The Impact of Massive Outflows on Lyman Continuum Escape from Local Starbursts

Cosmic Dawn at High Latitudes Conference
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Overview

1)SALT Model

2)Data and Model Fitting

   i. MMT + X-Shooter

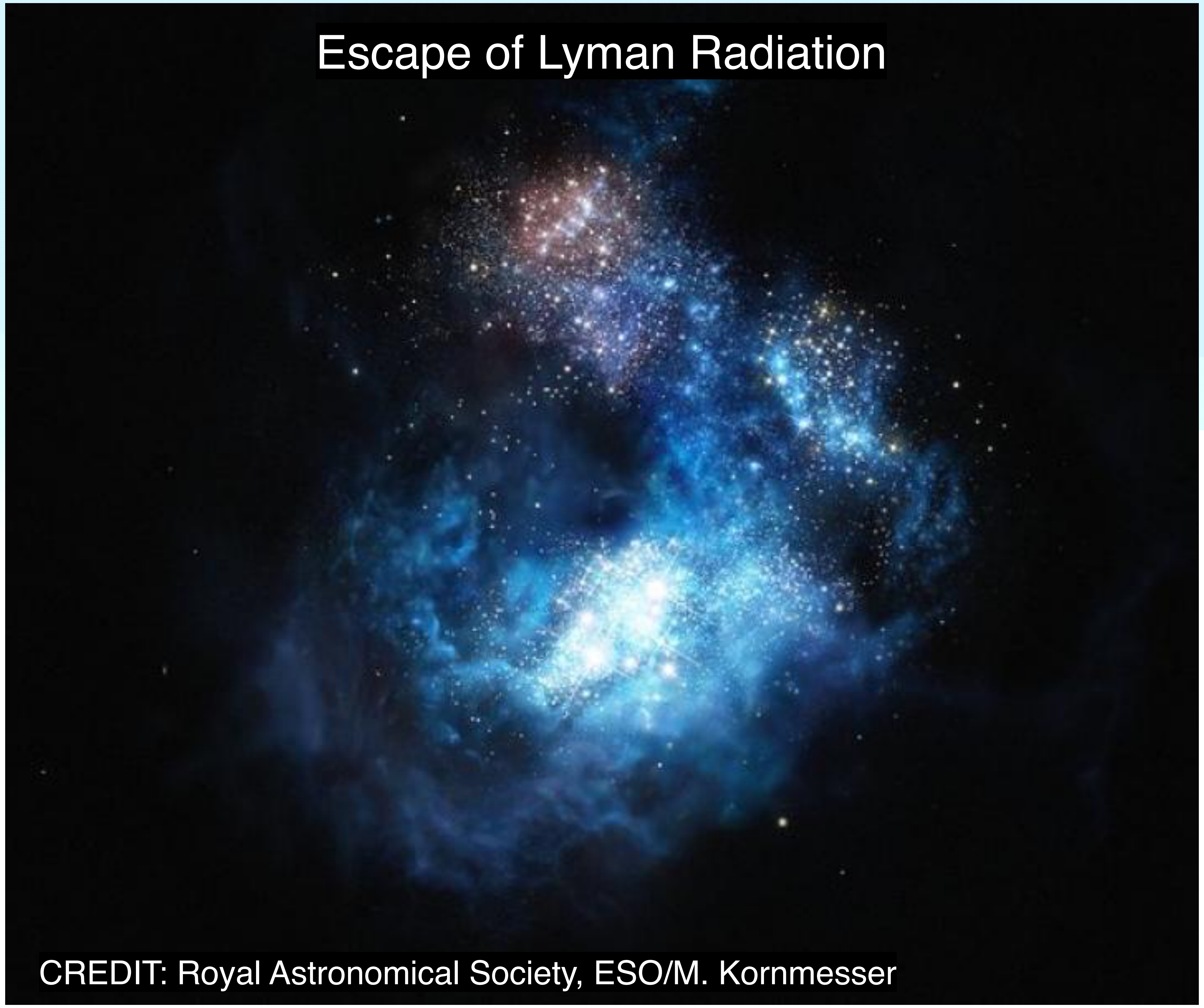
3)Predicting LyC Escape

4)The Massive Outflows of LzLCS

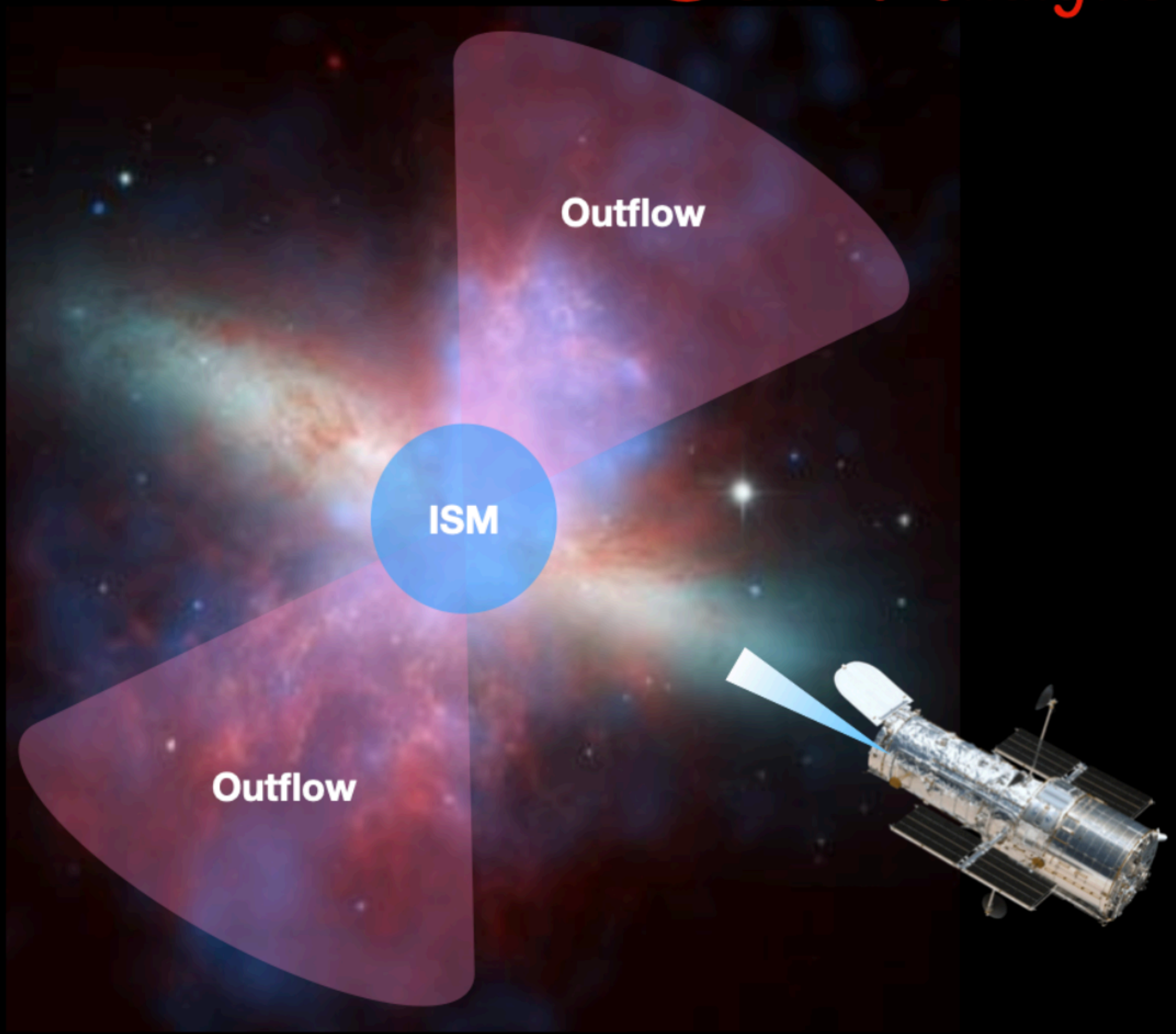
5)The Impact of Outflows on LyC Escape

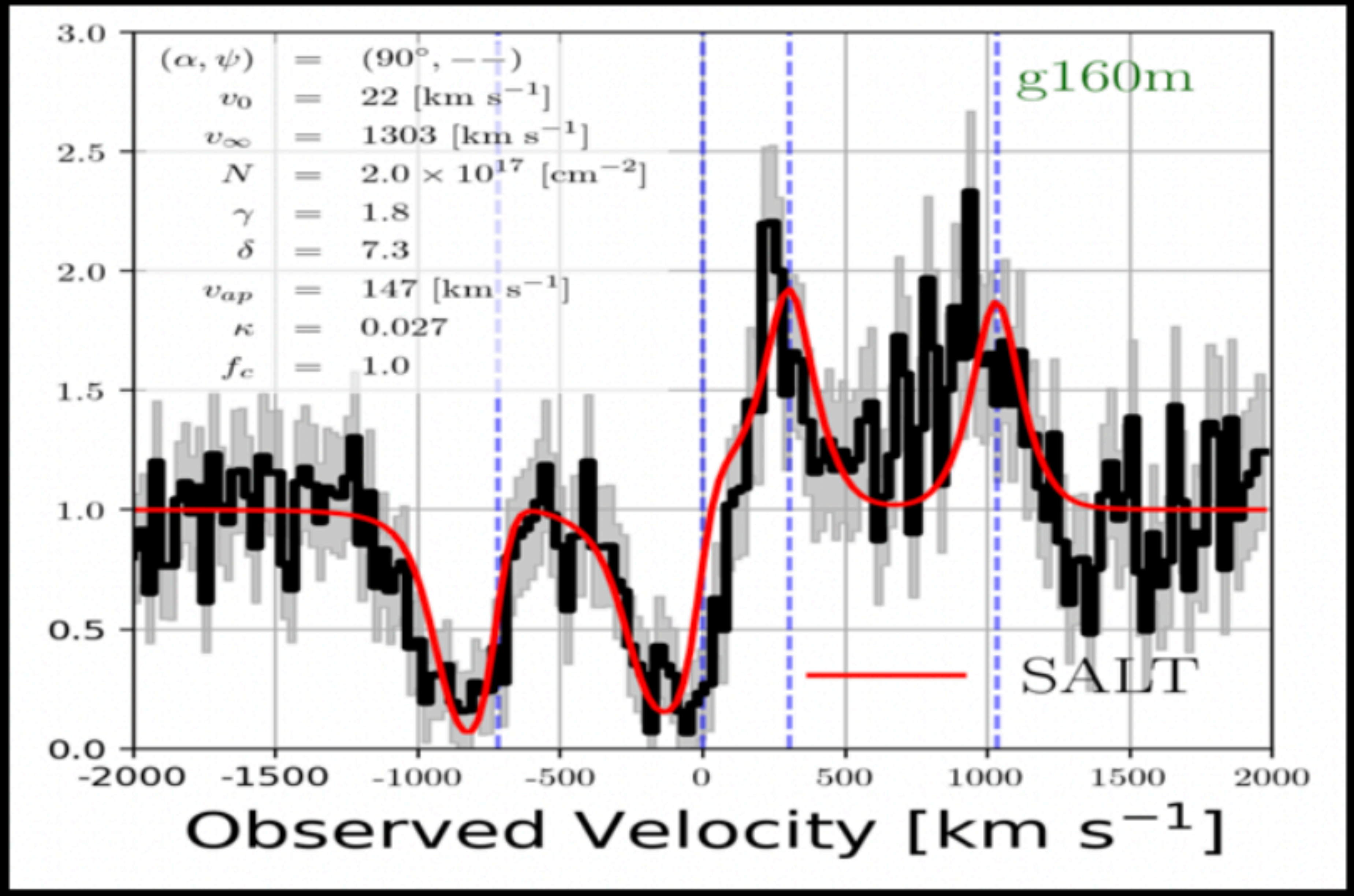
   i. Outflows+Indicators of Feedback

6)Conclusions



Semi-Analytical Line Transfer



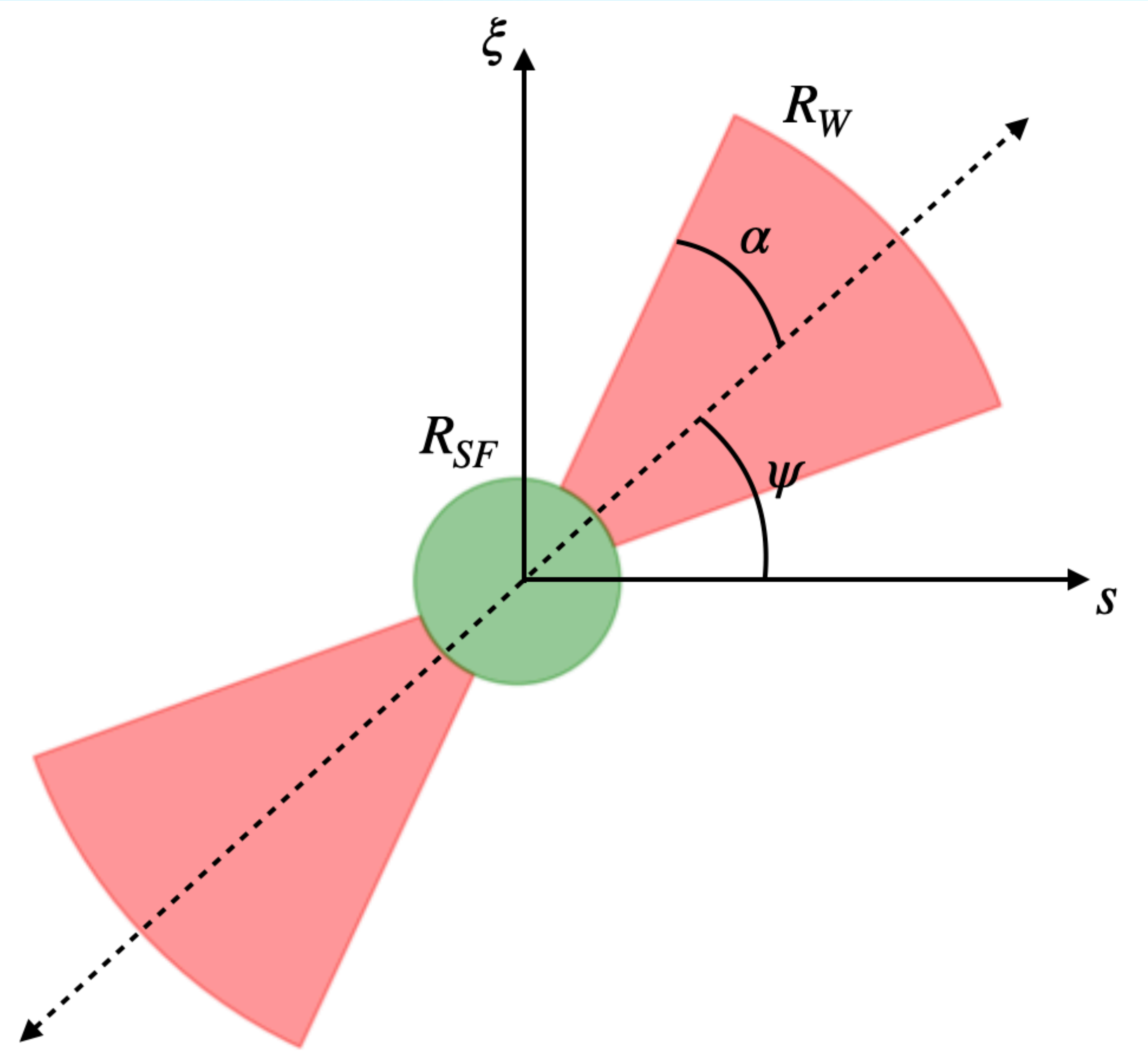


https://semi-analytic-line-transfer-salt.readthedocs.io

Carr et al. (2023)

SALT Model

SALT is a forward model of galactic outflows to spectral line predictions and represents a fully consistent picture of radiation transport in a 3-dimensional idealized outflow.



Density Field

$$n = n_0 \left(\frac{R_{\mathrm{SF}}}{r} \right)^{\delta}$$

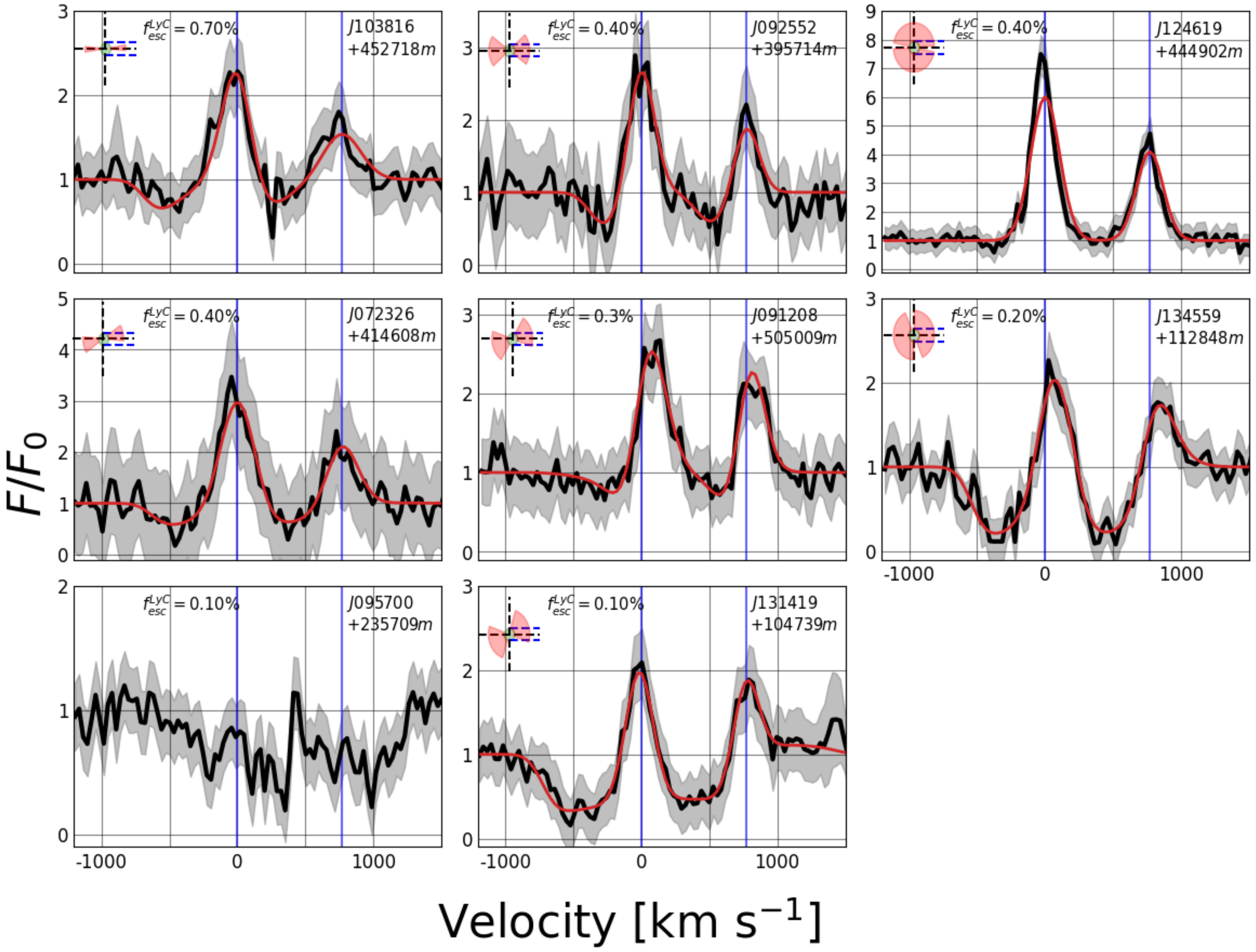
Velocity Field

$$v = v_0 \left(\frac{r}{R_{\mathrm{SF}}} \right)^{\gamma} \quad \text{for } r < R_W$$

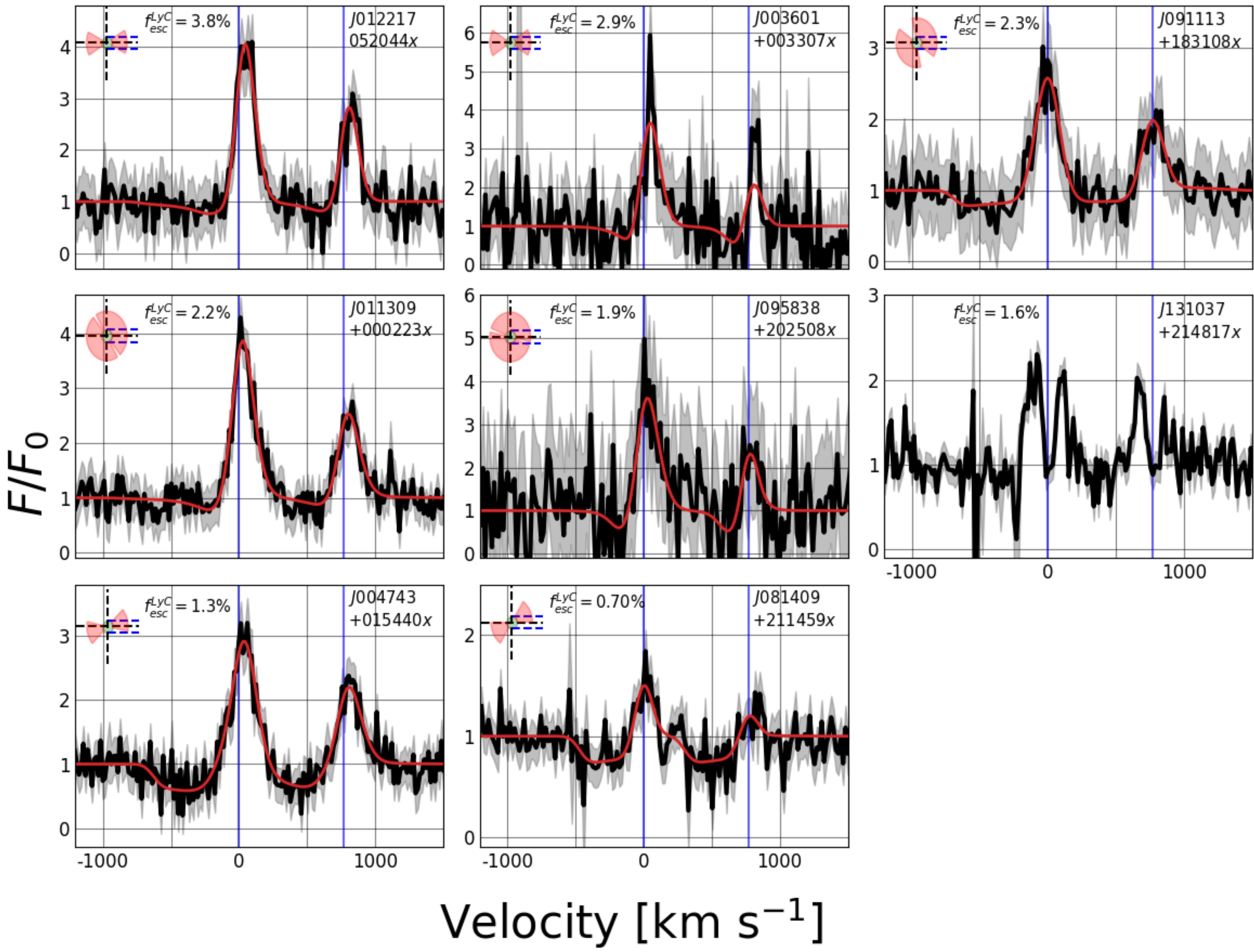
$$v = v_\infty \quad \text{for } r \geq R_W$$

Data+Model Fitting

MMT Blue Spectrograph, Res ~ 90 km/s



VLT X-Shooter, Res ~ 55 km/s



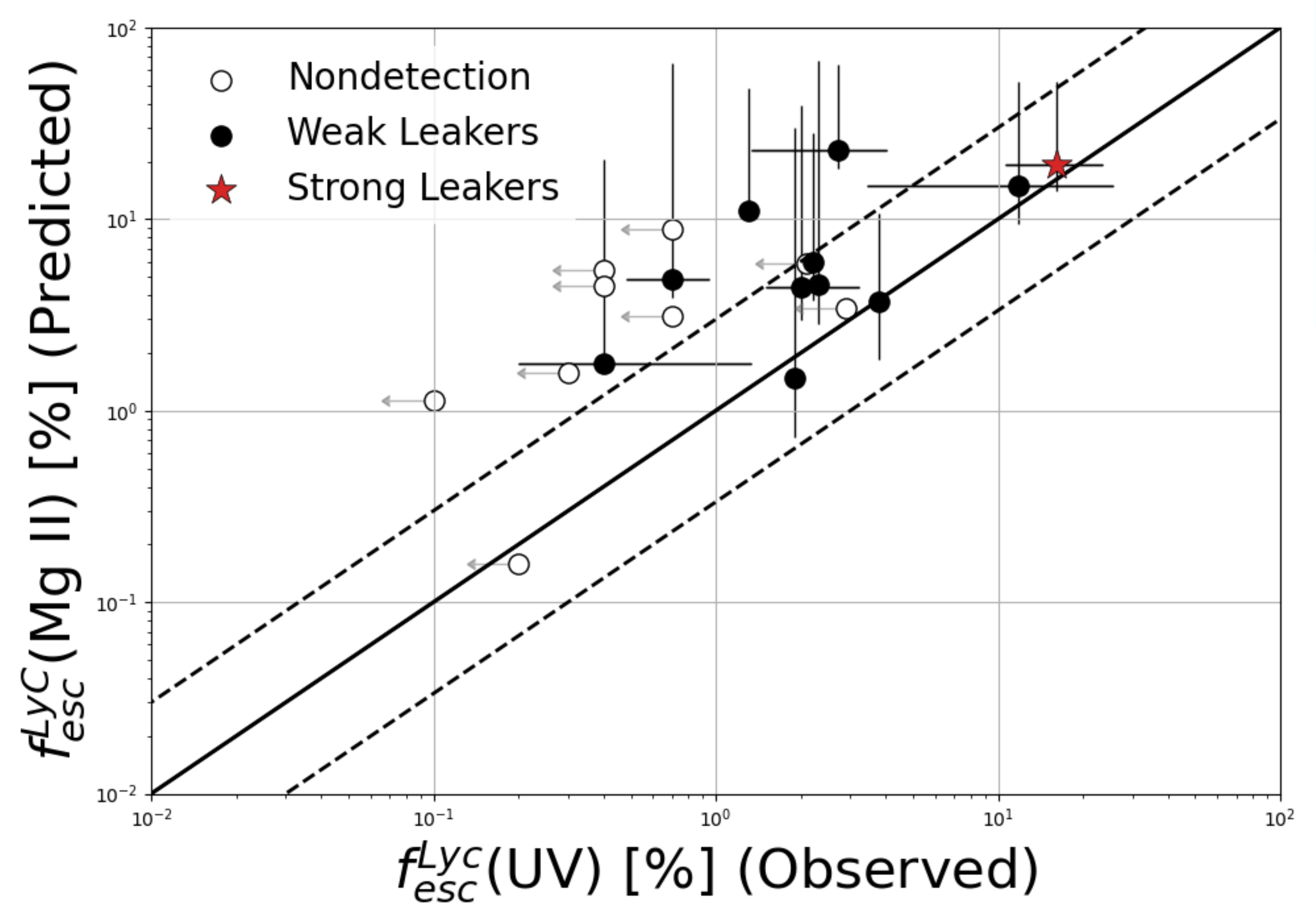
Predicting LyC Escape

Predicted LyC Escape Fraction from Mg II

$$f_{esc}^{LyC}(\mathrm{Mg\ II}) = \left(\mathrm{C_{f,Mg^+}} e^{-\tau_{\mathrm{Mg^+}}} + 1 - \mathrm{C_{f,Mg^+}}\right) \times 10^{-0.4\mathrm{E(B-V)_{UV}}}$$

Assumed - $\mathrm{Mg^+} \xrightarrow{\text{cloudy}} \mathrm{H^0}$

$$C_{f,\mathrm{Mg^+}} = C_{f,\mathrm{H^0}}$$



Predicting LyC Escape

Predicted LyC Escape Fraction from Mg II with Empirical-Based Correction

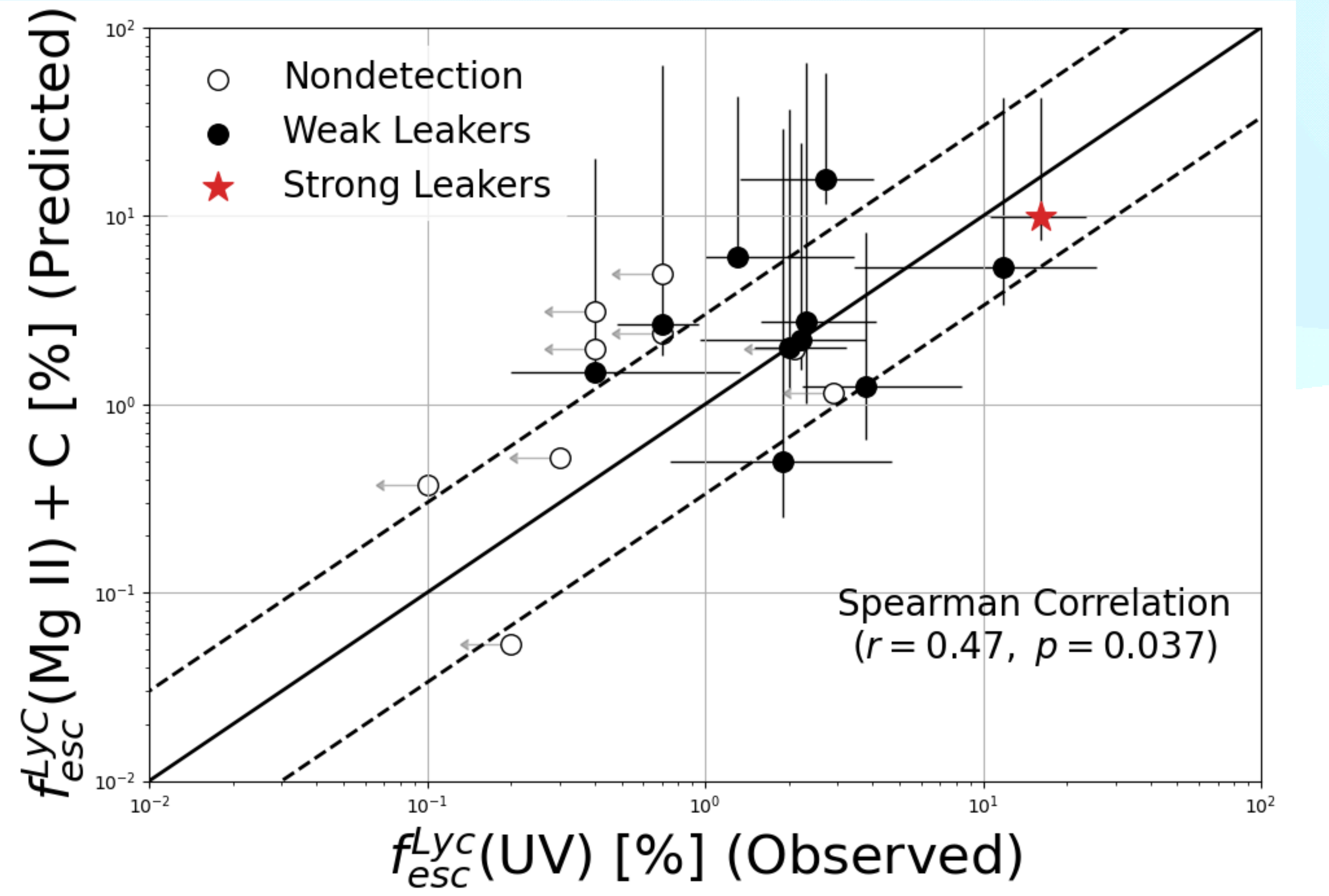
$$f_{esc}^{LyC} = \left(C_{f,\text{thick}} e^{-\tau_{\text{thick}}} + C_{f,\text{thin}} e^{-\tau_{\text{thin}}} + C_{f,\text{transparent}} \right) \times 10^{-0.4\text{E(B-V)}_{\text{UV}}}$$

Assumed - $C_{f,\text{H}^0} = (0.63 \pm 0.19) C_{f,\text{Mg}^+} + (0.54 \pm 0.09)$

Saldana-Lopez et al. (2022)

$$C_{f,\text{thick}} = C_{f,\text{Mg}^+},\ C_{f,\text{thin}} = C_{f,\text{H}^0} - C_{f,\text{Mg}^+},$$

$$C_{f,\text{transparent}} = 1 - C_{f,\text{H}^0}$$



Empirical Correction -

$$0.24 < \tau_{\text{thin}} < 2.4,\ \bar{\tau}_{\text{thin}} = 1.1 \implies \bar{N}_{\text{Mg}^+} = \bar{N}_{\text{H}^0} / \bar{\alpha}_{\text{Mg}^+ \to \text{H}^0} \sim 10^{13}\ [\text{cm}^{-2}],\ \bar{\alpha}_{\text{Mg}^+ \to \text{H}^0} \sim 10^4$$

The Massive Outflows of LzLCS

SN Deposition Rates

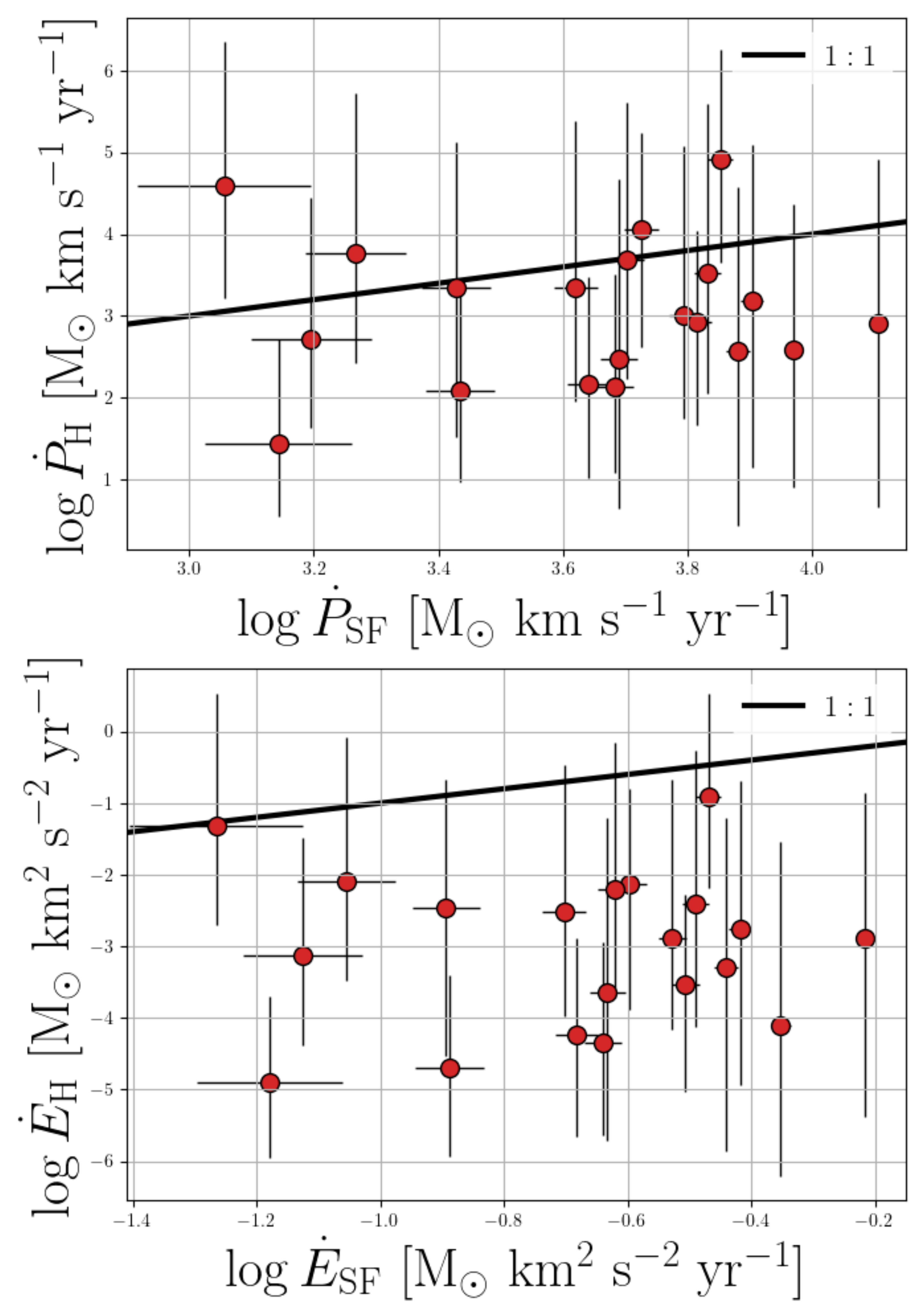
(1 SN per 100 $M_\odot$)

Momentum

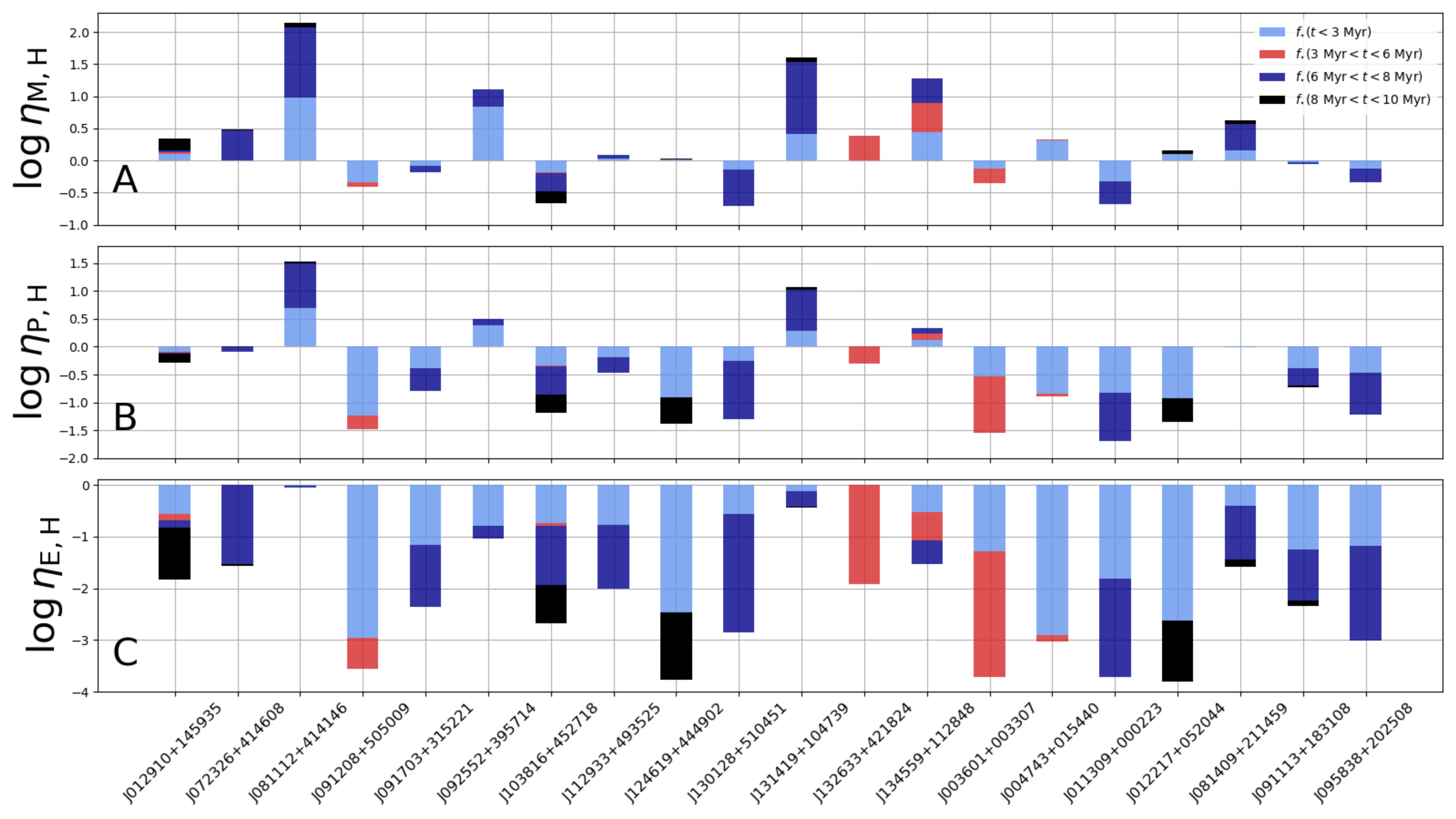
$$\dot{P}_{SF} = 317\ [M_\odot\ \mathrm{km\ s^{-1}\ yr^{-1}}]\left(\frac{\mathrm{SFR}}{1\ M_\odot\ \mathrm{yr}^{-1}}\right)$$

Energy

$$\dot{E}_{SF} = 0.0151\ [M_\odot\ \mathrm{km^2\ s^{-2}\ yr^{-1}}]\left(\frac{\mathrm{SFR}}{1\ M_\odot\ \mathrm{yr}^{-1}}\right)$$



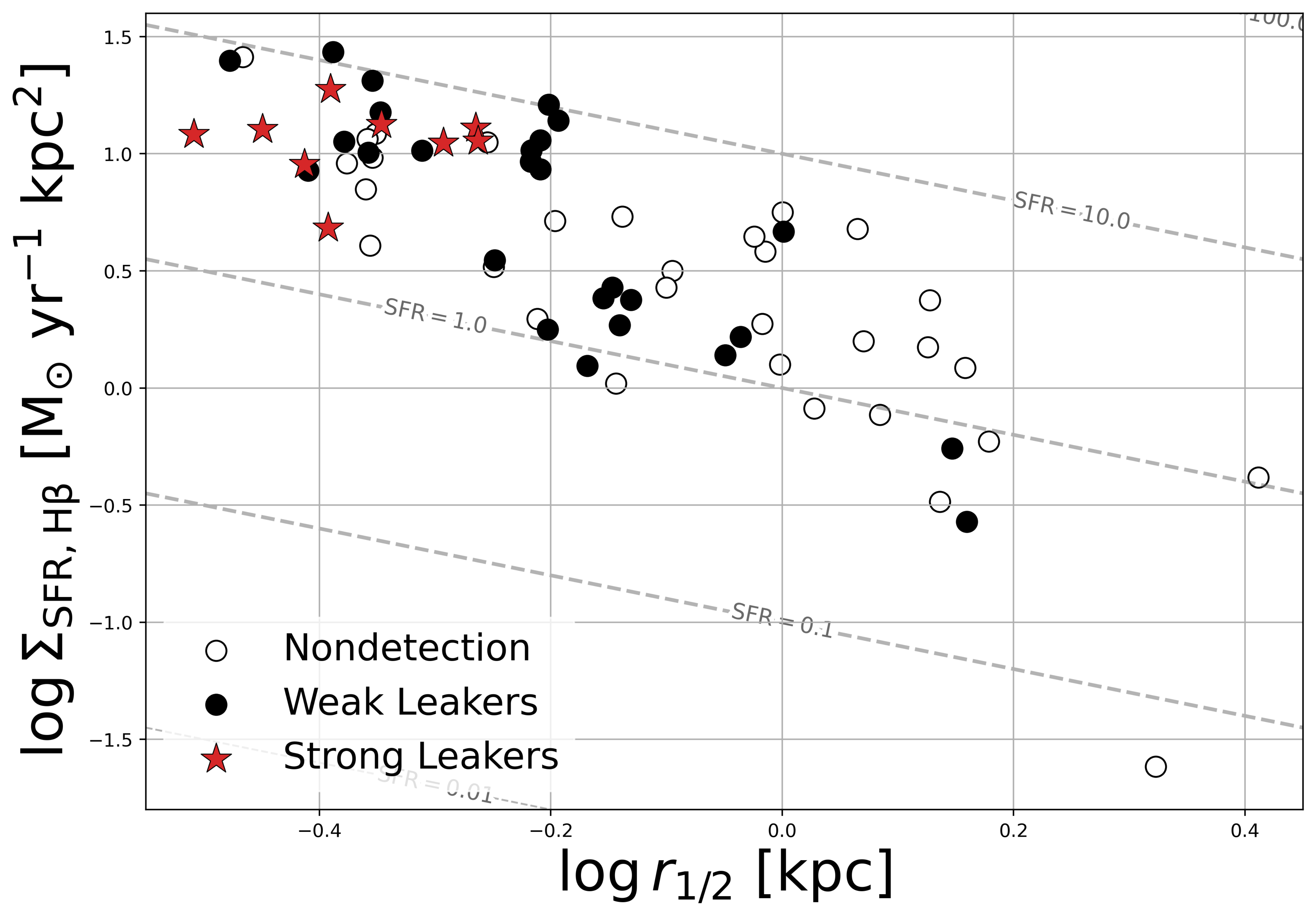
The Massive Outflows of LzLCS



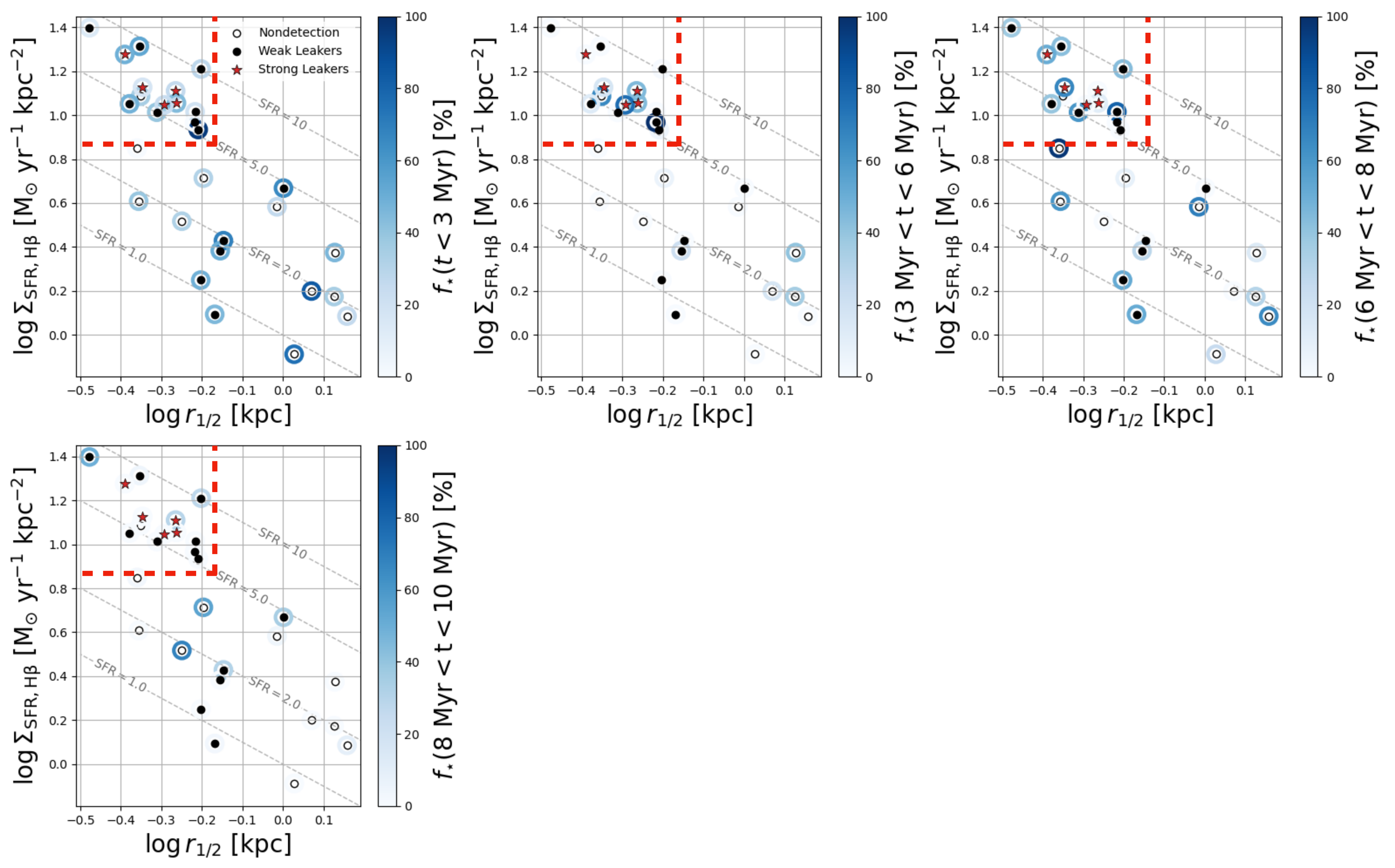
The Impact of Outflows on LyC Escape

Compact galaxies with high SFR surface densities should have the right conditions for feedback to clear the ISM/CGM for LyC Escape (see Cen 2020)

Full LzLCS Sample



The Impact of Outflows on LyC Escape

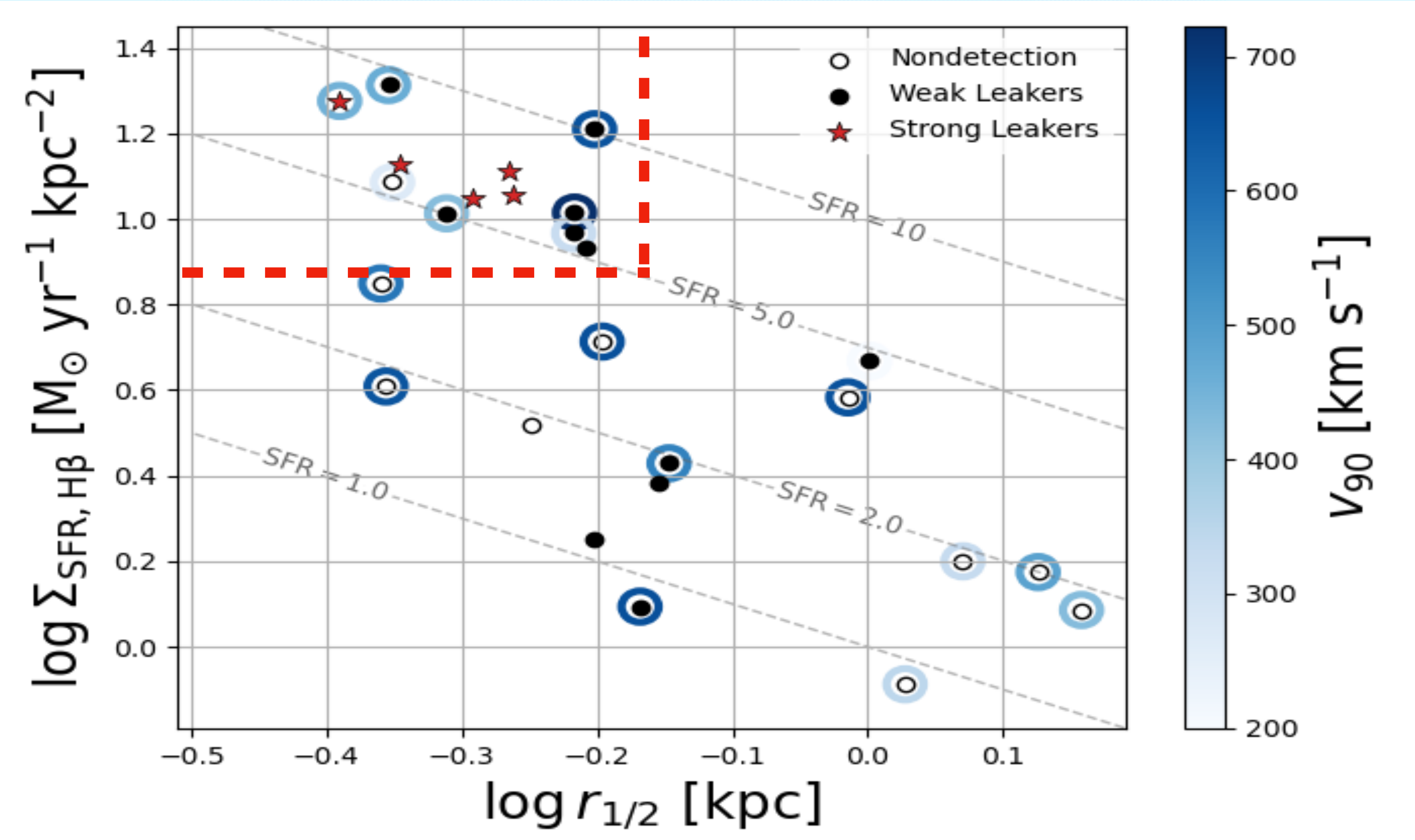


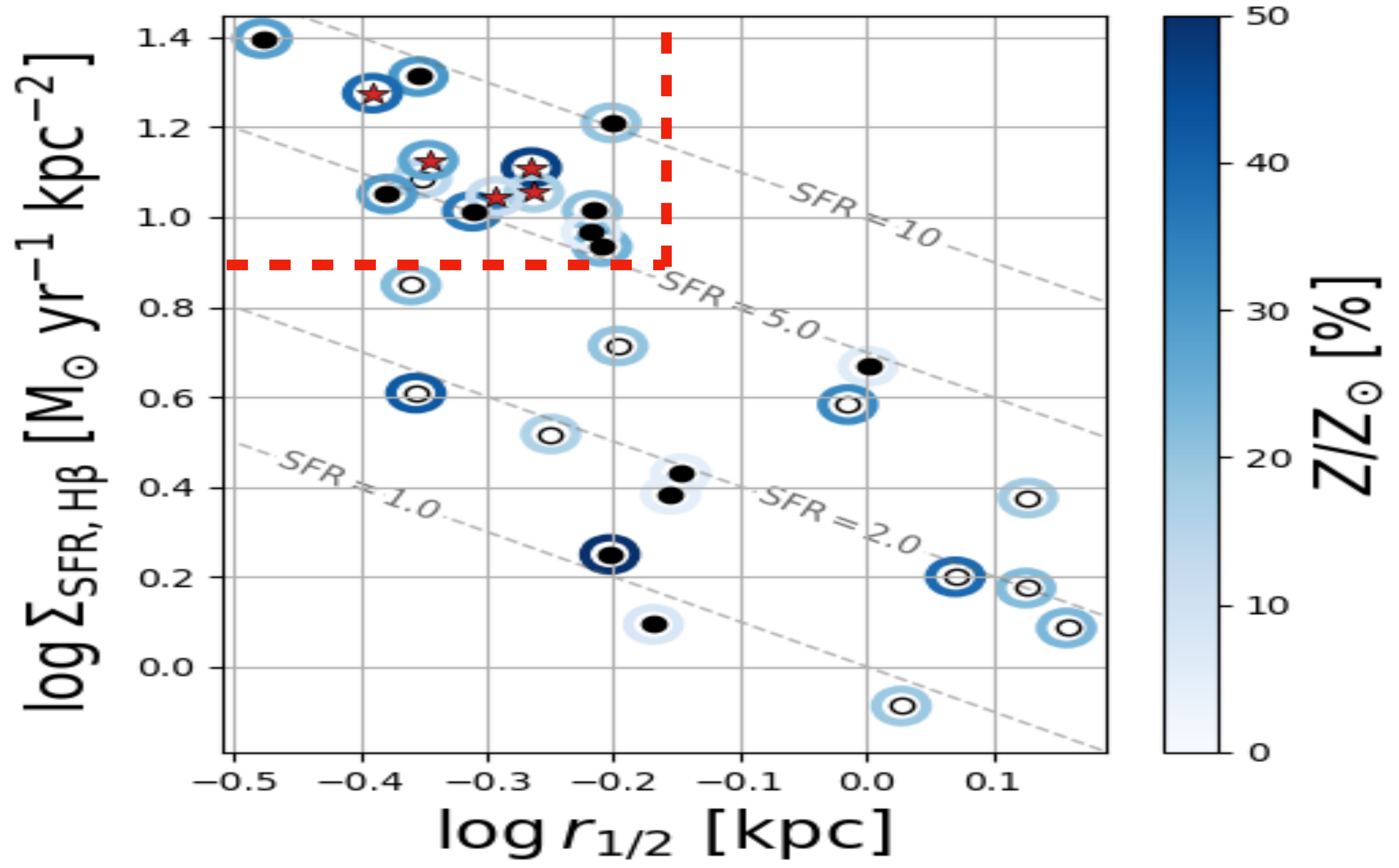
The Impact of Outflows on LyC Escape

Evidence for Catastrophic Cooling

(See Danehkar et al. 2021)

1) Strongest Leakers have young/middle aged stellar populations (< 6 Myr), timeline suggests radiation driven outflows
2) Outflows have low energy and momentum loading, but still moderate mass loading
3) Strongest leakers have high metallicities and low velocities, if even detectable
4) Many of the strongest leakers do not show signs of outflows as traced by Mg II (i.e., their winds are suppressed)





Conclusions

Claim 1: Our results favor a multi-phase model of the ISM/CGM consisting of high density cool clouds, containing Mg^+ and other LIS metals, embedded in a hotter lower density ambient medium. The cool clouds act to block LyC escape.

Claim 2: The method of LyC escape depends on the primary source of feedback. The strongest leakers tend to be radiation dominant, while the weak leakers tend to be supernovae dominant.

- **Radiation Driven Feedback**

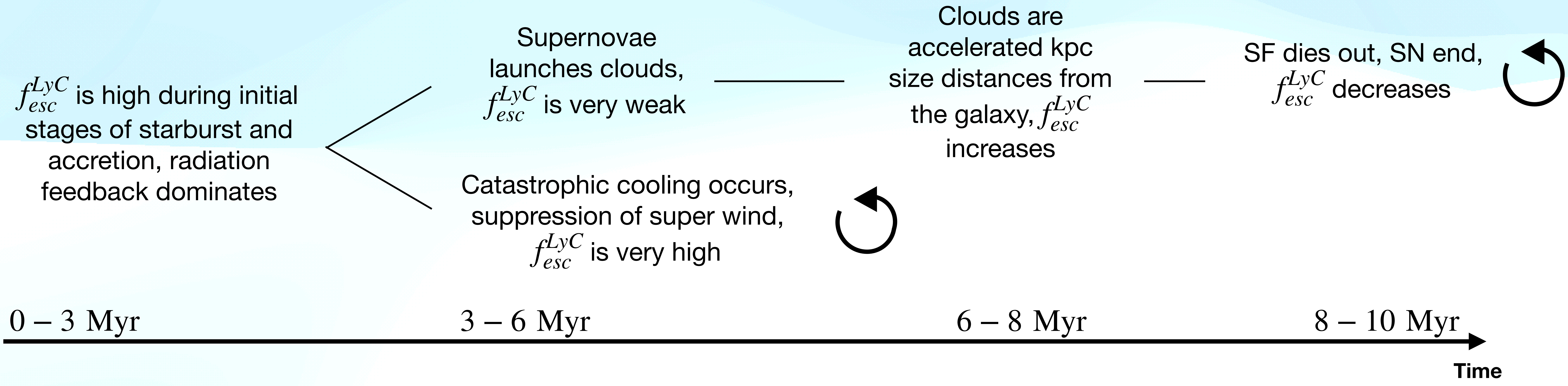
Radiation driven outflows have lower velocity, energy loading, and momentum loading than supernovae driven winds. These conditions are conducive to catastrophic cooling and the suppression of super winds. The latter may create the best conditions for LyC escape.

- **Supernovae Driven Feedback**

Supernovae driven outflows have higher velocities, energy loading, momentum loading, and comparable/larger mass loading factors than radiation driven outflows. These outflows are capable of accelerating cool clouds several kpc from the galaxy to create channels for LyC escape.

Conclusions

Claim 3: Our results suggest two main timelines for LyC escape relative to a star formation episode. Required Galaxy Conditions: compactness + high $\Sigma_{\rm SFR}$.



Claim 4: The outflows/feedback are highly anisotropic and f_{esc}^{LyC} should vary with the LOS. The claims in this paper should hold on average with potential variation on an individual by individual basis.