A Spectral Analysis of the Chemical Enrichment History of Red Giants in the Andromeda Galaxy Field (M31) Versus its Dwarf Spheroidal (dSph) Satellites

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Introduction

Galaxies are interesting organisms: they move, change, grow, and, strangely enough, consume. In a process known as **galaxy cannibalism**, a dwarf satellite galaxy is pulled in by a more massive galaxy. After the meal, what determines whether a dwarf satellite of a galaxy is a separate entity?

- Analyzed **chemical trends** as a function of **photometric properties** of stars
- **1st** time that **cannibalism survivors** (Field) were compared to **cannibalism victims** (Dwarf Spheroidals)
- **1st** time that **coaddition** was used to group *LIKE* stars strictly and with great detail

Why Andromeda?

- External yet close-by vantage point—**global but detailed** view of galaxy
- Spiral galaxy similar to our own—**results applicable to Milky Way**

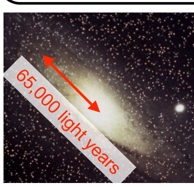


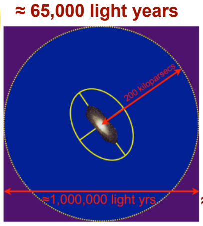
Photo taken by NASA Marshall Space Flight Center Collection

Traditional view of M31
Radius—**20 kiloparsecs**
≈ 65,000 light years

Why dSphs?

- **Small**, less chemically enriched than larger galaxies, **intact**
- Small galaxies = **building blocks of galaxy formation**
- Outskirts of M31—**longer shredding process / less memory erasure**

1



Area analyzed in this study
Radius—**200 kiloparsecs**
≈ 600,000 light years

Methods

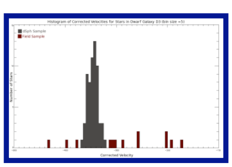
2

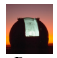
Separating dSph and Field Samples

Criteria

1. **Good Spectral Quality**
2. **Likely to be an M31 Red Giant**
3. **Velocity Cuts (via histograms)**

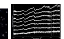
Example Histogram of **Corrected Velocities** [km/s] for Stars in dSph **Andromeda 3**



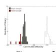


1 Data Collection

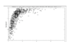

Photo part of NASA Collection



5 Spectral Analysis



2 Sample Differentiation



3 Create Metallicity Graphs

4 Binning and Coadding Spectra

Methods, continued

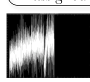
Graphing Metallicity Distributions and Binning and Coadding Spectra

3

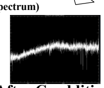
Metallicity graphs (Metallicity vs. Temperature) generated → Equal-sized bins (0.2 mag x 0.5 dex) used to grid Metallicity graphs → Program used to coadd spectra from stars in each bin → Adjustable Binning Process

- Assign each spectra an ivar value ("inverse of the variance")
- Weight the spectra in each bin according to the assigned value

4

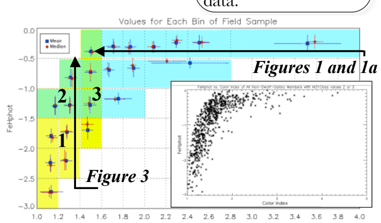


Before Coaddition
(Blue half of spectrum)

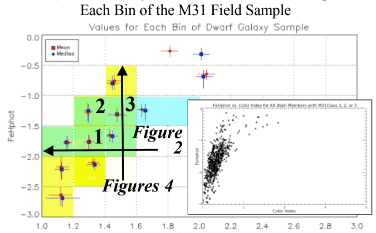


After Coaddition

- Bins with less than **10 stars** combined with adjacent bins.
- Bins only extended **horizontally** to preserve integrity of data.



The Mean and Median Values (with Root Mean Square Deviation) of Metallicity vs. Color for the Coadded Spectra of Each Bin of the M31 Field Sample



The Mean and Median Values (with Root Mean Square Deviation) of Metallicity vs. Color for the Coadded Spectra of Each Bin of the dSph Sample

Results

5

Analysis of Spectral Changes for Samples

As a function of $(V\text{-}I)_0$ at a given FeHphot range:

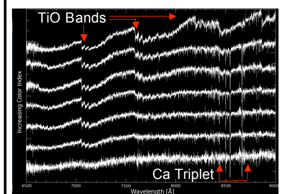


Figure 1: Field Sample; FeHphot [-0.5, 0.0]

- **Field Sample:** Titanium oxide (**TiO**) bands appear at **7100 [Å]**, **7600 [Å]**, and **≈8200 [Å]** for top spectrum
- (*Figure 1a*) Change in strength of **Calcium (Ca) triplet** absorption lines is **not monotonic**

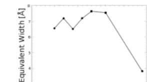
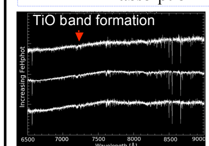


Figure 1a: Changing Equivalent Widths (0.1 [Å]) for Ca Triplet Average

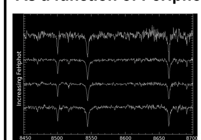
dSph sample: non-monotonic changes in absorption line strength



- Changes visible by observing at **6600 [Å]** and by inspecting the Ca triplet's changes

Figure 2: dSph Sample; FeHphot [-1.5, -1.0]

As a function of FeHphot at a given $(V\text{-}I)_0$ range:



- **Field Sample:** Metal absorption lines **in between** Ca lines become stronger

Figure 3: Field Sample; Ca Triplet for $(V\text{-}I)_0$ [1.2, 1.4]

- **dSph Sample:** Beginnings of **TiO band** formation are visible at **7150 [Å]**

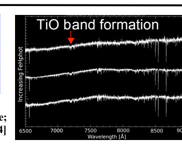
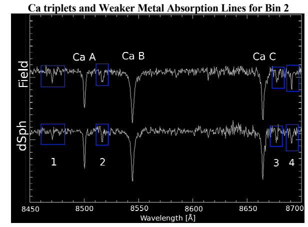


Figure 4: dSph Sample; $(V\text{-}I)_0$ [1.2, 1.4]

Single Bin Spectral Comparison

- **Bin 2** detailed in poster, other bins reflected same results (84 dSph stars, 88 Field stars)
- Field spectrum seems to have larger equivalent widths at each absorption line

Ca triplets and Weaker Metal Absorption Lines for Bin 2



Equivalent Widths for Ca Triplet and Weaker Metal Absorption Lines for Bin 2

	Average Ca Triplet	1 (8468-8472 [Å])	2 (8512-8520 [Å])	3 (8660-8670 [Å])	4 (8690-8697 [Å])
dSph Eq.	44.47 [Å]	10.96 [Å]	16.46 [Å]	19.87 [Å]	19.74 [Å]
Field Eq.	54.51 [Å]	22.15 [Å]	20.36 [Å]	20.36 [Å]	20.25 [Å]

Conclusions

Benefits of the Coaddition Process

- Individual stellar spectra have **low signal-to-noise**—coaddition suppresses noise while preserving actual absorption features

Spectral Analysis

- Changes in Metallicity and Temperature result in **systematic trends** for spectra
- Field Sample is **chemically richer** than dSph Population on average

Future Plans

- Compare coadded spectra to comprehensive computer models of stars with range of known chemical properties
- Take Metallicity Distribution Function (MDF) of dSphs into account to help reveal star formation history of galaxy