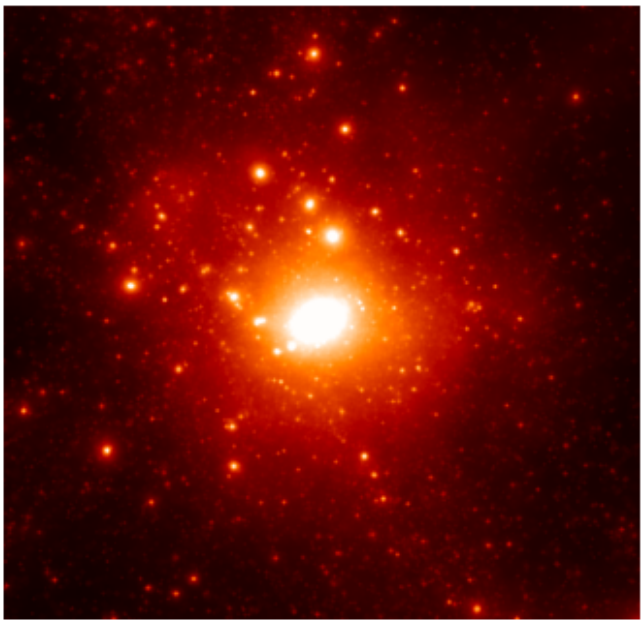
The ΛCDM Milky Way: On substructure and neutralino annihilation



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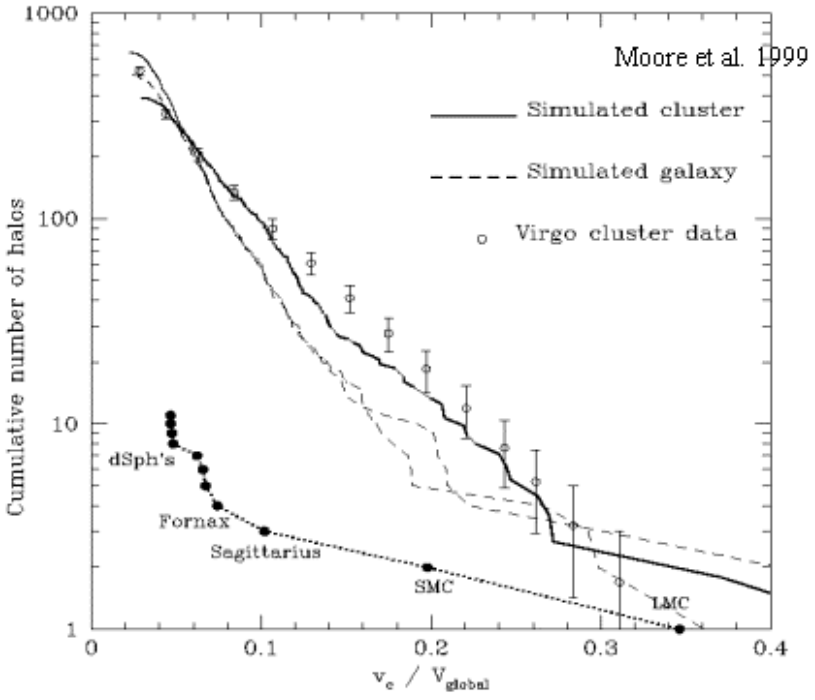
Substructure goal

Shed some light on the substructure problem. Revisit the comparison of the structure and kinematics of the Milky Way satellites with N-body simulations. (astro-ph/0203342)

- Substructure "Crisis"
- Simulations
- Substructure profiles
- Predicted velocity dispersions
- Conclusions

Substructure "crisis"



- Much more satellites seen in simulations than observed (photo-heating?)
- crisis: potential wells of simulated subhalos seem larger than of observed dwarfs
- WDM or self-interacting DM?
- rough conversion from central velocity dispersions to circular velocities.
  "Is this valid?" (Simon White, 2000)

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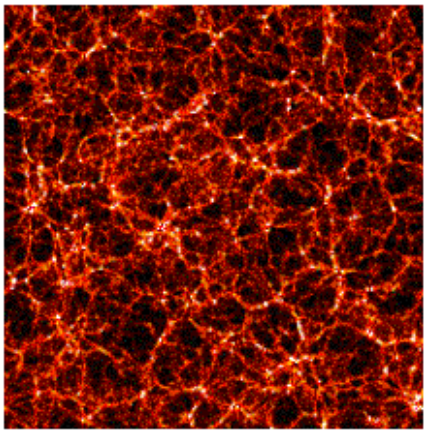
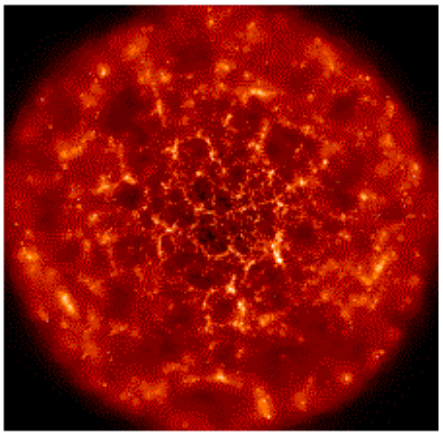
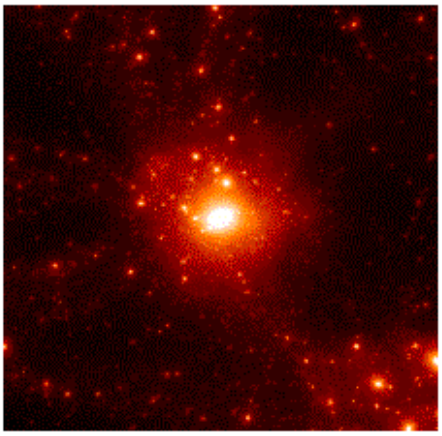
Simulations



684 Mpc
512^3LCDM
(Naoki Yoshida)



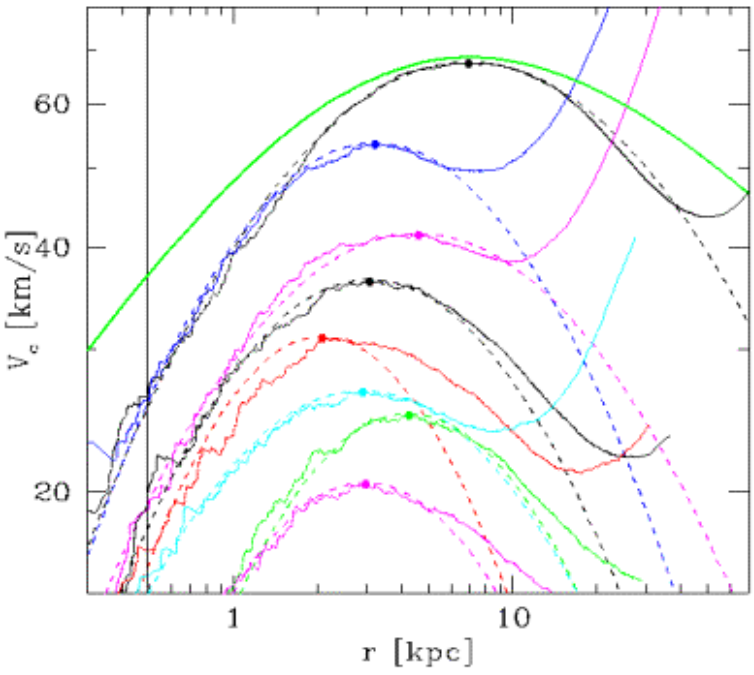
684 Mpc, High res: 75 Mpc
M3



2 Mpc
GA2

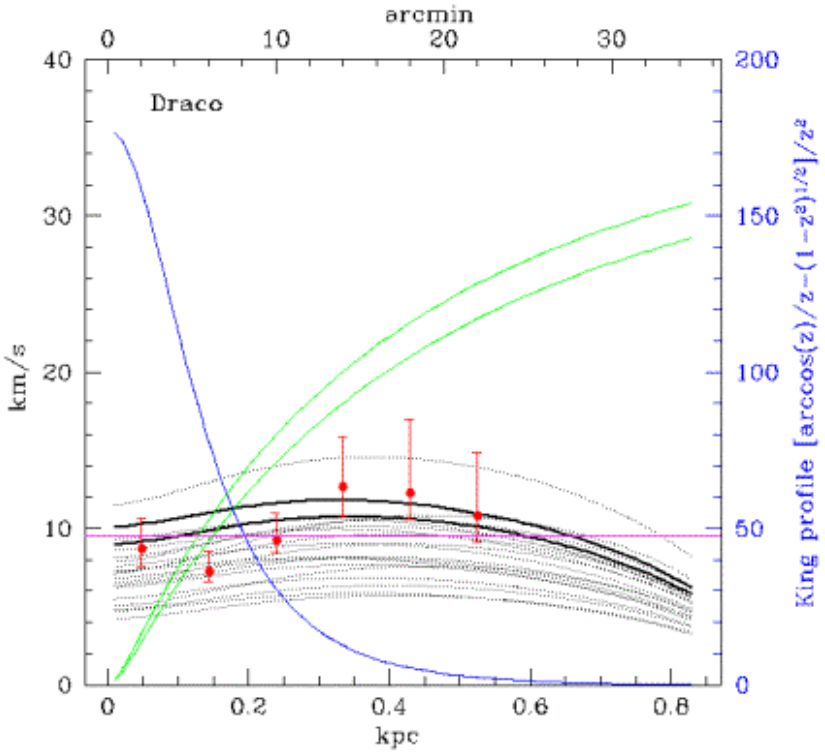
Codes: ZIC (Bepi Tormen), GADGET (Volker Springel)

Substructure profiles



- Subhalo profiles are **shallower** than NFW (see also Hayashi et al. 2002)
- Total mass in subhalos is about 5% of the halo mass
- Lensing data confirms predictions from CDM N-body simulations (Chiba 2001, Dalal & Kochanek 2001)

Velocity dispersion



Count the number of simulated halos that would give a larger central velocity dispersion than the observed one.

All 11 satellites fit into the first 20 simulated subhalos, 8 fit into the first 10.

⇒ No "substructure problem"

The **shape** of the profile is very well reproduced, too.

Data: Kleyna et al. 2002

Conclusions

- Excellent agreement between potential wells of the simulated subhalos and observed MW satellites
- $\Rightarrow$ No substructure crisis but "triumph"
- Dark halos extend much further out than observed stars
- Halos with the same central velocity dispersion/circular velocity may have very different luminosities
- Many small halos devoid of stars should be present in the MW halo
- Evidence against WDM or self-interacting DM
- $\rightarrow$ Why are halo substructures so inefficient in making stars?

Annihilation goal

Predicting the flux of γ-rays that may result from Dark Matter annihilation in the Milky Way using N-body simulations.

- Annihilation rate
- Velocity profile
- Substructure
- Conclusions

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Annihilationrate

Annihilationrate for a DM halo:

$$\Phi = \frac{\langle \sigma v \rangle}{m_{DM}^2} \int_V \rho_{DM}^2(r)\, dV = \frac{\langle \sigma v \rangle}{m_{DM}^2} 4\pi \int_0^{R_{vir}} \rho_{DM}^2(r)\, r^2\, dr = \frac{\langle \sigma v \rangle}{m_{DM}^2} \sum_{i=1}^{N_{vir}} m_i$$

particle physics | astro physics | spherical halo | simulation

Very sensitive to the actual inner slope of the halo profile:

- **isothermal** $\rho \sim r^{-2}$ $\rightarrow$ Γ diverges
- Moore $\rho \sim r^{-1.5}$ $\rightarrow$ Γ diverges
- NFW $\rho \sim r^{-1}$

No theoretical reason for a certain, a well-behaved or even an universal halo profile

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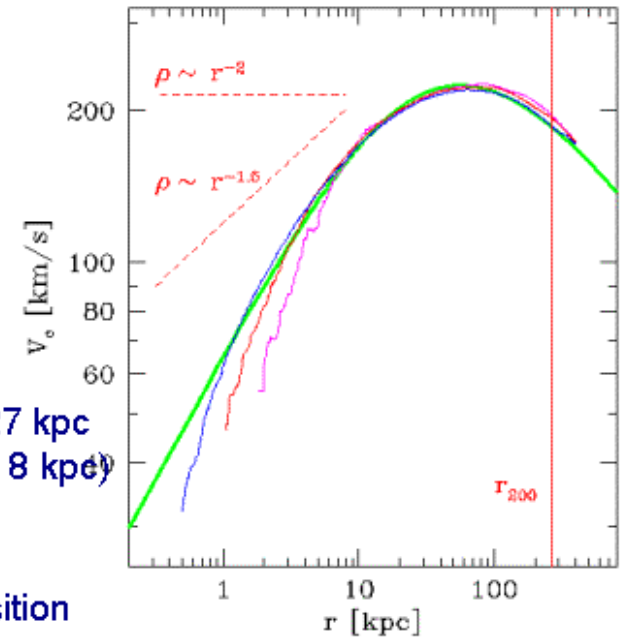
Velocity profile

- Profile has the NFW-form down to the resolution limit:

$$\langle (r) = \frac{\text{TM}_{c}}{\frac{r}{r_s}\left(1 \text{A} \frac{r}{r_s}\right)^2}$$



- For the GA-series:

  δ_c = 0.27 GeV c^{-2} cm^{-3}, r_s = 27 kpc

  (ρ_0 = 0.46 GeV c^{-2} cm^{-3}, r_0 = 8 kpc)

- Good agreement with Power et al. 2001
- NFW half light radius: 2.8% r_{200} ≈ sun's position

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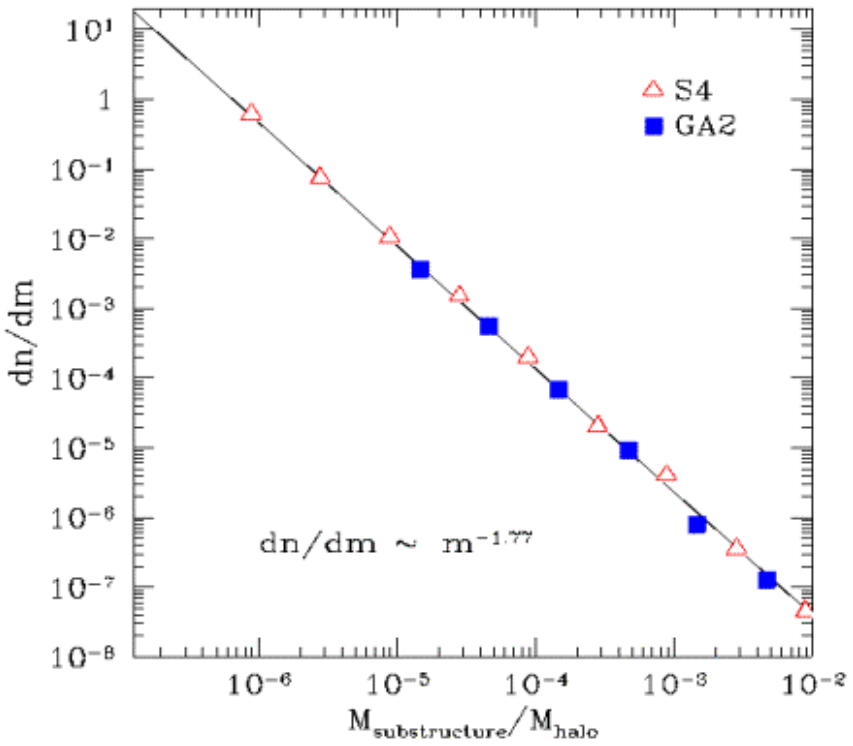
Substructure mass function



The slope of the mass function is

$dn/dm \sim m^{-1.77}$

→

Most of the total mass in substructures is concentrated in the largest objects

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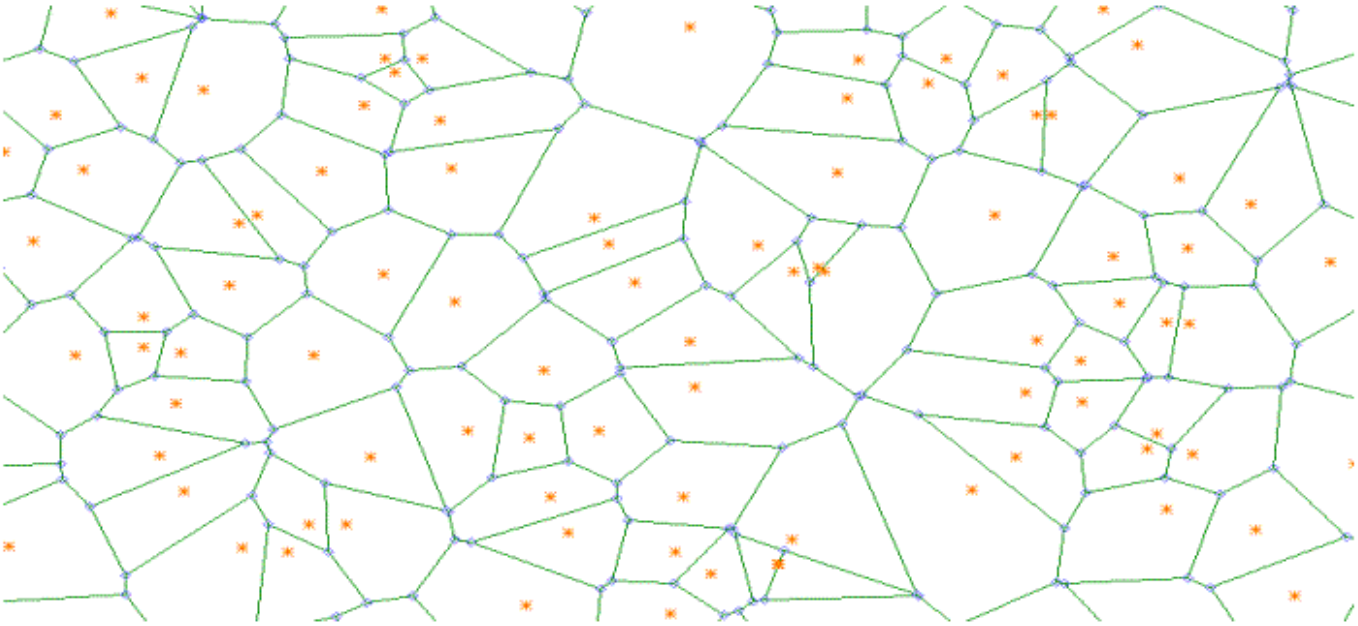
Voronoi tesselation



A Voronoi cell is the region of points that are nearer to a particle than to all other particles → for a given particle distribution highest possible resolution

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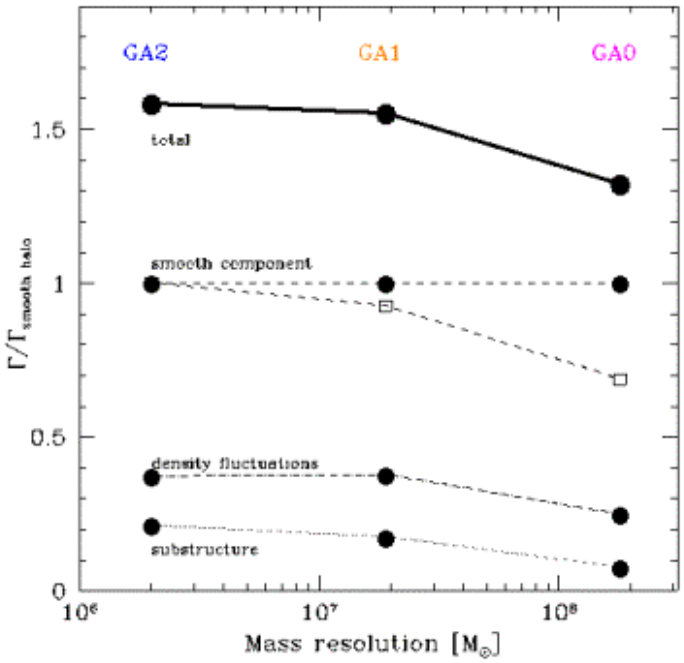
Measured annihilationrate



GA2: smooth halo ≈64(100)%, subhalos ≈14(21)%, unbound fluctuations ≈22(34) % of the total(smooth halo) Flux

Conclusions

- Main halo has NFW profile down to 0.37% of r_{200}
- Subhalos have slightly shallower profiles but are more concentrated → not self similar
- GA2: Total mass(flux) of self-bound subhalos is about 5(14)% of the halo mass(flux)
- GA2: measured half light radius is 3.5% r_{200}
- "Hint" of convergence of the **measured** annihilationrate to 2-3 times the smooth halo value
- Subclumps are fainter than the centre of the Milky Way even for the most optimistic assumptions