INCIDENCE, SCALING RELATIONS AND PHYSICAL CONDITIONS OF IONISED GAS OUTFLOWS IN MANGA

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(submitted to MNRAS).

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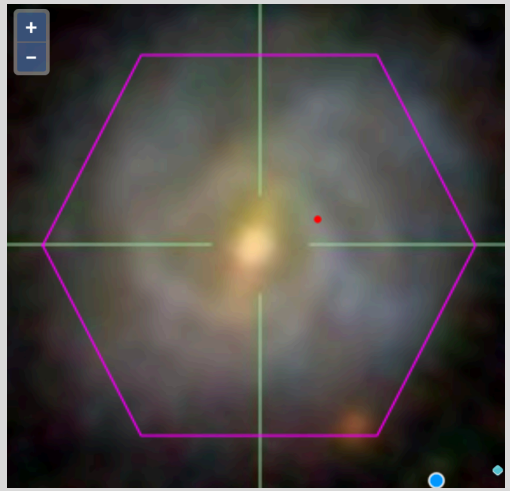
FEEDBACK

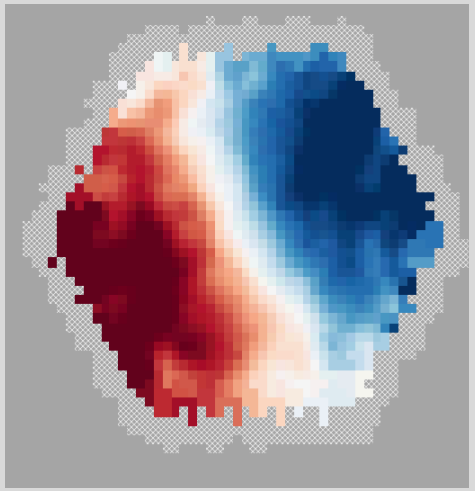
- Regulator of galaxy growth
- Which galaxies feature winds?
- How does outflow strength scale with galaxy properties?
- Physical conditions of outflowing material?

MaNGA DR15

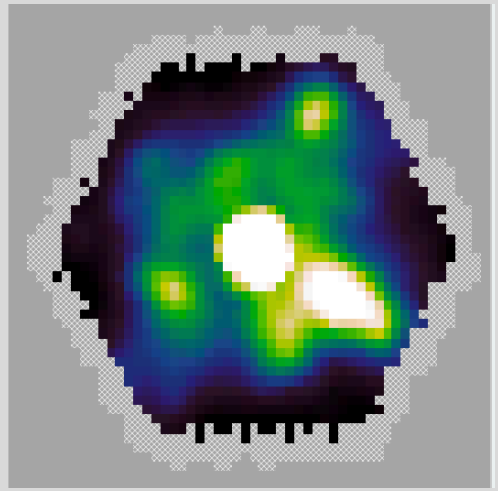
gri



Gas velocity



Hα

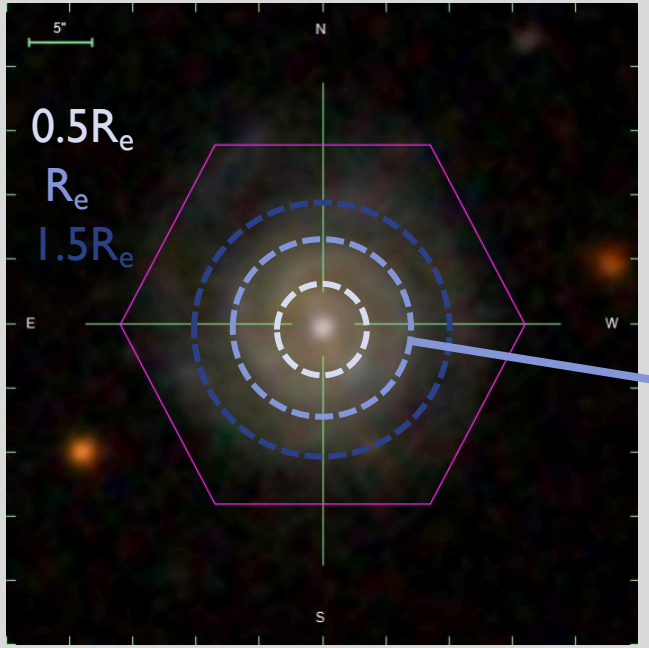


~4,800 datacubes; ⟨z⟩ ~ 0.03; θ ~ 2.5”; 3700Å - 10000Å at R~2000

- Well-defined population of typical galaxies
- Allows removing large-scale velocity field
- Allows identifying low-luminosity AGN

Law+2016, Wake+2017

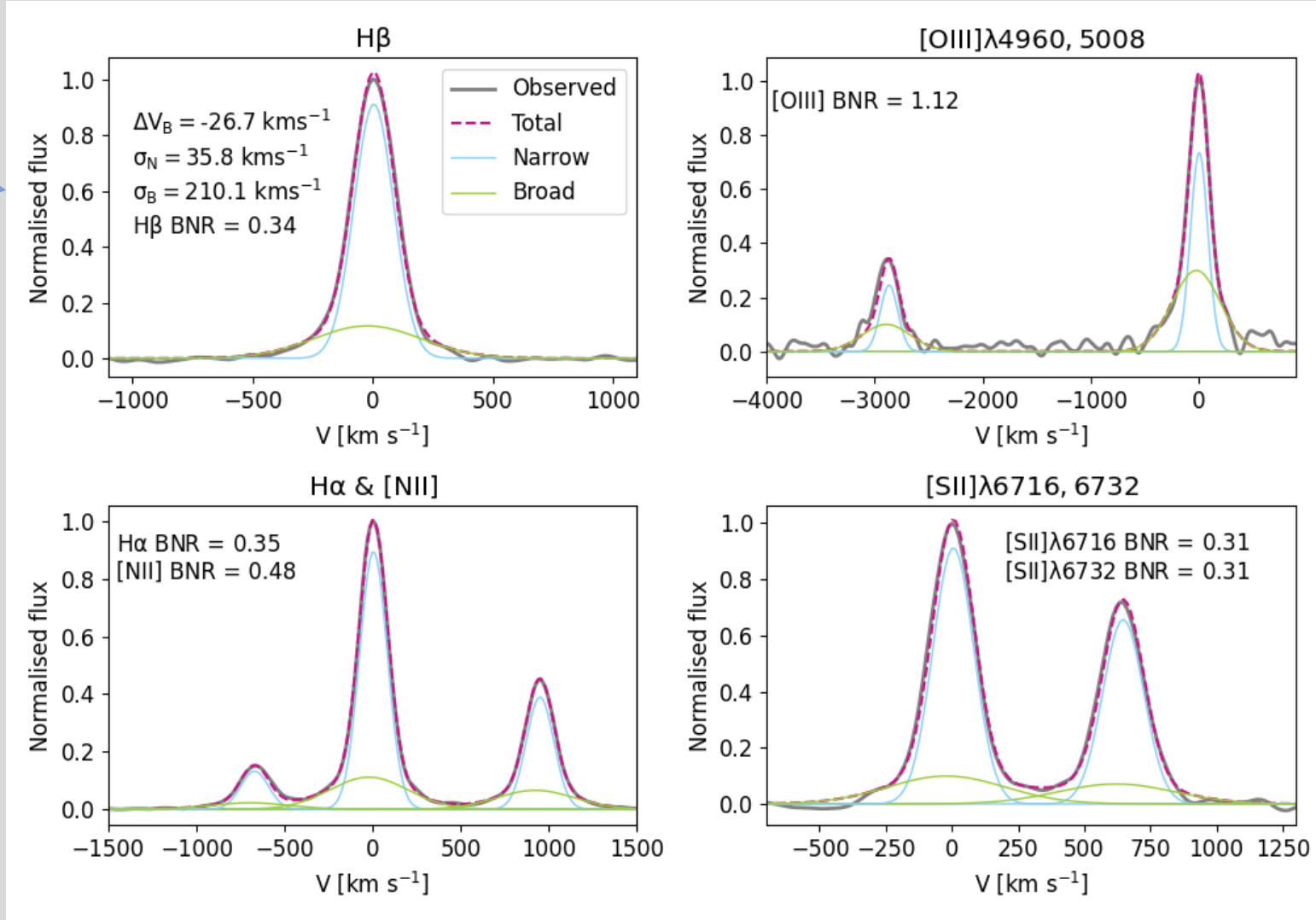
LINE PROFILE FITTING



- Stack within elliptical apertures
- Remove large-scale velocity field
- Continuum subtraction w/ PPXF

  (Cappellari+2017)
- Simultaneous double-Gaussian fitting
- Statistically preferred over single-Gaussian?

⟹ 300 galaxies w/ outflows (173 AGN)



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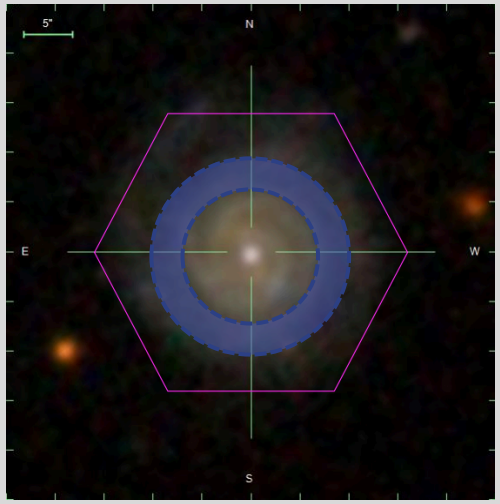
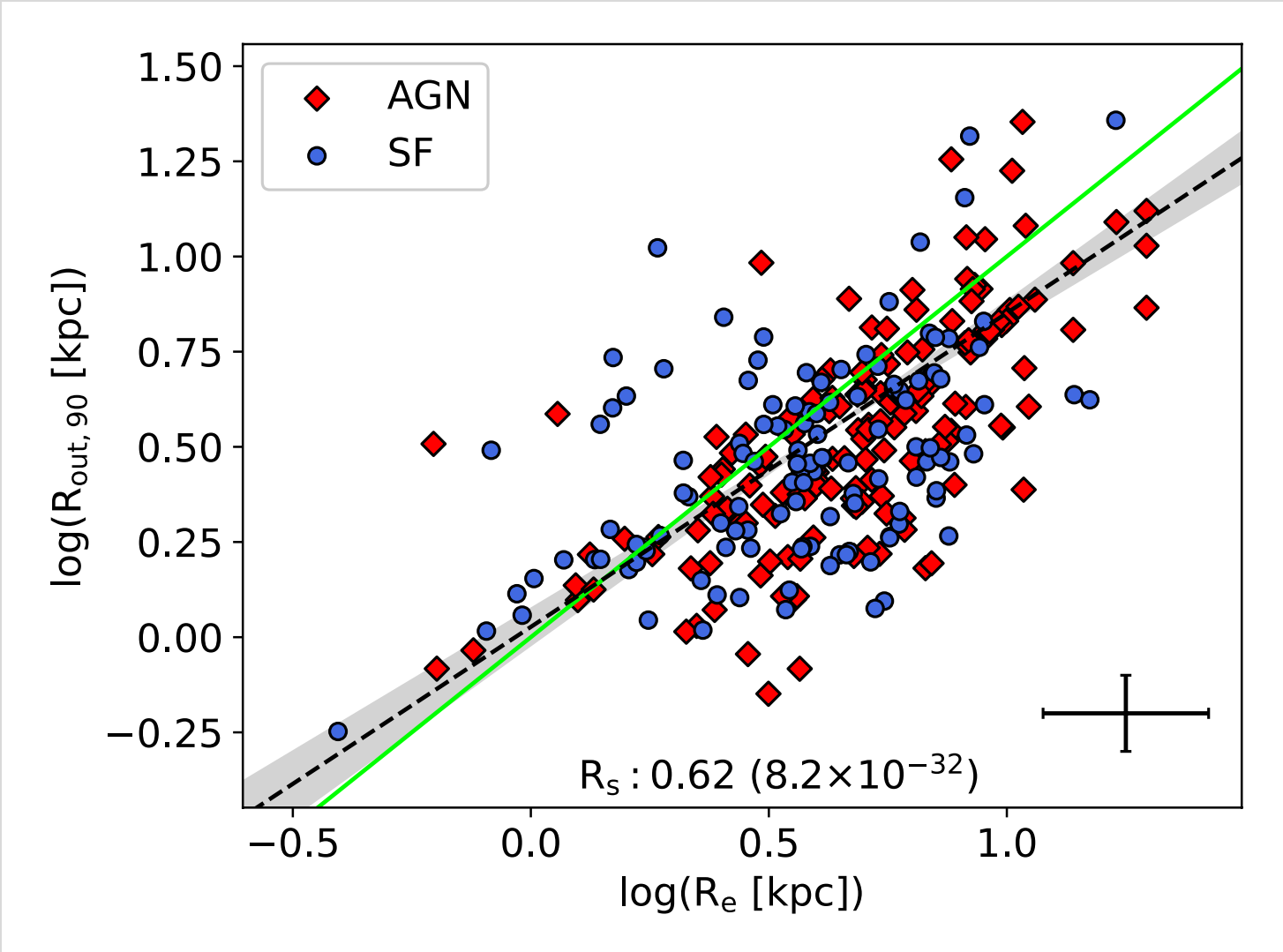


SPATIAL EXTENT

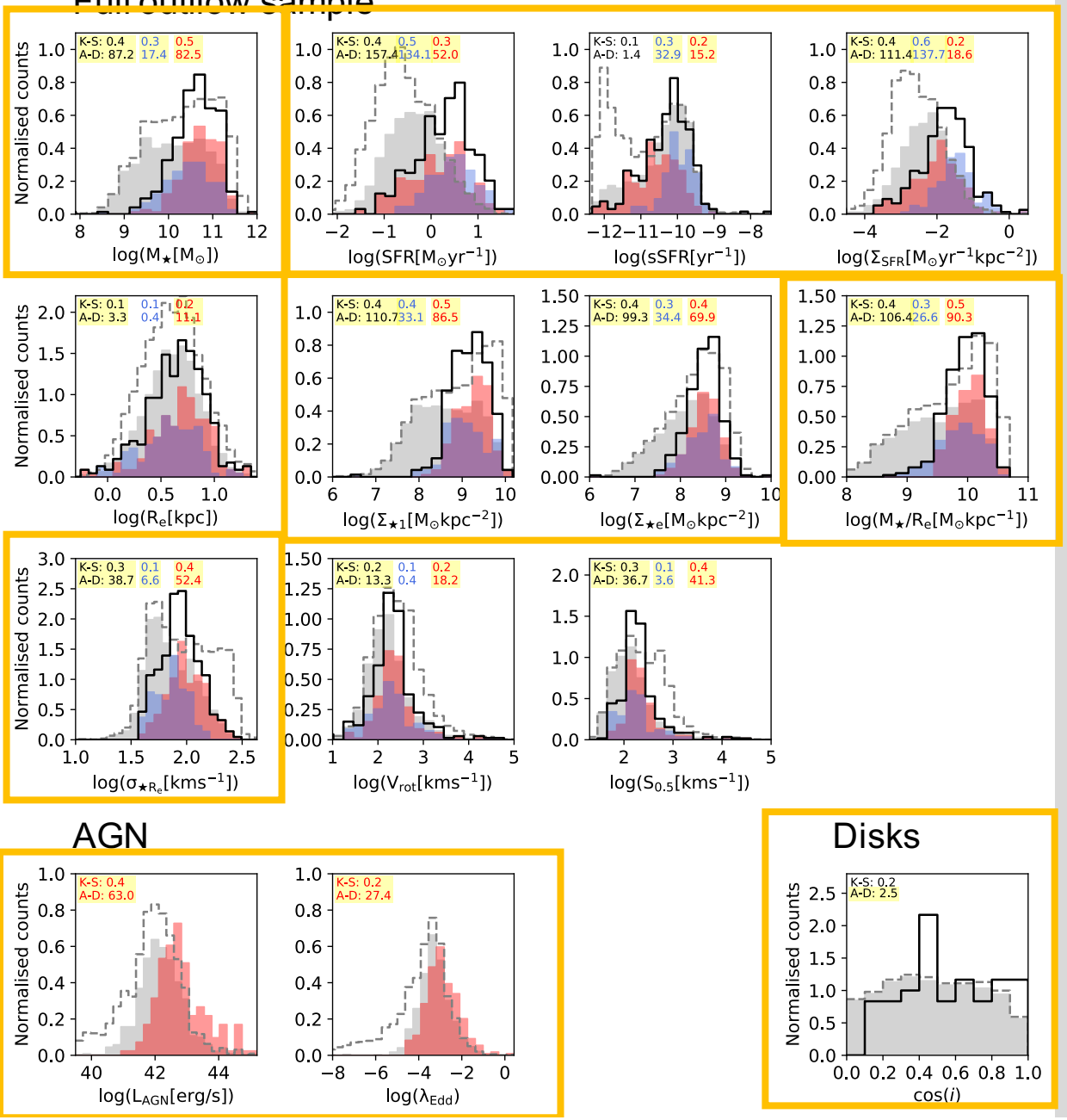
CENTRALLY CONCENTRATED

- **Stack within elliptical annuli**
- Remove large-scale velocity field
- Continuum subtraction w/ PPXF (Cappellari+2013)
- Simultaneous double-Gaussian fitting
- Statistically preferred over single-Gaussian?
- **Determine the radius containing 90% of the broad component flux**

see also, e.g,. Roberts-Borsani+20



OUTFLOW INCIDENCE



- More common at high mass and density
- More common at higher SFR (Σ_{SFR}) and/or L_{AGN}
- Weak inclination dependence → wide opening angles?

All outflows
SF outflows
AGN outflows

Underlying galaxy population

see also, e.g., Ho+16, Roberts-Borsani+20, Forster Schreiber+19 at high-z

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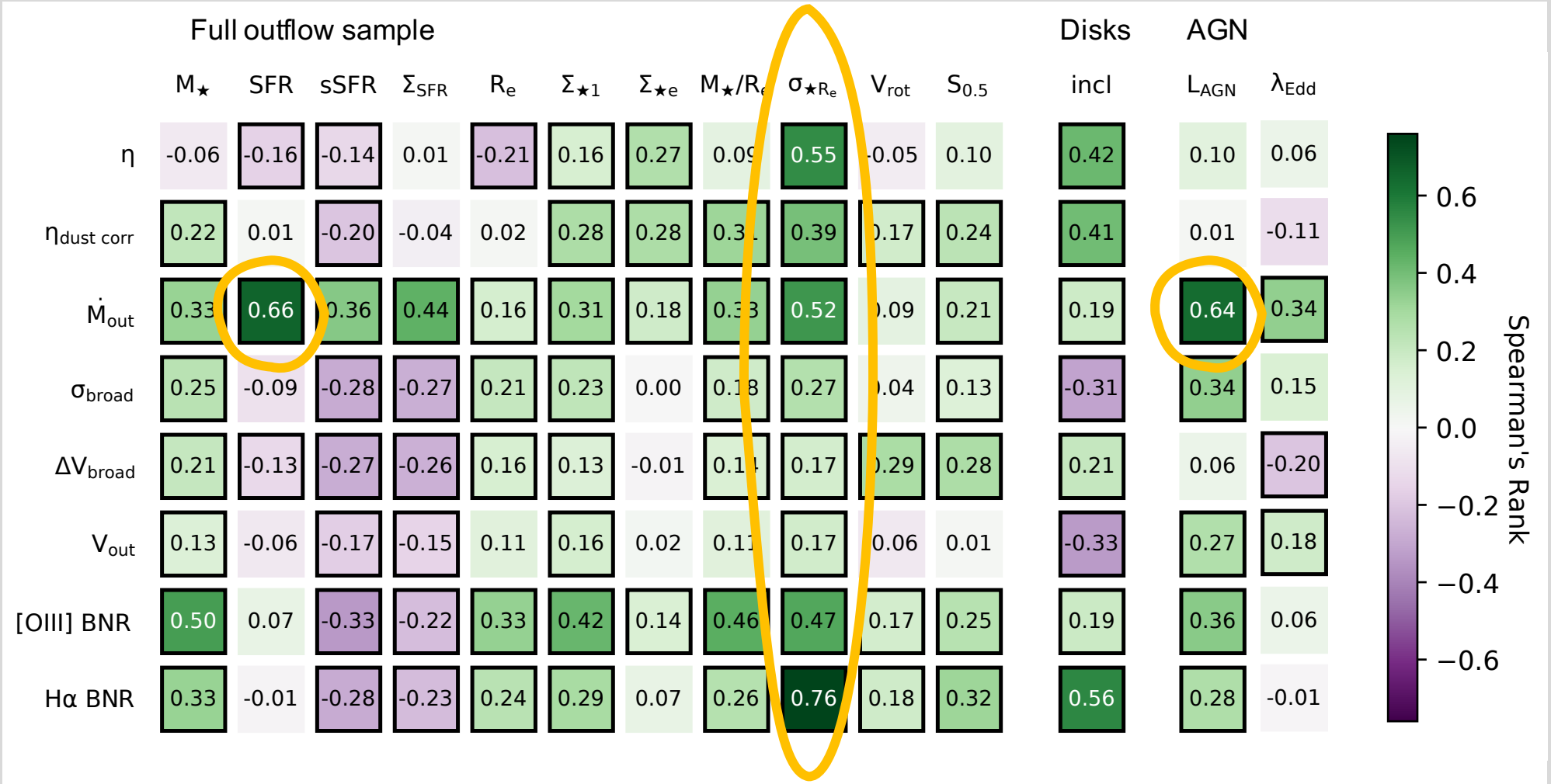
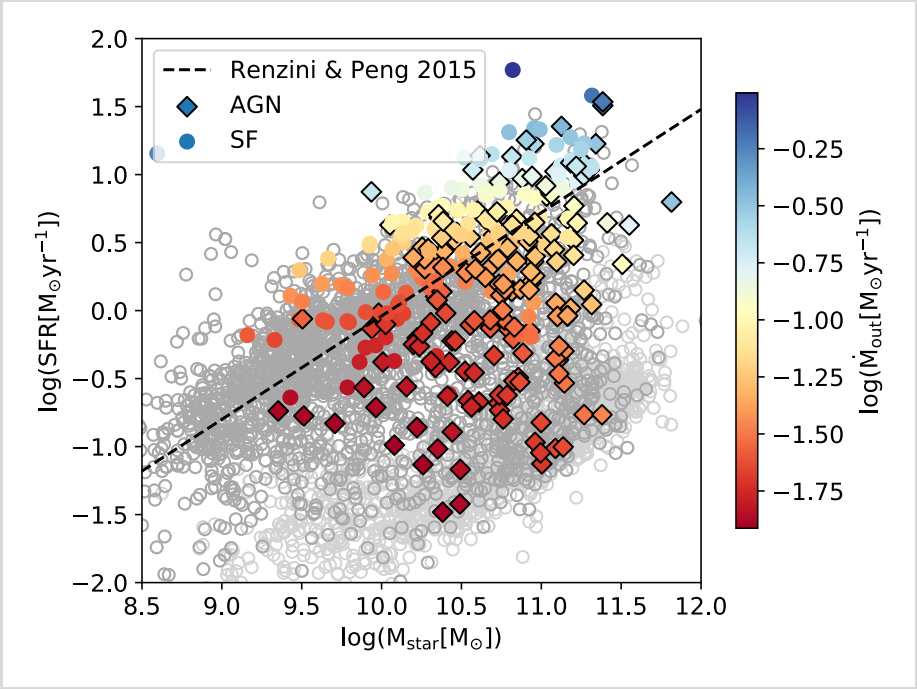
CORRELATIONS BETWEEN OUTFLOW AND HOST PROPERTIES



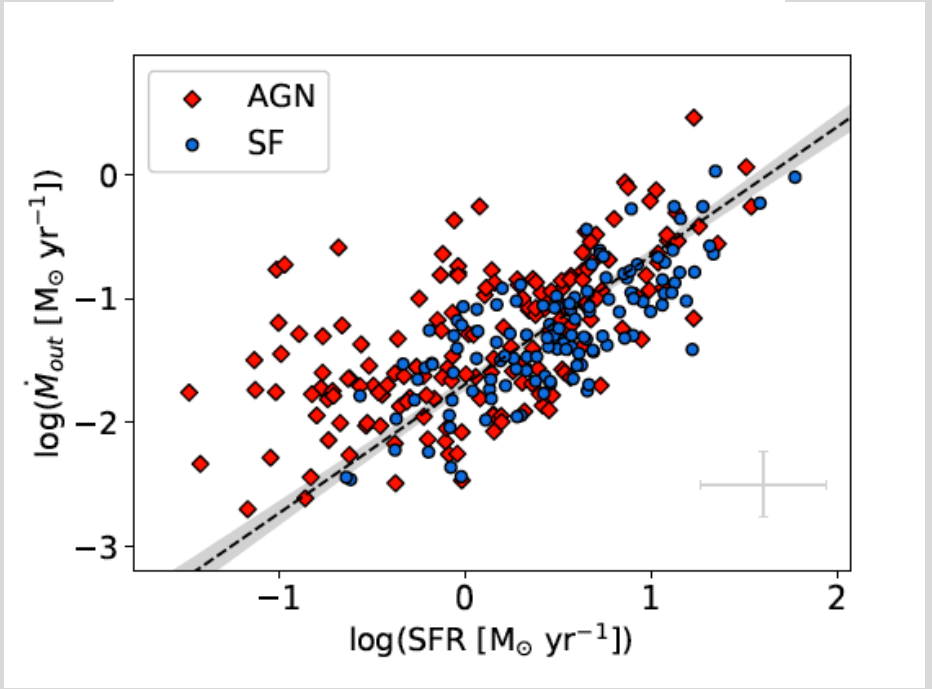
η: mass-loading factor; $\dot{M}_{out}$: mass outflow rate; BNR = broad-to-narrow line ratio

VARIATIONS ACROSS SFR – M_*



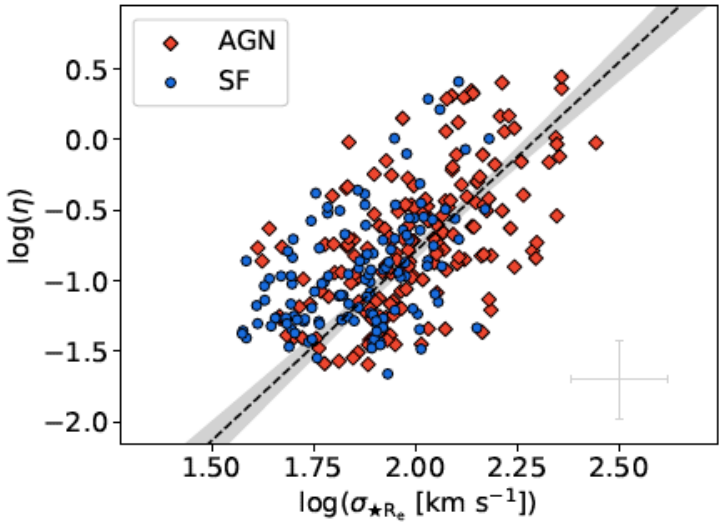
Colour-coding based on locally weighted regression (LOESS, Cappellari+2013)

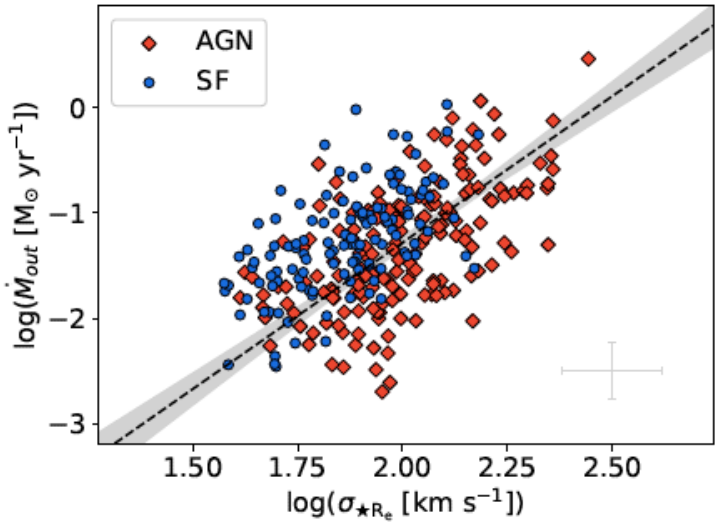
$$\dot{M}_{\rm out} \propto {\rm SFR}^{1.04}$$

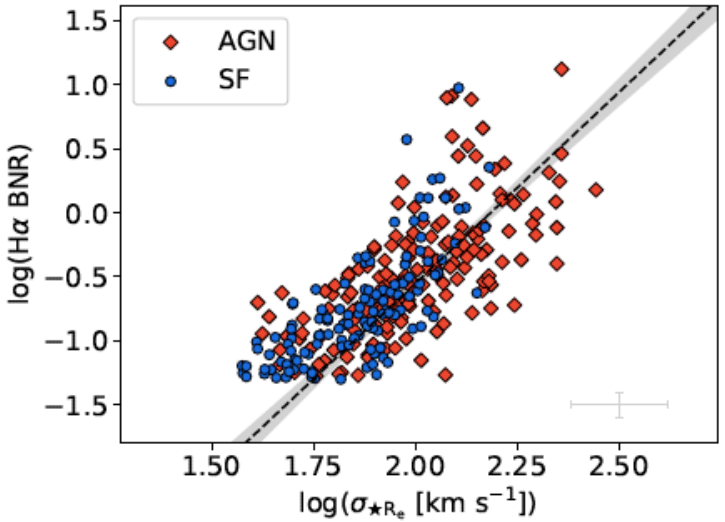


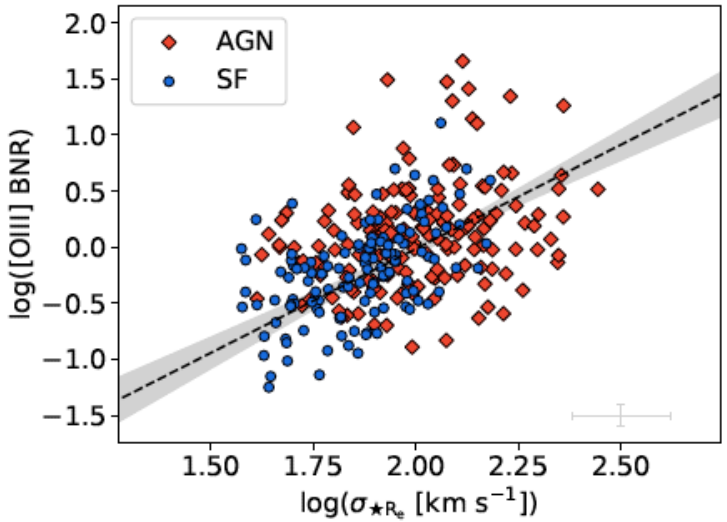
also, e.g., Arribas+14, Cicone+16, Rupke18, Fluetsch+19, Veilleux+20

STRONG DEPENDENCE ON STELLAR VELOCITY DISPERSION









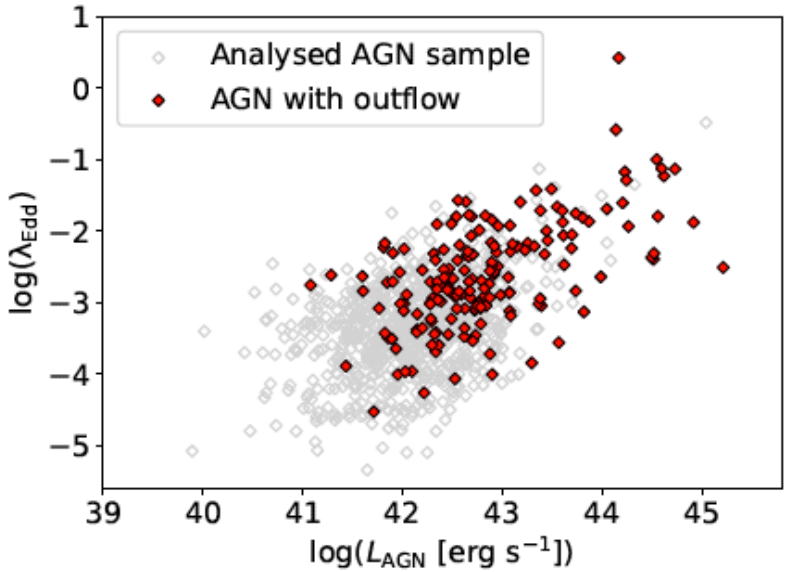
$\sigma_*(<R_e)$

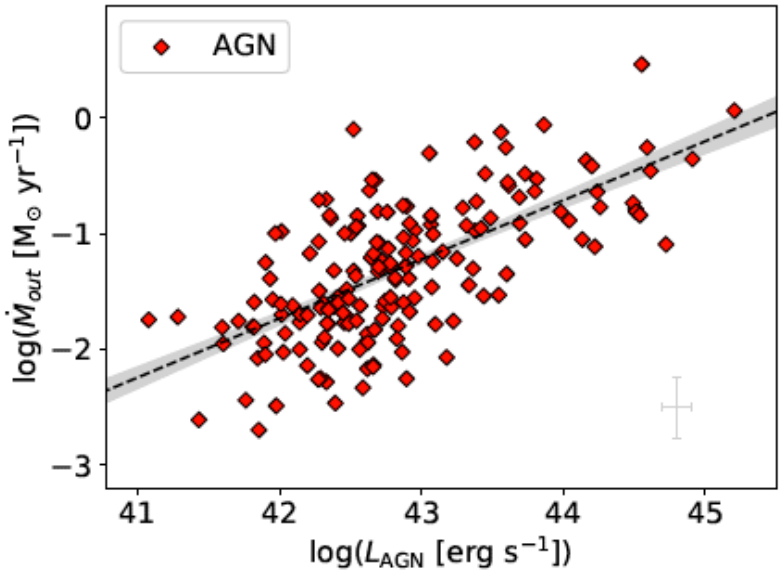
~ gravitational potential well

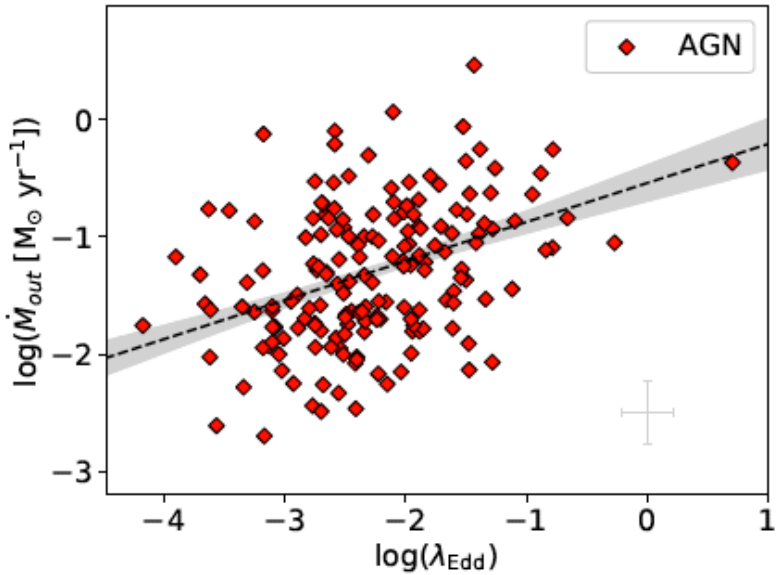
~ M_{BH}

see also Rupke+17, Fluetsch+19 & Asa Bluck's talk (Bluck+20)

AGN OUTFLOWS







Enhanced incidence at higher λ_{Edd} and/or L_{AGN}

Also, e.g., Rupke & Veilleux+11, Cicone+14, Fiore+17, Harrison+18, Fluetsch+19, Lutz+20, Wylezalek+20

Galactic winds over 4 dex in L_{AGN}, down to modest accretion rates

$$\dot{M}_{\rm out} \propto L_{\rm AGN}^{0.51}$$

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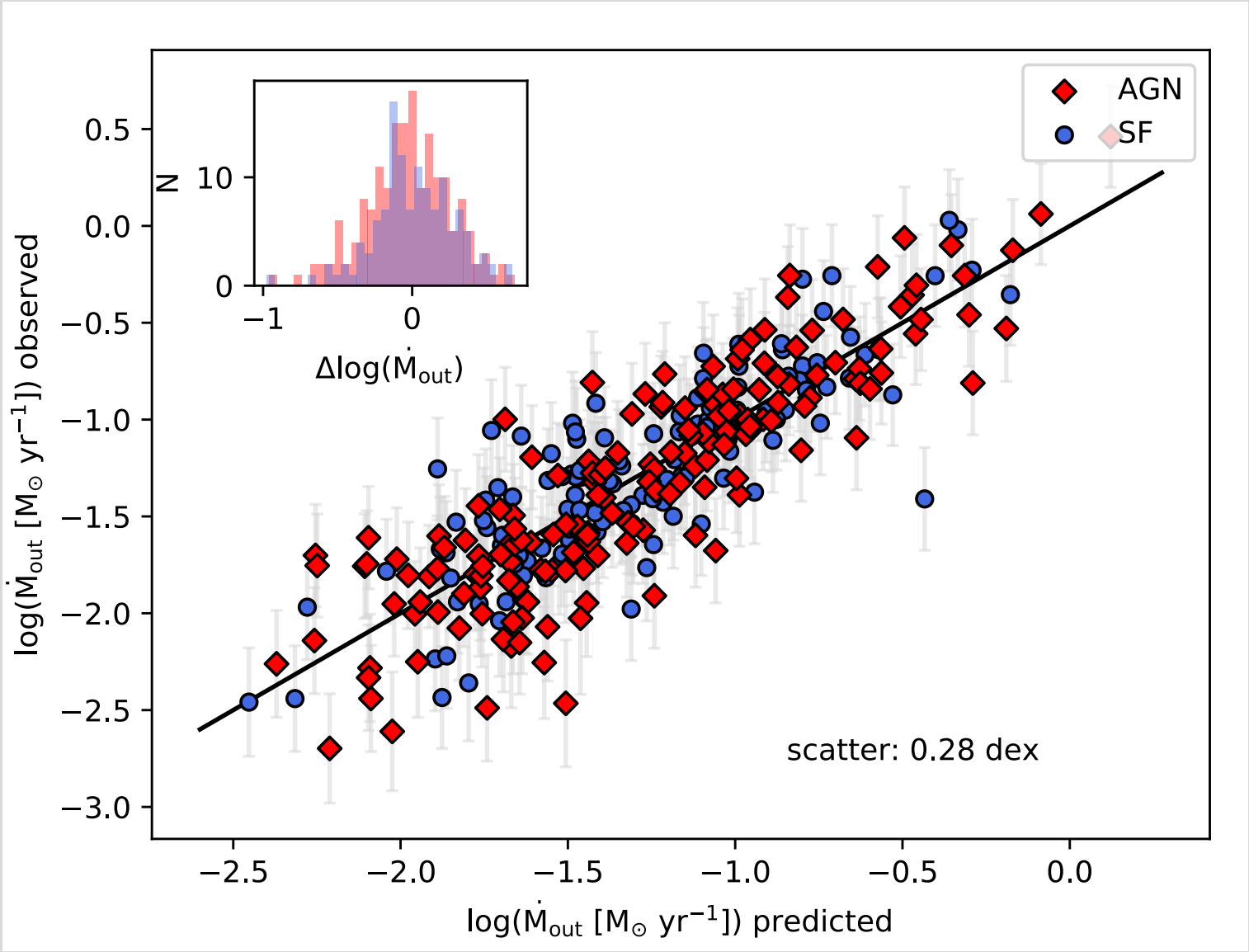
MASTER OUTFLOW SCALING RELATION



SF and AGN outflows jointly described by a unified scaling relation

$$\log(\dot{M}_{\rm out}) = b\ \log\left(\frac{M_\star}{5\times10^{10}\ {\rm M}_\odot}\right) + d\ \log\left(\frac{\sigma_{\star {\rm R_e}}}{100\ {\rm km\ s^{-1}}}\right) + \log\left[10^a\left(\frac{\rm SFR}{3\ {\rm M}_\odot\ {\rm yr^{-1}}}\right)^c + 10^e\left(\frac{L_{\rm AGN}}{1\times10^{43}\ {\rm erg\ s^{-1}}}\right)^f\right]$$

Fit with emcee (Foreman-Mackey+13)

see also Fluetsch+19

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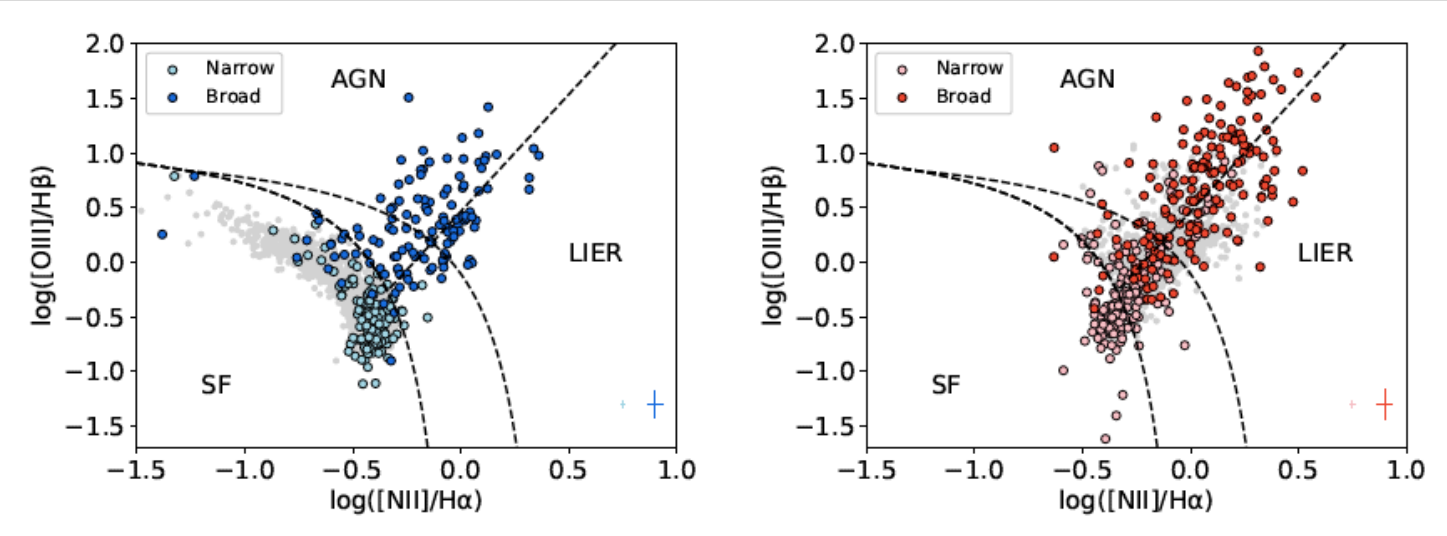
PHYSICAL CONDITIONS

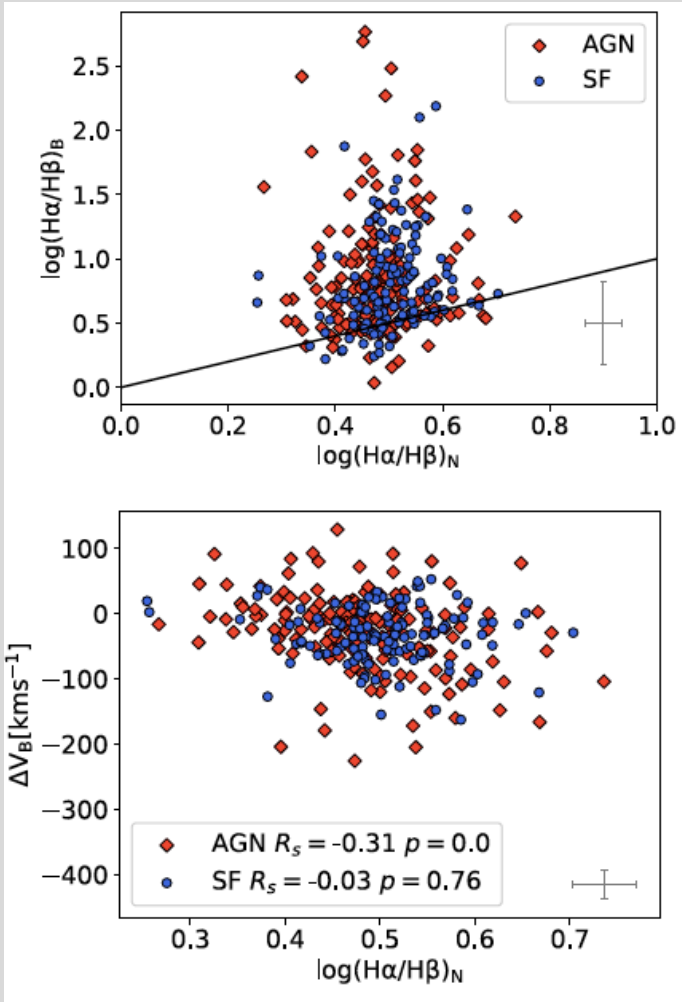
Broad components feature…
Higher excitation → shocks



(see also Ho+14).

(see also Perna+19,
Villar Martín+14,
Rodríguez Del Pino +19)

Enhanced attenuation?



CONCLUSIONS

- Minor fraction of MaNGA galaxies (~ 10% of line-emitting objects) exhibit ionised winds
- Star formation and AGN are both important drivers of galactic winds in galaxies with moderate AGN activity
- A tight scaling relation (0.28 dex scatter) parameterises the mass outflow rate of SF & AGN galaxies as a function of its drivers (SFR, L_{AGN}) and the galaxy's potential well depth (M_{star}, but most notably σ_{*1Re})
- Outflow rates may be enhanced once accounting for additional attenuation to the ionised gas by dust entrained in the wind
- Feedback in typical nearby galaxies comes mostly in the form of galactic fountains
  → only 25% have $v_{out} > v_{esc}$, among them both SF and AGN outflows
  → fraction of escaping winds increases to lower potential well depth
- Caveat: ionised phase only!