A first exploration of the Gaia sky

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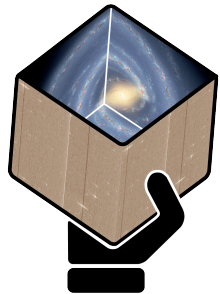
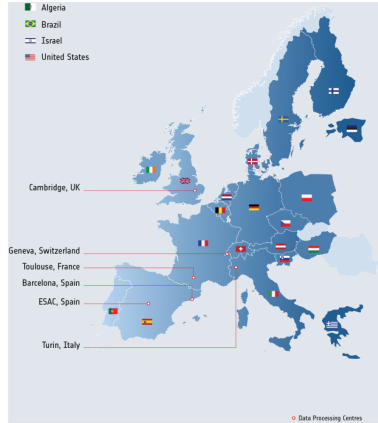
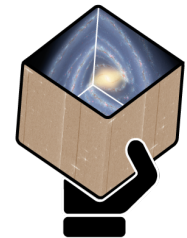


Teamwork to deliver the promise of Gaia

- 10+ years of effort
- 450 scientists and engineers
- 160 institutes
- 24 countries and ESA
- Six data processing centres





gaia

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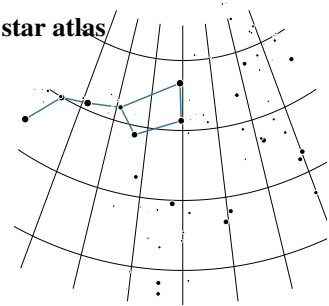
Gaia DPAC Data Processing & Analysis Consortium

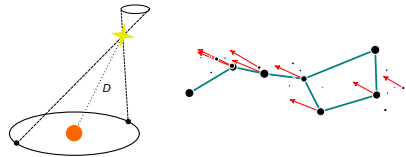
$\alpha\ \delta\ \varpi\ \mu_{\alpha*}\ \mu_\delta\ G\ \ldots$

What's in the Gaia DR1 delivery

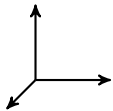
Billion star atlas

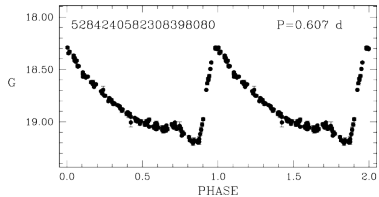


Tycho-Gaia Astrometric Solution



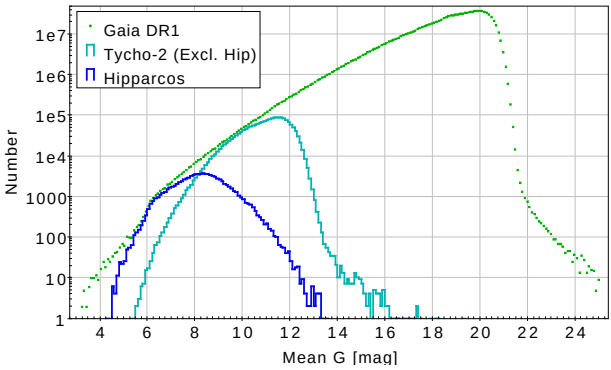
Positions and magnitudes for $\sim$ 2000 ICRF quasars





Variable stars near south ecliptic pole

Gaia DR1 summary statistics



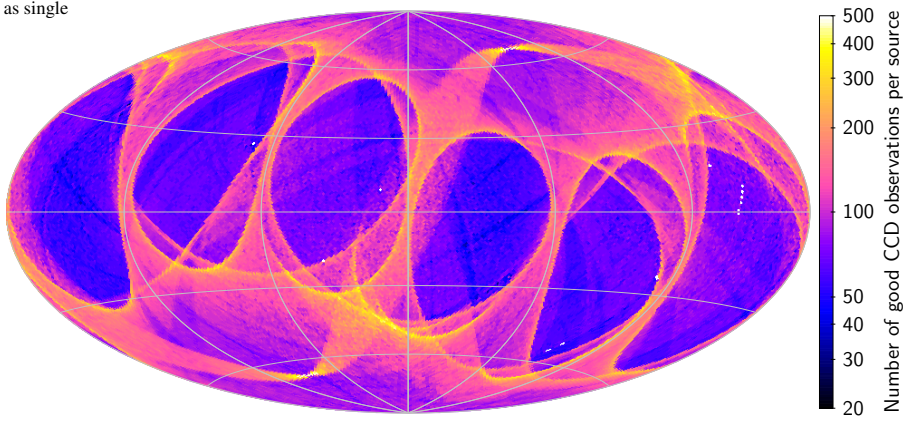
Source numbers	
Total number of sources	1 142 679 769
No. of primary (TGAS) sources	2 057 050
Hipparcos	93 635
Tycho-2 (excluding Hipparcos stars)	1 963 415
No. of secondary sources	1 140 622 719
ICRF quasars	2191
No. of sources with light curves	3194
Cepheids	599
RR Lyrae	2595

Magnitude distribution percentiles (G)	
0.135%	11.2
2.275%	14.5
15.866%	17.1
50%	19.0
84.134%	20.1
97.725%	20.7
99.865%	21.0

Gaia DR1 input data

- 14 months of input data used
- $\sim 2.3 \times 10^{10}$ transits across focal plane
- all sources treated as single

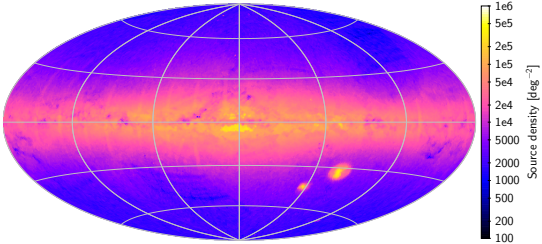
TGAS Mean no. observations per source (pixel $\sim$ 1 deg^2)



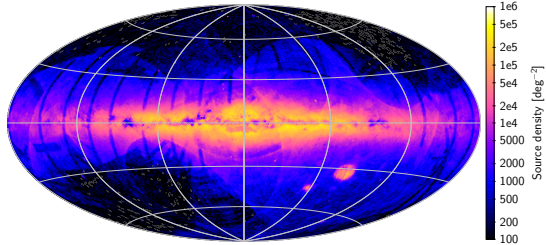
DPAC/CU3/Lindegren et al., 2016, A&A

Gaia DR1 astrometry

685 million sources matched to IGSL



456 million new sources in Gaia DR1



DPAC/CU3/Lindegren et al., 2016, A&A

- (α, δ) for $\sim$ 1.1 billion sources to $G = 20.7$
- Epoch J2015.0, alignment to ICRF < 0.1 mas, rotation < 0.03 mas yr^{-1}
- Typical position uncertainty $\sim$ 10 mas
- Positions of 2191 ICRF sources from special astrometric solution (Mignard et al., 2016, A&A)
  - 90% with $\sigma_{\rm pos} < 3.35$ mas
  - no systematic differences with radio positions of more than few tenths of mas

Gaia DR1 astrometry

Tycho-Gaia Astrometric Solution (Michalik et al., 2015, A&A)

- Use Hipparcos or Tycho-2 position as prior to disentangle parallax and proper motion
  - 2 million stars in common with these catalogues
- 5-parameter astrometry from $\sim$ 1 year of Gaia data
- *No Hipparcos parallaxes used*

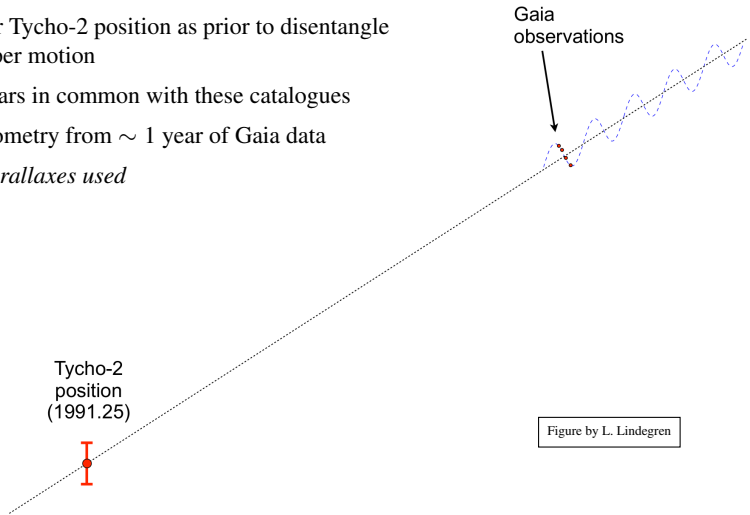
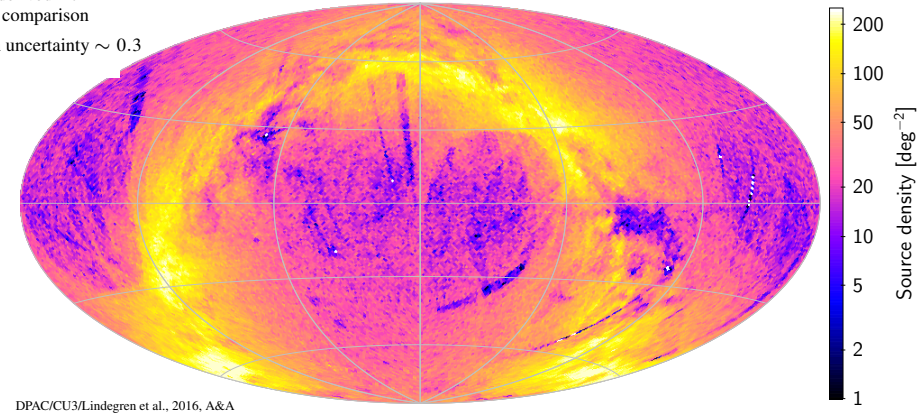


Figure by L. Lindegren

Gaia DR1 astrometry

- Parallaxes and proper motions for ~ 2 million sources to $G \sim 11.5$ (TGAS)
- Realistic errors derived from Gaia-Hipparcos comparison
- Median position uncertainty ~ 0.3 mas

TGAS source density over cells of ~ 0.84 deg^2

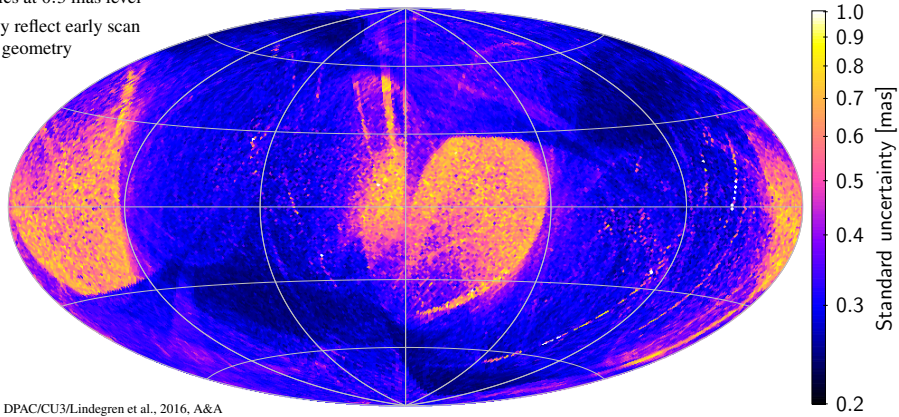


DPAC/CU3/Lindegren et al., 2016, A&A

Gaia DR1 astrometry

- Median parallax uncertainty ~ 0.3 mas
- Parallax systematics at 0.3 mas level
- Errors levels partly reflect early scan law coverage and geometry

TGAS median parallax uncertainty over cells of ~ 0.84 deg^2

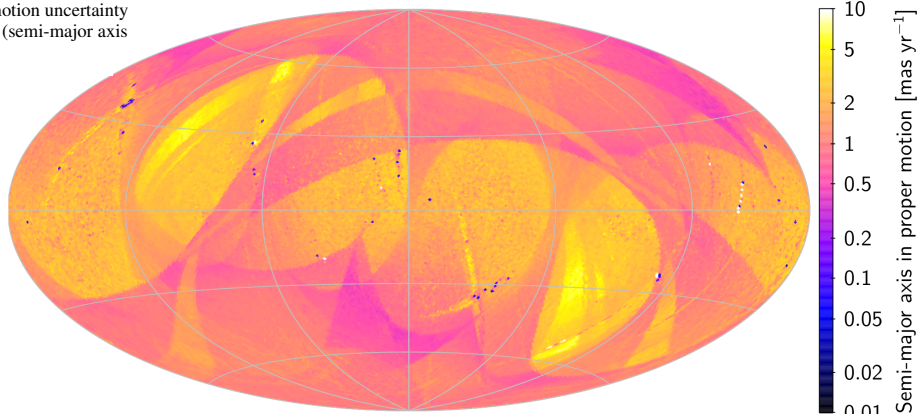


DPAC/CU3/Lindegren et al., 2016, A&A

Gaia DR1 astrometry

- Median proper motion uncertainty ~ 1.3 mas yr^{-1} (semi-major axis error ellipse)

TGAS median proper motion uncertainty over cells of ~ 0.84 deg^2

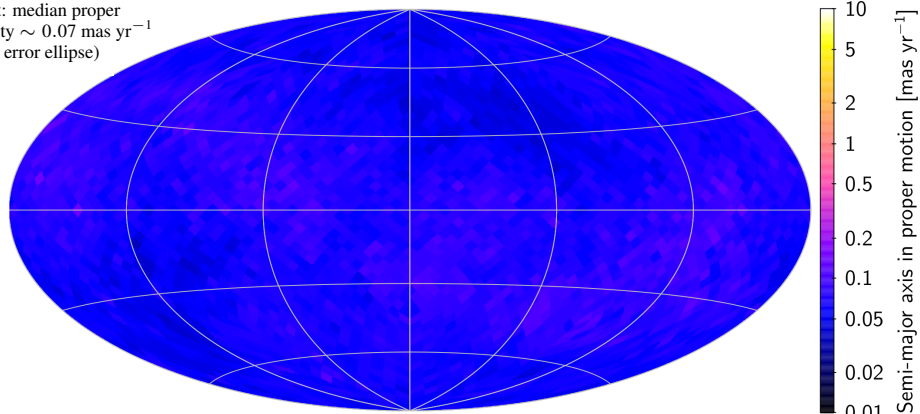


DPAC/CU3/Lindegren et al., 2016, A&A

Gaia DR1 astrometry

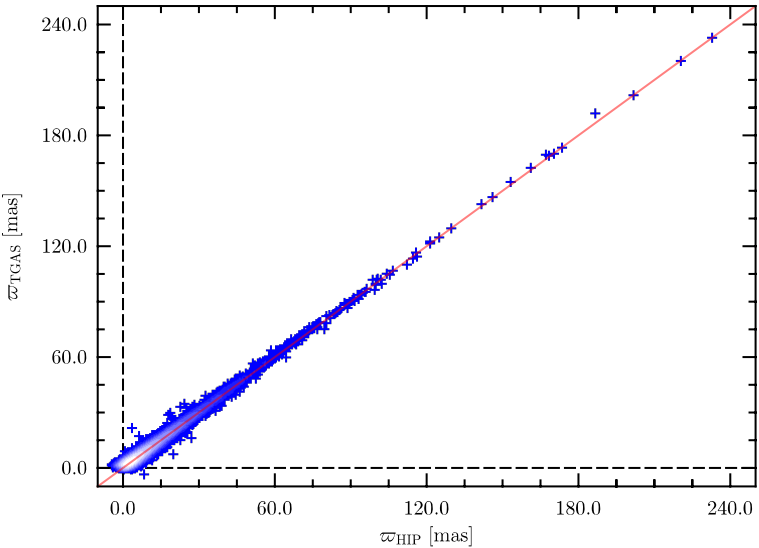
- Hipparcos subset: median proper motion uncertainty ~ 0.07 mas yr^{-1} (semi-major axis error ellipse)

TGAS Hipparcos sub-set median proper motion uncertainty over cells of ~ 13.4 deg^2



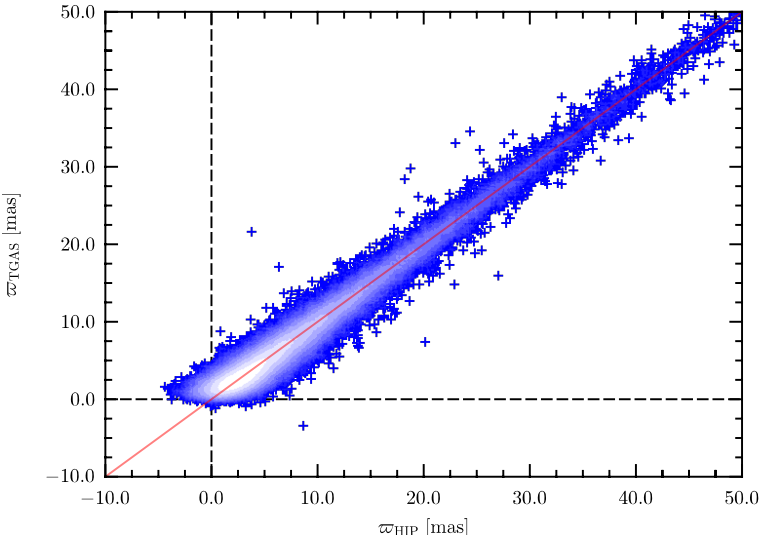
DPAC/CU3/Lindegren et al., 2016, A&A

Gaia DR1 astrometry



- TGAS and Hipparcos parallaxes are independent!
- Comparison confirms global quality of Hipparcos and Gaia
- Analysis allows for derivation of realistic error estimates
- These realistic errors are published in Gaia DR1

Gaia DR1 astrometry



- TGAS and Hipparcos parallaxes are independent!
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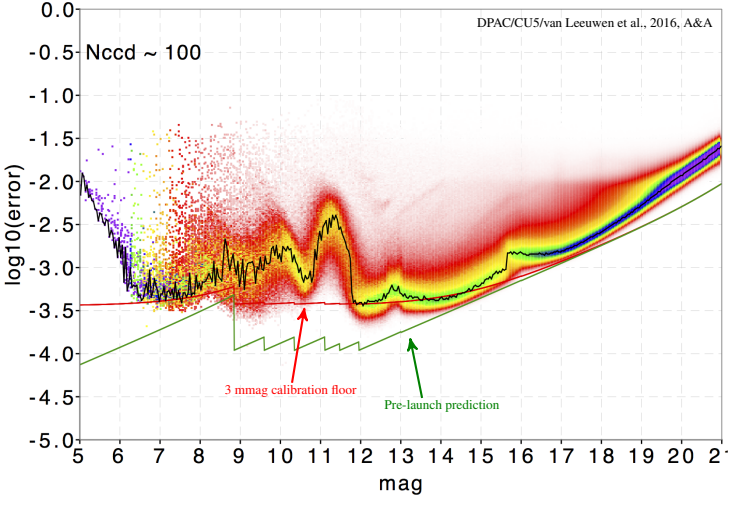
Gaia DR1 Photometry

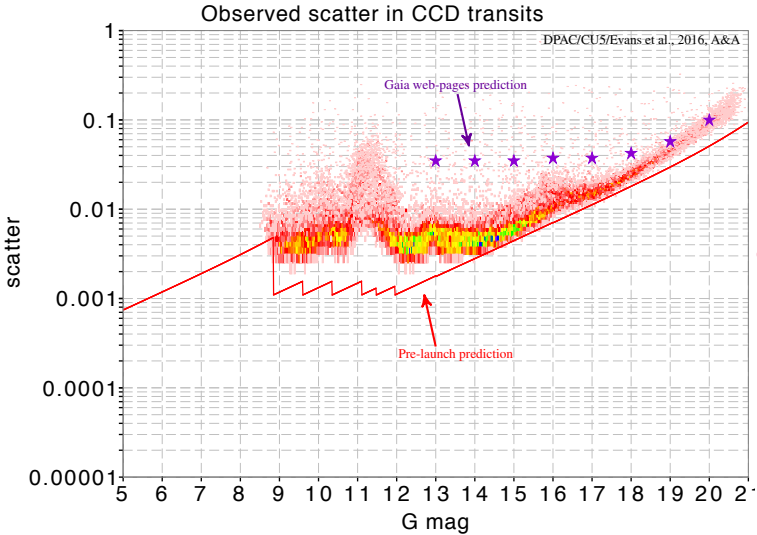
Error on the weighted mean G value for sources with $\sim$ 100 CCD transits



- Mean G-band fluxes and errors for all Gaia DR1 sources
  - G magnitudes in VEGAMAG, zeropoints for AB
  - No pass-band calibrations, transformations to other systems to be provided

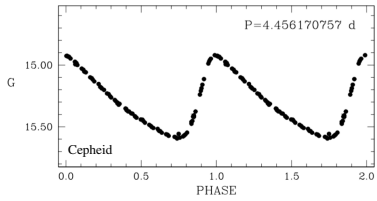
- CCD-transit G-band calibration systematics at the $\sim$ 3 mmag level
- Bright end features related to on-board instrument configuration changes
  - will be calibrated out in future releases

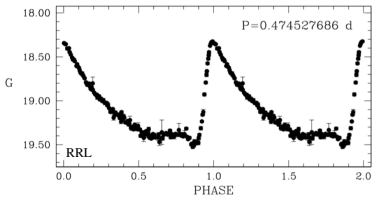
Gaia DR1 Photometry

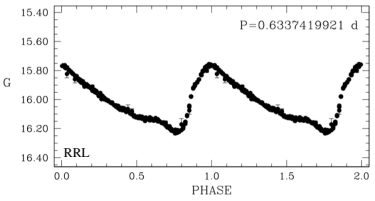


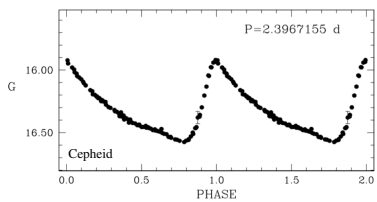
- Observed scatter in repeat measurements of constant sources demonstrates quoted uncertainties are good indicators of precision

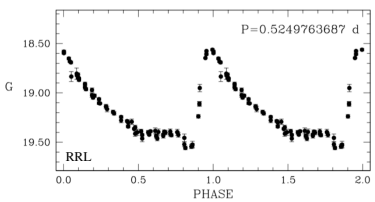
Gaia DR1 Variable Stars





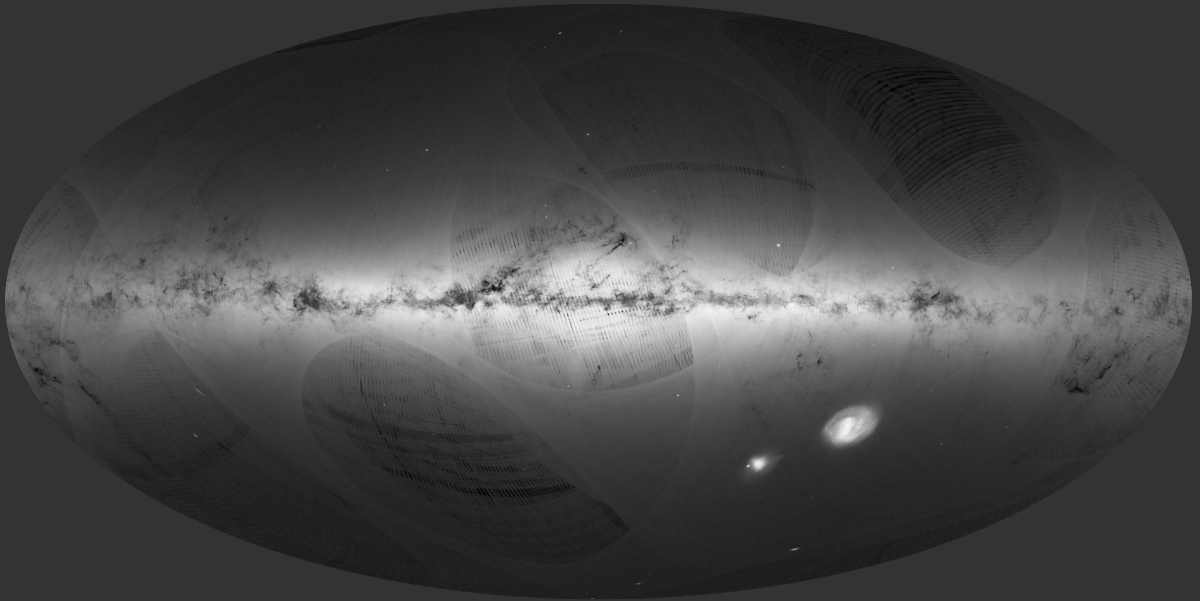




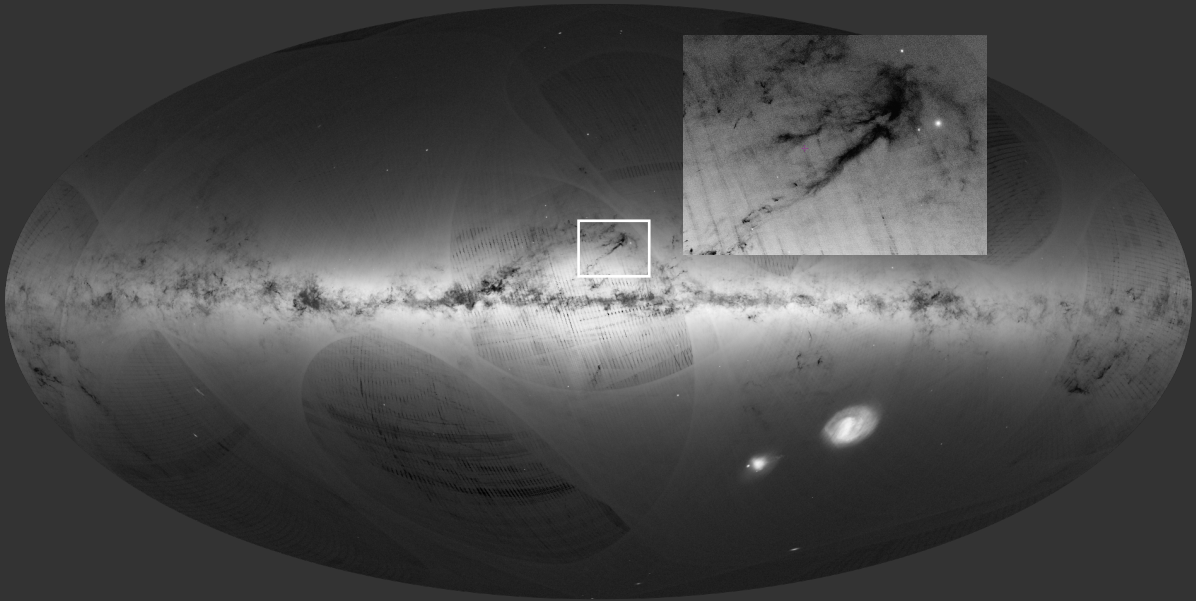


DPAC/CU7/Clementini et al., 2016, A&A

- *G*-band light curves for variables near South Ecliptic Pole
  - 599 Cepheids (43 newly discovered)
  - 2595 RR Lyrae (343 newly discovered)
- Classification information
- Statistical information on time series



ESA/Gaia/DPAC/André Moitinho & Márcia Barros (CENTRA - University of Lisbon)



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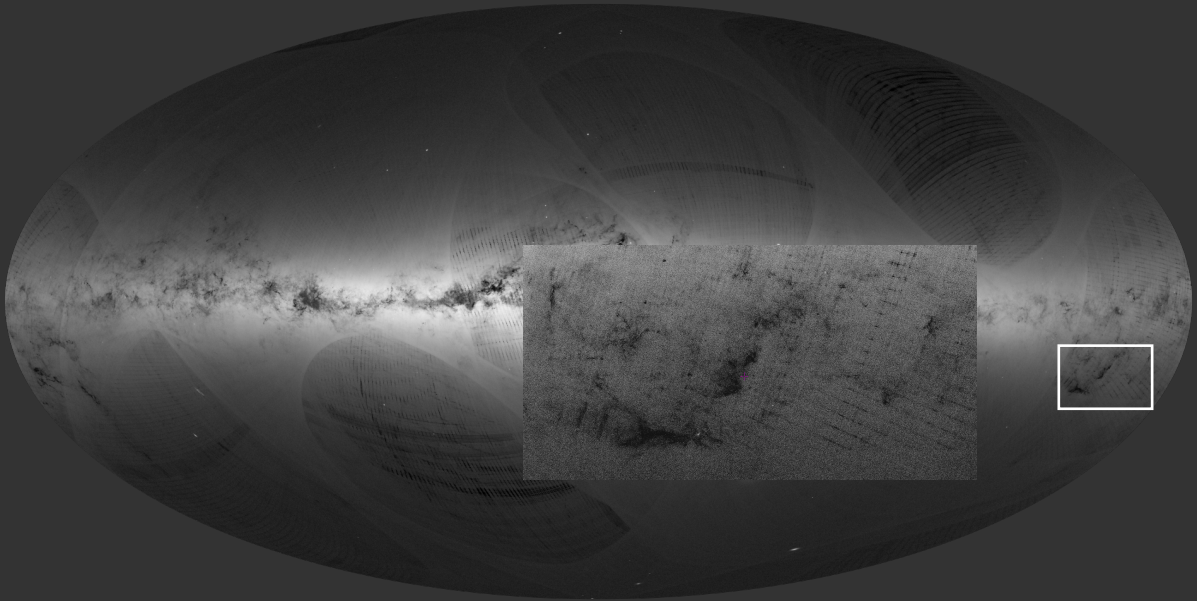

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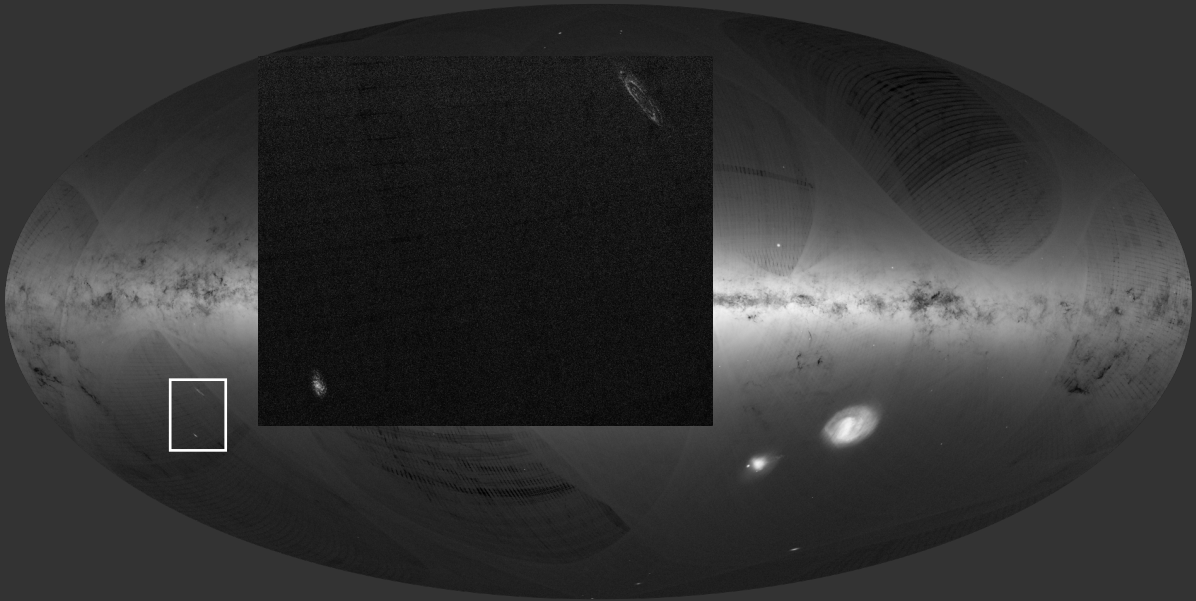

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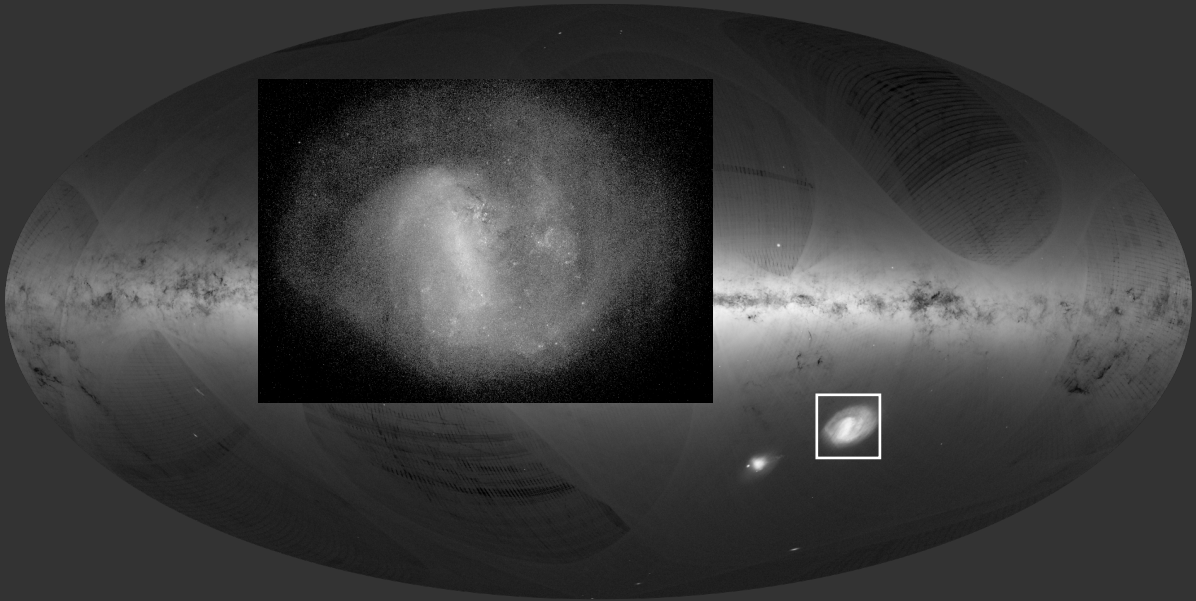
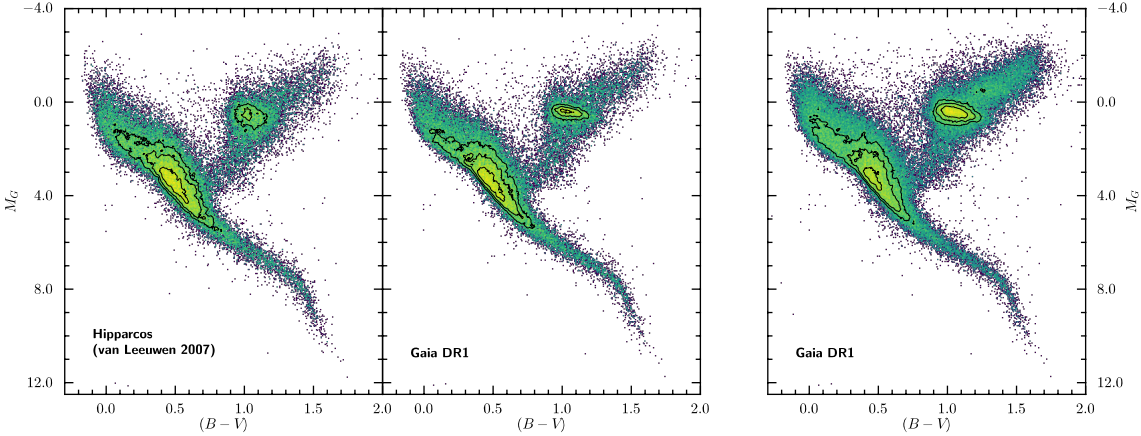


ESA/Gaia/DPAC/André Moitinho & Márcia Barros (CENTRA - University of Lisbon)

HR diagrams with TGAS

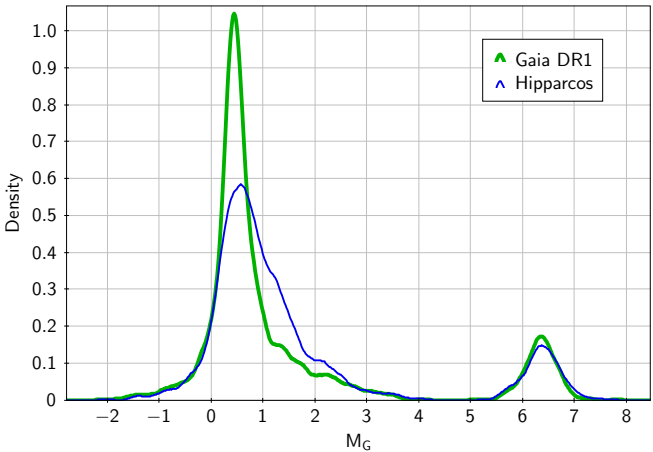
Hipparcos *and* Gaia DR1 parallaxes precise to $\leq 20\%$
43 546 stars, 90% stars inside 280 pc

Gaia DR1 parallaxes precise to $\leq 20\%$
77 771 stars, 90% inside 450 pc



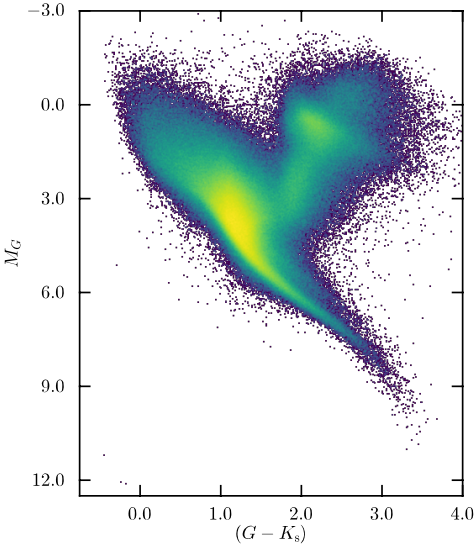
All stars from Hipparcos Catalogue

HR diagrams with TGAS



- Distribution of M_G for stars with $1.0 \leq (B-V) \leq 1.1$ and $\varpi/\sigma_{\varpi} \geq 5$
- Comparison robust scatter estimate for M_G:
  - Red clump: Hipparcos 0.5, Gaia DR1 0.3
  - Dwarfs: Hipparcos 0.4, Gaia DR1 0.3

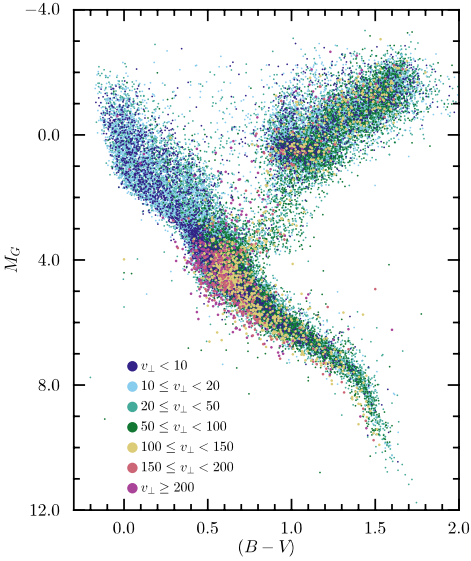
HR diagrams with TGAS



Full Gaia DR1 data set

- 1 million stars with parallaxes precise to $\leq 20\%$
- 90% inside 590 pc
- Future
  - $\sim$ 10 million parallaxes precise to 1%
  - $\sim$ 150 million precise to 10%
  - $\sim$ 280 million precise to 20%

HR diagrams with TGAS

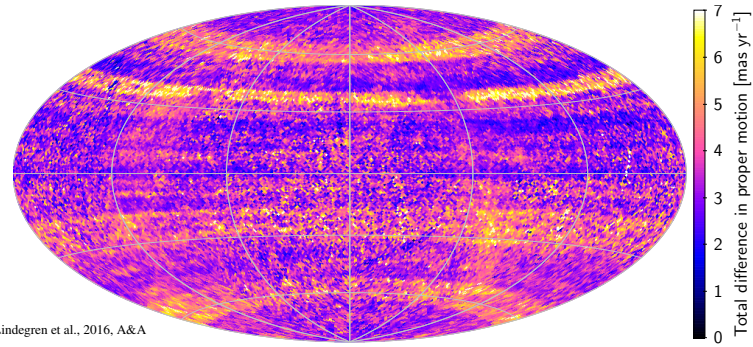


HR diagram colour coded by tangential velocity

- 41 136 stars with $(B-V)$ photometry selected according to: $G \leq 7.5$ or $\mu \geq 200$ mas yr^{-1} or $\varpi \geq 10$ mas
- 90% inside 360 pc

Proper motions Gaia DR1

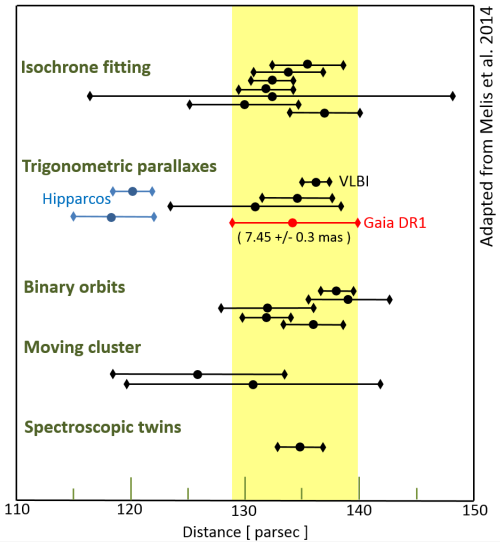
Median Tycho-2 – TGAS total proper motion difference over cells of ~ 0.84 deg^2



DPAC/CU3/Lindegren et al., 2016, A&A

- Declination zones visible in map indicate systematics in Tycho-2 proper motions
- Beware large Gaia DR1 – Tycho-2 proper motion discrepancies
  - likely a problem in Tycho-2

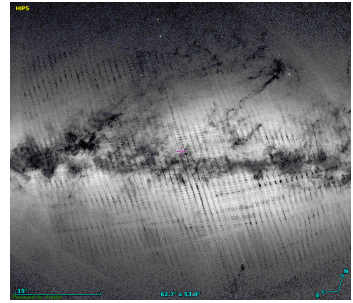
Comment on the Pleiades cluster distance



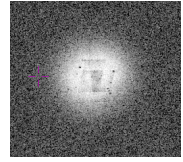
- Preliminary distance estimate 134 ± 6 pc
- Limited in accuracy by:
  - simplistic analysis
  - systematic and correlated errors in parallaxes
  - incomplete survey of the cluster
- Definitive conclusion on Pleiades distance not yet possible
- Excellent agreement between Hipparcos and Gaia for other clusters

Remarks on Gaia DR1 completeness

- Gaia DR1 not complete in any sense
- Ill-defined and celestial position dependent faint limit
- Scanning law in combination with filtering on data quality causes source density artifacts
- Many bright stars missing at $G \lesssim 7$
- High proper motion stars ($\mu > 3.5$) arcsec yr^{-1} missing
- High density regions (few 100 000 stars/deg^2) affected by:
  - onboard resource limitations
  - no treatment of overlapping observation windows
  - completeness limit can be several magnitudes brighter
- Effective angular resolution not yet at end of mission (HST-like) levels
  - below 4 arcsec separation many secondary components of binaries missing



Bulge region



ω Centauri

Know limitations astrometry and photometry

Photometry

- Limitations
  - incomplete PSF model
  - imperfect calibration across instrument configuration changes
  - difficulties in bright star data processing
- Level of systematics difficult to estimate

Know limitations astrometry and photometry

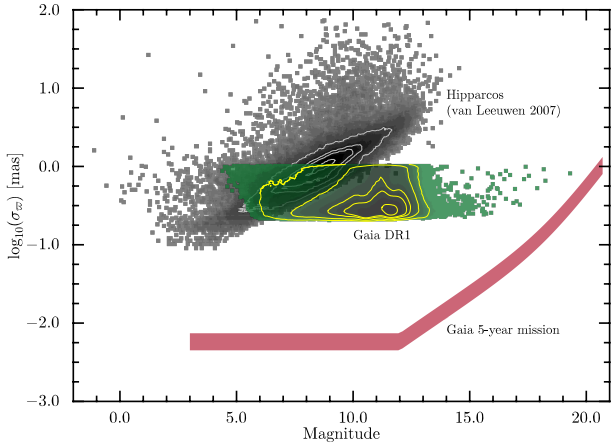
Astrometry

- Limitations
  - incomplete PSF model; incomplete attitude modelling
  - no treatment of source colour effects; source modelling errors (all sources treated as single stars)
  - imperfect correction for basic angle variations
- Global zero-point offset of ± 0.1 mas may be present
  - -0.04 mas found during validation
- Colour dependent and spatially correlated systematic errors at the level of ± 0.2 mas
- Over large spatial scales, the parallax zero-point variations reach an amplitude of ± 0.3 mas
  - Over a few smaller areas (2 degree radius), much larger parallax biases may occur of up to ± 1 mas
- Correlations between astrometric parameters of a given source can reach significant values of large regions of the sky
  - make use of the full covariance matrix when taking the standard uncertainties on (subsets and linear combinations of) the astrometric parameters into account

Recommendation: consider the quoted uncertainties on the parallaxes as $\pm\sigma_{\varpi}$ *(random)* ± 0.3 *mas (systematic). Averaging parallaxes over small regions of the sky will not reduce the uncertainty on the mean below the* 0.3 *mas level.*

Know limitations astrometry and photometry

All shortcomings will be addressed in future data releases with substantial improvements already foreseen for Gaia DR2



Data access

Main portal at ESDC: `http://archives.esac.esa.int/gaia`

- online documentation
- VO compatible, TAP interface, visualization apps

Partner data centres (data available today)

- Centre de Données astronomiques de Strasbourg (CDS): `http://cds.unistra.fr/gaia`
- ASI Science Data Center (ASDC): `http://gaiaportal.asdc.asi.it`
- Astronomisches Rechen-Institut (ARI): `http://gaia.ari.uni-heidelberg.de`
- Leibniz-Institut fr Astrophysik Potsdam (AIP): `http://gaia.aip.de`

Affiliate data centres

- US Naval Observatory (USNO)
- National Astronomical Observatory of Japana (NAOJ)
- Space Telescope Science Institute (STScI)
- South African Astronomical Observatory (SAAO)
- Observatoire the Paris-Meudon (ObsPM)
- Infrared Science Archive (IRSA)

Gaia Data Release 1

- Major advance in mapping of the heavens
- Significant increase in the amount and precision of available fundamental stellar data
- Documentation online and in Astronomy & Astrophysics Special Feature
- Scientific use of the early data will improve quality of future data releases
- Major improvements already planned for Gaia DR2
- Have fun with the data!