Does your favorite galaxy at z~0.5 drive a cool outflow?

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Goal: Catch Outflows in the Act

Local Universe:

Heckman et al. 1990
Martin 2005, 2006
Westmoquette et al. 2007,8,9

Questions:

1. Outflow velocity?
2. Rate of mass and energy loss?
3. Dependence on galactic environment?

Driving Mechanisms:

Massive star clusters (radiation pressure)?
Murray et al. 2005, 2010

Supernovae (kinetic energy, cosmic rays)?
McKee & Ostriker 1977
Strickland & Heckman 2009
Socrates et al. 2008

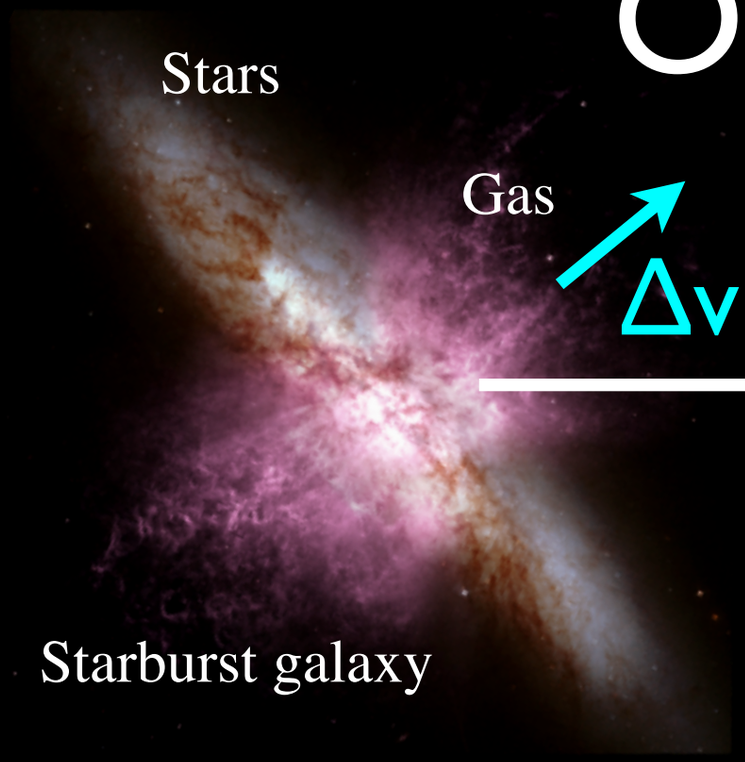
Theoretical Expectations:

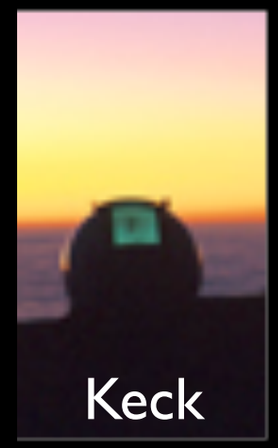
Must form a cluster massive enough to have the luminosity needed to drive a wind with velocity > galactic circular velocity

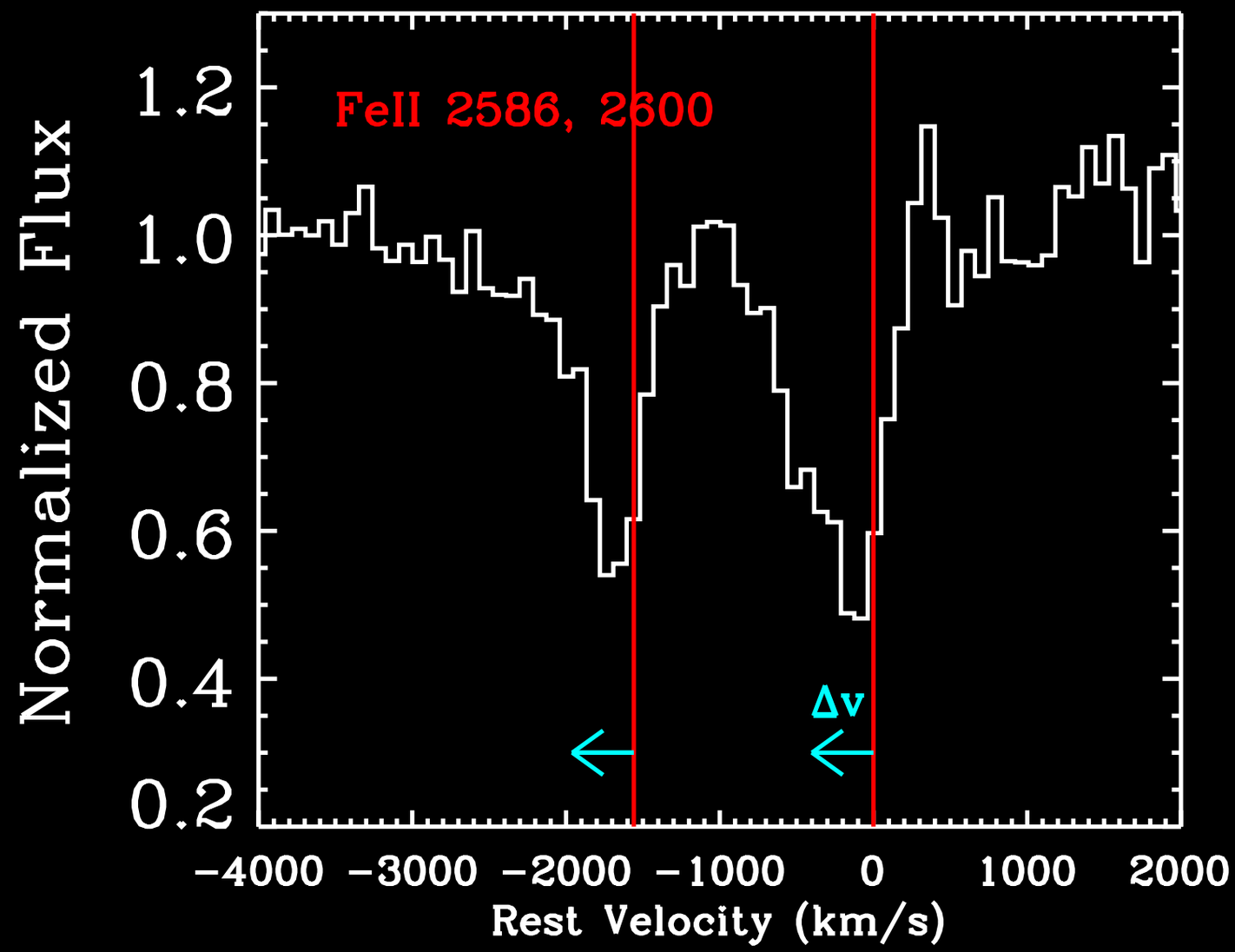
Must exceed filling factor for hot gas:
supernova volume density ↑ → filling factor ↑

Credit: M. Westmoquette (UCL), NASA/ESA

Our Technique:



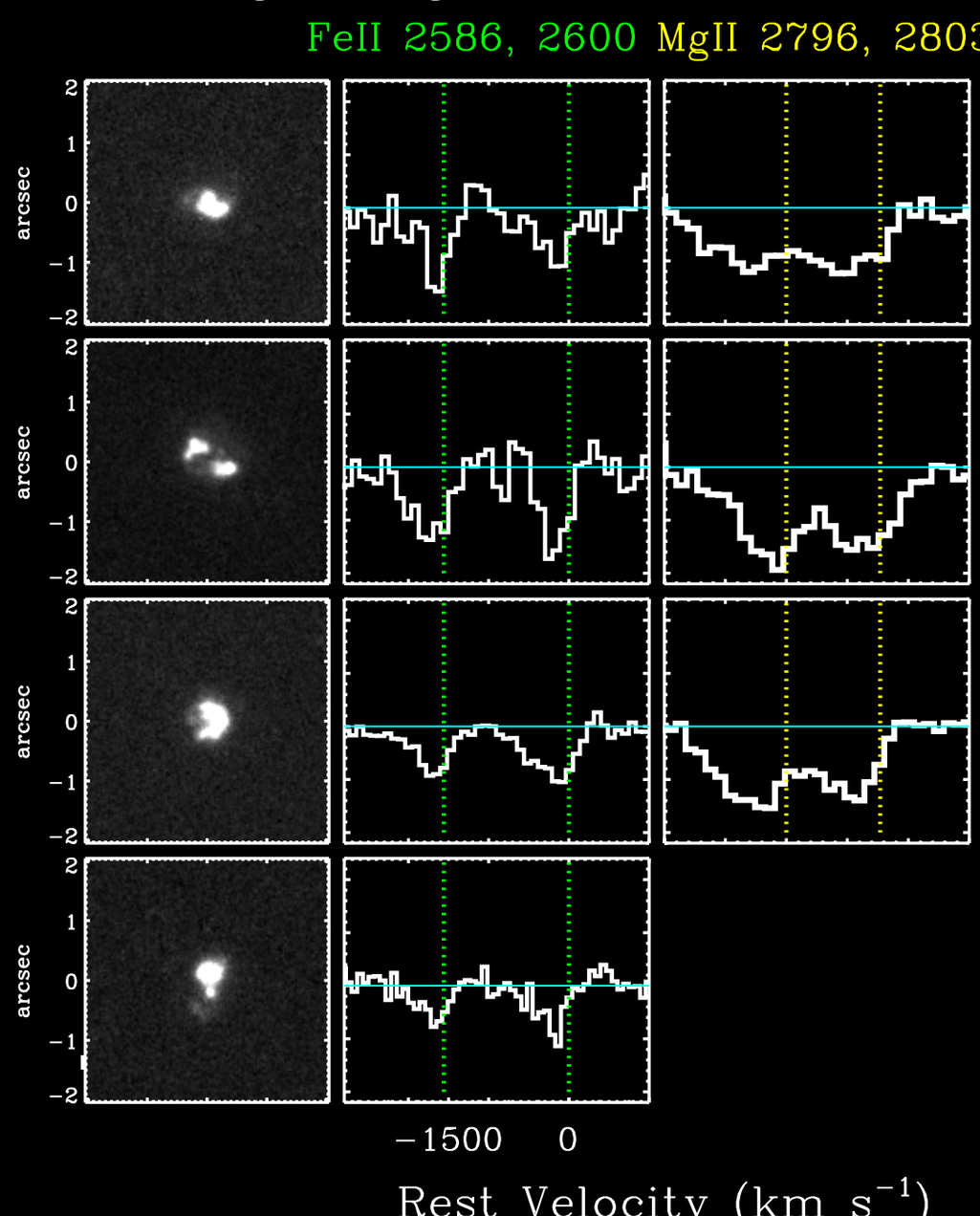


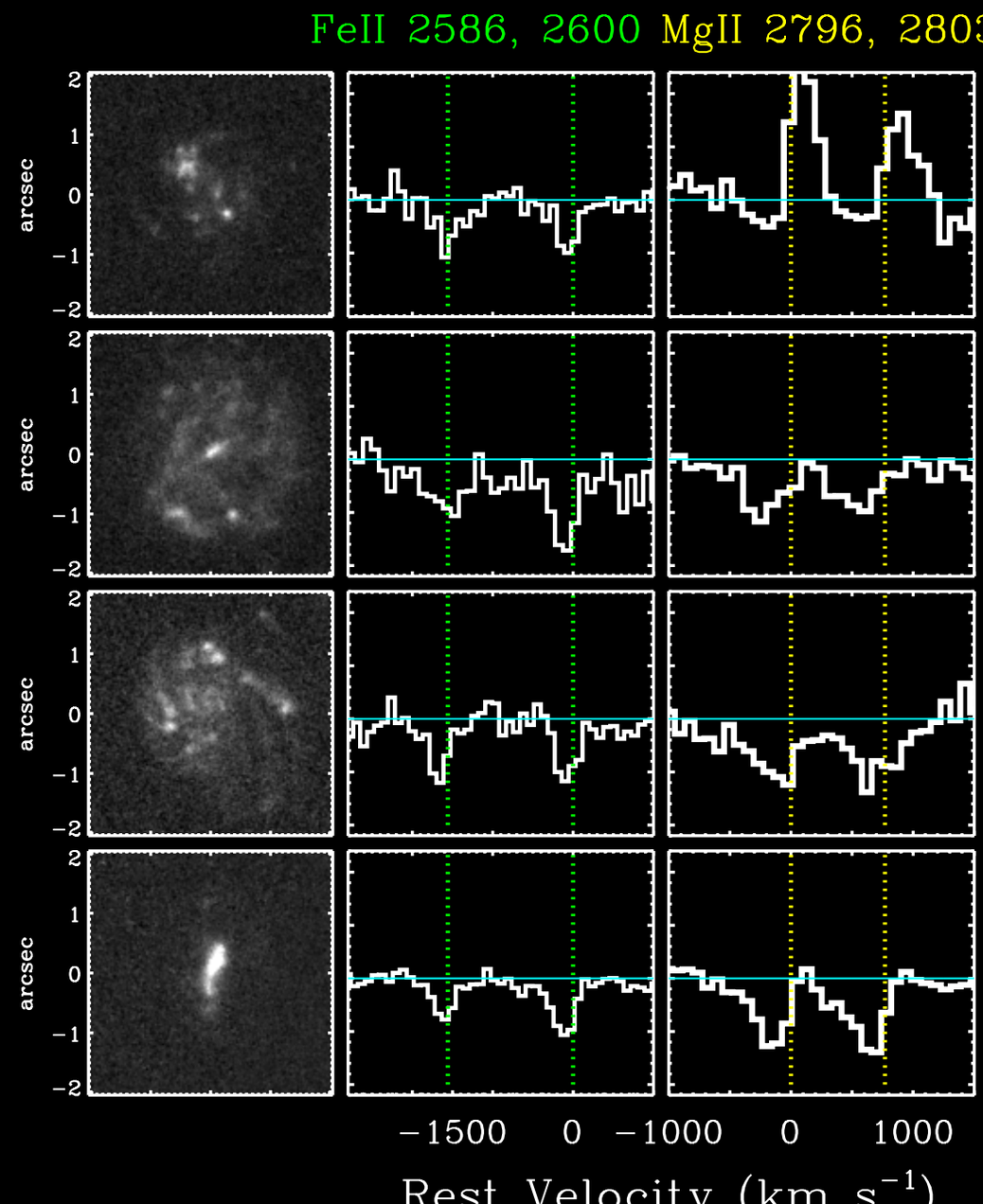


Our Data and Credits to Others

Spectroscopy:

- Keck/LRIS survey to B(AB) < 23 (3 hours/object)
- 180 - 400 km/s FWHM resolution
- ~ 140 galaxy spectra at 0.3 < z < 1.4
- coverage of MgII 2796, 2803 and FeII 2586, 2600





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HST/ACS Imaging:

- 2/3 of sample in GOODS: F435W, F606W, F775W & F850LP coverage (Giavalisco et al. 2004)
- 1/3 of sample in Extended Groth Strip: F606W, F814W coverage (Davis et al. 2007)

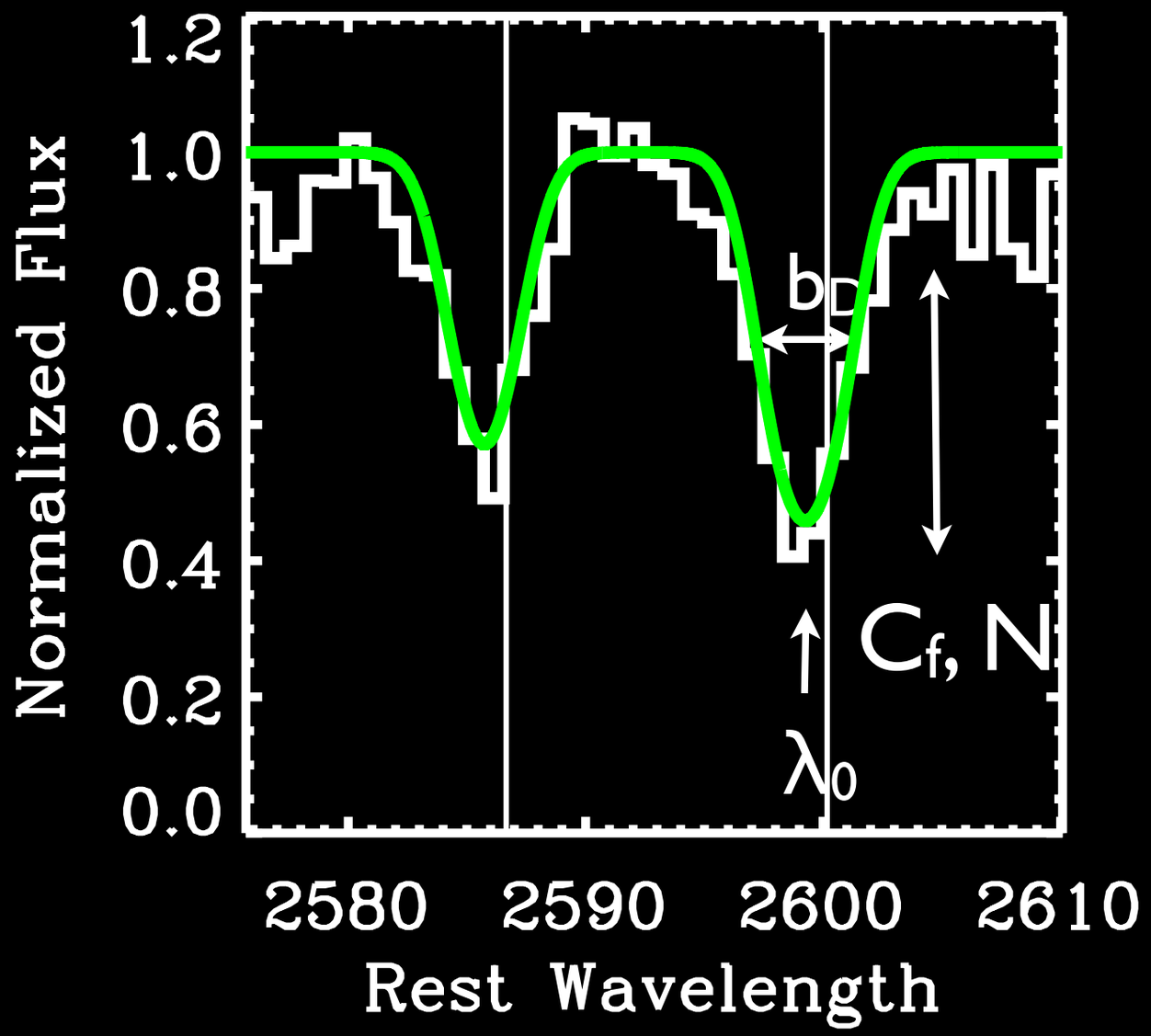
Ground-Based Optical / Near-IR Imaging:

- FIREWORKS (GOODS-S): *UBVRIzJHK$_S$* — Wuyts et al. 2008
- CFHTLS (EGS): *ugriz* — www.cfht.hawaii.edu/Science/CFHTLS
- AEGIS (EGS): *JK$_S$* — Bundy et al. 2006
- MOIRCS Deep Survey (GOODS-N): *JHK$_S$* — Kajisawa et al. 2010

→ SFRs, stellar masses
(SED fitting using MAGPHYS; da Cunha et al. 2008)

What does "outflow" mean?

FeII 2586, 2600



$I(\lambda) = F(\lambda, \lambda_0, C_f, b_D, N)$

A Single "Component":

central wavelength (λ_0)
Doppler parameter (b_D)
column density (N)
covering fraction (C_f)

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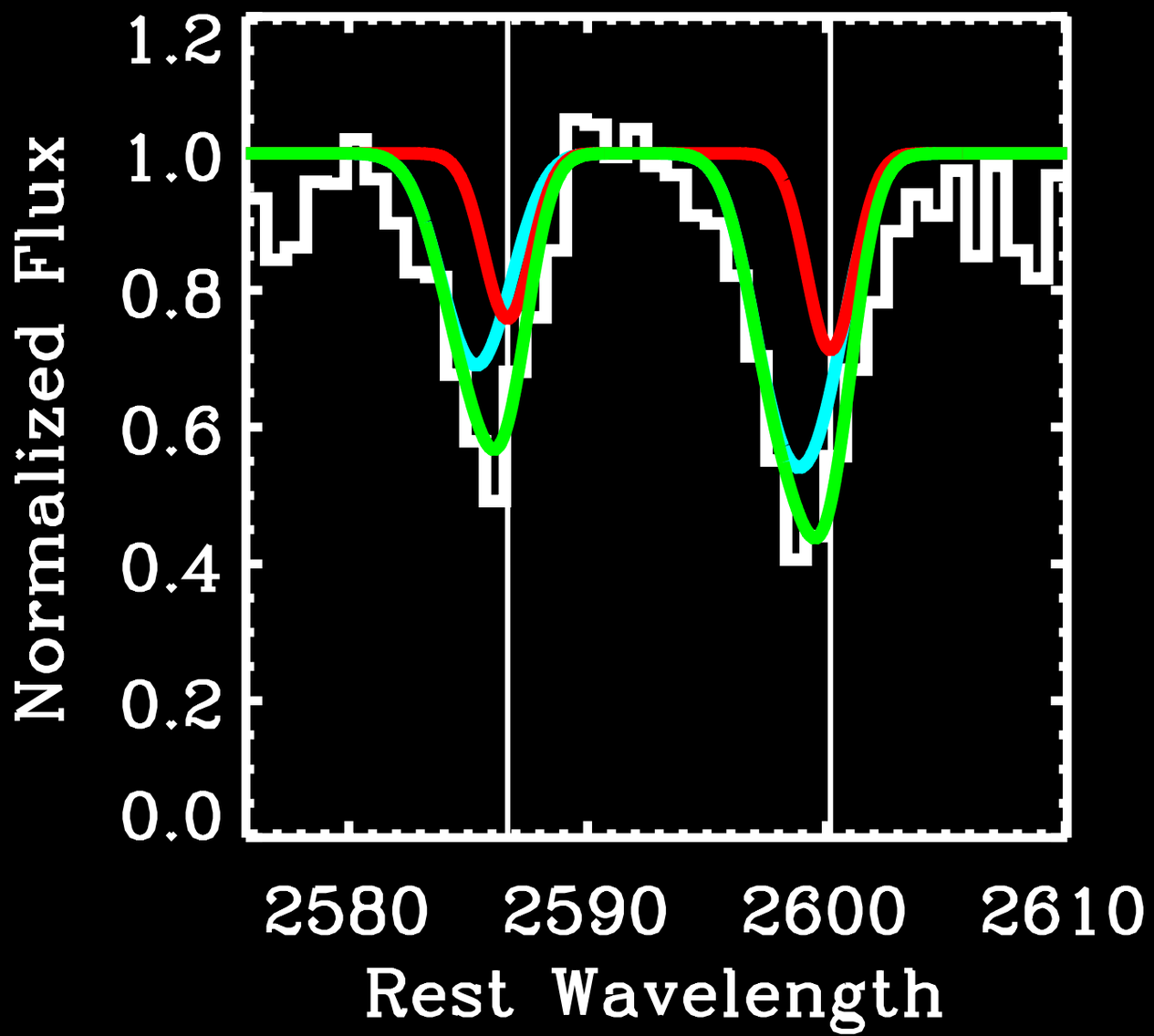

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We use 2 "components":
ISM: λ_0 = systemic wavelength
ISM: C_f = 1
WIND: 4 free parameters

6 free parameters!

We sample parameter likelihood space using "MCMC" to calculate robust parameter errors (e.g., Sato et al. 2009)

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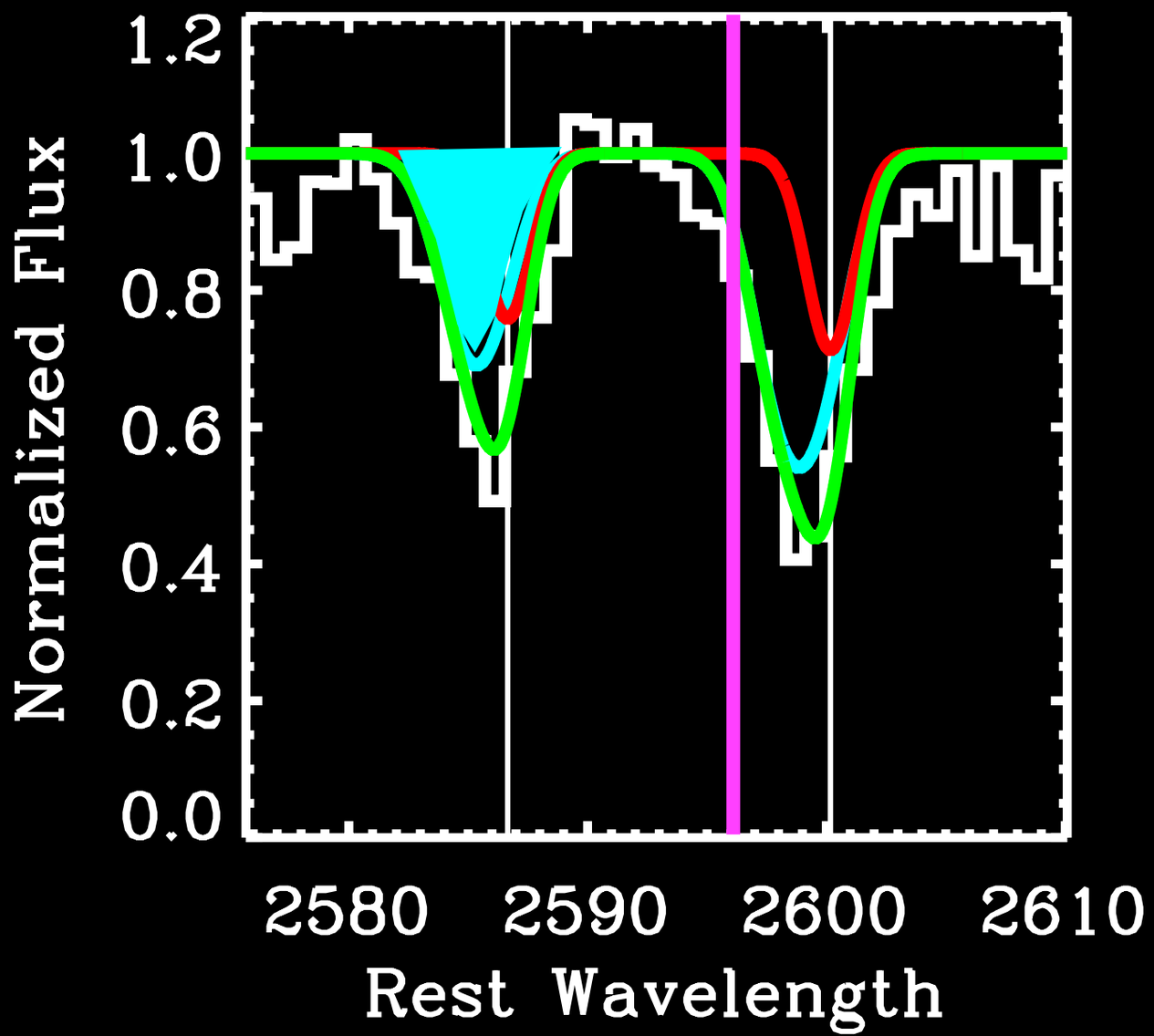

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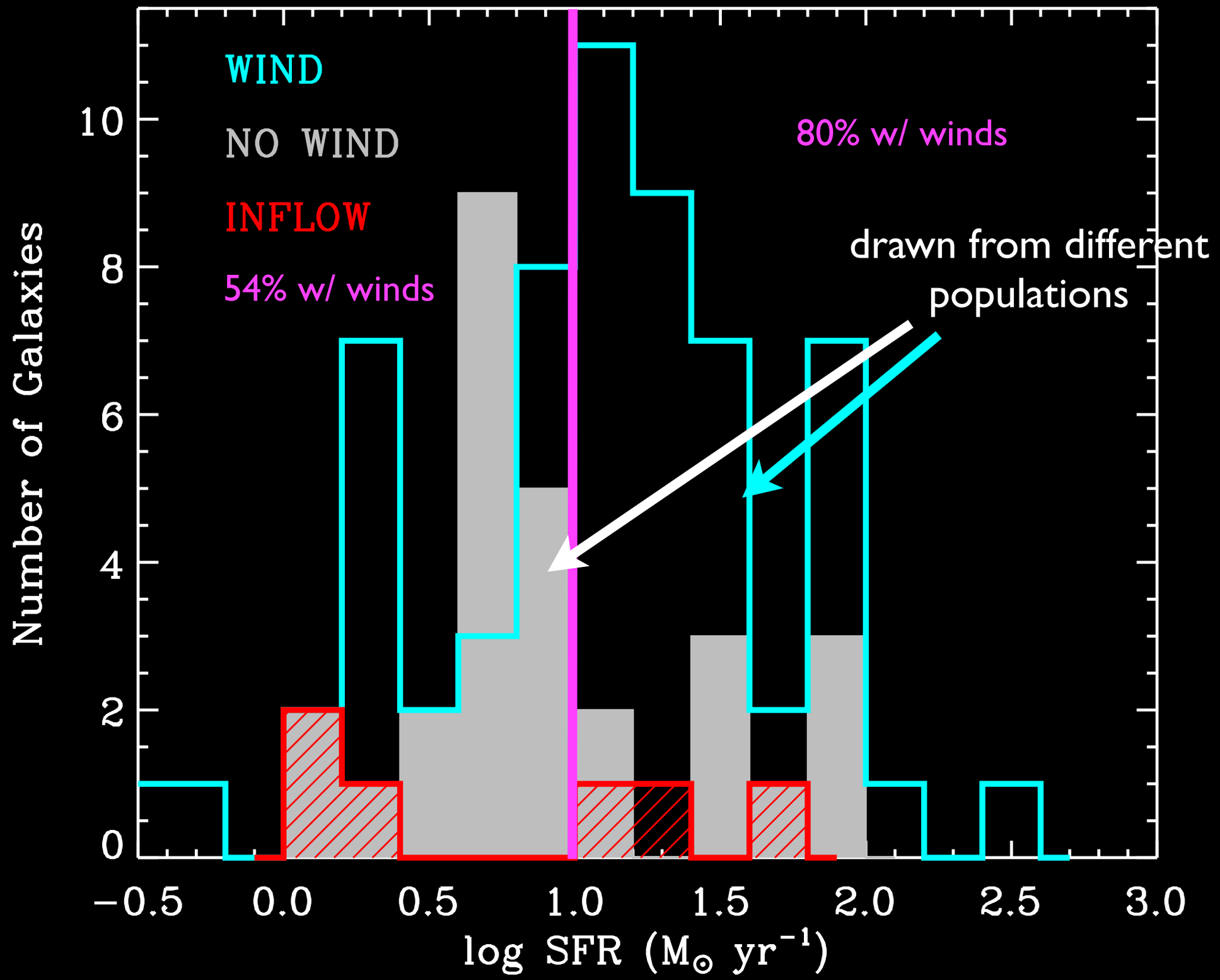
Relevant Measurements: EW, max v = v_0 - b_D/sqrt(2)

Winds and SFR



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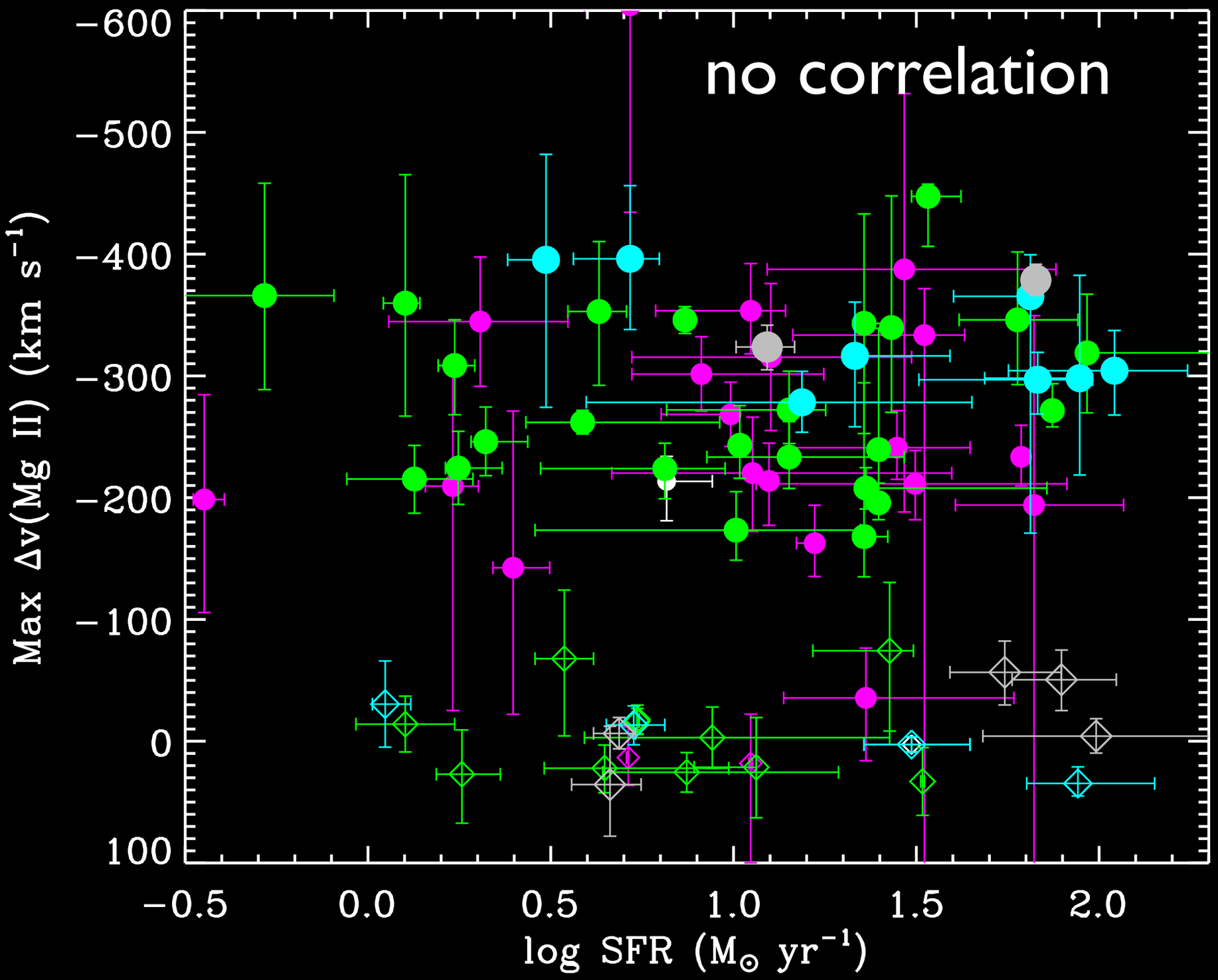
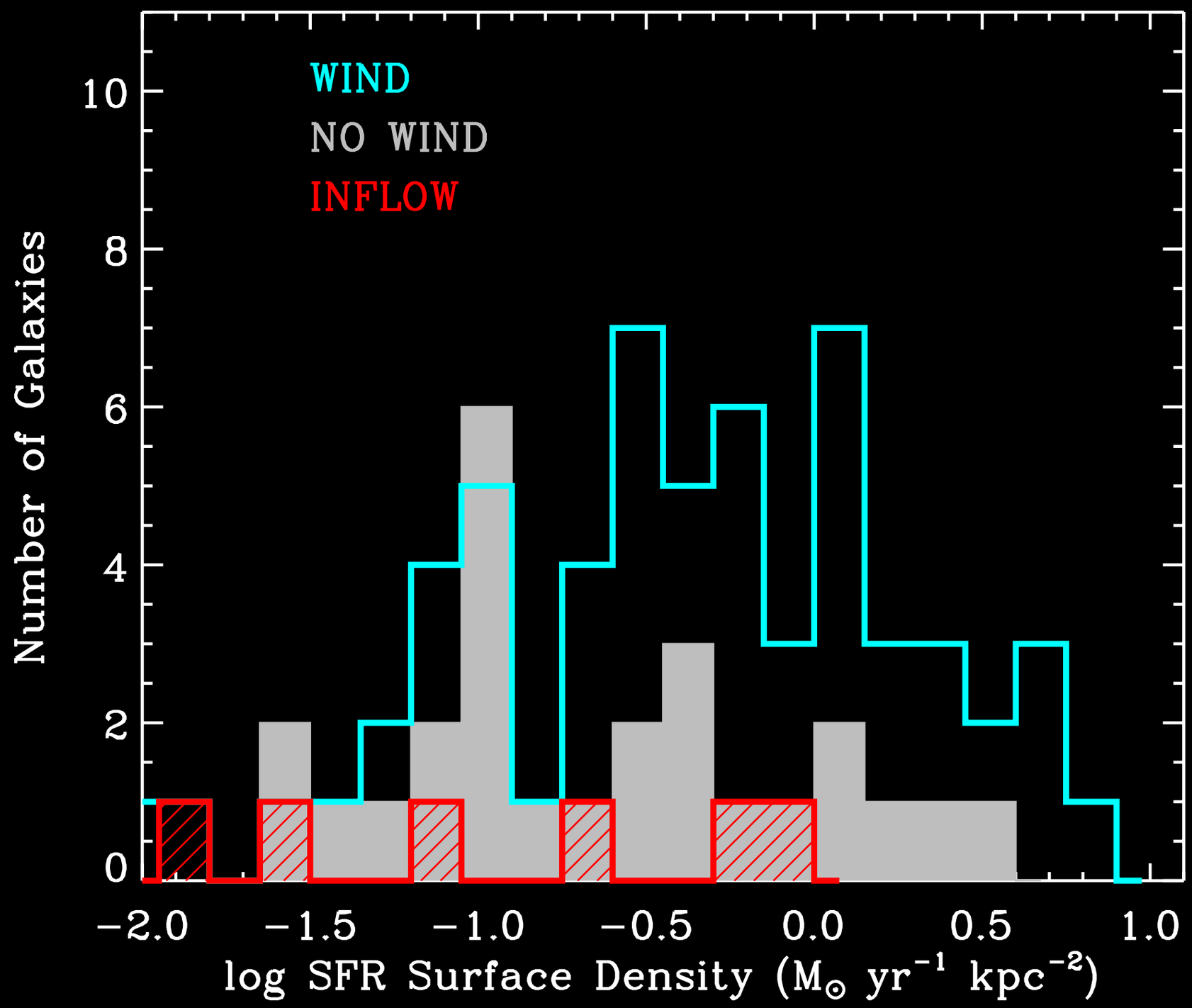


Wind EW:
0.5-1.5 Ang
1.5-2.5 Ang
2.5-3.5 Ang
> 3.5 Ang

● wind
◇ no wind

Winds and SFR Surface Density (Σ_{SFR})

$$\Sigma_{SFR} = SFR / \pi R^2$$



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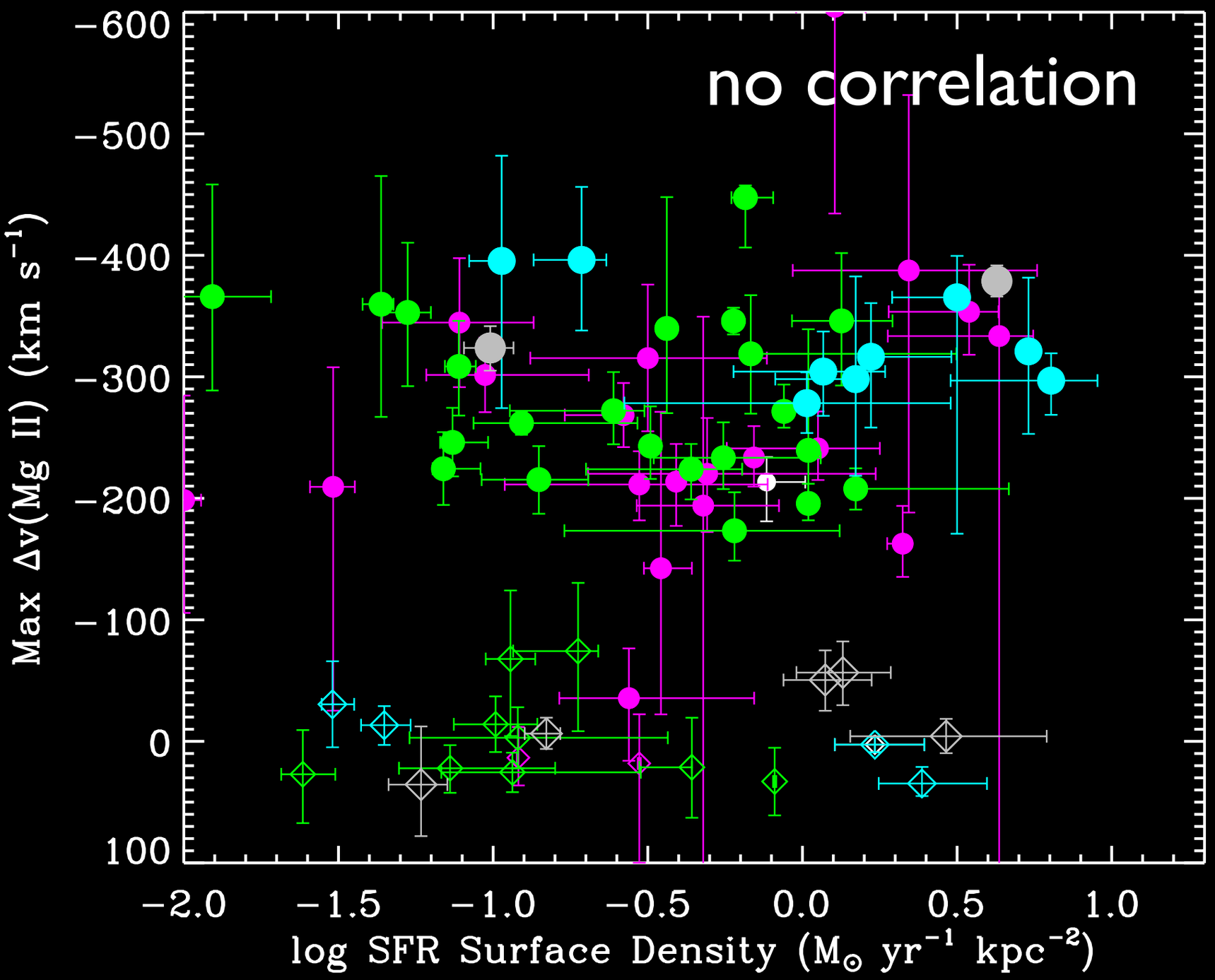

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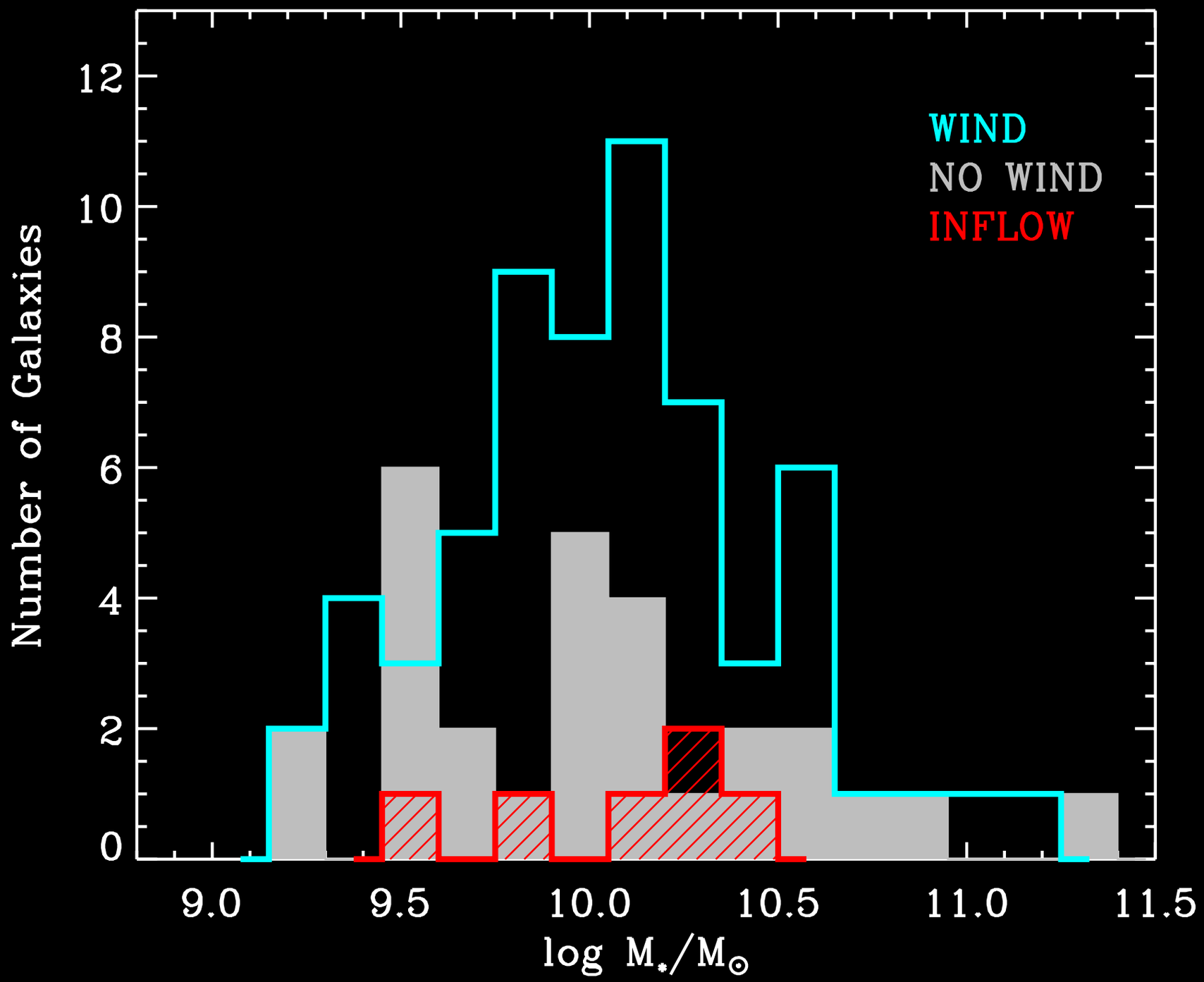
Winds and Stellar Mass



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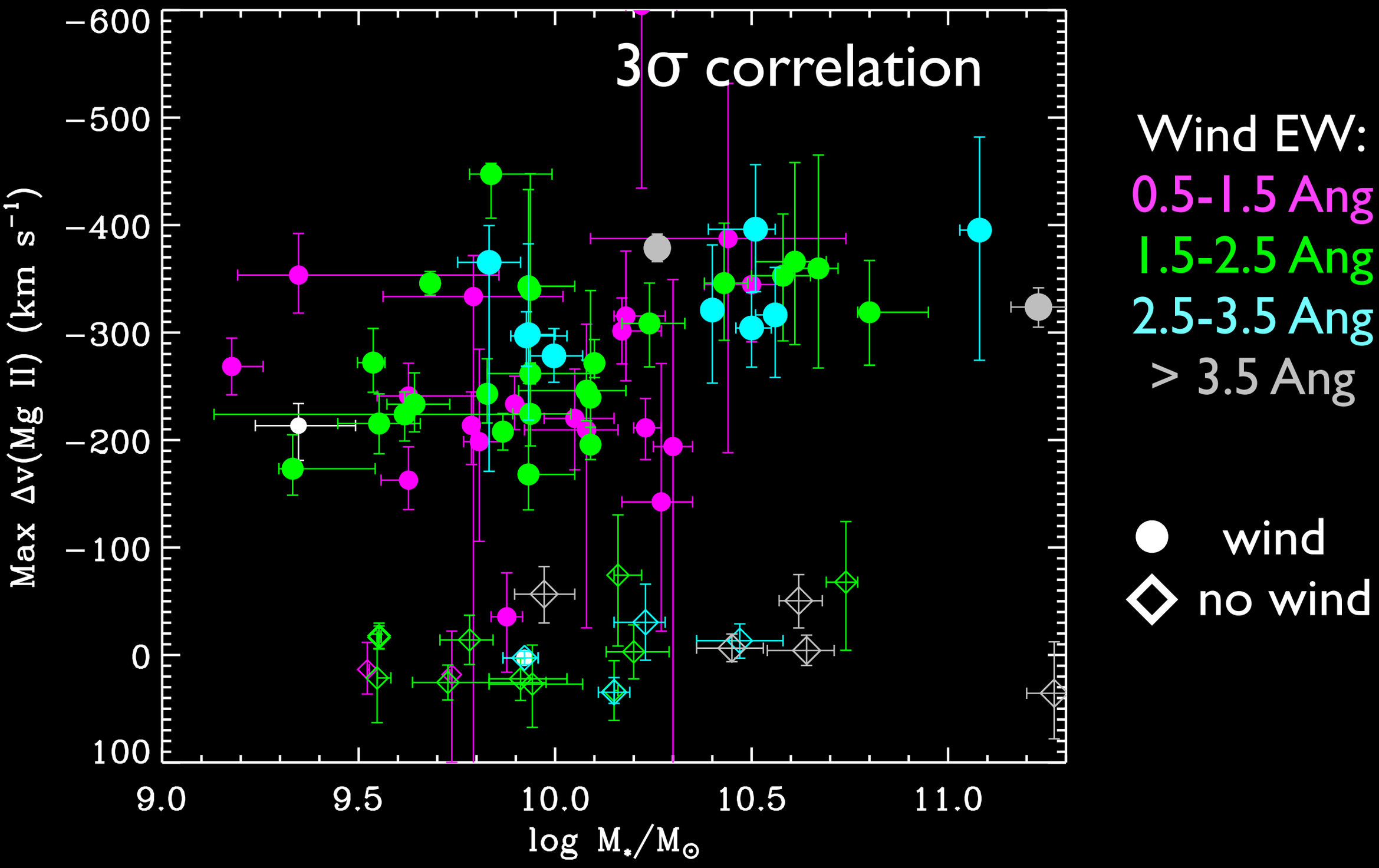

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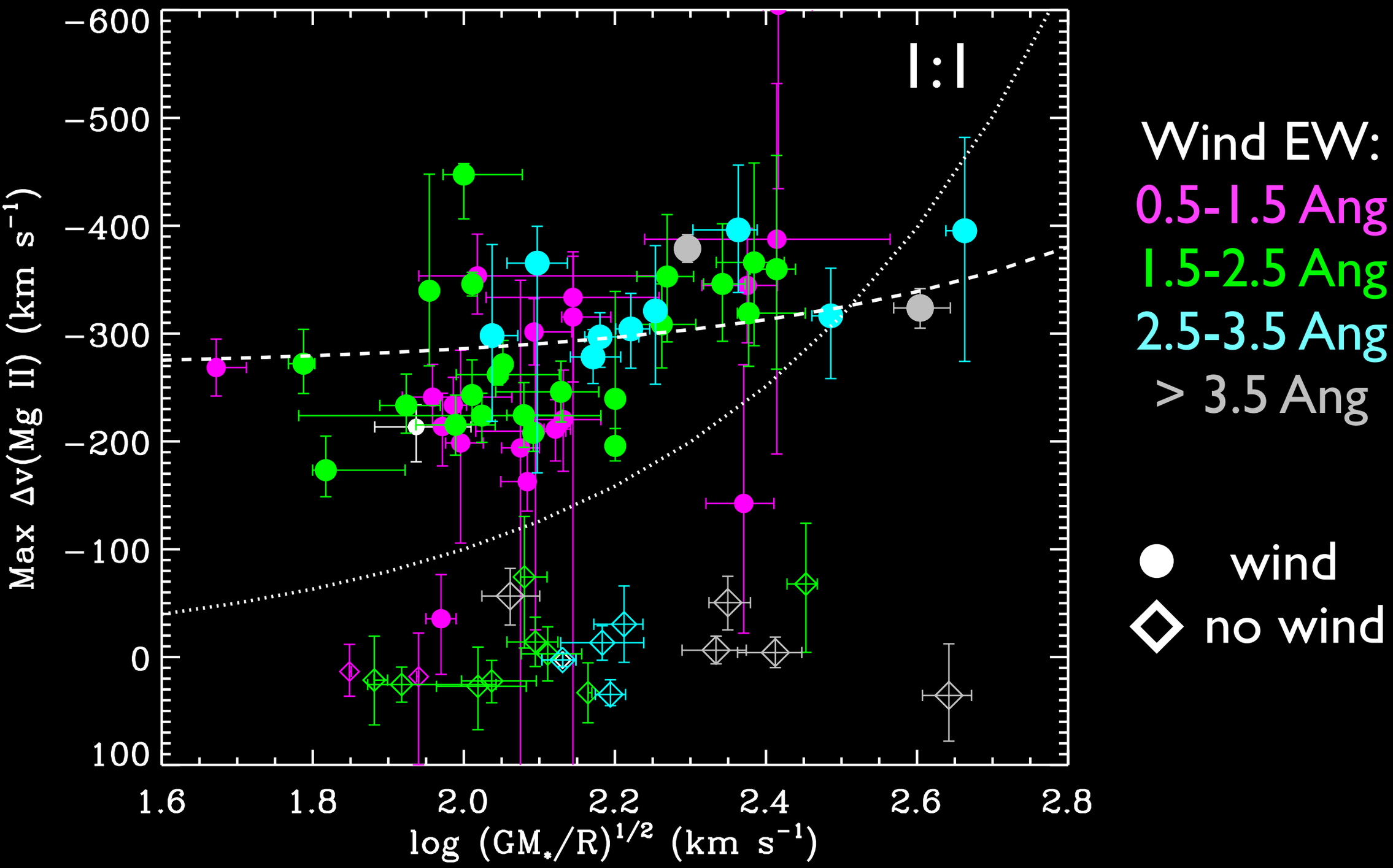

wind velocity ∝ 0.2 x "characteristic" velocity

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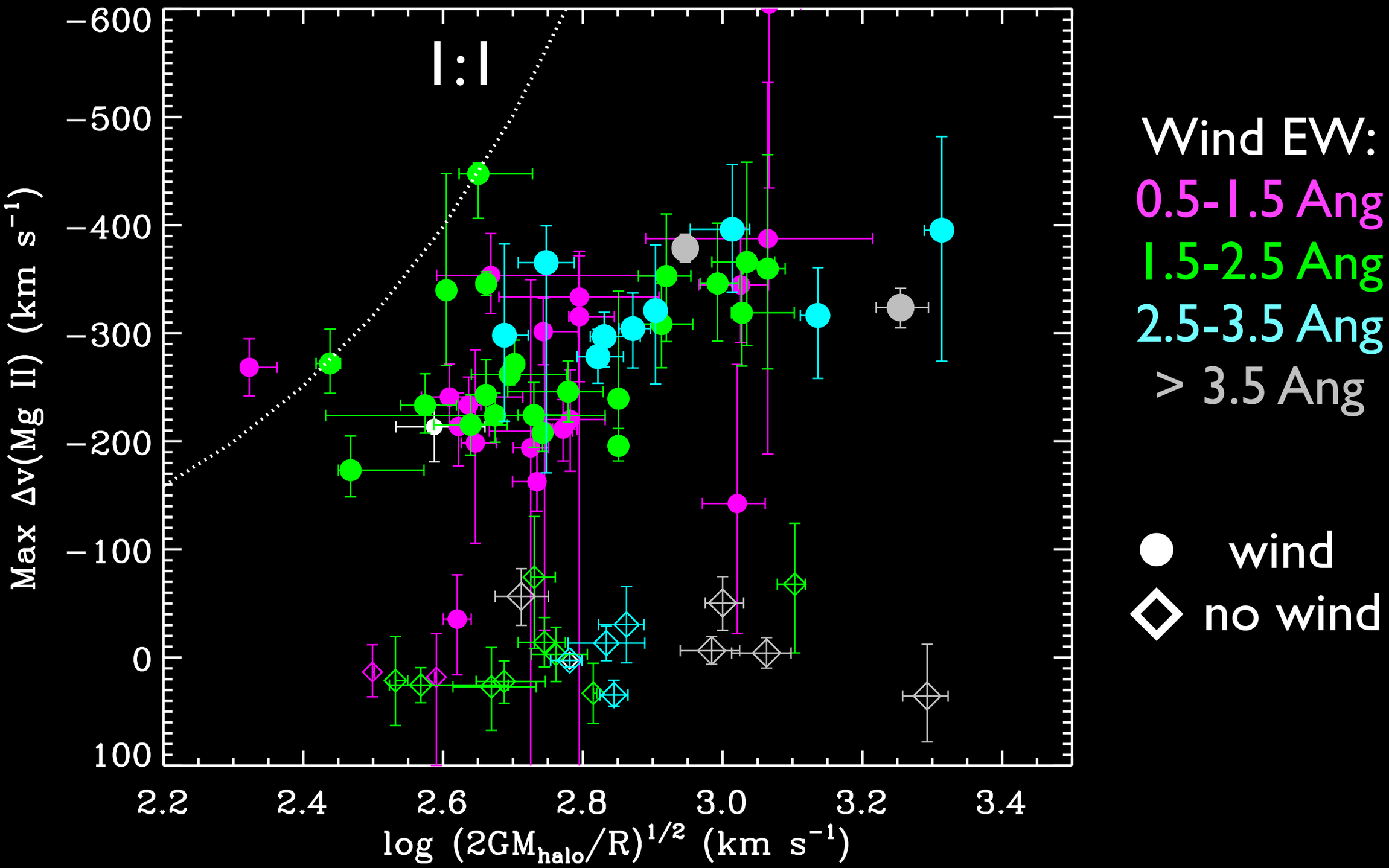

escape velocity (if $M_{halo} = 10M_*$)

Conclusions

Wind detection rate ~80% at
SFR > 10 M_{sun}/yr; just ~50% at lower SFR

Wind speed weakly correlated with stellar mass (3σ)

Wind will not likely be detected to > 400 km/s, no matter what the SFR or stellar mass!