The Global Sphere Reconstruction in the Astrometric Verification Unit

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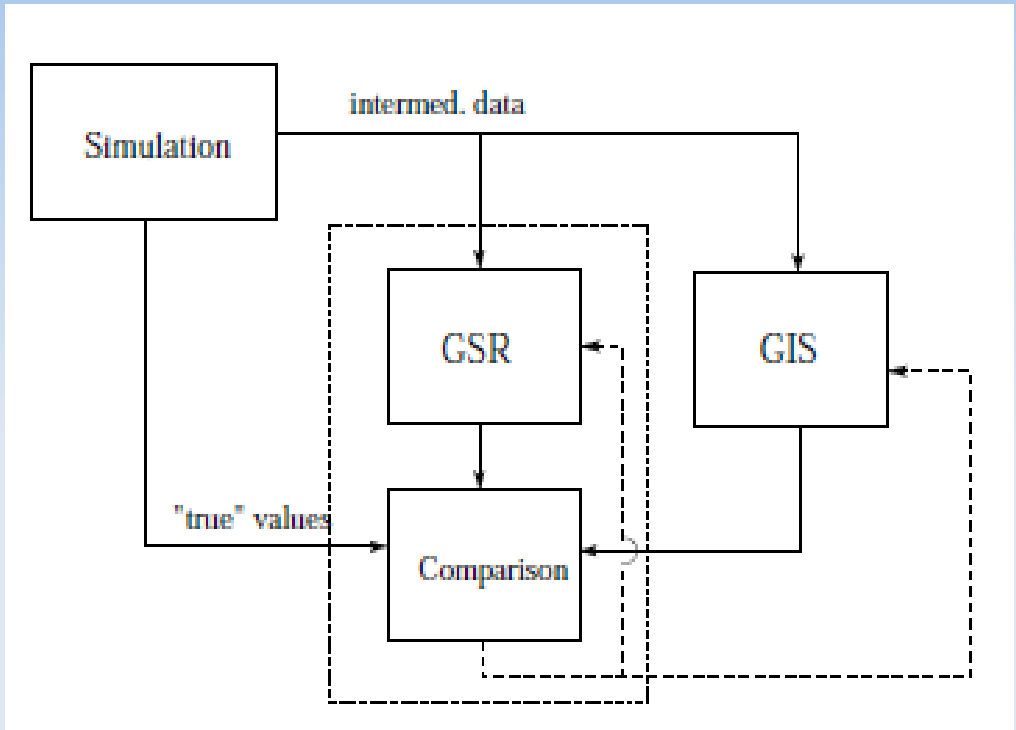
Outline

- What is AVU? What is GSR?
- Model and its ingredients
- Constants of motion
- Software design and various modules
- GSR hardware
- Summary

AVU and GSR

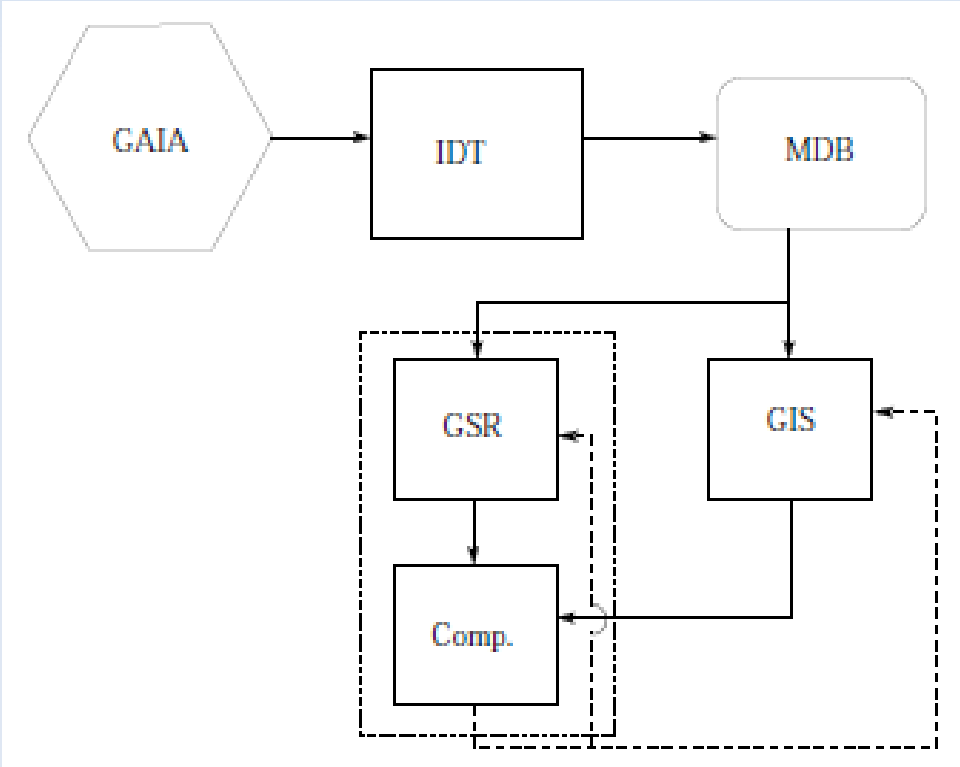
- AVU (Astrometric Verification Unit - inside CU3) will operate in the data processing areas critical to mission success.
- Independent procedures/models designed, and implemented whose results are cross-checked with those of the baseline processing pipeline.
- GSR (Global Sphere Reconstruction) is a scaled down independent version of the sphere reconstruction.
- GSR operates on a subsample of well-behaved stars.

Pre-launch and Post-launch phases



GSR pre-launch consolidation

GSR post-launch verification

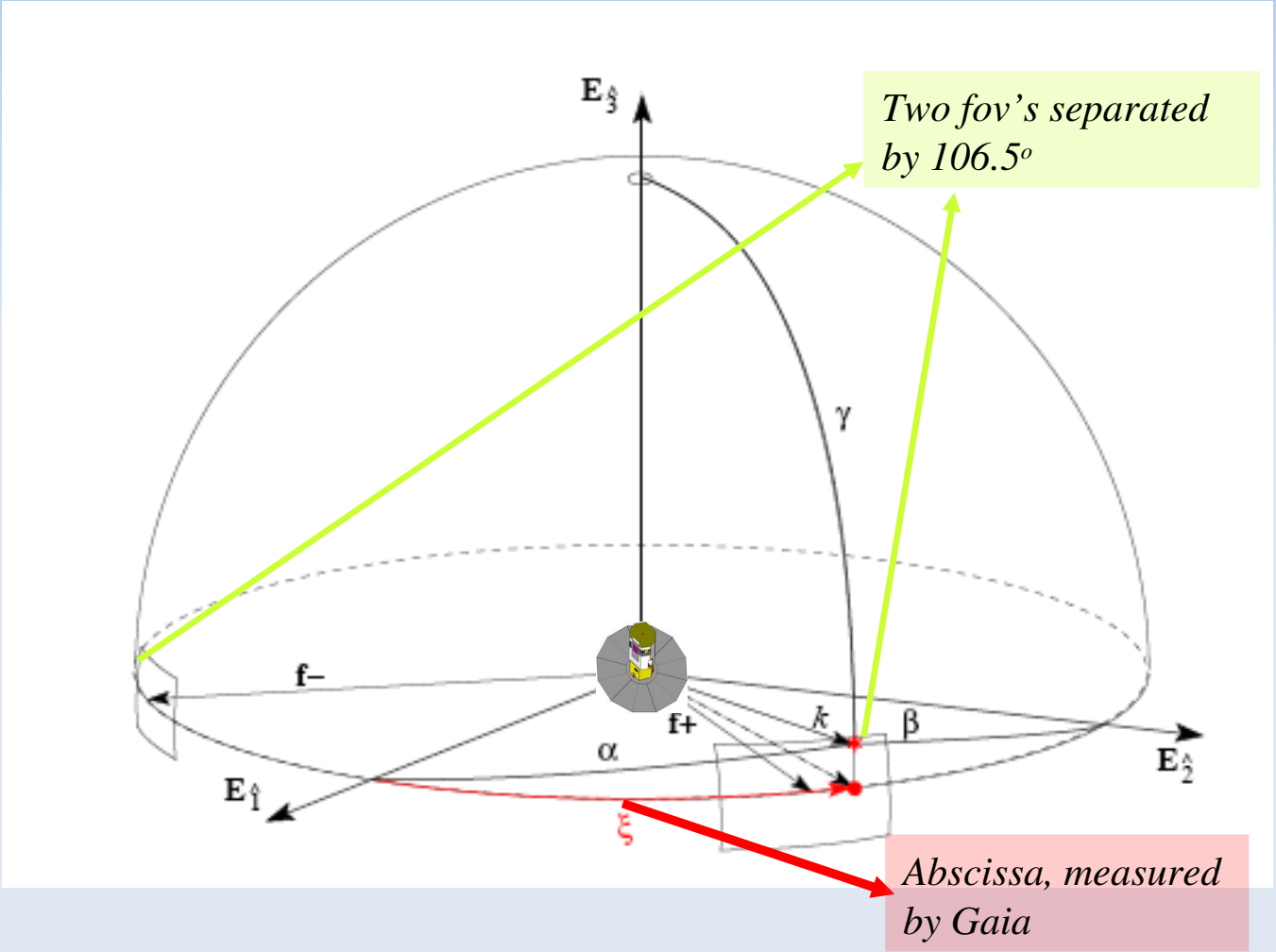


The Direction Cosines

Any direction on the celestial sphere can be identified by its direction cosines - cosα, cosβ, cos γ

or $\cos\psi_{(\bar{a},k)}$

$$\cos\xi = \frac{\cos\psi_{(1,k)}}{\sqrt{1-\cos^2\psi_{(3,k)}}}.$$

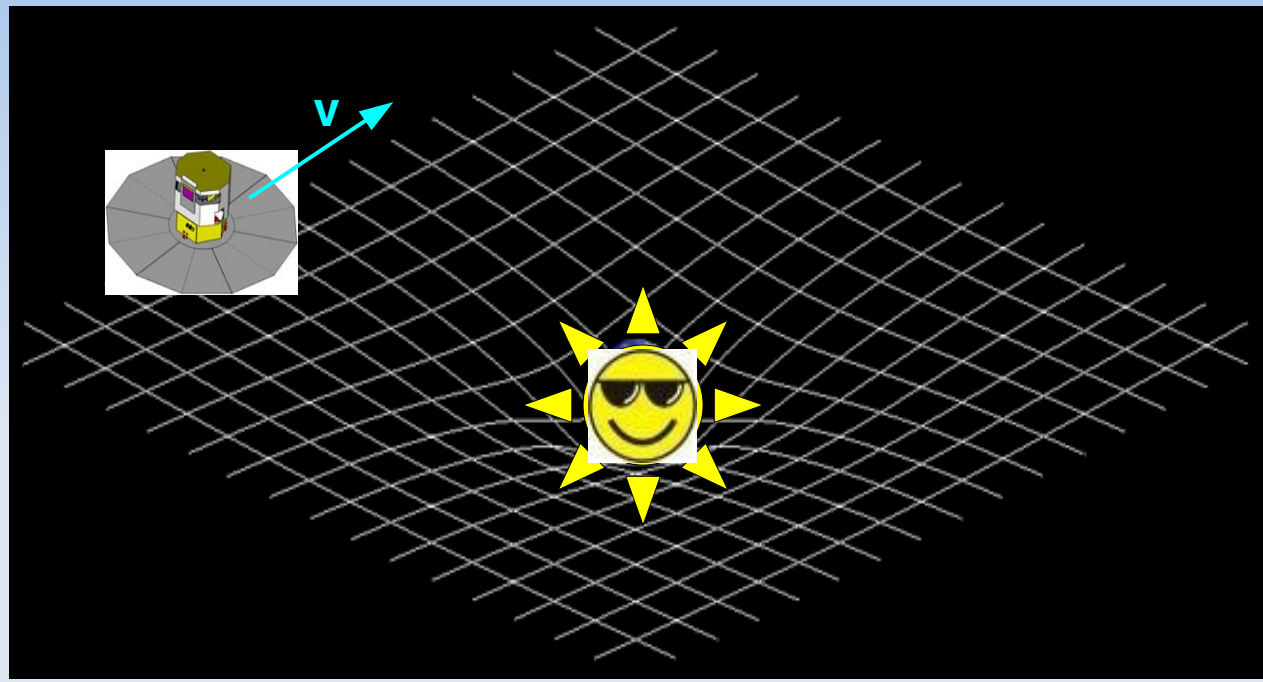


Model Ingredients - I

Direction cosine is:

$$\cos\Psi_{(\hat{a},k)} = \frac{P_{\mu\nu} E^{\mu}_{\hat{a}} k^{\nu}}{\sqrt{P_{\mu\nu} k^{\mu} k^{\nu}}}$$

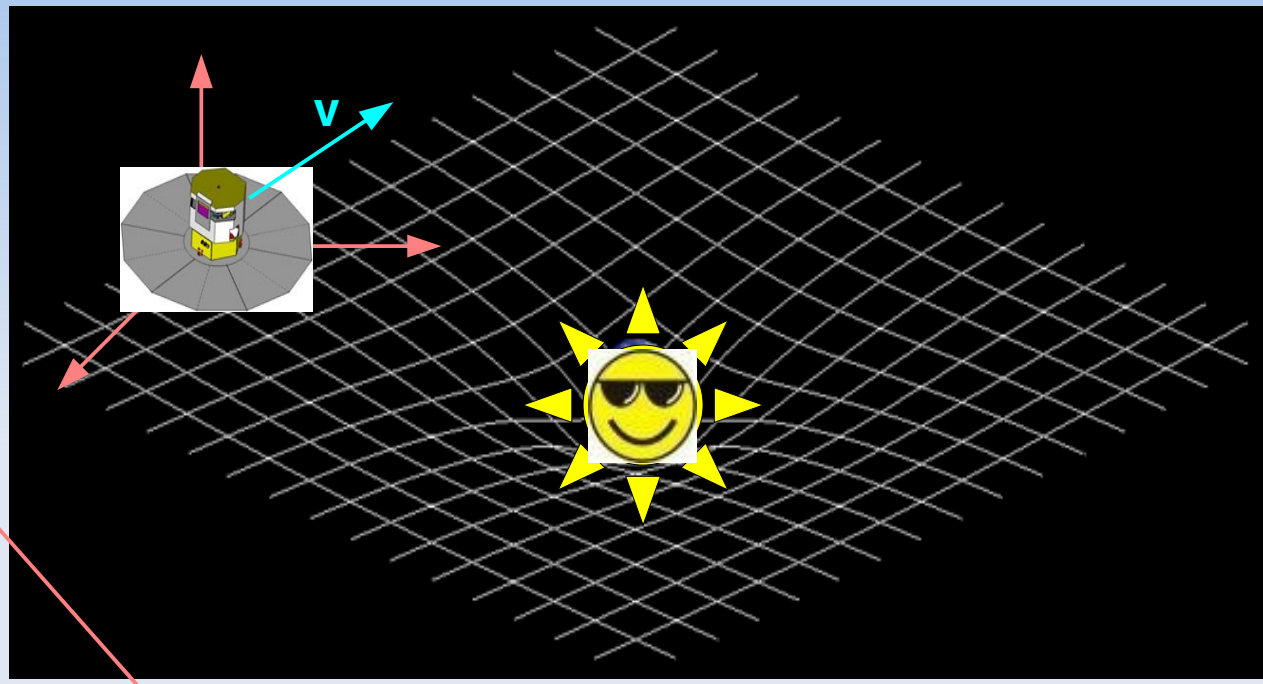
Transverse projector, depends on metric and 4-velocity of satellite



Model Ingredients - II

Direction cosine is:

$$\cos\Psi_{(\hat{a},k)} = \frac{P_{\mu\nu} E^{\mu}_{\hat{a}} k^{\nu}}{\sqrt{P_{\mu\nu} k^{\mu} k^{\nu}}}$$



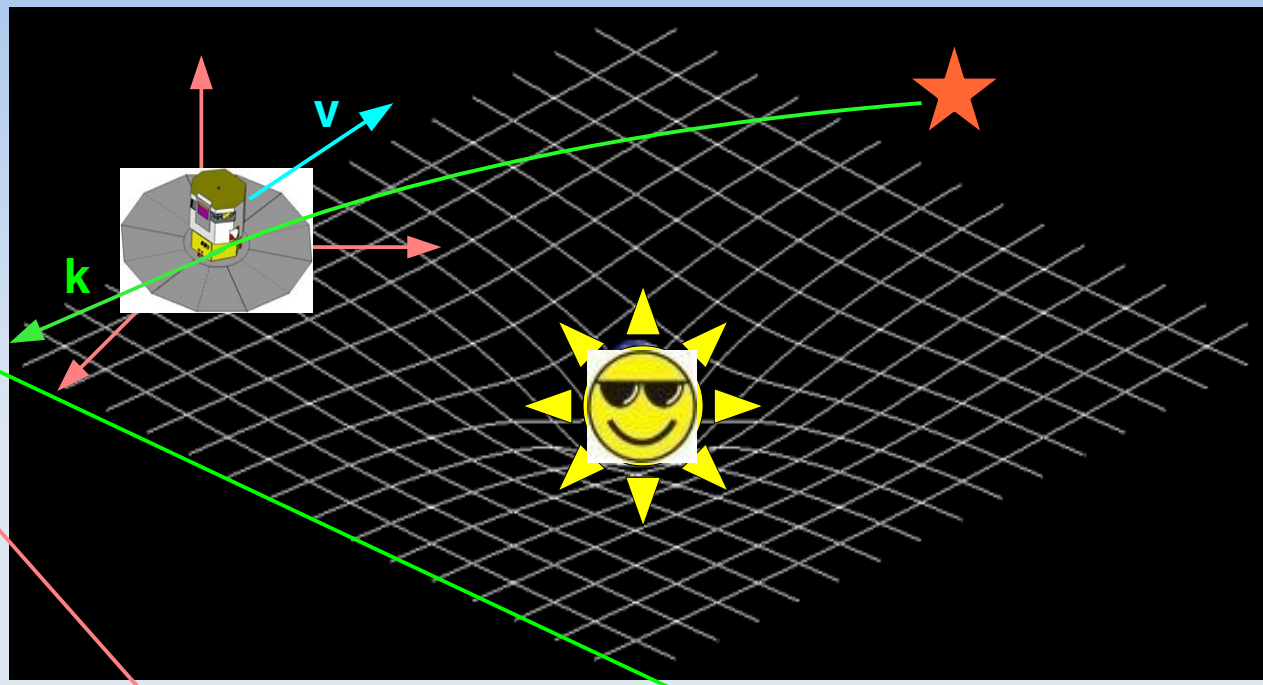
Transverse projector, depends on metric and 4-velocity of satellite

Satellite Relativistic Attitude (tetrad) Parametrized by means of Modified Rodrigues Params or quaternions.

Model Ingredients - III

Direction cosine is:

$$\cos\Psi_{(\hat{a},k)} = \frac{P_{\mu\nu}E^{\mu}_{\hat{a}}k^{\nu}}{\sqrt{P_{\mu\nu}k^{\mu}k^{\nu}}}$$



Transverse projector, depends on metric and 4-velocity of satellite

Satellite Relativistic Attitude (tetrad) Parametrized by means of Modified Rodrigues Params or quaternions.

Solution of Null geodesic of light path

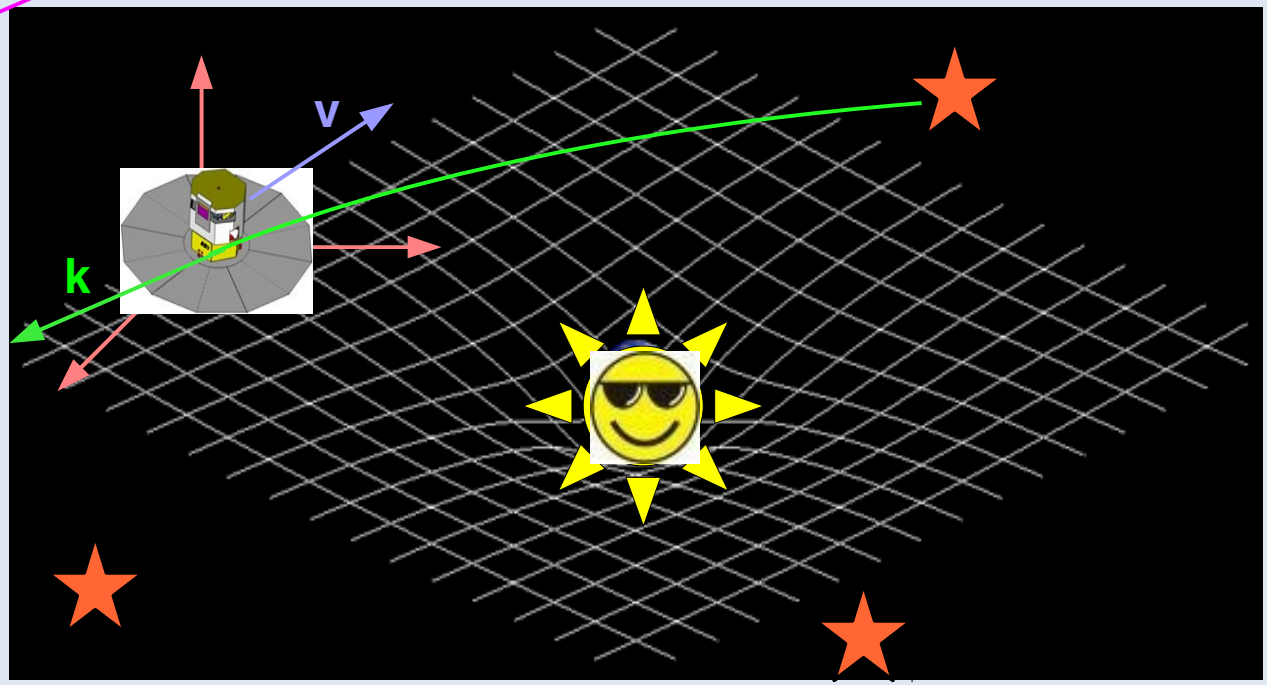
Constants of motion

Direction cosine is:

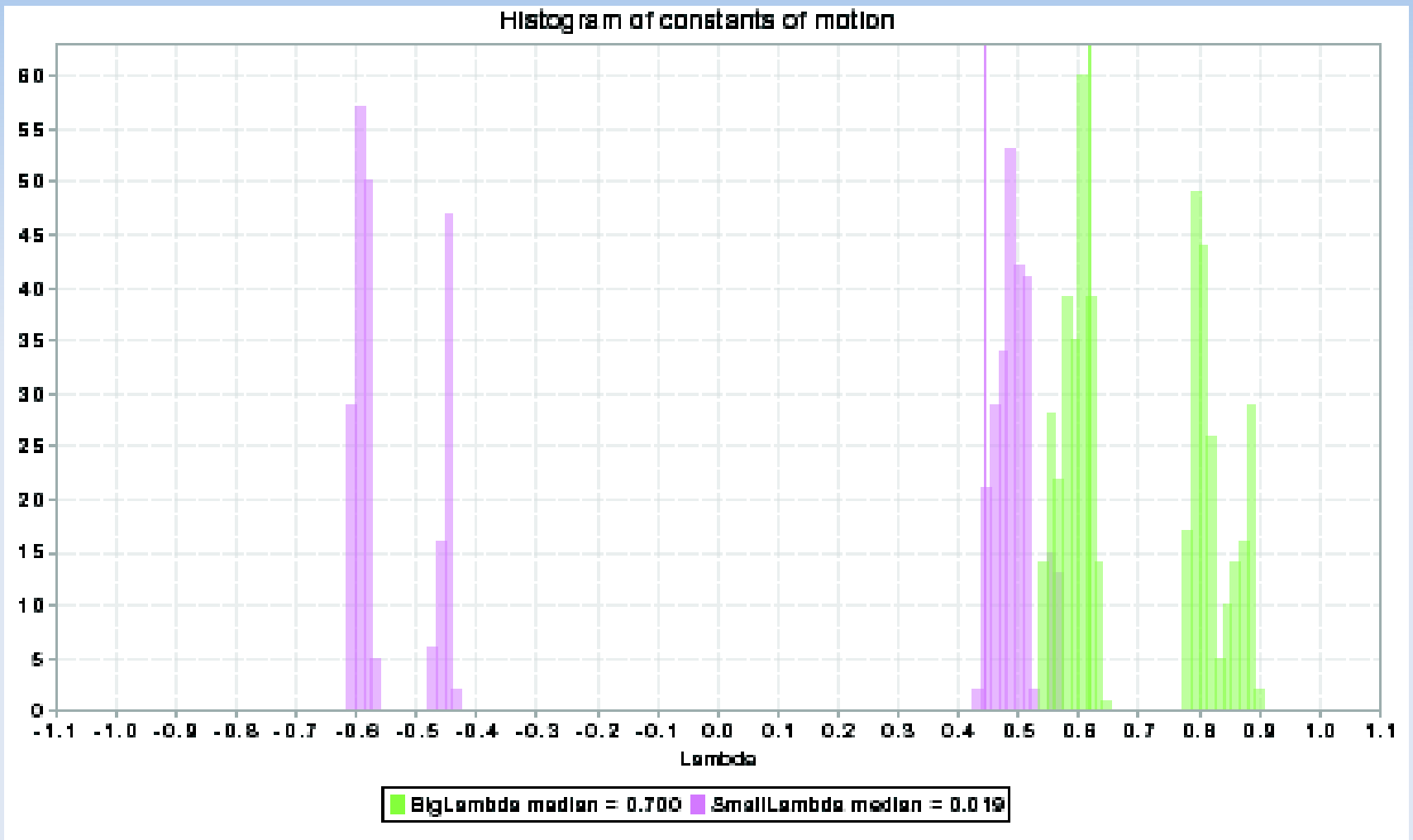
$$\cos\psi_{(\hat{a},k)} = \frac{P_{\mu\nu}E^{\mu}_{\hat{a}}k^{\nu}}{\sqrt{P_{\mu\nu}k^{\mu}k^{\nu}}} = F_{\hat{a}}(\Lambda_*, \lambda_*, \mathbf{r}_s, \mathbf{v}_s, \alpha, \omega_r(t), \omega_p(t)).$$

Constants of motion of photon, Depends on position of satellite Relative to sun and observed Object. Contain star astrometric params.

Presence or Absence of critical points

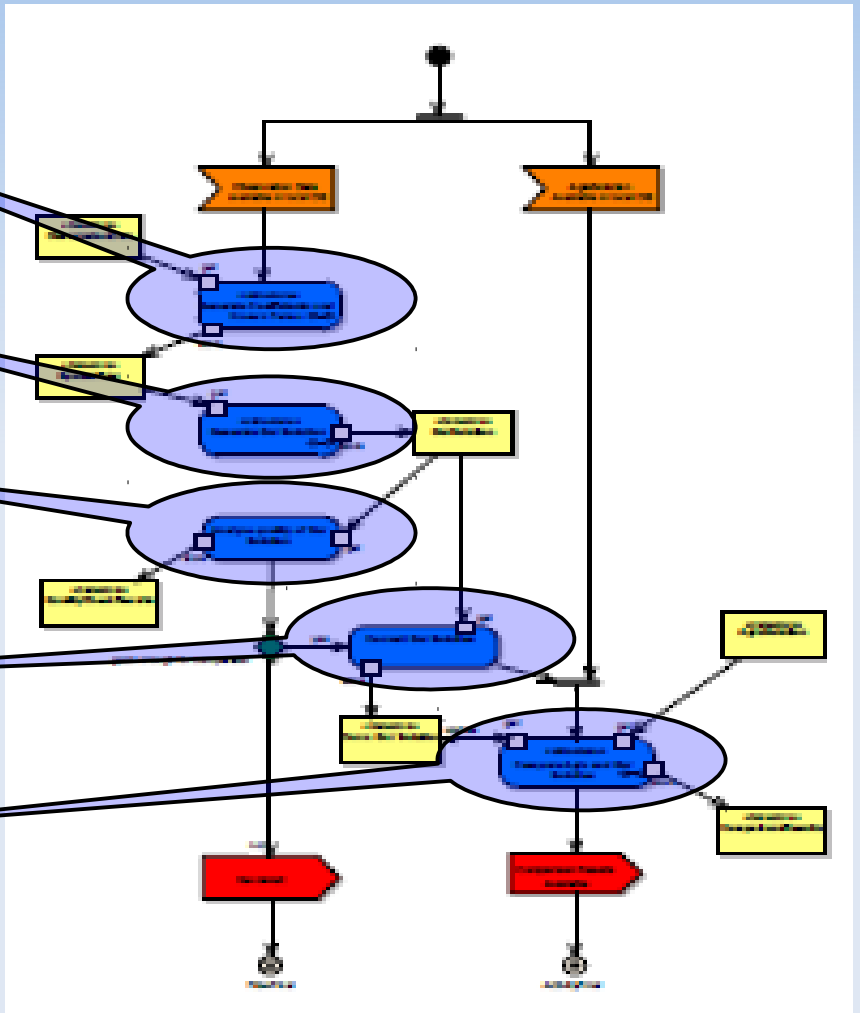


Sample histogram of constants of motion



The software modules

- Generate coefficients and known terms
- Generate solution
- Analyse quality of solution
- Convert solution
- Compare solution



Generate coefficients and known terms module

- Linearization of cos ξ

$$-\sin\xi\, d\xi = C_p\delta p_* + C_\theta\delta\theta_* + C_\phi\delta\phi_* + C_{\mu_\theta}\delta\mu_\theta + C_{\mu_\phi}\delta\mu_\phi + C_\alpha\delta\alpha + C_{\omega_r(t)}\delta(\omega_r(t)) + C_{\omega_p(t)}\delta(\omega_p(t)) + C_\gamma\delta\gamma$$

- Obtain the coefficients as partial derivatives

$$\text{e.g. } C_x = (\partial\cos\xi/\partial x)|_{x=x0}$$

- Observable from the Gaia measurements, starting values coefficient unknowns from initial Gaia catalog.

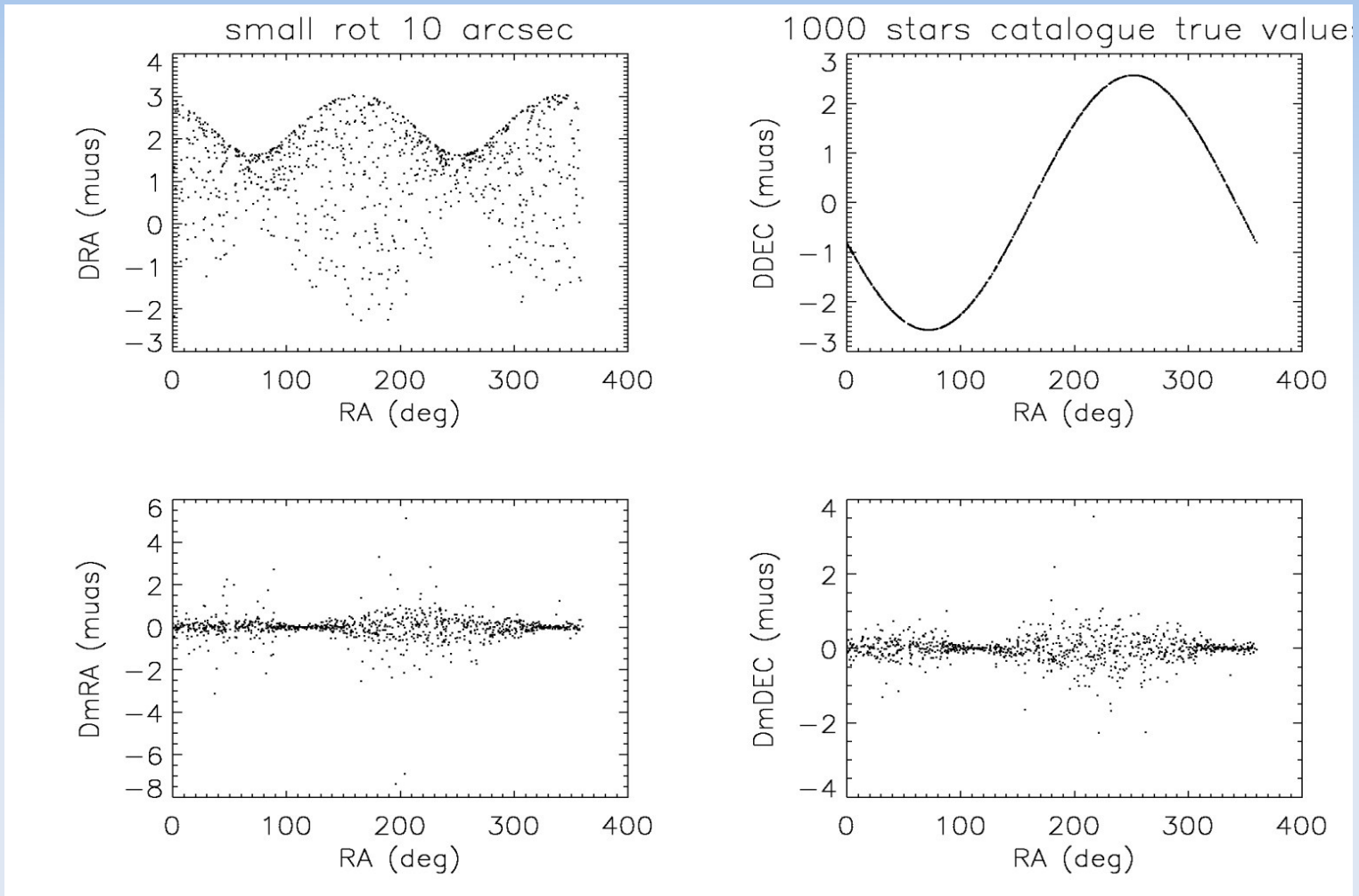
Generate solution module

- Solver based on LSQR algorithm (Paige & Saunders 1982, iterative method using conjugate gradients)
- Non-trivial parallelization => C implementation
- Usage of sockets protocol for java ↔ C intercommunication

Analyse quality, convert solution modules

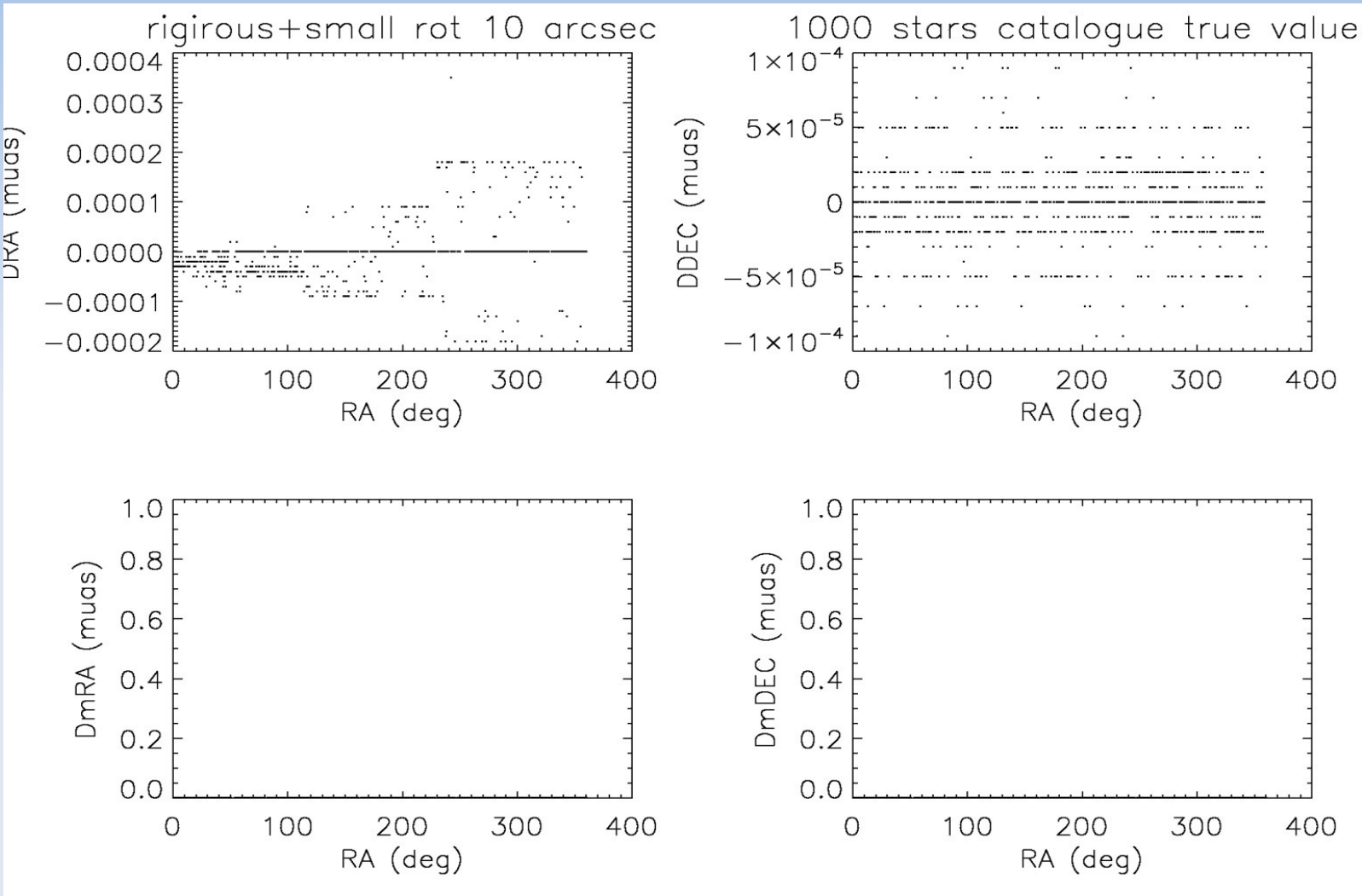
- Analyse the correct behaviour of the solution 'per se'
- Convert/de-rotate solution
  - Combination of exact and small angle approx. (Lindegren & Kovalevsky 1995)
- The two algorithms together assure the correct de-rotation without any a-priori knowledge of the rotation between the two systems within an accuracy of <0.05 μas.

Using only small angle approx.



- Residuals behaviour driven by systematics

Rigorous + small angle rotations

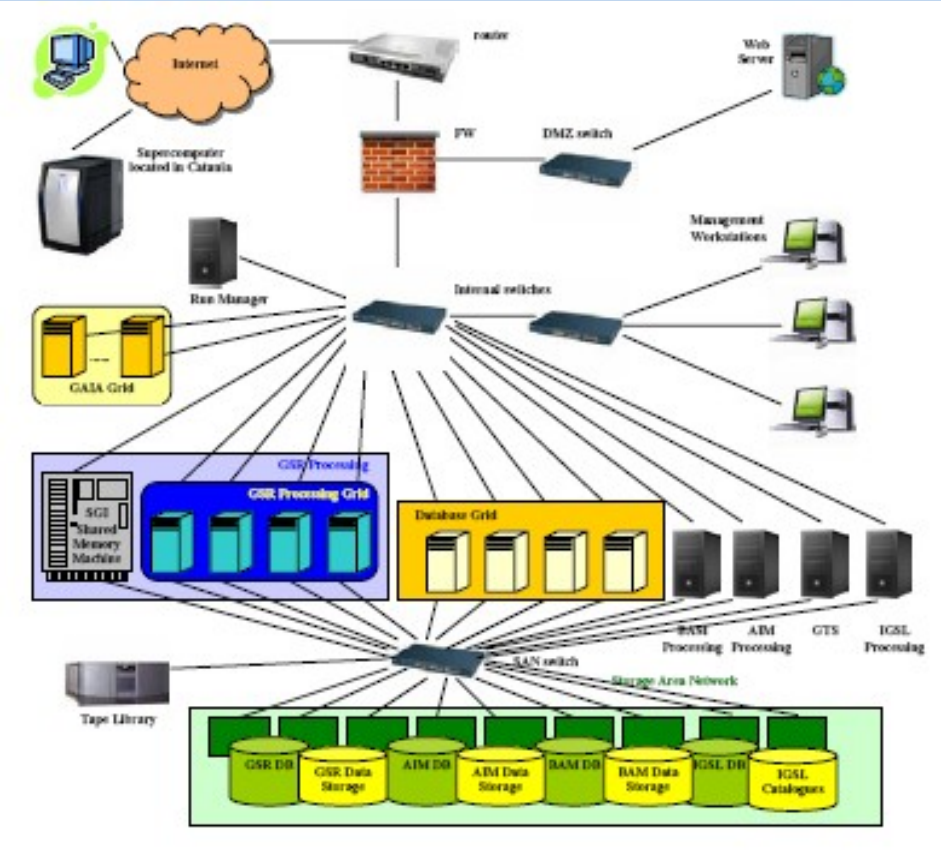


- Residuals due to numerical noise

Comparison module

- Chi-square, K-S test, IOC, spherical harmonics etc.
- Allows for studies of the systematics at different scales on the sphere.

GSR Hardware at DPCT



- Altix450 SGI 4 CPUs, 8 cores, 192GB RAM for the sphere inversion (LSQR)
- Quad-core servers, 16GB RAM, Fibre channel link, 8Gbps for database and java processing cluster
- HP EVA 4400 storage array

Summary

- GSR is a scaled down independent version of the sphere reconstruction.
- Based on an independent relativistic astrometric model (Vecchiato et al. 2003, de Felice et al. 2006) and relativistic attitude description (Bini et al. 2003, Crosta & Vecchiato 2010).
- Software design involves independent procedures for calculating the coefficients, obtaining the solution, and standard algorithms for the analysis, conversion, and comparison of the AGIS and GSR solutions.