FAME PIPELINE / SIMULATOR REVIEW REPORT

V.V. Makarov

USNO, February 13, 2001

Abstract

V. Makarov was assigned the task of analyzing the overall startegy of the FAME pipeline, locating the bottlenecks and yet unsolved problems.

There were 5 main directions of his work during the period 1 Dec 2000 – 15 Feb 2001.

1. FAME DATA PROCESSING SCHEME

A new version of the FAME data flow / processing diagram was produced. It is based on the previous schemes, but includes a number of novelties which seem important from the standpoint of a practical pipeline realisation. The new features are:

• Estimation of effective (empirical) PSFs is explicitly given as a major and critical stage of data reductions. The FAME data processing thus becomes a great loop that includes centroiding (image location estimation) and all the following steps of reductions. This was not reflected in the previous documents.

• A more viable global fit approach replaces the one-dimensional 'great-circle' reduction. This implies a conceptually simpler simultaneous solution of the system of construction equations all over the sphere and the mission time span.

• Two differently ordered observation data sets (time-sorted and object-sorted) are envisaged. This will help to split the huge design matrix into a large number of smaller matrices in a strightforward manner.

• A transit time prediction procedure is separated into a major reduction block in the scheme.

Things to do:

♣ Photometric estimation seems to be vital for the whole pipeline operation due to the need of chromaticity / magnitude instrument calibration corrections and the PSF characterization. The exact structure of the photometric data flows and their interrelations with other processes must be detailed.

♣ The data flow diagram must evolve into a workable interface document describing the contents and formats of data flows between different processes.

2. RIGIDITY OF THE GLOBAL ASTROMETRIC SOLUTION

A singular value decomposition (SVD) analysis was implemented for the idealized design matrix of the global parallax solution with the presently adopted FAME scanning law and basic angle parameters.

Results:

• It is confirmed that the global approach provides a stable well- conditioned solution for trigonometric parallaxes (Fig. 1) with respect to large-scale systematic and accidental disturbances.

• The basic angle of 84.5 deg is a good choice.

• The major threat seems to come from a periodic variation of the basic angle with a period of one spin, correlated with the Sun angle. This perturbation, if uncalibrated, produces a common shift of the parallax zero-point all over the sphere.

Things to do:

♣ Compute the propagation of in-scan centroiding errors of various wavelengths and basic angle variations into the large-scale astrometric distortions. This would be a kind of perturbation analysis of the global fit solution, in the first approximation.

♣ Compute the tolerances on the in-scan variations of the basic parameters, such as PSF centroids shifts and basic angle variations.

3. CALIBRATION OF THE FOCAL PLANE

This work has only commenced. The idea is to use a formalized representation of the medium-scale calibration parameters with, e.g., Chebyshev orthogonal polynomials, possibly with some redundancy, instead of a Hipparcos-like physical model. This formalism has the advantage of being able to to describe the maximum number of possible changes of the instrument as a set of uncorrelated free parameters, even if we cannot account their physical origin. The remaining, uncalibrated changes could be perhaps expressed numerically in terms of tolerances.

There is a hope that using orthogonal basic functions will make it possible to implement a wider SVD analysis of the design matrix, including some of the calibration parameters.

4. ESTIMATION AND STORAGE OF EMPIRICAL PSFs

A technique based on the Hermite orthogonal functions is proposed for the storage and evaluation of PSFs (Fig. 2). This gives a compact representation of the strongly asymmetric and non-Gaussian FAME PSFs.

Things to do:

♣ Use this technique for a polychromatic PSF evaluation

♣ Study on the possibility to describe certain kinds of the in-scan and cross-scan smearing by the polynomial coefficients. This would decrease the number of free PSF parameters.

5. MAXIMUM LIKELIHOOD – SIMPLEX DOWNHILL CENTROIDING EXPERIMENT

An operational ML–SD algorithm of centroiding was generated. It was tested on the monochromatic PSF at field point J, sampled into pixels.

Results:

• The ML–SD algorithm can cope with asymmetric undersampled PSFs, reaching close to the theoretical lower bound and achieving a single measurement error of 0.6 to 1.0 millipixel for a $V = 9$ mag star.

• However, even small errors in the assumed PSF cause unacceptably large pixel-phase biases, as was already found by Norbert, Dave and Rob.

Things to do:

♣ Experiments concerning sensitivity of the estimation to various sorts of errors in the assumed PSF.

♣ Study on the effect of the A/D quantization noise on the centroiding precision.

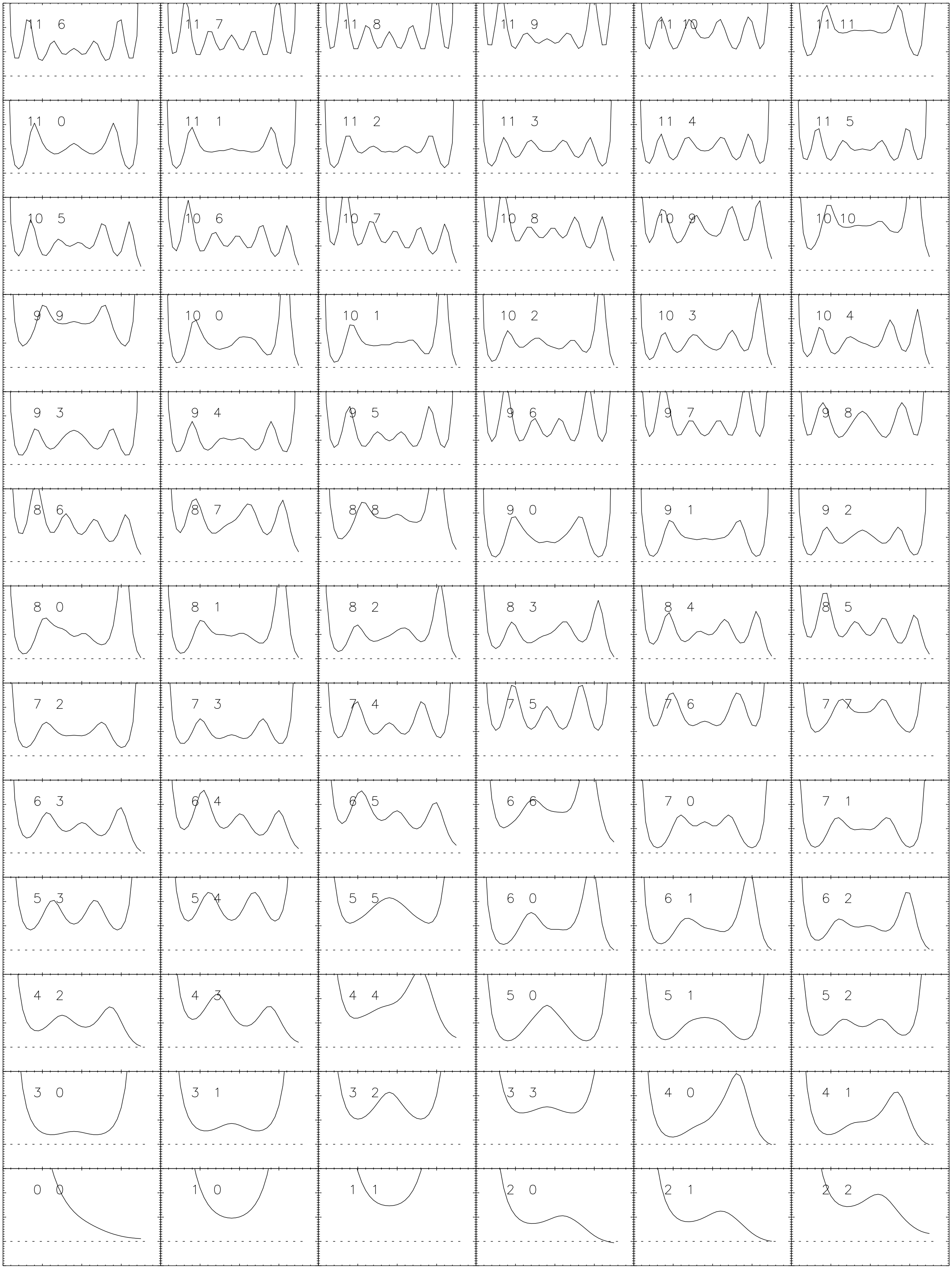

Figure 1. Power spectrum coefficients of low-order sperical harmonics of the overal parallax errors, computed with the FAME basic parameters, as functions of basic angle. The range of each plot is 0 deg *to* 180 deg *horizontally and 0 to 4 vertically. The indices of spherical functions are given inside each plot.*

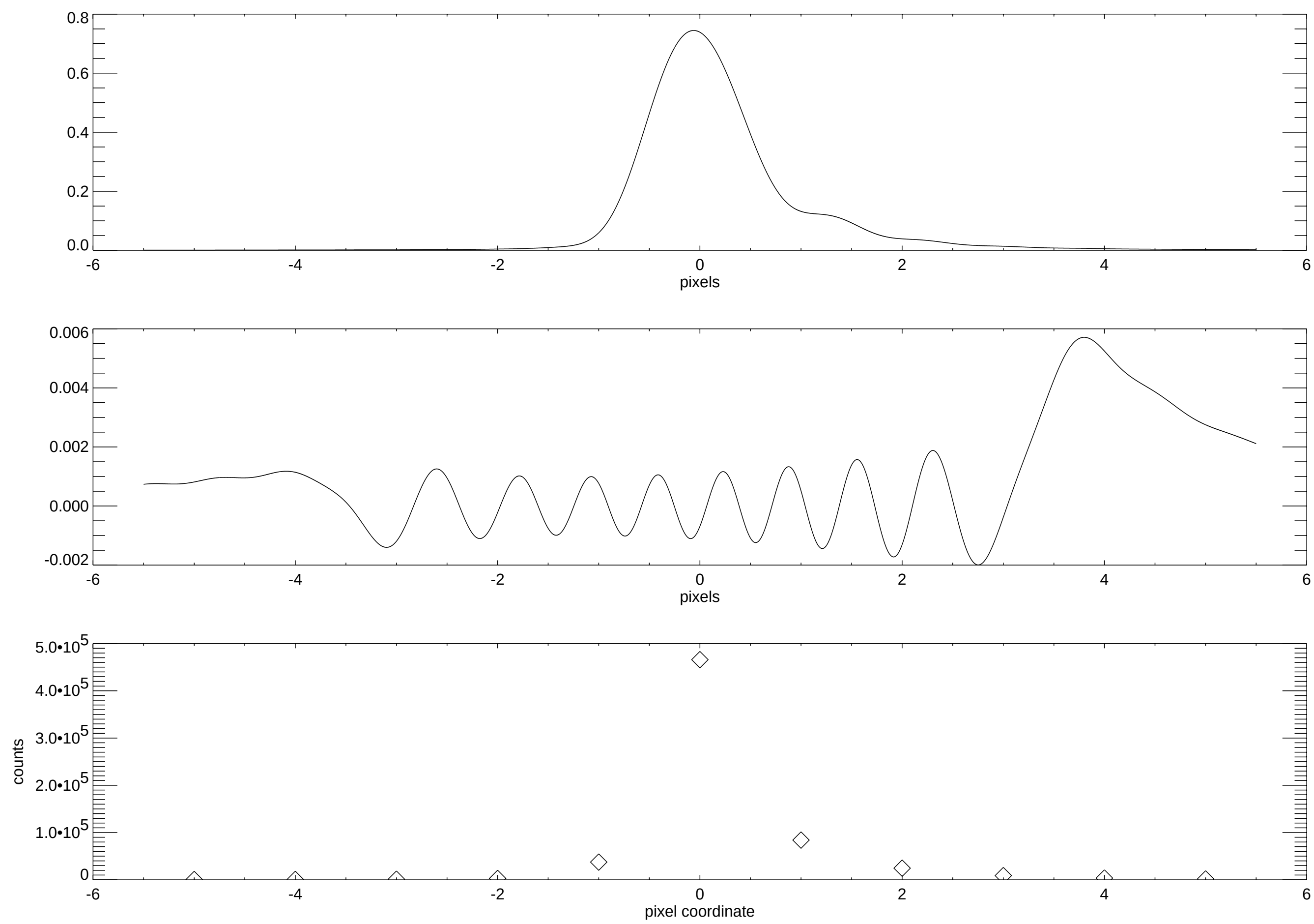

Figure 2. *Monochromatic PSF at* $\lambda = 450$ *nm for field point J, sampled into pixels 0.2 arcsec wide (top plot). The middle section shows the exploded difference between this PSF and a Hermite function fit with 17 terms. The maximum absolute difference between the fit and the PSF reaches* 0.7% *of the maximum PSF value. The bottom graph shows 'observed' pixel counts at a pixel phase of 0.*

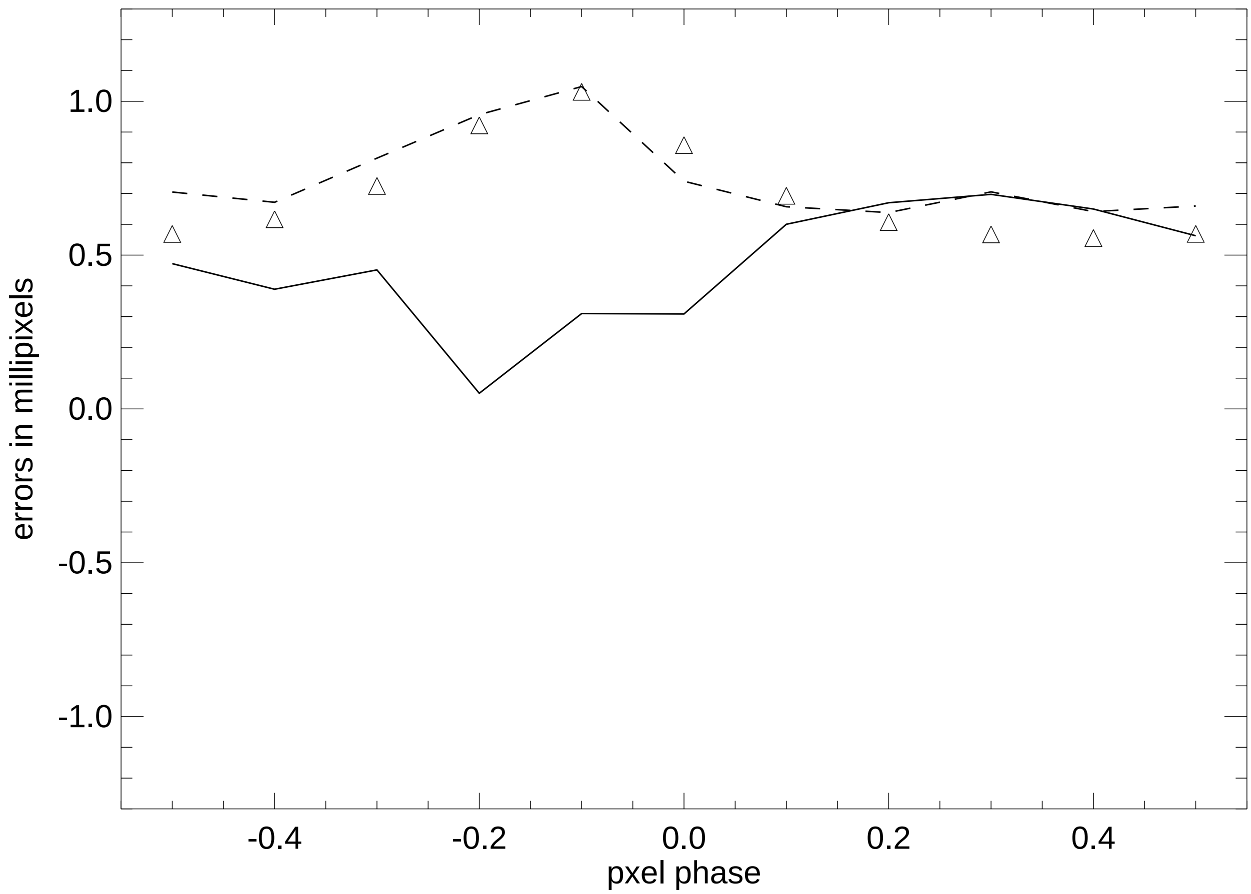

Figure 3. *Standard deviations (dashed line), bias (full line) and the Cramér-Rao lower bound (triangles) estimated by numerical simulations of a* $V = 9$ *mag star single observation. The centroiding is obtained by means of the ML-SD algorithm.*