Dark matter structure via 21-cm ‘observations’ of simulated galaxies

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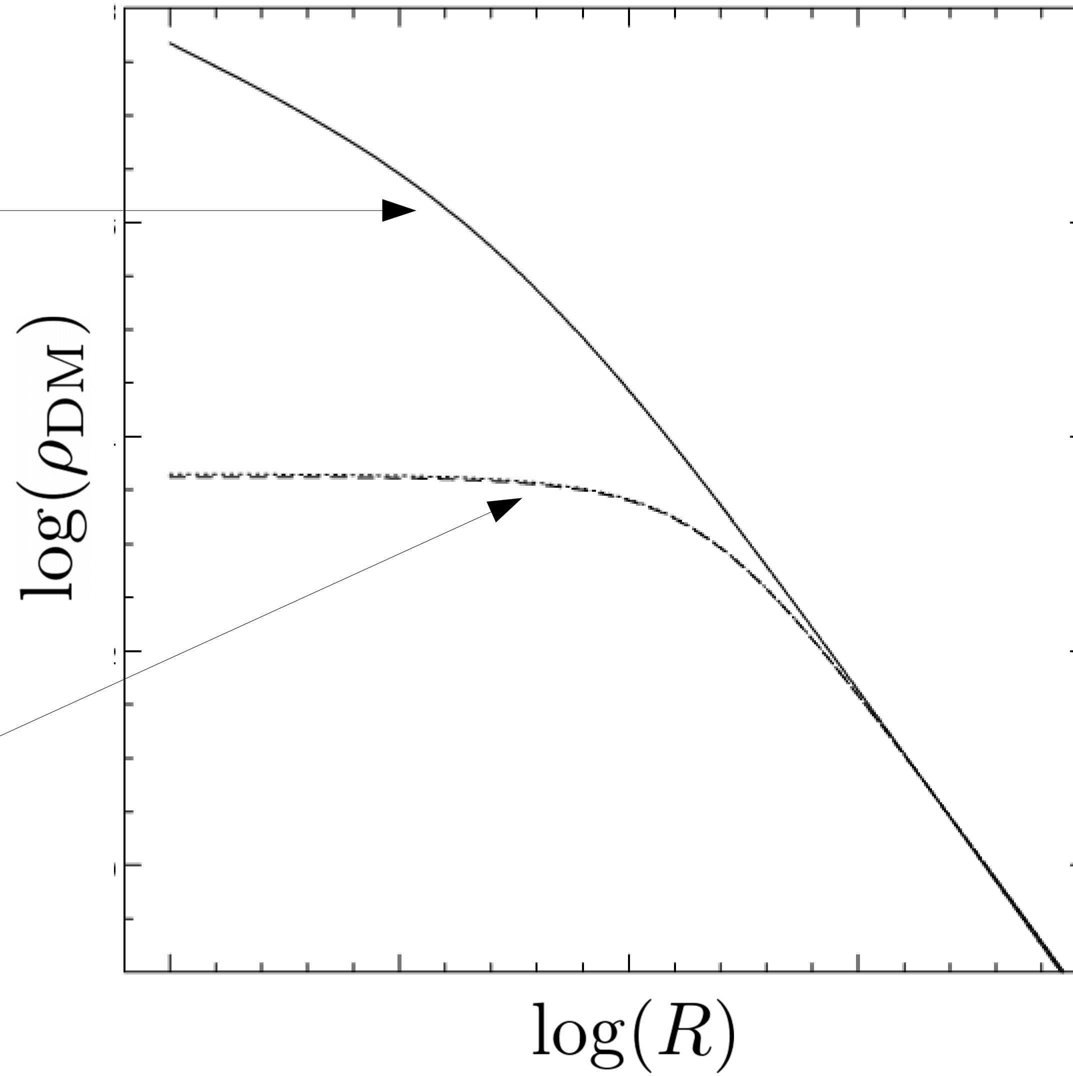
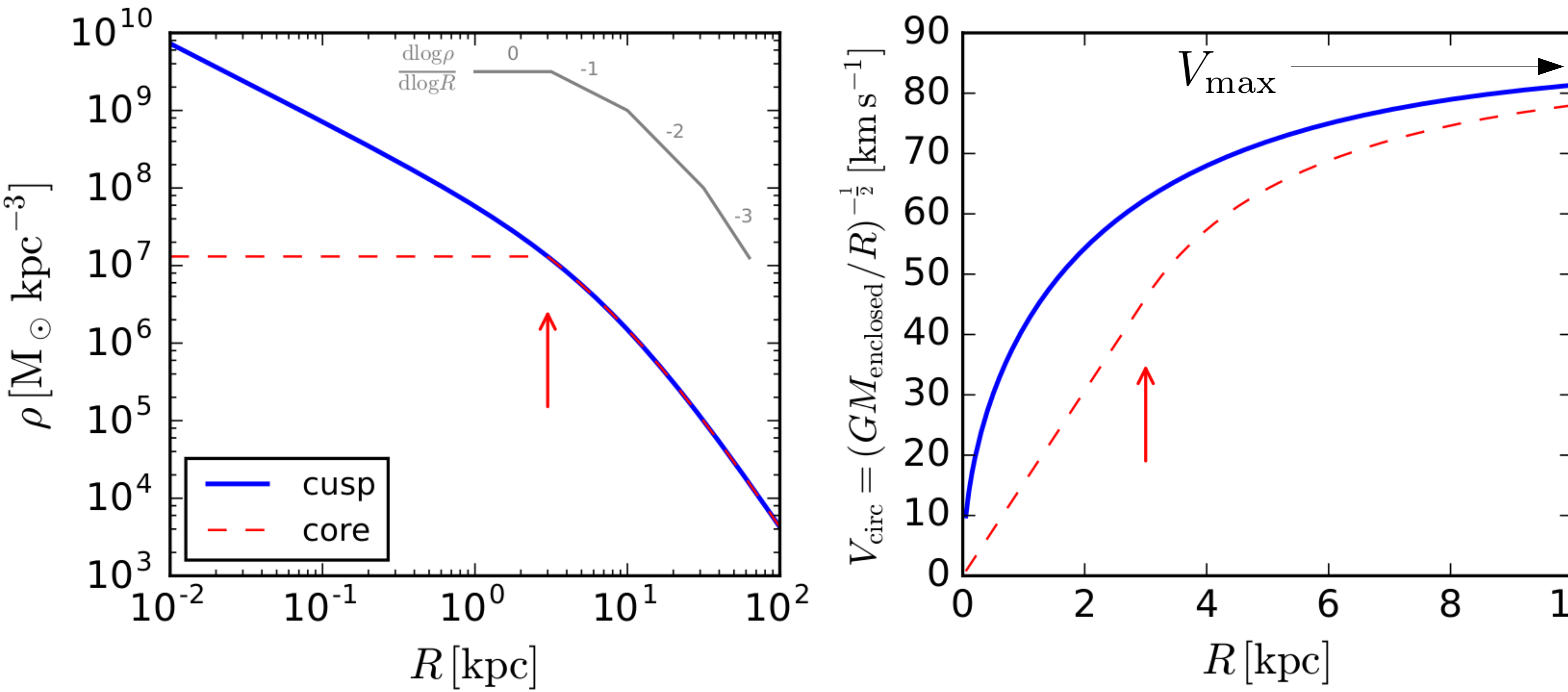
The cusp-core problem

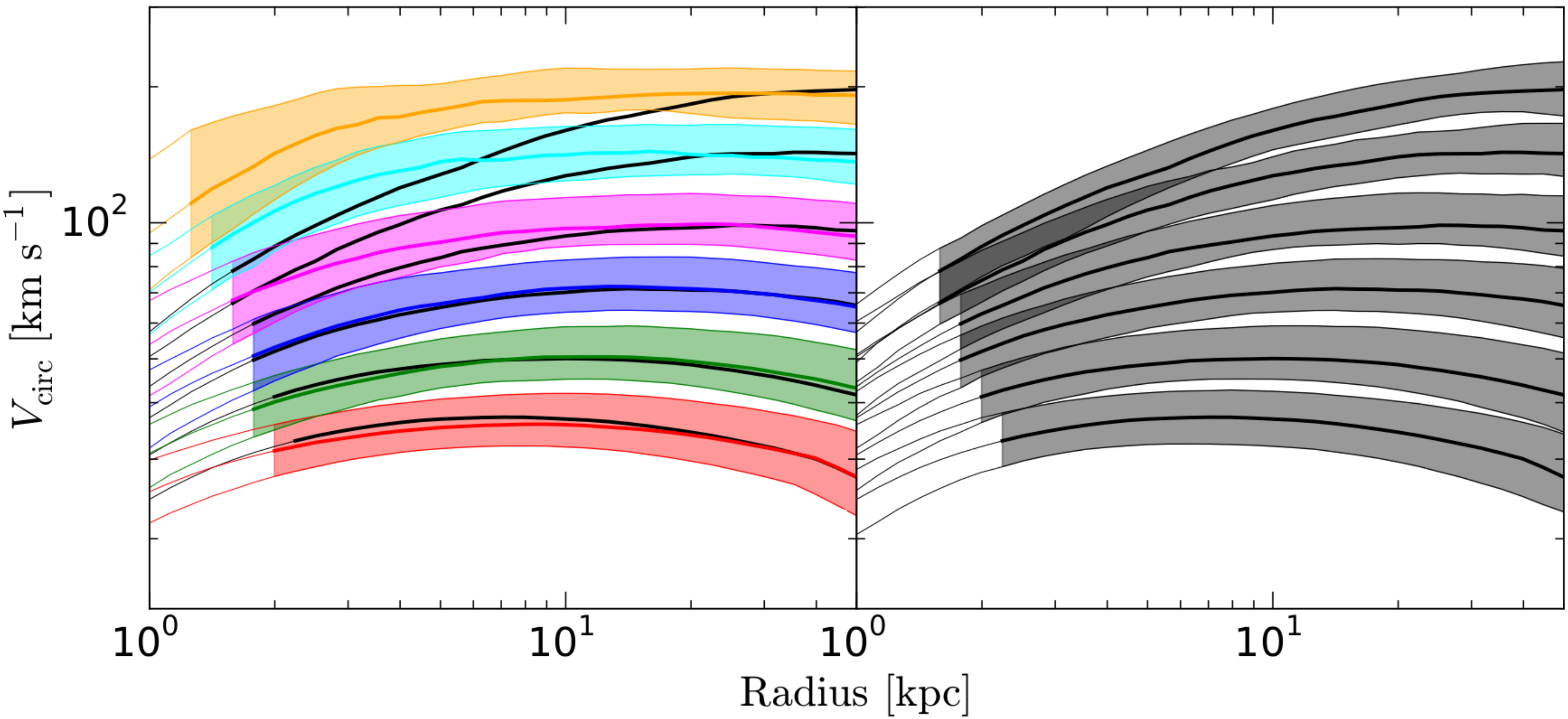


Rotation curves

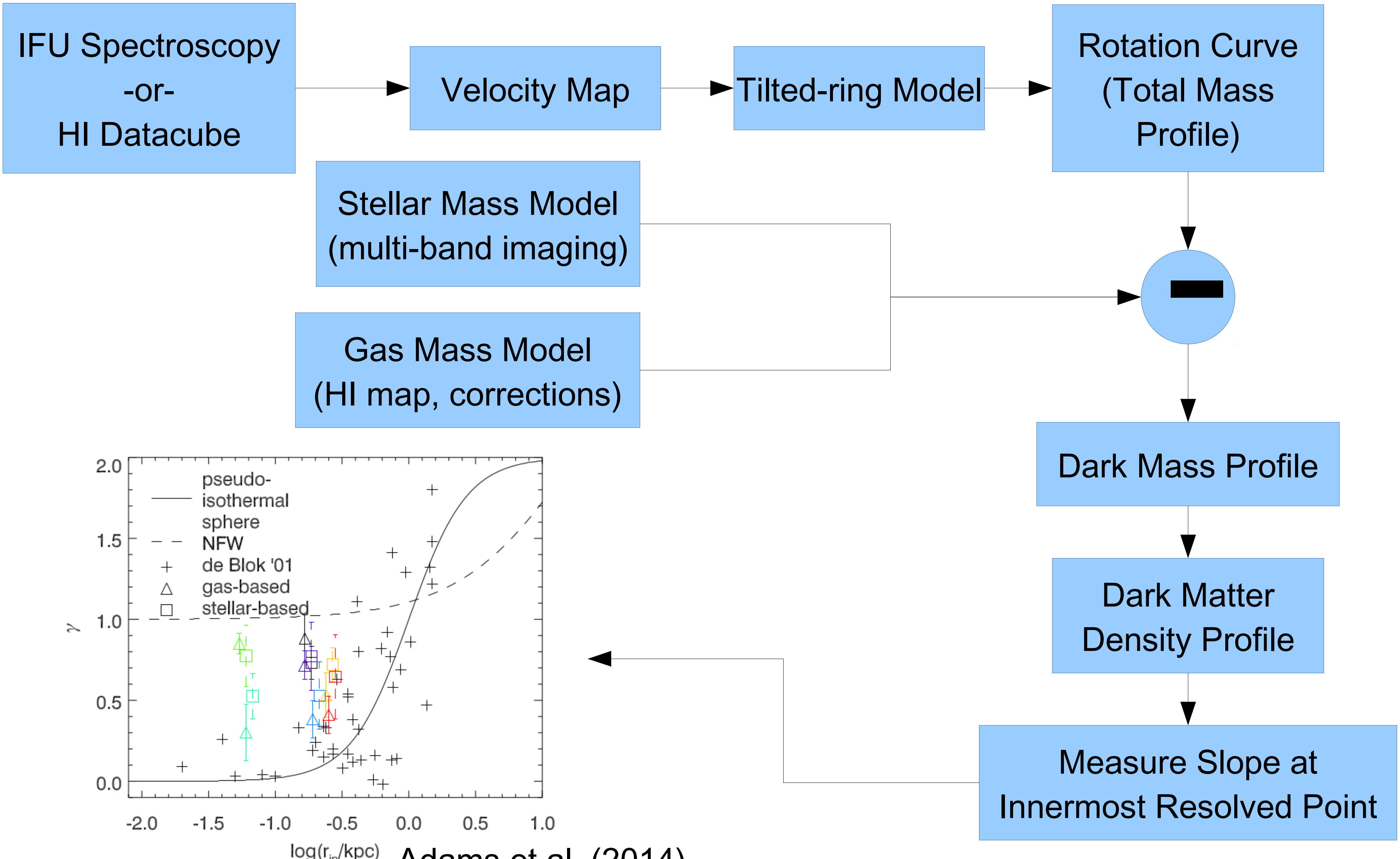
$$v_{\rm circ} = \sqrt{\frac{GM(<r)}{r}}$$



Rotation curves

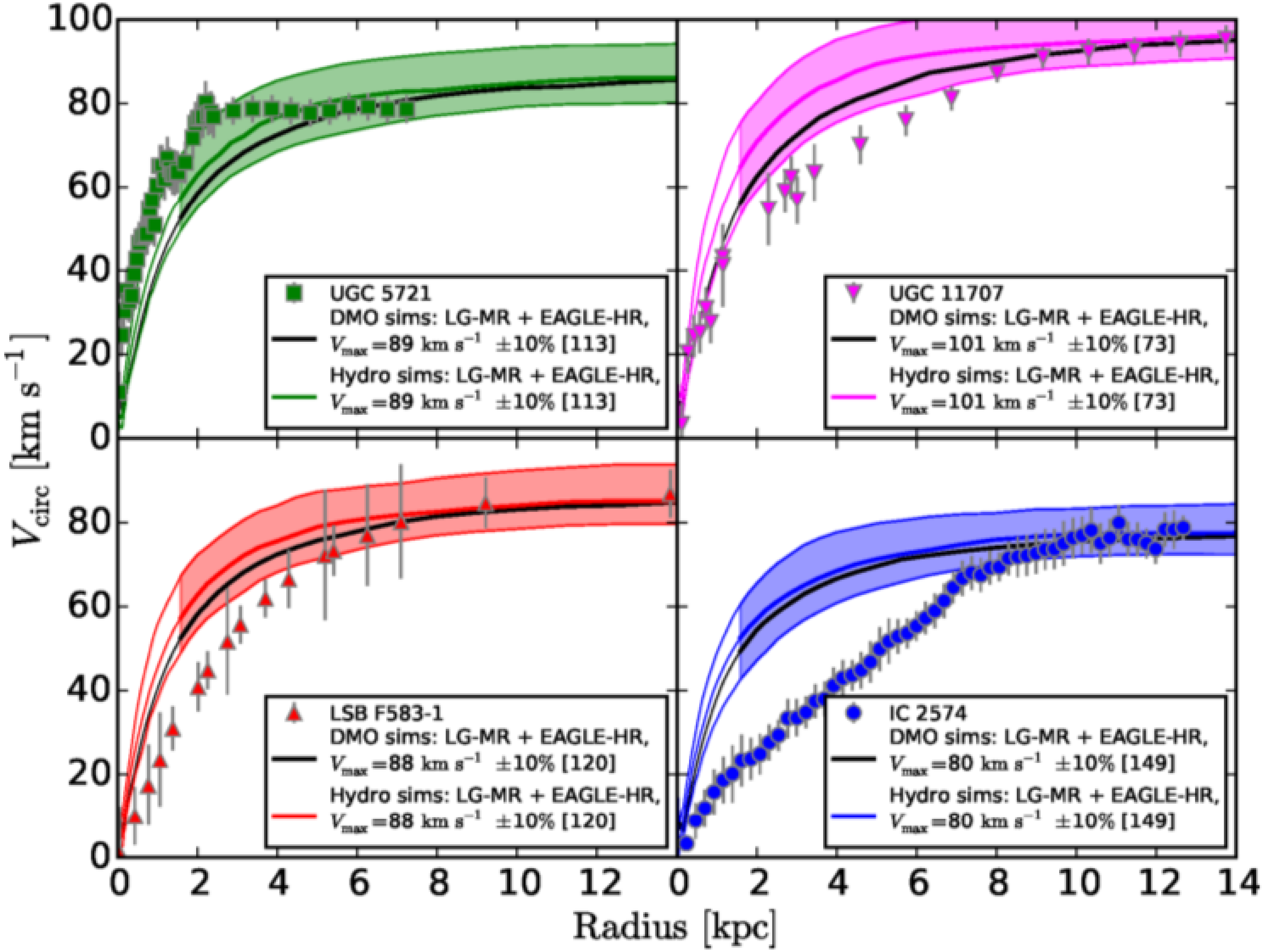


Mass modelling

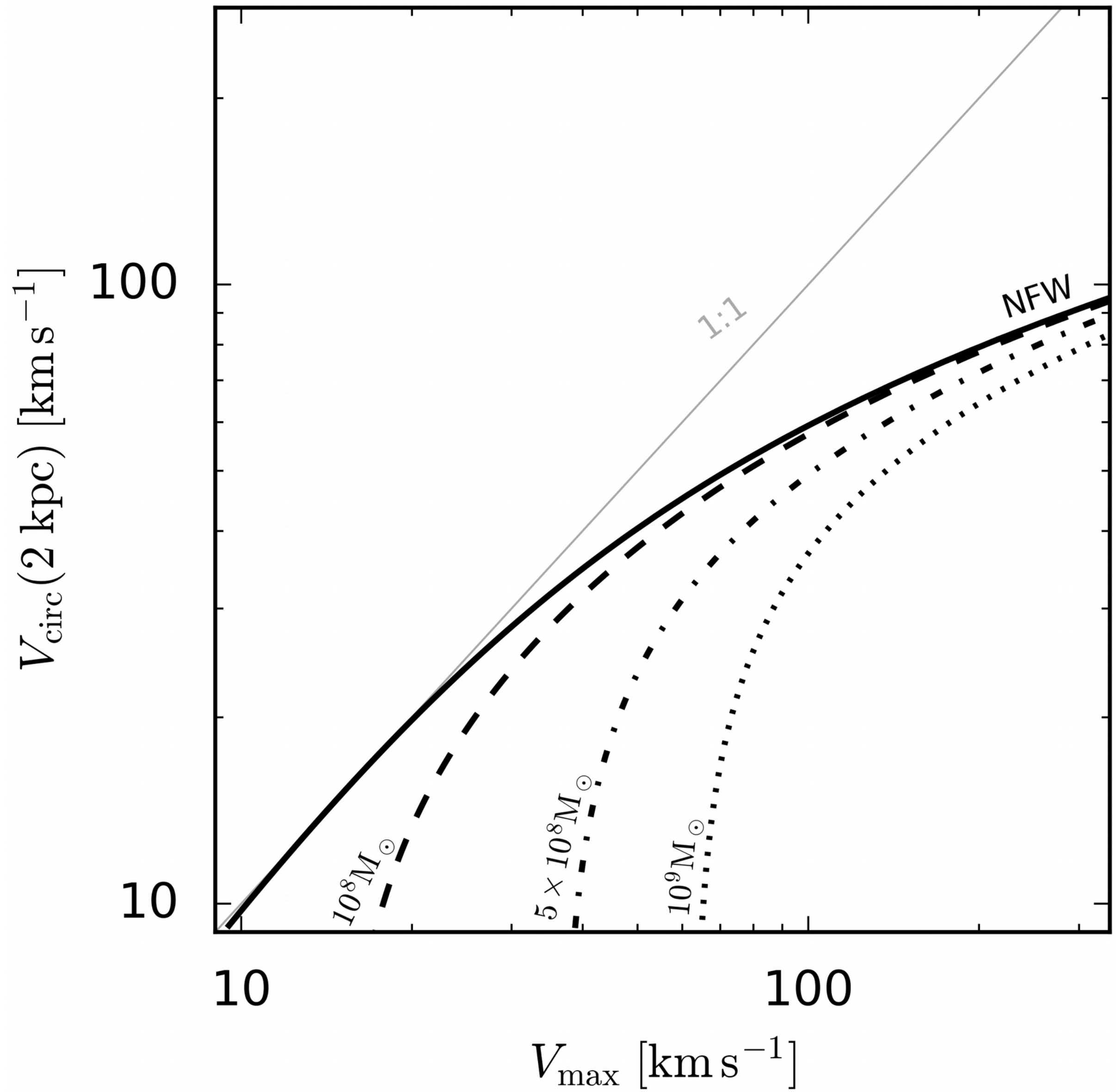


Adams et al. (2014)

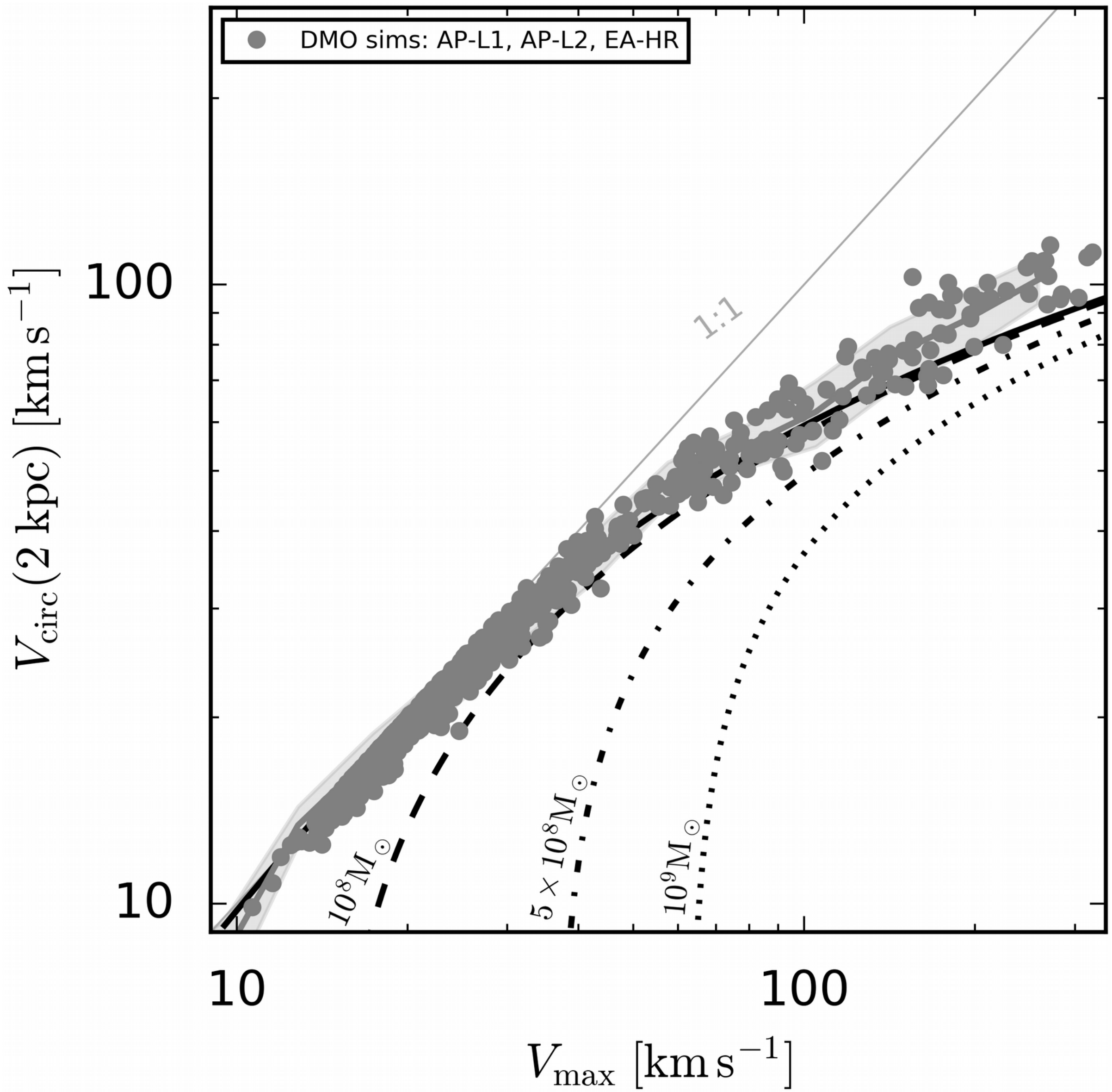
Rotation curve diversity



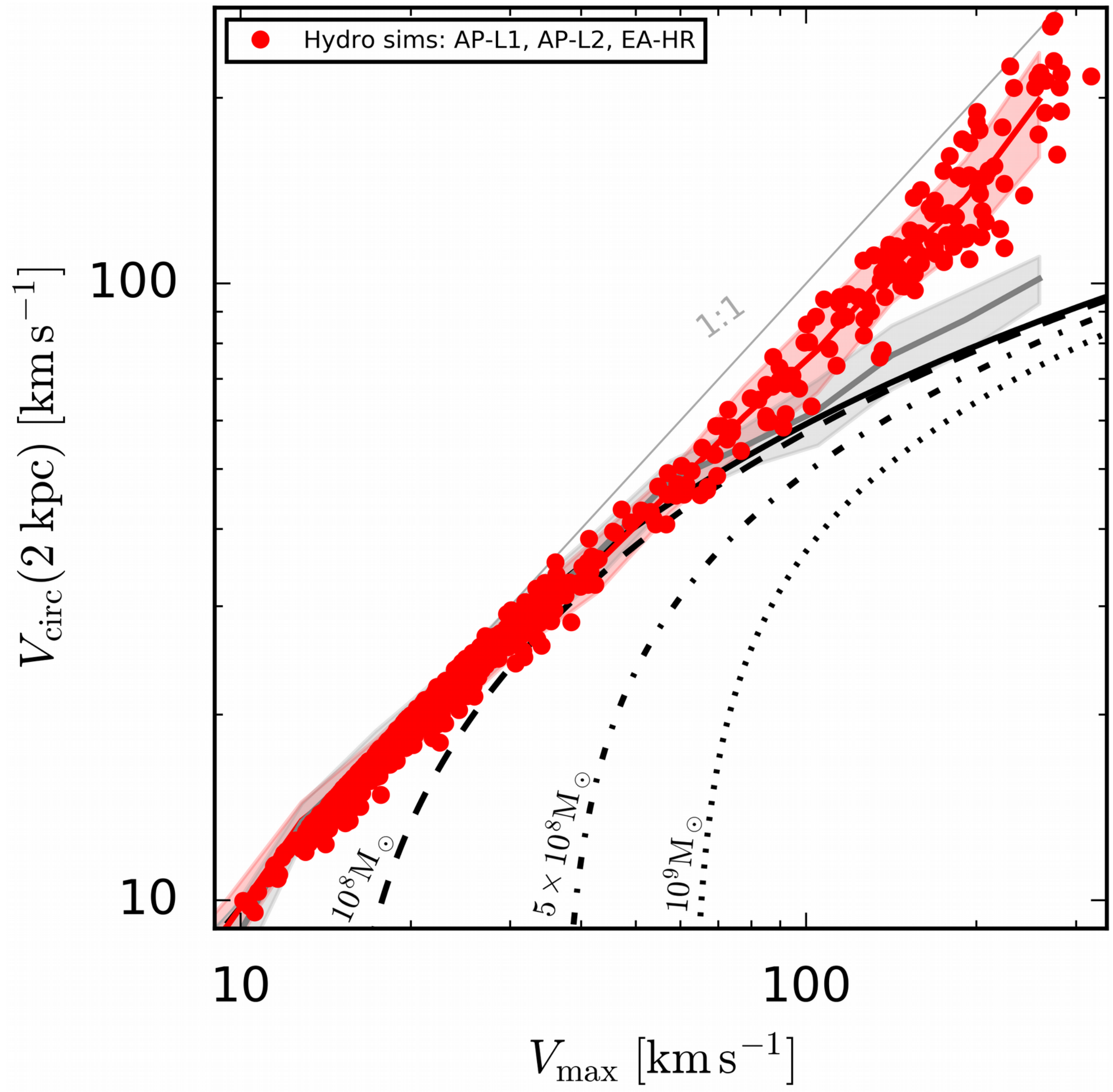
Inner mass diversity



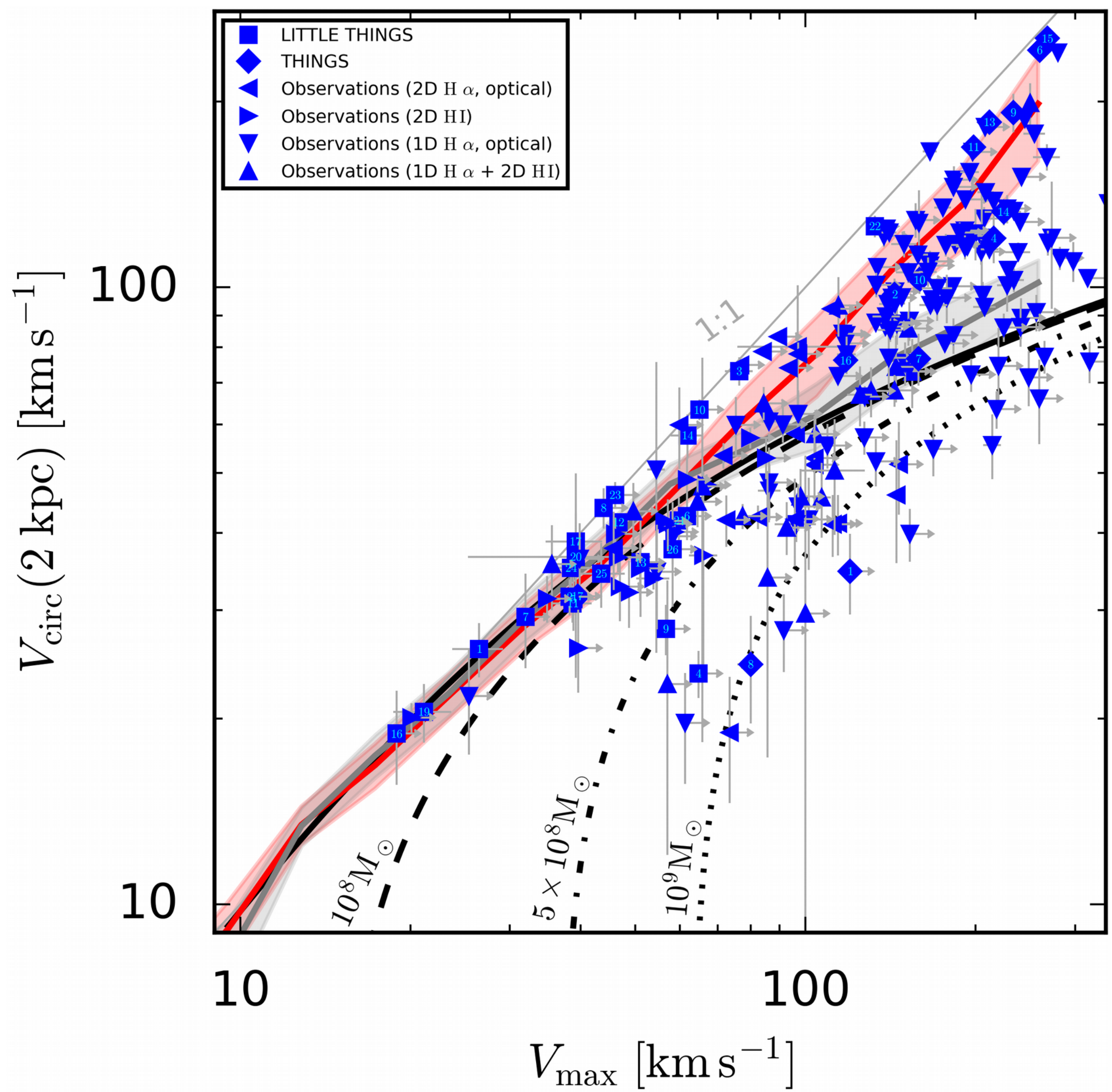
Inner mass diversity



Inner mass diversity

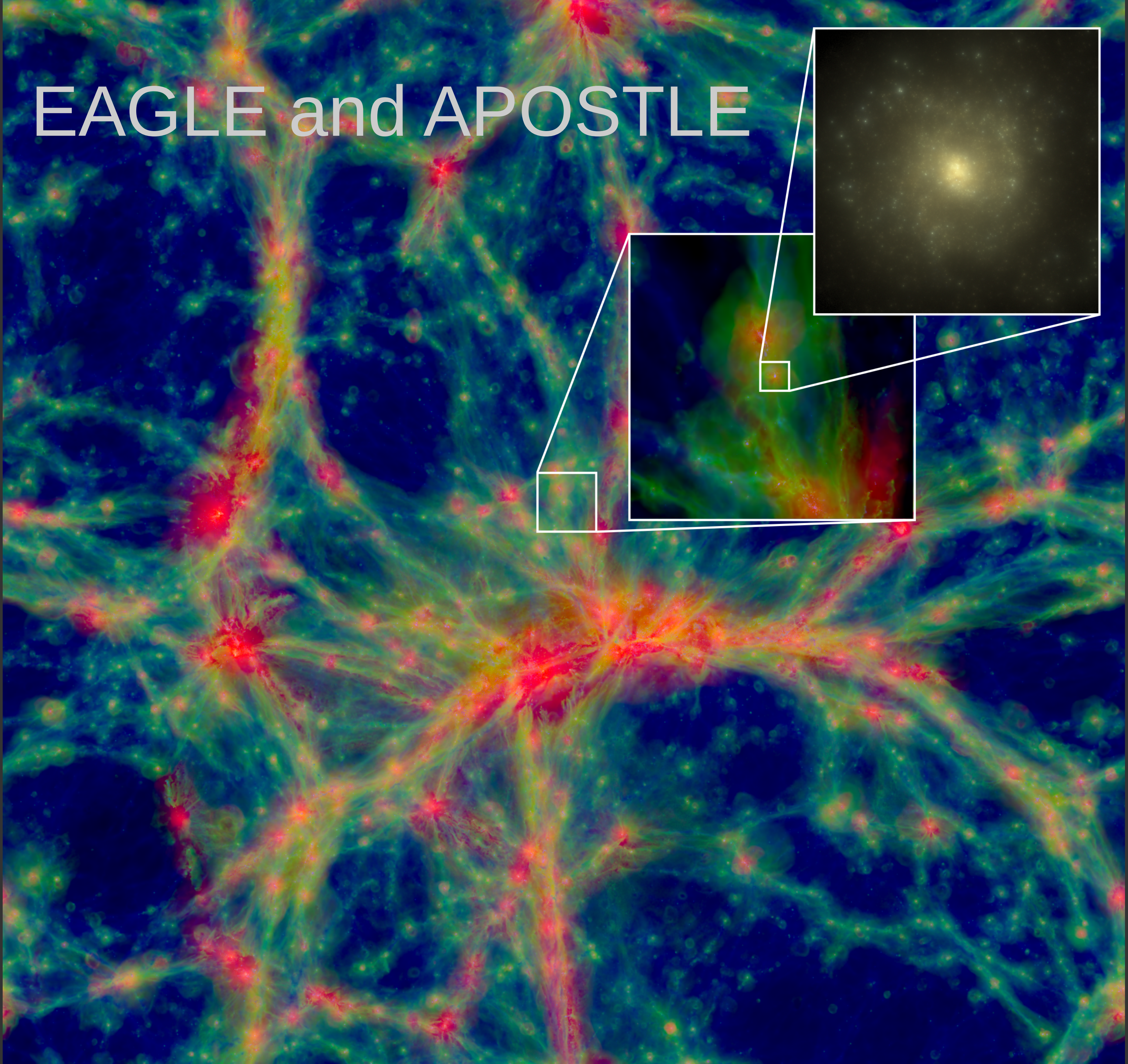


Inner mass diversity



Possible solutions

- Modify dark matter profile via “baryonic physics”
- Modify dark matter profile via dark matter physics
- Modify gravitational force law
- **Appeal to errors in modelling & interpretation**


EAGLE and APOSTLE

EAGLE project

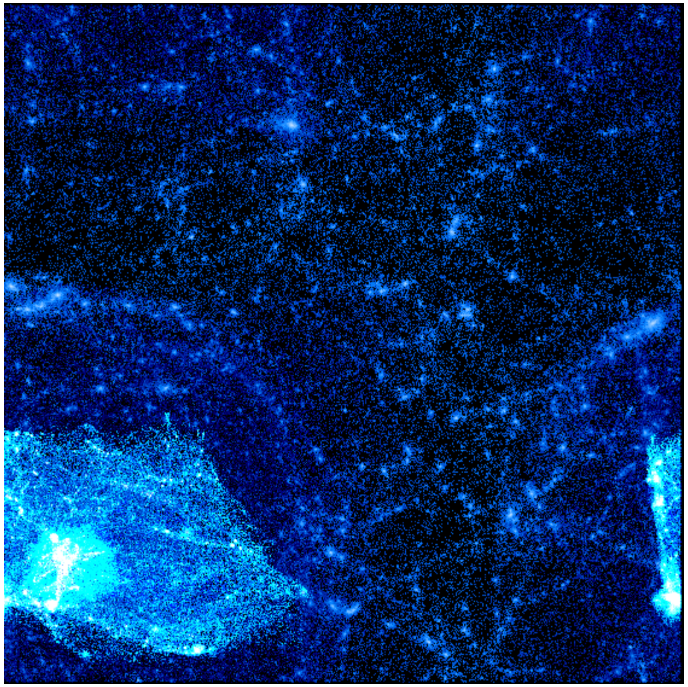
Evolution and Assembly of GaLaxies and their Environments

- First generation cosmological hydrodynamical simulation
- Physics included:
  - Star formation, winds, supernovae
  - Chemical enrichment
  - Reionization
  - Radiative cooling
  - AGN
- Calibration: galaxy stellar mass function, size distribution for

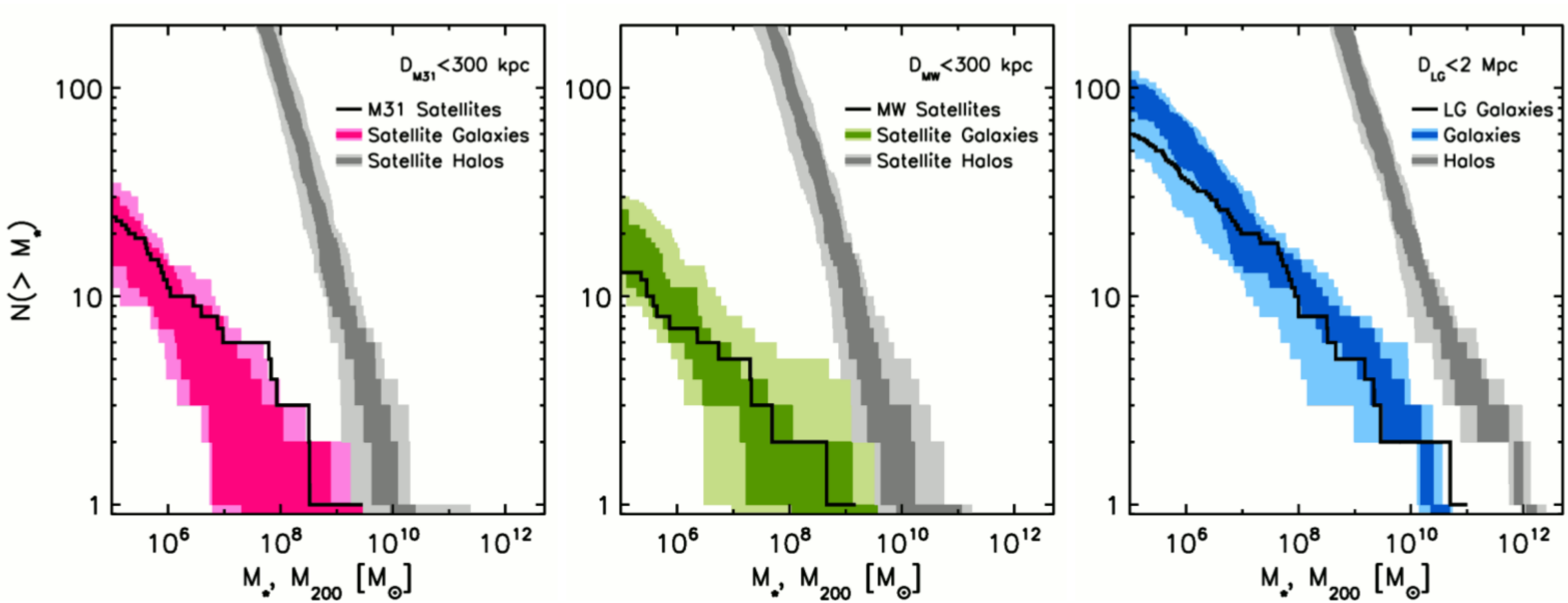
$M_* > 10^8\,\mathrm{M}_\odot$

APOSTLE simulation suite

- Same model & calibration as the EAGLE project
- Regions selected to match the mass, kinematics & environment of the Milky Way & M31
- 12 volumes, of which 5 at highest
  $(M_{\rm gas} \sim 10^4\,{\rm M_\odot})$

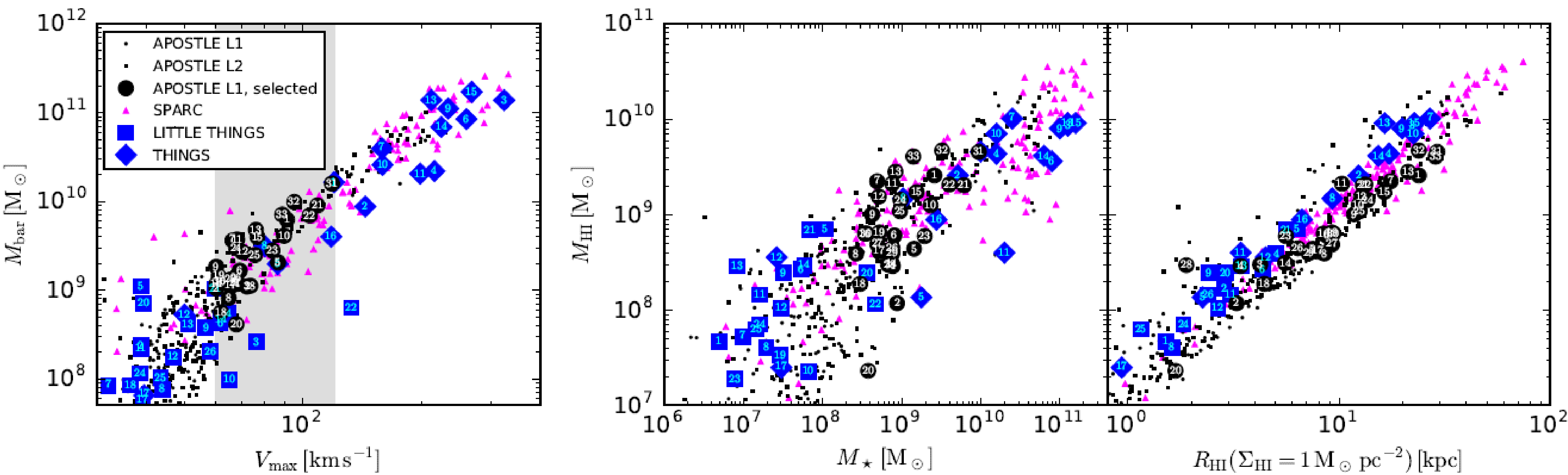


Stellar mass function

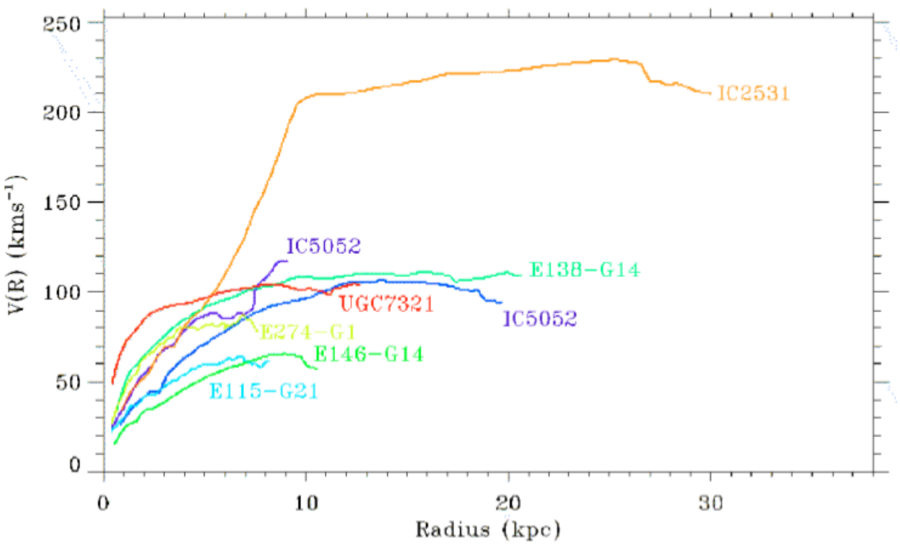


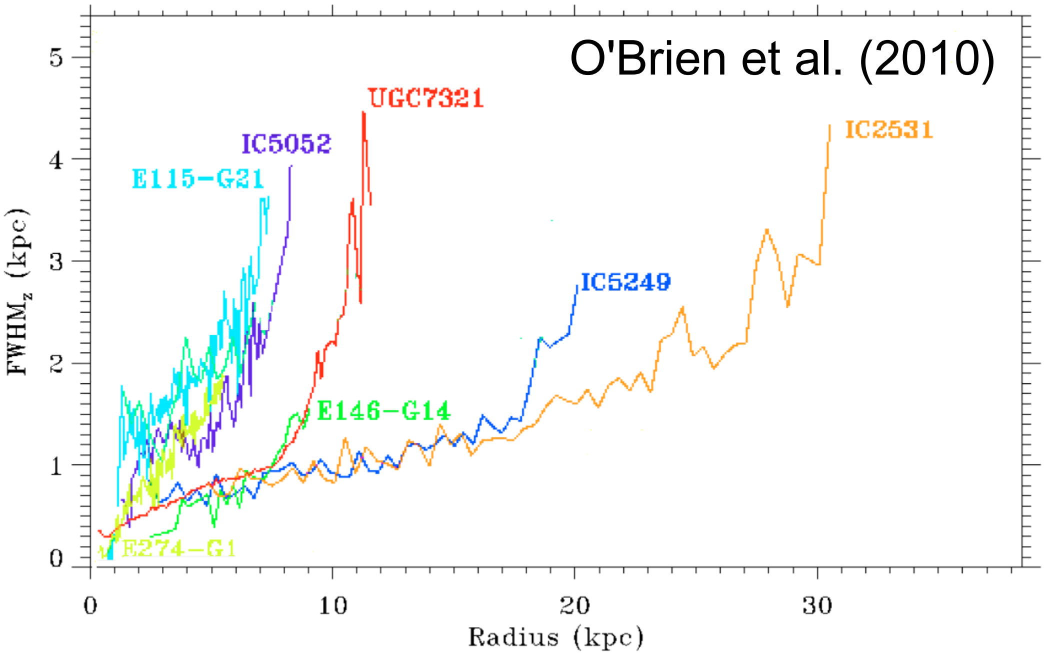
Sawala et al. (2016b)

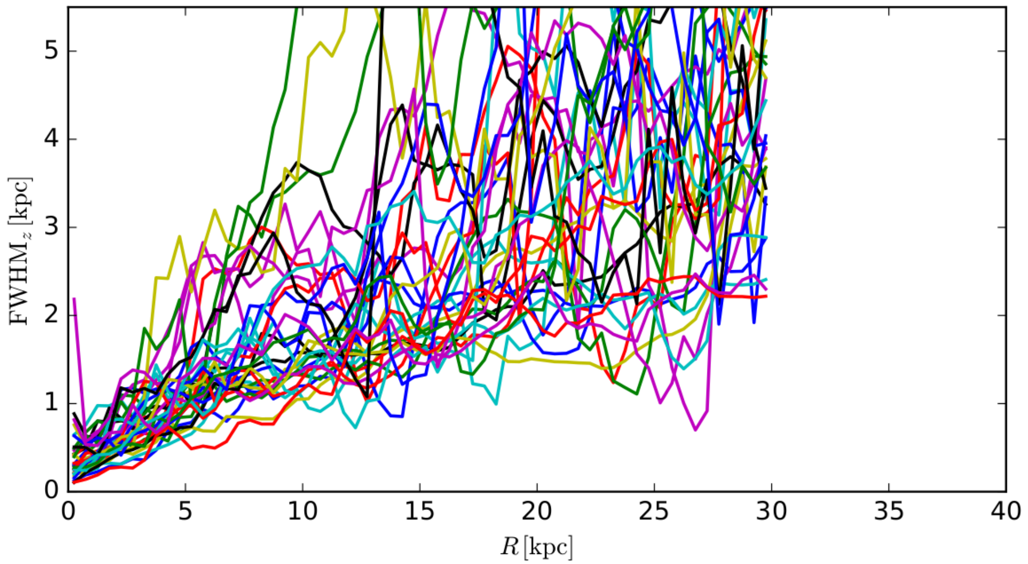
HI properties



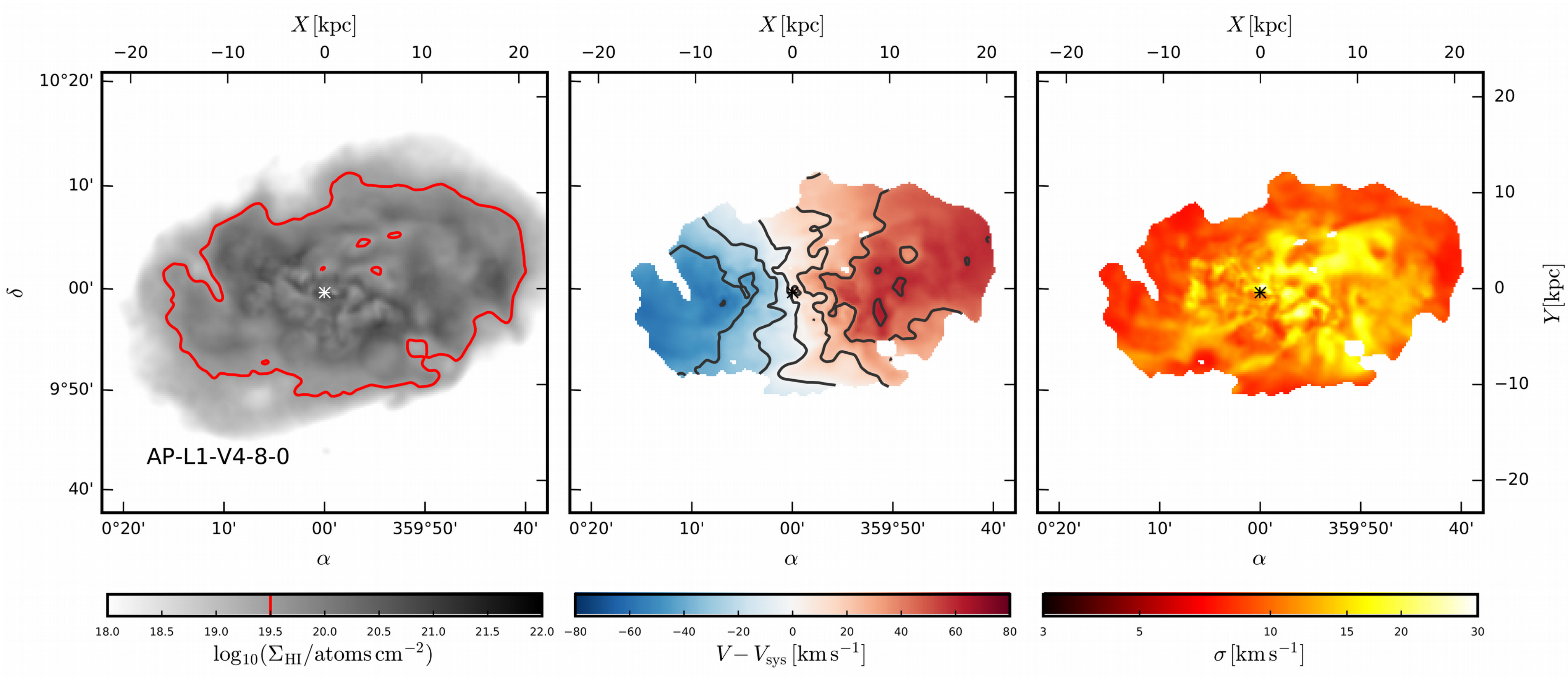
HI properties



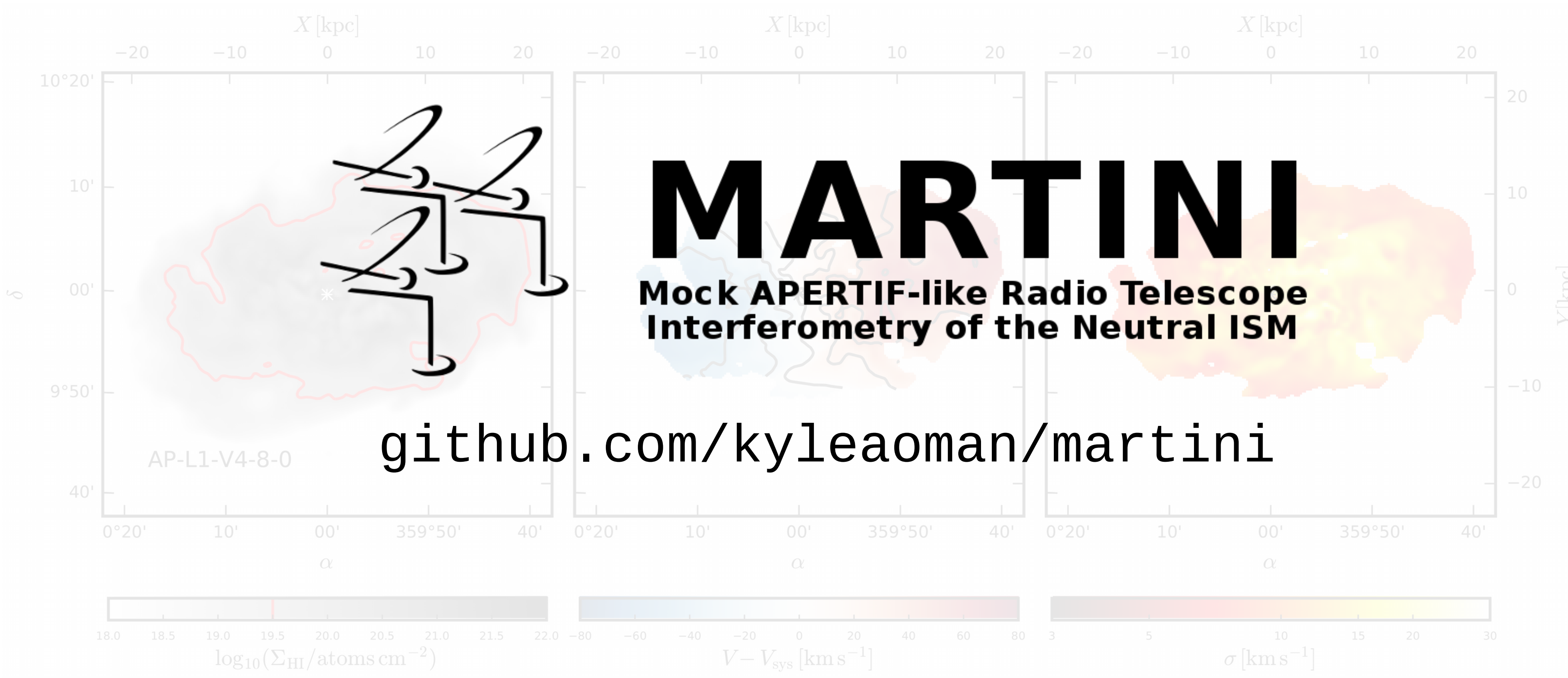




Synthetic HI observations



Synthetic HI observations

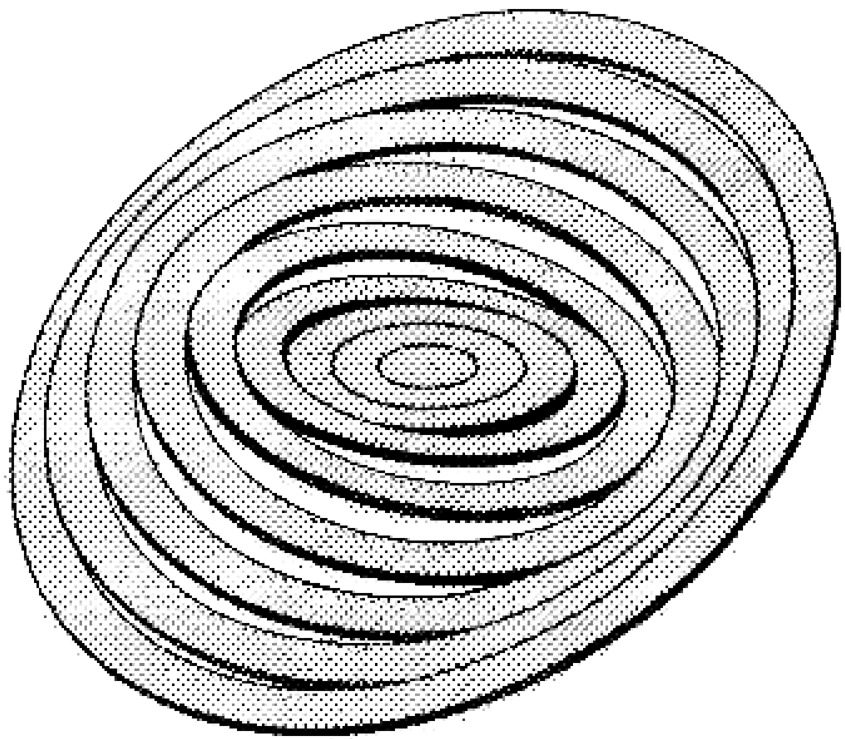


MARTINI

Mock APERTIF-like Radio Telescope Interferometry of the Neutral ISM

github.com/kyleaoman/martini

Kinematic modelling



For each ring:

$$(V_{\mathrm{rot}}, \sigma, \Sigma, i, \mathrm{PA}, \alpha_0, \delta_0, V_{\mathrm{sys}})$$

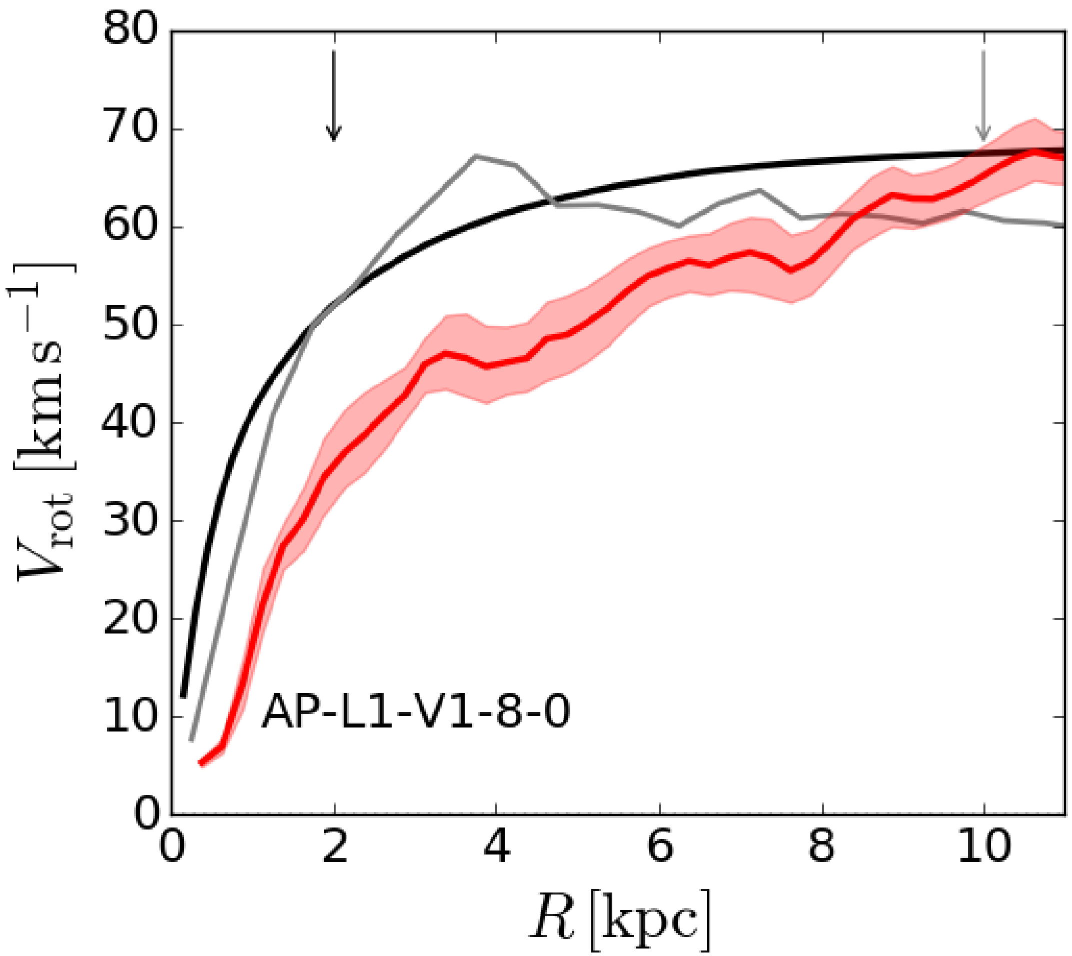
Rogstad et al. (1974)

3DBAROLO

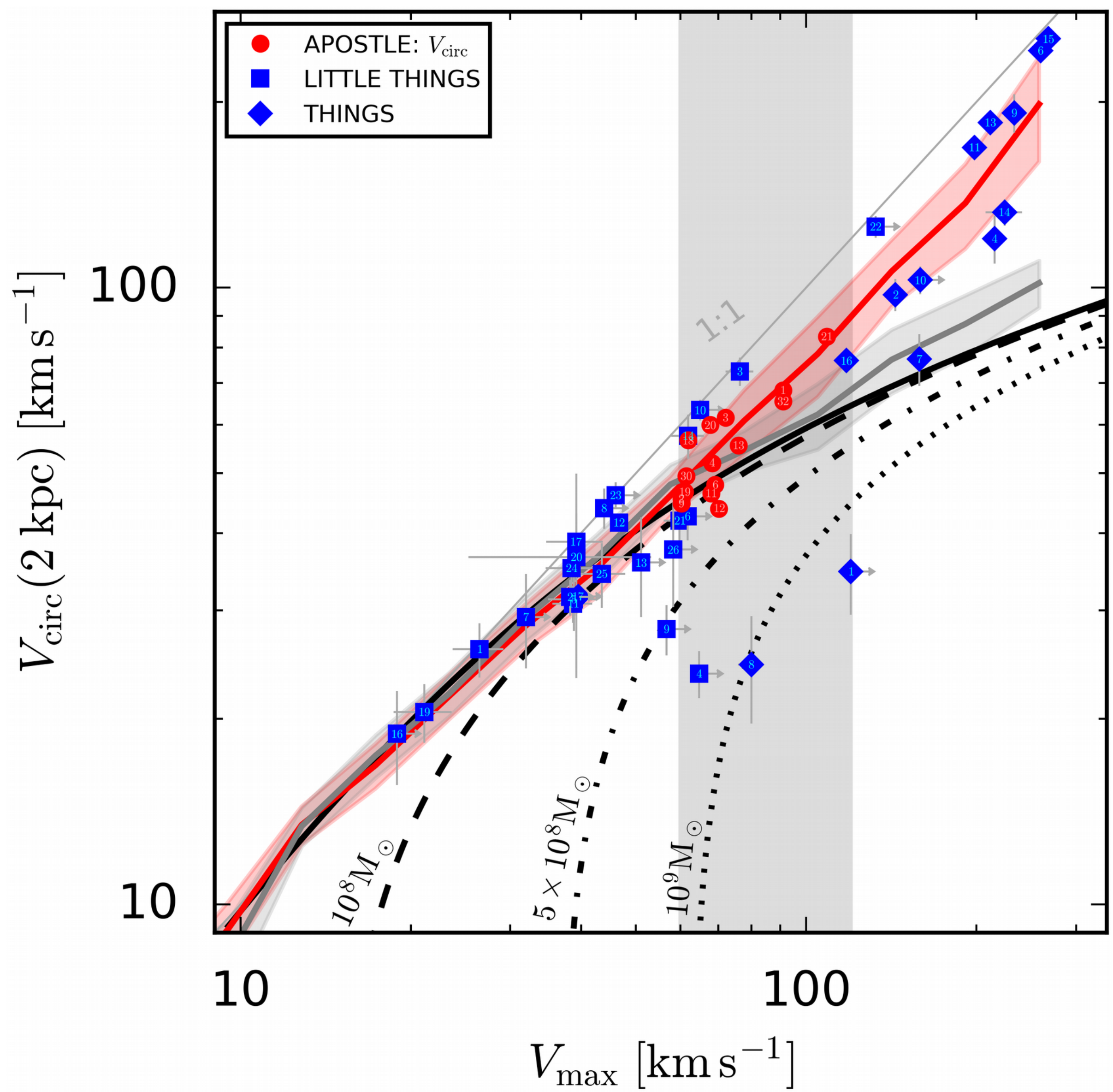
3D Based Analysis of Rotating Objects via Line Observations

Di Teodoro & Fraternali (2015)

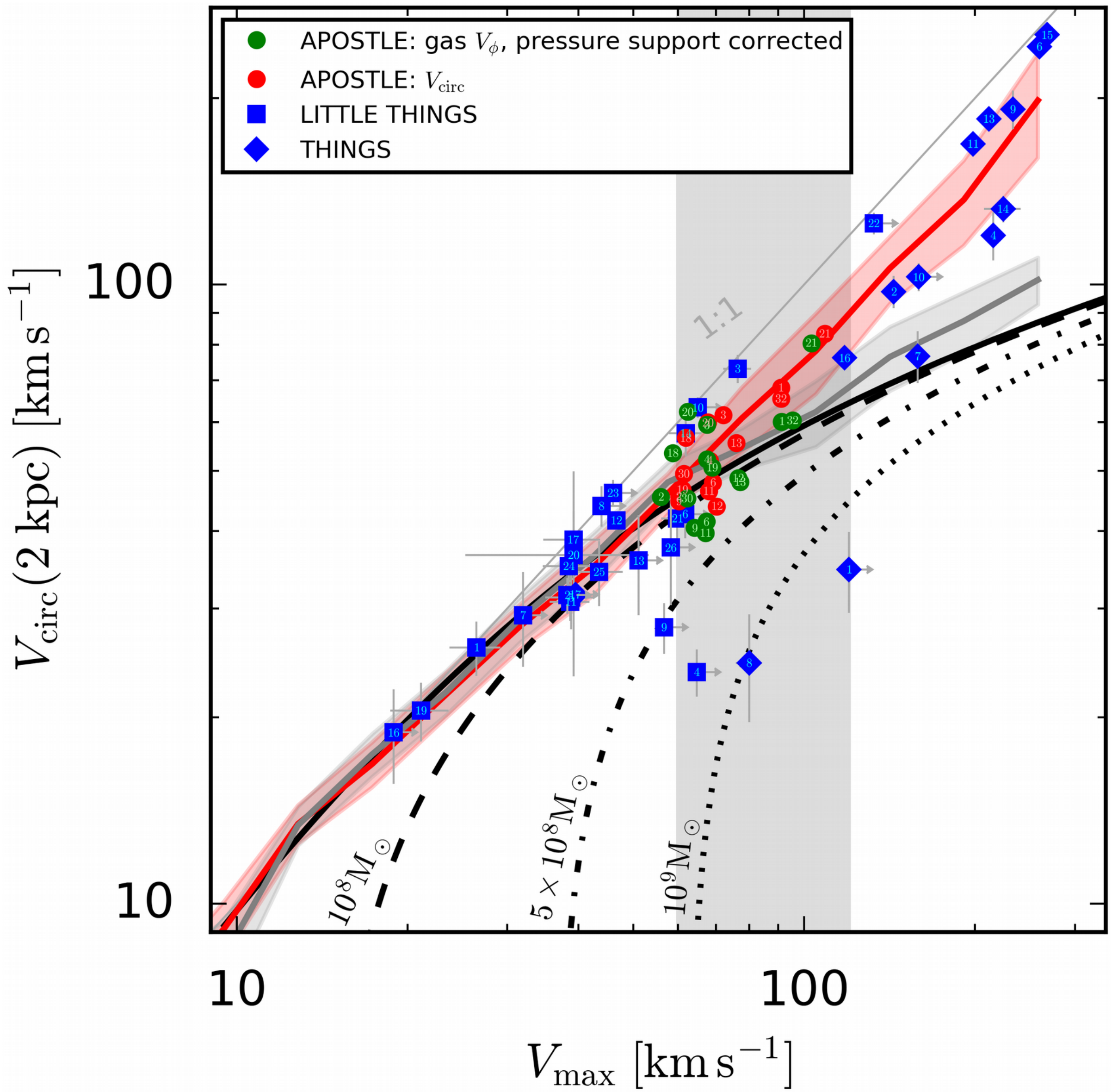
Kinematic modelling



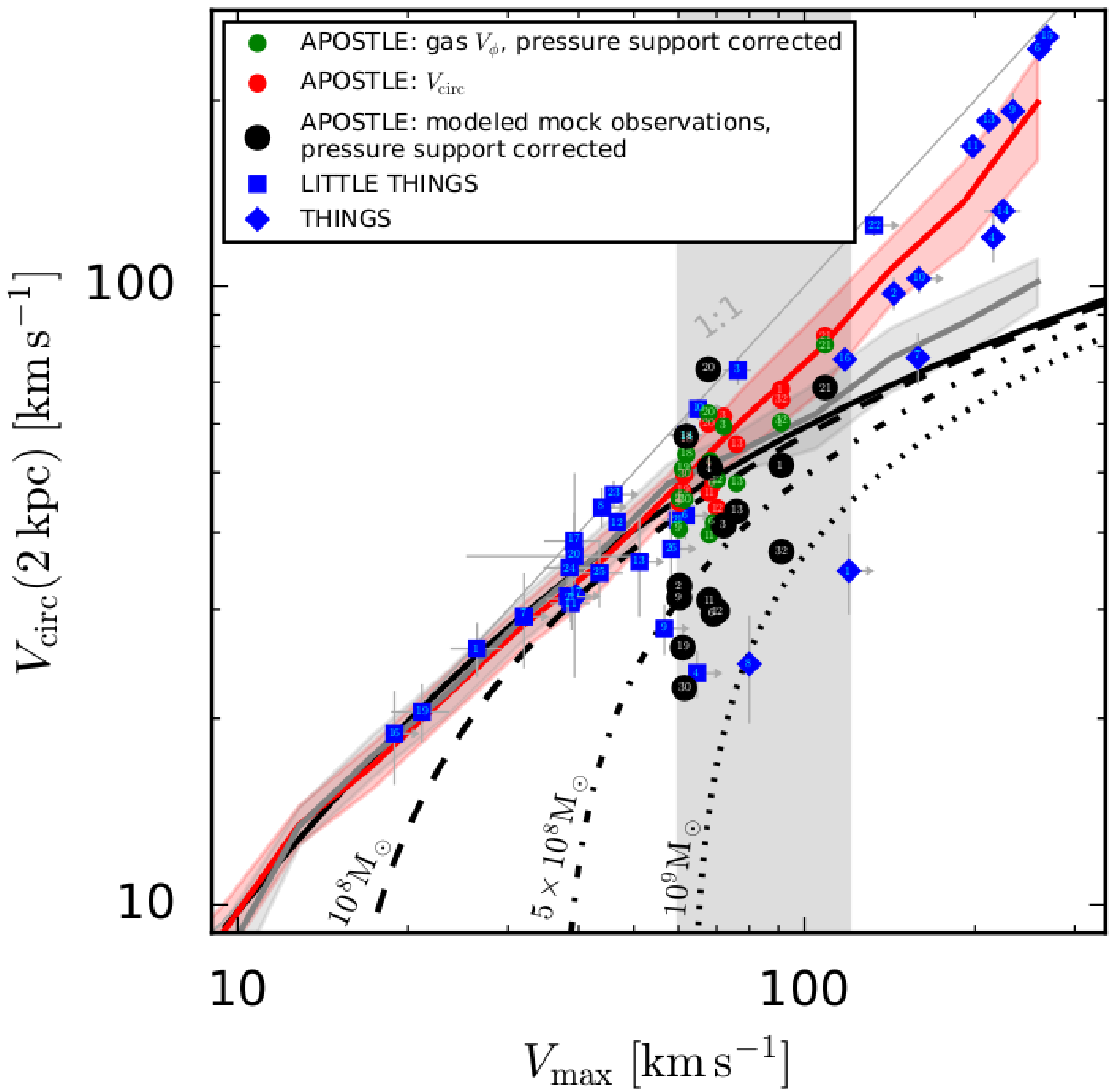
Inner mass diversity



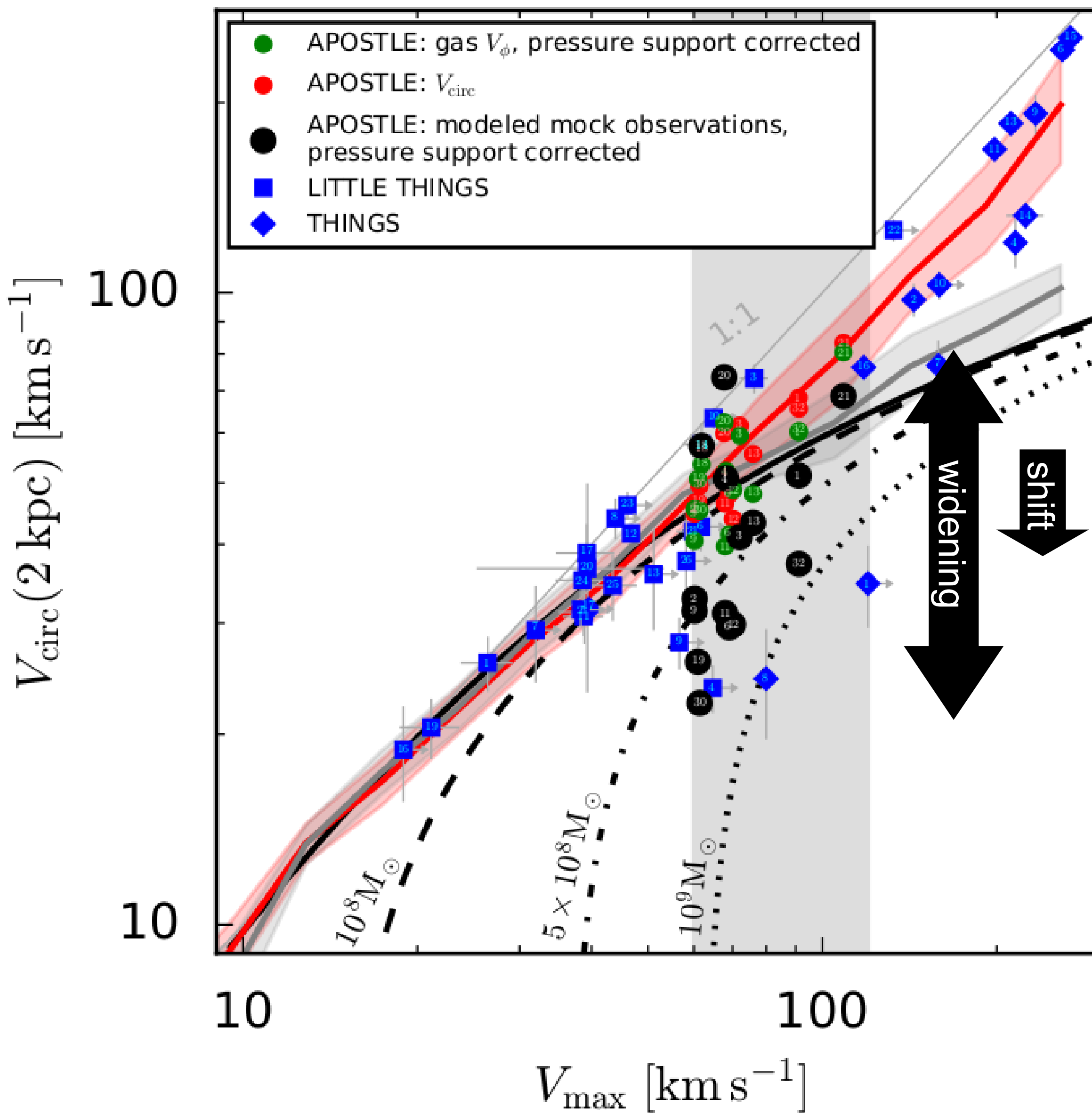
Inner mass diversity



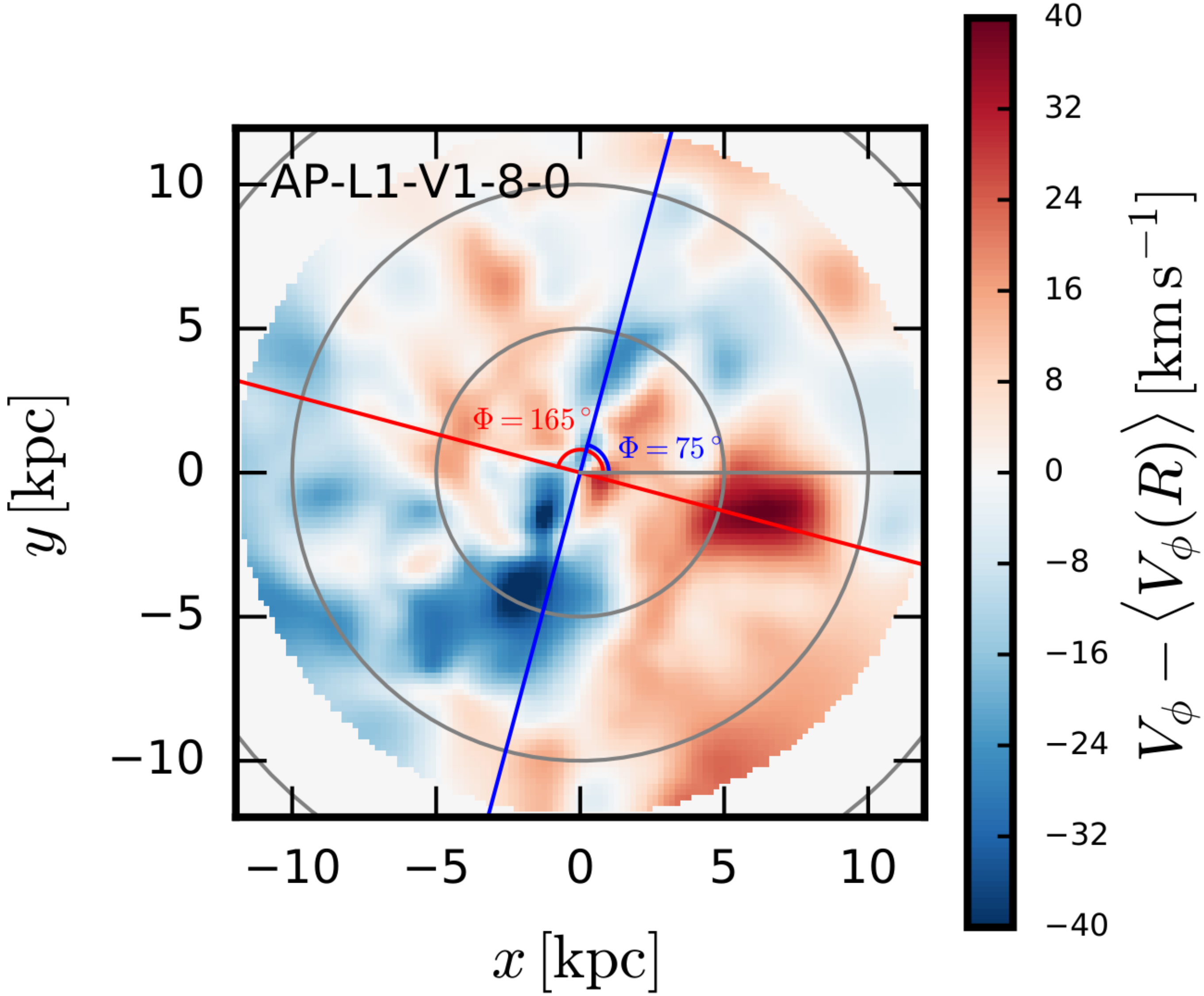
Inner mass diversity



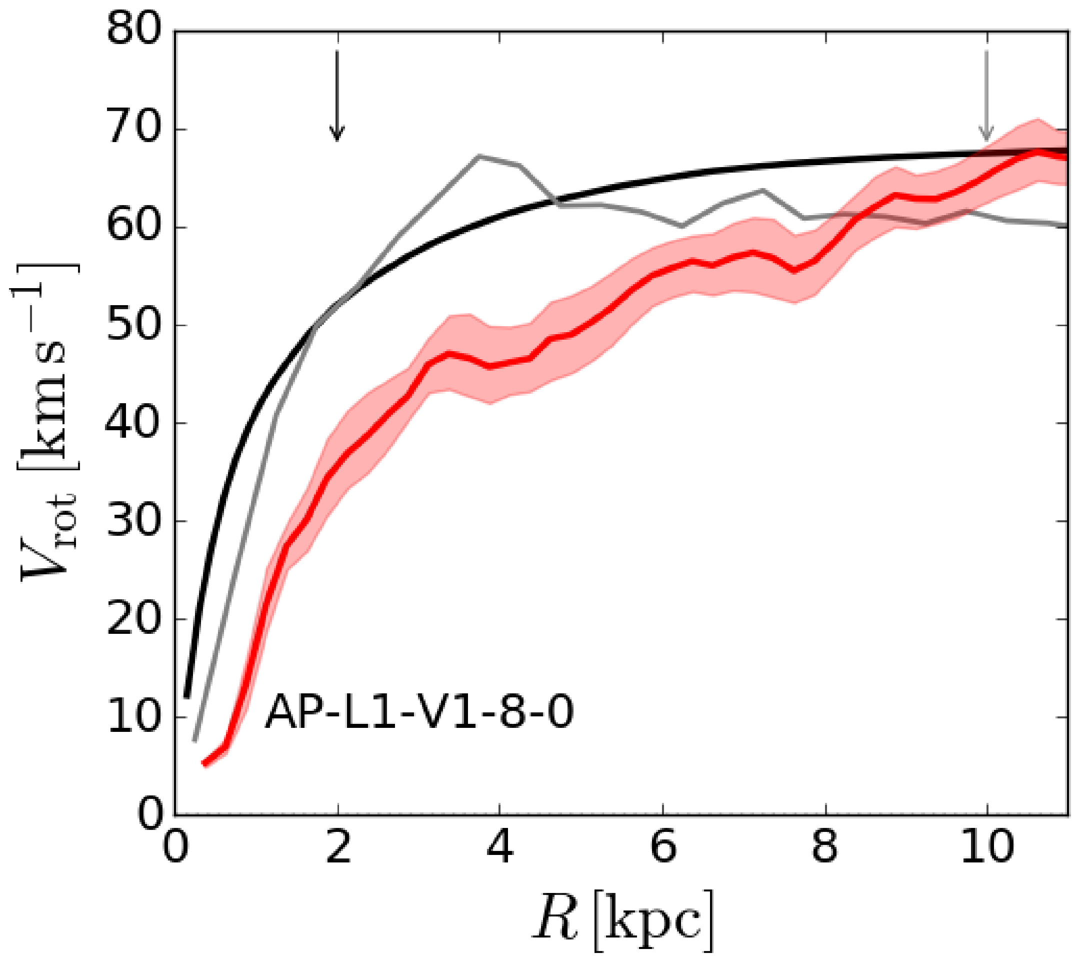
Inner mass diversity

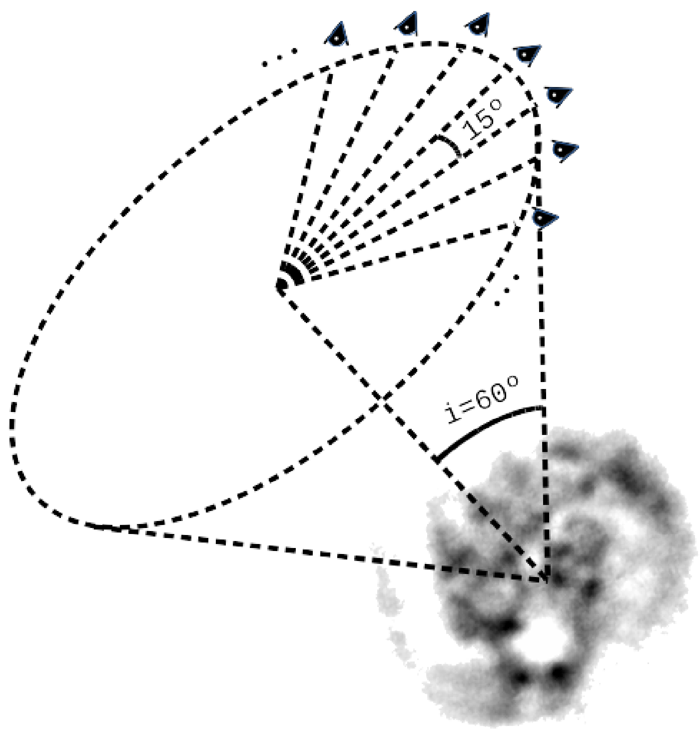


Non-circular motions

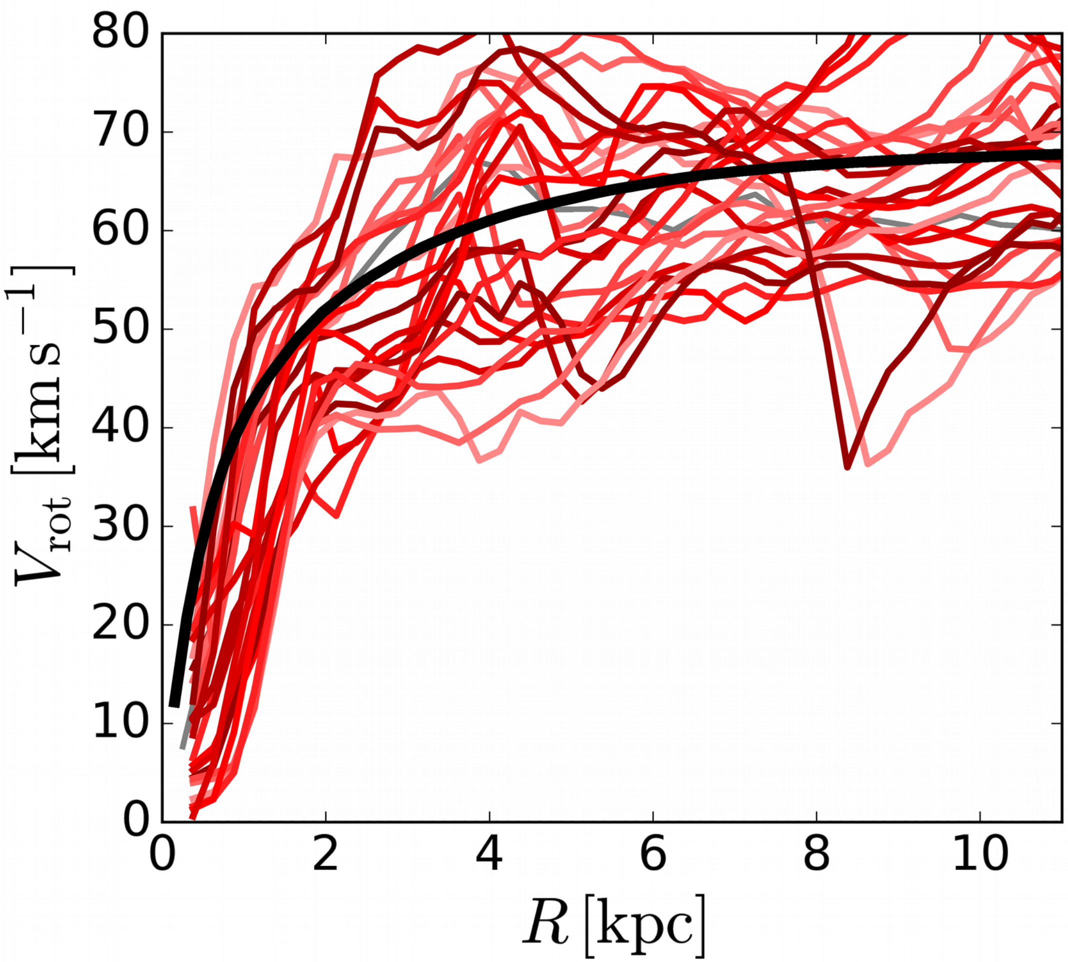


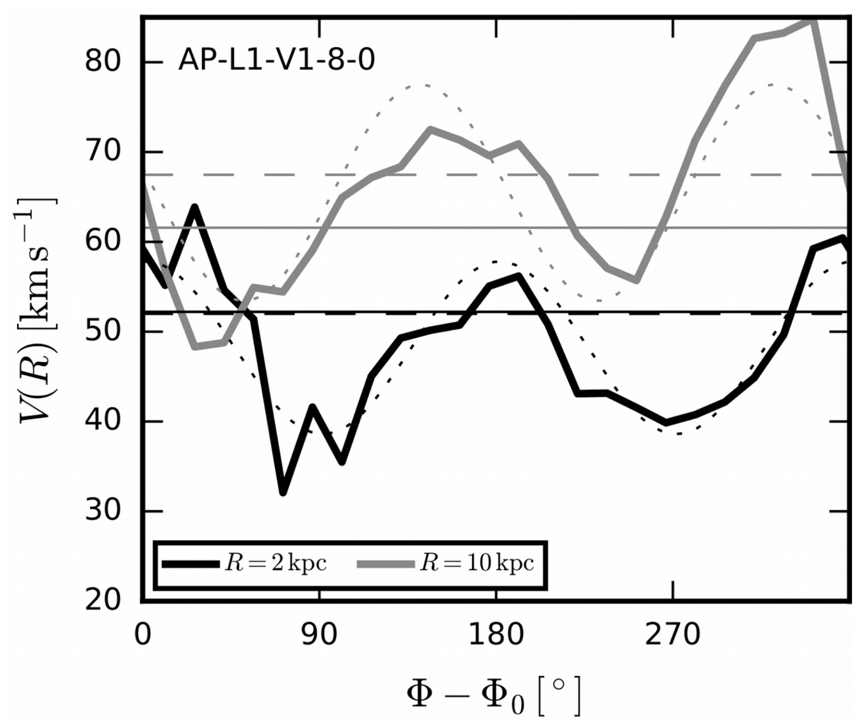
Non-circular motions



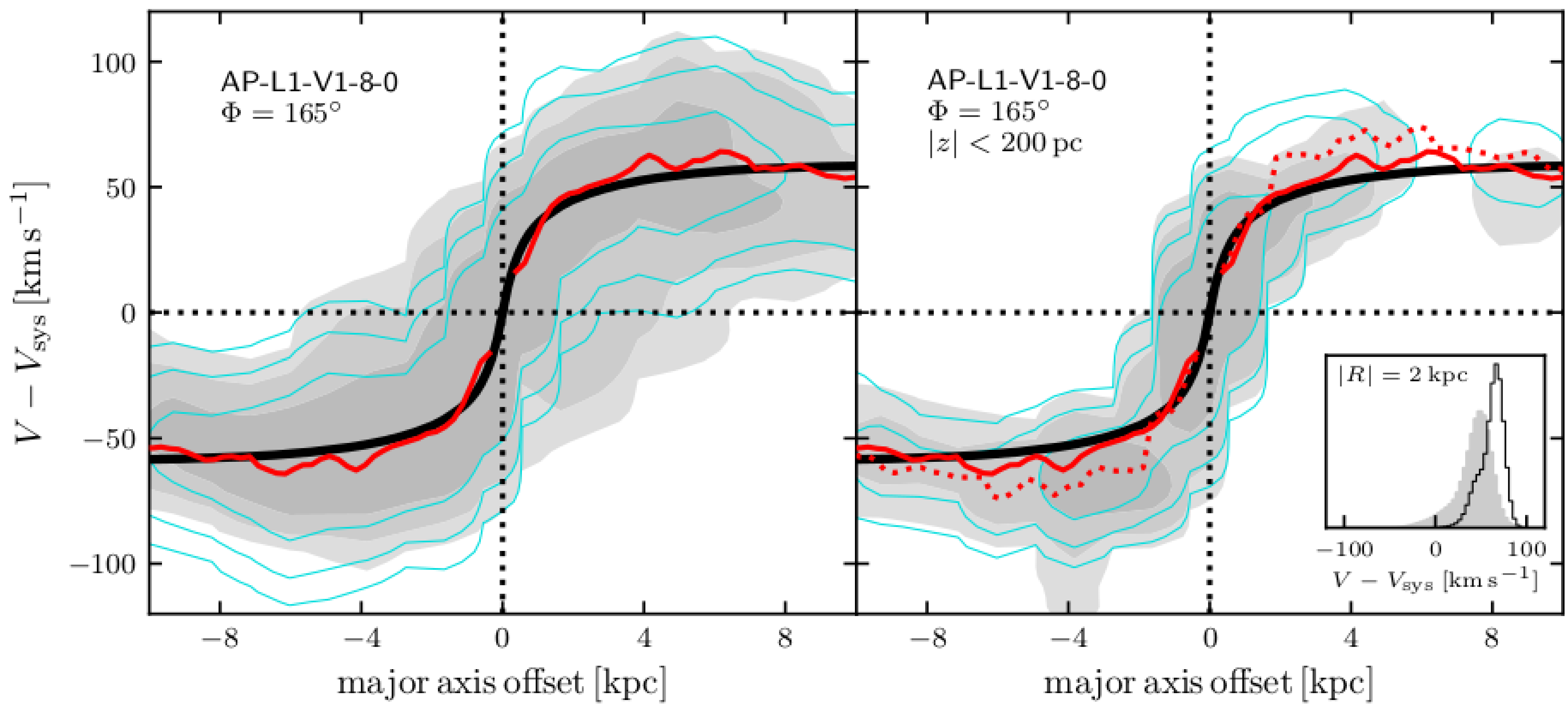


Non-circular motions

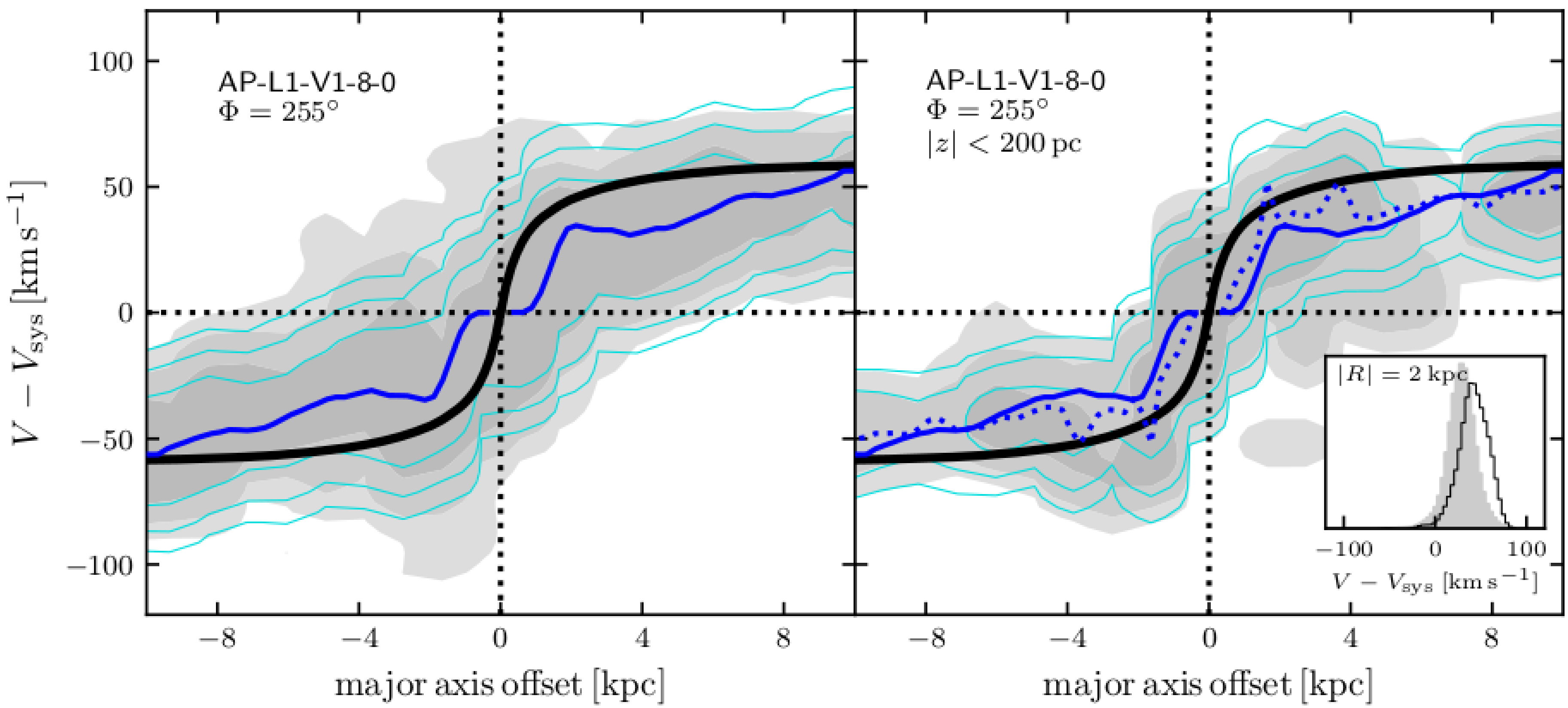




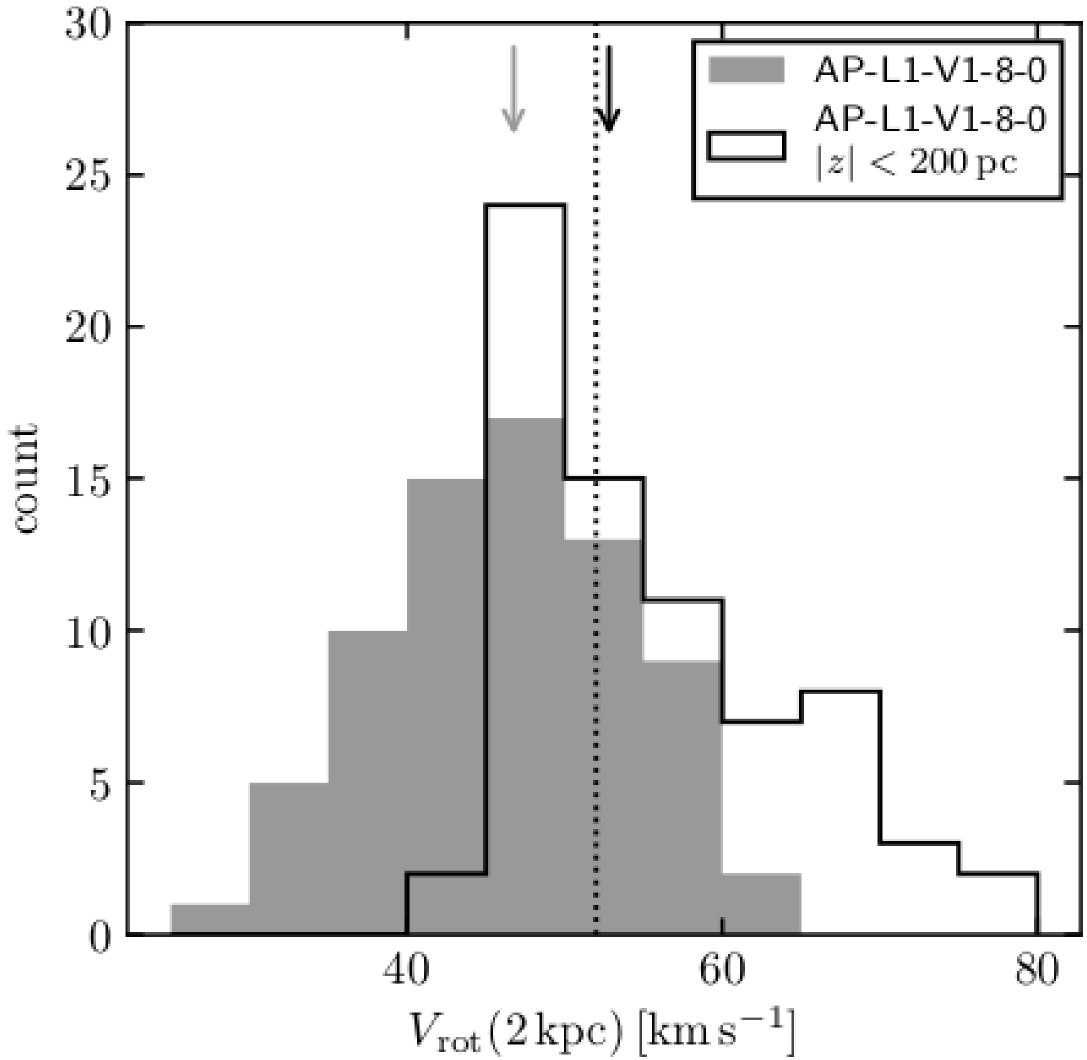
Thick discs


AP-L1-V1-8-0
$\Phi = 165°$
AP-L1-V1-8-0
$\Phi = 165°$
$|z| < 200$ pc
$|R| = 2$ kpc
$V - V_{sys}$ [km s^{-1}]
major axis offset [kpc]
major axis offset [kpc]
$V - V_{sys}$ [km s^{-1}]

Thick discs

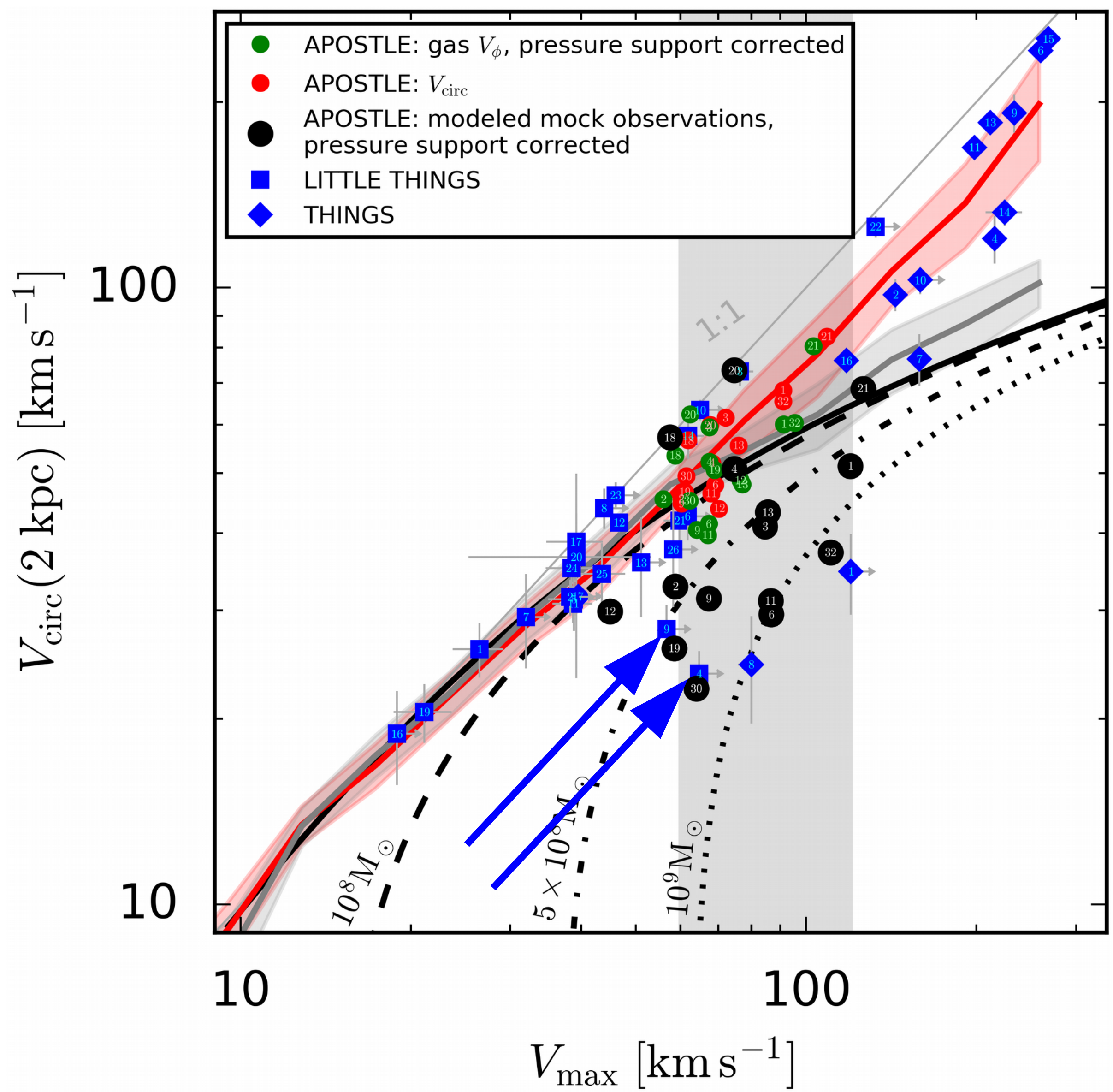

AP-L1-V1-8-0
Φ = 255°
AP-L1-V1-8-0
Φ = 255°
|z| < 200 pc
|R| = 2 kpc
V − Vsys [km s−1]
major axis offset [kpc]
100
50
0
−50
−100
−8
−4
0
4
8

Thick discs

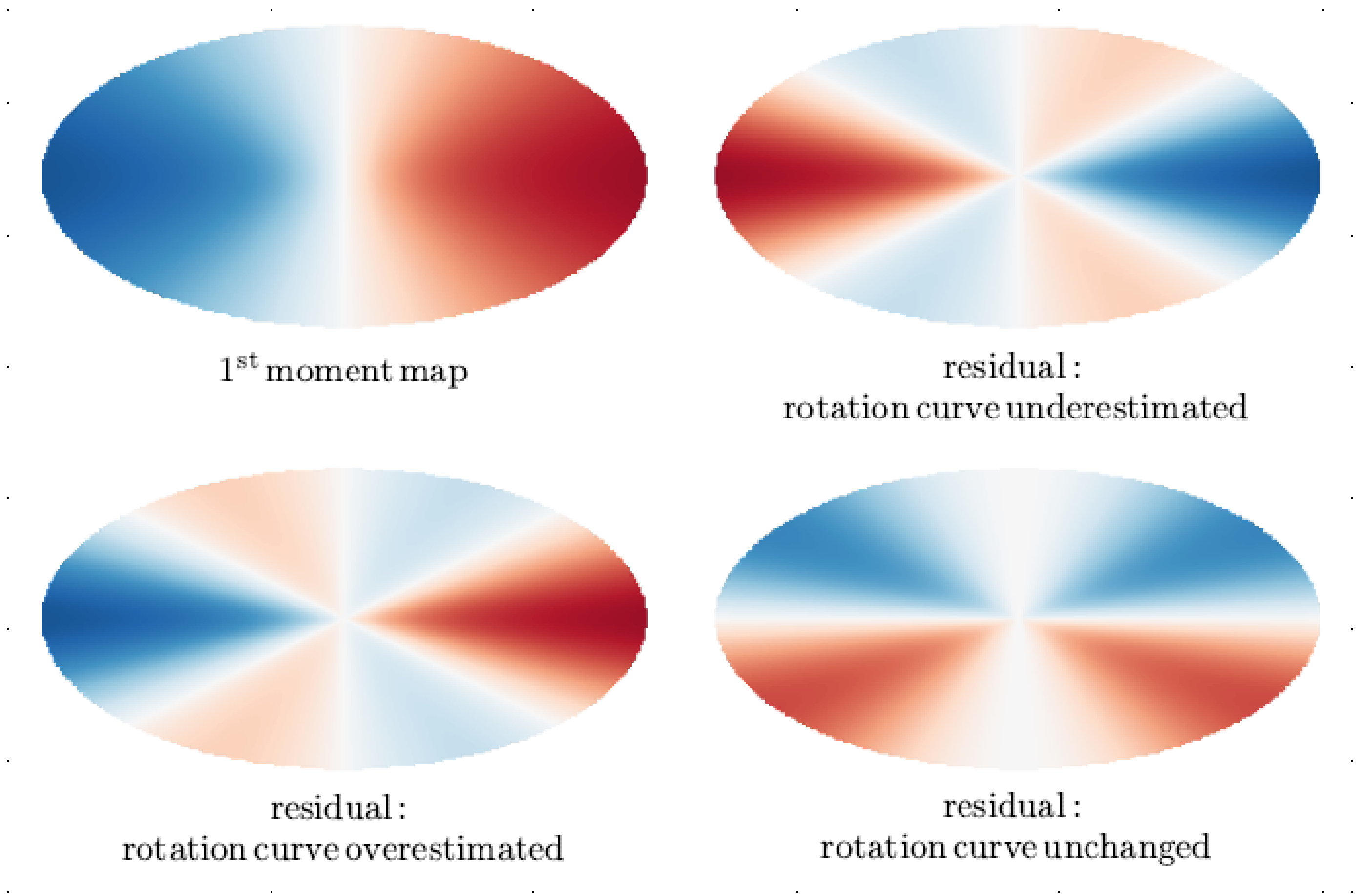


AP-L1-V1-8-0
AP-L1-V1-8-0
$|z| < 200$ pc
count
0
5
10
15
20
25
30
40
60
80
$V_{\rm rot}\,(2\,{\rm kpc})\ [{\rm km\,s^{-1}}]$

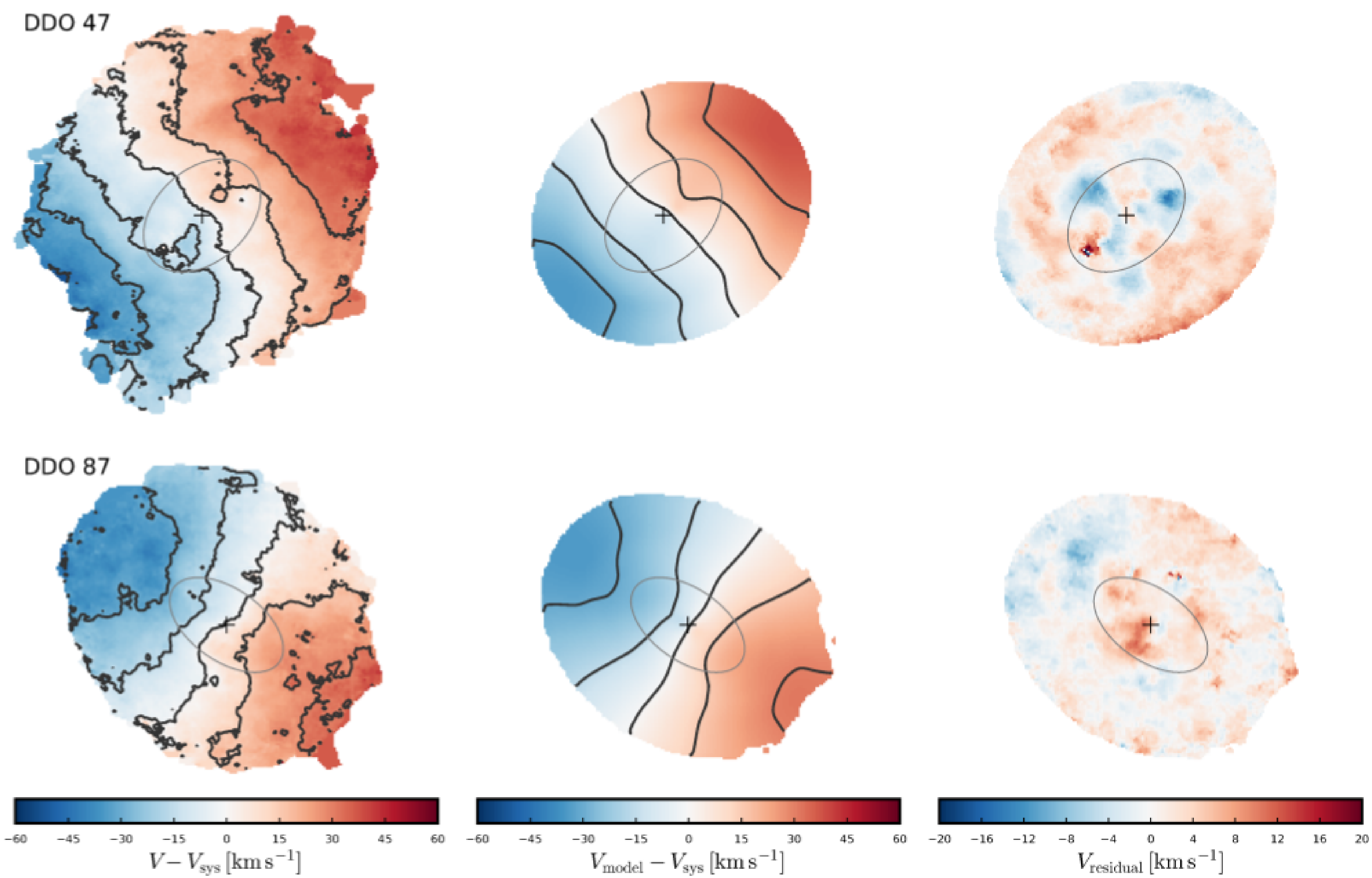
Applicability to reality?



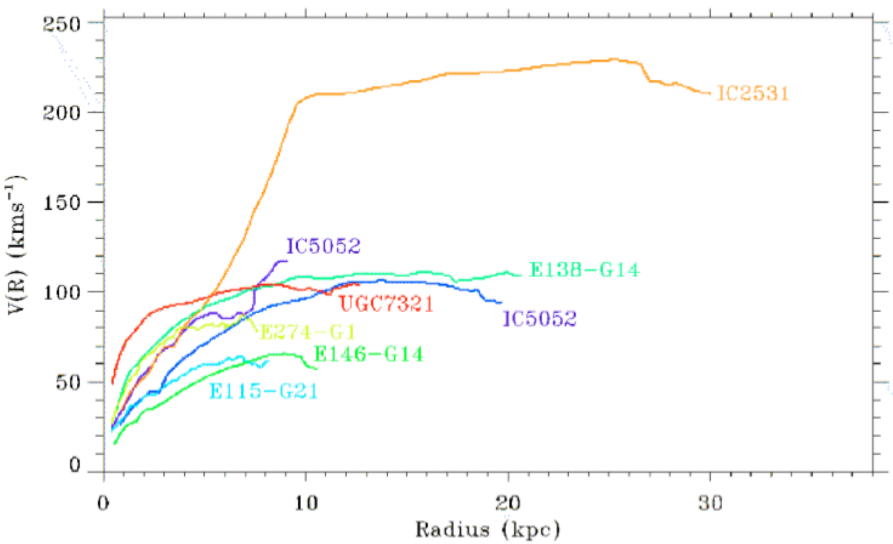
Applicability to reality?

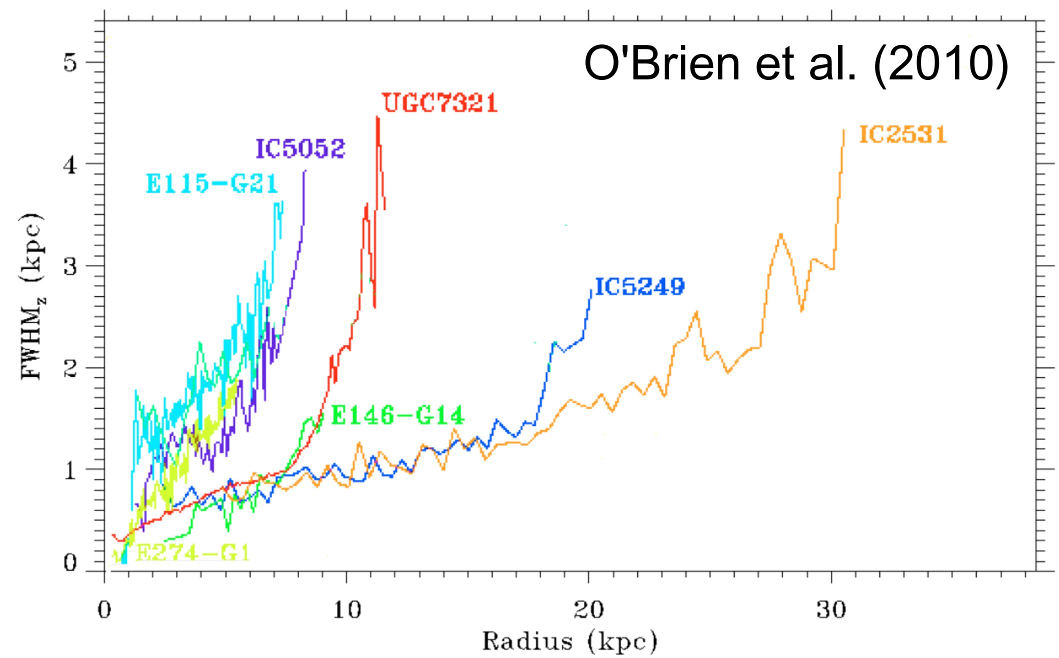


Applicability to reality?



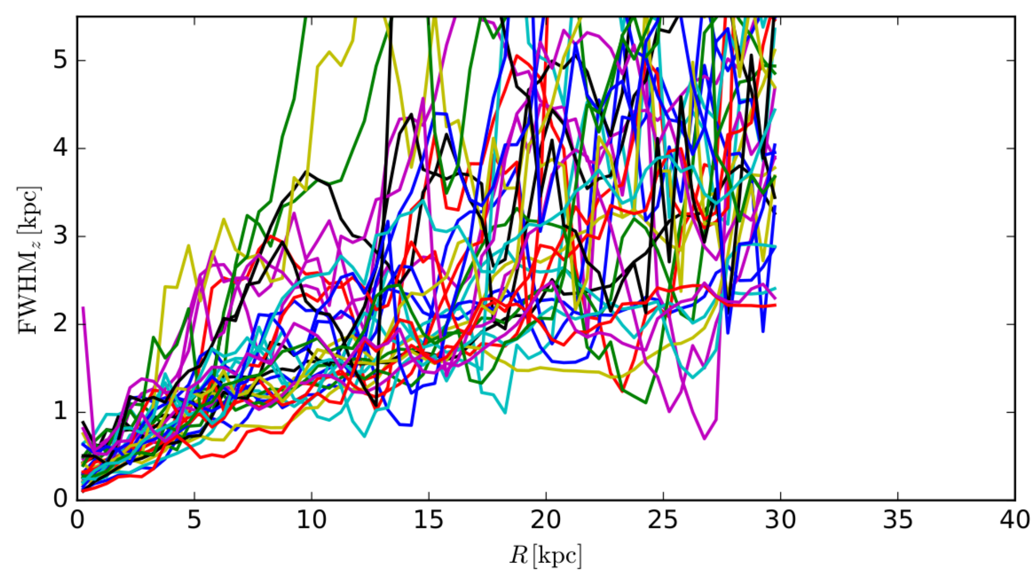
Applicability to reality?





NGC 891 $\frac{\mathrm{d}V_\phi}{\mathrm{d}z} = -15\,\mathrm{km\,s^{-1}\,kpc^{-1}}$

Fraternali et al. (2005)



Summary

- Non-circular motions & confusion along the line of sight hinder the recovery of accurate rotation curves.
- It’s unclear to me how severe the cusp-core problem actually is.
- Forward modelling of cosmological hydrodynamical is a powerful tool for learning about the limitations of analysis.