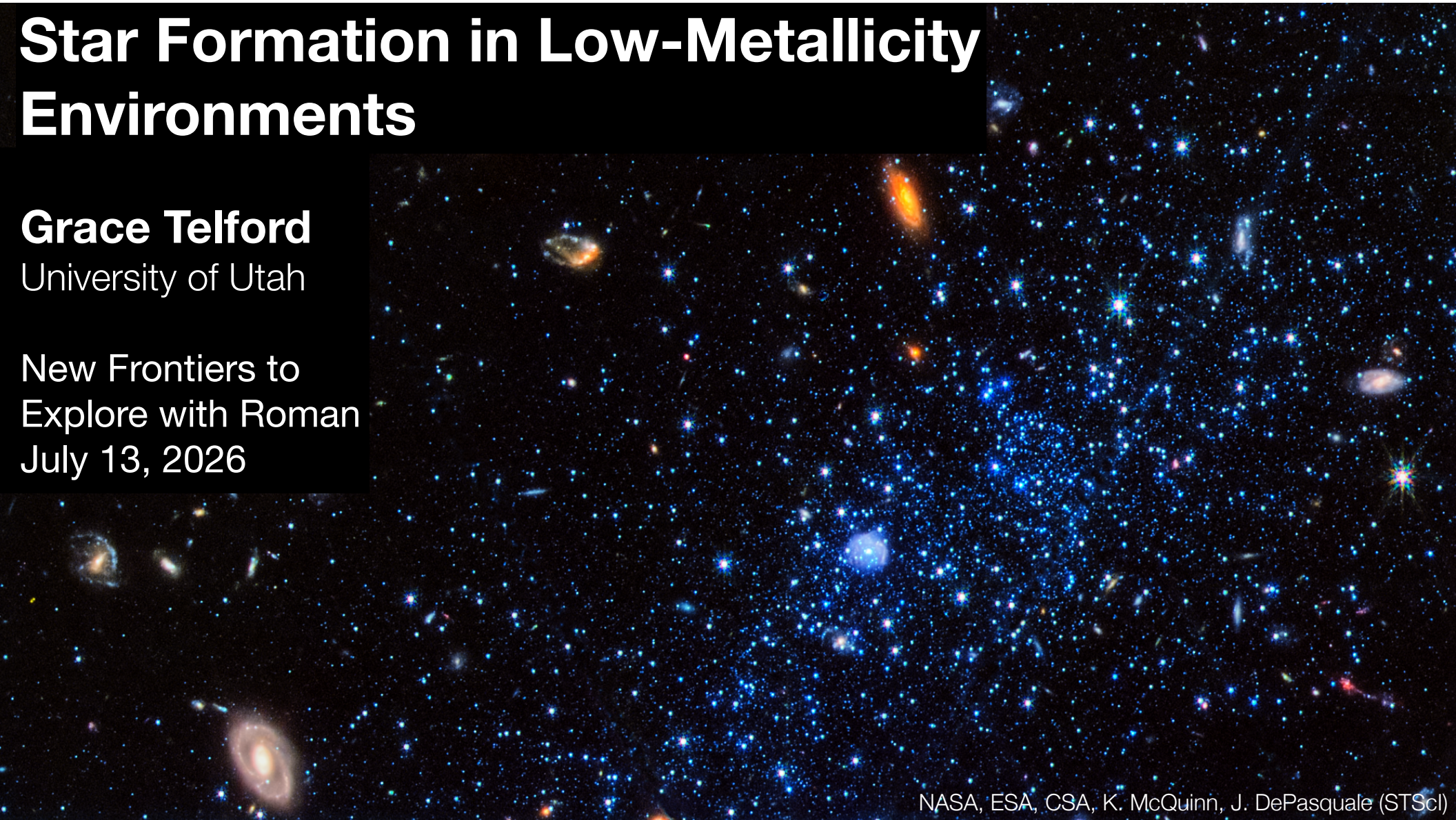


Star Formation in Low-Metallicity Environments

Grace Telford

University of Utah

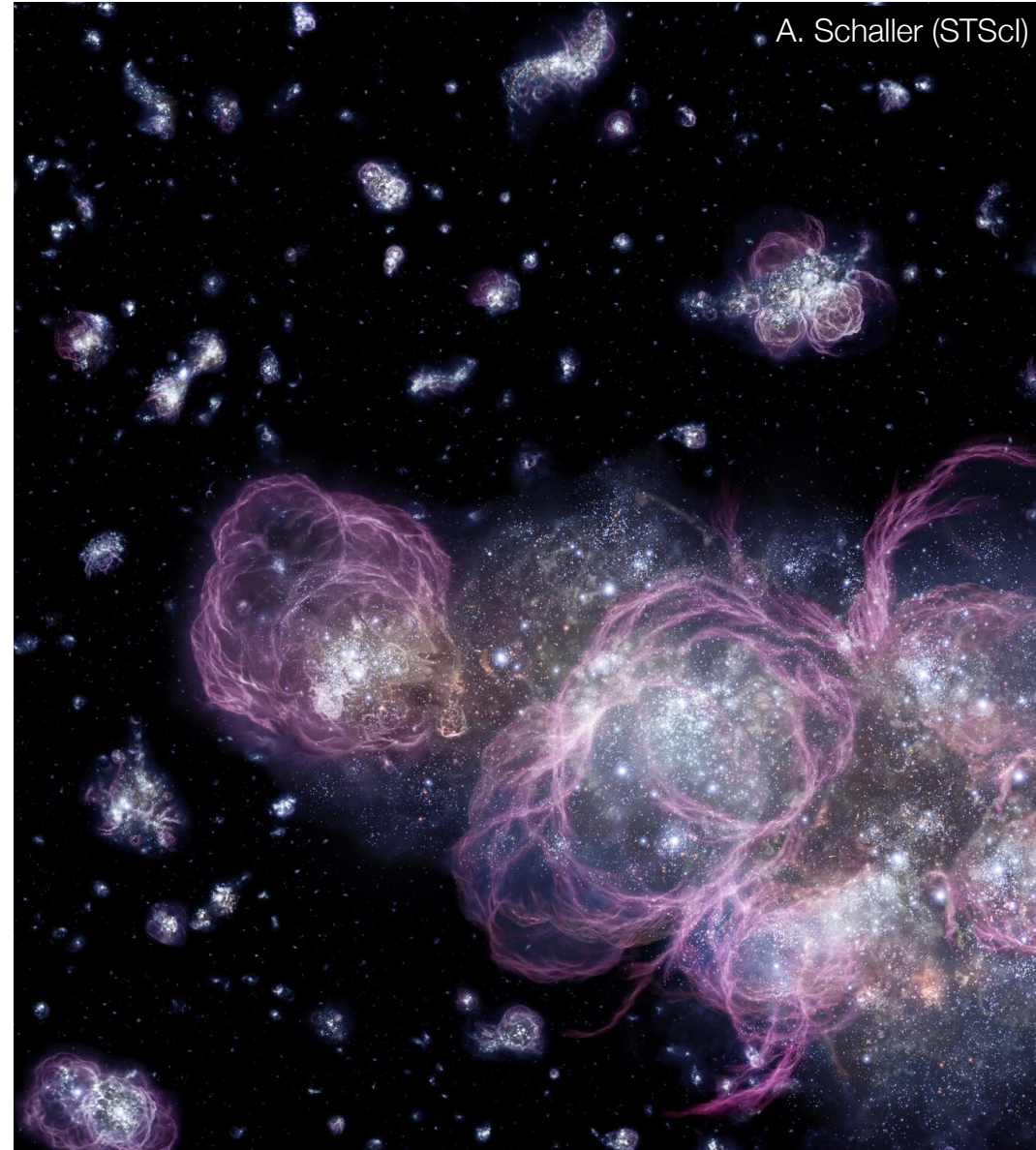
New Frontiers to
Explore with Roman
July 13, 2026



NASA, ESA, CSA, K. McQuinn, J. DePasquale (STScI)

Models of low-metallicity massive star formation, evolution, and spectra affect:

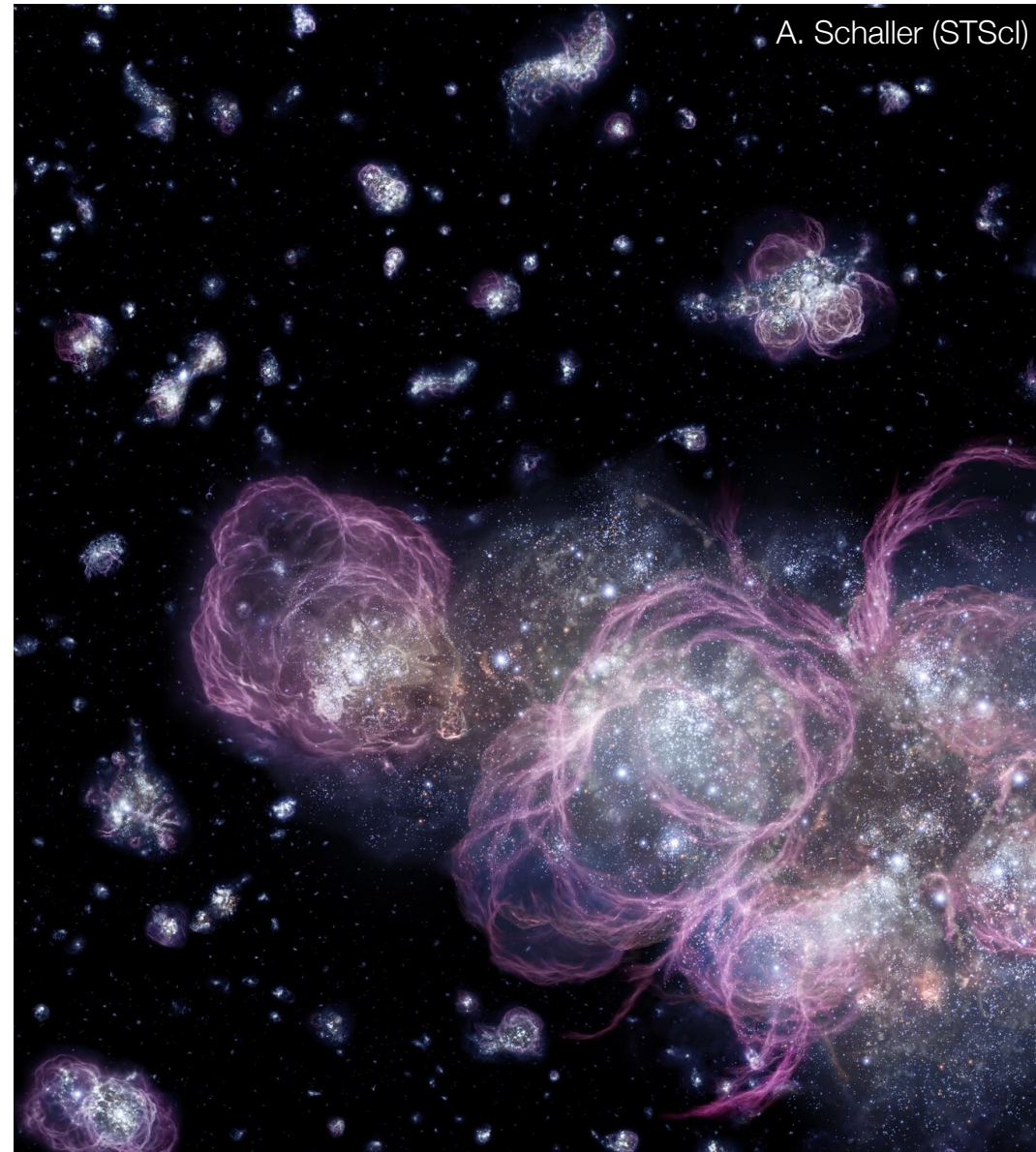
- feedback models for low-metallicity dwarf galaxies
- the implied drivers of cosmic reionization at high redshift



Models of low-metallicity massive star formation, evolution, and spectra affect:

- feedback models for low-metallicity dwarf galaxies
- the implied drivers of cosmic reionization at high redshift

Issue: empirical constraints are extremely rare below 20% $Z_{\odot}$, leaving models unconstrained

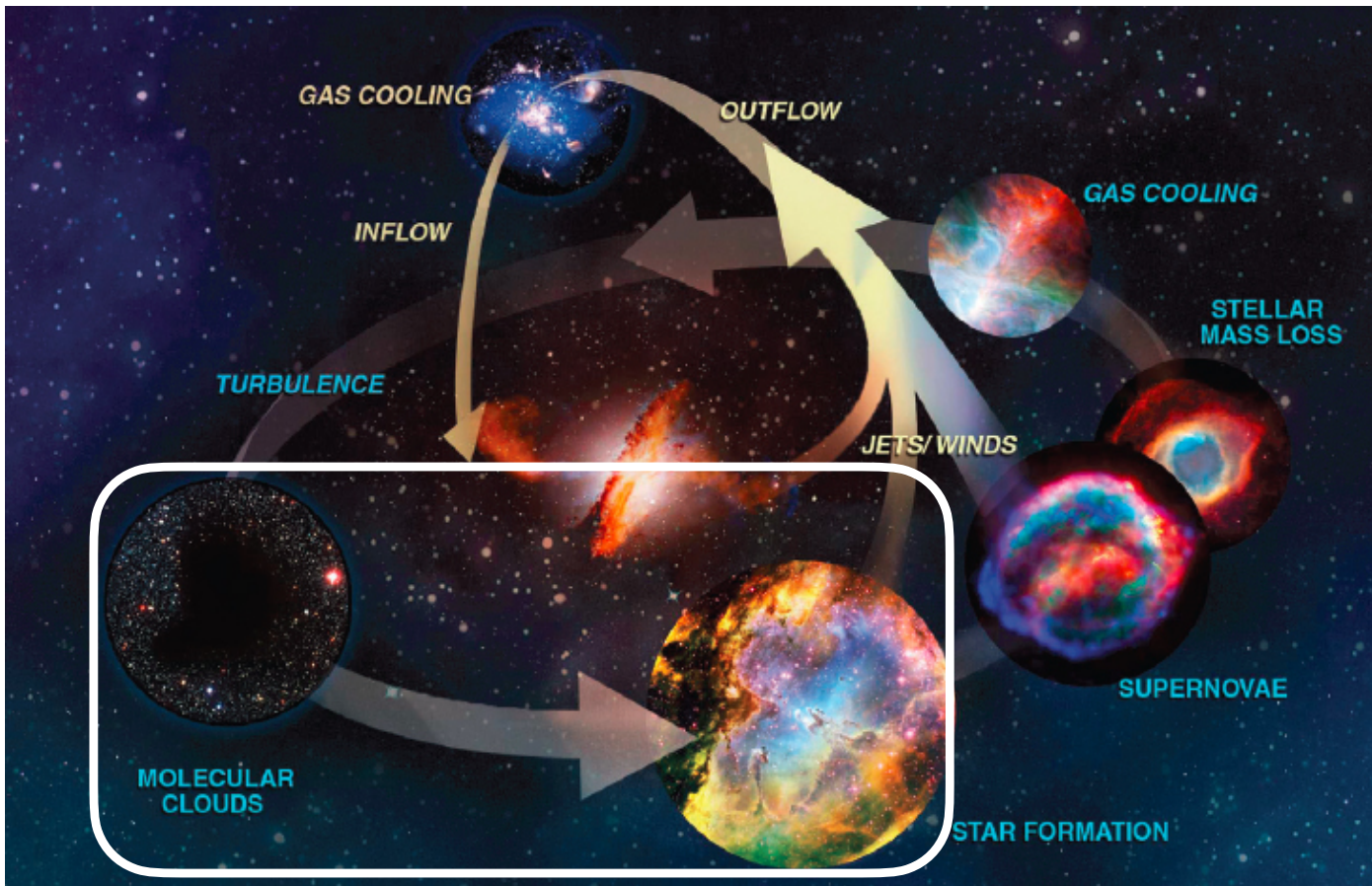


Leo P is a nearby, 3% $Z_{\odot}$ galaxy
containing just one O star that
ionizes its only H II region

Skillman+ (2013); McQuinn+ (2015); Evans+ (2019)

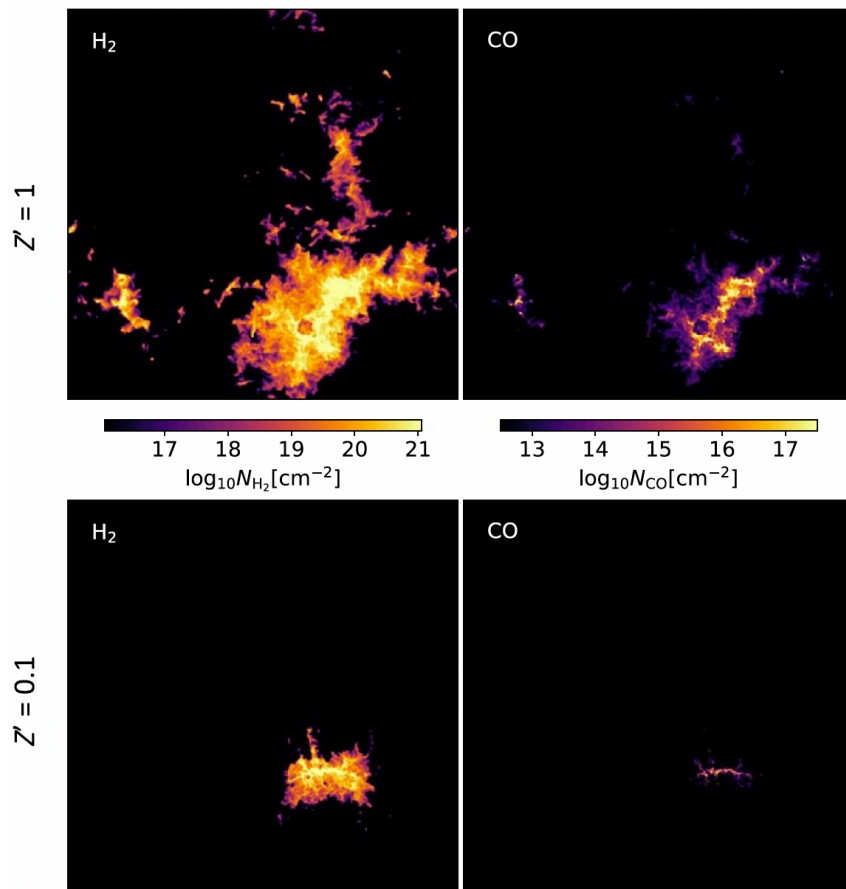


Baryons cycle between gas and stars within and beyond galaxies



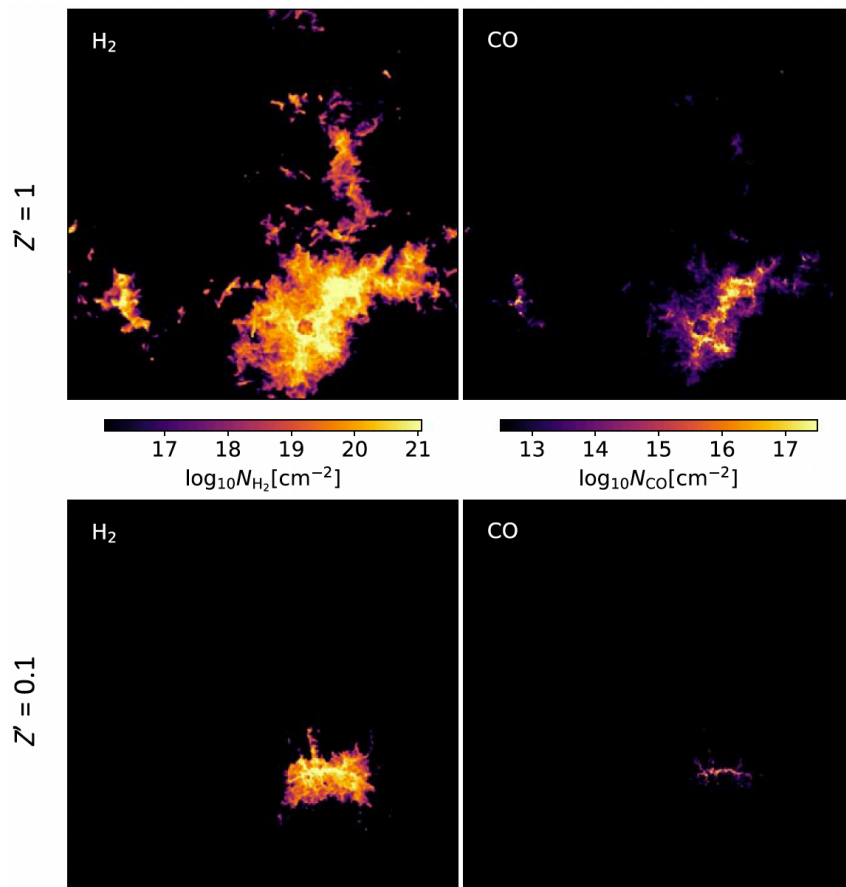
We observe that star formation occurs in cold, dense molecular clouds (dominated by H₂) in metal-rich galaxies like our Milky Way

Molecular gas formation is predicted to be inefficient at low metallicity



Metals cool gas and form dust
that catalyzes H_2 formation

Molecular gas formation is predicted to be inefficient at low metallicity

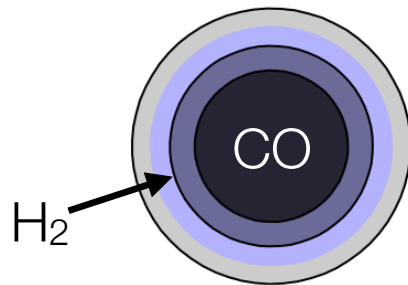


Metals cool gas and form dust that catalyzes H_2 formation

Simulations predict that star formation can occur in predominantly atomic gas at the very low metallicities typical of galaxies in the early Universe

Observing the fuel for star formation at low metallicity is challenging

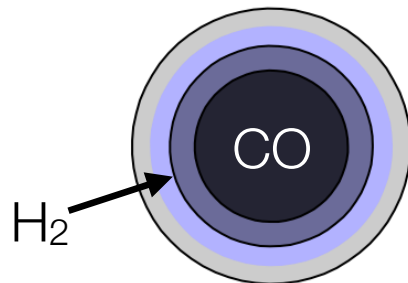
Milky Way-like Galaxies



CO is used as a tracer of unobservable, **cold** H₂

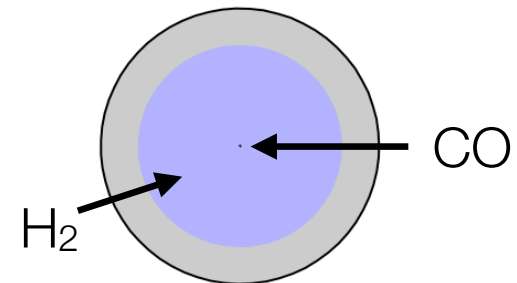
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Milky Way-like Galaxies



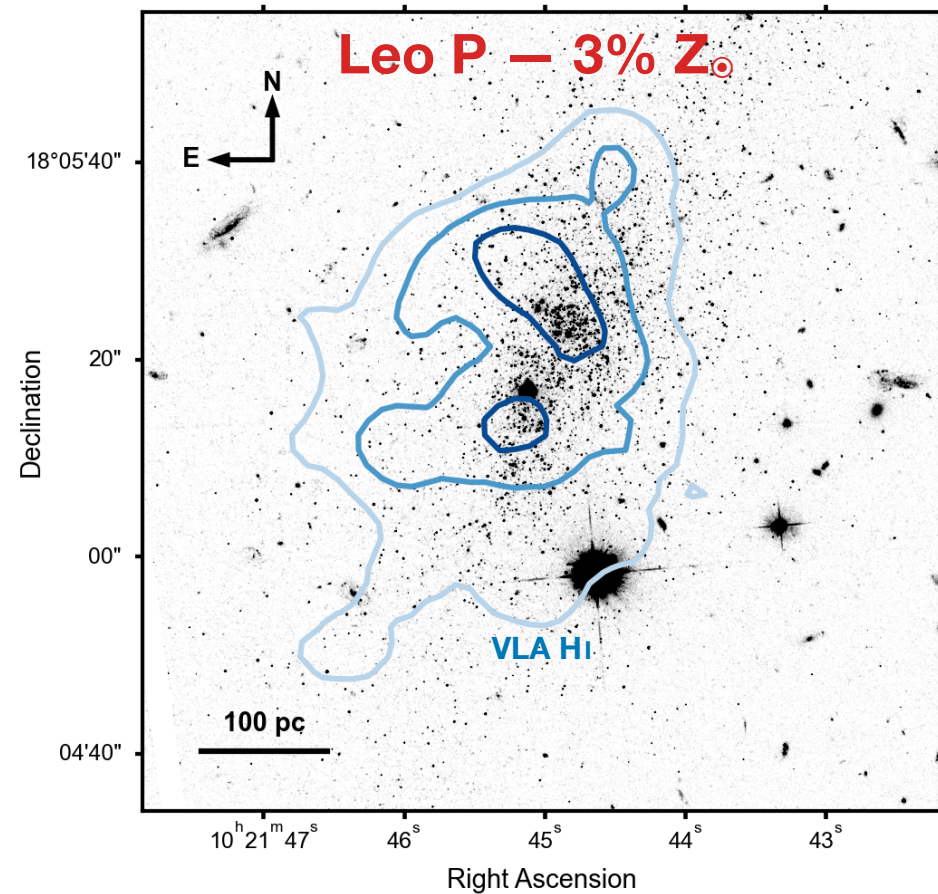
CO is used as a tracer of unobservable, **cold** H₂

Low-metallicity galaxies



CO-to-H₂ conversion factor (α_{CO}) becomes very large and uncertain

Is molecular gas abundant in very metal-poor galaxies?



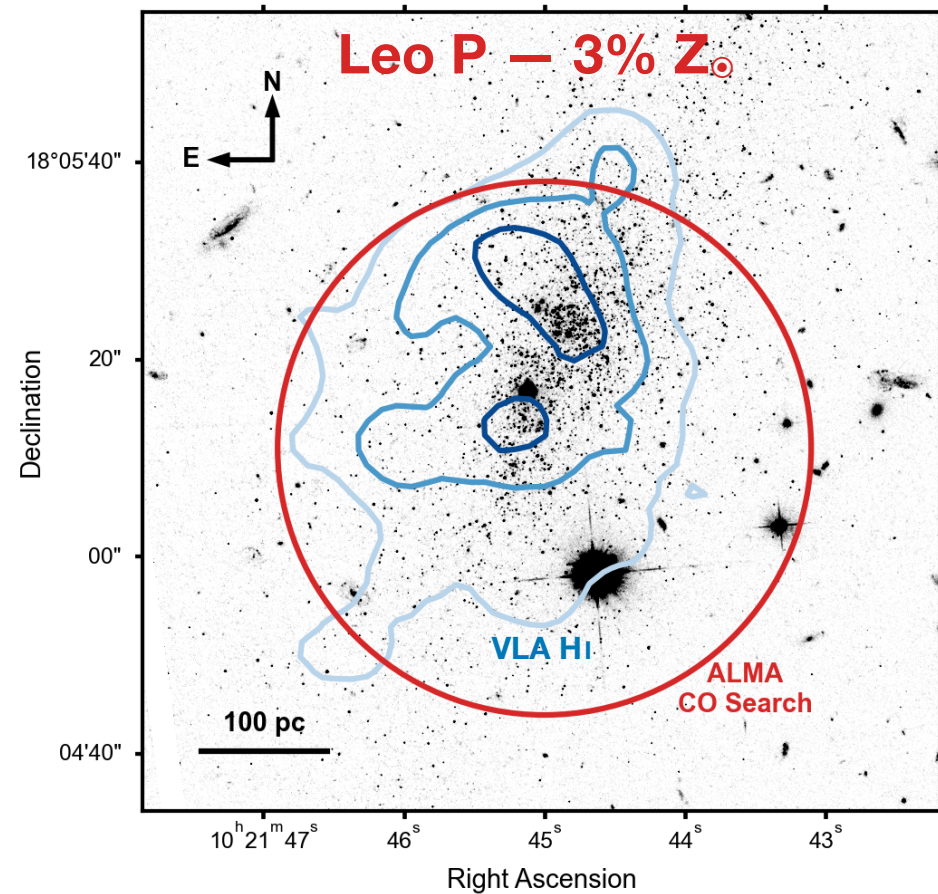
Secure CO detections at sub-SMC
metallicity in nearby dwarfs:

WLM: 14% $Z_{\odot}$
(Elmegreen+ 2013)

Sextans B: 7% $Z_{\odot}$
(Shi+ 2020)

Telford+ (2025, *Nature*)

Is molecular gas abundant in very metal-poor galaxies?



Secure CO detections at sub-SMC metallicity in nearby dwarfs:

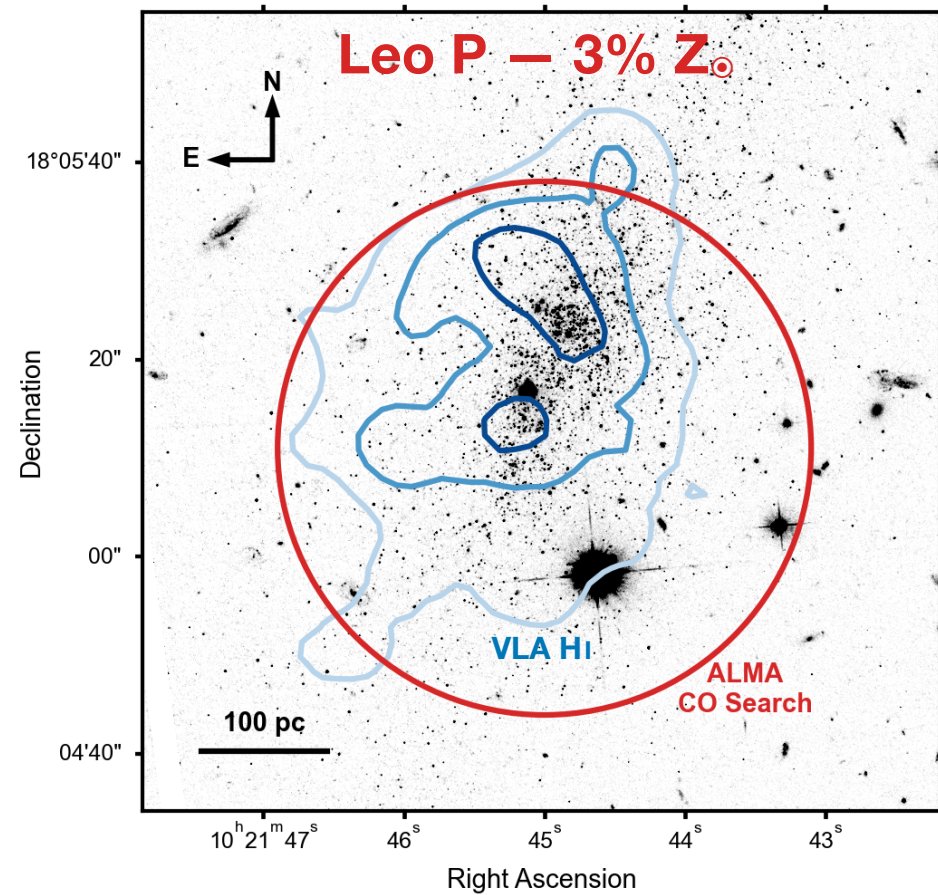
WLM: $14\% Z_{\odot}$
(Elmegreen+ 2013)

Sextans B: $7\% Z_{\odot}$
(Shi+ 2020)

An ALMA search of Leo P failed to detect CO in this more metal-poor environment

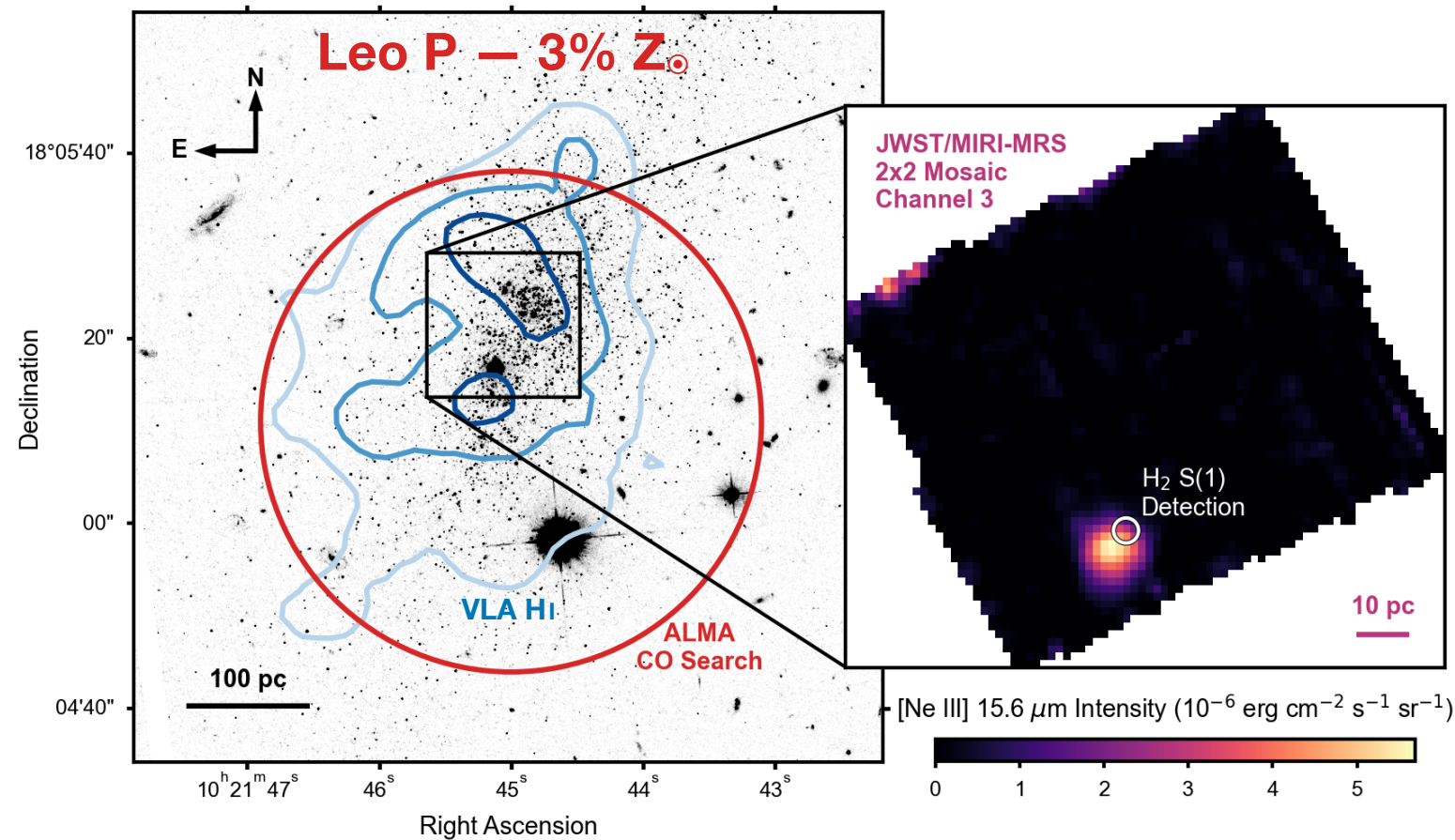
Telford+ (2025, *Nature*)

Is molecular gas abundant in very metal-poor galaxies?



Telford+ (2025, *Nature*)

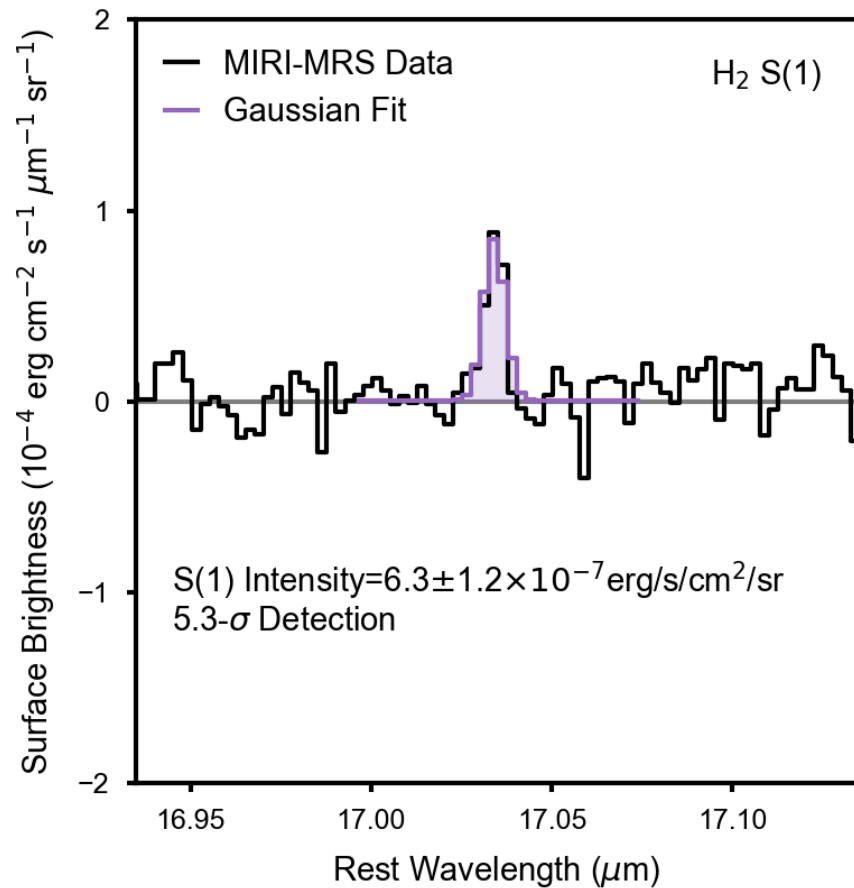
Is molecular gas abundant in very metal-poor galaxies?



First evidence of
molecular gas in
a star-forming
region at such
low metallicity!

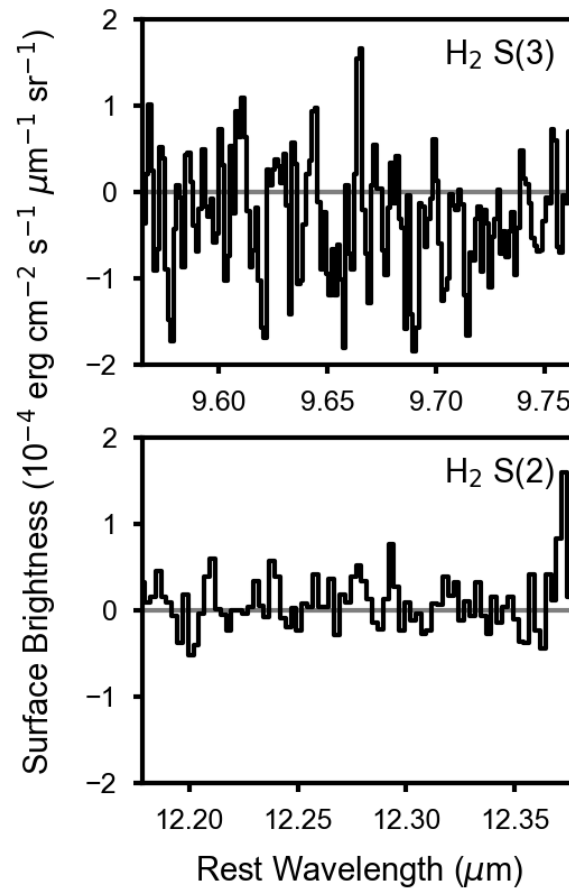
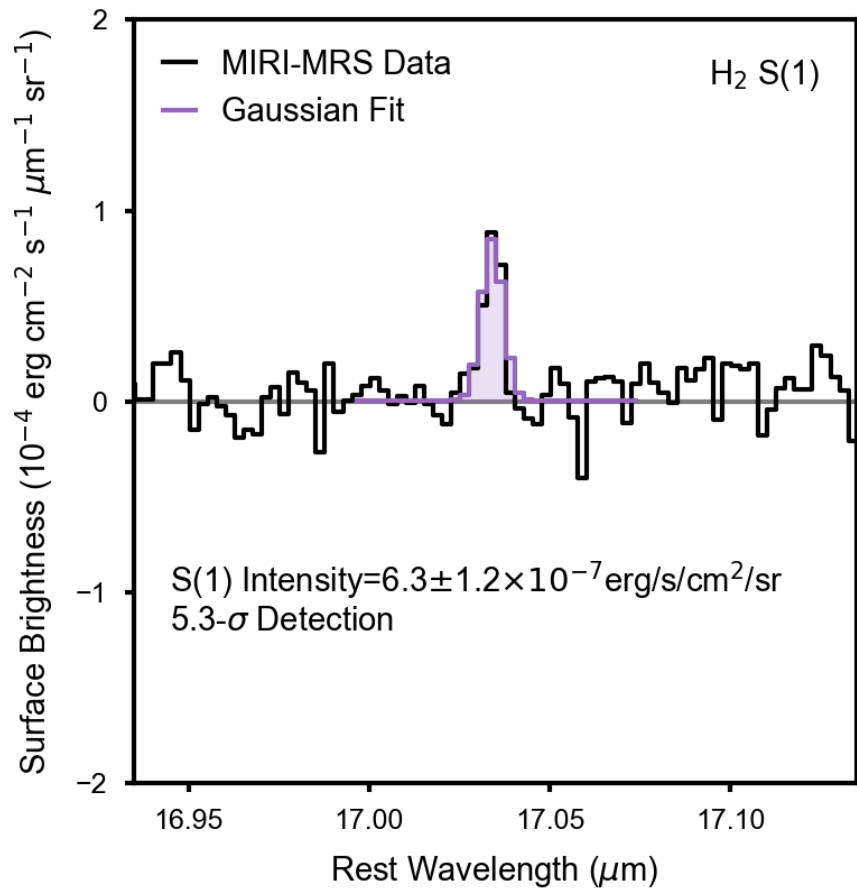
Telford+ (2025, *Nature*)

MIRI-MRS was *just* able to detect weak rotationally excited emission



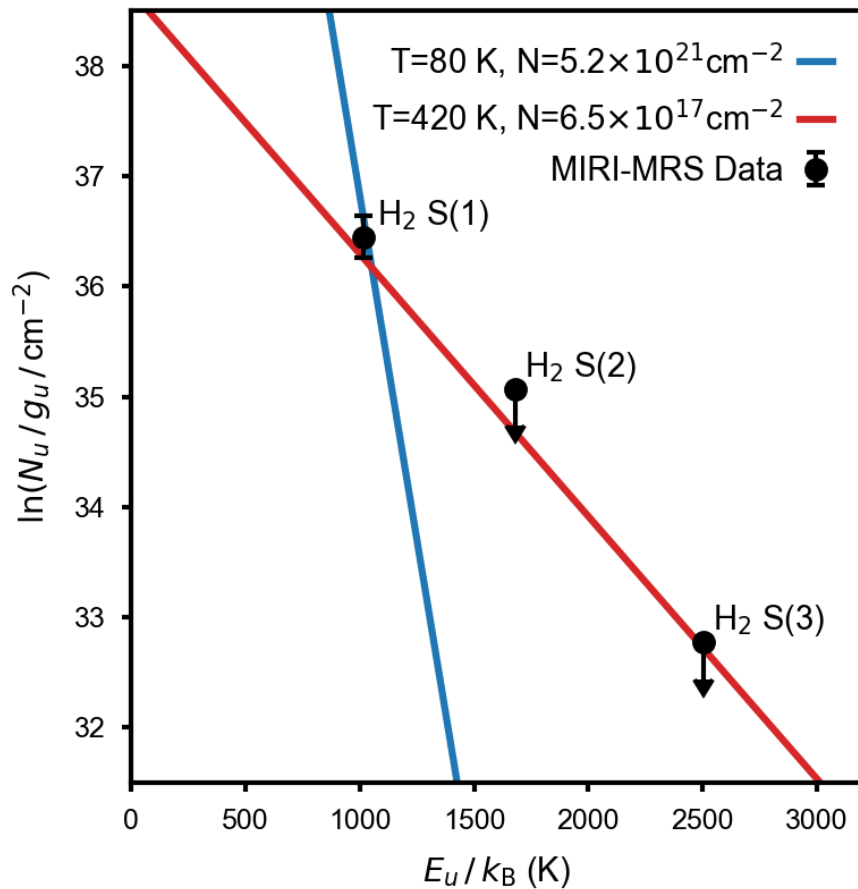
Telford+ (2025, *Nature*)

MIRI-MRS was *just* able to detect weak rotationally excited emission



Non-detections,
only upper limits
(and no useful
limit on the S(0)
line at 28.2 μm)

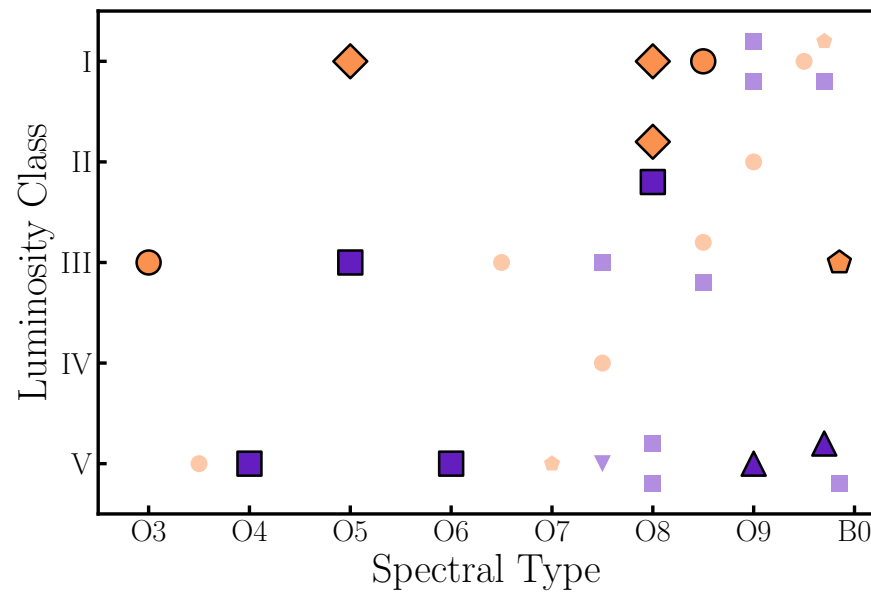
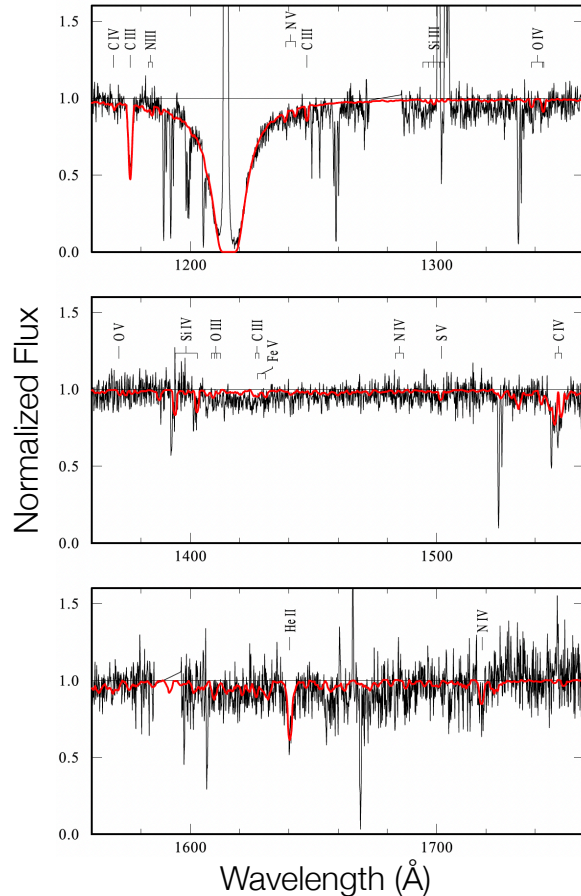
Upper limits alone allow for the warm H₂ to be up to ~400 K



Observations of the only O star's UV spectrum enabled us to model the surrounding gas

Far-UV spectroscopy from the TEMPOS HST Treasury Program

Leo P's O star

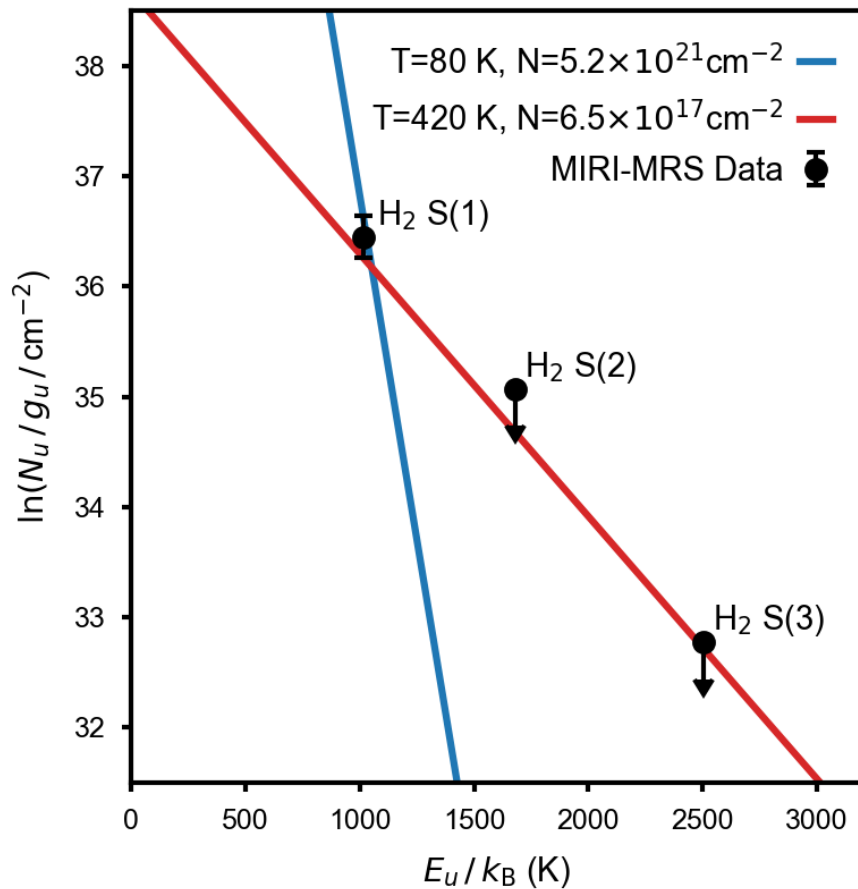


110 orbits of COS
time → FUV spectra
for 29 massive O
stars below 20% $Z_{\odot}$

New constraints on
stellar winds and
ionizing spectra in
dwarf and high-
redshift galaxies

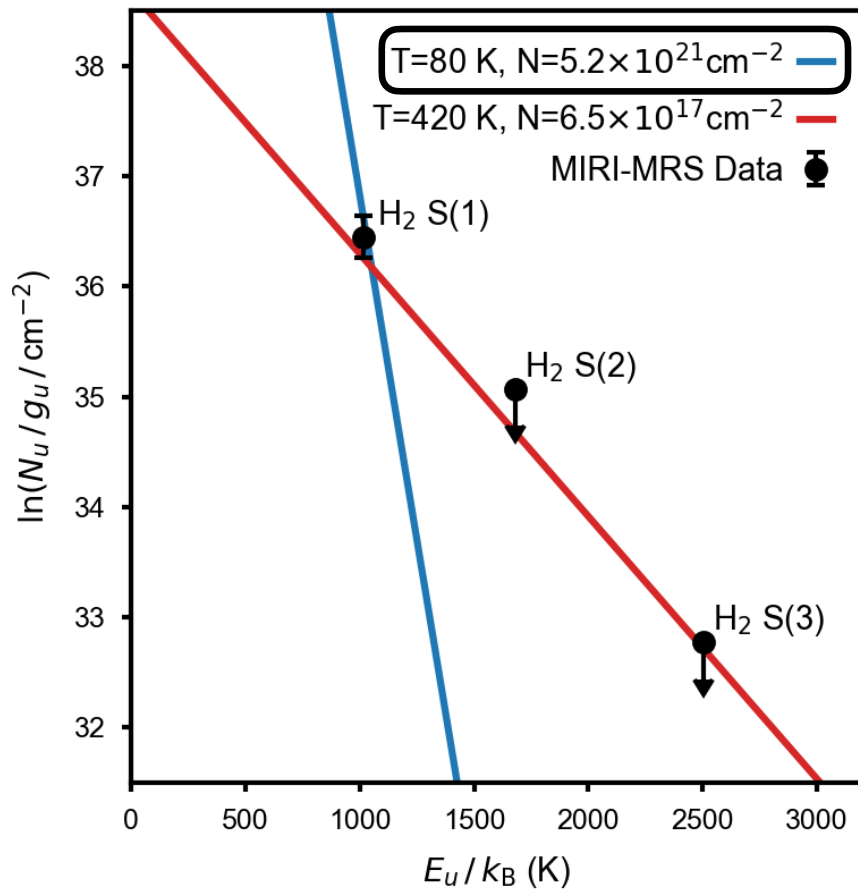
Telford+ (2024; 2026, submitted)

Modeling favors a low temperature for the detected H₂ in Leo P



Observations of the only O star's UV spectrum enabled us to model the surrounding gas

Modeling favors a low temperature for the detected H₂ in Leo P



Observations of the only O star's UV spectrum enabled us to model the surrounding gas

Likely scenario: ~ 80 K, $\sim 10^3 M_{\odot}$ clump of **warm** H₂, implying a larger mass of colder molecular gas not illuminated by the O star

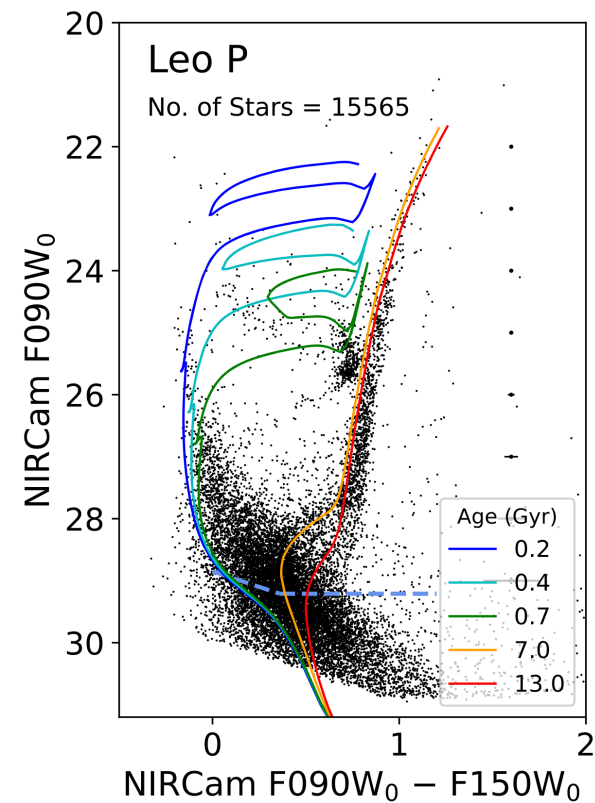
Roman will deliver a new view of star formation across local galaxies



Roman's resolution, wide field of view, and IR sensitivity will detect embedded young stellar objects to directly trace ongoing star formation

Dust mapping will probe the ISM in star-forming regions

Resolved stellar populations also probe feedback from star formation



Color-magnitude diagram (CMD) of resolved stars

→ infer history of star formation and metal enrichment

McQuinn, Newman, Skillman, Telford+ (2024)

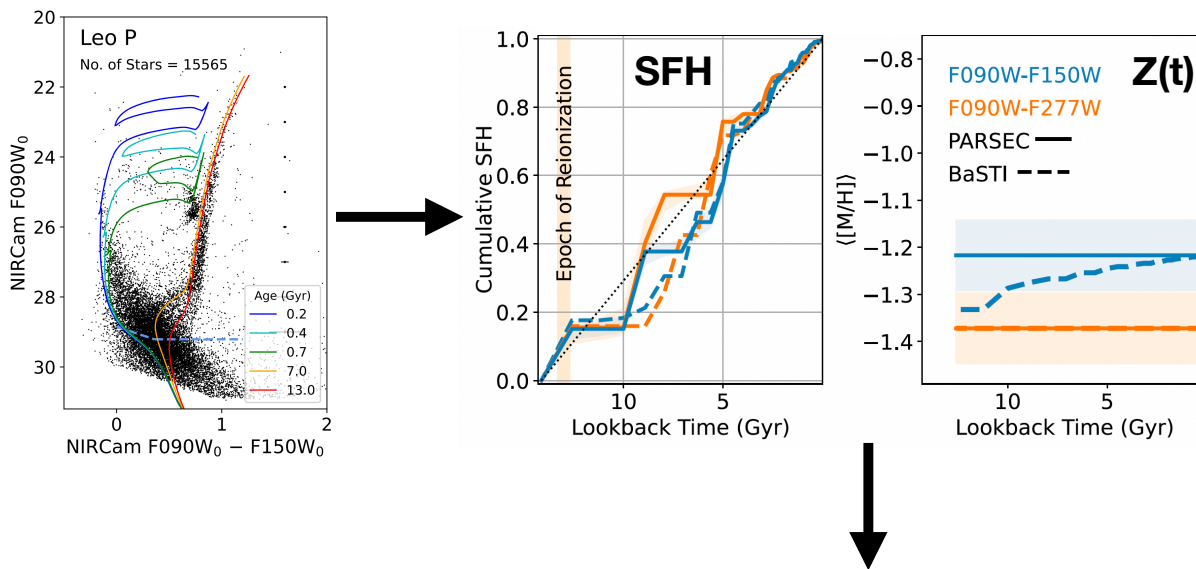
Low-metallicity dwarf galaxies are dramatically affected by feedback



Shallow potential wells and
bursty star formation →
outflows should more efficiently
remove gas and metals
produced by a galaxy's stars

The fraction of metals retained
in galaxies traces the impact of
outflows on their evolution

Metal production and census from CMDs, H I maps, and metallicities



Metal production
by stars over the
galaxy's lifetime

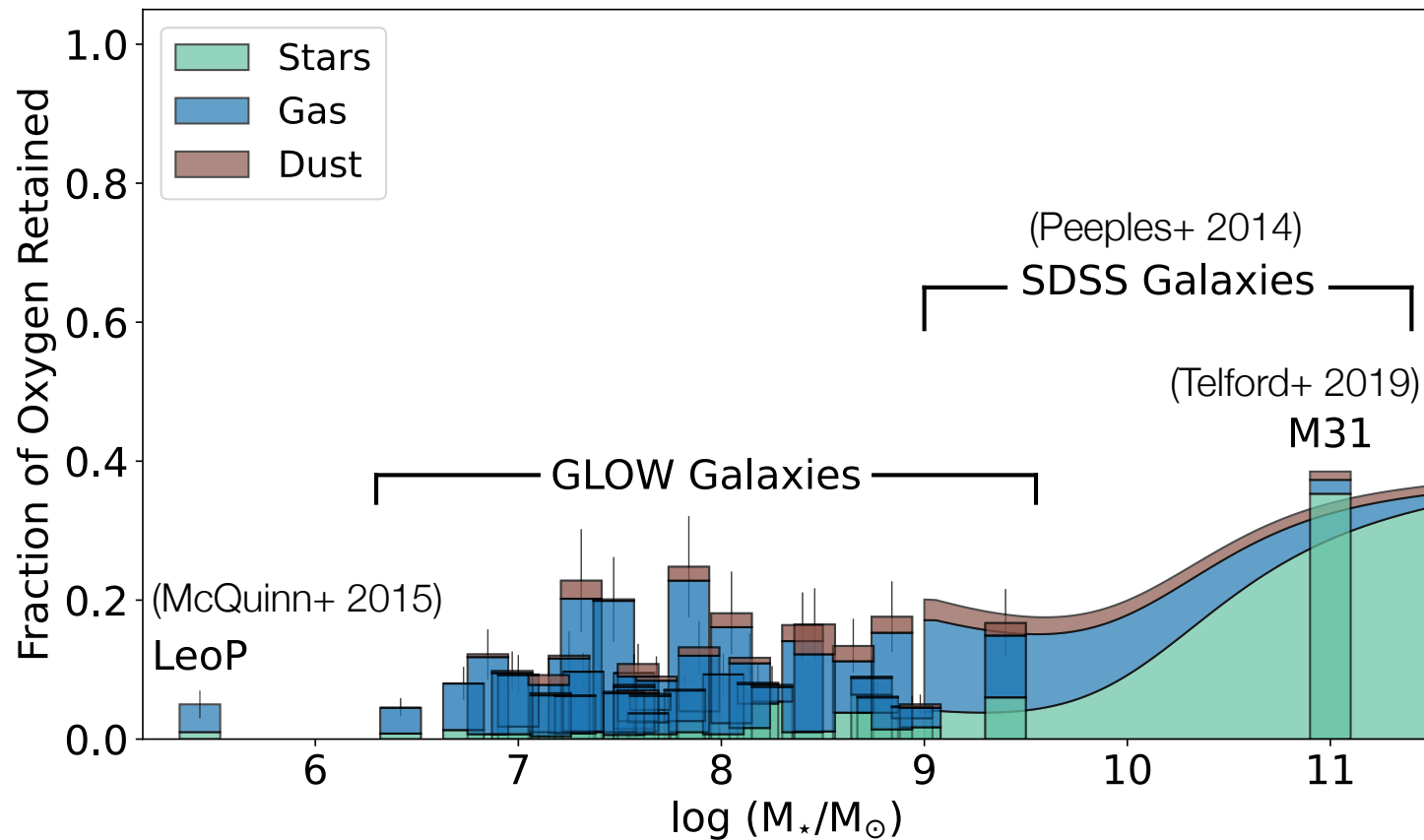
Metals in neutral
gas and dust from
ISM observations

+

Metals locked
into long-lived
stars today

**Fraction of metals
retained inside the galaxy**

GLOW: Galaxies Losing Oxygen via Winds



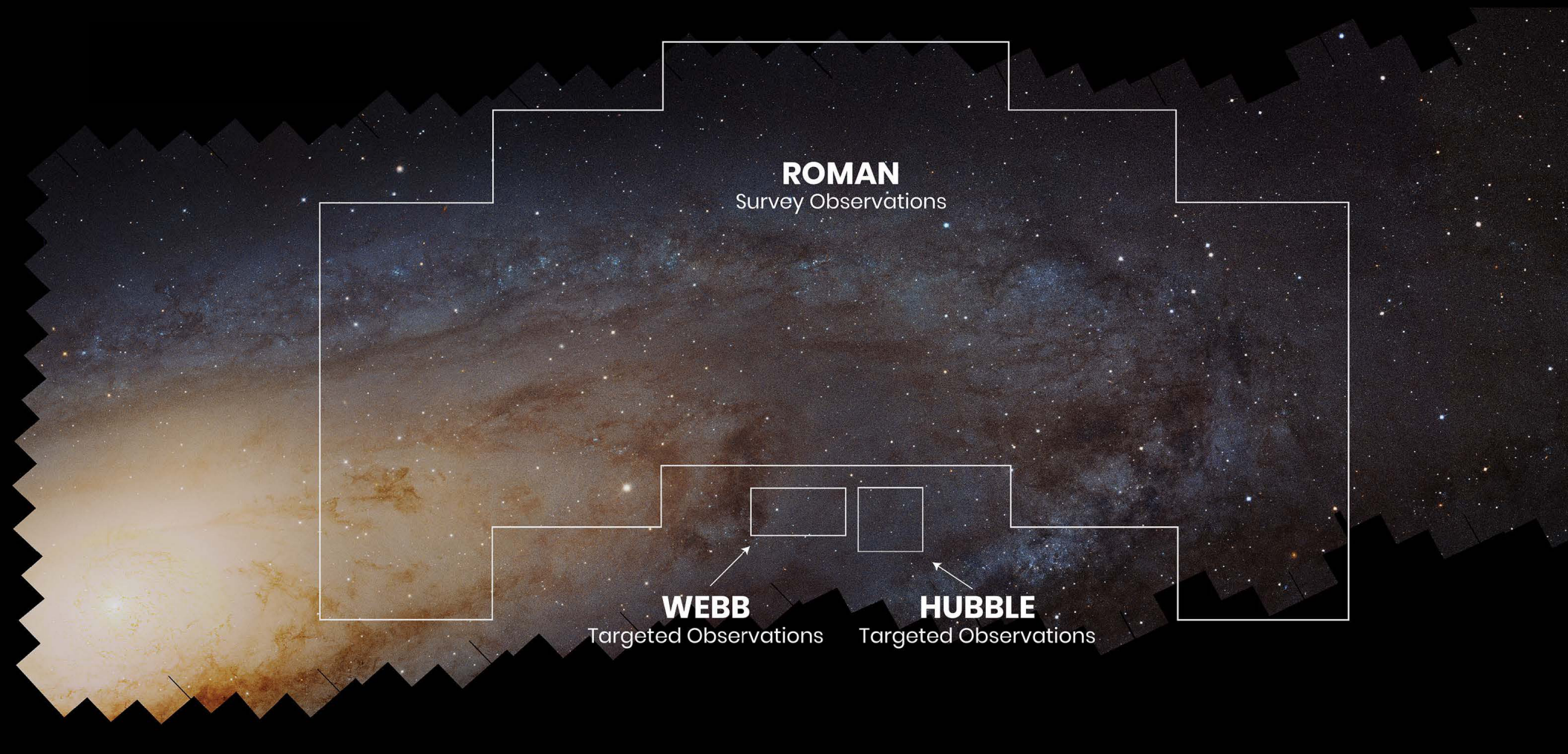
Most dwarf galaxies
($\sim 10^{6.5}-10^{9.5} M_{\odot}$)
retain < 15% of the
oxygen produced
by their stars

Lower than
predicted by
simulations that
reproduce the MZR

McQuinn, Telford+ (2026a,b, submitted)

This will now be a reality!

Cy1 GAS Program 2002 (PI: Karrie Gilbert)



The Nature of Star-Forming Gas at Low Metallicity

JWST enabled the first detection of low-temperature H_2 in a star-forming region at just 3% $Z_\odot$, confirming that extremely metal-poor galaxies can form substantial molecular gas reservoirs

Local dwarf galaxies like Leo P provide valuable constraints for models of the multi-phase ISM and star formation in pristine, early galaxies

Opportunities to Study Star Formation with Roman

Roman's spatial resolution, IR sensitivity, and wide field of view make it a powerful workhorse for resolved stellar populations in local galaxies — from embedded YSOs to ISM mapping to star-formation histories

Cy1 GAS Program 2002 (PI: Karrie Gilbert) will map M31+M33 and demonstrate Roman's ability to trace star formation and feedback

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