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

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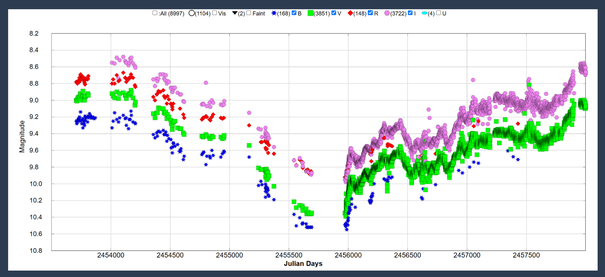
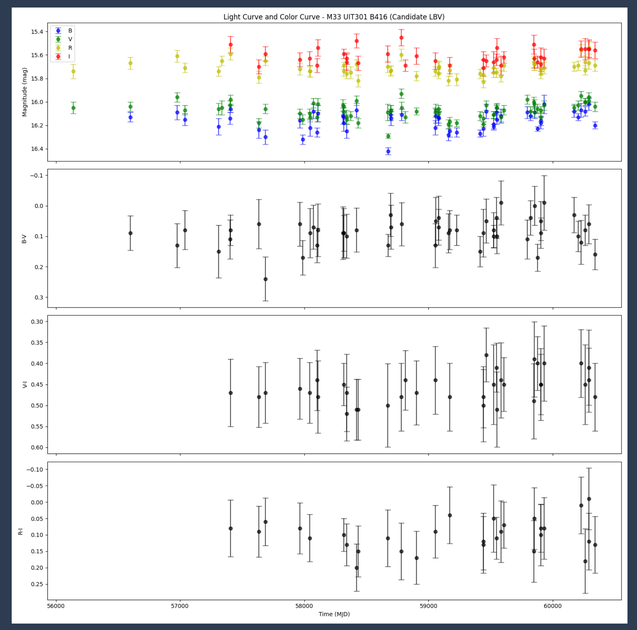
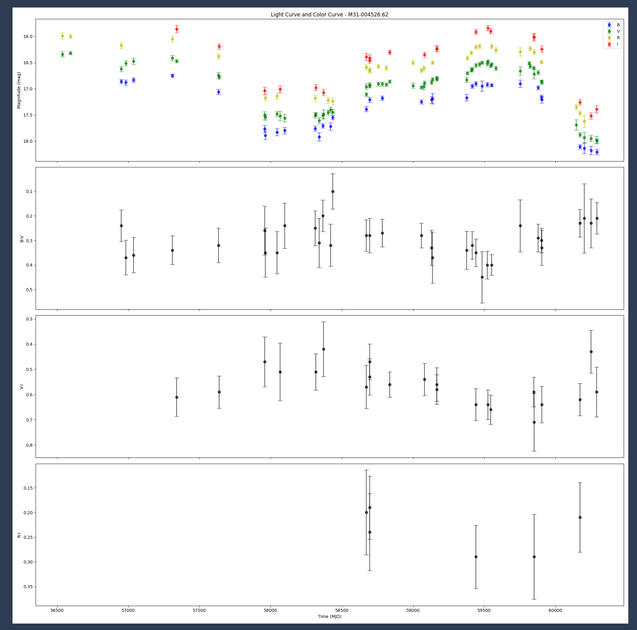
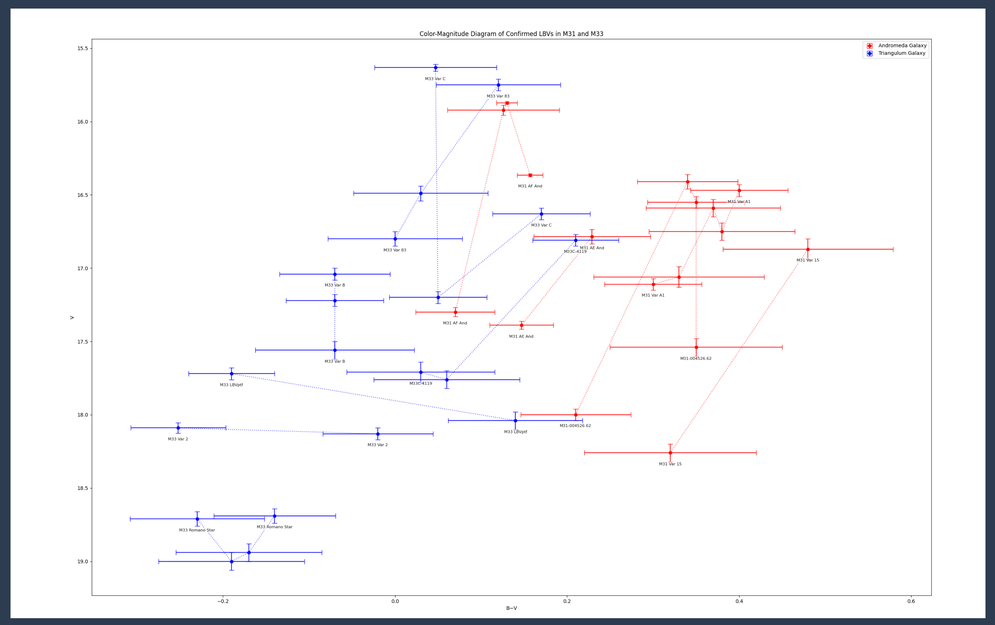
Overview

- **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 of type SA(s)b, located 2.5 Mly from Earth.
- **Triangulum Galaxy (Messier 33):** The third-largest galaxy in the Local Group after the Milky Way and Andromeda Galaxy. A spiral galaxy of type SA(s)cd, located 2.73 Mly from Earth.
- Mass loss plays an important role in dictating massive stars' post-MS 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.)
  - Their outbursts show a brightening at visible wavelengths due to the formation of a "pseudophotosphere" from enhanced mass outflow.
  - **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. 2020, see also Szeifert 1996.) **My goal is to test this theory.**









Methodology

- **Data Acquisition:**
  - Multi-epoch photometric data was obtained from John C. Martin at University of Illinois Springfield Henry R. Barber Research Observatory for all objects classified as an LBV or LBV candidate. Every epoch was imaged fully in standard Johnson-Cousins B,V,R,I filters.
  - Additional multi-epoch photometric data was obtained from the American Association of Variable Star Observers (AAVSO) International Database.
- **Data Analysis:**
  - Photometric data in bands other than Johnson-Cousins B,V,R,I was removed from AAVSO datasets.
  - B-V, V-I, and R-I color indices were calculated by subtracting the corresponding magnitudes.
  - Error bars of the color indices were computed by adding the error bars of band magnitudes in quadrature:

$$\Delta(B-V) = \sqrt{(\Delta B)^2 + (\Delta V)^2}$$
$$\Delta(V-I) = \sqrt{(\Delta V)^2 + (\Delta I)^2}$$
$$\Delta(R-I) = \sqrt{(\Delta R)^2 + (\Delta I)^2}$$

  - V-band magnitudes and B-V color indices were manually selected to be plotted on a color-magnitude diagram

Results & Future Works

- I obtained a total of **48 photometric datasets** for **44 confirmed LBVs and LBV candidates** from John Martin and AAVSO.
- I combined the available photometric data to write out a **photometry table for each object** as a comma-separated value (.csv) file.
- I plotted the light curves and color curves for all confirmed LBVs and LBV candidates
  - **LBV candidates and quiescent LBVs** show **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.**
- I also plotted B-V color index against V-band magnitude for all confirmed LBVs to monitor their stellar evolution
  - **Erupting LBVs are consistent with our theory.**
  - **LBVs in M31 appear redder than those in M33** because M31 has higher metallicity than the Milky Way while M33 has lower metallicity than Milky Way
- **Future implications:**
  - Obtain more photometric data that captures the missing outburst in currently quiescent LBVs.
  - Apply color correction factors to account for reddening due to different metallicities between Milky Way and M31 & M33.
  - Incorporate MESA Isochrones & Stellar Tracks (MIST) Model to understand where these LBVs and candidates sit in the stellar evolution process.
- **This work is part of a poster to be presented at 2025 Galileo Circle Scholar Poster Presentation.**

References

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- Smith N., E Andrews J., Moe M., Milne P., Bilinski C., Kilpatrick C.-D., Fong W.-F., et al., 2020, MNRAS, 492, 5897. doi:10.1093/mnras/staa061
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- Light Curve of S Doradus: AAVSO Enhanced Light Curve

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