THE HIPPARCOS IMAGE

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Abstract :
One presents hereafter the HIPPARCOS satellite payload which
is mainly constituted by a Schmidt telescope; a possible way
to approximate the Schmidt mirror elliptic deformation profile
is explained. Then, the signal expected from the optical chain
is briefly described and one displays a residual chromatic
effect which may introduce errors in the measure. To conclude,
numerical values of this effect are given and one shows the
necessity to take it into account in the data reduction
process.

1. INTRODUCTION

The space Astrometry mission HIPPARCOS of the European Space Agency aims
to build a catalog of the astrometric parameters (parallaxes, proper mo-
tion and positions) of 100,000 stars [1]. The Laboratoire d'Astronomie
Spatiale is involved in this project as the responsible of optics analy-
sis and develops, in close cooperation with Italian and Dutch Institutes,
a mathematical model of the payload for the Data Reduction Consortium
FAST [2]. One presents hereafter the results obtained during these last
months and one shows the parameters which shall be studied very care-
fully in the future.

2. THE PAYLOAD

2. 1. Description

The sky is observed by a special telescope with two ways allowing to
observe two fields of 0.9 degree by 0.9 degree separated by an angle of
about 58 degrees [3]. An observed star is imaged on a modulation grid
located on a field lens. Its image is transported by a relay optics and
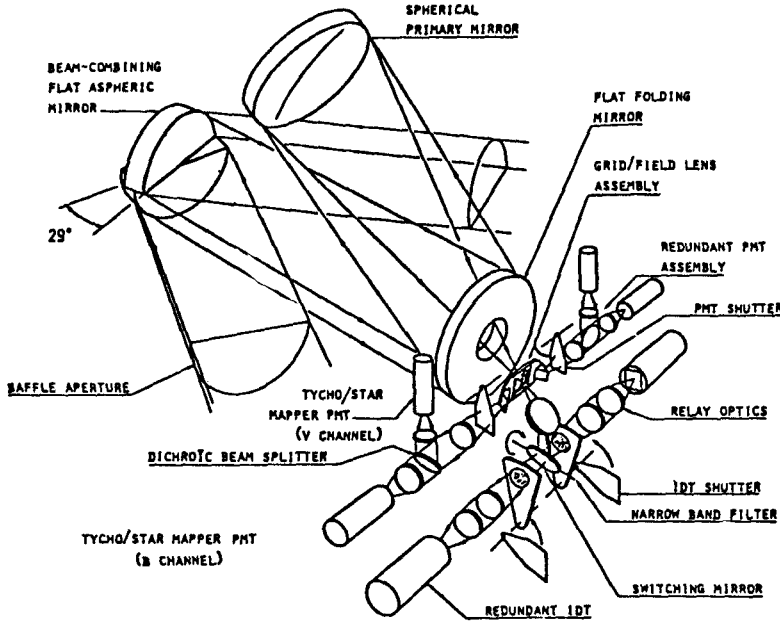a detector determines the intensity then observed.

Figure 1 .   The payload including the special telescope
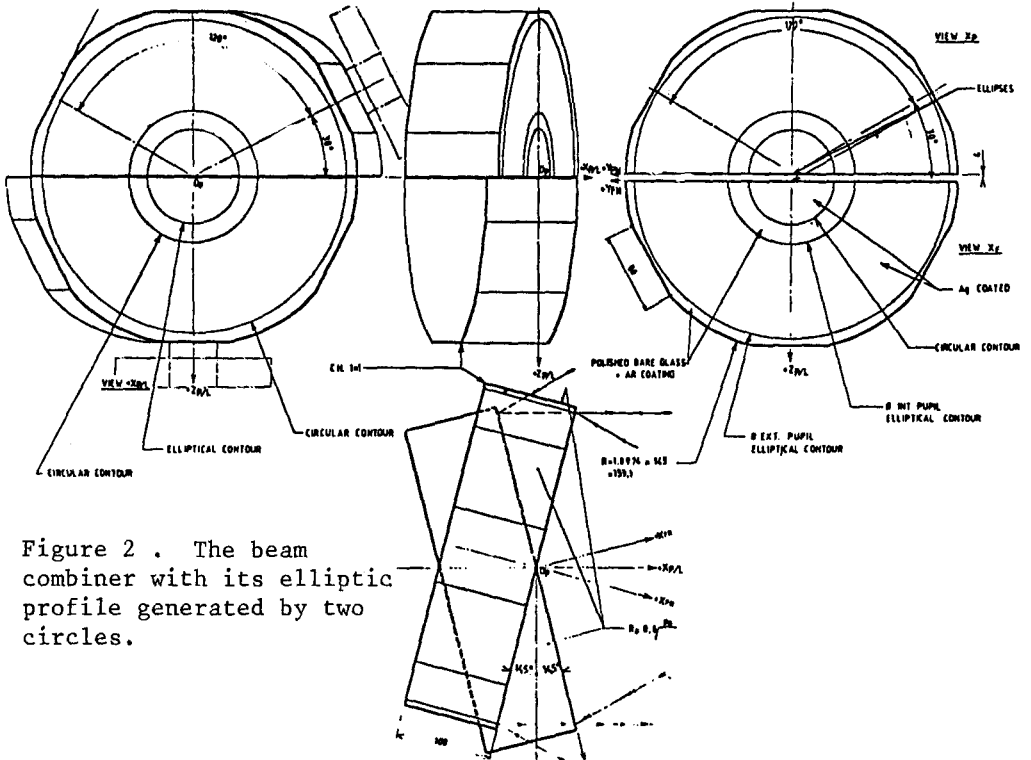   with two fields separated by 58 degrees.

Figure 2 .   The beam
combiner with its elliptic
profile generated by two
circles.

By knowing the separation angle of the two fields of view and the loca-
tion of two stars on the grid, one can deduce the separation angle
between the two stars. The final objective of the HIPPARCOS mission is
to determine this angle with an accuracy of 2 milliarcseconds (after
processing of the raw data expected from the satellite).

2. 2. The SCHMIDT telescope

The telescope which is an "All-Reflective" Schmidt system is formed by
the Schmidt mirror which also insures the role of "beam combiner", so it
works with a relatively strong incidence (14.5 degrees),a flat mirror
devoted to fold back the system in order to adapt it to the satellite
size constraints and the spheric mirror (figure 1). The Schmidt mirror
working with a high incidence consequently it ought to have an elliptic
deformation profile [4]. Such a profile is in fact very difficult to
realize, regarding the optics dimensions and taking into account the
manufacturing tolerances ($\lambda/60$ r.m.s on the wavefront, mirror diameter
= 290 mm, telescope focal length = 1400 mm).
Incidentally, after the polishing, the system will have to be cut out
in two equal parts (one by half pupil). In fact, the optical study
showed that the utilization of the mirror having a revolution profile
was acceptable, the elliptic form of the deformation profile being ob-
tained in slightly decentring each half-pupil [5]. (figure 2)

2. 3. Grid, relay optics and detector

The grid located on the telescope focal surface is periodic, its period
being equal to 1. 2 arcsecond on the sky which corresponds to a physical
stepsize of 8 micrometers. So, the light falling down on the grid is
modulated and, regarding the grid stepsize, diffracted. Then, the relay
optics conjugates the grid surface with that of the detector ; The de-
tector is an image dissector tube which counts photons. Its instanta-
neous field of view is about of 30 arcseconds of diameter and will be
steered by the board computer. This kind of detector reduces the back-
ground noise and limits the confusion which would result from the surim-
position of the light coming from different stars.

3. THE SIGNAL

In this paragraph we will assume the detector is perfect, the relay op-
tics is without aberrations and collects the whole light diffracted by
the grid and the system is monodimensional. If D is the signal due to
the detector, T the distribution of intensity on the grid for a given
wave-length and G the grid transmittance, it can be shown that D is the
convolution of T by G : $D = T \otimes G$ [6]

3. 1. Analytical expression

We can then deduce FT (D) = FT (T). FT (G) where FT denotes the Fourier

Transform . As the grid has a periodic profile constituted with battle-
ments, its Fourier Transform has only discrete terms corresponding to
the frequencies n . ν (ν is the grid frequency, ν = 125 mm^{-1}). Inciden-
tally, FT (T) is the telescope optical transfer function. Taking into
account the pupil dimensions, the cut-frequency is between 2 ν and 3 ν
over the interesting range of wavelength. Let a_0, a_1, a_2 be the values
of FT (G) for the frequencies 0, ν and 2 ν. Let M_1 . exp (j v_1) and
M_2 . exp (j v_2) be the values of the normalized optical transfer func-
tion to the frequencies ν and 2 ν. So the Fourier transform of D has
only discrete terms, the values of which are a_0 for the continuum,
 a_1 . M_1 . exp (j v_1) for the frequency ν and . a_2 . M_2 . exp (j v_2)
for the frequency 2 ν. So, the signal D can be written :

$$D = a_0 + a_1.M_1. \cos (2\pi\nu x + v_1) + a_2.M_2. \cos (4\pi\nu x + v_2)$$

introducing $x_1 = x + \dfrac{v_1}{2\pi\nu}$ and $x_2 = x + \dfrac{v_2}{4\pi\nu}$, it comes :

$$D = a_0 + a_1.M_1. \cos (2\pi\nu\, x_1) + a_2.M_2. \cos (4\pi\nu\, x_2)$$

This function depends :
* on x, that is to say on the angular coordinates of the considered
star.
* on the starlight spectral distribution

3. 2. The CHROMATICITY

Let us consider now a geometrical point of the object field and take a
blue star. The abscissa over the grid will be x_B and the phase corres-
ponding to the first harmonic will be v_{1B}.
In these conditions :

$$x_{1B} = x_B + \frac{v_{1B}}{2\pi\nu}$$

Let us place now a red star in the same geometrical point. With the same
conventions as before :

$$x_{1R} = x_R + \frac{v_{1R}}{2\pi\nu}$$

Now, let us calculate $x_{1B} - x_{1R}$:

$$x_{1B} - x_{1R} = x_B - x_R + \frac{1}{2\pi\nu} (v_{1B} - v_{1R})$$

The difference C = x_B - x_R corresponds to the usually defined lateral
chromatism ; incidentally, and the computation will verify it, v_{1B} and
v_{1R} have no reason to be equal.

Let us put now : $X = \dfrac{1}{2\pi\nu} (v_{1B} - v_{1R})$

We find again a new parameter [7] introduced by the studies carried out
at the ESTEC, which has been called CHROMATICITY. This parameter whose
values depends on the spatial frequency induces, in the absence of clas-
sical chromatism, a residual chromatic effect in the images formation

process; It is due to the repartition of the energy in the diffraction "rings" which depends on the wavelength.

3.3. Numerical results

The LASSO software has been especially developed to compute the CHRO-MATICITY. One made this software because the classical ones are not efficient enough to compute the CHROMATICITY with a sufficient accuracy (0.1 milliarcsecond). Moreover, a complete telescope analysis asks to modelize the thermo-mechanical effects and creates a lot of calculations which constraint the program to a very short execution time. The results obtained showed that the CHROMATICITY of the nominal instrument (theoretical values for the components profile and position) is of 1 milliarcsecond all over the field of view [8] .It has been established that the CHROMATICITY values depend on the payload thermo-mechanical conditions and least cases of distorted instrument have been evaluated to define the extreme conditions which will be endured by the payload.

4. CONCLUSION

This very quick study of the HIPPARCOS image showed the utilization of a Schmidt telescope in Space Astrometry. The results already established allowed the design of the telescope and displayed the CHROMA-TICITY. This effect appeared as a milestone in the data acquisition. Now, further investigations are undertaken to determine its real values and to propose solutions which might minimize its impact on the whole mission.

5. REFERENCES

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