A NEW ASTROLABE

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ASTRACT

To obtain a quite impersonal astrolabe, a new instrument has been built. The first UTo-UTC results show very good agreement with the BIH scale.

I - INTRODUCTION

In the same way as Danjon's astrolabe, the new photoelectric astrolave (ASPHO) allows the determination of local coordinates as well as the determination of catalogue corrections, using the general equal altitude method of Gauss. But the comparison between both astrolabes stops there: through its conception and through the computation methods that it involves, the ASPHO is quite a new instrument.

Every one here knows that an astrolabe is primarly designed to yield the transit time of a star at a given altitude, that is when the two images of the star coincide. The reliability of astrolabes comes from the fact that measurements are established by reference to a very stable optical angle master. It was already the case early in the century with Claude's and Driencourt's astrolabe; but as during night observers can accomodate on extra focal images, there was a large scale of personnal errors.

To overcome this drawback, Danjon superposed the images of the two entry pupils by means of his impersonnal birefringent micrometer. Anyhow, the two off axis pupils subsisted giving asymetrical chromatic images. In addition Wollaston prisms introduced more chromatism and a weak astigmatism. The observer was affected by these defects and Danjon's astrolabe was not definitely an impersonal instrument.

To obtain impersonal observations, the only way was to replace the observer by a suitable recording device. In that case perfect images are necessary: neither asymetrical chromatism, nor astigmatism, especially no coma. In 1971, a full pupil angle standard made of zero expansion material instead of a glass made prism was conceived (Billaud G. and

H. K. Eichhorn and R. J. Leacock (eds.), Astrometric Techniques, 389–395.

Guinot, B., 1971) (1). The reference stability was thus greatly improved and reached 0".01.

But above all, by the realisation of this new device, the separated pupils are suppressed and makes possible to obtain round images: consequently it allowed the construction of a photoelectric astrolabe.

II - THE NEW INSTRUMENT

ASPHO (fig 1) is essentially built as an optical bench fixed upon a castiron bearing and supporting the different pieces: the angle standard, the Maksutov-Cassegrain reflector, the photomulplier and its optics. The mercury bath lies in the middle of the pilar, on the rotation axis of the astrolabe. Mechanics and optics have been realized under the management of J. Texereau (Billaud, G., Texereau, J., 1982).

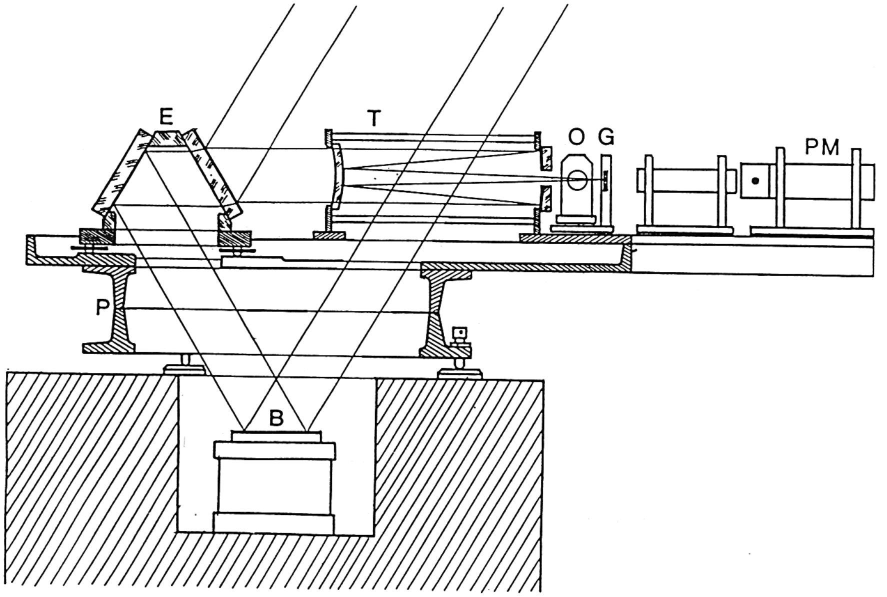

FIGURE 1. The photoelectric astrolabe: B= Mercury bath, P= Bearing, E= Angle standard, T= Maksutov-Cassegran Reflector, O= Monitoring eye piece, G= Modulation Grid, PM= Photomultiplier.

To ensure a perfect simultaneity of focusing for both images, the back mirror as well as the front plate of the angle standard have been polished up to a 50th of a wave taking into account the bending resulting in working conditions. The angle standard and the mirror are made of microcrystalline ceramics ZERODUR from Schott, while the front plate is made of fused Schieren grade silica from Corning. Plate and mirror are fixed on the central body by means of springs like plates of a Perrot-Fabry interferometer. As we have already mentioned, the reflector is a Maksutov-Cassegrain type (focal length 2 060 mm, diameter 100 mm). The main interest is to obtain a compact device and a very high stability of the secondary mirror which is simply part of the backface of the correcting plate. The whole frame of the reflector is made of Invar steel. The measuring device consists mainly of a modulation grid and a photomultiplier. Between them, an optical system equivalent to a Fabry lens images the entry pupil onto the photocathod. Morever, a monitoring eye piece with cross wires conjugate to the grid allows the operator to check the position of the images of a star with respect to the grid.

At the present time, the grid is a periodical type. It is basicaly a transparent glass plate with opaque stripes manufactured by Heidenhain. Each stripe is 690 μm wide and 17 mm long. Between two consecutive stripes there is a gap of 150 μm which acts like a slit. The transition between black and clear stands within 0.1 μm. There are only 8 slits: the limitation comes from the average duration of observation which is about 1 minute. Because of diurnal rotation the two images are drawn through the grid which is set up in such a way that no two images are simultaneously on a blank of the grid.

The transits of the images through the edges of the slits are alternatively and independtly recorded (Fig.2) by the photomultiplier which is fitted to operate as a photon counter. The grid thus appears to be equivalent to a micrometer, the wires of which would be the median of the slits.

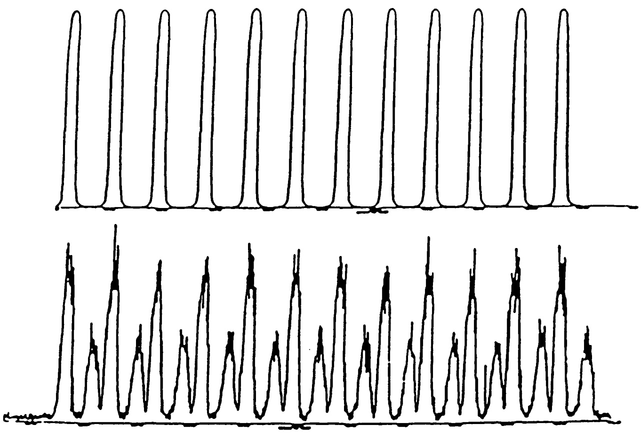

FIGURE 2 - Transif of a star. The upon part shows the transmission of a 12 slits grid while the lower part shows the actual record for both images with the same grid.

The relative position of the peaks in the modulation curve varies from one azimuth to another: it must be reminded that a depression of 1 μm of the bearing causes a 14 μm shift in the focal plane. But this has no effects on the determination of the crossing time: the observation altitude is only defined by the angle standard. A map of the bearing defects, which do not exceed 1".5 has been established and the operator,

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previously to the observation has the possibility of correcting either the grid position or the angle standard position in such a manner that the two flux records are independent, i e the interpeak distance remains approximatively equal.

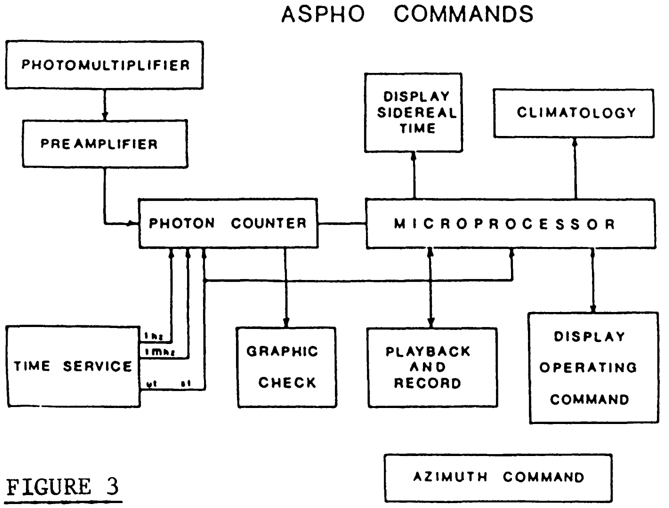

FIGURE 3

The sampling is directly under the control of the caesium clock. The time of the first sample is recorded and every sample begins and ends with a signal derived from the main clock. The observation program is available on a magnetic tape with sidereal time argument and a in-line microprocessor displays useful instructions to the operator: star characteristics, Moon position, retro-chrono (Fig.3). Such are the conditions of observation: they are quite impersonal and leave the possibility for a full automatization: this will be done, we hope, in the near future.

III - DATA PROCESSING

The data processing (fig.4) aims at restituting the transit and the computation of the concluded crossing time. Evidently, a global correlation treatment would be possible and surely we shall use it after one year of continuous observation. But at the present time individual peak correlation allows a fine analysis of the star transit and gives informations about refraction anomalies.

When using global correlation, another method is possible: it has been shown (Pochet, J.M., 1984), it is possible to use random coded grids to determine the star transit time with the same precision as that achieved with a conventional grid (Fig.5). This attractive method allows us to get more information (63 slits instead of 8) and avoids the shift problem. The only drawback is the greater sky background resulting of the higher transparency (50% instead of 20%). However, the use of a vertical

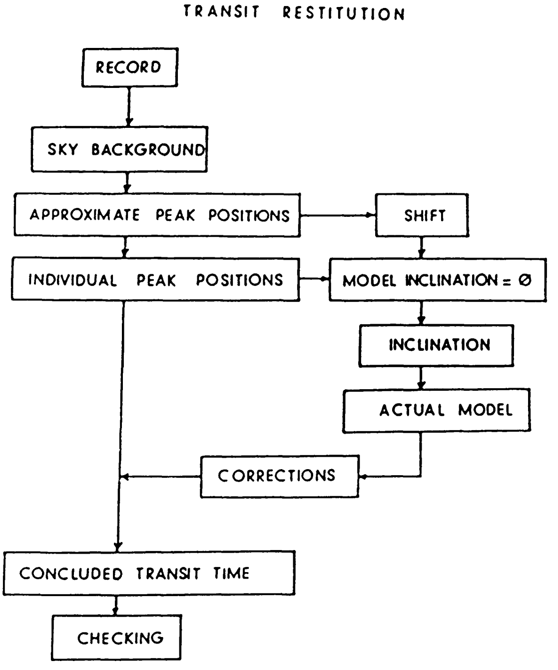

FIGURE 4

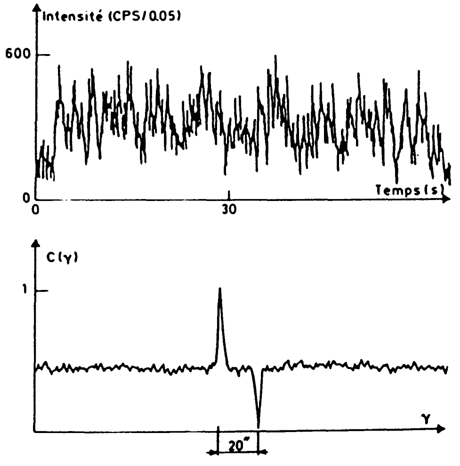

FIGURE 5 - The pseudo-noise grid. The grid consists of 60 slits, built with 262 elementary steps of 25 μm. The upper part shows the signal intensity as a function of time. In the lower part the autocorrelation signal between the reference grid and the record is shown.

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diaphragm would maintain the background noise to an acceptable level. Furthermore, this improvement is also necessary to observe latitude stars., i e stars that are less than 45° apart from the meridian.

IV - FIRST RESULTS

As regards to the results, the first point well established concerns the very constant error of the transit time determination: it usually oscillates between 7 and 9 ms, independently of short period agitation, and does not show significant magnitude or colour effect.

The data are then reduced by a classical least squares adjustment. In addition to UTo, latitude and zenith distance corrections, for each star a residual including the sysmetatic error in star catalogue is given. Over the successive nights the dispersion of the residuals is about 0ʺ.10, that is an improvement by a factor of nearly 2 compared to the classical astrolabe.

Because of hardware constraints only stars with a parallactic angle greater that 30° can be observed; it means that practically there are few latitude stars. As a result, the accuracy of the concluded latitude correction is not significantly better than with the full pupil astrolabe, althrough quite free of personnal equation (0ʺ.07).

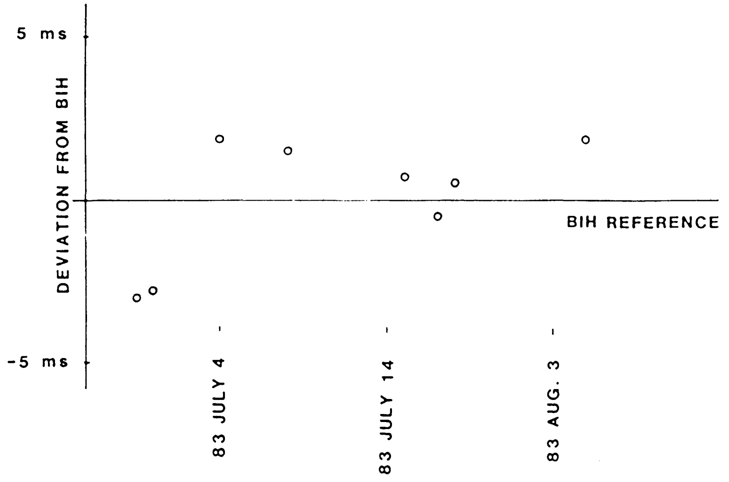

FIGURE 6 - Deviation from BIH results. The r.m.s. error is 0.0019 s.

As for UTo-UTC, the weights in the usual astrolabe scale are greatly improved, and the external agreement with BIH results is better that 2 ms for the period June 24th-July 18th, 83 (fig.6). To date, only are some PZT and surely the VLBI, capable of such an accuracy, over several weeks. The results are based on a limited number of observations and maybe unexpected difficulties will arise when treating a more important set of data. Nevertheless, taking into account the planned improvements as well on the technical side as on the computing one, these results are very encouraging and make us optimistic about the future of ASPHO.

The space exploration and the technological jump of the last decade have permitted the emergence of new methods of better precision, but far more difficult to operate and of which long term operations are subject to very high costs and consequently not guaranteed; and before Hipparcos is successfully lounched and its data are reduced (and a 100% success cannot be neither presumed) ground based astrometry of bright star has a word to say.

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Pochet, J.M., Détermination des instants de passage d'une étoile à l'aide d'une grille pseudo-aléatoire, Astron. and Astrophys., 1984, 139, pp 517-520.

Discussion:

HØG: One of your beams is inside the instrument before it reaches the beam combiner. It is therefore subject to those temperature gradients inside the instrument which are variable. How much instability of your basic angle does this produce?

BILLAUD: For a gradient of $1^{\circ}C$ between the mercury bath and the angle master, there is a differential refraction of $0\rlap{.}''2$.

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