, Hβ

Feltre+, in prep

MgIIλ2800 sample



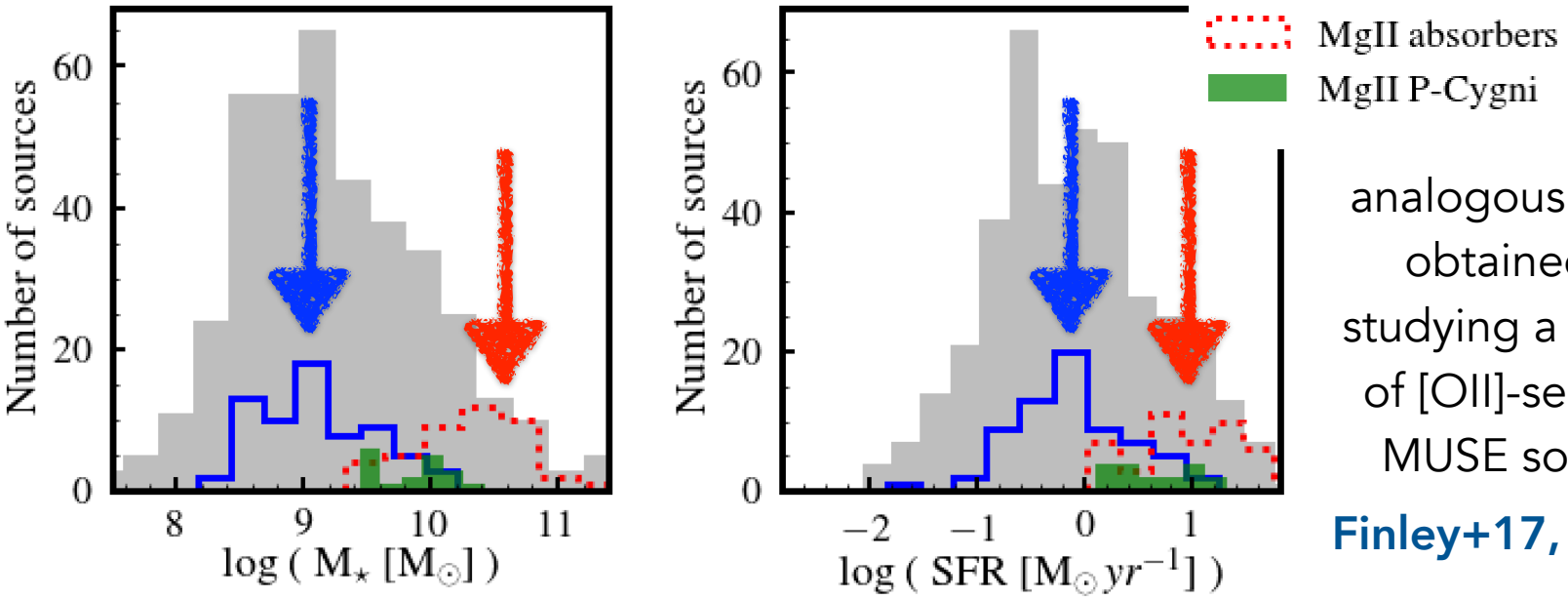
redshift distribution



example of BEAGLE fit

MgIIλ2800 sample

STELLAR MASS and STAR FORMATION



analogous results obtained by studying a sample of [OII]-selected MUSE sources

Finley+17, in prep

MgII emitters show

- similar sSFR to MgII absorbers
- bluer UV spectral slope
- lower dust optical depth
- similar nebular (O/H, ionization parameter) properties to MgII absorbers

what is the main driver for this difference?

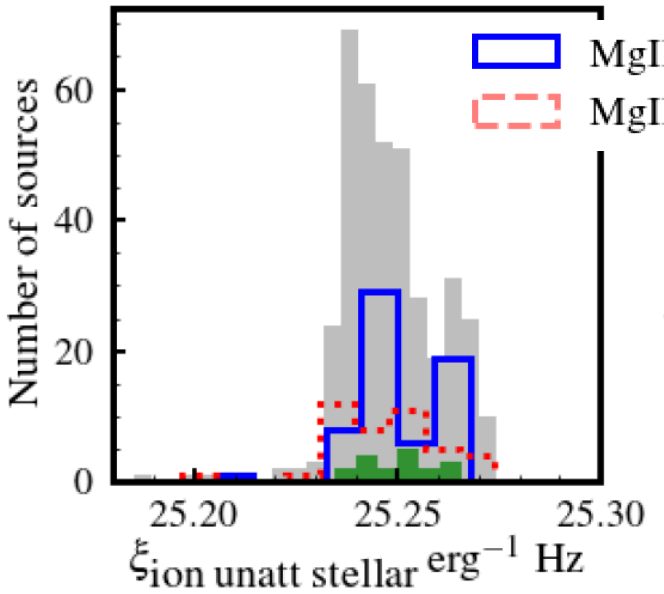
NB: current tests on selection bias confirm our findings

MgIIλ2800 sample

IONIZING EMISSIVITY $\xi_{\rm ion} = \dot{N}/L_{\rm UV}$

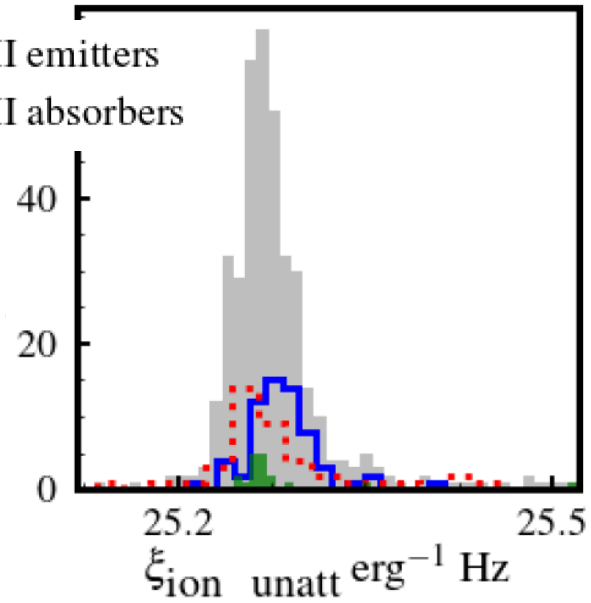
intrinsic *stellar* L_{UV}

wo dust / wo nebular



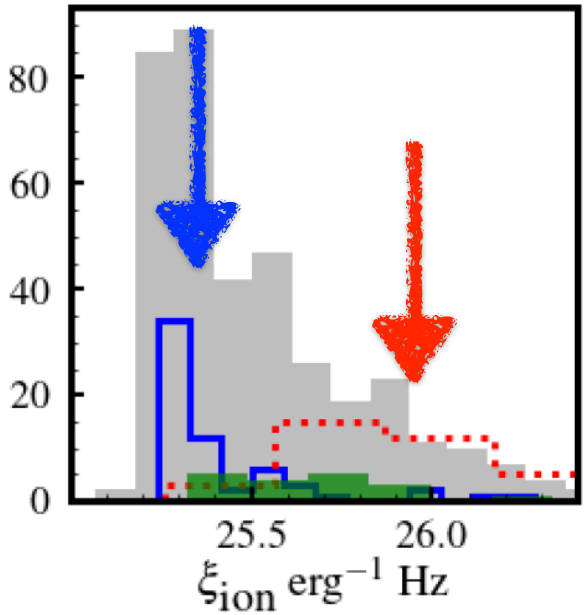
intrinsic L_{UV}

wo dust / w nebular



'observed' L_{UV}

w dust / w nebular



NB: MgII is

✳ strongly affected by ISM absorption

A. Vidal-Garcia's talk

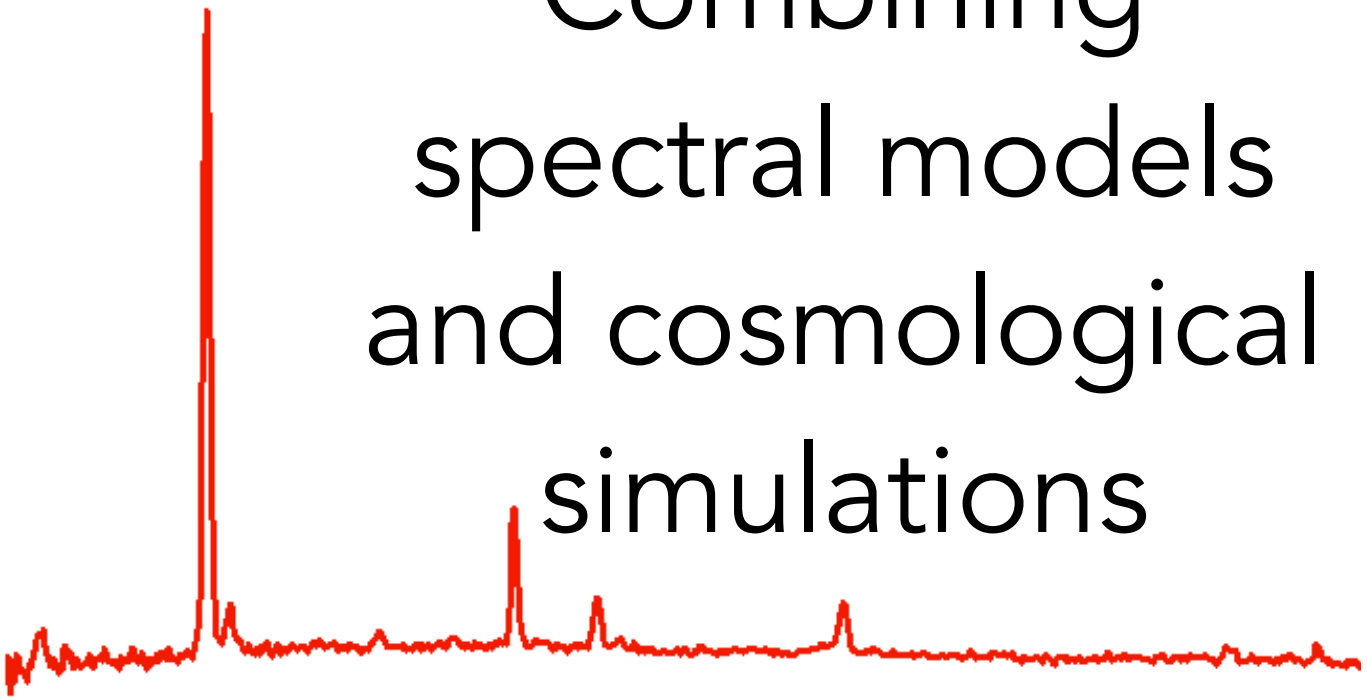
✳ a tracer of winds/outflows

=> dedicated radiative transfer modelling needed !!

Finley+, Garel+ in prep

(DUST) CONTENT of the ISM

Combining spectral models and cosmological simulations



M. Hirschmann's talk
for the detailed study

Synthetic nebular spectra

photoionization models from SF galaxies, AGN and PAGB stars

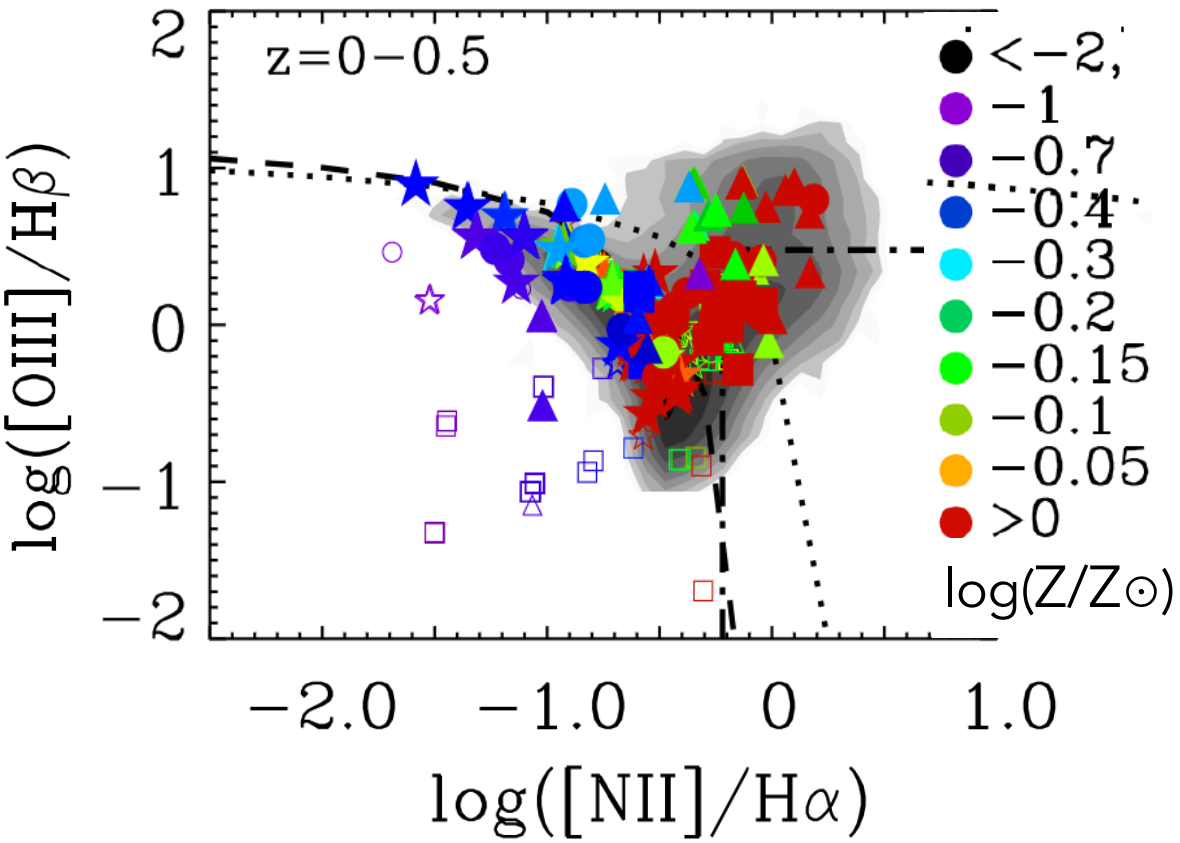
+

20 cosmological zoom-in simulations of massive galaxies
(spatial resolutions: 200 pc)
Choi+17; Hirschmann + 17, Naab + 17, in prep.

▲ AGN ● composite
★ SF gals ■ PAGB gals

defined on the basics of BHAR/SFR

Hirschmann + 17



successful at reproducing observations of SDSS galaxies

To conclude …

Comprehensive analyses of optical/UV spectra

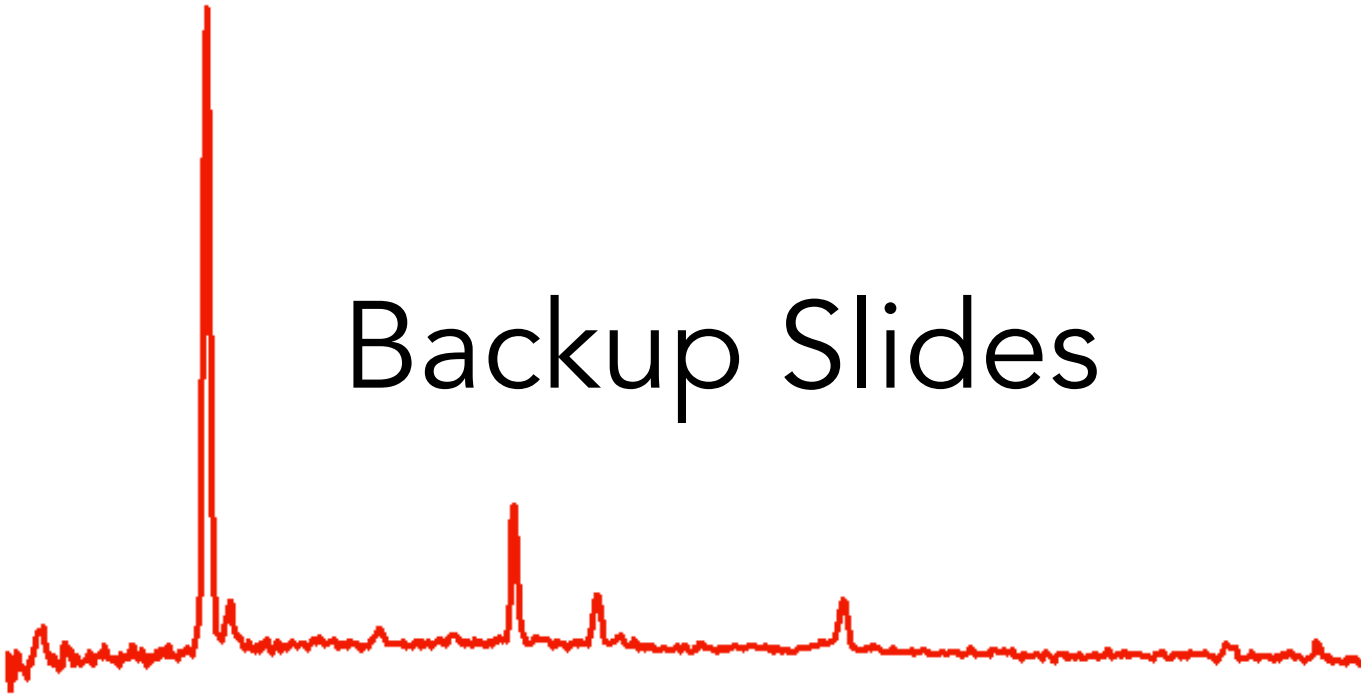
- ✳ allow the study of the nature of the ionizing source …
- ✳ … and of the physical properties of the ionized gas
- ✳ provide indirect information on galaxy properties

additional studies, accounting for e.g. the effects of shocks, binary stars and ISM absorption

high quality data from future facilities (e.g.JWST/NIRSpec)

increasingly broader view of the Universe

Backup Slides

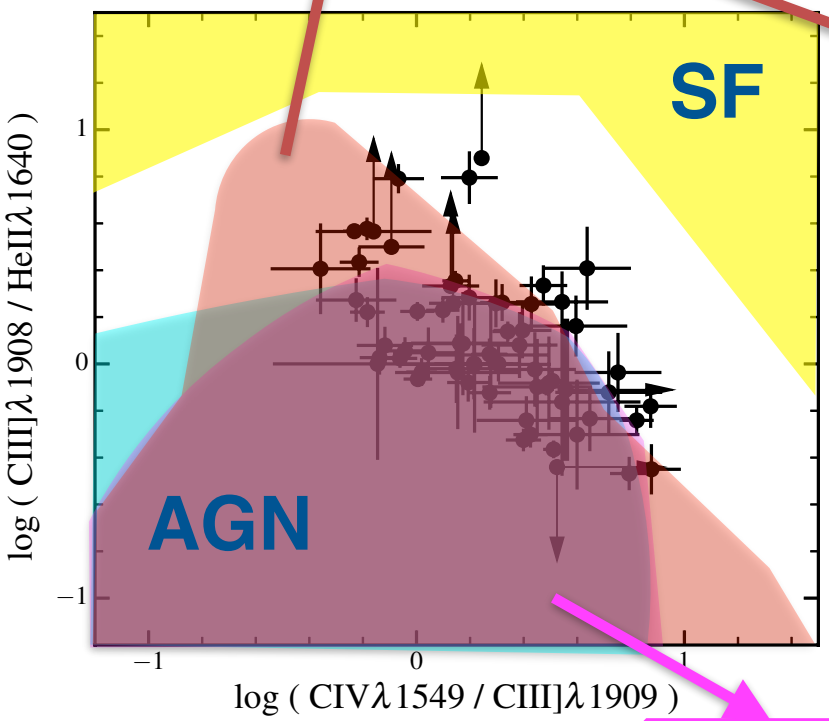


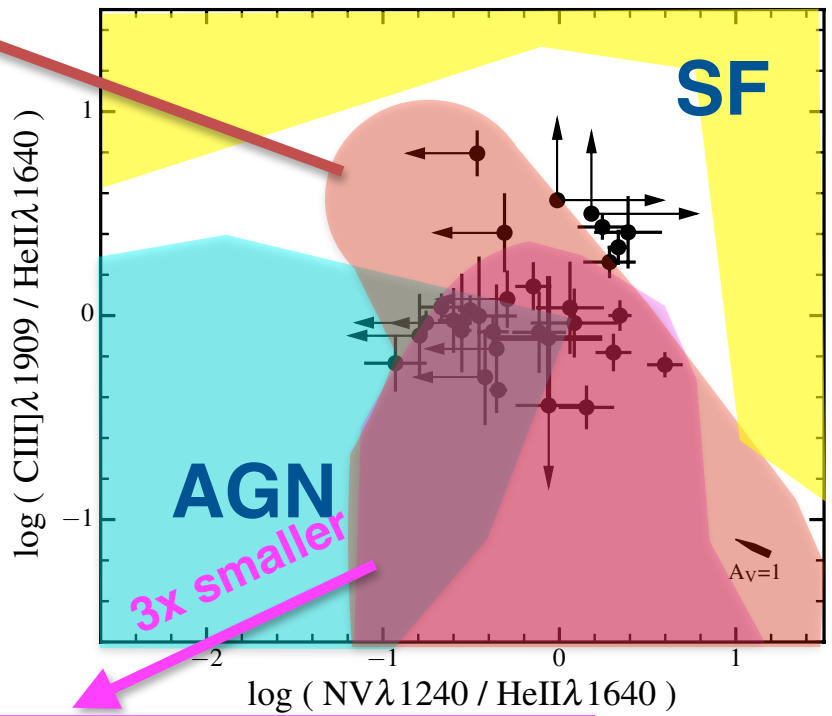
UV ratios of Type 2 AGN

+ internal microturbulence (v=100-200 km/s)

NB: optical line ratios are not significantly affected by smaller inner radius or internal microturbulence

100 km/s





Mignoli+ in prep
Feltre+ in prep

3-10 x smaller inner radius (30 - 90 pc)

Spectral modelling

ionization parameter $n\gamma/n_H$ log(U)	-1 to -5 [-2.5 to -5.0 PAGB]
hydrogen gas density log(n_H/cm-3)	2 to 4 [1 to 3 PAGB]
metallicity Z (gas+dust phase)	0.0001 to 0.03 [0.07 AGN, PAGB]
dust-to-metal mass ratio (**depletion**) ξd	0.1 to 0.5
C/O abundance ratio	0.1 to 1

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