

Understanding uncertainties in early Gaia astrometry

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Upcoming Gaia releases

Exciting times ahead!

- One month to launch
- Five data releases foreseen:
 - Stay tuned for the **first release end of 2015**
 - Be patient till the **final release end of 2022**
- Caveat: Preliminary schedule



Summary release schedule

- **Science Alerts:** as soon as possible (Oct 2015)
- **L + 22 months:** positions, G-magnitudes, proper motions to Hipparcos stars, ecliptic pole data
- **L + 28 months:** + first 5 parameter astrometry, radial velocities, integrated photometry
- **L + 40 months:** + first BP/RP spectrophotometry, RVS spectra, orbital solutions for short period binaries
- **L + 65 months:** + variability, solar system objects
- **L + 101 months:** final catalogue release (2022) incl. all individual observations, non-single stars, extra-Galactic sources etc.

BP/RP: Blue/Red Photometer, RVS: Radial Velocity Spectrometer



First release, launch + 22 months

Oct 2015

- Roughly one year of astrometric data
- Stars showing “single star behaviour” only



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- Impossible: 5 parameters (position, parallax, proper motion)
⇒ Publish **positions only** (and G magnitudes)
... what are their **uncertainties?**



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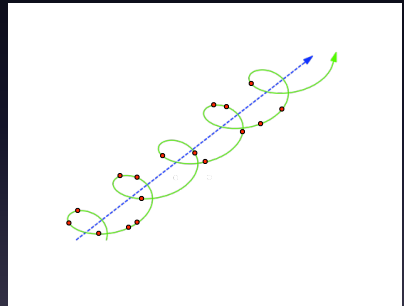
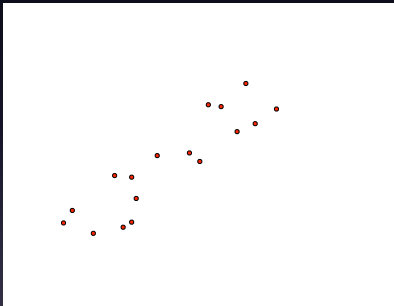
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- The **Hundred Thousand Proper Motions** project (HTPM):
Proper motions and improved parallaxes of Hipparcos stars



Number of parameters

- Gaia aims at determining at least five parameters for all stars: position (α, δ), parallax (ϖ), proper motion ($\mu_{\alpha^*}, \mu_{\delta}$)
- For some stars additional sixth parameter (radial motion μ_r)




But:

- Disentangling the components requires sufficient observations
- ⇒ Not possible for short time intervals



Solving for position only

- Assumes zero parallax and proper motion
- Real parallaxes and proper motions are non zero!
- Different values can lead to the same derived position \neq true position

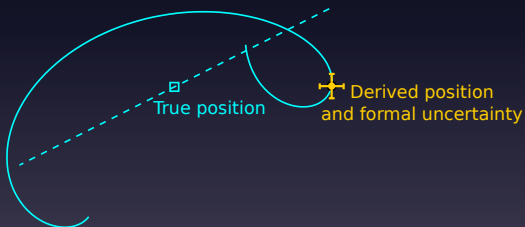
 Derived position
and formal uncertainty

- What is this observation?



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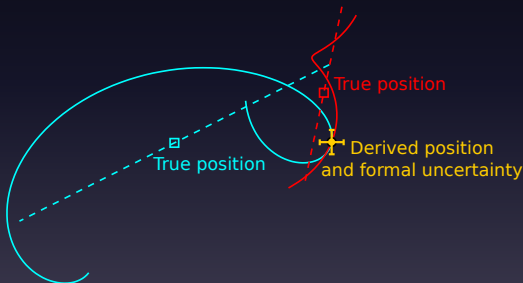


- Is this a nearby dwarf (cyan)?



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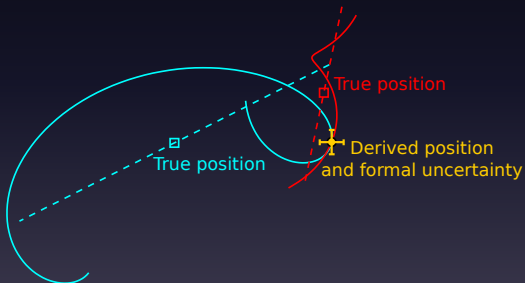


- Is this a nearby dwarf (cyan) or a distant giant (red)?



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- Formal uncertainties underestimate the actual errors



How to get more realistic uncertainties

Bayesian approach:

probabilistic modelling to constrain unknown parameters

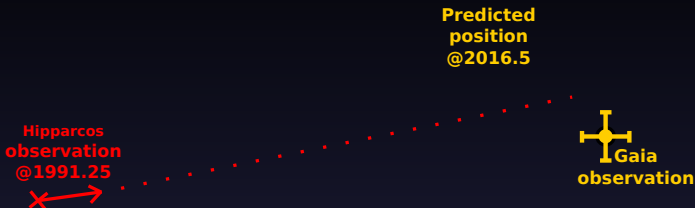
Prior information on unknown parameters could come from:

- 1 Previous astrometric results
 - **Hundred-Thousand Proper Motion project:**
Solving for five parameters of the Hipparcos stars
- 2 Upper limits on parameters
- 3 Monte Carlo simulations using a Galactic Model
- 4 ...



Hundred Thousand Proper Motions

Combination with previous astrometric results from Hipparcos



- Allows disentangling all five astrometric parameters
- Order of magnitude improvements of the Hipparcos star PM:

$$\sigma_{Hip} \simeq 1\,000 \mu\text{as/yr} \Rightarrow \sigma_{HTPM} \simeq 40 \mu\text{as/yr}$$

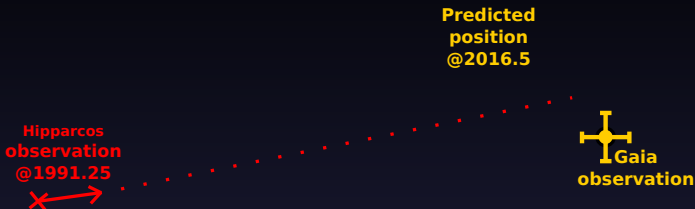
- Compare HTPM results to Gaia alone: allows to detect non-uniform space motion, long period binaries

⇒ L+22m release: publish five parameters for 10^5 stars



Hundred Thousand Proper Motions

Combination with previous astrometric results from Hipparcos



Documentation in preparation:

Optimal combination of astrometry from *Hipparcos* and *Gaia*

The Hundred Thousand Proper Motions project

Daniel Michalik¹, Lennart Lindegren¹, David Hobbs¹, and Uwe Lammers²



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 - Non-zero realistic parallax and proper motion
⇒ Understanding the uncertainties in early Gaia results



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- 3 **Monte Carlo simulations of a Galactic Model**
 - Non-zero realistic parallax and proper motion
⇒ Understanding the uncertainties in early Gaia results
 - Parameters themselves independent from our Galactic model



Summary

- One year of data is insufficient for five parameter solutions
- Instead: positions only (two parameters)
- Formal uncertainties grossly underestimate real errors
- Bayesian approach: use of prior information
 - ... to perform five parameter solutions with one year of data
 - ... to gain a much improved characterization of the real errors
- Same approach applicable to later releases (radial velocity etc)



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Two benefits:

- 1 **More realistic uncertainties for the position errors**
⇒ An improved understanding of the (early) Gaia releases
- 2 **The Hundred Thousand Proper Motion results ($\sigma \simeq 40 \mu\text{as/yr}$)**

