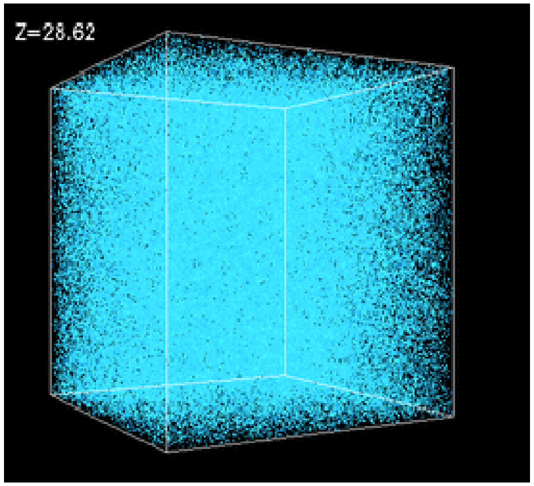
Galaxies as a Population I

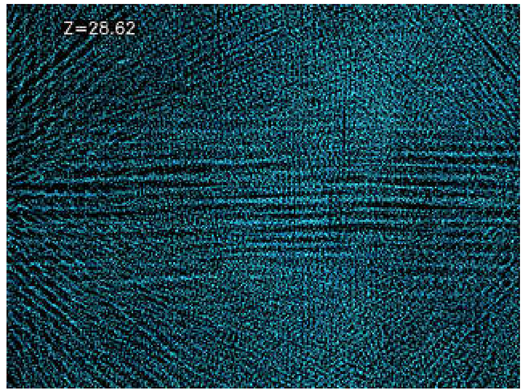
ASTR 503/703

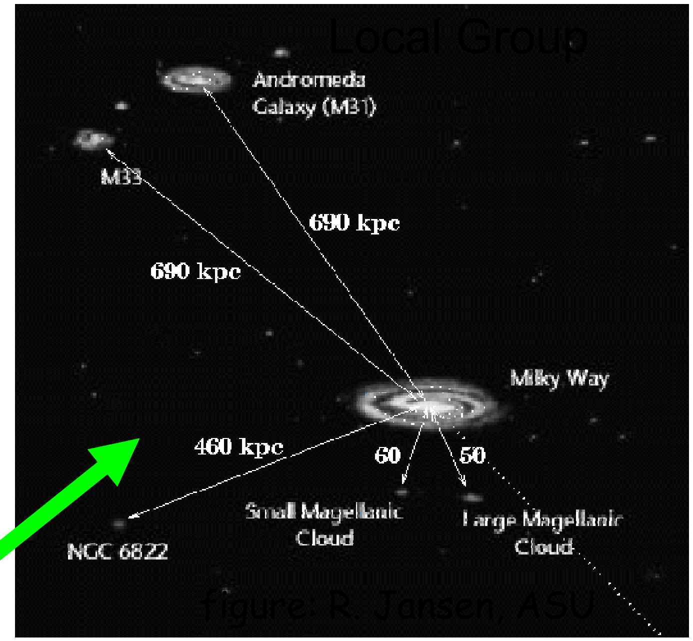
Hierarchical Galaxy Formation

dark matter halos merge & grow

http://cosmicweb.uchicago.edu/



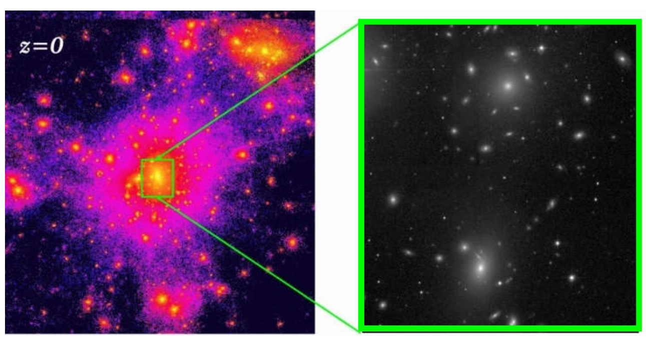




Credit: R. Jansen

galaxies form inside

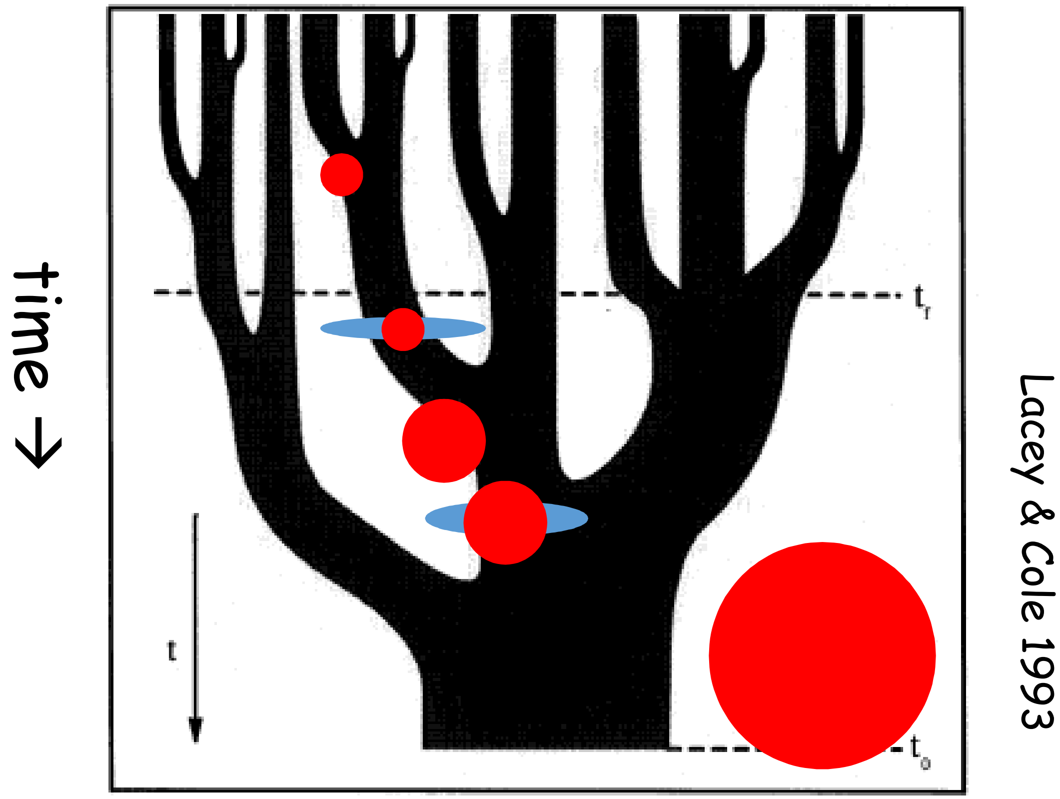
Moore www.nbody.net



high-resolution physics:

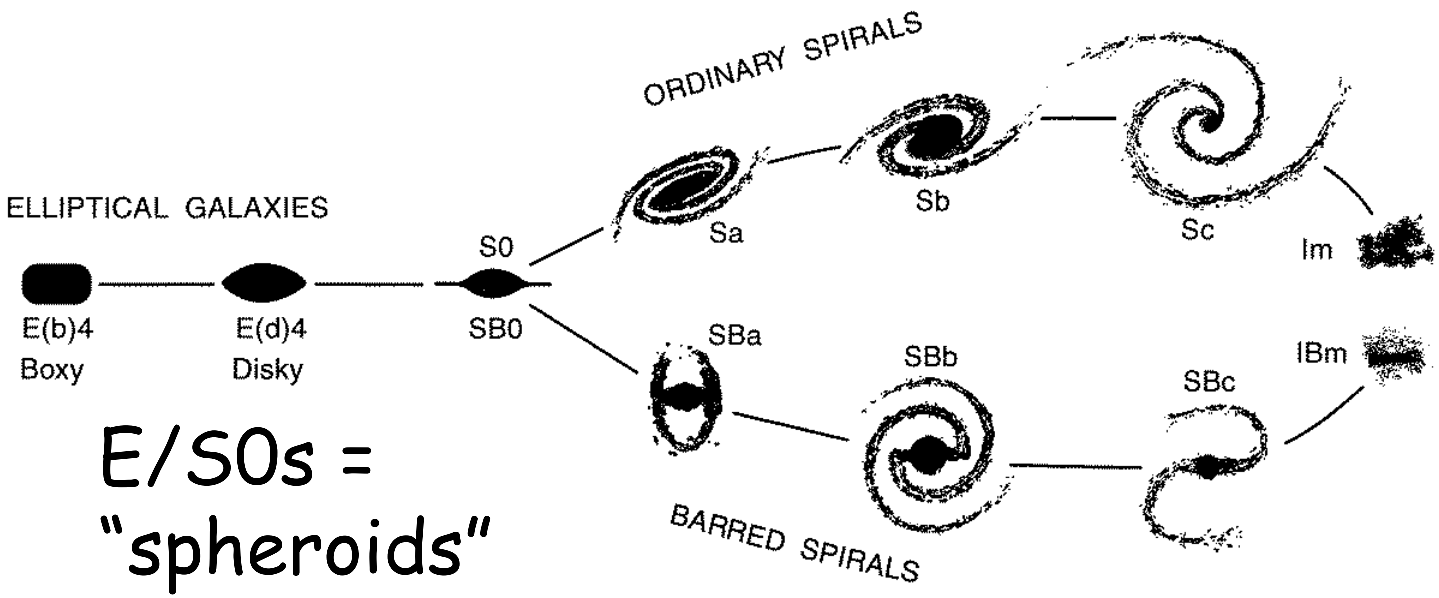
- galaxy-galaxy interactions
- gas inflow & star formation
- energy feedback (supernovae, AGN)

Alternating spheroid & disk growth



"merger tree"

Evolution in the Hubble Sequence



E/S0s =
"spheroids"

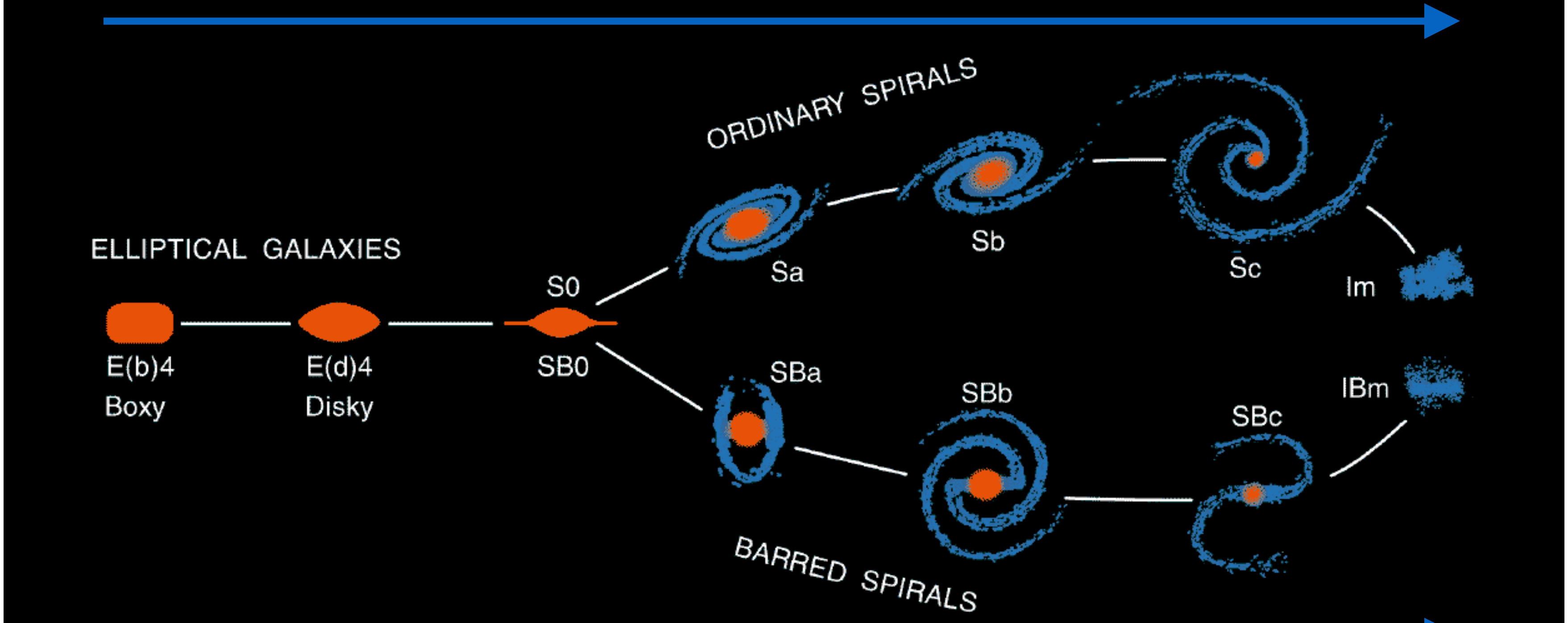
figure: Kormendy & Bender 1996

gas infall and disk growth

gas-depleting mergers & interactions

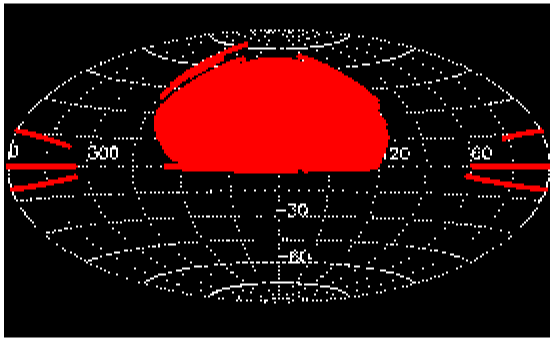
Properties in the Hubble Sequence

By “definition”: less spheroid, more (thin) disk, more rotation

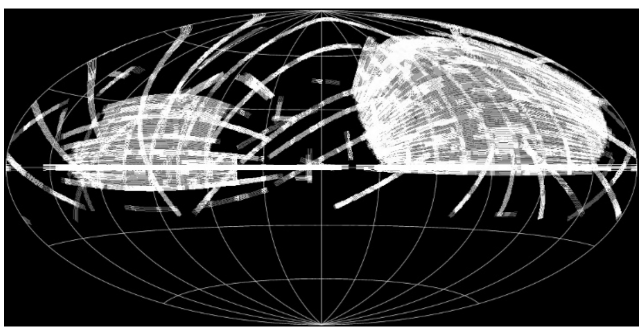


By association: more cold gas & young stars, bluer

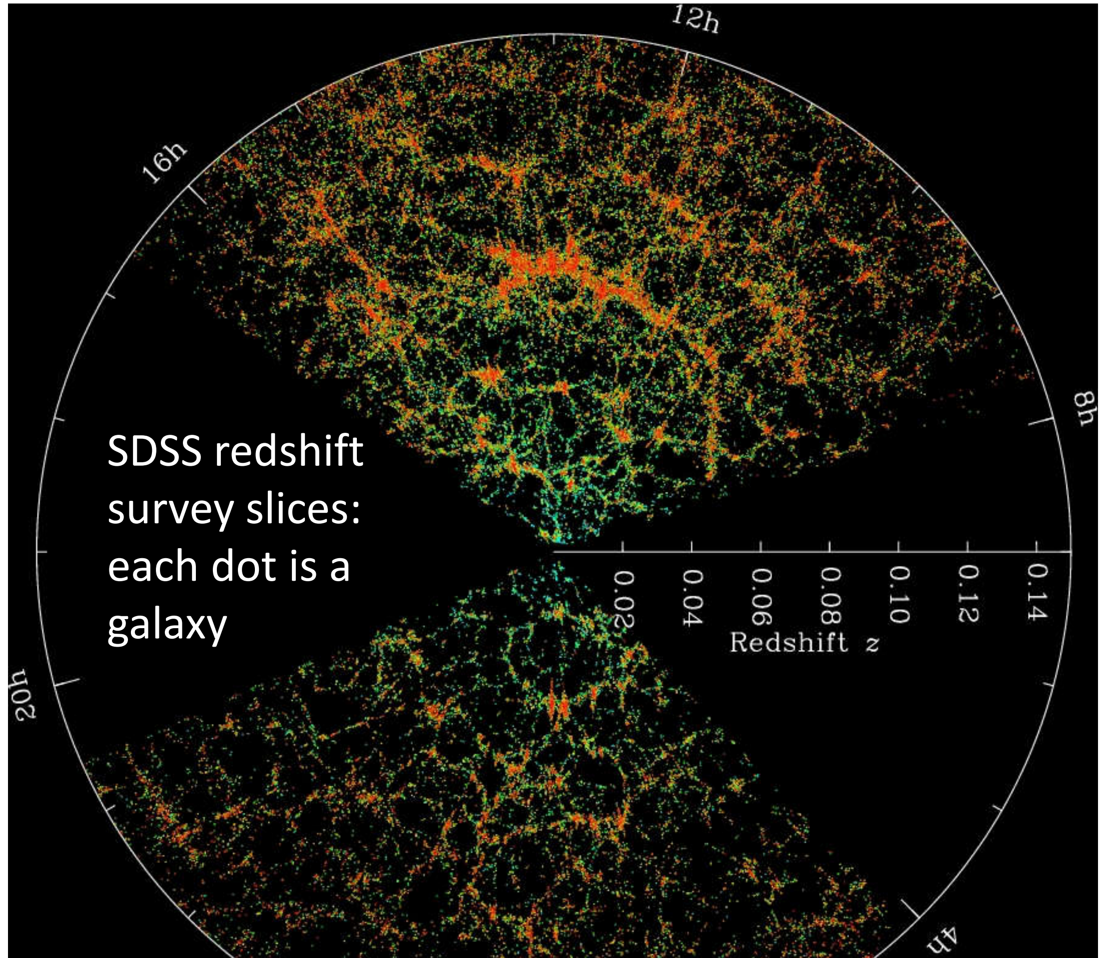
Sloan Digital Sky Survey (SDSS)



Original ("Legacy")
Survey Sky Footprint



Expanded Imaging
Survey Sky Footprint



Large-Scale Structure (LSS):
voids, filaments, walls, groups/clusters

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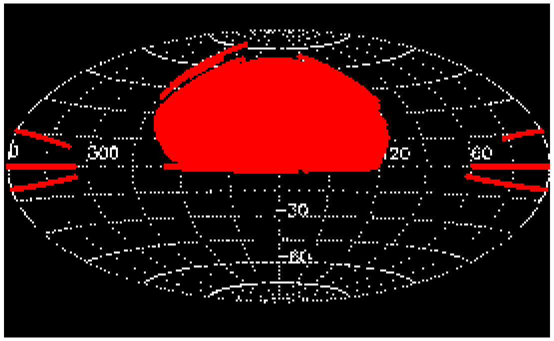

http://www.sdss.org/

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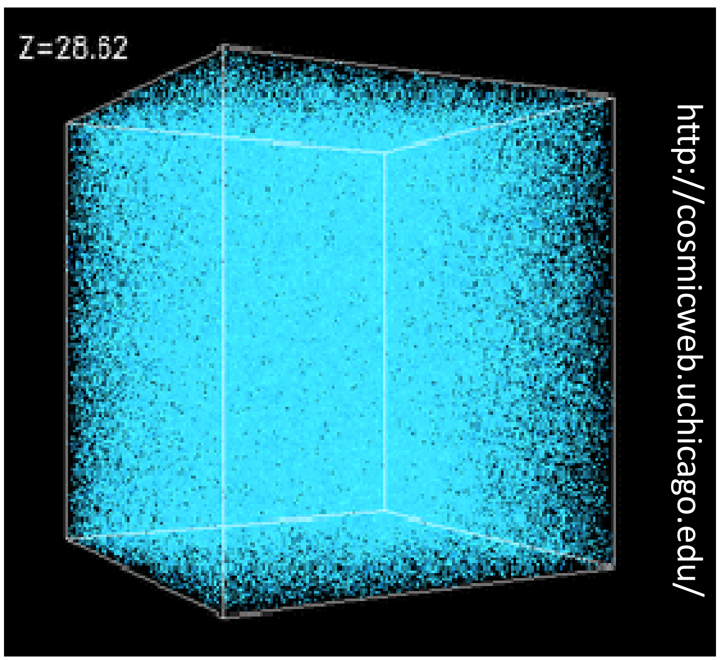

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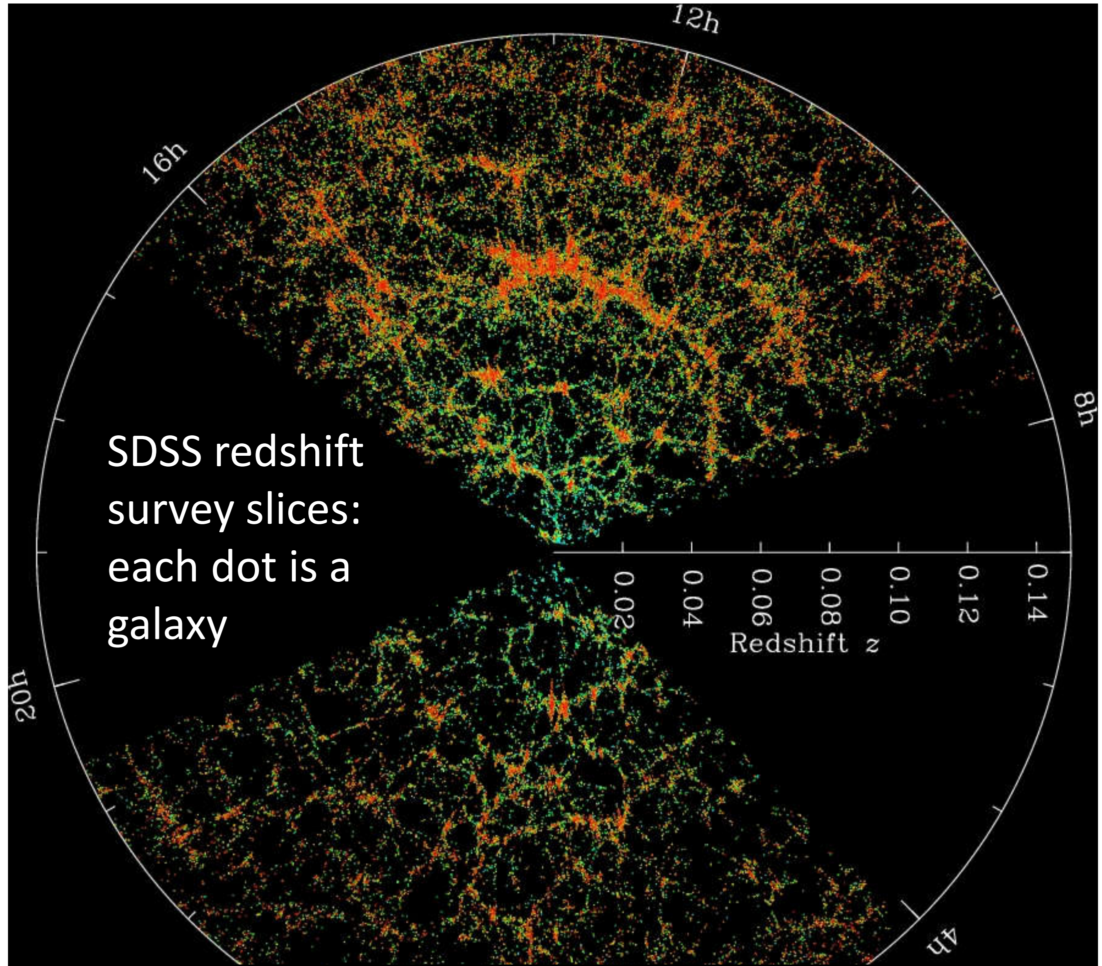

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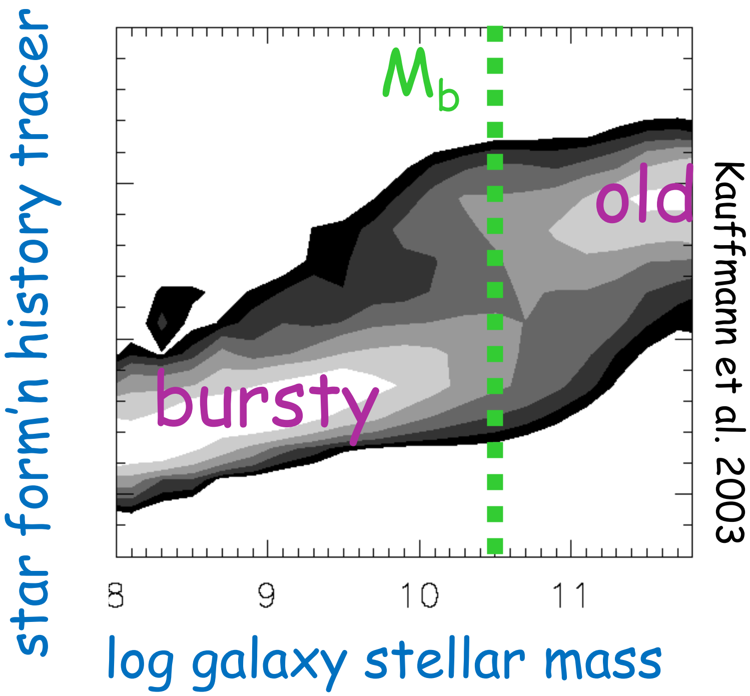
Survey science → discovery of "bimodality mass"



Rediscovery of dwarf and giant galaxies? Or something new?

→ bimodality, not smooth shift

→ reframed in terms of fundamental quantities – mass not light – connect with theory ($M_b=10^{10.5}M_\odot$)

→ mainstream use of advanced statistics, Bayesian modeling

The dependence of star formation history and internal structure on stellar mass for 10^5 low-redshift galaxies

Guinevere Kauffmann,[1★] Timothy M. Heckman,[2] Simon D. M. White,[1] Stéphane Charlot,[1,3] Christy Tremonti,[2] Eric W. Peng,[2] Mark Seibert,[2] Jon Brinkmann,[4] Robert C. Nichol,[5] Mark SubbaRao[6] and Don York[6]

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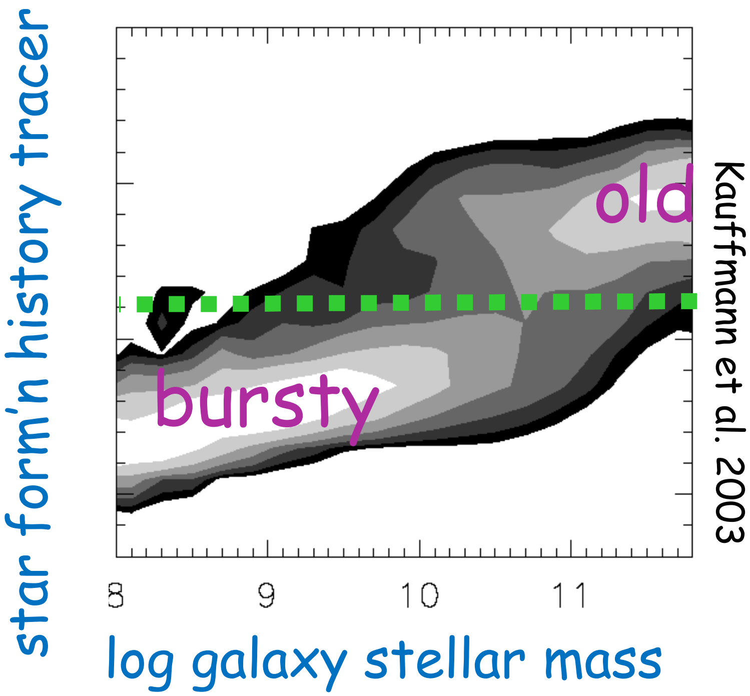

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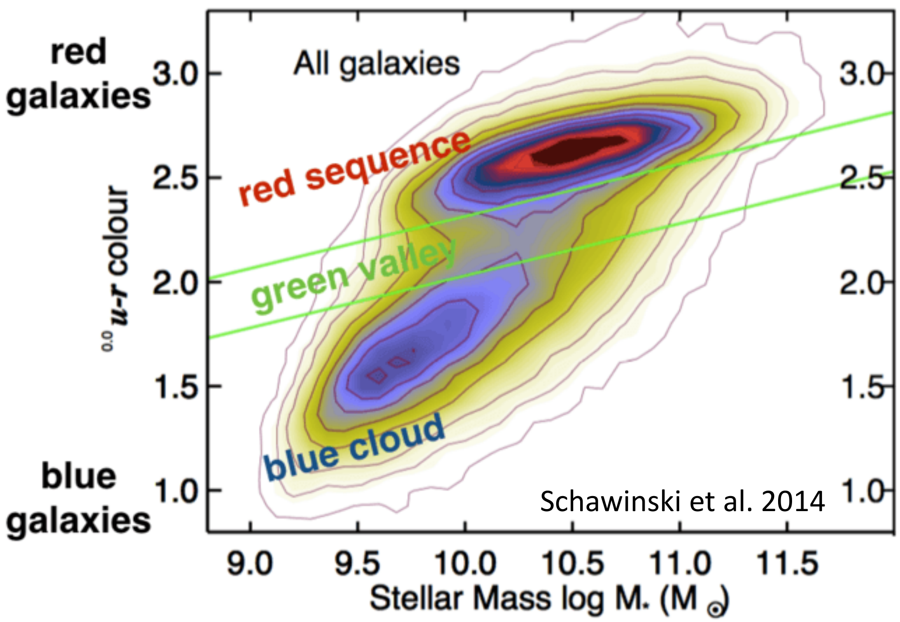

- conditional probability distribution hides inverse square law bias (SDSS is flux-limited a.k.a. magnitude-limited)

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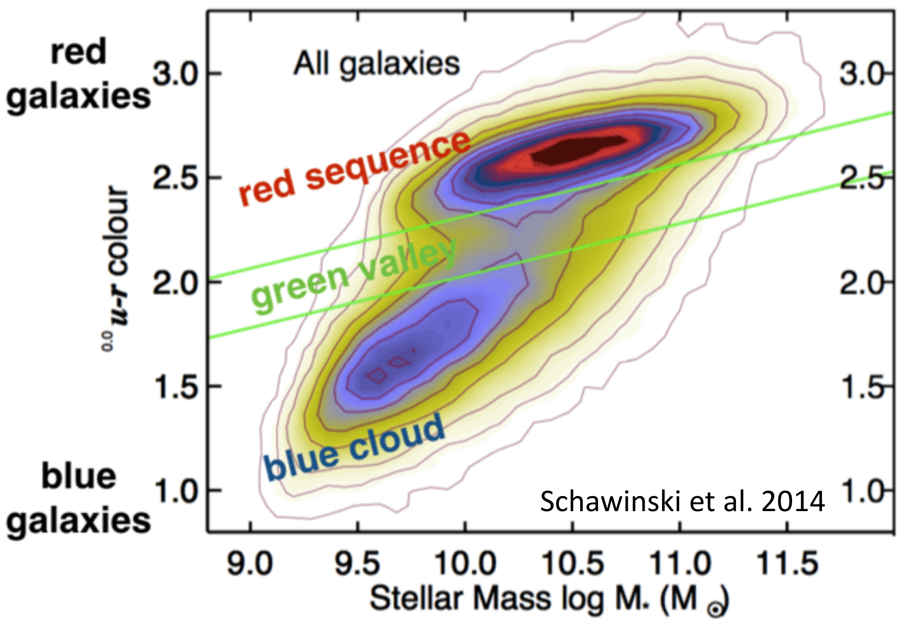

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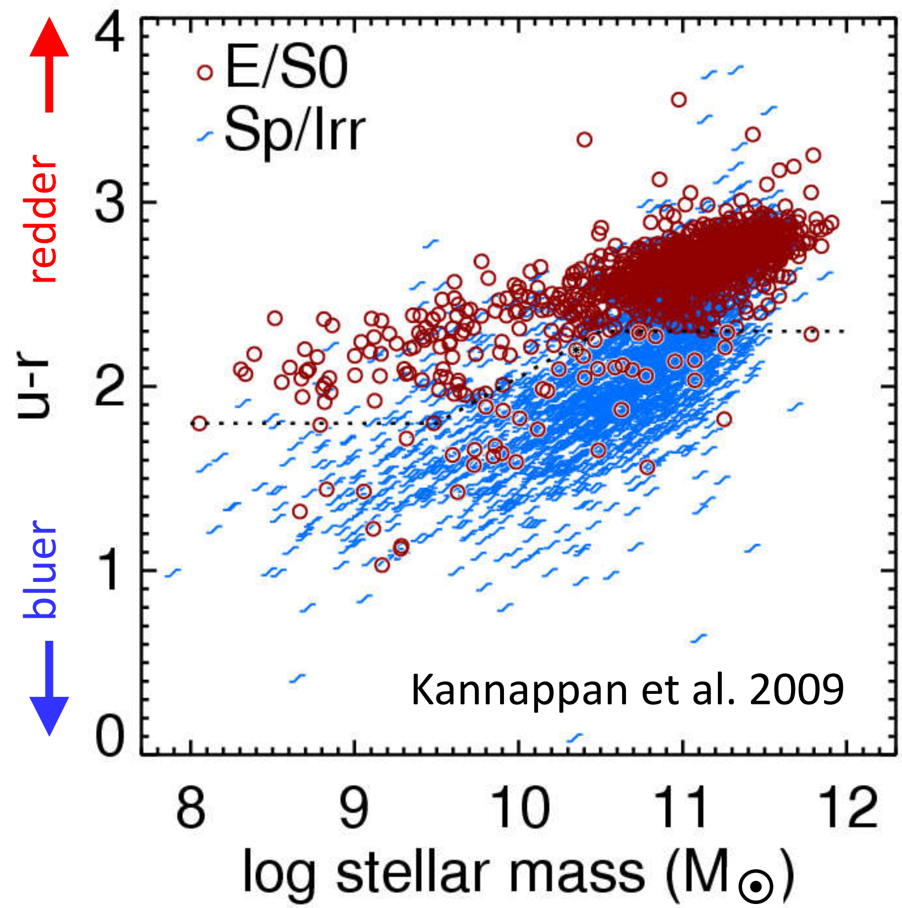

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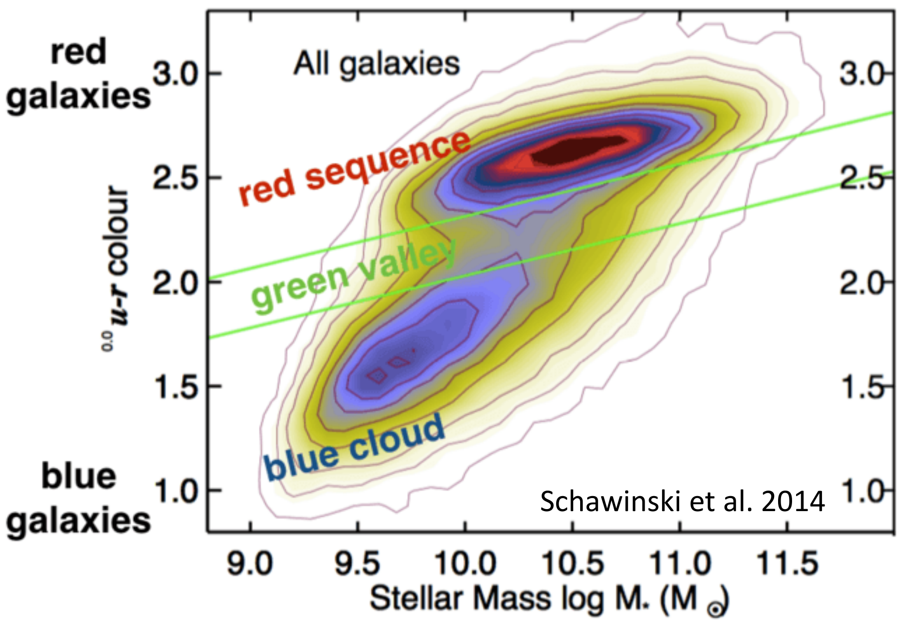
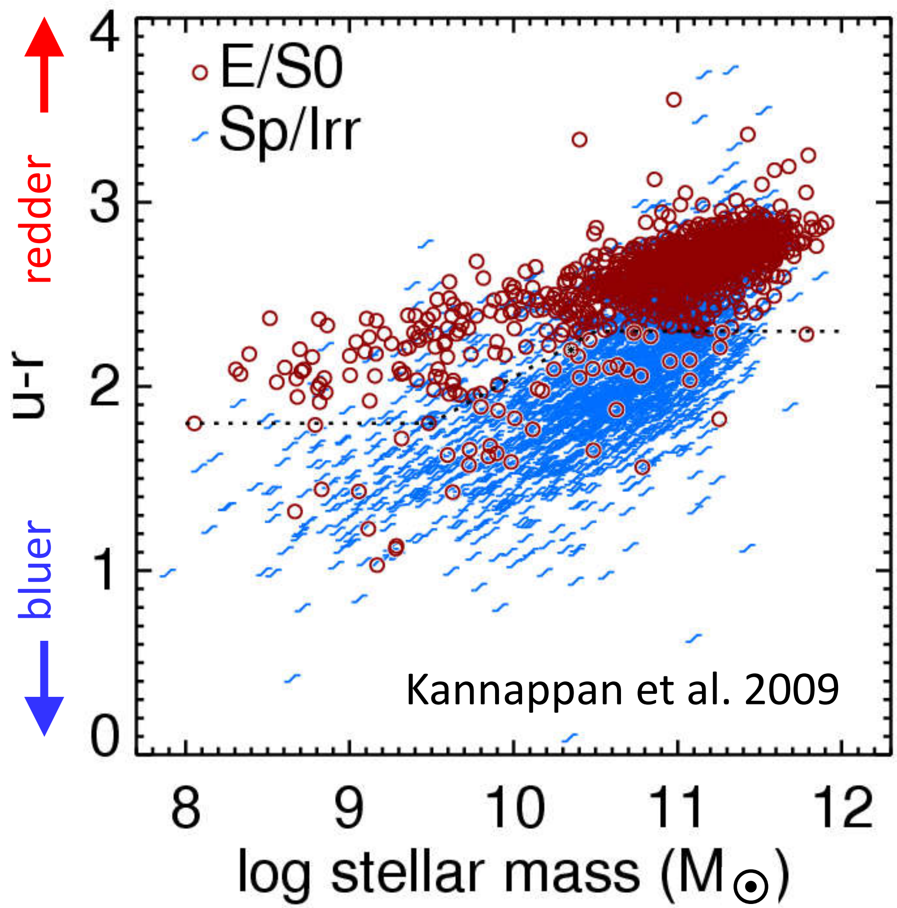


blue seq. = growing, disky
red seq. = 'red & dead' spheroids



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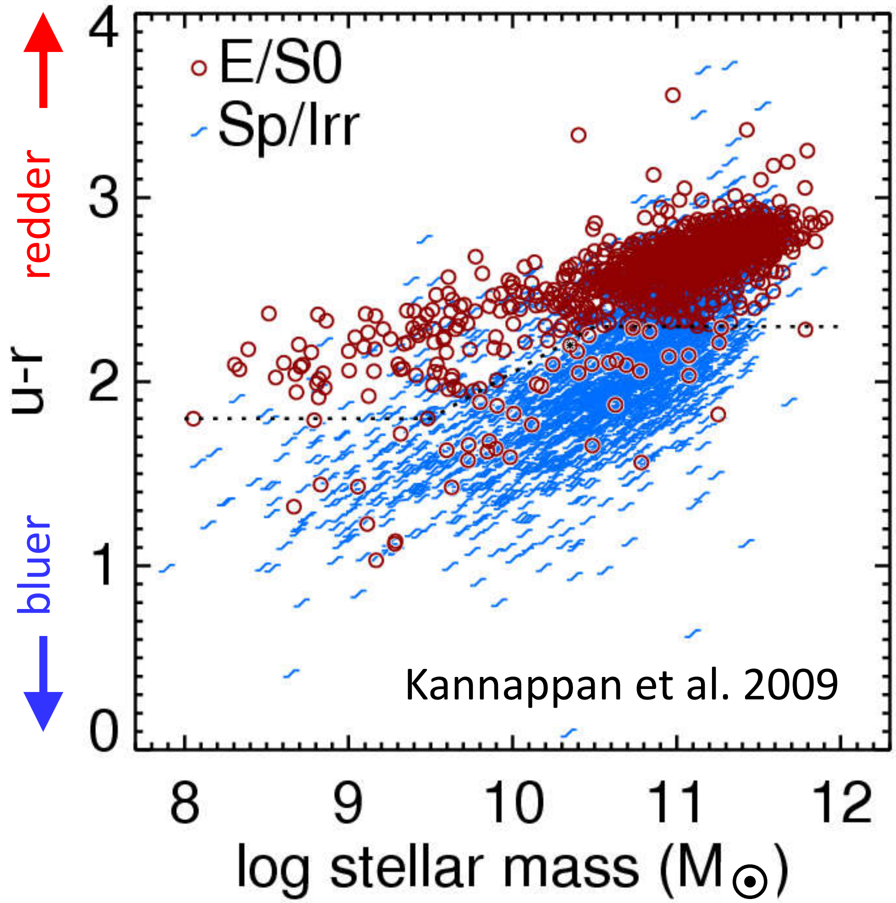
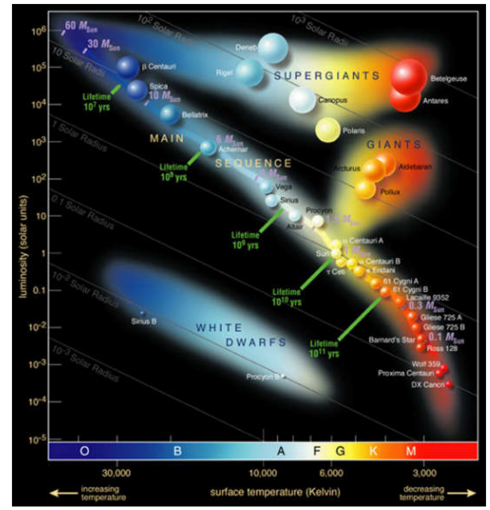


why u-r?

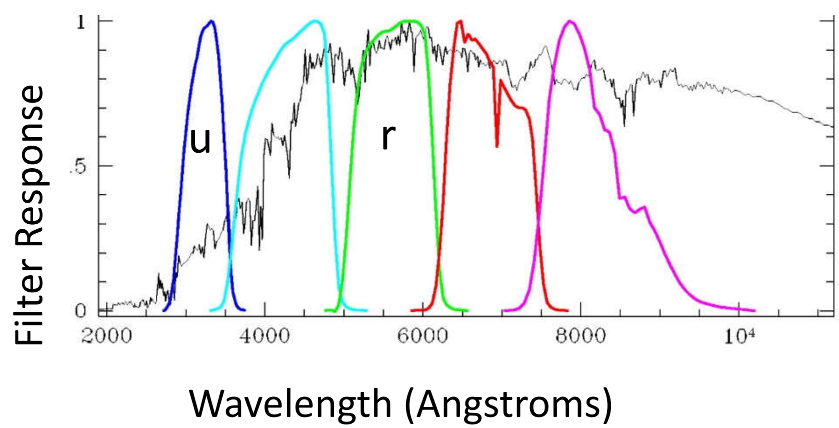
traces stellar population age (and secondarily metallicity)

HR diagram of stellar population



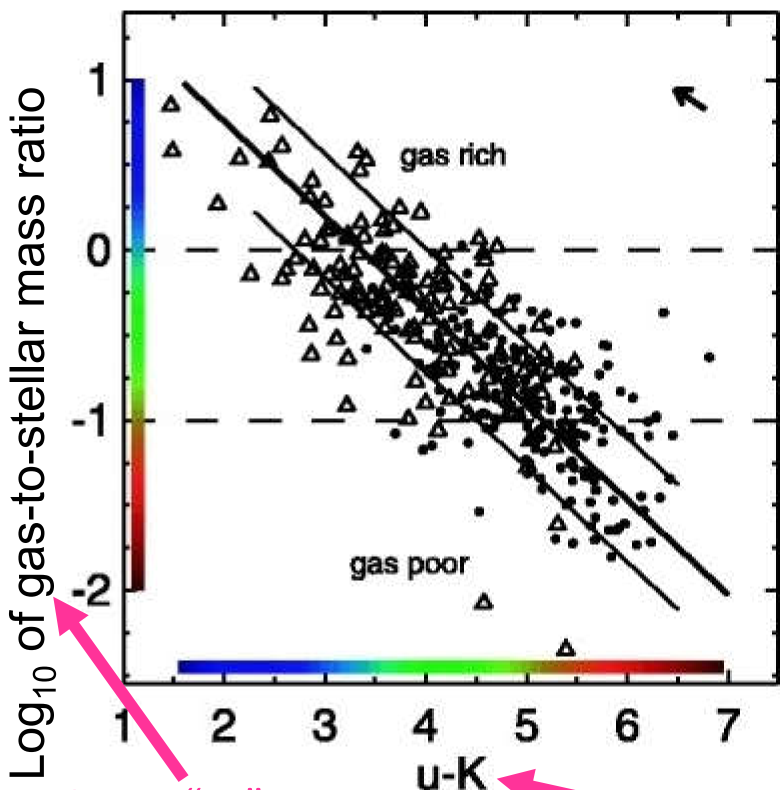
Credit: ESO

Middle-aged galaxy with "4000 Angstrom break"



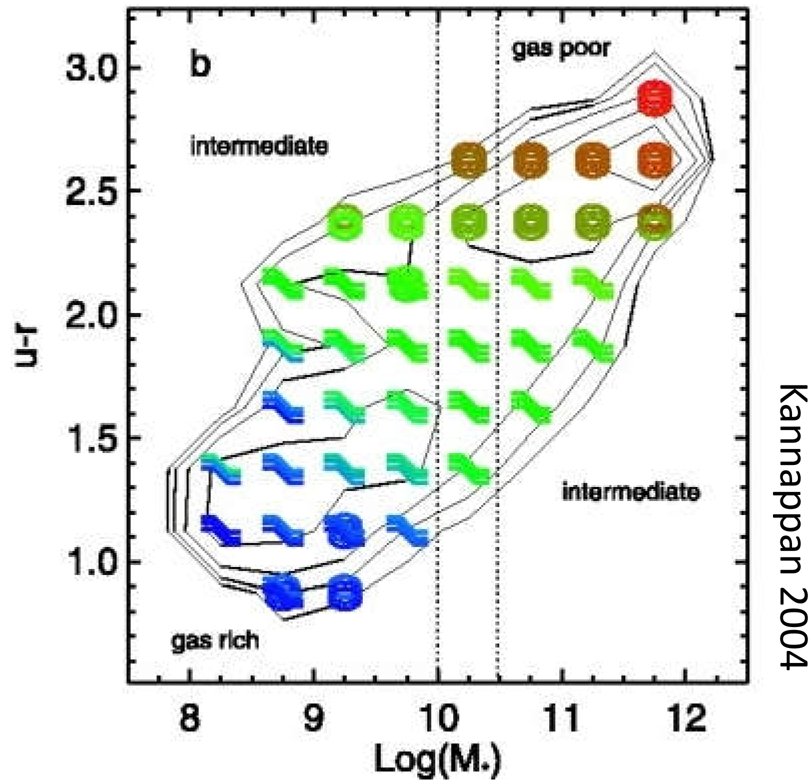
Blanton et al. 2003

How does gas fit into this picture?



21cm "HI" gas masses from homogenized literature data (346 galaxies)

near-infrared from all-sky 2MASS Survey

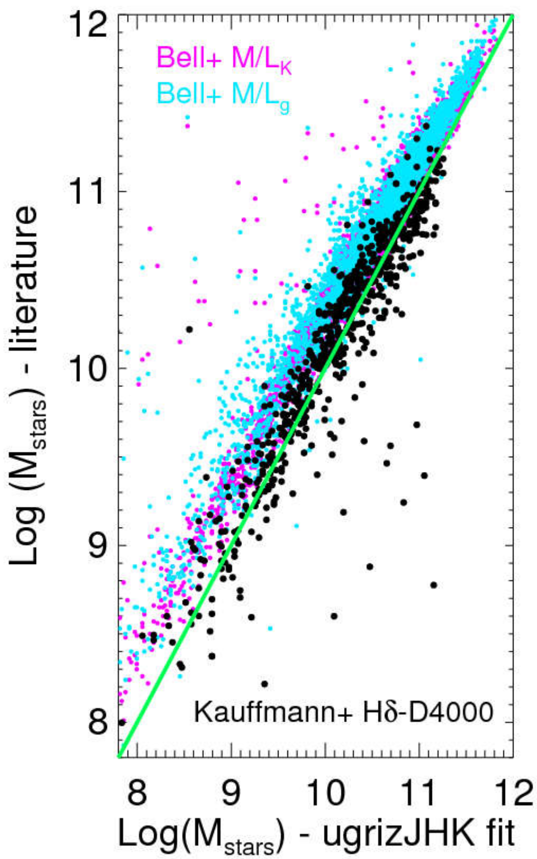


gas content for 35,000 cross-matched SDSS-2MASS galaxies using color-based "shortcut" for stellar masses

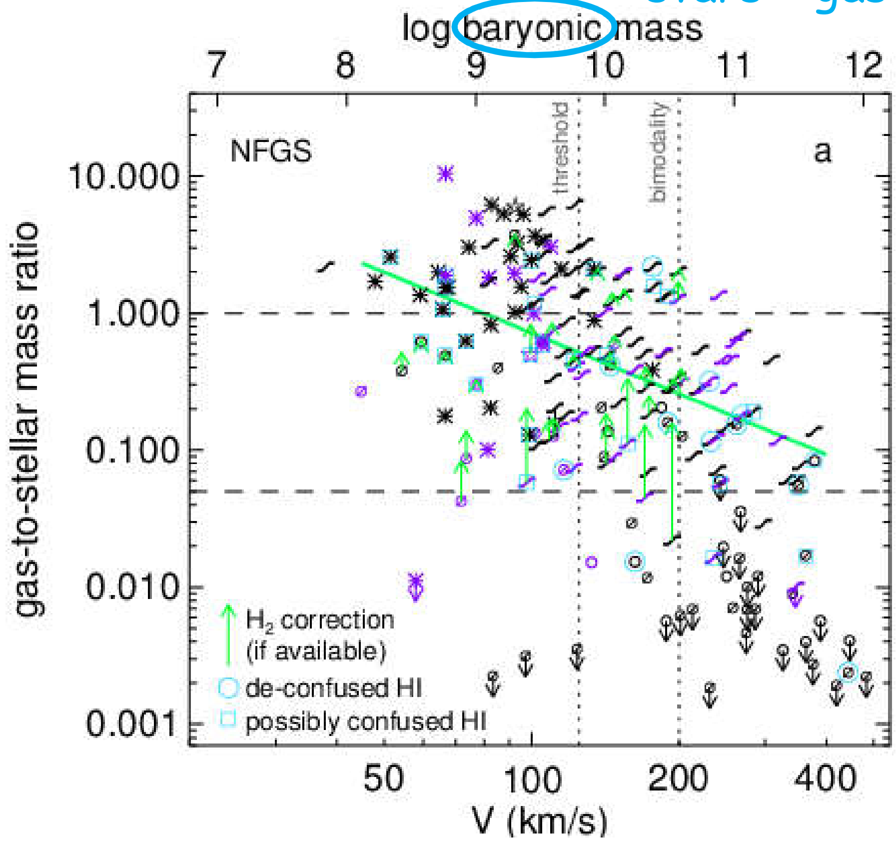
Hindsight: the gas-richness threshold mass is not the bimodality mass

Problem:

color-based masses were systematically higher than Kauffmann masses (Kannappan & Gawiser 07)



= stars + gas



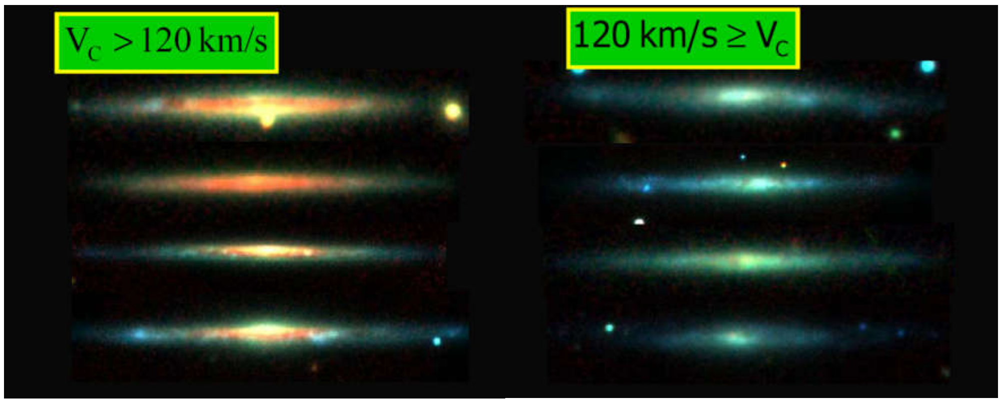
Kannappan+ 2013

Nearby Field Galaxy Survey (200 galaxies)

Lesson for posterity: Huge data sets do not mitigate systematic errors. They just multiply them – many, many times over.

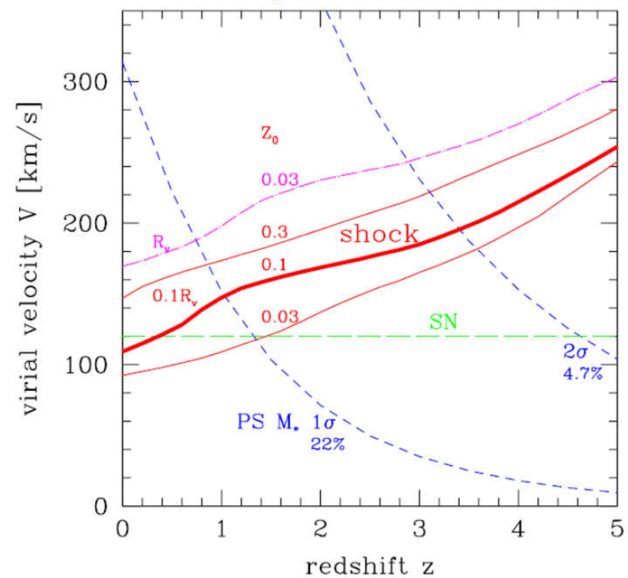
Threshold mass = known interstellar medium (ISM) transition scale

dust lanes



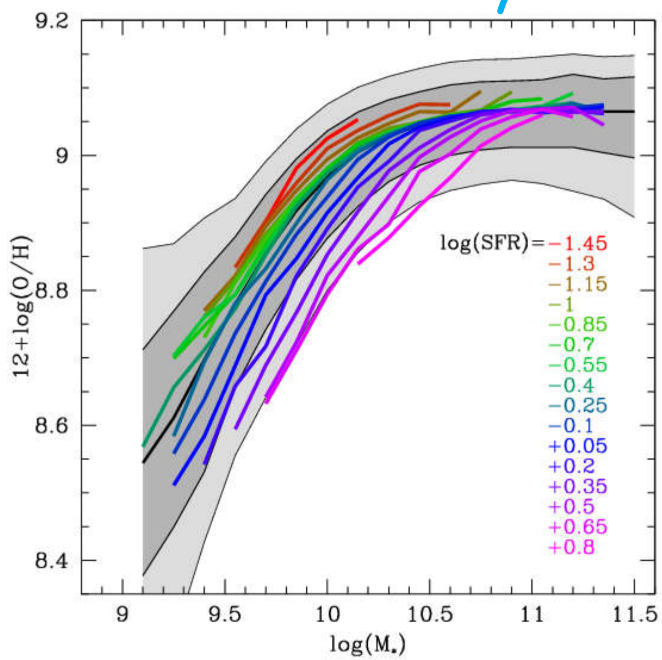
Dalcanton et al. (2004)

Link to theory of "cold-mode" gas accretion



Dekel & Birnboim (2005)

mass-metallicity relation



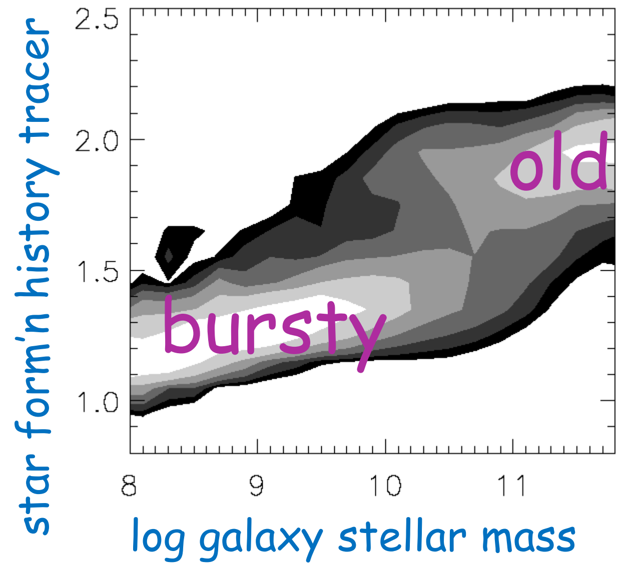
Mannucci et al. (2011) update to "fundamental metallicity relation" including Star Formation Rate (SFR)

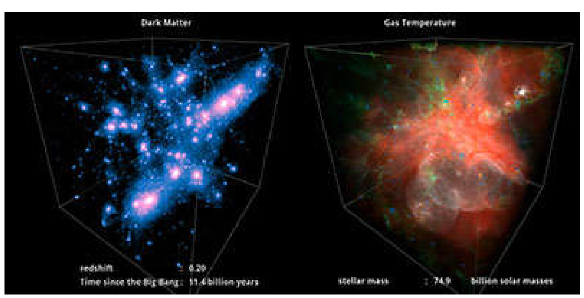
<u>*open box*</u> merger simulation

L. Mayer & the N-Body Shop

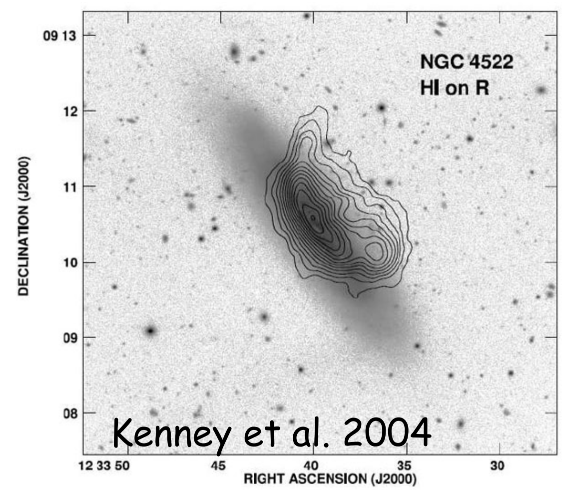
The hierarchical galaxy formation (non)paradox: why massive things are old

1) Peak initial overdensities in dark matter coalesce first
2) Even where largest halos are still coalescing today (galaxy clusters), the <u>*stars*</u> are already old → structure age ≠ stellar population age
3) Gas shock-heats in massive halos ➔ slows accretion, plus hot halo gas strips galaxy gas



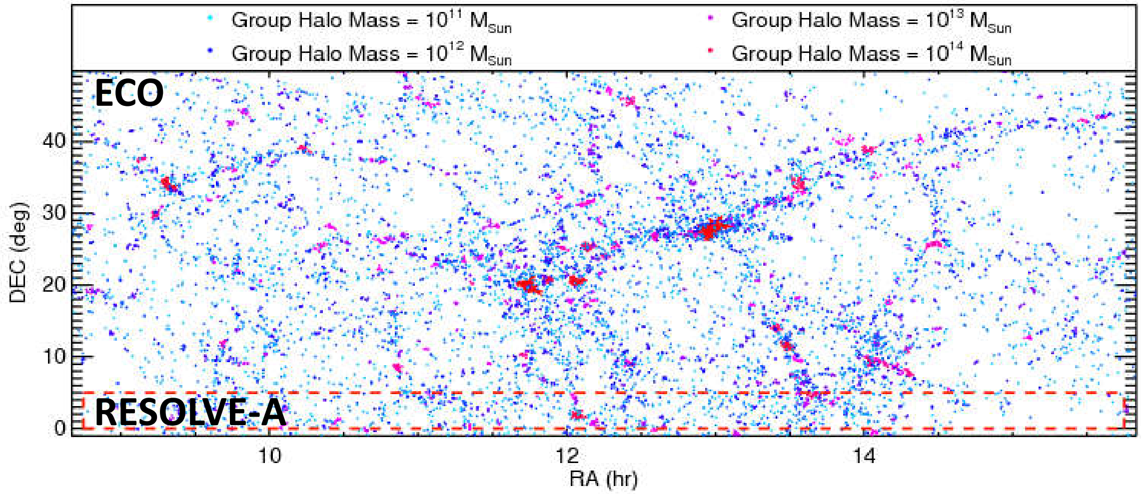


Credit: Illustris Collaboration



Motivation for RESOLVE & ECO

http://resolve.astro.unc.edu
= your data sets for this class
(real research in progress!)



In brief:

two volume-limited, unusually complete "census" surveys of stars, gas, and dark matter, plus star formation & merging, from dwarf galaxy to group & cluster scales

Key advantages of both RESOLVE and ECO:

- baryonic mass limit ~10^9 $M_{\odot}$, well below threshold scale
- volume-limited for robust & diverse environment data
- more complete than parent SDSS
- superior photometry (color gradients, star formation histories)

Additional benefits of RESOLVE:

- fractional-mass limited gas masses (<10% stellar mass)
- 3D spectroscopy for internal dynamics & star formation
- superior depth and archival data in equatorial strips

Complementary benefit of ECO:

- >10x larger volume with more extreme environments