Studying Galactic Winds at High Redshift with Keck, JWST, and ATLAS

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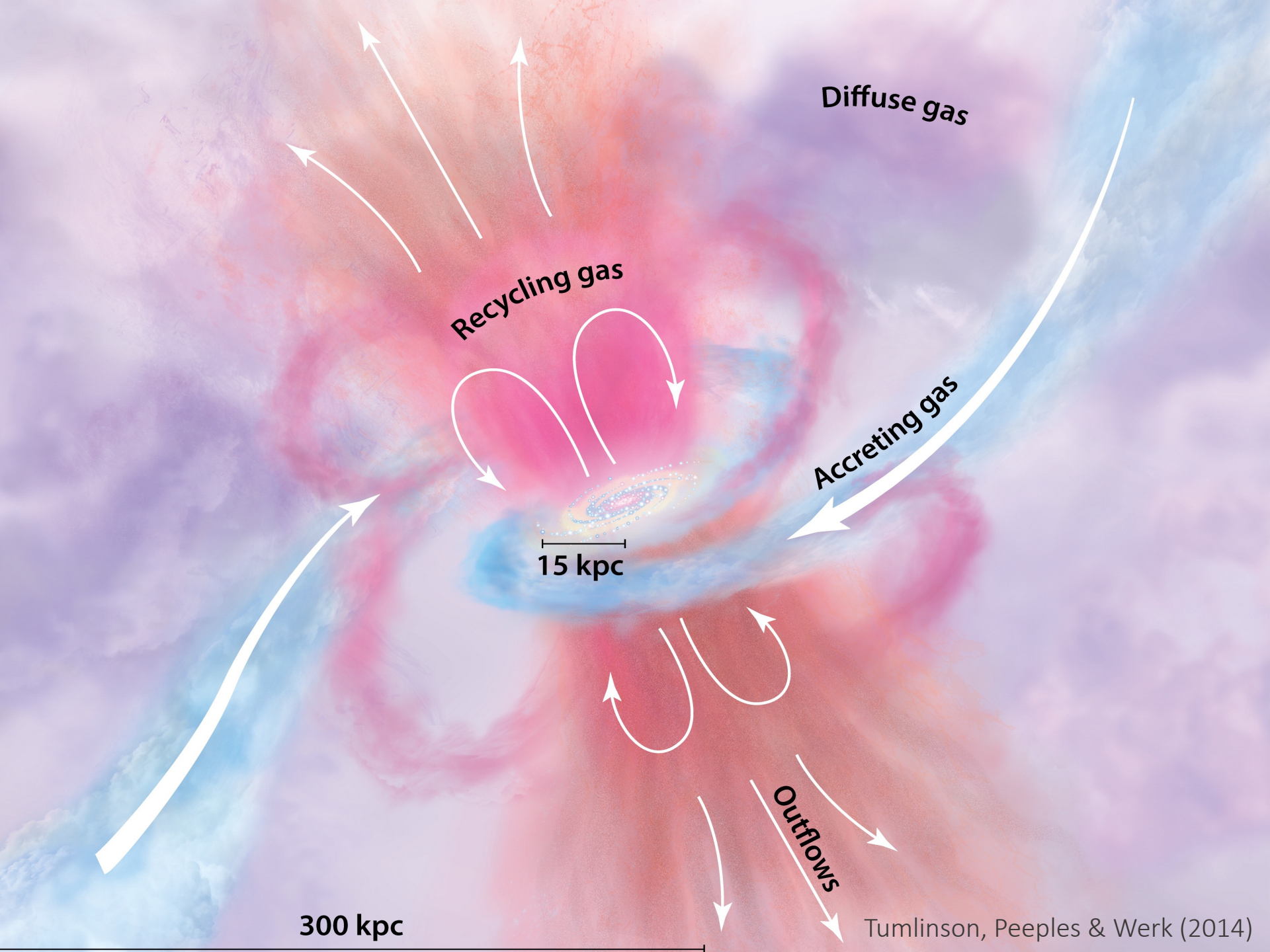


Tumlinson, Peeples & Werk (2014)

Part 1:
Where inside galaxies do winds come from?

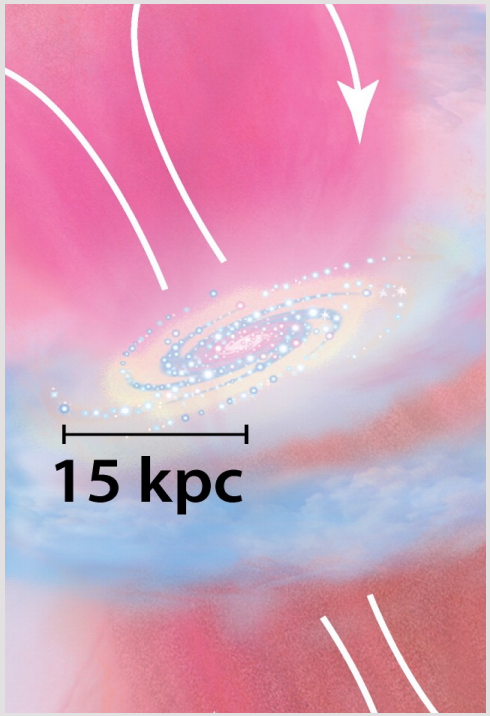
Local universe (z=0): mostly from the central regions or individual starburst regions.

Lehnert+1999; Westmoquette+2011; Kreckel+2014; Heckman & Thompson 2017; Rodríguez Del Pino+2019; Roberts-Borsani+2020

Not so well known at higher redshift:

Most previous studies of winds at this redshift are not spatially resolved.

e.g., Tremonti+2007; Weiner+2009; Rubin+2010, 2014.



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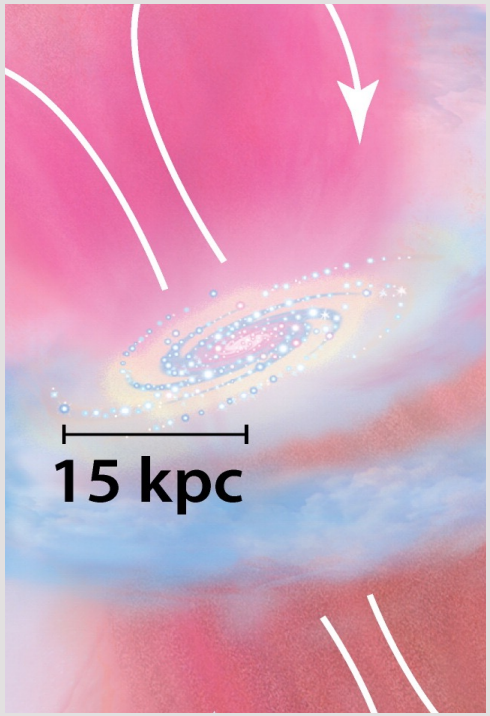
Not so well known at higher redshift:

Spatially resolved studies emerged recently for the warm ionized phase of winds.

Newman+2012; Förster Schreiber+2014, 2019; Davies+2019



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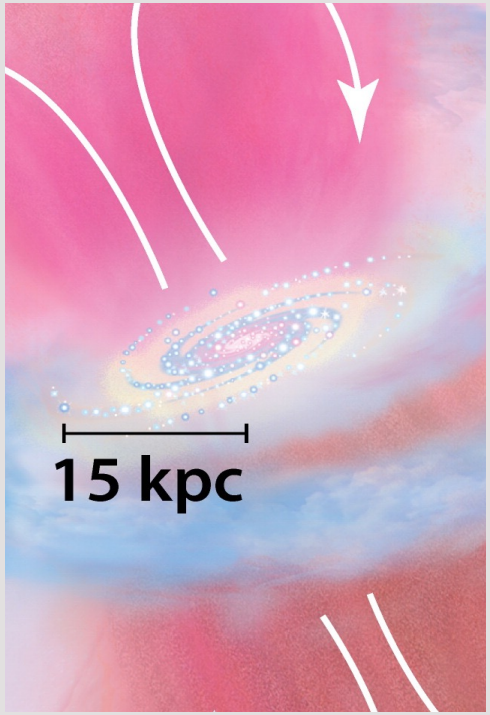
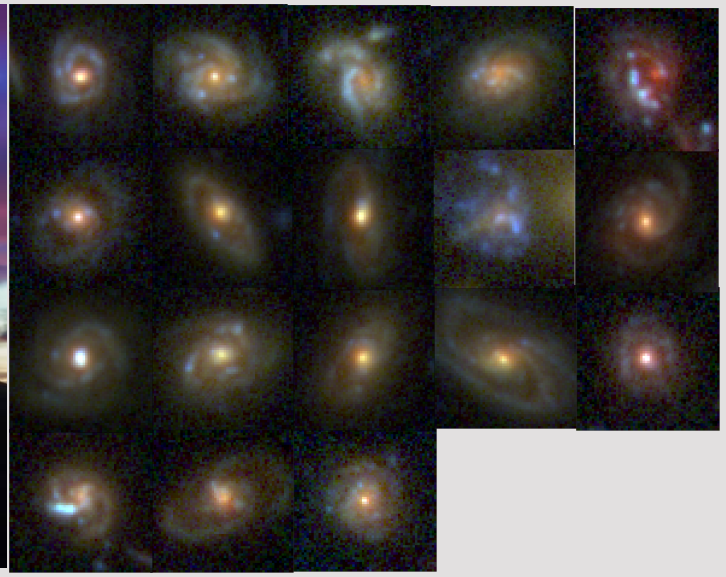
Not so well known at higher redshift:

Spatially resolved studies for the cool phase of winds are yet to be made.



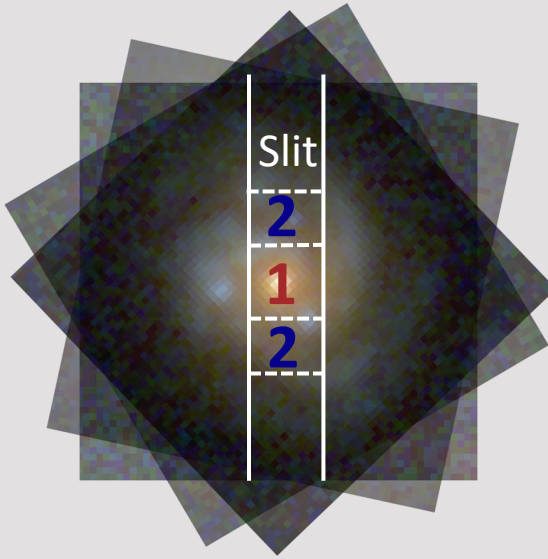
Tumlinson, Peeples & Werk (2014)

Part 1: Studying winds at z=1 with Keck



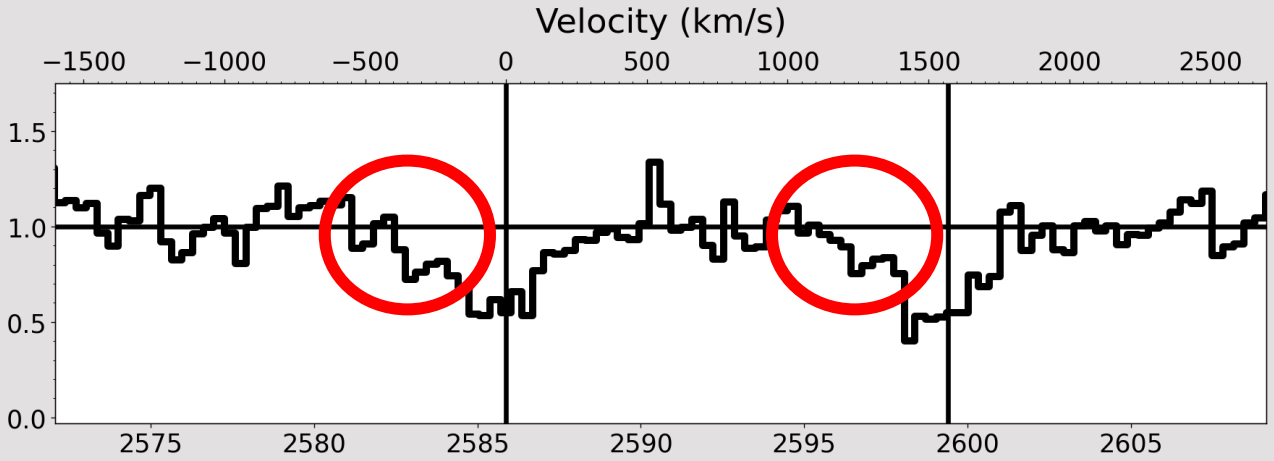
- A sample of 18 massive star forming galaxies at z∼1 were observed with the Keck/DEIMOS (Faber et al. 2003) at R ≃ 2000, as part of the HALO7D survey (PI: Guhathakurta).
- Each galaxy has an average exposure time of 8 hours.
- The Mg II and Fe II absorption lines are used as tracers of the cool phase of winds.

Stacked spectra show blueshifted absorption (up to 500 km/s) caused by the galactic winds.

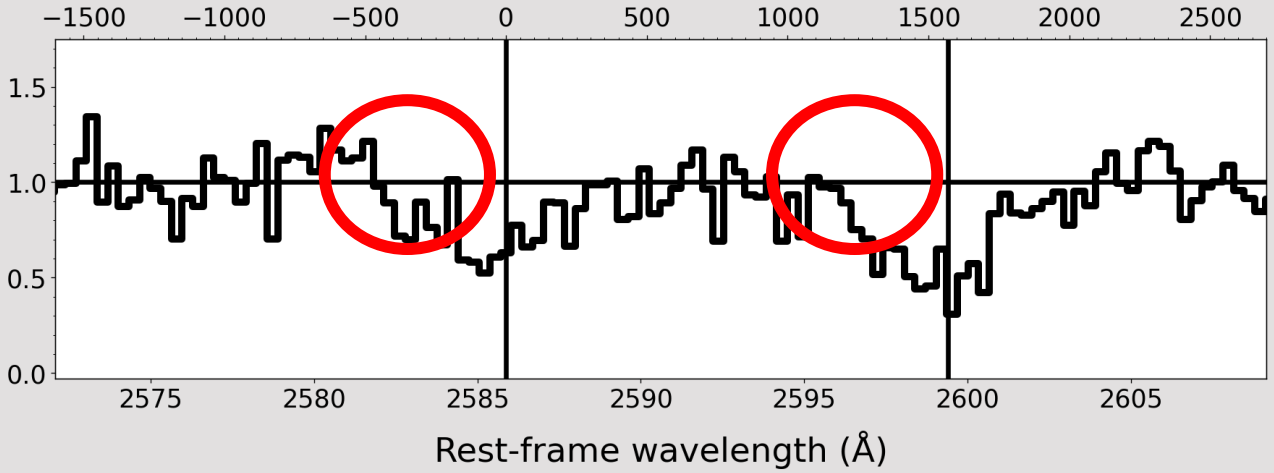


Vertical lines indicate systemic redshift.

1: Central Region

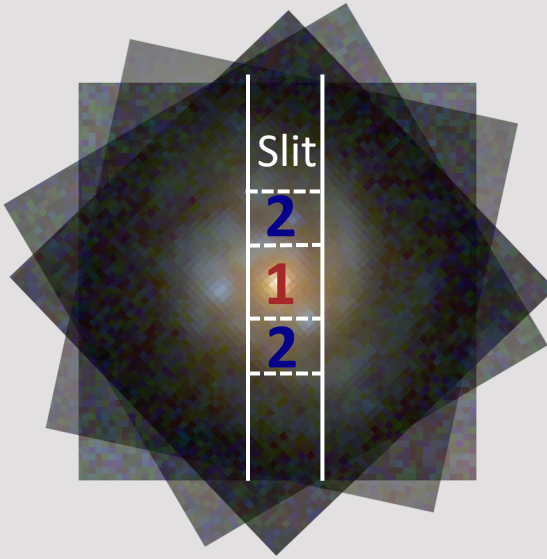


2: Outer Regions



W. Wang+ in prep.

Cool winds are found for both the centers and outer regions of the massive star forming galaxies at z=1.



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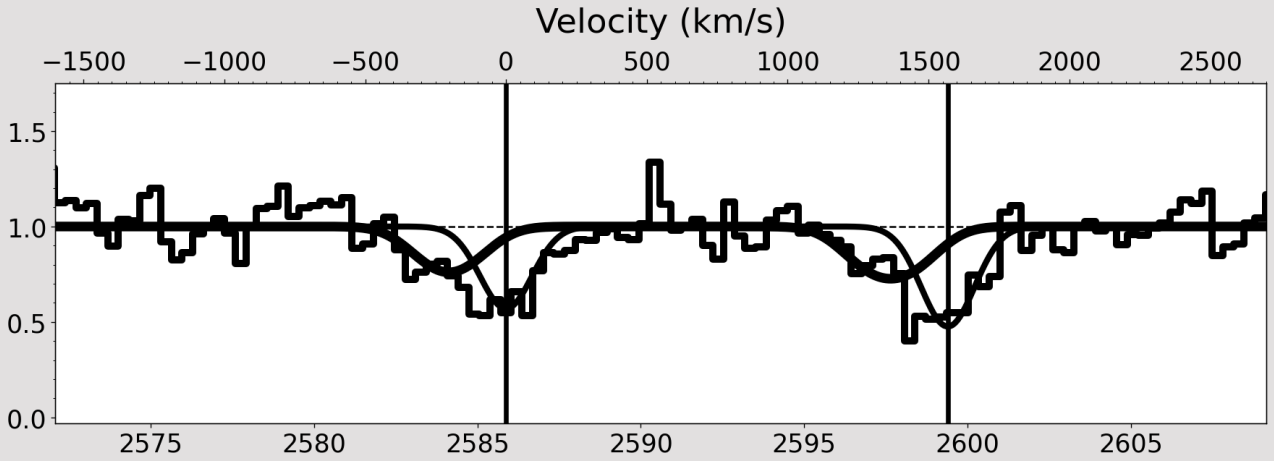
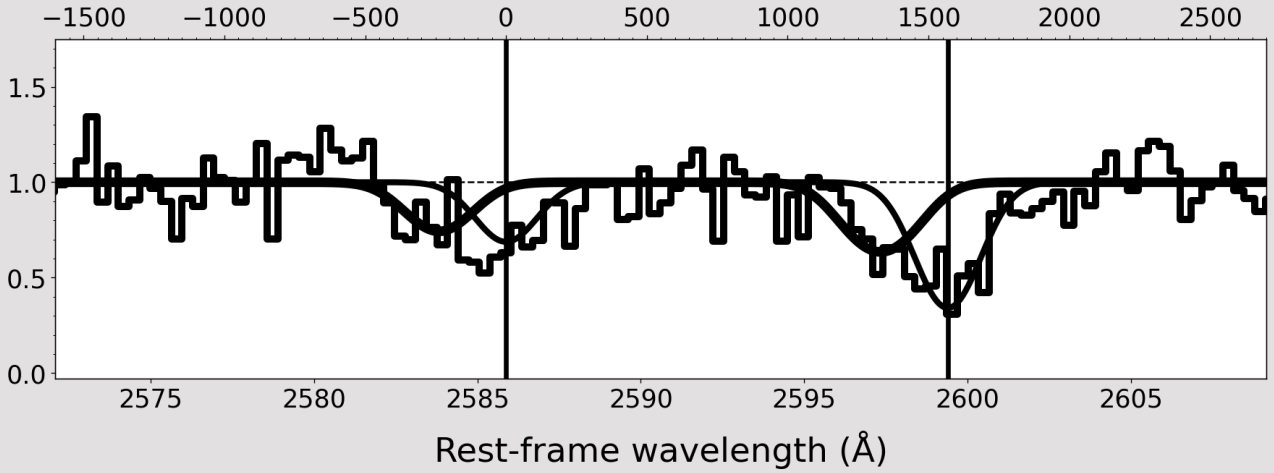


2: Outer Regions



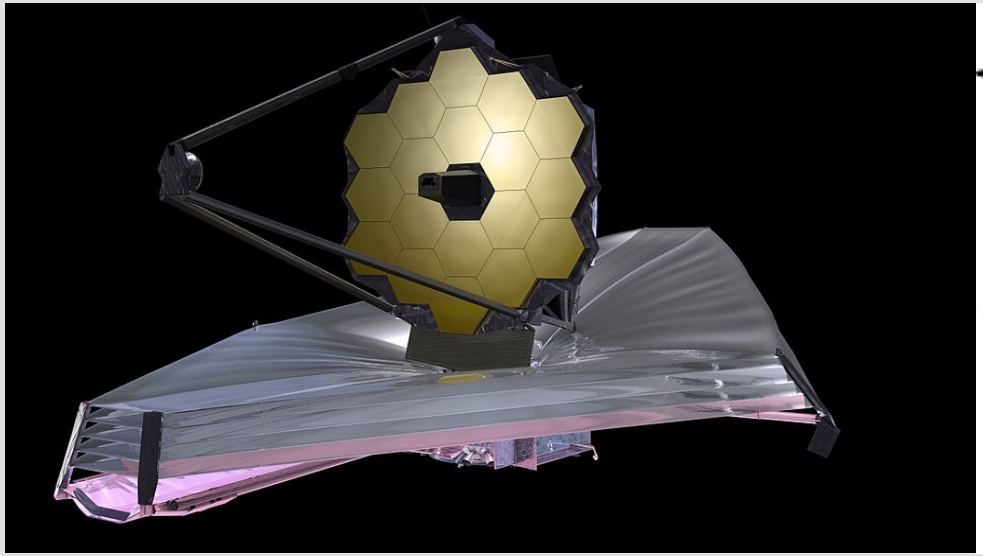
Vertical lines indicate systemic redshift.

Thin curve: component for the interstellar medium

Thick curve: component for wind

W. Wang+ in prep.

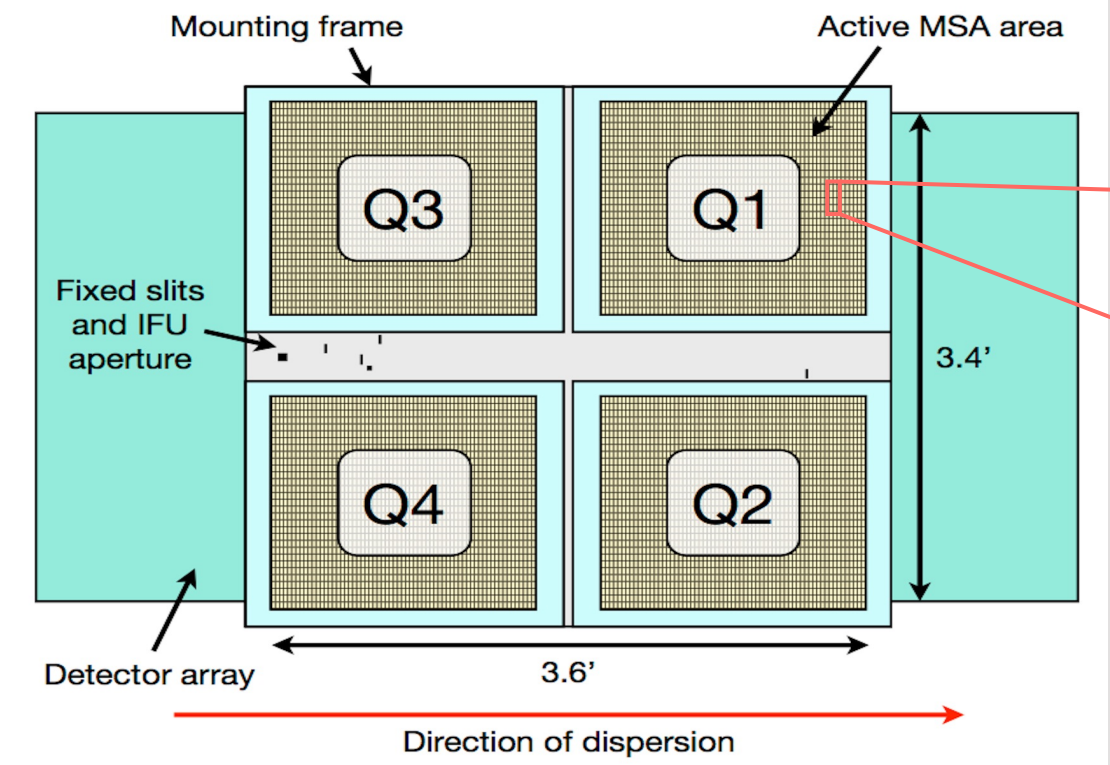
Part 2: Studying winds at z=2-5 with JWST



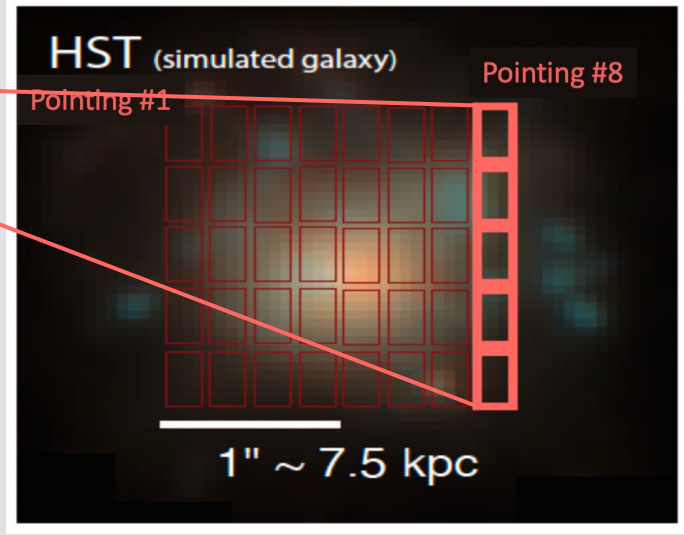
- Approved JWST Cycle-1 proposal (PI: Susan Kassin):
  A Pathfinder for JWST Spectroscopy: Deep High Spectral Resolution Maps of Galaxies over 1<z<6
- A total of 58 hours on source; R=2700; λ = 1.7-3.2 μm (F170LP)
- Technical lead for slitlet stepping: Weichen Wang
  Lead for wind projects: Ben Weiner & Weichen Wang
- Science goals: explore the relation between galactic winds, gas kinematics, and star formation across cosmic time

JWST: Slitlet stepping

JWST/NIRSpec Micro-Shutter Array (MSA)



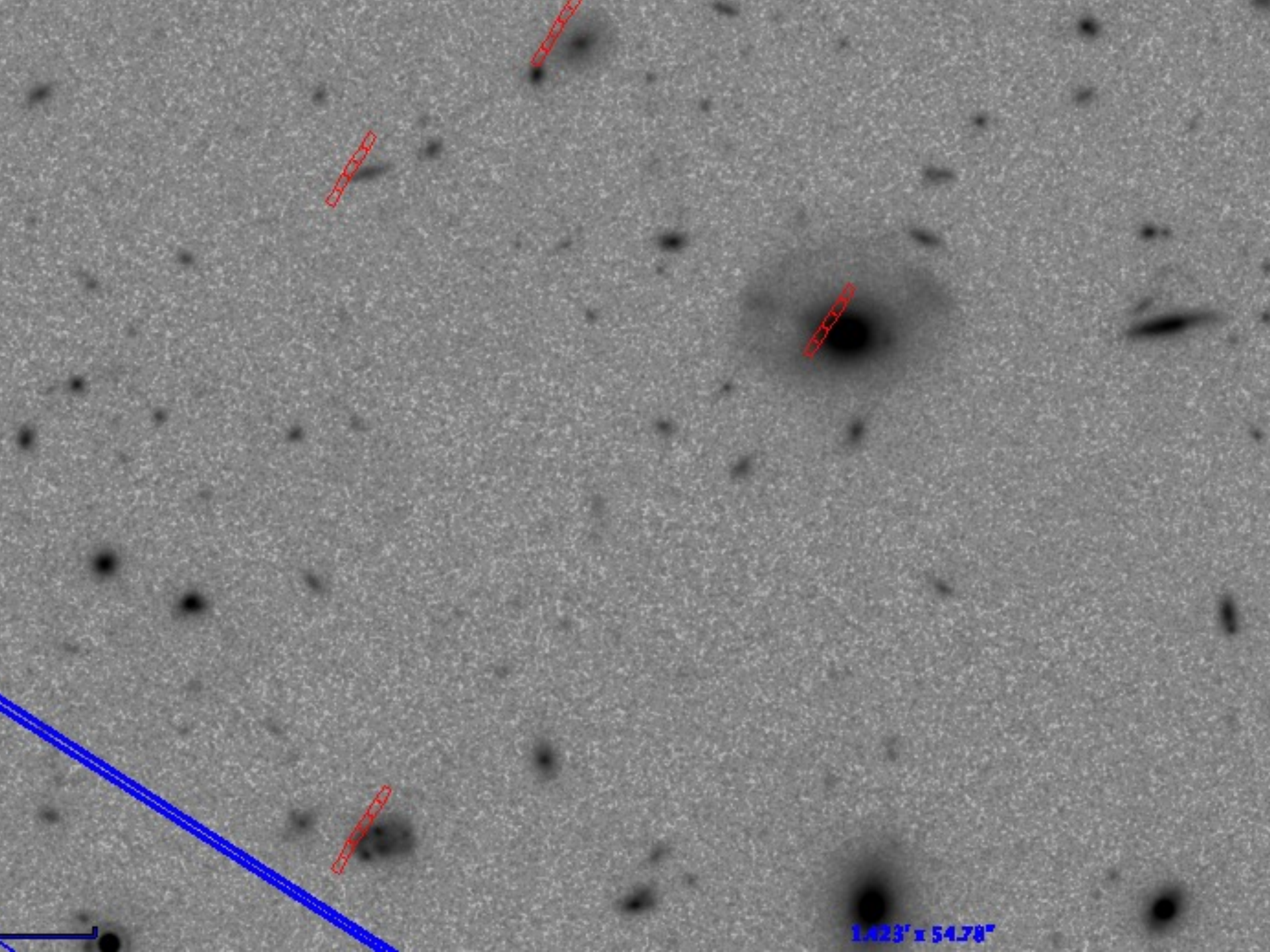
Observations with the MSA

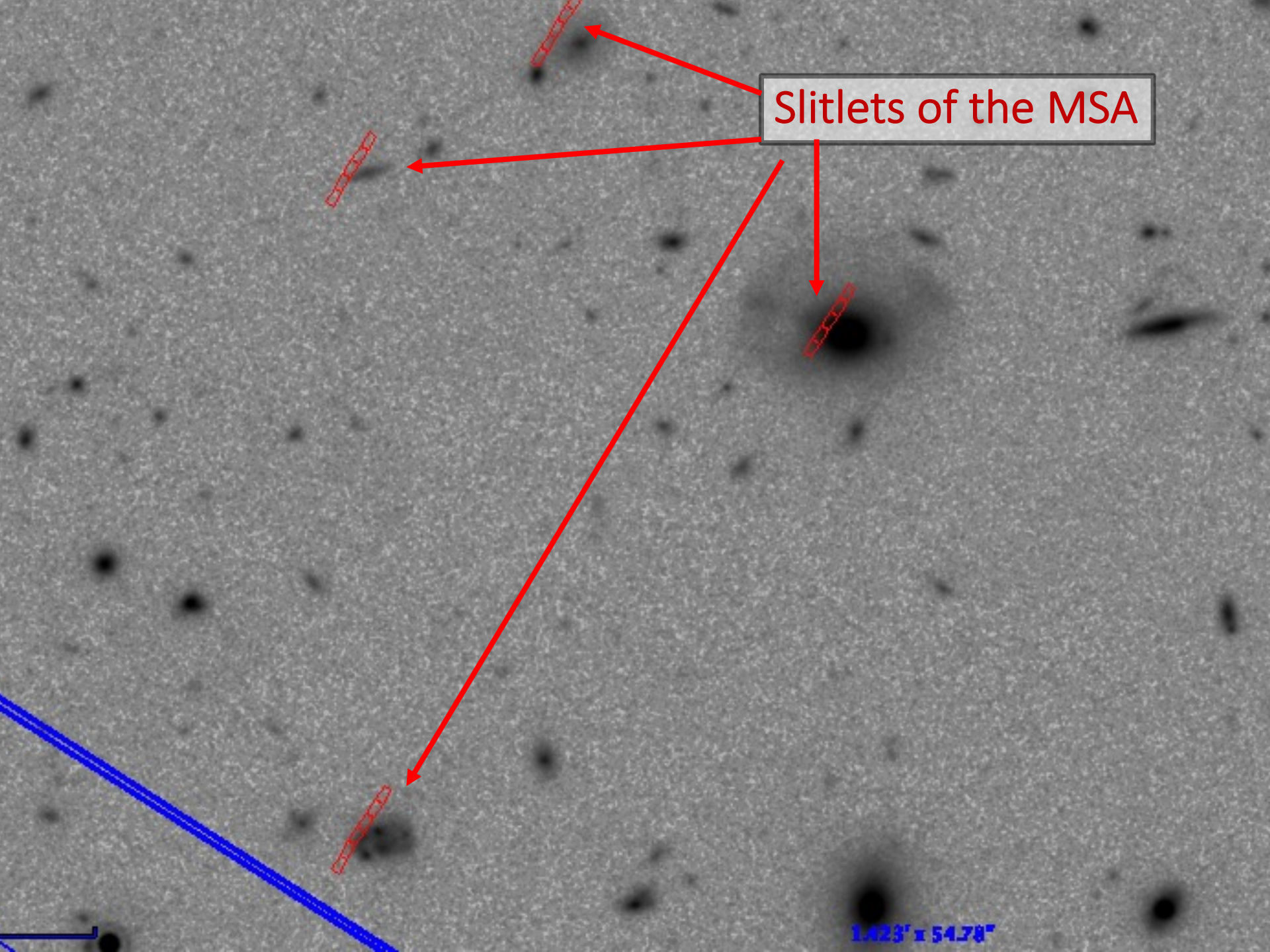


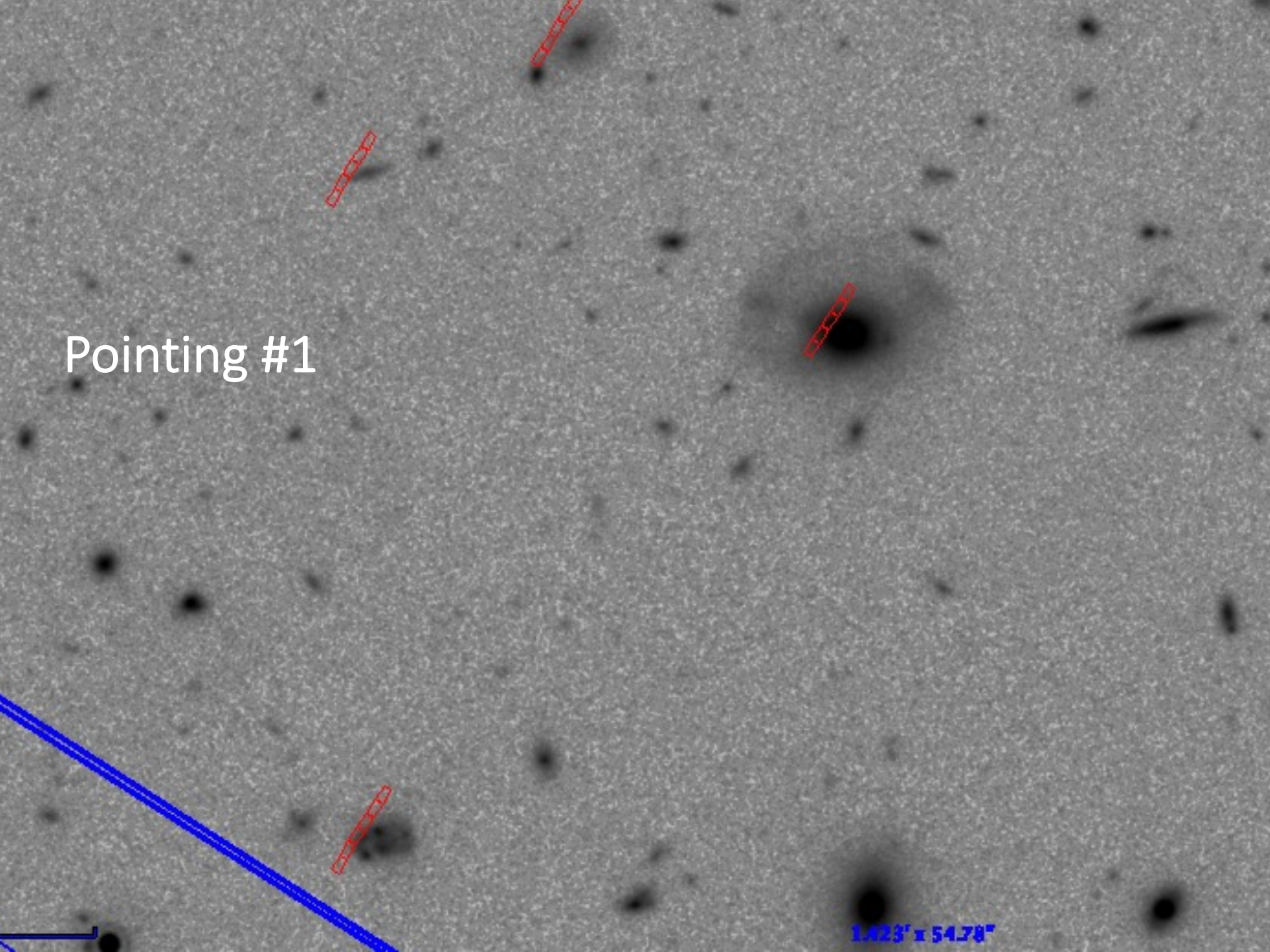
A novel mode to perform multiplex and resolved spectroscopic observations

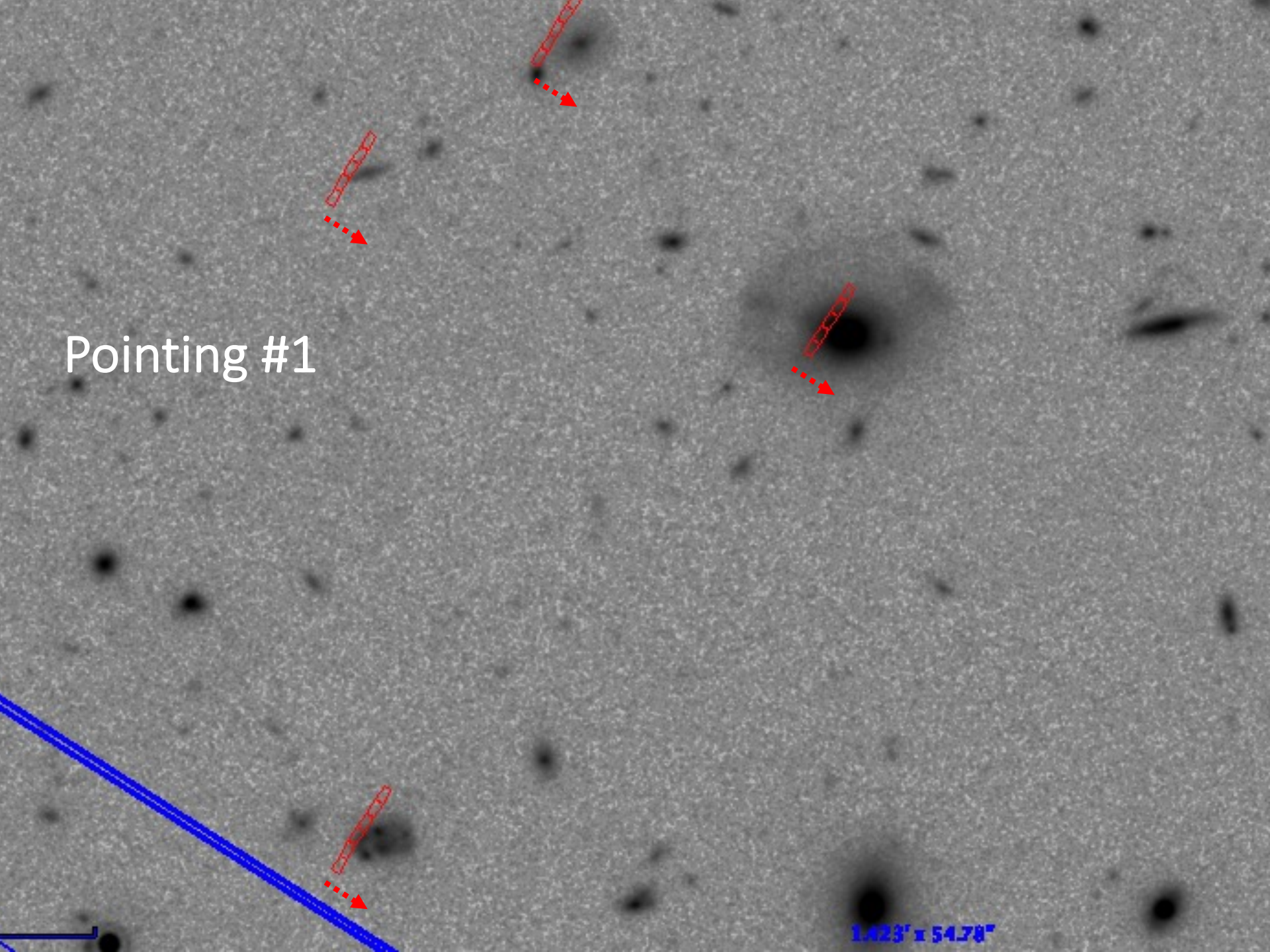
Credit: https://jwst-docs.stsci.edu/

JWST Cycle 1 Project, PI Kassin


1.423' x 54.78"


Slitlets of the MSA


Pointing #1
1.423' x 54.78"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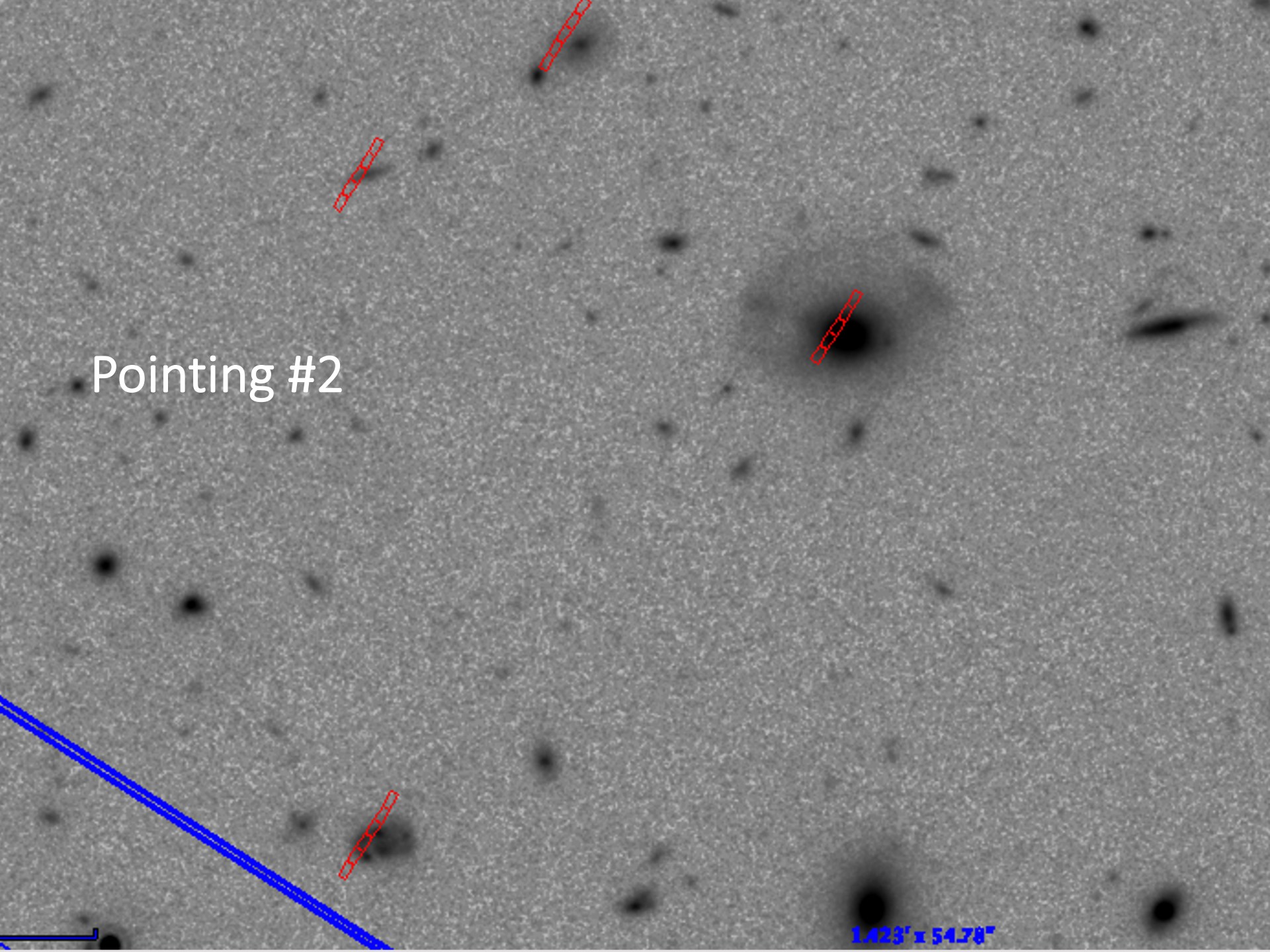
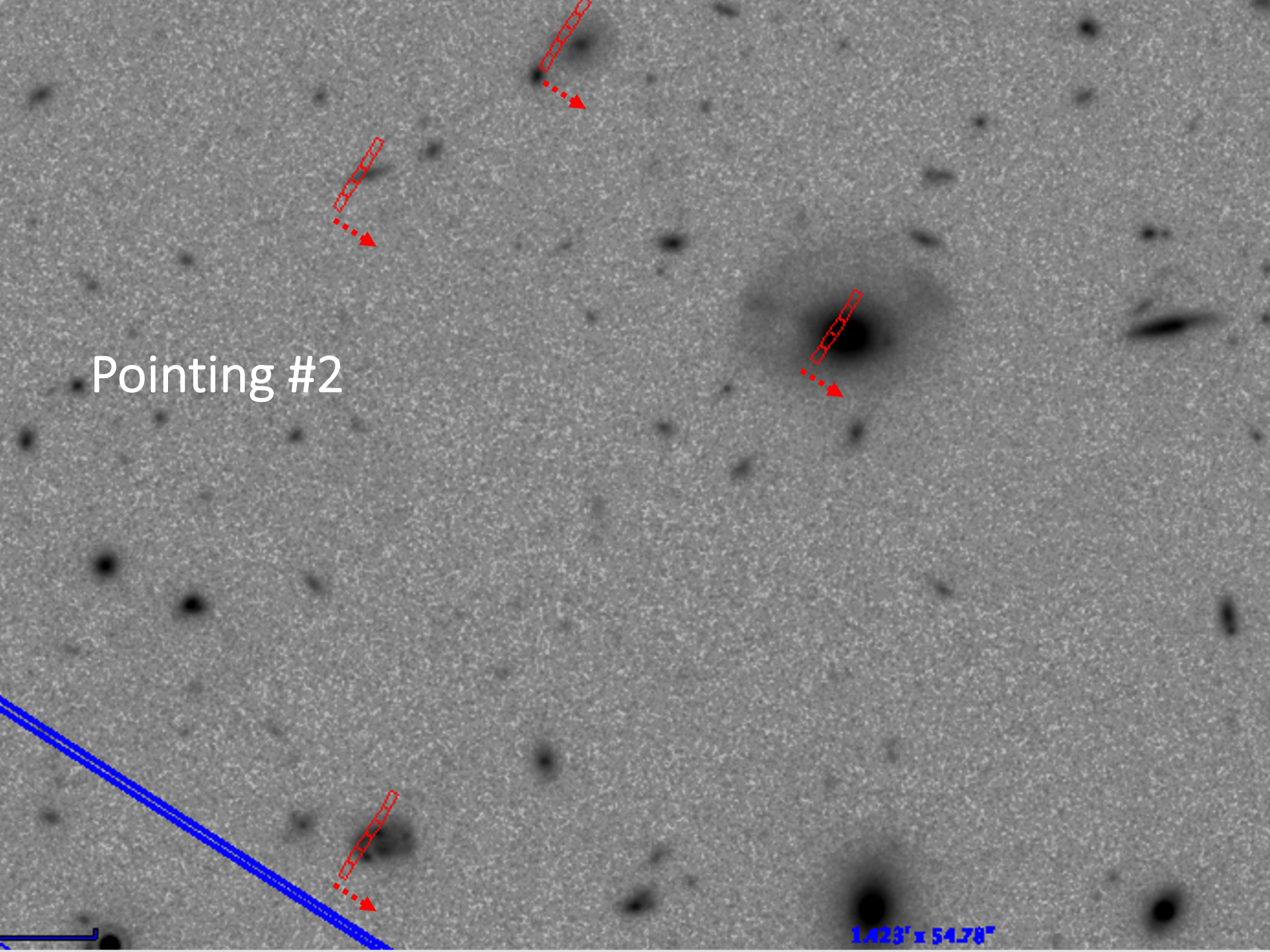

Pointing #2
1.423' x 54.78"


Pointing #2
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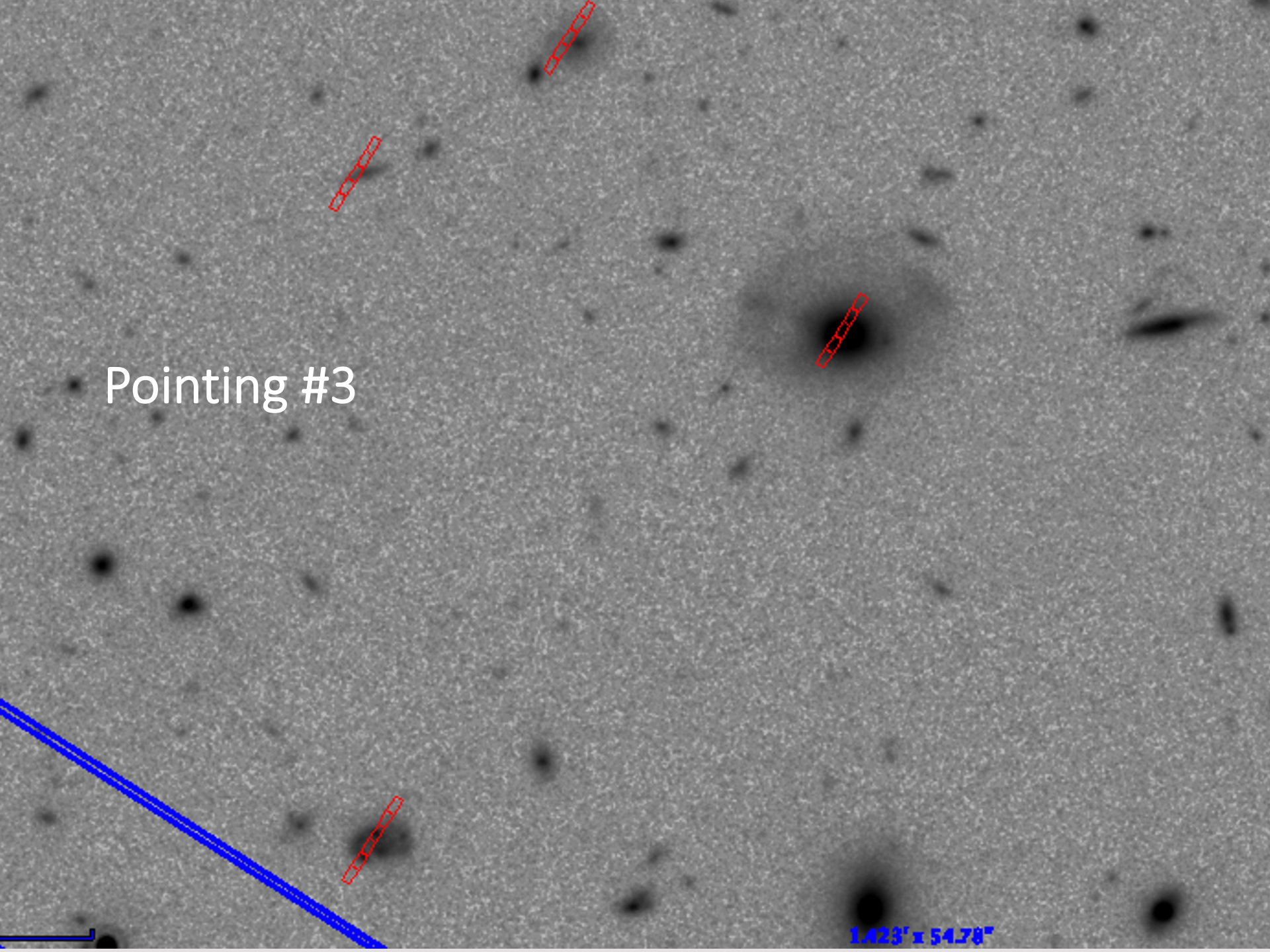
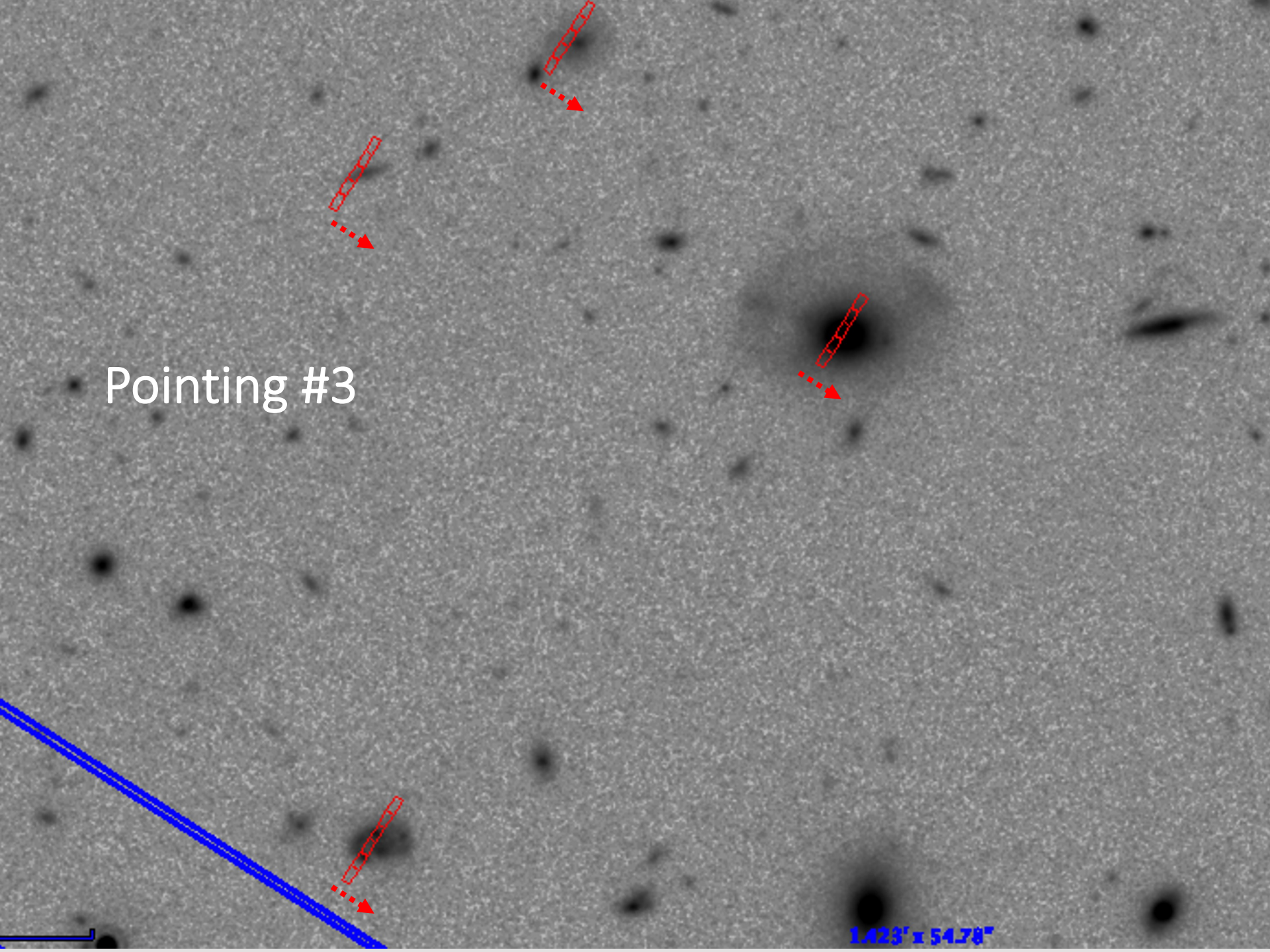
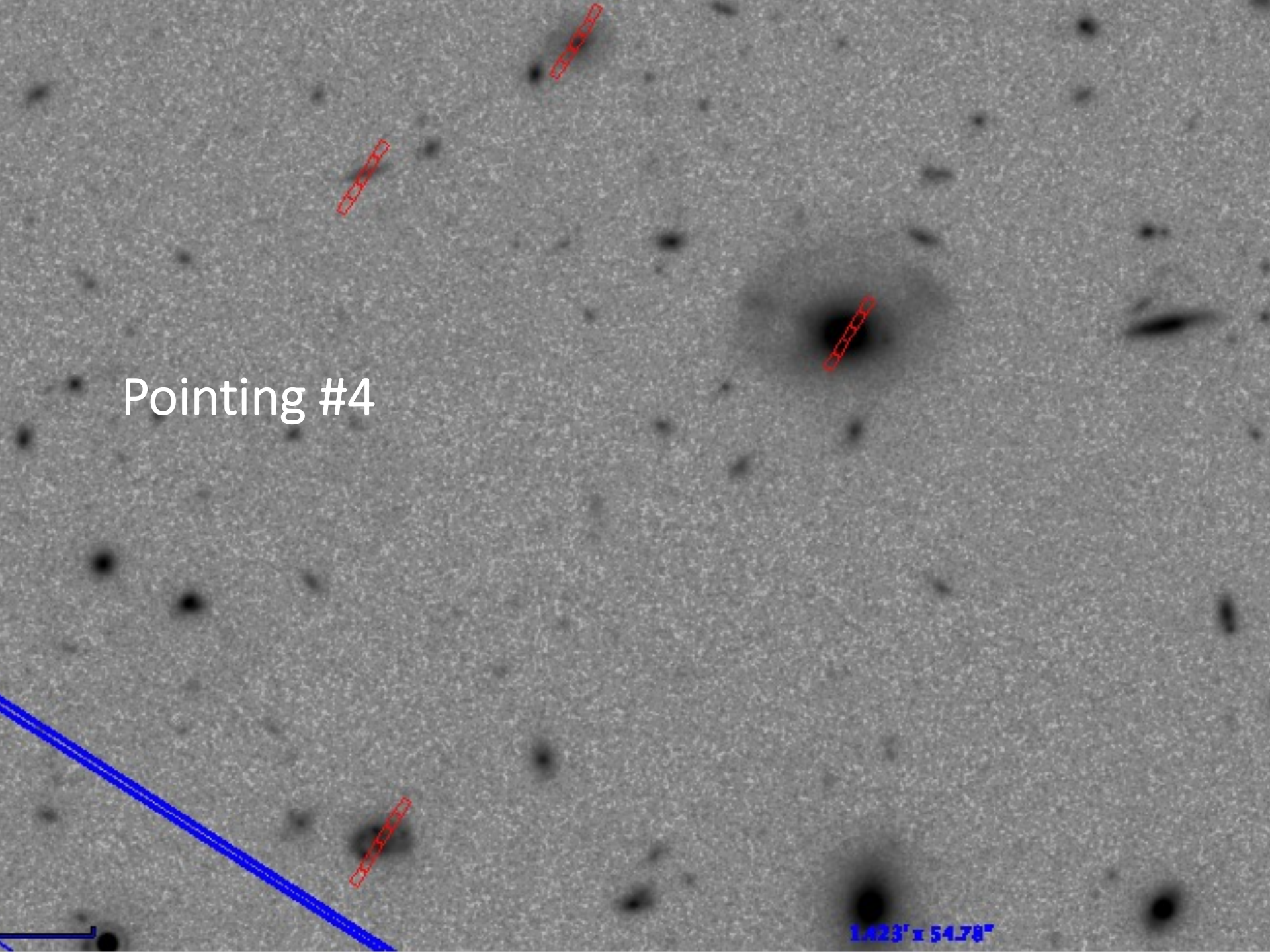
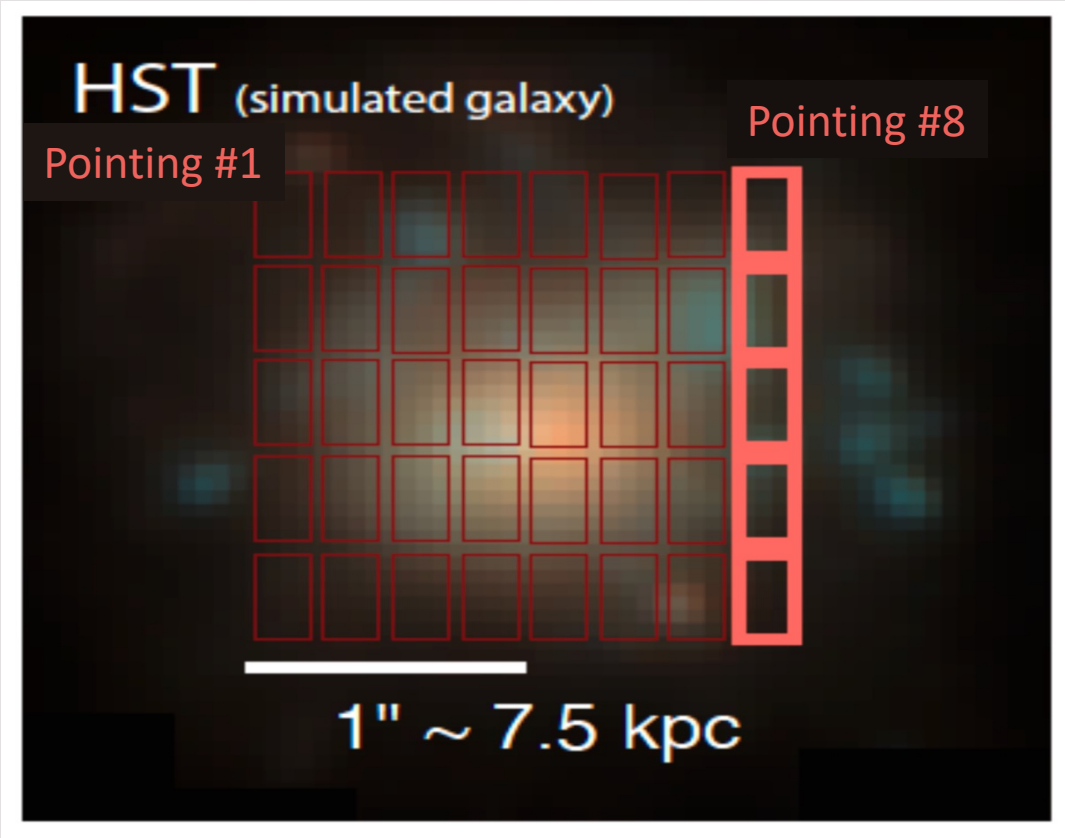

Pointing #3


Pointing #3


Pointing #4
1.423' x 54.78"

JWST: Slitlet stepping

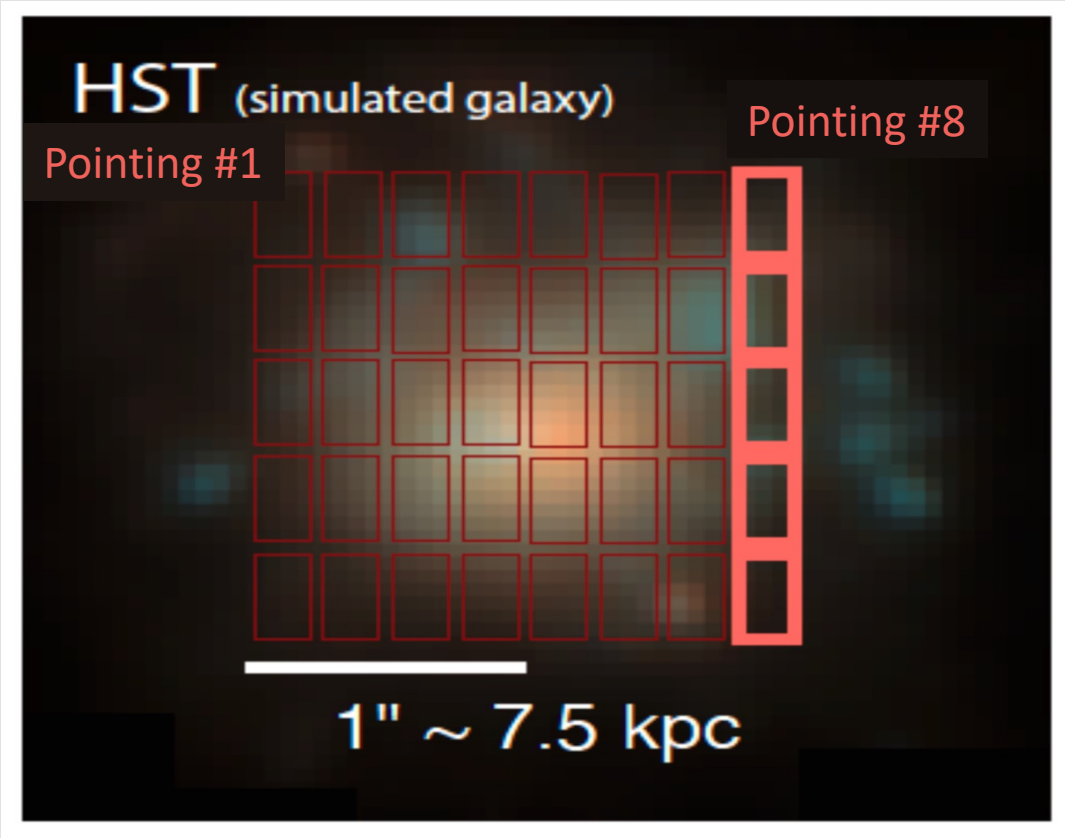


×40

With slitlet stepping, ~40 galaxies can be observed **simultaneously** using the Micro-Shutter Array.

This observation mode is x20 more efficient than the IFU of NIRSpec.

JWST: Slitlet stepping



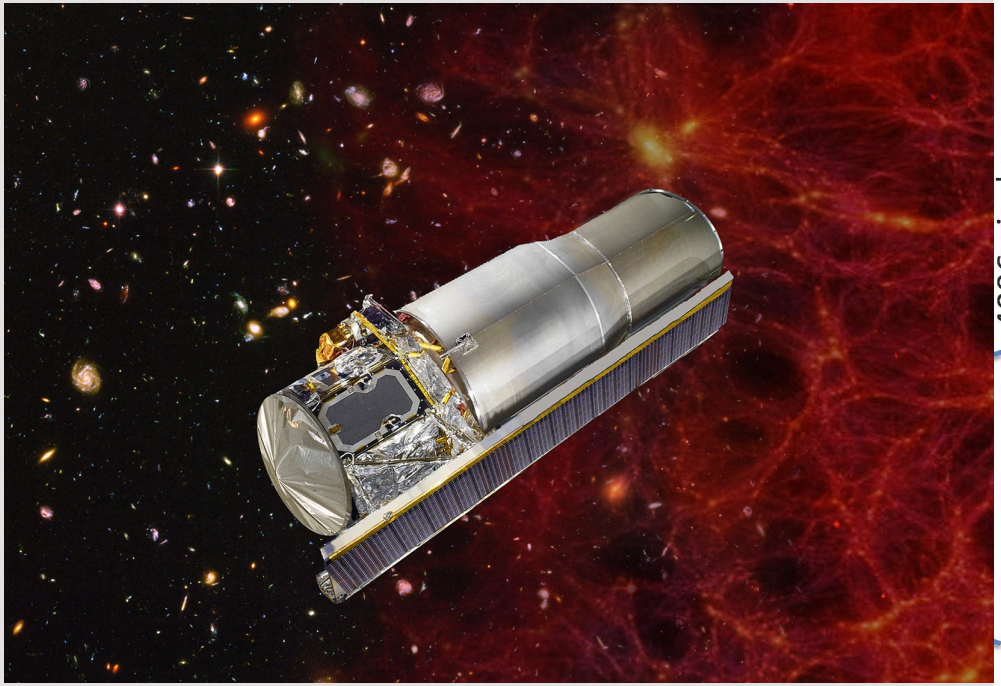
×40

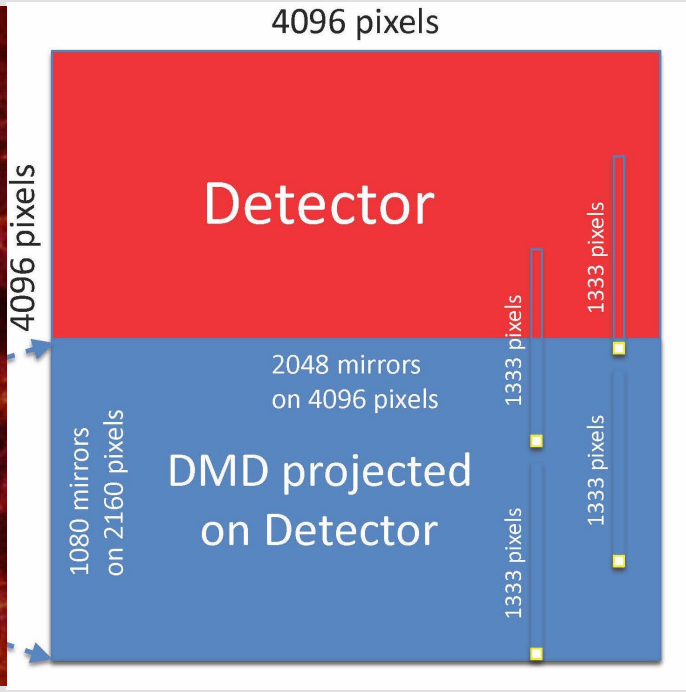
At z=2-4: Na D trace cool neutral winds;
Hα and O III trace warm ionized winds.

At z~5: Fe II and Mg II trace cool winds.

Part 3: Studying winds at high z with ATLAS

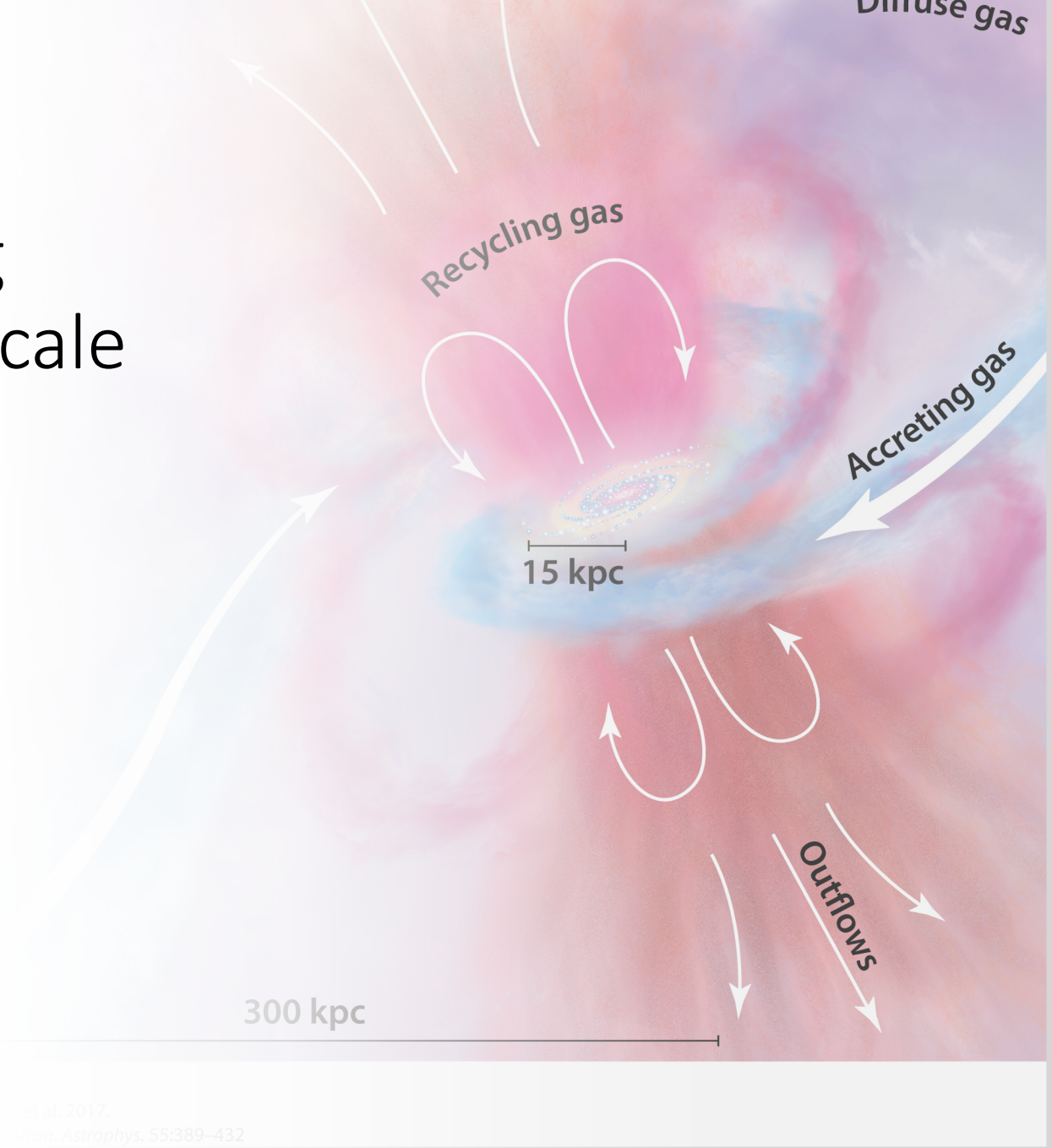
- A mode similar to “slitlet stepping” can be implemented with ATLAS to perform resolved observations of hundreds/thousands of galaxies at the same time. (talks by Richard Ellis, Alaina Henry)
- The Mg II and Fe II absorption lines can be probed at 3<z<8 with a spatial resolution better than 0.4”.





Credit: https://atlas-probe.ipac.caltech.edu/

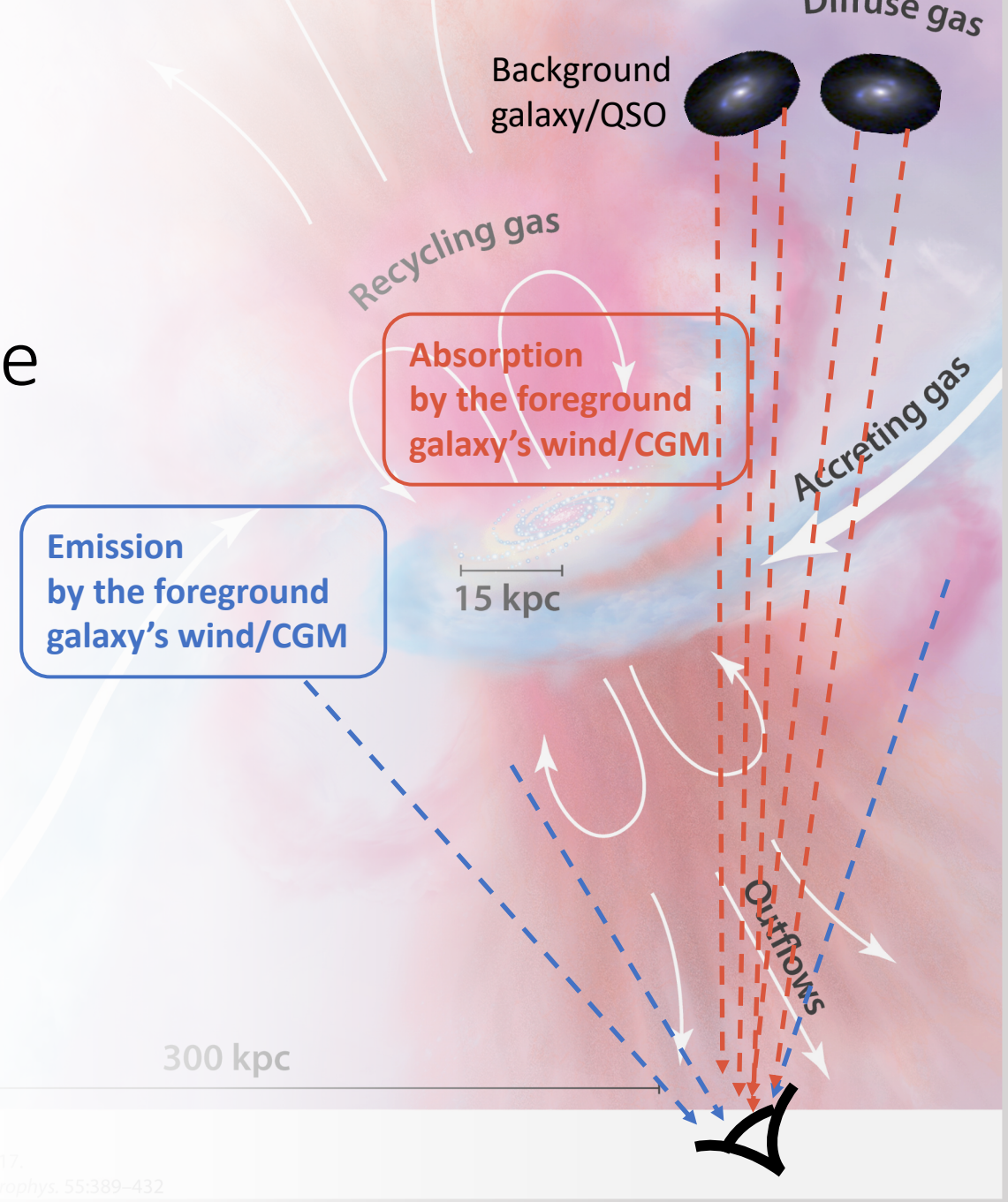
ATLAS: studying winds at large scale



Tumlinson, Peeples & Werk (2014)

ATLAS: studying winds at large scale

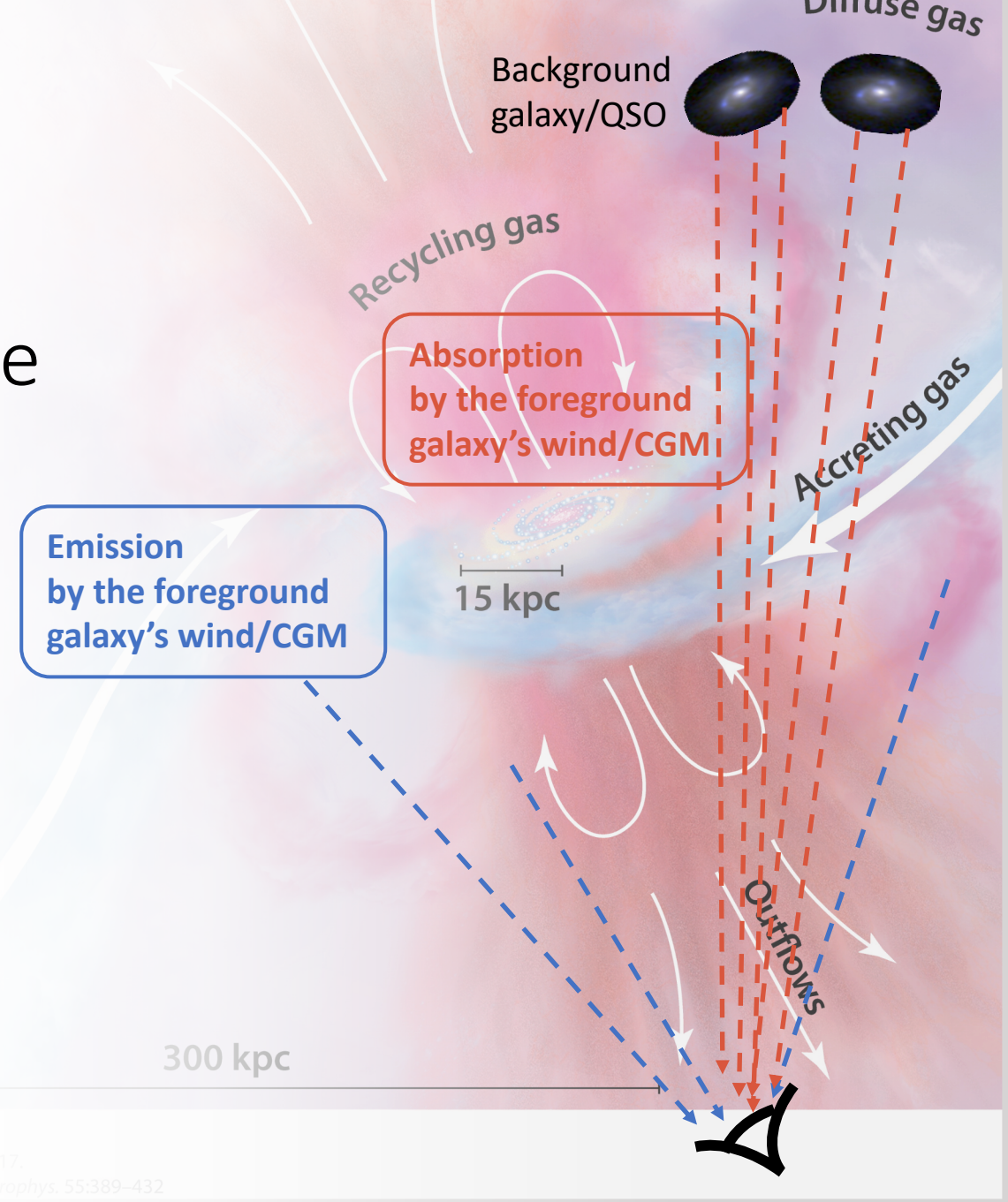
- ATLAS can study the wind or the circum-galactic medium (CGM) with slitlet stepping.



Tumlinson, Peeples & Werk (2014)

ATLAS: studying winds at large scale

- By stacking thousands of galaxies, we will obtain a comprehensive picture of galactic winds or the CGM in the early Universe.



Tumlinson, Peeples & Werk (2014)

Summary: study winds across cosmic time

1. At z=1 (Keck/DEIMOS):
   Cool galactic winds are found from both the inner and outer parts of the massive star forming galaxies.

2. At z=2-5 (JWST/NIRSpec):
   A novel mode, slitlit stepping, will soon be used to observe up to 40 galaxies **simultaneously**.

3. A similar mode can be used with ATLAS to perform resolved studies of winds/CGM with very high multiplexing capability.