The metallicity gradients of galaxies in the *Herschel* Reference Survey

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Overview

In our recent work, we found strong correlations between the stellar mass, metallicity and gas content in galaxies. At fixed stellar mass, gas-deficient galaxies are typically more metal-rich than their gas-rich counterparts. However, strong metallicity gradients may bias global metallicity estimates derived from integrated spectra. We are now working on a pilot project to measure metallicitiy gradients for a sample of twenty nearby galaxies drawn from the Herschel Reference Survey. Our sample is representative of normal, star-forming spiral galaxies. We have obtained optical spectroscopic observations using the Very Large Telescope with the FORS2 instrument in multi-object mode, targeting individual HII and star-forming regions across the galaxy discs. From the ratios of the strong emission lines, we estimate the local gas-phase oxygen abundance and construct metallicity gradients. Combining these new data with Herschel PACS/SPIRE far-infrared photometric observations and maps of the HI 21 cm line emission, to trace the dust content and cold gas respectively, will allow the study of the relationships between stars, gas, dust and metals on sub-kiloparsec scales.

1. The *Herschel* Reference Survey

The Herschel Reference Survey is a magnitude- and volume-limited sample covering 323 nearby galaxies in a range of environments, from isolated systems to Virgo cluster members (Boselli et al. 2010).

Sample selection criteria:

- 15 - 25 Mpc volume limit
- 2MASS $K_{sTot} \leq 12$ mag
- Galactic latitude > +55º
- Extinction $A_B < 0.2$

Ancillary data is complete for:

- H, B & V photometry ~ stellar mass
- NUV GALEX imaging ~ SFR
- HI 21cm ~ HI gas mass
- Drift-scan spectra ~ metallicity

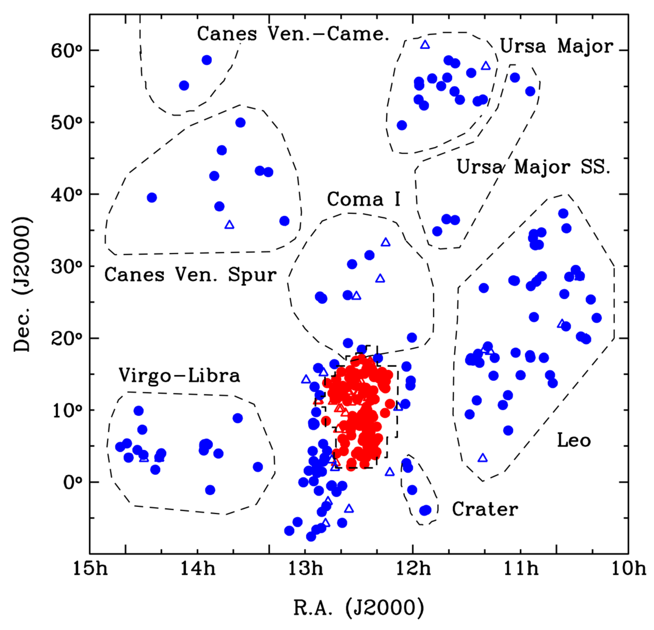

Fig. 1: Sky distribution of HRS galaxies. Virgo cluster members are shown as red circles.

We estimate global oxygen abundances from the ratios of the most prominent optical lines via the relations of Kewley & Ellison (2008).

2. Stellar mass, metallicity and gas relations

We study the role of gas in shaping the mass – metallicity relation, adopting a gas fraction equal to HI mass / (HI mass + stellar mass).

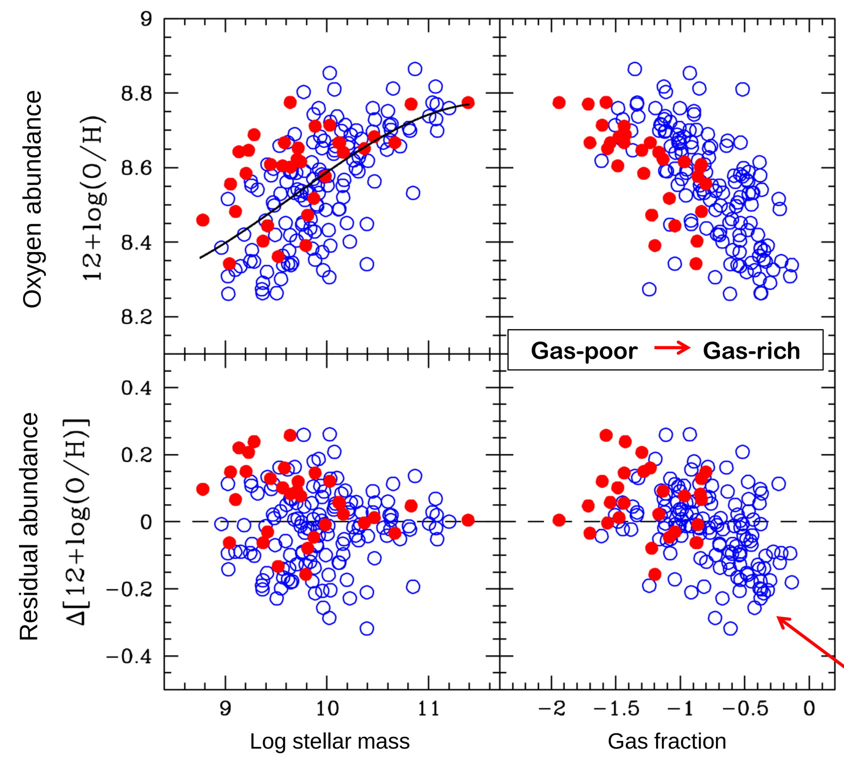

Fig. 2: The relationships between stellar mass (left panels) and gas fraction (right panels) with oxygen abundance (upper panels) and scatter (lower panels).

HI deficiency is:
the difference between the observed HI mass and that expected for an isolated galaxy of similar size and type.

Blue circles – Galaxies with normal gas content

Red circles – Gas deficient objects, i.e. galaxies missing up to 70% of their gas compared to healthy isolated systems.

Scatter in M-Z relation correlates with gas fraction. **Gas-deficient objects typically more metal-rich.**

3. Why do cluster galaxies have enhanced metallicities?

Metal enhancements in HI deficient galaxies may arise from a selection effect. Gas stripping by the environment will reduce number of observed HII Regions since there is less fuel for star formation.

Only HII regions within the stripping radius will contribute to the observed spectra, where gas remains as fuel for new stars to continue to be created. **Galaxies with strong metallicity gradients thus appear more metal rich.**

Metallicities "before" and "after" gas stripping are compared by integrating the luminosity-weighted metallicity profiles from Skillman et al. (1996).

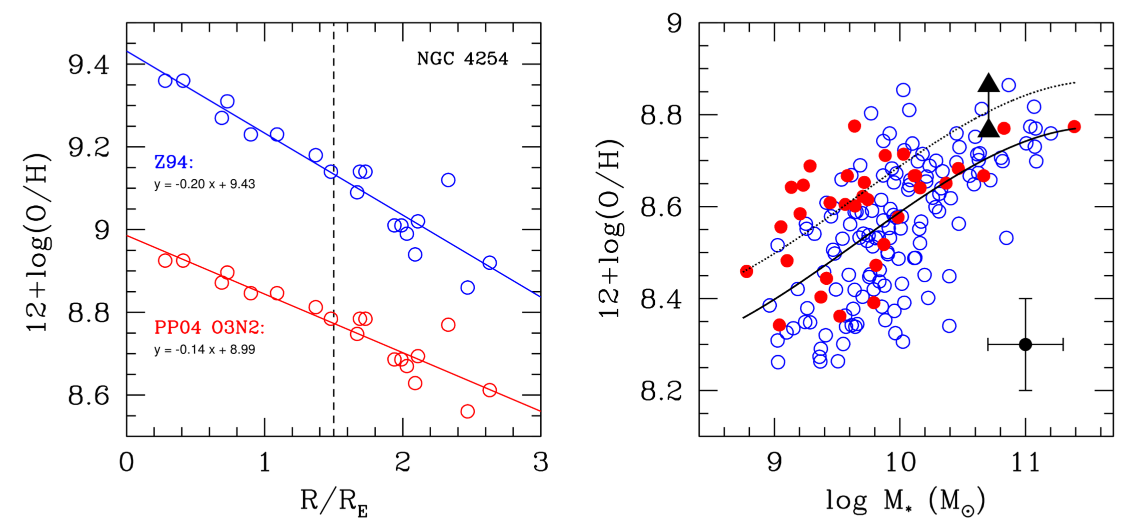

Fig. 3: The results of a simple model which may explain HI deficient cluster galaxies. **Left**: Radial metallicity gradient of NGC 4254 from Skillman et al., along which the mean metallicity was calculated for i) the whole profile and ii) $R<R_E$, i.e. before and after stripping. **Right**: The mass-metallicity relation, highlighting gas deficient (red circles) and normal star-forming galaxies (blue circles). For NGC 4254, the **model predicts a metallicity enhancement of 0.05-0.1 dex**, enough to shift a galaxy from the relation (solid black line).

4. VLT / FORS2 subsample

We obtained 32 hours of optical spectroscopic observations using the Very Large Telescope with the FORS2 instrument in multi-object mode (P.I.: L. Cortese), targeting individual HII and star-forming regions across the discs of twenty, face-on spiral galaxies in the HRS.

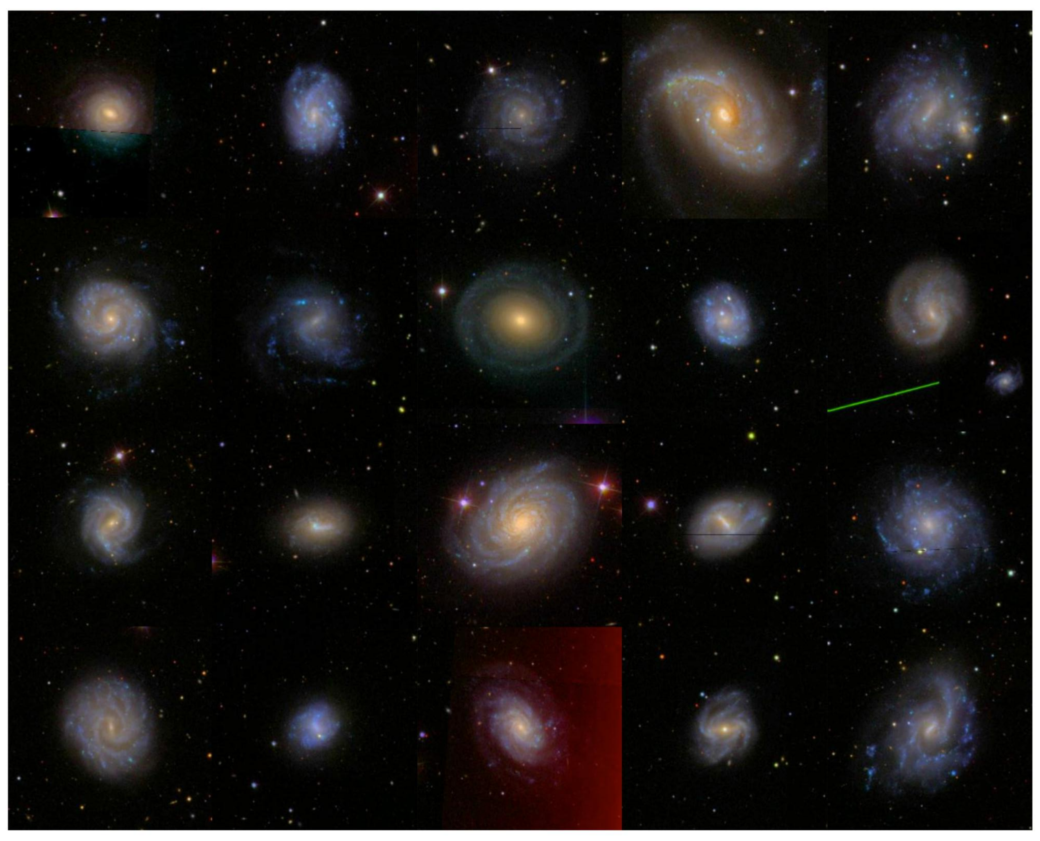

Fig. 4: SDSS composite images of the twenty HRS galaxies with VLT observations

5. VLT / FORS2 MXU observations of HRS 319

For each slit position, we simultaneously cover the wavelength range between 3500Å and 7000Å, including the Hα, Hβ, [OII], [OIII], [NII] and [SII] emission lines, with R>1000.

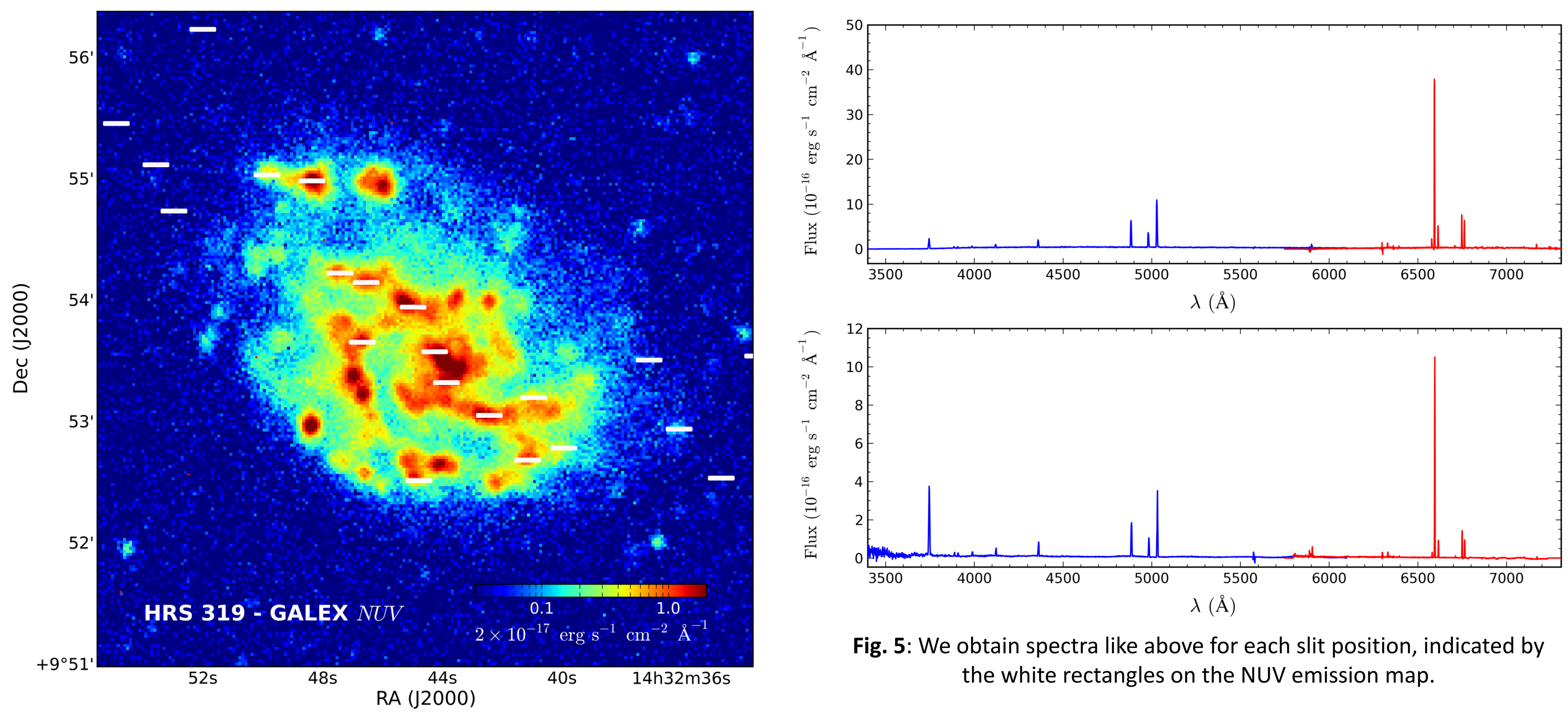

Fig. 5: We obtain spectra like above for each slit position, indicated by the white rectangles on the NUV emission map.

6. Ongoing work

We are currently verifying the data reduction performed using the ESO Reflex pipeline for the FORS2 instrument.

Once the data reduction is complete, we will use metallicity calibrations in the literature to estimate the oxygen abundance from the intensity ratios of the most prominent optical emission lines, following Hughes et al. (2013). We shall thus construct the metallicity gradients via the determination of the gas-phase oxygen abundance at each slit position.

References: Boselli et al. 2010, PASP, 122, 261B; Skillman et al., 1996, ApJ, 462, 147S; Hughes et al. 2013, A&A, 550, A115; Kewley & Ellison, 2008, ApJ, 681, 1183K

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