Uncovering galaxy evolutionary pathways with unsupervised machine learning techniques

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Motivation & Abstract

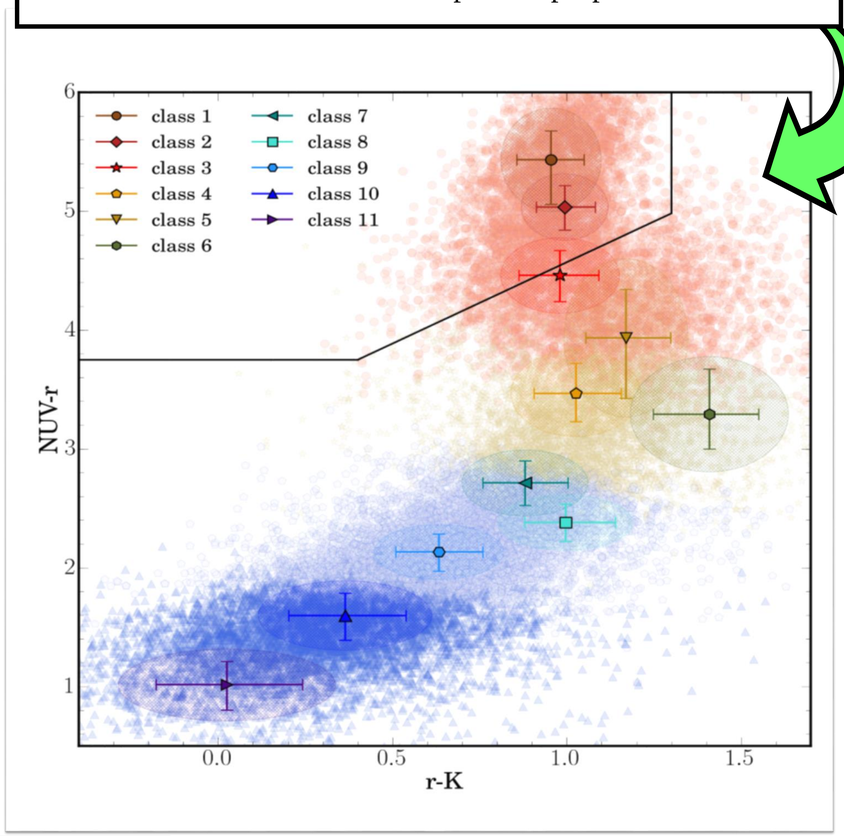
The diversity of galaxies in the Universe reflects the varying balance of processes that influence their evolution. Various galaxy classification schemes have been developed so far, however, in the era of a deluge of astrophysical information a new approach to galaxy classification has become imperative. **Using unsupervised algorithm working in a multidimensional space we revealed the true complexity of ~50,000 VIPERS galaxy population at z~0.7, a task that usual, simpler, colour-based approaches cannot fulfil**. Our clustering approach, which incorporates dimensionality reduction, partitions galaxies into 11 clusters. The galaxy classes follow the galaxy sequence from the earliest to the latest types, which is reflected also in their physical properties not included in the classification scheme.

VIPERS

Our sample of **~50000 galaxies** at **intermediate redshifts** ($0.4 < z < 1.3$) is from VIPERS. The **input features** to the clustering are **12 broad-band absolute magnitudes** and **spectroscopic redshifts**. The absolute magnitudes span the full wavelength coverage of VIPERS: ultraviolet to infrared. The spectroscopic redshifts are included to account for any cosmological evolution of galaxies within the redshift range of the survey. FEM found **11 clusters** of galaxies in this sample.

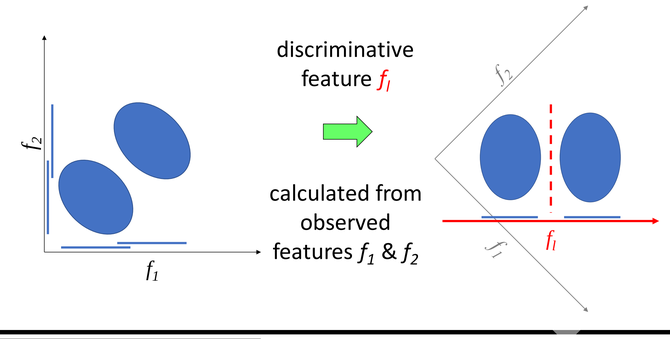
The *NUVrK*$_s$ plane

The colour-colour plane below offers a clear view of the **clustering results**, The black lines corresponds to the standard division of galaxies into passive (above), intermediate (in between), star forming (below) populations. Revealed subclasses have well separated properties.

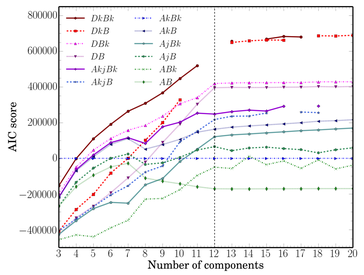


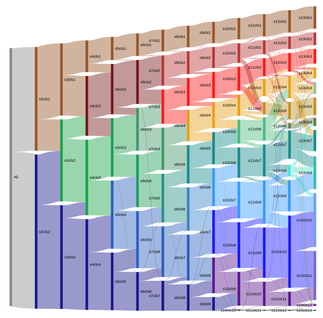
Clustering

We apply the Fisher Expectation-Maximisation **(FEM) clustering algorithm**. It uses **dimensionality reduction to model clusters** in a **discriminative latent subspace** of the input feature space using **Gaussian density functions**. This ensures that only distinguishing information encoded in the input features is used to model the clusters.



Evaluation





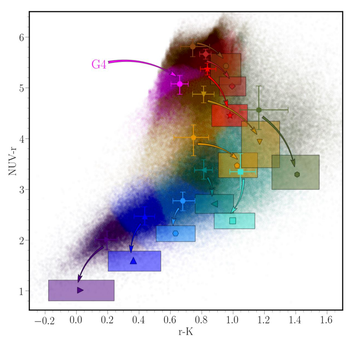
We use the Akaike Information Criterion to evaluate clustering. However, in order to pinpoint the diversity of physical properties among VIPERS galaxies, the final optimal number of clusters is based on the flow of the galaxy distribution among a different number of clusters and their physical properties.

Evolution of subpopulations from z~1 up to z~0

We derive low-redshift sample with the aim to understand the evolution of galaxy subpopulations. Our sample of **~600000 galaxies** at **low redshifts** ($z < 0.3$) is from GSWLC, itself based on SDSS. Clustering in this sample used the **same input features as** the **intermediate-redshift sample**. FEM found **12 clusters** of galaxies in this sample.

see Sebastian Turner talk on Friday!

The partitions of low- and intermediate- redshift galaxies are **broadly consistent.** The offset of results reflects the reduction in star formation of the galaxy population as a whole with time. Galaxies within cluster **G4** may be **post-starburst**. This cluster appears unique to the low-redshift sample.



References

FEM: Bouveyron, C. & Brunet, C., 2012, S&C, 22, 301 / *VIPERS:* Scodeggio, M., et al., 2018, A&A, 609, A84 / Garilli, B., et al., 2014, A&A, 562, A23 / Guzzo, L., et al., 2014, A&A, 566, A108 / *GSWLC:* Salim, S., et al., 2018, ApJ, 859, 11 / Salim, S., et al. 2016, ApJ SS, 227, 2 / *Clustering in VIPERS:* **Siudek, M.**, et al., 2018, A&A, 617, A70 / *Clustering in VIPERS with photometric redshifts:* **Siudek, M.**, et al., 2019. Submitted to A&A / *Clustering in GSWLC:* **Turner, S., Siudek, M.**, et al., in prep