

An empirical method to estimate distances using B-stars in eclipsing binary systems

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Eclipsing binaries: outline

Paczynski advocated the use EBs as distance indicator to **external** galaxies.

- Guinan et al. (1998) and other groups:
"Flux-fitting method"
- "Alternative empirical method"

Flux-fitting & Alternative method

Step 1:

- Photometric monitoring
- Radial velocity monitoring

⇒ Analysis with “Wilson-Devinney” type code gives masses and radii ($\log g$) for both components, individual colours and magnitudes, ratio of effective temperatures (one assumed, second derived)

Flux-fitting method II

Step 2:

- Guinan et al. 1998, Fitzpatrick et al. 2001, Ribas et al. 2002: high-resolution UV-optical spectra (HST FOS) + broadband photometry + model atmospheres + χ^2 fitting
- **Bye the way:** Harries et al. 2002 (MN in press): disentangle spectra, Spt. type by eye, T_{eff} – Spt. type, reddening from adopted $(B - I)_0$

Flux-fitting method III

$$f_{\text{model}}(\lambda) = \left(\frac{r_A}{d}\right)^2 [F_\lambda^A + (r_B/r_A)^2 F_\lambda^B] \\ \times 10^{-0.4 E(B-V) [k(\lambda-V)+R]}$$

$$k(\lambda - V) = c_1 + c_2 x + c_3 / (\gamma^2 + (x - x_0^2/x)^2) + c_4 F(x)$$

degeneracies: $R - c_1$, and $c_1 - \left(\frac{r_A}{d}\right)^2$
(Groenewegen & Salaris 2001, A&A 366, 752)

nine parameters: $T_{\text{eff,A}}$, $[\text{Fe}/\text{H}]$, $E(B - V)$, d
 R , x_0 , γ , c_3 , c_4 .

Flux-fitting method IV

- Observationally expensive
- Merging of FOS spectra (difficulty to get highly accurate flux-calibrated spectra over the entire wavelength region)
- Folding spectra with broadband transmission curve give magnitudes in disagreement with ground based photometry.
- Fitting procedure: relative weights of broadband data and spectral data
- Uncertainty in model atmospheres (Groenewegen & Salaris 2001)

Alternative method I

Purely empirical

surface brightness:

$$S_\lambda = m_\lambda + 5 \log \phi$$

or

$$\phi_{(m_\lambda=0)} = \phi \cdot 10^{m_\lambda/5},$$

and

$$d(\text{pc}) = 1.337 \times 10^{-5} R(\text{km}) / \phi (\text{mas})$$

Key step: calibrate $\phi_{(m_1=0)}$ versus colour $(m_2 - m_3)$

Choose m_1, m_2, m_3

Alternative method II

Wish list

- tight relationship for main-sequence B-stars
- local calibrators available
- depends as little as possible on reddening and metallicity

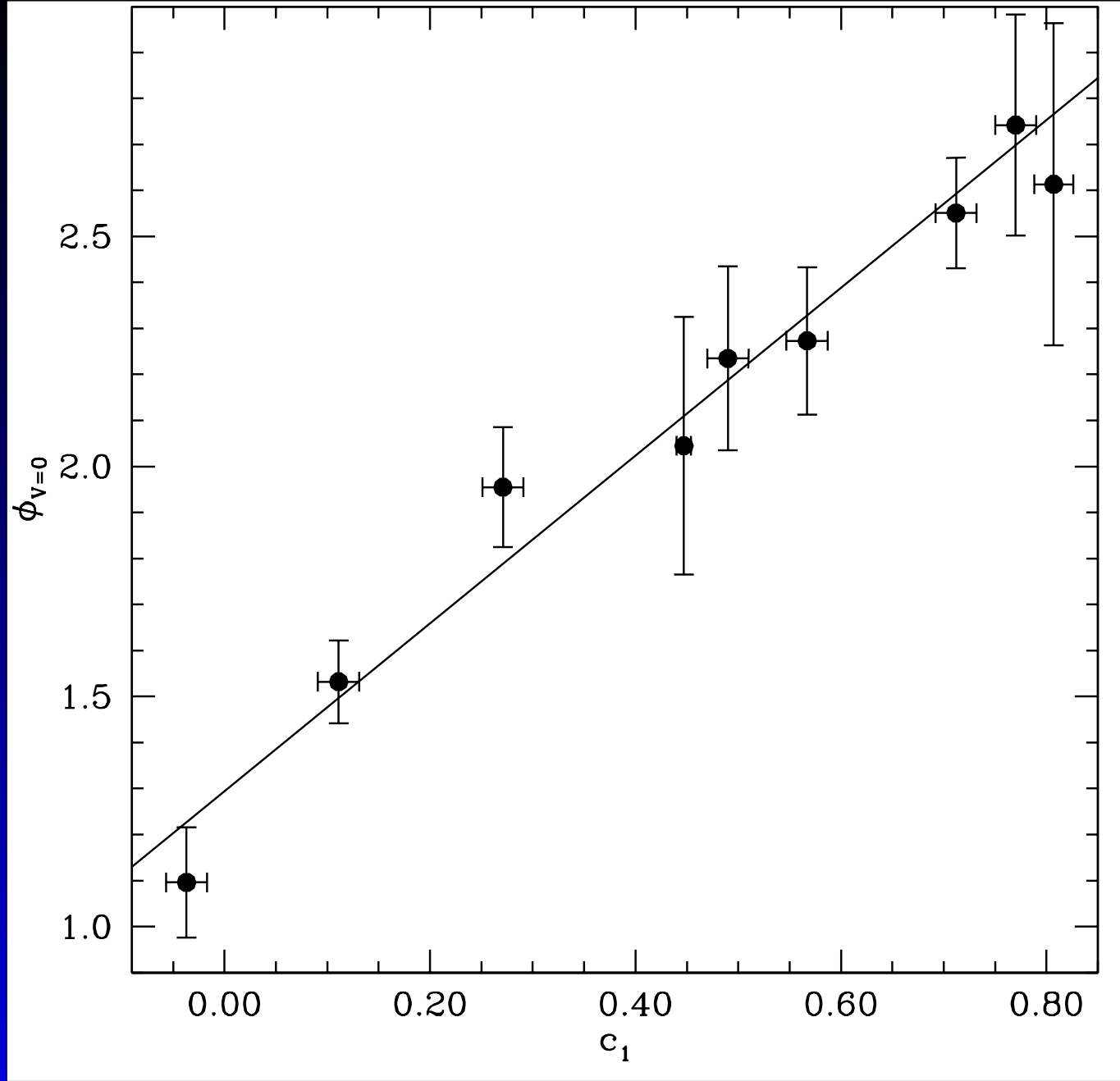
In the end.....: Strömgren photometry

$$\phi_{(V=0)} = 1.824(\pm 0.180) c_1 + 1.294(\pm 0.078)$$

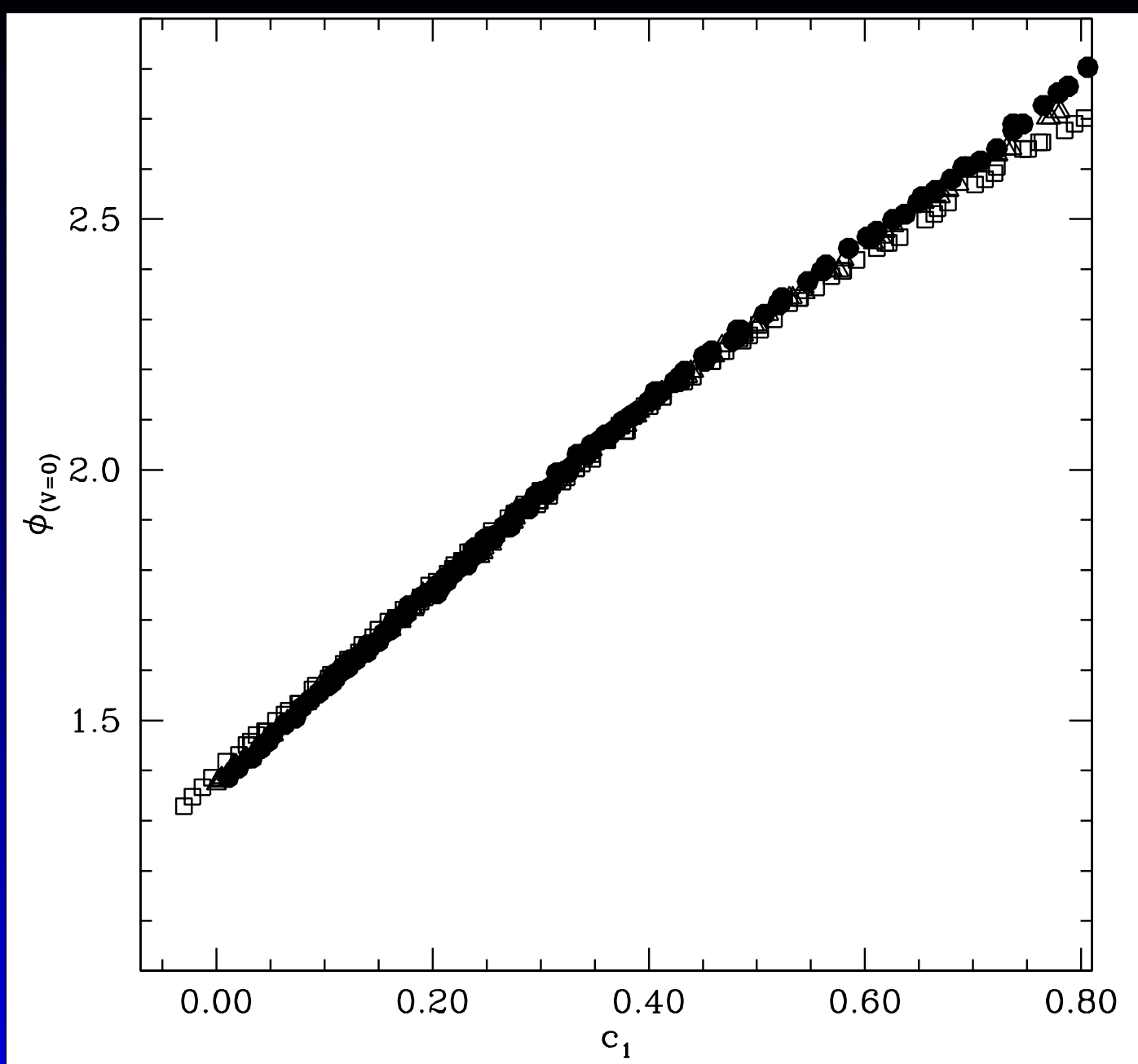
(Salaris & Groenewegen 2002, A&A 381, 440)

Calibrators

9 B-stars: 2 EB with accurate Hipparcos parallaxes +
5 with direct angular diameter determinations



The calibration



$[\text{Fe}/\text{H}] = -0.7(\bullet), -0.4(\triangle), 0.0(\square)$

Alternative method III

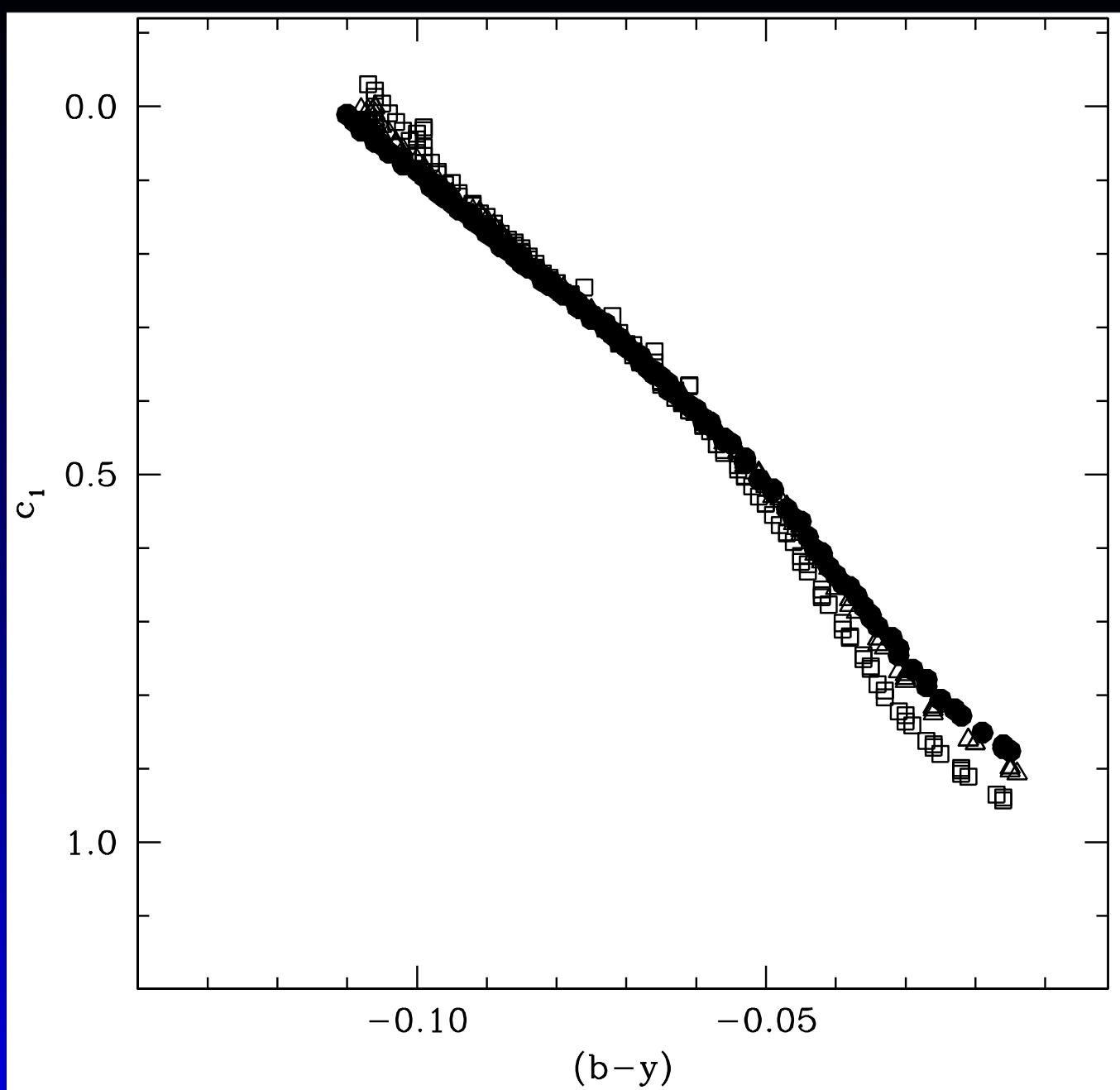
Advantage: reddening

Standard relationship $(c_1)_0$ versus $(b - y)_0$ for B-stars
(Perry et al. 1987)

c_1 depends very weakly on reddening –
 $(c_1)_0 = c_1 - 0.20E(b - y)$

$$E(b - y) = E(B - V)/1.4 = (b - y) - (b - y)_0$$

reddening determination is metallicity independent



$[Fe/H] = -0.7(\bullet), -0.4(\triangle), 0.0(\square)$

Applications I

3 Galactic EB systems with poor Hipparcos parallaxes

name	σ_V	$\sigma_{(b-y)}$	σ_{c_1}	$(m - M)_0$	$(m - M)_{0,Hip}$
HD24909A	± 0.014	± 0.004	± 0.011	7.29 ± 0.12	7.62 ± 0.78
HD161783A	± 0.010	± 0.005	± 0.010	7.83 ± 0.12	7.01 ± 0.52
HD218066A	± 0.04	± 0.010	± 0.015	9.60 ± 0.16	9.30 ± 1.53
HD218066B	± 0.04	± 0.010	± 0.015	9.62 ± 0.16	9.30 ± 1.53

Final accuracy in distance depends on accuracy in photometry

Applications II

LMC

name	σ_V	$\sigma_{(b-y)}$	σ_{c_1}	$(m - M)_0$
HV 982 A	± 0.02	± 0.041	± 0.045	18.43 ± 0.24
HV 982 B	± 0.02	± 0.041	± 0.045	18.42 ± 0.24

Summary

- Empirical surface-brightness method calibrated on main-sequence B-stars
- Calibrations almost independent of metallicity for [Fe/H] values spanning a range between the SMC and the Galactic bulge metallicity
- Reddening and distance can be derived simultaneously
- Single object accuracy of ~ 0.15 mag in distance modulus for ~ 0.02 mag photometric accuracy
- Observationally “cheap”
- Now extended to Geneva photometry

$$\phi_{(V_{\text{Geneva}}=0)} = 0.446(\pm 0.084) d + 0.265(\pm 0.128)$$

THE END