The Chemical Evolution of LSB Galaxies

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Abstract. We have derived oxygen and nitrogen abundances of a sample of late-type, low surface brightness (LSB) galaxies found in the Sloan Digital Sky Survey (SDSS). Furthermore, we have computed a large grid (5000 models) of chemical evolution models (CEMs) testing various time-scales for infall, baryon densities and several power-law initial mass functions (IMFs) as well. Because of the rather stable N/O-trends found both in CEMs (for a given IMF) and in observations, we find that the hypotheses that LSB galaxies have stellar populations dominated by low-mass stars, i.e., very bottom-heavy IMFs (see Lee et al. 2004), can be ruled out. Such models predict much too high N/O-ratios and generally too low O/H-ratios. We also conclude that LSB galaxies probably have the same ages as their high surface brightness counterparts, although the global rate of star formation must be considerably lower in these galaxies.

1. Late-type LSBGs in the SDSS

We use the data compilation by Caldwell & Bergvall (2006) consisting of a sample of 1199 close to edge-on ($b/a \leq 0.25$) low surface brightness (LSB) galaxies in the fourth data release of the Sloan Digital Sky Survey (SDSS-DR4). All galaxies in the sample were selected in order to obtain a sample of isolated, bulge-less systems, which is ideal for comparison with simple CEMs since the merger histories of such galaxies have less influence on the evolution of elemental ratios. This total sample is divided by $g - r$ colour limits into a blue Sample A (377 galaxies), a green (intermediate) Sample B (436 galaxies) and a red Sample C (386 galaxies). From these 1199 galaxies we pick out the ones with a relative error in the Hα-flux less than 25%.

2. Numerical Model Grid

We have computed a large grid (5000 models) of one-zone CEMs, testing time-scales for infall from $\tau_{\text{inf}} = 1.0$ Gyr to $\tau_{\text{inf}} = 7.9$ Gyr, baryon densities ranging between $\Sigma_{\text{final}} = 1.0 M_\odot$ pc$^{-2}$ and $\Sigma_{\text{final}} = 6000.0 M_\odot$ pc$^{-2}$, which should cover most of the possible variations within dwarf and late-type galaxies. Star formation is prescribed by a simple Schmidt-law, $\dot{\Sigma}_* = \eta \Sigma_{\text{gas}}^{1.5}$, where the constant $\eta$ is varied between $\eta = 0.001$ to $\eta = 0.2$. Furthermore, we have tried several power-law initial IMFs $\phi(m) \sim m^{-(1+x)}$ in order to test the bottom-heavy IMF hypothesis ($x = 2.85$) suggested by Lee et al. (2004). The nucleosynthesis prescriptions are taken from Chieffi & Limongi (2004) for high mass stars and van den Hoek & Groenewegen (1997) for low and intermediate stars and all model tracks where evolved over 13.7 Gyr (one Hubble-age).
Figure 1. Observed abundances and model results (grey dots) for different IMFs. Slowly evolving tracks populate the log(N/O)-plateau, while rapidly evolving tracks populate the "secondary branch". The abundances of the late-type LSBGs are shown as blue diamonds (Sample A), green triangles (Sample B) and red squares (Sample C). Black dots and circles show data for dwarf LSBGs from Rönback & Bergvall (1995), van Zee et al. (1996) and van Zee & Haynes (2006).

3. Results and Conclusions

In Fig. 1 we show a comparison between our abundances derived from spectral data from SDSS-DR4 using the so-called P-method (see, e.g., Pilyugin 2003) and our model results. Clearly, the late-type LSBGs do not deviate from the general, rising trend found in HSB galaxies. Based on the results from our model grid we draw the following conclusions:

- The log(N/O)-ratios in dwarf irregular and late-type LSBGs follow the same basic pattern as their HSB counterparts.
- The chemical evolution, as revealed by the HII-regions, is not compatible with an extremely bottom-heavy IMF as suggested by Lee et al (2004), nor is it compatible with a top-heavy IMF.
- The LSB property of these objects is most likely due to a low global star formation density, although the efficiency of star formation in star-forming regions must be as high as in HSBGs in order to explain the high log(N/O)-ratios.
- Given these results, it is unlikely (although not impossible) that the ages of LSBGs are significantly different from the ages of corresponding HSBGs.

References

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