Age and Metallicity Gradients in Disk Galaxies

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Abstract: We have used Lick indices to measure stellar age and metallicity gradients in a sample of edge-on late-type galaxies. Lower mass systems show age gradients and very small metallicity gradients, suggesting they have failed to chemically enrich despite signs of extended star formation. In more massive systems, the metallicity gradients are surprisingly large and comparable to gradients seen in galaxies with substantial bulge components. We compare these results to metallicities derived from emission line strengths, and find that our galaxy sample follows a surprisingly tight mass-metallicity relationship.

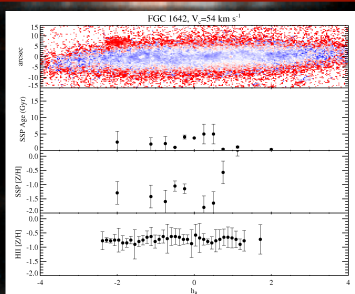

Figure 1: Top Panel: B-R color map of a low mass galaxy from our sample. The color range runs from B-R of 0.4 (blue) to 1.0 (white) to 1.7 (red). Middle Panels: Spectroscopically determined stellar ages and metallicities based on Lick indices. There is a hint of age and metallicity gradients, however, at such low overall metallicities the Lick indices may not be reliable. Bottom Panel: Metallicity calculated from the integrated spectrum emission lines using the N2S2 calibrator. The gas metallicity is consistent with zero gradient.

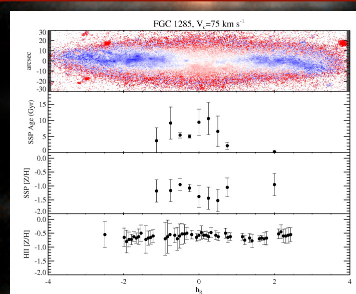

Figure 2: Top Panel: B-R color map of a medium mass galaxy from our sample. Middle Panels: Stellar age and metallicity gradients calculated from Lick indices. FGC 1285 shows a strong age gradient (as one would expect from the color map), but surprisingly small metallicity gradient. Bottom Panel: Metallicity gradient determined from emission lines. Like the low mass galaxy, there is little if any gradient.

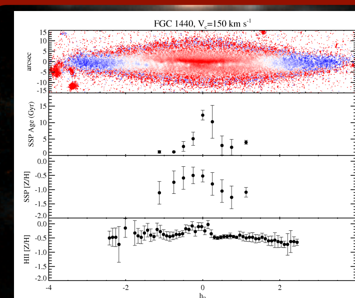

Figure 3: Top Panel: B-R color map of a higher mass galaxy from our sample. Middle Panels: Spectroscopic stellar ages and metallicities. There is a pronounced gradient in both stellar age and metallicity, similar in magnitude to gradients observed between bulge and disk components. Bottom Panel: Emission line metallicities. While not as pronounced as the stellar gradients, the central region is clearly enriched relative to the rest of the galaxy.

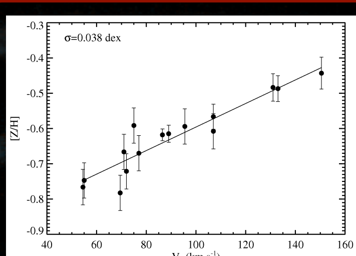

Figure 4: Mass-metallicity relationship for our full sample with metallicities derived from the N2S2 emission line diagnostic. Despite lingering doubts about the accuracy of N2S2 as well as projection effects and contamination from diffuse ionized gas, the scatter in our mass-metallicity relation is a factor of 3-4 lower than typically found in other studies.

Observations: As part of an observing campaign of thick disk stellar populations in nearby galaxies (visible as the red halos surrounding the galaxies in Figures 1-3), we have obtained deep optical and near-IR spectroscopy of the midplanes of 19 edge-on bulgeless disk galaxies, spanning a range of masses. Our midplane observations come from GMOS longslit observations from Gemini North and South (~45 min per galaxy) and the Apache Point 3.5m (~1 hr per galaxy). Our galaxies have been selected to be pure disk, undisturbed, isolated systems.

We use the Hβ, Mg b, and Fe 5270 absorption features defined in the Lick system to derive flux weighted SSP ages and metallicities as a function of projected radius. In addition, we estimate the metallicity of the HII regions using the S2N2 indicator (log(NII/Hα) v log(SII/Hα)). Metallicity and ionization parameter are derived from CLOUDY model grids. Using only the red emission lines has traditionally been shunned as too crude to derive accurate metallicities. While the outer regions of our galaxies are probably contaminated by emission from diffuse ionized gas (DIG), the inner regions of the galaxies appear to be well modeled as primarily HII emission.

Having measured the age and metallicity gradients (examples in Figures 1-3), we plot our gas-derived mass-metallicity and mass-gradient relationships in Figures 4 and 5. Our mass-metallicity relationship shows surprisingly little scatter (0.04 dex) compared to previous studies (0.12 dex).

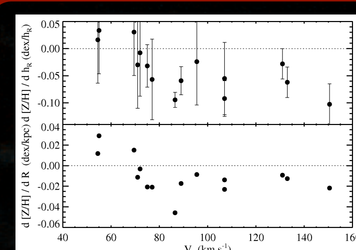

Figure 5: Mass-gradient relationship from our galaxies derived from the N2S2 calibrator. The top panel shows the gradients in terms of the galaxies' photometric scale length, while the bottom panel plots the gradients in physical units. We find our higher mass galaxies have significant negative metallicity gradients, while the lower mass systems are consistent with no gradient. These gradients are fairly shallow compared to other studies, probably a result of projection effects and contamination from the DIG smoothing out the gradients in our observations.

Discussion:

The most surprising result is the very low scatter in our mass-metallicity relationship. We did not expect the accuracy of the N2S2 diagnostic used on integrated galactic spectra to be accurate enough to produce such a low scatter. Other studies have found that the scatter is much larger, and that the scatter does not change significantly even if galaxies are segregated by morphology or specific star formation rate. This low scatter could be a result of our stringent morphological selection and use of dynamical mass instead of less certain derived stellar masses. We also recognize that our sample is fairly small, and the small dispersion could be a statistical fluke. However, if the true dispersion in the mass-metallicity relation is around 0.12 dex, as found in other studies, there is only a 0.5% chance of measuring a dispersion of 0.05 dex or less with our sample size.

Our second major result is the disappearance of metallicity gradients for galaxies less massive than V_c~75 km/s. The overall magnitude of our measured metallicity gradients is surprisingly small, about a factor of two smaller than typically found in large spiral galaxies. This is probably due to the smoothing caused by projection effects, and bias introduced by DIG contamination. Nevertheless, we also see a lack of age and metallicity gradients in the low mass stellar populations, suggesting that this might be a real change in the metallicity structure between low mass and high mass disks.