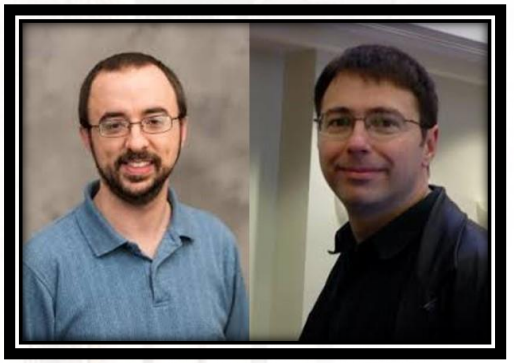
Journal Club on Galaxies

Revealing Strong Bias in Common Measures of Galaxy Properties Using New Inclination-Independent Structures

Brian M. Devour & Eric F. Bell, 2017,
MNRAS Letters, in press (arXiv:1702.06528)



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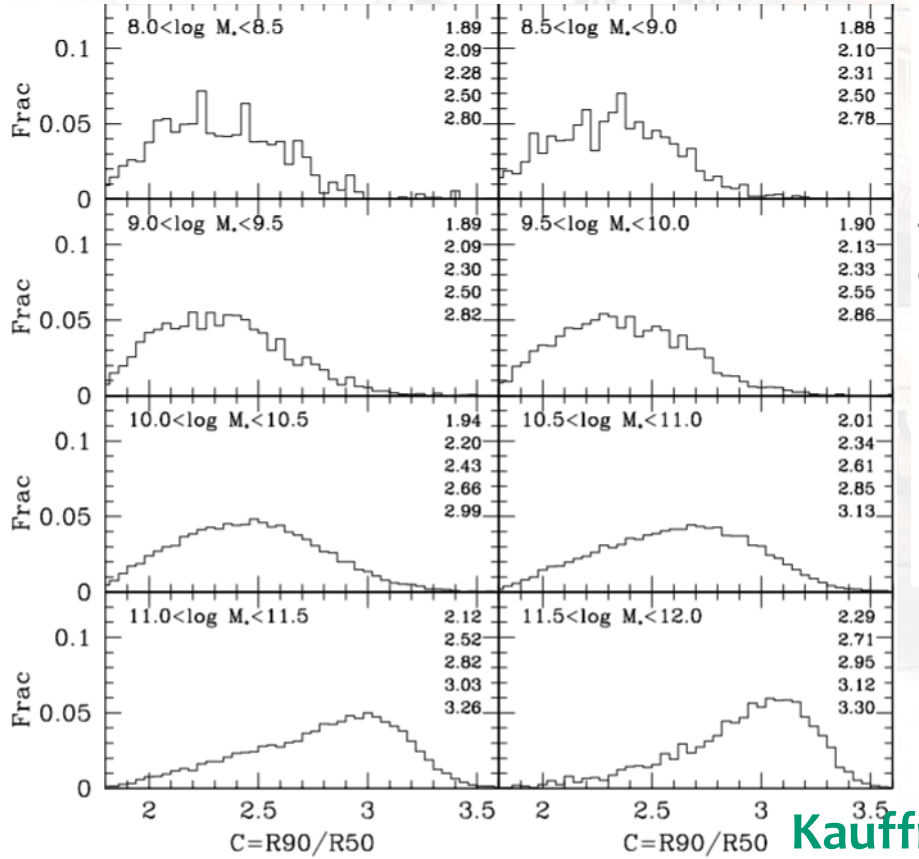
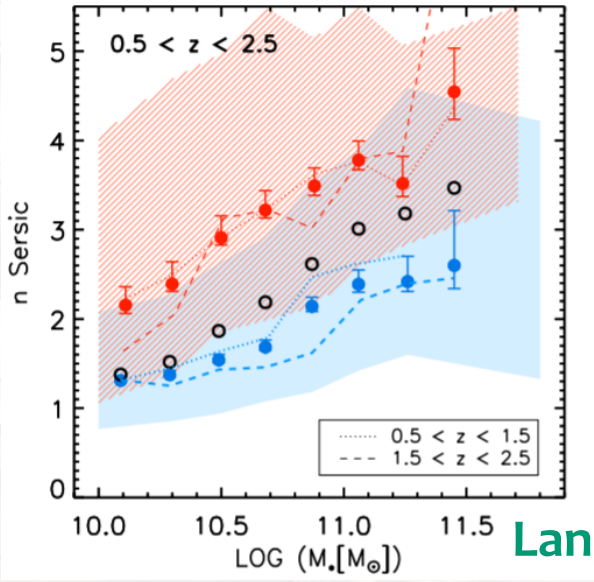
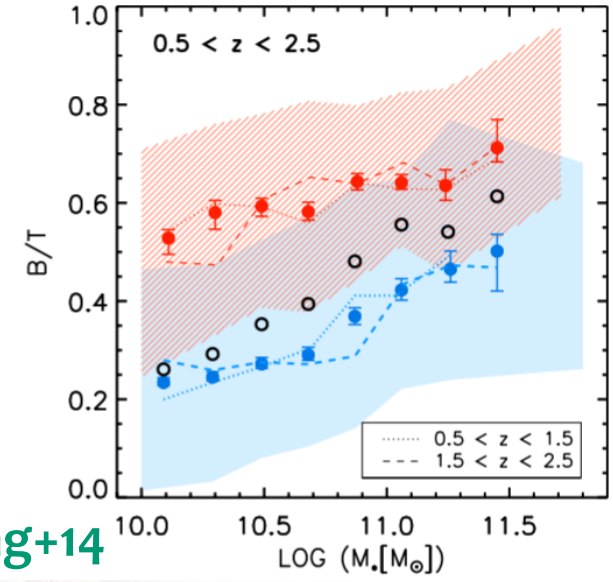
Structural parameters are very widely used to examine galaxy evolution in numerous studies.

- An accurate understanding of galaxy structure is a cornerstone of the study of galaxies.
- The astronomical community has devised many types of structure measurements.



Kauffmann+03





Lang+14

How reliable are the structural metrics that are widely used

Sersic index
n

Effective radius
R_e

Light concentration
c (= R90/R50)

De Vaucouleur fraction
f_{DeV}

Bulge-to-total ratio
B/T

… in consideration of the inclination bias?

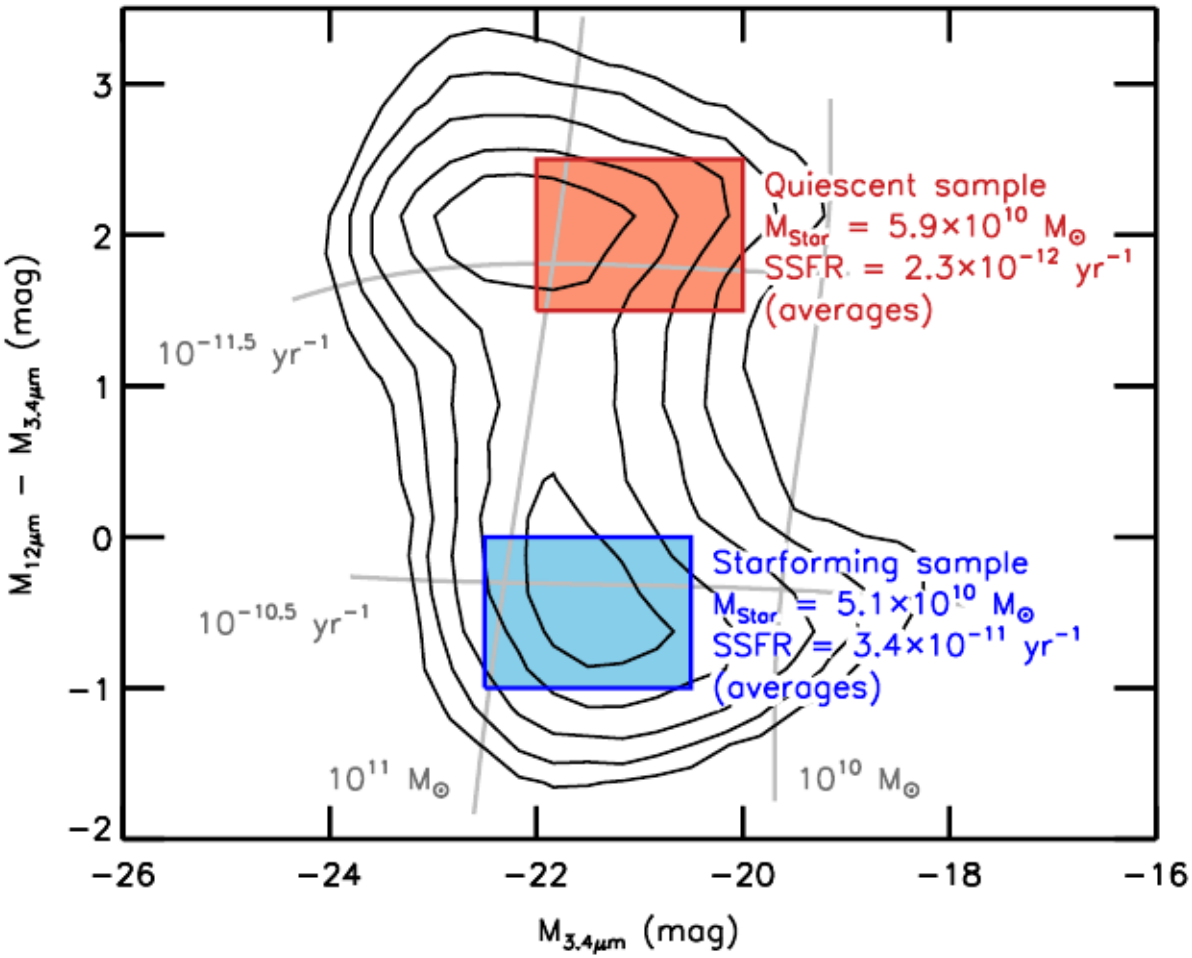
- Inclination differences lead to the same galaxy being mapped on to different 2D projections owing both to geometry and varying dust attenuation.
- Unfortunately, the inclination-driven biases of many commonly used structural metrics are currently poorly understood!

Research Goal

- Quantify the inclination dependence of commonly-used structural measurements and illustrate the impact of these systematic effects on our understanding of galaxy properties.
- Use inclination-independent metrics to reveal that common structural measurements systematically vary with inclination for a variety of galaxy types.

Analysis Concept

1. Select intrinsically similar galaxies.
2. Measure their properties using common structural metrics.
3. Check the effect of inclination: dust & geometry.



Critical Challenge:

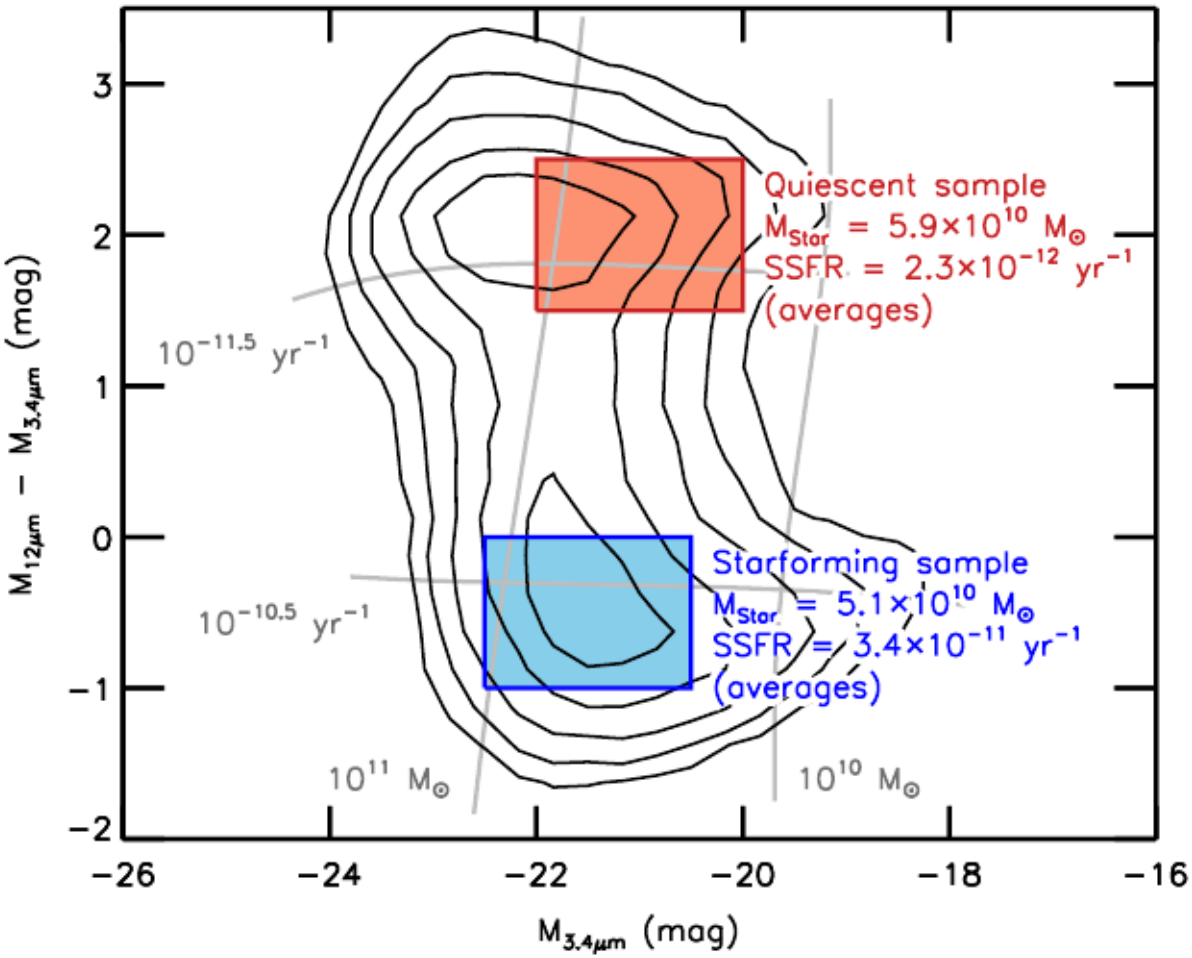
How to devise selection metrics that are inclination-independent?

WISE (Wide-field Infrared Survey Explorer):

- W1 (3.4μm): a reasonable proxy for stellar mass, almost free from dust attenuation and stellar M/L variation
- W3 - W1 (12μm - 3.4μm): a good proxy for SSFR, catching warm dust and PAH molecules

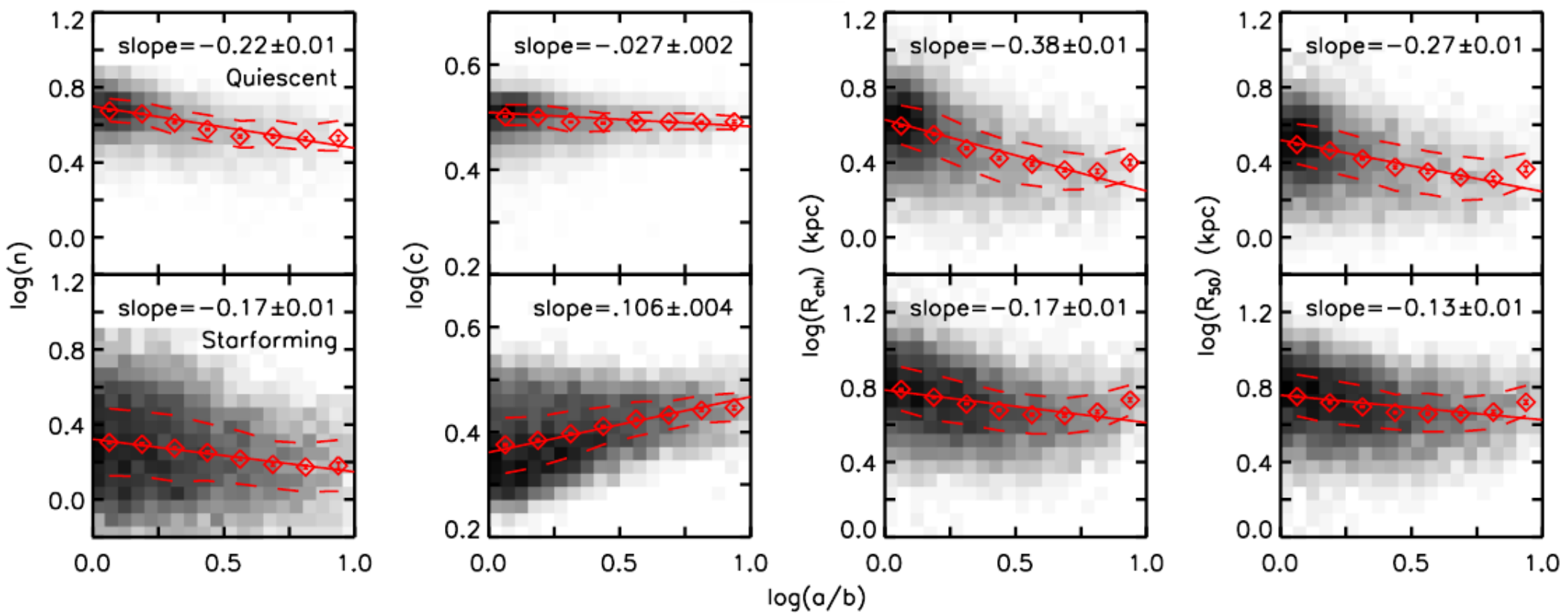
Sample Selection

1. Quiescent sample:
   $-22.0 < M_{3.4\mu m} < -20.0$
   $1.5 < [12] - [3.4] < 2.5$
   corresponding to
   disky quiescent galaxies
   with $4 \times 10^{10} < M_* < 8 \times 10^{10}\ M_\odot$
2. Star-forming sample:
   $-22.5 < M_{3.4\mu m} < -20.5$
   $-1.0 < [12] - [3.4] < 0$
   corresponding to
   SF main sequence galaxies
   with $3 \times 10^{10} < M_* < 6 \times 10^{10}\ M_\odot$



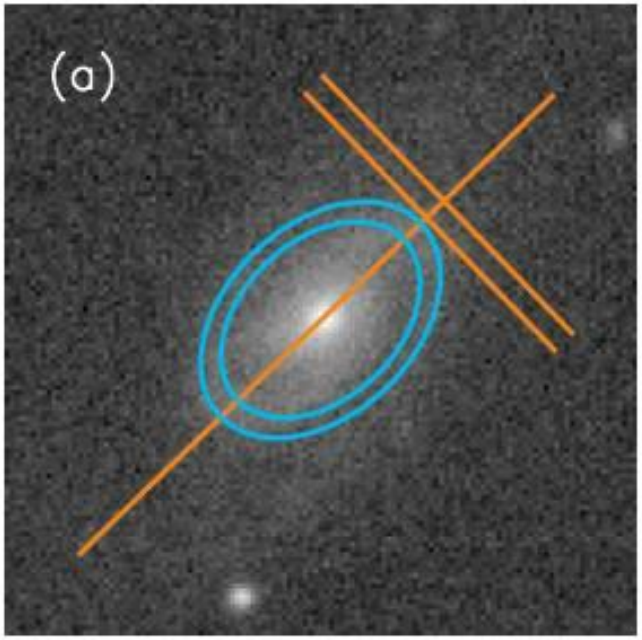
7044 quiescent + 6239 SF galaxies, 75% of which have $0.0279 < z < 0.0635$

→ Their properties in the commonly-used structural metrics?



- B… **This is a major concern; commonly used metrics of galaxy structure depend on inclination at a level comparable to the dispersion of structural metrics within a population.** …n fo… d…
- Sersic index also shows a strong dependence on inclination for the quiescent galaxies, while concentration shows almost no trend for quiescent galaxies.
- Both Sersic-derived & Petrosian half-light radii vary significantly with inclination.

Inclination-Independent Structural Measurements



- 2 primary obstacles:
  - dust attenuation
  - differing projection

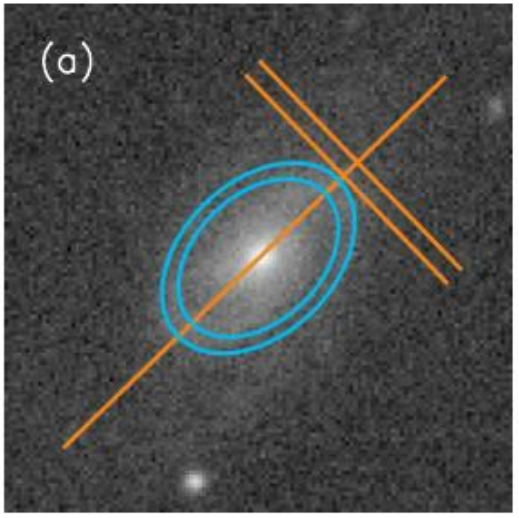
- Solution:

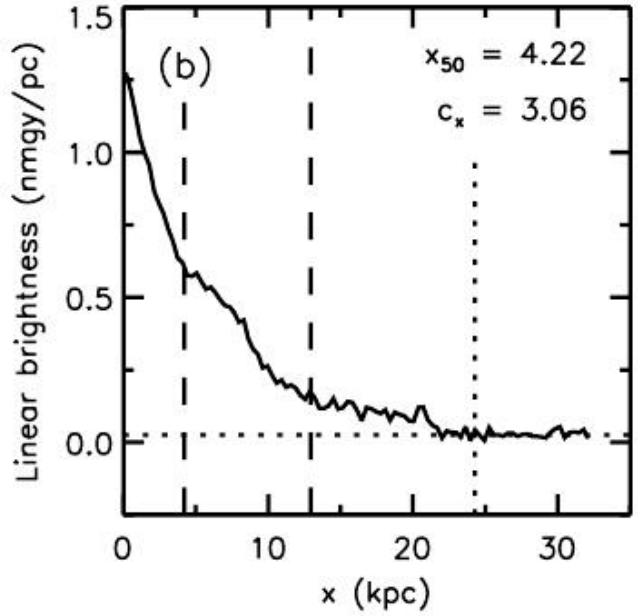
1. **Dust attenuation**
   - Using *K* band (2.2μm) from the UKIDSS survey
   - Dust attenuation at *K* band is 1/5 – 1/3 of the optical attenuation.
   - Galaxies are close to transparent across almost all viewing angles in *K* band.

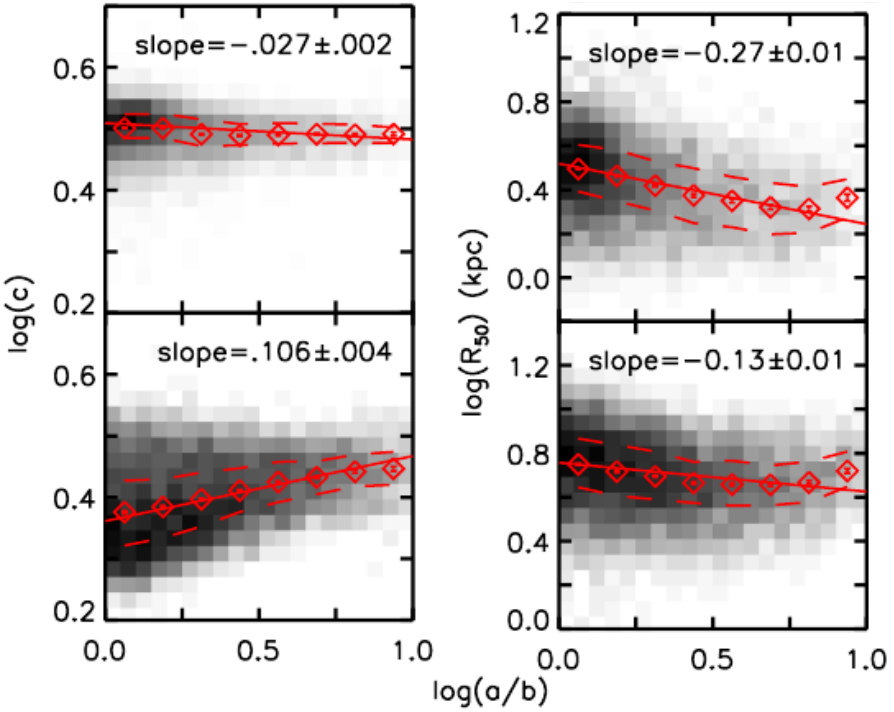
2. **Differing projection**
   - Circular annuli and apertures are obviously strongly affected by inclination.
   - Elliptical annuli/apertures still suffer from inclination-dependent projection effects. Towards larger inclination, an elliptical annulus become substantially more influenced by the vertical structure.
   - Take cuts parallel to the minor axis, collapsing all light down on to the major axis to for a linear brightness profile.

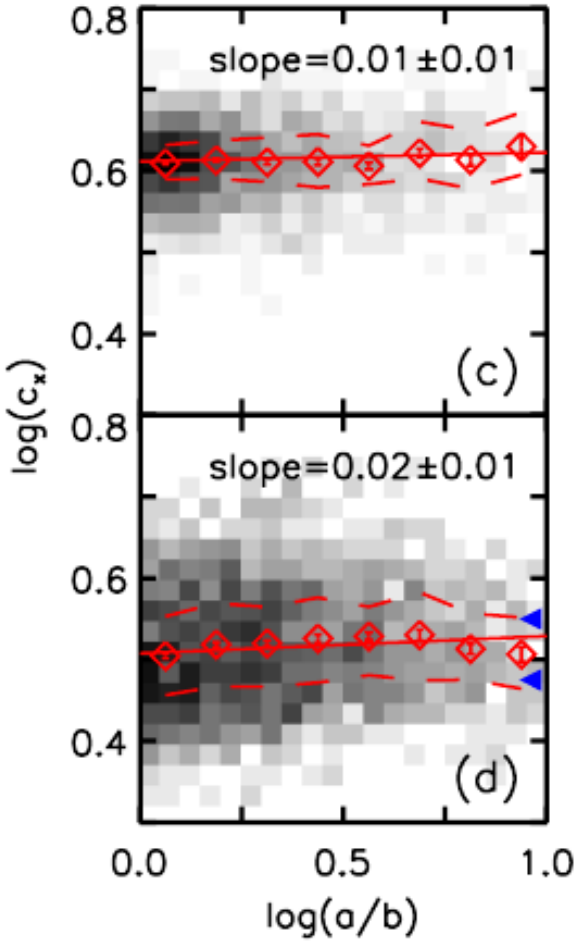
Inclination-Independent Structural Measurements

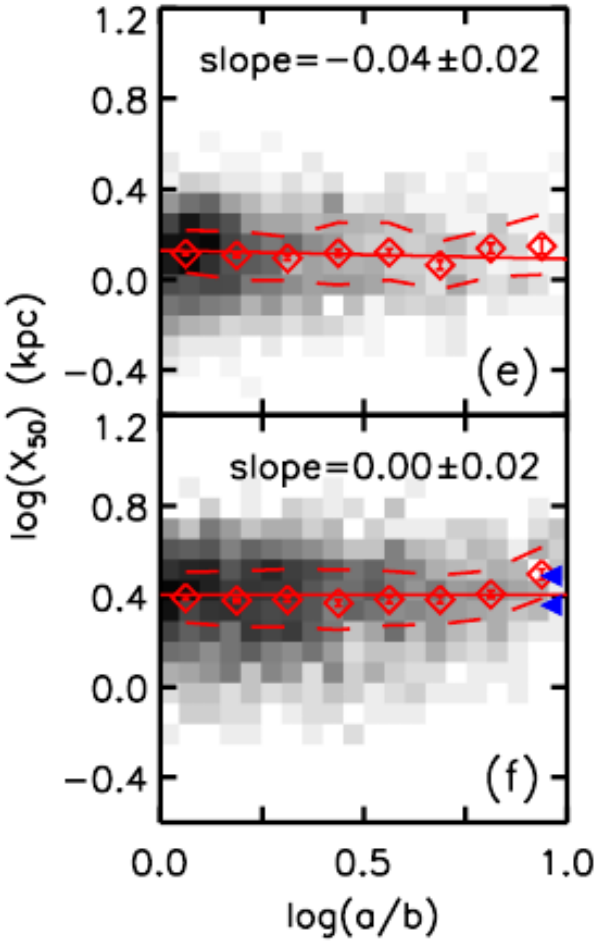
- Instead of r_{90}/r_{50}, use linear concentration $\mathbf{c_x = x_{90}/x_{50}}$, where x_{90} and x_{50} are linear sizes containing 90% and 50% light, respectively.
  → inclination-independent structural parameter!







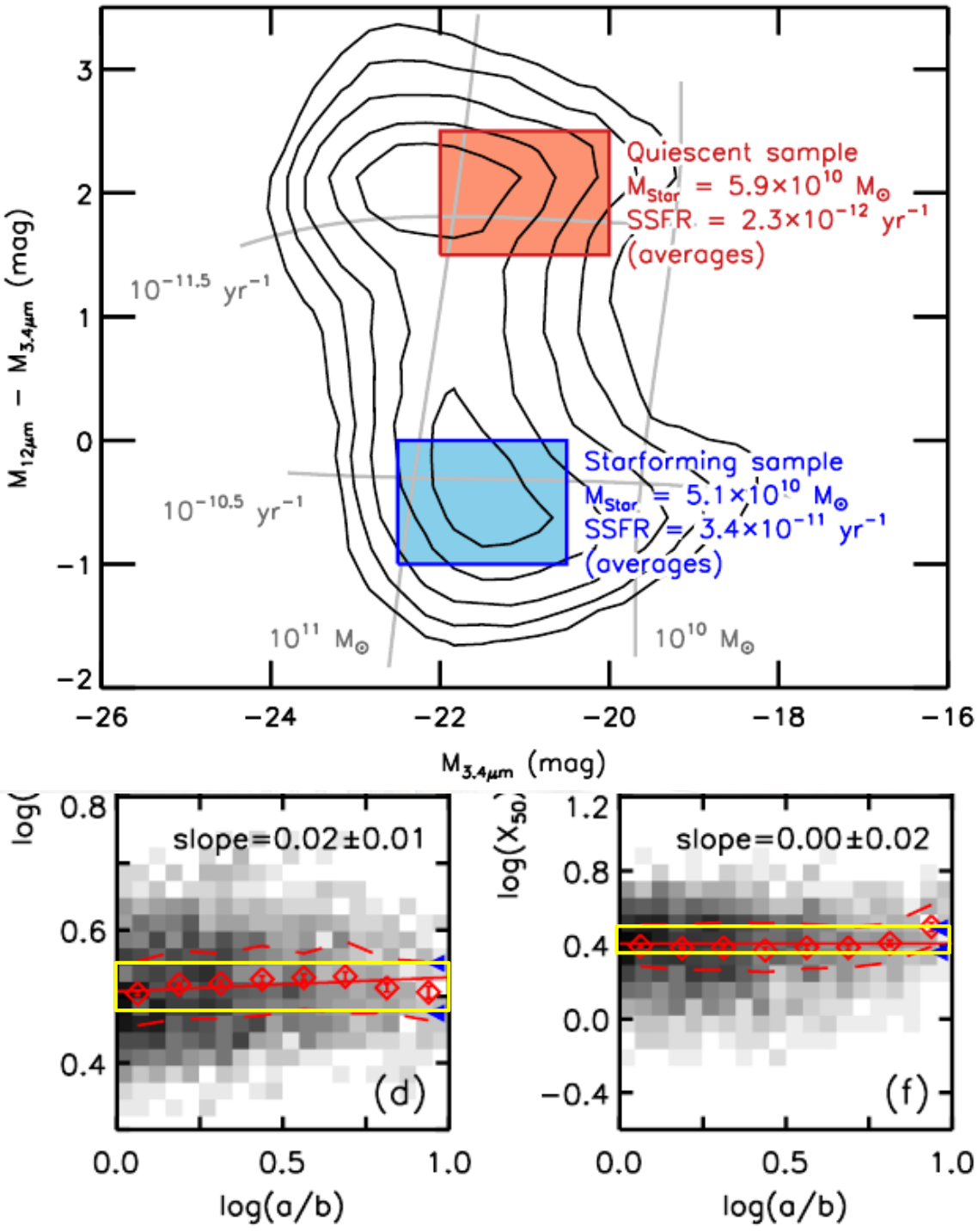




Testing Milky-Way-like Galaxies

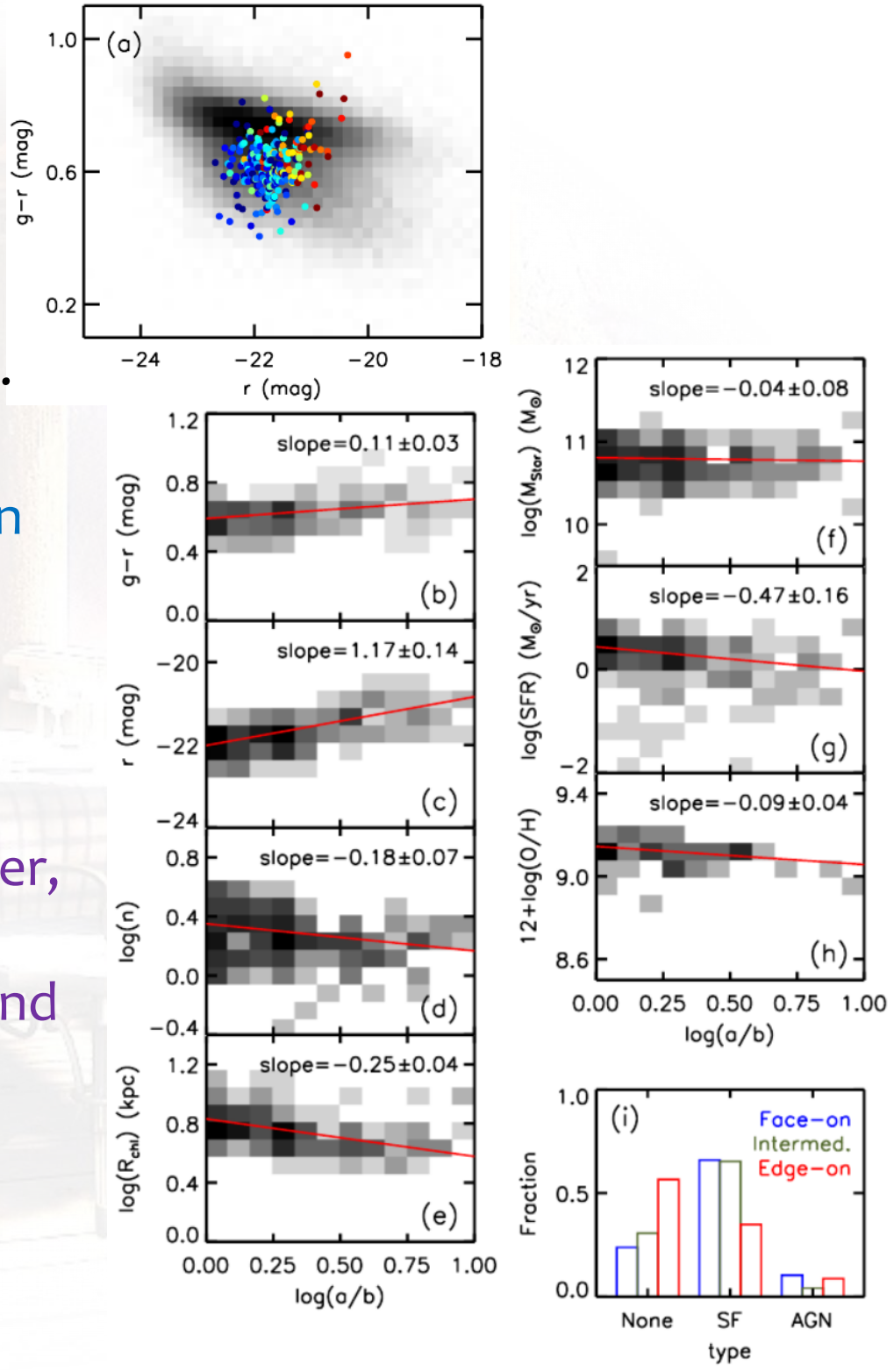
- MW properties:
  $M_* = 5 \times 10^{10}\ M_\odot$
  $SSFR = 3 \times 10^{-11}\ yr^{-1}$
- Selection of MW analogues:
  $-22.25 < M_{3.4\mu m} < -20.75$
  $-1.0 < [12] - [3.4] < 0$
  $0.475 < \log(c_x) < 0.55$
  $0.36 < \log(x_{50}/kpc) < 0.49$

  → **structurally average SF disk galaxies** broadly similar in stellar mass and SFR to the MW



How do the MW analogues look in commonly-used photometric & structural parameter spaces?

- Range from blue cloud (face-on) to red sequence (edge-on) in the CMD.
- Most photometric, structural, and spectral-line-based measurements in the optical band (SDSS) **strongly depend on axis ratio**, except stellar mass.
- The more edge-on members of this population are systematically dimmer, redder, less centrally concentrated, smaller, less actively star-forming, and lower metallicity than their face-on counterparts.



Summary

1. Traditional structural measurements suffer from **severe inclination biases**.
2. The authors present an alternative method for measuring structural parameters (**the linear brightness profile**), which is inclination independent.
3. For **intrinsically MW-like galaxies**, most photometric, structural, and spectral-line-based measurements depend strongly on inclination and dust attenuation.
4. These systematic errors in SDSS structural and spectral measurements **may impact a wide range of studies**.
5. This work highlights the **importance of IR imagery** (e.g., JWST).