Big Galaxies in 3D

KCWI Measurements Reveal the Intrinsic Shapes and Central Black Holes of the Most Massive Galaxies

Berkeley Big BH Bunch:
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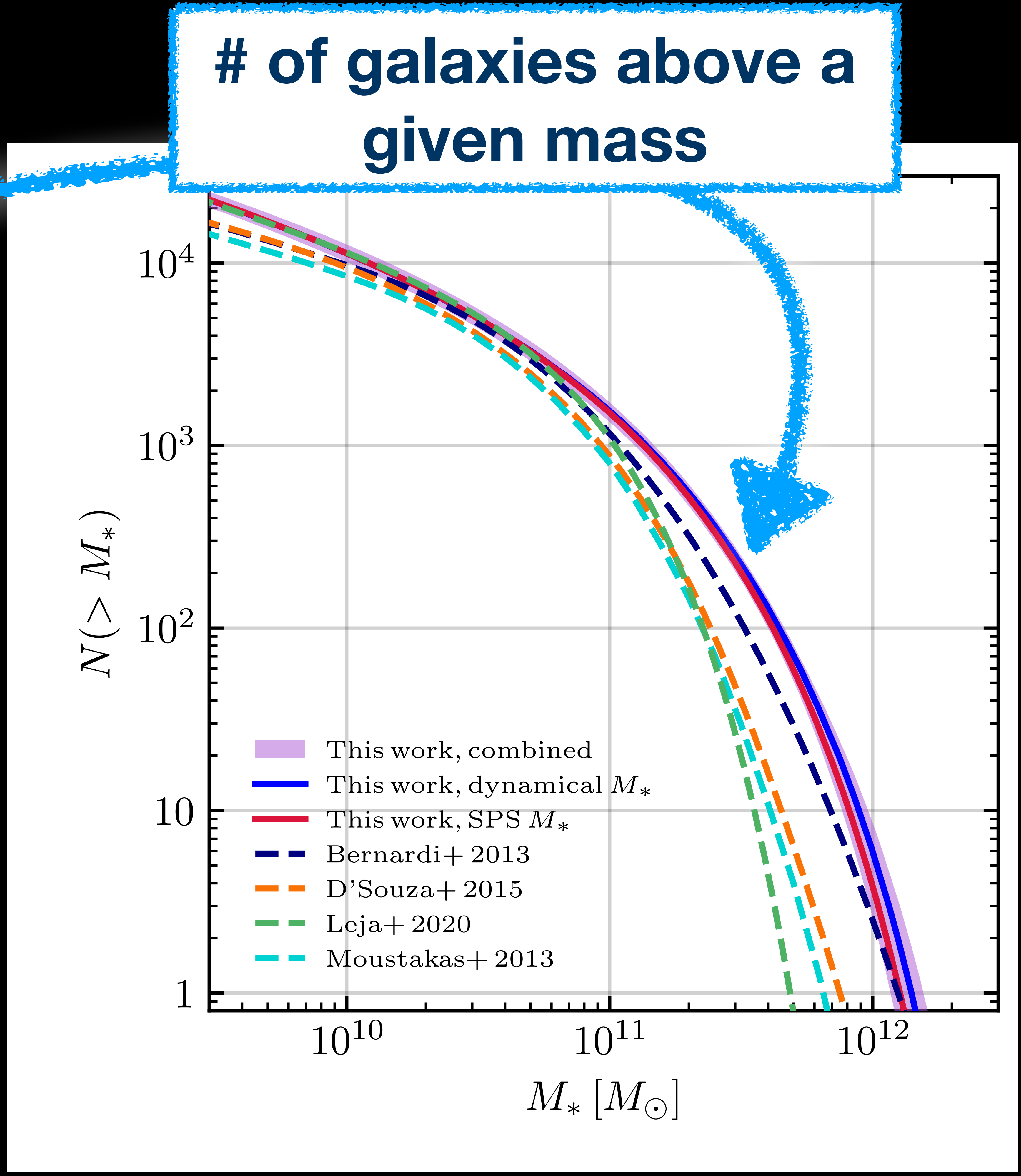
Liepold + Ma 2024

Big Galaxies are intriguing

- Extremely massive galaxies ($M_* \gtrsim 5 \times 10^{11} M_\odot$)
  - Are rare (~200 within 100 Mpc)
  - Are the endpoint of mergers + evolution?
  - Sometimes (but not always) the brightest galaxies in their groups or clusters
  - Host Ultramassive Black Holes ($M_{BH} \gtrsim \times 10^9 M_\odot$)



How to measure SMBH masses

(Integrated) Stellar Dynamics

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Idea:

Relative velocities ***doppler-shift*** a star's spectrum.

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What do we need?

- Spectra! (To observe the doppler shifts)
- High S/N (To measure shape of the velocity distribution: **8 moments!**)
- High spatial resolution (To probe the area dominated by the SMBH)
- Large spatial coverage (To probe the area dominated by dark matter)
- And a bunch of modelling!

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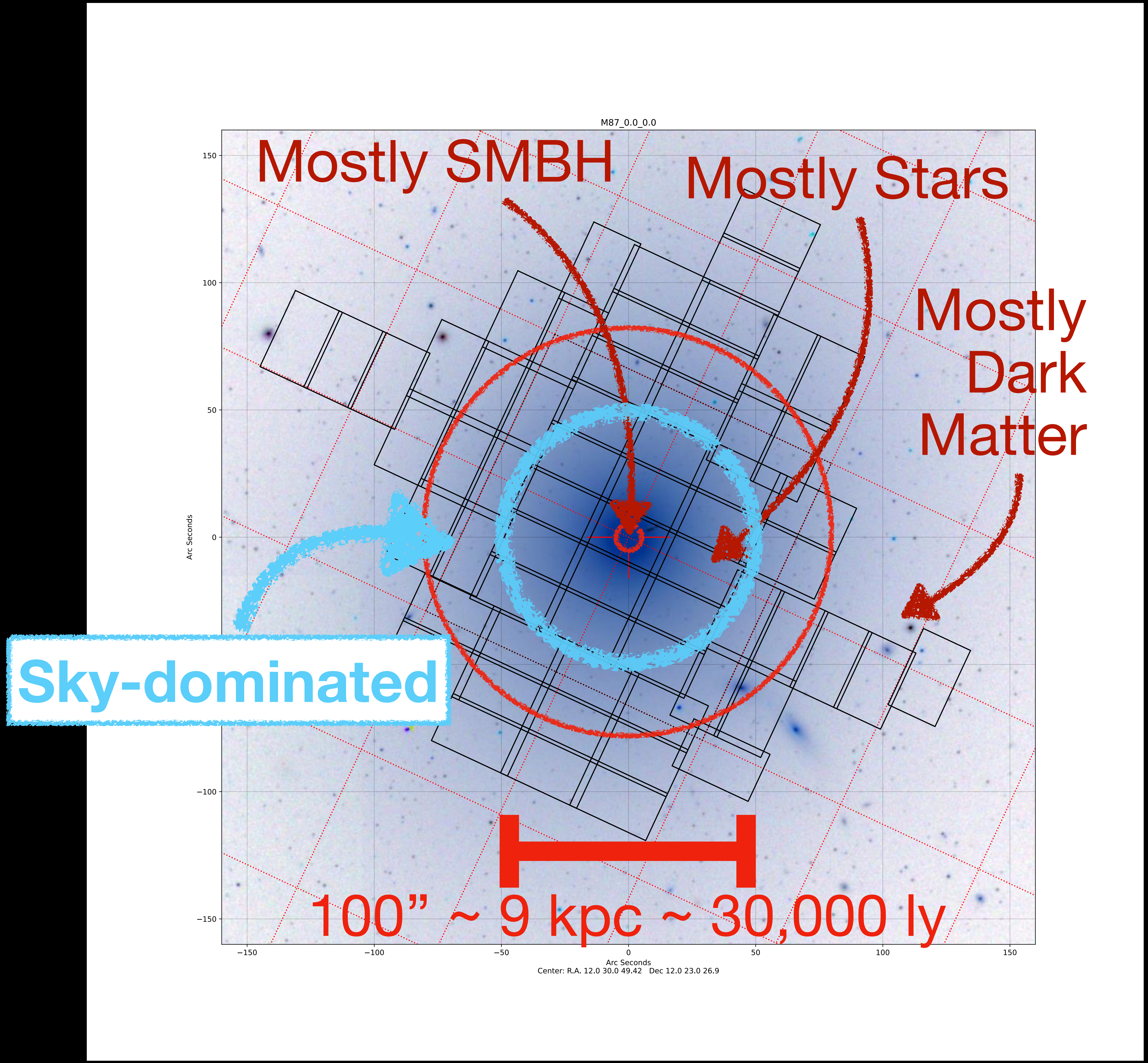
KCWI!

Not this talk!

An Example: M87

Liepold, Ma, Walsh 2023

- We observed M87 with KCWI during four observing runs from May 2020 - April 2022.
- 62 pointings were observed, each corresponding to a 20.4″ × 33″ FOV with 0.3″ × 1.4″ spatial pixels
- 13hr on target, 2.8hr on sky
- The full FOV spans about 23 kpc along the photometric major axis and 28 kpc along the minor (11.6 square arcmin in total!)



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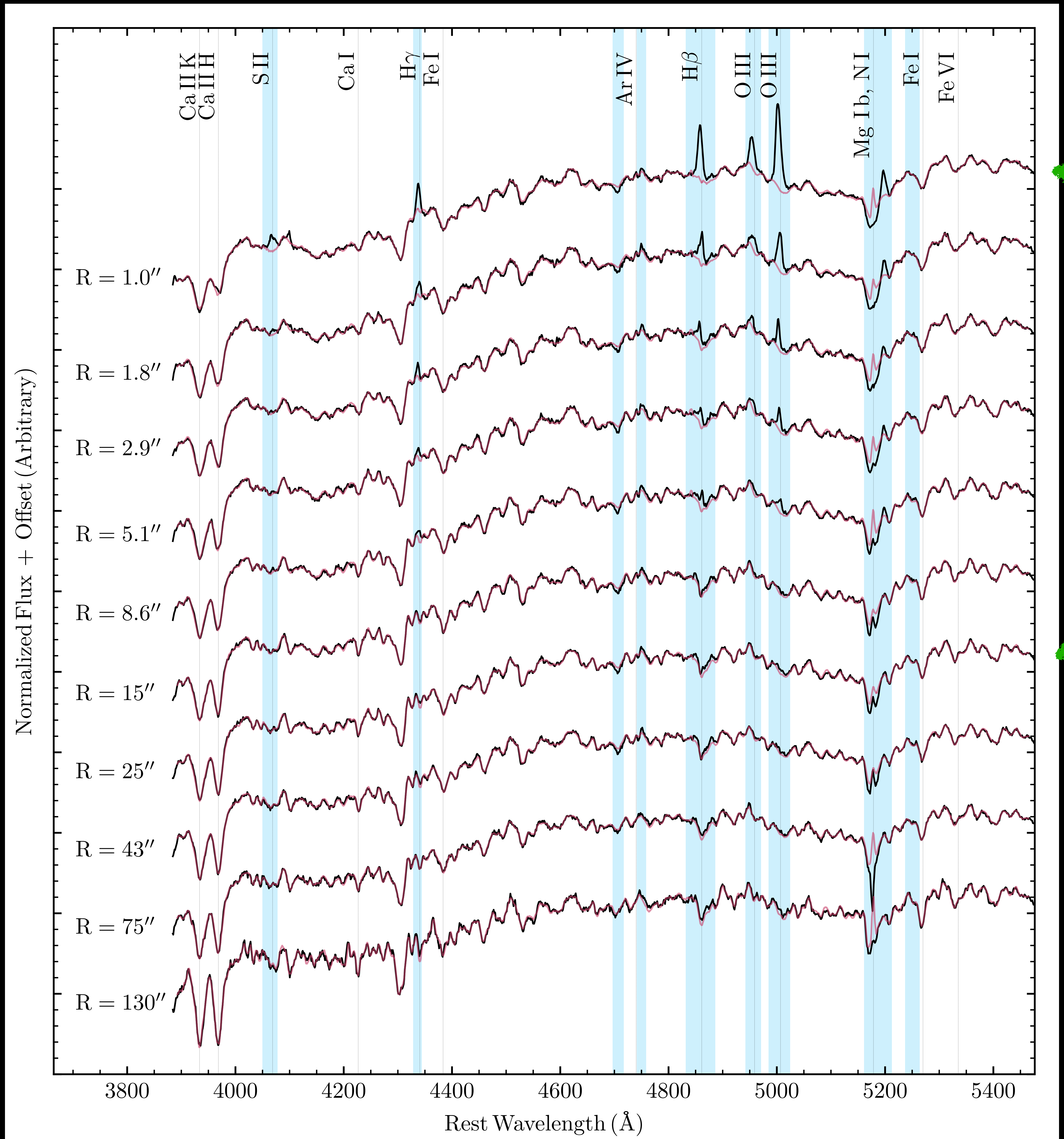
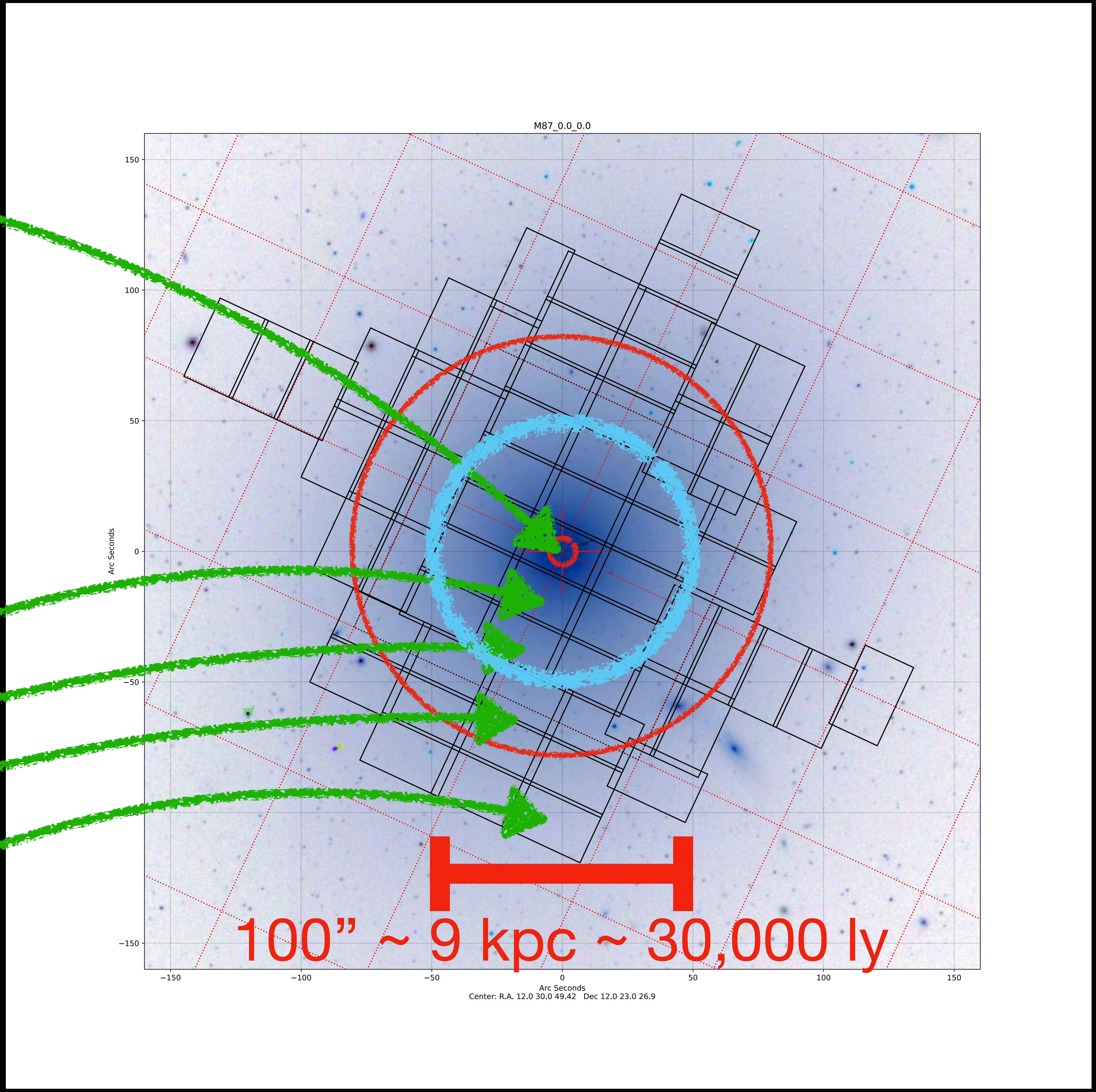
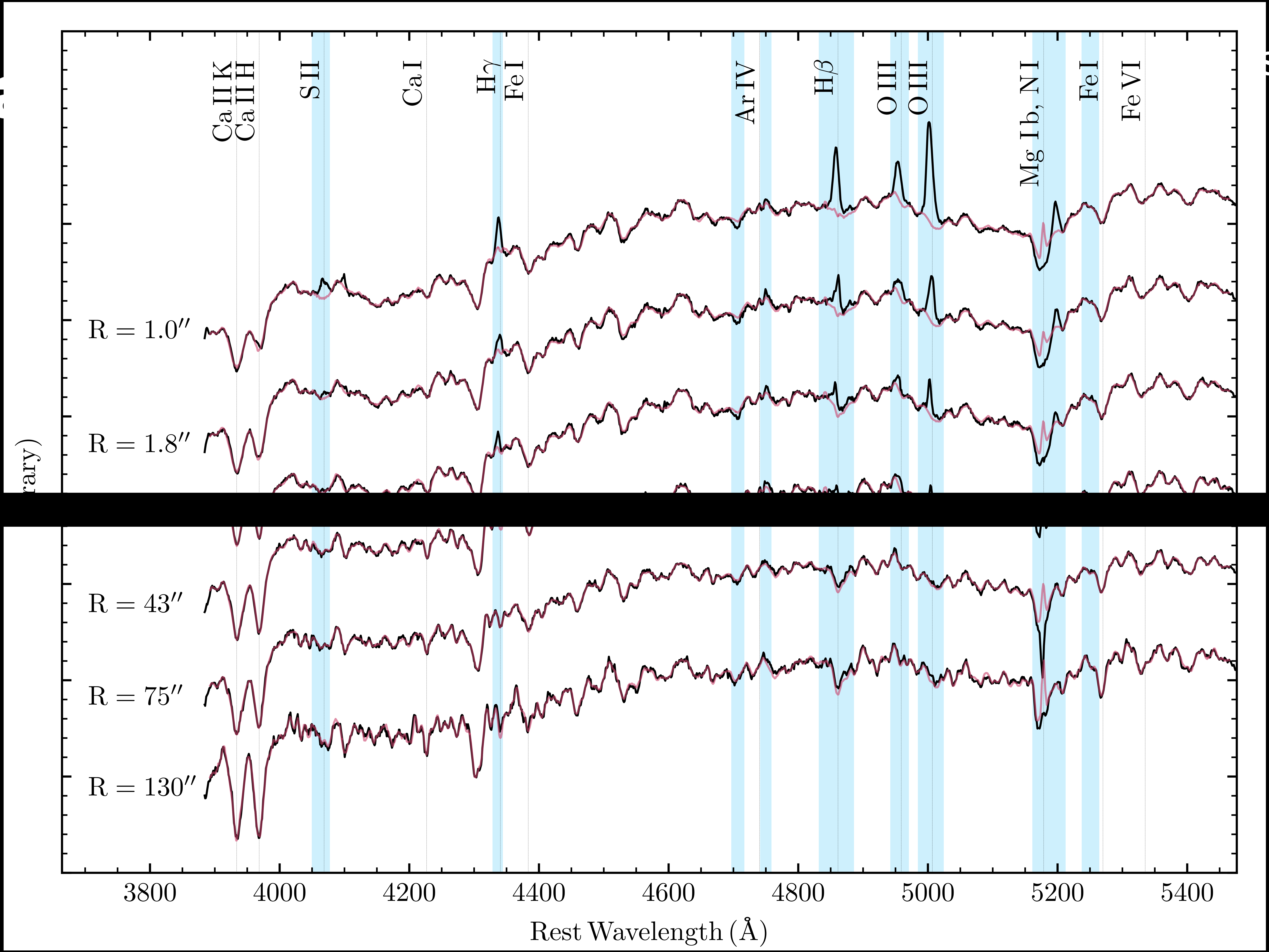




An Exa… sh 2023



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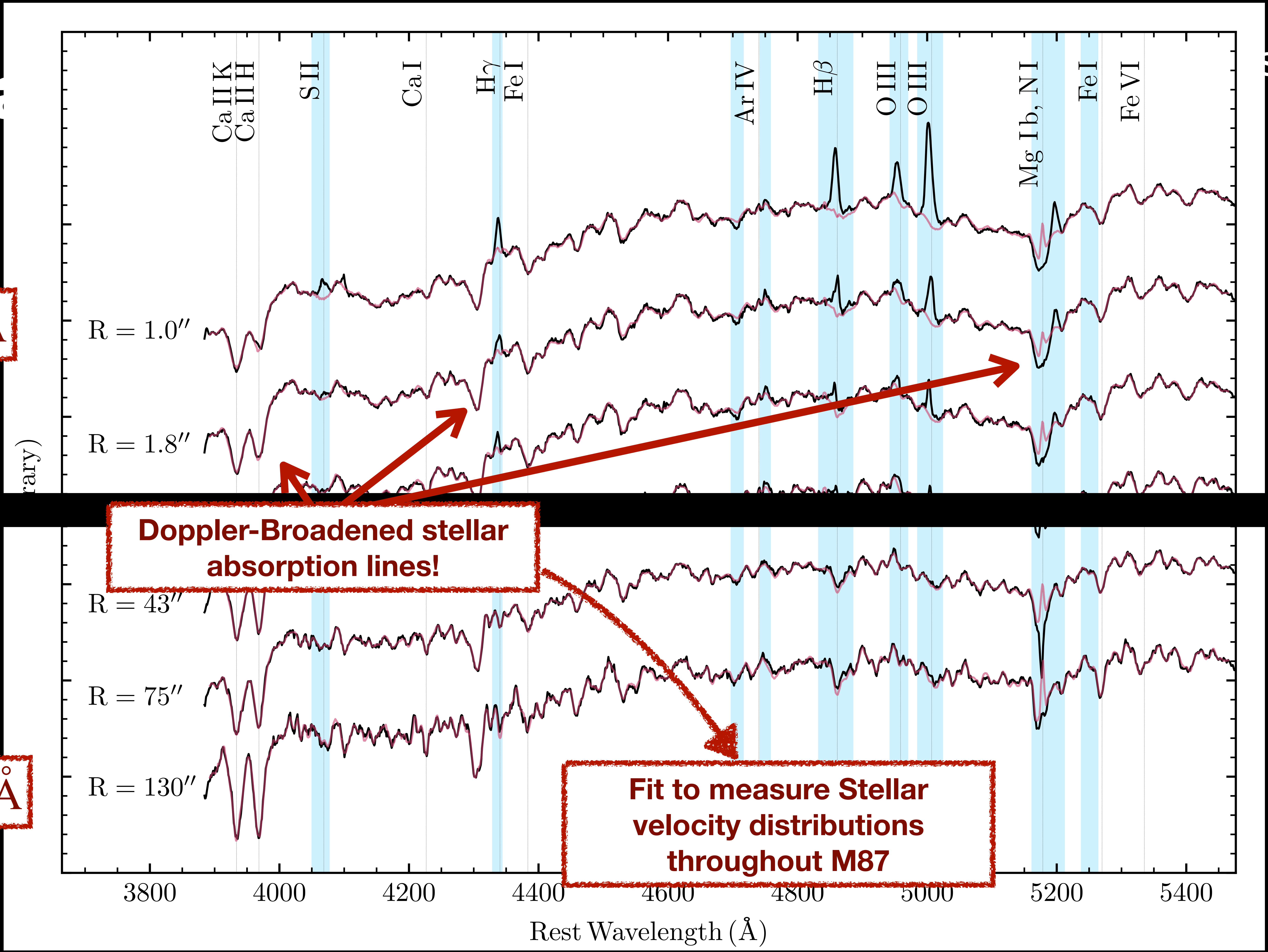
S/N ~ 200/Å



S/N ~ 100/Å

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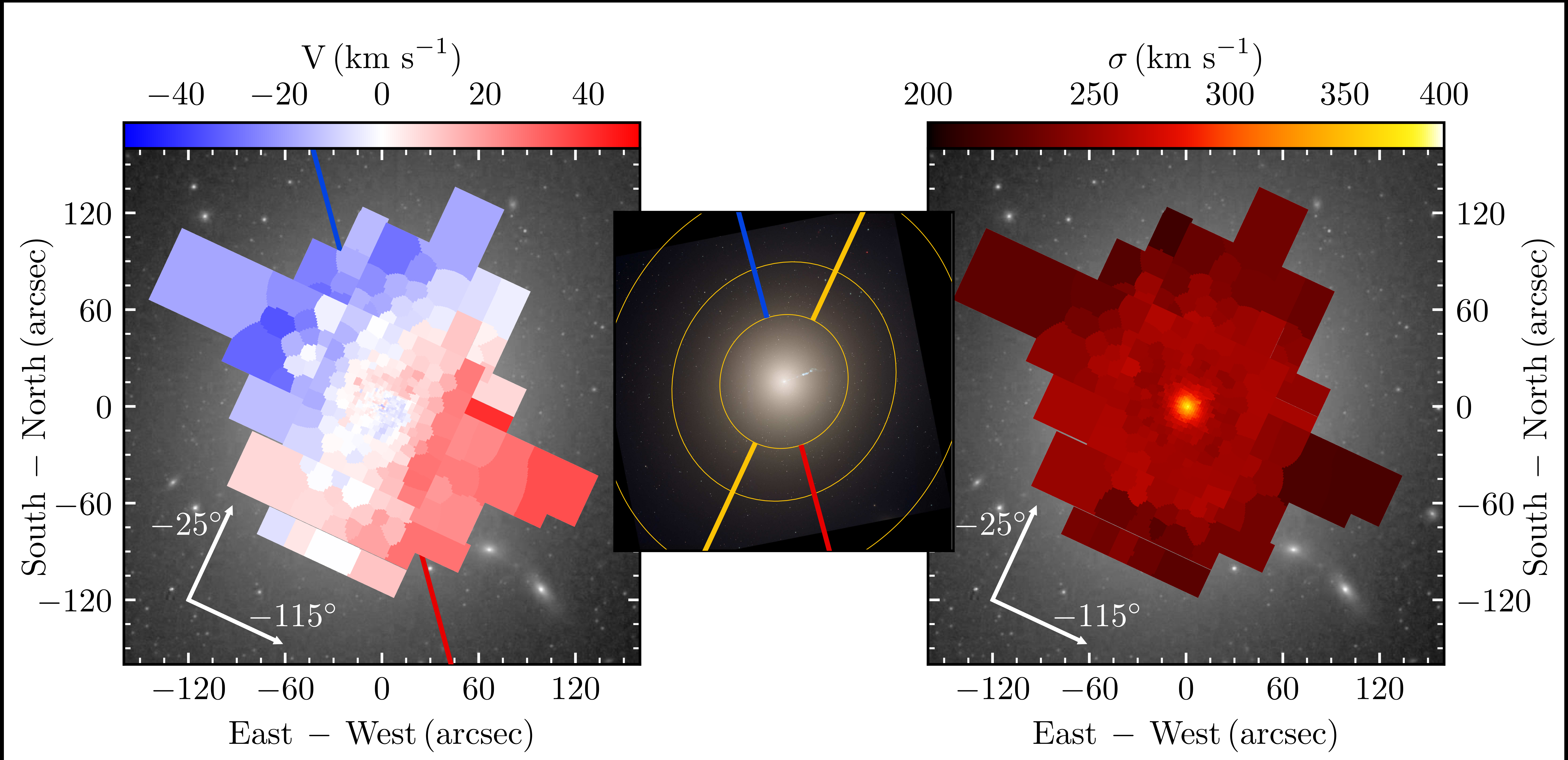

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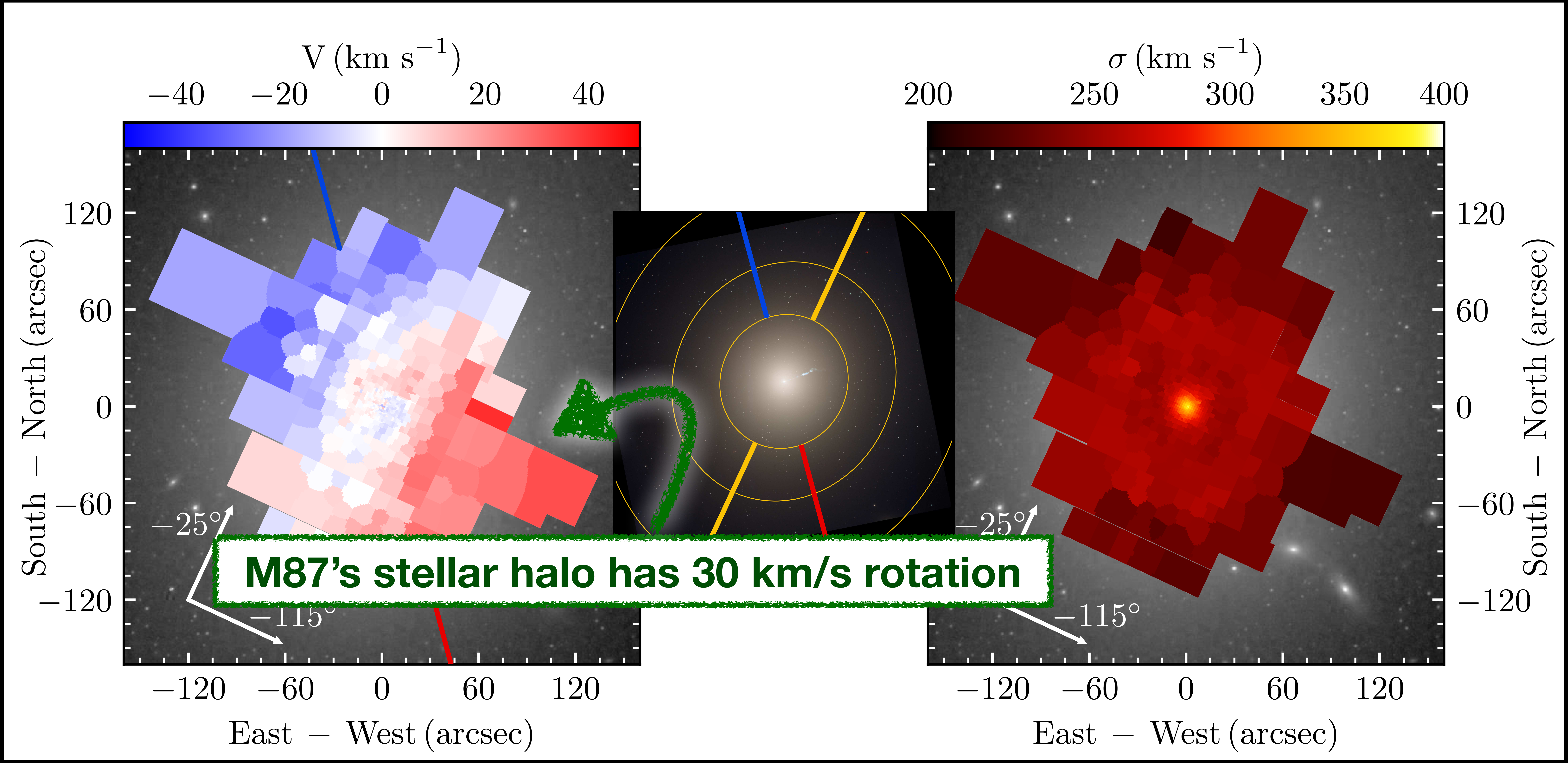

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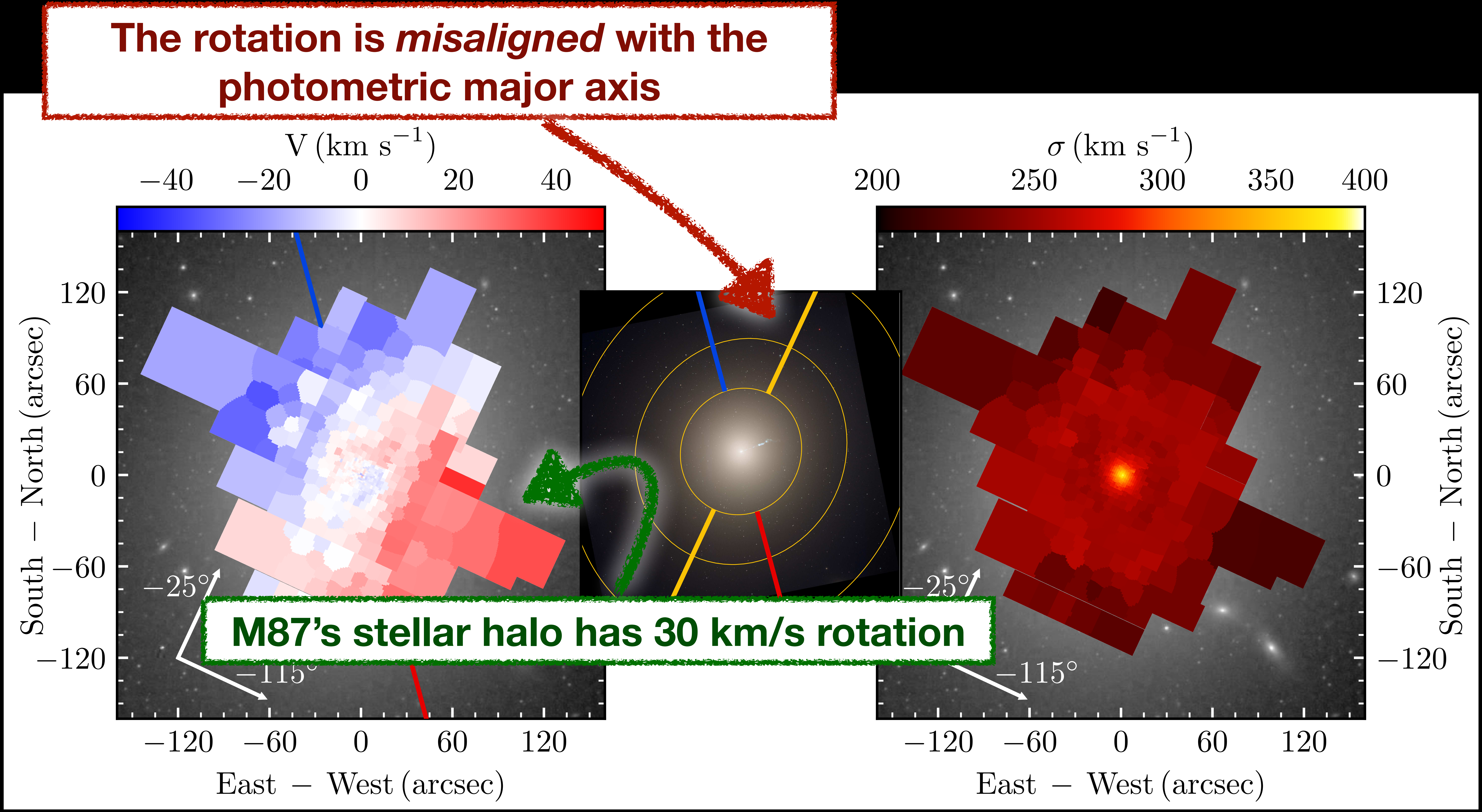

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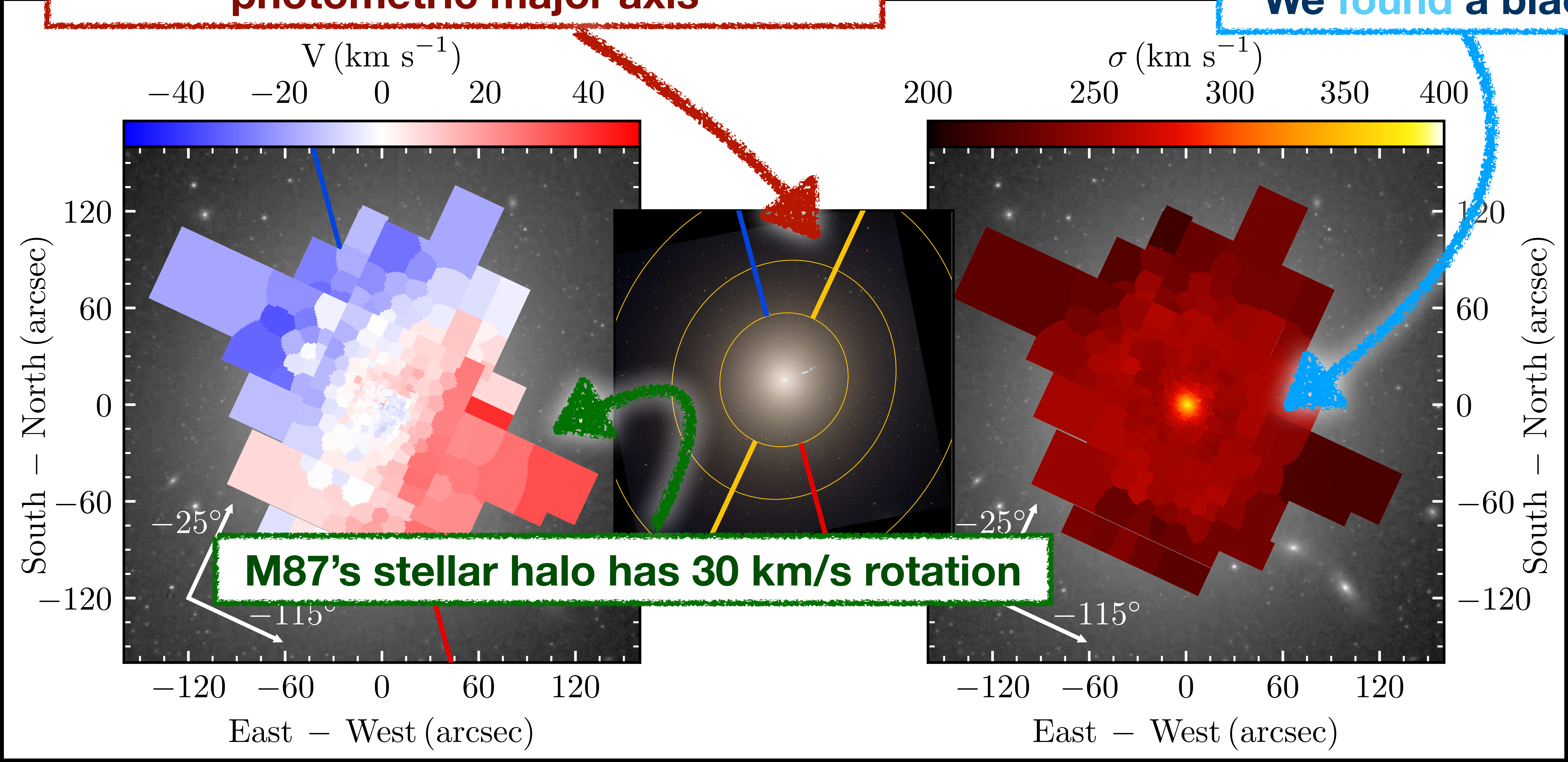
The velocity dispersion rises *quickly* towards the center!

We found a black hole!

The rotation is *misaligned* with the photometric major axis



M87's stellar halo has 30 km/s rotation

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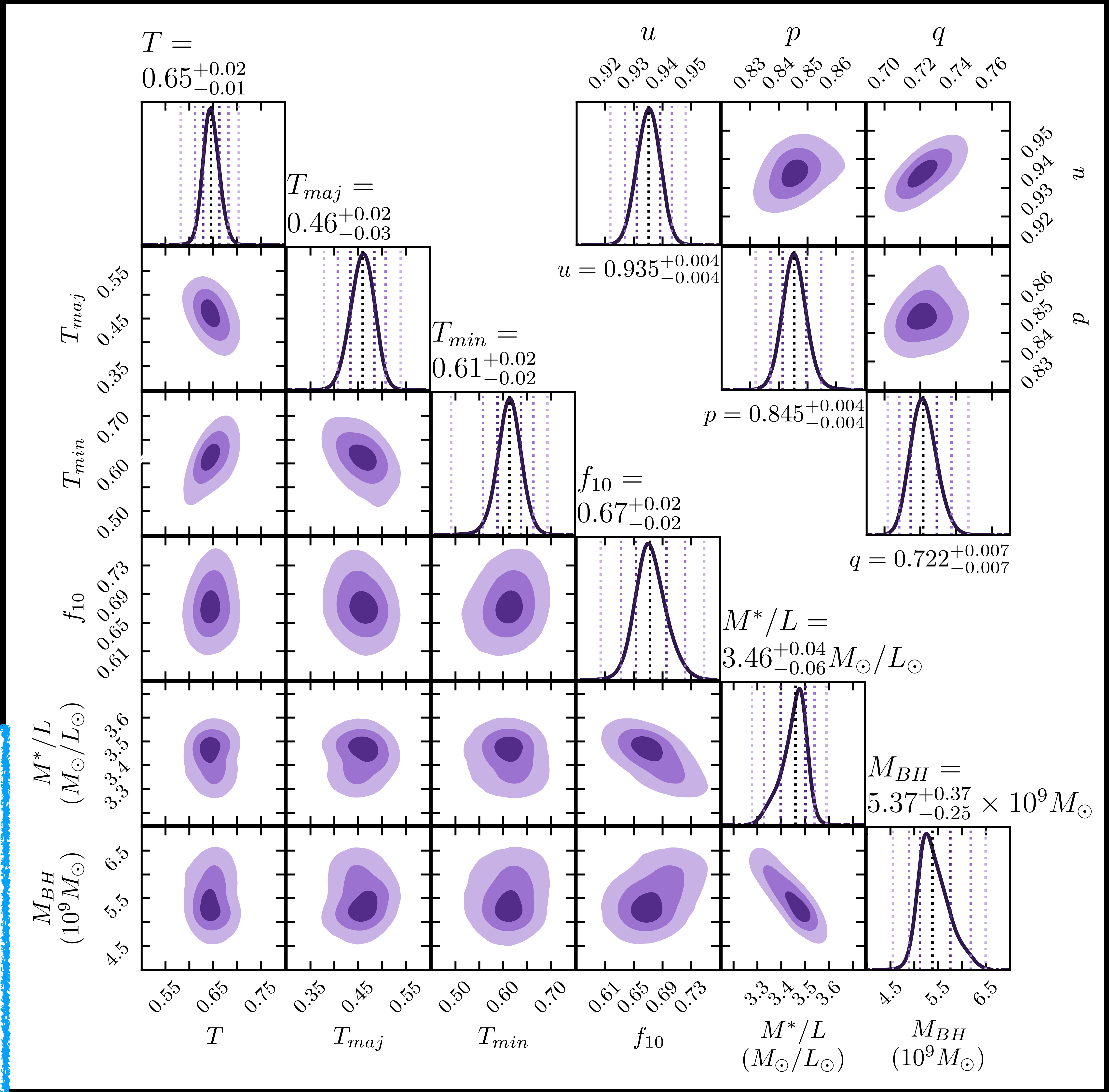
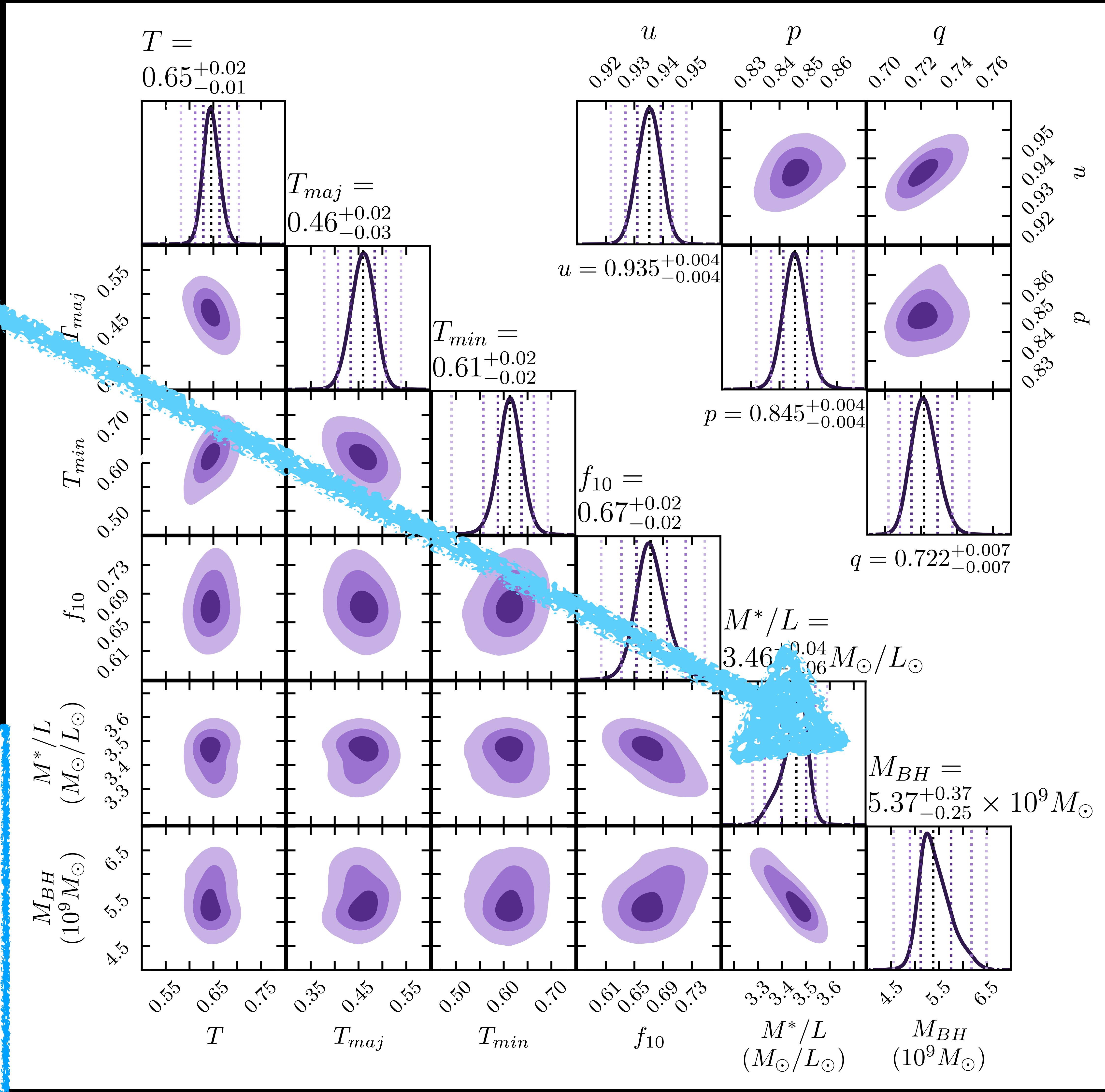


First simultaneous measurement of M87's BH mass and 3D shape

An Example: M87

Liepold, Ma, Walsh 2023

Black Hole Mass $5.37 \times 10^9\ M_\odot$



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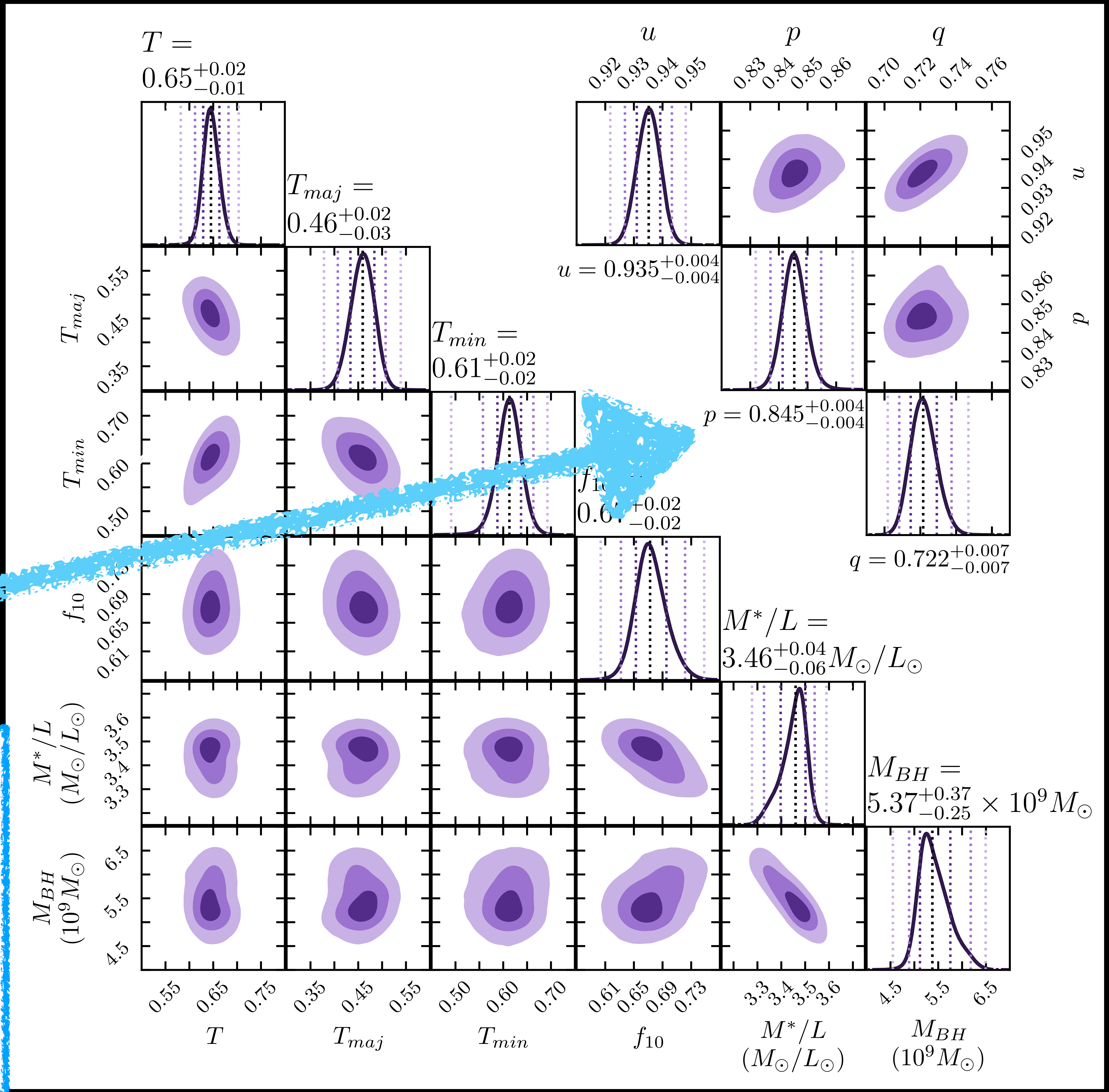
An Example: M87

Black Hole Mass **5.37 x 10⁹ M☉**

Average axis ratios 1 : 0.85 : 0.72



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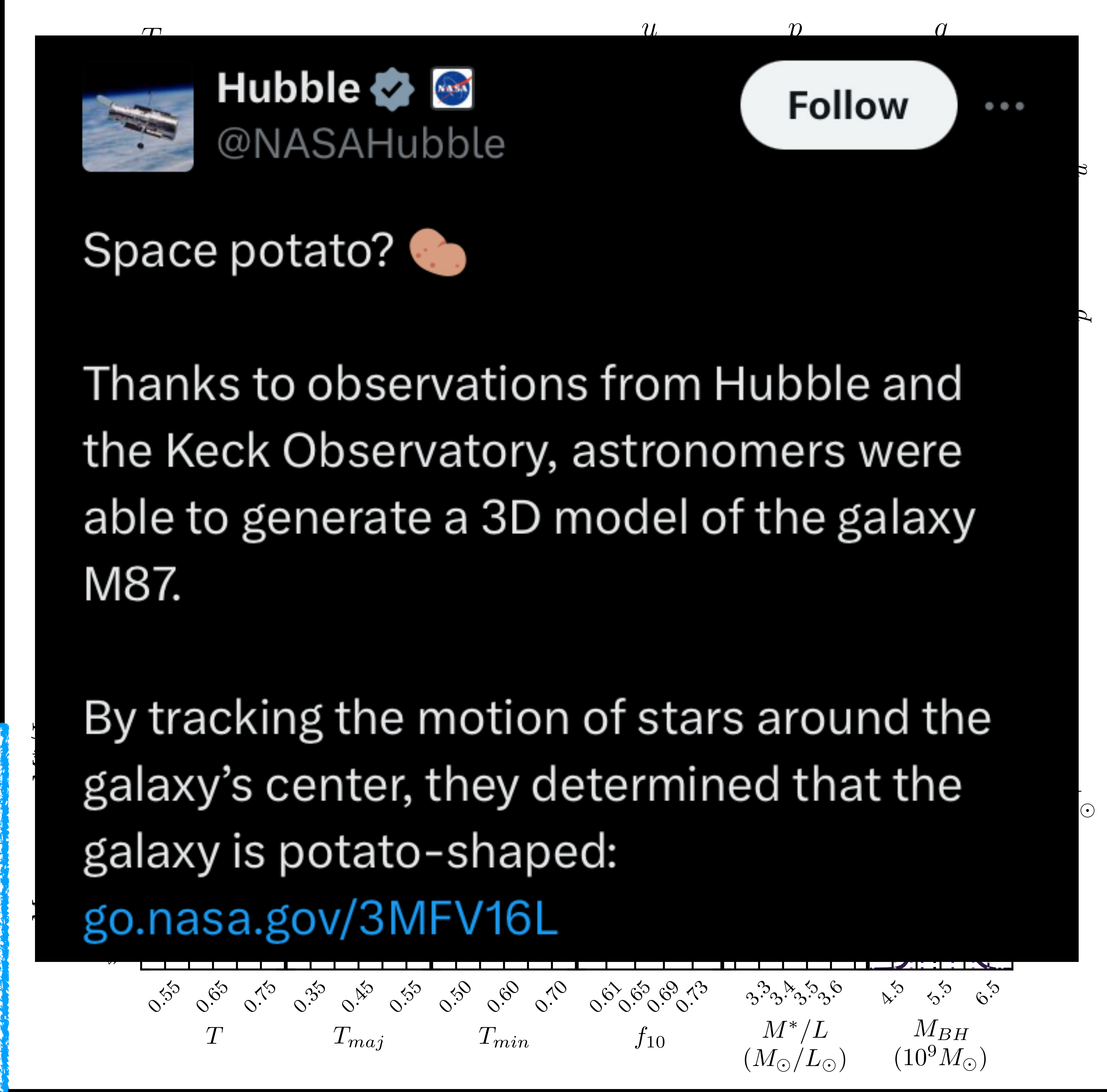


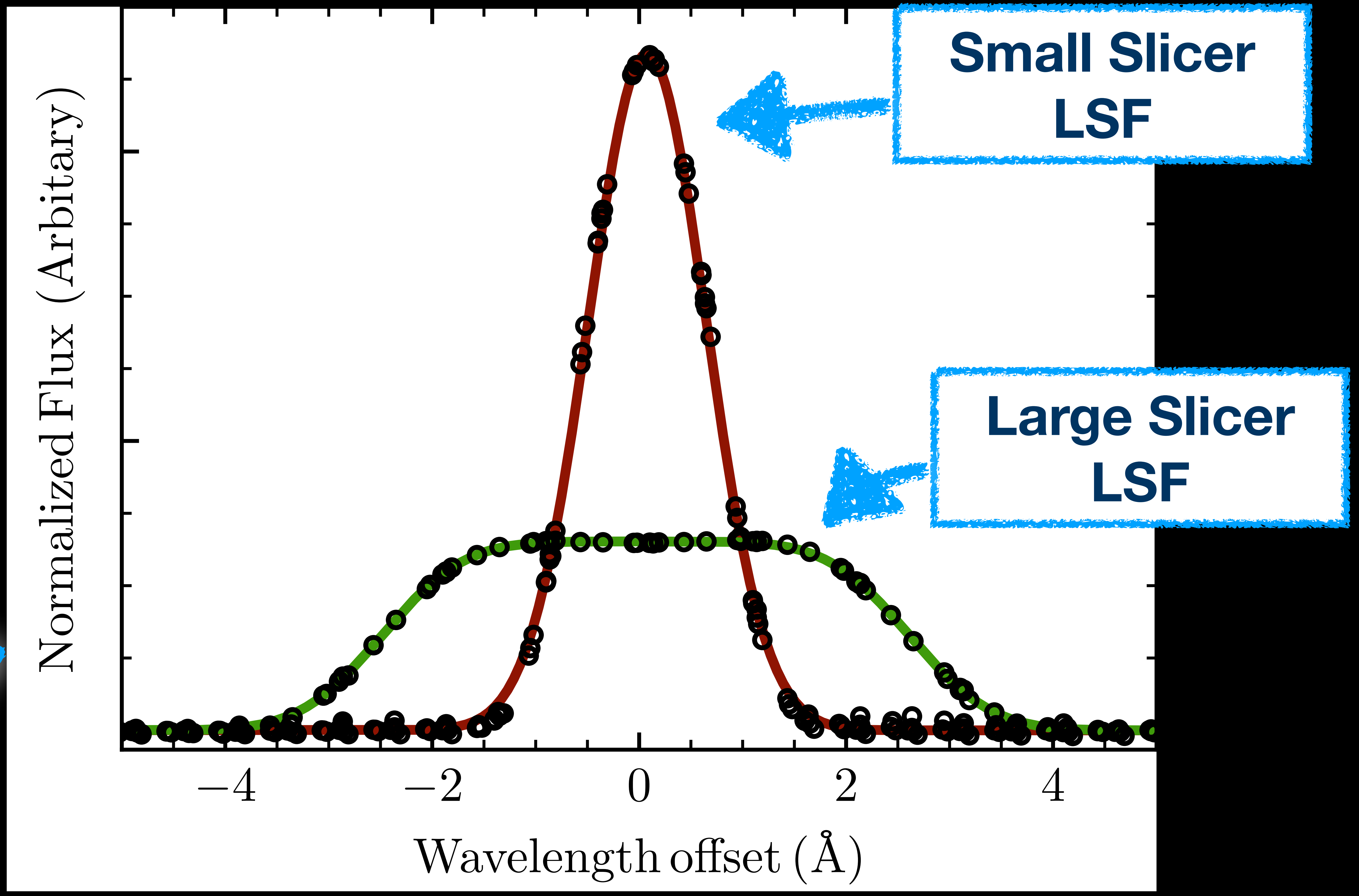
KCWI Lessons Learned

LSF, PCA, and Mosaicing

1. The KCWI large-slicer line-spread function is slit-limited and non-Gaussian!

   Instead, Top hat convolved with Gaussian

   This is important for determining accurate velocity distributions



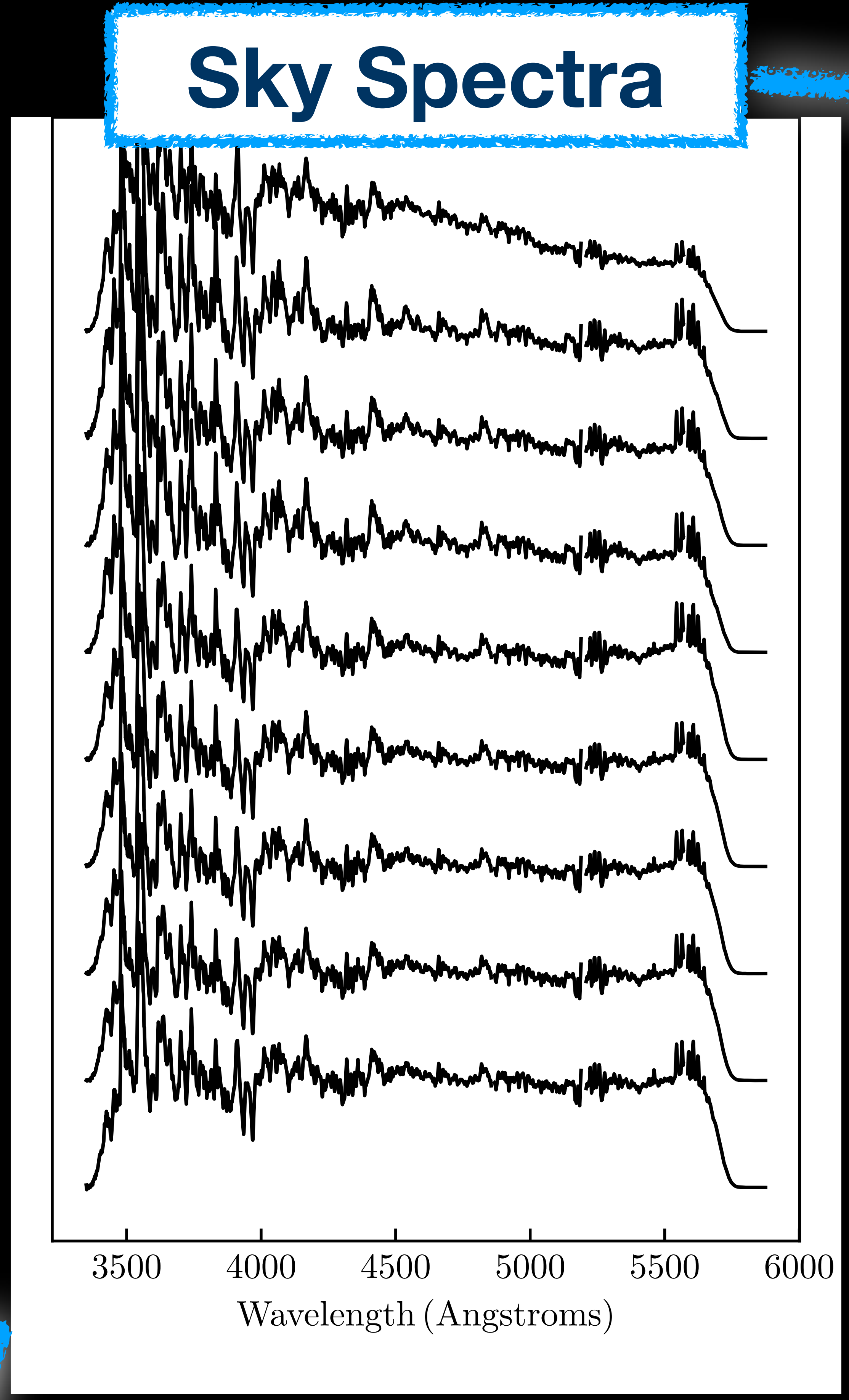
KCWI Lessons Learned

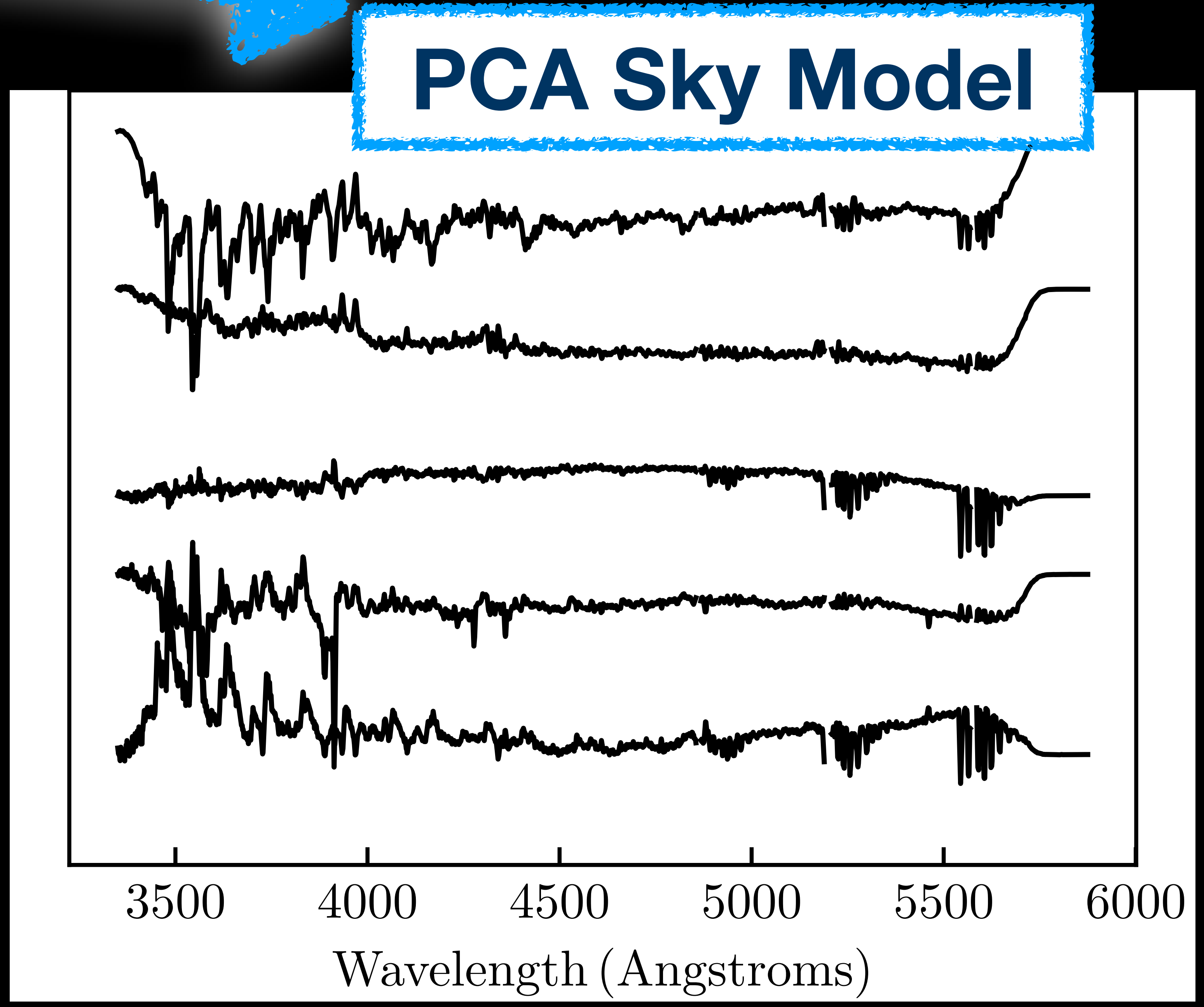
LSF, PCA, and Mosaicing

2. Use PCA sky model for residual sky corrections

   Include PCA components as additive terms in spectral fits

   This allows for robust kinematics in sky-dominated regions





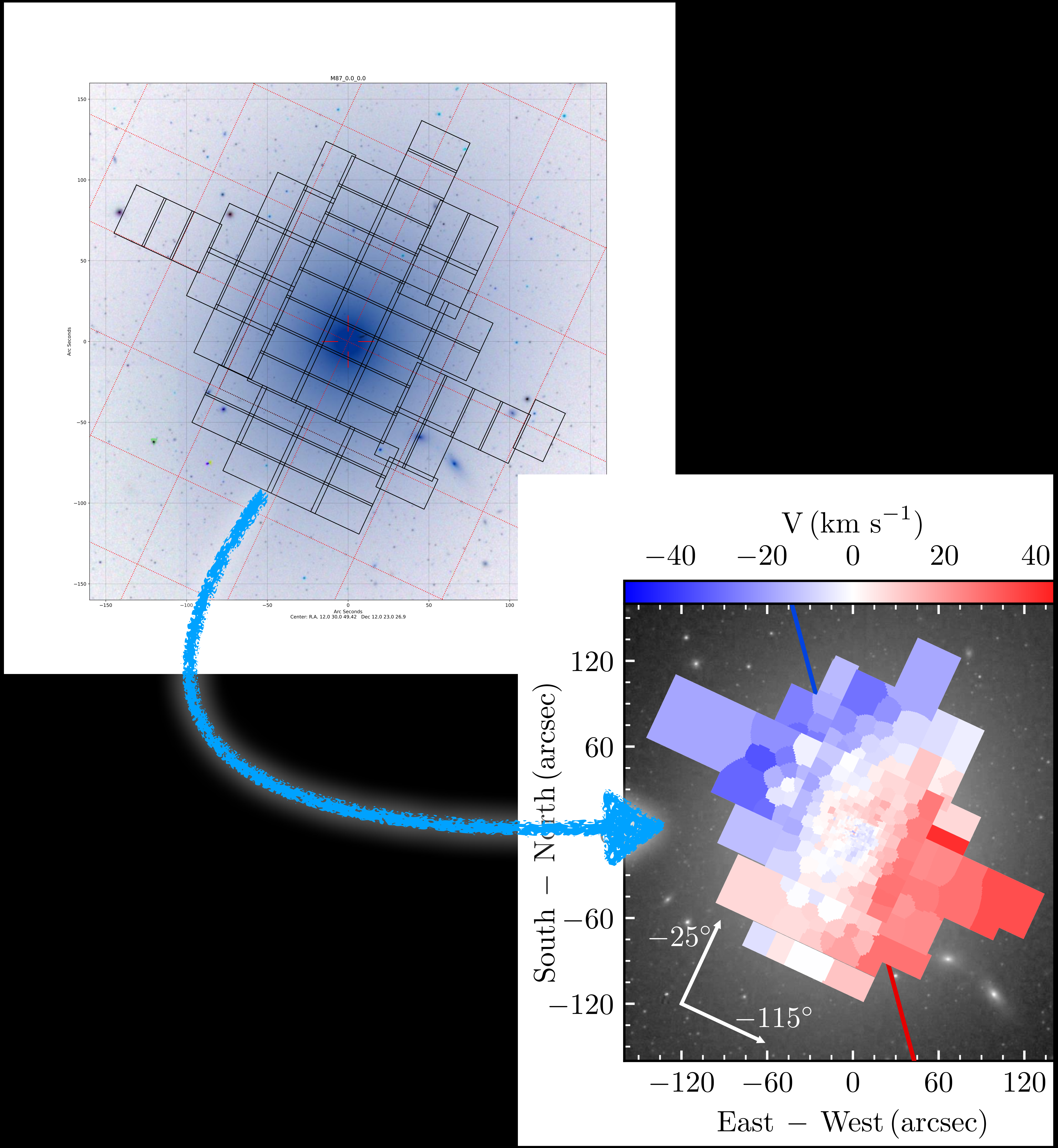
KCWI Lessons Learned

LSF, PCA, and Mosaicing

3. Use Gemini **gemcube** / **nifcube** to drizzle + mosaic science frames

   We rearrange KCWI datacubes to have NIFS-like structure, then use their established tools

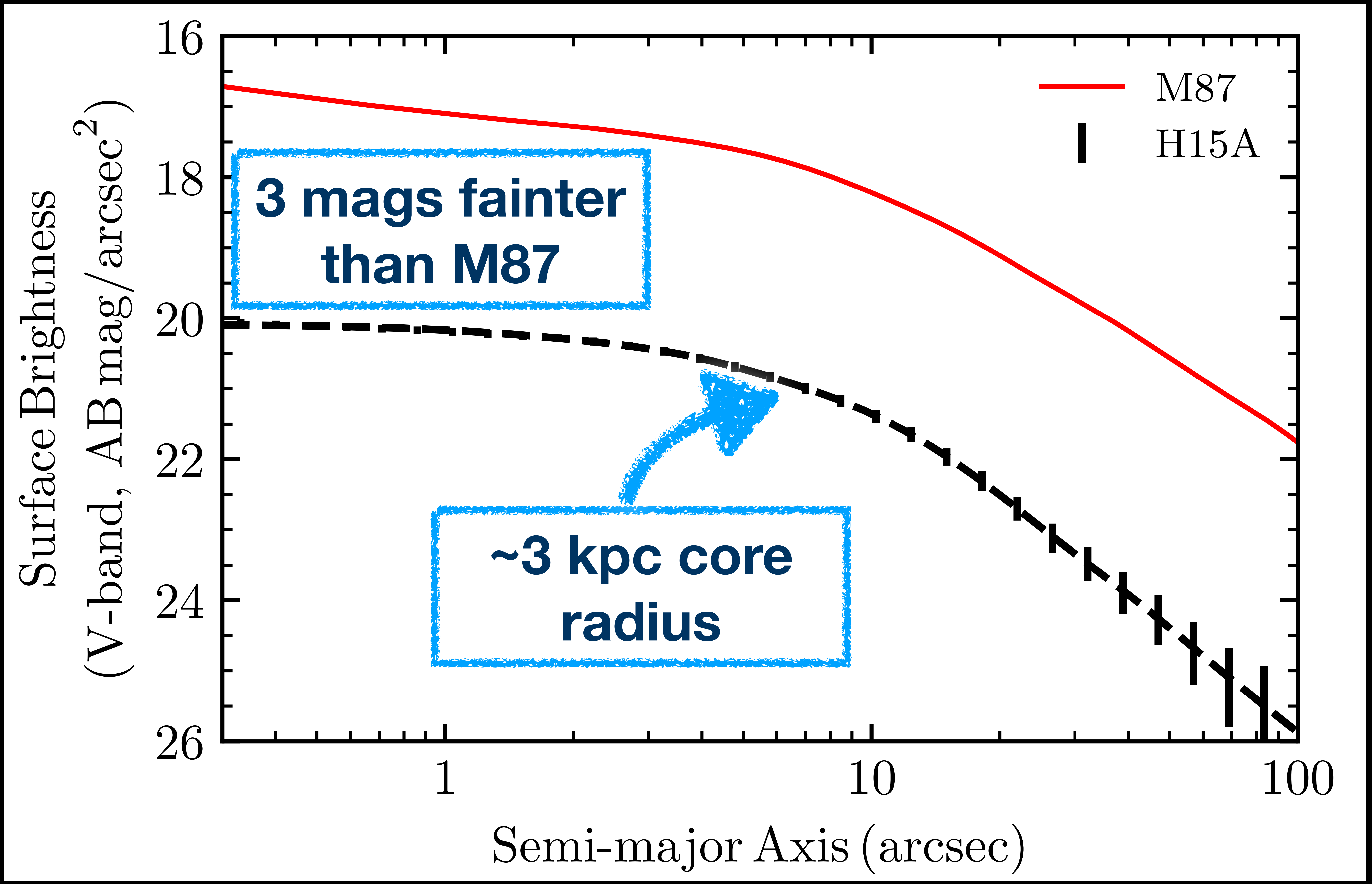
   This allows for robust mosaicing + drizzling without re-implementing those algorithms



Liepold, Ma, Walsh 2024
(Forthcoming)

Moving Forward: Holmberg 15A

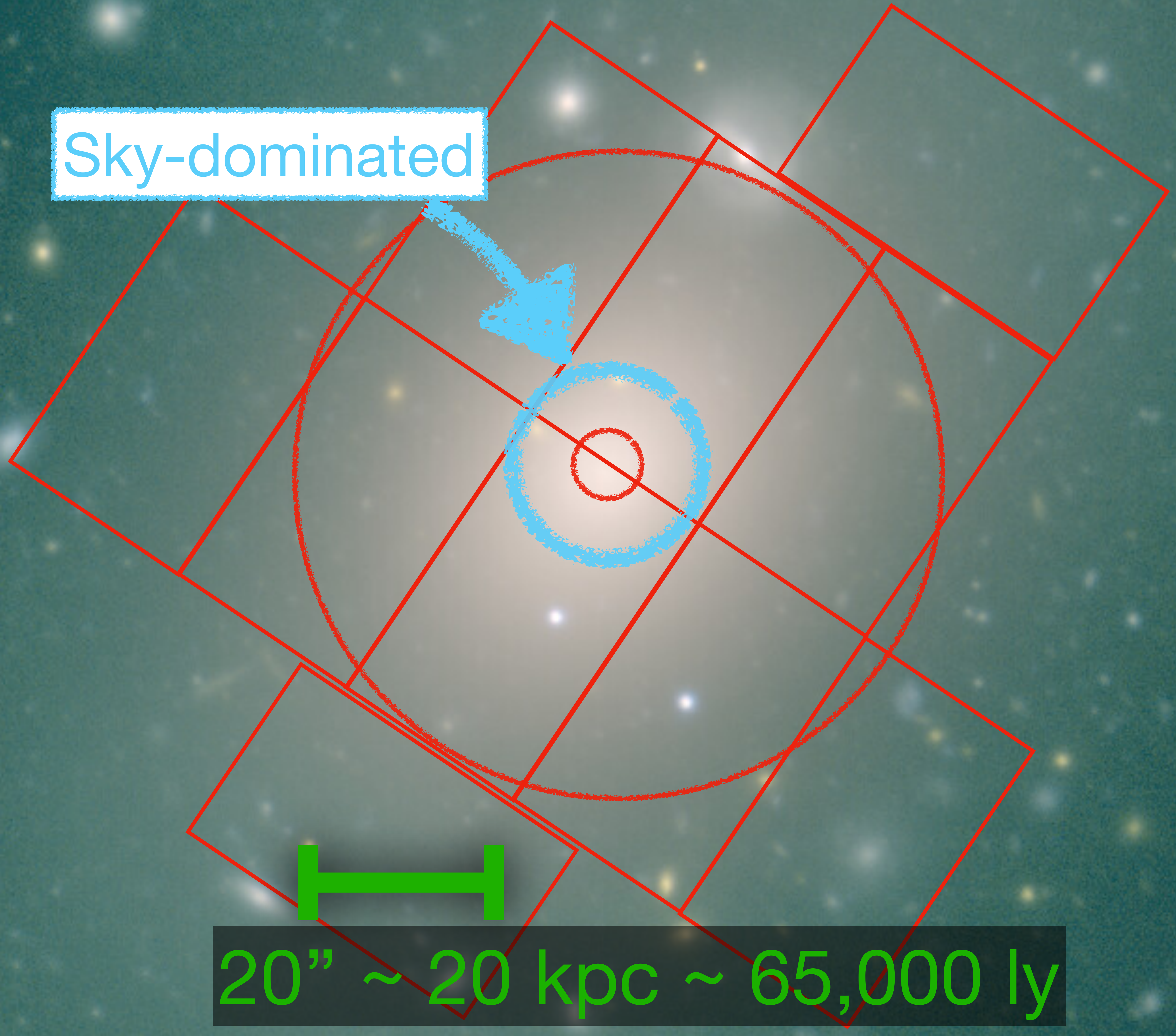
- BCG of Abell 85
- Largest known core! (~3 kpc)
- Faintest known Central SB! ($\mu_V = 20 \mathrm{mag/arcsec^2}$)
- The size of an ETG's core is correlated with the black hole mass
- The central surface brightness is ***anti***correlated with black hole mass
- (15x further away than M87)



Moving Forward: Holmberg 15A

Liepold, Ma, Walsh 2024
(Forthcoming)

- We observed H15 with KCWI small and large slicers during five observing runs from Nov 2018 - Nov 2021
- 2.5 hours on target with small slicer
- 9.5 hours on target with large slicer in 10 pointings
- 3.5 hours on sky
- The full FOV spans about 100 kpc along the photometric major and minor axes



Moving Forward: Holmberg 15A

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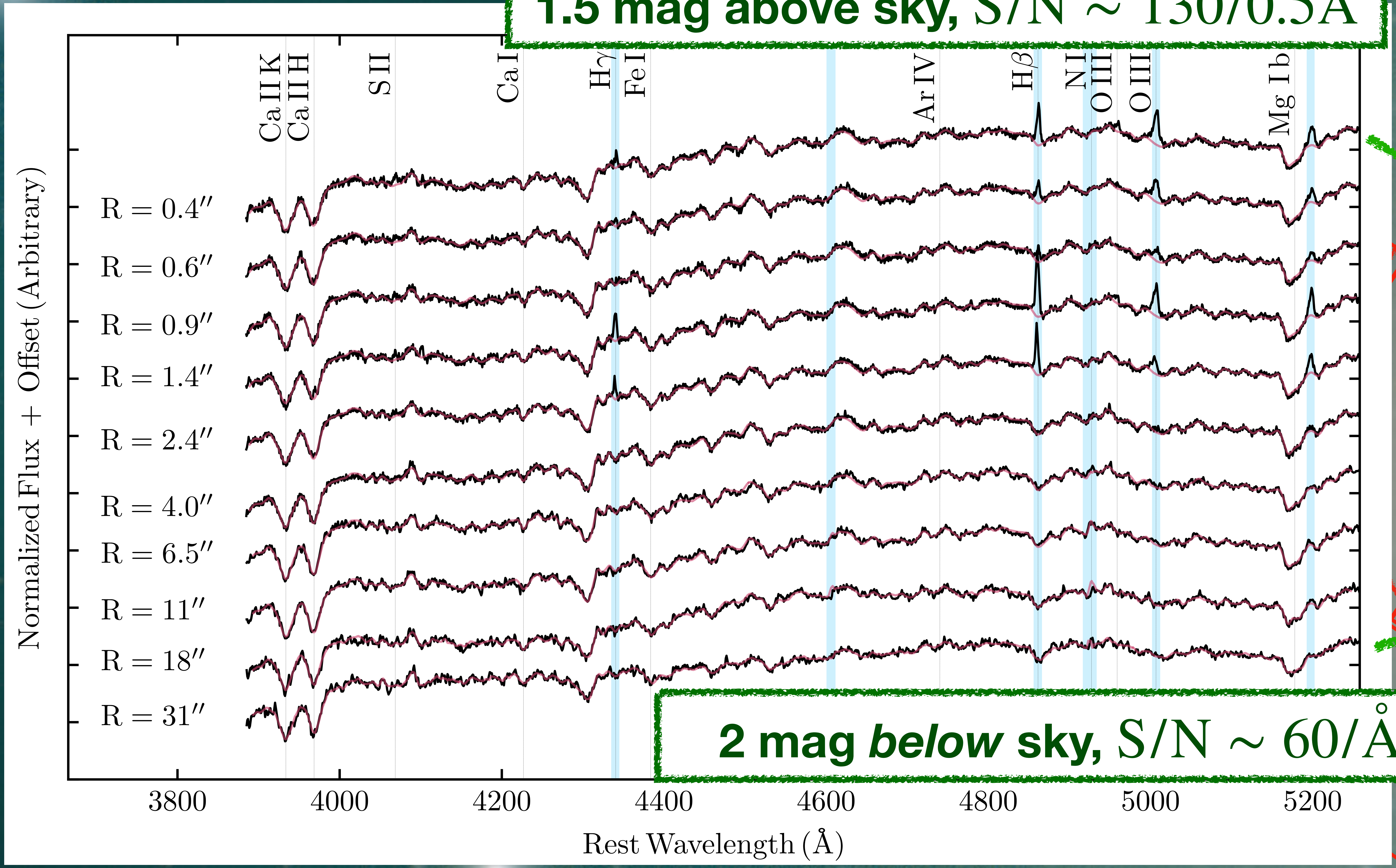
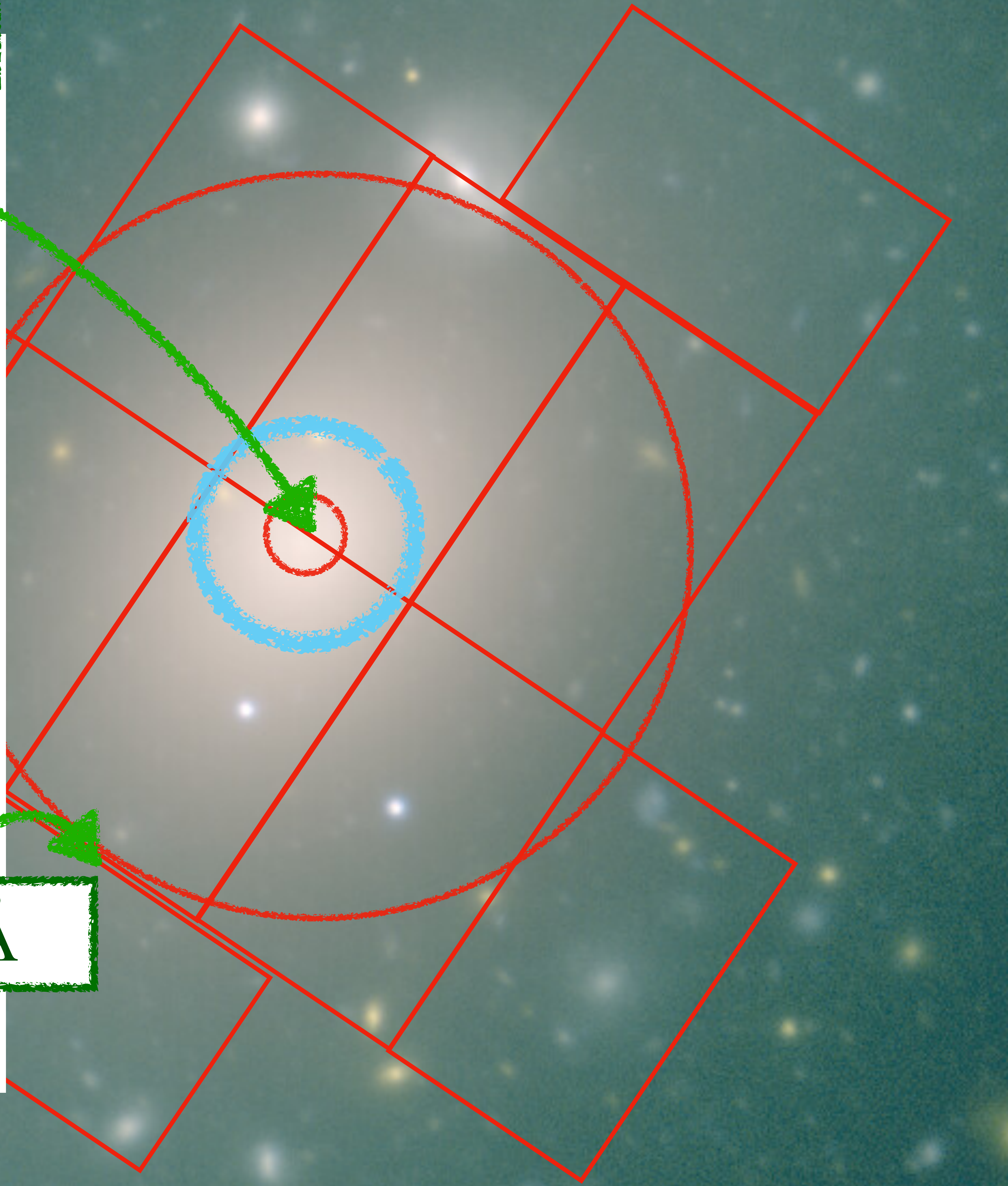
1.5 mag above sky, S/N ~ 130/0.5Å



2 mag *below* sky, S/N ~ 60/Å



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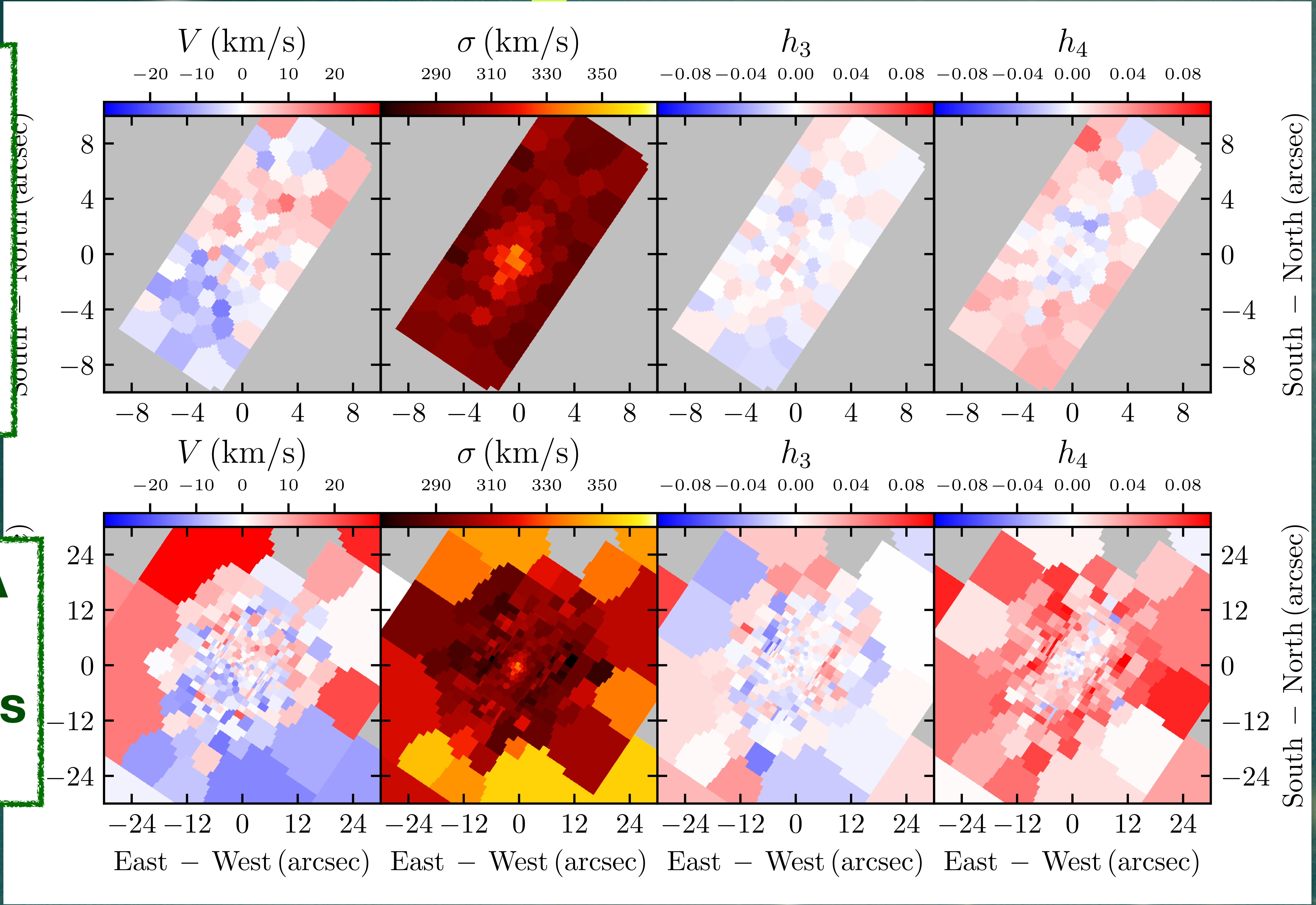
Measurements of 8 velocity moments in sky-dominated regions!

Only possible with KCWI!



Spoiler for paper: H15A has the largest SMBH from dynamical methods (and H15A is triaxial)

- KCWI / KCRM enables stellar kinematic measurements well-below sky level
- This makes SMBH measurements in galaxies with large diffuse cores possible (where ultramassive BHs live!)
- Ongoing efforts to model more w/ diffuse cores!
- New modeling schemes allow measurements of triaxial 3D shapes simultaneously with SMBH mass