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Reaching the boundary between stellar kinematic groups and very wide binaries

II. α Librae + KU Librae: a common proper motion system in Castor separated by 1.0 pc

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ABSTRACT

Aims. I investigate the gravitational binding of a nearby common proper motion system in the young Castor moving group ($\tau \sim$ 200 Ma), which is formed by the bright quadruple star α Lib (Zubenelgenubi) and the young solar analogue KU Lib. The system has an exceptionally wide angular separation of about 2.6 deg, which corresponds to a projected physical separation of about 1.0 pc.

Methods. I compiled basic information on the system, compared its binding energy with those of other weakly bound systems in the field, and studied the physical separations of resolved multiple systems in Castor.

Results. KU Lib has roughly the same proper motion, parallactic distance, radial velocity, and metallicity as the young hierarchical quadruple system α Lib. It also displays youth features. The resemblance between these basic parameters and the relatively high estimated binding energy indicate that the five stars are gravitationally bound. KU Lib and α Lib constitute the widest known multiple system in all mass domains, and probably represent the most extreme example of young wide binaries on the point of being disrupted. Besides this, I make a comprehensive compilation of star candidates in Castor, including new ones.

Key words. open clusters and associations: individual: Castor moving group – Galaxy: kinematics and dynamics – binaries: general – binaries: visual

1. Introduction

What is the widest separation between stars in a binary system? To answer this question, we must enter a range of separations in which arseconds and astronomical units are almost useless and must instead use arcminutes (or degrees) and thousands of astronomical units (or parsecs). For example, the nearest star to the Sun, Proxima Centauri, is located at an angular separation of about 185 arcmin (3.1 deg) to the binary system α Cen A and B, which at the heliocentric distances of the components is translated into a physical separation r = 12.0 ± 0.6 kAU (0.058 ± 0.003 pc – Innes 1915; Wertheimer & Laughlin 2006). Although Öpik (1932) had theoretically considered maximum apoapsides of up to 200 kAU (∼1 pc) in his novel investigation of the gravitational disruption of wide binary stars, afterwards consensus developed in the literature that there is a cutoff at $s \sim$ 20 kAU (∼0.1 pc) in projected physical separation of binaries (e.g. Tolbert 1964; Heggie 1975; Bahcall & Soneira 1981; Retterer & King 1982; Weinberg et al. 1987; Gliese & Jahreiss 1988; Close et al. 1990; but see Quinn et al. 2009). However, state-of-the-art analytical studies, such as the ones by Jiang & Tremaine (2009), allow the existence of wide binary stars separated by 200 kAU or more. Some of these systems may be formerly bound binaries that are slowly drifting away.

Multiple systems in the solar neighbourhood with $s >$ 20 kAU do exist. Six of them are Washington double stars in the astro-photometric follow-up of Caballero (2009), of which HD 6101 AB and G 1–45 AB (s = 26.9 ± 0.6 kAU), ξ^{02} Cap and LP 754–50 (s = 28.3 ± 0.3 kAU), and HD 200077 AE–D and G 210–44 AB (s = 49.7 ± 1.1 kAU) had higher binding energies (in absolute value) than α Cen AB and Proxima (see Sect. 3.2). Other systems with even wider projected physical separations of more than 50 kAU (a quarter parsec) have been reported. Some of the very wide multiple systems in Table 1 belong to the Galactic halo, where the probability of encountering stars is at a minimum (e.g. Quinn & Smith 2009), or to young moving groups, such as the Hyades supercluster or the Castor moving group. Young stars have had "less time to encounter individual stars and giant molecular clouds, whose gravity will eventually tear them apart" (Caballero 2009, and references therein). Other wide systems have been proposed by Wasserman & Weinberg (1991), Allen et al. (2000), or Chanamé & Gould (2004), but many of them do not pass a simple common proper motion filter with the Aladin sky atlas (Bonnarel et al. 2000) and USNO-B1 data (Monet et al. 2003).

This analysis is a continuation of the virtual observatory study in Caballero (2009), where I started a programme of identifying and investigating the widest common proper motion pairs.

2. The α Lib + KU Lib system

During a search for pairs of *Hipparcos* stars with small relative differences in proper motions and spatial vectors[1] but large angular separations (Caballero, in prep.), I noticed the resemblance between the parallaxes and proper motions of two stars

[1] The spatial vector of a star was defined by $\boldsymbol{r} = (x, y, z) \equiv (d \cos b \cos l, d \cos b \sin l, d \sin b)$, where d is the heliocentric distance of the star and l and b are the Galactic longitude and latitude, with the suitable sign convention.

Table 1. Very wide binaries and candidates in the literature with projected physical separations $s > 50$ kAU.

Primary	Secondary	s [kAU]	Reference
LP 268–35[a]	LP 268–33	84 ± 15	LB07, Ca09
HD 136654[b]	BD+32 2572	68.8 ± 1.7	LB07, Ca09
HD 149414 AB[c]	BD–05 3968B	~55.7	ZOM04
Ross 570[c]	WT 1370	~55.4	Al00
V869 Mon AB	BD–02 2198	~55.3	Po09
Fomalhaut[d]	TW PsA	~54.4	Gl69
BD–12 6174	LP 759–25	~50.5	Ma08

References. Gl69: Gliese (1969); Al00: Allen et al. (2000); ZOM04: Zapatero Osorio & Martín (2004); LB07: Lépine & Bongiorno (2007); Ma08: Makarov et al. (2008); Po09: Poveda et al. (2009); Ca09: Caballero (2009).

Notes. [(a)] Binary candidate of unknown true status; [(b)] young binary in the Hyades Supercluster; [(c)] halo "metal-poor" binaries with large distance uncertainties; [(d)] young binary in the Castor moving group.

separated by 155.8 arcmin (about 2.6 deg); see Fig. A.1. A quick glance at the system with Aladin and SIMBAD showed that the primary is actually the brightest star of a known hierarchical quadruple system (Table 2). With V = 2.75 mag, the primary α^{02} Lib AB (Zubenelgenubi, *az-Zuban al-Janubi*, "the southern claw"), is the second brightest star in the constellation of Libra after β Lib (Zubeneschamali, *az-Zuban ash-Shamali*, "the northern claw"). The star α^{02} Lib AB merited not only an Arabic name and a Bayer designation, but also a Chinese name of a zodiacal star in the 4–6th centuries (Liu 1986). The spectroscopic binarity of α^{02} Lib AB, with velocity variations of at least 80 km s^{-1} in about 60 d, has already been noticed by Slipher (1904). Additional variable radial velocity measurements have been published by a number of authors (e.g. Lee 1914; Young 1917; Wilson 1953). While most of the spectral type determinations of the brightest component are consistent with a peculiar A3–4 dwarf-subgiant classification, there is no consensus on the spectral type of the faintest component, which is not visible in the spectra. Besides, the system has never been resolved by speckle interferometry or any other imaging technique (e.g. Hartkopf & McAlister 1984).

Based on observations taken in June 1823, Herschel & South (1824) first tabulated a companion of the "6th magnitude" to the northwest of α^{02} Lib AB. They tabulated (with modern notation) an angular separation ρ = 230.853 arcsec and a position angle θ = 315.45 deg. Almost two centuries later, these values have stayed constant within uncertainties at ρ = 230.9 ± 0.3 arcsec, θ = 316.01 ± 0.11 deg, in spite of the system having travelled together more than 20 arcsec during this time. The proper-motion companion at about 5.4 kAU to α^{02} Lib AB is α^{01} Lib AB, which is in turn a single-lined spectroscopic binary with γ = −23.47 ± 0.15 km s^{-1} and K_1 = 3.69 ± 0.17 km s^{-1} (Duquennoy & Mayor 1991). Using near-infrared adaptive optics, α^{01} Lib AB was later resolved in a 0.383 arcsec-wide pair ($s \sim 0.01$ kAU) with $\Delta H \approx 3.40$ mag by Beuzit et al. (2004), who also provided a definitive orbital period of $P \approx 5870$ d based on radial-velocity measurements. The system offers good prospects for determining reasonably accurate masses. Afterwards, Makarov & Kaplan (2005) catalogued it as an astrometric binary with accelerating proper motion in *Hipparcos*[2].

[2] Besides, Pannunzio et al. (1992) confused α^{01} Lib AB with a fainter star ($V \sim 13.2$ mag) at 1.8 arcmin to the southwest, which they called AOT 53. However, the proper motion tabulated in the Positions and Proper Motions eXtended catalogue (PPMX – Röser et al. 2008) is inconsistent with membership in the α Lib system.

Table 2. The α Lib + KU Lib system[a].

Star	α^{02} Lib AB	α^{01} Lib AB	KU Lib
Flamsteed	9 Lib	8 Lib	...
HD	130841	130819	128987
HIP	72622	72603	71743
α^{J2000}	14 50 52.71	14 50 41.18	14 40 31.11
δ^{J2000}	−16 02 30.4	−15 59 50.0	−16 12 33.4
B [mag]	2.91	5.52	7.92
V [mag]	2.75	5.15	7.24
Spectral type	A4 IV–V + F:	F4 V + M:	G8 V (k)
$\mu_\alpha \cos\delta$ [mas a^{-1}]	−105.7 ± 0.2	−136.3 ± 0.4	−112.0 ± 0.5
μ_δ [mas a^{-1}]	−68.40 ± 0.12	−59.0 ± 0.3	−65.0 ± 0.4
d [pc]	23.24 ± 0.10	23.0 ± 0.2	23.7 ± 0.3
V_r [km s^{-1}]	+20/−60	−23.47 ± 0.15	−23.3 ± 0.2
U [km s^{-1}]	...	−25	−23
V [km s^{-1}]	...	−8	−7
W [km s^{-1}]	...	−13	−14
[Fe/H]	...	−0.07	+0.02

Notes. [(a)] Coordinates J2000, proper motions, and parallactic distances from van Leeuwen (2007), B and V magnitudes from Perryman et al. (1997), spectral types of primaries from Gray et al. (2006), UVW space velocities and [Fe/H] metallicities from Holmberg et al. (2009), and radial velocities from Slipher (1904 – α^{02} Lib AB), Duquennoy & Mayor (1991 – α^{01} Lib AB), and Nordström et al. (2004 – KU Lib).

The Vega-like status of the primary α^{02} Lib AB (see below) and the X-ray activity of the secondary α^{01} Lib AB (Morale et al. 1996; Hünsch et al. 1998) led several authors to classify them as a nearby young system, with an age of less than 800 Ma (e.g. Duncan 1984; Artymowicz & Clampin 1997; Rieke et al. 2005). Based on kinematics criteria, the quadruple system was listed as a member in the Castor moving group by Barrado y Navascués (1998) and Montes et al. (2001a). Subsequently, Ribas (2003) cast doubts on the membership in the moving group of the A-type star α^{02} Lib AB based on a faint overluminosity with respect to theoretical isochrones in a colour–magnitude diagram, but he did not account for the known binarity. The latest determinations of the most probable age of the Castor moving group point towards about 200 Ma (e.g. López-Santiago et al. 2009)[3]. Because of its youth, the quadruple system has also been the target of searches for circumstellar discs in the visible (Smith et al. 1992; Holweger et al. 1999), infrared (Aumann & Probst 1991; Oudmaijer et al. 1992; Cheng et al. 1992; Rieke et al. 2005), and microwave (Slee & Budding 1995). Known to be associated to the infrared source IRAS 14479–1547, the F-type star α^{01} Lib AB has strong flux excesses at 12, 70, and, especially, 24 μm due to a dusty disc and, possibly, mid-infrared emission features. The grains around α^{01} Lib AB are probably very warm, and the material around the star must be replensihed from a reservoir (Chen et al. 2005).

The "secondary" in my *Hipparcos* search at 2.6 deg to α Lib was the young solar analogue KU Lib. With proper motion, parallactic distance, radial velocity, and metallicity similar to those of the α Lib system (Table 2), KU Lib also displays youth features: it is a prominent X-ray emitter (Gaidos 1998), shows astrospheric absorption of the stellar H I Lyα emission line (in spite of the low interstellar-medium wind velocity seen by

[3] It is still under discussion whether the Castor moving group is younger (80–200 Ma) but contaminated by older stars of Hyades-like age of the Centaurus-Crux association and the Coma cluster (Chereul et al. 1999; Asiain et al. 1999; López-Santiago 2005).

the star – Wood et al. 2005a,b), and has a high lithium abundance log ϵ(Li) and a short period of photometric variability of $P = 9.35 \pm 0.04$ d, possibly associated to fast rotation and photospheric dark spots (Gaidos et al. 2000). Plavchan et al. (2009) gave KU Lib a Hyades-like age (i.e. $\tau \sim 600$ Ma) based on X-ray-age and rotation-age correlations. There have been numerous determinations of effective temperature, spectral type, and metallicity for KU Lib, consistent with late-G dwarf and solar abundance (Feltzing & Gustafsson 1998; Haywood 2001; Gaidos & González 2002; Valdes et al. 2004; Nordström et al. 2004). KU Lib has no flux excesses in the 24, 30−34, and 70 μm *Spitzer* bands (Lawler et al. 2009; Plavchan et al. 2009). Finally, the star is an exoplanet target with no known planetary companion (Grether & Lineweaver 2006).

3. Discussion

The stars α Lib and KU Lib are located at the same distance, move in exactly the same direction in space, and probably have the same age and metallicity (hence formed from the same parental cloud). However, they are separated by an enormous projected physical separation of $s \approx 217$ kAU (~1.0 pc). This value nearly quadruples the separations of the most reliable wide binaries in Table 1 and is close to the typical separation between stars in the Galactic disc (e.g. Proxima is located at $d = 1.296 \pm 0.004$ pc to the Sun). An inquisitive reader may consider that common distance, proper motion, age, metallicity, and location in the sky are disputable evidence of α Lib and KU Lib constituting the widest known multiple system (see e.g. Scholz et al. 2008, for the example of a debatable, extremely wide, very low-mass pair with common proper motion). Besides, the proper motions of α^{02} Lib AB, α^{01} Lib AB, and KU Lib are not identical, and there is no determination of the systemic radial velocity, γ, of the A-type primary. However, according to Beuzit et al. (2004), the mildly discrepant *Hipparcos* proper motions of α^{02} Lib and α^{01} Lib are consistent with the orbital motion of the photocentre of the secondary over the *Hipparcos* mission. The α Cen and Proxima system is the most obvious example that wide physically bound systems can still have slightly different proper motions (Wertheimer & Laughlin 2006; Caballero 2009). Lastly, the radial velocity measurements of α^{02} Lib A(B) are centred on the average value $\gamma \sim -20$ km s^{-1}, consistent with the ones of α^{01} Lib AB and KU Lib.

3.1. Resolved multiple systems in Castor

There are other young stars in moving groups that form wide (and ver wide) multiple systems. The stars HD 136654 and BD+32 2572 in the Hyades Supercluster (Table 1) and AU Mic and AT Mic AB in the β Pictoris moving group, with a projected physical separation $s = 46.4 \pm 0.5$ kAU, are among the widest young multiple systems (Caballero 2009).

There might be other wide systems in the Castor moving group, with separations of the order of 50–200 kAU. To determine the typical and maximum separations between multiple systems in Castor and to quantify the exceptionality of the α Lib and KU Lib system, I first had to compile a comprehensive list of candidate members, which is shown in Table A.1. To assemble it, I merged the shorter lists published by Barrado y Navascués (1998), Montes et al. (2001a,b), Ribas (2003), and López-Santiago et al. (2010). I discarded nine spectroscopic binaries[4] with *Hipparcos* parallactic distances $d \gtrsim 100$ pc and six stars that have been afterwards ascribed to other moving groups (AG Tri AB and AU Mic to the β Pictoris moving group; HD 98736 AB, BD+08 2599, and HD 162283 to the Local Association) or to the field (ι Peg AB). This made a list of 70 star candidates in the Castor moving group. Coordinates were taken from the *Hipparcos* catalogue except for a few faint targets, which were taken from the Tycho-2 or 2MASS catalogues, depending on availability. Heliocentric distances were retrieved from van Leeuwen (2007), except for LP 944–20 (from Tinney 1996), DX Cnc and V1436 Aql AB (from van Altena et al. 1995), and AD Leo (from Jenkins 1952). The distance to QT And is not parallactic, but photometric, and was estimated by Carpenter et al. (2005).

In the list in Table A.1, apart from KU Lib, there are two known common proper-motion secondaries and two primaries that had never been listed as members in the Castor moving group. They are VV Lyn AB (M2.5; companion to BL Lyn), 36 UMa A (F8V), μ Dra C (M3; also known as GJ 9584 C), and V447 Lac B (M4; G 232–62). Besides these, three stars, BD−46 11540 (Johnson et al. 2007), Fomalhaut (Kalas et al. 2008; in imaging), and HD 217107 (Marcy et al. 1999; Vogt et al. 2005), have exoplanet candidates, which supports the Caballero et al. (2009) hypothesis that some young stars ($\tau \lesssim 600$ Ma) pass the activity filters for radial velocity searches (see also Paulson & Yelda 2006).

A large fraction of the Castor star candidates in Table A.1 show some kind of multiplicity: 15 (21%) of them are spectroscopic binaries yet unresolved by imaging, nine (13%) are close binaries only resolved by *Hipparcos* and, in some cases, adaptive optics or micrometer techniques, and 13 (19%) are wide binaries resolved in the Tycho-2 and/or 2MASS catalogues. Accounting for all types of multiplicity (there are a few hierarchical systems containing wide and spectroscopic or close binaries), 40 stars (57%) are part of multiple systems.

Table 3 provides the angular and projected physical separations of the 22 resolved multiple systems in Castor. All the systems were known except for the "pairs" α Lib and KU Lib, and V450 And AB and V451 And. Within uncertainties, the two latter solar-like stars have the same parallaxes and proper motions as in *Hipparcos*, radial velocities and metallicities as in Nordström et al. (2004) and Karataş et al. (2005), and gyrochronous and kinematic ages as in Strassemier et al. (2000) and Montes et al. (2001a). The primary is a single-lined spectroscopic binary with acceleration of proper motion that was suspected for some time to harbour an exoplanet (Perrier et al. 2003; Makarov & Kaplan 2005). V450 And AB and V451 And are separated by about 16 kAU. With individual masses of about 1.1 $M_\odot$, the system is likely to be bound (see below).

Of the 22 resolved multiple systems, only seven have projected physical separations $s > 1$ kAU. Three of them, Castor AB and YY Gem, 36 UMa A–BC, and V447 Lac AB, have relatively small separations of $s \approx 1.10$–1.65 kAU. The four other wide "pairs" are the new triple V450 And AB and V451 And, the Gliese (1969)'s binary Fomalhaut (A4V) and TW PsA (K4V), with $s \approx 54.4$ kAU, and the α Lib and KU Lib system (α^{01} Lib and KU Lib are located at about 5.37 and 217 kAU to α^{02} Lib, respectively).

Finally, I investigated the separations from the closest neighbours of the stars in Table A.1 after discarding the multiple systems in Table 3, and found that the minimum angular separation

[4] The discarded distant spectroscopic binaries were: 5 Cet, HD 43516, VV Mon, FI Cnc, VX Pyx, FF UMa, EQ Leo, IL Com, and V894 Her.

Table 3. Resolved multiple system candidates in the Castor moving group.

Primary	Secondary	ρ [arcsec]	Ref.	s [kAU]
V450 And AB	V451 And	615.1	TYC	16.3
V575 Pup A	V575 Pup B	2.587	HIP	0.078
V356 CMa A	V356 CMa B	2.010	FM00	0.10
HD 51825 A	HD 51825 B	0.140	HIP	0.006
VV Lyn AB	BL Lyn	33.88	TYC	0.40
Castor A	Castor B	3.124	HIP	0.049
Castor AB	YY Gem	70.81	TYC	1.10
CU Cnc AB	CV Cnc AB	10.16	2M	0.11
ψ Vel A	ψ Vel B	0.679	HIP	0.013
36 UMa A	36 UMa BC	122.8	TYC	1.57
HD 119124 A	HD 119124 B	3.979	2M	0.10
α^{01} Lib A	α^{01} Lib B	0.383	Be04	0.009
α^{02} Lib AB	KU Lib	9344	2M	217
α^{02} Lib AB	α^{01} Lib AB	231.0	2M	5.37
μ Dra A	μ Dra B	2.160	HIP	0.059
μ Dra AB	μ Dra C	12.45	2M	0.34
V1436 Aql A	V1436 Aql B	17.33	2M	0.44
HD 186922 A	HD 186922 B	0.159	HIP	0.005
V447 Lac A	V447 Lac B	76.79	2M	1.65
Fomalhaut	TW PsA	7064	2M	54.4
HD 218739 AB	KZ And AB	15.64	TYC	0.38
EQ Peg A	EQ Peg B	5.029	HIP	0.031

References. HIP: *Hipparcos*, Perryman et al. (1997); TYC: Tycho-2, Høg et al. (2000); FM00: Fabricius & Makarov (2000); Be04: Beuzit et al. (2004); 2M: 2MASS, Skrutskie et al. (2006).

was between Castor AB and VV Lyn AB, of $\rho \sim 4.4$ deg. Although this angular separation is only about 1.7 times more than the one between α Lib and KU Lib, Castor AB (and its companion YY Gem) and VV Lyn AB (and its companion BL Lyn) are at different heliocentric distances by almost 4 pc. Remaining separations are much larger than this value. Thus, α Lib and KU Lib resembles a very wide physical system more than a fortuitous rendezvous of stars in the Castor moving group.

3.2. Binding energy and differential Galactic tidal force

One way to assert physical bounding of the α Lib and KU Lib system is by comparing the absolute value of its binding energy (actually, the minimum absolute value $|U_g^*|$ computed using the projected physical separation s instead of the true physical separation r – Caballero 2009) with those of other systems of very low-mass or very wide separations. For that, it is necessary to estimate the individual masses of the five components. Using the Siess et al. (2000) models for an age of 200 Ma, the spectral type and visual absolute magnitude of α^{01} Lib AB (derived from V and d), and the H-band magnitude difference between components measured by Beuzit et al. (2004), I estimate masses of about 1.4–1.5 and 0.5–0.6 $M_\odot$ for its A and B components. The expected spectral type of α^{01} Lib B is M0–1 V. In the same way, α^{02} Lib A and KU Lib have estimated masses of 2.2 and 1.0 $M_\odot$, respectively. There is not enough information for an accurate assessment of the mass of α^{02} Lib B. Since it produces a large radial-velocity amplitude on α^{02} Lib A and overluminosity in the colour–magnitude diagram, I guess a spectral type F and a mass of 1.5 $M_\odot$; therefore the total estimated mass of the α Lib and KU Lib system is 6.7 $M_\odot$. The 1.0 $M_\odot$-mass star KU Lib feels the gravitational pull of an equivalent single star of 5.7 $M_\odot$.

The derived binding energy and orbital period of α Lib and KU Lib are $U_g^* = -46 \times 10^{33}$ J and $P \approx 39$ Ma. Although the system may be slowly drifting away and will eventually be disrupted, it has a value of $|U_g^*|$ that is more than many known binaries (Fig. 1). For comparison, the α Cen and Proxima system has a true binding energy of $U_g = -32.1 \times 10^{33}$ J. Furthermore, the α Lib and KU Lib value of $|U_g^*|$ is one order of magnitude higher than those of the most fragile systems known: the Koenigstul 1-like, very low-mass ($\mathcal{M} < 0.2\,M_\odot$), very wide ($\rho > 1$ kAU) binaries (Caballero 2007; Artigau et al. 2007; Radigan et al. 2009), and the very young substellar wide binaries, such as the brown-dwarf exoplanet pair 2M1207–39 AB (Chauvin et al. 2004 – see Caballero 2009, for more examples *without* common proper motion confirmation). Besides, the orbit of KU Lib around α Lib may be highly eccentric, so the value of $|U_g^*|$ could be even higher than computed (and the orbital period would be shorter).

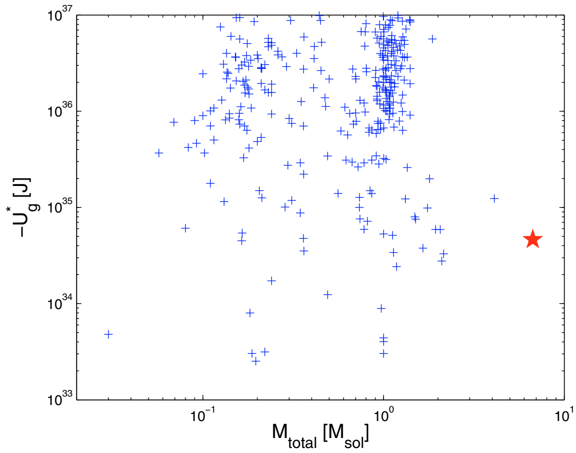

Fig. 1. Binding energy-total mass diagram. Crosses are for the 406 systems with very low-mass components and Washington double stars with the widest angular separations presented in Caballero (2009). The system α Lib and KU Lib is represented by a filled star. The nearby data point at $U_g^* = -120 \times 10^{33}$ J and $\mathcal{M}_{\rm total} = 4.1\,M_\odot$ corresponds to the system HD 200077 AE–D and G 210–44 AB.

According to Close et al. (1990), "the physical limit to the maximum separation [that] a candidate system could possibly have is the separation at which the differential Galactic force exceeds the gravitational binding force of the system". They computed that the physical limit for a wide binary system of two 1.0 $M_\odot$-mass stars was $r \sim 1.05$ pc. Since the gravitational binding force is proportional to the product of masses, the separation at which the system α Lib and KU Lib will be torn apart would be 5.7 (5.7 $M_\odot \times 1.0\,M_\odot$) times larger, at about 6.0 pc. Even accounting for a generous projection factor for transforming the measured projected physical separation $s \sim 1.0$ pc into a real physical separation r, the computations above allow the existence of α Lib and KU Lib during a few revolutions around the Galaxy centre.

4. Summary

Because of the resemblance between their parallaxes, proper motions, radial velocities, metallicities, and most probable ages, I first propose that α^{02} Lib AB, α^{01} Lib AB, and KU Lib form a hierarchical quintuple system separated by about 2.6 deg. At the distance of the system, $d \sim 23$ pc, the resulting projected physical separation is $s \sim 217$ kAU (~1.0 pc), which makes α Lib and KU Lib the widest multiple system candidate in all mass domains. The stars are likely members of the young Castor moving group ($\tau \sim 200$ Ma) and do not seem to be the result of a fortuitous approximation or alignment within the moving group. The stars have a binding energy that is greater than many other low-mass multiple systems reported in the literature and that is consistent with the system's survival to the Galactic tidal force. As spin-offs of this work, I compiled an exhaustive list of star candidates in Castor, including five new stars (KU Lib itself, VV Lyn AB, 36 UMa A, μ Dra C, and V447 Lac B), enumerated two young stars with radial-velocity exoplanet candidates, and found a new wide Castor pair separated by about 16 kAU (V450 And AB and V451 And).

Once we have a detailed six-dimensional picture of the solar nighbourhood, $(x, y, z, \dot{x}, \dot{y}, \dot{z})$, possibly with the European Space Agency *GAIA* mission, we will be able to corroborate or refute the existence of "ultra-wide" binaries with separations over one parsec, such as α Lib and KU Lib. In the meantime, its existence is *not* a challenge for star formation scenarios or studies of gravitational perturbations in the Galactic disc: α Lib and KU Lib simply constitute the most extreme example of young wide binaries caught in the process of disruption by the Galactic tidal force.

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Appendix A:

Table A.1. A compilation of star candidates in the Castor moving group.

Name	α^{J2000}	δ^{J2000}	d [pc]	Multiplicity
κ Phe	00 26 12.20	–43 40 47.4	23.81 ± 0.09	...
QT And	00 41 17.34	+34 25 16.9	50 ± 10	...
EW Cet	01 16 24.20	–12 05 49.2	25.9 ± 0.5	...
FN Cet	02 04 59.33	–15 40 41.2	25.6 ± 0.6	...
V450 And AB	02 12 55.01	+40 40 06.0	26.8 ± 0.4	SB, wide
V451 And	02 13 13.34	+40 30 27.3	26.2 ± 0.4	Wide
LP 944–20	03 39 35.22	–35 25 44.1	4.97 ± 0.10	...
HD 24053 AB	03 50 08.89	+06 37 14.5	33.0 ± 1.4	SB
HD 30957 AB	04 56 26.05	+64 24 09.6	39.1 ± 1.4	SB
V998 Ori AB	05 32 14.66	+09 49 14.9	12.8 ± 0.6	SB
HD 37216	05 39 52.35	+52 53 51.0	27.9 ± 0.7	...
ζ Lep	05 46 57.34	–14 49 19.0	21.61 ± 0.07	...
V575 Pup AB	06 04 46.68	–48 27 29.9	30.0 ± 0.5	Close
HD 41842	06 06 16.61	–27 54 21.0	32.1 ± 1.0	..
GJ 226.2	06 07 55.25	+67 58 36.5	24.5 ± 1.1	..
V356 CMa AB	06 39 11.63	–26 34 18.8	52 ± 4	Close
HD 50255 AB	06 52 02.38	–11 12 16.2	29.8 ± 1.7	SB
HD 51825 AB	06 57 17.58	–35 30 25.8	43.1 ± 0.8	Close
BL Lyn	07 31 57.33	+36 13 47.4	12.0 ± 0.6	Wide
VV Lyn AB	07 31 57.72	+36 13 09.8	11.9 ± 0.5	SB, wide
Castor AB	07 34 35.86	+31 53 17.8	15.6 ± 0.9	Close
YY Gem	07 34 37.41	+31 52 09.8	15.6 ± 0.9	Wide
DX Cnc	08 29 49.34	+26 46 33.7	3.63 ± 0.04	...
CU Cnc AB	08 31 37.60	+19 23 39.6	11.1 ± 1.0	SB, wide
CV Cnc AB	08 31 37.44	+19 23 49.5	11.1 ± 1.0	SB, wide
HL Cnc	09 01 22.78	+10 43 58.5	64 ± 4	...
V405 Hya	09 04 20.69	–15 54 51.3	28.3 ± 0.6	...
HD 79555 AB	09 14 53.66	+04 26 34.4	18.0 ± 0.5	SB
ψ Vel AB	09 30 42.00	–40 28 00.4	18.81 ± 0.13	Close
AD Leo	10 19 36.28	+19 52 12.1	4.69 ± 0.09	...
36 UMa BC	10 30 25.31	+55 59 56.8	12.80 ± 0.05	SB
36 UMa A	10 30 37.58	+55 58 49.9	12.80 ± 0.05	Wide
HD 93915 AB	10 51 14.62	+46 47 46.6	42.6 ± 1.6	SB
GY Leo	10 56 30.80	+07 23 18.5	17.3 ± 0.3	...
XZ LMi AB	10 59 48.28	+25 17 23.5	35.8 ± 1.0	SB
Ross 104	11 00 04.26	+22 49 58.7	6.66 ± 0.08	...
PR Vir	11 56 41.18	–02 46 44.2	42 ± 2	...
HD 119124 A	13 40 23.23	+50 31 09.9	25.3 ± 0.3	Wide
HD 119124 B	13 40 24.51	+50 30 57.6	25.3 ± 0.3	Wide
GY Boo	14 12 41.56	+23 48 51.5	33.3 ± 1.2	...
KU Lib	14 40 31.11	–16 12 33.4	23.7 ± 0.3	Wide
α^{01} Lib AB	14 50 41.18	–15 59 50.1	23.0 ± 0.2	Close, wide
α^{02} Lib AB	14 50 52.71	–16 02 30.4	23.24 ± 0.10	SB, wide
EV Dra AB	16 01 47.46	+51 20 52.0	57 ± 2	SB
μ Dra AB	17 05 20.12	+54 28 12.2	27.4 ± 0.3	Close
μ Dra C	17 05 20.27	+54 27 59.8	27.4 ± 0.3	Wide
BD–46 11540	17 28 39.95	–46 53 42.7	4.54 ± 0.03	...
MS Dra	17 39 55.69	+65 00 05.9	26.3 ± 0.4	...
BD+21 3245	17 53 29.94	+21 19 31.0	24.4 ± 0.6	...
HD 168442	18 19 50.84	–01 56 19.0	19.6 ± 0.6	...
Vega	18 36 56.34	+38 47 01.3	7.68 ± 0.02	...
V1436 Aql A	18 54 53.66	+10 58 40.2	16 ± 2	Wide
V1436 Aql B	18 54 53.81	+10 58 43.5	16 ± 2	Wide
V1285 Aql AB	18 55 27.41	+08 24 09.0	11.8 ± 0.2	SB
HD 181321	19 21 29.76	–34 59 00.6	18.8 ± 0.5	...
HD 186922 AB	19 39 06.37	+76 25 19.3	29.7 ± 0.5	Close
HD 191285	20 09 36.47	–14 17 12.9	31.6 ± 1.4	...
Alderamin	21 18 34.77	+62 35 08.1	15.04 ± 0.02	...
G 263–10	21 58 24.52	+75 35 20.6	20.8 ± 0.5	...
V374 Peg	22 01 13.12	+28 18 24.9	8.9 ± 0.2	...
V447 Lac A	22 15 54.14	+54 40 22.4	21.5 ± 0.2	Wide
V447 Lac B	22 16 02.59	+54 39 59.5	21.5 ± 0.2	Wide
TW PsA	22 56 24.05	–31 33 56.0	7.61 ± 0.04	Wide
Fomalhaut	22 57 39.05	–29 37 20.0	7.70 ± 0.03	Wide
HD 217107	22 58 15.54	–02 23 43.4	19.86 ± 0.15	...
HK Aqr	23 08 19.55	–15 24 35.8	22.3 ± 1.1	...
KZ And AB	23 09 57.36	+47 57 30.1	24 ± 2	SB, wide
HD 218739 AB	23 09 58.87	+47 57 33.9	25.0 ± 1.4	SB, wide
NX Aqr	23 24 06.34	–07 33 02.7	30.1 ± 0.6	...
EQ Peg AB	23 31 52.18	+19 56 14.1	6.18 ± 0.06	Close

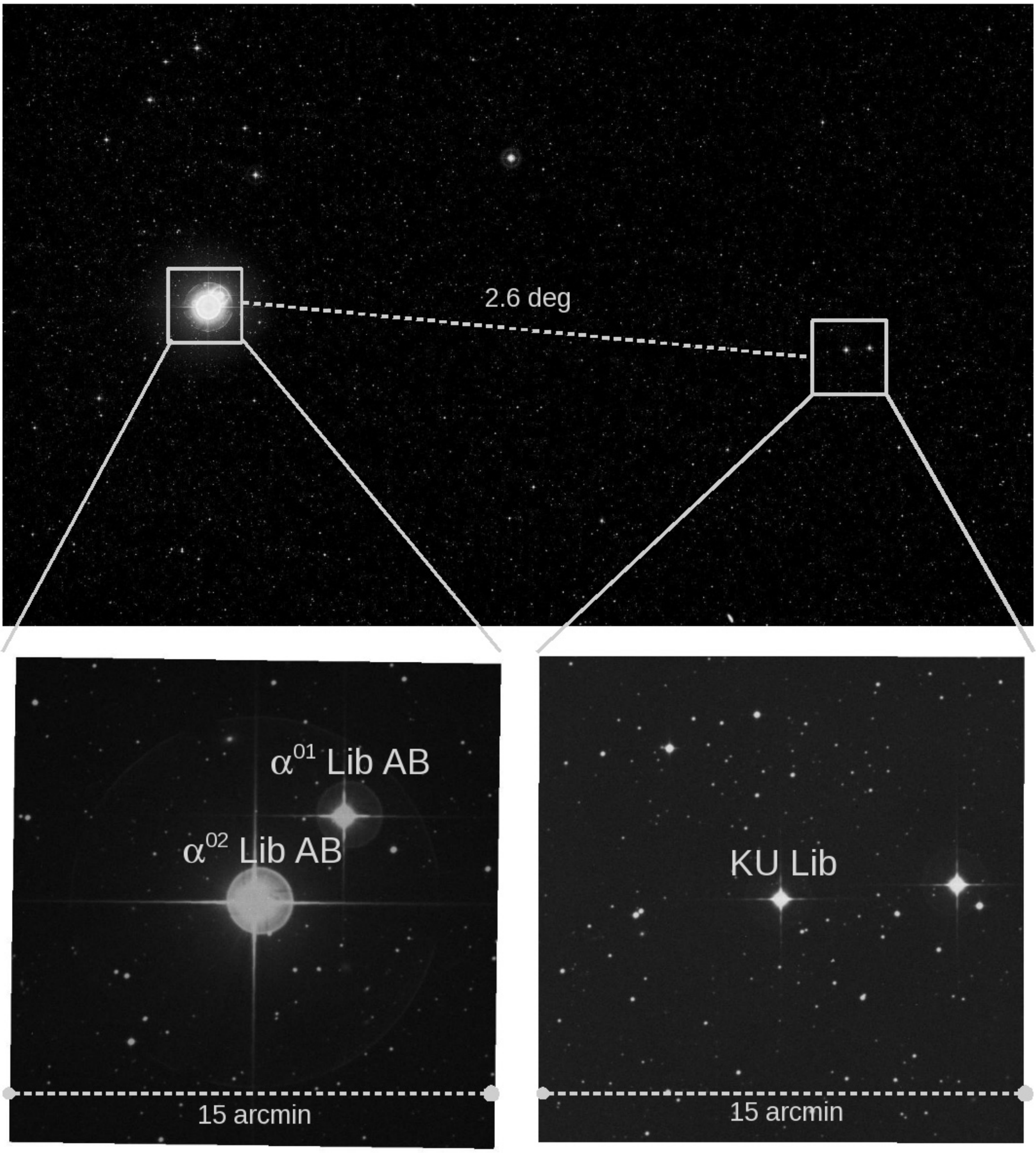

Fig. A.1. *Top panel*: finding chart, about 3 deg × 2 deg, showing the bright multiple system α^{02} Lib AB and α^{01} Lib AB to the east (*left*) and KU Lib to the west (*right*). *Bottom panels*: 15 arcmin × 15 arcmin captions of the innermost areas surrounding the stars from the SuperCOSMOS digitisations of the United Kingdom Schmidt Telescope photographic plates. Some angular separations and fields of view are indicated.