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INTRINSIC B-V COLORS FOR GALACTIC CEPHEIDS AND SOME COMMENTS ON THE SANDAGE-TAMMANN RELATIONSHIP

THOMAS KELSALL

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Thomas Kelsall

Theoretical Studies Branch
NASA-Goddard Space Flight Center
Greenbelt, Maryland 20771

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ABSTRACT

Transformations are found for converting the b-y color excesses for cepheids given by Williams (1966) and Kelsall (1971) into B-V excesses. The combination of these results with the E(B-V)'s determined by Sandage and Tammann (1971) gives precise data for eighty-eight galactic cepheids. The period-color and period-color-(amplitude defect) relationships, that are germane to the LogP intervals 0.4 to 1.4 and 0.4 to 1.3, respectively, are found.

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I. INTRODUCTION

The general reasons for determining accurate intrinsic colors for cepheids are by now obvious and well appreciated: (1) to give precise definition of the location of the instability strip; (2) to aid in calibrating the atmospheric modelling results; (3) to allow for an accurate estimate of the interstellar reddening; (4) to be of use in magnitude determination through a period-luminosity-color relationship; and, (5) to permit the use of cepheids as indicators of galactic structure, and as distance markers.

The above reasons are sufficient justifications for the restudy of cepheid colors, but in addition there is a more immediate motivation. In a recent, tightly-argued paper Sandage and Tammann (1971) show that the intrinsic B-V color for cepheids with $\mathrm{LogP}<0.86$ is well represented by the expression

$$\langle B\rangle_o - \langle V\rangle_o = 0.227\mathrm{LogP} - 0.311f_B + 0.584 \qquad (1)$$

The second term on the rhs of Eq. (1) is an innovation. This term uses the blue-amplitude defect, f_B, as defined by Kraft (1960), to account for the variation of the intrinsic color with position within the cepheid instability strip. A major conclusion of the Sandage and Tammann paper is contained in Eq. (1) - for the short period cepheids the brightest and bluest are those with the largest amplitudes ($f_B \to 1$). For the longer period cepheids their results are less conclusive. In the LogP range 0.86 to 1.3 there is an indication that the above correlation is inverted, i.e., the cepheids on the red side of the instability strip have the larger amplitudes. For the longest period cepheids, LogP > 1.3, there is weak evidence that the amplitude/(strip position) correlation is similar as is that for the shortest period cepheids.

A sensitive point in the Sandage-Tammann work is the question whether it is valid to include cepheids from extra-galactic systems (SMC, LMC, M31) in the determination of the correlations. At least in the case of the SMC cepheids, there is considerable doubt that they are identical to those in our galaxy, or the LMC. Gascoigne (1969) argues that his observations indicating the SMC cepheids of $P < 10^d$ to be $\sim 0\overset{m}{.}1$ bluer than those in our galaxy are the result of their being deficient in metals by a factor of approximately four, as compared to those in our galaxy. In a more powerful analysis, using synthetic-spectra-simulation calculations, Bell and Parsons (1972) show that a reduction in metals by a factor of four does give the $0\overset{m}{.}1$ color difference observed by Gascoigne. They propose a further observational test for this metal deficiency of the SMC using Strömgren uvby photometry, a test which should be forth-coming and aid in settling this point.

It seems clear then that it is advantageous to expand the data on the intrinsic B-V colors of galactic cepheids, and with the increased information, to see whether the Sandage-Tammann relationship can be verified. We derive color excesses for sixty-four cepheids, and determine their intrinsic colors. The combination of this data with that given by Sandage and Tammann gives us a sample of eighty-eight galactic cepheids. We compare the results from this enlarged body of data with those given by Sandage and Tammann.

II. THE DATA

The data on the blue and visual magnitudes on the UBV system come from the catalog of Schaltenbrand and Tammann (1971). The confining upper envelope for the magnitude of the B amplitude as a function of period is taken from Schaltenbrand and Tammann (1970). We accept the modification of this envelope for the shorter periods given by Sandage and Tammann (1971). The distribution of the total sample of cepheids (88) in the (ΔB,LogP) plane is shown in Fig. 1. The sample is reasonably good within the range 0.6 to 1.3 in LogP, but spotty elsewhere.

Williams (1966) and Kelsall (1971) have observed the cepheids on a composite photometric system made from the Strömgren uvby (1966) and the Crawford ABC (1961) systems. From these investigations we take only the color excesses for the blue-minus-yellow color, b-y. The procedure determining these excesses is identical in nature in both studies. An intrinsic relation in the (G,b-y) plane (G is Crawford's G-band strength color index, G = B-A) is ascertained. To obtain a color excess each phase point for a cepheid in the (G,b-y) plane is traced back following the reddening line until intersection with the intrinsic color curve. The displacement in b-y from the observed position to the intersection juncture is the color excess for that phase point. The adopted excess for a cepheid is the average of such manipulations to all the observed phase points.

In Fig. 2 the cepheid data from Kelsall's study is plotted in the (G,b-y) plane. His intrinsic G/(b-y) relation is shown, as well as his estimates for the reddening lines associated with F5 and G5 supergiants. We note that all the points are well confined by the two reddening lines. It is particularly to be noticed that the points near zero phase for the short period cepheids ($P<10^d$) are evenly distributed about the F5 Ib reddening line, as would be expected. This is distinctly not true for the two long period cepheids ($P>10^d$; ζ Gem, X Cyg), which is also what should be anticipated.

III. TRANSFORMATION OF E(b-y) TO E(B-V)

We consider as fundamental the E(B-V)'s given by Sandage and Tammann (1971). The overlap of Sandage and Tammann with Williams (1966) is twenty stars, and with Kelsall (1971) it is only six stars. From the stars in common we find, by the method of least squares, the regression relations --

$$E(B-V)_{ST} = 1.170E(b-y)_W + 0.137, \qquad (1a)$$

and

$$E(B-V)_{ST} = 1.121E(b-y)_K + 0.064. \quad (1b)$$

The slopes in Eqs. (1) are appreciably smaller than the value of 1.4 usually used for main-sequence stars. These slopes are also somewhat less than the theoretical estimate of 1.27, appropriate for F-G supergiants, given by Bell and Kelsall (1973). The straightforward use of Eqs. (1) introduces a systematic difference in the transformed estimates of E(B-V) from Williams' and Kelsall's E(b-y)'s. This systematic effect is detectable from studying the results for cepheids common to these two investigations. To reduce the systematic effect, to come closer to the theoretical estimate of the ratio E(B-V)/E(b-y), to make use of only a single slope for both Williams' and Kelsall's results, and to retain compatibility with the overlap results of Sandage and Tammann, we find as a most adequate compromise the relations --

$$E(B-V)_{ST} = 1.22E(b-y)_W + 0.10 \quad (2a)$$

and

$$E(B-V)_{ST} = 1.22E(b-y)_K + 0.05 \quad (2b)$$

In the lower panels of Fig. 3 we show the correlations of the E(B-V)'s from Sandage and Tammann with the E(b-y)'s from Williams, and Kelsall. We see that the compromise regression lines are reasonable. In the upper panels comparisons are made with the E(B-V)'s determined by Schmidt (1972). Schmidt conservatively speculates that his work supports the E(B-V)'s given by Sandage and Tammann, except for a possible zero point difference. While the sample of stars in common with Williams or Kelsall is small, we would, on the basis of the results in Fig. 3, support this contention. The results in Fig. 3 also demonstrate that there is good agreement between Schmidt and Kelsall. We therefore believe Schmidt's difficulty in reconciling his results with Kelsall's results from use of an incorrect relation converting E(b-y) into E(B-V), the relation used is not given in his article (see also Kelsall 1972a). The anomalous result for AW Per in the Schmidt/Kelsall comparison is not too surprising, as this star is a spectroscopic binary (Lloyd Evans 1968). Finally, we would note that consideration of the Schmidt data as fundamental would also force us to a compromise situation in the transformations of the excesses. The regression lines for this case are --

$$E(B-V)_S = 1.301E(b-y)_W + 0.052 \quad (3a)$$

and

$$E(B-V)_S = 0.997E(b-y)_K + 0.075 \quad (3b)$$

It is clear from the comments on the difficulties involved in the transformation of the excesses that the ultimately accepted procedure is not perfect. However, we do feel that E(b-y)'s are of high quality and are derived in a self-contained manner that requires a minimum of assumptions. In addition, the close similarity in the independently derived results for the supergiants (Kelsall 1971,1972a), and those for the cepheids is reassuring. We should expect errors in the separate transformed values for E(B-V)'s from Williams' or Kelsall's E(b-y)'s to be of the order of $\pm 0\overset{m}{.}05$, and an average of the results for the overlap stars to be good to $\sim\pm 0\overset{m}{.}03$. This expected precision is comparable to that for the Sandage and Tammann, or the Schmidt results. Sandage and Tammann's adopted excess for a star is the average of that given by Kraft (1961; but also see Sandage and Tammann (1968), Pg. 568 and Table A2) using Gamma-photometry, and that calculated using Tammann's (1970) method utilizing the mean UBV colors. The internal accuracy of Schmidt's results evaluated by comparing the excesses calculated at equal phase points (points separated in phase by ±0.04 at most) is of the order of ±0.04, so his average excess for a star should be of similar precision.

IV. THE COLOR EXCESSES AND INTRINSIC COLORS

The adopted E(B-V) for a particular cepheid is the simple average of the overlapping results from the three investigations. The assignment of weights would little change the adopted values, and as such weights are often of dubious subjective origins they are not used. We do make one caveat, which applies to Williams (1966) data. Williams' results are based on fewer points per star than are those of Kelsall's (1971), except for X Cyg. Williams emphasized observations near maximum light, while Kelsall attempted to obtain the full phase curve. Thus, as the cepheids do deviate from their apparent similarity to the supergiants near maximum light, a small systematic error may be introduced. Having the adopted color excess, the intrinsic color for a cepheid is simply found using the color data from Schaltenbrand and Tammann (1971), $\langle B \rangle_o - \langle V \rangle_o = \langle B \rangle - \langle V \rangle - E(B-V)$.

The final outcome for our eighty-eight cepheids is given in Table I. The table's columns (left to right) list the star's name, LogP, f_B, the color excesses calculated from the three investigations, the adopted E(B-V), the intrinsic B-V color, and a quantity δ(B-V) to be discussed below (section V). The commonly used colon marks to denote uncertainty are applied to the E(B-V) values from Williams' work, if the number of determining phase points is three or fewer. These marks are also given to the known binary cepheids (Lloyd Evans 1968) - FF Aql, RW Cam, AW Per, and S Sge.

We make two final checks on our adopted color excesses. In Fig. 4 we compare our E(B-V)'s to those calculated from atmospheric model results by Parsons and Bouw (1971). The Parsons and Bouw excesses have been recently reanalyzed by Parsons and Bell (1972), and confirmed within very small deviations. The tightness of the correlation is not the best, but the scatter about a line of slope equal to one is quite even, except for the values for EV Sct and the spectroscopic binary RW Cam. To see if there is a pronounced color (temperature) effect we plot the color excess differences ($\Delta E = E(B-V)_{adopted} - E(B-V)_{other}$) versus our intrinsic colors in Fig. 5. These comparisons between ourselves, Parsons and Bouw, Schmidt (1972), and Fernie and Hube (1968) indicate no strong color (temperature) dependence. However, in every case there is a transparent zero point difference. The resolution of the color zero point question is crucial in order that there can be a meshing of the observations, and atmospheric, pulsational and evolutionary models. On the basis of the evidences presented here there is no grounds for an intelligent and critical discussion. We will return to this question in a later paper, attacking the problem from an atmospheric modelling approach.

V. RESULTS

The dependence of color on LogP, P-C relationship, is of much interest. The data in Table I is sufficient to ascertain the P-C relationship for the LogP range 0.4 to 1.4. We find by least squares that --

$$\langle B\rangle_o - \langle V\rangle_o = 0.355\mathrm{Log}P + 0.275, \qquad (4)$$

which is to be compared to Sandage and Tammann's (1971) result of --

$$\langle B\rangle_o - \langle V\rangle_o = 0.323\mathrm{Log}P + 0.290. \qquad (5)$$

In our case, of course, no reference to cepheids outside our own galaxy is needed for definition of the P-C relationship. The Eqs. (4) and (5) differ maximally by $0\overset{m}{.}030$ at LogP = 1.4, which is an understandable amount. For the range LogP < 0.86 we determine --

$$\langle B\rangle_o - \langle V\rangle_o = 0.348\mathrm{Log}P + 0.280 \qquad (6)$$

which differs from Eq. (4) by less than $0\overset{m}{.}003$ through out the limited range in LogP covered by Eq. (6). This closeness in the results for cepheids of all LogP and for cepheids of LogP < 0.86 is distinct from the appreciable variance in the similar expressions found by Sandage and Tammann. Their result for the range LogP < 0.86 is --

$$\langle B\rangle_o - \langle V\rangle_o = 0.250\text{LogP} + 0.346. \qquad (7)$$

On the question of this variance it is pertinent to observe, that their galactic cepheid data for LogP < 0.86 would indicate a slope for the P-C relation of close to zero! It is only through the inclusion of the extra-galactic cepheids that the slope is increased to a reasonable value.

The run of the intrinsic colors with period is shown in Fig. 6. For illustrative purposes the SMC cepheids from Sandage and Tammann are also plotted. They are obviously not discordant with the galactic cepheid results. The reddness of the cepheids V496 Aql, SZ Cyg and CK Sct is pronounced. The probable cause for this behavior is discussed below. The blueness of RW Cam and AW Per is doubtless a product of their being spectroscopic binaries (Lloyd Evans 1968); while AB Cam and UX Per are suspected to be of anomalous chemical composition (Bahner et al. 1962; Kraft 1963).

To ascertain the dependence of color on position in the instability strip we approach the problem via the route used by Sandage and Tammann. We evaluate for each star a color difference defined as --

$$\delta(B-V) = (\langle B\rangle_o - \langle V\rangle_o) - (0.355\text{LogP} + 0.275), \qquad (8)$$

that is, the difference between the observed intrinsic color and that predicted by the statistical P-C relation. This is the quantity given in the last column of Table I. Accepting Sandage and Tammann's LogP divisions we plot the δ(B-V)'s against f_B in Fig. 7. With some subjectivity we label the most "divergent" stars in the first two panels of the figure with their names. The two regression lines shown for the shorter period groupings are eye-estimates, a more sophisticated analysis appearing academic. Each line is drawn to pick up the trend in the points and to segregate the sample by half. These correlation lines give the period-color-(amplitude defect) relations (P-C-f_B relations) --

$$\langle B\rangle_o - \langle V\rangle_o = 0.355\mathrm{LogP} - 0.440f_B + 0.601, \text{ for LogP} < 0.86 \quad (9)$$

and

$$\langle B\rangle_o - \langle V\rangle_o = 0.355\mathrm{LogP} + 0.297f_B + 0.048, \text{ for } 0.86 \le \mathrm{LogP} \le 1.3. \quad (10)$$

The relations are formed without reference to the SMC cepheids, but as can be seen from Fig. 7 these stars are in accord with the drawn correlation lines. No relation can be determined for the grouping of the longest period cepheids. The last panel has been expanded by only one star over that given by Sandage and Tammann. We do tentatively concur with them that the correlation of δ(B-V) with f_B appears to revert back to one similar to that for the shortest period grouping.

A comparison of Eq. (9) to Eq. (1) shows that for the "average" (f_B = 0.7) shorter period cepheids we agree quite well with Sandage and Tammann. For the blue-edge of the instability strip ($f_B = 1$) the difference of Eq. (9) to Eq. (1) as a function of LogP is --

$$(K - S\&T)_{blue-edge} = 0.128 LogP - 0.112. \quad (11)$$

From Eq. (11) we see that our blue-edge is $0^m.06$ bluer than theirs at LogP = 0.4, and identical at LogP = 0.86. For the red-edge of the strip ($f_B = 0.3$) we have --

$$(K - S\&T)_{red-edge} = 0.128 LogP - 0.022, \quad (12)$$

so our red-edge is redder by $0^m.03$ at LogP = 0.4, and by $0^m.09$ at LogP = 0.86. While the above differences in the two studies are not small for a comparison of statistical relationships, they do not appreciably exceed the possible expectations of precision.

Let us consider the discrepant stars labelled in Fig. 7. For the stars in the period range LogP $<$ 0.86 we have the following comments: (1) SU Cas's period is very short and falls within the region where the B_{max}/LogP relation is poorly defined; (2) FF Aql, SU Cyg, DT Cyg, and AW Per have, or are suspected to have, companions (Lloyd Evans 1968); (3) AB Cam and UX Per are possibly anomalous in chemical composition (Bahner et al. 1962; Kraft 1963); (4) SZ Tau is considered by some to be of Pop. II (see Schaltenbrand and Tammann (1971) for references); (5) CR Cep and X Lac are not noticeable eccentric, except in this situation. From the above we see that eight out of ten of the stars are known to possess characteristics sufficient to preclude them from the analysis. In the LogP interval 0.86 to 1.3 the comments are:

(1) RW Cam and SV Per have companions (Lloyd Evans 1968);
(2) SZ Cyg and UZ Sct are only observed by Williams (1966) and the consistency of the photometry on both appears marginal, resulting doubtlessly from their faintness. Thus, for this LogP grouping cogent excuses can be made for all the stars most displaced from the trend in the $\delta(B-V)/f_B$ diagrams.

It is clear that the expressions for the intrinsic color given by Eqs. (1), (9) or (10) are useful, and are capable of predicting viable answers for most stars; but they are not in any sense complete. Any star possesses a period and an f_B, and thus a color is calculable and the statistical estimate of precision of $\sim\pm0\overset{m}{.}05$ assigned; but and eccentric star will always appear "normal." This is a definite and strong limitation. What would comprise the perfect answer on any photometric system would be the determination of a method of accurate intrinsic color prediction, along with the development of ancillary information sufficient to delineate abnormal stars. We review this problem for the UBV system in another paper (Kelsall 1972b).

VI. CONCLUSIONS

The B-V color excesses for sixty-four cepheids are found through transformation of results from (b-y), G photometry. These excesses, when combined with the data on forty-six cepheids contained in the work of Sandage and Tammann (1971), raise the total data sample to eighty-eight galactic cepheids. All indications are that this total sample is self-consistent. The body of data is adequate to define a precise P-C relationship (Eq. (4)) applicable to the LogP range 0.4 to 1.4. The correlation of intrinsic color with position in the instability strip is expressible in the form of a P-C-f_B relationship (Eqs. (9) and (10)). The concept that a P-C-f_B relation is viable was first enunciated by Sandage and Tammann. Our contribution is to substantiate their claim without recourse to data on extra-galactic cepheids. Assuming the SMC cepheids are metal deficient (Gascoigne 1969; Bell and Parsons 1972), our results indicate that the P-C-f_B relation is little sensitive to metal content. This is evidenced by the SMC cepheids being basically well imbedded, without definite prejudice, amongst the results for the galactic cepheids.

To solidify these results more observations are needed, particularly for the smaller amplitude cepheids and all cepheids with LogP $>$ 1.3, on the UBV:G or UBV:Γ photometric systems. Our suggestion would be use of the UBV:G system as it is: (1) probably more easily duplicated; (2) gives a linear relationship between the pertinent quantities, B-V and G; (3) perhaps less sensitive to chemical differences (Bell and Rodgers 1969); (4) allows observations of fainter stars for a given telescope, as the G filters are broader than the narrowest Γ filter.

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TABLE I. The color data for the galactic cepheids.

Star	LogP	f_B	E(B-V) Sandage & Tammann	E(B-V) Williams	E(B-V) Kelsall	E(B-V) Adopted	$\langle B\rangle_o-\langle V\rangle_o$	δ(B-V)
SU Cas	0.290	0.274			0.38	0.38	0.34	-0.04
DT Cyg	0.398	0.348			0.15	0.15	0.39	-0.03
EV Sct	0.490	0.373	0.54	0.60		0.57	0.58	0.13
SZ Tau	0.498	0.388			0.40	0.40	0.45	0.00
SS Sct	0.565	0.488	0.37		0.37	0.37	0.59	0.11
RT Aur	0.571	0.753		0.17	0.13	0.15	0.45	-0.03
SU Cyg	0.585	0.670		0.24	0.19	0.22	0.34	-0.14
SY Cas	0.610	0.738	0.47			0.47	0.51	0.02
T Vul	0.647	0.598		0.17	0.12	0.14	0.50	0.00
FF Aql	0.650	0.412		0.35:	0.32:	0.34:	0.43:	-0.08:
DF Lac	0.651	0.601		0.61:		0.61:	0.57:	0.06:
XY Cas	0.653	0.575	0.50			0.50	0.63	0.12
V482 Sco	0.655	0.649	0.44			0.44	0.55	0.04
UX Per	0.660	0.887		0.69:		0.69:	0.29:	-0.22:
RY CMa	0.670	0.705			0.35	0.35	0.51	0.00
VZ Cyg	0.687	0.652			0.34	0.34	0.56	0.04
CF Cas	0.688	0.559	0.62	0.54		0.58	0.63	0.11
AP Sgr	0.703	0.824	0.32			0.32	0.50	-0.02
V386 Cyg	0.720	0.667	1.02			1.02	0.54	0.01
CR Ser	0.724	0.752		1.14		1.14	0.52	-0.01
δ Cep	0.730	0.845		0.19	0.17	0.18	0.48	-0.05
SW Cas	0.736	0.649	0.56			0.56	0.56	0.02
X Lac	0.736	0.453	0.39		0.45	0.42	0.52	-0.02
Y Sgr	0.761	0.700		0.24:		0.24:	0.62:	0.07:
GI Cyg	0.762	0.627		0.91		0.91	0.52	-0.03
AB Cam	0.762	0.991		0.89:		0.89:	0.31:	-0.24:
FM Cas	0.764	0.581	0.38			0.38	0.64	0.09
RV Sco	0.781	0.871	0.43			0.43	0.55	0.00
FM Aql	0.786	0.711			0.76	0.76	0.55	0.00
VV Cas	0.793	0.879	0.56			0.56	0.57	0.01
CR Cep	0.795	0.445	0.90			0.90	0.57	0.01
RR Lac	0.808	0.780	0.35			0.35	0.57	0.01
AW Per	0.810	0.724			0.69:	0.69:	0.39:	-0.17:
U Sgr	0.828	0.738	0.55	0.47		0.51	0.60	0.03

TABLE I (continued)

Star	LogP	f_B	E(B-V) Sandage & Tammann	E(B-V) Williams	E(B-V) Kelsall	E(B-V) Adopted	$\langle B\rangle_o - \langle V\rangle_o$	δ(B-V)
V496 Aql	0.833	0.441			0.42	0.42	0.75	0.18
AP Cas	0.836	0.603	0.87			0.87	0.53	-0.04
X Sgr	0.846	0.615		0.22		0.22	0.54	-0.04
U Aql	0.847	0.767			0.49	0.49	0.55	-0.03
η Aql	0.856	0.809	0.18	0.22	0.24	0.21	0.59	0.01
AK Cep	0.859	0.661	0.84			0.84	0.49	-0.09
CK Sct	0.870	0.530		0.86		0.86	0.74	0.16
RS Ori	0.879	0.847			0.52	0.52	0.46	-0.13
W Sgr	0.880	0.838		0.20		0.20	0.54	-0.05
CD Cas	0.892	0.895	0.86			0.86	0.59	0.00
VY Cyg	0.895	0.938	0.68			0.68	0.58	-0.01
RX Cam	0.898	0.879	0.59	0.60:	0.63	0.61	0.63	0.04
W Gem	0.898	0.959			0.38	0.38	0.55	-0.04
U Vul	0.903	0.785			0.76	0.76	0.55	-0.05
DL Cas	0.903	0.705	0.57	0.56		0.56	0.64	0.04
S Sge	0.923	0.935		0.24:	0.19:	0.22:	0.59:	-0.01:
V500 Sco	0.969	0.887		0.60		0.60	0.69	0.07
FN Aql	0.977	0.735		0.62		0.62	0.62	0.00
S Nor	0.989	0.759	0.28			0.28	0.62	0.04
DD Cas	0.992	0.705	0.55			0.55	0.67	0.04
BZ Cyg	1.006	0.581	1.01			1.01	0.59	-0.04
SY Aur	1.006	0.649	0.46			0.46	0.60	-0.03
ζ Gem	1.007	0.586	0.14	0.14	0.09	0.12	0.70	0.07
Y Sct	1.015	0.855	0.90	0.81		0.86	0.70	0.06
Z Lac	1.037	0.964	0.55			0.55	0.60	-0.04
TY Sct	1.043	0.851		1.14:		1.14:	0.59:	-0.06:
SV Per	1.046	0.705	0.54			0.54	0.49	-0.16
AA Gem	1.053	0.653		0.59:		0.59:	0.52:	-0.13:
RX Aur	1.065	0.596		0.42		0.42	0.55	-0.10
RY Cas	1.084	0.809	0.71	0.69		0.70	0.66	0.00
Z Sct	1.111	0.785		0.65		0.65	0.69	0.02
VY Sgr	1.132	0.697		1.41:		1.41:	0.56:	-0.12:
SZ Cas	1.134	0.316	0.89	0.93:		0.91	0.59	-0.09
TT Aql	1.138	0.955	0.55	0.58		0.56	0.74	0.06
CY Cas	1.158	0.759		1.02:		1.02:	0.68:	-0.01:
TX Cyg	1.168	0.871	1.23	1.31:		1.27	0.60	-0.09
UZ Sct	1.169	0.597		1.06		1.06	0.82	0.13
RW Cas	1.170	0.863	0.46	0.41		0.44	0.81	0.12

TABLE I (continued)

Star	LogP	f_B	E(B-V) Sandage & Tammann	E(B-V) Williams	E(B-V) Kelsall	E(B-V) Adopted	$\langle B\rangle_o - \langle V\rangle_o$	δ(B-V)
SZ Cyg	1.179	0.568		0.58:		0.58:	0.95:	0.26:
SV Mon	1.183	0.920		0.34:		0.34:	0.71:	0.02:
X Cyg	1.214	0.631	0.44	0.39	0.39	0.41	0.75	0.04
RW Cam	1.215	0.441		0.92:		0.92:	0.48:	-0.23:
CD Cyg	1.232	0.766	0.60	0.57		0.58	0.74	0.03
Y Oph	1.234	0.268	0.73	0.70		0.72	0.66	-0.05
SZ Aql	1.234	0.955	0.78	0.68		0.73	0.70	-0.01
CP Cep	1.252	0.483	0.93			0.93	0.71	-0.01
YZ Aur	1.260	0.555		0.72:		0.72:	0.69:	-0.03:
RU Sct	1.294	0.646		1.10		1.10	0.62	-0.11
VX Cyg	1.304	0.527		0.83:		0.83:	0.91:	0.17:
WZ Sgr	1.339	0.565	0.60	0.53		0.56	0.83	0.08
T Mon	1.432	0.535	0.40	0.36	0.37	0.38	0.82	0.04
AQ Pup	1.474	0.817	0.68			0.68	0.68	-0.12
RS Pup	1.617	0.780	0.60			0.60	0.83	-0.02
SV Vul	1.654	0.847	0.64	0.67		0.66	0.81	-0.05

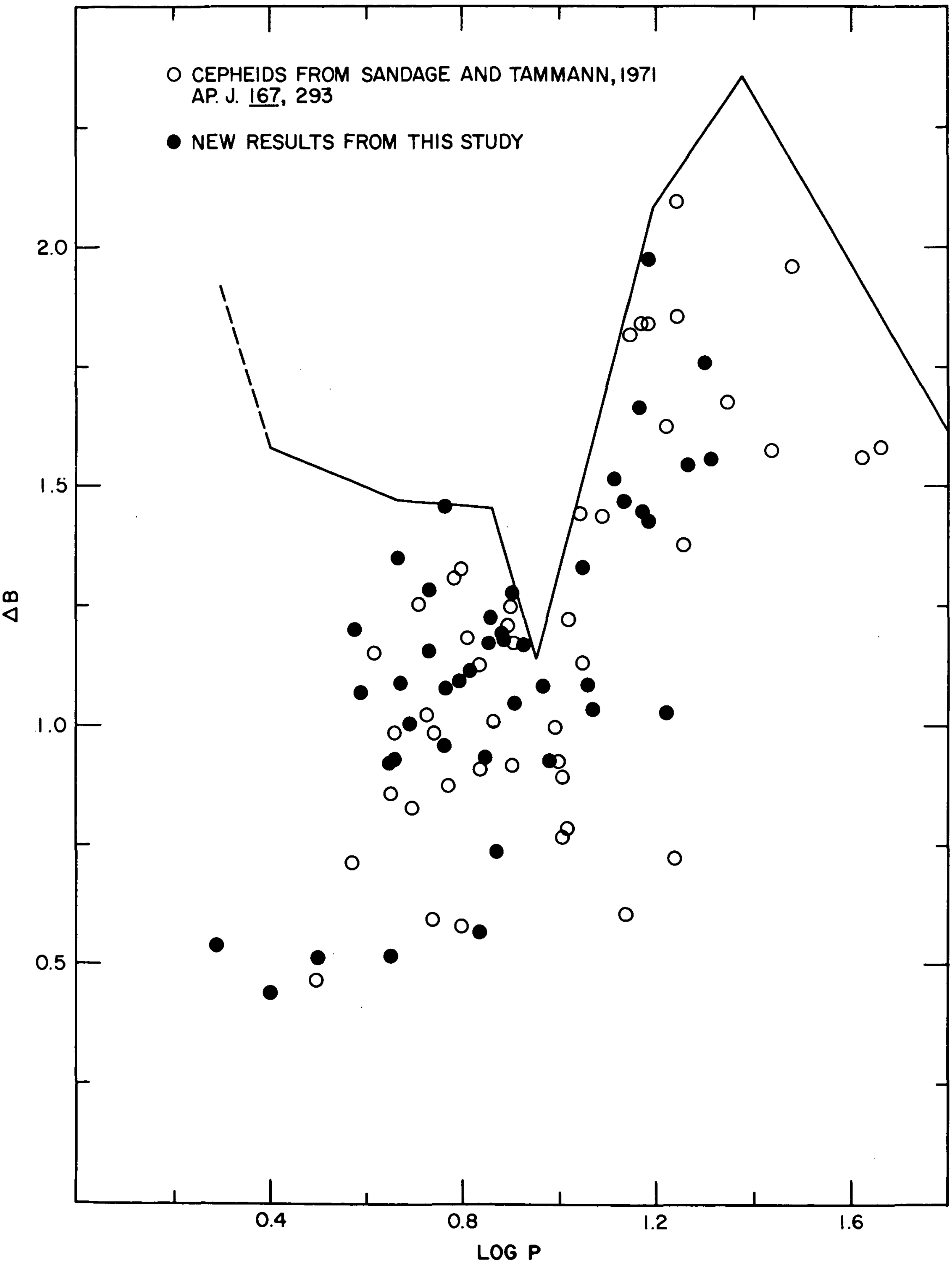

Fig. 1. Distribution of the cepheids in the blue-amplitude, ΔB, Log P diagram.

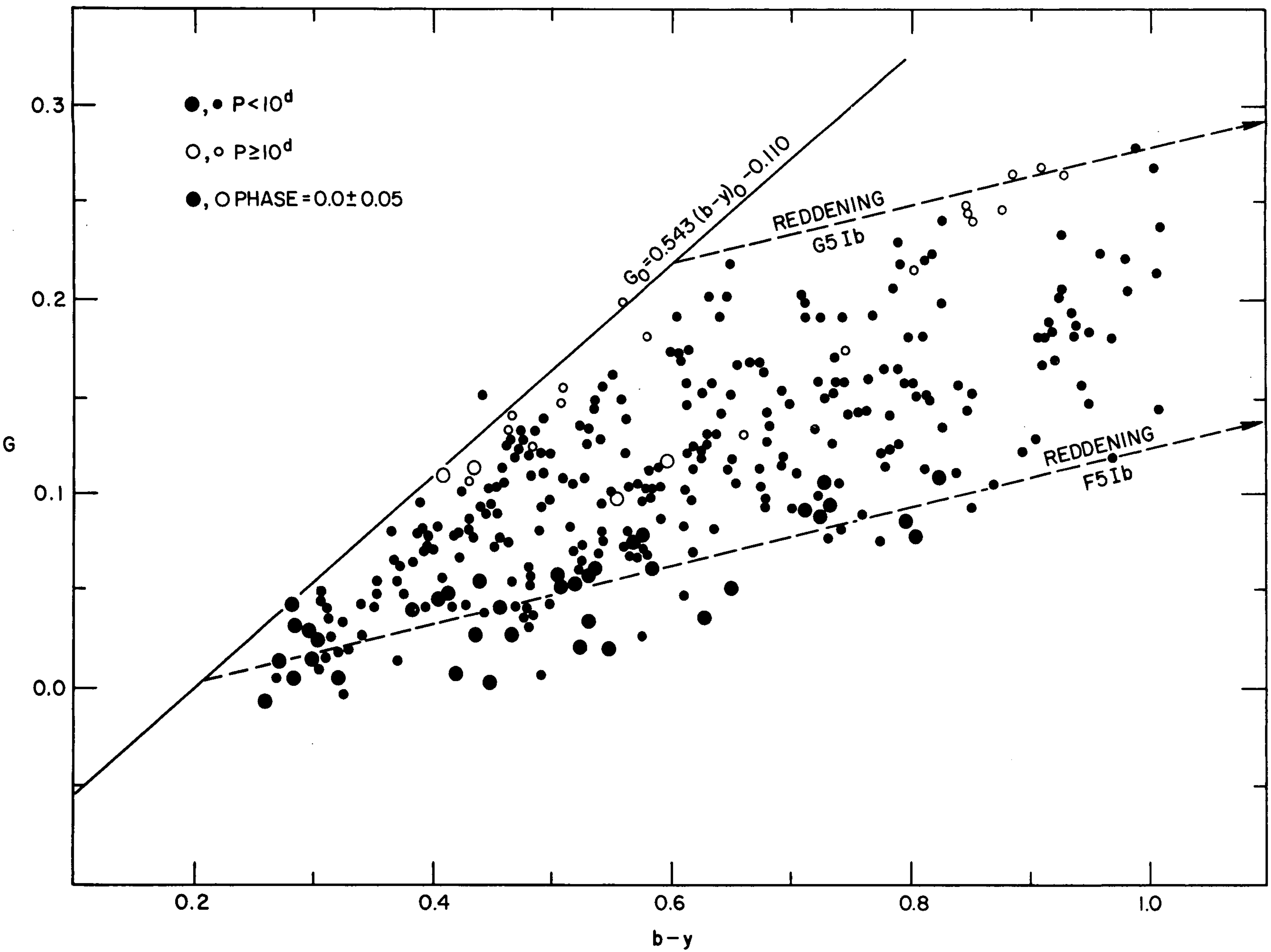

Fig. 2. Crawford's G-band photometric index, G, versus Strömgren's b-y for all of Kelsall's (1971) cepheid data.

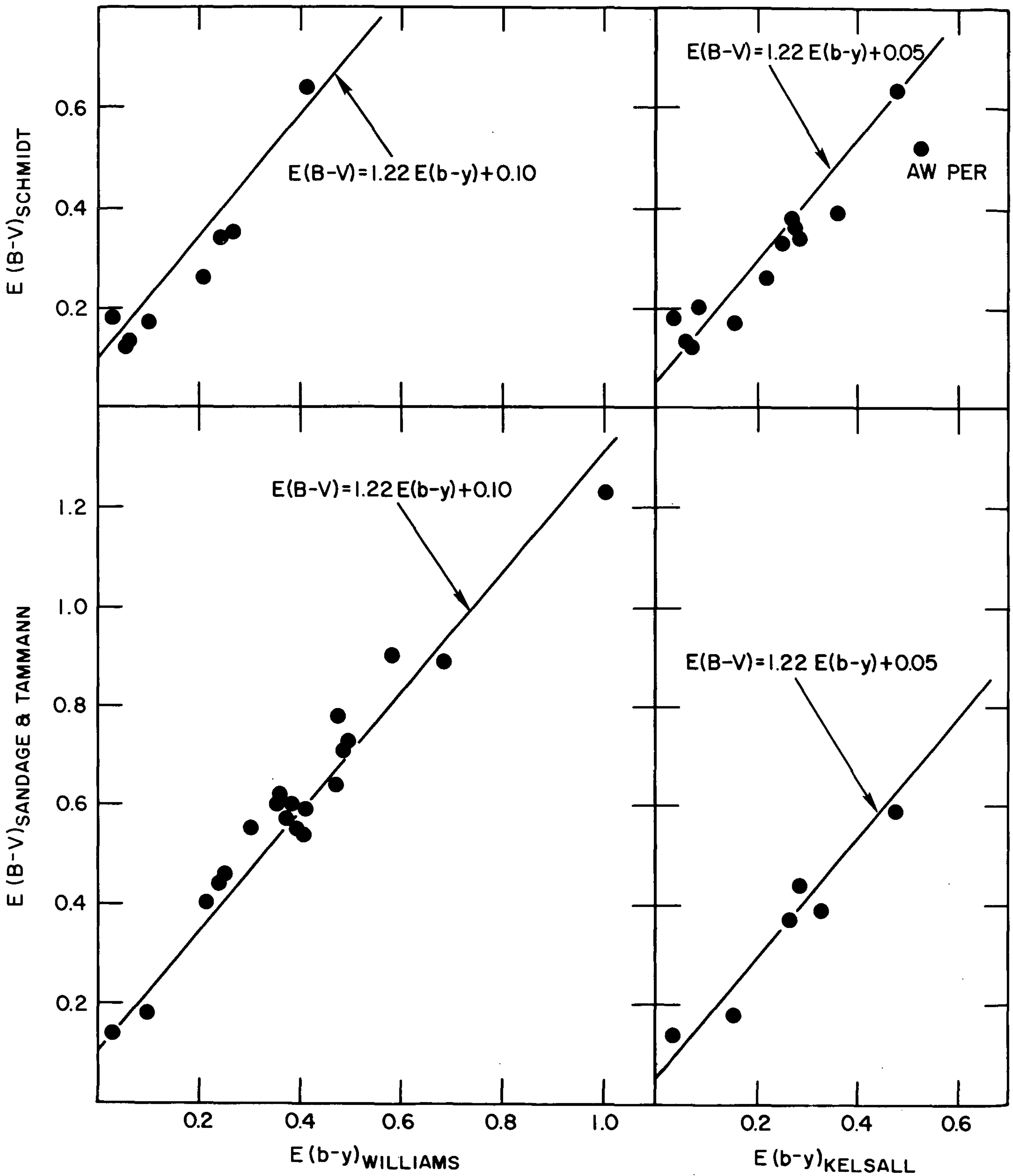

Fig. 3. Comparison of b-y color excesses of Williams (1966), and Kelsall (1971) to the B-V color excesses of Sandage and Tammann (1971), and Schmidt (1972).

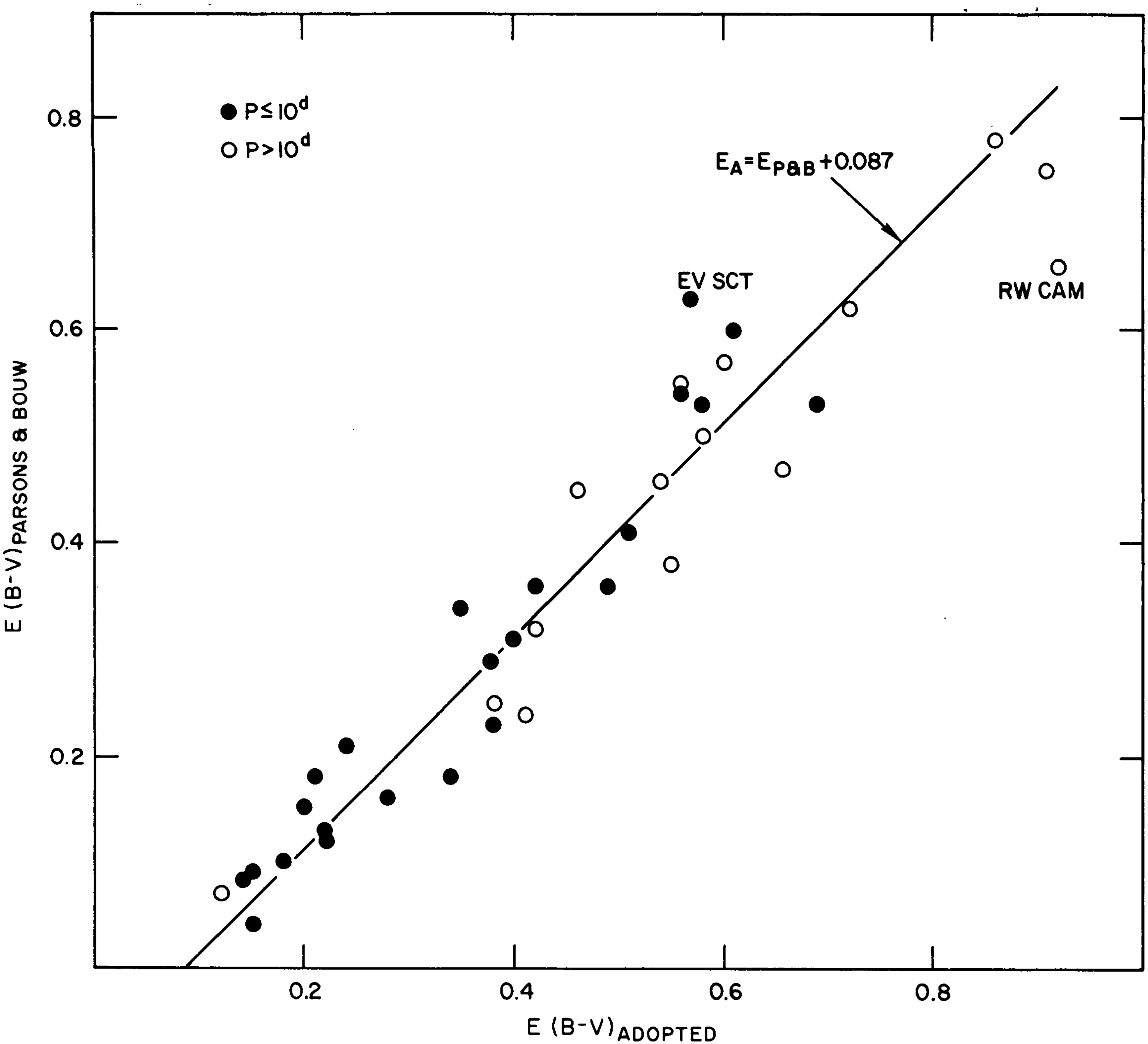

Fig. 4. Correlation of our adopted color excesses with those calculated by Parsons and Bouw (1971).

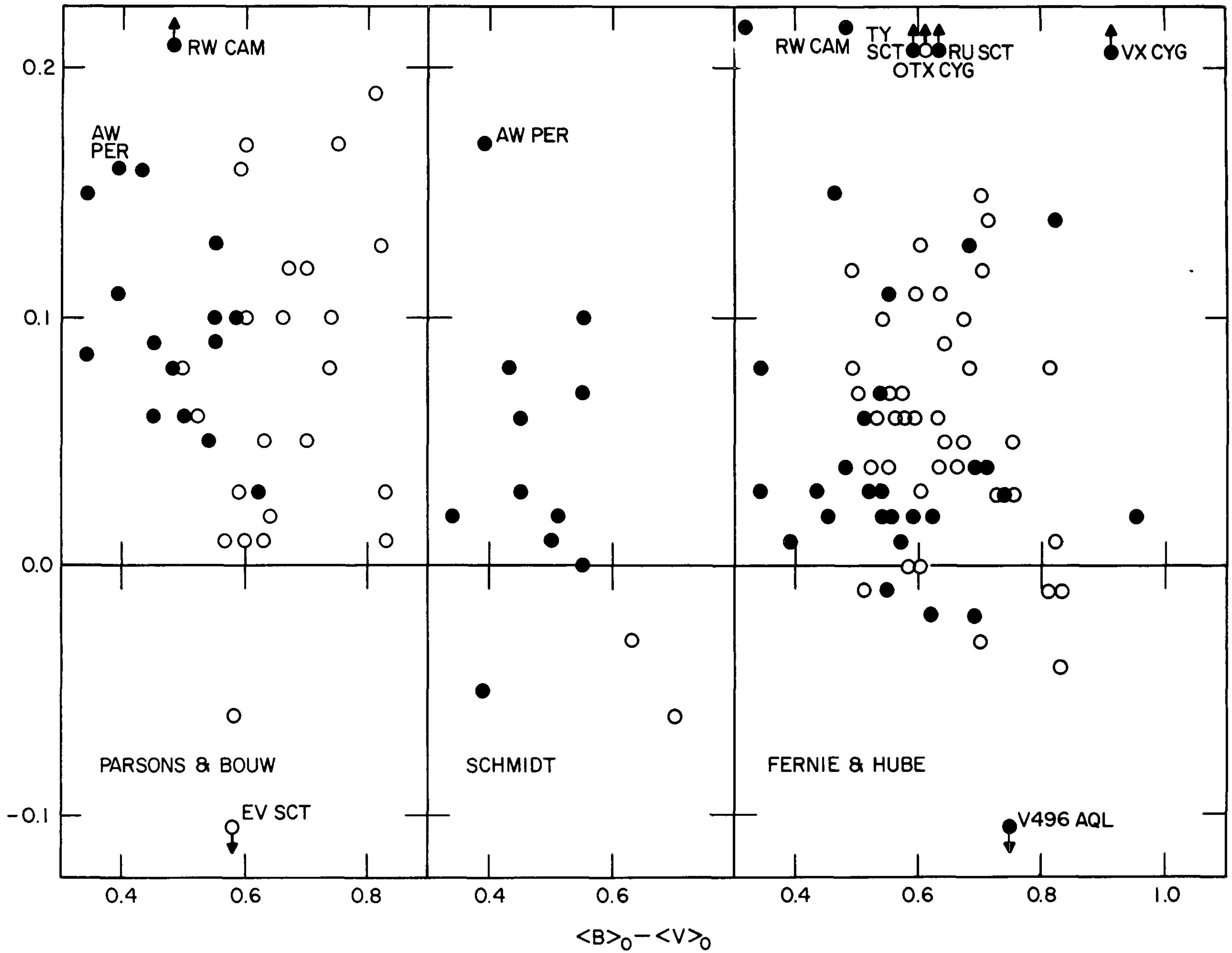

Fig. 5. Color excess differences, $\Delta E = E(B-V)_{adopted} - E(B-V)_{other}$, versus our adopted intrinsic colors for cepheids in common with three other investigations. The open circles represent stars whose color excesses are considered uncertain.

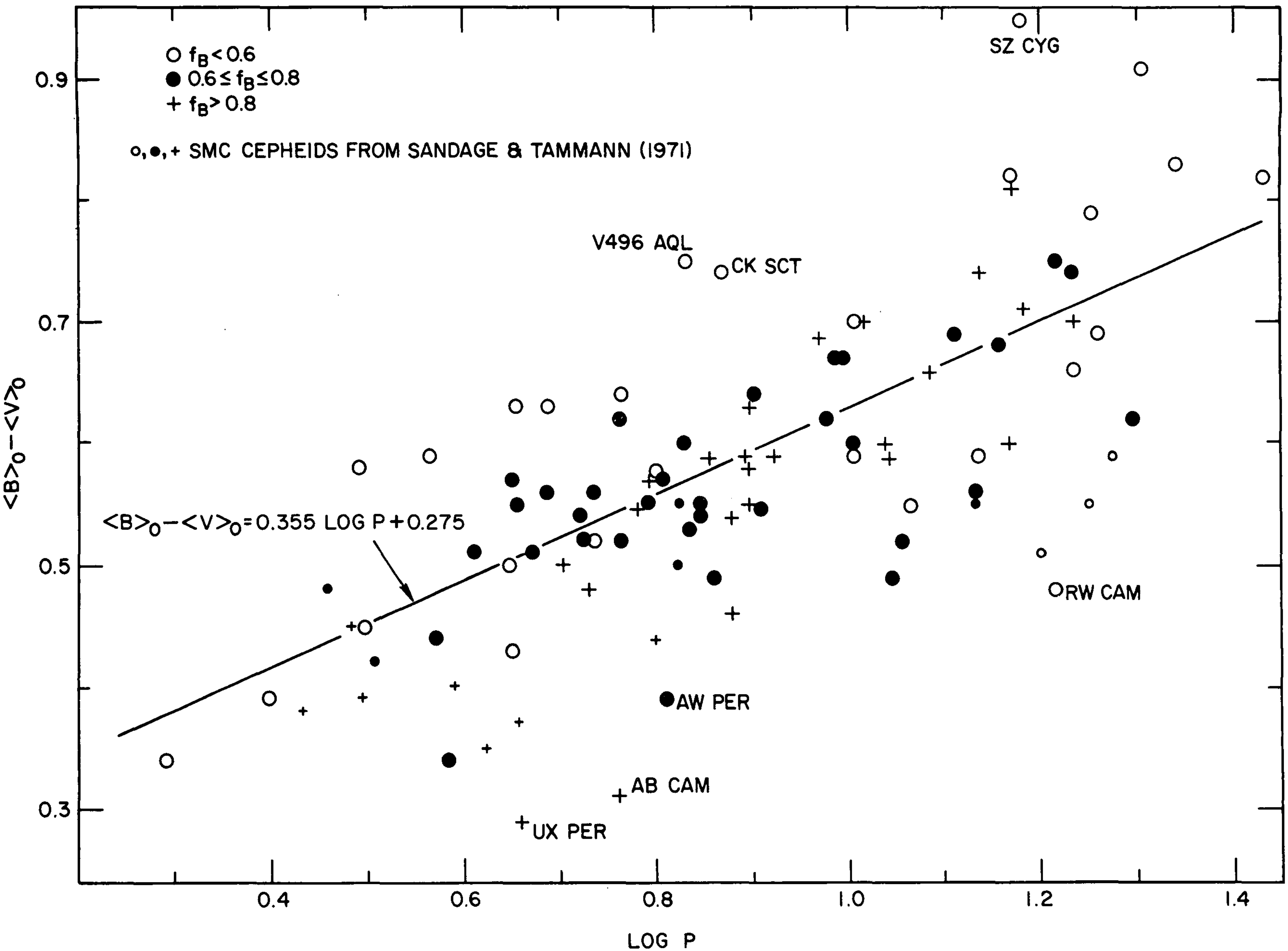

Fig. 6. Intrinsic color versus LogP for our eighty-eight cepheids. The results for the SMC cepheids are from Sandage and Tammann (1971).

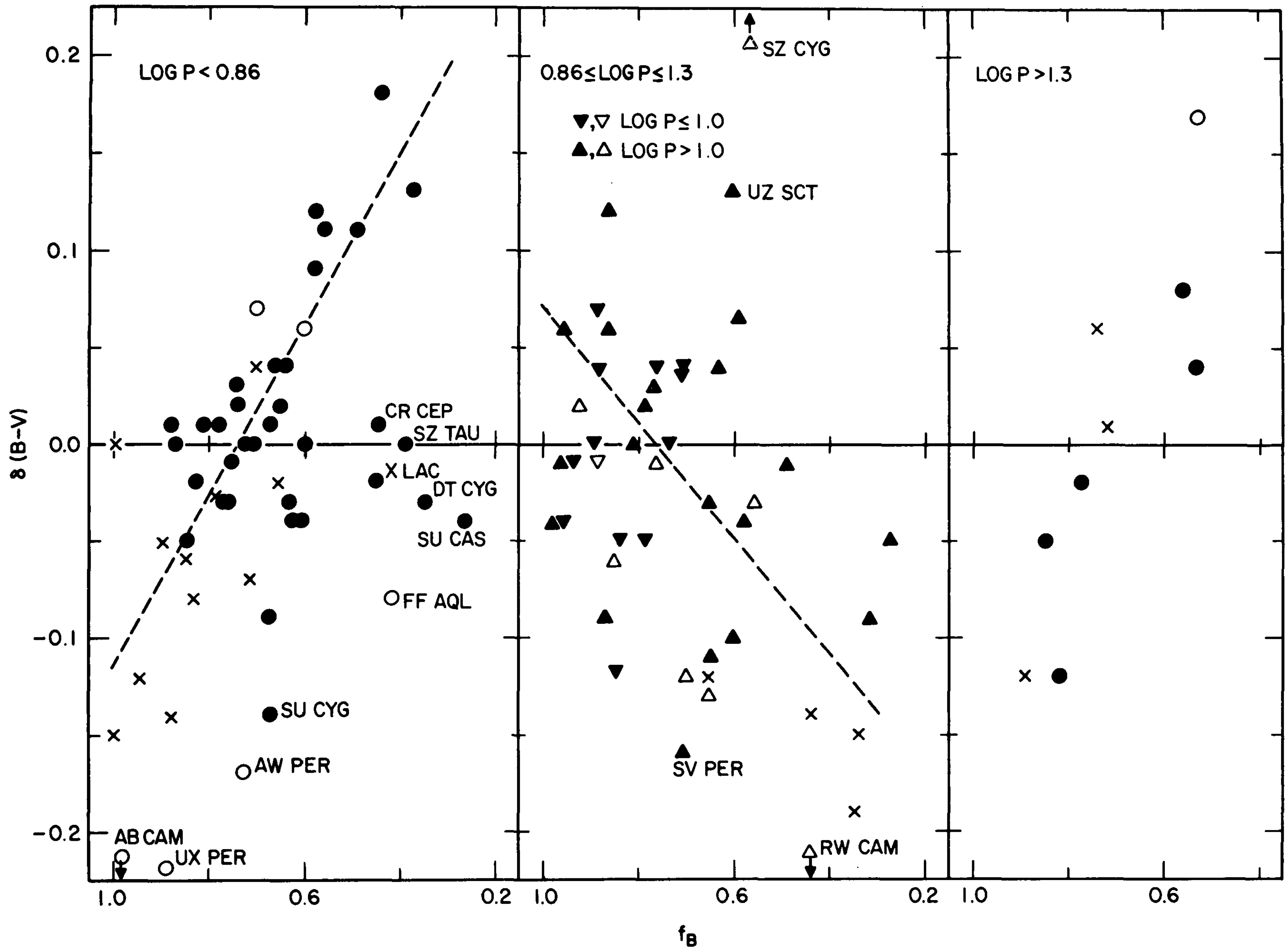

Fig. 7. The dependence of $\delta(B-V) = (\langle B\rangle_o - \langle V\rangle_o) - (0.355 \text{Log}P + 0.275)$ on the blue-amplitude-defect, f_B. The open symbols are for cepheids with uncertain color excesses. The crosses are data, taken from Sandage and Tammann (1971), for SMC cepheids.