I. Introduction:

Galaxies are not isolated islands but interact with their environment by various processes and in both directions.

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Subhalos as building blocks in the hierarchical CDM scenario
Density enhancements at filamentary knots lead to mass concentrations by streaming motions.
1.1. Cold accretion

Dekel et al. (2009) Nature, 457: Colours refer to inflow rate per solid angle of point-like tracers at the centres of cubic-grid cells. Box side length is 320 kpc.


1.2. The Milky Way experiences gas infall by High-velocity Clouds; 20-40% sky coverage
Gas Infall everywhere? The case of NGC 2403

HI gas with different velocity

2. Circumgalactic Medium

NGC 891

huge HI envelopes
• exist;
• raise problems to ΛCDM!

Oosterloo et al. (2007)
II.1. Disentangling Gas Infall and Outflow

Inflowing gas (mainly along disk plane)

Outflowing gas (mainly perpendicular to the disk plane)

Normalized Flux

radial velocity

A
B
C
D

Relative Velocity (km/s)

inclined disk to observers on the left

outflows

infall

$\Delta$

$V_{abs} - V_{gal}$

Z_{01} = 0.4188

MgII 2796
MgII 2803

10 kpc
Differences in metallicities of outflow vs. infall

Metal content of the cool (∼10^4 K) circumgalactic medium around 28 HI-selected LLS at z ≤ 1 observed in absorption against background QSOs.

2.2. Intergalactic hot Gas
3. Satellite Infall: Minor Mergers

In NGC 1531 a satellite DG approaches the galaxy and exerts perturbations to the disk, leading to disk thickening and bending of arms.

3.1. The Magellanic Stream

Fig. 5. Integrated H I emission image highlighting the Magellanic Clouds and Stream. The HIPASS data of Putman et al. (2003) is combined with the wide-field WSRT survey data in the region 90 < l < 160, -40 < b < -5. The grey-scale varies between log(N(HI)) = 17–21, for N(HI) in units of cm⁻². Contours are drawn at log(N(HI)) = 17.5, 18.5, 19, 19.5, 20, ... 21.5. Note that the HIPASS data is limited by sensitivity to log(N(HI)) > 18.3 and the WSRT data to log(N(HI)) > 17.3. Kinematic evidence of association with the Magellanic Stream only applies to a subset of the illustrated features (see the text and Fig. 3).
3.2. Satellites of the Milky Way

Brightness contours slightly above the background (Ibata et al. (1995))

Fig. 2. Optical image of the Milky Way with the Sagittarius dwarf galaxy overlaid. The satellite is being disrupted by the Galaxy while moving through the disk. [Image from G. Gilmore and R. Sword]

The tidal stream of Sgr DIG is detected from enhanced star density.
4. Galaxies in Groups and Clusters

- Morphologies in Clusters
- The Effect of ram-pressure stripping
- HI deficiency of spiral galaxies
- Galaxy transformation visible?
- Frequent encounters of galaxies in clusters: harassment
- Merging

4.1. Morphology-Density Relation

- Es at high densities
- Ss at low densities, i.e. in cluster outskirts
- Morphology-radius relation
- Es formed in-cluster cores

Cluster galaxies are radially distributed following a King profile. dEs supply the dominant fraction of galaxy types. gEs follow next. (Binggeli et al. 1987)
Dwarf Galaxies show similar trend:

- morphology-density relation not restricted to bright Hubble types but also found to apply to dwarf galaxies
- cluster and field luminosity functions show different morphological mixes
- dEs dominate the faint end of the cluster luminosity function

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4.2. HI-deficient Cluster Spirals

HI distribution of Virgo Cluster spirals
Gas Deficiency is defined according to the gas content in gas-poor vs. "normal" field galaxies.

Chemin et al. (2004)
2 spiral galaxies on the flight through the Virgo Cluster ICM

NGC 4569

NGC 4522

4.3. Ram-pressure stripping

NGC 4522 moves with ~1300 km/s relatively to the Virgo IGM. Gas is stripped off towards one direction.
Sun et al. (2009)

If not halo-gas RPS, HI filaments should be evaporated and mixed with hot ICM: X-ray filaments!

The case of ESO 137-001

Fig. 2.—Left: XMM-Newton 0.5–2 keV mosaic of A1367 from an 18 ks observation. The main tail of ESO 137-001 is significant in the XMM-Newton image. Right: the composite X-ray optical image of ESO 137-001’s tail. The Chandra 6.5–7 keV image (from the new 140 ks observation) is in blue, while the unHα emission is in red. Note that the X-ray image was adaptively smoothed (also for other X-ray contours shown in this work). The X-ray leading edge is in feet in the same place as the He emission (Figure 4).
NGC 4438 as member of the Virgo Cluster shows a disturbed disk in the optical, but in Hα an irregular octopus arm-like structure. Cause: tidal interaction of a neighbouring or fast passage by a companion galaxy: = Harassment.

RDCS 1252.9-2927
a young galaxy cluster at 1 Gpc
NGC 1275, the central cannibal of Perseus Cluster

UGC 7636 is in the state of tidal disruption by NGC 4472.

Cloud Parameters:

\[ M_{\text{HI}} = 6.5 \times 10^7 M_\odot \]
\[ v_{\text{HI}} = 472 \pm 4 \text{ km/s} \]
5. Interacting Galaxies
5.1. Tidal Interactions

Gravitational passages lead to tidal perturbations.

Tadpole Galaxy

The Mice • Interacting Galaxies NGC 4676
Hubble Space Telescope • Advanced Camera for Surveys
5.2. Merging Galaxies
5.3. Mergers as progenitors of Es
5.4. Star and Galaxy Formation in Tidal Arms

Mirabel et al. (1992)

Arp 188, the Tadpole Galaxy: bright knots as DG precursors?

bright star-formation knots are structured within the tail.