MeerKAT HI imaging of high-reshift analog galaxy Haro11: clues to Reionization

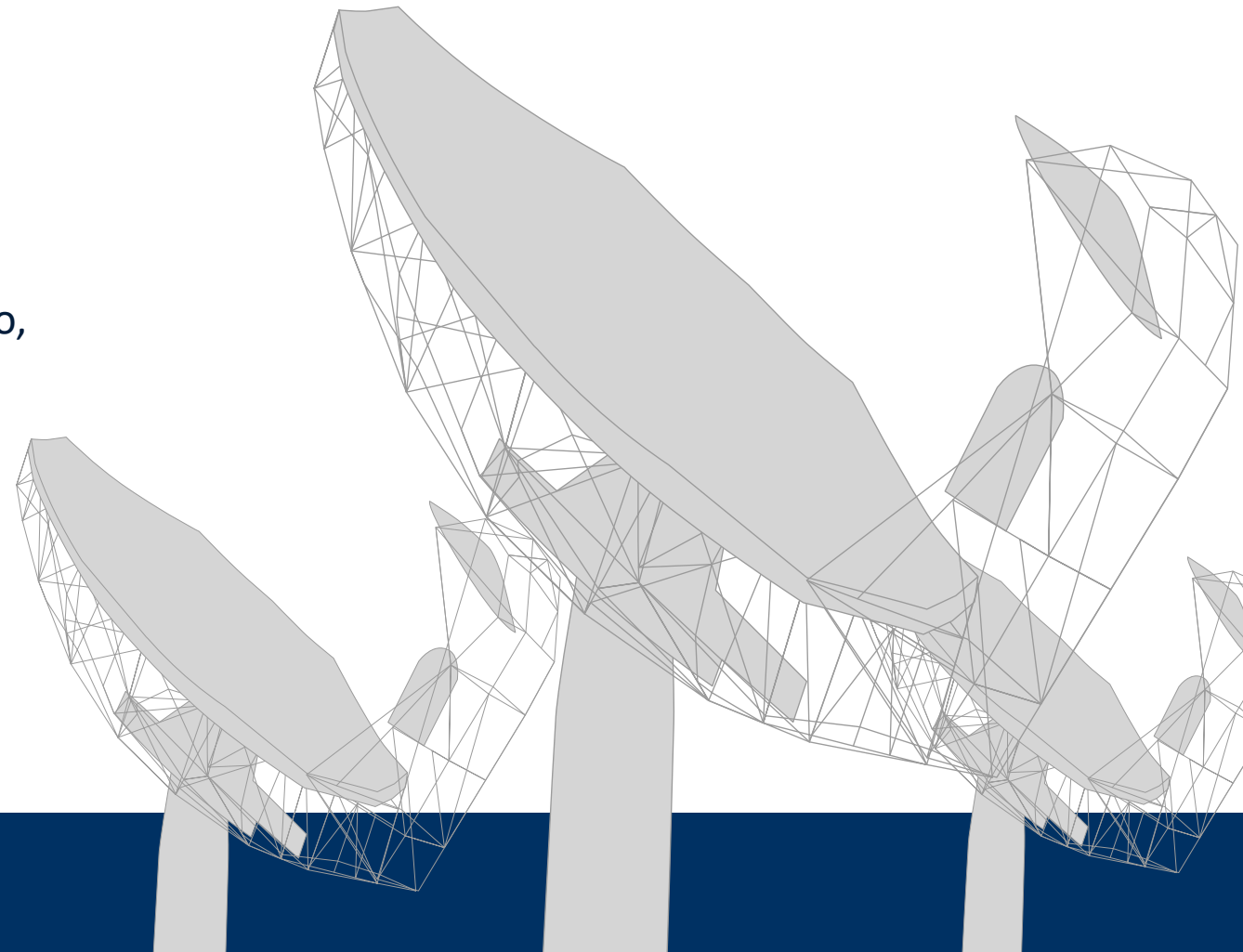## Alexandra Le Reste

Stockholm University

John Cannon, Matthew Hayes, John Inoue, Amanda Kepley, Jens Melinder, Veronica Menacho, Angela Adamo, Arjan Bik, Timmy Ejdetjärn, Gyula Józsa, Göran Östlin, Sarah Taft
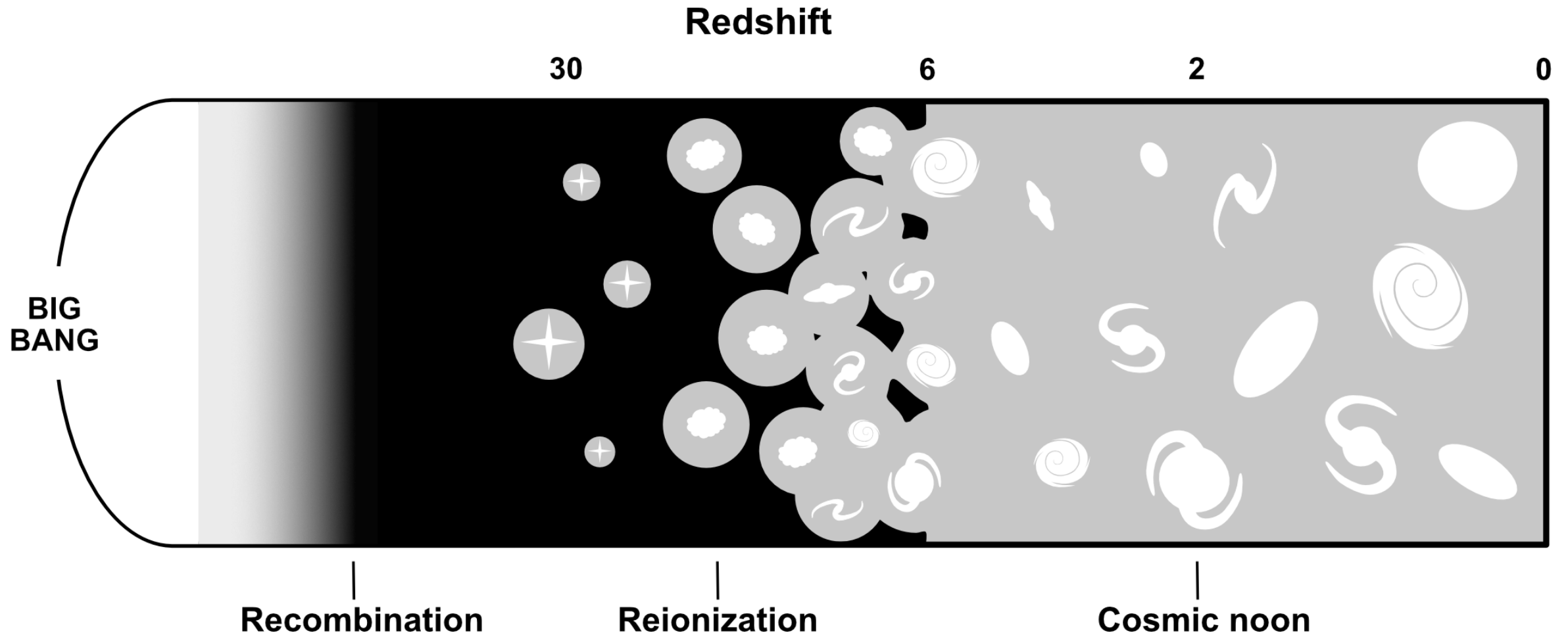
February 3rd, 2023
Swedish SKA Science day

Cosmic Reionization in context

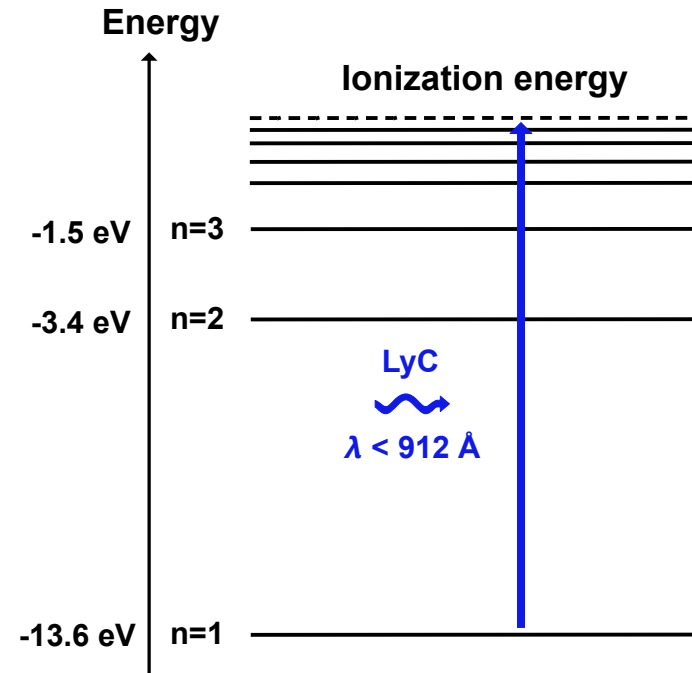# How was the Universe reionized ?

To Ionize Hydrogen: photons with E > 13.6 eV
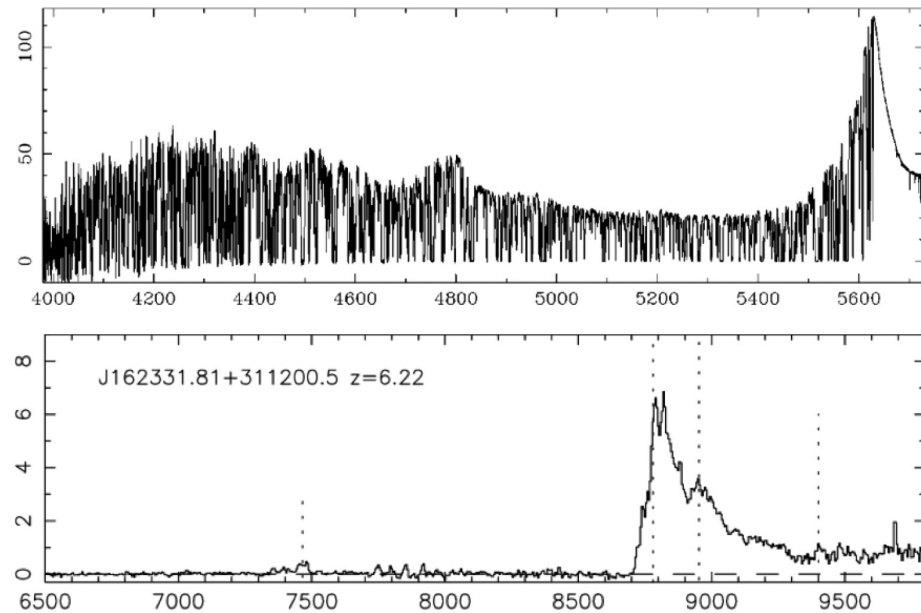
$$\lambda < 912 \text{ Å}$$

→ **Lyman Continuum (LyC)**

→ Need objects producing UV radiation

What we know about reionization

Observations
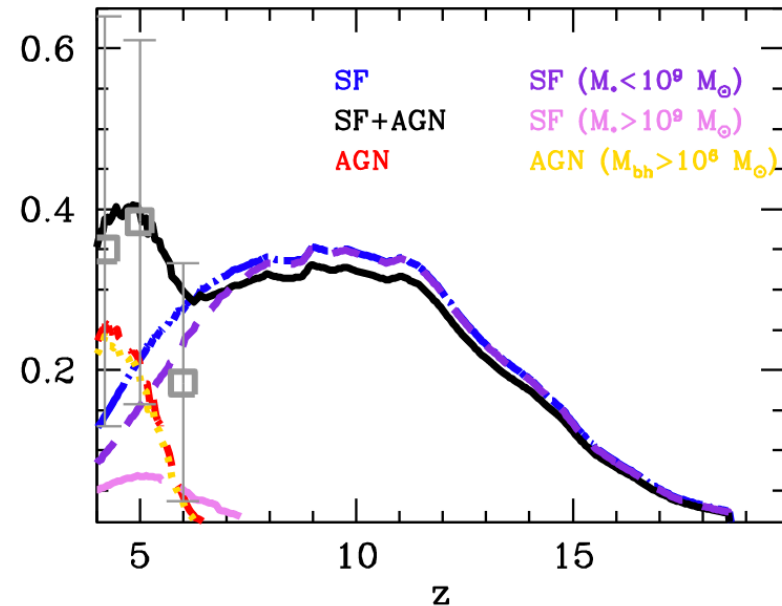
Lyα forest and Gunn-Peterson trough

Rauch 1998, Fan et al. 2004

Reionization over by redshift 6

Simulations

Ionizing photon emissivity evolution

Dayal et al. 2020

Dwarf galaxies are the main source of ionizing photons during reionization.
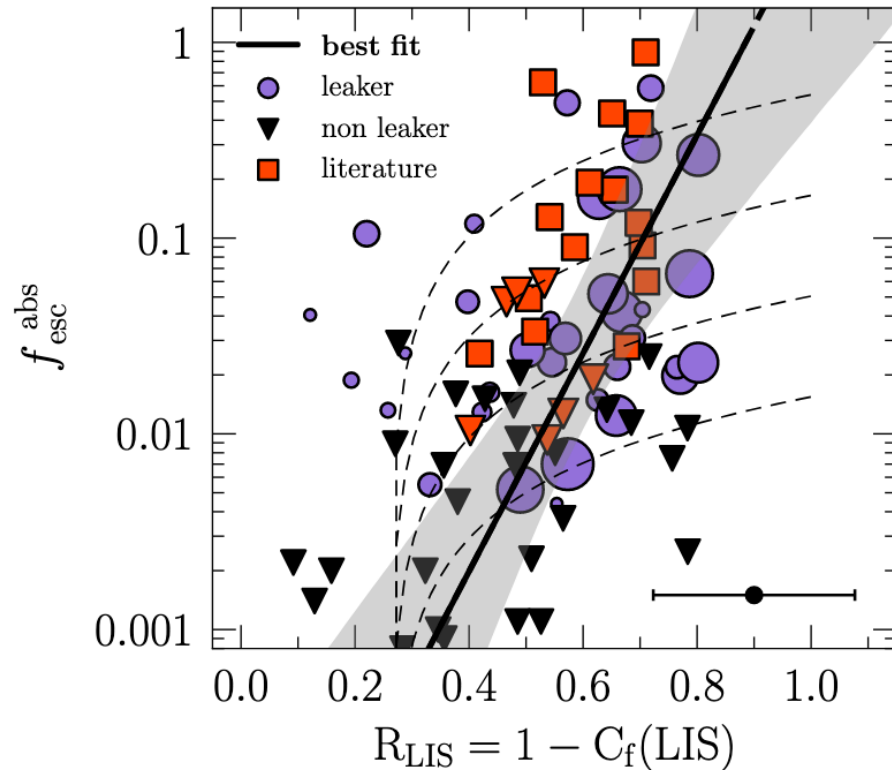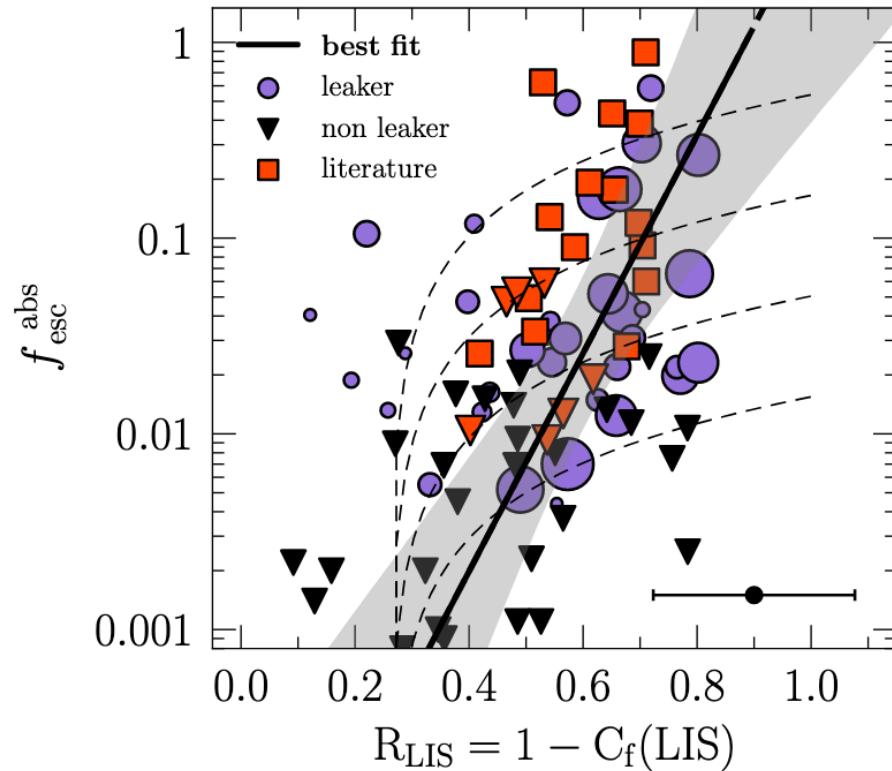
How did galaxies reionize the Universe?

Neutral gas in the Interstellar medium absorbs LyC

$\tau = 1$ at $\quad N_{HI} \sim 10^{17} cm^{-2}$

In galaxies, $N_{HI} \approx 10^{19} - 10^{22} cm^{-2}$

How did galaxies reionize the Universe?

Saldana-Lopez 2022

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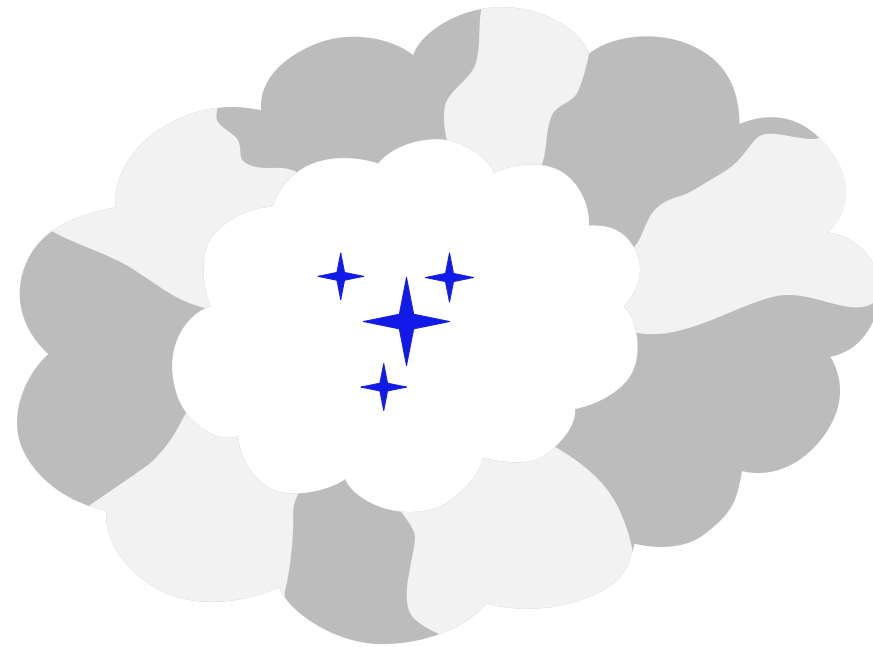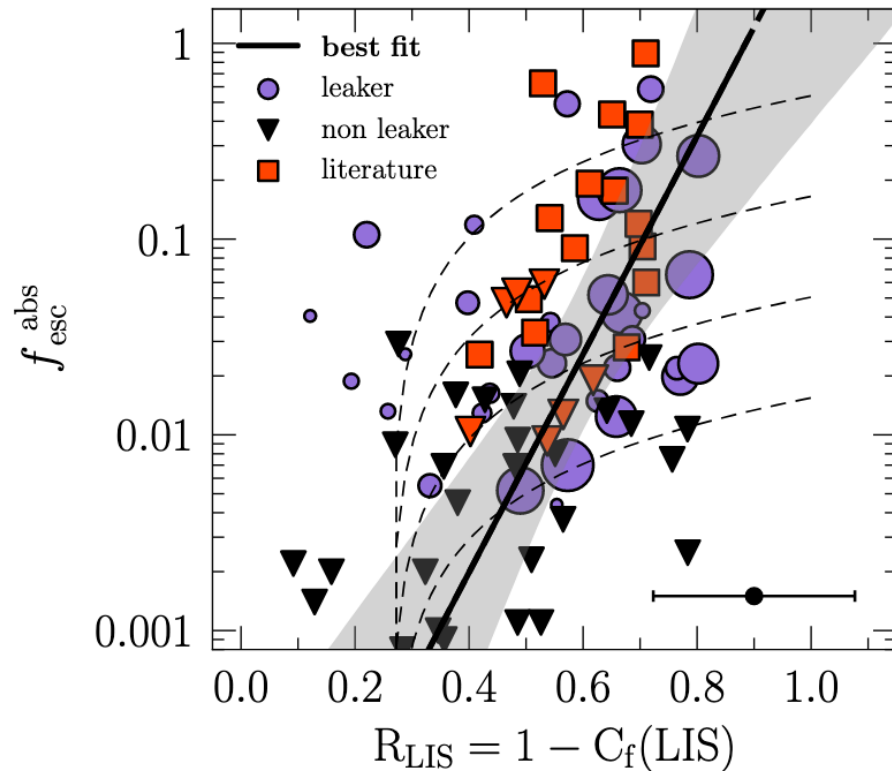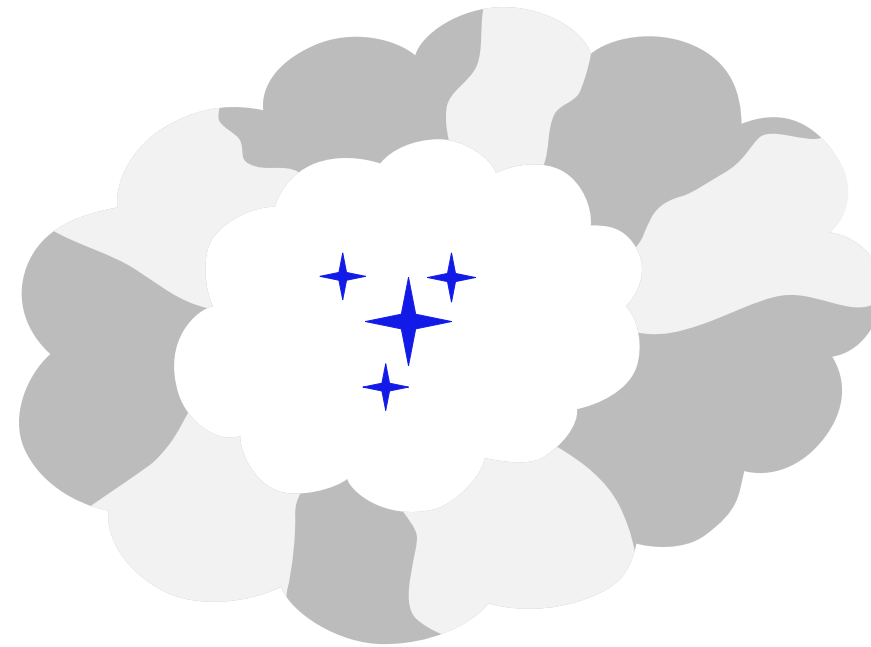# How did galaxies reionize the Universe?

Saldana-Lopez 2022

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How did galaxies reionize the Universe?

Saldana-Lopez 2022

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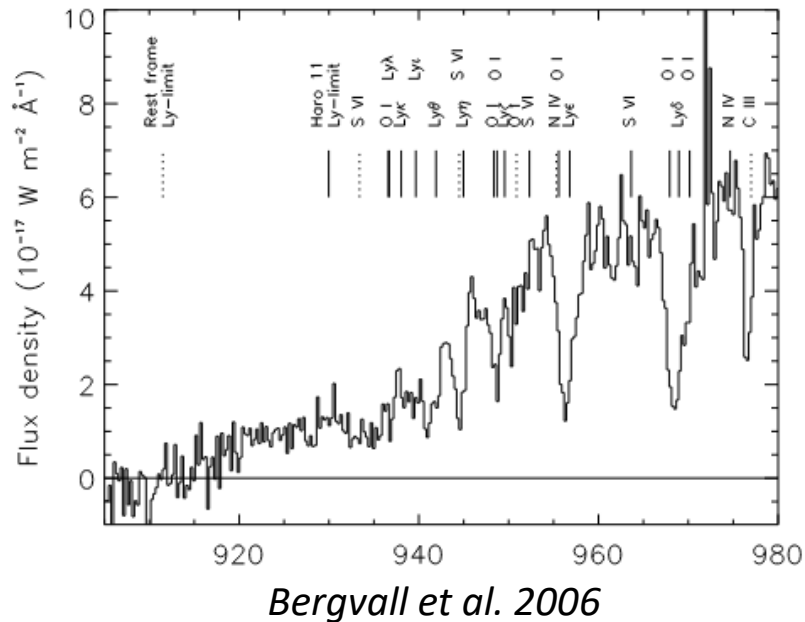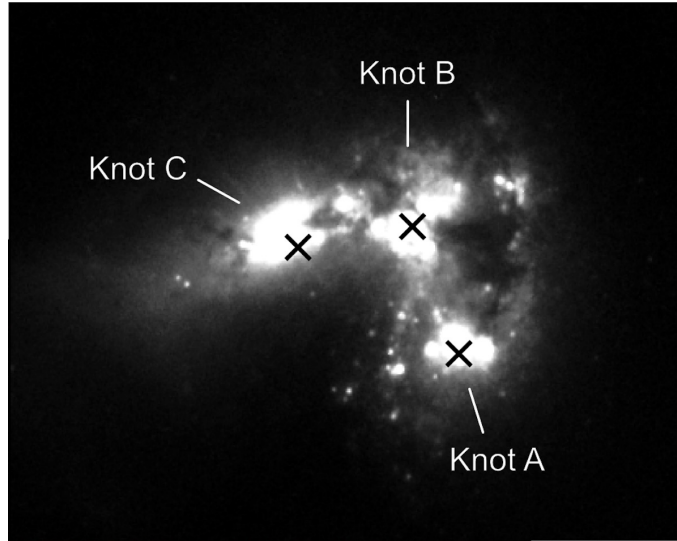

Need low column density, with **5-20%** LyC escape fraction to reionize the Universe.

How did galaxies reionize the Universe?

To understand LyC escape and reionization, we need **resolved observations of the neutral gas** distribution

→ 21cm line of Hydrogen

Haro 11 : a special laboratory

Bergvall et al. 2006

- First and closest (z~0.02) LyC emitter to be detected

- Blue compact galaxy

- SFR = 20-30 $M_\odot$/yr

- Escape fraction: 4-10%

- 12+ log O/H = 7.9

- $M_* = 1.6 \times 10^{10}\ M_\odot$

 → **Local analog to Reionization era galaxies**

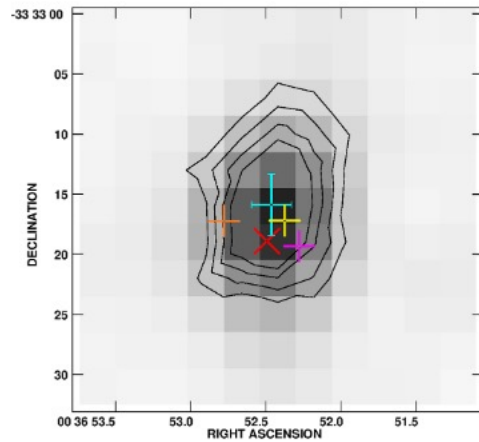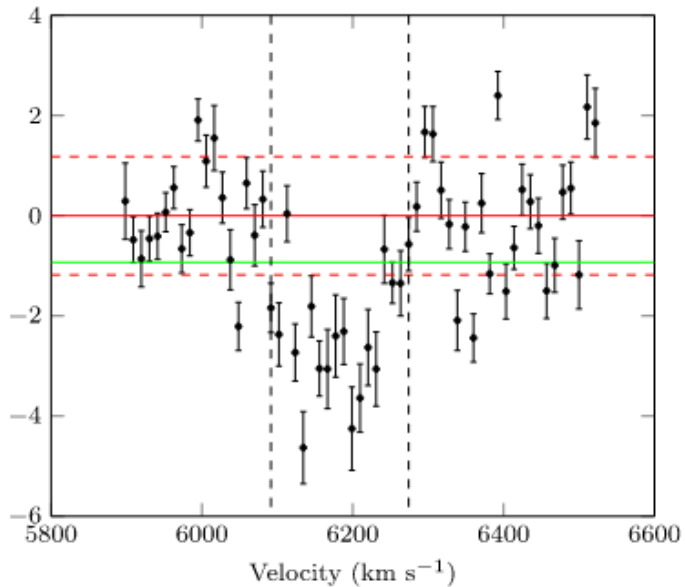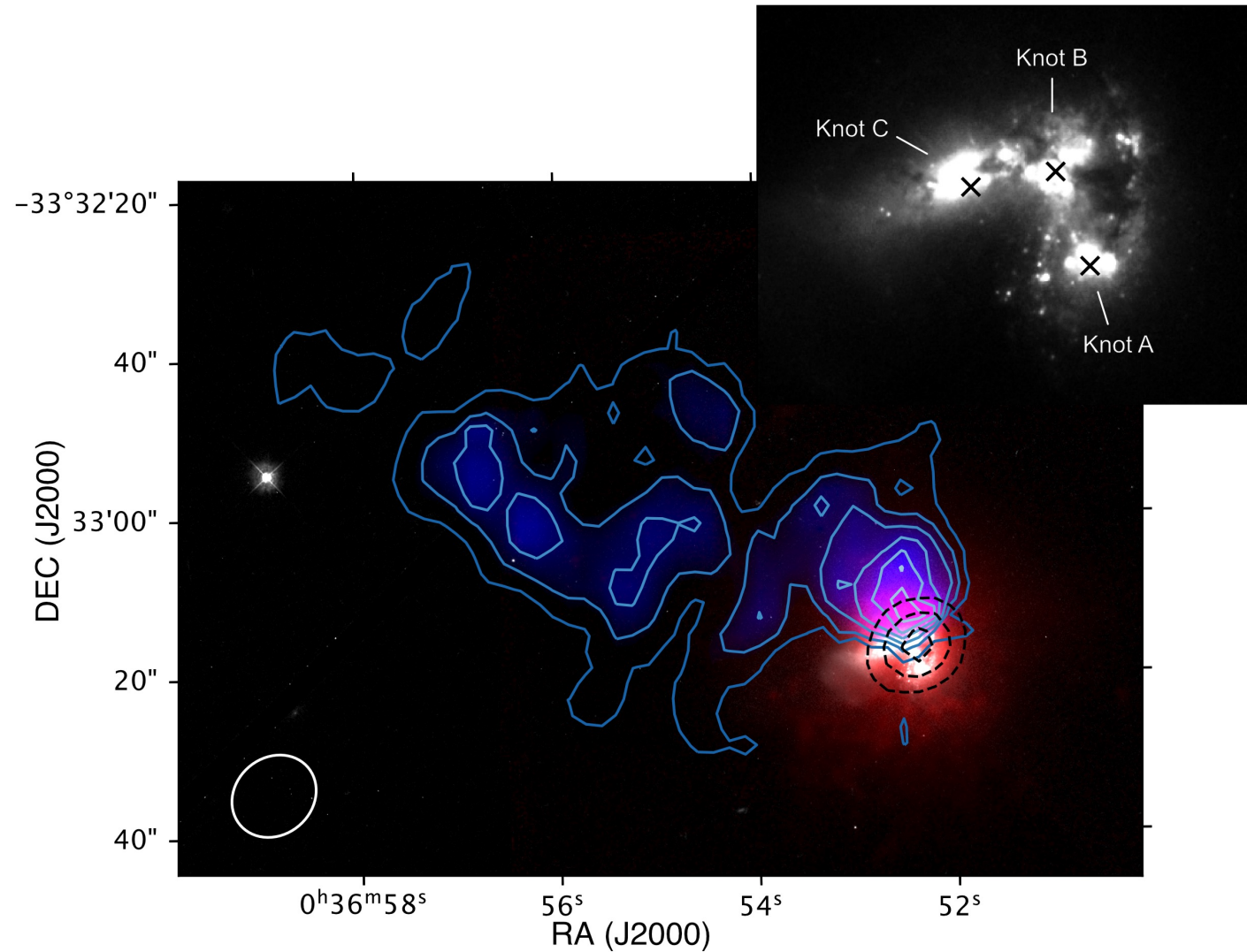# The Haro11 HI puzzle
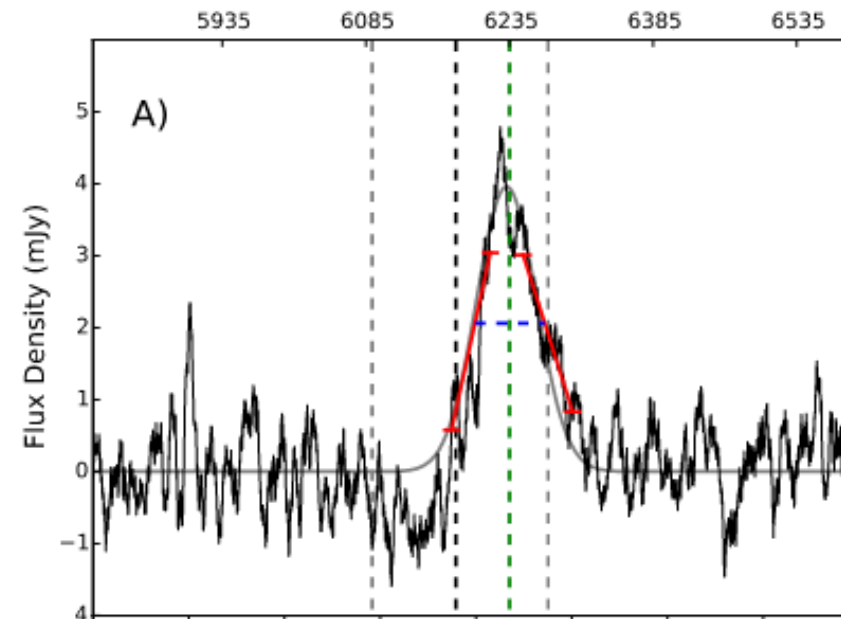
→ **How can the 21cm output be so different?**

21cm with MeerKAT
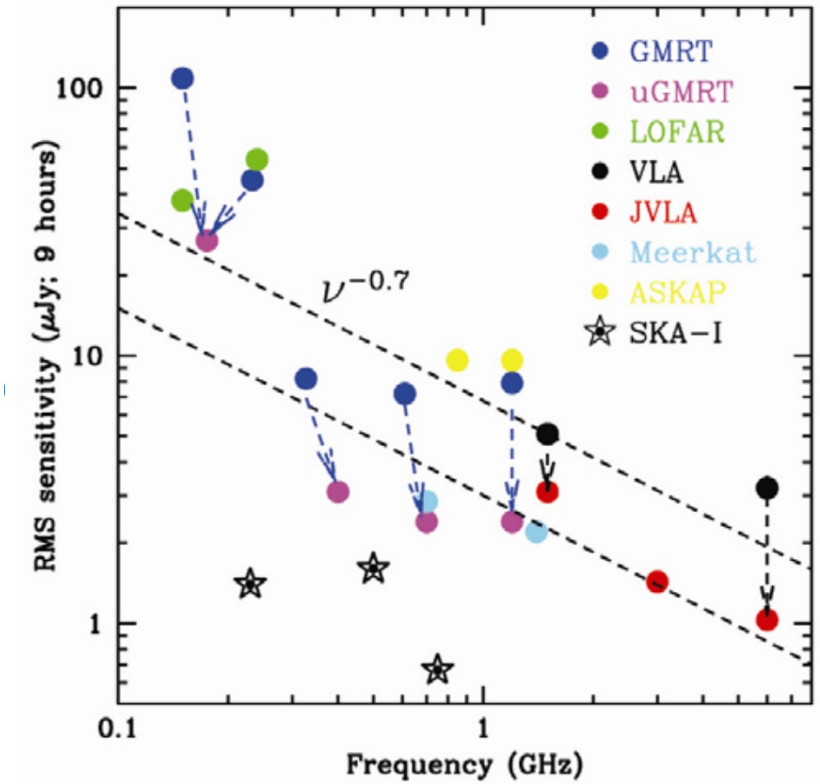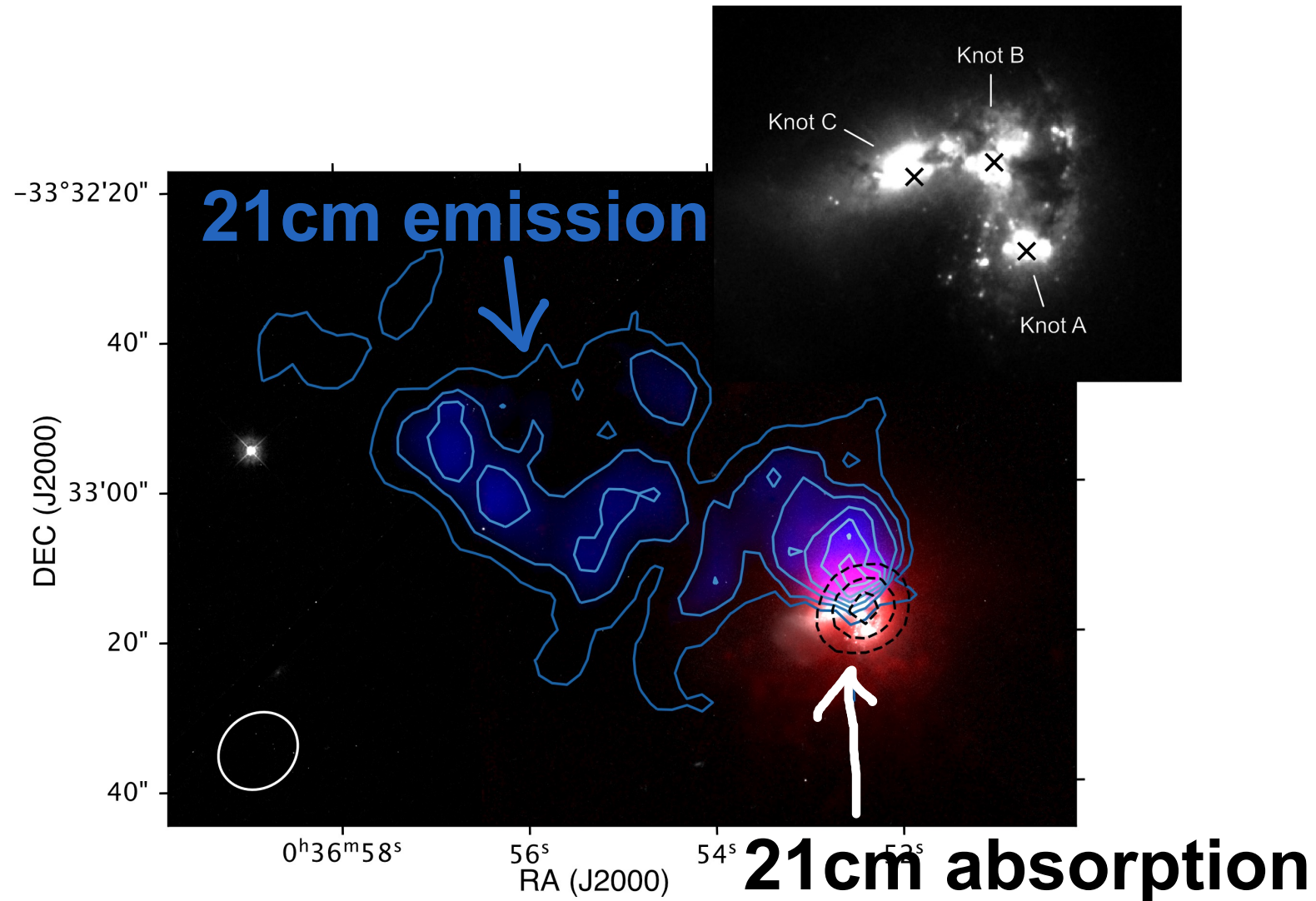

✓ The most sensitive telescope for HI studies
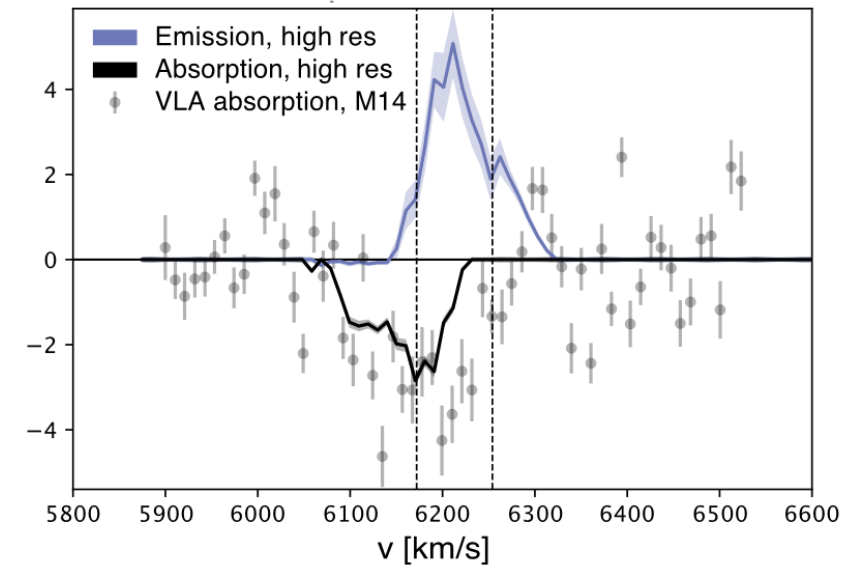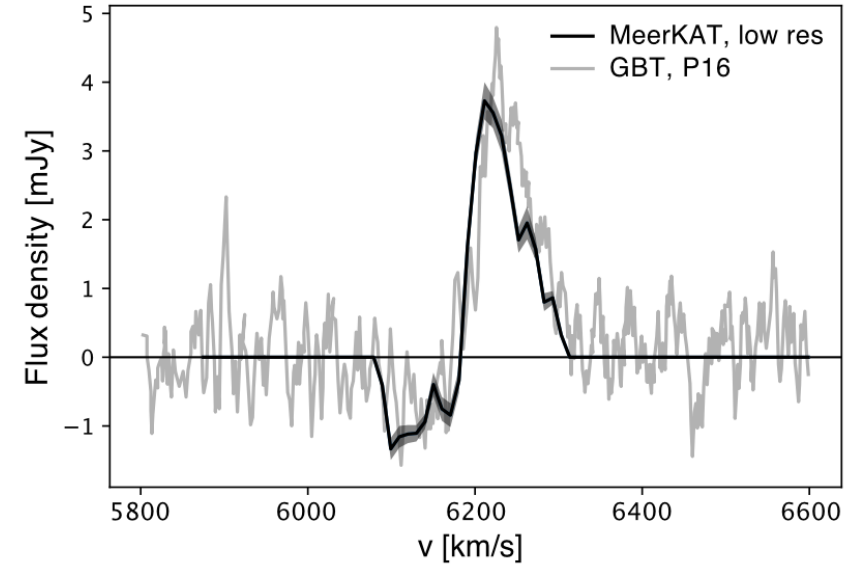✓ In the south
→ First international open call in 2020

What is happening in Haro11 ?

Le Reste et al. 2023, subm. to Nature Astronomy   arXiV: 2301.02676

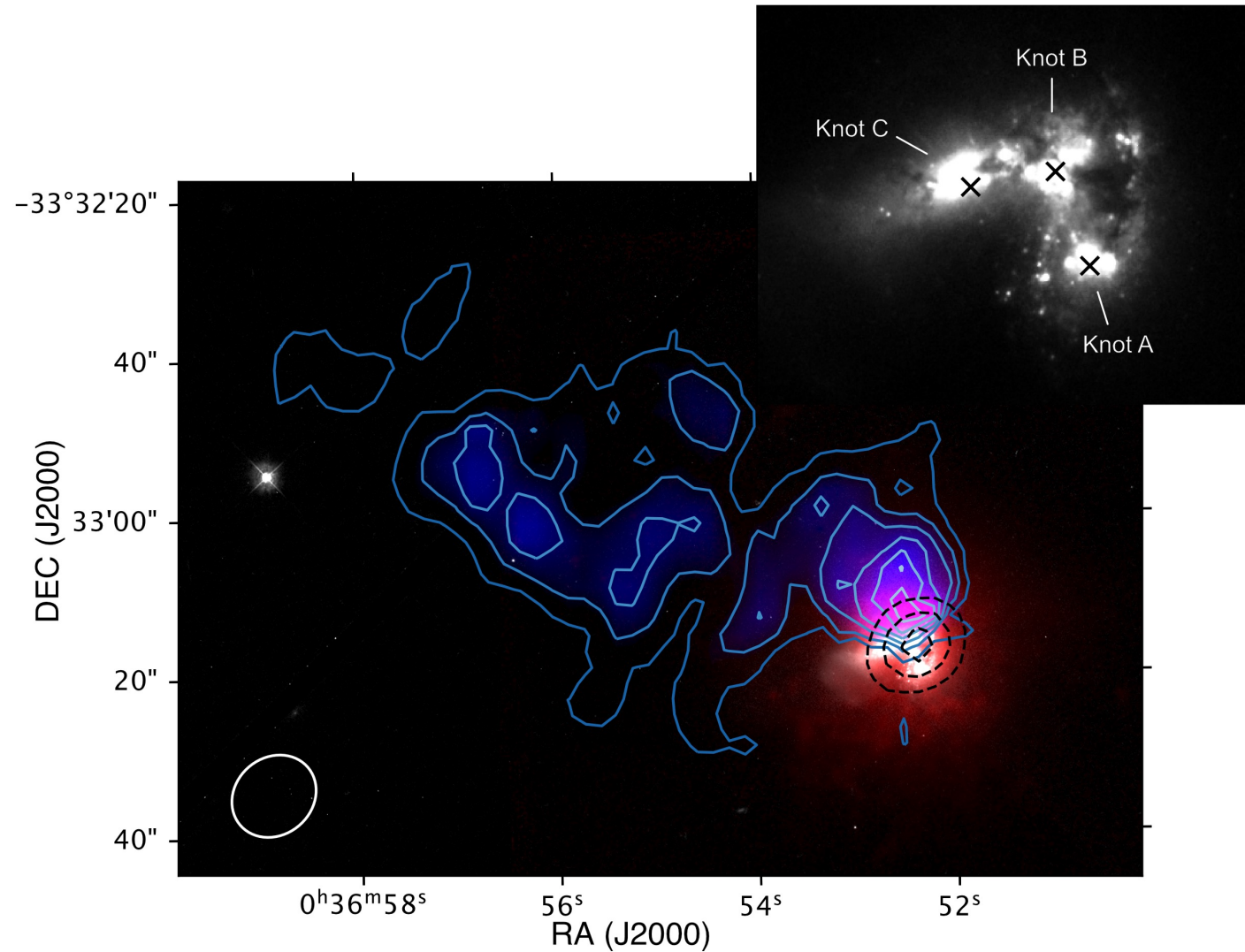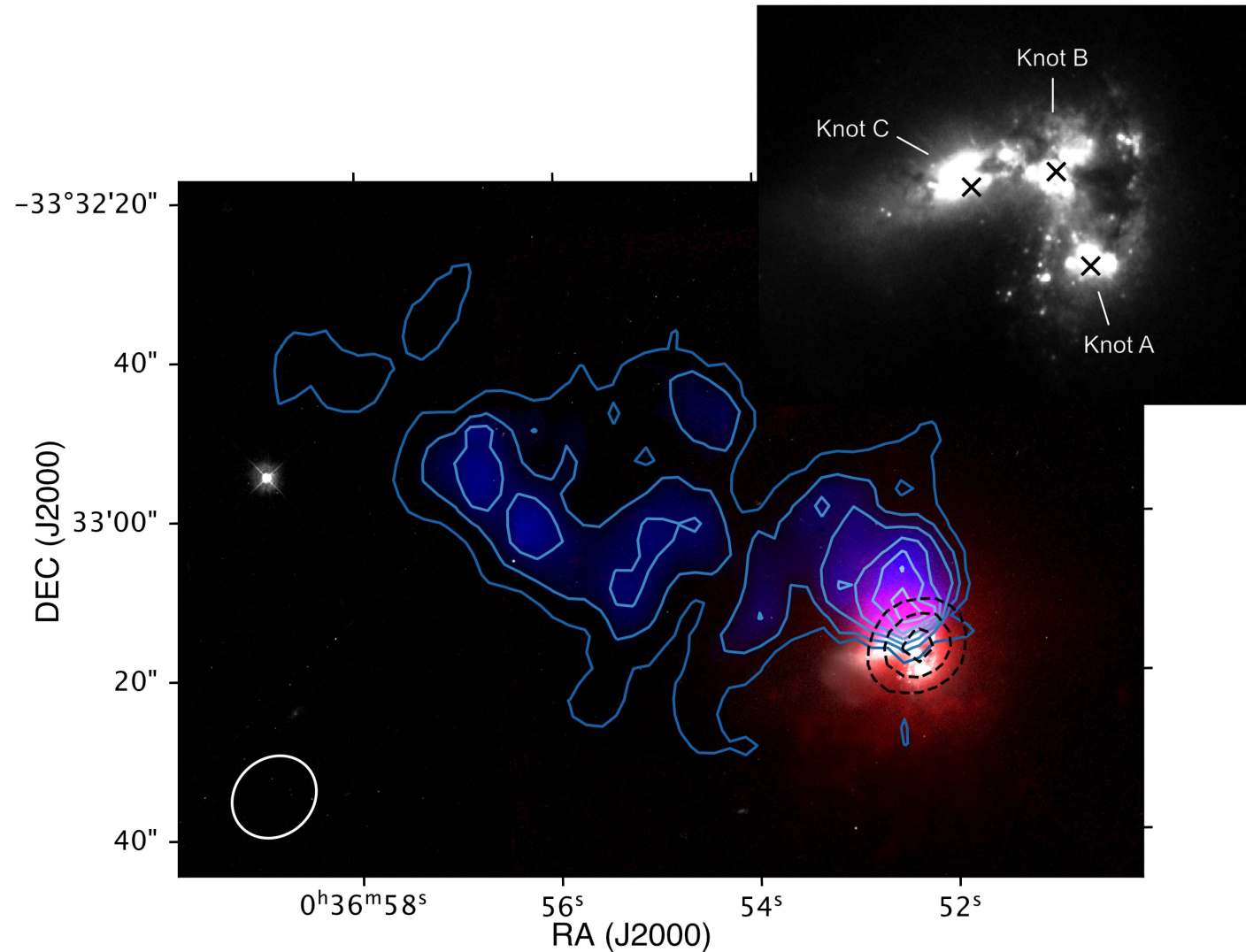# What is happening in Haro11 ?

What is happening in Haro11 ?

Neutral gas content of the galaxy

Neutral gas mass:

$$M_{HI,em} = 7.99 \pm 0.85 \times 10^8 M_\odot$$
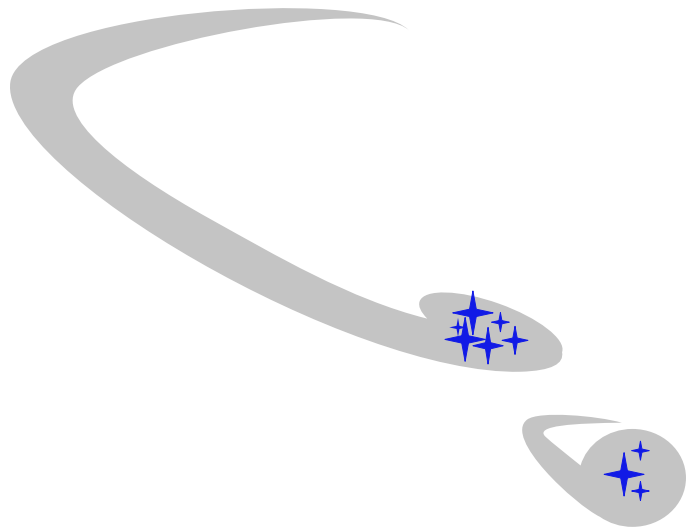$$M_{HI,abs} = 3.30 \pm 2.41 \times 10^8 M_\odot$$

Total mass of $1.1 \pm 0.3 \times 10^9$ $M_\odot$

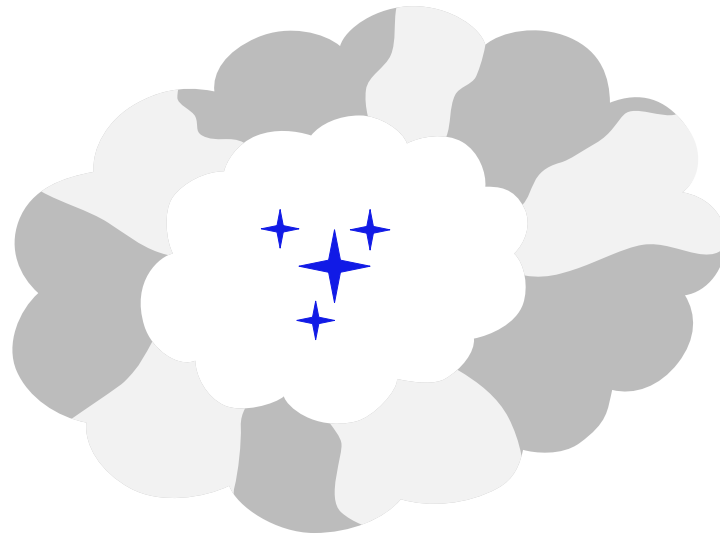**Up to 82% of the total gas mass is offset** from the locations where LyC is produced

Geometry results from **merger interactions**

The role of the merger

The merger plays several roles in enabling LyC escape in Haro11:

1) Cause several starburst episodes:
   Creates massive stars
   → LyC production
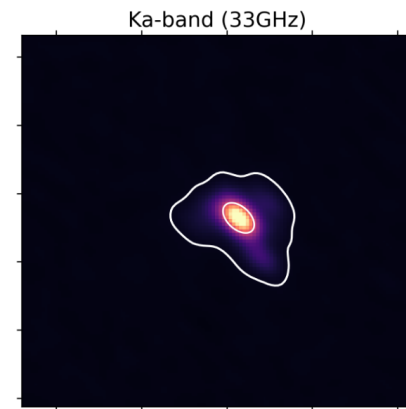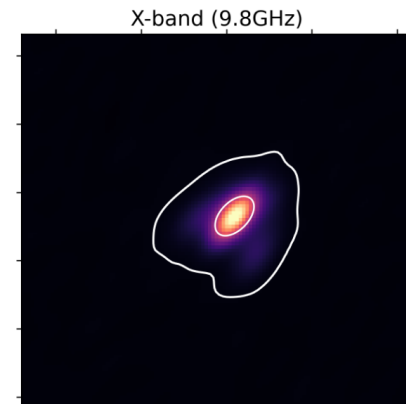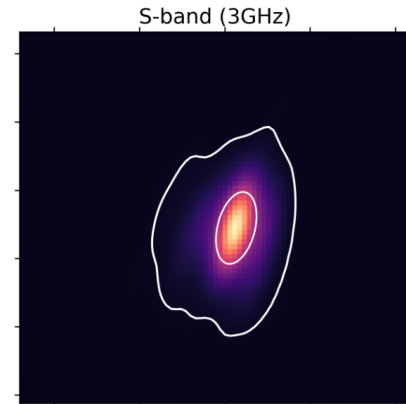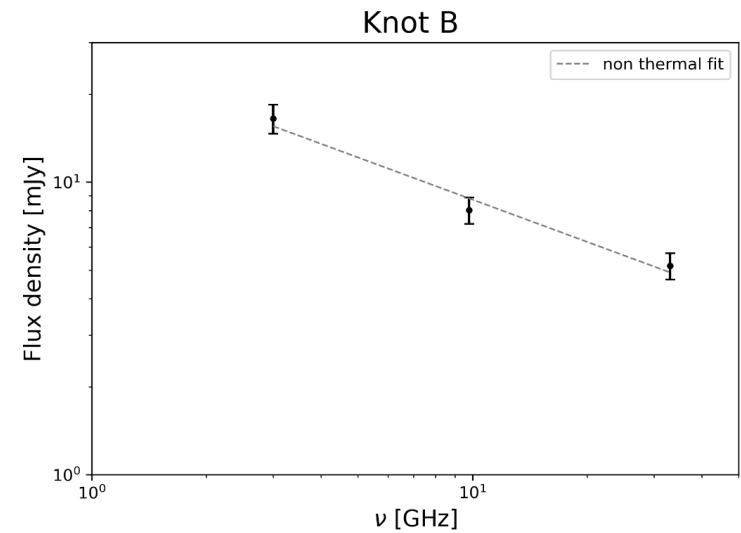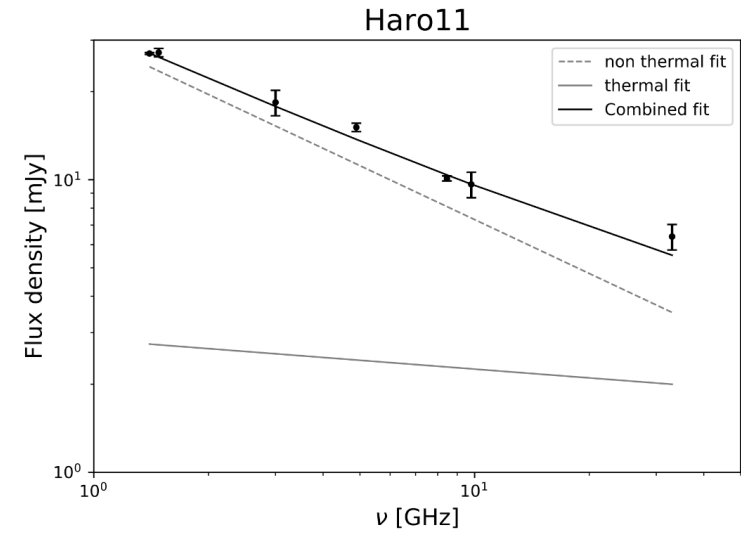
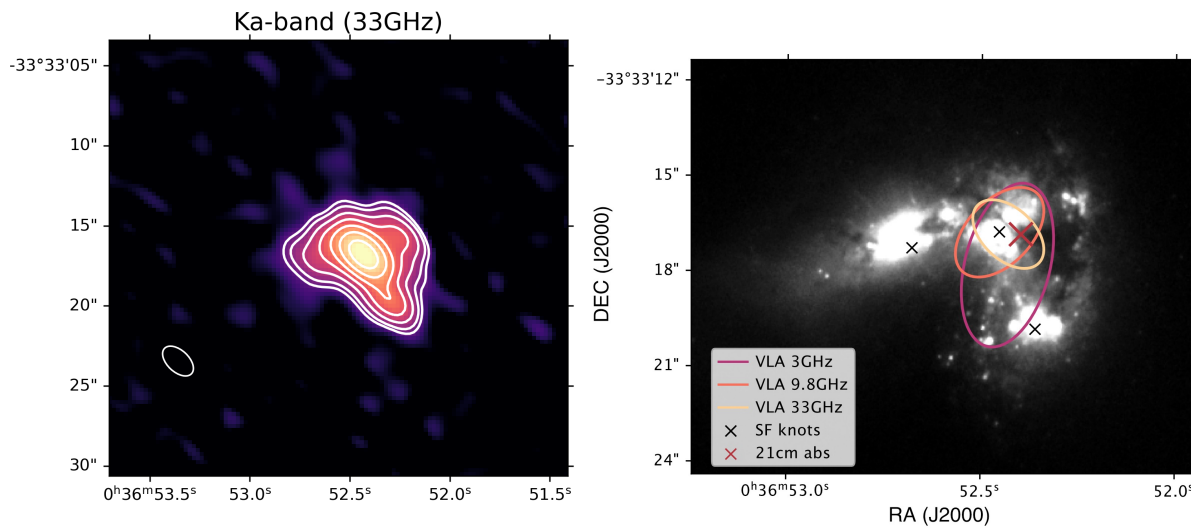2) Starburst generates large-scale ionized channels

3) Large scale displacement of HI
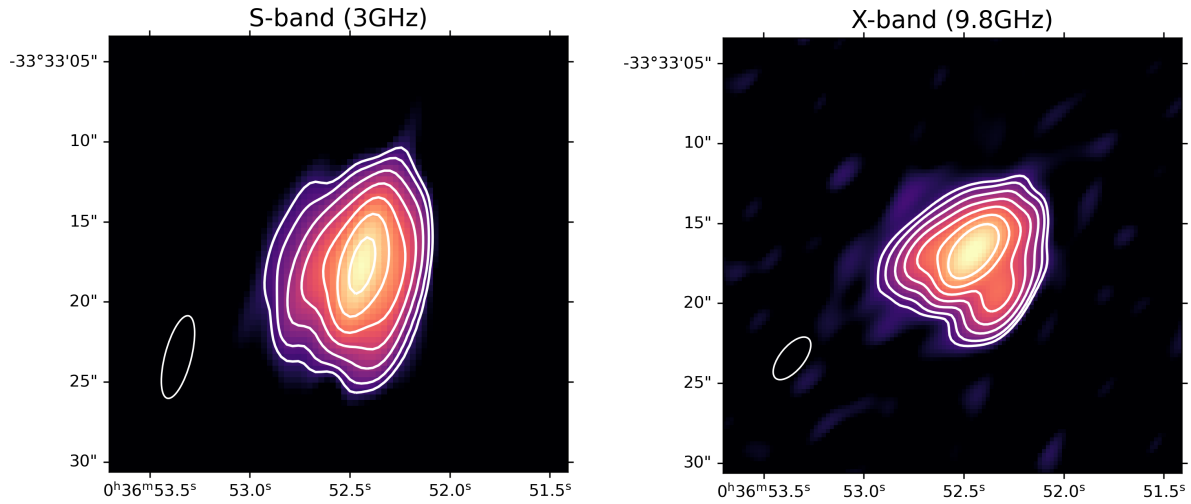   → anisotropic escape to IGM

Conclusions

- High-redshift analogs: detailed observations of physical and radiative processes

- First direct HI imaging in a confirmed LyC emitting galaxy, Haro11

- The neutral gas is offset due to merger interactions

- Mergers of galaxies/environment could contribute to reionization:
  → **Need systematic assessment of the impact of environment.**

Radio continuum source

S-band (3GHz)

X-band (9.8GHz)

Ka-band (33GHz)

Haro11

Knot B

S-band (3GHz)

X-band (9.8GHz)

Ka-band (33GHz)

Ionized gas structure
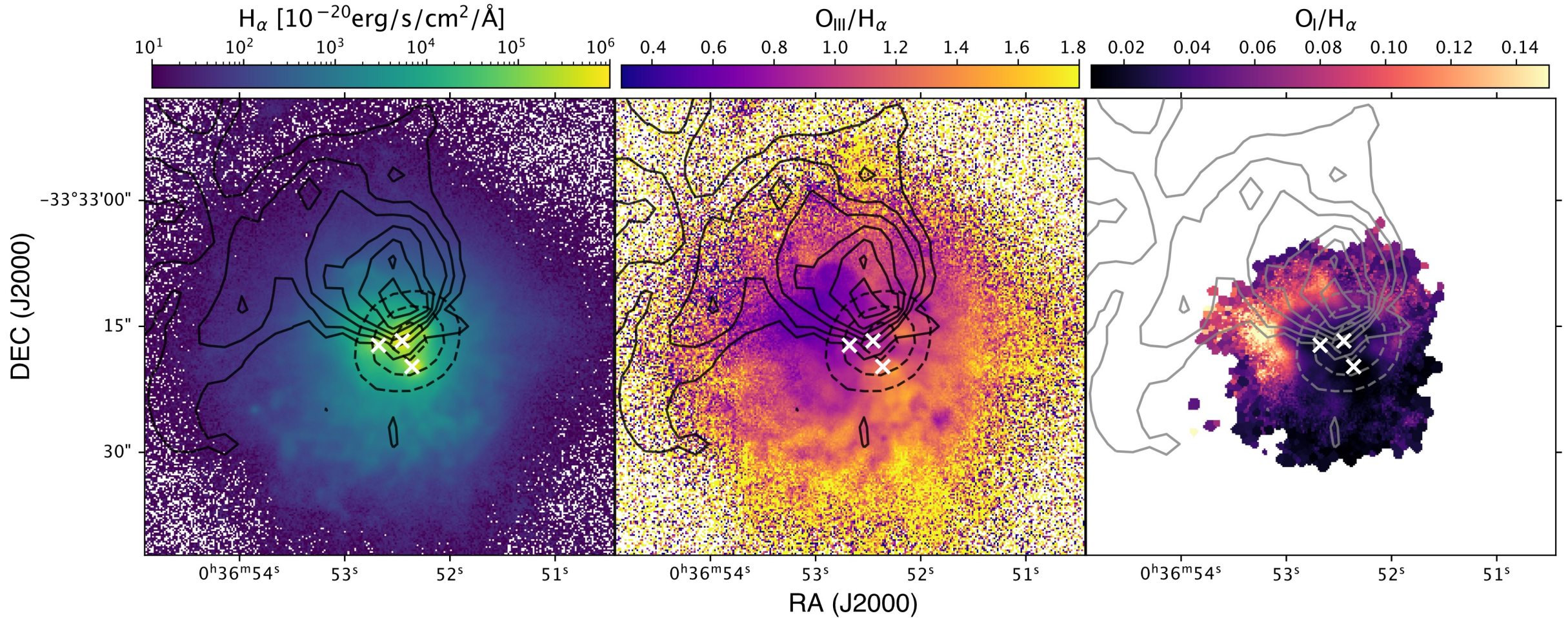
Interstellar medium of Haro11 - a model

Tidal gas falling back onto the galaxy

Redshifted HI gas seen in emission

Expanding Ionized gas

Shock front traced by OI/Ha

Radio continuum source in Knot B

Blueshifted HI gas seen in absorption