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Multivariate and phylogenetic analyses of galaxies

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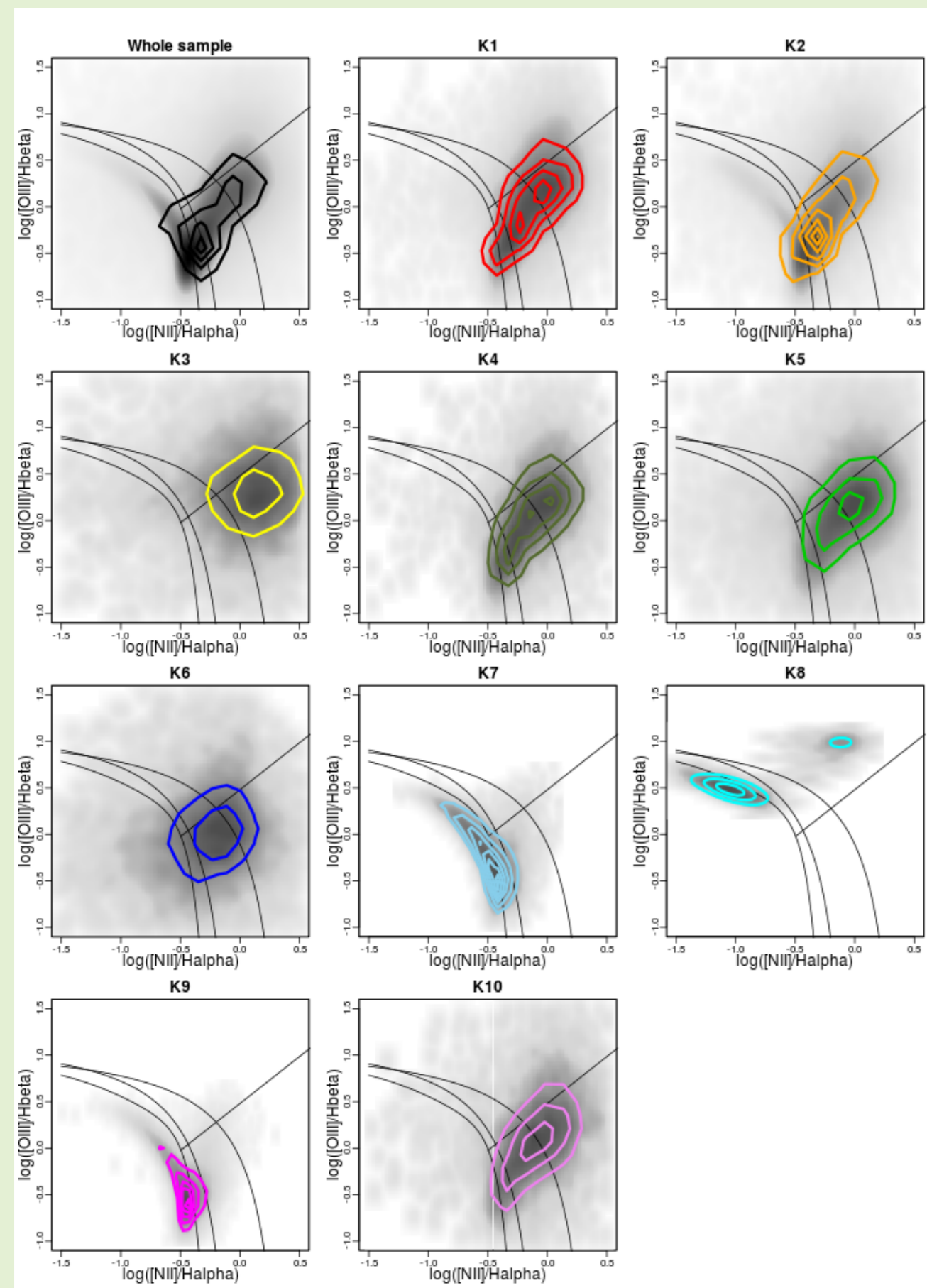
Abstract

Investigating the formation and evolution of galaxies is becoming a complicated process with the increased availability of huge databases as a result of instrumental improvements. In this poster we present preliminary results on two statistical studies using multivariate partitioning and cladistic analyses to find homogeneous groups and their evolutionary relationships.

NYU Value-Added Galaxy Catalog (VAGC)

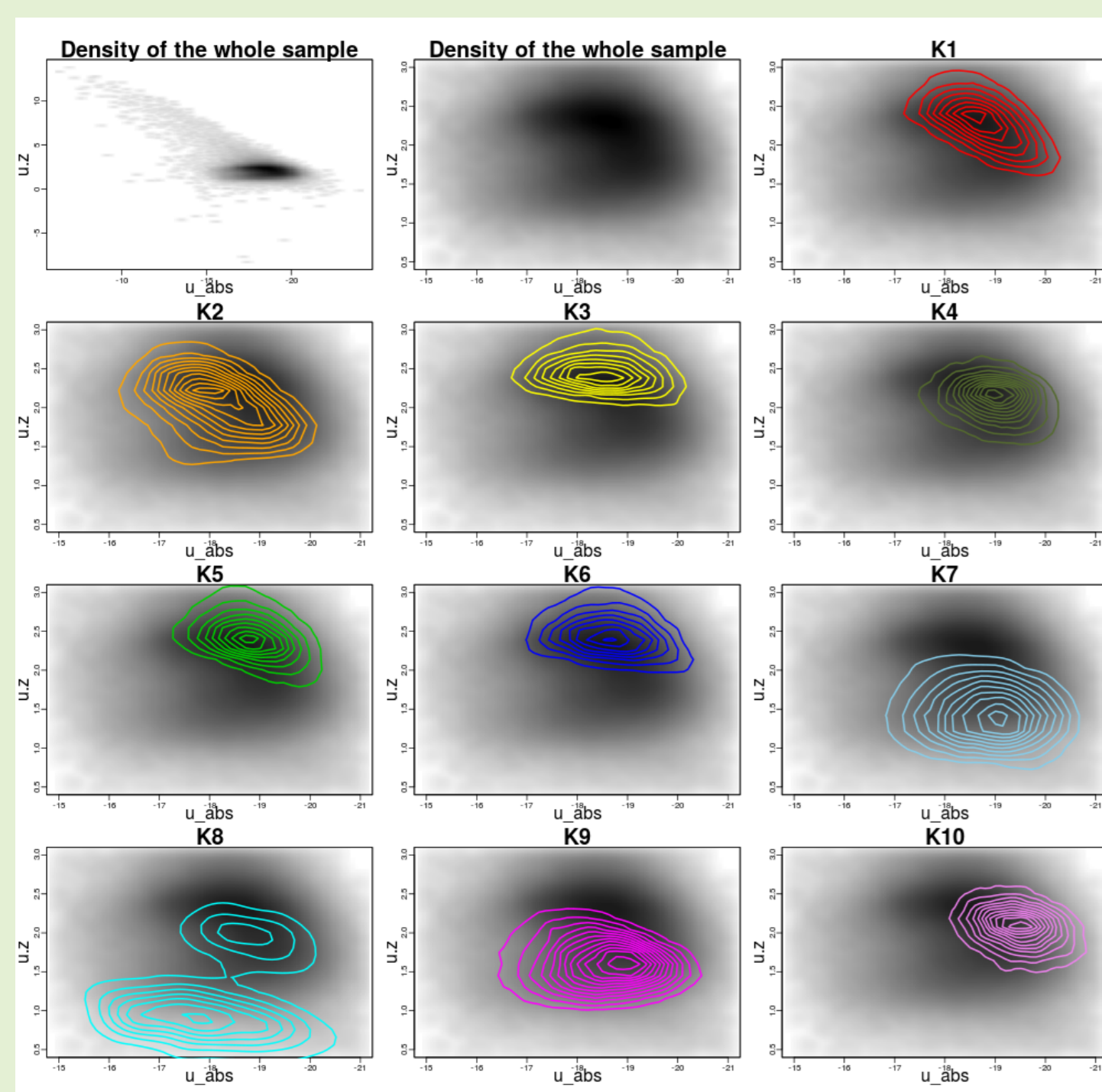
- ▶ We have carried out a **multivariate classification** of **362 923 galaxies** from the **VAGC Catalogue** (Blanton et al 2005).
- ▶ **Independent Component Analysis** is used to determine a set of derived independent variables as linear combinations of the various **49 observed parameters**.
- ▶ A **K-means cluster analysis** is applied on the independent components and the optimum number of homogeneous groups is found to be ten.
- ▶ A **cladistic analysis*** is performed on these ten groups using the median values of the 49 parameters.

BPT diagrams: a more refined classification



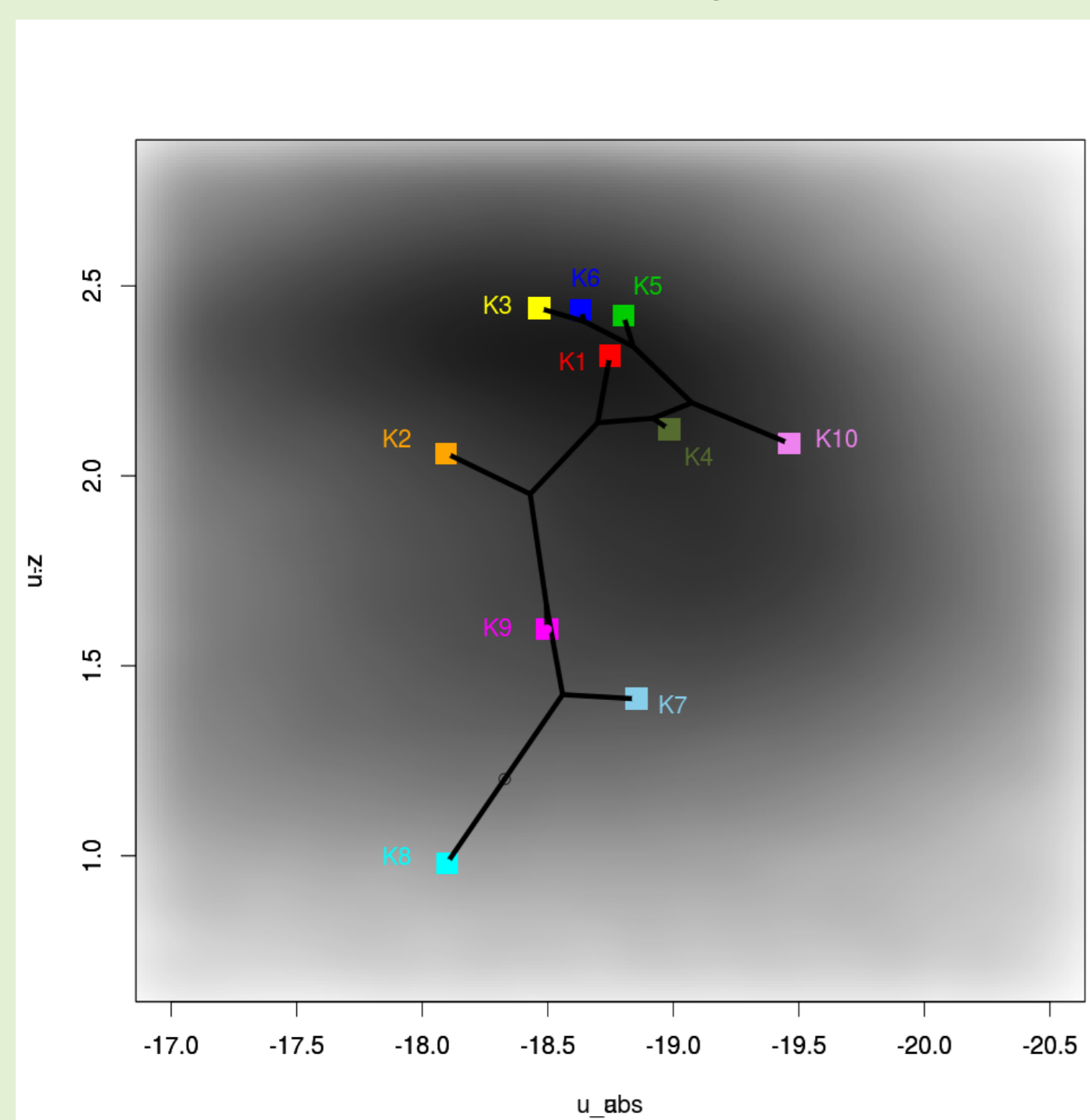
- ▶ K7 and K9 have no AGN, hence are pure star forming galaxies;
- ▶ K3 seems to be mainly composed of LINERs;
- ▶ K2 and K6 are clearly intermediate between star forming galaxies and AGNs;
- ▶ K1, K4, K5, K6 and K10 appear as a mixture of star forming and mainly LINERs galaxies;
- ▶ the very small group K8 is quite peculiar with two peaks, one in the pure star forming region, the other one in the pure AGN zone.

Colour-magnitude diagram: bimodality revisited



- ▶ K1 to K6 clearly belong to the red branch;
- ▶ K7 to K9 are on the blue branch;
- ▶ K10 is in a region often called the green valley;
- ▶ K2 and K4 seem to include also a part of this green valley;
- ▶ K8 appears peculiar, with a very blue part, and some galaxies from the red branch.

An evolutionary path in the colour-magnitude diagram



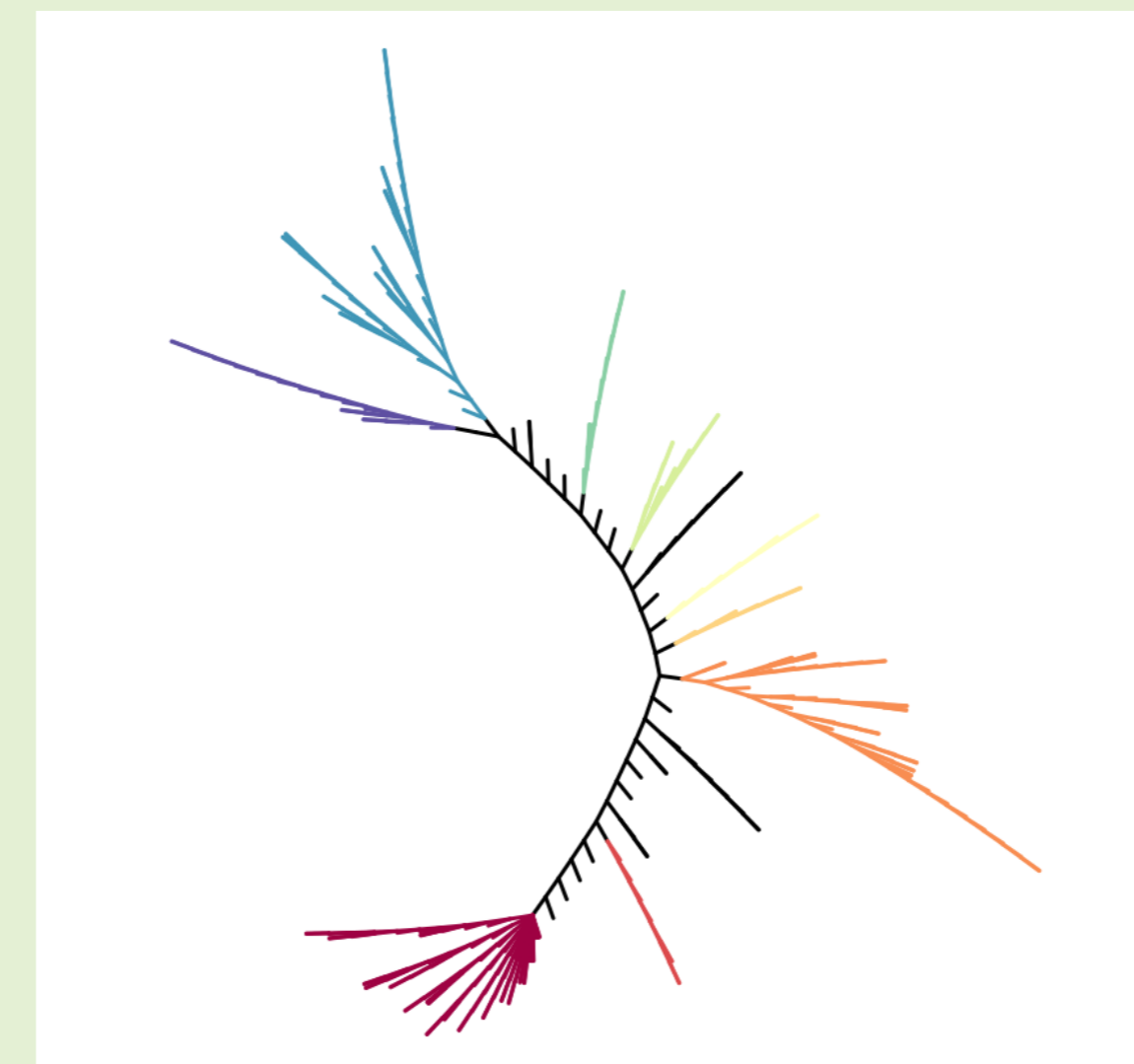
- ▶ The tree, built in a 49-D parameter space, provides an objective evolutionary path when projected on the 2-D colour-magnitude diagram.
- ▶ The tree globally goes from the blue to the red sequences, and shows a clear evolution within each of them.

Our multivariate analysis yields groups of galaxies that could not be identified with 2-D diagnostic diagrams. For instance, groups K1 to K6 belong to the red branch, but most contain mixtures of LINERs, AGNs and star forming galaxies.

Wide-field Nearby Galaxy-clusters Survey (WINGS) Catalogue

- ▶ We have applied a **hierarchical clustering method** followed by a **cladistic analysis***.
- ▶ We use a sample of **1991 galaxies** from the **WINGS survey** (Fasano et al 2006) which are mostly quiescent or host modest star formation activity and low-luminosity AGNs.
- ▶ 1494 galaxies are **members of nearby clusters**, while 497 are **field galaxies at higher redshifts** for purpose of comparison.
- ▶ We use **eleven parameters**: B-V, logRe, surface brightness, H β , D4000, Mass, Sersic index n, H α +NII, Gband, Mg and Na.

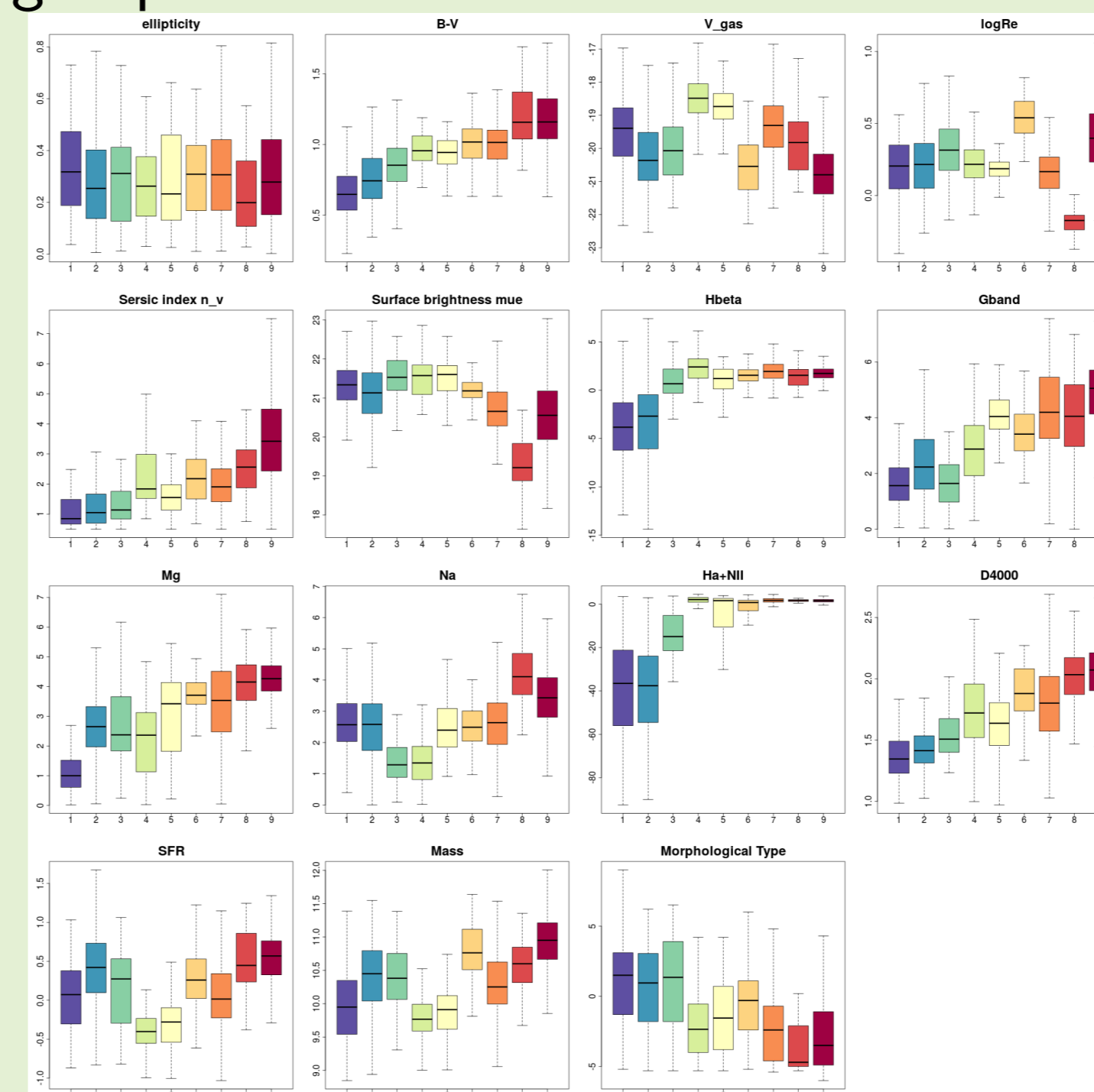
An evolutionary sequence



- ▶ We here show the most parsimonious unrooted tree given by the cladistic algorithm on the 300 "pre-groups" found by hierarchical clustering.
- ▶ The nine groups shown in colour are the larger ones with more than 30 galaxies.

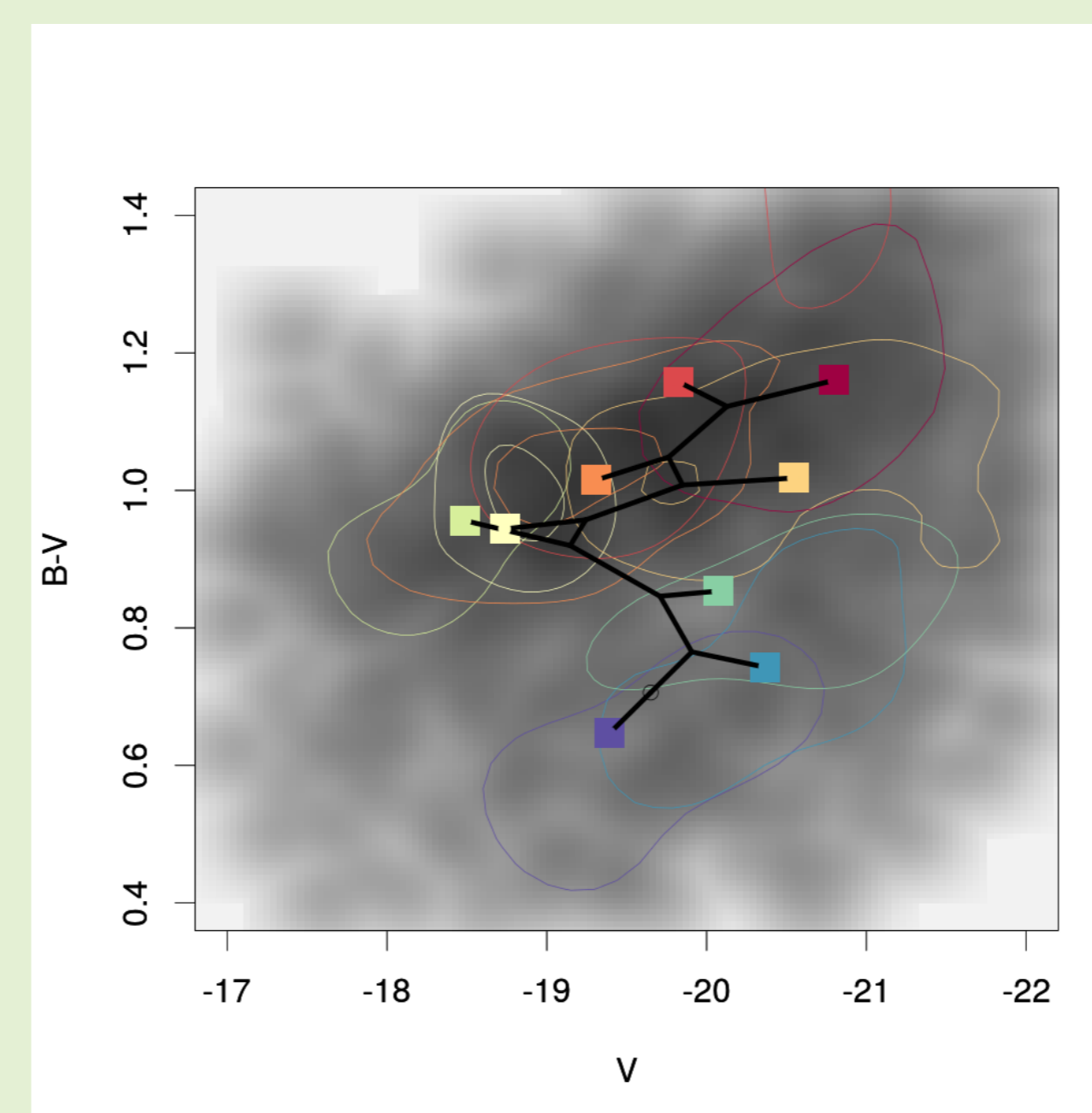
Multivariate properties of nine groups

The boxplots show the quantiles for several parameters for each of the nine main groups defined on the tree above.



- ▶ The colour progression from blue to red grossly matches several trends (B-V, Gband, D4000...).
- ▶ Some parameters are more erratic (logRe, SFR, Mass...).
- ▶ Groups 1, 2, 3 and 8 have roughly the same number of cluster and field galaxies.
- ▶ Groups 4, 5, 6, and 9 are mainly composed of cluster members.

Evolution in the colour-magnitude diagram



- ▶ The tree is here projected onto the 2-D colour-magnitude diagram. The coloured squares are the median values.
- ▶ The density contours show that the distributions are generally not symmetric at all.
- ▶ Despite the different bands, the global projection of the tree is somewhat similar to the one for the VAGC sample in this poster.

This multivariate and phylogenetic study shows that the evolution of galaxies is not driven by only one parameter, like mass or luminosity.

Conclusion

- ▶ The multivariate unsupervised classification analyses reveal groups which are often **mixtures of traditional empirical classes** based on only a few properties. These groups depict a **more realistic picture of galaxy diversity and complexity** than simple eye-based classifications.
- ▶ Phylogenetic tools like cladistics establish the optimal evolutionary paths of galaxies from the data themselves. The **inferred evolutionary scenario is thus more objective and complete**.

References

Blanton M. R., et al, 2005, The Astronomical Journal, 129, 2562
Fasano G. et al, 2006, A&A, 445, 805

* <http://astrocladistics.org>

