Publ. Astron. Obs. Belgrade No. 60 (1998), 110 – 113 *Contributed paper*

PROCESSING OF CCD ASTROMETRIC OBSERVATIONS WITH THE BUCHAREST ASTROLABE

R. POPESCU and P. PARASCHIV
Astronomical Institute of the Romanian Academy,
Str. Cuţitul de Argint 5,RO-75212, Bucharest, România
E–mail pradu@roastro.astro.ro

Abstract. At the Bucharest Observatory, a CCD camera (COHU 4710) was adapted to the modified Danjon astrolabe. In order to be determinated the star passage time at the fixed zenithal distance, it is necessary to register all the succesive positions during its deplacement in the field. The number of frames acquired by the camera for one passage is about 25-40, depending on the transit velocity. Because of the very short acquisition time, the photocentre location requires a special centring algorithm.

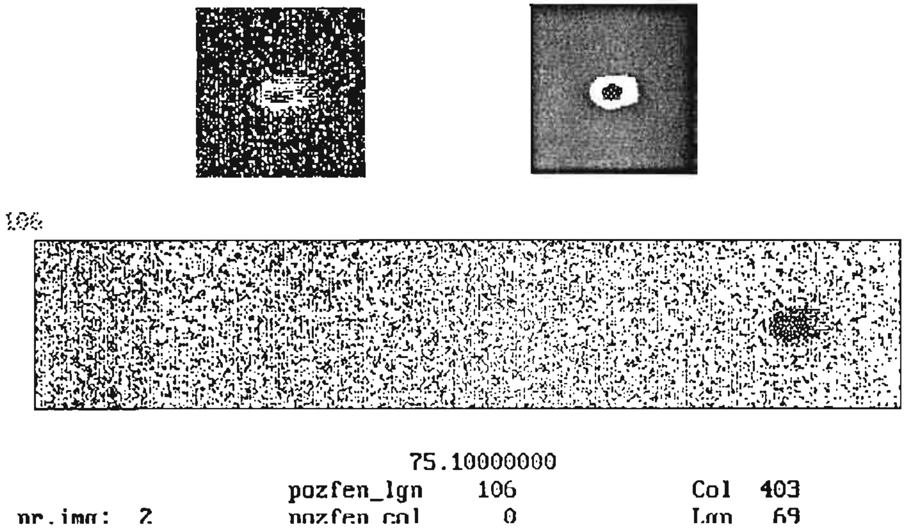
1. THE INFLUENCE OF PHYSICAL PARAMETERS UPON THE SHAPE AND POSITION OF IMAGES

The photoelectric detection development imposed the improvement of astrometrical observation techniques. The visual observations often contain systematical errors and cannot give enough accuracy in image centring process.The photoelectric devices used in astronomical observations allow us to save the information and to investigate it afterthat. The electrical output signal is either analogic (photomultipliers) or digital (CCD cameras).

In opposition with analogical centring techniques that cannot preserve the spatial resolution (Lindegren, 1977), the digital techniques are enabled to process the bidimensional images and offer the possibility of definition with great accuracy of the photocentre and limbs. The quality of a bidimensional image is influenced by both the quality of optical system and the atmosphere turbulence (Fried, 1965; Fried, 1966). In the absence of the atmosphere agitation, the quality of a star image and the photocentre detection accuracy are given by the set of internal optical parameters (diffraction, aberrations, and defocalisation) (Born & Wolf, 1993).

Assuming that the optical system is aberrations-free and well focused, the shape of a star image is given by the diffraction pattern. In the case of the modified Danjon astrolabe, the shape of the entering pupil is a vertical ellipse and the diffraction image is also an ellipse but horizontal.

In figure 1 can be observed the elliptical shape of the star image. In order to stress the ellipse, we have convoluted the original image with a Gaussian filter.



```
                         75.10000000
                    pozfen_lgn     106          Col  403
nr.img:  2          pozfen_col       0          Lgn   69
```

Fig. 1.

The instantaneous variations of the diffraction spot and the accidental variation of the image centre from the predicted position are generated by the atmospheric turbulence (Tatarski, 1967; Lindegren, 1978).

Because of the shortness of the acquisition time in the case of observations performed with a CCD camera adapted on the astrolabe (about 40 ms for an image), the atmosphere agitation is "frozen" and the angular dimensions of the image are given by the diffraction pattern and the accidental distortions of the light front. By studying the star trajectory (25-30 frames), the atmospheric turbulence (Fried, 1965; Fried, 1966) can be determined.

2. THE LOCATION PROCESS. IMAGE CENTERING TECHNIQUES

For sake of rapidity and precision (especially in the case of bright stars detection), two centering methods have been used: the momentum, and the derivative method.

The momentum method was widely described (Stetson, 1987; Stone, 1989; Lu Chun-lin, 1993). Along one of the axis of co-ordinates, the photocentre can result as the first order momentum of light intensity distribution:

$$X_{C_j} = \frac{\sum_i X_i(I(i,j)-N)}{\sum_i(I(i,j)-N)};\ Y_{C_i} = \frac{\sum_j Yj(I(i,j)-N)}{\sum_j(I(i,j)-N)},$$

where N is the background noise.

Unfortunately, this method is very sensitive to noise. In order to eliminate the spurious data, an threshold has been introduced, so that the distribution can be written as follows:

$$I(i,j) = (I(i,j) - N) \text{ if } I(i,j) \geq T;$$

$$I(i,j) = 0 \text{ if } I(i,j) < T.$$

The adopted value for T is one third the maximum intensity.

The derivative method was described (Stetson, 1979; Stone, 1989) and consists in computing the numerical first derivative of intensity distribution:

$$d = \frac{1}{2}(I(j,i-1) - I(j,i+1)) + \frac{1}{4}(I(j,i-2) - I(j,i+2)) + \frac{1}{6}(I(j,i-3) - I(j,i+3))$$

In the case of a Gaussian shaped intensity distribution, the centre is located at the point where the first derivative vanishes. In order to calculate the co-ordinates of this point, an iterative test must be imposed for determining where the derivative switches its sign. A simpler method consists in squaring the first derivative. The idea is to keep it all the time at positive values. The half distance between the two positive peaks gives us the photocentre.

Knowing the fact that the star intensity distribution for a short time integration has a quite irregular shape (image twinkling and quivering), we adopted a special centring algorithm. The explanations are given for the unidimensional case of light distribution. In the first step, the approximate star co-ordinates are found by pointing the mouse arrow upon the maximum isophote of the image, and the software "centres" a window of 100 by 100 pixels on these co-ordinates. Inside this window, we are looking for the maximum intensity co-ordinates (X_M, Y_M). For a set of eleven lines centered on $Y = Y_M$, we find the photocentre X_C by using one of the methods presented bellow.

The resulting set of data can be written:

$$X_{C_i} = X_{C_i}(Y_{M-i}), i \in [-5, +5].$$

By means of the least squares method, the data can be fitted to a stright line:

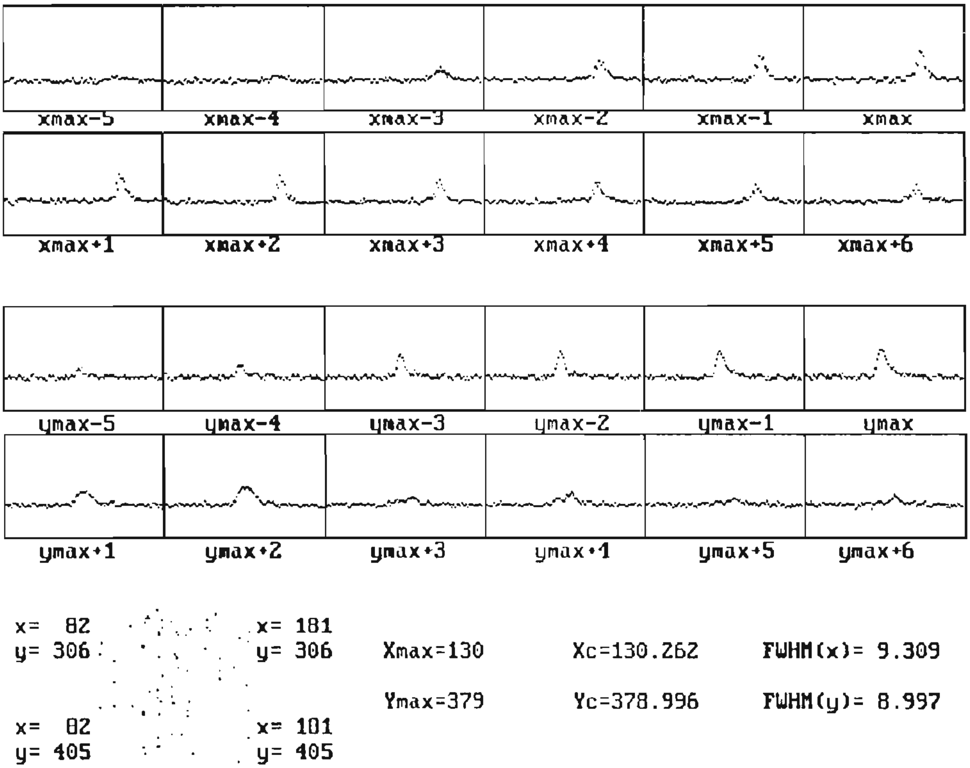
$$Y = a_1 \cdot X + b_1.$$

Similarly, on the Y axis, the regression line can be written as follows:

$$Y = a_2 \cdot X + b_2.$$

The co-ordinates of the star photocentre (X_C, Y_C) result from the intersection of the two regression lines.

In figure 2 are shown the intensity distributions of a star image along the two axis of co-ordinates.



```
Xmax=130        Xc=130.262      FWHM(x)= 9.309

Ymax=379        Yc=378.996      FWHM(y)= 8.997
```

Fig. 2.

References

Born, M., Wolf, E.: 1993, *Principles of optics*, Pergamon Press.
Fried, D.L.: 1965, *J. Opt. Soc. Am.* **55**(11), 1427.
Fried, D.L.: 1966, *J. Opt. Soc. Am.* **56**(10), 1372.
Lindegren, L.: 1977, *Astron. Astrophys.* 57(1/2), 55.
Lindegren, L.: 1978, *IAU Symp.* **109**, eds. Eichhorn H.K., Leacock R.J., 197.
Lu Chun-lin: 1993, *Astron. Astrophys.* **275**(1), 349.
Stetson, P.B.: 1979, *Astron. J.* **84**, 1056.
Stone, R.C.: 1989, *Astron. J.* **97**(4), 227.
Tatarski, V.I.: 1967, *Wawe Propagation in a Turbulent medium*, Dover Publ. inc. N.Y.