The first data from Gaia

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Data processing & analysis consortium

First (GAIA) workshop 1995

Gaia Data Release Nº 1

- Published 14 September 2016

- **2 M **** : **TGAS**: proper motions & parallaxes
  - Sub mas accuracy
- **1 G **** : **Secondary sources:** positions & G mag.
  - 10 mas accuracy
- **3 k **** : Light curves
  - 2595 RR Lyr; 599 Cepheids
- **2 k **** : QSO positions, auxiliary solution
  - 2191 QSOs for alignment to ICRF2

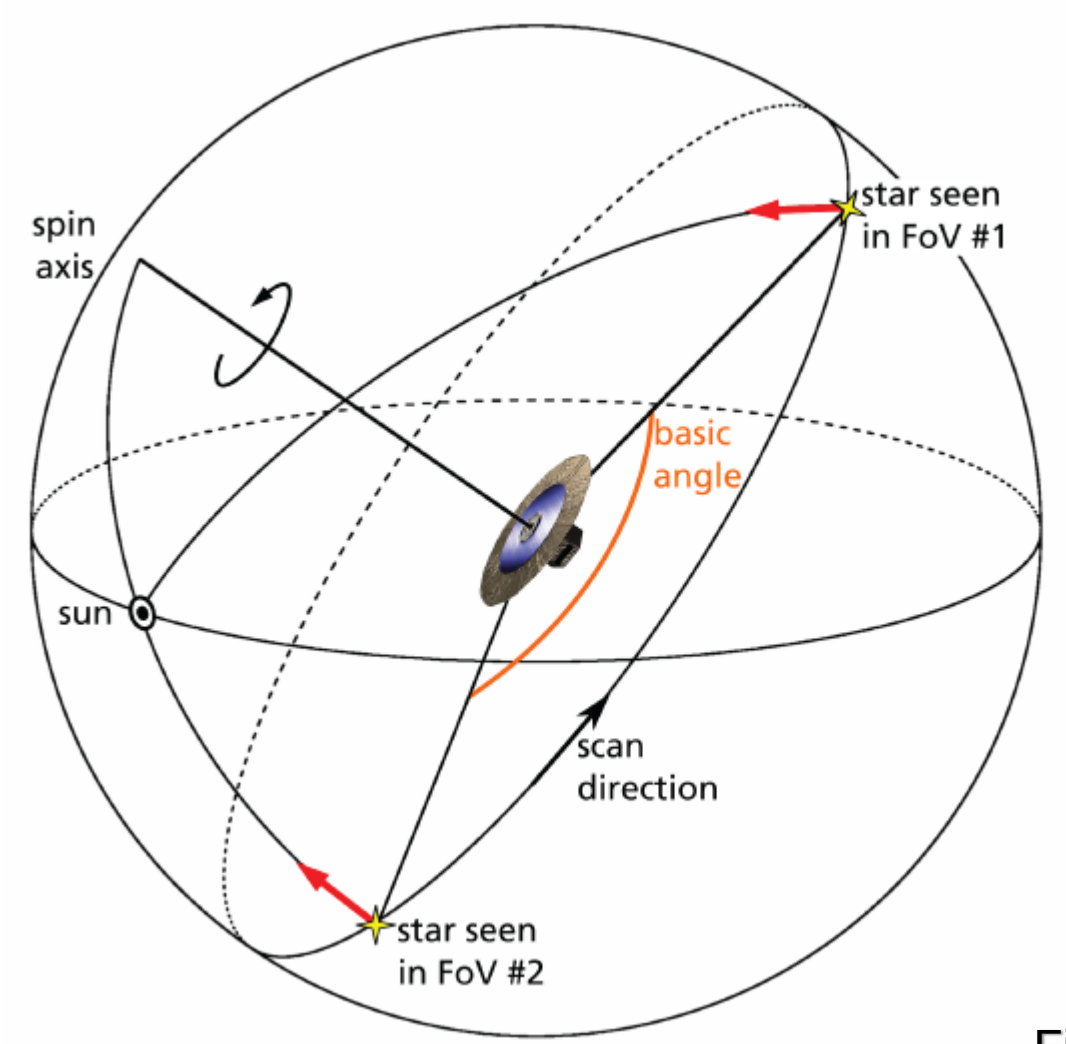
Gaia Data Release Nº 1

- Documentation:
  - 10-15 papers in A&A special feature (presently 5)
  - **gaia.esac.esa.int/documentation/GDR1/**
  - Must read: **Lindegren et al. 2016**

- Data: **archives.esac.esa.int/gaia**
  - Several mirror sites

- Already many papers in arXiv.org

Gaia measures absolute parallaxes

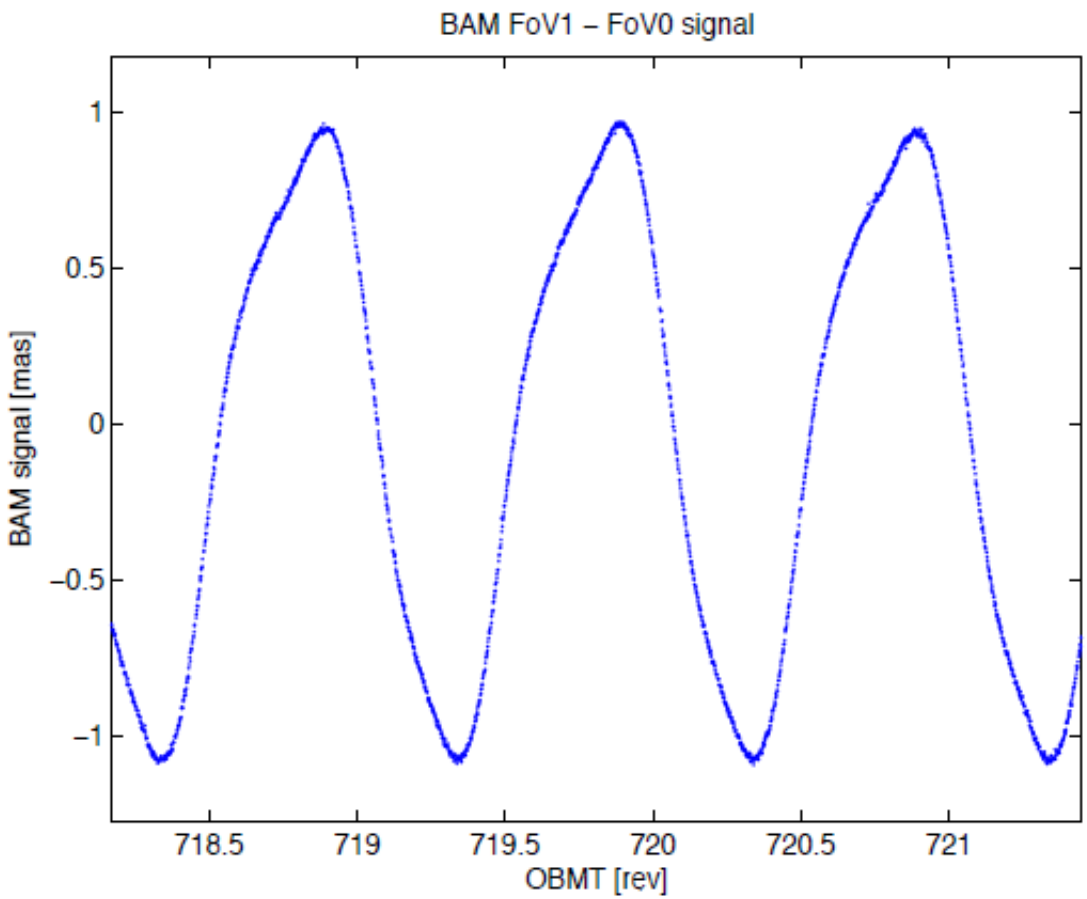


Basic angle must be very constant !

A special device Basic Angle Monitor checks for variations

Figure: Lindegren & Michalik

Basic angle variation



Amplitude: 1 mas
Period: 1 revolution

Offsets the
Parallax zero point

Solution:
Apply measured variation

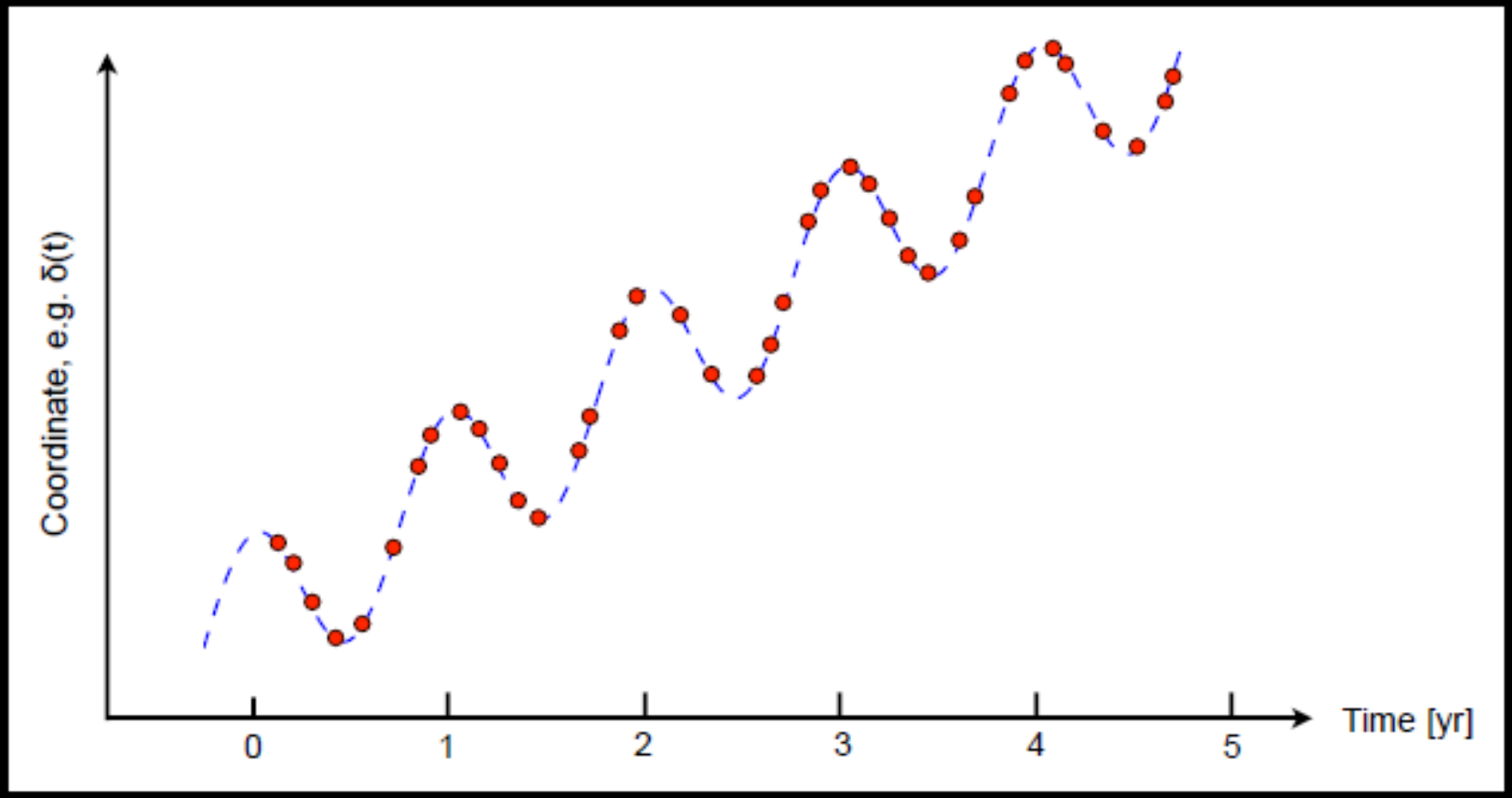
Validation needed

Figure: L. Lindegren

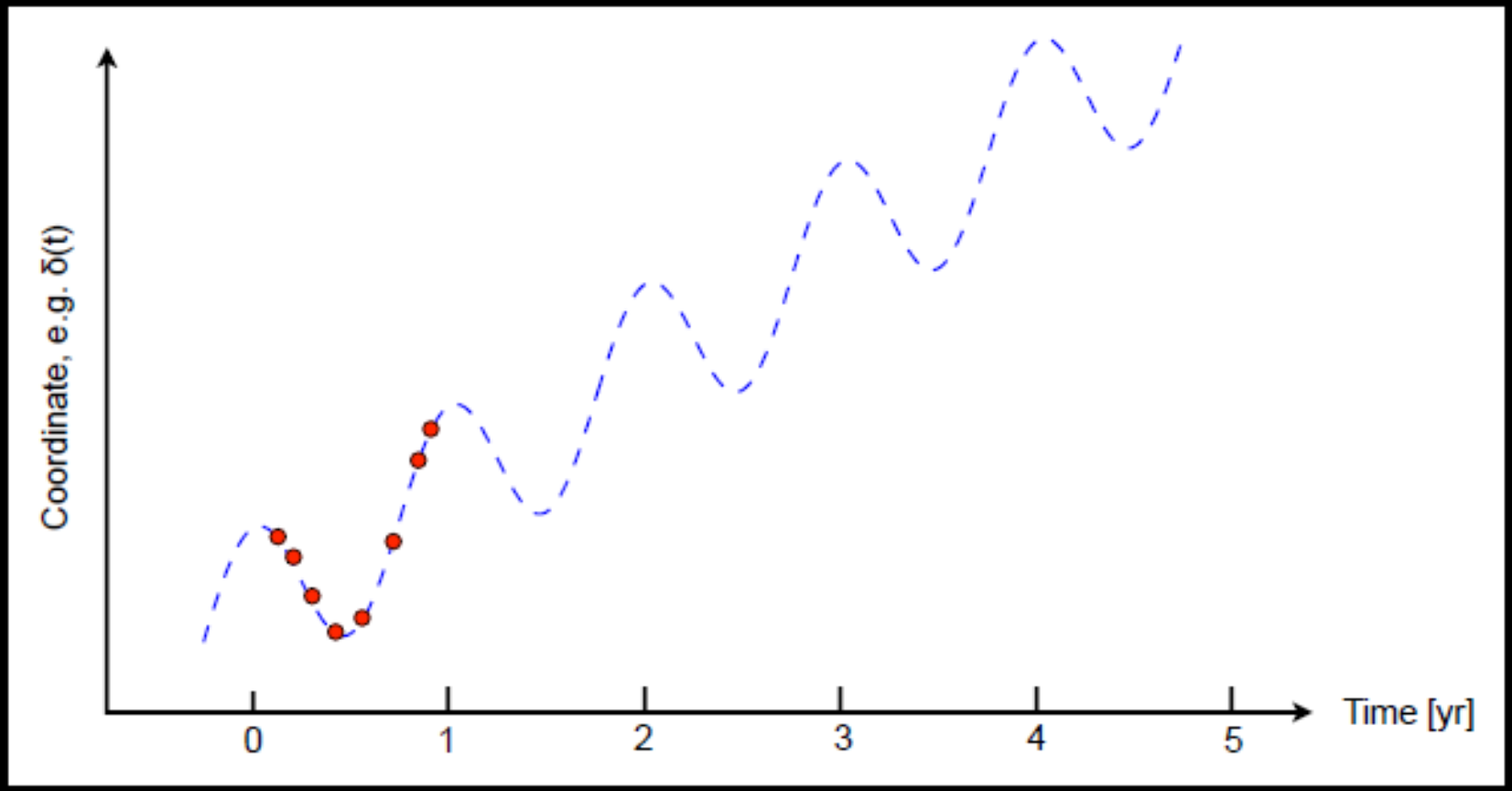
TGAS

- First idea
  - **HTPM**: take early Gaia data, get 1 mas accuracy position
  - Combine with Hipparcos to get proper motions
- Second thoughts
  - 100 000 stars are too few to calibrate Gaia
  - Additional stars will distort the solution (no p.m., parallax)
- Solution
  - Use the 2+ million Tycho-2 stars
    - Decent first epoch
- Benefit
  - 2+ million parallaxes
  - Much better accuracy for proper motion for Tycho-2

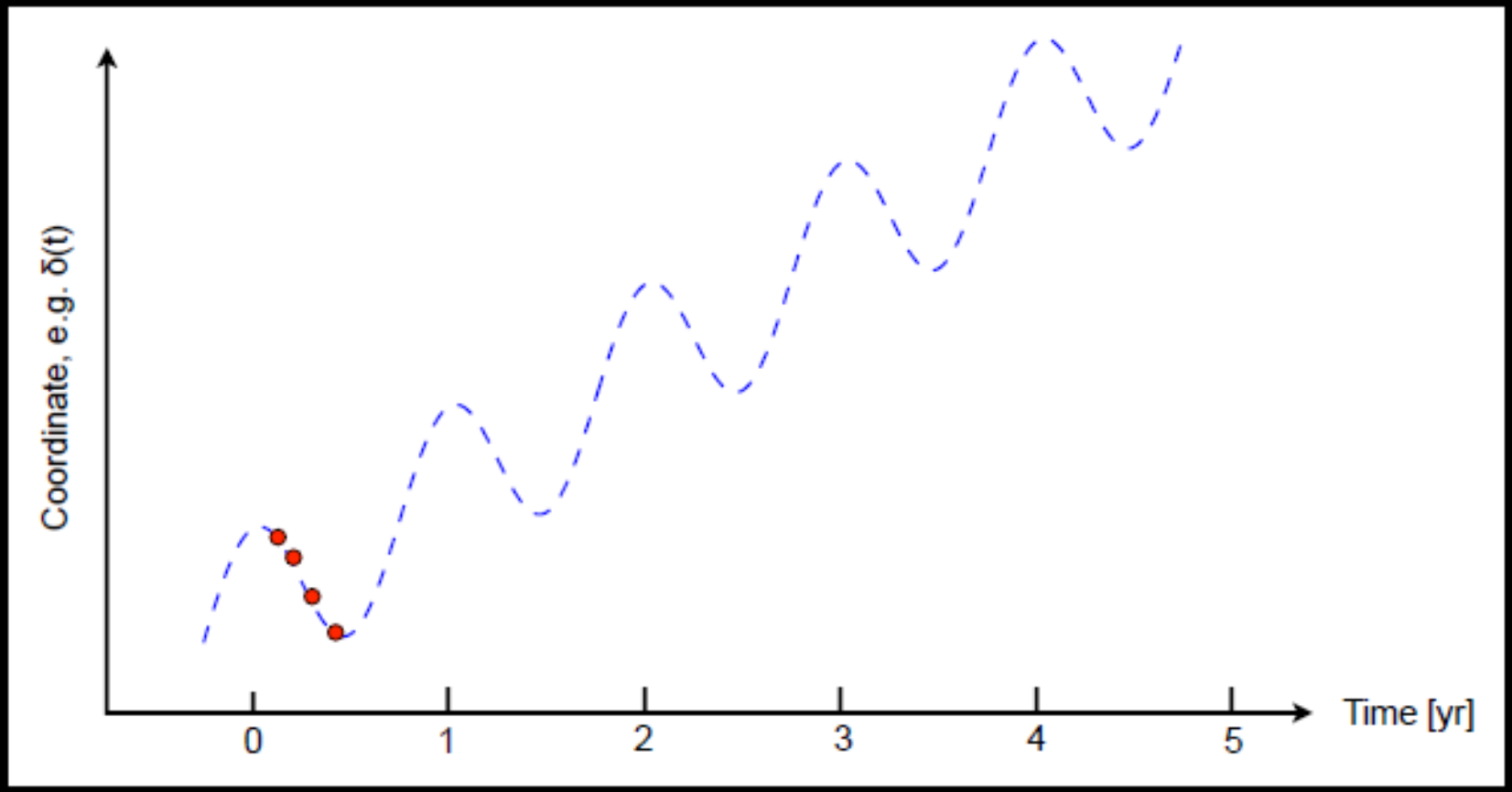
Gaia observations over 5 yr ⇒ pos, par, p.m.



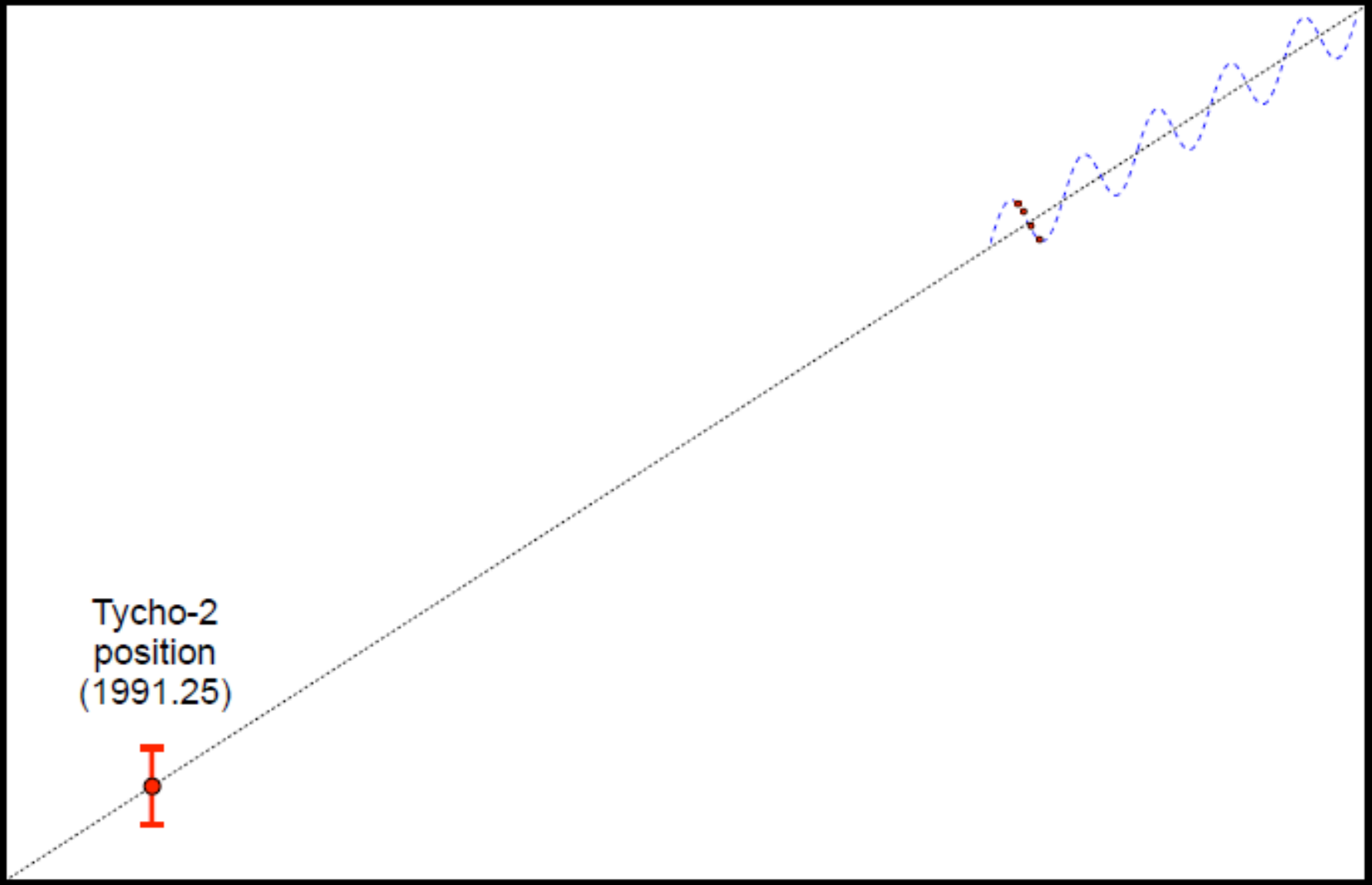
Gaia observations over 1 yr ⇒ marginal



$\mu - \varpi$ degeneracy for <1 yr observations



Tycho-2 position lifts the degeneracy



Secondary sources

- Only mean positions at epoch 2015.0
  - No proper motion or parallax
- This kind of solution is used in Gaia DR1
- Also needed in future releases
  - E.g. for faint stars with very few detections

Secondary source solutions

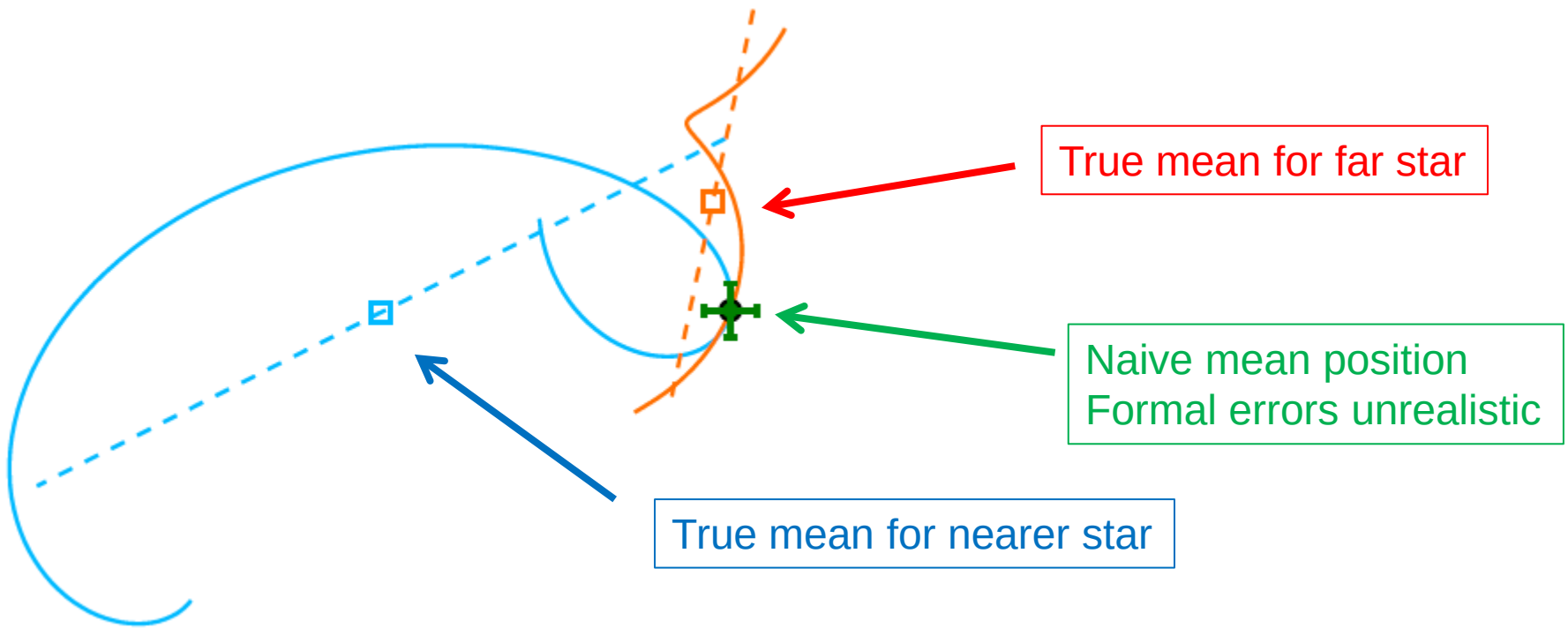


Figure: Lindegren & Michalik

- Solution: introduce realistic priors for proper motion and parallax
- See Michalik et al 2015, A&A 583, A68

TGAS proper motions

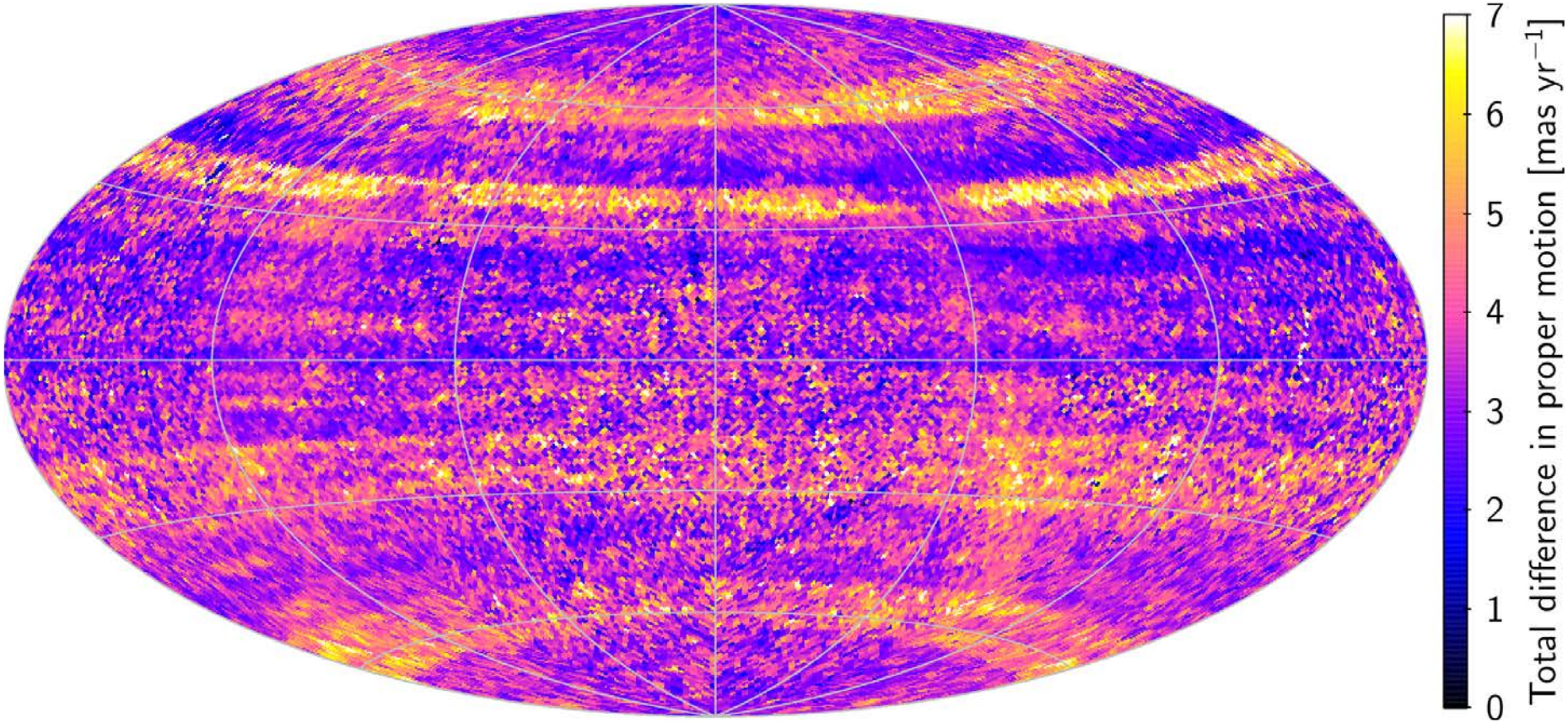
- Uses Hipparcos and Tycho-2 **positions** as priors
  - **Independent** of Hipparcos parallaxes
  - **Independent** of Hipparcos and Tycho-2 proper motions
- Proper motions are absolute at the ±0.03 mas/yr level
  - HIP has a rotation of 0.24 mas/yr w.r.t. Gaia DR1
- Precison
  - 0.06-0.10 mas/yr level for Hipparcos stars
  - 1-2 mas/yr for Tycho-2 stars

Tycho-2 proper motions

- Tycho-2 proper motions
  - Tycho observations, ~ 1991
  - Astrographic Catalogue
    - epoch ~ 1890-1950
  - Other ground based catalogues

Greenwich	+90°	+65°
Rom	+64°	+55°
Catania	+54°	+47°
Helsinki	+46°	+40°
Potsdam	+39°	+32°
Oxford	+31°	+25°
Paris	+24°	+18°
Bordeaux	+17°	+11°
Toulouse	+10°	+5°
Algier	+4°	-2°
San Fernando	-3°	-9°
Tacubaya	-10°	-16°
Santiago	-17°	-23°
La Plata	-24°	-31°
Rio	-32°	-40°
Kapstadt	-41°	-51°
Sydney	-52°	-64°
Melbourne	-65°	-90°

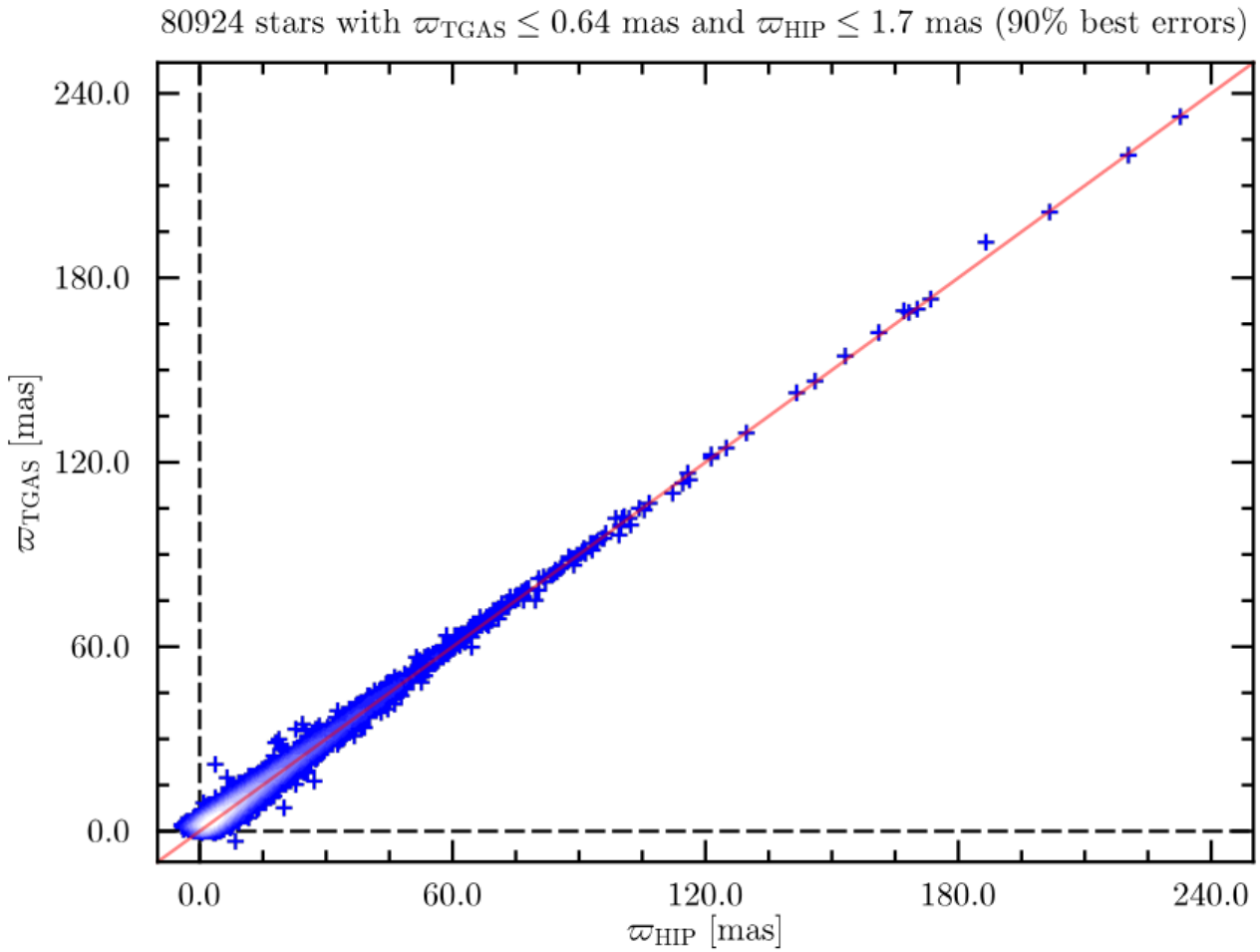
TGAS-Tyc2 proper motion difference



Median differences *after* rotating Tycho-2 pm.s to the Gaia frame

Lindegren et al. 2016

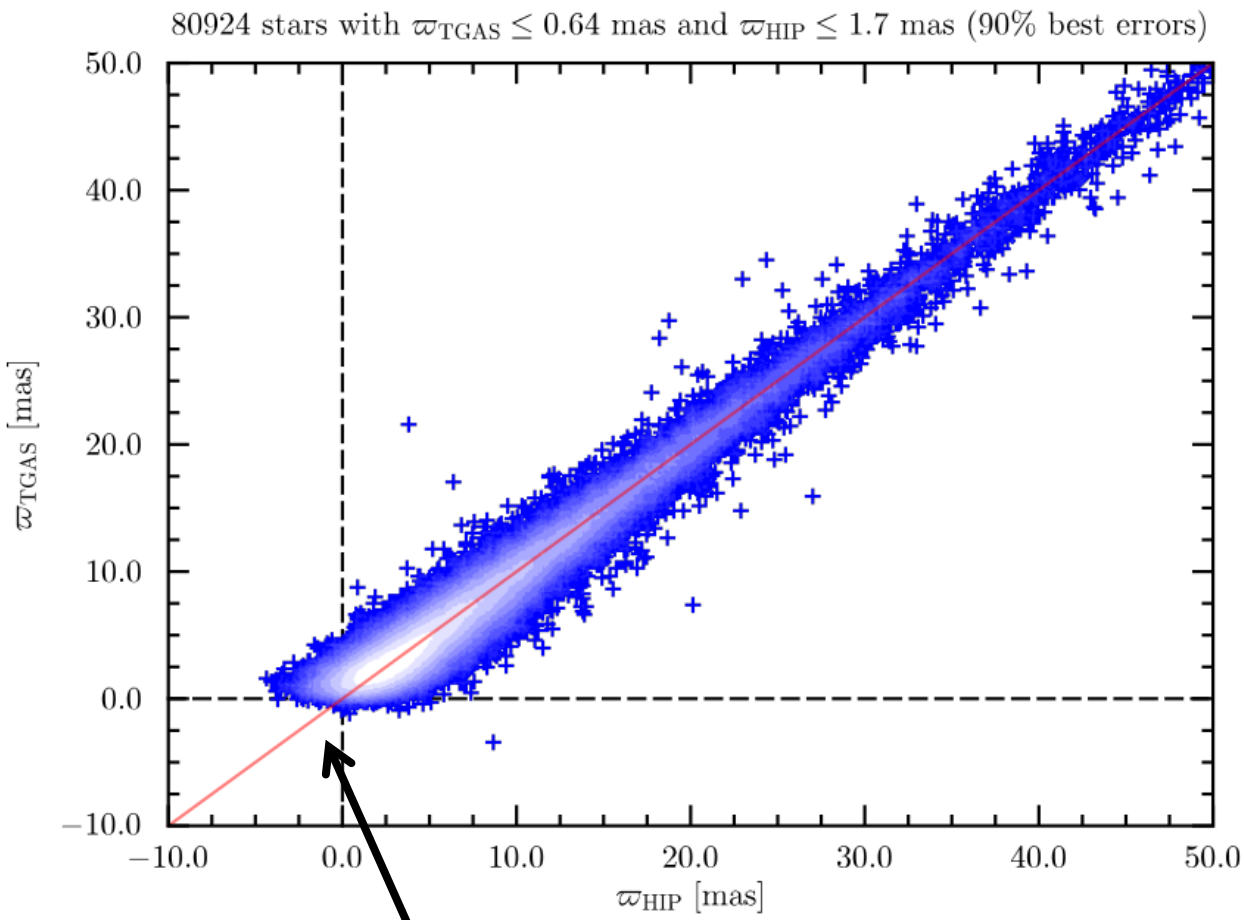
Parallaxes. TGAS vs Hipparcos



- 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

Slide by A. Brown

Parallaxes. TGAS vs Hipparcos



- TGAS and Hipparcos parallaxes are independent!
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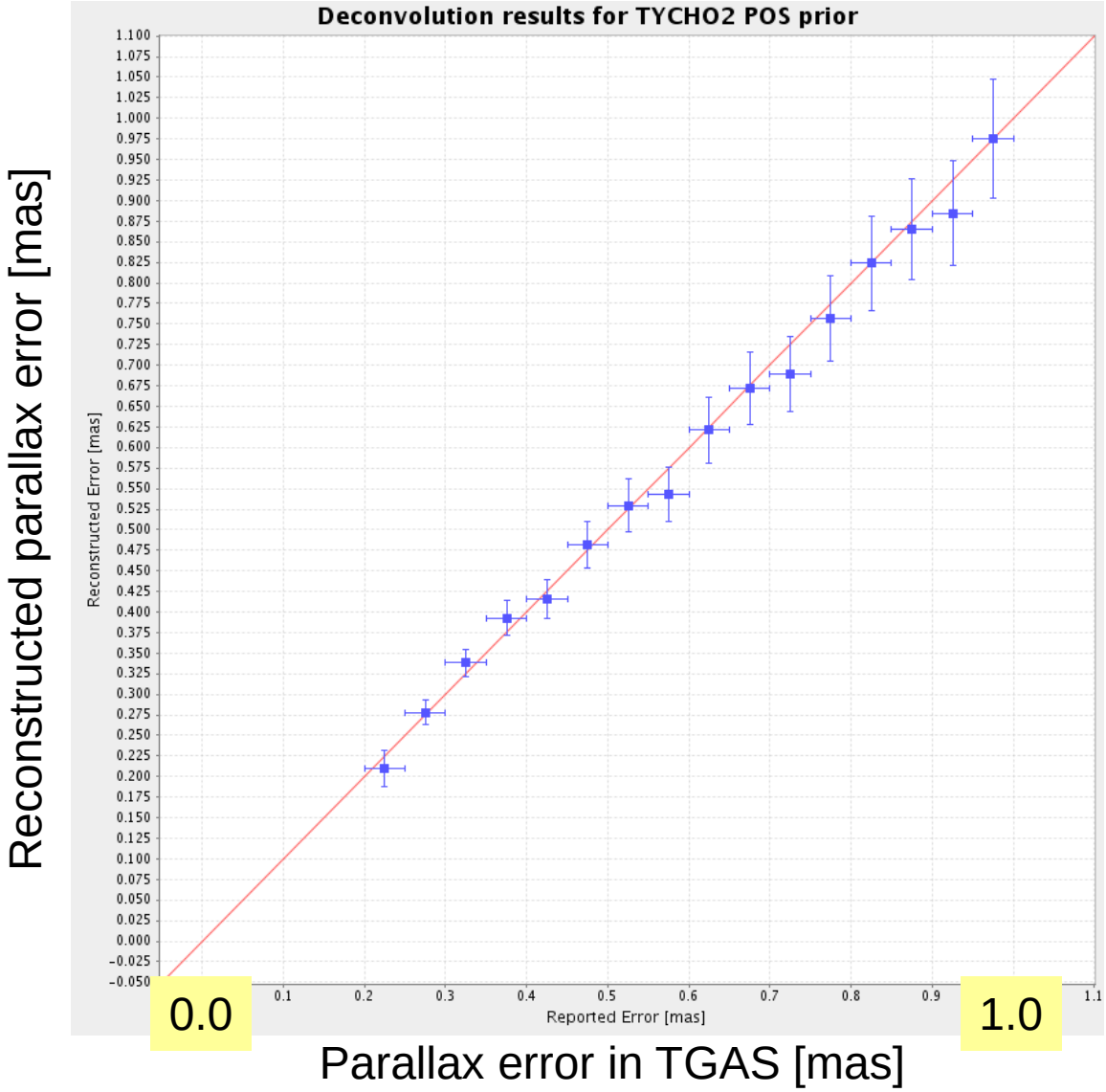
Much smaller negative tail in TGAS

Slide by A. Brown

Parallax Error Accuracy



- Deconvolving parallax distribution gives parallax errors consistent with reported errors

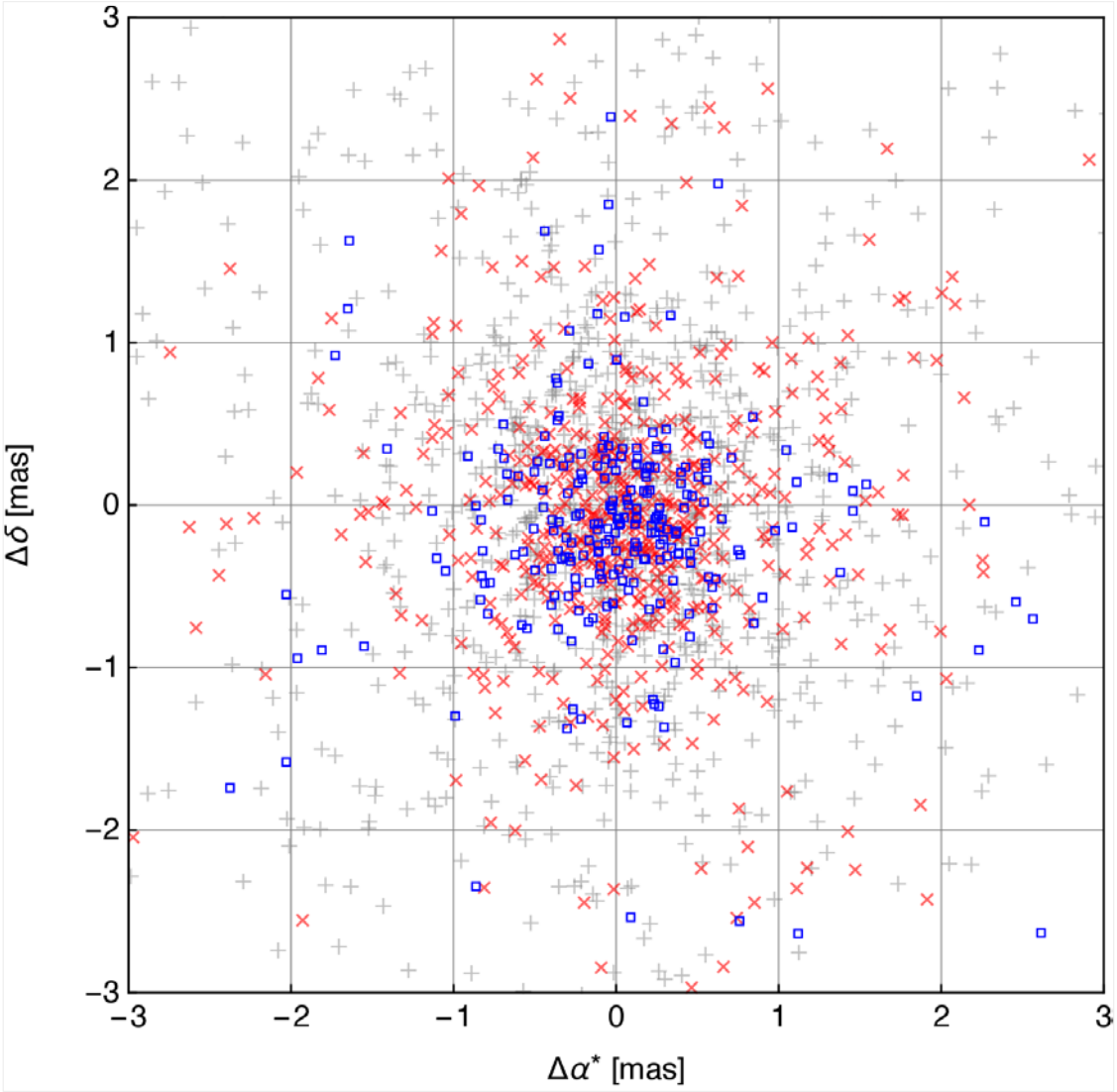
Arenou et al 2016

Special QSO solution

- 135 000 QSOs
  - Mostly in the northern sky
- Proper motion priors: 0±0.01 mas/yr
  - NB much smaller than in the general DR1 approach
- Solve position & parallax
  - Check on parallax zero point
  - 2191 QSOs used for alignment with ICRF2

HIP		Gaia
±0.6 mas	±0.03 mas/yr	±0.04 mas
1991.25		2015.0

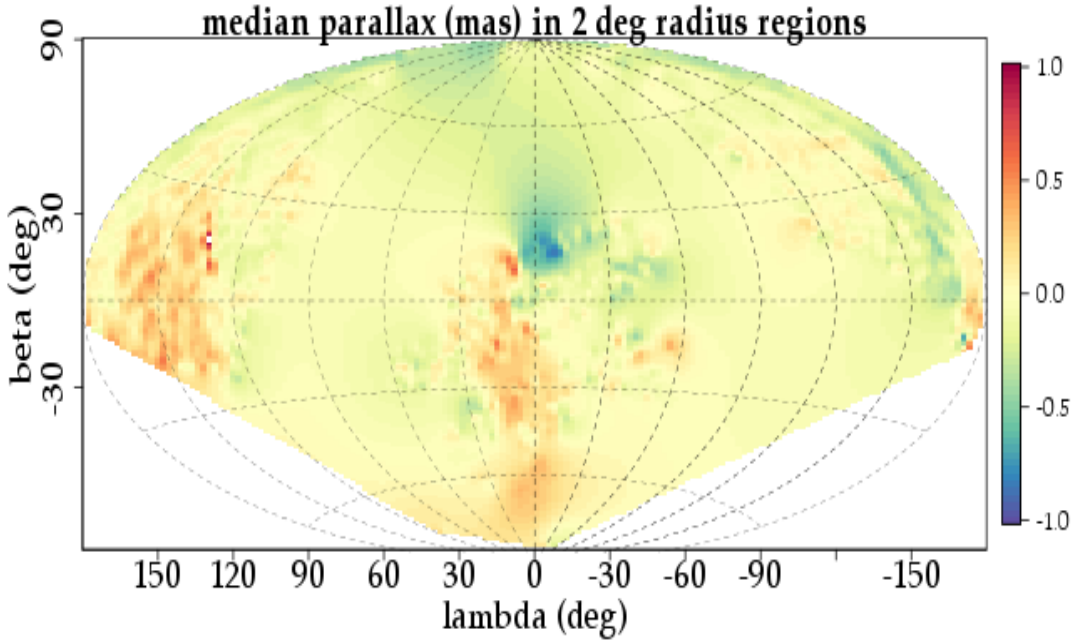
Gaia – ICRF2

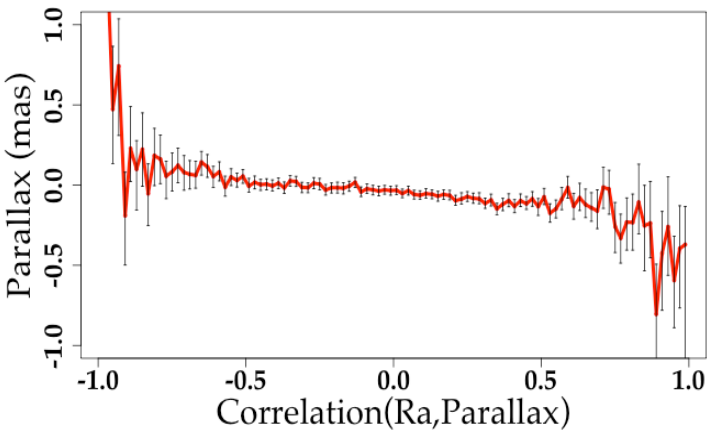


Slight negative shift

Mignard et al. 2016

Parallax errors from QSO

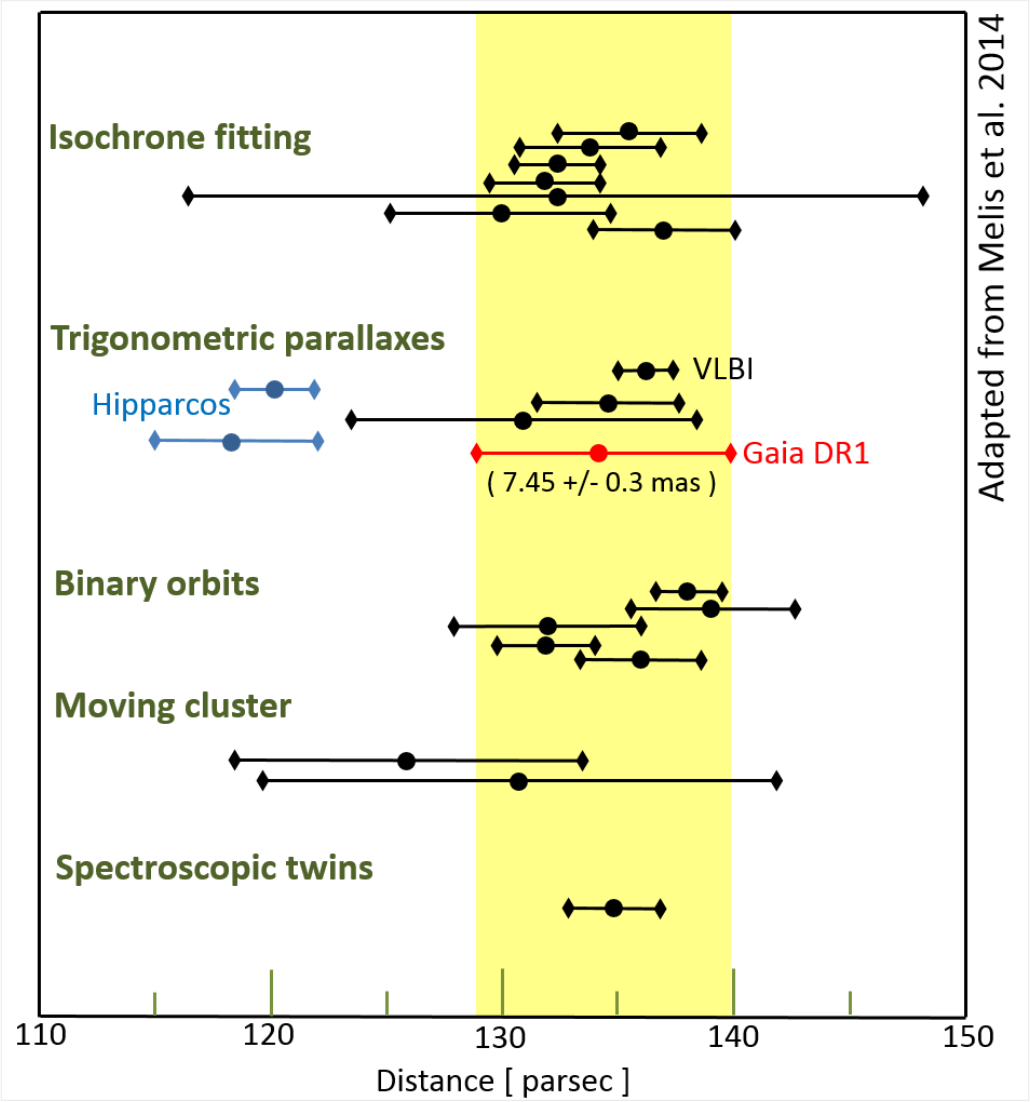




Arenou et al 2016

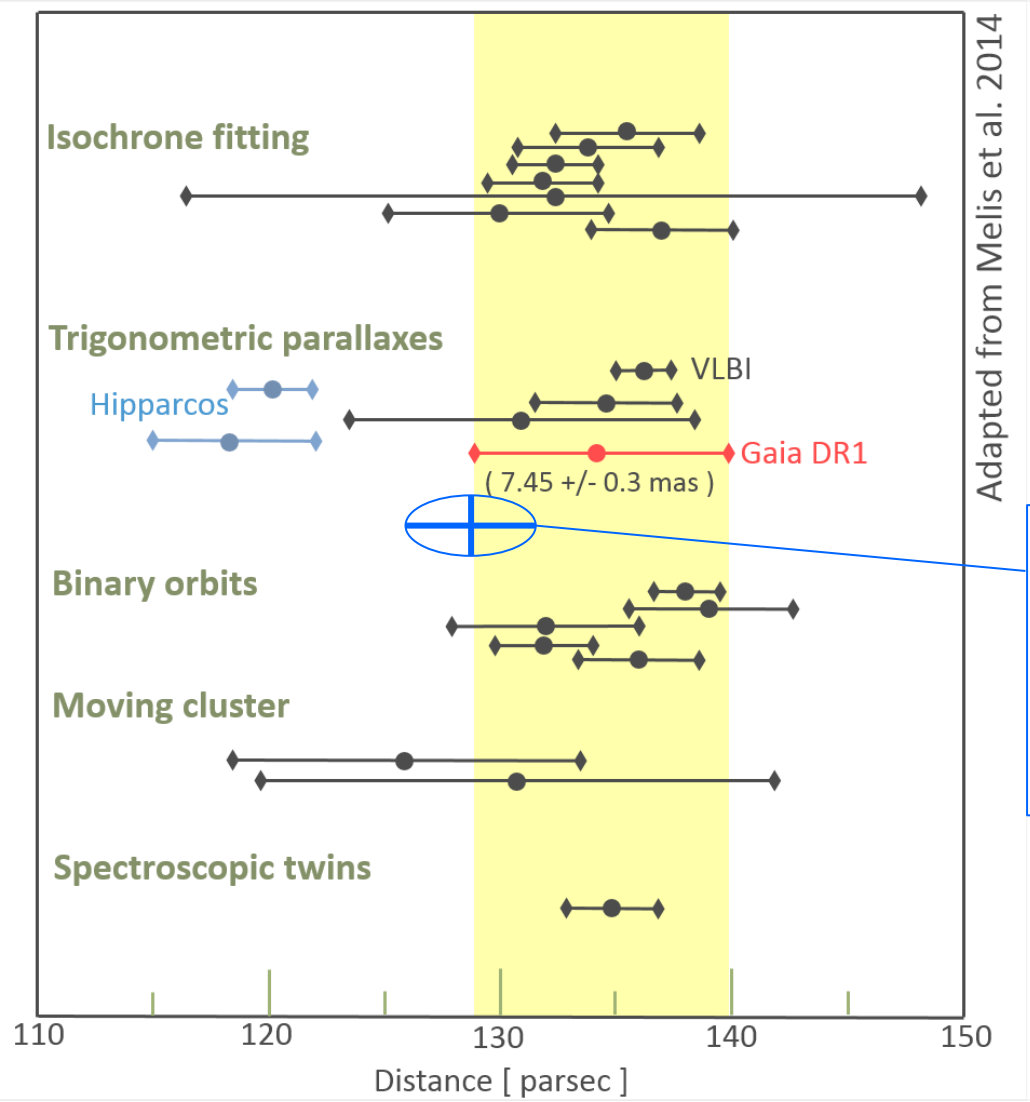
- Large scale variations: 90% of QSO sky has |median(ϖ)| < 0.3 mas
- Always assume systematic parallax errors of ±0.3 mas
- Some extreme regions may reach ±1 mas systematics
- Sky average value (QSOs global zero point): -0.04 mas

Pleiades discrepancy Hipparcos-Gaia



Brown et al 2016

Pleiades discrepancy Hipparcos-Gaia



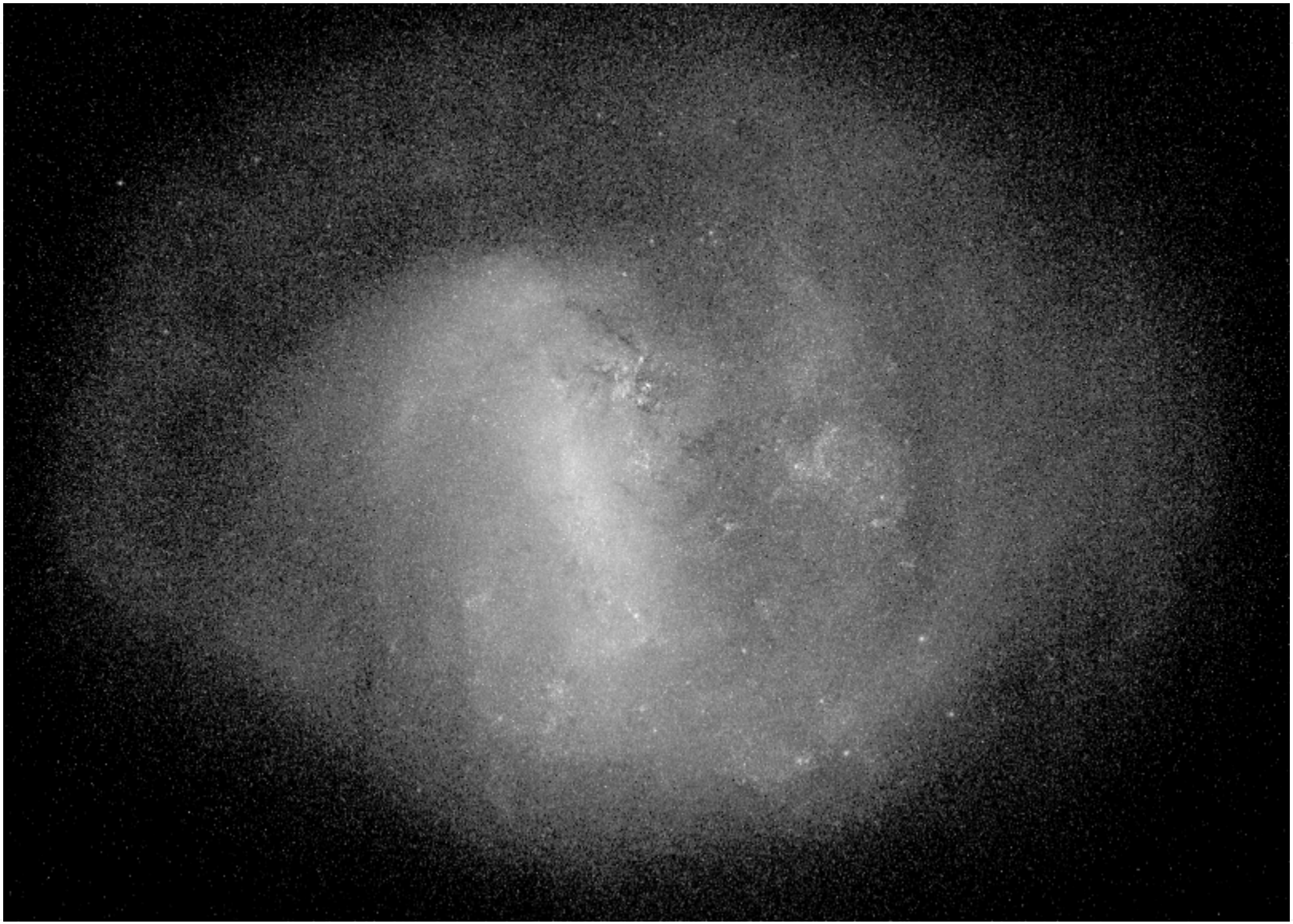
Makarov 2002
AJ 124,3299
Only using
Hipparcos
residuals

Brown et al 2016

Completeness of Gaia DR1

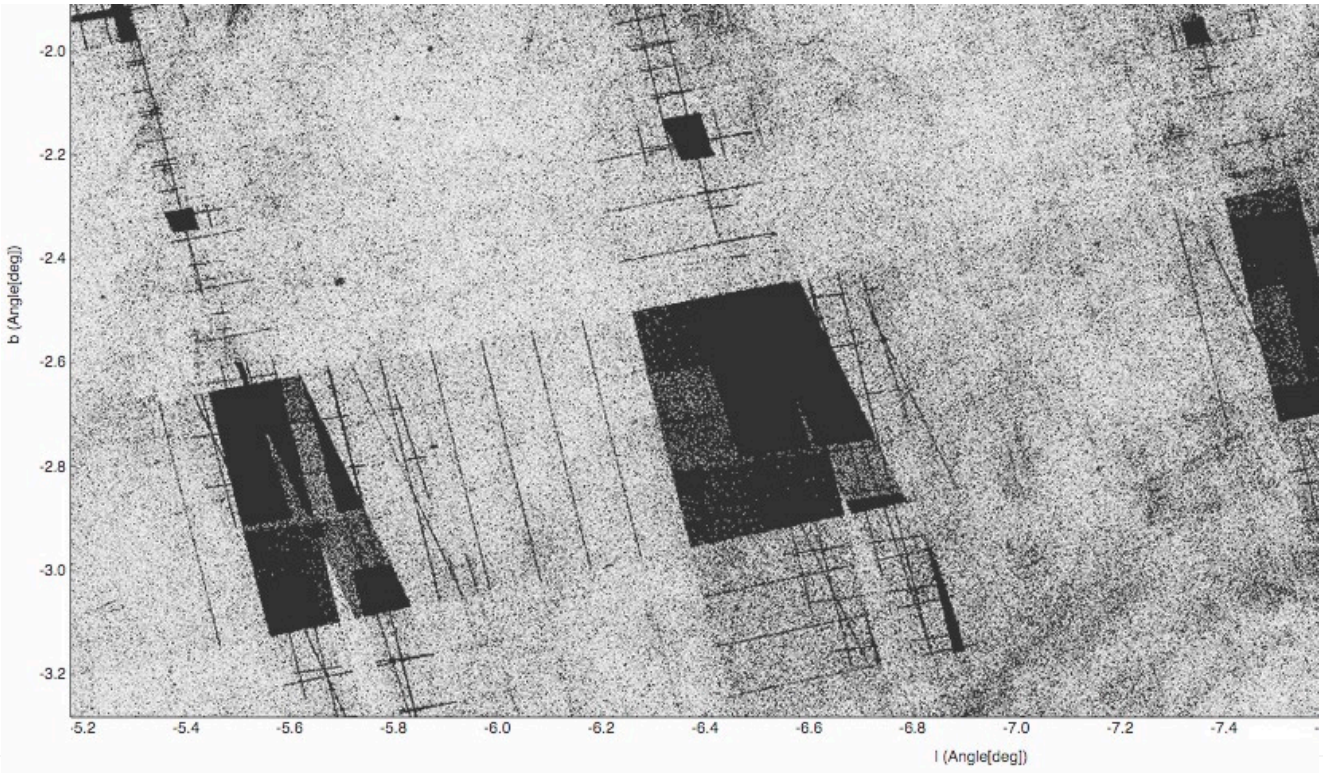
- Gaia DR1 is a **first, preliminary** data release
- It has several deficiencies
  - To be improved in future releases

LMC sources in Gaia DR1



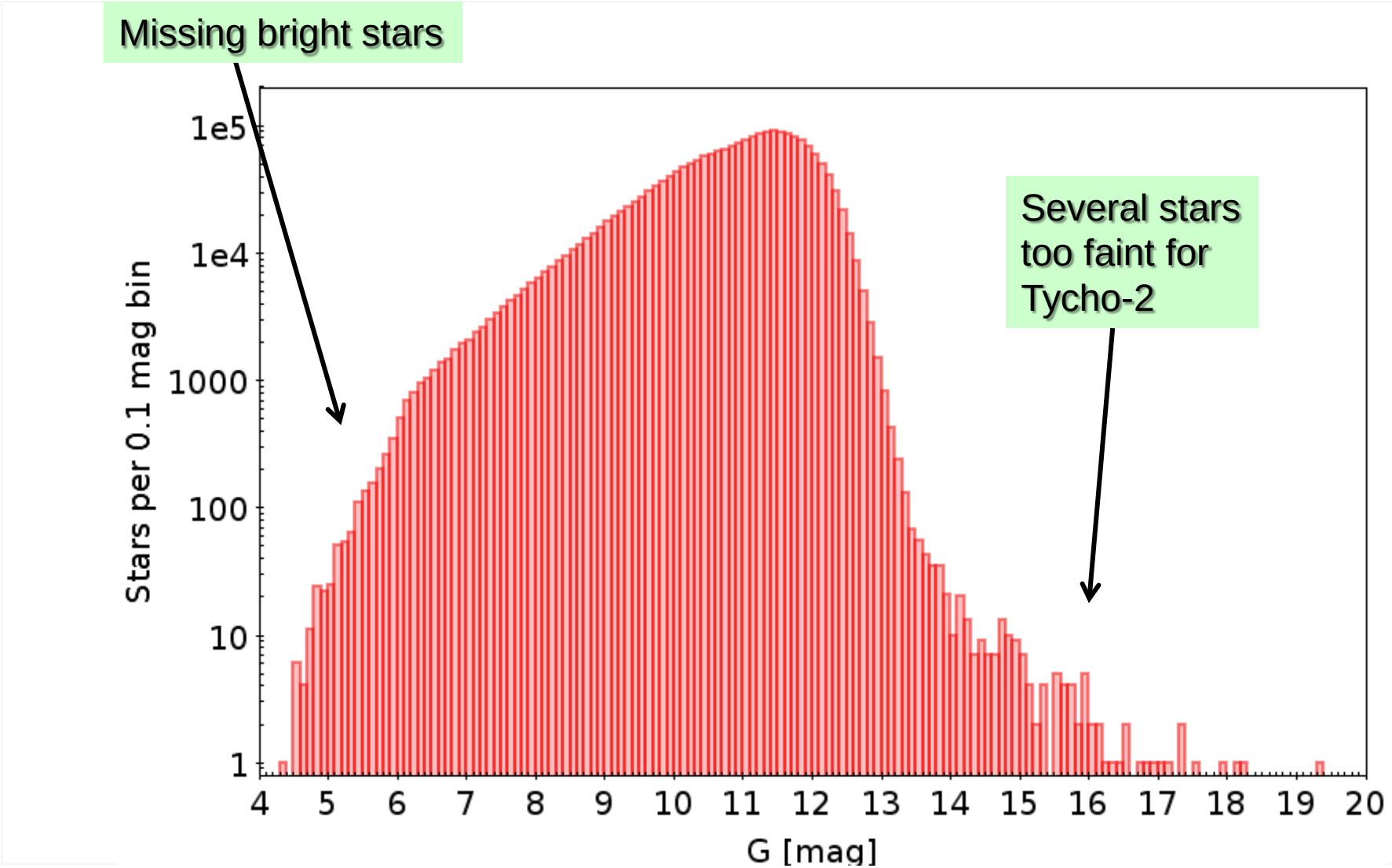
Completeness of Gaia DR1

- Holes in poorly scanned areas
- Faint stars missing in dense areas
- Stars often missing if they are bright, blue, red, or fast.

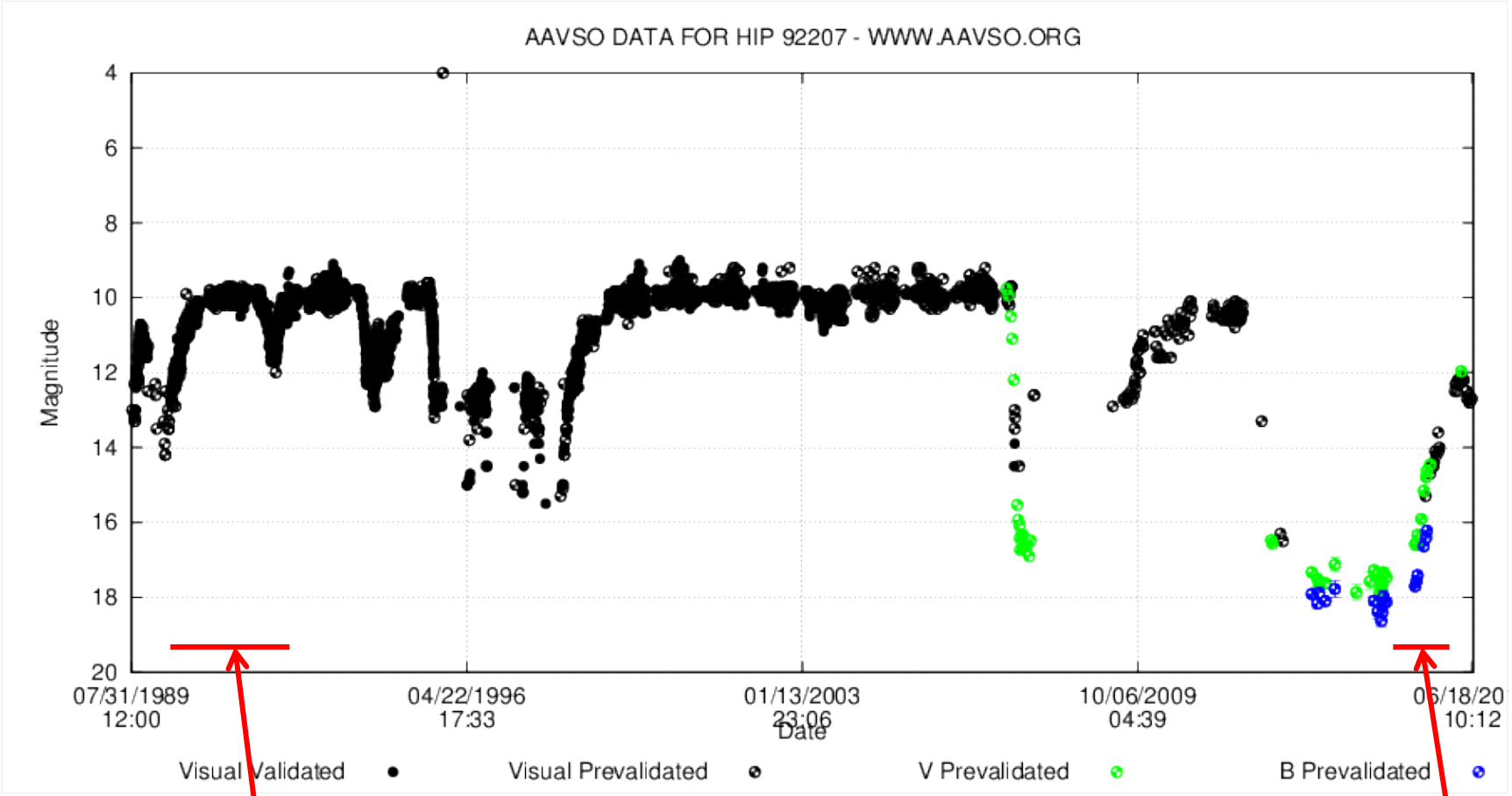


Arenou et al 2016

Completeness of TGAS



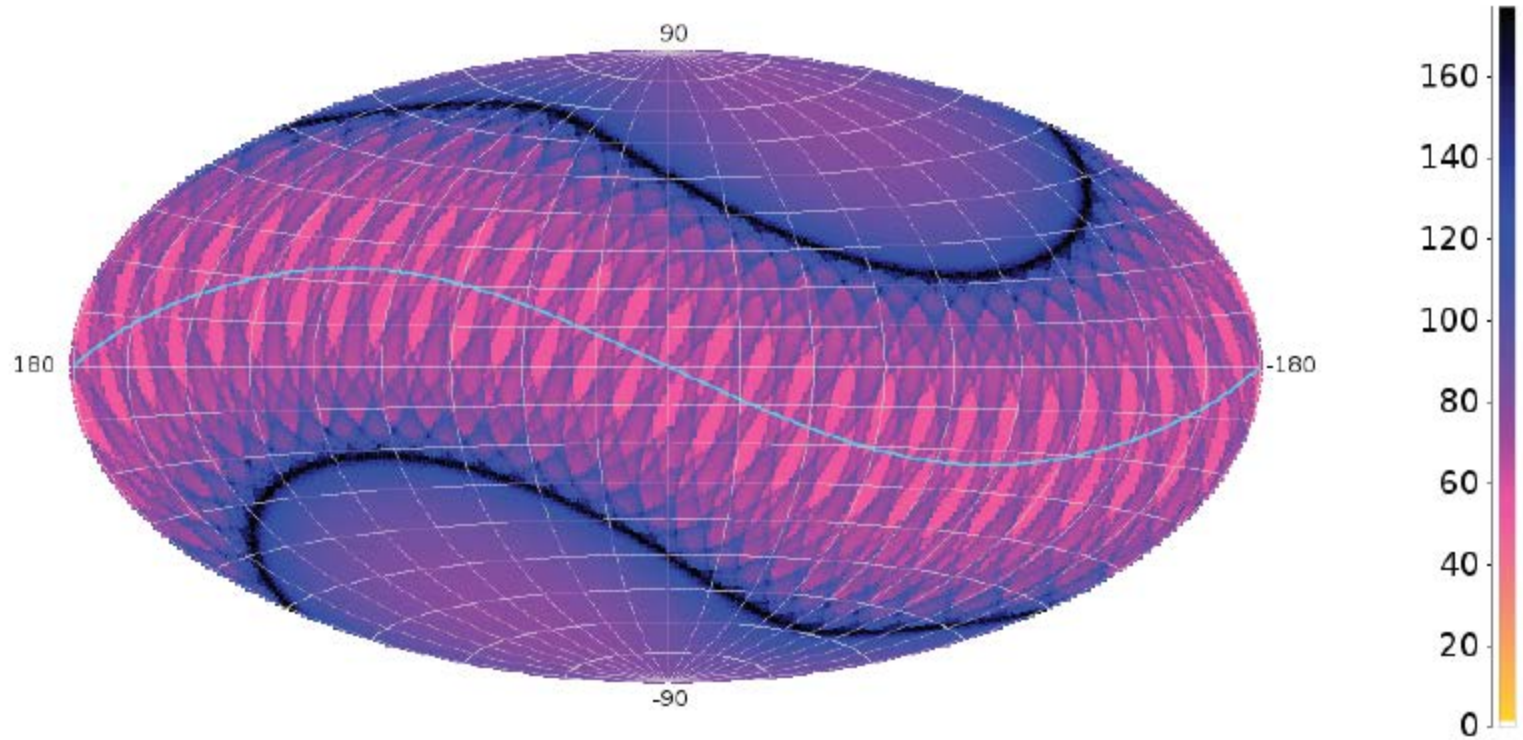
A very faint TGAS stars



Tycho epoch

Gaia epoch

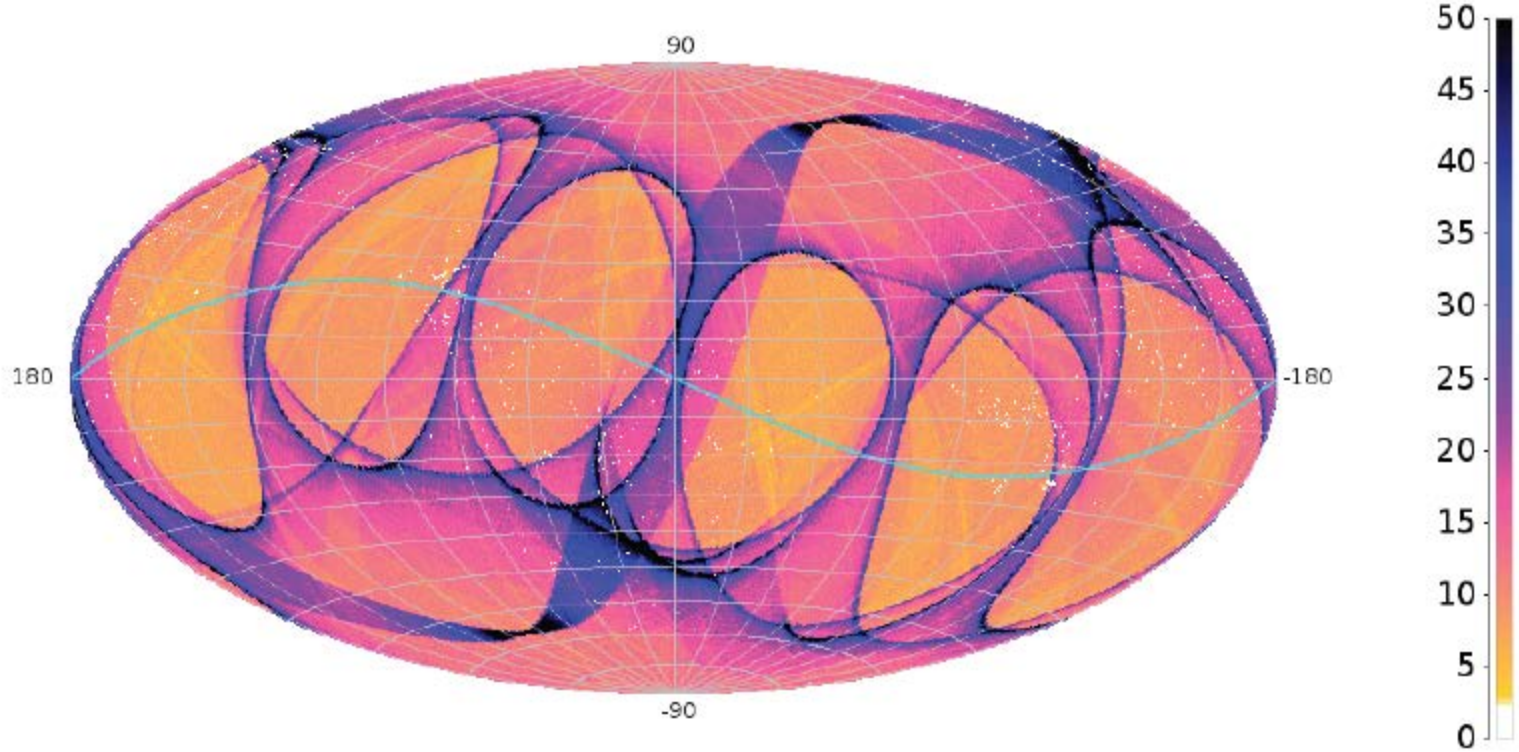
Five year sky coverage



Number of transits in a nominal 5 year interval: smooth coverage, 80 transits on average

Figure by D Michalik

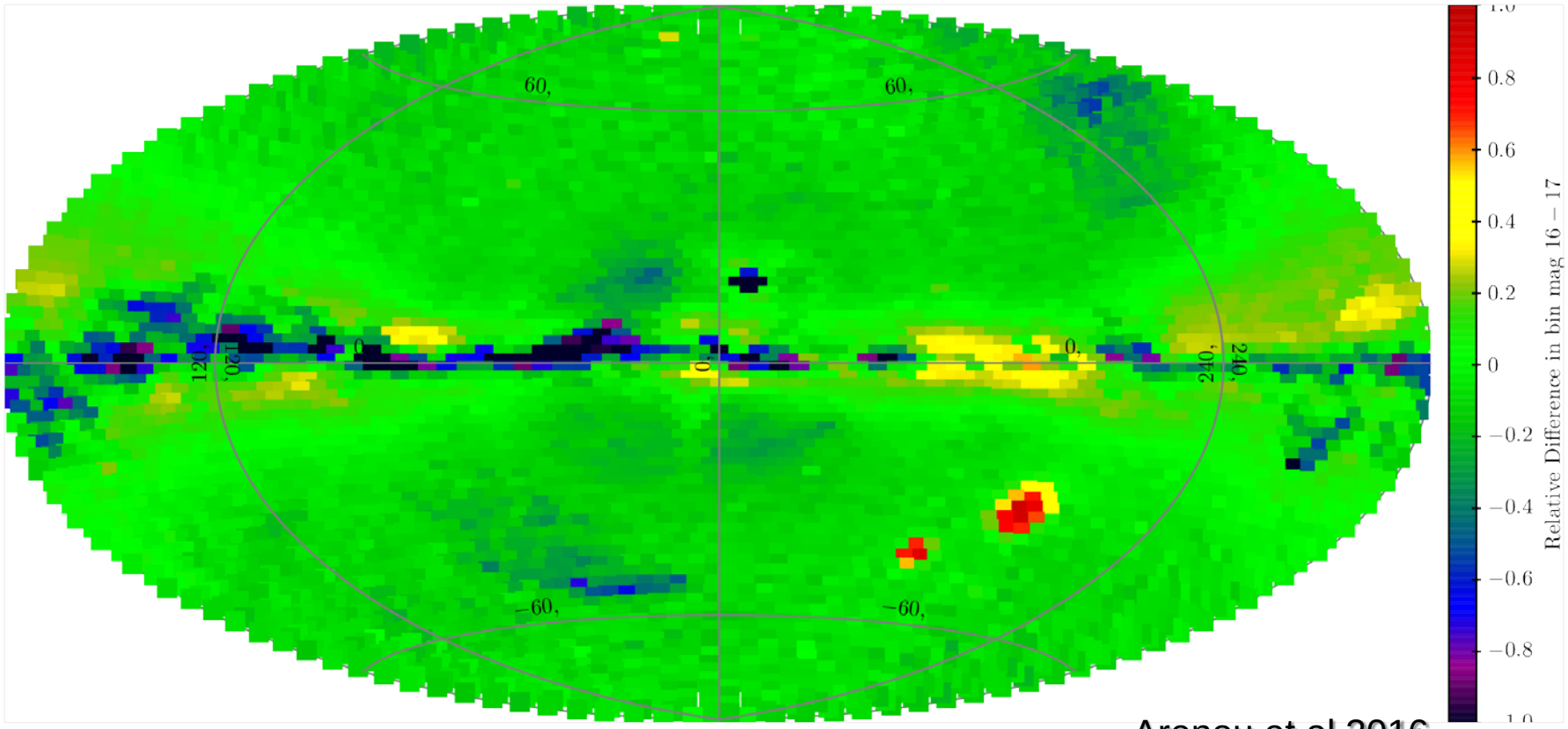
14 month sky coverage



Number of transits during the 14 months for Gaia DR1: some areas are poorly observed

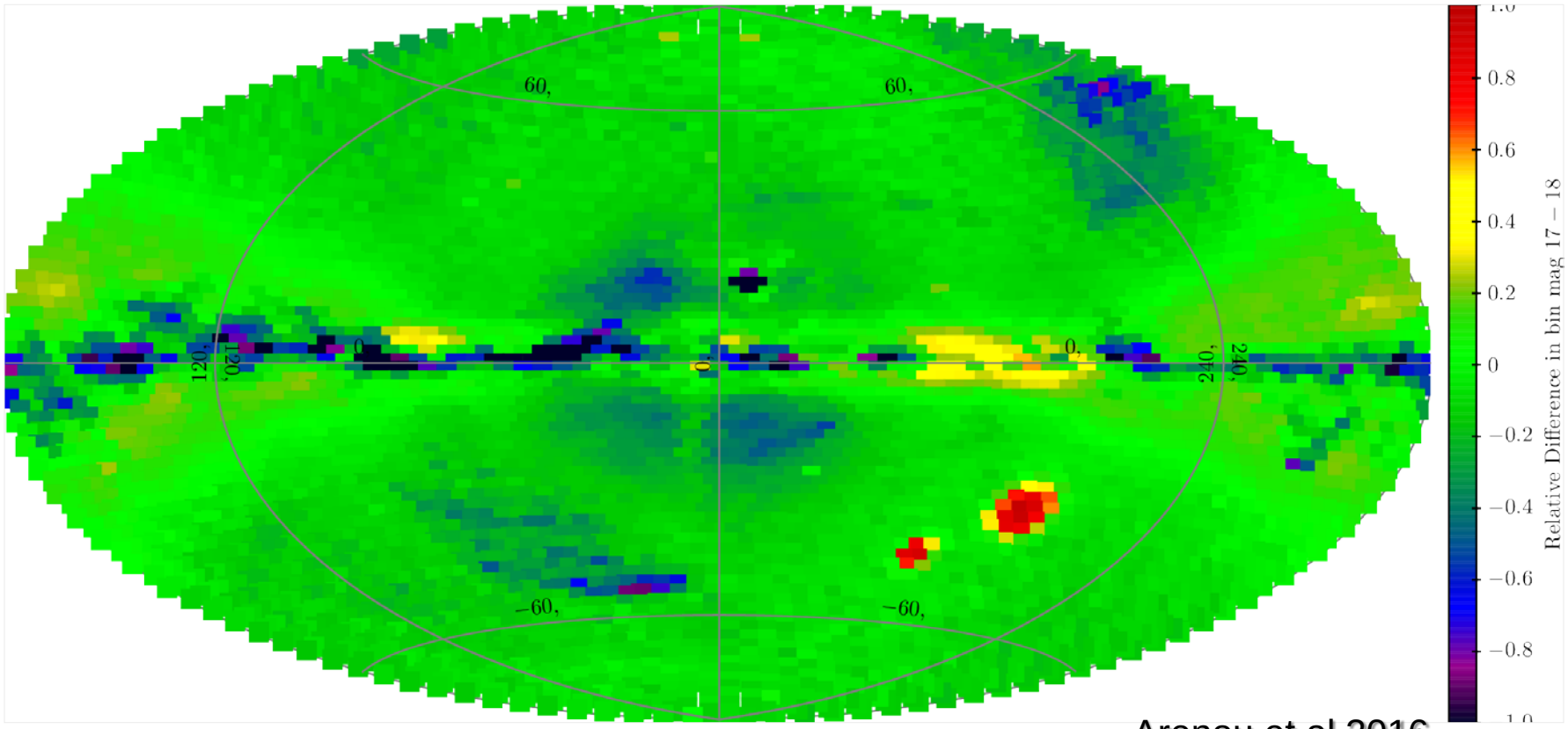
Figure by D Michalik

G 16-17 mag. Gaia relative to model



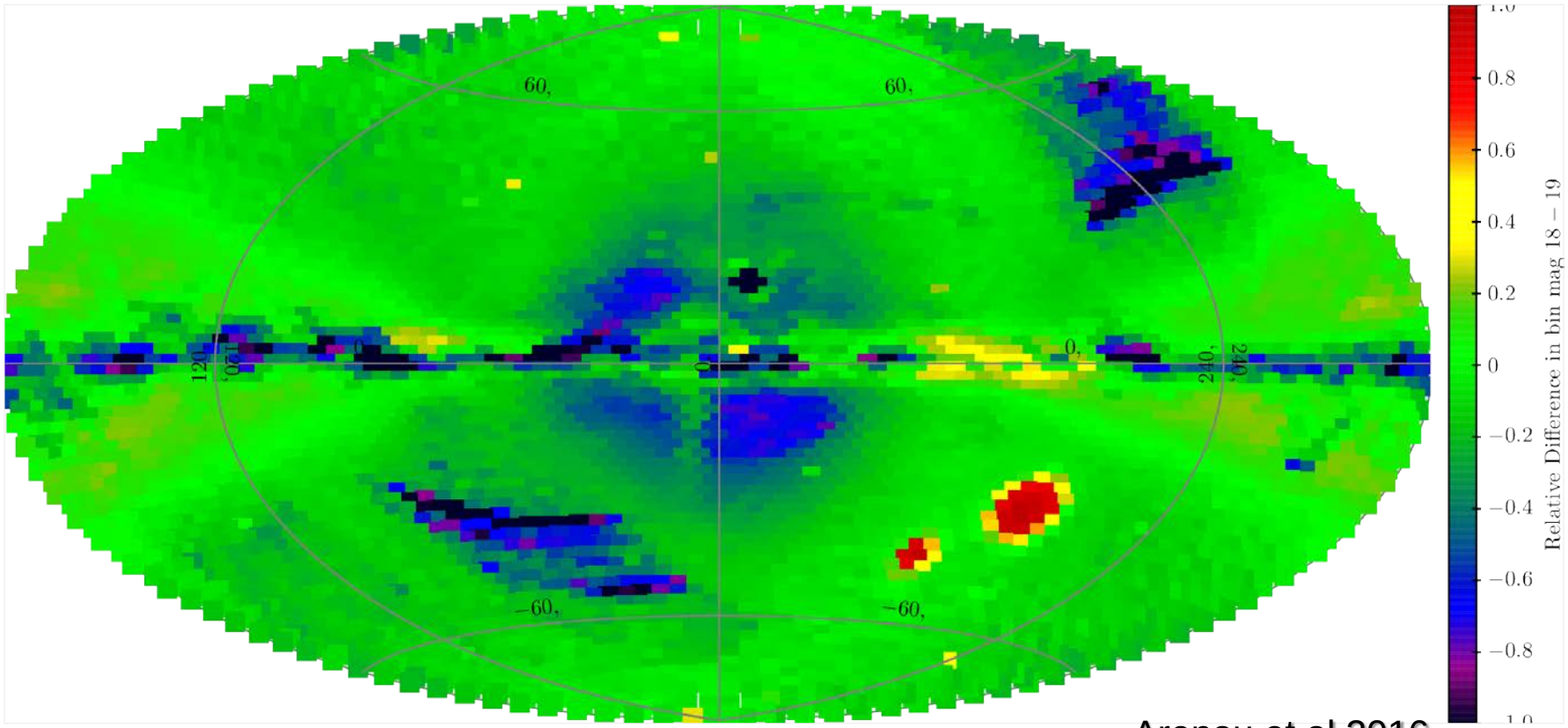
Arenou et al 2016

G 17-18 mag. Gaia relative to model



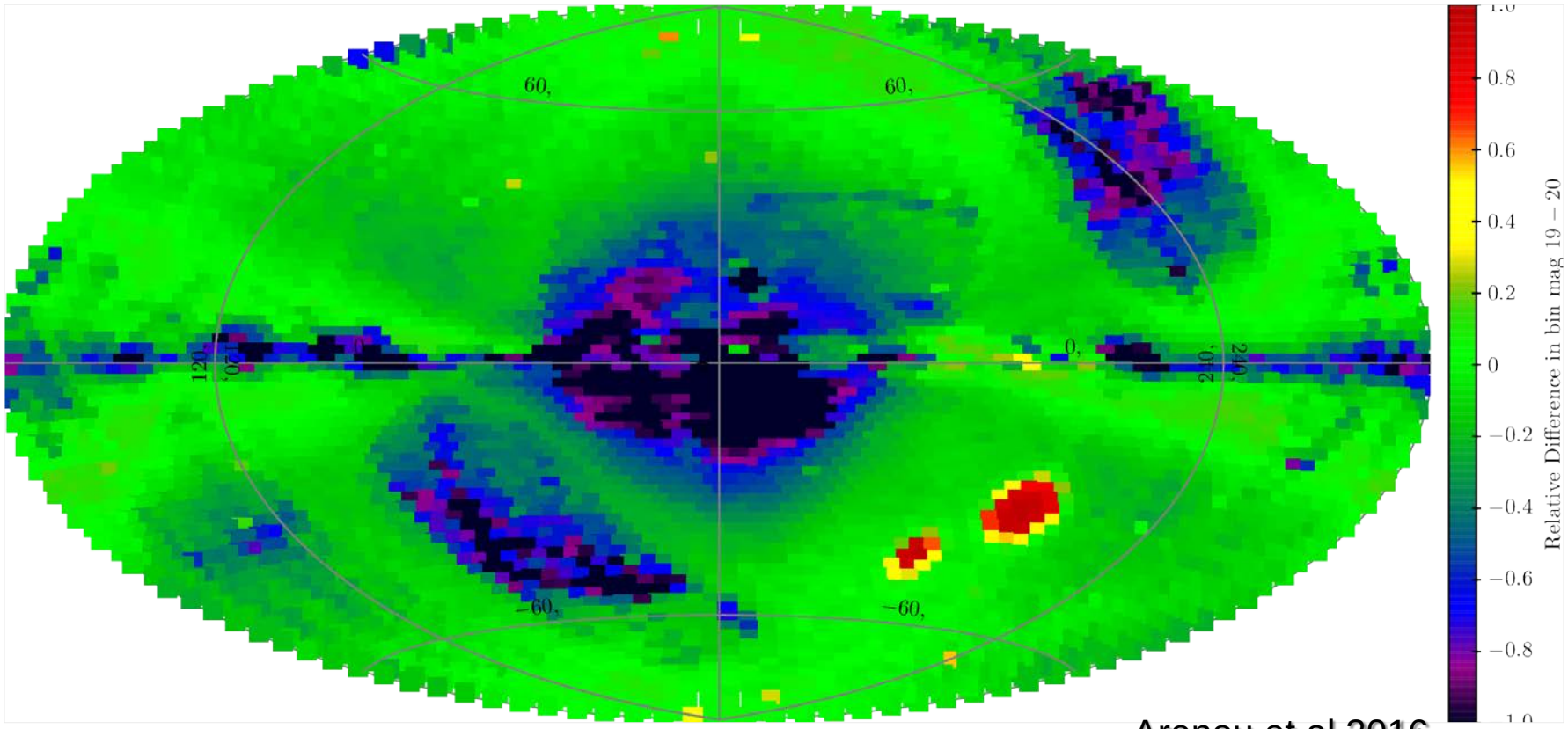
Arenou et al 2016

G 18-19 mag. Gaia relative to model



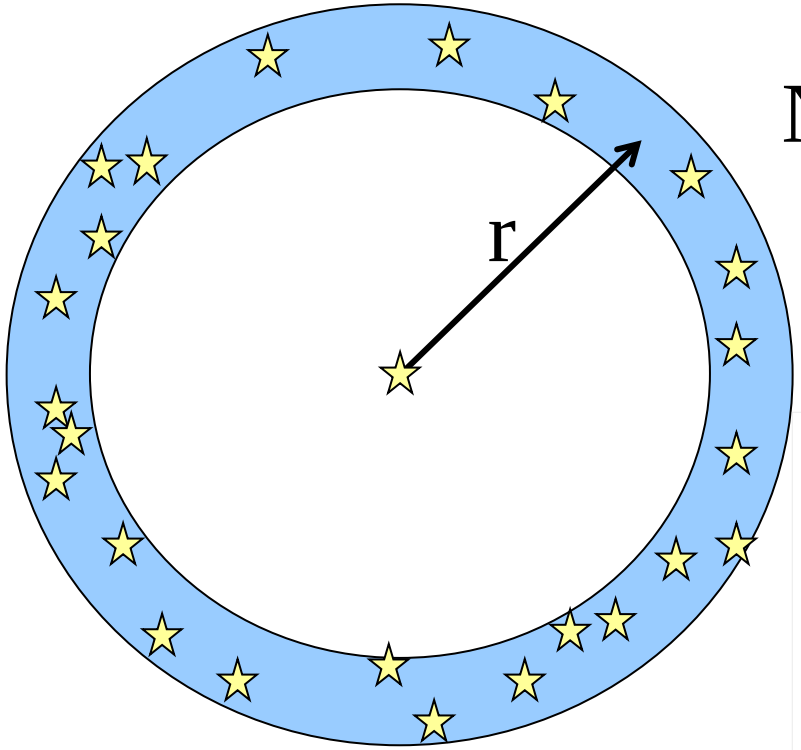
Arenou et al 2016

G 19-20 mag. Gaia relative to model



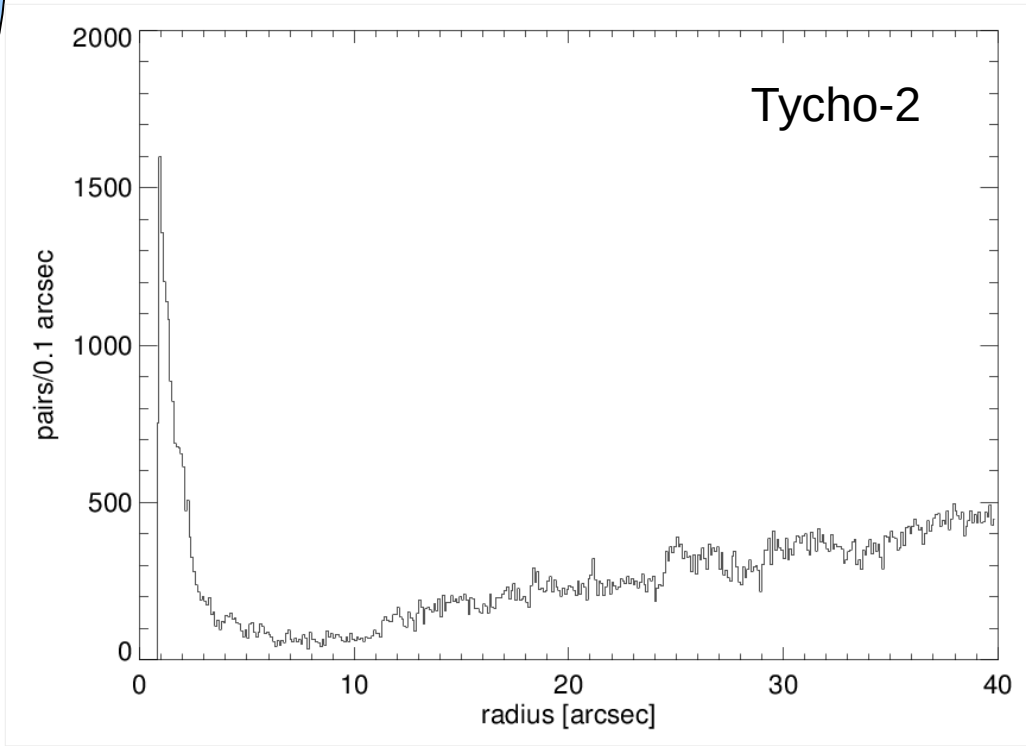
Arenou et al 2016

Completeness – neighbour distance

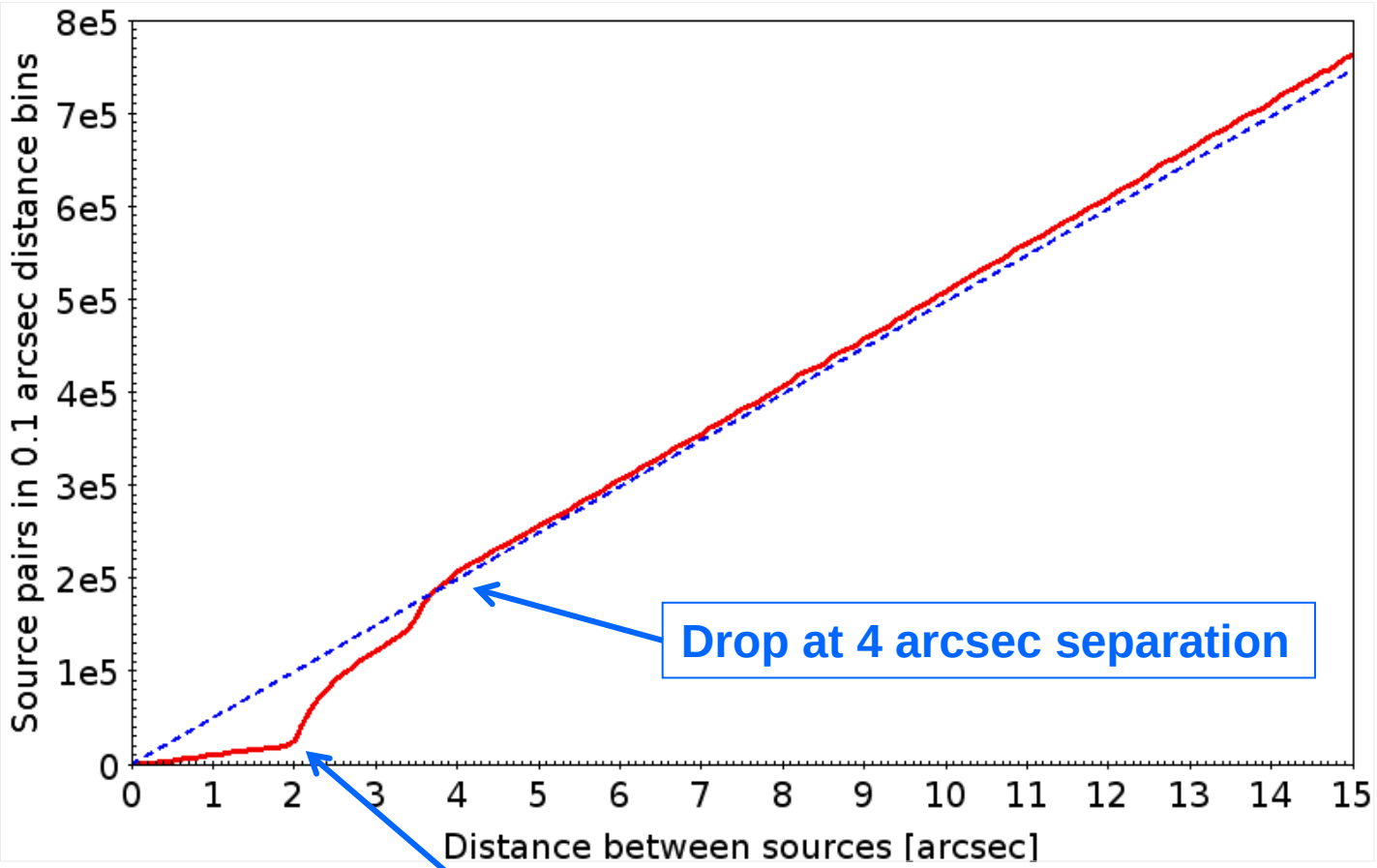


$$N = 2\,\pi\,r\,\delta_r\,\rho \;\sim\; r$$

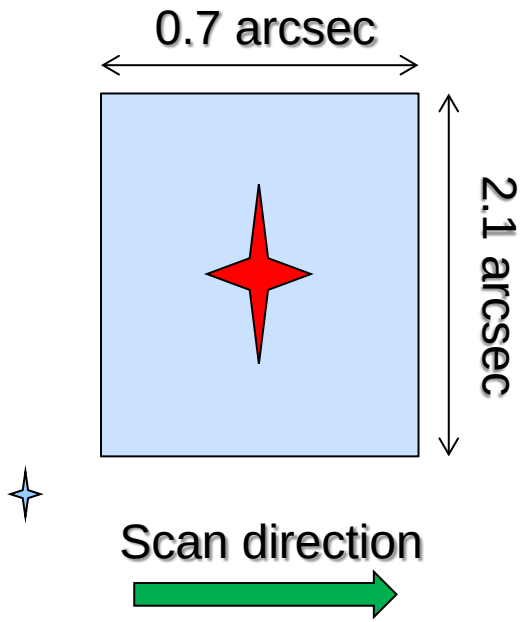
(random field stars)

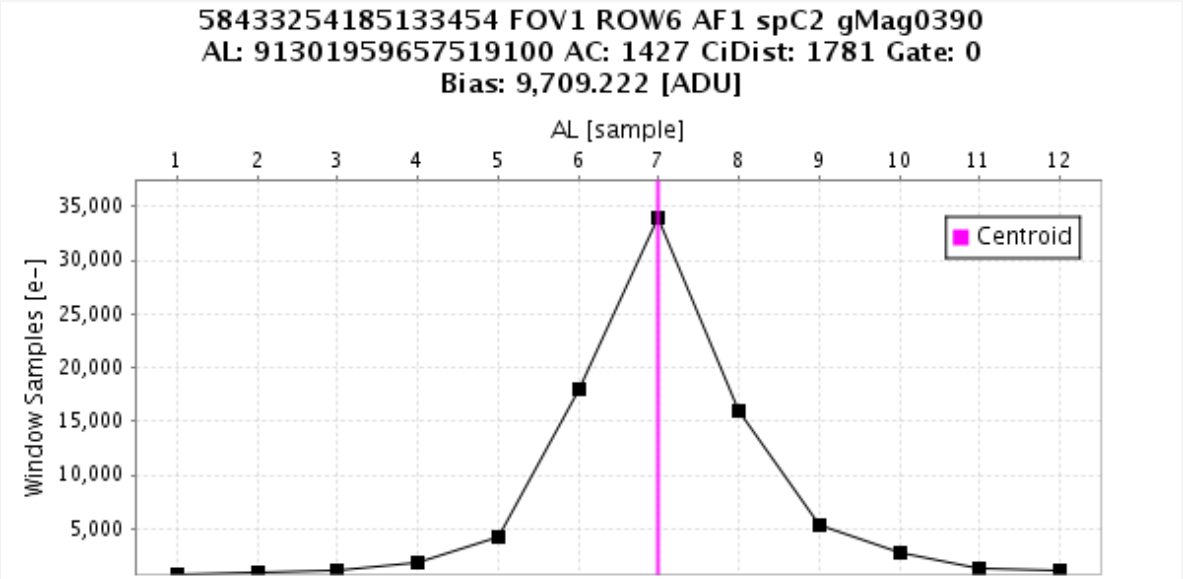


Neighbour distance – DR1 dense zone



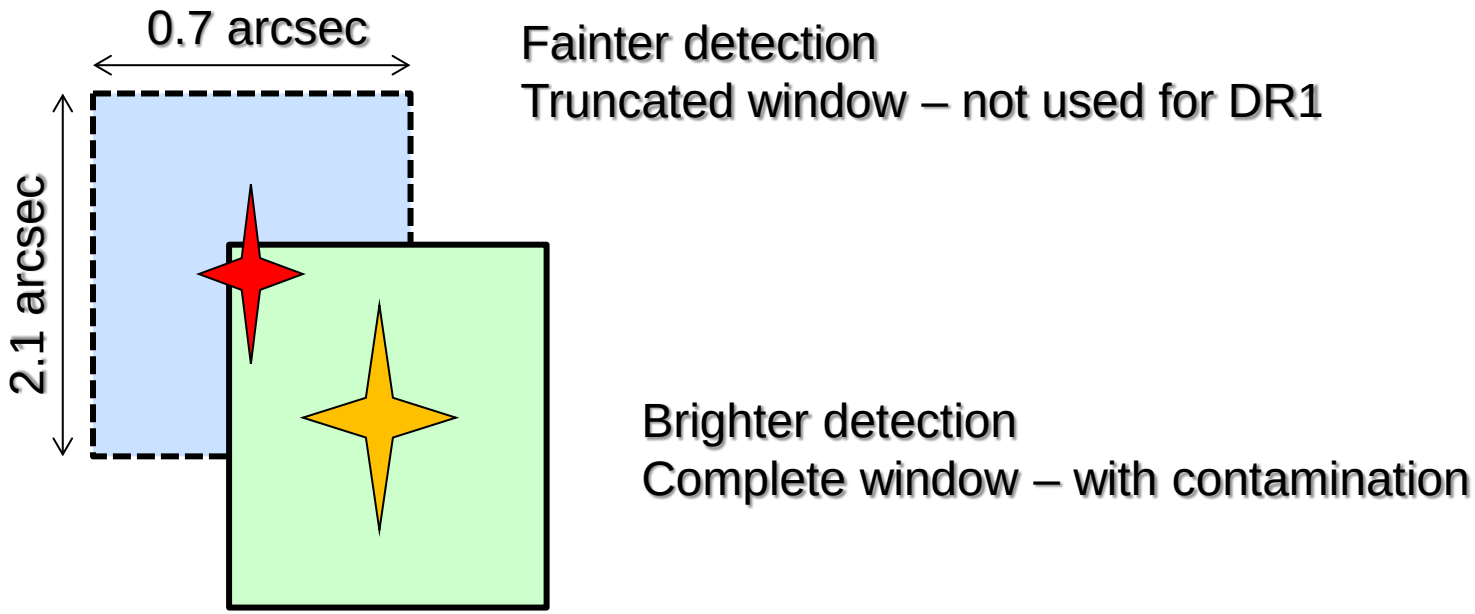
Windows read out around stars





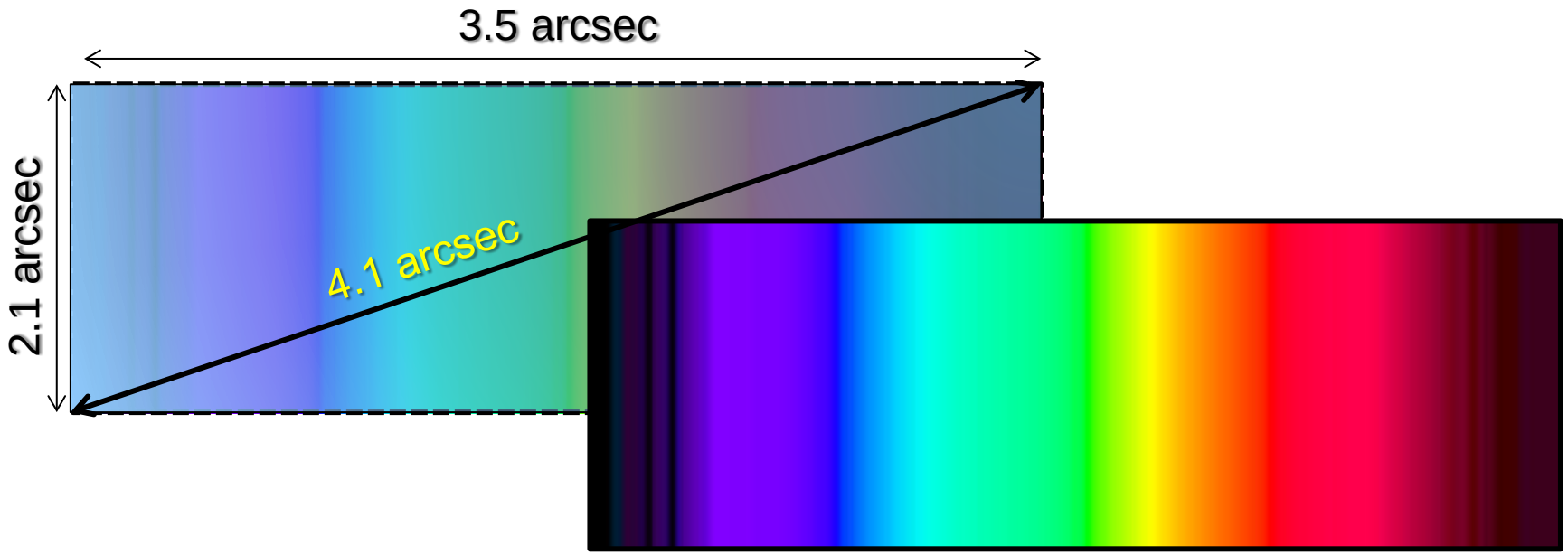
- Windows measure 12 x 12 pixels (typically)
- Pixels are binned on chip before reading
- We receive a string of 12 samples

Windows in case of conflict



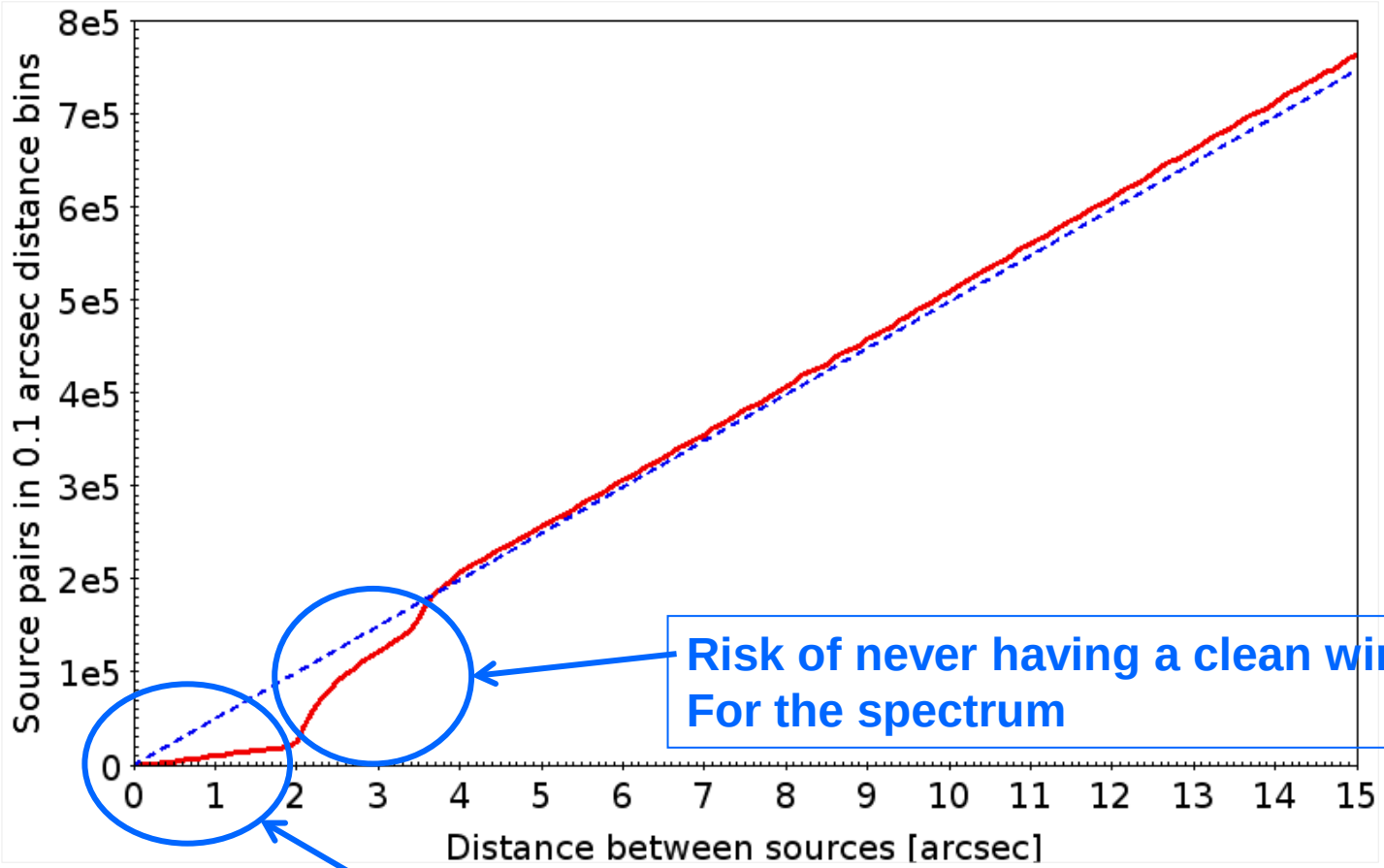
- Window for brighter detection is the winner
- Window for the fainter detection will lose
- Truncated windows are not used in Gaia DR1

Conflicts between spectra



- Window for brighter detection is the winner
- We need **at least one** good spectrum for a source
- Fainter source of a pair closer than 2″ is lost in DR1

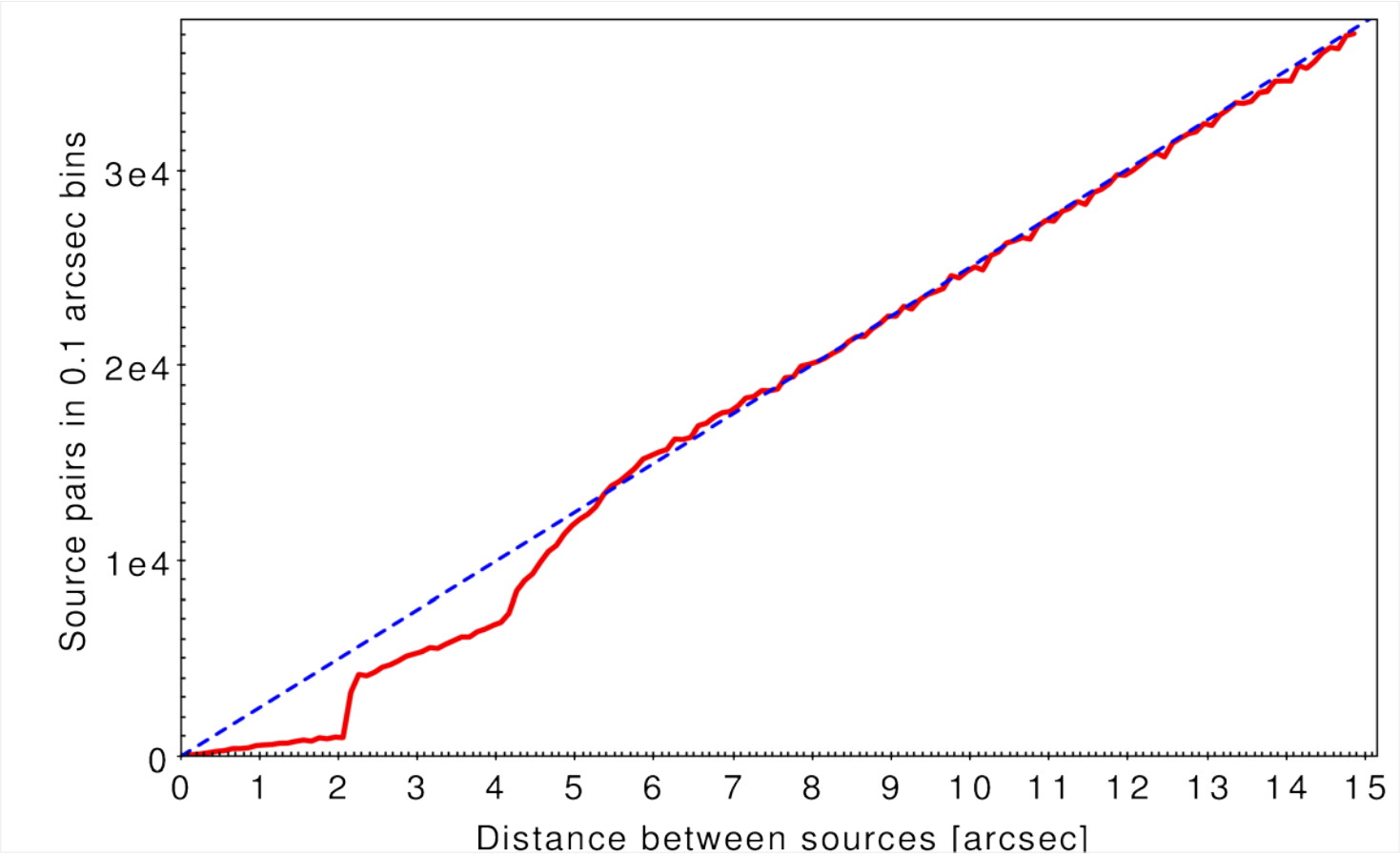
Neighbour distance – DR1 dense zone



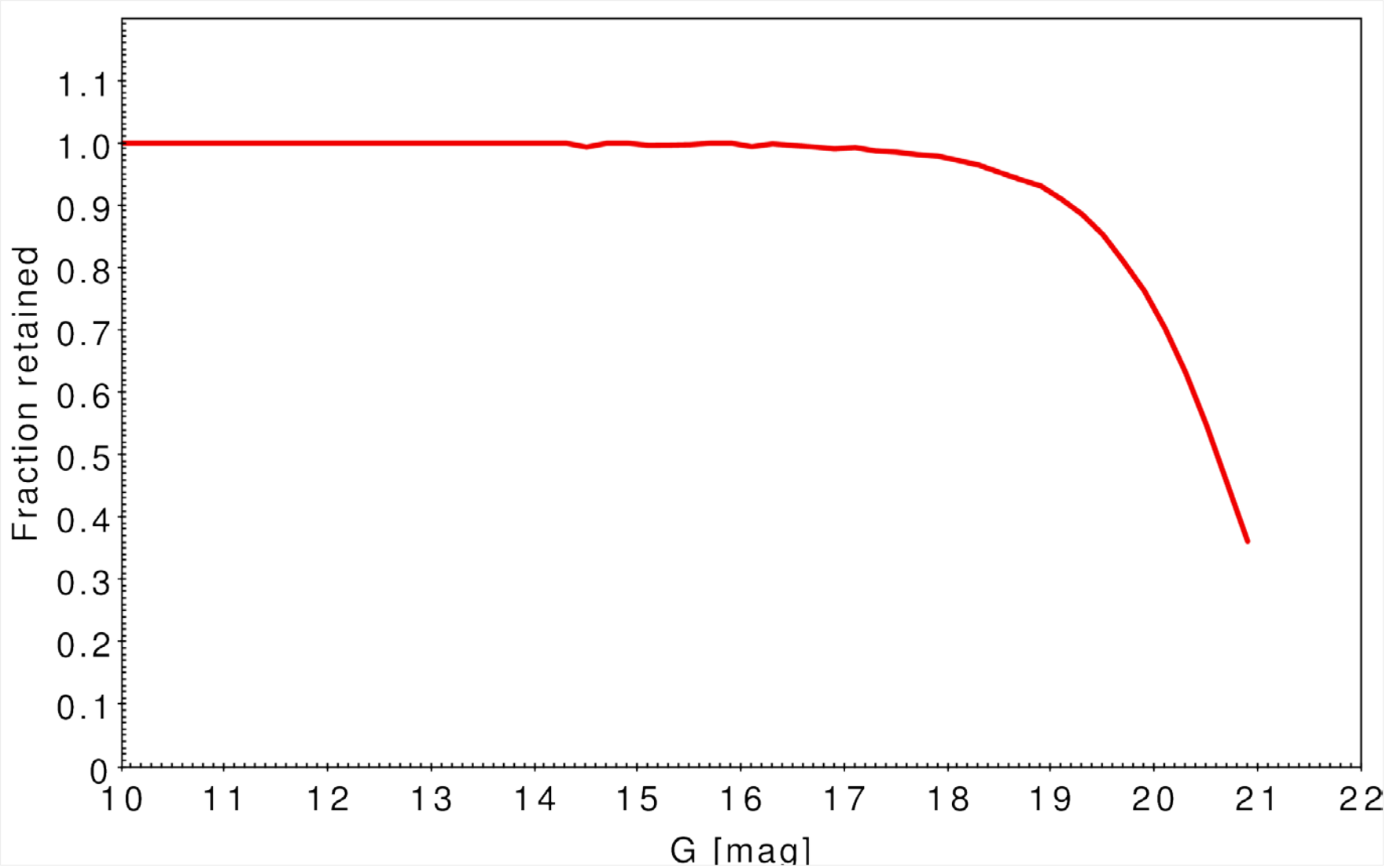
Risk of never having a clean window
For the spectrum

Pairs of similar magnitude
Both have a chance of brightest detection

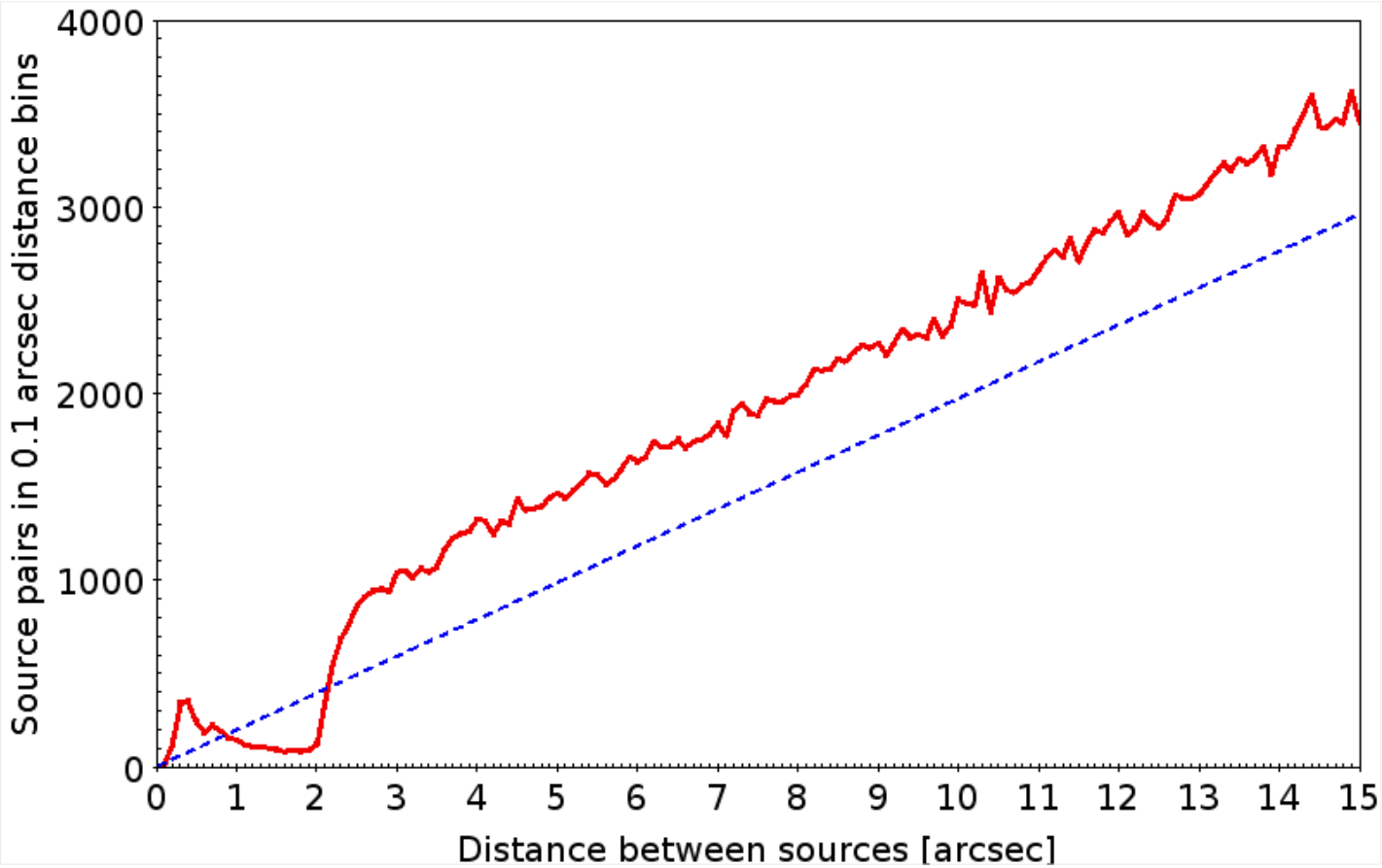
Simulation: 500000 stars/sq.deg



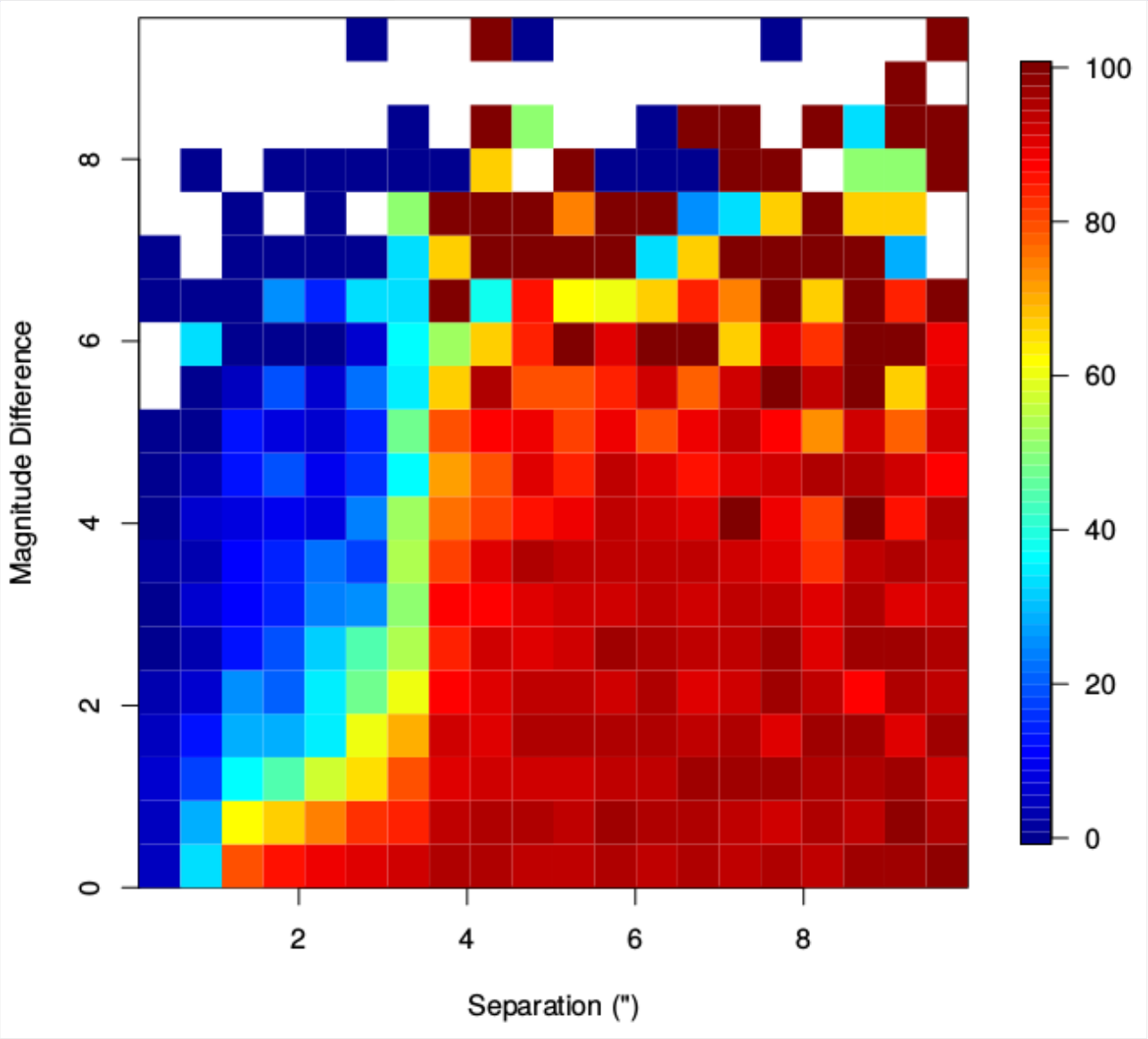
Simulation: 322000 stars remain



Neighbour distance – DR1 sparse zone



WDS seen by Gaia DR1

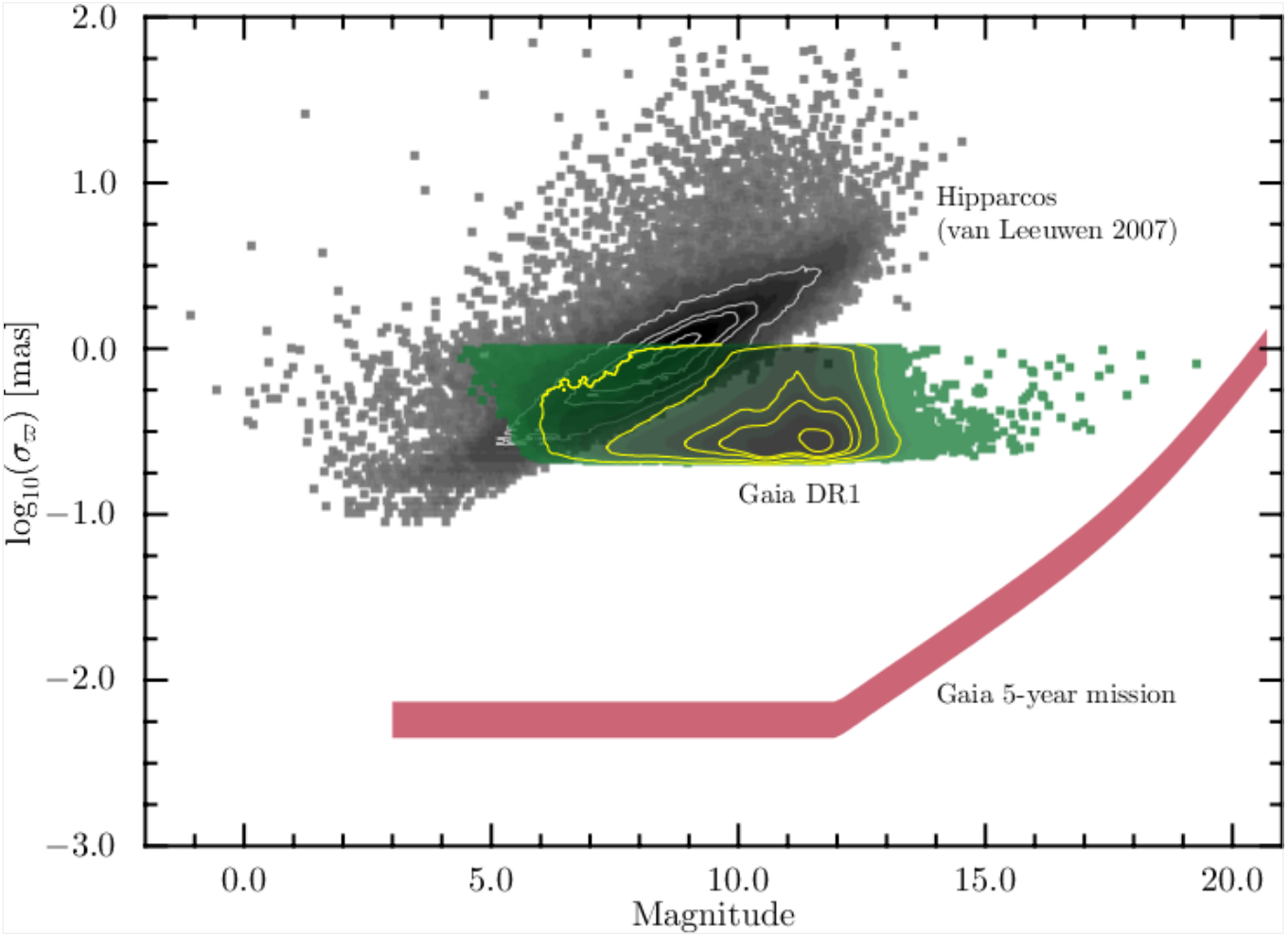


Gaia DR1 Documentation 7.4.3 Babusiaux & Turon

Gaia DR1 angular resolution

- Gaia PSF in ~ 100 mas, pixels 59 mas
  - Eventually we will have a good resolution
- Gaia DR1
  - Dense fields
    - Problems start at 2-4 arcsec separation
    - Faint sources severely affected
    - Max density 500000 stars/sq.deg.
  - Sparse fields
    - Problems start at 2 arcsec separation

Parallax uncertainties



Still a long way to go

- Micro-clanks
  - Attitude
- PSF calibration
  - Colour
  - Sub CCD
  - Sub pixel
  - …
- CTI
  - Readout
- Etc

Brown et al. 2016

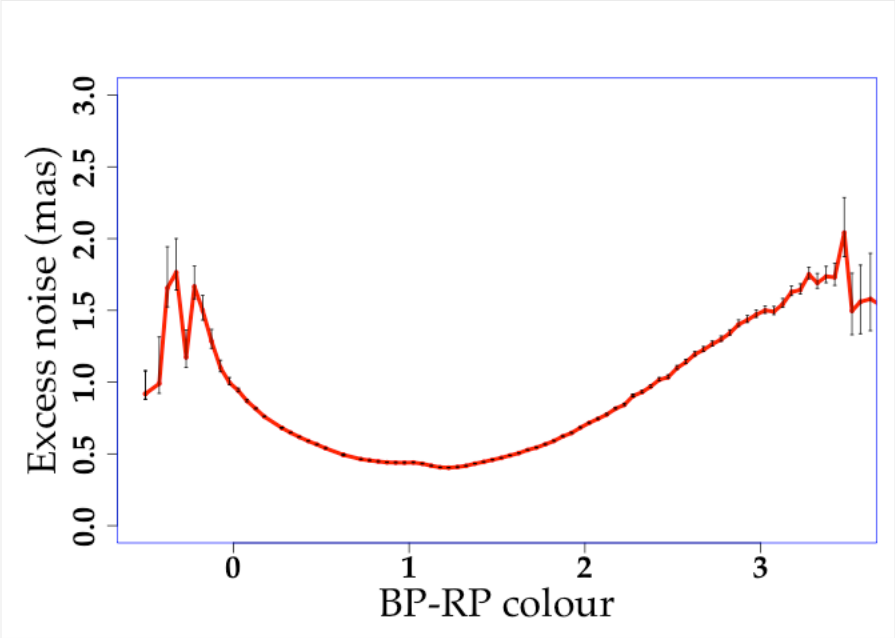
Gaia Data Release 2

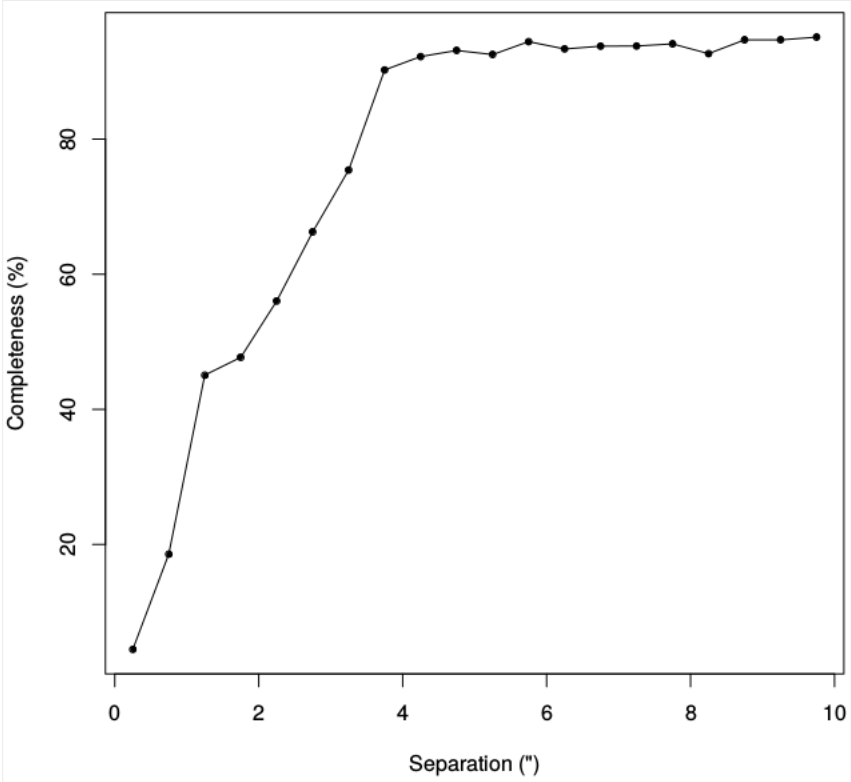
- 2017 last quarter (best case)
- 5 parameter astrometry for 1000+ million stars
  - No TGAS-2 foreseen
- G, BP, RP broad band magnitudes
  - Some astrophysical classification
  - No BP/RP spectra yet
- Radial velocities for bright stars

- Only “well-behaved” sources
  - Do not expect binaries yet

Farther future

- Onboard consumables
  - May last till 2023/24, i.e. 9-10 years of mission
- Mission extension
  - Will be decided later this year

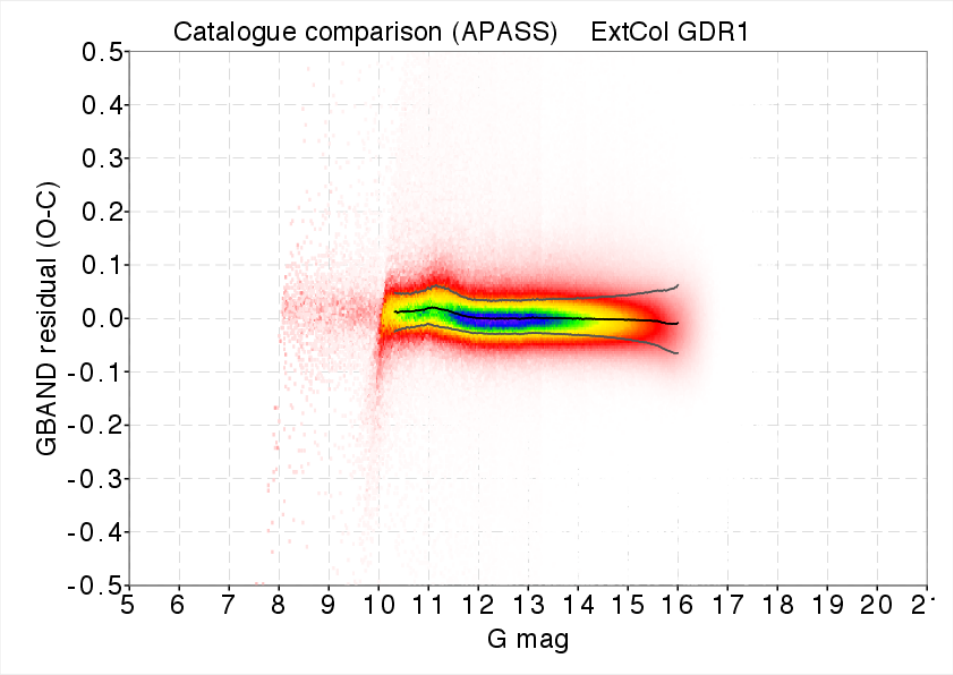

Excess noise (mas)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
1
2
3
BP-RP colour

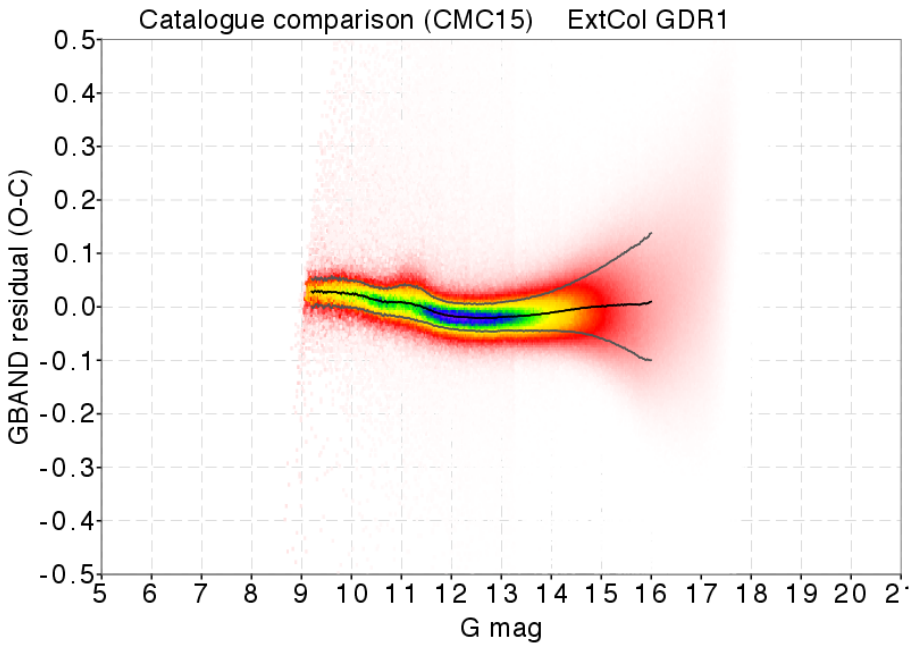

Completeness (%)
20
40
60
80
0
2
4
6
8
10
Separation (")

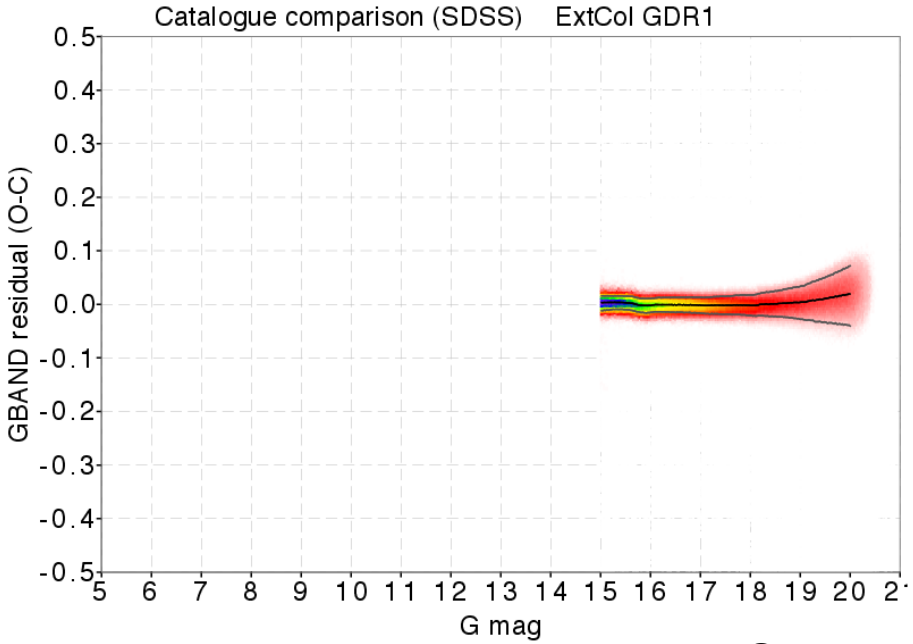
Conclusions: TGAS

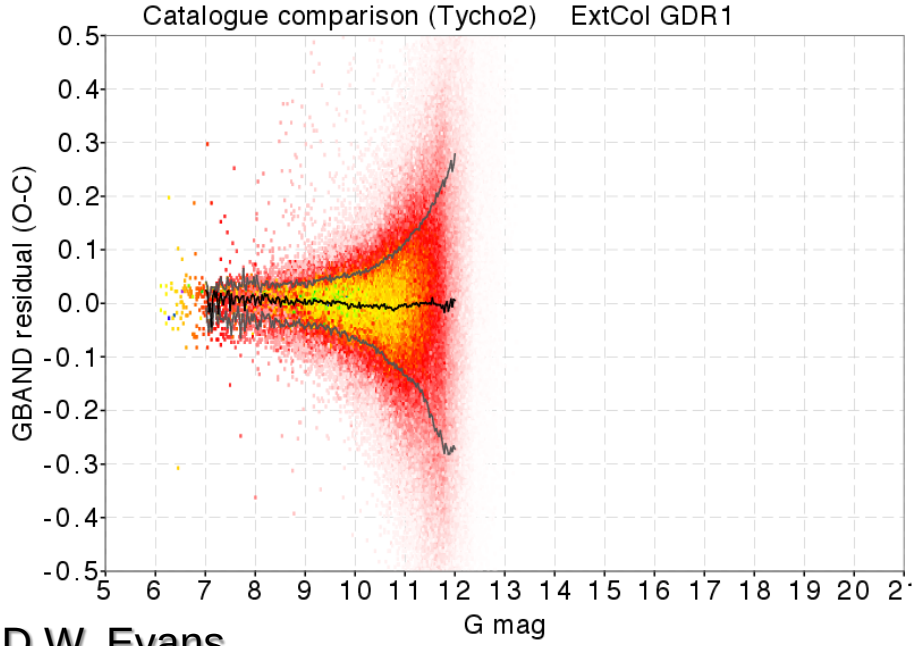
- TGAS parallaxes
  - Two million stars
  - Much superior to Hipparcos
  - Local systematic errors of order ~ 0.3 mas
    - Don't trust blindly $\sqrt{N}$

- TGAS proper motions
  - Systematically much better than Tycho-2









Courtesy : D.W. Evans