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Preliminary report

# DYNAMICS OF QUADRUPLE SYSTEM FINSEN 332 = ADS 11640 = HIP 92027 = WDS 18455+0530

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**SUMMARY: In 1829 Struve discovered a double star denoted as STF 2375 AB later on. Its separation was $2\overset{''}{.}2$. It was noticed by Finsen from the Southern Observatory (Johannesburg) in 1953 that the components A and B are close binaries with separations about $0\overset{''}{.}15$. The motion within this quadruple system - FIN 332 Aa and FIN 332 Bb - has been monitored from that time on. The data about the motion of these close binaries are analysed by the present authors and the preliminary orbital elements are calculated for each of them. The dynamical parallax from the obtained period and the semimajor axis for pair FIN 332 Bb agrees completely with that obtained from the Hipparcos programme. In the case of FIN 332 Aa a somewhat higher parallax, but within the error limits following from the errors of the period and semimajor axis, is obtained and it agrees with the parallax for FIN 332 Bb. The dynamical masses for the components of both systems are as expected for their spectral type A1V (all of them belong to the Main Sequence and here one uses Angelov's (1993) relation). According to our results, the motion of both systems takes place approximately in the same plane, confirming thus some general properties already noticed in the case of multiple stars.**

**Key words. binaries: close**

## 1. INTRODUCTION

In 1829 Struve detected a visual double star which at that moment had a separation of $2\overset{''}{.}3$. The total apparent magnitude is 5.72 and the spectrum is A0. The first designation of this pair was STF 2375. In the ADS Catalogue it is referred to as ADS 11640. Observing from the Southern Observatory (Johannesburg), Finsen in 1953 finds that the components A and B are close binaries, in both cases the separation was $0\overset{''}{.}14$.

Therefore, one has a quadruple system AaBb. The subsystems are referred to as FIN 332 Aa and FIN 332 Bb. From that time on, the motion of the components for this small and interesting system have been systematically observed, except in the interval between 1964 and 1976. During 1968-1969 the observations were performed by Finsen, only with his eyepiece interferometer. Small variations in the position angle, and more significant ones in the separation, seem to indicate high inclinations of the apparent orbit for both subsystems. This system was included in the Hipparcos Programme under designation HIP 92027 and, hence, its parallax is known: $0\overset{''}{.}00460 \pm 0\overset{''}{.}00110$.

The data are taken from Fourth Catalog of Interferometric Measurements of Binary Stars (Hartkopf et al. 2002).

## 2. THE METHOD

For the purpose of calculating the orbital elements, one used the method known as KOVOLE (Olević and Cvetković 2003). This method was developed by Olević; it is based on Koval'skij's method which yields acceptable results for all possible cases (of data) without requiring the approximate values of $P$, $T$ and $e$ to be known, unlike the method used at CHARA - Center for High Angular Resolution Astronomy (Hartkopf et al. 1989).

## 3. RESULTS AND DISCUSSION

### 3.1 Results

In Table 1, the basic data on the system considered, orbital elements, dynamical parallax and the individual values of absolute magnitudes and masses of the components are given. In the calculation of the dynamical parallax, individual absolute magnitudes and the masses, we use Angelov's (1993) relation since the system belongs to the Main Sequence.

**Table 1.** Orbital elements, absolute magnitudes, masses and parallaxes.

| Name | FIN 332 Aa | FIN 332 Bb |
|---|---|---|
| WDS | 18455+0530 | 18455+0530 |
| HIP | 92027 | 92027 |
| $m$ | 6.50-6.60 | 7.50-7.50 |
| Sp. | A1V+A1V | A1V |
| $P(yr)$ | 58.35 | 93.92 |
| $T$ | 1989.85 | 1972.23 |
| $a('')$ | 0.176 | 0.163 |
| $e$ | 0.12 | 0.24 |
| $i(^o)$ | 98.9 | 105.3 |
| $\Omega(^o)$ | 132.9 | 140.3 |
| $\omega(^o)$ | 61.1 | 278.6 |
| $M_1(mag)$ | 0.71 | 0.88 |
| $M_2(mag)$ | 0.81 | 0.88 |
| $\mathcal{M}_1(\odot)$ | 2.4 | 2.3 |
| $\mathcal{M}_2(\odot)$ | 2.4 | 2.3 |
| $\pi('')$ | 0.0069 | 0.0047 |
| $\pi_{HIP}('')$ | 0.00460 | 0.00460 |

Table 2 gives all available measurements and residuals used in the calculations. The asterisk indicates those observations where the quadrant is changed (rotation by 180°) in the orbit calculation, in the parentheses one gives the ephemeride values of the coordinates according to the calculated orbital elements.

Finally, Table 3 gives the ephemerides for the interval 2004-2009.

Figs. 1 and 2 give the apparent orbits of subsystems FIN 332 Aa and FIN 332 Bb.

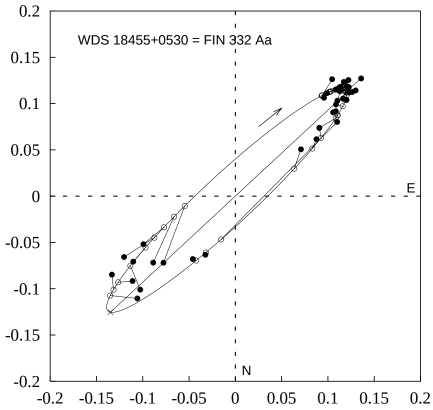


**Fig. 1.** *Orbit of FIN 332 Aa.*

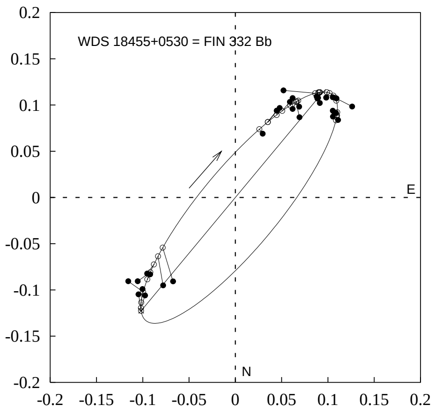


**Fig. 2.** *Orbit of FIN 332 Bb.*

### 3.2 Discussion

There are several difficulties in the measurements of this system. The pairs are close, and the components are relatively bright. The entire quadruple system appears in the view field of the instrument during observations. The position angles and the separations in the observation interval covered up to now are similar for both subsystems. This can affect the accuracy of the measurements and the errors in the determining of the position-angle quadrant, i.e. cause accidental erroneous assigning of the data to either subsystem, etc.

These problems were indicated by the observers in Note in the Fourth Catalog of Interferometric Measurements of Binary Stars, as well as by Mason and Hartkopf (2002). There are (and there will be) gaps in the observations due to the impossibility of observing so small separations of the components during their motion, also shown in our analysis. For example, according to the ephemerides, the components of FIN 332 Aa in the period 1964-1969 had apparently a separation less than $0''.05$. For FIN 332 Bb such a case took place in the period 1964-1973.

The present authors have corrected the speculated errors in the quadrants on the basis of their analysis of the observations. The individual masses

**Table 2.** Observations and residuals.

WDS 18455+0530 = FIN 332 Aa

| $t$ | $\theta°$ | $\rho''$ | $n$ | Obs. | $\Delta\theta°$ | $\Delta\rho''$ |
|---|---|---|---|---|---|---|
| 1953.73 * | 136.5 | .153 | 5 | Fin | 7.6 | −.019 |
| 1954.68 * | 122.7 | .158 | 4 | Fin | −5. | −.007 |
| 1955.72 * | 129.8 | .144 | 3 | Fin | 3.1 | −.013 |
| 1957.76 * | 134.7 | .144 | 1 | Fin | 10.7 | .008 |
| 1959.72 * | 122.9 | .131 | 3 | Fin | 2.6 | .020 |
| 1960.72 * | 118.9 | .137 | 1 | Fin | 1.3 | .039 |
| 1961.73 * | 117.8 | .112 | 3 | Fin | 3.8 | .029 |
| 1962.72 * | 129.2 | .114 | 5 | Fin | 20.1 | .045 |
| 1963.728 * | : 133.0 | : .106 | 4 | Fin | 31.5 | .051 |
| 1964.726 | – | $<$ .108 | 1 | Fin | (269.0 | .066) |
| 1966.758 | – | $<$ .107 | 1 | Fin | (214.4 | .077) |
| 1968.791 | – | $<$ .119 | 1 | Fin | (169.1 | .071) |
| 1976.2992 | 138.1 | .143 | 1 | McA | −1.2 | .000 |
| 1976.3702 | 138.5 | .149 | 1 | McA | −.7 | .005 |
| 1976.3728 | 140.5 | .164 | 1 | McA | 1.3 | .020 |
| 1977.3340 | 136.9 | .158 | 1 | McA | −1.0 | .007 |
| 1977.4815 | 136.4 | .162 | 1 | McA | −1.4 | .010 |
| 1977.4870 | 136.2 | .164 | 1 | McA | −1.6 | .011 |
| 1977.6400 | 135.9 | .175 | 1 | McA | −1.7 | .021 |
| 1978.5410 | 136.2 | .170 | 1 | McA | −.3 | .011 |
| 1978.6147 | 136.6 | .170 | 1 | McA | .2 | .011 |
| 1979.3601 | 134.0 | .170 | 1 | McA | −1.6 | .008 |
| 1979.5321 | 133.2 | .151 | 1 | McA | −2.2 | −.012 |
| 1979.7725 | 132.5 | .166 | 1 | McA | −2.6 | .003 |
| 1980.4769 | 131.4 | .173 | 1 | McA | −2.9 | .008 |
| 1980.4794 | 134.7 | .169 | 1 | McA | .3 | .004 |
| 1980.7173 | 131.0 | .159 | 1 | McA | −3.1 | −.006 |
| 1980.7199 | 131.8 | .169 | 1 | McA | −2.3 | .004 |
| 1981.356 | 133.2 | .186 | 1 | Tok | −.2 | .022 |
| 1982.5248 | 135.2 | .160 | 1 | McA | 3.0 | −.002 |
| 1983.4203 | 132.3 | .157 | 1 | McA | 1.1 | −.001 |
| 1984.3760 | 132.4 | .147 | 1 | Hrt | 2.4 | −.004 |
| 1985.4816 | 130.7 | .139 | 1 | McA | 2.2 | −.002 |
| 1985.5231 | 130.3 | .142 | 1 | McA | 1.8 | .002 |
| 1995.6008 | 126.1 | .136 | 1 | Hrt | −2.2 | −.004 |
| 1985.8424 | 129.2 | .117 | 1 | McA | 1.2 | −.020 |
| 1987.7618 | 129.2 | .117 | 1 | McA | 4.8 | .005 |
| 1988.6655 | 125.1 | .107 | 1 | McA | 3.1 | .009 |
| 1990.2734 | 125.6 | .087 | 1 | Hrt | 10.2 | .017 |
| 1996.6930 * | 153.0 | .071 | 1 | Hrt | 0.6 | .003 |
| 1997.3945 | 326.0 | .082 | 1 | Bag | −2.7 | .002 |

**Table 2.** (continued)

WDS 18455+0530 = FIN 332 Bb

| $t$ | $\theta°$ | $\rho''$ | $n$ | Obs. | $\Delta\theta°$ | $\Delta\rho''$ |
|---|---|---|---|---|---|---|
| 1953.73 * | 135.3 | .148 | 5 | Fin | −5.0 | −.012 |
| 1954.48 * | 137.6 | .144 | 4 | Fin | −1.9 | −.014 |
| 1955.72 * | 134.9 | .141 | 3 | Fin | −3.3 | −.012 |
| 1957.76 * | 128.3 | .147 | 1 | Fin | −7.5 | .004 |
| 1959.72 * | 132.3 | .124 | 3 | Fin | −0.7 | −.006 |
| 1960.72 * | 130.9 | .139 | 1 | Fin | −0.5 | .016 |
| 1961.73 * | 131.0 | .126 | 3 | Fin | 1.4 | .012 |
| 1962.72 * | 140.8 | .123 | 5 | Fin | 13.4 | .018 |
| 1963.728 * | : 143.6 | : .113 | 4 | Fin | 18.8 | .017 |
| 1964.726 | . | $<$ .117 | 1 | Fin | (301.6 | .086) |
| 1966.758 | . | $<$ .109 | 1 | Fin | (291.9 | .064) |
| 1968.791 | . | $<$ .123 | 1 | Fin | (272.6 | .043) |
| 1976.4549 | 156.9 | .075 | 1 | McA | −3.6 | −.003 |
| 1977.4815 | 154.6 | .104 | 1 | McA | −2.0 | .015 |
| 1977.4870 | 154.6 | .104 | 1 | McA | −2.0 | .015 |
| 1978.6147 | 153.8 | .108 | 1 | McA | 0.5 | .008 |
| 1979.3601 | 150.5 | .119 | 1 | McA | −1.0 | .012 |
| 1980.4769 | 150.2 | .124 | 1 | McA | 1.1 | .008 |
| 1981.356 | 141.5 | .111 | 1 | Tok | −6.0 | −.012 |
| 1981.4681 | 147.2 | .114 | 1 | McA | −0.1 | −.010 |
| 1981.6975 | 145.0 | .120 | 1 | McA | −1.9 | −.005 |
| 1984.783 | 155.9 | .127 | 1 | Tok | 13.4 | −.015 |
| 1985.4816 | 141.3 | .140 | 1 | McA | −0.3 | −.005 |
| 1985.5231 | 140.4 | .139 | 1 | McA | −1.1 | −.006 |
| 1985.744 | 138.3 | .137 | 1 | Tok | −3.0 | −.009 |
| 1985.8424 | 140.4 | .140 | 1 | McA | −0.7 | −.006 |
| 1987.7618 | 137.8 | .146 | 1 | McA | −1.1 | −.005 |
| 1988.6655 | 137.8 | .146 | 1 | McA | −0.0 | −.006 |
| 1990.2734 | 135.9 | .151 | 1 | Hrt | −0.2 | −.002 |
| 1991.25 * | 308.0 | .16 | 1 | Hip | −7.0 | .007 |
| 1992.3105 | 134.5 | .153 | 1 | Hrt | 0.7 | .002 |
| 1995.6061 | 131.8 | .141 | 1 | Hrt | 2.0 | −.002 |
| 1996.3215 | 130.7 | .141 | 1 | Hrt | 1.8 | .000 |
| 1996.3270 | 130.1 | .142 | 1 | Hrt | 1.2 | .001 |
| 1996.7012 | 127.1 | .139 | 1 | Hrt | −1.3 | −.001 |
| 1997.3945 | 129.7 | .137 | 1 | Bag | 2.2 | .000 |

**Table 3.** Ephemerides.

| | FIN 332 Aa | | FIN 332 Bb | |
|---|---|---|---|---|
| $t$ | $\theta^\circ$ | $\rho''$ | $\theta^\circ$ | $\rho''$ |
| 2004.0 | 315.8 | .168 | 115.5 | .103 |
| 2005.0 | 314.8 | .175 | 112.9 | .097 |
| 2006.0 | 313.9 | .180 | 110.0 | .092 |
| 2007.0 | 313.0 | .183 | 106.6 | .086 |
| 2008.0 | 312.2 | .184 | 102.9 | .080 |

for FIN 332 Aa obtained here are 2.4$\odot$ and 2.4$\odot$ as expected in view of the spectral types A1V+A1V. For FIN 332 Bb the component masses are 2.3$\odot$ and 2.3$\odot$, also according to the expectation in view of their spectral type - A1V.

The dynamical parallax obtained for FIN 332 Bb agrees fully with that given by the Hipparcos Mission. A somewhat worse agreement in the dynamical parallax for FIN 332 Aa can be explained by a higher heterogeneity of the data causing the orbital elements to be obtained less accurately.

The main conclusion derivable, at this moment from the present results, is that the orbital planes of both subsystems almost coincide and that the direction of the motion is the same. All the four components have approximately the same spectral type. Hence, this quadruple system is very interesting and deserves permanent observation because it can be of importance in the study of formation, dynamics and evolution of stellar systems.

The change of the position angle in the system FIN 332 Aa - FIN 332 Bb in the period 1829-1977 of 12 degrees makes impossible at present even a crude estimate of the orbital elements.

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# ДИНАМИКА КВАДРУПОЛНОГ СИСТЕМА FINSEN 332 = ADS 11640 = HIP 92027 = WDS 18455+0530

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*Претходно саопштење*

Струве је 1829. године открио двојни систем који је добио ознаку STF 2375 AB, чија је сепарација била $2''\!.2$. Финзен запажа, 1953. године са јужне опсерваторије (Јоханесбург), да су компоненте A и B тесни двојни системи са сепарацијама око $0''\!.15$. Од тада се прати кретање тог квадруполног система: FIN 332 Aa и FIN 332 Bb. Аутори су анализирали податке о кретању ових тесних двојних система и израчунали прелиминарне путањске елементе за сваки од њих. Динамичка паралакса из израчунате периоде и велике полуосе за пар FIN 332 Bb је у потпуној сагласности са оном која је добијена из Hipparcos програма. За пар FIN 332 Aa добијена је нешто већа паралакса која је у оквиру граница грешака које следе из грешака за период и велику полуосу и у сагласности је са паралаксом за FIN 332 Bb. Динамичке масе компонената оба система су очекиване за њихов спектрални тип A1V (све припадају главном низу па је коришћена формула Ангелова (1993)). Према нашим резултатима оба система се крећу у приближно истој равни што потврђује неке опште карактеристике које су раније запажене код вишеструких система.