The Gaia mission: the dawn of Astrometric Cosmology?

Status and prospects after 14 months of science operations.

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INAF – Osservatorio Astrofisico di Torino

TAUP 2015 - Turin (I) , 7 September 2015

Un update on the Gaia mission: where are we at?

- Launch on Dec 19, 2013 at 09:12:19 UTC from ESA/CNES Launch base in Kourou, French Guiana
- Extended commissioning phase formally ended on July 18, 2014 (7 months/4 months)
- Followed by approximately 1-month of science calibrations with Gaia in EPSL (spin axis not precessing at 45 deg on ecliptic) using EP special catalog
- Routine science operations started end-of-August 2014: beginning 11th month into science operations (Gaia in Nominal Scanning Law NSL)
- Decision finalized at last GST meeting (March): Gaia's survey extended to G=20.7 (i.e., ~ V=21), but not complete at this mag lim.
- Schedule for first general all-Gaia data delivery confirmed: Summer of 2016

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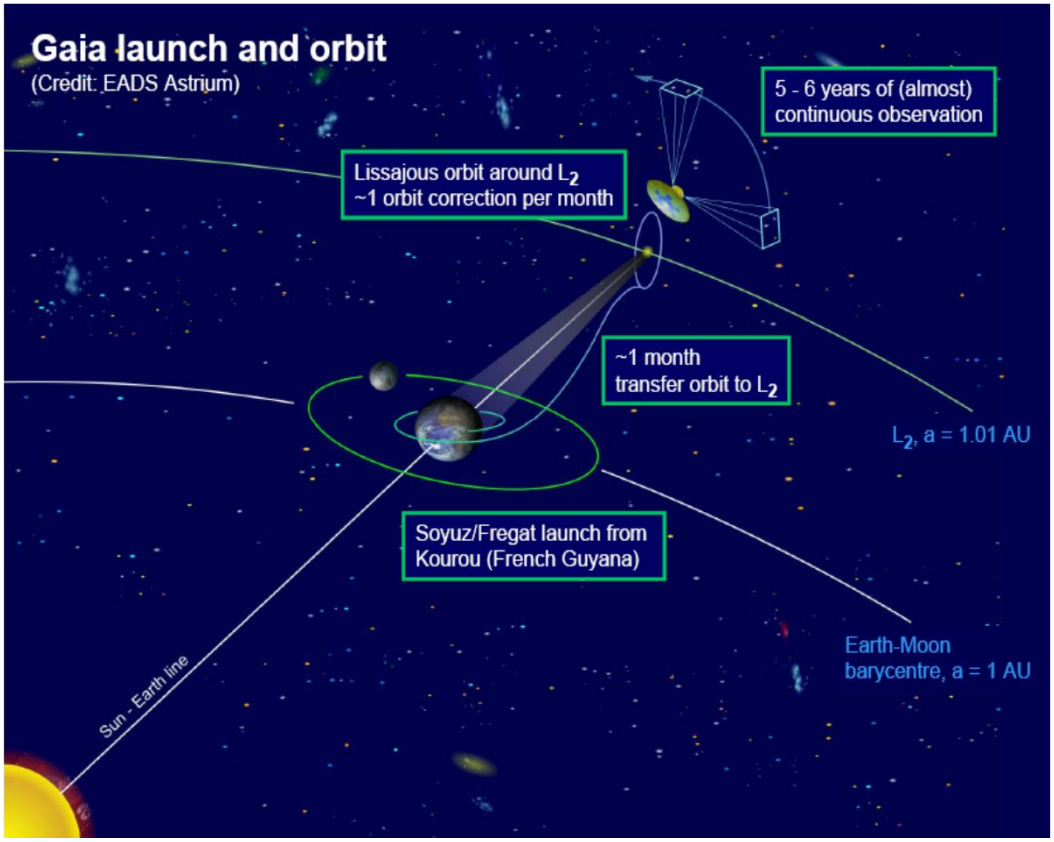
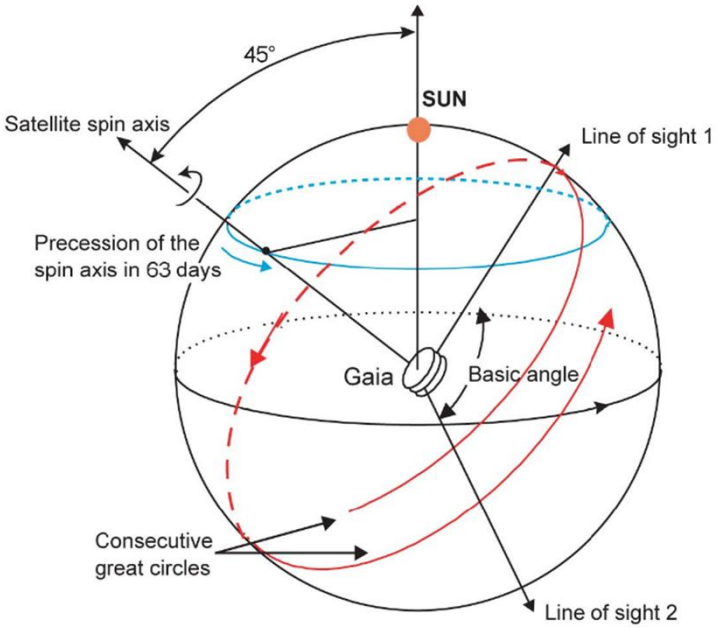
The Gaia mission





Scanning satellite (predetermined law) at L2 of the Earth-Sun system

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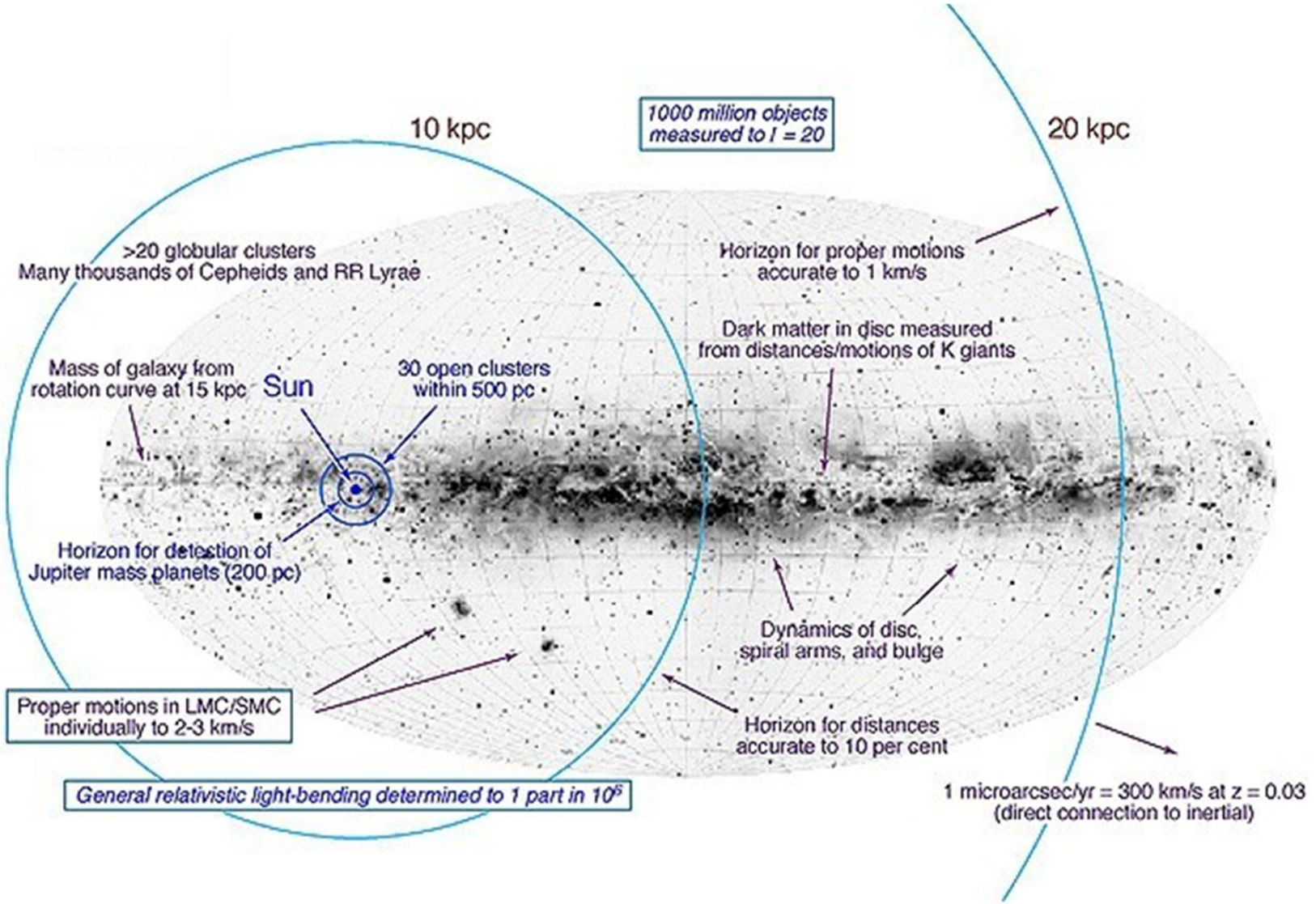

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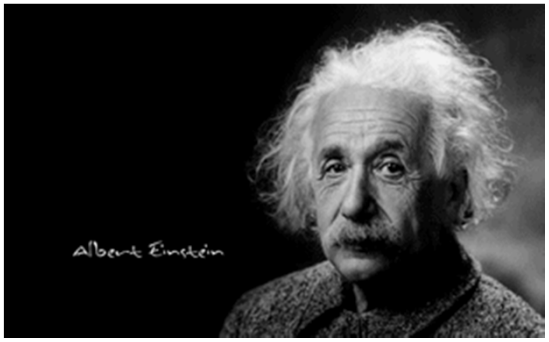
For unreddened Solar type (G2V) star

V-magnitude	*Astrometry (parallax)*	*Photometry (BP/RP integrated)*	*Spectroscopy (radial velocity)*
6 to 12	*5-14 μas*	*4 mmag*	*1 km/s*
15	*25 μas*	*5 mmag*	*13 km/s*
20	*540 μas*	*60 (RP) – 80 (BP) mmag*	

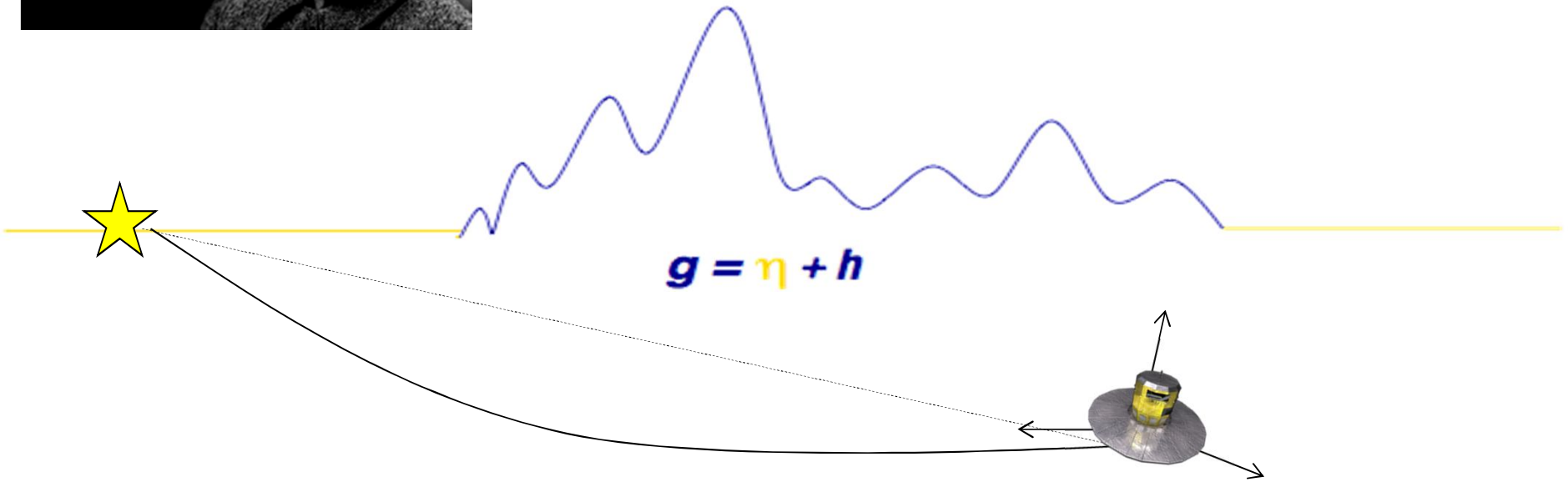
Last update

c. Prusti

Calculations by: Airbus DS, D. Katz, C. Jordi, L. Lindegren, J. de Bruijne



h pertubations at **μ-arcsec** due to the solar system bodies



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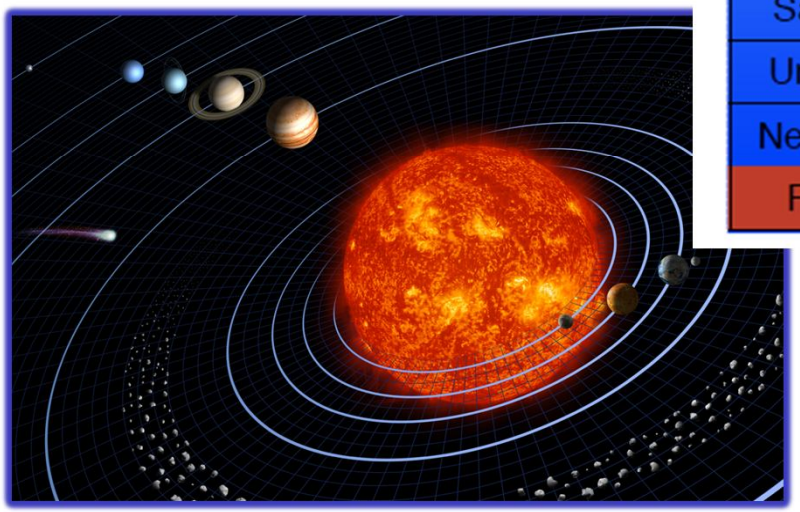
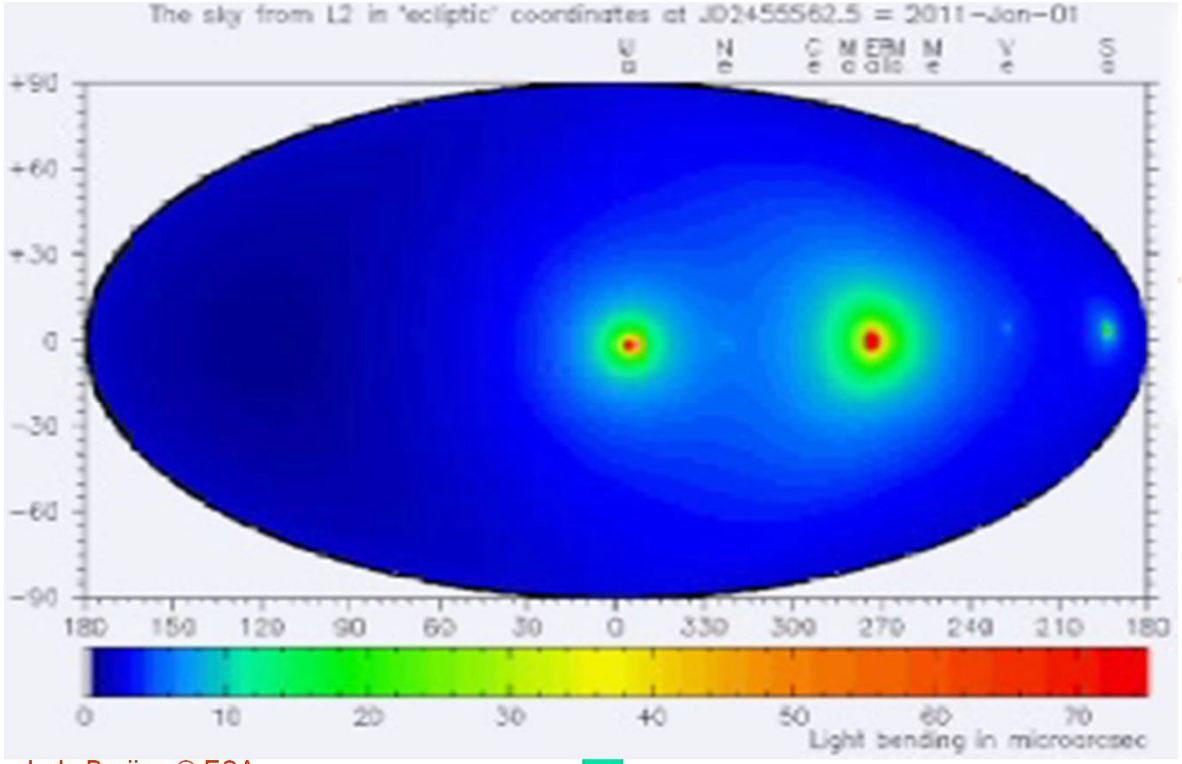
Detectable relativistic deflections at L2

	$\delta\chi_{\rm PN}$	$\delta\chi_{J_2}$	$\delta\chi_L$	$\chi_{\rm max}$
Sun	$1''.75$	$\sim 1\ \mu$as	$0.7\ \mu$as	$(180°)$
Mercury	$83\ \mu$as	–	–	$(7')$
Venus	493	–	–	$(4.0°)$
Earth	574	0.6	–	$(101°)$
Moon	26	–	–	$(2.3°)$
Mars	116	0.2	–	$(17')$
Jupiter	16290	240	0.2	$(87°/3')$
Saturn	5772	94	–	$(16°/51'')$
Uranus	2030	7	–	$(67'/4'')$
Neptune	2487	8	–	$(50'/3'')$
Pluto	7	–	–	$(0''.3)$





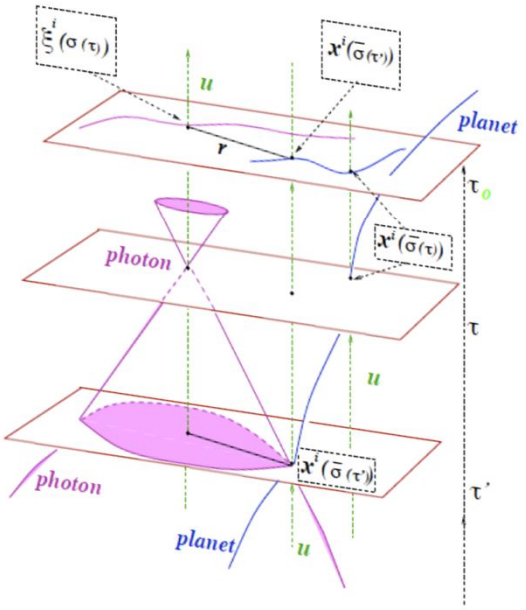
J. de Bruijne © ESA

$$h_{00} = \sum_a \frac{2M_{(a)}}{r_{(a)}} + O(\epsilon^4)$$

$$h_{0i} = -\sum_a \frac{4M_{(a)}}{r_{(a)}} \tilde{\beta}_{i(a)} + O(\epsilon^5)$$

$$h_{ij} = \sum_a \frac{2M_{(a)}}{r_{(a)}} \delta_{ij} + O(\epsilon^4),$$

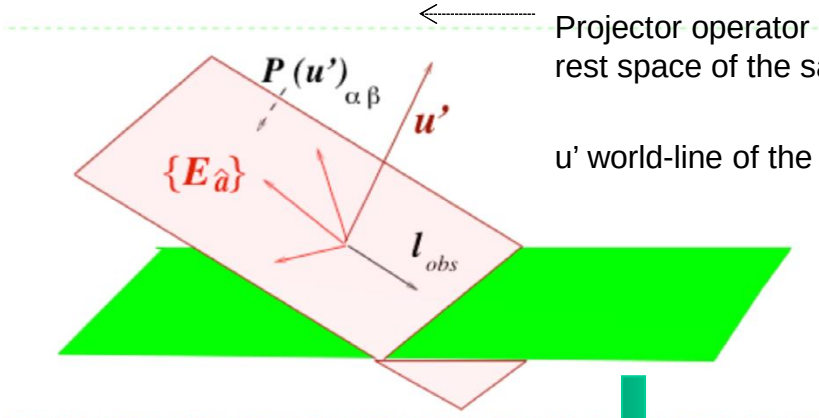
$$\tilde{\beta}^j = (1 - h_{00}/2)\tilde{v}^i(\tilde{\sigma}) + O(h^2)$$



$$t' - t = r_{(a)}/c$$

RELATIVISTIC ASTROMETRY
micro-arcsecond accuracy+
dynamical gravitational fields,
relativistic models of
Light propagation

R.A.MOD. models (Crosta et al., Classum Quantum Gravity, 32 (2015) 1655008 and references thererein)



Projector operator onto the rest space of the satellite

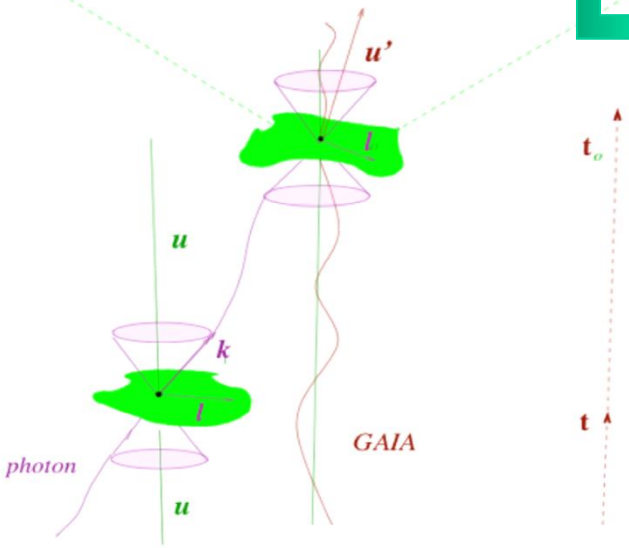
u' world-line of the satellite

Observation equation for Gaia

$$\cos\psi_{(E_{\hat{a}},\ell_{obs})} \equiv \mathbf{e}_{\hat{a}} = \frac{P(u')_{\alpha\beta}k^{\alpha}\boldsymbol{E}^{\beta}_{\hat{a}}}{(P(u')_{\alpha\beta}k^{\alpha}k^{\beta})^{1/2}}$$

E_{α}^{β} "attitude tetrad"-> ESSENTIAL to define the boundary condition (Bini et al. , CQG 20, 4695, 2003

The RAMOD local-line-of-sight is not exactly equal to the light direction used in the pM or pN approximation



Gravitational abberation for stellar direction

$$\bar{l}^{i} = n^{i}\left(1-\frac{U}{c^{2}}\right)+\mathcal{O}\left(\frac{v^{4}}{c^{4}}\right)$$

n^i "aberration free" direction

U potential

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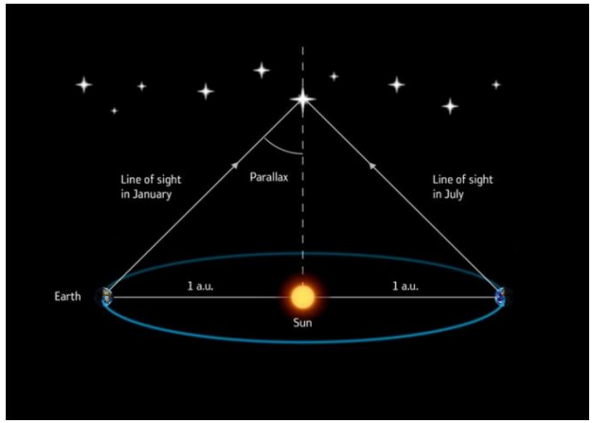
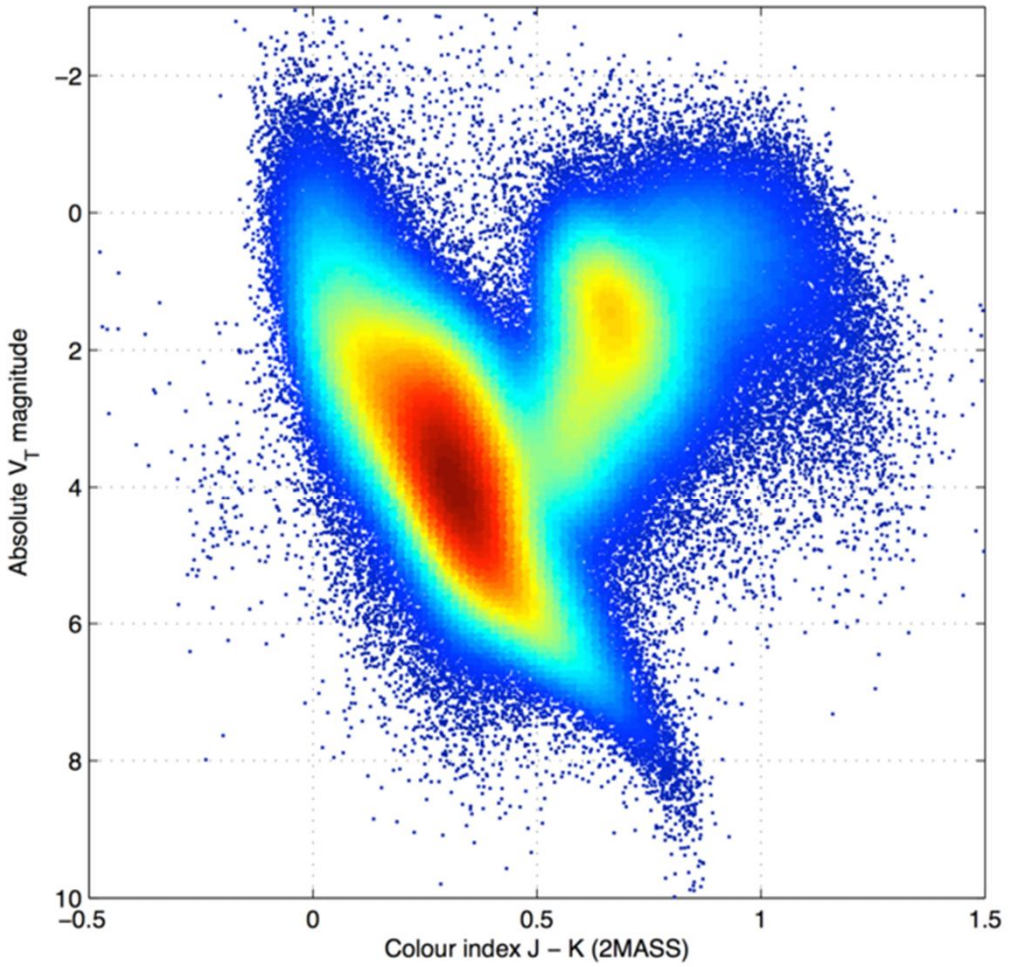
First results

Trigonometric parallaxes for 2 million bright stars from the Tycho 2 catalog



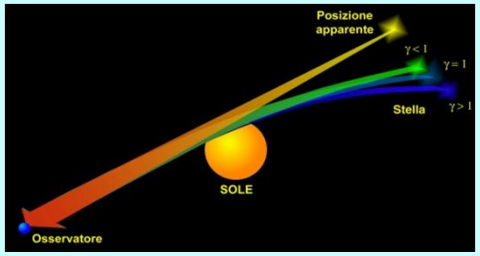
Tycho 2 HR diagram



Gaia scientific highlights

(Lattanzi 2012, MemSAIt, vol.83 No.3)

Beyond Einstein?

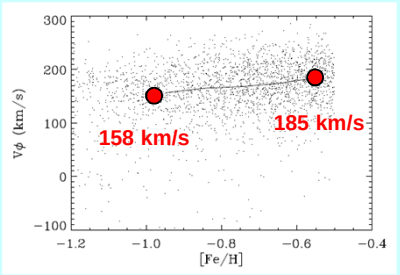


Deviations from GR to **$3*10^{-7}$ detectable**: presence of residual scalar field from within the Solar System?

(Vecchiato, Lattanzi et al 2003)

Challenging GR and Concordance Model

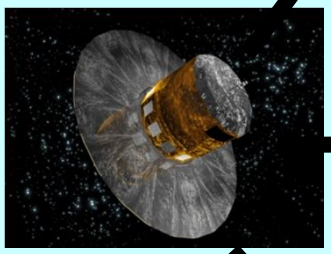
Local cosmology



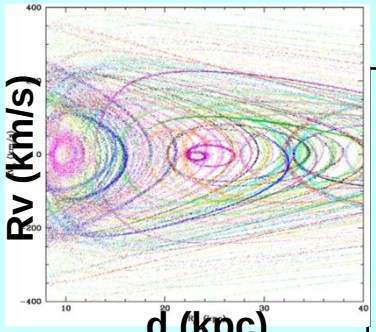
Circular velocity-metallicity relation in the Galaxy Thick Disk

(Spagna, Lattanzi et al. 2010, Curir, Lattanzi, et al. 2012, Curir et al. 2014)

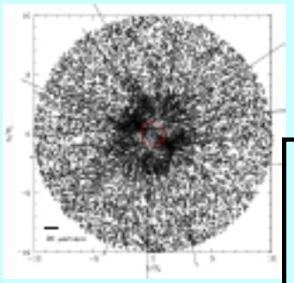
(Vϕ) vs. [Fe/H] : **50 ± 5 km/s /dex**



Testing light bending properties of matter



(Λ)CDM prediction for the Galactic halo. Structure in phase space: **true?**

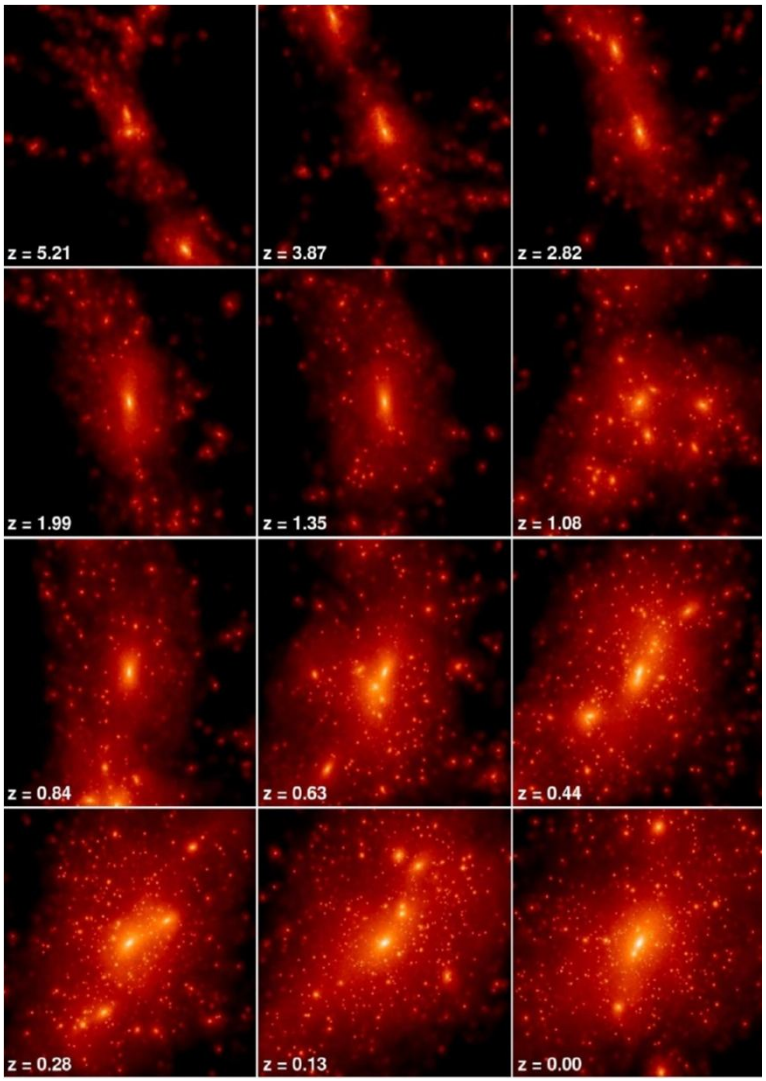


First detection of light deflection by Jupiter's quadrupole (J_2)

Extrasolar planets

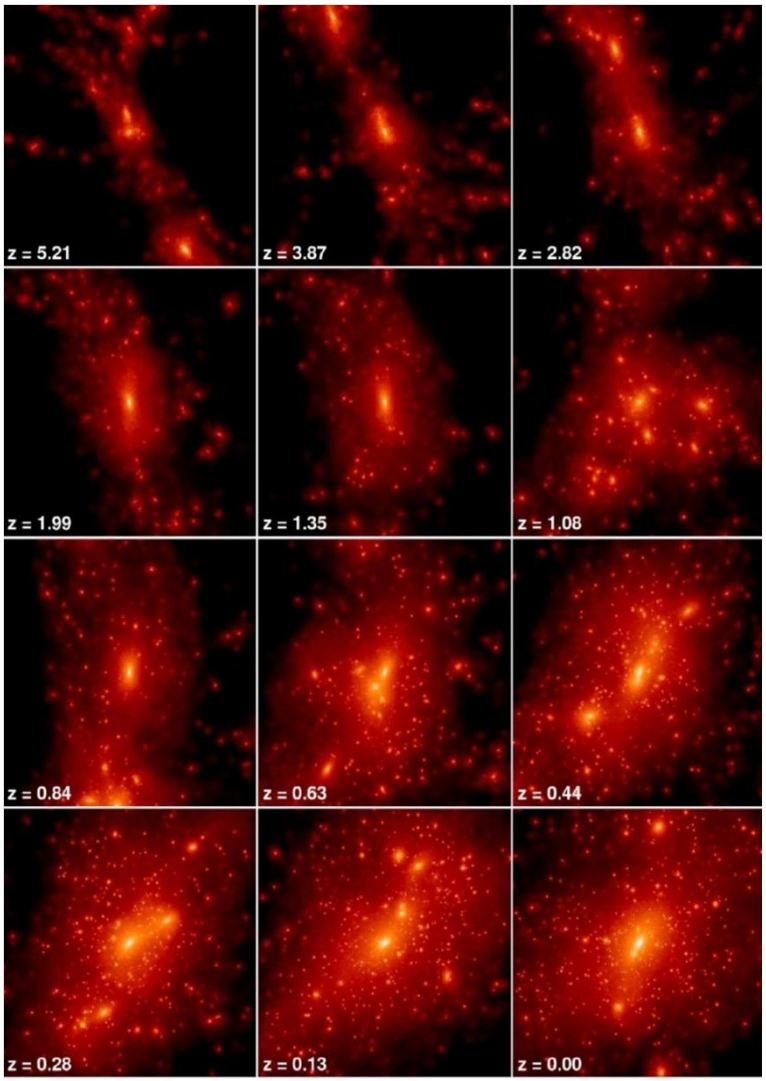
2,000 fully reconstructed **systems** (orbits and masses) **around FGK stars**; expected **10,000 new planets around M dwarfs**.

(Sozzetti, Giacobbe, Lattanzi et al. 2014)



CDM hierarchical model of Galaxy formation

Simulation by *Helmi, White & Springel* (2002, astro-ph/0201289) **rescaled** of a factor **10** the Springel's simulation in order to study the evolution of **CMD galactic halo** and investigate the kinematics of CMD streams in the solar neighborhood.



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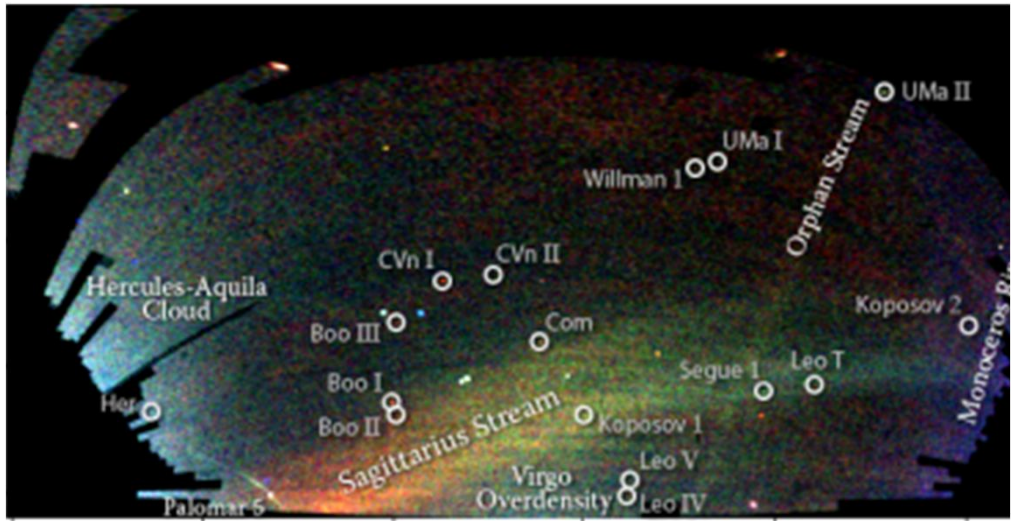
dSphs/UFDs as "building blocks" of the galactic halo

dSphs: Most numerous, Most DM dominated, Complex and unique SFH

But: Missing Satellites, Metallicity Problem

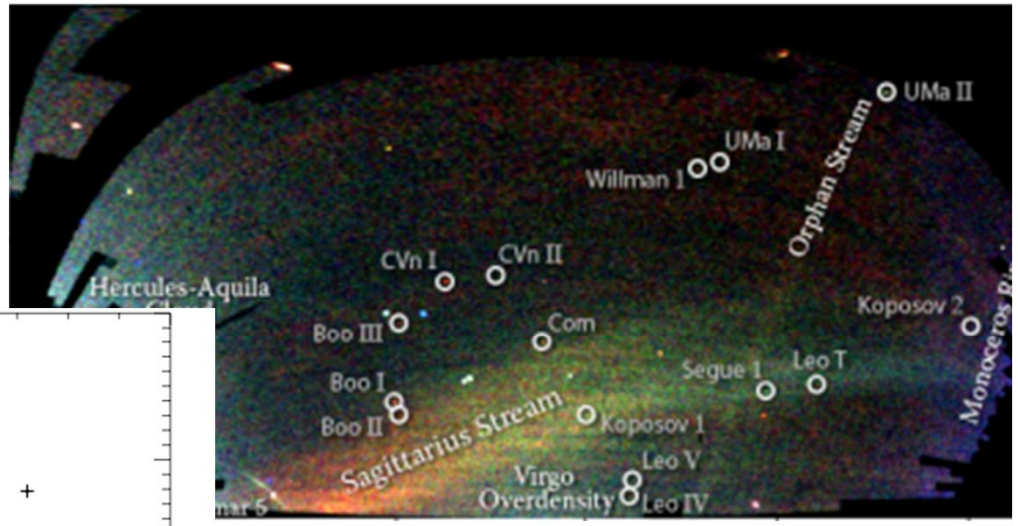
Variable Stars Problem

Finding streams in the Galactic halo - *Observations* -



Tidal tails and satellites in the Milky Way from the SDSS survey

Finding streams in the Galactic halo
- *Observations* -



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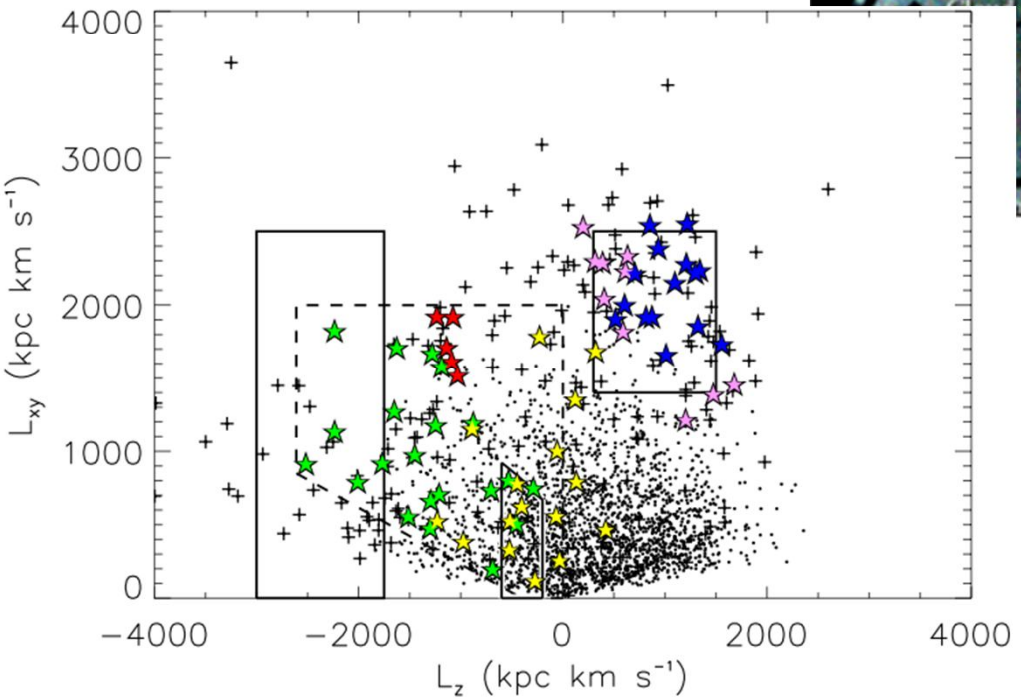
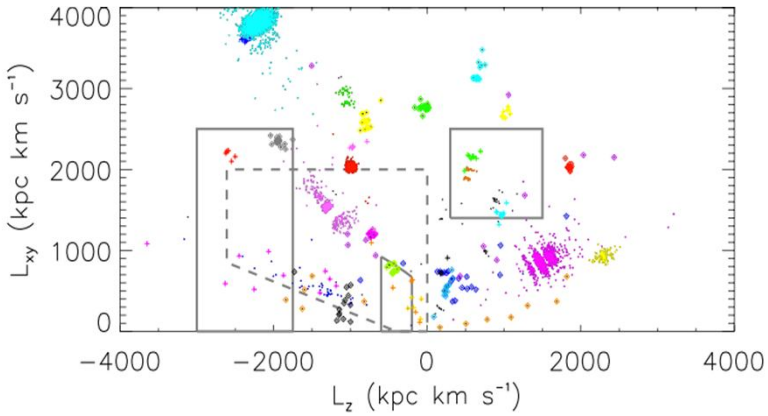


Kinematic groups in the inner halo (d<3kpc), as debris of merging events
(from Re Fiorentin et al 2015)

Finding streams in the Galactic halo
- *Simulations* -

True 'simulated' data set



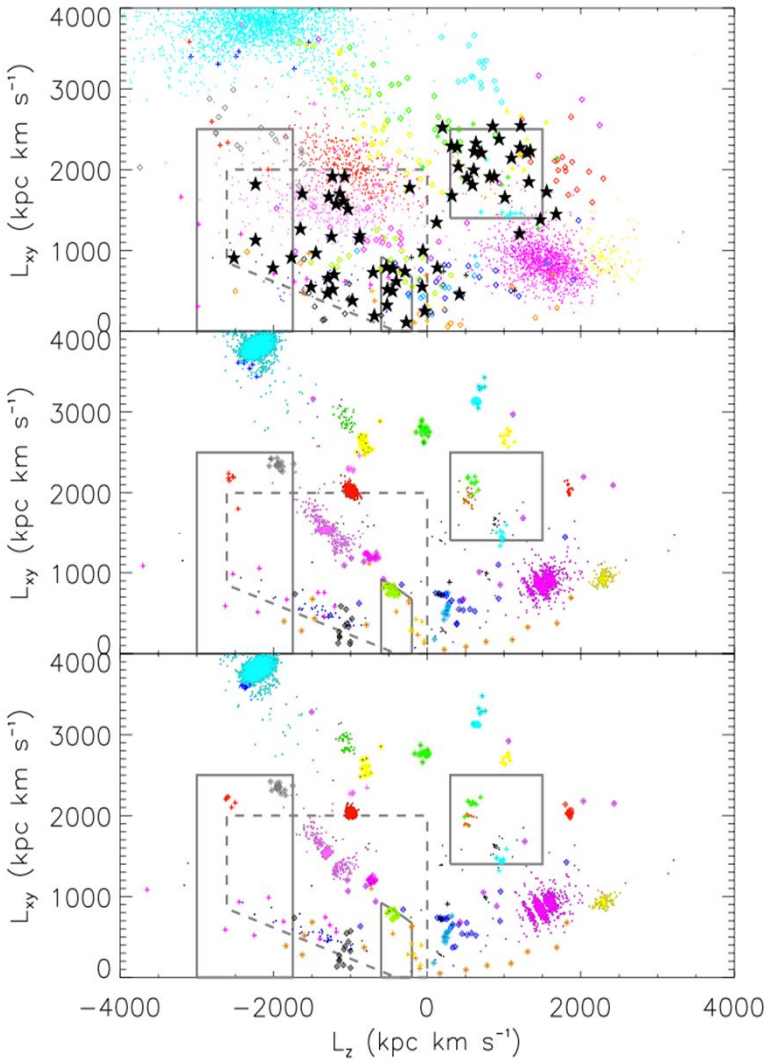
Simulations from Sanderson et al. (2014) and error model from Re Fiorentin et al. (2015)

Finding streams in the Galactic halo - *Simulations* -

Accuracy of the current ground-based catalogs

Expected Gaia observations

True 'simulated' data set



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Thanks

Info: http://www.cosmos.esa.int/web/gaia