Where are the Missing Galactic Satellites?

Satellites of the MW and Andromeda

V_{circ} (km s^{-1})	Milky Way (286/571 kpc)	Andromeda (286/571 kpc)	Average (286/571 kpc)	Comments
10	11/13	13/15	12/14	Sculptor, Carina, Sextans, Leo II, And I–III, V, VI, CAS, Pegasus
15	7/9	7/8	7/8.5	Phoenix, Fornax, Leo I, Urs Min, Draco, Sagit, Lgs3
20	2/3	6/7	4/5	IC1613
30	2/3	6/6	4/4.5	SMC, NGC 6822, IC 10, NGC 147, NGC 185
50	1/1	3/3	2/2	LMC
70	0/0	3/3	1.5/1.5	M33, M32, NGC 205

Parameters of Simulations

Model	Ω_0	h	σ_8	$m_{\rm particle}$ ($h^{-1}\,M_\odot$)	$N_{\rm steps}$	Resolution (h^{-1} pc)	Box (h^{-1} Mpc)	$N_{\rm part}$
SCDM	1.0	0.5	1.0	2.05×10^6	650–40,000	150	2.5	128^3
ΛCDM	0.3	0.7	1.0	1.66×10^7	650–40,000	450	7.5	128^3

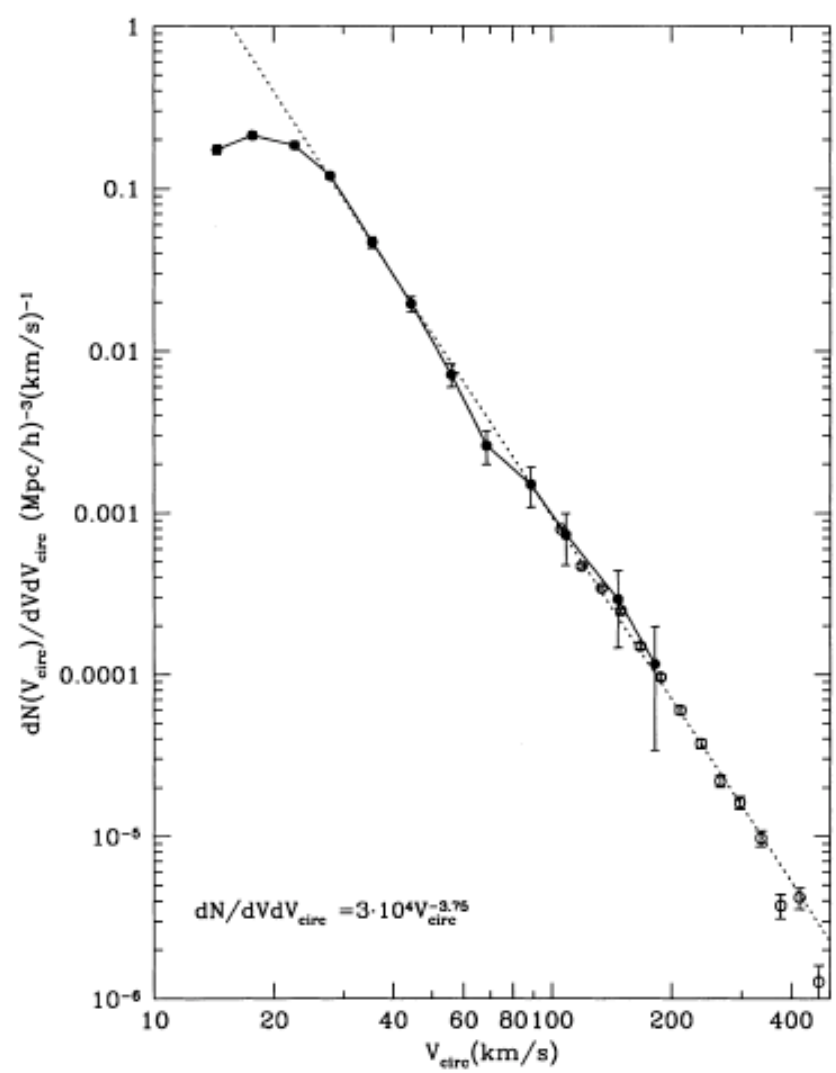


FIG. 1.—Differential circular velocity distribution function of DM halos in the ΛCDM model. The solid curve and the filled circles are results of the small box (box size of 7.5 h^{-1} Mpc) simulation. Open circles show the corresponding velocity function in a larger (box size of 60 h^{-1} Mpc) simulation. Error bars correspond to the Poisson noise. The dotted curve is the power law with the slope of -3.75 motivated by the Press-Schechter approximation (see § 4 for details).

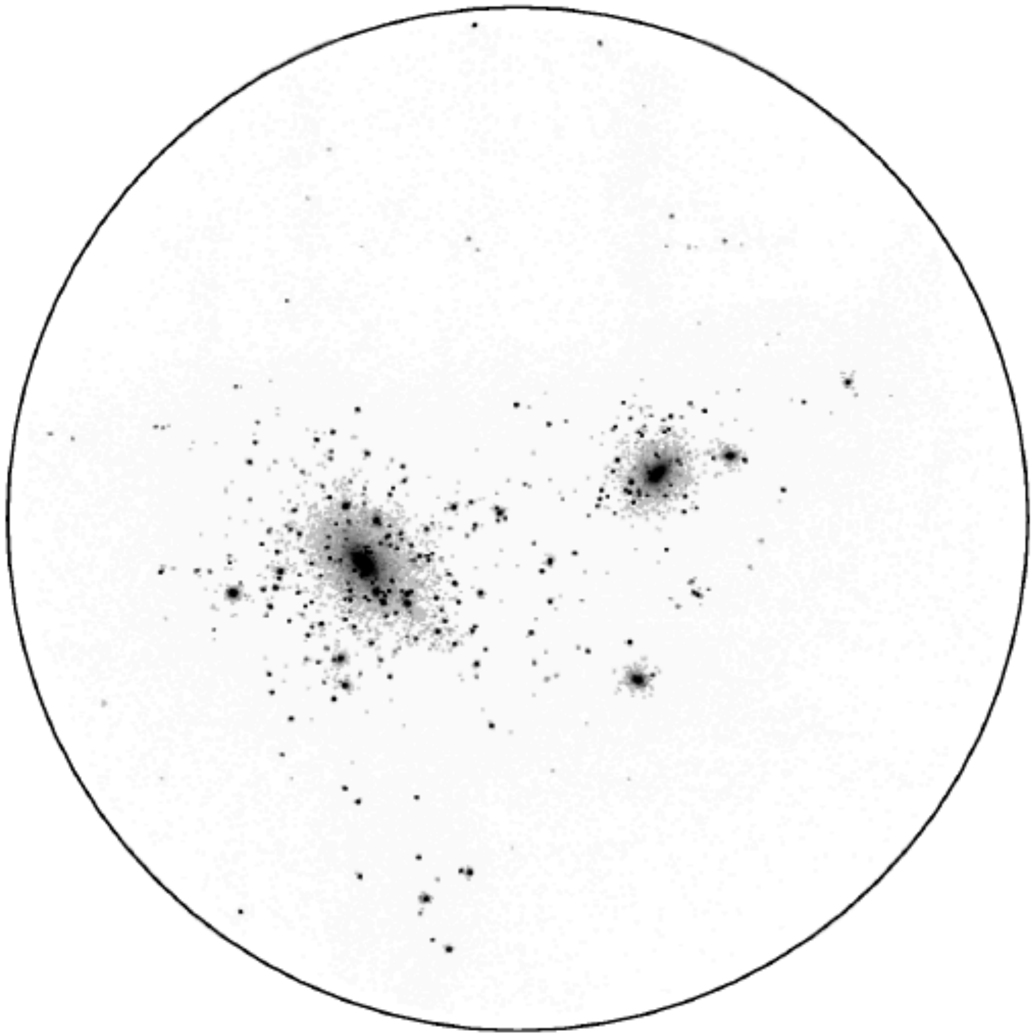


FIG. 2.—Distribution of DM particles inside a sphere of radius 1.5 h^{-1} Mpc (*solid circle*) for a small group of DM halos (similar in mass to the Local Group) in the ΛCDM simulation. The group consists of two massive halos with circular velocities of 280 and 205 km s^{-1} (masses of 1.7×10^{12} and 7.9×10^{11} h^{-1} $M_{\odot}$ inside a 100 h^{-1} kpc radius) and 281 halos with circular velocities greater than 10 km s^{-1} inside 1.5 h^{-1} Mpc. The distance between the halos is 1.05 h^{-1} Mpc. To enhance the contrast, we have color coded DM particles on a gray scale according to their local density: the intensity of each particle is scaled as the logarithm of the density, where the density was obtained using a top-hat filter with 2 h^{-1} kpc radius.

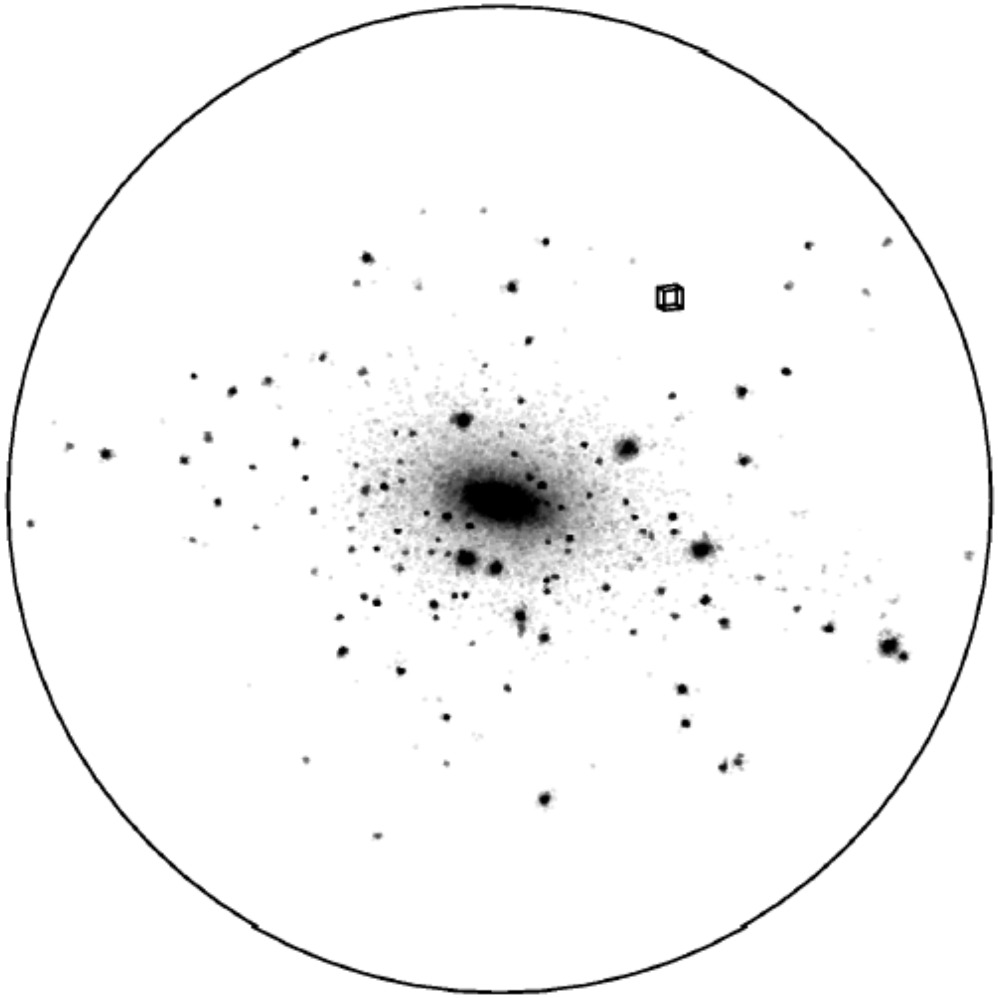
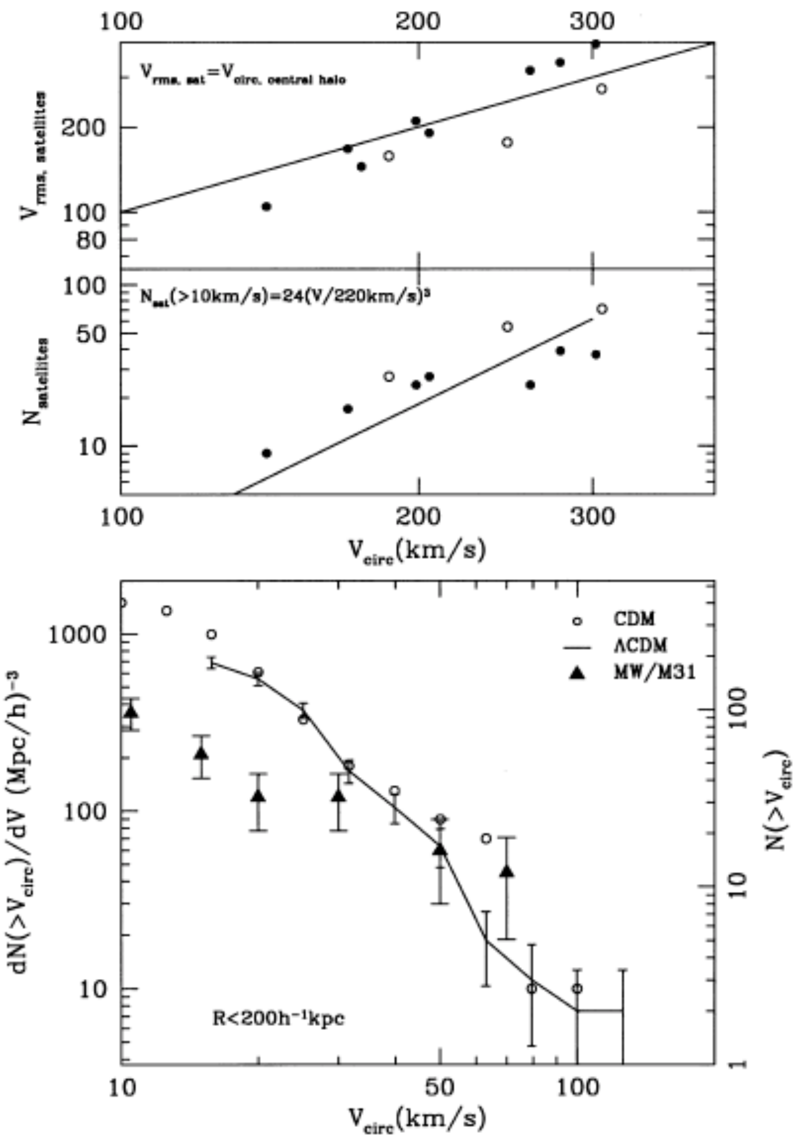


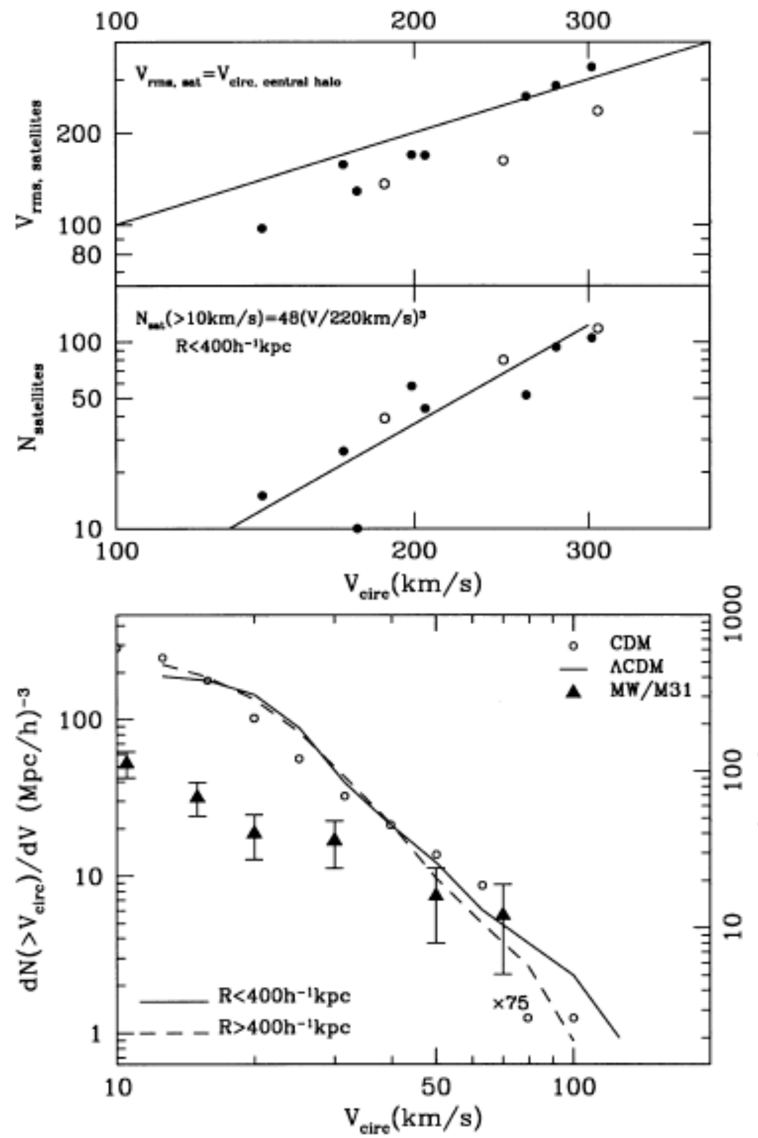
FIG. 3.—Distribution of DM particles inside a sphere of the radius of 0.5 h^{-1} Mpc (*solid circle*) centered on the more massive halo shown in Fig. 2. The small box in the figure has size 20 h^{-1} kpc. The color coding is similar to that in Fig. 2 except that the local density was obtained using a top-hat filter of 3 h^{-1} kpc radius.

TABLE 3

SATELLITES IN ΛCDM MODEL INSIDE $R = 200/400\ h^{-1}$ kpc FROM CENTRAL HALO

Halo V_{circ} (km s^{-1})	Halo Mass ($h^{-1}M_{\odot}$)	Number of Satellites	Fraction of Mass in Satellites	V_{rms} (km s^{-1})	$V_{rotation}$ (km s^{-1})
140.5......	2.93×10^{11}	9/15	0.053/0.112	99.4/94.4	28.6/15.0
278.2......	3.90×10^{12}	39/94	0.041/0.049	334.9/287.6	29.8/11.8
205.2......	1.22×10^{12}	27/44	0.025/0.051	191.7/168.0	20.0/11.3
175.2......	6.26×10^{11}	5/10	0.105/0.135	129.1/120.5	41.5/45.2
259.5......	2.74×10^{12}	24/52	0.017/0.029	305.0/257.3	97.1/16.8
302.3......	5.12×10^{12}	37/105	0.055/0.112	394.6/331.6	39.4/15.7
198.9......	1.33×10^{12}	24/58	0.048/0.049	206.1/169.3	17.7/12.1
169.8......	7.91×10^{11}	17/26	0.053/0.067	162.8/156.0	9.3/5.0


$V_{rms, sat} = V_{circ, central\ halo}$
$V_{rms,\ satellites}$
$N_{sat}(>10km/s) = 24(V/220km/s)^3$
$N_{satellites}$
$V_{circ}(km/s)$
CDM
ΛCDM
MW/M31
$dN(>V_{circ})/dV\ (Mpc/h)^{-3}$
$N(>V_{circ})$
$R<200h^{-1}kpc$


$V_{rms, sat} = V_{circ, central\ halo}$
$V_{rms,\ satellites}$
$N_{sat}(>10km/s) = 48(V/220km/s)^3$
$R<400h^{-1}kpc$
$N_{satellites}$
$V_{circ}(km/s)$
CDM
ΛCDM
MW/M31
$dN(>V_{circ})/dV\ (Mpc/h)^{-3}$
$R<400h^{-1}kpc$
$R>400h^{-1}kpc$
×75

Local Group

$$n(>V_{\rm circ}) = 385 \pm 83\left(\frac{V_{\rm circ}}{10\ {\rm km\ s^{-1}}}\right)^{-1.3\pm0.4}(h^{-1}\ {\rm Mpc})^{-3}\ ,$$

$$\text{for } R < 200\ h^{-1}\ {\rm kpc},\quad V_{\rm circ} > 10\ {\rm km\ s^{-1}}\ , \quad (1)$$

$$n(>V_{\rm circ}) = 55 \pm 11\left(\frac{V_{\rm circ}}{10\ {\rm km\ s^{-1}}}\right)^{-1.4\pm0.4}(h^{-1}\ {\rm Mpc})^{-3}\ ,$$

$$\text{for } R < 400\ h^{-1}\ {\rm kpc}\ . \quad (2)$$

Simulation

$$n(>V_{\rm circ}) = 5000\left(\frac{V_{\rm circ}}{10\ {\rm km\ s^{-1}}}\right)^{-2.75}(h^{-1}\ {\rm Mpc})^{-3}\ ,$$

$$\text{for } R < 200\ h^{-1}\ {\rm kpc}\ , \quad (3)$$

$$n(>V_{\rm circ}) = 1200\left(\frac{V_{\rm circ}}{10\ {\rm km\ s^{-1}}}\right)^{-2.75}(h^{-1}\ {\rm Mpc})^{-3}\ ,$$

$$\text{for } R < 400\ h^{-1}\ {\rm kpc}\ . \quad (4)$$

Where are the missing satellites?

- High Velocity Clouds
- Dark Satellites
- Possible Observational Caveats

New ultra-faint dwarf galaxies are found (**arXiv:0706.0516**):