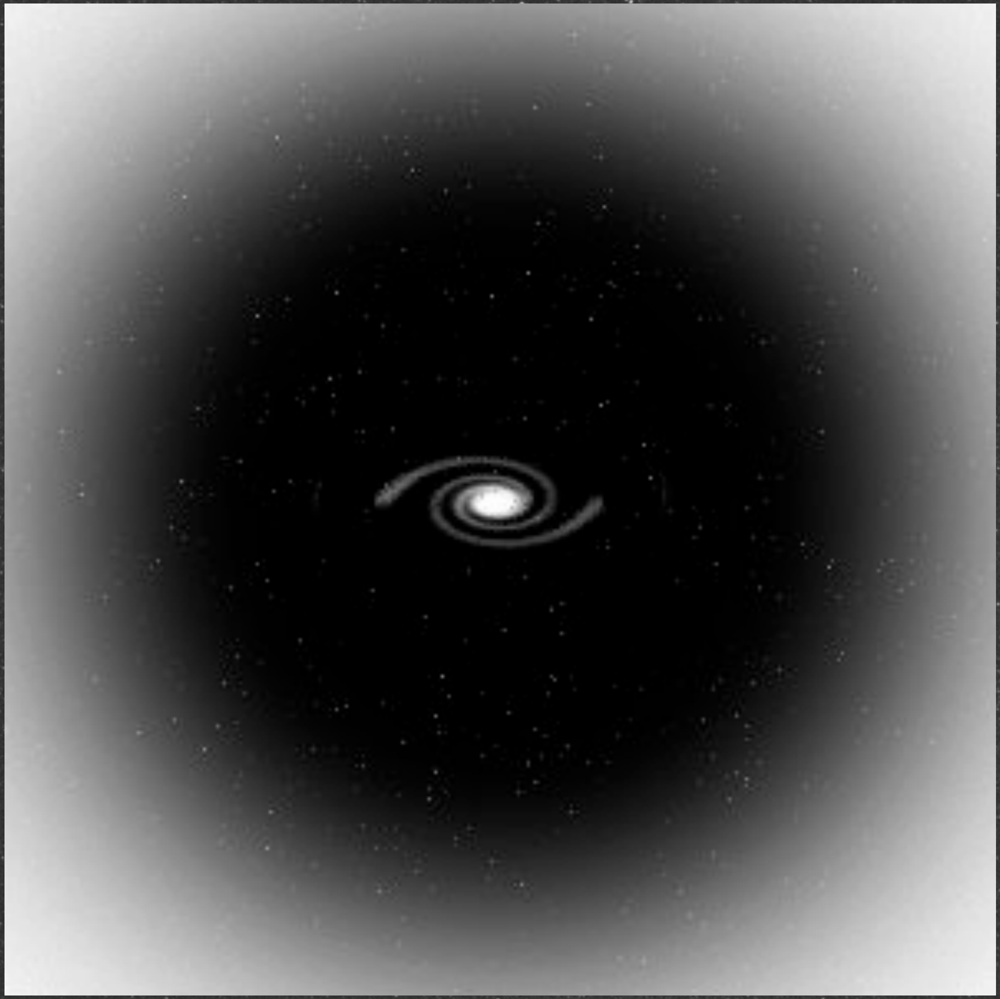
Cold Dark Matter vs. Galactic Dynamics

Matthew Walker – Harvard/CfA



Aspen, 30 January 2013

Cold Dark Matter in N-body simulations

THE STRUCTURE OF COLD DARK MATTER HALOS

JOHN DUBINSKI AND R. G. CARLBERG
Department of Astronomy, University of Toronto, Toronto, Ontario, Canada M5S 1A1
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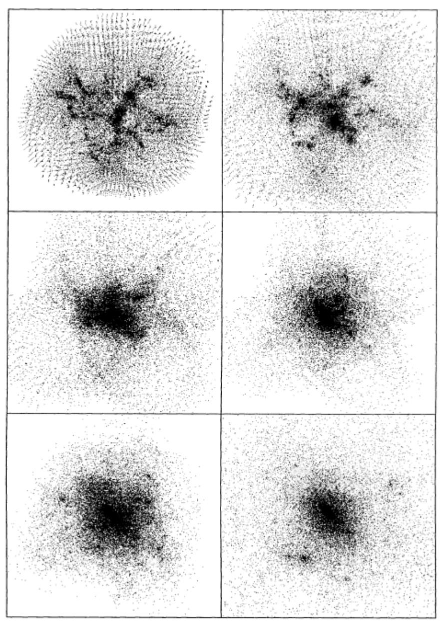
ABSTRACT

The density profiles and shapes of dark halos are studied using the results of *N*-body simulations of the gravitational collapse of density peaks. The simulations use from 3×10^4 to 3×10^5 particles, which allow density profiles and shapes to be well resolved. The core radius of a typical dark halo is found to be no greater than the softening radius, $\epsilon = 1.4$ kpc. The density profiles can be fitted with an analytical model with an effective power law which varies between -1 in the center to -4 at large radii. The dark halos have circular velocity curves which behave like the circular velocity contribution of the dark component of spiral galaxies inferred from rotation curve decompositions. The halos are strongly triaxial and very flat, with $\langle c/a \rangle = 0.50$ and $\langle b/a \rangle = 0.71$. There are roughly equal numbers of dark halos with oblate and prolate forms. The distribution of ellipticities in projection for dark halos reaches a maximum at $\epsilon = 0.5$, in contrast to the ellipticity distribution of elliptical galaxies, which peaks at $\epsilon = 0.2$.

Subject headings: dark matter — galaxies: structure — numerical methods

Dubinski & Carlberg (1991)



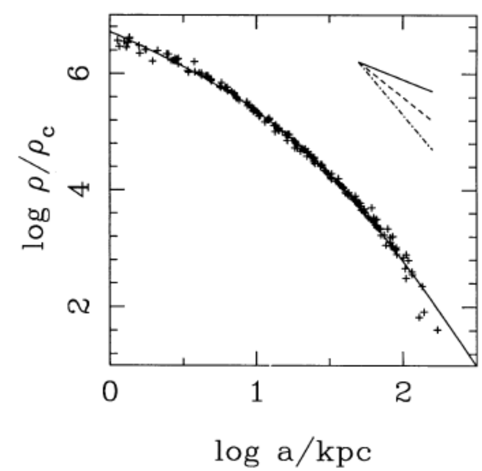
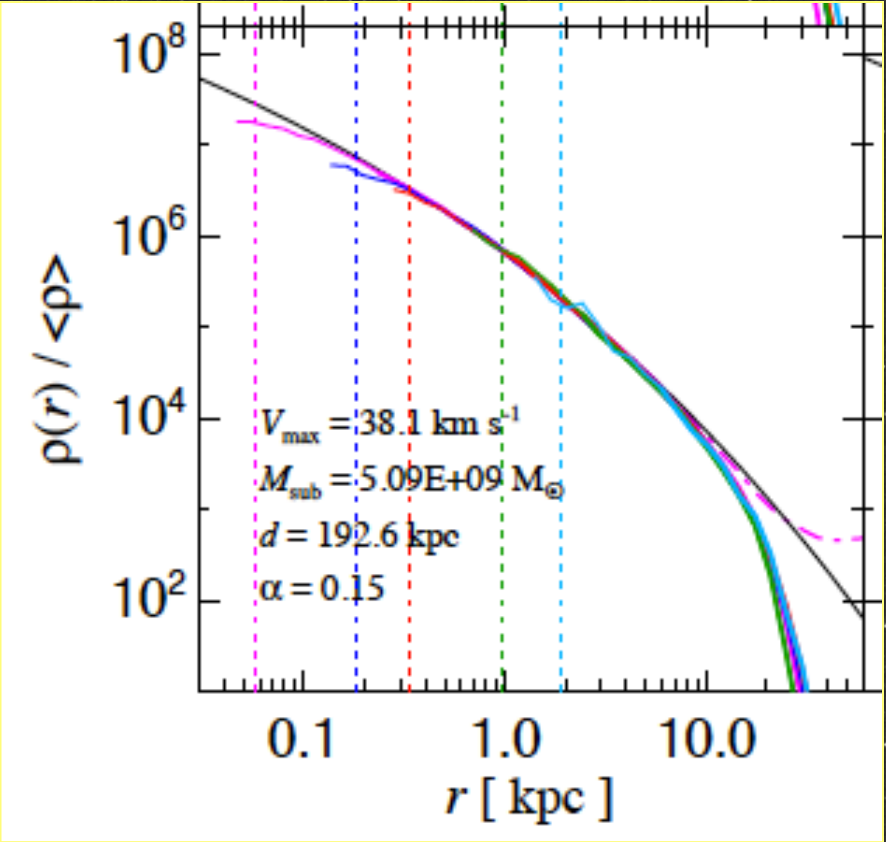


FIG. 2.—Density profiles of dark halos. Density is in units of the critical density ρ_c, and the elliptical radius a is in kpc. Thirteen points were used for the two-parameter fit of Hernquist's profile for each of the 14 halos. Each set of points has been renormalized to the fiducial Hernquist profile, with $r_s = 28$ kpc and $M_s = 2.1 \times 10^{12}\ M_\odot$ represented by the solid line. The lines in the upper right-hand corner present power-law slopes of -1, -2, and -3, respectively.

Cold Dark Matter in N-body simulations



Springel etal. 2008, also Diemand et al. 2007, etc.

$$\frac{\rho(r)}{\rho_{\rm crit}} = \frac{\delta_c}{(r/r_s)(1+r/r_s)^2}$$

NFW(1997)

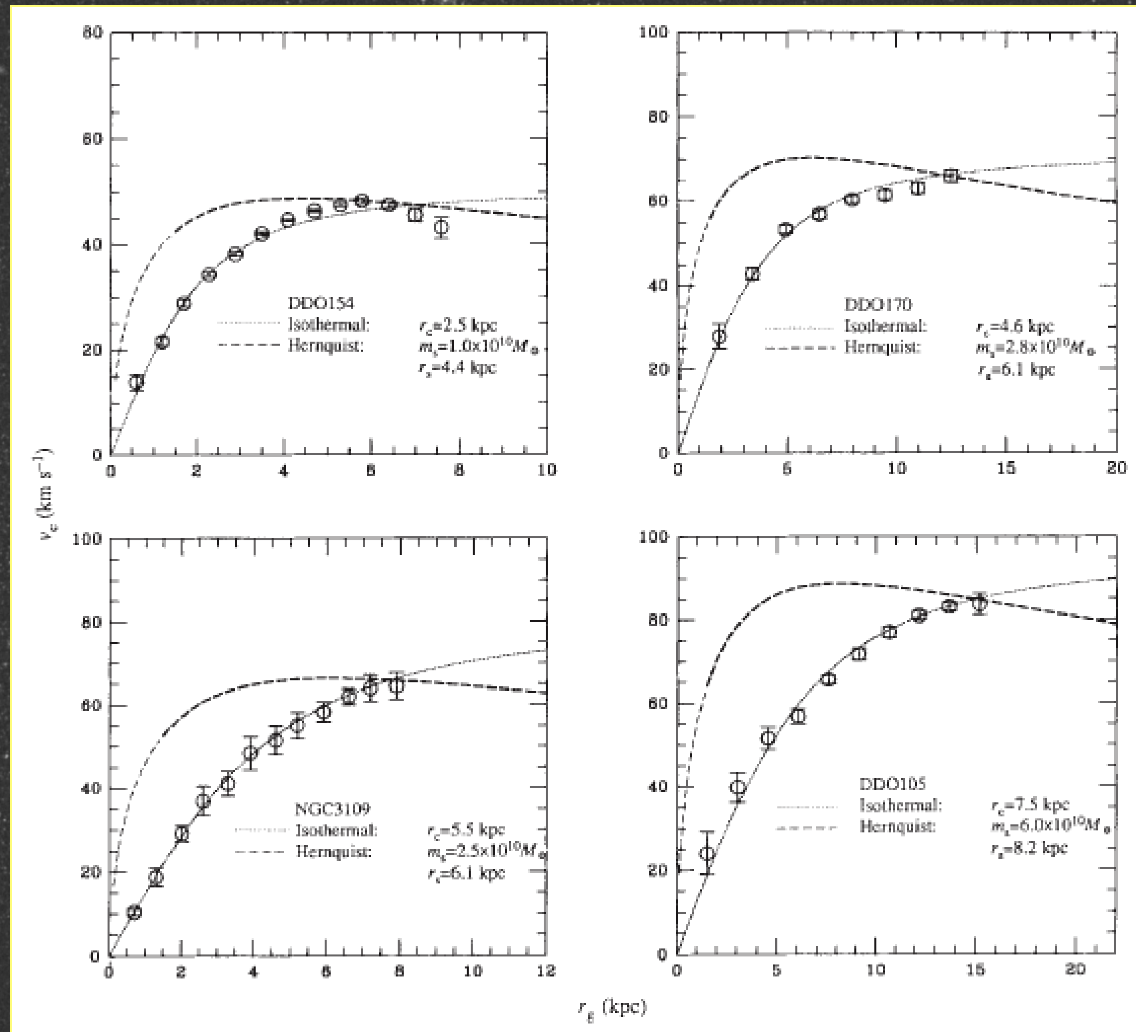
observations

Nature **370**, 629-631 (25 August 1994) | doi:10.1
Accepted 11 July 1994

Evidence against dissipation-less dark matter from observations of galaxy haloes

Ben Moore*

1. Department of Astronomy, University of California, Berkeley, California 94720, USA
2. *Present address: Department of Astronomy, FM-20, University of Washington, Seattle, Washington 98195, USA.



observations

The Astronomical Journal, 141:193 (45pp), 2011 June
doi:10.1088/0004-6256/141/6/

DARK AND LUMINOUS MATTER IN THINGS DWARF GALAXIES

Se-Heon Oh[1,5], W. J. G. de Blok[1], Elias Brinks[2], Fabian Walter[3], and Robert C. Kennicutt, Jr.[4]
[1] Department of Astronomy, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa; seheon_oh@ast.uct.ac.za, edeblok@ast.uct.ac.za
[2] Centre for Astrophysics Research, University of Hertfordshire, College Lane, Hatfield, AL10 9AB, UK; E.Brinks@herts.ac.uk
[3] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany; walter@mpia.de
[4] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK; robk@ast.cam.ac.uk
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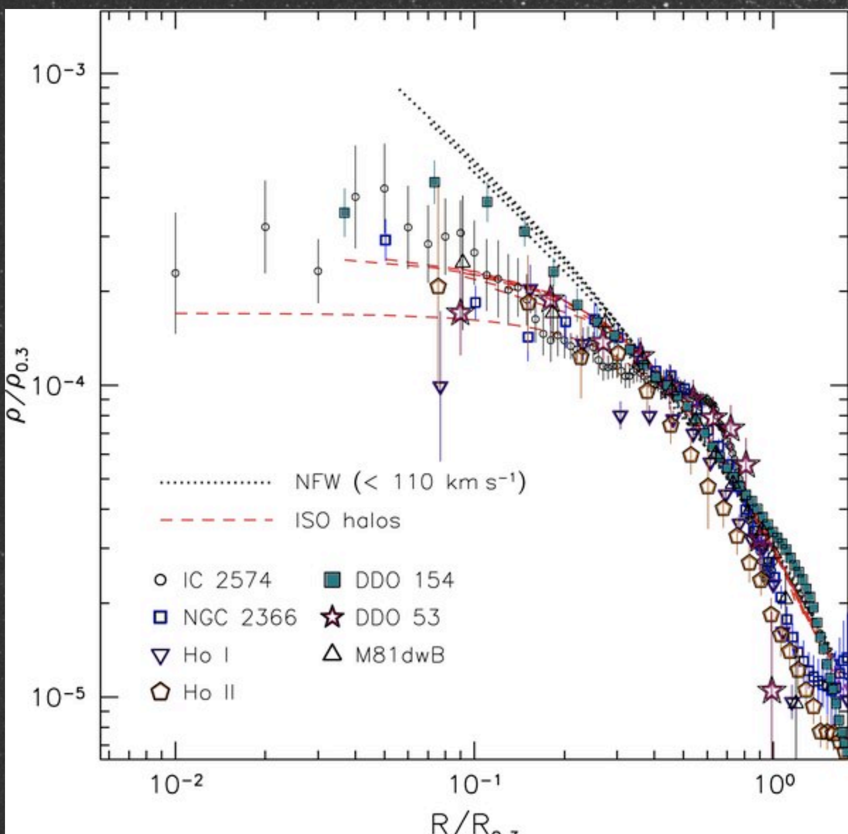

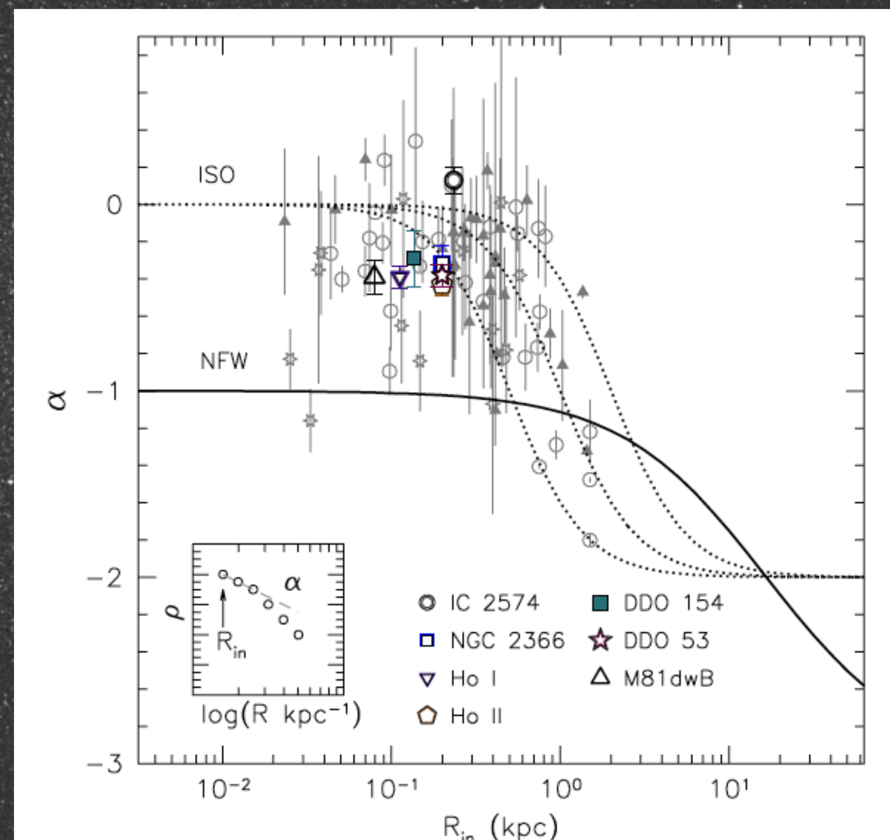

The cores of dwarf galaxy haloes

Julio F. Navarro,[1,2]★ Vincent R. Eke[2] and Carlos S. Frenk[2]

[1]*Steward Observatory, The University of Arizona, Tucson, AZ 85721, USA*
[2]*Physics Department, University of Durham, South Road, Durham DH1 3LE*

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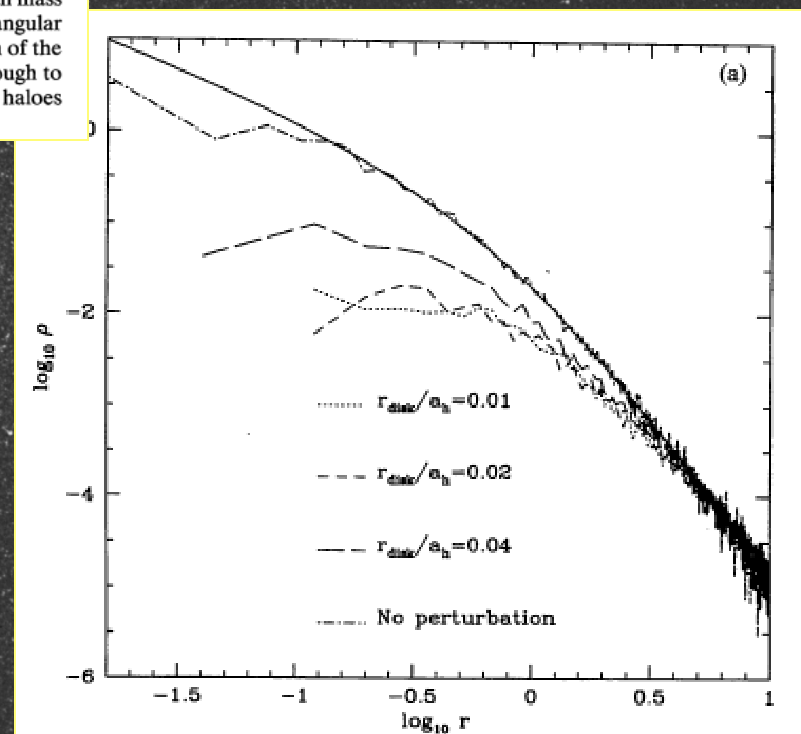
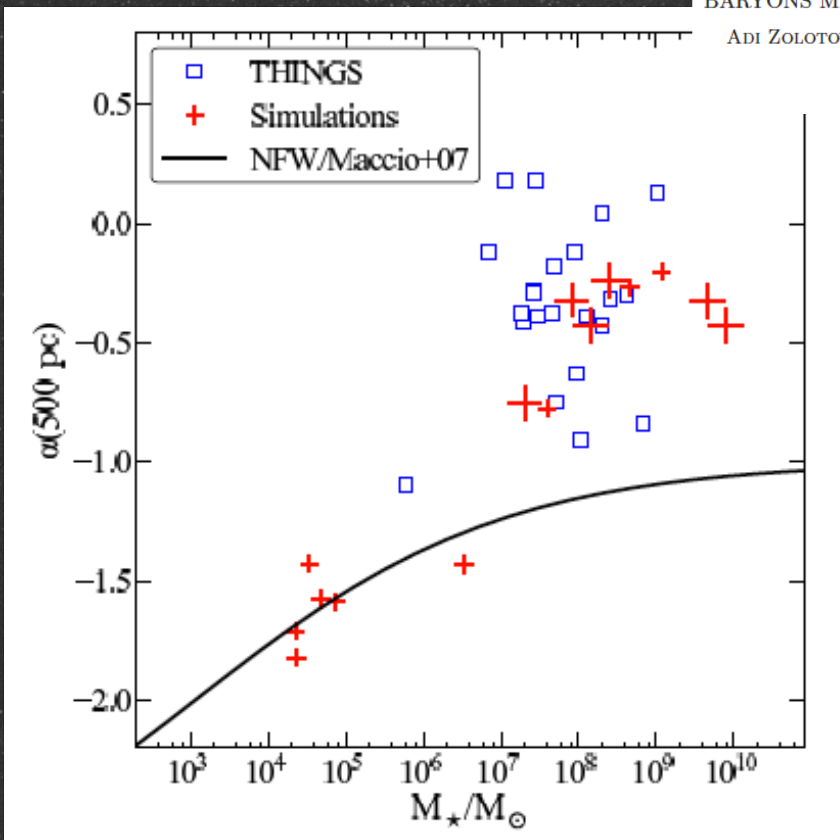
ABSTRACT

We use *N*-body simulations to examine the effects of mass outflows on the density profiles of cold dark matter (CDM) haloes surrounding dwarf galaxies. In particular, we investigate the consequences of supernova-driven winds that expel a large fraction of the baryonic component from a dwarf galaxy disc after a vigorous episode of star formation. We show that this sudden loss of mass leads to the formation of a core in the dark matter density profile, although the original halo is modelled by a coreless (Hernquist) profile. The core radius thus created is a sensitive function of the mass and radius of the baryonic disc being blown up. The loss of a disc with mass and size consistent with primordial nucleosynthesis constraints and angular momentum considerations imprints a core radius that is only a small fraction of the original scalelength of the halo. These small perturbations are, however, enough to reconcile the rotation curves of dwarf irregulars with the density profiles of haloes formed in the standard CDM scenario.



Cuspy No More: How Outflows Affect the Central Dark Matter and Baryon Distribution in ΛCDM Galaxies.

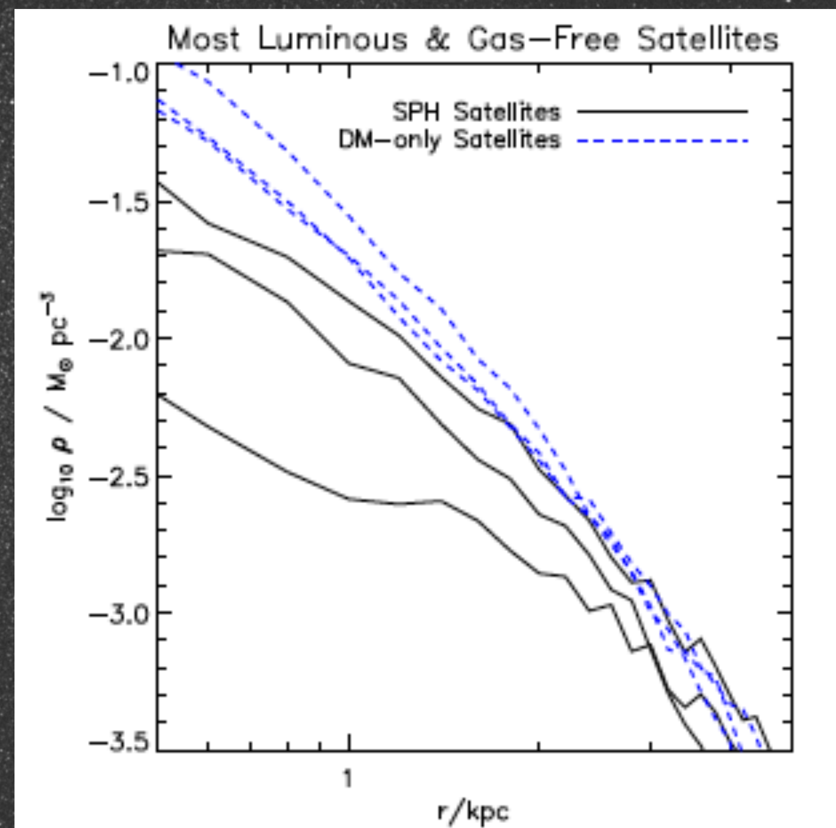
F.Governato[1*] A.Zolotov[2], A.Pontzen[3], C.Christensen[4], S.H.Oh[5,6], A. M.Brooks[7], T.Quinn[1], S.Shen[8], J.Wadsley[9]

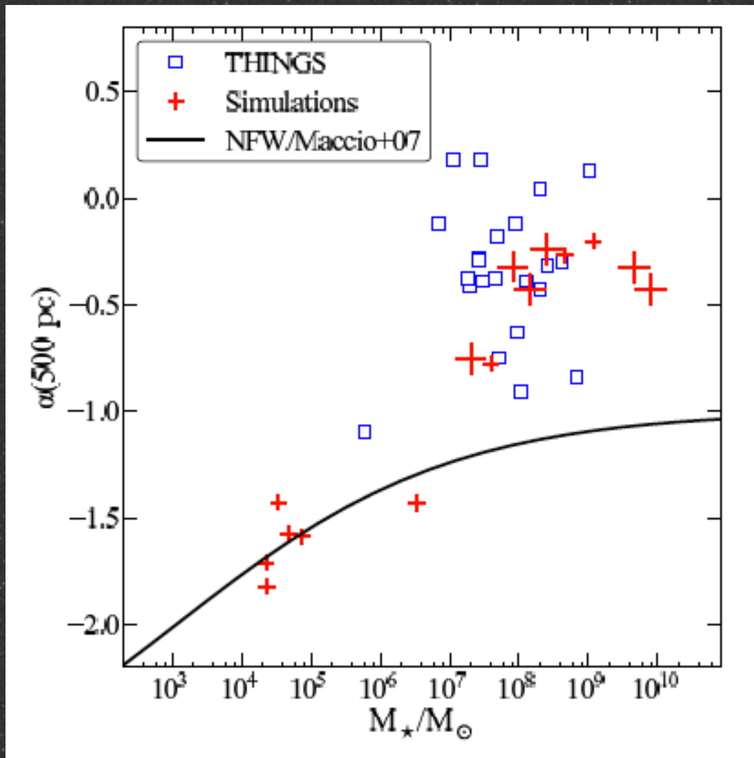


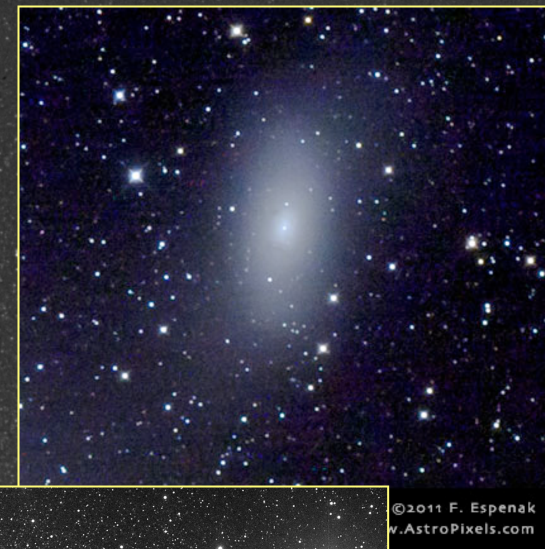
BARYONS MATTER: WHY LUMINOUS SATELLITE GALAXIES HAVE REDUCED CENTRAL MASSES

Adi Zolotov[1], Alyson M. Brooks[2], Beth Willman[3], Fabio Governato[4], Andrew Pontzen[5], Charlotte Christensen[6], Avishai Dekel[1], Tom Quinn[4], Sijing Shen[7], James Wadsley[8]

(Dated: July 12, 2012)
Submitted for publication in ApJ




THINGS
Simulations
NFW/Maccio+07
α(500 pc)
0.5
0.0
−0.5
−1.0
−1.5
−2.0
10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^{10}
$M_\star/M_\odot$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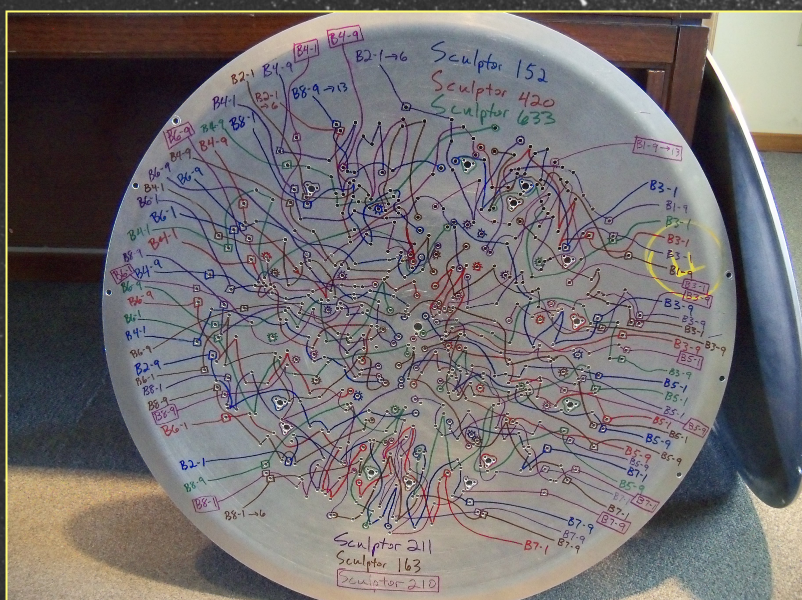
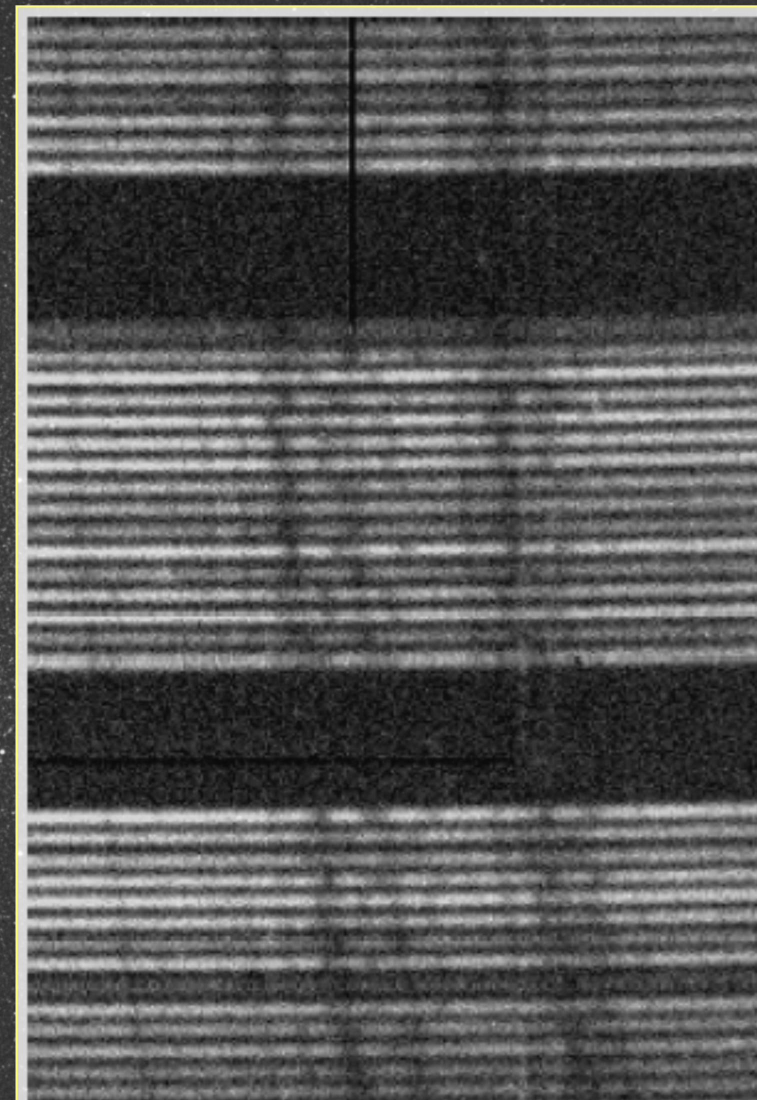
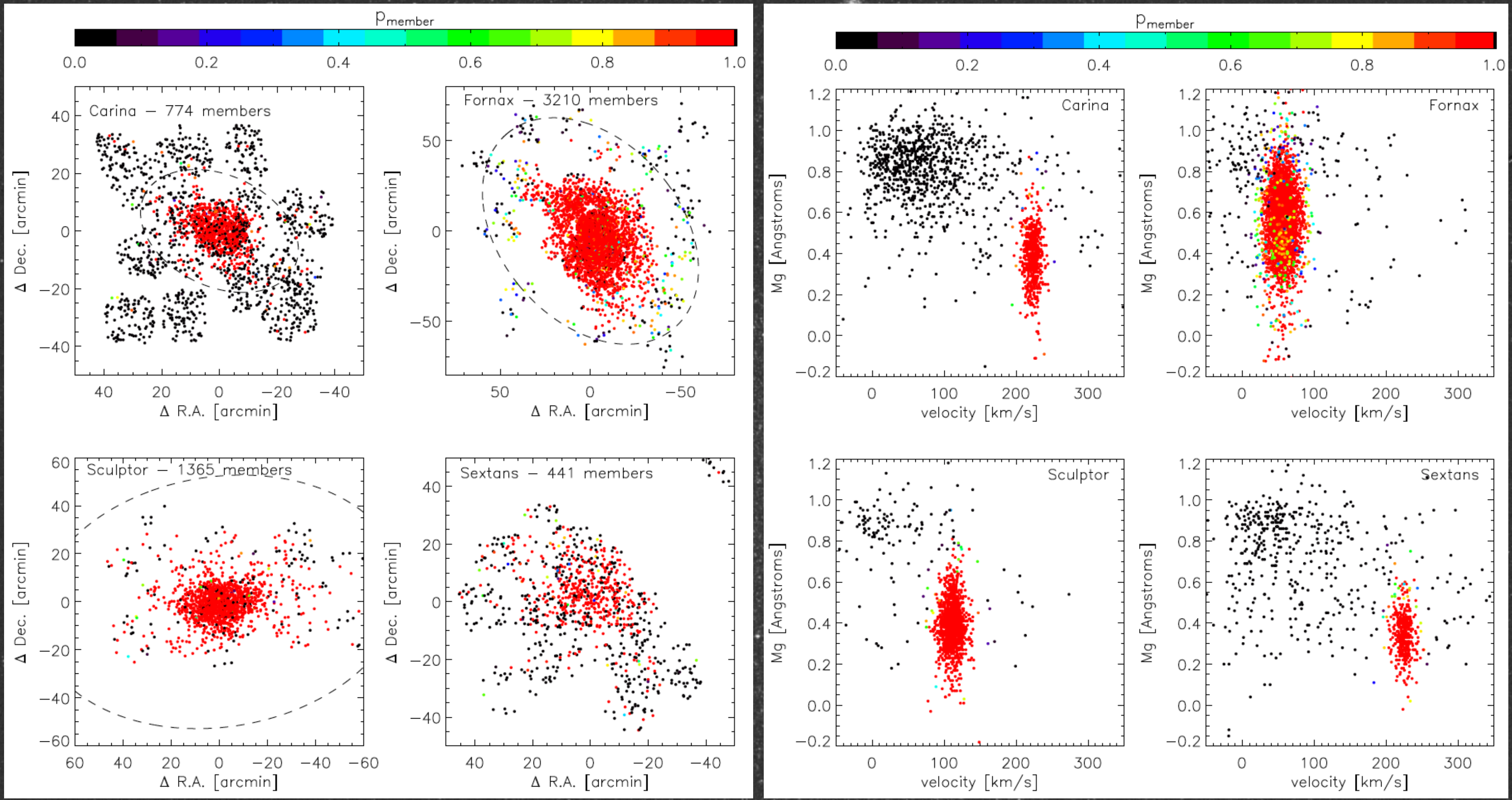
Magellan Spectroscopic Observations
w/ Mario Mateo & Ed Olszewski



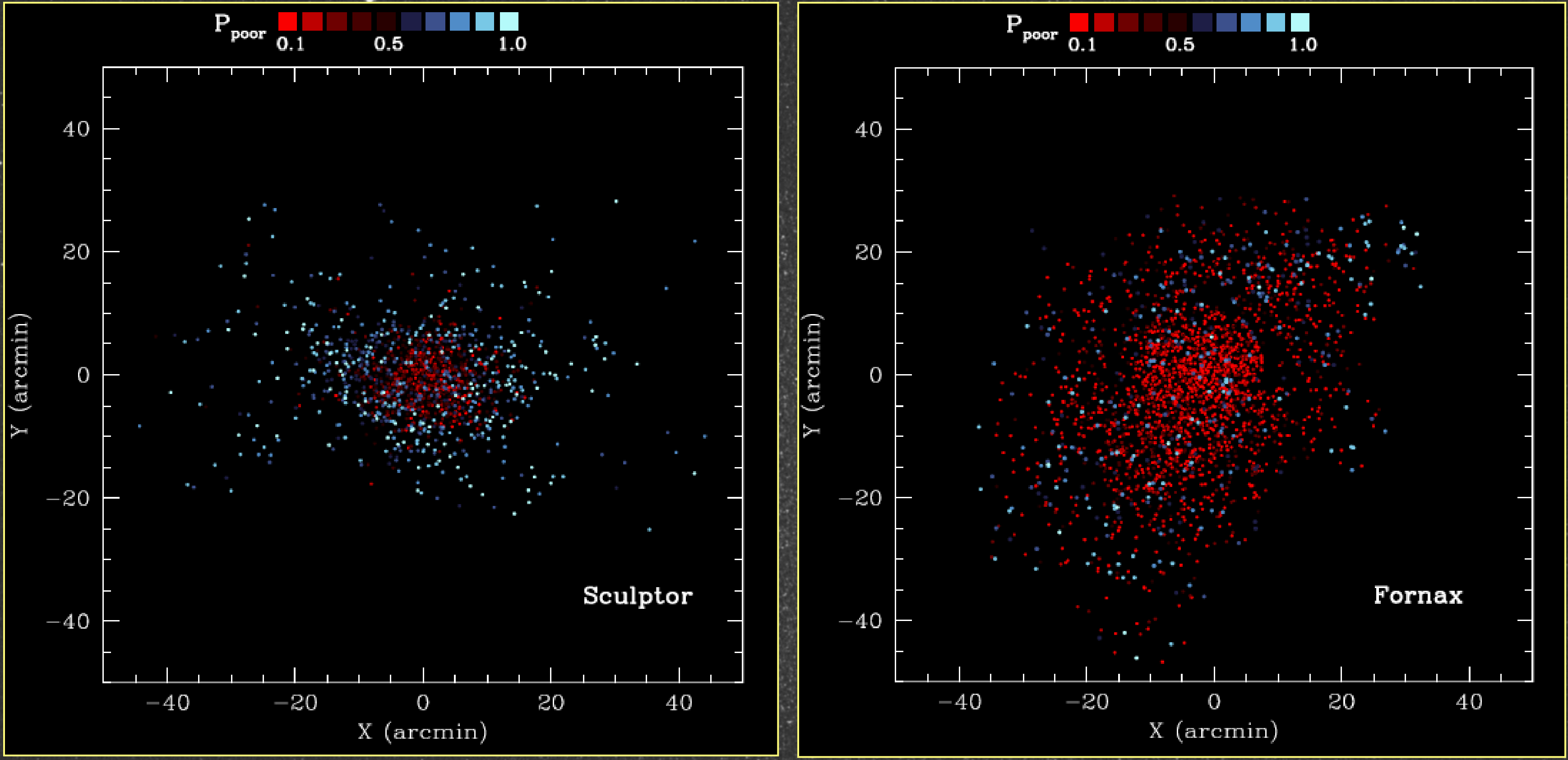


Data: Magellan Samples



Walker, Mateo & Olszewski (2009)

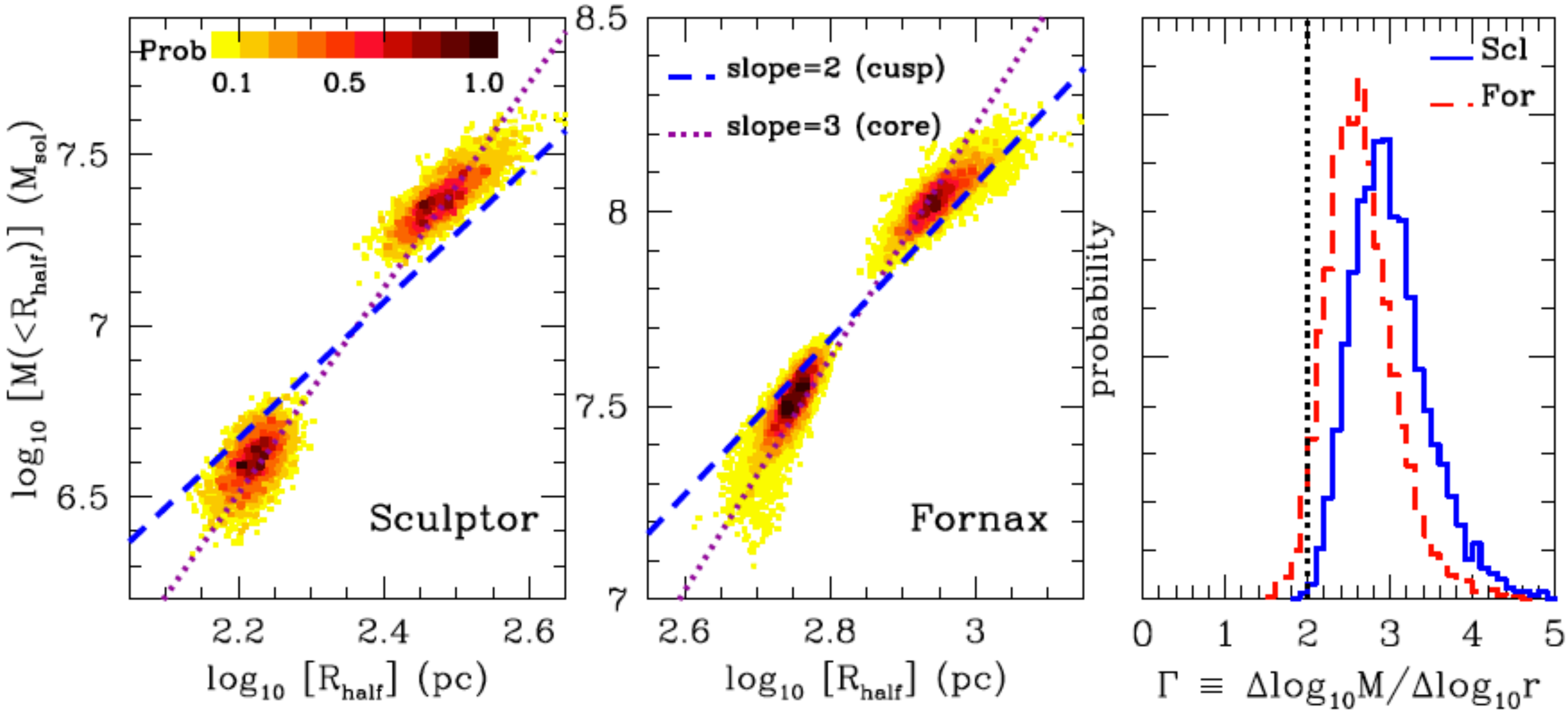
Chemo-dynamics of Dwarf Galaxies



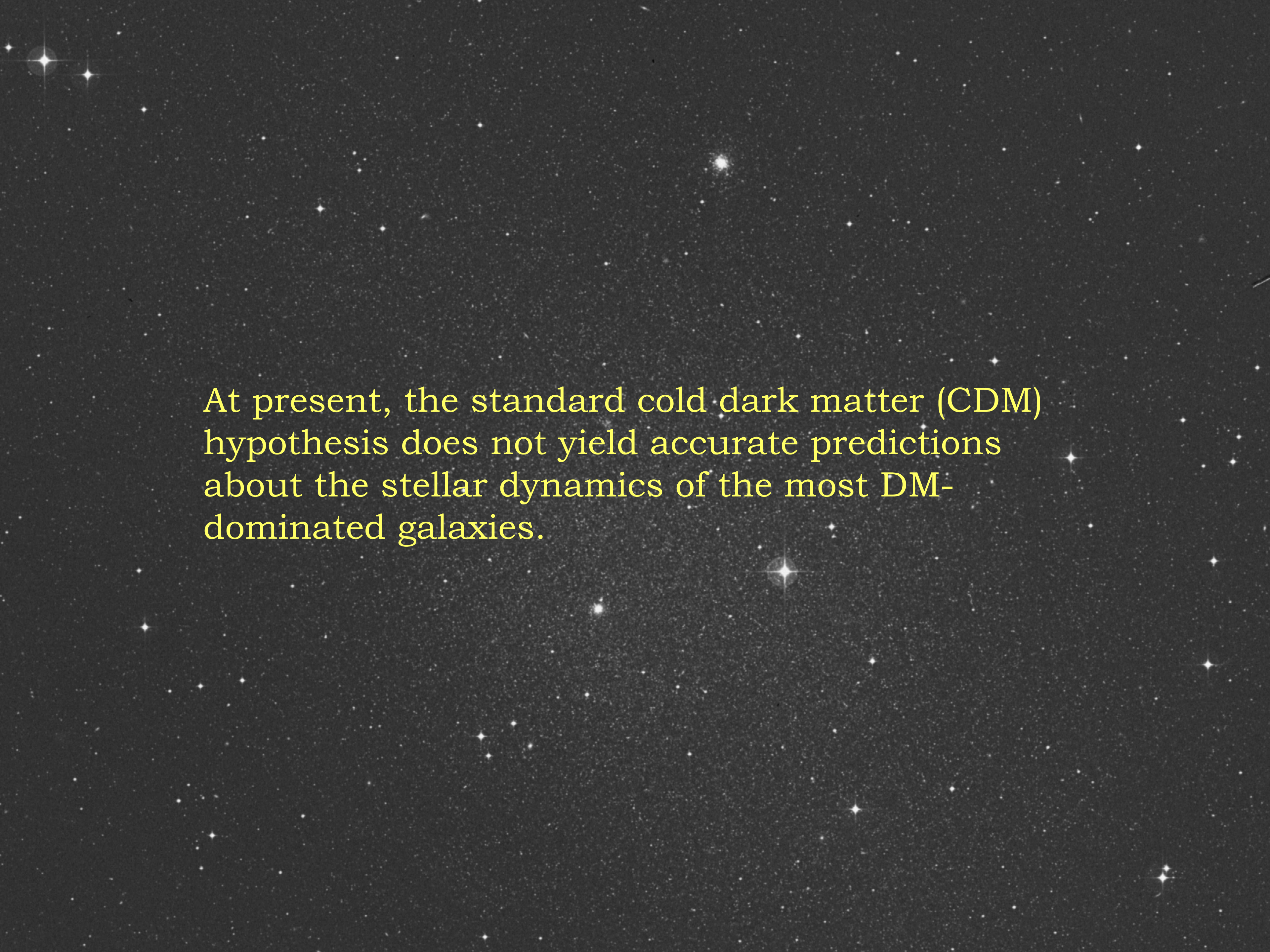
$$M(R_{half}) \sim 5\sigma_V^2 \frac{R_{half}}{2G}$$

Walker & Peñarrubia 2011

Result: cores, not cusps



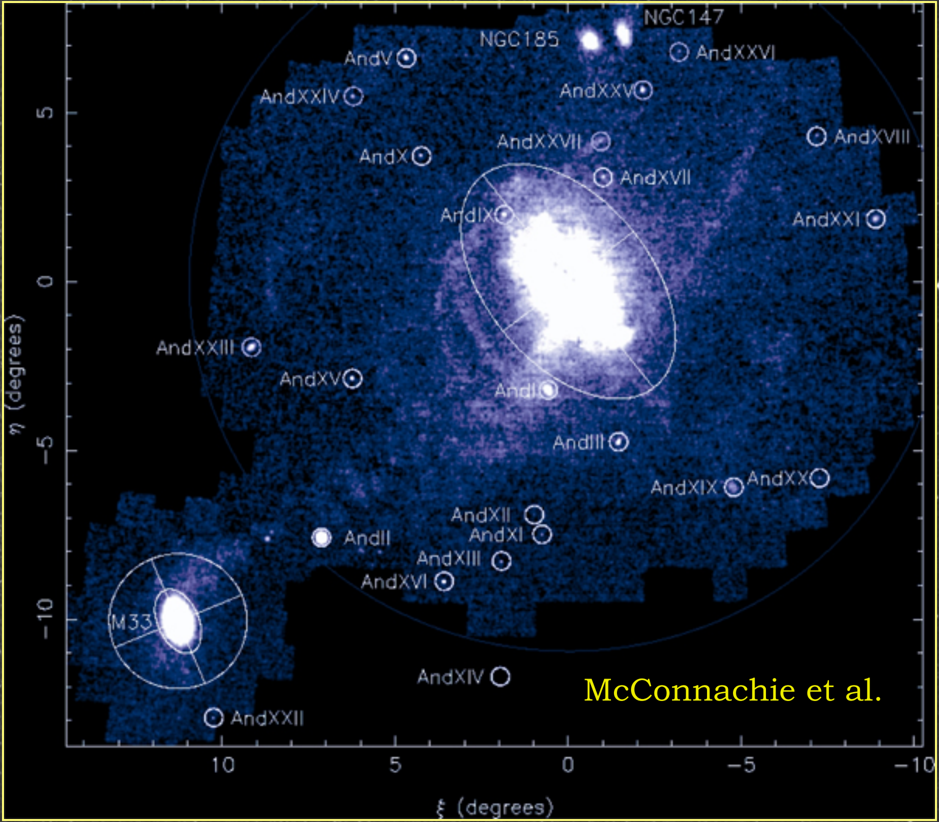
Walker & Peñarrubia 2011



At present, the standard cold dark matter (CDM) hypothesis does not yield accurate predictions about the stellar dynamics of the most DM-dominated galaxies.

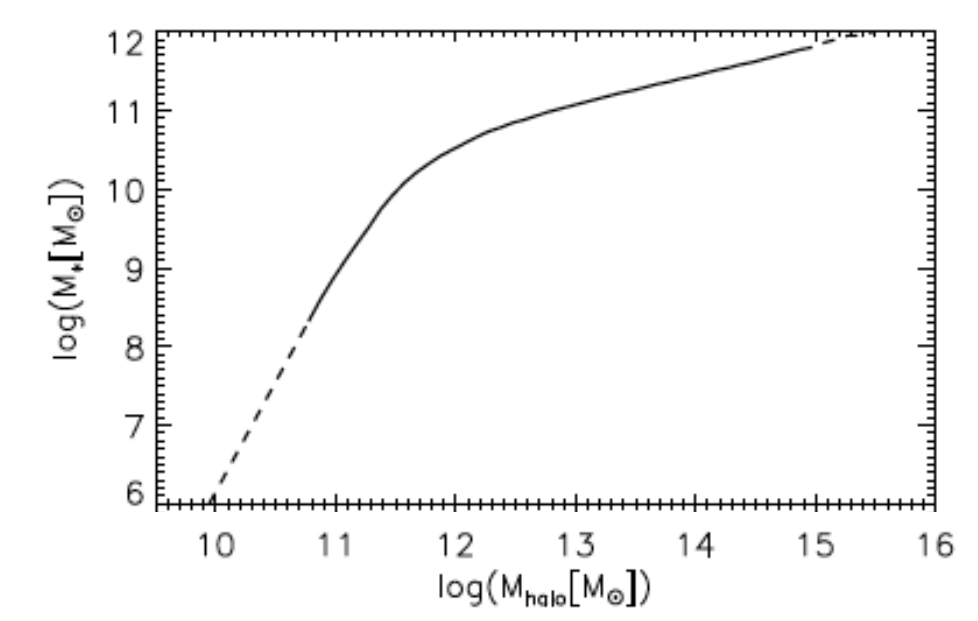
missing satellites

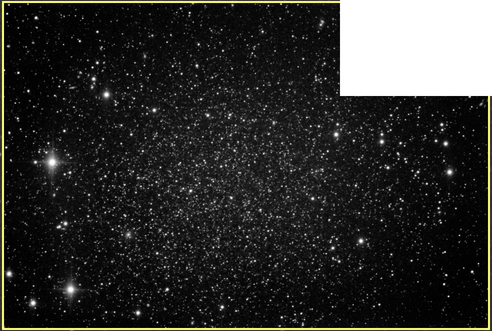
Springel et al. (2008)



McConnachie et al.

missing satellites





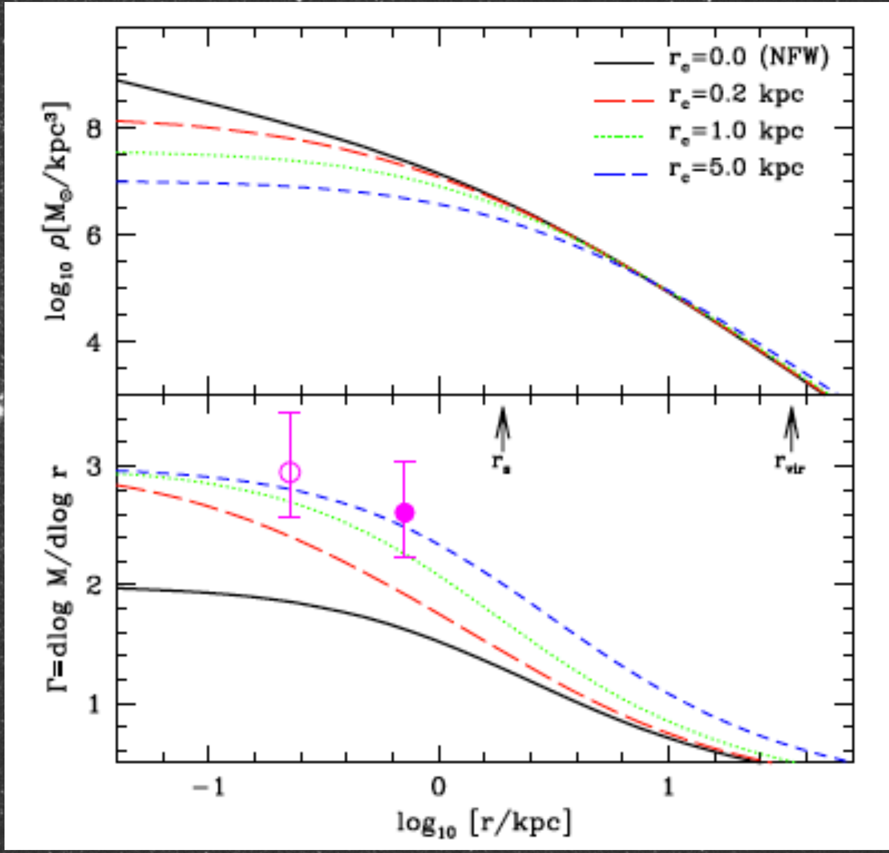
Guo et al. 2010

THE COUPLING BETWEEN THE CORE/CUSP AND MISSING SATELLITE PROBLEMS

Jorge Peñarrubia[1,2], Andrew Pontzen[3], Matthew G. Walker[4] & Sergey E. Koposov[2,5]

Draft version July 13, 2012

$$\rho(r) = \frac{\rho_0 r_s^3}{(r_c + r)(r_s + r)^2}$$



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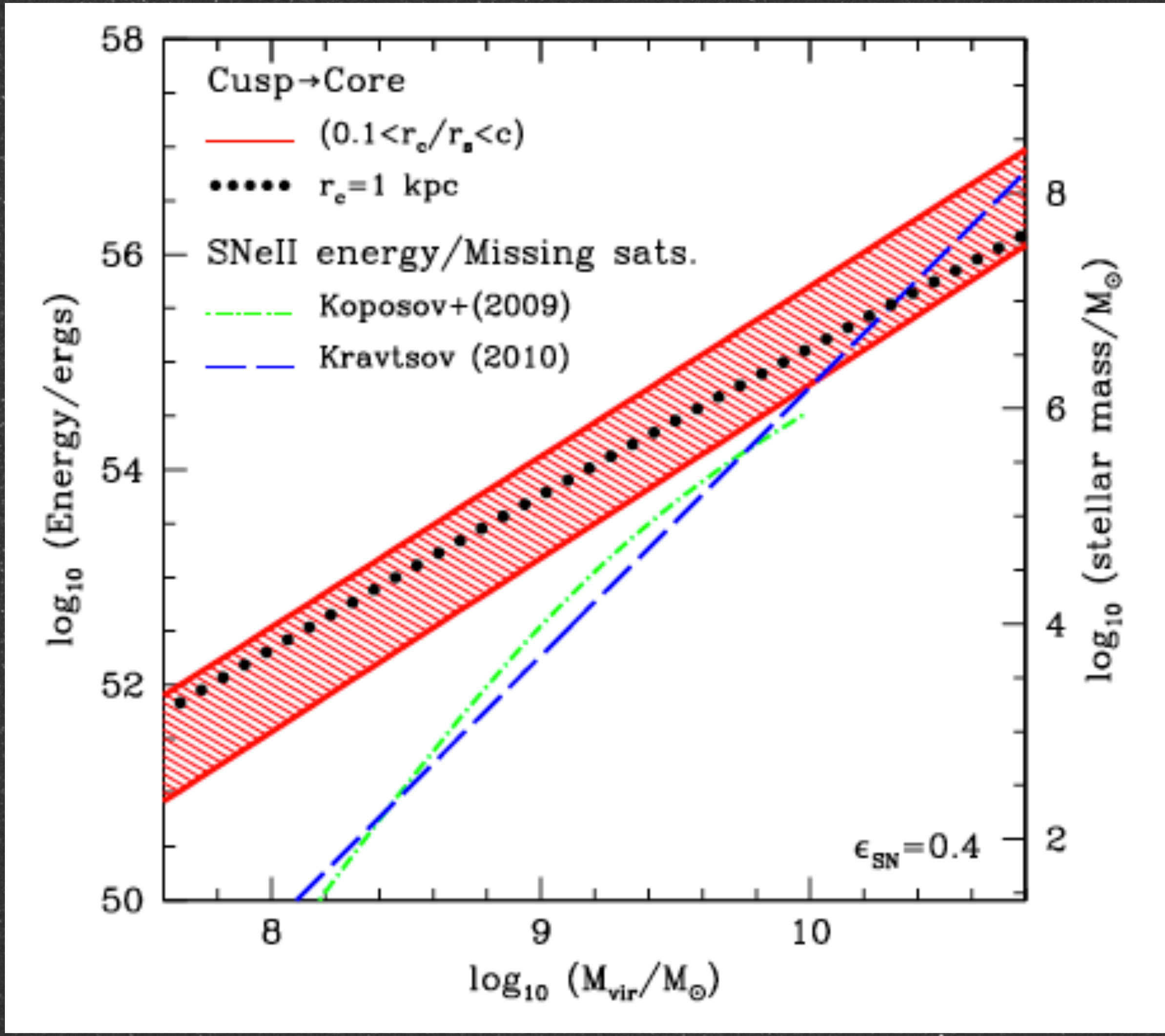


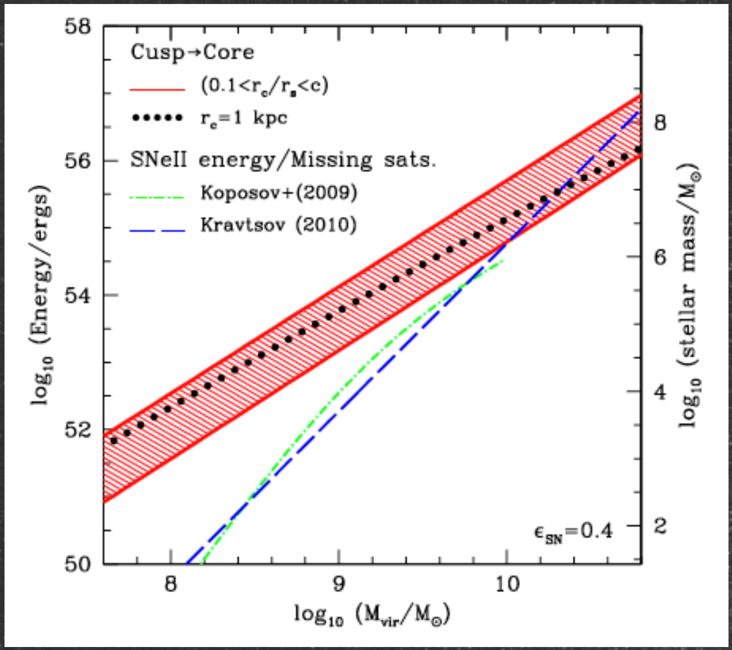
THE COUPLING BETWEEN THE CORE/CUSP AND MISSING SATELLITE PROBLEMS

JORGE PEÑARRUBIA[1,2], ANDREW PONTZEN[3], MATTHEW G. WALKER[4] & SERGEY E. KOPOSOV[2,5]

Draft version July 13, 2012

tion efficiency implied by the abundance of luminous satellites. Considering that CDM's well-known 'core/cusp' and 'missing satellite' problems place opposing demands on star formation efficiencies, existing observational evidences for large cores in the most luminous dSphs require that CDM models invoke some combination of the following: (i) efficient (of order unity) coupling of SNeII energy into kinetic energy of gas, (ii) star formation histories peaking at unexpectedly high redshifts ($z \gtrsim 6$), (iii) a top-heavy stellar IMF, and/or (iv) substantial satellite disruption or other stochastic effects to ease the substructure abundance constraints. Our models show that the tension between CDM problems on small scales would increase if cored DM profiles were to be found in fainter dwarves.

(Near) Future Work: R_{core} vs Luminosity



- -Fornax: 10^7 L_{sun}
- -Sculptor: 10^6 L_{sun}
- -Sextans: 10^6 L_{sun}
- -Leo II: 10^5 L_{sun}
- -CVnI: 10^5 L_{sun}