Contribution to the history of astrometry No. 2

Lennart Lindegren's first years with Hipparcos

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***ABSTRACT**: Lennart Lindegren has played a crucial role in the Hipparcos project ever since he entered the scene of space astrometry in September 1976. This is an account of what I saw during Lennart's first years in astrometry after I met him in 1973 when he was a young student in Lund.*

A new era of my life began on 1 September 1973 when I returned to Denmark with my family of five, after 15 years in Hamburg. I had obtained a tenure at the Copenhagen University where I was going to work on the construction of automatic control of the meridian circle in Brorfelde. Very soon, however, I heard of a young student at Lund Observatory who worked alone on modernizing the old meridian circle there. I went to Lund and "found" Lennart. A few years later, Andrew Murray, my old colleague and member of the Hipparcos science team, would say: "Erik, the best you have ever done for astronomy was to find Lennart!" and I agreed.

At my visit in the autumn of 1973, Lennart showed all he had done on the mechanics, the chronograph etc. I was impressed, but very curious about his intentions. He explained that he had been attracted by the fine mechanics of the old instrument, but he knew well that he could not make it operational without a large funding, which he did not aim for.

I offered two subjects for a thesis which he wanted to think about. He visited me in Brorfelde some time later and had made his choice: The Glass Meridian Circle, a new type of horizontal meridian circle which I had proposed several years earlier. But that subject had just been taken by a Danish student. Lennart then immediately chose the second proposal: Data analysis of astrometric observations of the major planets made with the photoelectric meridian circle in Perth. He made a brilliant analysis where he, e.g., took physical limb darkening into account, not only the classical

geometric darkening. Nobody had done that before, and he used available satellite observations of the planets to get the most correct darkening.

By the time he had finished that work, time was ripe to introduce him to the astrometric satellite project which then consisted of two concepts or proposals: Option A and Option B (see Høg 2008). I called a meeting in Copenhagen on 22 September 1976 with Lennart, a Danish student, and a colleague where I explained the project and especially the challenging task of data analysis. I wanted a student to propose methods especially related to Option A, to derive the astrometric parameters from one-dimensional observations with the satellite operating in revolving scanning mode, i.e. with the spin axis at a constant angle from the sun direction and moving around the sun. I had proposed such scanning in December 1975, but I did not know whether the observations would at all produce a rigid coordinate system nor whether the computations could be accomplished with computers of the time.

In the two hour meeting the Danish student repeatedly said that it was a too big task for him. Lennart only asked two or three questions and made no comments, but the meeting started an intensive correspondence between us two. Four weeks later I received a letter and a nicely typed report. On 9 pages (Lindegren 1976a) he gives the mathematical description of the "three-step procedure" for Option A which later became the fundamental method used by both Hipparcos data reduction consortia. It broke down the enormous system of least-squares equations to smaller systems that could be solved with an acceptable computational effort. He gives the variances of the five parameters and the coefficients of correlation between them. He finds much higher variances for some of the parameters than in the previous ESA study report. He has found a very good resolution for all five parameters with revolving scanning for the whole sky in this mode.

Two weeks thereafter came a report (Lindegren 1976b) of 8 pages with more complete results of the first simulated observations with one-dimensional scanning and a revolving spin axis. It included tables and plots showing the accuracies of the five parameters as function of ecliptic latitude and longitude.

This pace of meticulous and crucial reports coming from Lennart's hand has been maintained ever since. He once said: "If a problem can be stated mathematically it is simple to solve." This could be construed as immodesty,

but everybody knowing Lennart, will say that for him it is simply true. I do not recall any error of mathematics has been found in his reports, or for that matter any other kind of error; nor any other sign of immodesty.

ESA has a system of advisory groups, one of them is Astronomy Working Group (AWG). I had become a member of this group in December 1975, just after I had made my TYCHO mission proposal, later named Option A, and the working group had altered its name from *Astrophysical* Working Group in order to accommodate, for the first time, an astrometrist in this group otherwise solely astrophysicists. On 9 December the AWG had to select members for a Space Astrometry Team (SPT) to follow the coming feasibility study. Many had applied to become member of this astrometry team, and that was of course very good so that a real selection could be made.

At some moment there were still too many candidates for the team, and the discussion was about including Lennart or not. I had urged Lennart to apply and in AWG I argued strongly for his membership pointing, e.g., at his recent reports about the data analysis and saying that it might be crucial for the success of the entire study to include him. A person (probably Niels Lund from Copenhagen) then injected: “Lund Observatory is so close to Copenhagen that you might be able to collaborate with Lindegren even if he is not in the astrometry team.” I answered: “OK, if there is only room for one of us in the team, it must be Lennart Lindegren.”

A team of seven astronomers was thus selected. It included Pierre Lacroute, although a leading member of the AWG had previously questioned the usefulness hereof, but this matter was not brought up at the meeting. Of course, Lacroute deserved to be able to follow the project study closely. We owe him so much as the originator of space astrometry and as the never doubting believer in its future.

When the meetings of the Space Astrometry Team began we noticed that Lennart never said anything, except when asked, and that he then gave his opinion, often quite brief, but always clear and well spoken, while everyone would listen. He took notes in a protocol, and does so even today although he now brings also a laptop. Historians of astronomy will once appreciate his clear hand when they have to read these protocols; there must be dozens.

Of his numerous papers I will only mention two. He wrote a paper on "Photoelectric astrometry" (Lindegren 1978), a subject I had proposed, where he systematically discussed the performance of methods for precise image location from observations. It remains a classical paper. The second paper to mention is about the rigidity of the celestial coordinate system obtained by the one-dimensional observations in a scanning satellite as TYCHO/Option A/Hipparcos. The question was asked in 1976 as mentioned above, but it took years before we had the answer which was affirmative as given by Høyer et al. (1981). The study was lead by Lennart and contains his brilliant mathematical analysis of the simulations, but he modestly left the position as first author to another person.

More information about the scientific environment in which Lennart played a crucial role is given in a recent report (Høg 2008) on the development of photoelectric astrometry including the Hipparcos mission.

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