# Estimating Interstellar Reddening from the Intrinsic (V-I) Colors of RR Lyrae Variables

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## ABSTRACT

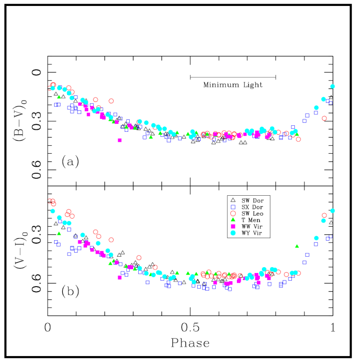
We present refined BVI light curves for six field RR Lyrae variable stars. The refinements include new data and improved photometric calibration compared to our previous work. For each star, we derive the intensity-mean magnitudes, light amplitudes, and colors at minimum light. We combine our results with literature data to estimate the mean, dereddened RR Lyrae color at minimyn light to be $(V\text{-}I)_{0,min}$ = 0.58 ± 0.02 mag with a star to star scatter of 0.024 mag. Any dependence of color on metallicity is too weak to be formally detected with the available data. One of our stars exhibits the Blazhko Effect. The star's minimum light color is unchanged at the two observed phases of the star's Blazhko cycle, while the maximum light color changed significantly. This insensitivity further supports the reliability of minimum light (V-I) colors as a tool for measuring interstellar reddening.

## INTRODUCTION

RR Lyrae variable stars (RRL) are widely used as distance indicators for old stellar populations. However, many targets such as the Galactic bulge, globular clusters, thick-disk RRL, and the Sagittarius dwarf galaxy lie at low Galactic latitudes where the foreground reddening is high and spatially variable. For these objects, it is ideal if reddening estimates can be derived directly from the RRL themselves, rather than relying on low-resolution reddening maps such as those of Burstein & Heiles (1982) or Schlegel, Finkbeiner, & Davis (1998).

Sturch (1966) found that, after small corrections for period and metallicity differences between the stars, all RRL have nearly the same dereddened (B-V) color at minimum light (phase between 0.5 and 0.8). Sturch developed this property into a tool for measuring the interstellar reddening toward RRL, and Blanco (1992) refined the calibration. Day et al. (2002) presented new BVI light curves for six RRL to test the hypothesis of Mateo et al. (1995), who suggested that (V-I) color at minimum light might make and even better indicator of foreground reddening.

In this research, we report on new data gathered to correct both these deficiencies, and to update the mean, dereddened (V-I) color calibration at minimum light described above.

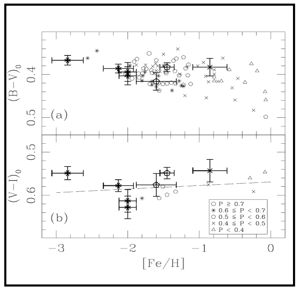



## COLOR CURVES

(ABOVE)

Above we present the dereddened color curves for all six RRL. Different symbols are used to represent the individual variable stars as shown in the key.

The $(B\text{-}V)_0$ curves have a smaller scatter in color at minimum light than the $(V\text{-}I)_0$ curves (rms = 0.019 mag and 0.031 mag, respectively). This could arise from the larger error found in our I-band transformation relations, or from increased contamination by background LMC stars which are more visible in the I-band images. However, individual stars appear to display fairly flat behavior in both $(B\text{-}V)_0$ and $(V\text{-}I)_0$ across the minimum light phase interval, supporting the idea that this is an effective range of phases on which to base mean color and reddening estimates.



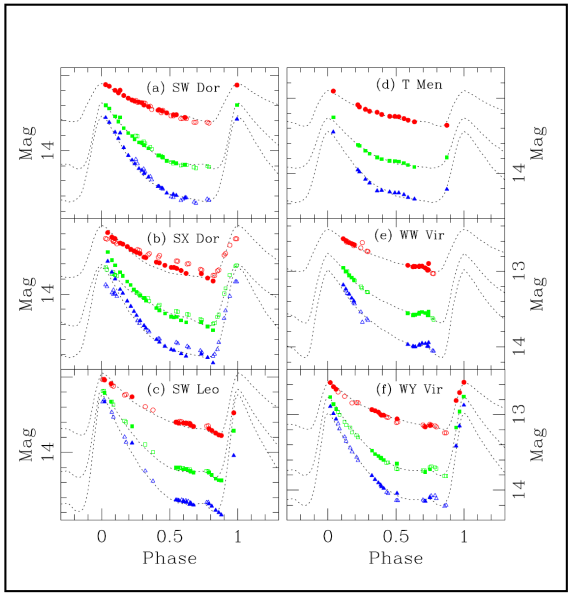
## METAL ABUNDANCE

(LEFT)

Dereddened minimum-light colors are shown as a function of metallicity. Bold symbols mark the six RRL from this study while light symbols indicate data taken from the literature. The symbols indicate the period of each star as shown in the key.

Our new RRL agree well with the $(B\text{-}V)_{0,min}$ values of stars from the literature, following their color-metallicity-period behavior.

A simple average of the 16 stars indicates $(V\text{-}I)_{0,min}$ = 0.58 ± 0.02 mag with a star to star scatter of 0.024 mag and little dependence of color on metallicity .




## LIGHT CURVES

(ABOVE)

We present light curves for the six variable stars. Points represent observed data in B (triangles), V (squares), and I (circles). 2001 (Schmidt) and 2002 (0.9-m) data are indicated by open and filled points, respectfully.

The Data for each star were then folded by the period specified in the General Catalogue of Variable Stars (Kholopov 1985). By combining the 2001 (Schmidt) data set and the 2002 (0.0-m) set, we obtained more complete phase coverage for each star, except in the case of T Men which was not observed by Day et al. (2002).

The resulting light curves are shown above. To help exhibit the stars' behavior, each light curve was fit with a series of six RRL light curve templates as described in Layden (1998) in each of B, V, and I, with the best fitting template show above.

For most of the stars the fitted template describes the light curve shapes for both the 2001 (Schmidt) and 2002 (0.9-m) data sets. The exception is SX Dor, which displays different light curve shapes and amplitudes for the two data sets. We interpret this to mean that SX Dor exhibits the Blazhko Effect, in which these parameters change gradually in a cycle with a periodicity much longer that the pulsation cycle (Blazhko 1907).

We estimated intensity-mean magnitudes and pulsation amplitudes in all B,V, and I for each star from the observed data. In the case of WW Vir, which lacks data around maximum and minimum light, we obtained these values from the fitted templates instead.

We also computed the colors at minimum light via an arithmetic mean of the observed (B-V) and (V-I) data values, in magnitude units, having phases between 0.5 and 0.8.

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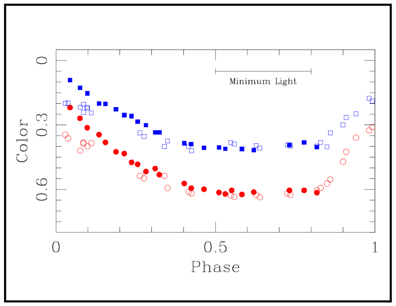
## OBSERVATIONS AND REDUCTIONS

Images were obtained at the 0.9-m telescope at the Cerro Tololo Inter-American Observatory (CTIO) on six nights over 2002 January 22-27. The Tek#3 2048 CCD camera was used and filters were selected to reproduce the Kron-Cousins I and Johnson B and V passbands. Each time the telescope was pointed to a particular variable, a BVI sequence of images was obtained.

In the previous study done by Day et al. (2002) the CTIO Schmidt telescope was used, which provided a larger field of view than the 0.9-m. Although the larger field of view provided the previous study with more bright comparison stars, the 0.9-m telescope still had ample comparison stars and the internal photometric accuracy of the 0.9-m data proved to be superior to that of the Schmidt.

These comparison stars were used to perform differential photometry with respect to the variable on night that were photometric. Two of the six nights were photometric and several Landolt (1992) standard star fields were observed one ach night at a range of airmasses and times bracketing the RRL observations. These images were used to calibrate the differential photometry for this run and to recalibrate the photometry taken with the Schmidt.




## BLAZHKO EFFECT

(ABOVE)

Above we present the dereddened color curves specifically for the Blazhko star SX Dor. Squares indicate $(B\text{-}V)_0$ while circles indicate $(V\text{-}I)_0$ data. Open and filled symbols indicate data obtained in 2001 (Schmidt) and 2002 (0.9-m) respectfully.

This star provides us with an opportunity to study whether the Blazhko Effect influences the star's color and reddening estimated from it. Around maximum light, the colors obtained in 2001 and 2002 deviate significantly, whereas at minimum light the deviation is small or nonexistent. This supports the idea that basing the colors on the phase range 0.5-0.8 provides more reliable reddening estimate than on wider phase ranges. Further study of this and other Blazhko stars would help to clarify and strengthen this result.

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