Diversity of dwarf galaxy rotation curves:
baryons, dark matter or non-circular motions?

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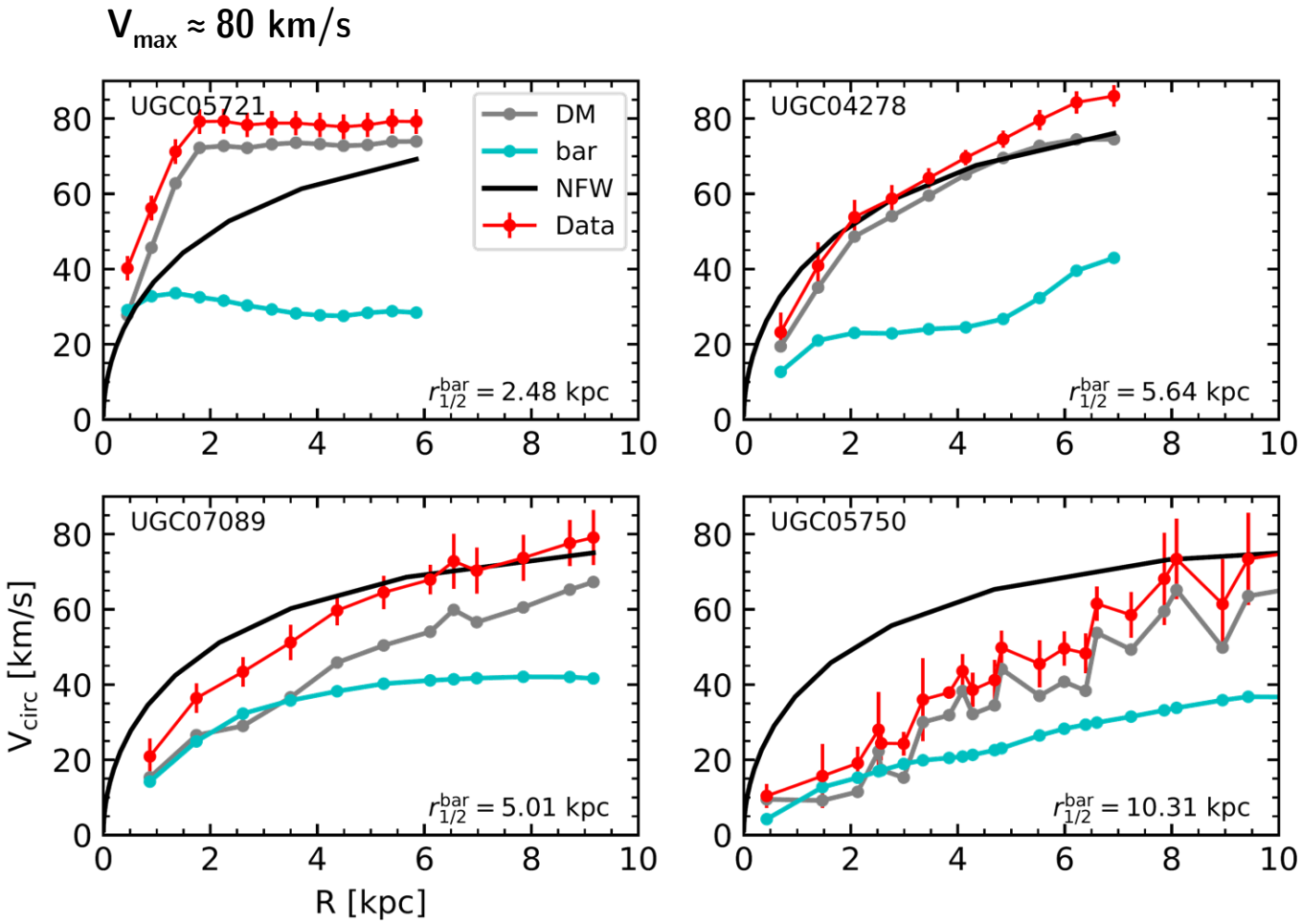
Diversity of rotation curve shapes in observed disc galaxies

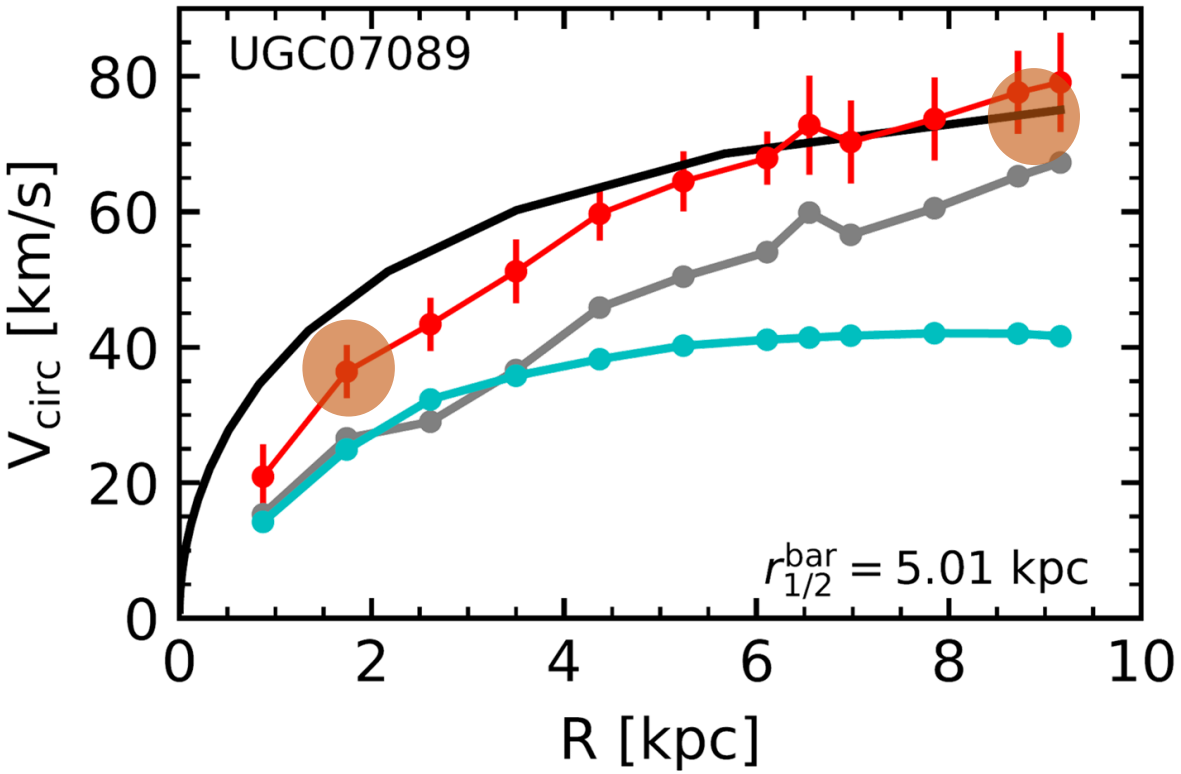


- Dwarf galaxies present a wide diversity of rotation curve shapes
- CDM predicts a single profile for a given velocity scale, *unlike* observed rotation curves
- Some galaxies are consistent with CDM, others are not: either "cuspier" or "cored"

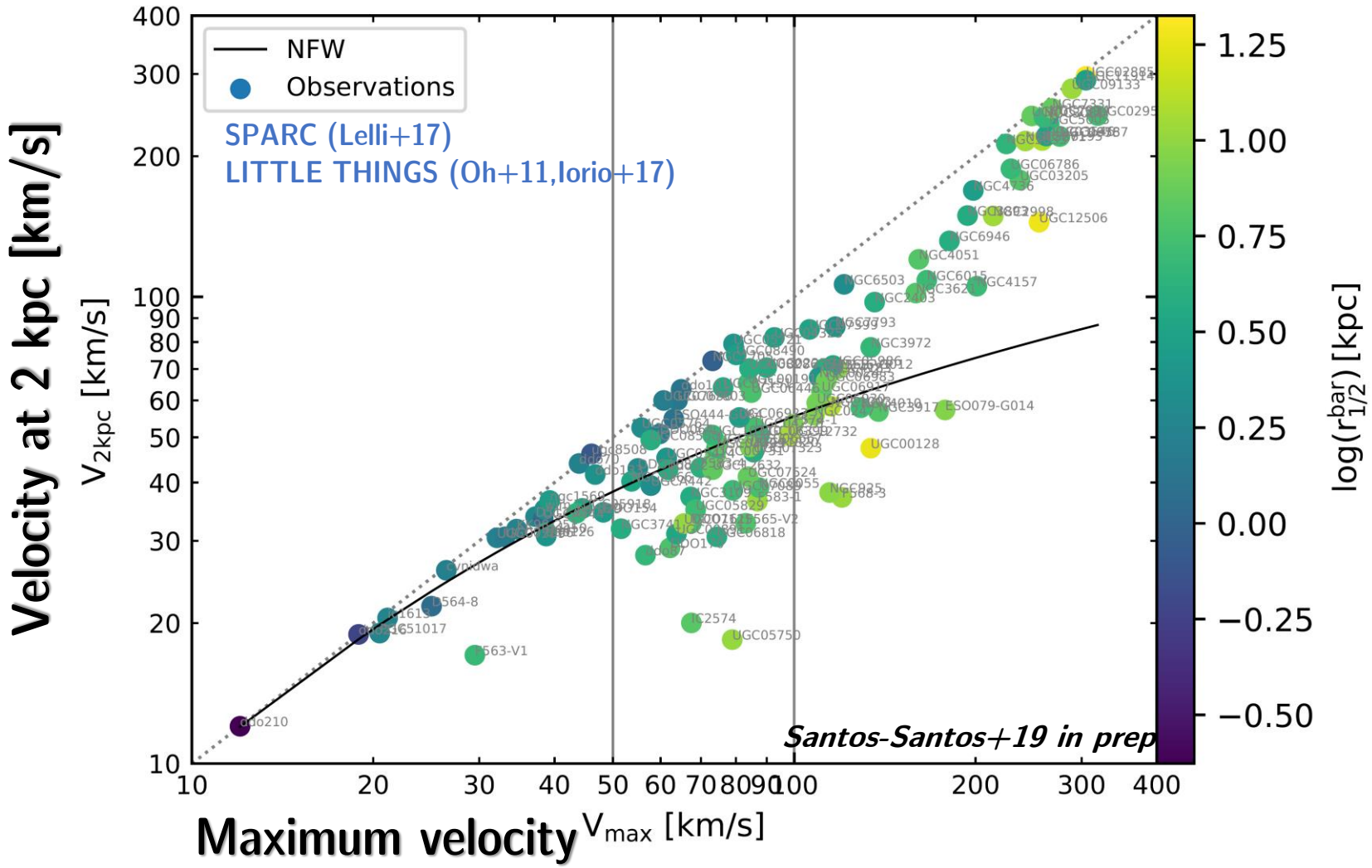
Diversity of dwarf Galaxy rotation curves problem (Oman+15)=="Cusp-core problem" (see Moore94, de Blok+08, Oh+15)

Diversity of rotation curve shapes in observed disc galaxies

Diversity can be quantified by comparing:

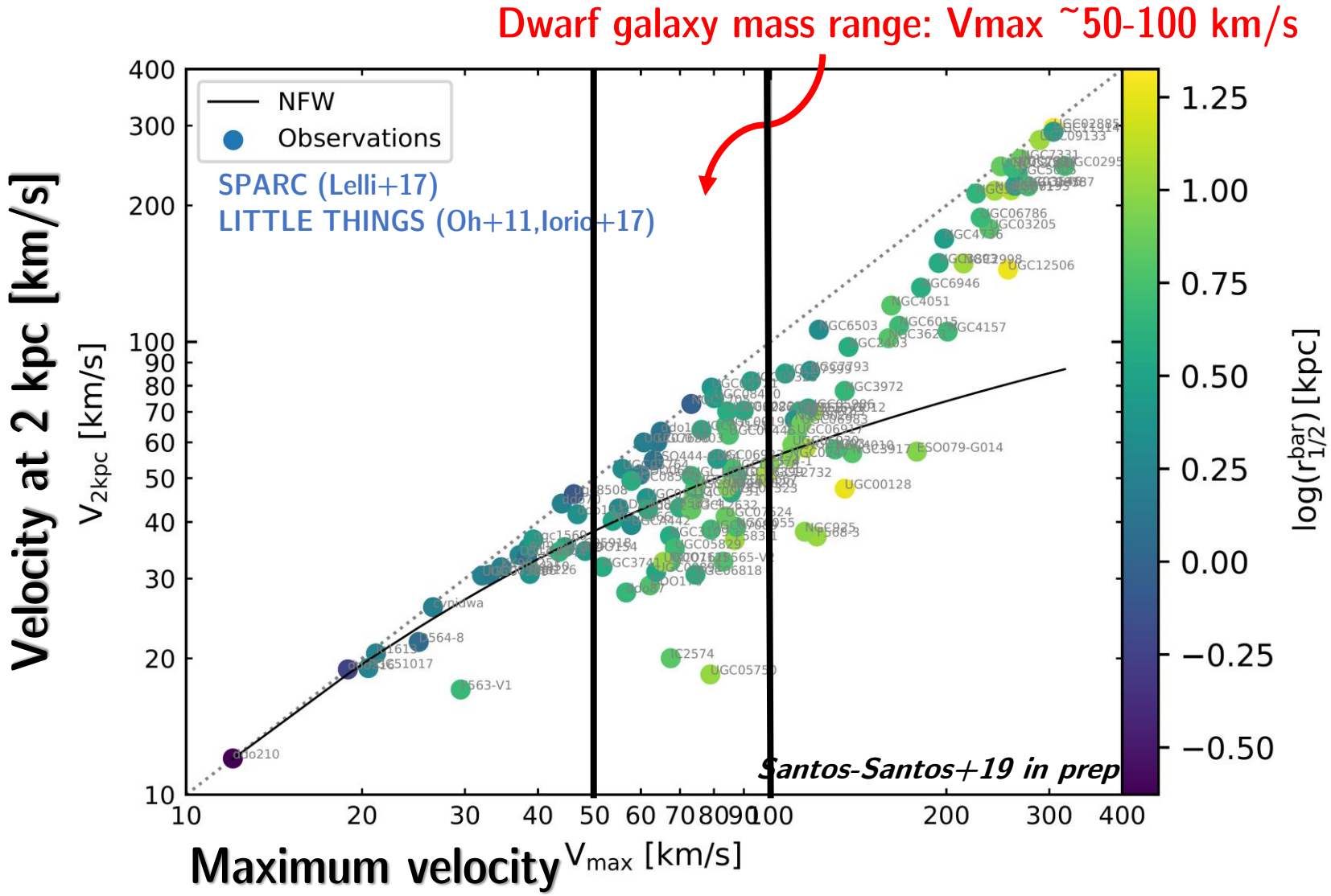


Diversity of rotation curve shapes in observed disc galaxies



See Oman+15,Santos-Santos+18

Diversity of rotation curve shapes in observed disc galaxies



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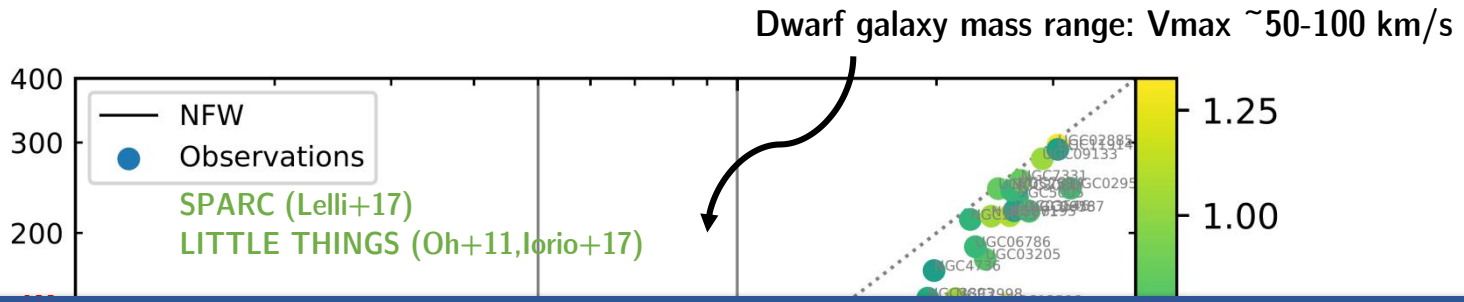


Possible solutions to the "Rotation curve diversity problem"

a) Galaxy formation can modify DM mass profiles?

b) DM is not CDM (e.g., self-interacting, SIDM)?

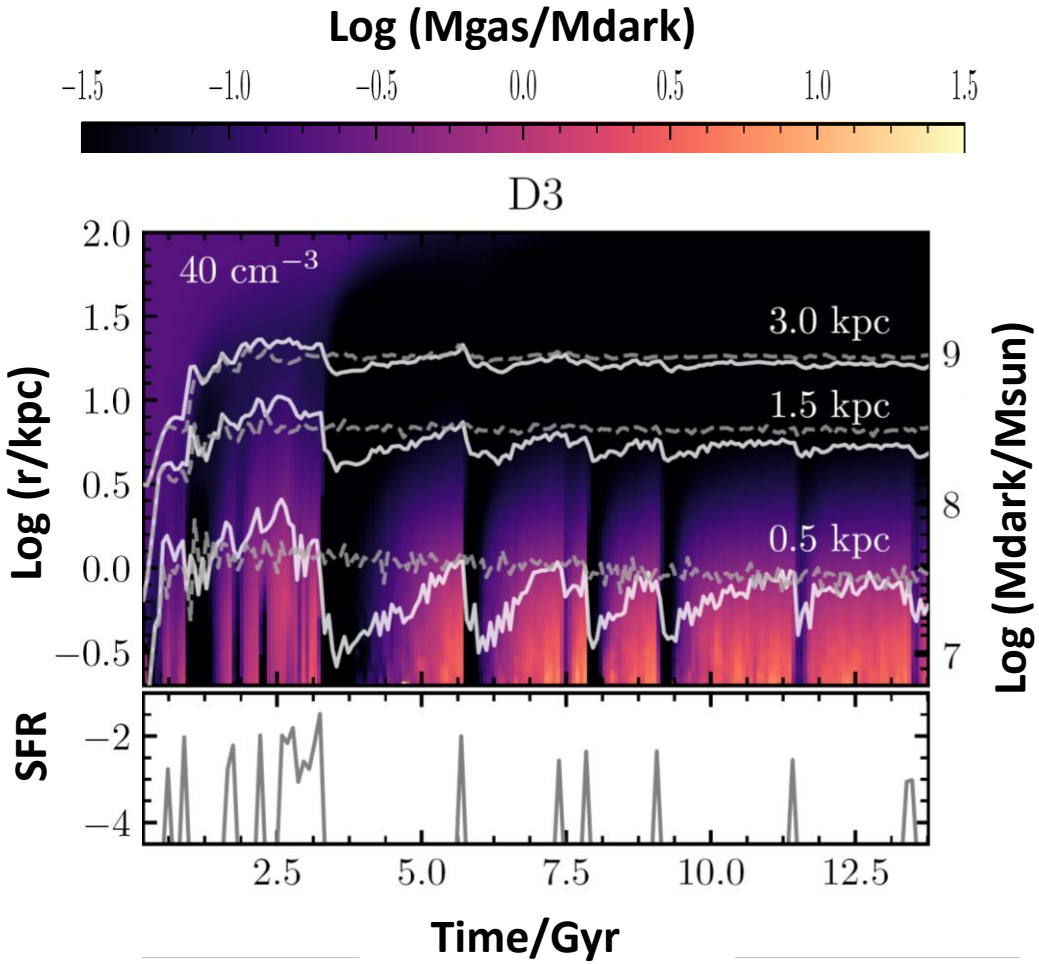
c) Uncertainties in data modeling and gas non-circular motions?

Velocity outer radii: maximum velocity

See Oman+15,Santos-Santos+18

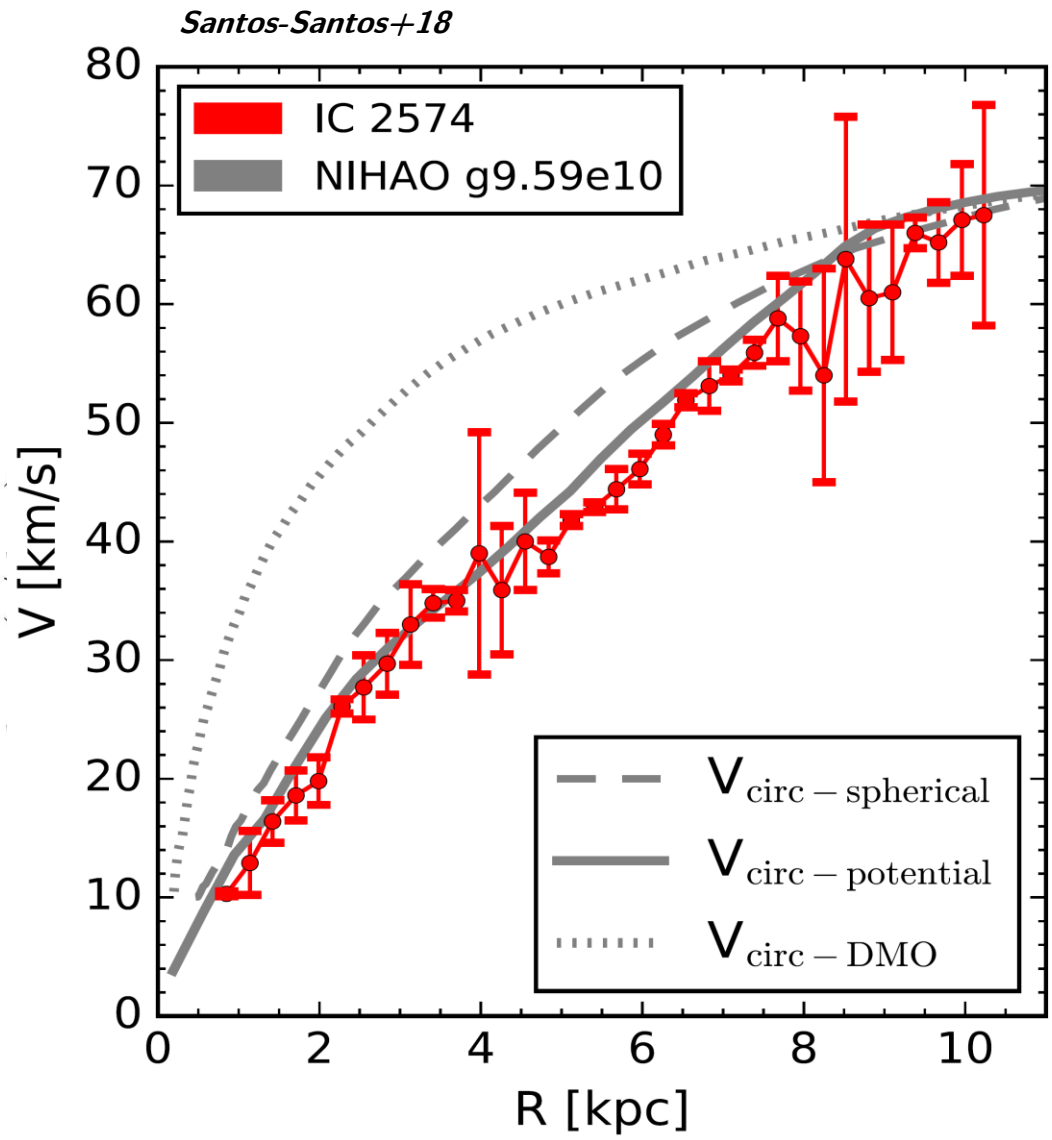
A) Galaxy formation can modify DM profile: baryon-induced cores

Benitez-Llambay+18



- Supernova explosions may lead to massive gas outflows that cause variations in the gravitational potential and the consequent reduction of dark matter in the inner regions *(e.g., Navarro+96, Pontzen & Governato12)*
- This creates cores in the dark matter that may be reversed if baryons are re-accreted *(Benitez-Llambay+18, Read+16)*
- It can lead to large rotation curve diversity *(see Santos-Santos+18 with NIHAO simulated galaxies)*

A) Galaxy formation can modify DM profile: baryon-induced cores



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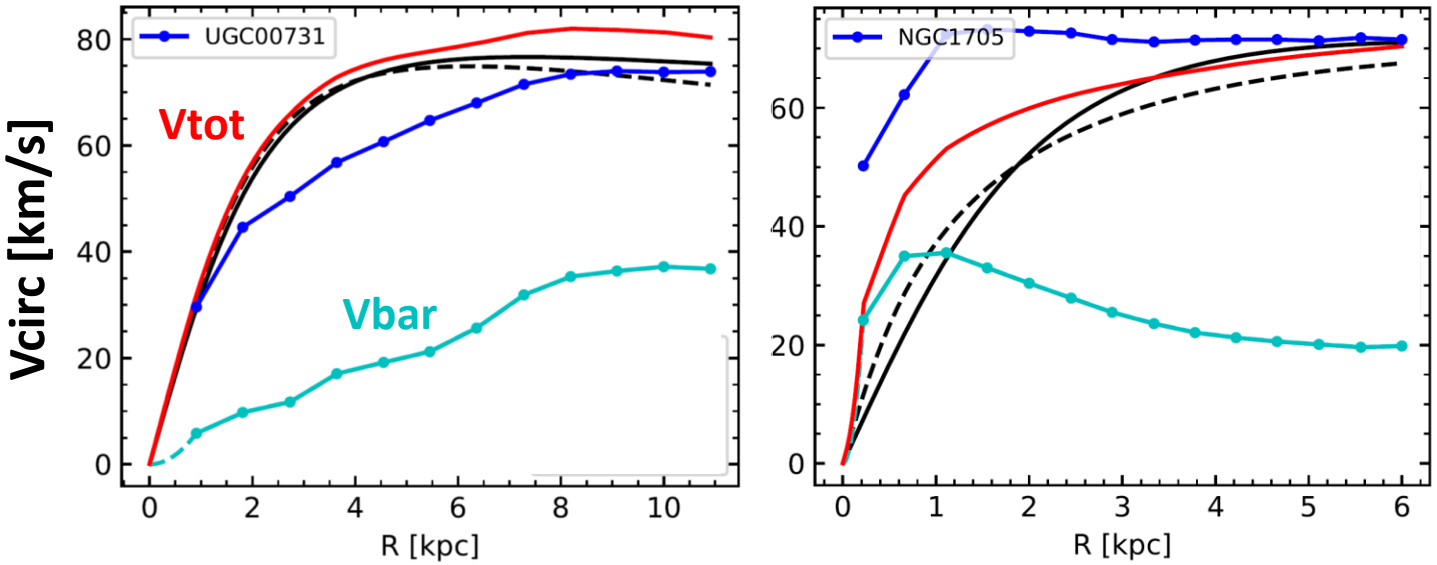
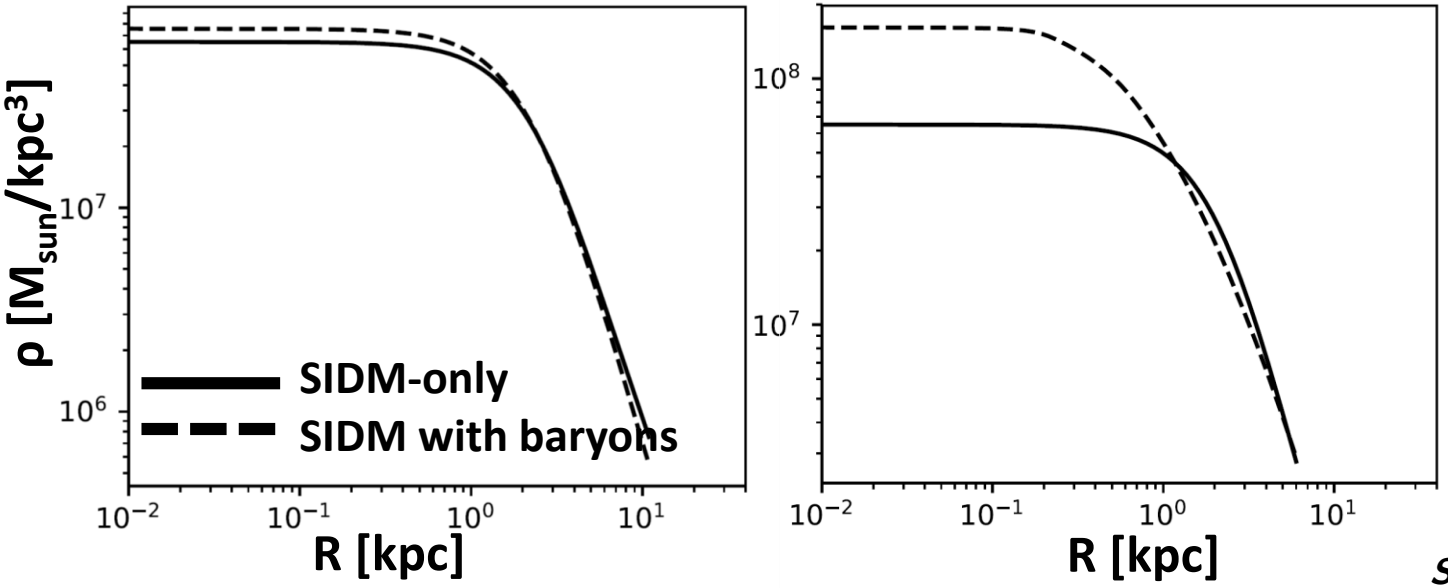
B) Self-interacting dark matter (SIDM)





SIDM → "heat transfer" from the outside in → reduction of dark matter in the inner regions *(e.g.Kamada+16)*

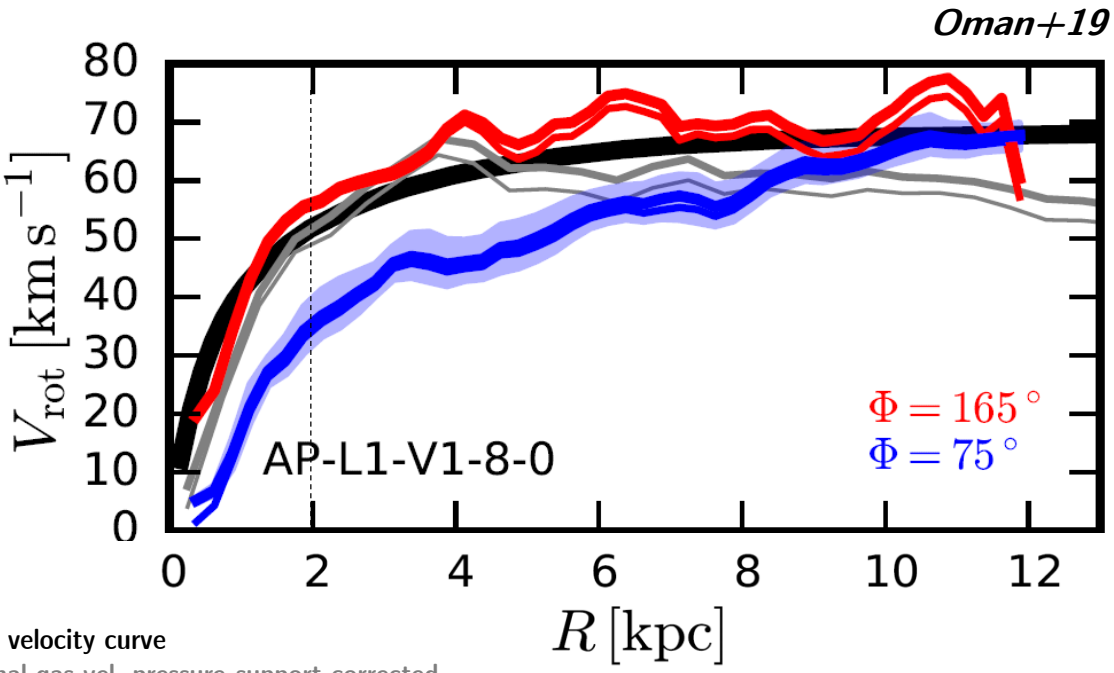
If baryons accumulate to the center, core size decreases → rotation curve diversity *(Kaplinghat+14, Ren+18)*

Santos-Santos+19 in prep

C) Non-circular motions?

Simulated galaxies "observed" *(Oman+19, see also Hayashi&Navarro06, Read+16, Pineda+17)*

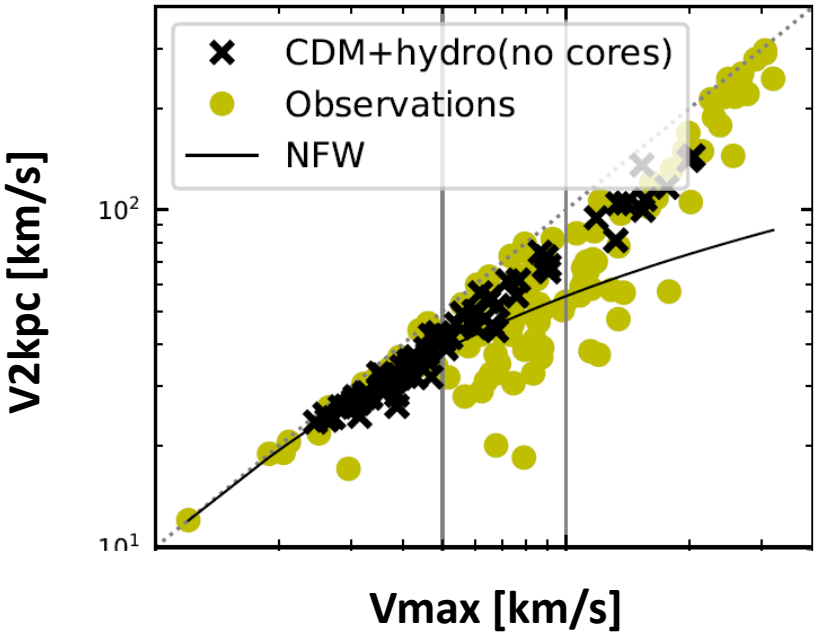
- Synthetic observations of the HI velocity field, using same tools as in observations
- Rotation curves derived using *3D-BAROLO* *(DiTeodoro+Fraternali15)* "tilted-ring" model
- If there are non-circular motions in the gas, velocities are generally underestimated



Circular velocity curve
Azimuthal gas vel. pressure support corrected
Kinematic model pressure support corrected,
different orientations of line-of-sight Φ

Cusp?
or
Core?

How do these scenarios match the diversity?



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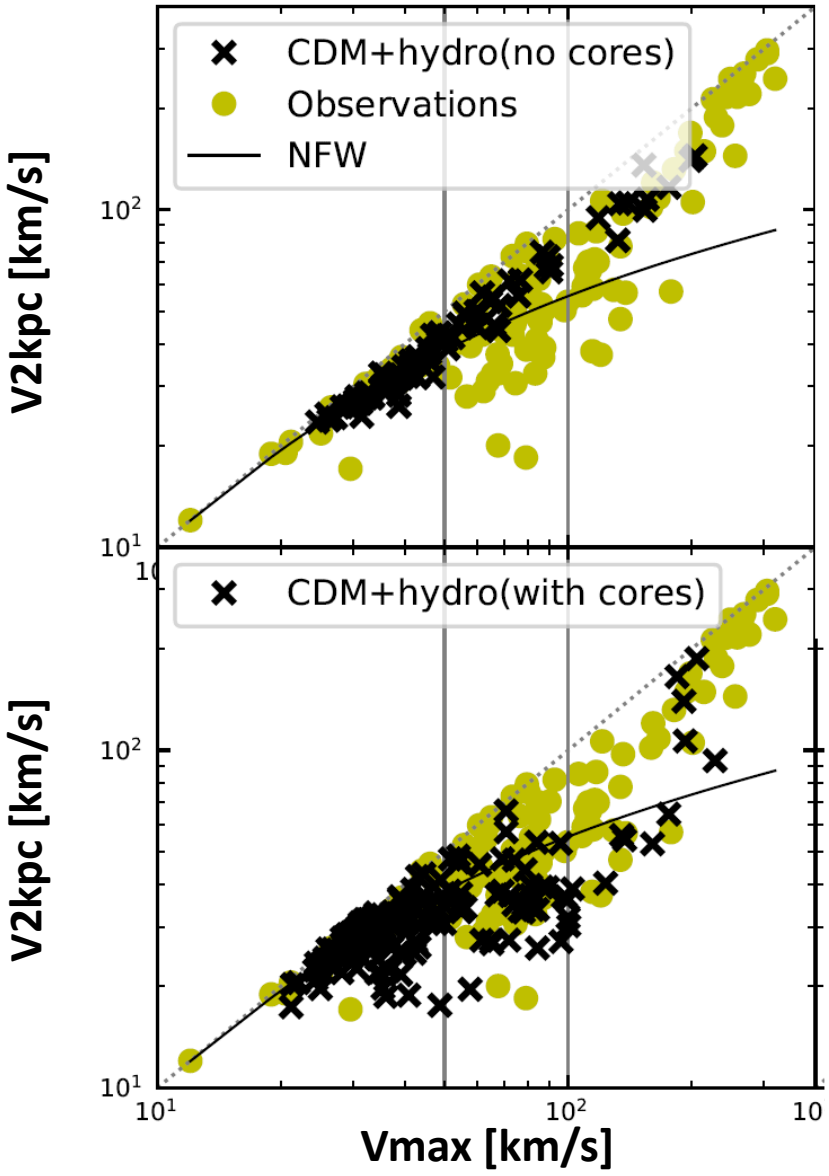

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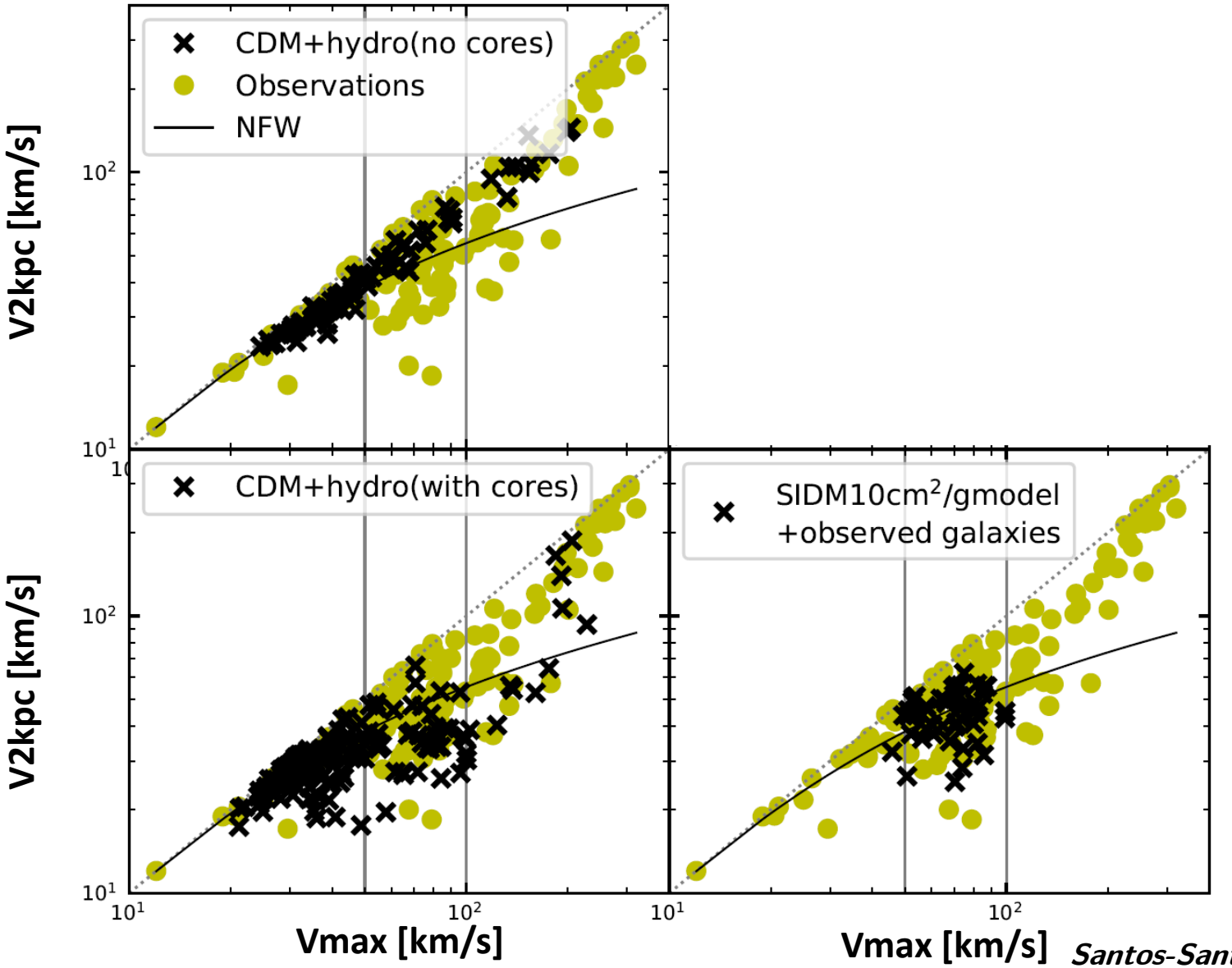

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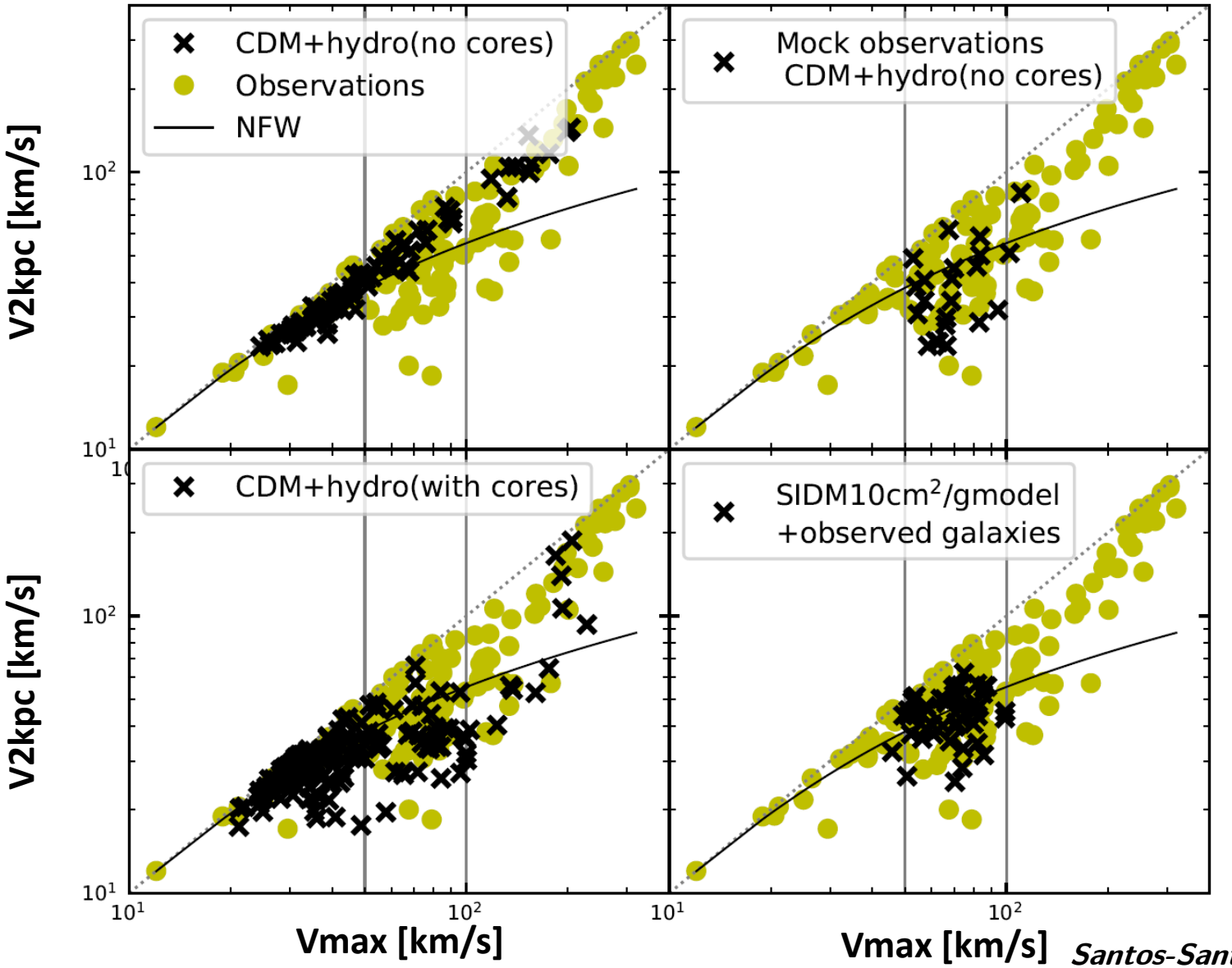

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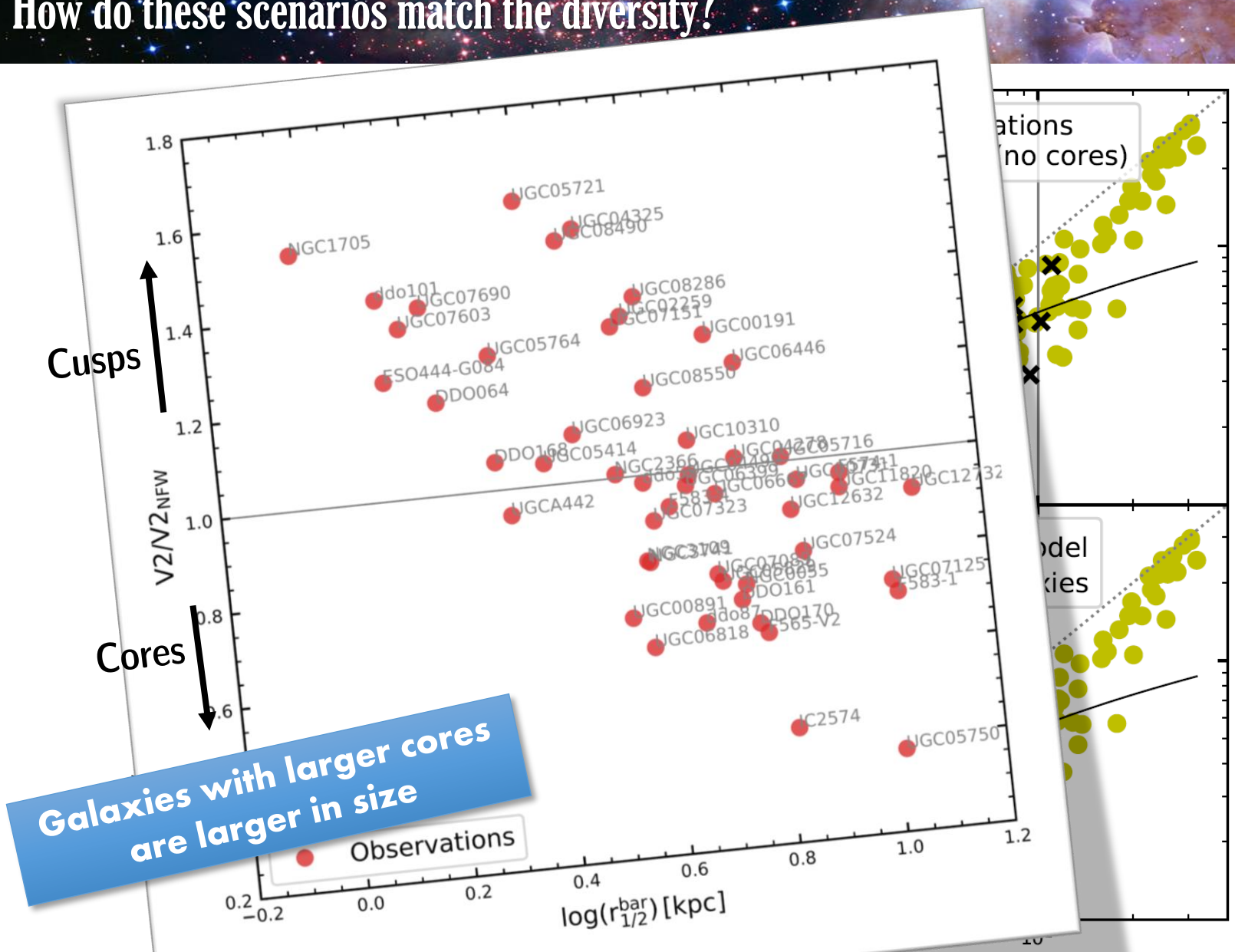

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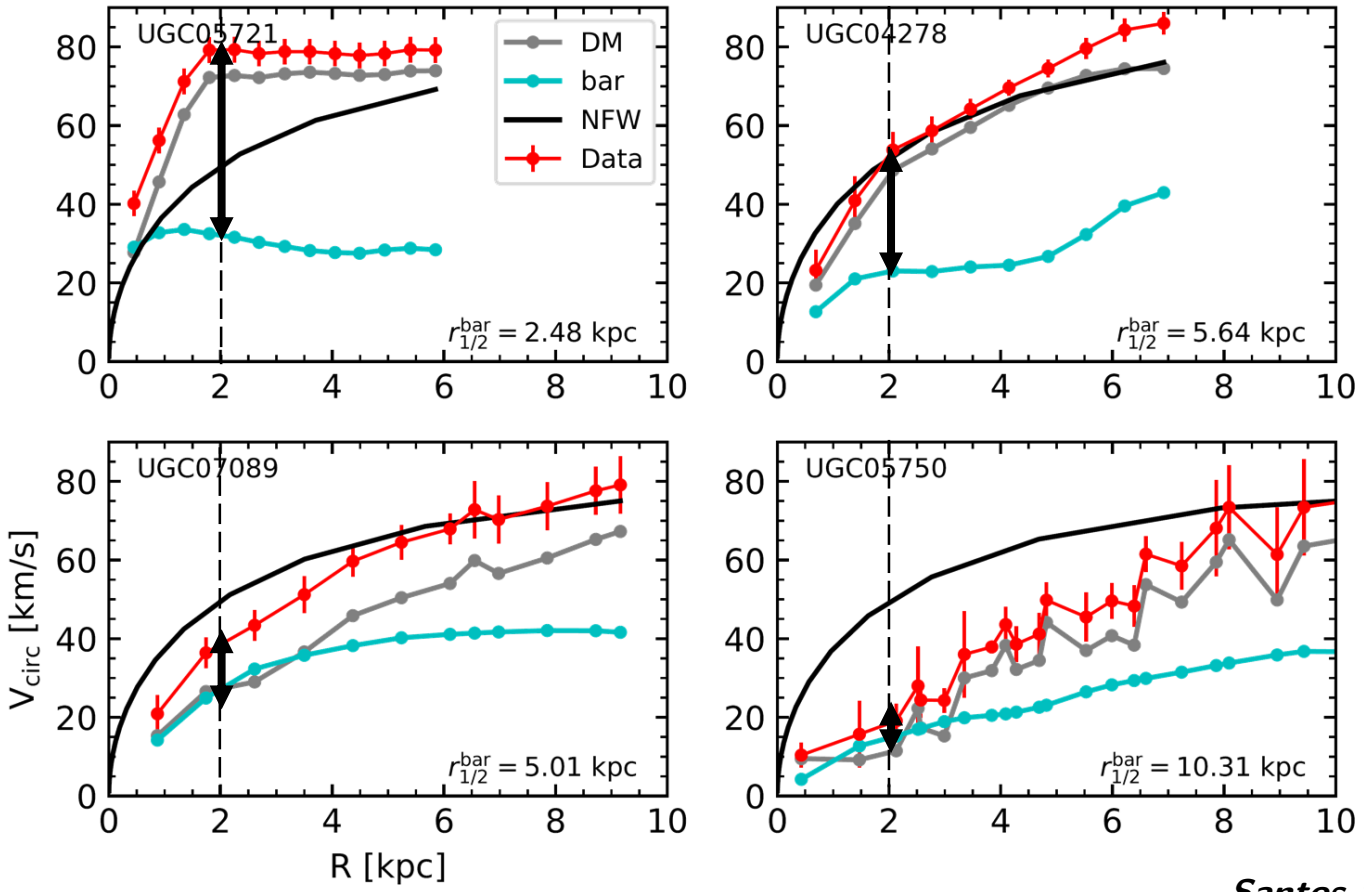
How to tell these scenarios apart?: correlations

$V2_{bar}/V2$ Baryon contribution to total velocity at 2kpc



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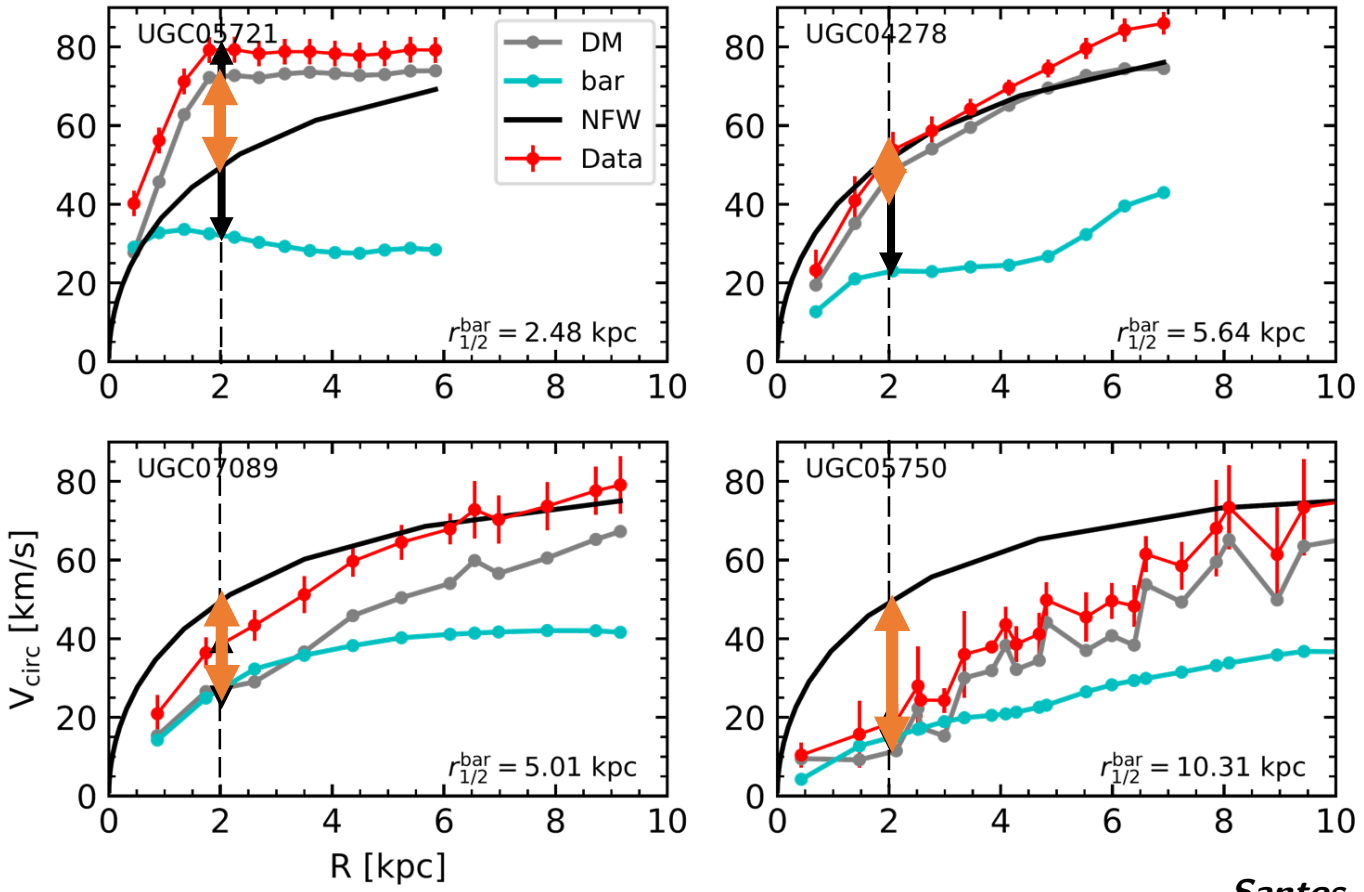
How to tell these scenarios apart? correlations

$V2_{bar}/V2$ Baryon contribution to total velocity at 2kpc

$V2_{DM}/V2_{NFW}$ Dark matter core size at 2kpc



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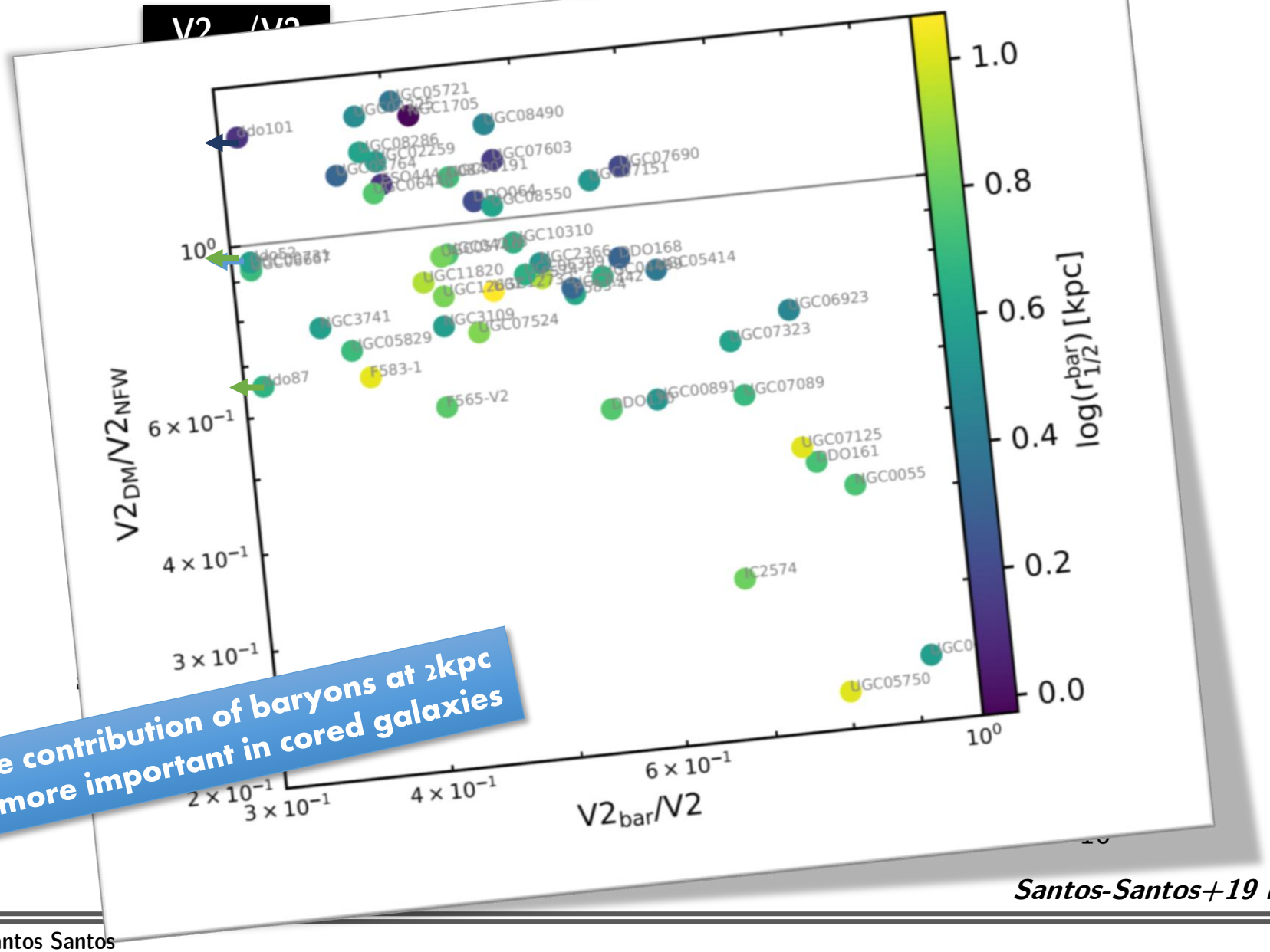

The contribution of baryons at 2kpc is more important in cored galaxies

Santos-Santos+19 in prep

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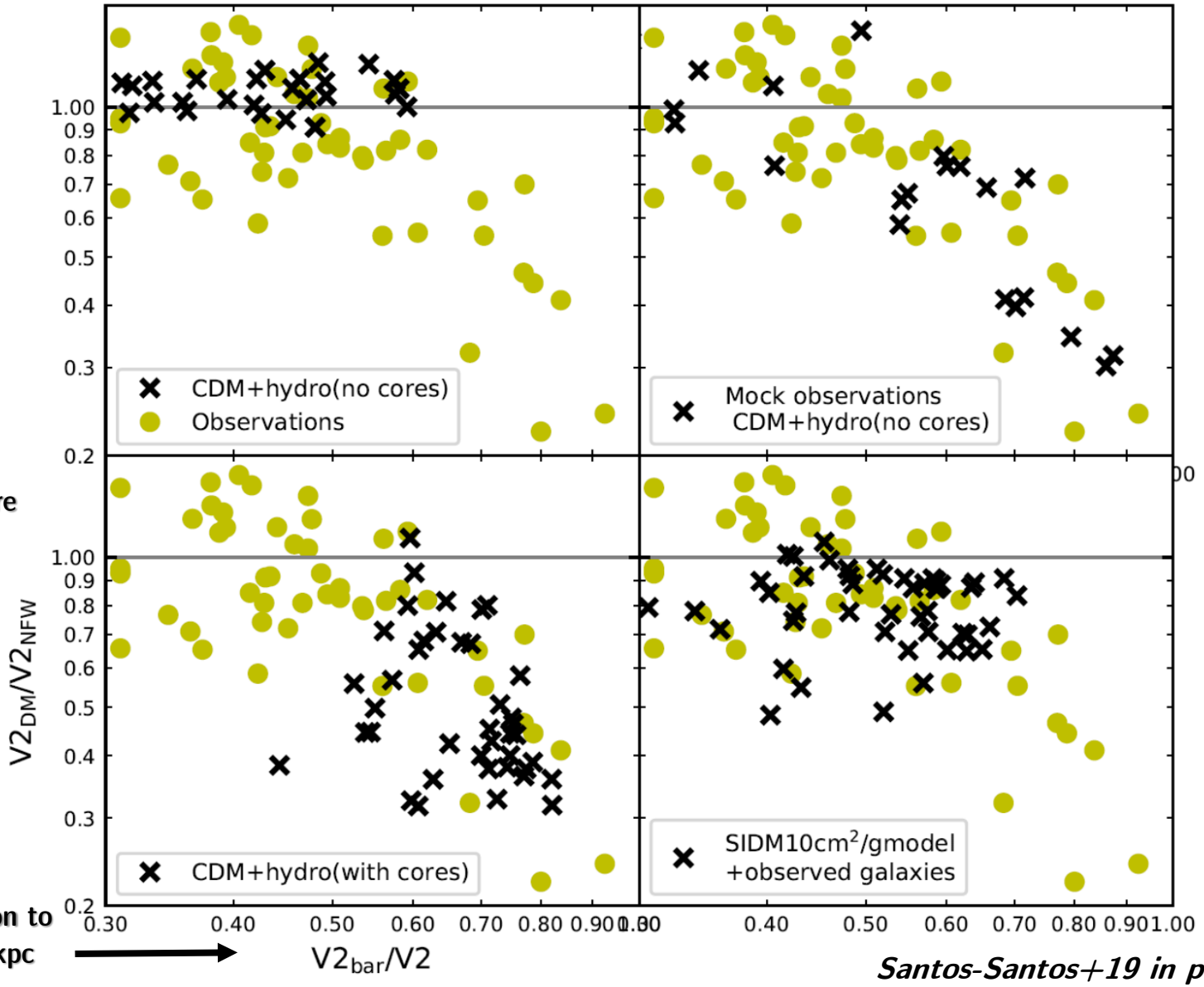

Dark matter core size at 2kpc

Baryon contribution to total velocity at 2kpc

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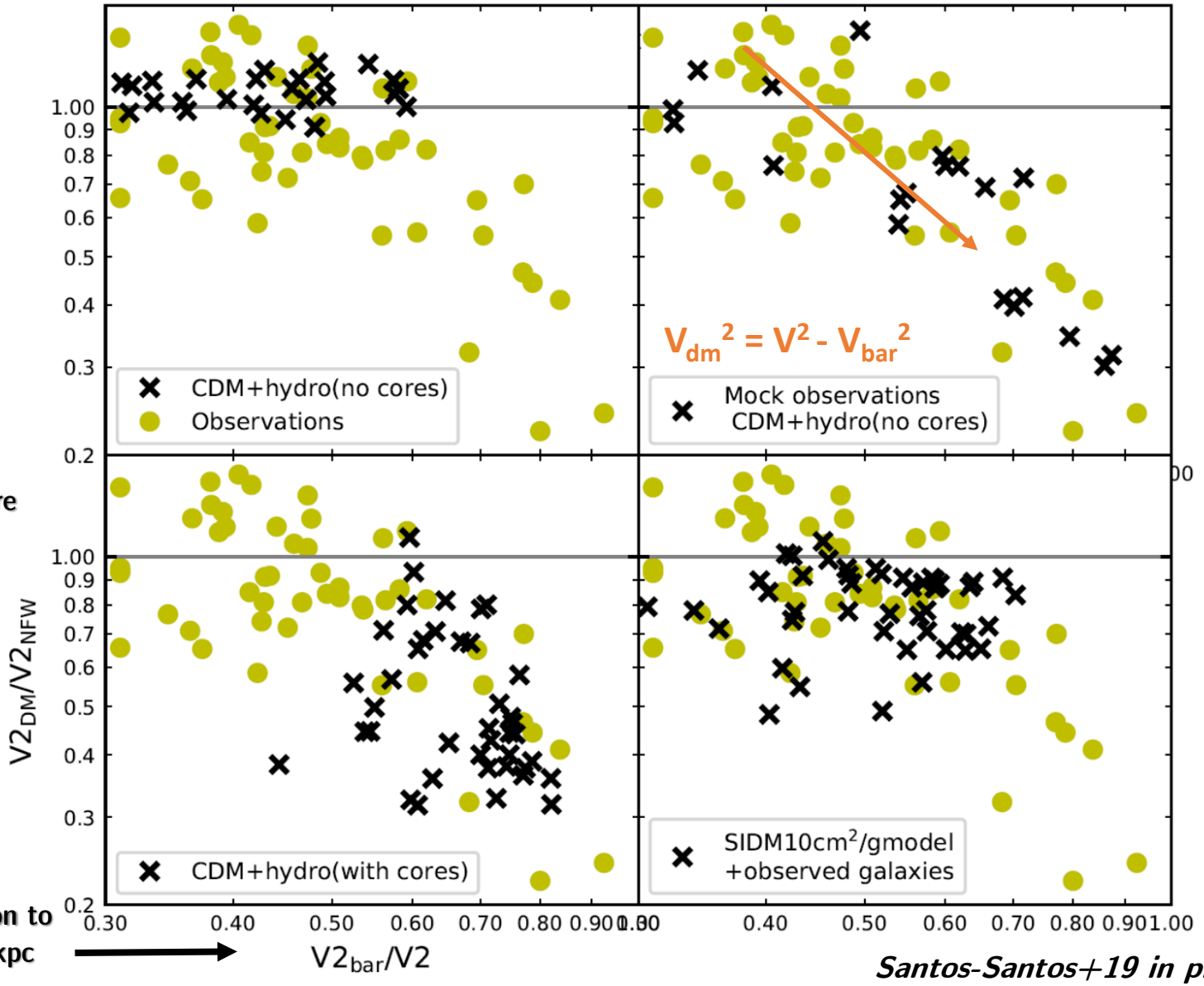

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Summary/future work:

A model that explains diversity has to explain correlations as well

- **Baryon-induced cores**
  - can reproduce the largest cores
  - lacks the most extreme cuspy cases (i.e., galaxies with low baryonic contribution in their inner regions)

- **SIDM+observed galaxies**
  - Produce cored galaxies in general, but not as extreme as observed.
  - There is no trend between the size of the core and the importance of baryons.

- **Mock observations of CDM+baryons (no core) simulated galaxies**
  - reproduce the range of diversity in core size
  - and the trend with baryonic contribution, though more statistics is needed.

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- **Exploring other possibilities:**
  i. CDM+hydro simulations with a variety of SF density thresholds
  ii. CDM+hydro simulations with different feedback schemes
  iii. SIDM+hydro simulations, with baryonic outflows

Thank you.