Gaia DR3 and its foreseen binary star content

by

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Exploring a 1.8 billion sources catalogue is not like analysing one’s favourite binary star.

Searching (automatically) for binaries has been done only on sources that do not appear single, seen from their large Goodness-of-Fit (GoF) either astrometric, photometric or spectroscopic.

This allowed to select and process:
- Astrometric binaries (AB), G < 19
- Spectroscopic binaries (SB1/2)
- Eclipsing binaries (EB)
- And combinations of the above
- not for DR3: Resolved doubles/binaries
- not for DR3: Multiple star orbits

Our choice for Gaia data release DR3: this is the first publication of Gaia NSS, a conservative approach has been adopted, filtering out many solutions, keeping the most significant only.
Managing the binary zoo

- Main outcome of the catalogue: orbital or trend parameters
  - Also an improvement on system parameters (parallax, velocity…)

- Astrometric binaries (ordered by decreasing periods)
  - VIMF (fixed variable binary), acceleration 7p (5 astrometric parameters+2 derivatives), acceleration 9p, orbital solutions
  - Processing cascade: the simplest NSS model which fitted the data with an acceptable GoF has been accepted

- Spectroscopic binaries (by decreasing periods)
  - Trend solution (polynomial from 1st to 4th degree), SB1 / SB1C (e~0), SB2 / SB2C

- Eclipsing binaries
  - For DR3: orbital parameters + temperature ratio + sum of radii
Unfortunately, with 1.8 billion sources, what can go wrong does go wrong…

Most bad GoF actually originate from resolved double stars or calibration issues
- E.g., over the 40-millions sources with a bad single star fit (RUWE > 1.4 & G < 19), a very small fraction only may actually be processed as unresolved astrometric binaries.

When looking for periodicity, one always finds significant periods related to some non-astrophysical signals, e.g. the scanning law (2h/6h spin, 63d precession, one year…)
- To avoid spurious frequencies, a strong filtering has been applied on all kind of binaries
- Drawback of producing a weird selection function, while possibly some contamination still
Rough upper limits of the number of solutions

- Astrometric binaries
  - Acceleration $\sim 3.10^5$
  - Orbital $\sim 10^5$
  - Including $\sim 7.10^2$ known substellar hosts

- Spectroscopic binaries
  - SB1+SB1C $\sim 1.5 \times 10^5$
  - SB2+SB2C $\sim 5.10^3$
  - Trends $\sim 5.10^4$

- Eclipsing binaries
  - $\sim 4.10^4$ ($> 10^6$ from the variability analysis)

- Astrometric + Spectroscopic $\sim 3.10^4$

- Spectroscopic + Eclipsing $\sim 10^2$

NB: astrometry gives the orbit (or acceleration) of the photocentre, not the primary: a low astrometric signal may originate either from a low mass companion or from twins.

These preliminary numbers may strongly decrease after validation. They will remain anyway larger than existing catalogues.
Period-eccentricity diagrams

Eclipsing Binaries

SB1

Astro-Spectro combinations

Astrometric orbits

NB: Astrometric orbits have an expected dip around one-year periods
Median precision for orbital parameters

- A good overlap between periods of the various orbital types (+ trends)

- Astrometric orbits
  - Period range (1%-99%) ~ 100-1500d, median relative uncertainty of period ~ 2%
  - Median relative uncertainty of angular semi-major axis ~ 5% (better than 20%)

- Spectroscopic binaries
  - Period range ~ 1-1000d, median relative uncertainty of period ~ 1%
  - Median relative uncertainty of semi-amplitude ~ 6% (better than 20%)

- Combined astrometric + spectroscopic solutions
  - Period range ~ 80-2000d, median relative uncertainty of period ~ 1%
  - Median relative uncertainty of angular semi-major axis ~ 3%

- Eclipsing binaries
  - Period range ~ 0.3-5d, excellent relative uncertainty of period