RNAAS RESEARCH NOTES OF THE AAS

AAS IOP

Measuring the Chemodynamics and Ages of the M32 and M110 Dwarf Galaxies with APOGEE

To cite this article: Alondra Álvarez-Castro *et al* 2024 *Res. Notes AAS* **8** 112

Draft version April 23, 2024
Typeset using LaTeX **twocolumn** style in AASTeX631

Measuring the Chemodynamics and Ages of the M32 and M110 Dwarf Galaxies with APOGEE

Alondra Álvarez-Castro,[1, 2] Benjamin J. Gibson ,[2] and Gail Zasowski [2]

[1] *Department of Physics, University of Puerto Rico, San Juan, PR 00925-253, USA*
[2] *Department of Physics & Astronomy, University of Utah, Salt Lake City, UT 84112, USA*

ABSTRACT

We present a full-spectrum-fitting analysis of the central kinematics and chemistry of the Andromeda dwarf satellite galaxies M32 and M110. We use an MCMC routine to fit high-resolution, near-infrared, integrated-light spectra from APOGEE with empirical simple stellar population (SSP) templates constructed from individual APOGEE stellar spectra. This yields the best-fitting mean radial velocity, velocity dispersion, metallicity, α abundance, and age for each spectrum. In general, our results are consistent with literature values where available, and we explore possible reasons where offsets are measured. This study was presented in a poster at the 243rd meeting of the American Astronomical Society in January 2024.

Keywords: Dwarf galaxies (416)

1. INTRODUCTION

Galaxies are complex, gravitationally-bound structures of stars, gas, and dust that provide insight into aspects of the universe's evolution. Our Local Group hosts dozens of galaxies with stellar masses spanning $\sim 10^6 - 10^{11}\ M_\odot$, making it invaluable for studying these systems and enhancing our understanding of observations of distant galaxies.

We target the central regions of two dwarf satellite galaxies, M32 and M110, that orbit around the Andromeda galaxy (M31). M32 (NGC 221) is a compact elliptical galaxy whose origins and evolutionary scenario have long been the subject of debate (e.g., D'Souza & Bell 2018). M110 (NGC 205) is an elongated dwarf elliptical with signatures of recent star formation at the center (e.g., Monaco et al. 2009).

This Research Note describes a spectroscopic analysis of the mean stellar dynamics and chemistry in the central $\sim 2''$of these satellite galaxies. In Section 2, we describe a Markov-Chain Monte Carlo (MCMC) fitting routine to fit Simple Stellar Population (SSP) spectral templates to near-infrared APOGEE spectra, to determine the best-fitting mean velocity, velocity dispersion, metallicity, α abundance, and age of these galaxy centers. In Section 3, we compare our findings with literature values and place them in context.

2. METHODS

Integrated-light observations of the centers of M32 and M110 were taken as part of APOGEE-2 (Majewski et al. 2017; Zasowski et al. 2017). M32 was observed for 60 ten-minute visits, and each visit spectrum had a sufficiently high signal-to-noise ratio (SNR). M110 was observed for 48 ten-minute visits; these individually had much lower SNR, so we combined eight visits apiece into six spectra.

We employ the APOGEE Library of Infrared SSP Templates for data analysis (A-LIST[1]; Ashok et al. 2021), which span a grid of population [M/H], [α/M], and age. We use *The Cannon* (Ness et al. 2015; Casey et al. 2016) to interpolate between A-LIST grid points, based on a training set of templates with luminosity fraction > 0.32, $|\Delta T_{\rm eff}| < 500$ K, $[{\rm M/H}] > -1.0$, and age < 6 Gyr (Ashok et al. 2021).

Using the `emcee` package (Foreman-Mackey et al. 2013), we run an MCMC routine to determine the single best-fitting (interpolated) template and kinematics for each spectrum. The A-LIST [M/H] values range from -0.8 to $+0.2$, and [α/M] from 0.0 to $+0.3$. We run `emcee` with 30 walkers for 400 iterations, and use `pPXF` (Cappellari 2017) to evaluate the likelihood of each. We take the best-fitting parameters to be the median values for the final 200 iterations, with uncertainties being the

[1] https://github.com/aishashok/ALIST-library

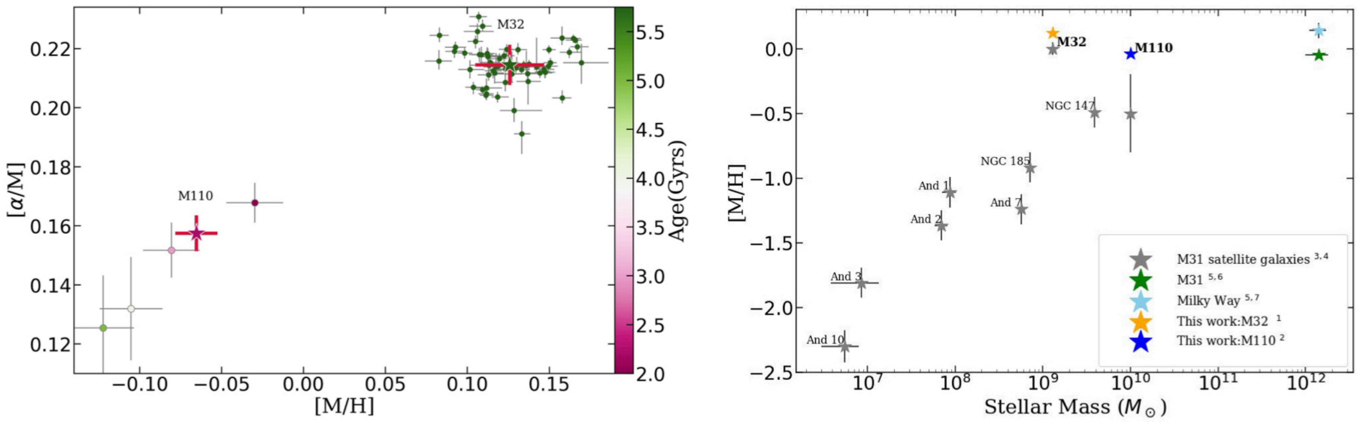

Figure 1. *Left:* Best-fitting [M/H] and [α/M] for different SSP ages. *Right:* M32 and M110 [M/H] values from this work, with stellar masses ([1] Richstone & Sargent (1972); [2] Hannah et al. (2021)), along with those of other M31 satellites, ([3] Kalirai et al. (2010); [4] Vargas et al. (2014)) M31 and the Milky Way ([5] Watkins et al. (2010); [6] Gibson et al. (2023); [7] Cunha et al. (2007)).

standard deviations. To verify consistency with literature ages, we analyze each spectrum with age fixed from 2 to 5 Gyr with a four-dimensional MCMC. Results are shown in the left panel of Figure 1.

See Gibson et al. (2023) for a detailed description of similar data processing (Section 2.2), A-LIST interpolation (Section 3.2), and full spectrum fitting (Section 4.2).

3. RESULTS & CONCLUSIONS

We find a $\sim$20 km s^{-1} velocity offset in both galaxies compared to the range reported before, with $V = -180 \pm 16$ km s^{-1} for M32 (compared to Kalirai et al. 2010; Howley et al. 2008) and $V = -220 \pm 0.013$ km s^{-1} for M110 (compared to Howley et al. 2013). This may be due to slight differences in the positions of the apertures, as the velocity structure at the galaxy centers is complex. However, the central velocity dispersions are consistent with literature: $\sigma_V = 69.0 \pm 2.3$ km s^{-1} for M32 and $\sigma_V = 21.2 \pm 0.2$ km s^{-1} for M110.

For chemical abundances, the M32 [M/H] results are consistent with Howley et al. (2008); Nguyen et al. (2018). In M110, we find [M/H] $= -0.06 \pm 0.01$, higher than other works (e.g., Rose et al. 2005; Schiavon et al. 2004). For M32, the α abundances are higher than expected, with [α/M] $= +0.21 \pm 0.006$ (compared to Nguyen et al. 2018; Kalirai et al. 2010). This issue may be related to the higher age that was determined for this galaxy. For M110, our [α/M] $= +0.15$ result is consistent with literature (Schiavon et al. 2004).

Our derived age of M32 is higher than Nguyen et al. (2018) and Kalirai et al. (2010). From our 4D MCMC results, the closest best-fitting age is 5 Gyrs, consistent with the best-fitting age from the 5D MCMC. For M110 our derived age seems consistent with literature (Schiavon et al. 2004). The closest best-fitting age from the 4D MCMC is 3 Gyrs (Figure 1).

Galaxies' masses and metallicities follow a trend in which more massive galaxies tend to have higher [M/H], possibly due to a more prolonged star formation and enrichment history (e.g., Tremonti et al. 2004). This is consistent with our results (right of Figure 1), as we compare a set of dwarf galaxies along with the Milky Way and M31.

Galaxies' present-day chemodynamical structures are tracers of their chemical evolution and formation history; full-spectrum modeling of integrated-light spectra is useful for complementing the ages and chemistry of galaxies for which we also have resolved-star data.

4. ACKNOWLEDGMENTS

A.A.C. acknowledges support from NSF REU Grant PHY-1950409, and B.J.G. acknowledges support from NSF Grant AST-1911129.

REFERENCES

Ashok, A., Zasowski, G., Seth, A., et al. 2021, AJ, 161, 167

Cappellari, M. 2017, MNRAS, 466, 798

Casey, A. R., Hogg, D. W., Ness, M., et al. 2016, arXiv e-prints, arXiv:1603.03040

Cunha, K., Sellgren, K., Smith, V. V., et al. 2007, ApJ, 669, 1011, doi: 10.1086/521813

D'Souza, R., & Bell, E. F. 2018, Nature Astronomy, 2, 737, doi: 10.1038/s41550-018-0533-x

Foreman-Mackey, D., Hogg, D. W., Lang, D., & Goodman, J. 2013, PASP, 125, 306

Gibson, B. J., Zasowski, G., Seth, A., et al. 2023, ApJ, 952, 23, doi: 10.3847/1538-4357/acd9a9

Hannah, C. H., Seth, A. C., Nguyen, D. D., et al. 2021, AJ, 162, 281, doi: 10.3847/1538-3881/ac282e

Howley, K. M., Geha, M., Guhathakurta, P., et al. 2008, ApJ, 683, 722, doi: 10.1086/589632

Howley, K. M., Guhathakurta, P., van der Marel, R., et al. 2013, ApJ, 765, 65, doi: 10.1088/0004-637X/765/1/65

Kalirai, J. S., Beaton, R. L., Geha, M. C., et al. 2010, ApJ, 711, 671

Majewski, S. R., Schiavon, R. P., Frinchaboy, P. M., et al. 2017, AJ, 154, 94, doi: 10.3847/1538-3881/aa784d

Monaco, L., Saviane, I., Perina, S., et al. 2009, A&A, 502, L9, doi: 10.1051/0004-6361/200912412

Ness, M., Hogg, D. W., Rix, H.-W., Ho, A. Y. Q., & Zasowski, G. 2015, ApJ, 808, 16

Nguyen, D. D., Seth, A. C., Neumayer, N., et al. 2018, ApJ, 858, 118, doi: 10.3847/1538-4357/aabe28

Richstone, D., & Sargent, W. L. W. 1972, ApJ, 176, 91, doi: 10.1086/151611

Rose, J. A., Arimoto, N., Caldwell, N., et al. 2005, AJ, 129, 712, doi: 10.1086/427136

Schiavon, R. P., Caldwell, N., & Rose, J. A. 2004, AJ, 127, 1513, doi: 10.1086/381950

Tremonti, C. A., Heckman, T. M., Kauffmann, G., et al. 2004, ApJ, 613, 898, doi: 10.1086/423264

Vargas, L. C., Geha, M. C., & Tollerud, E. J. 2014, ApJ, 790, 73

Watkins, L. L., Evans, N. W., & An, J. H. 2010, MNRAS, 406, 264

Zasowski, G., Cohen, R. E., Chojnowski, S. D., et al. 2017, AJ, 154, 198