Radio Study of analogues of the Sources of Reionization

Omkar Bait
Observatoire de Genève

Daniel Schaerer, **Sanchayeeta Borthakur**, **Emmanuel Momjian,** Yuri Izotov, Biny Sebastian, Anne Jaskot, + LzLCS team

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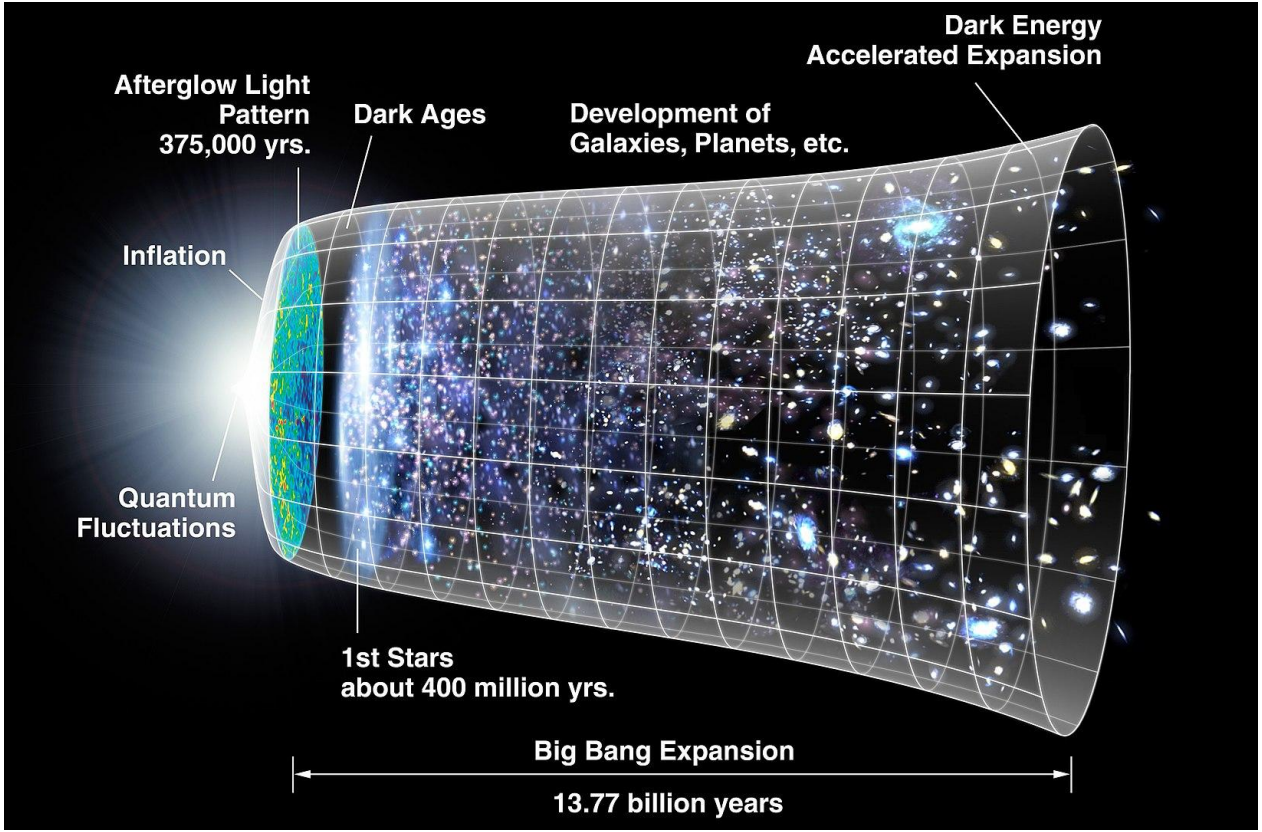
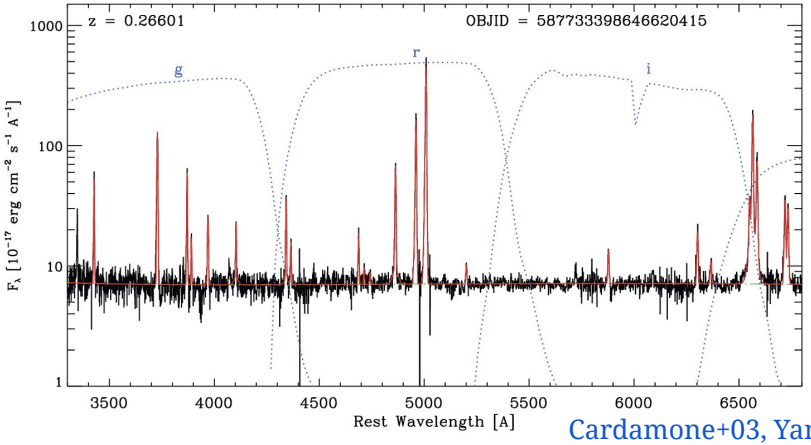
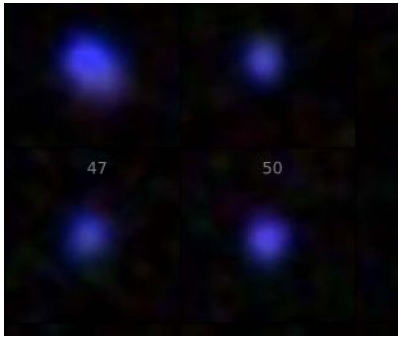
Cosmic Reionisation

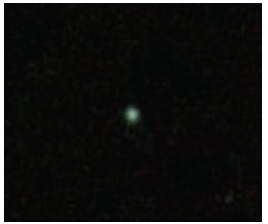


Credit: NASA

Local analogues of high-z galaxies







Cardamone+03, Yang+17

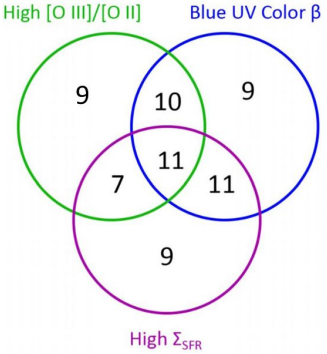
- Compact sizes, high SFR, young starbursts
- Low metallicity (12+log(O/H) < 8.0)
- High [OIII]/[OII] ratio
- **High LyC escape** ⇨ best candidates for cosmic reionisation (Izotov+16, Nature, Izotov+18, 21, 22, Schaerer+16, 18, 22)

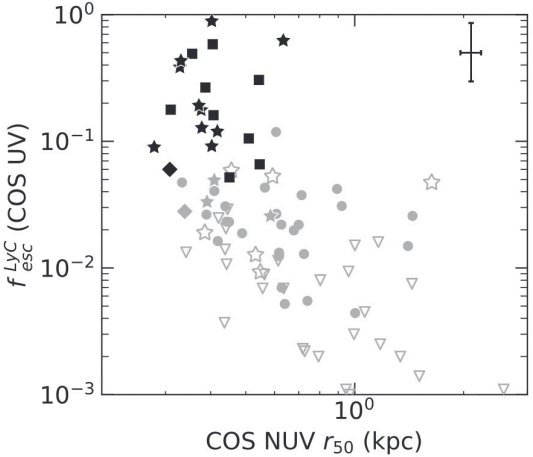
Recent JWST observations of $z > 6$ galaxies have similar properties to local analogues!

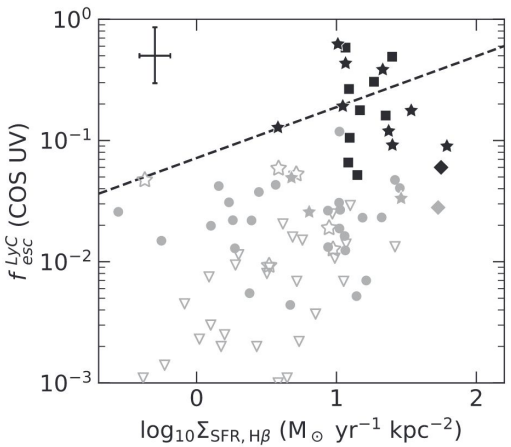
See Schaerer+22, Sun+22a,b, Brinchmann+22, Rhoads+22, Curti+22, Carnall+22, Tacchella+22, Matthee+22, Cameron+23

Nature of LyC Emitters: Low-z LyC Survey (LzLCS)

- HST large program (136 orbits): PI Anne Jaskot
- **89** low-z ~ 0.25 - 0.35 galaxies with LyC measurements
- f_{esc} correlates with O32, SFR density, sizes. (Flury +22)
- Correlates with UV absorbing line strengths (Saldana-Lopez+22)
- What leads to LyC leakage in galaxies?
- **The role of supernovae feedback is still not completely understood.**





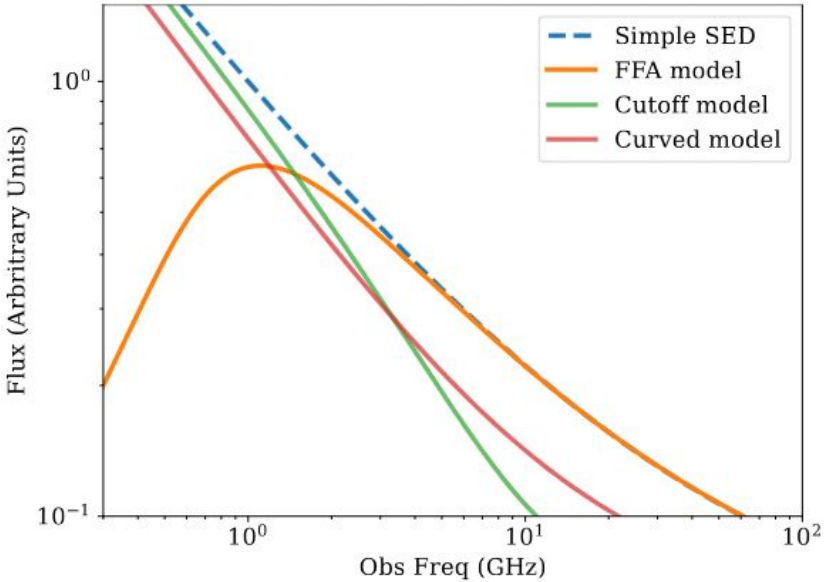


Flury et al. 2022

Why a Radio Study of Local Analogues?

- Radio provides a complementary view
- **Non-thermal emission directly related to SNe rate – thus related to SNe feedback**
- **Radio is a dust-free tracer of SFR**

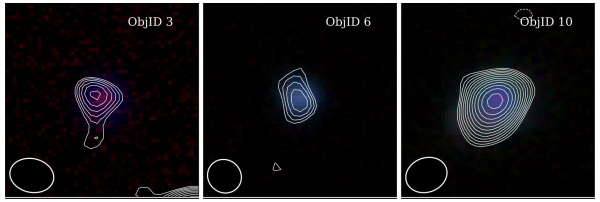
$$S_\nu = S_\nu^{\rm th} + S_\nu^{\rm nth} = A_1 \left(\frac{\nu}{\nu_\circ}\right)^{-0.1} + A_2 \left(\frac{\nu}{\nu_\circ}\right)^{\alpha_{\rm nth}}$$



Bait+23, in prep

- Gives unique insights in the ISM conditions (cosmic-rays, magnetic fields).
- No systematic study of LyC leakers in radio
- Important for high-z radio observations with the SKA.

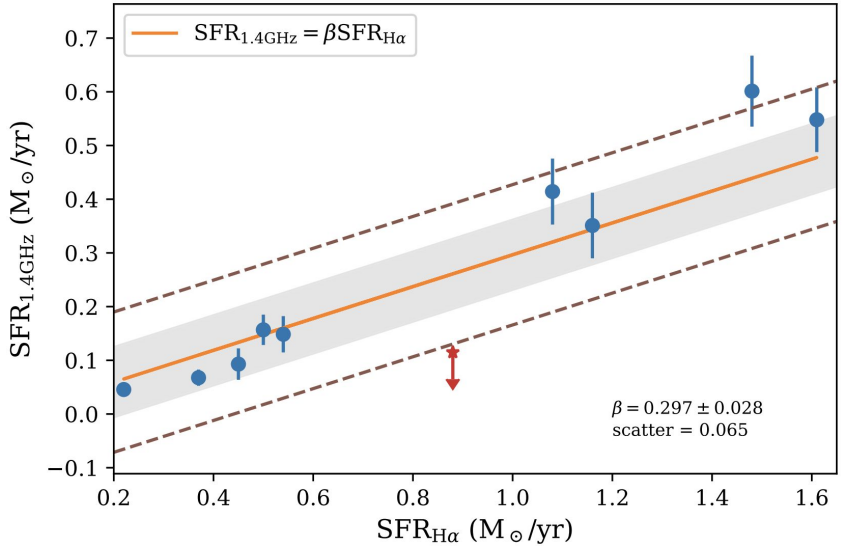
Radio Study of local analogues



Local analogues do not follow the standard radio-SFR relation
(Sebastian & Bait 19, Chakraborty+13)

RC@1.4 GHz is highly suppressed!

Young ages or free-free absorption?

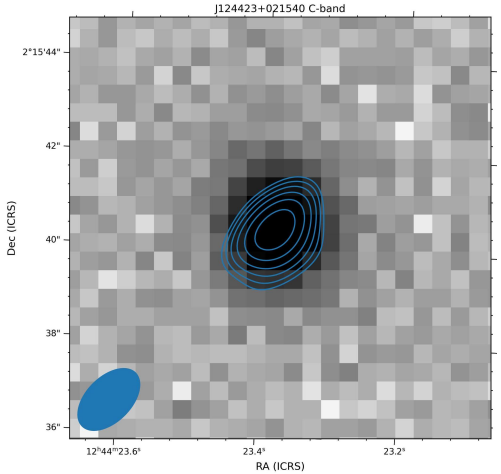


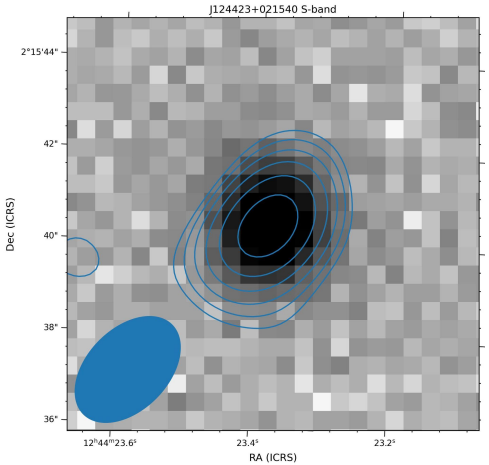
Sebastian & Bait 2019, ApJ, 882L, 19S

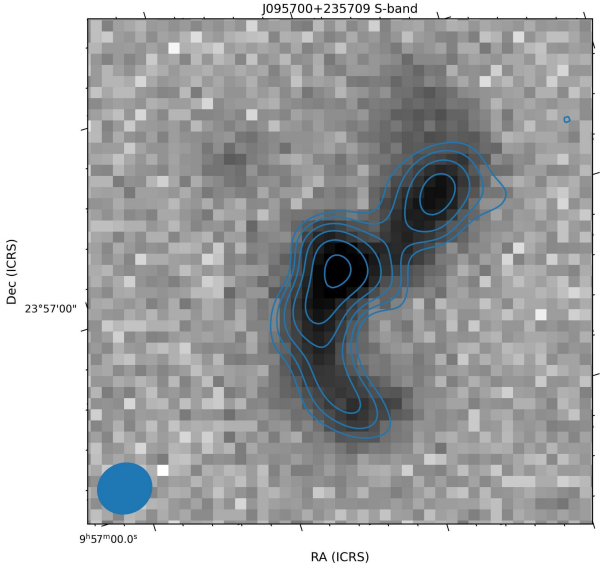
VLA Observations of LzLCS

PI: Sanchayeeta Borthakur

- **53 LzLCS sources observed** with the JVLA at **C- (6 GHz)** and **S- (3 GHz)** bands. RMS ~ 5 - 8 μJy/beam
- **24/53 detected in both C and S bands.**

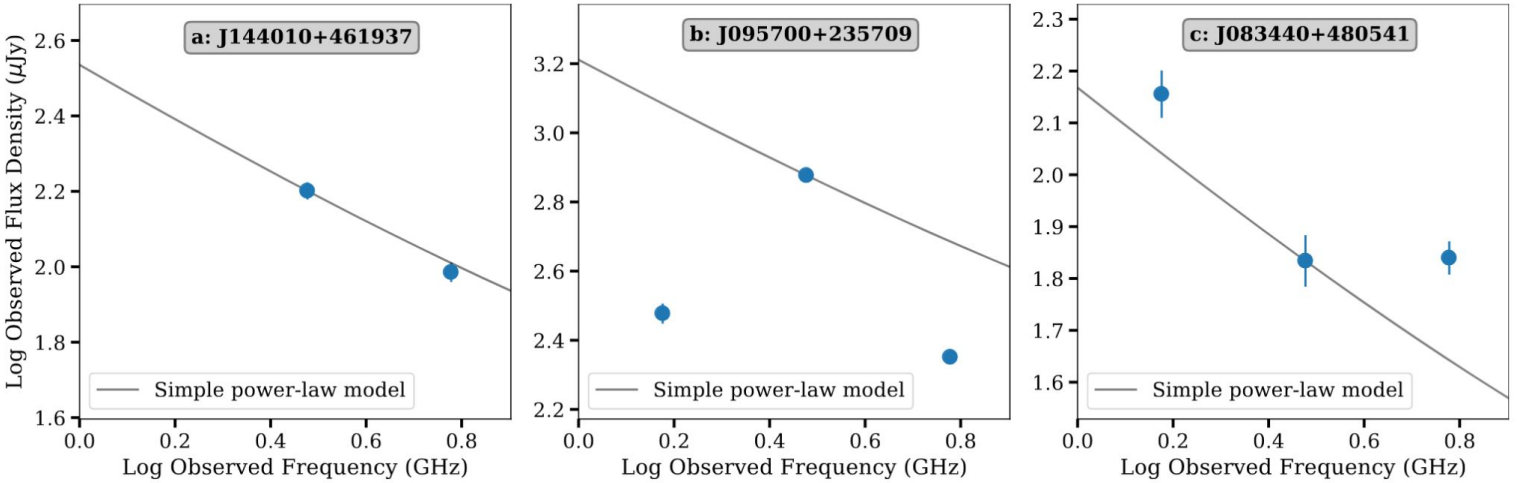






Bait+23, in prep

A diversity in the radio-SEDs



Flat spectrum with turnover | Steep spectrum | Broken spectrum

- ½ of the sample shows steep spectrum, and 1/4th shows flat and the other 1/4th shows standard spectrum.
- uGMRT observations of six sources in Band-3 (0.4 GHz), Band-4 (0.65 GHz) for the VLA detected sources.
- JVLA observations of 62 more LzLCS sources.

Bait+23, in prep

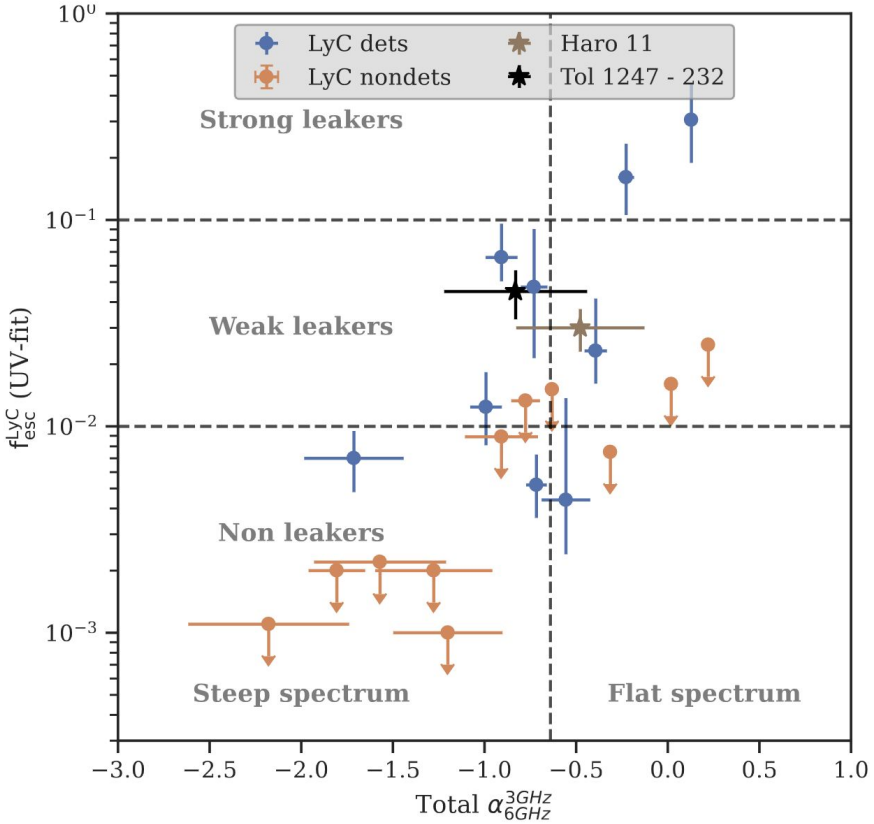
f_{esc} correlated to spectral index?

Do high f_{esc} galaxies show a flat spectrum?

Young ages/free-free absorption, flat cosmic-ray energy spectrum.

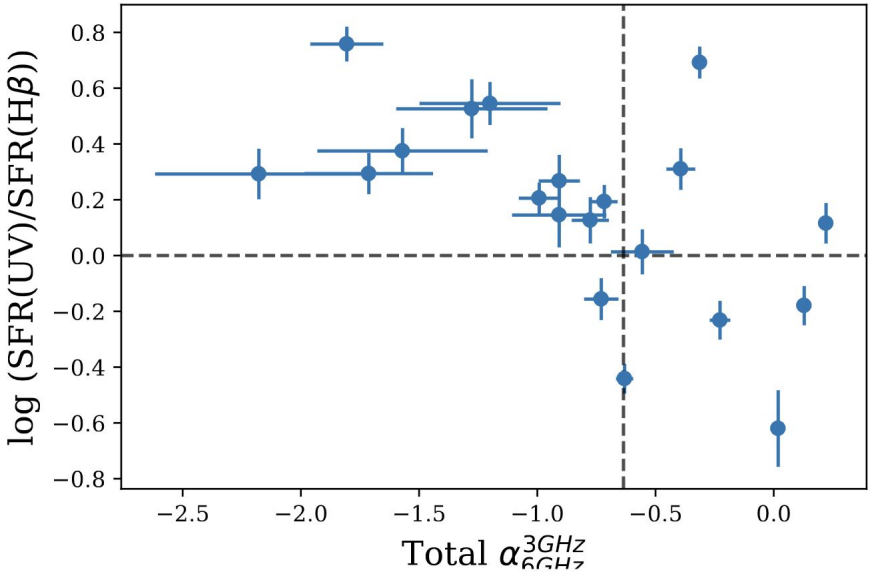
Need more data for high f_{esc} sources!

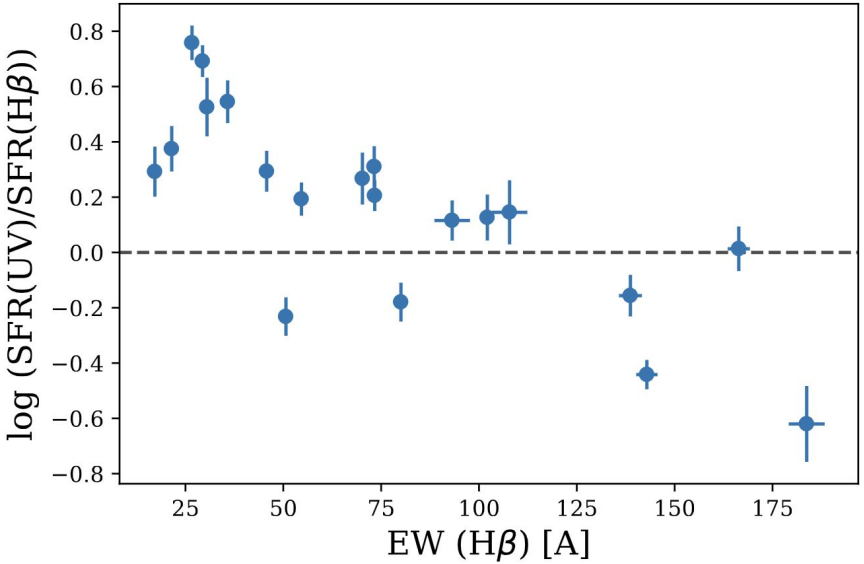
Non-leakers systematically show steep radio spectrum.



Bait+23, in prep

Steep spectrum sources are post-starburst?

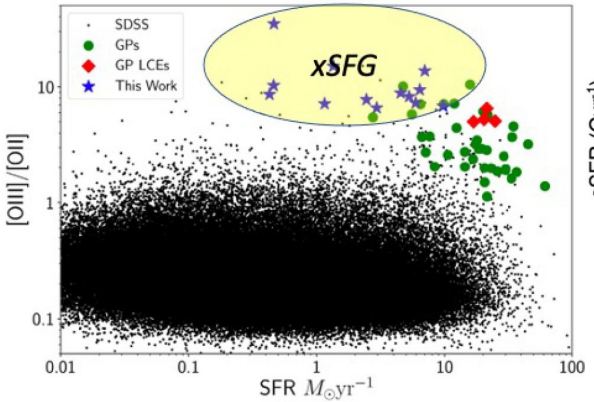


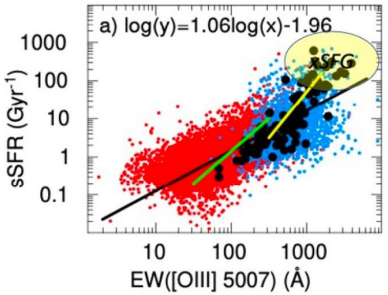


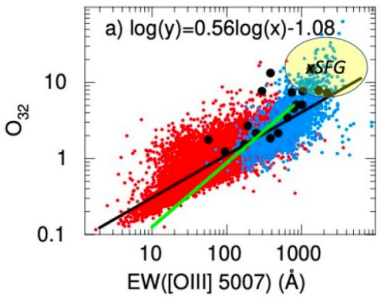
- Steep spectrum sources have higher UV-SFR (~100 Myrs tracer) vs. Hβ-SFR (~10 Myrs tracer).
- Thus is a sign of galaxies with a declining star-formation histories (or post-starbursts).

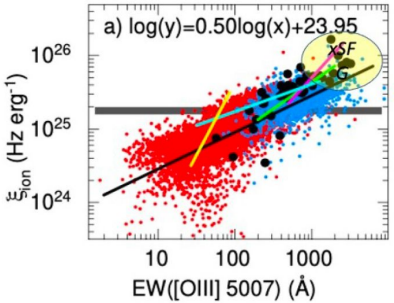
Bait+23, in prep

Local extreme-SFGs



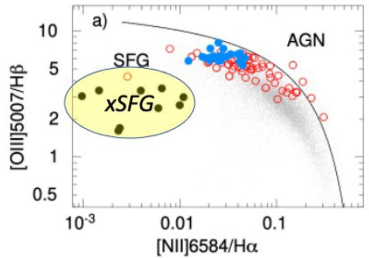


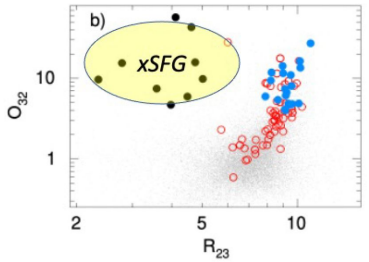


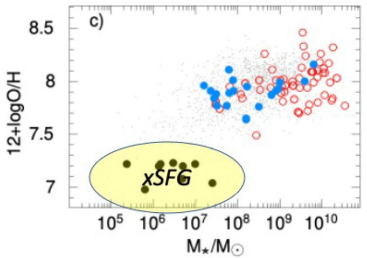


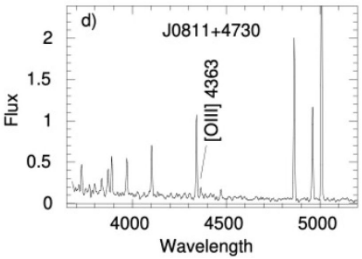
Izotov+21

- z~0.02-0.076
- Down to 12+log(O/H) = 6.98
- Extreme than Green peas, blueberries
- Ongoing HST-COS programs to measure LyC



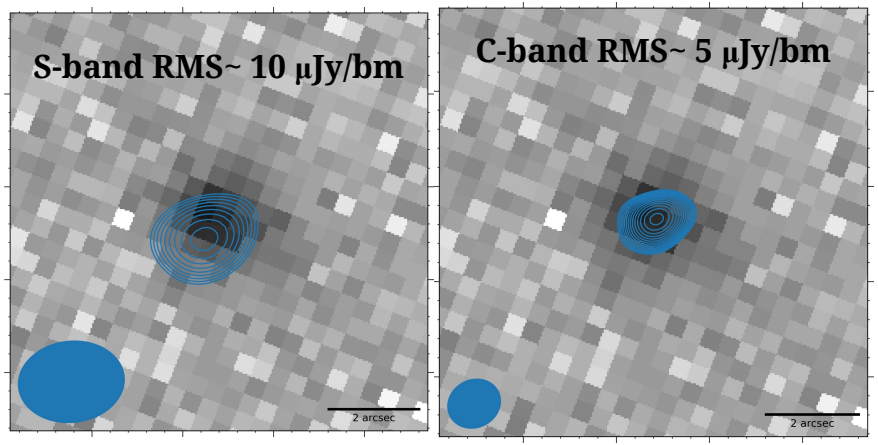






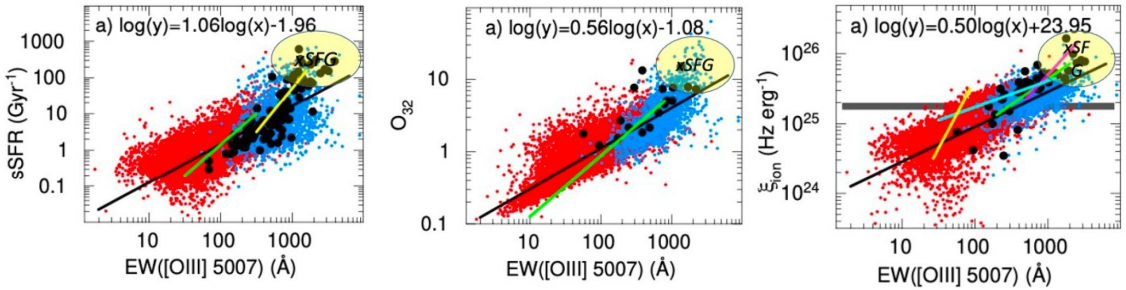
Radio follow up of extreme-SFGs

- **Ongoing VLA B-array L, S and C-band** observations
- uGMRT **325+610 MHz** follow up
- Study the **radio-SED** from (0.3-6 GHz)
- Thermal fraction, ISM properties



Flat spectral index ~ -0.23

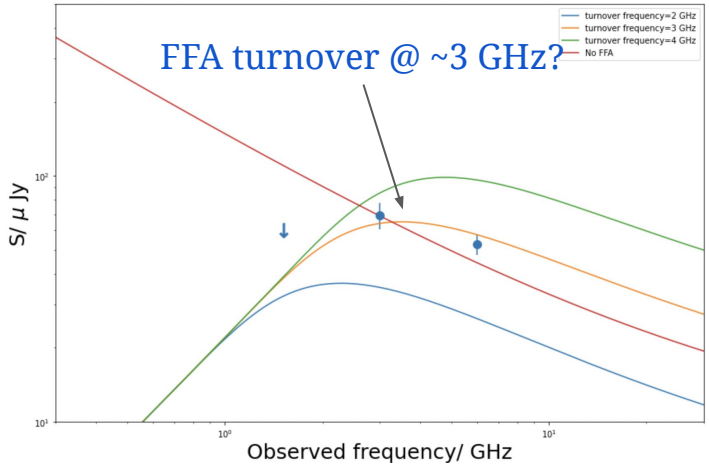
Bait+23, in prep



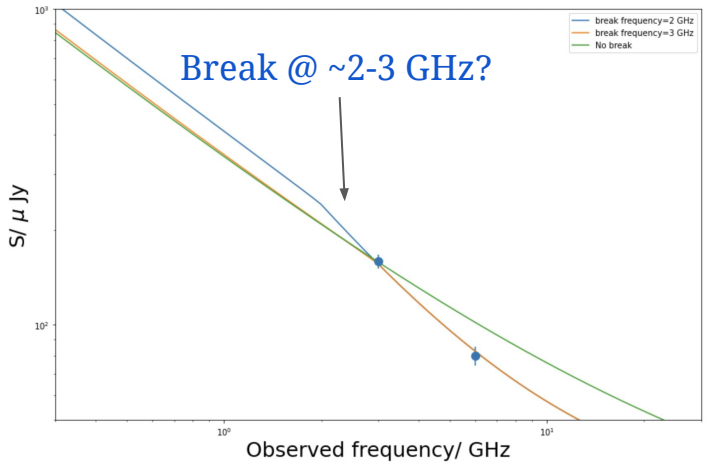
Summary

- Large diversity in their radio-SEDs at GHz frequencies: steep spectrum, turnover and breaks in the spectrum.
- **LyC escape is correlated to the radio spectral index at ~GHz frequencies.**
- Our study highlights the role of cosmic-rays and magnetic fields in LyC leakage.
- Ongoing low-frequency (< 1 GHz) follow up using the GMRT, to properly constrain the non-thermal emission.
- Radio study of analogues important to predict radio emission from high-z star forming galaxies with the advent of the SKA.

A variety of radio-SEDs



Flat spectrum



Steep spectrum

Bait+23, in prep

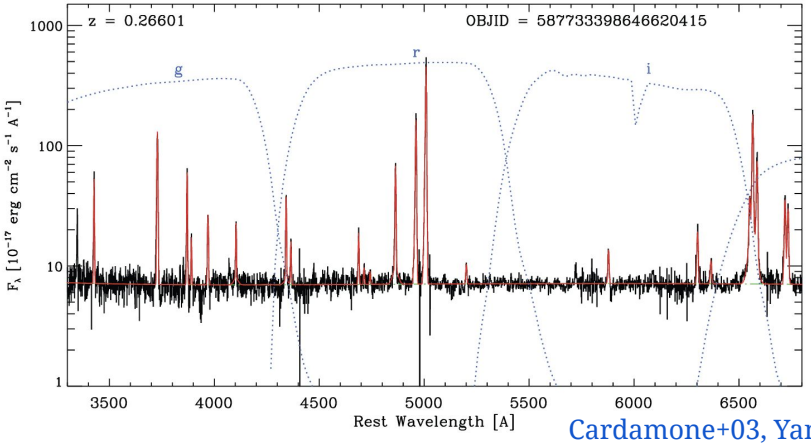
- **Flat spectrum sources** - high thermal fraction? Or free-free absorption at ~GHz? (e.g, Hunt+04, Clemens+10, Galvin+18)
- **Steep Spectrum sources** - Break in the spectrum? (e.g., Lisenfield+04, Klein+18)
- ½ of the sample shows steep spectrum, and 1/4th shows flat and the other 1/4th shows standard spectrum.

LzLCS VLA Observations

- **53 LzLCS sources observed** with the JVLA at **C (6 GHz)** and **S (3 GHz)** bands **(PI: Sanchayeeta Borthakur)**.
- We imaged all the JVLA **online calibrated data** using CASA **tclean**.

Band	Bandwidth (GHz)	Sources	Integration Time (mins)	Resolution (arcsec)	RMS (μJy)	Detections
C (6 GHz)	4	53	30	1.6	4.6	25
S (3 GHz)	2	53	30	3.2	8.1	25
L (1.5 GHz)	1	17	90	6.9	8.1	4

Local analogues of high-z galaxies



Cardamone+03, Yang+17

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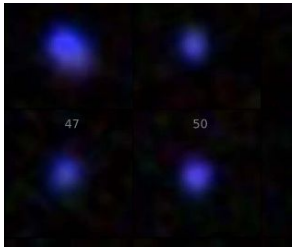

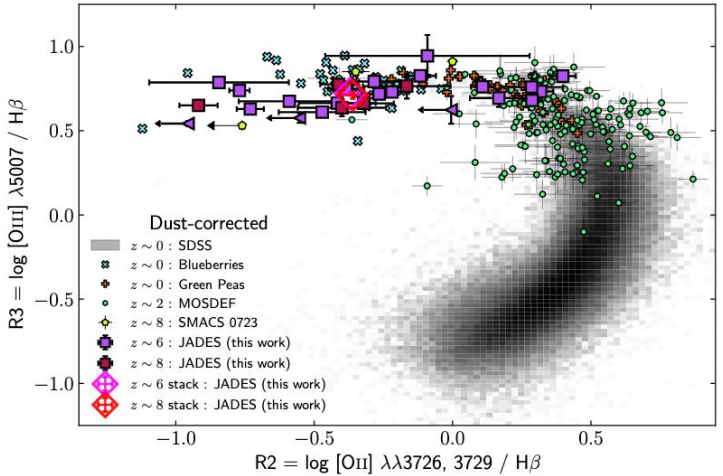

Cameron+23

See also Schaerer+22, Sun+22a,b, Brinchmann+22, Rhoads+22,, Curti+22, Carnall+22, Tacchella+22, Matthee+22