

The background of the slide is a deep space image featuring a large, textured, reddish-brown nebula in the center. Surrounding it are various blue and purple nebulae and star trails, creating a dynamic and colorful cosmic scene.

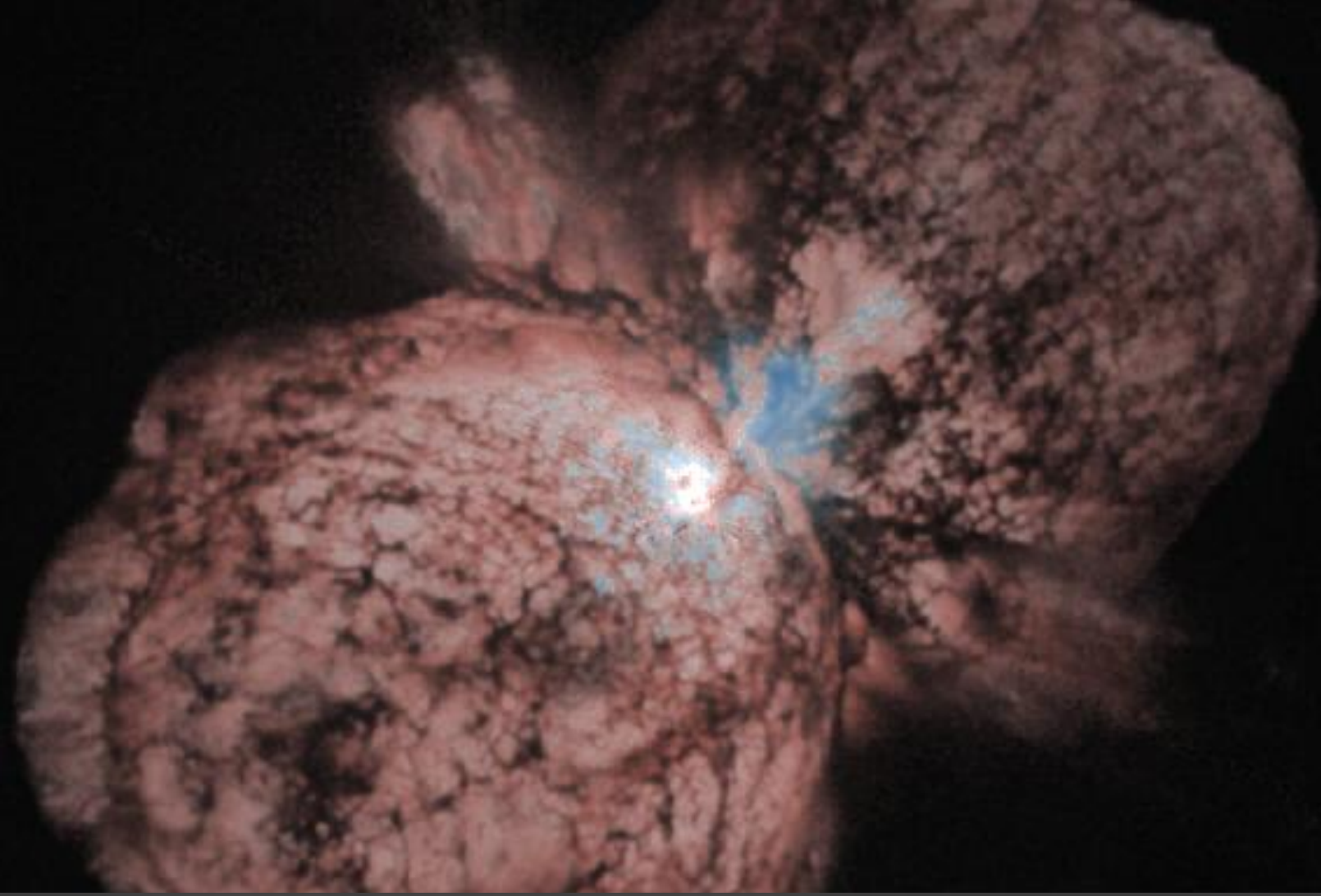
Multi-Epoch Photometry of Luminous Blue Variables (LBVs) in M31 and M33

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Agenda

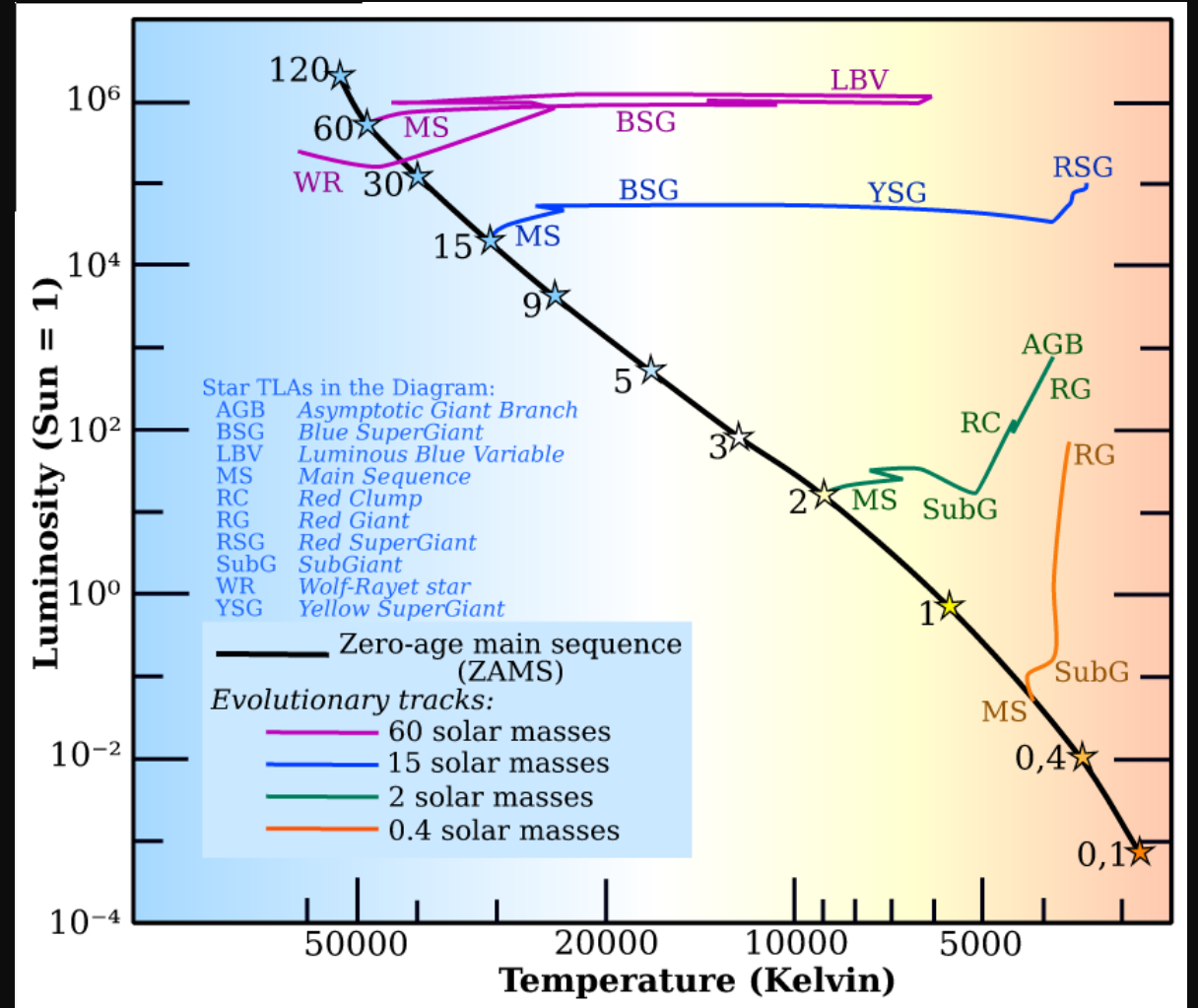
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|-----------|-------------------------|
| 01 | Luminous Blue Variables |
| 02 | Methodology |
| 03 | Preliminary Results |
| 04 | Future Implications |



1. Luminous Blue Variables (LBVs)

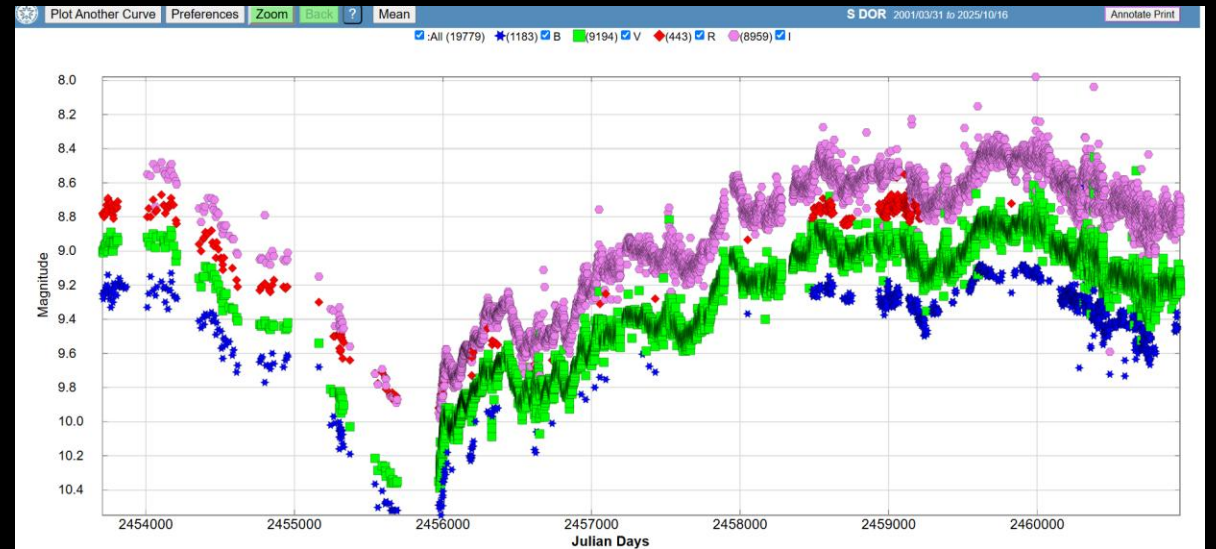
Post-MS Evolution of Massive Stars

- Post-MS evolution for stars with $M_{ZAMS} \geq 30 M_{\odot}$ is different from those with lower mass
 - Evolve with constant bolometric luminosity
 - Vary depending on luminosity
 - E.g., stars with $\log\left(\frac{L}{L_{\odot}}\right) > 5.8$ may not become RSGs (Humphreys & Davidson 1994)
 - Mass loss also plays a *deterministic* role (Smith & Tombleson 2015)
- One of the typical evolutionary scheme is: (Sholukhova et. al. 2018, see also Smith & Tombleson 2015)
 $O \rightarrow Of/ WNH \rightarrow \underline{LBV} \rightarrow WN \rightarrow WC \rightarrow SN$



LBVs

- Also classified as Hubble-Sandage variables (Hubble & Sandage 1953) or S Dor variables (Wolf 1989)
- Have the **highest** mass loss rates of any stars (Smith et. al. 2020)
- Unstable, massive, evolved stars with irregular outbursts, leading to the formation of a “pseudo-photosphere” (Szeifert et. al. 1996)



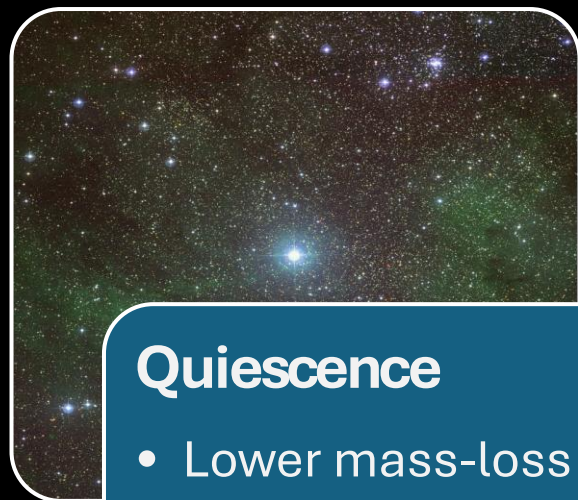
(Credit: AAVSO enhanced LCG)

Pseudo-photosphere?



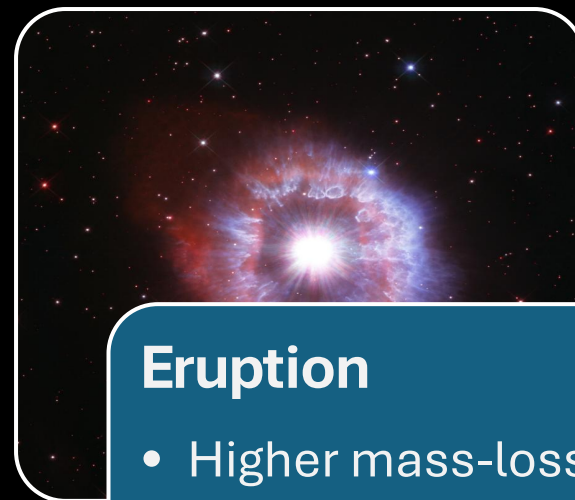
(Credit: NASA, ESA, STScI)

Pseudo-photosphere?



Quiescence

- Lower mass-loss rate
- “Normal” high temperature ($> 15,000$ K)



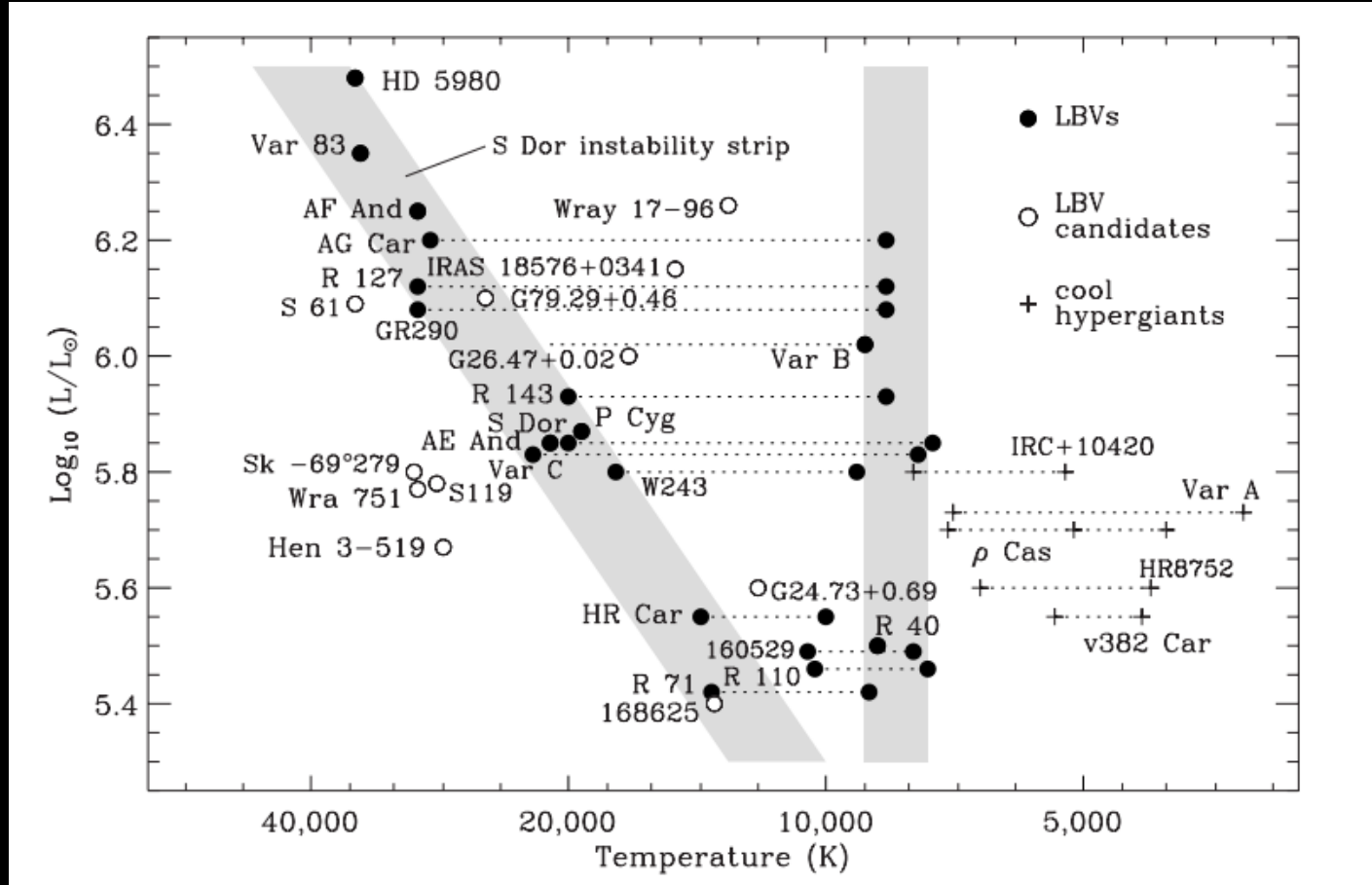
Eruption

- Higher mass-loss rate
- Cool (7000-9000 K) and dense ($N \sim 10^{11} \text{ cm}^{-3}$) expanding envelope

→ Brightening in visible wavelengths at constant bolometric luminosity

(Szeifert et. al. 1996, see also Humphreys & Davidson 1994)

S Dor instability & constant-temperature strips



(Smith, Vink, & de Koter 2004)



2. Methodology

Methodology

- Data Analysis:
 - All LBV and LBV candidates: John Martin at the University of Illinois Springfield Henry R. Barber Research Observatory
 - For M31 AE And & AF And and M33 Var 2 and Var C: American Association for Variable Star Observers



Methodology

- Photometric Data Acquisition

- Calculate color index
- Apply color correction: $E(B - V) = 0.16$ for M33 and 0.48 for M31
 $m_V = V - 3.1 \times E(B - V)$

- Convert to absolute V-band magnitude: $d = 784 \pm 0.006 \text{ kpc}$ for M31 and $d = 869 \pm 0.018 \text{ kpc}$ for M33

$$M = m - 5 \log \left(\frac{d}{10} \right)$$

- Plot a Color-Magnitude Diagram ($B - V$ vs. M_V)
 - Stellar evolution tracks from MESA Isochrone and Stellar Tracks (MIST)
 - S Doradus instability strip and constant-temperature strip
- Plot the change in (color-corrected) color indices against the change in absolute V-band magnitude

$$\Delta M_V = M_{V,peak} - M_{V,trough}$$

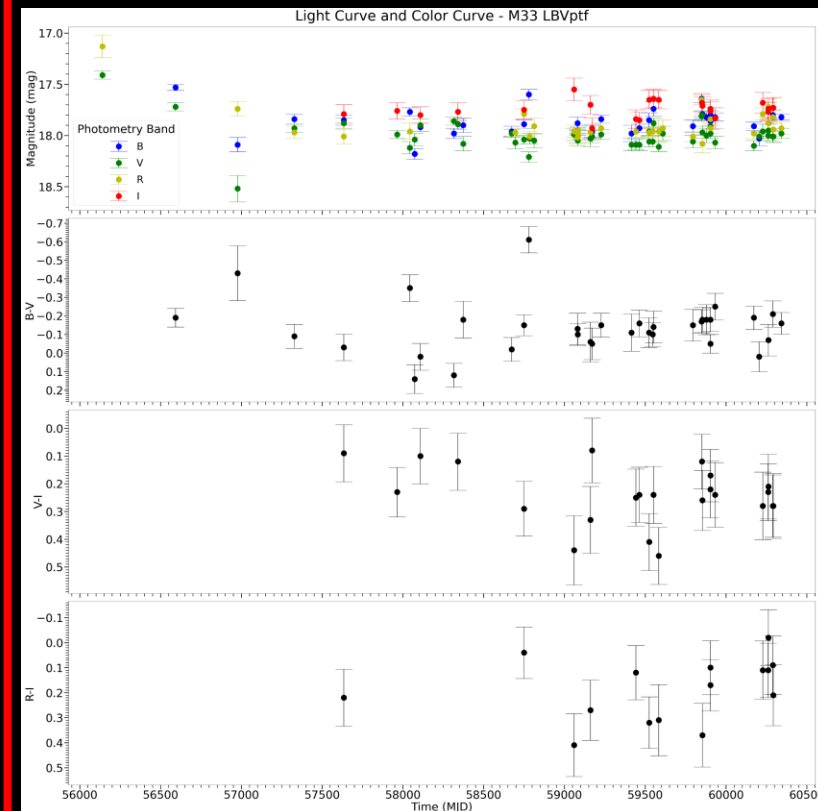
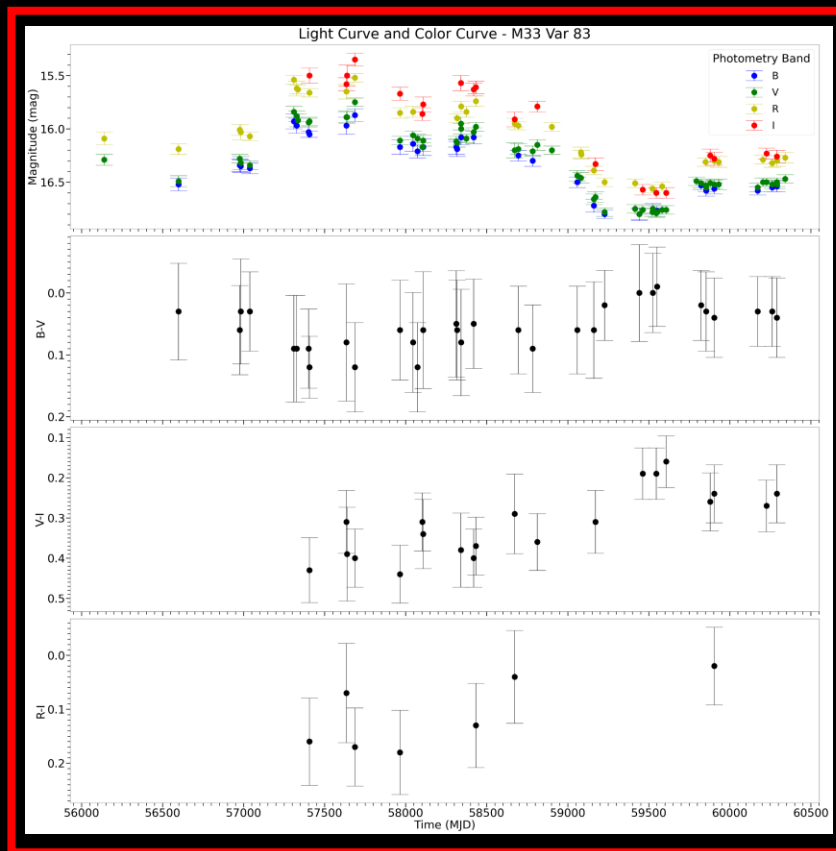
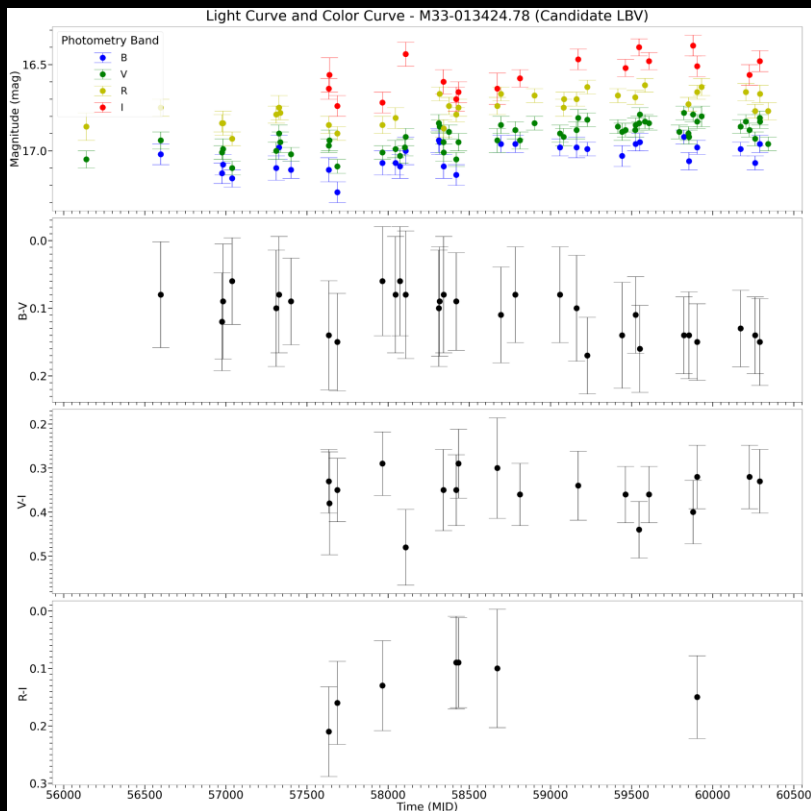
$$\Delta(B - V) = (B - V)_{peak} - (B - V)_{trough}$$

The logo for the MESA Isochrone and Stellar Tracks (MIST) project. It features the word "MIST" in a stylized, light blue font. The letter "I" is composed of two vertical bars. The letter "S" is a continuous, flowing curve. The letters "M", "T", and the second "I" are solid light blue. The entire logo is set against a dark grey rectangular background.



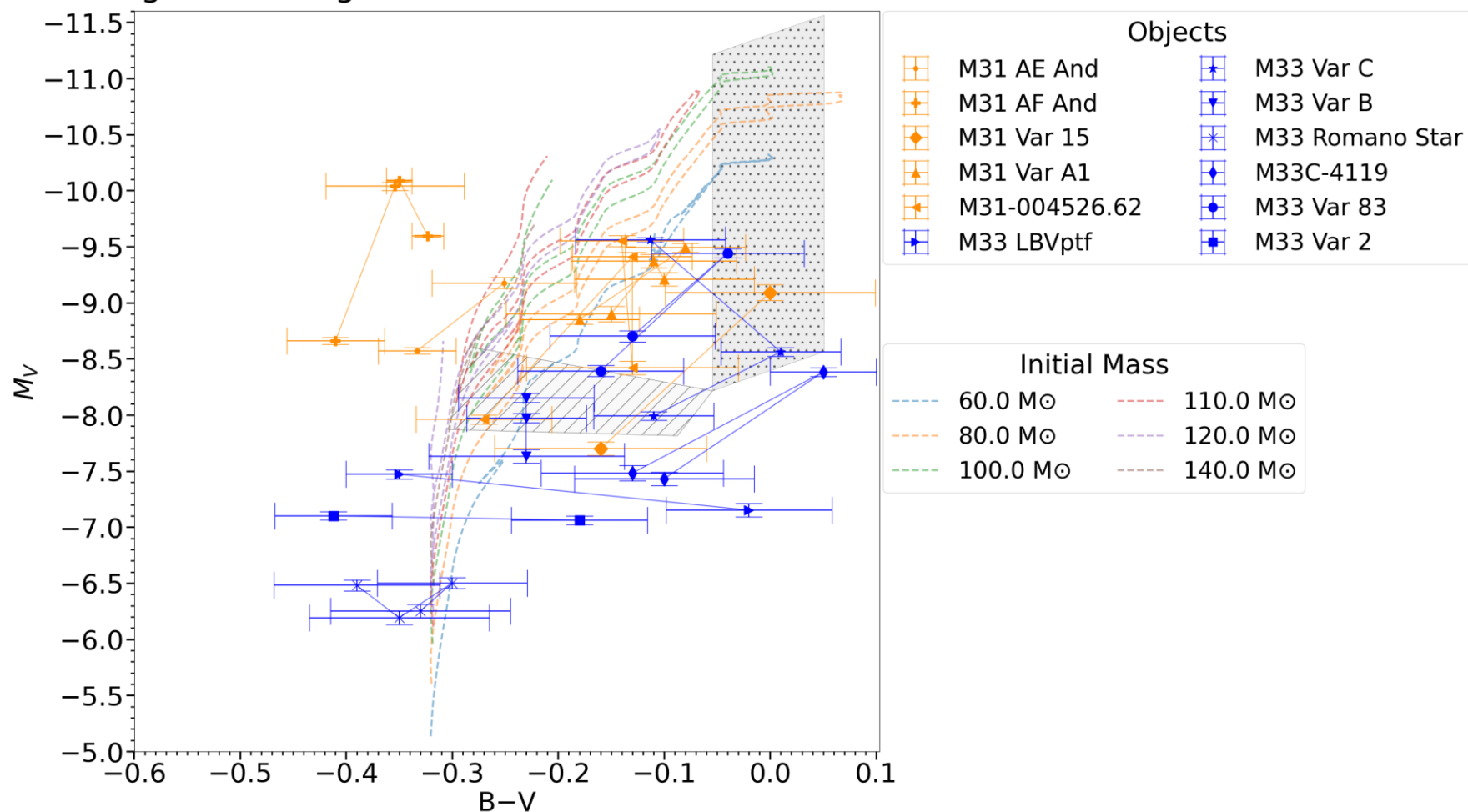
3. Preliminary Results

Light Curves and Color Curves

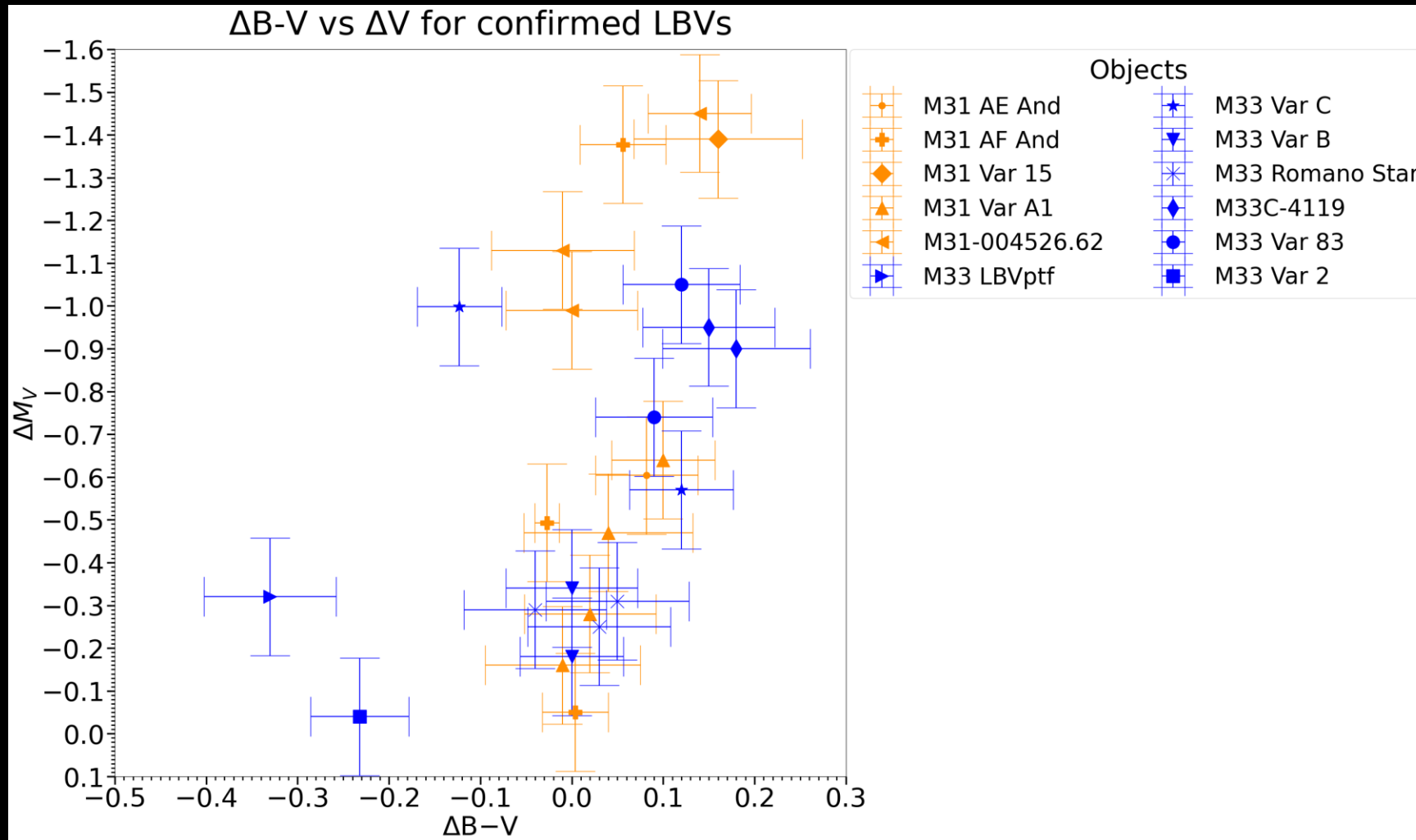


Color-Magnitude Diagram

Color-Magnitude Diagram of Confirmed LBVs in M31 and M33



$\Delta(B - V)$ vs. ΔV

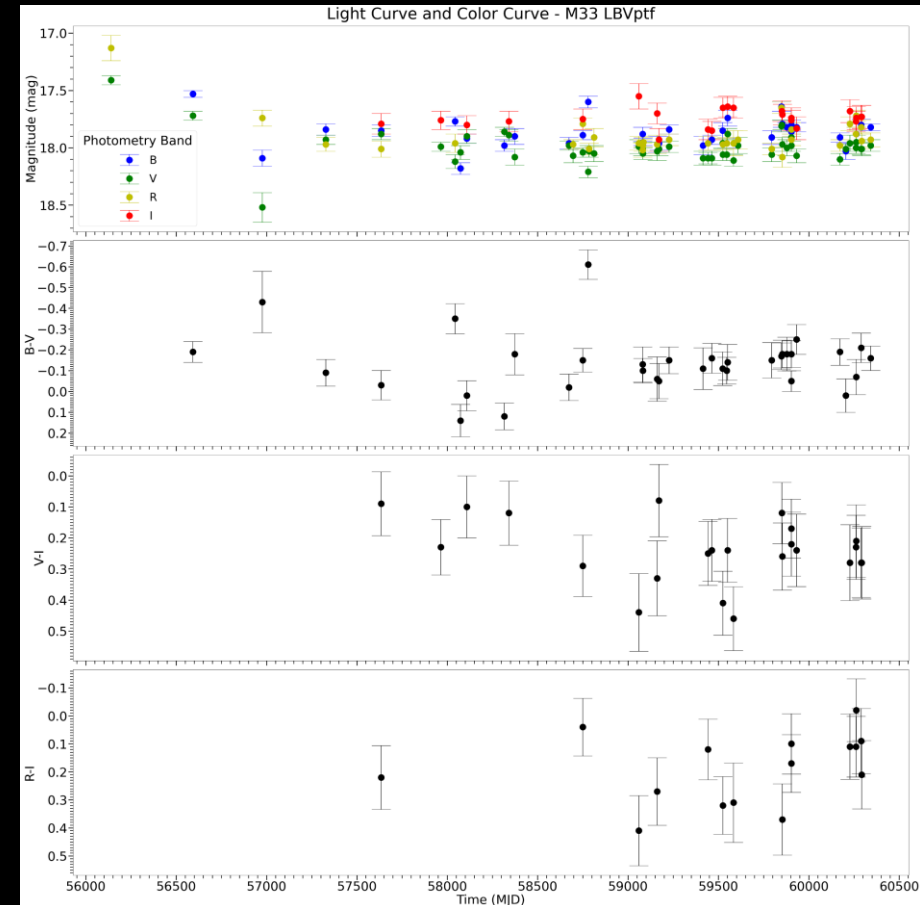
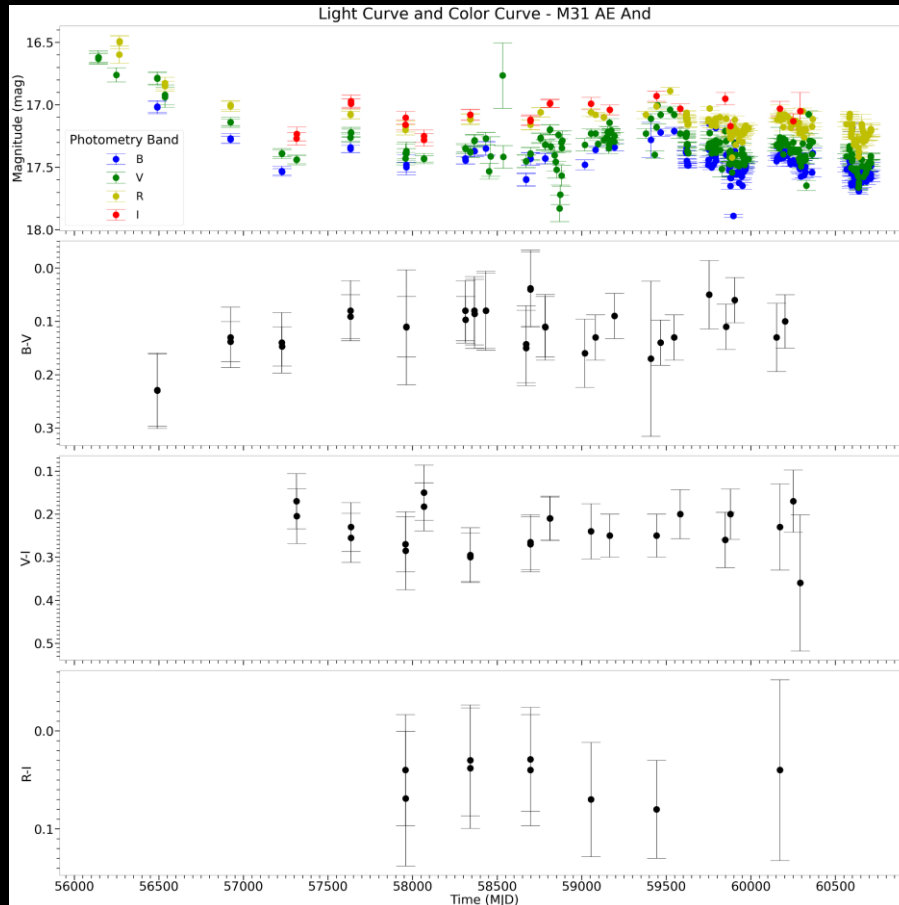




4. Future Implications

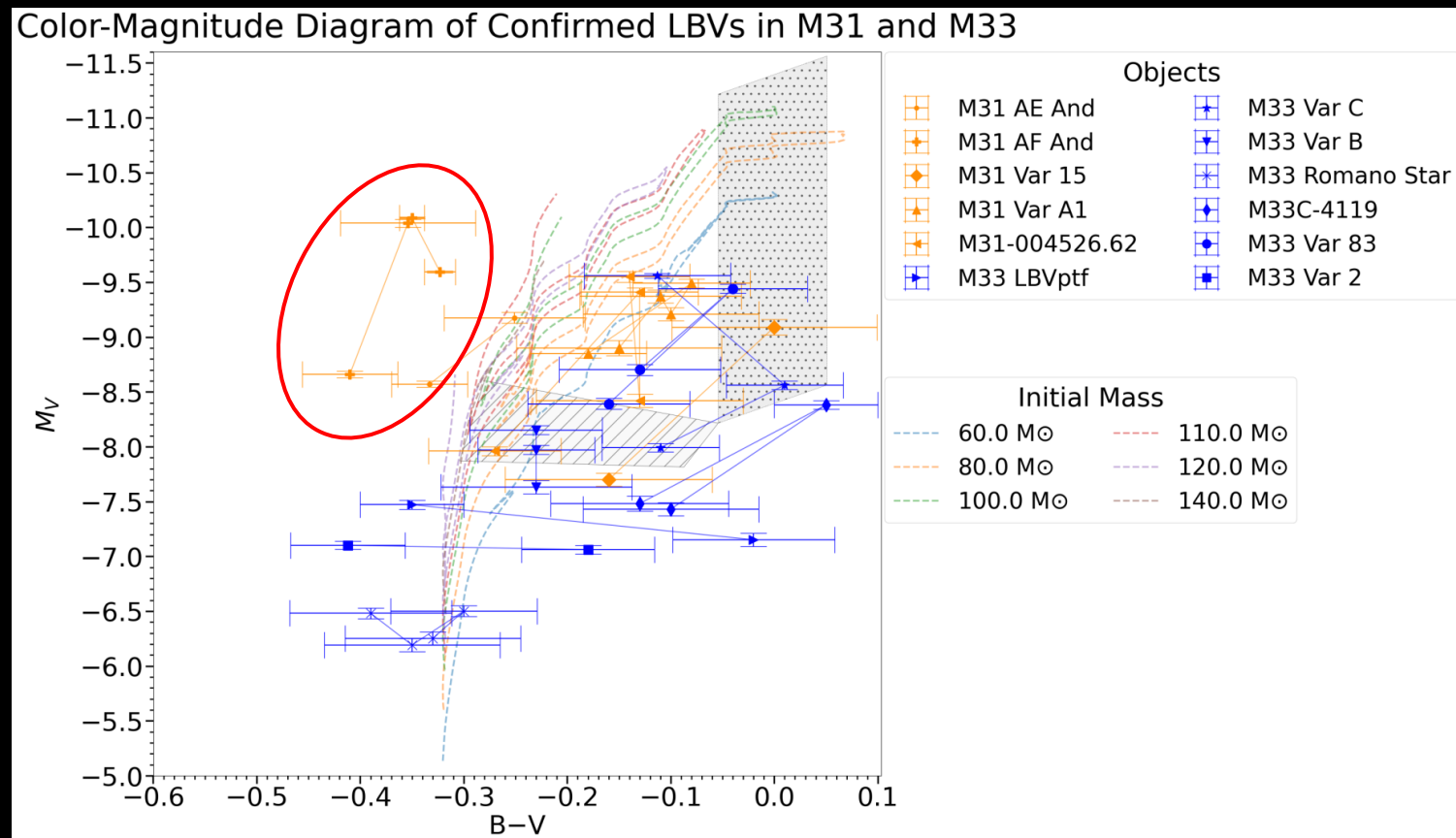
Future Implications

- Obtain more photometry to capture missing outbursts



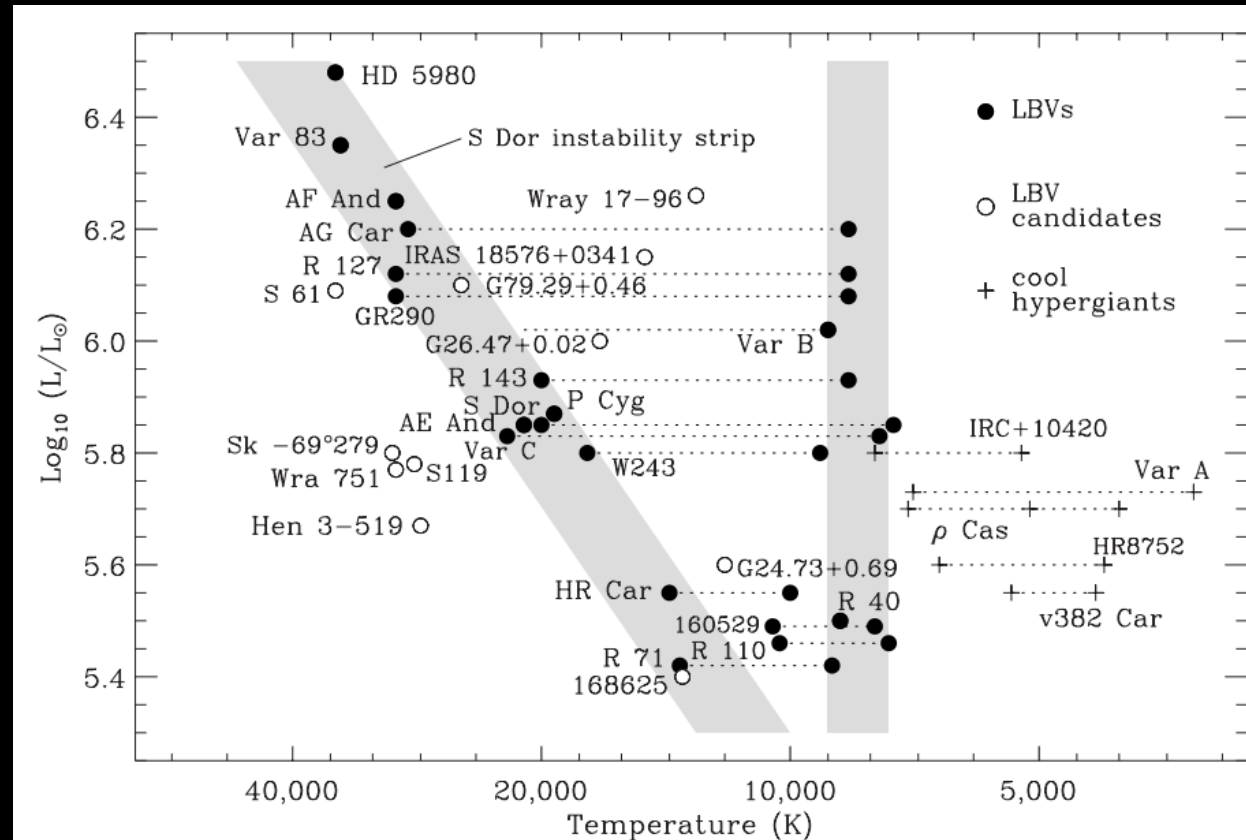
Future Implications

- Apply color correction for individual objects



Future Implications

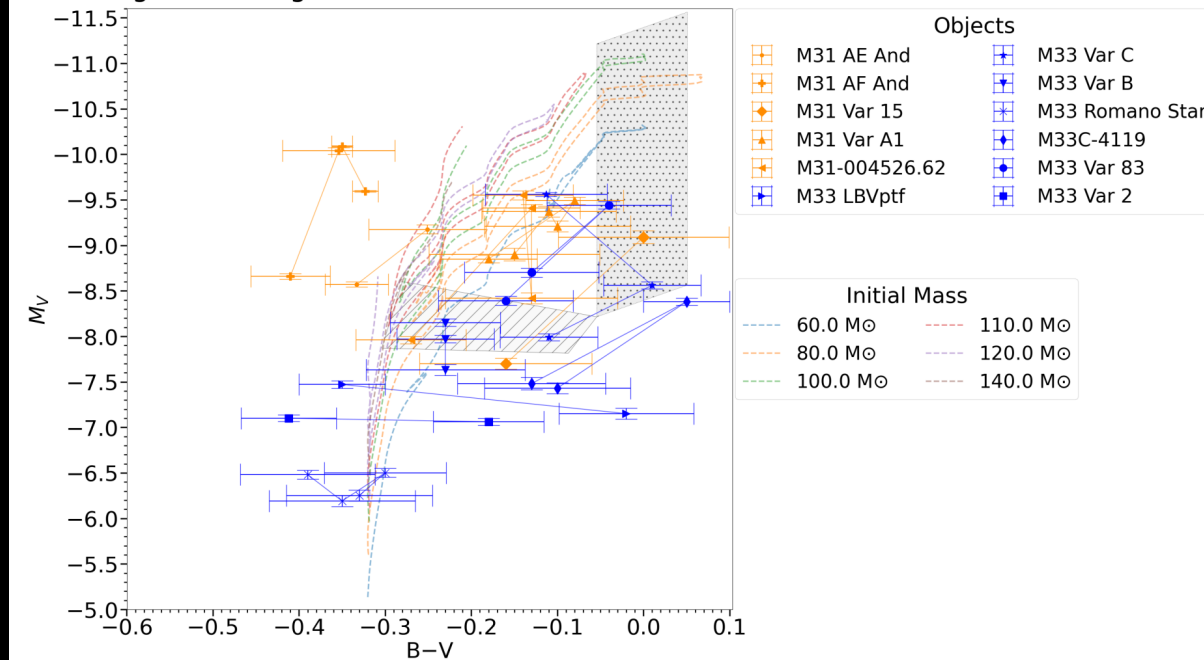
- Do they get brighter with constant bolometric luminosity?



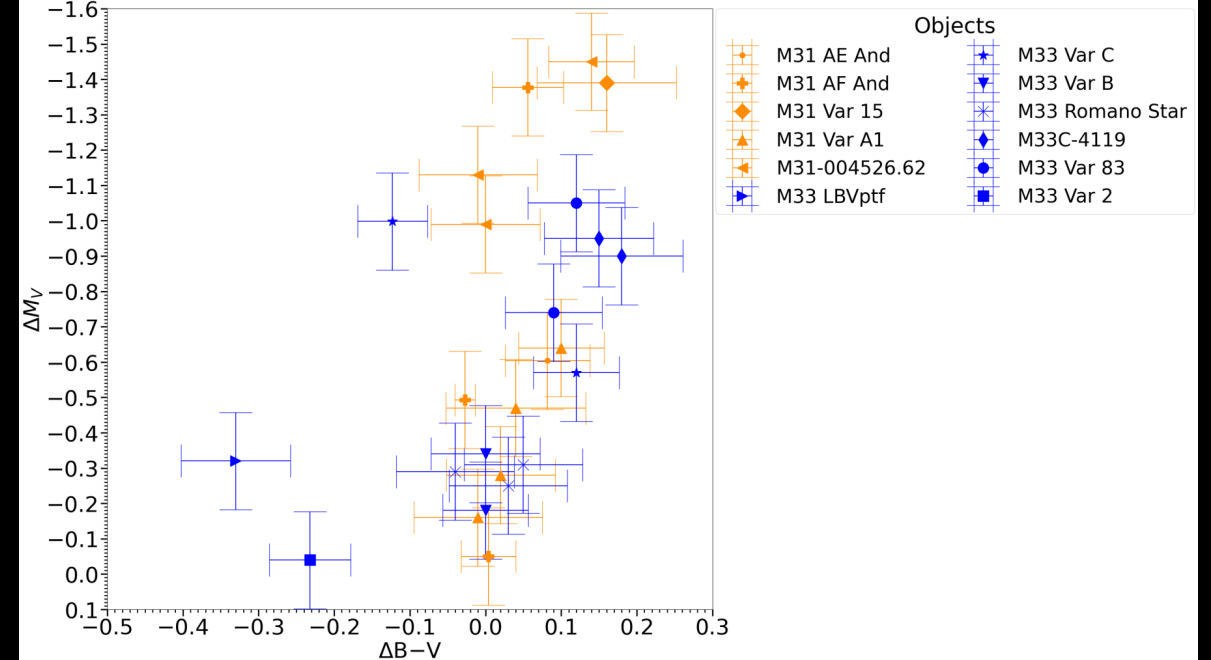
Future Implications

- Do they get brighter with constant bolometric luminosity?

Color-Magnitude Diagram of Confirmed LBVs in M31 and M33



$\Delta B-V$ vs ΔV for confirmed LBVs



References

- Humphreys, R. M., & Davidson, K. 1994, PASP, 106, 1025
- Sholukhova, O. N., Fabrika, S. N., Valeev, A. F., & Sarkisian, A. N. 2018, AstBulletin, 73 (4), 413-424
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- Szeifert, Th., Humphreys, R. M., Davidson, K., Jones, T. J., Stahl, O., Wolf, B., Zickgraf, F. J. 1996, A&A, 314, 131-145
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The background of the slide is a deep space image featuring a large, textured, reddish-brown nebula in the center. Several bright stars with prominent diffraction spikes are visible in the upper left corner. Faint, wispy clouds of blue and purple gas are scattered throughout the scene. Thin, intersecting lines of light, possibly representing a celestial coordinate system or data paths, crisscross the image.

Thank you for Listening!
