What Drives LyC Escape: Supernovae or Radiation?

Escape of Lyman Radiation from Galactic Labyrinths
7-11 April 2025, Orthodox Academy of Crete, Kolymbari, Crete

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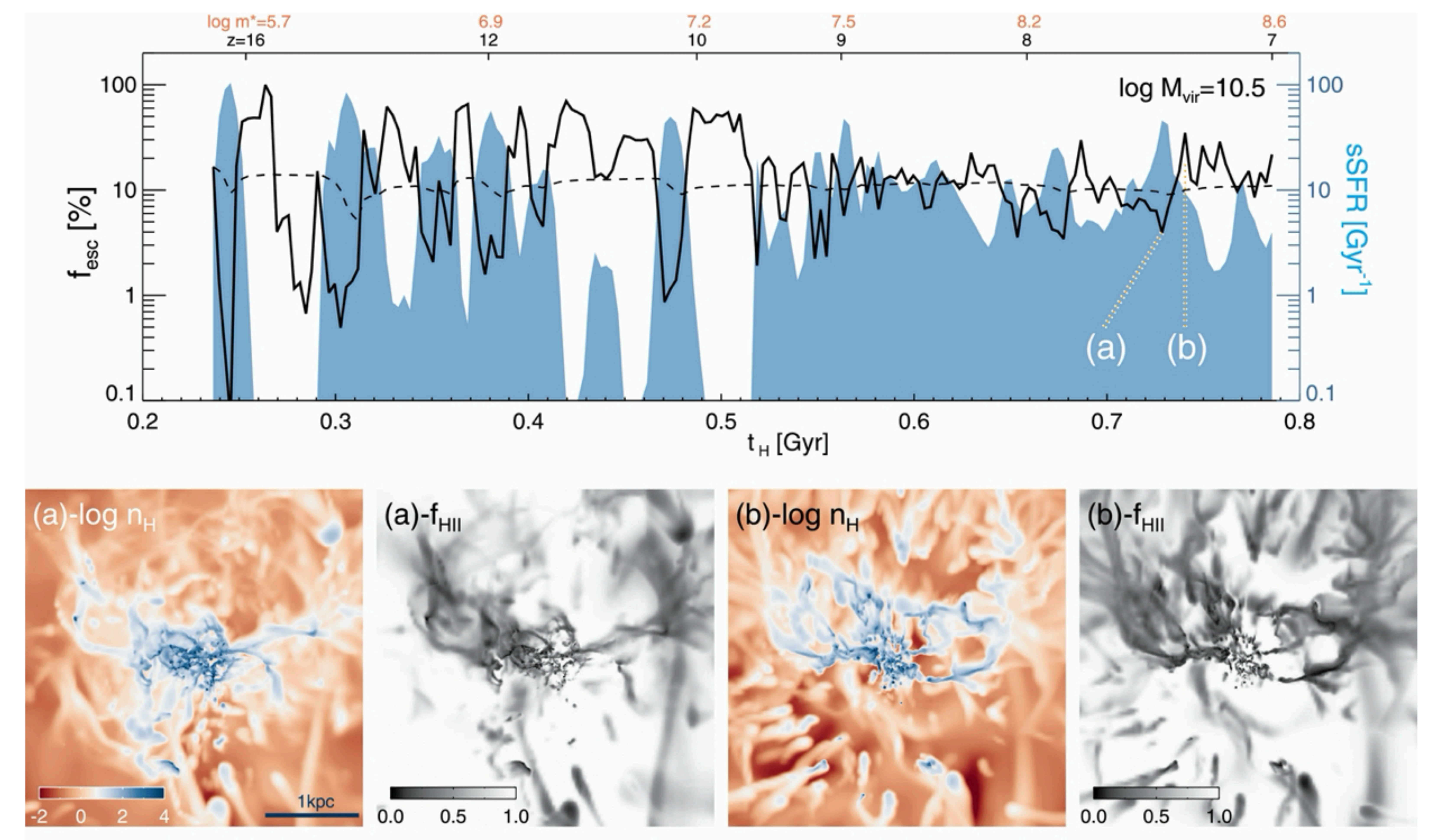
Mechanisms of Escape: SNe-Driven Winds

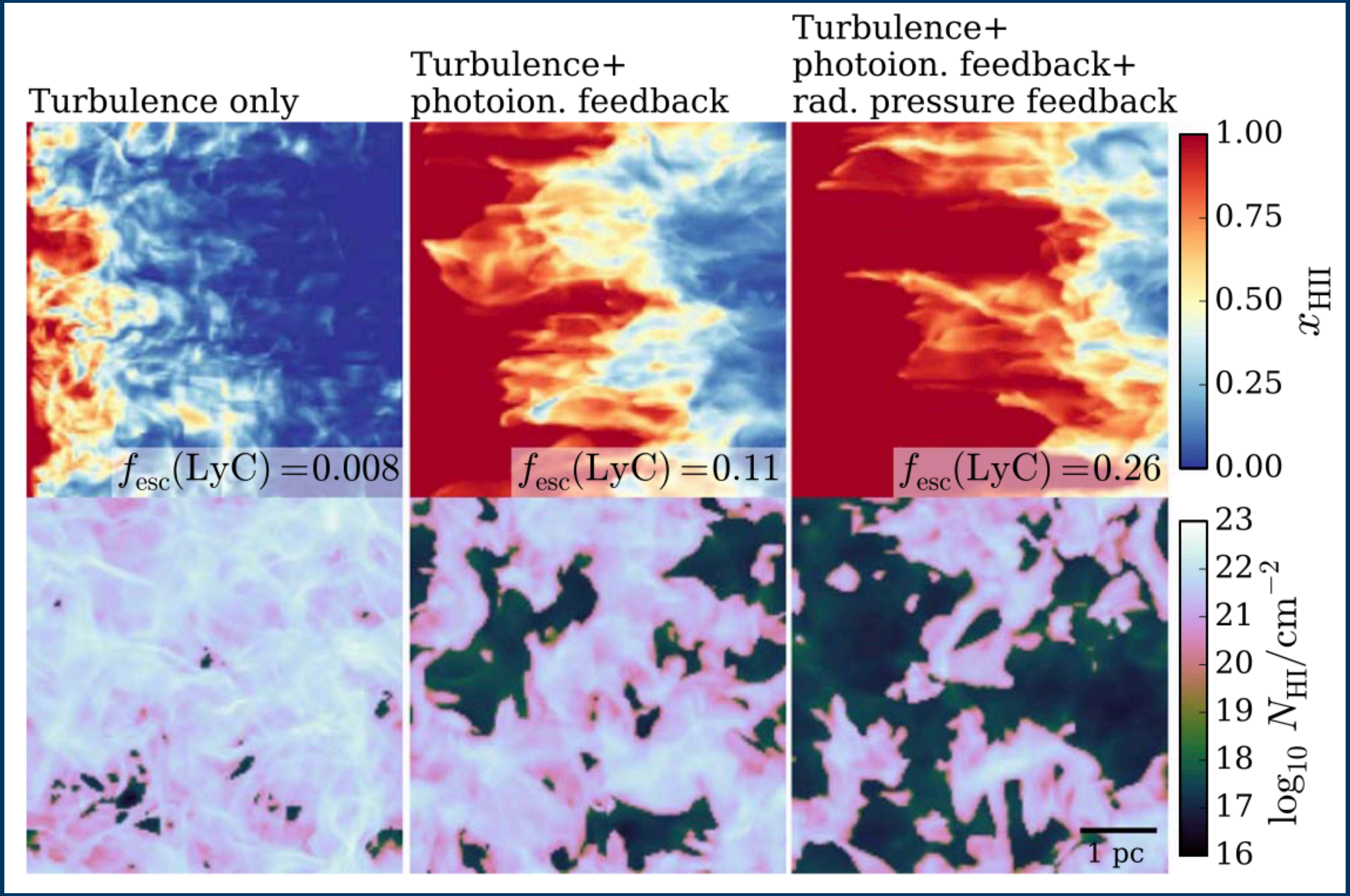
Theory



Kimm & Cen (2014)

Mechanisms of Escape: Radiation Evacuated Channels

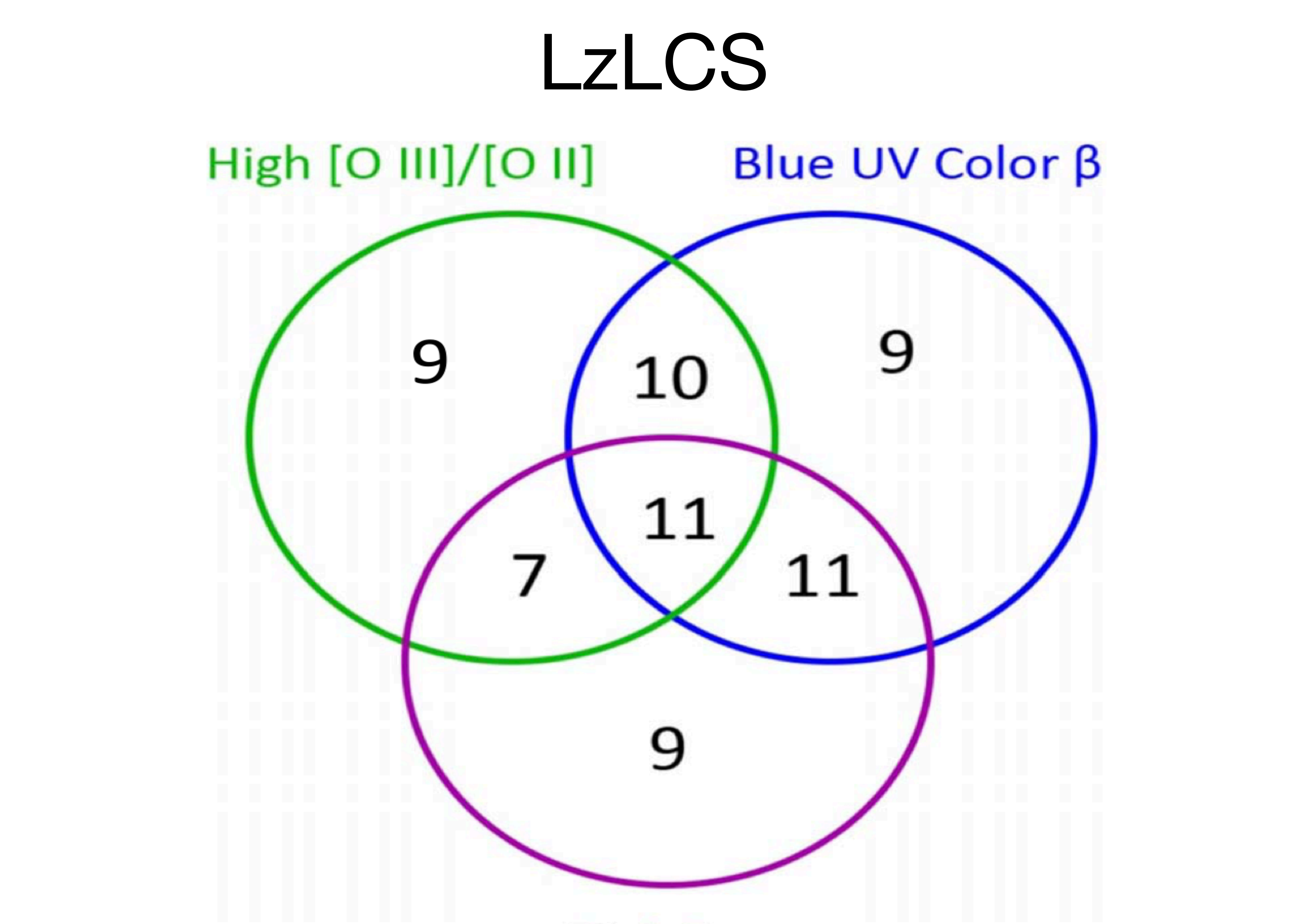
Theory



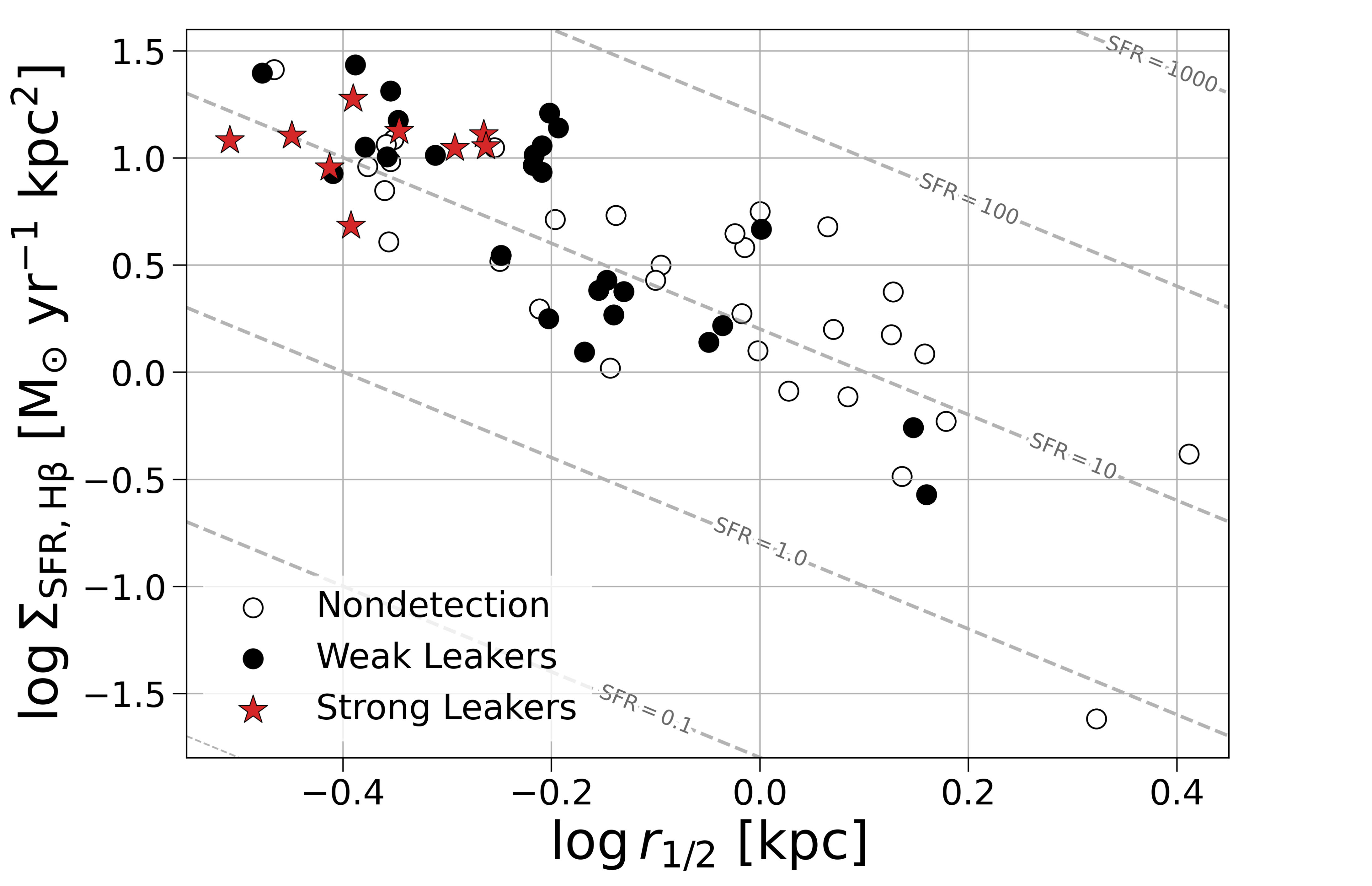
Kakiichi & Gronke (2021)

Goal: Map the Neutral Outflows in LzLCS

1) High res follow-up observations of 28 galaxies in LzLCS to study Mg II 2796 Å, 2803Å lines.
2) RT modeling of Mg II winds, $\mathrm{Mg}^{+} -> \mathrm{H}^{0}$ with Cloudy
3) Determine stellar ages (SNe vs. radiation feedback) with SED fitting

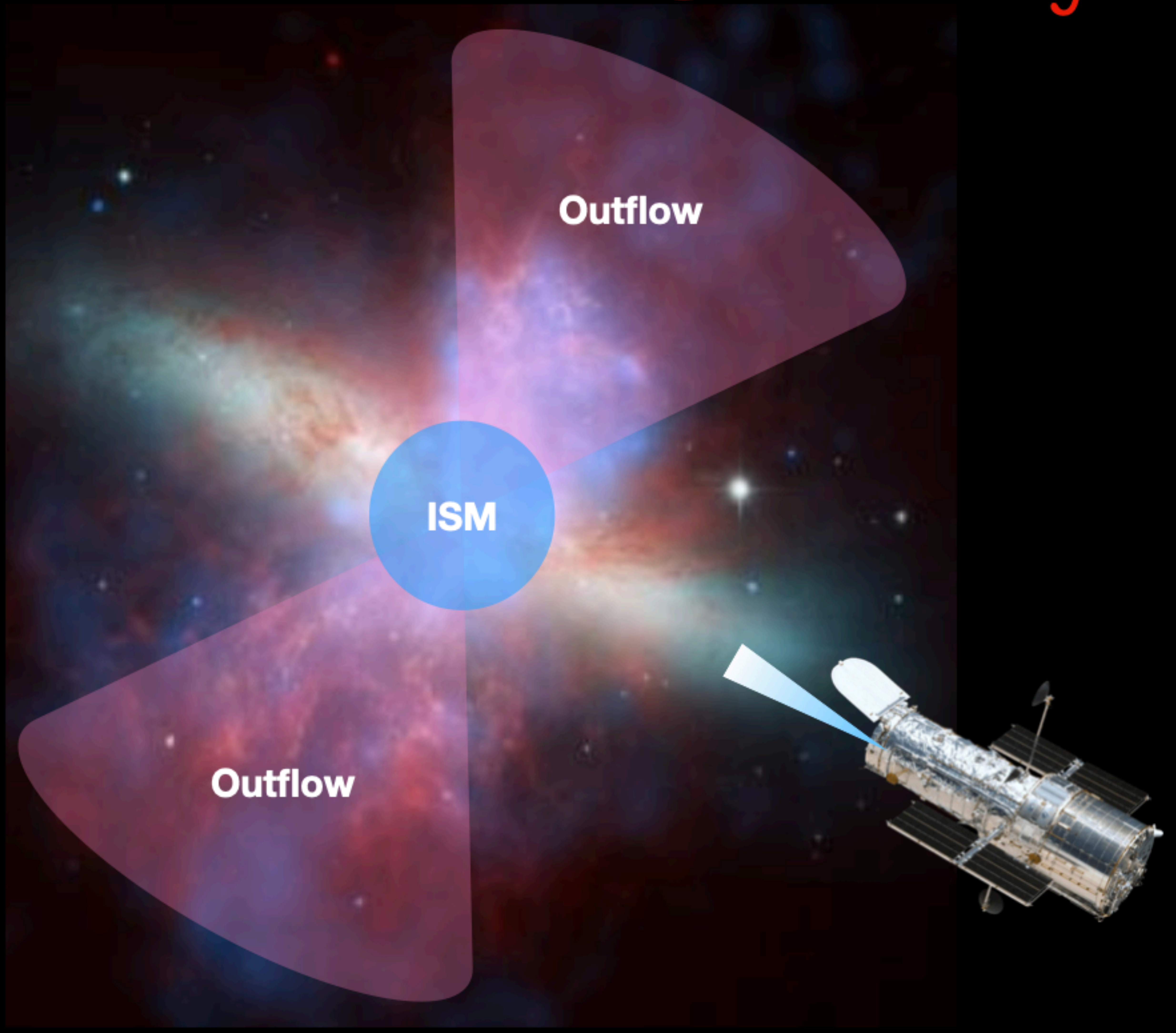


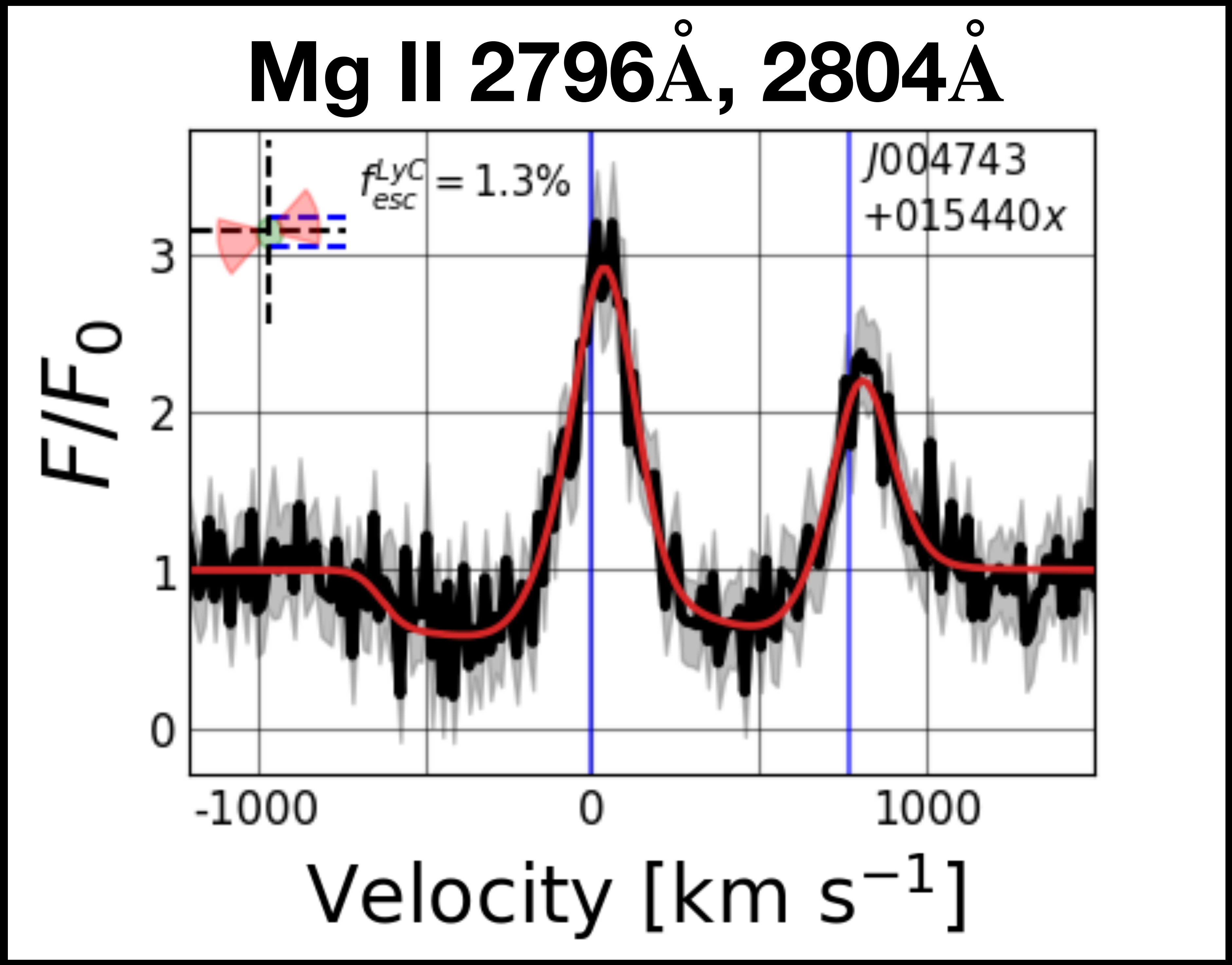
Flury et al. (2022)



Carr + Cen et al. (2025); see also Cen (2020)

Semi-Analytical Line Transfer





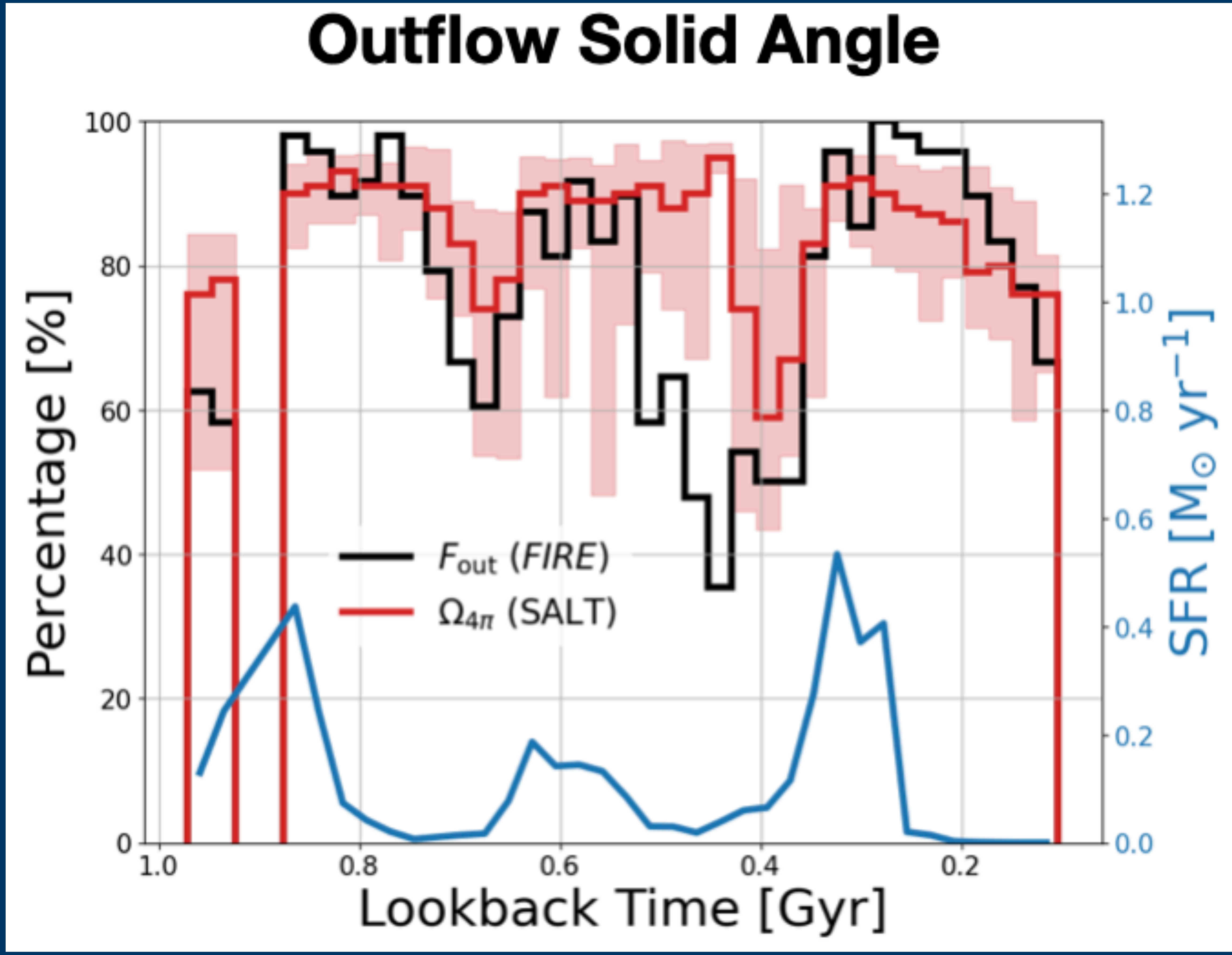
https://semi-analytic-line-transfer-salt.readthedocs.io

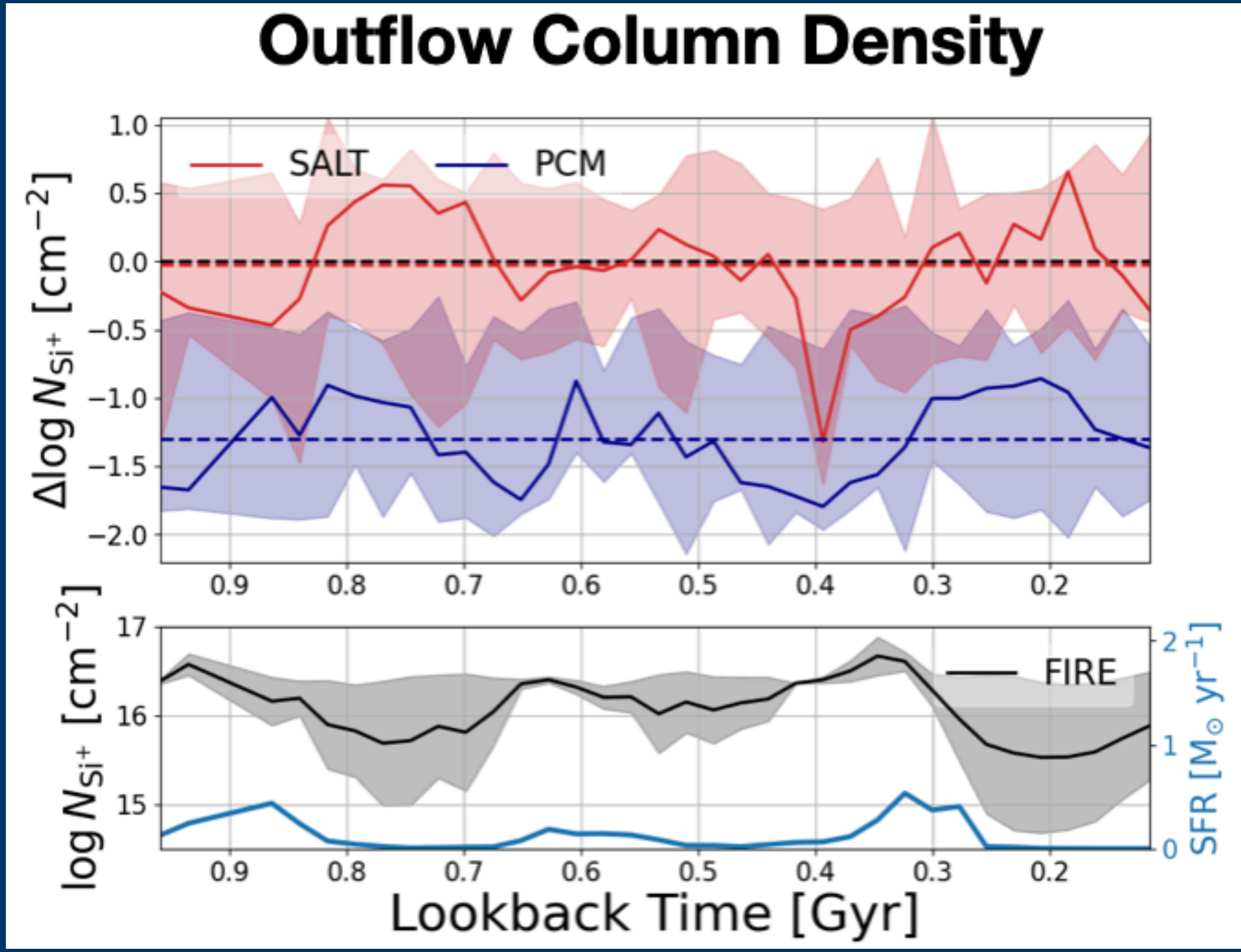
Carr + Cen et al. (2025)

See also Carr et al. (2023)

Tests against Simulations

Recovery of Outflow Geometry from FIRE-2 Simulations with SALT (Carr + Smith et al. 2025)



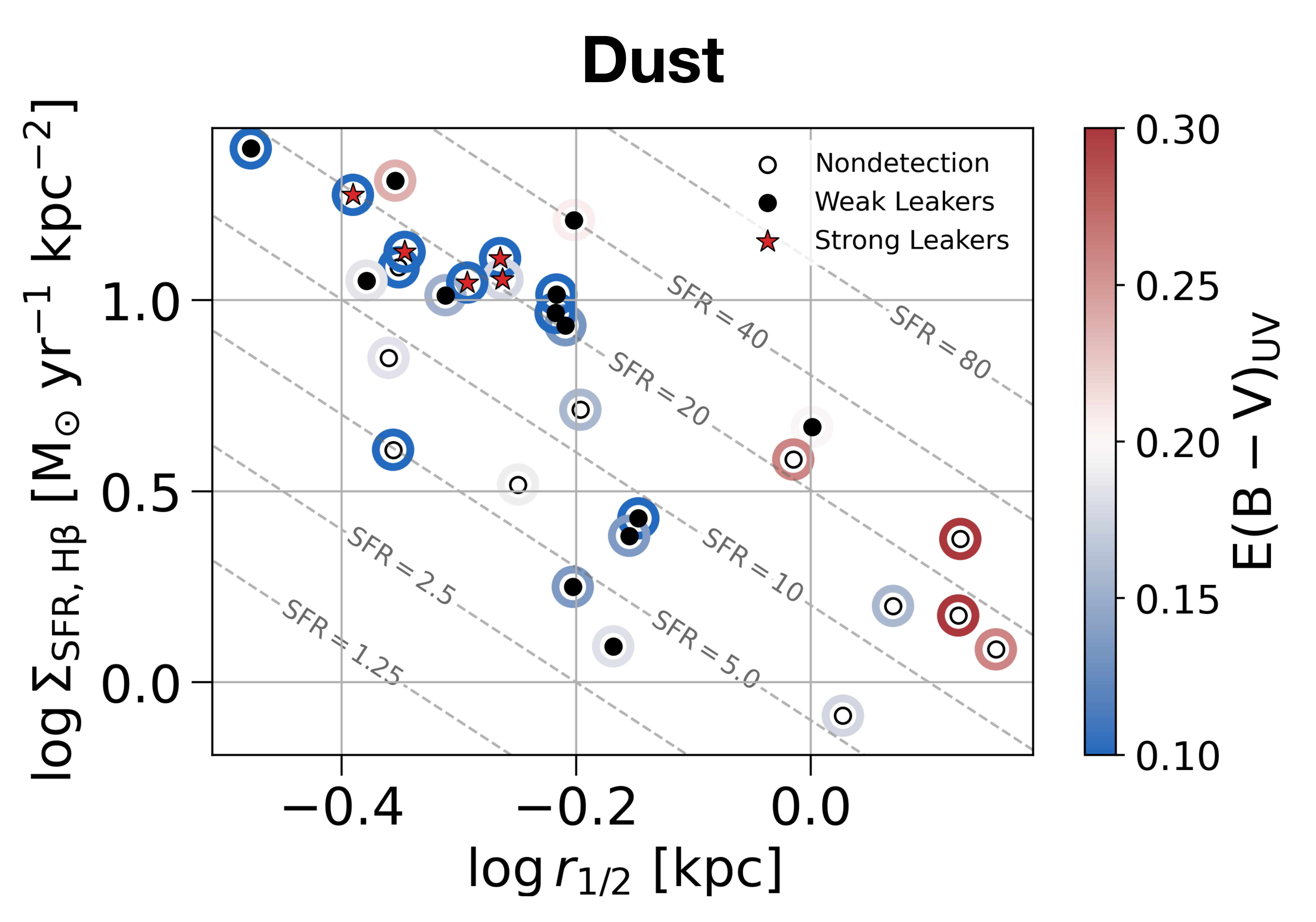


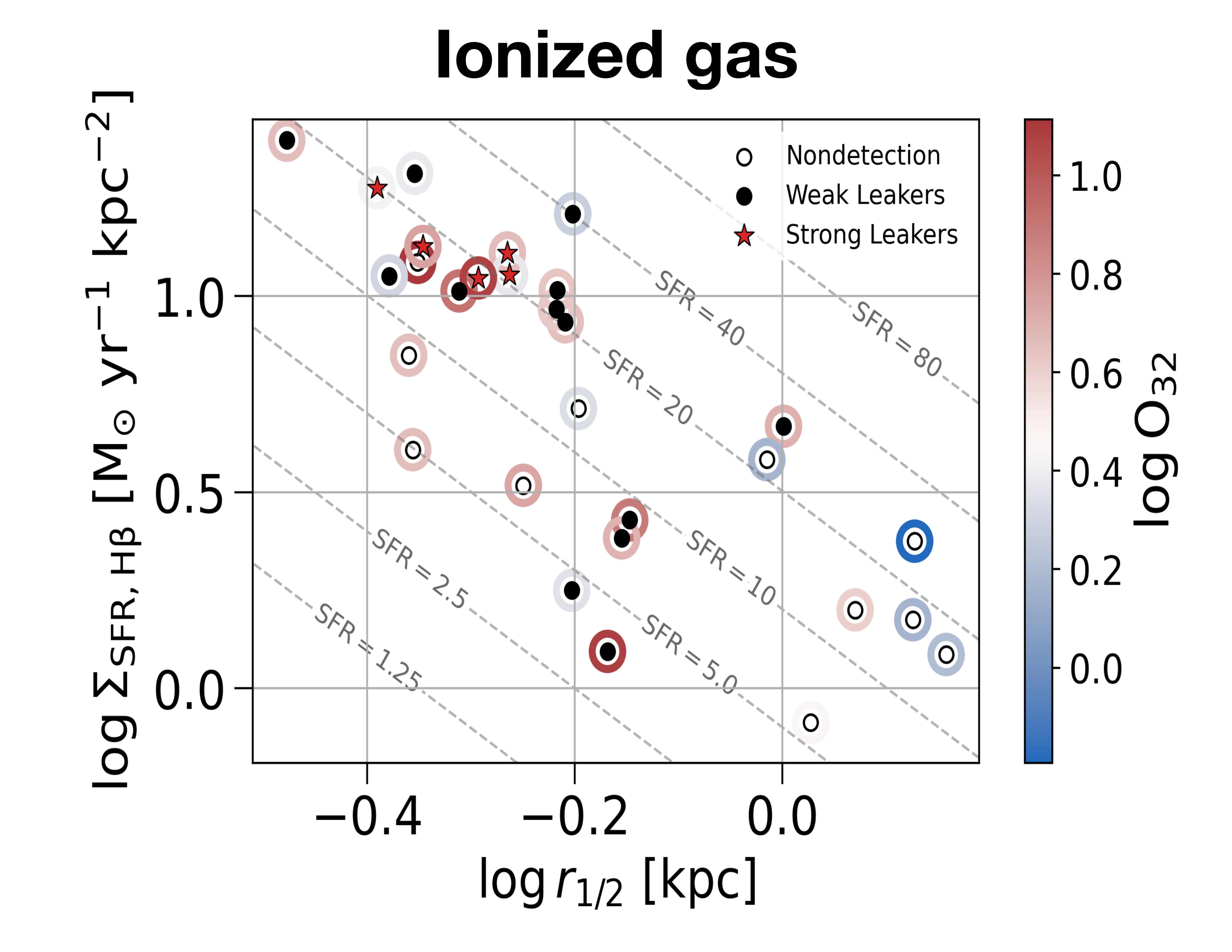
Carr + Smith et al. (2025)

Carr + Cen et al. (2025)
See also Flury et al. (2022)

Galaxy Properties

Strong LyC leakers show lower dust extinction and higher O_{32} = [O III] 5007Å / [O II] 3737,9Å ratios



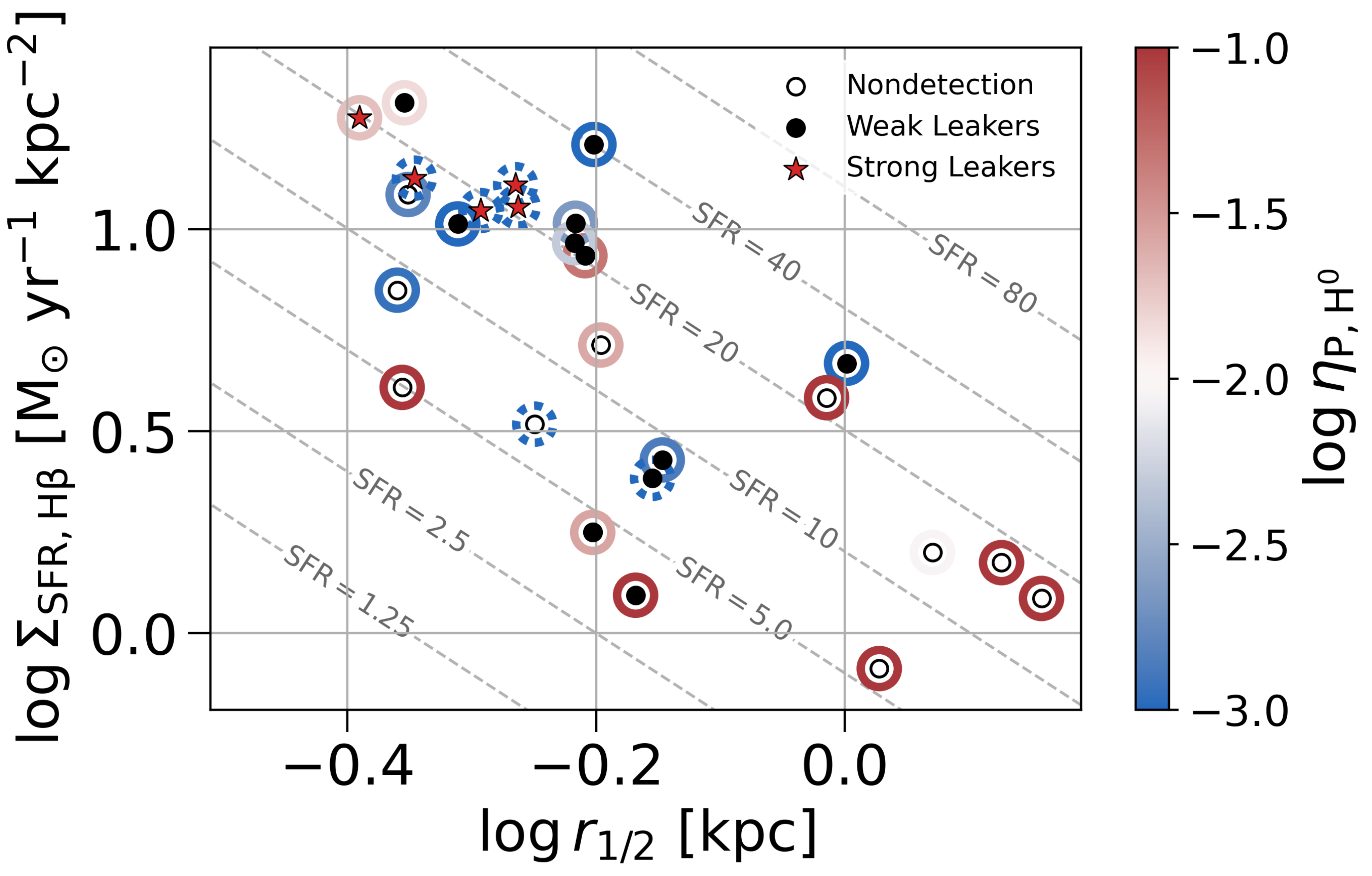


Carr + Cen et al. (2025)

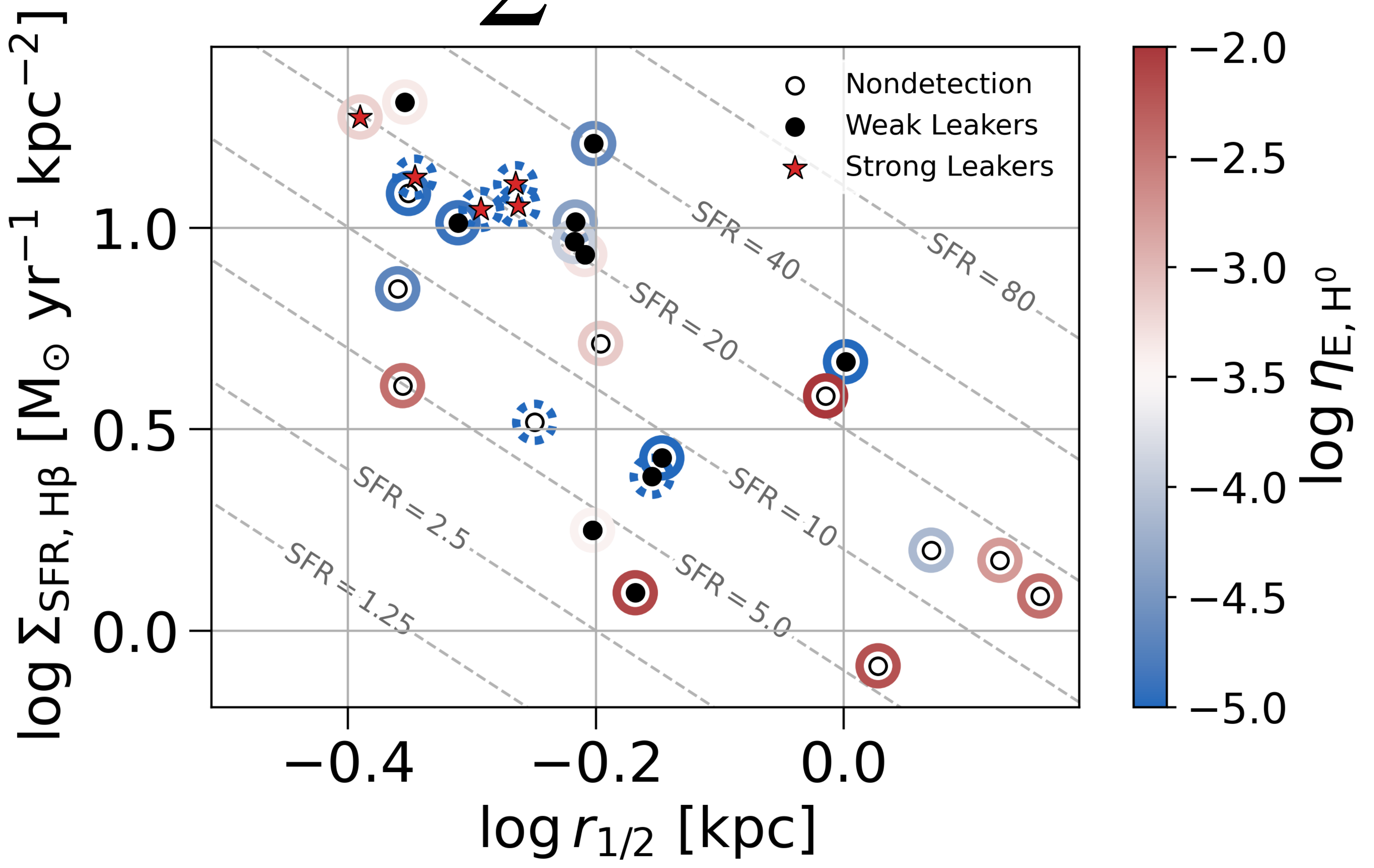
Momentum and Energy Loading

Strong leakers have lower momentum and energy outflow loading in neutral winds

$$\eta_P = \dot{M}v \;/\; SFR$$



$$\eta_E = \frac{1}{2}\dot{M}v^2 \;/\; SFR$$



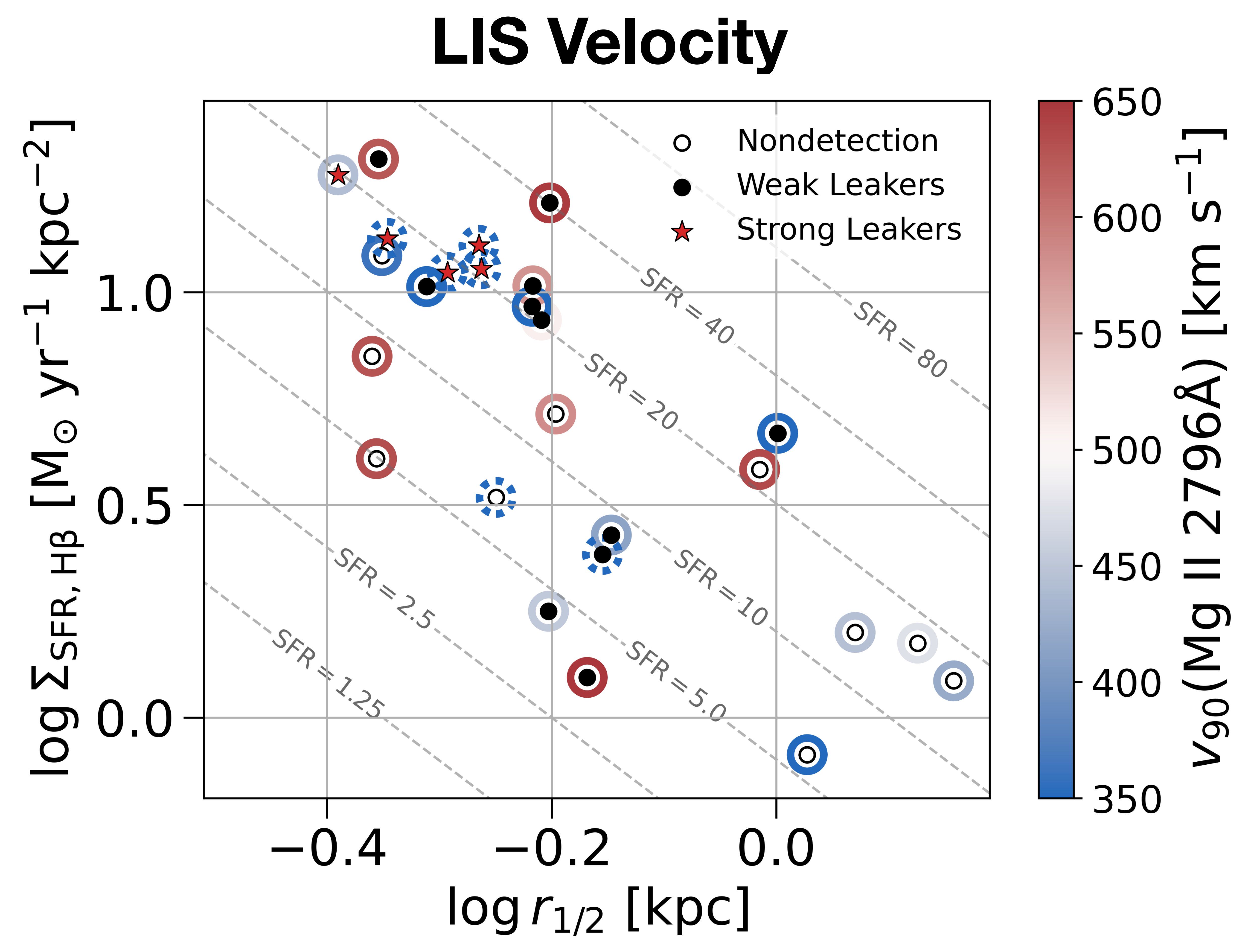
Carr + Cen et al. (2025)

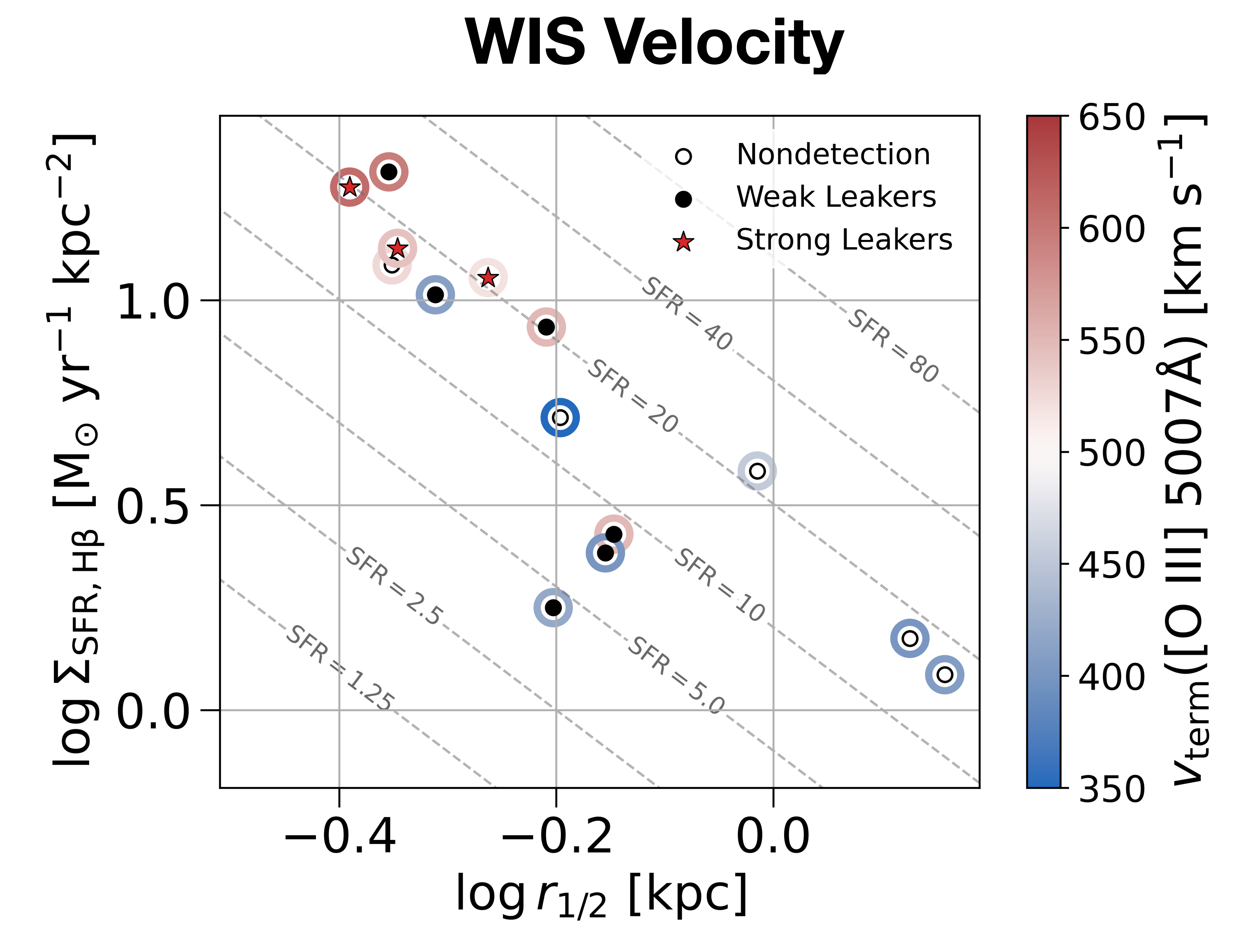
See also Amorín et al. (2024) and Komarova et al. in prep

Outflow Kinematics

Low-ionization state (LIS) gas is kinematically decoupled from the warm-ionization state (WIS) gas in strong leakers?

Color bars are on the same scale!





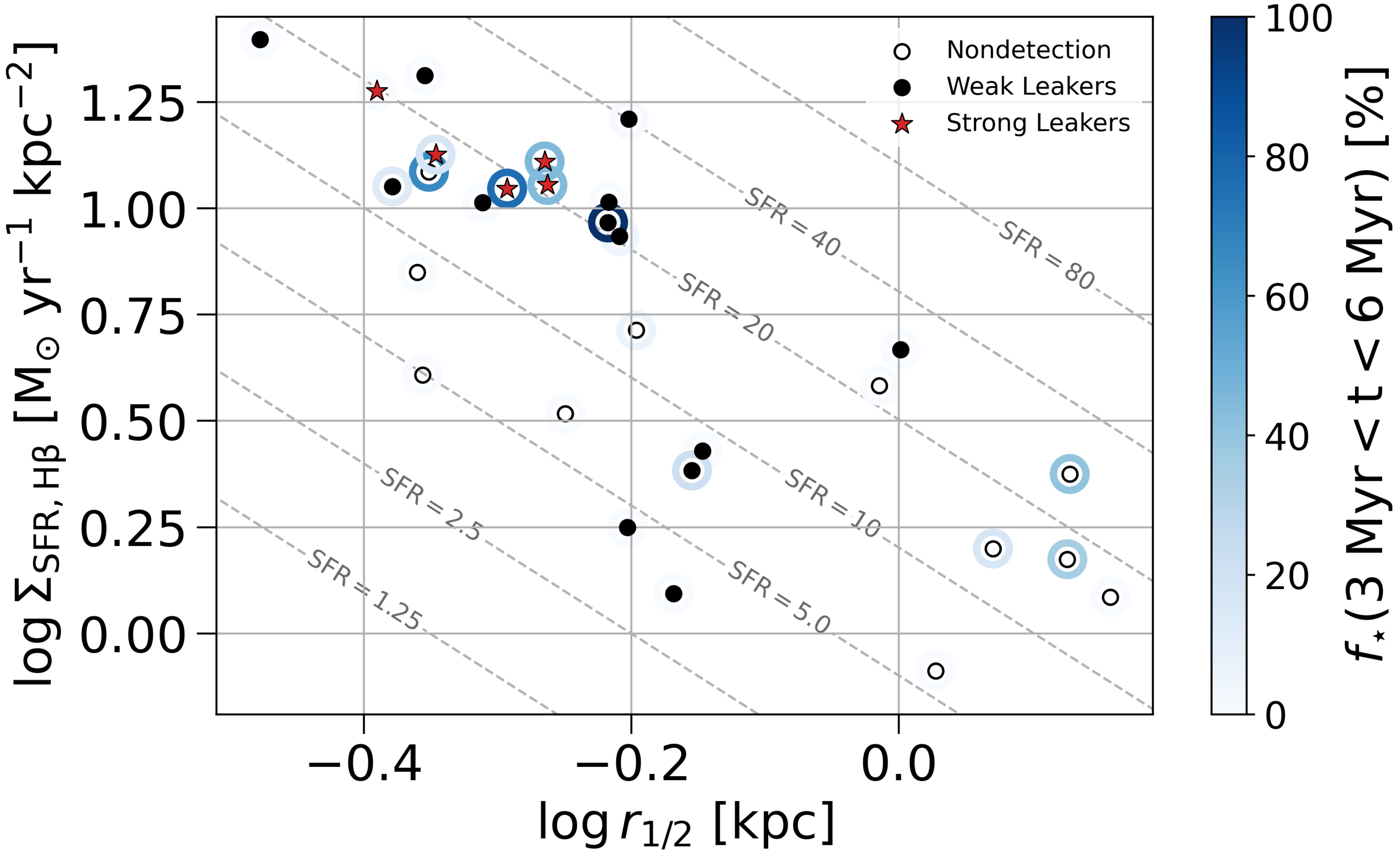
Carr + Cen et al. (2025)

See also Flury et al. (2025)

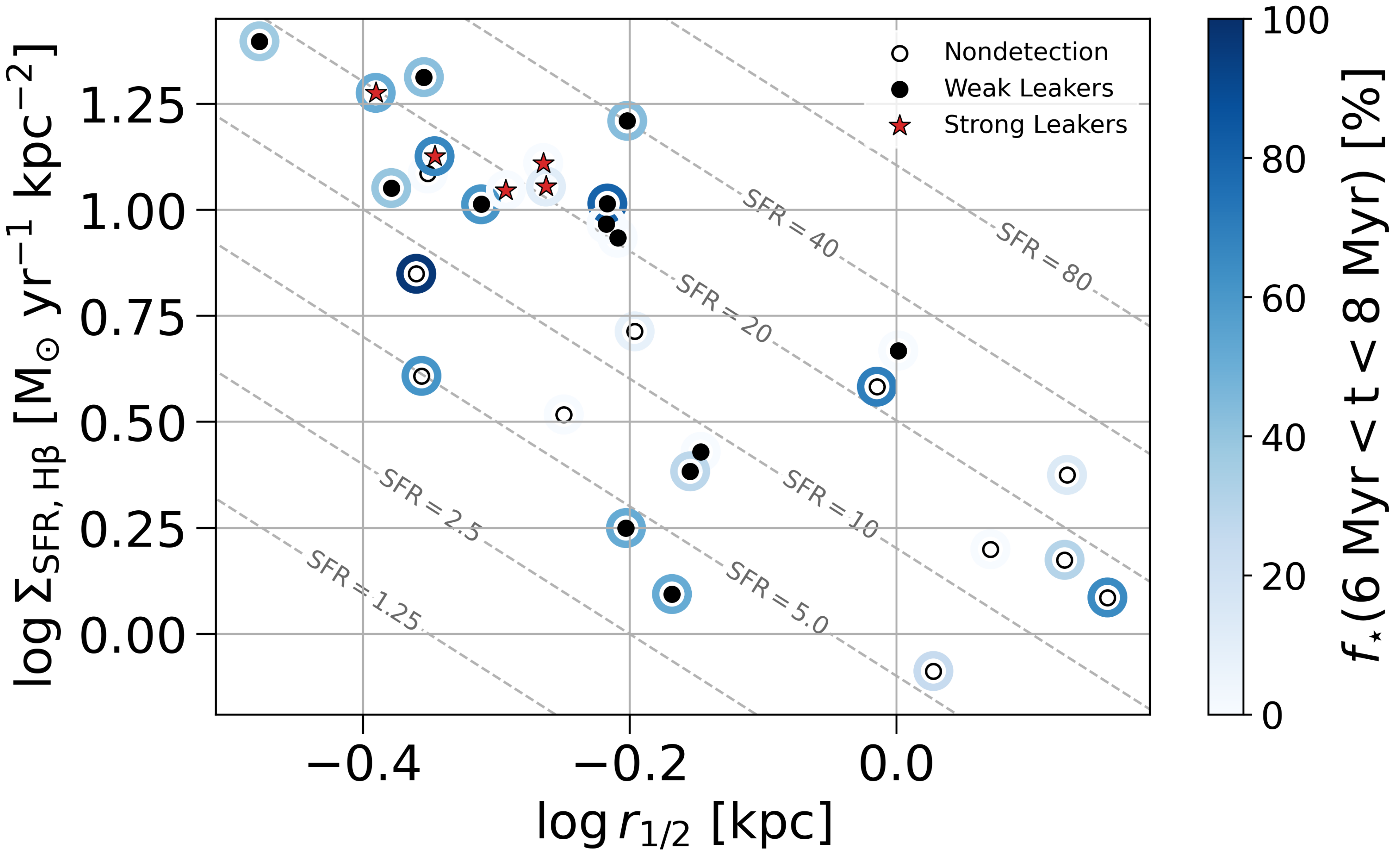
Stellar Populations

The strongest LyC leakers have younger stellar populations while the weak leakers have older stellar populations

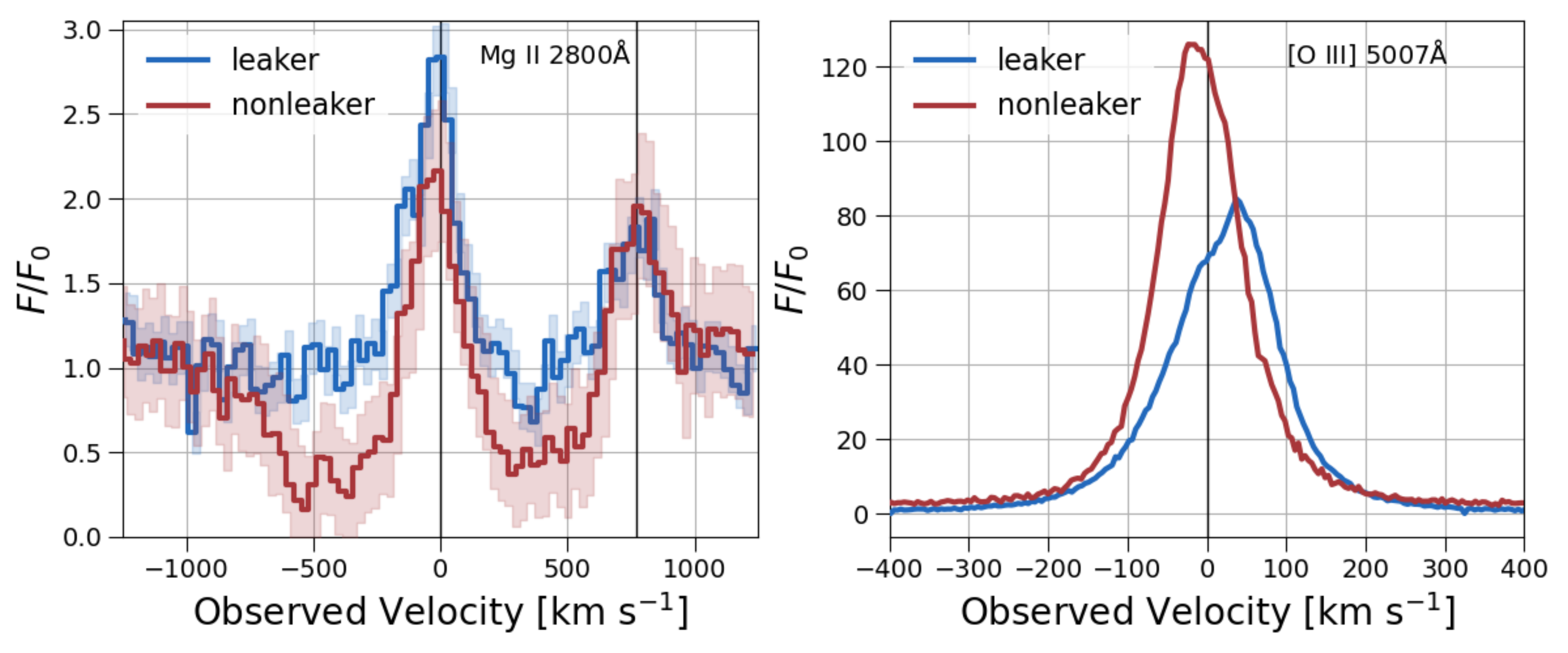
Younger Stars (Radiation Feedback)



Older Stars (Supernovae Feedback)



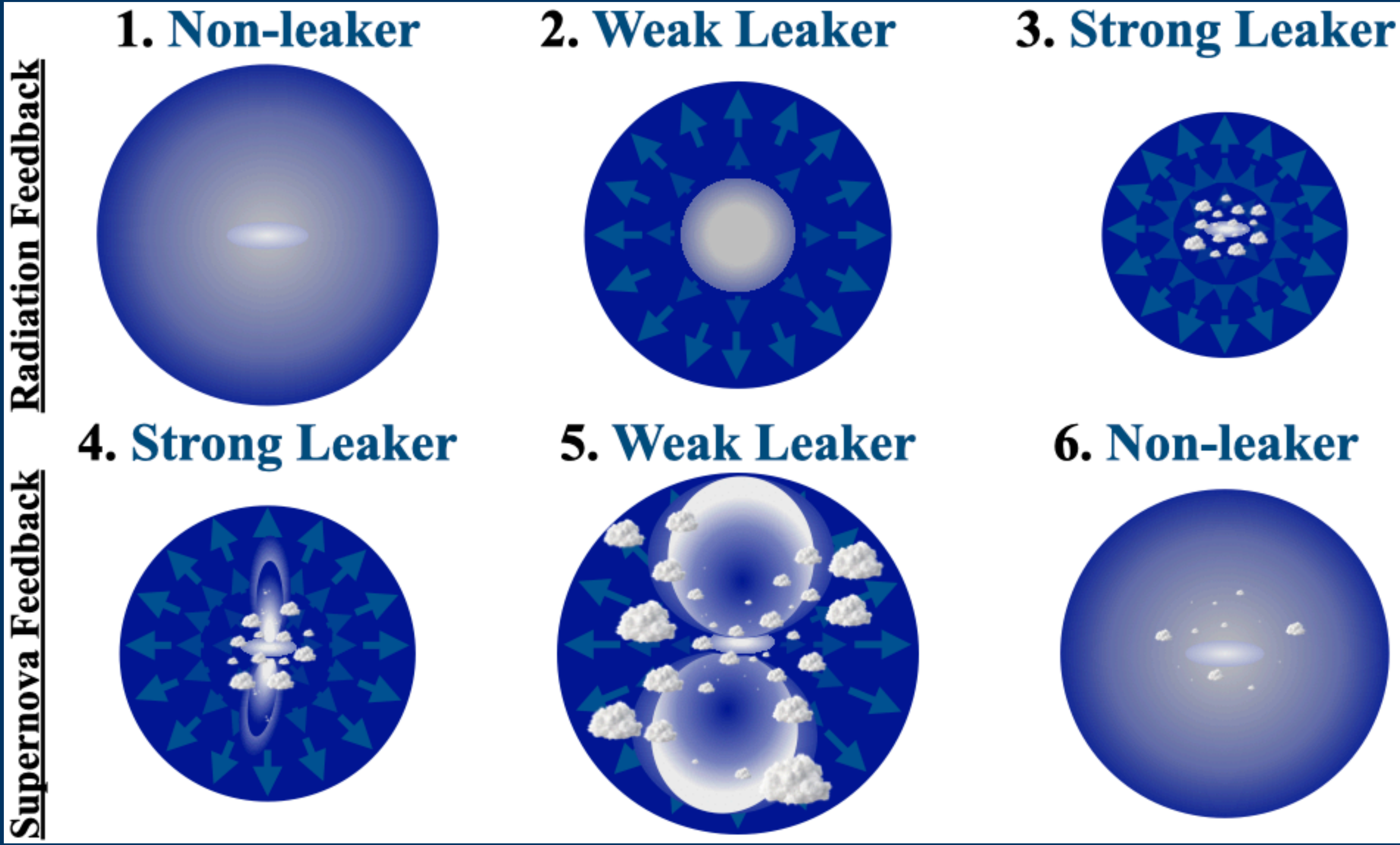
Supernovae vs. Radiation Feedback



Carr + Cen et al. (2025)

Conclusion

See also Hayes et al. (2023), Bait et al. (2024), Flury et al. (2022,25), Komarova et al. In prep.



HST-GO-17433: High Resolution Follow-up

COS G130M follow up observations of the Lyman Series

Near Future

Spectral imaging (IFU, MOS) with future instruments such as the Extremely Large Telescopes (ELTs) and the Habitable Worlds Observatory (HWO) will resolve feedback on the scale of super star clusters (1-100 pcs)

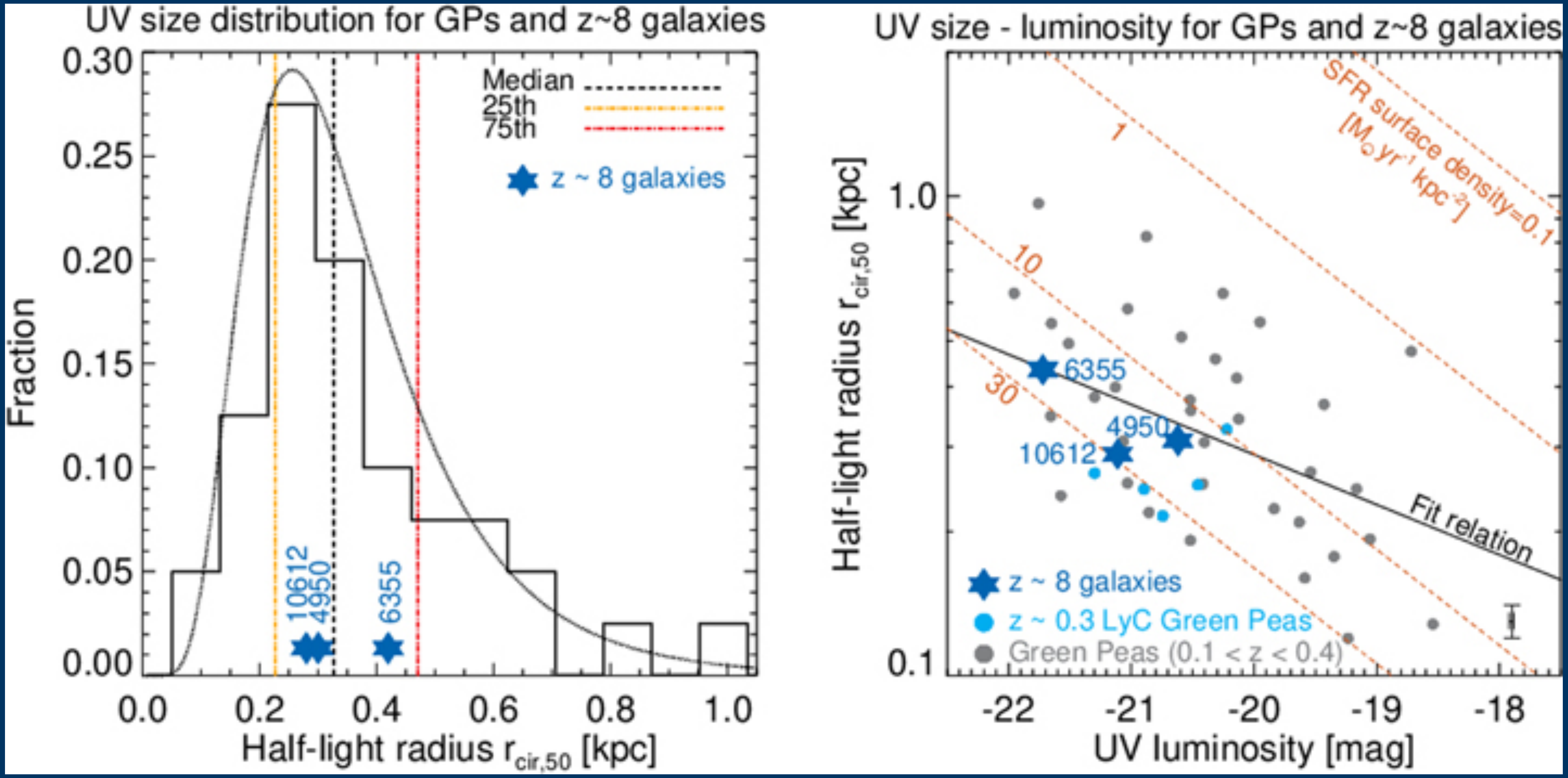
Komarova et al. (2024)
Östlin et al. (2015)

Summary

1) Strongest leakers in LzLCS are radiaiton feedback dominant, lack deep Mg II absorption features, but have extended broad components in [O III] emission (Amorín et al. 2024)
2) Galaxies experiencing supernovae feedback exhibit lower escape fractions, and show outflows in absorption in both Mg II and [0 III]
3) We propose a sequence for LyC escape in compact, intensely star-forming galaxies, where fesc is initially high during phases of radiation dominant feedback, potentially boosted by rapid cooling and cloud fragmentation in the ISM. As the starburst evolves and supernovae begin to dominate, fesc declines, likely due to the lifting of neutral gas and the death of the most massive stars that produce ionizing photons.

Which LyC Escape Pathway Dominates at High Redshifts

Do Green Peas exist at high-z?



How Do Galaxies Clear Pathways Through the ISM/CGM?

1) **Full Ionization of Clouds:** There is sufficient LyC radiation to completely ionize the clouds, resulting in a fully density bounded ISM/CGM.
2) **Suppression of Cloud Formation:** Strong ionization fronts, shearing, and sufficiently long cooling times prevent clouds from forming in otherwise highly ionized winds, facilitating LyC escape.
3) **Cloud Fragmentation + Turbulence:** In the absence of strong mechanical feedback, clouds are subject to dynamical and gravitational instabilities that cause clumping. This in turn creates a "picket fence" geometry conducive to LyC escape (Jaskot et al. 2017,19, Kakiichi & Gronke 2021, Menon et al. 2024).
4) **Ram Pressure Acceleration:** Outflows exert enough ram pressure on clouds to accelerate them to distances where they can no longer hinder LyC escape (Heckman et al. 2011,14, Cen 2020).