Binary stars in the space era
Keele University – Friday 4th July 2025

# Exploring spectroscopic binaries: From SB9 to the 4MOST large survey

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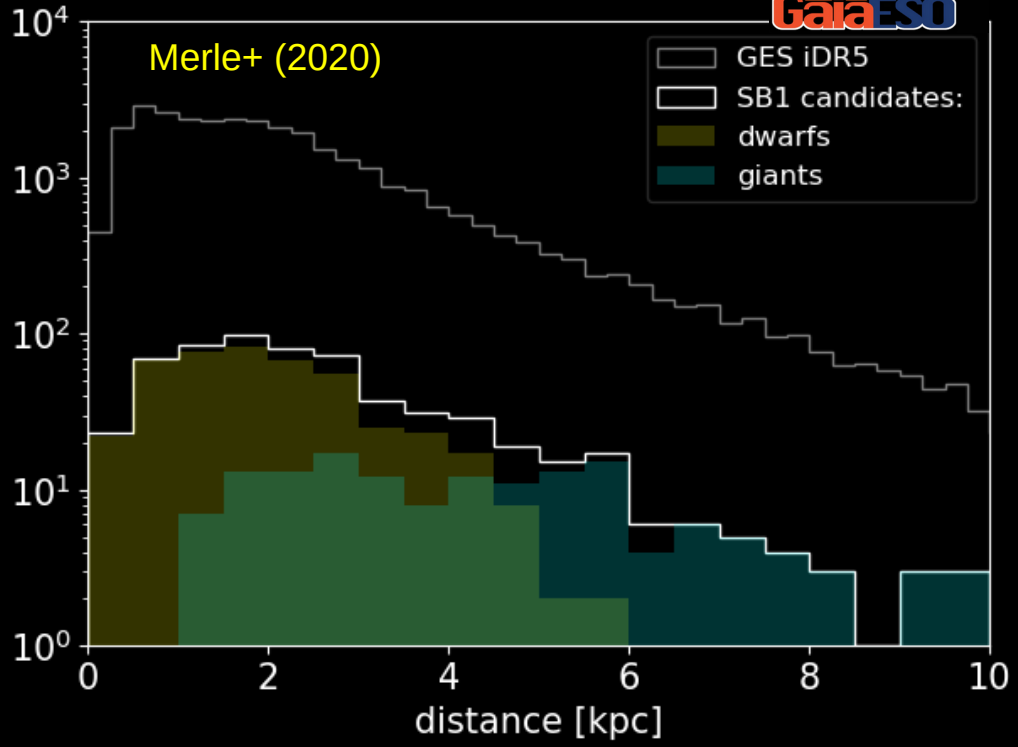
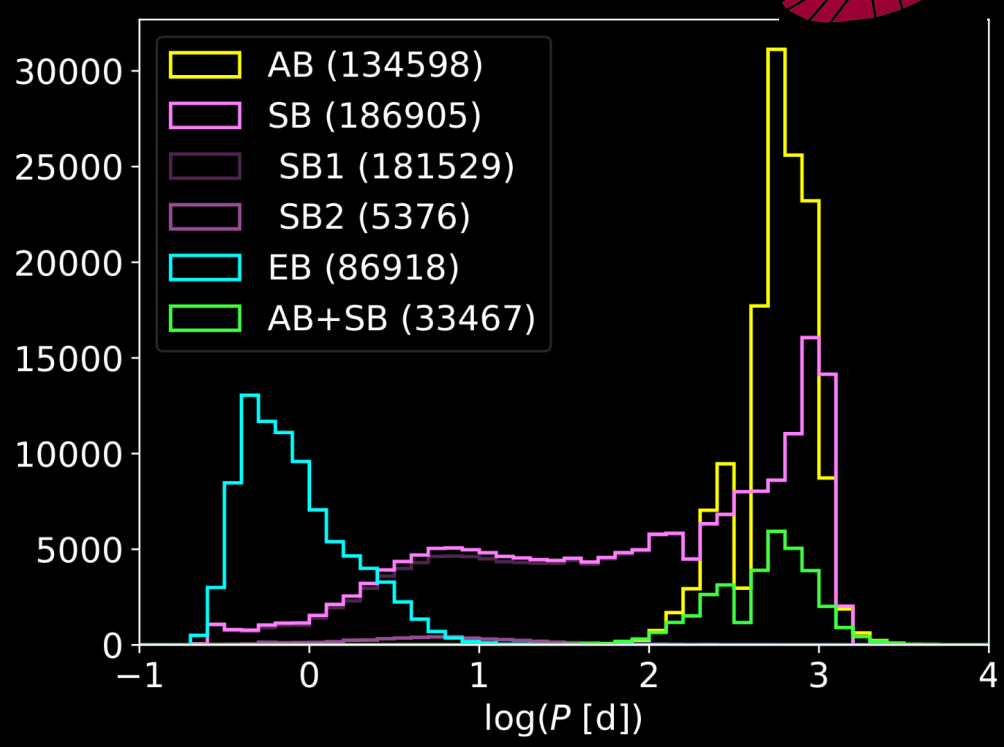
FED-tWIN
belspo

# Why spectroscopic binaries (SB)?

Insensitive to the distance

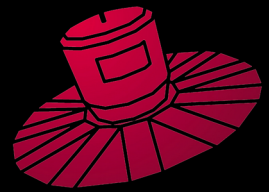



Wide range of orbital periods



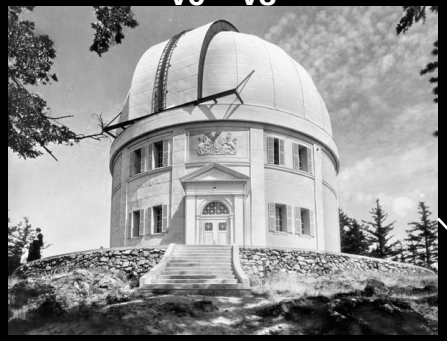
# Outline

- The SB9 catalogue and its evolution
  - History
  - Content including triples and quadruples
  - Evolution
- Comparison of SB9 with Gaia DR3
  - Gaia color-absolute magnitude diagram
  - SB9 x NSS common sample
  - Its characteristics
- Spectroscopic binaries in 4MOST
  - A massive MOS survey
  - Many SB projects
  - Multiple stars detection and characterisation



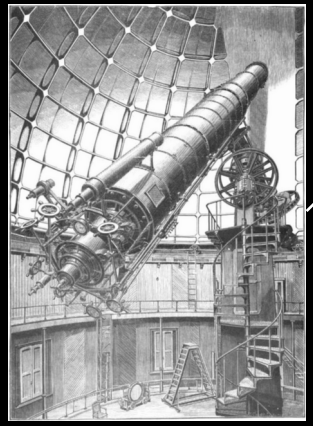
# History of the ***SB9*** catalogue

**v6 – v8**

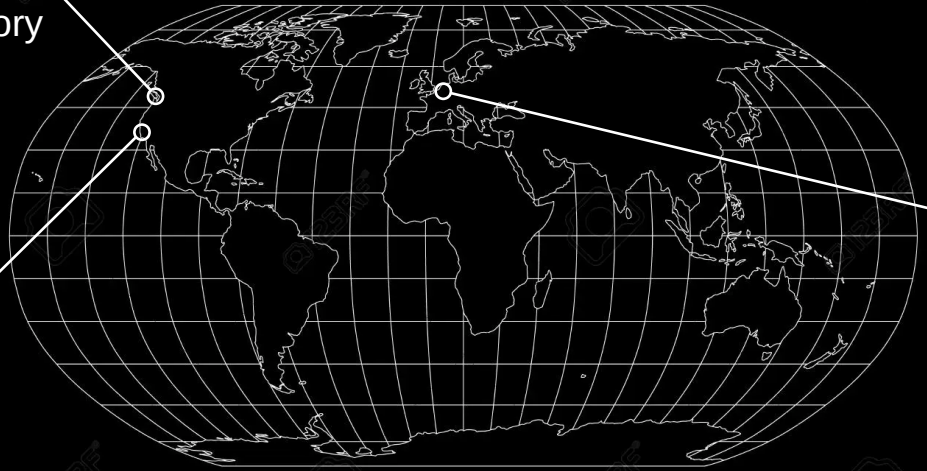


Dominion Astrophysical Observatory
Batten (1967) 740 SB

**v1 – v5**



Lick Observatory
Campbell & Curtis (1905) 140 SB



https://sb9.astro.ulb.ac.be

VizieR **B/sb9**

2000: IAU initiative
from commission G1

ULB

***SB9***
Pourbaix+ (2004)
2390 SB

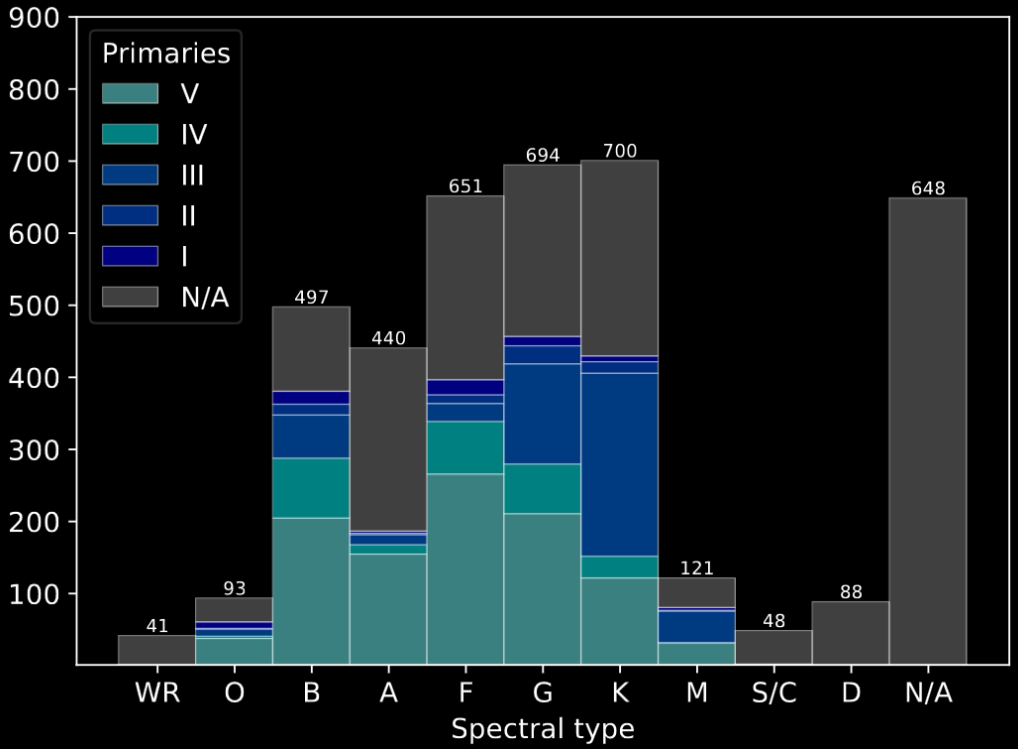
2021
4000 SB

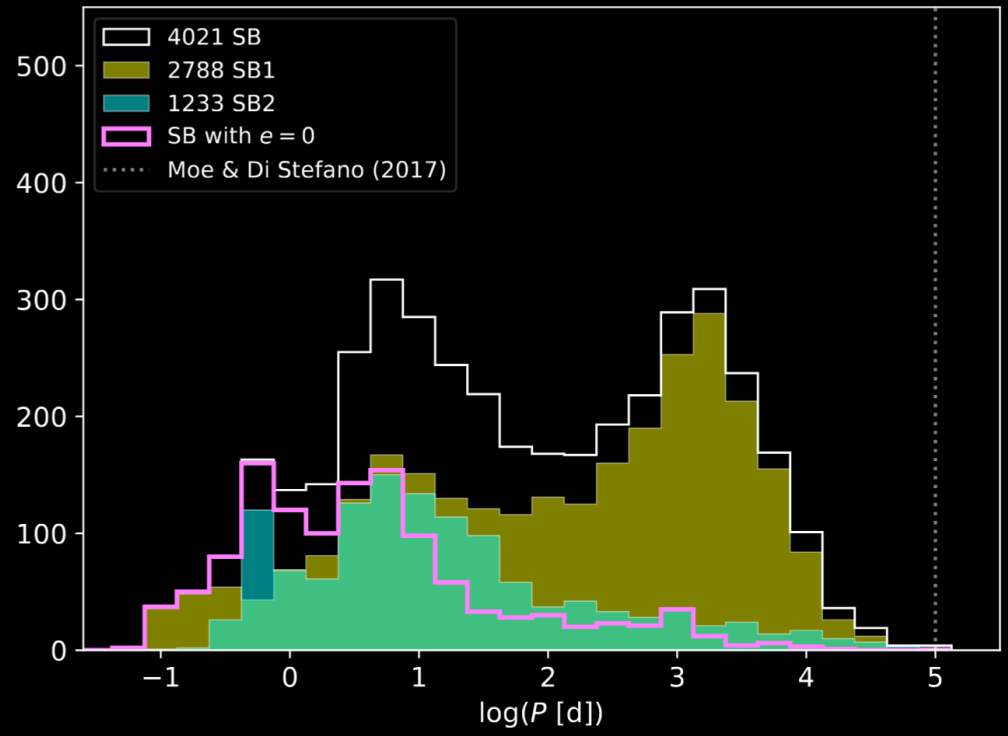
# Content of ***SB9*** catalogue

- 5000 orbits
- 4000 systems

70% SB1

30% SB2

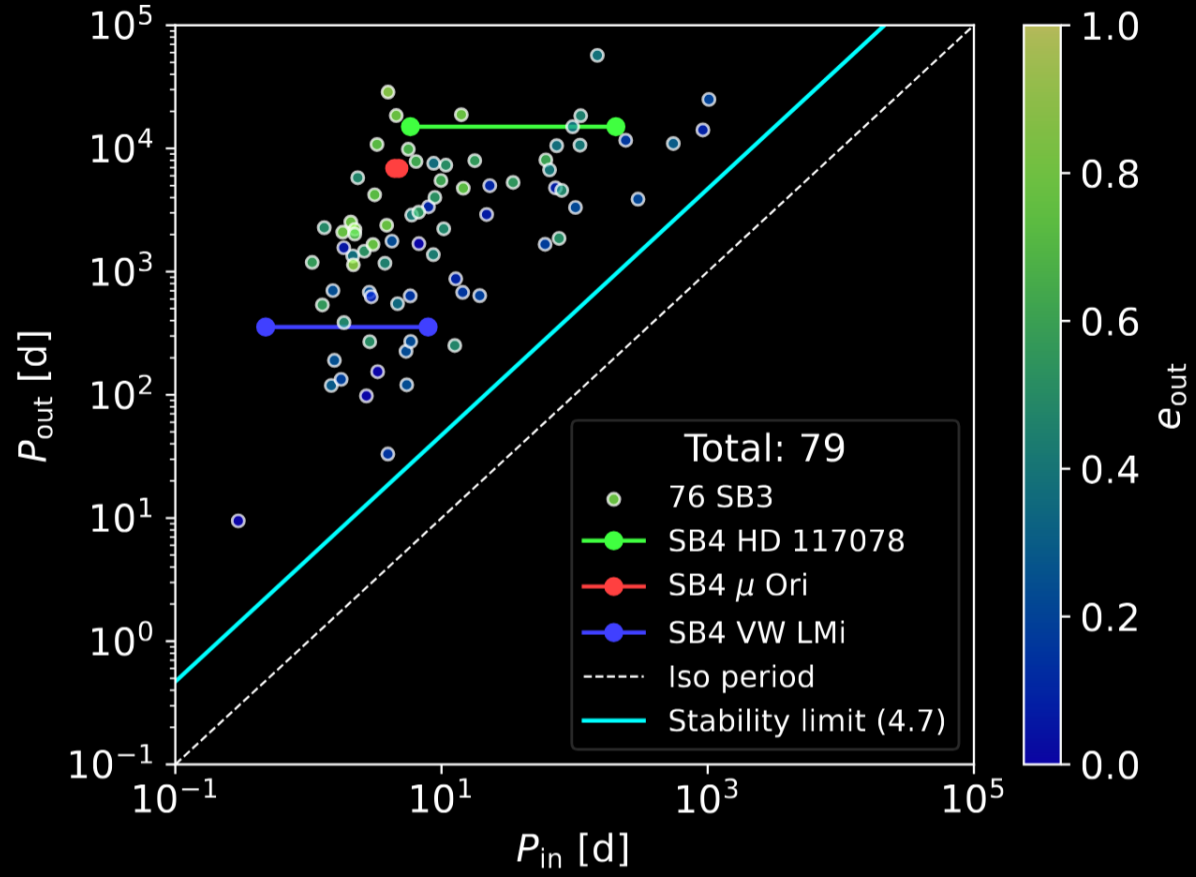


# Content of ***SB9*** catalogue

**Hierarchies**

- ~75 spectroscopic triples
- ~30 spectroscopic quadruples (including 3 optical)
- 3 quadruples (2+2 configuration) with complete orbits:
  - μ ori
  - HD 117078
  - VW LMi
- 5 systems with multiplicity > 4 having at least 2 subsystems in SB9:
  3 quintuplets (1 in the Orion Trapezium),
  and 2 sextuplets (3+3 and 4+2 configurations)

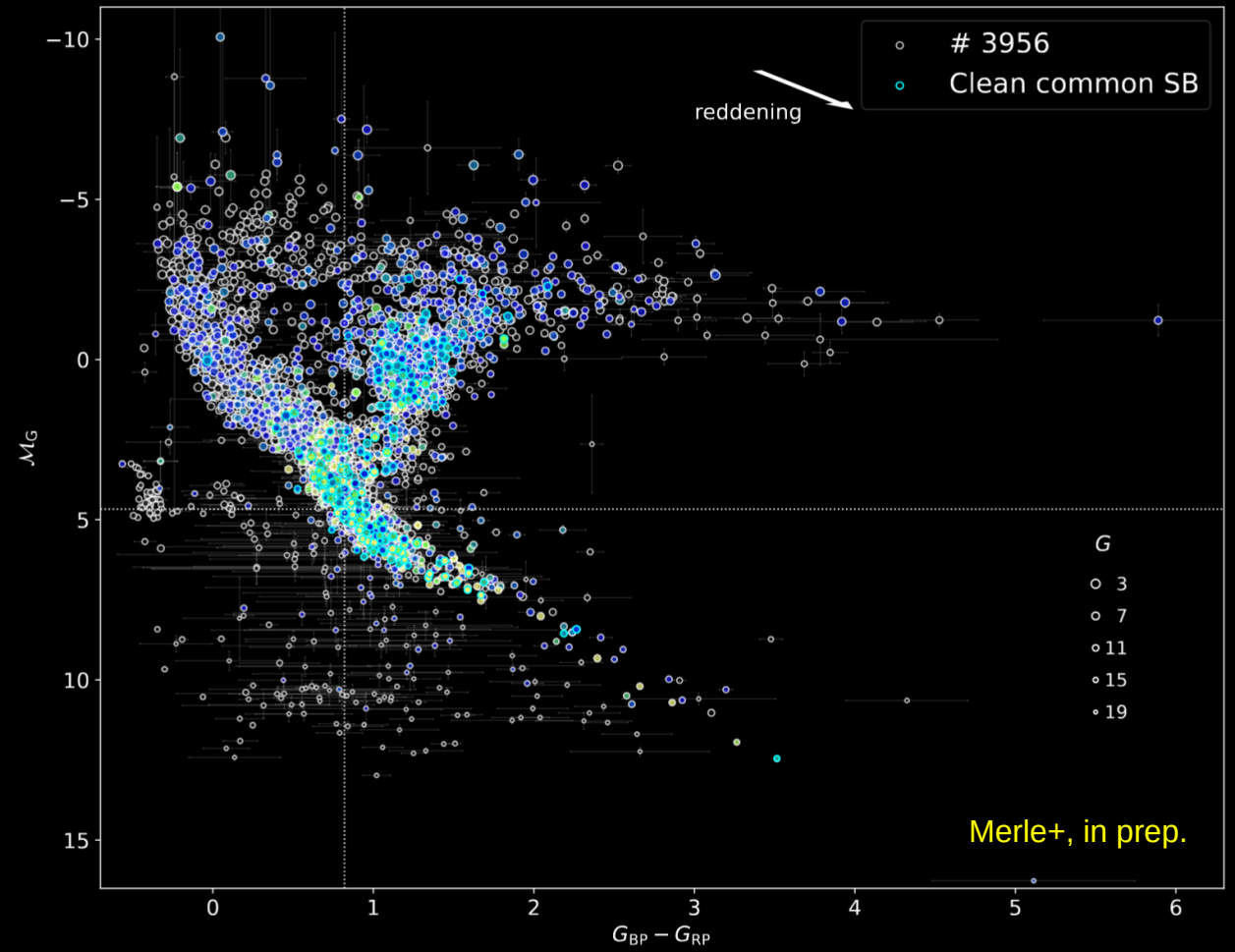


# The eXtended catalogue of SB orbits

**http://astro.ulb.ac.be/sbx** **Poster 16**

- **SB9** is outdated in web design, data access and storage
- **SBX** has a PostgreSQL database management system
- **SBX** uses a Simbad name resolver API
- **SBX** is following IVOA standards with a TAP service using ADQL

# Gaia color-magnitude diagram of SB9 systems



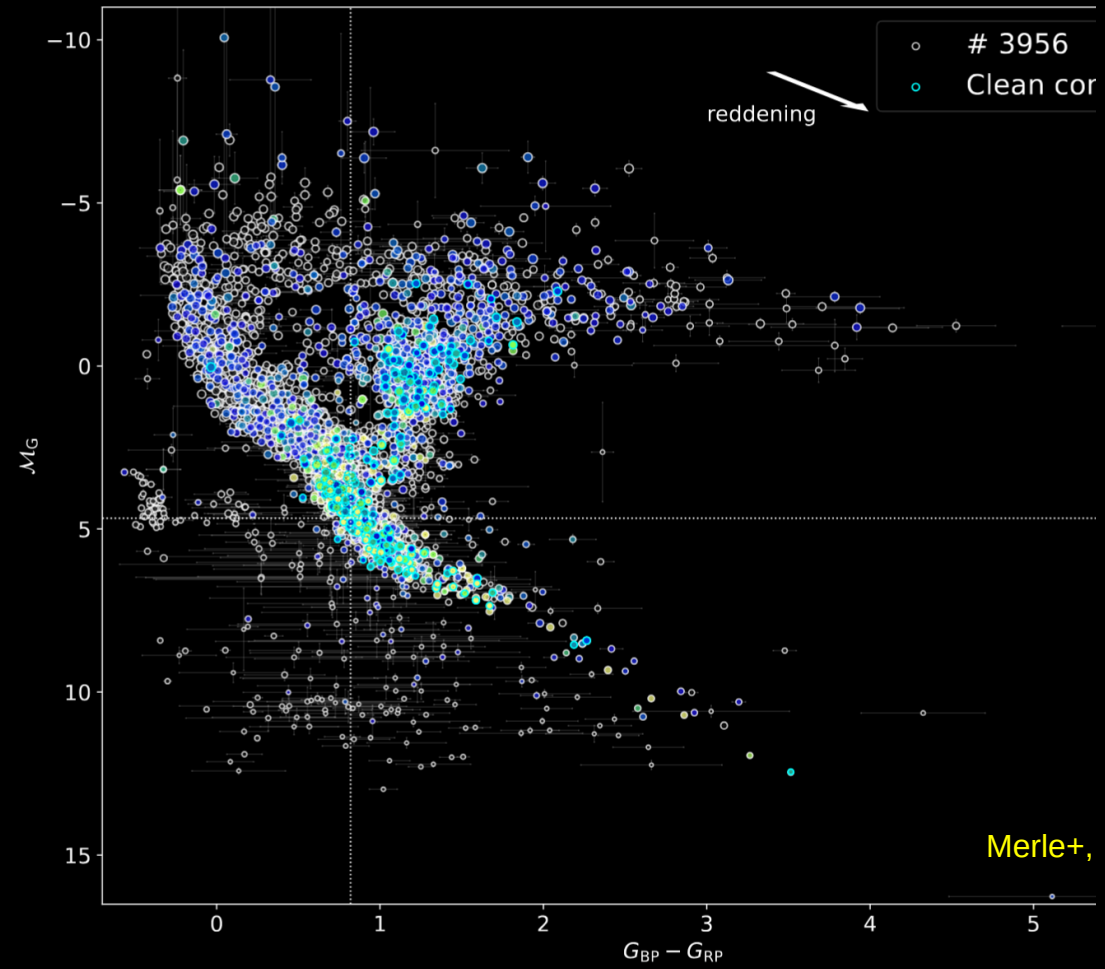

Not in Gaia DR3:

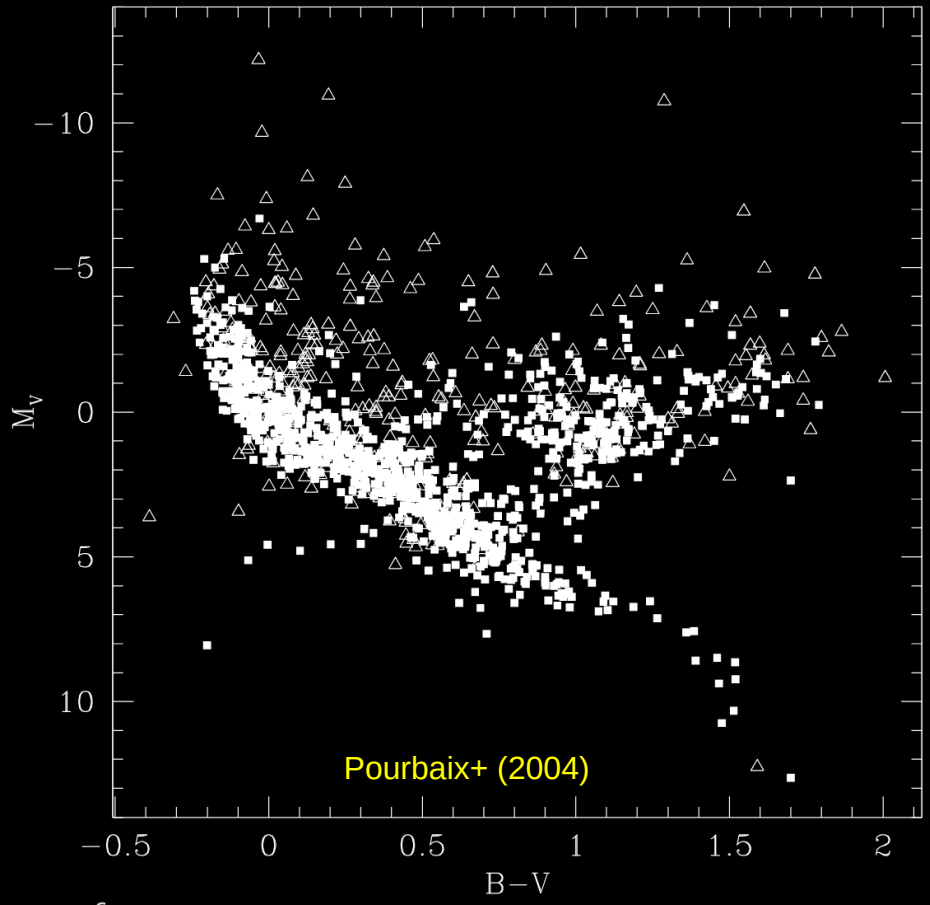
- The 21 brightest systems
- 6 faint systems
- 18 duplicates

Late type SB are under-represented

Cataclysmic variables
MS+WD binaries

# Gaia color-magnitude diagram of SB9 systems



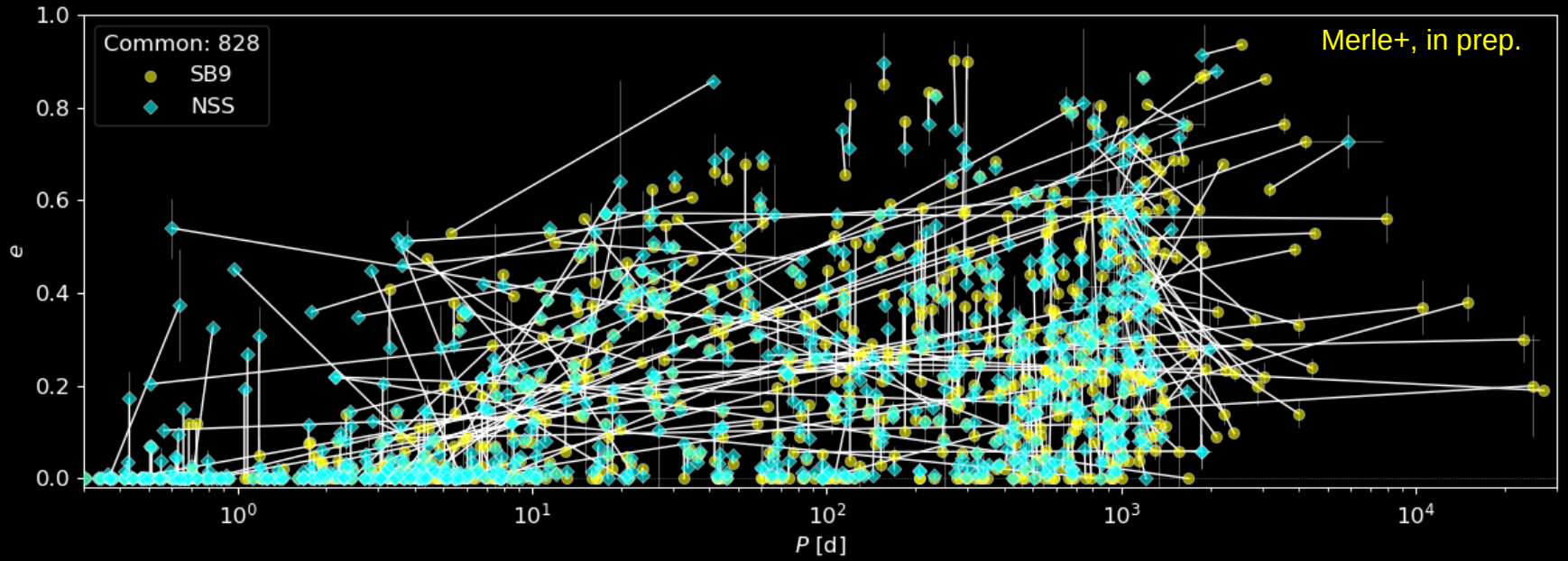




6

# SB9 x Gaia DR3 NSS common sample

828 binaries:

- This only represent 1/5 of SB9 catalogue
- Many SB9 binaries with periods larger than 1000 d
- Some Gaia binaries with high eccentricities at short periods



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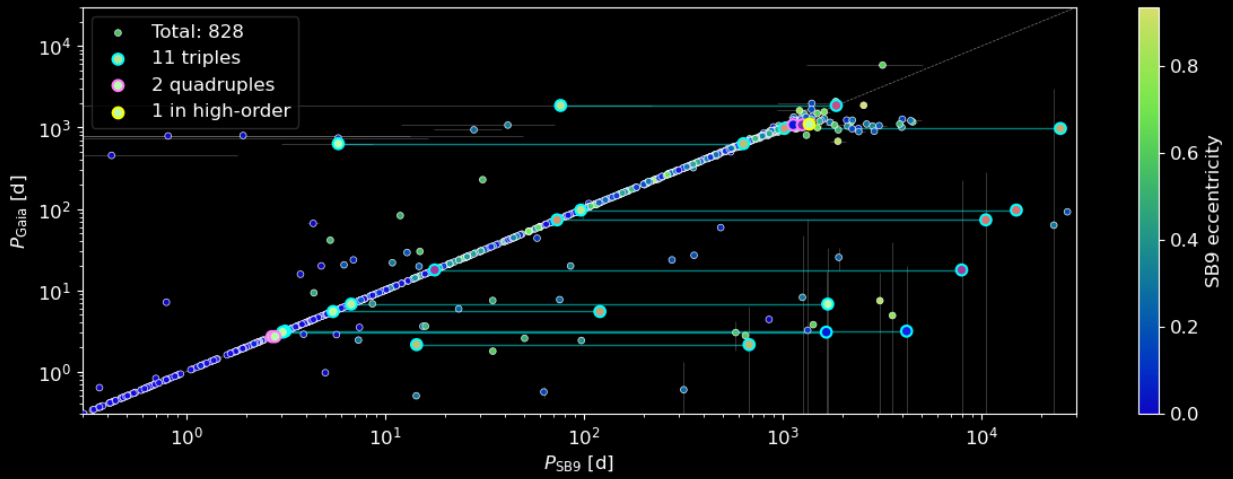


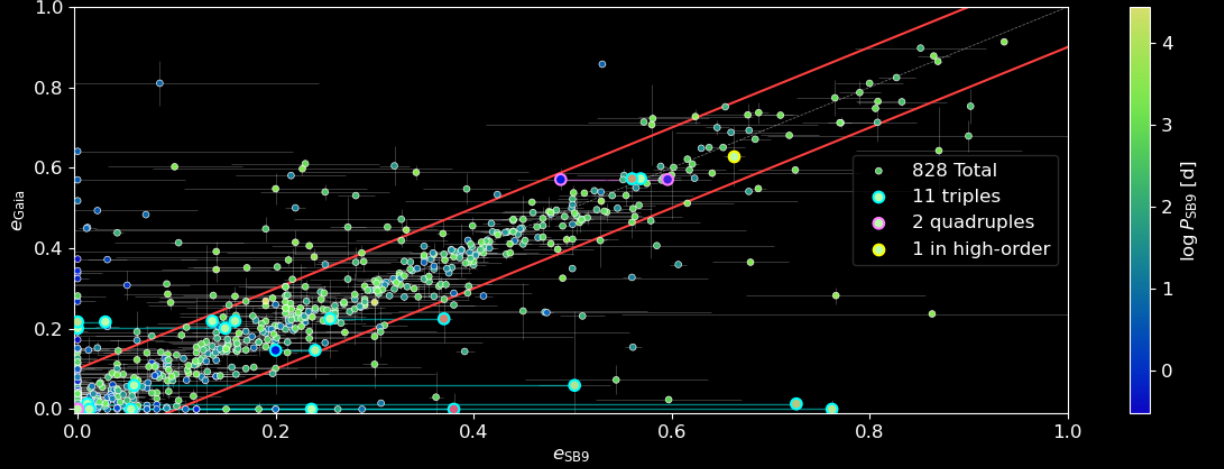


$P_{Gaia}$ vs. $P_{SB9}$

Selection 1: $|\Delta P|/P < 0.1$
=> ~70 outliers

$e_{Gaia}$ vs. $e_{SB9}$

Selection 2: $|\Delta e| < 0.1$
=> ~170 outliers

Clean sample
= selection 1 & selection 2

Common sample: 850
Clean sample: 660

# SB9 x Gaia DR3 NSS common sample

Common sample of 828 binaries:

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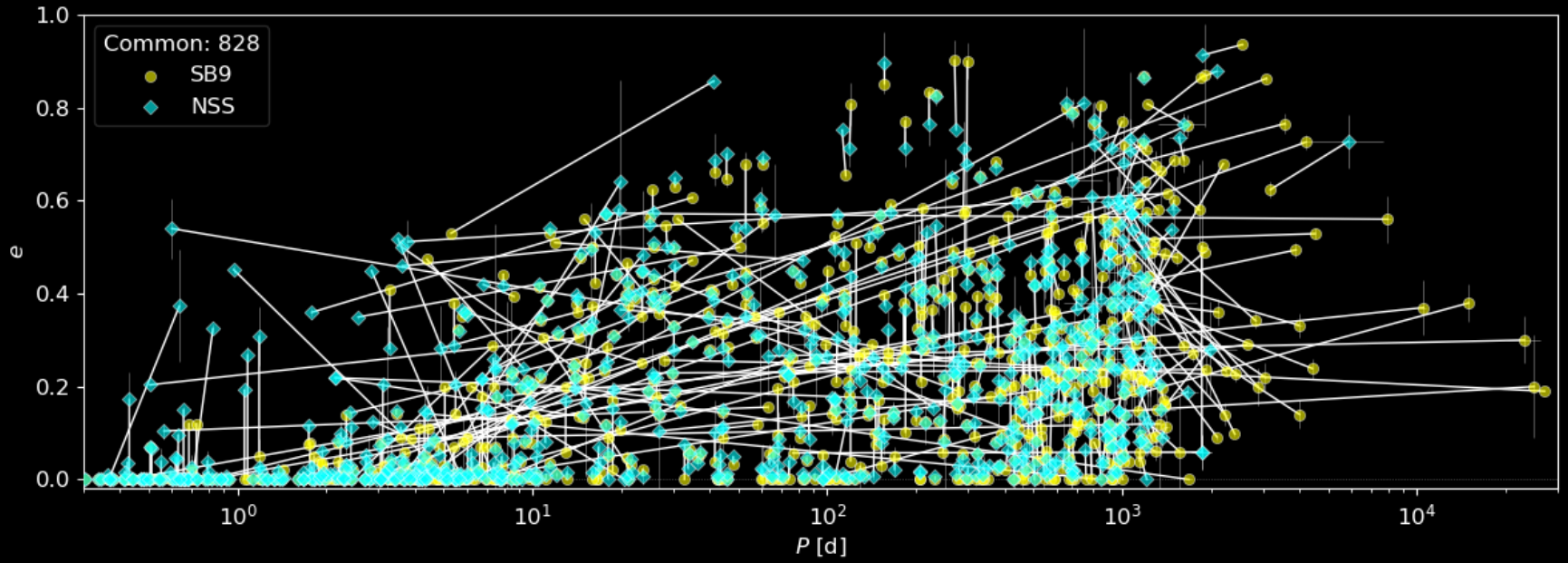

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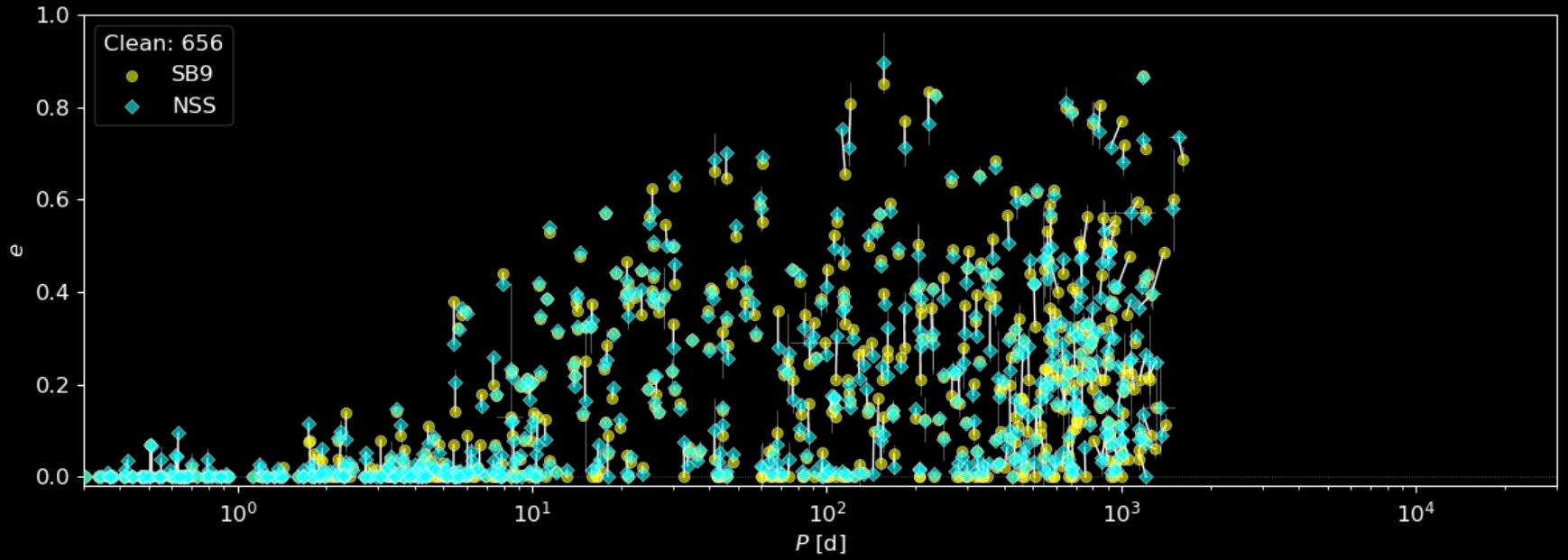

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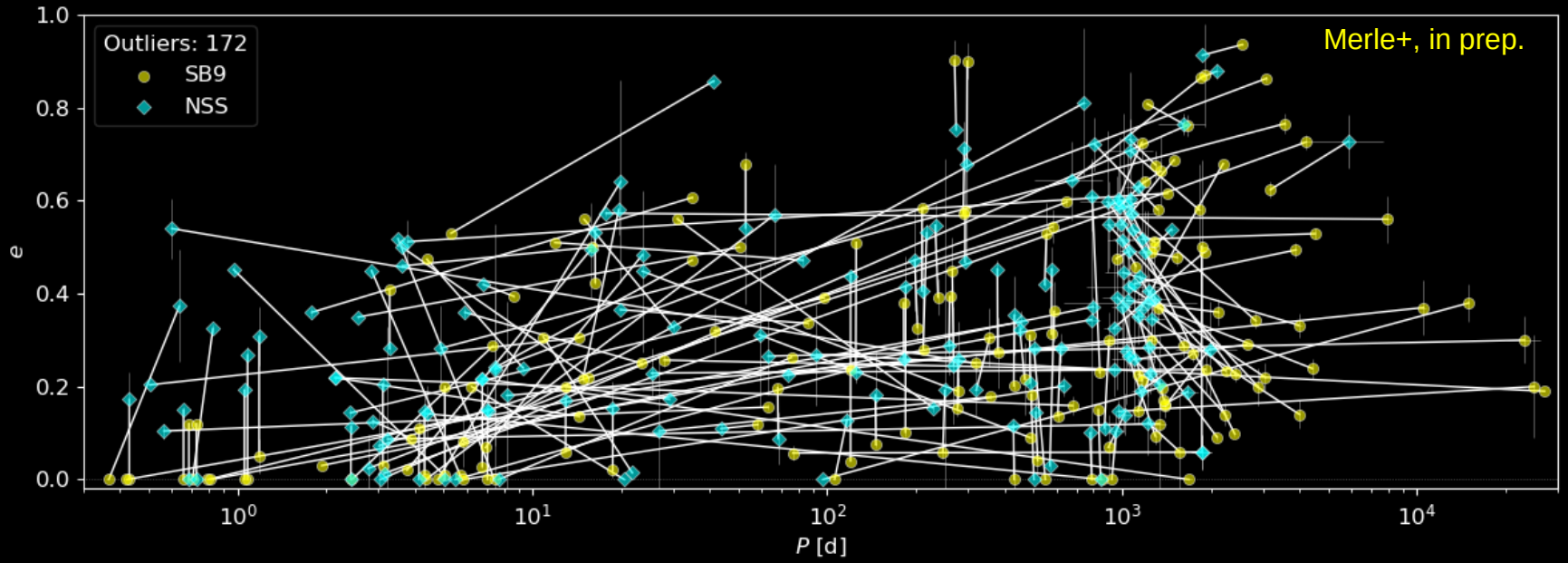
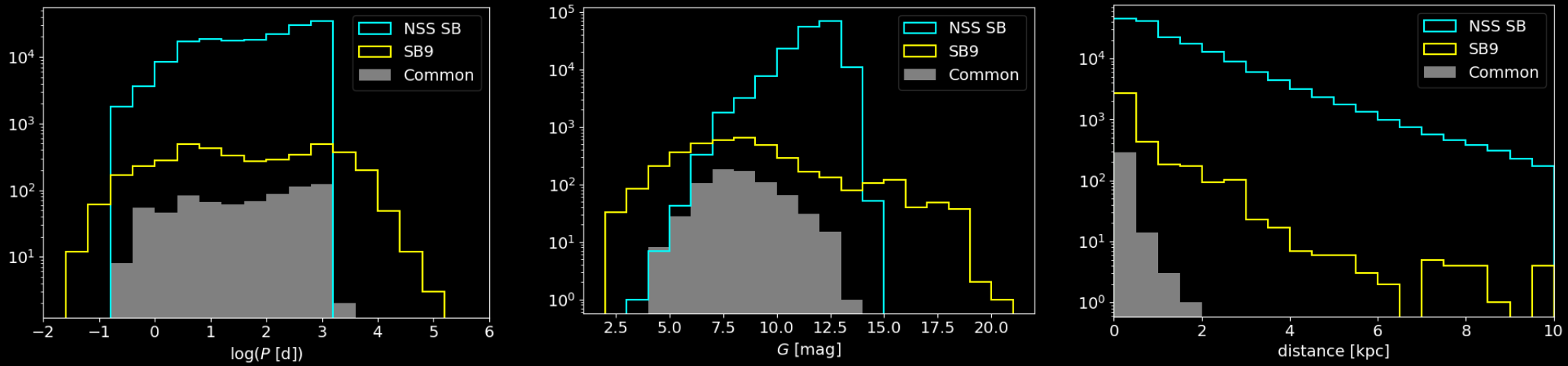


# SB9 x Gaia DR3 NSS common sample

Merle+, in prep.




- Only 20% of SB9 systems in NSS.
- Increase to 25% when restricting to the same period and magnitude ranges.

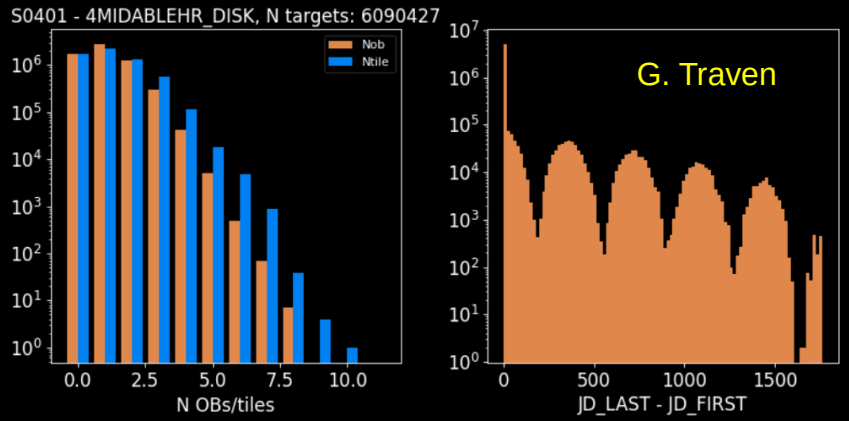
- Many internal filtering processes in DR3 (Gosset+ 2025, Damerdji, in prep.)

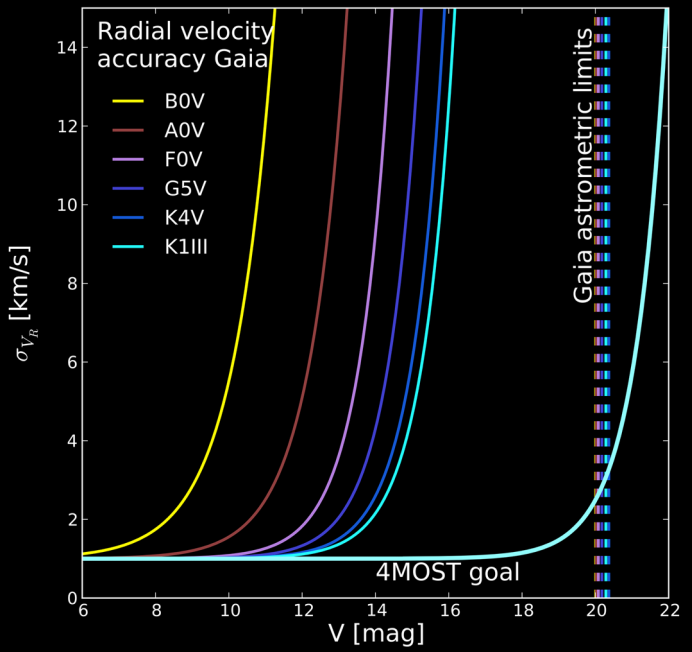
# A massive spectroscopic survey

- 4-m Multi-Object Spectroscopic Telescope on VISTA/ESO
- 2400 fibres per single exposure
- 4 square degrees field of view
- Optical wavelength coverage
- Low-resolution: 4 000 – 8 000,  1 600 fibres, Vmax ~20
- High resolution: ~20 000, 800 fibres, Vmax ~16
- 5 y survey starting in 2026

# A massive spectroscopic survey

- 10 consortium surveys: 70%
- 14 ESO community surveys: 30%
- 9 infrastructure working groups (IWG)
  including a Stellar Multiplicity Working Group
  as part of IWG2 (survey strategy and simulations)
- Implementation of cadence:
  - For free
  - On request




https://www.4most.eu/cms/science/overview/

# Spectroscopic binaries in 4MOST

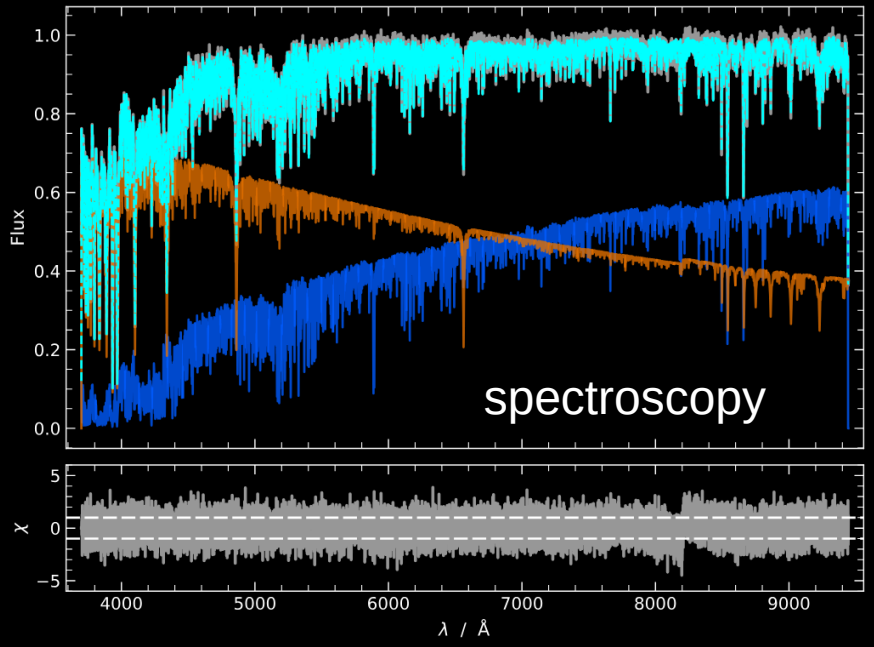
**Binary nature of SB candidates (LR/HR) - T. Merle**
**Dependence of binary fraction on metallicity (LR/HR) - G. Traven**
**Composite-colour hot subdwarf binaries - M. Dorsch**

Detecting spectroscopic stellar systems – T. Merle
MULTIFIT pipeline and parameter biases (LR/HR) – M. Dorsch

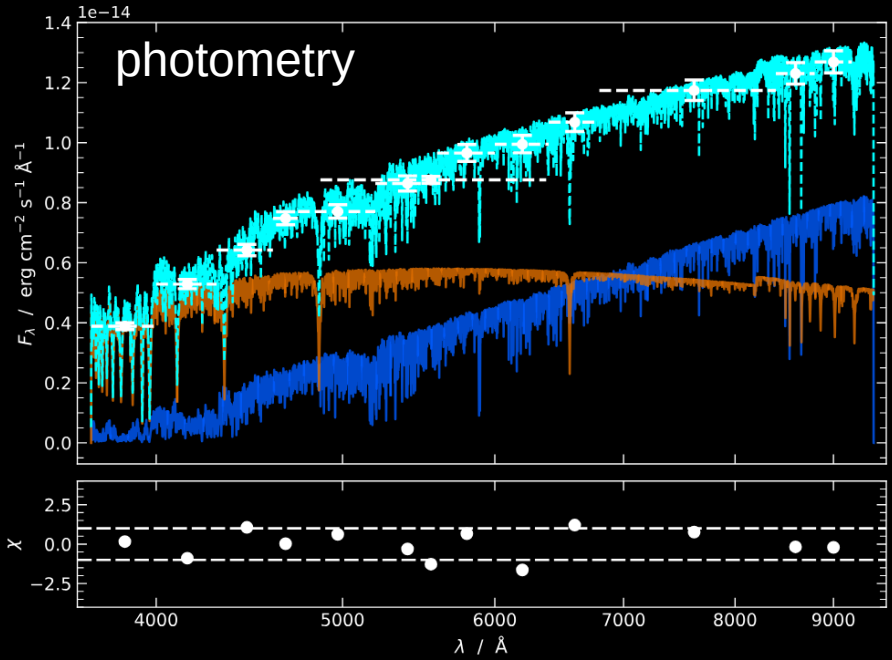
Population properties of binary stars in our Galaxy – G. Traven, **B. Jamnik (see poster P41)**
Double white dwarf binaries – **I. Pelisoli (talk on Tuesday)**
WDs with unseen low-mass MS (or brown dwarf) companions – Rebassa-Mansergas
Dormant Black Holes survey overview and catalogue – M. Pawlak
Abundance analysis of multiple stars – H. Ernandes
Spectroscopic binarity of the Gaia astrometric binaries – T. Mazeh
The distribution of the rotational broadening of all 4MOST spectra – T. Mazeh
Characterising sources with significant astrometric excess noise (LR/HR) – P. Gandhi
Fundamental parameters (mass, radius) of eclipsing binaries – T. Merle
Wolf-Rayet stars and spectral disentangling of SB1 – **T. Shenar**
Etc.

# Multiple stars detection & characterization

Composite spectrum =
Main sequence F + subgiant K




MULTIFIT from M. Dorsch
Approach similar to El-Badry+ (2018) in APOGEE
Using neural networks (*The Payne*, Ting+ 2017)




$$\chi^2_{SB} = \chi^2_{spec} + \chi^2_{phot}$$

# Binary nature of many candidates

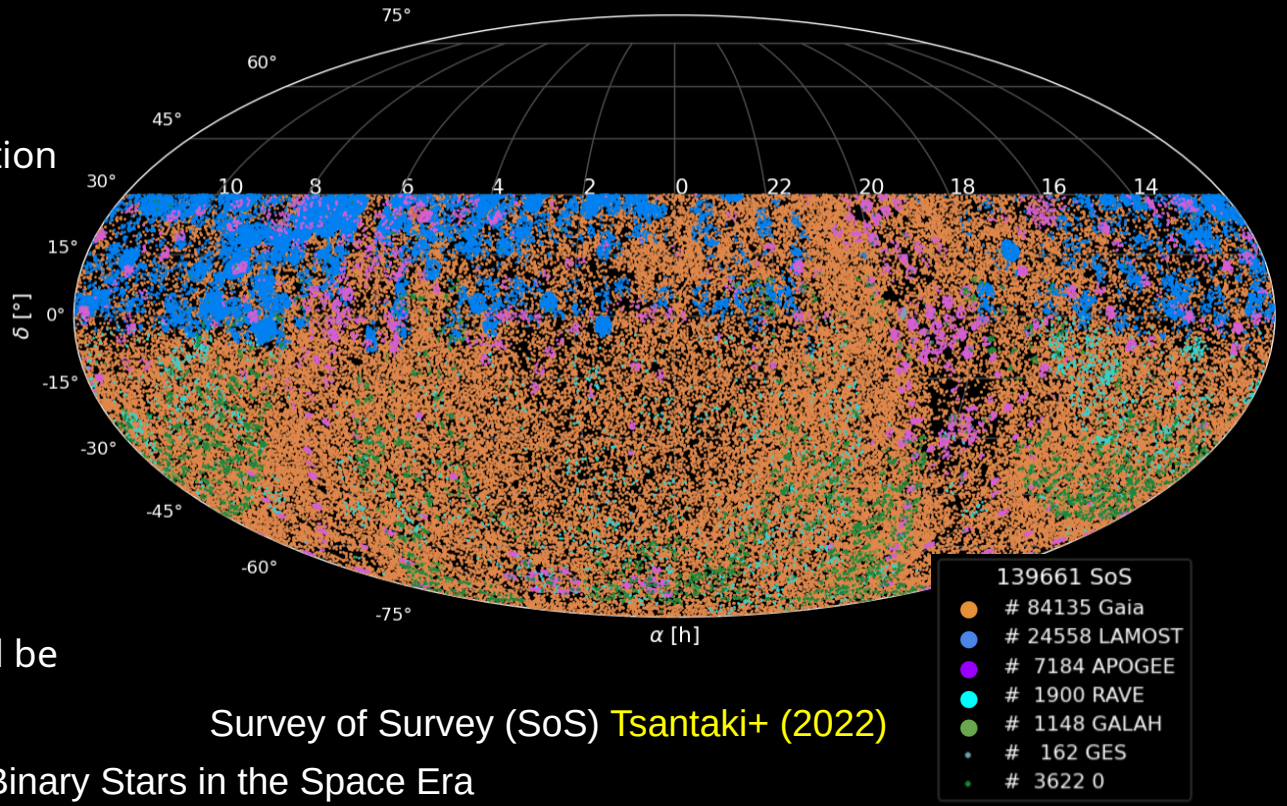
For unresolved SB2 (~15%):
- Derivation of atmospheric parameters

For SB1 (~1.5%):
- Minimum RV dispersion for SB1 detection
- Set upper limits on orbital periods
- Estimation of the period distribution

For SB2 (few thousands):
- Partial orbital characterization
- Derivation of atmospheric parameters

For <1% of SB*n*, *n*≥1:
- Full orbital characterization
- Full atmospheric characterization

In addition few tens to hundreds of SB2 will be turn into triples or quadruples.




Survey of Survey (SoS) Tsantaki+ (2022)

# Summary

- **SB9 Catalogue and Its Evolution**

The SB9 catalogue compiles thousands of spectroscopic binary orbits, including higher-order multiples, and has evolved into the modern SBX database with improved data access and standards.

**http://astro.ulb.ac.be/sbx**

- **Comparison with Gaia DR3**

Cross-matching SB9 with Gaia DR3 NSS reveals only a partial overlap (about 20–25%), highlighting differences in detection limits, period coverage, and the need for further investigation into the completeness of binary catalogues.

- **Spectroscopic Binaries in the 4MOST Survey**

The upcoming 4MOST survey will massively expand spectroscopic binary detection, enabling detailed studies of binary fractions, period distributions, and higher-order multiples across the Galaxy, with new tools and strategies for characterizing both resolved and unresolved systems.

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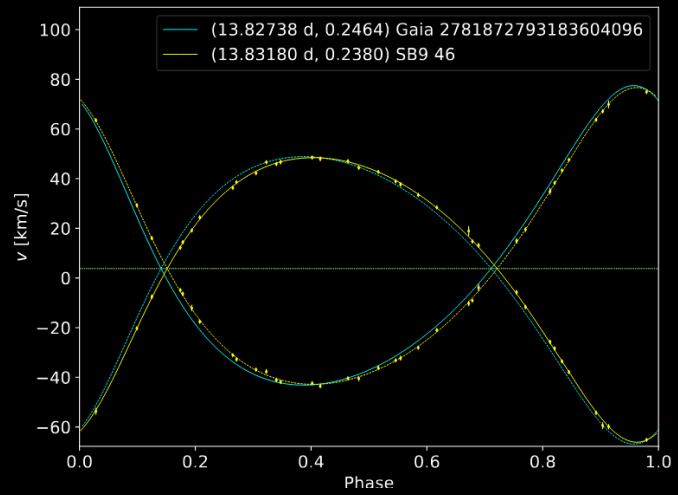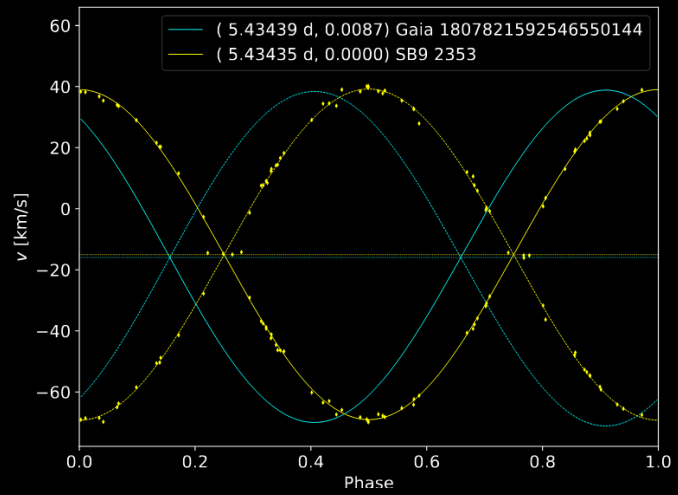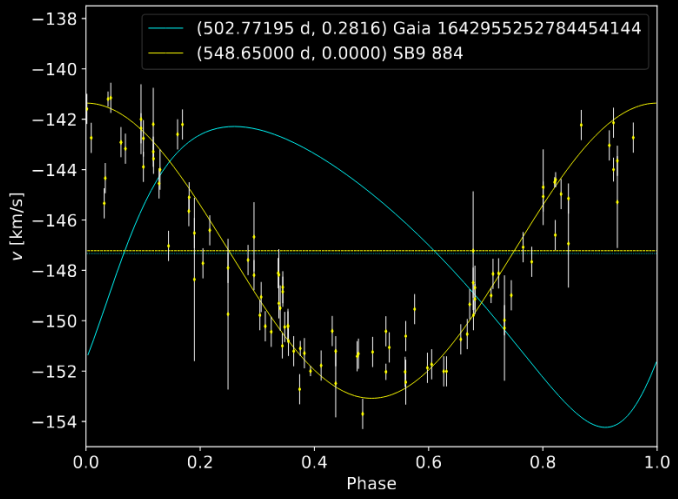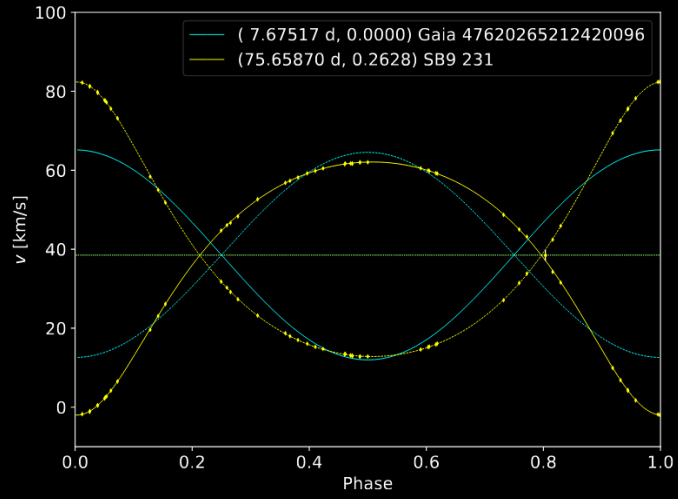
# RV curves: SB9 vs Gaia DR3 NSS