

NOVA LINEARNA REŠENJA ZA 13 DVOJNIH ZVEZDA

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Belogradchik, 16.05.2018.

- vizuelno dvojne zvezde se izučavaju na AOB skoro 70 godina, tj. od kraja 1950. godine
- posmatranja vizuelno dvojnih zvezda rađena pomoću Zeiss refraktora (65/1055 cm) – mikrometarska merenja – otkriveno preko 260 novih parova
- krajem XX veka – kraj posmatračkih aktivnosti na AOB
- **od 2004-2007. godine**
- nastavak posmatranja vizuelno dvojnih zvezda pomoću 2 m teleskopa na NAO Rožen – u okviru regionalne saradnje – UNESCO-ROSTE
- beogradski tim: Georgije Popović, Dragomir Olević, Rade Pavlović i Zorica Cvetković
- bugarska strana: Anton Strigačev
- CCD posmatranja - kamera VersArrey 1300B

- **od 2009. godine do danas**

- posmatranja vizuelno dvojnih zvezda pomoću 2 m teleskopa na NAO Rožen – zahvaljujući razumevanju bugarskih kolega (2009-2011)

- u okviru zajedničkih trogodišnjih projekata SANU i BAN (2012-2014; 2014-2016 i 2017-2019)

- beogradski tim: Zorica Cvetković, Rade Pavlović, Goran Damljanović, Slobodan Ninković (2012-2014; 2014-2016), Milan Stojanović (2012-2014), Miljana Jovanović (2017-2019)

- bugarska strana: Svetlana Boeva, Alexander Antov, Renada Konstantinova-Antova, Rumen Bogdanovski, Borislav Spassov (2012-2014) Georgi Latev, Maya Belcheva (2014-2016; 2016-2019) Janko Nikolov (2017-2019)

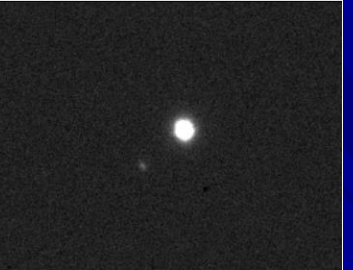
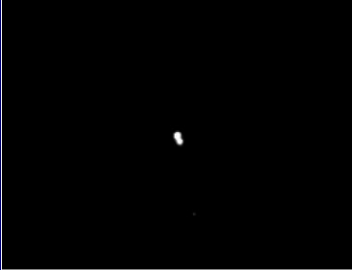
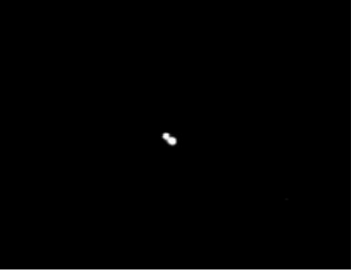
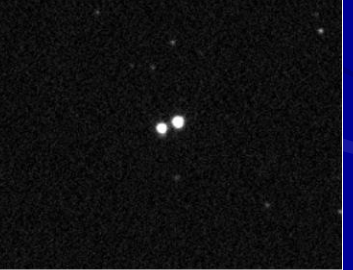
- od sredine 2011. godine do danas

posmatranja vizuelno dvojnih zvezda pomoću 0.6 m teleskopa na ASV

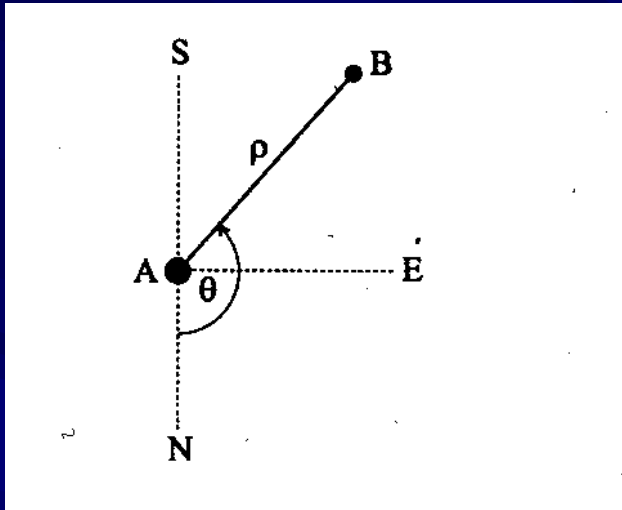
- od sredine 2016. godine do danas

posmatranja vizuelno dvojnih zvezda pomoću 1.4 m teleskopa na ASV

- CCD posmatranja kamerama Apogee Alta U42 i SBIG ST-10ME

				
WDS17248+3044 $m=10.8-11.1$ $\rho=1.8''$	WDS14416+5124 $m=8.0-8.1$ $\rho=1.8''$	WDS19143+1904 $m=7.9-9.5$ $\rho=2.0''$	WDS18222+1126 $m=9.6-10.8$ $\rho=2.9''$	WDS18347+3506 $m=8.5-11.9$ $\rho=9.2''$
				
WDS22032+2358 $m=12.2-12.5$ $\rho=1.7''$	WDS22455+1112 $m=10.2-11.4$ $\rho=2.5''$	WDS20240+2505 $m=11.2-11.2$ $\rho=2.8''$	WDS20314+2054 $m=12.2-12.8$ $\rho=4.0''$	WDS20122+0255 $m=9.9-10.4$ $\rho=5.9''$

Merenja relativnih koordinata



ugaono rastojanje između komponenti
A (primar) i B (sekundar) tj. separacija ρ

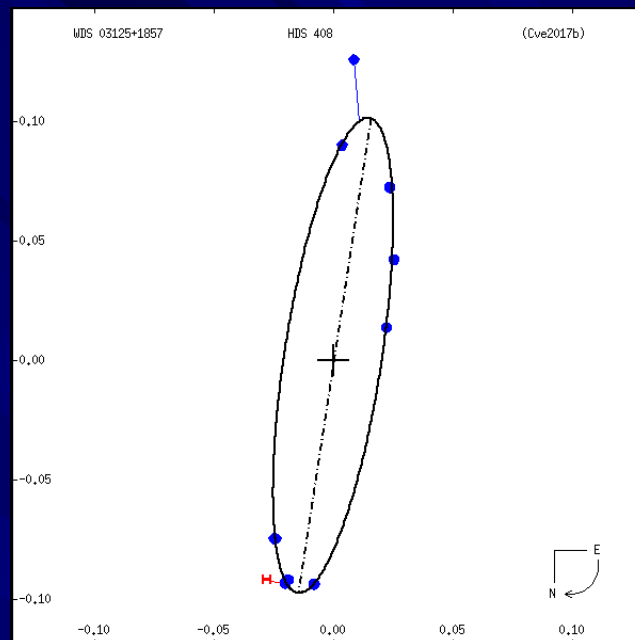
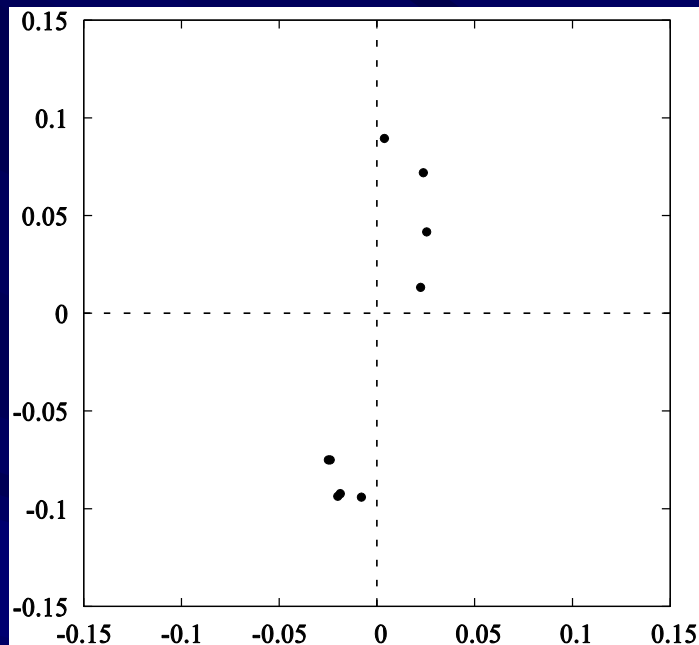
pozicioni ugao θ

t, ρ, θ

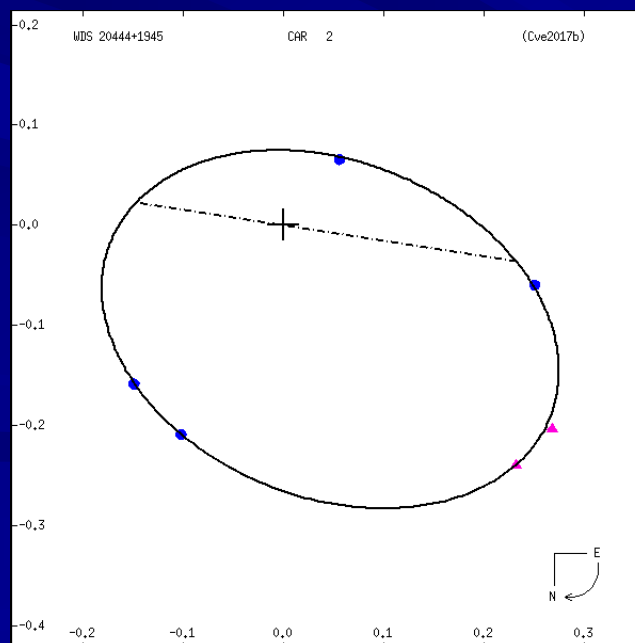
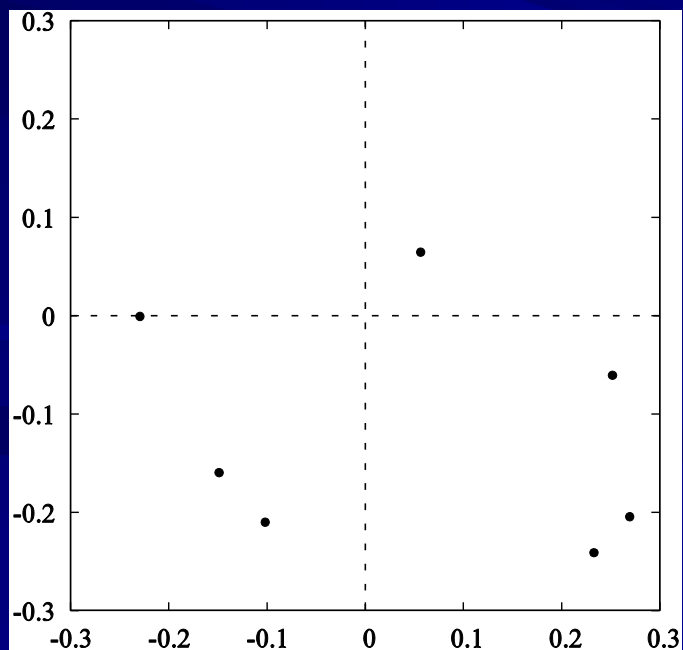
Zadatak – odrediti koje dvojne su gravitaciono vezane tj. orbitalne, a koje su optički parovi tj. nisu gravitaciono vezane već su bliske projekcije u tangencijalnoj ravni

Izračunavanje orbitalnih ili linearnih elemenata, određivanje zvezdanih masa, dinamičkih paralaksi i drugih parametara

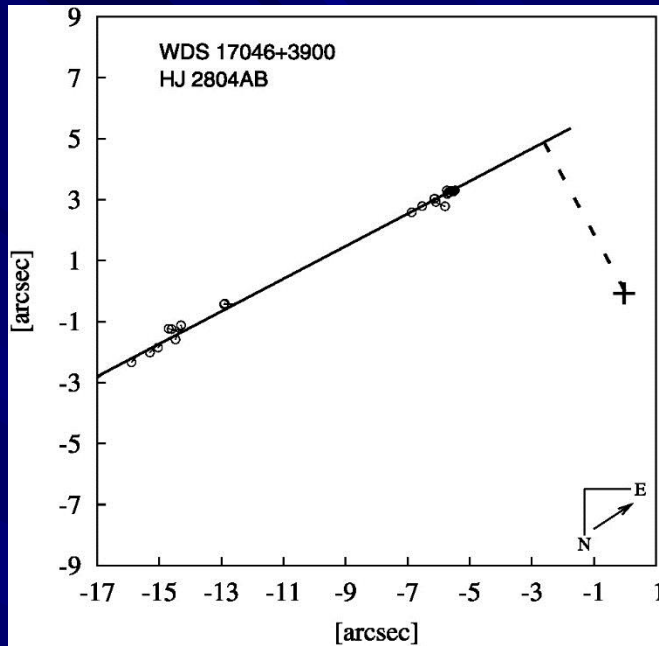
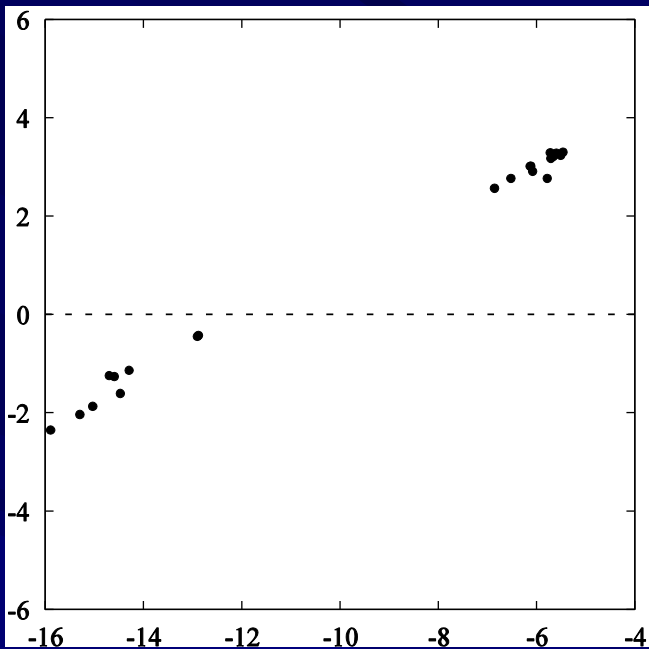
Poboljšanje metoda za izračunavanje što tačnijih orbita, posebno iz vrlo kratkih lukova



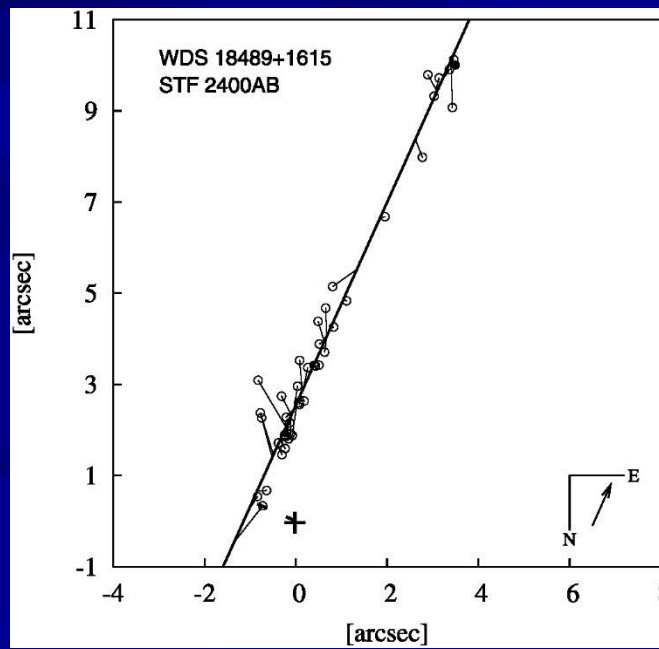
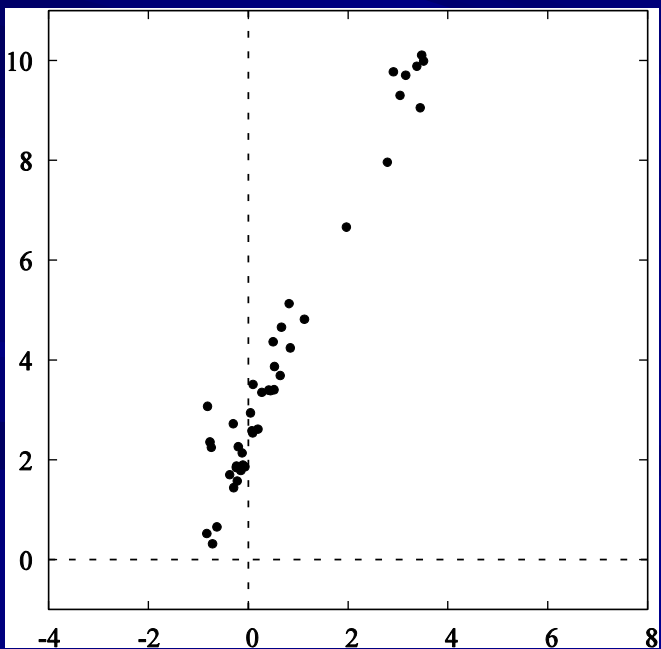
$P = 19.4 \text{ yr}$
 $e = 0.032$
 $i = 101.7 \text{ deg.}$



$P = 14.3 \text{ yr}$
 $e = 0.587$
 $i = 129.4 \text{ deg.}$

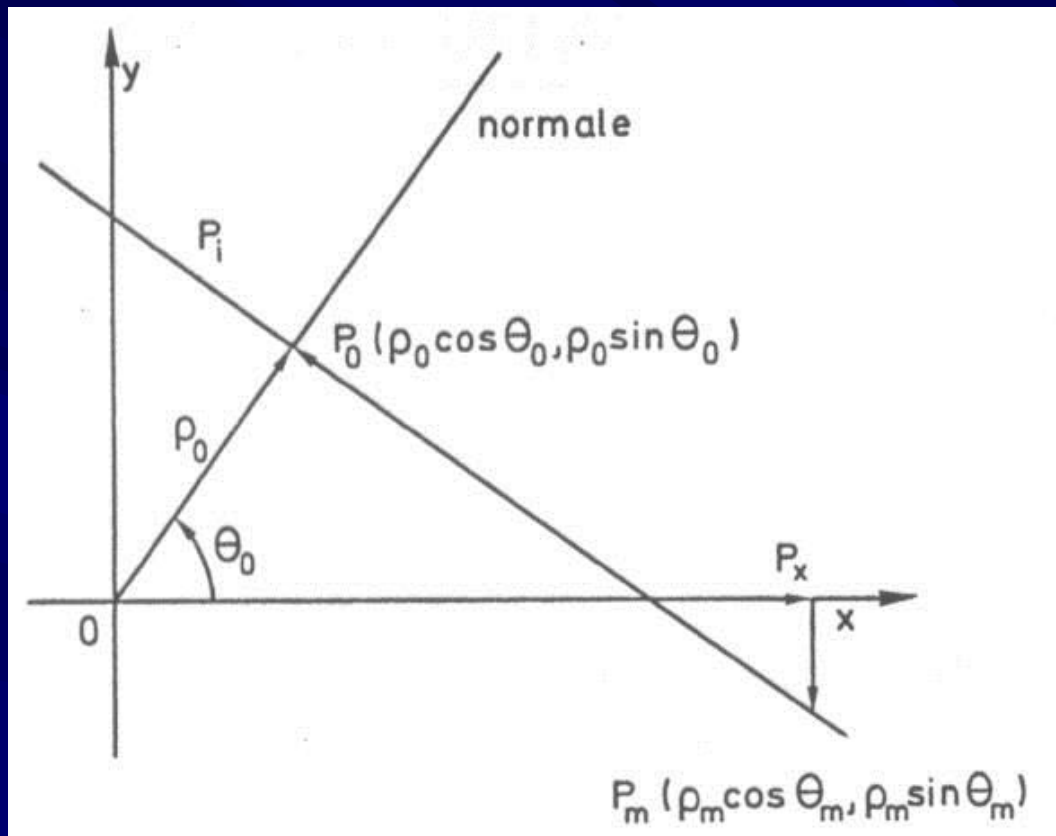


1831-2015



1855-2014

LINEARNI ELEMENTI



$$x_i = \rho_i \cos \theta_i$$

$$y_i = \rho_i \sin \theta_i$$

$$y_i = a \cdot x_i + b, \quad \rightarrow \quad a, b$$

$$P_0(x_0, y_0) \equiv P_0\left(-\frac{ab}{a^2 + 1}, \frac{b}{a^2 + 1}\right)$$

$$\rho_0 = \sqrt{x_0^2 + y_0^2}$$

$$\theta_0 = \arctan \frac{y_0}{x_0}$$

$$\rho_i \cos(\theta_0 - \theta_i) = \rho_0$$

$$\rho_i \sin(\theta_0 - \theta_i) = V \cdot (t_i - T_0)$$

X_0 i Y_0 – koordinate tačke sa najmanjom relativnom separacijom

V_x i V_y – komponente brzine relativnog kretanja sekundara u odnosu na primar

T_0 – epoha najbližeg prolaza

ρ_0 – najmanja relativna separacija

θ_0 – pozicioni ugao najbližeg prolaza

Objavljeni linearni elementi mogu se naći u Washington-skoj bazi podataka

WDS	Discov.Des.	$X_0[']$	$V_x[']/yr$	$Y_0[']$	$V_y[']/yr$	$T_0[yr]$	$\rho_0[']$	$\theta_0[^\circ]$
01057+3304	MLB 444	7.184849	-0.029876	-2.073079	-0.103544	1948.782	7.478	73.91
02516+4803	HJ 2160	-5.833506	-0.013444	3.726437	-0.021046	1743.980	6.922	237.43
03342+4837	BU 787	-1.744095	-0.020860	1.467897	-0.024785	1878.073	2.258	229.91
04312+5858	STI2051	5.579910	0.042772	2.330326	-0.102417	1939.958	6.047	112.67
04556+1653	HJ 3263	-3.459261	0.039617	-2.136124	-0.064157	1834.786	4.066	301.70
05492+2941	BRT2521	-1.248724	-0.076498	2.026629	-0.047135	1940.824	2.380	211.64
06092+6424	MLB 259	-3.980805	0.013260	1.576882	0.033474	1910.178	4.282	248.39
07106+1543	J 703	0.415380	-0.082381	-1.745080	-0.019609	1892.897	1.794	3.39
08503+0125	J 74	2.191639	0.034511	-1.685230	0.044882	1857.508	2.765	52.44
09388+0242	J 78	0.562050	0.067989	3.036883	-0.012583	1948.224	3.088	169.51
17046+3900	HJ 2804	-2.604337	0.083382	4.882575	0.044476	2049.773	5.534	208.08
18269+2950	HJ 1325	-5.030179	0.009846	-4.126053	-0.012003	2001.494	6.506	309.36
19500+0637	J 1336	-0.370453	0.047707	-2.036395	-0.008679	1904.829	2.070	349.69

Kontrola:

Iz linearnih rešenja dobijamo brzinu V relativnog kretanja sekundara u odnosu na primar

Iz komponenti sopstvenog kretanja $\mu_{\alpha} \cos \delta$ i μ_{δ} za obe komponente para može se izračunati relativno sopstveno kretanje μ_{rel} :

$$\mu_{rel} = \sqrt{(\mu_{\alpha A} \cos \delta - \mu_{\alpha B} \cos \delta)^2 + (\mu_{\delta A} - \mu_{\delta B})^2}$$

Poređenje V i μ_{rel} :

slaganje je jedna potvrda da je to optički par

neslaganje ukazuje da par može biti gravitaciono vezan sa dugim periodom

Od 2012. god. - mi smo izračunali linearne elemente za 27 dvojnih zvezda

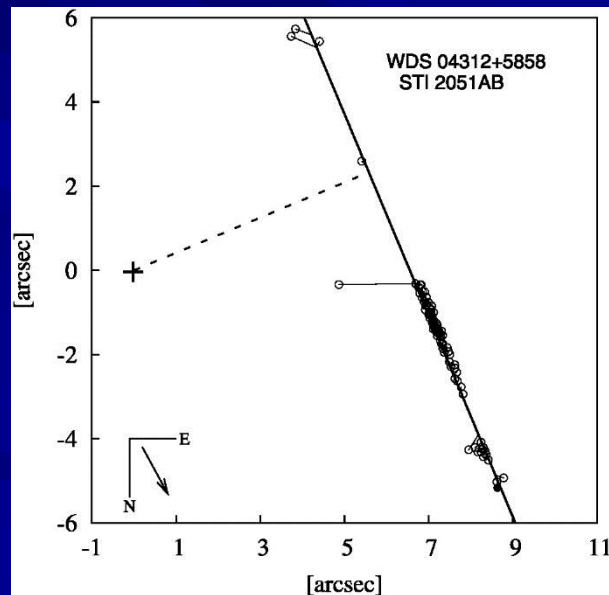
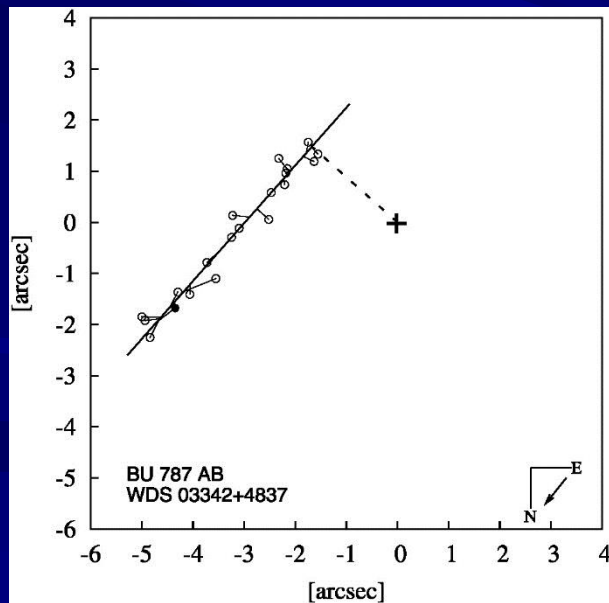
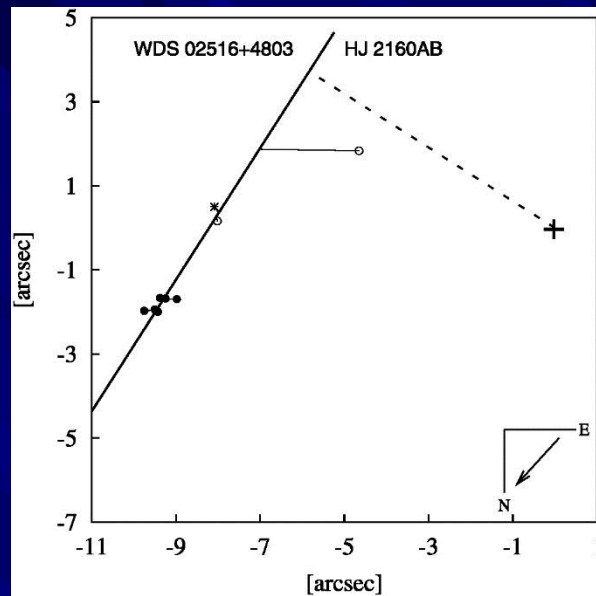
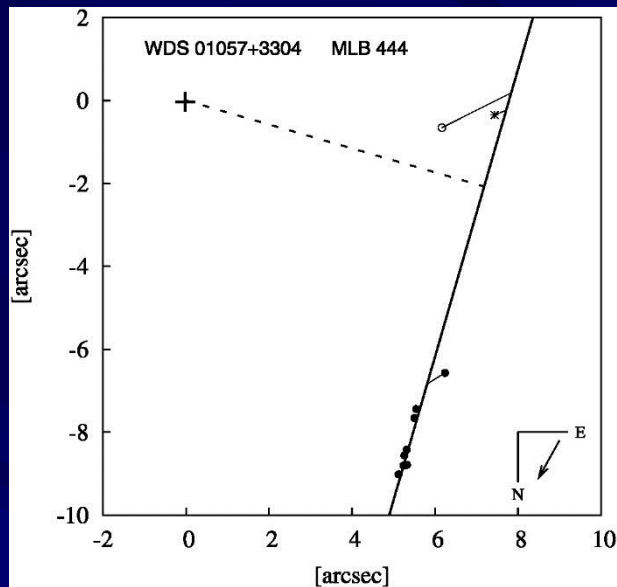
Za račun su korišćena, osim merenja sakupljenih u bazi podataka, i naša CCD merenja dobijena na NAOR i ASV

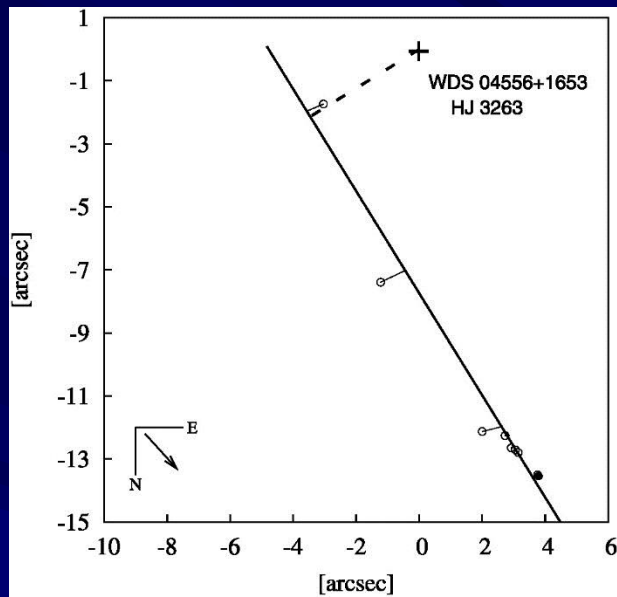
Paralakse i komponente sopstvenog kretanja za obe komponente uzete iz dva kataloga WDS i GAIA DR2

Pair	π_A	π_B	WDS catalogue				GAIA DR2 catalogue			
			$\mu_{\alpha A} \cos \delta$	$\mu_{\delta A}$	$\mu_{\alpha B} \cos \delta$	$\mu_{\delta B}$	$\mu_{\alpha A} \cos \delta$	$\mu_{\delta A}$	$\mu_{\alpha B} \cos \delta$	$\mu_{\delta B}$
	[mas]	[mas]	[mas/yr]	[mas/yr]	[mas/yr]	[mas/yr]	[mas/yr]	[mas/yr]	[mas/yr]	[mas/yr]
01057+3304=MLB 444	3.5453	3.4627	-18.8	-102.8	87.7	23.7	11.900	-88.981	-14.926	9.472
02516+4803=HJ 2160	1.0469	2.3594	8.8	-7.3	-8.0	13.9	9.259	-7.452	-1.936	14.074
03342+4837=BU 787	5.8057	1.6200	21.4	-26.5	22.1	17.8	22.419	-26.732	-4.788	1.288
04312+5858=STI2051	180.4215	181.2815	1300.2	-2049.0	1335.6	-1962.6	1303.270	-2043.847	1335.042	-1947.632
04556+1653=HJ 3263	2.7324	0.8136	-44.3	-56.5	5.7	5.9	-48.778	-61.537	2.802	-2.488
05492+2941=BRT2521	7.6388	0.9987	92.0	-55.8	-14.9	-41.9	67.125	-56.269	-7.493	-5.842
06092+6424=MLB 259	2.9454	1.3870	4.6	17.8	-15.0	-33.2	-4.564	13.385	11.251	-21.119
07106+1543=J 703	2.7841	12.1025	8.9	-16.9	-23.0	15.8	-12.119	-5.208	-93.538	14.491
08503+0125=J 74	4.4225	1.6365	-61.7	55.8	40.1	-15.5	-40.064	38.112	-7.610	-5.594
09388+0242=J 78	7.9151	5.5372	-76.0	0.0	-30.9	-58.1	-94.165	-30.793	-22.601	-17.829
17046+3900=HJ 2804	5.5242	3.4322	-51.7	2.0	25.3	-44.2	-53.121	1.738	30.945	-43.992
18269+2950=HJ 1325	0.3623	0.4096	-1.3	-11.6	-21.0	12.1	-3.200	-11.248	5.956	0.604
19500+0637=J 1336	1.0174	4.5890	-11.4	-18.0	28.8	8.7	0.246	-6.148	44.409	-6.481

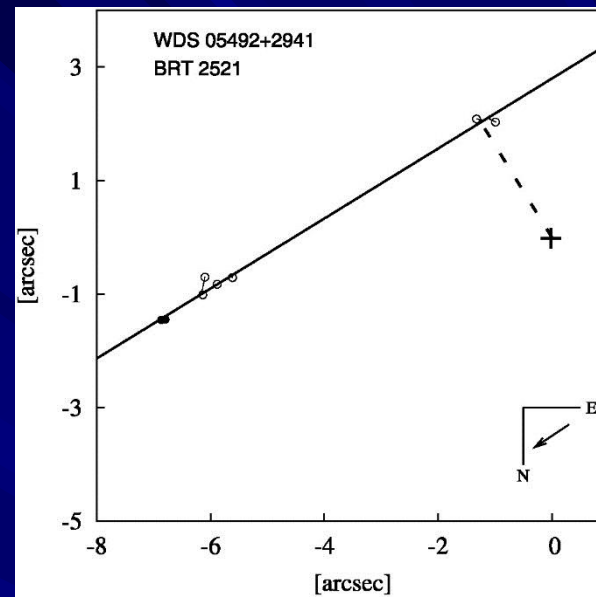
Washington Double Star Catalog, WDS, <http://ad.usno.navy.mil/wds/Webtextfiles/wdsnewframe.html>

Gaia DR2 (Gaia data release 2, 2018), <http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=I/345/gaia2>

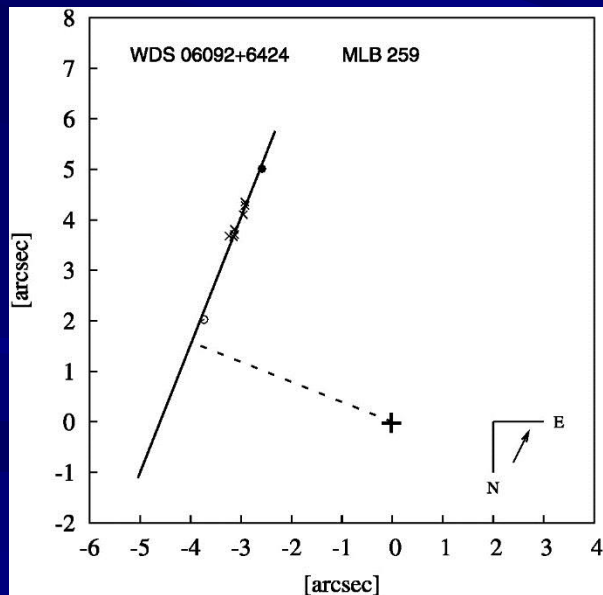




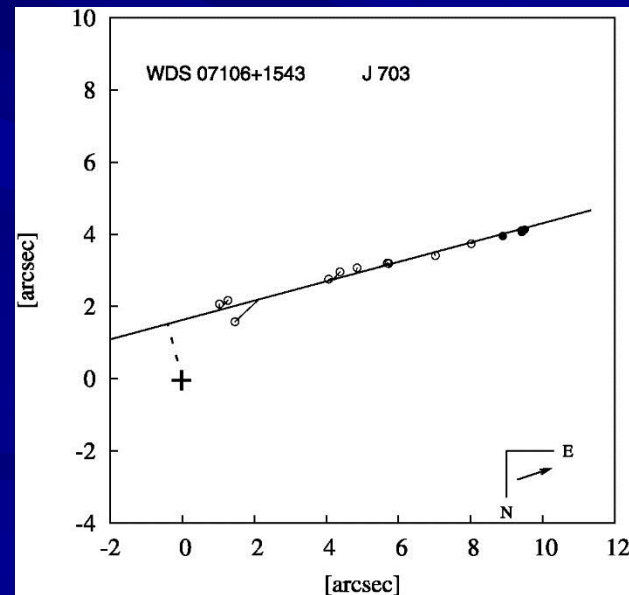
1832-2015
 W: 0.080 "/yr
 G: 0.078 "/yr
 V: 0.075 "/yr



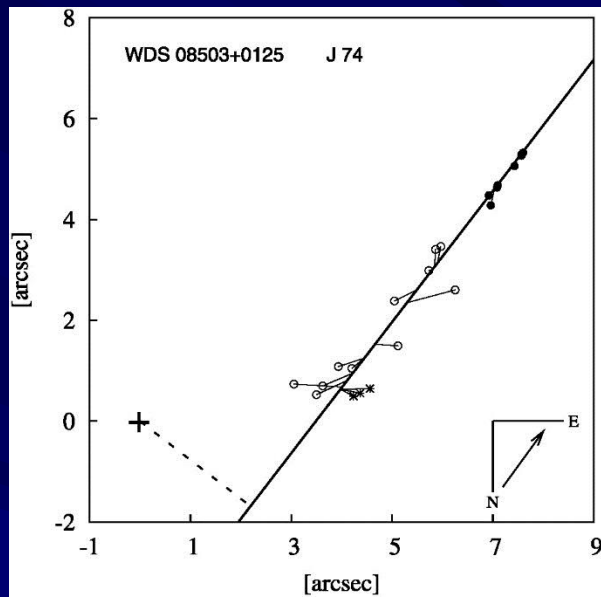
1939-2015
 W: 0.108 "/yr
 G: 0.090 "/yr
 V: 0.090 "/yr



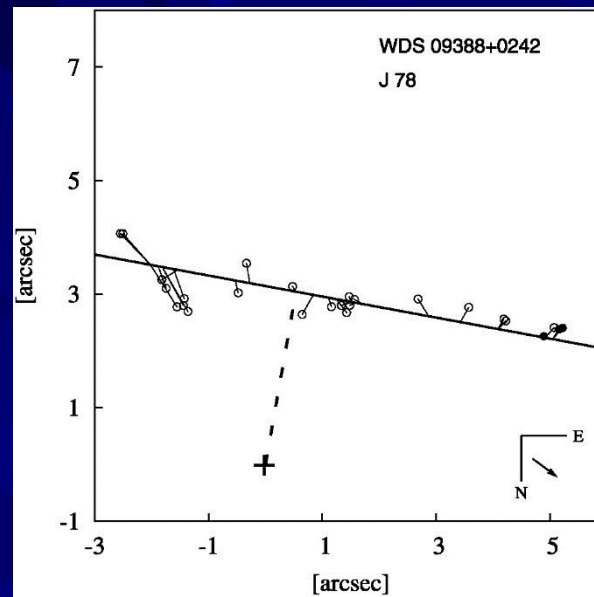
1922-2015
 W: 0.055 "/yr
 G: 0.038 "/yr
 V: 0.036 "/yr



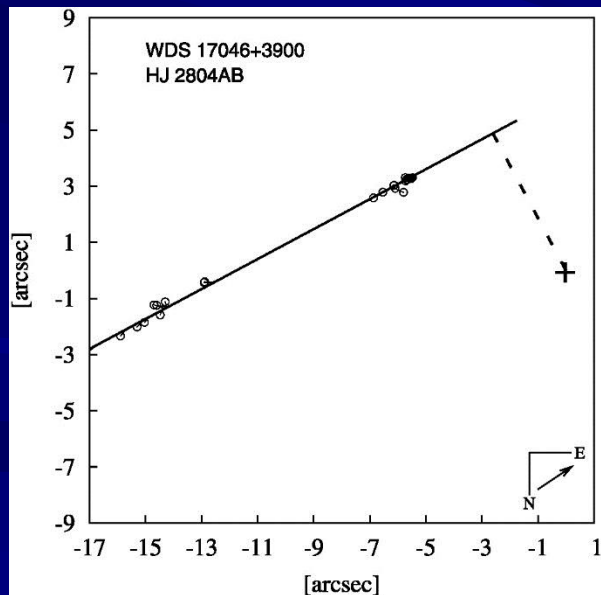
1912-2013
 W: 0.046 "/yr
 G: 0.084 "/yr
 V: 0.085 "/yr



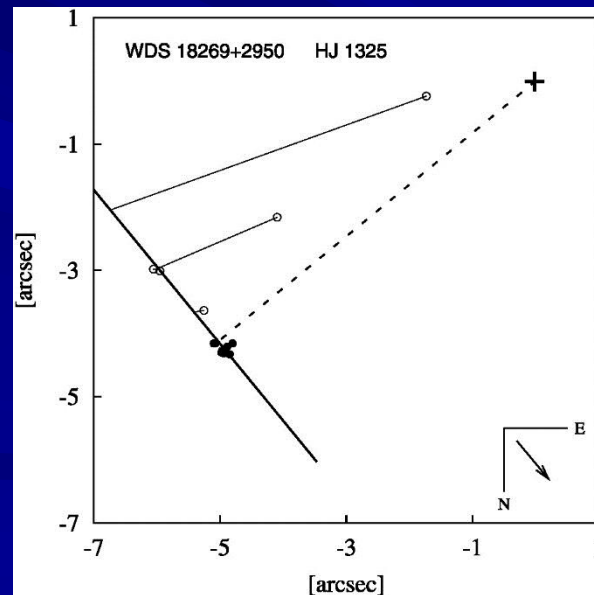
1909-2017
W: 0.124 "/yr
G: 0.054 "/yr
V: 0.057 "/yr



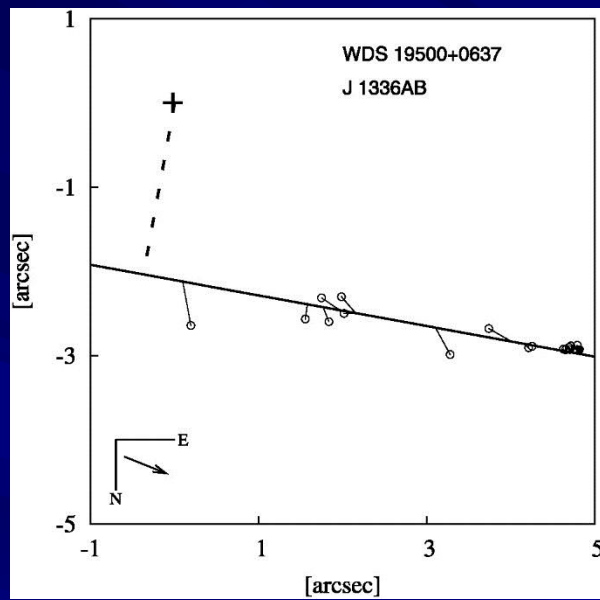
1910-2015
W: 0.074 "/yr
G: 0.073 "/yr
V: 0.069 "/yr



1831-2015
W: 0.090 "/yr
G: 0.096 "/yr
V: 0.094 "/yr



1828-2015
W: 0.031 "/yr
G: 0.015 "/yr
V: 0.016 "/yr



1914-2015

W: 0.048 "/yr

G: 0.044 "/yr

V: 0.048 "/yr

Relativna sopstvena kretanja i brzine

Pair	$\mu_{rel}(W)$ ["/yr]	$\mu_{rel}(G)$ ["/yr]	V ["/yr]
01057+3304=MLB 444	0.165	0.102	0.108
02516+4803=HJ 2160	0.027	0.024	0.025
03342+4837=BU 787	0.032	0.039	0.032
04312+5858=STI2051	0.093	0.101	0.111
04556+1653=HJ 3263	0.080	0.078	0.075
05492+2941=BRT2521	0.108	0.090	0.090
06092+6424=MLB 259	0.055	0.038	0.036
07106+1543=J 703	0.046	0.084	0.085
08503+0125=J 74	0.124	0.054	0.057
09388+0242=J 78	0.074	0.073	0.069
17046+3900=HJ 2804	0.090	0.096	0.094
18269+2950=HJ 1325	0.031	0.015	0.016
19500+0637=J 1336	0.048	0.044	0.048

- WDS katalog sada sadrži informacije o merenjima 142645 dvojne zvezde
- orbite su određene za 2775 dvojna sistema – date su u Sixth Catalog of Orbits of Visual Binary Stars, ORB6, <http://ad.usno.navy.mil/wds/orb6.html>
- linearni elementi su određeni za 1574 dvojne zvezde

- zaključak

- ima još mnogo vizuelno dvojnih zvezda za koje treba odrediti orbitalne ili linearne elemente – potrebno je prikupljati nove posmatračke podatke tj. relativne koordinate
- GAIA podaci, naročito paralakse, će znatno doprineti boljem određivanju masa zvezda kod gravitaciono vezanih parova; paralakse i sopstvena kretanja će omogućiti pouzdanije određivanje optičkih parova

References

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HVALA NA PAŽNJI