DOUBLE STAR MEASUREMENTS IN CHAMELEON

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ABSTRACT:

This paper details the results of 9 measurements of double stars made between May and June 2023 in the constellation Chameleon, in order to update the values of the position angle (θ), the angular separation (ρ) and to determine their nature.

EQUIPMENT AND METHODOLOGY:

All the chosen pairs were discovered during the first half of the 19th century but WDS 13300-7634 (RSS18) was discovered in 1895.

For the measurements we used a 254/1270 telescope and a Logitech C270 camera modified to capture images with a resolution of 0.4564' per pixel and a frame size of 1280 x 720, controlled by SharpCap Version 3.1 software, processing the images obtained with Reduc Version 5.39, a free analysis software developed by the French astronomer Florent Losse.

In order to minimise measurement errors, the goal was to make 5 captures for each pair on different days of each of the 15 double stars originally chosen, i.e. a total of 75 captures, but in reality there were slightly more than that number because the ones that were not detected took longer than the ones that were detected due to the fact that with the first ones we had to record several videos testing the gain and burst time in the SharpCap and then manually adjust the different parameters of the Reduc with each frame to see if we could detect them on the screen; In this way, some could be detected and measured but others could not and therefore there was no alternative but to discard 6 pairs, leaving only 9 of the 15 chosen.

For each measurement of the 9 remaining pairs, a 15-second video was recorded, obtaining 250 frames for each one and for each pair, totalling 45 videos (5 individual captures for each pair on different nights), obtaining a total of 11,250 frames.

The captures were made with the Lucky Imaging Method, as the telescope used had a Dobson mount with no motorisation or tracking so that the field of view remained fixed as the pair drifted.

This Lucky Imaging Method consists of recording the video of the drift of the pair and then decomposing it into its component frames and measuring each one of them, a task that Reduc performs automatically, discarding between 30% and 60% of the frames to reduce the distorting values, although not all the measurements were automatic, as on several occasions they had to be performed manually because the pair was very close and could not be resolved, because there was a large light imbalance between both components (dM) or because the secondary component was not visible at the beginning because it was too weak.

The choice of the double stars to be measured was made from those listed in the WDS Catalogue, and taking into account the limitations of the equipment used and the sky conditions where the captures were taken, only those with a separation greater than 3' and maximum magnitudes of 9 for the main component and 11 for the secondary component were selected.

In order to minimise the error of each of the measurements, the hypothesis of the quadratic propagation of errors was used and the fact that increasing the number of measurements results in a lower uncertainty of their mean value, which is the reason why 5 measurements were attempted for each pair.

That is, starting from the value of the standard deviation, dividing it by the square root of the number of measurements gives an estimate of the error in making 'N' measurements.

The following expression was used to calculate the standard deviation:

$$S_x = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \bar{x})^2}{(N-1)}}$$

As for the standard error of the mean (sometimes referred to as the standard error), it was calculated using the following expression:

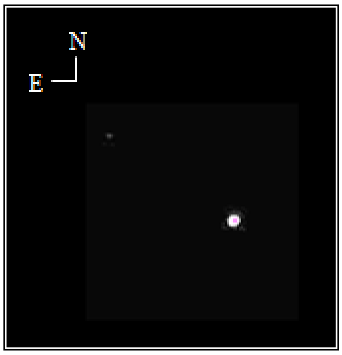
$$\sigma_{N-1} = \frac{S_x}{\sqrt{N}}$$

Table 1: Table of Measurements..

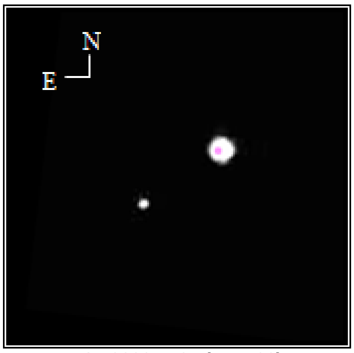
WDS	NAME	NUMBER OF HISTORICAL MSRMNTS AND YEARS OF FIRST AND LAST MSRMNTS	POSITION ANGLE AND SPACING RECORDED IN WDS	MAGNITUDE	MEASURED POSITION ANGLE AND ERROR	MEASURED SEPARATION AND ERROR	NUMBER OF MSRMNTS PERFOMED	MEAN DATE OF MEASUREMENTS (BESSELIAN EPOCH)
13085-8243	HJ4565	14 1837 – 2015	73.10º – 46.557"	8.15 – 10.45 (dM 2.3)	74.69º ± 0.2º	47.589" ± 0.17"	5	2023.417
13332-7734	HJ4590	18 1837 – 2016	132.80º – 22.022"	6.58 – 9.22 (dM 2.64)	134.46º ± 1.9º	21.978" ± 0.43"	5	2023.428
13300-7634	RSS18	13 1835 – 2016	46.80º – 33.190"	8.16 – 9.24 (dM 1.08)	48.7º ± 0.8º	32.89" ± 0.32"	5	2023.430
11410-8306	HJ4468	13 1837 – 2015	138.50º – 25.935"	6.45 – 10.45 (dM 4.00)	140.29º ± 4.8º	25.77" ± 0.35"	4	2023.427
11373-8304	HJ4462	10 1837 – 2015	262.90º – 4.961"	8.73 – 10.10 (dM 1.37)	263.06º ± 2.8º	4.944" ± 0.26"	4	2023.405
10319-8155	HJ5444	15 1835 – 2015	235.60º – 41.376"	7.03 – 9.08 (dM 2.05)	237.74º ± 0.6º	41.05" ± 0.39"	5	2023.410
09283-7815	HJ4226	19 1837 – 2016	124.80º – 22.700"	8.69 – 9.04 (dM 0.35)	124.88º ± 0.8º	22.31" ± 0.33"	5	2023.415
09194-7739	HJ4214AB	27 1837 – 2016	194.10º – 8.990"	8.41 – 9.66 (dM 1.25)	195.04º ± 1.5º	8.946" ± 0.23"	5	2023.416
08228-7626	HJ4109	20 1836 – 2010	129.80º – 26.030"	7.24 – 8.17 (dM 0.93)	128.14º ± 0.7º	25.93" ± 0.44"	5	2023.416

IMAGES OF MEASURED DOUBLE STARS:

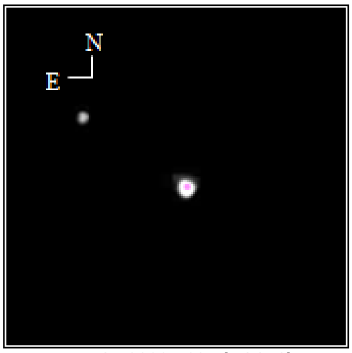
For better interpretation, all captured images are oriented with North at the top and East to the left, following the order in Table 1 for better searching:



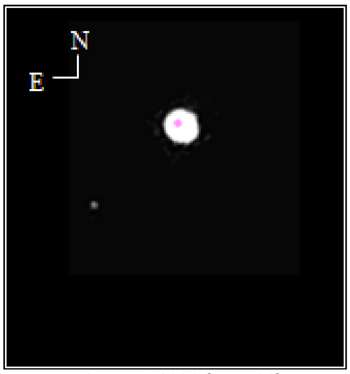
WDS 13085-8243 (HJ4565)



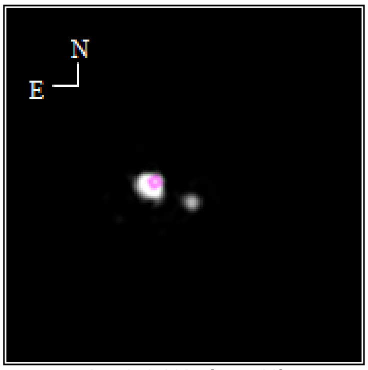
WDS 13332-7734 (HJ4590)



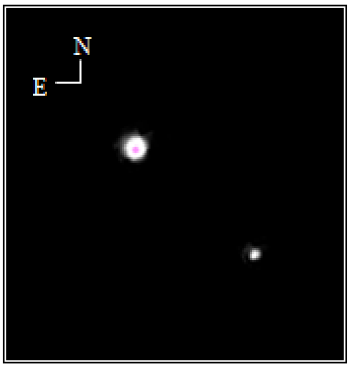
WDS 13300-7634 (RSS18)



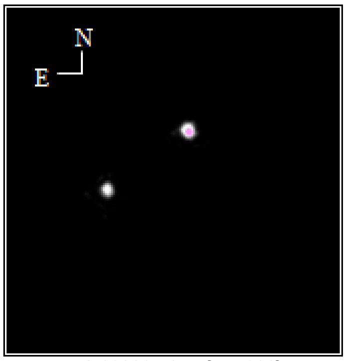
WDS 11410-8306 (HJ4468)



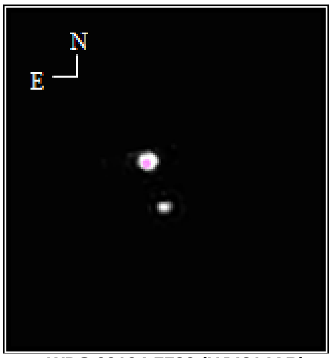
WDS 11373-8304 (HJ4462)



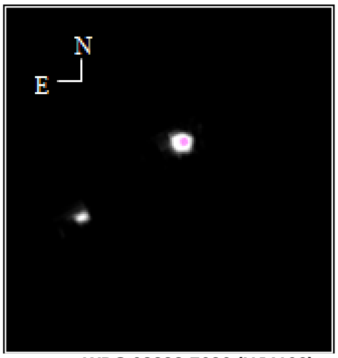
WDS 10319-8155 (HJ5444)



WDS 09283-7815 (HJ4226)



WDS 09194-7739 (HJ4214AB)



WDS 08228-7626 (HJ4109)

DISCUSSION:

It will be divided into the following 2 parts:

1.- Relative Own Movement Analysis:

The aim of this analysis is to determine the physical nature of the measured torques and is based on the explanation given by Richard W. Harshaw in 2016 (see References).

For this purpose, use is made of the ratio 'rPM' (relative proper motion of the torque), which is defined by the following relation:

$$rPM = \frac{R}{V}$$

Where:

- R is the vector resultant of the eigenmotion of the pair
- V is the unit vector of the component that has the largest eigenmotion

To calculate these 2 factors, the following expressions were used:

$$R = \sqrt{(PM_{1AR} - PM_{2AR})^2 + (PM_{1Dec} - PM_{2Dec})^2}$$

$V = \sqrt{(PM_{1AR})^2 + (PM_{1Dec})^2}$ o well $V = \sqrt{(PM_{2AR})^2 + (PM_{2Dec})^2}$ (whichever is higher)

Where:

- PM_{1AR} is the motion vector developing the primary component in AR, i.e. along the abscissa (X) axis
- PM_{1Dec} is the motion vector that develops the primary component at Dec, i.e. along the Y-axis
- PM_{2AR} is the motion vector developing the secondary component in AR, i.e. along the abscissa (X) axis
- PM_{2Dec} is the motion vector developing the secondary component at Dec, i.e. along the Y-axis

Once the values of R and V have been obtained, they are entered into the first expression and rPM is calculated, and the result is interpreted as follows:

- If rPM < 0,2 => The torque would be of a physical nature (**CPM = Common self-motion torques**)
- If 0,2 < rPM < 0,6 => The pair would be of uncertain nature (**SPM = Pairs of similar own motion**)
- If rPM > 0,6 => The torque would not be physical, but visual (**DPM = Differing Proper Motion Pairs**)

This interpretation is reasonable from the point of view that for them to be gravitationally bound, the discrepancy between the proper motions of the 2 components should not be greater than 60%, which is achieved by dividing the resultant of the pair's motion vector by the largest motion vector of the component that moves the most.

It should be noted that some astronomers take the uncertainty limit in the range 0.3 < rPM < 0.8, but in this work the former criterion will be applied.

The analysis of this procedure will be developed only for WDS 13085-8243 (HJ4565) and the remaining values will be dumped in Table 2.

The eigenmotion (PM) vectors of this pair are:

- PM_{1AR} = - 132 mili arc seconds per year [mas]
- PM_{1Dec} = - 29 mili arc seconds per year [mas]
- PM_{2AR} = - 8 mili arc seconds per year [mas]
- PM_{2Dec} = + 4 mili arc seconds per year [mas]

The simplified notation of these eigenmotion (MP) vectors is (-132 -29) for the primary and (-8 +4) for the secondary and is used in practice.

The calculations are as follows:

$$R = \sqrt{[(-132 - (-8)]^2 + (-29 - 4)^2} \;=>\; R = \sqrt{15376 + 1089} \;=>\; R = 128.32$$

$$V = \sqrt{(-132)^2 + (-29)^2} \;=>\; V = \sqrt{17424 + 841} \;=>\; V = 135.15$$

Replacing the values:

$$rPM = \frac{128.32}{135.15} = 0.95$$

Therefore, this pair would not be physical and its components would not be gravitationally bound because it would only be visual due to a matter of perspective as seen from the Earth, so its study would not be of interest from an astrophysical point of view.

Using the same calculation procedure, the following table was produced:

Table 2: Table of relative own movements.

PAIR	MP_{1AR}	MP_{1DEC}	MP_{2AR}	MP_{2DEC}	R	V	RPM	NATURE
WDS 13085-8243 (HJ4565)	-132	-29	-8	4	128.316	135.148	0.949	Non-physical
WDS 13332-7734 (HJ4590)	-367	-152	-351	-118	37.577	397.232	0.095	Physics
WDS 13300-7634 (RSS18)	-24	-6	-10	-4	14.142	24.739	0.572	Uncertain
WDS 11410-8306 (HJ4468)	-6	10	-3	-4	14.318	11.662	1.228	Non-physical
WDS 11373-8304 (HJ4462)	1	-4	S/data	S/data	-	-	-	-
WDS 10319-8155 (HJ5444)	-14	7	-5	-1	12.042	15.652	0.769	Non-physical
WDS 09283-7815 (HJ4226)	-27	19	-27	20	1	33.601	0.030	Physics
WDS 09194-7739 (HJ4214AB)	-107	69	-107	71	2	128.413	0.016	Physics
WDS 08228-7626 (HJ4109)	-13	29	-15	28	2.236	31.780	0.070	Physics

The physical, uncertain and non-physical natures of these pairs would seem to be corroborated by analysing the historical records of the measurements made as follows:

A.- <u>WDS 13085-8243 (HJ4565)</u>:

This system of spectral class GOV, whose main component is located at 325 light years, shows a clear variation in the separation (ρ) but almost no change in the position angle (θ) over 186 years, thus confirming its non-physical nature.

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HJ 4565      1837 2015   14  75  73  28.0  46.6  8.15 10.45 G0V        -132-029 -008+004 -82  561 NL U 130828.93-824315.8
        1837.20      75.3    .      28.      .       8.    .     11.    .               0.5   1 HJ_1847a Mb   0
        1895.40      73.0    .      32.798   .       .     .     .      .               0.3   1 WFC1998  Pa   6
        1895.45      72.1    .      32.421   .       .     .     .      .               0.3   1 WFC1998  Pa   6
        1896.35      73.3    .      31.742   .       .     .     .      .               0.3   1 WFC1998  Pa   6
        1896.35      72.9    .      31.510   .       .     .     .      .               0.3   1 WFC1998  Pa   6
        1919.36      73.0    .      35.30    .       8.4   .     10.5   .               0.4   2 Daw1922  Ma   0
        1956.30      72.6    .      39.790   .       .     .     .      .               0.1   1 WFC1971  Pa   6
        1971.24      73.1    .      41.270   .       .     .     .      .               0.2   4 WFC1992  Pa   6
        1983.34      73.5    .      43.26    .       .     .     .      .               0.3   4 Trr1985a Ma   4
        1991.66      73.0    .      43.842   .       8.146 0.012 10.454 0.044  530 100  0.3   1 TYC2000b Ht   5
        1991.66       .      .       .       .       8.826 0.017 11.895 0.097  430  90  0.3   1 TYC2000b Ht   7
        1998.162     73.3   0.3     44.470  0.083    8.96  0.06  10.26  0.01   609  70  0.2   6 UC_2013b Eu   7
        2000.19      73.2    .      44.75    .       6.943 0.023  7.765 0.020 1256 245  1.3   1 TMA2003  E2   7
        2000.19       .      .       .       .       6.643 0.026  7.041 0.023 1633 160  1.3   1 TMA2003  E2   7
        2000.19       .      .       .       .       6.556 0.026  6.774 0.024 2210 300  1.3   1 TMA2003  E2   7
        2010.         .      .       .       .       9.028 0.180 10.541 0.040  550  89  0.2   1 AAV2012  Zc   7
        2010.         .      .       .       .       9.187 0.050 12.220 0.020  440  98  0.2   1 AAV2012  Zc   7
        2010.         .      .       .       .       8.000 0.040  9.486 0.060  763 153  0.2   1 AAV2012  Zc   7
        2010.         .      .       .       .       8.919 0.050  9.961 0.080  623 137  0.2   1 AAV2012  Zc   7
        2010.         .      .       .       .       9.696 0.030 11.375 0.010  477 139  0.2   1 AAV2012  Zc   7
        2010.5       73.1   0.2     45.86   0.12     6.476 0.035  6.674 0.033 3350      0.4   1 WIS2012  Hw   7
        2010.5        .      .       .       .       6.500 0.019  6.859 0.018 4600      0.4   1 WIS2012  Hw   7
        2010.5        .      .       .       .       6.530 0.015  6.741 0.015 11.6   u  0.4   1 WIS2012  Hw   7
        2010.5        .      .       .       .       6.518 0.053  6.671 0.054 22.1   u  0.4   1 WIS2012  Hw   7
        2015.0       73.171  .      46.557   .       7.900  .     9.861  .     673 440  1.0   1 Kpp2018m Hg   7
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B.- <u>WDS 13332-7734 (HJ4590)</u>:

This system of spectral class F6V, whose main component is 62 light years away, shows almost no variation in separation (ρ) or position angle (θ) over 186 years, so that if it were not for the analysis of the relative proper motions that assigns a physical nature to it, we would be in the presence of a visual pair.

The explanation for this almost null variation in almost 2 centuries could be found in the fact that we would be dealing with a system with an orbital period of millennia.

HJ 4590	1837 2016	18 137 133	25.0	22.0	6.58		9.22 F6V		-367-152	-351-118	-76	767 N		133313.66-773409.8		
1837.25	136.6	.	25.	.	6.5	.	11.	.				0.5	1	HJ_1847a	Mb	0
1851.29	132.8	.	23.7	.	8.5	.	9.5	.				0.1	2	Gli1868	T	0
1875.46	132.6	.	22.5	.	6.6	.	9.3	.				0.1	3	CGA9999	T	0
1880.41	134.9	.	22.41	.	6.	.	10.	.				0.2	1	Hrg1871	Ma	0
1918.64	133.7	.	22.62	.	6.6	.	10.2	.				0.4	2	Daw1922	Ma	0
1920.	e135.	.	25.	.	7.5	.	13.0	.				0.6	1	Luy1941	Po L	6
1931.33	133.7	.	22.371	.	.	.	2.7	.				0.7	1	Hzg1942b	Po	0
1940.	.	.	.	.	.	.	2.74	.	553			.	2	Frw1946	Po D	7
1947.40	133.8	.	22.394	.	.	.	.	.				0.1	1	WFC1966d	Pa	6
1956.36	133.3	.	22.178	.	.	.	.	.				0.1	1	WFC1971	Pa	6
1971.25	133.2	.	22.160	.	.	.	.	.				0.2	6	WFC1992	Pa	6
1991.25	133.2	.	22.12	.	6.630	0.026	9.506	0.287	511	222		0.3	1	HIP1997a	Hh	5
1991.25	.	.	.	.	6.559	0.004	9.218	0.030	530	100		0.3	1	TYC1997	Ht	7
1991.25	.	.	.	.	7.055	0.004	10.291	0.049	430	90		0.3	1	TYC1997	Ht	7
1991.48	133.2	.	22.12	.	6.576	0.009	9.218	0.030	530	100		0.3	1	TYC2002	Ht	6
1991.48	.	.	.	.	7.053	0.015	10.291	0.049	430	90		0.3	1	TYC2002	Ht	7
1998.150	133.0	0.7	22.108	0.281	7.88	0.30	9.56	0.04	609	70		0.2	2	UC_2013b	Eu	7
2000.18	132.8	.	22.07	.	5.618	0.019	7.586	0.032	1256	245		1.3	1	TMA2003	E2	7
2000.18	.	.	.	.	5.405	0.055	7.096	0.038	1633	160		1.3	1	TMA2003	E2	7
2000.18	.	.	.	.	5.299	0.024	6.984	0.024	2210	300		1.3	1	TMA2003	E2	7
2010.	.	.	.	.	6.559	.	9.218	.	550	89		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	7.055	.	10.291	.	440	98		0.2	1	AAV2012	Zc	7
2010.5	132.8	0.3	22.11	0.13	5.246	0.067	6.987	0.028	3350			0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	5.102	0.033	7.011	0.019	4600			0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	5.320	0.015	6.982	0.014	11.6		u	0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	5.269	0.031	7.068	0.076	22.1		u	0.4	1	WIS2012	Hw	7
2010.5589	133.1	0.2	21.620	0.080	5.250	0.192	6.944	0.034	3350			0.4	1	WIS2016	Hw	7
2010.5589	.	.	.	.	5.132	0.068	6.989	0.021	4600			0.4	1	WIS2016	Hw	7
2010.5589	.	.	.	.	5.266	0.032	6.683	0.064	22.1		u	0.4	1	WIS2016	Hw	7
2010.5589	.	.	.	.	5.321	0.015	6.924	0.017	11.6		u	0.4	1	WIS2016	Hw	7
2015.5	.	.	.	.	6.654	.	9.567	.	502	228		1.0	1	E1B2018	Hg	7
2015.5	.	.	.	.	6.014	.	8.401	.	759	294		1.0	1	E1B2018	Hg	7
2015.5	132.871	0.000	22.02421	0.00013	6.387	.	9.041	.	584	436		1.0	1	E1B2018	Hg	7
2015.5	.	.	.	.	6.014	.	8.401	.	759	436		1.0	1	Tia2020	Hg	7
2016.0	132.87	0.00	22.02220	0.00002	6.401	.	9.049	.	584	436		1.0	1	E1B2021	Hg	7
2016.0	.	.	.	.	6.006	.	8.389	.	759	294		1.0	1	E1B2021	Hg	7
2016.0	.	.	.	.	6.638	.	9.547	.	502	228		1.0	1	E1B2021	Hg	7

C.- WDS 13300-7634 (RSS18):

As in the previous case, this system of spectral class B9.5V, whose main component is 1240 light years away, shows almost no variations in separation (ρ) or position angle (θ) over 128 years, so it would be a non-physical pair if we were not guided by the analysis of the relative proper motions, which assigns it an uncertain nature.

In any case, if its physical nature is confirmed, it would also be a system with an orbital period of millennia.

RSS 18	1895 2015	13 45 47	32.4	33.2	8.16		9.24 B9.5V		-024-006	-010-004	-75	874 N		133000.62-763423.7		
1895.38	45.4	.	32.358	.	.	.	.	.				0.3	1	WFC1998	Pa	6
1895.39	48.1	.	32.408	.	.	.	.	.				0.3	1	WFC1998	Pa	6
1895.41	47.0	.	32.305	.	.	.	.	.				0.3	1	WFC1998	Pa	6
1947.40	46.8	.	32.681	.	.	.	.	.				0.1	1	WFC1966d	Pa	6
1956.36	47.1	.	32.713	.	.	.	.	.				0.1	1	WFC1971	Pa	6
1971.24	46.6	.	32.917	.	.	.	.	.				0.2	4	WFC1992	Pa	6
1975.34	46.5	.	32.453	.	8.20	.	9.00	.				1.0	1	Rss1996	Pa	5
1991.25	.	.	S .	.	8.17	.	.	.	511	222		0.3	1	HIP1997h	Hh	7
1991.25	46.7	.	33.045	.	8.19	.	9.31	.	511	222		0.3	1	HIP1997b	Hh	5
1991.25	.	.	.	.	8.17	.	9.14	.	550			0.3	1	HIP1997b	Hh	7
1991.69	46.7	.	33.050	.	8.163	0.012	9.237	0.018	530	100		0.3	1	TYC2000b	Ht	5
1991.69	.	.	.	.	8.222	0.016	10.406	0.033	430	90		0.3	1	TYC2000b	Ht	7
1998.159	46.9	0.1	33.029	0.070	9.12	0.07	9.44	0.05	609	70		0.2	4	UC_2013b	Eu	7
2000.18	46.7	.	33.19	.	7.959	0.027	7.022	0.021	1256	245		1.3	1	TMA2003	E2	7
2000.18	.	.	.	.	7.962	0.049	6.501	0.042	1633	160		1.3	1	TMA2003	E2	7
2000.18	.	.	.	.	7.915	0.020	6.316	0.021	2210	300		1.3	1	TMA2003	E2	7
2010.	.	.	.	.	9.043	-0.010	9.541	0.080	550	89		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	9.533	-0.010	10.456	0.150	440	98		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	10.079	-0.010	10.793	-0.010	477	139		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	8.340	0.060	8.383	0.120	763	153		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	8.975	-0.010	9.141	-0.010	623	137		0.2	1	AAV2012	Zc	7
2010.5	46.7	0.2	33.19	0.13	7.906	0.023	6.202	0.045	3350			0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	7.929	0.020	6.321	0.020	4600			0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	7.971	0.019	6.255	0.016	11.6		u	0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	8.330	0.220	6.221	0.045	22.1		u	0.4	1	WIS2012	Hw	7
2015.0	46.897	.	33.190	.	8.161	.	8.694	.	673	440		1.0	1	Kpp2018m	Hg	7

D.- WDS 11410-8306 (HJ4468):

Although this system of spectral class KOIII and whose main component is 360 light years away shows significant variations in both separation (ρ) and position angle (θ) over 186 years, the analysis of the relative proper motions assigns it a non-physical nature because the displacement vectors would be indicating a non-elliptical law of variation as can be seen in the following image from the GAIA catalogue.

HJ 4468	1837 2015	13 159 139	15.0	25.9	6.45	10.45 K0III	-060+010	-003-004	-82	469				114101.60-830559.9			
1837.20	158.6	.	15.	.	.	.	.	.				0.5	1	HJ_1847a	Mb		0
1871.33	153.4	.	20.10	.	7.	.	11.	.				0.2	1	R__1871	Ma		0
1895.32	151.0	.	21.092	.	.	.	.	.				0.3	1	WFC1998	Pa		7
1895.32	148.6	.	22.073	.	.	.	.	.				0.3	1	WFC1998	Pa		7
1896.42	151.1	.	21.576	.	.	.	.	.				0.3	1	WFC1998	Pa		7
1919.27	147.2	.	22.28	.	7.3	.	11.4	.				0.4	3	Daw1922	Ma		0
1940.	.	.	.	.	.	.	3.73	.				0.4	4	Wal1948	Zw	D	7
1956.23	142.5	.	23.865	.	.	.	.	.				0.1	1	WFC1971	Pa		6
1991.47	140.3	.	24.871	.	6.447	0.010	10.446	0.062	530	100		0.3	1	TYC2000d	Ht		7
1991.47	.	.	.	.	7.696	0.015	11.863	0.146	430	90		0.3	1	TYC2000d	Ht		7
1998.15	140.9	0.2	25.761	0.158	7.74	0.29	10.72	0.02	609	70		0.2	3	UC_2013b	Eu		7
1999.556	140.0	1.0	25.41	0.57	.	.	.	.	609	70		0.2	2	UC_2013b	Eu		7
2000.10	139.8	.	25.28	.	4.590	0.248	8.768	0.037	1256	245		1.3	1	TMA2003	E2		7
2000.10	.	.	.	.	3.877	0.246	8.228	0.059	1633	160		1.3	1	TMA2003	E2		7
2000.10	.	.	.	.	3.832	0.212	8.065	0.031	2210	300		1.3	1	TMA2003	E2		7
2010.	.	.	.	.	6.444	.	10.446	.	550	89		0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	7.698	.	11.863	.	440	98		0.2	1	AAV2012	Zc		7
2010.5	138.8	0.3	25.79	0.14	3.566	0.129	7.927	0.024	3350			0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	3.256	0.058	7.969	0.020	4600			0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	3.644	0.015	7.920	0.018	11.6		u	0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	3.588	0.021	7.936	0.133	22.1		u	0.4	1	WIS2012	Hw		7
2015.0	138.584	.	25.935	.	5.912	.	10.428	.	673	440		1.0	1	Kpp2018m	Hg		7

E.- <u>WDS 11373-8304 (HJ4462)</u>:

This system, of spectral class A2V, shows variations in the position angle (θ) but not in the separation (ρ) over 186 years.

However, an assessment of its nature cannot be made because no data on the proper motion of the secondary component are available.

HJ 4462	1837 2015	10 259 263	6.0	5.0	8.73	10.1 A2V	+001-004		-82	467		113716.18-830412.9			
1837.20	258.7	.	6.	.	9.	.	10.	.			0.5	1	HJ_1847a	Mb	0
1850.38	250.3	.	6.5	.	9.5	.	10.	.			0.1	1	Gli1868	T	0
1880.38	257.7	.	4.38	.	8.	.	9.	.			0.3	1	R__1871	Ma	0
1891.33	264.	.	.	.	9.	.	10.	.			0.3	1	Slr1893b	Ma	0
1891.34	258.2	.	4.	.	.	.	.	.			0.3	1	Slr1893b	Ma	0
1899.33	260.8	.	4.69	.	9.	.	10.	.			0.3	1	Slr1910	Ma	0
1919.27	261.5	.	5.01	.	9.2	.	10.9	.			0.4	3	Daw1922	Ma	0
1941.36	261.5	.	4.99	.	8.5	.	9.5	.			0.7	1	B__1956a	Ma	0
1953.30	255.3	.	4.338	.	.	.	.	.			0.1	1	WFC1968a	Pa	6
2000.10	262.9	.	4.86	.	7.768	0.054	7.746	0.032	1256	245	1.3	1	TMA2003	E2	7
2000.10	.	.	.	.	7.537	0.063	7.263	0.069	1633	160	1.3	1	TMA2003	E2	7
2000.10	.	.	.	.	7.482	0.069	7.146	0.042	2210	300	1.3	1	TMA2003	E2	7
2015.0	262.903	.	4.961	.	8.608	.	9.567	.	673	440	1.0	1	Kpp2018m	Hg	7

F.- <u>WDS 10319-8155 (HJ5444)</u>:

This system, of spectral class B5III-IV and whose main component is 1175 light years away, does not show variations in the separation (ρ) or in the position angle (θ) over 188 years, so it would be a non-physical pair according to the analysis of the relative proper motions.

MEASURES:

HJ 5444 1835 2015 15 230 236 40.0 41.4 7.03 9.08 B5III-IV -014+007 -005-001 -81 449 N 103151.69-815515.9

1835.15	230.3	.	40.	.	6.	.	8.	.				0.5	1	HJ_1847a	Mb		0
1895.38	235.3	.	42.428	.	.	.	.	.				0.3	1	WFC1998	Pa		6
1902.24	234.7	.	41.745	.	.	.	.	.				0.3	1	WFC1998	Pa		6
1903.15	235.5	.	41.280	.	.	.	.	.				0.3	1	WFC1998	Pa		6
1919.43	235.1	.	41.88	.	7.4	.	9.8	.				0.4	2	Daw1922	Ma		0
1928.1	236.9	.	43.678	.	.	.	.	.				0.2	2	WFD1947	T		6
1953.30	235.7	.	41.224	.	.	.	.	.				0.1	1	WFC1968a	Pa		6
1956.17	236.0	.	41.610	.	.	.	.	.				0.1	1	WFC1971	Pa		6
1970.36	235.5	.	41.605	.	.	.	.	.				0.2	5	WFC1992	Pa		6
1979.	.	.	.	.	7.059	0.016	9.436	0.015	550			0.9a	1	Lnd1983	Z	D	7
1983.24	235.8	.	41.75	.	.	.	.	.				0.3	2	Trr1985a	Ma		4
1991.67	235.6	.	41.476	.	7.033	0.010	9.084	0.018	530	100		0.3	1	TYC2000b	Ht		5
1991.67	.	.	.	.	6.949	0.015	9.261	0.019	430	90		0.3	1	TYC2000b	Ht		7
1998.139	235.9	0.4	41.367	0.246	8.19	0.18	9.77	0.03	609	70		0.2	6	UC_2013b	Eu		7
2000.03	235.8	.	41.42	.	7.140	0.020	8.782	0.024	1256	245		1.3	1	TMA2003	E2		7
2000.03	.	.	.	.	7.234	0.042	8.731	0.038	1633	160		1.3	1	TMA2003	E2		7
2000.03	.	.	.	.	7.202	0.024	8.657	0.026	2210	300		1.3	1	TMA2003	E2		7
2010.	.	.	.	.	8.529	-0.010	9.767	0.070	440	98		0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	8.578	-0.010	9.616	0.080	550	89		0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	7.752	0.190	9.373	0.020	763	153		0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	8.704	0.210	9.649	0.160	623	137		0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	9.587	0.190	10.216	0.150	477	139		0.2	1	AAV2012	Zc		7
2010.5	235.8	0.2	41.33	0.13	7.183	0.030	8.586	0.022	3350			0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	7.234	0.020	8.605	0.020	4600			0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	7.298	0.015	8.616	0.019	11.6		u	0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	7.293	0.079	9.256	0.393	22.1		u	0.4	1	WIS2012	Hw		7
2015.0	235.613	.	41.376	.	7.071	.	9.353	.	673	440		1.0	1	Kpp2018m	Hg		7

G.- WDS 09283-7815 (HJ4226):

This system of spectral class F4V+6IV, also shows no significant variations in separation (ρ) and position angle (θ) over 186 years but would nevertheless be of a physical nature from the analysis of the relative proper motions.

HJ 4226 1837 2016 19 122 125 30.0 22.7 8.69 9.04 F4V+F6IV -027+019 -027+020 -77 519 NT 092815.02-781522.4

1837.25	121.6	.	30.	.	9.	.	9.	.				0.5	1	HJ_1847a	Mb	0
1850.64	110.2	.	22.5	.	9.2	.	9.2	.				0.1	2	Gli1868	T	0
1892.26	123.8	.	22.998	.	.	.	.	.				0.3	1	WFC1998	Pa	6
1893.19	123.0	.	22.916	.	.	.	.	.				0.3	1	WFC1998	Pa	6
1896.19	123.1	.	22.561	.	.	.	.	.				0.3	1	WFC1998	Pa	6
1919.31	123.5	.	22.80	.	9.0	.	9.2	.				0.4	2	Daw1922	Ma	0
1948.20	124.2	.	22.722	.	.	.	.	.				0.1	1	WFC1966d	Pa	6
1956.12	124.2	.	22.723	.	.	.	.	.				0.1	1	WFC1971	Pa	6
1970.44	124.5	.	22.740	.	.	.	.	.				0.2	5	WFC1992	Pa	6
1974.233	124.0	.	23.07	.	.	.	.	.				0.3	2	War2001	Ma	6
1978.106	124.9	.	22.60	.	8.6	.	8.9	.				1.2	1	Tob2003	Pa	6
1983.13	124.9	.	22.98	.	.	.	.	.				0.3	1	Trr1985a	Ma	4
1991.181	124.7	.	22.30	.	.	.	.	.				0.3	4	War1992b	Ma	4
1991.73	124.8	.	22.721	.	8.687	0.013	9.039	0.015	530	100		0.3	1	TYC2000b	Ht	5
1991.73	.	.	.	.	9.109	0.017	9.516	0.019	430	90		0.3	1	TYC2000b	Ht	7
1998.15	124.8	0.6	22.793	0.169	9.36	0.03	9.56	0.02	609	70		0.2	7	UC_2013b	Eu	7
1999.99	124.7	.	22.64	.	7.828	0.024	8.124	0.021	1256	245		1.3	1	TMA2003	E2	7
1999.99	.	.	.	.	7.677	0.026	7.931	0.051	1633	160		1.3	1	TMA2003	E2	7
1999.99	.	.	.	.	7.651	0.024	7.828	0.033	2210	300		1.3	1	TMA2003	E2	7
2010.	.	.	.	.	9.289	-0.010	9.409	0.140	550	89		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	9.427	-0.010	9.840	0.220	440	98		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	8.443	-0.010	8.769	-0.010	763	153		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	9.182	-0.010	9.357	-0.010	623	137		0.2	1	AAV2012	Zc	7
2010.	.	.	.	.	9.737	-0.010	9.950	-0.010	477	139		0.2	1	AAV2012	Zc	7
2010.5	125.0	0.3	22.73	0.13	7.577	0.025	7.775	0.024	3350			0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	7.607	0.020	7.801	0.019	4600			0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	7.604	0.017	7.818	0.017	11.6		u	0.4	1	WIS2012	Hw	7
2010.5	.	.	.	.	7.677	0.102	7.920	0.126	22.1		u	0.4	1	WIS2012	Hw	7
2015.0	.	.	22.70	.	.	.	.	.	673	440		1.0	1	Gai2017	Hg	7
2015.0	125.044	0.001	22.70161	0.00039	8.507	.	8.872	.	673	440		1.0	1	Gai2016	Hg	7
2015.0	.	.	22.68	.	8.507	.	8.872	.	673	440		1.0	1	Oh_2017	Hg	7
2016.0	124.87	0.00	22.69993	0.00001	8.538	.	8.935	.	584	436		1.0	1	ElB2021	Hg	7
2016.0	.	.	.	.	8.184	.	8.539	.	759	294		1.0	1	ElB2021	Hg	7
2016.0	.	.	.	.	8.740	.	9.171	.	502	228		1.0	1	ElB2021	Hg	7

H.- WDS 09194-7739 (HJ4214AB):

In this system of spectral class G3V+K0IVe and whose main component is 235 light years away, neither variations in separation (ρ) nor in position angle (θ) were found over 186 years, although the analysis of the relative proper motions would suggest that this would be of a physical nature.

HJ 4214AB 1837 2016 27 193 194 10.0 9.0 8.41 9.66 G3V+K0IVe -107+069 -107+071 -77 503 NT 091924.66-773836.4

	1837.25	193.3	.	10.	.	10.	.	10.5	.			0.5	1	HJ_1847a	Mb		0
	1850.65	203.3	.	7.6	.	9.	.	11.	.			0.1	2	Gli1868	T		0
	1872.22	191.7	.	9.64	.	9.	.	9.5	.			0.2	1	R__1871	Ma		0
	1893.19	194.5	.	9.266	.	.	.	.	.			0.3	1	WFC1998	Pa		6
	1896.19	192.6	.	9.257	.	.	.	.	.			0.3	1	WFC1998	Pa		6
	1919.30	193.3	.	9.25	.	8.5	.	9.6	.			0.4	3	Daw1922	Ma		0
	1940.14	193.8	.	9.08	.	.	.	.	.			0.2	3	Ged1940c	Ma		0
	1948.20	192.5	.	9.083	.	.	.	.	.			0.1	1	WFC1966d	Pa		6
	1956.13	194.6	.	9.564	.	.	.	.	.			0.1	1	WFC1971	Pa		6
	1976.254	193.6	.	8.90	.	8.3	.	9.3	.			1.2	1	Tob2003	Pa		6
	1984.18	193.2	.	9.06	.	.	.	.	.			0.3	2	Trr1986	Ma		4
	1987.355	192.35	.	9.02	.	.	.	.	.			1.5	1	Sin1988	C		4
	1991.25	194.0	.	9.025	.	8.462	0.007	9.610	0.021	511	222	0.3	1	HIP1997a	Hh		5
	1991.25	.	.	.	.	8.399	0.019	9.376	0.043	530	100	0.3	1	TYC1997	Ht		7
	1991.25	.	.	.	.	9.175	0.024	10.321	0.064	430	90	0.3	1	TYC1997	Ht		7
	1991.252	194.3	.	8.63	.	.	.	.	.			0.3	3	War1992b	Ma		4
	1991.75	194.1	.	8.980	.	8.413	0.013	9.664	0.029	530	100	0.3	1	TYC2000b	Ht		5
	1991.75	.	.	.	.	9.177	0.018	10.638	0.043	430	90	0.3	1	TYC2000b	Ht		7
	1998.16	194.0	0.2	9.134	0.143	9.07	0.04	9.11	0.06	609	70	0.2	7	UC_2013b	Eu		7
	2000.01	194.4	.	8.99	.	7.161	0.032	7.947	0.021	1256	245	1.3	1	TMA2003	E2		7
	2000.01	.	.	.	.	6.78	.	7.44	.	2210	200	1.3	1	Tok2011a	E2	X	7
	2000.01	.	.	.	.	7.16	.	7.95	.	1256	245	1.3	1	Tok2011a	E2	X	7
	2000.01	.	.	.	.	6.780	0.021	7.440	0.024	2210	300	1.3	1	TMA2003	E2		7
	2000.01	.	.	.	.	6.850	0.047	7.563	0.046	1633	160	1.3	1	TMA2003	E2		7
	2000.01	.	.	.	.	7.161	0.032	7.947	0.021	1256	245	1.3	1	TMA2003	E2		7
	2000.013	194.396	0.797	8.9907	0.0881	.	.	.	.			1.3	1	Vgt2012	E2		7
Aa,B	2008.1329	194.218	1.400	8.9727	0.1357	.	.	0.796	0.130	2180	350	8.2	1	Vgt2012	A		7
	2008.1329	194.487	1.400	8.9567	0.1355	.	.	.	.	2180	350	8.2	1	Vgt2012	A		7
Ab,B	2008.1329	194.858	1.400	8.9351	0.1352	.	.	1.141	0.114	2180	350	8.2	1	Vgt2012	A		7
Aa,B	2008.1329	.	.	.	.	8.236	.	7.440	.	2180	350	8.2	1	Vgt2012	A		7
Ab,B	2008.1329	.	.	.	.	8.581	.	7.440	.	2180	350	8.2	1	Vgt2012	A		7
Aa,B	2010.0841	193.63	.	9.077	.	.	.	0.71	.	2272	35	8.1	1	Tok2010c	Ao		7
Aa,B	2010.0841	193.65	.	9.076	.	.	.	1.23	.	1587	15	8.1	1	Tok2010c	Ao		7
	2010.14	.	.	.	.	8.32	.	9.47	.	550		1.3	1	Tok2011a	C		7
	2015.0	194.125	.	8.990	.	8.122	.	9.164	.	673	440	1.0	1	Kpp2018m	Hg		7
	2015.5	.	.	.	.	8.526	.	9.683	.	502	228	1.0	1	ElB2018	Hg		7
	2015.5	.	.	.	.	7.691	.	8.675	.	759	294	1.0	1	ElB2018	Hg		7
	2015.5	194.129	0.000	8.98830	0.00017	8.170	.	9.237	.	584	436	1.0	1	ElB2018	Hg		7
	2015.5	194.13	.	8.9883	.	8.170	.	9.237	.	584	436	1.0	1	Gai2018	Hg		7
	2015.5	.	.	.	.	7.691	.	8.675	.	759	294	1.0	1	Gai2018	Hg		7
	2015.5	.	.	.	.	8.526	.	9.683	.	502	228	1.0	1	Gai2018	Hg		7
	2015.5	.	.	8.9883	.	8.170	.	9.237	.	584	436	1.0	1	Tia2020	Hg		7
	2016.0	194.13	0.00	8.98972	0.00024	8.187	.	9.277	.	584	436	1.0	1	ElB2021	Hg		7
	2016.0	.	.	.	.	7.679	.	8.690	.	759	294	1.0	1	ElB2021	Hg		7
	2016.0	.	.	.	.	8.507	.	9.695	.	502	228	1.0	1	ElB2021	Hg		7

I.- <u>WDS 08228-7626 (HJ4109)</u>:

This system of spectral class AOV and whose main component is 960 light years away, also showed no change in separation (ρ) and position angle (θ) in 187 years, but it would be of a physical nature judging from the analysis of the relative proper motions.

MEASURES:

HJ 4109 1836 2010 20 124 130 30.0 26.0 7.24 8.17 A0V -013+029 -015+028 -76 514 NZ 082248.14-762550.9

1836.06	124.0	.	30.	.	8.	.	8.5	.			0.5	1	HJ_1847a	Mb		0
1850.18	125.5	.	26.3	.	8.7	.	9.2	.			0.1	2	Gli1868	T		0
1879.29	127.2	.	25.98	.	8.	.	9.	.			0.2	1	Hrg1871	Ma		0
1893.13	128.0	.	26.090	.	.	.	.	.			0.3	1	WFC1998	Pa		6
1893.19	129.4	.	26.004	.	.	.	.	.			0.3	1	WFC1998	Pa		6
1910.40	128.2	.	26.135	.	.	.	.	.			0.2	4	WFD1928d	T		6
1918.74	128.1	.	26.08	.	7.7	.	8.5	.			0.4	2	Daw1922	Ma		0
1940.04	128.2	.	26.4	.	.	.	.	.			0.2	1	Ged1940c	Ma		0
1948.20	125.4	.	26.253	.	.	.	.	.			0.2	3	WFD1959	T		6
1948.20	128.6	.	26.114	.	.	.	.	.			0.1	1	WFC1966d	Pa		6
1956.04	129.1	.	26.258	.	.	.	.	.			0.1	1	WFC1971	Pa		6
1959.879	128.88	.	26.010	.	.	.	.	.			0.3	3	Sms1965	Pa		2
1970.32	129.2	.	25.989	.	.	.	.	.			0.2	4	WFC1992	Pa		6
1983.21	129.4	.	26.31	.	.	.	.	.			0.3	1	Trr1985a	Ma		4
1984.50	129.2	.	26.170	.	.	.	.	.			0.2	4	WFC1994	Pa		6
1991.25	129.4	.	26.01	.	7.262	0.057	8.340	0.119	511	222	0.3	1	HIP1997a	Hh		5
1991.25	.	.	.	.	7.205	0.007	8.258	0.014	530	100	0.3	1	TYC1997	Ht		7
1991.25	.	.	.	.	7.233	0.006	8.398	0.012	430	90	0.3	1	TYC1997	Ht		7
1991.66	129.5	.	26.005	.	7.236	0.010	8.170	0.013	530	100	0.3	1	TYC2000b	Ht		5
1991.66	.	.	.	.	7.244	0.015	8.281	0.016	430	90	0.3	1	TYC2000b	Ht		7
1998.164	129.3	1.0	25.87	0.35	8.42	0.22	9.14	0.09	609	70f	0.2	4	UC_2013b	Eu	P	7
1999.97	129.7	.	25.98	.	7.170	0.021	7.984	0.023	1256	245	1.3	1	TMA2003	E2		7
1999.97	.	.	.	.	7.172	0.021	7.937	0.053	1633	160	1.3	1	TMA2003	E2		7
1999.97	.	.	.	.	7.129	0.016	7.866	0.034	2210	300	1.3	1	TMA2003	E2		7
2010.	.	.	.	.	8.939	0.120	9.187	-0.010	550	89	0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	9.213	0.140	9.483	-0.010	440	98	0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	8.040	0.130	8.632	0.130	763	153	0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	8.933	0.080	9.364	0.180	623	137	0.2	1	AAV2012	Zc		7
2010.	.	.	.	.	9.792	0.060	10.137	0.090	477	139	0.2	1	AAV2012	Zc		7
2010.5	129.8	0.3	26.03	0.12	7.120	0.032	7.863	0.024	3350		0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	7.138	0.020	7.888	0.020	4600		0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	6.963	0.016	7.853	0.018	11.6	u	0.4	1	WIS2012	Hw		7
2010.5	.	.	.	.	5.989	0.031	7.356	0.068	22.1	u	0.4	1	WIS2012	Hw		7

2.- <u>Feasibility analysis for building orbital charts</u>:

Unfortunately, we did not have the possibility to make any orbital diagram with the available data of the 4 pairs of physical nature and the one of uncertain nature, since in these cases of WDS 13332-7734 (HJ4590), WDS 09283-7815 (HJ4226), WDS 09194-7739 (HJ4214AB), WDS 08228-7626 (HJ4109) and WDS 13300-7634 (RSS18), none of them show variations in separation (ρ) nor in position angle (θ) in the span of almost 2 centuries, none of them show variations in separation (ρ) or position angle (θ) in the span of almost 2 centuries, and despite appearing to be physical pairs when compared to the calculations, this lack of orbital trends in the historical data would indicate a potential lack of gravitational relationship between the components of these pairs.

While it is beyond the scope of this paper and so will not be done, it is useful to mention that to determine definitively in a theoretical way whether these pairs are gravitationally bound, it would be necessary to calculate their escape velocities, and in the case that these are greater than the relative motion of the components, this would suggest that the systems are gravitationally bound and would be physical pairs.

CONCLUSIONS:

The resulting values of the measurements performed fall within the average standards of the existing WDS records, and the measurements of the chosen pairs updated the existing records by an average of about 8 years.

As for the determination of the nature of the 5 pairs classified as physical and uncertain, the analyses performed were inconclusive because stars that have a common proper motion are a major difficulty for the relative astrometry of double stars, because although they appear to move with equal angular velocity, we have no way to tell if they are close enough to be gravitationally bound together.

Another difficulty they present is the problem of perspective, since it may be the case that they have shown no displacements from 1837 to the present day but in reality they are moving around each other and we do not notice it because their orbital plane could be almost normal to our line of vision and the secondary one at one of its extremes, so that it moves away or approaches in a perpendicular line towards us.

In any case, we should not despair and be patient because 4 or 5 centuries constitute a mere blink of an eye in the history of the Universe and they pass quickly, so our great-great-grandchildren will be able to confirm if there is indeed any gravitational interaction between the components of these 5 pairs analysed to determine if they are really physical or simply visual.

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- General information and existing files in the JDSO (Double Star Journal Observations) have been consulted (http://www.jdso.org/)
- Data from the European Space Agency (ESA) Gaia mission have been used for this work (https://www.cosmos.esa.int/gaia), which were processed by Gaia's Data Processing and Analysis Consortium (DPAC) (https://www.cosmos.esa.int/web/gaia/dpac/consortium), group funded by institutions participating in the Gaia Multilateral Agreement