Spectral classification of S0 galaxies in the nearby universe: a tale of two sub-populations

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Epoch of Galaxy Quenching

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A bit of context

NGC 4111, ESA/Hubble & NASA Acknowledgement: Judy Schmidt

Formation in clusters → hydrodinamics

NGC 4402, NASA & ESA

Dressler 1980
Postman et al. 1984
Giovanelli et al. 1986
Goto et al. 2003
Cappellari et al. 2011
Houghton 2015

Formation in the field → gravity

NGC 2207 & IC 2163, NASA/ESA and The Hubble Heritage Team (STScI)

Barnes 1999
Querejeta et al. 2015
Eliche-Moral et al. 2018

- **Previous works.**

  → Photometry (Solanes et al.1989; Burstein et al. 2005; Barway et al. 2007; Williams et al. 2010; Davis et al. 2016…).

  → Spectroscopy (Helmboldt et al. 2008; Xiao et al. 2016…).

- **More recently…**

  → IFS (Fraser-McKelvie et al. 2018; Domínguez Sánchez et al. 2020; Deeley et al. 2020…).

- **Our approach.**

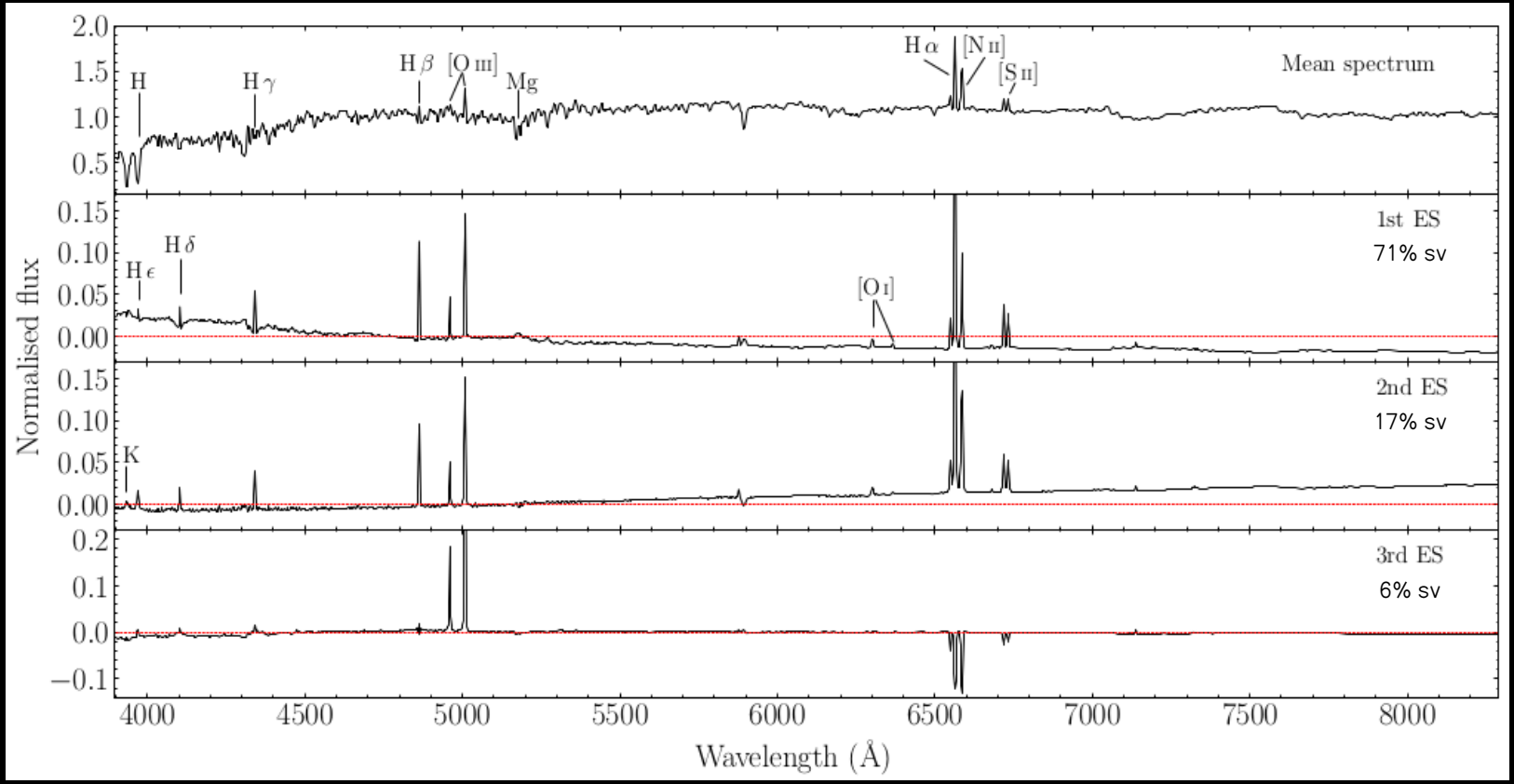
  → Spectroscopy + photometry + a large sample of S0.

Method

- **Sample selection.**

  A magnitude-limited sample of 68,043 SDSS optical spectra of S0 galaxies with $z \leq 0.1$ + large set of spectrophotometric properties from public catalogs. Morphologies are inferred from the automated T-type classification of Legacy SDSS galaxies provided by Domínguez Sánchez et al. (2018).

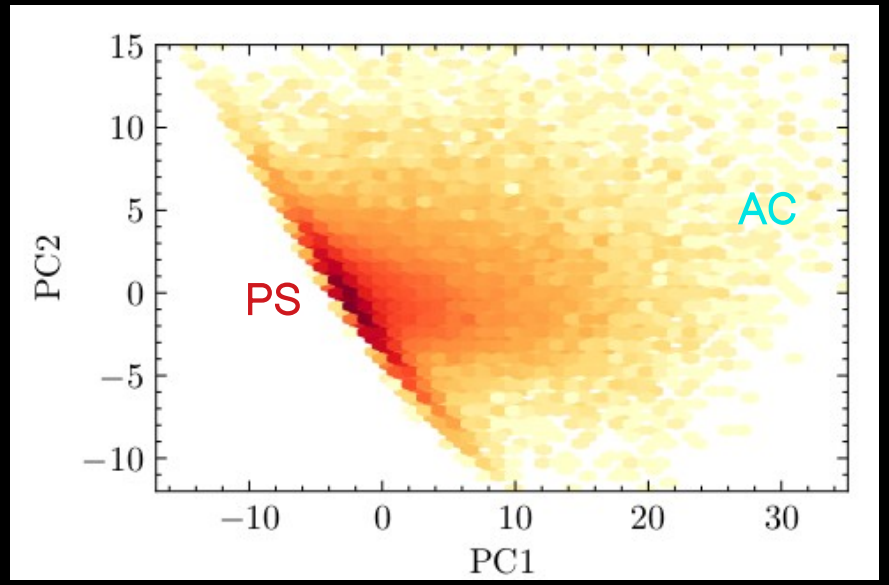
- **Principal Component Analysis.**



Nearly 90% of the sample variance (sv) is captured by the first 2 principal components (ES).

- **Dimensionality reduction.**

  By projecting the S0 spectra on the first 2 principal components 2 main spectral modes are revealed:



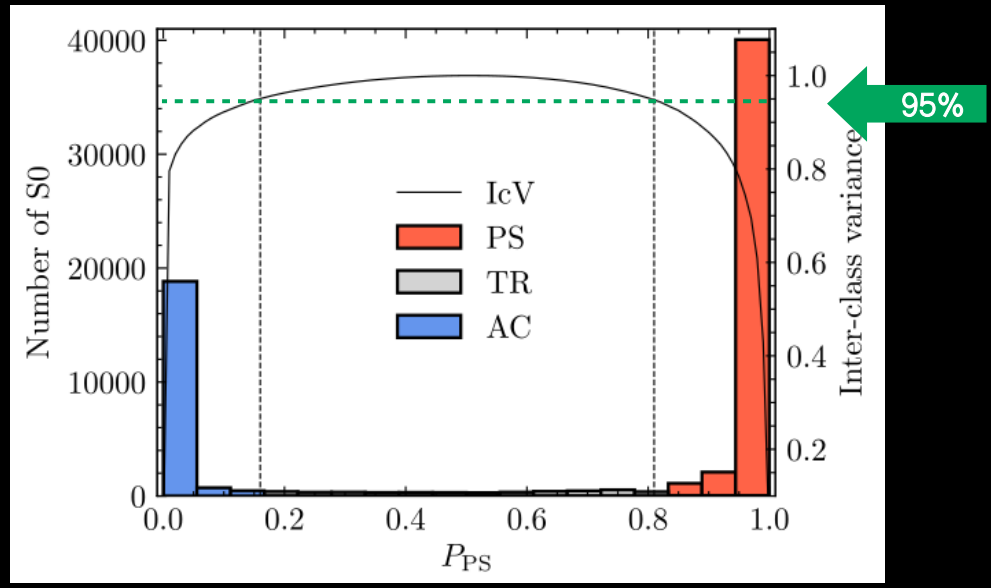
  → Passive Sequence (PS).

  → Active Cloud (AC).

- **Classification.**

  1) Logistic regression.

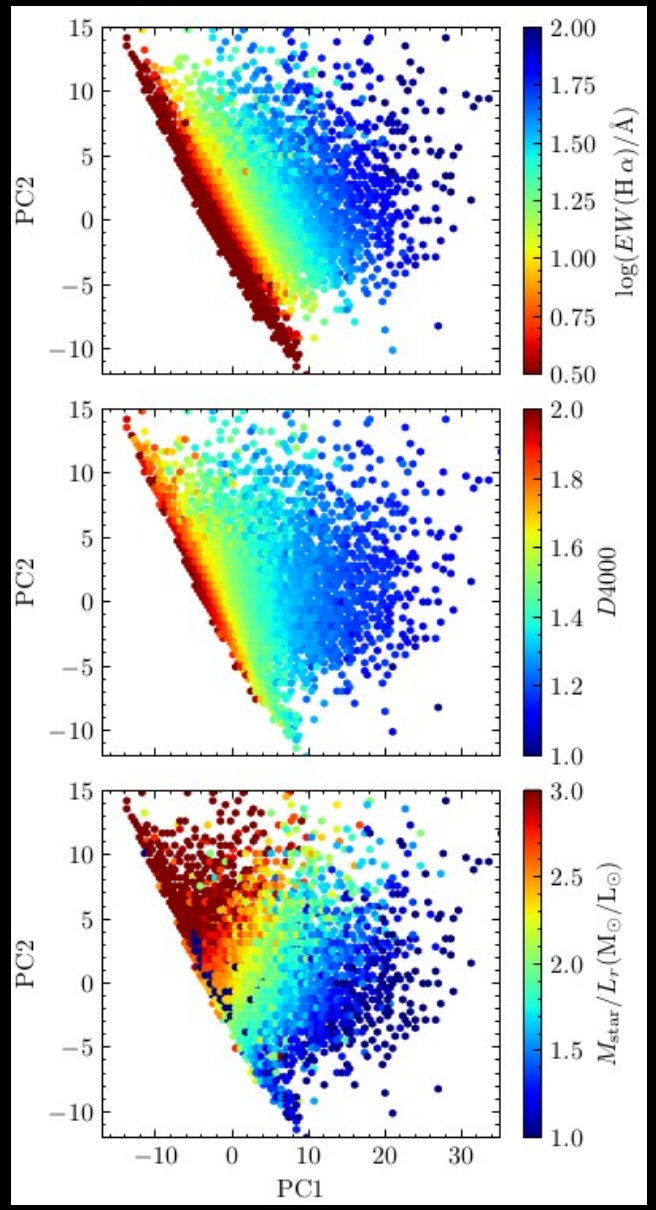
  2) Maximization of the IcV (Otsu 1979).



  PS → 69% of the local S0; AC: → 25% of the local S0.

  The rest of lenticulars are located in an intermediate Transition Region (TR).

Results

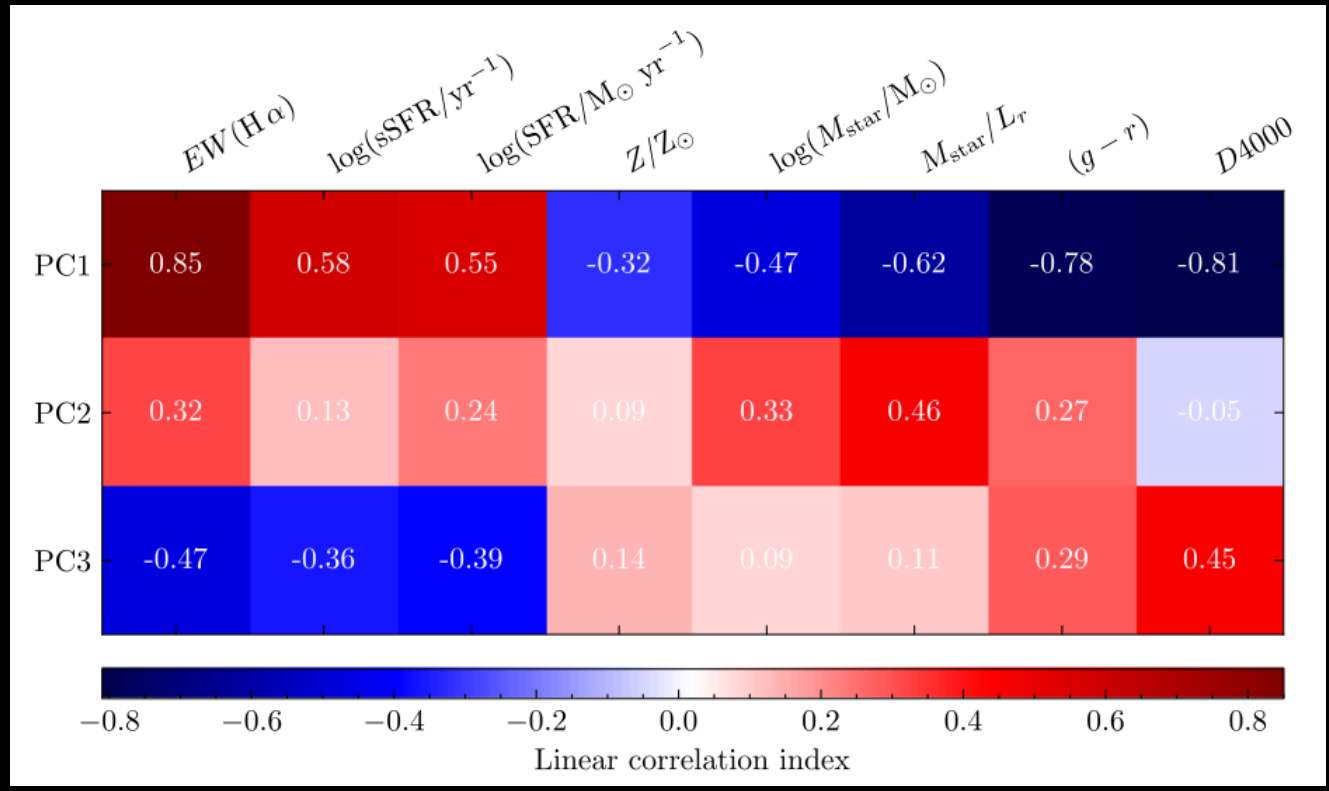


- Correspondence of the modal division with SF properties of S0.

  → galaxies in the AC show active spectra with strong emission lines;

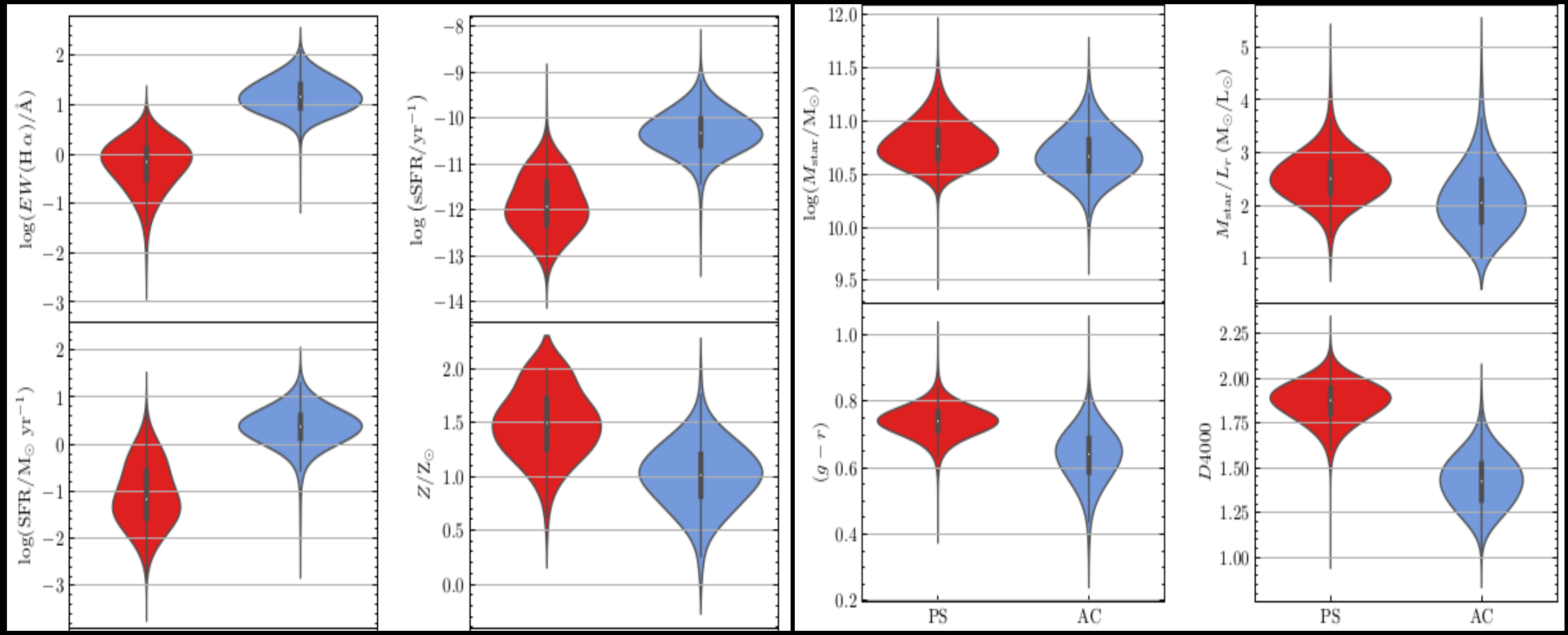
  → expected differences in, at least, those physical properties related with the SF.

- Linear correlations between the PC and some properties of the S0.



✅ For the comparison of the physical properties we use a volume-limited subset of 32,188 S0.

- Comparison of some physical properties of the two main spectral modes.



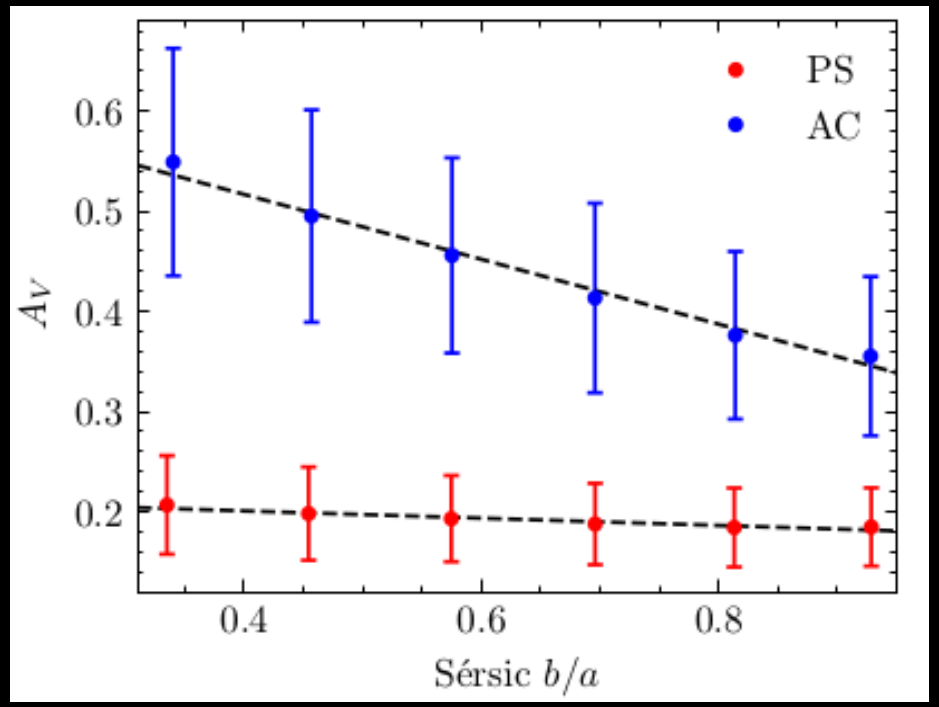
The S0 belonging to the AC mode differ from their PS counterparts in that the former:

i. are slightly less massive (c.f. Fraser-McKelvie et al. 2018; Domínguez Sánchez et al. 2020), although more luminous → lower M_{star}/L;

ii. have a younger, bluer stellar population, which is poorer in metals;

iii. are actively star-forming systems with SFRs ~ $2M_{\odot}yr^{-1}$ → more than one order of magnitude higher than the PS rate.

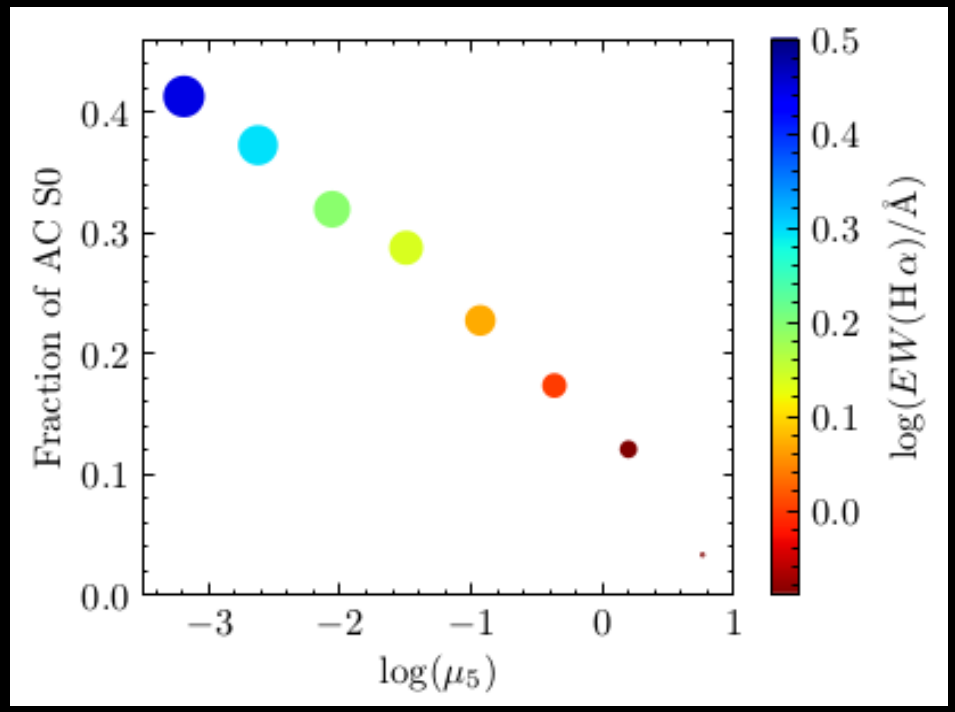
- The ISM of each subpopulation is also different.



✅ Exhaustive tests indicate that our spectral classification is internal-extinction-proof.

✅ Also indicate that the potential effects of the fixed fiber aperture have a negligible impact on the classification.

- The local environment.

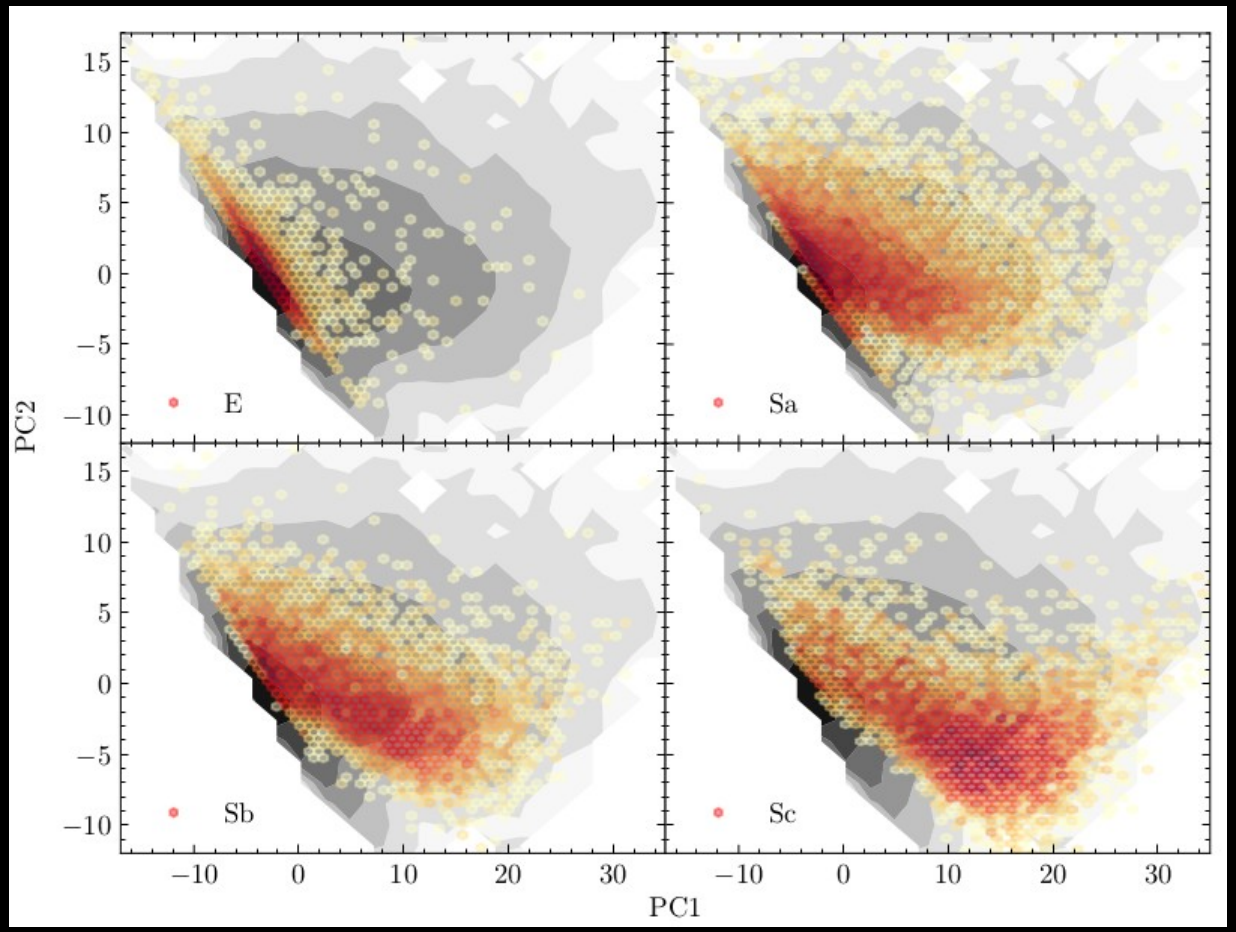


→ Linear decline of the fraction of AC lenticulars with the log of the local galaxy density.

$$\mu_5 = C(\Delta m)\left(R^2 \sum_{i=1}^{5} d_i^2\right)^{-1}$$

→ The strength of the emission lines of AC galaxies and its SFR is also reduced with increasing density.

- Projection of the optical spectra of the other Hubble types on the PC1-PC2 subspace defined by the S0.



→ The concordance between the AC objects and late-type disk galaxies is not restricted to their similar levels of star formation, but extends to the whole optical spectrum.

→ PS lenticulars essentially occupy the same region in the PC1-PC2 subspace than E galaxies.

Summary

- Carried out the most extensive *unbiased* statistical study of the global spectral and photometric properties of the S0 population in the Local Universe.

- Uncovered two main subpopulations of S0 galaxies: ~ 70% of the local lenticulars conform to the traditional view of S0 as passive systems; ~ 25% show spectra with strong emission lines typical of disk galaxies with active star formation. Active S0 have average SFR comparable or higher than the MW's:

  → confirmation of previous findings (e.g. Barway et al. 2013; Gavazzi et al. 2018) that not all S0 are ‘red and dead’. Both the fraction and the activity of AC S0 have been found to be significant.

- There is no clean one-to-one relationship between morphology and spectral class for S0 galaxies:

  → this suggests a difference between dynamic and star-formation time-scales for (S0) galaxies.

- Quantified the relative abundances of passive and active S0 in terms of the local density. Linear decline in both the fraction of star-forming S0 (and the strength of their star-formation activity) with the log of the density that extends across more than four decades. Passive S0 populate all kind of environments.

- Further progress: Our analysis is being extended using MaNGA data.

https://arxiv.org/abs/2005.09016