Galaxies: Structure, formation and evolution
Lecture 9

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The V/V_{max} test to check for completeness

In addition to Malmquist bias, samples can be incomplete for other reasons: magnitude errors near m_{lim} include fainter galaxies and often magnitude corrections (e.g. for internal absorption) are only applied after the sample is defined. In practice, magnitude dependent weighting factors are applied to compensate for the incompleteness.
It is possible to check for completeness with the V/V_{max} test: For each galaxy, find the ratio V/V_{max} where: V is the volume out to that galaxy V_{max} is the volume out to d_{max}, the distance that the galaxy would be at the flux limit.
If the average of that ratio, $\langle V/Vmax \rangle = 0.5$ then the sample is complete Why 0.5?. We separate the sample into bins of apparent magnitude, When $\langle V/Vmax \rangle$ begins to deviate from 0.5 you've hit the completeness limit of the survey.
Unfortunately, this test also assumes a constant space density.

Schecter LF

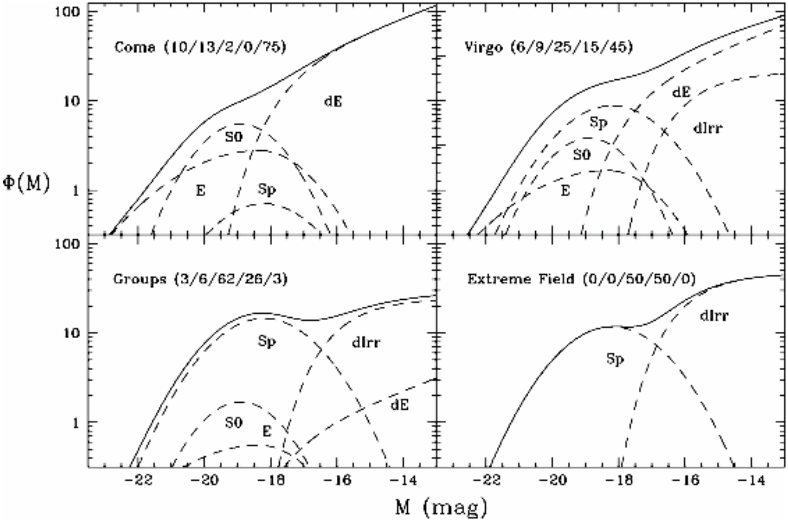
Early work showed that the Schechter function is a good fit to many galaxy samples, but the parameters (L_*,α) can vary depending on: sample depth, cluster or field, cluster type, morphological type. **Which one is more important?**

In general, cluster LFs are well fit by a Schechter function have similar L*, α is often steeper than in the field ($\sim$ -1.3), there can be a dip/drop near $M_B \sim -16 + 5\log(h)$, there can be an excess at higher luminosities for cD galaxies ($\sim 10L_*$).

Understanding the cluster LF

Recent research shows that different LFs usually arise from **different proportions** of Sp, S0, E, dE, and dIrr specifically, more E, S0, dEs are in clusters, while more Spirals and dIrr are in the field. This is evidence for a morphological dependence on galaxy density - the **morphology density relation** (Dressler 1980). The dip at $M_B \sim -16$ occurs at the changeover from “normal” to “dwarf” galaxies. cD galaxies have clearly had a different history, probably growing by accretion in dense galactic environments.

Decomposing LF by morphology



Abell 1689 - cD galaxy more luminous than LF predicts

This was already discovered by Schecter (1976)!

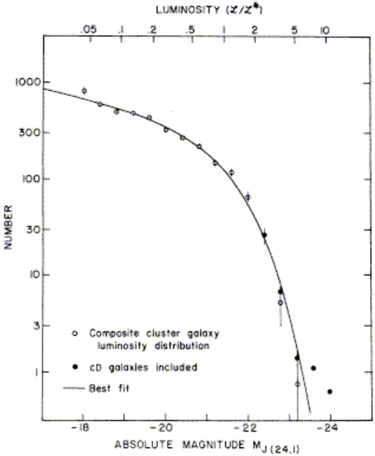


FIG. 2.—Best fit of analytic expression to observed composite cluster galaxy luminosity distribution. Filled circles show the effect of including cD galaxies in composite.

Physical origin of the LF

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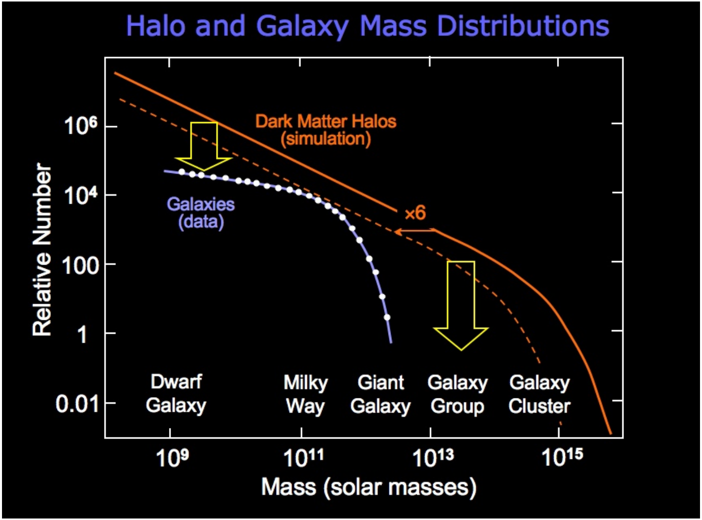
Making galaxies involves at least two steps.

1. dark matter halos must form (relatively straightforward and well understood)
2. baryons must fall in and make stars (complex physics)

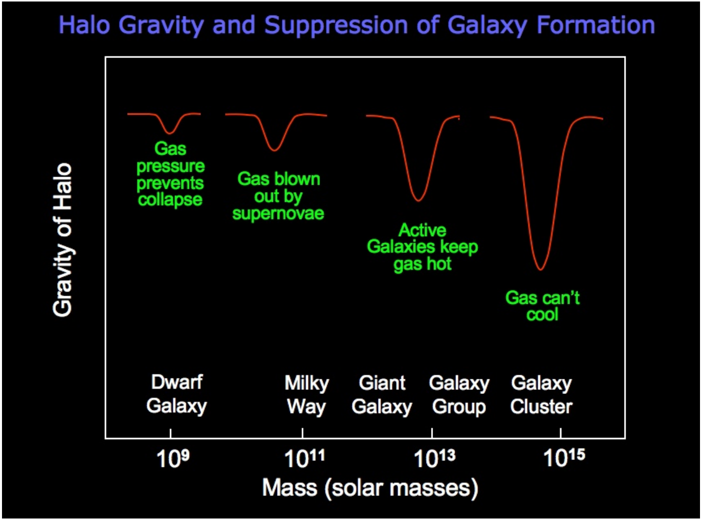
Cosmological simulations follow cold dark matter from initial slight perturbations to make many halos by hierarchical assembly. The mass distribution of these halos follows the Schechter form (Press & Schecter 1974). Hence one might expect a Schechter function for the galaxy mass distribution. Under what assumption?
The **observed** galaxy mass function has completely different upper cutoff and lower slope. Specifically, there are too many huge and dwarf halos (in simulations) without huge and dwarf galaxies (in the real universe).

Too many haloes too few galaxies

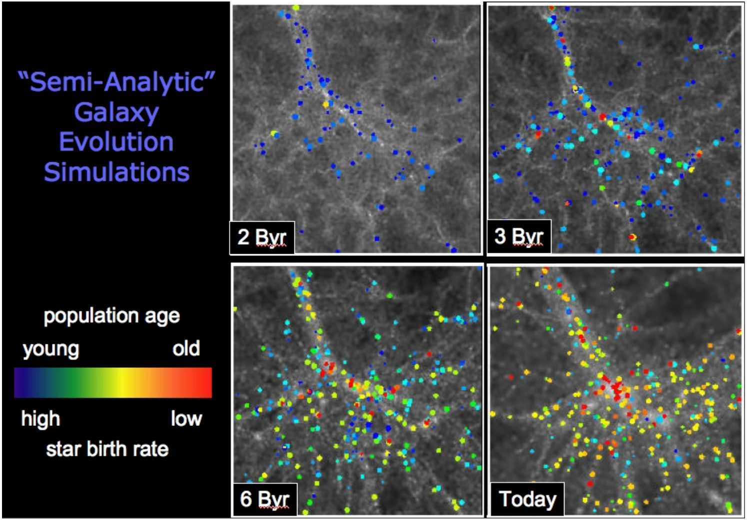


See: http://www.illustris-project.org/

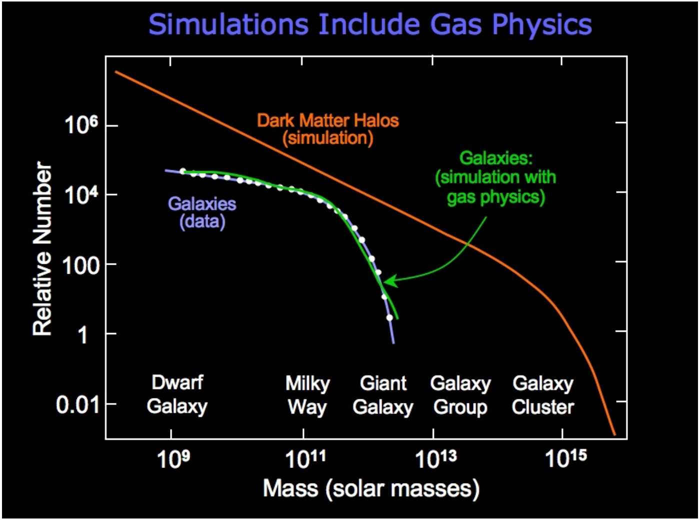
Schematic explanation of the halo galaxy mismatch



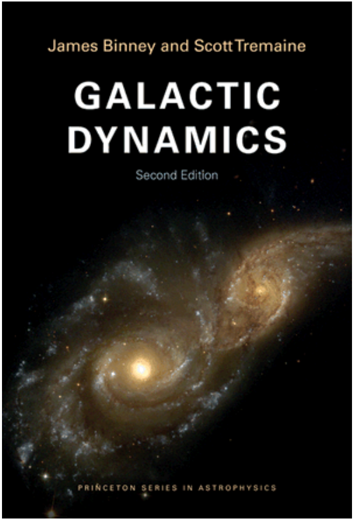
Semi analytic models



Semi analytic models reproduce the observed LF well



Binney and Tremaine - Galaxy Dynamics



Disk galaxies

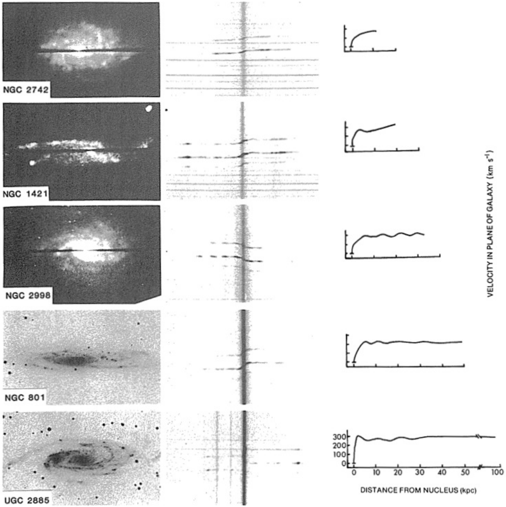
- stellar populations: old, intermediate, young and currently forming with ongoing chemical enrichment
- Wide range in stellar dynamics: “cold” rotationally supported disk stars , “hot” mainly dispersion supported bulge and halo stars. How to quantify hot and cold in dynamics?
- Significant cold ISM

Vertical disk structure - in edge on disk galaxies

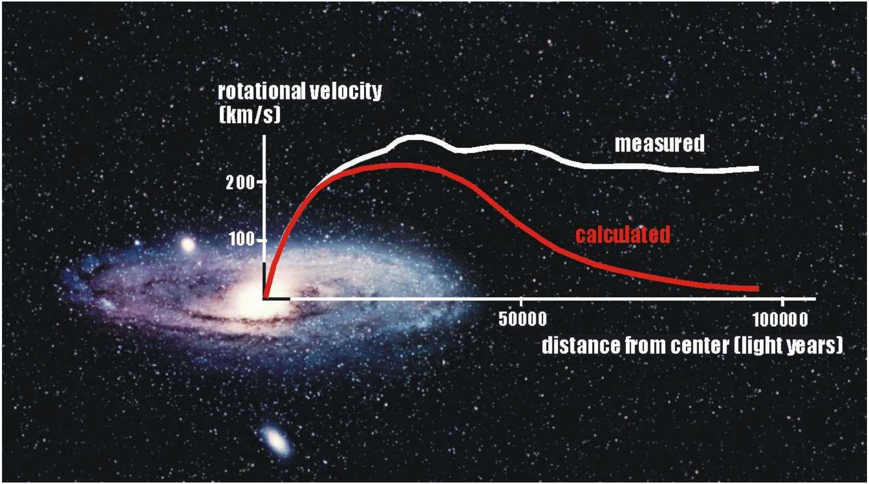
$$I(z) = I(0)e^{-|z|/z_0} \tag{1}$$

where z_0 is the scale height of the disk. In some galaxies, a thick disk with larger scale height is also seen. How should the vertical variation be modeled in such galaxies?

Spiral rotation curves



Why dark matter must be present?



3 major modes of optical spectrocopy

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- 3D spectroscopy - “2D” lenslets/bundled fibres input is dispersed producing a 3D spectrum (data cube)