GJ 282 AB (WDS 07400-0336 AB = BGH 3 AB) and GICLAS 112-29: A Very Wide System in Process of Dissociation

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Abstract: Very wide binaries are interesting objects that shed light on the binary formation process and their dynamical evolution. Poveda et al. (2009) studied the possible physical relation of the near (14.2 pc) and wide (~58”) binary star GJ 282 AB and the extremely wide (1.09º; ~55,000 AU) companion, NLTT 18149, and they concluded that this very wide system is in the process of dynamical disintegration. In this work, we confirm the same conclusion but using a different method. We first study dynamically GJ 282 AB, confirmed that it is a bound system and then we determine possible orbital solutions. Later, we calculate the relative velocity of NLTT 18149 with respect to the GJ 282 AB’s center mass using their (*U*, *V*, *W*) galactocentric velocity. The relative velocity, $V_{\rm rel} = 1.98 \pm 0.16$ km s^{-1}, is much larger than the escape velocity (0.25 ± 0.01 km s^{-1}). Therefore, with a significance level of 11σ, we also conclude that this very wide system is in a process of dynamical disintegration.

1. Introduction

The very wide binaries after formation are subject to dynamical process that causes their evolution. In environments with high or moderate stellar density, most pairs with separations of a few hundreds to a few thousands AU are disintegrated (that is, disrupted) within a few million years (Parker et al. 2009). In the stars field, outside of these high density environments, Galactic tides and weak interactions with passing stars disrupt binary stars with separations of a few times 10,000 AU on a time scale of about 10 Gyr (Heggie 1975; Weinberg et al. 1987).

Recently, astronomers discovered that stars of disrupted binaries don’t quickly leave the binary environment but escaping stars drift apart with low relative velocity and remain within the Jaboci radius during millions or tens of millions of years.

In order to study the process of dissociation of very wide systems, Poveda et al. (2009) presented the very wide and nearby system GJ 282 AB–NLTT 18149 as the most interesting object in his very wide common proper motion binary search. GJ 282 AB is a wide pair (~58 arcsec) composed by two red stars of 7.20 and 8.87 magnitudes at 14.2 pc of distance. The high common proper motion, common radial velocity, and common age strongly suggest a bound nature for AB.

NLTT 18149 (= Giclas 112-29) is a red dwarf star located at 1.09 deg (0.27 pc) of separation to GJ 282 AB. Its common distance, common age, common proper motion, common radial velocity to GJ 282 AB strongly suggest possible physical relation. Poveda et al. (2009) concluded that the system GJ 282 AB–NLTT 18149 is in the process of dynamical disintegration. The large physical separation of very wide binaries such as these is larger than the isolate stars formation regions. Astronomers think that these systems can only form during the dissolution phase of open clusters of low density (Kouwenhoven et al. 2010).

The main objective of this work is to confirm the bound status of GJ 282 AB and the dynamical disintegration status of GJ 282 AB–NLTT 18149.

The organization of this paper is as follows. In Section 2, we detail the characteristic of the AB pair, the

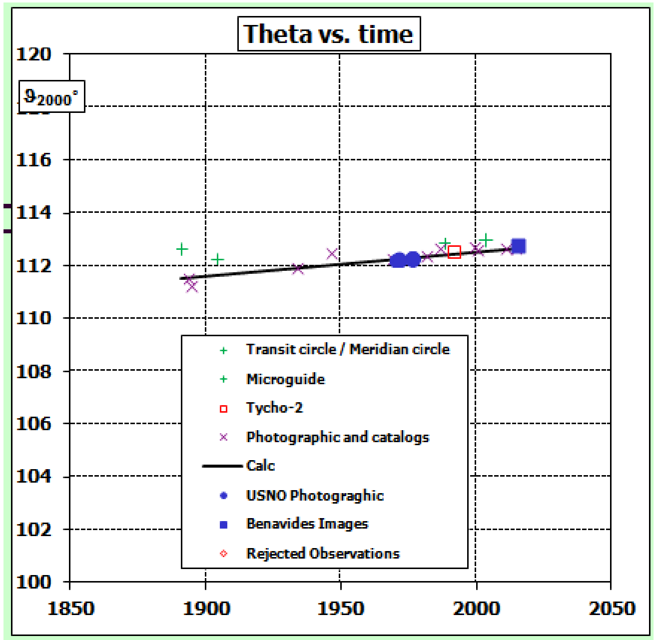

Figure 1. Historical position angle, θ, of GJ 282 AB and its evolution with time. We determined a very significant change of +0.0090 ± 0.0004 deg yr^{-1}

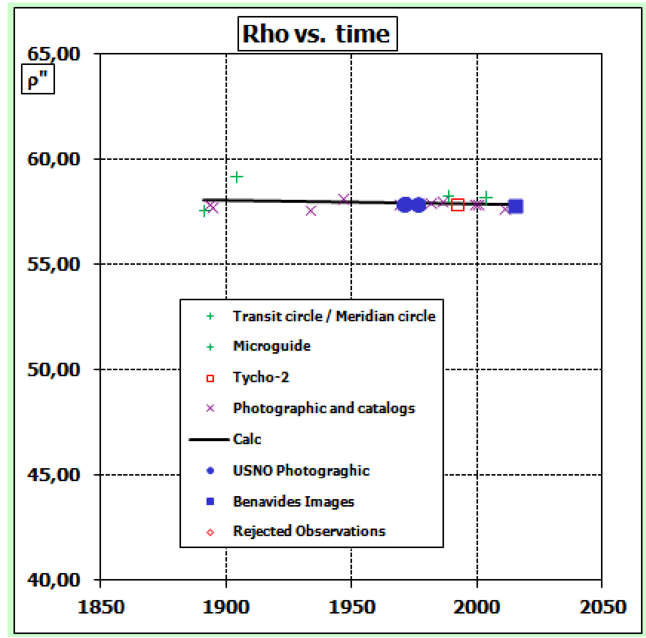

Figure 2. Historical distance, ρ, of GJ 282 AB and its evolution with time. We determined a change of -0.0021 ± 0.0005 arcsec yr^{-1}.

new astrometric measures performed, the dynamic study and the orbital calculation. In Section 3, we present the very wide component, the calculus of the characteristics of the mass center and the study of the possible physical relation of C with respect to AB.

2. The Close System GJ 282 AB

S. van den Bergh in 1949 discovered, using the photographic technique with astrograph, two red stars with high common proper motions. This object was catalogued as GJ 282 AB, a wide pair (~58 arcsec, 825 UA) listed as WDS 07400-0336 AB (= BGH 3 AB) in the Washington Double Star Catalog (hereafter WDS). It is composed of two young stars of 7.20 (K2V) and 8.87 (K6/7V) magnitudes at 14.2 pc of distance The high common proper motion, common radial velocity, and common age strongly suggest a bound nature for AB.

To confirm this bound status, we study the relative motion of B component with respect to A by weighted linear fits using dθ/dt, dρ/dt, dx/dt, and dy/dt plots (see Figures 1 and 2). The WDS catalog lists 27 astrometric measures from 1890 to 2003 and was kindly provided by Brian Mason. We assign initial weights for astrometric measures using a data-weighting scheme and process based on Rica et al. (2012).

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In this work, we add two more astrometric measures to the WDS for epochs 2010.5589 and 2014.131 using the catalogs WISE and URAT1 (Zacharias et al. 2015). In addition to this, Rafael Benavides used a f/10 Celestron telescope of 0.3 m with a ASCOM QHY9 CCD camera, to take 5 CCD images of 0.6 seconds of exposition on 2015 February 8th. The telescope is located at the Posadas Observatory (Córdoba, Spain) with the MPC code J53. The pixel size of the camera was of 5.4 µm (0.86" in the focal plane). We use Astrometrica 4.8.2 for the calibration and astrometric process.

All the astrometric measures, with a time baseline of 125 years, are listed in Table 1. This table lists, from the left to right, the observational epoch, the position angle (2000 equinox), and distance as listed in WDS in the three first columns. The number of nights (N), the reference (as used in WDS), the aperture of the telescope (in meters), the observational technique (as listed in WDS), the weights assigned to θ and ρ, and the O – C residuals are also listed.

The United State Naval Observatory (USNO) per-

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Table 1. Astrometric data, weights and residuals for the linear trend of GJ 282 AB

Date	ϑ°	ρ"	N	Ref.	Ap	Tec	w ϑ	w ρ	O-Cϑ°	O-Cρ"
1890.600	112.1	57.623	2	WFD1906b	0.2	T	0	9	1.10	-0.49
1893.200	111.0	57.963	1	WFC1998	0.3	Pa	20	22	-0.04	-0.14
1894.180	110.7	57.799	1	WFC1998	0.3	Pa	20	22	-0.35	-0.30
1903.500	111.8	59.240	4	WFD1940	0.2	T	3	0	0.62	1.16
1933.500	111.6	57.654	1	WFC1945b	0.1	Pa	20	22	0.00	-0.37
1946.000	112.2	58.200	1	Bgh1958	0.1	Pa	20	32	0.42	0.21
1968.650	112.1	57.943	4	WFC1992	0.2	Pa	79	86	0.01	-0.01
1970.235	112.1	57.943	1	USN1974	0.7	Po	6596	16020	0.00	0.00
1970.238	112.1	57.935	1	USN1974	0.7	Po	6596	16020	0.00	-0.01
1970.915	112.1	57.957	1	USN1974	0.7	Po	6596	16020	-0.01	0.01
1971.174	112.1	57.943	1	USN1974	0.7	Po	6596	16020	0.01	0.00
1971.185	112.1	57.947	1	USN1974	0.7	Po	6596	16020	0.00	0.00
1971.185	112.1	57.940	1	USN1974	0.7	Po	6596	16020	-0.01	0.00
1975.876	112.2	57.919	1	USN1978	0.7	Po	3298	8010	-0.02	-0.01
1975.876	112.2	57.917	1	USN1978	0.7	Po	6596	8010	-0.01	-0.02
1976.092	112.2	57.932	1	USN1978	0.7	Po	6596	16020	0.00	0.00
1976.155	112.2	57.946	1	USN1978	0.7	Po	6596	16020	-0.01	0.01
1976.155	112.2	57.928	1	USN1978	0.7	Po	6596	16020	0.00	0.00
1976.158	112.2	57.928	1	USN1978	0.7	Po	6596	16020	0.00	0.00
1976.158	112.2	57.933	1	USN1978	0.7	Po	6596	16020	0.01	0.00
1981.200	112.3	58.011	2	WFC1999	0.2	Pa	56	61	0.03	0.09
1985.960	112.6	58.105	4	WFC1994	0.2	Pa	79	86	0.26	0.19
1987.800	112.8	58.340	4	WFD1985	0.2	T	6	6	0.44	0.43
1991.850	112.5	57.920	1	TYC2002	0.3	Ht	79	86	0.08	0.02
1998.860	112.7	57.960	1	TMA2003	1.3	E2	99	108	0.18	0.07
2000.102	112.6	57.974	6	UC_2013b	0.2	Eu	40	43	0.07	0.09
2003.068	113.0	58.260	1	Arn2003e	0.2	Mg	3	2	0.43	0.38
2010.559	112.7	57.710	1	WISE	0.4	Hw	123	123	0.02	-0.15
2014.131	112.7	57.900	1	URAT1	0.2	E	1111	1111	0.01	0.05
2015.108	112.79	57.85	1	Benavides	0.3	C	400	400	0.12	0.00

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Table 2. Positional, Dynamical, and Kinematic Parameters for GJ 282 AB.

Mean Epoch	1990.000		
θ (deg) for mean epoch	112.445	±	0.007
ρ (arcsec) for mean epoch	57.904	±	0.009
x (AU) [East-West]	+763	±	14
y (AU) [North-South]	-315	±	6
dρ/dt (mas yr^{-1})	-2.06	±	0.51
dθ/dt (deg yr^{-1})	+0.0090	±	0.0004
dx/dt (mas yr^{-1})	-5.31	±	0.53
dy/dt (mas yr^{-1})	-7.65	±	0.41
Vx (km s^{-1}) [East-West]	-0.36	±	0.04
Vy (AU) [North-South]	-0.52	±	0.03
Vz (km s^{-1}), radial velocity	-0.1	±	0.2
Vtot (km s^{-1})	0.67	±	0.04
Vesc_max (km s^{-1})	1.74	±	0.05
Mass of A (Msun)	0.80	±	0.05
Mass of B (Msun)	0.65	±	0.05
Distance (pc)	14.3	±	0.3

formed a very accurate series (root mean square, RMS, of ~0.01º and ~0.01" for position angles and distances) of astrometric measures using the Alvan Clark 0.7 m refractor telescope. For the observing condition, the correction of relative astrometry for atmospheric refraction is negligible for position angle (< 0.01º) but significant (+0.02") for the USNO distances. We correct for atmospheric refraction in the USNO distances.

Our dynamic study shows that the angular separation decreases about 2.06 ± 0.51 mas yr^{-1} while the position angle clearly increases 0.0090 ± 0.0004 deg yr^{-1}. The total relative motion (9.3 ± 0.5 mas yr^{-1}) has a significance of 13σ, therefore we can reject the non-motion hypothesis. The positional, dynamical, and kinematical parameters for the linear fit are shown in Table 2. The RMS of this fit is 0.02º and 0.013" and the mean absolute, MA, 0.01º and 0.007". The RMS gives the mean spread of the measures with respect to the mean. And the MA gives the uncertainty of the near future ephemerids. The adopted values for the stellar masses are 0.80 and 0.65 solar mass.

The total relative velocity of B with respect to A is 0.67 ± 0.04 km s^{-1} much smaller than the upper limit of the escape velocity (1.74 ± 0.05 km s^{-1}). By using the work of Winsberg et al. (1987) about dynamic evolution, we can conclude that GJ 282 AB is immune to external perturbations (gravitational binding energy of -8.8×10^{-42} ergs) and that is a high common proper motion, common distance, common age binary, composed by stars gravitationally bound.

We determined orbital solutions for GJ 282 AB using the method of orbital calculation presented by Hauser & Marcy (1999). This method only needs instant position (x, y, z) and velocity vectors (V_x, V_y, V_z) in addition to a parallax and stellar masses to obtain a family of orbits depending on z (the line-of-sight position of the component). The input parameters are those of Table 2. The only unknown input data is the z parameter. We constrained the value of z following the procedure in Hauser & Marcy (1999) and one orbit for each value of z is obtained.

We study the empirical distribution of r (in arcsecond) as a function of ρ. For this task, we select about 300 grade 1-2 orbital solutions from the *Sixth Catalog of Orbits of Visual Binary* (Hartkopf & Mason 2003), calculate the ephemerides for ρ and r for different epochs. The comparison between ρ and r give us the distribution of r as a function of s. We see that the values for r/ρ are highly dependent on the orbital inclination (see Figure 3). For highly-inclined orbits, the 3D effect is greater and therefore we could find r-values much greater than ρ. Figure 4 shows the cumulative distribution.

Table 3 shows same numbers (quartiles, percentiles, mean, median, etc.) about the distribution of r/ρ. The median happens for r/ρ = 1.11 (that is, 50% of possible orbital solutions have values of r/ρ from 1.0 to 1.11). If we center over the median, 50% of the orbital solutions ranges from 1.02 to 1.38 (from 1.00 to 1.38 for the 75% of the possible orbital solutions). Finally, the 90% of possible orbital solutions have r/ρ ≤ 2.0 approximately. Only the high-inclined orbits have greater

Table 3. Statistics for the r/ρ Distribution

Name	Mean	Minimum	Maximum	Q10	Quartile1	Median	Quartile3	Q90
r/ρ	1.40	1.00	17.14	1.00	1.02	1.11	1.38	1.96

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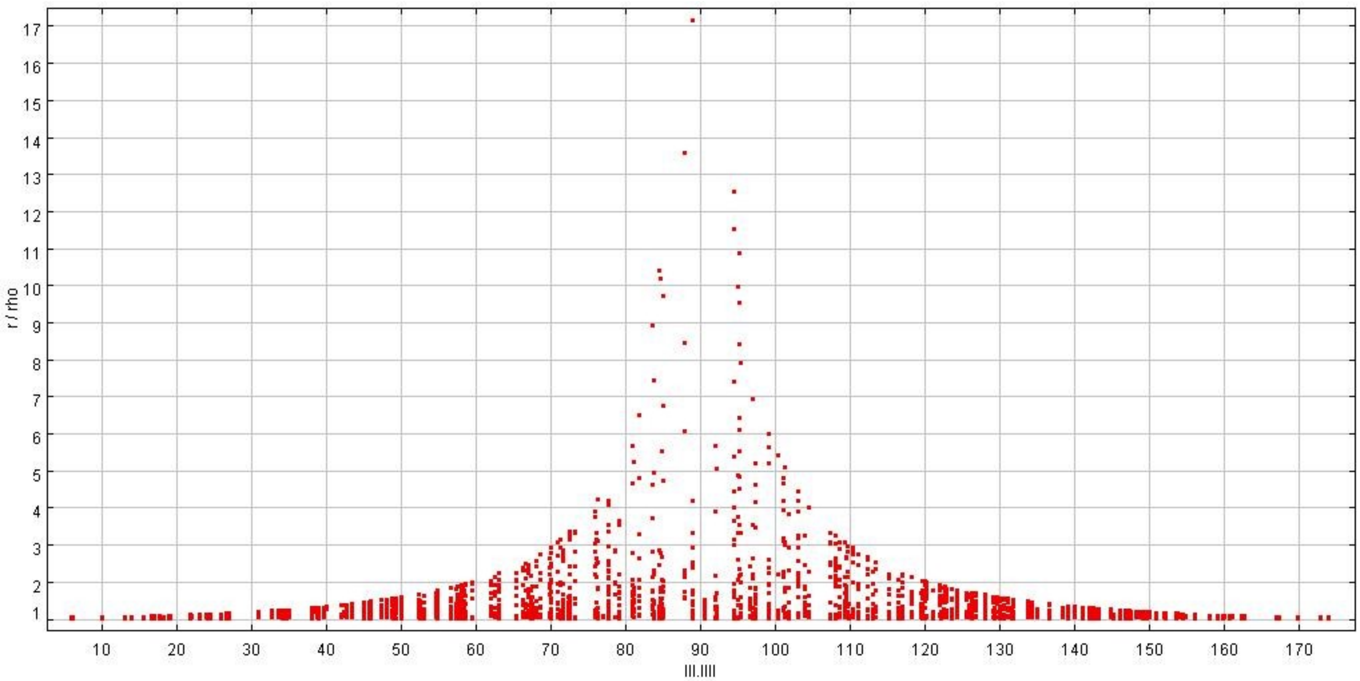

Figure 3. The relation of r/ρ with the orbital inclination (in degrees).

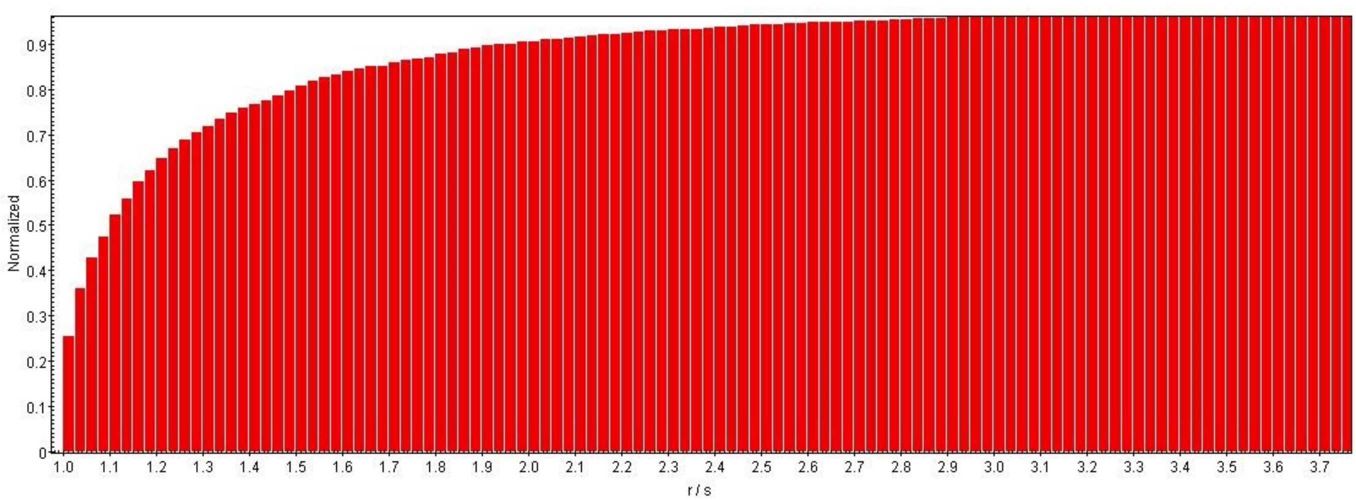

Figure 4. Cumulative distribution of r/s in AU (or r/ρ in arcseconds).

Table 4. Computed Orbital Parameters

COMPUTED ORBITAL PARAMETERS FOR WDS 07400-0336 = BGH 3 AB WITH r = s r = 1.11 s and r = 1.38 s					
Parameter	-783 AU	-396 AU	0 AU	+396 AU	+783 AU
P (yr)	15000	10172	8493	10172	15000
T (yr)	9259	6728	5776	6365	8274
e	0.651	0.724	0.761	0.742	0.681
a (arcsec)	48.4	37.4	33.2	37.4	48.4
a (AU)	688.4	531.3	471.2	531.3	688.4
i (deg)	45.7	29.0	9.4	25.8	43.6
ω (deg)	72.8	60.6	355.9	270.2	260.0
Ω (deg)	-135.6	-127.8	-67.6	15.9	25.6
q (AU)	240.18	146.52	112.74	136.93	219.31

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values. The maximum value is 17.14.

Table 4 lists orbital solutions for different values of the radius-vector (***r***) chosen in function of the empirical distribution of r (in arcsecond) in function of ρ. An orbital solution for the minimum value of the radius-vector, $r = s$ (that is $z = 0$ AU) is shown. In the 50th percentile of the distribution of r in function of s, $r = 1.11s$ ($z = \pm 396$ UA) and in the 75th percentile, $r = 1.38s$ ($z = \pm 783$ UA) two orbital solutions. Therefore, in this table is represented the 75% range of possible orbital solutions.

Figure 5 shows orbital solutions for the AB components calculated in this work. The thick black ellipse is the orbital solution for $z = +396$ UA (when $r = 1.11\,s$, the median value) while the dash ellipse is for $z = -396$ UA. The legends in the inner box are self-explicative. The possible regions ("zone possible" in the inner box) of possible orbital solutions cover the 90% of the confidence interval for z parameter.

3. The Very Wide Companion NLTT 18149

Giclas 112-29 (= NLTT 18149) is a red dwarf (M1.5V) star located at 1.09 deg of separation to GJ 282 AB. Its common distance, common age, common proper motion, and common radial velocity to GJ 282 AB strongly suggest a possible physical relation: It is not listed in WDS. Poveda et al. (2009) concluded that the system GJ 282 AB–NLTT 18149 is in the process of dynamical disintegration. They determined that the perspective effect for the wide pair and the orbital motion of GJ 282 AB cannot explain the large difference in proper motion between GJ 282 and NLTT 18149.

In this work, we want to confirm the dynamical disintegration status of GJ 282 AB–NLTT 18149 by the study of the relative velocity of NLTT 18149 with respect to the center of mass of GJ 282 AB (CM_{AB}).

To determine the properties (AR and DEC, proper motion and radial velocity) for CM_{AB}, we assign weights to the A and B members in function of the stellar masses, as in Kiselev, Romanenko & Gorynya (2009). The values for the weights are $p_A = 0.55$ and $p_B = 0.45$ for A and B components respectively. The adopted values for the stellar masses are 0.80 and 0.65 solar mass for A and B components.

In 1991.25, the CM_{AB} has an offset of 23.42" East and 9.66" South to GJ 282 A. To obtain the (AR, DEC) coordinate for CM_{AB} in this epoch, we use the *Hipparcos* coordinate for GJ 282 A and the offset determined previously. For the proper motion and radial velocity of CM_{AB}, we calculate the weighted mean of the values for A and B using the weights p_A and p_B. We assume that the CM_{AB} is at the same distance that the A component.

The (U, V, W) galactocentric velocities were calculated following the work of Przybylski (1962). We calculate the relative velocity of NLTT 18149 with respect to the CM_{AB} from the difference of their (U, V, W) velocities:

$$V_{rel} = \sqrt{(U_C - U_{CMab})^2 + (V_C - V_{CMab})^2 + (W_C - W_{CMab})^2} \quad (1)$$

The positional, kinematical, and dynamical data of the stellar components and the CM_{AB} are listed in Table 5. The relative velocity (V_{rel}) obtained using formula (1) is 1.98 ± 0.16 km s^{-1}. We determined the errors using a Monte Carlo approach with Gaussian errors for the input data.

From the Tycho-2, 2MASS and URAT1 AR and DEC coordinates of the three components, we determine the relative position of C with respect to CM_{AB}:

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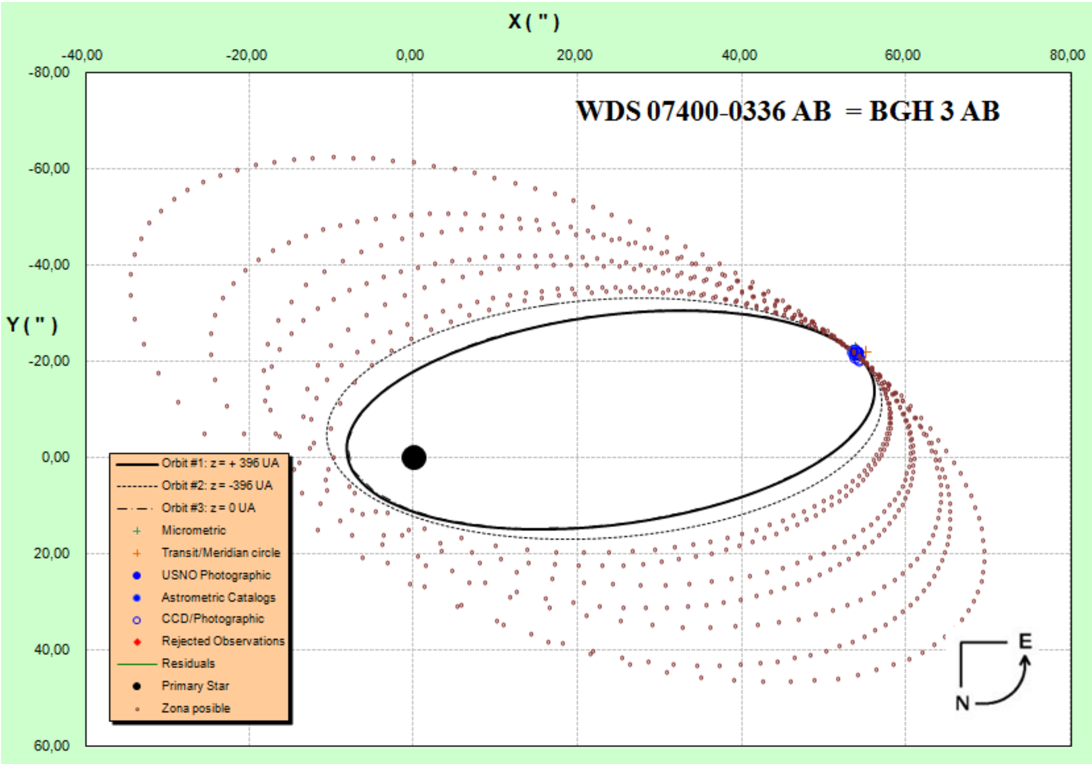

Figure 5 Orbital solutions for the AB components calculated in this work. The legends in the inner box are self-explanatory. The possible regions ("zone possible" in the inner box) of possible orbital solutions cover the 90% if the confidence interval for z parameter.

Table 5. Data for the Stellar Components and the CM_{AB}

	A Component	B Component	CM_{AB}	C Component
α_{2000} for 1991.25	07h 39m 59.29s	...	07h 40m 00.85s	07 36 07.06
δ_{2000} for 1991.25	-03° 35' 48.6"	...	-03° 35' 58.26"	-03 06 36.6
$\mu(\alpha)$ (mas yr^{-1}) 2)	+71.7 ± 1.2	+66.8 ± 1.3	+69.5 ± 0.9	+36.3 ± 1.6
$\mu(\delta)$ (mas yr^{-1}) 2)	-276.1 ± 1.3	-286.2 ± 1.4	-280.5 ± 1.0	-253.5 ± 0.8
V_{rad} (km s^{-1}) 1)	-21.8 ± 0.2	-22.0 ± 0.2	-21.9 ± 0.2	-22.7 ± 0.2
Parallax (mas) 3)	70.37 ± 0.64	...	70.37 ± 0.64	70.55 ± 1.64
U (km s^{-1})	...	...	+28.12 ± 0.15	+27.59 ± 0.15
V (km s^{-1})	...	...	+0.13 ± 0.13	+1.28 ± 0.13
W (km s^{-1})	...	...	-8.22 ± 0.03	-9.34 ± 0.03
1) Poveda et al. (2009); 2) Tycho-2 catalog; 3) Hipparcos				

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Tycho-2: 296.649 ± 0.001° and 3899.61 ± 04" (1991.78)
2MASS: 296.652 ± 0.001° and 3899.81 ± 0.08" (1998.865)
URAT1: 296.650 ± 0.001° and 3899.88 ± 0.06" (2014.05)

The errors in the relative measures were determined using the (AR, DEC) astrometry uncertainties listed in the Tycho-2, 2MASS and URAT1 catalogs. At the distance of this system, the angular separation corresponds to a projected physical separation (*s*) of 55,345 UA (= 0.268 pc). So *s* is the lower limit of radius-vector (*r*) which allows us to calculate an upper limit for the escape velocity (V_{esc_max}) of 0.25 ± 0.01 km s^{-1}.

The binding energy for GJ 282 AB–NLTT 18149 is -2.0x10^{41} ergius and in the Fig. 15 and 16 of Close et al. (2007) we can see that there is no binary with such as low binding energy. And in his Fig. 17, our very wide system is located in the "field unstable" region. Weinberg, Shapiro and Wasserman (1987) studied the dynamical evolution and survival probability of very wide binaries. GJ 282 AB–NLTT 18149 has a binding energy between the curves for a_o = 0.063 pc (-2.7x10^{41} ergius) and a_o = 0.16 pc (-1.1x10^{41} ergius) in their Fig. 6, therefore the probability of survival at the age of the system (300-500 Myr) is about 80%.

But our result shows that $V_{rel} > V_{esc\_max}$ with a significance of nearly 11σ. Trigonometric parallax listed in *Hipparcos* catalog for the A and C components yield greater values for *r* and therefore smaller values for V_{esc} reinforcing our conclusion. Our result confirms that GJ 282 AB–NLTT 18149 is in the process of gravitational dissociation with significance of at least 11σ.

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This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory and the Simbad database operated at CDS, Strasbourg, France.

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