Hidden type 1 AGNs & type 2 AGNs

- Gas outflows and AGN feedback

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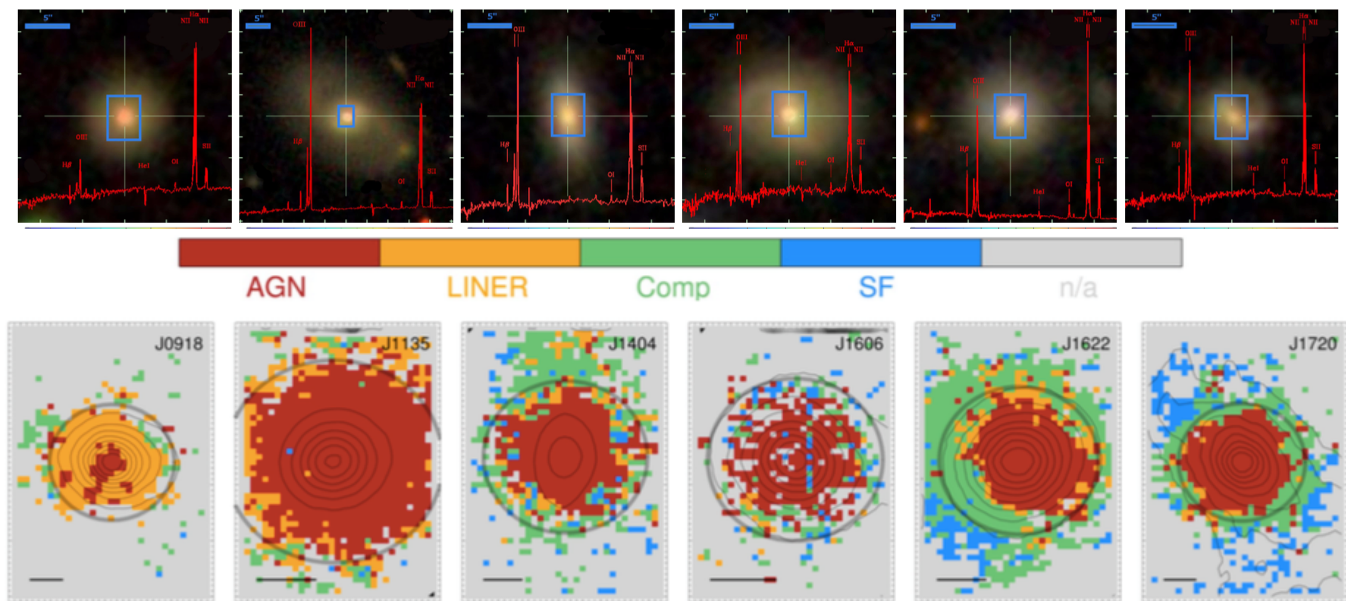
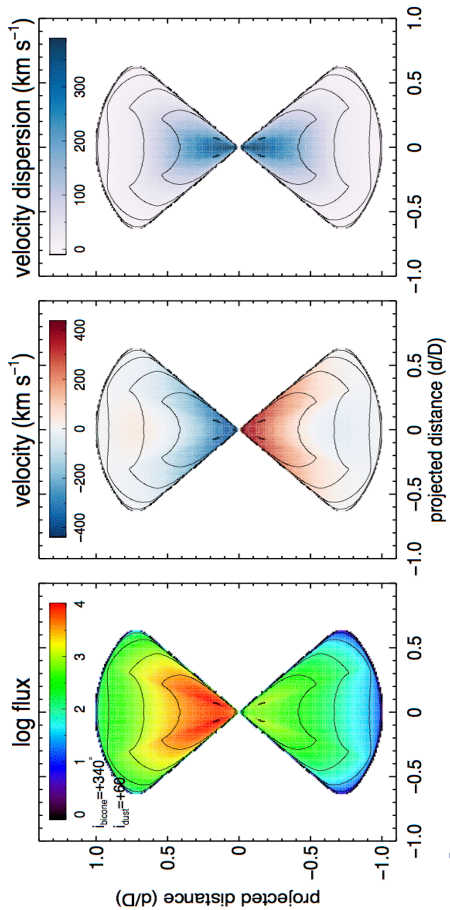
Gemini GMOS-IFU (Karouzos+16a)



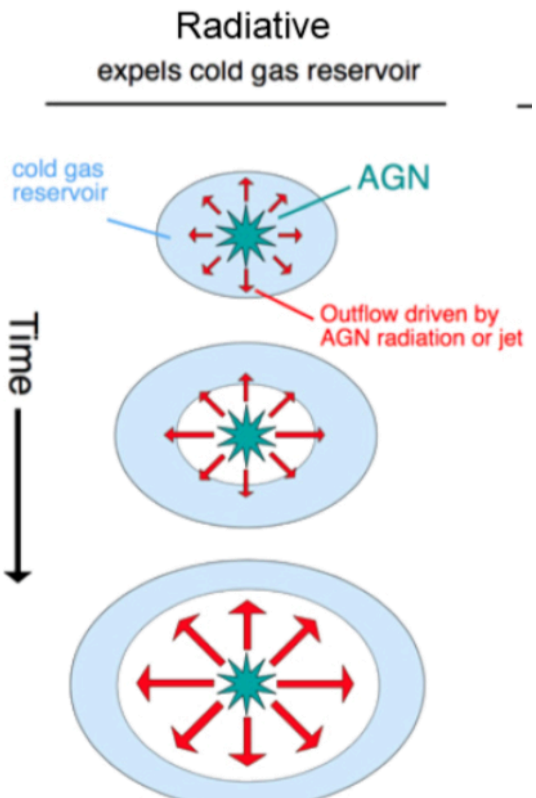


Outflow models (Bae & Woo 16)

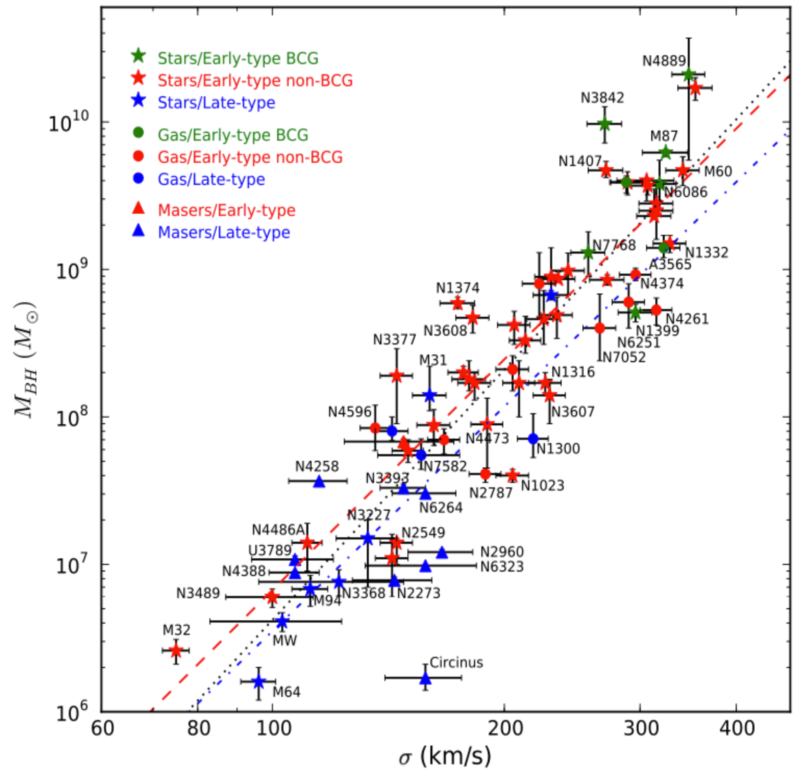
BH-galaxy coevolution: AGN feedback

- What is the nature of BH-galaxy connection?
- AGN feedback is frequently adopted in galaxy evolution models
- Observational evidence - suppress or trigger SF?

(e.g., Greene+12, Liu+13, Cresci+15, Vilar-Martin+16, Karouzos+16b).



Alexander & Hickox 12



McConnell & Ma 2013

Gas outflows – a channel of AGN feedback?

1. Outflow demography – using SDSS type 2 AGNs:

- how strong, how common, relation to AGN energetics?
  (Bae & Woo 14, Woo+16, Woo+17, Bae & Woo 17 submitted, Kang+17)
- Connection to star formation: negative or positive feedback? (Woo+17)

2. Kinetic model simulations – 3D outflow models & MC

- intrinsic properties of outflows? (Bae & Woo 16)

3. Integral field spectroscopy – using local type 2 AGNs:

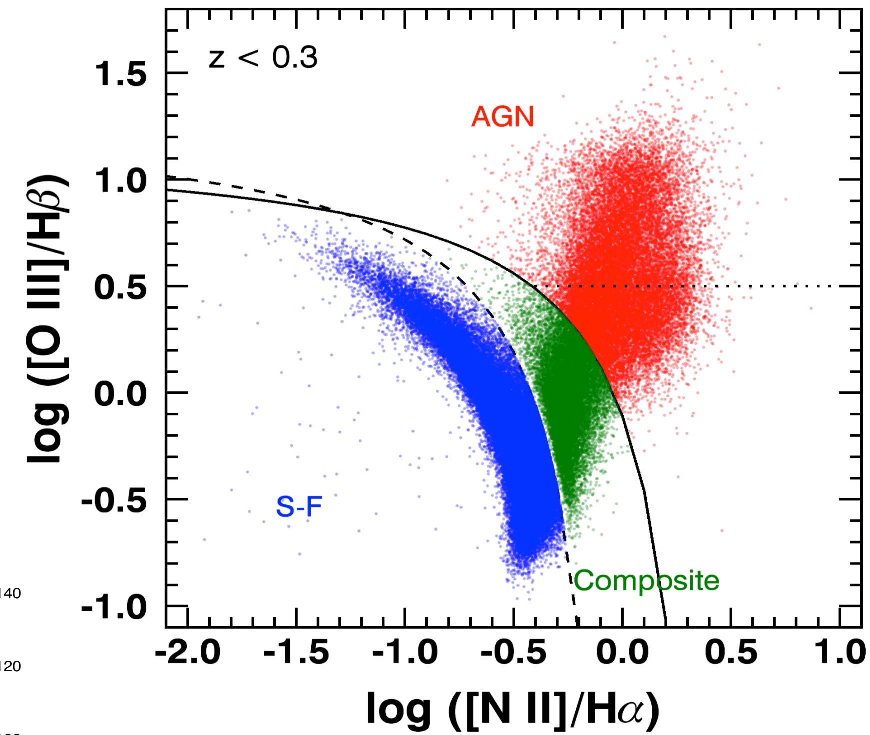
- IFU data: Complex nature of outflows and SF
  (Karouzos+16a, Karouzos+16b, Bae+17, Kang+ to be submitted)

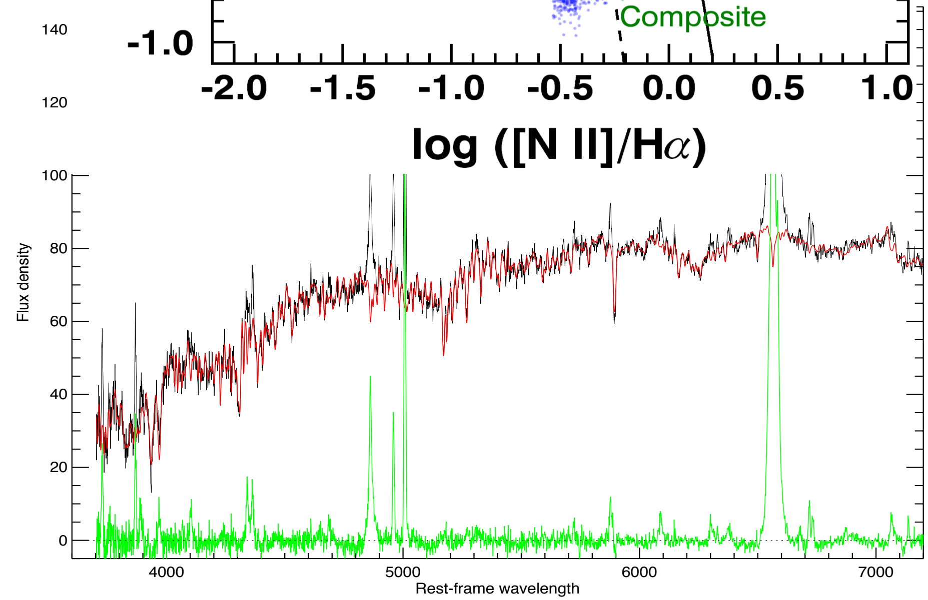
Statistical sample of AGNs and SF galaxies at z<0.3

- We selected AGNs and SF galaxies with well-defined emission lines from SDSS (A/N>5).

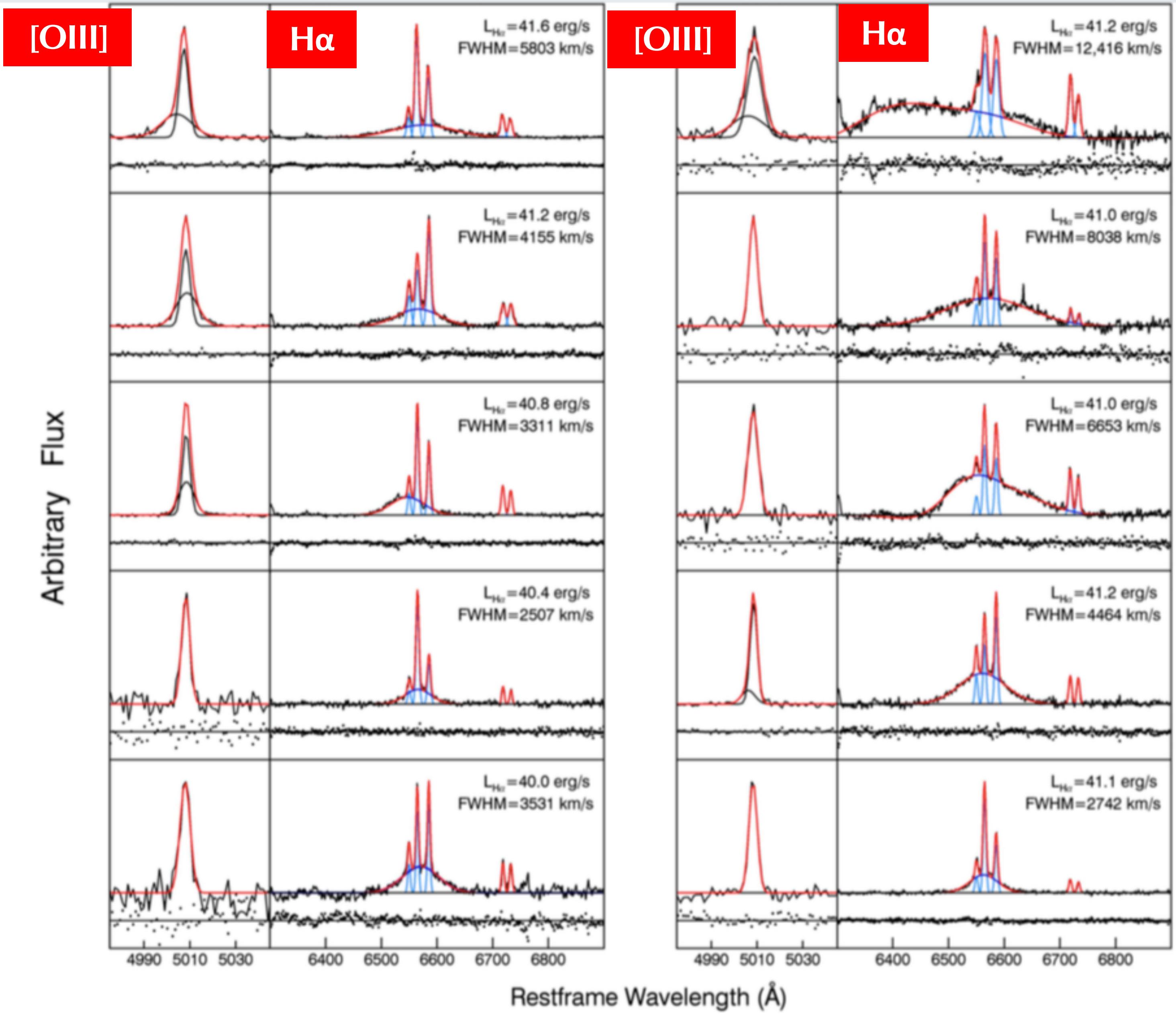
type	N
pure AGNs	~23,000
composite obj.	~16,000
SF galaxies	~69,000

- For each AGN, we subtract stellar population model, and measure systemic velocity and stellar velocity dispersion (σ_*).



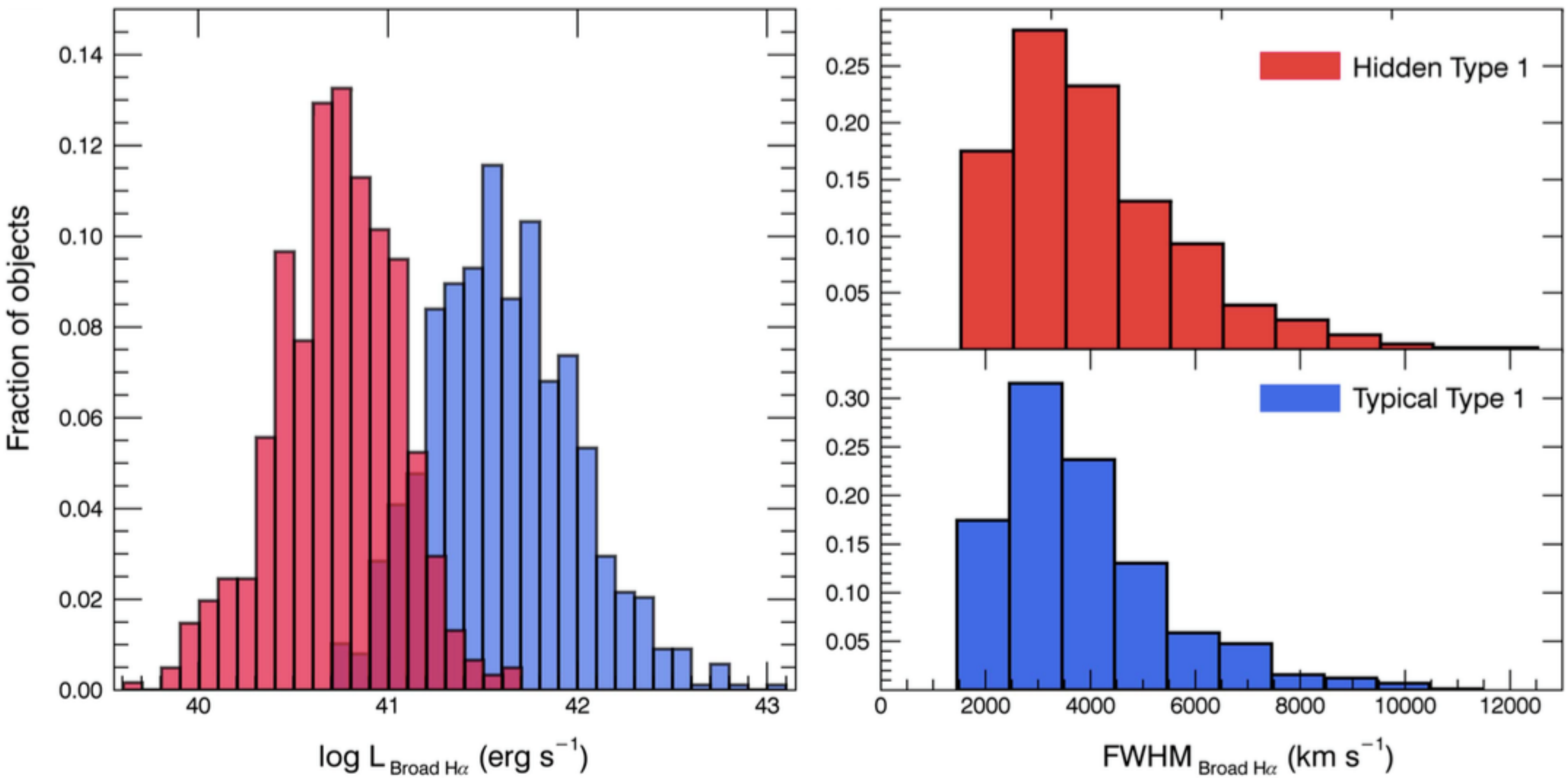


Hidden type 1 AGNs with a broad Ha component (Eun+17)



Hidden type 1 AGN sample

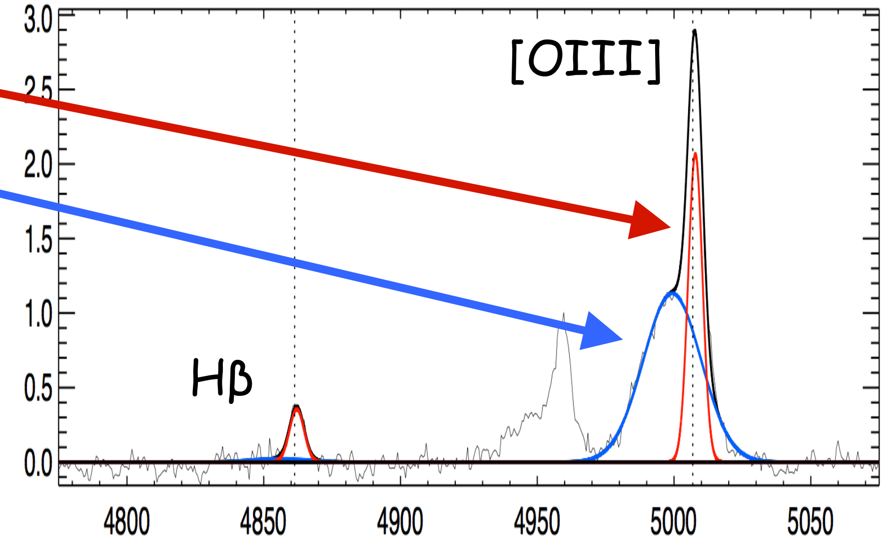
- We detected 611 hidden type 1 AGNs at $z < 0.1$ out of ~24,000 type 2 AGNS (Woo+14, Eun+17)
- They are low-luminosity AGNs while the distribution of Ha line width is similar to normal type 1 AGNs at similar z.



[OIII] λ5007 traces ionized gas outflows.

- **Narrow core**: virial component
- **Broad wing**: outflow component

- A majority of luminous AGNs have a broad wing - Outflows are common.



Outflow kinematics are measured based on the total profile of [OIII]

- σ_{OIII} **(Velocity dispersion)** compared to stellar VD.
- V_{OIII} **(velocity shift)** w.r.t the systemic velocity.

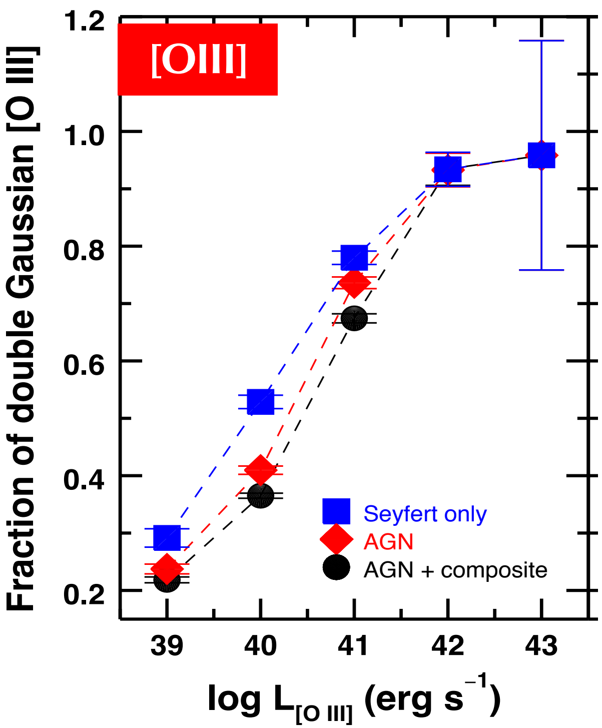
Y. Toba's talk

Outflows are prevalent, particularly in luminous AGNs.

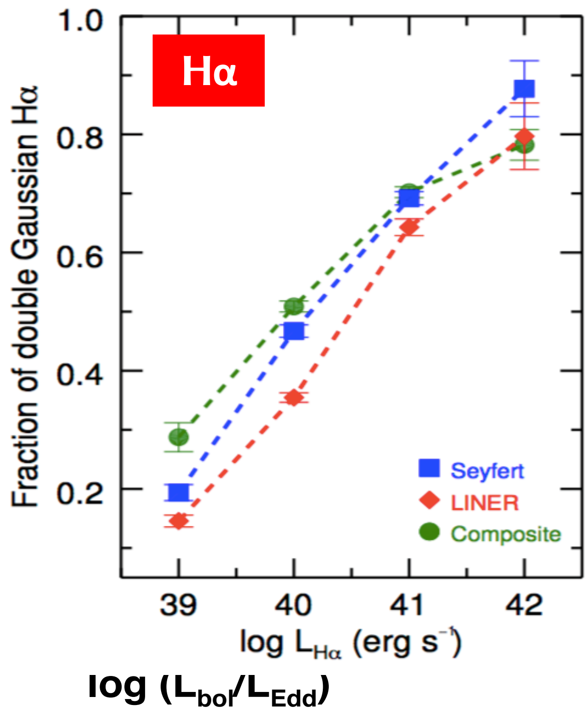
- Fraction of AGN with OIII wing dramatically increases with L and L/L_{edd}.
- Outflows are prevalent among luminous AGNs.

Type 2 AGNs

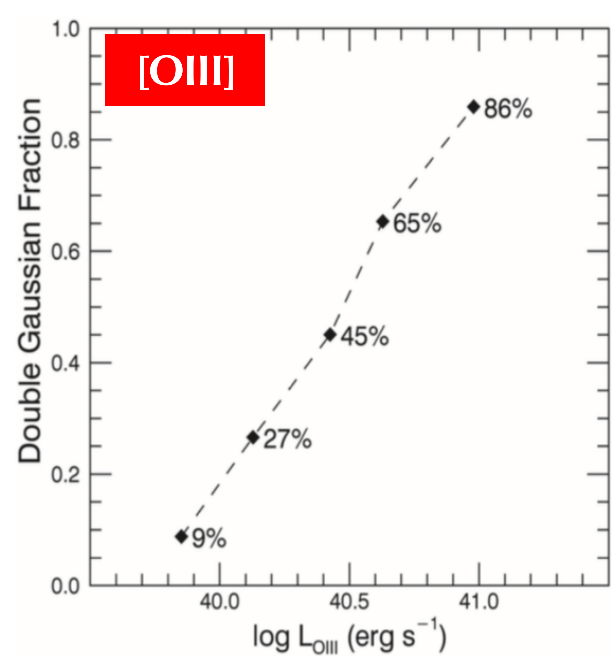
Hidden type 1 AGNs



Woo+16



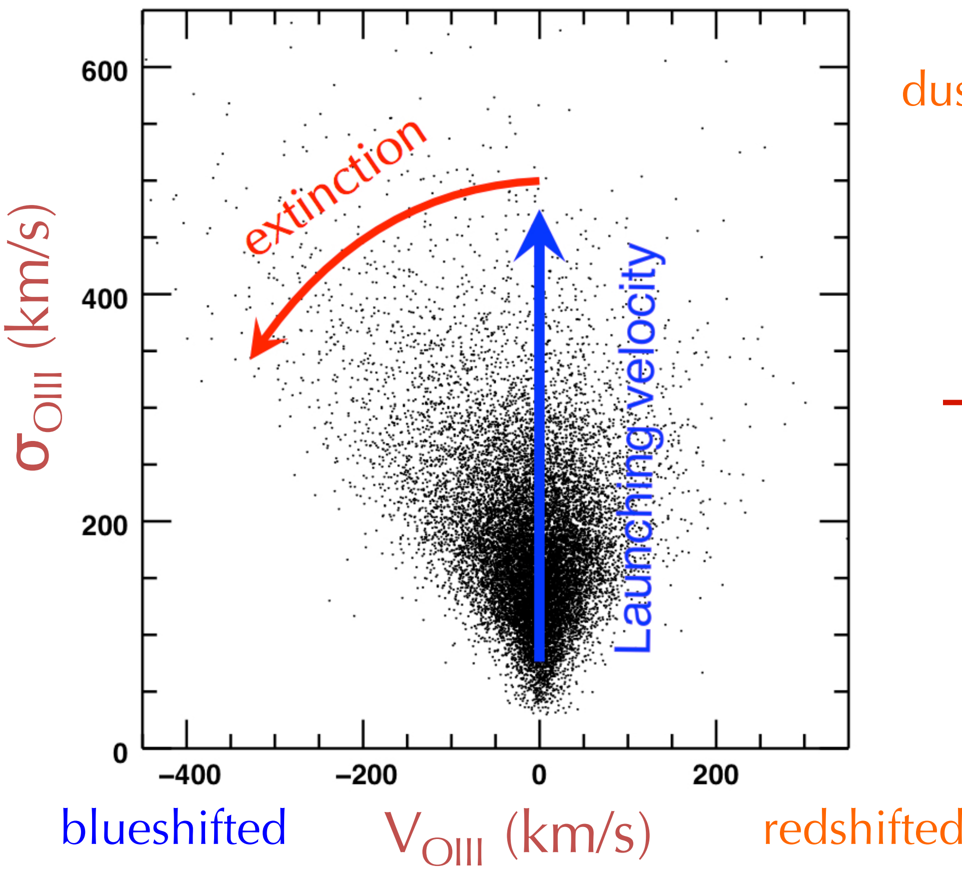
Kang+17



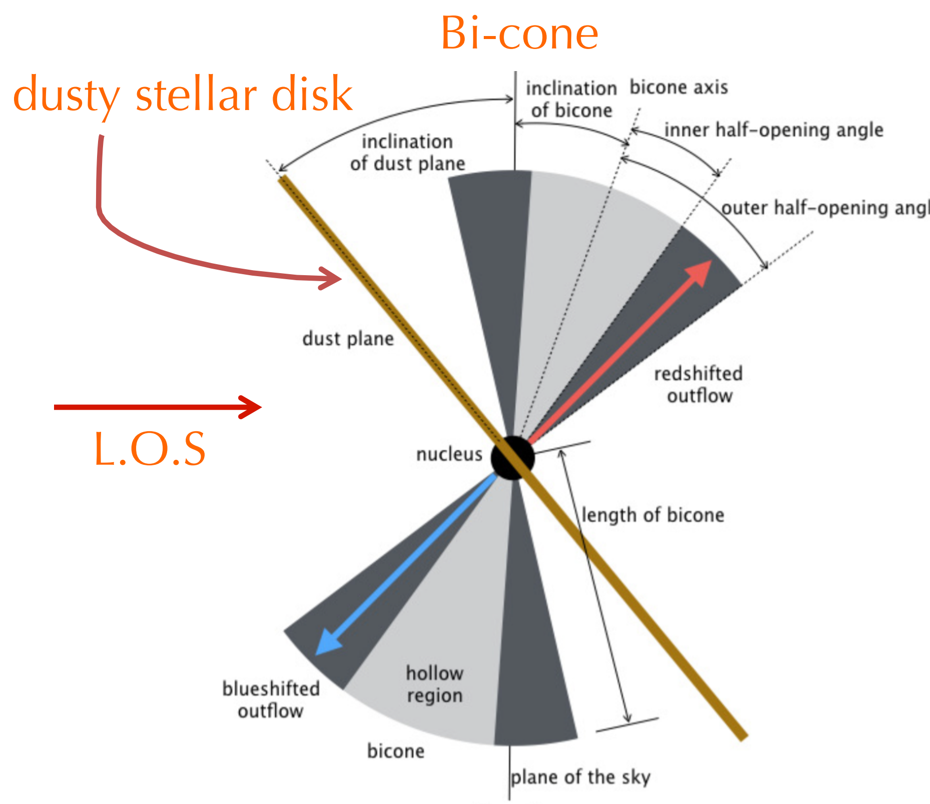
Eun+17

VVD (vel.-vel. dispersion) diagram of SDSS type 2 AGNs

- Characteristic V shape (V and VD are correlating).
- Higher launching V, higher inclination -> higher VD
- Higher dust extinction -> blue or red shift



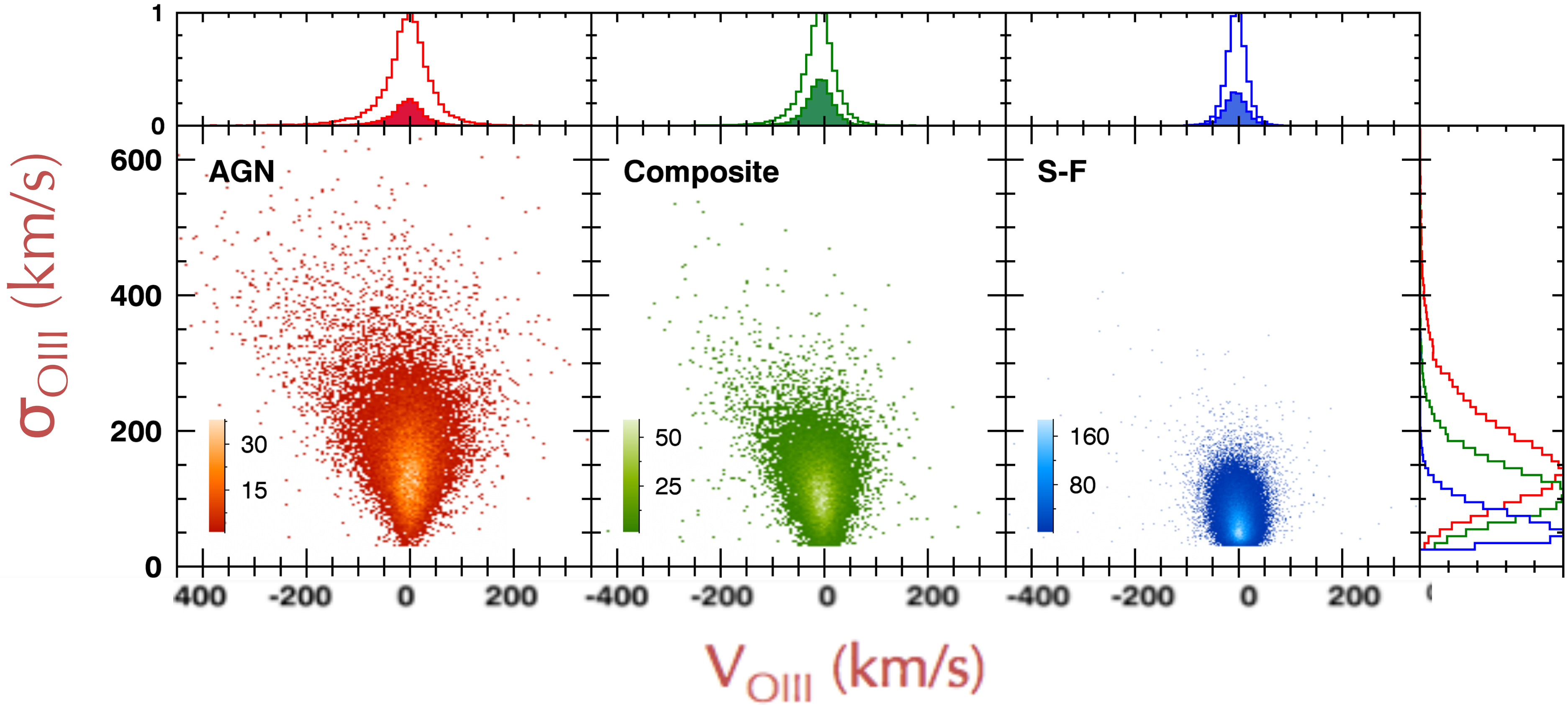
Woo+16



Bae & Woo 16

VVD distribution is clearly different between AGNs and SFGs

- Strong outflows in type 2 AGNs vs. no outflows in SFGs.



Woo+17

Kinetic modeling of biconical outflows (Bae & Woo 16)

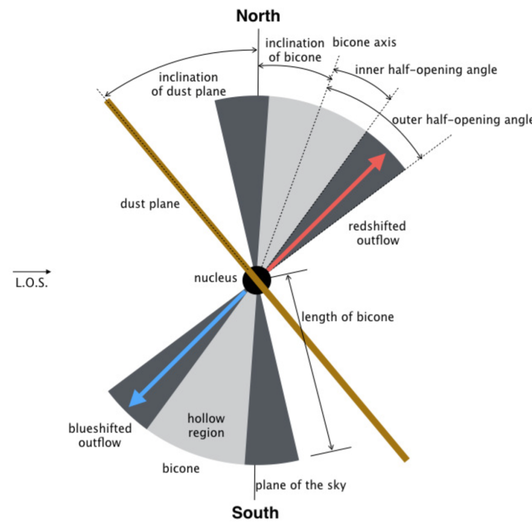
3-D Model (f, v_{rad})

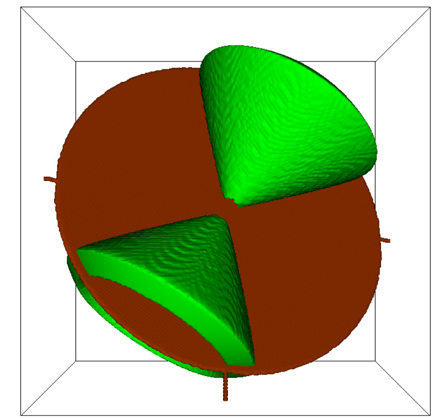
$$F(x,y) = \int f(x,y,z)dz,$$

$$f(x,y,z) = \begin{cases} f(x,y,z) & \text{if } z < z_{\rm dust} \\ f(x,y,z)\times A & \text{if } z \geq z_{\rm dust}, \end{cases}$$

$$V(x,y) = \frac{\int v_p(x,y,z) f(x,y,z)dz}{\int f(x,y,z)dz},$$

$$\sigma^2(x,y) = \frac{\int v_p^2(x,y,z) f(x,y,z)dz}{\int f(x,y,z)dz} - V^2(x,y).$$

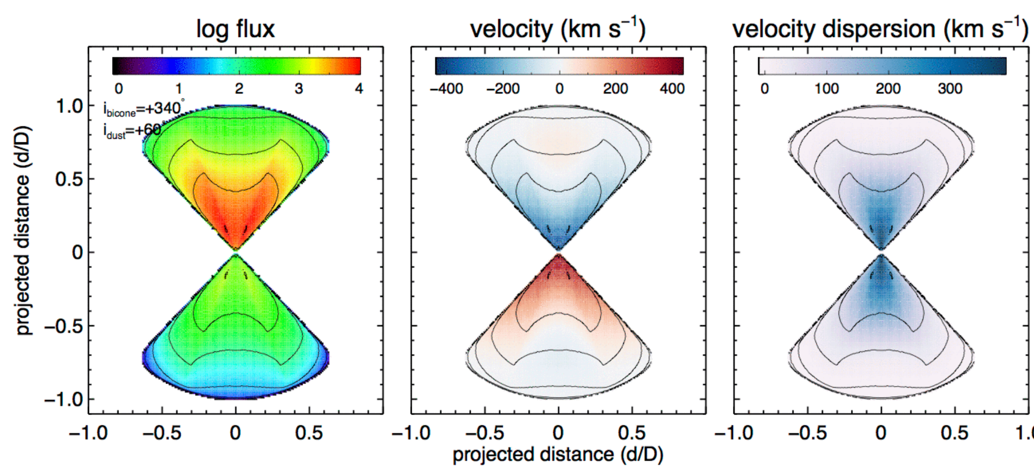




2-D Projection(F,V,σ)

$$v_{\rm int} = \frac{\iint V(x,y)F(x,y)dxdy}{\iint F(x,y)dxdy},$$

$$\sigma_{\rm int}^2 = \frac{\iint V^2(x,y)F(x,y)dxdy}{\iint F(x,y)dxdy} - v_{\rm int}^2.$$



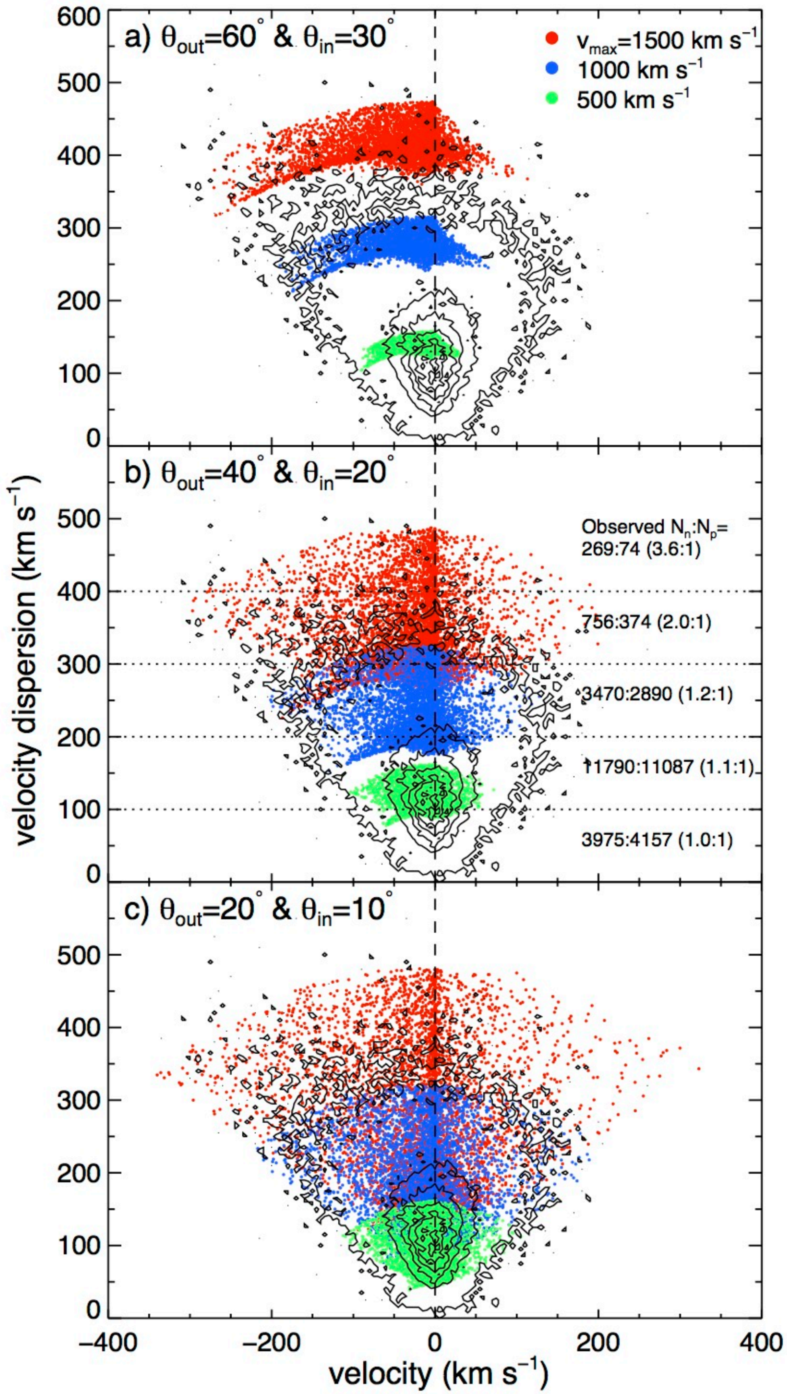
Integration (v_{int}, σ_{int})

Observations ($v_{[O\,III]}$, $\sigma_{[O\,III]}$)

MC simulations of VVD diagram

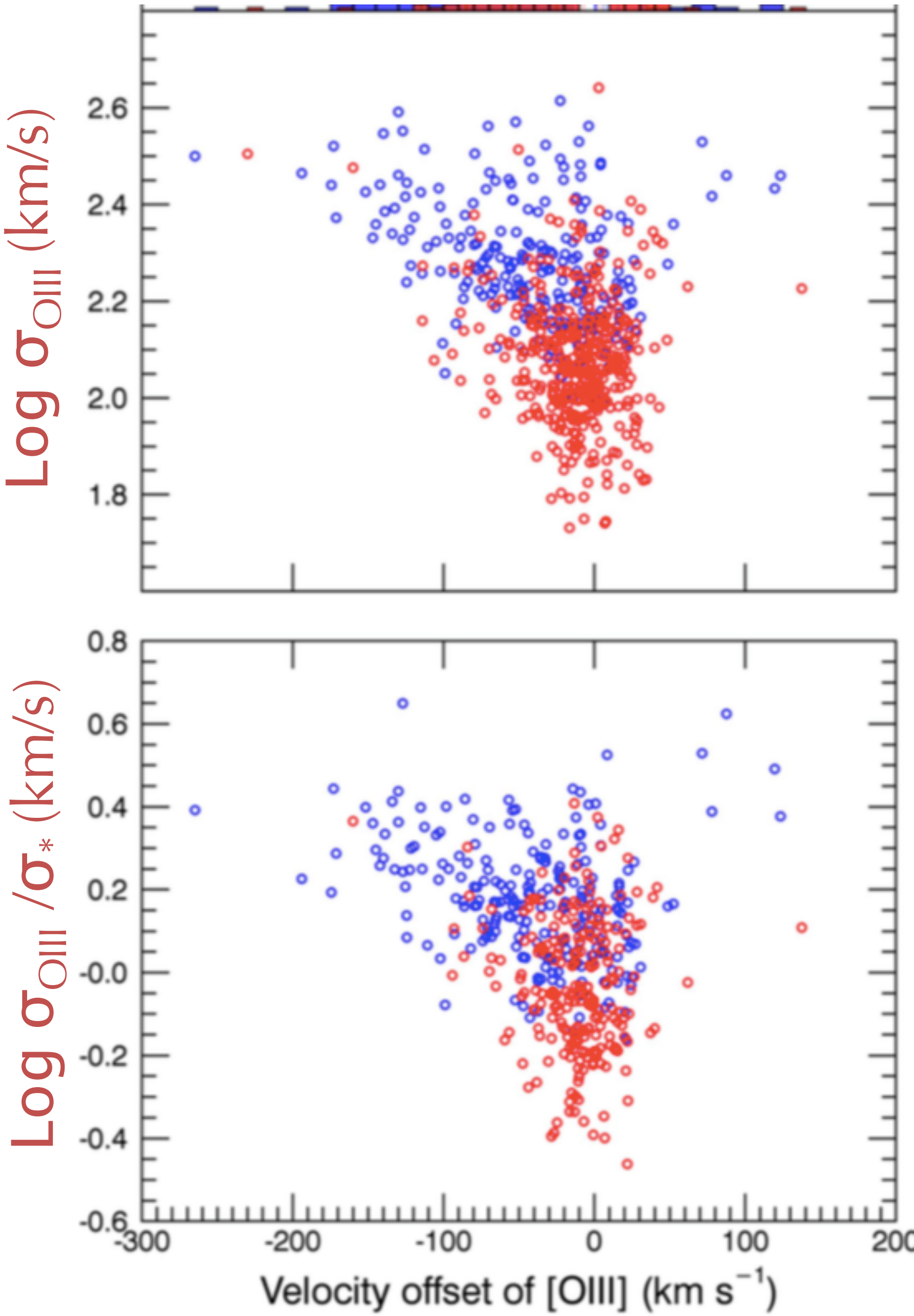
- Using random distributions of orientation angle of the bicone, dust plane, and intrinsic velocity, we simulated the VVD diagram.
- Dust extinction plays an important role.
- The intrinsic velocity ranges from ~200 to ~2,000 km/sec.

Bae & Woo 16



VVD distribution of hidden type 1s

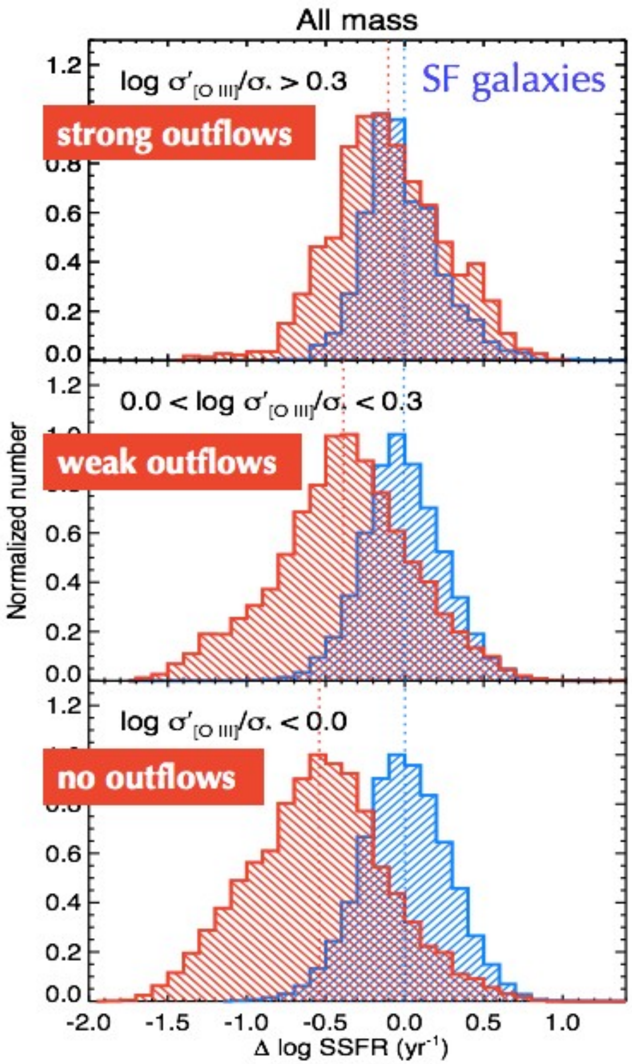
- Outflow signatures are well detected.
- VVD diagram is similar to that of type 2 AGNs.
- The ratio of blueshifted to redshifted OIII is larger due to the inclination of the outflow direction toward L.O.S

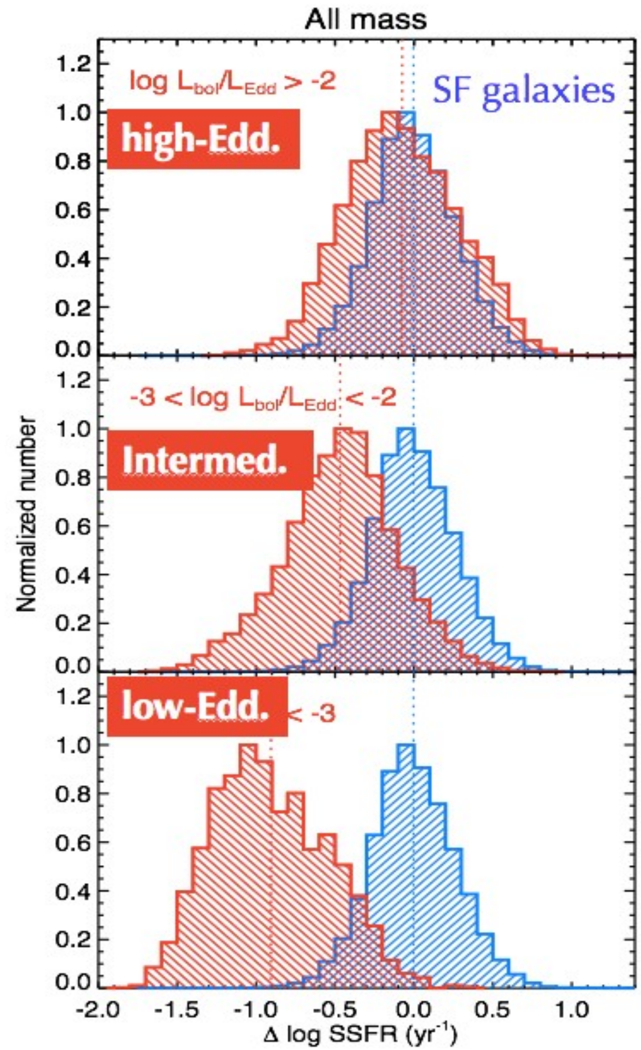


Eun+17

Delayed feedback or gas supply (Woo+17)

- Strong outflow (high Edd.) AGNs on the SF main sequence.
- No outflow (low Edd.) AGNs have lower sSFR.





Delayed AGN feedback or gas depletion?

high Eddington + strong outflow + MS SFR	vs.	low Eddington + no/weak outflow + low SFR

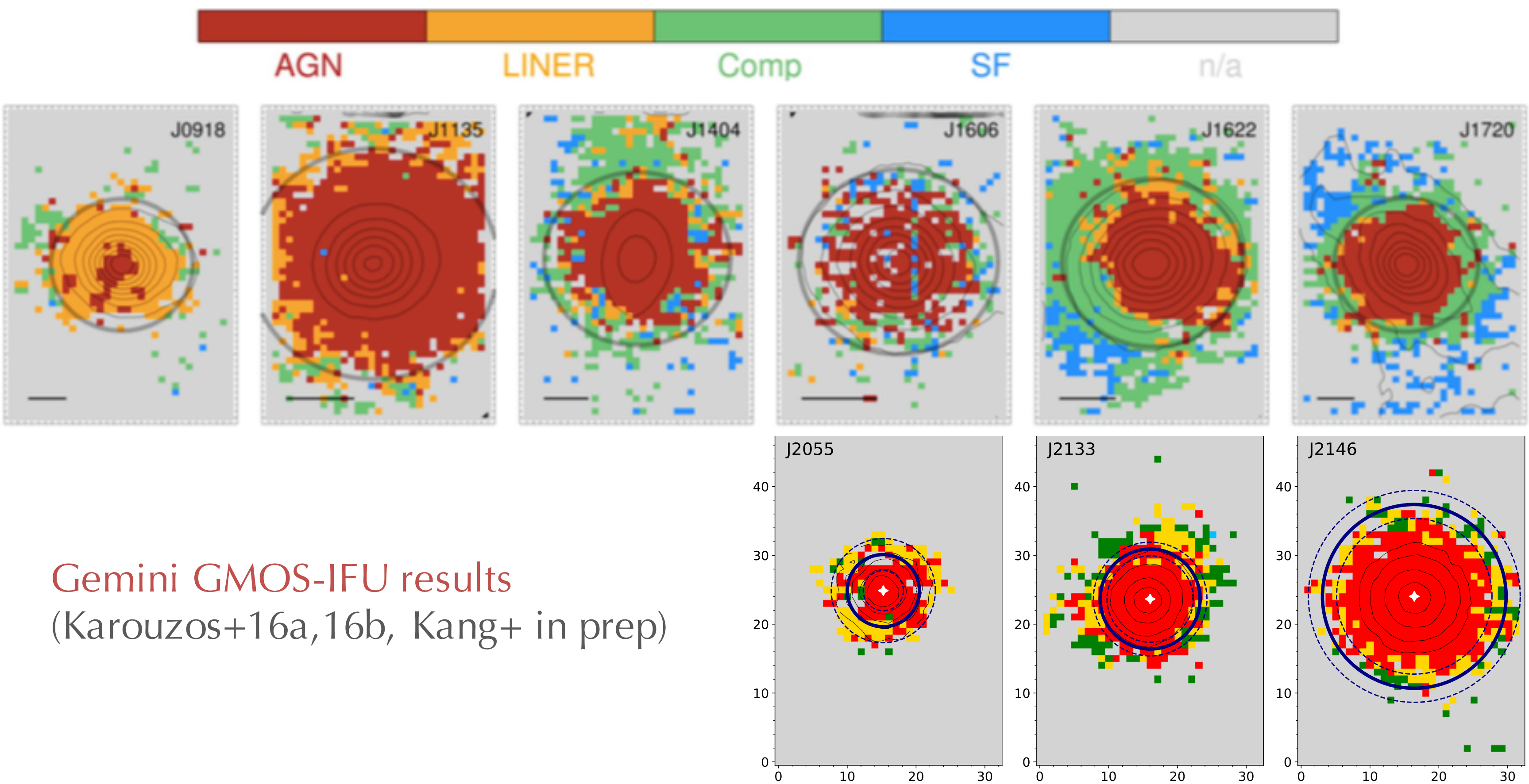
- Delayed AGN feedback?

1. Gas supply
2. SF + AGN + outflows : AGN and SF coexist
3. Delayed AGN feedback (suppressed SF + no outflows)
   --- Outflows impact on ISM after dynamical time scale ($10^{6\text{-}7}$ yrs)
4. Decrease SFR and AGN activity (low Eddington, no outflows)
5. normal SF galaxies

- Transition due to gas depletion
- Intrinsic difference in gas content

Complex nature of outflow-SF connection

- ~40 luminous type 2 AGNs with Gemini/Magellan
- $R_{outflow}$ is relatively small (1-5 kpc) – no effect on the disk scales?
- Center is dominated by AGNs – no SF? negative feedback?
- SF (or LINER) ring at the edge of outflows – positive feedback?

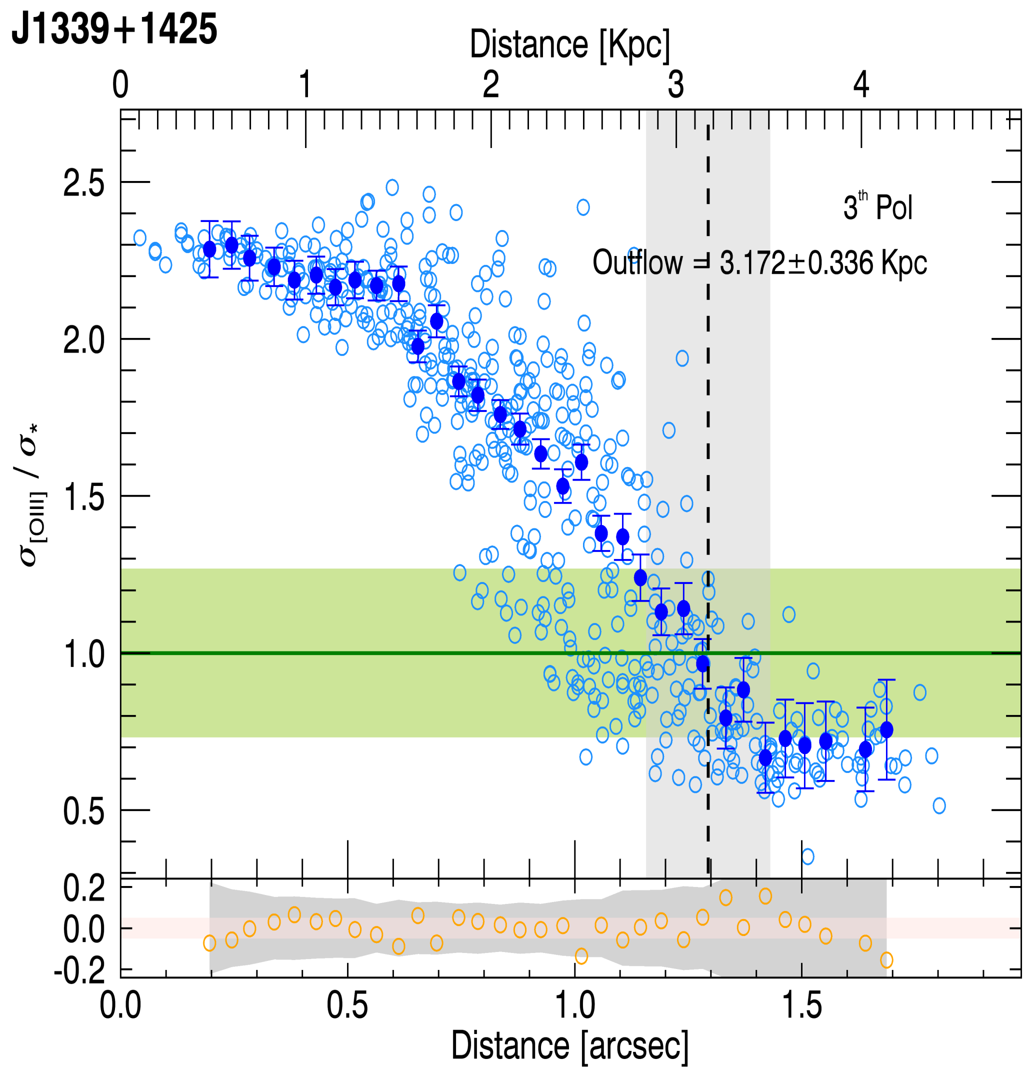


Gemini GMOS-IFU results
(Karouzos+16a,16b, Kang+ in prep)

Daeun Kang's talk

Kinematically measured outflow size

- We measure the outflow size based on kinematics.
- Outflow size is typically smaller than NLR size (**$R_{outflow} \neq R_{BLR}$**)
- Outflow size is more relevant than NLR size in AGN feedback context.



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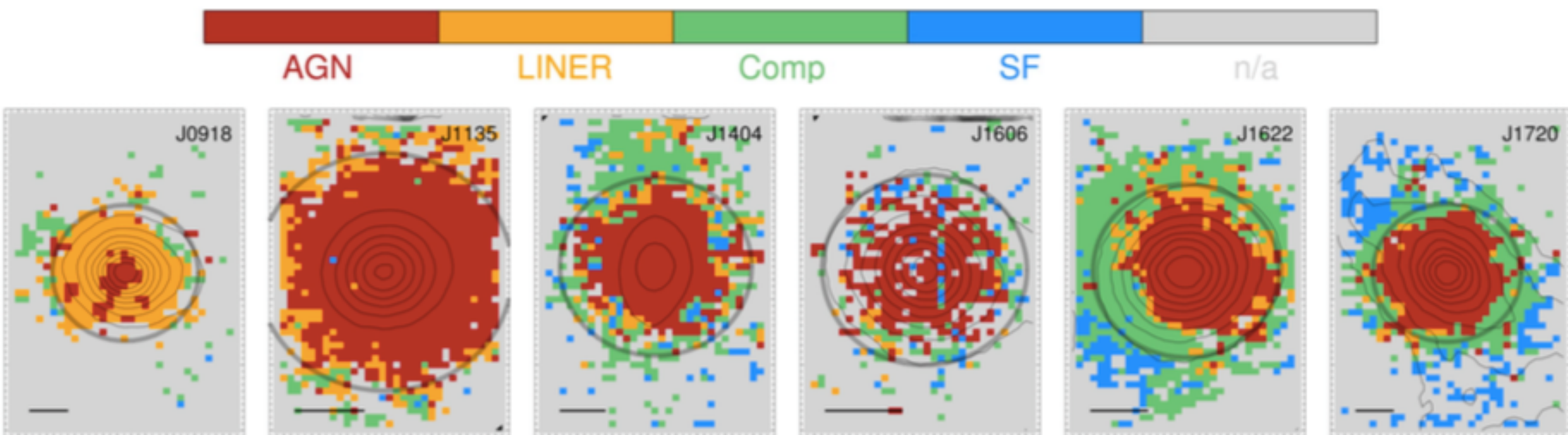

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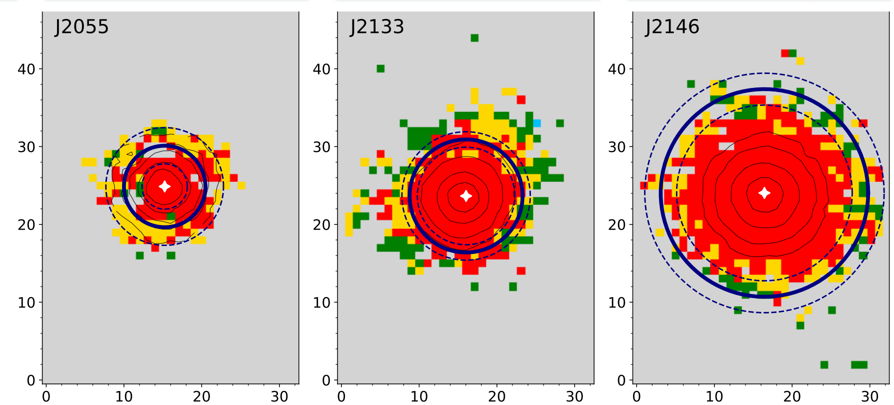
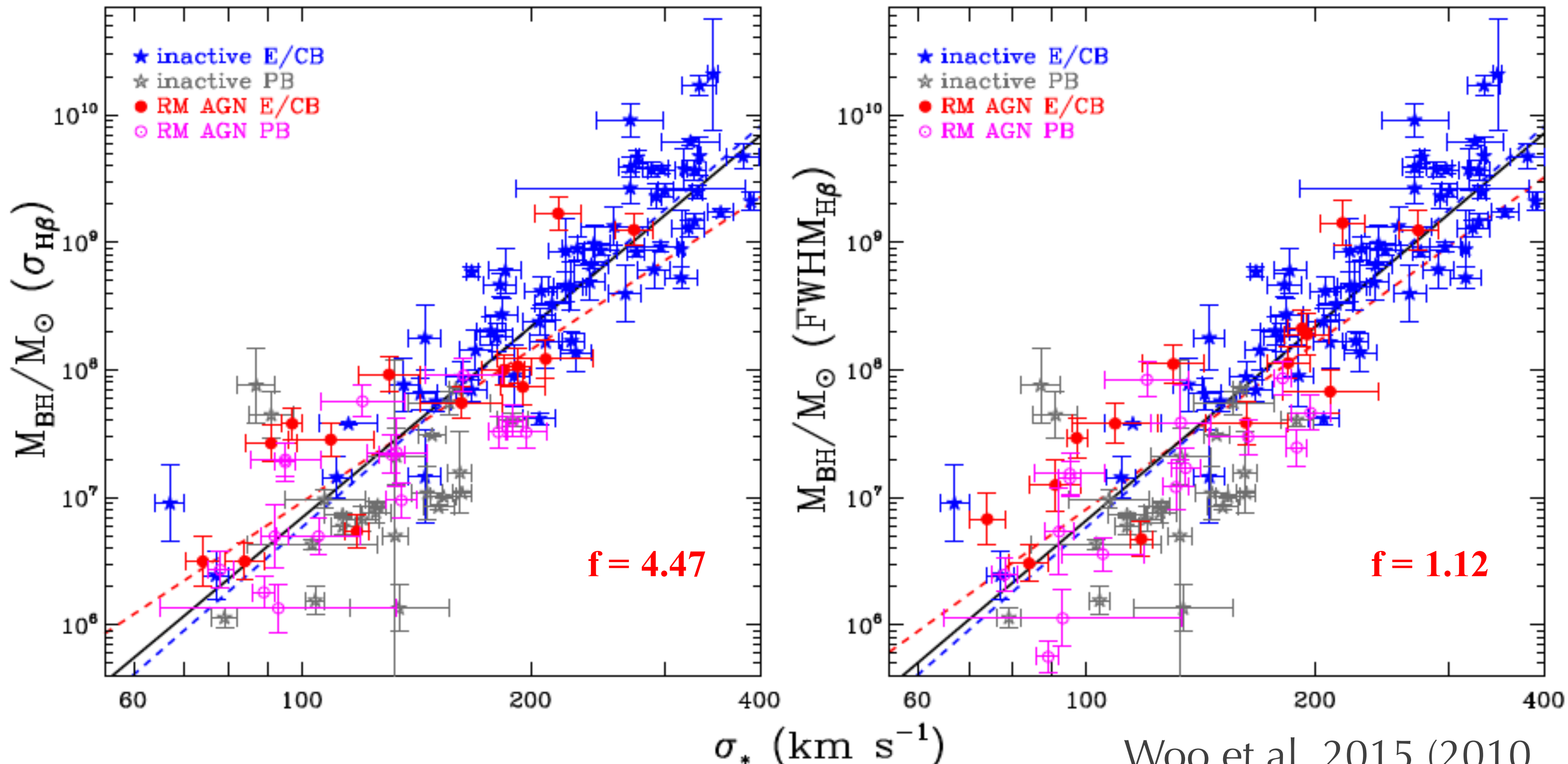


Present-day AGNs seem to follow the M_{BH}- σ relation.

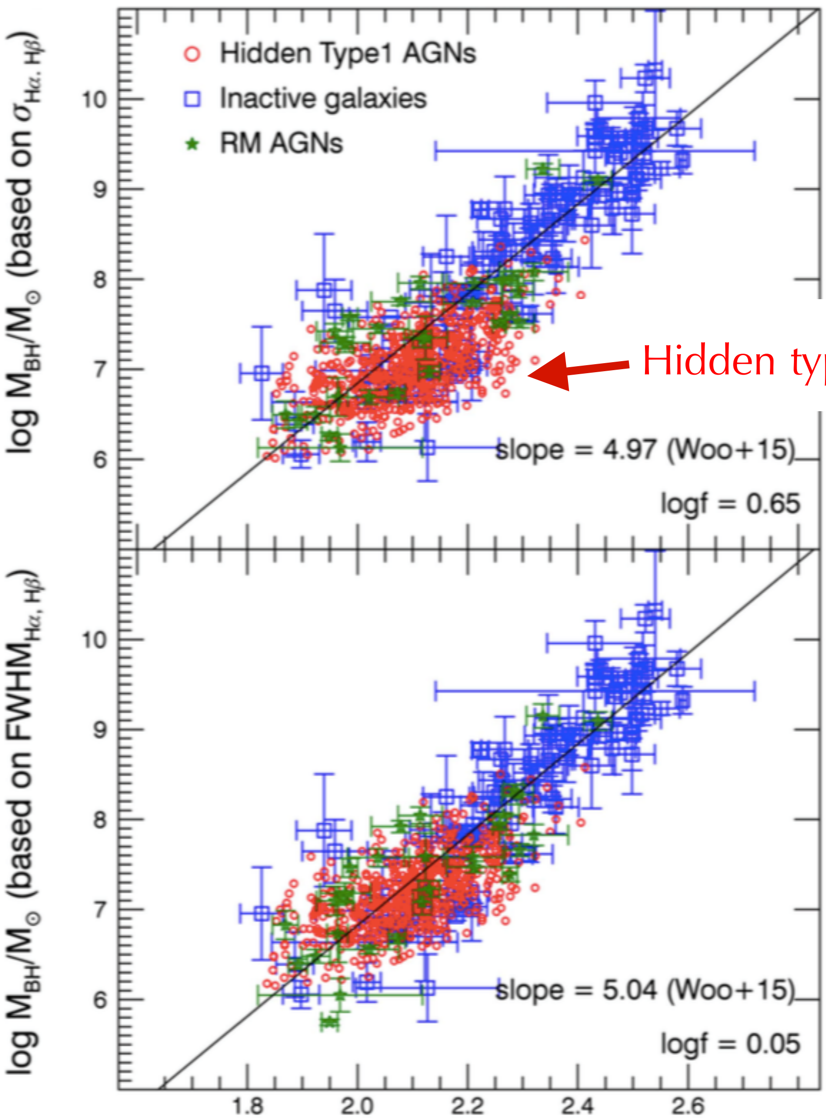
AGN reverberation $M_{BH} = f \ R_{BLR} V^2 / G$

- Between non-AGNs and AGNs, comparable intrinsic scatter ~0.4-0.5 dex
- No systematic difference between classical bulges and pseudo bulges



Woo et al. 2015 (2010, 2013, Park et al. 2012)

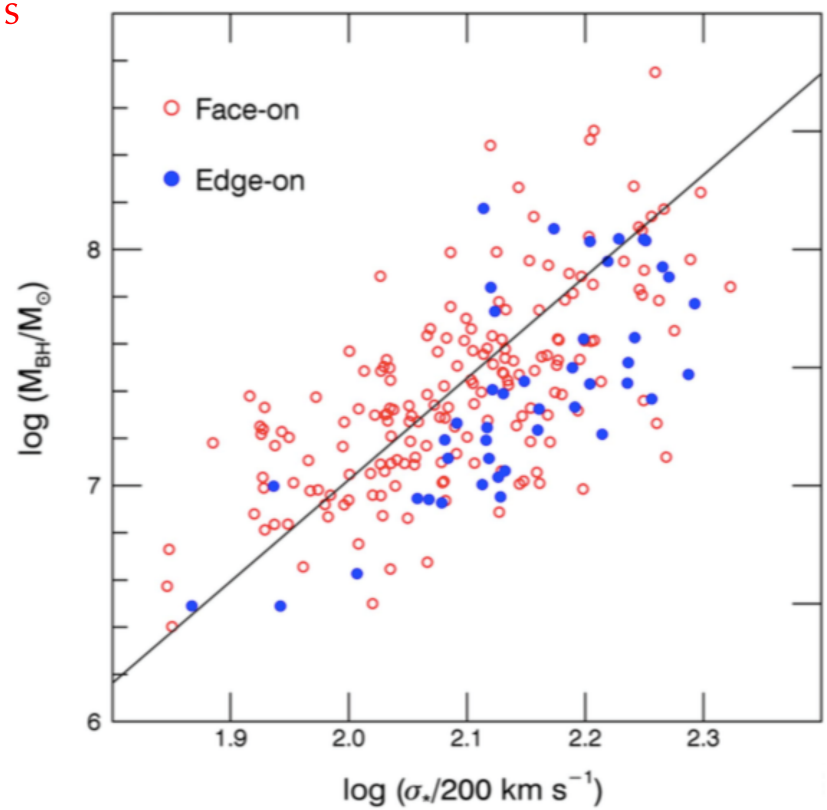
Hidden type 1 AGNs follow the M_{BH} - σ relation



log (σ/200 km/s)

Hidden type 1s

- Face-on galaxies have higher stellar velocity dispersion
- Presumably due to Inclination effect



Summary

- Gas outflows are detected in the majority of luminous type 2 AGNs.
- OIII kinematics correlates with AGN luminosity, suggesting that **outflows are driven by AGNs**.
- **While strong outflow AGNs have regular SFR, no outflow AGNs** have much lower sSFR. This can be explained by either **delayed feedback or gas depletion.**
- IFU data indicates **the complexity of the interaction between outflows and SF, including negative and positive feedback.**
- AGNs, including hidden type 1 AGNs, seem to follow the same M-sigma relation, indicating BHs and galaxies do not evolve significantly at z~0