Galaxy morphology and environment

Q What are some examples of processes important in forming galaxies that

- are fairly independent of the galaxy's environment
- that depend on a galaxy's environment

?

Density-morphology relation

No of ellipticals & S0 galaxies increases as local density of galaxies ↑

No. of spirals ↓

Dressler (1980), Postman & Geller (1984)

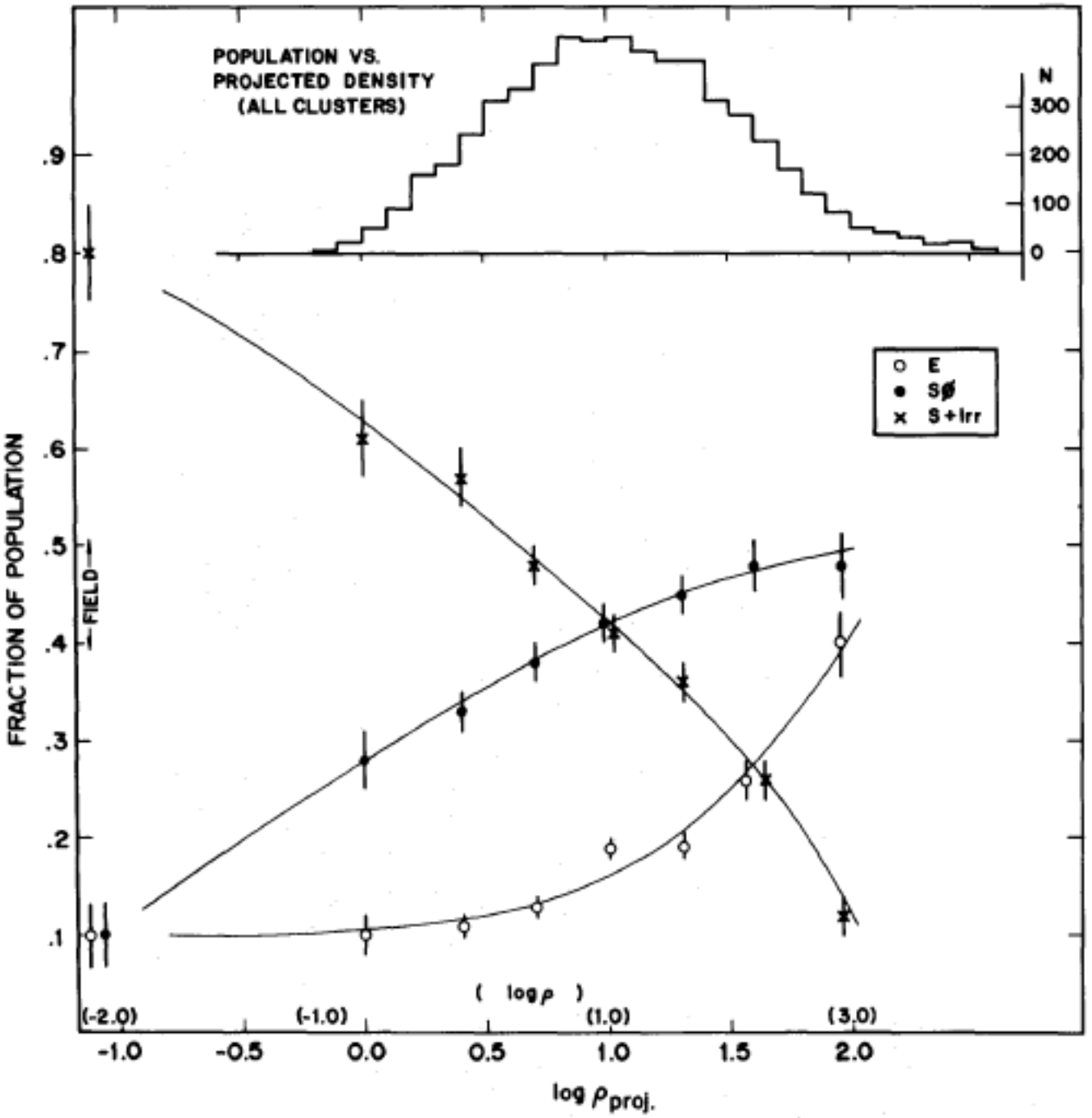


FIG. 4.—The fraction of E, S0, and S+I galaxies as a function of the log of the projected density, in galaxies Mpc^{-2}. The data shown are for all cluster galaxies in the sample and for the field. Also shown is an estimated scale of true space density in galaxies Mpc^{-3}. The upper histogram shows the number distribution of the galaxies over the bins of projected density.

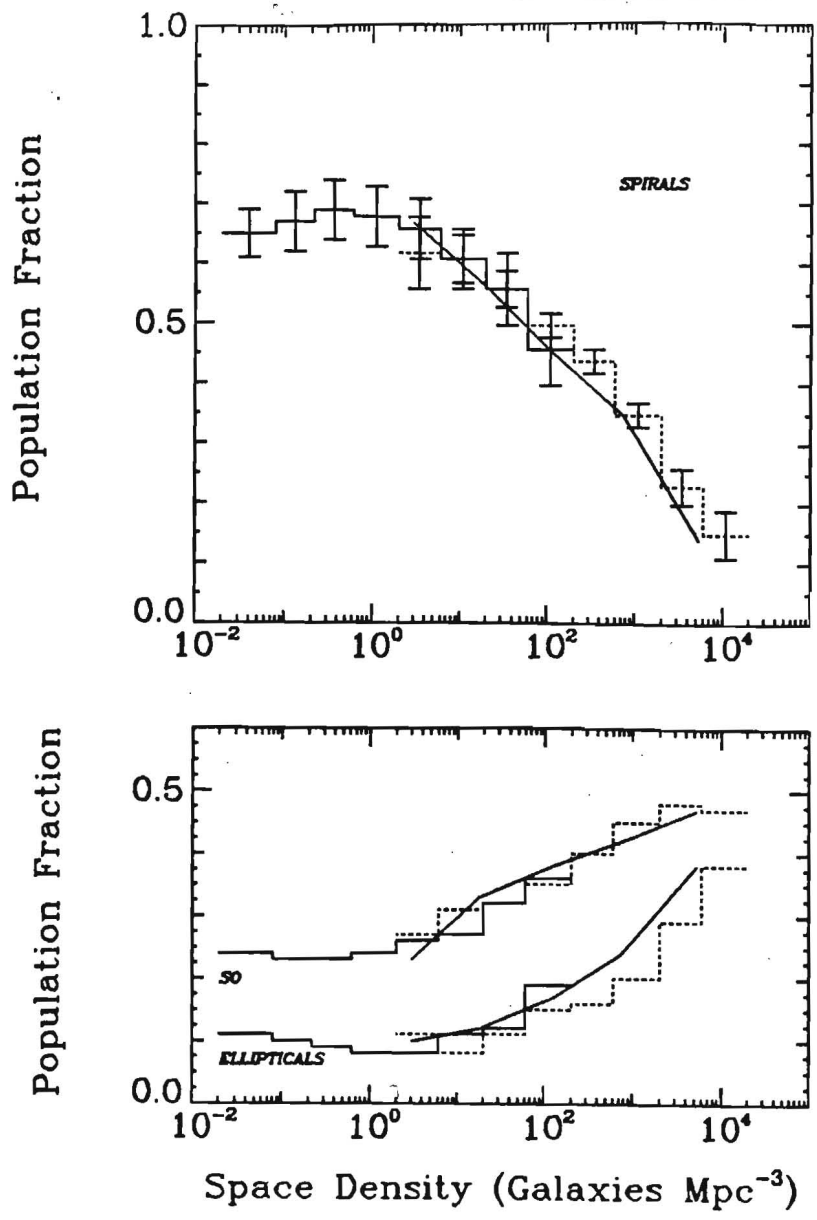


FIG. 1.—Population fraction as a function of space density for the CfA sample. The group contribution to the morphology-density relation is indicated by the solid histograms; the cluster contribution, by the dashed histograms. Dressler's morphology-density relation is indicated by the solid curves which are color corrected and shifted to correspond to $H_0 = 100$ km s^{-1} Mpc^{-1}.

Galaxy zoo: citizen science and galaxy morphology

An amazingly successful SDSS science outreach project

Q: Is the galaxy simply smooth and rounded, with no sign of a disk?


Smooth


Features or disk


Star or artifact

For most of the questions we want you to concentrate on the galaxy which is right in the middle of the picture. If the galaxy has just a smooth shape, often which gets brighter towards the middle, you should click **Smooth**. If you can see anything other than a smooth shape, for example a pattern, bar or distortion, then choose **Features or disk:**. Sometimes there are no obvious features, but the galaxy looks like it must be a flat disk. This might be because it appears very thin, or because it seems to have a well-defined edge, rather than becoming gradually fuzzier the further from the centre you look. In this case you should also choose **Features or disk.**

Have a go yourself... click on the galaxy images below to find out what we think the answer should be for each one.





Q: How rounded is it?

Completely round | In between | Cigar shaped

If the galaxy is smooth and rounded, exactly how rounded does it appear? Is it more or less **Completely round**, very flattened and '**Cigar shaped**', or somewhere **In between**?

Why not have a go yourself... click on the galaxy images below to see our answers.

Q: Could this be a disk viewed edge-on?

Yes

No

How a galaxy appears depends on the angle we look at it. When we look at a disk galaxy from the side, the disk appears as a thin line. This may be all there is, it may have a bulge in the middle, or the disk might be embedded in some larger fuzziness. If the galaxy isn't very thin, or you can see spiral arms, then the disk isn't edge on and you should choose **No**.

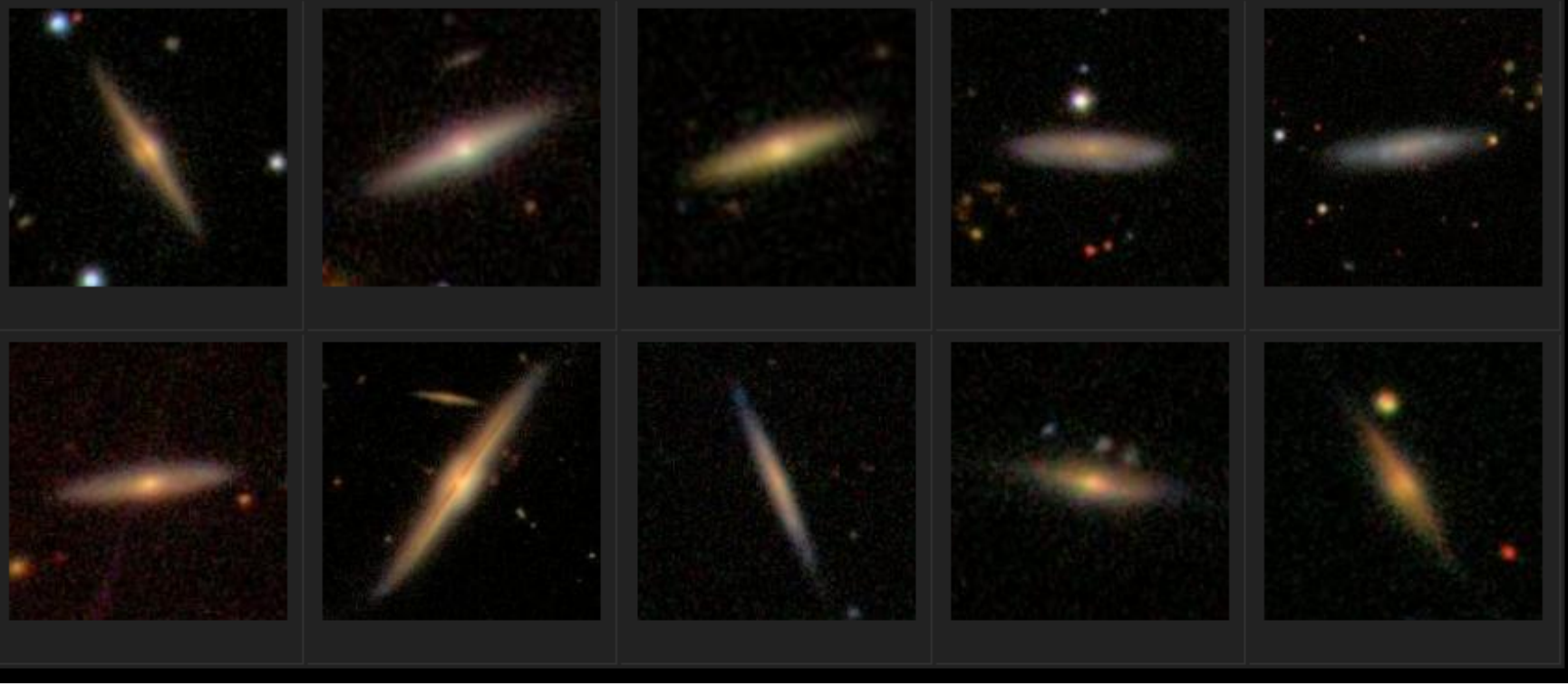
Have a go... click on the galaxy images below.

Q: Does the galaxy have a bulge at its centre? If so, what shape?

Rounded | Boxy | No bulge

There is often a bulge of stars at the centre of a disk galaxy. If your answers to previous questions have indicated that the galaxy is an edge-on disk we would like to know about its bulge. Most bulges appear roughly round in shape. However, if you notice a bulge that appears square or rectangular, then please click **Boxy**. These are often rather subtle! If you don't see any bulge, then answer **No Bulge**, otherwise click **Rounded**.

Have a go... click on the galaxy images below to see our answers.



Q: Is there any sign of a spiral arm pattern?


Spiral


No spiral

A straightforward question — no matter how many arms there are, or how obvious they are, if you can see them then click the **Spiral** button.

Why not have a go... click on the galaxy images below.

Q: How tightly wound do the spiral arms appear?


Tight


Medium


Loose

This question is a little tricky. Do the spiral arms wrap **Tight** around the galaxy's nucleus, or are they **Loose** or perhaps some **Medium** between the two?

Try clicking on the galaxy images below to get an idea of what we mean.










etc etc .....

- See galaxy zoo homepage for rest of questions that are asked http://www.galaxyzoo.org

- Q: you are on the galaxy zoo science team. You have morphological classifications (elliptical vs spiral) from over 80,000 participants in the general public. How should you best use these classifications ?

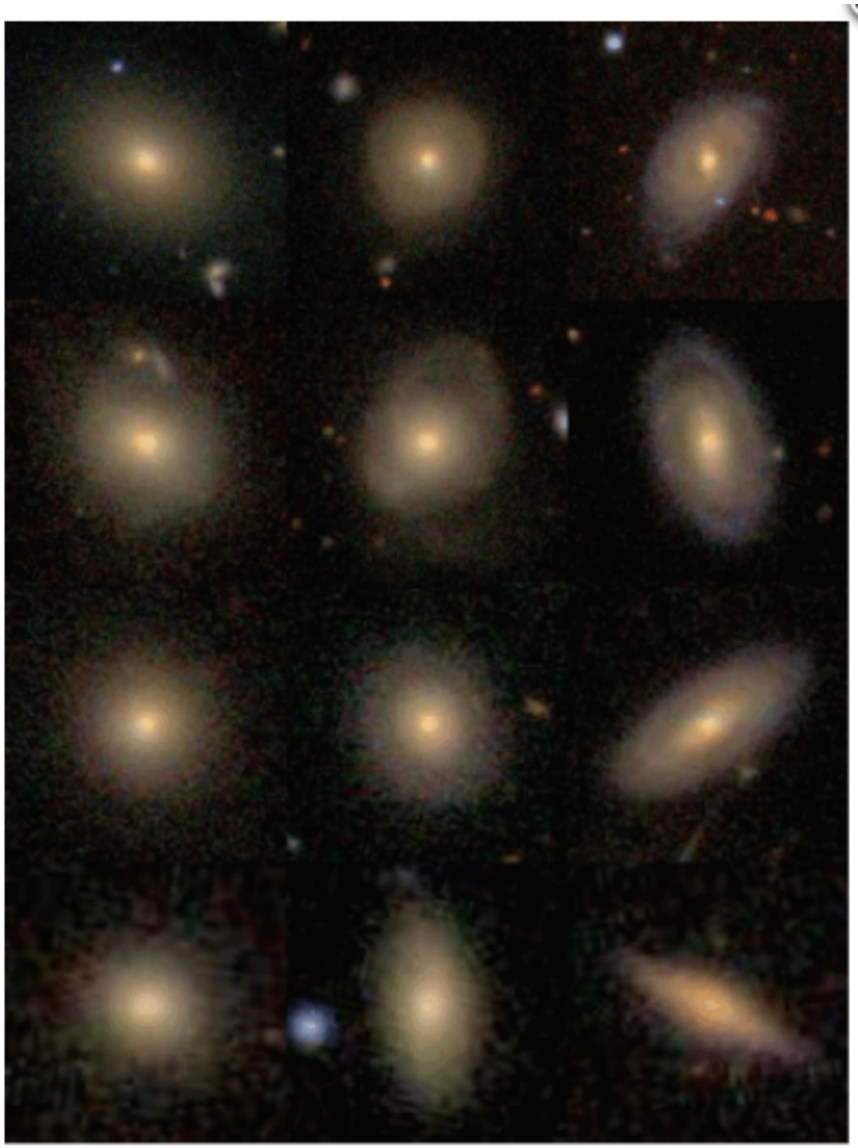


Figure 3. Example images illustrating the appearance of galaxies with different morphological-type likelihoods. Objects in the left-hand, centre and right-hand columns have p_{sp}~ 0.1, 0.5 and 0.9, respectively. All objects are at a redshift z~ 0.05, but each row

- Each galaxy is assigned a 'likelihood' of being spiral or elliptical, depending on the proportion of classifications for that type

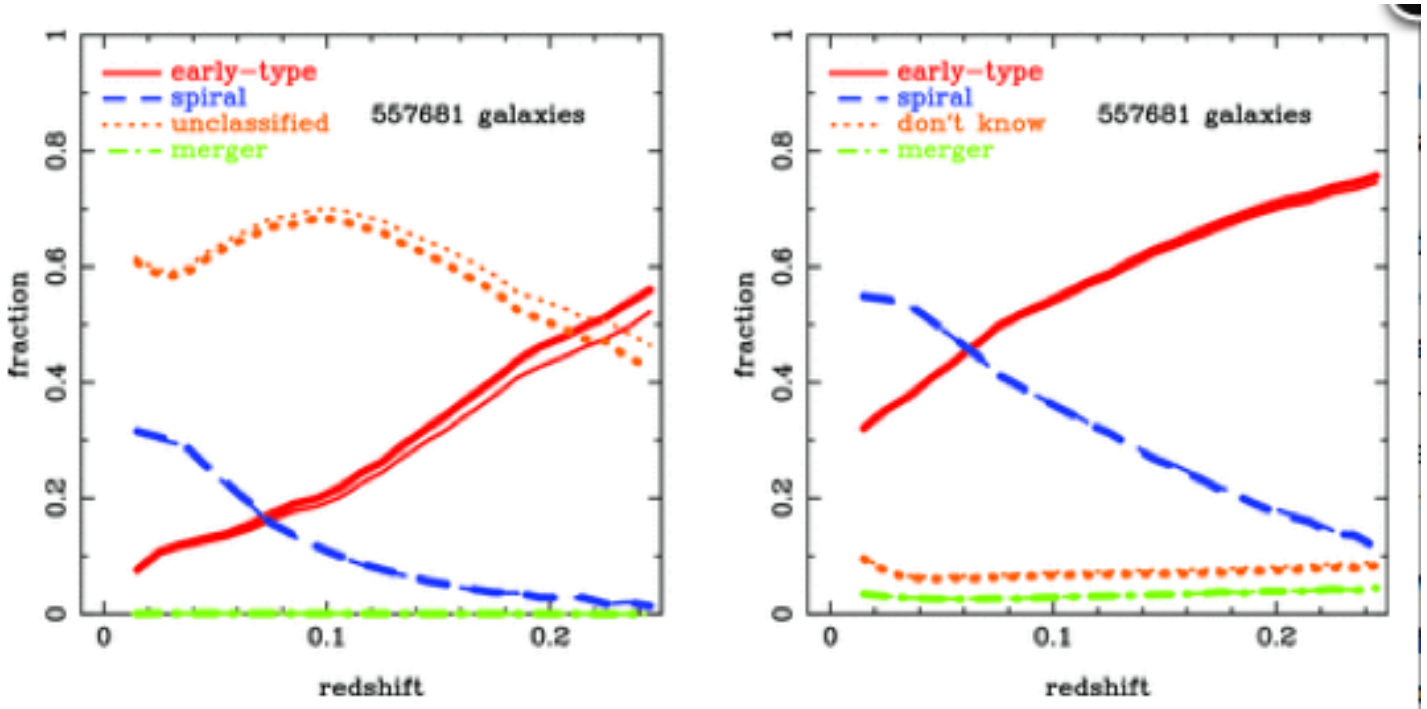


Figure 1. Morphological-type fractions from our *full sample* of raw Galaxy Zoo likelihoods, plotted as a function of redshift. Classifications are based (left) on a likelihood threshold of $p > 0.8$, and (right) directly on the likelihoods themselves. The thick and thin lines

- Then either only use galaxies with high probability (left) or assign fractionally to each class
- Q: which is the best way?

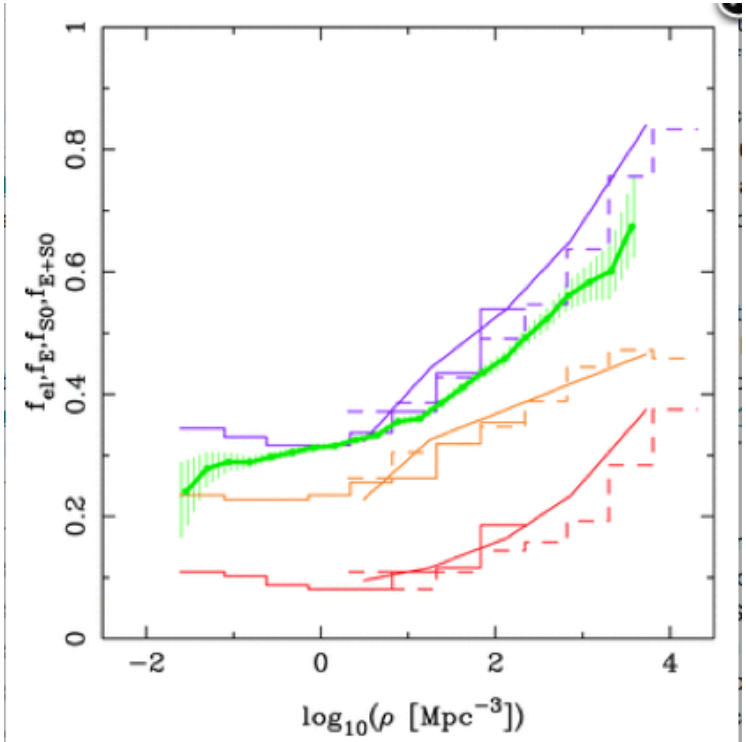


Figure 9. The thin lines reproduce the morphological-type fractions versus local galaxy volume density from fig. 1 of PG84. From low to high, the groups of lines correspond to ellipticals (red), S0 galaxies (orange) and ellipticals and S0 galaxies combined (purple). In each group, the solid and dashed histograms represent data from CfA groups and clusters, respectively (Huchra et al. 1983), and the line indicates the converted cluster relation of Dressler (1980a). For comparison, the points joined by a thick green line show the Galaxy Zoo early-type fraction versus local surface density relation from Fig. 8 converted to the volume density scale of PG84, as described in the text.

Then calculate local density, and we have a new density-morphology relation

Note that S0s are thought to be mostly put in the elliptical class

Environment's effect on galaxies

Galaxies in dense environments are :

- older
- redder
- more concentrated
- higher in surface brightness
- more luminous

than galaxies in voids

large galaxy samples like SDSS's have allowed us to investigate which correlations are the strongest ..... using statistics to investigate these, to cast some light on their causes, in processes of galaxy formation & evolution.

Kauffmann et al (2004) : distinguishes between two different threads in morphological classification

→ structure : concentration, surface brightness, disk-to-bulge ratio

→ star formation : spiral arm strength
#& luminosity of H II regions
dust lanes