

SMILES: A Census of Neutral Feedback at Cosmic Noon

Yang Sun

Graduate Student

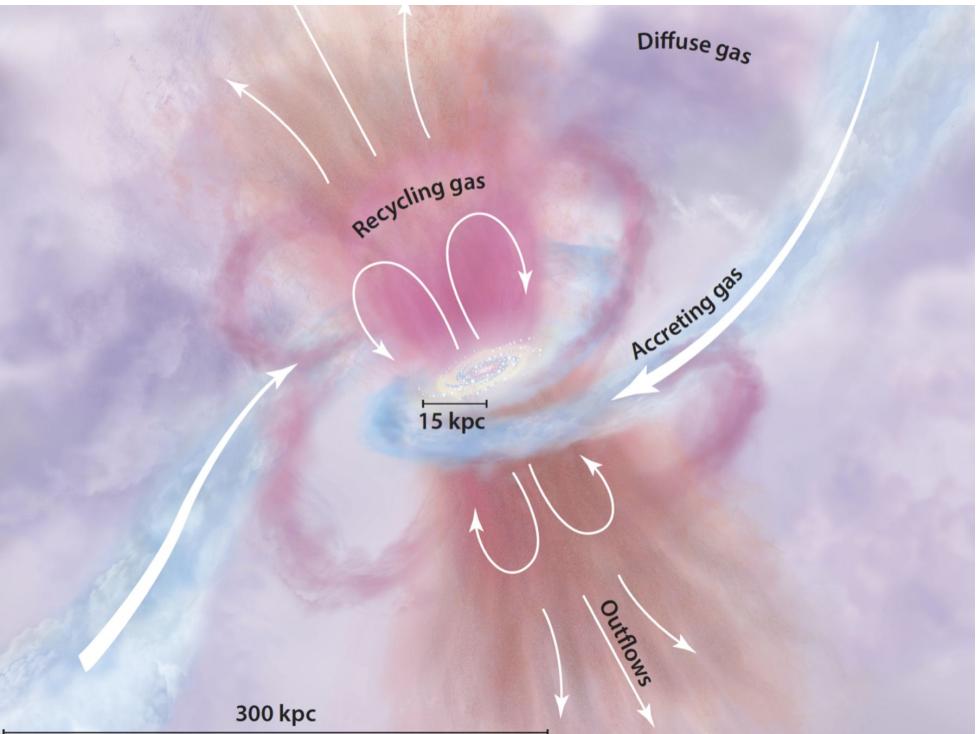
University of Arizona

with Zhiyuan Ji, Yongda Zhu, George Rieke, and the
SMILES and JADES team

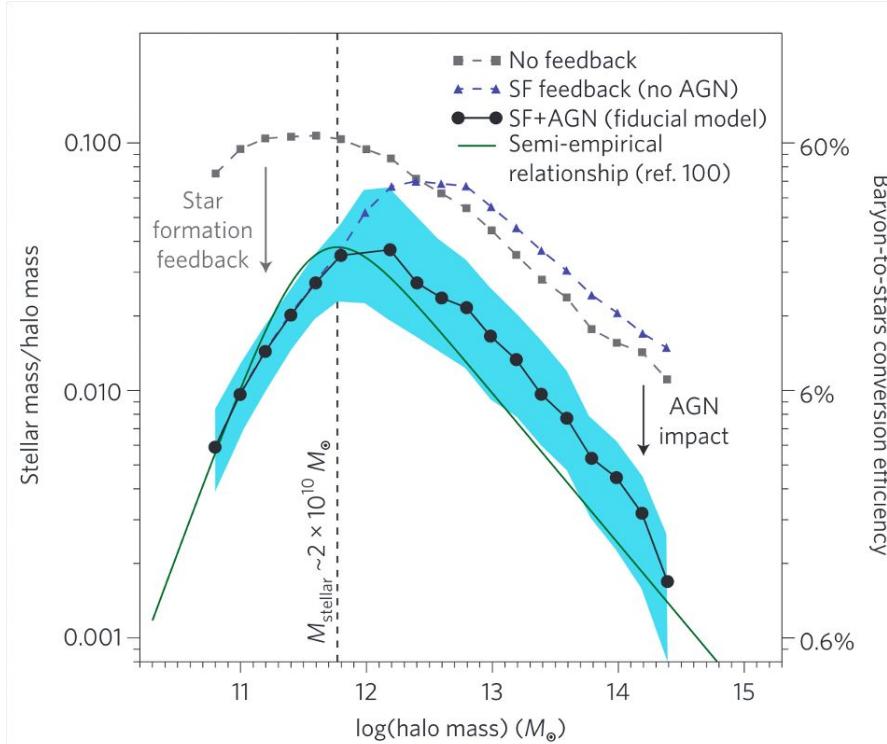


Credits: NASA, ESA and the Hubble Heritage Team (STScI/AURA)

Galactic Feedback is Necessary

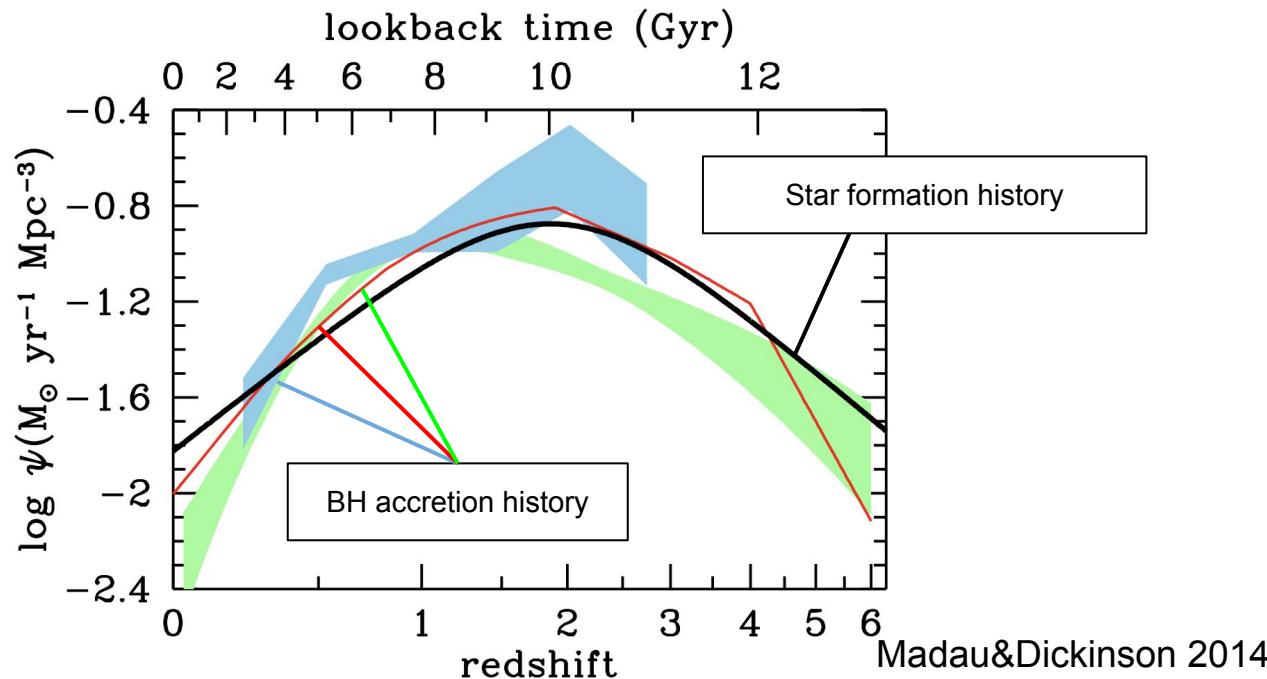


Tumlinson+17



Harrison+17

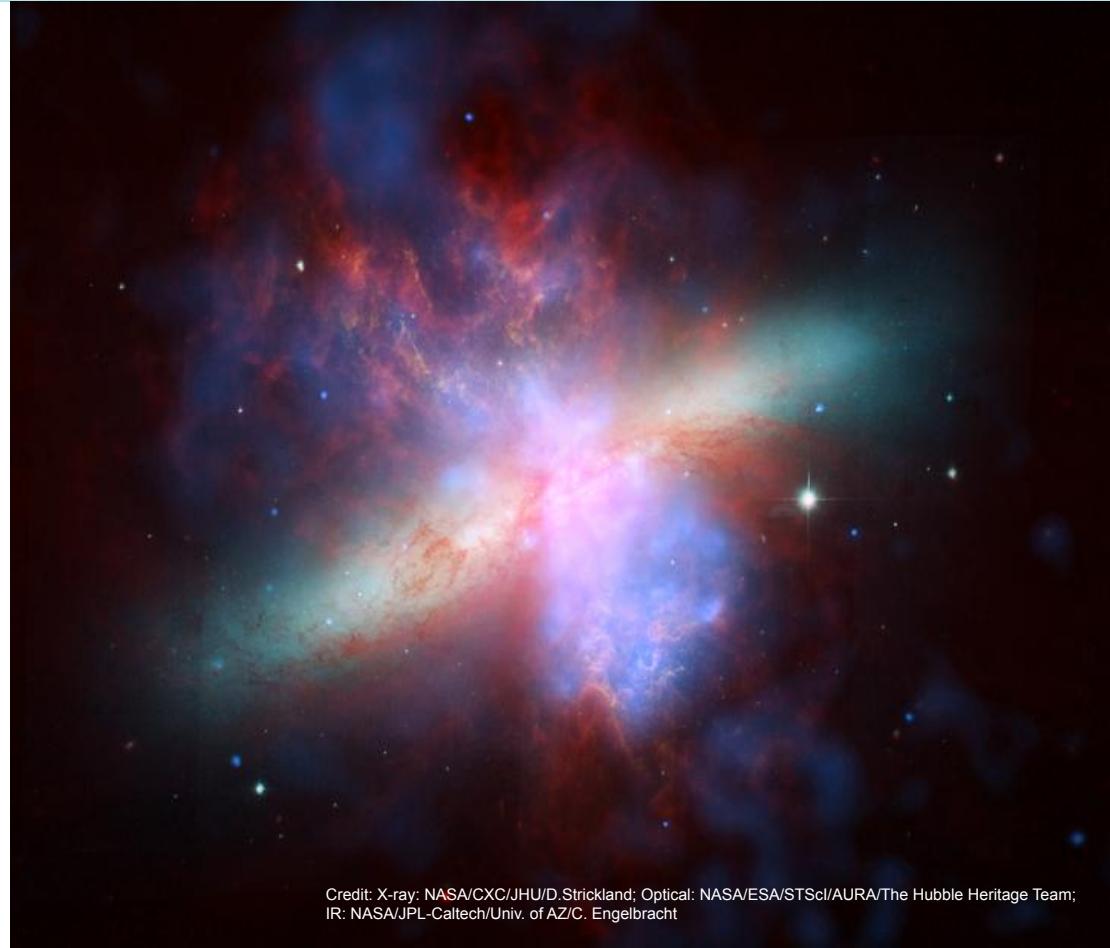
Cosmic Noon: Peak of the Cosmic Growth



Intense and frequent feedback process should happen at this epoch.

Multiphase Outflow

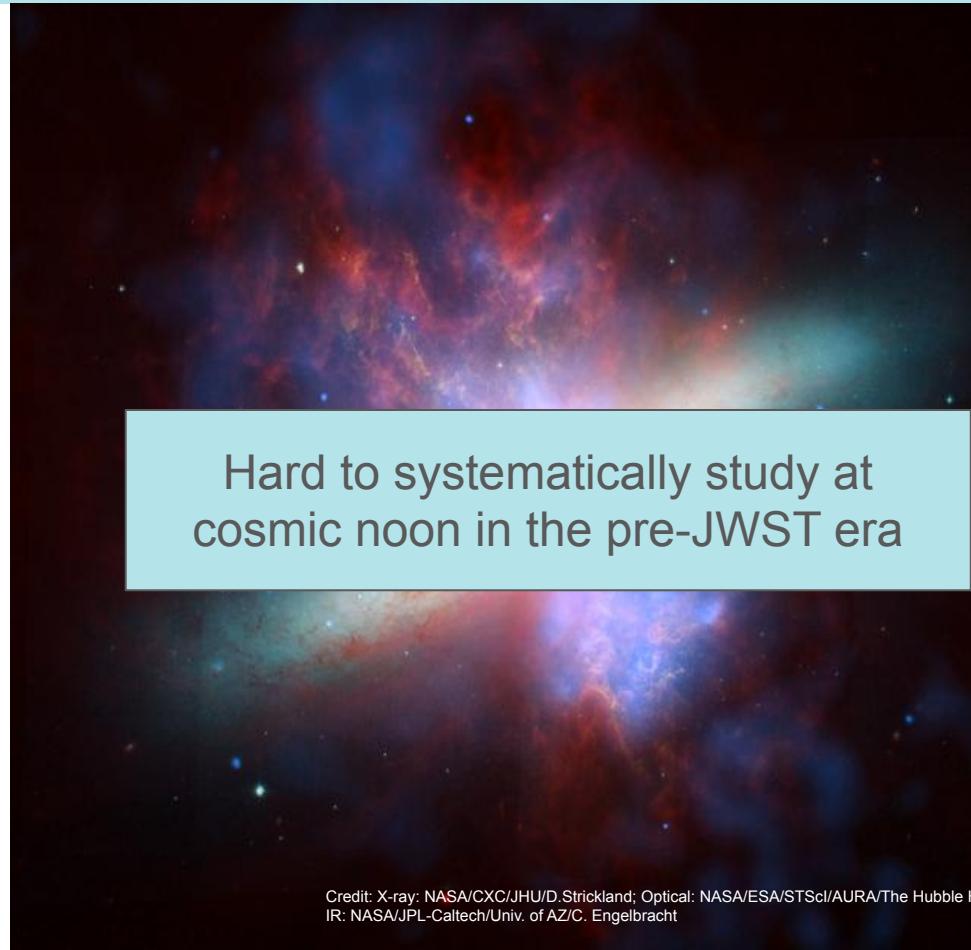
- Hot X-ray phase ($T \sim 10^{6-7} K$)
- Warm ionized phase ($T \sim 1000 K$): e.g. [OIII] 5007, Halpha
- Cool Neutral phase ($T \sim 100 K$): e.g. UV absorption lines, [CII] 158 micron, Na D
- Cold Molecular phase ($T \sim 10 K$): e.g. [CII] 158 micron, CO



Credit: X-ray: NASA/CXC/JHU/D.Strickland; Optical: NASA/ESA/STScI/AURA/The Hubble Heritage Team; IR: NASA/JPL-Caltech/Univ. of AZ/C. Engelbracht

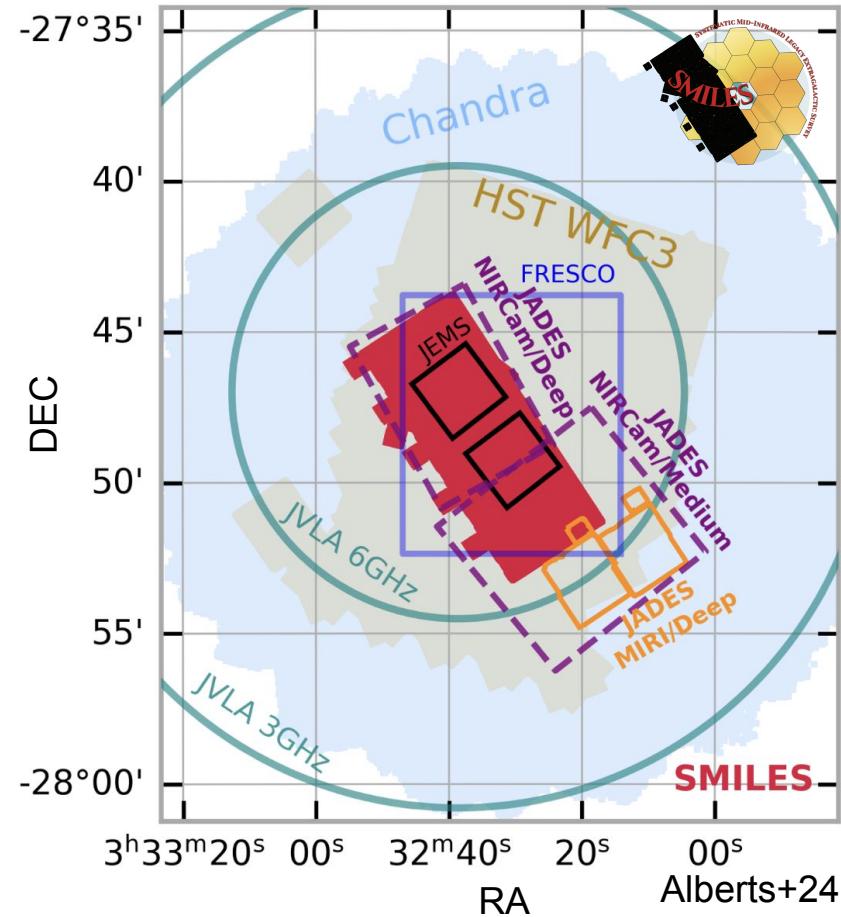
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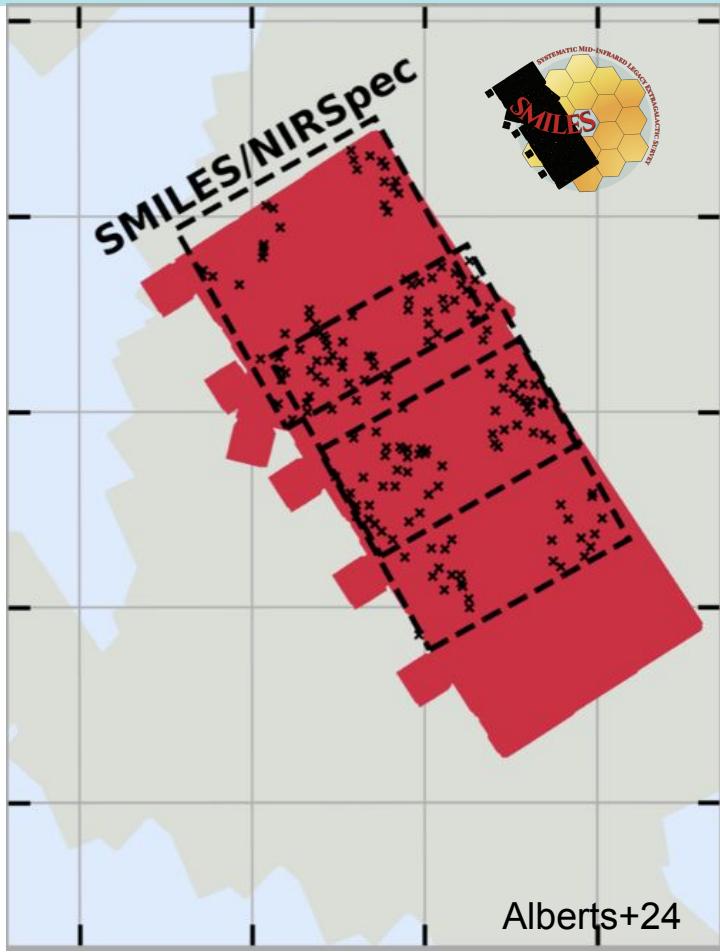
SMILES

- Systematic Mid-infrared Instrument (MIRI) Legacy Extragalactic Survey (Rieke+24, Alberts+24)
- GOODS-S/HUDF
- **The only program that takes MIRI's full continuous coverage from 5.6 – 25.5 μm , over a $\sim 34 \text{ arcmin}^2$**
- Designed for **cosmic noon science**: PAH (Shivaei+24), Obscured AGN (Lyu+24), ...

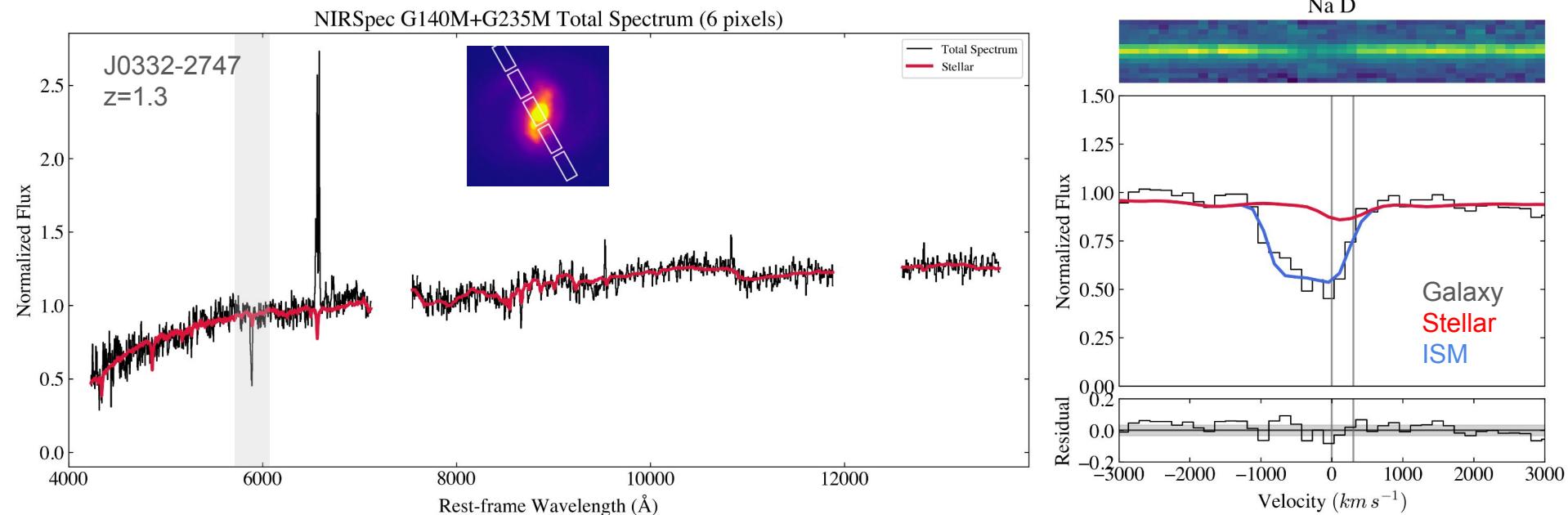


SMILES

- 17 hours NIRSpec/MSA follow-up
- Medium Grating ($R \sim 1000$) at $\sim 1 - 3 \mu\text{m}$ (G140M+G235M)
- Well representative target selection (175 targets):
 - star forming galaxies with PAH and Pa a
 - MIRI-selected AGN
 - Massive quiescent galaxies
 - High-z overdensities
- 113 targets have success spectra at Na D



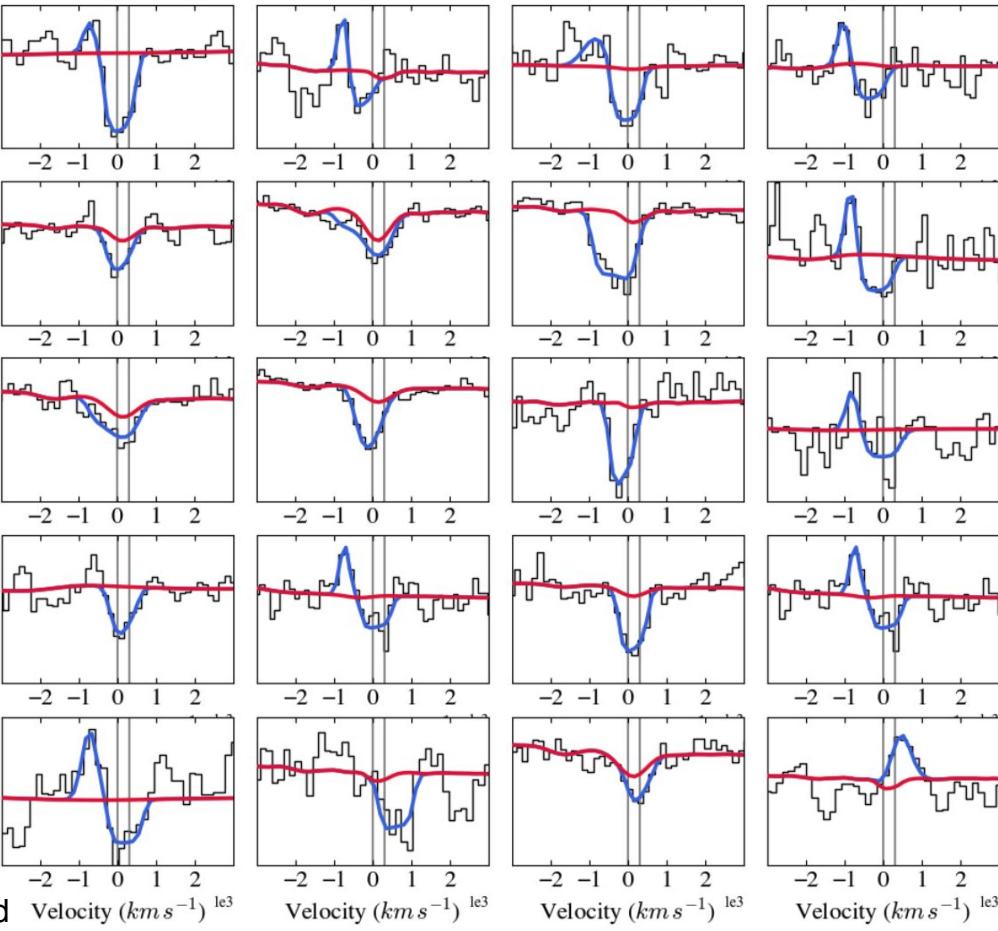
Na D-traced ISM



Sun+ to be submitted

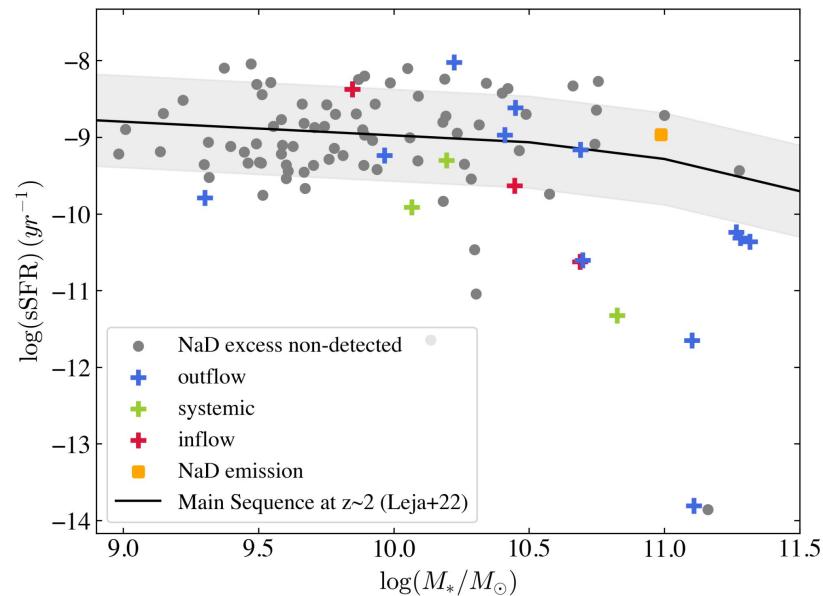
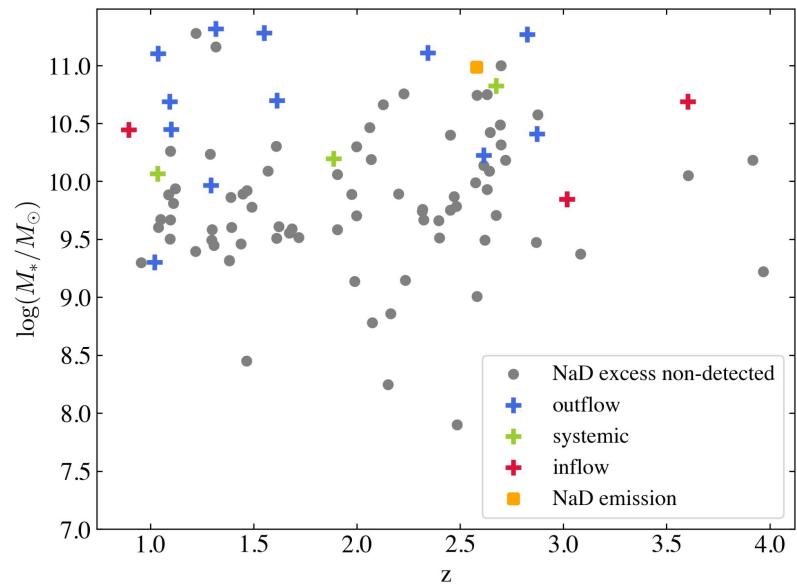
Na D-traced ISM

- 12 Outflows, 3 Inflows, 3 Systemic
ISM, 1 Emission/P-Cygni (outflow)
- Profile is parametrized using the
standard partial covering model



Na D-traced ISM

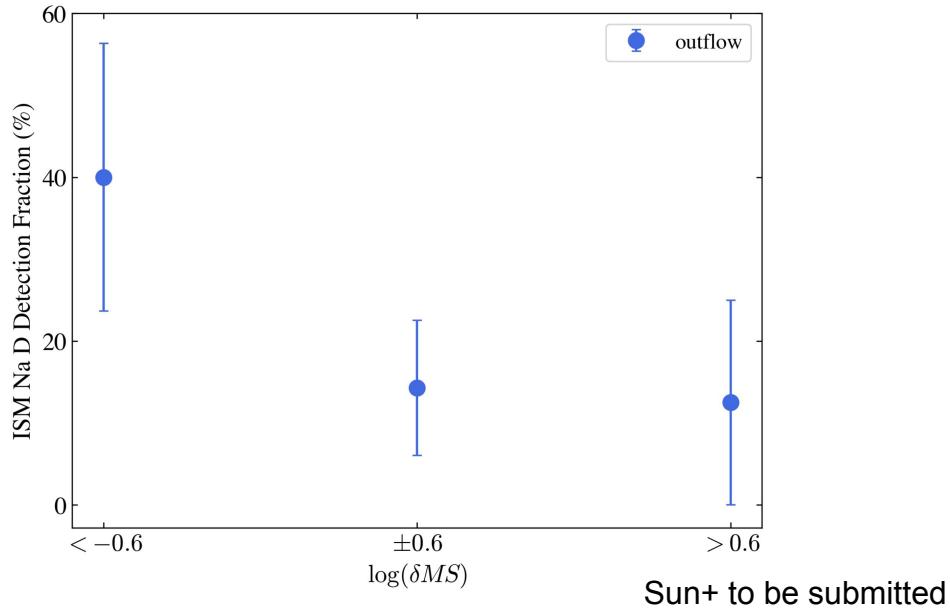
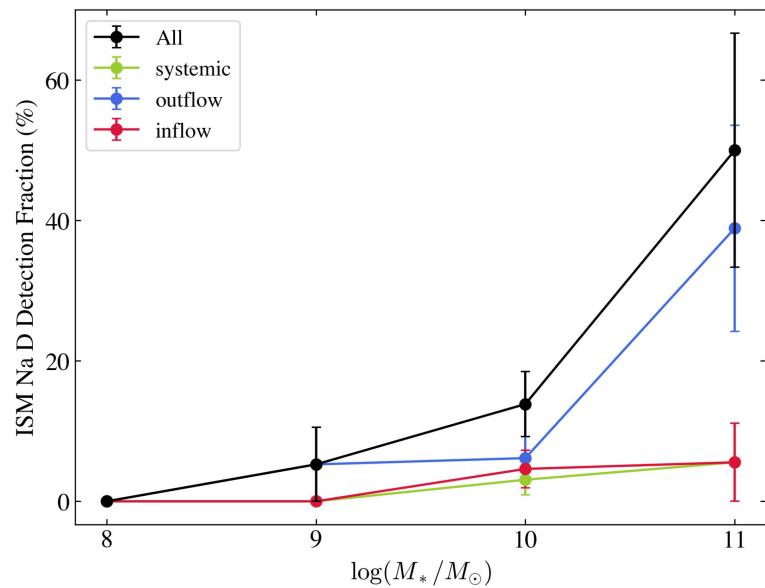
- Detections across a wide redshift ($z=1\sim3$) and sSFR range (Star-forming to Quiescent)



Sun+ to be submitted

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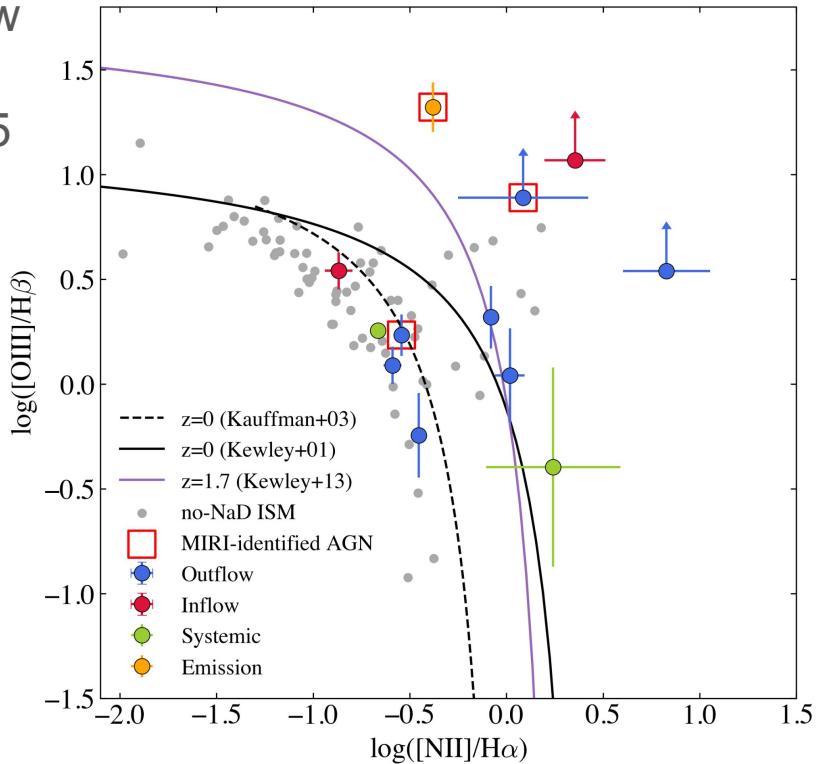
- Mostly at massive galaxies ($\log(M_*/M_\odot) > 10$)
- The outflow detection rate is higher at quenching galaxies, indicating the strong connection between outflow and galaxy quenching.



Sun+ to be submitted

Na D-traced Outflow Census

- 26 galaxies with Na D-traced neutral outflow
 - 12 SMILES (this work)
 - 14 Blue Jay Na D outflows at $z=1.7\text{--}3.5$ (Davies+24)
- A large fraction of neutral outflows are detected in AGN hosts
 - SMILES: 6/12 (50%):
 - 3 MIRI-identified AGNs (Lyu+24)
 - 4 BPT-identified AGNs
 - Blue Jay: 11/14 (79%)

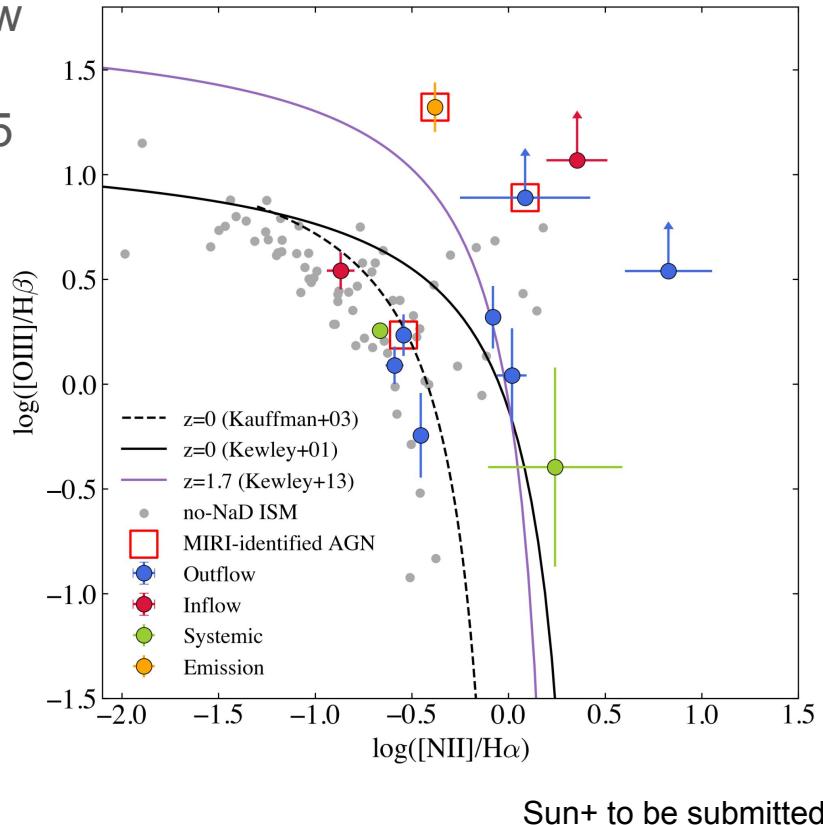


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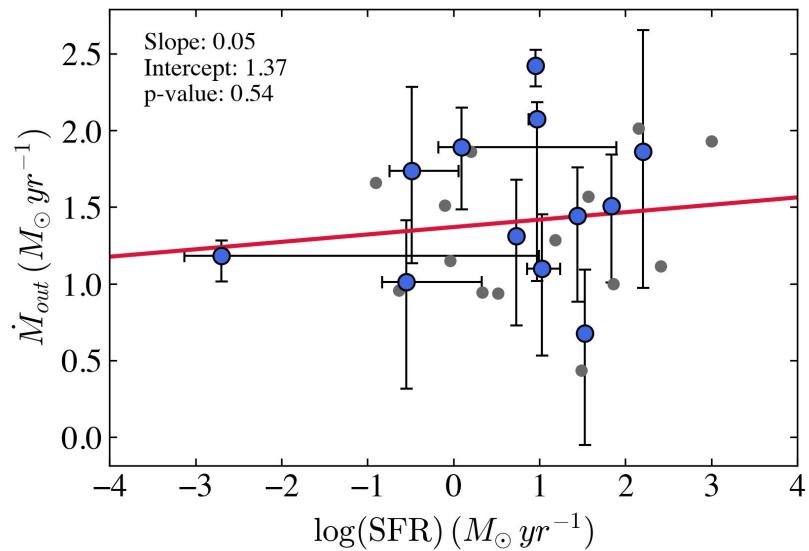
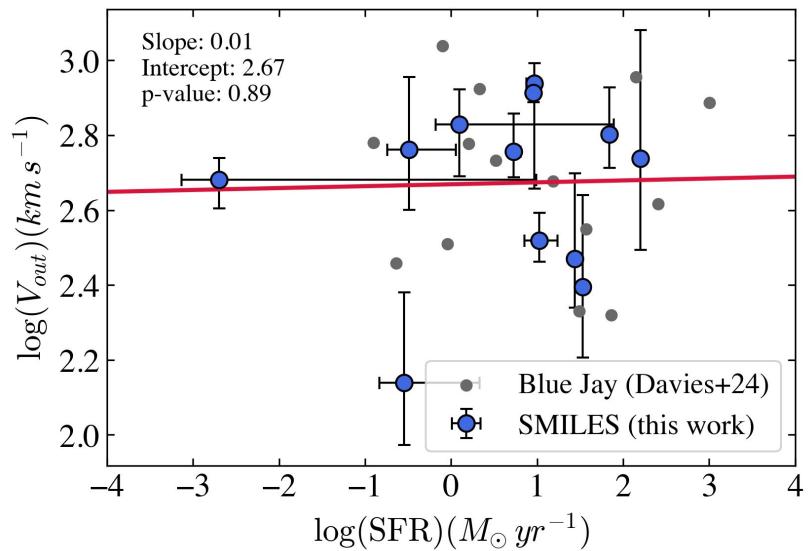
Outflow are dominantly driven by AGN at cosmic noon?



Sun+ to be submitted

Na D-traced Outflow Census

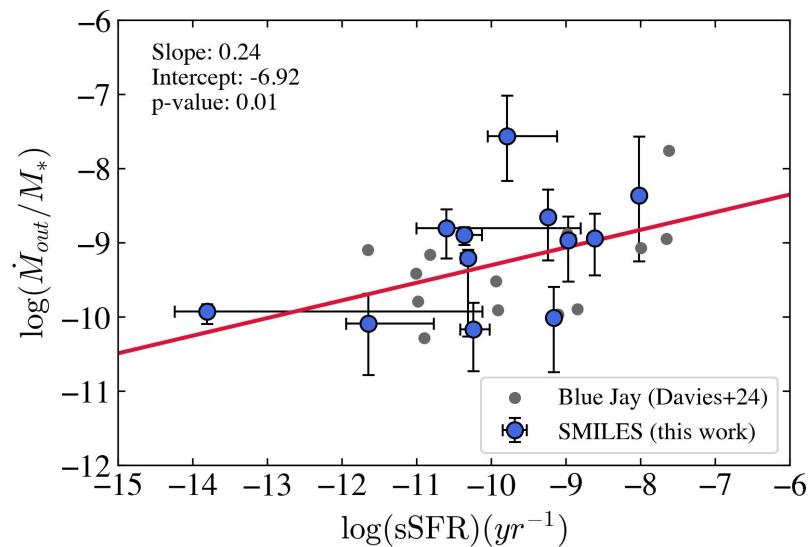
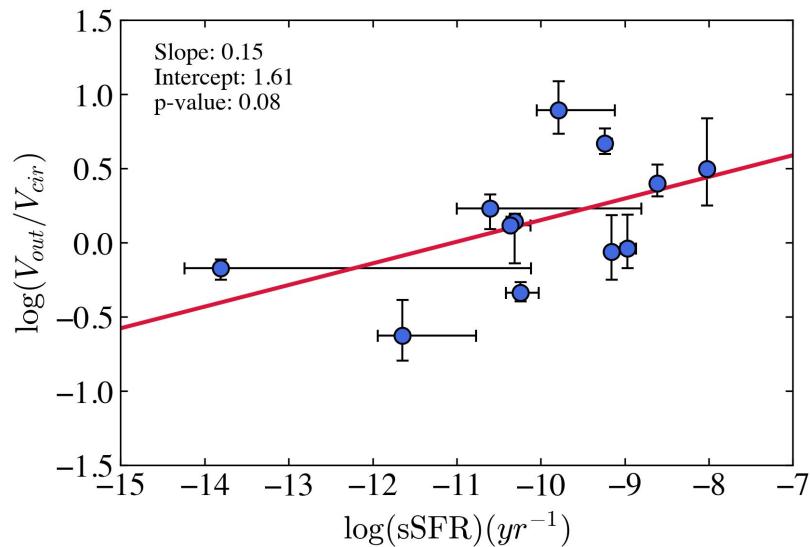
- Outflow properties vs SFR



Sun+ to be submitted

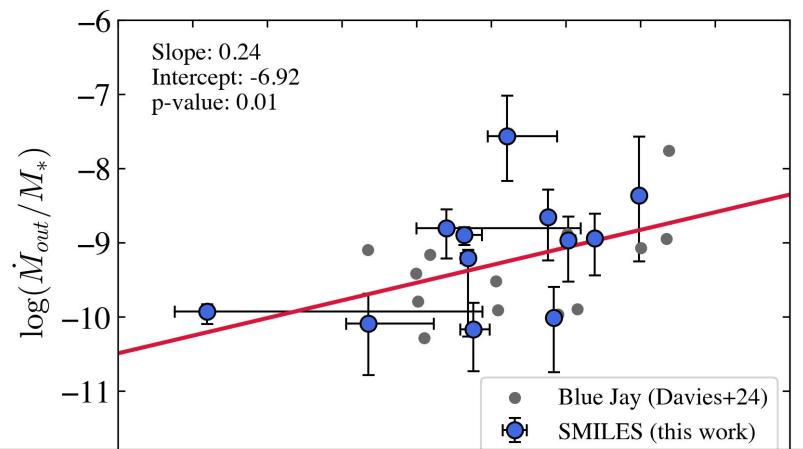
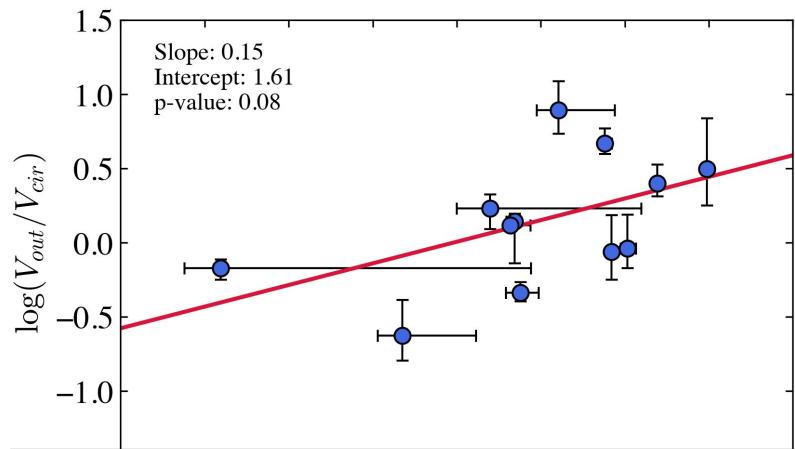
Na D-traced Outflow Census

- Outflow properties vs SFR (after taking out of the M_* dependency)



Na D-traced Outflow Census

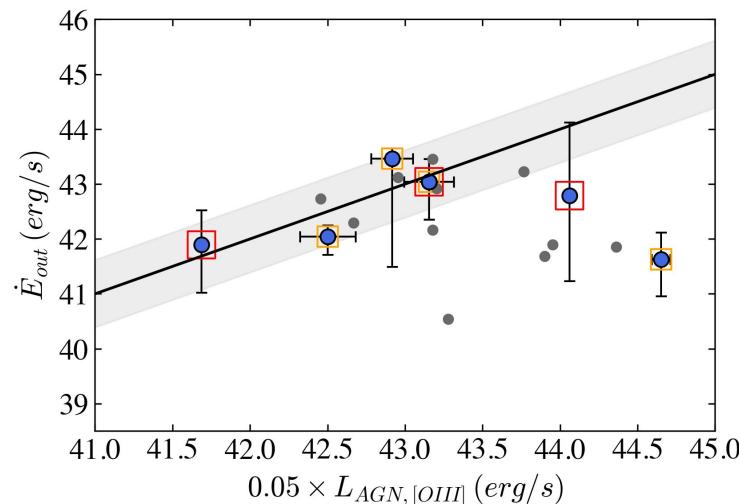
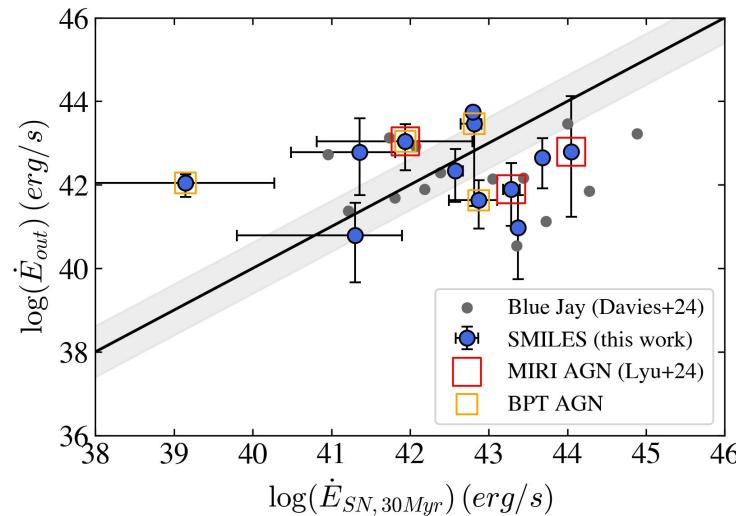
- Outflow properties vs SFR (after taking out of the M_* dependency)



Outflow properties is correlating with SFR, indicating the non-negligible SF-driven feedback at cosmic noon.

Na D-traced Outflow Census

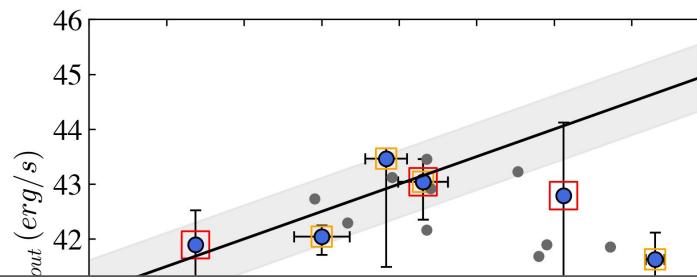
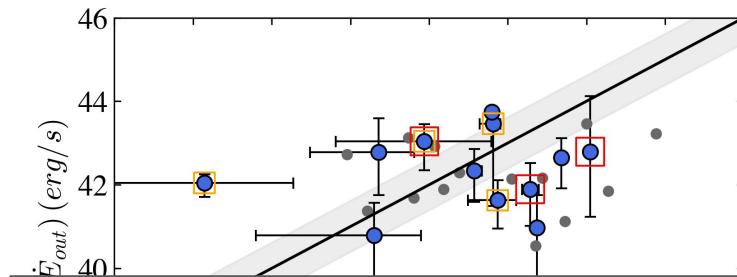
- Driving Mechanism
 - **SF-driven:** Type-2 Supernova could provide $\dot{E}_{\text{SN}} \sim 7 \times 10^{41} \text{ SFR erg s}^{-1}$
 - **AGN-driven:** $\dot{E}_{\text{AGN}} \sim 5\%$ of the AGN bolometric luminosity for E-conserved outflow (King & Pounds 2015)



Sun+ to be submitted

Na D-traced Outflow Census

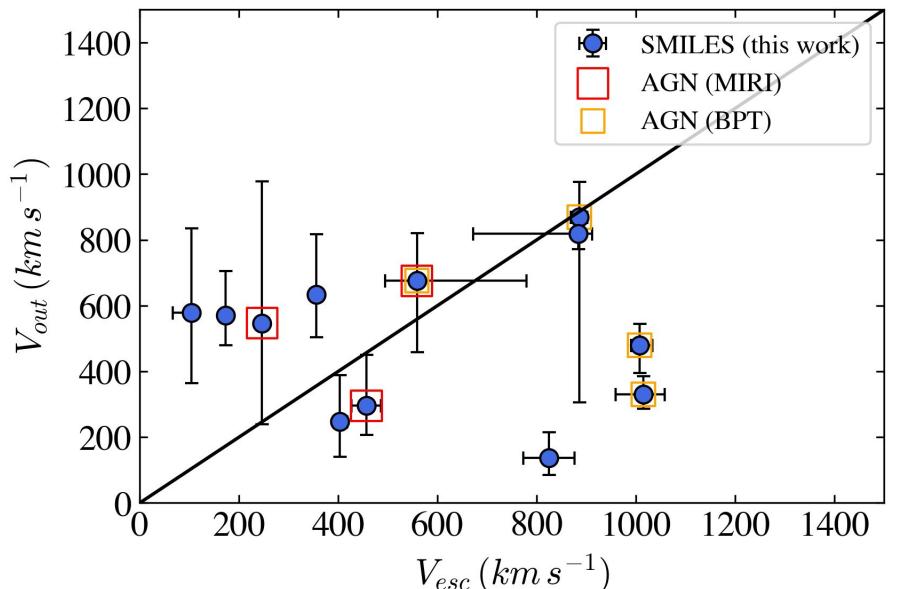
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At $z \sim 2$, neutral outflows of star-forming galaxies are SF-driven, but those of quenched galaxies have to be contributed by AGN.

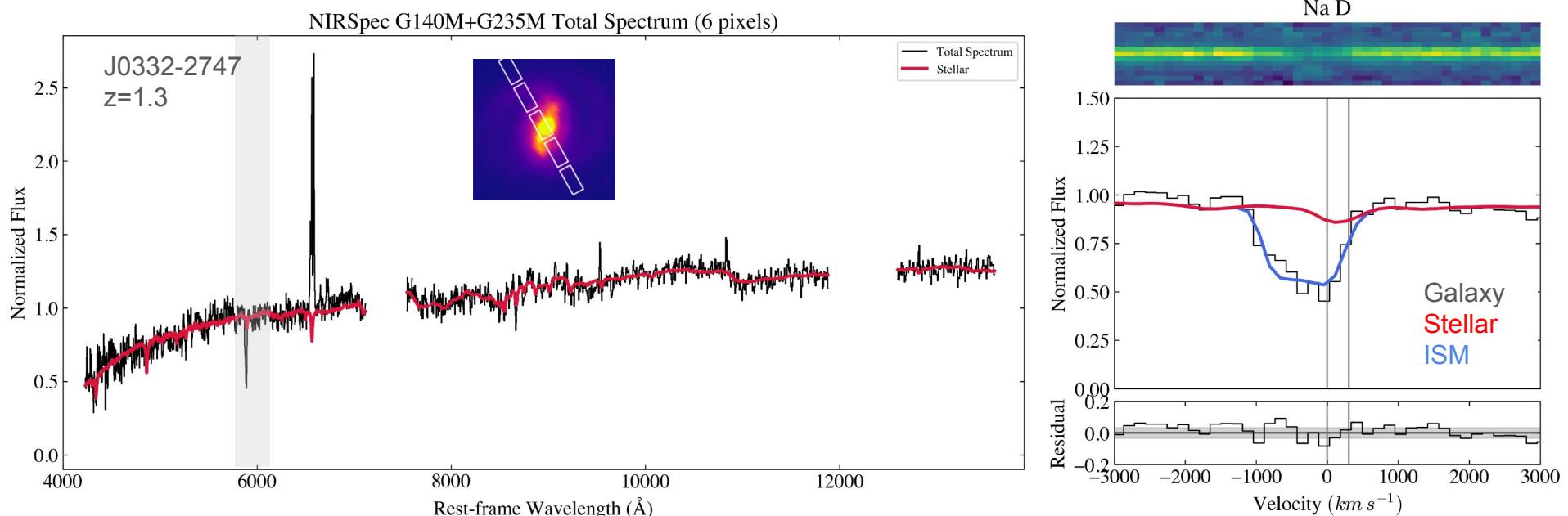
Na D-traced Outflow Census

- Fate
 - Escape velocity estimated from stellar mass and F356W half-light radius
 - Only 3/12 are fast enough to escape galaxy, others will fall back as “galactic fountain”.



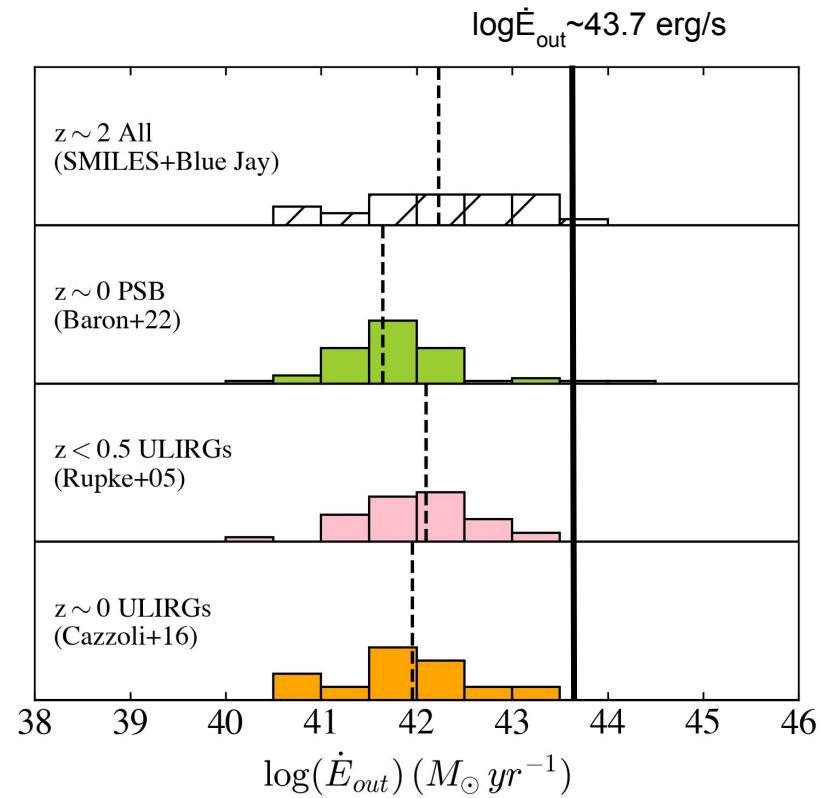
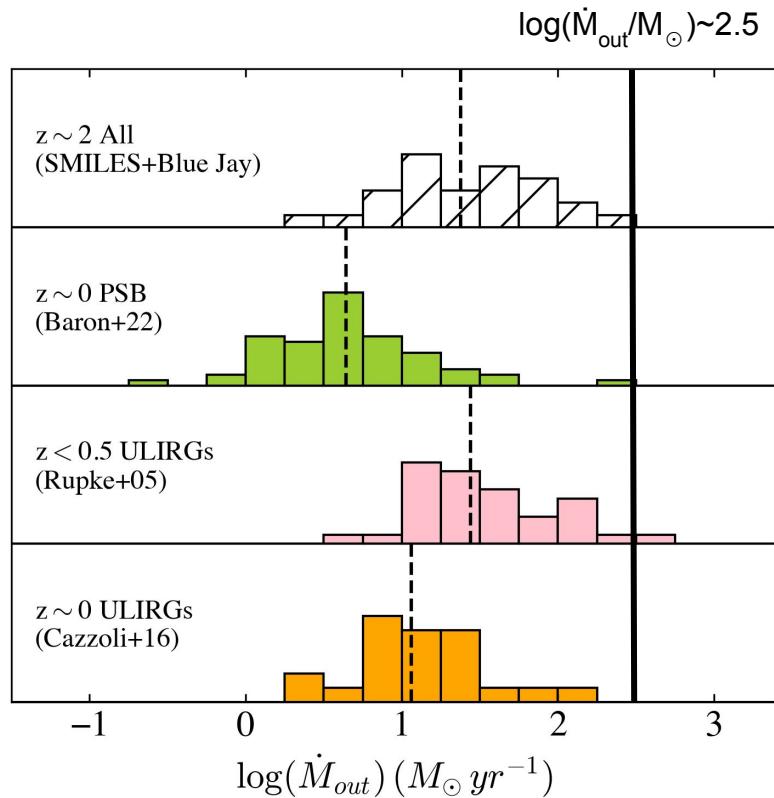
Sun+ to be submitted

A $z \sim 1.3$ Quenching Galaxy with Extreme Neutral Outflow



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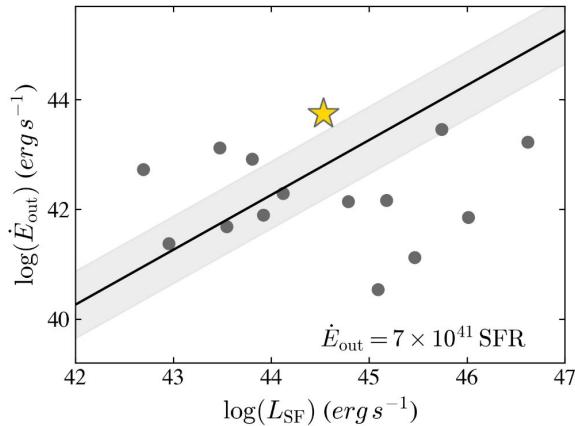
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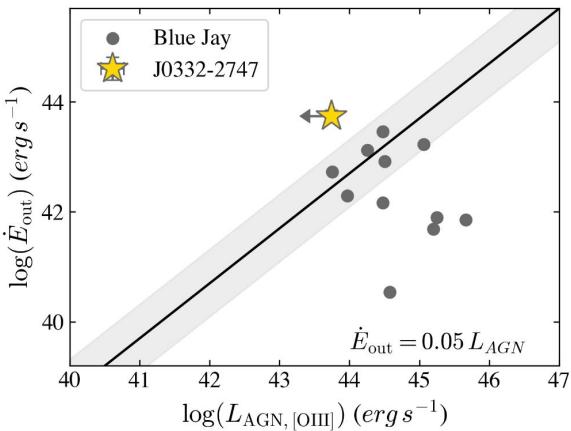
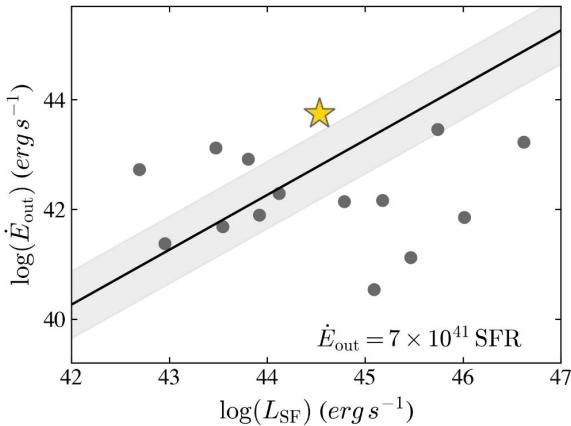
A z~1.3 Quenching Galaxy with Extreme Neutral Outflow

- Driving Mechanism?
 - Accurate SFR measurement: Low Pa
alpha-derived SFR = $9 \pm 0.6 M_{\odot}/\text{yr}$



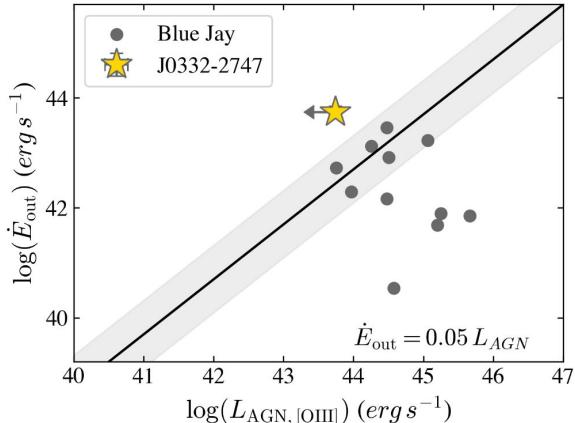
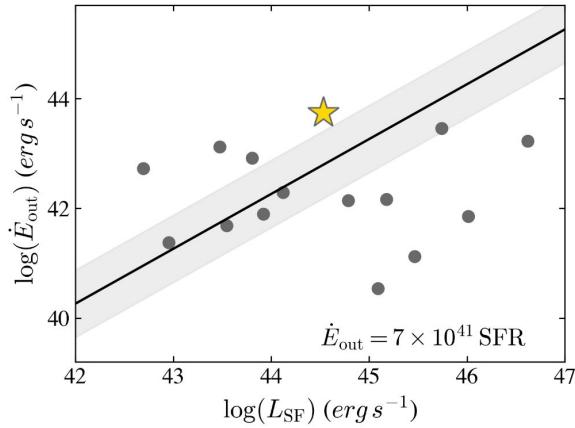
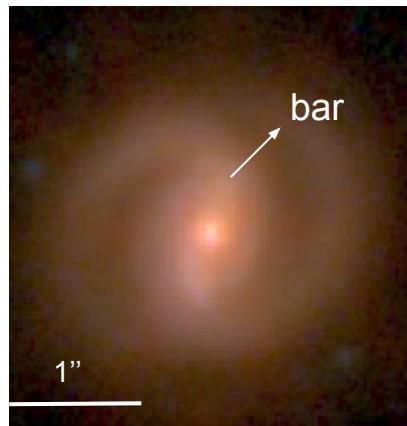
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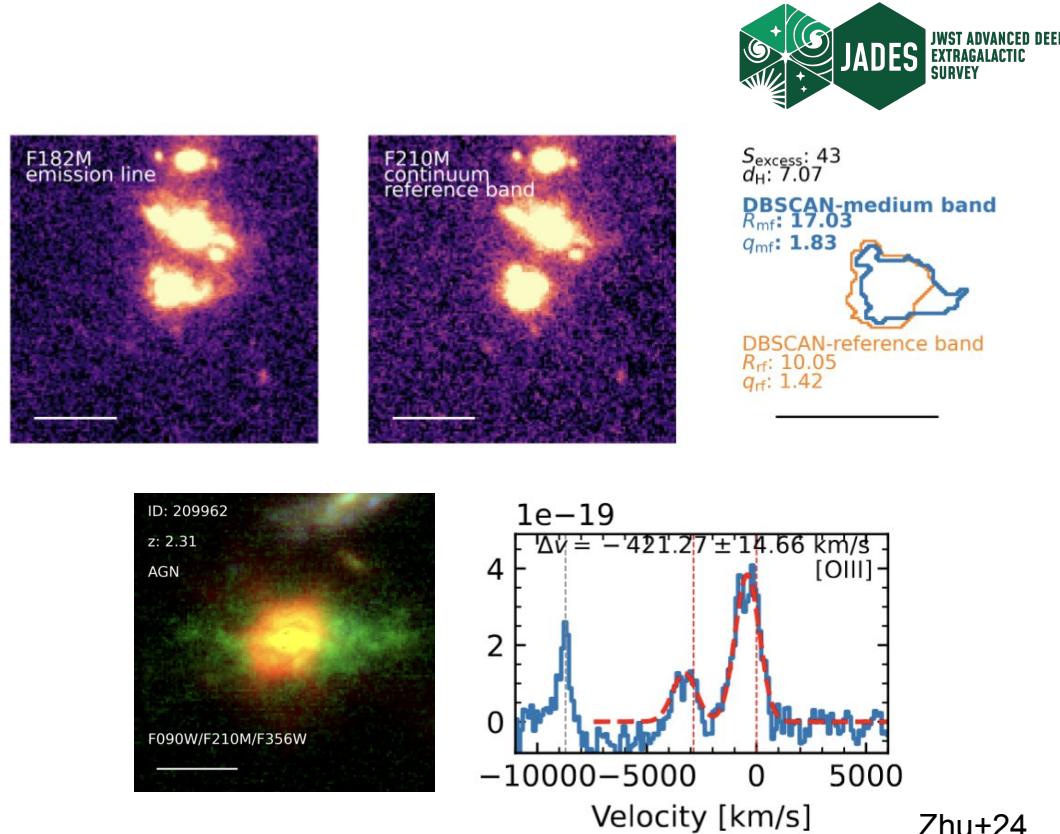
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- Driving Mechanism?
 - Accurate SFR measurement: Low Pa alpha-derived SFR = $9 \pm 0.6 M_{\odot}/\text{yr}$
 - No on-going AGN activities
 - Relic outflow? driven by bar-triggered previous intense starburst and AGN activities?



Ionized Outflow with Extended Emission Line

- JADES NIRCam multi-band images: searching for outflow candidates with extended emission line
- Candidates with SMILES or JADES NIRSpec spectra also exhibit strong blueshifted emission lines
- Ideal sample for
 - spatially-resolved study of the impact of ionized outflow on host galaxy properties
 - Multiphase outflows



Zhu+24

Takeaways

- **SMILES and Blue Jay provide the largest $z \sim 2$ Na D outflow sample to date** for systematically studying the properties of neutral phase outflows;
- Na D absorption is preferentially detected at massive and dusty systems, tracing neutral hydrogen which is well shielded by dust.
- At $z \sim 2$, neutral outflows are detected in massive galaxies across a wide range of sSFR, i.e., both star-forming and quenching galaxies, but the detection rate is higher for quiescent galaxies.
- At $z \sim 2$, both SF and AGN contribute to neutral outflows, outflows of quenched galaxies have to be contributed by AGN.