Mon. Not. R. Astron. Soc. **360,** 360–363 (2005) doi:10.1111/j.1365-2966.2005.09039.x

Colour equations for UK Schmidt Telescope Tech-Pan film exposures

D. H. Morgan[1⋆] and Q. A. Parker[2,3]

[1] *Institute for Astronomy, University of Edinburgh, Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ*
[2] *Department of Physics, Macquarie University, NSW 2109, Australia*
[3] *Anglo-Australian Observatory, PO Box 296, Epping, NSW 2121, Australia*

Accepted 2005 March 22. Received 2005 March 12

ABSTRACT

Kodak Technical Pan (Tech-Pan) film is a standard panchromatic emulsion that was used at the UK 1.2-m Schmidt Telescope (UKST) for a variety of broad-band exposures between 1992 and 2003. However, despite its versatility and frequent use, no formal presentation of its colour-term stability has been provided. A sample of 32 short-exposure Tech-Pan films was specifically acquired in five wavebands with a view to establishing the photometric relationships between Tech-Pan and the equivalent glass-based emulsions previously used. These films have been measured using the SuperCOSMOS measuring machine and the data reduced to provide the appropriate quantitative information. New colour terms relating these measurements to the Cousins photoelectric system are presented. They are shown to be stable, reproducible, generally small and similar to colour terms previously derived for the older emulsions on glass that Tech-Pan effectively replaced. These results give confidence in the use of Tech-Pan photometry from on-line UKST legacy survey archives.

Key words: instrumentation: miscellaneous – instrumentation: photometers – techniques: photometric – telescopes.

1 INTRODUCTION

The UK 1.2-m Schmidt Telescope (UKST), located at Siding Spring Observatory in Australia and operated since 1988 by the Anglo-Australian Observatory, routinely used Kodak[1] panchromatic Tech-Pan emulsion on estar film as a detector between 1992 and 2003 for a variety of broad-band survey and other programmes. Although the last UKST photographic survey was completed in 2003, the various UKST surveys of the southern sky form scientifically valuable, on-line, archival data bases that will continue to be used extensively for many years to come. While the majority of these wide-field surveys were undertaken on IIIa− emulsions on glass (for details, see Morgan 1995), the introduction in 1992 of Tech-Pan film into the UKST's range of detectors led to the incorporation of this film into surveys that were not then complete, and also generated a large increase in the extent and scope of the telescope's programme of wide-field astrophotography. It is important to place these Tech-Pan exposures in the context of the more traditional glass-based IIIa− emulsions, and to establish that the use of Tech-Pan film has no adverse effect on the photometric uniformity and utility of the various UKST surveys into which it was incorporated.

Details of how the UKST was adapted to use film instead of the usual glass plates have been described by Russell et al. (1992) and Parker (1992), while the hypersensitization techniques developed for Tech-Pan film have been detailed by Parker & Malin (1999). Tech-Pan film has a much finer grain than its equivalent spectroscopic emulsion on glass (IIIa-F) and consequently records images typically one magnitude fainter than IIIa-F when properly hypersensitized and used with the OG590 or RG630 filters (Phillipps & Parker 1993). Its improved depth, resolution and low noise also permit better differentiation between stars and galaxies (Parker et al. 1994). Hence, Tech-Pan film became one of the most useful and commonly used emulsions at the UKST during the final 10 yr of its photographic work and led directly to the AAO/UKST Hα Sky Survey of the Southern Galactic Plane and Magellanic Clouds – the last major UKST sky survey (Parker & Phillipps 2003).

Although the panchromatic spectral sensitivity of Tech-Pan film broadly matches that of IIIa-F, it is important to be sure what, if any, colour terms are present in the passbands commonly used with Tech-Pan film and to see whether they differ from those found by Blair & Gilmore (1982) for IIIa-F and other older emulsions.

2 OBSERVATIONS

A sample of 32 Tech-Pan exposures was specially acquired with the UKST in order to establish colour equations. Five wavebands were included, but most (20) of the films were in the two red photographic bands (*OR* and *R*) used in the sky surveys. The exposure times were short (2–5 min) to ensure that the images of the relatively bright photoelectric standard stars were not overexposed. Two plate centres (1950.0) were used, i.e. $20^{h}04^{m}$, $-45^{\circ}0'$

⋆E-mail: dhm@roe.ac.uk

[1] Eastman Kodak, Rochester, NY, USA.

© 2005 RAS

Table 1. UKST films measured.

Plate	Exp.	Date	Airmass	Plate	Exp.	Date	Airmass
(a) Harvard Standard Region E8							
OR15704	5 min	1993 Aug 18	1.06	VF15859	5 min	1993 Nov 10	1.31
OR15705	5 min	1993 Aug 18	1.04	VF15860	5 min	1993 Nov 10	1.38
OR17152	2 min	1996 Jul 24	1.03	VF17242	5 min	1993 Sep 13	1.04
OR17153	2 min	1996 Jul 24	1.03	VF17243	5 min	1993 Sep 13	1.03
OR17157	2 min	1996 Aug 5	1.04	BF15861	5 min	1993 Nov 10	1.50
OR17158	2 min	1996 Aug 5	1.03	BF15862	5 min	1993 Nov 10	1.61
OR17162	2 min	1996 Aug 7	1.06				
OR17163	2 min	1996 Aug 7	1.04				
R15674	5 min	1993 Aug 9	1.04	(b) Harvard Standard Region E9			
R15675	5 min	1993 Aug 9	1.06	OR17720	2 min	1997 Sep 9	1.18
R17166	2 min	1996 Aug 7	1.03	OR17726	2 min	1997 Sep 10	1.22
R17236	2 min	1996 Sep 12	1.04	OR17727	2 min	1997 Sep 10	1.31
U15811	5 min	1993 Oct 9	1.53	OR17734	2 min	1997 Sep 21	1.03
U15812	5 min	1993 Oct 9	1.71	R17735	2 min	1997 Sep 21	1.05
U17164	5 min	1993 Aug 7	1.03	R17736	2 min	1997 Sep 21	1.09
U17165	5 min	1993 Aug 7	1.03	R17737	2 min	1997 Sep 21	1.14
U17237	5 min	1993 Sep 12	1.03	R17738	2 min	1997 Sep 21	1.18
U17238	5 min	1993 Sep 12	1.03				

and $22^{h}40^{m}$, $-44^{\circ}25'$, which include the Harvard Standard Regions E8 and E9, respectively. Details of these exposures are given in Table 1.

The filters are identified through the plate number prefix as follows: *OR* ≡ OG590, *R* ≡ RG630, *U* ≡ UG1, *VF* ≡ AAOV and *BF* ≡ AAOB. Filters AAOB and AAOV are special broad-band cut-on/cut-off filters that broadly match the Johnson *B* and *V* wavebands. The former was designed for use with blue-sensitive IIIa-J emulsion and has a strong red leak when used with panchromatic Tech-Pan. [See the UKSTU Handbook (1983) for more details of these filters.]

The films were measured at the Royal Observatory Edinburgh using the SuperCOSMOS machine in its Image Analysis Mode (Hambly et al. 2001), thereby providing the instrumental photometry. Stars outside the central unvignetted region (see the UKSTU Handbook) were excluded from further analysis.

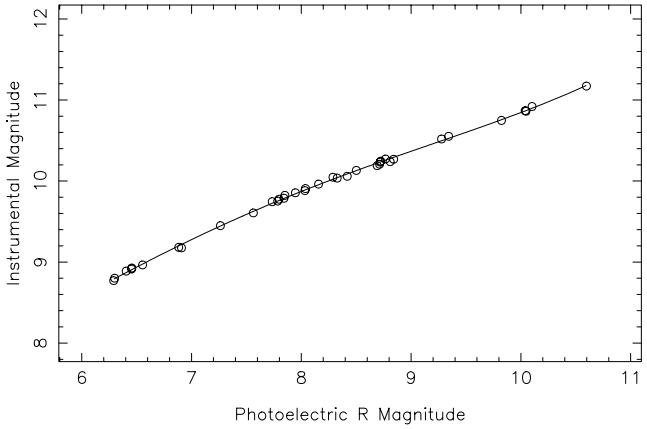

Figure 1. Calibration fit for film OR17720.

3 ANALYSIS

The SuperCOSMOS instrumental magnitudes were calibrated using low-order polynomials fitted to the photoelectric photometry of 42 A0–M0 standard stars measured in the Cousins system (Menzies et al. 1989) and not thought to be variable. A few stars deviated from the calibration fit by more than 2.5σ as a result of image contamination from nearby stars or minor plate defects. These were excluded from the calibration. Typical values of σ (the rms scatter of the residuals) were ∼0.03 mag. The differences between the standard photoelectric magnitudes and magnitudes calculated from the calibrated SuperCOSMOS data were then plotted against photoelectric colour. Colour terms were then derived from linear fits to these plots. The calibration curve and colour fit for one *OR* film are shown in Figs 1 and 2: these plots are typical of all such films.

Mean colour terms are given in Table 2; those for the *R* and *OR* films were calculated for regions E8 and E9 separately and combined. The quoted error is the mean of the standard errors of the individual linear regression coefficients. In each red band, this error is significantly larger than the rms scatter (field-to-field variation) of the mean colour terms. It probably reflects a systematic error due to the choice of standards, whereas the level of the field-to-field variation is small due to the constancy of the films. The colour terms are generally small and close to the values derived by Blair & Gilmore (1982) for IIIa− emulsions on glass, and are consistent with preliminary values presented by Morgan & Parker (1997).

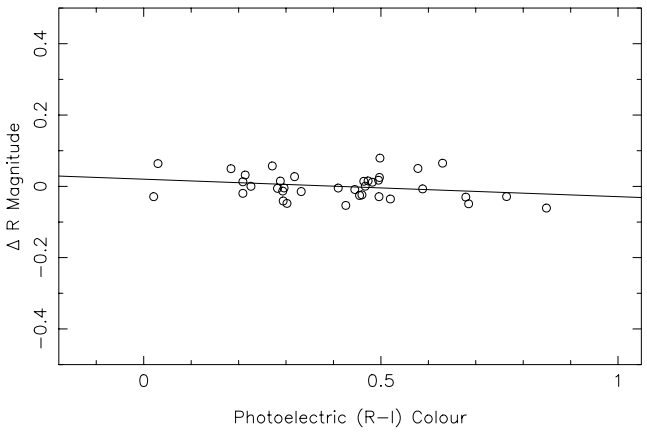

Figure 2. Colour term fit for film OR17720.

Table 2. Colour terms. Unprimed values are standard photoelectric magnitudes. Primed values are calibrated instrumental magnitudes. The last column (N) is the number of films in the specified standard region.

Colour term	Valid range	Region	N
$U - U' = (+0.005 \pm 0.014) \times (U - B)$	$-0.3 < (U - B) < +2.0$	E8	6
$V - V' = (+0.031 \pm 0.014) \times (B - V)$	$-0.1 < (B - V) < +1.6$	E8	4
$OR - OR' = (-0.046 \pm 0.030) \times (R - I)$	$-0.1 < (R - I) < +1.6$	E8	8
$OR - OR' = (-0.039 \pm 0.030) \times (R - I)$	$-0.1 < (R - I) < +1.6$	E9	4
$OR - OR' = (-0.043 \pm 0.030) \times (R - I)$	$-0.1 < (R - I) < +1.6$	E8+E9	12
$R - R' = (+0.075 \pm 0.035) \times (R - I)$	$-0.1 < (R - I) < +0.9$	E8	4
$R - R' = (+0.080 \pm 0.043) \times (R - I)$	$-0.1 < (R - I) < +0.9$	E9	4
$R - R' = (+0.078 \pm 0.039) \times (R - I)$	$-0.1 < (R - I) < +0.9$	E8+E9	8

Therefore, no large photometric colour problems will arise for programmes that mix IIIa− emulsions and Tech-Pan film.

Comments on each waveband follow.

3.1 *R*/*OR* wavebands

The difference between the results for the *OR* and *R* passbands is consistent from film to film and is the same in E8 and E9. For the *R* passband, the result of 0.08 ± 0.04 is close to the value of 0.00 ± 0.04 measured by Blair & Gilmore (1982) for the IIIa-F emulsion.

3.2 *V* waveband

The colour term in Table 2 is smaller than that of Blair & Gilmore (1982) (0.10 ± 0.02), probably because the AAOV filter more closely matches the standard photoelectric waveband, having a lower effective wavelength than the older photographic waveband used at the UKST (GG495 filter with IIa-D emulsion).

3.3 *B* waveband

The AAOB filter, which was designed for use with a blue-sensitive emulsion, is known to have a strong red leak. Consequently, the results for the BF films are not formally presented here. However, it is worth stating that the analysis gave a strong colour term [$B - B' = (0.25 \pm 0.04) \times (B - V)$] as expected for such a filter when used with a panchromatic red-sensitive emulsion. The red leak is expected to have a much greater effect for stars redder than those used here.

3.4 *U* waveband

The UG1 filter is also known to have a slight red leak when used with red-sensitive emulsions, though its effect was estimated at just 0.05 per cent of the *U*-band peak and hence considered inconsequential for photometry from UKST Tech-Pan films (Parker, Morgan & Phillipps 1993). The result here substantiates this conclusion and shows that the red leak has no effect on the photometry of stars within the colour range quoted above. Again, the colour term is very close to that determined by Blair & Gilmore (1982) (0.03 ± 0.04) for the IIIa-J emulsion.

It is not possible to distinguish between the colour terms for the *U* films exposed at high airmass (1.5–1.7) and those exposed at low airmass ($\sim$1.0). However, this would not necessarily be true for stars bluer than the present sample limit – stars for which the effective ultraviolet atmospheric extinction is not reduced by the Balmer discontinuity (Cousins & Caldwell 1988).

4 SUMMARY

With its many and significant advantages, Tech-Pan film has been routinely used at the UKST since 1992 for most (>60 per cent) non-survey projects and with a variety of filters. About 30 Tech-Pan films have been incorporated into the second epoch *R*-band survey (the AAO-R Survey). Its most common use has been as a replacement for the IIIa-F emulsion, and it was used solely for both the short-red and Hα exposures of the AAO/UKST Hα Survey of the Southern Galactic Plane and Magellanic Clouds.

Measurements made with the SuperCOSMOS machine of 32 short-exposure Tech-Pan films of Harvard Standard Regions E8 and E9 have been used to determine the colour equations for Tech-Pan film in five wavebands. The results show that the derived colour terms for the *OR* and *R* bands of the sky surveys are small, stable and reproducible, and are broadly in agreement with those derived for the equivalent IIIa-F emulsion by Blair & Gilmore (1982). Hence, no photometric problem is incurred in these wavebands through replacing the standard IIIa-F emulsion with Tech-Pan film.

ACKNOWLEDGMENTS

The authors would like to thank the staffs of the UK Schmidt Telescope Unit (Anglo-Australian Observatory) and the SuperCOSMOS Unit (Royal Observatory, Edinburgh) for their help in producing the films and measurements. The analysis was carried out while DHM was with the Royal Observatory, Edinburgh.

REFERENCES

Blair M., Gilmore G., 1982, PASP, 94, 742
Cousins A. W. J., Caldwell J. A. R., 1998, Observatory, 118, 85
Hambly N. C. et al., 2001, MNRAS, 326, 1279
Menzies J. W., Cousins A. W. J., Banfield R. M., Laing J. D., 1989, SAAO Circ. No. 13, p. 1
Morgan D. H., 1995, in Chapman J. M., Cannon R. D., Harrison S. J., Hidayat B., eds, ASP Conf. Ser. Vol. 84, The Future Utilisation of Schmidt Telescopes. Astron. Soc. Pac., San Francisco, p. 137
Morgan D. H., Parker Q. A., 1997, in McLean B. J., Golombek D. A., Haynes J. J. E., Payne H. E., eds, Proc. IAU Symp. 179, New Horizons from Multi-Wavelength Sky Surveys. Kluwer, Dordrecht, p. 374
Parker Q. A., 1992, Kodak Tech-Pan Estar-Based Emulsion, AAO Internal Report

Parker Q. A., Malin D., 1999, PASA, 16, 288
Parker Q. A., Phillipps S., 2003, in Ikeuchi S., Hearnshaw J., Hanawa T., eds, Proc. IAU 8th Asian-Pacific Regional Meeting, Vol. 1. Astron. Soc. Pac., San Francisco, p. 165
Parker Q. A., Morgan D. H., Phillipps S., 1993, IAU Commission 9 Working Group on Wide-Field Imaging, Newsletter No. 3, p. 60
Parker Q. A., Phillipps S., Morgan D. H., Malin D. F., Russell K. S., Hartley M., Savage A., 1994, in MacGillivray H. T., Thomson E. B., Lasker B. M., Reid I. N., Malin D. F., West R. M., Lorentz H., eds, Proc. IAU Symp. 161, Astronomy from Wide-Field Imaging. Kluwer, Dordrecht, p. 129
Phillipps S., Parker Q. A., 1993, MNRAS, 265, 385
Russell K. S., Malin D. F., Savage A., Hartley M., Parker Q. A., 1992, in MacGillivray H. T., Thomson E. B., eds, Astron. & Space Sci. Lib., Vol. 174, Digitised Optical Sky Surveys. Kluwer, Dordrecht, p. 23
UKSTU Handbook, 1983, Royal Observatory, Edinburgh

This paper has been typeset from a TEX/LATEX file prepared by the author.