Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

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Abstract: The stars and star systems in the solar neighborhood are for obvious reasons the most likely best investigated stellar objects besides the Sun. Very fast proper motion catches the attention of astronomers and the small distances to the Sun allow for precise measurements so the wealth of data for most of these objects is impressive.

This report lists 94 star systems (doubles or multiples most likely bound by gravitation) in up to 10 parsecs distance from the Sun as well over 60 questionable objects which are for different reasons considered rather not star systems (at least not within 10 parsecs) but might be if with a small likelihood.

A few of the listed star systems are newly detected and for several systems first or updated preliminary orbits are suggested.

A good part of the listed nearby star systems are included in the GAIA DR2 catalog with parallax and proper motion data for at least some of the components – this offers the opportunity to counter-check the so far reported data with the most precise star catalog data currently available.

A side result of this counter-check is the confirmation of the expectation that the GAIA DR2 single star model is not well suited to deliver fully reliable parallax and proper motion data for binary or multiple star systems.

1. Introduction

The answer to the question at which distance the solar neighborhood ends is somewhat arbitrary – the 25 parsecs limit (which means parallax >40 mas) used for the last edition of the Gliese-Jahreiß catalog and also for the RECONS (Research Consortium On Nearby Stars) project seems to me a good choice. Star systems within this range are often very interesting for the visual observer because some of these pairs come not only with an angular separation large enough for easy resolution but move also fast enough against the background star field to notice changes in position from year to year. In addition, a few of these objects have also orbits fast enough to notice changes in angular separation and position angle from year to year. Yet most listed nearby star systems are spectroscopic binaries with angular separations <0.4 arcseconds and for this reason of little interest for direct visual observation with amateur telescopes due to resolution issues even if high proper motion speed might cause visually noticeable position changes from year to year.

The GAIA DR2 catalog served as a starting point for the search of star systems in the solar neighborhood, despite the well-known weaknesses of this catalog regarding double stars in the solar neighborhood, which are:

- Resolution limit of 0.4 arcseconds.
- Weak resolution performance for double stars below 1" separation.
- Weak performance for very bright light sources.
- Weak performance for very high proper motion stars leading to a far less than average coverage of fast moving stellar objects.
- All light sources are considered to be single stars ignoring the effects of gravitational relationship between the components of binaries leading to systematic data errors beyond the given error range.

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Despite these shortcomings, the DR2 data for resolved systems offer together with the DR2 StarHorse mass values in most cases provides valuable additional information useful for assessing the so - far known data about a star system as plausible or not.

To compensate for the lack of full coverage of solar neighborhood objects in DR2 a multitude of other sources were additionally taken into account.

References to sources with regular updates like the WDS and 6th Orbit Catalog are per Dec 2019 and might at the time of publication no longer be up to date. This is to be expected, especially for the latter as several hundred newly calculated orbits were published by Izmailov 2019 but most of them are not yet included in the 6th orbit catalog.

In several cases, I used a program for calculating orbits by the Thiele-Innes method published by Izmailov 2019 (http://izmccd.puldb.ru/vds.htm, hereafter simply "Izmailov program"), being well aware that a small number of observations covering an insignificant part of the "true" orbit provides only the seemingly current best of many possible solutions. Lucy 2013 explains very clearly, that for a given set of measurements many obits with a reasonable small root mean square error may exist and that the one with the least RMS value is not necessarily the "true" one. Izmailov also published an additional program for calculating a set of 200 possible orbits for a given observation history, pushing this issue to the extreme. A third program provided by Izmailov corrects the position angles given in observation histories for precession.

2. Star Systems in the Solar Neighborhood up to 10 Parsecs

Selection of GAIA DR2 (hereafter DR2) objects with parallax >40 mas and parallax error <0.5% and Gmag <18 yielded with the help of CDS TApVizieR 3,463 stars. 438 star systems (pairs or multiples) remained for closer inspection with 34 at a distance up to 10 parsecs. This result seems modest compared to 85 such systems reported by the RECONS team (http://www.recons.org/census.posted.htm) per April 12, 2018 with details given only for a part of them in the RECONS list of the 100 closest stellar objects (including also single stars and stars hosting planets – hereafter RECONS list). The Nearby Stars Catalog (NSC) from the Planetary Habitability Laboratory lists 67 doubles/multiples up to 10 parsecs from the Sun. Other sources searched for nearby star systems are the updated MSC catalog (Tokovinin 2018) as well as several reports on this topic like, for example, Benedict et al. 2016 on solar neighborhood objects, Henry et al. 2018 on RECONS discoveries within 10 parsecs, and Winters et al. 2019 on the stellar multiplicity rate of M dwarfs.

A total of 94 star systems within 10 parsecs are listed which means nine objects were added to the current census of the RECONS team mentioned above. A second list with 67 objects gives "might be" star systems with little evidence so far for being physical multiples with sufficient likelihood.

The list of star systems within 10 parsecs is given without claim to be complete: A few already known systems might have been overlooked and several additional ones wait to be detected by better equipment and methods especially in the range of <1" angular separation or very faint brown dwarfs. On the other hand, a few of the listed systems might be questionable as physical since the available data is not as precise as required and in some cases the reported components are close enough for gravitational relationship but might be just random encounters without significant gravitational consequences. The star systems are listed in the sequence of distance mostly based on DR2 parallaxes with several older sources in between with the caveat that some of these values might not sufficiently precise to give a reliable order.

Most systems (but a few) are already included in the Washington Double Star Catalog (hereafter WDS) and many are also included in the 6th orbit catalog. A few 6th orbit catalog objects are listed with astrometric orbits without a corresponding WDS object due to missing precise measurements of position angle and angular separation.

For a part of the listed systems with currently sufficient altitude for successful imaging, I have also processed new CCD-images to get most recent separation and position angle measurements (see table in Appendix B).

The descriptions of the found objects with sufficient DR2 data include also an estimation for a minimum period of a potential circular orbit using mass-data (always in $M_\odot$ if not indicated otherwise) mostly from the DR2 StarHorse catalog (Anders et al. 2019) and based on a Monte Carlo simulation using the given DR2 data (see Appendix A) hereafter referenced as "simulation". The table with the simulation results is given in Appendix C.

The DR2 StarHorse catalog also provides the Renormalised Unit Weight Error (hereafter RUWE) value for the objects allowing an additional check for the validity of the DR2 astrometric data. According to the GAIA documentation RUWE "… is expected to be around 1.0 for sources where the single-star model provides a good fit to the astrometric observations. A value significantly greater than 1.0 (say >1.4) could indicate that the source is non-single or otherwise problematic for the astrometric solution".

3. List of Star Systems within 10 Parsecs from the Sun

1. RHD 1 (Alpha Centauri, WDS 14396-6050, GJ 559, LDS 494, SCZ 1, GJ 551, HD128620, HD128621) – multiple star system at a distance of ~1.35 parsecs (~4.4 light-years) from the Sun, number 1 on the RECONS list with masses of 1.14/0.92/0.11. A and B not listed in DR2 due to the brightness of these components. Component C Proxima listed in DR2 with parallax and proper motion data and without duplicated_source indication. StarHorse median mass is 0.15 M$_{\odot}$ and RUWE ~1. The observation history of this multiple goes back to the year 1689 – more details in Argyle et al. 2019 page 290. Proxima itself is listed in the WDS catalog as SCZ 1 Ca,Cb double star sub-system with so far only two observations in 1996. Kervella et al. 2019 also support the binary property of Proxima by detecting significant proper motion anomalies. Current discussions (see Damasso et al. 2020) suggest that the proper motion anomalies of Proxima are most likely caused by a high mass planet with a period of ~5.2 years in addition to a low mass planet detected earlier. The estimated mass of ~0.05 might also indicate a sub-brown dwarf.

2. LUH 16 (WDS 10493-5319, WISE J104915.57-531906.1) – brown dwarf binary at a distance of ~2 parsecs. Not included in the RECONS list. Resolved in DR2 (source_id 5353626573562355584 and 5353626573555863424) without parallax and proper motion data and with huge position error size most likely due to the fast proper motion. Both components without duplicated_source marker. Listed in the WDS catalog with 93 observations since 1984. Listed in the 6th orbit catalog with a grade 5 orbit with a period of ~27.5 years. Boffin et al. 2018 found the proper motion of the pair "to be perturbed, which leads us to suspect the presence of a substellar companion around one of the two components". Lazorenko and Sahlmann 2018 reported slightly different orbit parameter compared to the 6th orbit data based on new measurements data assumed to be more precise and refined the mass estimations to ~34/29 Jupiter masses for A/B. Crossfield 2014 reports LUH 16 as L7.5/T0.5 pair.

Proper motion speed is an extremely fast ~3"/yr and angular separation is currently ~1.3", but the components are far too faint to be of interest for visual observation with an amateur telescope. The Hubble Space Telescope image gallery shows a stack of 12 images covering the movements of LUH 16 over three years (https://www.spacetelescope.org/images/potw1723a/). The Hubble data also suggest that the above-mentioned proposed existence of an additional component is highly unlikely.

3. AGC 1 (Sirius, WDS 06451-1643, GJ 244) – binary star system with a huge delta in brightness at a distance of ~2.6 parsecs, number 5 on the RECONS list with masses of 1.99/1.0. Detected by Bessel in 1834 due to proper motion anomaly (see Argyle et al. 2019, page 172). The three RECONS objects listed closer to the Sun are single stars (including Barnard's star potentially hosting an extra massive planet – see Ribas et al. 2018). Only Sirius B is listed in DR2 with parallax and proper motion data but without a duplicated_source indication. StarHorse gives no data on this object indicating serious DR2 data quality issues.

4. LDS 838 (WDS 01388-1758, GJ 65, L 726-8) – binary star system at a distance of ~2.7 parsecs, number 6 on the RECONS list with masses of 0.11/0.1. Both components listed in DR2 with parallax and proper motion data and without duplicated_source marker. LDS 838 is listed in the 6th orbit catalog with a grade 2 orbit (from Kervella et al. 2018) with ~26.3 years period with 103 observations beginning in 1935 up to 2015. At first glance, the reported measurements seem to be a bad match with this orbit. These should cover 3 full orbits, but this is not the case as shown in Figure 1 with a gap in the observations in one third of the calculated orbit. Also, the average deviation of a huge part of the observations from the path of the orbit seems quite large. A closer look reveals that the seemingly "missing" observations are in the time frame of the smallest angular separation, which might explain the lack of observations in this part of the orbit. The DR2 parallax data suggest a spatial distance between the components of 3, 343 AU, which means in combination with the DR2 StarHorse median mass values of ~0.15/0.14 an orbit period of nearly 360,000 years. Benedict et al. 2016 report masses of ~0.12/0.12. Even the best-case calculation with minimum distance of ~430 AU according to the simulation suggests a period of >16,000 years. This extremely bad match with the given orbit data suggests that the GAIA DR2 data for this system are at least to some degree questionable not only for the parallaxes but may be also for the RA/Dec coordinates of the components. Slightly enhanced error sizes for these parameters and RUWE values >2 support this impression. Own recently taken images provide only shaky evidence due to heavily overlapping star disks but the measurements for angular separation with 1.9" and position angle with 346° suggest also that the calculated orbit is most likely valid. Applying the Izmailov program on the existing measurements gives values very similar to the 6th orbit catalog data. The additionally calculated set of possible orbits indicates

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a     =      2.096375695593301
e     =      0.629856094424595
T     =   1971.910421521981300
P     =     26.386457713540768
omega=    284.613941618924570
Node =    149.171780417255150
i     =    125.478603110233050
```

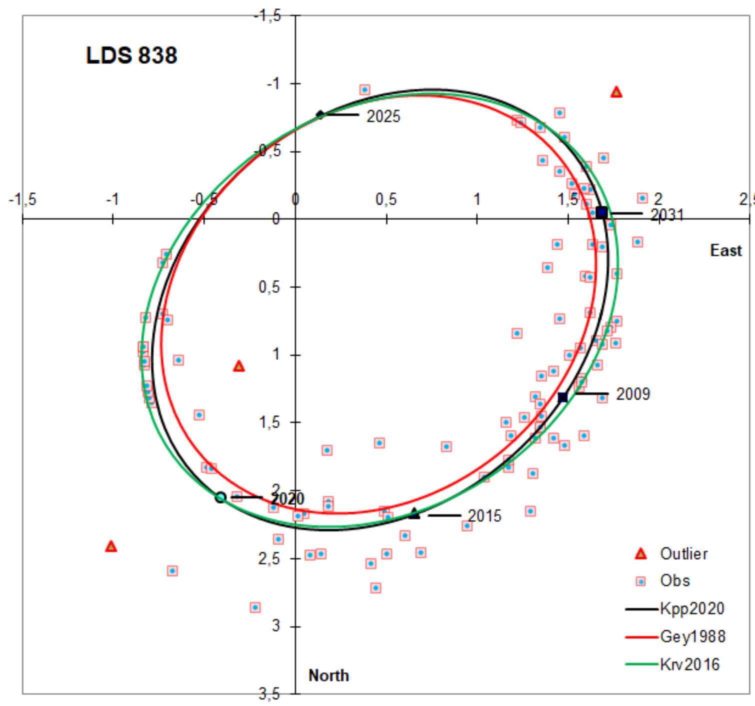

Figure 1. Plot of system 4: LDS 838 orbit comparison

some spread but within narrow limits around the given values.

The fast change of position angle and separation from year to year makes this object of high interest for long term observation project even if both components are rather faint in the ~12-13 Vmag range.

5. KPP 4431 – wide star system at a distance of ~2.75 parsecs distance newly detected in DR2 and not yet included in the RECONS list. StarHorse offers no data on these stars, suggesting DR2 data quality issues. The primary is marked as duplicated_source. Simulation gives a minimum spatial distance of ~15,000 AU and even with very small estimated masses of ~0.1 for both components, a potential gravitational relationship seems very likely given even for the maximum spatial distance of ~29,000 AU (the outer rim of a corresponding tidal radius would in this case be larger than 30,000 AU for each component). Proper motion for both components is quite different, so it seems plausible that these stars are not in an orbit but just in a close random encounter yet heavily influenced by mutual gravitational force.

6. BLA 10 (WDS 22385-1519, GJ 866, EZ Aquarii) – close triple star system at a distance of ~3.5 parsecs, number 12 on the RECONS list. Not resolved in DR2, combined object listed without parallax and proper motion data but with duplicated_source marker. The 6th

271.4138803034	RA J2000 in degrees
-27.9798246991	Dec J2000 in degrees
77.507	Position angle J2015.5
0.000	Error position angle
4037.13732	Separation in arcseconds J2015.5
0.00119	Error separation
17.25877	Estimated Vmag primary from G/B/R-mag
0.08153	Error estimated Vmag primary
17.8	Estimated Vmag secondary from Gmag
	Error estimated Vmag secondary
353.9577	Parallax primary in mas
0.8695	Error parallax primary
2.738	Distance primary from the Sun in parsecs
365.2450	Parallax secondary in mas
0.7525	Error parallax secondary
2.825	Distance secondary from the Sun in parsecs
4.443	Proper motion RA primary in mas/yr
-83.358	Proper motion Dec primary in mas/yr
9.530	Proper motion RA secondary in mas/yr
-19.190	Proper motion Dec secondary in mas/yr
14498	Minimum spatial distance between the components in AU
0.1	Estimated mass for primary in Sun mass
0.1	Estimated mass for secondary in Sun mass
3925048	Minimum period of a potential orbit in years

Table 1. Data for KPP4431 (WDS 18057-2759) based on GAIA DR2 values for source_id 4062844895337938688 and 4050970483187934464.

orbit catalog lists a grade 2 orbit for BLA 10 AB with a period of ~2.25 years based on 45 observations listed in the WDS catalog since 1985 and also a grade 7 orbit for GJ 866 Aa,Ab (object not included in the WDS catalog) with a period of less than 4 days. The involved masses are according to the RECONS list rather small with 0.11/0.11/0.08 and the components are according to the WDS catalog fainter than 12 mag with an angular separation between 0.1 and 0.5 arcseconds –this star system is for these reasons of little interest for visual observation with amateur telescopes.

7. STF 2758 AB (WDS 21069+3845, GJ 820, 61 Cygni) – binary or triple (may be even quadruple) star system at a distance of ~3.5 parsecs. Listed as number 13 on the RECONS list with the other objects in between being single stars. Components A and B listed in DR2 with parallax and proper motion data with duplicated_source marker for A. The WDS catalog lists a huge number of additional components, all of them obviously opticals. The 6th orbit catalog lists a grade 4 orbit with a period of ~664 years based on the huge number of observations of, so far, 1,790. The most recent orbit calculation is from Izmailov 2019 with a period of ~593 years, indicating some spread regarding possible orbit solutions. Simulation results in a minimum spatial distance between the components of 110 AU giving with StarHorse median masses of ~0.7/0.6 (quite close to the RECONS list values of 0.70/0.63) and a minimum orbit period of 1,021 years. However, the primary (but not the secondary) is marked as a duplicated_source in DR2 and might be binary itself (the 6th orbit catalog contains a grade 9 orbit for Aa,Ab. See also Argyle et al. 2019, Page 411) so this DR2 parallax is, despite the given moderate error range, to be taken with some caveats even if the RUWE value ~1 is rather inconspicuous. Kervella et al. 2019 support the binary property of 61 Cygni A, but propose that B is also a binary itself. The astrometric result from my own imaging rather corresponds, with some allowance, very well with the calculated orbit values for 2019 – the proper motion speed is simply amazing and poses even a bit of a problem for plate solving. The change in position is >5 arcseconds/yr, quite significant, so this object should be very attractive for regular visual observation especially as separation >30" and magnitudes of 5.2/6.0 Vmag pose no resolution issues.

8. SHB 1 (Procyon, WDS 07393+0514, GJ 280) – binary star system at a distance of ~3.5 parsecs, number 14 on the RECONS list with masses of 1.57/0.5. Missed completely in DR2 likely due to the brightness of Procyon A. Listed in the WDS catalog with ~100 observations so far and in the 6th orbit catalog with a grade 3 orbit with a period of ~41 years. The most recent orbit update by Izmailov 2019 confirms this period. The secondary is a white dwarf detected first by Bessel due to astrometric anomalies similar to Sirius B. WDS lists several other components down to designation "H", all of them obviously optical.

I mentioned already in Knapp 2019/Appendix C that Luyten's star is most likely part of the Procyon system, but did not check this proposition in detail. GJ 273 (Luyten's star) is number 22 on the RECONS list as single star at a distance of ~3.75 parsecs with a mass of ~0.26. See Table 2. Ward-Duong et al. 2015 list GJ 273 as star system with masses of 0.24/0.14 but this seems a bit questionable. Simbad lists up to 3 planets for GJ 273 with a question mark. The WDS catalog lists WDK 2 (WDS 07274+0514) as close pair with 0.2" angular separation with only one observation so far, so this looks like a bogus object. GJ 273 is listed in the DR2 catalog with source_id 3139847906304421632 without parallax and proper motion values but at a position corresponding very well with the Hipparcos proper motion values. Based on Hipparcos data GJ 273 is quite close to the Procyon system at a median spatial distance of ~71,000 AU. The Procyon system is listed on the RE-

114.82724202	RA J2000 in degrees
+05.22750758	Dec J2000 in degrees
270.140	Position angle J1991.25
0.000	Error position angle
10670.99691	Separation in arcseconds J1991.25
0.00189	Error separation
0.46	Estimated Vmag primary from WDS
9.872	Estimated Vmag secondary from Simbad
284.56	Parallax primary in mas
1.26	Error parallax primary
3.514	Distance primary from the Sun in parsecs
262.98	Parallax secondary in mas
1.39	Error parallax secondary
3.803	Distance secondary from the Sun in parsecs
-714.59	Proper motion RA primary in mas/yr
-1036.80	Proper motion Dec primary in mas/yr
572.51	Proper motion RA secondary in mas/yr
-3693.51	Proper motion Dec secondary in mas/yr
71 149	Median spatial distance between the components in AU
2.07	Estimated mass for primary (A+B) in Sun mass from RECONS list
0.26	Estimated mass for secondary in Sun mass from RECONS list
12 489 782	Median period of a potential orbit in years

Table 2. Data for KPP4432 AI (WDS 07393+0514 AI, GJ 273, Luyten's star, Procyon C) based on Hipparcos J1991.25 values (CDS I/311/HIP2, New Reduction, van Leeuwen 2007):

CONS list with masses of ~1.57/0.50 giving together a tidal radius of >140,000 AU which makes potential gravitational relationship with GJ 273 most likely. The likely third physical component of the Procyon system should then get, according to the WDS designation scheme the component identification "I", but a physical component of the Procyon system "Procyon C" seems more appropriate.

The difference in proper motion is significant and might mean that Luyten's star just crosses path with Procyon and will likely never enter an orbit around Procyon. However, Luyten's star will certainly be heavily influenced in its path through space by Procyon. The question is if Luyten's star will be catched by Procyon (a possible explanation for the difference in proper motion) or if it will escape.

9. STF 2398 AB (WDS 18428+5938, GJ 725) – binary star system at a distance of ~3.5 parsecs. Listed as number 15 on the RECONS list with masses of 0.35/0.26. Both components listed in DR2 with parallax and proper motion data with duplicated_source marker for A. The 6th orbit catalog lists a grade 4 orbit with a period of ~408 years. The most recent orbit calculation by Izmailov 2019 suggests a period of ~640 years but indicates some spread regarding possible orbit solutions. The simulation with the DR2 data gives a minimum spatial distance between the components of 41 AU. This means together with the StarHorse median masses of 0.38/0.30 a minimum period of ~318 years. The masses 0.26/0.19 given by Wand-Duong et al 2015 result in a minimum period close to ~400 years. As already mentioned, the primary is marked as a duplicated source in DR2 so its DR2 parallax is to be taken with some caution, but both components have RUWE values ~1 indicating good DR2 data quality. The possibility of a third component (may also be a planet) was already discussed 60 years ago (see Argyle et al. 2019, page 371) but so far without conclusive result. That A might be a binary is also supported by Kervella et al. 2019 diagnosing proper motion anomalies. The astrometric results from my own imaging correspond with some allowance very well with the calculated orbit values for 2019 (see Appendix B). Proper motion is with >2 arcseconds/yr quite significant, but less spectacular compared to STF 2758. The separation of currently >10" poses, despite the somewhat faint components with 9.1/10 Vmag, no resolution issues even for smaller telescopes.

10. GRB 34 AB (WDS 00184+4401, GJ 15) – binary star system at a distance of ~3.6 parsecs. Listed as number 16 on the RECONS list with masses of 0.49/0.16. Both components listed in DR2 with parallax and proper motion data without duplicated_source marker. The 6th orbit catalog lists a grade 5 orbit with a period of ~1,253 years. The most recent orbit calculations by Izmailov 2019 suggest a period of ~1,600 years but indicate some spread regarding possible orbit solutions. Simulation suggests a minimum spatial distance of ~120 AU but even the maximum distance of ~1,000 AU is sufficiently small to make a gravitational relationship most likely. DR2 StarHorse median mass values of 0.45 and 0.18 allow for a minimum period of ~1,700 years. The observations so far cover a time span of ~150 years; only about 10% of the assumed orbit period. DR2 data suggests good quality, with very small parallax errors, no duplicated source issues (although B seems to be a spectroscopic binary and additionally a large exoplanet might be part of this system, see Argyle et al. 2019, page 83), and perfect RUWE values ~1 for both components indicating good DR2 data quality. Position angle and angular separation from my own imaging correspond very well with the calculated orbit values for 2019. The orbit is too slow to be of interest for visual observing but proper motion speed is with ~3"/yr; high enough to notice changes in star positions over some years.

11. KPP 4437 (BUP 25, WDS 01441-1556, Tau Cet, GJ 71, YZ Cet, GJ 54.1, LHS 138) – wide binary at a distance of ~3.7 parsecs. See Table 3. Tau Cet is listed as a single star object as number 19 on the RECONS list at a distance of ~3.65 parsecs and a mass of 0.92. DR2 indicates for the A component a duplicated_source and Kervella et al. 2019 report Tau Cet as potential host of planets based on proper motion anomalies. BUP 25 is a wide double star listed in the Second Catalog of Rectilinear Elements, suggesting an optical pair. StarHorse median mass is ~0.85. The RUWE value of ~1 gives no hint for duplicity. Tau Cet is rather close to YZ Cet (with a median StarHorse mass of ~0.16) with a median spatial distance of ~103,000 AU. YZ Cet is number 21 on the RECONS list at a distance of ~3.7 parsecs and a mass of 0.13. No duplicated_source indication in DR2, RUWE ~1 offers also no indication for YZ Cet being a multiple. Kervella et al. 2019 report a proper motion anomaly and Simbad suggests three potential planets with a question mark, a brown dwarf as companion might be possible as well. YZ Cet is not quite within the tidal radius of Tau Cet but the tidal radii of ~92,000/40,000 AU overlap to a degree making gravitational relationship most likely. The degree of gravitational relationship might not allow for an orbit but for mutual influence of speed and direction of movement through space.

12. SOZ 1/VLK 1 (WDS 22034-5647, GJ 845, Eps

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26.01704802	RA J2000 in degrees
-15.93748189	Dec J2000 in degrees
262.015	Position angle J2015.5
0.000	Error position angle
27457.16343	Separation in arcseconds J2015.5
0.00055	Error separation
5.76229	Estimated Vmag primary from G/B/R-mag
0.01217	Error estimated Vmag primary
12.23604	Estimated Vmag secondary from G/B/R-mag
0.00215	Error estimated Vmag secondary
277.5162	Parallax primary in mas
0.5173	Error parallax primary
3.6034	Distance primary from the Sun in parsecs
269.3628	Parallax secondary in mas
0.0785	Error parallax secondary
3.7125	Distance secondary from the Sun in parsecs
-1729.726	Proper motion RA primary in mas/yr
855.493	Proper motion Dec primary in mas/yr
1205.176	Proper motion RA secondary in mas/yr
637.758	Proper motion Dec secondary in mas/yr
102 069	Minimum spatial distance between the components in AU
0.84756	StarHorse median mass for primary in Sun mass
0.16031	StarHorse median mass for secondary in Sun mass
32 661 478	Minimum period of a potential orbit in years

Table 3. Data for KPP4437 AC (WDS 01441-1556, GJ 71, GJ 54.1) based on GAIA DR2 values for source_id 2452378776434276992 and 2358524597030794112.

Ind) – triple star system at a distance of ~3.6 parsecs with only the A component listed in DR2 with no duplicated_source indication and RUWE value ~1. The in DR2 missing B component is the close brown dwarf binary VLK 1 Ba,Bb listed in the 6th orbit catalog with a grade 7 orbit with a period of ~11 years. Dupuy and Liu 2012 report resolution of Ba,Bb. Kervella et al. 2019 suggest that also the A component might have a close dark companion (might also very well be a massive planet) based on proper motion anomalies making this system a potential quadruple

13. BIL 1 (WDS 18451-6358, SCR J1845-6357) – star system at a distance of ~4 parsecs with a secondary at the limit between brown dwarf and planet detected by Biller et al. 2006. Number 23 on the RECONS list with masses of 0.07/0.03. This is a neglected double star system with only five observations so far listed in the WDS catalog since 2005 with the last one in 2006. Not resolved in DR2 but parallax is given for AB with duplicated_source indication supporting the suggestion that this is a binary. StarHorse offers no data for this object. Vigan et al. 2012 report SCR J1845-6357B as T6 brown dwarf and Faherty et al. 2019 suggest masses for both components of 0.09/0.04. So far no orbit is known for this object although orbital motion should have been evident within a few years after discovery because the spatial distance between the components is estimated to be only ~4.5 AU. Henry et al. 2018 suggest "The orbital period is likely a century or more" but with ~4.5 AU spatial distance and the masses given above the orbit period should be rather in the range of ~33 years

14. KR 60 AB (WDS 22280+5742, GJ 860, Kruger 60) – at a distance of ~4 parsecs. Listed as number 28 on the RECONS list with masses of 0.28/0.16. The grade 2 orbit gives a period of ~45 years compared to a minimum period of ~17 years according to the simulation with the DR2 data using the StarHorse median mass values of ~0.42/0.25 based on a minimum simulation distance of only 6 AU. Wand-Duong et al. 2015 propose masses of 0.27 to 0.32 for the primary and 0.17 to 0.20 for the secondary suggesting a minimum period of ~21 years. The DR2 parallax error for the secondary is rather large, the RUWE value for the secondary is >13 and the primary is marked as a duplicated source in DR2 so some caution regarding DR2 data quality is appropriate. WDS lists a multitude of additional components – all of them most likely optical. Proper motion speed is ~1"/yr and the change in angular separation and especially position angle from year to year is quite significant, so this object is of great interest for visual observation. More details about this interesting object in Knapp & Nanson 2018

15. B 2601 (WDS 06293-0248, GJ 234, Ross 614) – star system at a distance of ~4.1 parsecs not resolved in DR2 due to an angular separation <0.4" but parallax for AB is given without duplicated_source indication. Nevertheless, the RUWE value >11 suggests that the DR2 single star model is not suited for this object. Kervella et al. 2019 report a proper motion anomaly. The 6th orbit catalog lists a grade 3 orbit with a period of ~16.6 years. Ward-Duong et al. 2015 report masses of ~0.2/0.1 – a good match with the StarHorse combined median mass of ~0.3. Benedict et al. 2016 report masses of ~0.22/0.11. WDS lists a multitude of additional components – all of them most likely opticals

16. REU 1 (WDS 12335+0901, GJ 473, Wolf 424) – star system at a distance of ~4.4 parsecs completely missed in DR2. The 6th orbit catalog lists a grade 3 orbit with a period of ~15.9 years. Benedict et al. 2016 report masses of ~0.12/0.11 and WDS lists so far 81 observations. The short orbit period would make this object of interest for long term visual observation but angular separation between 0.5 and 1" and visual magnitudes between 12 and 13 offer some resolution challenges

17. KPP 4436 (GJ 674, CD-46 11540, WDK 3, WDS 17371-4419, GJ 682, CD-44 11909) – wide binary star system at a distance of ~4.55 parsecs. See Table 4. GJ 674 is number 38 on the RECONS list with a planet. Kervella et al. 2019 report a minor proper motion anomaly. No duplicated_source indication in DR2. StarHorse median mass is ~0.40. The RUWE value of ~1 offers also no hint for duplicity. GJ 674 is rather close to GJ 682 with a median spatial distance of ~107,500 AU. GJ 682 is number 51 on the RECONS list at a distance of ~5 parsecs. WDS lists this object as WDK 3 (WDS 17371-4419) with only one observation, might be bogus. In the Cordoba Durchmusterung catalog this object is listed with 2 planets, so this is likely not a star system. Kervella et al. 2019 report a rather small proper motion anomaly. No duplicated_source indication in DR2. StarHorse median mass ~0.32 compared to 0.20 on the RECONS list. The RUWE value of ~1 gives also no hint for duplicity. On the other side Wand-Duong et al. 2015 give masses of 0.23/0.14 speaking rather for a star system. The GJ 682 StarHorse median mass of ~0.32 suggests together with the ~0.4 for GJ 674 an overlap of the tidal radii even for the maximum spatial distance of the simulation. Quite different proper motion values do not suggest an orbit, but at least mutual influence on speed and direction of the movement through space of these two planet-hosting stars.

262.1664398	RA J2000 in degrees
-46.89519257	Dec J2000 in degrees
29.017	Position angle J2015.5
0.000	Error position angle
10662.46882	Separation in arcseconds J2015.5
0.00014	Error separation
9.95732	Estimated Vmag primary from G/B/R-mag
0.00491	Error estimated Vmag primary
11.24747	Estimated Vmag secondary from G/B/R-mag
0.00590	Error estimated Vmag secondary
219.8012	Parallax primary in mas
0.0487	Error parallax primary
4.5496	Distance primary from the Sun in parsecs
199.7031	Parallax secondary in mas
0.0832	Error parallax secondary
5.0074	Distance secondary from the Sun in parsecs
572.582	Proper motion RA primary in mas/yr
-880.251	Proper motion Dec primary in mas/yr
-706.117	Proper motion RA secondary in mas/yr
-937.912	Proper motion Dec secondary in mas/yr
105 379	Minimum spatial distance between the components in AU
0.39851	StarHorse median mass for primary in Sun mass
0.32356	StarHorse median mass for secondary in Sun mass
40 480 075	Minimum period of a potential orbit in years

Table 4. Data for KPP4436 (WDS 17287-4654, GJ 674, GJ 682) based on GAIA DR2 values for source_id 5951824121022278144 and 5955305209191546112:

18. GIC 159/MCY 3 (WDS 19539+4425, GJ 1245) – triple star system at a distance of ~4.7 parsecs. Listed as number 37 on the RECONS list with masses of 0.11/0.1/0.07. The 6th orbit catalog has no entry for GIC 159 because the number of observations is only 20 since 1954. Simulation suggests a minimum distance of 28 AU and StarHorse median masses of ~0.19/0.13 give a minimum orbit period of 264 years, but the large parallax error of the primary would also allow for a much longer period. The primary, while not marked as duplicated_source in DR2, is a binary itself (MCY 3 Aa,Ab) and is listed in the 6th orbit catalog with a grade 3 orbit with a period of ~16.8 years. This might explain the mentioned large parallax error for A in DR2. The RUWE value for the primary is >10, supporting doubts regarding the DR2 astrometric data quality for this object. Benedict et al. 2016 list for Aa,Ab masses of ~0.11/0.08 – perfect match with the StarHorse median mass of ~0.19 for A. The number of measurements so far is as already mentioned is certainly too small to calculate a reliable orbit for GIC 159 AB, although the changes of separation and position angle since 1954 suggest a systematic development.

Applying the Izmailov program on the given observation history for GIC 159 AB plus an my own recent measurement (see Appendix B), results in the following values for a preliminary orbit given in Figure 2.

Proper motion speed is with 0.5"/yr, significant but not fast enough to be of interest for visual observation and the same is true for the rather small changes in separation and position angle from year to year. Besides the components are rather faint with Vmag 13.5/14.

19. VBS 18 (WDS 11055+4332, GJ 412) – binary

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```
a     =     9.900580643595916
e     =     0.704360566048512
T     =  1924.452324527843800
P     =   223.133925291275600
omega=   263.762475885019850
Node =   118.209901338370230
i     =   106.922252157261250
```

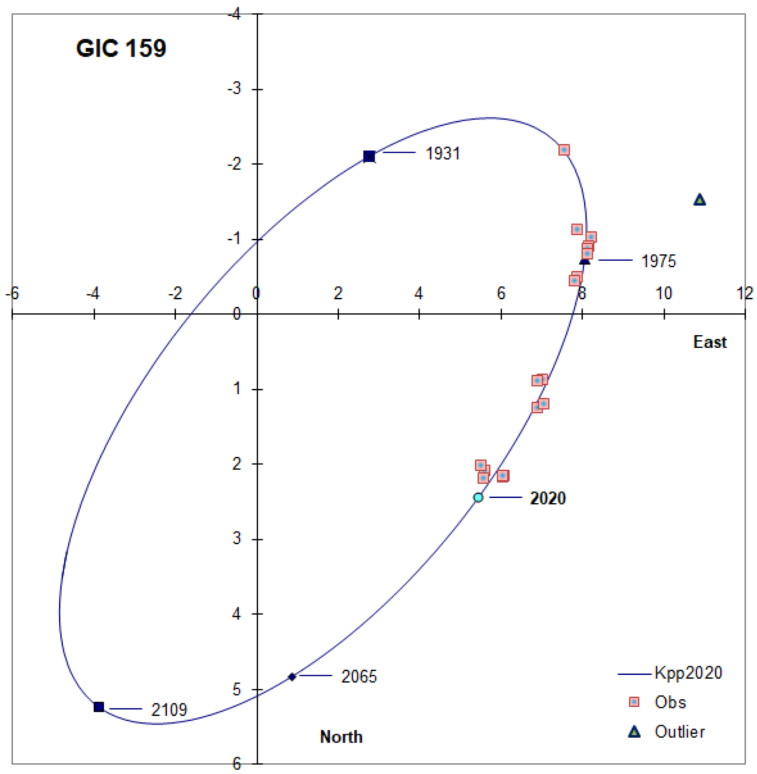

Figure. 2. Plot system 18: Orbit for GIC 159 AB

star system at a distance of ~4.9 parsecs. Number 43 on the RECONS list with masses of 0.48/0.10. Resolved in DR2 but parallax and proper motion missing for the primary. Ward-Duong et al 2015 list masses of 0.4/0.1. Very fast proper motion of >4"/yr. So far only 9 observations since 1950 most likely due to the very faint 14.6 Vmag companion. Not listed in the 6th orbit catalog. Processing of a recently taken own image (see Appendix B) more or less confirms the last precise measurement listed in the WDS catalog as well as the common proper motion of the components.

20. BAG 32 (WDS 10200+1950 Ca,Cb, GJ 388, BD+20 2465) – spectroscopic binary at a distance of ~4.9 parsecs, number 45 on the RECONS list as single star. Not resolved in DR1 with parallax and proper motion data for a combined object without duplicated_source marker. According to the WDS catalog there have been four observations since 1981. Listed in the 6th orbit catalog with a grade 9 orbit with a period of ~26.5 years – confusingly with a reference to a 1943 paper. Simple explanation according to Brian Mason (private communication): Orbit based on detection 1943 due to astrometric perturbations, first time effectively resolved and measured in 1981. This object is part of STF 1424 with the components AB listed in the WDS and the 6th orbit catalog – but this binary is far outside 10 parsecs. STF 1424 AC is listed with a linear solution and the parallax values for A and C are completely different – for this reason there is no physical relationship between STF 1424 AB and BAG 32 Ca,Cb. Several other components listed in the WDS catalog for this object are most likely optical.

21. STF 518 (WDS 04153-0739, GJ 166) – triple star system at a distance of ~5 parsecs. Listed as number 49 on the RECONS list with masses of 0.89/0.5/0.18. Resolved in DR2 with parallax and proper motion data for A and C both with duplicated_source marker and without parallax and proper motion data for B but also with duplicated_source marker. STF518 offers some riddles beginning with A,BC as WDS anchor object, but the data given here are obviously for the components A and B, at least according to my own measurements (see Table 1 in Appendix B) and the last precise WDS values. Such a designation is certainly proper for Tokovinin 2018 (Updated Multiple Star Catalog MSC, VizieR J/ApJS/235/6) with BC then standing for a system. However, the WDS catalog data is based on components and BC would then stand for a visually unresolved object, but in this case BC is easily resolved with even a very small telescope and the WDS catalog offers consequently also data for the BC pair. Neither STF 518 A,BC nor AC are listed in the 6th or-

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bit catalog, but for BC a grade 3 orbit with a period of 230 years is given (Izmailov 2019 reports a period of ~221 years). The MSC catalog lists the orbit period for A,BC at ~6,021 years and for BC at ~252 years. The riddle continues with DR2 with missing proper motion data for B, making it difficult to match this component properly. This confusion leads to Argyle et al. 2019 listing for STF 518 B in error the DR2 data of C while commenting later on that DR2 data is given only for A and C. And Tokovinin 2018 notes in error that “Not found A and BC in Gaia DR2”, obviously having missed the DR2 objects for A and B. Using the DR2 data for A and C for the simulation shows ~390 AU as minimum spatial distance between the components. DR2 StarHorse median mass values for A and C of ~0.84/0.30 (a reasonable good match with Tokovinin 2018 with 0.85/0.23) suggest a minimum period for an orbit of ~7,260 years, but then this is not a reasonable approach, because C does not orbit alone around A but wobbles along the path of the BC barycenter. Using the combined mass of BC given by Tokovinin 2019 with 0.73 gives a minimum period of ~6,180 years – quite close to the Tokovinin 2018 value mentioned above. By just using the parallax data of C also for B and the mass values from Tokovinin 2018 the simulation minimum orbit period for BC is 322 years – a bit higher than the 6th orbit and MSC catalog values but reasonably close. As there is no analytic gravitational solution for the three-body problem, all such considerations reflect more guesses than facts. This is also the case for the 6th orbit catalog entry for BC (Mason et al. 2017), because it is most unlikely that the A component has no influence on the BC orbit, especially if the BC orbit around A has some eccentricity. The other components of STF 518 listed in the WDS catalog are most likely optical with linear solutions.

STF518 is a very interesting physical triple not only because of its complexity but also for visual observation, because the proper motion speed is extraordinarily high, so the change of position against the background stars from year to year should be clearly noticeable. STF518 travels also with a total spatial velocity >100 km/s with a deviation of ~33° in the direction of our solar system covering a distance >5 parsecs within 50,000 years, but most likely not close enough for potential future gravitational effects between Sun and STF518. Bailer-Jones 2015 and Bailer-Jones et al. 2018 made an attempt to calculate such potential star encounters better than by galactic orbits instead of just linear motion, but the caveats and exceptions are too numerous to take these results seriously.

22. STF 2272 (WDS 18055+0230, GJ 702, 70 Oph) – binary star system at a distance of ~5.1 parsecs. Number 52 on the RECONS list with masses of 0.92/0.70. DR2 gives parallax and proper motion values for component B without duplicated_source marker, but no such data for A yet with duplicated_source marker. WDS lists a multitude of components, all of them except AB most likely optical. The 6th orbit catalog lists for AB a grade 1 orbit with a period of ~88.5 years based on 1,713 observations since 1777. StarHorse median mass is ~0.71 (good match with the RECONS list) and RUWE ~1 indicates no DR2 data quality issues. The changes in position angle and angular separation from year to year are too small to be noticed by visual observation, the proper motion speed is >1”/yr, impressive but also not fast enough to notice position changes relative to background stars within a reasonably small time frame.

23. LDS 3836 (WDS 08582+1945, GJ 1116) – binary star system at a distance of ~5.1 parsecs. Listed as number 54 in the RECONS list. Listed in DR2 with parallax and proper motion data for both components without duplicated_source marker. LDS 3836 is not listed in the 6th orbit catalog. The minimum spatial distance between the components is according to simulation only 11 AU with a minimum orbit period of 68 years using the median mass StarHorse values of ~0.145/0.14 (compared with 0.11/0.10 on the RECONS list). The maximum distance of the simulation is smaller than 7,700 AU so this pair is most likely gravitationally bound. With a RUWE value of ~1.2 for both components, reasonably small parallax errors, and no duplicity issues, the DR2 data quality seems sound. It should be easy to calculate an orbit for this one if the true orbit period is near the calculated minimum, but only 6 WDS observations exist so far. Too few for such a task even if basically 5 data points would be sufficient to define a conic section (hyperbola, parabola or ellipse) if less than three of the points are collinear. The

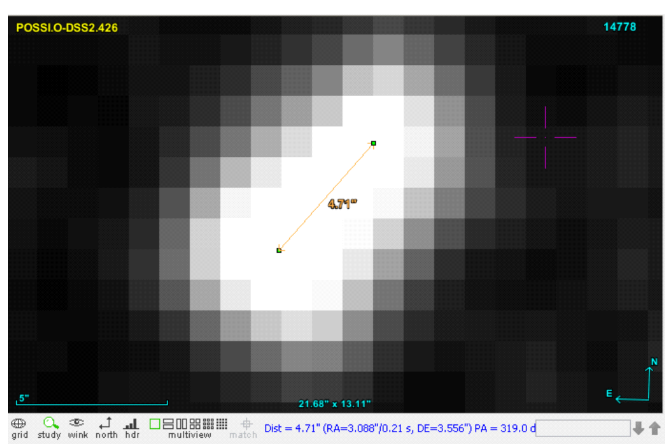

Figure 3. LDS 3836 in POSS I image from 1950-03-21

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```
a    =     3.144924078819730
e    =     0.488799870191957
T    =  2002.285786519821800
P    =   123.641156691160990
omega=   351.541527869910450
Node =   139.997107226309480
i    =    38.922457106894399
```

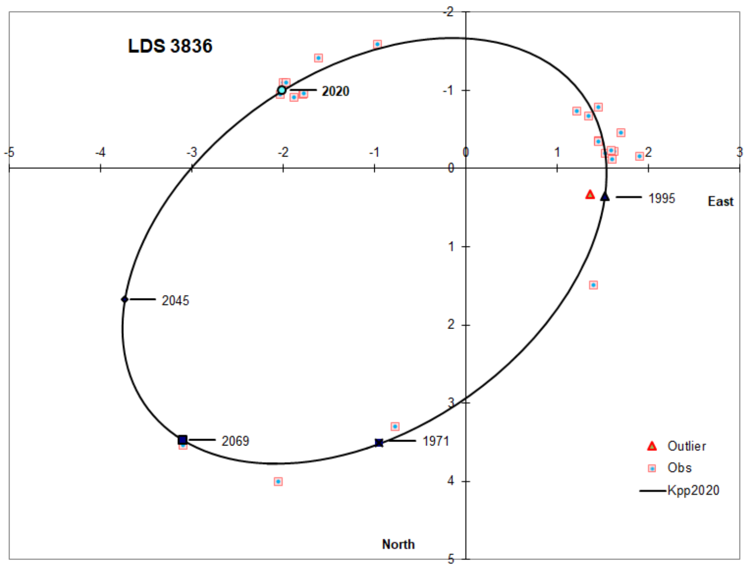

Figure 4. Plot system 23: Orbit LDS 3836

POSS I image from 1950 rather confirms the WDS data from the first observation per 1960, which means that the changes in separation and position angle in the last 60 years are quite significant. This makes this pair an interesting target for regular visual observation with the caveat that a sufficiently large aperture is required to resolve such a faint pair with magnitude ~14 in the visual band for both components.

The observation history listed in the WDS catalog plus two estimations from POSS I and POSS II images (see Figure 3.) plus my own recent measurements (see Appendix B) cover a total time span of 70 years.

The Izmailov program provides with these measurements the preliminary orbit values given in Figure 4.

24. STI 2051 (WDS 04312+5858, GJ 169.1) – triple star system at a distance of ~5.5 parsecs. Listed as number 60 in the RECONS list with masses of 0.2/0.5. DR2 objects for A and B with a rather large parallax error and a duplicated_source indication for A. The AB pair has currently no entry in the 6th orbit catalog. STI 2051 Aa,Ab is listed with a grade 9 orbit although no such object exists in the WDS catalog. The existing observation data for AB suggests a linear fit and the WDS catalog lists note code "L" speaking against an orbit but allowing for the possibility of a long period orbit.

The large DR2 parallax error for A causes some spread in the simulation results for the spatial distance between the components. The minimum spatial distance between A and B is ~56 AU, rather small, but even the maximum distance of <24,000 AU strongly suggests a gravitational relationship. The StarHorse median mass value for the primary is ~0.35, but there is no such value given for the secondary, a white dwarf.

The Stein 1977 paper on STI 2051 gives mass estimations for A and B of 0.2 and 0.5 and alternatively 0.19/0.17 for Aa/Ab and 0.72 for B – in both scenarios the given mass of B is by far larger than the mass of A or Aa+Ab. The StarHorse median mass value of ~0.35 for A matches nicely with the combined masses 0.19+0.17 given in Stein 1977 for the Aa+Ab scenario and DR2 indicates A as duplicated_source – this supports together the second Stein 1977 scenario.

The mass values given in the MSC catalog updated in 2018 with 0.35/0.5 seem rather questionable because if the mass for A is compared with Stein 1977 changed from 0.2 to 0.35 then why should the mass for B remain unchanged with 0.5?

Another completely independent mass estimation for STI 2051 B is given in Suha et al. 2017 with ~0.675 based on astrometric microlensing. Using the StarHorse median mass value of 0.35 for A and the Sahu et al. 2017 mass value of 0.675 for B results with the minimum spatial distance given above in a minimum orbit period of 420 years.

The Relative Motion Calculator tool from Francisco Rica (see Rica 2015) confirms the conclusion that STI 2051 AB is most likely bound by gravitation, as the relative velocity of this pair seems to be smaller than the calculated escape velocity. The observation time frame of ~110 years with a measurements number of ~140 so far is a bit too small to allow for calculating a reliable orbit with a period of 420 years or longer, but the noticeable rather systematic changes in separation

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =    32.219103025008060
e     =     0.705407637918984
T     =  1798.986427773167900
P     =  1799.890014081724800
omega=   333.254946239346110
Node =    10.388804756151629
i     =   105.250934668525010
```

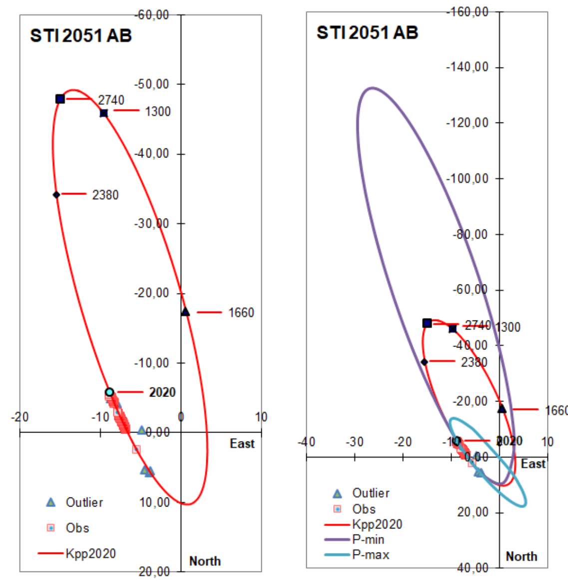

Figure 5. Plot of system 24: Orbit for STI2051 AB (inverted PA) and comparison with shortest and longest period in the set of 200 possible orbits

and position angle since 1908 suggest a high likelihood for a reliable long period orbit.

The assumed larger mass of B compared to A (or Aa+Ab) would mean that if we consider the possibility of an orbit then B will be closer to the center of mass and all position angle measurements should be inverted as is done for the graph below.

Applying the Izmailov program on the existing observation history plus a recent measurement of my own (see Appendix B) gives the preliminary orbit values shown in Figure 5 with a period spread in the set of orbits between ~493 and ~6,316 years.

25. NAJ 1 (WDS 06106-2152, GJ 229, HD 42581) – binary star system at a distance of ~5.8 parsecs, number 67 on the RECONS list with masses of 0.56/0.03. DR2 lists the primary with parallax and proper motion data without duplicated_source marker. Secondary is missing in DR2 despite a generous angular separation (according to WDS 6.8" in 2006) and a visual magnitude of 17.1 well within the photometric range covered by GAIA. B is assumed to be a brown dwarf of <0.08 Solar masses, but according to Simbad this might also be an extra massive planet. Kervella et al. 2019 report a significant proper motion anomaly supporting rather the brown dwarf assumption. Wagner et al. 2019 report direct imaging of GJ 229b with a projected spatial separation of ~45 AU. StarHorse combined median mass is 0.55 and RUWE ~1 suggests no DR2 astrometric data quality issues and DR2 indicates for A no duplicated_source. There is no 6th orbit catalog entry. At this time, the WDS catalog lists 8 observations since 1994 with the last one in 2006, so this looks like a neglected object

26. H N 28 (WDS 14575-2125, GJ 570, 33 Libra, HD131977) – multiple star system at a distance of ~5.8 parsecs. Number 71 in the RECONS list. DR2 lists A with parallax and proper motion data and B without, both objects without duplicated_source indication. RECONS component designations B and C correspond with Ba,Bb in the WDS catalog. The RECONS masses of 0.78/0.55/0.36/0.03 mean that the center of mass is closer to B than to A. The 6th orbit catalog lists a grade 5 orbit for AB based on 160 observations since 1806 with a period of 2,130 years calculated 1994 and for Ba,Bb a grade 3 orbit of ~0.85 years based on 26 observations since 1987 calculated 1999. Burgasser et al. 2000 first reported an additional brown dwarf companion for GJ 570 (listed as BUG 4 BG in the WDS catalog, component G corresponding with D in the RECONS list) with an estimated mass of ~0.05 (compared to 0.03 in the RECONS list) making this system a quadruple. Number of listed observations for BUG 4 is so far only one but Wagner et al. 2019 report direct imaging of this brown dwarf at a projected spatial distance of 1.520 AU from GJ 570. The WDS catalog lists five additional most likely optical components.

The XY-plot (Figure 6) of the given observation history of H N 28 AB suggests a linear solution instead of an orbit, which means a likely optical pair or. if physical, then with a very long period. However, if the Hipparcos parallax value for the secondary is close to reality, despite the huge error range, then gravitational

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```
a     =    86.764750669345815
e     =     0.659753620119124
T     =  2152.763350424671000
P     =  6488.553709223856500
omega=   185.081352912595210
Node =   134.198476677512990
i     =    80.943537180516429
```

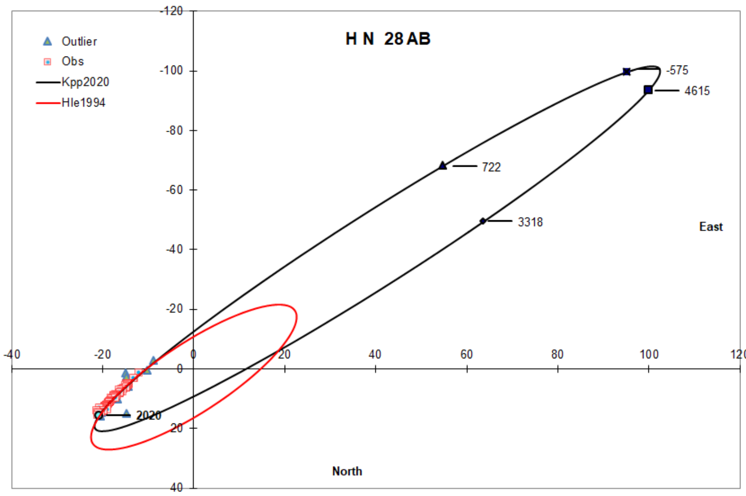

Figure 7. Plot of system 26: H N 28 AB orbit comparison

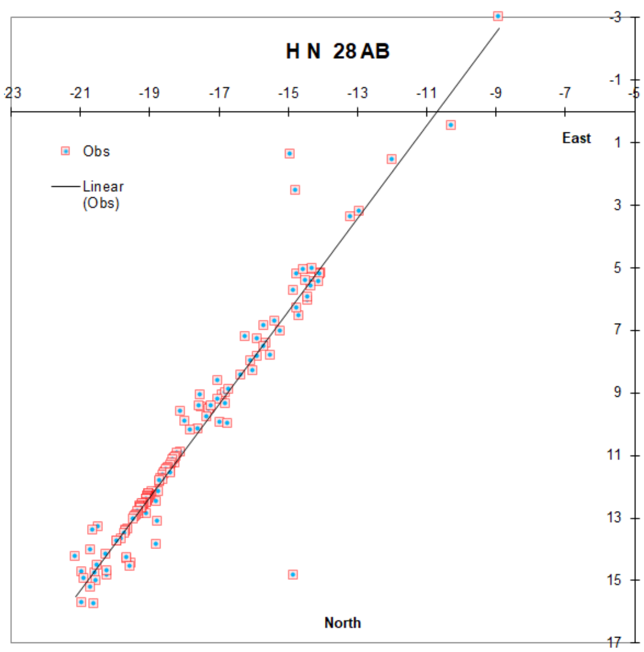

Figure 6. Plot system 26: H N 28 AB orbit or linear?

relationship would most likely be given with a minimum spatial distance of ~151 AU with a minimum potential circular orbit period of ~1,440 years. Yet some caveats remain until a reliable parallax value is available. Using the Izmailov program on the observation history of H N 28 AB along with ~10 additional measurements, the DR2 result, and my own measurement give a preliminary orbit quite different from the current 6th orbit data. See Figure 6.

As the H N 28 Ba,Bb observation history lists ~10 new measurement since the last orbit calculation, I used the Izmailov program also on this object only to find that the combination of a very short orbit period with in relation long observation lags is not suited for using this otherwise very useful program. Yet the comparison of calculated orbit values with the new measurements indicate the excellent quality of the >20 years old Frv1999 orbit.

With a proper motion speed >2"/yr, GJ 570 is an interesting object for visual observation of the position change against the background stars from year to year.

27. STF 60 (WDS 00491+5749, GJ 34, HD4614, eta Cas) – binary star system at a distance of ~5.8 parsecs. Listed as number 75 in the RECONS list with masses of 1.11/0.6. Listed in DR2 with parallax and proper motion data for both components with duplicated_source marker for the primary. STF 60 is listed in the 6th orbit catalog with a grade 3 orbit from Izmailov 2019 with a period of ~453 years based on 1,079 observations since 1779, the orbit listed before gave a period of 480 years calculated in 1969. A duplicity marker and a rather large parallax error make the GAIA DR2 data for the primary a bit questionable. WDS notes indicate a potential spectroscopic binary for A and an exoplanet might also be involved, but Bonavita and Desidera 2020 list HD6414 as star pair without planets. According to the simulation, the minimum spatial distance is ~204 AU, while the given 6th orbit catalog parameters suggest a widest distance of less than 90 AU. The StarHorse median mass value for the primary is ~1, but there is no such value available for the secondary. Argyle et al. 2019 (page 88) provide masses of ~1.08/0.63 resulting

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =    11.900629037547578
e     =     0.491232950692725
T     =  1889.570524041618900
P     =   471.258459300038000
omega=     87.705011531962398
Node =     99.338680896094061
i     =    35.748739512021530
```

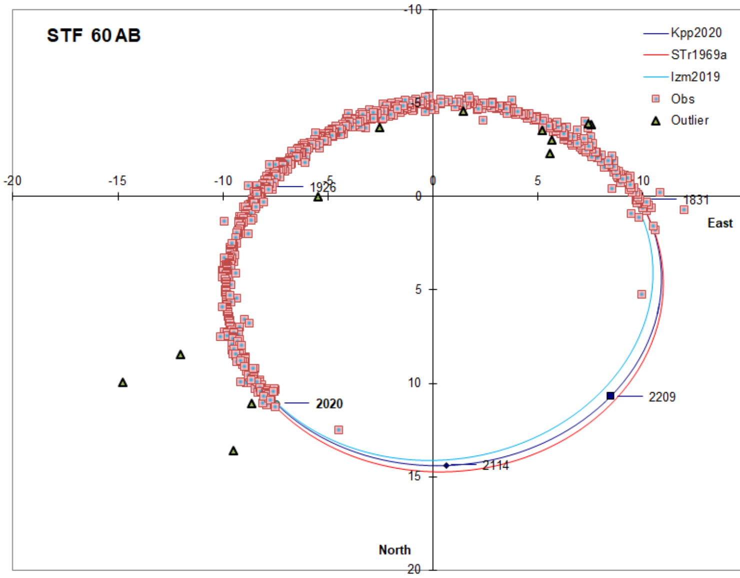

Figure 8. Plot system 27: STF 60 AB orbit comparison

in a minimum potential orbit period of ~2,200 years. Bonavita and Desidera 2020 list masses of 0.99 and 0.58, giving a similar result. This suggests either that the listed orbit is a bit too optimistic or that the DR2 data quality is questionable. Most likely, the latter is the case as the 1,079 observations since 1779 cover a good part of the assumed orbit and rather confirm the suggested orbits as in both cases the most recent measurements are only slightly different from the calculated orbit data. Just to look for confirmation, I used the Izmailov 2019 program on the given observation history with the result rather close to the Str1969a orbit show in Figure 8.

The WDS catalog lists a large number of additional components but the proper motion speed of STF 60 AB is larger than one arcsecond per year making obvious that these "components" are background stars - so this is an interesting object for visual observation if just to check the position change against the background.

28. HEI 299 (WDS 00155-1608, GJ 1005, G 158-50) – binary star system at a distance of ~5.9 parsecs. Listed as number 74 in the RECONS list with masses

```
a     =     0.303852089456875
e     =     0.362747294491989
T     =  1999.917750602014400
P     =     4.553609640043534
omega=    346.513427411657860
Node =     62.592318769963008
i     =   145.844293910359280
```

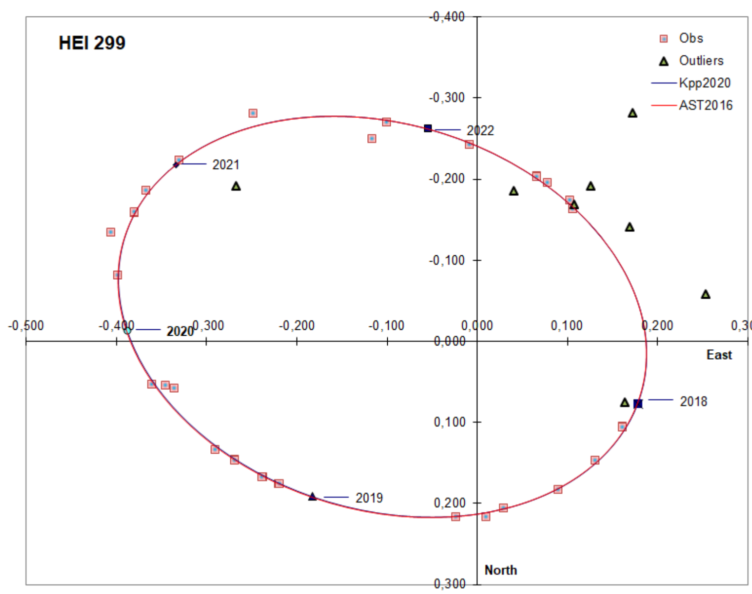

Figure 9. Plot system 28: HEI 299 – "comparison" of identical orbits

of 0.18/0.11. Not resolved in DR2 due to the angular separation <0.4". Combined DR2 object without parallax and proper motion data but with duplicated_source marker. Listed in the 6th orbit catalog with a grade 2 orbit with a period of ~4.6 years. Number of observations since 1985 listed in WDS is 51. Benedict et al. 2016 report masses for A/B of ~0.18/0.11 and Ward-Duong et al. 2015 of 0.15/0.11. Using the Izmailov program on the given observation history gives. with one additional measurement since 2016, a more or less identical result to the current 6th orbit catalog entry besides inverted Node and omega values. See Figure 9.

29. LDS 6334 AB (WDS 19169+0510, GJ 752, HD 180617) – binary star system at a distance of ~5.9 parsecs, number 70 in the RECONS list with masses of 0.5/0.07. Resolved in DR2 with parallax and proper motion data for both components without duplicated_source marker. RECONS list gives a slightly larger parallax than DR2. There is no orbit listed for LDS 6334 in the 6th orbit catalog, as the number of observations is with 6 since 1942 far too small to draw any conclusions for a potential orbit. The reason for this small number of observations is most likely the faintness of the secondary. The DR2 data suggests according to the simulation a maximum distance between the components of ~6,000 AU proposing strongly a gravitational relationship if with the caveat of a slightly larger than average parallax error for the secondary and missing StarHorse data for the secondary suggesting some DR2 data quality issues. The StarHorse median mass for the primary is ~0.5 and the mass of the secondary is according to the RECONS list 0.07. This corresponds well with the masses given by Wand-Duong et al. 2015 as 0.49/0.09 and gives together with the minimum distance of 446 AU a minimum orbit period of ~12,500 years. It will take some time to get enough measurements for this pair to be able to calculate a preliminary orbit. The WDS catalog lists ~10 additional components for this star system with CSN 12 designation –all of them obviously opticals

30. SHJ 243 (WDS 17153-2636, GJ 663/4, 36 Oph) – triple star system at a distance of ~6 parsecs, number 76 on the RECONS list with masses of 0.85/0.85/0.71. Listed in DR2 with parallax and proper motion data for all three components. The parallax errors for A and B are slightly above average and B is listed with a duplicated_source marker but the RUWE value for all components is below or near 1. The 6th orbit catalog lists a grade 4 orbit for AB with a period of 471 years but none for AC. Izmailov 2019 reports an orbit period for AB of ~808 years. The WDS catalog mentions the possibility that A might be a spectroscopic binary. Simulation suggests a minimum distance for AB of 30 AU giving with the StarHorse median mass values of 0.79/0.79/0.70 a minimum orbit period of 132 years and for AC a minimum distance of 4,360 AU with a minimum orbit period of ~237,000 years. The number of SHJ 243 AB observations so far is ~280 and the time frame of ~250 years since discovery in 1777 should be sufficient to support the suggested grade 4 orbit. At the same time, it seems a bit surprising that the given measurements over 250 years should cover far less than 50% of the suggested orbit with a period of 471 years.

Using the given observation history for SHJ 243 AB with the Izmailov program results in quite different preliminary orbit values shown in Figure 10. The differ-

```
a     =     9.527855964304855
e     =     0.390305188516449
T     =  2096.367147903525200
P     =  1937.789712297395200
omega=   352.157991892117480
Node =   112.349893118736620
i     =   125.037161391634400
```

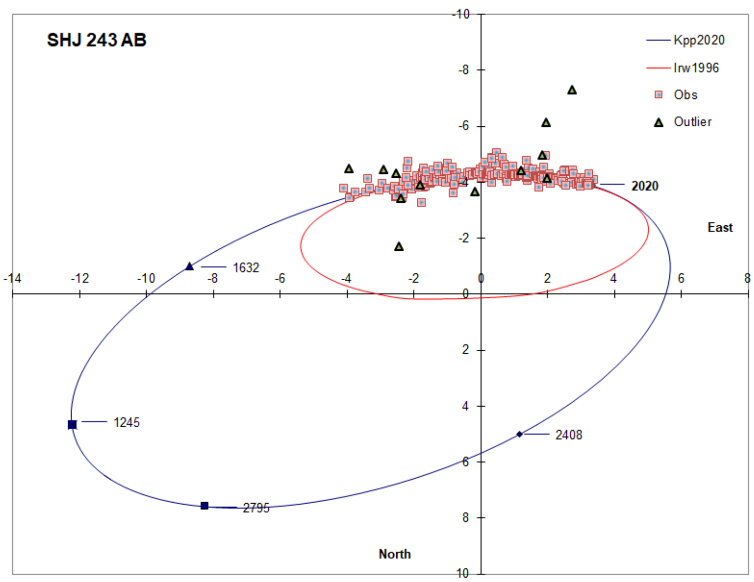

Figure 10. Plot system 30: Orbit SHJ 243 AB comparison

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

ence with the current SHJ 243 AB 6th orbit catalog values is huge (period of ~1,938 compared to ~471 years), but the set of possible orbits shows a large spread with periods from ~455 to ~7,353 with a median value of ~931 – so some room for improvement seems to be given here.

The number of observations for SHJ 243 AC is (including DR2 values currently not listed in WDS) only 7 so far. This is too small for a serious orbit calculation so the use of the Izmailov program was just a thought experiment and the resulting period of ~584,000 years corresponds to some degree with the simulation results.

The WDS catalog lists two additional components for the SHJ 243 system – all of them with a linear solution and therefore most likely opticals.

31. HJ 5173 (WDS 20112-3606, GJ 783) – star system at a distance of ~6 parsecs, number 79 on the RECONS list. DR2 provides despite a generous angular separation of currently ~4" data only for the primary. StarHorse lists a median mass of ~0.75 and RUWE <1 suggests good DR2 data quality. Bonavita and Desidera 2020 list masses of 0.69/0.24 and a projected separation of 42 AU. The number of observations since 1834 is with 23 rather low and the 6th orbit catalog lists most likely for this reason no entry for this star system. Kane et al. 2019 report a negative result in detecting a companion due to linear trends in radial velocity combined with no directly imaged stellar companion. The reason might be the large magnitude difference at a currently close angular separation – the Gliese catalog as well as the LHS catalog list two resolved components with a more generous angular separation several decades ago. Using the identical parallax data for primary and secondary in the simulation with an average angular separation of ~6" results in a minimum spatial distance between the components of 35 AU. Using the RECONS mass values of 0.82/0.19 gives a minimum orbit period of 207 years – the observation history since 1834 should then despite the mentioned low number of observations deliver enough data points to support such a proposition. With exception of the first two the remaining observations show a systematic change in angular separation and position angle supporting at first look indeed the idea of an orbit with a period of several hundred years.

Using the Izmailov program gives a result with a period of ~6,192 years thus rather not confirming this expectation and the plot below shows that this result seems a very long shot not suited for a preliminary orbit, Figure 11.

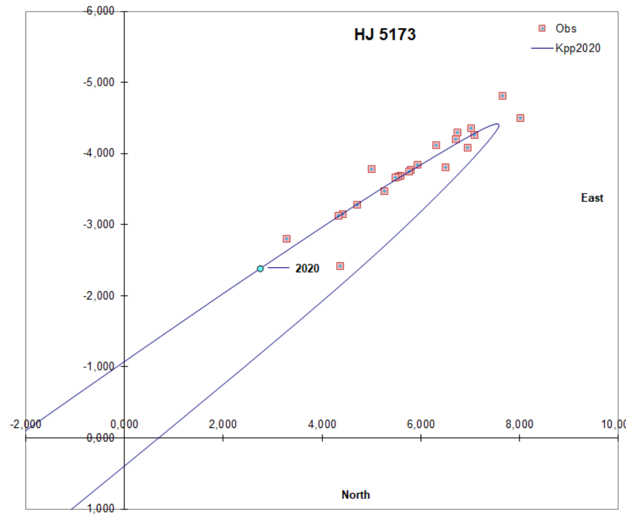

Figure 11. Plot system 31: HJ 5173 orbit

32. GJ 268 (QY Aur, Ross 986, LHS 226) – spectroscopic binary at a distance of ~6.1 parsecs, number 84 on the RECONS list with masses of 0.17/0.16. Not resolved in DR2 but parallax and proper motion data for AB given with duplicated_source indication. StarHorse indicates a combined median mass of 0.2 and the RUWE value of ~1 suggests no DR2 data quality issues. Also listed as variable star RS CVn type. Reported as not resolved by Ward-Doung et al. 2015. No WDS object, but the 6th orbit catalog lists a grade 8 orbit for GJ 268 (WDS 07100+3832) with a period of ~10 days. Baroch et al. 2018 report in table D1 similar if slightly different orbital parameters for this system but from a source older than the current 6th orbit catalog entry.

33.WIR 1 (WDS 23317+1956, GJ 896) – binary star system at a distance of ~6.3 parsecs. Listed as number 88 in the RECONS list. Resolved in DR2 with parallax and proper motion date for both components without duplicated_source marker. Listed in the 6th orbit catalog with a grade 5 orbit with a period of ~359 years based on 71 observations since 1941. Izmailov 2019 suggests a period of ~230 years. WDS lists two additional components considered most likely optical. The simulation with DR2 data and StarHorse median mass values of 0.45/0.25 gives a minimum spatial distance of 34 AU and a minimum period of 234 years. Wand-Duong et al 2015 give masses of 0.35 to 0.39 for the primary and 0.17 to 0.20 for the secondary resulting in a minimum period of 273 years. The DR2 data quality seems solid with moderate parallax errors and RUWE values near 1. The mass values given in the RECONS list are with 0.33/0.16 a bit smaller compared to StarHorse, which would mean a small increase in the minimum orbit period. As the current 6th orbit data is from 1984 I used the Izmailov program on the meanwhile

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```
a     =     4.727603213625397
e     =     0.299996534298788
T     =  1887.665380611639000
P     =   182.79125584690632O
omega=   119.880904119121570
Node =    67.996226949373323
i     =   127.668521889364810
```

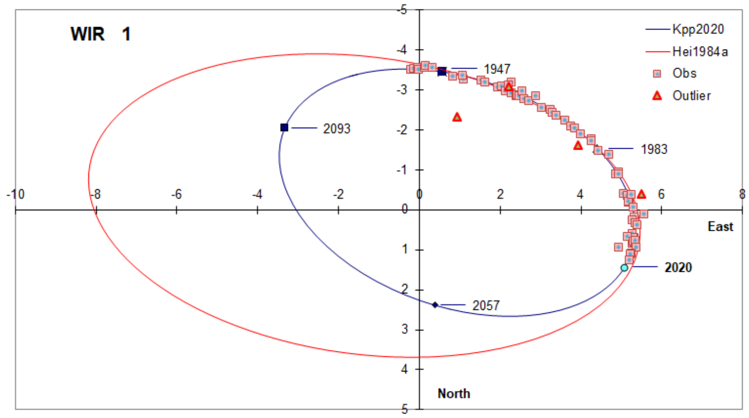

Figure 12. Plot system 33: WIR 1 orbit comparison

significant expanded observation history with quite a different preliminary orbit proposal not only compared with the current 6th orbit catalog but also Izmailov 2019 (and Figure 12 shows an excellent match with the observations so far).

Proper motion is not very fast, ~0.5"/yr, the changes of separation and position angle per year are negligible and the components are rather faint – so this object does not offer interesting features for visual observation.

34. STF 1321 (WDS 09144+5241, GJ 338) – binary star system at a distance of ~6.3 parsecs. Resolved in DR2 with parallax and proper motion data for both components without duplicated_source marker. Listed as number 82 in the RECONS list with masses of 0.6/0.6. This means a jump back in the list due to a slightly smaller DR2 parallax value. STF 1321 AB is listed in the 6th orbit catalog with a grade 4 orbit with a period of 975 years based on measurements from sever-

```
a     =    19.147524244782989
e     =     0.299906003961022
T     =  1537.621749297630500
P     =   933.910541044704700
omega=   257.910974748905630
Node =    21.830699943886600
i     =    47.424813310553958
```

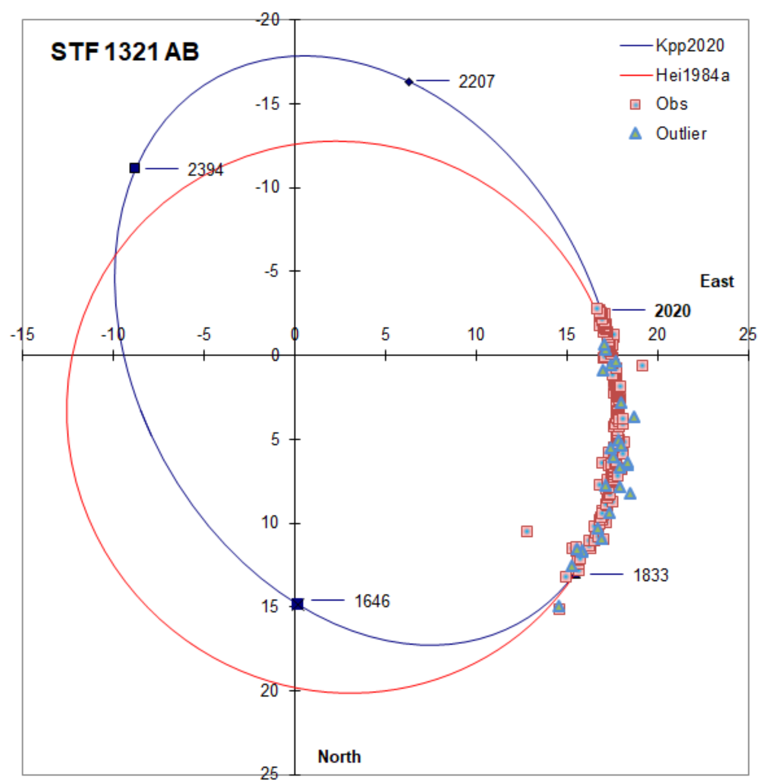

Figure 13. Plot system 34: STF 1321 AB orbit comparison

al hundred observations. WDS lists two additional components considered most likely opticals. Rather small DR2 parallax errors and RUWE ~1 for both components indicate good DR2 data quality. Simulation using these data and the StarHorse median masses of ~0.6 for both components results in a minimum distance of 108 AU and a minimum orbit period of ~1,030 years which is quite close to the given 6th orbit period value. Argyle et al. 2019 mention some discussion in the past that both components might be spectroscopic binaries themselves (page 207) – this proposition has since been rejected. As the current 6th orbit data is based on a calculation from 1972 it seems appropriate to have a closer look at the >200 additional observations since then including one own recent measurement. The Izmailov program suggests the preliminary orbit values given in Figure 13 with the expected not huge but significant differences.

The changes in separation and position angle caused by the orbit are too small to be noticeable by visual observation, but the proper motion is >1.5"/yr, fast enough to make this an interesting pair for visual observation. Both components have visual magnitude of ~8.5, reasonably bright for smaller apertures.

35. KUI 79 (WDS 17121+4540, GJ 661, HD 155876) – spectroscopic binary at a distance of ~6.4 parsecs. Not resolved in DR2, combined object without parallax and proper motion values but with a duplicated_source marker. Number 92 on the RECONS list with masses of 0.39/0.33. StarHorse provides no data for this object, which indicates DR2 data quality issues. The 6th orbit catalog lists a grade 1 orbit based on over 200 observations since 1934 with a period of ~13 years. About 25 new measurements have been added to the WDS catalog since the calculation of the current 6th orbit catalog entry so I used the Izmailov program on the extended observation history with the results shown in Figure 14 indicating minor changes.

The angular separation is currently close to 1", so this object, with both components having visual mag ~10, might be a reasonable target for visual observation of changes in separation and position angle from year to year with larger amateur telescopes even if the last observation from 2011 suggests the need for a very professional equipment (Horch et al. 2017).

The WDS catalog also lists a most likely optical C component.

36. KUI 75/UC 3253(WDS 16555-0820, GJ 644, LHS 428, LHS 427, LHS 429) – multiple star system at a distance of ~6.5 parsecs. Number 95 on the RECONS list as quintuple system with masses of 0.42/0.33/0.27/0.08/0.18. DR2 misses 3 of the 5 components of GJ 644. AB is due to an angular separation <0.4” not resolved in DR2 and listed as combined object without parallax and proper motion data and without duplicated_source marker. The sub-pair Ba,Bb is anyway far below the GAIA DR2 resolution threshold of 0.4". The component letters given in the RECONS list do not correspond with the WDS catalog and the WDS C component (LHS 427) is even a “blank” component in the RECONS list. LHS 427 is marked as duplicated_source in DR2 so the data quality might be

```
a     =     0.739024146094673
e     =     0.743744067434288
T     =  1965.143929679531800
P     =    12.951410932291196
omega=     99.110901734152904
Node =    159.502264816562840
i     =    150.854297239410470
```

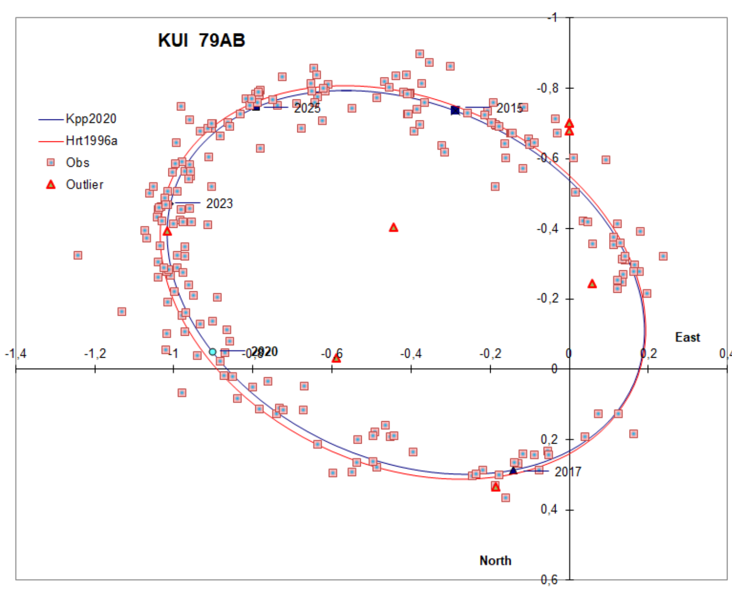

Figure 14. Plot system 35: KUI 79 orbit comparison

Date	PA orb	Sep orb	PA obs	Sep obs	dPA
2000.28857	18.30	0.21300	16.98	0.21012	1.32
2000.47473	340.30	0.21600	335.55	0.22362	4.75
2001.49880	135.30	0.22400	135.08	0.22893	0.22
2002.25360	327.20	0.22300	322.80	0.22684	4.40
2003.40500	275.00	0.11000	94.52	0.21286	180.48
2005.55100	173.80	0.22000	351.55	0.21847	177.75
2006.20000	220.20	0.22900	221.15	0.23143	0.95
2006.44480	174.00	0.23600	174.40	0.23595	0.40
2008.45000	297.20	0.21500	117.98	0.22228	179.22
2008.45590	115.50	0.21900	116.73	0.22175	1.23
2008.53550	96.90	0.21160	99.22	0.21461	2.32
2009.42000	81.00	0.22400	263.47	0.22968	182.47
2012.23100	216.03	0.20600	35.54	0.20596	180.49
2015.49510	76.10	0.21080	77.67	0.20775	1.57
2018.39830	6.60	0.23770	186.73	0.23543	180.13

Table 5. Comparison KUI 75 AB measurements with calculated orbit values

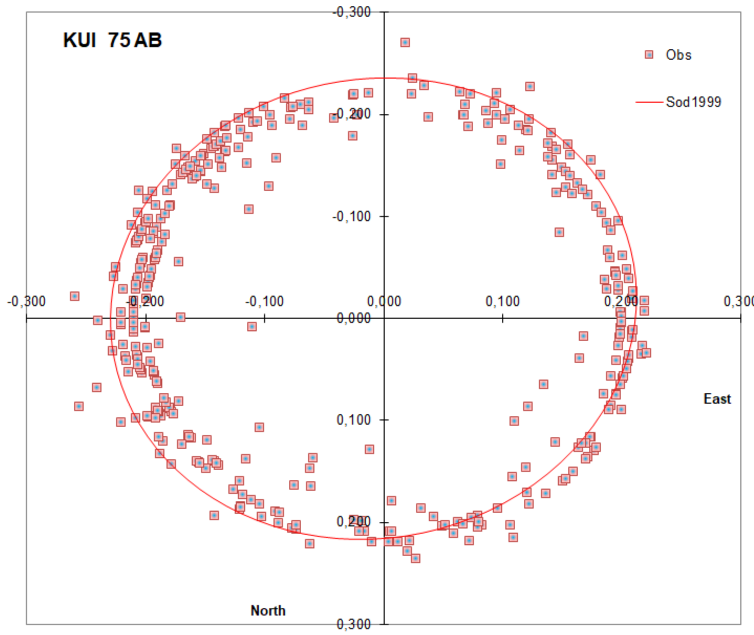

Figure 15. Plot system 36: KUI 75 AB Orbit calculated 1999

questionable. The 6th orbit catalog lists a grade 1 orbit for KUI 75 AB with a period of ~1.7 years (based on an observation history with >300 measurements) and another one grade 7 for Gl 644 Ba,Bb with a period of ~3 days (this object is missing a corresponding WDS object). The 6th orbit catalog orbit for AB seems a bit on the outer rim of the observations (see Figure 15). Yet the comparison of the last 15 measurements with the calculated orbit values showed a surprisingly excellent match if with several obvious quadrant issues as shown in Table 5.

The maximum spatial distance between the components of UC 3253 CF (LHS 427 and LHS 429) is, according to simulation, ~8,000 AU so a gravitational relationship seems most likely. The minimum orbit period using the StarHorse median mass of ~0.25 for the primary and roughly estimated 0.1 for the secondary with missing StarHorse data is ~150,000 years, so no human observation time span is long enough to allow for an orbit calculation. Ward-Duong et al. 2015 give the masses for the A/B/C and F components with 0.43/0.38/0.20 and 0.09. Proper motion speed of CF is close to 1"/yr, but F is very faint and the angular separation is huge, so this object seems of little interest for visual observation. The WDS components D and E are most likely opticals

37. GJ 829 (Ross 775, LHS 508) – spectroscopic binary star system at a distance of ~6.7 parsecs, listed as number 102 on the RECONS list but so far not WDS listed. Not listed in the 6th orbit catalog. Not resolved in DR2 but with parallax given for the system yet without duplicated_source marker. StarHorse gives a combined median mass of ~0.33 (compared to 0.26/0.26 given in the RECONS list) and the RUWE value indicates with ~1.4 good DR2 data quality. Delfosse et al. 1999 report an orbit for GJ 829 AB with a period of ~53 days with the remark "Gl 829 was mentioned as a possible double-lined spectroscopic binary by Marcy et al. (1987). It is clearly seen as such by both CORAVEL (67 measurements) and ELODIE (11 measurements) and the orbital elements are well constrained". Winters et al. 2019 consider this object a single star. Baroch et al. 2018 list this object in table D1 as eclipsing binary with a period of ~1.5 days with reference to Kraus et al. 2011. I could not retrace this proposed match as the corresponding object MG1-78457 is according to the MG1 Variable Star Catalog ident with 2MASS J03262072+0312362 and not GJ 829. Ward-Duong et al. 2015 do not list GJ 829 (HIP 106106) as with a companion confirmed. So this object offers a riddle to be solved in future but the Delfosse et al. 1999 evidence seems convincing

38. BUG 17 (WDS 07200-0847, WISE J072003.20-084651.2, Scholz's star) – binary star system at a distance of ~6.8 parsecs with only one matching object in DR2 lacking parallax and proper motion data with Gmag >15 suggesting this might be the secondary. According to Burgasser et al. 2015, this was then one of only two star systems known so far within 10 parsecs of

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =      0.321108702939975
e     =      0.248445533903962
T     =   2015.718841357620700
P     =      8.263735493724633
omega=    182.721476352271110
Node =     59.415043372243503
i     =    106.500338610526580
```

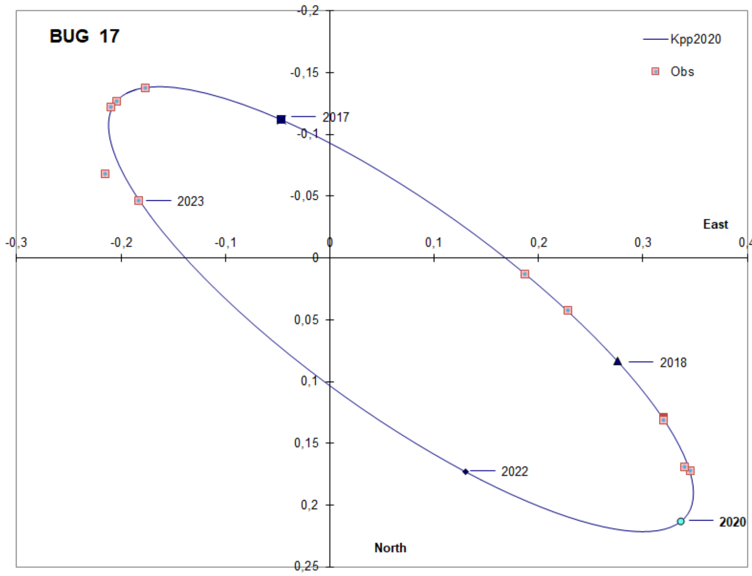

Figure 16. Plot system 38: BUG 17 orbit

the Sun consisting of a late M dwarf's primary and a mid T-type brown dwarf companion. No object on the RECONS list, not even as single star object (most likely due to the so far with ~6 ±1 parsecs reported large distance error). Listed in the WDS catalog with (per Dec 2019) only 2 observations and listed in the 6th orbit catalog with a grade 5 orbit with a period of 3.1 years.

Dupuy et al. 2019 report about 10 recent observations of this pair and, based on their new and more precise data, suggest a distance of ~6.8 parsecs with masses of ~0.095/0.063 and an orbital period of ~8 years. Using the Izmailov 2019 orbit calculation program on these measurements results in a preliminary orbit with a period of ~8.26 years, see Figure 16.

Dupuy et al. 2019 report also that this star system had a close encounter with our Solar system 80,000 years ago, passing through the Oort cloud at a distance of ~69,000 AU. Henry et al. 2018 report that this star system ranks as the second slowest moving system known within 10 pc.

39. DEL 2 (WDS 08589+0829, GJ 3522, G 041-014, LTT 12352, LHS 6158) – triple star system at a distance of ~6.8 parsecs, number 103 on the RECONS list with masses of 0.18/0.17/0.17. Completely missed in DR2. Parallax of 147.66 reported in Henry et al 2006. Reported as triple system again in Davison et al. 2015. In the WDS catalog listed as double star with an angular separation of currently 0.6". Listed in the 6th orbit catalog with a grade 3 orbit with a period of ~5.6 years based on 9 observations since 1997 up to 2015. Meanwhile 3 measurements have been added, so I used the Izmailov program on the extended observation history and got (after elimination of 2 obvious outliers) a similar period, but slightly different results for a preliminary orbit, Figure 17.

40. STF 1888 (WDS 14514+1906, GJ 566, psi Boo, HD 131156) – binary star system at a distance of ~6.8 parsecs. Resolved in DR2 with parallax and proper motion data for both components without duplicated_source marker. Listed as system number 104 on the RECONS list with masses of 0.95/0.67. Listed in the

```
a     =      0.368097218112645
e     =      0.819267815969905
T     =   2011.822648261995500
P     =      5.635208209982505
omega=    189.027009652445680
Node =     94.900945961933317
i     =    130.779637634010900
```

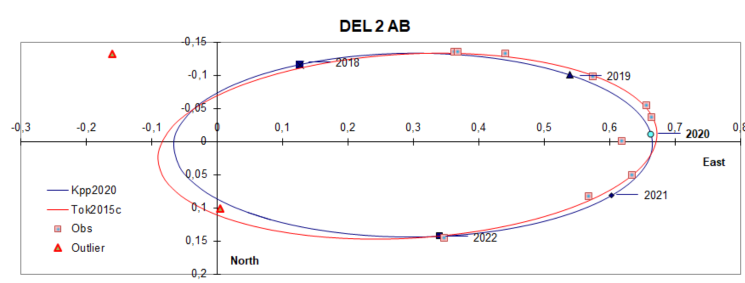

Figure 17. Plot system 39: DEL 2 orbit comparison

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =     4.922192702951961
e     =     0.511680309096703
T     =  1909.376504514756800
P     =   151.870304571739520
omega=     23.839970402638201
Node =    167.957579119518560
i     =   140.281601411959460
```

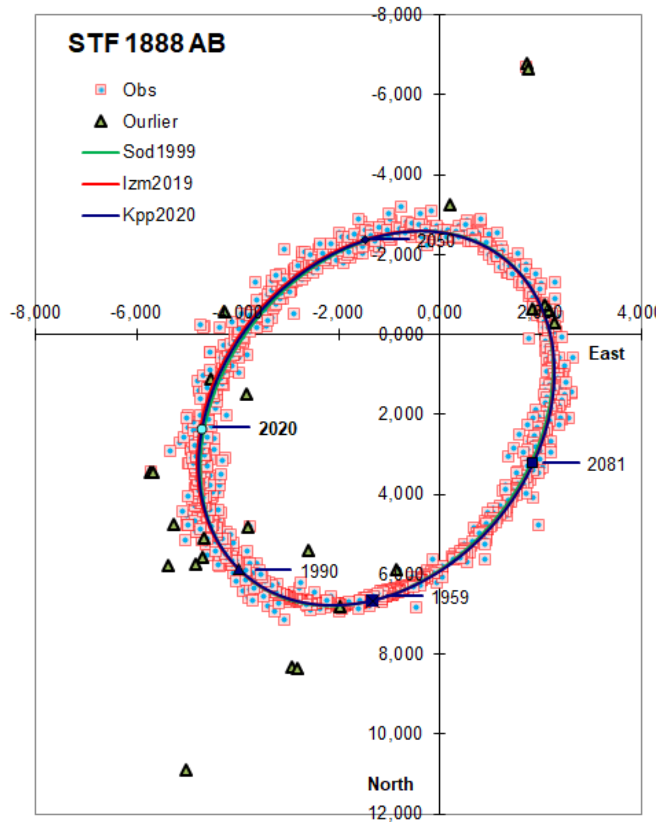

Figure 18. Plot system 40: STF 1888 AB orbit comparison – differences hardly noticeable

6th orbit catalog with a grade 2 orbit with a period of ~153 years based on >1,000 measurements. DR2 lists for the primary a rather large parallax error but else the data seem of good quality. The simulation results give a minimum spatial distance between the components of 38 AU giving with the StarHorse median masses of ~0.87/0.70 a minimum orbit period of 192 years. Using the Izmailov program with the existing observation history delivers a result quite similar to the 6th orbit catalog data but certainly not ident – the differences might be the result of the weights used by Izmailov. The suggested orbit period is with 151.87 years closer to the earlier 6th orbit catalog entries. Slightly curious is the fact, that the number of excluded observations is larger than the observation history of many other star systems.

The suggested minimum orbit period from the simulation is ~40 years longer than for the calculated orbits, which suggests that the DR2 data is not sufficiently precise.

The changes in separation and position angle from year to year are far too small to be noticeable by direct visual observation and proper motion is visually hardly visually noticeable as position change from year to year

41. RST 2292 (WDS 03019-1633, GJ 3192/3, LP 771-095/ LP 771-096, BD-17 588, LTT 1445) – triple star system at a distance of ~6.9 parsecs with components B and C not resolved in DR2. Combined BC object listed without parallax and proper motion data and without duplicated_source marker. With number 108 the currently last object on the RECONS list with masses of 0.25/0.19/0.16. StarHorse median mass for A is 0.3 and RUWE ~1.1 indicates good DR2 data quality. No entry in the 6th orbit catalog. The WDS catalog lists ~10 observations since 1944 each for AB and BC. Winters et al. 2019 report a preliminary orbit for BC with a period of ~36 years and propose the existence of a transiting exoplanet around component A (giving a planet with 3 Suns). Comparing the observation history for BC from the WDS catalog with the measurements listed in Winters et al. 2019 gave some riddles to solve:

Tiny differences in the observation dates are caused by a mix-up of Julian and Besselian date in Winters et al. 2019. There is also a note that the position angles of the two 2014 observations from Horch et al. 2015 are inverted by 180° due to quadrant ambiguity. Retracing this information is a bit difficult due to a WDS ID typo in the corresponding VizieR catalog J/AJ/150/151 with 03019-1636 instead of 03019-1633 – no such quadrant

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =     1.353680325931299
e     =     0.902910344583515
T     =  1996.058680373598900
P     =    18.480936054951652
omega=   241.358118969291870
Node =   136.676368970011710
i     =    89.496240043336016
```

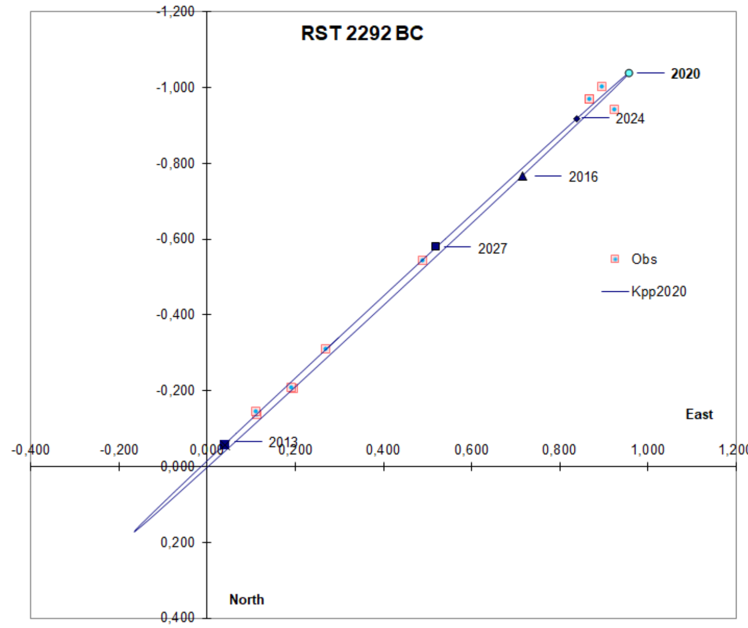

Figure 19. Plot system 41: RST 2292 BC orbit

issue is specified here. Both issues seem to make the in Winters et al. 2019 reported preliminary orbit invalid. On the other side the calculated orbit values compared with the WDS observation history provide a nearly perfect match with the exception of the measurements in 1994 and 2014 suggesting potential quadrant issues.

Using the WDS observation history as given with the Izmailov program gives a preliminary orbit with a period of ~18.5 years with an excellent match with all observations, see Figure 19.

Therefore, there is obviously no need to assume quadrant issues to be able to calculate a reasonable good matching preliminary orbit. Just to try it I used the Izmailov program also on the observation history with quadrant changes in 1944 and 2014 measurements and got an orbit with a period of ~77 years offering also a reasonable good match with the observations but certainly not a better one. A new measurement in 2020 would be very useful to get a better grip on the preliminary orbit for RST 2286 BC

42. MLO 4/HJ 4935 (WDS 17190-3459, GJ 667, HD 156384) – triple star system at a distance of ~7.2 parsecs (already outside the RECONS list). Components A and B are missing in DR2 (angular separation 2015.5 <1"), but C is listed with parallax and proper motion data and without duplicated_source indication. StarHorse lists a median mass for C of ~0.30 and with RUWE ~1 good DR2 data quality. MLO 4 AB is listed in the 6th orbit catalog with a grade 2 orbit based on ~250 observations since 1876 with a period of ~42 years recently confirmed by Izmailov 2019. There is currently no orbit listed for HJ 4935 AC despite 64 observations since 1875 and although there is no doubt that C is part of this star system (see also Tokovinin 2017). The parallax for A is, according to Leeuwen 2007 (Hipparcos), 146.29 quite different from 138.02 for C from DR2. Maybe the Hipparcos parallax is wrong, but even with the given values, simulation indicates a spatial distance of ~75,000 AU between A and C strongly suggesting a

```
a     =    71.578053383128449
e     =     0.907526433835907
T     =  1717.194575504137200
P     =  2055.785396511355400
omega=   273.752159772495080
Node =    99.031411033192583
i     =    74.579931033820301
```

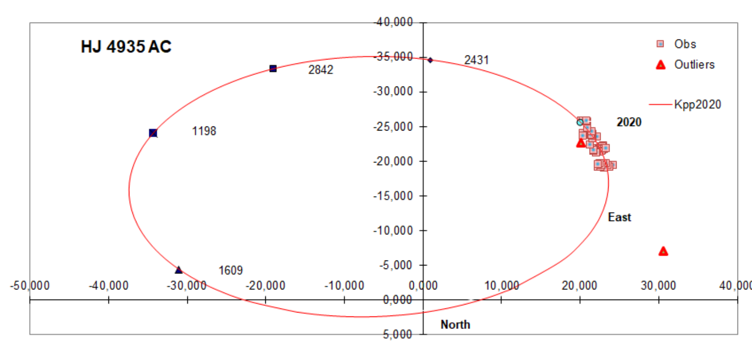

Figure 20. Plot system 42: Orbit HJ 4935 AC

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =     2.497366153129268
e     =     0.455358448984570
T     =  1974.490448741983800
P     =    53.534760421820401
omega=     37.421286837862837
Node =    102.117364915894330
i     =    68.753652801807718
```

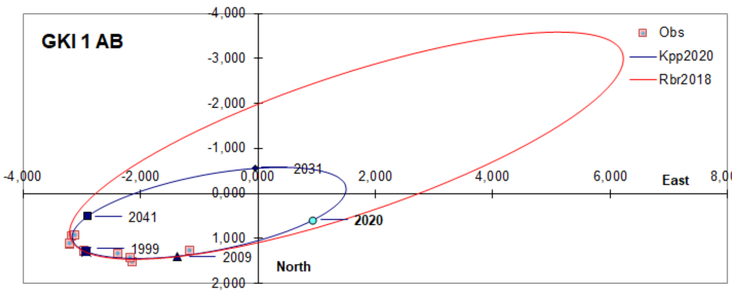

Figure 21. Plot system 43: GKI 1 AB orbit comparison

gravitational relationship if with a huge orbit period. Using the Izmailov program on the current HJ 4935 AC observation history gives the result for a preliminary orbit shown in Figure 20.

The set of possible orbits shows as to expect a rather large spread for the orbit period.

Simbad lists up to 7 possible planets for C aka LHS 443. The other components listed in the WDS catalog are most likely optical. More details on MLO 4 to be found in Argyle et al. 2019, page 346

43. GKI 1/PLQ 32 (WDS 02361+0653, GJ 105, HD 16160, LHS 15) – multiple star system at a distance of ~7.2 parsecs. The labelling of the components is slightly confusing as the components GJ 105 B and C correspond with the components C and B in the WDS catalog. GKI 1 AB not resolved in DR2, most likely due to the small angular separation in 2015.5 below 1 arcsecond with parallax and proper motion given for a combined object but without duplicated_source marker. StarHorse combined median mass is 0.8 and RUWE ~1; suggests no DR2 data quality issues. Bonavita and Desidera 2020 list masses of 0.76/0.09 with a semi-major axis of 15 AU and an eccentricity of 0.75 with reference to Golimowski et al. 2000 and obviously in ignorance of the most recent 6th orbit catalog data. Consequently, the latter values are a bad match with the currently listed grade 5 orbit (published 2018) for GKI 1 AB with a period of ~201 years based on 11 observations beginning with 1993 up to 2010. No recent measurements are available, most likely due to the huge delta in magnitude. Using the Izmailov program with the given observation history gives the values shown in Figure 21 with a rather different period of ~60 years (although the given spread covers also the period given in the 6th orbit catalog).

44. G 203-47 (GJ 3991, HIP 83945) – binary star system at a distance of ~7.4 parsecs combining according to Delfosse et al. 1999 a M3.5 dwarf (mass ~0.30 to 0.35) with a white dwarf (mass ~0.50) in a rather tight orbit with a period of ~15 days. Not resolved in DR2, but parallax and proper motion data for AB are given yet without duplicated_source marker. StarHorse provides a combined median mass of ~0.32 with a RUWE value >12 indicating serious DR2 data quality issues. Not listed in the WDS and the 6th orbit catalog. No companion detected by Ward-Duong et al. 2015

45. SHY 106/MAM 1 (Fomalhaut, WDS 22577-2937, GJ 881, GJ 879, LP 876-10) – wide triple star system at a distance of ~7.4 parsecs with the primary missing in DR2. Mamajek et al. 2013 proposed LP 876-10 as third component "Fomalhaut C" of this assumed triple. B and C are listed in DR2 with parallax values with a rather small error range and no duplicated_source indication. Kervella et al. 2019 report a proper motion anomaly for Fomalhaut B indicating potentially a planet, but which might actually correspond with the gravitational pull from Fomalhaut A. StarHorse gives median masses of ~0.72/0.14 for B and C and RUWE values of ~1. In the Mamajek et al. 2013 report, the tidal radius of Fomalhaut is assumed to be 1.9 parsecs, which means about 6 light-years – this seems somewhat over-optimistic even if the mass of Fomalhaut is far larger than the Sun's mass. If the outer rim of the Oort cloud is accepted as border of the gravitational field of the Sun, then the corresponding value for the barycenter of Fomalhaut A+B with a combined mass of ~2.6 would be ~161,250 AU means <0.8 parsecs. Simulation suggests with a median distance between B and C larger than 200,000 AU near zero likelihood for any gravitational relationship but this is of little relevance as the main body in this star system is Fomalhaut A with missing DR2 data. Using Hipparcos J2000 position and parallax for A with J2000 position and DR2 parallax for C in the simulation gives a medi-

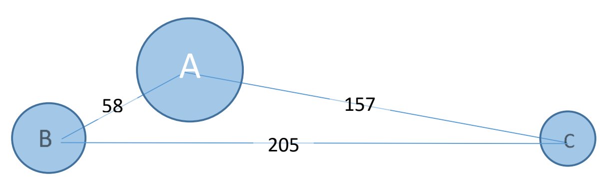

Figure 22. Plot system 45: Fomalhaut median distances between the components in 1000 AU

an distance A to C of 157,000 AU. This positions LP 876-10 very well within the tidal radius of Fomalhaut A+B even if the distance to the barycenter should be a bit larger than the distance to A (see Figure 22).

Regrettably, this most interesting star system is not suited for visual observation because the angular distance between the components is several degrees and far too large for even a very generous telescope field of view.

46. BLA 9 (WDS 21313-0947, GJ 831, Wolf 922) – binary star system at a distance of ~7.5 parsecs not resolved in DR2 due to an angular separation <0.4". Parallax and proper motion data given for AB without duplicated_source indication. StarHorse combined median mass is ~0.3, RUWE >6 and large parallax error indicate questionable DR2 data quality. The 6th orbit catalog lists a grade 2 orbit with a period of ~1.93 years based on 30 observations listed in the WDS catalog since 1982. Wand-Duong et al. 2015 suggest masses of 0.27 to 0.31 for the primary and 0.15 to 0.17 for the secondary. Benedict et al. 2016 suggest masses of ~0.27/0.15.

47. WCK 1 (WDS 01083+5455, GJ 53, mu. Cas) – close binary at a distance of ~7.5 parsecs. Not resolved in DR2, combined object listed without parallax and proper motion data yet with duplicated_source marker. WCK 1 Aa,Ab is listed in the WDS catalog with 24 observations since 1973 and in the 6th orbit catalog with a grade 4 orbit with a period of ~21.5 years recently confirmed by Izmailov 2019. Most recent observations reported in Horch et al. 2019. Several additional components listed in the WDS catalog are most likely optical.

48. AST 2 (WDS 20298+0941, GJ 791.2, G 24-16) – binary star system at a distance of ~7.5 parsecs not resolved in DR2 due to an angular separation <0.4". Parallax and proper motion data given for AB without duplicated_source indication. AST 2 is member of the Hyades Moving Group and listed in the WDS catalog with 14 observations since 1995, with the last one in 1997, so this looks like a neglected object. Last observation with positive resolution reported for 2002 by Dieterich et al. 2012. The 6th orbit catalog lists, with a reference to Benedict et al. 2016, a grade 4 orbit with a period of ~1.47 years. StarHorse lists a combined median mass of ~0.22 and the RUWE value is >20 questioning for good reasons if the GAIA single star model is suited for this object and supporting the suggested binary character of GJ 791.2. Benedict et al. 2019 report masses for AB of ~0.24/0.11. Using the Izmailov program on the existing measurements (after excluding several observations of questionable quality) results in values very similar to the existing 6th orbit data, Figure 23.

The older AST2000 orbit was listed with an erroneous inverted Node value, else it would be a good match with the newer orbits. Additional components listed in the WDS catalog are most likely optical.

49. LAB 5 (WDS 18211+7244, GJ 713, chi Dra) – spectroscopic binary at a distance of ~7.5 parsecs. Not resolved in DR2 due to angular separation <0.4”, combined object listed without parallax and proper motion data and without duplicated_source indication. LAB 5 Aa,Ab is listed in the 6th orbit catalog with a grade 1 orbit with a period <1 year based on 56 observations listed in the WDS catalog since 1973 with the last one in 2009. Additional components listed in the WDS catalog are most likely optical.

50. LEI 1 (WDS 00247-2653, GJ 2005, LHS 1070, LP 881-64) – triple star system at a distance of ~7.6 parsecs not resolved in DR2. Combined DR2 object listed without parallax and proper motion data but with duplicated_source indication. The 6th orbit catalog lists a grade 2 orbit for BC based on 67 observations since 1993 with a period of ~17 years and grade 5 orbit for A,BC with a period of ~44 years based on 66 observations since 1993. Henry et al. 2018 suggest for A,BC a period close to 100 years and mention that the compo-

```
a     =     0.108604288866185
e     =     0.511550687436521
T     =  2003.011404129284300
P     =     1.472028011596956
omega=     15.403304133511741
Node =    102.891595362412530
i     =    140.024130670312810
```

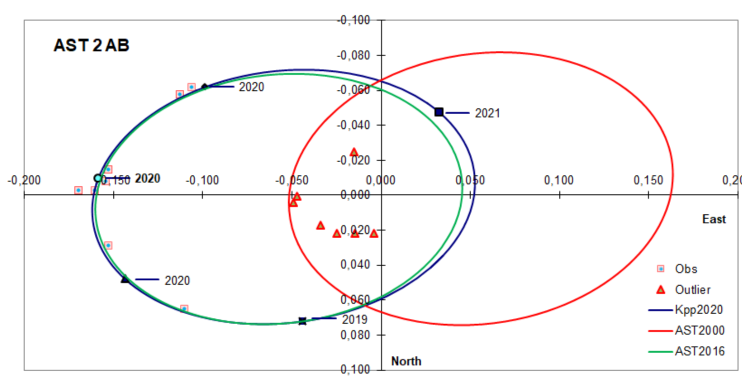

Figure 23. Plot system 48: AST 2 AB Orbit comparison

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nents B and C are, having masses of 0.07 to 0.08, in the transition region between stars and brown dwarfs. Resolved as triple also by Dupuy and Liu 2012. WDS 00247-2653 object HEN 5 Aa,Ab is marked bogus. Using the Izmailov program with the given WDS observation history for LEI 1 A,BC gives the preliminary orbit values shown in Figure 24.

The few additional measurements since 2012 have noticeable impact on the orbit values as the comparison between 6th orbit catalog and new calculation shows. The period of the preliminary orbit given above is with ~87 years, close to the Henry et al. 2018 estimation. The pattern of the observations looks a bit curious, suggesting an optical impression of two different orbits.

Regarding LEI1 BC: Using the Izmailov program with the given observation history simply confirms the current 6th orbit catalog data

51. HEN 1 (WDS 16240+4822, GJ 623) – binary star system at a distance of ~7.8 parsecs not resolved in DR2 due to an angular separation <0.4". Parallax and proper motion data given for AB without duplicated_source indication. StarHorse combined median mass is 0.45. RUWE >16 and a rather large parallax error indicate poor DR2 data quality. The 6th orbit catalog lists a grade 3 orbit with a period of ~3.75 years based on 13 observations since 1982 with the last one in 2006 – so this looks a bit like a neglected object. Benedict et al. 2016 report masses of ~0.38/0.11. The WDS catalog lists with discoverer designation BUP two additional components which are according to the very different DR2 parallax values most likely opticals

```
a     =     1.911123174495131
e     =     0.178946463709917
T     =  2014.169565141601400
P     =    88.628405821951290
omega=     38.934780213933244
Node =     20.722954751992852
i     =     69.684978105633988
```

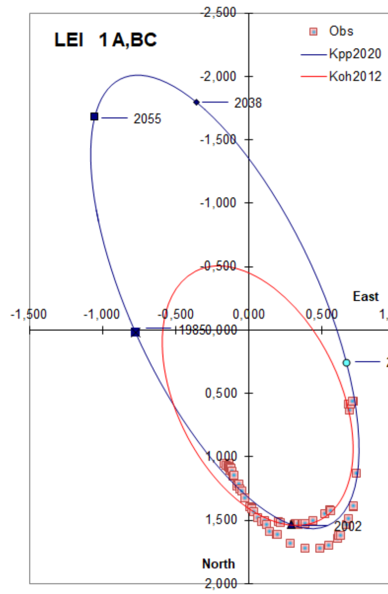

Figure 24. Plot system 50: Orbit LEI 1 A,BC comparison

52. LPM 248 (WDS 06579-4417, GJ 257, CD-44 3045) – binary star system at a distance of ~8 parsecs. Resolved in DR2 with parallax and proper motion data for both components, B is marked as duplicated_source. Small parallax errors and RUWE value near 1 for both components indicate good DR2 data quality. Simulation results in a minimum spatial distance between the components of ~19 AU, suggesting combined with StarHorse median masses ~0.30/0.38 a minimum orbit peri-

```
a     =     9.231497033966008
e     =     0.989999999942050
T     =  1991.507722529292600
P     =    94.969108516841487
omega=     94.534920476491251
Node =    168.662230445585810
i     =     98.237231852592899
```

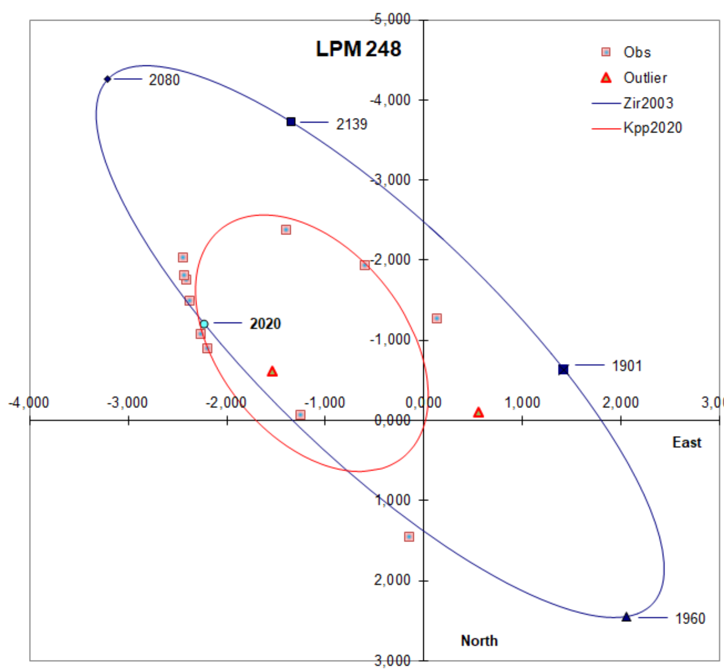

Figure 25. Plot system 52: Orbit comparison LPM 248

od of ~100 years. The masses given in Ward-Duong et al. 2015 of 0.24/0.24 would give a minimum period of 123 years. The 6th orbit catalog lists a grade 5 orbit with a period of ~300 years based on so far 11 observations since 1933. The inverted position angle in the orbit reflects the fact that the barycenter is closer to B with the larger mass. The given orbit values for 2016 do not match very well with the DR2 data so there should be some room for improvement. Using the Izmailov program with the given observation history plus my own recent measurement gives compared to the current 6th orbit catalog the results for a much shorter preliminary orbit shown in Figure 25.

The Izmailov program eliminated 2 observations from 1993 and 1998 for a better fit with the rest of the observations and the current 6th orbit catalog seems to ignore even more observations. The referenced Zirm 2003 paper does not offer any clues how these 6th orbit values were calculated and if measurement weights were used.

Proper motion speed of LPM 248 is ~1" per year and the changes in position angle and separation might be noticed by visual observation over some years but both components are with magnitudes of ~11.5 rather faint so resolution with currently ~2.5" separation will need a correspondingly large aperture.

53. KUI 90 (WDS 19074+3230 Ca,Cb, GJ 747) – close binary star system at a distance of ~8.1 parsecs not resolved in DR2. Combined object listed without parallax and proper motion data and without duplicated_source indication. Listed in the WDS catalog with 32 observations since 1936, the last one in 2010. As resolved reported for example in Mason et al. 2018 with measurements about 10 years ago. Listed in the 6th orbit catalog with a grade 3 orbit with a period of ~5.8 years. This orbit provides a rather poor match with a good part the recorded measurements and in several cases, quadrant issues are obvious. The Izmailov program does not offer useful orbit suggestions for this object most likely for these reasons. The WDS catalog lists with the discoverer designation STF 2461 ten additional components, all of them most likely optical.

54. KPP 4430 (WDS 21516+5918, IRAS 21500+5903) – very wide star system at a distance of ~8.1 parsecs. Detected during the research for this paper and reported separately in Knapp 2020. Ongoing research revealed that this pair was already earlier detected by Hollands et al. 2018, but not reported as double star and for this reason so far not included in the WDS catalog. It is a bit surprising to find a likely physical pair with such a large parallax delta of ~5 mas between the two components – but in this case this means a median distance between the components of "only" ~70,000 AU or about 1 light year. This strongly suggests a gravitational relationship even if a potential orbit would have a period of several million years. With a StarHorse median mass of ~0.50 the tidal radius for the primary is >70,000 AU which means that the secondary is (with the median distance) within this radius. Moreover, even with the maximum simulation distance of ~105,000 AU, the fictive Oort radii would still overlap. The DR2 parallax data for the primary is somewhat questionable, the RUWE value >16 indicates a serious data quality issue and the parallax error is with 0.5944 indeed rather large.

55. GKI 3 (WDS 01104-6727, GJ 54) – binary star system at a distance of ~8.2 parsecs. Due to the angular separation <0.4", not resolved in DR2. Parallax and proper motion data given for AB without duplicated_source indication. The WDS catalog lists 22 observations since 1998. The 6th orbit catalog lists a grade 2 orbit with a period of ~1.15 years proposed by Henry et al. 2018. StarHorse median mass is 0.46 (which would according to Wand-Duong et al. 2015 rather correspond to the mass of the primary alone) and RUWE >43 indicates an obvious DR2 data quality issue. Benedict et al. 2016 suggest masses of 0.43/0.30. The Izmailov program used with the existing WDS observation history quite confirms the 6th orbit catalog values currently

```
a    =     0.124997770168892
e    =     0.161382817350723
T    =  2008.842004427030800
P    =     1.144874610298842
omega=    40.630179003240002
Node =    91.429005020307528
i    =   126.561388832321630
```

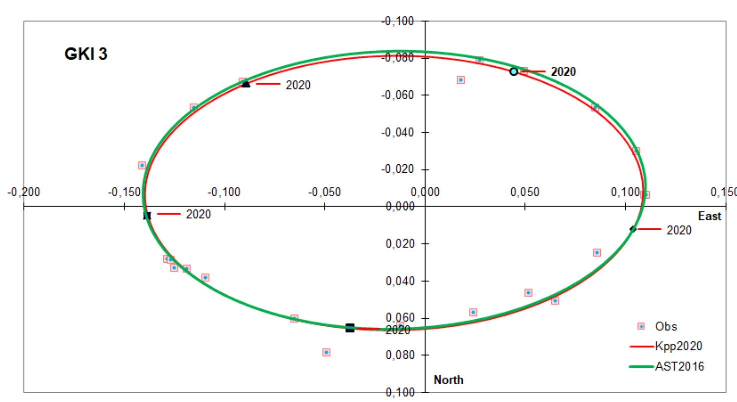

Figure 26. Plot system 55: GKI 3 orbit comparison

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```
a     =    7.955635984605983
e     =    0.462287086316210
T     = 1806.598955376269900
P     =  467.699574480512980
omega=   18.009571733320424
Node =   13.883152360104166
i     =  135.429907876497650
```

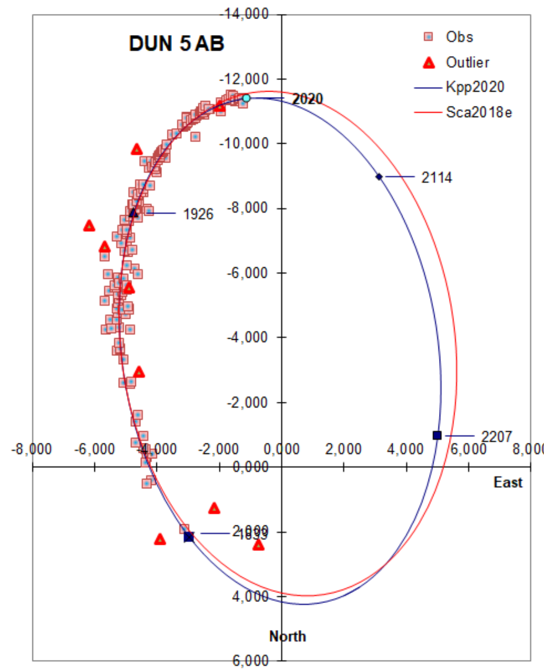

Figure 27. Plot system 56: DUN 5 orbit comparison

listed, Figure 26.

56. DUN 5 (WDS 01398-5612, GJ 66, p Eri, HD10360, HD10361) – binary star system at a distance of ~8.2 parsecs. Resolved in DR2 with parallax and proper motion data for both components without duplicated_source marker. Listed in the 6th orbit catalog with a grade 4 orbit with a period of 493 years based on 176 observations since 1825. The available DR2 data seem of good quality, parallax errors are small and RUWE values are ~1, but missing StarHorse data suggest data issues may be due to the brightness of the components. Estimated masses from luminosity are ~0.77/0.75 matching the data given by Bonavita and Desidera 2020. The minimum spatial distance between the components based on simulation results is 93 AU, giving a minimum orbit period of ~740 years. The maximum spatial separation according to simulation is ~6,190 AU, so there is no question that DUN 5 is most likely a binary. However, the DR2 data suggest that the orbital period is a bit longer than so far assumed. Argyle et al. 2019 mention on page 105 a third component discovered by Tokovinin – this is in error as TOK 454 AC shares the primary with HJ 3430 but not DUN 5. The most recent orbit calculation for DUN 5 is from Izmailov 2019 with a period between ~582 and ~646 years (depending on measurement weights) indicating at the same time a large spread of possible orbit solutions. My own calculation with the Izmailov program using the given observation history including one most recent own measurement (see Appendix B) provides the preliminary orbit values shown in Figure 27, with a significantly shorter period of only ~468 years (rather similar to the current 6th orbit catalog data).

The significant difference between calculated orbit period and simulation based result seems to suggest that the DR2 data might be questionable – but this is not the case as the simulation based period ignores the effects of eccentricity and inclination

57. STF 2220/TRN 2/AC 7 (WDS 17465+2743, GJ 695, mu. Her, HD 161797) – double-double star system at a distance of ~8.4 parsecs. Both pairs not resolved in DR2, but combined objects listed with parallax and proper motion data and duplicated_source marker. The WDS labeling for this system is slightly confusing with Aa,Ab for the first and BC for the second pair plus an A,BC object for the pair of pairs combined with a mix-up of different discoverer designations. The 6th orbit catalog lists a grade 5 orbit for TRN 2 Aa,Ab with a period of ~99 years and a grade 1 orbit for AC 7 BC with a period of ~43 years, no orbit is given for STF 2220 A,BC. The DR2 data quality seems rather questionable – large parallax error and the RUWE value for BC is larger than 16. Despite these caveats it seems evident that both binaries are bound by gravitation for a double-double star system with, according to the simulation, the smallest possible spatial distance of 294 AU giving with the StarHorse median masses of ~1.27/0.70 a minimum period of ~3,600 years. The number of ob-

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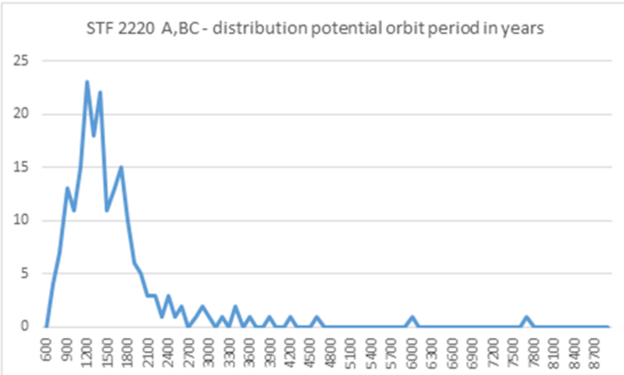

Figure 28. Plot system 57: STF 2220 A,BC - distribution potential orbit period in year

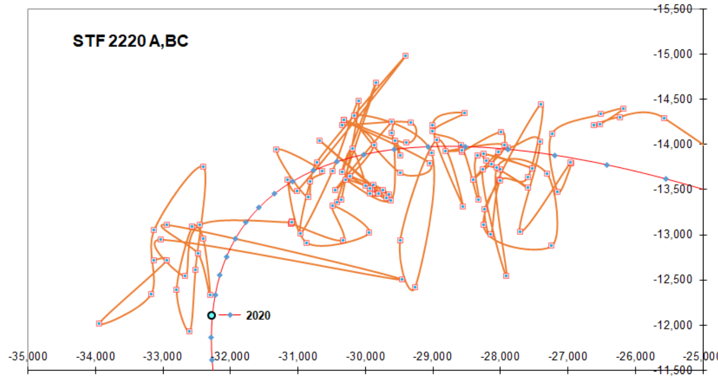

Figure 29. Plot system 57: STF 2220 A,BC – pattern of measurements compared to one of the "possible" orbits

servations so far is ~120 since 1781 – thus covering only a small part of such a potential orbit period and making the calculation of a reliable orbit at least currently a bit questionable. Ignoring the complexity of a 4-body system by simply using the Izmailov program with the existing measurements provides a preliminary orbit with a period of ~1,760 years far below the DR2 simulation minimum. Very surprising is then the fact that the set of 200 possible orbits gives on average an even smaller orbit period – but the currently available pattern of measurements (see Figures 28 and 29) does not give a serious hint for a preliminary orbit.

The given observation history for the BC pair clearly supports the current 6th orbit catalog parameters even if the many measurements are not very good covered by the calculated orbit values. Applying the Izmailov program on the given observation history including new 2015 measurements gives a slight but obvious difference to the current 6th orbit catalog entry which seems visually a bit better adapted to the given observation history, Figure 30.

Most interestingly, the so far last AC 7 BC measurement listed in the WDS catalog per 2015.71600 seems to be an outlier.

The WDS catalog lists an additional component D most likely optical due to very different DR2 parallax data.

The proper motion speed of the STF 2220 system is significant but offers with less than 1"/yr, a barely noticeable position change from year to year. The BC pair is currently too close and the magnitude difference between Aa and Ab is too large to be of interest for observation with an amateur telescope.

58. DON 91 (WDS 05025-2115, GJ 185) – binary star system at a distance of ~8.4 parsecs not resolved in DR2 most likely due to the angular separation <1". Parallax and proper motion data given for a combined ob-

```
a     =     1.351841860643832
e     =     0.187995359728376
T     =  1922.171646156190000
P     =    42.981771463130791
omega=   172.038740743895090
Node =    60.664775032683700
i     =    67.036784115771965
```

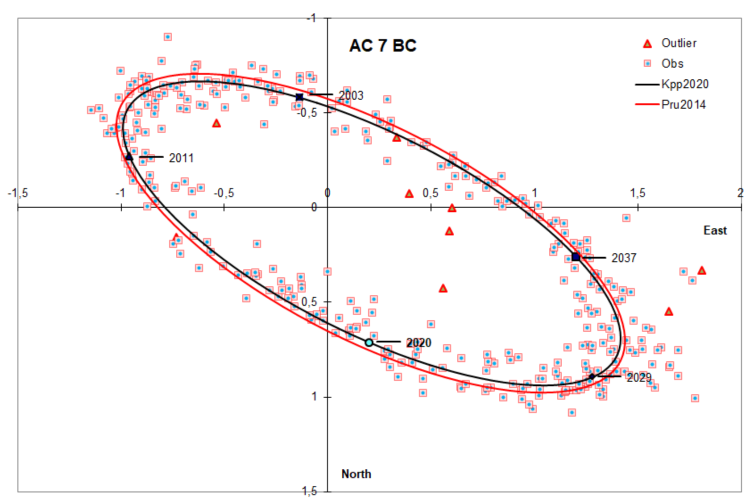

Figure 30. Plot system 57: STF 2220 BC orbit comparison

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```
a     =     1.043548138311017
e     =     0.750517538483561
T     =  1997.182087456311100
P     =    42.937200115282920
omega=     97.015442633582779
Node =     70.274004323388127
i     =    62.831886614891729
```

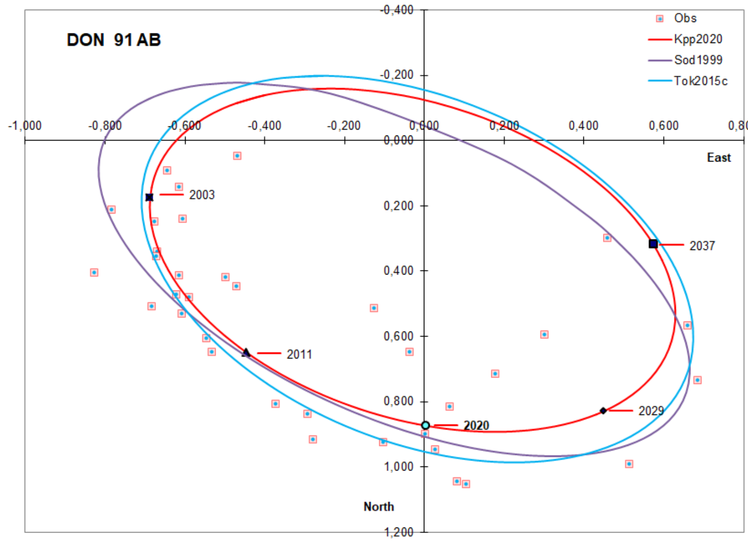

Figure 31. Plot system 58: DON 91 AB orbit comparison

ject but without duplicated_source indication. Ward-Duong et al. 2015 report masses of 0.59/0.37. StarHorse median mass of ~0.68 is not a very good match and RUWE ~4.7 suggests some issues with the DR2 astrometric data quality. The 6th orbit catalog lists a grade 3 orbit with a period of ~44 years based on 34 observations since 1929. The Izmailov program suggests with one additional 2018 measurement very similar preliminary orbit data as shown in Figure 31.

59. HEN 3 (WDS 07364+0705, G 89-32, GJ 3454, LTT 17993) – binary star system at a distance of ~8.5 parsecs not resolved in DR2. Combined DR2 object without parallax and proper motion data, but with duplicated_source marker. The 6th orbit catalog lists a grade 4 orbit with a period of ~24 years with a rather small sample of so far, 11 measurements since 1996. Using the given measurements with the Izmailov program results in preliminary orbit values quite close to the 6th orbit catalog data and shown in Figure 32.

60. LDS 6312 (WDS 16202-3734, GJ 618) – binary star system at a distance of ~8.5 parsecs. Resolved in DR2 with parallax and proper motion data only for A,

```
a     =     0.652735797475584
e     =     0.594361991542476
T     =  2016.199944261219800
P     =    24.129402711882406
omega=     81.165806350963820
Node =     60.851288682569049
i     =    25.424471217442203
```

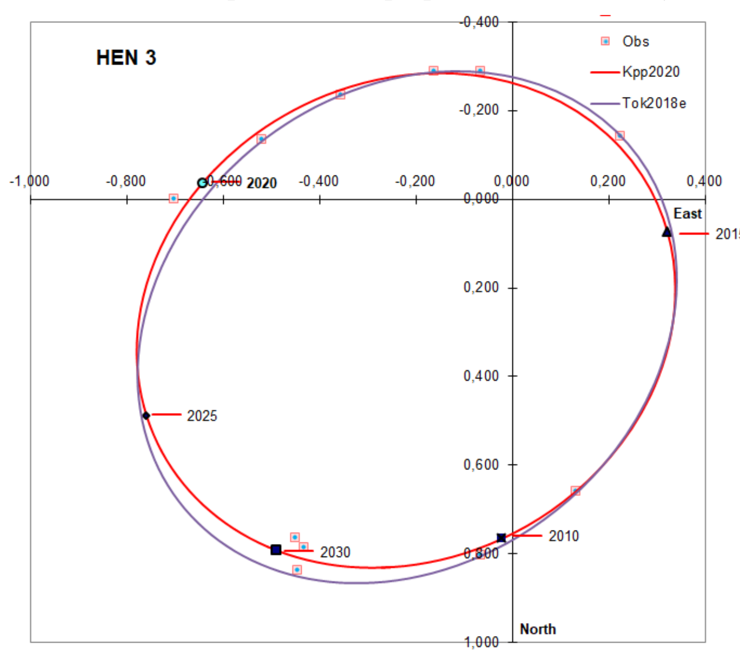

Figure 32. Plot system 59: HEN 3 orbit comparison

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =    63.110685739861204
e     =     0.973520101103271
T     =  1915.268798421298900
P     =   611.807986627762600
omega=     96.308755963038621
Node =     47.211283201683827
i     =    90.005177481860684
```

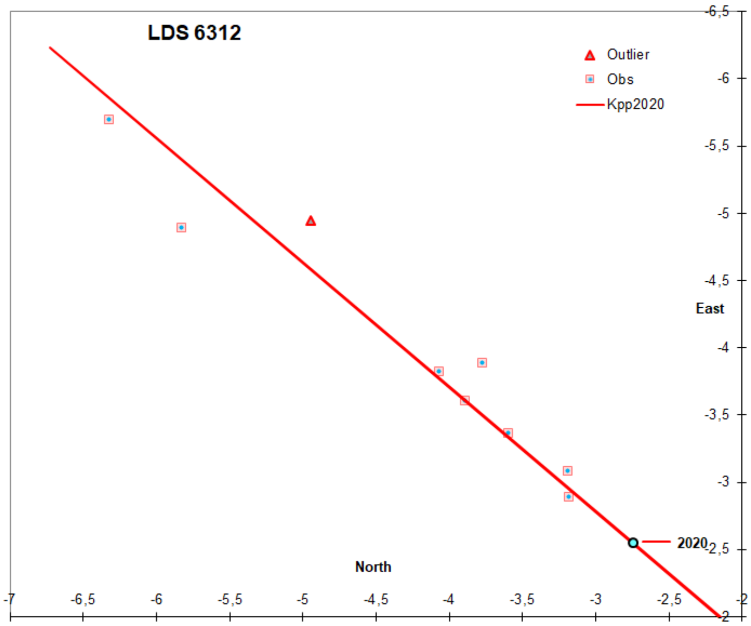

Figure 33. Plot system 60: LDS 6312 orbit?

data for B without parallax and proper motion values but with duplicated_source marker. Assuming ident parallax for B would result in a minimum spatial distance in the simulation of ~36 AU giving with the StarHorse median mass for A of ~0.45 and based on magnitude data estimated mass for B of 0.15 a minimum orbit period of ~285 years. Ward-Duong et al. 2015 give masses of 0.38 and 0.10, which would add ~35 years to the mentioned minimum period. So far, the number of observations is only 8 since 1922, so it is for the near future difficult to calculate a reasonable reliable orbit for this pair especially as the first observation seems rather off. An attempt with the Izmailov program for calculating orbits with the given measurements plus the added DR2 observation resulted in the values given in Figure 33.

This result seems to suggest a rather linear solution, making LDS 6312 questionable as binary, but Dieterich et al. 2012 list explicitly GJ 618 as star system so additional evidence regarding parallax for the secondary is required for a reasonable founded conclusion

61. STF 1523 (WDS 11182+3132, GJ 423, ksi UMa B) – multiple star system at a distance of ~8.7 parsecs. Resolved in DR2, but the primary without parallax and proper motion data. The 6th orbit catalog lists for AB a grade 1 orbit with a period of ~60 years based on 1640 observations since 1890 and an astrometric grade 9 orbit for A (means Aa,Ab) with a period of ~1.8 years without a corresponding WDS object. The WDS catalog lists additionally a CHR 178 Bb,Ba pair with an angular separation <0.1" which means that STF 1523 is a quadruple system in form of a double-double. Griffin 1998 reports an assumed orbit period of ~4 days for Ba,Bb. The WDS catalog lists two additional compo-

```
a     =     2.483993033827798
e     =     0.389272083935876
T     =  1995.190009343429400
P     =    59.474790734346414
omega=    127.452511837322530
Node =    100.265485392931680
i     =    124.165052633349960
```

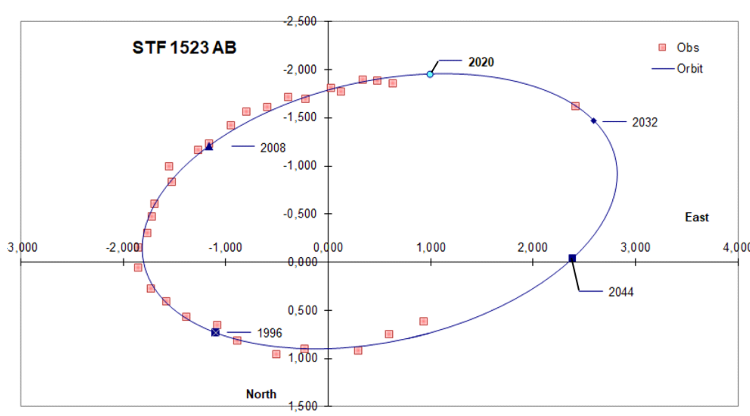

Figure 34. Plot system 61: STF 1523 AB orbit based on measurements of Bob Argyle

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nents C and D, which are most likely optical. More details on this object in Argyle et al. 2019 (page 236) with the measurements of Bob Argyle since 1970 covering nearly a full orbit. Using the Izmailov program only with the Argyle measurements gives more or less ident values to the current 6th orbit catalog entry, Figure 34.

STF 1523 AB offers noticeable changes in position angle and separation from year to year and is for this reason a very attractive object for direct visual observation with amateur telescopes

62. WNO 17 (WDS 06523-0510, GJ 250, HD 50281) – binary star system at a distance of ~8.7 parsecs. Both components listed in DR2 with parallax and proper motion data without duplicated_source marker. StarHorse gives median masses of 0.75/0.50 and RUWE is ~1 for both components, suggesting good DR2 data quality. Bonavita and Desidera 2020 list masses of 0.76/0.63. Simulation suggests a minimum spatial distance between the components of ~514 AU giving, with the StarHorse masses, a minimum circular orbit period of ~10,500 years, so gravitational relationship most likely given, although the difference in proper motion seems amazing. The WDS catalog lists 23 observations since 1894. Mason et al. 2018 reported the resolution of Ba,Bb as spectroscopic binary but WSI 125 Ba,Bb is meanwhile marked bogus. An additional C component listed in the WDS catalog is most likely optical. The given observation history indicates a hint of a systematically change in position angle and angular separation if with several outliers. Using these plus two own most recent measurement with the Izmailov program gives the very preliminary orbit values shown in Figure 35.

The set of possible orbits shows as to expect a huge spread with ~3,775 years as median value for the period – the number of existing measurements is simply too small for a reliable calculation of a preliminary orbit with such a long period

63. BSO 13 (WDS 17191-4638 AB, GJ 666, 41 Ara, HD 156274) – binary star system at a distance of ~8.8 parsecs. Both components listed in DR2 with parallax and proper motion data and without duplicated_source indication. Listed in the WDS catalog with 137 observations since 1880. The 6th orbit catalog lists a grade 5 orbit with a period of 953 years based on a calculation 2013. Izmailov reported 2019 a period of ~724 years. The DR2 parallax values with a difference of ~6 mas indicate a rather large spatial distance between the components, which is according to the simulation between a minimum of ~66,000 AU and a maximum of ~126,000 AU. These values suggest a high likelihood for gravita-

```
a     =    65.213588498405457
e     =     0.857452137532194
T     =  1159.560029147359300
P     =  3476.076169613531900
omega=    257.342678673527530
Node =    143.396155424237970
i     =    66.163898730391580
```

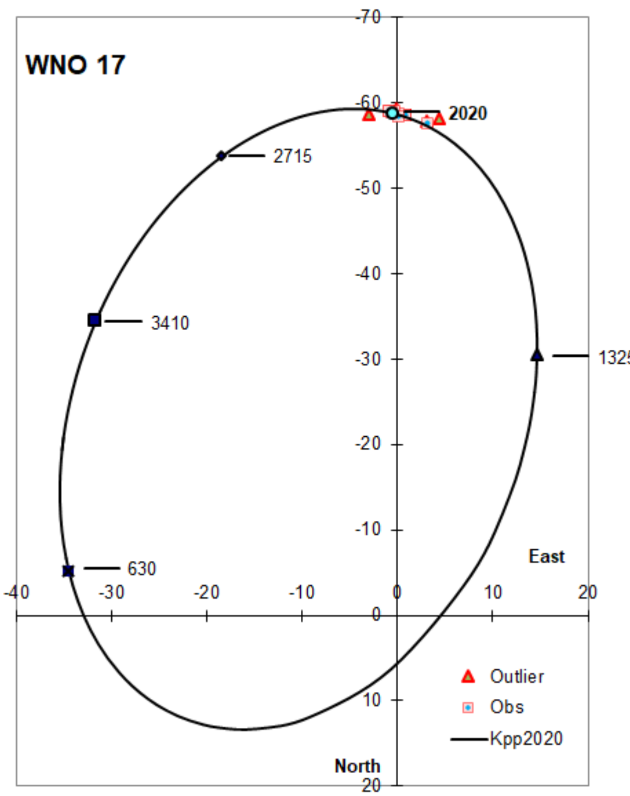

Figure 35. Plot system 62: WNO 17 AB orbit

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a    =    11.936279611229471
e    =     0.808720434260279
T    =  1907.619874225702900
P    =   846.560124451442560
omega=   332.255985743725720
Node =   134.584549550155880
i    =    37.173966359903886
```

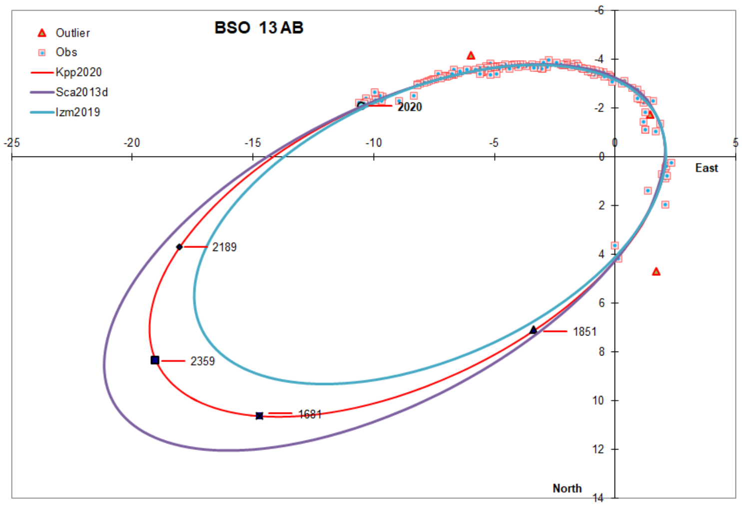

Figure 36. Plot system 63: BSO 13 AB orbit comparison

tional relationship but a potential orbit would have a huge period in the range of many millions of years. The DR2 parallax error for the secondary is rather large and StarHorse lists no object for the secondary, which indicates some data quality issues. StarHorse median mass for the primary is ~0.83 and RUWE <1. Bonavita and Desidera 2020 list masses of 0.79/0.55. Argyle et al. 2019 mention on page 349 that the calculated orbit seems rather very preliminary because there is a gap of 50 years in the observations resulting in missing measurements for the time span of the largest angular separation. Using the Izmailov program with the given WDS observation history results in the preliminary orbit values given in Figure 36.

The set of possible orbits shows as to expect a huge spread with ~3,775 years as median value for the period – the number of existing measurements is simply too small for a reliable calculation of a preliminary orbit with such a long period.

Regardless which variant might be closer to reality – this means that either the DR2 parallax values are completely off beyond any given error range or the calculated orbits are very preliminary indeed. The former is assumed.

Fuhrmann and Chini 2015 mention that the Raghavan et al. 2010 proposition that there might be an Aa,Ab subsystem with a period of ~80 days remained so far unconfirmed and seems for this reason rather questionable.

Jenkins et al. 2015 report HD 156274 B being a spectroscopic binary based on radial velocity variations. However, this seems to be a mix up of components as the given data (especially parallax and magnitude) match rather with component A. Later on Jenkins et al. 2015 confusingly refer to GJ 666 A supposed to be a spectroscopic binary. But the reported extremely long period of ~524 years suggests that the radial velocity variations might simply be a side effect the BSO 13 AB orbit.

The WDS catalog lists two additional components C and D, which are most likely optical

64. LDS 1017 (WDS 19072+2053, GJ 745, Ross 730, Ross731, HD 349726) – binary star system at a distance of ~8.8 parsecs. Resolved in DR2 with parallax and proper motion data for both components but also with duplicated_source marker for both components suggesting a potential quadruple. Crossfield et al. 2019 report spectroscopic research showing that the components of GJ 745 "… formed from an interstellar medium significantly enriched by material ejected from an exploding core collapse supernova". The 6th orbit catalog lists a grade 5 orbit with a period of 36,000 years based on 26 observations since 1897 reported in the WDS catalog – interesting idea. Reasonable DR2 parallax errors and RUWE ~1 for both components suggest reliable DR2 data quality. StarHorse mass values are ~0.35 (Wang-Duong et al. 2015 suggest 0.32) for both components and the simulation results in a minimum spatial distance of ~1,000 AU and a minimum orbit period of 38,000 years, which surprisingly seems to support the period listed in the 6th orbit catalog. Using the Izmailov program on the given observation history (with several odd measurements excluded and one most recent own measurement added) provides a huge spread of potential orbits with periods from ~1,311 to ~616,000 years. This demonstrates very

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =    253.017397472959710
e     =      0.577077586820384
T     =    163.429659612178280
P     =  38845.549757662098000
omega=     148.143411404933200
Node =     117.925836947510660
i     =    101.550539738734570
```

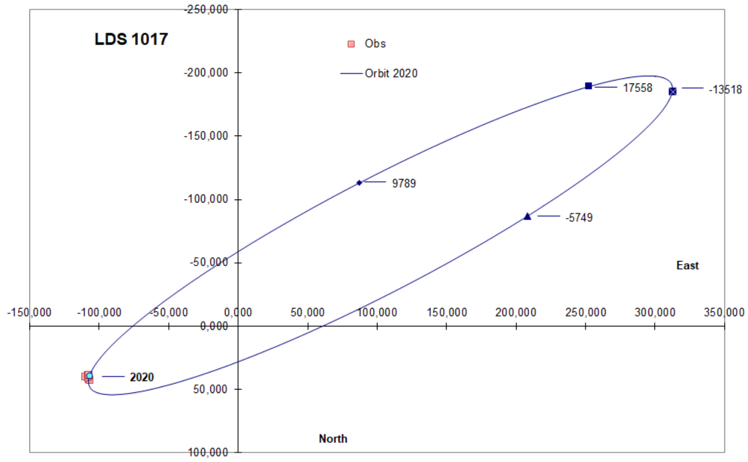

Figure 37. Plot system 64: LDS 1017 newly calculated orbit

clearly, that it is highly questionable to calculate long period orbits with such a short observation time span. I selected from the set of orbits an example with a similar period to the 6th orbit catalog entry as given in Figure 37.

The 6th orbit catalog Kiy2012 orbit provides values for an inverted position angle so there is no direct comparison in one plot possible, but the differences are anyway obvious by comparing Figure 38.

65. LDS 169 (WDS 06337-7538, L032-009) – wide binary at a distance of ~8.8 parsecs. Resolved in DR2 with parallax and proper motion data for both components without duplicated_source marker. Not listed in the 6th orbit catalog. StarHorse median masses are given with 0.36/0.35 (slightly different from the 0.45/0.32 given in Ward-Duong et al. 2015) and RUWE is ~1 for both components. The simulation results in a minimum spatial distance between the components of ~192 AU with a minimum orbit period of ~3,200 years. So far only 14 observations listed in the WDS catalog since 1893 making it rather questionable to calculate an orbit with such a long period. Processing of a recently taken own image suggests a small change in separation since 2015. An attempt with the Izmailov 2019 program resulted in the values for a preliminary orbit given in Fig-

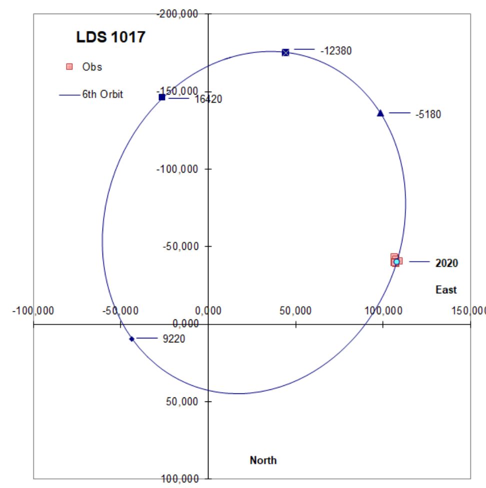

Figure 38. Plot system 64: LDS 1017 6^{th} orbit

```
a     =    36.321279316664366
e     =     0.877580493141251
T     =  2175.893414872075900
P     =  2126.008782227506300
omega=    102.675010745165990
Node =     31.391614365242027
i     =    94.467505072692973
```

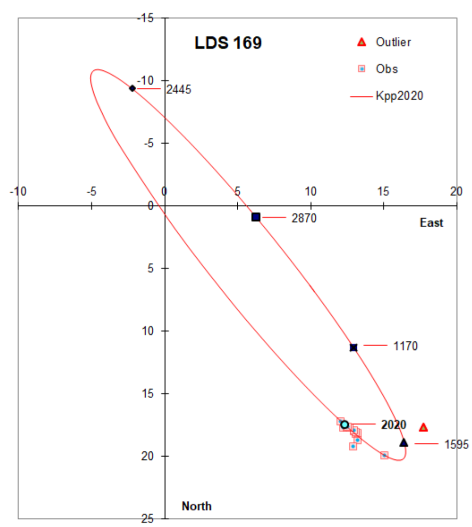

Figure 39. Plot system 65: LDS 169 orbit

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

```
a     =     2.502104080477937
e     =     0.800910038622950
T     =  2020.133514565010500
P     =    50.787435322428195
omega=     83.206119165501107
Node =     85.796107840358388
i     =    78.971833160258882
```

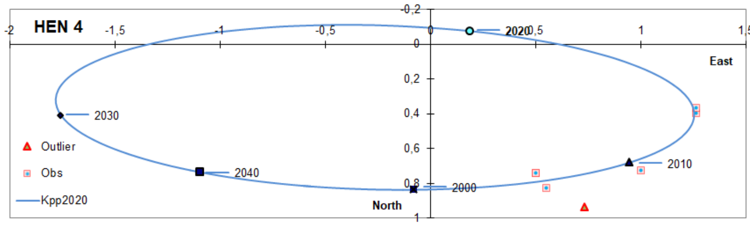

Figure 40. Plot system 67: HEN 4 orbit

ure 39.

66. KNG 1 (WDS 05544+2017, GJ 222, chi01 Ori, 54 Ori, HD39587) – binary star system at a distance of ~8.8 parsecs. Not resolved in DR2 due to an angular separation 2015.5 most likely <0.4”. Parallax and proper motion data given for combined object without duplicated_source marker. StarHorse gives a combined median mass of 0.98 and RUWE ~1 indicates solid DR2 data quality. The WDS catalog lists only 2 observations in 1982 and 2002 so this is a neglected WDS object. Fuhrmann et al 2017 list chi01 Ori as binary but without own observation. Han and Gatewood 2002 reported to have “… derived an accurate orbit … by combining precise astrometric and radial velocity data” listed as grade 9 in the 6th orbit catalog with a period of ~14 years. König et al. 2002 report the direct detection of the companion and masses of ~1/0.15. Hutter et al. 2019 were unable to resolve chi01 Ori owing to the huge magnitude delta between the components but state that other evidence indicates that this system contains two stars. Bonavita and Desidera 2020 list HD39587 as resolved binary with masses of 1.05/0.14 and suggest a semi-major axis of 5.9 AU and an eccentricity of 0.45 without specific reference.

67. HEN 4 (WDS 06308-7643, SCR J0630-7643) – binary star system at a distance of ~8.9 parsecs. Resolved in DR2 with parallax and proper motion data for both components without duplicated_source marker. Parallaxes with rather large errors and missing magnitudes in the B- and R-band and a RUWE value of 5.9 for A indicate some DR2 data quality issues. StarHorse median mass for A is ~0.12 but no value for B is given. Rough estimated mass ~0.1 based on magnitudes. Simulation results in a minimum spatial distance between the components of ~12 AU and using masses of ~0.12/0.10 gives a minimum orbit period of 85 years. Henry et al. 2018 estimate the orbit period as ~70 years. 7 observations since 2003 are listed in the WDS catalog with significant changes in separation and position angle but with at least one obvious outlier. Not listed in the 6th orbit catalog. The angular separation of currently most likely far less than 2” is too small for own astrometry with the equipment available to me. Applying the Izmailov program for calculating orbits on the given measurements results in the values given in Figure 40.

A new measurement in 2020 would greatly enhance the reliability of a new preliminary orbit calculation.

68. H 6 40 (WDS 05445-2227, GJ 216, Gam Lep) – binary star system at a distance of ~8.9 parsecs. H 6 stands for Herschel list 6. Both components listed in DR2 with parallax and proper motion values but the quality of the DR2 data is with a rather large parallax error as well as a duplicated_source marker for the primary a bit questionable. The simulation results suggest a minimum spatial distance of 866 AU with a minimum orbit period of ~17,400 years using the StarHorse median mass values of ~1.38/0.79. The number of observations listed in the WDS catalog is with 46 since year 1800 rather small and the changes between first and last measured position angle and angular separation is according to the potential minimum orbit period as to expect rather small. The minimum spatial distance is according to the simulation ~866 AU so gravitational relationship seems most likely but even observations covering several hundred years would cover only a tiny fraction of such a long orbit period. There is no entry for this object in the 6th orbit catalog and also not none in the MSC catalog. The currently available observation data (including a recent own measurement) shows a slight change in position angle over time so this might suggest very well a slow orbit but the rather messy observation history is overall clearly not suited for an at-

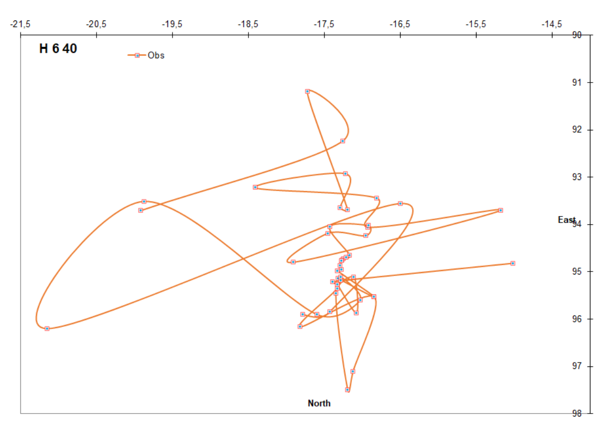

Figure 41. Plot system 68: H 6 40 observation history

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tempt to calculate a preliminary orbit, Figure 41.

The WDS catalog lists with H 5 40 C another most likely optical component due to a very different parallax.

69. HJ 3126 (WDS 22388-2037, GJ 867) – double-double star system at a distance of ~8.9 parsecs. DR2 parallax and proper motion data given for both doubles as combined objects. WDS catalog lists object HJ 3136 with two components A and B with 17 observations since 1830. The DR2 data quality seems sufficient, although the RUWE value for A is ~1.6, a bit high, and B is marked as duplicated_source. The simulation gives a minimum spatial distance between the components AB of ~4,500 AU. StarHorse lists median masses of ~0.60/0.38 (corresponding rather well with the values given by Ward-Duong et al. 2015 with 0.60/0.32) giving a minimum orbit period of ~350,000 years. Little surprise that this object is not listed in the 6th orbit catalog. Winters 2015 as well as Davison et al. 2015 list GJ 867 as quadruple with A and B being close pairs themselves, supported for B by the DR2 duplicated_source indication. Henry et al. 2018 mention A and B as spectroscopic binaries with very short orbit periods of ~4 and ~1.8 days but there so far are no entries for Aa,Ab and Ba,Bb in the 6th orbit catalog.

70. MTG 3 (WDS 14120-4132, WT 460) – close binary star system at a distance of ~9 parsecs not resolved in DR2. Parallax and proper motion data given for AB with a rather large error range but without duplicated_source indication. Listed in the WDS catalog with only one observation, but obviously observed frequently in the RECONS project (Henry et al. 2018). Consequently, the 6th orbit catalog has no entry for this object ,but Henry et al 2018 suggest an angular separation of <1" and an orbit period of at least several decades. According to Faherty et al. 2019, this system is a pair of brown dwarfs with masses of 0.12/0.075. StarHorse gives a combined median mass of ~0.14 and RUWE ~2.6 indicates that the GAIA DR2 single star model is not very well suited for this object.

71. KPP 4433 (STT 557, WDS 03194+0322 A,D, GJ 137, GJ 1057) – wide double star at a distance of ~9.1 parsecs. GJ 137 is the A component of WDS object STT 557 with a StarHorse median mass of ~0.94 and RUWE ~0.9, which indicates good DR2 data quality. STT 557 B has a completely different parallax and is clearly optical. GJ 1057 is a variable of BY Dra type at a minimum spatial distance of ~109,000 AU with a StarHorse median mass of ~0.20. The given masses correspond with tidal radii of ~97,000 and ~45,000 AU, which means an overlap large enough for a most likely gravitational relationship. Quite different proper motion values suggest a random encounter making an orbit rather unlikely – a potential minimum period of ~34 megayears would anyway be beyond any human observation time span. There is another optical component listed with BUP 42 C in the WDS catalog for STT 557. GJ 1057 gets for this reason the WDS component designation "D". The data for the KPP 4433 AD star system is given in Table 6.

49.84040002	RA J2000 in degrees
3.370193722	Dec J2000 in degrees
313.387	Position angle J2015.5
0.000	Error position angle
7357.87867	Separation in arcseconds J2015.5
0.00031	Error separation
6.45276	Estimated Vmag primary from G/B/R-mag
0.00742	Error estimated Vmag primary
13.84357	Estimated Vmag secondary from G/B/R-mag
0.00918	Error estimated Vmag secondary
109.3409	Parallax primary in mas
0.3072	Error parallax primary
9.12009	Distance primary from the Sun in parsecs
116.1536	Parallax secondary in mas
0.0882	Error parallax secondary
8.61583	Distance secondary from the Sun in parsecs
269.769	Proper motion RA primary in mas/yr
95.072	Proper motion Dec primary in mas/yr
1741.859	Proper motion RA secondary in mas/yr
86.017	Proper motion Dec secondary in mas/yr
109 068	Minimum spatial distance between the components in AU
0.94268	StarHorse median mass for primary in Sun mass
0.19904	StarHorse median mass for secondary in Sun mass
33 937 046	Minimum period of a potential orbit in years

Table 6. Data for KPP4433 AD (WDS 03194+0322) based on GAIA DR2 values for source_id 3269362645115584640 and 3179036008830848

72. KPP 4434 (GJ 451, GJ 450, HD 103095, MCC 135) – wide star system at a distance of ~9.1 parsecs. GJ 451 is a high proper motion star with a suspected flaring companion according to Heintz 1984, but it is so far not clear if such a companion actually exists. Kervella et al. 2019 exclude the possibility that GJ 451 is a star system and discuss a potential planet system but DR2 gives no duplicated_source indication. Star-

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178.2448683	RA J2000 in degrees
37.71867780	Dec J2000 in degrees
189.055	Position angle J2015.5
0.000	Error position angle
8827.38587	Separation in arcseconds J2015.5
0.00007	Error separation
7.53453	Estimated Vmag primary from G/B/R-mag
0.00274	Error estimated Vmag primary
10.18609	Estimated Vmag secondary from G/B/R-mag
0.00352	Error estimated Vmag secondary
108.9551	Parallax primary in mas
0.0490	Error parallax primary
9.17397	Distance primary from the Sun in parsecs
114.1376	Parallax secondary in mas
0.0390	Error parallax secondary
8.76435	Distance secondary from the Sun in parsecs
269.769	Proper motion RA primary in mas/yr
95.072	Proper motion Dec primary in mas/yr
4002.567	Proper motion RA secondary in mas/yr
-5817.856	Proper motion Dec secondary in mas/yr
113 570	Minimum spatial distance between the components in AU
0.64938	StarHorse median mass for primary in Sun mass
0.50005	StarHorse median mass for secondary in Sun mass
35 896 414	Minimum period of a potential orbit in years

Table 7. Data for KPP4434 (WDS 11530+3743) based on GAIA DR2 values for source_id 4034171629042489088 and 4031586157514097024

Horse gives a median mass of ~0.65. GJ 450 is located at a minimum spatial distance of ~113,600 AU. DR2 gives no duplicated_source indication for GJ 450 and StarHorse gives a median mass of ~0.50. In both cases, RUWE ~1 suggests good DR2 data quality. The given masses correspond with tidal radii of ~80,500 and ~70,500 AU, which means an overlap large enough for most likely gravitational relationship. Extremely different proper motion values indicate that this is a random encounter – a potential minimum period of ~36 megayears would be anyway beyond any human observation time span. The data for this star system is given in Table 7.

73. BEU 8 (WDS 07039+5242, GJ 3421, G 193-027, LHS 224) – binary star system at a distance of ~9.1 parsecs. Not resolved in DR2 due to angular separation <0.4" but parallax is given for a combined object yet without duplicated_source indication. The 6th orbit catalog lists a grade 3 orbit with a period of ~3.3 years based on 14 observations listed in the WDS catalog since 2000. StarHorse gives a combined median mass of 0.22 and Benedict et al. 2016 report masses of ~0.13/0.12. The RUWE value >6 indicates that the GAIA DR2 single star model is, for good reasons, not suited for this object.

74. LUY 5693 (WDS 07402-1724 AC, VBS 41, GJ 283, LAWD 25, LP 783) – binary star system at a distance of ~9.1 parsecs. The WDS catalog lists two pairs VBS 41 AB and LUY 5693 AC. The B component of VBS 41 AB with only one observation 1965 seems to be bogus – no DR2 object exists for B and there are no other sources indicating a triple system. The components A and C for LUY 5693 are listed in DR2 with parallax and proper motion values and without duplicated_source indication. StarHorse provides a median mass only for the secondary with ~0.11 yet RUWE ~1 indicates good DR2 data quality. According to Toonen et al. 2017, the A component is a white dwarf with a mass of 0.62. Simulation gives a minimum spatial distance between A and C of 186 AU giving a potential minimum orbit period of ~3,000 years. Spectral type for WDS component C (= GJ 283) is M8.6 according to Houdebine et al. 2019, while Davison et al. 2015 report spectral type M6.5 with a mass of 0.16. The WDS catalog lists only 10 observations for LUY 5693 AC since 1953 and there is no entry in the 6th orbit catalog. Using the Izmailov program on the given measurements for LUY 5693 AC plus my own recent measurement gives a set of possible orbits with a huge spread regarding period indicating that the currently given observation history is not suited for calculating an even very preliminary orbit.

75. HU 664, CHR 193 (WDS 13198+4747, GJ 508, HD 115953, HIP 65026) – triple star system at a distance of ~9.1 parsecs not resolved in DR2 due to an angular separation of currently <0.4". Combined object with parallax and proper motion values but parallax error is rather large and no duplicated_source indication is given. StarHorse gives a combined median mass of ~0.75, which seems a bad match with the values given by Ward-Duong with 0.67 and 0.50. RUWE >36 indicates a massive problem with the GAIA single star model. The 6th orbit catalog lists a grade 2 orbit with a period of ~49 years based on so far >140 observations since 1904. The WDS catalog lists also a CHR 193 Aa,Ab pair with an even smaller angular separation with so far 10 observations. Sperauskas et al 2019 suggest an orbit for this Aa,Ab pair with a period of ~1.2

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```
a     =     1.511073228441406
e     =     0.239893511321578
T     =  1968.743147336638200
P     =    48.915445877491287
omega=    74.728983744848662
Node =    90.990760456429172
i     =    93.967974103636962
```

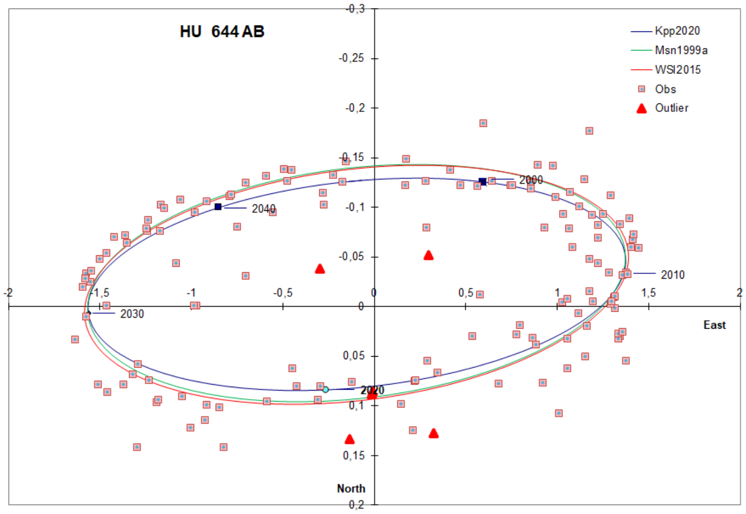

Figure 42. Plot system 75: Orbit HU 664 AB comparison

years so far not listed in the 6th orbit catalog. Tokovinin et al. 2019 declare DR2 data quality for this object as rather poor, suggest a distance of ~9.9 parsecs and masses of 0.58/0.42/0.48 for this triple system. Using the Izmailov program on the observation history of HU 664 AB essentially confirms, despite minor variations, the given 6th orbit catalog data, Figure 42.

The Izmailov program used with the CHR 193 Aa,Ab observation history suggests after elimination of two outliers a preliminary orbit with a period of ~26 years. The two assumed "outlier" observations from 2009.45020 and 2010.46860 seem to be measurements with quadrant ambiguities and are with inverted position angle also very close to the calculated values. A closer look at the observation history reveals some other oddities like 4 pairs of measurements at the same point of time but with noticeable different results especially the one at 2019.0578. This result seems obviously a reasonable good match with the given observation history but is heavily at odds with the spectroscopic orbit period of ~1.2 years suggested by Sperauskas et al. 2019. The 6th orbit catalog lists currently no entry for CHR 193 Aa,Ab but a note refers to a spectroscopic orbit Tok2019b for Aa,Ab with a corresponding period of 447 days. Overall, this is most likely just another example that the Izmailov program does not work well with short period orbits with large time deltas between measurements

76. WSI 72 (WDS 05086-1810, GJ 190) – close binary star system at a distance of ~9.2 parsecs not resolved in DR2. Combined DR2 object with parallax and proper motion data listed with rather small error range yet without duplicated_source indication. Listed in the WDS catalog with 21 observations since 2003. The 6th orbit catalog lists a grade 2 orbit with a period of ~1 year from Tokovinin 2017. StarHorse gives a combined median mass of ~0.45 while Ward-Duong et al. 2015 lists 0.43/0.41 so this is rather a bad match. RUWE is ~1.6 suggesting minor issues with the DR2 data quality.

There might be an issue with the current 6th orbit catalog data as the most recent measurement per 2018.9709 is in comparison with the calculated values off by ~15° in position angle and ~52% in angular separation. I tried to verify the 6th orbit catalog entry by using the Izmailov program with the given measurements but this did not work as hoped for – as in other cases the Izmailov program does not work well with short period orbits with observation histories with time gaps larger than the orbit period.

The "nearby" DR2 object with source_id 2976850598890038784 (marked as duplicated_source itself, but a RUWE value of ~1.2 indicates good DR2 data quality) with a distance of ~50,000 AU is close enough for a gravitational relationship. The tidal radius of AB is ~67,000 AU and of the third component ~55,000 AU (using the StarHorse median masses of ~0.45/0.30) and these radii overlap significantly. Therefore, this object is most likely a triple even if the given very different proper motion values suggest a random encounter. Data for this system are given in Table 8.

To make things a bit more complicated: this C component is identical with the primary of the optical double star B 2583 (WDS 05033-1722).

77. SOZ 3 (WDS 14164+1348, SDSS J141624.08+134826.7, 2MASS J14162408+1348263) – brown dwarf pair at a distance of ~9.3 parsecs not

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77.14601845	RA J2000 in degrees
-18.1720517	Dec J2000 in degrees
302.705	Position angle J2015.5
0.000	Error position angle
5356.32656	Separation in arcseconds J2015.5
0.00010	Error separation
10.69599	Estimated Vmag primary from G/B/R-mag
0.00133	Error estimated Vmag primary
11.91015	Estimated Vmag secondary from G/B/R-mag
0.00127	Error estimated Vmag secondary
108.7231	Parallax primary in mas
0.0942	Error parallax primary
9.20565	Distance primary from the Sun in parsecs
108.3263	Parallax secondary in mas
0.0500	Error parallax secondary
9.22711	Distance secondary from the Sun in parsecs
503.670	Proper motion RA primary in mas/yr
-1399.811	Proper motion Dec primary in mas/yr
-228.056	Proper motion RA secondary in mas/yr
-444.616	Proper motion Dec secondary in mas/yr
49 348	Minimum spatial distance between the components in AU
0.45152	StarHorse median mass for primary in Sun mass
0.30119	StarHorse median mass for secondary in Sun mass
12 705 267	Minimum period of a potential orbit in years

Table 8. Data for KPP 4435 AB,C (WDS 05086-1810) based on GAIA DR2 values for source_id 2976507997939000064 and 2976850598890038784.

```
a     =     0.613547483069623
e     =     0.312337495378080
T     =  2002.182894303783300
P     =    18.395292694699112
omega=   288.302036578933210
Node =    54.677765127578667
i     =   135.033379189120520
```

resolved in DR2 but parallax and proper motion data is given for a combined object yet without duplicated_source indication. Discovered by Scholz 2010 and parallel by Burningham et al. 2010, reported also in Henry et al. 2018. Listed in the WDS catalog with 7 observations since 2003. Not listed in the 6th orbit catalog. No StarHorse data available due to Gmag >18 but masses of ~0.06/0.04 are given by Faherty et al. 2019

78. KUI 41 (WDS 09313-1329, GJ 352, Ross 440) – close binary at a distance of ~9.3 parsec not resolved in DR2, combined object without parallax and proper motion data but with duplicated_source indication. 27 observations since 1942 according to the WDS catalog. The 6th orbit catalog lists a grade 2 orbit with a period of ~18 years from 2015. Ward-Duong et al. 2015 lists masses of ~0.5 for both components. Some additional measurements since 2015 suggest a new orbit calculation with the Izmailov program with the result rather close but not identical with the 6th orbit catalog data, Figure 43.

79. LDS 6248 (WDS 11467-4029, GJ 442, HD 102365) – wide binary at a distance of ~9.3 parsecs. DR2 objects given for both components with parallax and proper motion data without duplicated_source marker. Listed in the WDS catalog with only 3 observations since 1960 so this is a neglected system. Not listed in the 6th orbit catalog. Simulation results in a minimum spatial distance of ~211 AU. StarHorse median masses of ~0.93/0.20 give a minimum orbit period of ~2,900 years. RUWE values ~1 for both components indicate good DR2 data quality. Bonavita and Desidera

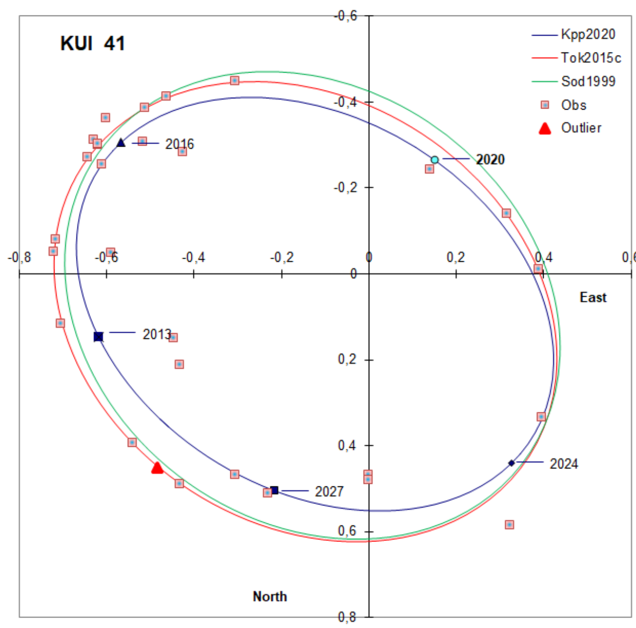

Figure 43. Plot system 78: Orbit KUI 41 comparison

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

2020 list similar masses of 0.86/0.18

80. BEU 3 (WDS 02051-1737, GJ 84, BD-18 359, LHS 145) – spectroscopic binary at a distance of ~9.4 parsecs. Not resolved in DR2 but parallax and proper motion data given for a combined object with duplicated_source indication. StarHorse gives a combined median mass of 0.55 (good match with Ward-Duong et al. 2015 giving 0.47/0.11) und RUWE value is ~1.6 indicating potential DR2 data quality issues. No entry in the 6th orbit catalog and the number of observations listed in the WDS catalog since 2002 is only 5 suggesting a rather neglected object

81. AST 1 (WDS 19121+0254, GJ 748, Wolf 1062) – close binary at a distance of ~9.4 parsecs not resolved in DR2 due to an angular separation <0.4". Parallax and proper motion data given for a combined object with a rather large error range and duplicated_source indication. The 6th orbit catalog lists a grade 1 orbit with a period of ~2.5 years but for unknown reasons with inverted node value. Wand-Duong et al. 2015 suggest masses of 0.34 to 0.41 for the primary and 0.23 to 0.28 for the secondary, so the mass ratio seems no cause for such a step. The reference paper for this orbit (Benedict et al. 2016) lists with ~0.37/0.19 similar mass values. Number of observations listed in the WDS catalog is 52 since 1982. Using the Izmailov program with the given observation history gives results very close to the current 6th orbit catalog data (with node value inverted back again), Figure 44.

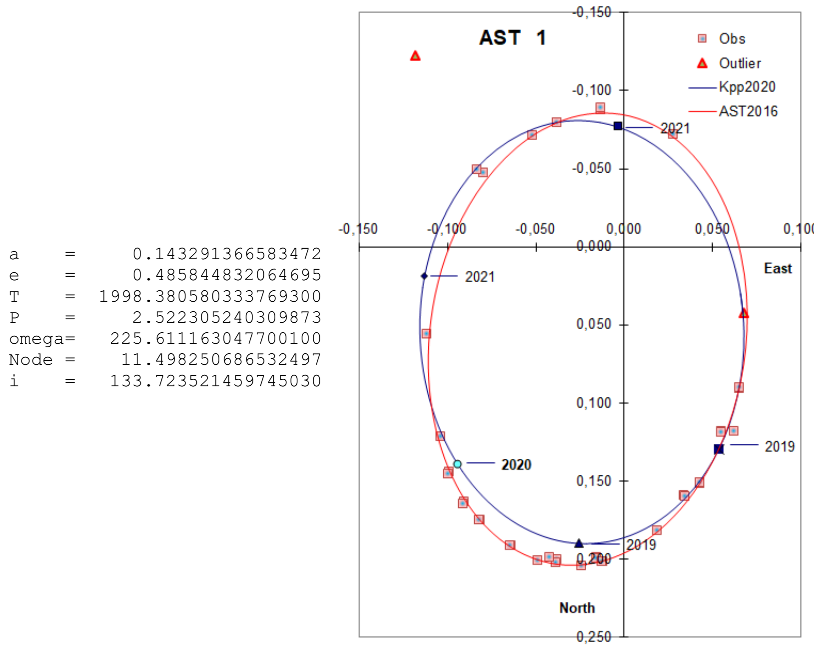

Figure 44. Plot system 81: Orbit AST 1 comparison

82. GJ 595 (L 768-119, LHS 54) – spectroscopic binary at a distance of ~9.4 parsecs not resolved in DR2. Parallax and proper motion data given for a combined object with a medium large error range and a duplicated_source indication. Not listed in the WDS catalog, mentioned in Henry et al. 2018 with a proposed period of ~62 days (the 6th orbit catalog lists a corresponding grade 9 orbit with WDS ID 15421-1928 and the discoverer designation "NONE") and the suggestion, that the companion is a brown dwarf with a mass of 0.05. StarHorse combined median mass is 0.30 and RUWE ~3.8 suggests duplicity.

83. SCR J2049-4012 (UCAC4 249-180185, BPS CS 22879-0089, 2MASS J20490993-4012062) – close binary star system at a distance of ~9.5 parsecs. Not resolved in DR2 but parallax and proper motion data given for a combined object without duplicated_source indication. No WDS object. Reported in Henry at al. 2018 with a photocentric orbit listed in the 6th orbit catalog as grade 9 orbit with WDS ID 20492-4012 and discoverer designation "NONE" and a period of ~1.8 years. Proper motion speed is a remarkably slow <0.2"/yr.

84. LDS 6245 (WDS 11345-3250, GJ 432, HD 100623, WD 1132-325) – wide binary at a distance of ~9.5 parsecs. Both components listed in DR2 with parallax and proper motion data with rather small error range and without duplicated_source marker. Simulation results in a minimum spatial distance of 146 AU. StarHorse lists the primary with a median mass of 0.78 and RUWE ~1 but gives no data for the secondary. The secondary is WD 1132-325, a white dwarf for which Holberg et al. 2016 list a mass of 0.58. This gives then a minimum period of ~1,500 years for a potential circular orbit. Bonavita and Desidera 2020 list masses of 0.77/0.66 giving a similar result. The WDS catalog lists only five observations since 1960 so this is a neglected object. My own recent measurement supports the impression of a systematic change of position angle and angular separation, but the number of observations is currently far too small for a reasonable calculation of a preliminary orbit with such a long period.

85. SKF 104 (WDS 17352-4841, GJ 680, CD-48 11837) – wide binary at a distance of ~9.6 parsecs. Resolved in DR2 with parallax and proper motion data for both components with a rather small error range and without duplicated_source indication. StarHorse masses are ~0.50/0.23 (Wand-Duong et al. 2015 suggest

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```
a     =     0.199400951323380
e     =     0.473833284272940
T     =  2014.149753489854200
P     =     5.029728916457340
omega=   272.222301198713010
Node =   114.164690097985560
i     =   116.404557596397960
```

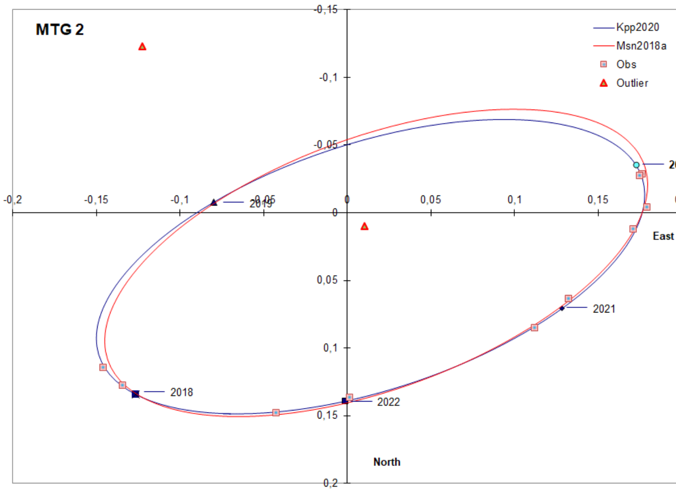

Figure 45. Plot system 87: Orbit MTG 2 comparison

0.46/0.18) and RUWE is ~1 for both components. Simulation gives a minimum spatial distance of 45 AU giving with the StarHorse masses a minimum orbit period of ~350 years. With a maximum spatial distance of less than 20,000 AU. a gravitational relationship seems likely due to heavily overlapping tidal radii of ~68,000/42,000 AU, although the proper motion values do not suggest common proper motion. Not listed in the 6th orbit catalog. WDS lists despite a generous angular separation >4" and reasonable brightness of both components of ~10.5/13 Vmag so far only 4 observations since 2000 so this seems to be another neglected WDS object. No entry in the 6th orbit catalog due to the obvious lack of a sufficient long observation history.

86. BEU 14 (WDS 10498+3533, GJ 1138, G 119-36, LHS 293) – close binary at a distance of ~9.7 parsecs. Not resolved in DR2 but parallax and proper motion data given for combined object a duplicated_source indication. StarHorse provides a combined median mass of 0.25 and RUWE >2 suggests a minor issue with DR2 data quality. Neglected WDS pair with so far only one observation from 2000, no entry in the 6th orbit catalog. Dieterich et al. 2012 report GJ 1138 as resolved without giving details regarding angular separation and position angle.

87. MTG 2 (WDS 09156-1036, G 161-7, LHS 6167) – close binary at a distance of ~9.7 parsecs. Not resolved in DR2, combined object without parallax and proper motion data and without duplicated_source marker. Listed in the WDS catalog with 12 observations since 2003. First orbit reported in Mason et al. 2018 (listed as grade 3 in the 6th or bit catalog) and shortly afterwards a photocentric orbit was reported in Henry et al. 2018 with a similar period of ~5 years. With the exclusion of two obviously questionable measurements (most likely with quadrant ambiguities), the results gained with the Izmailov program matches rather well with the current 6th orbit catalog values, Figure 45.

88. DEL 4 (WDS 12490+6607, GJ 487, G 237-078) – according to Winters et al. 2019 a close triple at a distance of ~9.7 parsecs. Not resolved in DR2, combined object without parallax and proper motion data but with a duplicated_source indication. Hipparcos parallax suggests a distance >10 parsecs. The inner spectroscopic subsystem Aa,Ab reported by Delfosse et al. 1999 is so far not resolved, an orbit with a period of 54 days is suggested but not yet listed in the 6th orbit catalog. The outer AB pair is listed in the WDS catalog with so far only 4 observations since 1997 so this is just another neglected WDS pair. Tokovinin et al. 2019 report 79 observations of this object from 1984 to 2003 with masses of 0.52/0.25 for AB and suggest an orbit with a period of ~7.4 years so far not included in the 6th orbit catalog. The VizieR catalog J/AJ/158/167 based on Tokovinin et al. 2019 lists 12 measurements for AB and using these measurements with the Izmailov program gives the results shown in Figure 46 for a preliminary orbit

The inner subsystem Ab,Ab is reported by Tokovinin et al. 2019 as not resolved but the masses are estimated as equal (means 0.26/0.26) and an orbit is estimated with a period of ~0.15 years corresponding with Delfosse et al. 1999.

89. Wolf 227 (GJ 3253, LHS 1610, Wolf 227) – spectroscopic binary at a distance of ~9.7 parsecs. Not

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```
a     =      0.334984482981958
e     =      0.426987356264326
T     =   2009.262199602437700
P     =      7.307817611106429
omega=     83.385715375552081
Node =     21.926264665089956
i     =     76.117134058372031
```

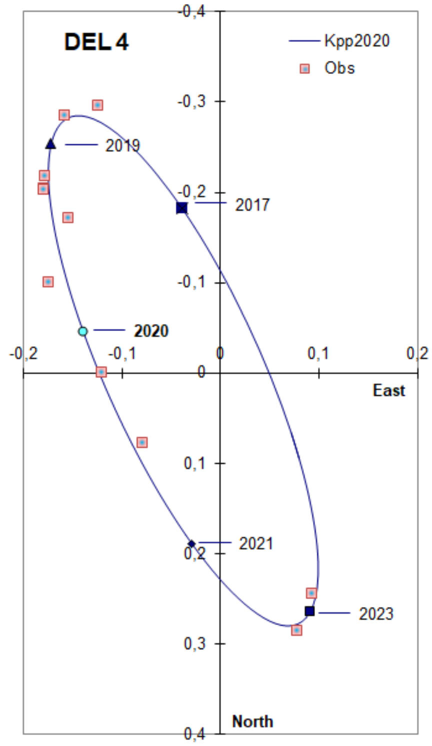

Figure 46. Plot system 88: DEL 4 orbit

resolved in DR2 with parallax and proper motion data given for a combined object without duplicated_source marker. StarHorse gives a combined median mass of ~0.2 and a RUWE value of ~2 indicates a potential duplicity issue. This system consists according to Winters et al. 2018 of a mid-M dwarf with a companion that is likely a brown dwarf. No WDS catalog object. Winters et al. 2018 suggest preliminary orbit parameters with an extremely short period of ~10.6 days, yet no corresponding 6th orbit catalog entry exists so far.

90. WNO 51 (WDS 01026+6221, GJ 49, BD+61 195) – wide pair at a distance of ~9.9 parsecs. Resolved in DR2 with parallax and proper motion data for both components with small to moderate parallax errors and duplicated_source marker for B, RUWE for both components is ~1 suggesting good data quality. Simulation results in a minimum spatial distance of ~2,900 AU giving with the StarHorse median masses of ~0.55/0.25 (good match with Ward-Duong et al. 2015 with 0.56/0.20) a minimum orbit period of ~175,000 years. Number of observations listed in the WDS catalog since 1952 is eight. No entry in the 6th orbit catalog. The WDS catalog lists with CSN 3 C an additional component most likely optical.

91. UCAC4 332-044363 (UPM J0815-2344) – binary star system at a distance of ~9.9 parsecs. Not resolved in DR2, combined object with parallax and proper motion data but without duplicated_source marker. No WDS object. Reported in Henry et al. 2018 with an estimated angular separation of 1.5" and proper motion speed <200 mas/yr

92. VYS 2/MCY 1 (WDS 00321+6715, GJ 22) – quadruple (double-double) star system at a distance of ~9.9 parsecs. DR2 parallax and proper motion data available only for main components A and B standing each for an unresolved close binary. Duplicated_source marker only for A with RUWE >4 suggesting also duplicity. B is not marked as duplicated_source but this does not necessarily suggest that B is not very well a binary. DR2 StarHorse median mass values for A/B are ~0.45/0.30. The double-double pair VYS2 AB is listed in the 6th orbit catalog with a grade 5 orbit with a period of ~228 years (based on 91 observations since 1923). Benedict et al. 2016 suggested an orbit period of ~320 years and a 6th orbit catalog entry from 1993 listed a corresponding period of 323 years. The pair MCY 1 Aa,Ab is listed in the 6th orbit catalog with a grade 3 orbit with a period of ~15.6 years (based on 32 observations since 1989). Benedict et al. 2016 report masses for Aa,Ab of ~0.41/0.16. VYS 2 Ba,Bb is listed with a grade 9 orbit with a period of ~15 years without

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```
a     =     3.024212940509425
e     =     0.363216656116143
T     =  1883.634965336576900
P     =   206.706896488203200
omega=    170.244284266291910
Node =    169.148772904487290
i     =    39.221465416927401
```

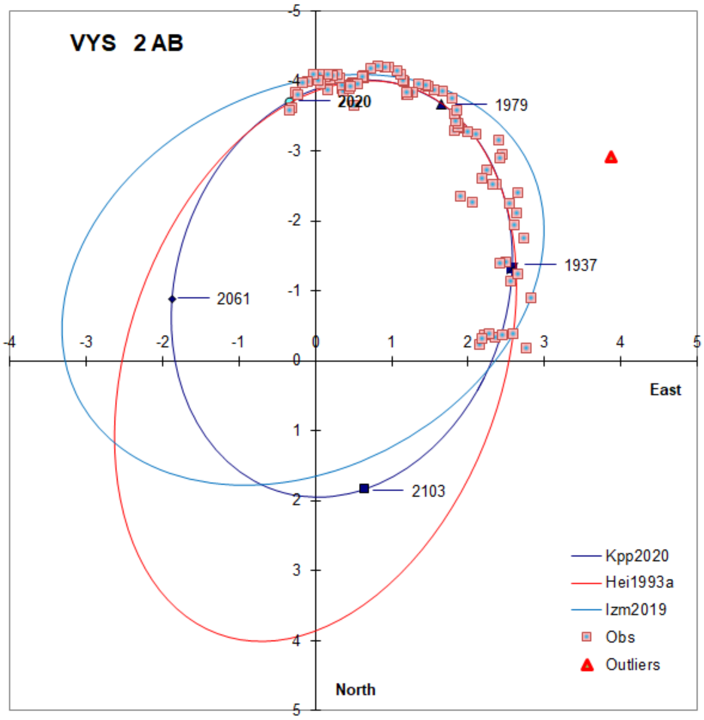

Figure 47. Plot system 92: VYS 2 orbit comparison

a corresponding WDS object.

Simulation gives for AB a minimum distance of ~38 AU indicating a minimum orbit period of 275 years. The spread caused by the large parallax error for the primary is huge yet the maximum distance is smaller than 62,000 AU so gravitational relationship between this pair of doubles seems given for sure. Own images provide no useful information due to overlapping star disks. Using the Izmailov program with the existing observation history of VYS 2 AB brings (with one excluded outlier) a slightly different result compared to the orbit variants suggested earlier, see Figure 47.

From a purely visual point of view the Izm2019 orbit does not fit the observations as well as the two other preliminary orbits. The reason for the visually slightly off result of the Izm2019 orbit seem to be the weights applied on the observations. Why the orbits published in Izmailov 2019 with and without weights are both different from the orbit gained by simply applying the Izmailov program on the given observation history is unclear

93. LDS 720 (WDS 20452-3120, GJ 803, AU Mic, HD 197481, GJ 799, AT Mic, HD 196982) – triple star system at a distance of ~9.9 parsecs. The WDS catalog lists a very wide AB and a close BC pair. All components resolved in DR2 with parallax and proper motion data and without duplicated_source marker. RUWE is for all components ~1 suggesting good DR2 data quality. The minimum spatial distance between A and B is according to the simulation ~52,000 AU and between B and C ~360 AU. StarHorse median masses for A/B/C are ~0.70/0.49/0.51, which means that the barycenter is close to BC with heavily overlapping tidal radii of ~105,000/84,000 AU. The minimum orbit period for BC would with these values be ~6,800 years and for BC,A >9 mio years. The 6th orbit catalog lists for BC a grade 5 orbit with a period of ~141 years and Izmailov 2019 suggests an orbit with a period of ~244 years (without weights) and ~252 years (with weights). All preliminary orbit values are completely different from the simulation result raising doubts about the quality of the DR2 data despite the reasonable small parallax errors given. My own calculation using the Izmailov program with the given observation history (excluding three outliers) results in the values given in Figure 48 for a preliminary orbit.

94. LDS 6330 (WDS 18411+2447, GJ 1230, G 184-19, LHS 3405) – triple system at a distance of ~9.9 parsecs. Components A and B listed both with parallax and proper motion values in DR2. Sub-pair Aa,Ab is not resolved and no duplicated_source marker is given for A. RUWE ~1.2 for both components and rather small parallax errors indicate solid DR2 data quality. DR2 parallax for GJ 1230 is with ~101 much smaller than

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```
a     =     3.234220233778289
e     =     0.266684867920221
T     =  2042.031289616232700
P     =   207.958137415386120
omega=   317.169614766843550
Node =    21.872044590921163
i     =   135.547830668132180
```

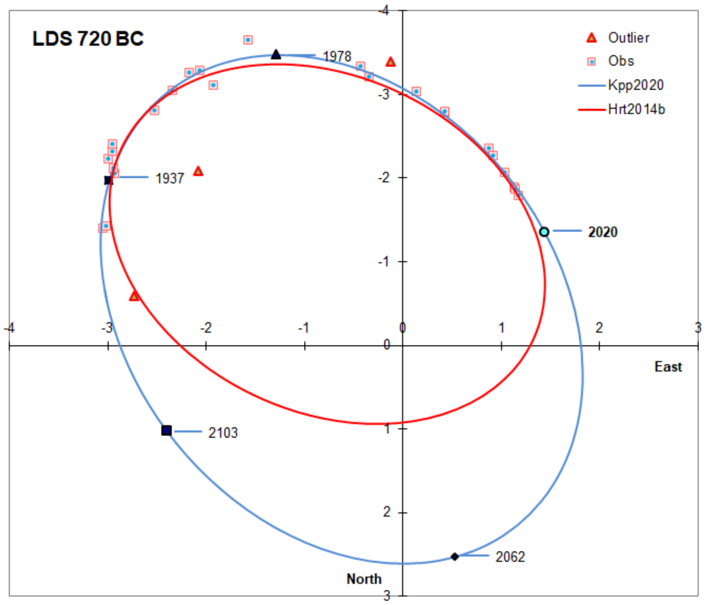

Figure 48. Plot system 93: LDS 720 BC orbit comparison

the ~120 given by Winters et al. 2019. DR2 StarHorse median mass values for A/B are ~0.23/0.22. Davison et al. 2015 suggest a mass of 0.19 for B close to the StarHorse value. Simulation with DR2 and StarHorse data gives a minimum distance of ~47 AU indicating a minimum orbit period of ~482 years. The WDS catalog lists no object for Aa,Ab but similar to DR2 only for AB. No entry for neither in the 6th orbit catalog. Similar to LDS 3836 the number of observations is too small for any serious orbit calculation with such a long period but in this case also the data quality of the observations seems highly questionable – just a counter-check with the POSS1 image from 1951 makes the observation data from 1960 looking obsolete. With the addition of a few measurements estimated from existing images (POSS etc.) the Izmailov program gives the results

```
a     =    45.493864171921423
e     =     0.913263721581385
T     =  1900.653322012725500
P     =  2116.622398078399300
omega=   296.540657818761300
Node =    12.220877074463729
i     =    91.145336118888551
```

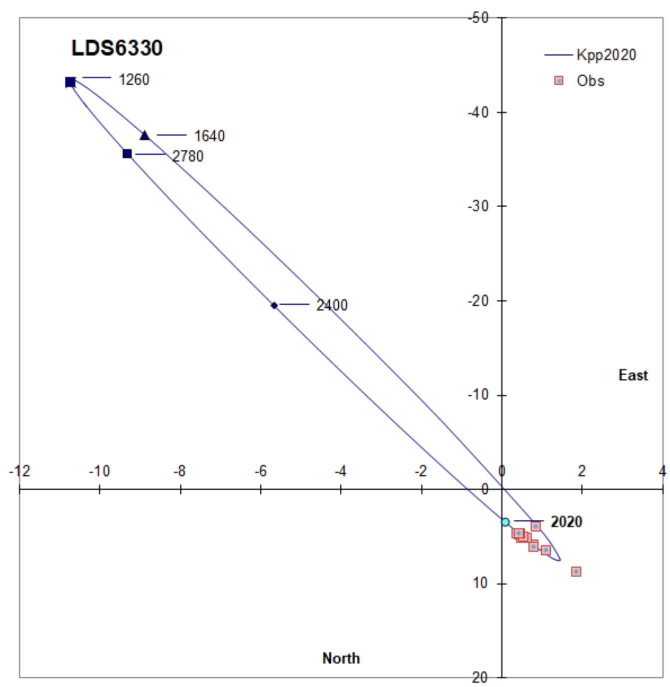

Figure 49. Plot system 94: LDS 6330 AB orbit

shown in Figure 49 for a preliminary orbit.

4. Questionable Objects

The given list includes objects so far considered most likely star systems within 10 parsecs from the Sun including a few objects with incomplete or contradicting evidence, such as GJ 829, but still considered plausible star systems. Additionally, many objects found during the research for this paper were dismissed as likely not star systems at least not within 10pc, although there are some hints they might be. There is a multitude of reasons why an object might be considered as questionable; for example, objects listed in one catalog as star system while other sources indicate rather a star hosting one or more planets and the latter seems more plausible. Several of the listed objects are questionable regarding the precise distance from the Sun, but also for the property of being a physical star system and not a mere optical pair or simply a single star. Finally, there are cases with single star objects with a duplicated_source indication in DR2 or a reported proper motion anomaly – not much of an argument for a potential close binary, but at least possible because many spectroscopic binaries come with a DR2 duplicated_source marker. The decision, which objects should be declared as questionable enough to be listed separately or not is somewhat arbitrary, so both lists are communicating containers and future research will certainly additionally detect additional star systems within 10pc especially spectroscopic binaries.

The objects found questionable are listed below in the order of distance from the Sun.

1. Barnard's star (GJ 699) – number 2 on the RECONS list as single star at a distance of ~1.83 parsecs. There is a close companion suspected (most likely a very massive extra-solar planet) supported also by Kervella et al. 2019 with an estimated mass of 0.04. The 6th orbit catalog lists three GJ 699 (WDS 17578+0442) grade 9 orbits published 1969 without a corresponding WDS object.

2. GAIA DR2 source_id 6027985603507525120 (UCAC4 297-101556) at a distance of ~2.73 parsecs with a duplicated_source indication. StarHorse gives no data for this with ~16.4 Gmag rather faint object, which suggests DR2 data quality issues. The lack of significant proper motion speed indicates rather a background star as cause for the duplicated_source indication.

3. TNN 13 (WDS 18498-2350, GJ 729, Ross 154) – as single star object number 7 on the RECONS list at a distance of ~3 parsecs. Proper motion anomalies indicate according to Kervella et al. 2019 a 0.06 mass companion to a ~0.18 mass primary. DR2 provides no resolution for Aa,Ab but also no duplicated_source indication. StarHorse combined (if indeed for a close binary) median mass is ~0.2 and RUWE ~1 gives again no hint for duplicity. The WDS object TNN 13 seems to be a wide likely optical triple.

4. GJ 905 (Ross 258) – as single star number 8 on the RECONS list at a distance of ~3.15 parsecs with a mass of ~0.12 giving a corresponding "Oort" radius of ~34,500 AU. This object is with a spatial distance of ~115,000 AU rather close to GJ 15 (star system with the number 8 on the RECONS list) with a combined mass of ~0.65 giving a corresponding "Oort" radius of ~80,500 AU – this means that the "Oort" radii of these two systems are just touching but not overlapping making potential gravitational relationship rather unlikely.

5. Eps Eri (BLA 2, WDS 03329-0927 with with only one observation so far and meanwhile declared bogus) – number 9 on the RECONS list (with 1 planet) at a distance of ~3.2 parsecs. Kervella et al. 2019 consider this object based on proper motion anomalies as a potential close binary with a 0.21 $M_{\odot}$ companion. Other authors report two suspected planets. GAIA DR2 gives no duplicated_source indication and RUWE is ~1.

6. GJ 887 (HD 217987) – number 10 on the RECONS list as single star at a distance of ~3.3 parsecs. In DR2 single source object without any hint for duplicity. Parallax is given with very small error range, no duplicated_source indication and RUWE value is ~1. StarHorse combined median mass is 0.50 quite close to the values given by Kervella et al. 2019 declaring a minor proper motion anomaly. Wand-Duong et al. 2015 give masses of 0.44/0.25 suggesting a star system.

7. Ross 128 – number 11 on the RECONS list at a distance of ~3.4 parsecs. Proper motion anomalies indicate according to Kervella et al. 2019 a 0.12 $M_{\odot}$ companion to a ~0.18 $M_{\odot}$ primary. Other authors suspect an extra-solar planet. DR2 gives no duplicated_source indication and RUWE ~1 gives also no hint for a multiple.

8. HIP 82724 – double star according to Hipparcos at a distance of ~3.7 parsecs. Distance according to DR2 ~62.5 parsecs. This is with some likelihood a physical pair but curiously not listed as such in the WDS catalog but only as B component of the optical double star HDS 2393 (WDS 16545-6224).

9. Kapteyn's star (GJ 191) – number 25 on the RECONS list at a distance of ~3.9 parsecs. Fast moving variable star of BY Dra type. DR2 gives no duplicated_source indication. Kervella et al. 2019 report a proper motion anomaly and Simbad suggests two potential planets with a question mark, brown dwarfs might be possible.

10. AX Mic (GJ 825) – number 26 on the RECONS list at a distance of ~3.95 parsecs. DR2 gives no duplicated_source indication. Kervella et al. 2019 report a proper motion anomaly and suggest a giant planet.

11. NHR 2 (WDS 10482-3956, DENIS J1048.0-3956) – a rather wide (>5" angular separation) brown dwarf star system at a distance of ~4 parsecs reported by Neuhäuser et al. 2002. Neglected system with so far only two observations listed in the WDS catalog. DR2 lists only the primary (with a moderate parallax error and without a duplicated_source indication) but not the secondary most likely due to its faintness. No data for this object in StarHorse indicating caveats regarding DR2 data quality. Simbad gives a mass of 0.08 for the primary. Neuhäuser et al. 2002 declared the suspected companion as likely optical due to the missing co-movement detected by comparison with another image taken six months after the first one – so this is most likely no star system but a single star object.

12. GAIA DR2 source_id 4129144660321847040 (UCAC4 356-084032) – with ~16.3 Gmag rather faint object at a distance of ~4.1 parsecs with duplicated_source indication. StarHorse offers no data on this object suggesting DR2 data quality issues.

13. LAF 56 (WDS 16303-1240, BD-12 4523 (GJ 628) – number 30 on the RECONS list at a distance of ~4.25 parsecs. The WDS catalog lists for this object a multiple with up to 8 components – all of them but the primary extremely faint and opticals as it seems. With so far only one observations this is either a neglected or bogus object. No duplicated_source indication in DR2 with a RUWE value ~1. Kervella et al. 2019 report a proper motion anomaly and Simbad suggests three planets with a question mark.

14. Van Maanen's Star (Wolf 28, GJ 35) – number 31 on the RECONS list at a distance of ~4.3 parsecs. DR2 without duplicated_source indication. StarHorse offers no data on this object suggesting a DR2 data quality issue. Makarov 2004 suggested a 0.08 Sun mass companion but this proposition seems meanwhile no longer plausible .

15. GJ 1 (HD 225213) – number 32 on the RECONS list at a distance of ~4.35 parsecs. With ~7.7 Gmag rather bright object with duplicated_source indication. StarHorse offers a median mass of ~0.50 and RUWE ~1 suggests no DR2 data quality issue. Kervella et al. 2019 report this object with a minor proper motion anomaly. Star system or not – this object moves with an amazing speed of ~6"/yr against the background stars and is for this reason of interest for visual observation.

16. ENG 61 (WDS 17364+6820, BD+68 947 for A, GJ 687 for B) – listed in the updated MSC catalog with B in ~4.55 parsecs distance, but A seems rather a background star with a distance of ~107 parsecs. So it seems a bit unclear why this object should be considered a physical star system (see also Winters et al. 2019, page 23). No entry in the 6th orbit catalog given for AB but a grade 9 orbit for Aa,Ab with a period of 24.5 years – this is a spectroscopic binary but too distant to be part of the solar neighborhood. GJ 687 is listed in the WDS catalog as STU 10 BC, but C is according to DR2 an optical background star.

17. GJ 440 (LAWD 37, HIP 57367, LTT 4364) – at a distance of ~4.6 parsecs, number 38 on the RECONS list. Kervella et al. 2019 discuss the possibility of a planet detected by proper motion anomaly. No duplicated_source indication in DR2. StarHorse offers no data on this object suggesting some DR2 data quality issues. Rather close to GJ 3618 at a median spatial distance of ~139,500 AU but the involved masses (similar magnitudes of GJ 440 and GJ 3618 suggest similar mass between 0.1 and 0.15) are too small to allow for gravitational relationship as the tidal radii do not overlap.

18. GJ 876 (G 156-57, IL Aqr) – at a distance of ~4.7 parsecs, number 40 on the RECONS list with 4 planets. Delfosse et al. 1999 list this object as binary with an orbit period of ~61 days but declare the companion as planet. Corresponding 6th orbit catalog entry Gl 876 (WDS 22533-1416) with a grade 9 orbit, no matching WDS object.

19. GJ 3618 (L 143-23) – at a distance of ~4.85 parsecs. For unknown reasons not even listed as single star on the RECONS list. DR2 indicates duplicated_source. StarHorse lists a median mass of 0.12 and RUWE <1 indicates no specific DR2 data quality issue.

20. ENG 42 (WDS 10114+4927, GJ 380) – number 44 on the RECONS list as single star at a distance of ~4.9 parsecs. WDS multiple with a linear solution. DR2 parallaxes give with the WDS secondary zero likelihood for gravitational relationship. Most interestingly, GJ 380 is with a spatial distance of slightly less than 200,000 AU rather close to GJ 412. StarHorse offers no median mass for GJ 380 but with ~5.9 Gmag at this distance less than 0.6 might be estimated giving a tidal radius of ~77,500 AU and about the same for the combined masses of GJ412 with 0.48/0.10. This means that the tidal radii of GJ 380 and GJ 412 do not even overlap so potential gravitational relationship seems most

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unlikely.

21. GJ 832 (HD 204961) – at a distance of ~5 parsecs, number 46 on the RECONS list with a planet. DR2 without a duplicated_source indication. StarHorse gives a median mass of ~0.47 (compared to 0.50 on the RECONS list) and RUWE ~1 suggests no DR2 data issues. Kervella et al. 2019 report a proper motion anomaly.

22. TNN 17 (WDS 22468+4420, HER 5, GJ 873) – at a distance of ~5 parsecs number 50 on the RECONS list as single star object. HER 5 is a wide WDS pair most likely optical. Tanner et al. 2010 reported two companions to GJ 873 but this observation lacks so far confirmation.

23. STFB 10 (WDS 19508+0852, GJ 768, Altair) – at a distance of ~5.1 parsecs. Number 53 on the RECONS list as single star. The WDS catalog lists a multitude of components, all of them obviously opticals.

24. ABE 12 (WDS 09396-2449, 2MASS J09393548-2448279) – brown dwarf at a distance of ~5.1 parsecs. Listed as number 57 on the RECONS list with a mass of 0.03. Fontanive et al. 2018 report a mass of ~0.04. The WDS catalog lists here with ABE 12 a close faint pair with an angular separation of 0.2” detected 2010 so far without confirmation. No entry in the 6th orbit catalog. No corresponding DR2 object. Burggasser et al. 2008 suggest that this object might be an unresolved binary based on luminosity and atmospheric properties – but with a question mark. Crossfield 2014 reported no indication of binarity and Dupuy and Liu 2012 stated “Our interpretation does not necessarily require unresolved binarity to explain the observations since we find that 2MASS J0939−2448 is unusual in color rather than in magnitude”.

25. WISEA J154045.67-510139.3 (2MASS J15404341-5101357) – assumed binary at a distance of ~5.3 parsecs. DR2 offers a parallax for this system but no resolution, also no duplicated_source indication. StarHorse lists a combined median mass of ~0.12 and RUWE ~1 – the latter means again no indication of a multiple source object. Burggasser et al. 2015 have this object on a list of “Dwarf Primaries within 10 pc” and Simbad lists this object as “Double or multiple star”. Not listed in the WDS catalog, not listed in the 6th orbit catalog and not on the RECONS 100 list (curiously not even as single source object). The reference given by Burgasser et al. 2015 with Pérez Garrido et al. 2014 reports the identification of this late-M dwarf but without any binary indication – so the property “double or multiple” seems a bit unclear.

26. LP 816-60 (HIP 103039) – number 64 on the RECONS list as single star at a distance of ~5.6 parsecs. DR2 indicates duplicated_source. StarHorse gives a median mass of 0.22 (compared to 0.19 on the RECONS list) and the RUWE value of ~1 suggests no DR2 data quality issues.

27. ENG 20 (WDS 05314-0336, GJ 205) – listed on the RECONS list as number 63 at a distance of ~5.7 parsecs as single star object. The wide WDS double star ENG 20 is according to the very different DR2 parallaxes for the components obviously optical.

28. STT 590 (WDS 19324+6940, GJ 764) – number 66 on the RECONS list as single star at a distance of ~5.8 parsecs. DR2 indicates duplicated_source. StarHorse gives a median mass of ~0.82 (compared with 0.89 on the RECONS list) and RUWE ~1 indicates good DR2 data quality. The WDS object STT 590 is listed with a linear solution and most likely optical – this assessment is clearly supported by the very different parallax values for the STT 590 components. Remains the DR2 duplicated_source indication as question mark.

29. GJ 693 (L 205-128) – number 69 on the RECONS list as single star at a distance of ~5.8 parsecs. DR2 indicates duplicated_source. StarHorse gives a median mass of ~0.30 (compared with 0.26 on the RECONS list) and RUWE ~1 indicates good data quality. GJ 693 is listed in the Clements et al. 2017 paper suggesting single star property.

30. GJ 754 (L 347-14) – number 72 on the RECONS list as single star at a distance of ~5.8 parsecs. DR2 indicates duplicated_source. StarHorse give a median mass of 0.21 (compared with 0.16 on the RECONS list) and RUWE ~1 indicates good DR2 data quality.

31. LAF 36 (WDS 07447+0333, GJ 285) – listed on the RECONS list as number 78 as single star at a distance of ~6 parsecs. The WDS catalog lists a wide double star with only one observation, so far unconfirmed and obviously either bogus or lost or optical.

32. GJ 139 (e Eri) – at a distance of ~6 parsecs. Number 80 on the RECONS list. DR2 indicates duplicated_source. StarHorse gives a median mass of ~0.90 (compared to 0.97 on the RECONS list) and RUWE ~1 indicates good DR2 data quality. Kervella et al. report proper motion anomaly and Simbad lists up to 6 planets. Proper motion is larger than 3”/yr so the fast change in position against the background stars might be of interest for visual observation.

33. GJ 780 (Del Pav) – number 83 on the RECONS list at a distance of ~6.1 parsecs as single star object. DR2 indicates duplicated_source. StarHorse gives a median mass of ~1.08 (compared to 1.1 on the RECONS list) and RUWE is smaller than 1.4 indicating no DR2 data quality issue.

34. LDS 611 (WDS 17461-3204, GJ 2130) – star system at a distance of 6.2 parsecs according to Hipparcos parallax values and also Delfosse et al. 2019. But this pair is according to DR2 data located at a distance of ~14.1 parsecs, most likely physical if with an extremely long period orbit.

35. BWL 43 (WDS 16254+5418, GJ 625, G 202-48) – number 96 on the RECONS list as single star at a distance of ~6.5 parsecs. The WDS catalog lists with BWL 43 a 5.4" wide double star with an extremely faint companion and so far only one observation. Simbad lists a possible planet with a question mark with reference to Mascareña et al. 2017.

36. STT 599 (WDS 23133+5710, GJ 892) – number 99 on the RECONS list as single star at a distance of ~6.5. The WDS catalog lists a wide most likely optical double star with a linear solution plus several other components also most likely opticals.

37. LAF 42 (WDS 10509+0648, GJ 402, Wolf 358) – number 105 on the RECONS list as single star at a distance of ~6.8 parsecs. The WDS catalog lists here with LAF 42 wide triple star with extremely faint companions and so far only one observation not confirmed since 2005. Was not found to be a star system in Winters et al. 2019.

38. HJ 2071 (WDS 01425+2016, 107 Psc, GJ 68, HD 10476) – at a distance of ~7.2 parsecs. Triple star listed in the WDS catalog with a linear solution. DR2 parallax values too different to be physical.

39. GJ 300 (HEI 202, WDS 00484+0517) – at a distance of ~7.4 parsecs. DR2 without duplicated_source indication. StarHorse gives a median mass of ~0.77 and a RUWE value <1 indicates good DR2 data quality. HEI 202 is a neglected WDS pair with so far only 2 observations, the last one in 1978. Companion not resolved in DR2 despite an angular separation of 2.7" – looks like a bogus object.

40. H 5 39 (WDS 18369+3846, Vega) – at a distance of ~7.7 parsecs, incredible dense star field, large number of obviously optical components listed in the WDS catalog. See Argyle et al. 2019, page 369.

41. GJ 109 (VX Ari) – suspected star system according to Winters 2015 (with reference to Lindegren et al. 1997) at a distance of ~7.7 parsecs. Winters et al. 2019 consider GJ 109 no longer as a candidate multiple.

42. WSI 138 (WDS 22481-2422) – supposed binary at a distance of ~7.7 parsecs without corresponding object in DR2 but close to Fomalhaut C (LP 876-10). This object is either a star system of its own listed as such in the WDS catalog (as neglected system with so far only one observation) or part of the Fomalhaut system. This system is listed in Simbad as WDS 22577-2937 Ca,Cb means as part of the Fomalhaut system while such a Ca,Cb object does not exist in the WDS catalog. If WSI 138 is real then it seems lost else it might be considered bogus.

43. GJ 1151 (G 122-49) – at a distance of ~8 parsecs with a duplicated_source indication in DR2. StarHorse median mass is 0.20 and the RUWE value of ~0.8 suggests no DR2 data quality issues.

44. GJ 178 (STT 560, WDS 04498+0658) – at a distance of ~8 parsecs. STT 560 is a wide double star with a linear solution in the Second Catalog of Rectilinear Elements and with completely different DR2 parallax values of the components. GJ 178 is listed in DR2 with duplicated_source indication. StarHorse offers no data on this object indicating DR2 data quality issues. GJ 178 is part of the IC 2391 open cluster.

45. GJ 1154 (G 13-22, LHS 2531) – in Bonfils et al. 2013 reported as unresolved spectroscopic binary star system at a distance of ~8.1 parsecs. Not resolved in DR2 but with parallax given for AB yet without duplicated_source indication. No WDS object. Bar et al. 2017 looked here in vain for a white dwarf companion and the Davison et al. 2015. The Rodriguez et al. 2015 efforts were also negative regarding duplicity. Henry at al. 2018 express caveats to list this object as close double.

46. HEL 2 (WDS 08127-2133, GJ 300, L 674-15) – proposed double star at a distance of ~8.1 parsecs with component B missed in DR 2 despite an angular separation of ~2" listed in the WDS catalog. Passegger et al. 2018 report a stellar mass of ~0.19. Cortés-Contreras et al 2017 did not find a companion with high-resolution imaging. Reiners et al. 2018 did not find an exoplanet for GJ 300. Only one observation in 2002 listed in the WDS catalog and never confirmed – so this is most likely a single star. An additional component listed in the WDS catalog as CRC 16 is according to Cortés-Contreras et al 2017 optical.

47. L 173-19 (2MASS J02003830-5558047) – at a distance of ~8.2 parsecs. Duplicated_source indication in DR2. StarHorse lists a median mass of 0.31 and RUWE with ~1.2 suggesting no DR2 data quality issues.

48. GJ 1289 (G 130-4) – at a distance of ~8.35 parsecs. Duplicated_source indication in DR2. StarHorse lists a median mass of 0.25. RUWE is slightly larger than 1.4 suggesting minor DR2 data quality issues.

49. SCR J1546-5534 (2MASS J15464185-5534468) – supposed star system at a distance of ~8.4 parsecs not resolved in DR2, parallax given with a rather large error range yet without duplicated_source indication. No WDS object. No 6th orbit catalog object. Reported in Boyd et al. 2011 with a distance of ~6.7 parsecs (marked as suspect) and later in Henry et al. 2018 with a distance of 9.7 parsecs. No data given for this object by StarHorse indicating rather serious DR2 data quality issues – the given DR2 error ranges are rather large not only for parallax but also for RA/Dec and proper motion. Henry et al. 2018 suggest that the secondary contributes significant light to the system and is not of low mass. Overall the evidence that this object is a binary seems scarce.

50. BU 1433 (WDS 12337+4121, GJ 475, HD 109358) – wide double star at a distance of ~8.45 parsecs, resolved in DR2 with the secondary obviously optical due to a very different parallax. Bonavita and Desidera 2020 list HD 109358 still as binary with masses of 1.05/0.31. WDS lists additionally a spectroscopic binary BNU 4 Aa,Ab meanwhile declared bogus.

51. GJ 318 (WD 0839-327, CD-32 5613) – at a distance of ~8.5 parsecs. According to Toonen et al. 2017 a potential white dwarf double star system.

52. GJ 17 (Zet Tuc) – at a distance of ~8.5 parsecs. Duplicated_source indication in DR2. StarHorse lists a median mass of ~1.0 and RUWE <1 suggests no DR2 data quality issues. Fuhrmann et al. 2017 consider GJ 17 (HD 1581) as single star.

53. GJ 493.1 (Wolf 461) – at a distance of ~8.6 parsecs. Duplicated_source indication in DR2. StarHorse median mass is ~0.21 and RUWE of ~1.3 suggests no DR2 data quality issue.

54. BWL 20 (WDS 06049-3434, LP 949-15) – at a distance of ~8.7 parsecs. Listed as quadruple system in the WDS catalog but most likely the assumed companions are background stars. The AB pair is listed with WDS code "U" which means "Proper motion or other technique indicates that this pair is non-physical". WDS lists so far only 3 observations.

55. LP 991-84 (2MASS J01392170-3936088) – at a distance of ~8.75 parsecs. Duplicated_source indication in DR2. StarHorse median mass is ~0.16 and RUWE of ~1.2 suggests no DR2 data quality issue. Bartlett et al. 2017 report for this object 14.48 Vmag and spectral type M4.5V. Missing Hα emission indicates that LP 991-84 is an old star.

56. GL 465 (Ross 695, LHS 45) – at a distance of ~8.9 parsecs. According to Winters et al. 2019 a "candidate" binary (with reference to Heintz 1986). No resolution in DR2, no duplicated_source marker. StarHorse median mass ~0.3 and RUWE ~1.2 suggests good DR2 data quality. No WDS and no 6th orbit catalog object. Not resolved by Ward-Duong et al. 2015, no other sources found indicating multiplicity for GL 465.

57. TAM 1 (WDS 11200+6551, GJ 424, SZ UMa) – suspected spectroscopic binary at a distance of ~9.1 parsecs not resolved in DR2, parallax given without duplicated_source indication. StarHorse median mass is given with ~0.50 and RUWE is ~1. Listed in the WDS catalog with so far only one observation in 2004 reported by Docobo et al. 2006. The suspected companion is assumed an M 4.5 dwarf with a mass of ~0.18 and with a possible orbital period of about 2.5 years. Not listed in the 6th orbit catalog. Reported as not resolved by Jodar et al. 2013 and Ward-Duong et al. 2015. This is a neglected WDS object so far not confirmed, might be bogus.

58. GJ 433 (LHS 2429, CD-31 9113) – at a distance of ~9.1 parsecs. Not resolved in DR2, parallax and proper motion data given with duplicated_source indication. StarHorse combined median mass is ~0.50 and RUWE of ~1.1 suggests no DR2 data quality issue. Detected as star system by Hipparcos, but not confirmed. Currently considered a planet-hosting star. Not listed in the WDS catalog but the 6th orbit catalog gives for GJ 433 a grade 9 orbit with a period of ~500 days.

59. 2MA 1750-0016 (2MASS J17502484-0016151) – suspected pair of brown dwarfs at a distance of ~9.2 parsecs with the secondary so far visually not resolved. Not resolved in DR2, parallax and proper motion data for combined object without duplicated_source marker. Not included in the WDS catalog, reported in Henry et al. 2018 ("We have discovered an unseen companion, presumably a lower mass brown dwarf, that causes the perturbation on the photocenter") with a photocentric grade 9 orbit with a period of ~6.7 years listed in the 6th orbit catalog with WDS ID 17504-0016 and discoverer designation "NONE". Not confirmed as candidate with rotational modulations and composite atmosphere by Manjavacas et al. 2019.

60. GJ 3801 (Ross 1015) – at a distance of ~9.2 parsecs. Duplicated_source indication in DR2. StarHorse median mass is ~0.32 and the RUWE value of ~1 suggests no DR2 data quality issue.

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61. GJ 502 (STT 578, WDS 13119+2753) – at a distance of ~9.2 parsecs. STT 578 is a wide double star with a linear solution declaring it most likely optical and very different DR2 parallaxes of the components support this assessment. Duplicated_source indication for GJ 502 in DR2. StarHorse gives a median mass of ~1.0 and RUWE <1 suggests no DR2 data quality issues.

62. GJ 451 (HD 103095, no WDS object) – potential star system at a distance of ~9.2 parsecs with component B missing in DR2. Parallax error for A is moderate and no duplicated_source indication is given. StarHorse gives a combined median mass of 0.65 and RUWE is ~1 – again no duplicity indication. Simbad notes "… suspected flaring companion; it is not clear that it actually exists". Kervella et al. 2019 dismiss the discussed possibility of an M dwarf companion but consider planetary companions as possible.

63. GJ 827 (HR 8181, Gam Pav) – at a distance of ~9.3 parsecs. Duplicated_source indication in DR2. StarHorse median mass is ~1.0 and RUWE of ~1 suggests no DR2 data quality issue. Fuhrmann et al. 2017 consider GJ 827 as single star.

64. LDS 6210 (WDS 07519+0001, GJ 1103) – according to the WDS catalog a double star at a distance of ~9.3 parsecs. However, the given companion could not be observed since 1960 and also Henry et al. 2018 report negative efforts in this direction. Bogus might be assumed.

65. KAM 1 (WDS 06109+1020, GJ 228, BD+10 1032, LHS 1830) – at a distance of ~9.9 parsecs. Not resolved in DR2, object without parallax and proper motion data but with duplicated_source indication. Listed in the WDS catalog with 15 observations since 1945, not listed in the 6th orbit catalog. Sperauskas et al. 2019 mention an estimated orbit period of 20 years but Izmailov 2019 suggests an orbit with a period of ~168 years. A third most likely optical component is listed in the WDS catalog with the designation LMP 35. Ward-Duong et al. 2015 report masses of 0.45/0.22. Gliese et al. 1991 give for GJ 228 a parallax of 100.8 mas used here to derive the distance of ~9.9 parsecs but van Leeuwen 2007 (Hipparcos new reduction) suggests a parallax of 91.65 mas. So it remains open until the next GAIA data release if this object is within a distance of 10 parsecs or not.

66. GJ 172 (HD 232979) – at a distance of ~9.9 parsecs. Duplicated_source indication in DR2. StarHorse median mass is ~0.60 and RUWE of ~1.1 suggests no DR2 data quality issue.

67. FRT 1/MEL 2 (WDS 14545+1606, GJ 569) – assumed triple star system at a distance of ~10 parsecs. FRT 1 is a curious pair with A at ~9.9 and B at ~10.7 parsecs distance but the barycenter should due to the huge mass difference be rather close to the primary which locates the system most likely within the 10 parsecs limit used for this report. Reported as star system within 10 parsecs from the Sun also from BOUY et al. 2003. DR2 RUWE for A is >4 so some caveats regarding DRs data quality are appropriate. So far 12 observations are listed in the WDS catalog since 1985, no entry in the 6th orbit catalog. The difference in parallax has necessarily a noticeable effect on the spatial distance between the components in the simulation with a minimum of ~70,000 AU and a median value of ~150,000AU. The StarHorse median masses of ~0.51/0.12 indicate tidal radii of ~71,000/34,600 AU and suggest a best-case scenario with the companion located just within the tidal radius of the primary. Overall, the given data suggest only a tiny likelihood of 0.41 for gravitational relationship. The minimum period of a potential orbit would be >29 million years – far too long to have any chance to get enough measurements for a reasonable orbit calculation in a human time span. The DR2 proper motion values do not suggest common proper motion but are not different enough to suggest a simple random encounter. The J2000 positions calculated from the J2015.5 positions using the given proper motion values seem to be a bad match with the effective J2000 positions. So the DR2 proper motion data quality might either be considered questionable or else we might just now observe a phase of significant change in proper motion due to gravitational forces not reflected by the currently available data.

The subsystem MEL 2 Ba,Bb is a spectroscopic binary of late M-dwarfs (Crossfield 2014 reports Ba,Bb as M8.5/M9 pair) with a distance already outside 10 parsecs. Listed in the 6th orbit catalog with a grade 2 orbit with a period of ~2.4 years based on 32 observations since 1999 listed in the WDS catalog. Despite the obvious duplicity, DR2 indicates no duplicated_source for B but the parallax error is rather large. Ward-Duong et al. 2015 report for these triple star system masses of 0.49/0.09/0.08 – a reasonable close match to the StarHorse values.

5. Discussion

- Most systems listed have a corresponding DR2 object if in many cases lacking resolution due to close angular separations and often also without parallax and proper motion data. About half of the objects are listed in DR2 with parallax and proper motion data for at least a part of the components allowing for reliable assessment of potential gravitational relationship (see Appendix C)

- A slightly disturbing pattern of the simulation results vs. listed orbits is the tendency that the calculated minimum values for distance and orbit period are often very close to suggested orbits, which are in most cases rather good supported by the existing measurements. From a simple statistical point of view, it would be to expected that in on average the median distance and orbit period values would be the corresponding ones. The reason for this pattern seems to be that the GAIA DR2 single star model is for good reasons not suited to deliver fully convincing astrometric data for the components of star systems
- A few objects detected with obviously questionable DR2 data quality support this impression. Yet is has to be stated again that the provided DR2 parallax data is reliable enough for assessing star systems as physicals
- The Izmailov program is an extremely valuable tool for calculating preliminary orbits with a weakness in case of short period orbits with observation time deltas larger than the orbit period (often combined also with quadrant ambiguities)
- With only few exceptions, nearly all listed systems are included in the WDS catalog but over 15% of these are neglected objects with a poor observation history. The high technical requirements for resolving very close and faint pairs might in most such cases be the cause
- A bit surprising is the fact that several systems have an entry in the 6th orbit catalog without a corresponding WDS object due to a missing observation history – usually a grade 9 astrometric orbit based for example on observed proper motion or radial velocity anomalies
- About 2.82% of the DR2 objects are marked as duplicated_source but about 40% of the listed spectroscopic or very close unresolved binaries are marked as duplicated_source. The likelihood that this is a result just by chance is actually zero while the result that about 60% or more are not listed as such has a likelihood of 1. This does not suggest that a large percentage of duplicated_source objects has to be binaries but commands to have a closer look at such objects. On the other side, it has little relevance if an object is not marked as duplicated_source as this is a result to expect.
- The number of known star systems within 10 parsecs will certainly get larger over time, but detecting new pairs within this distance might take some time. Most recent ongoing spectroscopic binary research (Merle et al. 2020) reports in total >800 new candidates with the closest one in ~187 parsecs. The currently nearest "newly" detected wide physical pair is GJ 3346 reported by Bonavita et al. 2020 in ~23.8 parsecs distance – already listed in the WDS catalog some time ago as KPP2710 with note code "T" for physical by common parallax.

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- DSS2 and 2MASS images
- Aladin Sky Atlas v10.0
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- USNO Second Catalog of Rectilinear Elements
- USNO 6th Orbit Catalog
- Hipparcos Catalog (CDS I/311/HIP2, New Reduction, van Leeuwen 2007)
- Observations of binary stars at the WIYN telescope (VizieR J/AJ/153/212)
- Orbits of 451 wide visual double stars (VizieR J/PAZh/45/35)
- CDS VizieR
- CDS TAPVizieR
- MSC – Updated Multiple Star Catalog (VizieR J/ApJS/235/6)
- GAIA Archive (ADQL Search)
- Gaia@AIP Services hosted by the Leibniz-Institute for Astrophysics Potsdam (AIP)
- RECONS list with 100 nearest stars and star systems (http://www.recons.org/TOP100.posted.htm)
- Nearby Stars Catalog (NSC) from the Planetary Habitability Laboratory
- CNS3 – Preliminary Version of the Third Catalogue of Nearby Stars (VizieR V/70A)
- ARICNS Astronomisches Rechen-Institut Heidelberg Data Base for Nearby Stars
- AstroPlanner V2.2
- Program for calculating orbits by Thiele-Innes method published by Izmailov 2019 (http://izmccd.puldb.ru/vds.htm)
- Program for plotting orbits: Binary Star Calculator (Brian Workman: http://www.saguaroastro.org/wp-content/sac-docs/ObservingDownloads/binaries_6th_Excel97.zip)
- RMC tool for assessing double stars as potential binary (Rica 2015)

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Appendix A

Description of the PGR assessment procedure (according to Knapp 2018, extended):

- GAIA DR2 data for RA/Dec and Plx are used for a Monte Carlo simulation assuming a normal distribution for these parameters with the given error range as standard deviation. The distance between the components is calculated from the inverted simulated parallax data and the simulated angular separation using the law of cosine with *a* and *b* = distance vectors for the stars A and B in lightyears calculated as (1000/Plx)*3.261631 and γ = angular separation in degrees calculated as

$$c = \sqrt{a^2 - 2ab\cos(\gamma) + b^2}$$

- The tidal radius of the Sun TR($M_\odot$) is considered to correspond with the outer rim of the assumed Oort cloud at a distance of ~100,000 AU as the radius at which the Sun's gravitational force is equivalent to the gravitational force of the stellar neighborhood. For objects with significantly different mass from the Sun this tidal radius TR has to be recalculated for a corresponding gravitational acceleration of 5.8732910^{-13} m/s^2. Potential gravitational relationship PGR is assumed to be given with overlapping tidal radii of two stellar objects, which does not necessarily mean that an orbit exists but that at least the movement of both stars through space should be noticeable influenced mutually by gravitational forces.

$$\gamma = \arccos\left[\sin(DE1)\sin(DE2) + \cos(DE1)\cos(DE2)\cos(|RA1 - RA2|)\right]$$

- The likelihood for potential gravitational relationship (LPGR) is the percentage of simulation distance results smaller than the sum of the tidal radii TR1+TR2 out of the simulation sample with a size of 120,000 corresponding with the likelihood that the real distance is smaller than TR1+TR2 with an margin of error of 0.37% at 99% confidence.

- The minimum, median and maximum distance is the smallest, median and largest result of the simulation sample.

- Ignoring the likely effects of eccentricity the smallest/median/largest distance is used as estimation for the value for the semi-major axis of a potential circular orbit. This allows for the calculation of a minimum/median/maximum orbit period assuming zero inclination using either median mass data from StarHorse (Anders et al. 2019) or if not available mass data from other sources (for example estimation from luminosity^(1/4) for assumed masses between 0.43 and 2 solar masses).

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

Appendix B

Table 2: Astrometric and Photometric Measurements

Content description:
WDS = WDS ID
Disc = Discoverer code
C = Components (AB if blank)
RA/Dec = Positions for primary and secondary in HH:MM:SS.sss/DD.MM.SS.ss format
dRA/dDec = Plate solving errors for RA and Dec in arcseconds
Sep = Calculated separation in arcseconds
e_Sep = Separation error
PA = Calculated position angle in degrees
e_PA = Position angle error
Mag = Vmags for both components measured by differential photometry
e_Mag = Magnitude errors
SNR = Signal to noise ratio for both components
dVmag = Plate solving error in Vmag
Date = Julian observation epoch
Notes = Additional comments listed below table 1

WDS	Disc	C	RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
18411+2447	LDS6330		18 41 10.484	24 47 16.23	0.07	0.07	4.51976	0.09899	5.359	1.255	12.345	0.071	124.31	0.07	2019.71160	5	1)
			18 41 10.515	24 47 20.73							14.893	0.077	33.12				
19539+4425	GIC 159		19 53 55.226	44 24 42.60	0.10	0.09	6.02025	0.13454	68.566	1.280	13.618	0.091	72.48	0.09	2019.72275	5	1)
			19 53 55.749	44 24 44.80							14.271	0.093	48.61				
21516+5918	KPP4430		21 51 38.084	59 17 39.90	0.10	0.09	14.80181	0.13454	111.980	0.521	10.678	0.090	205.48	0.09	2019.72276	4	2)
			21 51 39.876	59 17 34.36							14.675	0.094	37.80				
18428+5938	STF2398		18 42 43.252	59 38 24.84	0.07	0.06	11.29407	0.09220	181.539	0.468	8.180	0.140	198.84	0.14	2019.72526	5	3)
			18 42 43.212	59 38 13.55							8.970	0.140	147.29				
21069+3845	STF2758		21 07 00.931	38 46 02.18	0.08	0.08	31.84981	0.11314	153.008	0.204	4.278	0.150	364.20	0.15	2019.72527	5	4)21)
			21 07 02.167	38 45 33.80							5.001	0.150	384.17				
00184+4401	GRB 34		00 18 28.166	44 01 30.92	0.11	0.10	34.06866	0.14866	66.326	0.250	7.696	0.140	137.70	0.14	2019.72850	5	3)
			00 18 31.059	44 01 44.60							10.675	0.141	63.53				
00491+5749	STF 60		00 49 08.936	57 48 43.49	0.07	0.08	13.55377	0.10630	326.712	0.449	2.626	0.150	244.32	0.15	2019.73136	4	5)22)
			00 49 08.005	57 48 54.82							6.055	0.150	159.15				
01388-1758	LDS 838		01 39 06.065	-17 56 51.63	0.06	0.10	1.90552	0.11662	346.135	3.502	12.247	0.092	52.39	0.09	2019.73222	6	6)23)
			01 39 06.033	-17 56 49.78							12.325	0.093	47.99				

Table 2: Astrometric and Photometric Measurements

Table 2 continues on the next page.

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

WDS	Disc	C	RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
01398-5612	DUN 5		01 39 48.425	-56 11 35.58	0.05	0.12	11.28329	0.13000	186.072	0.660	5.463	0.080	241.31	0.08	2019.73787	4	7)21)
			01 39 48.282	-56 11 46.80							5.597	0.080	250.61				
04153-0739	STF 518	A	04 15 13.396	-07 40 17.87	0.06	0.08	82.69054	0.10000	101.998	0.069	5.721	0.060	611.63	0.06	2019.73494	5	8)24)
		B	04 15 18.837	-07 40 35.06							9.498	0.060	197.52				
04153-0739	STF 518	A	04 15 13.396	-07 40 17.87	0.06	0.08	77.51383	0.10000	97.472	0.074	5.721	0.060	611.63	0.06	2019.73494	5	8)24)
		C	04 15 18.566	-07 40 27.95							11.298	0.061	82.04				
04153-0739	STF 518	B	04 15 18.837	-07 40 35.06	0.06	0.08	8.17200	0.10000	330.464	0.701	9.498	0.060	197.52	0.06	2019.73494	5	8)
		C	04 15 18.566	-07 40 27.95							11.298	0.061	82.04				
05445-2227	H 6 40		05 44 27.416	-22 27 01.35	0.06	0.07	97.53578	0.09220	349.493	0.054	3.802	0.080	192.97	0.08	2019.73788	5	9)22)
			05 44 26.133	-22 25 25.45							5.796	0.080	290.14				
04312+5858	STI2051		04 31 14.825	58 57 57.16	0.11	0.10	10.47241	0.14866	56.632	0.813	10.621	0.161	67.80	0.16	2019.76183	5	3)
			04 31 15.956	58 58 02.92							12.256	0.164	31.61				
04312+5858	STI2051		04 31 14.857	58 57 57.11	0.08	0.08	10.61075	0.11314	56.865	0.611	10.413	0.151	79.69	0.15	2019.76995	5	3)
			04 31 16.006	58 58 02.91							11.855	0.152	40.47				
00321+6715	VYS 2		00 32 35.451	67 14 02.99	0.09	0.12	2.93986	0.15000	188.173	2.921	10.132	0.131	63.14	0.13	2019.72851	3	10)23)
			00 32 35.379	67 14 00.08							10.857	0.132	42.08				
09144+5241	STF1321		09 14 19.426	52 41 00.54	0.15	0.18	16.90172	0.23431	99.158	0.794	7.124	0.130	147.85	0.13	2019.82759	3	11)
			09 14 21.261	52 40 57.85							7.232	0.130	132.11				
08582+1945	LDS3836		08 58 14.008	19 45 46.34	0.08	0.11	2.08207	0.13601	244.389	3.738	14.016	0.077	32.29	0.07	2019.83164	9	12)25)
			08 58 13.875	19 45 45.44							14.342	0.089	18.98				
08582+1945	LDS3836		08 58 13.983	19 45 46.13	0.03	0.04	2.00714	0.05000	242.397	1.427	13.985	0.056	43.38	0.05	2019.99443	5	13)
			08 58 13.857	19 45 45.20							14.553	0.067	24.22				
08582+1945	LDS3836		08 58 13.976	19 45 46.24	0.10	0.12	2.00404	0.15620	241.703	4.457	13.992	0.089	19.01	0.07	2019.99740	4	14)26)
			08 58 13.851	19 45 45.29							14.418	0.111	12.11				
08582+1945	LDS3836		08 58 13.989	19 45 46.17	0.07	0.06	2.26455	0.09220	241.516	2.331	14.057	0.035	56.76	0.03	2019.99982	5	15)
			08 58 13.848	19 45 45.09							14.426	0.040	41.49				

Table 2 (continued). Astrometric and Photometric Measurements

Table 2 concludes on the next page.

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

WDS	Disc	C	RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
08582+1945	LDS3836		08 58 13.971	19 45 46.05	0.10	0.07	2.24462	0.12207	240.948	3.113	14.073	0.067	37.27	0.06	2020.00664	5	15)
			08 58 13.832	19 45 44.96							14.529	0.075	23.56				
08582+1945	LDS3836		08 58 13.970	19 45 46.22	0.02	0.02	2.22259	0.02828	245.264	0.729	14.085	0.031	125.67	0.03	2020.12265	5	15)
			08 58 13.827	19 45 45.29							14.483	0.032	96.10				
02361+0653	PLQ 32	A	02 36 07.276	06 53 41.71	0.06	0.15	164.18328	0.16155	109.543	0.056	5.535	0.170	378.97	0.17	2019.89260	2	16)
		C	02 36 17.666	06 52 46.79							11.395	0.171	52.53				
02361+0653	PLQ 32	A	02 36 07.280	06 53 41.77	0.09	0.13	164.24694	0.15811	109.605	0.055	5.632	0.160	1098.98	0.16	2019.96350	2	10)
		C	02 36 17.670	06 52 46.66							11.544	0.162	46.42				
11055+4332	VBS 18		11 05 20.535	43 31 55.13	0.10	0.11	32.26727	0.14866	125.484	0.264	8.664	0.100	186.87	0.10	2019.89883	4	17)
			11 05 22.951	43 31 36.40							14.520	0.114	19.44				
06337-7538	LDS 169		06 33 41.937	-75 37 42.50	0.06	0.07	21.06120	0.09220	35.007	0.251	10.603	0.084	23.18	0.07	2019.89927	3	18)
			06 33 45.182	-75 37 25.25							11.782	0.084	23.00				
19072+2053	LDS1017		19 07 12.502	20 52 30.67	0.08	0.06	113.81944	0.10000	290.134	0.050	10.093	0.142	49.49	0.14	2019.90034	3	11)
			19 07 04.877	20 53 09.85							10.073	0.141	53.62				
06579-4417	LPM 248		06 57 44.323	-44 17 30.44	0.07	0.08	2.49576	0.10630	64.613	2.439	11.252	0.082	61.44	0.08	2019.90204	5	8)
			06 57 44.533	-44 17 29.37							11.170	0.082	64.82				
06523-0510	WNO 17		06 52 17.321	-05 10 25.50	0.08	0.09	58.86532	0.12042	180.771	0.117	6.309	0.080	348.57	0.08	2020.05202	5	8)
			06 52 17.268	-05 11 24.36							9.880	0.080	144.37				
07402-1724	LUY5693	A	07 40 22.378	-17 25 00.10	0.08	0.08	20.26724	0.11314	279.658	0.320	12.852	0.090	162.23	0.09	2020.05211	4	19)
		C	07 40 20.982	-17 24 56.70							16.659	0.098	26.91				
11345-3250	LDS6245		11 34 28.444	-32 49 36.23	0.07	0.09	15.12676	0.11402	128.516	0.432	5.892	0.090	211.21	0.09	2020.05526	5	20)
			11 34 29.383	-32 49 45.65							15.198	0.130	11.11				
14575-2125	H N 28		14 57 29.509	-21 25 30.67	0.08	0.07	26.19354	0.10630	306.854	0.233	5.561	0.090	366.67	0.09	2020.16209	5	20)
			14 57 28.008	-21 25 14.96							7.777	0.004	250.54				

Table 2 (conclusion). Astrometric and Photometric Measurements

Table Notes:

1) iT24 5x30s
2) iT24 4x25s
3) iT24 5x3s
4) iT24 5x2s
5) iT24 4x1s
6) iT32 6x10s
7) iT32 4x1s
8) iT32 5x3s
9) iT32 5x1s
10) iT24 3x3s
11) iT24 3x2s
12) iT24 9x15s
13) iT24 5x25s
14) iT24 4x15s
15) iT24 5x45s
16) iT24 2x3s
17) iT24 4x10s
18) iT32 3x3s
19) iT32 4x60s
20) iT32 5x5s
21) A and B too bright for reliable photometry
22) Star disk A saturated
23) Overlapping star disks
24) Star disk for A saturated
25) SNR B <20 26) SNR A and B <20

Appendix C

Table 3: Assessment potential gravitational relationship

```
Content description:
#           =  System number
Object      =  Object name
Comp        =  Components
PA          =  Position angle 2015.5
e_PA        =  PA error
Sep         =  Separation 2015.5 in arcseconds
e_Sep       =  Sep error
Vest1       =  Visual magnitude estimation primary
Vest2       =  Visual magnitude estimation secondary
Plx1        =  Parallax primary in mas from Gaia DR2
Plx2        =  Parallax secondary in mas from Gaia DR2 (red type if from Hipparcos)
Min_D_AU    =  Minimum spatial distance in AU between components
M1_50       =  Mass50 value primary from StarHorse catalog (red type if other source)
M2_50       =  Mass50 value secondary from StarHorse catalog (red type if other source)
P_M50_min   =  Minimum period for circular orbit with mass50 value
P_M50_med   =  Median period for circular orbit with mass50 value
TR1_AU      =  Tidal radius accordint to M1_50
TR2_AU      =  Tidal radius accordint to M2_50
LPGR        =  Likelihood of potential gravitational relationship
```

Note: The provided data is given for assessing potential gravitational relationship but is not intended for updating the WDS catalog.

#	Object	Comp	PA	e_PA	Sep	e_Sep	Vest1	Vest2	Plx1	Plx2	Min_D_AU	M1_50	M2_50	P_M50_min	TR1_AU	TR2_AU	LPGR
4	LDS 838		13.186	0.010	2.26848	0.00041	12.68284	13.08279	369.9318	372.1631	429	0.15337	0.14118	16 478	39 162	37 574	100.00
5	KPP4431		77.507	0.000	4037.13732	0.00119	17.25877	17.79940	353.9577	365.2450	14 989	0.10000	0.10000	4 126 297	31 623	31 623	100.00
7	STF2758		152.491	0.000	31.56493	0.00013	6.79598	7.36499	285.9459	286.1457	110	0.69579	0.60451	1 021	83 414	77 750	100.00
8	KPP4432	AI	270.140	0.000	10670.99691	0.00189			284.5600	262.9800	50 969	2.07000	0.26000	7 580 096	143 875	50 990	100.00
9	STF2398		179.642	0.001	11.60023	0.00022	9.56599	10.21280	283.9489	283.8624	41	0.37965	0.30127	318	61 615	54 888	100.00
10	GRB 34		65.447	0.000	34.37728	0.00006	8.89724	11.32636	280.6902	280.7866	122	0.45006	0.18283	1 712	67 087	42 759	100.00
11	KPP4437		262.015	0.000	27457.16343	0.00055	5.76229	12.23604	277.5162	269.3628	101 989	0.84756	0.15967	32 633 762	92 063	39 958	100.00
14	KR 60		290.352	0.040	1.41861	0.00098	10.20511	10.82552	249.3926	249.9668	6	0.42406	0.25001	17	65 120	50 001	100.00
17	KPP4436		29.017	0.000	10662.46882	0.00014	9.95732	11.24747	219.8012	199.7031	105 568	0.39851	0.32356	40 589 063	63 128	56 882	100.00
18	GIC 159		69.605	0.007	6.00158	0.00075	13.46954	14.02837	213.1329	214.5285	28	0.18933	0.13184	263	43 512	36 310	100.00
21	STF 518	AC	97.487	0.001	78.10102	0.00097	6.22881	11.49909	198.5657	199.4552	391	0.84291	0.30201	7 261	91 810	54 955	100.00
23	LDS3836		228.791	0.005	2.13136	0.00020	14.01049	14.65003	194.7225	195.0836	11	0.14445	0.14083	68	38 007	37 528	100.00
24	STI2051		58.407	0.001	10.22257	0.00017	11.37987	12.40241	180.4215	181.2815	56	0.34966	0.67500	420	59 132	82 158	100.00
26	H N 28	AB	306.551	0.003	25.72452	0.00153	7.12475	8.87789	170.0112	168.7700	151	0.78000	0.91000	1 440	88 318	95 394	76.73
27	STF 60		324.232	0.004	13.31607	0.00094	5.76711	8.32128	171.2861	168.7521	465	0.99074	0.63000	7 933	99 536	79 373	100.00
29	LDS6334		152.491	0.000	75.48951	0.00016	9.70421	17.19779	169.1590	168.9620	446	0.50067	0.07000	12 536	70 758	26 458	100.00
30	SHJ 243	AB	140.934	0.004	5.06461	0.00039	6.65991	6.65250	167.8221	167.7764	30	0.79360	0.78808	132	89 084	88 774	100.00
30	SHJ 243	AC	74.144	0.000	733.52716	0.00021	6.65991	7.51951	167.8221	168.0689	4 360	0.79360	0.69728	237 117	89 084	83 503	100.00
33	WIR 1		78.037	0.001	5.38071	0.00012	10.66408	12.54770	159.7098	160.0598	34	0.45071	0.25146	234	67 135	50 146	100.00

Table 3. Assessment potential gravitational relationship

Table 3 concludes on the next page.

Star Systems in the Solar Neighborhood up to 10 Parsecs Distance

#	Object	Comp	PA	e_PA	Sep	e_Sep	Vest1	Vest2	Plx1	Plx2	Min_D_AU	M1_50	M2_50	P_M50_min	TR1_AU	TR2_AU	LPGR
34	STF1321		97.728	0.000	17.08255	0.00006	8.51341	8.58641	157.8796	157.8851	108	0.60142	0.60063	1 031	77 551	77 500	100.00
36	UC 3253	CF	150.093	0.000	298.80544	0.00023	11.93522	16.57629	153.9189	153.8139	1 938	0.24959	0.10000	145 069	49 959	31 623	100.00
40	STF1888		302.677	0.003	5.69834	0.00029	6.36456	7.94896	148.5195	148.2131	38	0.86517	0.69574	192	93 014	83 411	100.00
43	PLQ 32	AC	109.531	0.000	164.16488	0.00018	7.14764	11.89127	138.2084	138.4637	1 184	0.79540	0.30221	39 102	89 185	54 974	100.00
45	MAM 1	BC	346.155	0.000	26737.95765	0.00013	7.61212	12.71215	131.4380	130.3032	204 136	2.61772	0.14080	55 839 085	161 794	37 524	0.00
52	LPM 248		68.030	0.002	2.35430	0.00009	11.74682	11.76171	124.3810	124.5740	19	0.37545	0.30225	103	61 274	54 977	100.00
54	KPP4430		111.954	0.003	14.64214	0.00078	10.93868	14.58762	123.0568	118.1243	33 031	0.50268	0.15000	7 472 048	70 900	38 730	100.00
56	DUN 5		186.778	0.000	11.41301	0.00008	7.08969	7.18319	122.0552	122.1333	93	0.76806	0.74678	738	87 639	86 416	100.00
57	STF2220	A,BC	248.887	0.002	35.31150	0.00123	5.76548	10.19625	119.1128	119.7908	293	1.27105	0.69979	3 601	112 741	83 653	100.00
62	WNO 17		180.624	0.000	58.82786	0.00009	7.69497	10.49320	114.2968	114.4148	514	0.75177	0.50168	10 470	86 705	70 830	100.00
63	BSO 13		77.858	0.003	10.38411	0.00051	9.39590	6.91379	120.1791	113.8158	66 233	0.83219	0.52000	14 739 776	91 225	72 111	100.00
64	LDS1017		290.221	0.000	114.05612	0.00024	11.06163	11.06649	113.2063	113.3401	1 006	0.35008	0.35020	38 349	59 167	59 178	100.00
65	LDS 169		35.126	0.000	21.74217	0.00006	10.79539	11.64998	113.1206	113.1455	192	0.35798	0.34785	3 186	59 831	58 979	100.00
67	HEN 4		253.783	0.011	1.31850	0.00025	13.73770	14.88175	112.6759	112.4936	12	0.12240	0.10000	85	34 986	31 623	100.00
68	H 6 40		349.601	0.000	97.41947	0.00047	5.73603	7.37987	112.6109	112.4005	866	1.37901	0.79112	17 396	117 431	88 945	100.00
69	HJ 3126		169.577	0.000	24.87462	0.00013	11.66897	9.69613	113.1171	112.3669	4 459	0.60029	0.38573	347 511	77 479	62 107	100.00
71	KPP4433	AD	313.387	0.000	7357.87867	0.00031	6.45276	13.84357	109.3409	116.1536	109 068	0.94268	0.19636	33 937 046	97 092	44 312	100.00
72	KPP4434		189.055	0.000	8827.38587	0.00007	7.53453	10.18609	108.9551	114.1376	113 570	0.64938	0.50005	35 896 414	80 584	70 714	100.00
74	LUY5693	AC	279.447	0.000	20.34426	0.00008	12.96823	16.41788	109.2156	109.0542	186	0.62000	0.11124	2 987	78 740	33 353	100.00
76	KPP4435	AB,C	302.705	0.000	5356.32656	0.00010	10.69599	11.91015	108.7231	108.3263	49 348	0.45152	0.30119	12 705 267	67 195	54 881	100.00
79	LDS6248		54.043	0.000	22.72165	0.00018	6.48007	13.16191	107.6210	107.3106	211	0.93207	0.19988	2 905	96 544	44 708	100.00
84	LDS6245		128.298	0.000	15.29717	0.00010	7.21779	14.68333	104.7828	104.7419	146	0.77908	0.58000	1 519	88 265	76 158	100.00
85	SKF 104		319.066	0.003	4.61770	0.00024	10.61269	12.99844	103.3500	103.7153	45	0.50025	0.23263	351	70 729	48 232	100.00
91	WNO 51		75.532	0.000	294.45980	0.00017	10.04606	13.61768	101.4650	101.6371	2 899	0.55042	0.24989	175 476	74 190	49 989	100.00
92	VYS 2		183.599	0.006	3.83676	0.00038	10.82176	12.37219	101.4335	100.4054	38	0.44881	0.29607	275	66 993	54 412	100.00
93	LDS 720	A,BC	212.830	0.000	4681.14396	0.00009	9.33879	11.25119	102.8295	101.1982	52 032	0.69765	1.00000	9 159 630	83 525	100 000	100.00
93	LDS 720	BC	146.366	0.003	2.13601	0.00012	11.25119	11.25291	101.1982	101.7170	358	0.48690	0.50800	6 828	69 778	71 274	100.00
94	LDS6330		5.577	0.001	4.74018	0.00009	12.41393	14.76443	100.7234	100.6830	47	0.23050	0.22200	482	48 011	47 116	100.00
	Questionable objects:																
18	GJ 440/GJ 3618		299.123	0.000	28215.91717	0.00016	11.51107	13.87833	215.7373	206.8172	139 070	0.15000	0.11528	101 250 636	38 730	33 953	0.00
67	FRT 1		40.561	0.009	4.91699	0.00081	10.49217	16.96996	100.6811	93.8140	80 760	0.50719	0.11967	29 147 864	71 217	34 593	0.41

Table 3 (conclusion). Assessment potential gravitational relationship