Metallicity Distribution Function and Chemical Evolution Models for Four Local Group Dwarf Galaxies

Teresa Ross¹, Jon Holtzman¹, Barbara Anthony-Twarog², Abhijit Saha³

¹New Mexico State University, ²University of Kansas, ³NOAO

Abstract

Metallicity, age, and mass are fundamental characteristics of a stellar population. Metallicity distribution functions (MDFs) along with chemical evolution models, contain information on the history of enrichment, inflow, and outflow within the galaxy. MDFs for Leo I, Leo II, IC 1613, and Phoenix dwarf galaxies were derived from photometry from the Wide Field Camera 3 (WFC3) instrument aboard the Hubble Space Telescope (HST). While the metallicity accuracy (~0.2 dex) in our study is lower than spectroscopic measurements, we can reach fainter magnitudes and measure every star in the field, producing an order of magnitude more stellar metallicities than previous studies. We fit the MDFs of four Local Group dwarf galaxies to analytical chemical evolution models to quantify the affect of gas flows and star formation within the galaxies.

Why metallicity distributions are important

- Metallicity, age, and mass are fundamental characteristics of all stellar populations.
- Stellar metallicity = snap shot of gas in the past.
- Lots of stellar metallicities = time lapse of the gas for the entire history of the galaxy.
- The Metallicity Distribution Function (MDF) is the relative number of stars per bin of metallicity.

Measuring Photometric Metallicities

Why photometry instead of spectroscopy?

- We can measure all stars in the field, making our sample orders of magnitude larger than previous studies.
- We can measure fainter stars than are available to spectroscopy.

Dwarf Galaxies CMDs, color-color plots, and Metallicity Distribution Functions

We obtained HST images in F814W, F555W and F390M for each dwarf galaxy, then measure magnitudes for all stars in the field. We made error cuts of < 0.04 mag. CMDs are shown as reference.

We used color-color plots and empirically corrected Dartmouth isochrones to measure metallicity for GB stars. Each star is matched to the closest isochrone and assigned that metallicity.

We created MDFs for each dwarf. A galactic MDF records the gas dynamics within that galaxy, making the MDF important to chemical evolution models. Each MDF was then fit with a simple chemical evolution model and a ‘Best Accretion’ model.

Simple chemical evolution models

Van den Bergh (1962) and Schmidt (1963) created the first ‘Simple’ closed box models:

\[ g = (1 - s) \]

where \( g \) is the gas mass fraction, and \( s \) is the stellar mass fraction. This produces a MDF of the form:

\[ \frac{dN}{d[\text{Fe/H}]} = \frac{1}{(\frac{\text{Fe/H}}{0.1})^{10^{\text{Fe/H}}} \times (1 + x)^{3} \times (1 + \frac{x}{10^{0.1}})^{-2}} \]

Where \( p \) is the effective yield. The best fit simple models are shown as orange dashed lines over plotted on the MDFs below.

Best Accretion chemical evolution model

The best accretion model of Lynden-Bell 1975 incorporates a declining inflow rate to account for gas being depleted as it is converted into stars:

\[ g(s) = \left(1 - \frac{1}{s}\right) \times \left(1 + \frac{s}{0.1}\right) \]

The analytic form relates the initial gas and stellar mass (\( g \) and \( s \)), to the final stellar mass, \( M \). Larger \( M \) values represent more accretion.

In the simple model the only free parameter is the effective yield, \( p \).

In the accretion model, we fit for the best effective yield, \( p \), and extra gas parameter, \( M \).

References

Holtzman et al. (2000). Based on the massmetallicity relationship Phoenix should be more metal poor (~1.6). The discrepancy can partially be attributed to measuring stars near the center of Phoenix. A recent star formation history study by Hidalgo et al. (2013) showed a metallicity gradient across the galaxy with [Fe/H] ~1.4 in the center. Neither of the evolution models reproduce the distribution well.