# Unveiling the Cosmic Noon: 3D mapping of the AGN feedback in the overall galaxy population

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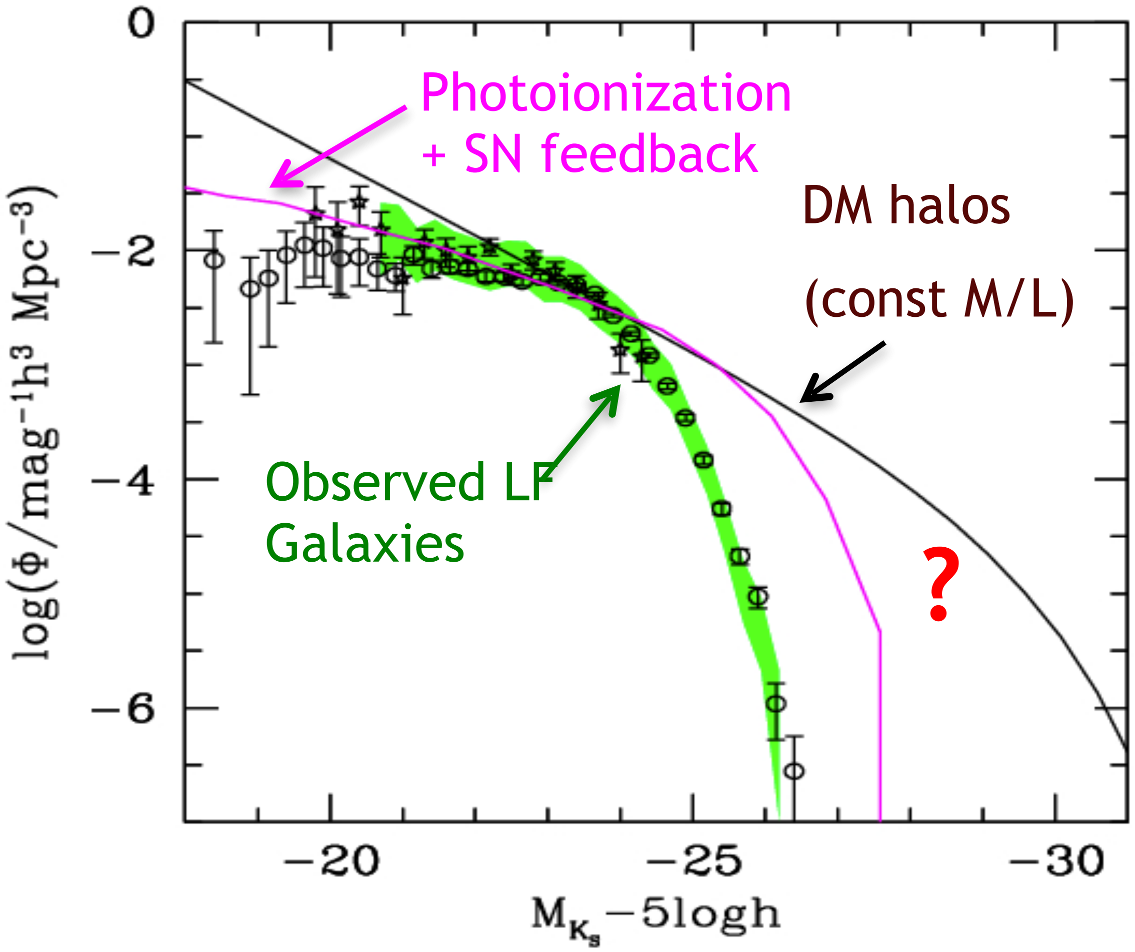
# AGN–GALAXY CO–EVOLUTION




Theory predicts
too many small galaxies
&
too many big
Galaxies

**AGN feedback via AGN-driven Outflows**
- remove gas
- quench SF

## $M_{SMBH} \sim 2 \times 10^{-3} M_{Bulge}$

Binding energy of a bulge

$E_{Bulge} \sim M_{Bulge}\,\sigma_{vel}^2$

$\sim 10^{-6} M_{Bulge}\, c^2$

AGN energy output

$E_{AGN} \sim 0.1\, M_{SMBH}\, c^2$

$\sim 2\; 10^{-4} M_{Bulge}\, c^2$

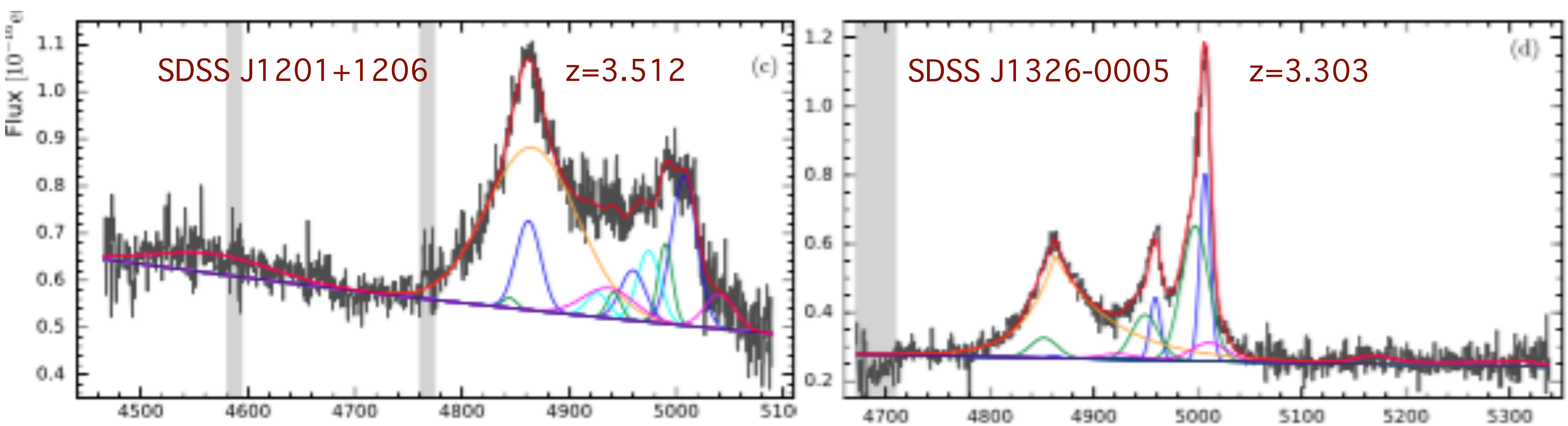
~1% of the AGN liberated radiative
energy is enough
to unbind the galactic bulge

SMBHs can regulate galaxy evolution
and their own growth

# Longslit Hyper-lum QSOs: WISSH survey

- Cosmic noon —-> redshift range z~1.5-3.5 peak of vigorous star-formation and QSO activity
- The most luminous quasars are the best targets to hunt for powerful AGN-driven outflows
- [OIII] proxy of outflows —-> cheap spectroscopic follow-ups for bright targets

85 WISE/SDSS Selected Hyper-luminous broad-line Quasars
$L_{Bol} > 2 \times 10^{47}$ erg $s^{-1}$

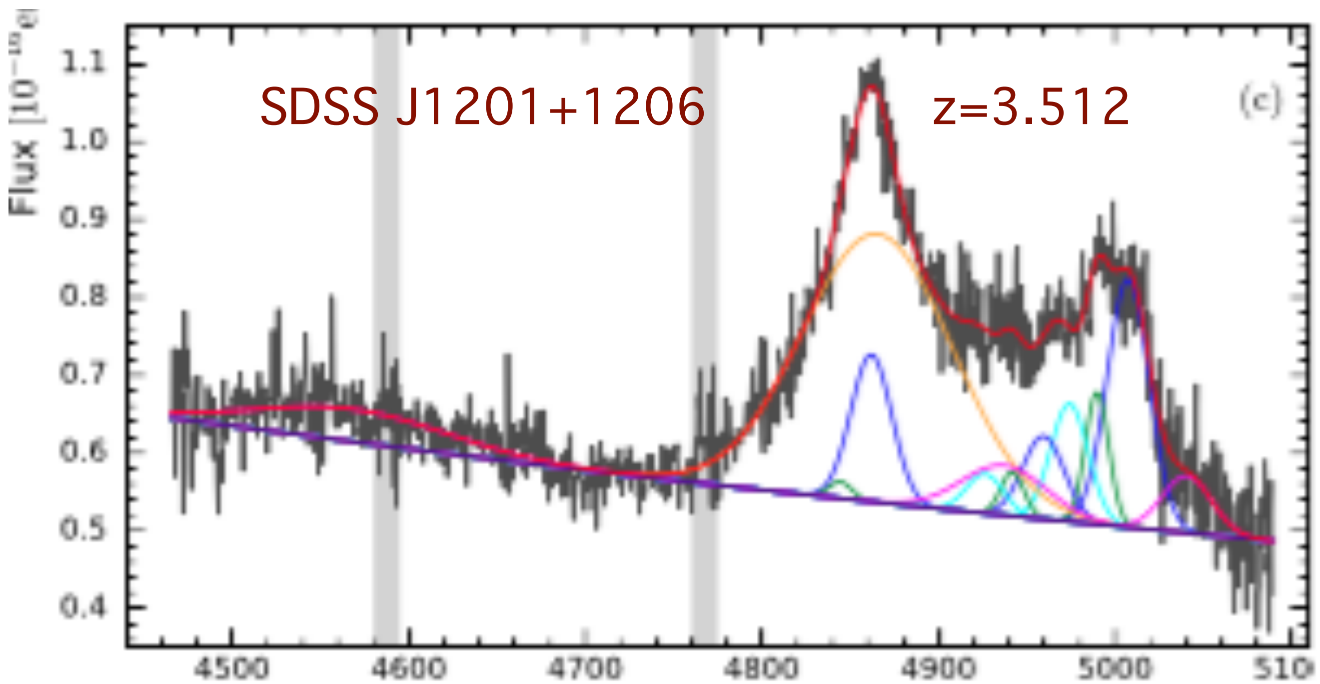



Bischetti, Piconcelli, Vietri + 2017

Very broad blue-shifted [OIII] lines
$FWHM_{[OIII]} \sim 1200 - 2200$ km $s^{-1}$
Strong [OIII] lines observed so far
$L_{[OIII]} > 10^{44}$ erg $s^{-1}$
Fast [OIII] emission v(max) ~ 1400 -3000 km $s^{-1}$

LBT- LUCI longslit campaign
of ~40 QSOs to observe
[OIII] —-> proxy of NLR outflows
Hβ —-> BH mass

# Longslit Hyper-lum QSOs: WISSH Survey




Bischetti, Piconcelli, Vietri + 2017

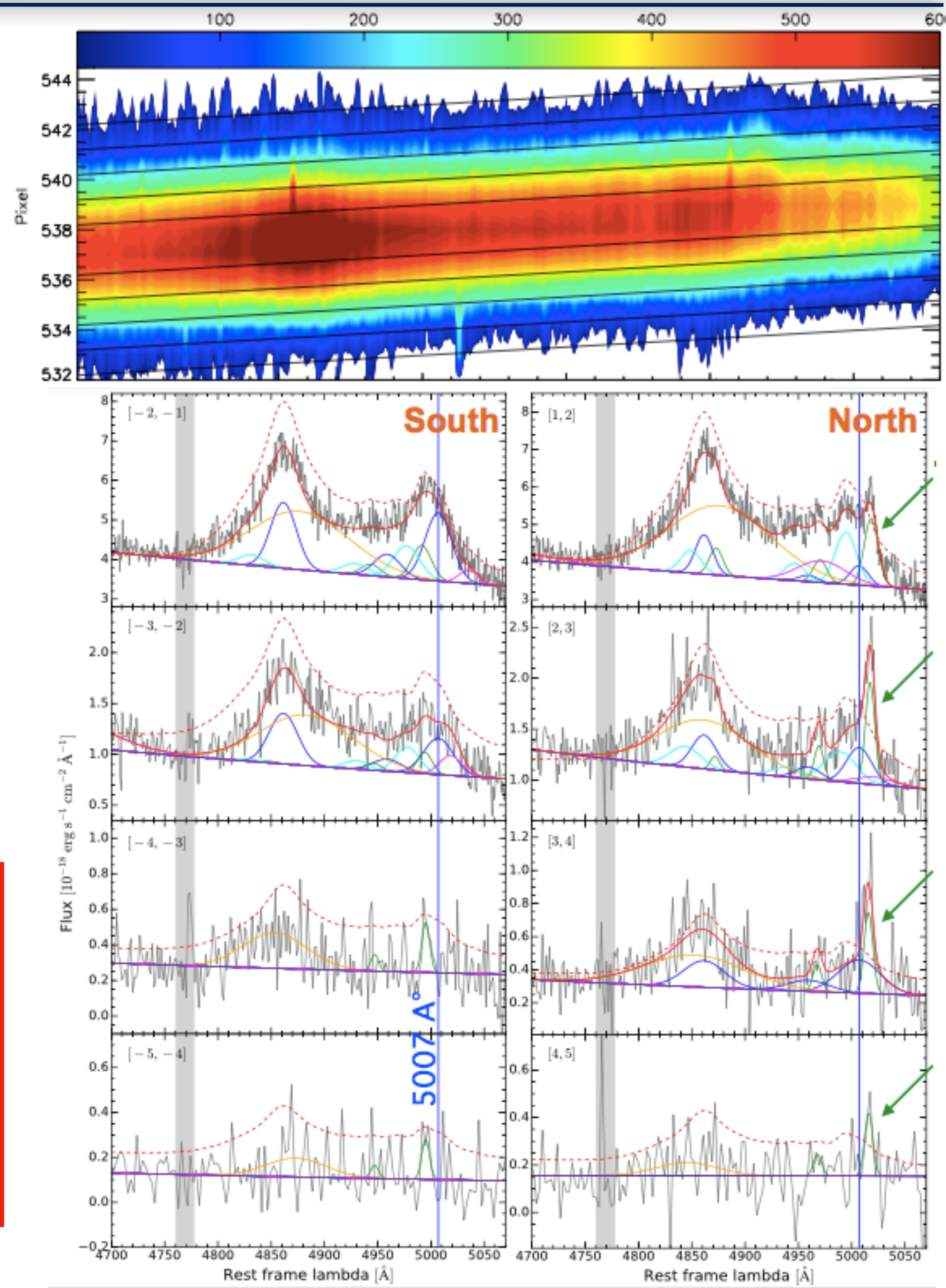
Very broad blue-shifted [OIII] lines

$FWHM_{[OIII]} \sim 1200$ -2200 km s $^{-1}$

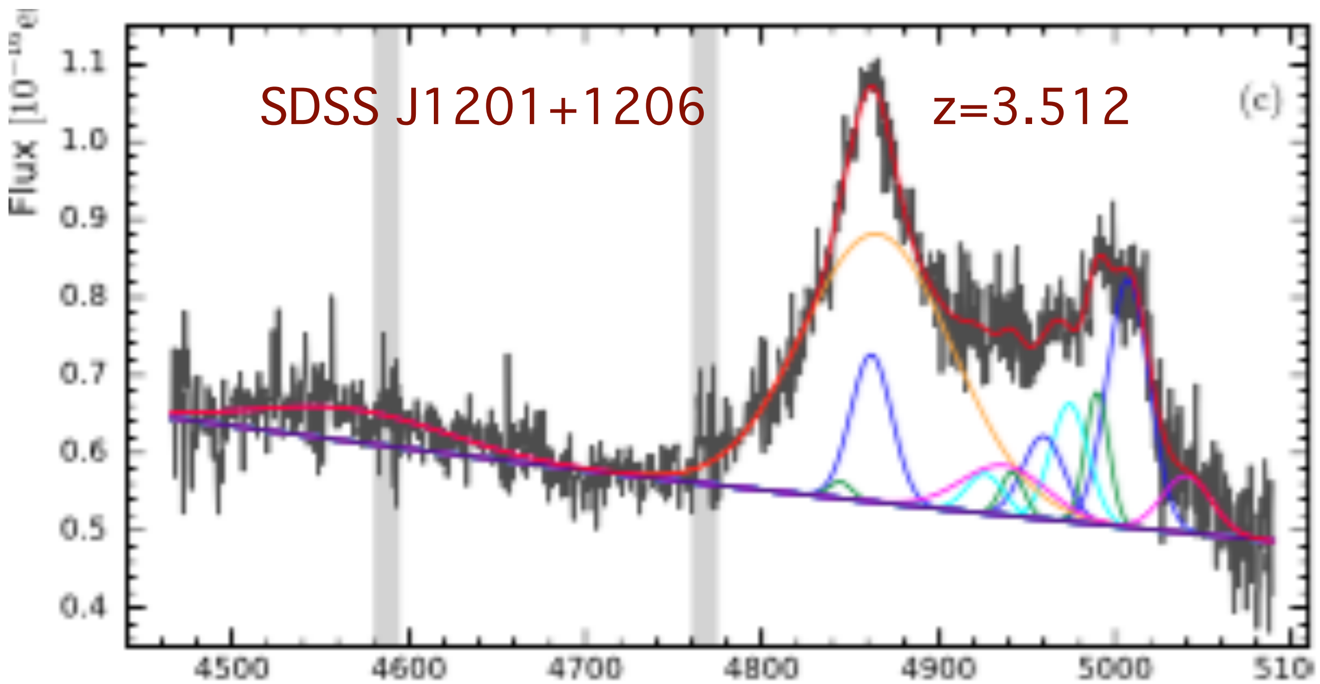
Strong [OIII] lines observed so far

$L_{[OIII]} > 10^{44}$ erg s $^{-1}$

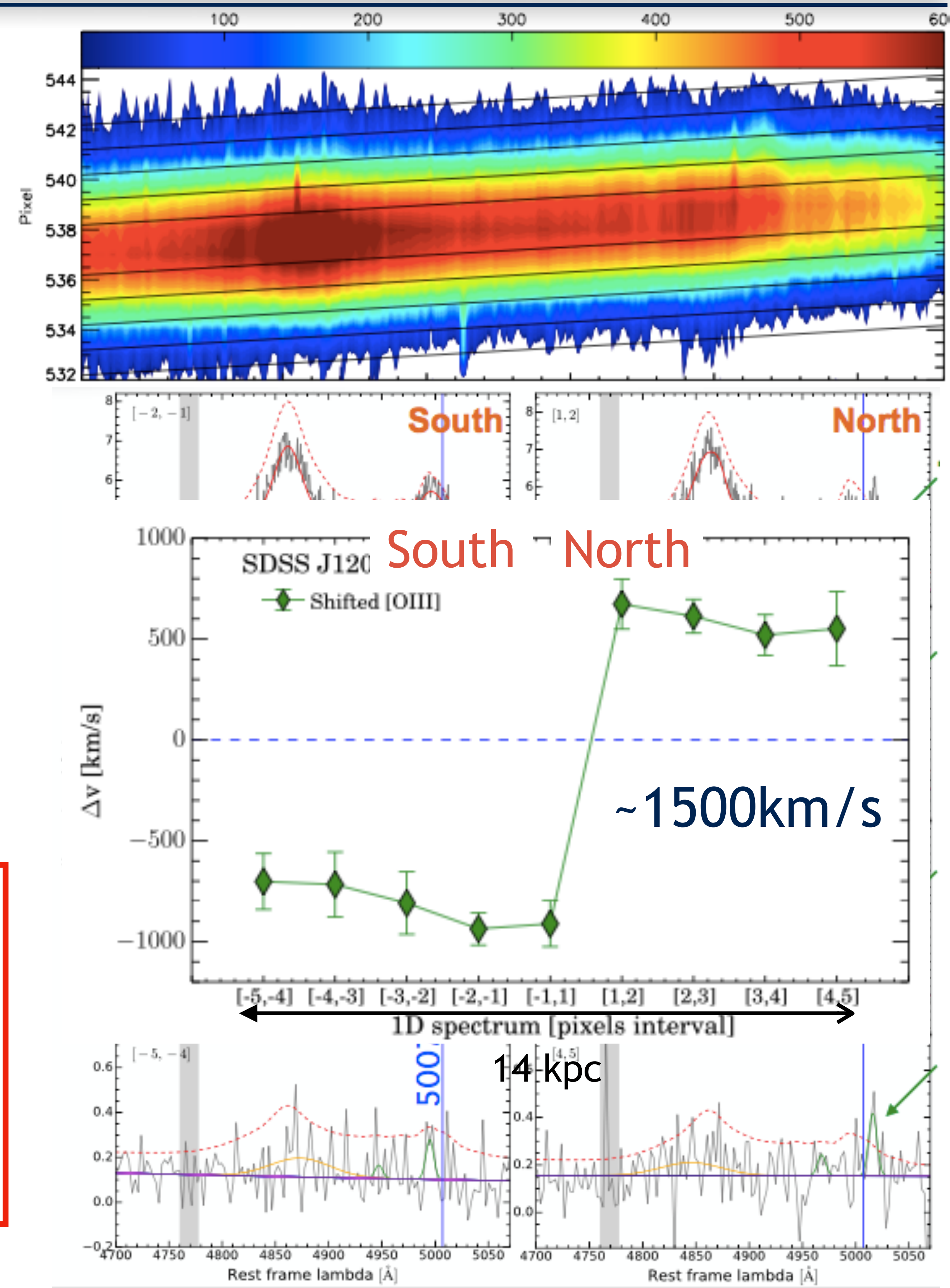
Fast [OIII] emission v(max) ~ 1400 -3000 km s $^{-1}$



# Longslit Hyper-lum QSOs: WISSH SURVEY




Bischetti, Piconcelli, Vietri + 2017

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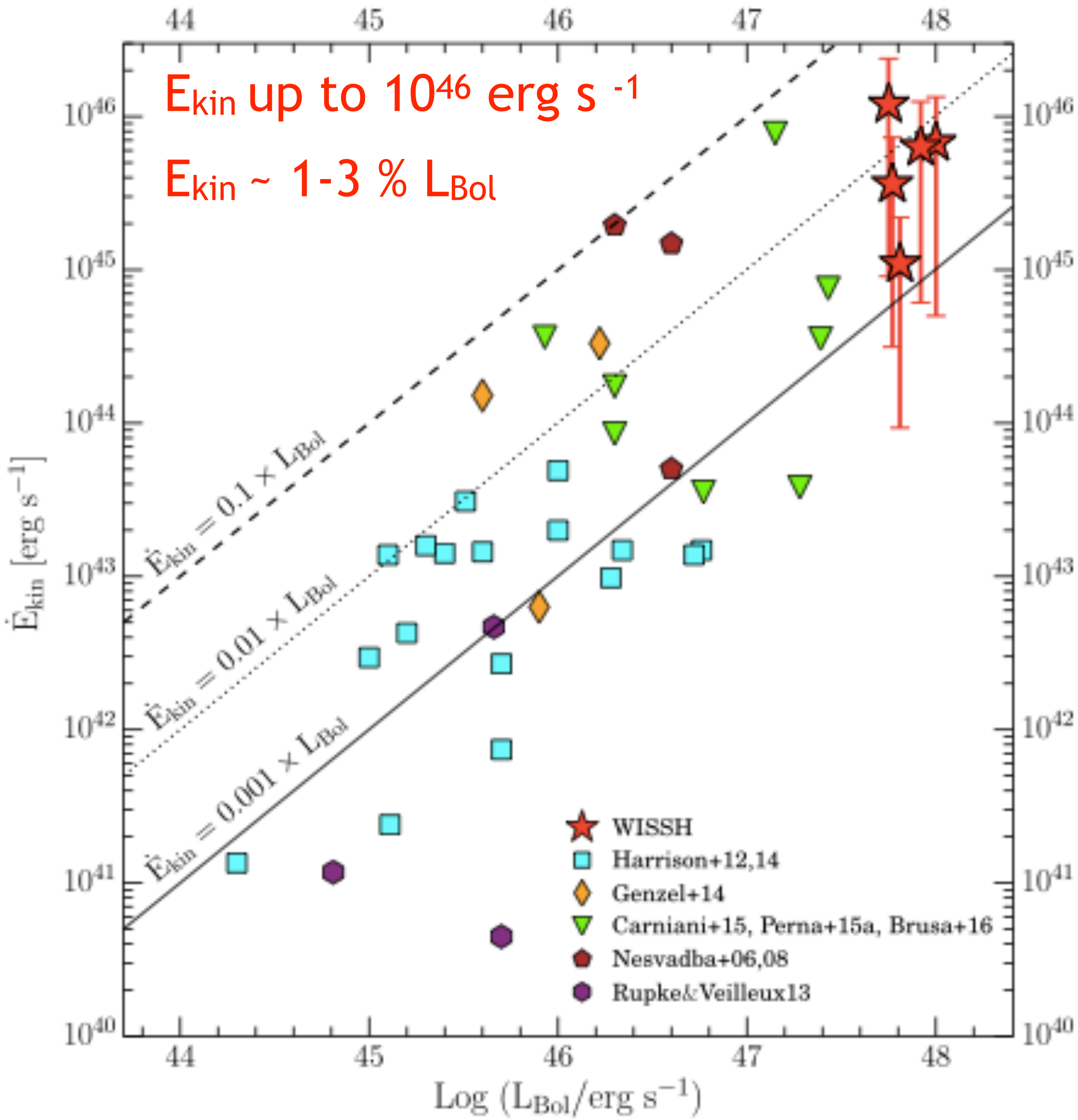
# Powerful [OIII] outflows in WISSH Quasars




$L^{broad}_{[OIII]} \longrightarrow M_{ion}$

$\dot{M} \sim \frac{3\ M_{ion}\ v_{max}}{R}$

$\dot{E}_{kin} = \frac{\dot{M} v^2_{max}}{2}$

Bischetti, Piconcelli, Vietri + 2017

WISSH quasars allow to reveal extremely powerful outflows

# STATISTICAL APPROACH: MOSDEF SURVEY

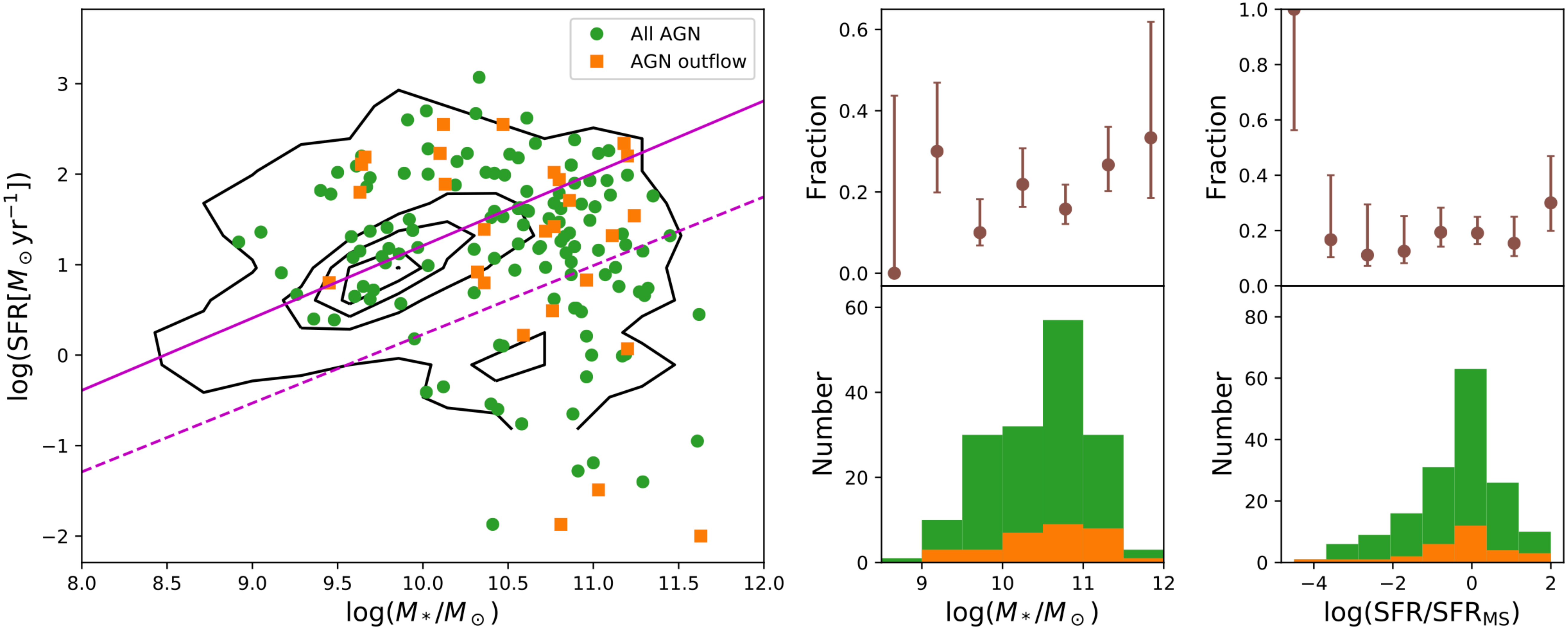
Spectroscopic survey at $1.4 < z < 3.8$ using Keck/MOSFIRE
1500 galaxies+AGN

Leung+2019

159 AGN $L_{Bol}=10^{44-47}$ erg/s

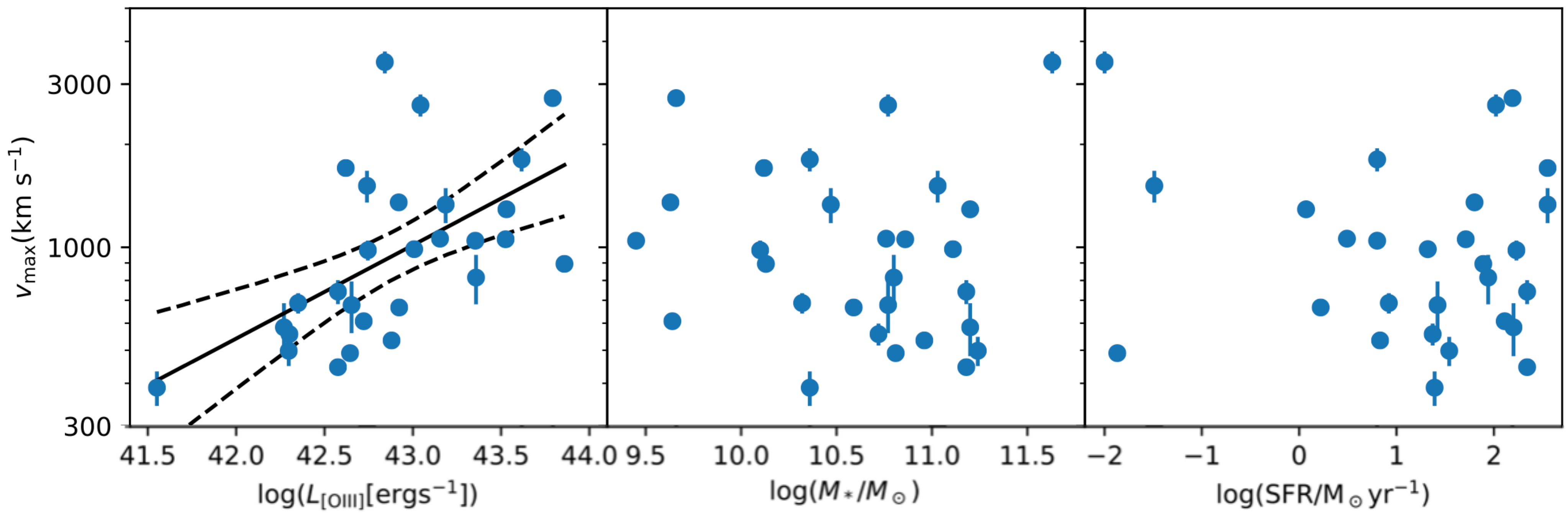
Hβ,[OIII],Hα,[NII]

3 dex in M* and SFR

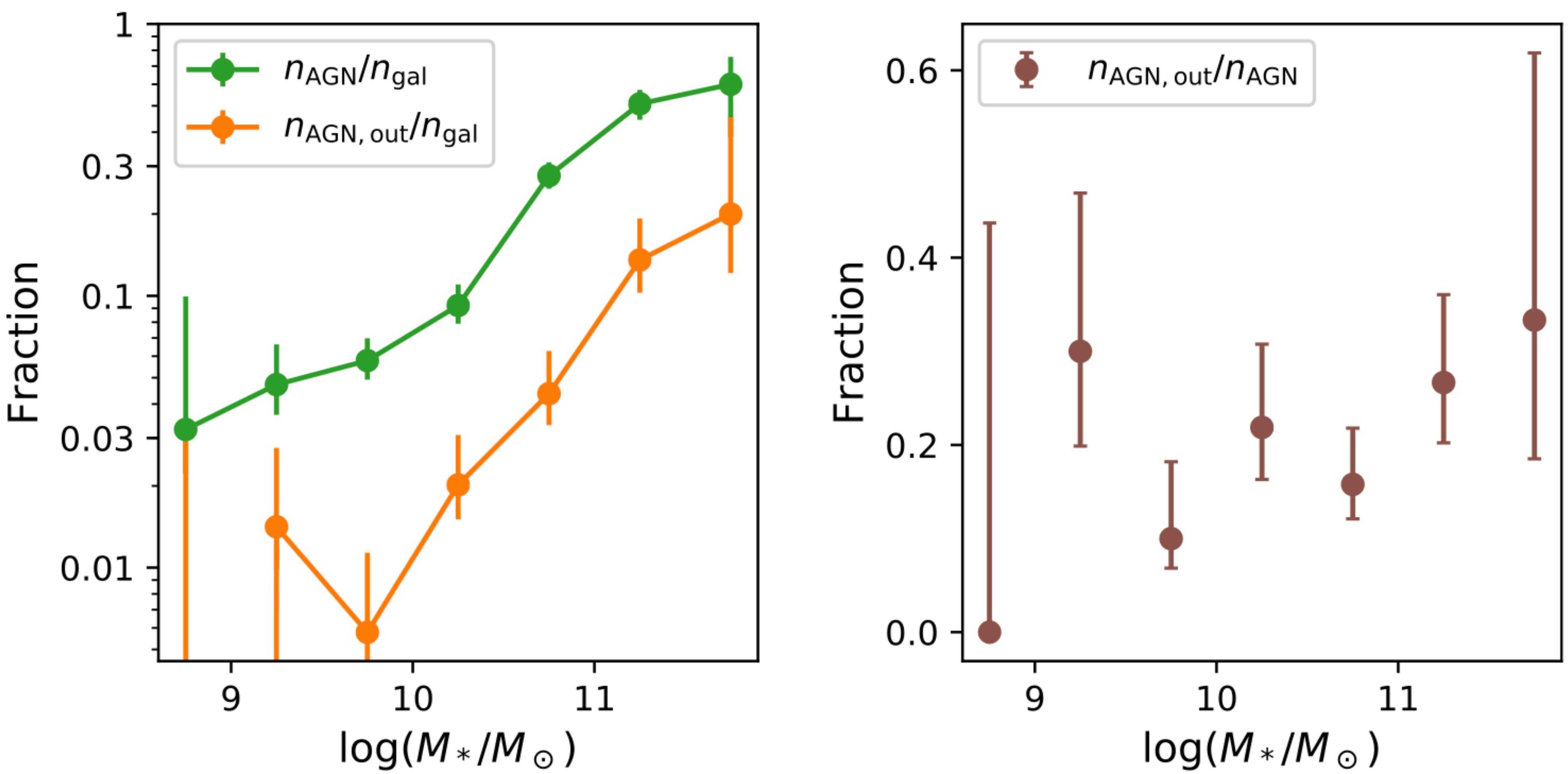



- outflow detected in 17% of AGN
- 7 times more often than in mass-matched inactive

# Statistical approach: MOSDEF survey




outflows are fast 400-3500 km/s with extention=0.3-11 kpc




AGN outflows indipendent of stellar mass

Leung+2019

# STATISTICAL AND 3D APPROACH: KMOS 3D SURVEY

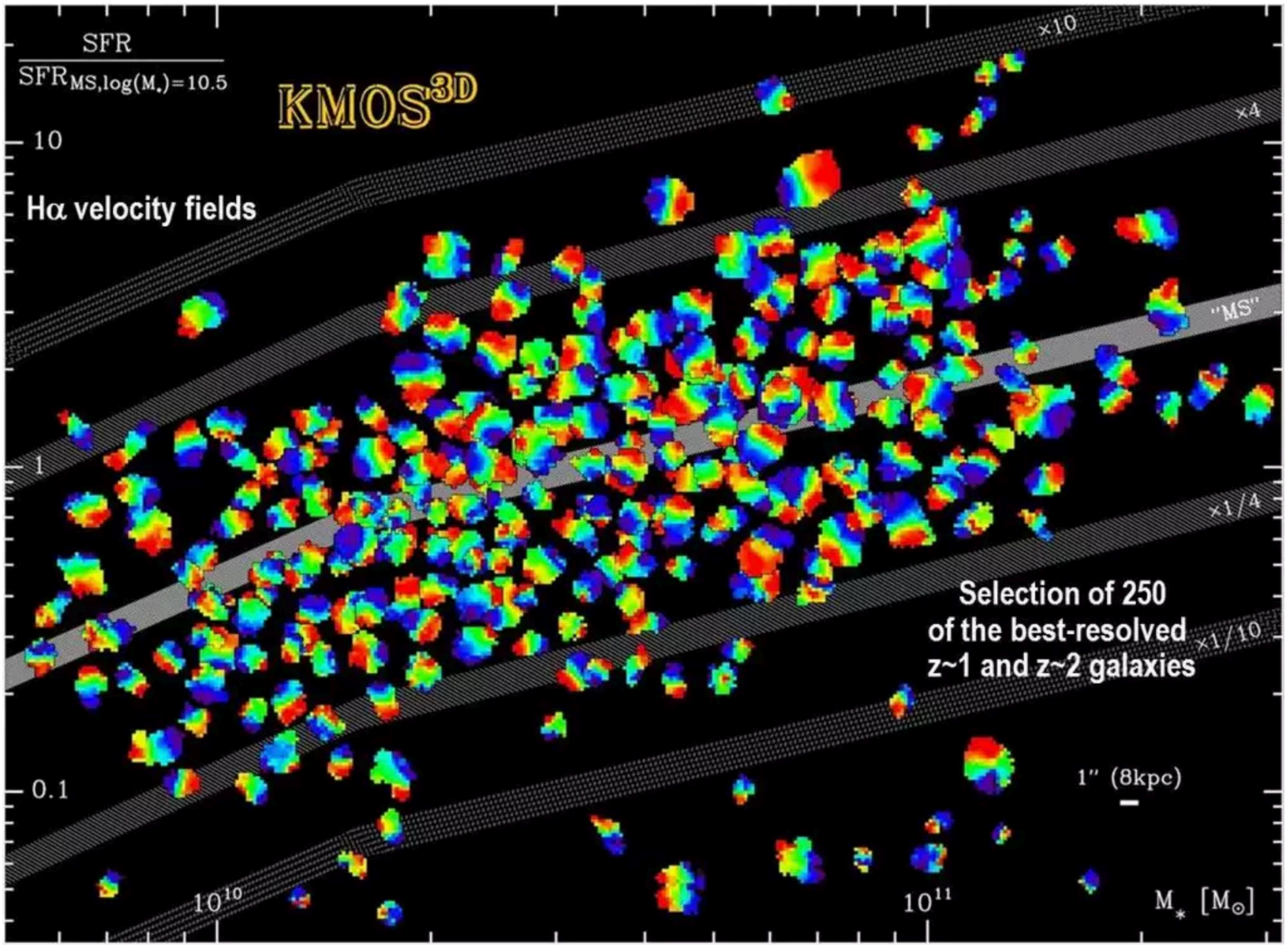
Wisnioski+2019

599 normal galaxies at redshift 0.6-2.7

VLT/KMOS IFU in seeing limited mode

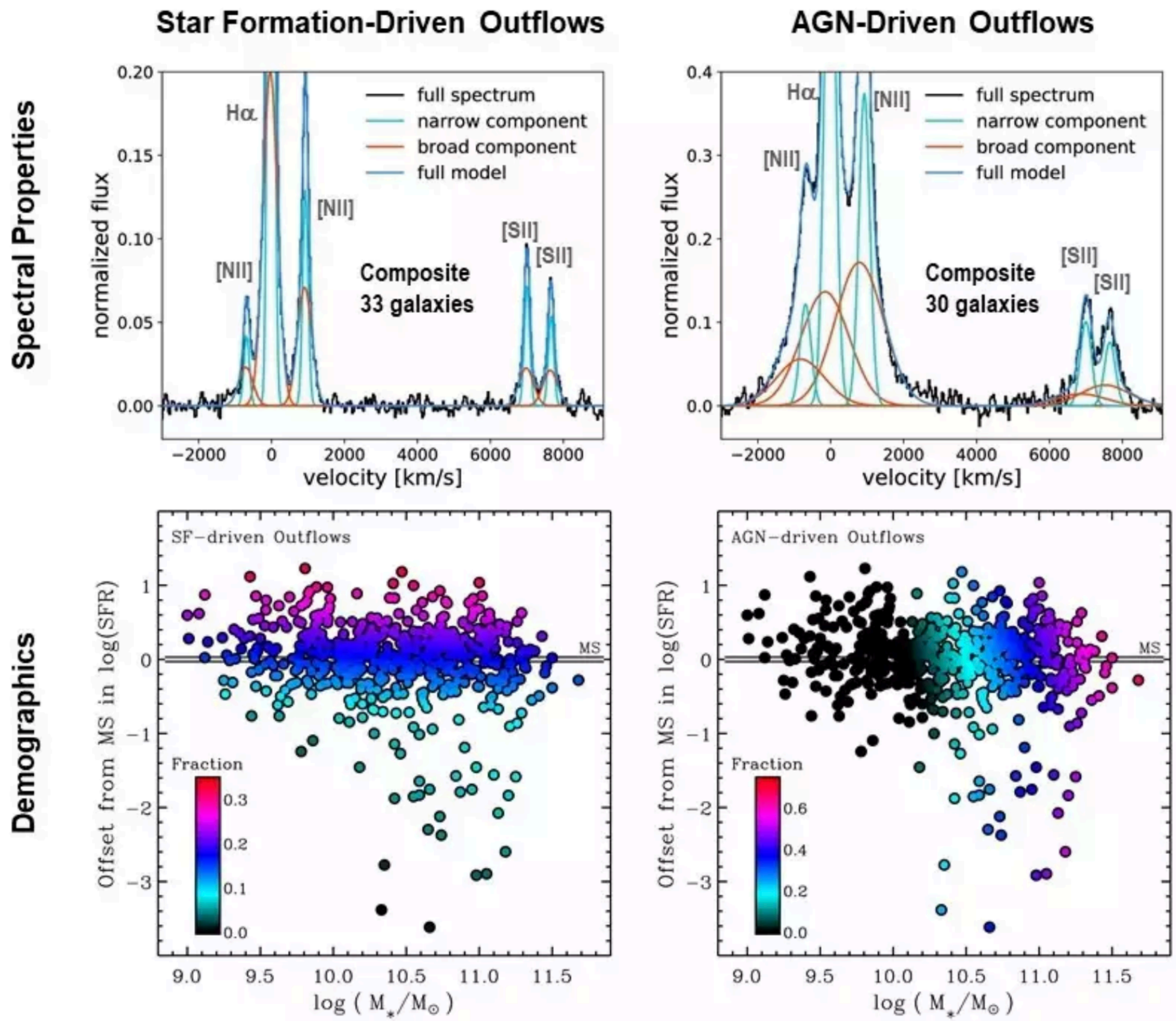
Hα, [N II], and [S II] line emission.  $M^{*}=10^{9-11}\,M_{sun}$

Best resolution achieved 0.5” seeing = 4 kpc at z~2



# Statistical and 3D approach: KMOS 3D survey

- SF-driven winds correlates mainly with SF properties.
- AGN-driven outflows (~1000–2000 km s[−1]) are commonly detected above log(M*/Msun)~10.7
- The incidence, strength, and velocity of AGN-driven winds strongly correlates with stellar mass

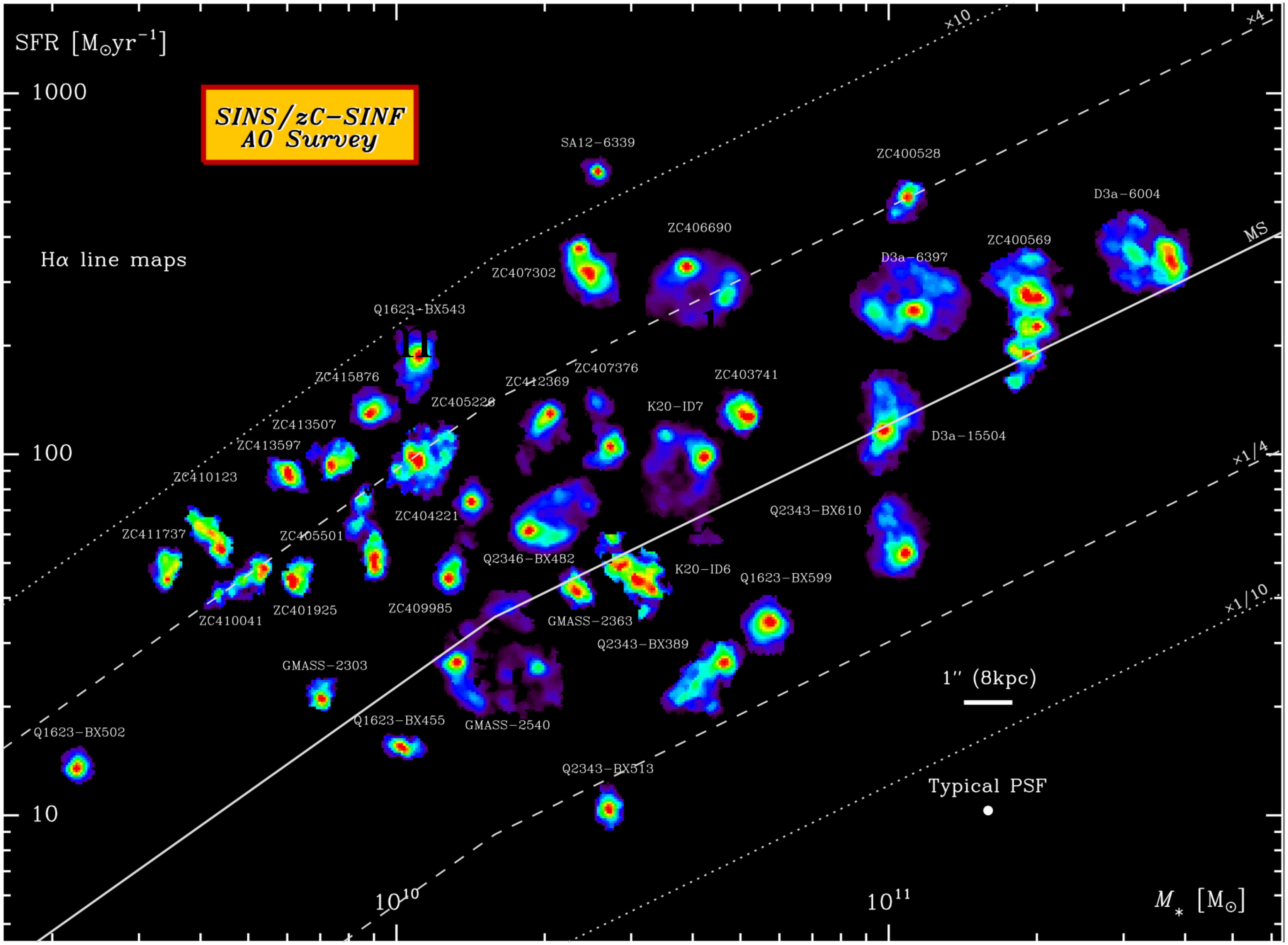



Forster Schreiber+2019

# 3D AO approach for galaxies: SINS/zC SINFONI

VLT/SINFONI IFU program
35 MS galaxies with AO-Assisted (the result of 12 yr!)
z=1-3 resolve at 1.5 kpc

Forster Schreiber+2018

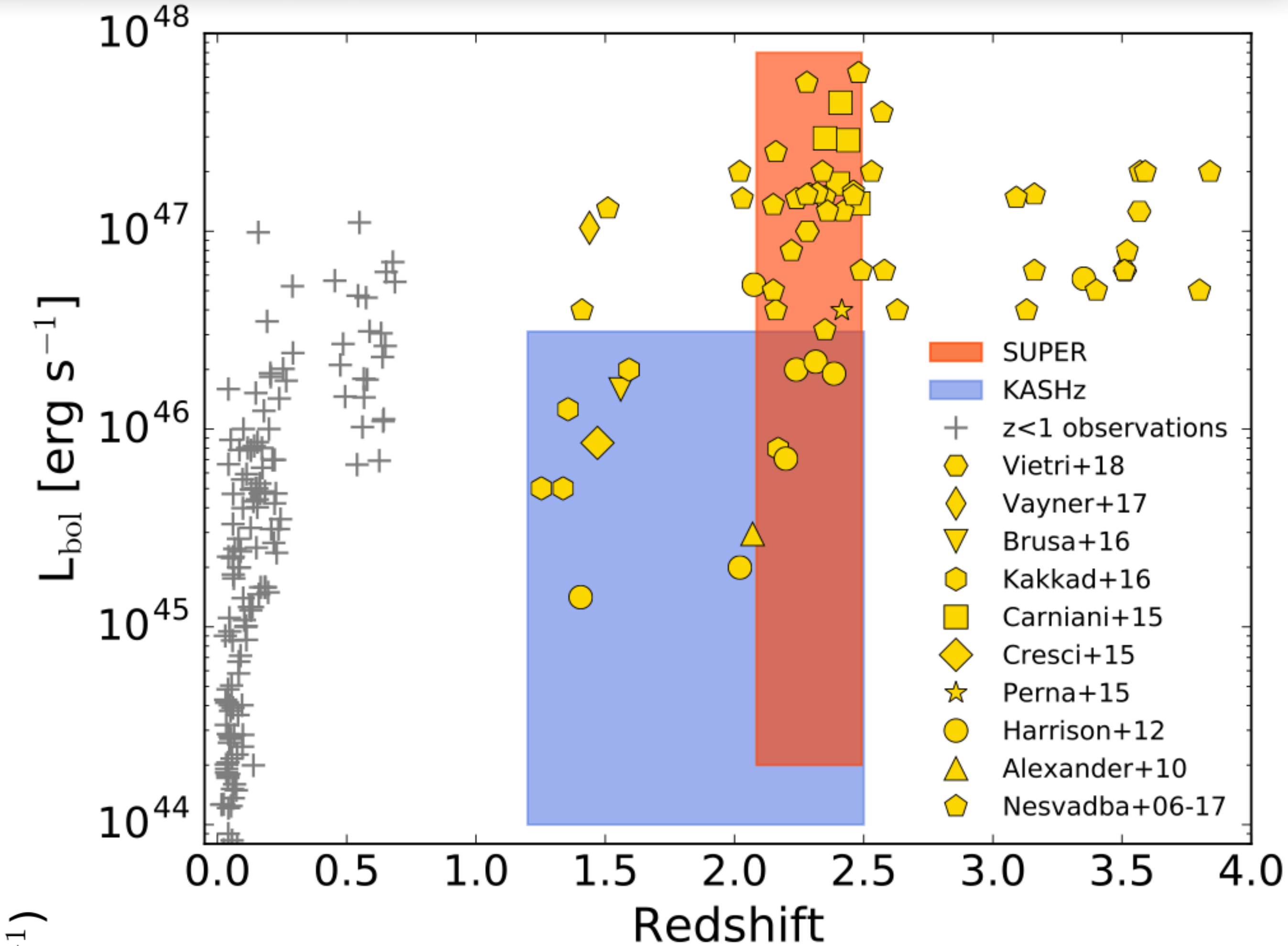


# 3D AO APPROACH FOR AGN:  SURVEY

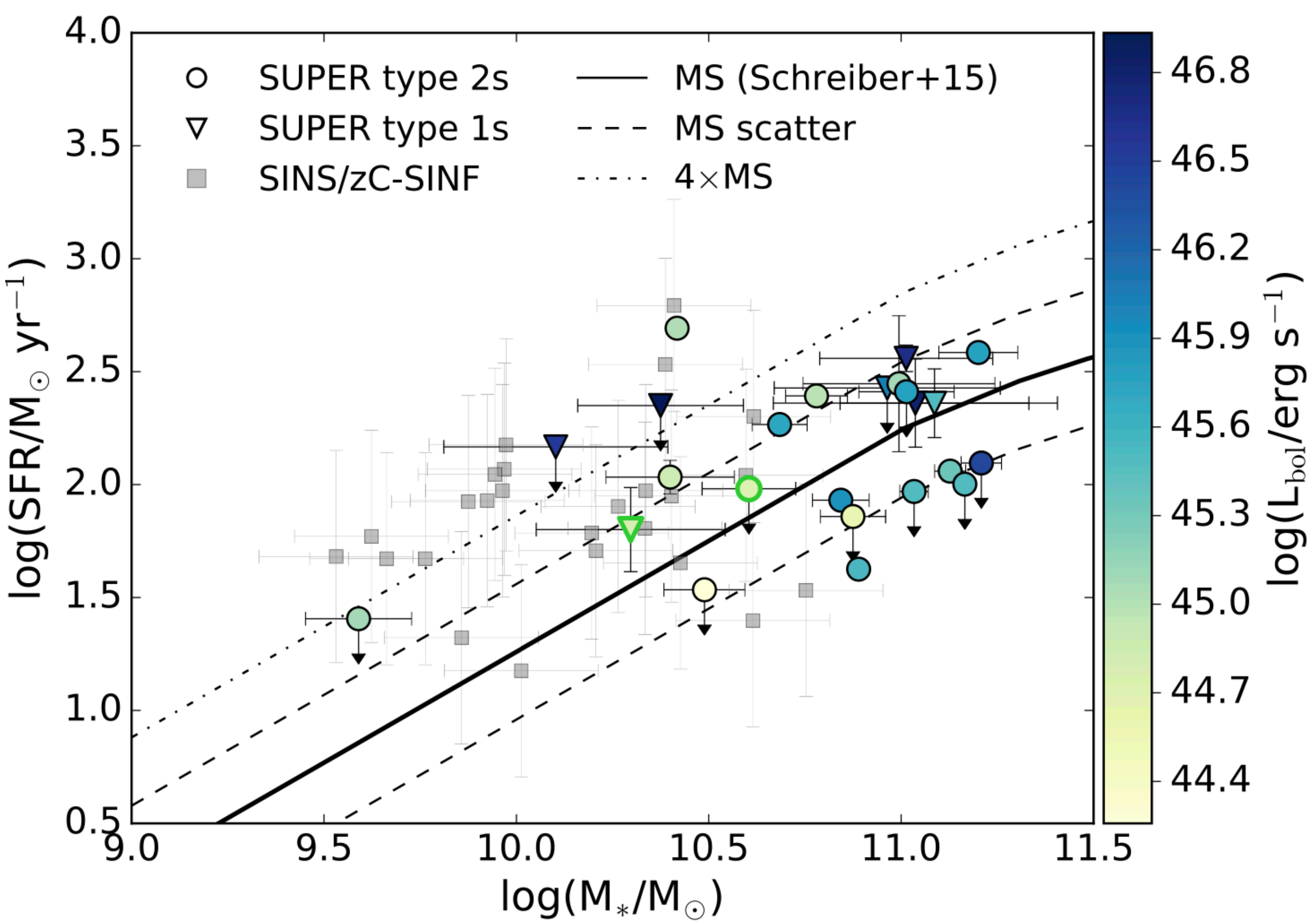


PI: V. Mainieri

- 280 hours @ VLT/SINFONI (IFS) with AO
- PSF FWHM≈0.2”-0.3” ≈1 kpc spatial resolution
- Blind survey, ~40 AGN at z=2.12-2.49
- Ionized outflows -> [OIII]$\lambda$5007 (H band)
- Star formation -> H$\alpha$ (K band)





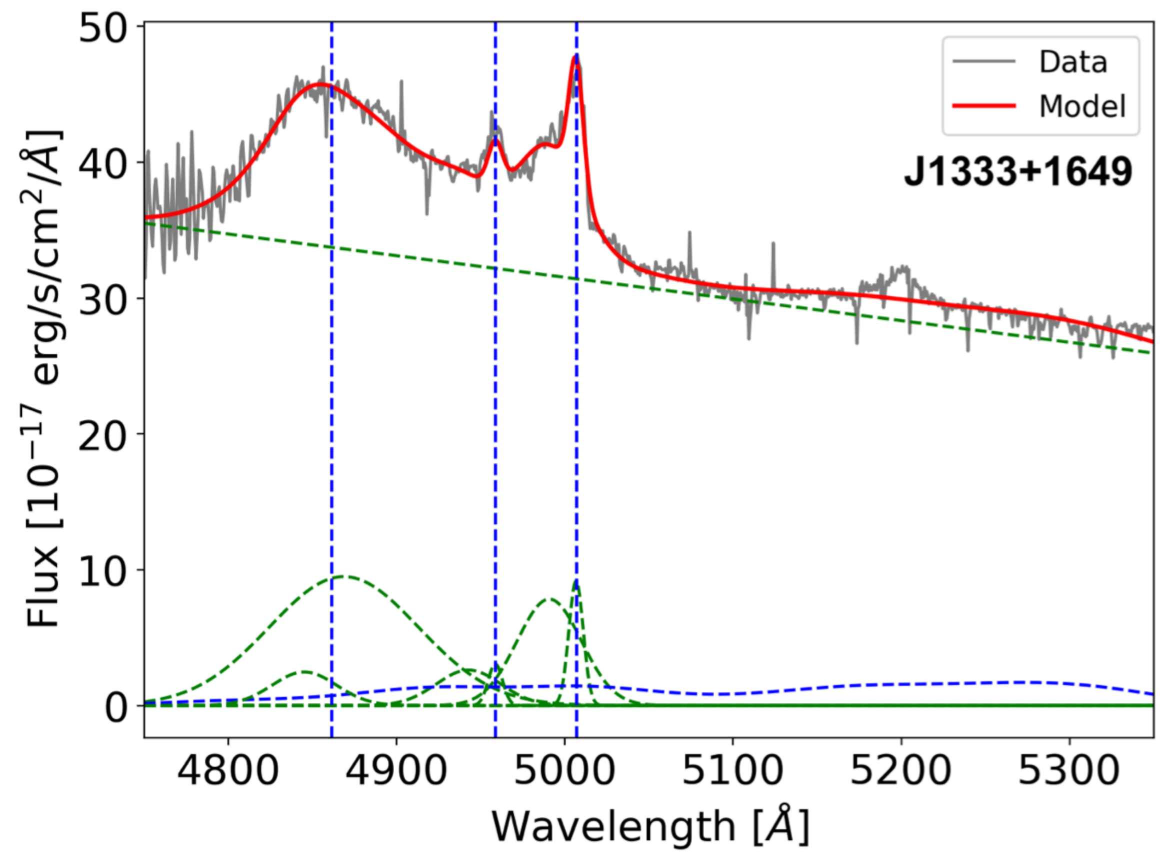




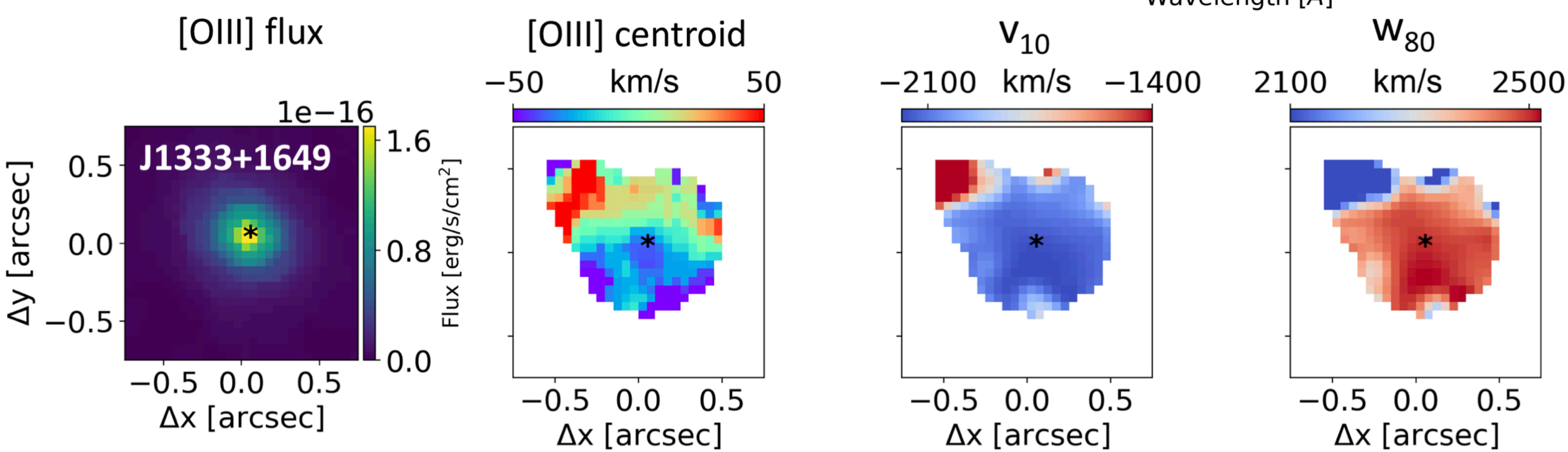
Circosta+18

# 3D AO approach for AGN: UPER SURVEY

- ~100% of the Type 1 and Type 2 AGN show ionized outflows (Kakkad+2020, Tozzi+2024)
- [OIII] emission spatially resolved for ~35% of the Type 1 sample and the outflows show an extension up to ~6 kpc; 85% of Type 2 extended 2-4 kpc
- Hα—> no clear evidence of outflows impacting SF




Kakkad, Mainieri, Vietri+20

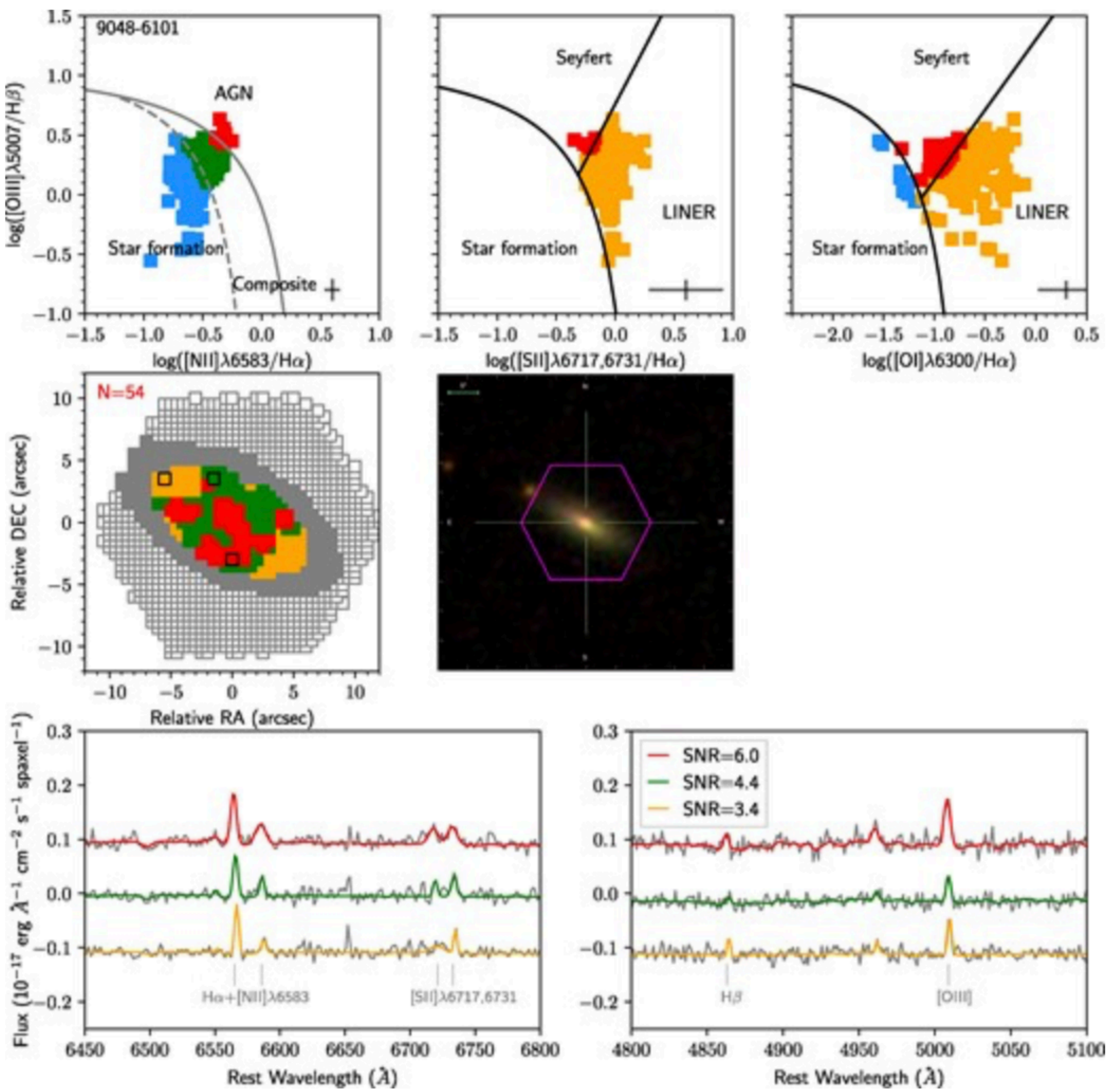


# AGN IN DWARF GALAXIES

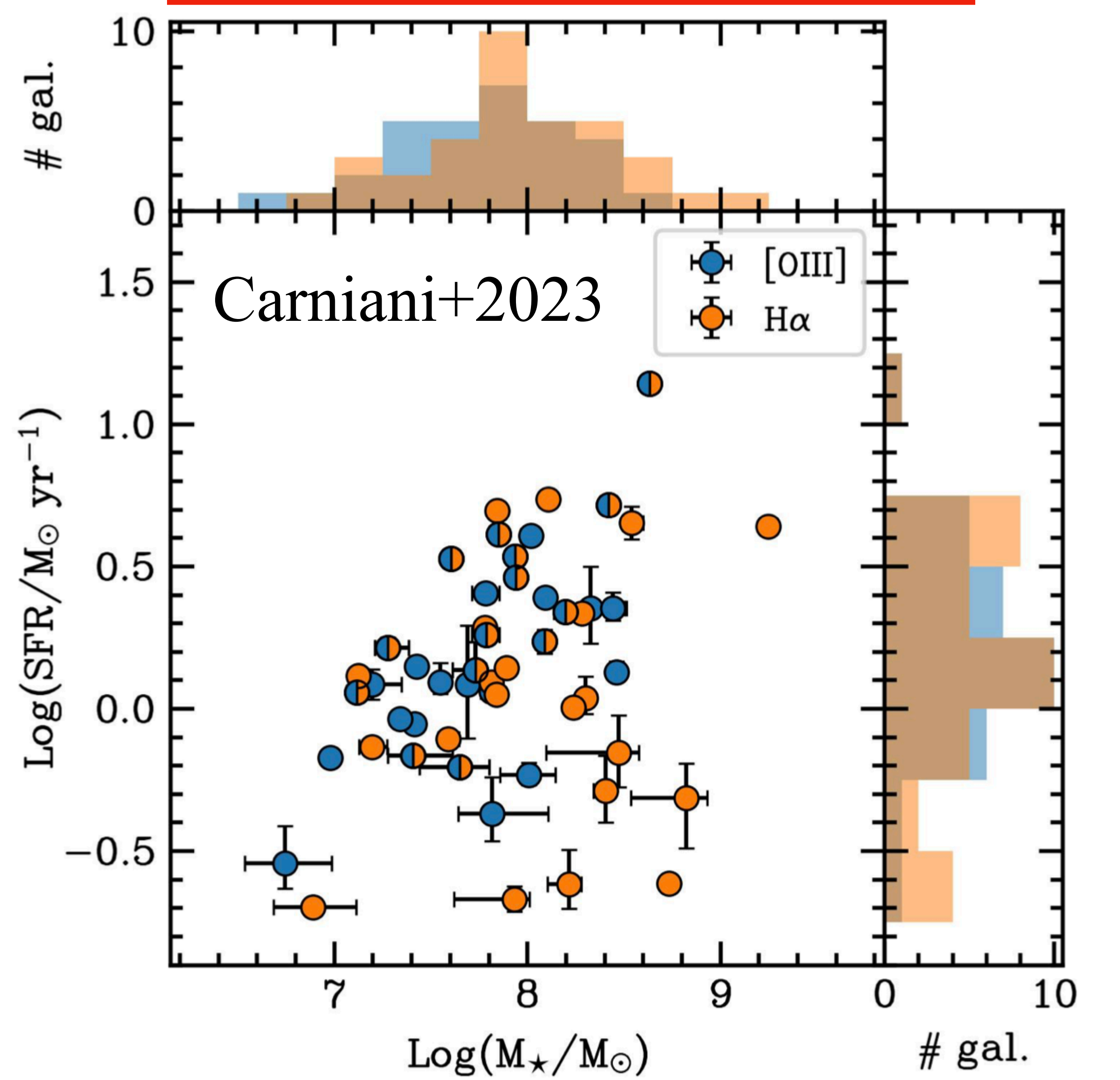
- Low mass galaxies <$10^{10}$ $M_{sun}$ studied in local universe
- At high redshift lack of sensitivity of ground-based facilities in the NIR to detect faint broad component
- SDSS MaNGA: 10% of the galaxies in quenched dwarf galaxy sample appear to host genuine AGN, based on BPT diagnostics with outflowing gas (e.g. Penny+18, keck/gemini Liu+2020)

MaNGA: 17 IFUs in the Optical R~2000 z~0.03

JADES 52 galaxies z=3.5-8.5 LogM*~7-9 S/N>5 [OIII] or Ha with JWST/NIRSpec MSA




outflow incidence rate of ~25%

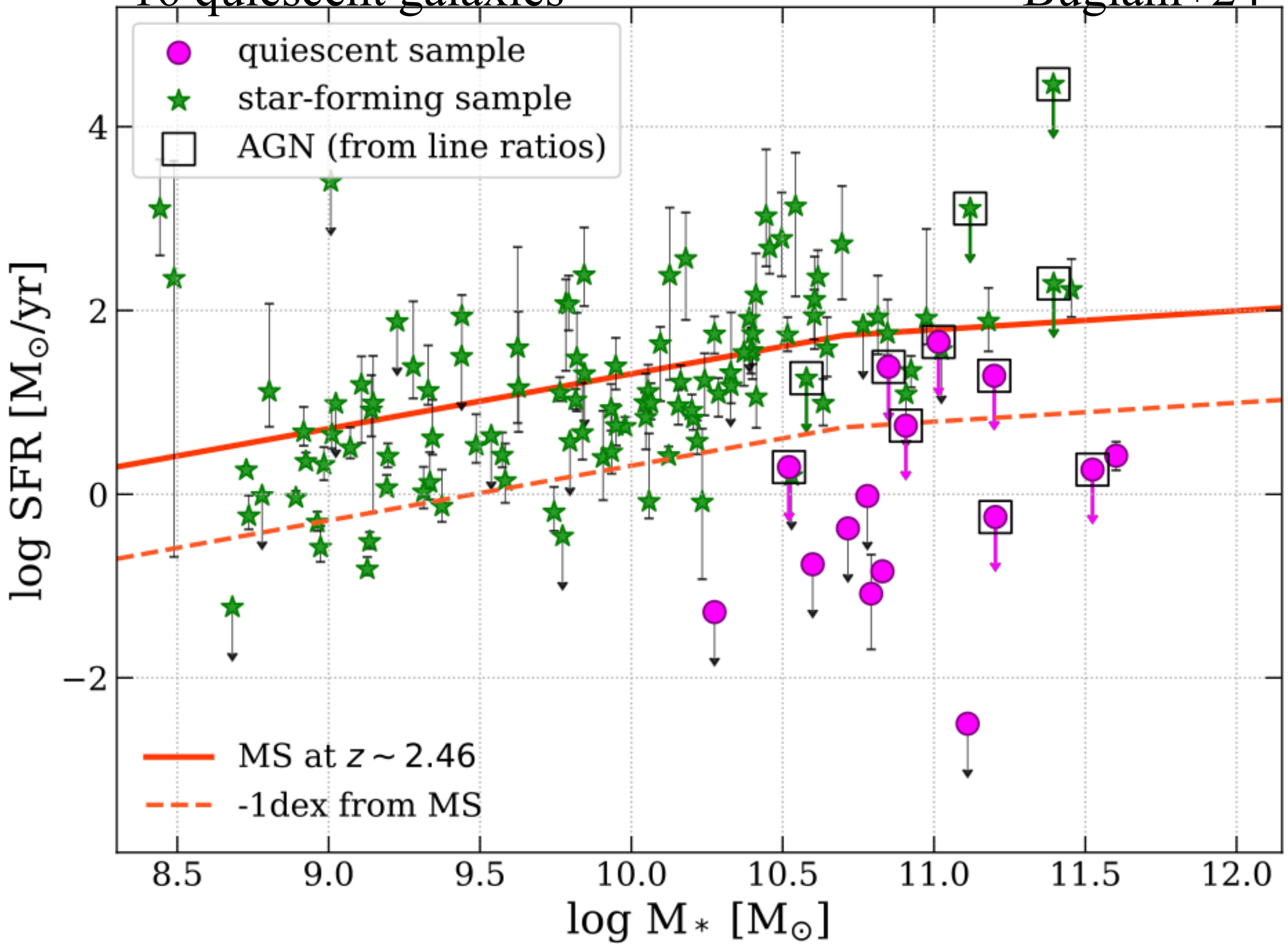


# AGN IN PASSIVE GALAXIES

Blue Jay survey (PI Belli)
147 galaxies at cosmic noon with JWST/NIRSpec MOS
1.7 < z < 3.5 LogM*~9-11.5

16 quiescent galaxies

Bugiani+24




1D JWST spectra

lack of X-ray detections; BPT classification; weak AGN luminosities

# 3D SHARP VIEW AT COSMIC NOON

Sample of galaxies without any preselection $1.5 < z < 3.6$ $M^*=10^{8-11}$ Msun

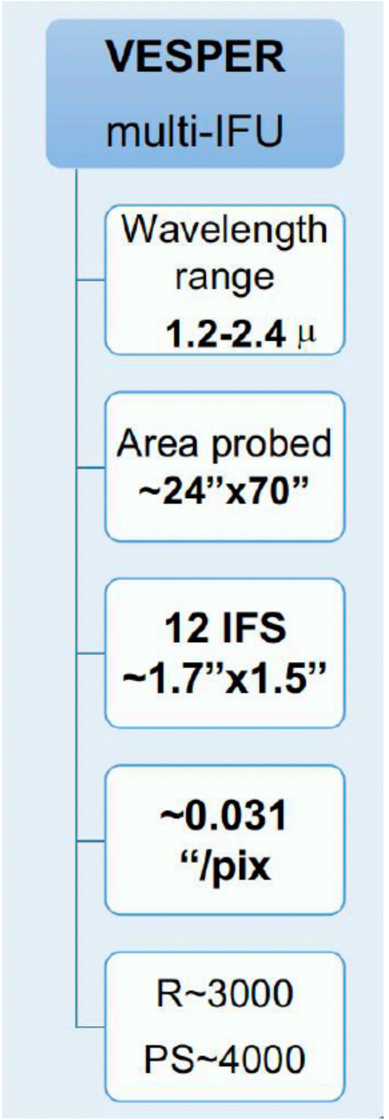
[OII] up to z=3.6 and Hα up to z=2.6 —-> trace instantaneous star formation (<10 Myr)
[OIII] covering the entire selected redshift range —> tracing the NLR gas and ionized outflows

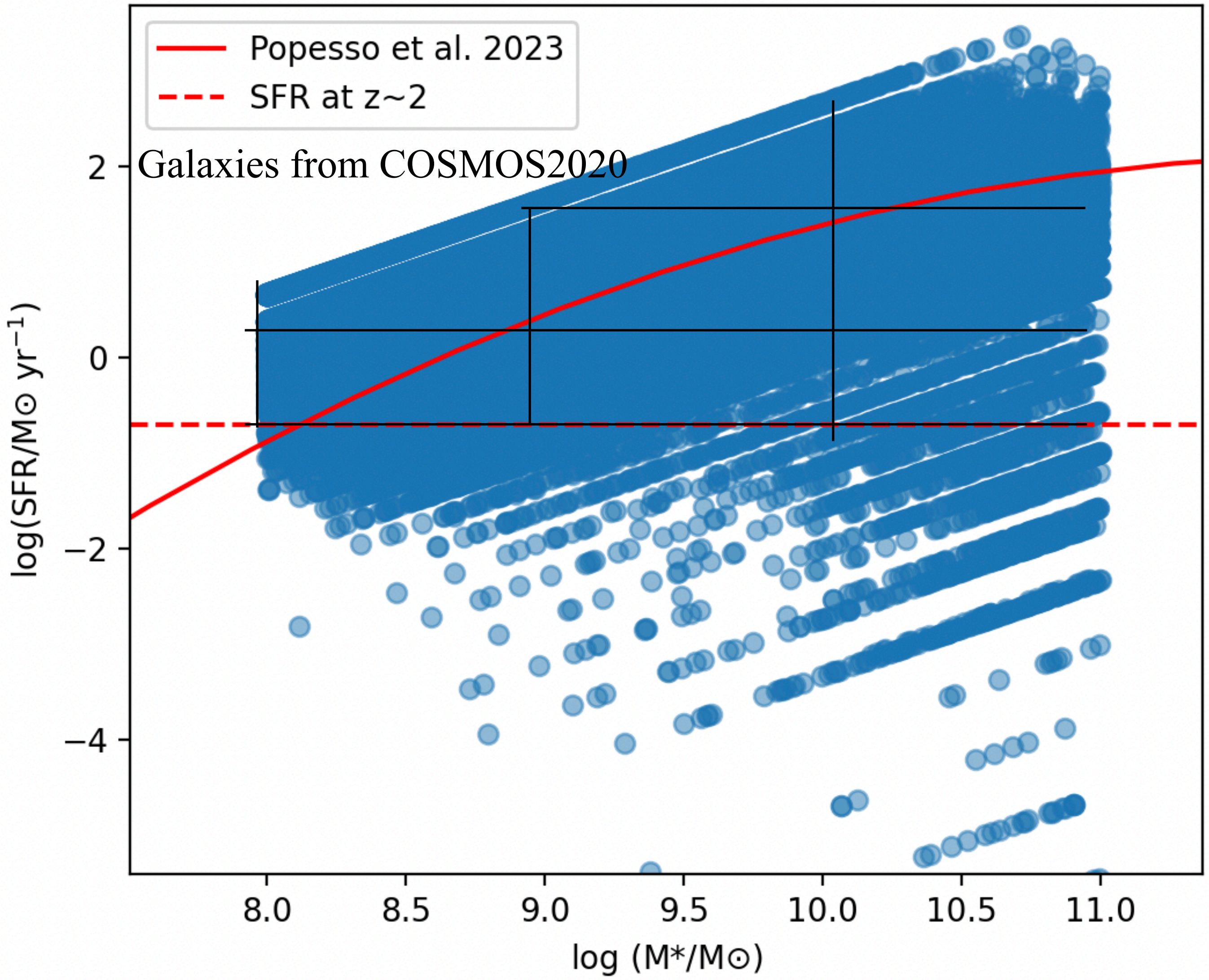
- The line flux limit—-> Hα- or [OII]-based SFRs on the MS for dwarf galaxies; below the MS at $M_*=10^{10}$ $M_{sun}$

SNR>~3 (Leung+2019) Texp=9hr on each galaxy —> ~12 galaxies in VESPER FOV (12 IFU!)

Survey of ~400 galaxies along SFR vs Mass plane —> 300 hours

VESPER can probe scales down to ~0.3 kpc at z~2




JWST 3"x3" FOV

0.1"scale

~1 kpc at z~2