background:Lyα nebula of radio galaxy

JWST finds the ionization cone but no radiative-driven feedback in a powerful z~3.5 RL AGN

Wuji Wang(王无忌)

ARI, Center for Astronomy of Heidelberg University

Dominika Wylezalek
Joël Vernet (ESO)
Carlos De Breuck (ESO)

My web

1st December 2023
EURECA@Steward Observatory

Galaxy evolution & AGN feedback at Cosmic (high) Noon

- Gas accretion fuels black hole growth and star formation
- Feedback ejects material/energy back to surrounding medium
- State-of-the-art IFUs can detect feedback processes from ISM to CGM and have access to different gas phases

Tumlinson J, et al. 2017.
Annu. Rev. Astron. Astrophys. 55:389–432

Tumlinson et al. 2017

AGN feedback at Cosmic (high) Noon – powerful jets

- Cosmic high-noon is the epoch of the fastest build-up of the most massive galaxies

- Epoch of powerful feedback from most energetic AGN

- Evidence of quenching found in z~3.5 massive galaxies (Suzuki+22); consuming/expelling gas fast ~100s Myr

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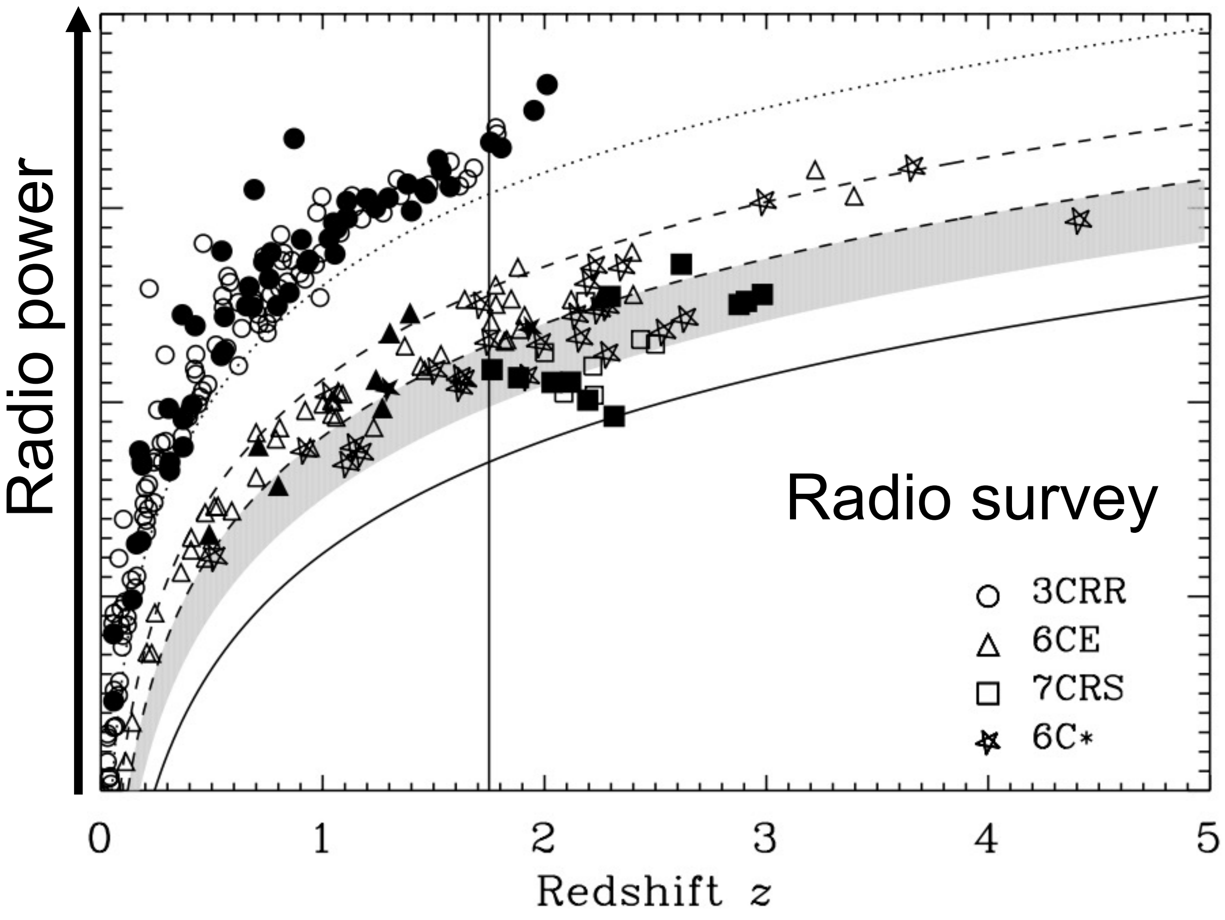
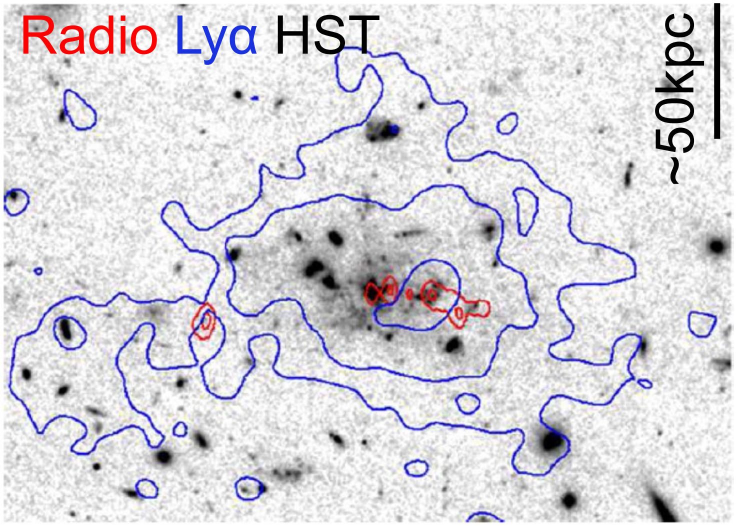
Jarvis et al. 2001



High-redshift radio galaxies (HzRGs)

- Type-2 quasars + powerful jet, $z>1$ McCarthy 1993; Miley & De Breuck 2008



Spiderweb
Miley+06

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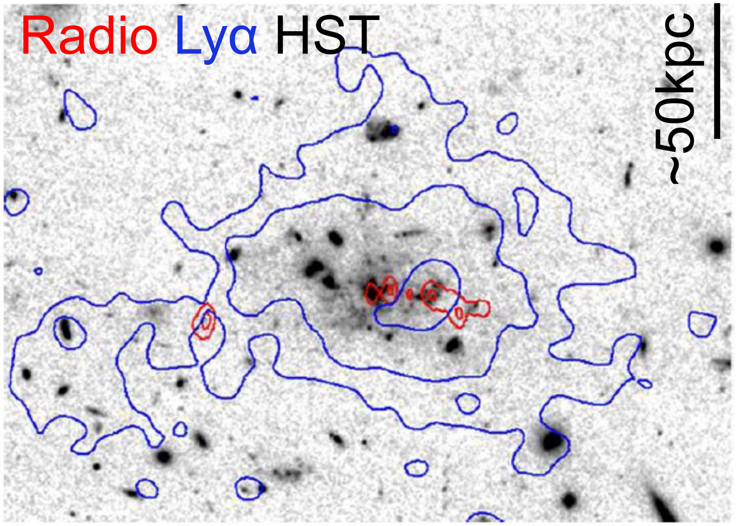
- Live in dense proto-cluster environment Venemans+07; Wylezalek+13, 14



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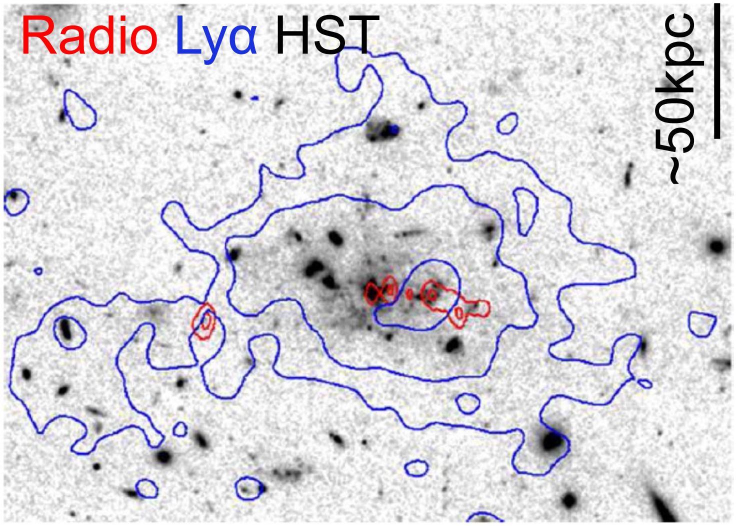

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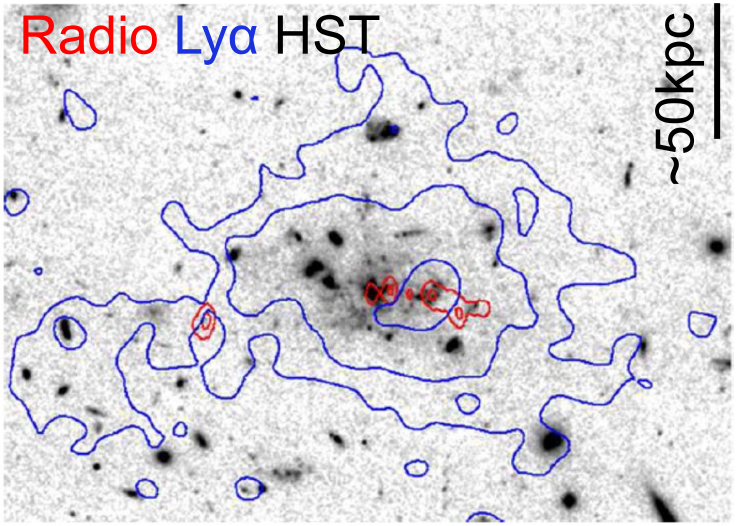

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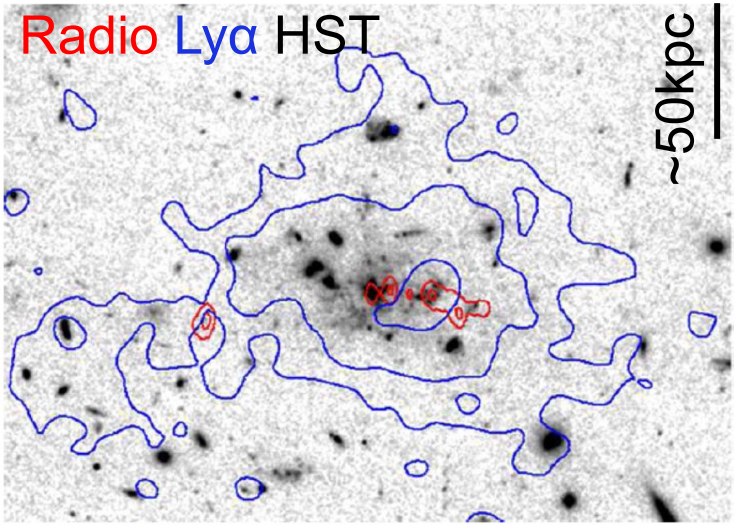

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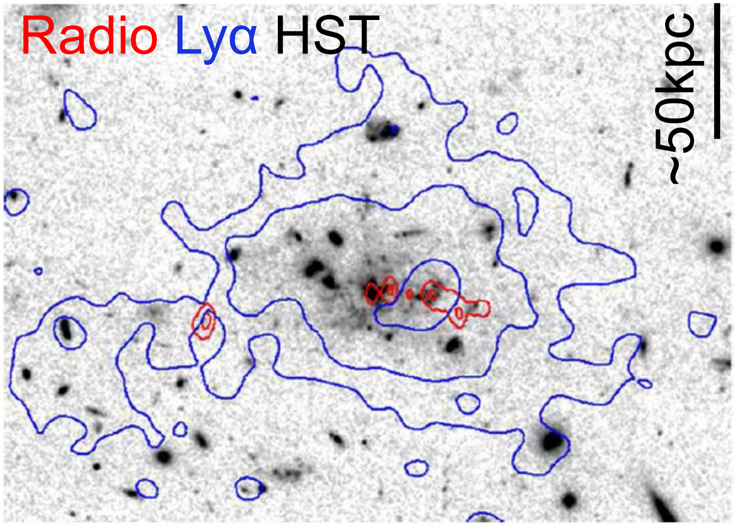


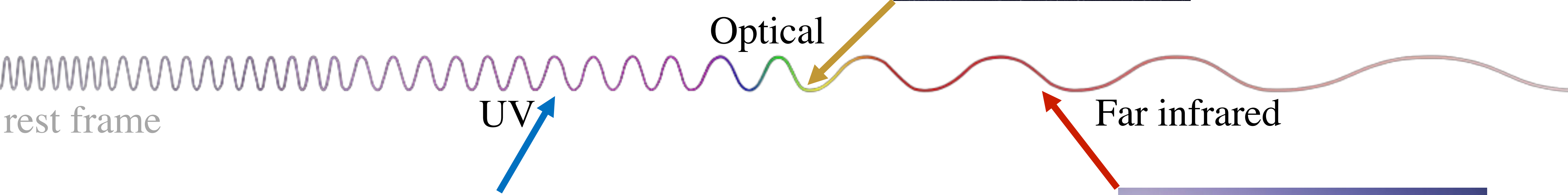
Spiderweb
Miley+06

Missing the detailed sub-kpc view near the AGN

Zooming into the monster's mouth – JWST NIRSpec IFU View

- NIRSpec IFU observation of 4 HzRGs at z~3.5
- Targeting all frequently studied optical emission lines at sub-kpc resolution, e.g., [OIII]5007
- All observed (one is presented in this talk)

JWST Cycle1
PI: Wuji Wang



MUSE
PI: J. Vernet

ALMA Band8 [CII]
PI: Wuji Wang

image credit:
ALMA collobration, NASA

HzRG: 4C+19.71 (MG2144+1928)

- Multi-wavelength observations: VLA, ALMA, Herschel, Spitzer, SINFONI, HST, MUSE, Chandra… Carilli+97; Pentericci+99; Seymour+07; De Breuck+10; Smail+12; Nesvadba+17; Falkendal+19,21, W.Wang+23
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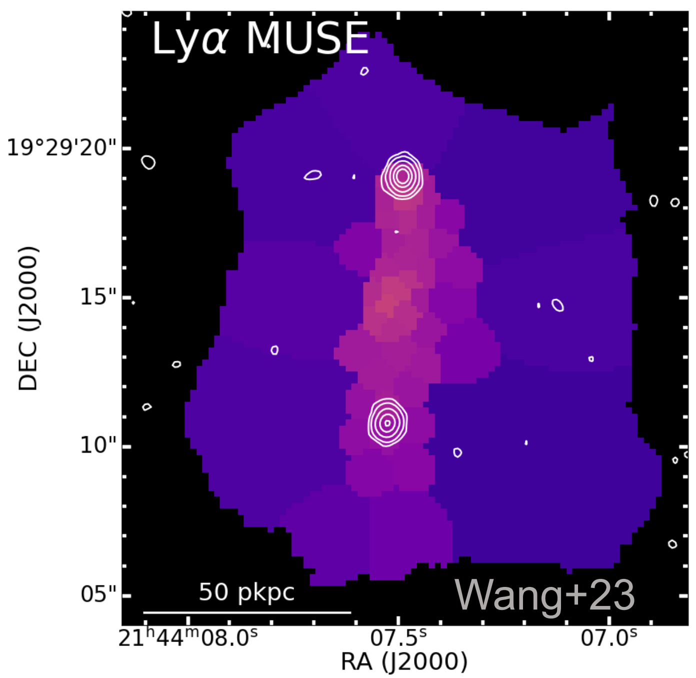
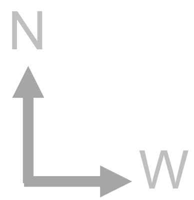
- Lyα nebula ~143 kpc, ~60 kpc X-ray halo Inverse Compton





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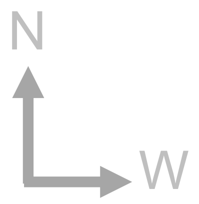

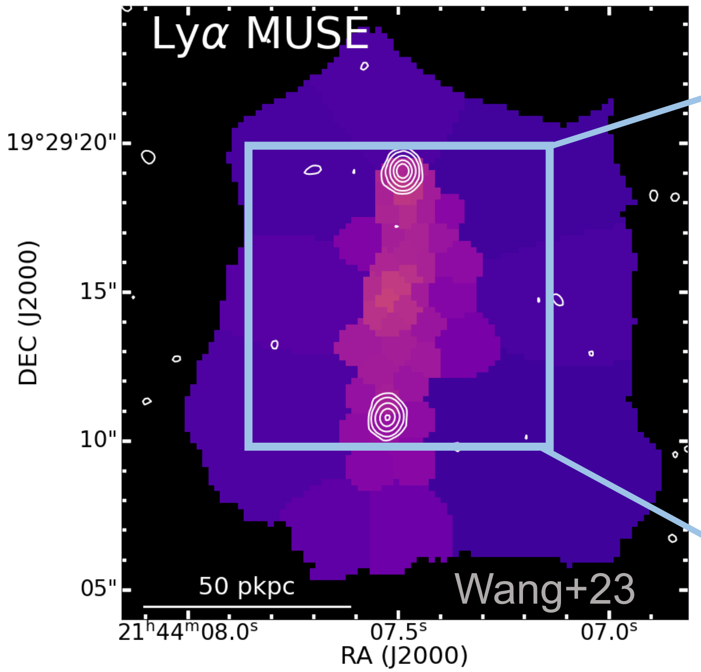

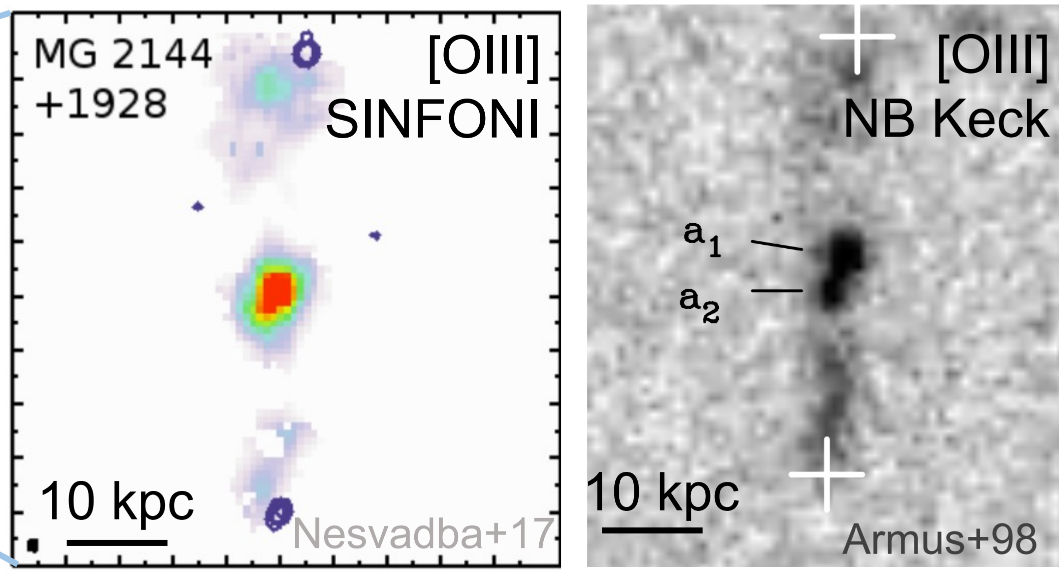

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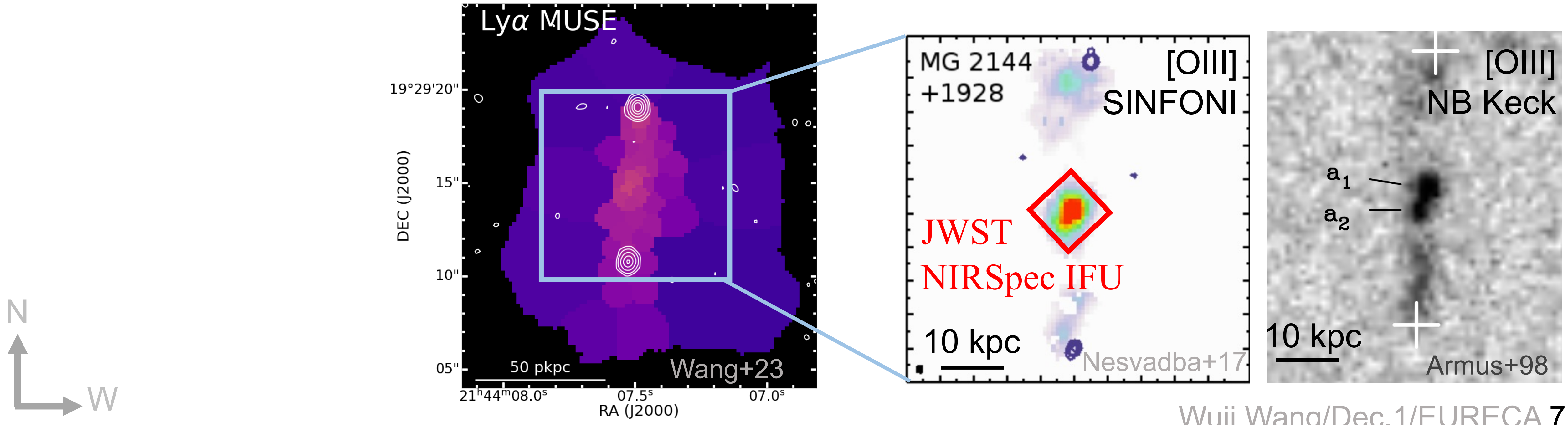

JWST NIRSpec IFU Observation

Wuji Wang et al. submitted

In collobration with: D. Wylezalek, C. De Breuck, J. Vernet, D. Rupke, A. Vayner, N. Zakamska, M. Lehnert, N. Nesvadba, D. Stern

- Just received (positive), referee report, read the paper HERE by Scan the QR code!
- Or through the link on my web page: wujiwang-astro.github.io

JWST NIRSpec IFU Observation

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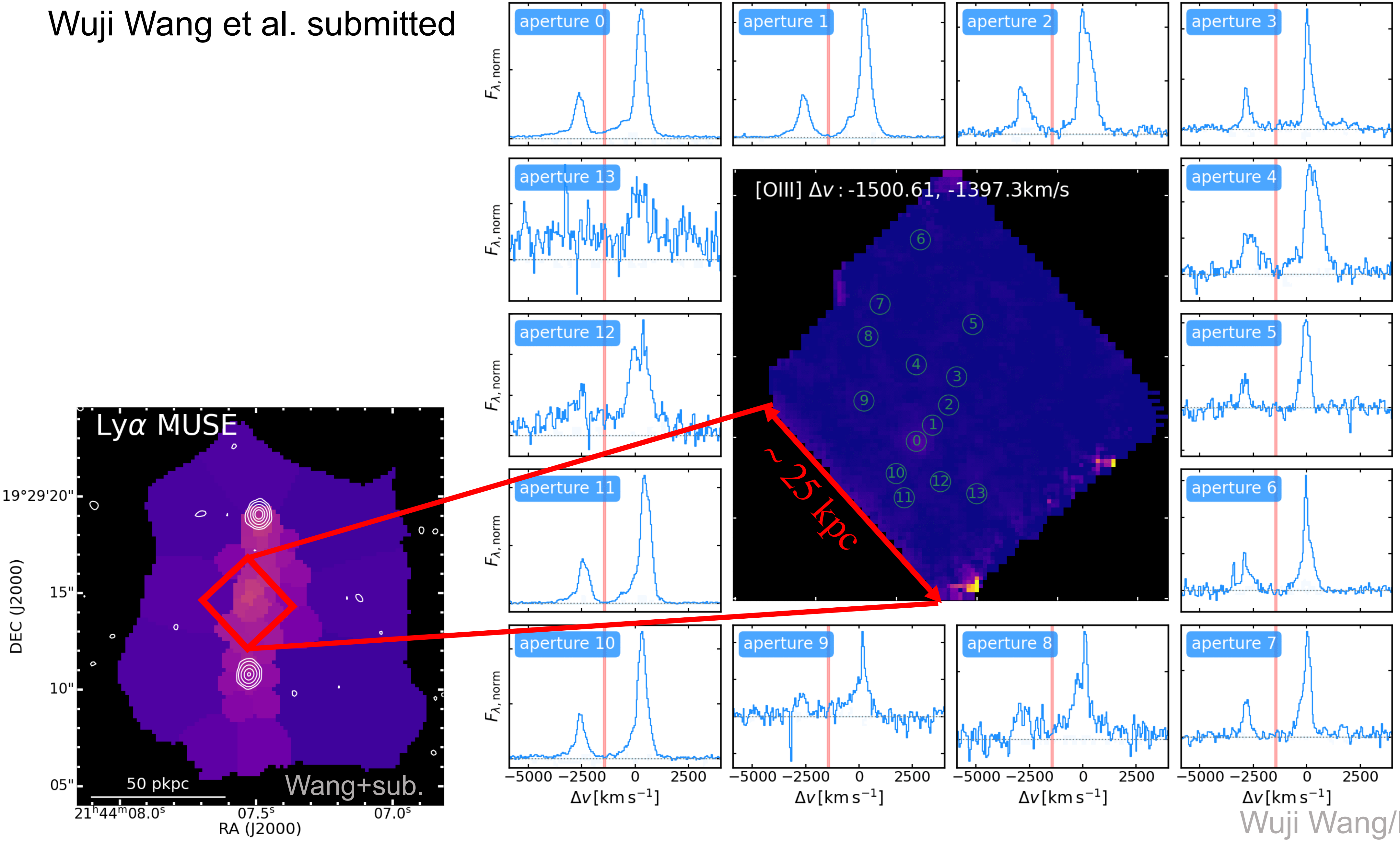
paper



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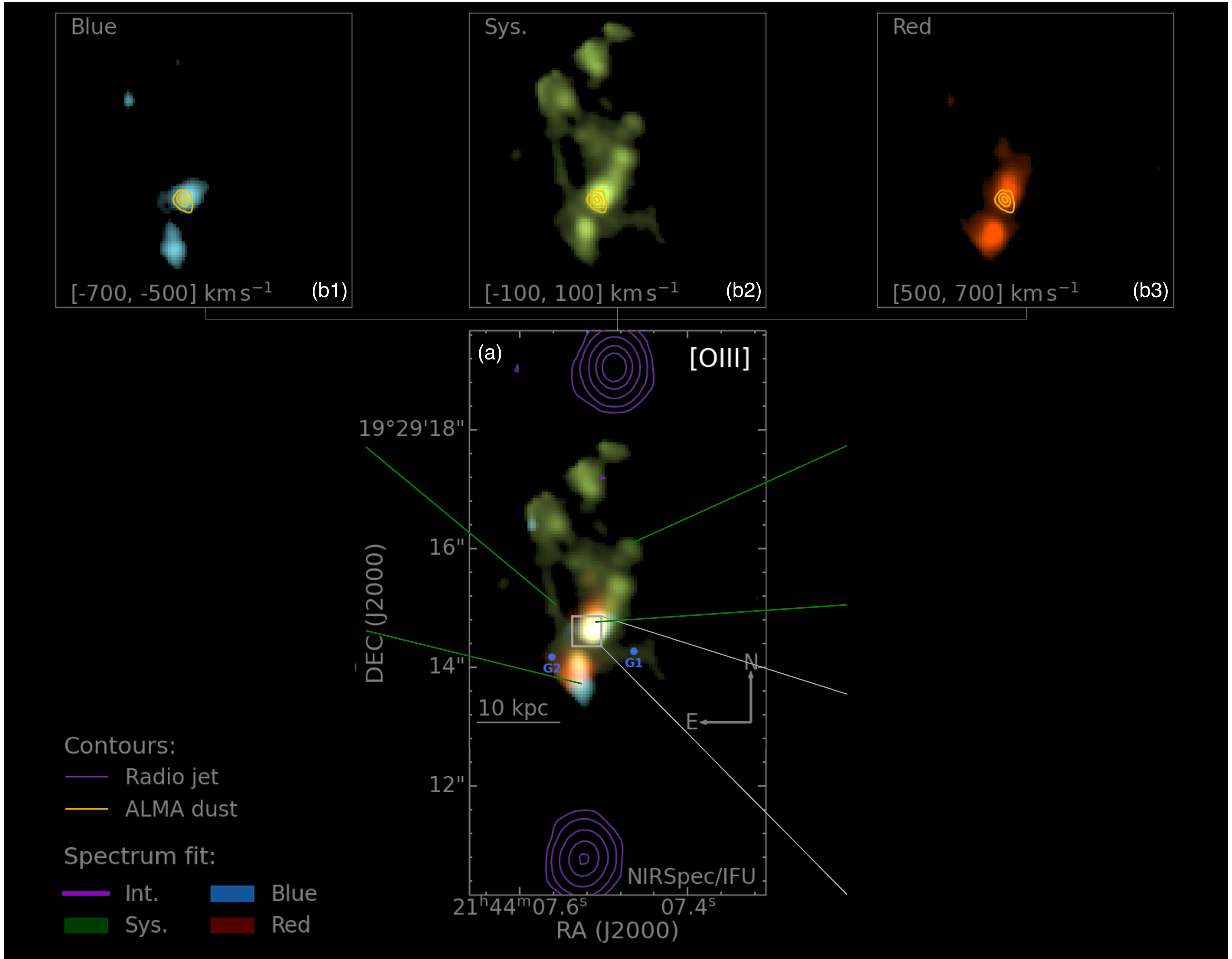

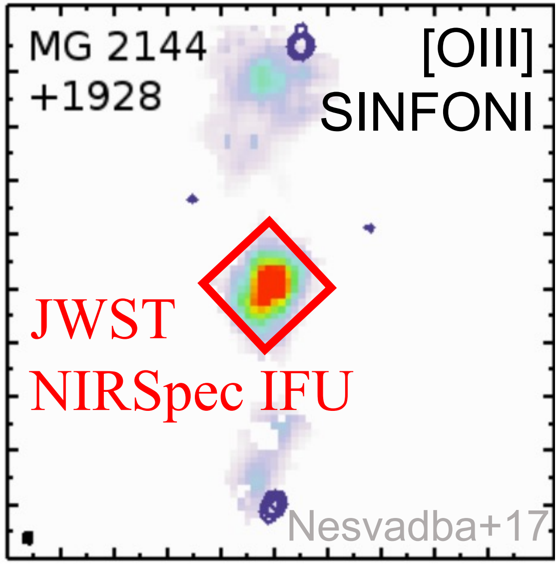

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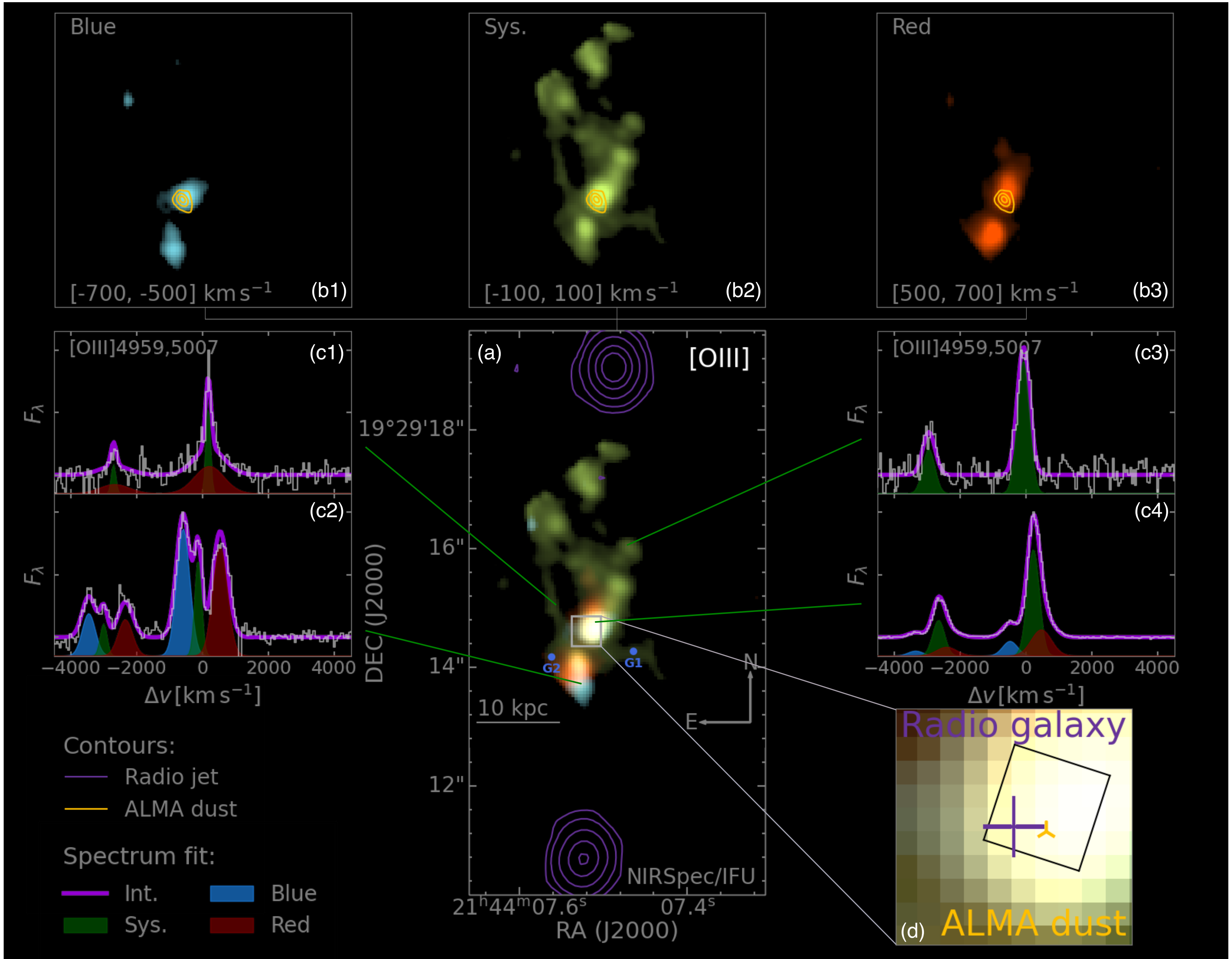
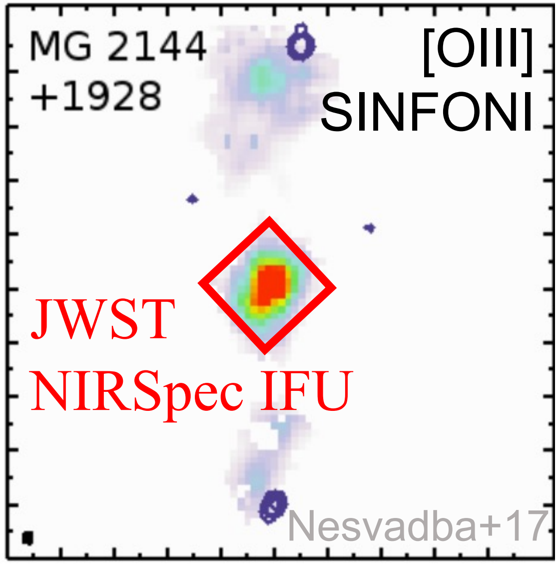


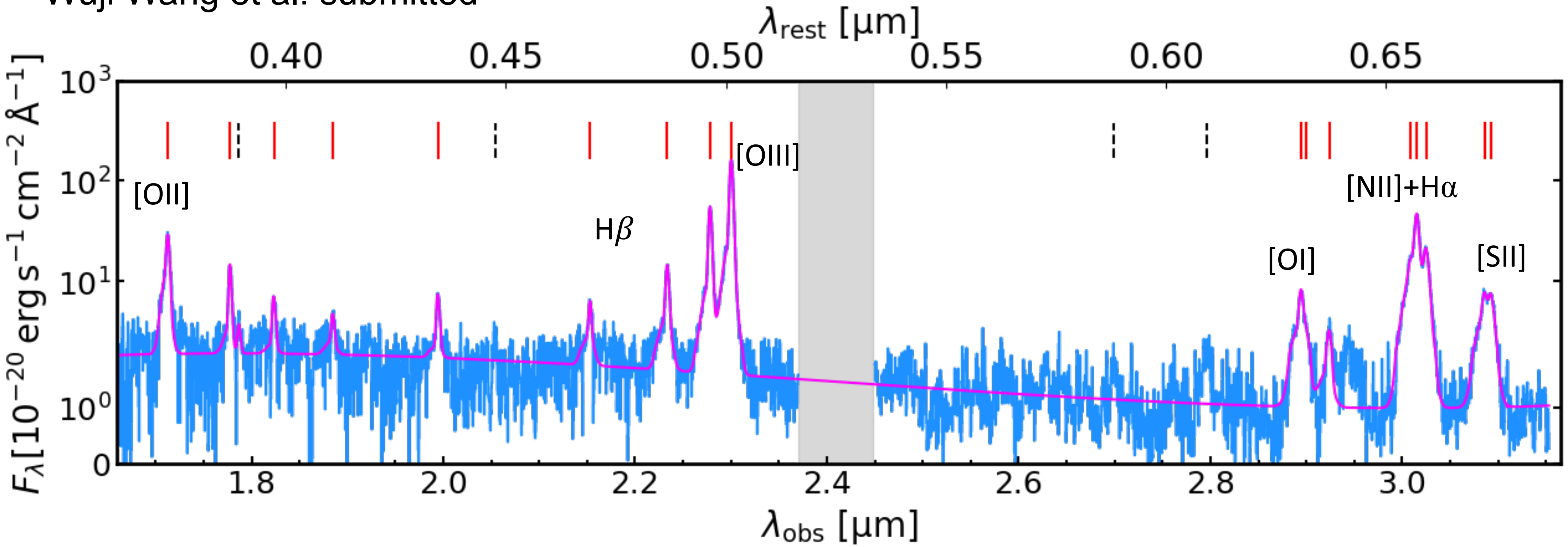


- No strong outflow >10 kpc

Full spectrum at AGN

paper

Wuji Wang et al. submitted

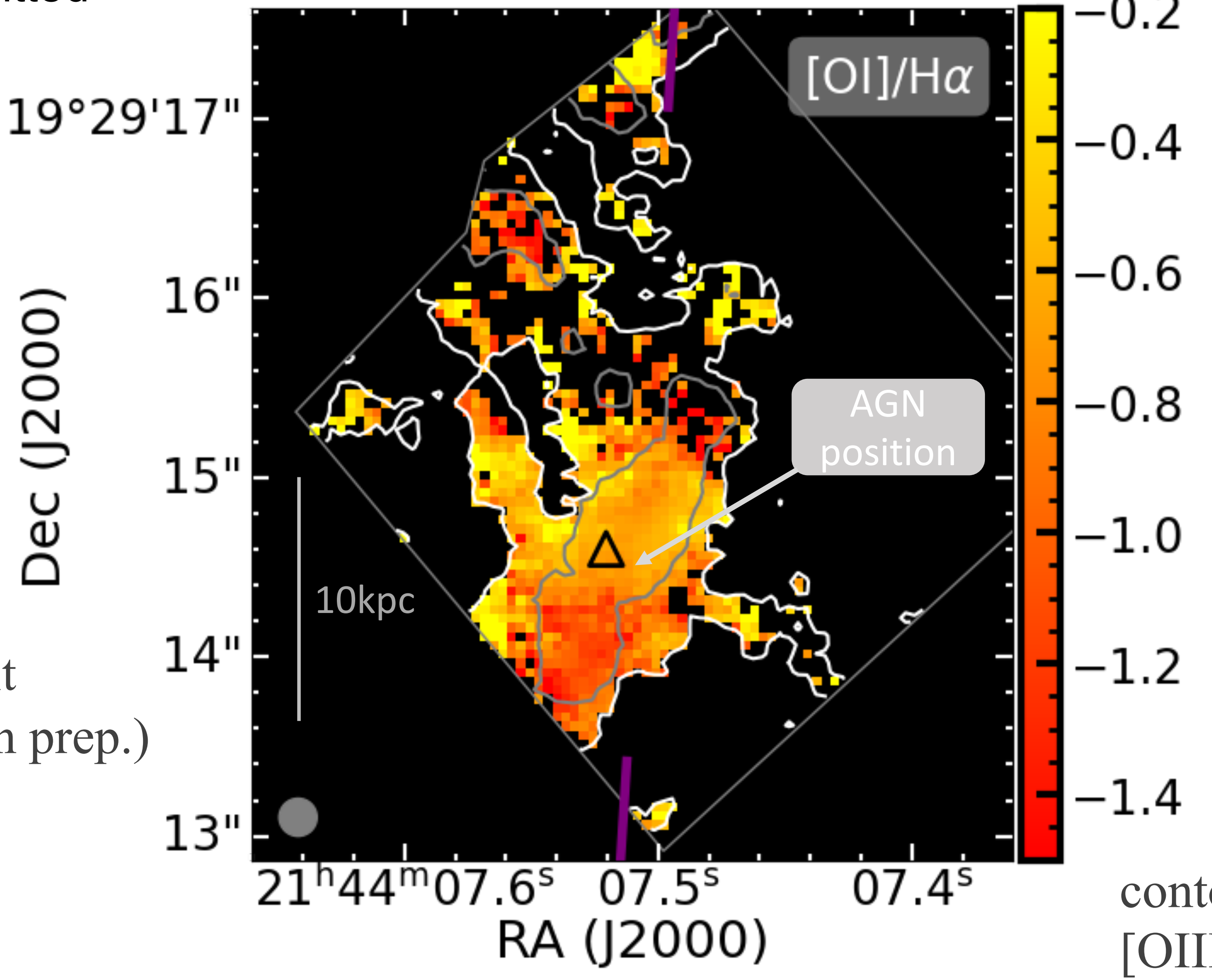


- ~ 24 emission line detected, from [OII] to [SII]
- A wealth of lines for line ratio diagnostics

Line ratio diagnostics – example [OI]/Hα

paper

Wuji Wang et al. submitted



- Ratio map based on fit (q3dfit, Rupke et al. in prep.)

contours:
[OIII] surface brightness

Line ratio diagnostics – example [OI]/Hα

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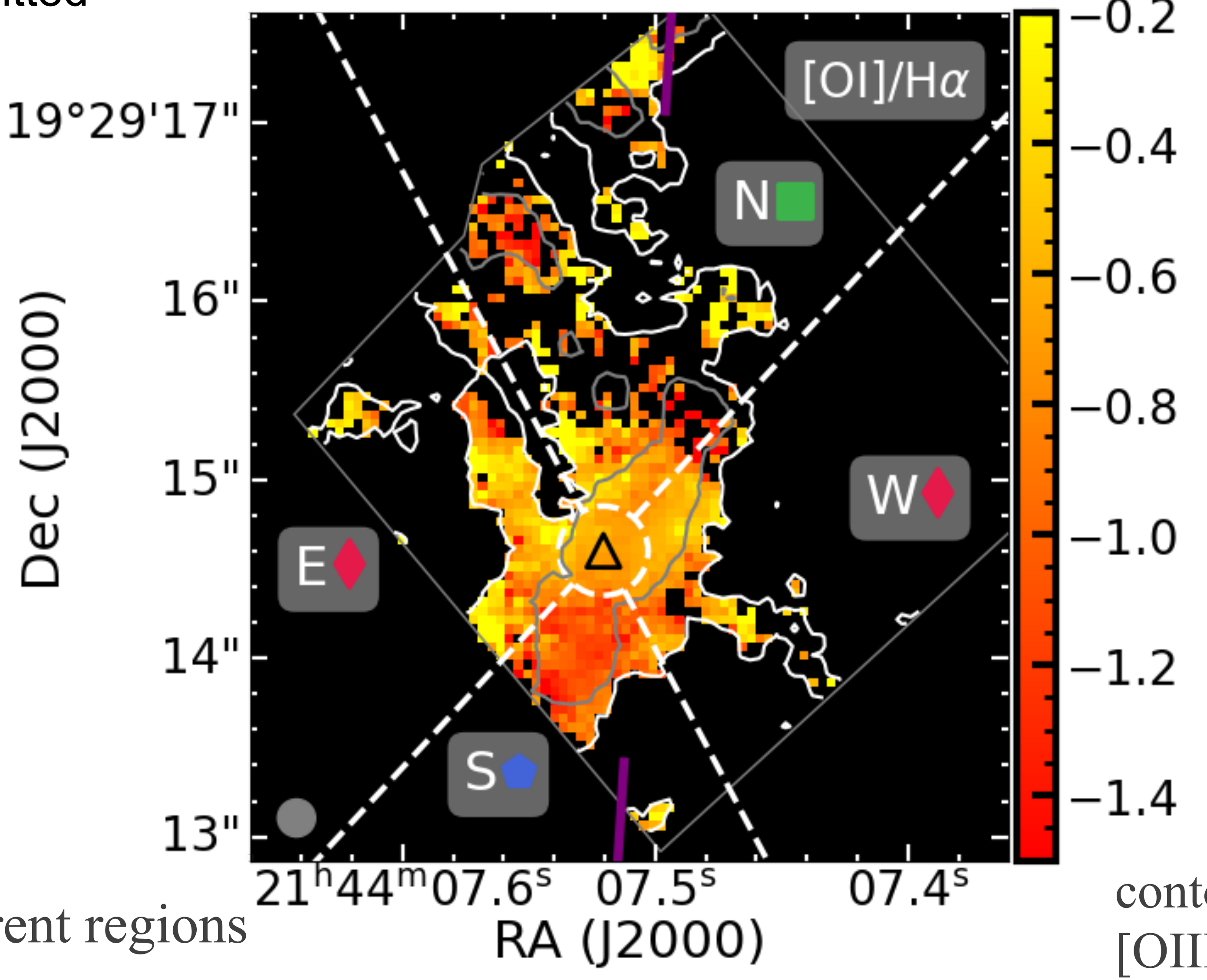

- Examine in different regions

contours:
[OIII] surface brightness

Line ratio diagnostics – example [OI]/Hα

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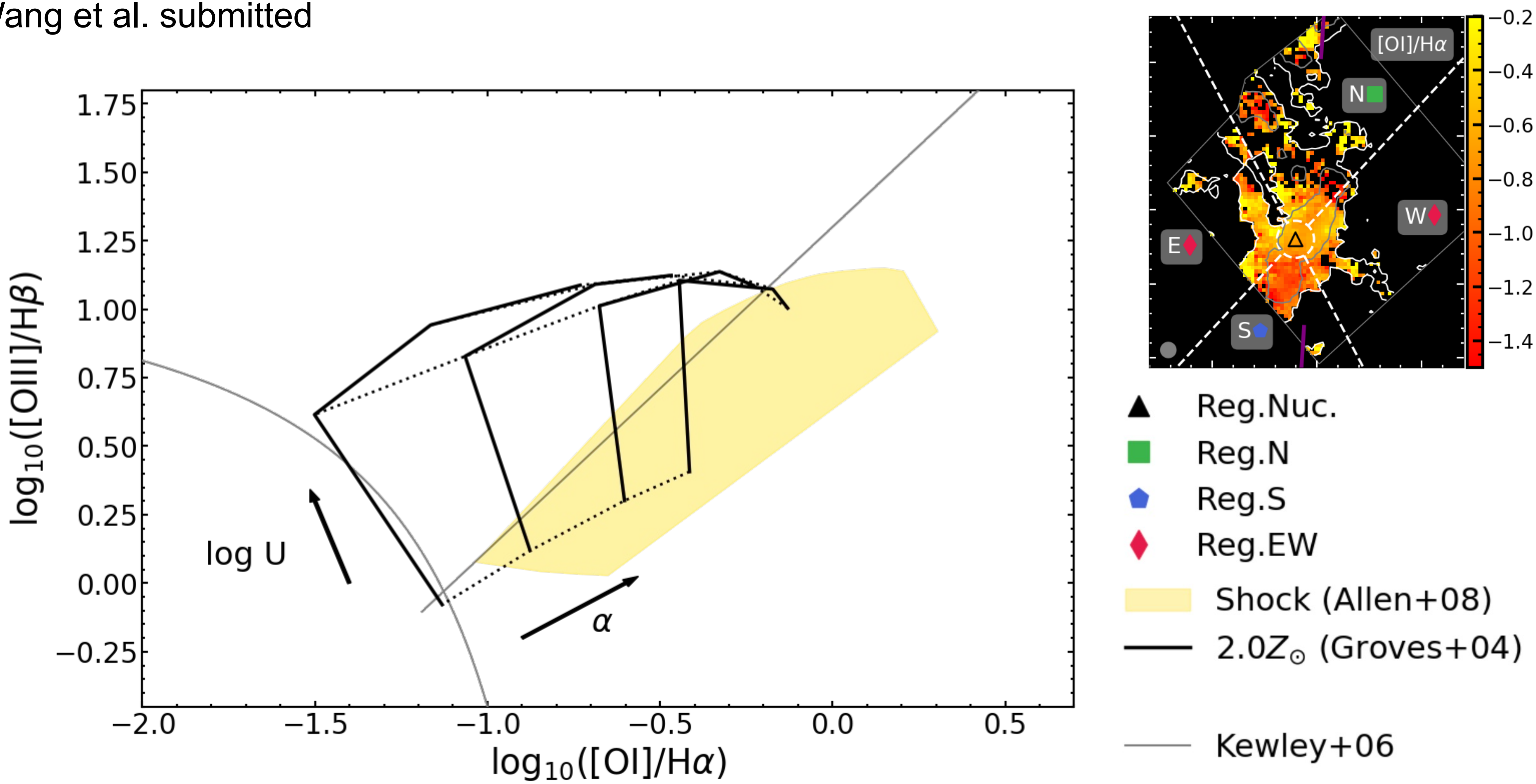

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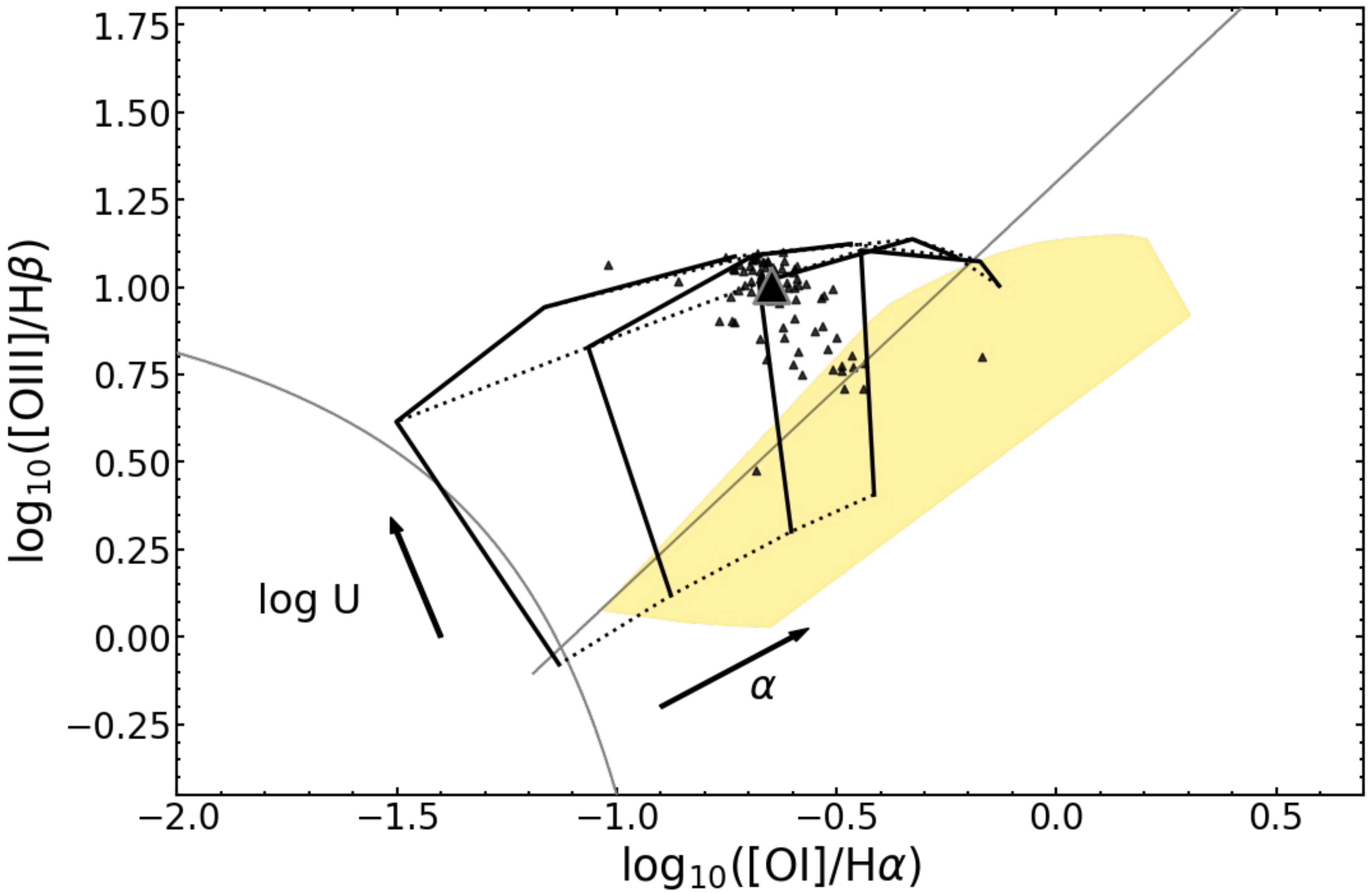

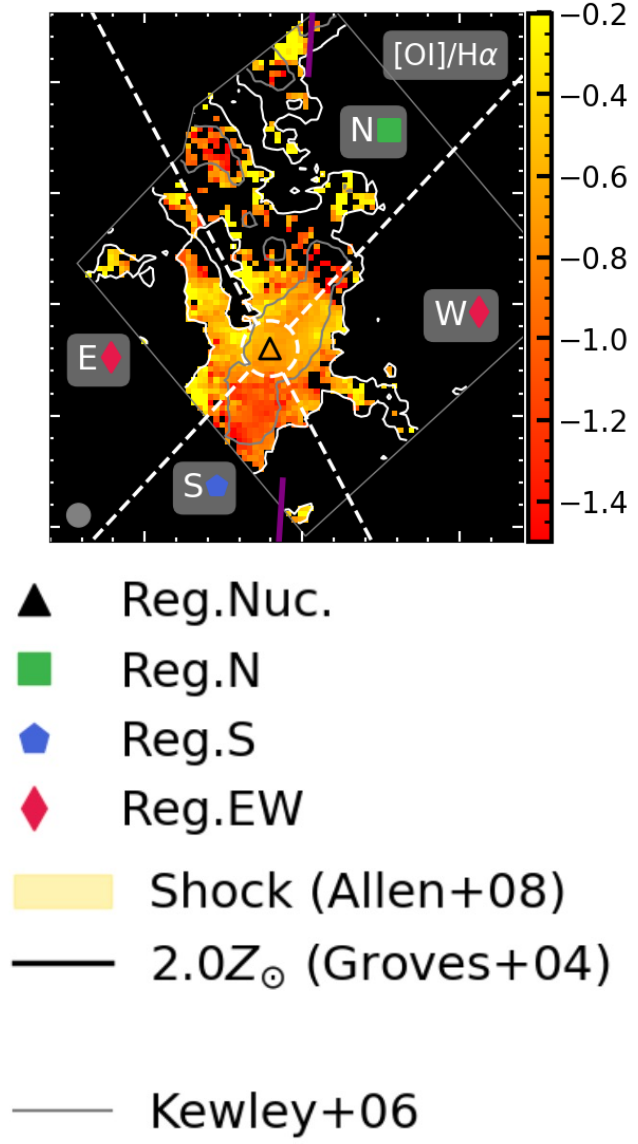

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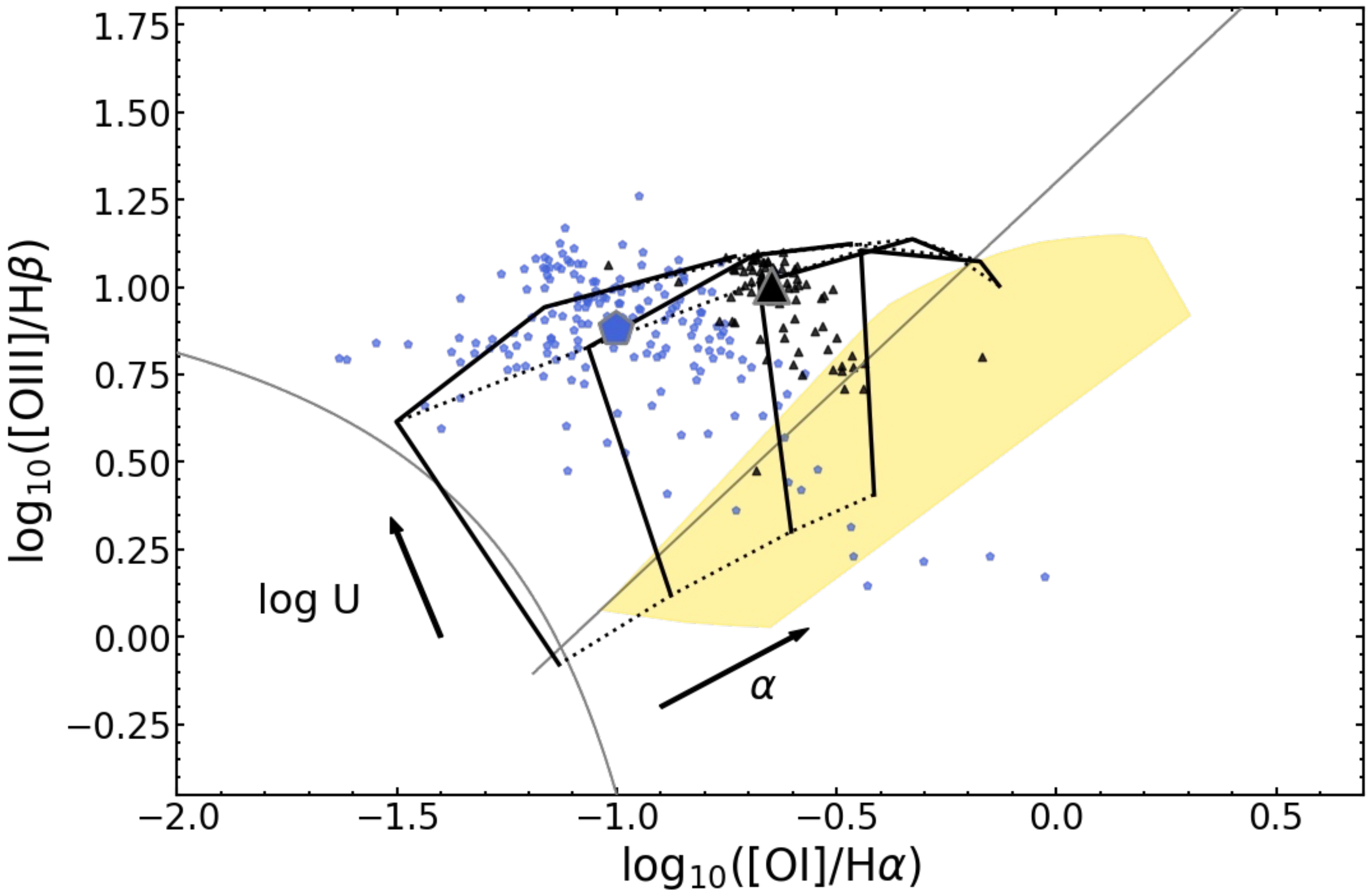

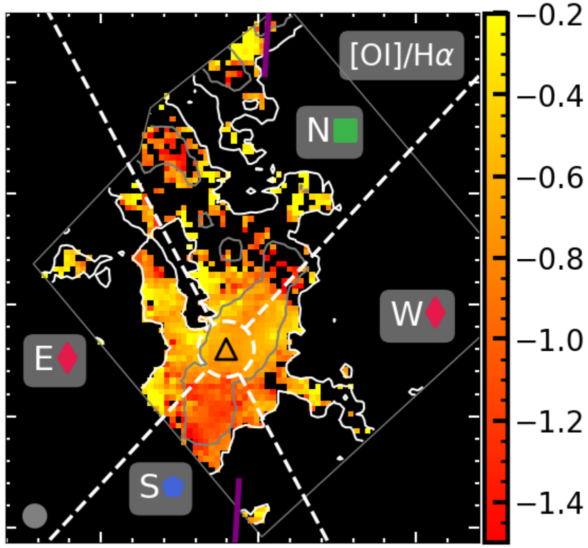

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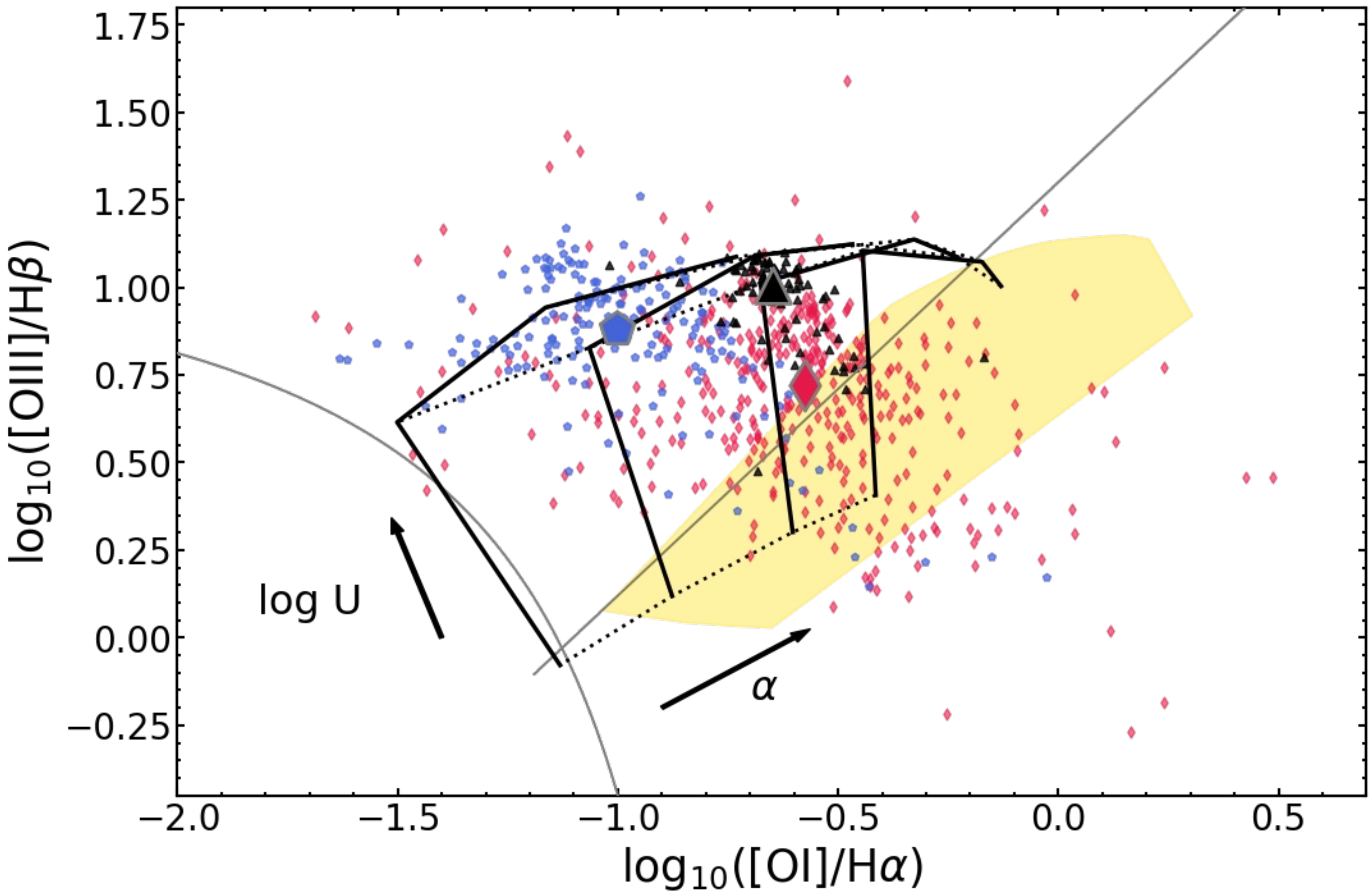

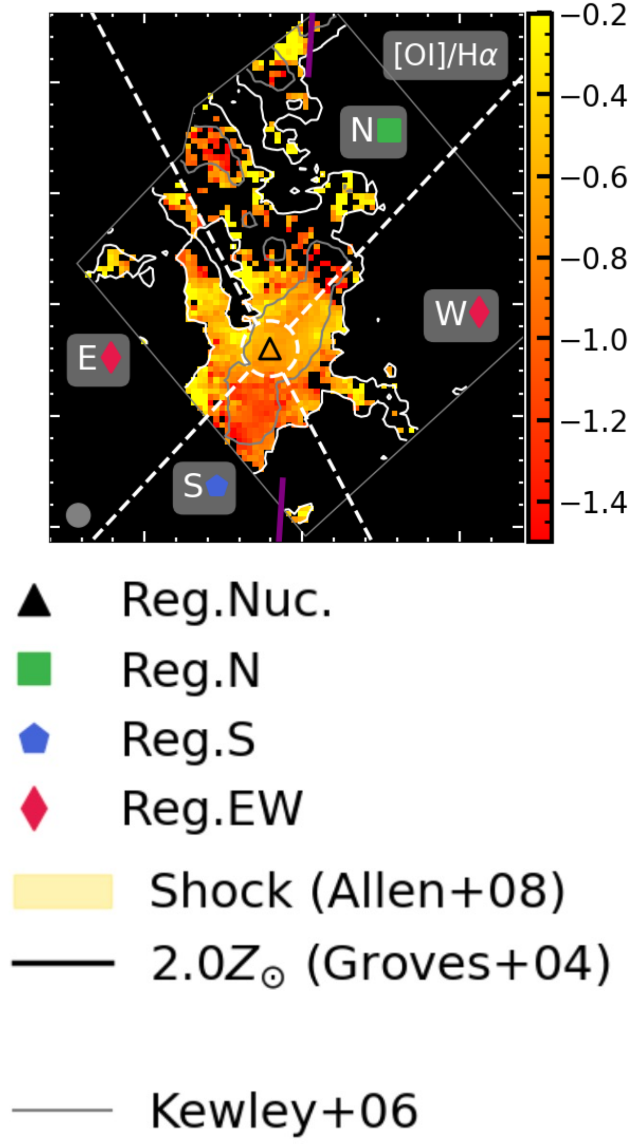

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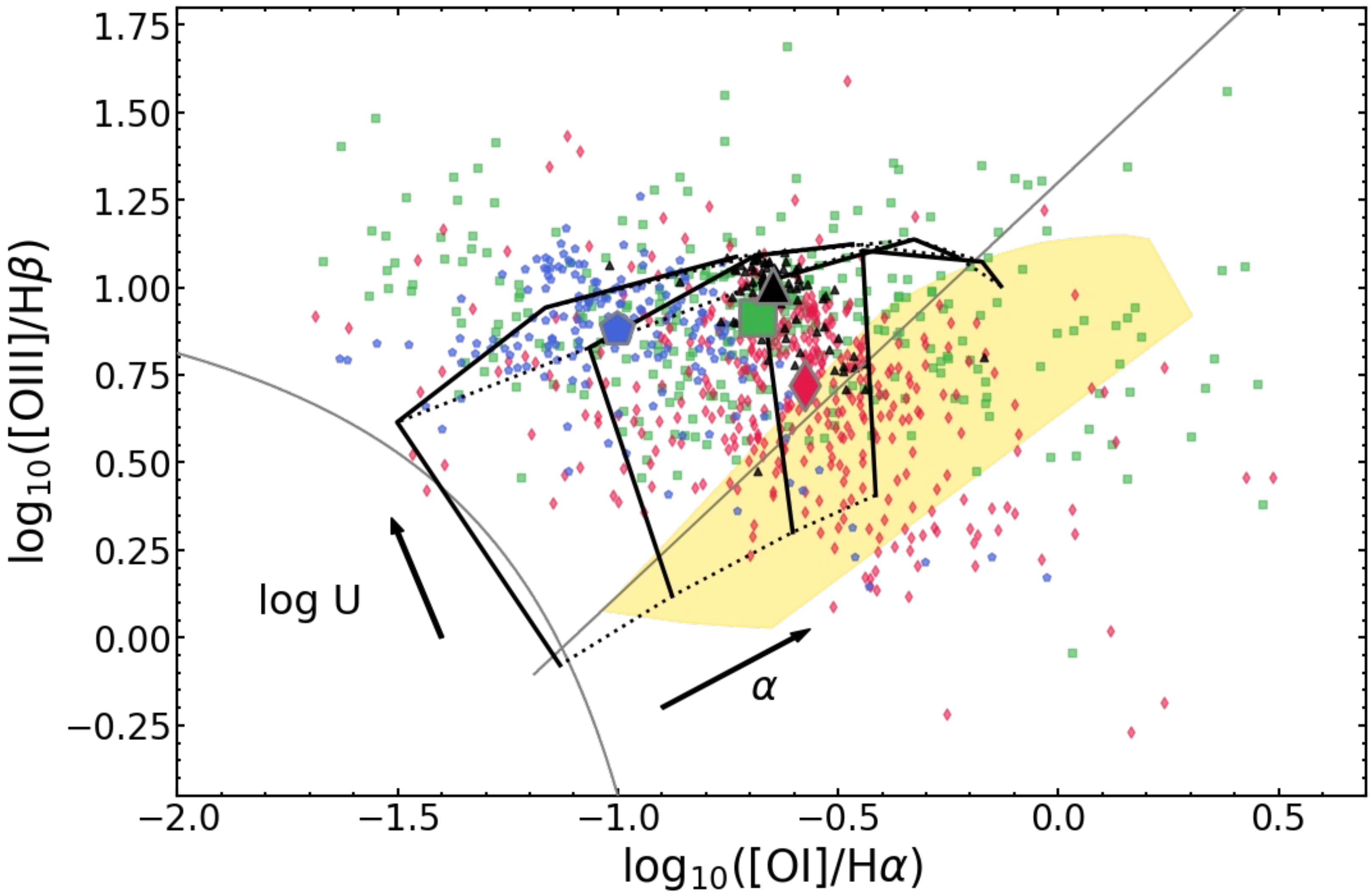
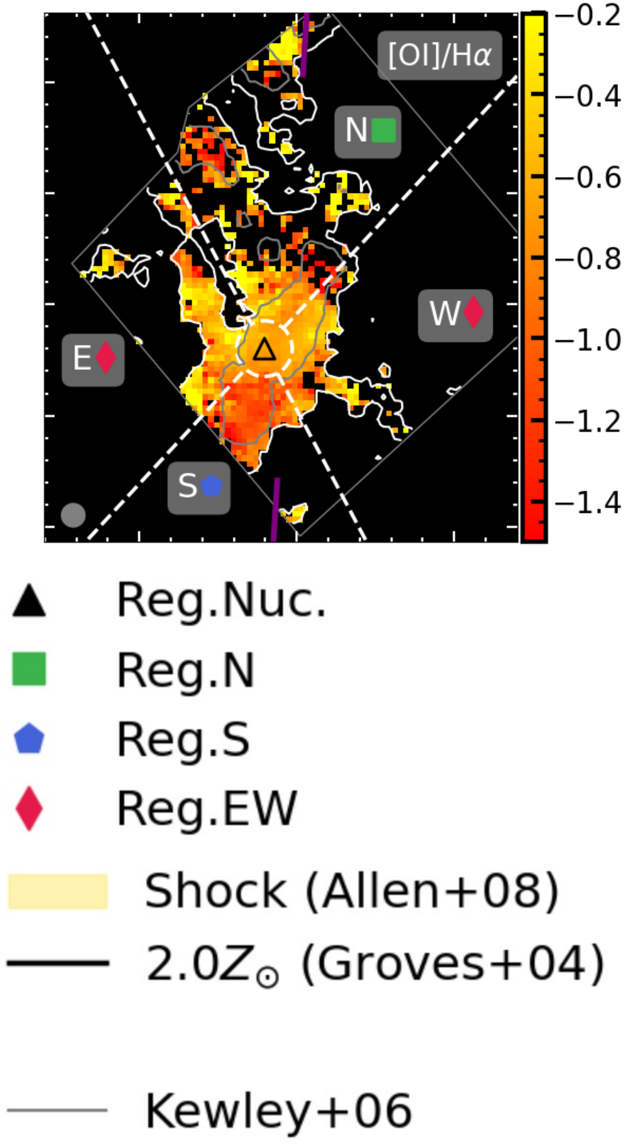
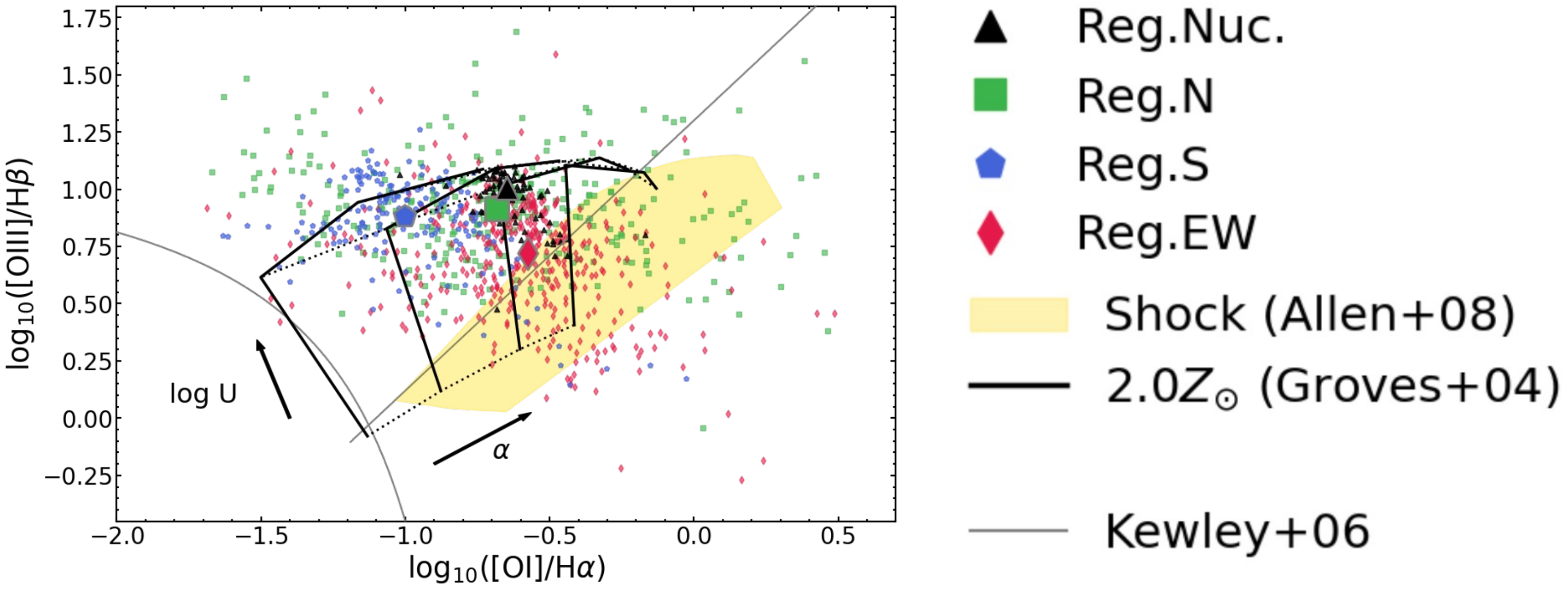


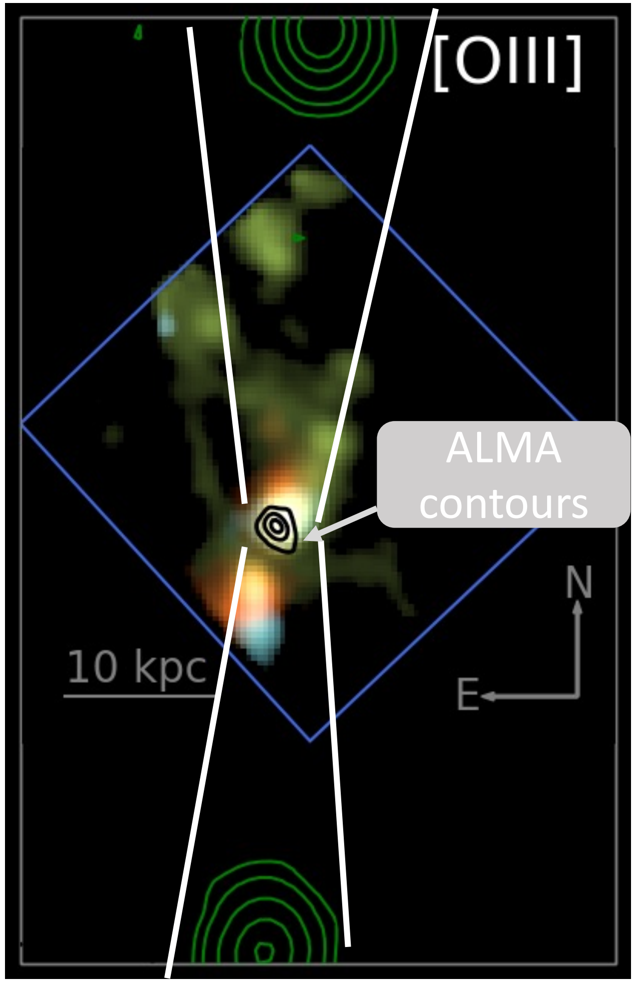


paper

Adequate quasar photons but inefficient in quasar-driven outflow

- Higher ionization parameter in north-south, i.e., jet axis → ionization cone (Drouart+12)





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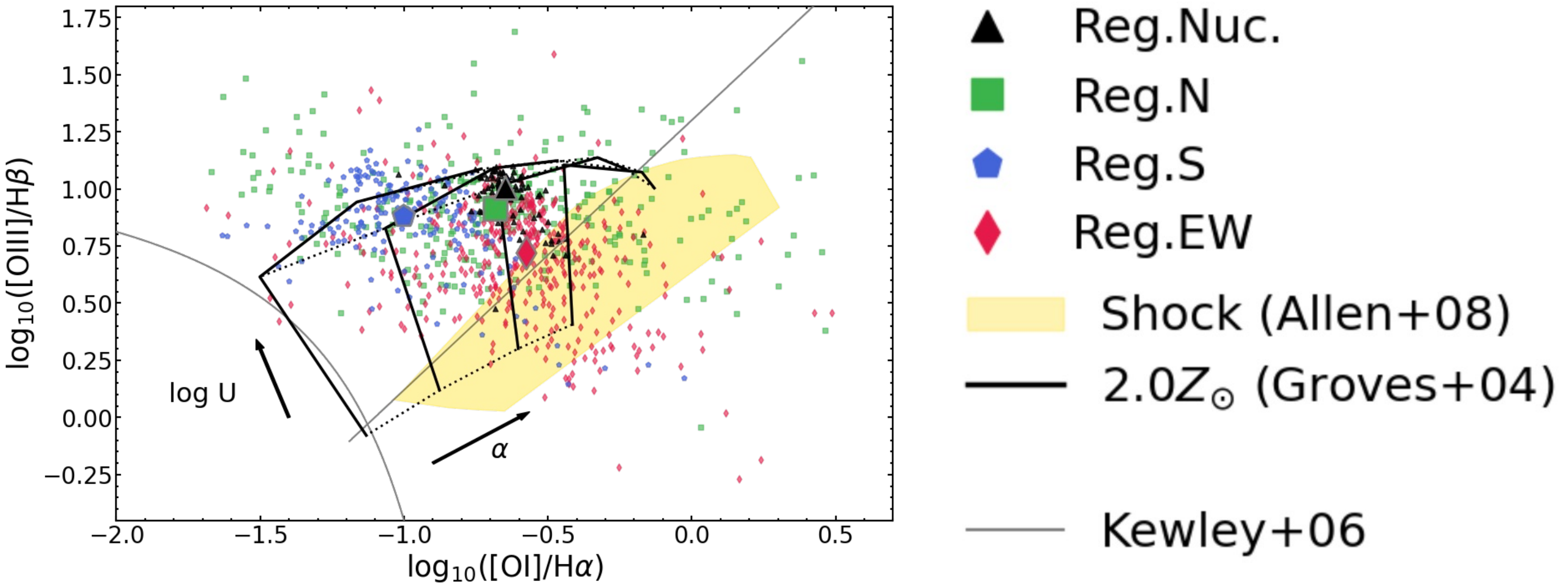
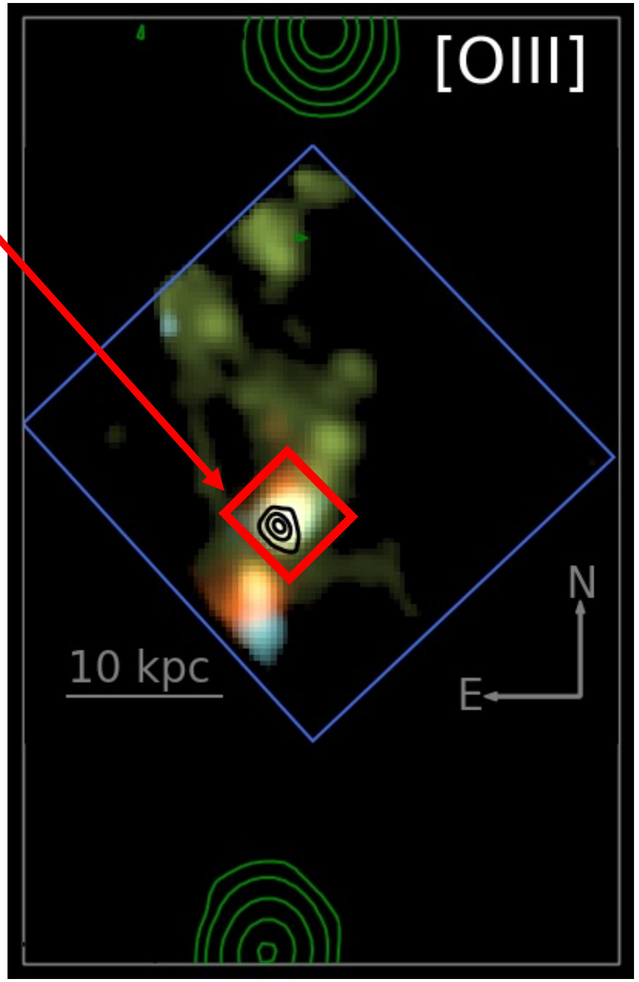
→ $\dot{E}_{\mathrm{kin}}/L_{\mathrm{bol}} \sim 10^{-5}$





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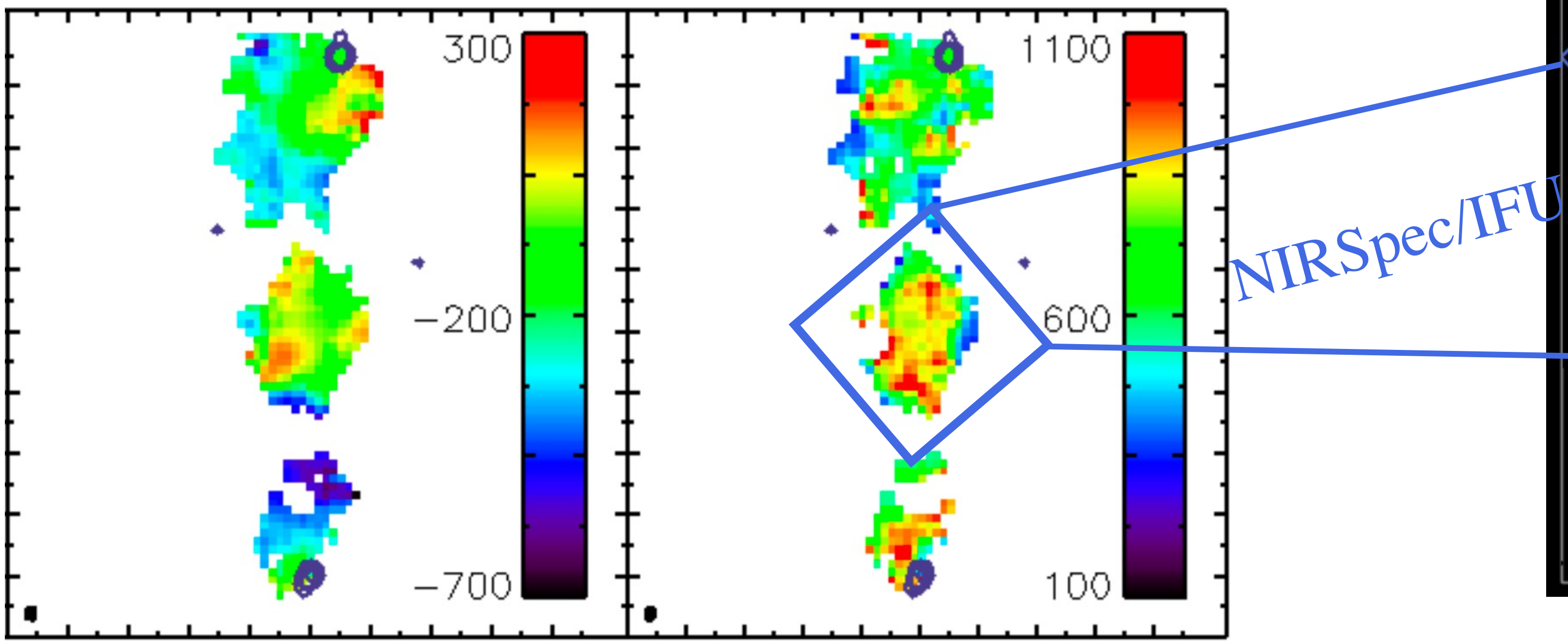
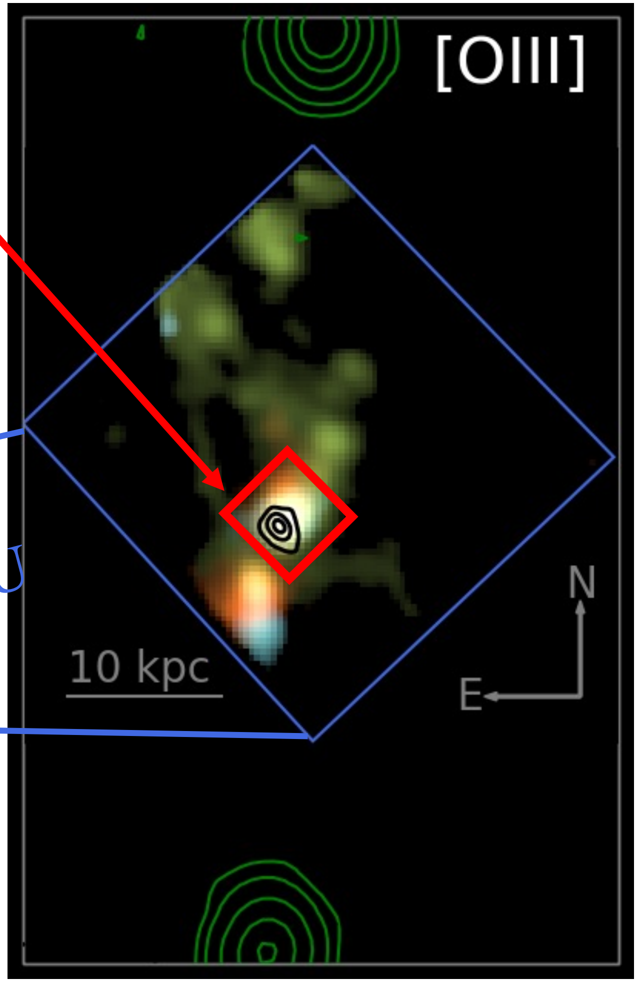
→ 2 dex lower than outflow coupling efficiency between jet on larger scales (Nesvadba+17)



SINFONI [OIII] velocity shift & velocity dispersion



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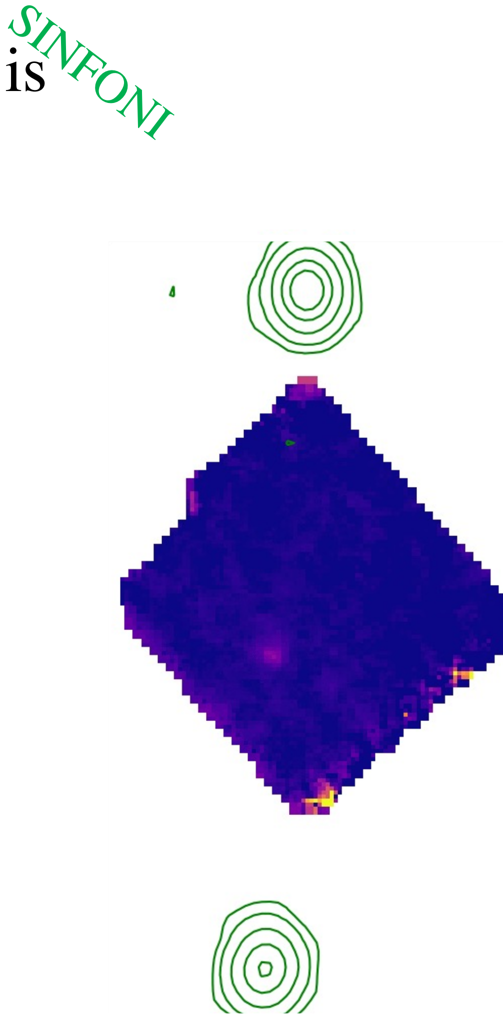
Summary & Conclusion

- $L_{\mathrm{bol}} \sim 10^{47} \mathrm{erg\ s^{-1}}$ AGN is dominating the ionization of the ~20 kpc filamentary ISM of the z~3.5 quasar. **BUT** no strong quasar-driven outflow even at the center

- Jet-mode is the dominating mechanism for driving outflow in HzRGs and is happening on larger scale (around the radio lobes) at least for 4C+19.71



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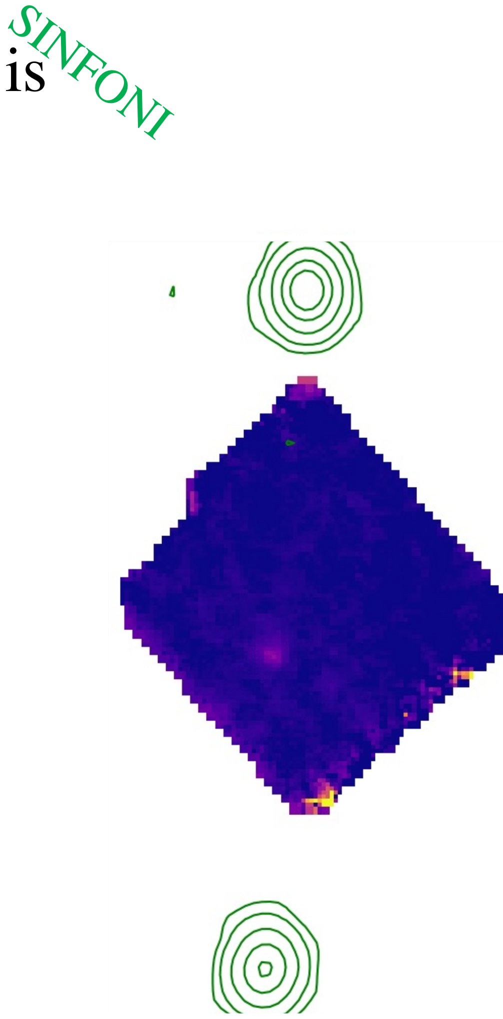
- Full sample (with diverse jet morphologies) analysis will unveil different scenarios



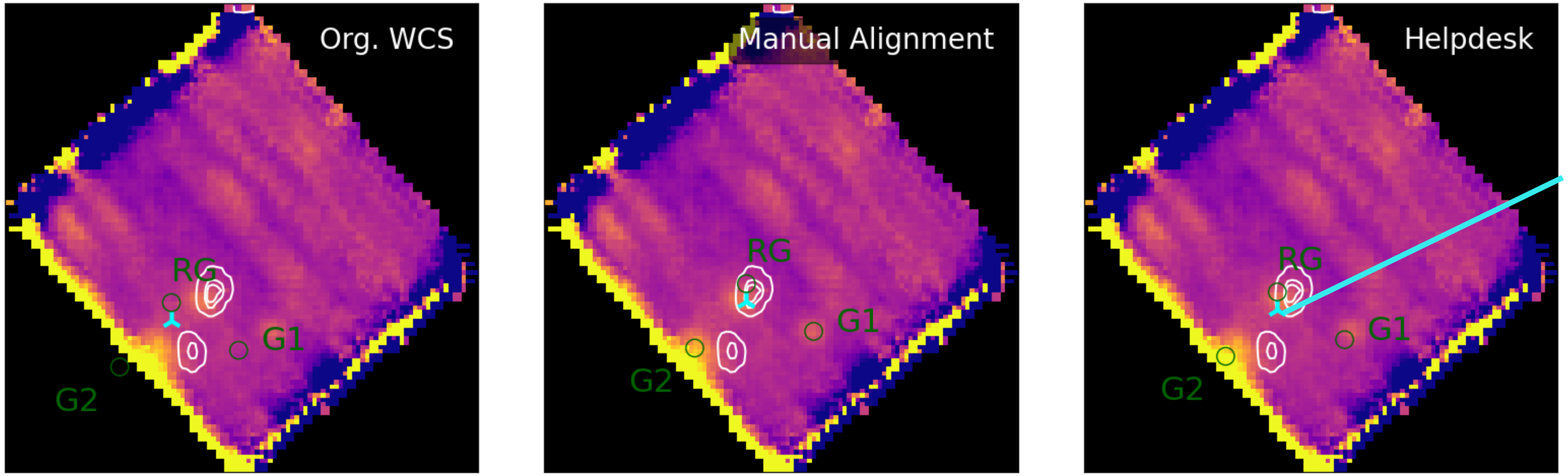
Discussion Time

JWST NIRSpec IFU Observation - Astrometry

Wuji Wang et al. submitted

- Long story short: Absolute WCS is off
- ~0.1" (0.73 kpc) is critical for our case when aligning with resolution matched ALMA data

Shift 0.43", -0.22" in RA, Dec



-[OIII] contour
-HST continuum positions
-ALMA band8 continuum emission peak

e.g.,
Wylezalek+22 (RA-0.04",DEC-1.02")
Perna+23 (RA-0.49",DEC-0.062")

JWST NIRSpec IFU Observation - Astrometry

jwst_1063.pmap:

- New Nirspec optical telescope element (OTE) files were delivered to Calibration Reference Data System (CRDS), these files affect all data taken with NIRSpec since launch, one has a useafter date of 1 January 2023 and the other 22 September 2023. An error was found in the creation of the previous files which these will replace that caused transforms in the WCS step to be applied incorrectly. This delivery corrects that error.

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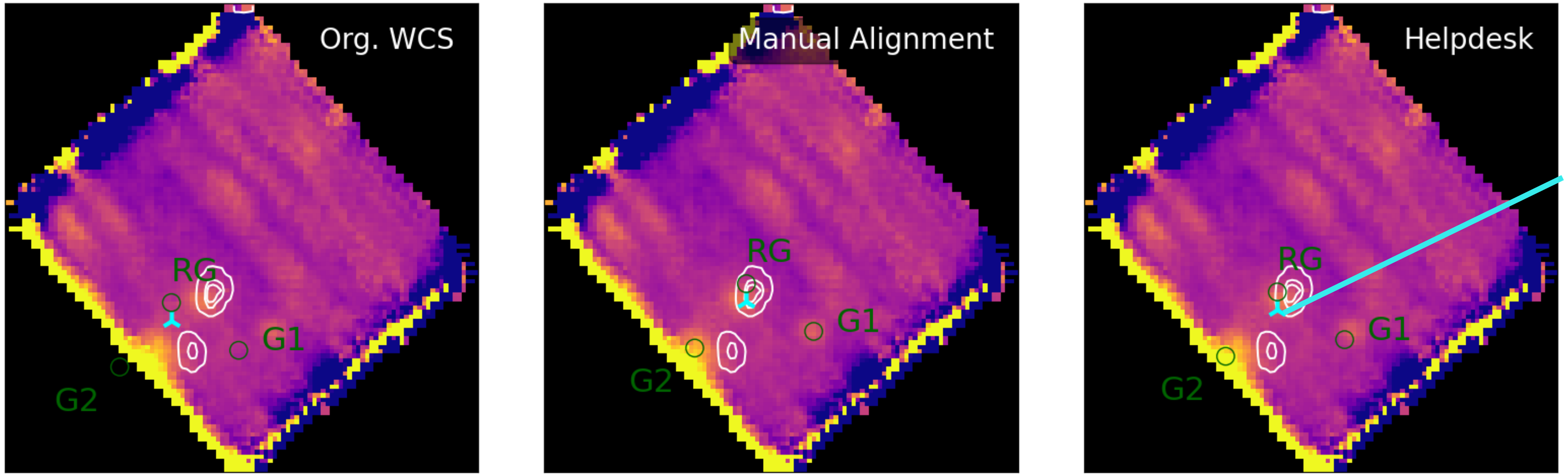
- Solution: manual aligment of one forground galaxy (NIRSpec continuum/HST); Helpdesk suggestion is still off with unknown shift direction
- Lesson: IFU + position verification image

Shift 0.43", -0.22" in RA, Dec



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JWST NIRSpec IFU Astrometry – Position verfication

- The NIRSpec VERIFY_ONLY target positioning check can be used for (MOS and) IFU observing modes … does not do any corrective acquisition activities. It only acquires an image through the NIRSpec micro-shutter array …

JWST-User Documentation: NIRSpec Verify Only Target Acquisition

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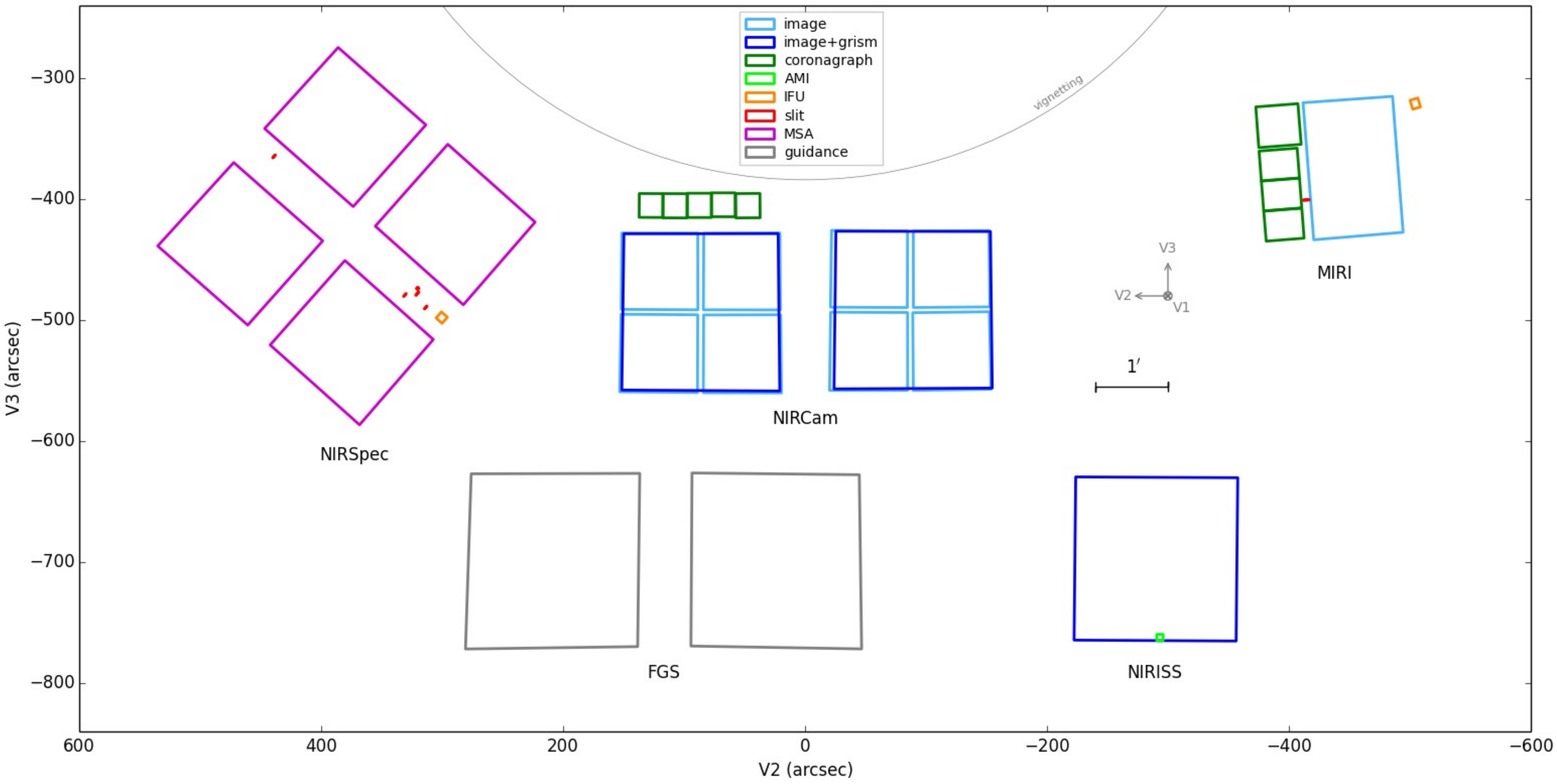
- The NIRSpec VERIFY_ONLY target positioning check can be used for (MOS and) IFU observing modes … does not do any corrective acquisition activities. It only acquires an image through the NIRSpec micro-shutter array …

- This is so that the precise pointing can be determined by analyzing positions of unsaturated stars seen through the MSA, after the observation executes

- In the undispersed light, the MSA quadrants and the IFU slices project onto different locations on the NIRSpec detectors and in principle this can allow an image of the IFU field of view as seen through the selected target acquisition filter to be reconstructed and precisely aligned relative to field objects imaged through the MSA. However, there are currently no tools to support such image IFU reconstruction and alignment, and in many cases collapsing the dispersed IFU science observations over wavelength to produce an image will provide similar information in a more easily used form.

JWST-User Documentation: NIRSpec Verify Only Target Acquisition

JWST NIRSpec IFU Astrometry – Position verfication



JWST-User Documentation: JWST Field of View