3 Strategies of Astrometric Solution

The FAME pipeline deals with 3 basic types of unknowns:

1. Astrometric parameters
2. Instrument calibration data
3. Space craft attitude

The space craft attitude angles are the most rapidly varying parameters. Pipeline strategies depend on the way they are dealt with.

3 Strategies

- Super-Global Solution

All unknowns are solved for in one large design matrix

+ Mathematically most direct and rigorous
+ Free of propagating zonal errors
- Least transparent; does not lend itself for a Quick-Look Analysis
- Computationally demanding

3 Strategies

- Global-1D Solution

Empirical attitude angles are derived in the Quick-Look analysis of the grid stars. The rest is solved in a global design matrix

+ Free of propagating zonal errors

+ Suitable for a Quick-Look analysis

+ Computationally simpler, but takes more iterations

- Requires more pipeline algorithms development

3 Strategies

- Quasi-Hipparcos Approach

Attitude angles are derived by direct fit to observations, but no great-circle reductions and sphere reconstruction!

+ Computationally simple, but takes more iterations
+ Lends itself for a Quick-Look Analysis
- Prone to propagating zonal errors, therefore less accurate?

Space Craft Attitude Model

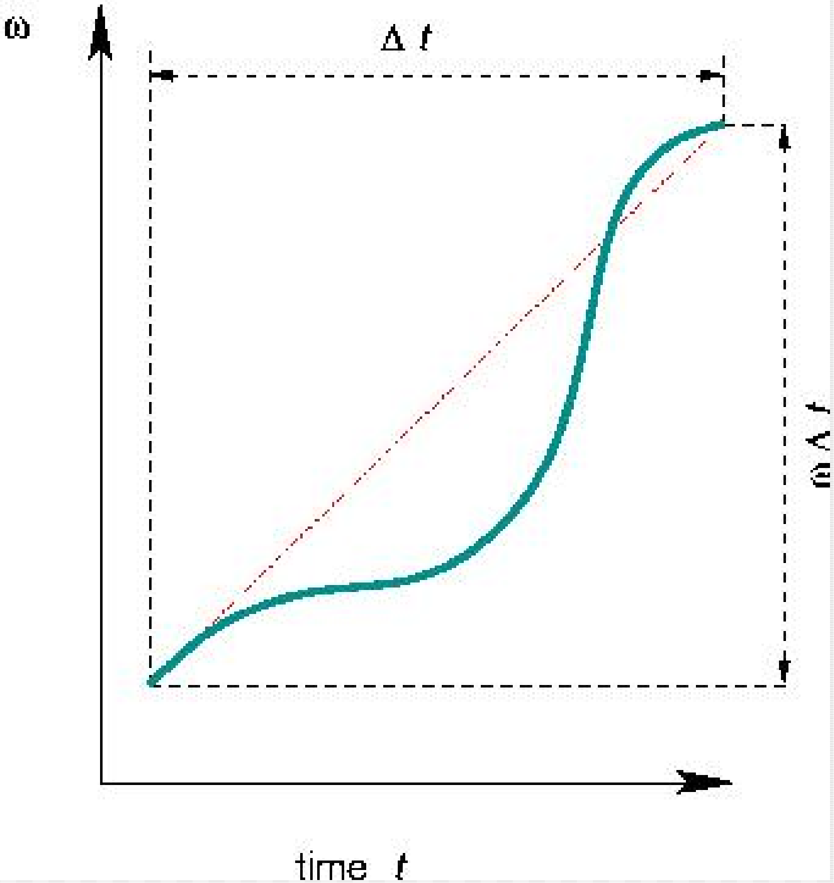
Rotation velocities about each of the optical axes of the instrument are determined strictly from observations. Fourier series are used to represent them as functions of time.

$$\omega(t) = \dot{\omega}\, t + \sum_{k=0}^{K} [c_k \cos(k\dot{\omega}\, t) + s_k \sin(k\dot{\omega}\, t)], \qquad K \leq \frac{m}{2}$$

The number of terms *K* is determined by a dynamical model of the space craft rotation. It is of utmost importance that this number is low.

Global-1D Recipe

1. Determine the average velocity of rotation from the closure conditions
2. For each spiral, construct conditional equations utilizing the basic angle closure condition
3. Solve the equations by least squares
4. Pass the model $\omega(t)$ to the Global astrometric solution



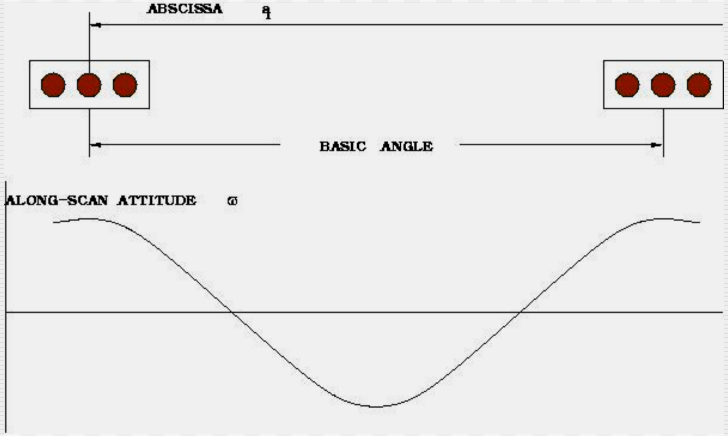
Non-Rigidity of 1D Solutions

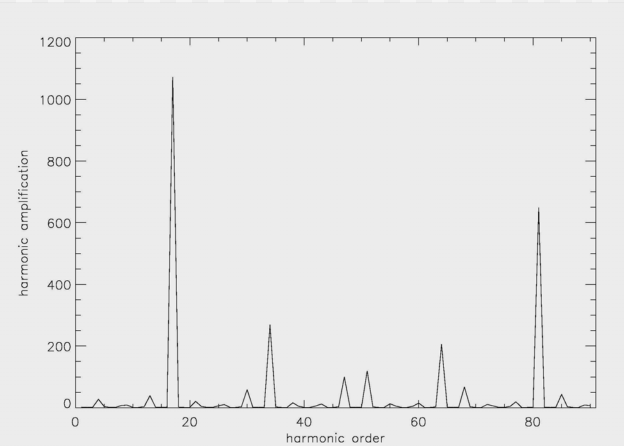
- The basic 1D equation:

$$a_i - \omega(t_i) \pm \frac{1}{2}\gamma = o_i,$$

- Star abscissae can be eliminated by the basic angle closure condition. The variance of attitude error is then

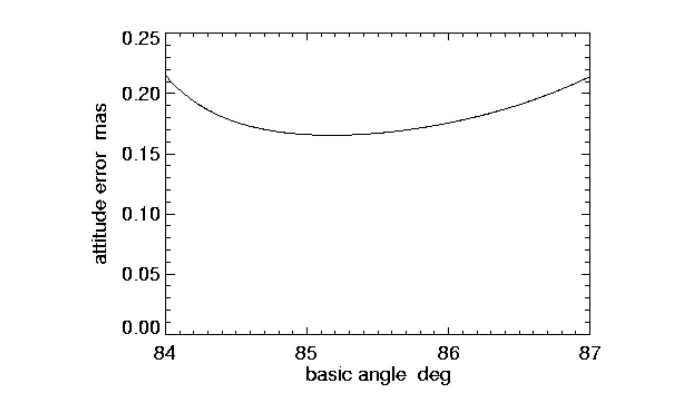
$$\sigma_\omega^2 = \frac{2\sigma_o^2}{m} \sum_{k=1}^{K} \sin^{-2} \frac{k\gamma}{2}.$$



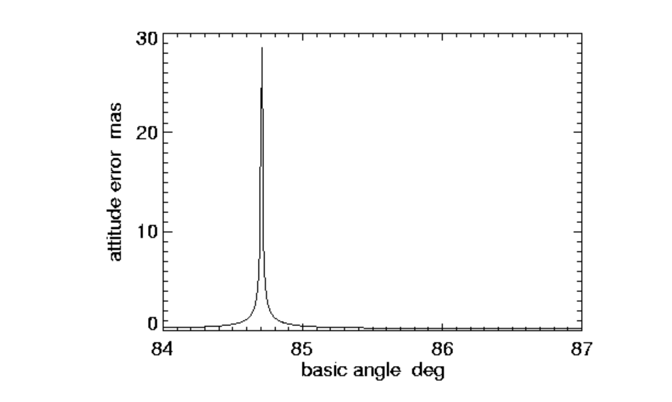


How to Choose the Right Basic Angle

The precision of along-scan attitude is very sensitive to the choice of basic angle, and to the number of non-negligible harmonics in s/c rotation.



Number of harmonics to solve for	Attitude angle error mas
20	0.60
15	0.18
6	0.11



Jitter

Higher order harmonics that are not solved for in the present model are called jitter. Their cumulative contribution to the error of attitude ω is the total spectral power:

$$\sigma^2_{\omega(\mathrm{jitter})} = \sum_{k=K+1}^{\kappa} (c_k^2 + s_k^2)$$

The cut-off order *k* approximately corresponds to the frequency 1/1.56 Hz. At higher orders the net effect of jitter is some widening of PSF. The requirement on jitter is:

The total spectral power of jitter at basic harmonics *K+1* to *k* should be less than about 0.1 mas

Global-1D Blueprint

1. Solve for attitude angles ω_x , ω_y , ω_z in Quick-Look for grid stars using closure conditions
2. Construct global condition equations with only the instrument and star parameters as unknowns, solve it iteratively by least squares
3. With the corrected instrument parameters, go to step 1 and iterate until converged
4. Re-compute the final attitude model, including attitude zero-points
5. Use the final attitude and instrument calibration to solve the regular stars one by one

Breaking the Degeneracies

- The rank of the global design matrix is deficient by approximately 6 since the differential angular measurements can not determine the zero-point of the coordinate system and its rotation
- Similarly, the 1D attitude reconstruction is not capable of providing the zero-point of attitude on each spiral
- This degeneracy can probably be bypassed by setting up global equations in a differential manner, e.g., by always coupling the nearest in time observations of two stars in the separate ports

Basic Angle Variations

- Periodic variations of the basic angle within one revolution are impossible to distinguish from oscillations of along-scan attitude angle
- Basic angle variations with <u>random phase</u> are not solvable. Their cumulative amplitude should be kept less than ~0.1 mas on the time scale of one revolution (40 min)
- Thermal basic angle variations synchronized with the relative sun direction, are solvable in the global reductions (see Hipparcos)

Quasi-Hipparcos = Spiral Reduction?

- This approach suffers from zonal systematic errors
- Zonal harmonics in the Hipparcos Catalog (~2 mas amplitude) transfer into the attitude angle
- High-frequency errors are especially dangerous with the differential global setup
- These errors are reduced by the global solution, but we don't know exactly how it works