Cold Molecular Outflows in Active Galaxies Observed with ALMA

EWASS

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Motivation

- M - σ relation, overgrowth problem, properties of "red-and-dead" ellipticals

- Characterising in detail and with "large" statistics the properties and scaling relations of molecular outflows —> comparison with models

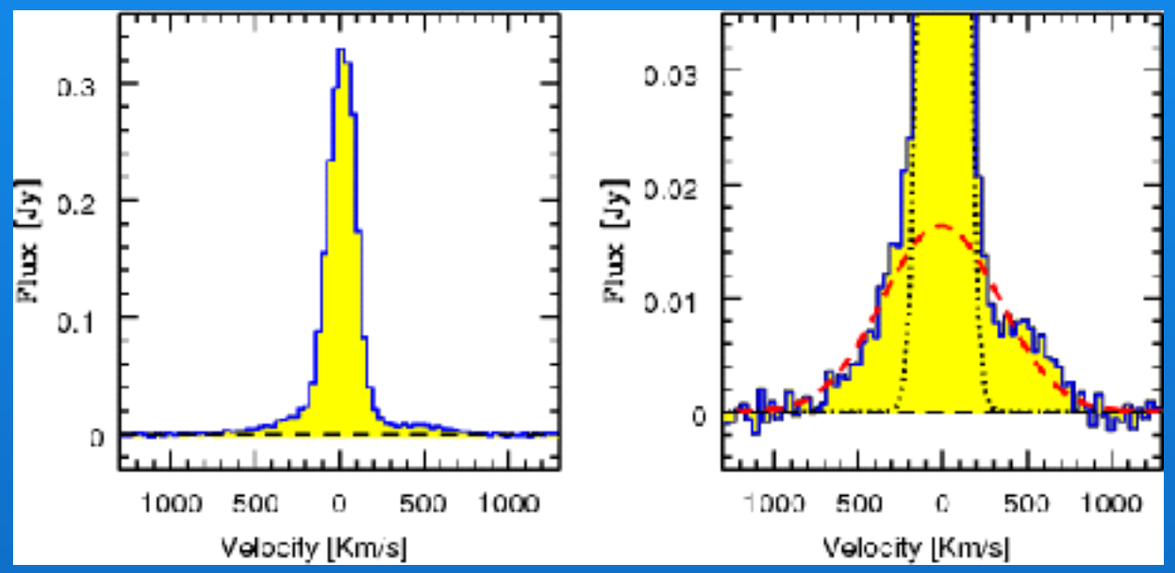
  - stellar mass dependence, star formation rate, AGN luminosity

- link to ionised and neutral gas phases

Previous Results

- AGN boosts: η (Ṁ/SFR) up to several hundred

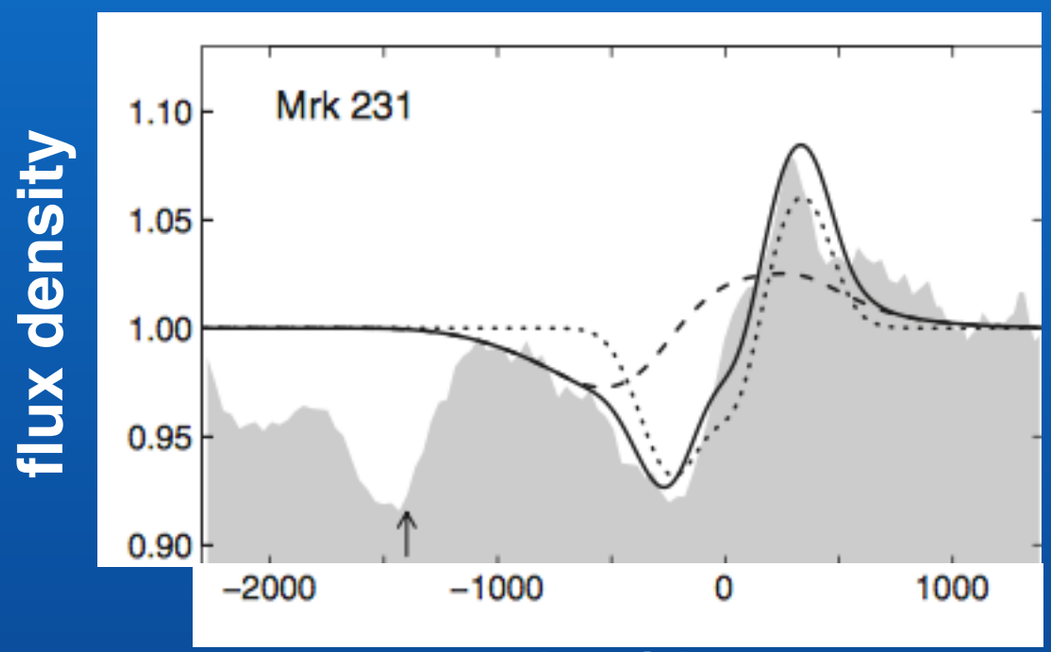
- shorter depletion times in AGN host galaxies (Sturm+11)



Feruglio+10

- energy-driven outflows in AGN hosts (Cicone+14, Fiore+17)

- **—> This work: Test trends in sample more than twice as large as in previous studies and homogenised analysis**



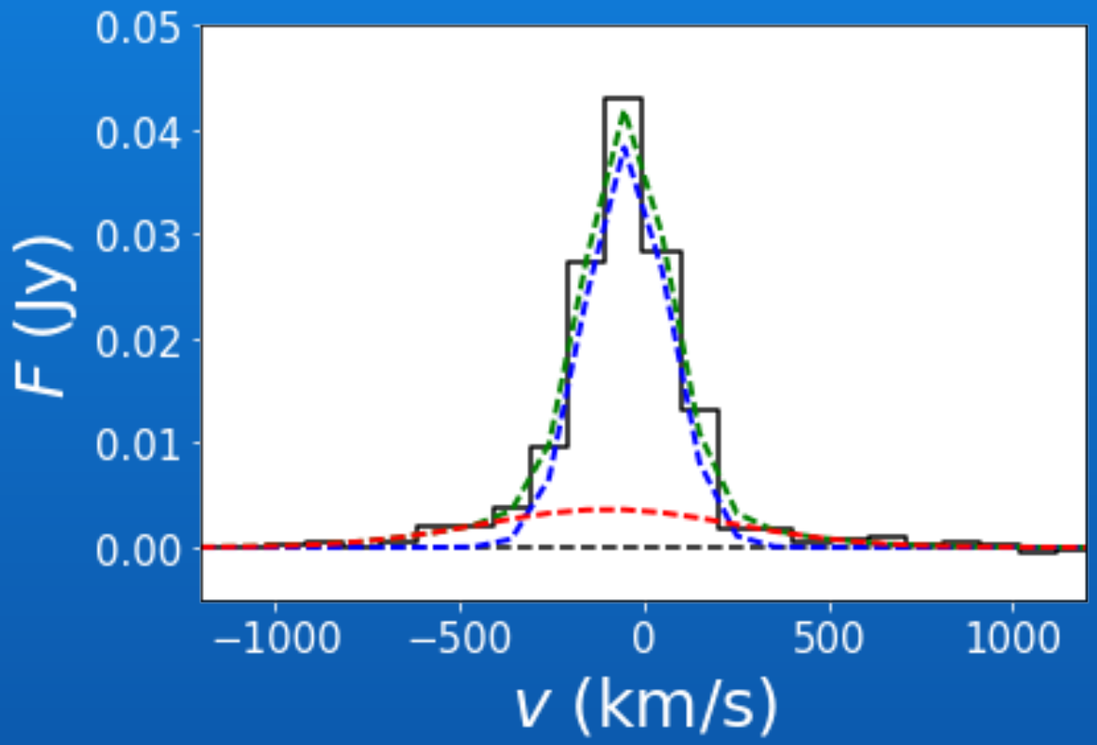
Sturm+11

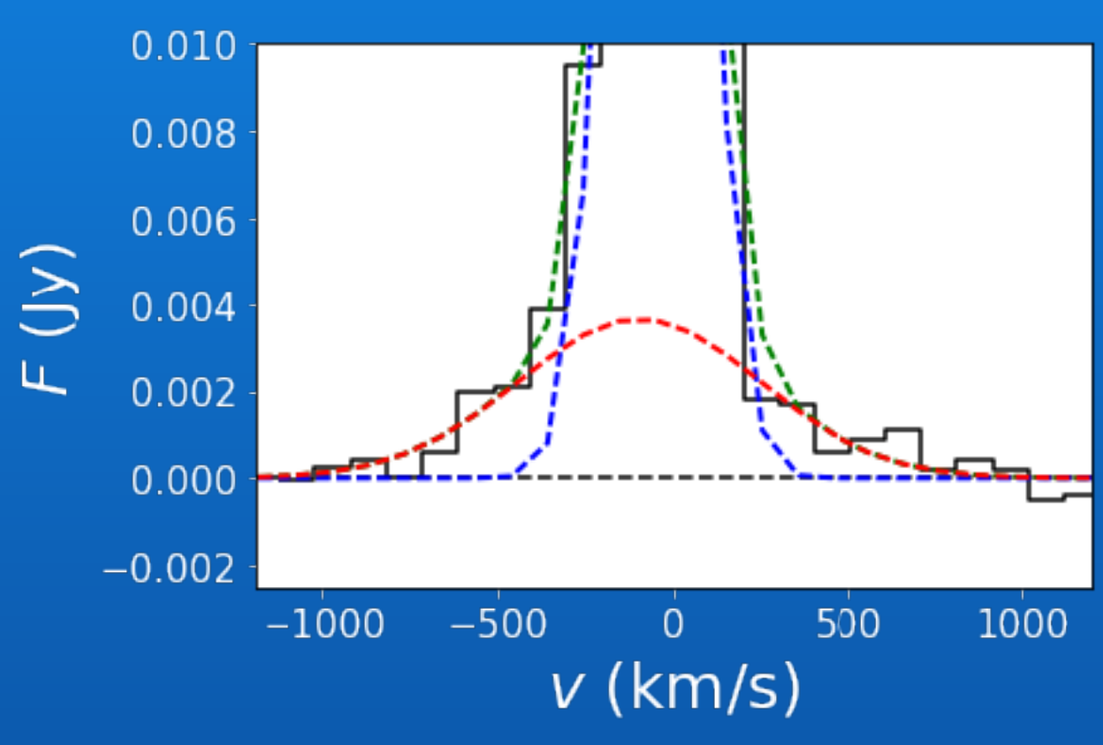
Methods

- Molecular outflows using low-*J* CO lines
- 44 galaxies (literature & ALMA archive)
  - $z < 0.2$
  - $\sim 0\ M_\odot/yr < SFR < \sim 750\ M_\odot/yr$
  - $10^{10}\ M_\odot < M_* < 10^{12.2}\ M_\odot$
- homogenise (outflow & ancillary properties)
- **outflow identification (a) and b) required, c) optional)**
  - a) double component fitting of continuum-subtracted CO spectra
  - b) line maps of wings
  - c) position-velocity (pv) diagrams
- $r_{outflow}$: 2D fitting of wings, $v_{outflow}$: FWHM/2 - (v_{broad}-v_{narrow}) (Rupke+05)

Outflow Identification

a) double component fitting





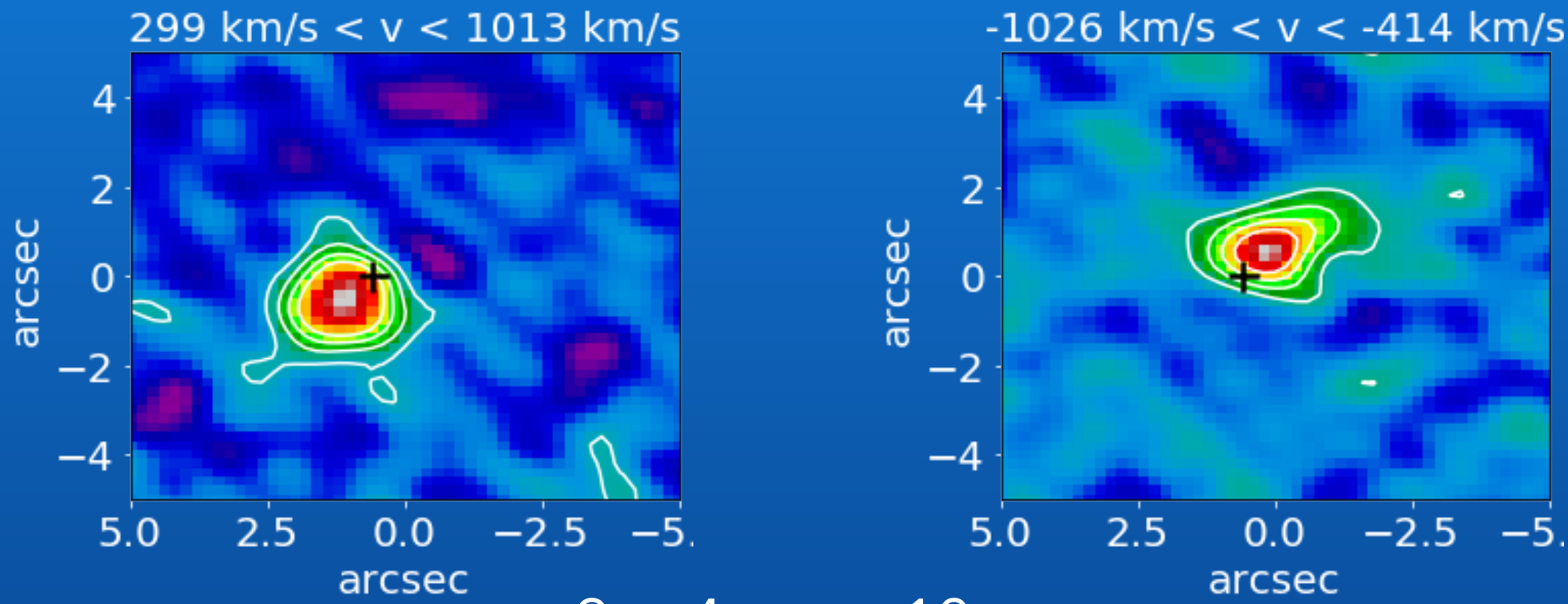
$\dot{M}$= 3700 $M_\odot$/yr

v_{OF} = 450 km/s

Outflow Identification

b) line maps of wings

>4σ detection of high-velocity gas and
offset not in same direction as rotation



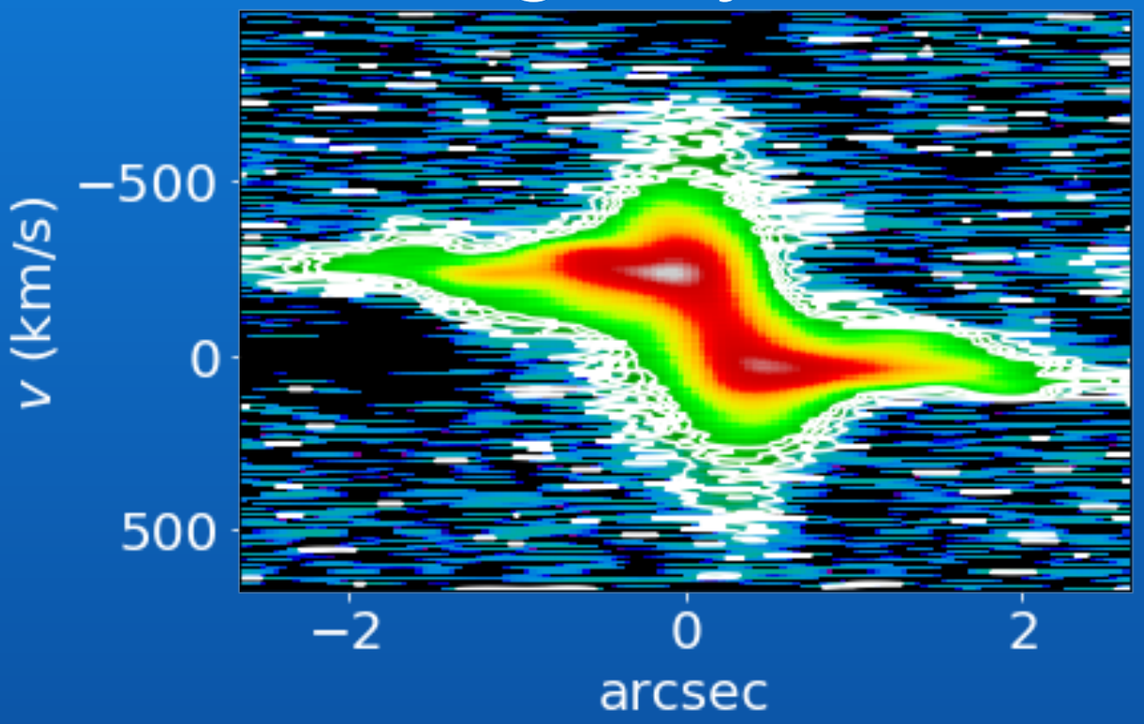
2σ, 4σ, …, 10σ

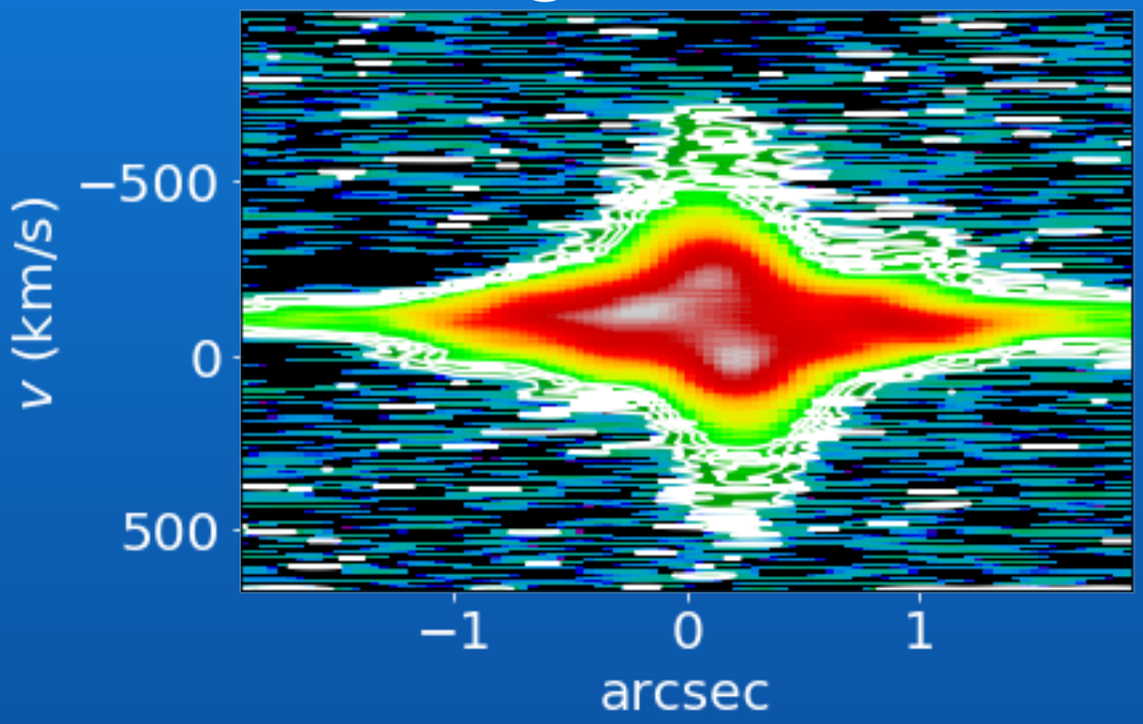
Outflow Identification

c) position-velocity diagrams

along major axis

along minor axis

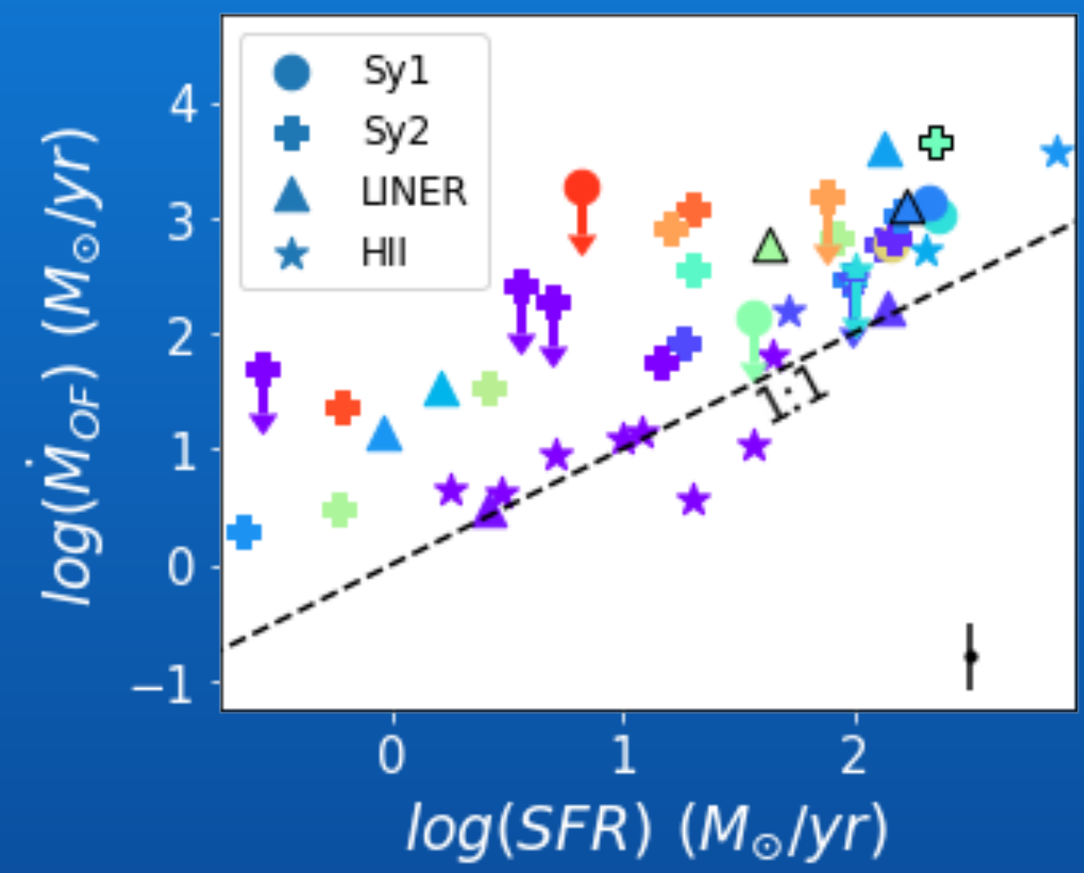


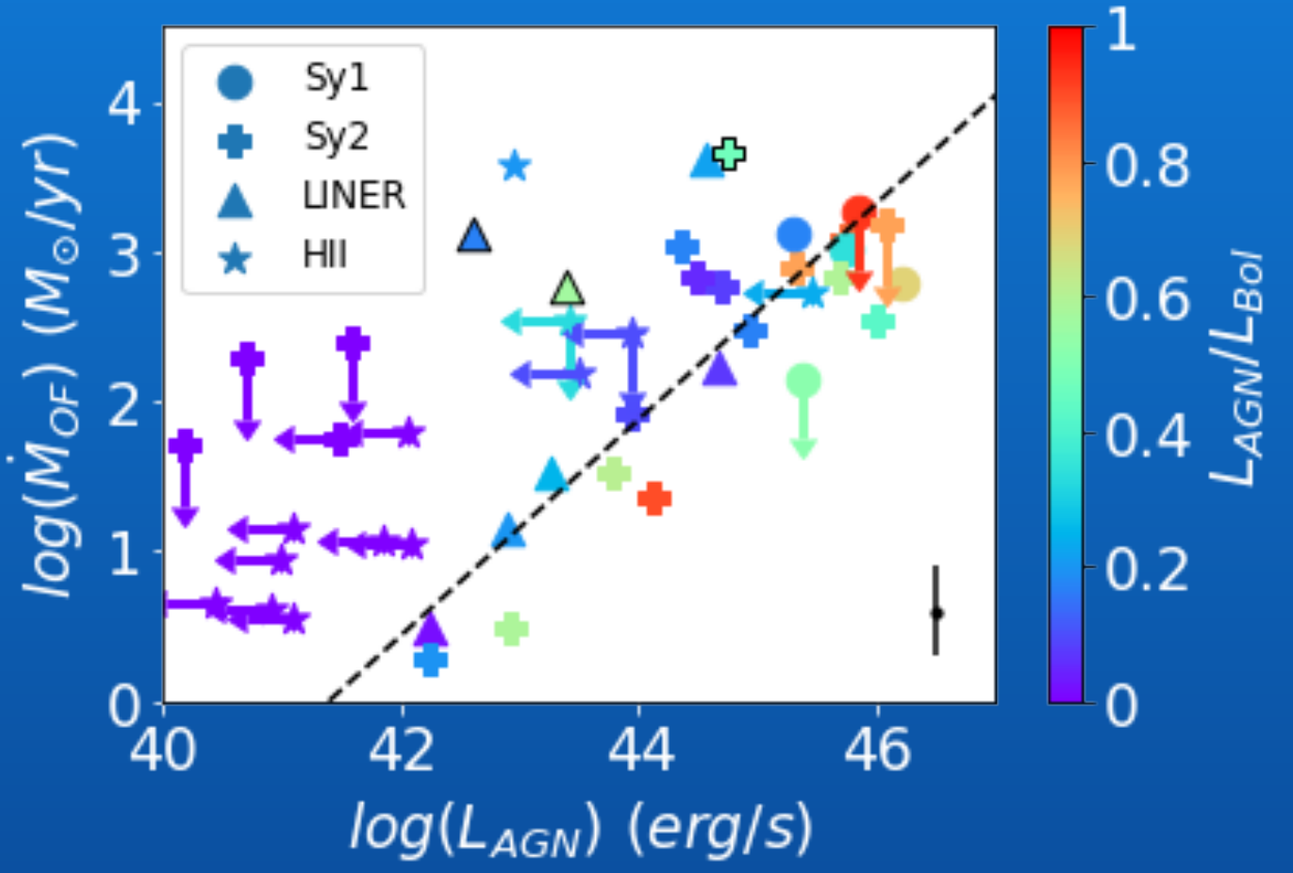


2σ, 4σ, …, 10σ

Starburst- or AGN-driven Outflows?

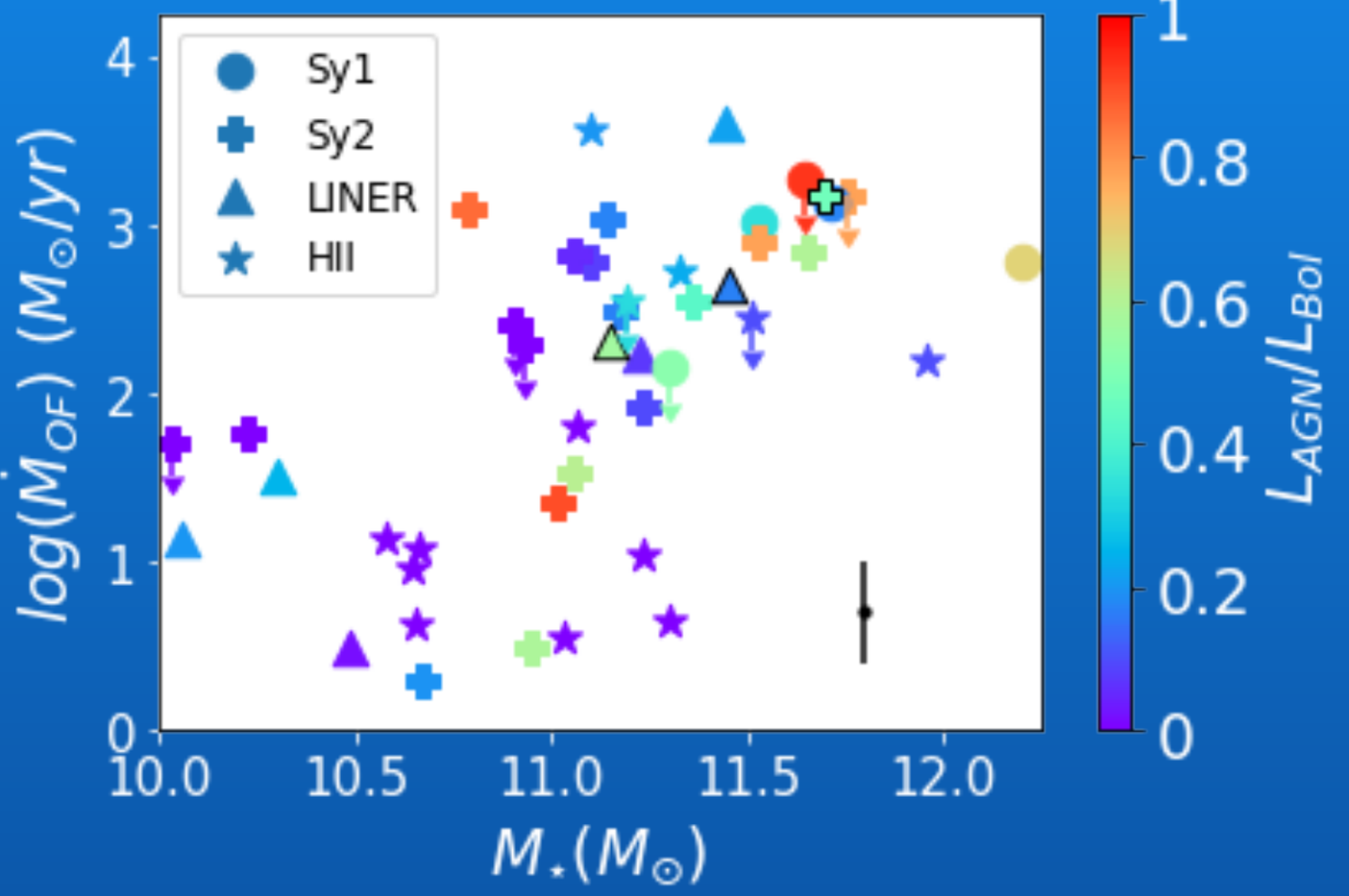
1) AGNs boost the outflow rate
2) SB-dominated galaxies and weak AGNs can also have large outflow rate





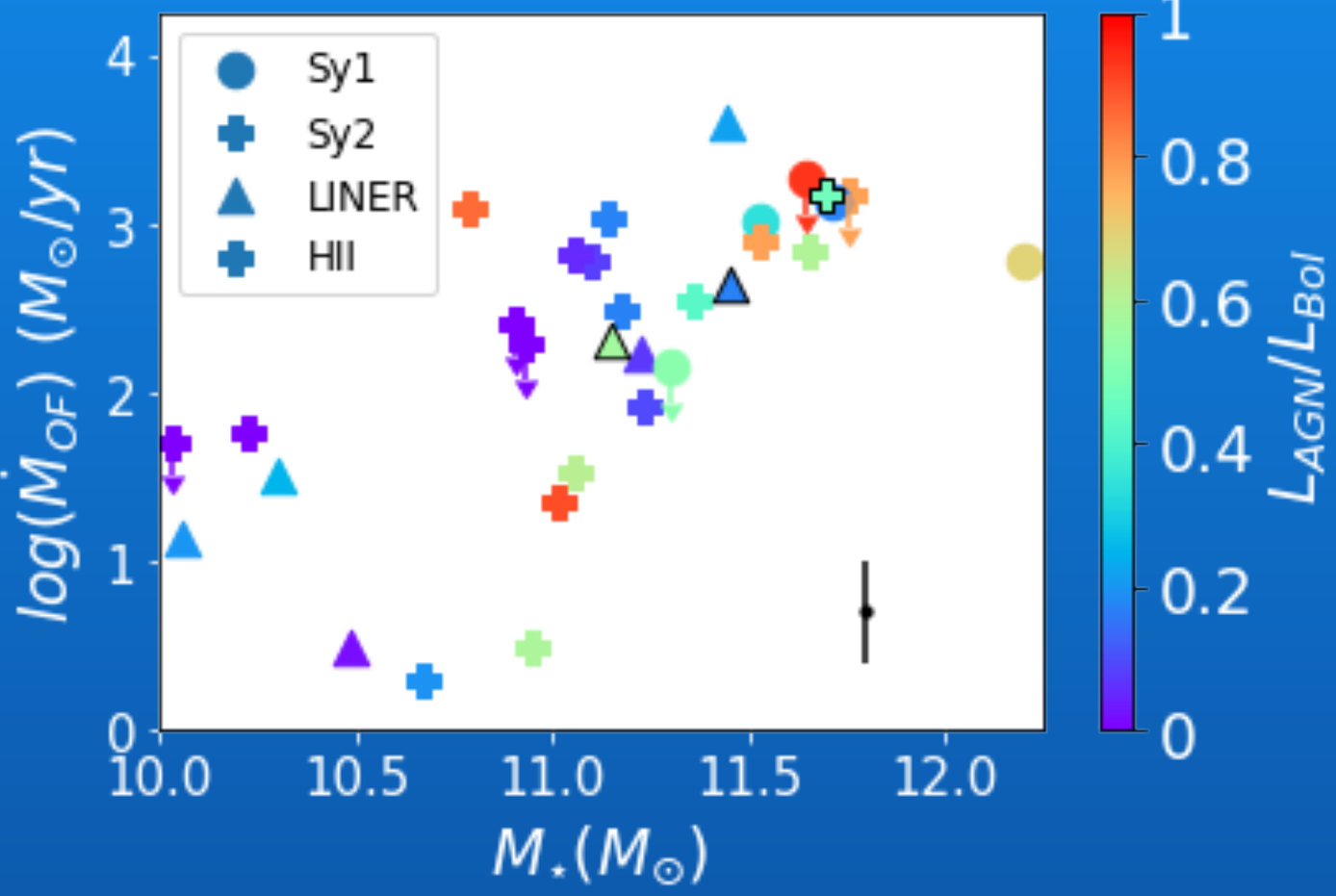
Flutsch+17 in prep

Stellar Mass Dependence



Flutsch+17 in prep

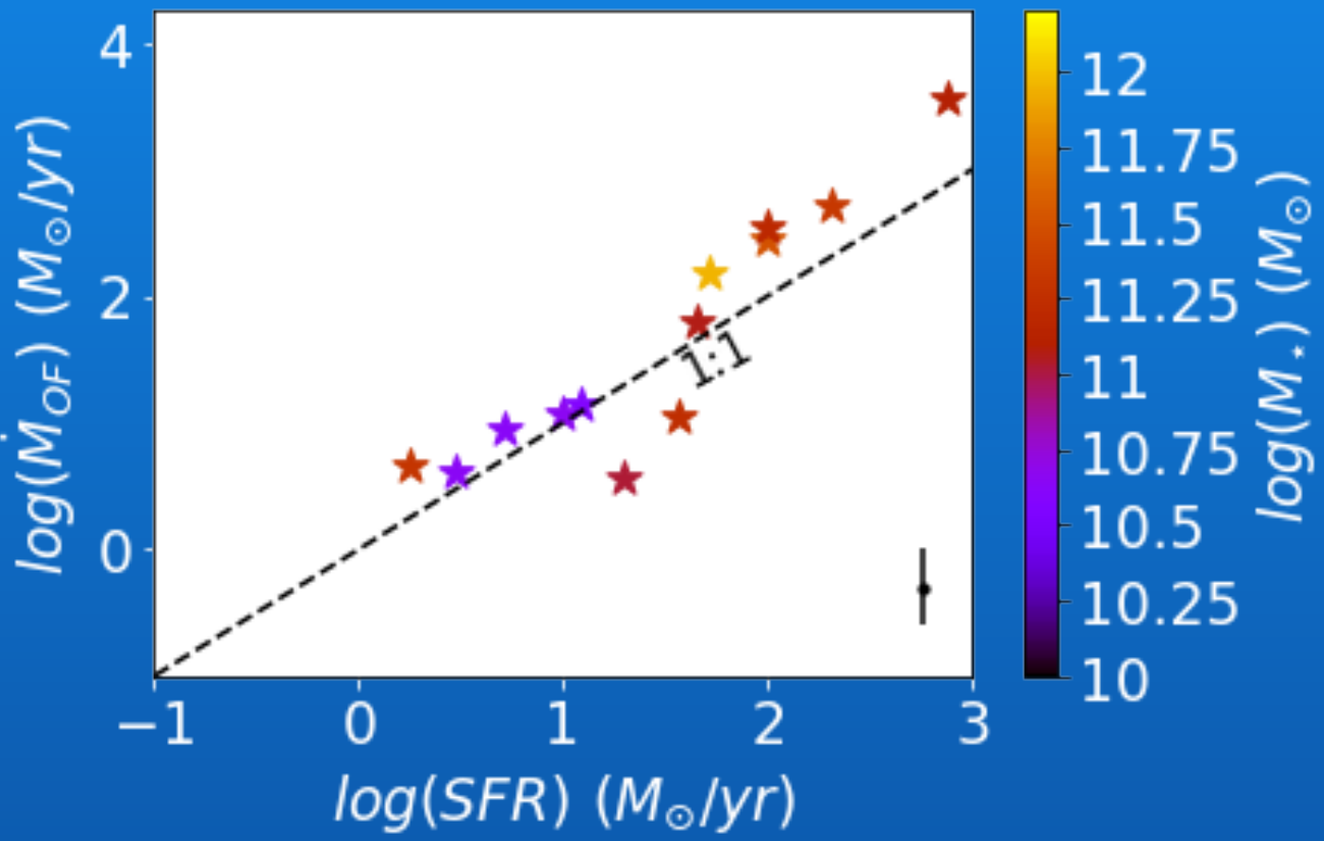
Stellar Mass Dependence



AGN host galaxies: More massive galaxies have higher mass outflow rate

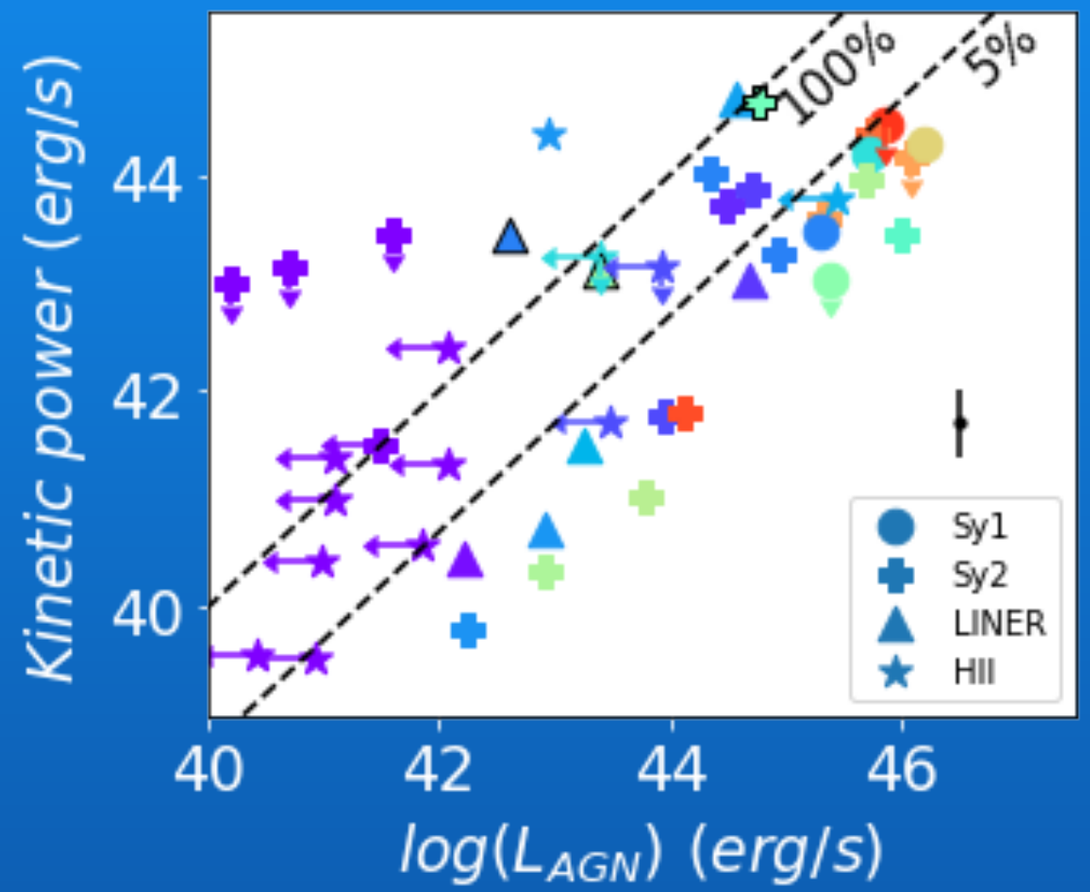
Stellar Mass Dependence

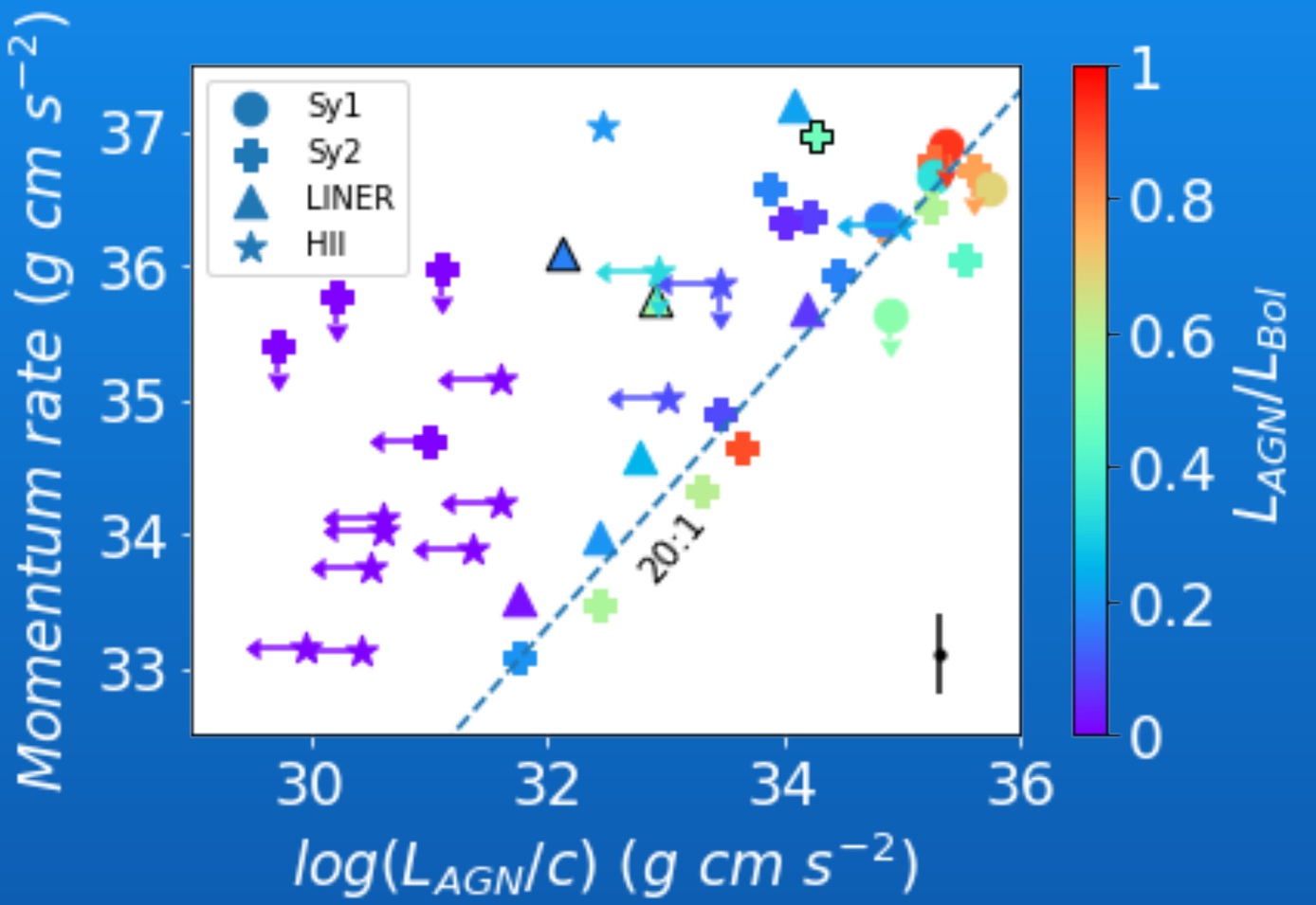
SB galaxies



SB galaxies: outflow rate dominated by SFR, no dependence on stellar mass, seem in tension with model expectations (e.g. Somerville & Davé+14)

Physical Nature of Outflow





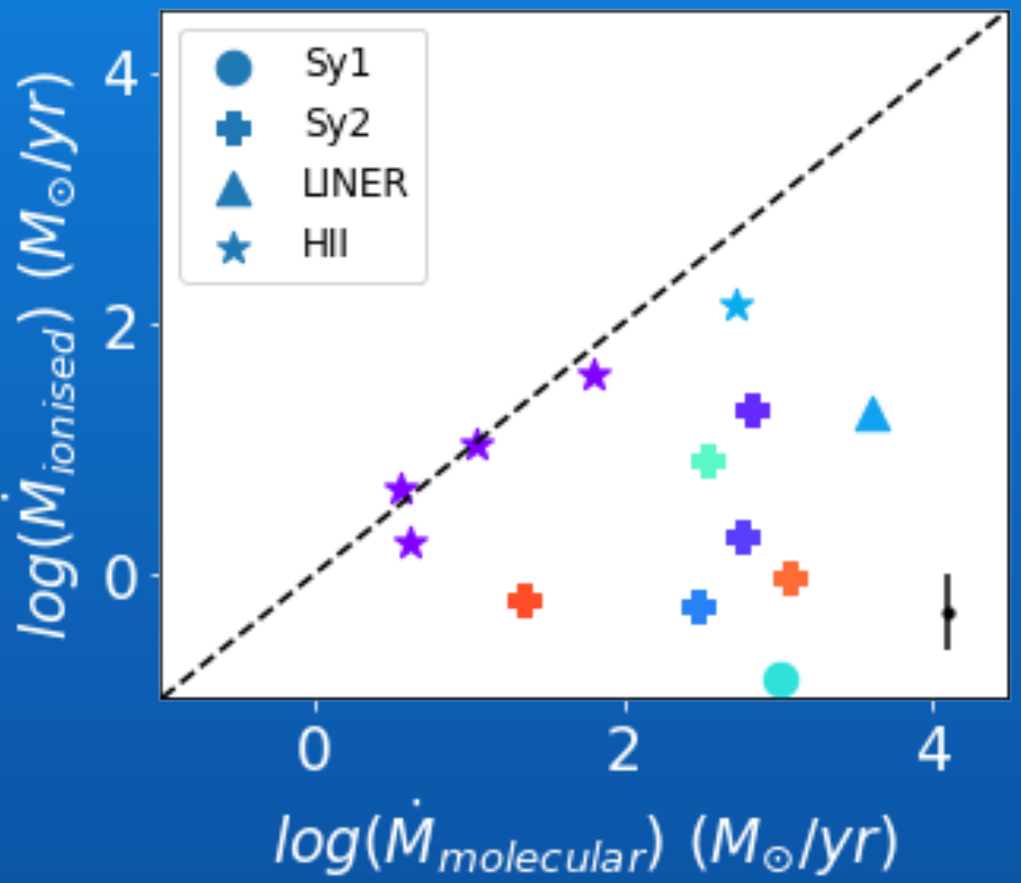
Flutsch+17 in prep

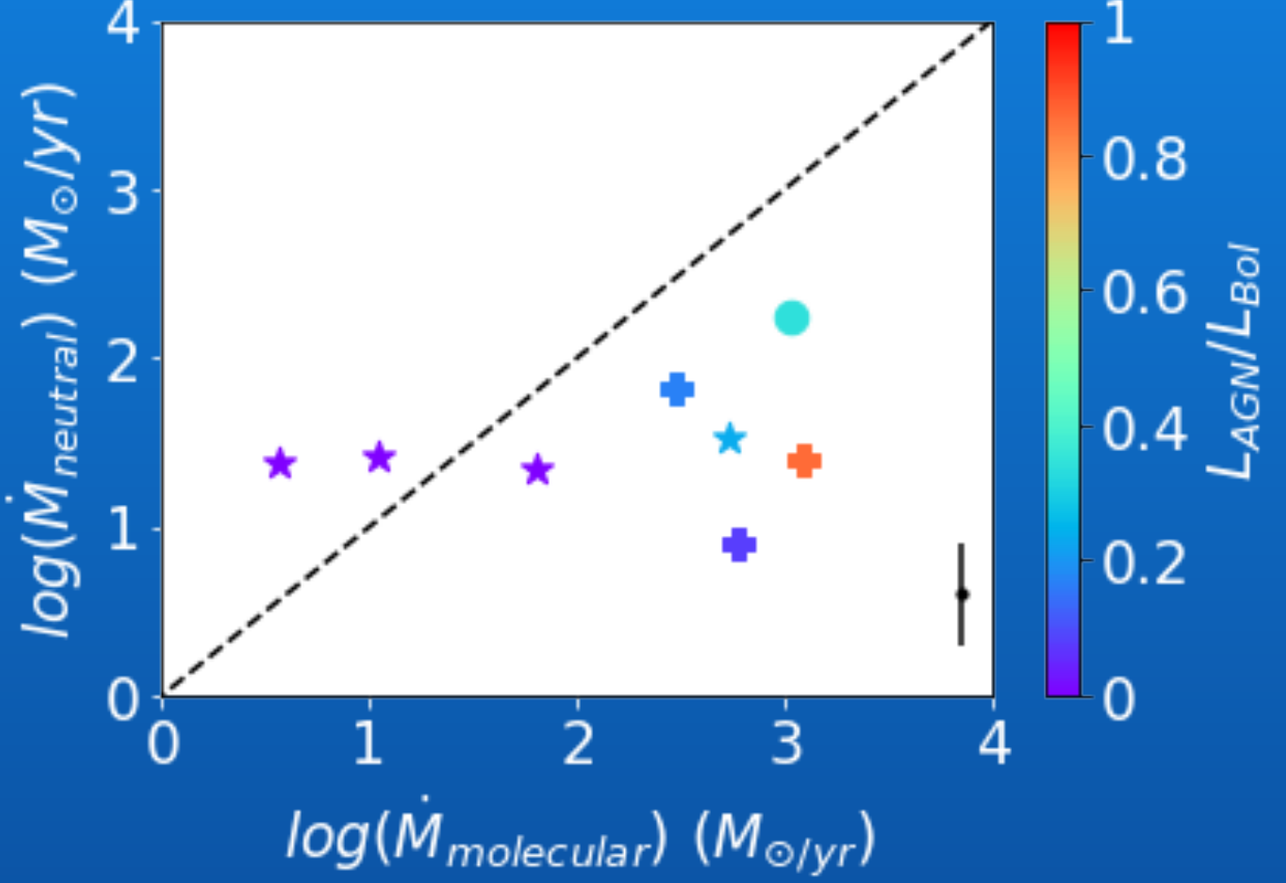
Weak AGN with high kinetic power and momentum rate: outflow outlasting faded AGN or large contribution from SNe

Atomic Neutral and Ionised Outflow from Nebular Emission Lines

galaxies with BOTH molecular and atomic measurements

from Na I D absorption





in SB galaxies, winds have substantial contribution of both ionised and neutral atomic gas, whereas in AGNs the molecular phase dominates

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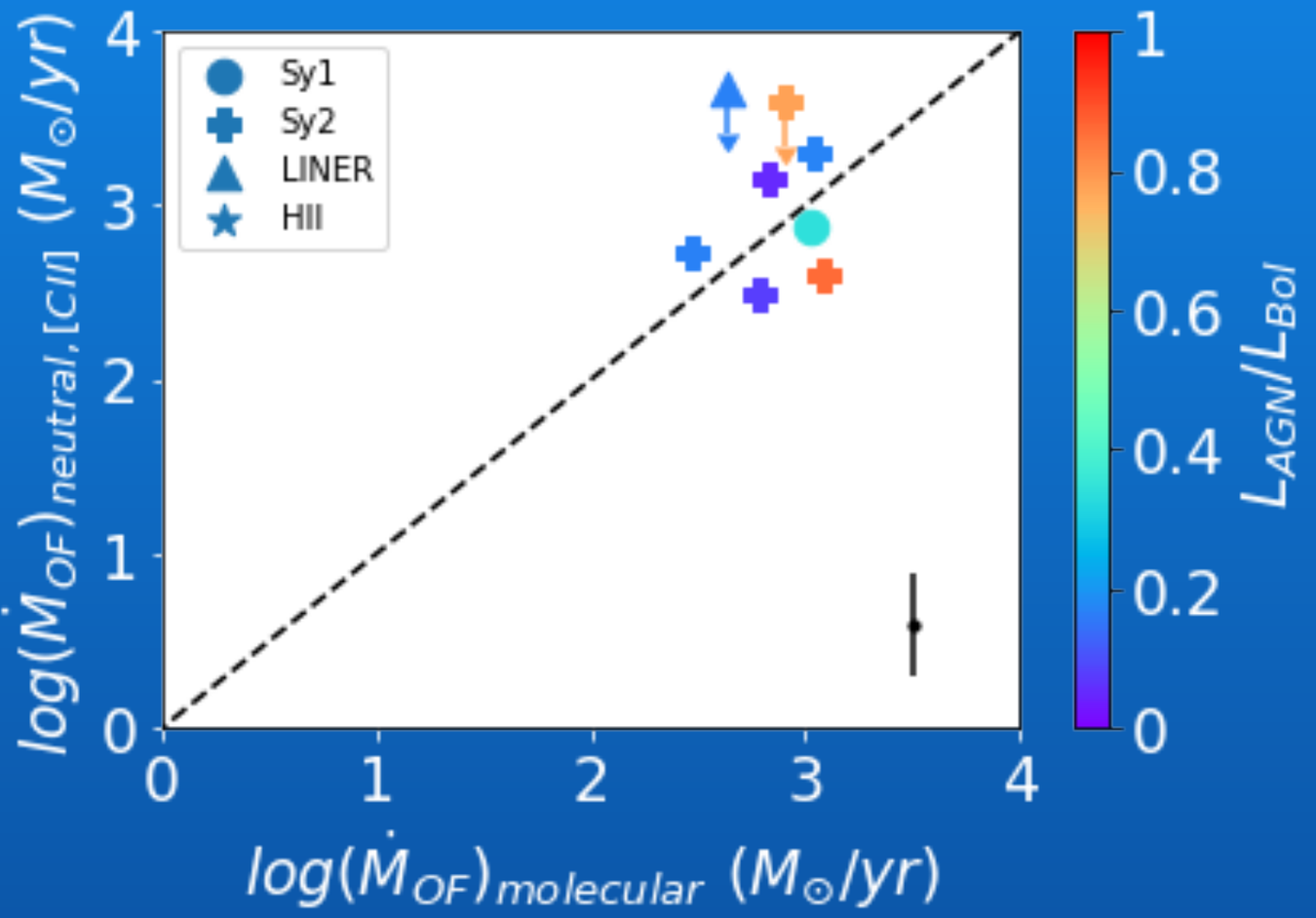
Atomic Neutral and Ionised Outflow



[CII] data from Janssen+16

Similar contribution of atomic neutral gas and molecular gas in AGN outflow

Conclusion

- In local galaxies:
  - SB-dominated galaxies or galaxies with weak AGN characterised by large outflow rates
    - Outflow outlasting faded AGN
      - Significant contribution from SNe-driven outflow
  - More massive AGN hosts show higher mass outflow rates, while no mass-dependence is seen in SB-dominated galaxies
  - Energy-driven AGN outflows
- **Future work:** ionised phase; targets for positive feedback (Maiolino+17)