DARK MATTER IN DWARF SPHEROIDAL GALAXIES

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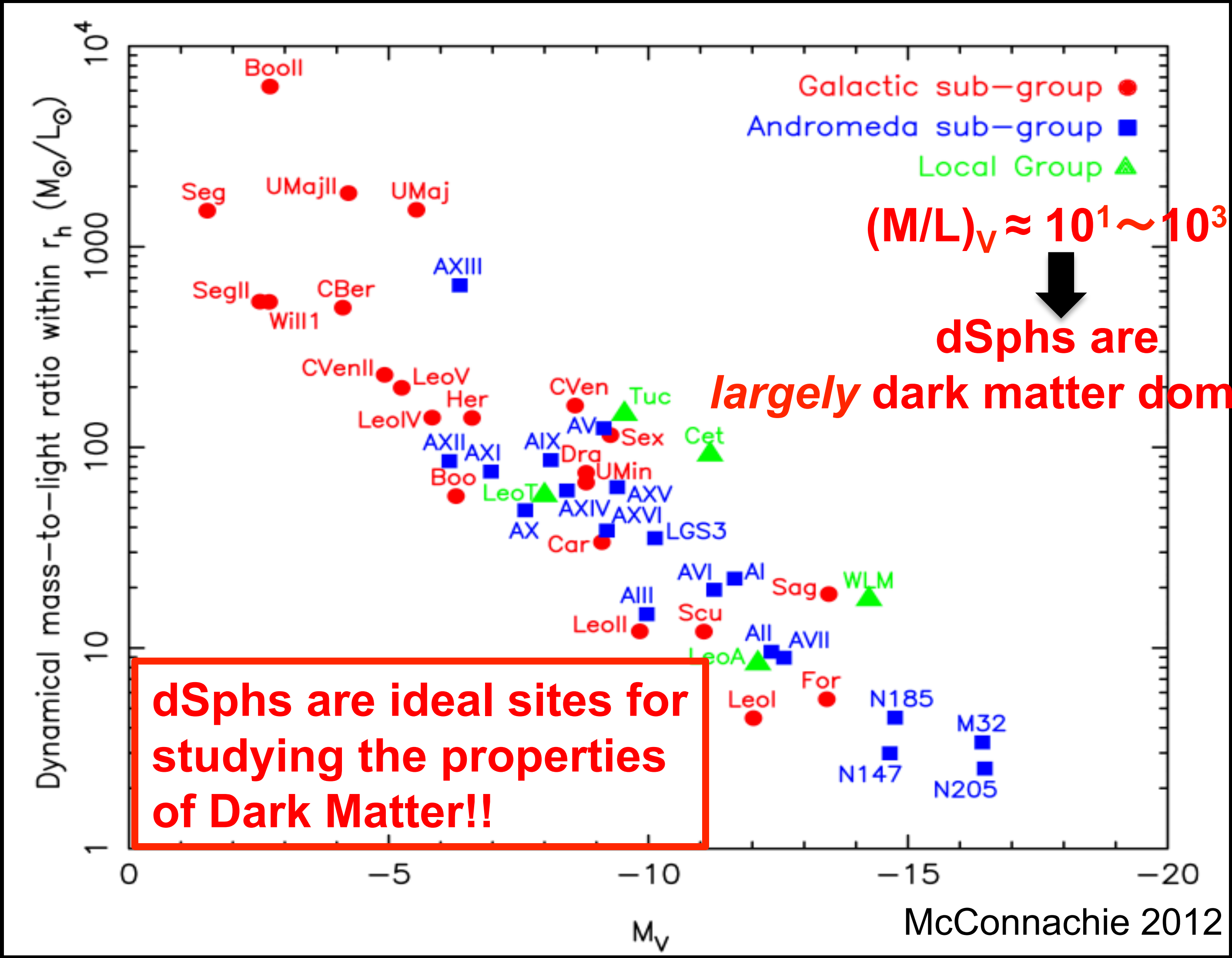
Galactic dSphs as a probe of DM

Mass to Light ratio (M/L) within stellar extent in dSphs



$(M/L)_V \approx 10^1 \sim 10^3$

dSphs are *largely* dark matter dominated !

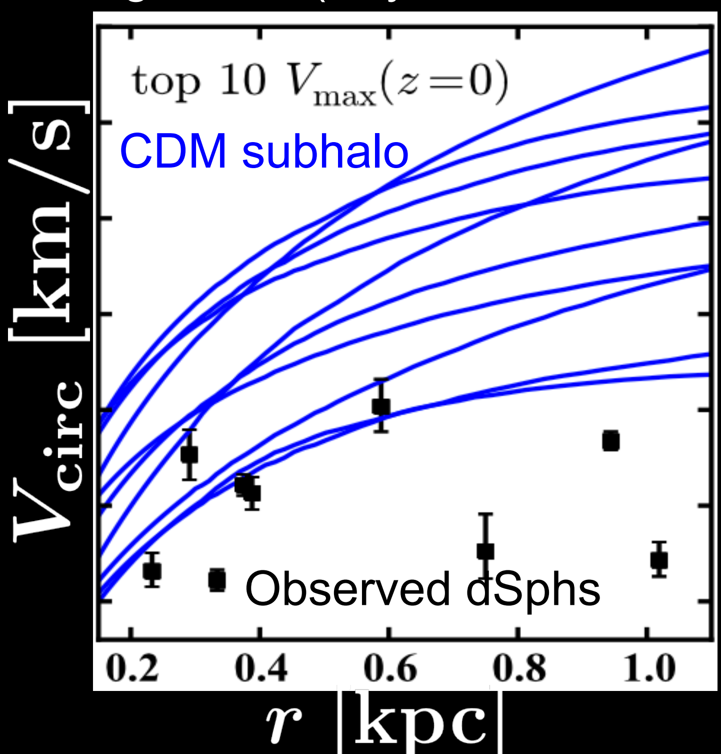
dSphs are ideal sites for studying the properties of Dark Matter!!

The Outstanding issues in ΛCDM

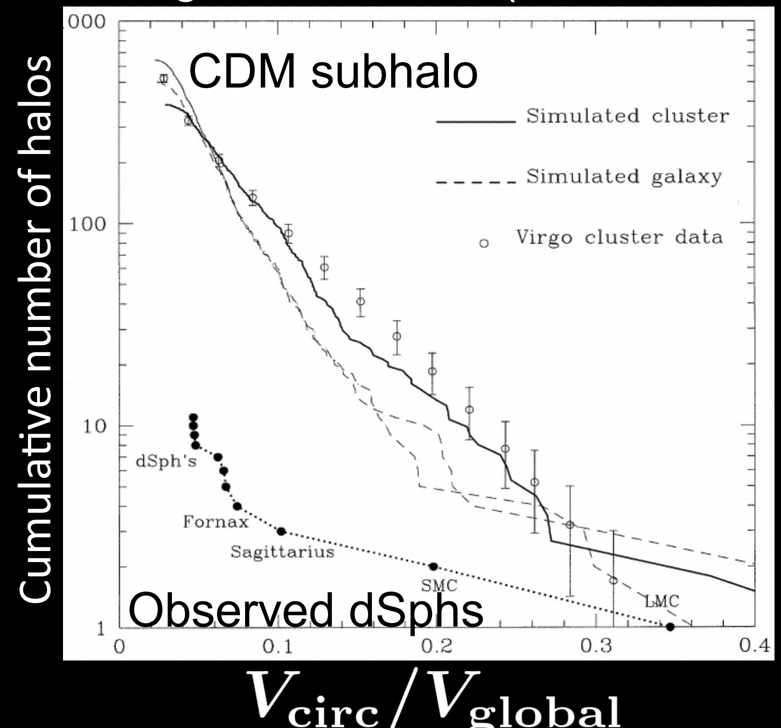
- Too-big-to-fail problem (Boylan-Kolchin+ 2012)
- Missing satellites problem (Moore+ 1999, Klypin+ 1999)

+ several other issues (core-cusp, global shape of dark halo, disk-like structure of satellite distribution)

Too-big-to-fail (Boylan-Kolchin+ 2012)



Missing satellites (Moore+ 1999)



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- Too-big-to-fail problem (Boylan-Kolchin+ 2012)
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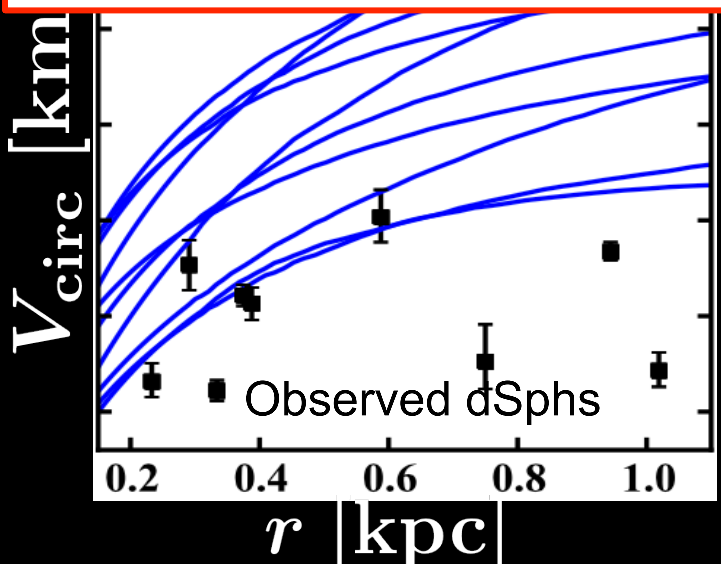
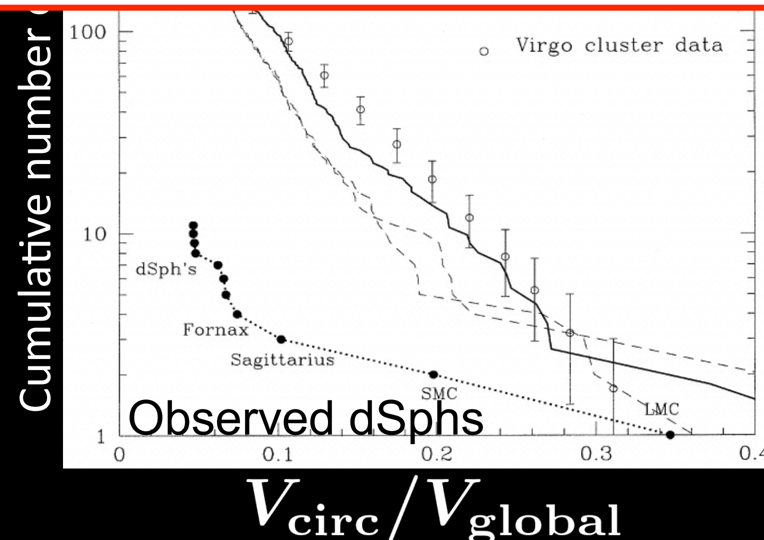
+ several other issues (core-cusp, global shape of dark halo, disk-like

Candidate to solve these issues:
- Baryon feedbacks?
- Alternative dark matter models, such as WDM?
- Incomplete observational data and dynamical analysis?





Deriving DM profiles from spherical mass models

Spherical mass models

Dark halo model :

$$\rho(r) = \rho_0 \left(\frac{r}{r_0}\right)^{-\gamma} \left[1 + \left(\frac{r}{r_0}\right)^{\alpha}\right]^{\frac{\gamma-3}{\alpha}}$$

Plummer model for stellar density :

$$\nu \propto \left[1 + r^2/r_{\rm half}^2\right]^{-5/2}$$

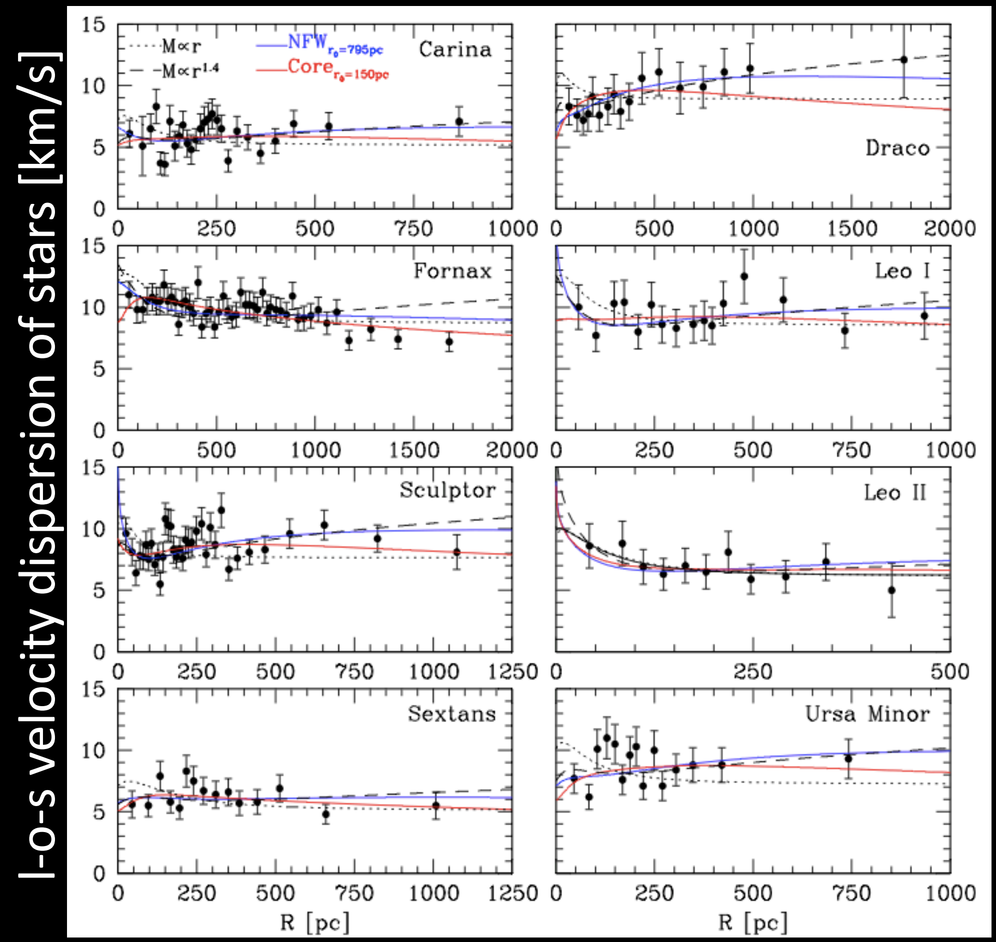
Spherical Jeans equation

$$\nu \bar{v_r^2} = G r^{-2\beta} \int_r^{\infty} s^{2\beta-2} \nu(s) M(s) ds$$

Velocity anisotropy β= *constant*

It is too simple, isn't it?

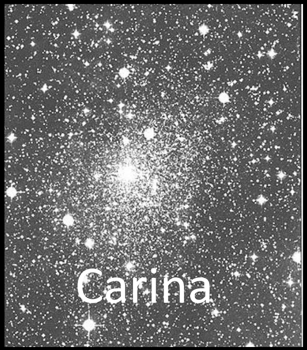
"Spherical averaged"
l-o-s velocity dispersion profiles



Walker+ 2009

Major systematic uncertainty: Spherical symmetry

✓ Stellar distributions of dSphs are actually not spherical



✓ CDM models predict non-spherical virialized halos

Springel et al.2008

Major systematic uncertainty: Spherical symmetry

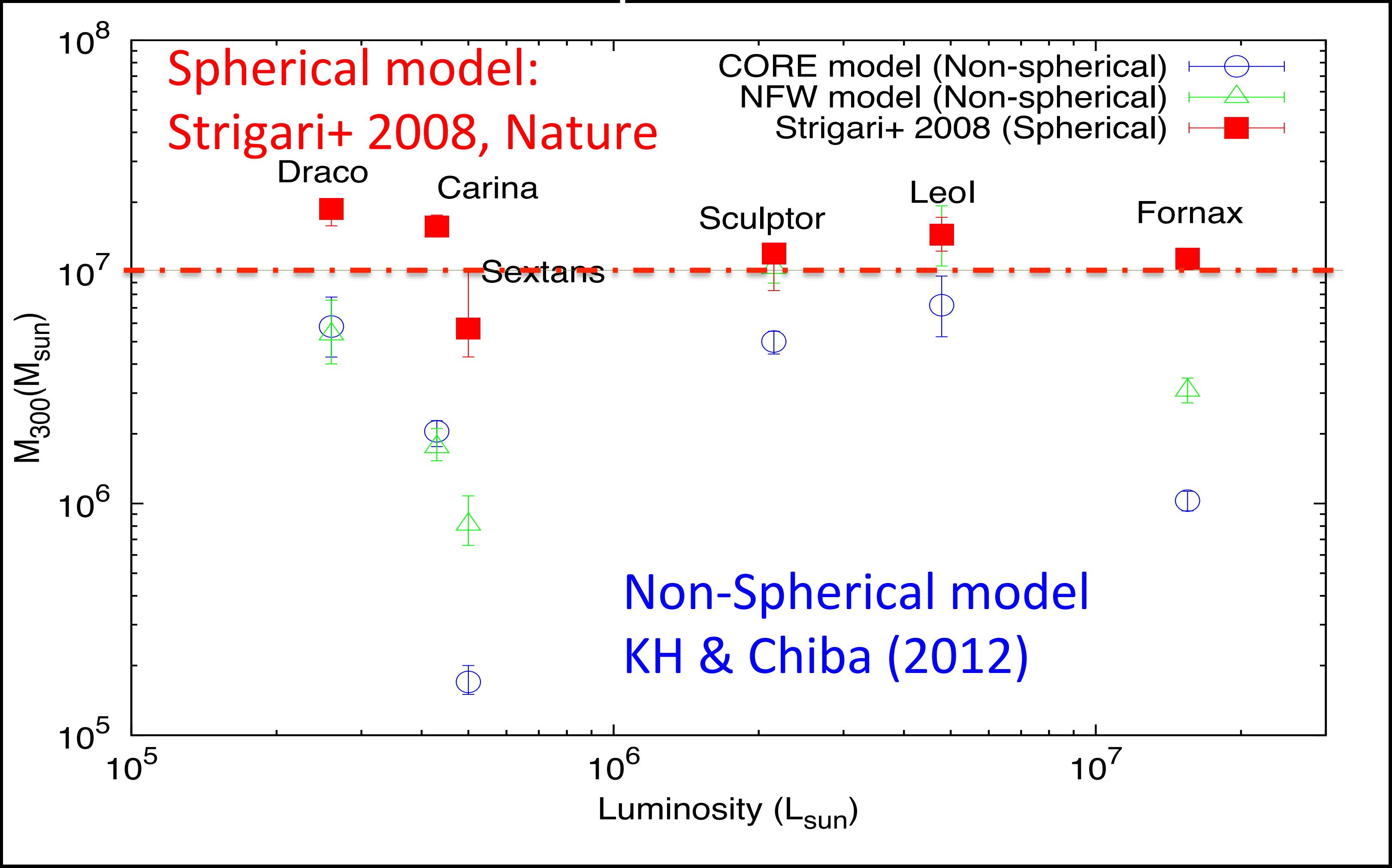
✓ Stellar distributions of dSphs are actually not spherical

Construction of axisymmetric mass models for dSphs
to obtain plausible limits on
their density profiles and shapes of their DM halos
(KH & Chiba 2012, 2015a, b).

Springel et al.2008

Major systematic uncertainty: Spherical symmetry

Mass within a radius of 300 pc



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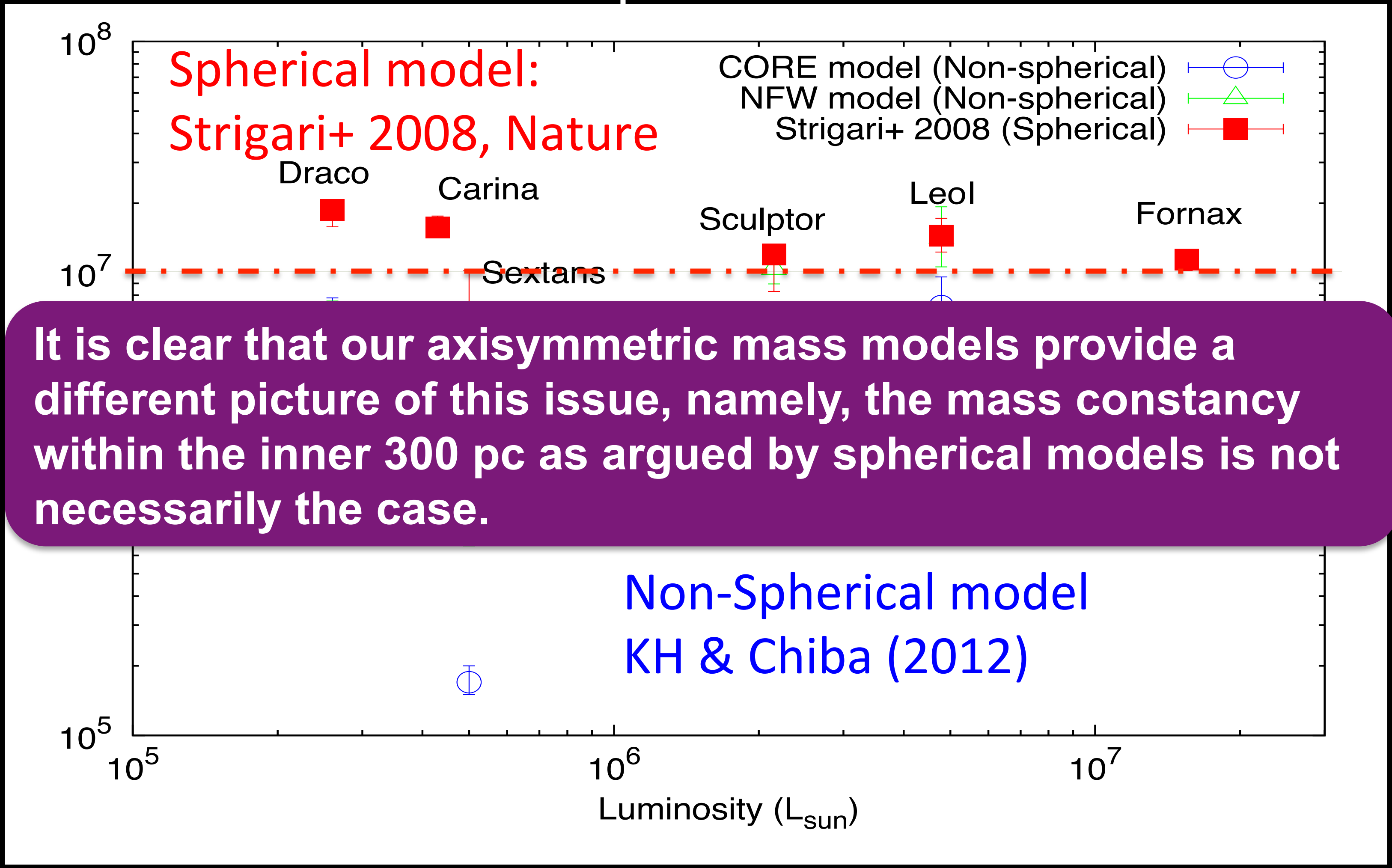
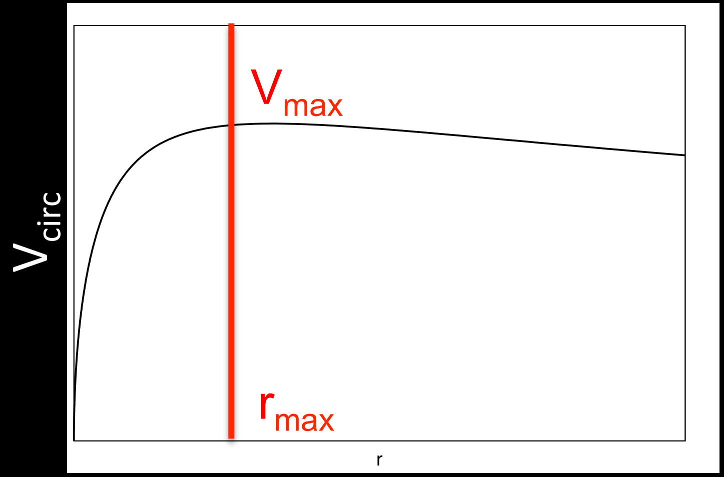


It is clear that our axisymmetric mass models provide a different picture of this issue, namely, the mass constancy within the inner 300 pc as argued by spherical models is not necessarily the case.

New universality for the DM halos

KH & Chiba(2015a,b) based on axisymmetric mass models

- ✓ Maximum circular velocity



We suppose that a test particle perform circular motion in a DM halo potential.

$$V_{\mathrm{circ}}(r) = \sqrt{\frac{GM(<r)}{r}}$$

r_{max} indicates the radius of the maximum value of circular velocity, V_{max}.

- ✓ DM surface density within r_{max}

$$\boxed{\Sigma_{V_{\max}} = \frac{M(r_{\max})}{\pi r_{\max}^2}}$$

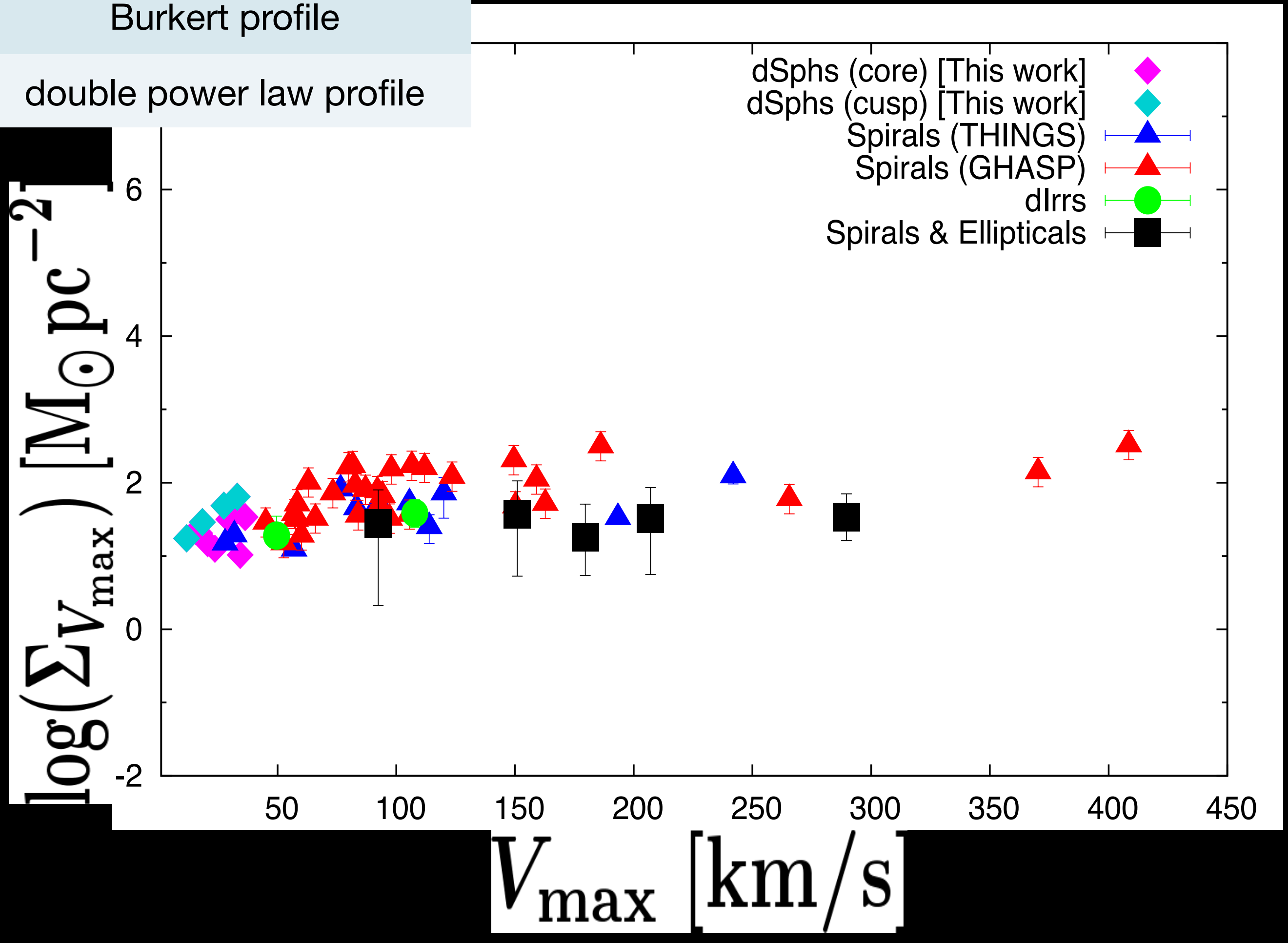
$$\Sigma_{V_{\max}} \propto \rho_s r_s$$

for NEW profiles

$$\rho(r) = \rho_s (r/r_s)^{-1} (1 + r/r_s)^{-2}$$

A common surface density scale for dark halos

Galaxy type	Assumed DM profile
spirals (THINGS & GHASP)	pseudo-isothermal profile
dwarf irregulars	Burkert profile
spirals and ellipticals	Burkert profile
MW and M31 dSph	double power law profile



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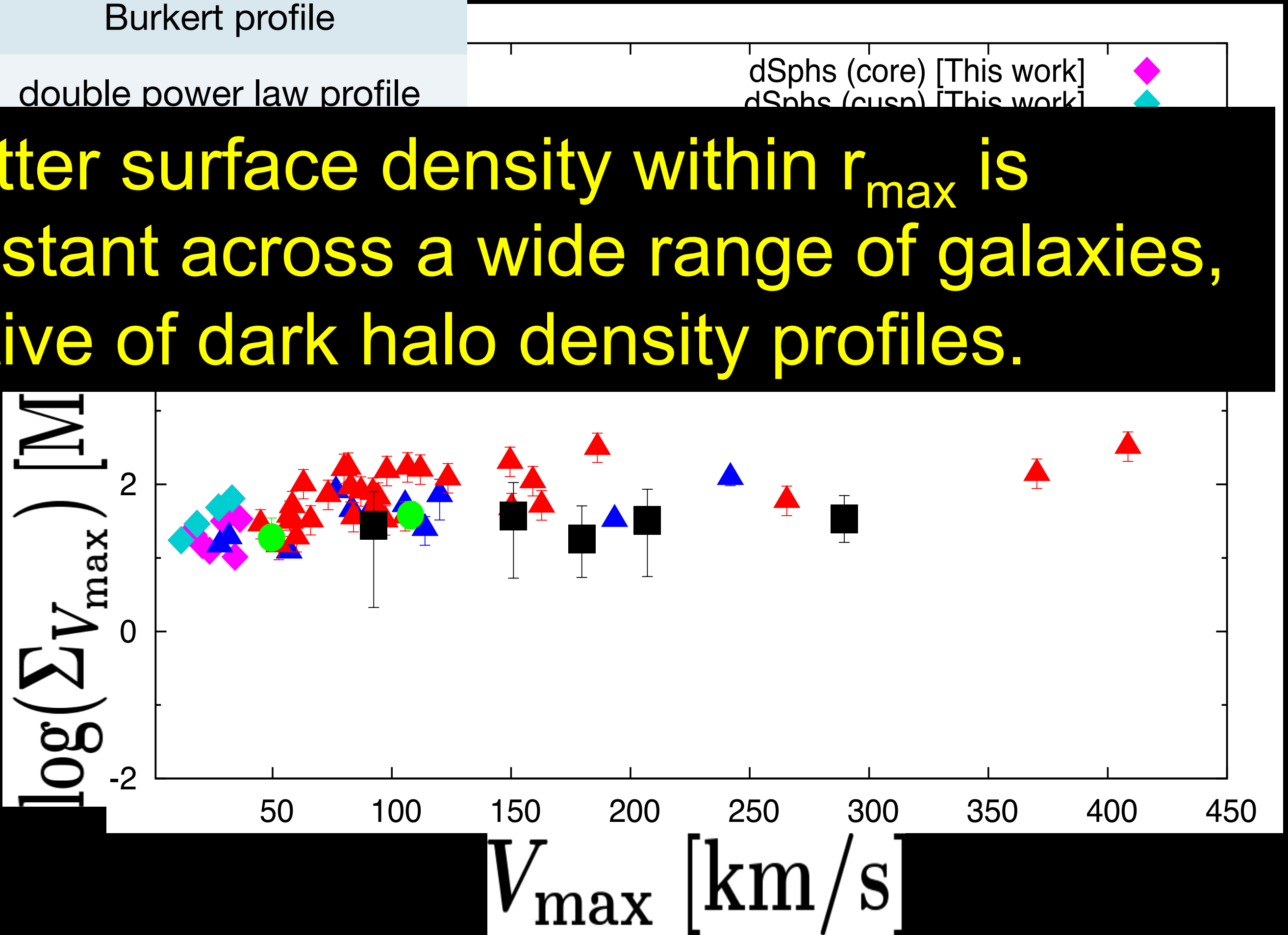
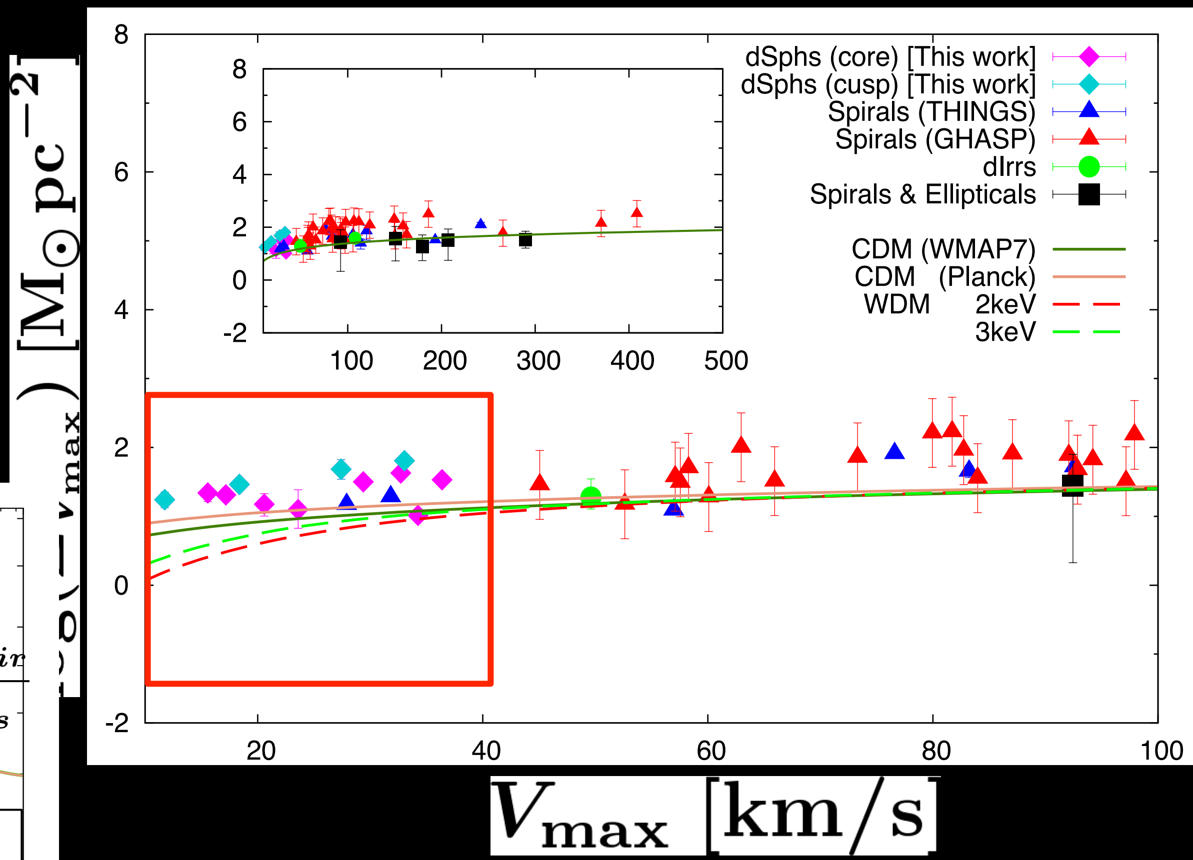
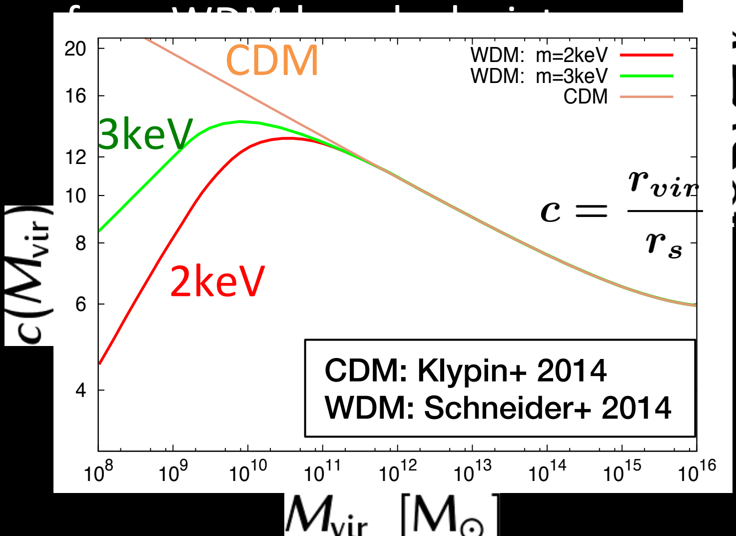


Dark matter surface density within r_{max} is sufficiently constant across a wide range of galaxies, irrespective of dark halo density profiles.

Comparison with dark matter scenario

- ✓ At higher halo-mass range, this constancy for real galaxies can be naturally reproduced by both CDM & WDM, even though do not perform any fitting to the data!
- ✓ Mean surface density derived





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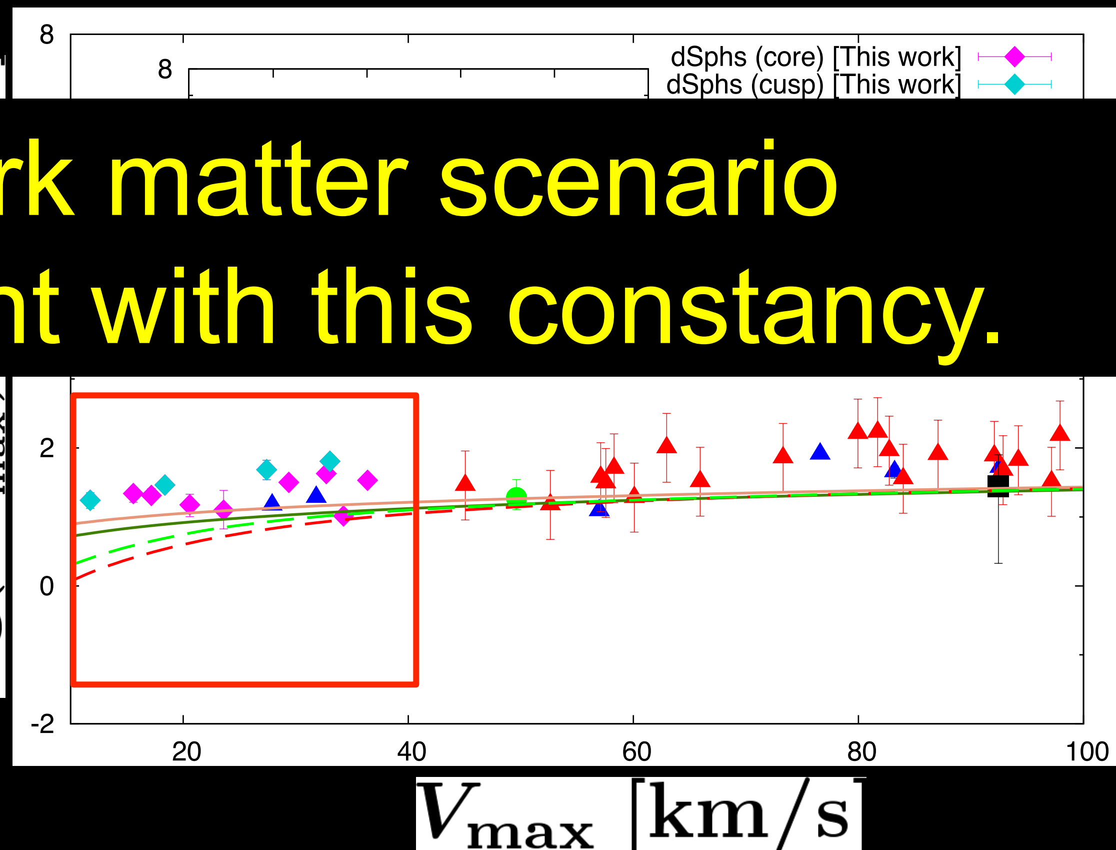
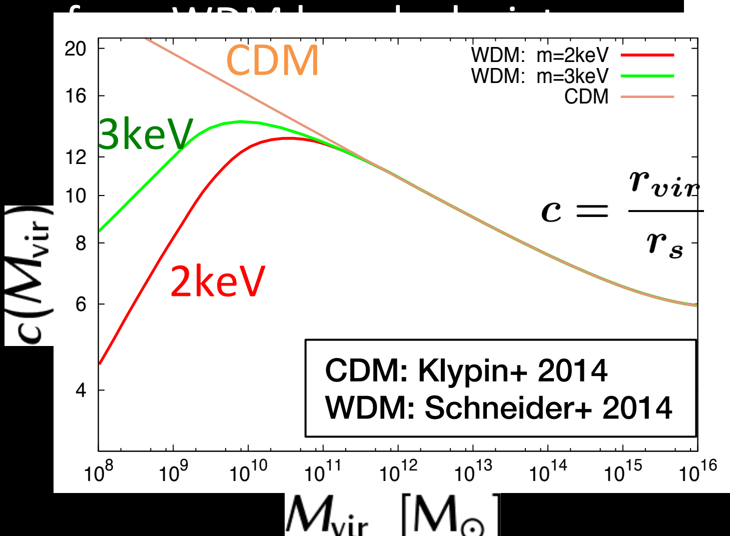


Warm dark matter scenario is inconsistent with this constancy.



Summary

1. We have constructed axisymmetric mass models for dSphs in the MW and M31 to obtain plausible limits on the structure of their dark halos.

2. The global shapes of dark halos have largely effects on the limitation of particle mass and cross section of dark matter.

3. We find that the total mass of the dSphs enclosed within 300 pc varies from 10^6 $M_\odot$ to 10^7 $M_\odot$. This is quit different from the conclusion based on spherical models.

4. It is found that dark matter surface density within a radius of Vmax is nearly constant across a wide range of galaxies, and this universality is enable us to obtain the limits on particle masses of WDM scenario.