Double stars assembling Celestial Y

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Abstract

In a popular area of the sky, near alpha Persei, there is a Y-shape of stars around 9th magnitudes, which contains three separate double stars that can also be observed with a small telescope. Only one of these is listed in the WDS, but not with the observed component either. At first glance, they look like optical pairs, but with precise astrometric measurements using nova.astrometry.net, AstroImageJ software and Gaia Data Release 3, it was possible to prove the physical connection between the components. Thus, they can be considered new possible binary stars. Deeper analysis also revealed additional components, that may also in a gravitational relationship with each other. The history of the presented observations covers more than three decades.

1. Introduction

In Hungary, we founded the Hungarian Astronomical Association Double Star Section in 1992. As a result, Hungarian measurements played a significant role in the growth of the Washington Double Stars Catalog in the 21st century. (1) In addition to managing the joint work, I carried out the measurements in my self-built private observatory. (2)

The history of this publication dates back to the early 1980s, when Glenn F. Chaple wrote an article in Deep Sky Monthly based on a letter from a reader. Magazine reader John Vlasic spotted a strange Y-shaped group in the sky while scanning the sky with his telescope. He found three of the four stars he observed to be double and those at the time were thought to be optical, so they stopped measuring them further, hoping that one day someone would pay attention to them. (3)

I observed this group for the first time on August 11, 1991 with a 102/820 Starfire apochromat and made a drawing of it at 175x magnification. I made the next observation visually of this group on September 27, 2001 with a 25cm reflector using 234x magnification. I observed this group again in January 2023, when I started working on the astrometry of double stars. In my observatory, a spectacular series of imaging of these doubles was made. The result was remarkable, as in all three cases it was possible to demonstrate the presence of a physical connection.

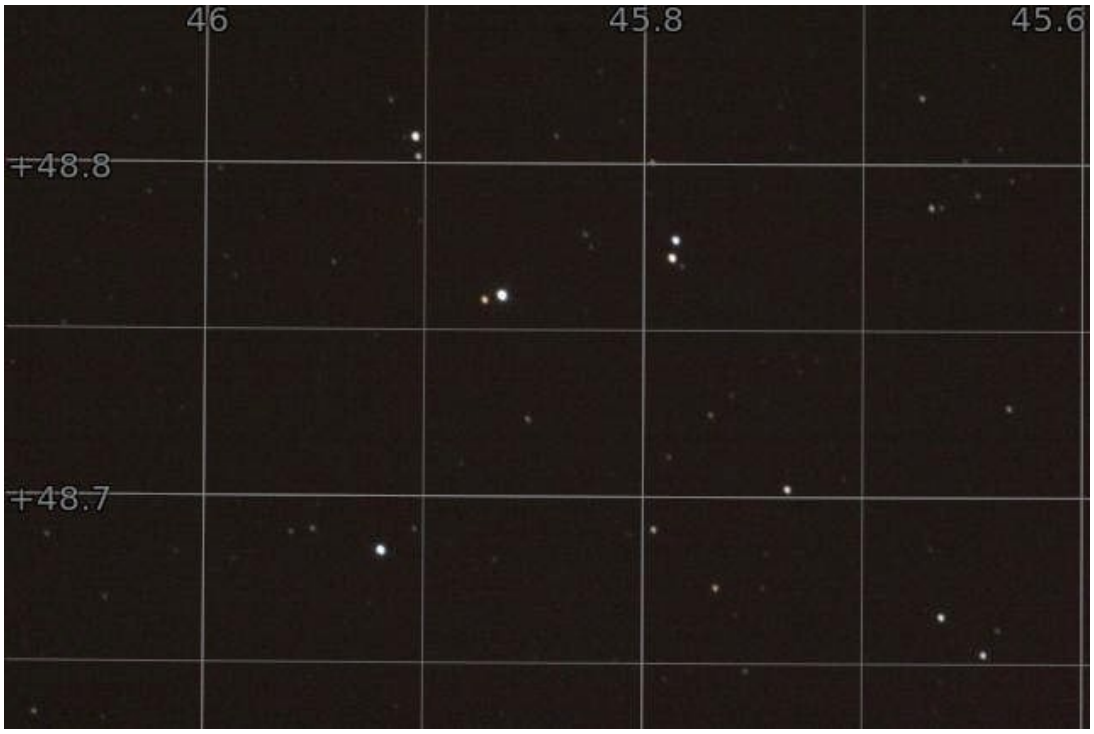

Figure 1: The image of the area adjusted to the equatorial coordinate system with the values of right ascension and declination based on the website https://nova.astrometry.net/.

2. Equipment and Methods

The Castor Observatory is located in the city of Veszprem in Hungary in the following geographical coordinates: N47° 06' 58.00" E17° 55' 14.00" and at an altitude of 217m above sea level. The main instrument of the building with a rolling roof is a 250mm diameter custom-made Cassegrain reflector with a focal length of 3550mm. Tracking is ensured by a Fornax 50 mount. The observatory built in the garden of my family house was inaugurated in 2003 and was named after the famous binary system, Castor. I used several tools to measure binary stars: a Zeiss eyepiece micrometer and an ATK-1 HS CCD camera. The measurements were taken from the suburb area of a small town, which confirms that double stars can be detected effectively even from a moderately light-polluted environment (SQM value: 19,85 mag/arcsec^2). (4)

Figure 2: The 250mm Cassegrain reflector of the Castor Observatory, which I use for double star measurements. The image shows the International Space Station and the Space Shuttle Discovery passing overhead on March 23, 2009. [5] Directly above the telescope is the Perseus constellation, in which I marked the location of the Celestial Y with a red cross.

For astrometry, I use a Canon EOS 600D DSLR camera connected to the main telescope. The camera has a 22.3x14.9mm 18.7MP resolution CMOS sensor. I calibrated the system using nova.astrometry.net. The size of the field of view is 19.6 x 13.1 arcmin, radius 0.196 deg, pixel scale 0.227 arcsec/pixel. The most effective setting in the camera was the 30s exposure time with ISO 6400 sensitivity, where the image quality also depended on the seeing of the atmosphere. In all cases, I had saved the images in JPG and CR2 format, and afterwards I subtracted the dark image manually. I collected the raw material of the presented image and measurements over 3 nights (JD 2023,030 - JD 2023,106) and used the 14 best quality images for the analysis. The specific measurements were made with AstroImageJ version 5.1.0.00, after the astrometric calibration of each image is done using the WCS menu item Plate solving with Astrometry.net. After measuring the exact positions using the star centroid algorithm, I was able to calculate the current separation and position angle data. [6]

As a check, I always compare the resulting separation and position angle data with the data calculated from the Gaia DR3 coordinates. Thus, by comparing the values obtained from the exact 2016 coordinates, possible larger errors can be rejected. The standard deviation of my measurements of the angular distance in the case of the brighter stars is much more favorable ±0.11 arcsec, than ±0.74 in the case of components fainter than 13.5 magnitude. The deviation of the position angles is based on a similar tendency, ±0.4 for the brighter components, and ±1.33 deg for the fainter components. Atmospheric seeing and the effect of urban light pollution also play a role in this.

3. Data

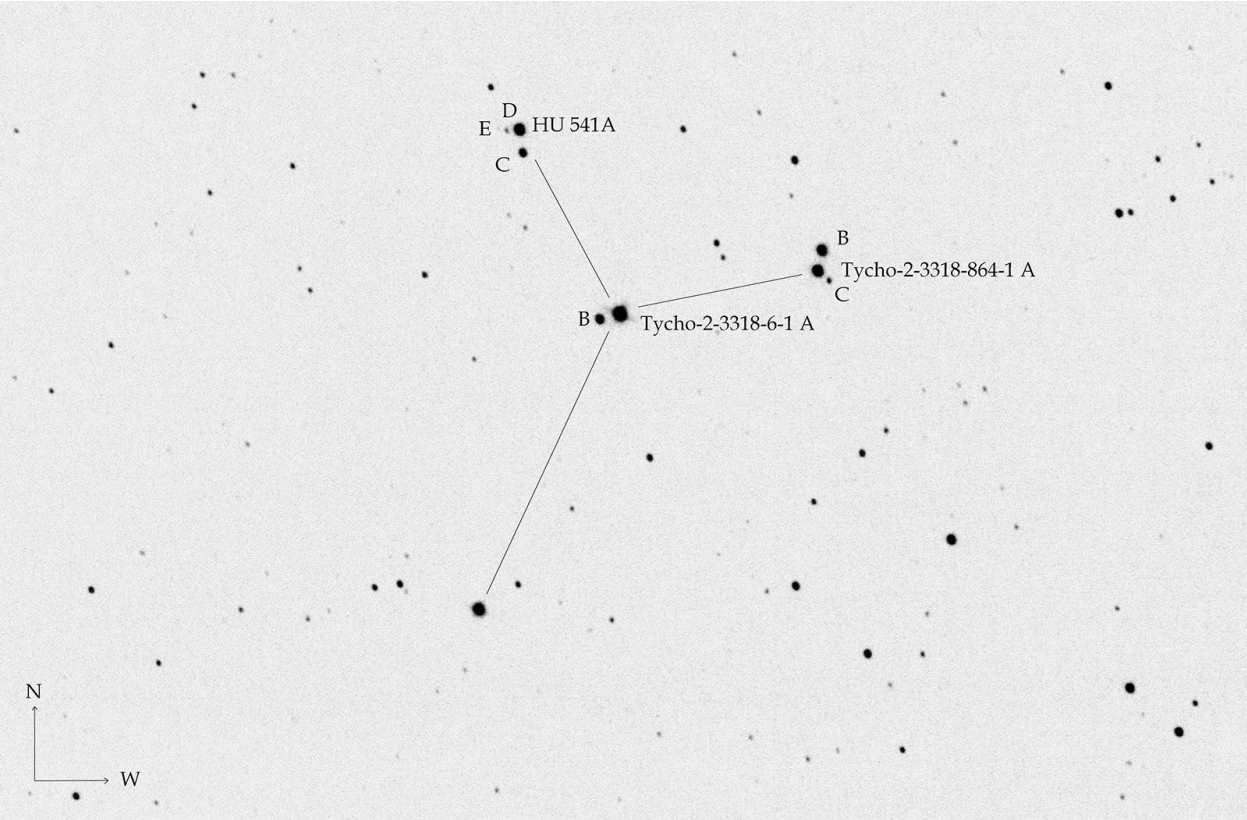

Figure 3: An image of Celestial Y that is centered on RA=03^h 03^m 22,461^s and Dec +48^o 44^m 19,954^s, the field of view 19,6 x 13,1 arcmin, radius 0,196 deg, pixel scale 0,227 arcsec/pixel, up is 359,7 degrees.

Tycho-2-3318-6-1: measurements of Y's central star

Table 1. Measures of Tycho-2-3318-6-1

RA A	DEC A	Discoverer Code	PA	PA (err.)	S	S (err.)	G Mag A	G Mag B
03 03 27	+48 45 35	Tycho-2-3318-6-1	104,71	0,4	19,55	0,08	8,58	10,57

This star is not listed as a double in the WDS, I identified its primary star based on the Tycho-2 database. For the brightness values, I indicated the Gaia DR3 G magnitude.

HU 541: measurements of the northeast star of Y

Table 2. Measures of HU 541

RA A	DEC A	Discoverer Code	PA	PA (err.)	S	S (err.)	G Mag A	G Mag B
03 03 36	+48 48 27	HU541 AC	188,41	0,16	21,68	0,11	9,99	11,66
		HU541 AD	92,28	1,09	11,97	0,26	9,99	14,46
		HU541 DE	76,87	1,33	7,36	0,74	14,46	15,96

The primary star of this is listed in the WDS as HU 541 WDS03036+4849, but the close 1.6" separation of AB components [8] are not resolved in the image. Additional components are not included in WDS. For the brightness values, I indicated the Gaia DR3 G magnitude.

Tycho-2-3318-864-1: measurements of Y's northwest star

Table 3. Measures of Tycho-2-3318-864-1

RA A	DEC A	Discoverer Code	PA	PA (err.)	S	S (err.)	G Mag A	G Mag B
03 03 08	+48 46 17	Tycho-2-3318-864-1 AB	349,05	0,1	19,55	0,03	9,59	10,16
		Tycho-2-3318-864-1 AC	229,71	0,52	13,55	0,17	9,59	13,64

This star is not listed as a double in the WDS, I identified its primary star based on the Tycho-2 database. For the brightness values, I indicated the Gaia DR3 G magnitude.

4. Discussion

Table 4. Discussions of Harshaw Rating and physical connection

Discoverer Code	WTD SEP (AU)	Harshaw Rating	Physical	GAIA ID A	GAIA ID B
Tycho-2-3318-864-1 AB	8 445	62,06%	Maybe	43614355656656985	436143625286045568
Tycho-2-3318-864-1 AC	9 746	12,13%	No		436143556566570880
HU541 AC	6 709	92,43%	Yes	43614101394738086	436141013945917184
HU541 AD	5 305	28,34%	No		436141013945915648
HU541 DE	5 384	72,59%	Yes		436141048305653760
Tycho-2-3318-6-1	3 069	75,54%	Yes	43614049854985344	436140498551310848

The table contains the conclusions calculated based on the Gaia DR3 parallax, proper motion and radial velocity values for the parameters weighted separation in AU, Harshaw Rating and physical connection. [9] Columns 2 and 3 show the Gaia DR3 IDs of each component.

5. Conclusions

This area was worth the invested energy, which proved to be much more than an apparent asterism. Four types of physical relations were also revealed, of which the most interesting is HU 541 AC with its 92,43% Harshaw Rating. Since HU 541 DE is not physically connected to A, it can also be interpreted as an independent double star. It would be worth examining this pair with a larger telescope, because the 25C I use is at the limit of its performance. It would also be worth targeting the resolution of HU 541 AB, which

is also a physical pair (Harshaw Rating 85%). The planned release of Gaia DR4 will be able to provide more precise information.

By analyzing the GAIA data, we can draw further conclusions about the physical characteristics of the components, and we can also plot the stars on a Hertzsprung-Russel diagram. [10]

Table 5. Calculation of the physical characteristics of stars (using Plot Tool Excel spreadsheet)

	Mag App	Lum ⊙	Rad ⊙	Mass ⊙	Abs Mag	T-eff	Spect
Tycho-2-3318-864-1 A	9,59	31,89	6,15	2,44	1,08	4 870	K
Tycho-2-3318-864-1 B	10,16	10,73	3,24	1,81	2,26	5 913	G
Tycho-2-3318-864-1 C	13,64	5,09	2,00	1,50	3,07	7 378	F
HU541 A	9,99	8,25	2,97	1,69	2,55	5 416	G
HU541 C	11,66	1,88	1,33	1,17	4,15	6 134	F
HU541 D	14,46	0,79	0,95	0,94	5,08	5 114	G
HU541 E	15,96	0,16	0,45	0,64	6,79	4 628	K
Tycho-2-3318-6-1 A	8,58	2,38	1,48	1,24	3,89	6 250	F
Tycho-2-3318-6-1 B	10,57	67,54	8,83	3,03	0,27	5 000	K

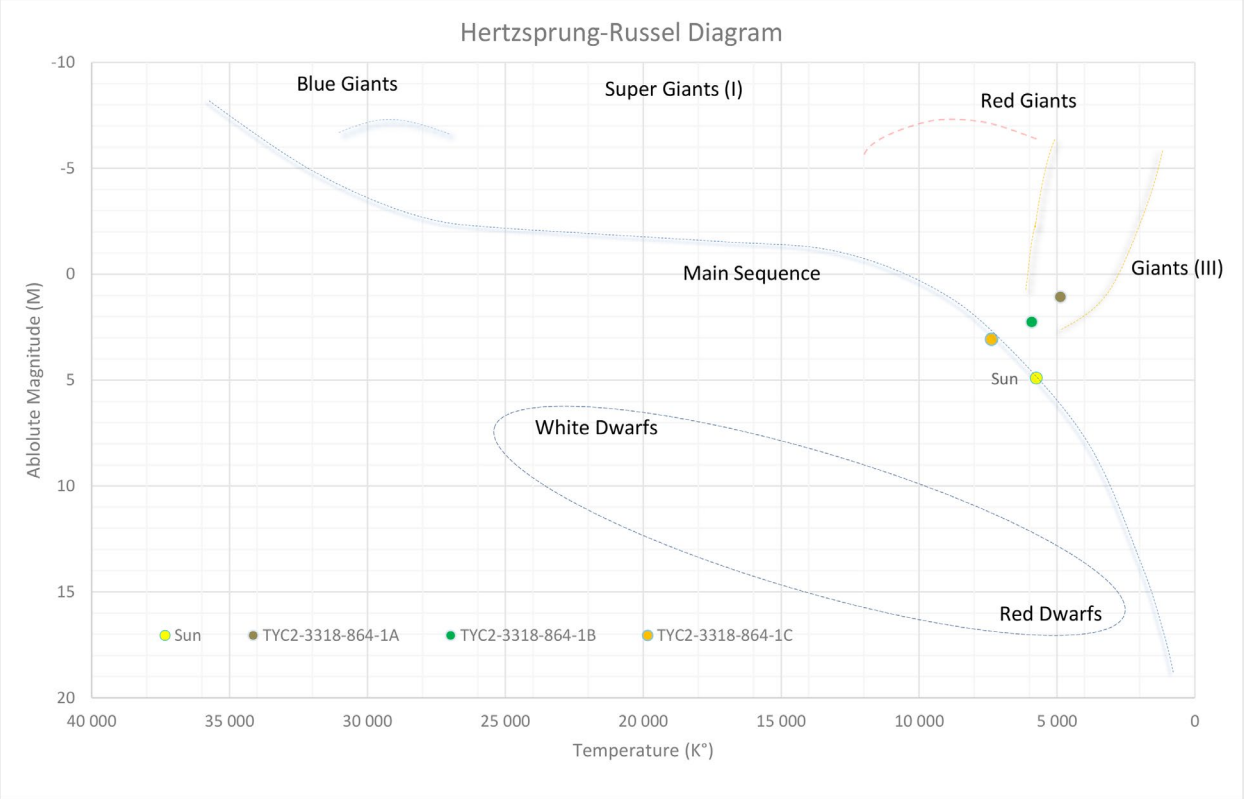

Figure 4: Representation of the measured stars of Tycho-2-3318-864-1 on the HRD.

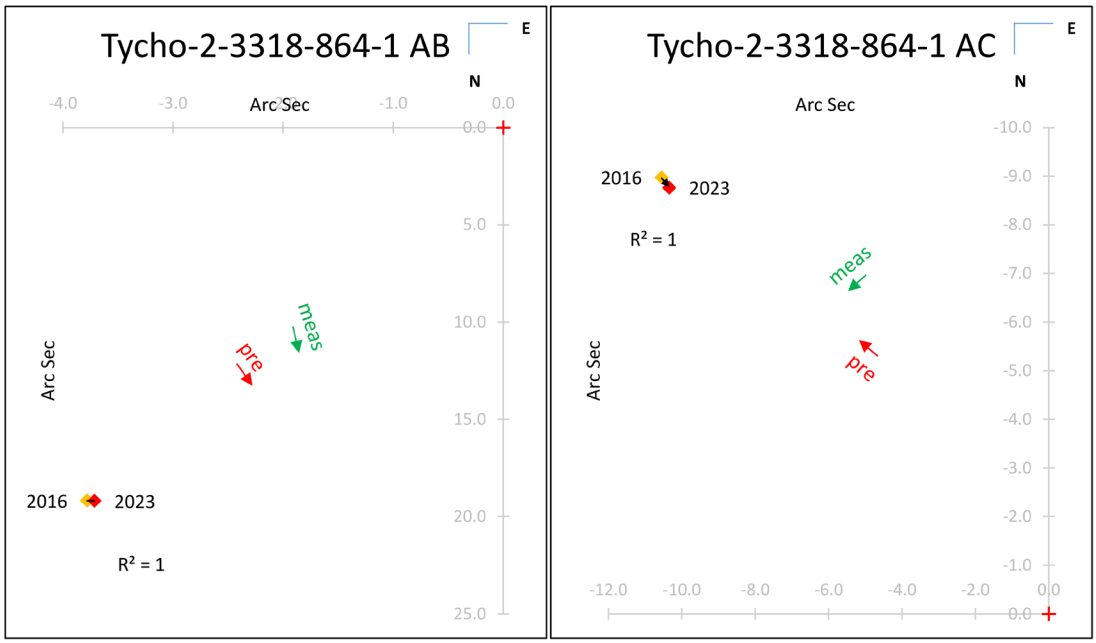

Figure 5: Representation of motion vectors and positions of Tycho-2-3318-864-1 using Plot Tool 3.19.

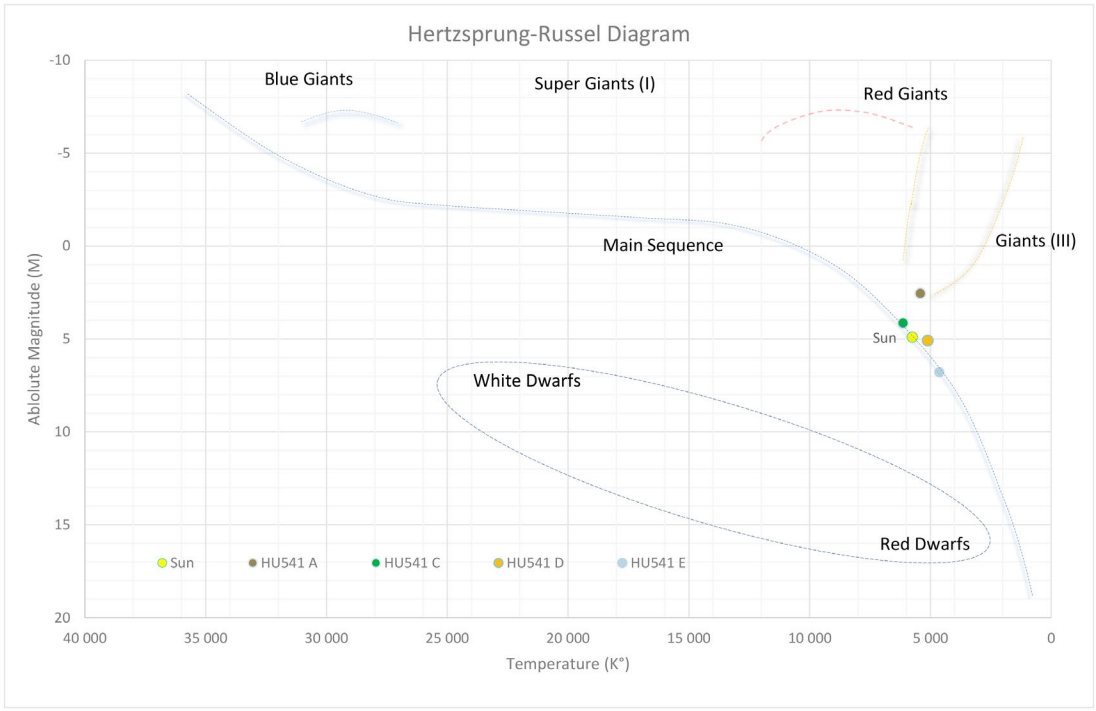

Figure 6: Representation of the measured stars of HU 541 on the HRD.

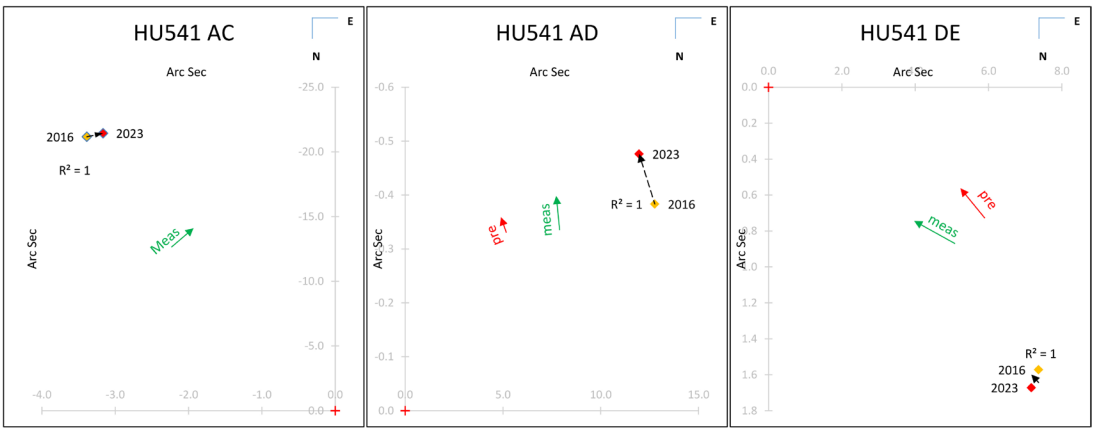

Figure 7: Representation of motion vectors and positions of HU 541 using Plot Tool 3.19.

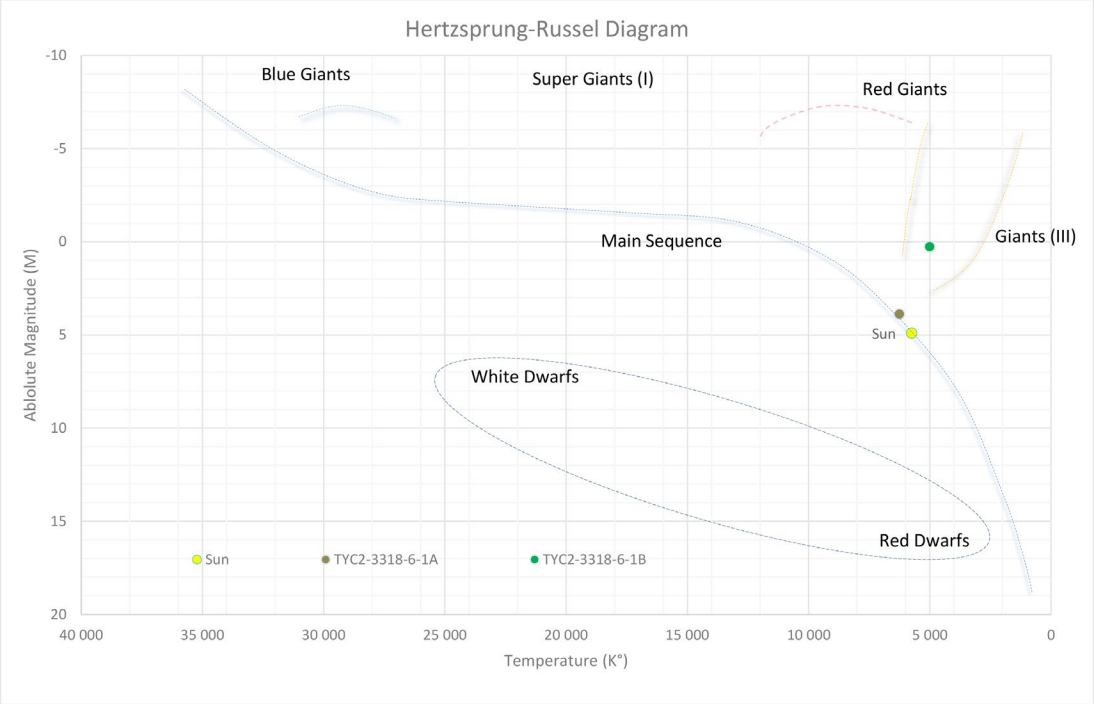

Figure 8: Representation of the measured stars of Tycho-2-3318-6-1 on the HRD.

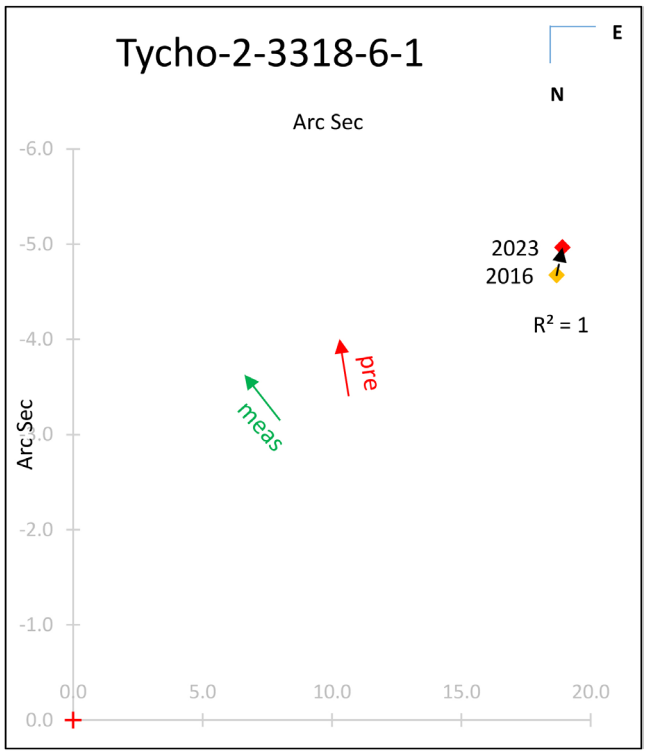

Figure 9: Representation of motion vectors and positions of Tycho-2-3318-6-1 using Plot Tool 3.19.

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