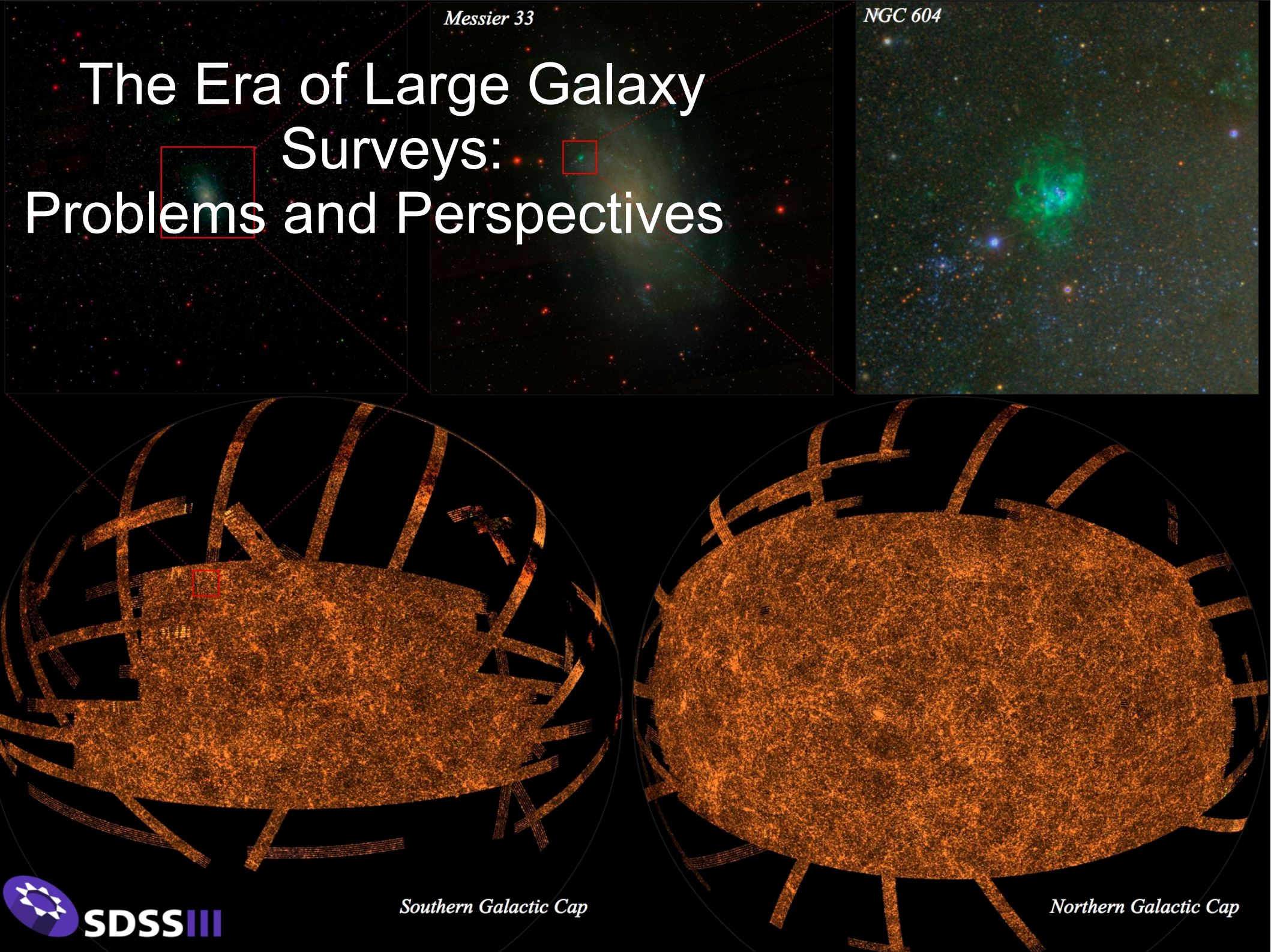
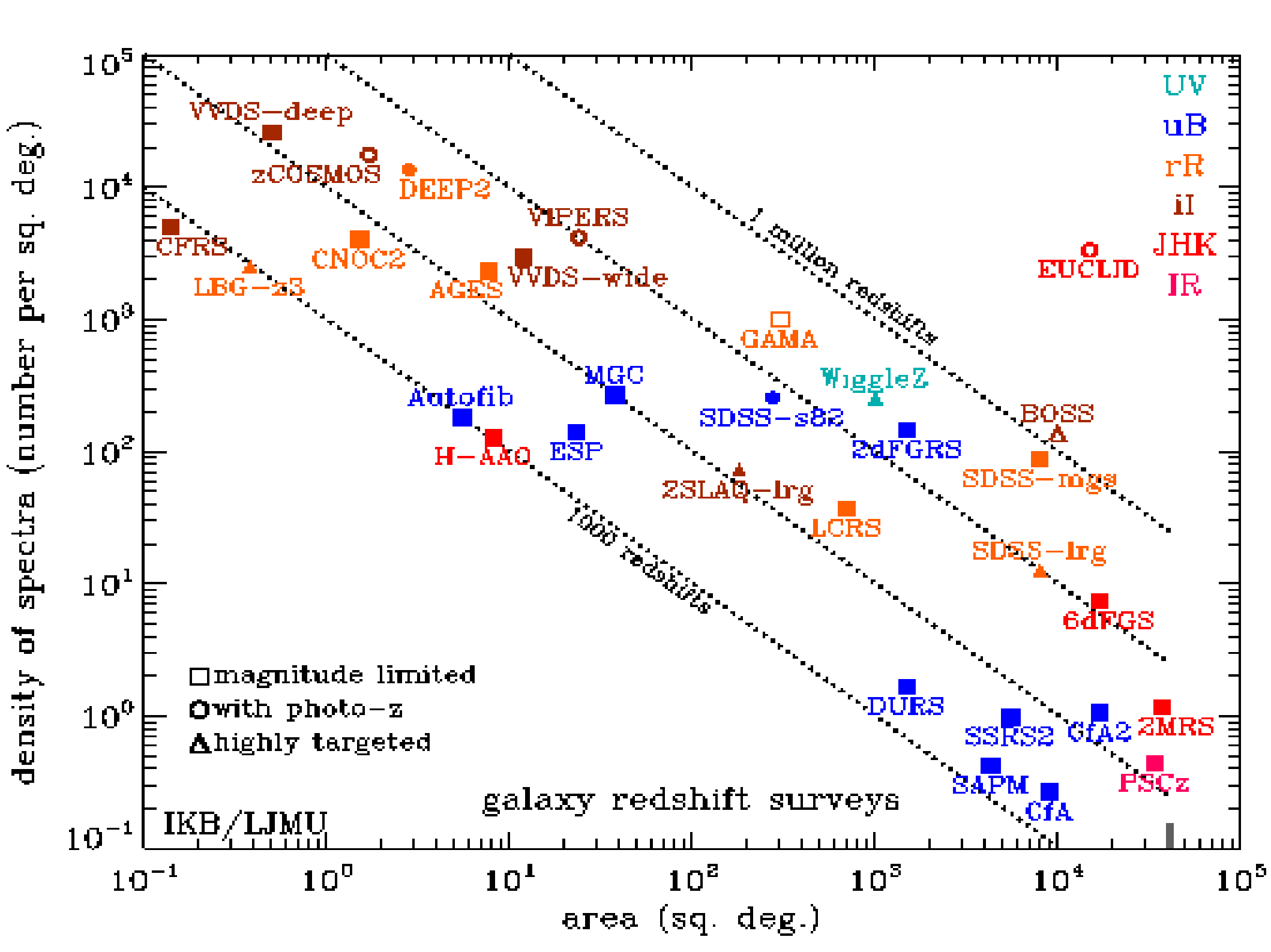
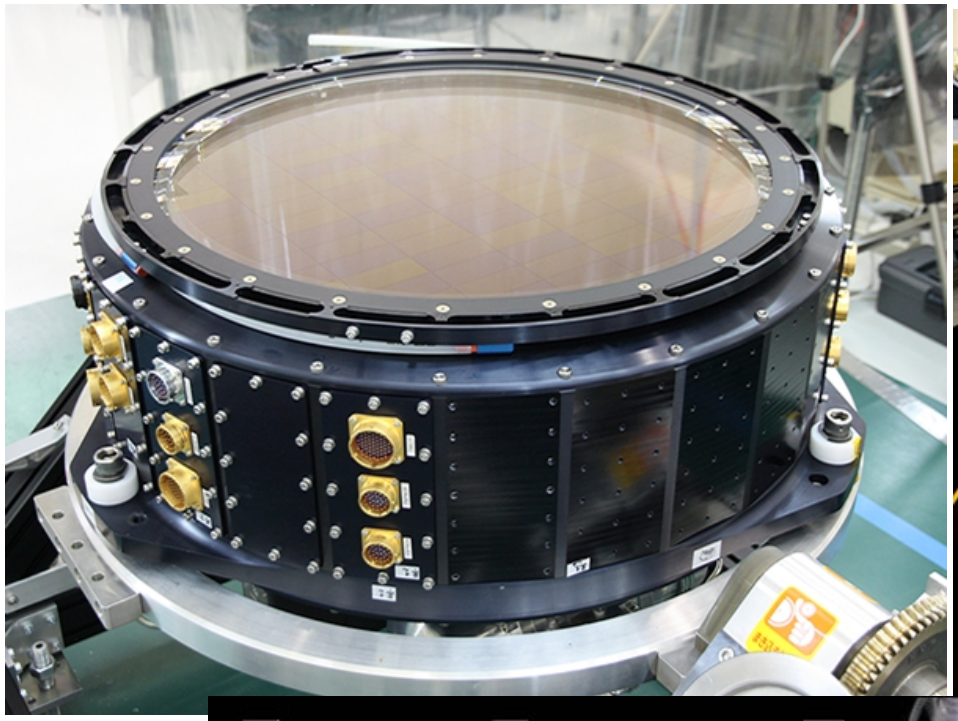
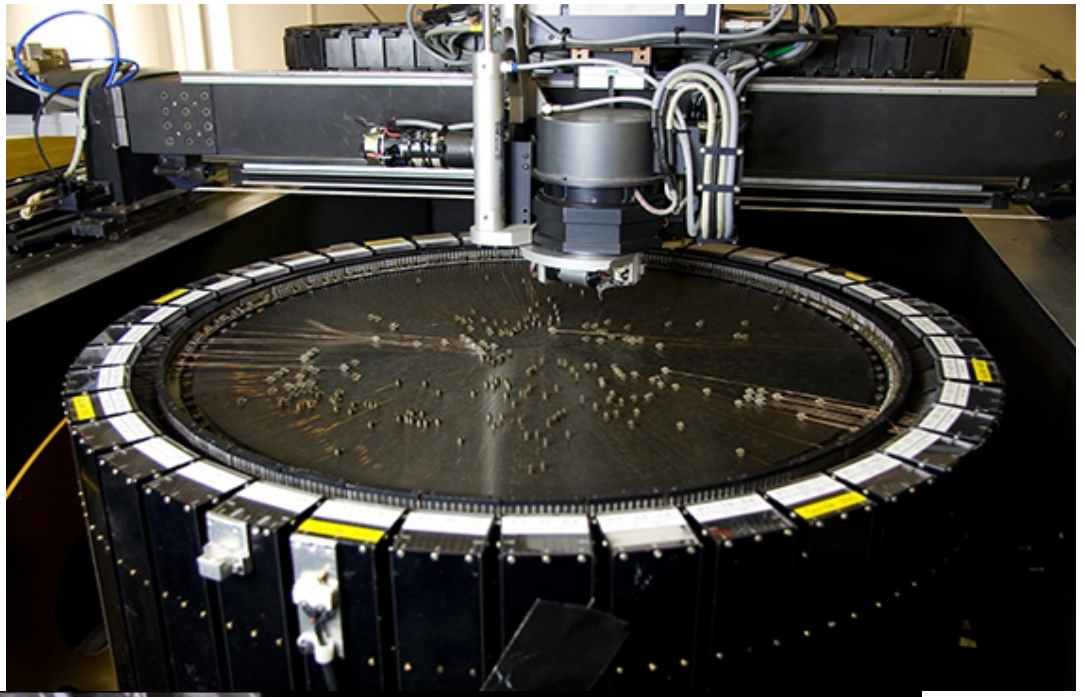
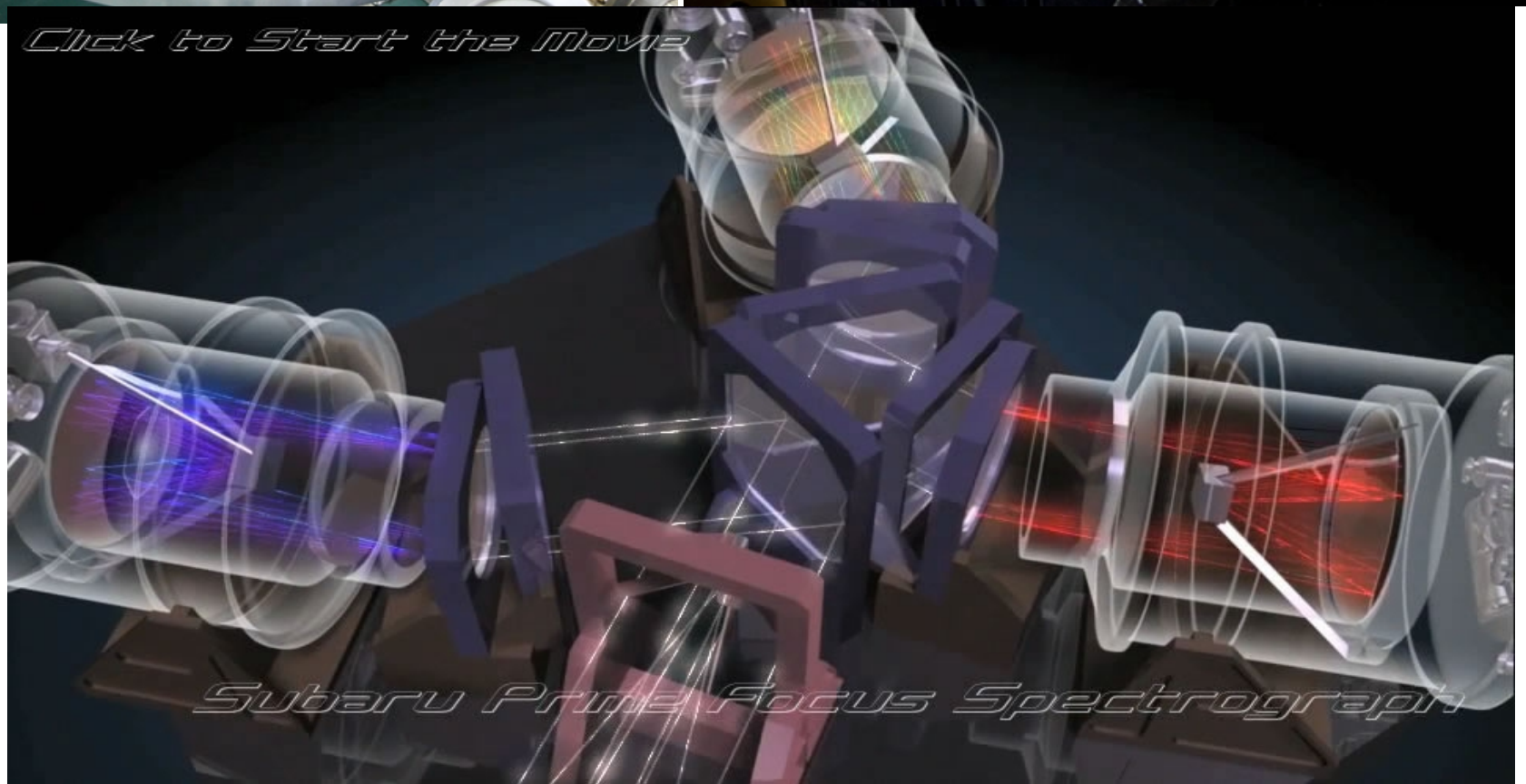
The Era of Large Galaxy Surveys: Problems and Perspectives

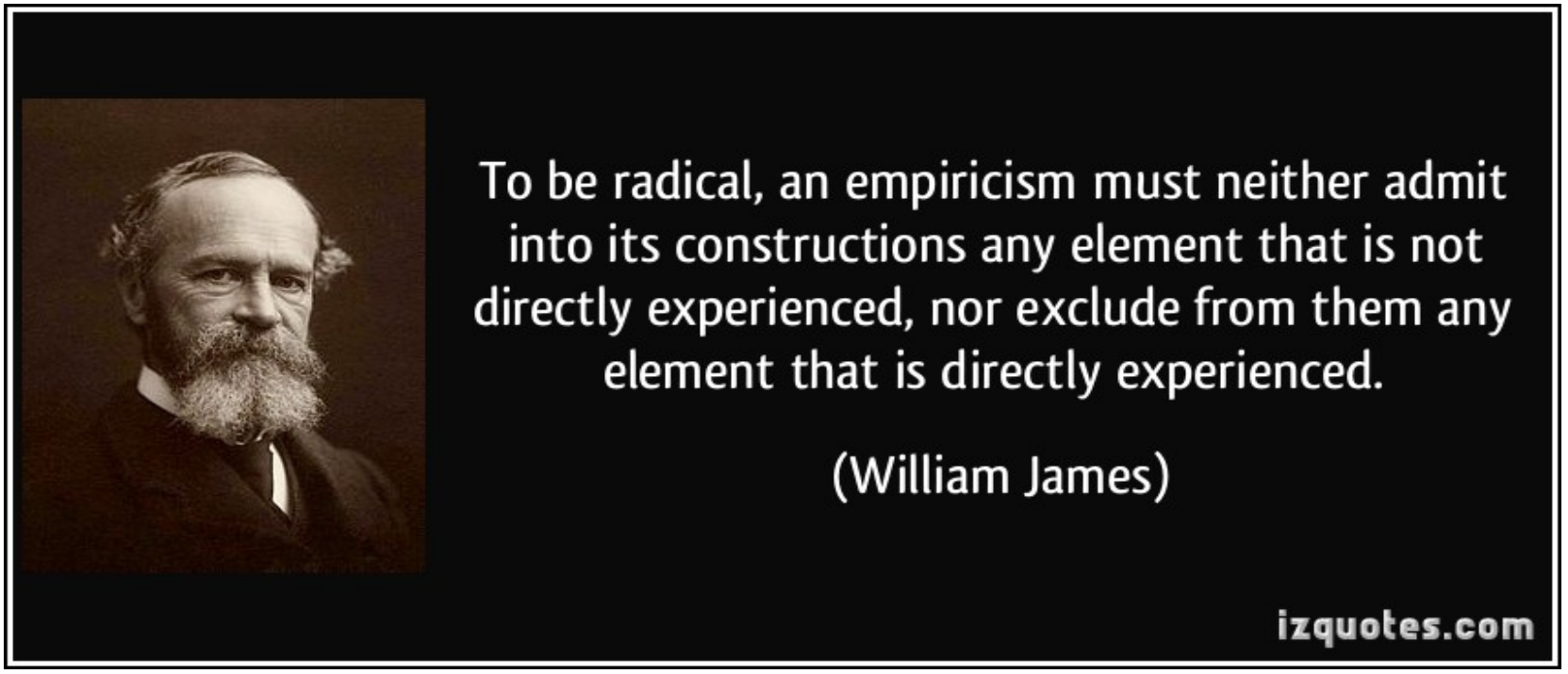



density of spectra (number per sq. deg.)
area (sq. deg.)
galaxy redshift surveys
IKB/LJMU
magnitude limited
with photo-z
highly targeted
1 million redshifts
1000 redshifts
UV
uB
rR
iI
JHK
IR
VVDS-deep
zCOSMOS
DEEP2
VIPERS
CFRS
CNOC2
LBG-z3
AGES
VVDS-wide
EUCLID
GAMA
MGC
WiggleZ
Autofib
SDSS-s82
BOSS
H-ANO
ESP
2dFGRS
SDSS-mgs
2SLAQ-lrg
LCRS
SDSS-lrg
6dFGS
DURS
SSRS2
CfA2
2MRS
SAPM
PSCz
CfA






Click to Start the Movie
Subaru Prime Focus Spectrograph



The postulate is a basic statement of the empiricist method: our theories shouldn't incorporate supernatural or trans-empirical entities. Empiricism is a theory of knowledge that emphasizes the role of experience, especially sensory perception (observations), in the formation of ideas, while discounting a priori reasoning, intuition, or revelation.

+ Dark Matter + Black Holes!

Synthetic Forward Modelling

Acknowledge complexity and linkages. Galaxy formation is an iterative dialogue between theory and observations.

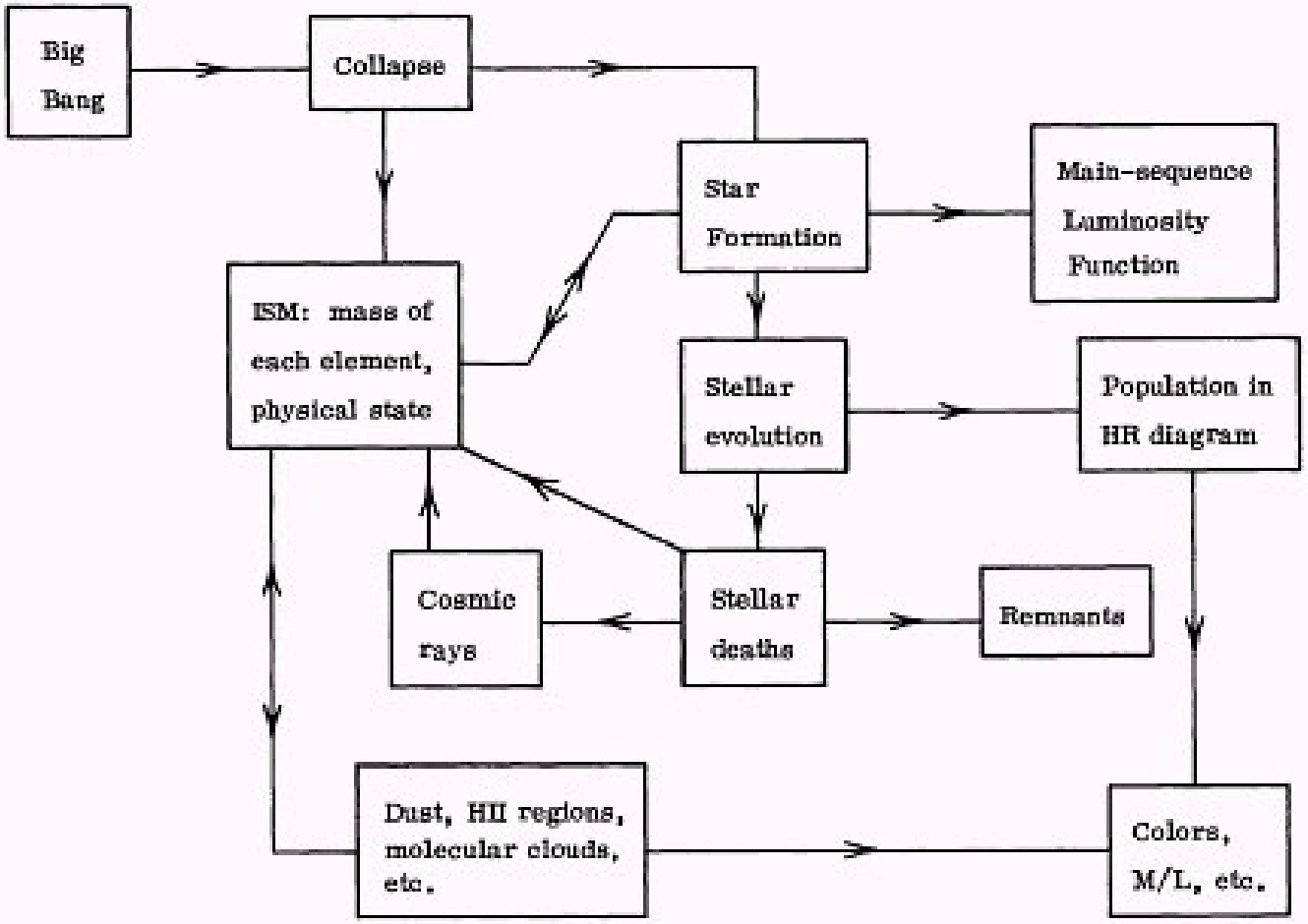
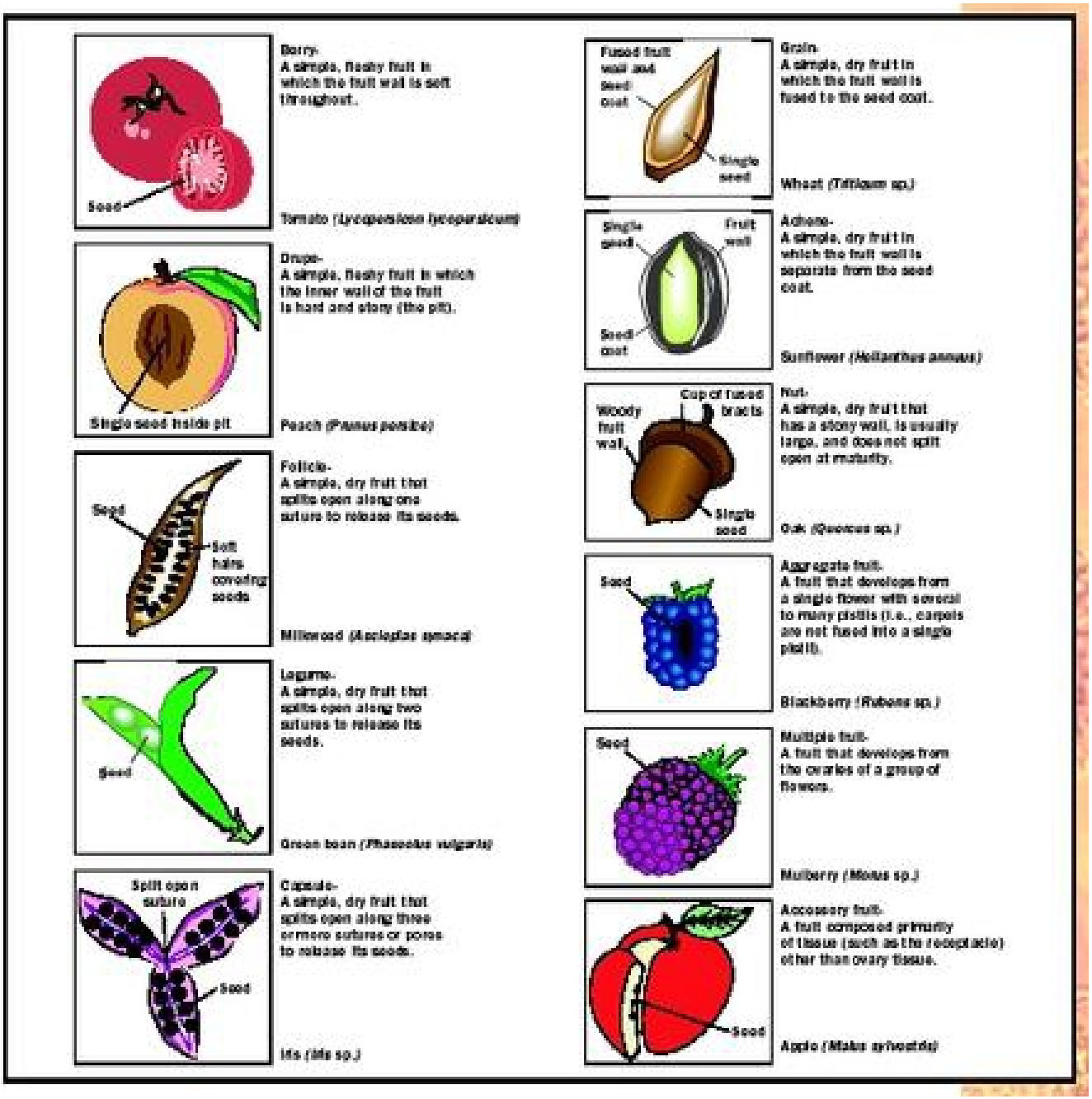


Figure 4 Flow chart, as a guide to the relations between some processes and quantities that affect galactic evolution or that may be observed as constraints on evolutionary models. The arrows indicate the following processes: Starting from protogalactic gas, stars are born, evolve, and die; they can be observed individually if they are nearby or, otherwise, in integrated light. Stellar deaths release again gas with changed composition to the interstellar medium (ISM) and perhaps produce cosmic rays, which give rise to interstellar nucleosynthesis. The mass and physical state of the interstellar medium affect the stellar birthrate as well as the observed colors and luminosities (by gaseous emission and extinction by dust). Gas flows and stellar motions to and from the system under study are not indicated, but may be very important.

EXAMPLES OF RADICAL EMPIRICISM:
1) CLASSIFICATION SYSTEMS



Galaxy Tutorial

Galaxy Analysis

Galaxy Zoo - Thank You

Show My Galaxies

Galaxy Analysis

Welcome to Galaxy Zoo's view of the Universe. If you're here you should already have seen the Tutorial, but feel free to go and remind yourself. There's no need to agonise for too long over any one image, just make your best guess in each case.

Show Grid Overlay on the next Image

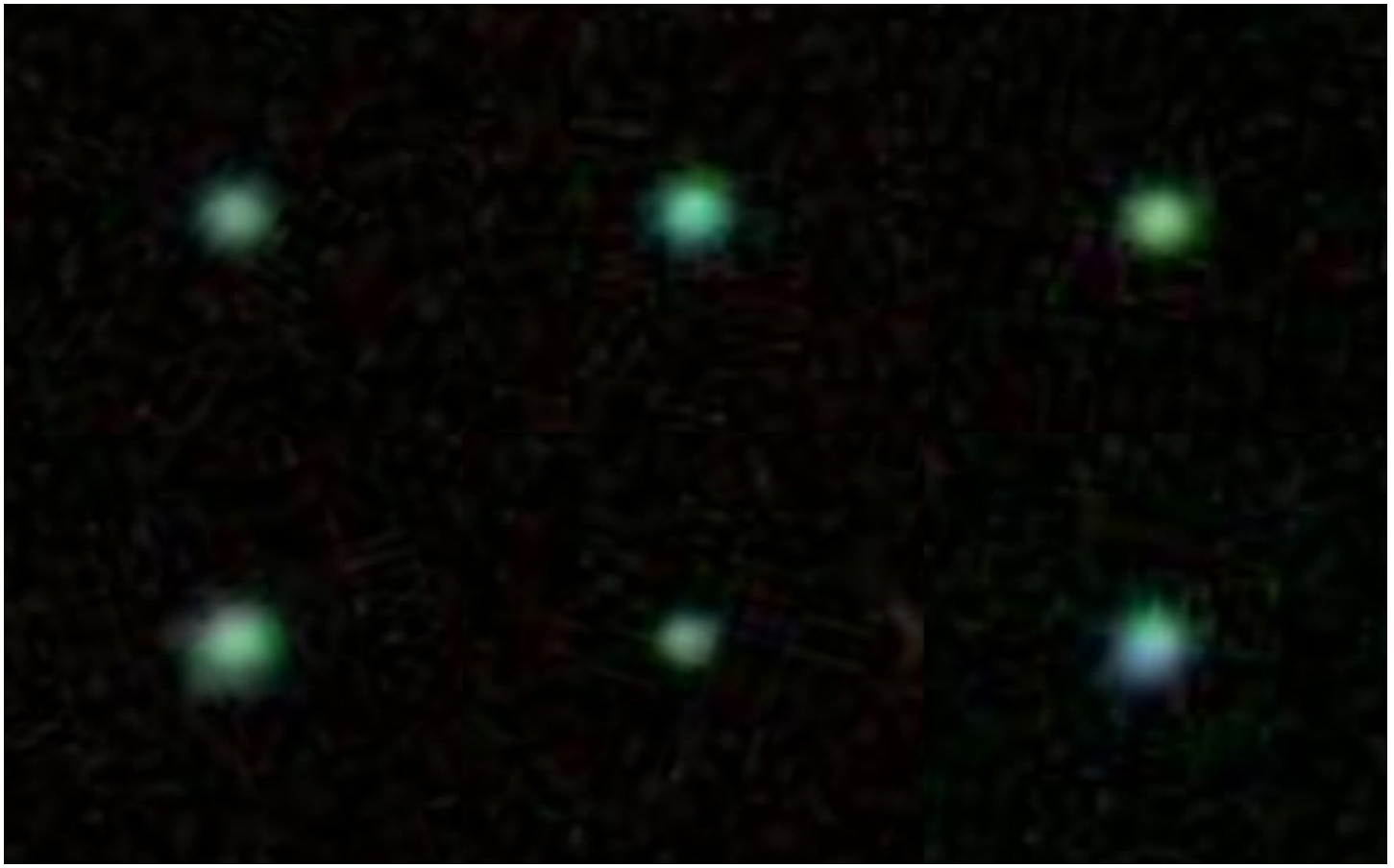
Galaxy Ref:
587729387677679742

Choose the Galaxy Profile by clicking the buttons below

Pea Galaxies were first discovered in 2007 by the volunteer users within the forum section of the online astronomy project Galaxy Zoo

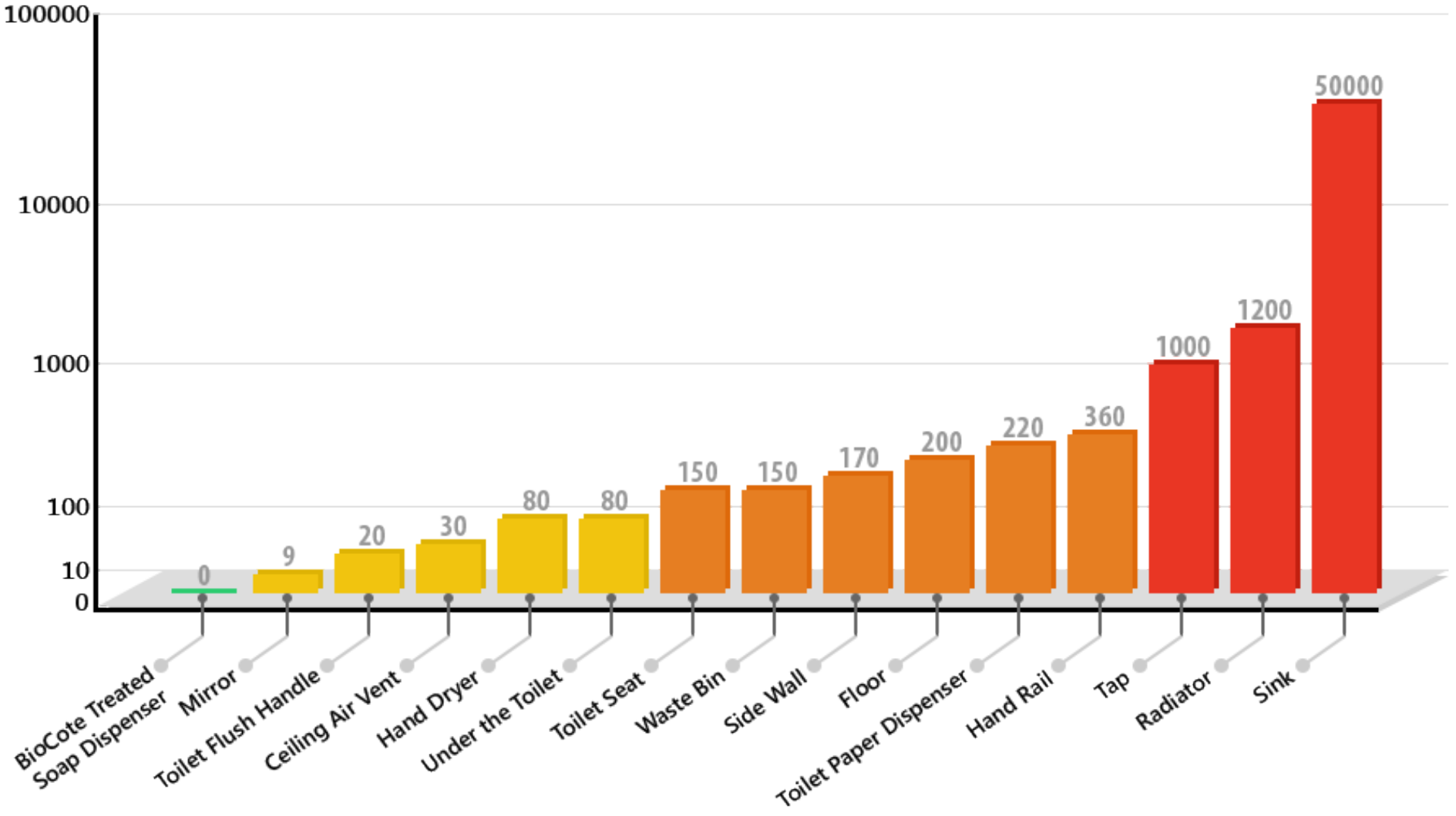
Wikipedia says: might be a type of Luminous Blue Compact Galaxy which is undergoing very high rates of star formation

Moral: watch out for the colour scheme

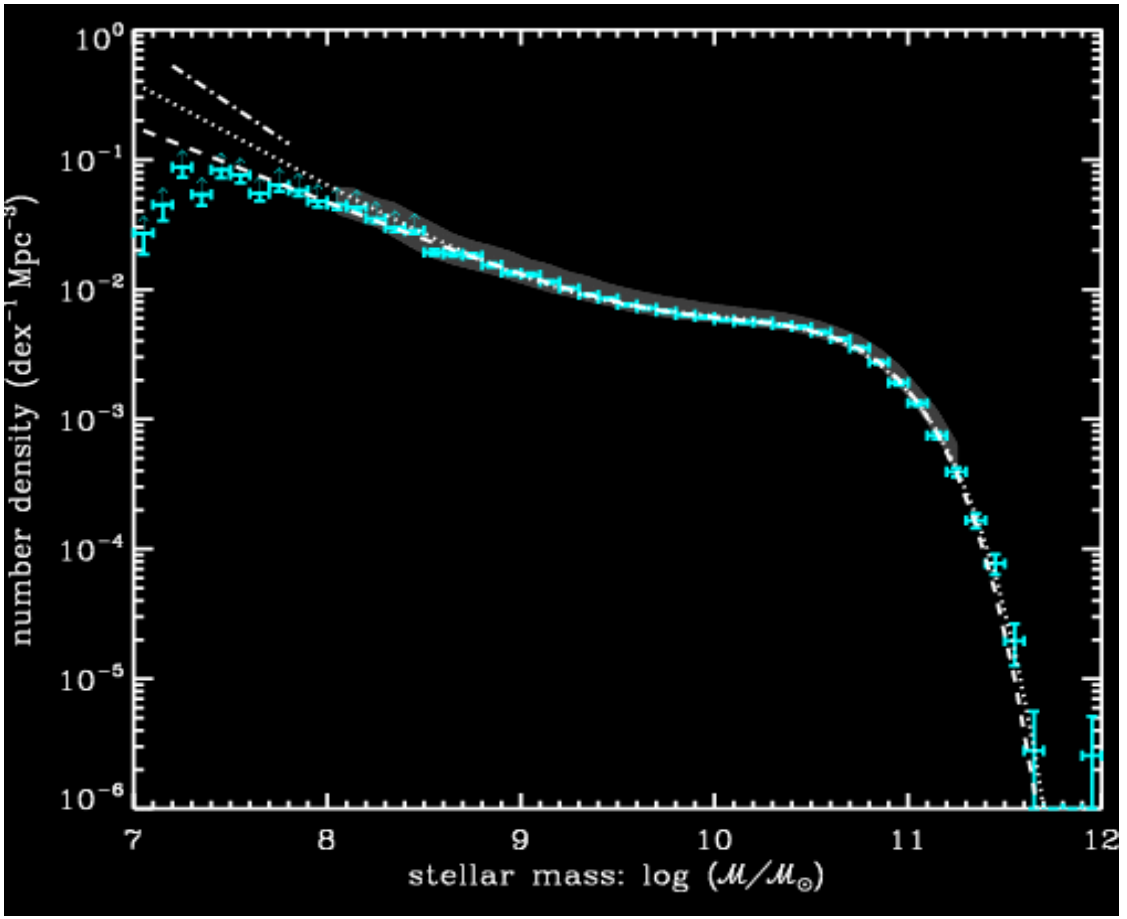


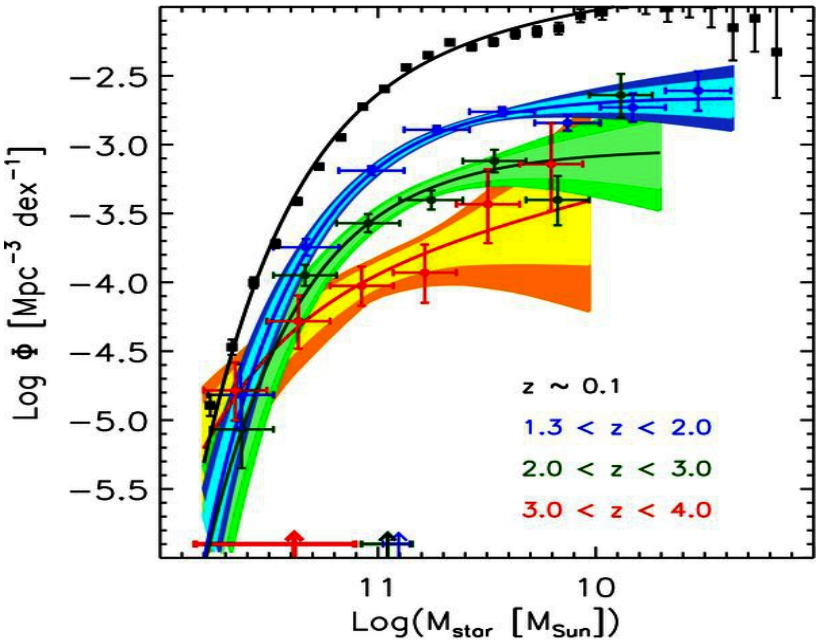
2) QUANTIFICATION, i.e. COUNT HOW MANY THERE ARE

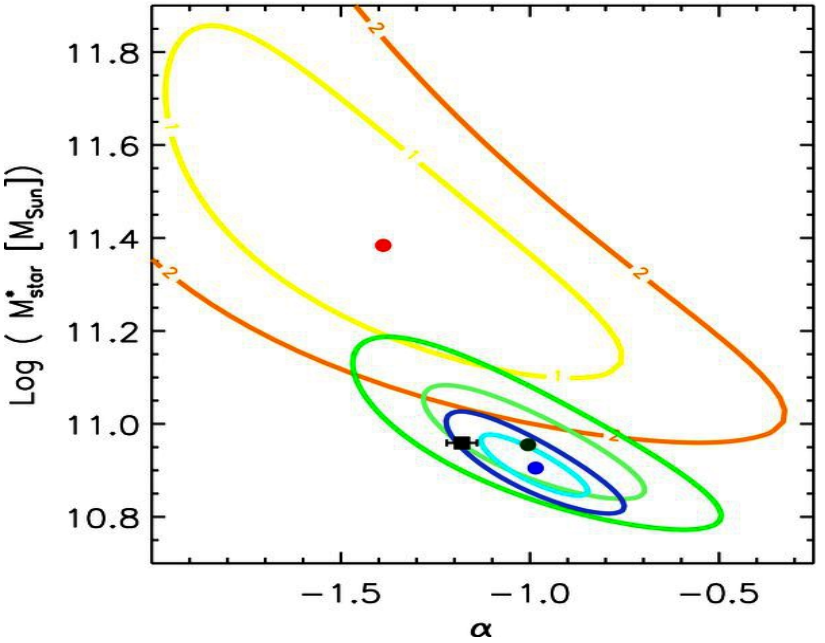
N(bacteria) as function of environment

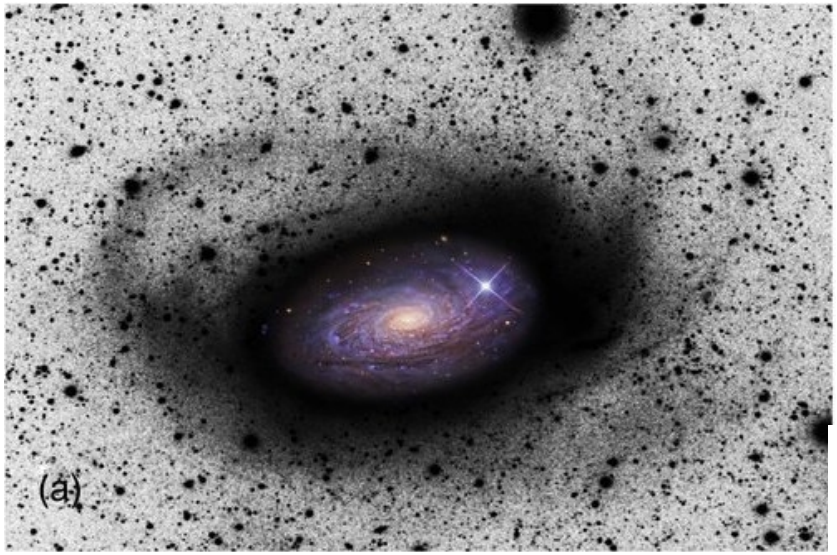


The Galaxy Stellar Mass Function









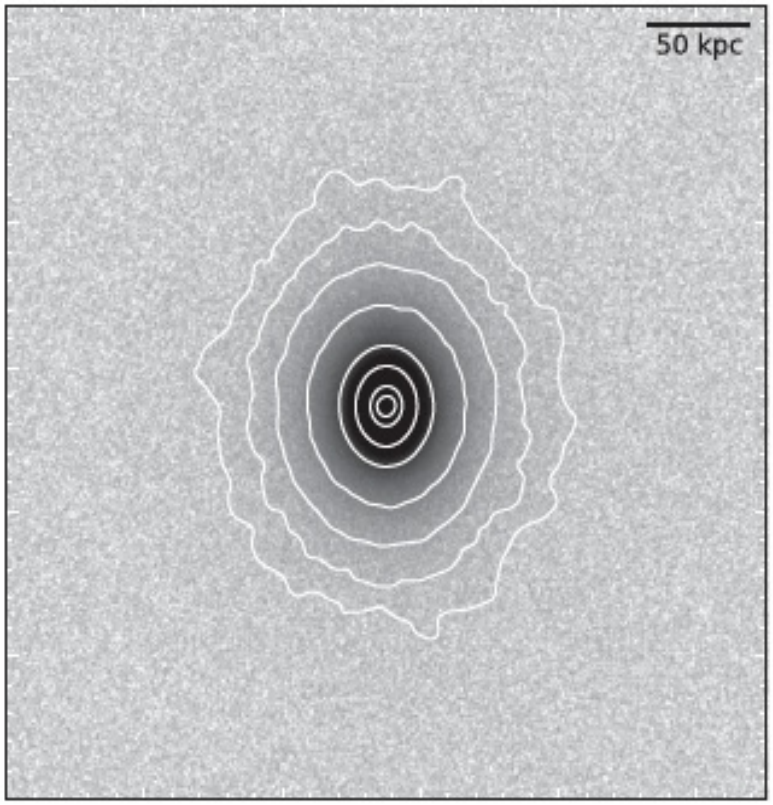
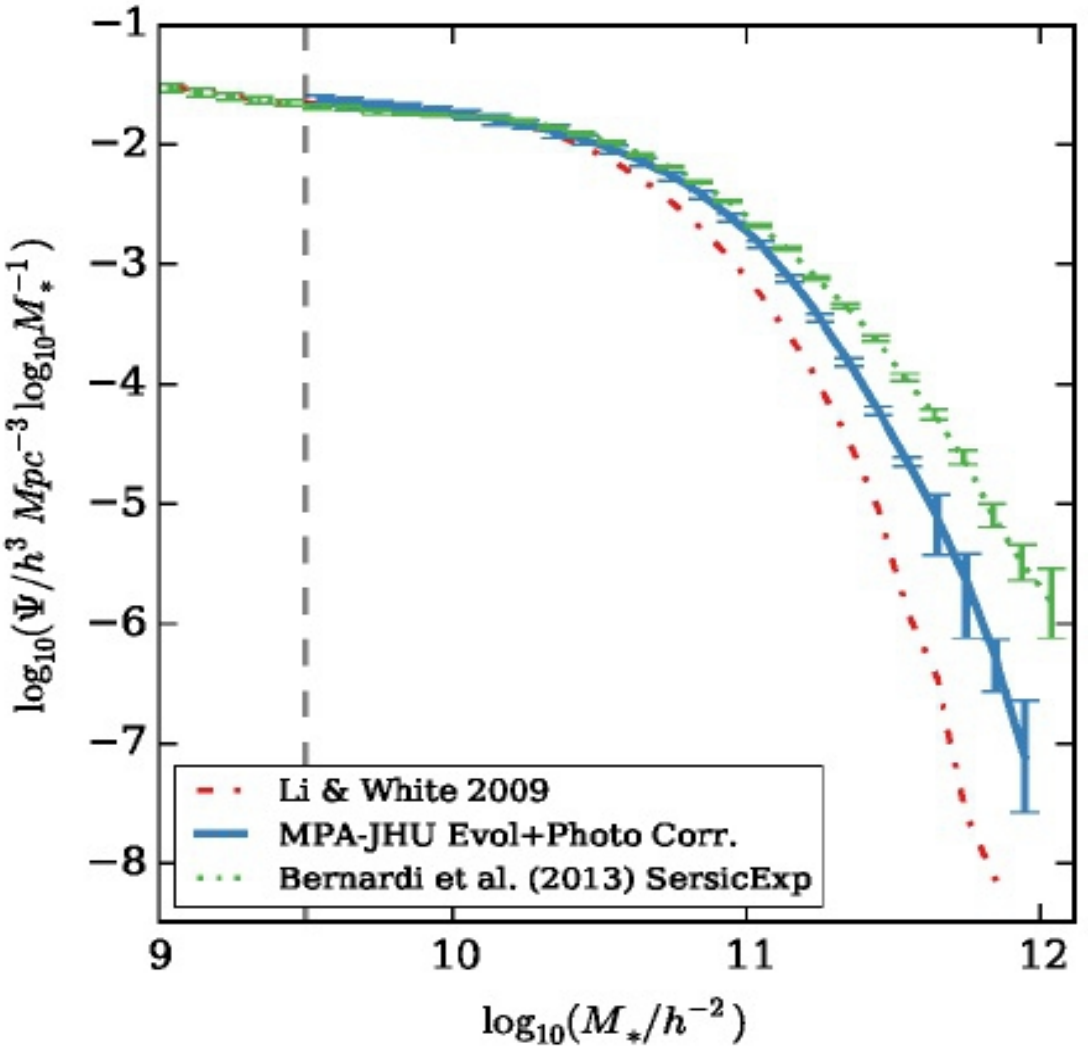
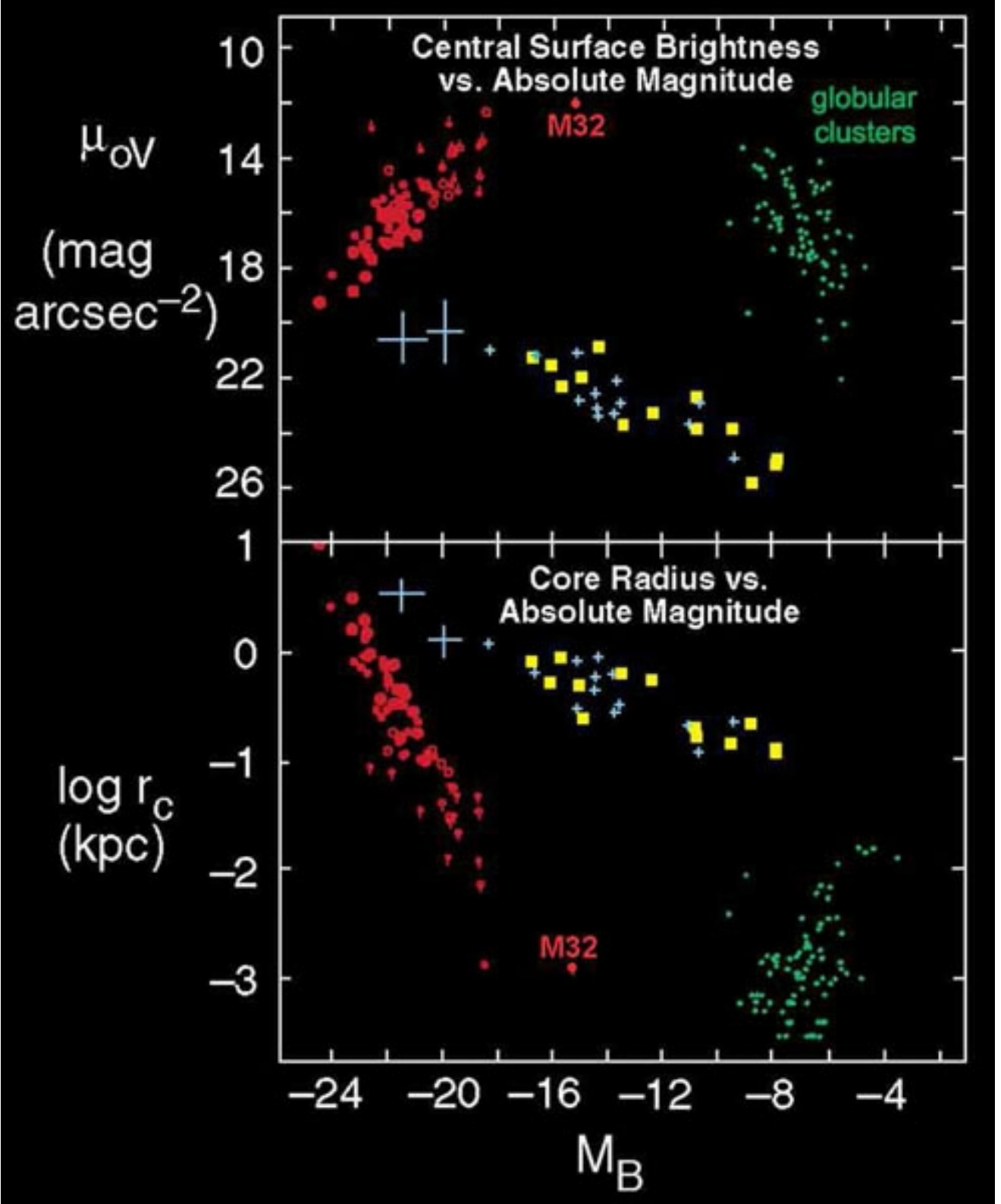


Figure 5. The stacked image consisting of 4040 images in the mass range $10^{11.0}\,M_\odot < M_* < 10^{11.4}\,M_\odot$ and $C > 2.6$. Elliptical contours are drawn at 5, 10, 20, 30, 50, 70, 90 and 110 kpc.

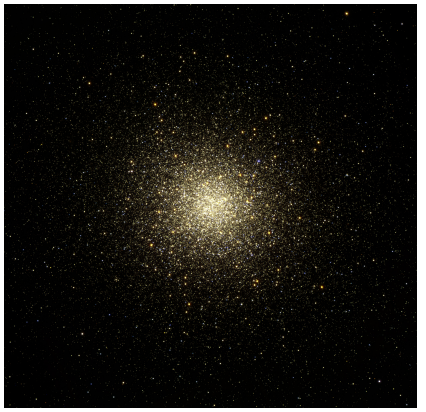
D'Souza et al (2015) reports a mean co-moving stellar mass density of galaxies with stellar masses log(**M∗/M⊙**) > 11**.**0 that is a factor of 3.36 larger than the estimate by Li & White (2009), but is 43% smaller than reported by Bernardi et al. (2013).





3) SCALING RELATIONS AND CORRELATIONS

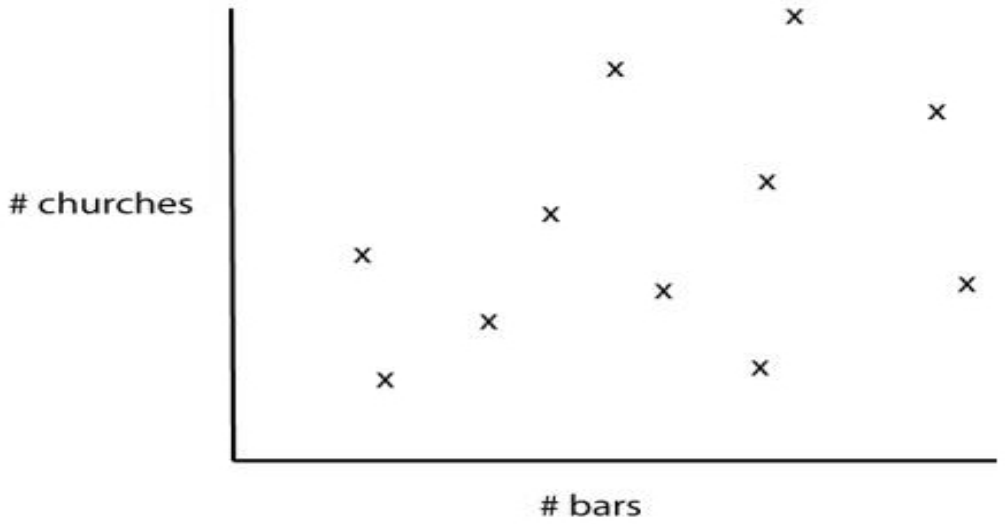
Quantitatively establish different classes of objects



GLOBULAR CLUSTER

GIANT ELLIPTICAL GALAXY

CORRELATIONS AND CAUSALITY:
the major pitfall of the radical empiricists



To argue causation from these data, we would either have to say that churches cause people to drink more (whether intentionally or unintentionally), or argue that lots of drinkers in a town causes more churches to be built (e.g., churches move in where there are sinners). Furthermore, causation would suggest either that banning bars would reduce the number of churches in the town, or that the way to cut down on the number of bars was to close down churches (depending on which way the causation went).

In reality, the correlation is due to a **hidden variable** -- population size. That is, larger towns have more demand for churches and for bars, as well as other social institutions.

CONTROLLING HIDDEN VARIABLES THOUGH STUDYING TWINS

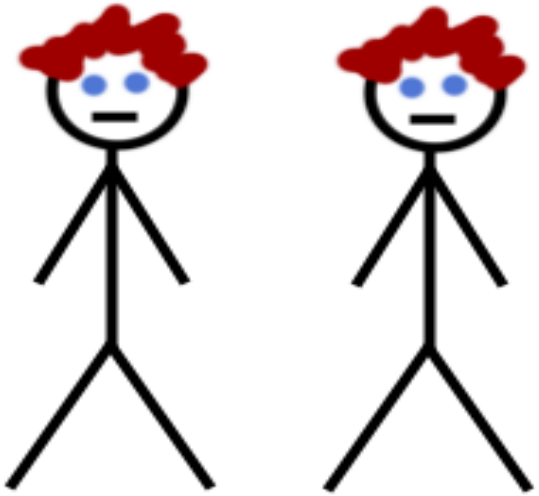
DZ Twins

Different DNA
Same Environment

If inteligence is the **same** it must be due to the **environment.**

If inteligence is **different** it must be due to **genetics.**

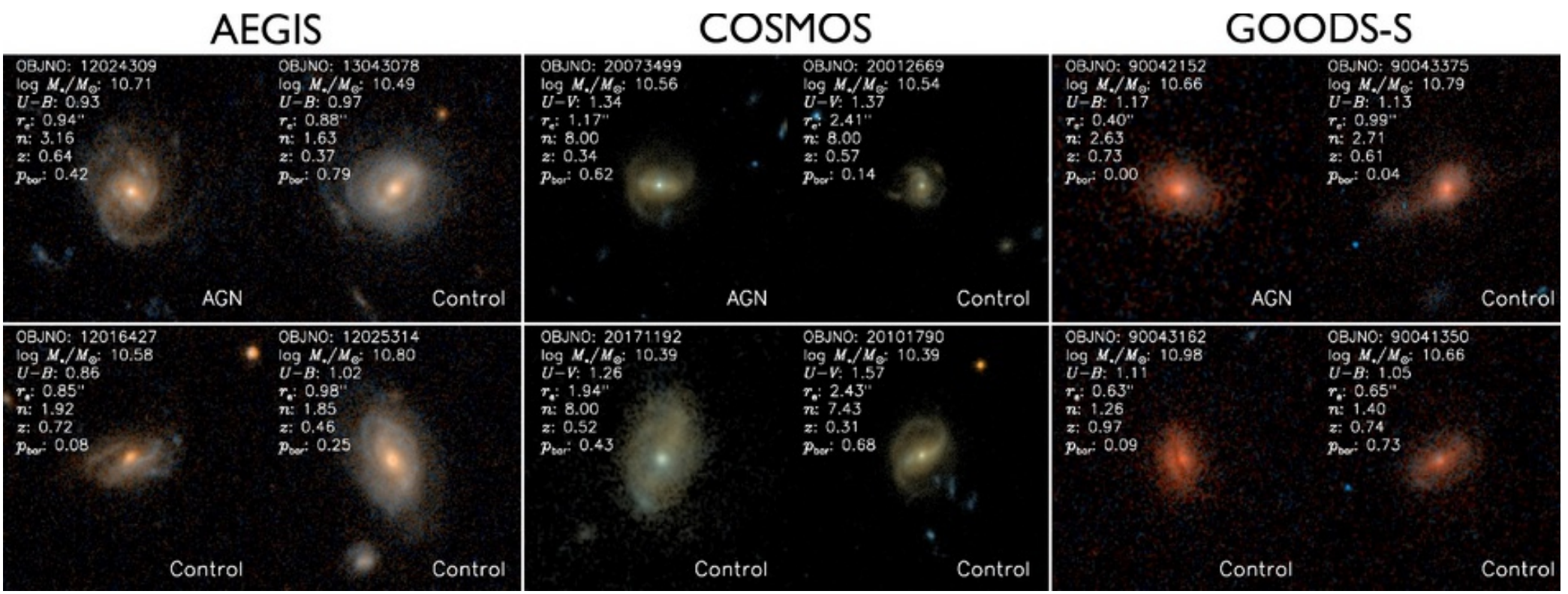
MZ Twins

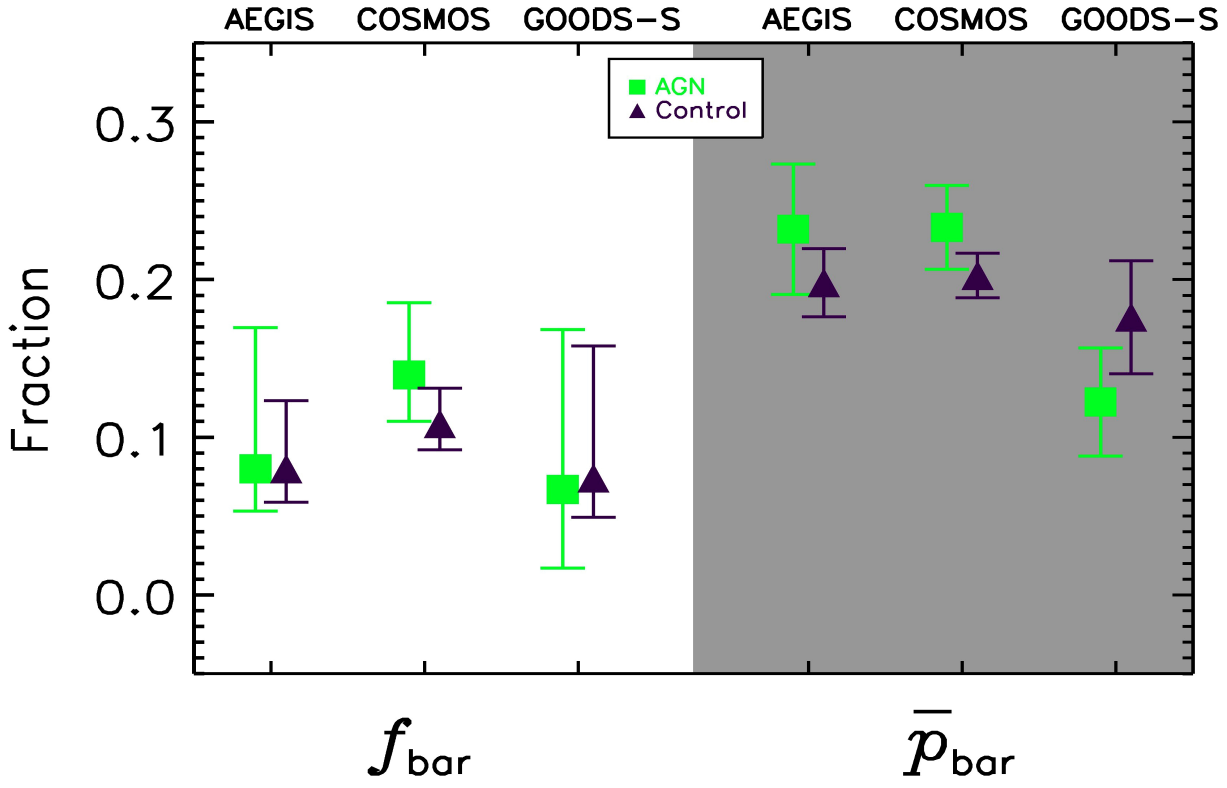


Same DNA
Different Environment

If inteligence is the **same** it must be due to **genetics.**

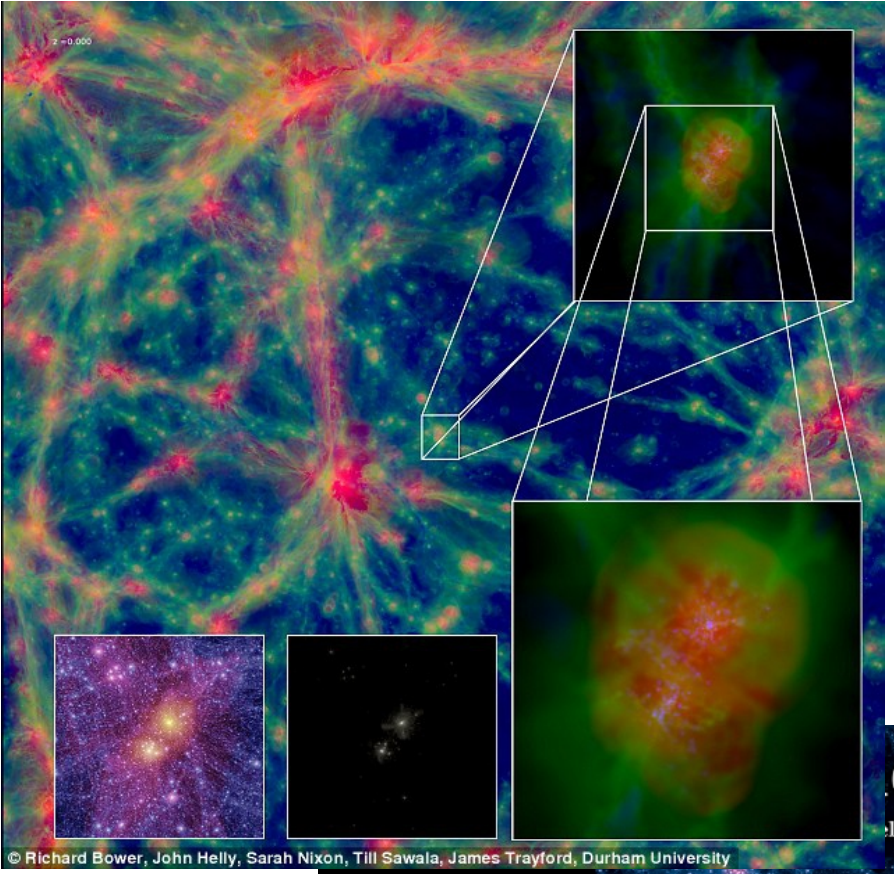
If inteligence is **different** it must be due to the **environment.**



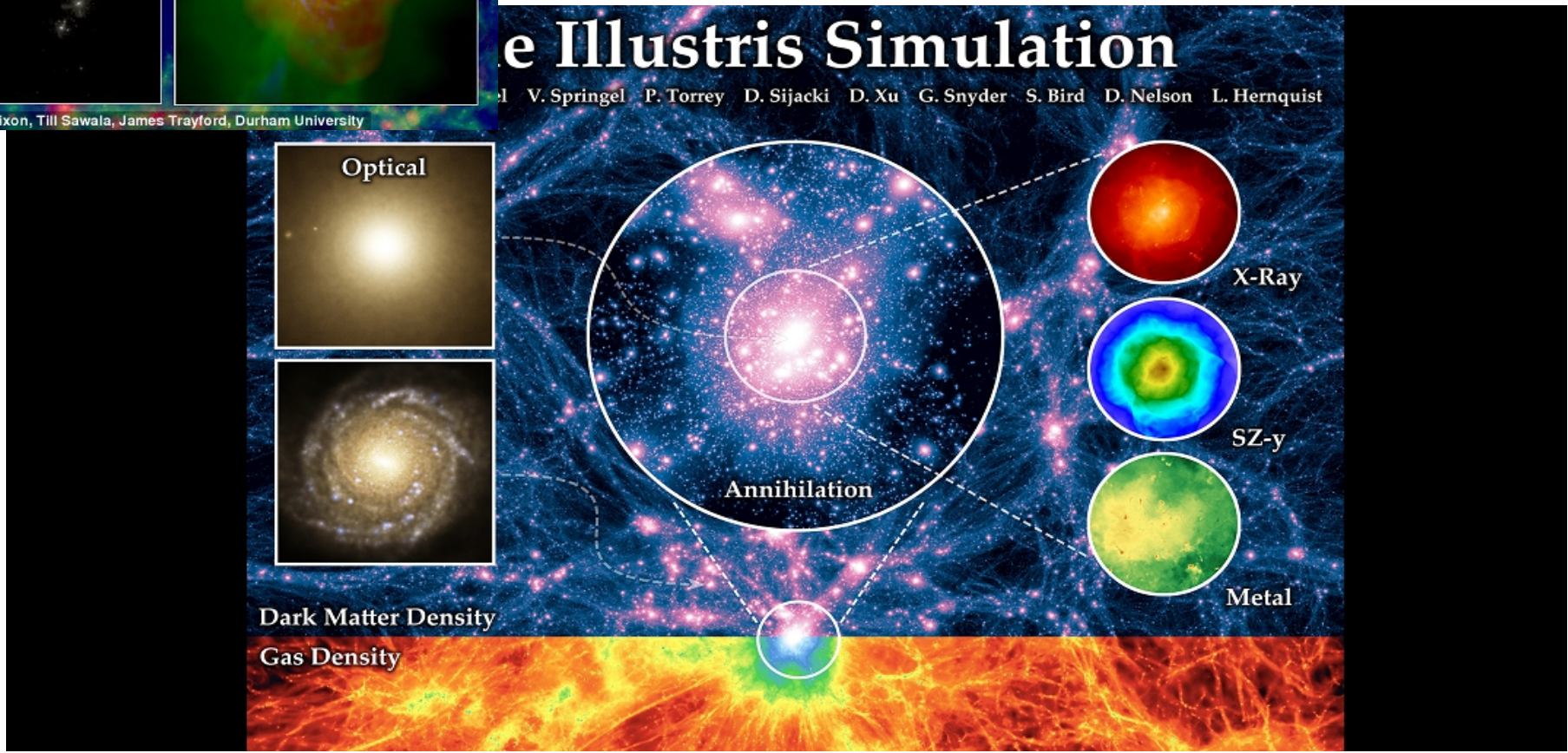


Do bars fuel AGN?

(uh oh, we started with a question, is this apriori revelation??)



Antithetical approach:
“put in all the physics”,
run the code, and it must be right.



Bear in mind which aspects are super-natural, trans-empirical entities!

(commonly known as uncertain sub-grid physics)

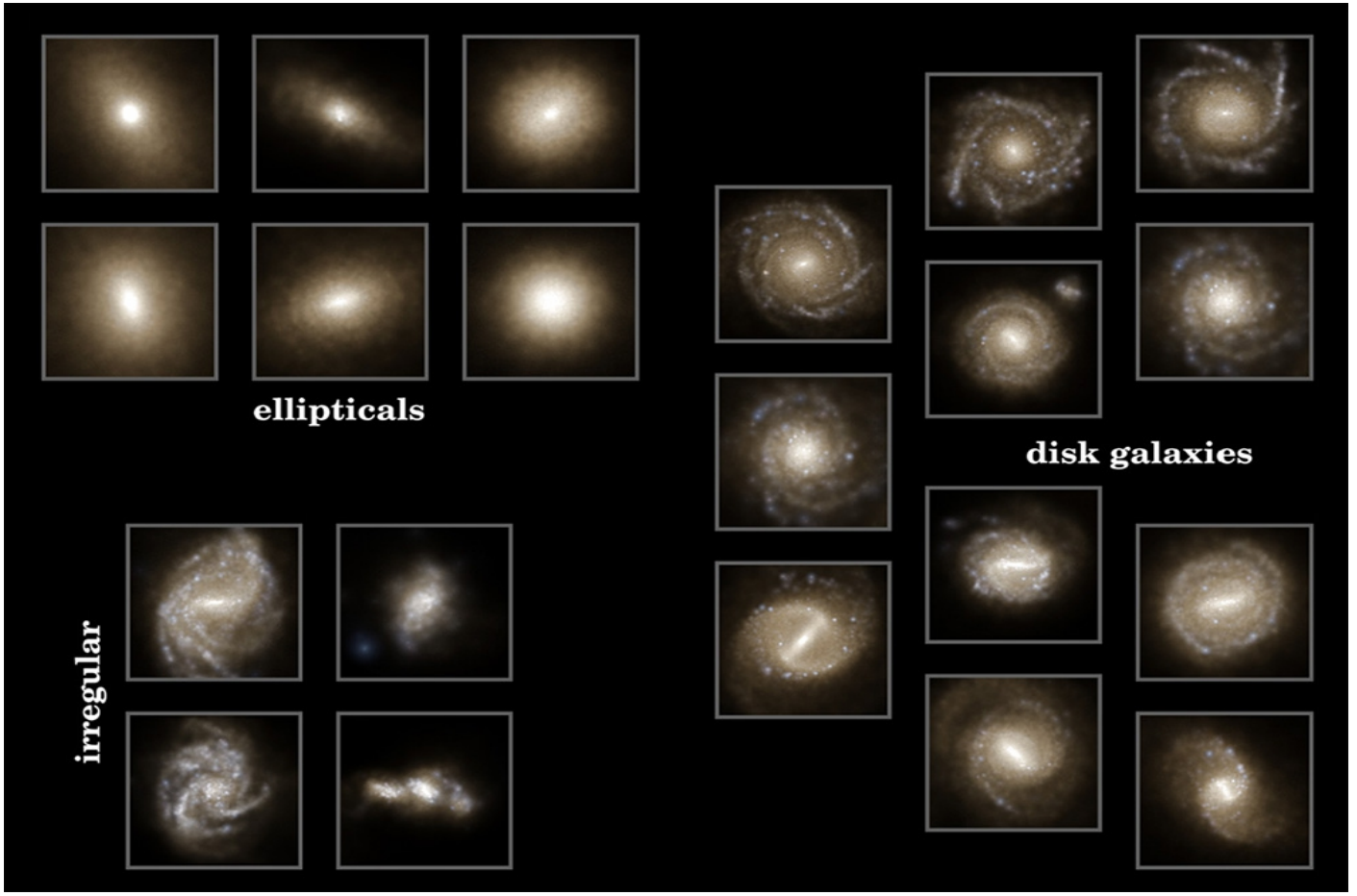
2.2 Star Formation

2.3 Stellar evolution and chemical enrichment (SN rates, mass and metal return into the ISM, mixing of metals through the ISM)

2.4 Stellar feedback (SN feedback, local or non-local, wind metal loading)

2.5 BH growth and AGN feedback (BH seeding, BH growth, quasar and radio mode feedback)

?? missing: cosmic rays?



The new simulations are game-changing for 2 reasons:

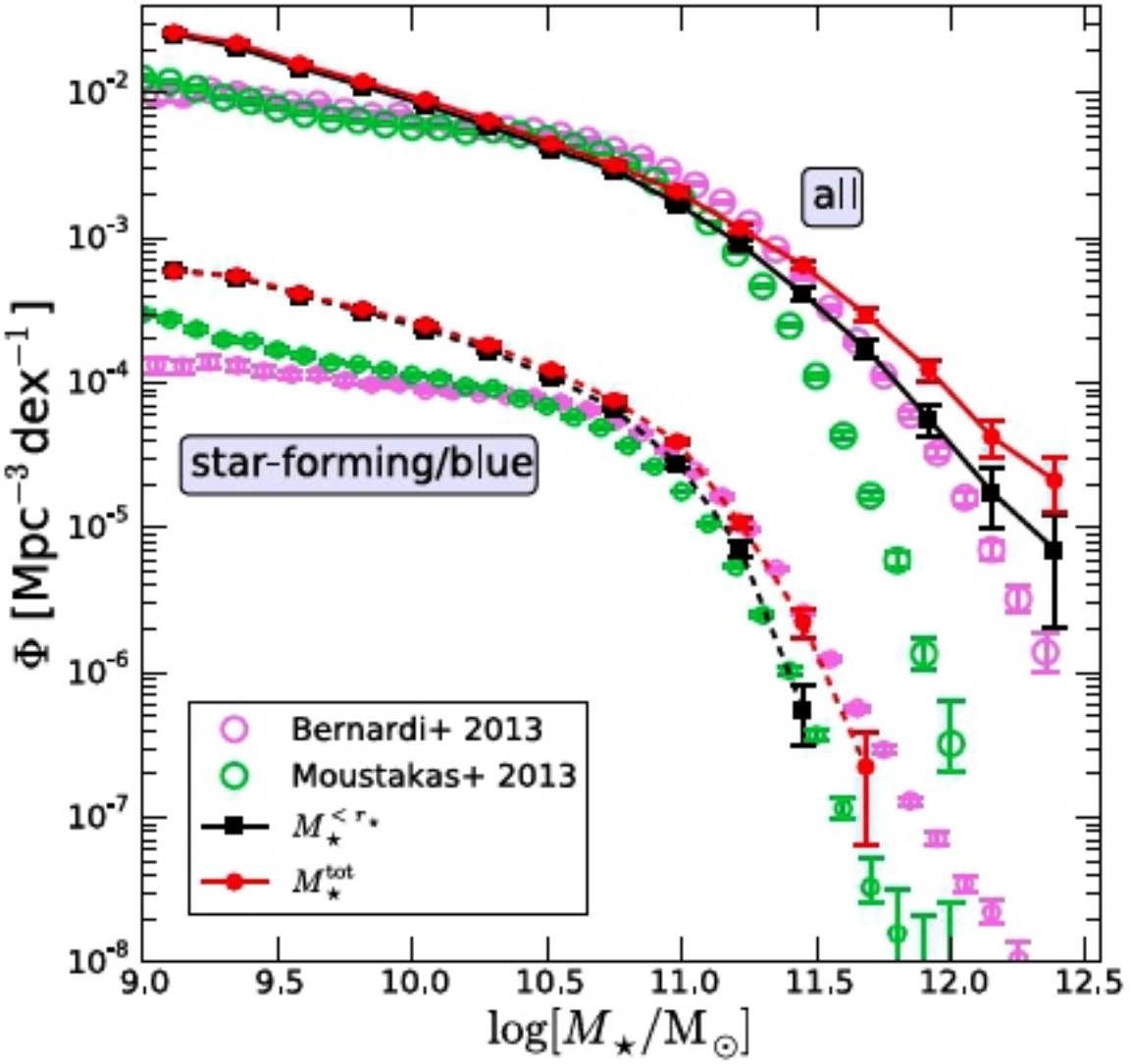
1) For the first time, disk galaxies and ellipticals can be created in the same hydro simulation.

2) All the simulation data is publically available!

Public Data Access Overview

All of the results and data products of the Illustris simulation project, as described in Nelson+ (2015), are made publicly available on this page. A number of tools for exploration and analysis are provided as a starting point.

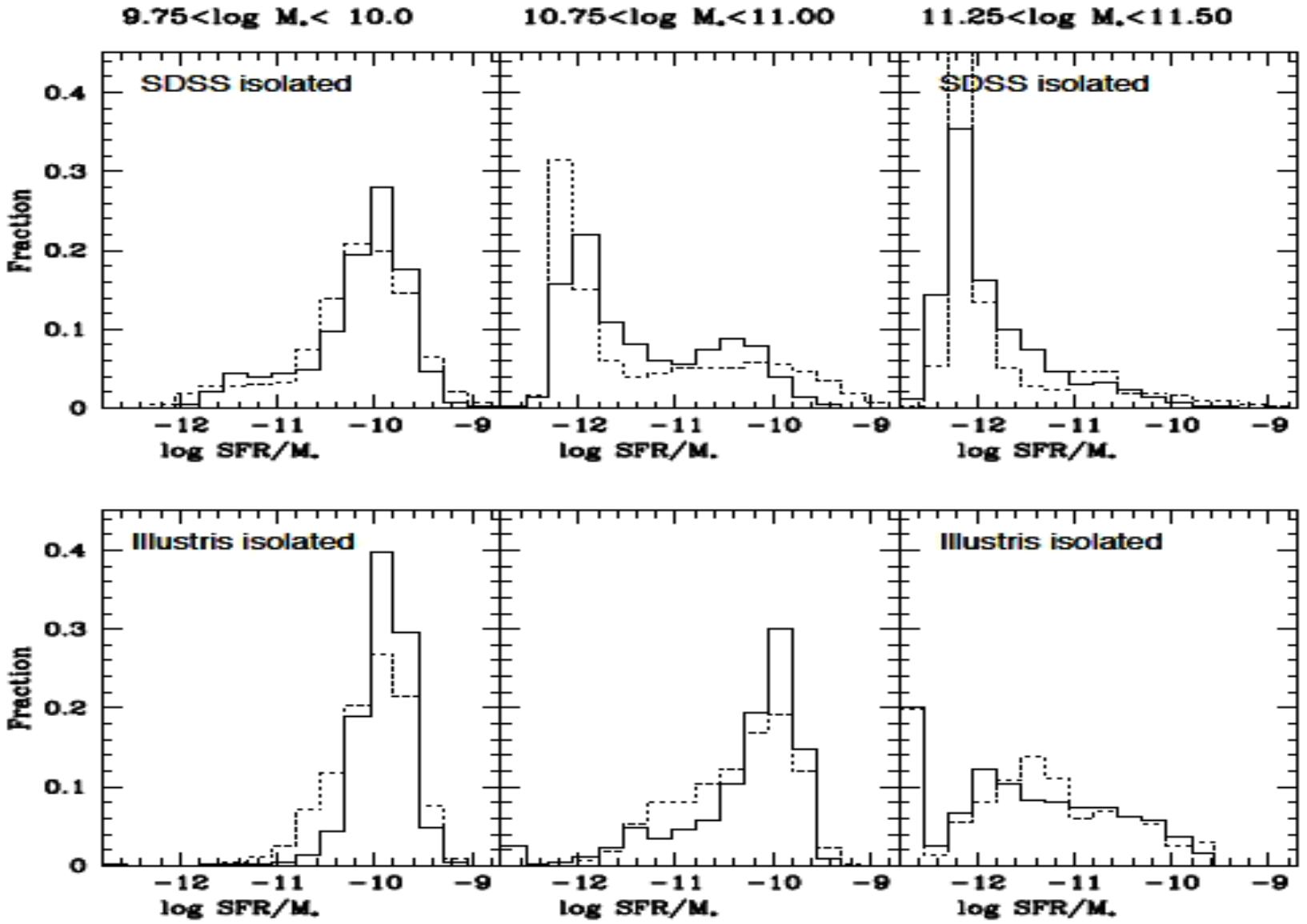
WATCH OUT FOR THE HYPE – THESE SIMULATIONS STILL DON'T FIT OBSERVATIONS VERY WELL!!



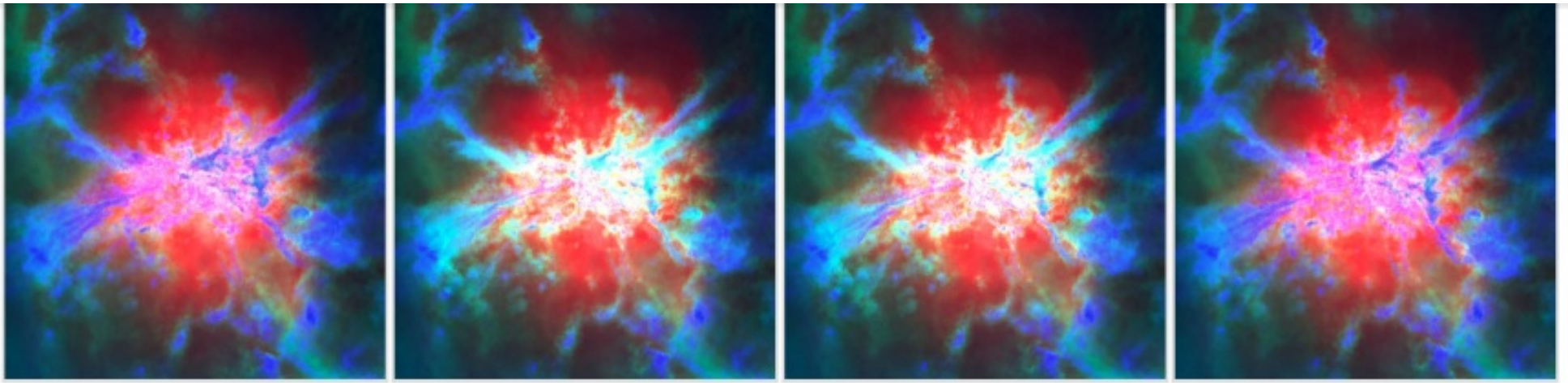
Too many massive galaxies!

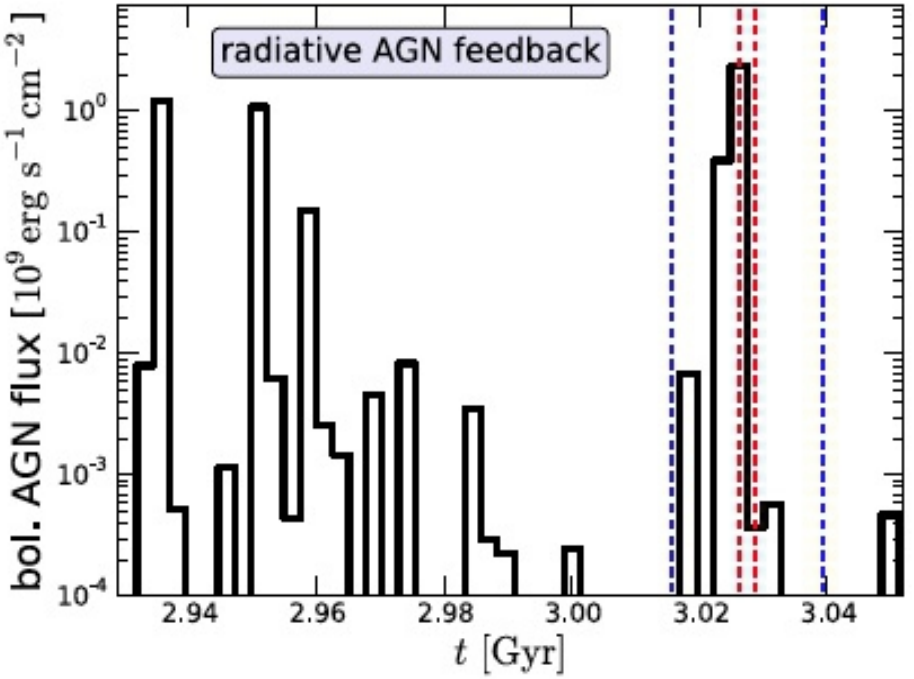
Too many low mass star-forming galaxies!

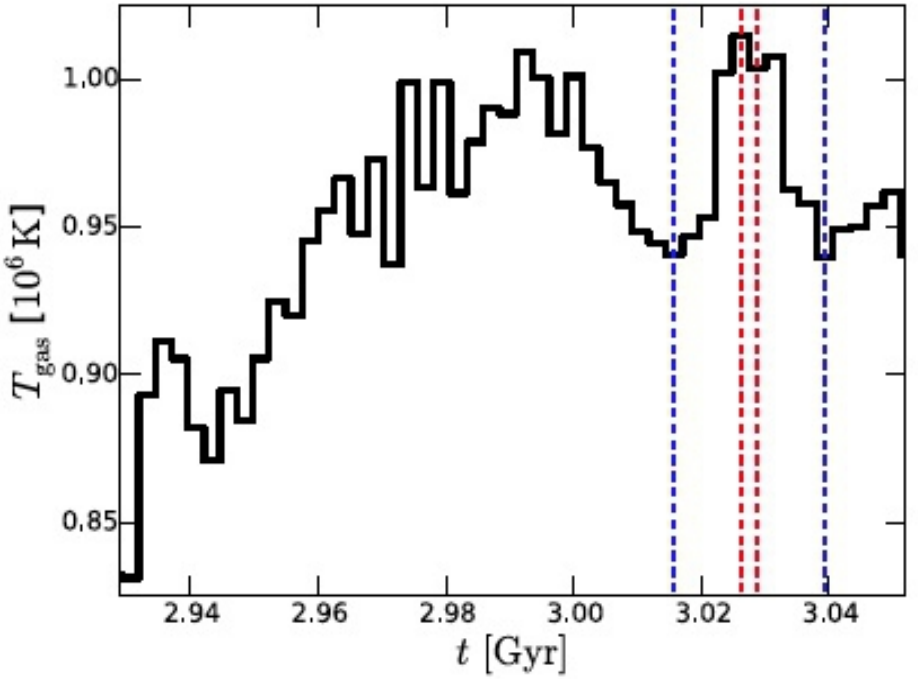
STAR FORMATION "QUENCHING PROCESSES" NOT EFFECTIVE ENOUGH IN ILLUSTRIS



VERY SMALL IMPACT OF A “QUASAR” EPISODE ON THE GAS IN A SUBHALO

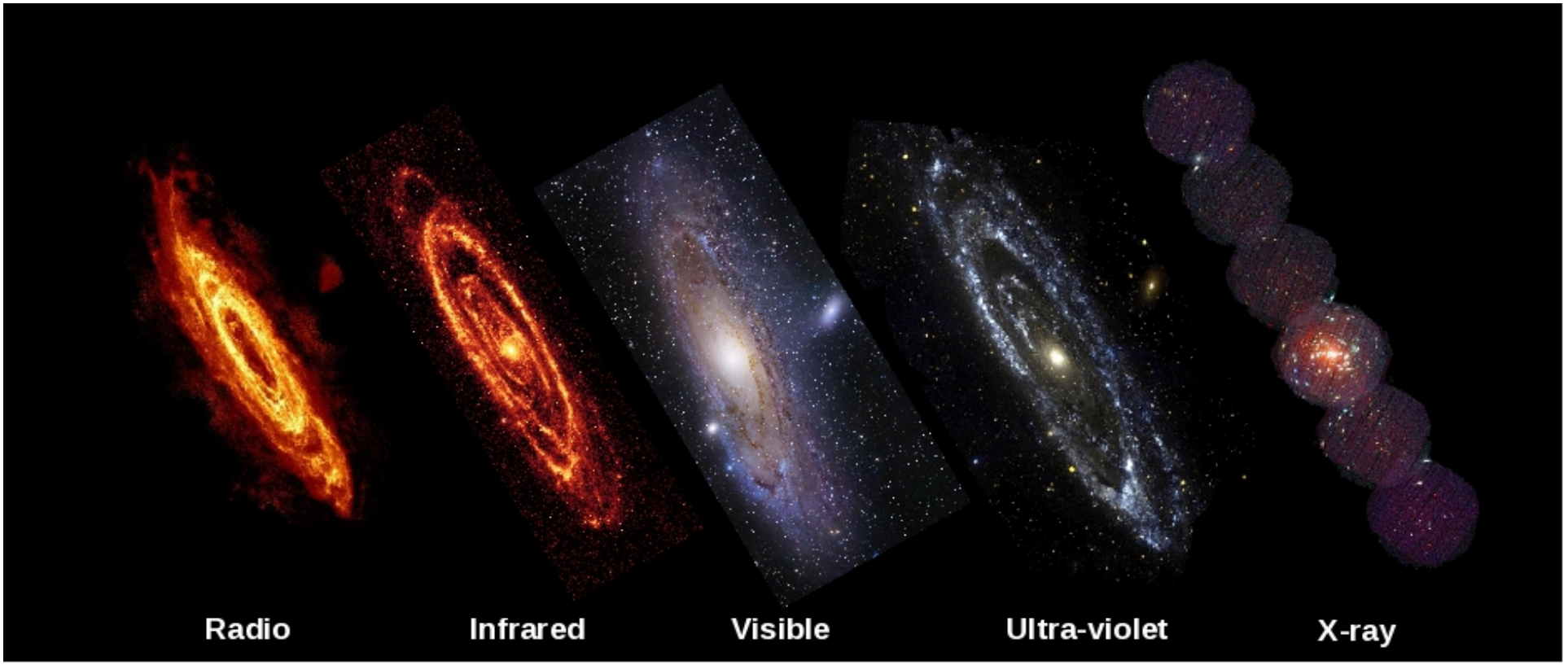






HOW DO OBSERVERS MAKE PROGRESS IN FUTURE?

Re-observe the same galaxy/galaxies/patch of the sky at more wavelengths, and the answer to galaxy formation will be obvious



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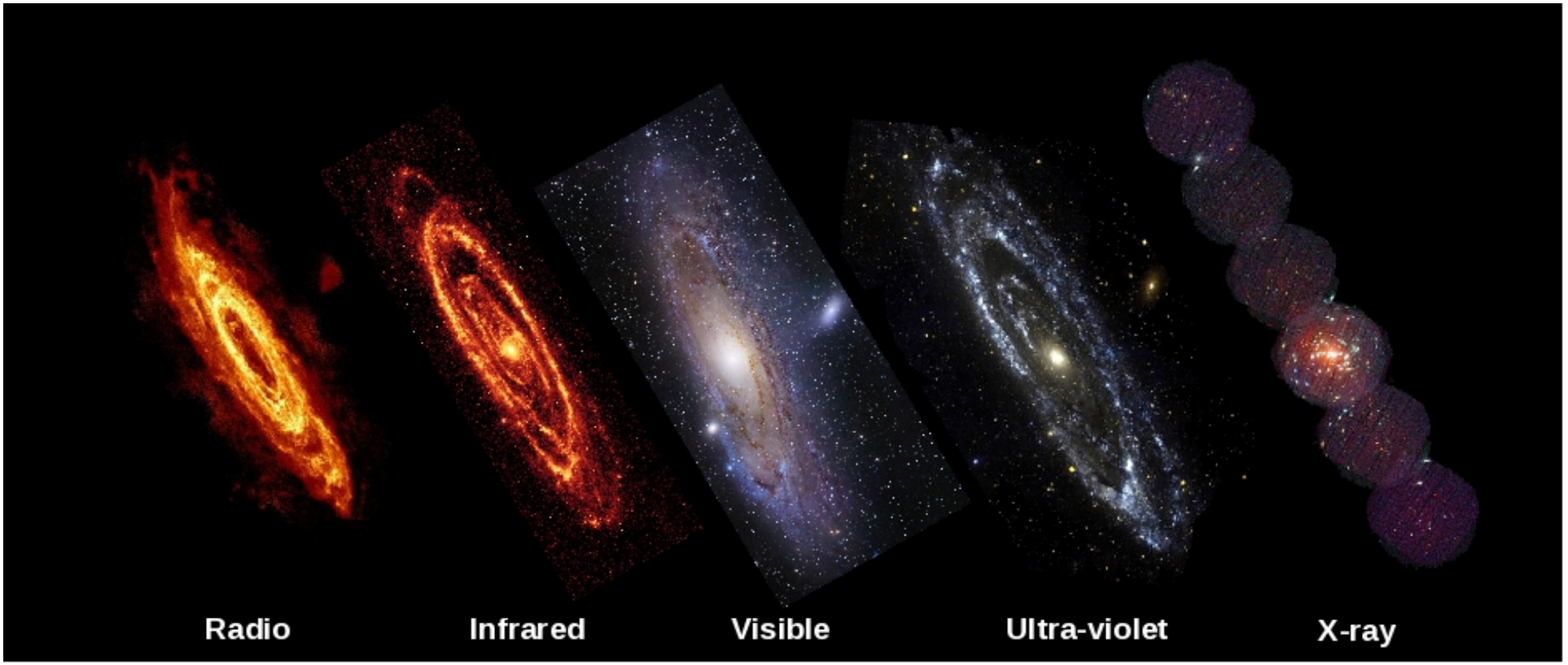


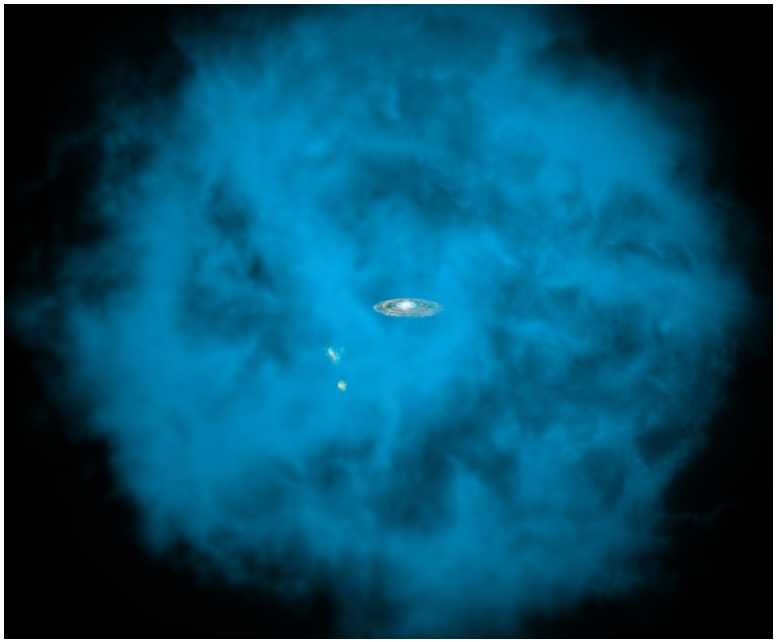
THE SCIENTIFIC METHOD AS TAUGHT IN SCHOOL

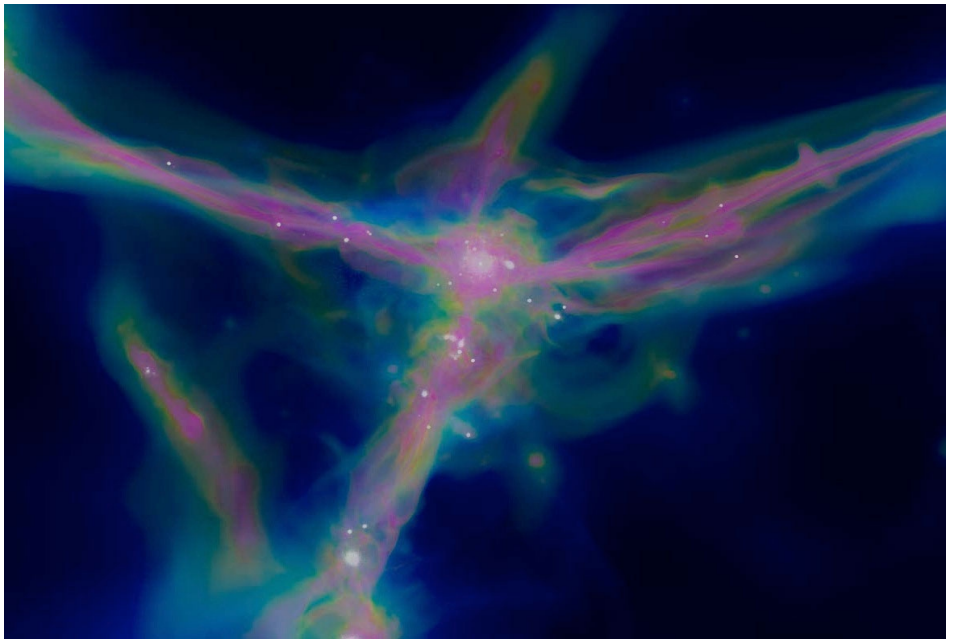
- The scientific method is a way to ask and answer scientific questions by making observations and doing experiments.
- The steps of the scientific method are to:
  - **Ask a Question**
  - **Do Background Research**
  - **Construct a Hypothesis**
  - **Test Your Hypothesis by Doing an Experiment**
  - **Analyze Your Data and Draw a Conclusion**
  - **Communicate Your Results**
- It is important for your experiment to be a fair test. A "fair test" occurs when you change only one factor (variable) and keep all other conditions the same.
- While scientists study how nature works, engineers create new things, such as products, websites, environments, and experiences.

WHAT DOES THIS MEAN IN PRACTICE FOR GALAXY FORMATION SCIENCE?

VERY MANY OF THE EXPERIMENTS ONE WOULD LIKE TO DESIGN TO ANSWER KEY QUESTIONS REQUIRE OBSERVATIONS OF GAS. THE GAS IN AND AROUND GALAXIES RANGES WIDELY IN BOTH DENSITY AND TEMPERATURE. COMPILING THE FULL RANGE OF DATA NEEDED TO ANSWER THESE QUESTIONS IS VERY CHALLENGING..

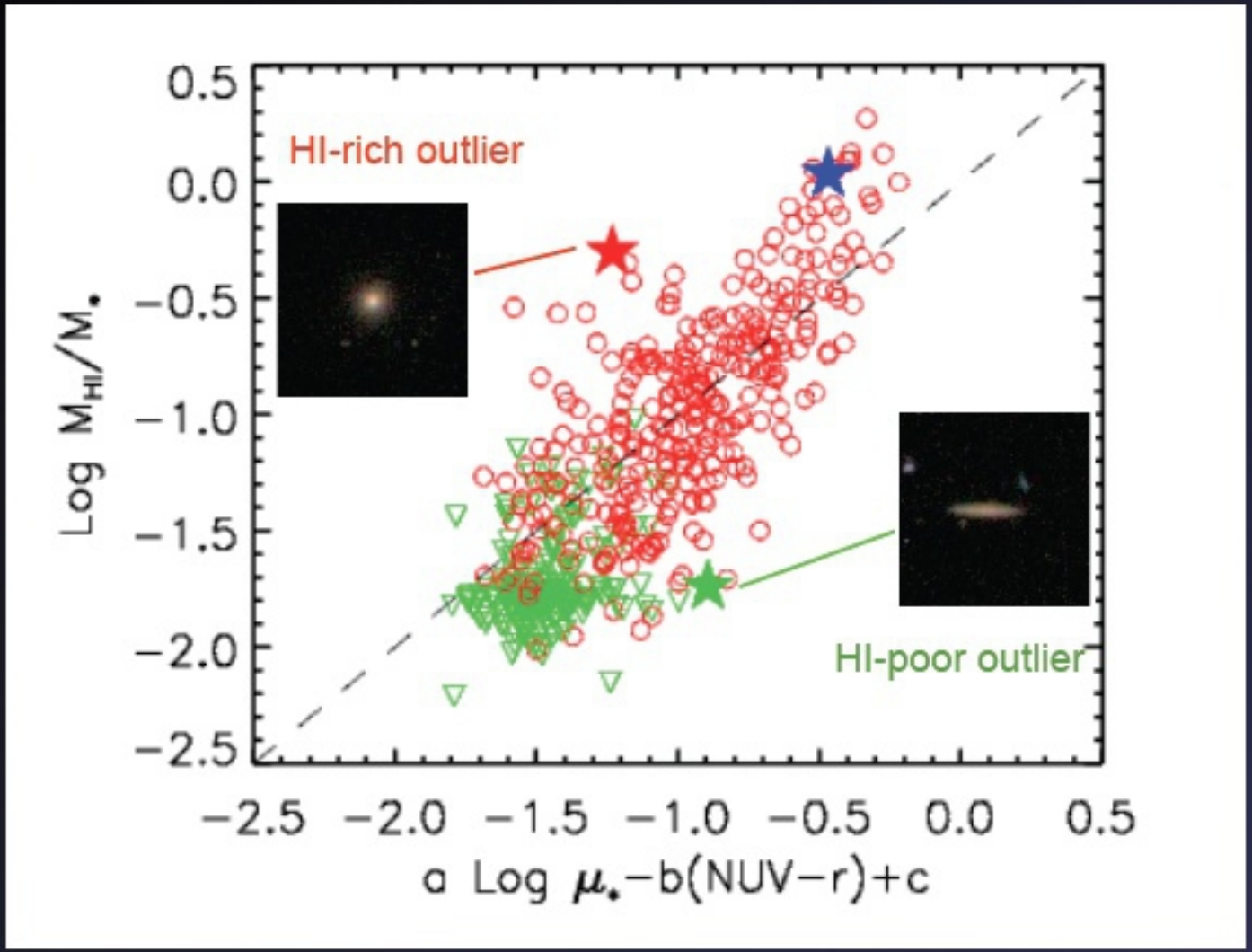
Question: Which mode of accretion is relevant for present-day galaxies?





HYPOTHESIS: HI-RICH OUTLIERS ARE CURRENTLY ACCRETING GAS

DR2 HI gas fraction plane

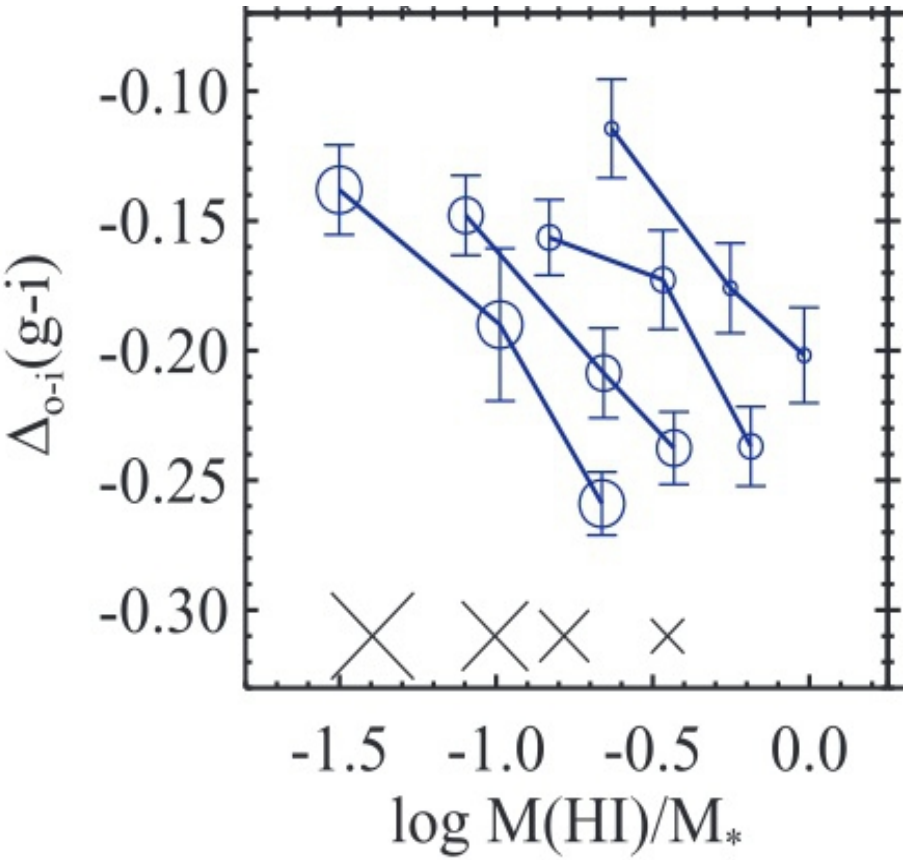


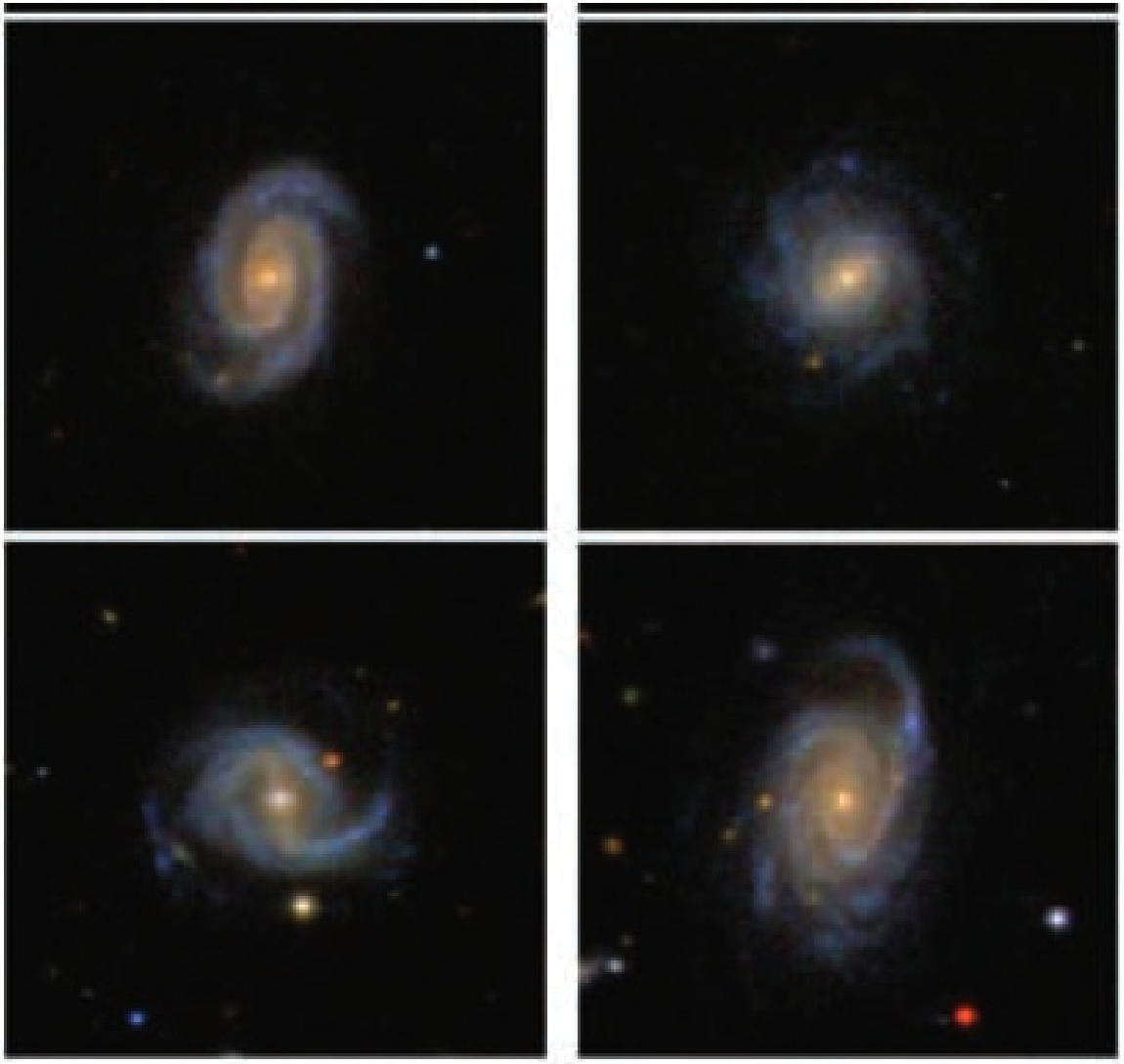
Transition galaxies: anomalous gas content given their optical/NUV colors and μ_*

SOME INDIRECT EVIDENCE IN THE OPTICAL

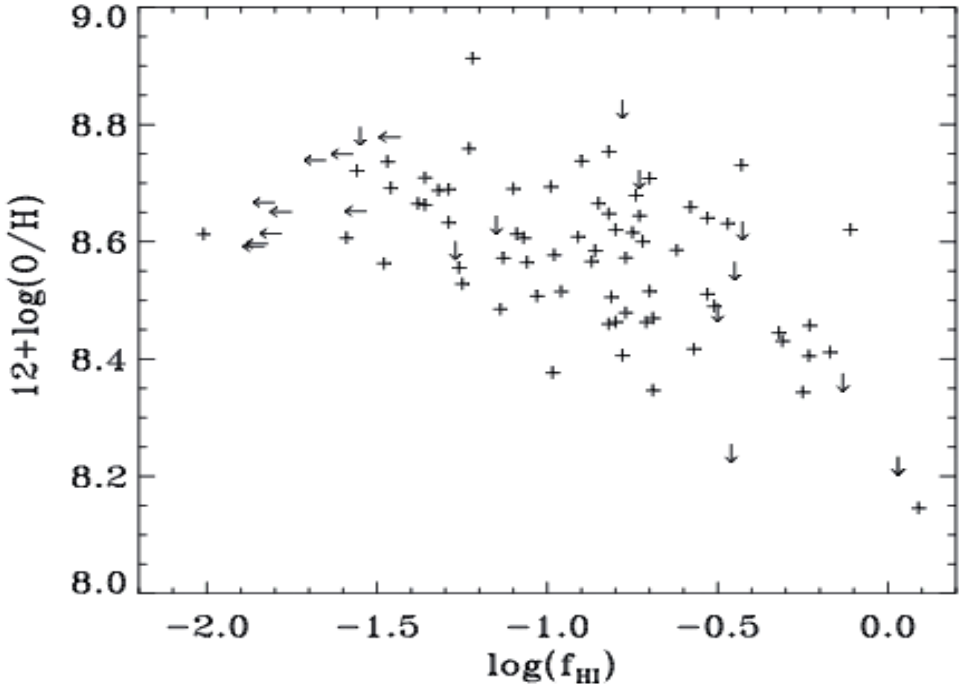
As HI mass fraction increases, outer disks become bluer in colour

Wang et al 2010



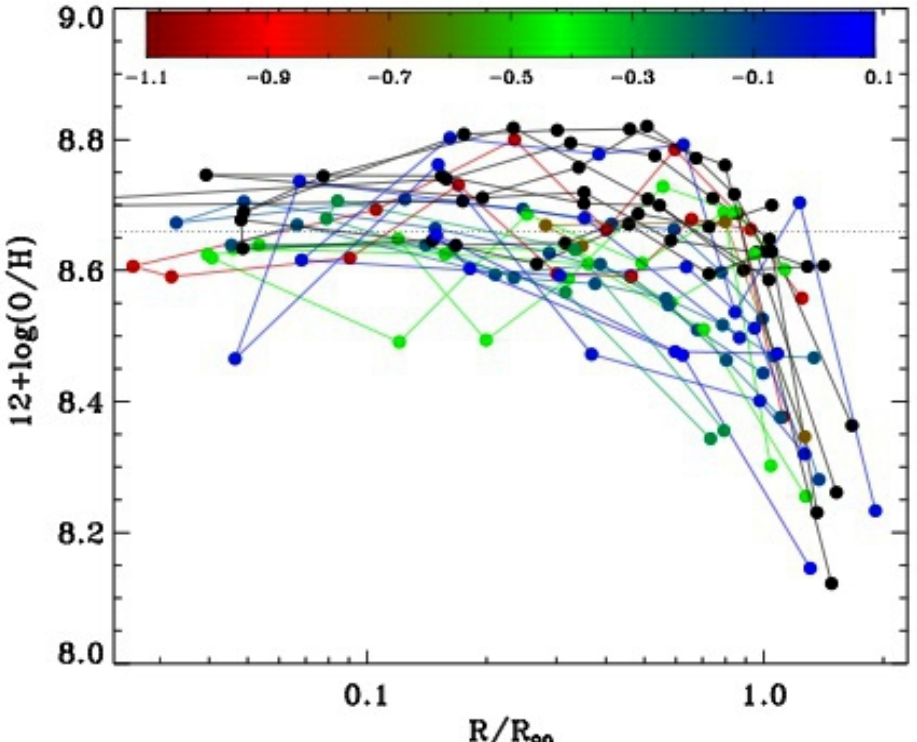


Wang et al 2011

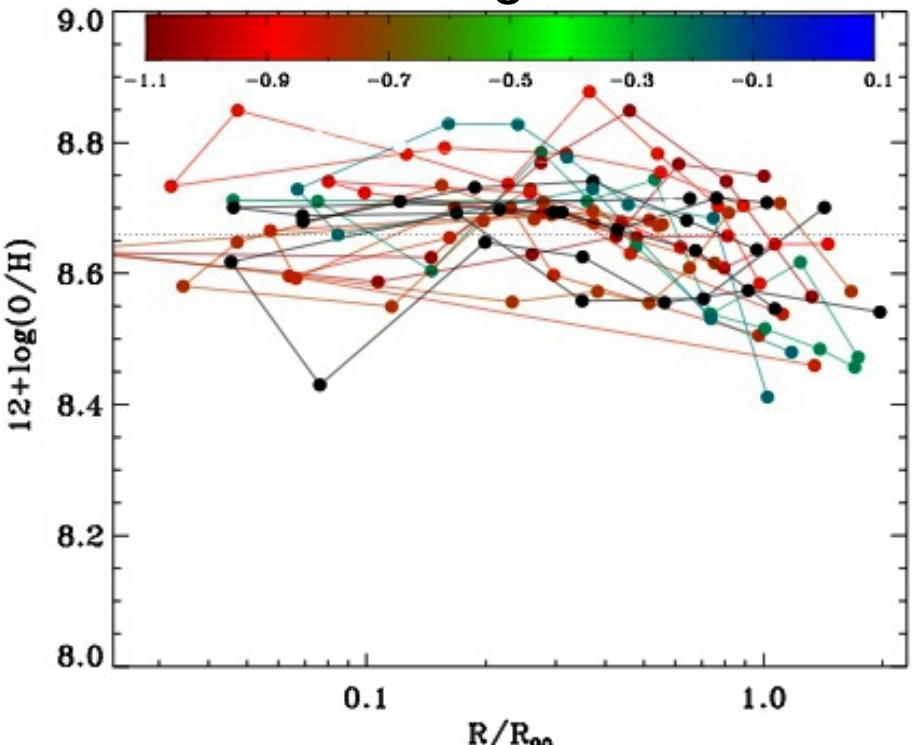


Outer gas-phase metallicity correlates with HI mass fraction.

Metal-drop galaxies



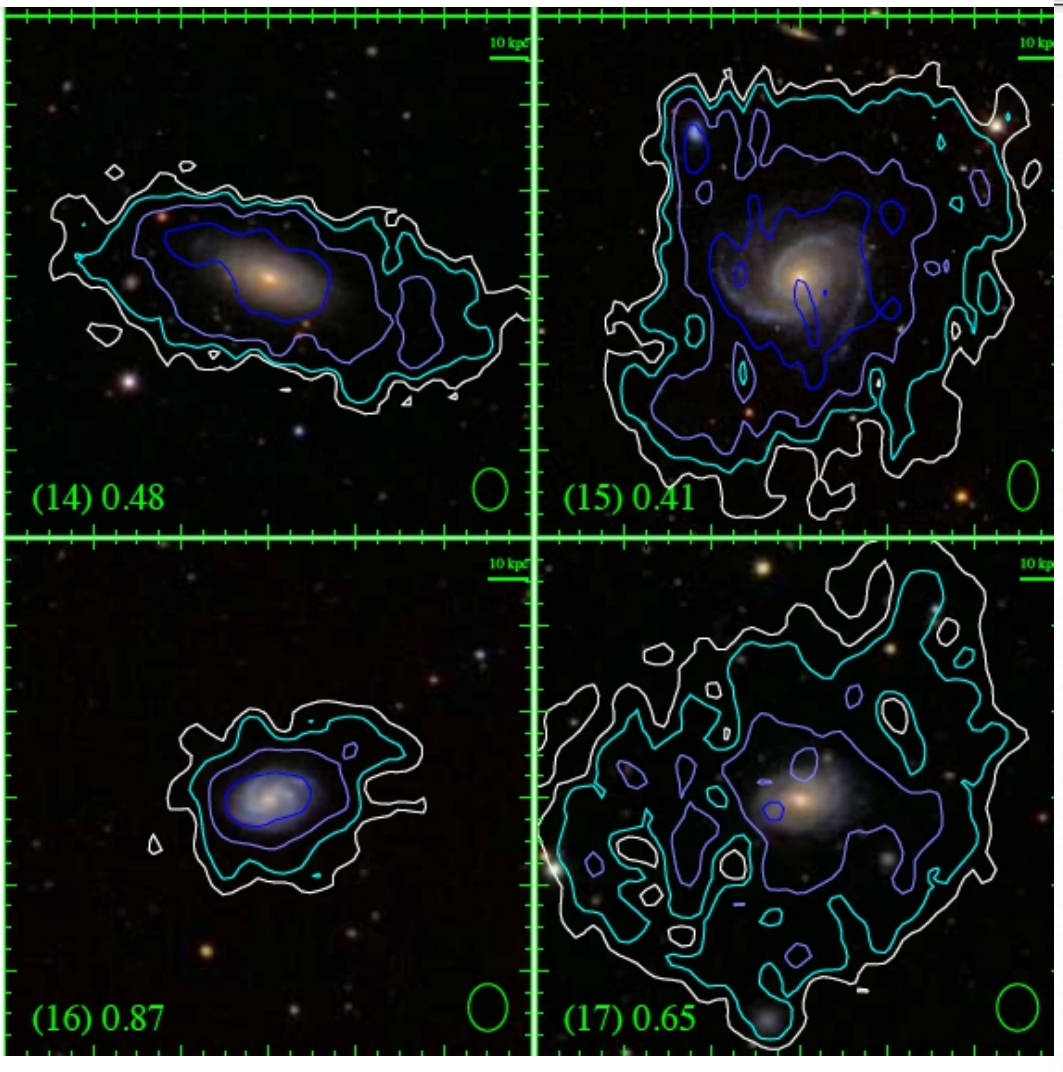
Flat metal gradients

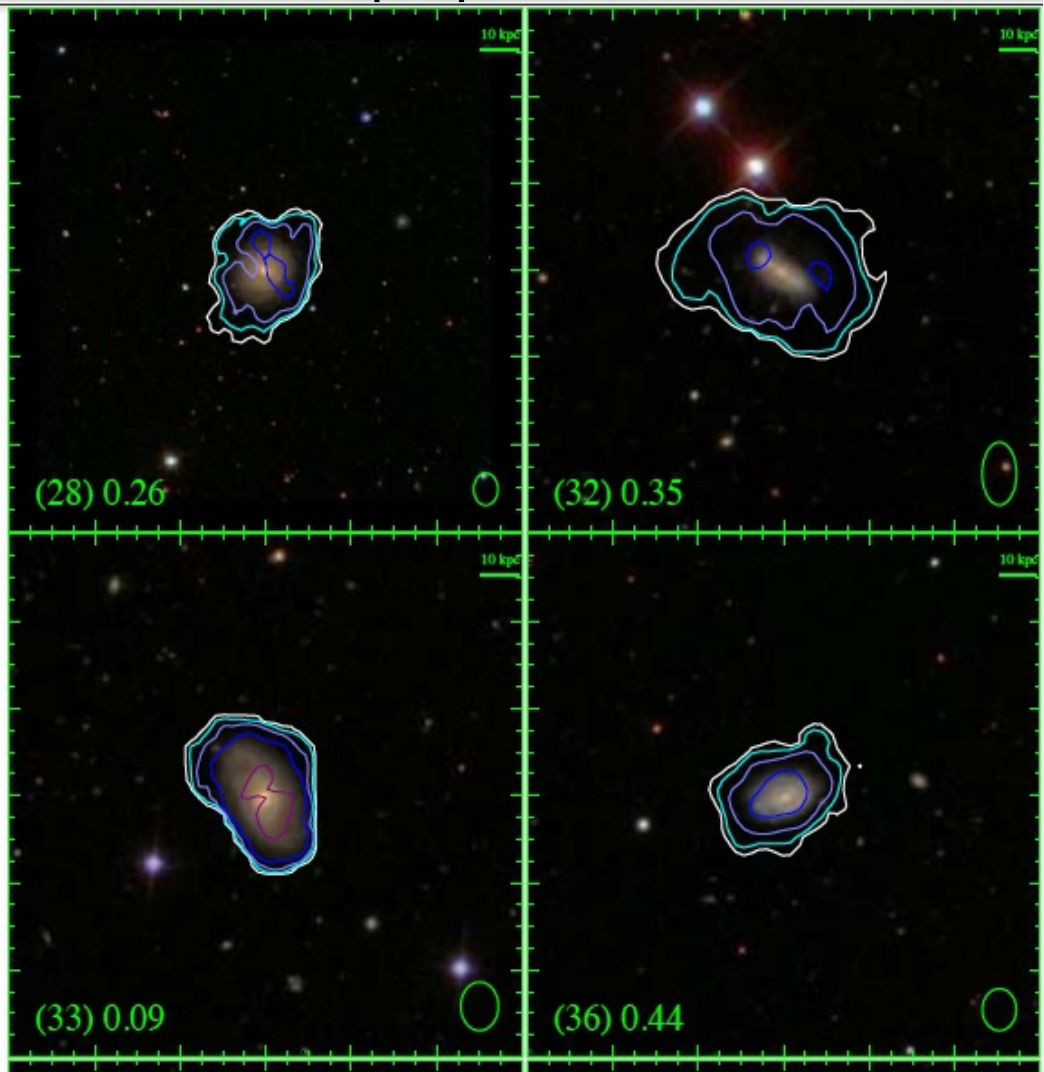


At 21cm wavelengths.....

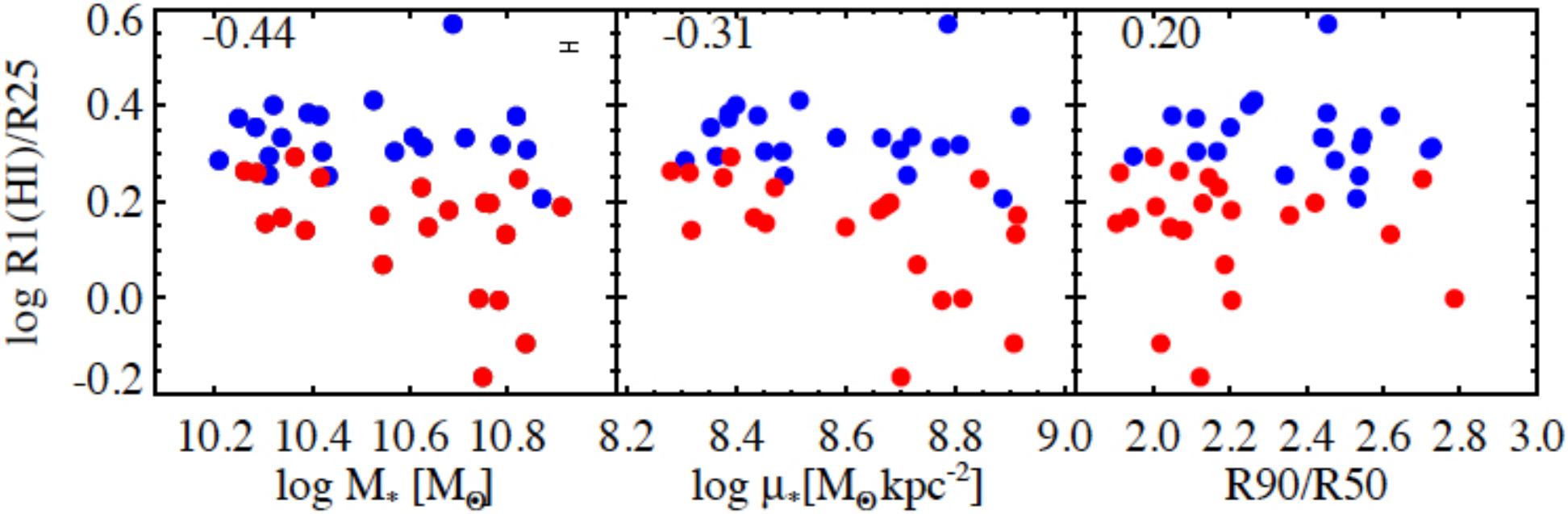
Galaxies with unusually blue outer disks

Control sample matched in optical properties



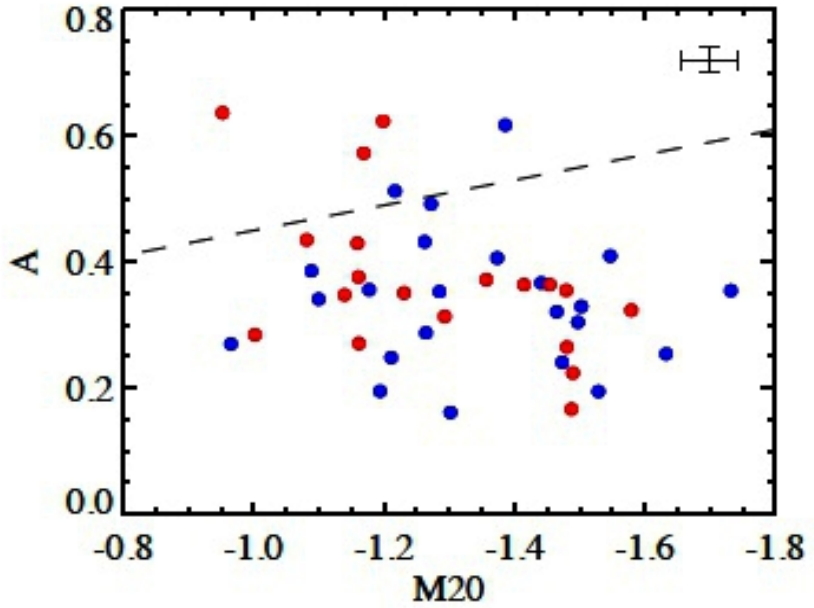


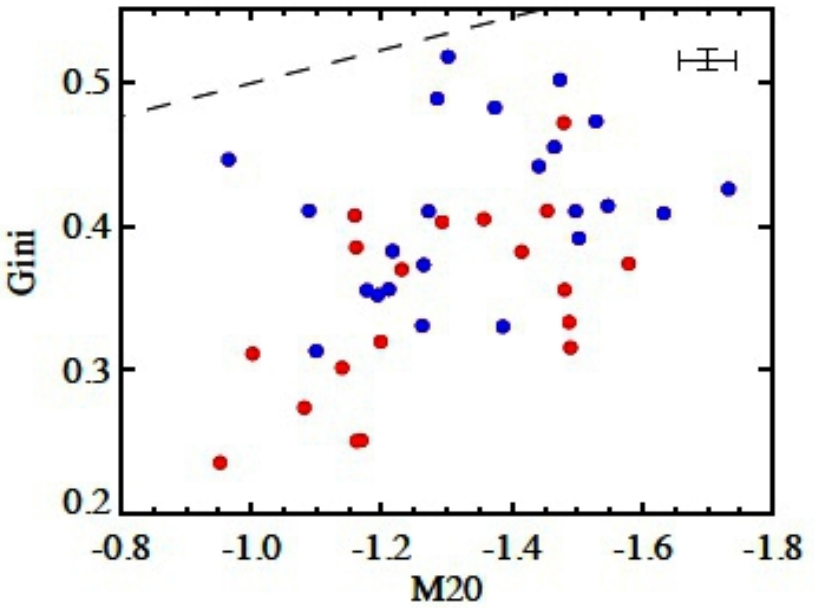
The BlueDisk galaxies have larger HI/optical disk size ratios



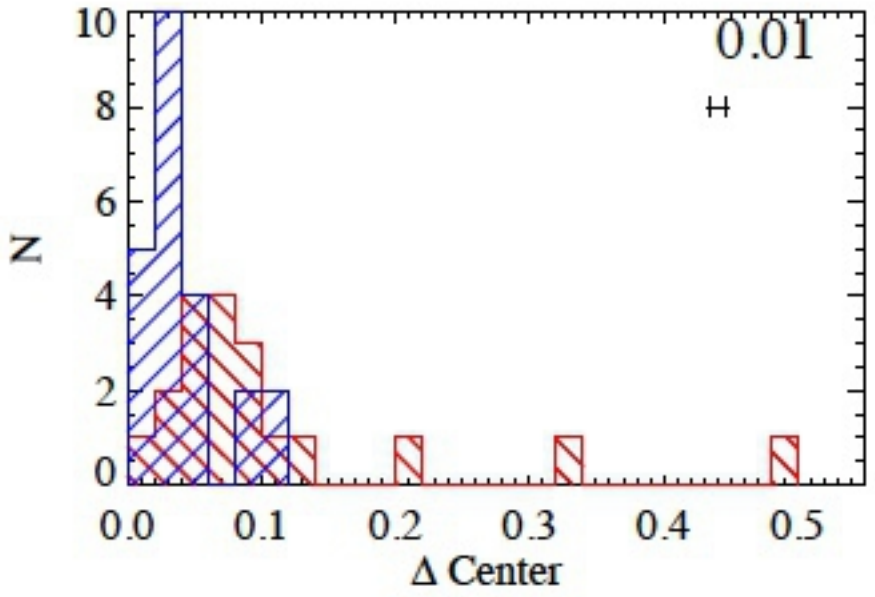
Wang et al 2013

The HI-rich galaxies display no signs of distrurbances due to interactions and have CAS parameters similar to the controls.

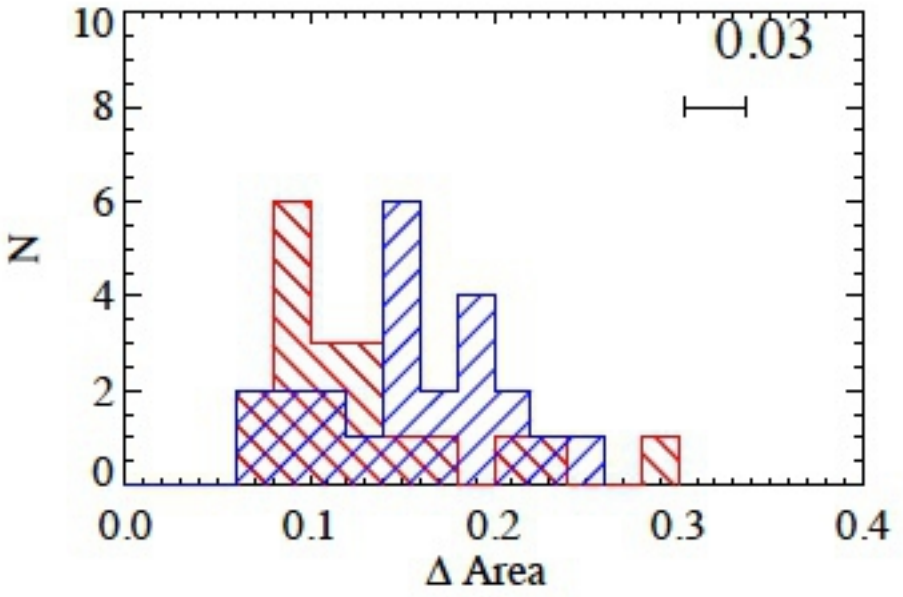


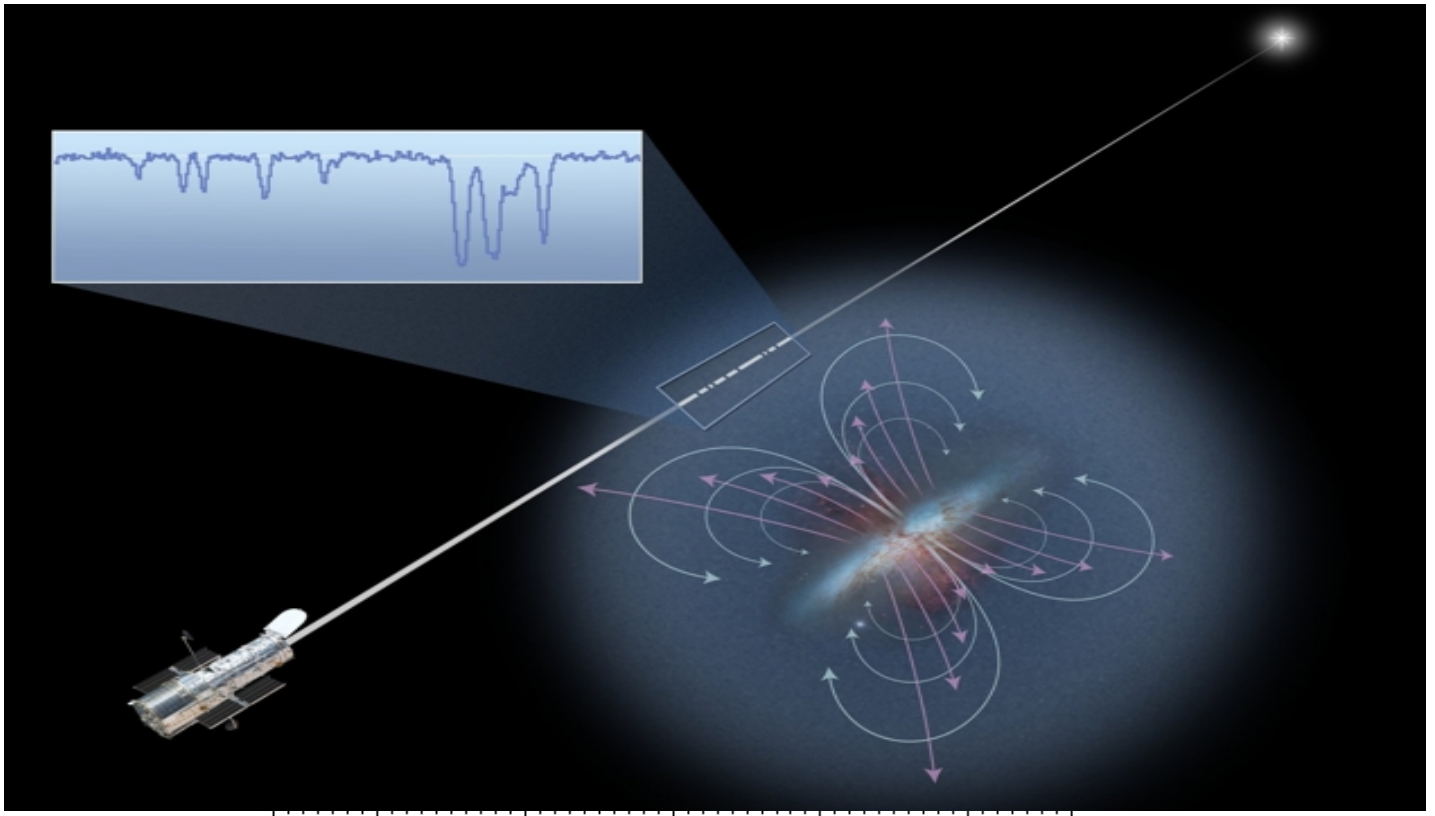


Their optical and HI centers are MORE aligned

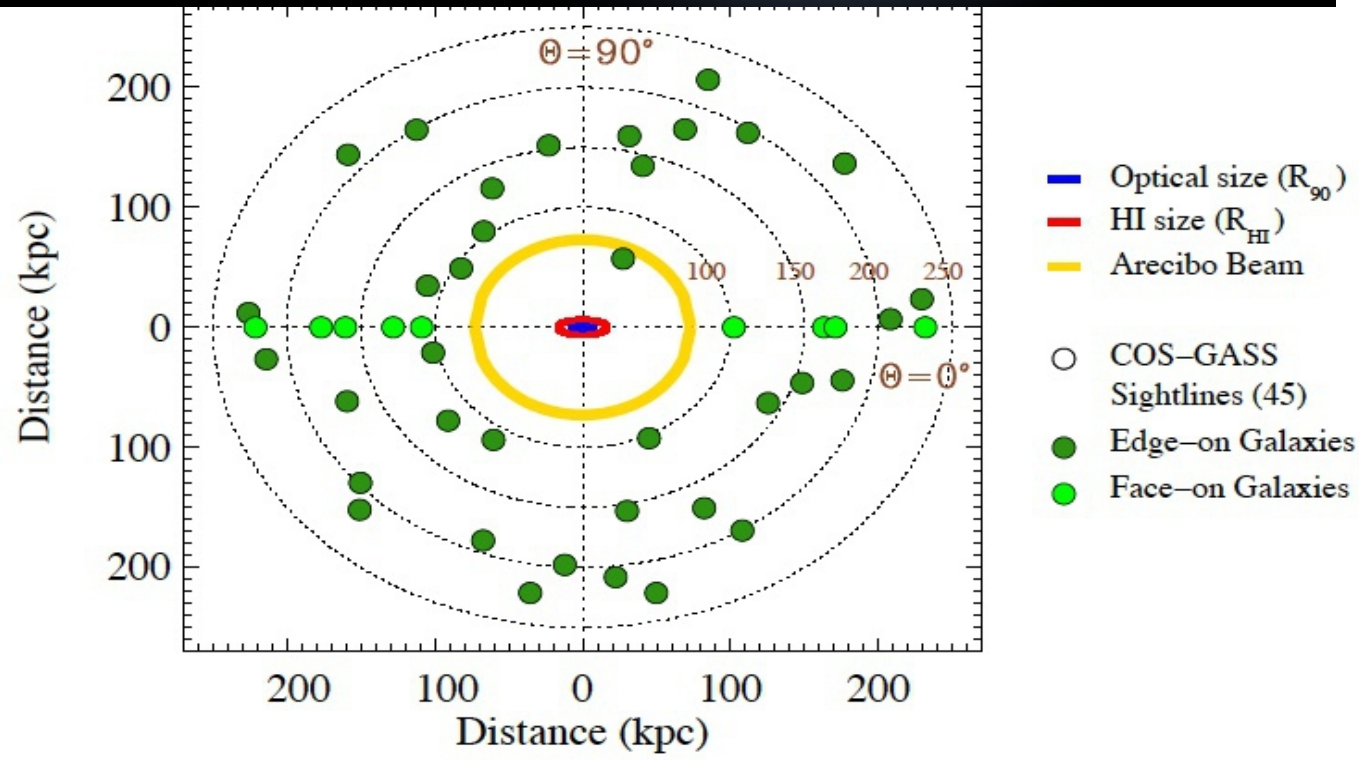


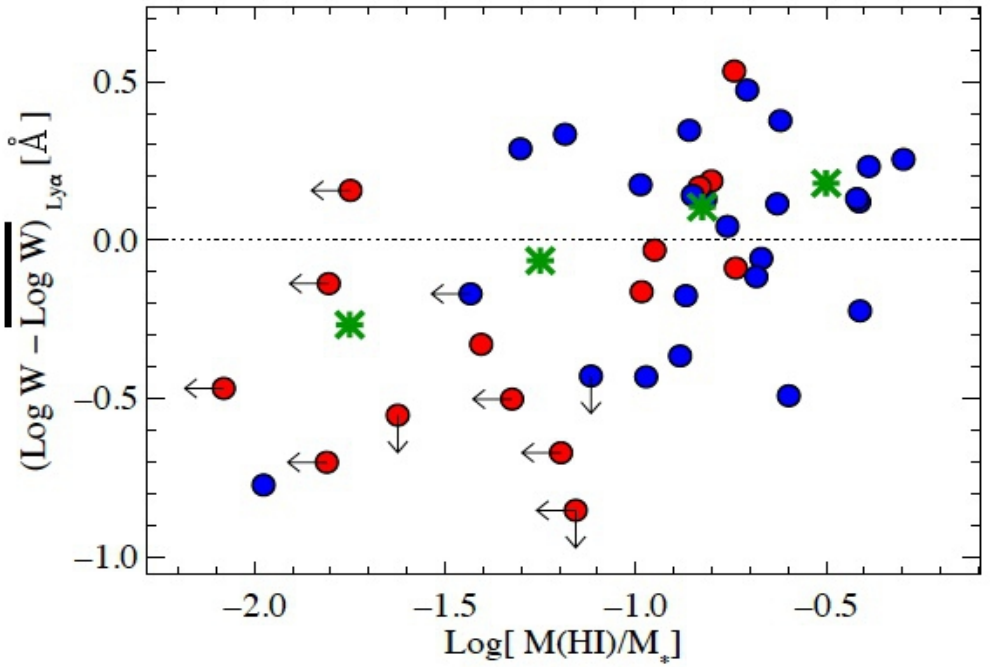
Outer HI contours more irregular

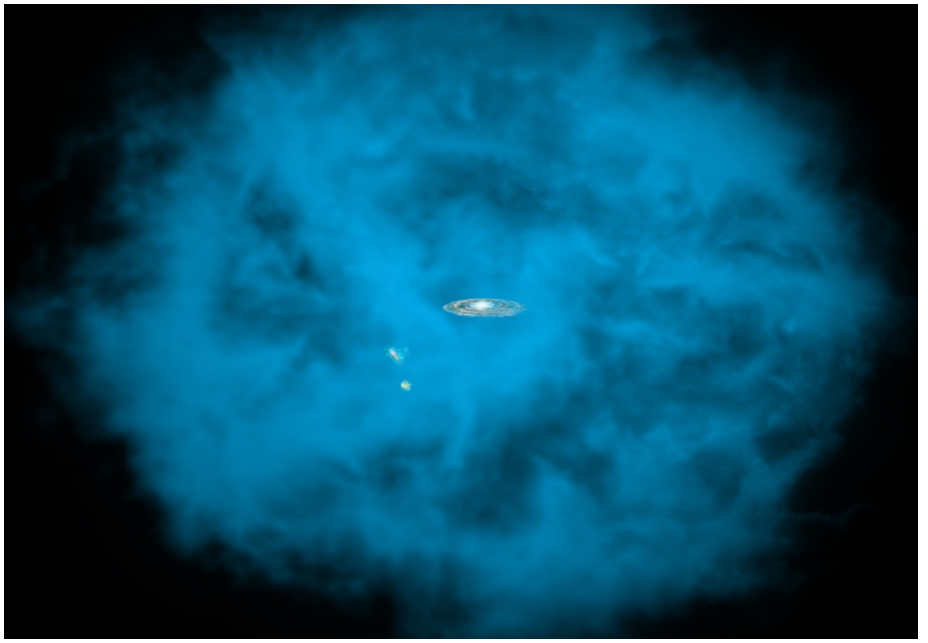


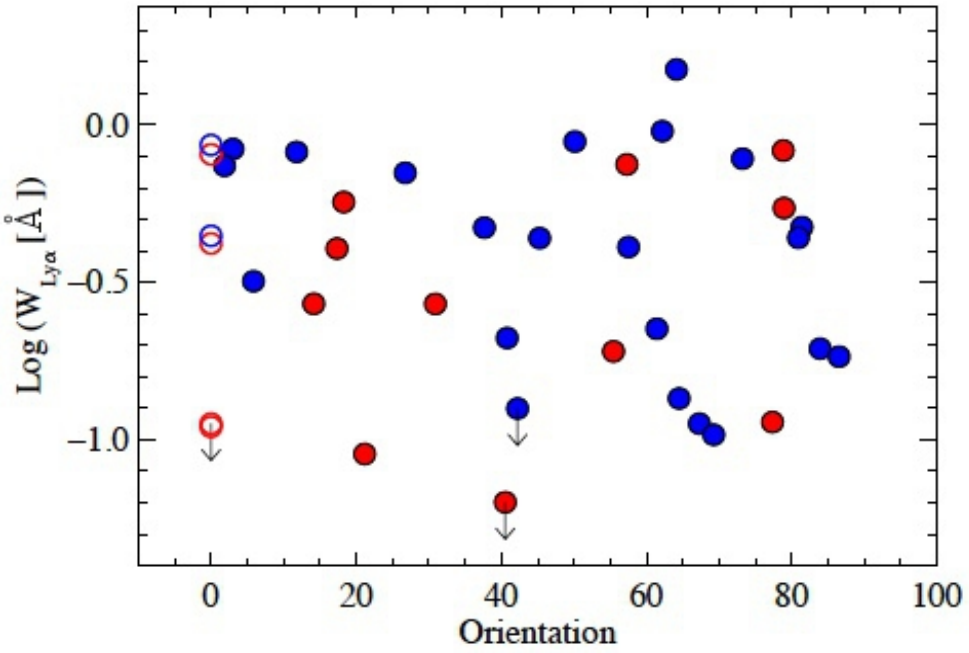


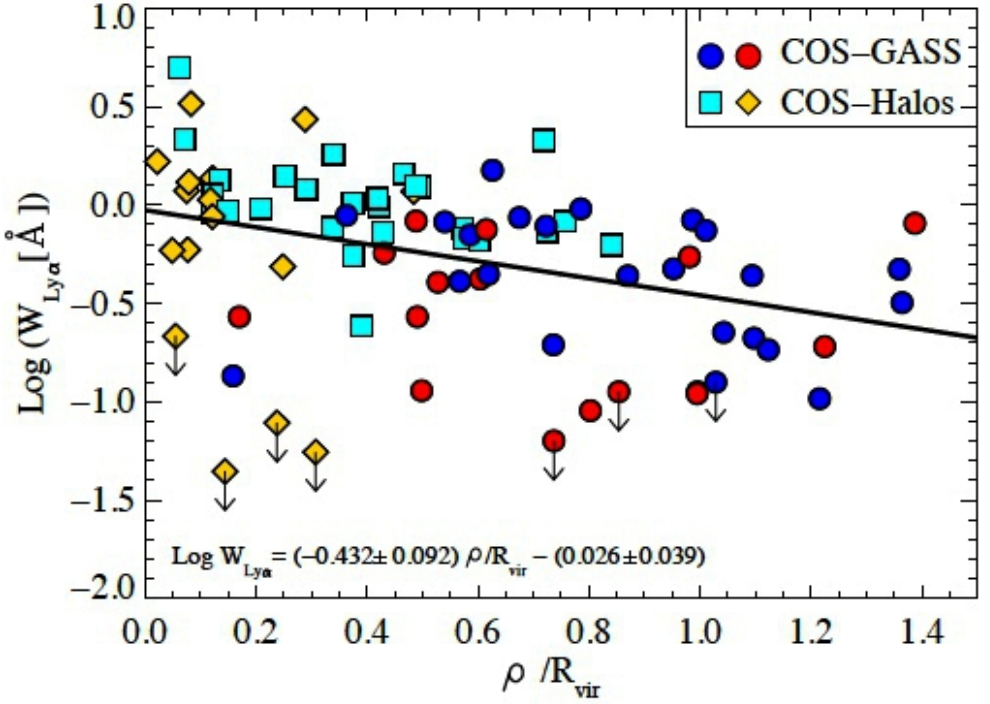
UV absorption-line spectroscopy of diffuse gas from COS HST observations




0.5
0.0
−0.5
−1.0
−2.0
−1.5
−1.0
−0.5
(Log W − Log W)$_{Ly\alpha}$ [Å]
Log[M(HI)/M$_*$]




0.0
−0.5
−1.0
0
20
40
60
80
100
Log (W$_{Ly\alpha}$ [Å])
Orientation


1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
COS−GASS
COS−Halos
Log W$_{Ly\alpha}$ = (−0.432± 0.092) ρ/R$_{vir}$ − (0.026±0.039)
Log (W$_{Ly\alpha}$ [Å])
ρ /R$_{vir}$

These are small targeted programs.

The “dream” is to make this possible across large surveys – the range of questions that could be addressed would be very much larger.

Coordination, transparency, willingness to make data and tools public is key

Many sociological issues often prevent the dream from being realized. The astronomical science community consists of many warring cliques who believe the way forward is to kill off competing programs. The ability to recognize SCIENTIFIC linkages and complementarity Is important and needs much more nurturing.