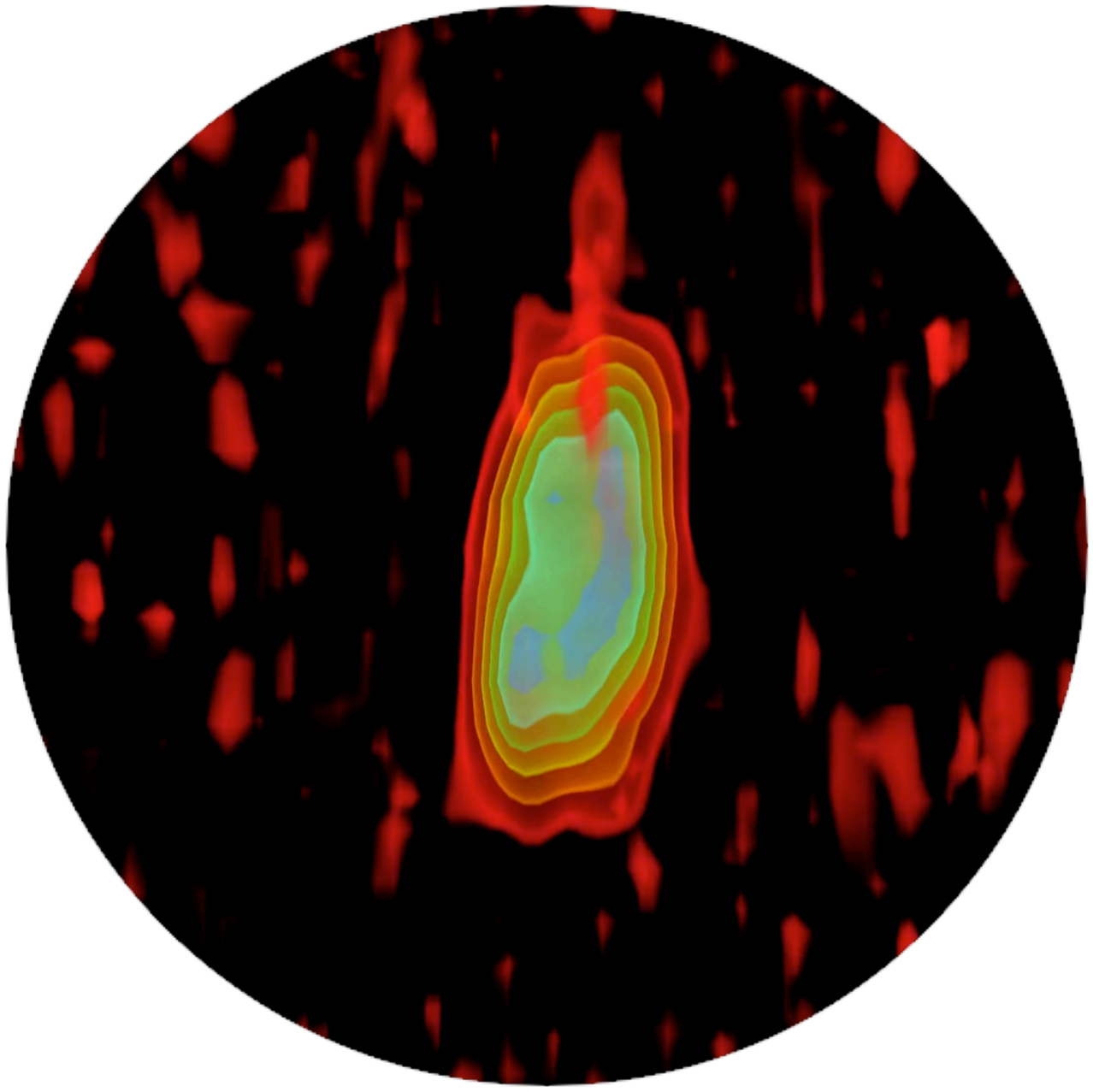
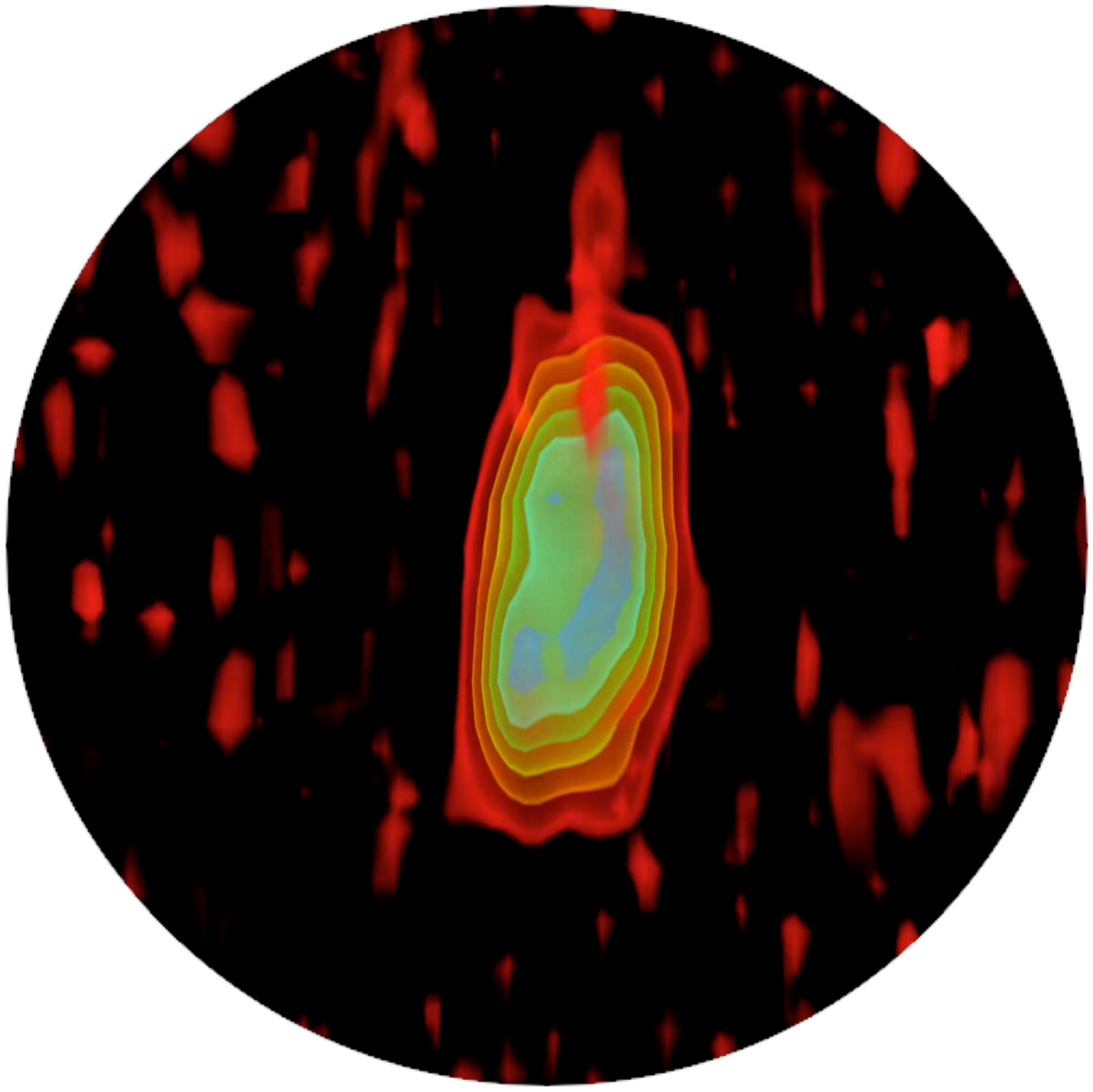


HI-rich, ultra-diffuse galaxies lie way above the baryonic Tully-Fisher relation

Kyle Oman (Kapteyn Institute → Durham ICC)



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Pavel Mancera Piña

Filippo Fraternali, Betsey Adams,
Antonino Marasco, Tom Osterloo
Lucas Leisman

Michael Battipaglia, John Cannon, Lexi Gault, Martha Haynes,
Steven Janowiecki, Elizabeth McAllan, Hannah Pagel,
Kameron Reiter, Katherine Rhode, John Salzer, Nicolas Smith

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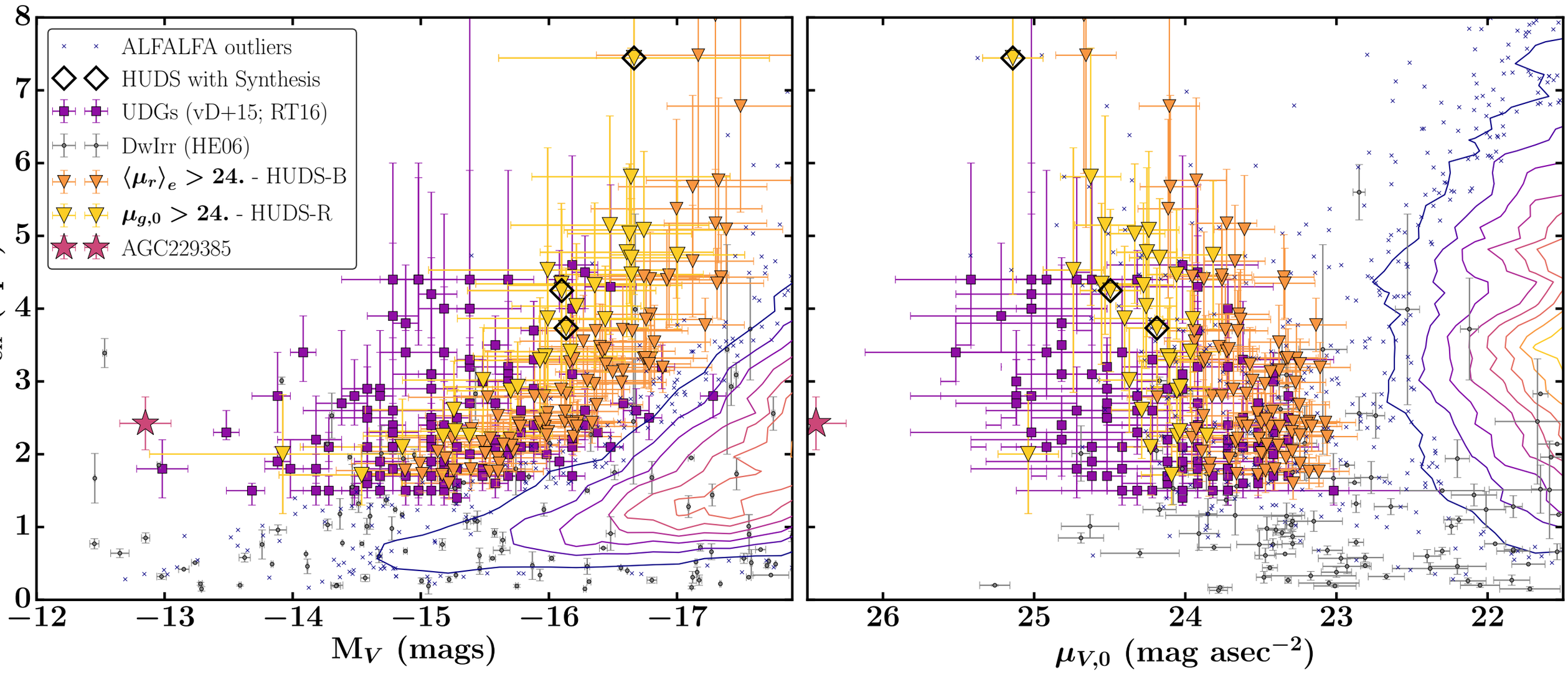
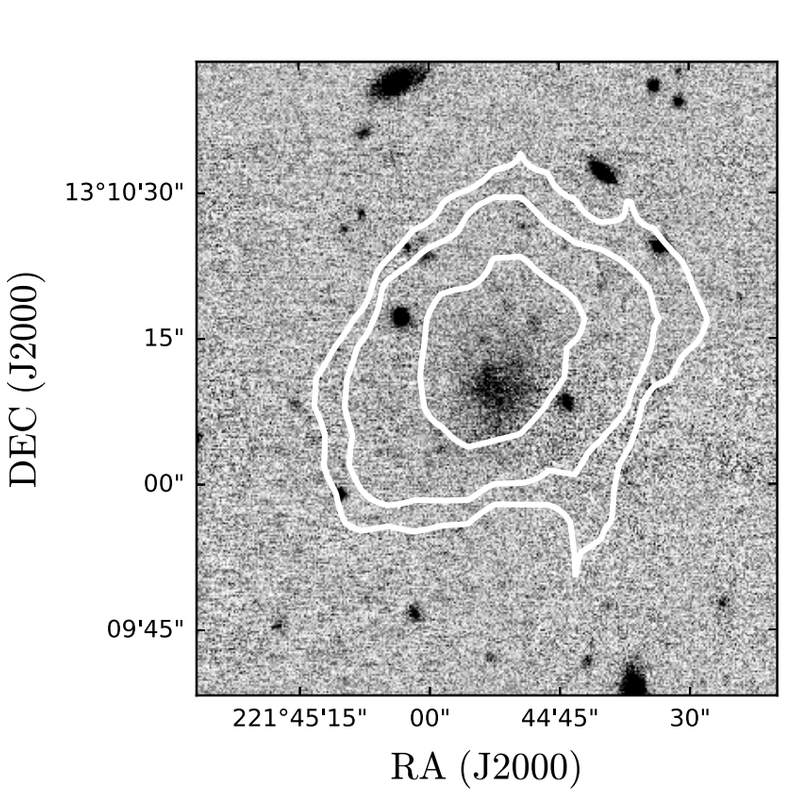
Sample & Method

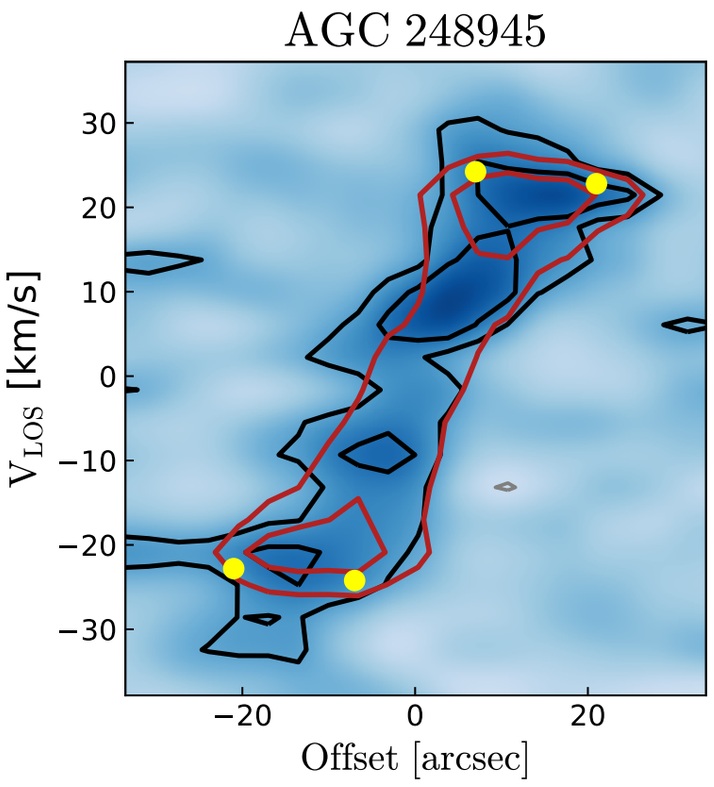
- Parent sample from Leisman et al. (2017), 30 objects

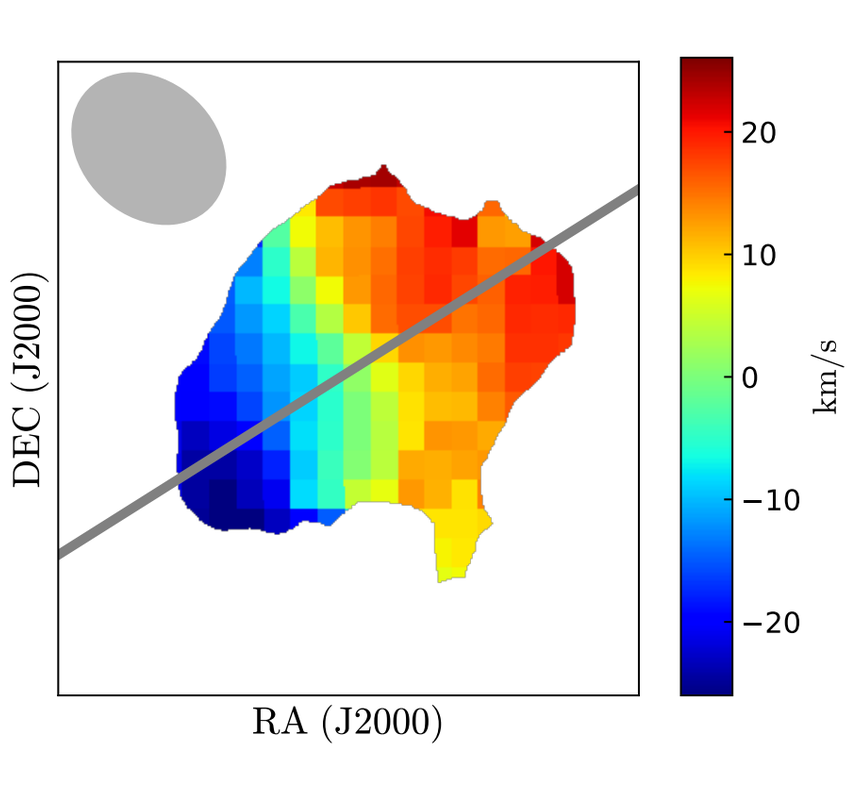


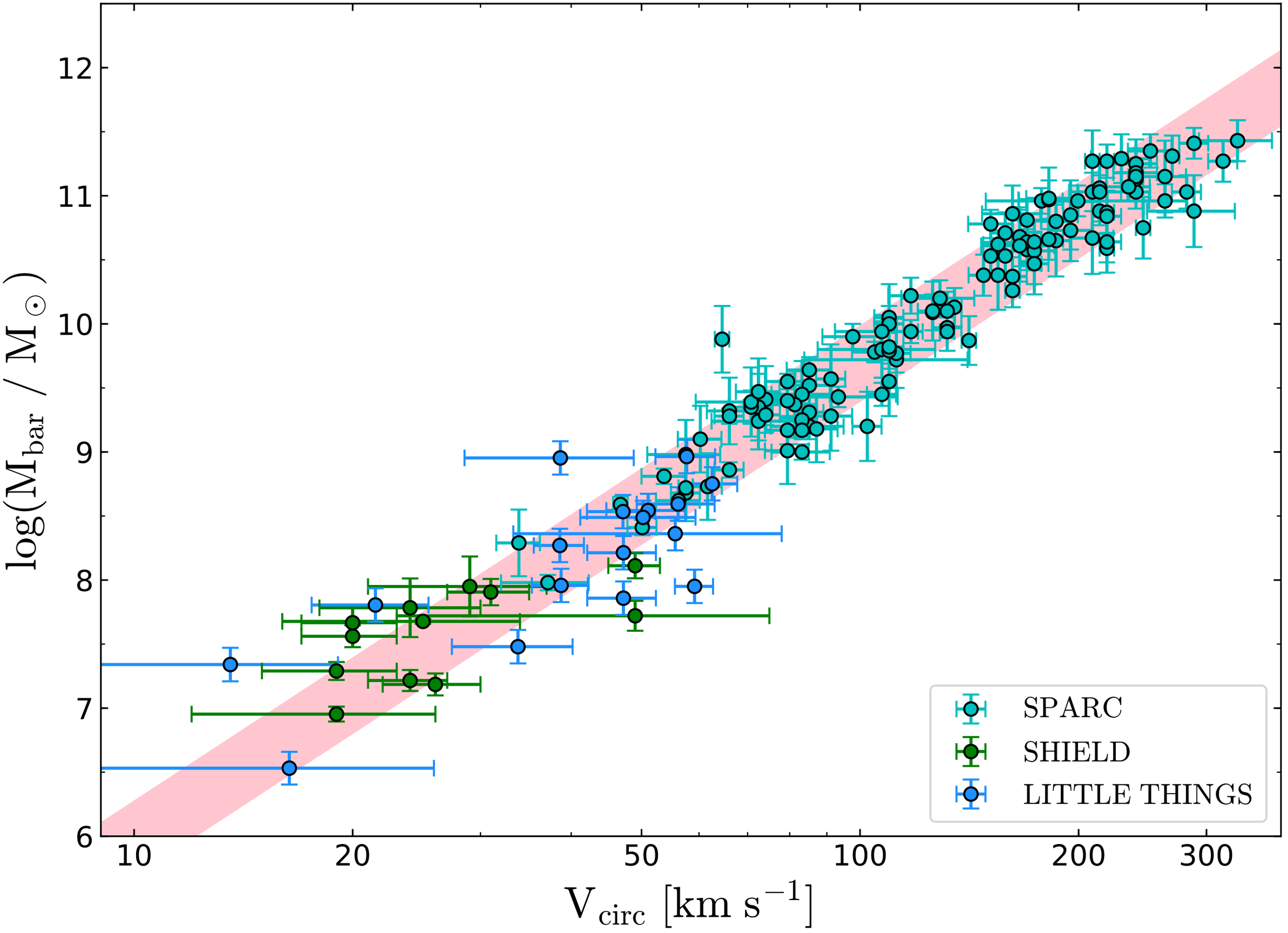
Sample & Method

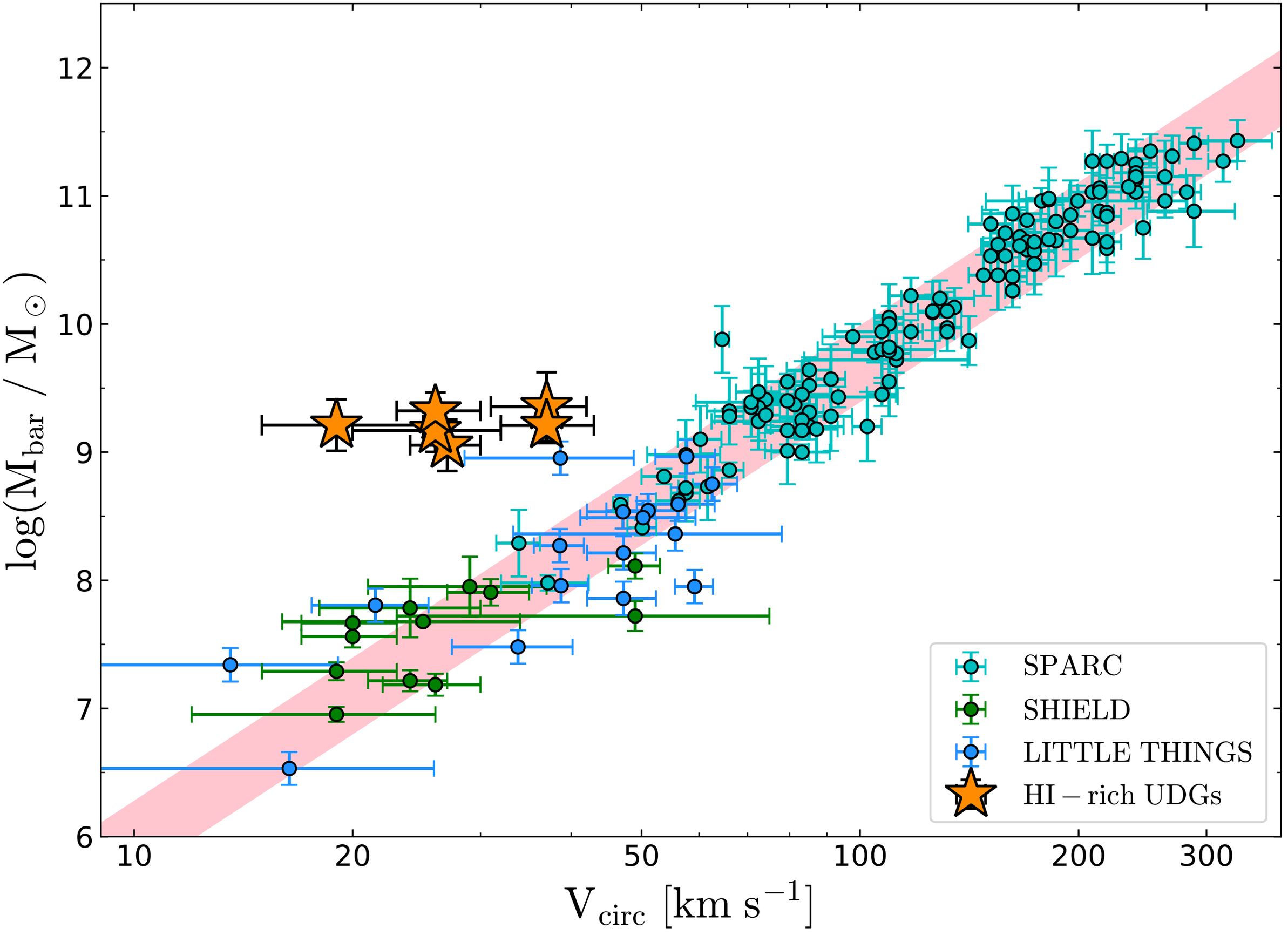
- Parent sample from Leisman et al. (2017), 30 objects
- UDGs : from SDSS, $\langle \mu_r(R_e) \rangle \geq 24\,\mathrm{mag/arcsec^2}$ and $R_e > 1.5\,\mathrm{kpc}$
- Gas rich : from ALFALFA, $M_{\mathrm{HI}} \sim 10^9\,\mathrm{M}_\odot$
- Isolated : any ALFALFA detections within $500\,\mathrm{km/s}$ has $D > 350\,\mathrm{kpc}$
- Observed with Karl G. Jansky Very Large Array (C configuration), or Westerbork Sythesis Radio Telecope
- 6 objects with useable data, kinematic modelling using 3D-BAROLO








log(M_bar / M_⊙)
V_circ [km s^-1]
12
11
10
9
8
7
6
10
20
50
100
200
300
SPARC
SHIELD
LITTLE THINGS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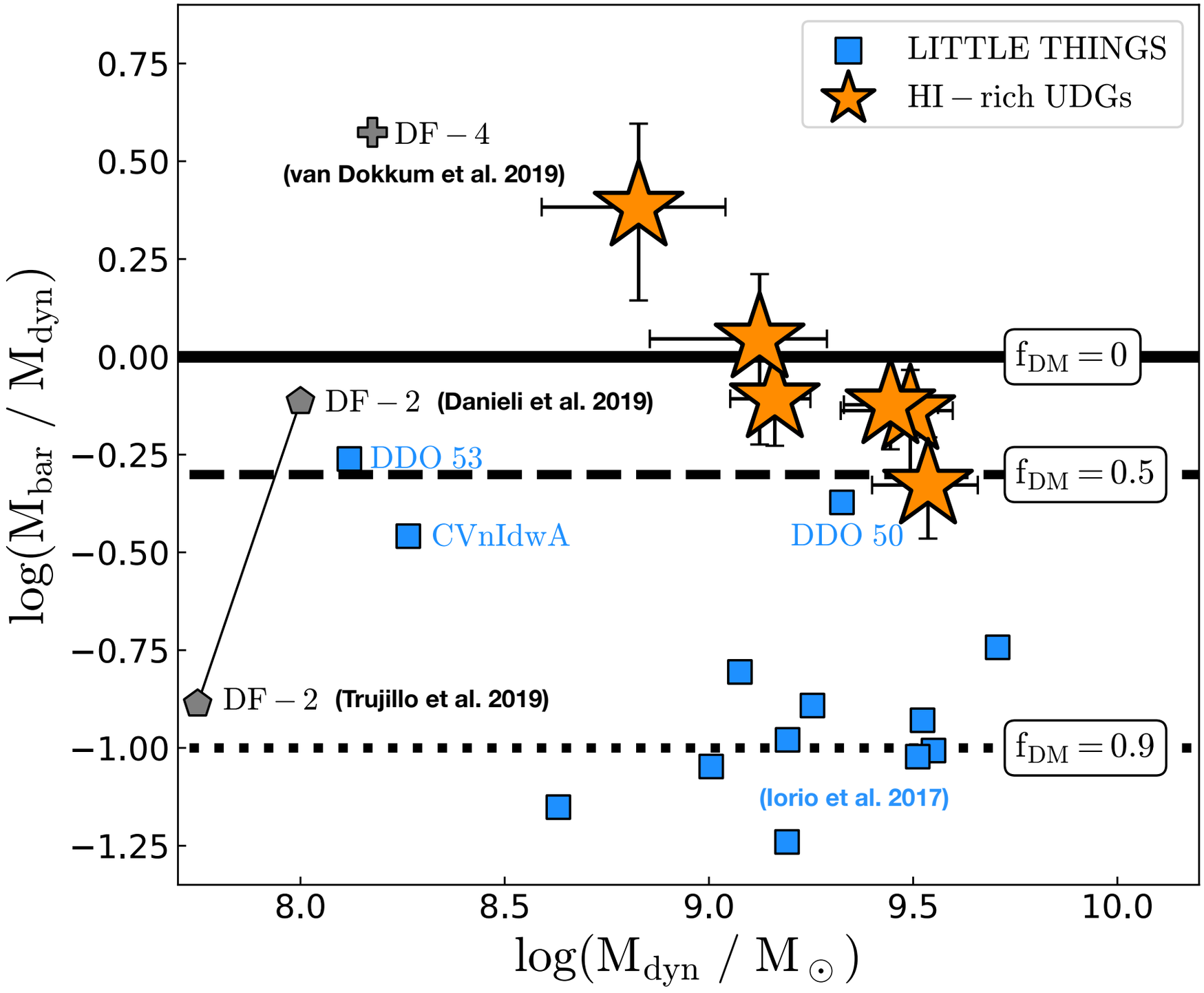
HI − rich UDGs

Baryon-dominated within $R_{\rm out}$



Systematic errors, biases

- **Distance** — At 70-90 Mpc Hubble flow is robust.
- **HI mass** — ALFALFA & VLA/WSRT fluxes agree.
- **Stellar mass** — $M_\star \ll M_{\rm HI}$
- **Outer radius** — 7-18 kpc should reach flat part of rotation curve.
- **Beam smearing** — 3D-BAROLO convolves beam with model to compare with data.
- **Inclination** — All 6 galaxies would need $i \sim 10 - 20°$.

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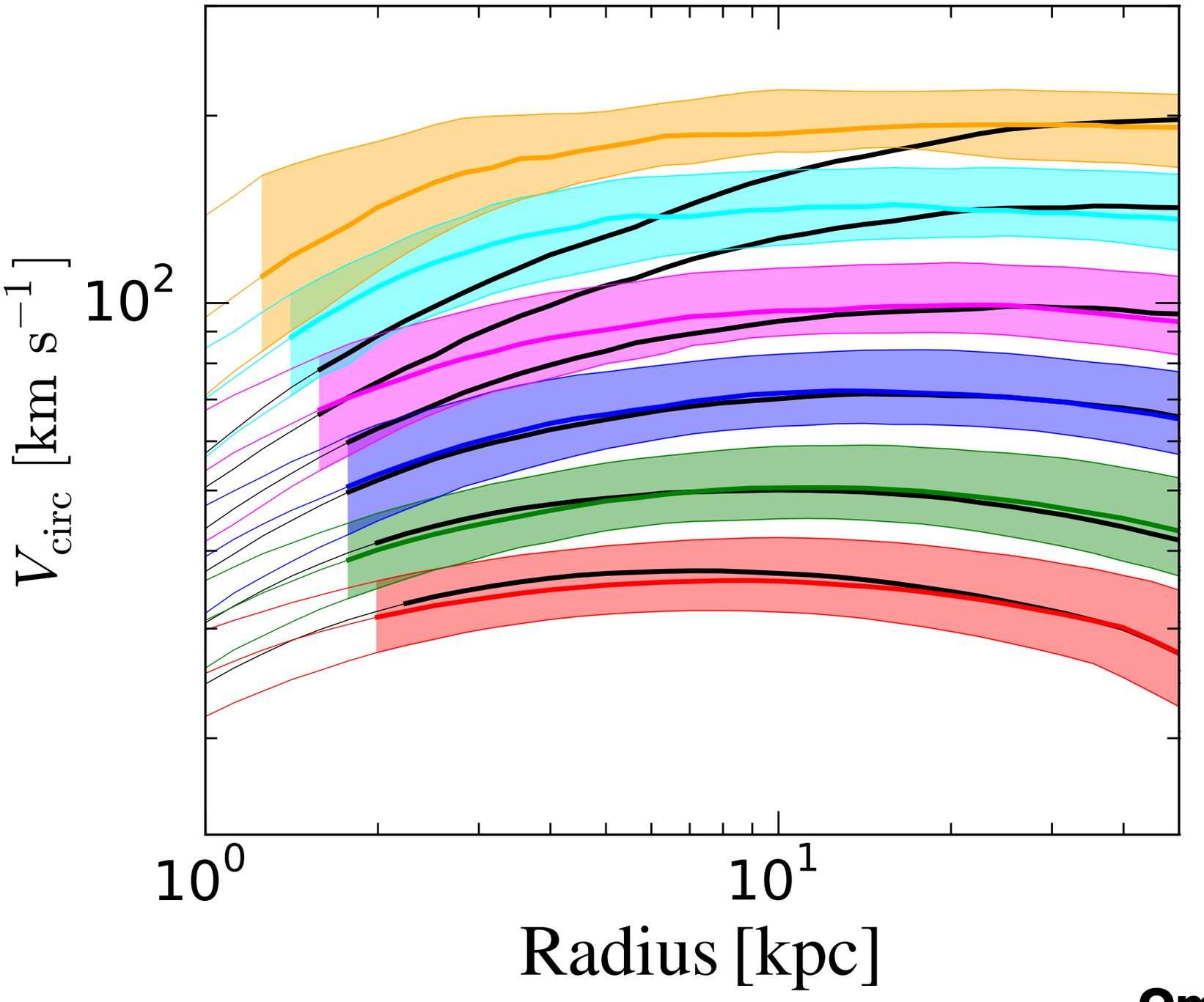

Oman et al. (2015)

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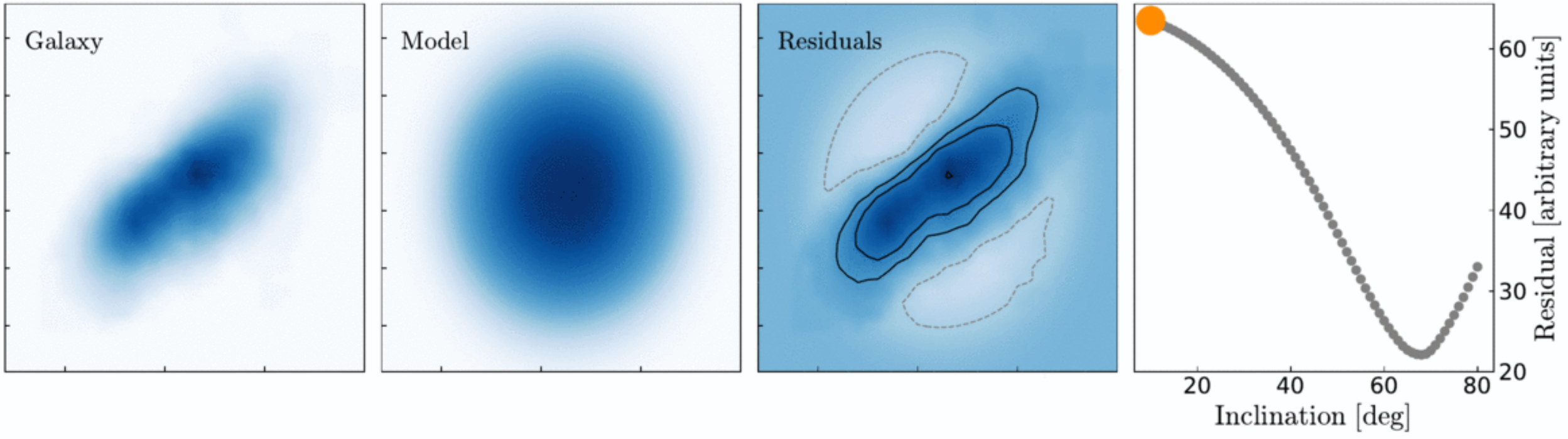
Inclination tests

- Sample of 4 simulated galaxies from the APOSTLE suite.
- Similar HI masses to HI-rich UDG sample, but lie on BTFR.
- "Observed" at several inclinations using MARTINI code.
- Matched beam, S/N, distance, channel width, etc.
- Construct models at different inclinations and compare to "observations".



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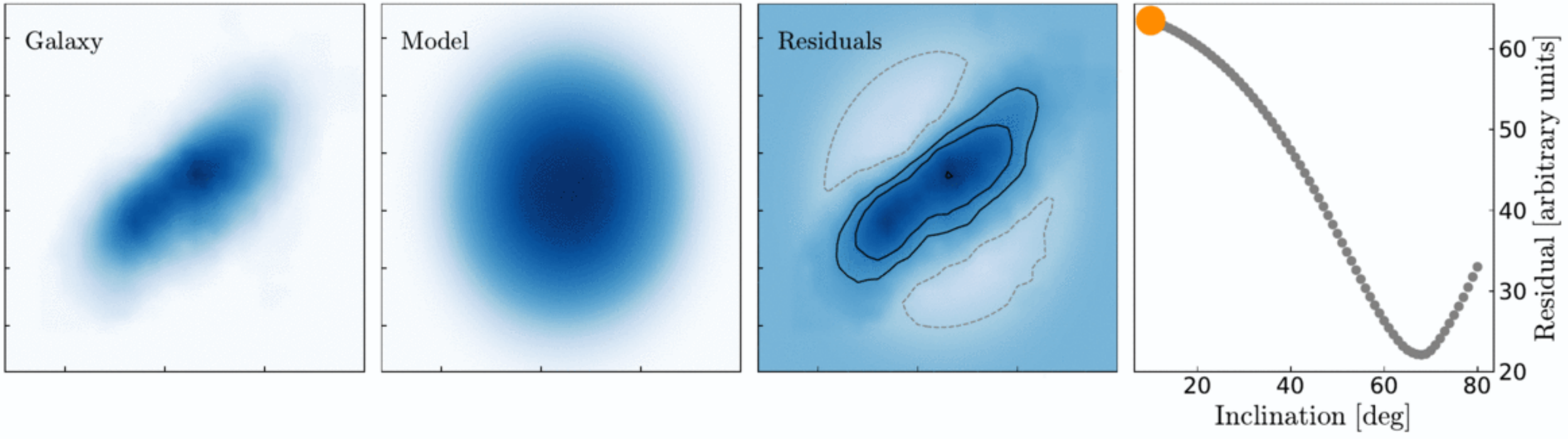

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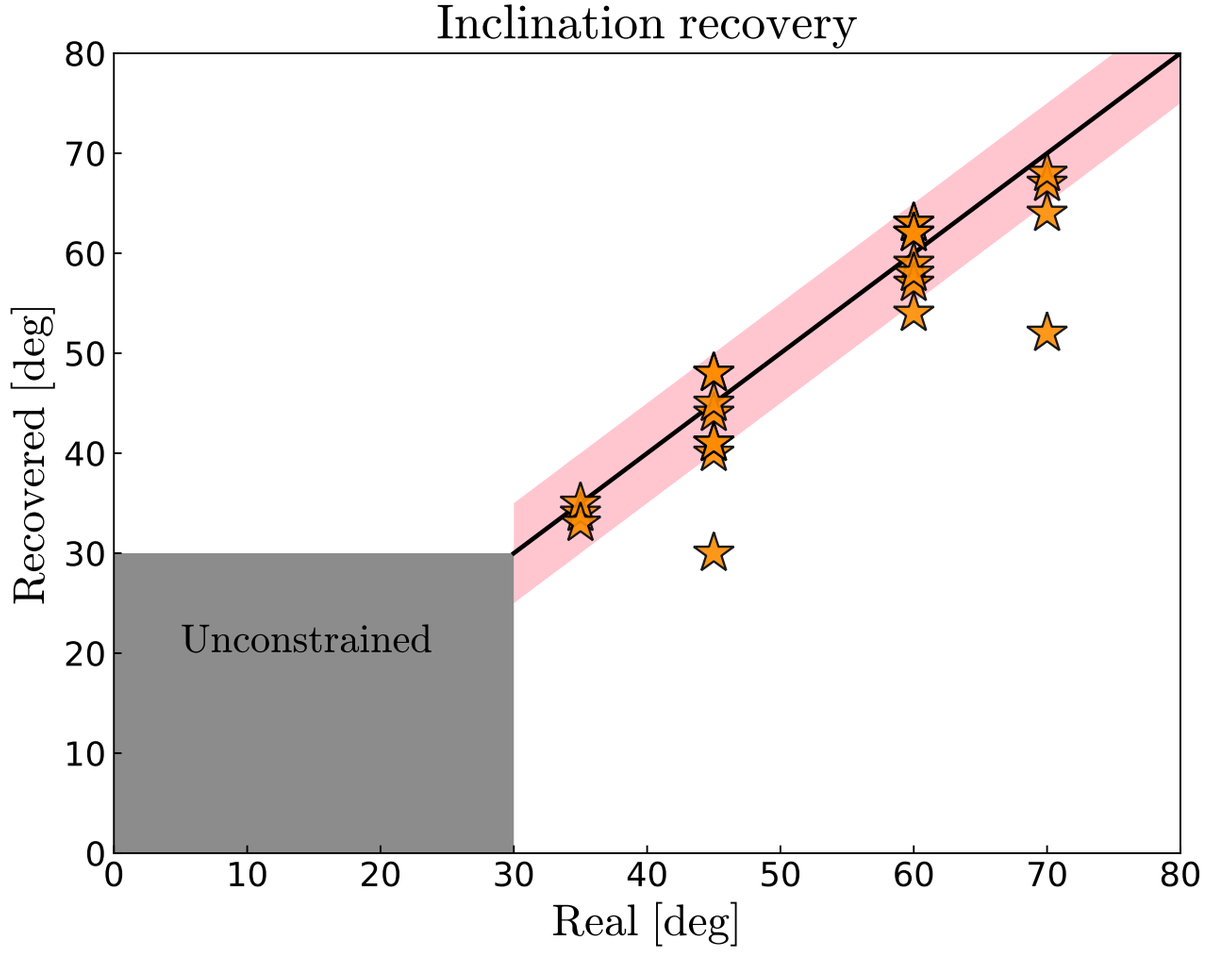
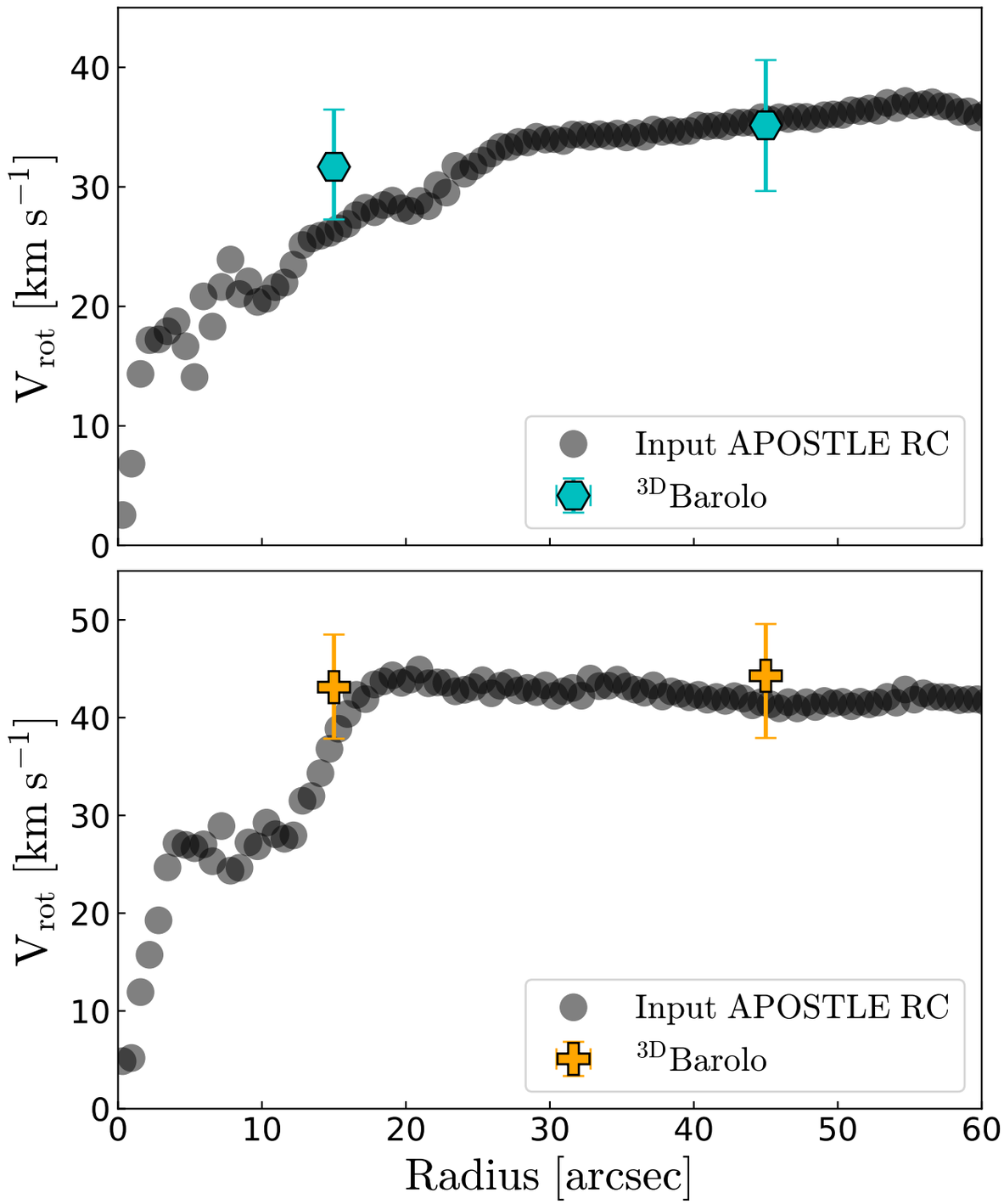


Kinematic modelling tests

- Same mock-observed sample from APOSTLE.
- Fully blind analysis.
- Reliably recover $V_{\rm max}$ within estimated error.



Finally some cosmology

- High spin ↔ low concentration DM halos?
  - $V_{\rm max}$ drops and occurs further out.
  - Need to be in $\sim 4-5\sigma$ tail of distribution.
  - Given parent survey volume expect $\ll 1$ such object.
- MOND?
  - Fail strong prediction for BTFR: $M_{\rm bar} \propto V^4$.

Finally some cosmology

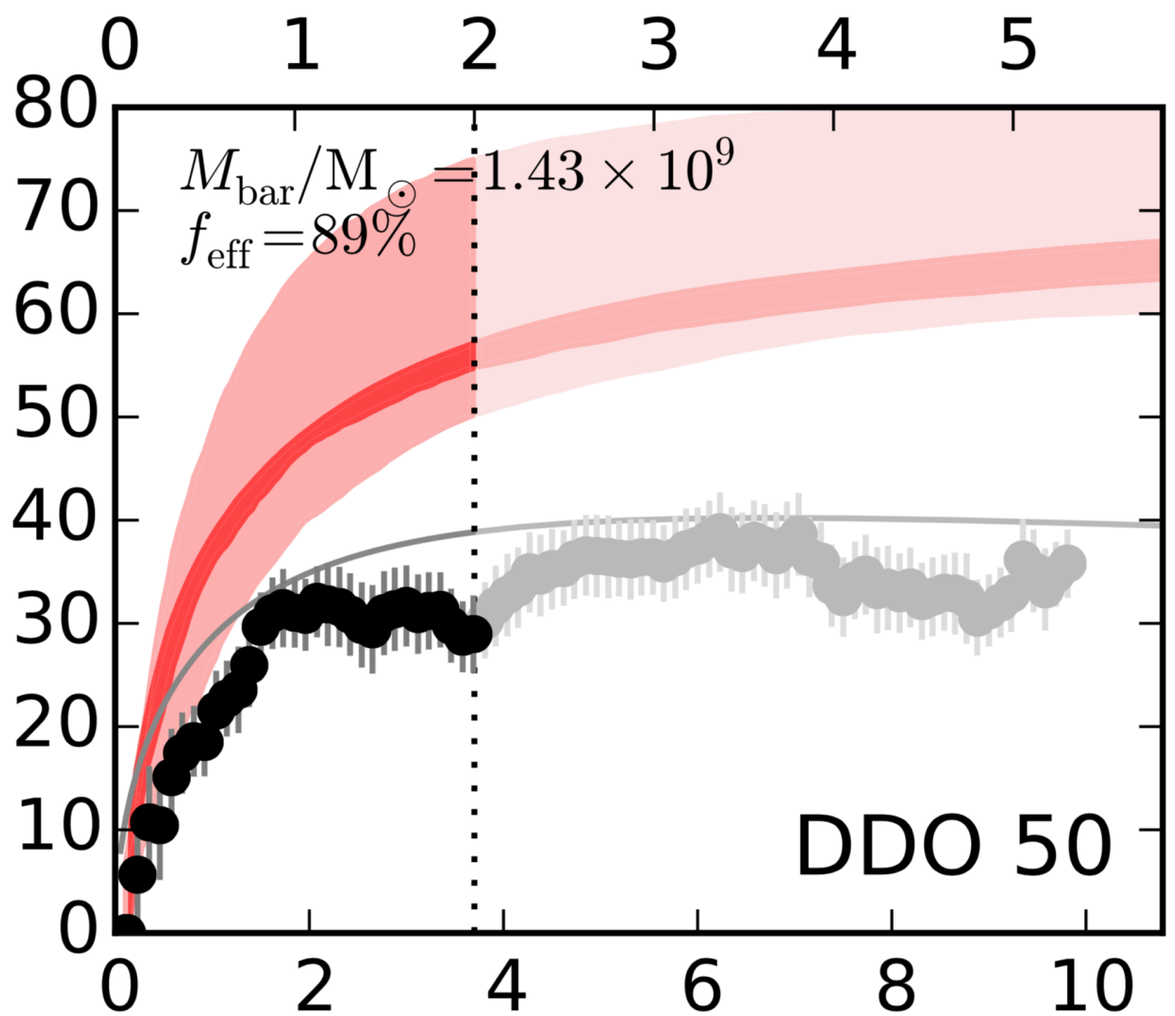
- Extremely inefficient feedback?
  - Helps explain extreme $M_{\rm bar}/M_{\rm dyn}$.
  - Consistent with low velocity dispersions.
  - May conflict with some dwarf formation models, e.g. feedback-driven UDG formation, dark matter core formation.

Finally some cosmology

- Out of dynamical equilibrium?
  - Why should 6 out of 6 be out of equilibrium?
  - What prevents them from equilibrating?
- Triaxial DM haloes?
  - Should cause over- and underestimates of $V_{\rm max}$ with equal probability.

Missing dark matter in dwarf galaxies?

- With only ~2 "clear" examples, conclusions were tentative.
- We attributed "missing DM" in DDO 50 to an inclination error.
- Not quite in the UDG regime with $\mu_{R,0} = 22.5$, but seems like an interesting, well-resolved target.
- Time to revisit other previously dismissed "BTFR outliers"?



Oman et al. (2016)

Summary

- Seemingly real outliers of the BTFR, with bizarre implications.
- Time to revisit outliers in other areas? The LSB Universe seems to be full of surprises.

Mock HI observing:

MARTINI
Mock APERTIF-like Radio Telescope Interferometry of the Neutral ISM

github.com/kyleaoman/martini

Kinematic modelling:

BBAROLO
3D Based Analysis of Rotating Objects via Line Observations

editeodoro.github.io/Bbarolo/

Title slide visualization:

kapteyn astronomical institute
erc
Slicer Astro

github.com/Punzo/SlicerAstro