THE WISDOM OF POWER SPECTRA:

HOW THE GALACTIC GRAVITATIONAL POTENTIAL IMPACTS THE STRUCTURE OF A GALAXY'S CENTRAL GAS RESERVOIR

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Based on Gensior+23: https://arxiv.org/abs/2310.06890

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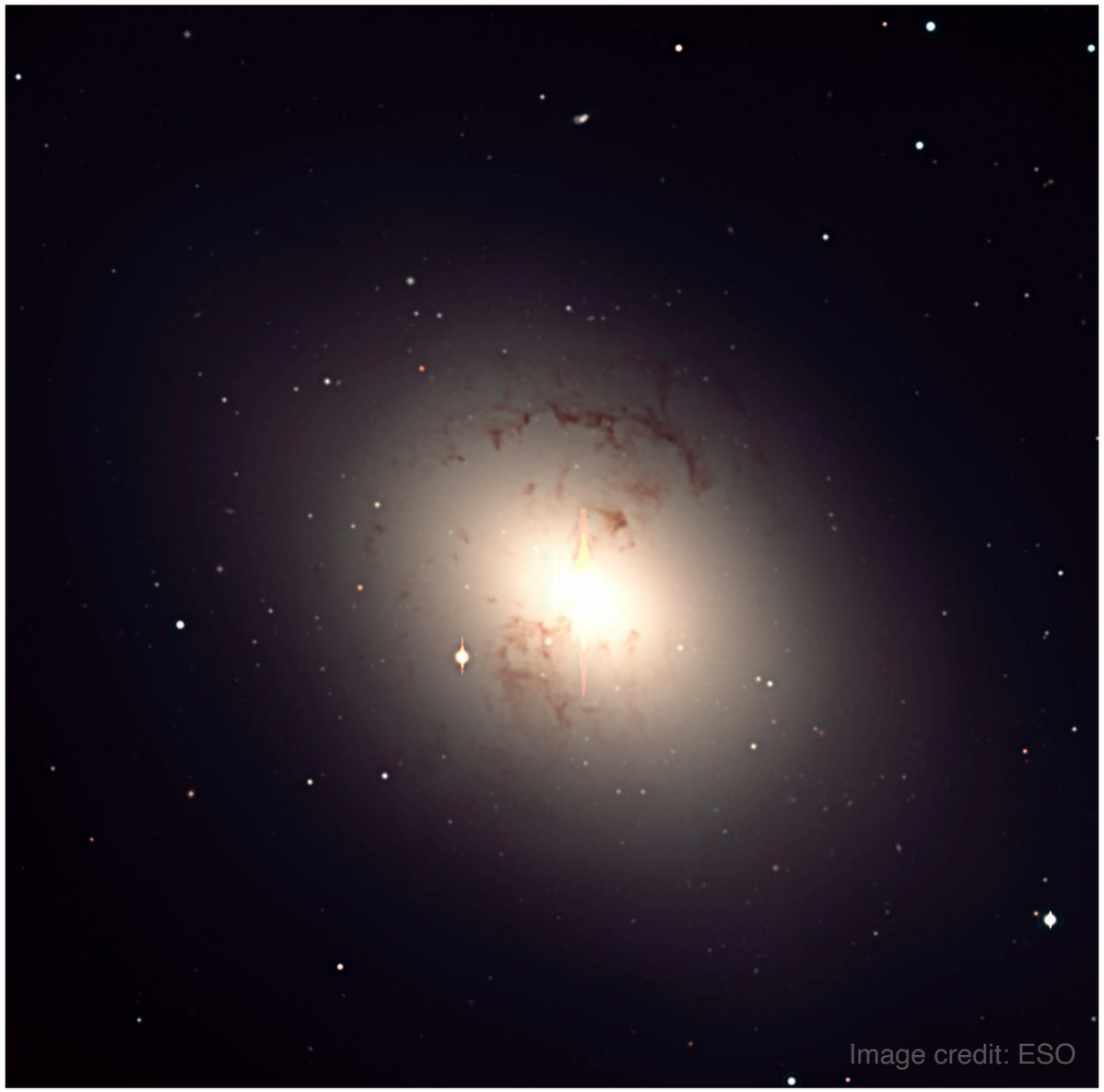
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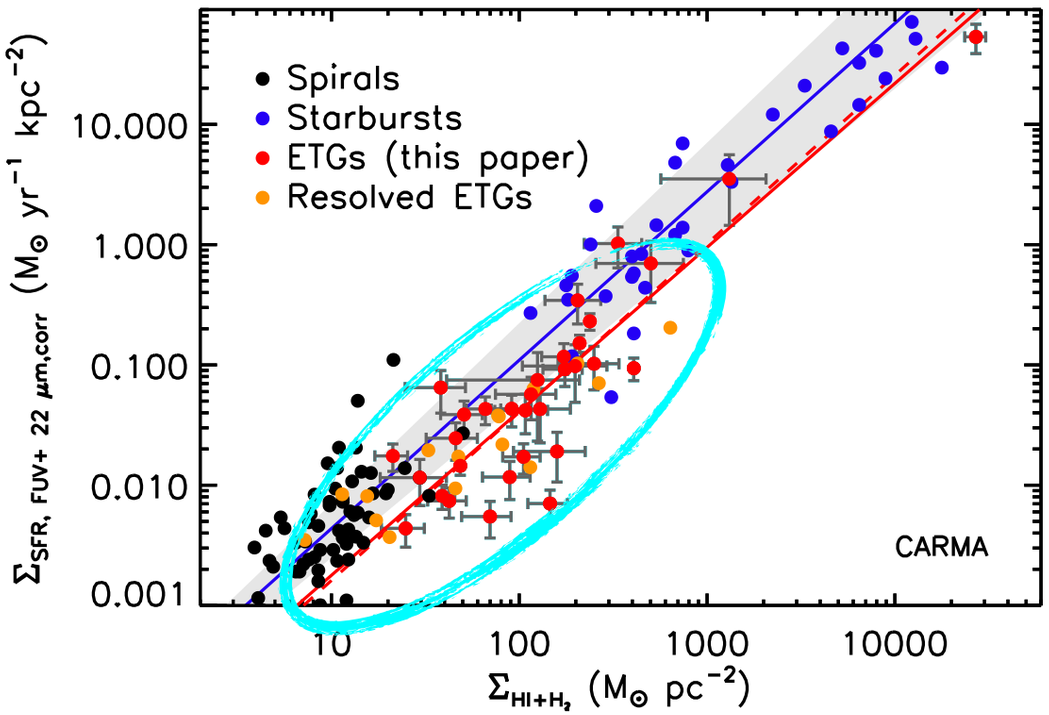
DYNAMICAL SUPPRESSION OF STAR FORMATION IN ETGS



Davis+ 2014
(also e.g. Kennicutt 1989,
van de Voort+2018)

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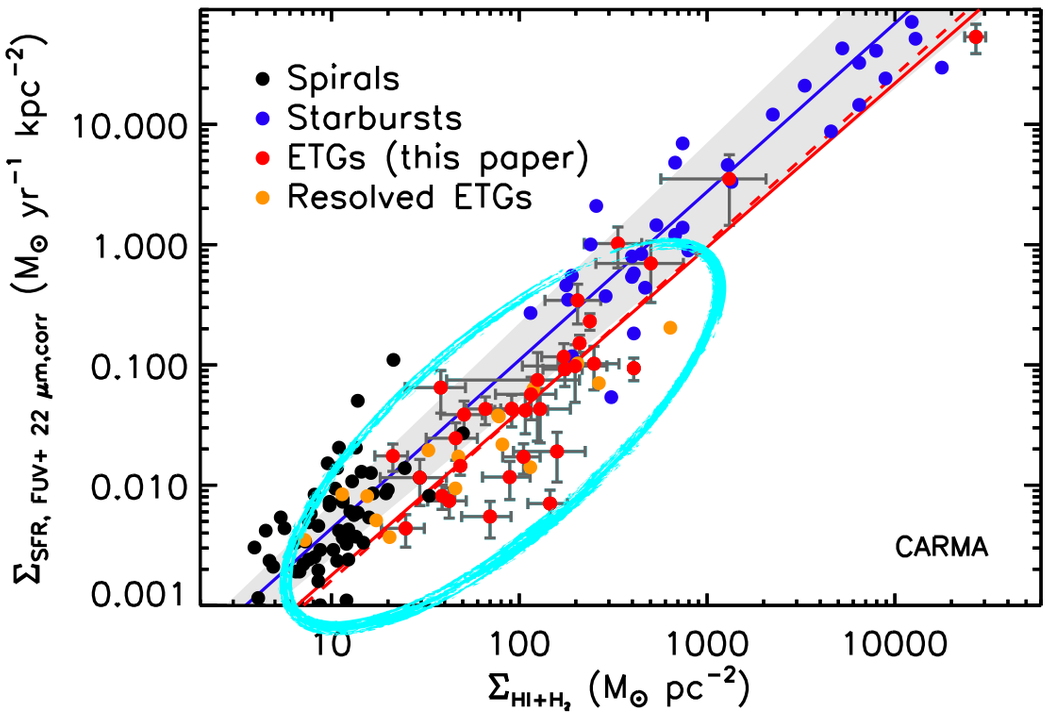

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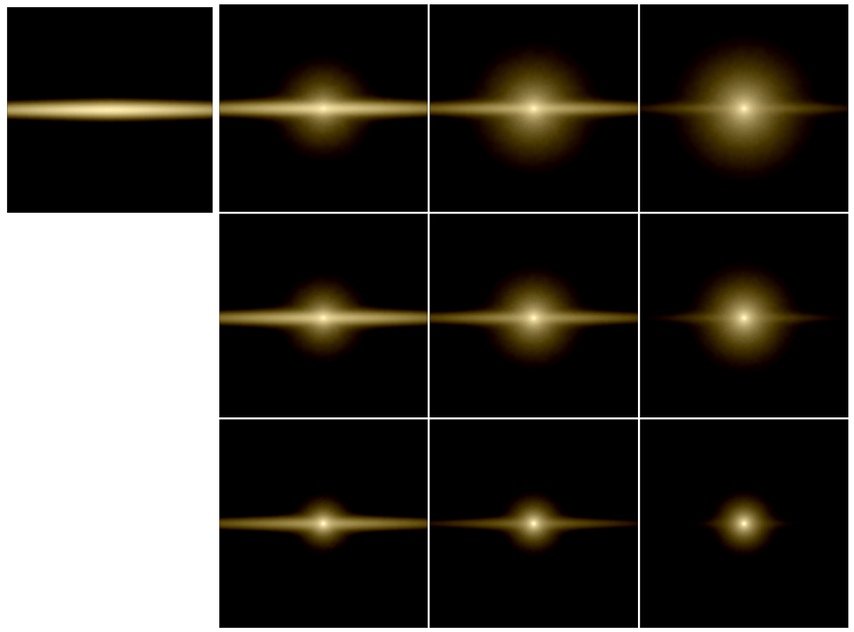
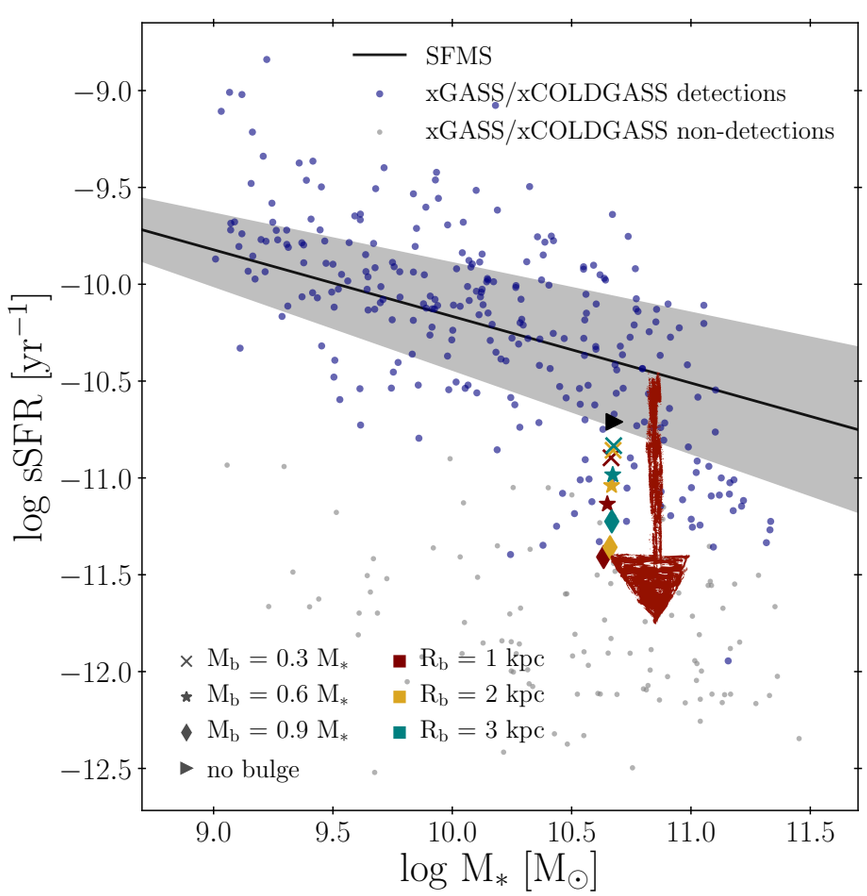
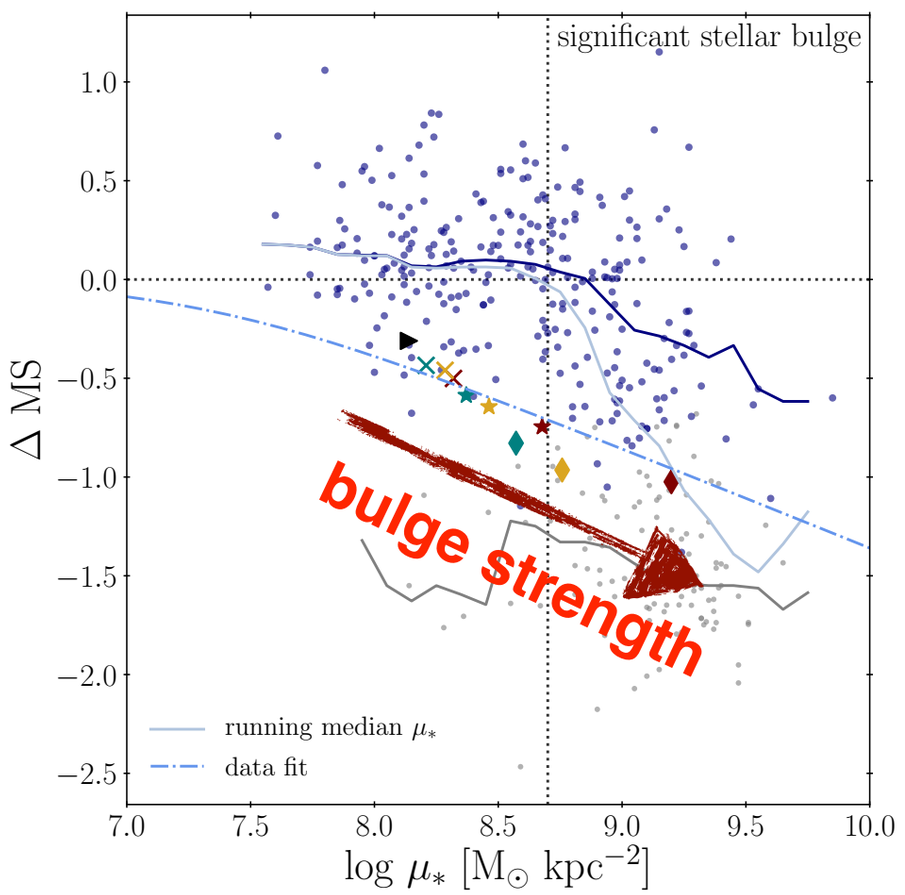
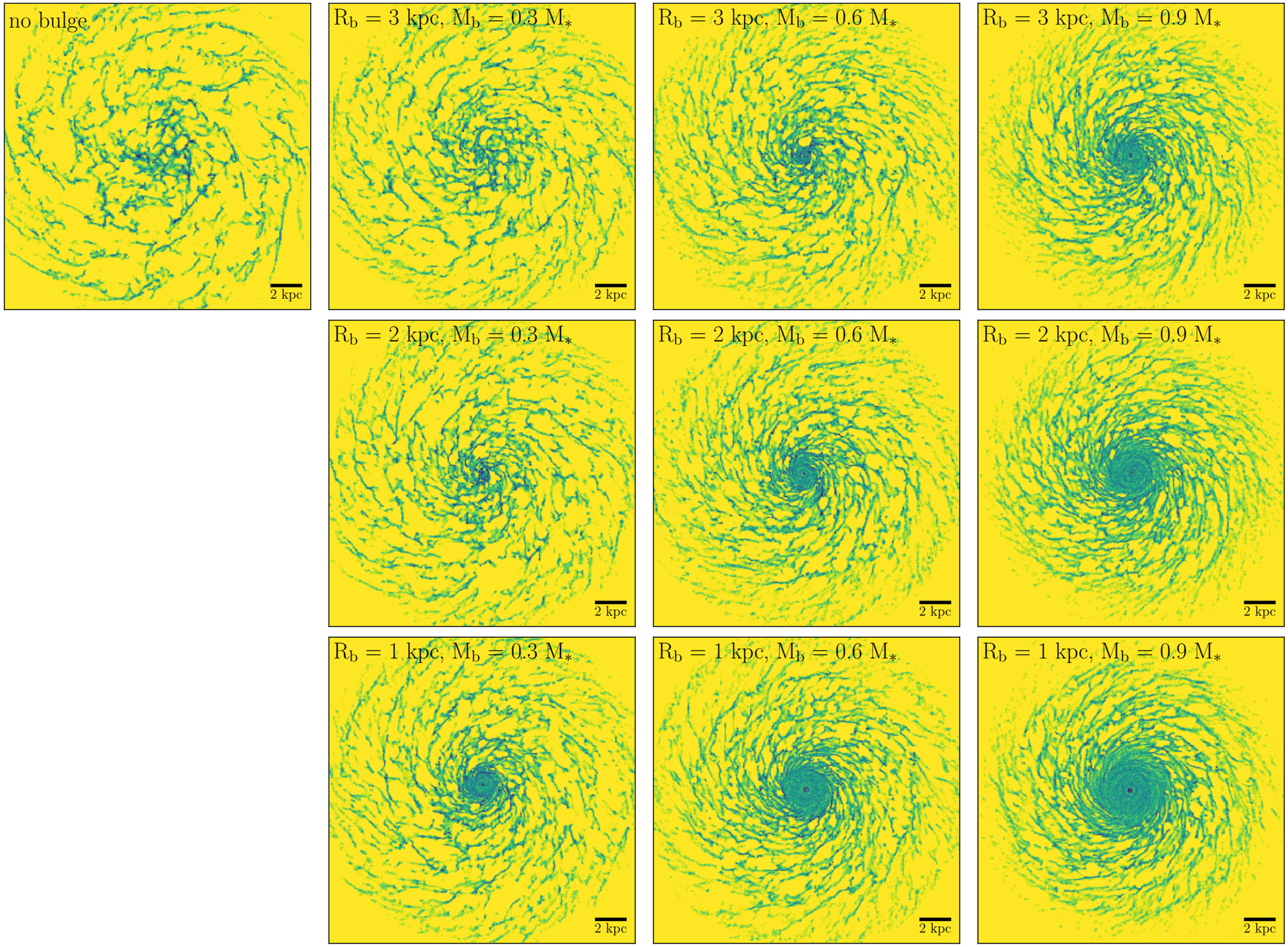






Gensior+ 2020

ISM MORPHOLOGY - AFFECTED BY GRAVITATIONAL POTENTIAL



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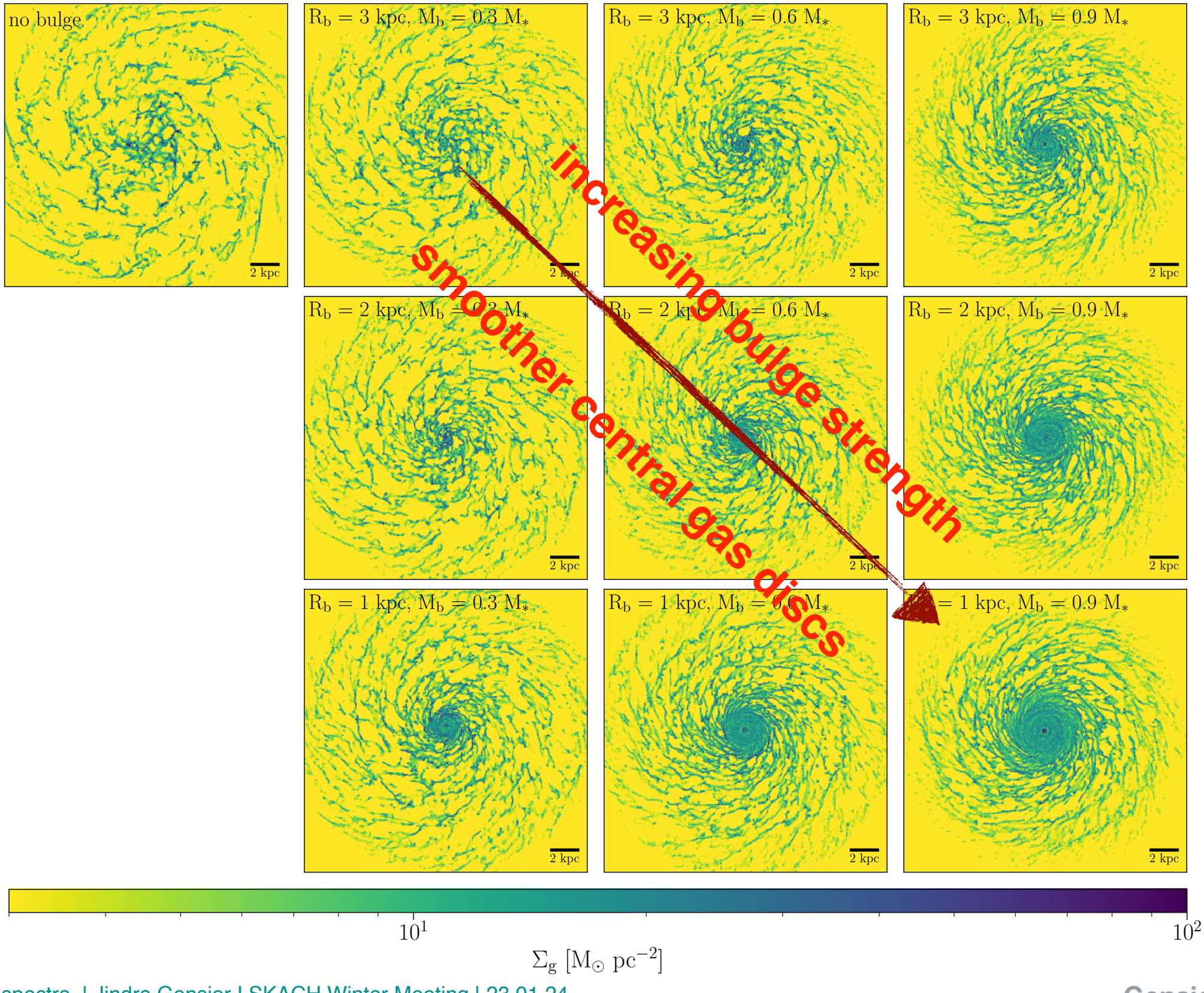


Gensior+ 2020

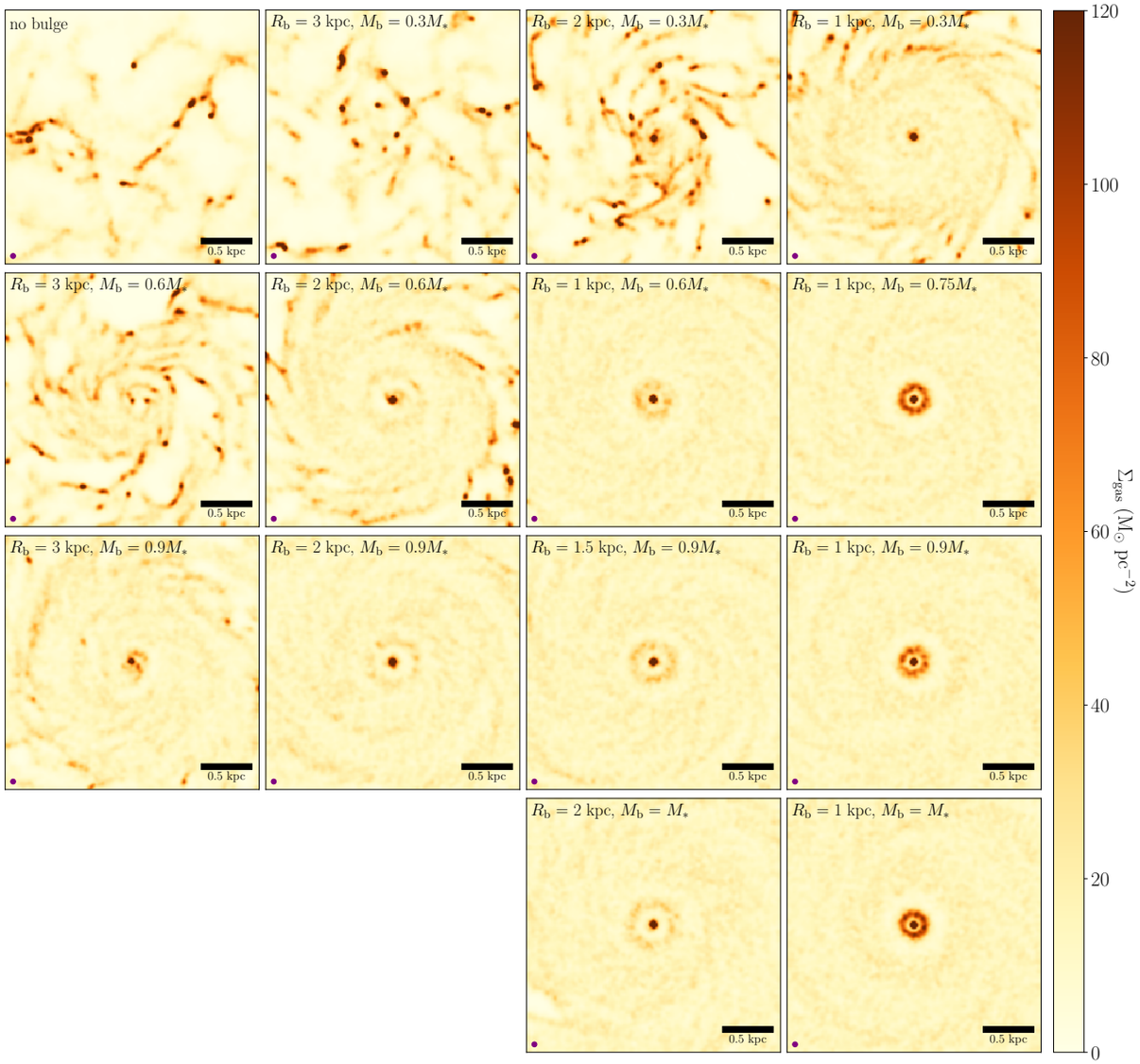
- WISDOM sample: high resolution ALMA CO observations (mainly J=2->1, sometimes J=3->2) of galaxy (centre)s
  - Original aim: dynamically measure SMBH masses (e.g. Onishi+2017, Davis+2017, 2018, 2020, North+2019, 2021, Smith+2019, 2021, Lelli+2021, Ruffa+2023, Liang+2024)
  - Wealth of GMC science possible (e.g. Liu+2021, 2022, Lu+2022, Choi+2023, Williams+2023)
- Galaxy morphologies ranging from LTGs to ETGs

Selection Criteria

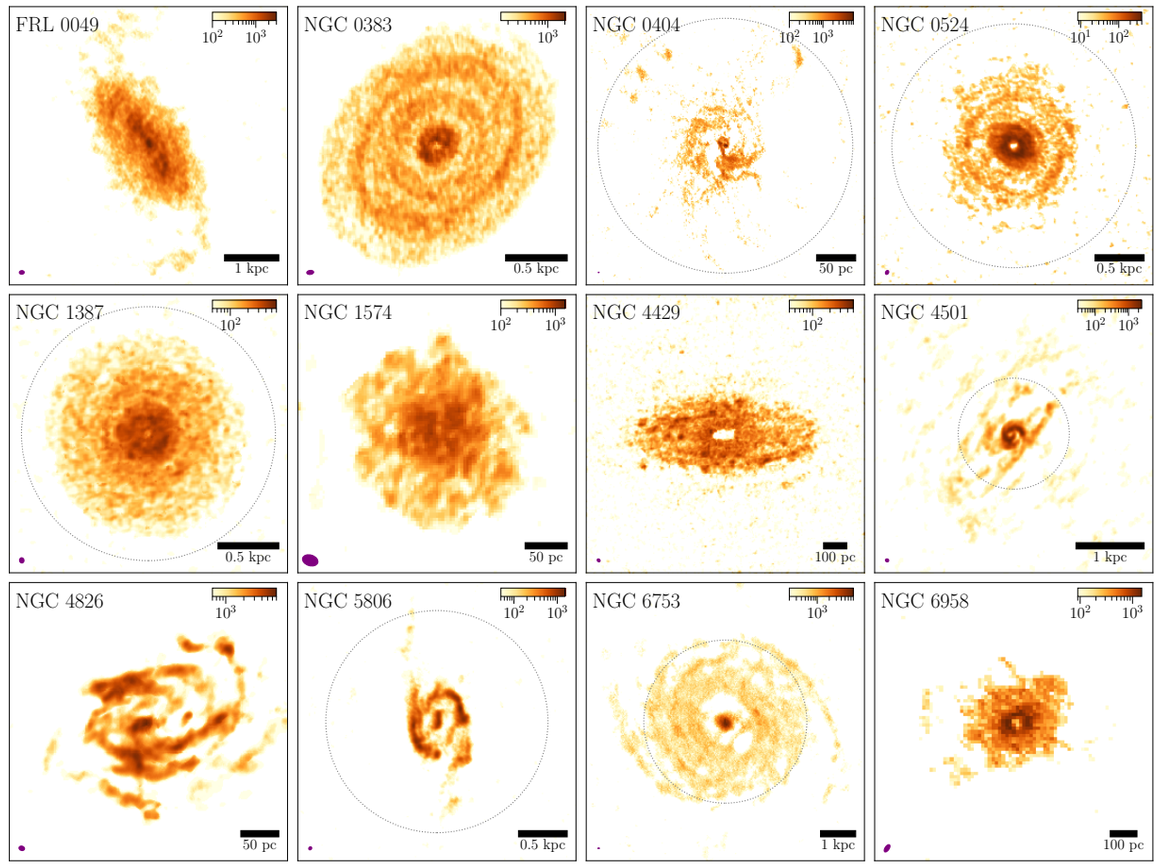
- Inclination < 65°
- Geometric beam average axis < 100pc

THE SAMPLE

Central regions of 14 simulated galaxies

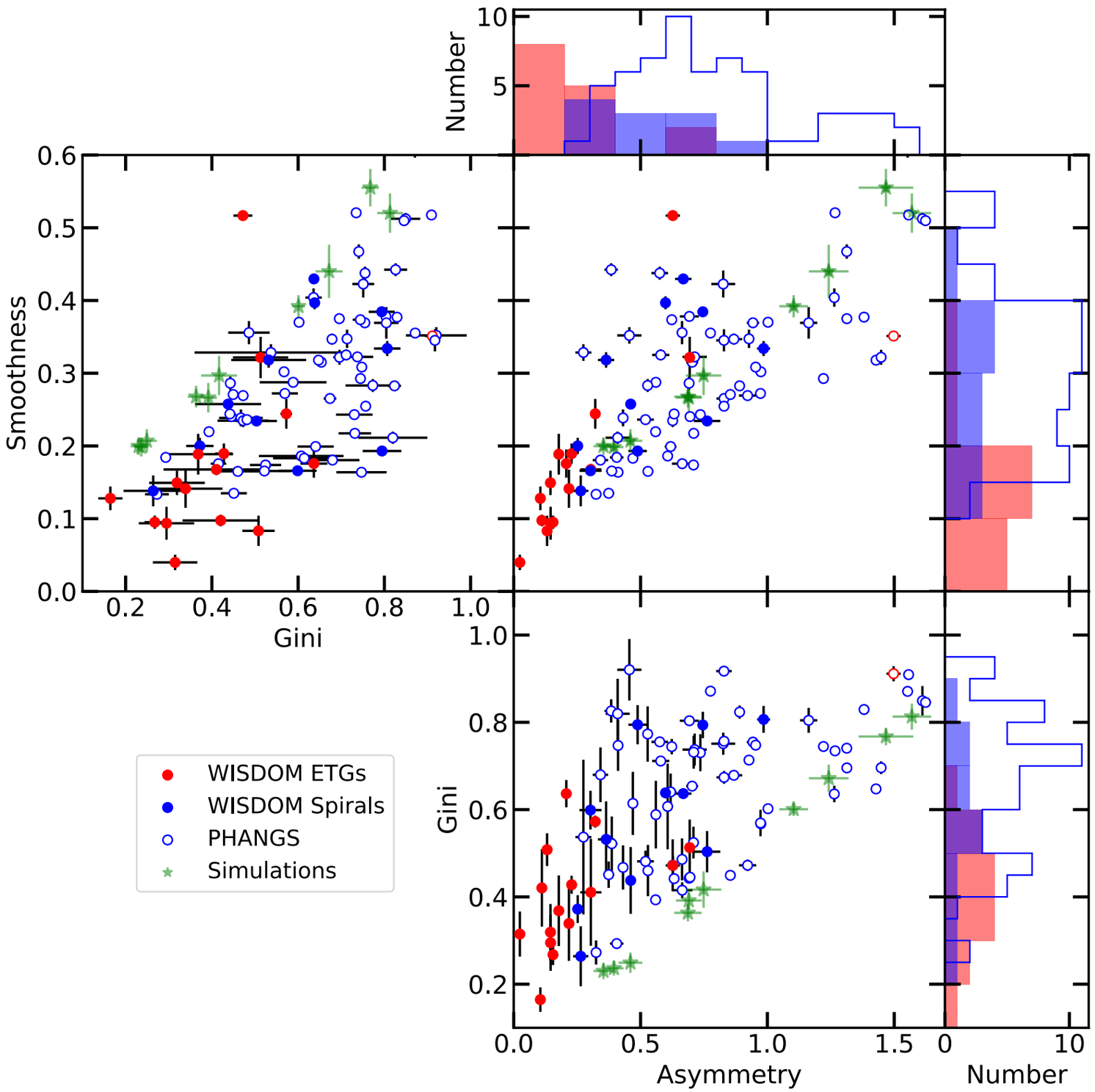


12 WISDOM galaxies



Use **TurbuStat** (Koch+ 2019) to obtain power spectra

QUANTIFYING ISM MORPHOLOGY WITH NON-PARAMETRIC INDICATORS



- ISM morphology traces galaxy (stellar) morphology

Davis, Gensior+ 2022

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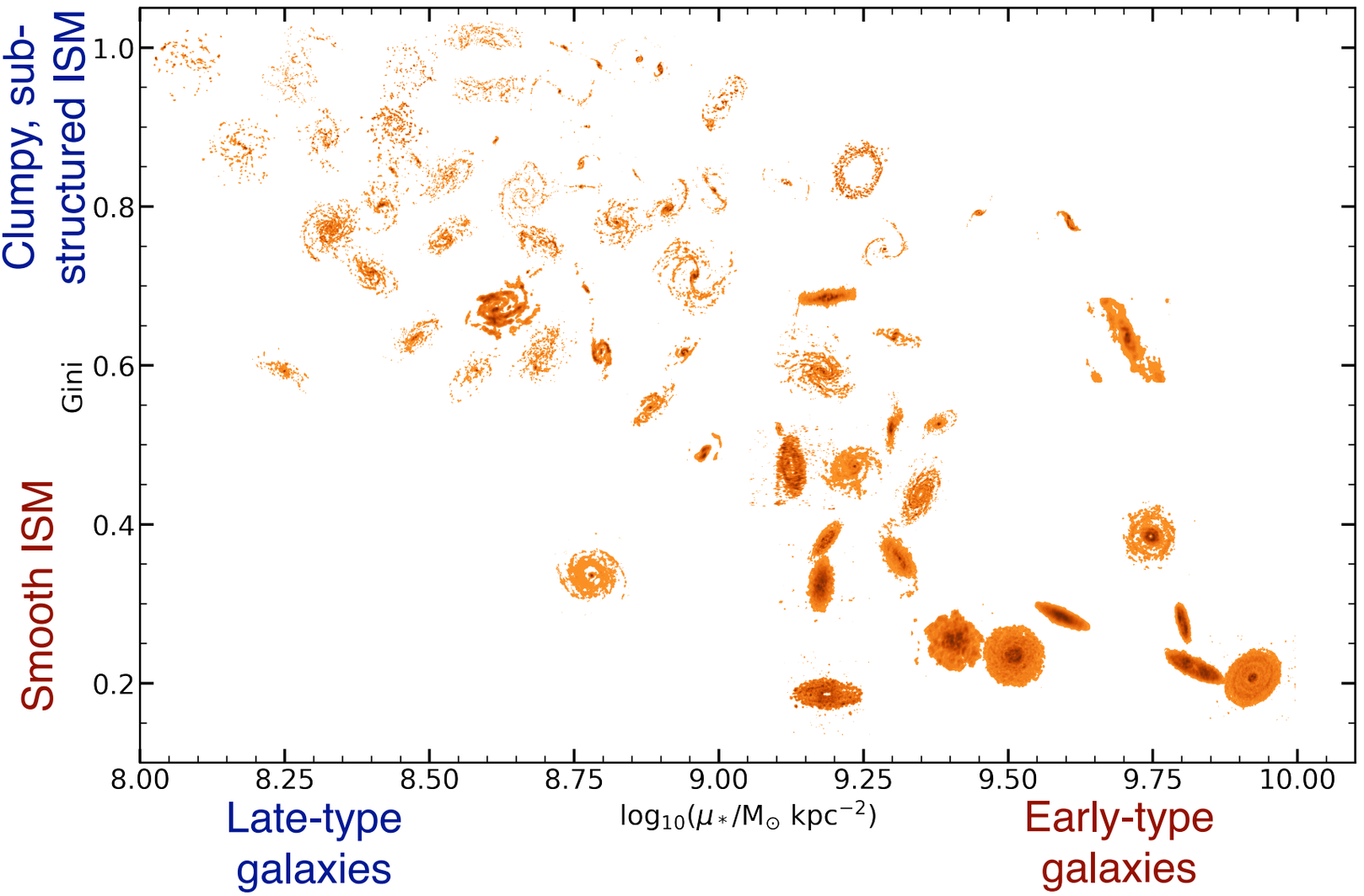
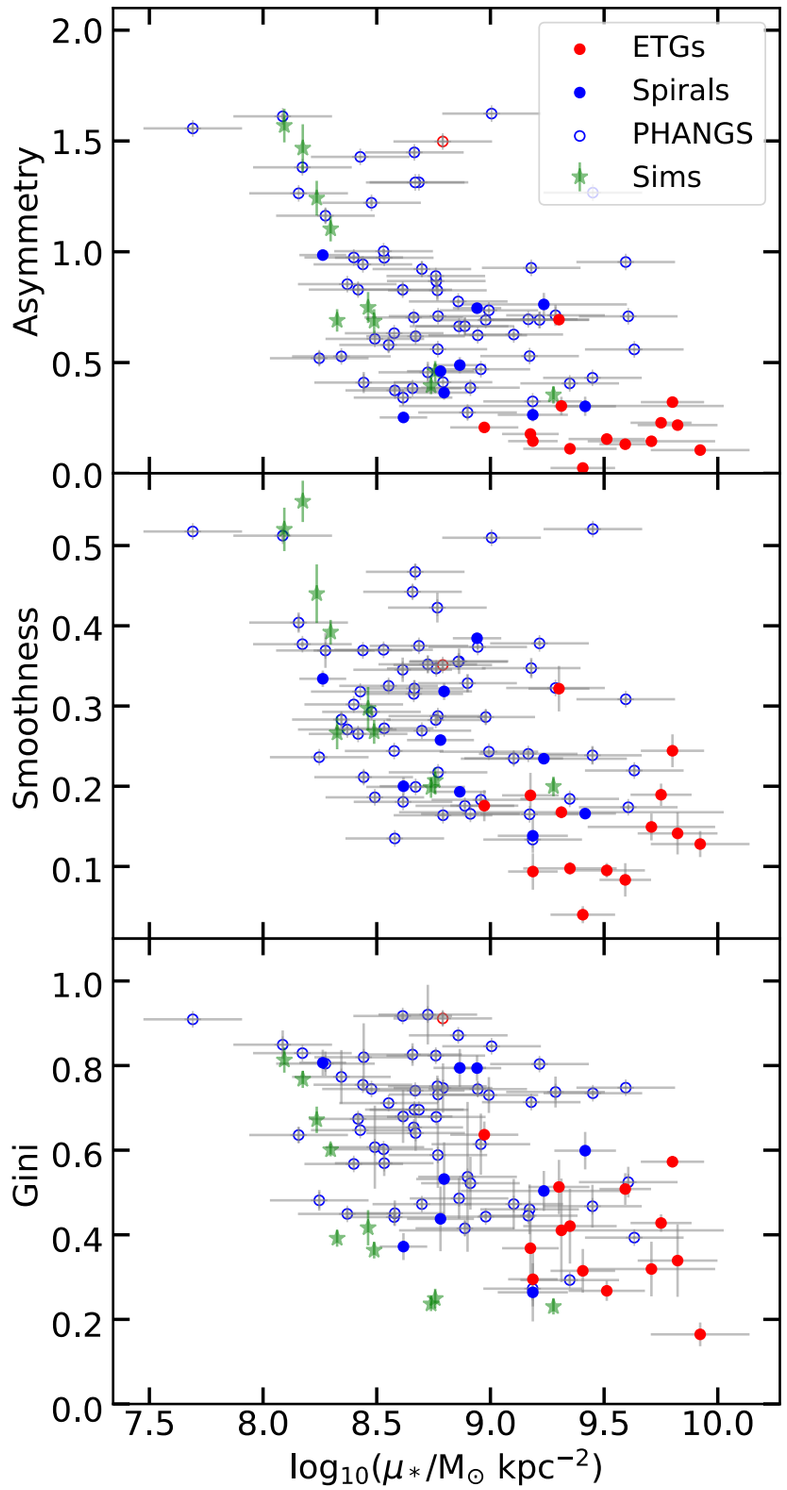
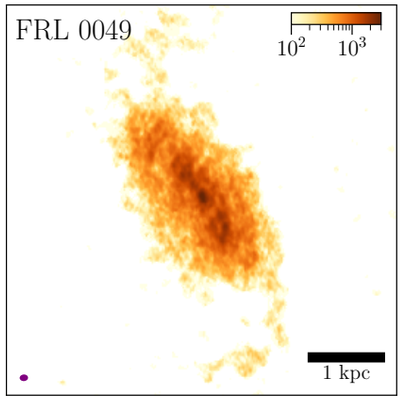


- ISM morphology strongly correlated with μ_* (stellar potential)



Davis, Gensior+ 2022

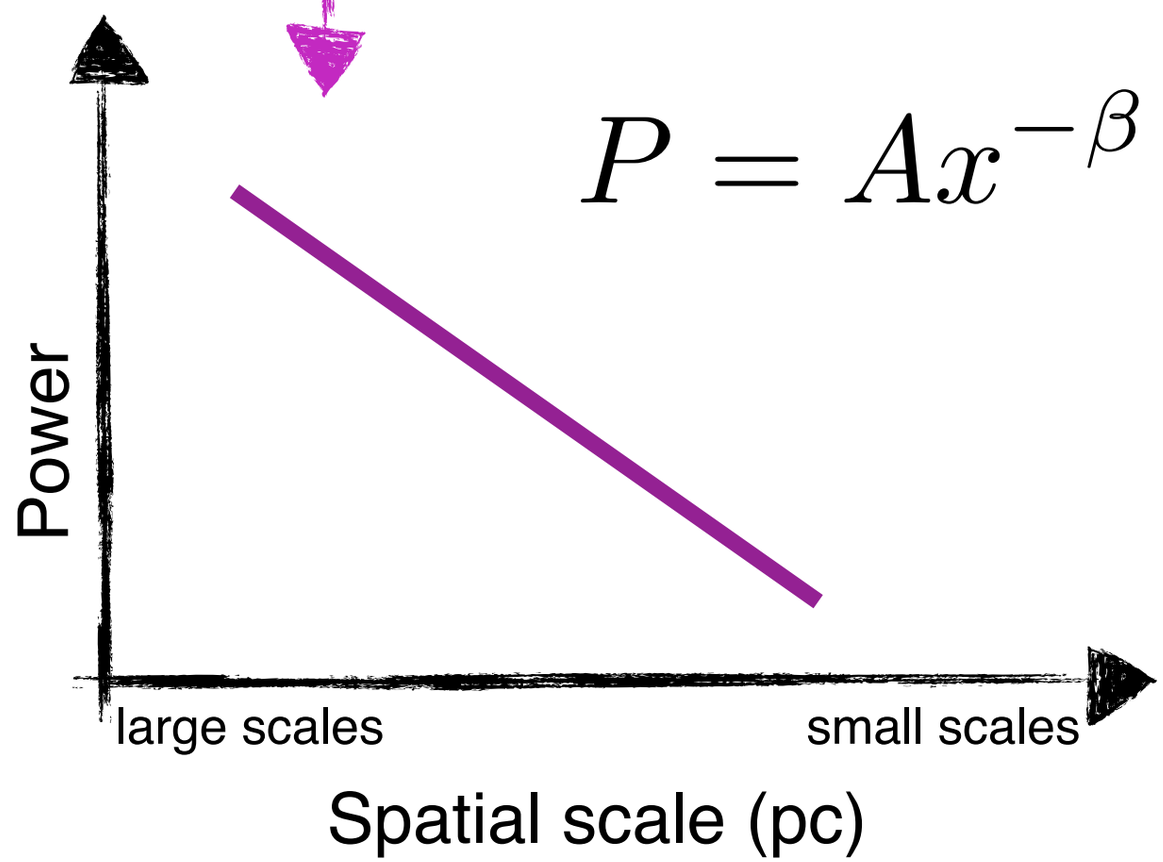
WHAT IS THE SPATIAL POWER SPECTRUM?



1. Fourier transform x complex conjugate

2. Azimuthal average

3. Fit power law



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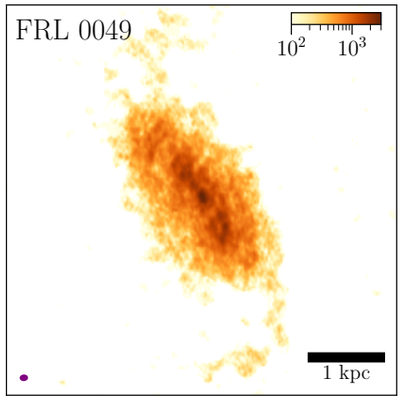

1. Fourier transform x complex conjugate
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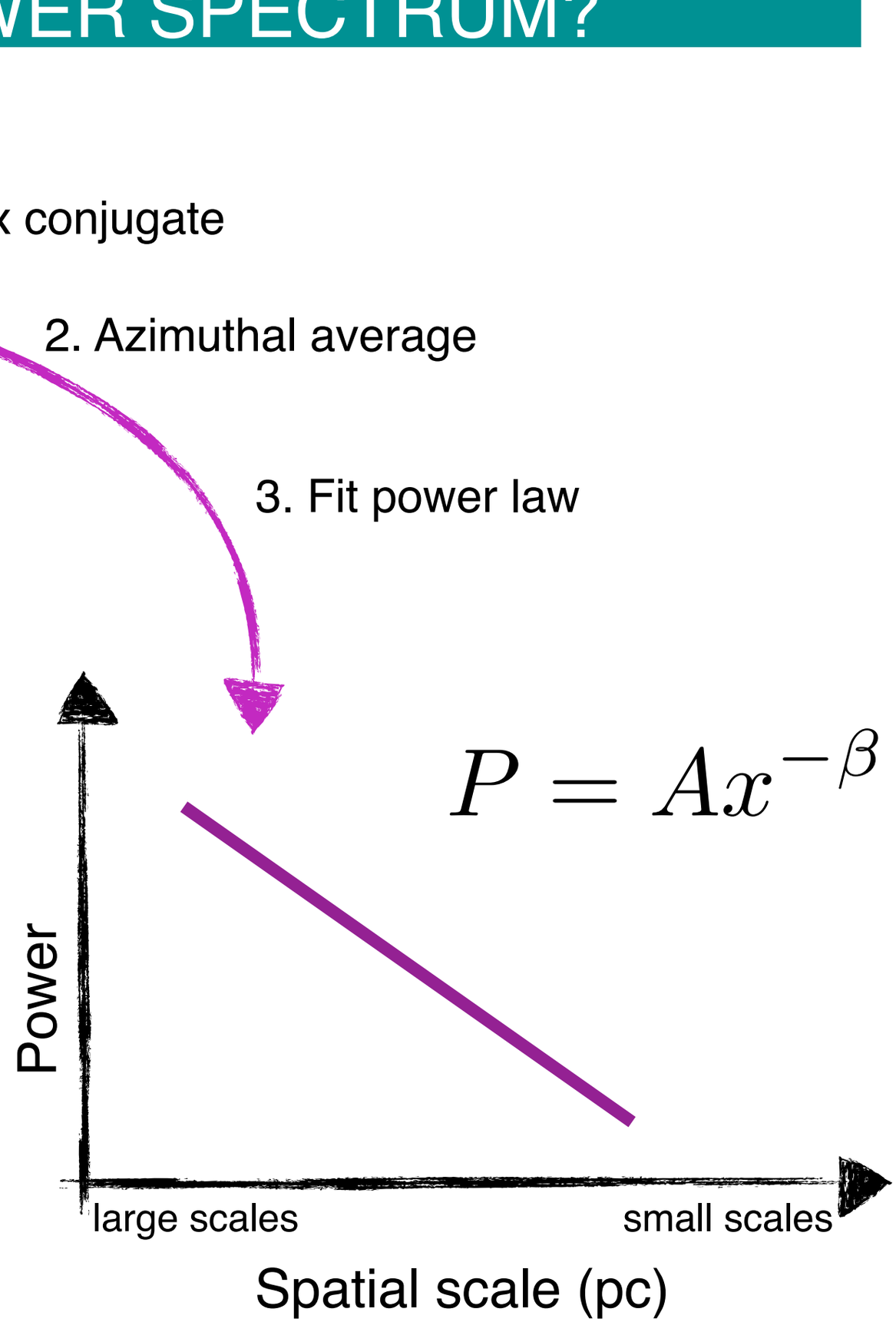
3. Fit power law

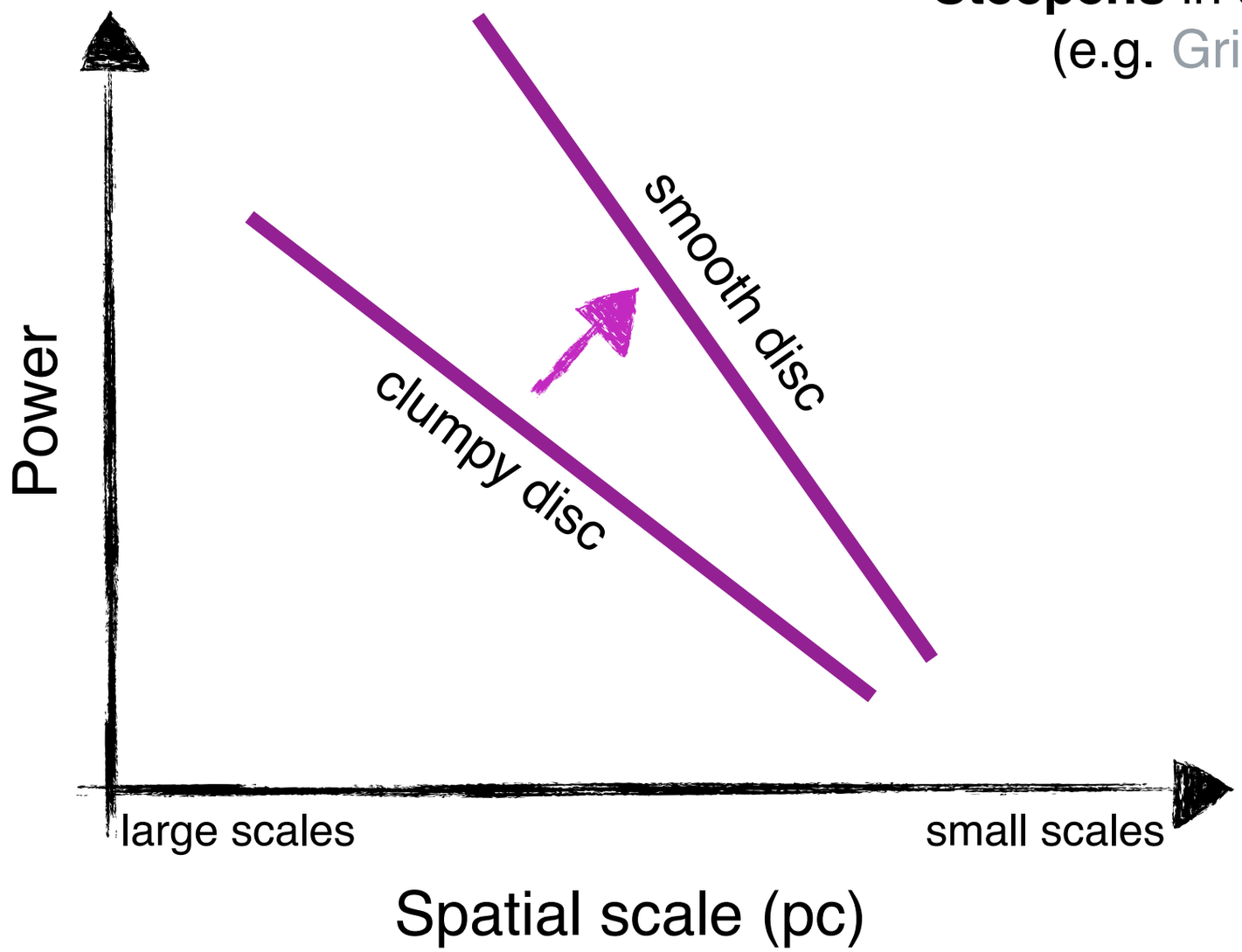
- Power spectrum index (β) expected to depend on nature of turbulence (e.g. Elmegreen & Scale 2004, Federrath+2013, Nandakumar & Dutta 2020)
- β sensitive to ISM morphology (e.g. Walker+2014, Grisdale+2017, Koch+2020)
  - Predominantly HI studied for HI observations of galaxies
- Has been used to highlight need for stellar feedback + validate feedback models (e.g. Walker+2014, Grisdale+2017)



QUANTIFYING ISM MORPHOLOGY WITH THE DENSITY POWER SPECTRUM

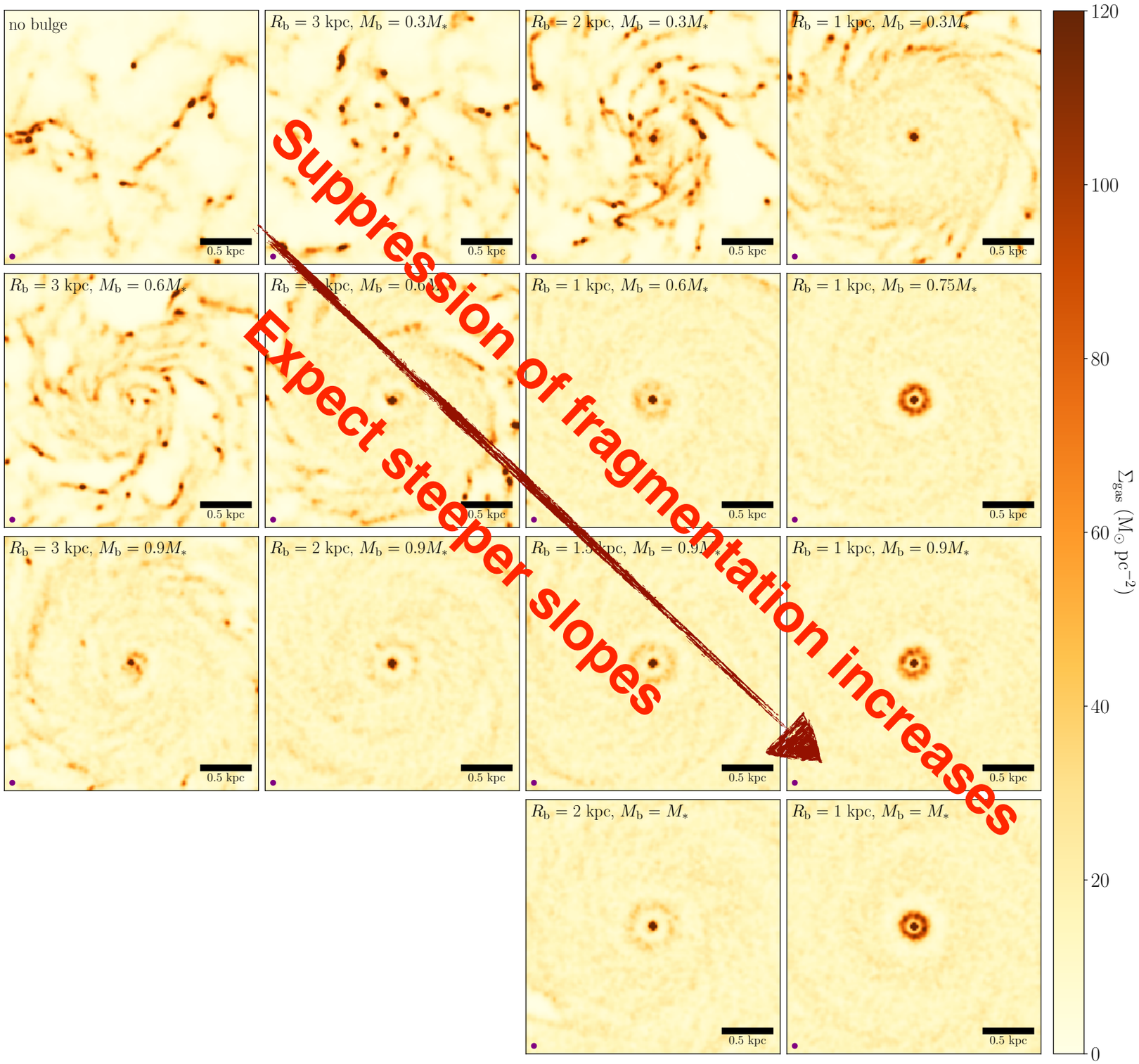
$$P = Ax^{-\beta}$$

Steepens in absence of fragmentation
(e.g. Grisdale+17, Koch+20)



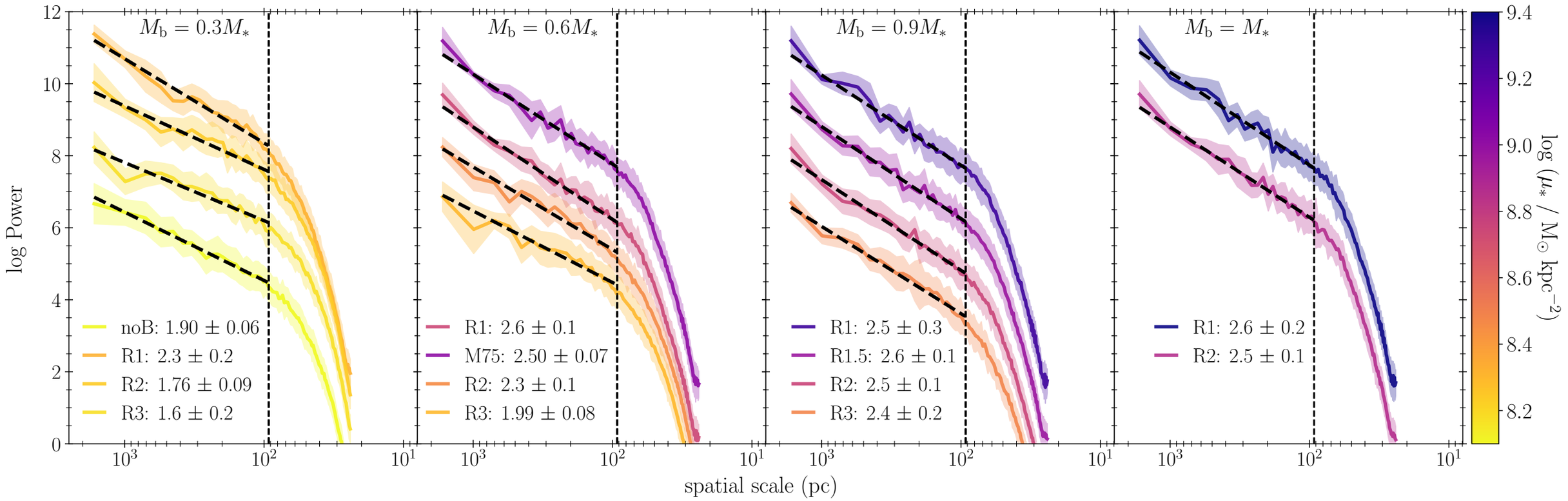
SIMULATIONS:

EXPECTATIONS FOR POWER SPECTRUM SLOPES



SIMULATIONS:

QUANTIFYING THE DYNAMICAL SUPPRESSION OF FRAGMENTATION



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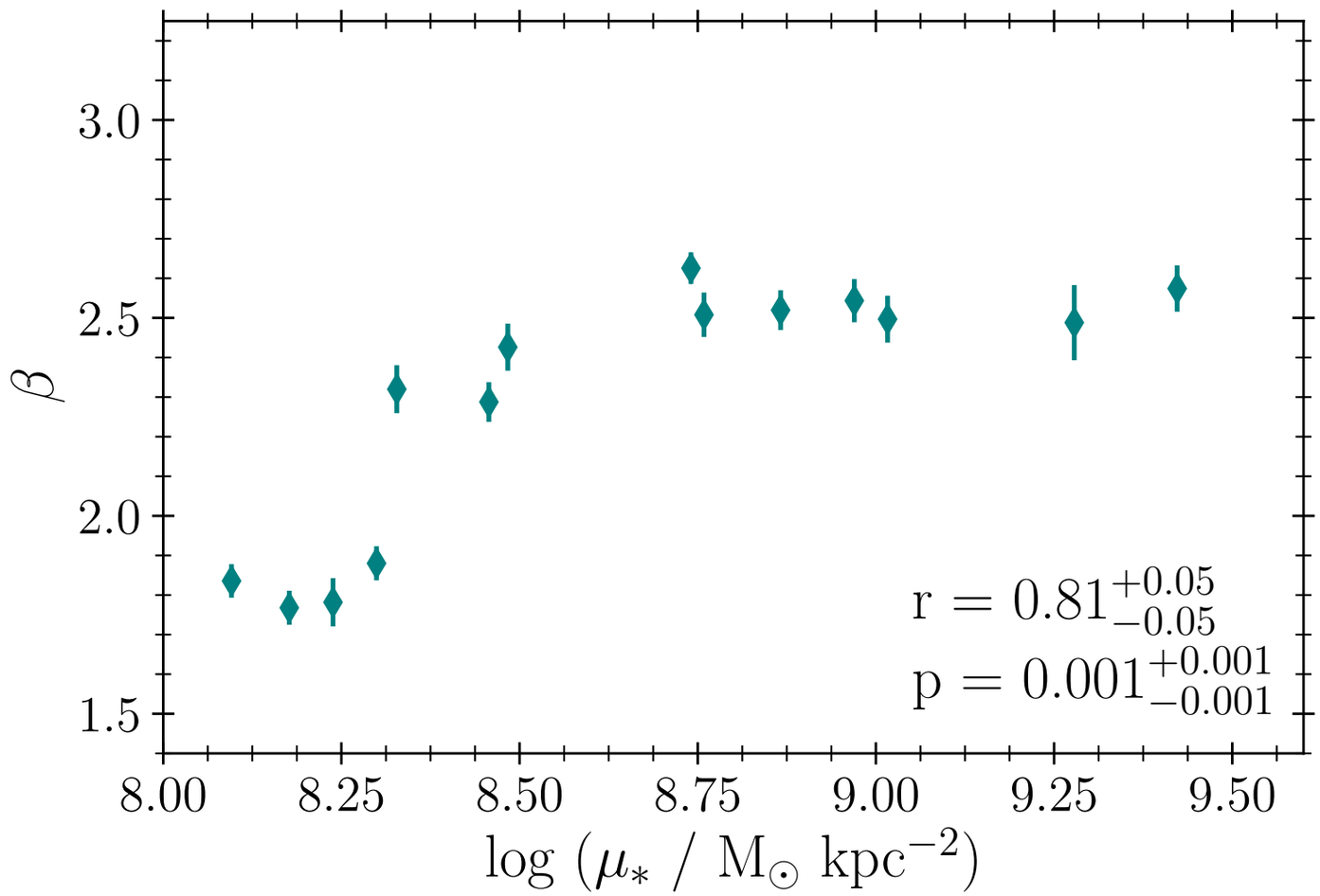
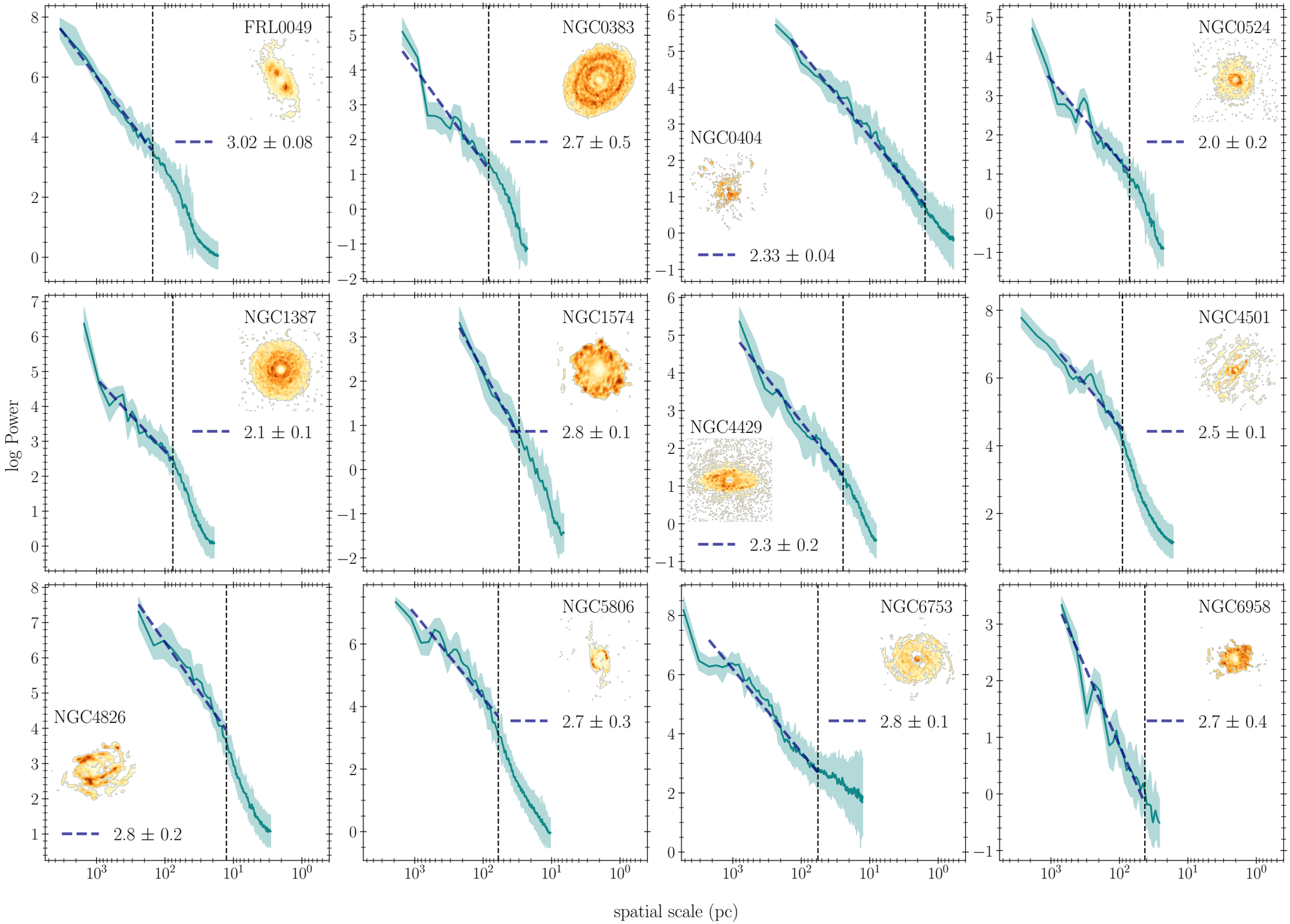


- Steeper slopes with increasing μ_* (bulge strength)

➡ Dynamical suppression of fragmentation measurable with power spectrum

OBSERVATIONS:
QUANTIFYING THE DYNAMICAL SUPPRESSION OF FRAGMENTATION



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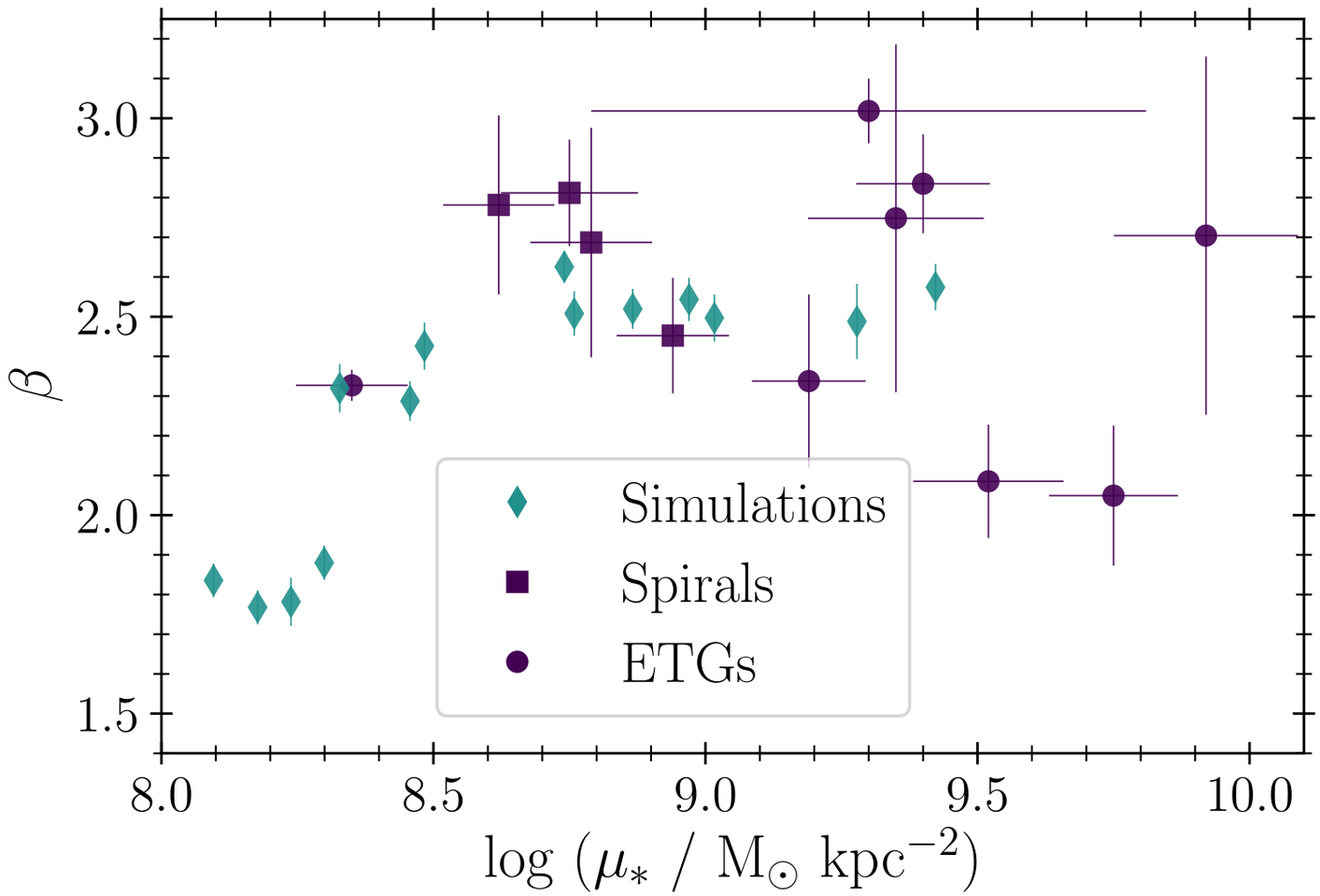

- No clear trend with μ_*

➡ WISDOM galaxies probably have more sources of turbulence cf. isolated galaxy simulations

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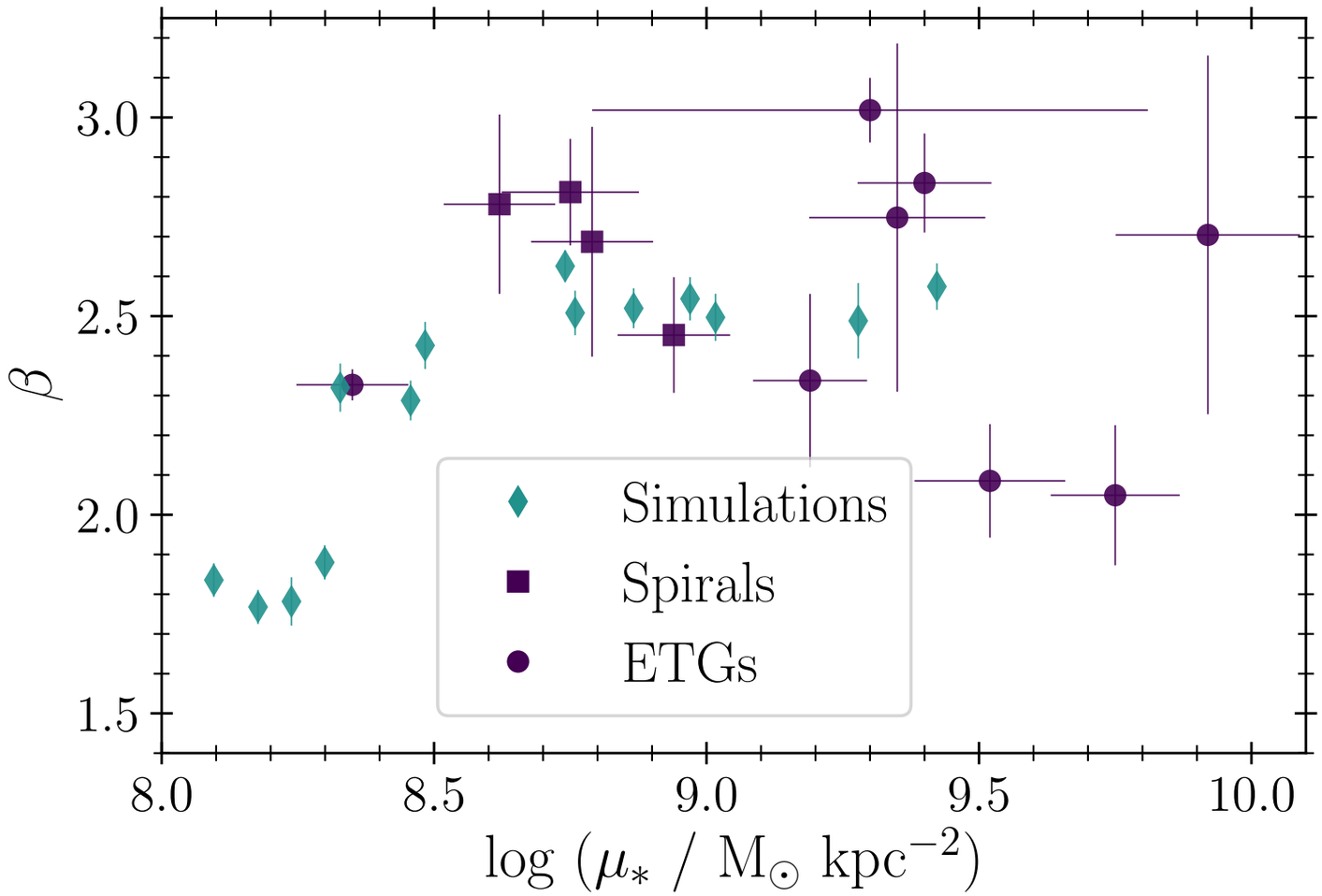

- No clear trend with μ_*

- ➡ WISDOM galaxies probably have more sources of turbulence cf. isolated galaxy simulations
- ➡ Scatter around β~2.6-2.7 could indicate incompressible turbulence driven by shear

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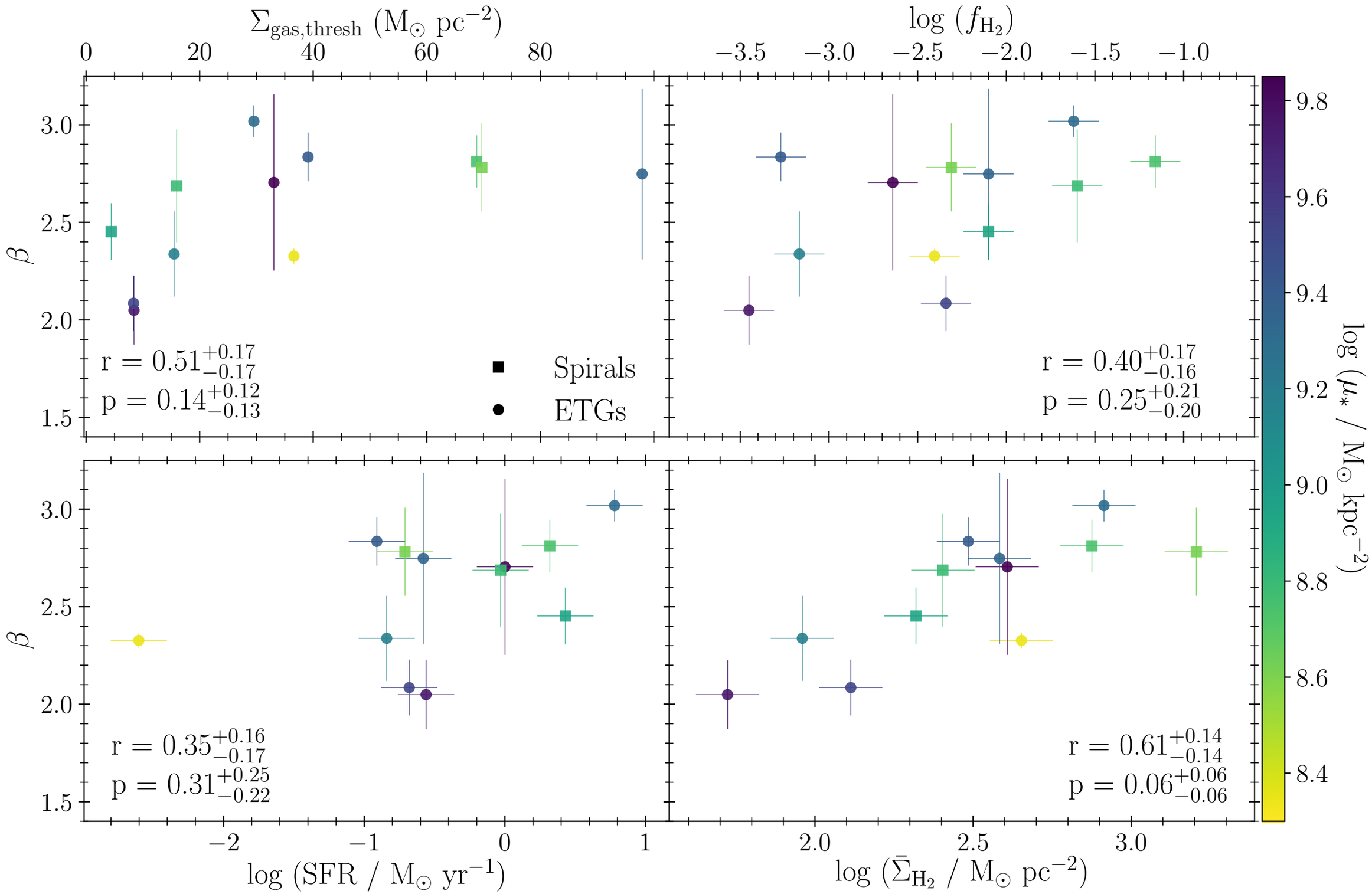
OBSERVATIONS:

POWER SPECTRUM SLOPE CORRELATES WITH CENTRAL GAS SURFACE DENSITY



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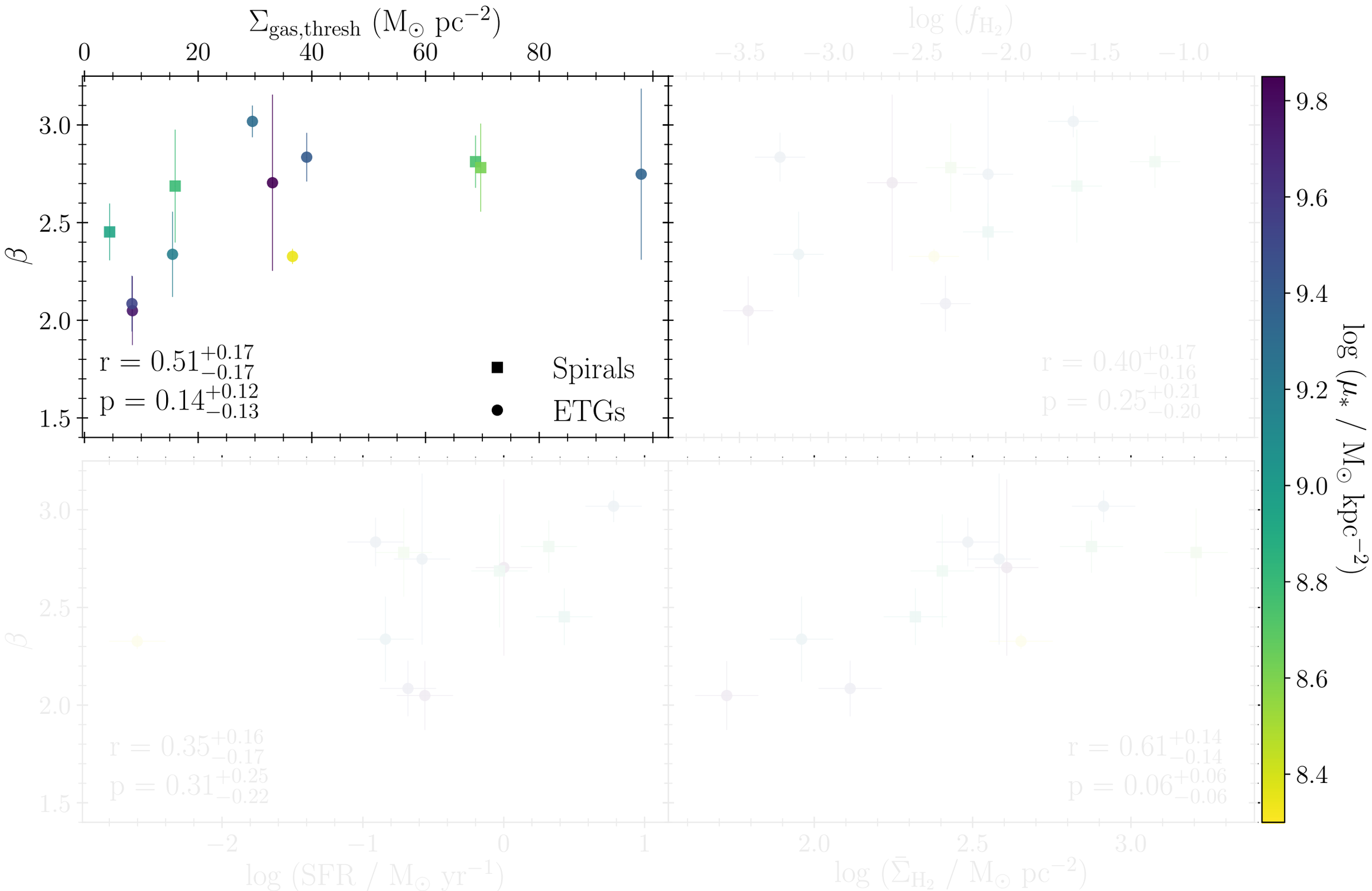

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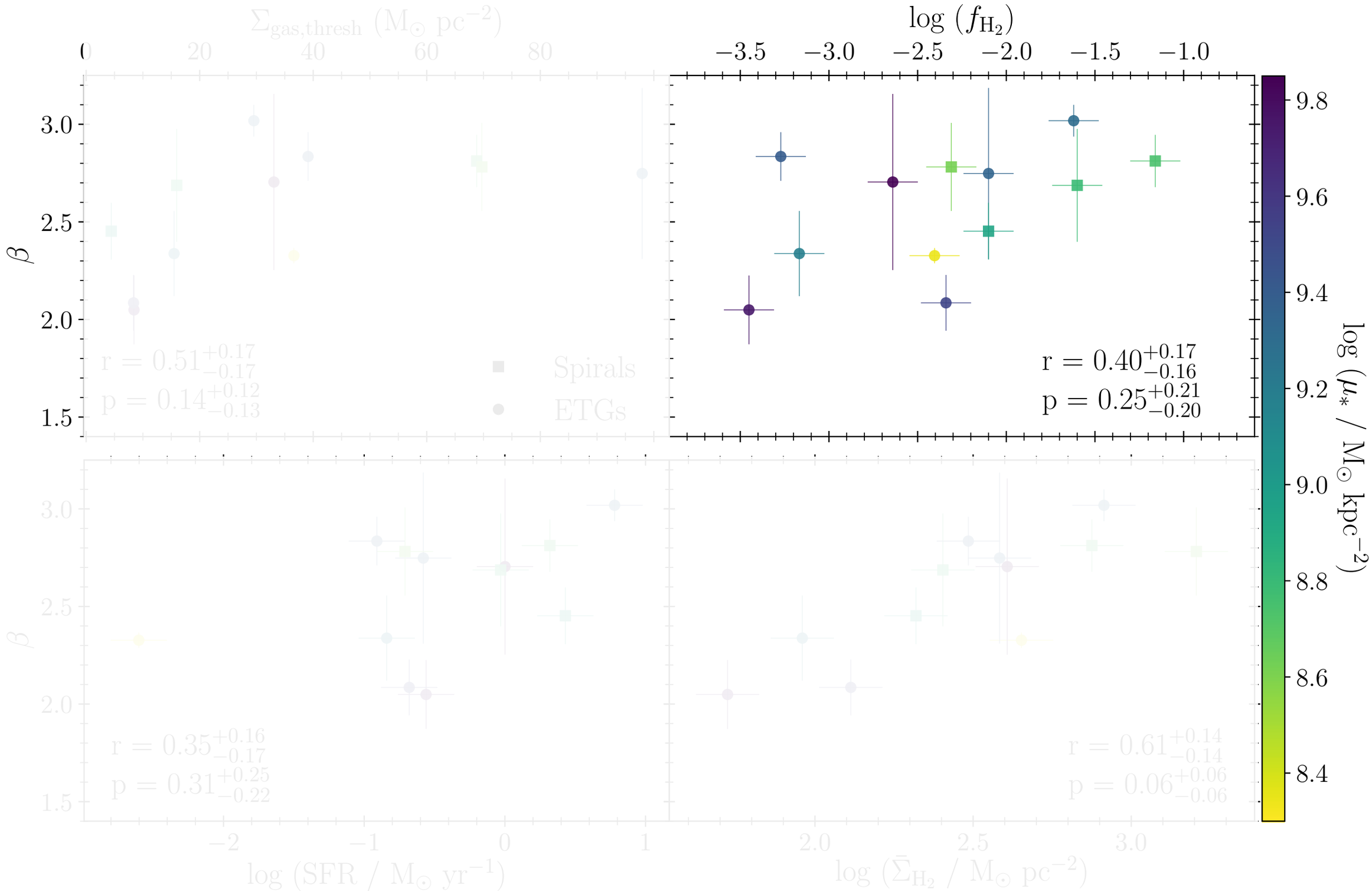

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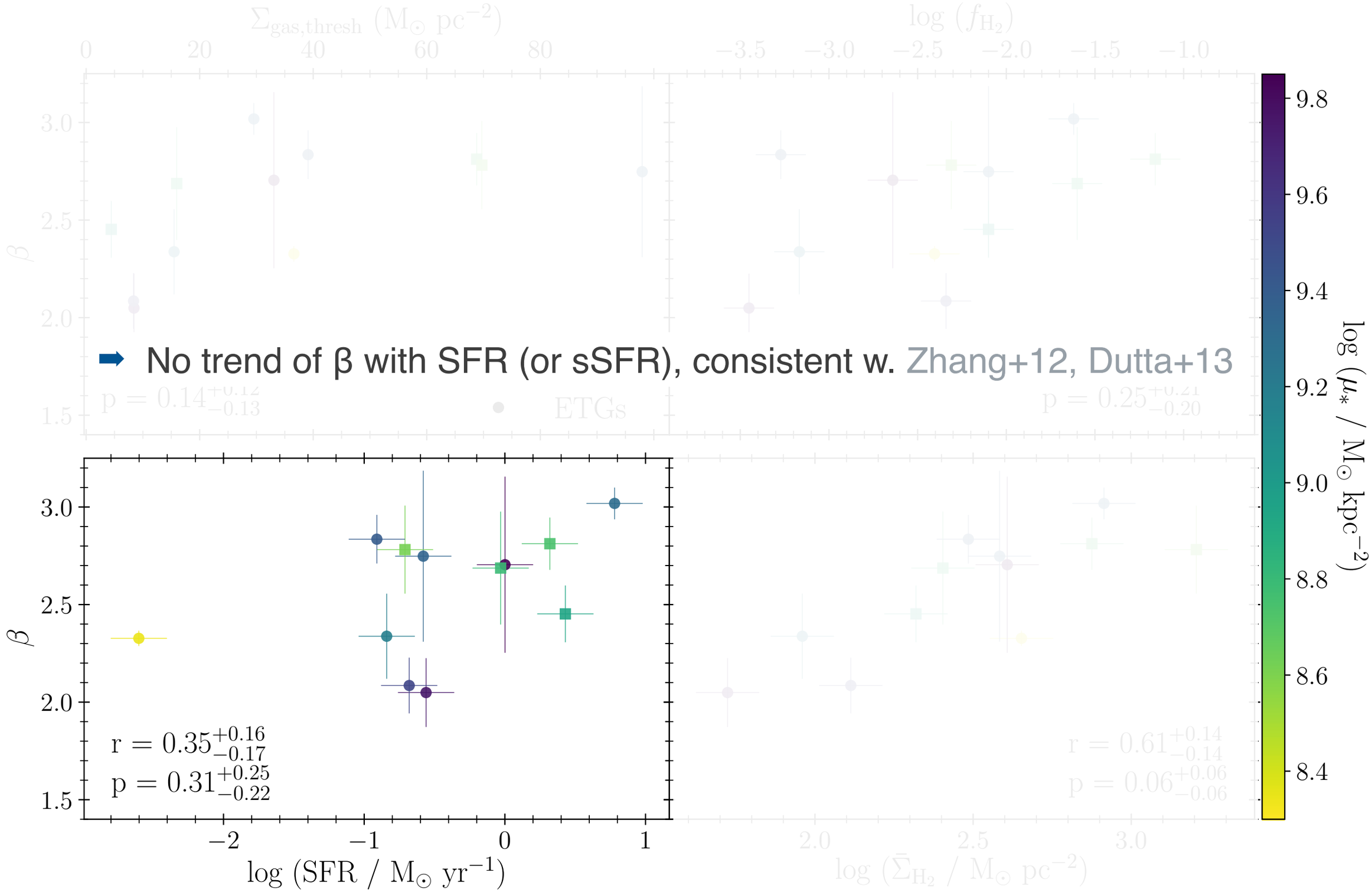

➡ No trend of β with SFR (or sSFR), consistent w. Zhang+12, Dutta+13

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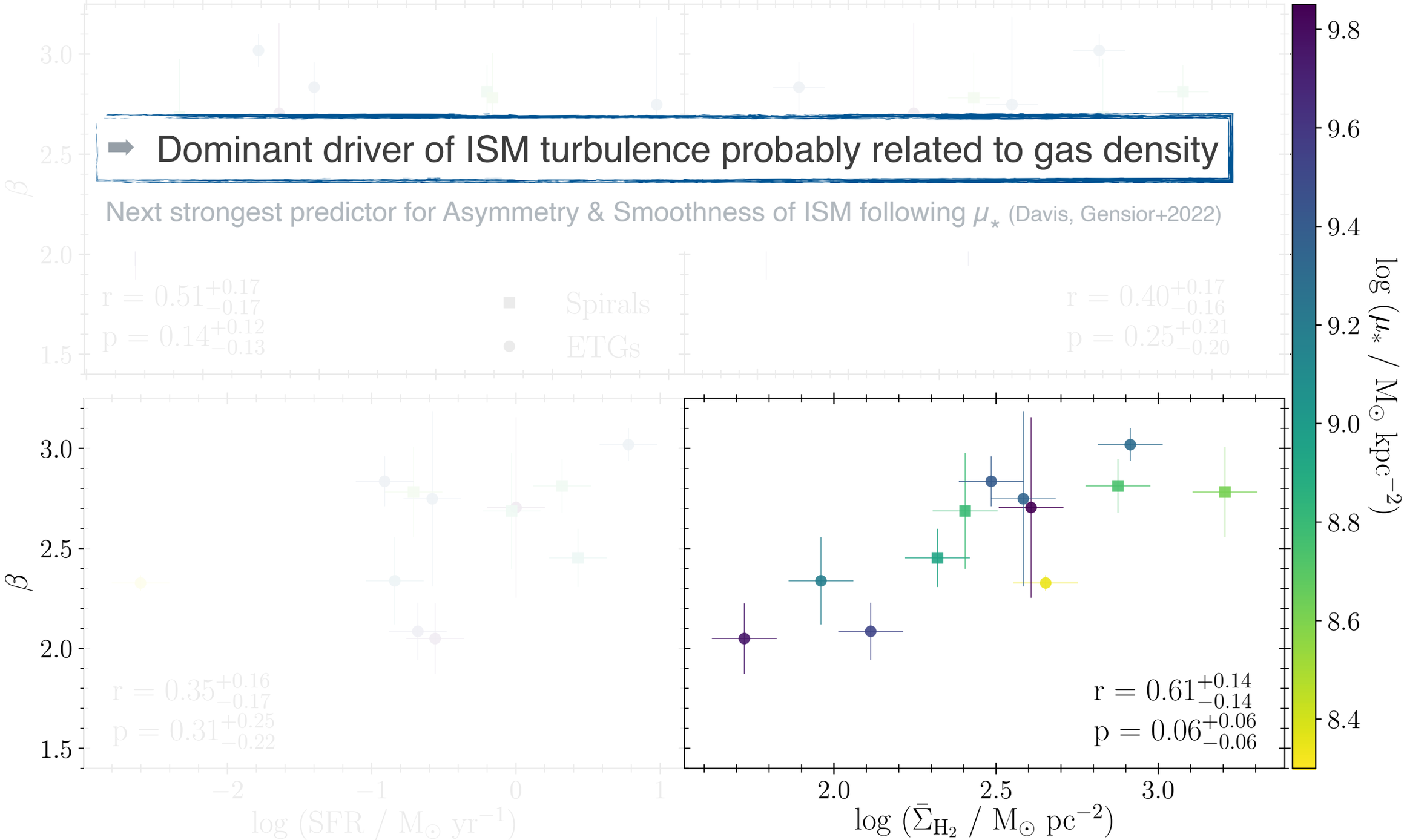
OBSERVATIONS:

POWER SPECTRUM SLOPE CORRELATES WITH CENTRAL GAS SURFACE DENSITY

➡ Dominant driver of ISM turbulence probably related to gas density

Next strongest predictor for Asymmetry & Smoothness of ISM following μ_* (Davis, Gensior+2022)

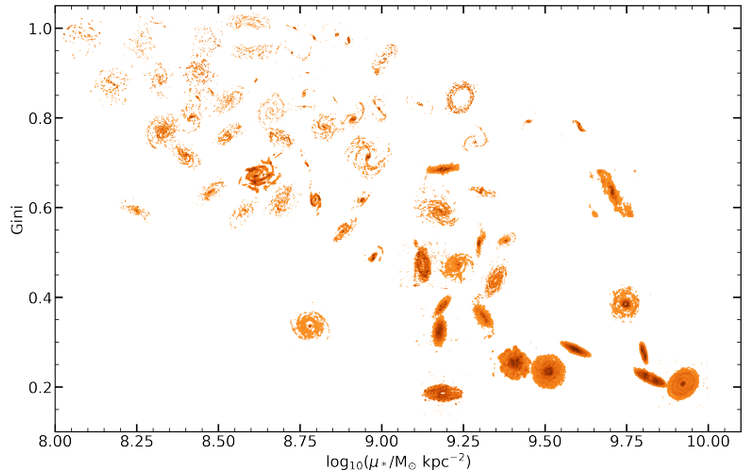


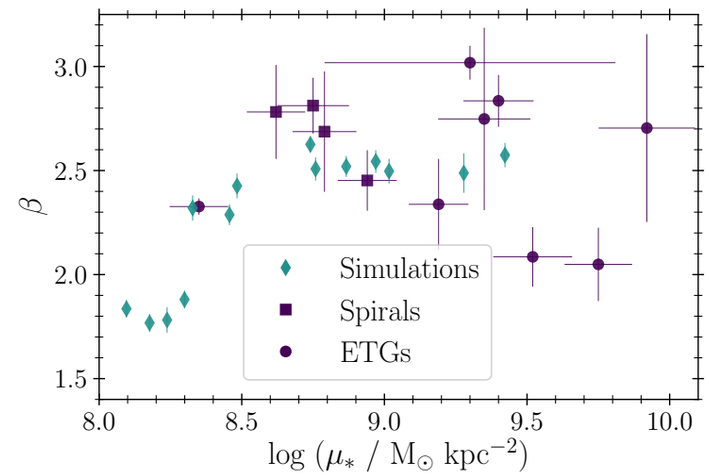
Gensior+ 2023

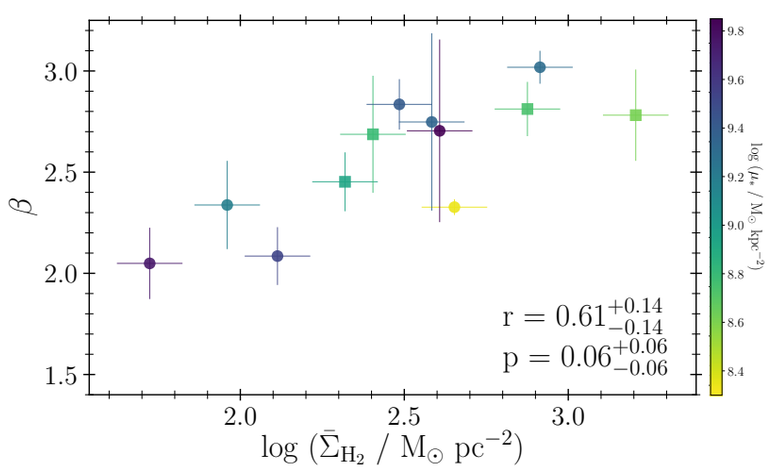
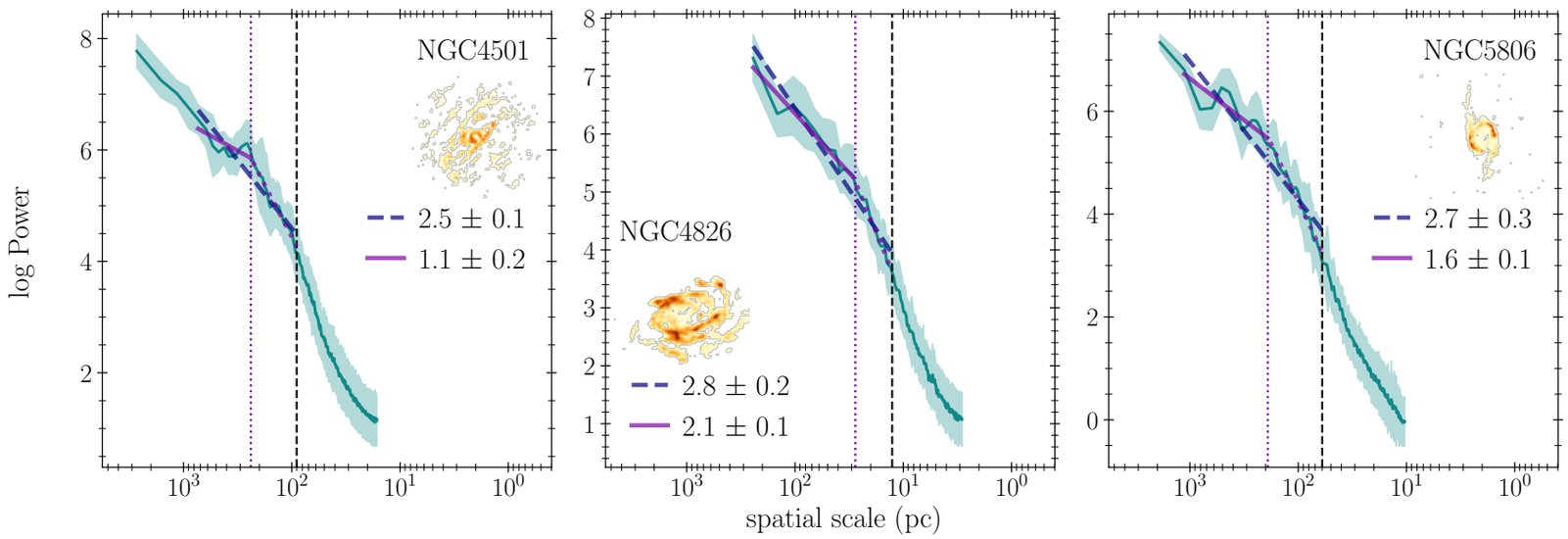
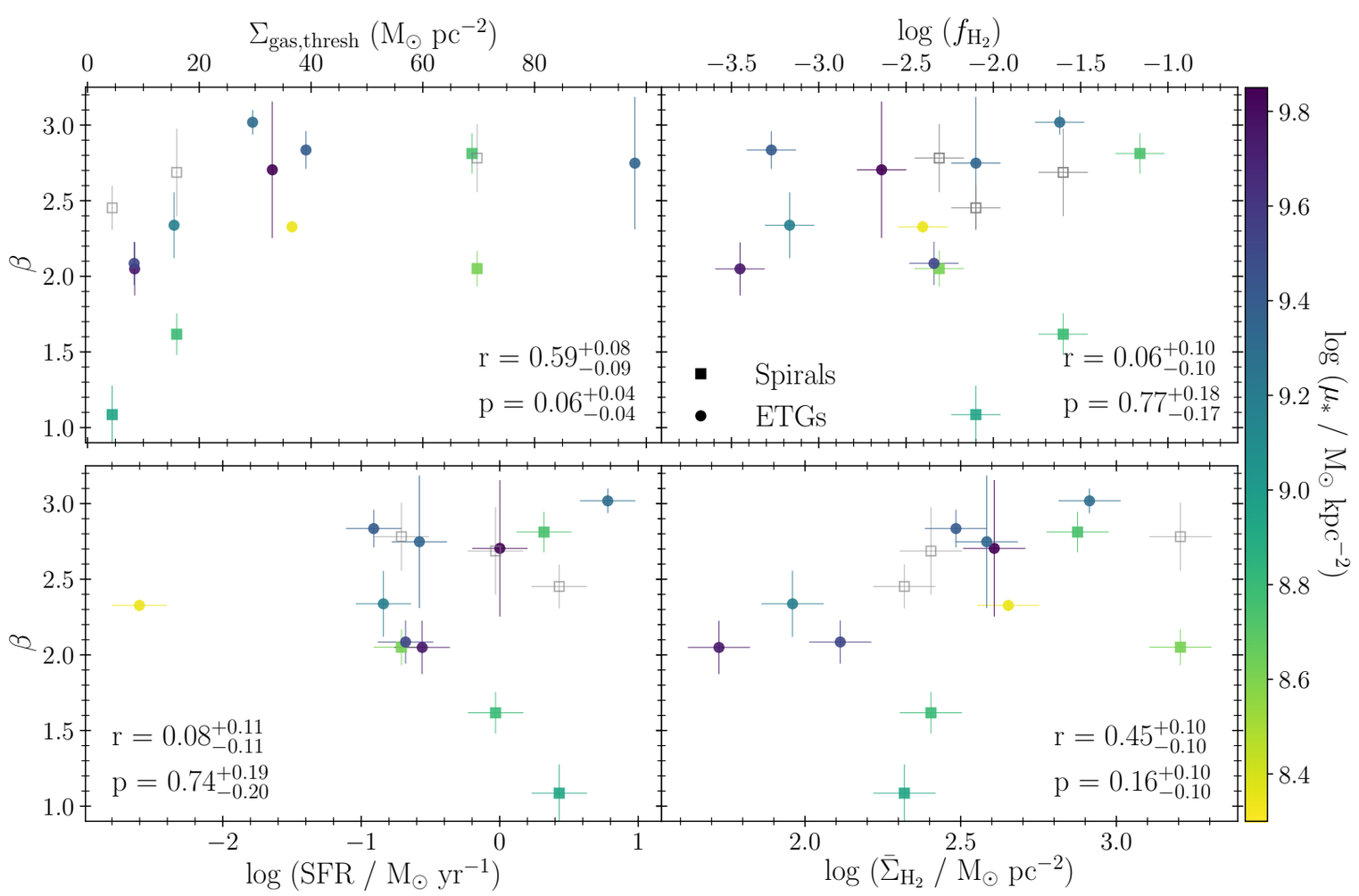
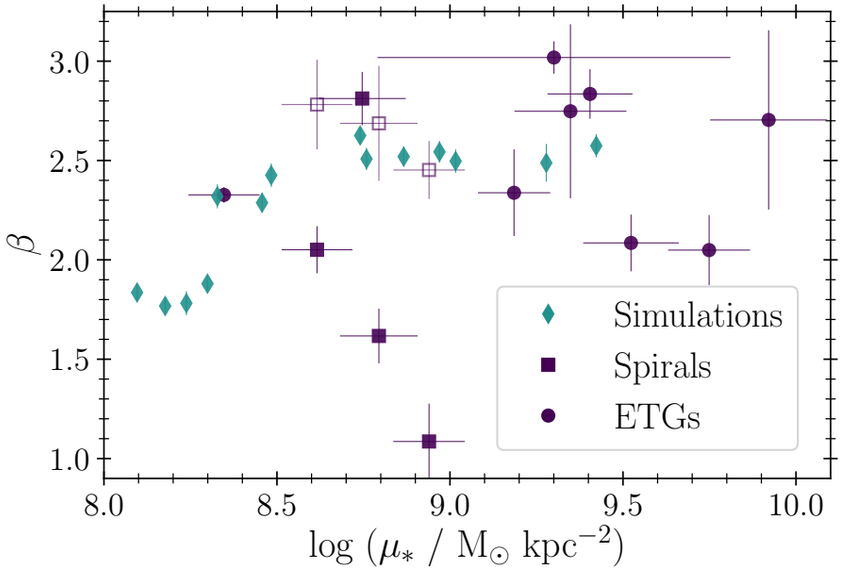
SUMMARY

- Galactic gravitational potential and galactic dynamics matter: high shear creates smooth gas discs at the centres of spheroids
  - Low Gini, Asymmetry & Smoothness coefficients (simulations & observations)
  - Strong correlation between power spectrum slope (β) and central stellar mass surface density (μ_*) confirms suppression of fragmentation in spheroid-dominated galaxies (simulations)

- Observations show no correlation between β and μ_*
  - Could indicate that missing physics in the simulations
  - Scatter around β~2.6-2.7 at high-μ_*, consistent with the slopes of the simulations could indicate shear-driven incompressible turbulence in this regime
  - β correlates with central gas mass surface density
    - ➡ Dominant driver of ISM turbulence probably related to gas density







MULTI-COMPONENT POWER-LAWS