

Satellites and Tidal Streams
ING–IAC joint Conference
La Palma, May, 2003

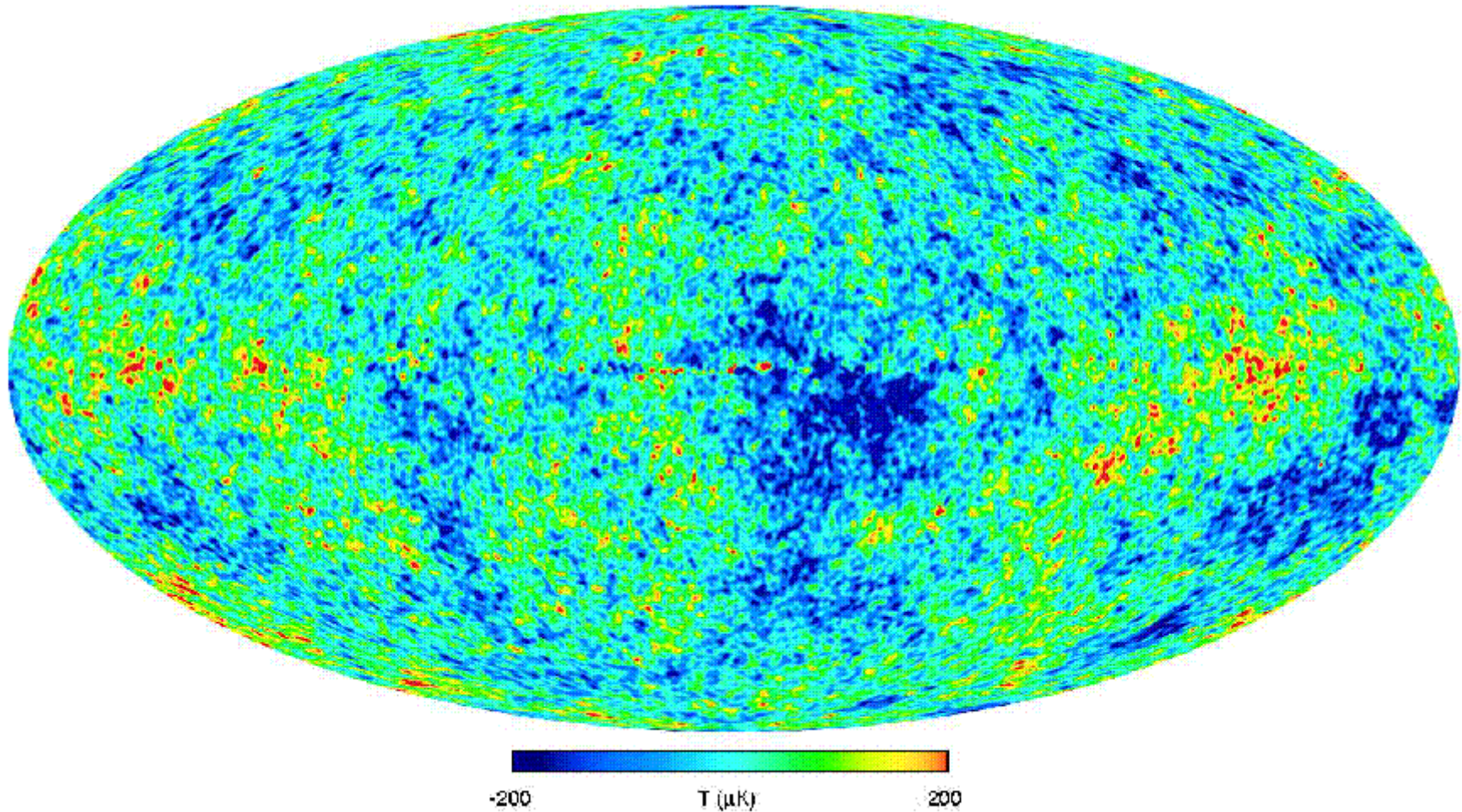
**Use and abuse of satellite
galaxies**

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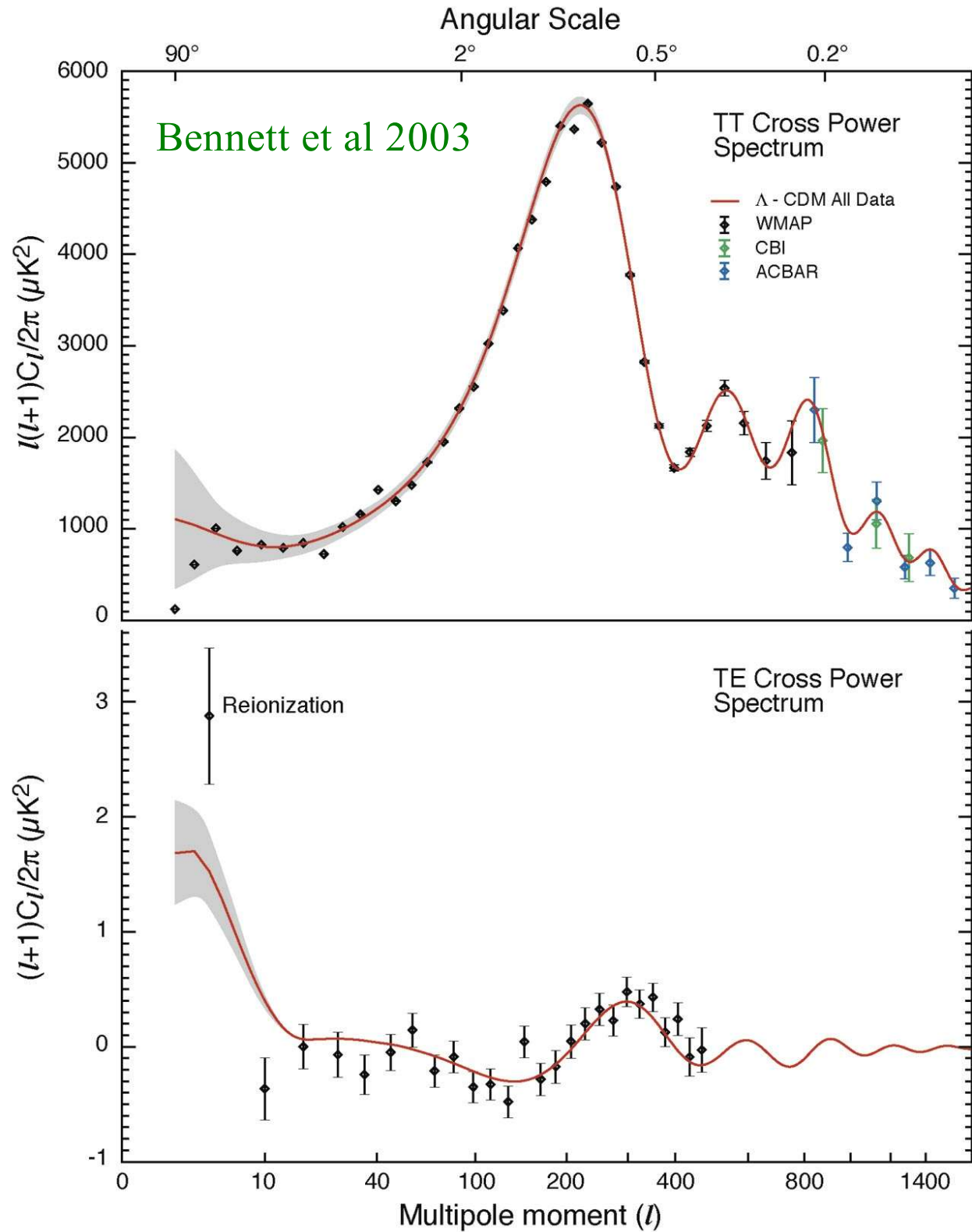
Why study satellites/streams?

- Probes of the nature and distribution of dark matter
- Accessible examples of the lowest mass galaxies
- Fossils of galaxy assembly
- Progenitors of the Milky Way's stellar halo? bulge?
- Laboratories for star formation, feedback and enrichment
- Perturbers/suppliers of the Galactic disk

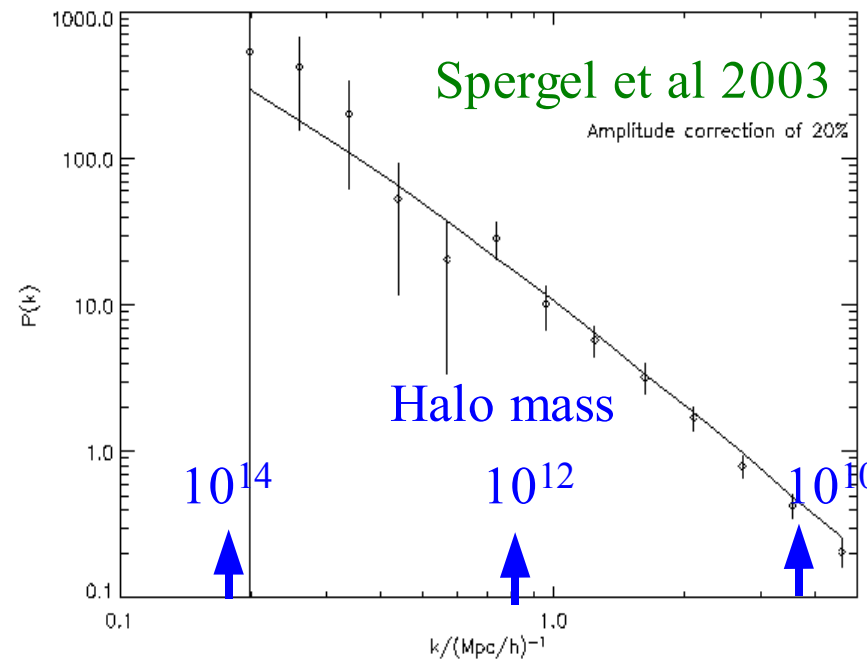
WMAP Map of the Cosmic Microwave Background



Bennett et al 2003



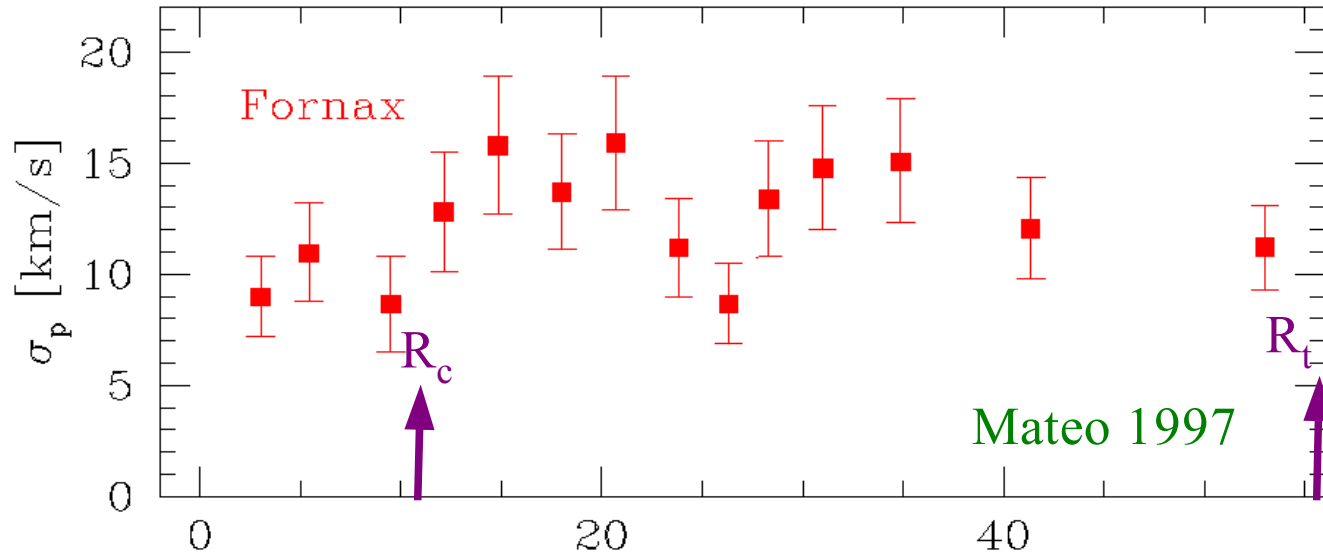
- $> 10^5$ near-independent 5σ temperature measurements
 - Gaussian map: PS fit by a CDM model with parameters consistent with other data
 - Extrapolation fits the Ly- α forest power spectrum
- Confirms standard model to scales well below those of clusters and bright galaxies**



Weighing galaxy halos

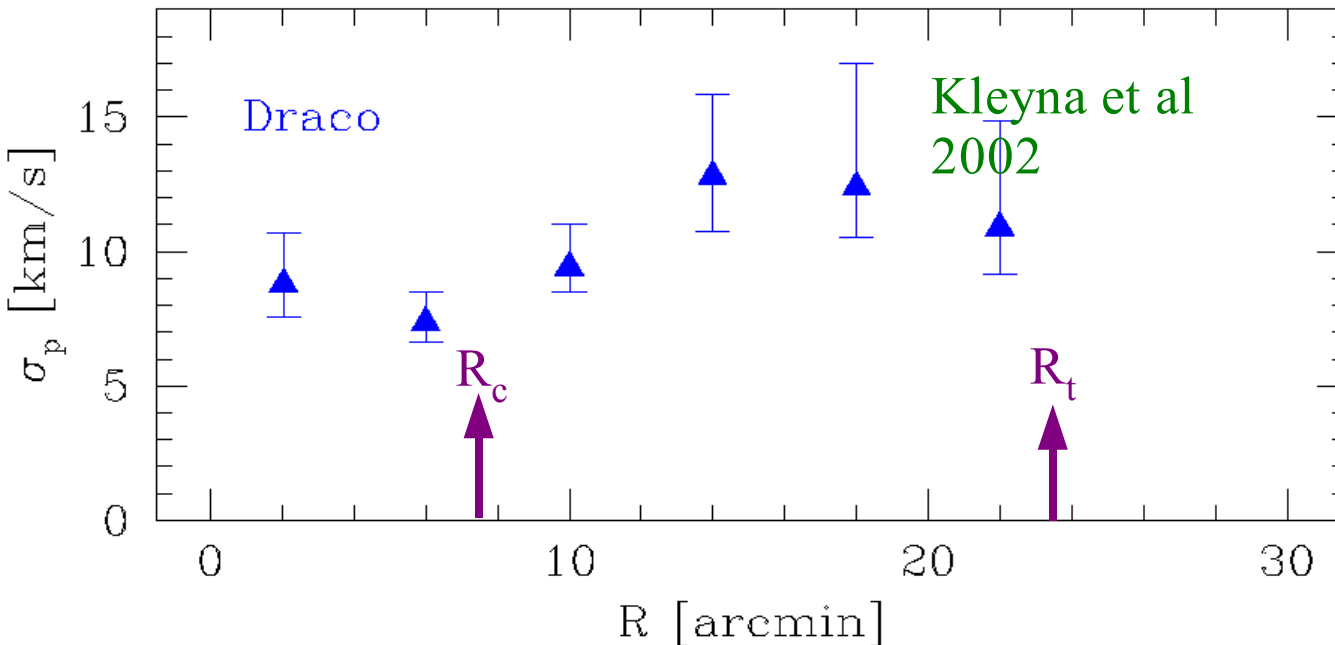
- The massive and extended galaxy halos expected in CDM theories can be weighed only by
 - gravitational ('galaxy-galaxy') lensing
 - static X-ray halos (for massive central ellipticals)
 - satellite galaxy dynamics
- Analysis of satellite dynamics is complicated by
 - need to stack many 'similar systems' (external galaxies)
 - small number of satellites (Milky Way)
 - lack of information about orbital eccentricity
 - orbital times comparable to the Hubble time
- Data can explore relation of halo mass to galaxy type
 - Insights into galaxy formation

Dark Matter within Satellites



- Flat stellar velocity dispersion out to the tidal radius
 → *rising* V_c curve

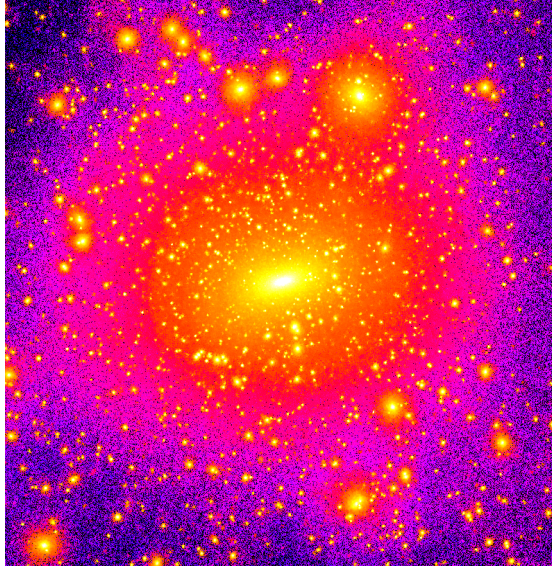
- Extended DM halos?



- High DM phase density? ~~WDM?~~

- $V_{c,max} \gtrsim 25$ km/s?

- Critical observation: extratidal stars?

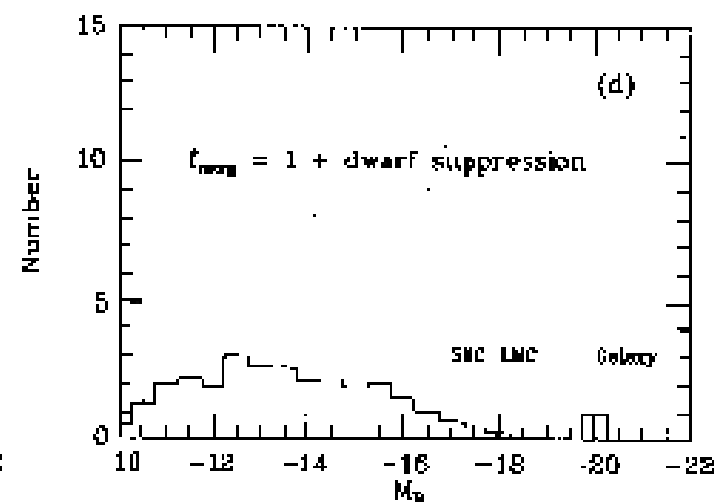
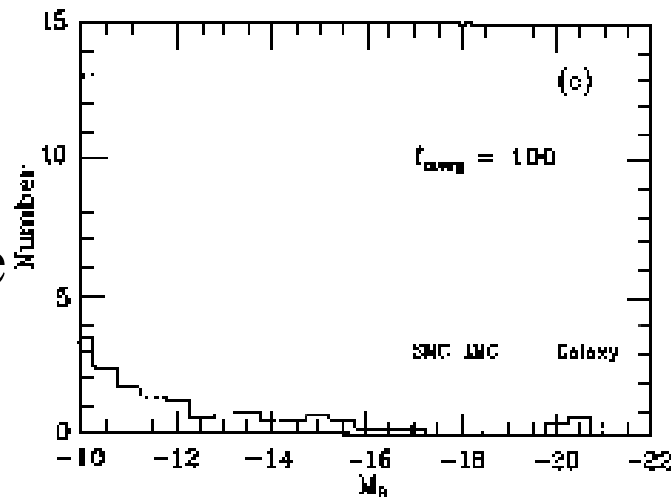
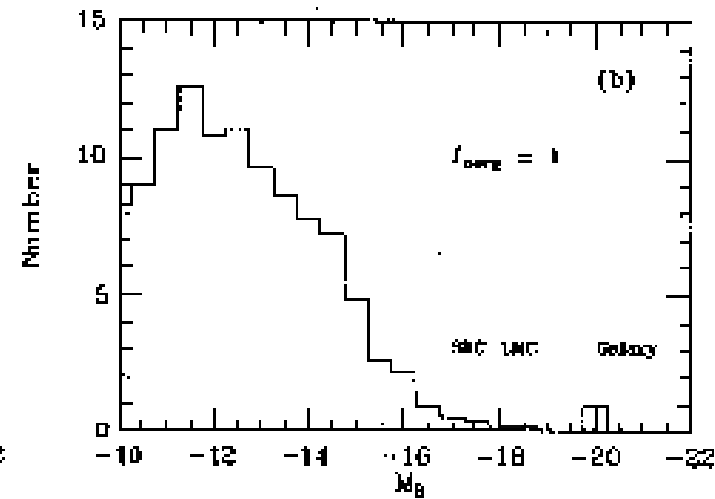
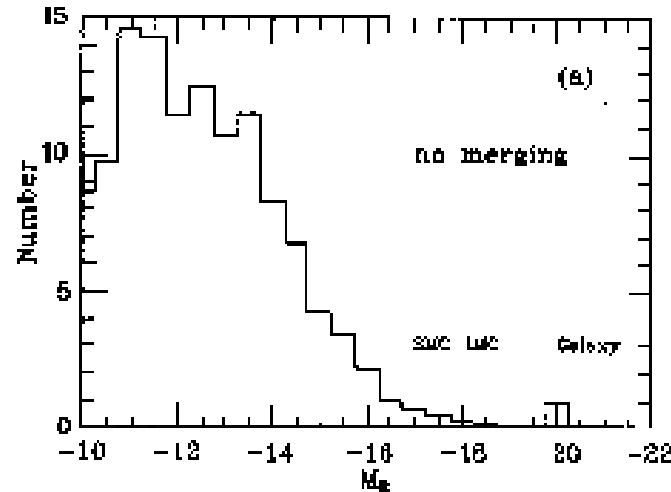


Too many satellites for CDM?

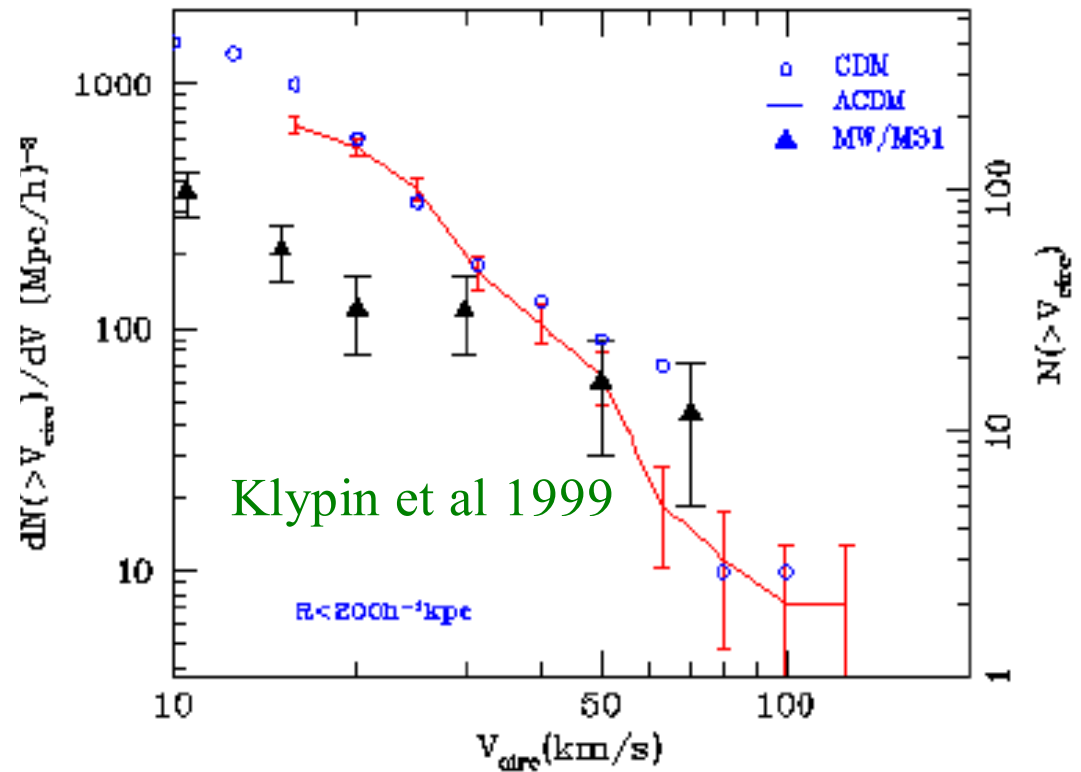
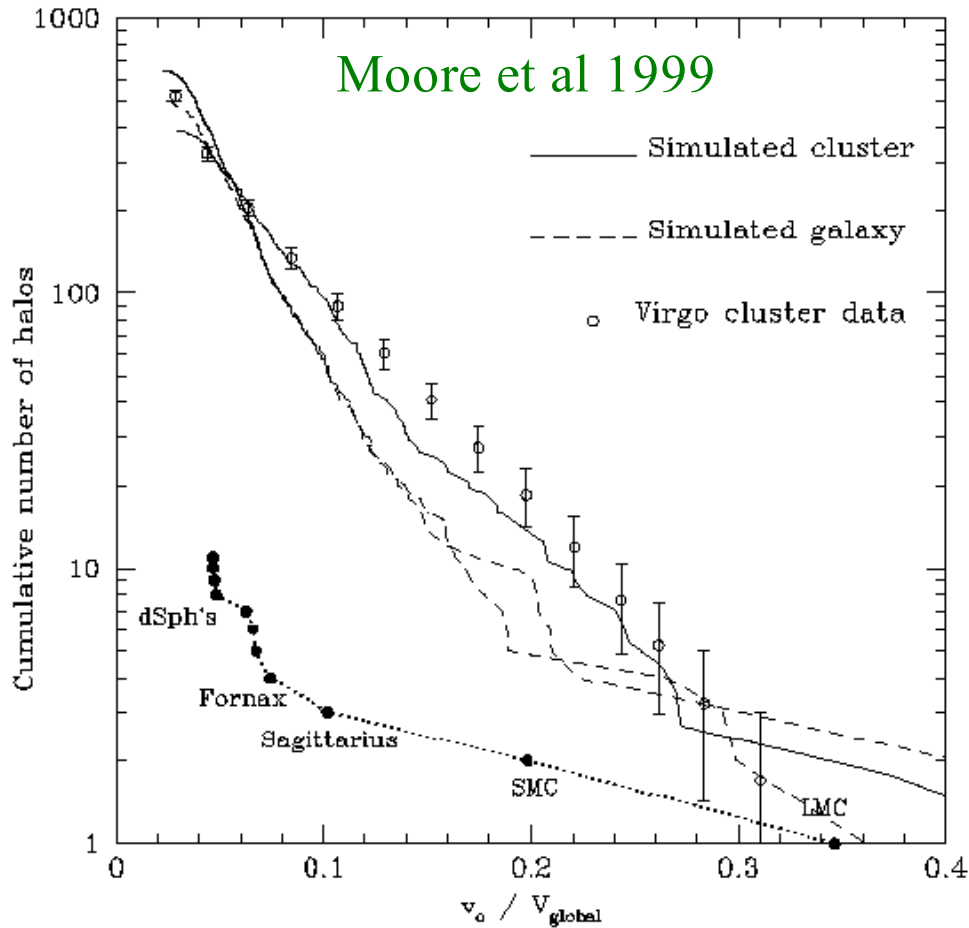
Kauffmann, Guiderdoni, White 1993

- In hierarchical models like CDM the Milky Way's halo formed out of many smaller halos
- If all progenitors made stars with *reasonable* efficiency too many satellites result
- Star formation must be strongly suppressed in low mass progenitors

Reionisation effects?

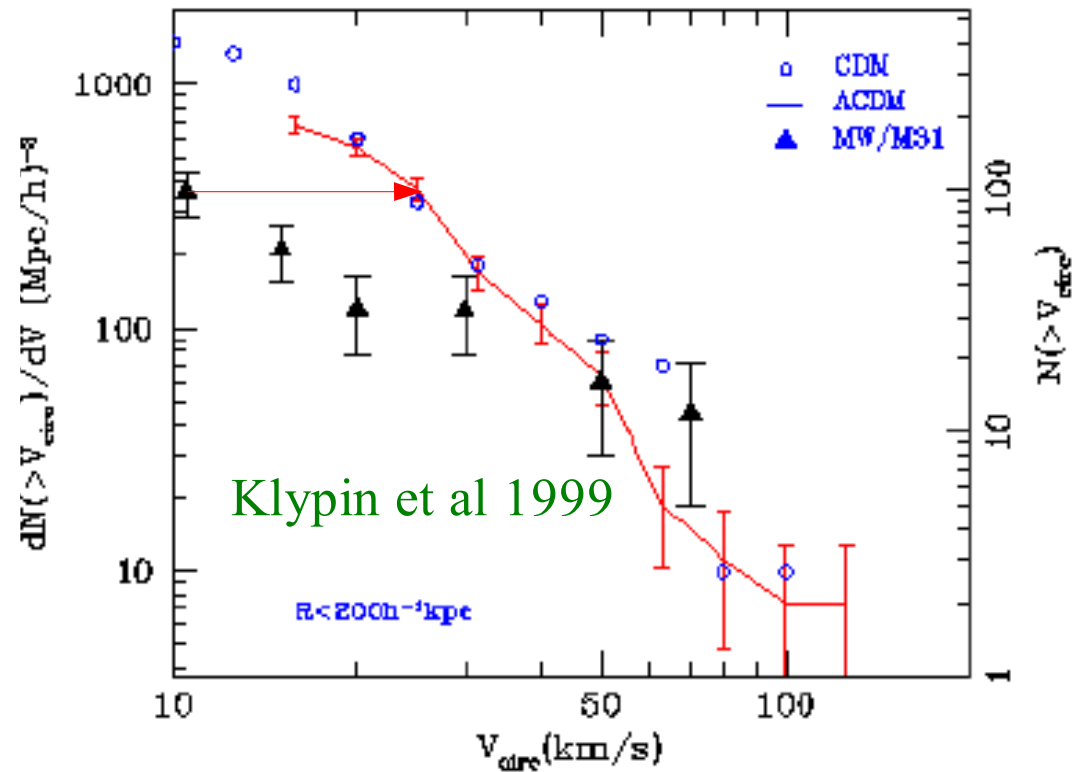
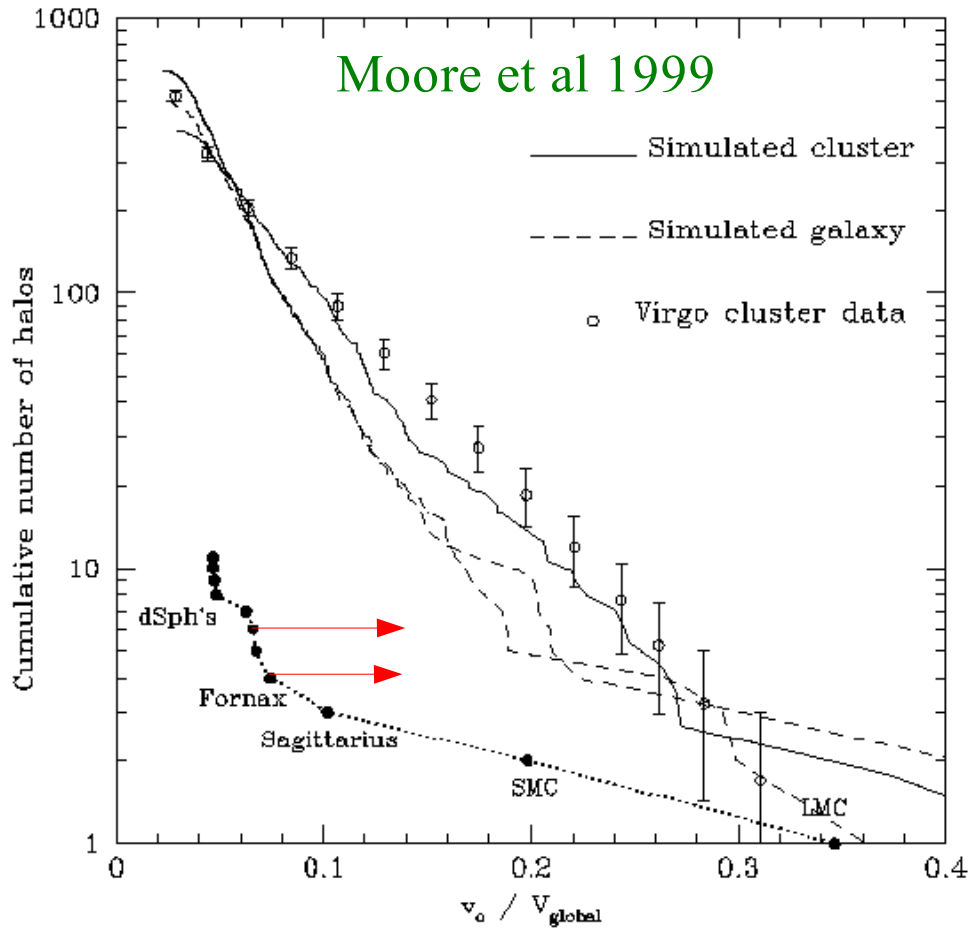


Inconsistency with observed satellite kinematics?



- The number of observed satellites with circular velocity $V = (GM/r)^{1/2}$ (inferred from the *mean* velocity dispersion) exceeding 10 km/s is at least 10 times smaller than the number expected in a Λ CDM halo

Inconsistency with observed satellite kinematics?



- Inconsistency is much less dramatic when one uses the *limiting* circular velocity inferred from the velocity dispersion profiles

Effects of CDM substructure

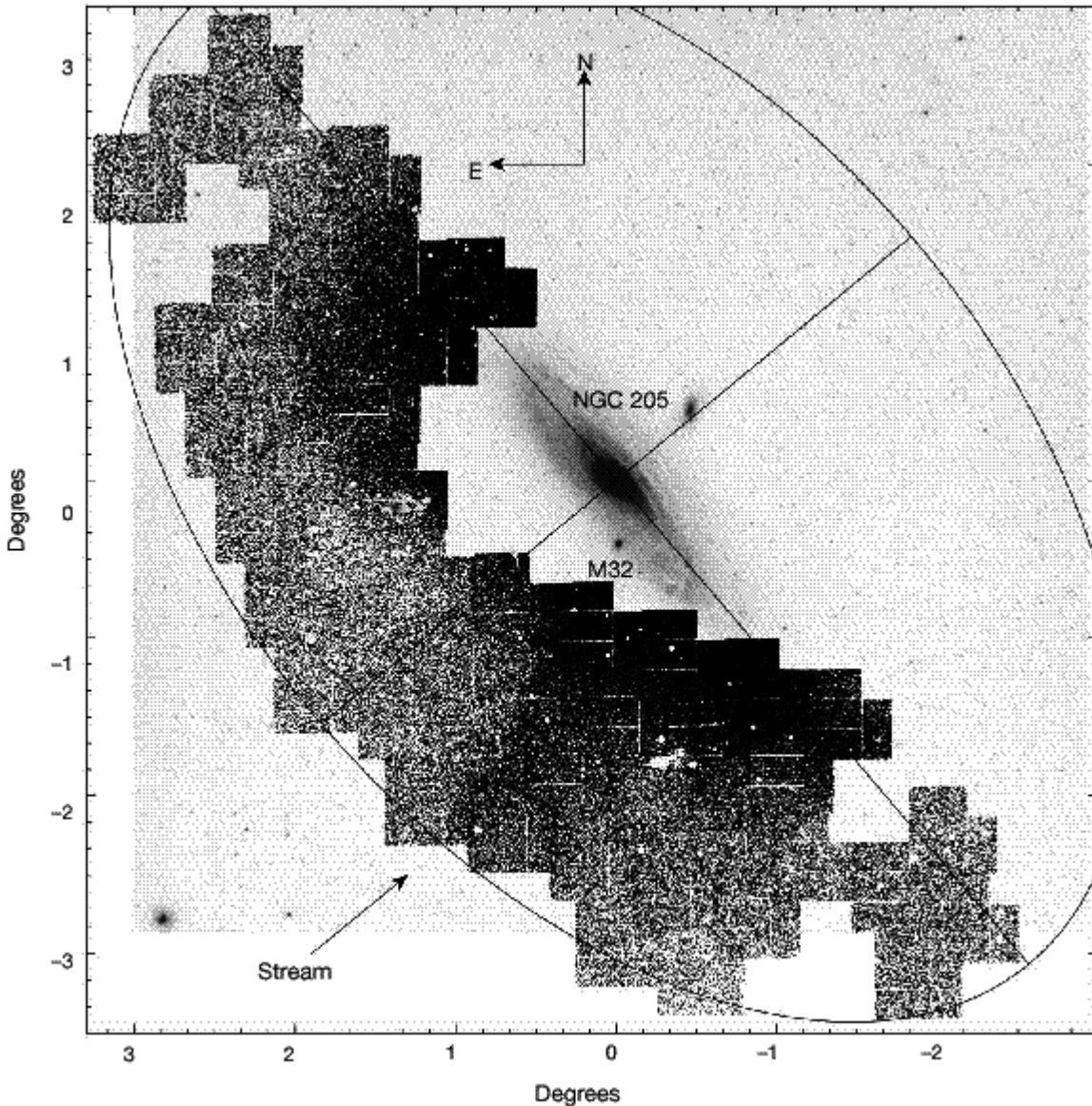
- Dynamical heating of Galactic substructures
 - the disk? globular clusters? halo streams?
 - effects dominated by most massive objects -- LMC, SMC
- Differential image magnification in multiply imaged QSOs
 - dominant substructures have lensing scale smaller than image separation but larger than image size
 - intermediate masses
- Relation to high-velocity clouds?

The lowest mass galaxies

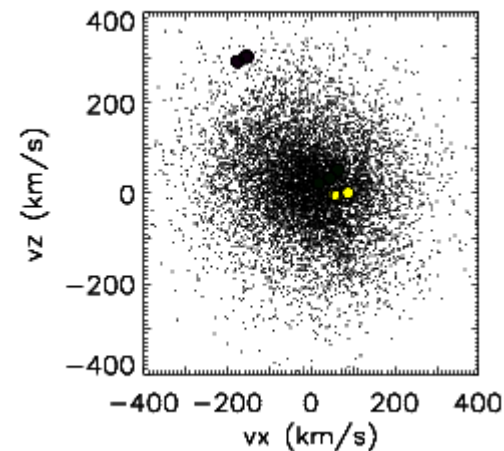
- What limits star formation?
 - breakdown of $L - \sigma$ relation (cf Draco, Fornax)
 - star formation in widely separated bursts
 - reionization effects?
 - galactic wind effects?
- What is the relation of D_{wSph} to D_{wIrr} ?
- What is the role of tidal limitation?
 - do satellites differ from the field? from cluster dwarfs?

Streams -- fossils of galaxy assembly

Ibata et al 2001



- Which progenitors produced streams? When?
- How many mergers were there?
- How many streams from each?
- Streams near the Sun? In the disk? In DM detectors?
- Did the metal-poor halo form this way? the bulge?
- Relation to globular clusters?



Helmi &
White 2002

Uses of streams

- To measure the *shape* of the Galactic halo
- To detect the effects of substructure
- To characterise the accretion history of the Milky Way
- To characterise element abundances in early dwarfs

Star formation issues and satellites

- What initiates star formation bursts?
 - tidal effects?
 - interactions with halo gas?
 - internal latency/activity cycles?
- How active are winds in dwarfs?
 - only during bursts?
 - heavy element loading?
 - differential loss of elements (α /Fe/CNO, dust...)
- Is IMF or binary fraction variable?
 - low metallicity, low dust conditions
 - low escape velocity

Satellites and the Galactic gas supply

- Does satellite accretion refuel the galactic disk?
- Is satellite gas lost by ram-pressure stripping on a hot halo?
- Are some high velocity clouds stripped from satellites?
- Are some satellites stripped out of disks? tidal dwarfs?