A mass-dependent density profile for dark matter haloes including the influence of galaxy formation: cusp vs cores in real galaxies

Arianna Di Cintio[1,2★], C. B. Brook[1], A. V. Macciò[3], A. A. Dutton[3], G. S. Stinson[3], A.Knebe[1]

[1] Universidad Autonoma Madrid [2] DARK Copenhagen [3] MPIA

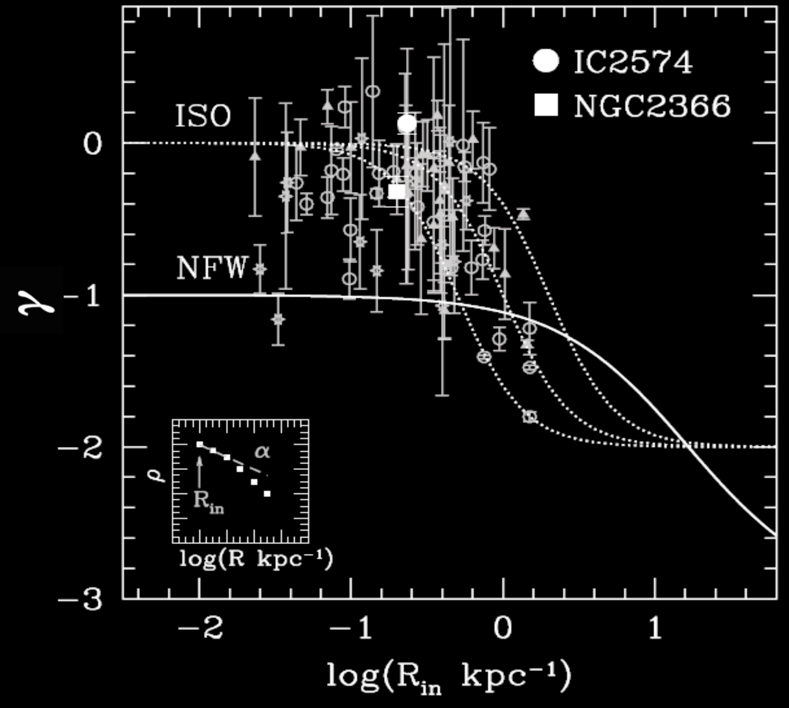
★arianna.dicintio@uam.es

Di Cintio, Brook +14a, MNRAS, 437, 415
Di Cintio, Brook +14b, MNRAS, 441, 2986
Brook, Di Cintio +14, ApJ, 784, L14
Brook & Di Cintio 2014 submitted

Potsdam - August 2014

Observations predict 'CORES'

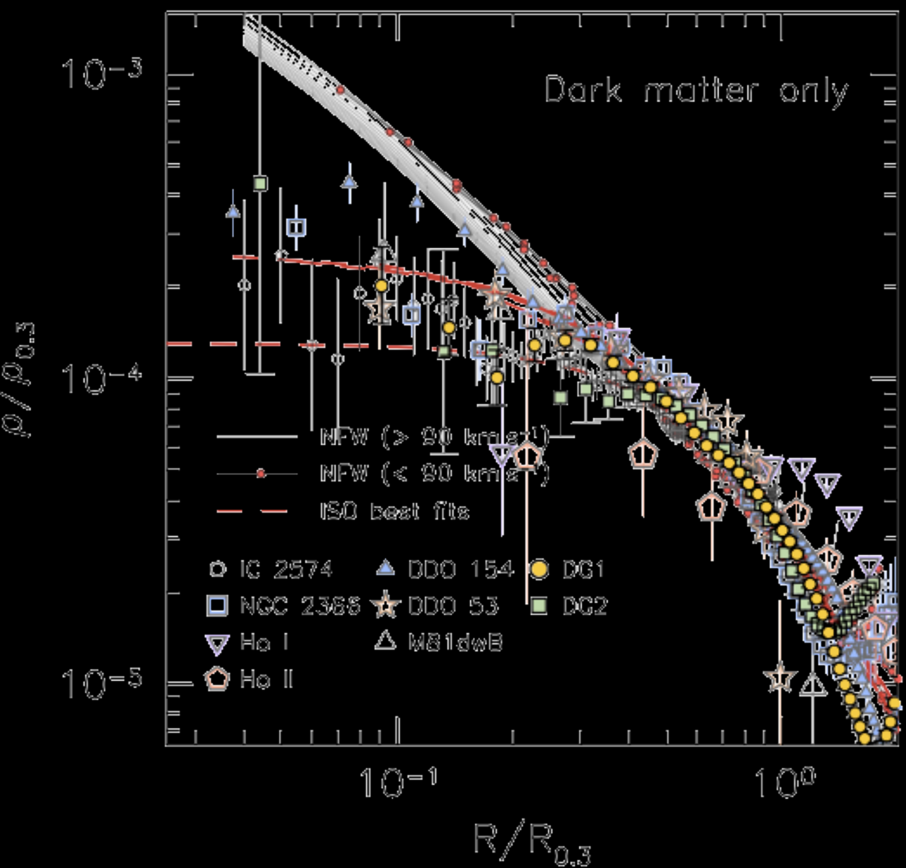
Oh+08



'CORED' profile

Inner slope $\gamma < 1$

Oh+11



Cusp/core problem

(see Pontzen & Governato 14 for review)

Can baryons help?

Making Galaxies in a Cosmological Context
MaGICC project

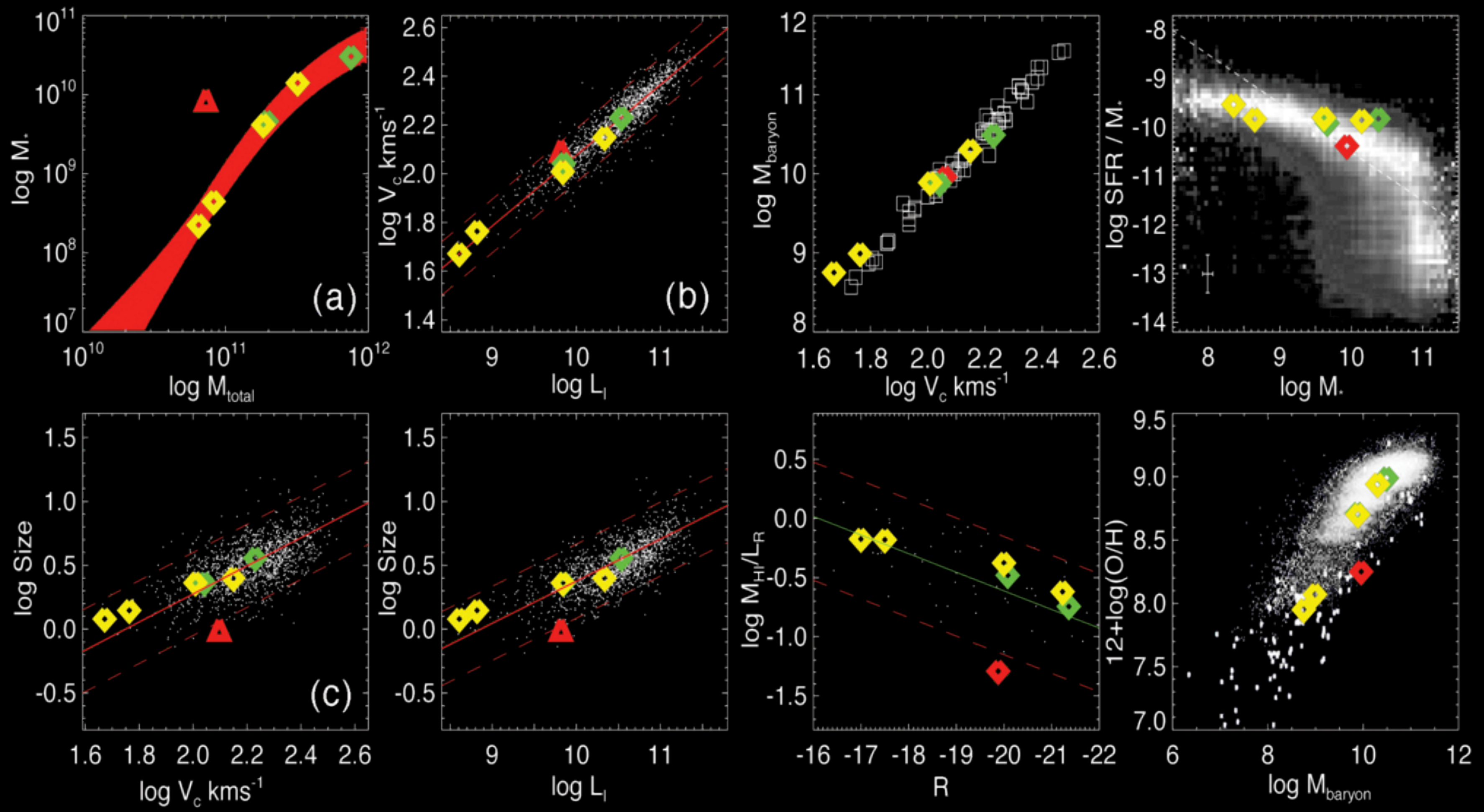
Stinson+13, Brook +12

(Brook+12b, Maccio'+12, Penzo+14, Herpich+14, Kannan+14, Obreja+14 etc)

Hydrodynamical simulations of galaxies including dark matter, gas, stars and..

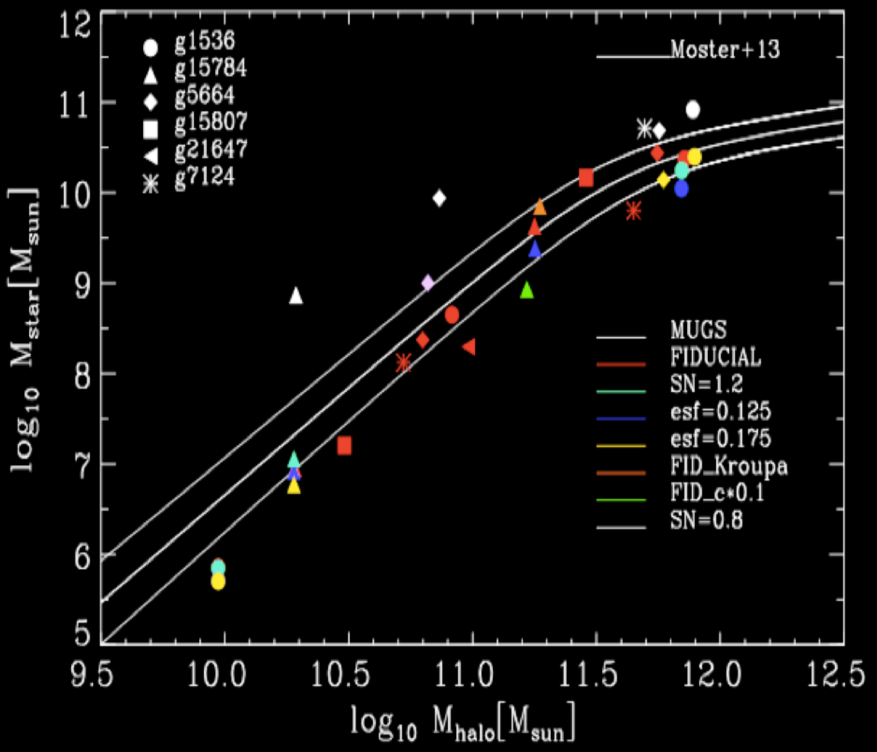
.. feedback from SNe and massive stars

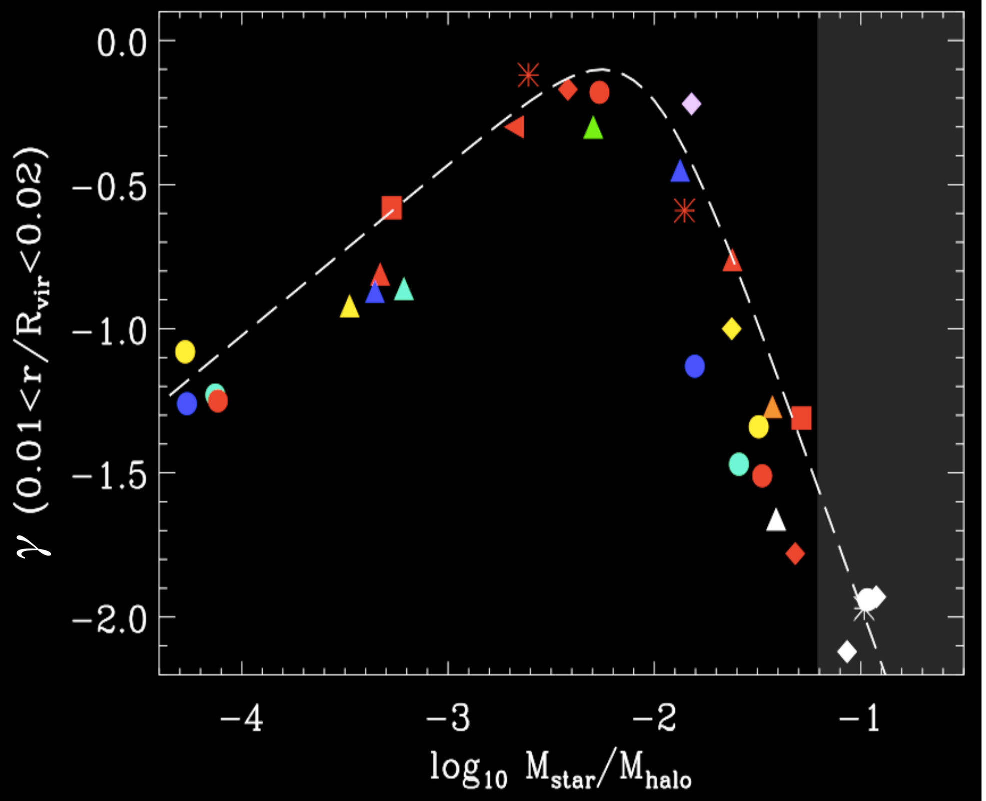
Stinson+06,+13



Brook +12

Inner slope dependence on $M_\star/M_{halo}$





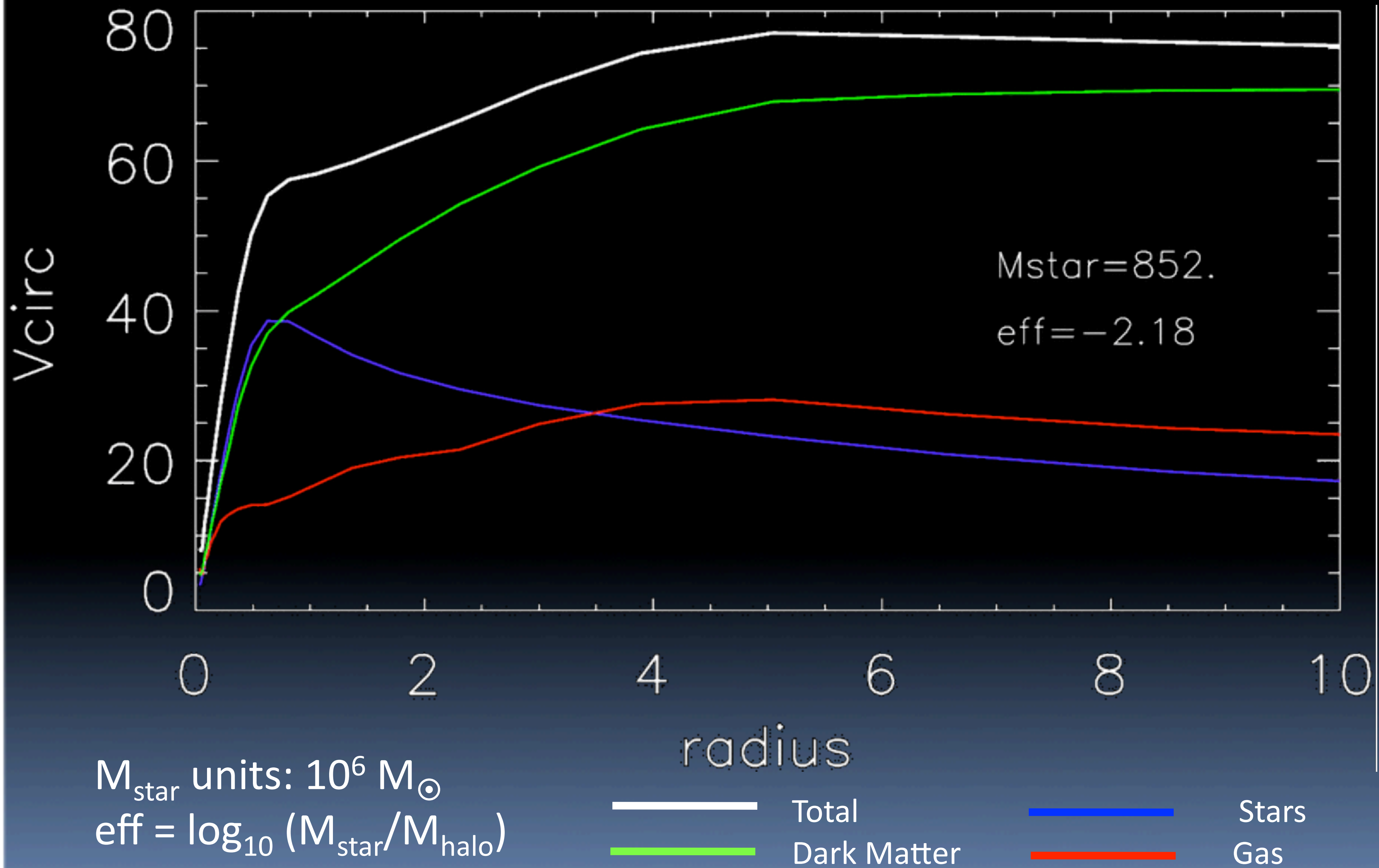
Dark matter profiles determined by two opposite effects: energy from Sne vs Increasing gravitational potential

$$\gamma(X) = n - \log_{10}\left[\left(\frac{X}{x_0}\right)^{-\beta} + \left(\frac{X}{x_0}\right)^{\gamma}\right]$$

see Pontzen & Governato 12 for core creation mechanism

Di Cintio+14a

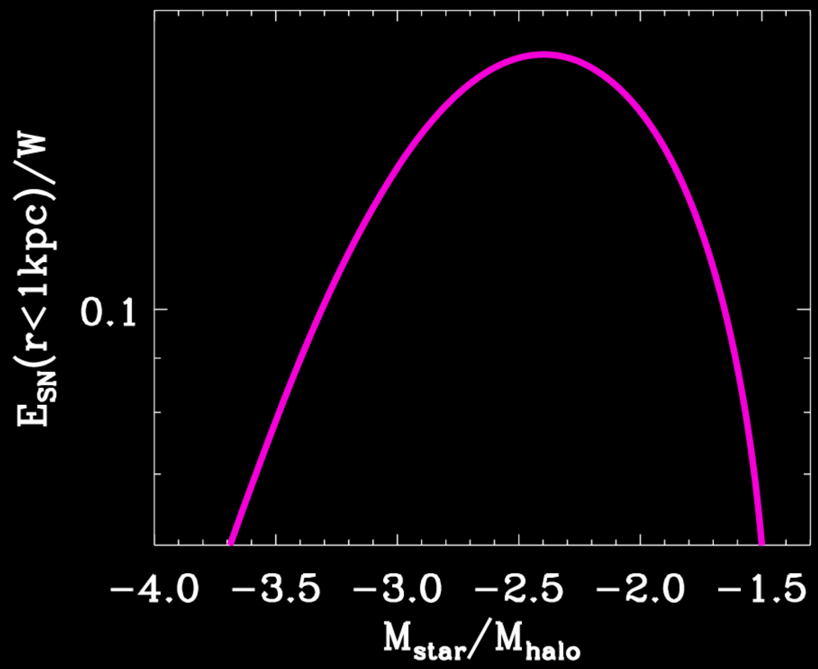
CLUES + ChaNGa + Gasoline at z=1.2

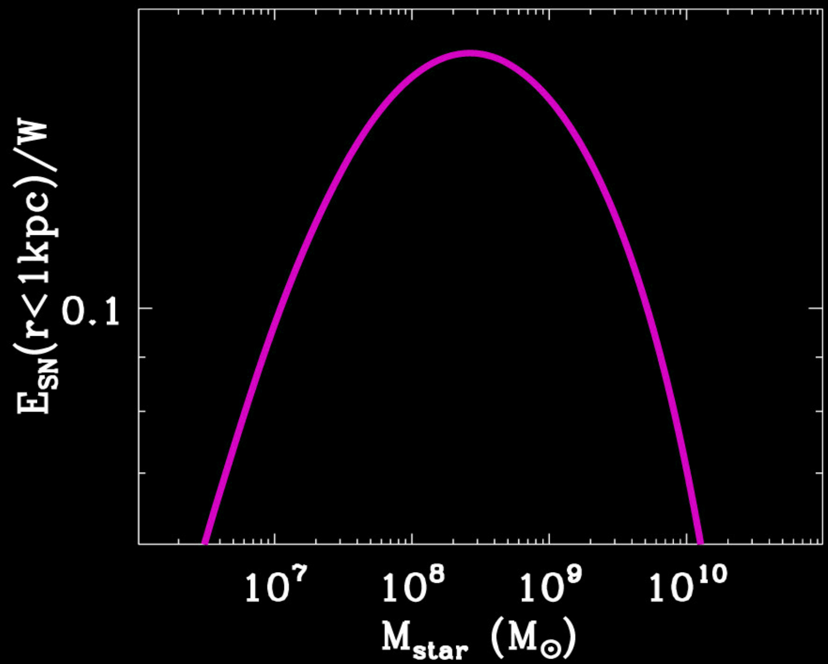


M_{star} units: $10^6\ M_{\odot}$

eff = $\log_{10} (M_{star}/M_{halo})$

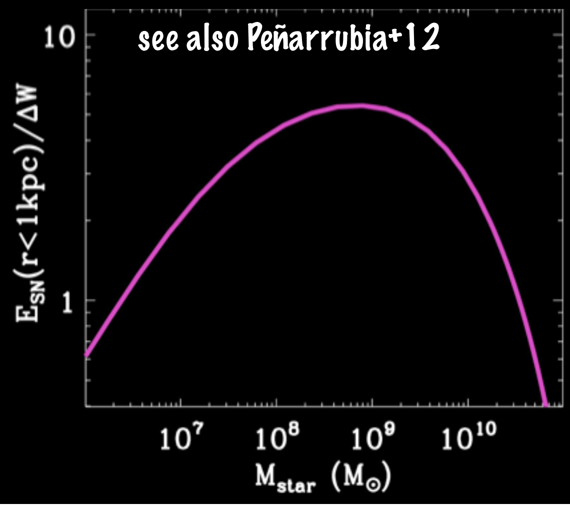
Peak in CORE formation efficiency



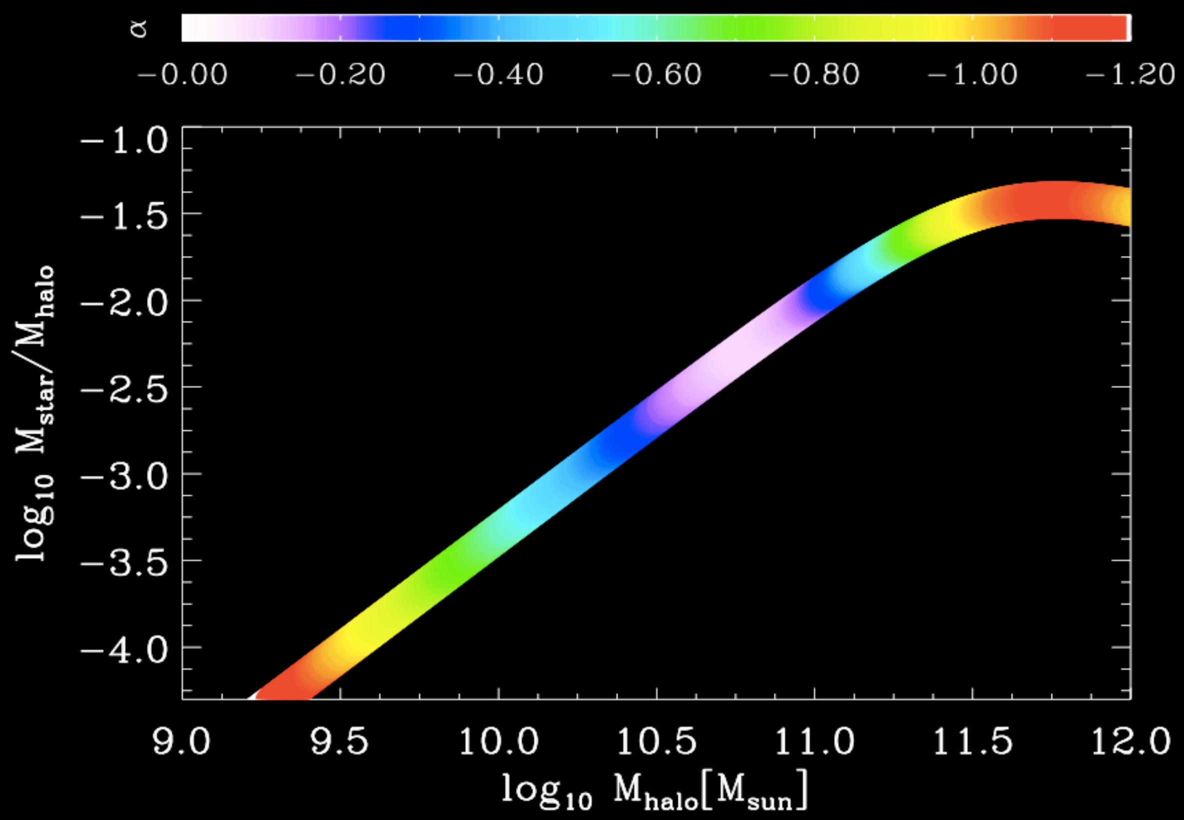


Energy balance between SNe energy and potential energy of NFW halo.
Flattest profiles expected at $M_* \sim 10^{8.5} M_\odot$

Brook & Di Cintio submitted



Cusp/core abundance matching

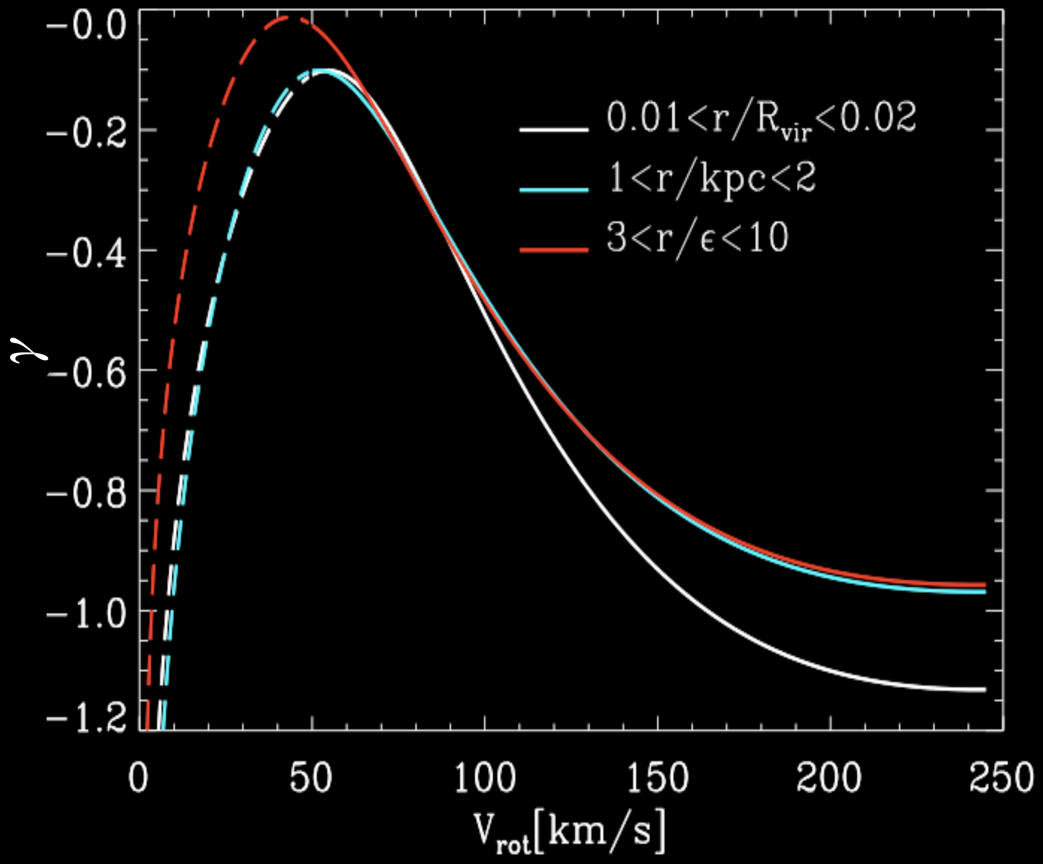


Di Cintio+14a

For $M_* > 10^{8.5} M_\odot$ increasingly CUSPY profiles

For M_* approaching $10^{8.5} M_\odot$ increasingly CORED profiles (see also Governato+10)

Predictions for observed galaxies



THINGS galaxy survey
$10^7 < M^*/M_{sun} < 10^9$, provides mean γ=-0.3 (Oh+08, Oh+11)
Flattest profiles in galaxies with V_{rot}~50km/s
Clear observations of cores in LSB galaxies with V_{rot}< 100km/s
(de Blok+08, Kuzio de Naray+08,+09)

Di Cintio+14a

TF from Dutton+11

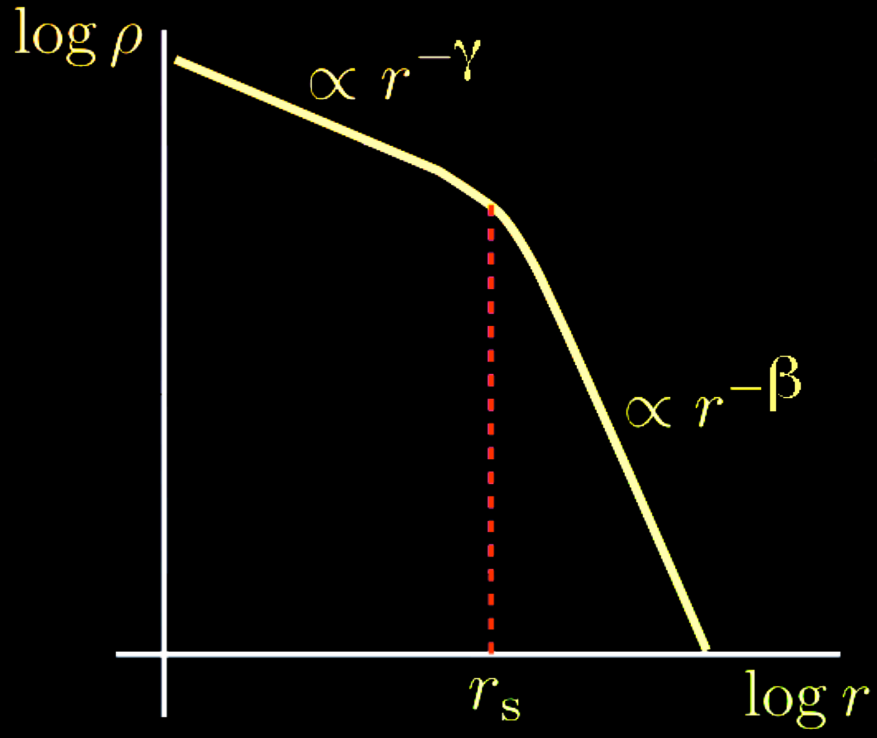
A double power law profile

$$\rho(r) = \frac{\rho_s}{\left(\frac{r}{r_s}\right)^{\gamma}\left[1+\left(\frac{r}{r_s}\right)^{\alpha}\right]^{(\beta-\gamma)/\alpha}}$$

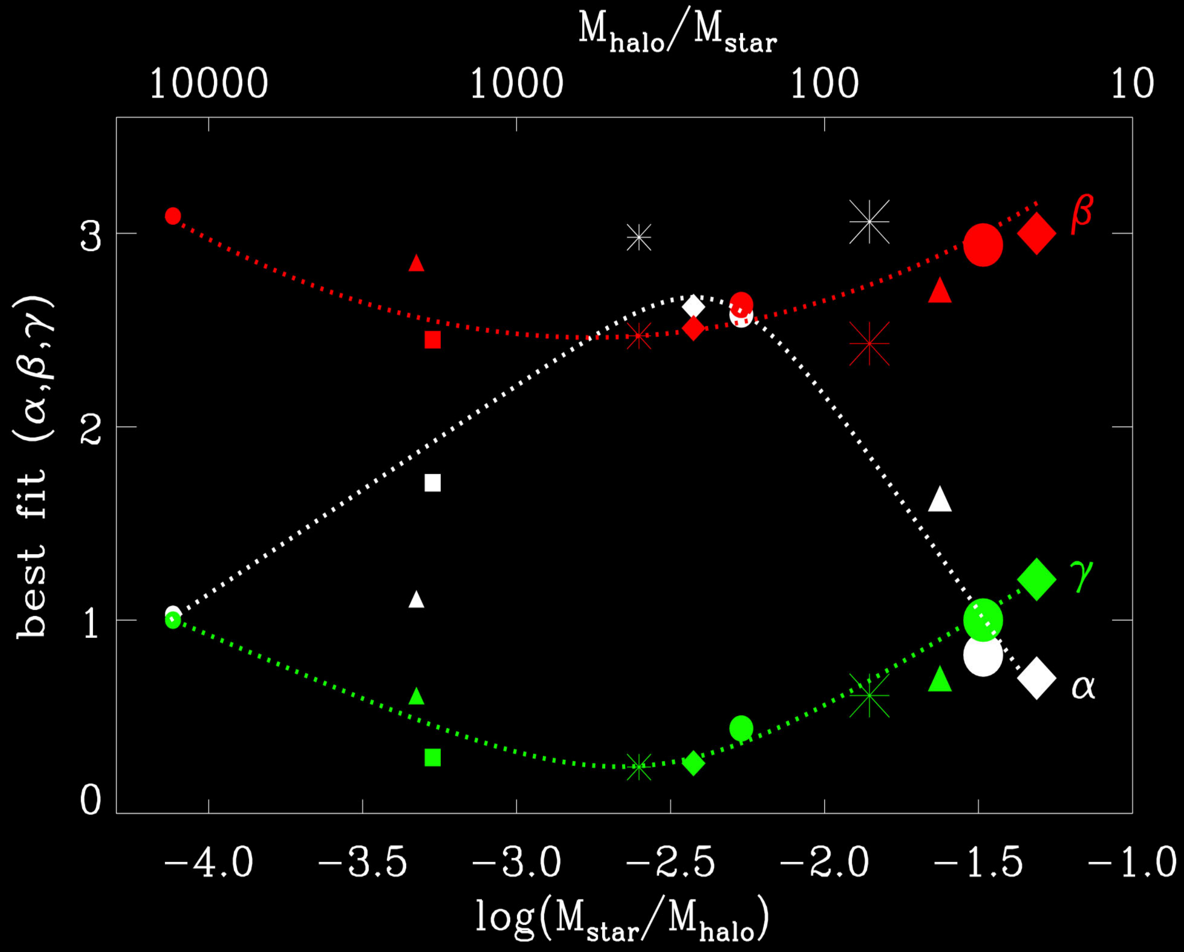
γ inner slope
β outer slope
α sharpness of transition

NFW: (α,β,γ)=(1,3,1)

$$\rho(r) = \frac{\rho_0}{\frac{r}{R_s}\left(1 + \frac{r}{R_s}\right)^2}$$

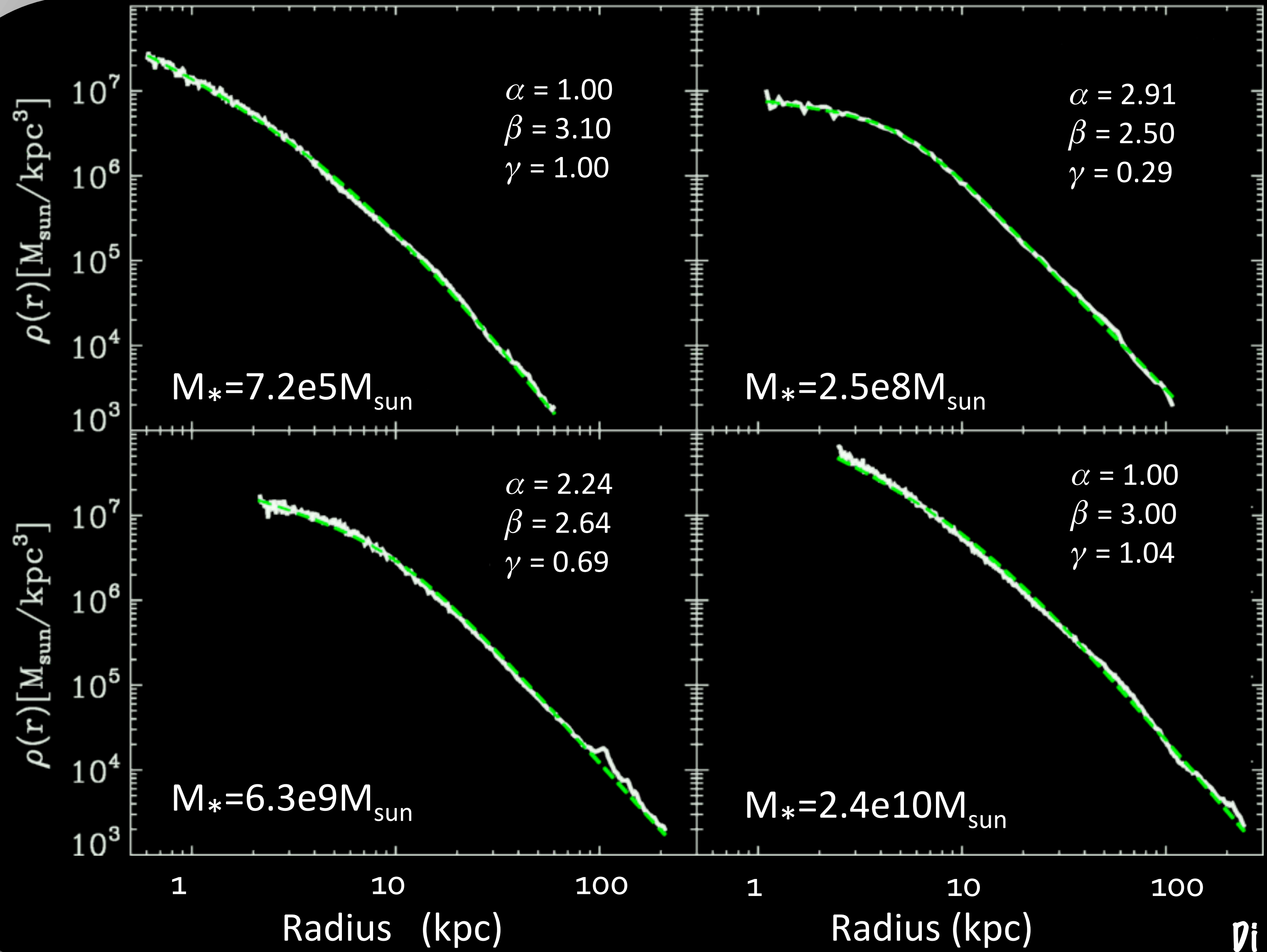


α, β, γ constrained via $M_{\star}/M_{halo}$



Di Cintio+14b

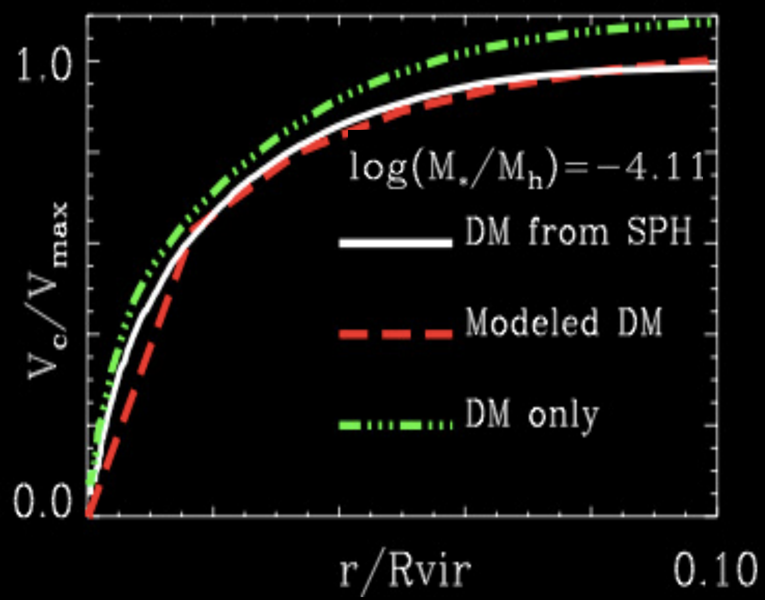
Mass dependent DM profile



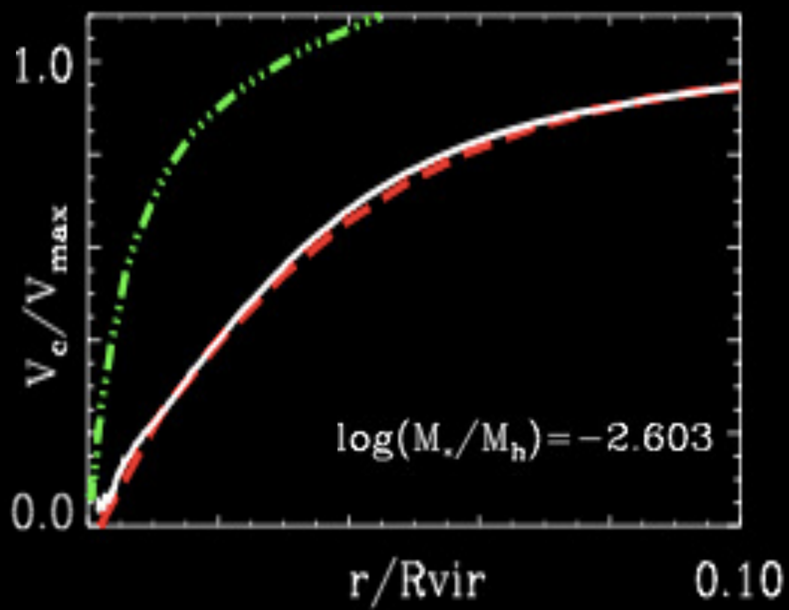
Di Cintio+14b

Derived rotation curves

Low efficiency dwarf: retains NFW



Higher efficiency: expanded halo

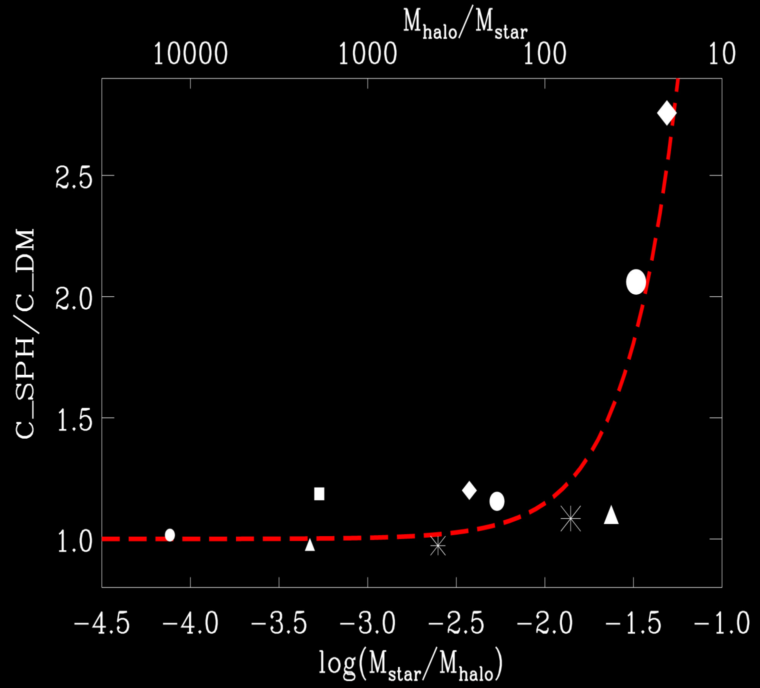


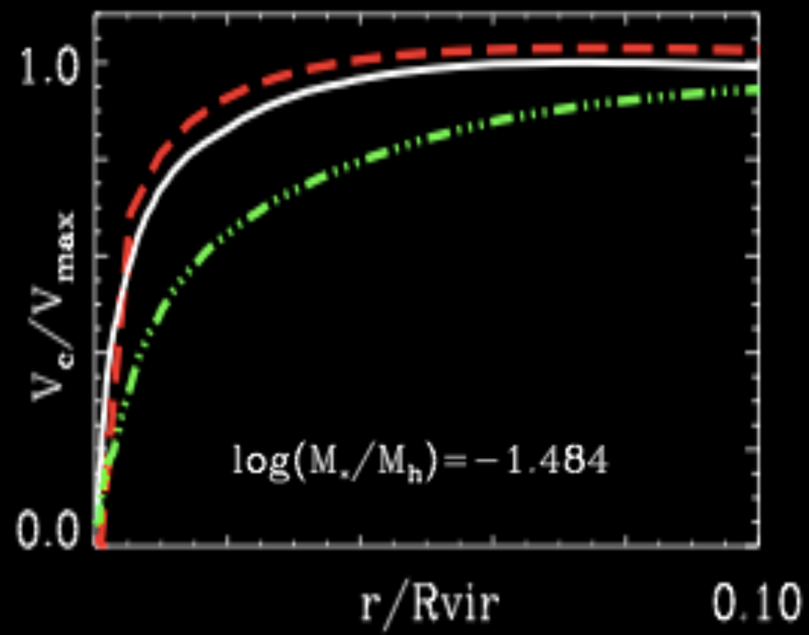
Di Cintio+14b

Concentration-mass relation

High concentration in MW-like galaxies

Di Cintio+14b

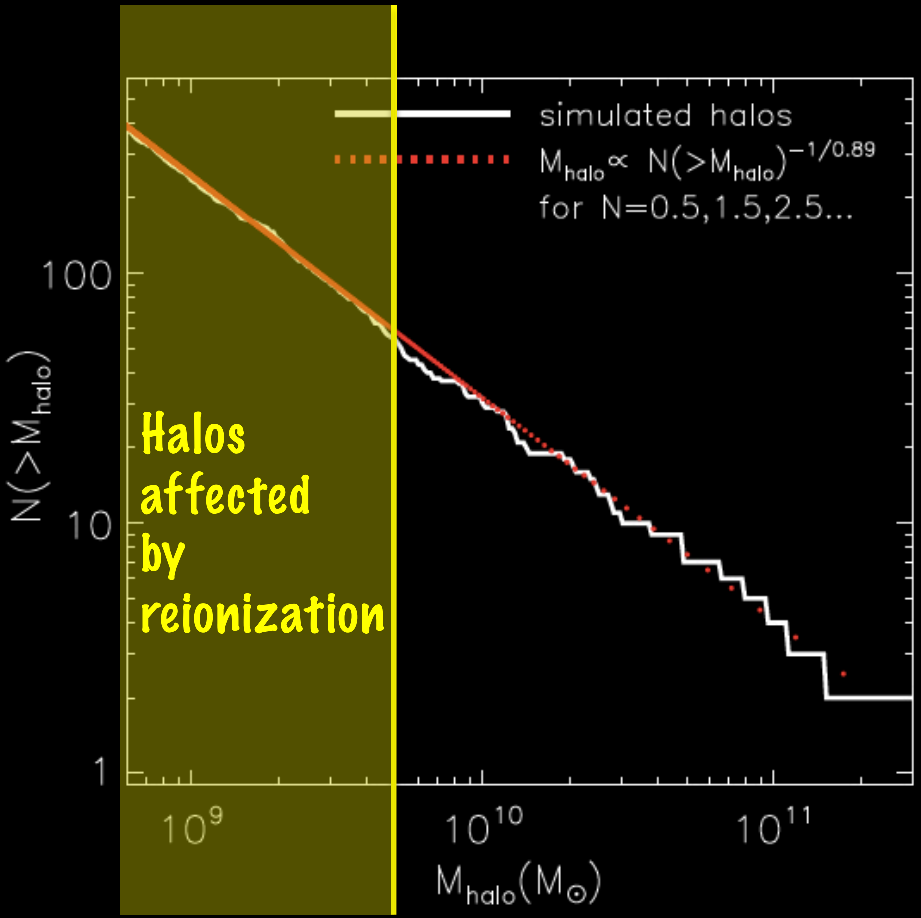




NFW halo with high concentration $c \approx 18\text{-}20$ fits well MW data

see Battaglia+05, Catena&Ullio10, Deason+12, Nesti&Salucci13

Mass function of the Local Group



LG simulations

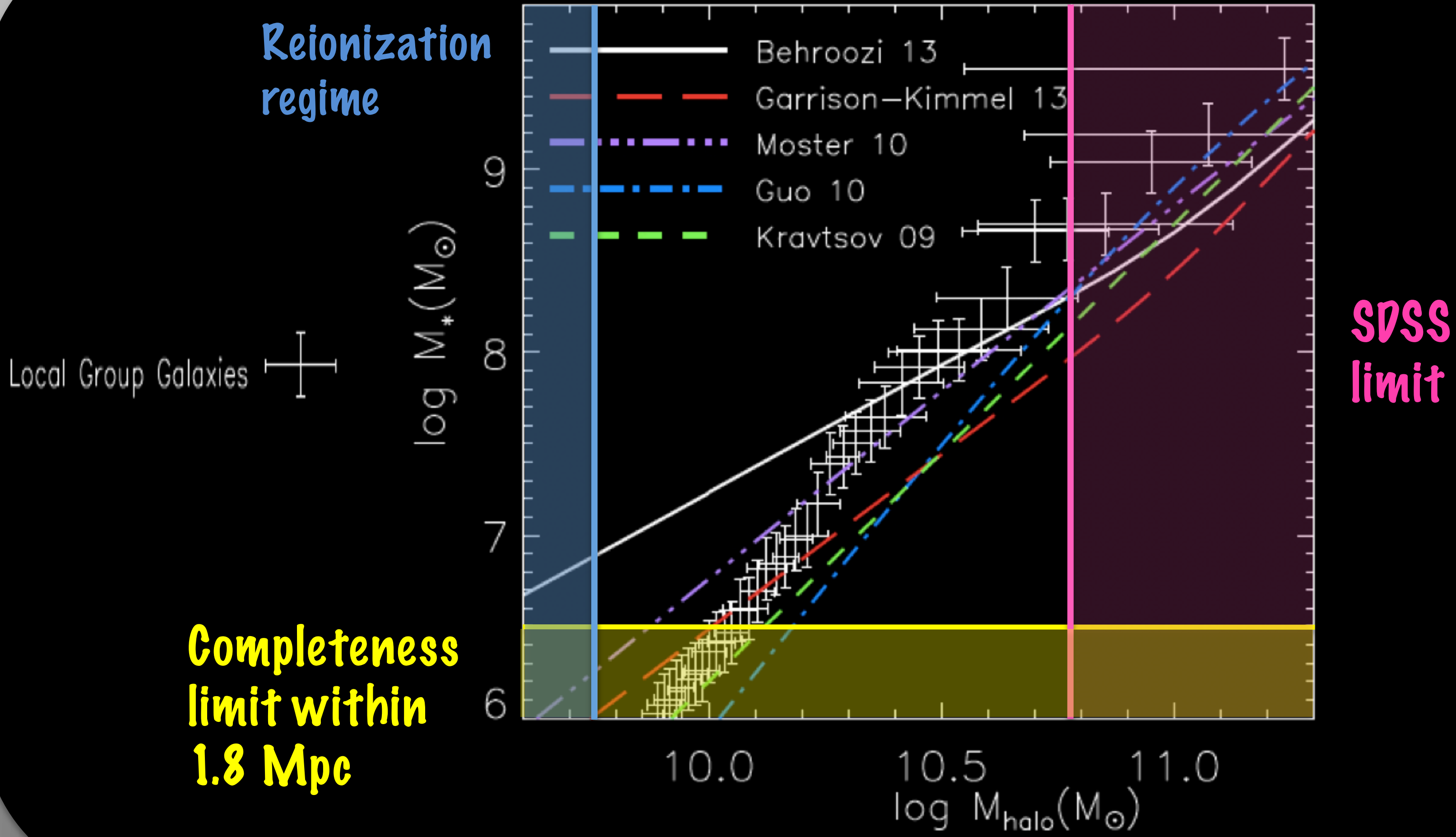
CLUES-Gottloeber +10
ELVIS-Garrison-Kimmel+14
LG analogue-Sawala+14

$N(>M_{halo})$ is a well defined power law

There are 40-50 halos bigger than 7*10^9 M_{sun} a region where **ALL** halos have been shown to form stars in simulations

Brook, Di Cintio +14

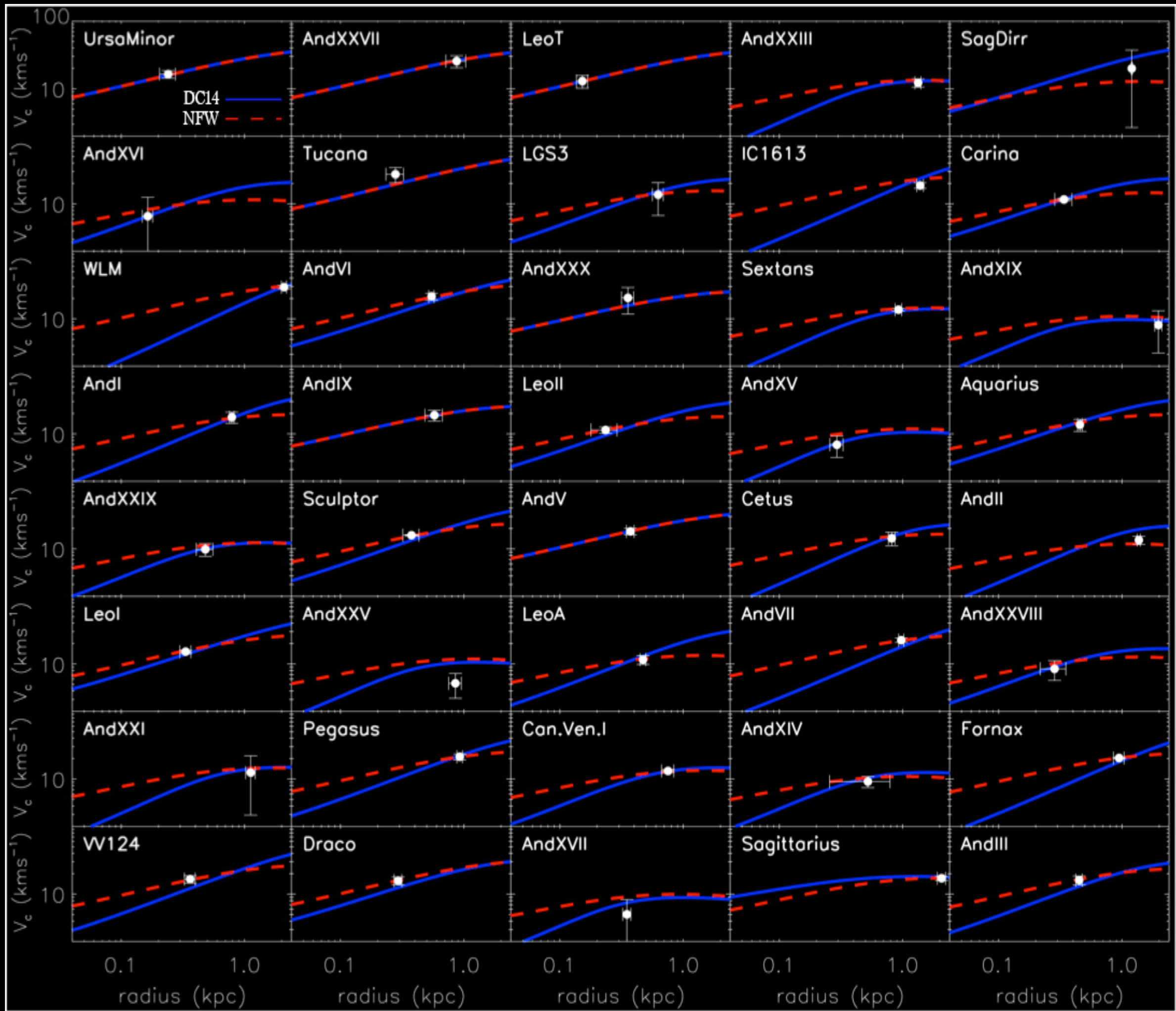
Abundance matching in the Local Group



Brook, Di Cintio +14

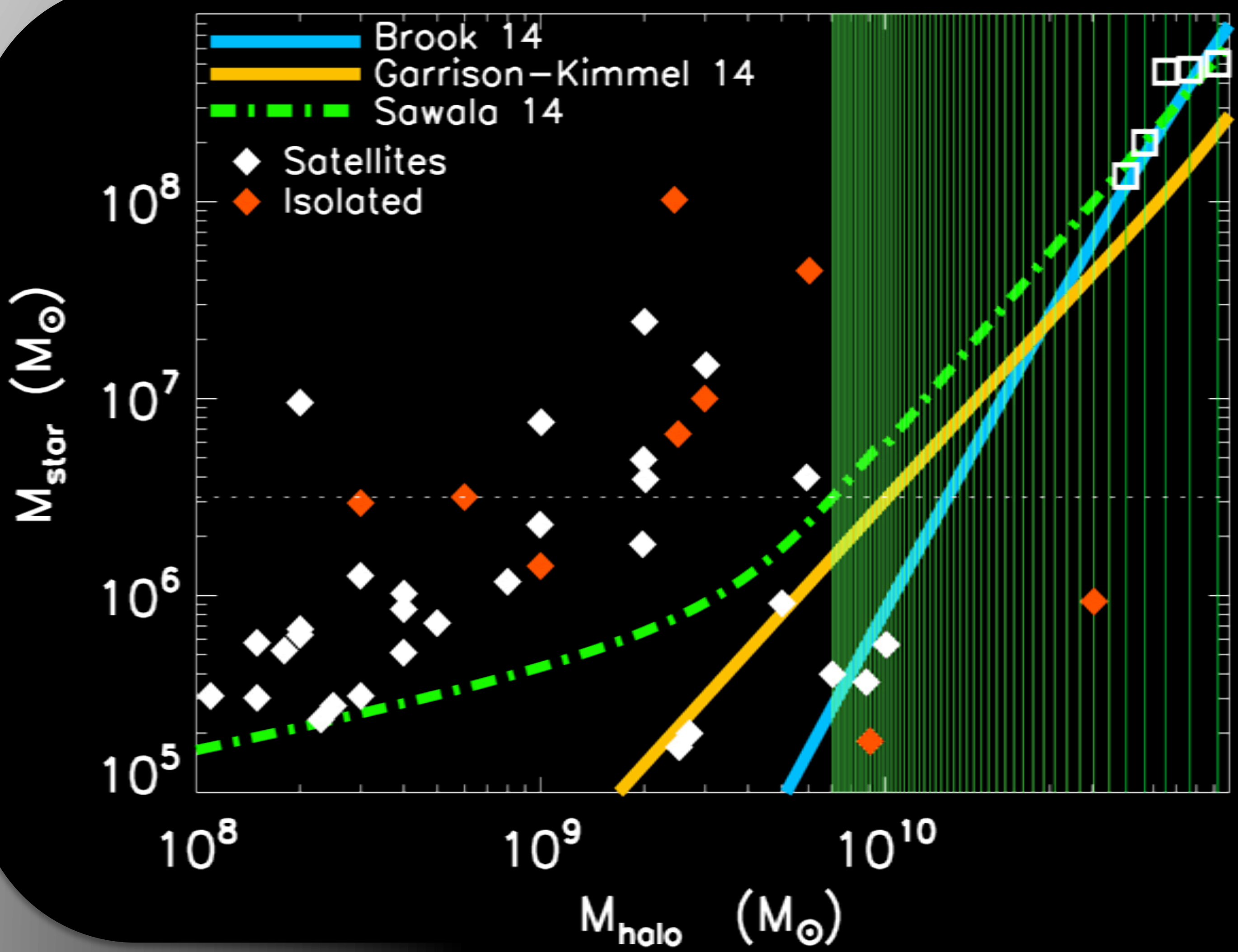
$M_\star/M_{halo}$ in the LG

Kirby+14
Tollerud+14
Wolf+10



Brook & Di Cintio submitted

$M_\star/M_{halo}$ in the LG with NFW



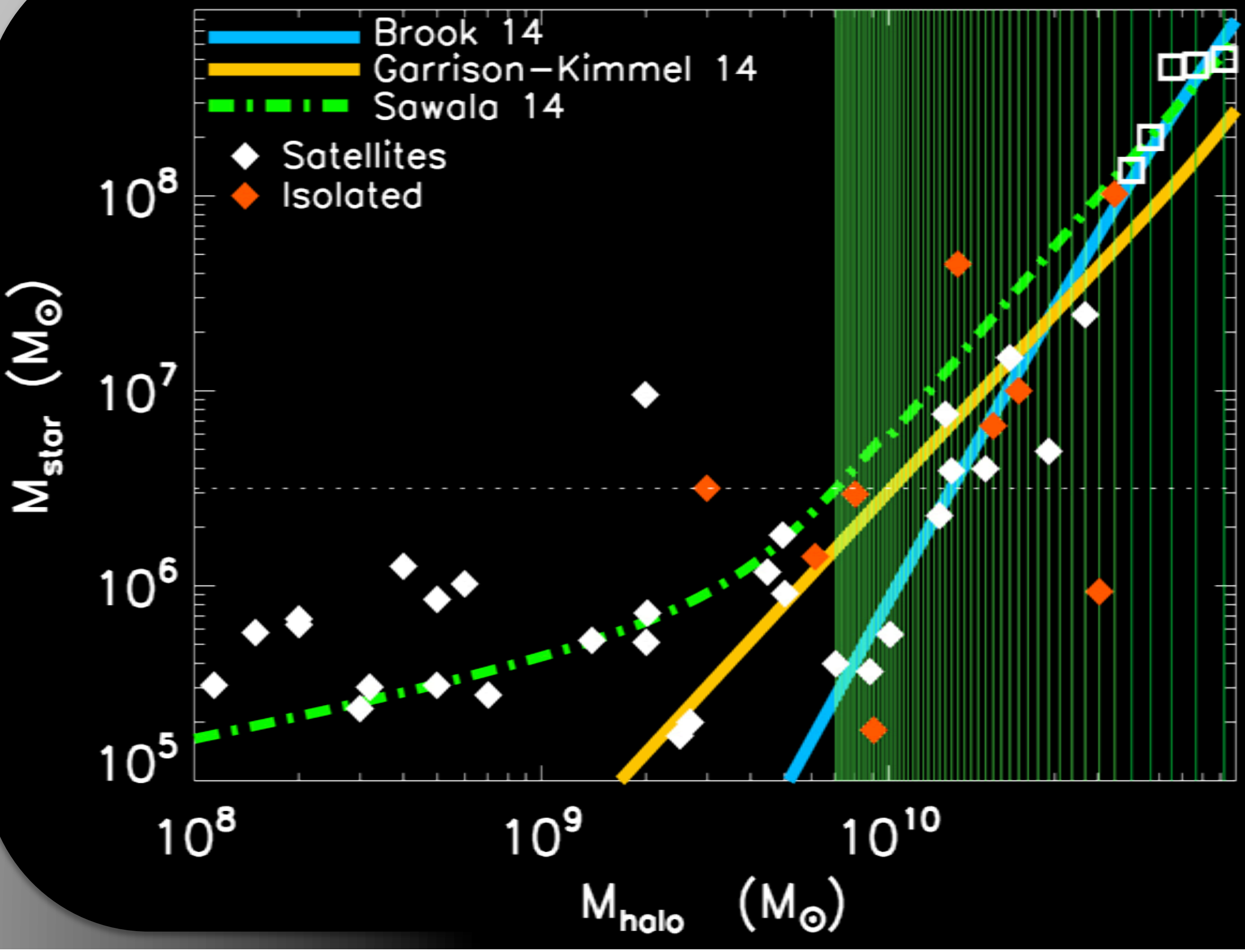
Too big to fail haloes

see also
TBTF in the
Local Group

Garrison-Kimmel+14
Kirby+14
Tollerud+14

Brook & Di Cintio submitted

$M_\star/M_{halo}$ in the LG with mass-dependent profile

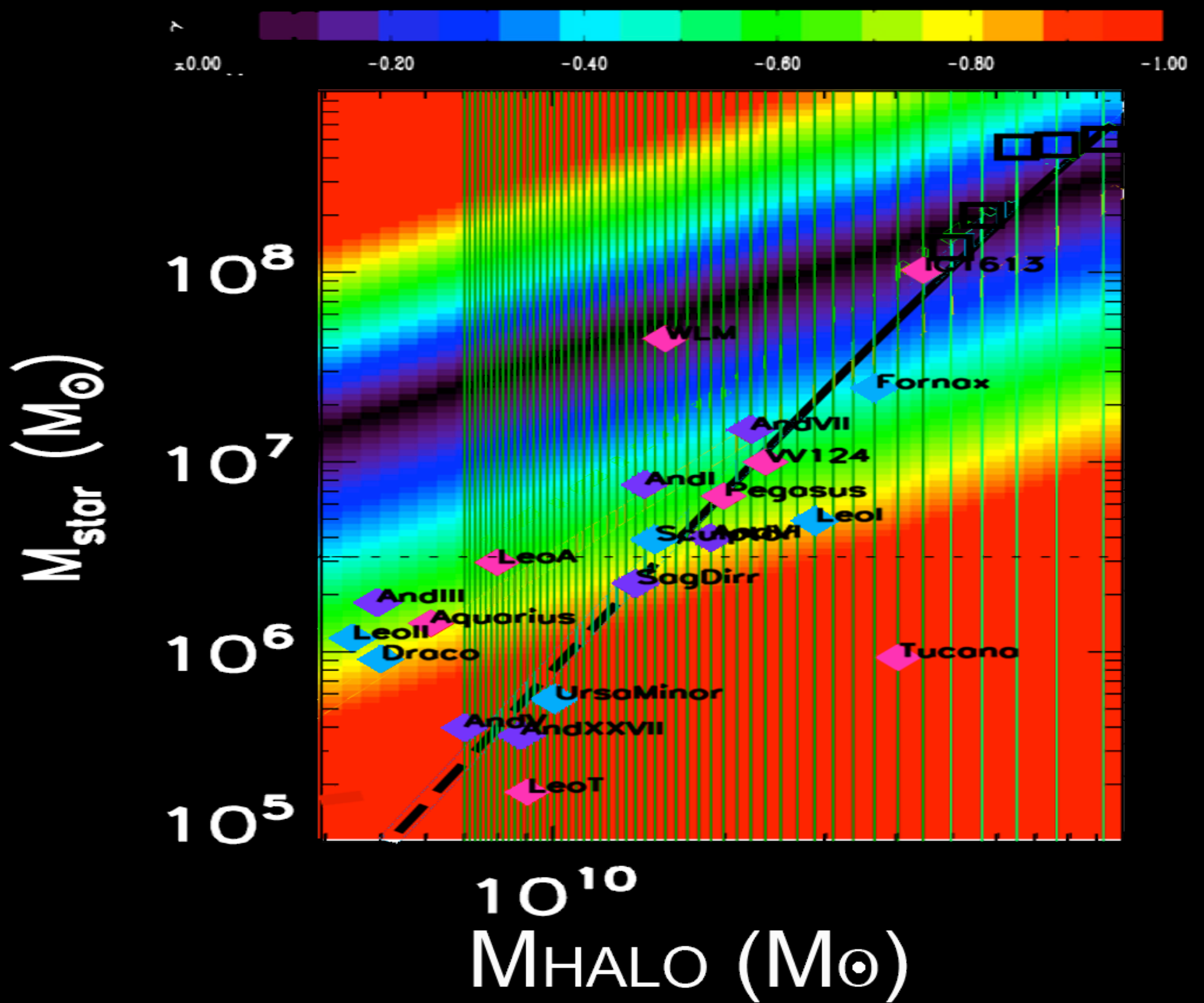


Too big to fail haloes

see
effects of tides
with baryons

Peñarrubia+10
Zolotov+12
Brooks+13
Arraki+13

Brook & Di Cintio submitted



Brook & Di Cintio submitted

Conclusions

✓Baryonic physic DOES affect dark matter profiles in galaxies

✓There is a peak in core formation efficiency, cored-most galaxies at $M_{*} \approx 10^{8.5}$

✓Mass dependent dark matter profile to be used in observations and semi-analytic models as the theoretical framework to understand the cusp-core DICHOTOMY

✓Looking at the ensemble of LG galaxies provides a way to do it

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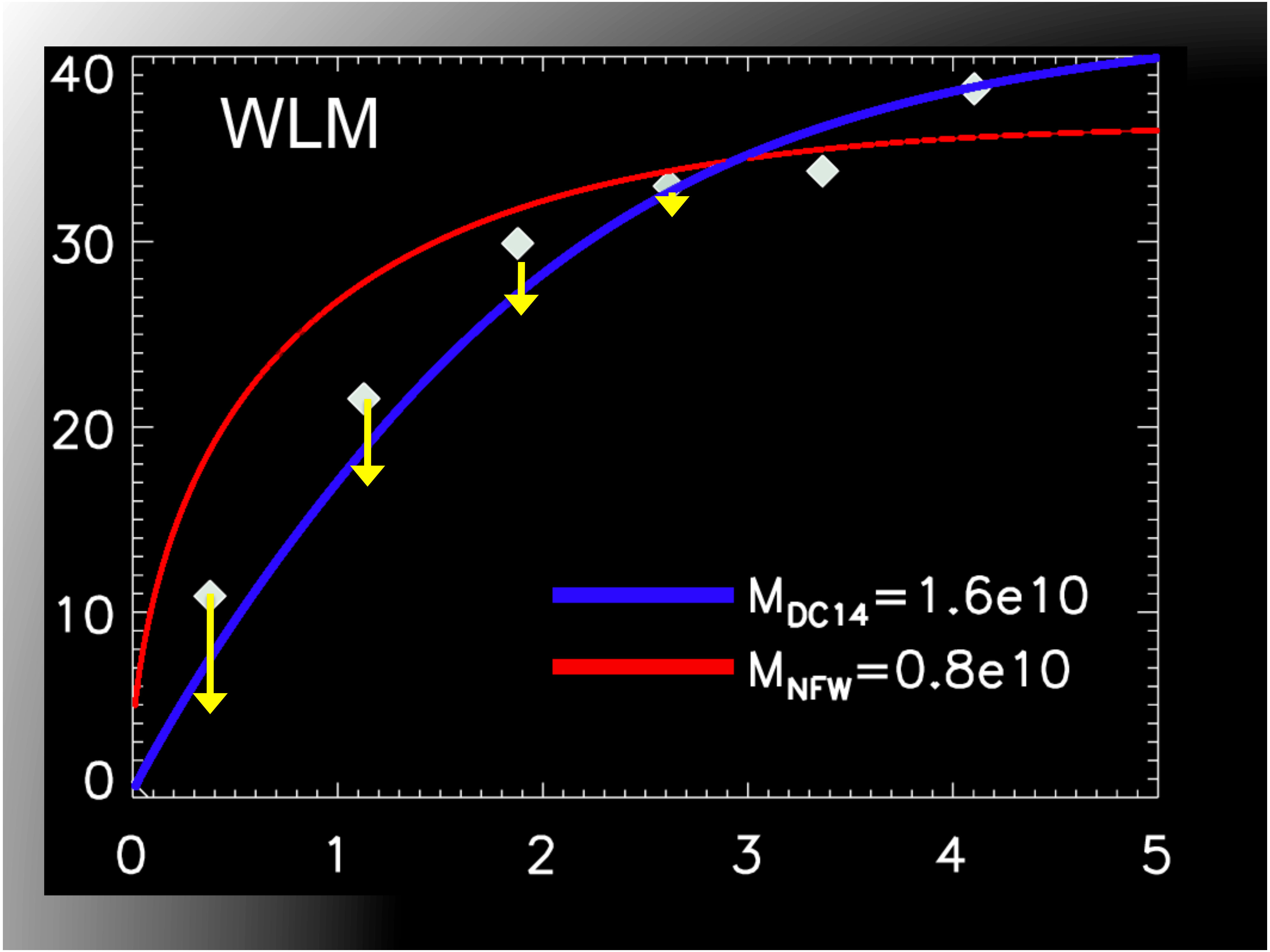
...and of course we solved the TBTF problem, as everyone else at the conference...



WLM
40
30
20
10
0
0
1
2
3
4
5
M_DC14=1.6e10
M_NFW=0.8e10