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A Catalog of Wide Binary and Multiple Systems of Bright Stars from *Gaia*-DR2 and the Virtual Observatory

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Why wide comoving systems?

- Test stellar formation and evolution theories
  - s > 20,000 au are challenging to binary formation models
- They are valuables indicators of Galactic environment
  - s > 1 pc provide further constrains in the Galactic gravitational potential
- Age indicators

Gaia-DR1 & TGAS

- Tycho-Gaia Astrometric solution for 2 million sources
  - Proper motion ($\sigma \sim 1{,}3$ mas/yr)
  - Parallax ($\sigma \sim 0{,}3$ mas)

- 3 Binary/Mult. Star Catalogues (Andrews et al. 2017 , Oelkers et al . 2017 , Oh et al. 2017)
  - Sophisticated Galactic models
  - Two binary populations:
    - Wide stable systems, high U and short s, expected to live > 10 Gyr
    - Ultra-wide unstable systems, low U and large s, expected to live < few Gyr (No Andrews et al.)

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Gaia-DR2

- Gaia Astrometric solution for 1,3 billion sources
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  - Parallax ($\sigma \sim 0{,}04$ mas)
  - G_{BP} - G_{RP} & RV

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Check the results from TGAS

Methodology

Gaia-DR2 & Tycho-2: the ~2,5 Million brightest stars (G < 13 mag)

1. **Good astrometry** → 1,936,422 sources
   - RUWE < 1.4
   - Parallax > 0
   - External error < 10% in parallax and both pm components

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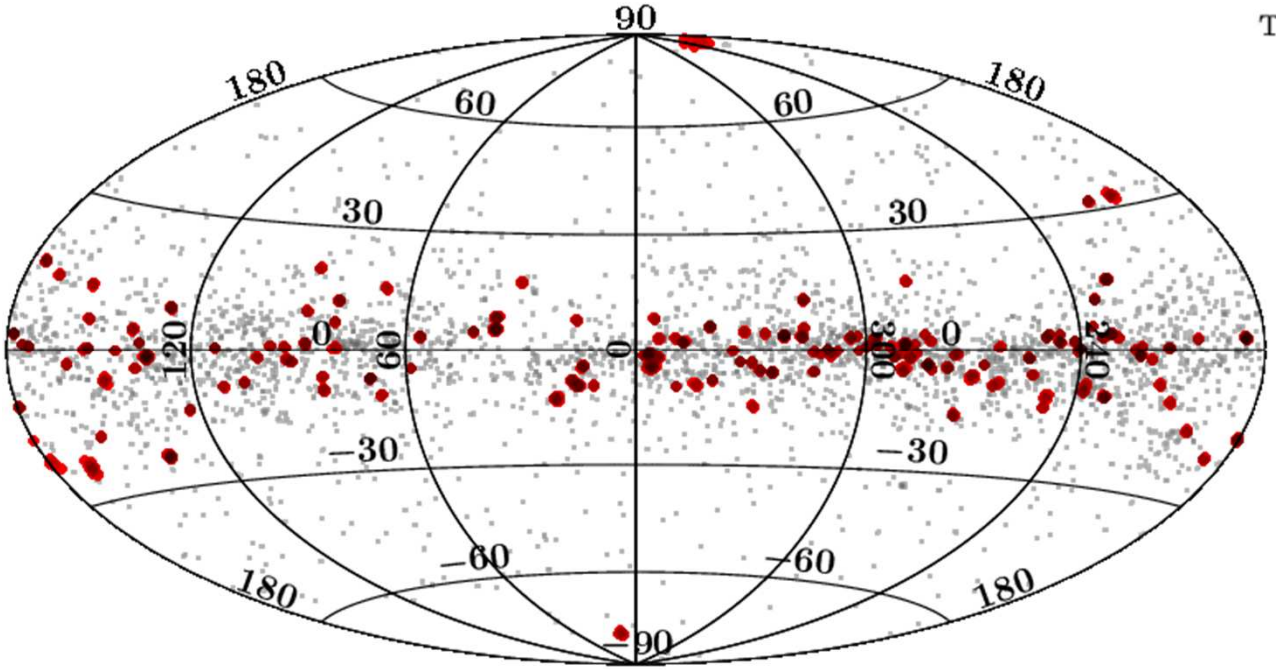
4. **RV rejection**
   - Gaia-DR2 & RAVE
   - σ < 5 km/s → RV for 678 candidates pairs
   - Similar RV within 2.5σ → 16% of pairs had discrepant

Catalogue

11,552 sources grouped in 3741 commoving binary and multiple systems



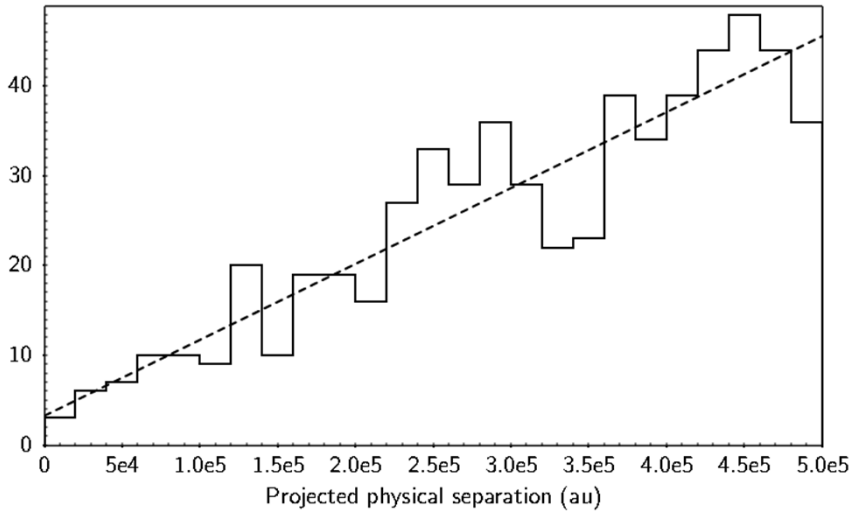
Galactic coordinates. Red dots: > 7 members

Table 1. Number of systems according to multiplicity

Members	Systems	similar RV
2	3055	570
3	288	4
4	104	
5	63	
6	42	1
7	34	
8	21	
9	16	
10	14	
>10[a]	104	
Total	3741	575

Chance alignment contamination

1. **Galaxy Specular Star**
   - Virtually move each star to the opposite side to the Galactic plane
   - Search for comoving companions
   - Any match is a false positive
   - 714 false comoving systems
   - False positives increase with s



~ 20% expected contamination

- ~1% for s < 50,000 au
- ~10% for 50,000 < s < 100,000 au
- Up to 40% for the largest separations

Chance alignment contamination

2. Expected chance alignment counterparts (ECAC)

- Searching area: Circle (C) of 500.000 au sky projected radius (R_C)
- Testing area: Surrounding annulus with outer radius $5 \cdot R_C$
- Search for comoving companions in the annulus
- Assumption: Any match in the testing regions is a false positive

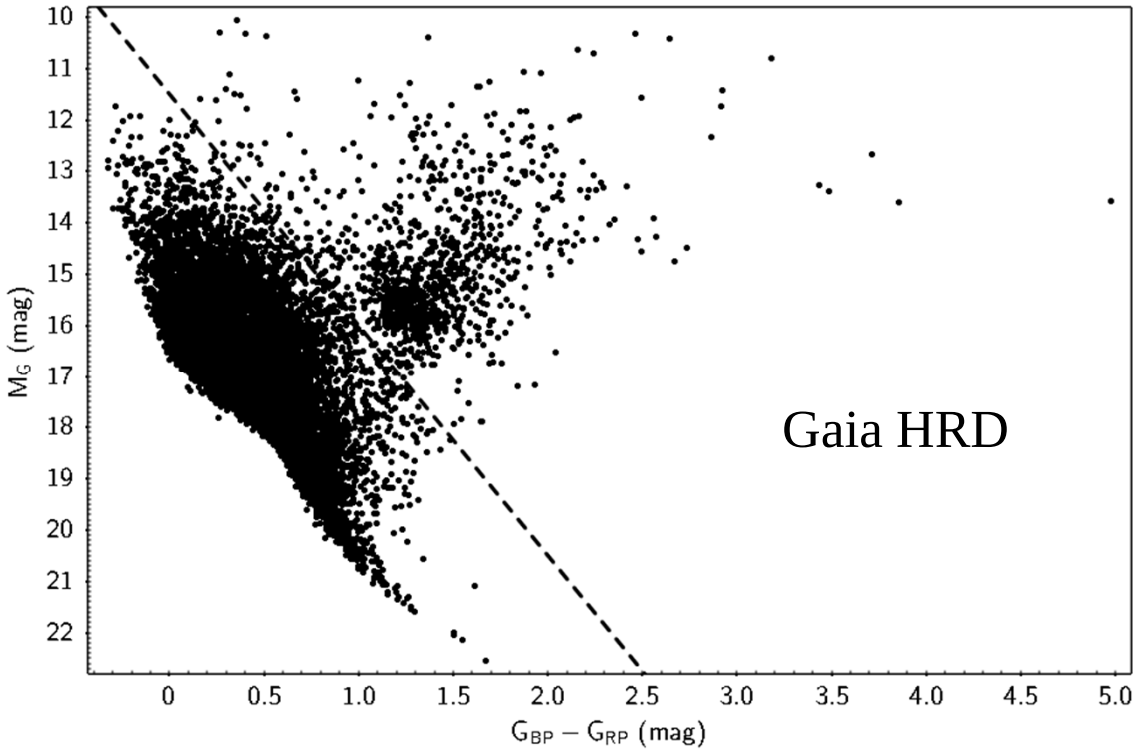
$$ECAC = M_A \cdot N_C / N_A$$

ECAC is not dependent on the physical properties of the system

- ECAC = 0 for 4,212 systems
- **ECAC > 0 (~ 31%)**
  - ~ 5% for s < 50,000 au
  - ~ 18% for 50,000 < s <100,000 au
  - Up to 51% for the largest separations

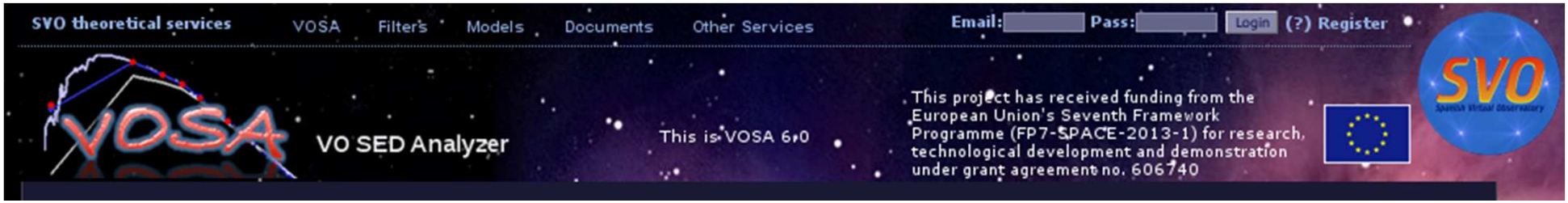
Physical Properties

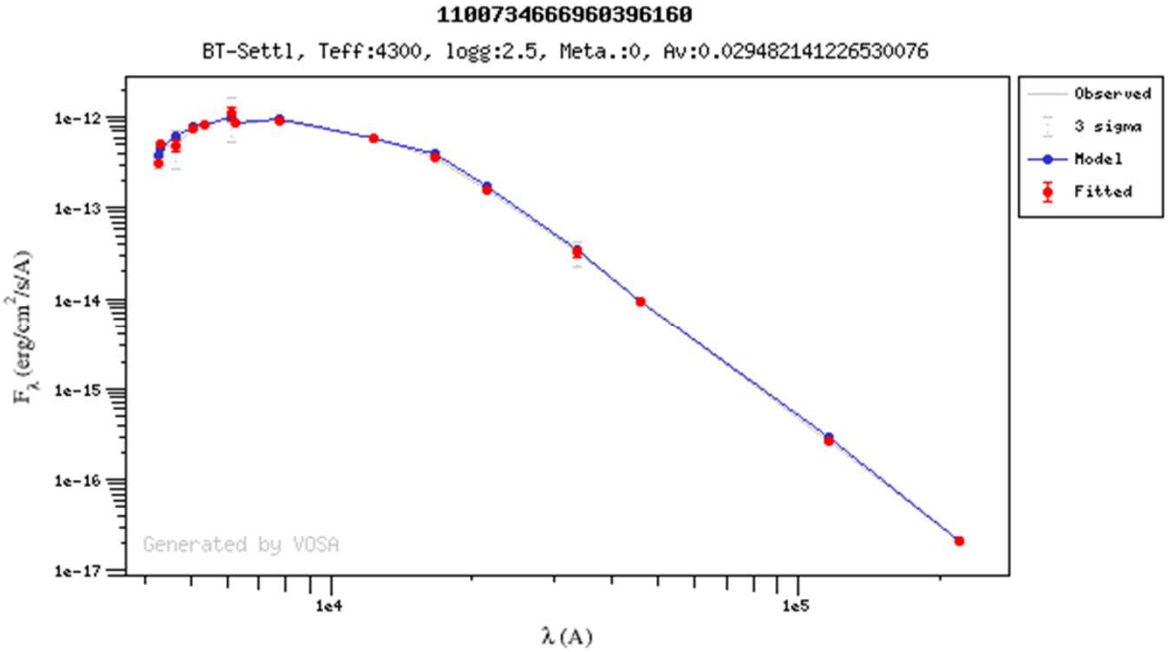
Dwarfs / Subgiant & Giant separation



1,094 Giants (~ 10%)

Physical Properties





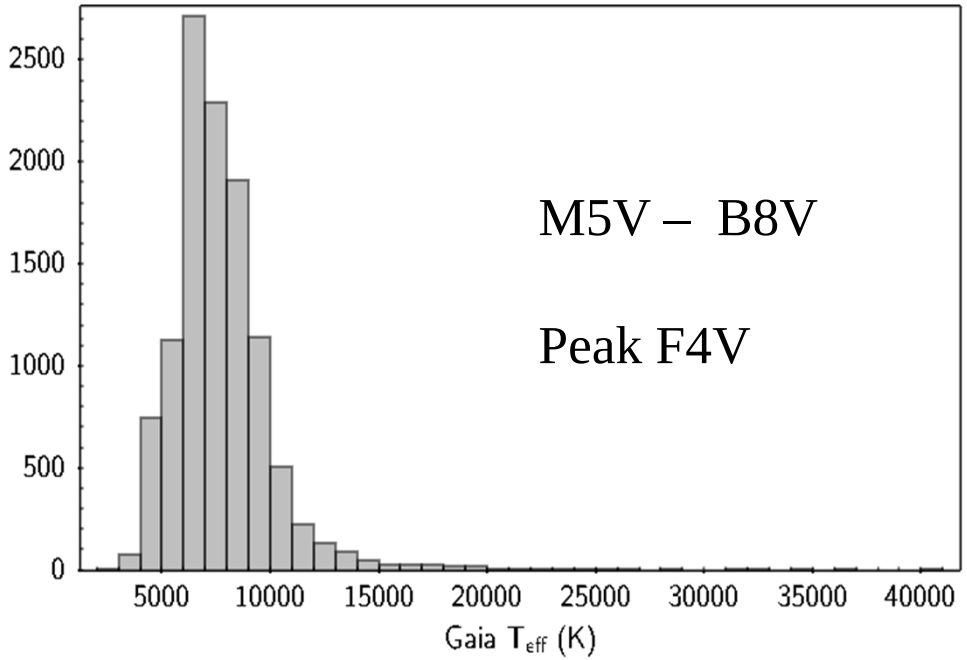
- SEDs: **GALEX** & **Tycho2** & **Gaia-DR2** & **APASS** & **2MASS** & **WISE**
- Extinction from VO & Gaia-DR2 (or no extinction)
- BT-Settl with solar metallicity and ≠ log*g* for D/G

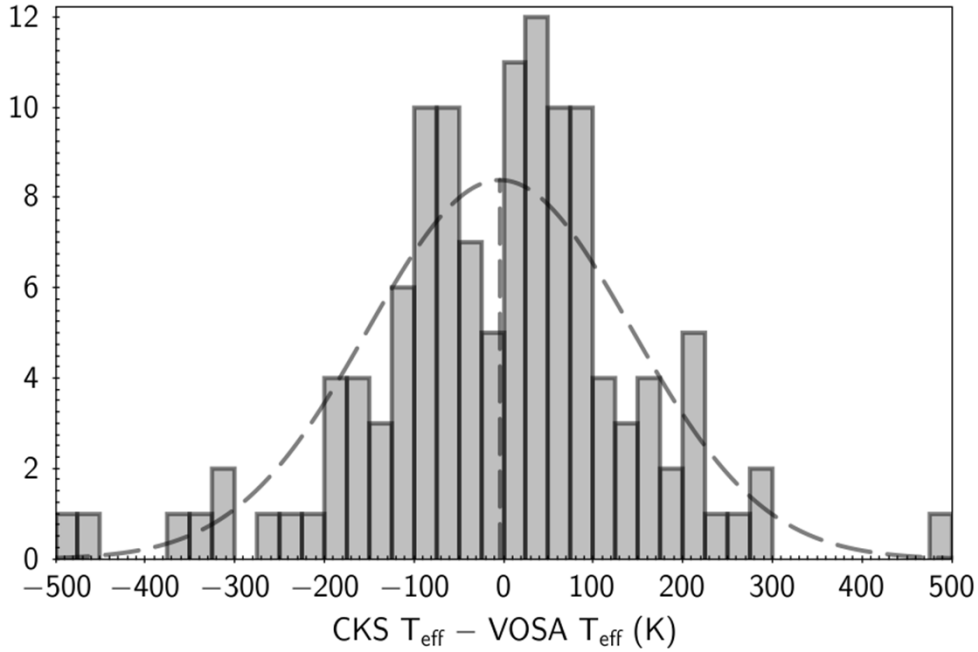
Physical Properties

Effective temperature

- 11,143 T_{eff} (~ 96%)
- σ ~ 135 K

California-Kepler Survey
(High-resolution Spectroscopy)





Physical Properties

- **Mass** ($\sigma < 0.2\ M_{\odot}$) from T_{eff}
  - Interpolating Tables of Gray (2008)
  - Relationship Reid & Hawley (2005) for later than M0

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  - $U = -GM_1M_2/a$ a: physical separation (a = 1.26s; Fischer & Marcy 1992)

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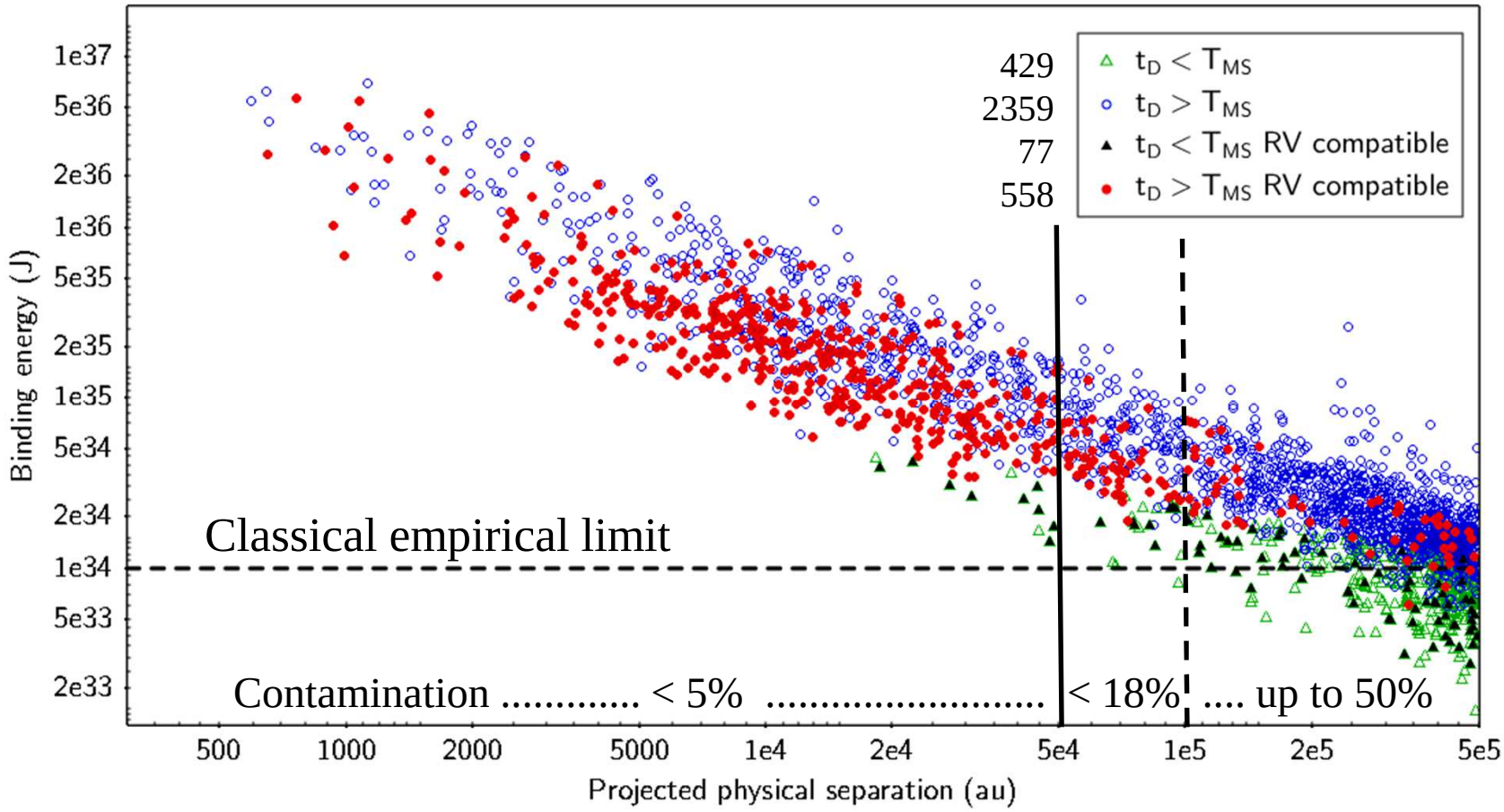
- **Main sequence lifetime**
  - Upper limit for the star age
  - At the MS $L \sim M^{3.5} \rightarrow t_{MS} \sim 10M/L = 10M^{-2.5}$

- **Dissipation lifetime**
  - Upper limit for the system age
  - $t_D \sim 1.212M_{tot}/a$ (Oelker et al. 2017)

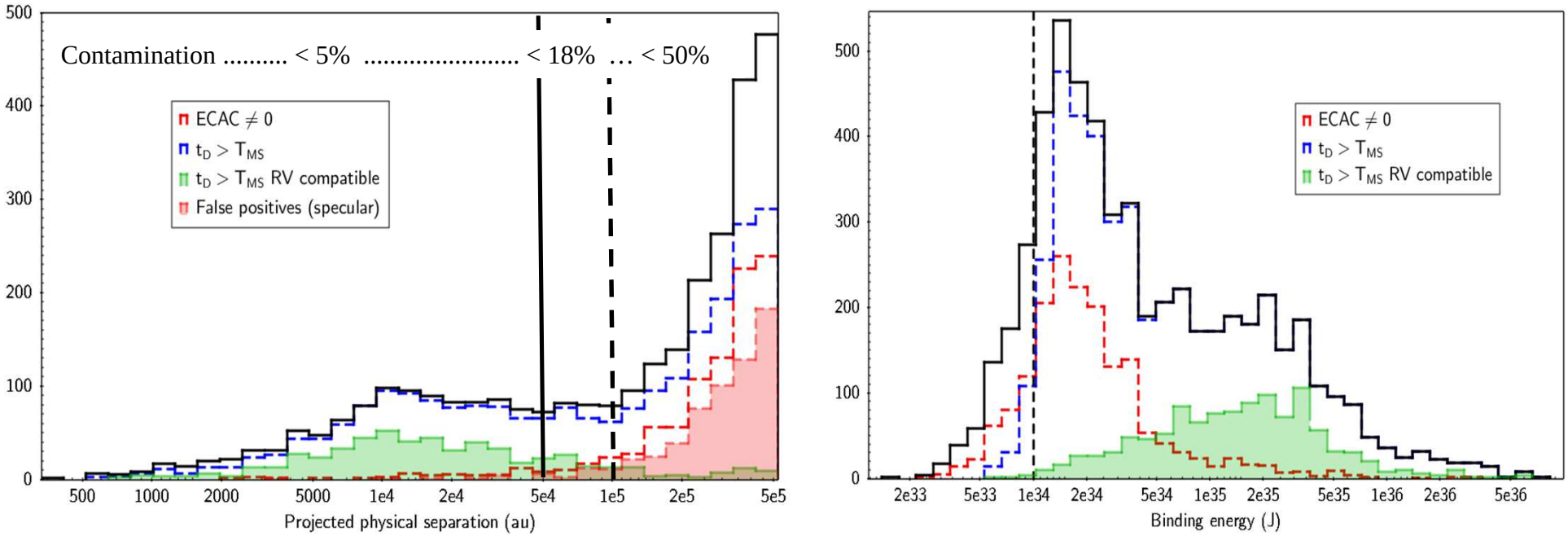
$t_D > t_{MS}$ more reliable
(but it could be false)

$t_D < t_{MS}$ less reliable
(but it could be real)

Physical Properties

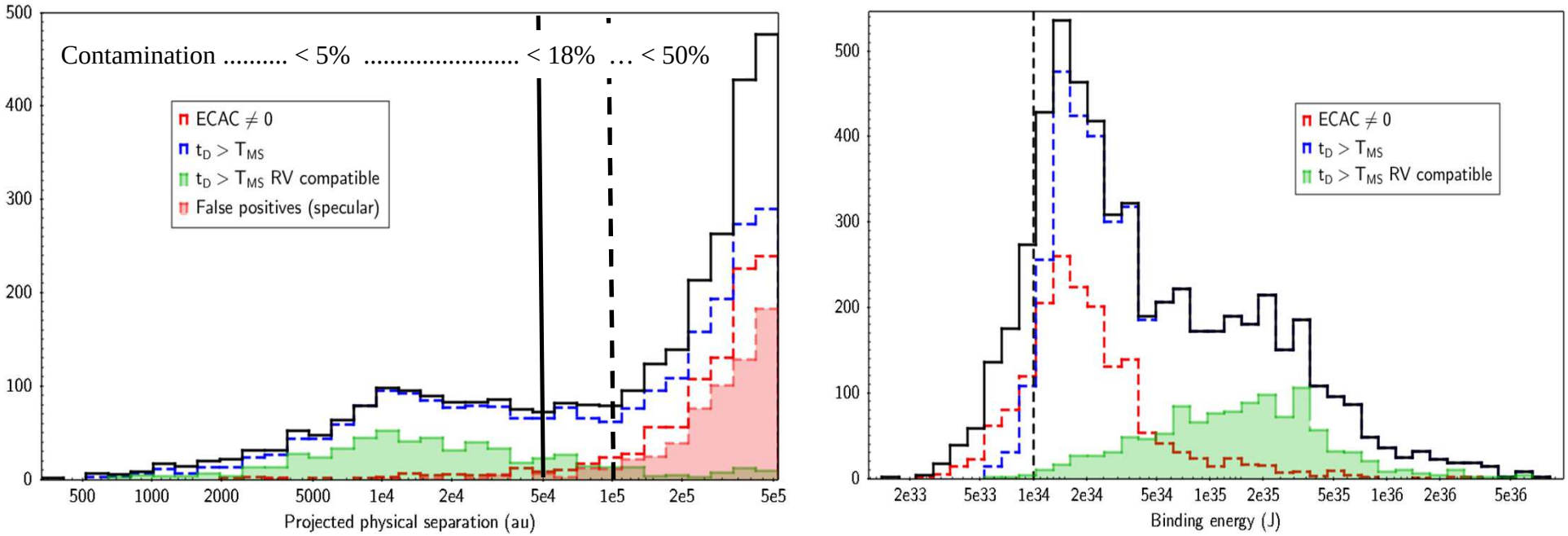


s & U Distributions



Clear bimodality in agreement with previous results from TGAS

s & U Distributions



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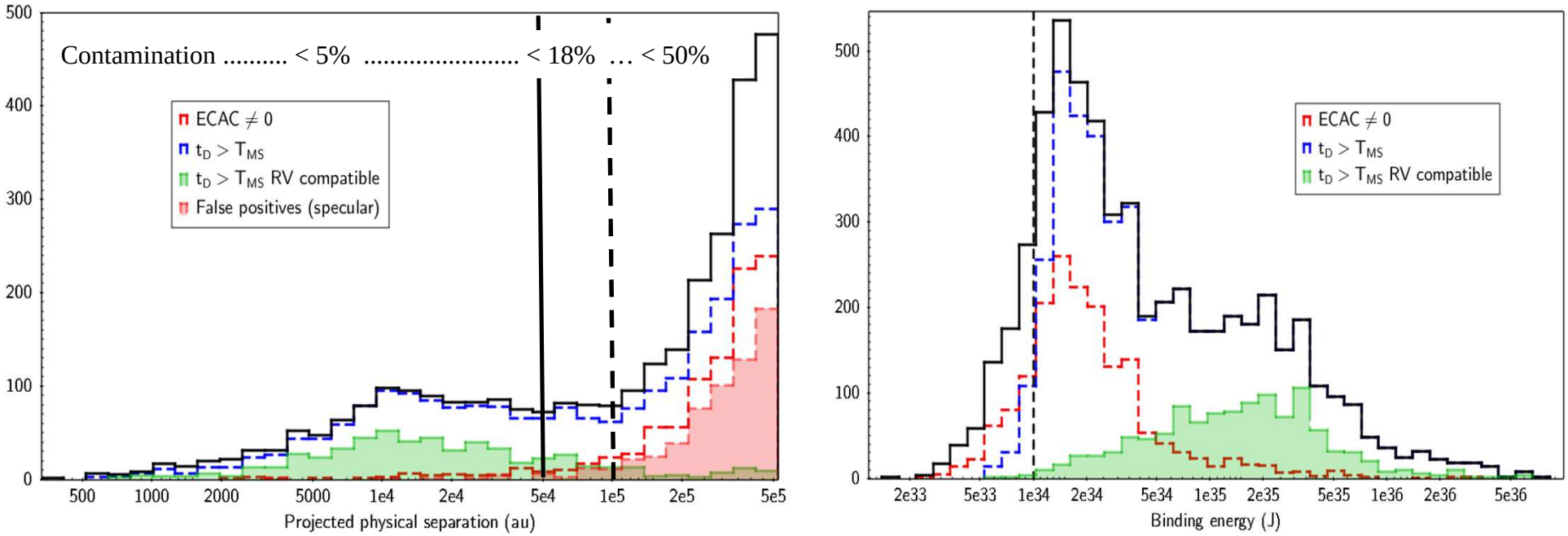
Two different populations??

s & U Distributions



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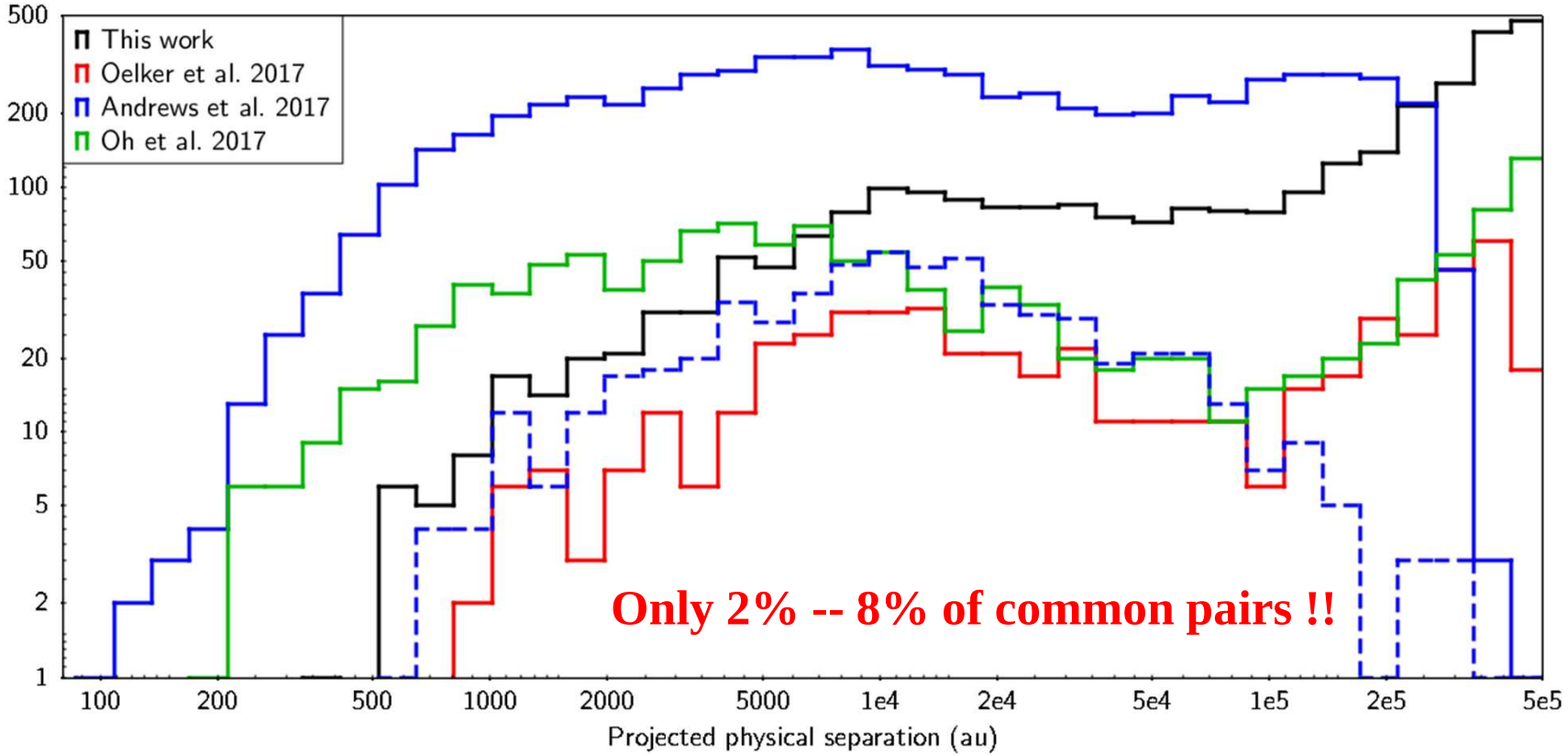
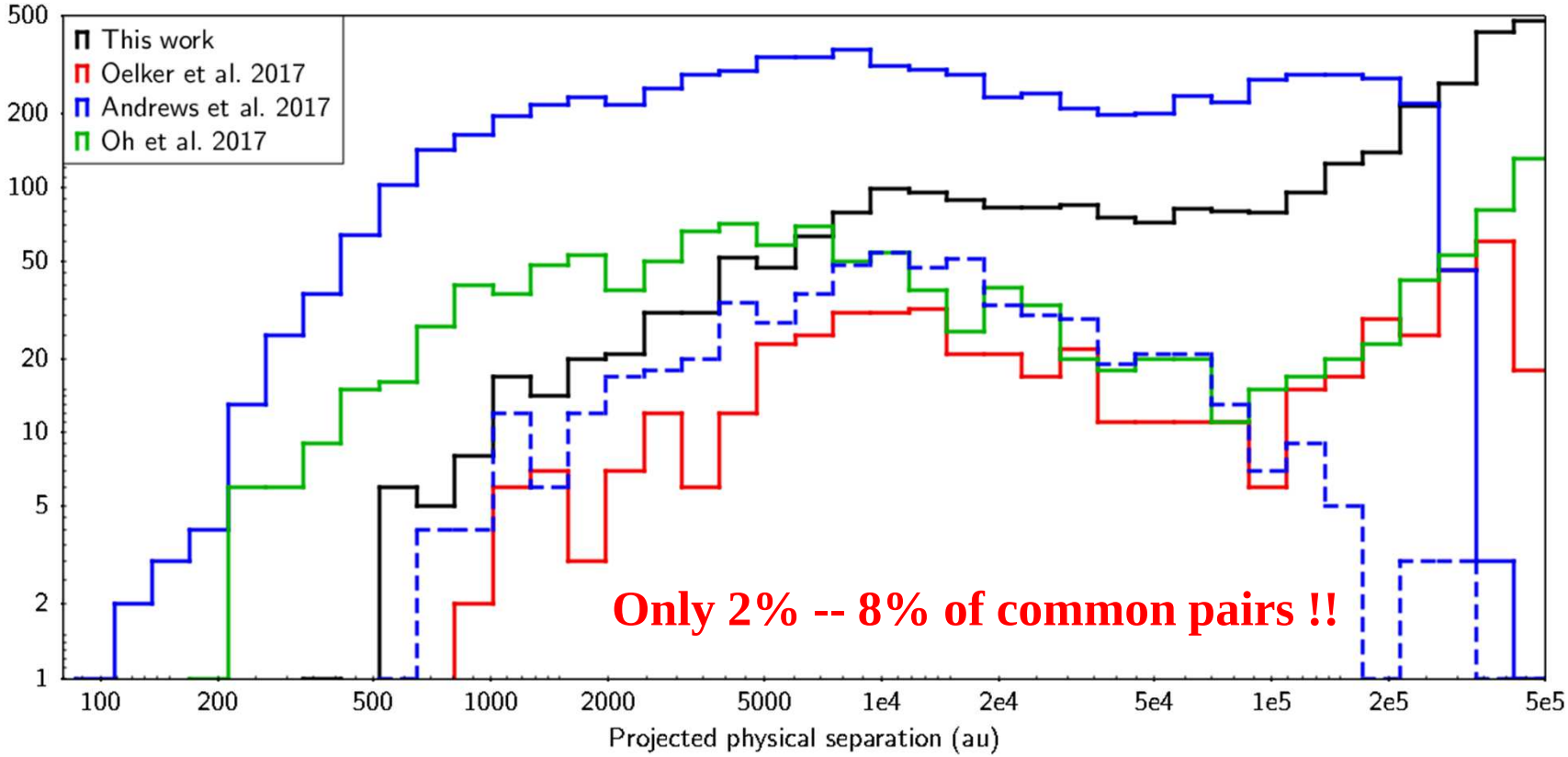
Ultra-wide binaries may exits but they should be rare

Our vs. TGAS


This work
Oelker et al. 2017
Andrews et al. 2017
Oh et al. 2017
500
200
100
50
20
10
5
2
1
100
200
500
1000
2000
5000
1e4
2e4
5e4
1e5
2e5
5e5
Projected physical separation (au)
Only 2% -- 8% of common pairs !!

Our vs. TGAS



- Large TGAS errors
- Andrews et al. claimed a low contaminations of only 6% (??!!)

Bright Wide Binary/Mult. Stars with Gaia & VO

The SVO archive of double and multiple star systems from Gaia-DR2

Home | Data retrieval | News | Documentation | Coverage Map | Credits | Help-desk

RA (?) | DEC (?) | Radius (?) | Search | Reset

180 | 0 | 180 | 50 results | default verb. | (Maximum Search Radius allowed: 180 degrees)

Don't use coordinates as search criterion

[-] Hide additional search fields

Magnitude ranges (?) | Color ranges (?)

GroupSize (?) | Sep. Ang (?)
Sep. Sky (?) | Parallax (?)
RUWE (?) | Teff (?)
Mass (?) | U (?)
ECAC (?)
Obj.Name: (?)

First 50 results shown (11550 found)

RA (J2000) (deg)	DEC (J2000) (deg)	RA (J2000) (hh:mm:ss)	DEC (J2000) (hh:mm:ss)	RA (Gaia-DR2) (?) (deg)	DEC (Gaia-DR2) (?) (deg)	Gaia-DR2 (?)	Tycho2 (?)	Si
258.1358	62.8743	17:12:32.58	62:52:27.59	258.1359	62.8745	1631010158460327168	4202-1457-1	HD
257.7838	62.9523	17:11:08.12	62:57:08.39	257.7840	62.9525	1631025482903503744	4202-885-1	TYC
66.3542	22.2000	04:25:25.02	22:12:00.01	66.3548	22.1998	145484629809228544	1277-1627-1	*
66.5769	22.8136	04:26:18.46	22:48:48.90	66.5774	22.8134	145727729254950912	1816-1893-1	*
68.4049	21.1509	04:33:37.18	21:09:03.06	68.4054	21.1507	144377799556207488	1278-1315-1	HD
68.2477	15.8190	04:32:59.45	15:49:08.29	68.2482	15.8189	3312644885984344704	1266-1286-1	V*
67.6620	15.6919	04:30:38.89	15:41:30.76	67.6625	15.6918	3312628358950130176	1265-1174-1	*
68.4622	14.8444	04:33:50.92	14:50:39.94	68.4626	14.8443	3309419984020071552	681-1151-1	*

http://svo2.cab.inta-csic.es/vocats/v2/comovingGaiaDR2/

Conclusions

- We used a simple method to discover commoving systems
- We created an online catalogue with 3,741 commoving systems
- We estimated a contamination rate between 20-30%
  - Contamination increase with the projected physical separation
  - 1-5% for s < 50,000 au → 1,040 high reliable binary systems
- TGAS catalogues:
  - High degree of contamination
  - Bimodality disappears
  - We cannot confirm the ultra-wide binary population (RV from Gaia-DR3)

Thank you!!