RADIAL GRADIENTS IN LOW-SPIN GALAXIES

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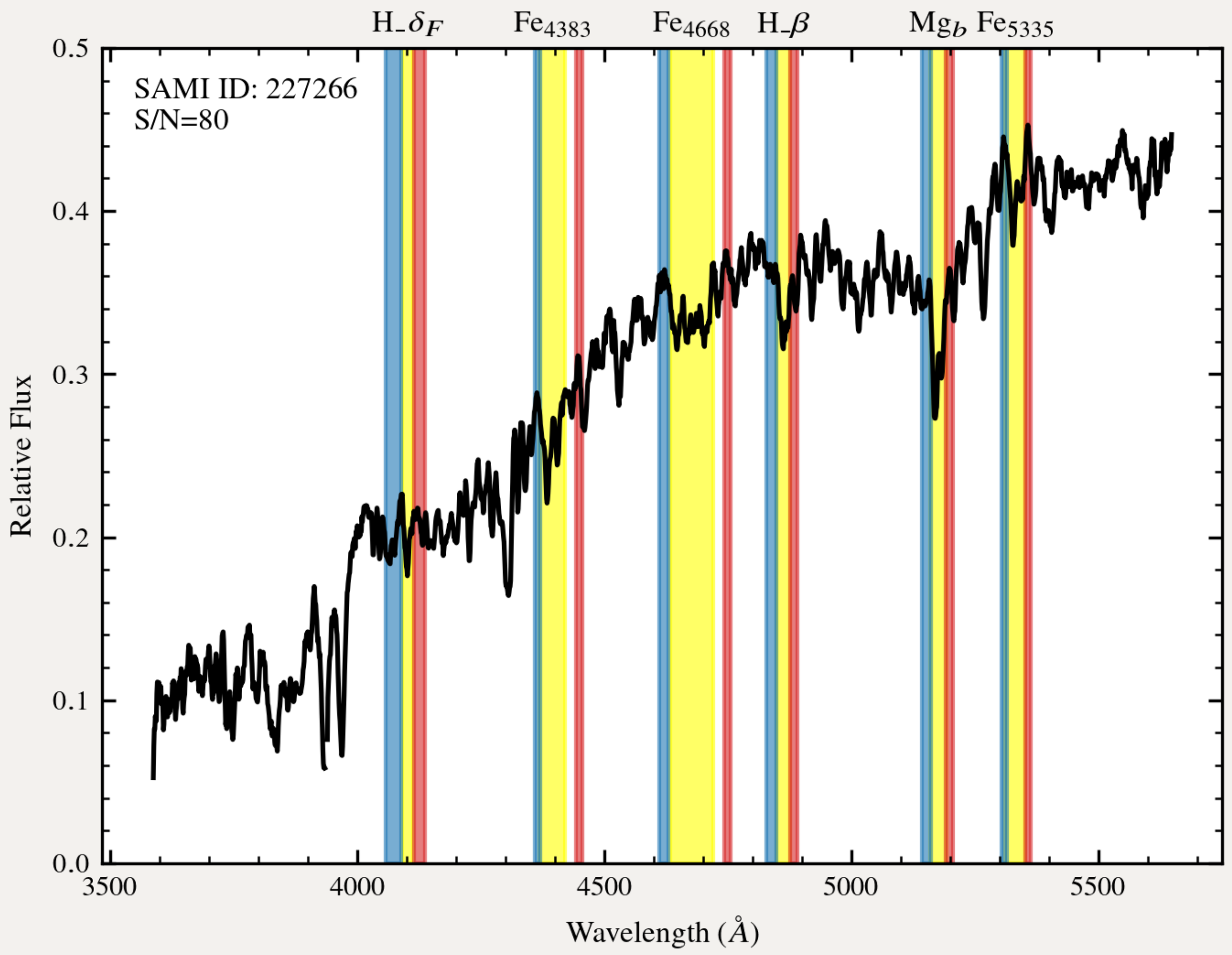
SAMI/Hector Busy Week

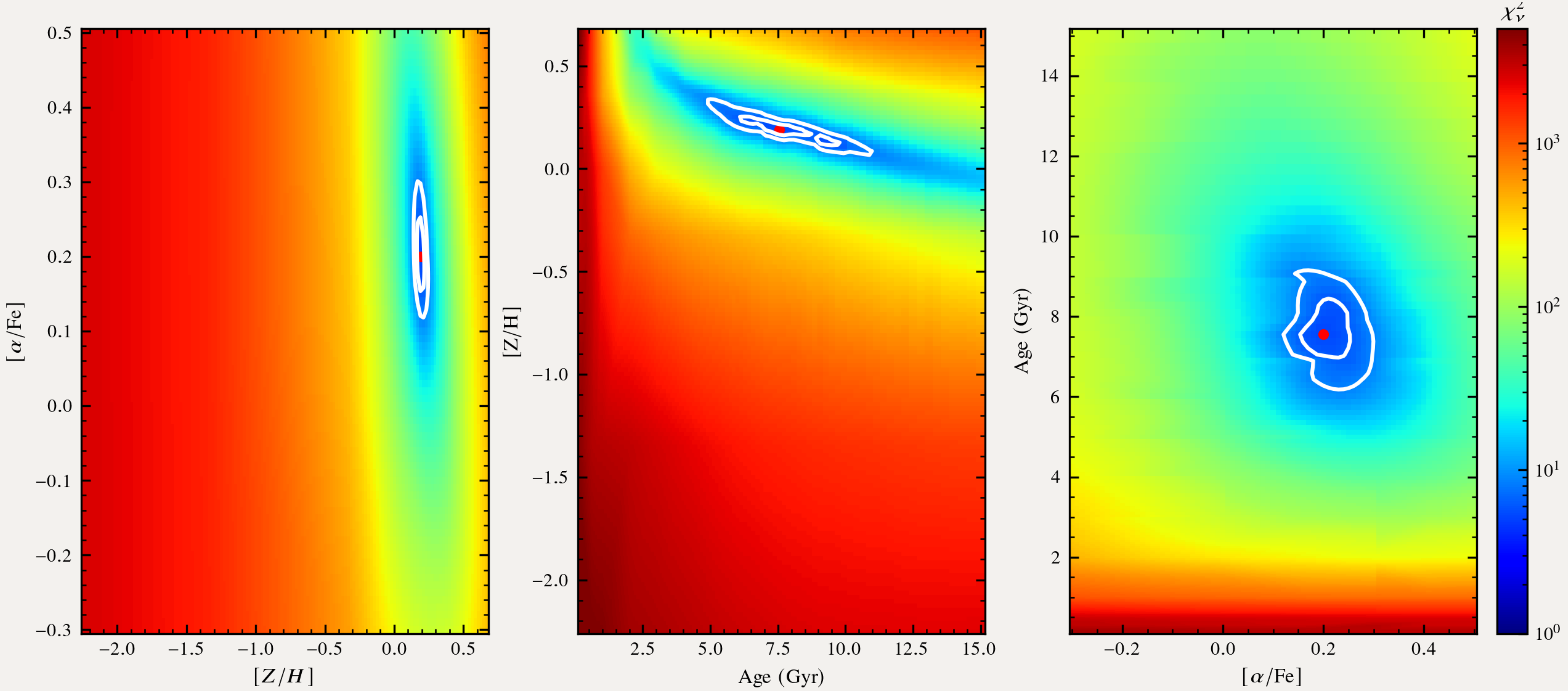
HINTZE CENTRE FOR ASTROPHYSICAL SURVEYS
ARC CENTRE OF EXCELLENCE FOR ALL SKY ASTROPHYSICS IN 3D

LINE INDICES

- Blue/red sidebands set the pseudo-continuum level
- Use variance weighting (Cenarro+01) to avoid bad pixels skewing results
- 20 indices available in SAMI blue arm
- Not all indices are created equal!
- Require **at least** one Balmer line, one Mg index, and one Fe index
- Stellar populations are determined through χ^2 minimisation (Proctor+04)
- SSP models of Thomas, Maraston & Johannson (TMJ+11)
- Uncertainties measured directly from χ^2 contours

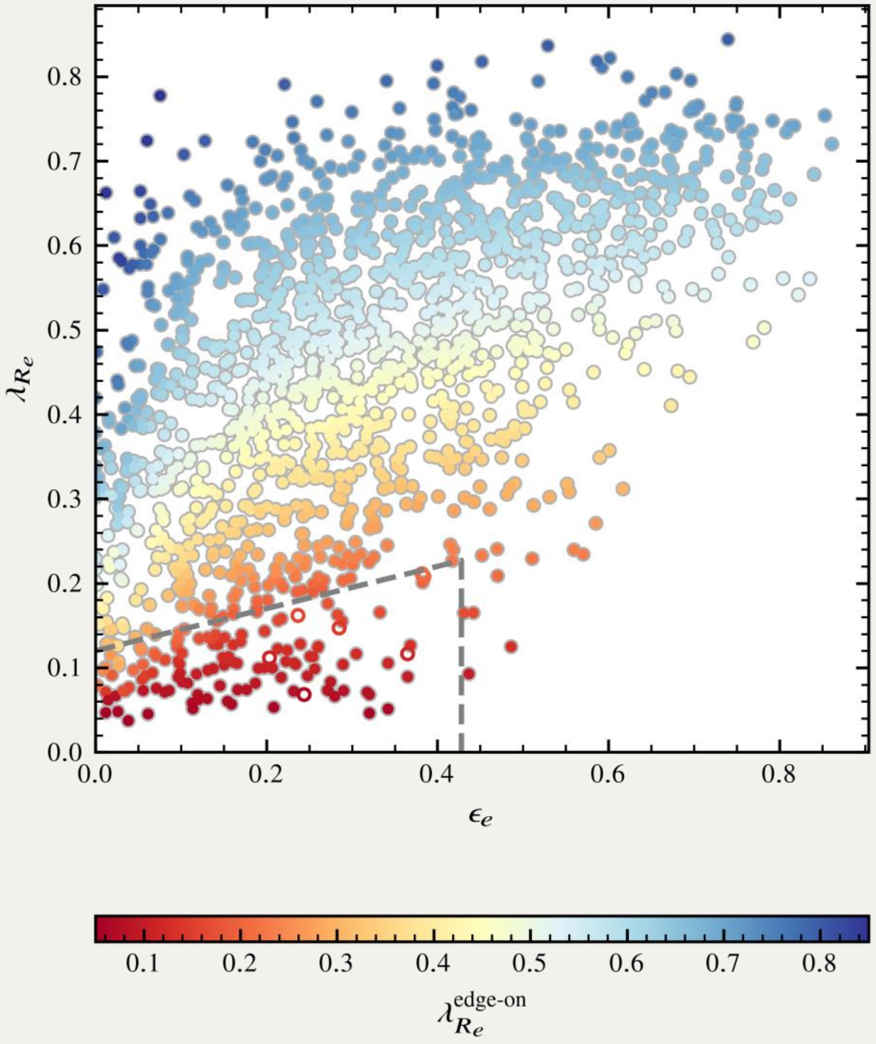


STELLAR POPULATIONS



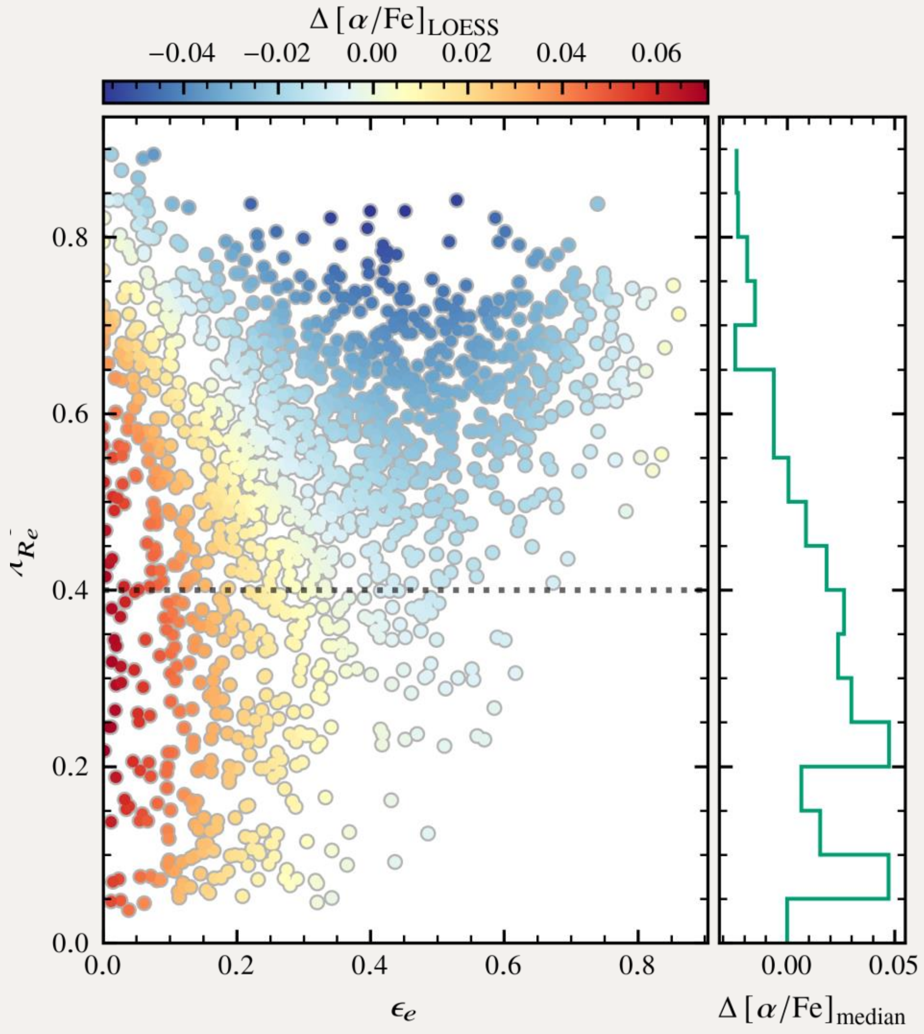
KINEMATIC CLASSIFICATION

- Known correlation between [α/Fe] and σ
- Looking for second-order correlations:
  - Environment
  - Mass
  - Morphology
- Kinematic morphology uses spin proxy (λ_R) and ellipticity to classify galaxies
- Fast rotators (FRs) have ordered rotation, often disk-dominated
- Slow rotators are dispersion-dominated, with complex velocity fields
- Classification needs to account for inclination



INTEGRATED POPULATIONS

- Residual correlation between [α/Fe] and λ_R
- Uncertainty over interpretation – correlation vs causation
- Slow rotators and low- λ_R fast rotators show little difference in α-enhancement
- Utilise spatial data from SAMI
- Also investigate age, [Z/H]



RADIAL GRADIENTS

- Multiple methods of measuring radial trends
- Measure of radius – half-light or dynamical?
- Elemental abundance requires higher S/N than kinematics
- Compromise between spatial resolution and spectral S/N
- Binning scheme has a significant impact on results
- Stacking spectra from different galaxies
    - Substantial increase in S/N for each bin
    - Smooths over underlying variation in sample

BINNING SCHEME

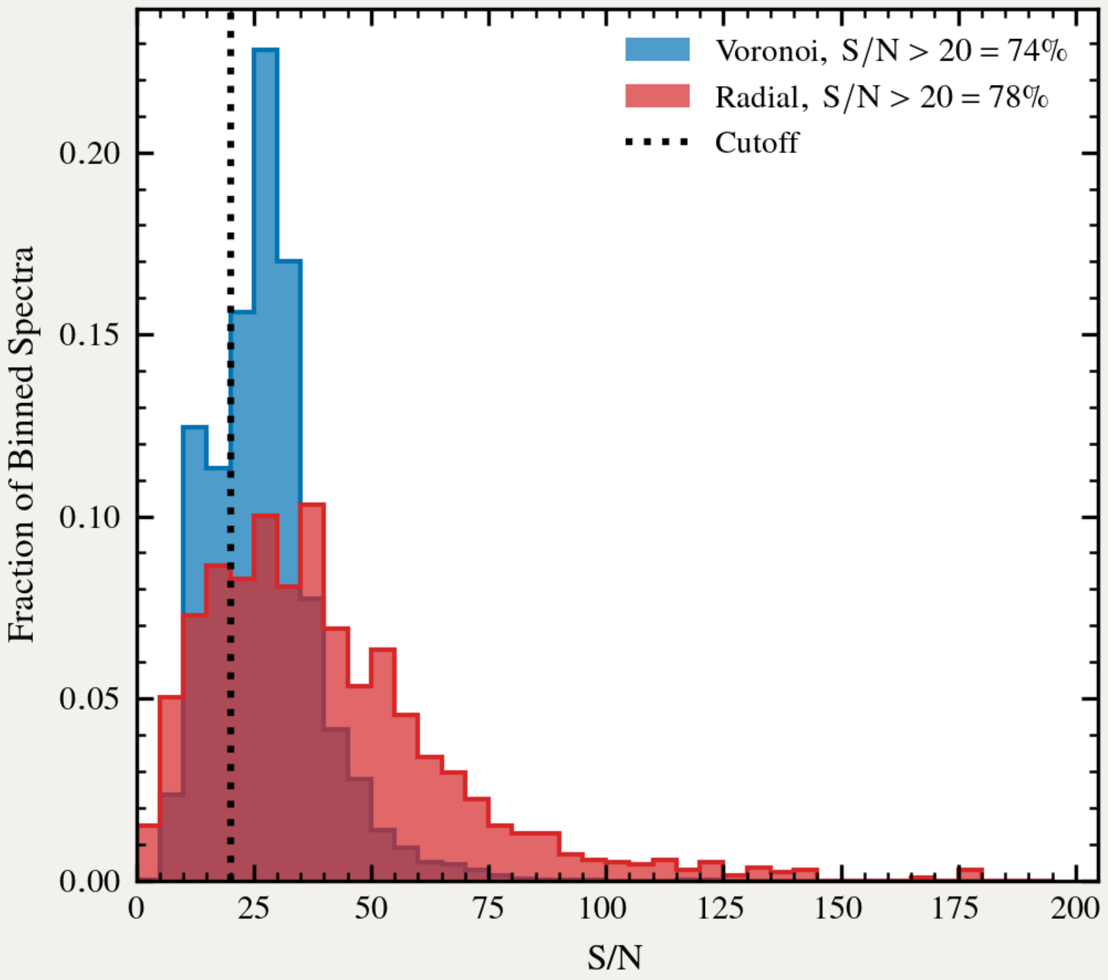
Voronoi bins:

- Set a target S/N=25
- Long tail from high S/N galaxies

Radial bins:

- Target 4 radial annuli
- Log-scaling to match gradients
- Significant scatter in resulting S/N

- Similar proportion of binned spectra fail to meet target S/N
- Absolute number of spectra significantly higher using Voronoi method
- Number of bins unevenly distributed amongst galaxies



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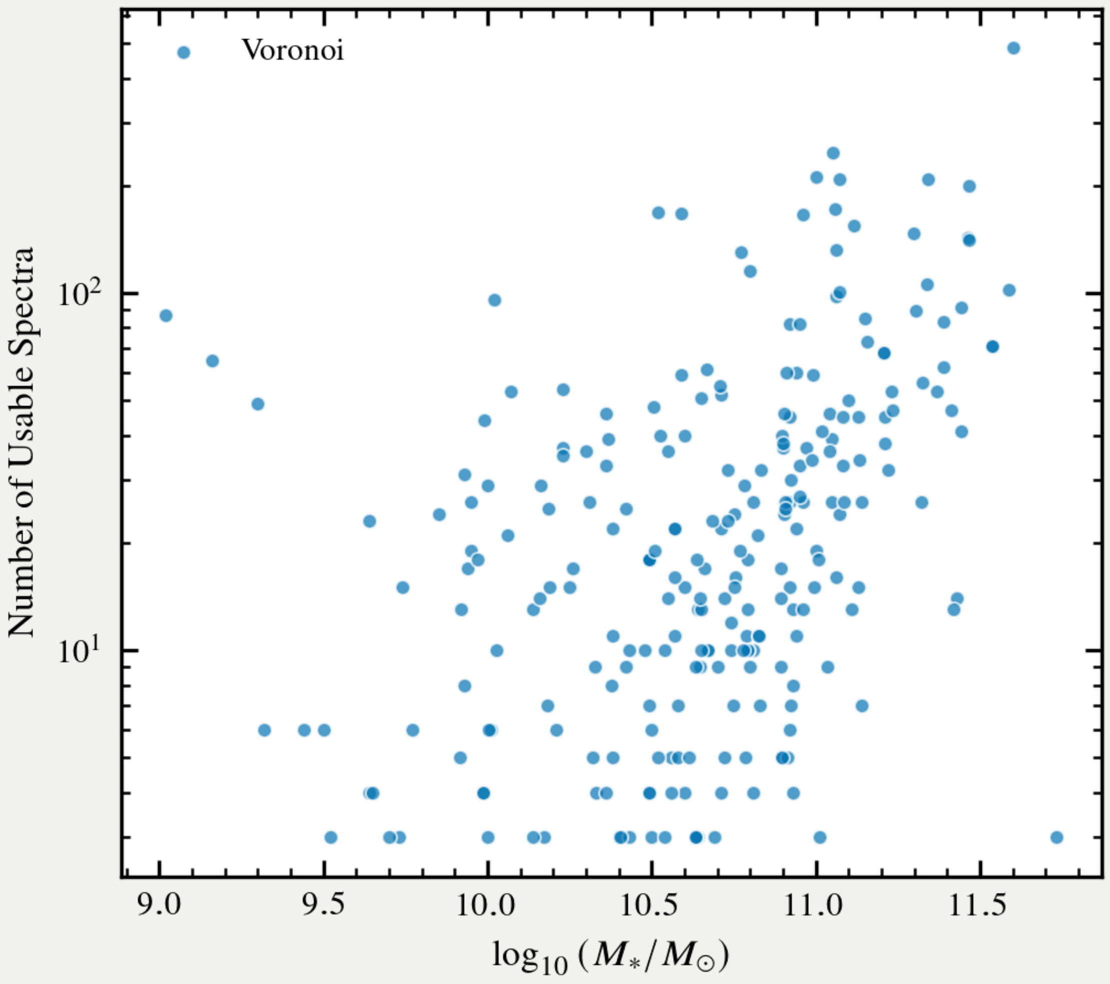
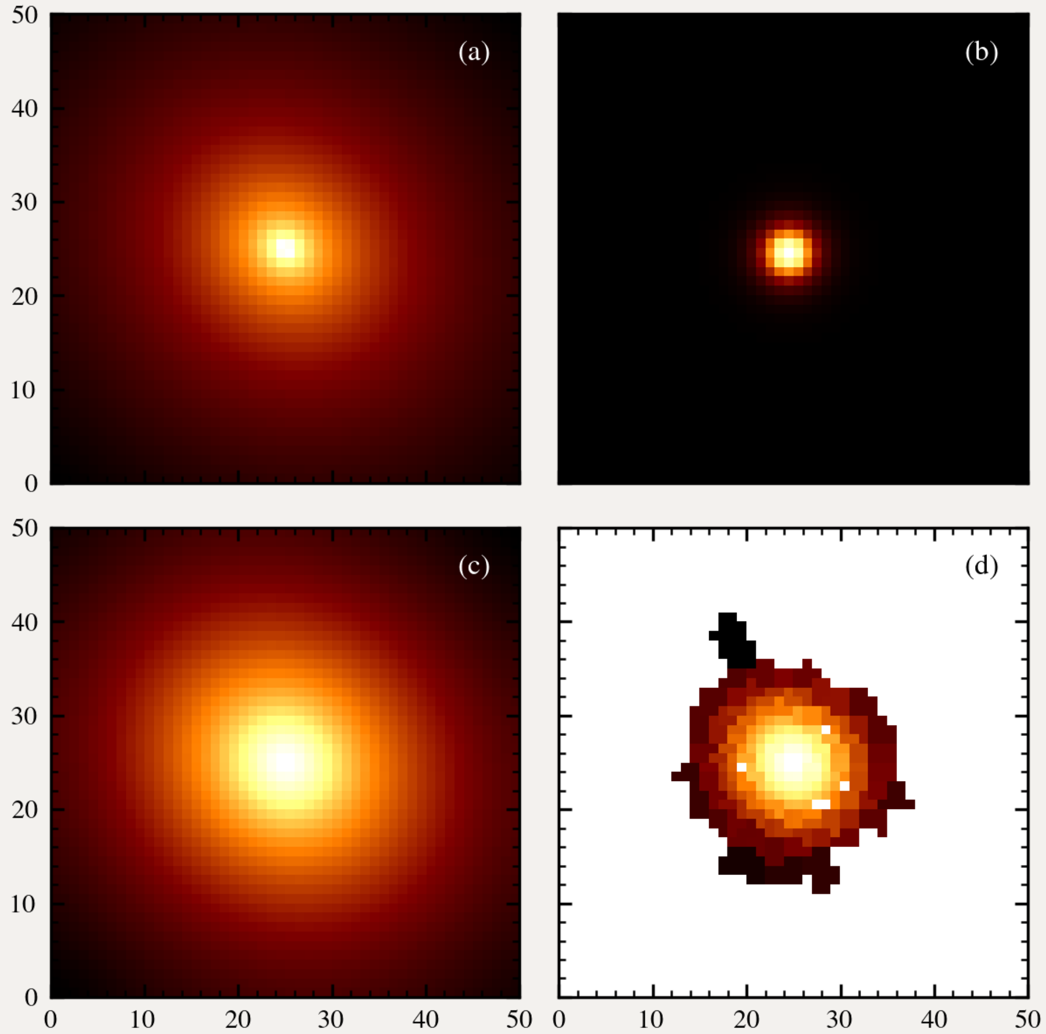
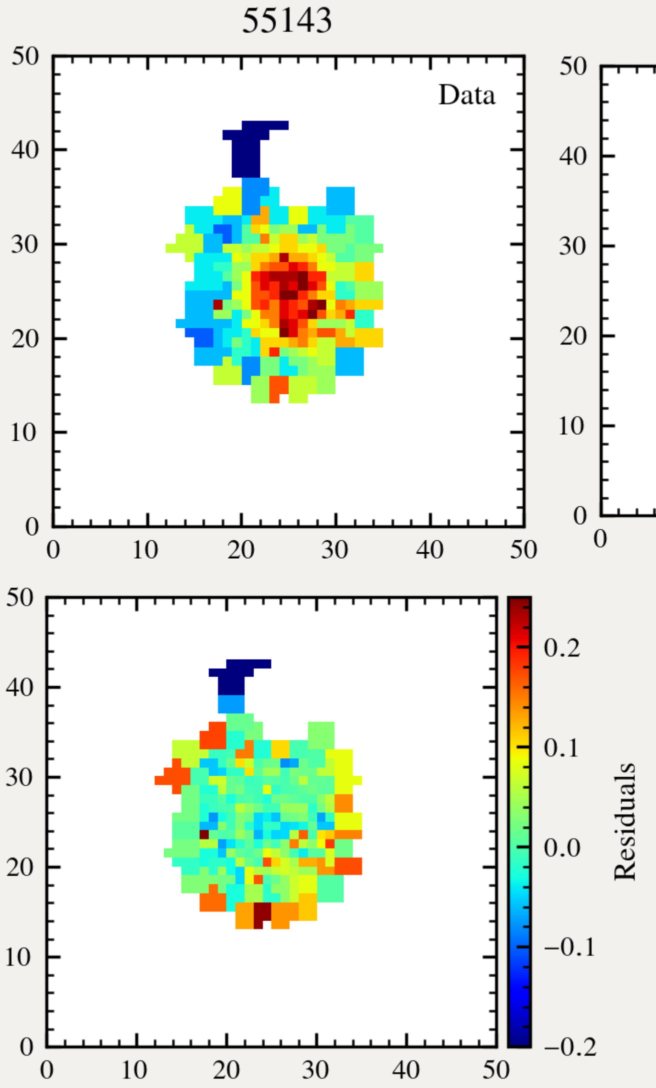


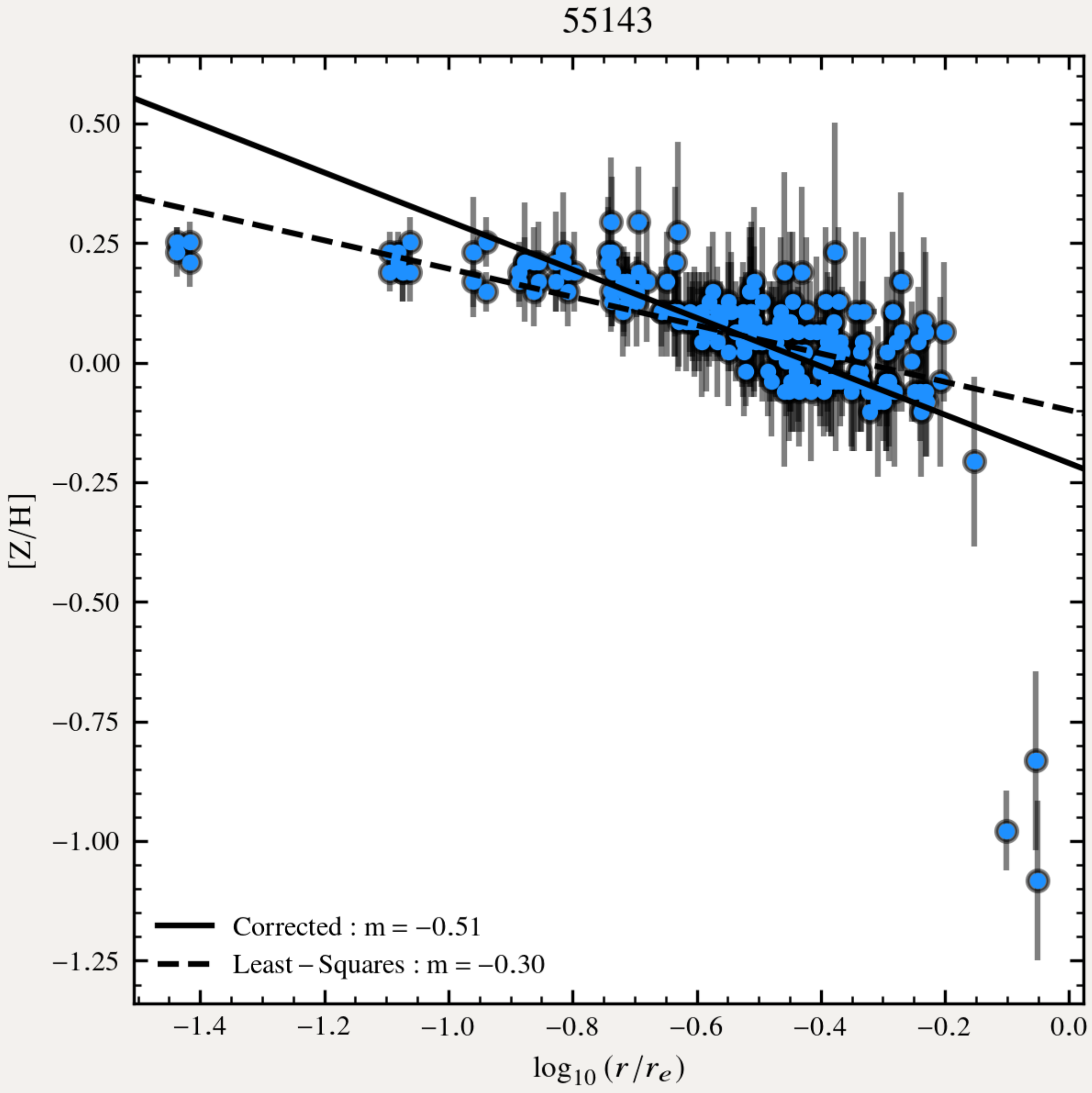
RECOVERING GRADIENTS

- Seeing has a huge impact on the measured gradient
- Failing to account for this can significantly bias results
- Use forward modelling approach (Ferreras+19)
- Model a simple gradient as
  - $X = m\log_{10}(r/r_e) + c$ (a)
- Convolve the model with a Moffat profile of the seeing (b)
- Remap the convolved model (c) on to the binning scheme (d)
- Calculate residuals -> can determine most probable solution through χ^2 minimisation or maximising log-likelihood
- Calculating uncertainties requires MC methods



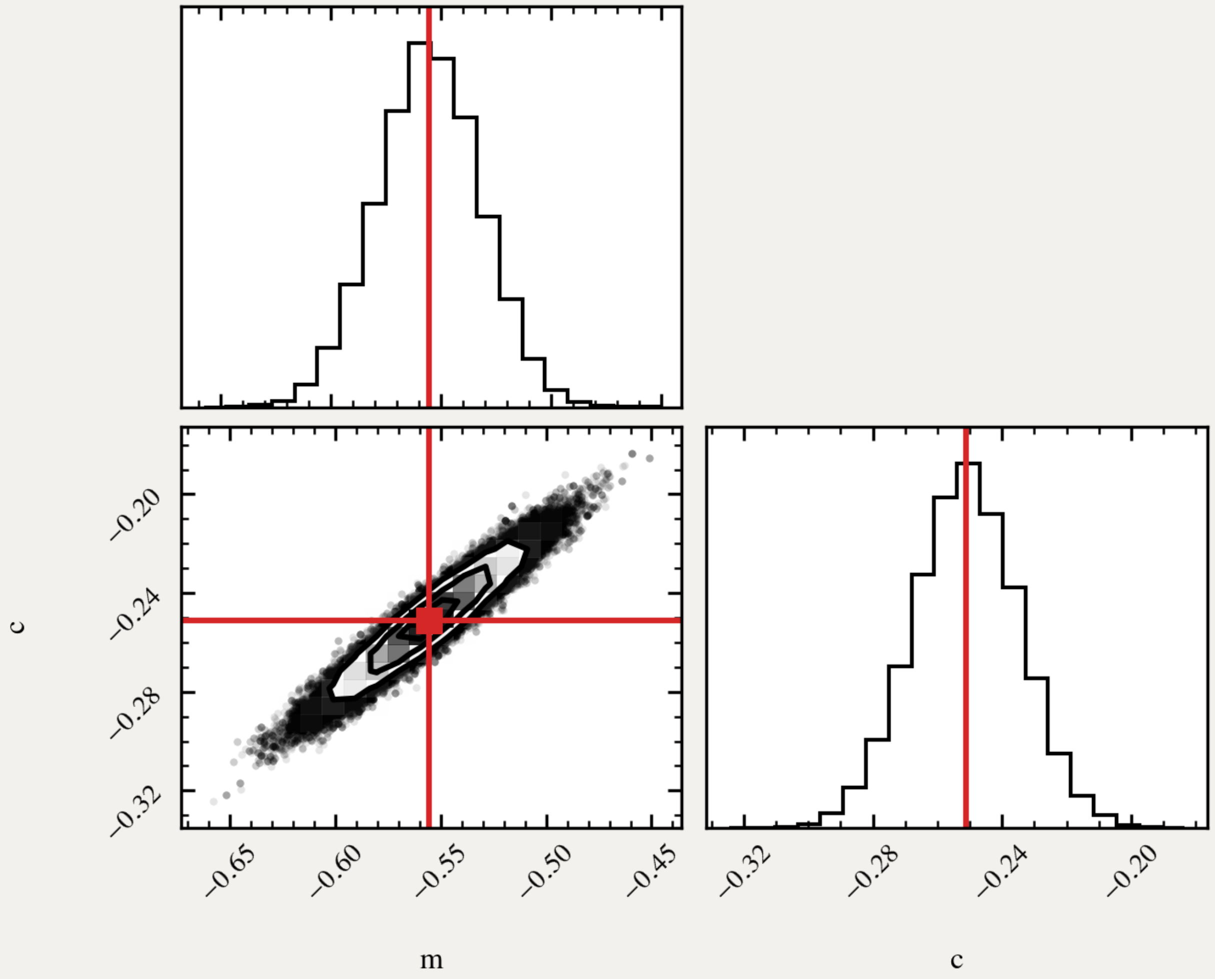
RECOVERING GRADIENTS





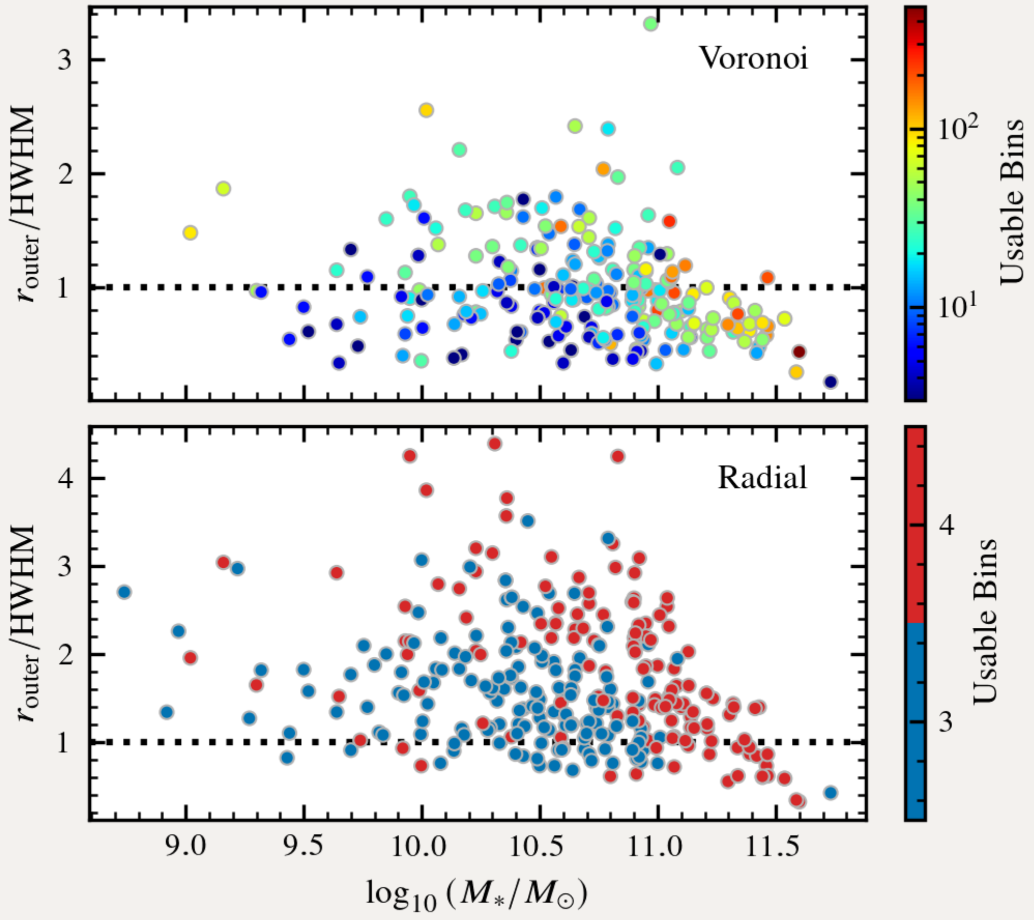
RECOVERING GRADIENTS

- Most galaxies show correlations between gradient and intercept
- More bins (i.e. data points) reduce this correlation
- Low uncertainties require both:
    - Fine spatial sampling in centre (smaller bins than ePSF)
    - Coverage extending out to large radii
- Voronoi scheme excels at spatial sampling, but roundness criterion reduces coverage on outskirts of galaxy
- Reverse is true for radial scheme – good coverage to edge of cube, but can undersample ePSF

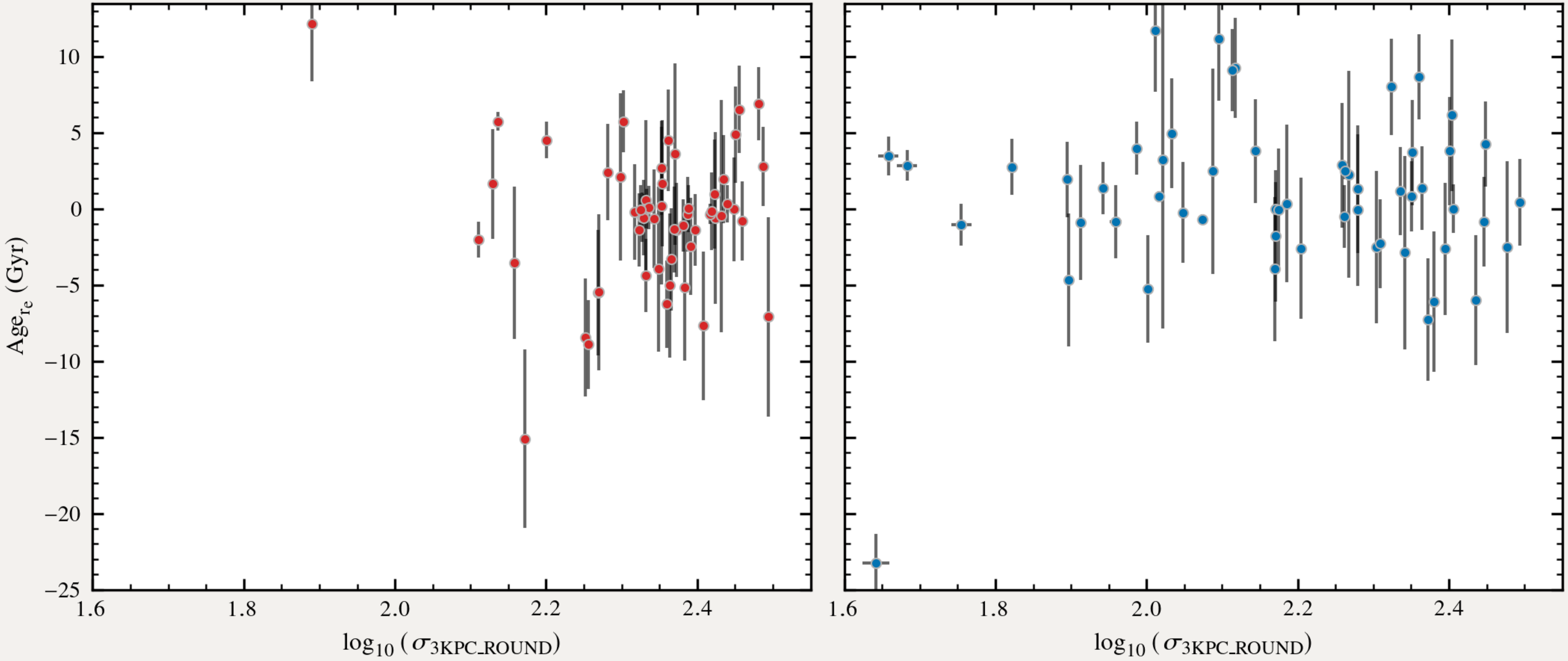


RECOVERING GRADIENTS

- Some obvious quality cuts are applied – reliable gradients clearly cannot be determined from only two data points
- Only 38% of galaxies are sampled out to 1Re using Voronoi binning
- This compares to 83% using the radial scheme
- Considering radial sampling, number of reliable Voronoi gradients reduces even further
- Results from methods are consistent, despite sampling differences



GRADIENT INTERCEPTS



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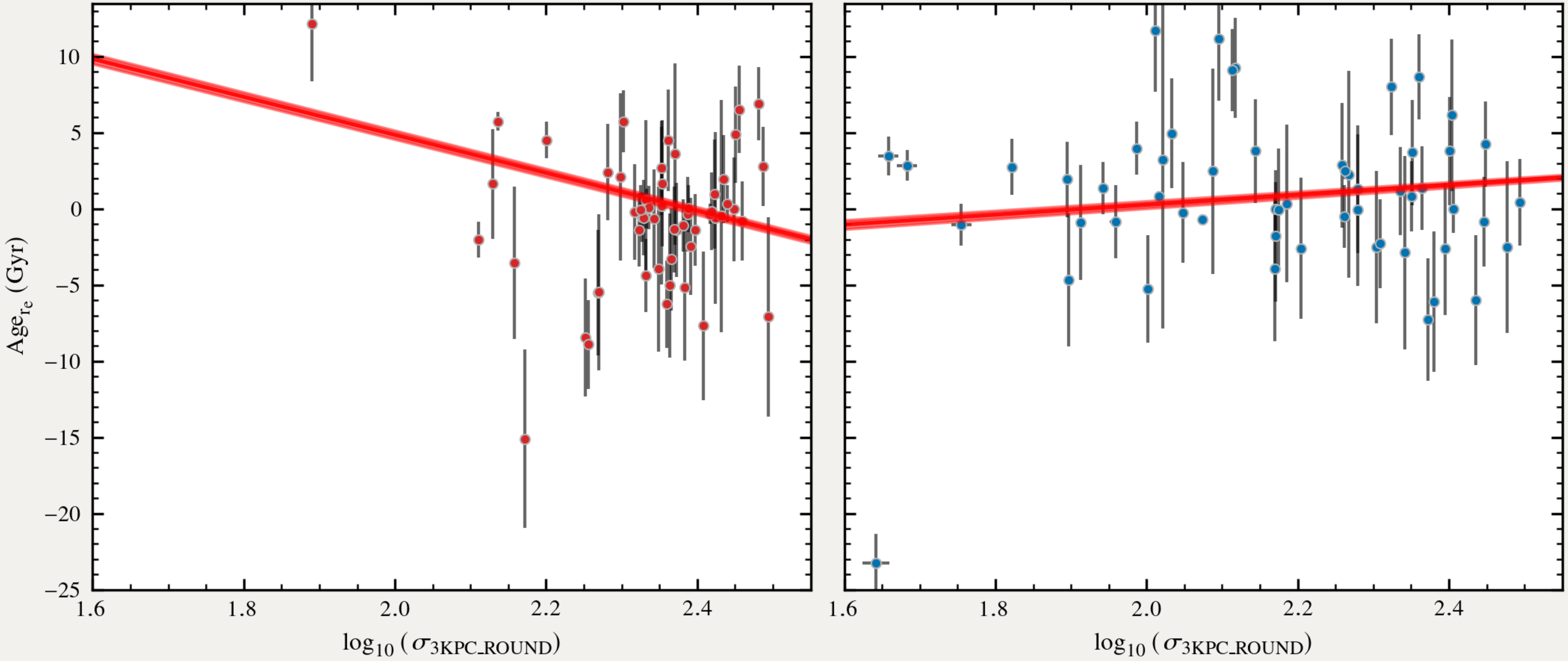

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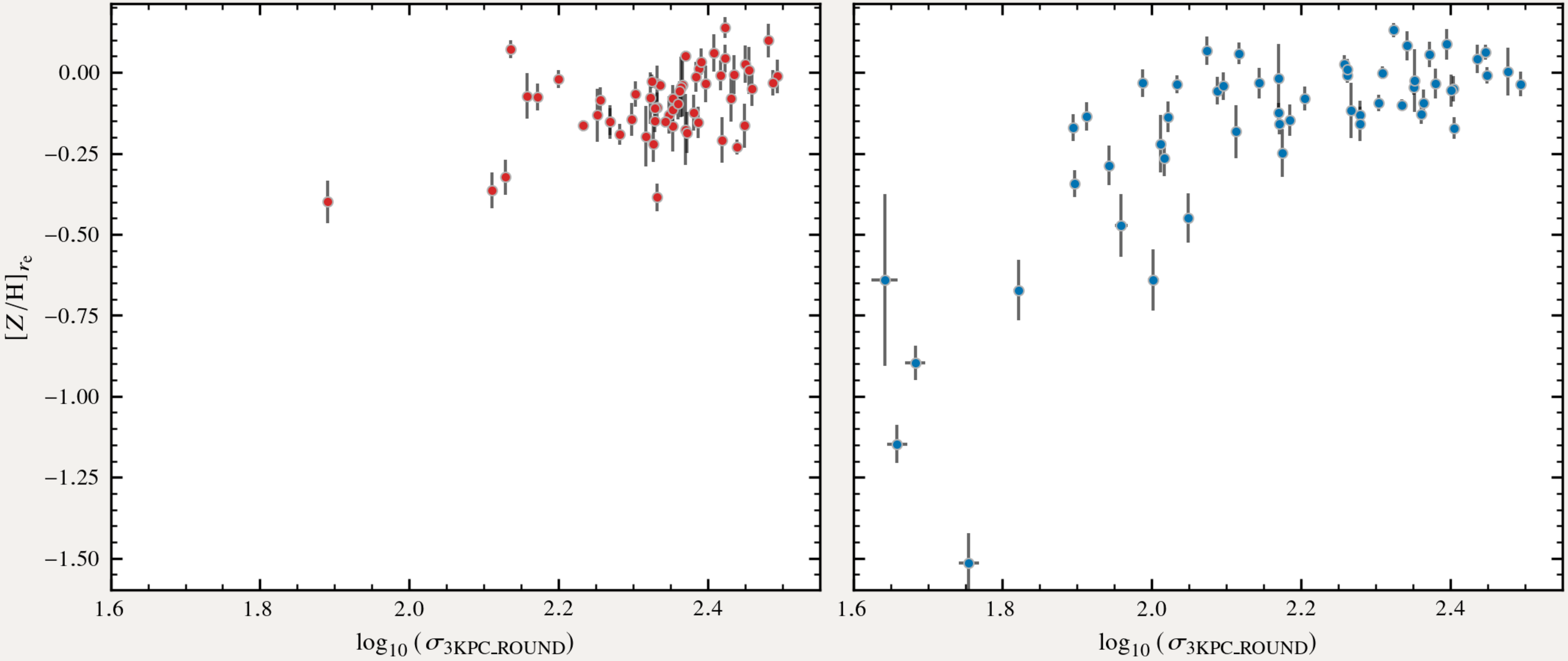

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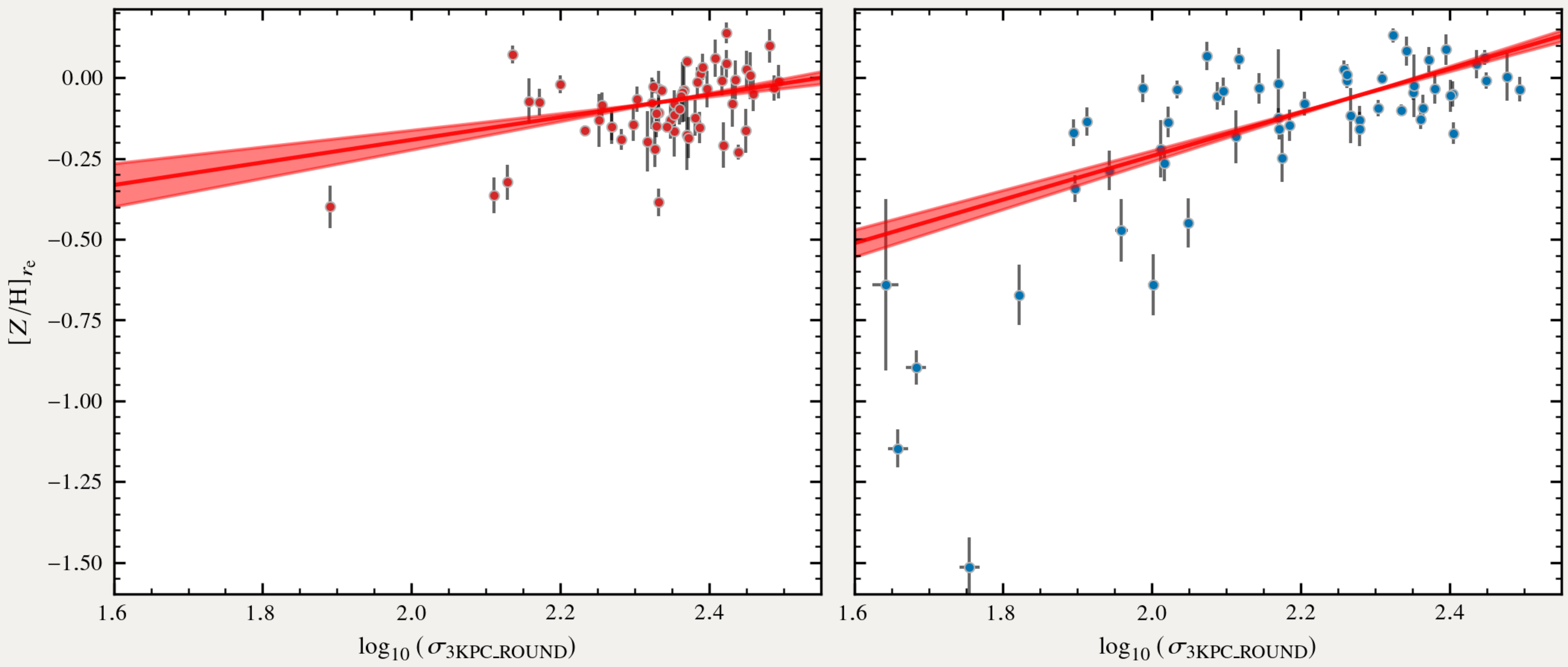

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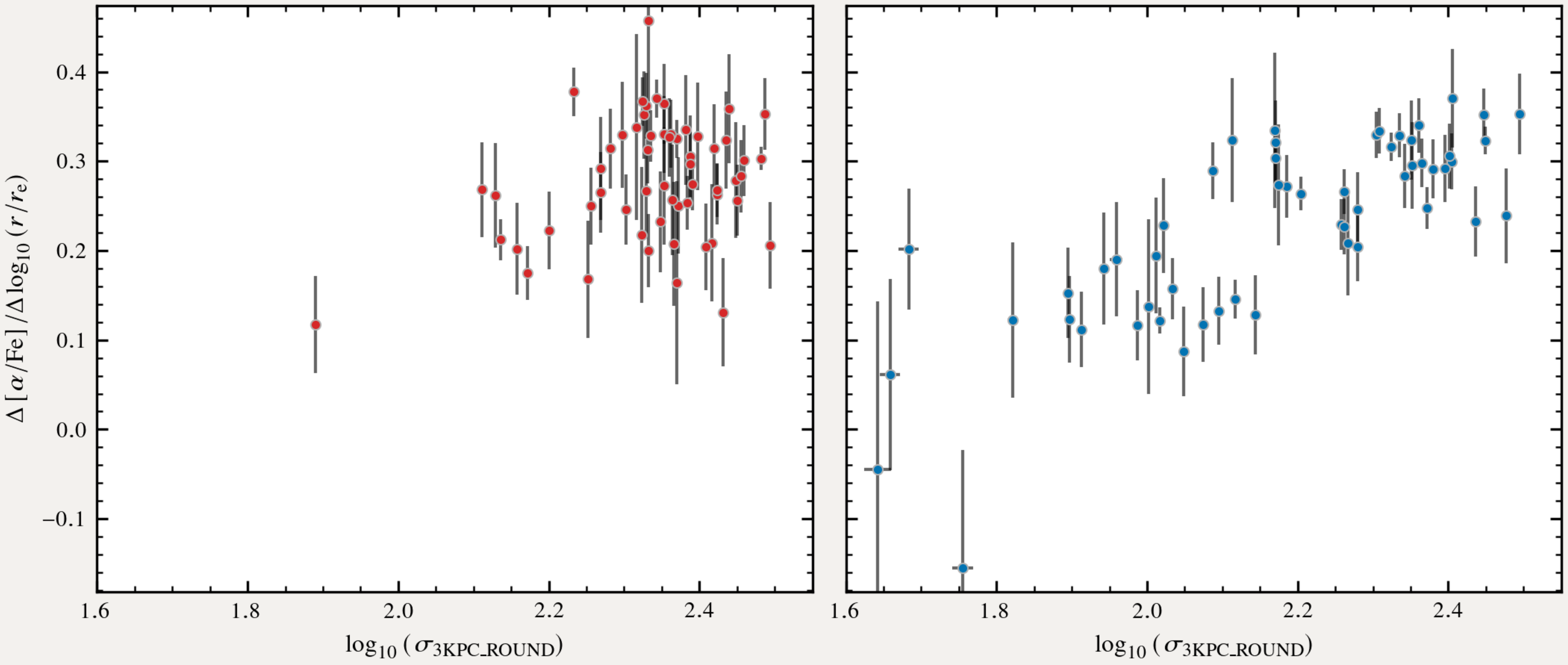

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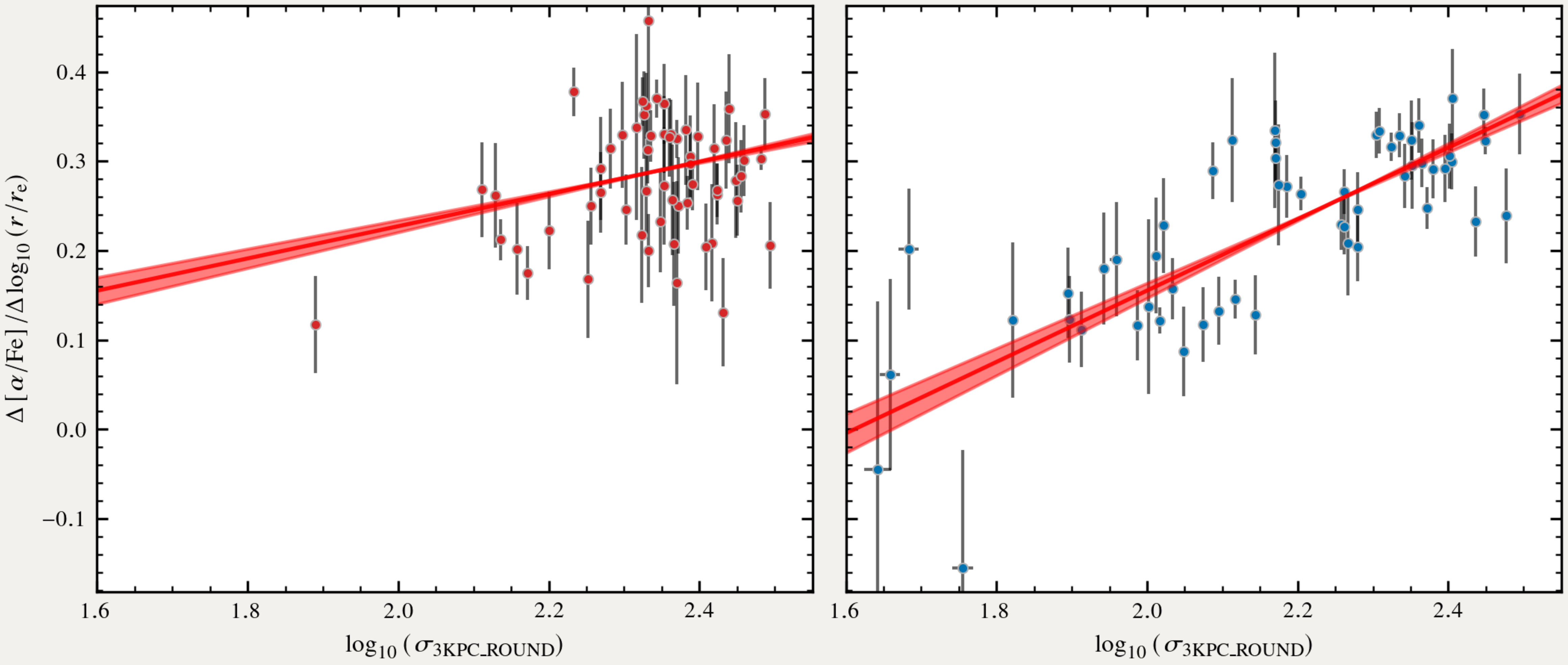

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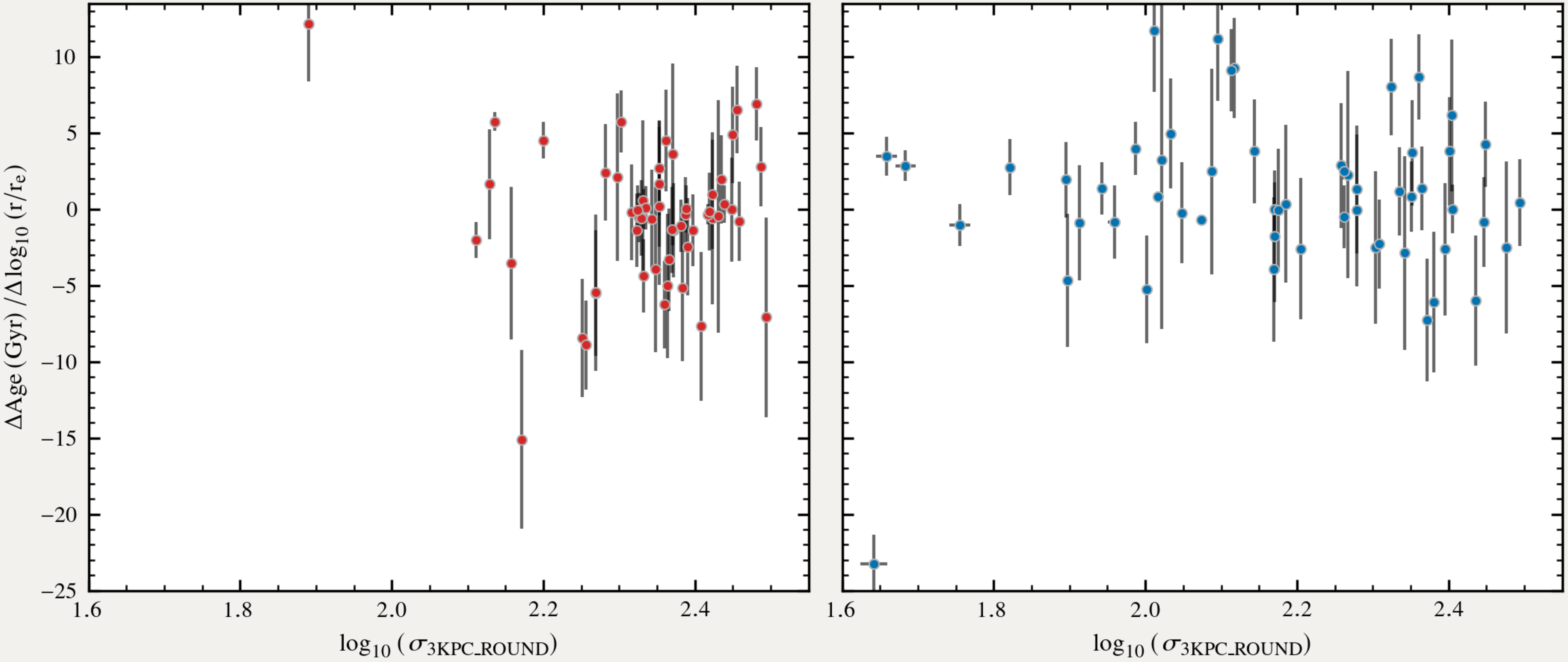
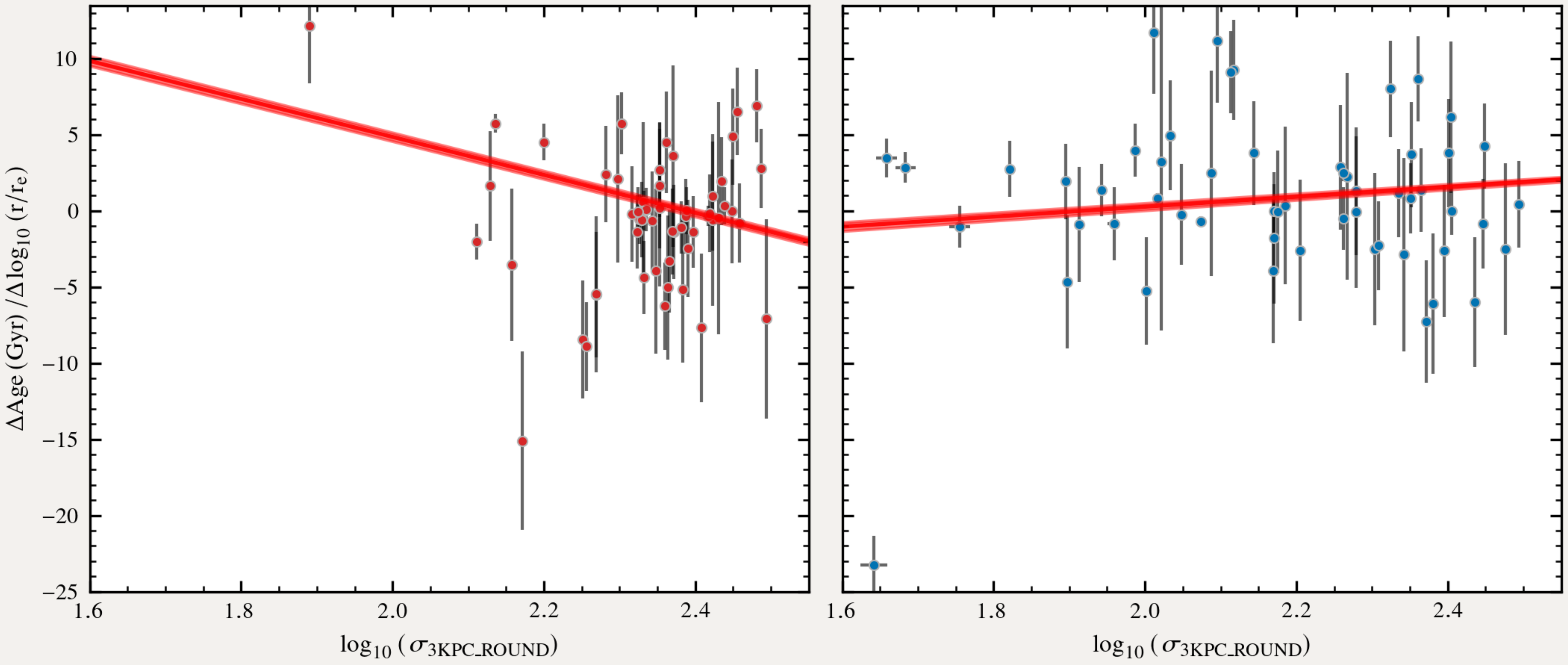


ΔAge (Gyr) /Δlog10 (r/re)
10
5
0
−5
−10
−15
−20
−25
1.6
1.8
2.0
2.2
2.4
log10 (σ3KPC_ROUND)
1.6
1.8
2.0
2.2
2.4
log10 (σ3KPC_ROUND)

GRADIENTS



ΔAge (Gyr) /Δlog10 (r/re)
10
5
0
−5
−10
−15
−20
−25
1.6
1.8
2.0
2.2
2.4
log10 (σ3KPC_ROUND)
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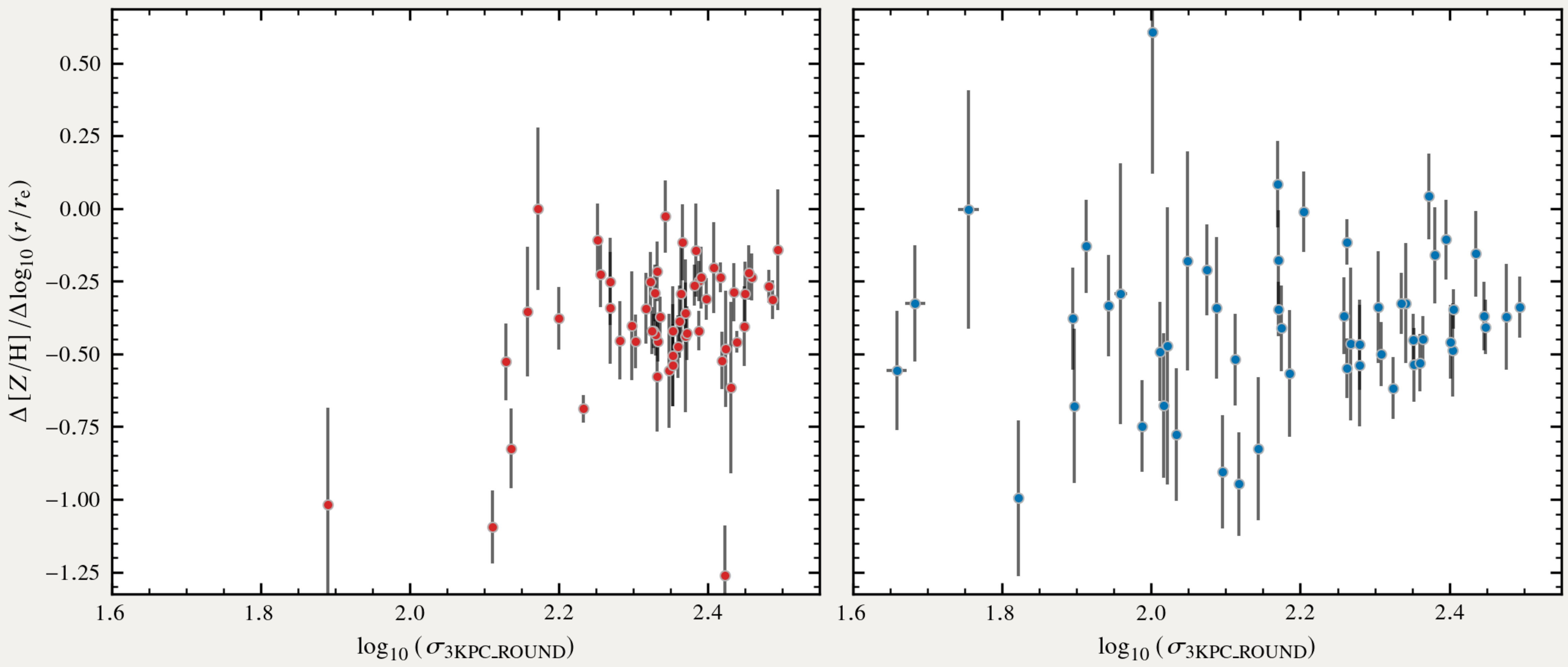
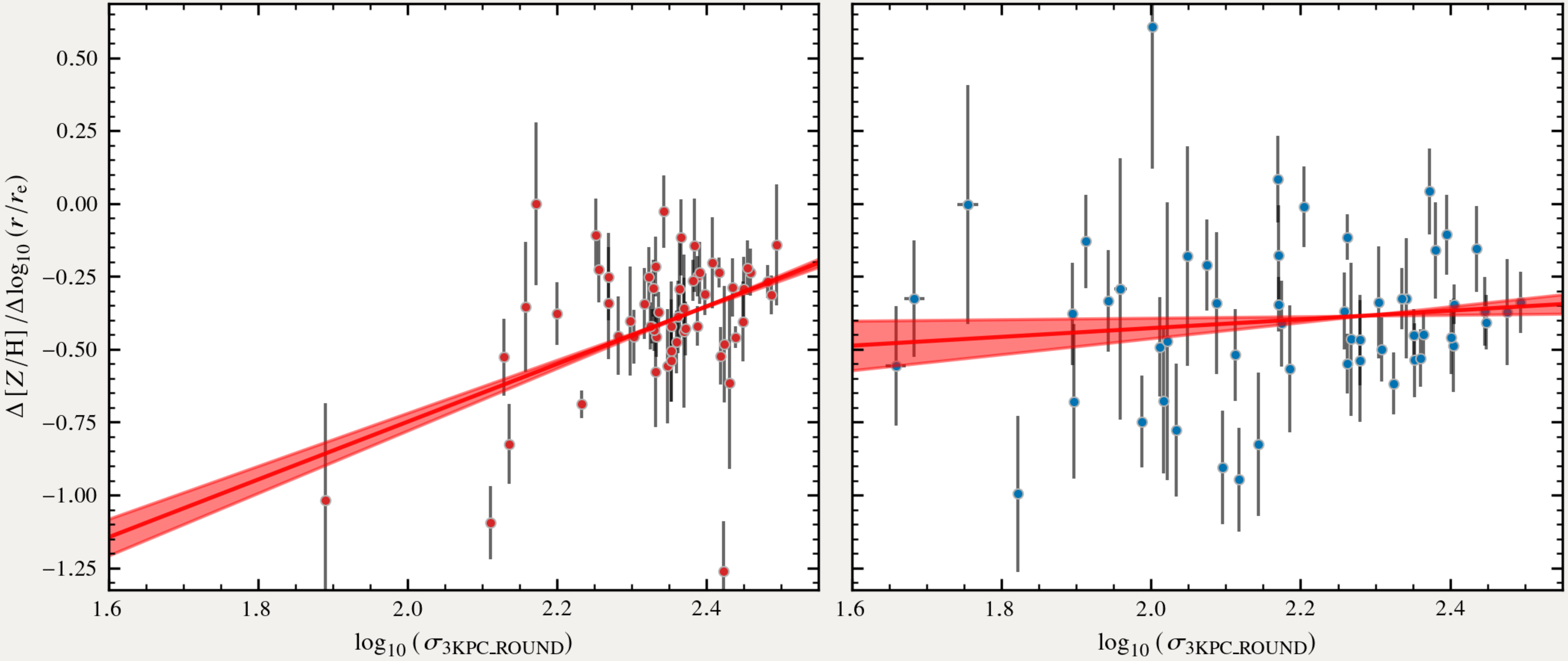
GRADIENTS



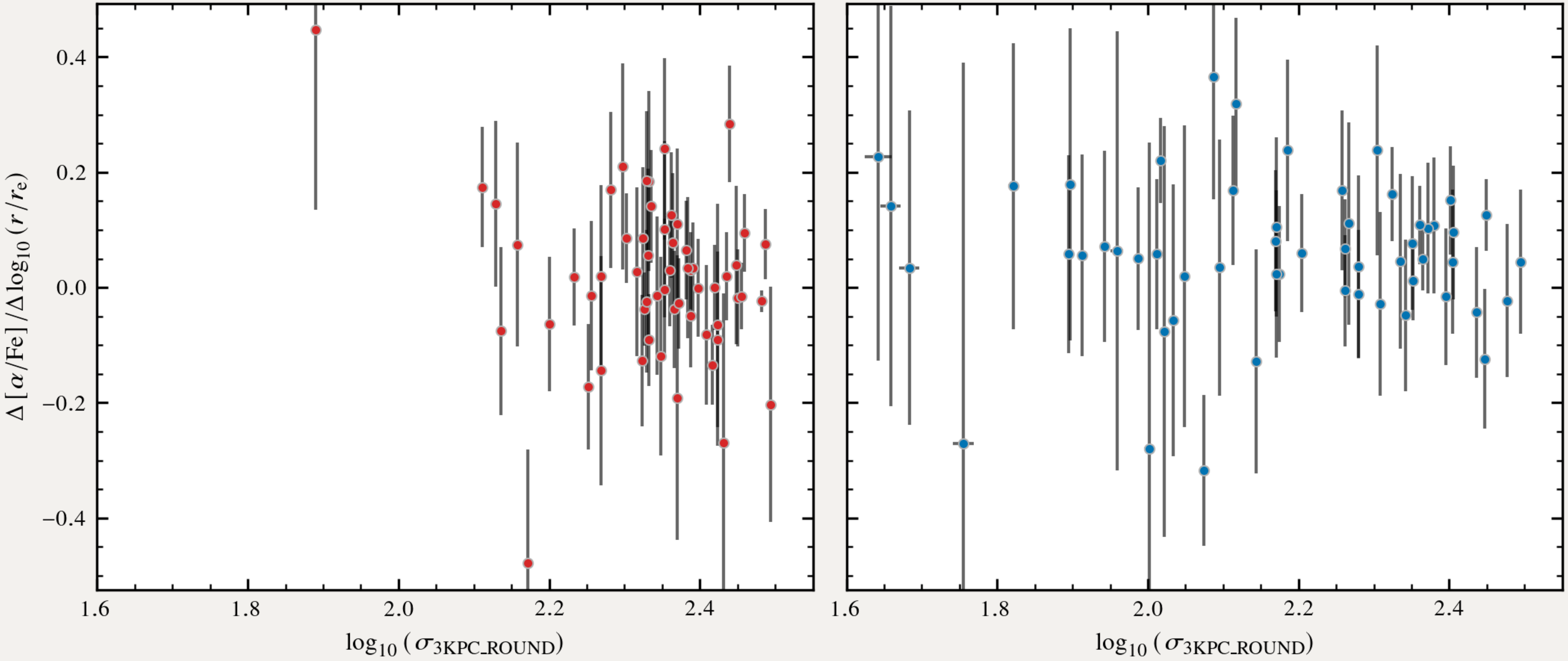
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
Δ [Z/H] /Δlog10 (r/re)
1.6
1.8
2.0
2.2
2.4
log10 (σ3KPC_ROUND)

GRADIENTS



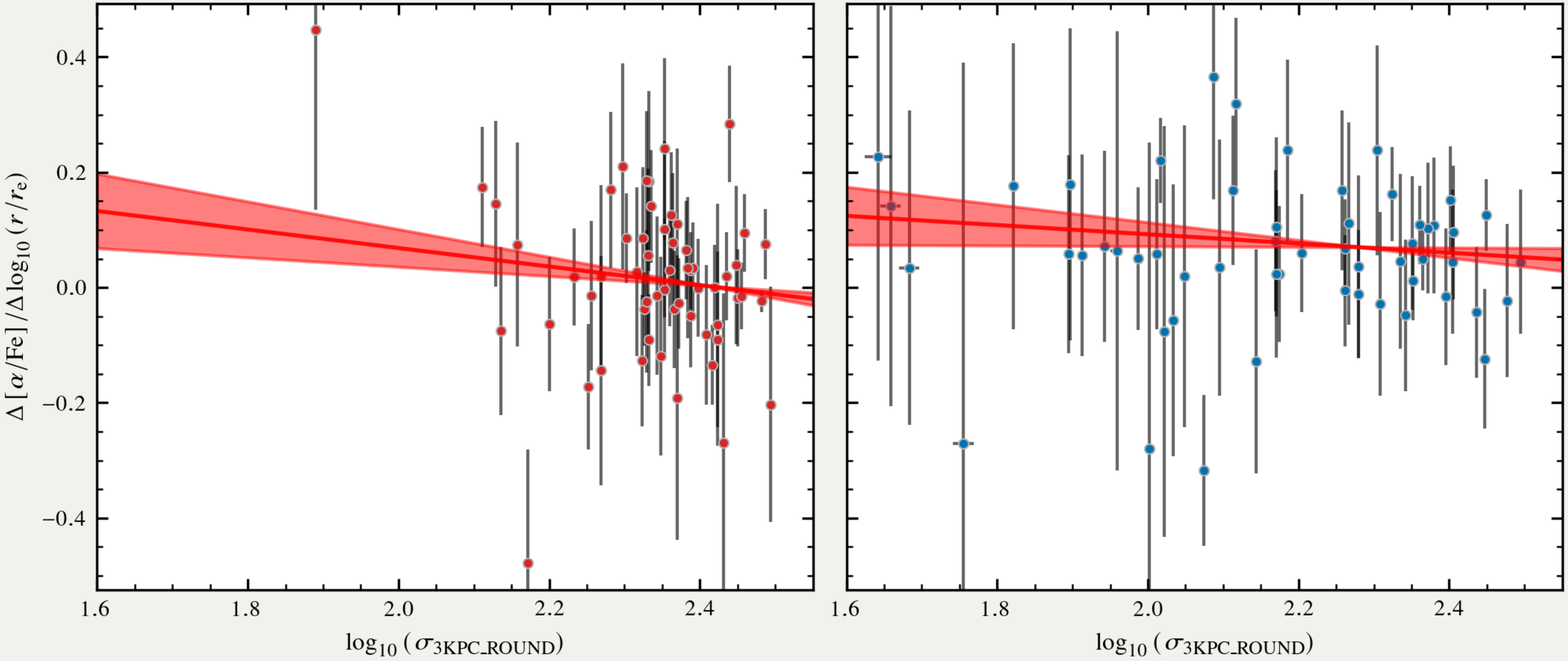
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
$\Delta[Z/H]/\Delta\log_{10}(r/r_e)$
1.6
1.8
2.0
2.2
2.4
$\log_{10}(\sigma_{3KPC\_ROUND})$
$\log_{10}(\sigma_{3KPC\_ROUND})$

GRADIENTS



0.4
0.2
0.0
−0.2
−0.4
Δ [α/Fe] /Δ log10 (r/re)
1.6
1.8
2.0
2.2
2.4
log10 (σ3KPC_ROUND)
1.6
1.8
2.0
2.2
2.4
log10 (σ3KPC_ROUND)

GRADIENTS



0.4
0.2
0.0
−0.2
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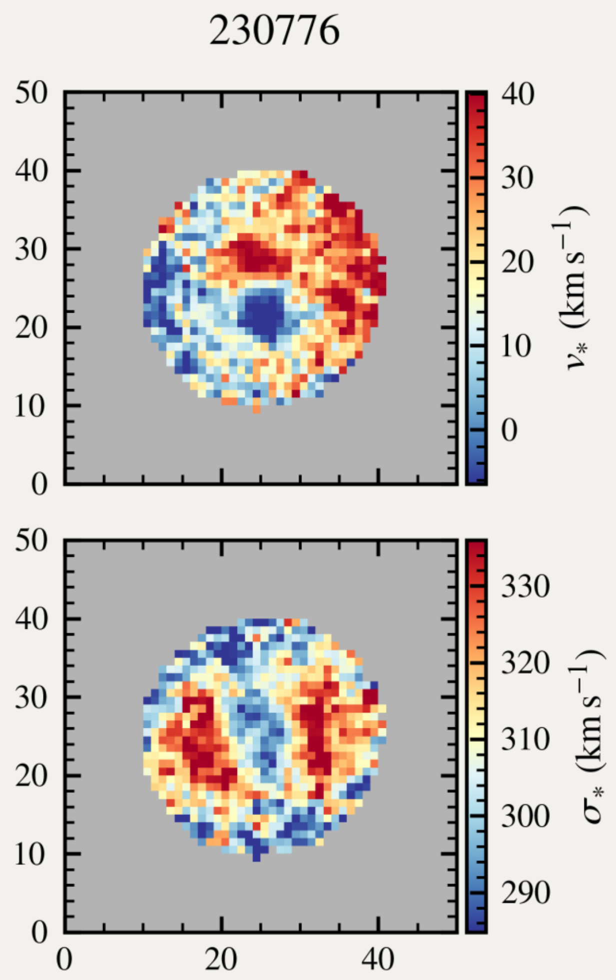
$\Delta\,[\alpha/\mathrm{Fe}]\,/\,\Delta\log_{10}(r/r_e)$
1.6
1.8
2.0
2.2
2.4
$\log_{10}(\sigma_{3KPC\_ROUND})$
$\log_{10}(\sigma_{3KPC\_ROUND})$

CONFOUNDING FACTORS

- Not all galaxies are well-behaved
  - Embedded disks
  - Kinematically-decoupled cores (KDCs)
  - Counter-rotating cores (CRCs)
- Contamination of slow rotators still an issue
- Fraction of SAMI galaxies conclusively identified as hosting KDC/CRCs much lower than local IFS surveys
- Embedded disks:
  - Foster+18: 3/384 (SAMI)
  - Arnold+14: 6/22 (SLUGGS)
- 2σ:
  - Davor+11: 11/260 (ATLAS3D)
  - 4/116 slow rotators



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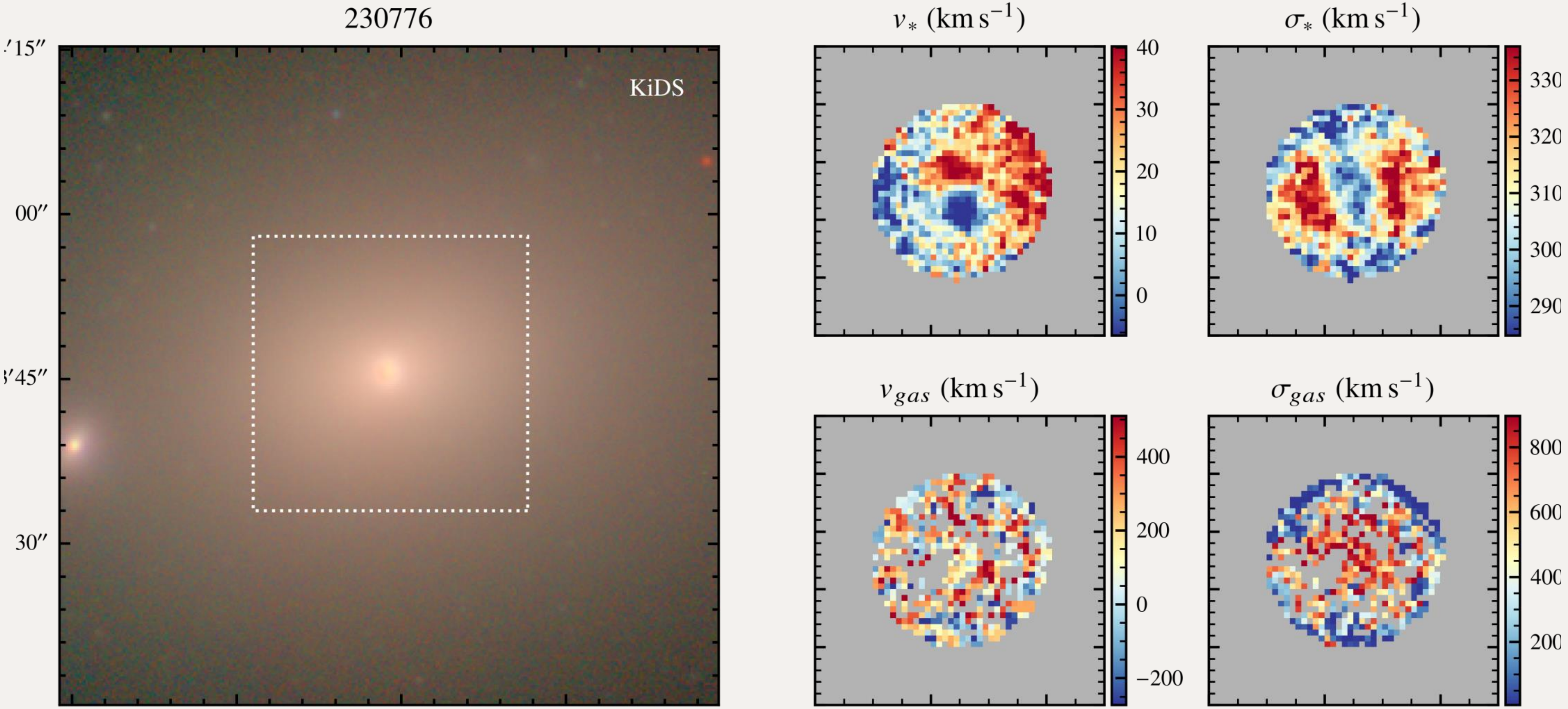

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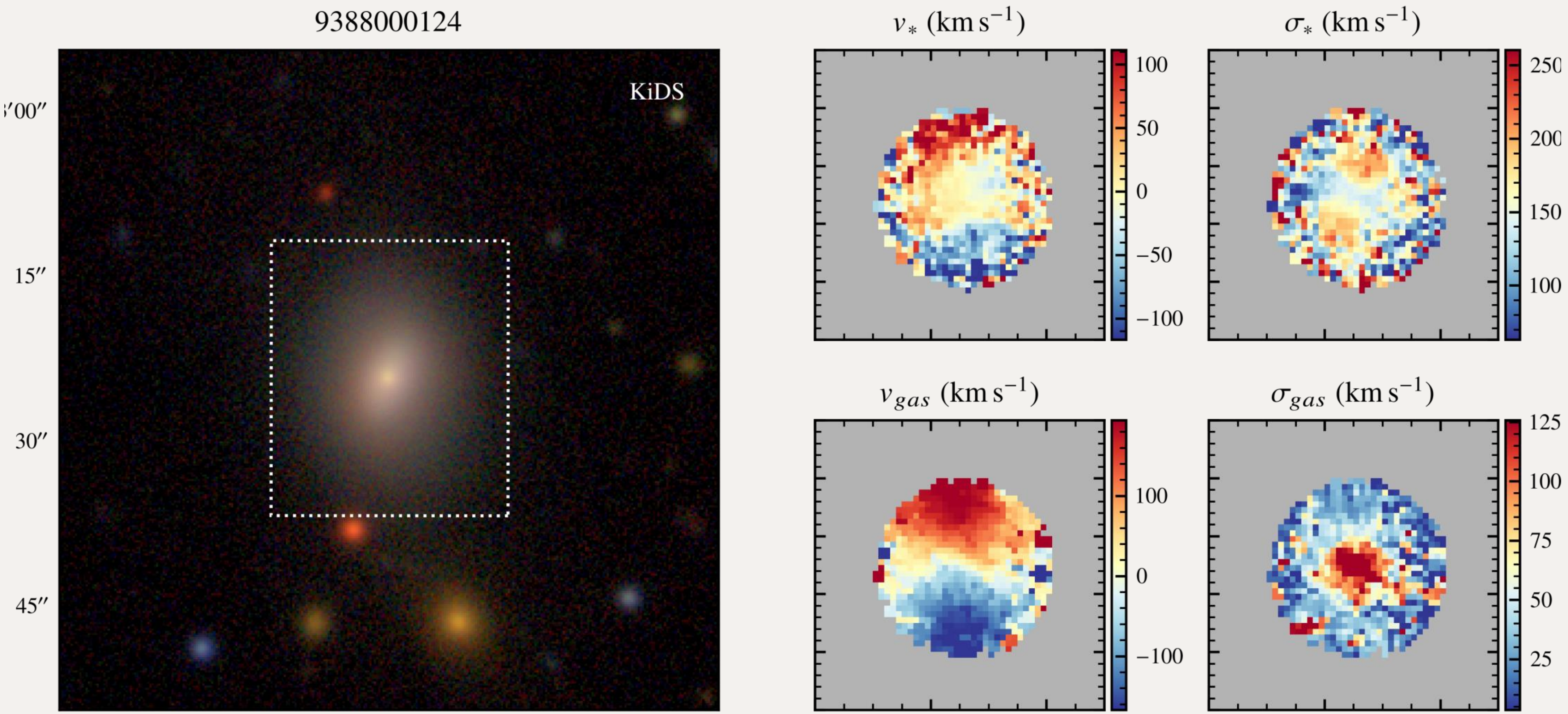

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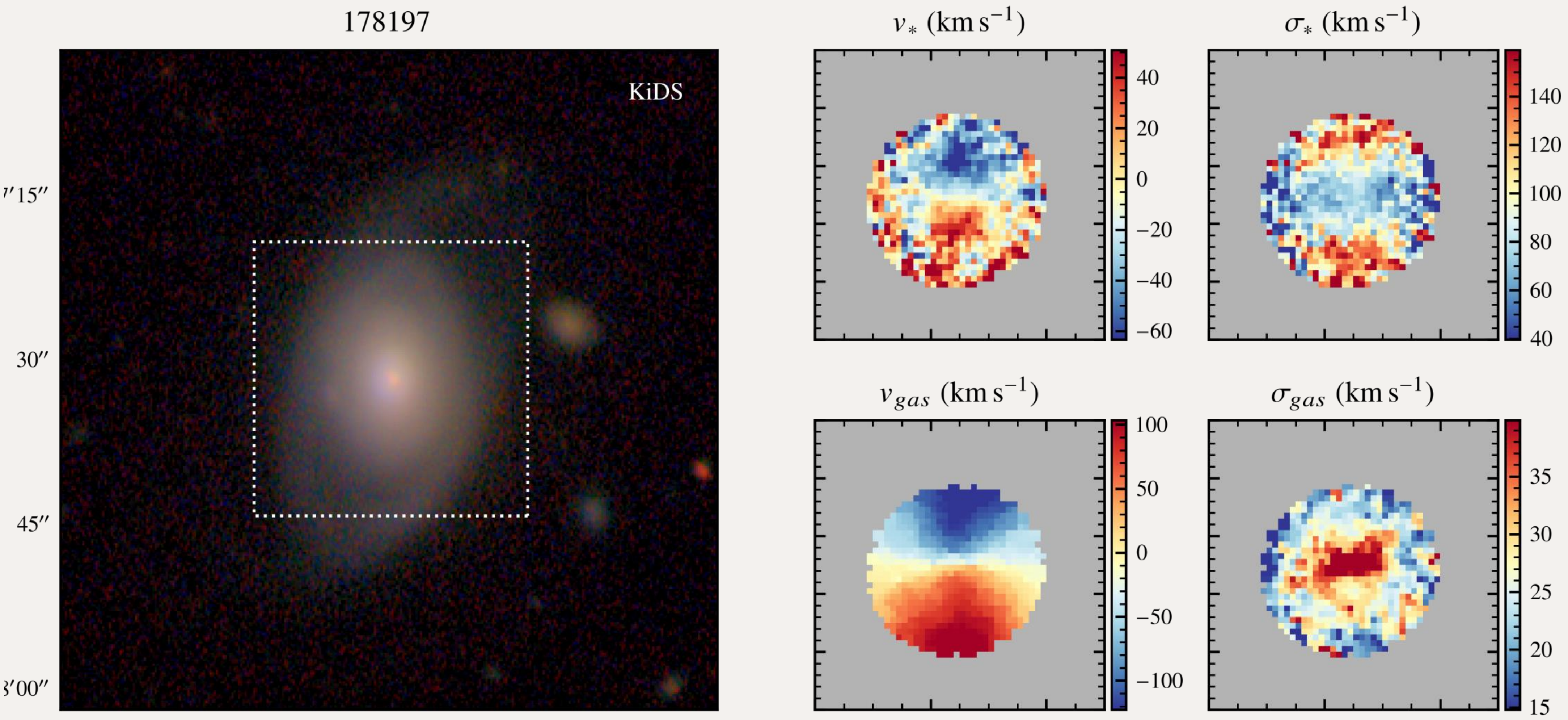

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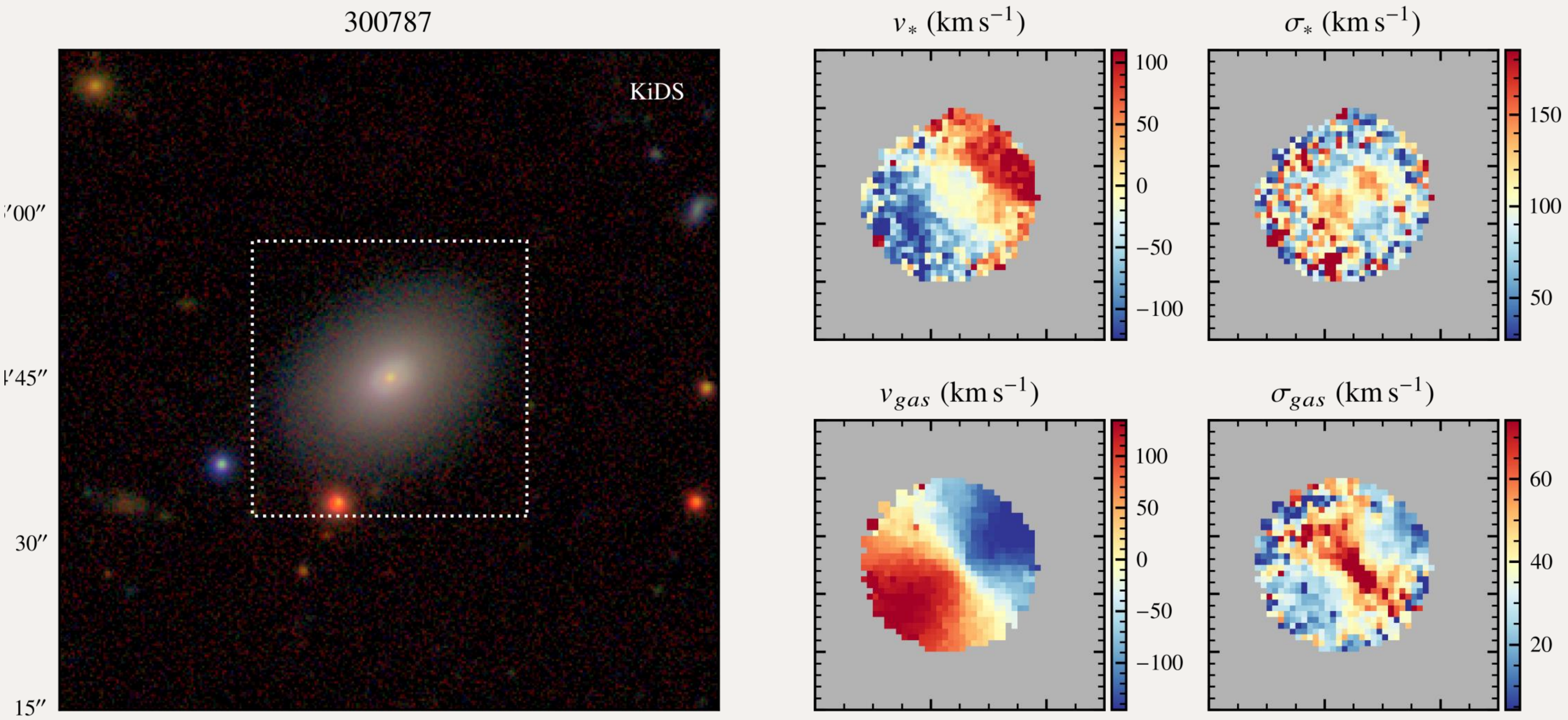

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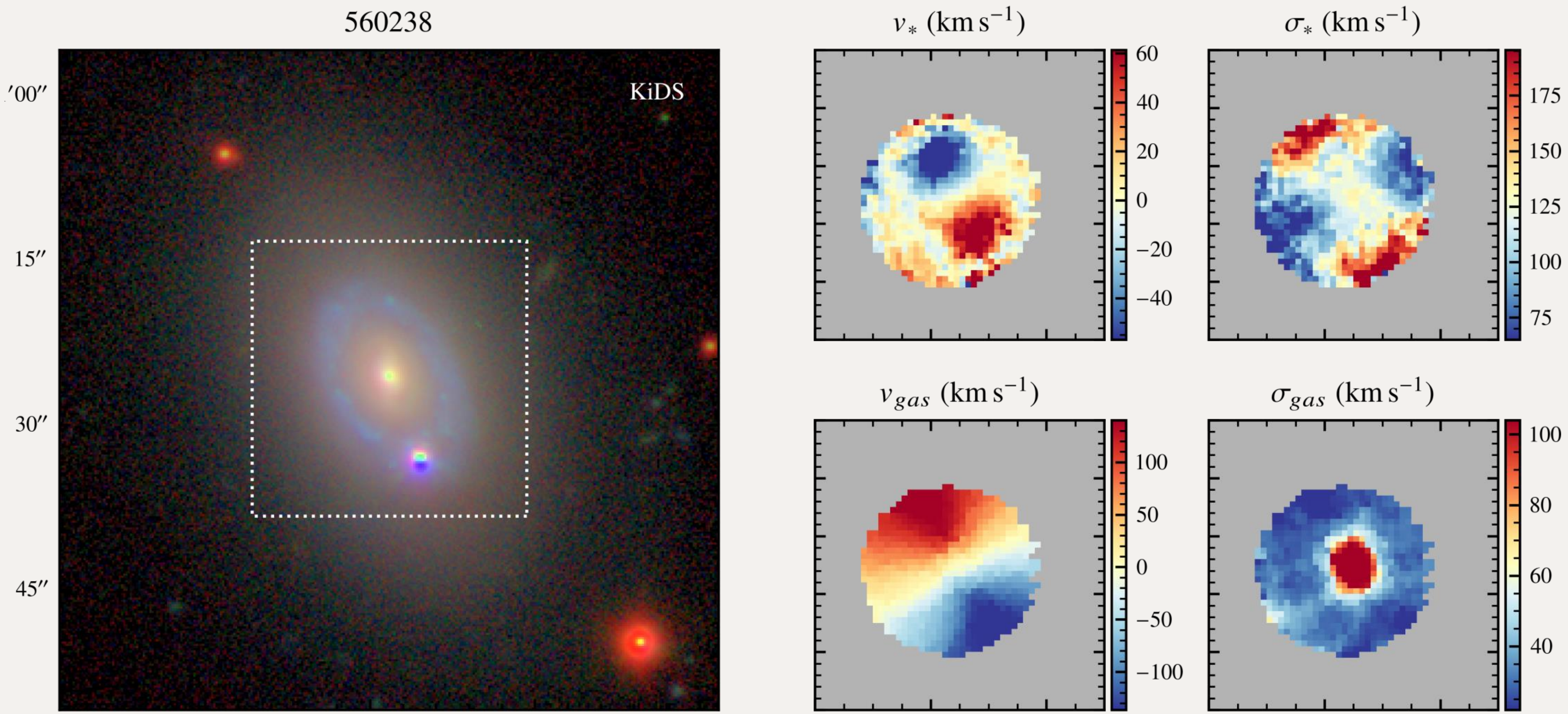

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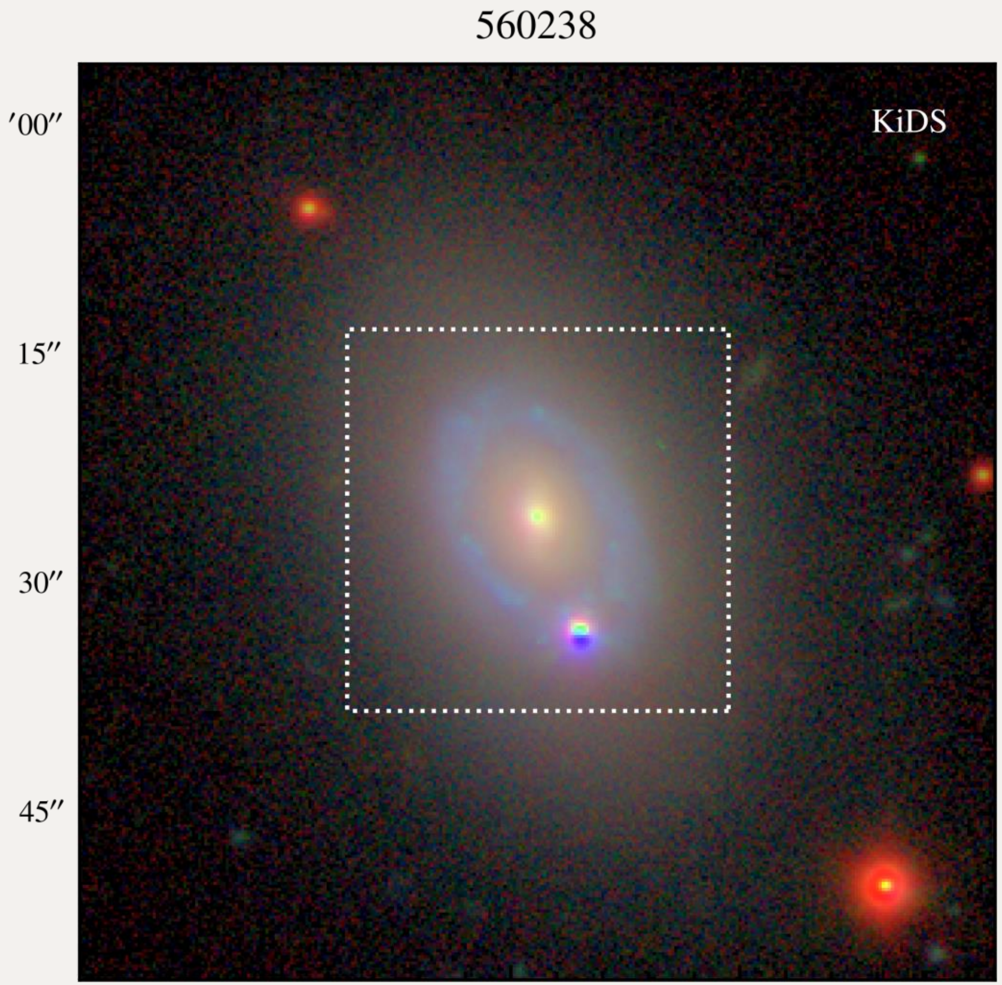

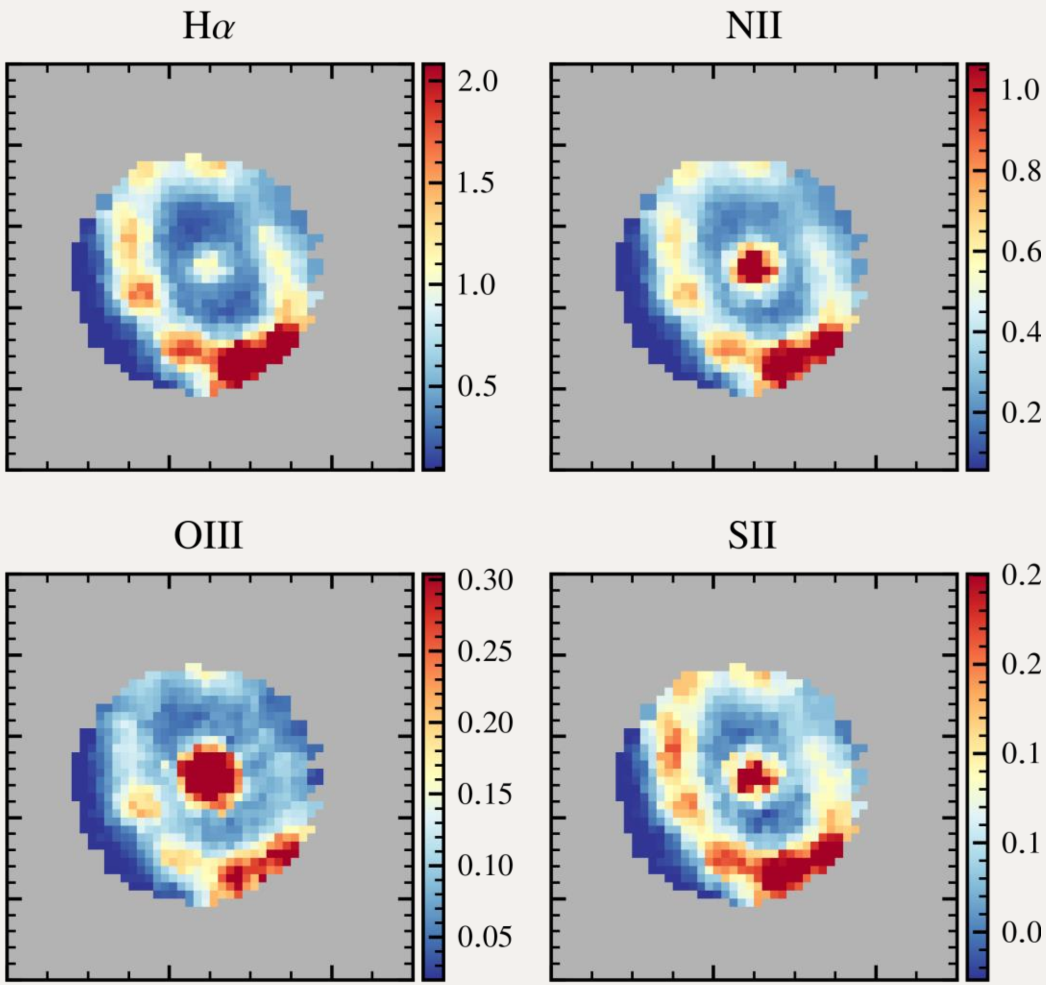

FUTURE DIRECTION

- Larger sample to improve statistical significance:
  - Hector/MaNGA
- Robust detection/classification of KDC/CRCs:
  - Account for seeing limitation
  - Utilise ionised gas kinematics & flux