REPRODUCING THE UBV AND COUSINS (RI) PHOTOMETRIC SYSTEMS WITH A HAMAMATSU GA-AS PHOTOMULTIPLIER.

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ABSTRACT. The Hamamatsu R943-02 photomultiplier appears to be suitable for $UBV(RI)_C$ photometry. This paper discusses the tube's characteristics on the basis of one year's experience in the use of such a device on the 0.5m telescope at Sutherland.

1. INTRODUCTION

The 0.5m telescope at the Sutherland observing site of the SAAO is used extensively for photoelectric photometry. Since 1984 November a single-channel photometer equipped with a Hamamatsu R943-02 photomultiplier has been used for $UBV(RI)_C$ photometry. This tube has a 10 x 10mm² GaAs photocathode inclined at about 10° to the incoming beam.

2. PHOTOMETRIC SETUP

Because of the extended red sensitivity of the GaAs tube, it is necessary to use blocking filters with U, B and V. The filters used, with thicknesses in mm given in brackets are as follows:

U :UGI(1) + Solid $CuSO_4$(5)	Rc :OG570(2) + KG3(2)
B :BG12(1) + GG385(2) + BG18(1)	Ic : RG9(3)
V :GG495(2) + BG18(1)	

All except the solid $CuSO_4$ are glass filters made by Schott. The tube is operated at 1700V and is maintained at -15C in a Products for Research thermoelectrically cooled cold box. The dark current is typically about 7 count sec^{-1} which is remarkably low for a red-sensitive tube. The overall gain of the tube appears to be sensitive to temperature and there is sometimes a progressive increase in the V zero point if the ambient temperature falls during the night.

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3. PHOTOMETRIC PERFORMANCE

The tube is kept cooled with the operating voltage applied day and night. This leads to high photometric stability. The transformation equations are determined every three to six months by means of observations on one or two good photometric nights of numerous E-region standards (60 or more) covering a wide range of colours. The transformations are well represented by the following linear relations:

$$V = v_O + 0.007(v - i)_0 + Zv$$

$$(B-V) = 1.008(b-v)_0 + Z_{bv} \qquad (V-R)_c = 1.043(v - r)_0 + Zvr$$

$$(U-B) = 0.987(u-b)_0 + Z_{ub} \qquad (V-I)_c = 1.006(v - i)_0 + Zvi$$

Here, the subscript zero refers to natural colours corrected for extinction and the Z's are the zero points. The coefficients are all close to 1.0 so the match to the standard systems is quite satisfactory. For (B-V) and (U-B), non-linear corrections must also be applied. The correction to (B-V) applies only redder than 1.2 and can be represented as a function of (B-V) by a straight line of slope -0.08 mag/mag. The (U-B) correction as a function of (B-V) is an S-shape curve with a maximum value of +0.02 mag at (B-V) = 0.1 and a minimum of -0.02 at (B-V) = 0.5.

The magnitudes which give 1 count sec^{-1} above sky are given in the following list, where a comparison is also made with the tubes in use immediately before the change to the Hamamatsu tube was made.

	Hamamatsu	EMI6256		Hamamatsu	EMI9658
V	20.1	19.7	V	20.1	19.7
B	20.1	20.55	R_c	20.0	19.2
U	19.6	19.7	I_c	19.3	19.4

After all linear transformations, non-linear corrections and zero points have been applied, the standard deviation for a single observation during a typical colour equation run when 85 E-region standards were observed was:

	V	(B-V)	(U-B)	$(v-R)_c$	$(v-I)_c$
S.D.(mag)	0.007	0.008	0.010	0.006	0.007

A disadvantage of the Hamamatsu tube is that there is an upper limit to the count rate measurable with it beyond which there is a signal-induced increase in dark count rate. This occurs at about 3×10^5 count sec^{-1} which corresponds to V about 6.4mag. To measure bright stars it is necessary to introduce neutral density filters.

However, the tube appears to be robust. For example, after an accidental exposure to Jupiter, the dark count rose to more than 10^4 count sec^{-1} but had returned to normal 14 hours later. There has not been any subsequent change in the colour equations or zero points.

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DISCUSSION

Graham: Have you had any experience of the non-linear corrections to your U-B and B-V transformations depending on the metallicity of the star? I had a lot of trouble with this when I did my $UBV(RI)_{KC}$ photometry with an RCA 31034 tube.

Menzies: I haven't investigated this. We use Cousins standards, most of which are nearby, solar metallicity stars. Some of the (U-B) problem may be due to a metallicity effect.

Rucinski: The RCA tubes were known for frequent failures, e.g. they just stopped working. Are these tubes any better?

Menzies: I don't have any more information apart from the limiting count rate and their subsequent increased noise. The count rate effect produces a bright limiting magnitude of $\sim 6^{m}_{\cdot}5$ on a 0.5 m telescope. As far as durability is concerned, our current Hamamatsu tube has been in use for about one year without any deterioration in performance.

Warner: RCA tubes are much better now as they no longer leak through the pins.

Breger: Nonlinear corrections required for (B-V) transformations may be quite common. I find a similar curvature when transforming to Landolt's (GaAs) standards. Since the nonlinearity only becomes evident when stars redder than (B-V)=1.2 are measured, it can be missed when very red standard stars are not measured.

Menzies: I agree, people often don't see the effect because they don't observe the full colour range or enough standards. We have compared E region and Landolt standards and still found non-linearities. This probably means that there is no "standard" UBV system and that everybody has their own system.

Gaustad: With all the talk (see Latham) about the wonders of CCDs for photometry, and the report (see Jacoby) that KPNO is phasing out photomultipliers, I want to ask a provocative (and somewhat tongue-in-cheek) question : Why bother to develop photomultiplier systems, which seem to be a relic of the past?

Menzies: Not everybody can afford CCDs, and then there are the electronics, and maintenance requirements.