Multi-epoch Photometry of Luminous Blue Variables (LBVs) in the Andromeda & Triangulum Galaxies

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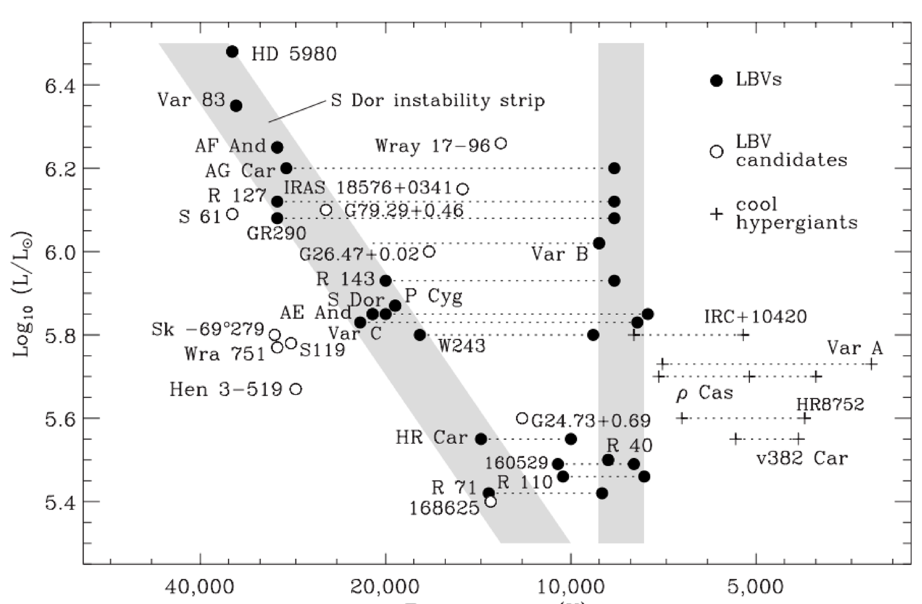
Overview

- **Photometry:** measuring the brightness of a star in an image.
- **Andromeda Galaxy (Messier 31):** The nearest major galaxy to the Milky Way. A barred spiral galaxy located 2.5 Mly from Earth.
- **Triangulum Galaxy (Messier 33):** The third-largest galaxy in the Local Group. A spiral galaxy located 2.73 Mly from Earth.
- Mass loss plays an important role in dictating massive stars' post-main-sequence evolution, and **LBVs have the highest mass-loss rates** of any stars (Smith 2014.)
- **Luminous Blue Variables (LBVs):**
  - Massive, evolved stars that show instabilities via irregular (S Doradus) outbursts (Szeifert et al. 1996.), forming a "pseudophotosphere".
  - **The pseudophotosphere was thought to explain the shift in energy distribution from UV to optical wavelength, causing the brightening at constant bolometric luminosity** (Smith et al. 2004, see also Wolf 1989)

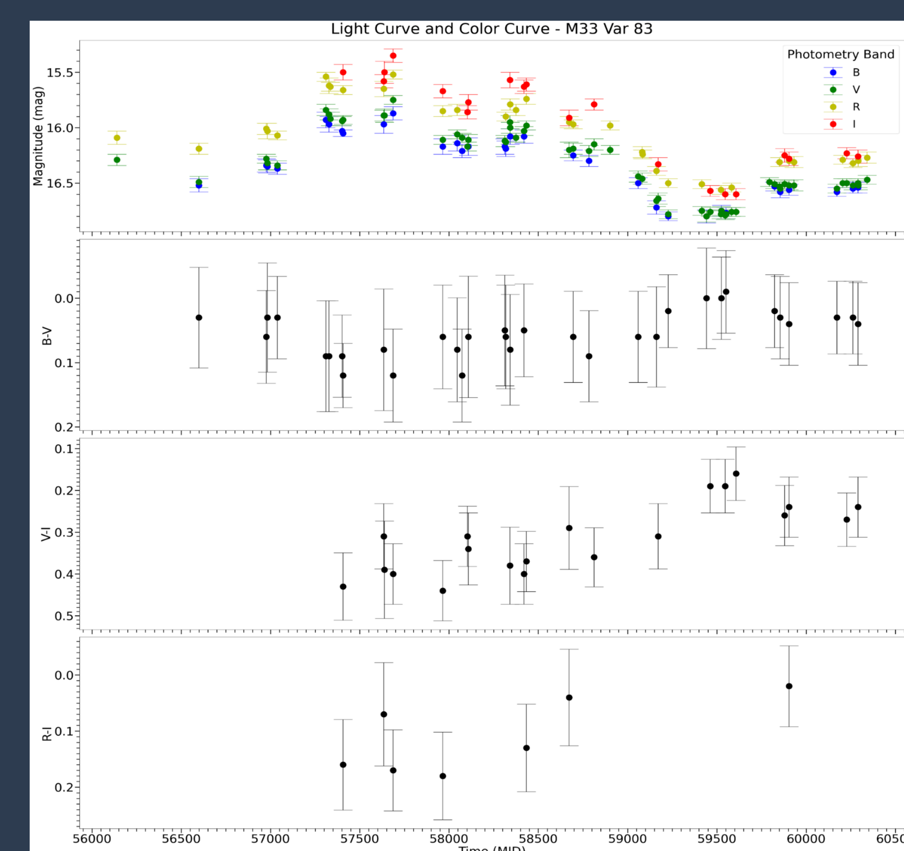


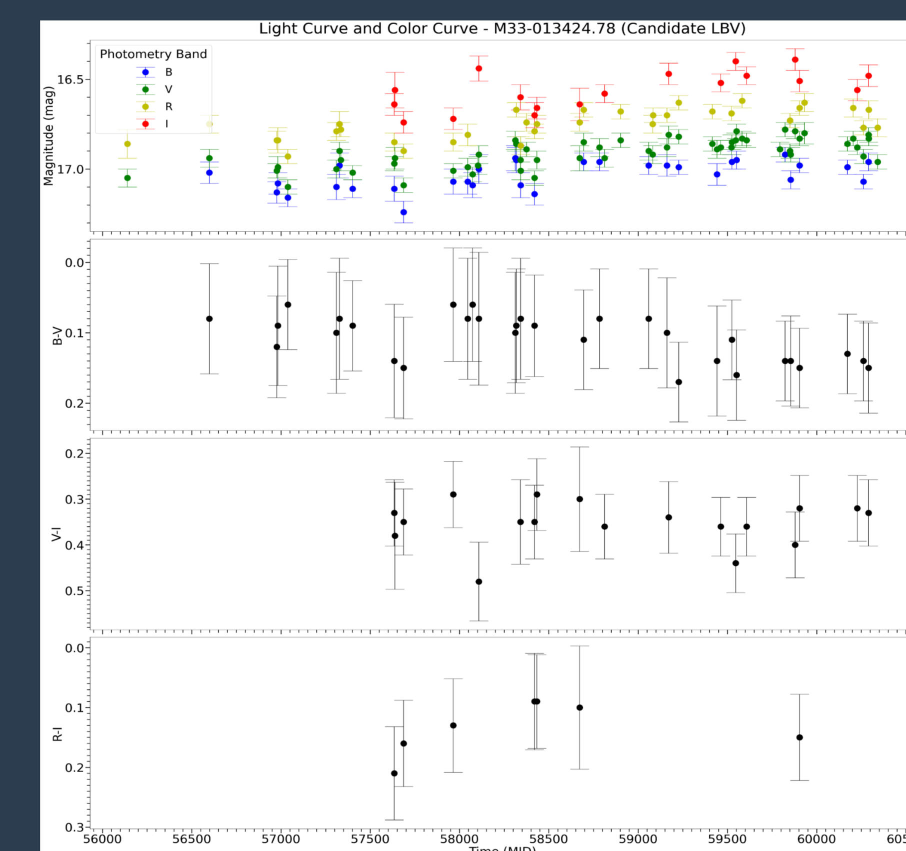
Methodology

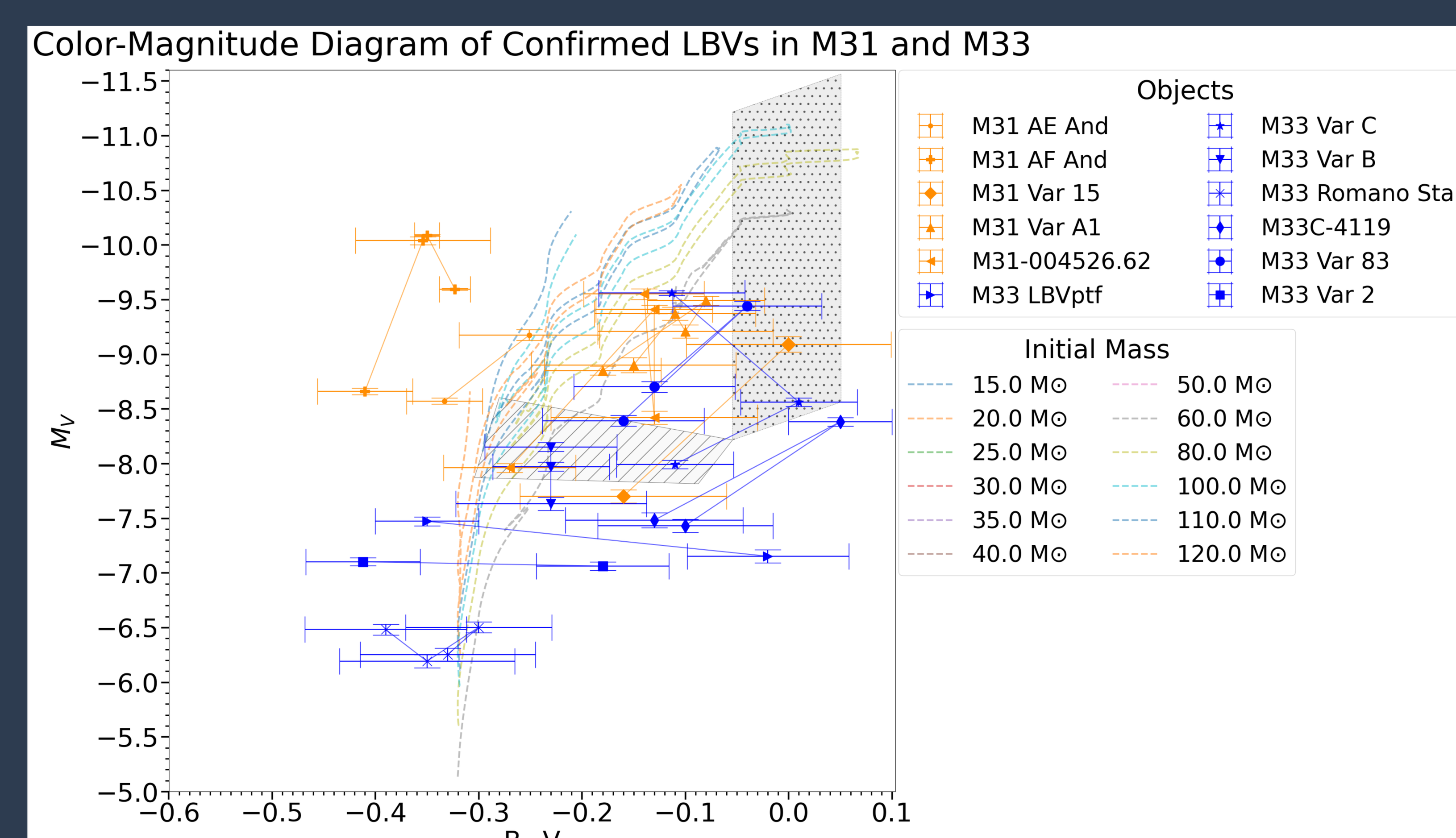
- **Data Acquisition:**
  - Photometric data for all LBVs or LBV candidate was obtained from John C. Martin at University of Illinois
  - Additional data was obtained from the American Association of Variable Star Observers (AAVSO) International Database.
- **Data Analysis:**
  - Photometric data in non-B,V,R,I bands was removed.
  - Calculate color indices, for example: $(B-V) = B - V$
  - V-band magnitudes and B-V color indices were manually selected to be plotted on a **Color-Magnitude Diagram**
    - Color correction: $m_V = V - 3.1 \times A_V$ (A_V = 0.16 for M33 and 0.48 for M31)
    - Convert to absolute magnitude: $M_V = m_V - 5\log_{10}(\frac{d}{10})$
    - Stellar evolution tracks from MESA Isochrone & Stellar Tracks (MIST) for masses from 20-120 $M_\odot$
    - S Doradus instability strip & quiescent phase
  - From the selected V-band magnitudes and B-V color indices, I also calculated and plotted **the change in color-corrected B-V index against the change in absolute V-band magnitudes** with error bars.

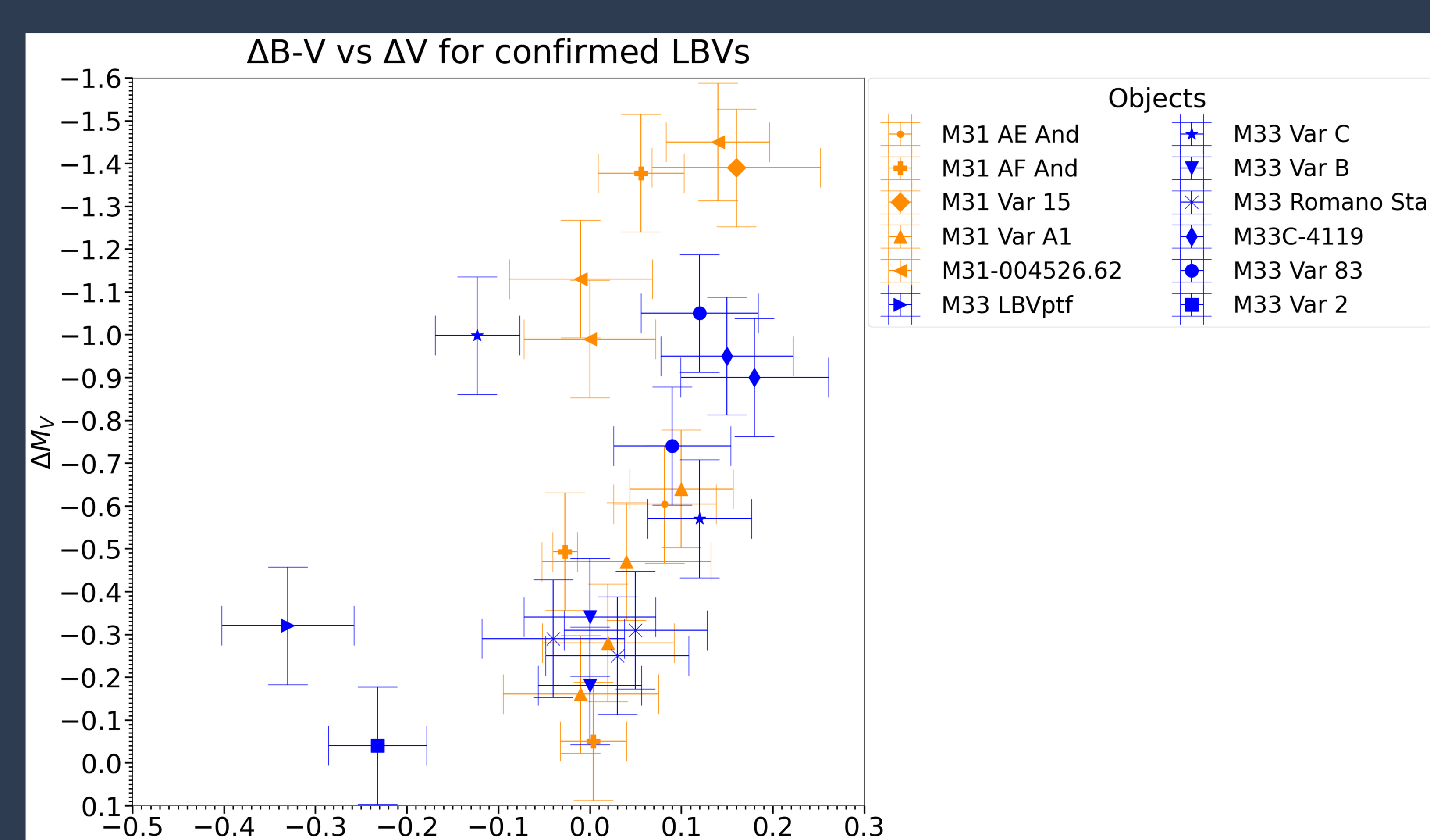
$$\Delta M_V = M_{V,peak} - M_{V,trough}$$
$$\Delta(B-V) = (B-V)_{peak} - (B-V)_{trough}$$

Plots









Results & Future Works

- **48 photometric datasets** for **44 confirmed LBVs and LBV candidates** from John Martin and AAVSO (one photometry table for each object)
- From light curves and color curves:
  - LBV candidates and quiescent LBVs: **no prominent change** in brightness and color indices.
  - **Erupting LBVs** show a **change in brightness of approx. 1.5 magnitudes** and **change in B-V color index of approx. 0.2 magnitudes.**
- From Color-Magnitude Diagram and Δ(B-V) vs. ΔV
  - M31 and M33 LBVs tend to **stay away from S Doradus instability strip and quiescent zone**, unlike Milky Way counterparts
  - **They do get redder as they get brighter**
- **Future implications:**
  - Obtain more photometric data that captures the missing outburst in currently quiescent LBVs.
  - Do a linear fit to the Δ(B-V) vs. ΔV plot to check whether the LBVs get red enough as predicted by previous models
  - **This poster is part of a research paper that I am preparing to write with my advisor**

References

- Wolf B., 1989, A&A, 217, 87-91
- Szeifert T., Humphreys R.-M., et. al., 1996, A&A, 314, 131.
- Smith N., Vink J., Kotter A., 2004, ApJ, 615:475-484
- Smith N., 2014, ARAA, 52, 487
- Smith N., Milne P., E Andrews J., et al., 2020, MNRAS, 492, 5897. doi:10.1093/mnras/staa061
- Choi J, Dotter A., et. al., 2016, ApJ, 823, 102. (MIST)

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