The ideas that led ESRO to consider a space astrometry mission

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It seems now natural to consider space as the best place to make high precision astrometry. The present sophistication and power of embarked instrumentation on board of space vehicles and the highly developed service platforms allows now to prepare such a wonderful mission as GAIA. But in the beginning of the space era, when the design of satellites was very simple, even the idea of space astrometry requiring, among other capabilities, very precise orientation of the instrument, was pure fiction.

To the best of my knowledge, the first astronomers who dared presenting some ideas about astrometry in space, were Paul Couteau and Jean-Claude Pecker (1964), who wrote a paper in the first issue of a very confidential yearly publication of the Nice Observatory called “Bulletin d’information”. In this paper, they discuss several opportunities that space could offer by suppressing atmospheric turbulence and attenuation. They consider the following fields.

1°) *Double stars*. With a telescope matching the best astrometric telescopes, one would multiply by 200 the volume that can be explored. If interferometry were used, this number would be 1600. They proposed also to use a rotating grid as described by Bacchus in 1959.

2°) *Search for planetary systems*. The idea was to use the Van de Kamp method and possibly also interferometry.

Now, conscious of the orientation problems, they see the solution by installing the telescope on the Moon! As we now know, this road to space astrometry was not pursued.

Initial proposal by P. Lacroute

Pierre Lacroute, then Director of Strasbourg Observatory, was the first to study, in close relation with Pierre Bacchus, how in practice one could make astrometric measurements in space from an artificial satellite. It seems that the first time he presented his ideas in public outside his own observatory, was in June 1965 at a colloquium in Bordeaux Observatory. A written report came the next year.

In a 33 pages typed manuscript (Lacroute, 1966), he describes in details a payload, feasible with the technical capabilities of that time, which could be launched on board of a satellite. He even did not exclude to make first tests on board of a balloon at an altitude of 30 km. He presented it shortly at the IAU meeting in Prague (Lacroute, 1967a). I present here a short description of the project, essentially from the above-mentioned document, with some details taken from others of the same epoch.

The objective as stated by Lacroute was to determine the positions of a number of stars on a celestial sphere with an accuracy of 0.01 arcsecond. The method is to compare the angular distance between two stars to a constant reference angle by superposing the images of two fields separated by this angle. This is exactly the principle of Hipparcos.

Initially, he envisaged a pentagon shaped prism with a glued triangular prism with an angle of 22.5° which would concentrate rays from two fields whose axes are separated by 90° (Fig. 1) on a single telescope. He studied the thermal deformations of such prisms and concluded that one should not use a single bloc prism, but a series of thin prisms separated by intervals through which the direct light penetrates, a solution that avoids the secondary triangular prism.

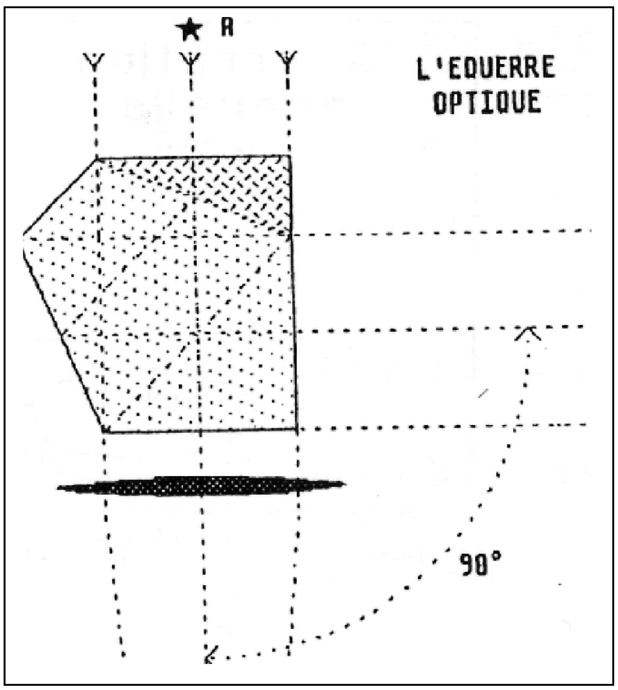

Figure 1: Shape of the block prism in the plane of the two optical axos

While the satellite is rotating the star images are drifting in the focal plane of the telescope and are analysed photo-electrically through a grid analogous to the one described by P. Bacchus (1959). There were two photo-multipliers, each devoted to the observation of one of the images. Lacroute considered a grid extending over 30' along track and 15' in height, with a step of 2" (1" transparent, 1" black). With the proposed focal length of 2 metres, the size is 36x18 mm. In order to avoid the effect of other stars, he proposed two moving diaphragms of a few arc minutes aperture around each image, whose size depended on the accuracy of the attitude control. This was a materialised version of the image dissector.

In order to get the expected precision, P. Lacroute considers that one should have at least 10 counts for each slit, which still would limit the magnitude to 7. This has also consequences on the rate of rotation of the satellite, and Lacroute analysed this problem at length with a goal of reaching a final accuracy of 0.01 arc seconds.

A year later, in November 1967, P. Lacroute presented his project to the French space agency (CNES).

Analysis of the project by CNES

The document presented to CNES differs from the initial ideas, essentially by proposing another concept of the complex mirror. The light does not any more enter a prism, but is reflected by a set of 16 mirrors, making alternatively 22.5° angles with respect to a median plane (fig2). In later proposals, these will be

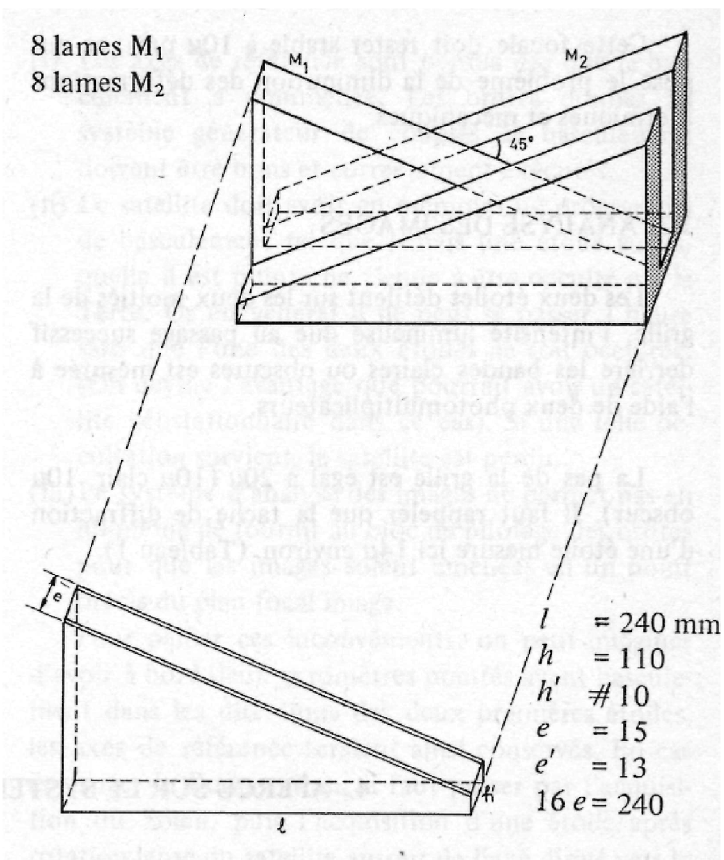

Figure 2 Multiple prism in the proposal of CNES (Husson, 1975)

reduced to three: a wide one and two thinner ones in both sides so as to give images centred in the same plane. The remaining features were not modified. After some time, in 1969, CNES decided to make a technical feasibility study of the Lacroute project while its Scientific Committee appointed a working group of a dozen of French astronomers, chaired by J. Kovalevsky, in order to assess the scientific interest of the project.

The latter compared what can be expected from ground-based astrometry in the future, taking into account the atmospheric and instrumental limitations of the meridian circles and astrolabes. It concluded that it was highly unlikely that it could reach an accuracy of 0.05 arc seconds for a global reference system.

The group presented its conclusions in May 1970. It was of the opinion that a space programme is worthwhile only if it provides a very significant improvement to the present situation. So, the conclusion was that the scientific interest of the experiment is fundamental if a 0.”01 is achieved for a reference sphere defined by at least 1500 stars. This statement was no more strong if the accuracy is 0.”02. Would it be only 0.”03 or, if there were much less observed stars, the group gave a negative opinion.

The technical assessment by CNES was described in the Frascati symposium by J.-Cl. Husson (1975). It concluded that the critical points were the stability of the optics and the difficulty to build the complex mirror, especially taking into account the vibration problems at launch. The study could not prove that even a 0.1 arc second precision could be achieved and it concluded that such a mission should be on board of an automatic space vehicle.

Actually, CNES stopped the study at this point. The alleged reason was that the policy of the Agency changed and that it will not pursue any purely french scientific mission, but support European programmes.

Towards a proposal to ESRO

This decision did not stop Lacroute to publicising his ideas. At the IAU General Assembly in Brighton, he described his project and even obtained a positive recommendation in its favour (IAU, 1971). But, in the same time, Lacroute and Bacchus continued to improve the project with the goal to present it to ESRO. So, during the years 1971-74, they studied how to design a better instrument and how to adapt it to existing types of satellites with three-axial stabilisation. Only two were available: Spacelab used as a platform, and TD1, the first ESRO astronomical satellite, launched in 1972 for UV, X ray and γ ray observations (TD for Thor Delta launcher).

The state of the art in 1973 for the TD1 version was presented at the Perth IAU Symposium 61 on "New Problems in Astrometry" (Bacchus and Lacroute, 1974). The interesting point is the description of the grid formed by three ensembles separated by 1° and consisting of a vertical and two inclined by 45° segments. Each segment consists of 20 one-arcsecond slits (Fig.3).

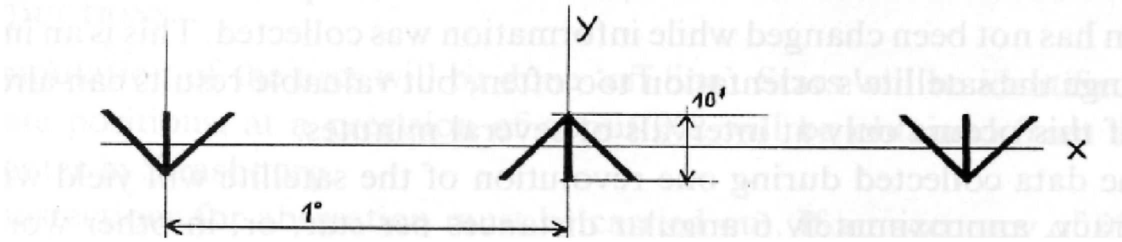

Figure 3 Shape of the system of slits presented in Perth (Bacchus and Lacroute, 1974)

In parallel, Bacchus and Lacroute studied the "Spacelab" version, which allowed observing fainter stars, but did not allow for enough observing time unless it is embarked in many successive launches. One may note that this concept is retained for the US SIM project, which is still not approved.

In November 1973, Lacroute and a group of astronomers sent to ESRO a "Proposal of an Experiment in Space Astrometry" at a time when there were meetings of the ESRO Astronomy and Solar System Working Groups in Frascati. I was there as a member of the latter. The date at which the Lacroute was received by ESRO was too late, so that it was not part of the projects discussed by the Working Groups. Each of them selected six projects for a "Mission definition study". I presented the Lacroute project to the Solar System working group, but the reaction was that the subject did not fit in the domain of the working group. But I was invited to present it at the plenary meeting of both working groups which found it interesting and suggested that it be added to the twelve already recommended

ESRO took notice of this suggestion but, before going further, it wanted to ascertain that such a mission would interest a sufficiently important scientific community. For this reason, it convened a Symposium on Space Astrometry in Frascati. It was held on 22-23 October 1974 and gathered 41 participants from Europe and the United States. The project was presented by Lacroute (1975), and by Bacchus (1975a, b). The reaction was very positive, and ESRO decided to go along studying the project.

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