GSR: il sistema di verifica della ricostruzione della sfera celeste

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a nome del team GSR

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L'Italia in Gaia,
Roma, 14 febbraio 2013

Outline

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The reconstruction of the Global Astrometric Sphere

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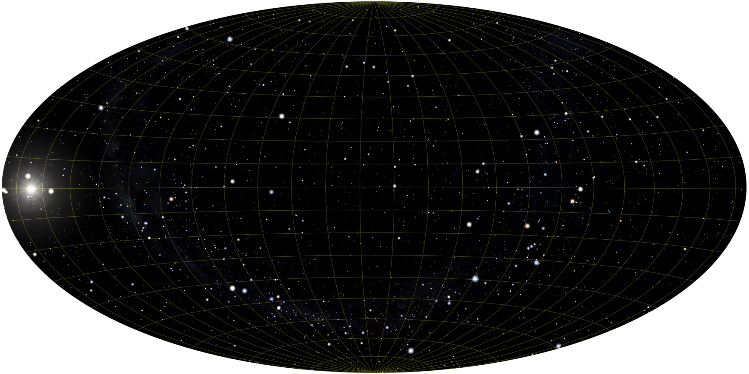
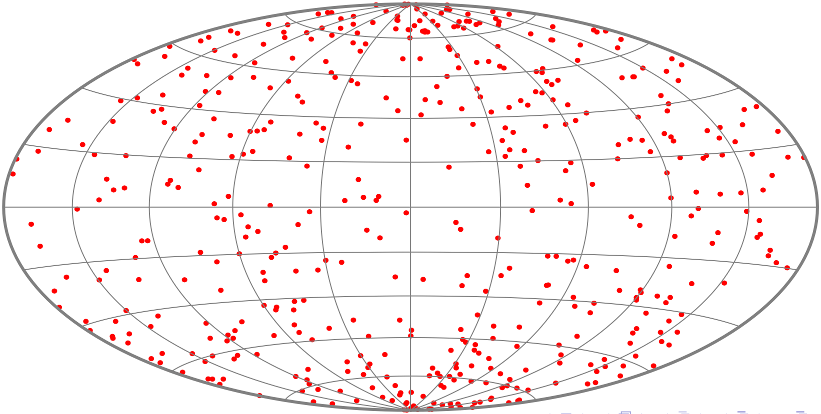


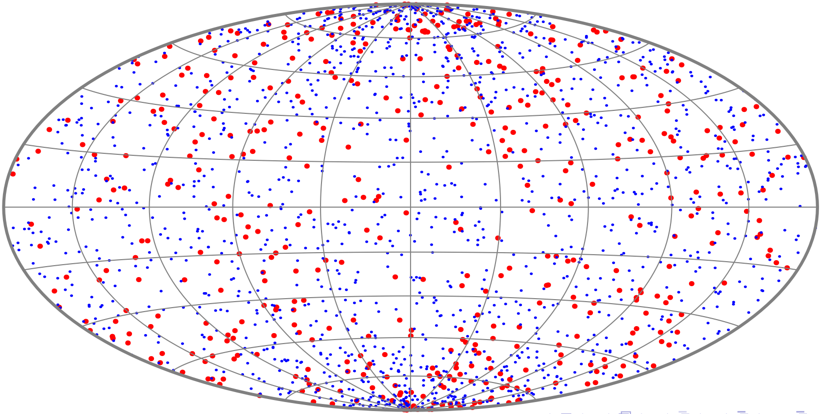
Primaries/Non-primaries

The Global Astrometric Sphere is first reconstructed with respect to a subset of well-behaved stars called primaries.



Primaries/Non-primaries

The reference frame materialized by the primaries is used by other pipeline processes to include the other stars into the Gaia sphere.



What GSR stands for

- GSR stands for Global Sphere Reconstruction (and Comparison)
- GSR's twofold goal is to provide the DPAC with an independent way of reconstructing the Global Astrometric Sphere, and to compare its solution with the AGIS one, which is run at ESAC
    - independent relativistic astrometric model
    - independent solution method for the sphere reconstruction
    - GSR depends on AGIS for the selection of the primary stars
    - AGIS depends on GSR for the comparison

AGIS vs. GSR

The AGIS and GSR reconstructions in comparison

	AGIS	**GSR**
Astrometric model	GREM	RAMOD
Solution algorithm	Block-Iterative	Iterative (LSQR)
Programming language	Java	Java + C (MPI+OMP)
Primaries' selection	YES	NO
Comparison	NO	YES
# of objects	$\gtrsim$100 million	50 to 100 million

Outline

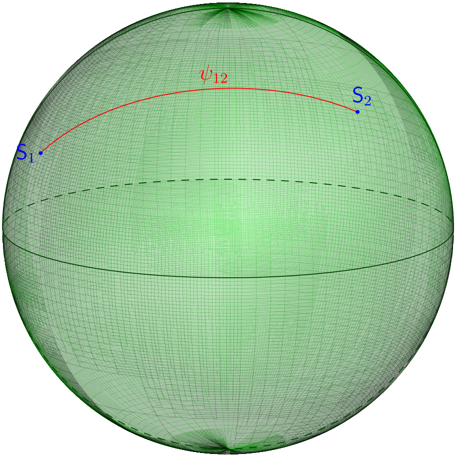
Principles of the sphere reconstruction

Create a "geodetic" network of measurements

$N_* = 2$

$N_{\text{unk}} = 4$

$N_{\text{arcs}} = 1$



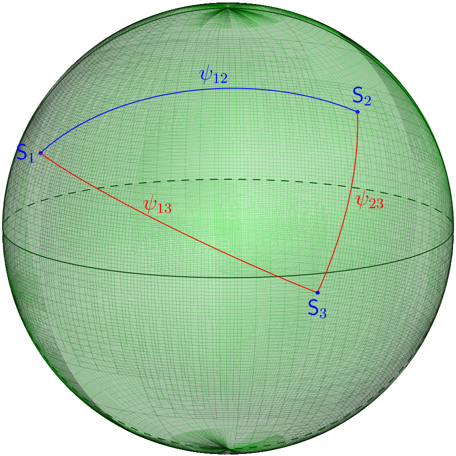
Principles of the sphere reconstruction

Create a "geodetic" network of measurements

$$N_* = 3$$

$$N_{\text{unk}} = 6$$

$$N_{\text{arcs}} = 3$$



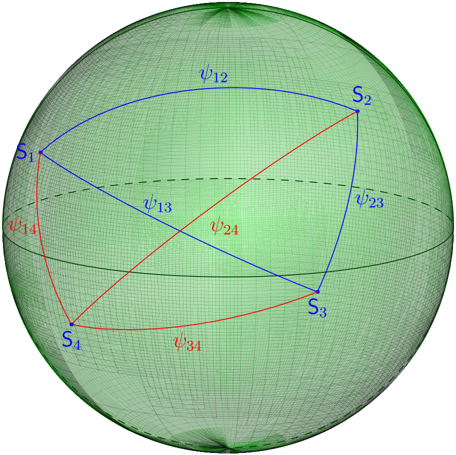
Principles of the sphere reconstruction

Create a "geodetic" network of measurements

$N_* = 4$

$N_{\text{unk}} = 8$

$N_{\text{arcs}} = 6$



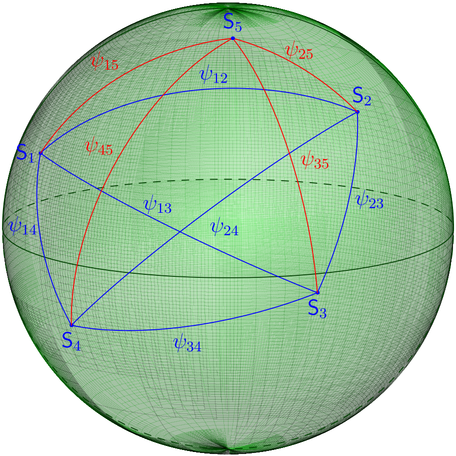
Principles of the sphere reconstruction

Create a "geodetic" network of measurements

$$N_* = 5$$

$$N_{\rm unk} = 10$$

$$N_{\rm arcs} = 10$$



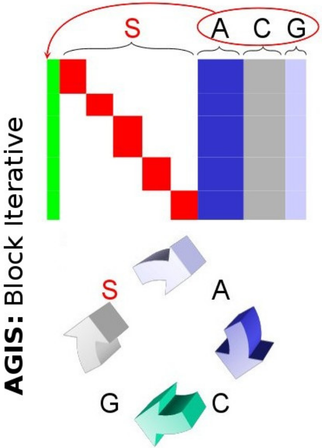
The Linearized system of equations

- In principle, each observation is a function of Astrometric, Attitude, Instrument, and Global parameters

$$\cos\psi_{(\hat{a},k)} = F_{\hat{a}}\left(\underbrace{\alpha_*, \delta_*, \pi_*, \mu_{\alpha*}, \mu_{\delta*}}_{\text{Astrometric parameters}}, \underbrace{q_1^{(a)}, q_2^{(a)}, q_3^{(a)}, q_4^{(a)}}_{\text{Attitude parameters}}, \underbrace{\gamma, \dots}_{\text{Global}}\right)$$

which is accumulated in a large (linearized) system of equations:

- dimensions: $\sim 10^{10} \times 10^{8}$
- solution approaches: AGIS and GSR



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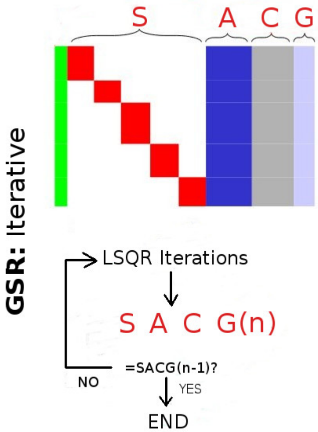
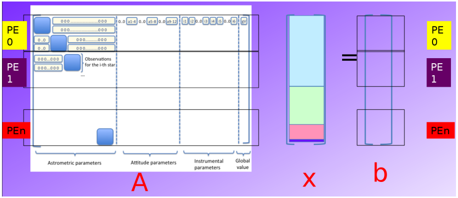


The need for HPC parallelization

- Contrary to the Block Iterative one, the Iterative approach needs “non-embarrassingly” parallel techniques
- This called for using:
  - C+MPI+OMP language for the Solver module
  - HPC-dedicated hardware



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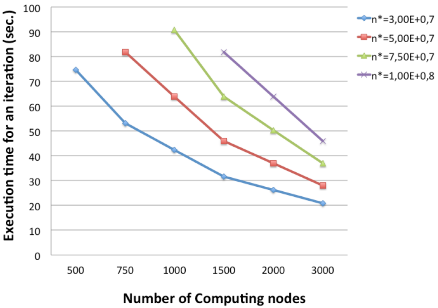
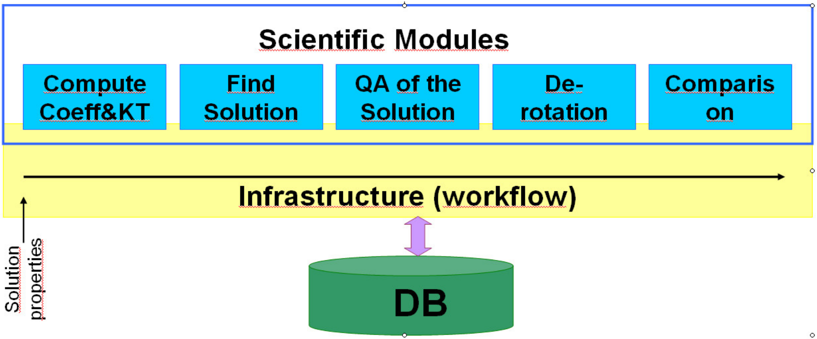


Structure of the pipeline



Outline

GSR in the mission timeline

- GSR is a cycle process (daily vs. cycle processing)
- The milestones for the GSR processing are approximately the following (L means launch time):
  - November 2014 (**L+12.5 months**) test processing of 6-8 months of validation data (Cycle 00)
  - April 2015 (**L+17.5 months**) starting of regular processing. First 12 months of operational data (approx. Cycles 00+01)
  - not sooner than September 2015 (**L+21.5 months**) reprocessing of the first 12 months of operational data (after IDU)
  - between December 2015 and February 2016 (**L+25.5 to L+27.5**) processing of the first 18 months of operational data (12 from IDU + 6 from IDT) (approx. Cycles 00+01+02)
  - from #03 on **cycles will last for 12 months**. GSR processing will then proceed accordingly.

Outline

GSR @ ALTEC

- All the scientific and infrastructure SW of GSR but the Solver module (i.e. all the "Java code") will run on the ASI-funded DPCT facilities installed at ALTEC, which will take advantage of the ALTEC infrastructure HW
- It will also be possible to run the whole pipeline for small validation spheres (up to 2 million stars) @ ALTEC
- The GSR-dedicated computing HW consists of 4 HP DL570G7, each of which is equipped with 4 Intel Xeon-class 8-cores CPUs and 256GB RAM, for a total of 128 cores and 1TB RAM

GSR @ CINECA

- The new FERMI system will be the main facility to run the parallel AVU-GSR Solver module
- CINECA will officially support the Italian participation to the GAIA mission (MoU formalization in progress)
- FERMI: IBM Blue Gene/Q FERMI, 10,240 Computing Nodes (CN) PowerA2, 1.6GHz, each with 16 cores. Totally: 163,840 computing cores (2.1 Pflops Peak, ranked 9th on Nov 2012 Top500 supercomputers). Each CN has 16Gbyte of RAM (1 GB per core)
- GSR @ FERMI: up to 2,048 computing nodes will be used to compute the system solution

Outline

1. GSR... What?
2. ... How?
3. ... When?
4. ... Where?
5. ... Why?
6. ... Who?

The importance of having an independent sphere reconstruction

- The Global Astrometric Sphere as a reference system determination (absolute measurements/parameters)
- Possible problems and pitfalls:
  - in no way the sphere reconstruction can be verified at the 10 μas-level by means of ground-based observations
  - known correlations between different unknowns (e.g. ϖ vs. BAV, ϖ vs. γ)
  - estimation of variance-covariance matrix
- Possibility of re-reducing the Astrometric Sphere at will
  - *understanding* vs. *passive acceptance* of the sphere reconstruction results
  - alternative, more efficient methods to reduce the Astrometric Sphere can be conceived
- There will only be two places in the world with the capabilities of reducing a global astrometric sphere

Scientific goals of the sphere reconstruction

- The challenge of *defining* and *solving* precise observations assembled in such a large system of equations is of huge scientific interest *per se*
  - calls for the determination of the best way to model the observations
  - helps to develop new perspectives on the reduction of global astrometric data
  - computationally intensive task (parallelization)
  - the problem of the variance-covariance matrix determination is still being investigated in the literature
- The determination of a full-sky "pseudo" inertial reference frame is a problem of fundamental physics
- An order of magnitude improvement of light deflection test for competing theories of Gravity in the PPN framework

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The (enlarged) GSR team

- The development of GSR is an 8-year-long (up to now!) scientific effort that is involving the expertise of several people in many different research fields
  - **People:** Ummi Abbas, Ugo Becciani, Luca Bianchi, Beatrice Bucciarelli, Mariateresa Crosta, Mario G. Lattanzi, Alberto Vecchiato (INAF) + Rosario Messineo, Fabio A. Mulone (ALTEC)
  - **Skills and expertise:** classical and relativistic astrometry, numerical algorithms, sparse systems of linear equations, catalog comparison, HPC parallelization, Java and C programming
  - **Scientific collaborations:** Stefano Bertone (ObsPM), Donato Bini (CNR & ICRA), Carlo Cavazzoni (CINECA), Fernando de Felice (UniPD)
- 7 INAF people, for a total of 3.3 INAF FTEs