INTERNATIONAL HALLEY WATCH WIDE FIELD NETWORK FOR LARGE-SCALE PHENOMENA, CALIBRATION OF SCHMIDT PLATES USING STAR PROFILES

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1. INTRODUCTION

The International Halley Watch Wide Field Network for Large-scale Phenomena (Niedner, Rahe and Brandt, 1982) will be receiving several thousand original or first copy images of the large scale structure of comet Halley. These images will be coming from over 90 telescopes at 70 different observatories around the world. Some but not all of the photographic material will have associated sensitometry. It is anticipated that since this network is looking for changes in the plasma tail structure most, if not all, observations will be made with unfiltered Kodak IIaO emulsion. One of the major tasks of the network will be to study the plasma tail variations at the highest time resolution possible. In order to do this, it will be necessary to combine photographs taken at many observatories. This implies creating calibrated intensity images from a sequence of diverse photographic plates. We will need to provide a method for calibrating individual photographic plates, that is not only fast but also accurate using only information that can be obtained on a single Schmidt plate.

There exists in the current astronomical literature two methods that have been suggested to handle this problem. The first is due to Agnelli, Nanni, Pitella, Trevese and Vignato (1979). Their method assumes that the star profiles can be modeled with an analytical function and that this profile is circularly symmetric. Then only the magnitudes of a number of unsaturated stars on the plate in some standard magnitude system is needed to convert the density at a specific radius into an intensity transfer function. The second method (Zou, Chen and Peterson, 1981) eliminates the the assumption about the form of the stellar profile but requires that the intensity transfer function be approximated by a polynomial in opacitance.

This paper will show how well both methods provide surface brightness measurements on extended objects. The object used for this test is the Andromeda Galaxy, M31. The photographically calibrated results are compared to photoelectric scans by De Vaucouleurs (1958). Two plates have been obtained at the Joint Observatory for Cometary Research (Brandt, Colgate, Hobbs, Hume, Maran, Moore, Roosen, 1975) in Socorro, New Mexico.

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They are 4 by 5 inch plates with approximately 8 by 10 degrees of the sky recorded. The exposures are long (16 and 40 minutes) so that the sky background is high. The density values for the sky are 1.0D and 1.5D respectively.

2. MODIFICATION OF THE AGNELLI METHOD

The Agnelli method assumes the total point spread function for the star plus the sky is given by

$$I(r) = I_o f(r) + I_s. \tag{1}$$

We will assume that the sky background is constant for any one star profile, but need not be the same for all stars. The form of the analytical function that Agnelli et al. used was given by Moffat (1969) as

$$f(r) = [\ 1 + (r/R)^2\ ]^{-\beta}. \tag{2}$$

The total flux from a star is given as the area integral of equation 1. If the flux is expressed as a magnitude, then the magnitude for one star can be expressed as

$$m_i = -2.5 \left\{ \log \frac{2\pi R}{2(\beta-1)} + \beta \log \left[1 + \frac{r_{ij}^{\ 2}}{R} \right] + \log\ [I_i(r_j) - I_i(sky)] \right\}. \tag{3}$$

This equation states that if we know the radius at which a particular density is reached for each star in a sequence of stars whose magnitudes are known on some standard magnitude scale; we can, using a non-linear least squares technique, solve a set of equation 3's for the three unknown quantities β, R and log $[I_i(r_j) - I_i\ (sky)]$. If this is done at "many" densities, with the constraint that the shape parameters are held constant, we would create the needed intensity transfer function.

3. THE DENSITY MOMENT SUMS METHOD

Zou, Chen and Peterson (1981) have proposed another method for doing the same type of problem. Their method assumes that the intensity transfer function can be approximated by a polynomial in opacitance,

$$I = \sum_{k=1}^{n} b_k\ (10^D - 1)^{pk} \tag{4}$$

and that the magnitudes of a number of stars, with unsaturated density images are known. With these two assumptions the intensity for any one star can be written as

$$m_i = I_o 10^{-0.4M_i} = \sum_{k=1}^{n} b_k \left[\sum_{j=1}^{m} (10^{D_{ji}} - 1)^{pk} - m(10^{D_{si}} - 1)^{pk} \right]. \tag{5}$$

The only unknowns are the b_ks. Thus this set of equations, one for each known star, can be solved by least squares techniques to provide the required intensity transfer function (equation 4).

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4. RESULTS

Two plates from the JOCR of M31 have been digitized and used as a test case for these two methods. A photoelectric sequence near M31 by Racine (1967) was used for the stellar magnitudes. Figure 1a and 1b show the extracted magnitudes of the 16 minute and 40 minute exposure respectiviely using the Agnelli et. al. method. The 16 minutes exposure does not reach the faint sky limit achieved by the 40 minute exposure. The values of "β" and "R" are given in table 1. The same digitized data was processed with the Zou, Chen and Peterson method with the results shown in figure 2. The values for the "b_ks" and the best value of "p" and "n" for each are shown in table 2.

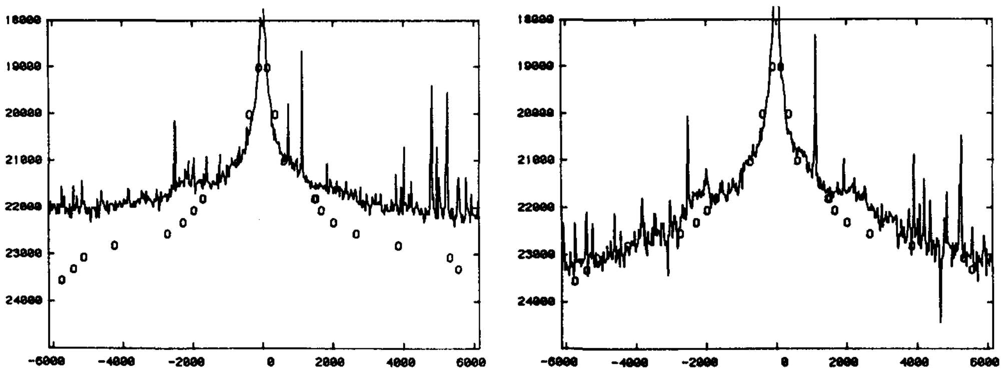

Figure 1a and 1b. Magnitude profile of major axis for M31 using Agnelli et. al. The lines are for the extracted magnitude and the circles are from De Vaucouleurs (1958). The left hand graph is for a 16 minute exposure and the right hand one is for a 40 minute expousre.

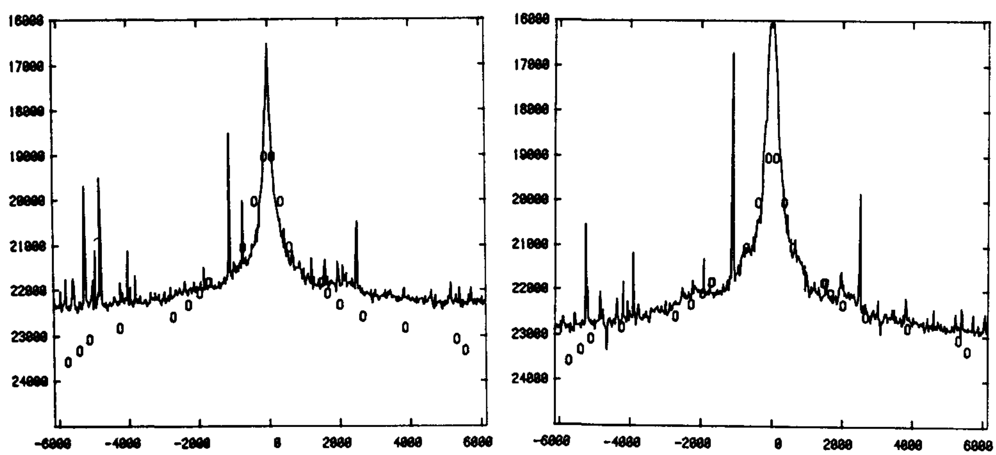

Figure 2a and 2b. Magnitude profile of major axis of M31 using Zou, Chen and Peterson method.

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Both methods give similar results. For our application, cometary images where the stars are trailed due to the motion of the comet during the exposure, the advantage lies with the Zou et. al. method because it is not necessary to assume a shape for the star profile.

The availability of sensitometry would provide data on the nature of the intensity transfer function for each plate. However, it is not clear that we can use the same ITF curve all over a large Schmidt plate taken near the horizon and still expect to maintain 5 to 10% accuracy. With these methods and enough calibration stars, for example blue magnitudes from the Catalogue of Stellar Identification (Ochsenbein, 1976) we will be able to proivde an intensity transfer function varying with sky background. We will use what ever data we have to provide the best possible photographic photometry.

TABLE 1

PLATE	β	R
S 855	1.7	1.5
S1590	2.1	1.4

TABLE 2

	S 855	S1590
P	0.9	0.7
n	4	3
B1	1.233E-10	1.707E-09
B2	1.813E-13	1.101E-11
B3	-3.141E-17	-6.602E-15
B4	1.357E-21	

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