

Nearby, halo and hypervelocity white dwarfs in *Gaia* DR2



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STARS ON THE RUN II

Potsdam, Germany from 25.8. to 30.8.2019

Based on and motivated by:

References:

- Bromley, B. C., et al., 2018, ApJ, 868, 25
- Du, C, et al., 2019, ApJS, accepted, arXiv:1907.06348
- Gaia Collaboration, Brown, A. G. A., et al., 2018, A&A, 616, A1
- Geier, S., et al., 2019, A&A, 621, A38
- Hattori, K., et al., 2018, ApJ, 866, 121
- Hollands, M. A., et al., 2018, MNRAS, 480, 3942
- Kepler, S. O., et al., 2015, MNRAS, 446, 4078
- Kilic, M., et al., 2019, MNRAS, 482, 965
- Lindgren, L., 2018, Gaia Technical Note GAIA-C3-TN-LU-LL-124-01
- Raddi, R., et al., 2019, MNRAS, in press
- Scholz, R.-D., et al., 2018, A&A, 613, A26
- Scholz, R.-D., 2018, RNAAS, 2, 4
- Shen, K. J., et al., 2018, ApJ, 865, 15
- Smart, R. L., et al., 2019, MNRAS, 485, 4423
- Torres, S., et al., 2019, MNRAS, 485, 5573

Be careful with the data!

Used Gaia DR2 quality criteria for reliable data (Gaia Collaboration+18, Lindegren18):

good astrometry:

**(Plx/ePlx>10 @ Plx>10mas) | (Plx/ePlx>5 @ Plx>0.2mas)
& RUWE<1.4 & visibility_periods_used(Nper)>8**

good photometry:

RFBP>10 & RFRP>10 & E_BR_RP<(1.3+0.06*(BP-RP)2)**

colours of symbols and lines in plots:

green: bad astrometry + bad photometry

magenta: good astrometry + bad photometry

blue: bad astrometry + good photometry

red: good astrometry + good photometry

Additional criteria considered for WD hypervelocity candidates:

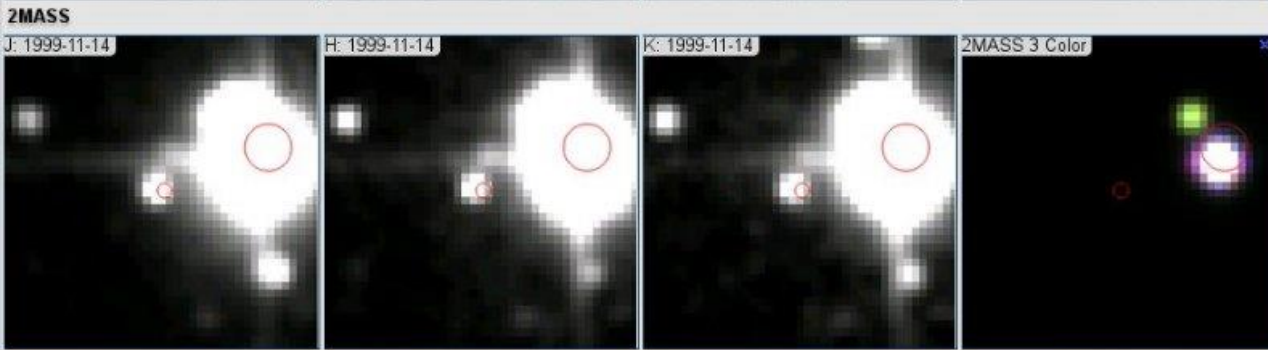
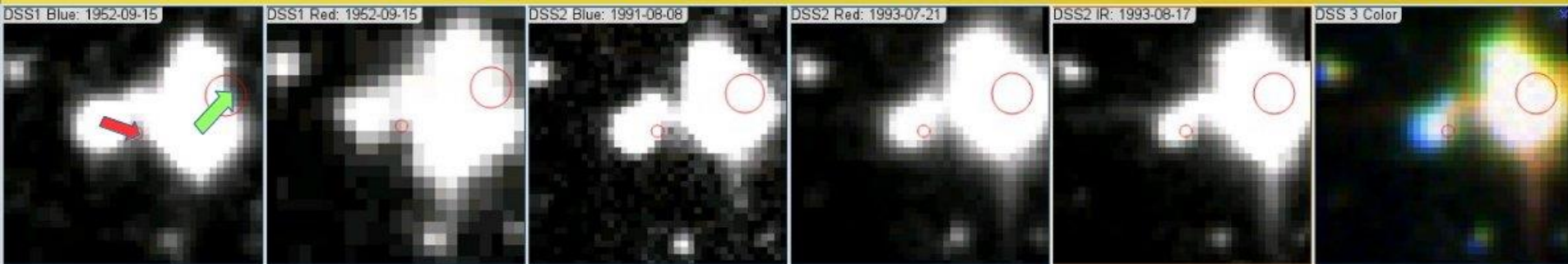
astrometric_gof_al (gofAL), astrometric_excess_noise_sig (sepsi)

TYC 3980-1081-1 B = new WD within 10pc

found as a common proper motion companion of a new nearby star (Scholz+18) using *Gaia* DR1, UCAC5, and URAT1 catalogues

Optical DSS (BRI photographic plates) 1952-1993

BRI colour composite



Open circles:
Gaia DR1 positions 2015

Arrows:
proper motions

NIR (2MASS JHKs) 1999

JHKs colour composite

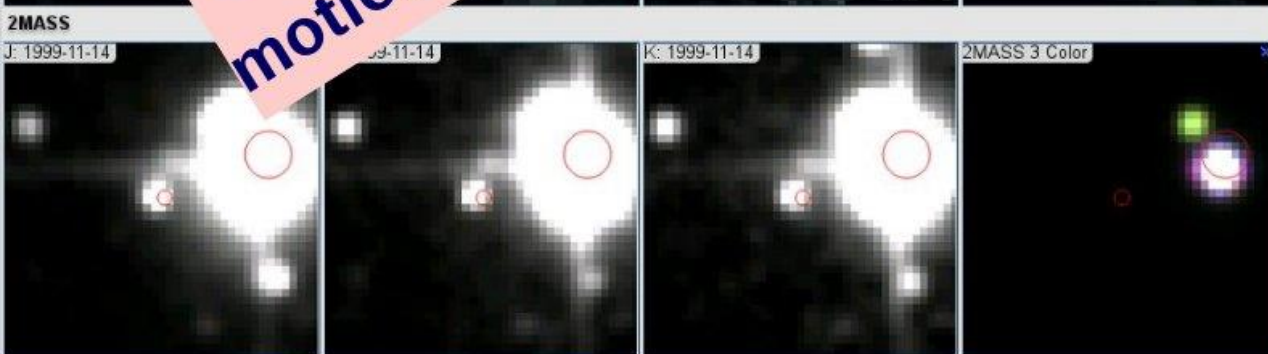
Finder charts from Infrared Science Archive (IRSA)

TYC 3980-1081-1 B = new WD within 10pc

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Optical DSS (BRI photographic plates) 1952-1993

BRI colour composite



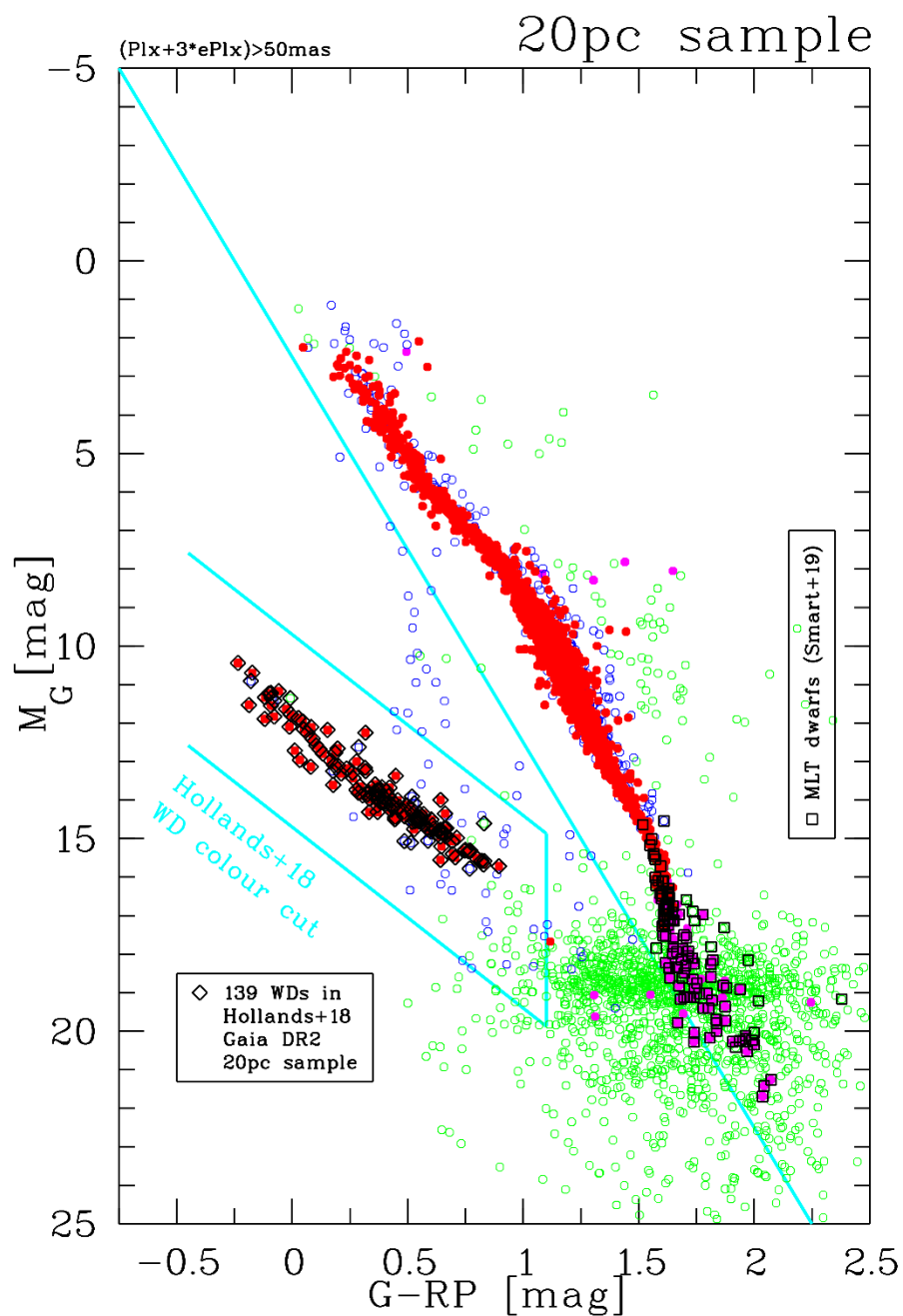
Open circles:
Gaia DR1 positions 2015

Arrows:
proper motions

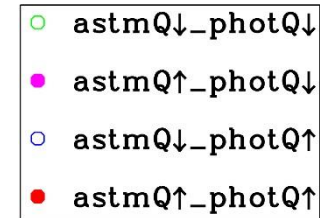
NIR (2MASS JHKs) 1999

JHKs colour composite

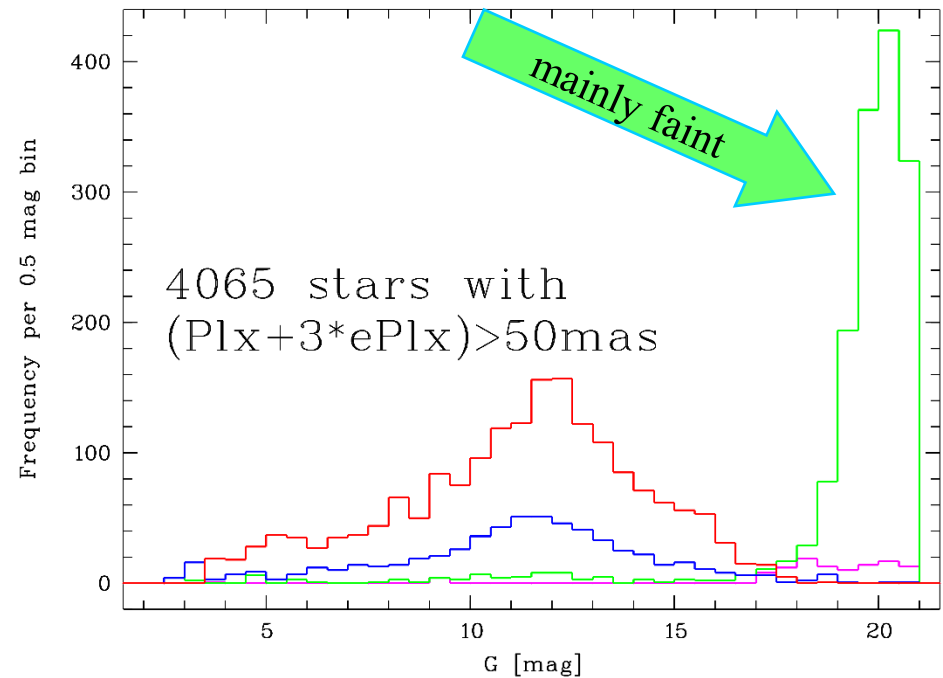
Finder charts from Infrared Science Archive (IRSA)



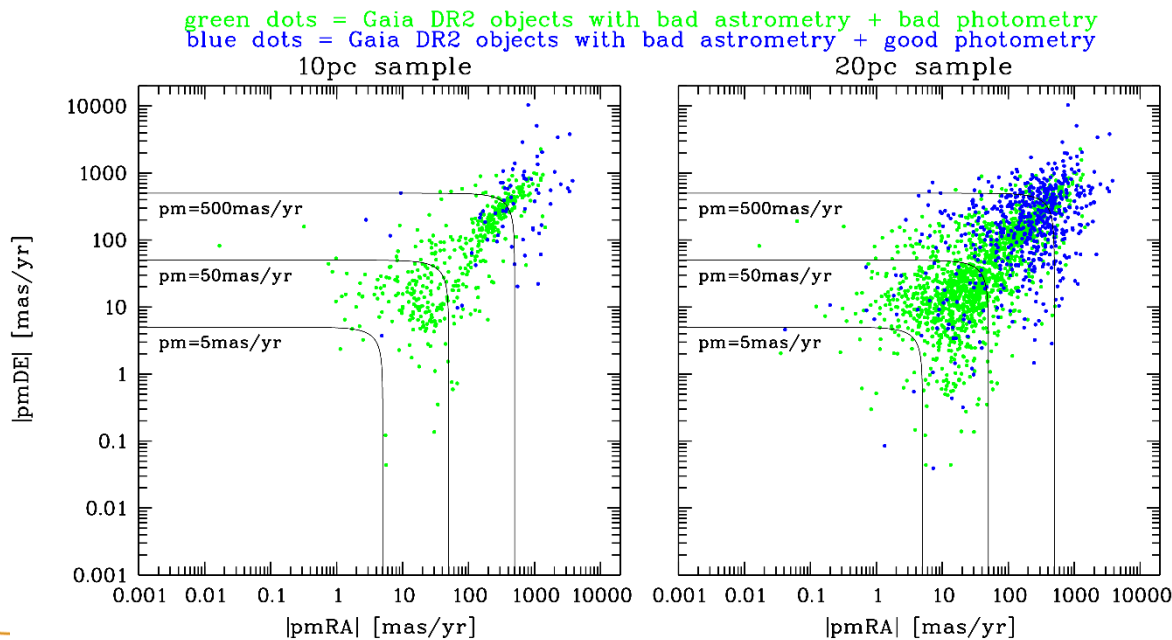
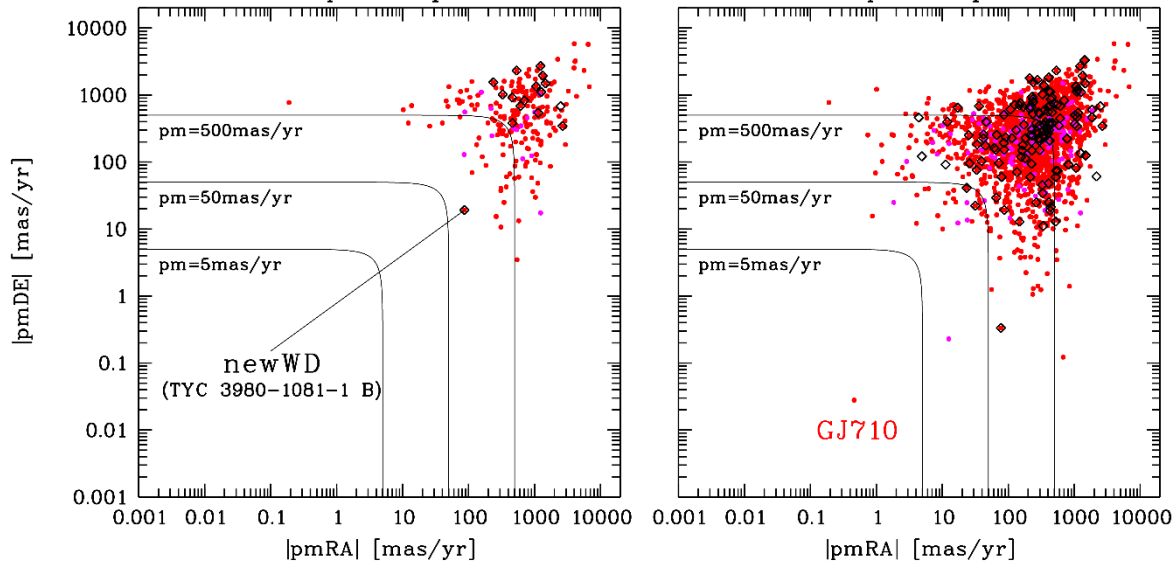
Gaia's DR2 20pc census of WDs (see Hollands+18)



The full 20pc stellar census (tbd)
38% with astm_Q↓ and phot_Q↓



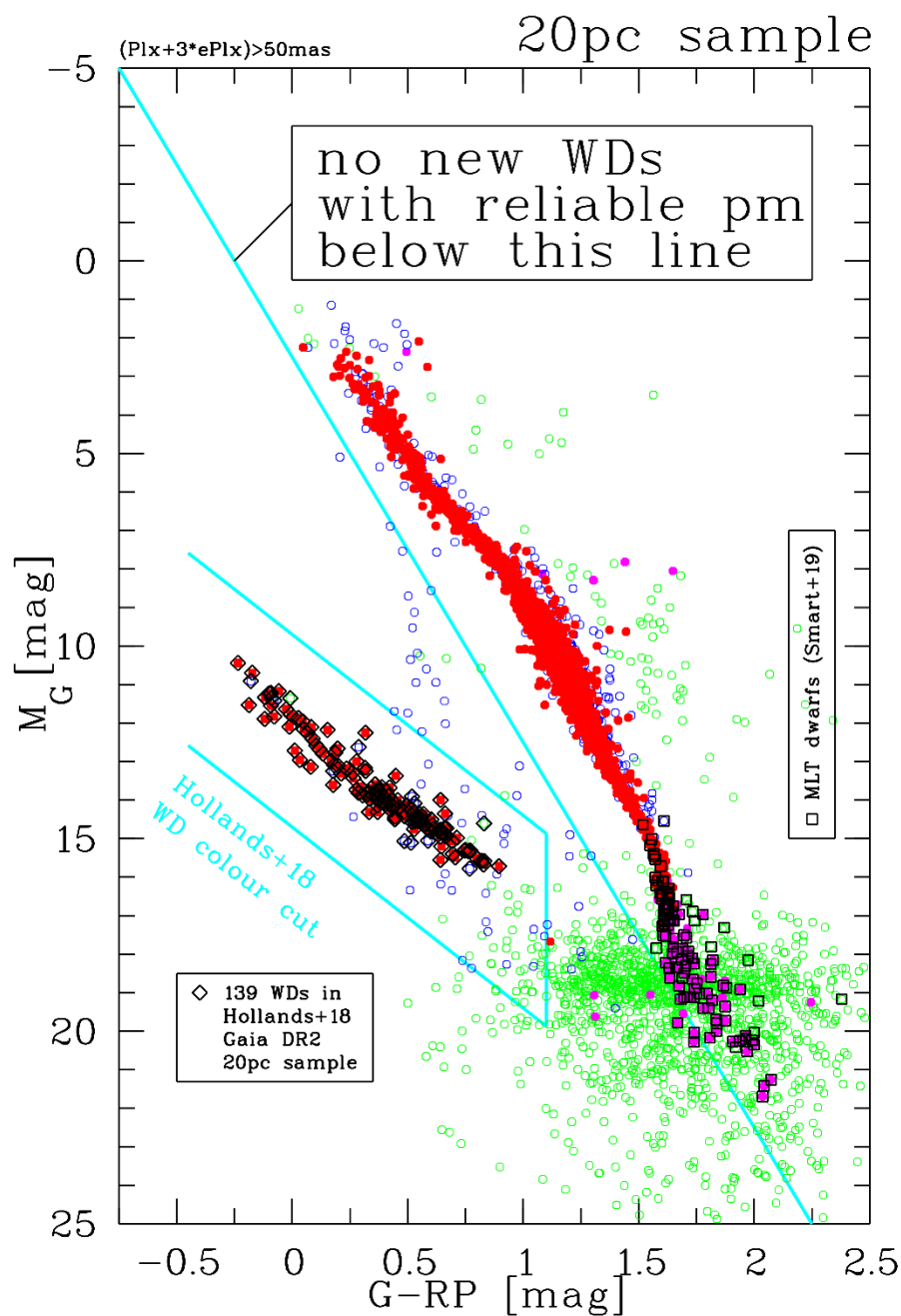
red dots = Gaia DR2 objects with good astrometry + good photometry
 magenta dots = Gaia DR2 objects with good astrometry + bad photometry
 open lozenges = known WDs in Gaia DR2 (Hollands+18)



Checking the proper motions (pm) within 10pc and 20pc

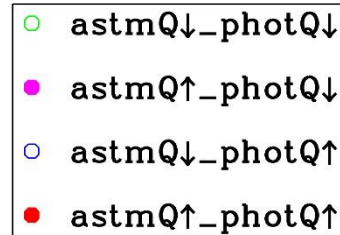
- New WD within 10pc has small pm compared to other WDs (large pm!) and stars
- One well-known nearby star (GJ710) has an exceptional small (zero!) pm
- Stars with bad astrometry and photometry tend to have smaller pm or equally large pm components (matching problems?)
- *Gaia*'s pm can be checked with finder charts and other pm catalogues

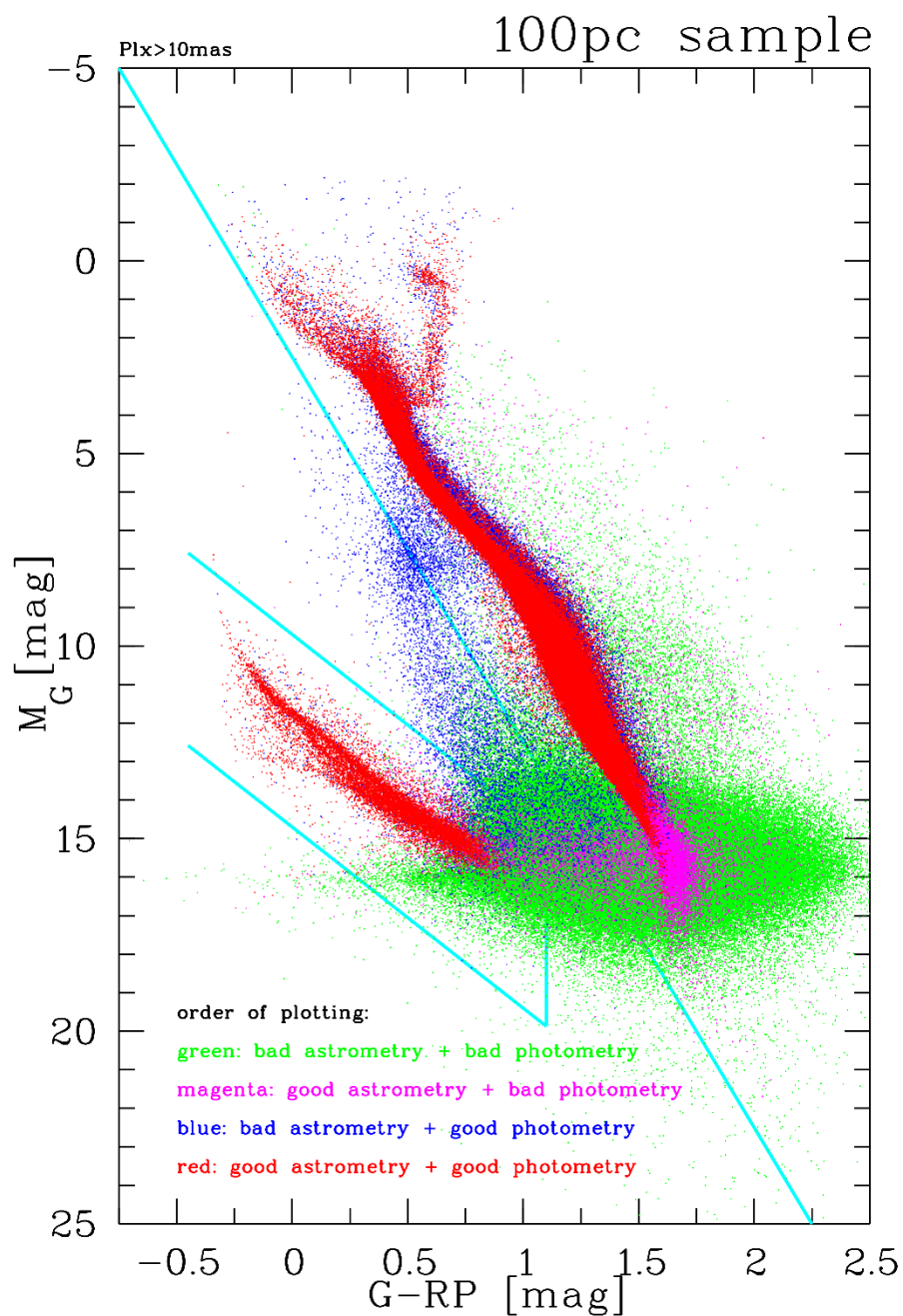
Gaia's DR2 20pc census of WDs (see Hollands+18)



➤ No other WDs, in addition to the 139 identified by Hollands+18, were found when checking finder charts and other pm catalogues for:

- blue and green circles within the WD colour cuts
- blue circles below dividing line but outside WD colour cuts
- a few red and magenta points falling out of WD colour cuts at $1.1 < G-RP < 1.4$
- many green circles below dividing line and with $G-RP < 1.4$

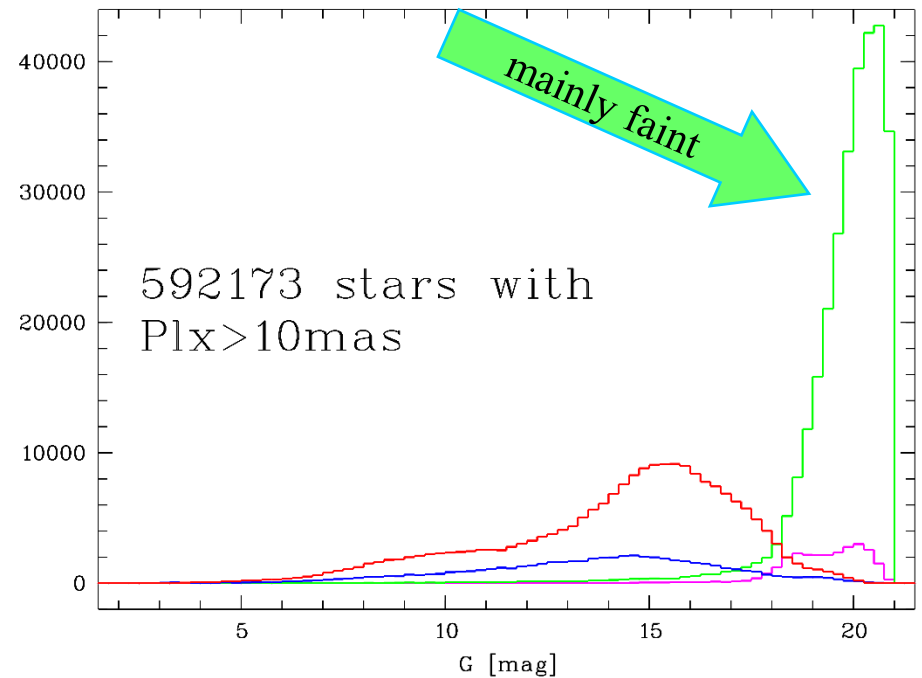




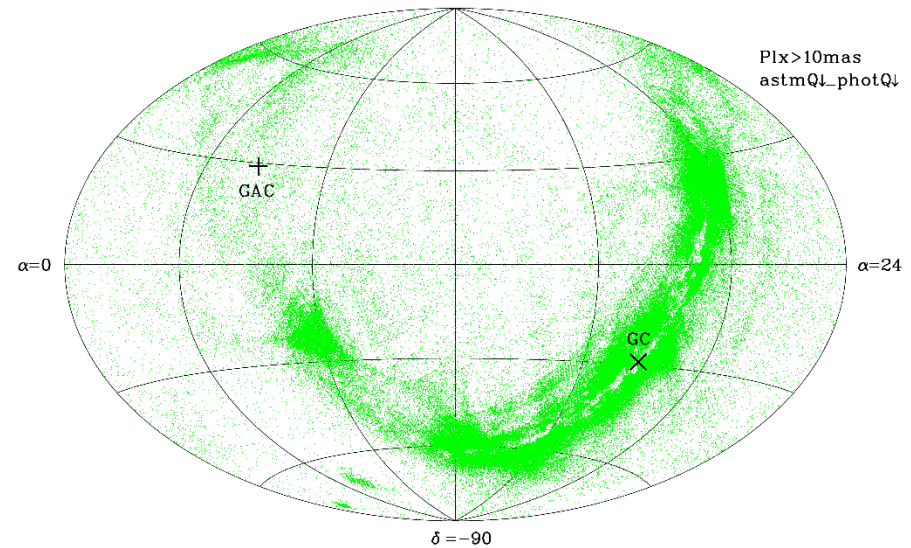
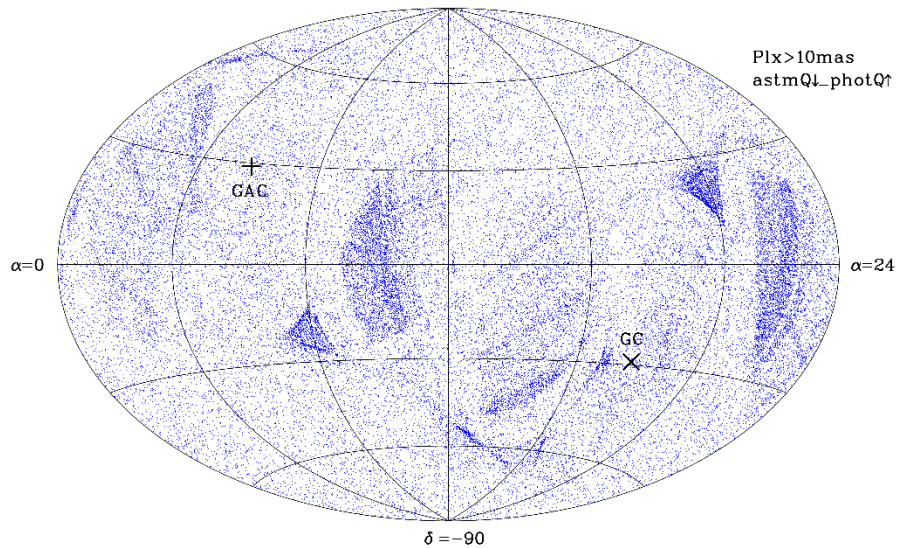
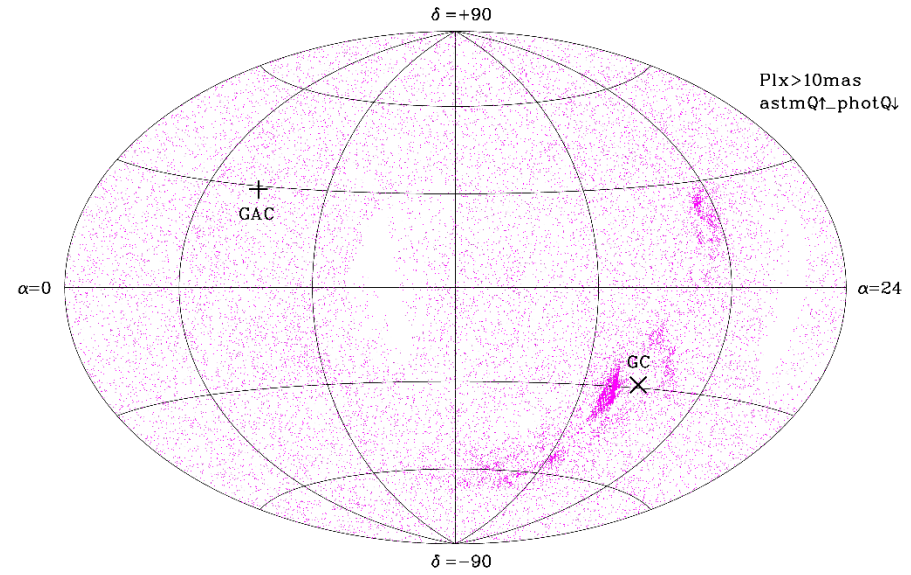
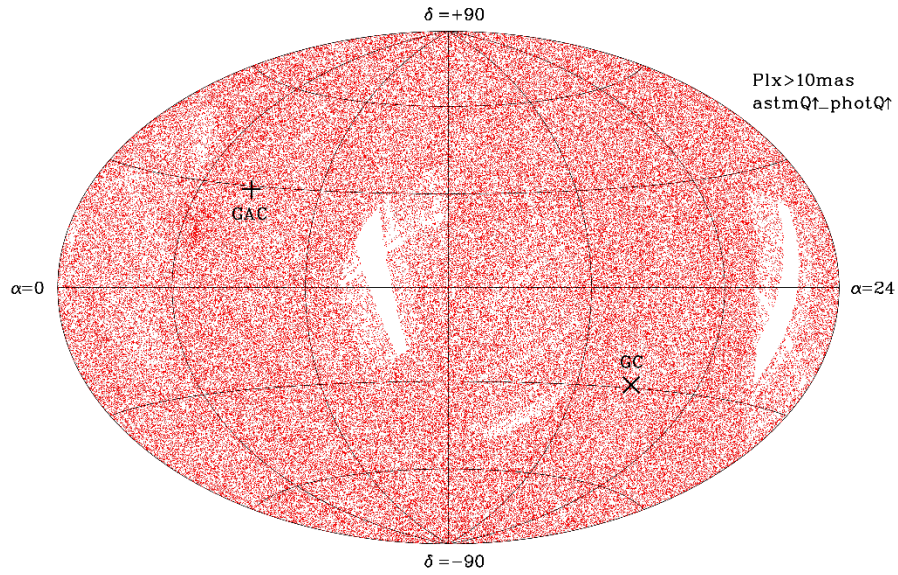
Gaia DR2 100pc horizon for WDs

- Of all reliable stars (red dots) 12821 WDs fall in Hollands+18 colour box
 - $\approx 93\%$ of 13732 WDs in Torres+19
 - = 6.11% of all 209793 stars
 - only 62 (0.03%) are not in WD colour box and below WD/MS+sd dividing line!

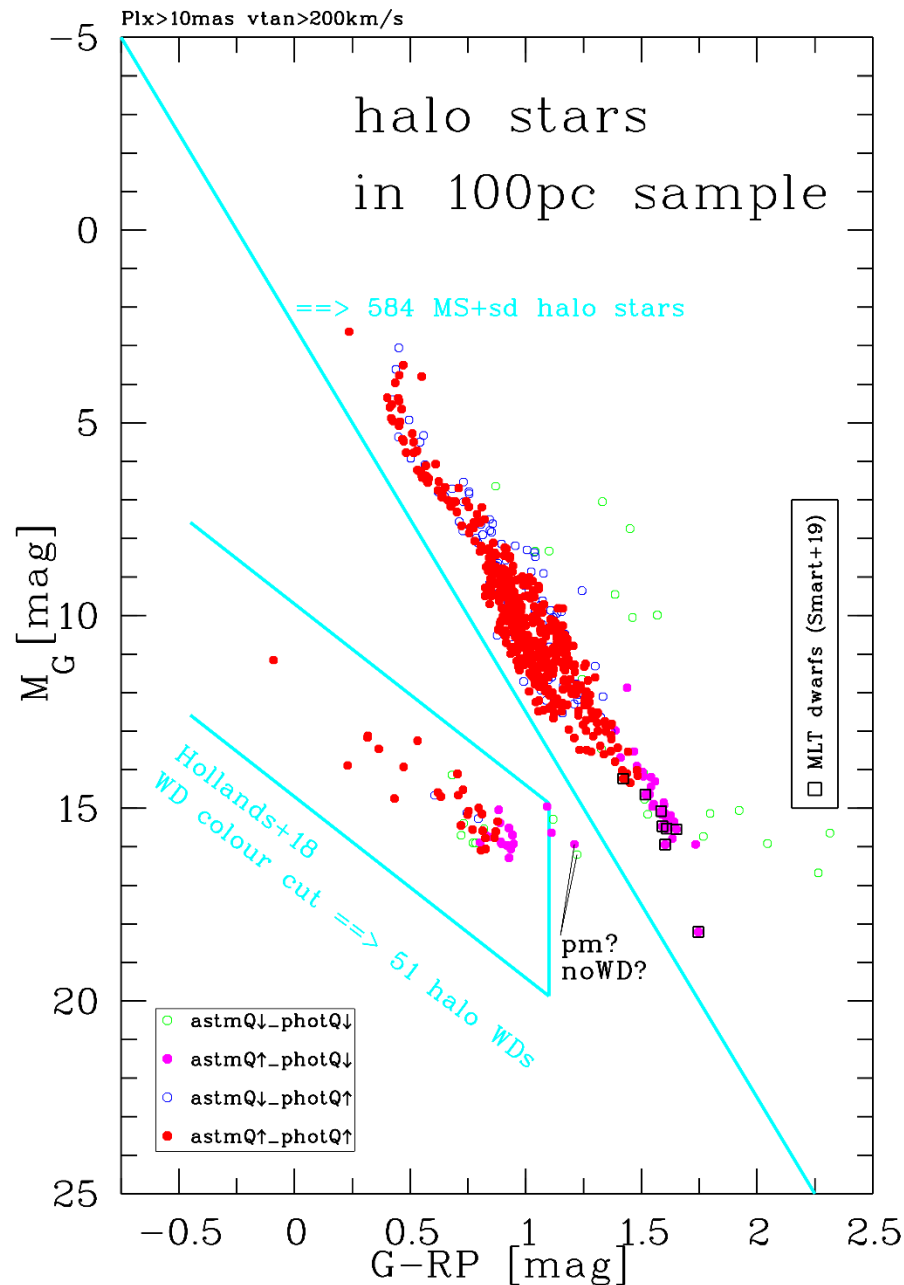
50% with astm_Q↓ and phot_Q↓



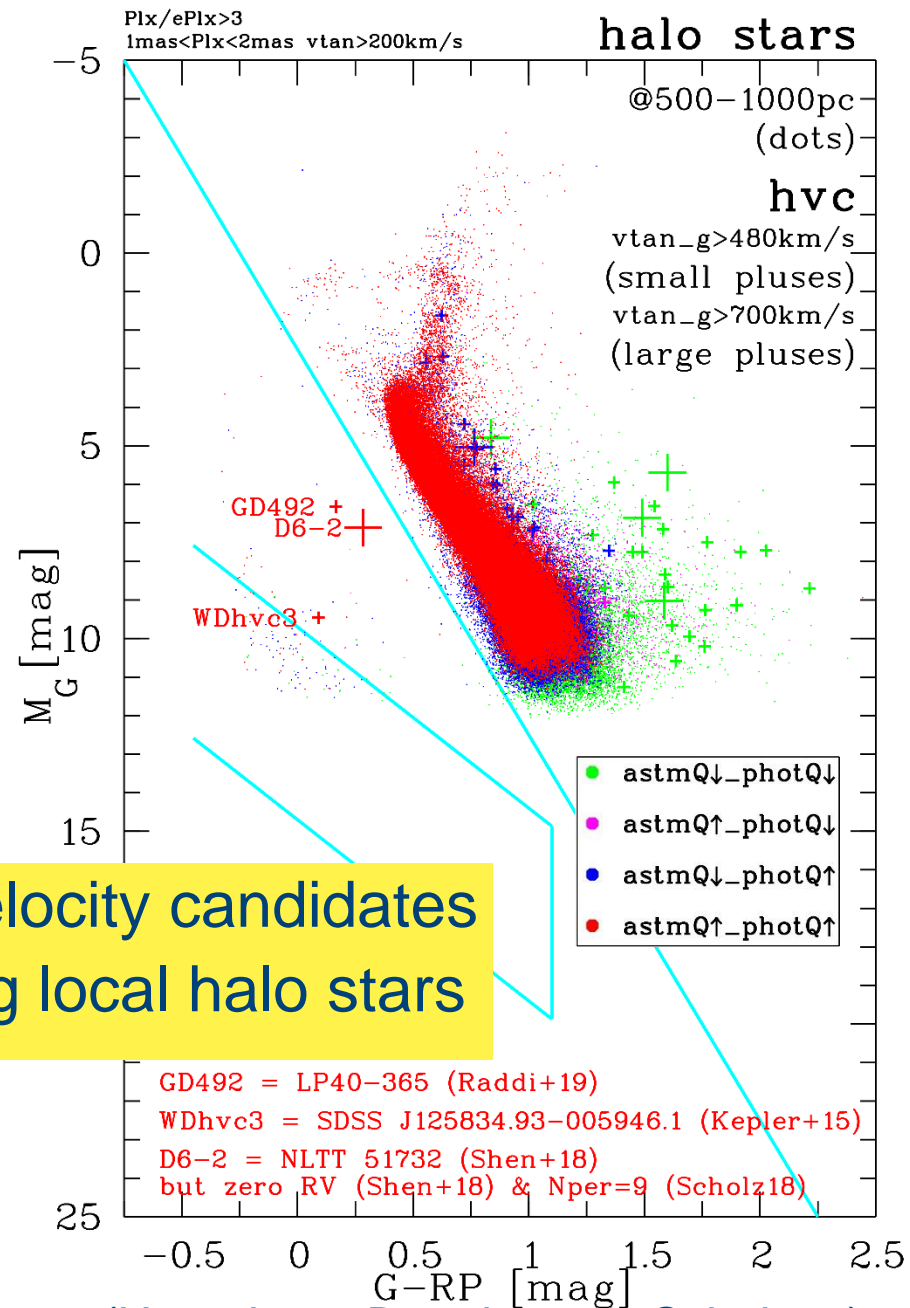
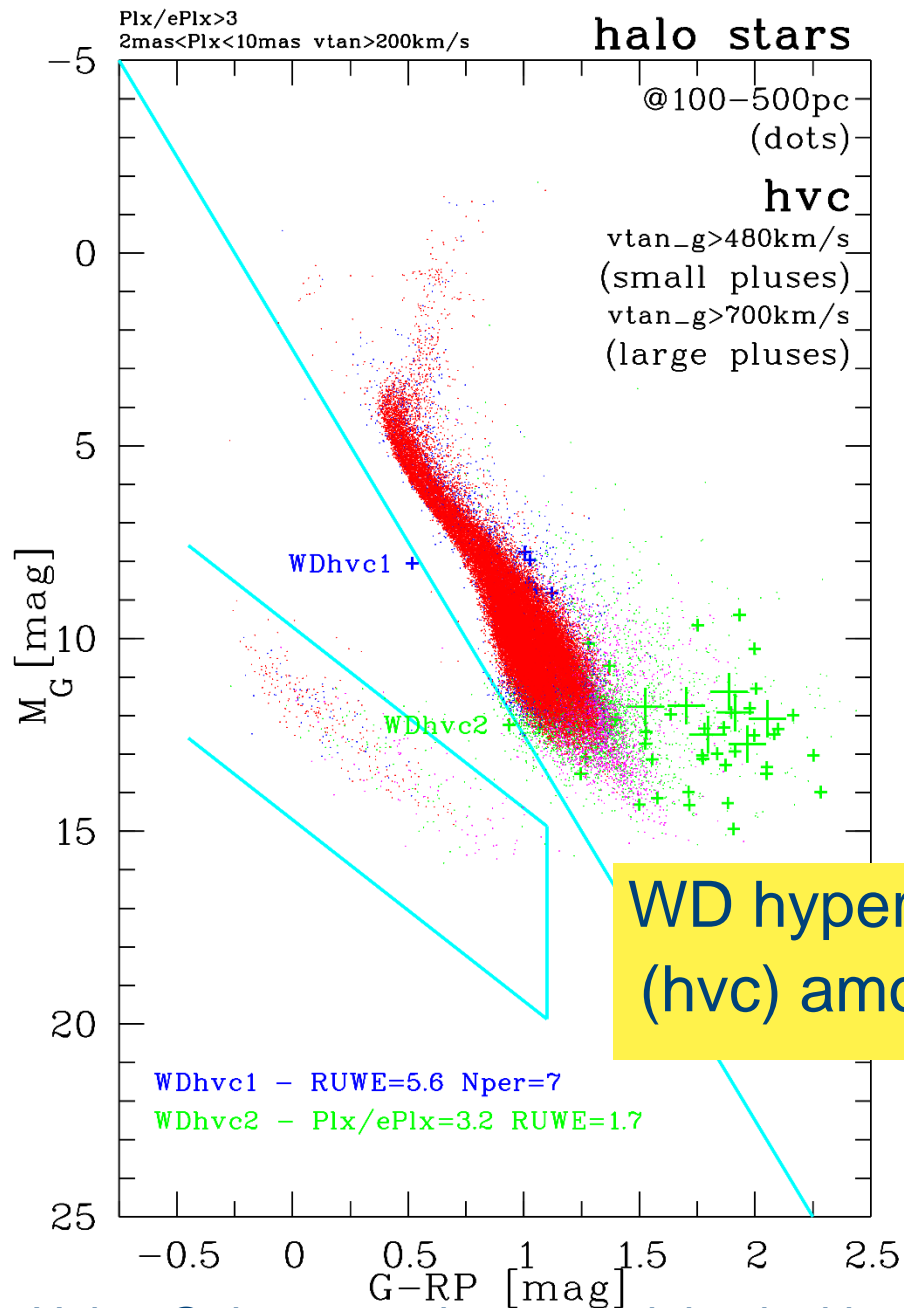
Distribution of different *Gaia* DR2 100pc subsamples on the sky



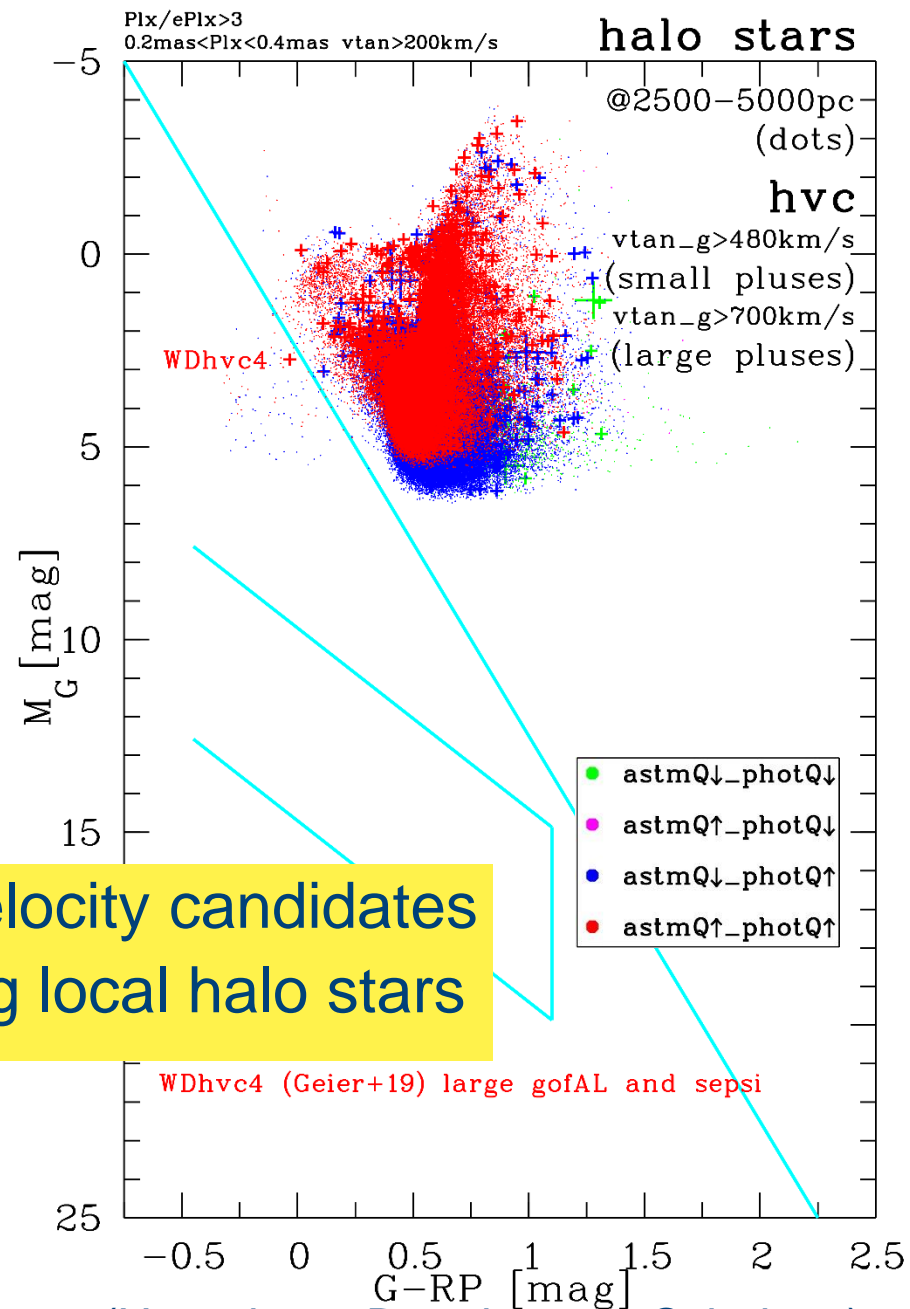
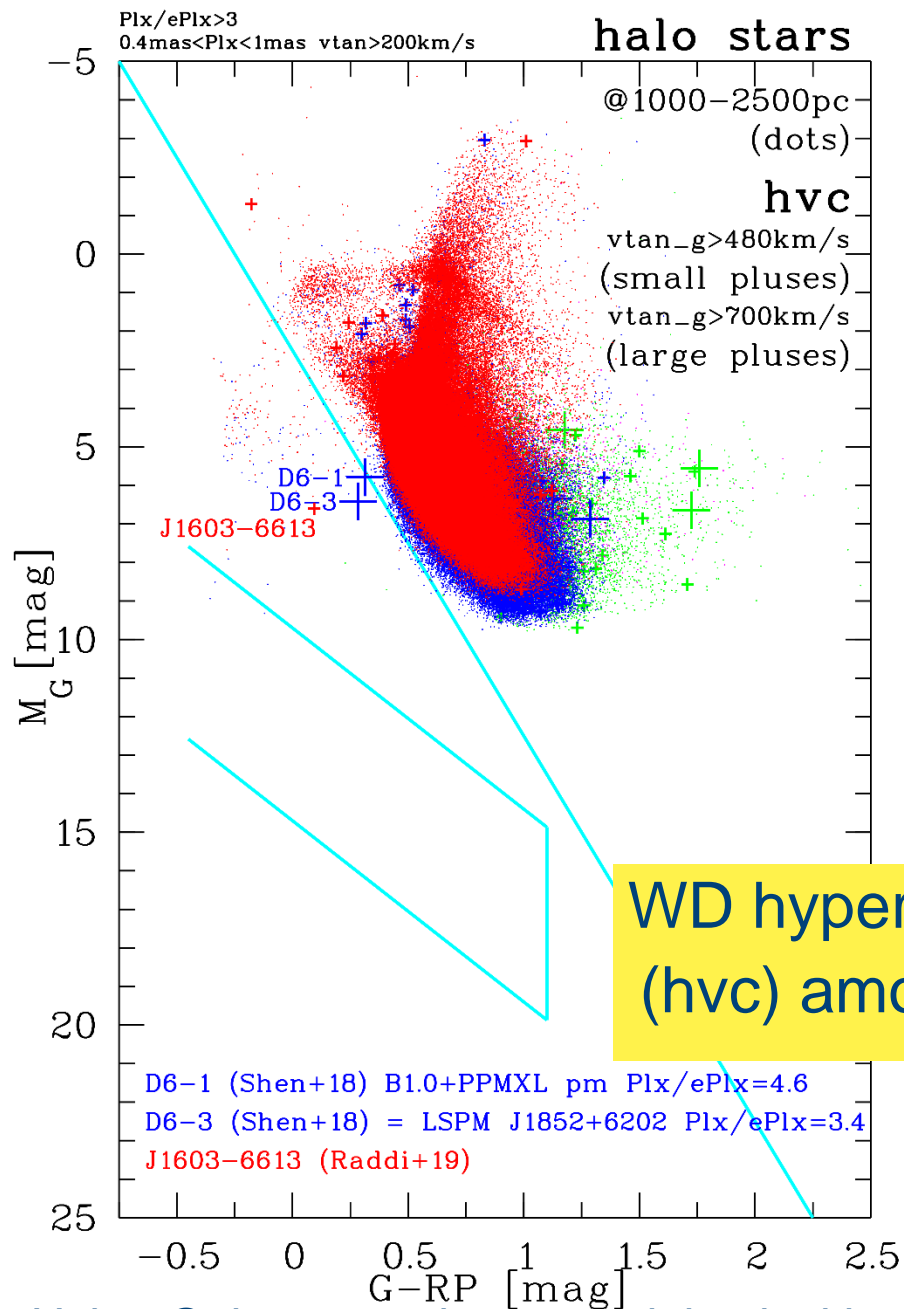
Kinematically defined halo stars (*Gaia* DR2 tangential velocities $v_{\text{tan}} > 200 \text{ km/s}$)



- Clear separation of WD sequence from other halo stars within 100pc
 - very small contamination by false pm objects (only 2 of 53 WD candidates)
 - most halo WDs are cool (see also Torres+19), some have $G-RP > \approx 1.1$, at the edge of the Hollands+18 colour box
 - other halo stars seem to form two sequences: MS+sd
 - 51 halo WDs compared to 584 MS+sd
→ 8% of all halo stars are WDs
- Only partly overlap with other halo WD samples mainly caused by phot criteria
 - 29 of 51 in Torres+19
 - 32 of 51 in Kilic+19

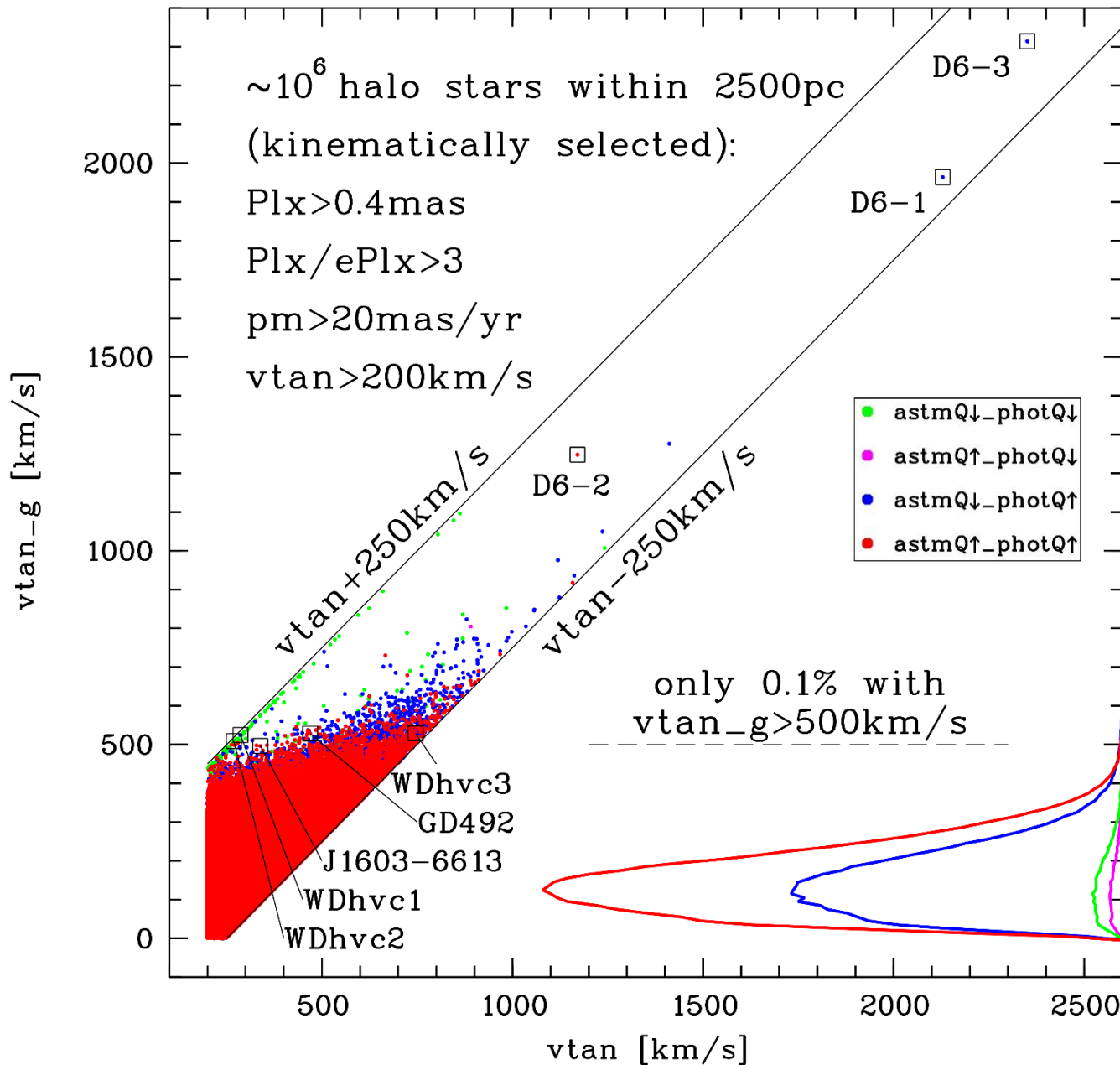


Using Galactocentric tangential velocities v_{tan_g} (Hattori+18, Bromley+18, Scholz18)



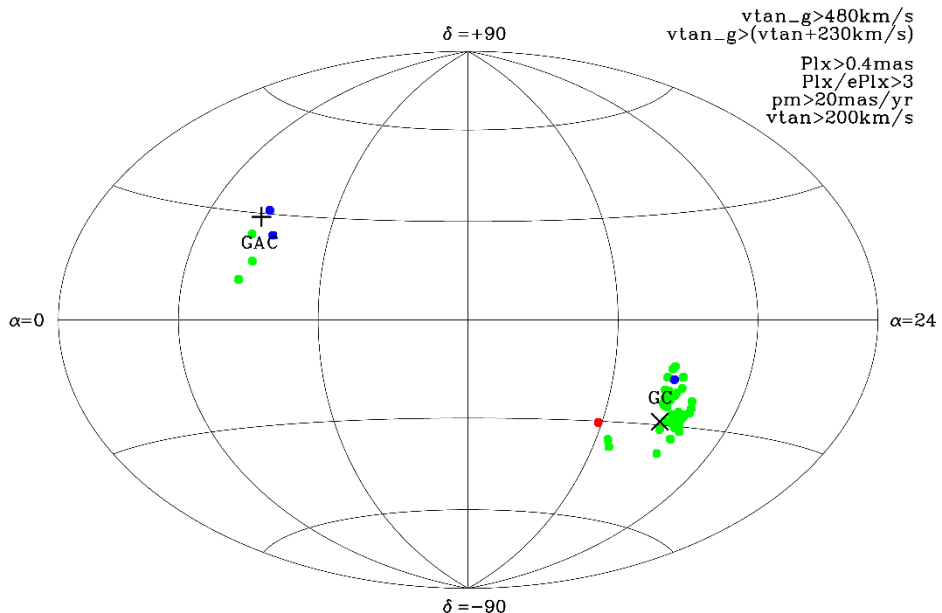
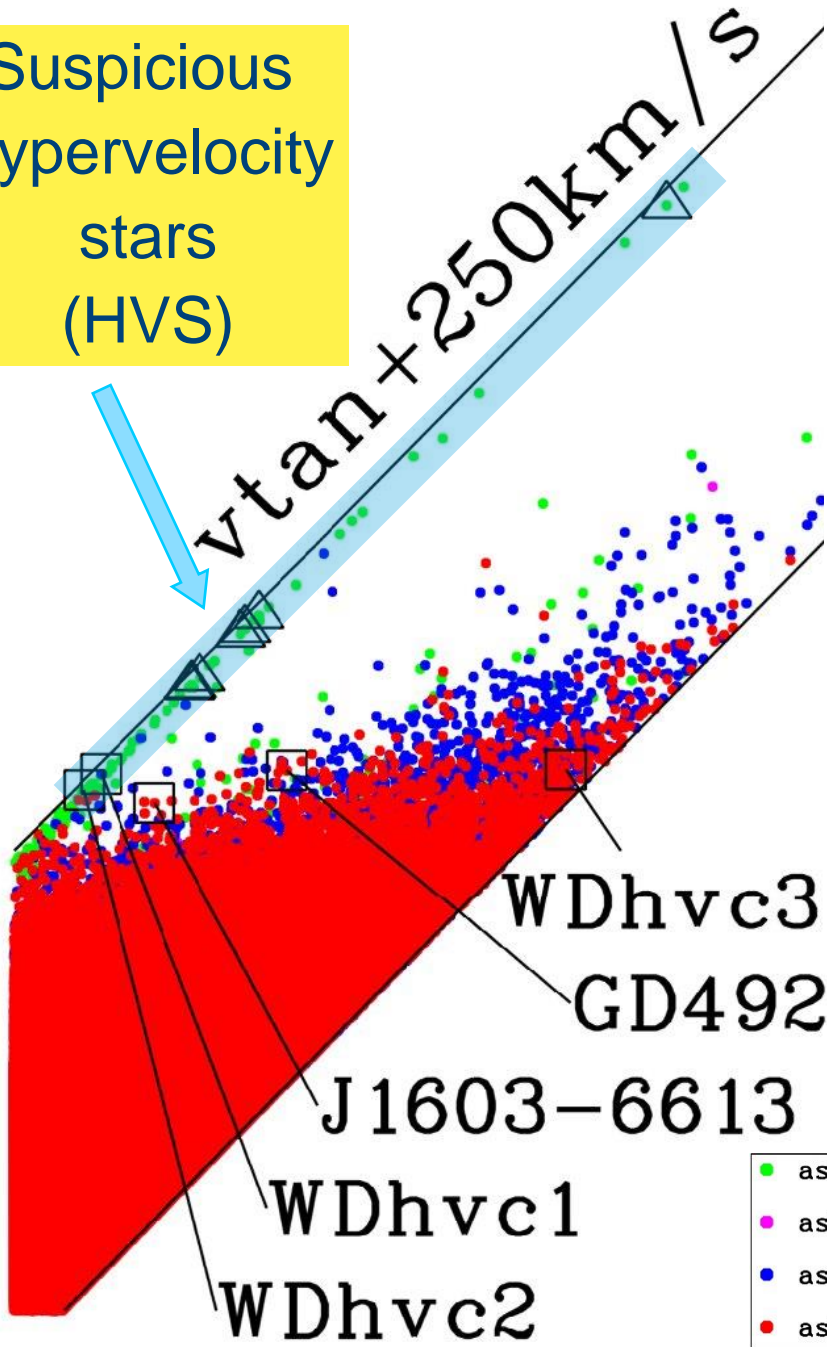
Using Galactocentric tangential velocities v_{tan_g} (Hattori+18, Bromley+18, Scholz18)

Galactocentric and heliocentric tangential velocities

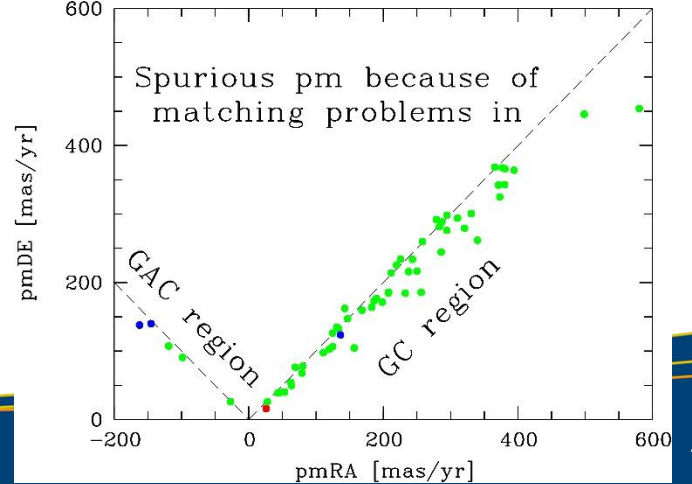


- The few candidates with $vtan_g > 500 \text{ km/s}$ are mostly objects with bad astrometry (blue and green dots)
- D6 WD candidates of Shen+18 have largest $vtan_g$ of nearby HVS
- Suspicious HVS stars (row of green dots) close to upper limit ...!

Suspicious hypervelocity stars (HVS)



- Triangles: false nearby HVS in Du+19
 - 14 of their 28 candidates have spurious pm!
 - all 14 have Nper < 8 and are faint (G > 18 mag)
- WDhvc1 (G = 15.3 mag), WDhvc2 (Nper = 9) also have spurious pm near GC/GAC



Reliable v_{tan_g} of WD hypervelocity candidates ?

- astmQ↓_photQ↓
- astmQ↑_photQ↓
- astmQ↓_photQ↑
- astmQ↑_photQ↑

Plx (mas)
 Plx/ePlx (>5 ?)
 Nper (>8 ?)
 RUWE (<1.4 ?)
 sepsi (<3 ?)
 pm (<2 ?)
 pm check ok?
 photometry ok?
 v_{tan_g} (>480km/s)

Object [Ref]

| Object [Ref] | Plx (mas) | Plx/ePlx (>5 ?) | Nper (>8 ?) | RUWE (<1.4 ?) | sepsi (<3 ?) | pm (<2 ?) | pm check ok? | photometry ok? | v _{tan_g} (>480km/s) |
|-----------------|-----------|-----------------|-------------|---------------|--------------|-----------|--------------|----------------|-------------------------------|
| GD492 [1]# | 1.58 | + | + | + | = | + | + | + | 528±10 |
| J1603-6613 [1]# | 0.57 | = | + | + | + | + | + | + | 497±63 |
| D6-1 [2]# | 0.47 | - | + | + | + | + | + | + | 1964±461 |
| D6-2 [2]\$ | 1.05 | + | = | + | = | = | + | + | 1248±122 |
| D6-3 [2]\$ | 0.43 | - | + | + | + | + | + | = | 2314±691 |
| WDhvc1 [3] | 3.53 | + | - | - | - | - | - | + | 525±31 |
| WDhvc2 [3] | 3.31 | - | = | - | - | - | - | - | 509±84 |
| WDhvc3 [3,4]* | 1.35 | = | + | + | + | + | + | = | 529±142 |
| WDhvc4 [3,5] | 0.32 | + | + | + | - | - | + | + | 500±61 |

Ref: [1] Raddi+19, [2] Shen+18, [3] this work, [4] Kepler+15, [5] Geier+19
 # large RV (as expected for HVS), \$ zero RV (suspicious), * SDSS J125834.93-005946.1
 - criterion not met, = close to allowed limit, + ok

Reliable v_{tan_g} of WD hypervelocity candidates ?

- astmQ↓_photQ↓
- astmQ↑_photQ↓
- astmQ↓_photQ↑
- astmQ↑_photQ↑

Plx (mas) Plx/ePlx (>5 ?)
 Nper (>8 ?) RUWE (<1.4 ?)
 gofAL (<3 ?) sepsi (<2 ?)
 pm check ok? photometry ok?
 v_{tan_g} (>480km/s)

| Object [Ref] | Plx (mas) | Plx/ePlx (>5 ?) | Nper (>8 ?) | RUWE (<1.4 ?) | gofAL (<3 ?) | sepsi (<2 ?) | pm check ok? | photometry ok? | v _{tan_g} (>480km/s) |
|-----------------------|-----------------|-----------------|--------------|---------------|--------------|--------------|--------------|----------------|-------------------------------|
| GD492 [1]# | 1.58 | + | + | + | = | + | + | + | 528±10 |
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| WDhvc3 [3,4]* | 1.35 | = | + | + | + | + | + | = | 529±142 |
| WDhvc4 [3,5] | 0.32 | + | + | + | - | - | + | + | 500±61 ? |

Ref: [1] Raddi+19, [2] Shen+18, [3] this work, [4] Kepler+15, [5] Geier+19
 # large RV (as expected for HVS), \$ zero RV (suspicious), * SDSS J125834.93-005946.1
 - criterion not met, = close to allowed limit, + ok

Summary

- *Gaia*'s new nearby WDs: 1 within 10 pc (Scholz+18), 9 within 20 pc (Hollands+18)
- New WD at 8.5pc, TYC 3980-1081- 1 B, has smallest pm in the 10pc sample and shows orbital motion with respect to its primary
- Half of the 100pc sample has bad astrometry+photometry (faint + in Galactic plane)
- Using only the 35% well-measured stars → clean CMD with 6% WDs, 94% MS+sd
- Nearby halo stars with $v_{\text{tan}} > 200 \text{ km/s}$ are much less affected by unreliable data and show a WD sequence extended to cooler objects and representing 8% of the halo
- Check of finder charts + other pm catalogues recommended (for the nearest HVS)!
- Compared to other nearby ($d < 5 \text{ kpc}$) HVS candidates, the luminous D6 (Shen+18) WD hypervelocity candidates have very large but uncertain tangential velocities
- Reliable WD HVS with large RV (GD492, J1603-6613) have max. $v_{\text{tan}_g} \approx 500 \text{ km/s}$
- New candidate WDhvc3 = SDSS J125834.93-005946.1 only slightly overluminous

Thank you!