Project OLED

Lunar Occultation of Double Stars

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Project OLED - people

Philippe Laurent
Société Astronomique de France (SAF)
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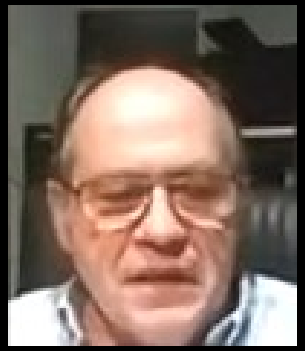

Rosendo Jorba
Coordinator Grupo de Estudios (AAM)

Patrick Wullaert
SAF
President Commission des Étoiles Doubles

José Prieto
President of Madrid Astronomical Association (AAM)

… and also thanks to…

- **many other observers**
- Simbad CDS
- Gaia / ESA
- stelledoppie.it
- USNO WDS

Current distribution of participating stations

Outline

- Project OLED: general results
- Double stars
- Accelerated stars

Extra topics

- High sampling rate and near-infrared observations
- Lunar-limb supression
- Analysis of O – C for “single stars”: rolling shutter

Project OLED: general results

https://sites.google.com/aam.org.es/oled

AGRUPACIÓN ASTRONÓMICA DE MADRID

Federación de Asociaciones Astronómicas de España

Ocultaciones Lunares de Estrellas Dobles
Occultations Lunaires d'Étoiles Doubles

https://sites.google.com/aam.org.es/oled/

Sociedad Española de Astronomía

SOCIÉTÉ ASTRONOMIQUE DE FRANCE

Commission des Étoiles Doubles

Lunar occultation of double stars - Project OLED

OBSERVING PROGRAMME - JUNE 25

The programme for this month includes targets from the following campaigns:

Double star WDS programme

DOUBLE STAR WDS PROGRAMME

The table below (check here for key) shows the occultations of the WDS programmme for JUNE 25. Please report observations by writing an email to *enrique.velasco@uam.es*. For more accurate predictions on these occultations for your position, visit this link and choose "WDS (double stars)" as the "Object catalogue". A summary of these predictions with detailed information for each observer of the project, as well as an ics calendar file, can be found here. To quickly check for visibility of an occultation from your particular station, click on column "OLED", look for your acronym and have a look at the contact map.

Urg	Day	UTC	Star (WDS)	RA	DEC	Mags	Year	# obs	Sep	PA	Type	Flux	Illum	Def	γ	hSun	hMoon	OLED
B	3	20:24:49	J11268+0301AB	11 26 45.32	+ 3 0 47.2	6.5/ 7.5/ 6.2	2019	144	28.6	146	I	0.71/0.29	57.0	757	146	-8	48	●
B	3	21:15:32	J11279+0251AB	11 27 56.23	+ 2 51 22.5	5.0/ 7.5/ 4.9	2019	77	89.2	181	I	0.90/0.10	57.3	769	129	-15	41	●
B	3	21:17:54	J11279+0251BD	11 27 56.17	+ 2 49 53.5	7.5/ 9.5/ 7.3	2019	9	767.5	86	I	0.87/0.13	57.3	765	133	-15	41	●
A	5	20:34:08	J12521-0831	12 52 4.05	- 8 31 24.9	9.6/ 9.6/ 8.8	1976	0	0.2	-	I	0.50/0.50	75.0	191	175	-9	42	●
B	13	03:25:29	J18560-2808	18 55 58.83	-28 7 49.0	8.5/ 9.2/ 8.1	2016	21	0.9	127	E	0.66/0.34	-96.6	43	311	-12	18	●
A	17	02:39:30	J22281-1153	22 28 8.36	-11 53 25.1	9.0/ 9.4/ 8.4	2008	9	0.3	116	E	0.59/0.41	-68.4	378	307	-18	29	●
A	18	02:17:18	J23166-0558	23 16 38.64	- 5 58 25.2	9.6/ 9.6/ 8.8	1987	0	0.1	-	E	0.50/0.50	-58.0	800	249	-20	24	●
B	22	03:05:12	J02475+1922AB	2 47 27.35	+19 22 20.0	7.5/ 8.2/ 7.1	2020	330	3.5	306	E	0.66/0.34	-15.2	-	224	-15	14	●

ACKNOWLEDGEMENTS

Information on the stars in the tables above has been collected with the help of

WDS - USNO

Stelle Doppie

Last revised 01 JUN 25
E. Velasco
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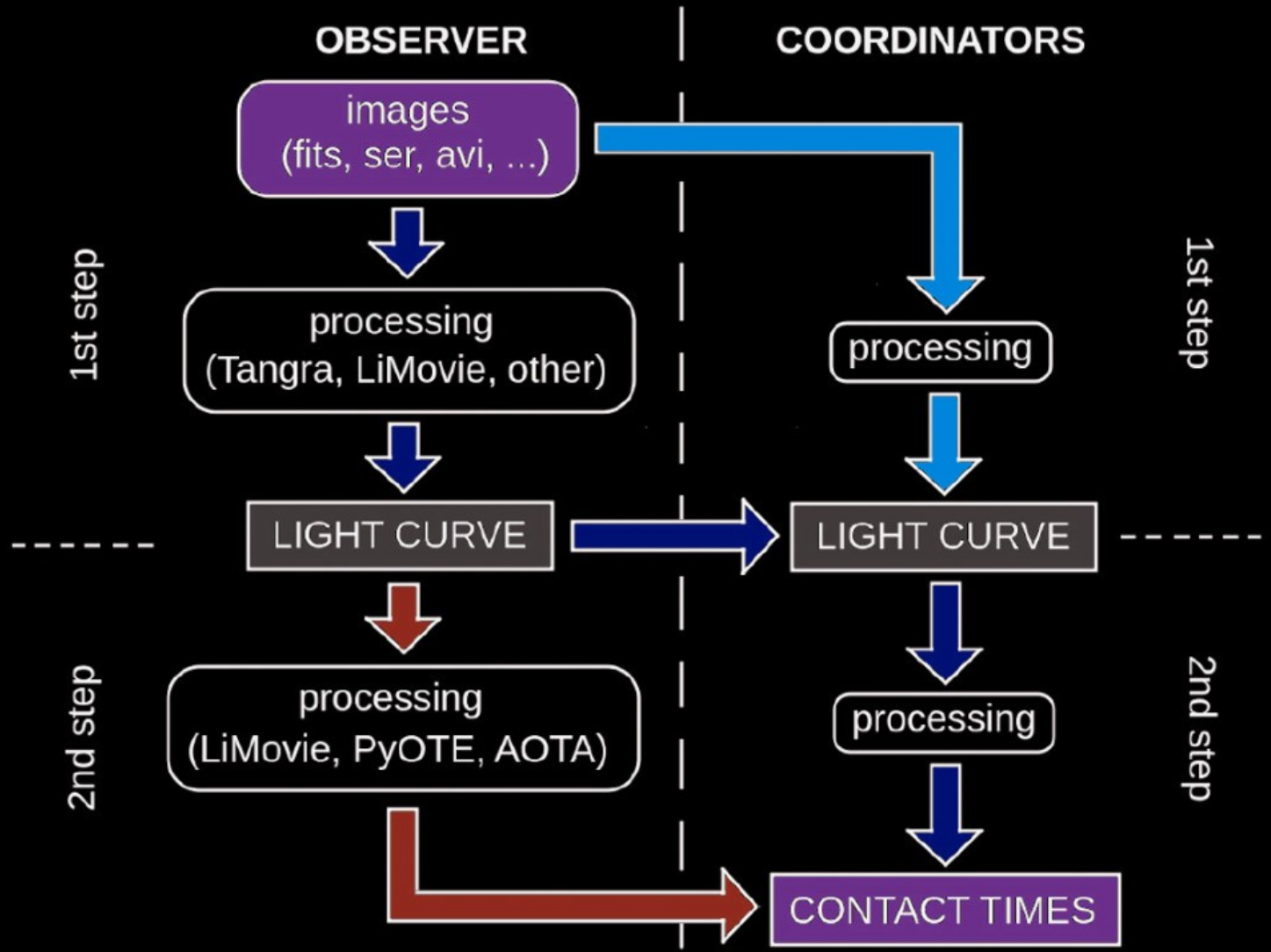
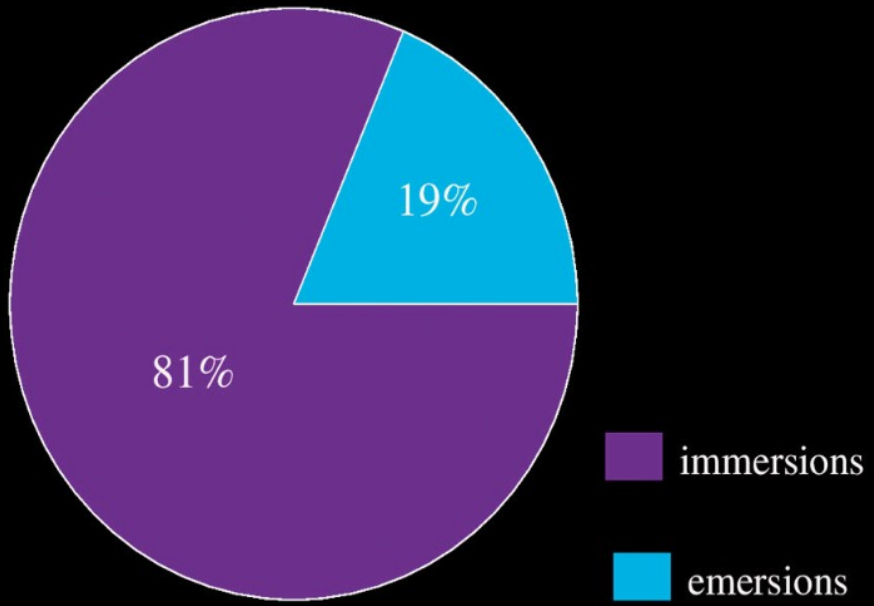
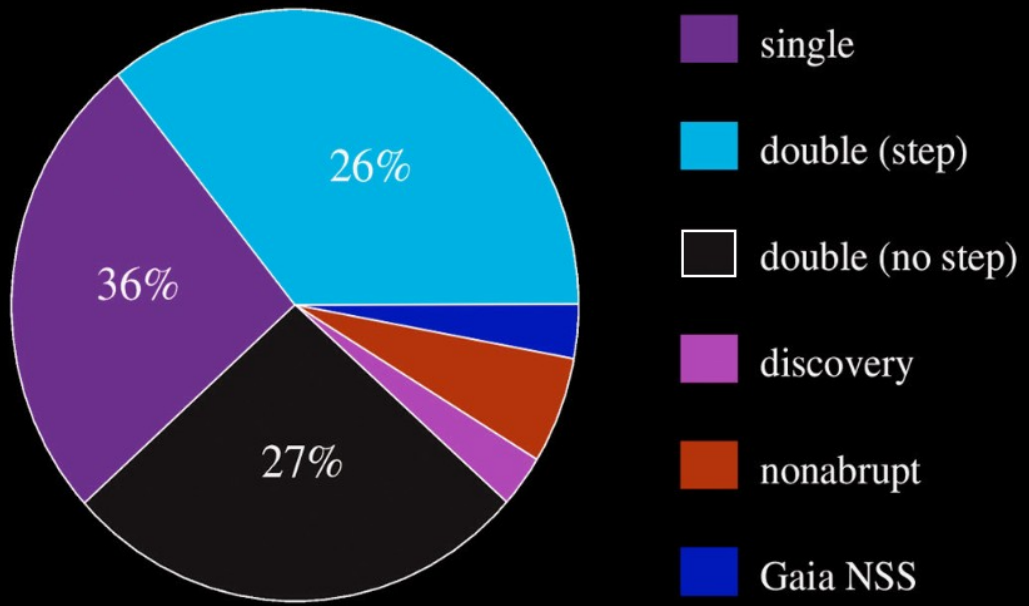
Universidad Autónoma de Madrid
Spain


OBSERVER
COORDINATORS
images
(fits, ser, avi, ...)
1st step
processing
(Tangra, LiMovie, other)
processing
1st step
LIGHT CURVE
LIGHT CURVE
2nd step
processing
(LiMovie, PyOTE, AOTA)
processing
2nd step
CONTACT TIMES

Distribution of observations as per event & star type





Project OLED: general

336 *contacts start – April 2024* (published *Étoiles Doubles*)

144 *contacts April 2024 – present*

{ *ED Dec 23*
{ *ED Jun 24*

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480 *contacts*

Current lines:

- *WDS double stars* – **306** contacts / **126** stars
- OCC stars (*occultation binaries*) – **3 / 60** positive
- Gaia NSS and Kervella stars – **0 / 15** positive

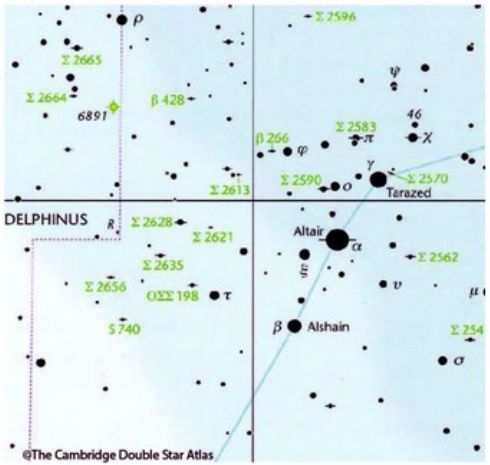
  [nonresolved, accelerated stars]

Étoiles Doubles

Revue francophone des observateurs d'étoiles doubles

contact@etoilesdoubles.org

La revue Étoiles Doubles



La **revue Étoiles Doubles** apporte aux amateurs un support de publication pour leurs travaux.
Les mesures de position publiées dans « Étoiles Doubles » seront intégrées dans le catalogue d'étoiles doubles WDS (Washington Double Star Catalog) pour bénéficier à l'ensemble de la communauté astronomique.
Les articles à portée scientifique seront archivés au SAO/NASA Astrophysics Data System.
La qualité scientifique des articles est garantie par un comité de relecture constitué d'astronomes professionnel(le)s.

Étoiles Doubles et le site internet associé sont là pour accompagner les astronomes amateurs intéressés par ce domaine. Consultez nos pages « Les Étoiles Doubles » pour y trouver des articles pédagogiques et les différentes rubriques de ressources pour accéder à plus d'information. Vous pouvez également nous contacter.

La revue Étoiles Doubles est gratuite et publiée exclusivement sous forme numérique.

PROJET OLED - OCCULTATIONS D'ÉTOILES DOUBLES PAR LA LUNE

RAPPORT ANNUEL #1 (2021-2024)

Project OLED - Lunar Occultations of Double Stars - ANNUAL REPORT # 1 (2021-2024)

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Observateurs : José Antón, Gonzalo Arriarás, Pedro Benedicto, Ricard Casas, Jean François Coliac, Esteban Donate, Javier de Elías, Faustino García, Bernat Garreta, José Luis Hernández, Jaime Izquierdo, Rosendo Jorba, Philippe Laurent, Ángel Manuel López, Jordi Marco, Josep Masalles, Pablo Molina, Joan Miquel Perales, José Prieto, Joan Rovira, Francisco Soldán, Tófol Tobal, Enrique Velasco, Patrick Wullaert

Résumé

L'occultation d'étoiles par la Lune est une méthode d'astrométrie puissante et précise. Appliquée aux étoiles doubles, elle permet d'en obtenir l'astrométrie relative (Thêta et Rhô à une époque donnée). Il faut pour cela disposer de deux observations réalisées par des observateurs distants, de sorte que pour chacun d'eux, l'occultation n'intervienne pas au même endroit du limbe lunaire. Le présent rapport présente les résultats du projet OLED, regroupant des observateurs espagnols et français observant ce type d'évènement. Les mesures d'étoiles doubles qui ont pu être réalisées y sont publiées en vue de leur intégration au WDS. Les observations incomplètes ou infructueuses sont également présentées, car elles peuvent se révéler utiles dans l'avenir. Quelques cas de couples intéressants sont également détaillés.

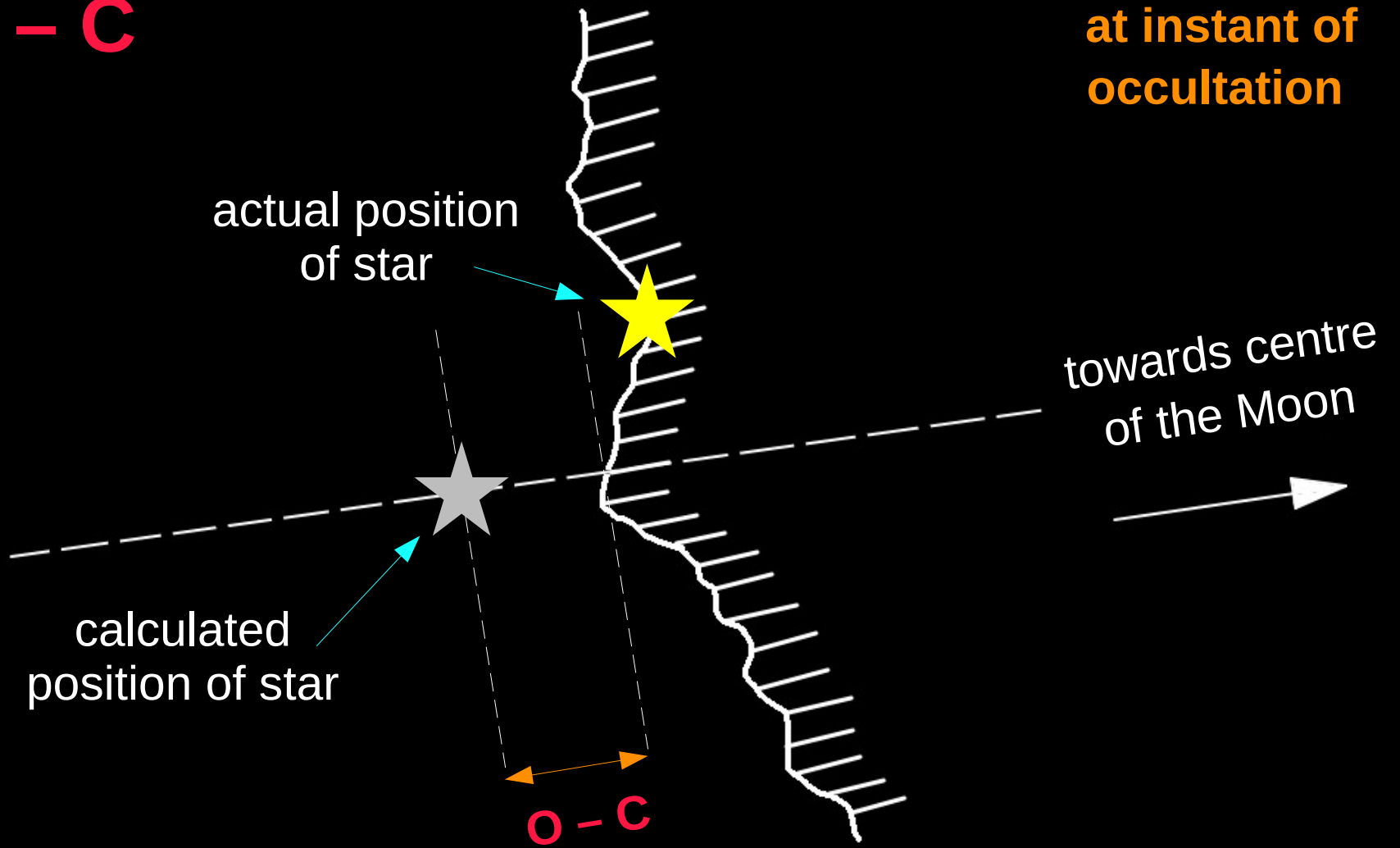
Abstract

Occultation of stars by the Moon is a powerful and precise method of astrometry. Applied to double stars, it can be used to obtain their relative astrometry (Theta and Rhô at a given epoch). This first annual report presents the results obtained by the OLED project, which brings together Spanish and French observers observing this type of phenomenon. The measurements of double stars that were carried out are published here with a view to their integration into the WDS. Incomplete or unsuccessful observations are also presented, as they may prove useful in the future. Some cases of interesting pairs are also detailed.

Table III : Étoiles avec solution astrométrique bidimensionnelle						
WDS	Nom	Époque J	Obs.	Rhô (")	Thêta (°)	Notes
J01406+0846	TOK872	2023,0725	EVC, RC1, JDE	0,039±0,027	71±45	Incertaine. Dernière mesure: 2021, 0.045", 260.3°. 5 observations. JDE n'a pas détecté de duplicité.
J01437+0934	BU509	2023,0728	JAI, EVC	0.796±0.084	21±19	Binaire physique avec orbite de grade 3. O-C=242 mas
J01443+0929AB	STF155AB	2023,0729	JAI, EVC	5.016±0.024	312±3	Physique sans orbite. Dernière mesure: 2018, 4.945", 324.6°, 129 observations
J03206+1911AB	STF377AB	2023,0782	RC1, JMR	1.155±0.028	102±5	Incertaine. Dernière mesure: 2018, 1.119", 110.3°, 51 observations
J03233+2058	STF381	2023.9764	EVC, JMR	0.991±0.069	104±5	Incertaine. Dernière mesure: 2018, 1.09", 108.7°, 72 observations.
J03261+2015AB	A2344AB	2023,6019	JAI, RJL	1.31±0.64	189±10	Incertaine. Dernière mesure: 2018, 1.166", 193°, 33 observations, Occultation de la composante C aussi observée par JAI.
J03280+2028Aa,Ab	COU260Aa,Ab	2023,6020	JAI, RJL	0.66±0.20	83±18	Incertaine. Dernière mesure: 2014, 0.235", 24.4°, 44 observations
J03280+2028AB	STF394AB	2023,6020	JAI, RJL	6.33±0.92	214±29	Incertaine. Dernière mesure: 2016, 6.909", 163.3°, 87 observations
J05017+2640AB	A1844AB	2024,0559	RJL, PLA	0.205±0.034	168±6	Binaire physique avec orbite de grade 2. O-C=64 mas
J06026+2724	OCC767	2023,3112	PBE, JAI, RJL	0.335±0.066	106±26	Incertaine. Première mesure complète.
J06364+2717	STT149	2023,1630	JAI, JMR, JDE	0.831±0.370	262±19	Binaire physique avec orbite de grade 2. O-C=199 mas
J07128+2713AB	STF1037AB	2023,2397	RC1, PLA	0.790±0.034	303±2	Binaire physique avec orbite de grade 2. O-C=60 mas
J07171+2641	CHR218	2023,2400	RJL, RC1, PLA	0.082±0.037	255±11	Incertaine. Dernière mesure: 2016, 0.183", 235.3°, 17 observations

O – C

at instant of occultation



ε = star – Moon distance

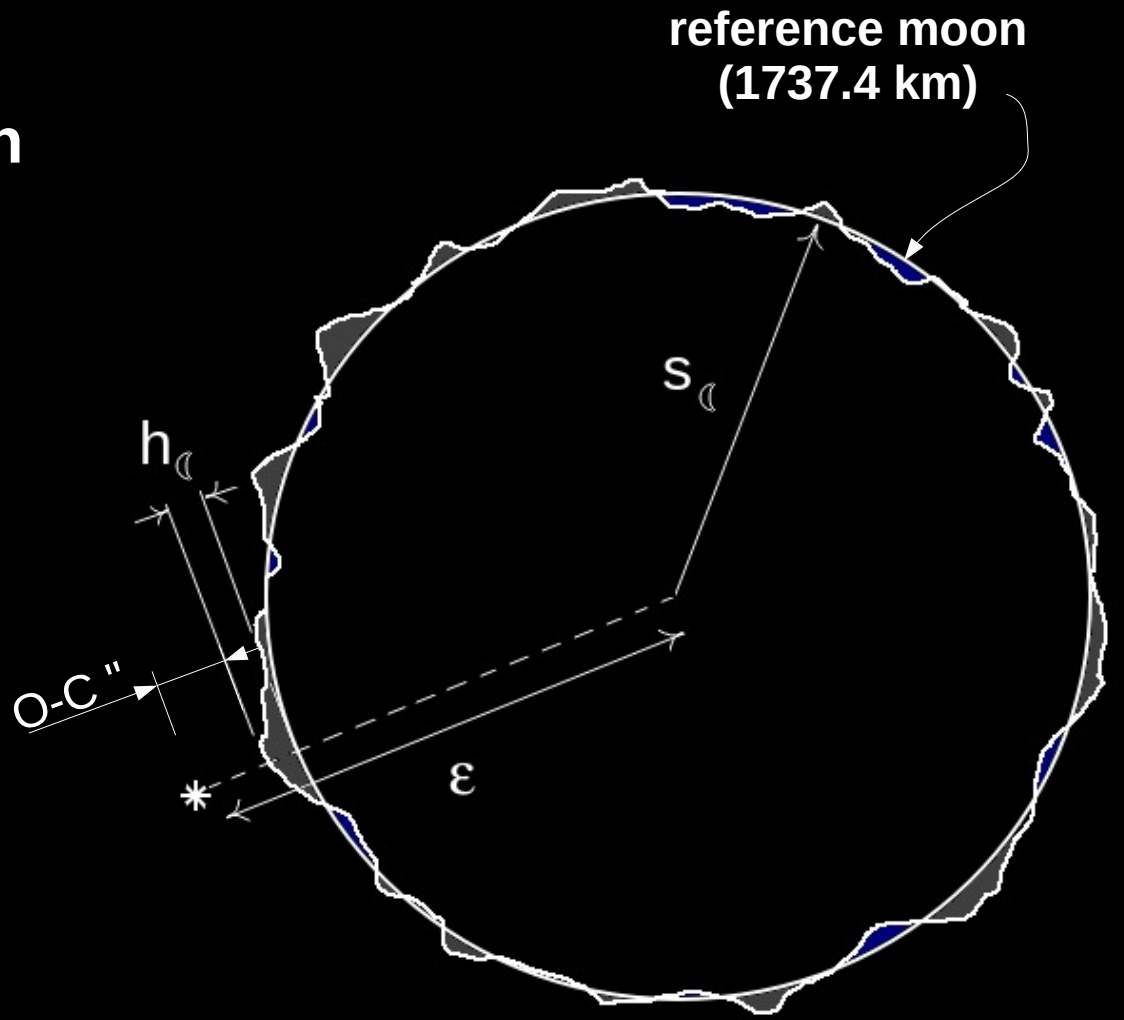
$s_{\leftmoon}$ = semidiameter of Moon

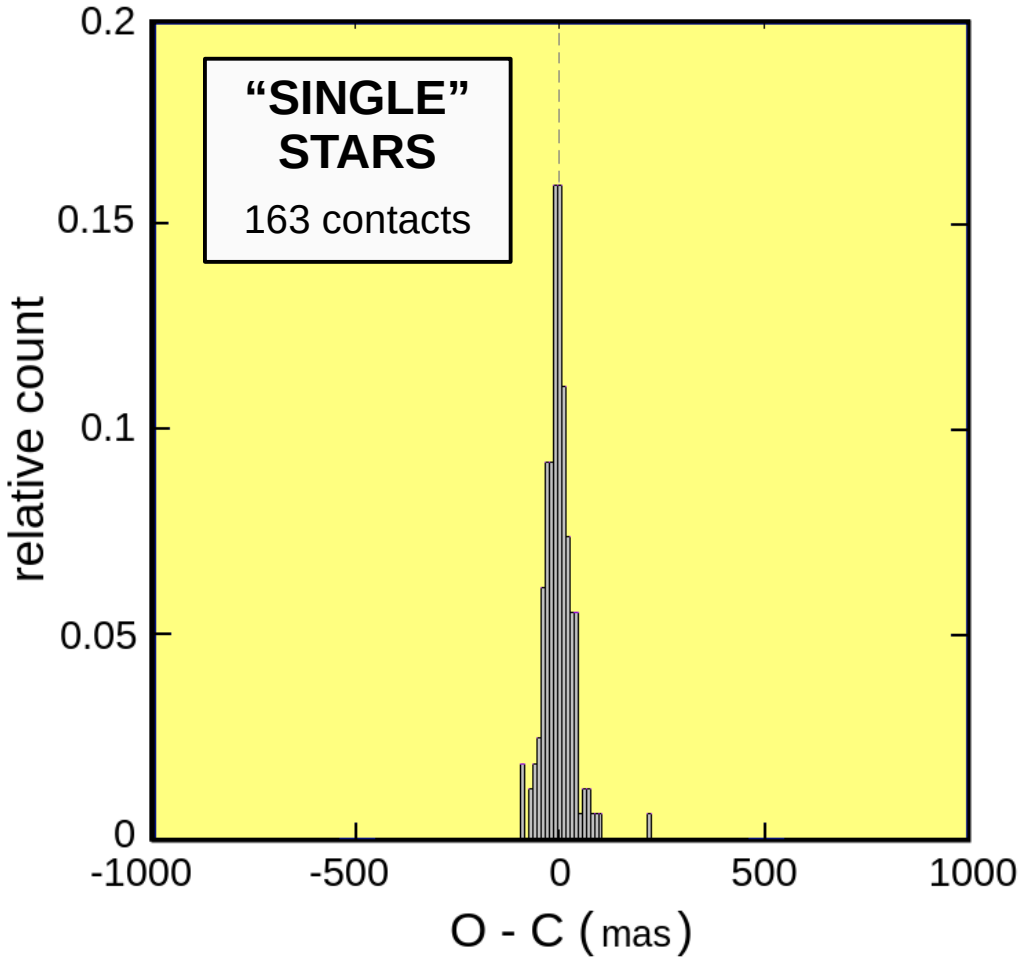
$h_{\leftmoon}$ = limb elevation

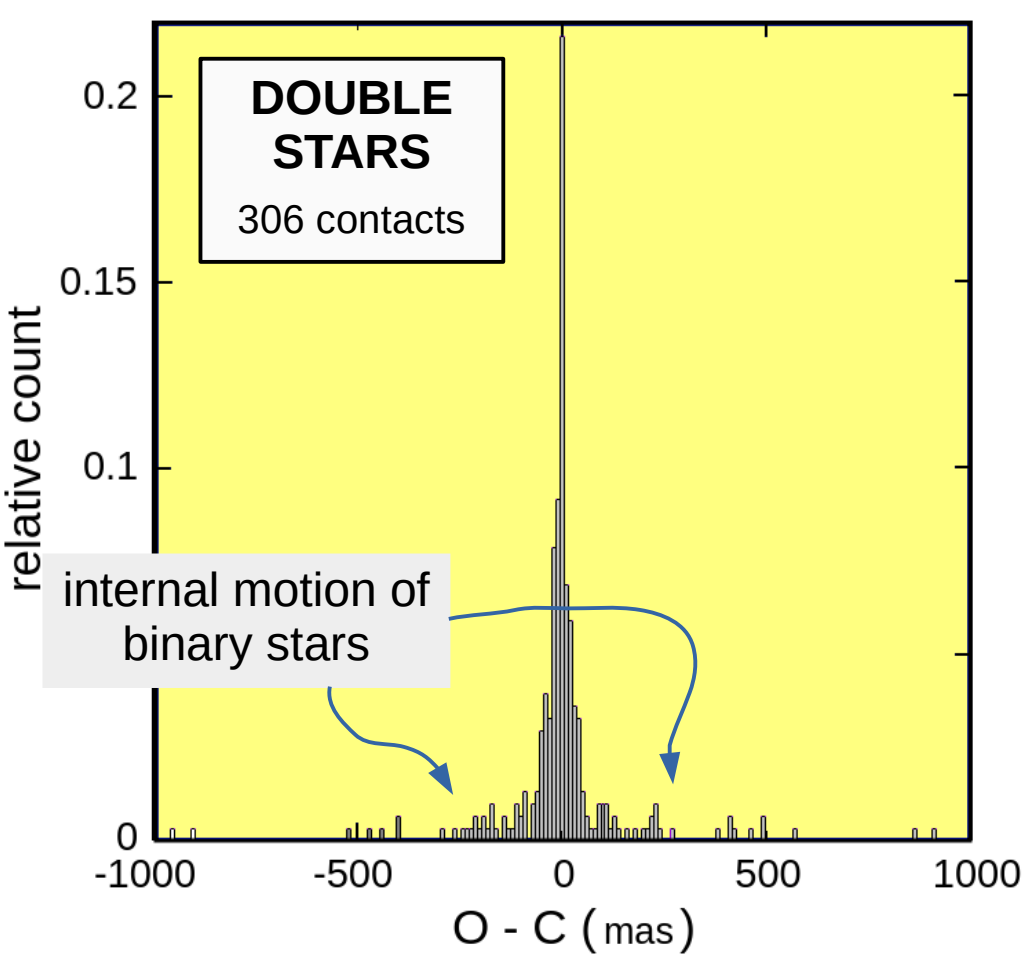
$$O - C = s_{\leftmoon} + h_{\leftmoon} - \varepsilon$$

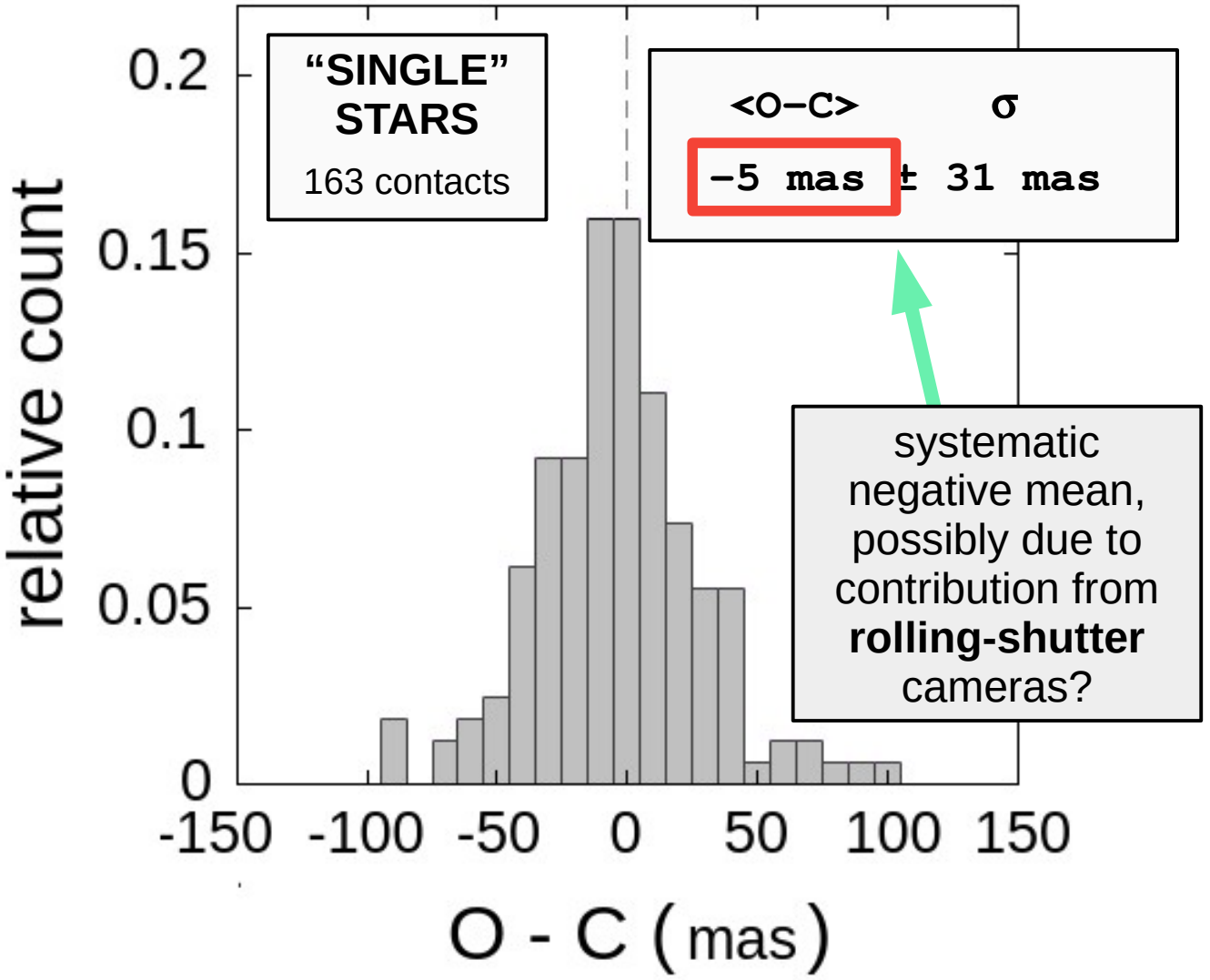
Ingredients:

- ★ Star’s position
- ★ Moon’s position
- ★ Observer’s position
- ★ Lunar limb profile
- ★ UTC time base

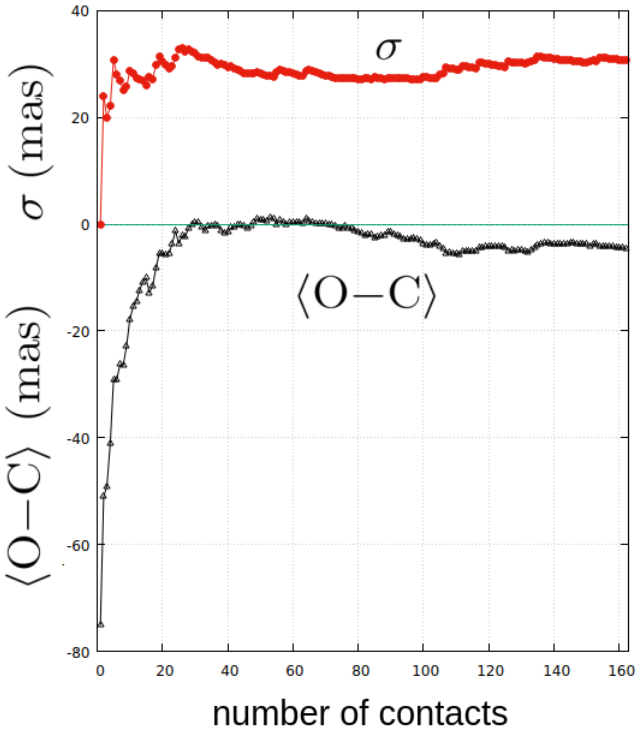



"SINGLE" STARS
163 contacts
relative count
0.2
0.15
0.1
0.05
0
-1000
-500
0
500
1000
O - C (mas)

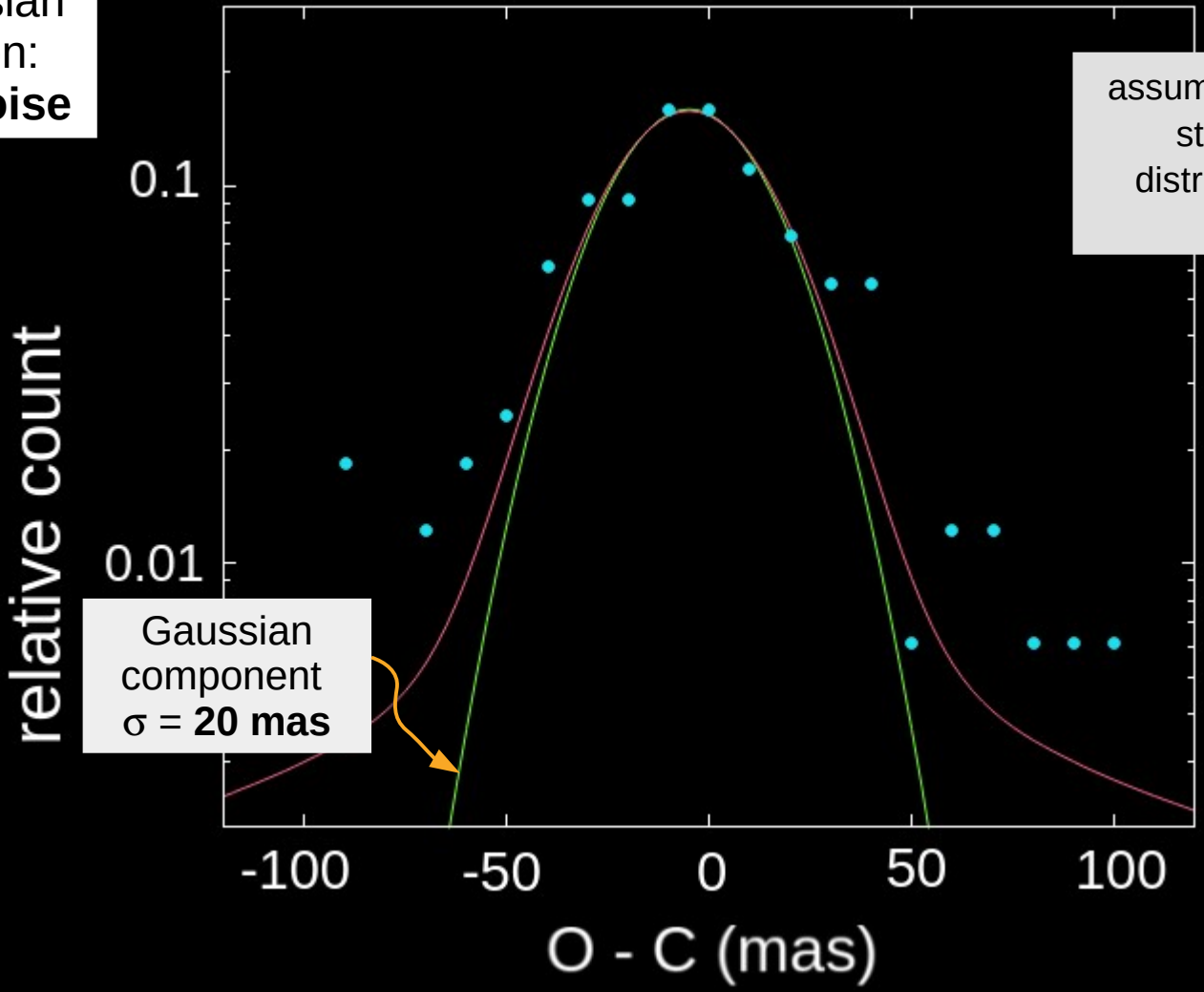

DOUBLE STARS
306 contacts
internal motion of binary stars
relative count
0.2
0.15
0.1
0
-1000
-500
0
500
1000
O - C (mas)



cumulative mean and standard deviation (with 163 PPM "single" stars)



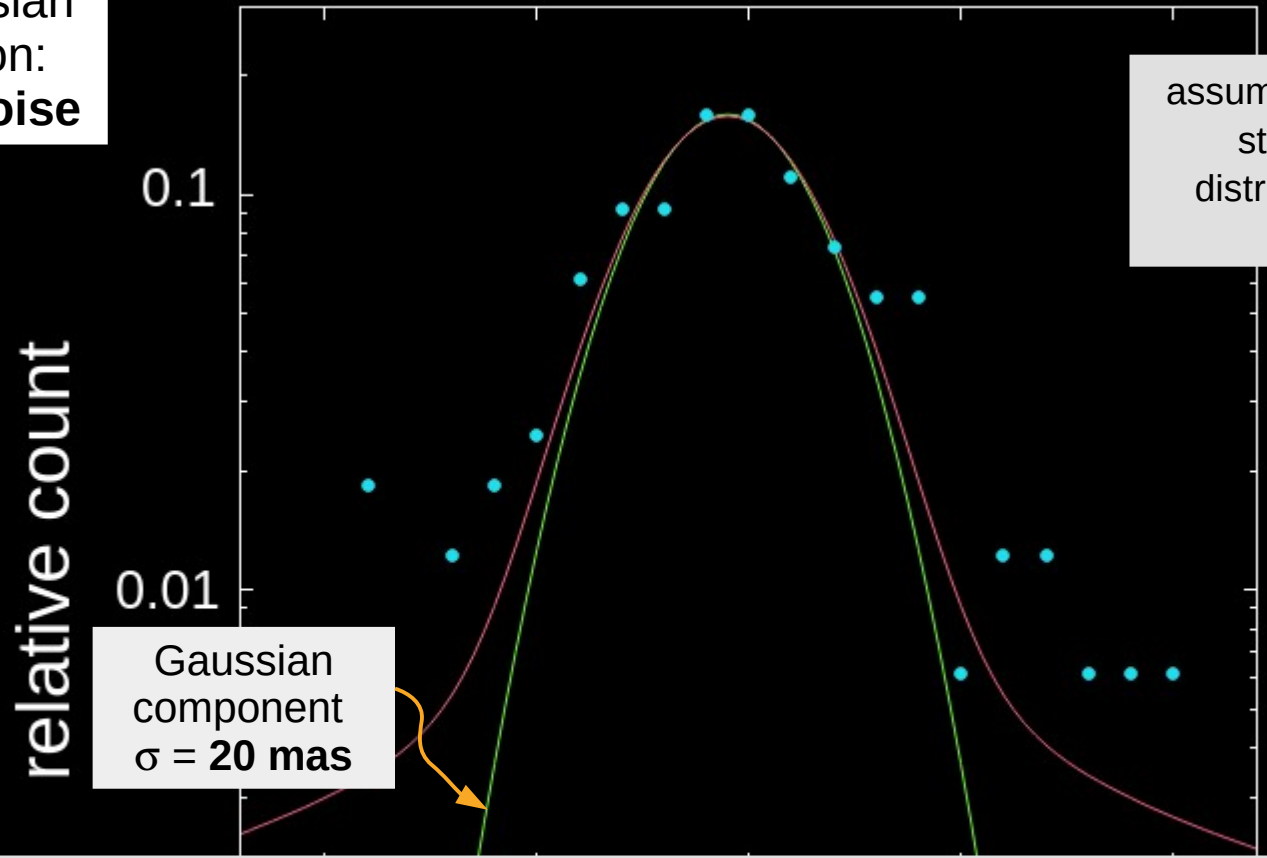
non-Gaussian distribution: **not just noise**



assuming 20% nonsingle stars with Öpik's distribution of angular separations

Gaussian component σ = **20 mas**

non-Gaussian distribution: **not just noise**



assuming 20% nonsingle stars with Öpik's distribution of angular separations

Gaussian component σ = **20 mas**

Stars with O-C > 20 mas should be monitored

Catalogue of high O-C stars

Direct estimation of accuracy

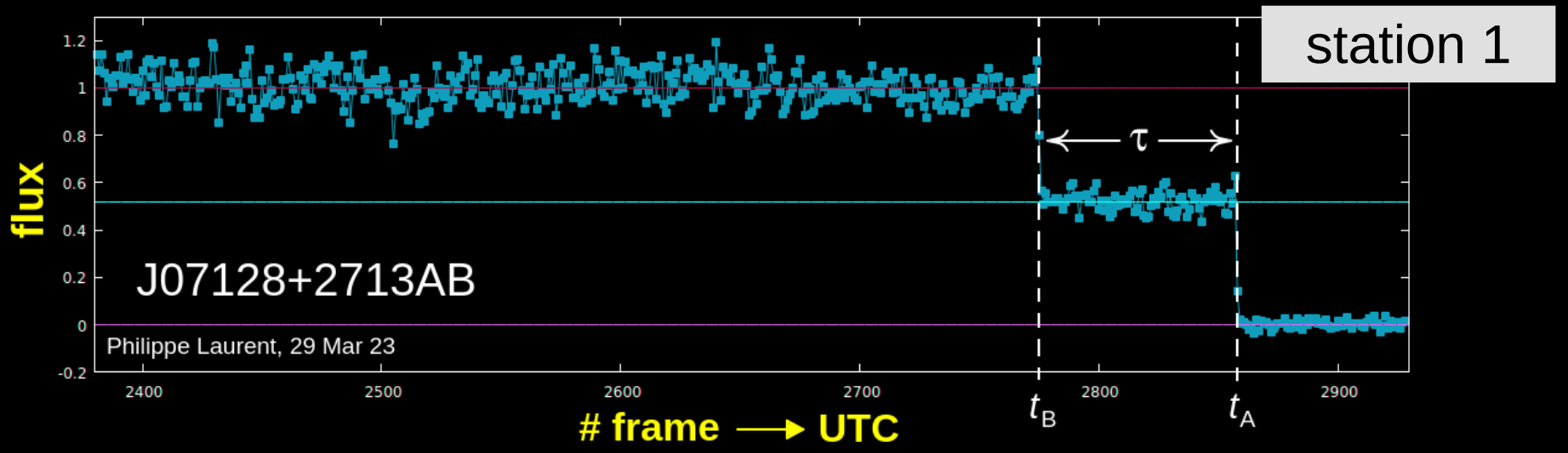
assuming accurate proper motion and linear path in 3D space

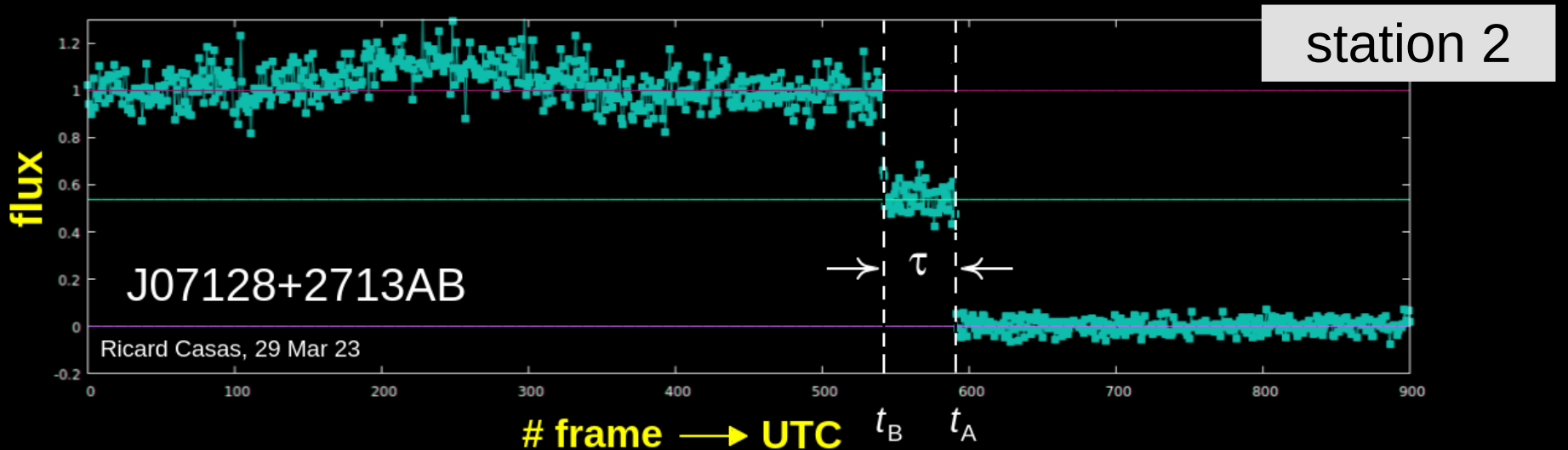
Star’s position	**< 0.3 mas**
Moon’s position	**< 0.2 mas**
Observer’s position	**2 mas (4 m)**
Lunar limb profile & lunar orientation	**5 mas**
UTC time base & contact time estimation	**10 mas**
	~ 15 mas

Except for particular cases, we should expect O-C > 20 mas to imply an incorrect star position: acceleration, binarity, ...

Double stars

- Methods of analysis
- Examples
  - J07128+2713AB
  - J01406+0846
- Grazing occultations
- 1D (linear) solutions
  - Orbit fitting
  - Catalogue of 1D solutions


station 1
flux
J07128+2713AB
Philippe Laurent, 29 Mar 23
τ
frame → UTC
t_B
t_A


station 2
flux
J07128+2713AB
Ricard Casas, 29 Mar 23
τ
frame → UTC
t_B
t_A

Absolute vs. relative astrometry on double stars

- **METHOD 1: UTC contact times**

$t_A^{(1)}, t_A^{(2)} \xrightarrow{f} \alpha_A, \delta_A$

$t_B^{(1)}, t_B^{(2)} \xrightarrow{f} \alpha_B, \delta_B$

$$\rho = \sqrt{(\alpha_B - \alpha_A)^2 \cos^2 \delta_a + (\delta_B - \delta_A)^2}$$

$$\tan\theta = \frac{(\alpha_B - \alpha_A)\cos\delta_a}{\delta_B - \delta_A}$$

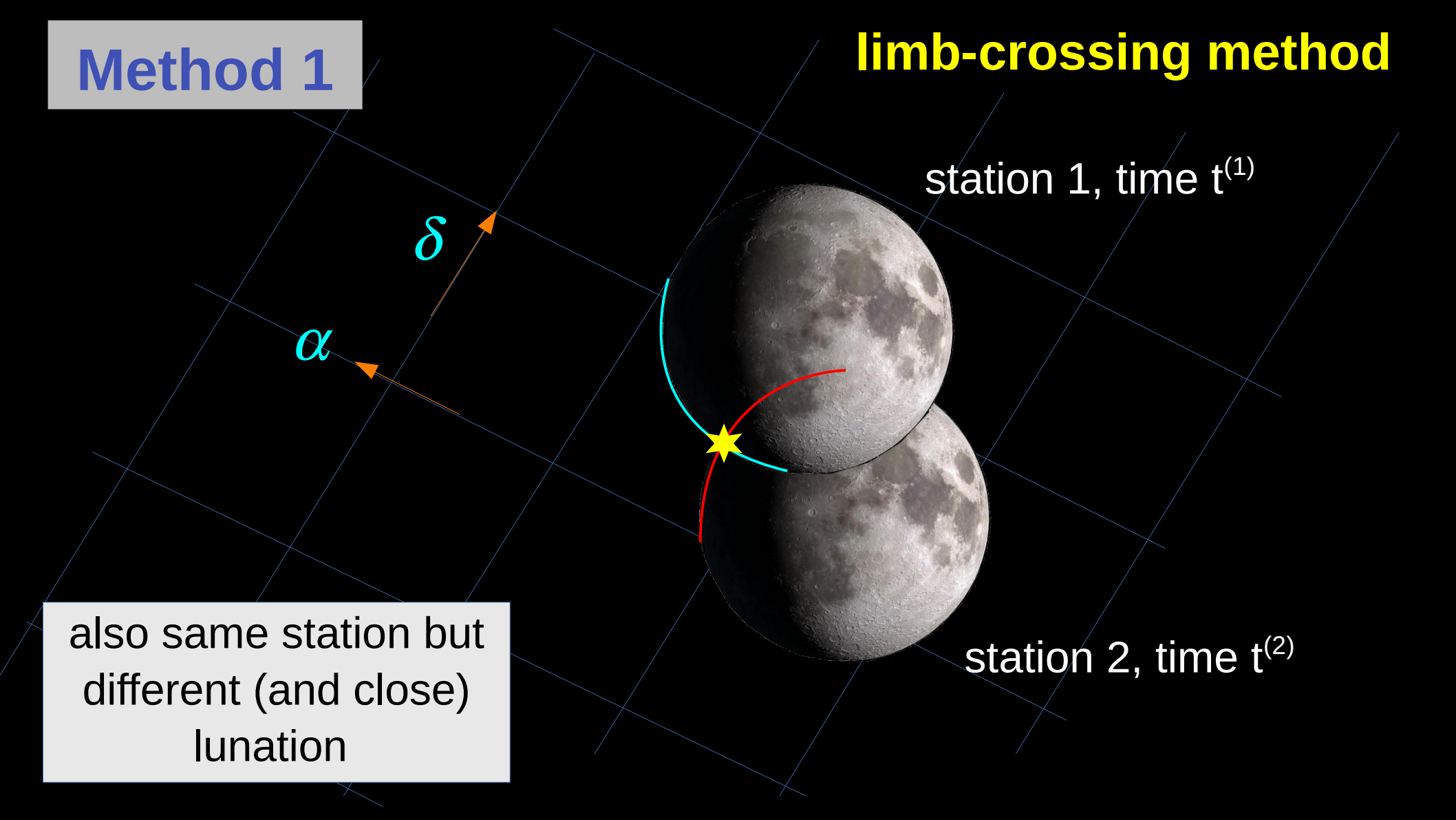
- **METHOD 2: Step intervals (D. Herald, *Occult*?)**

$\tau^{(1)}, \tau^{(2)}$ + **linear limb approx.** → ρ, θ

no need to estimate absolute astrometry of the components

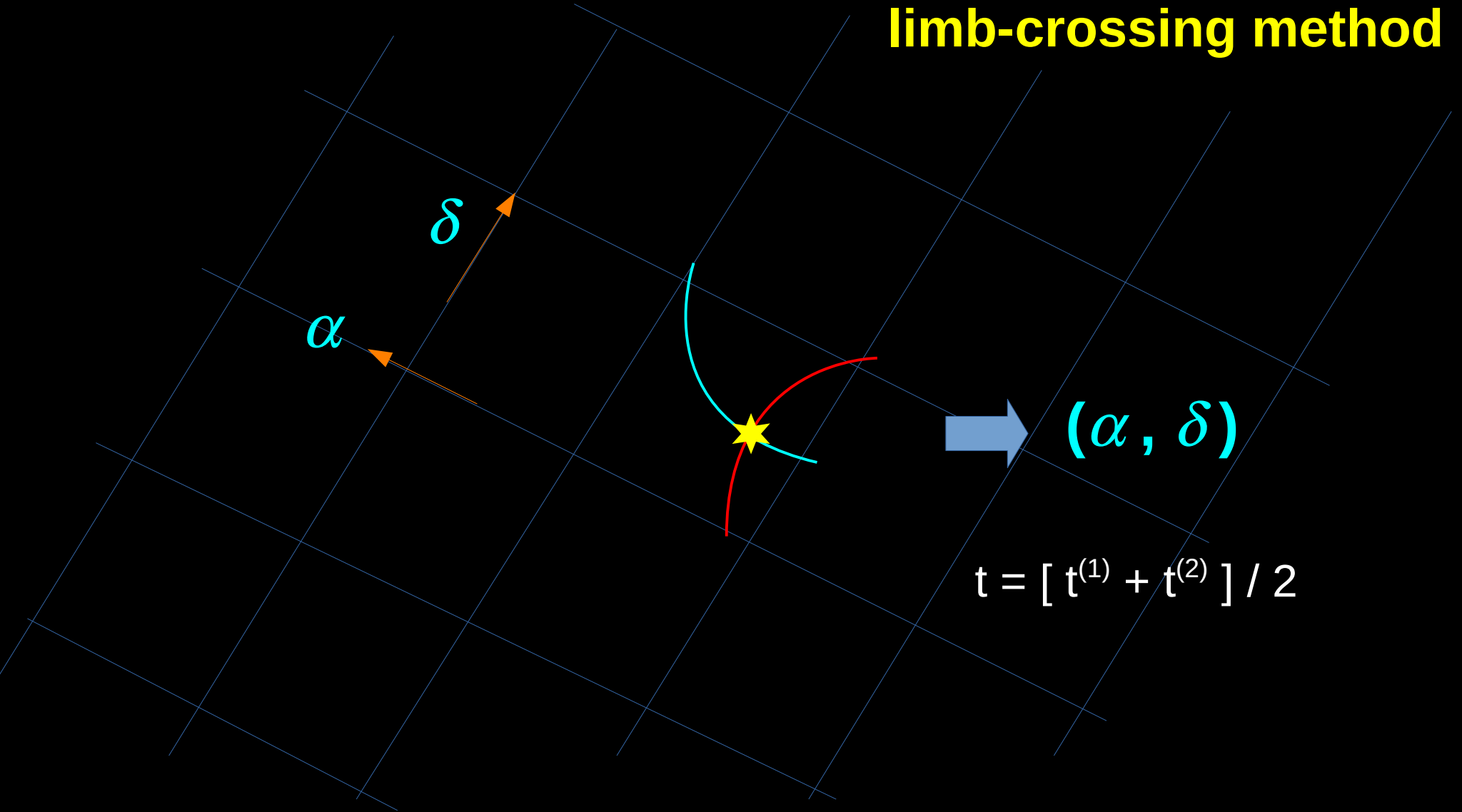
Method 1

limb-crossing method



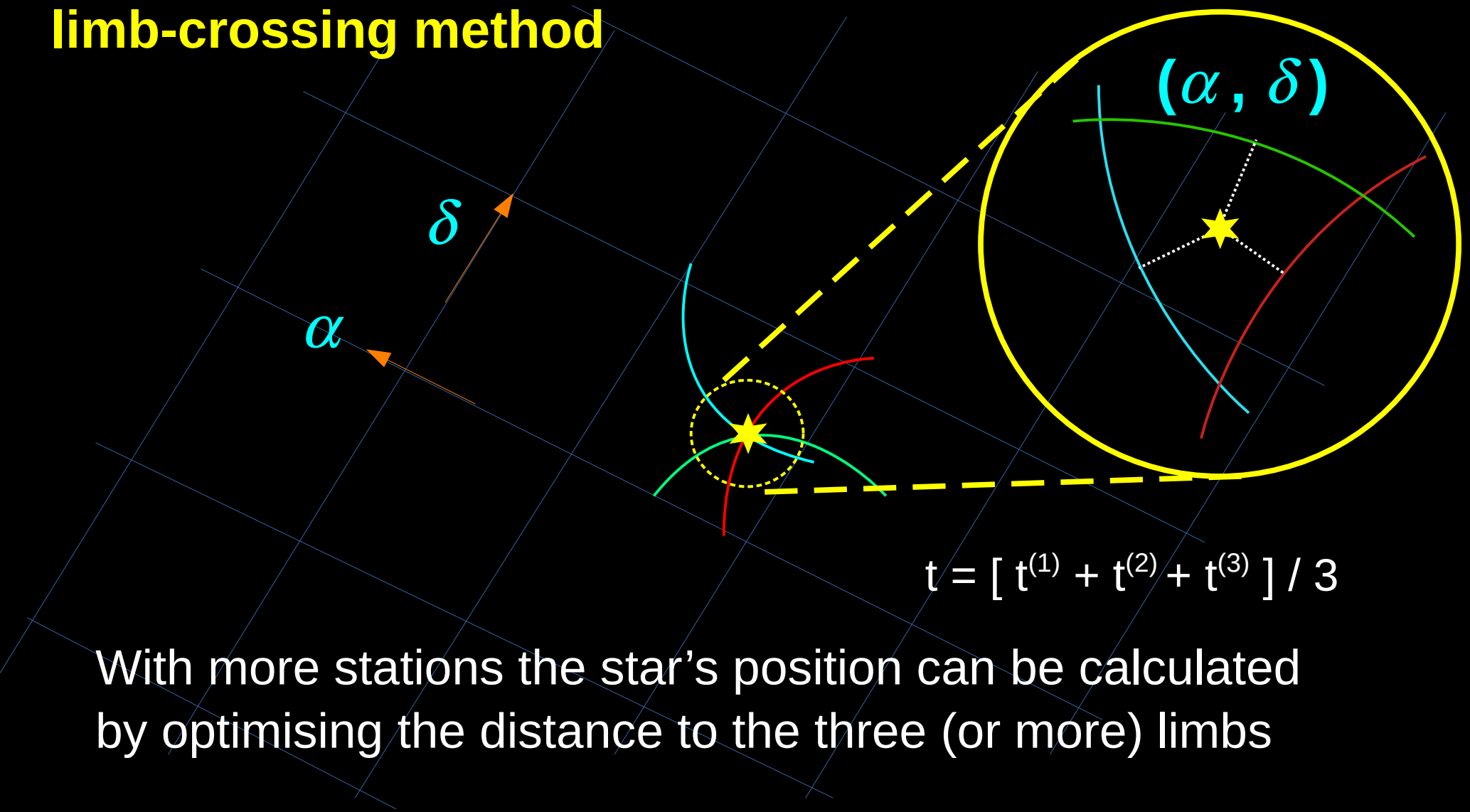
also same station but different (and close) lunation

limb-crossing method



$$t = [\, t^{(1)} + t^{(2)} \,] / 2$$

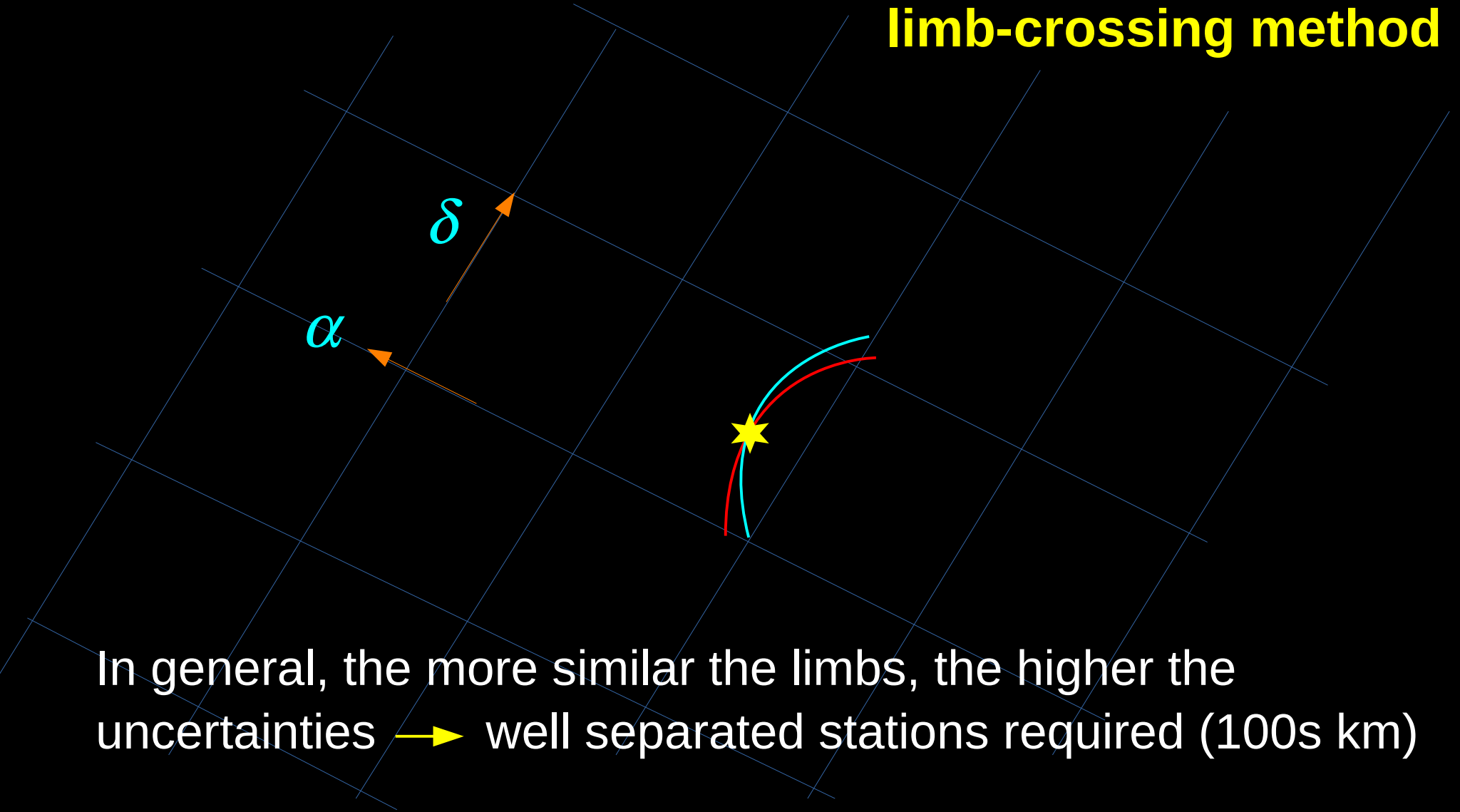
limb-crossing method



$$t = [\, t^{(1)} + t^{(2)} + t^{(3)} \,] / 3$$

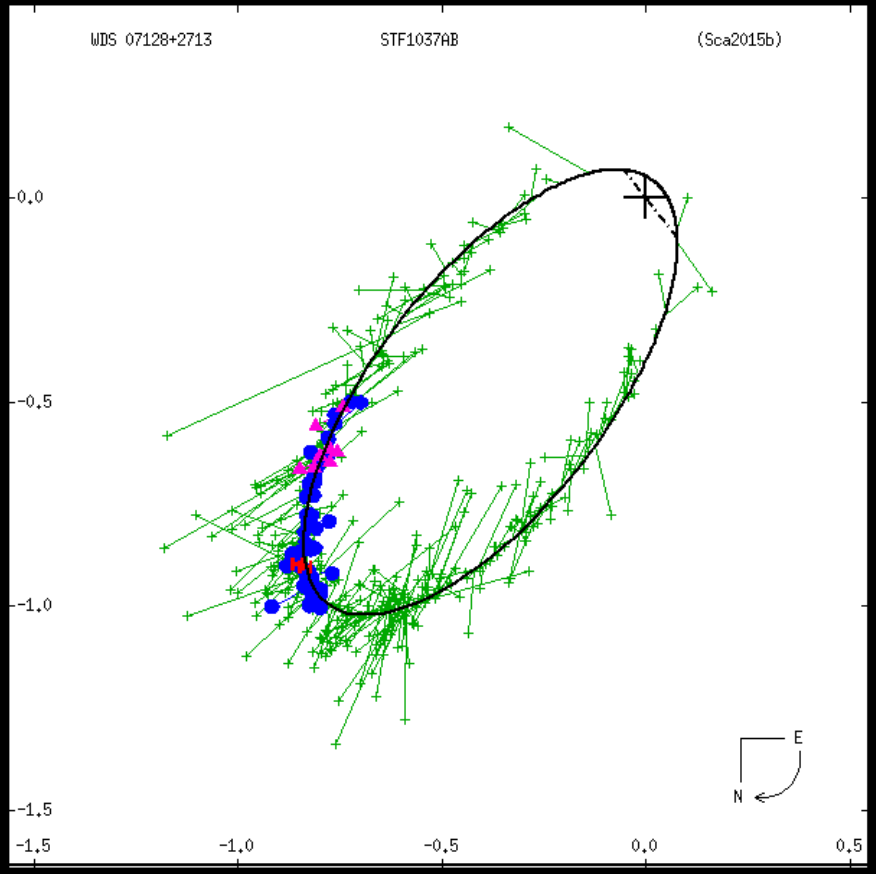
With more stations the star's position can be calculated by optimising the distance to the three (or more) limbs

limb-crossing method



In general, the more similar the limbs, the higher the uncertainties → well separated stations required (100s km)

Example: J07128+2713AB



Sixth Catalog of Orbits of Visual Binary Stars

https://www.astro.gsu.edu/wds/orb6/orb6orbits.html

07128+2713 STF 1037 AB (NSV3453)

https://www.stelledoppie.it/

07h 12m 49.08s +27° 13' 30.2" P.A. 302.00 sep 0.8 mag 7.24,7.27 Sp F8V dist. 42.48 pc (138.57 l.y.)

Coord 2000	07128+2713	**Discov num**	STF1037	**Comp**	AB	**Coord arcsec 2000**	07 12 49.08 +27 13 30.2
Date first	1827	**Date last**	2021	**Obs**	449		
Pa first	338	**Pa last**	302.3	**P.A. Now (θ)**	299.8°		
Sep first	1.2	**Sep last**	0.77	**Sep. Now (ρ)**	0.759"		
Mag pri	7.24	**Mag sec**	7.27	**delta mag (ΔM)**	0.03	**Spectral class**	F8V (yellow-white)
Pri motion ra	+014	**Sec motion ra**	+014				
Pri motion dec	-101	**Sec motion dec**	-101				
Notes	N O (See Notes, Orbital solution)						

This double is physical.

07128+2713 SYSTEM COMPONENTS

SHOW	NAME	SAO	COORD	WDS_NAME	LAST	OBS	PA	SEP	MAG1	MAG2	D_MAG	ORB	CURRENT
Show	NSV3453	79170	07 12 49 +27 13 30	STF 1037 AB	2021	449	302	0.8	7.24	7.27	0.03	Y	<===
Show		79170	07 12 49 +27 13 30	STT 166 AC	2015	18	77	13.8	7.24	12.80	5.56		
Show			07 12 49 +27 13 30	STT 166 BC	2014	11	71	14.2	7.27	12.70	5.43		

Triple system
3 estimated visually detectable stars in this system

OTHER CATALOGS AND DESIGNATIONS

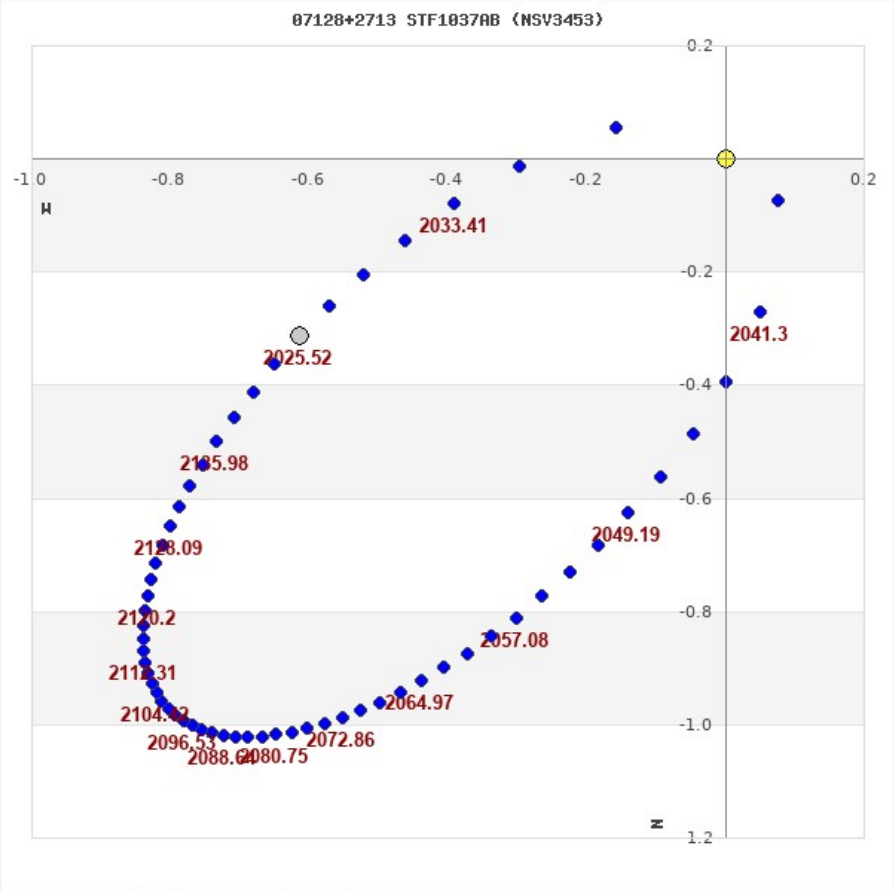
Var name	NSV3453	**Constellation**	Gemini	**SAO**	79170	**HIP**	34860
Tycho2	1904-01418-1	**Gaia DR2**	883596165745303680	**HD**	55130	**HR**	2711
GC	9532	**ADS**	5871	**BD**	BD+27 1337	**Distance**	42.48
Distance ly	138.57						

https://www.stelledoppie.it/

ORBITAL ELEMENTS

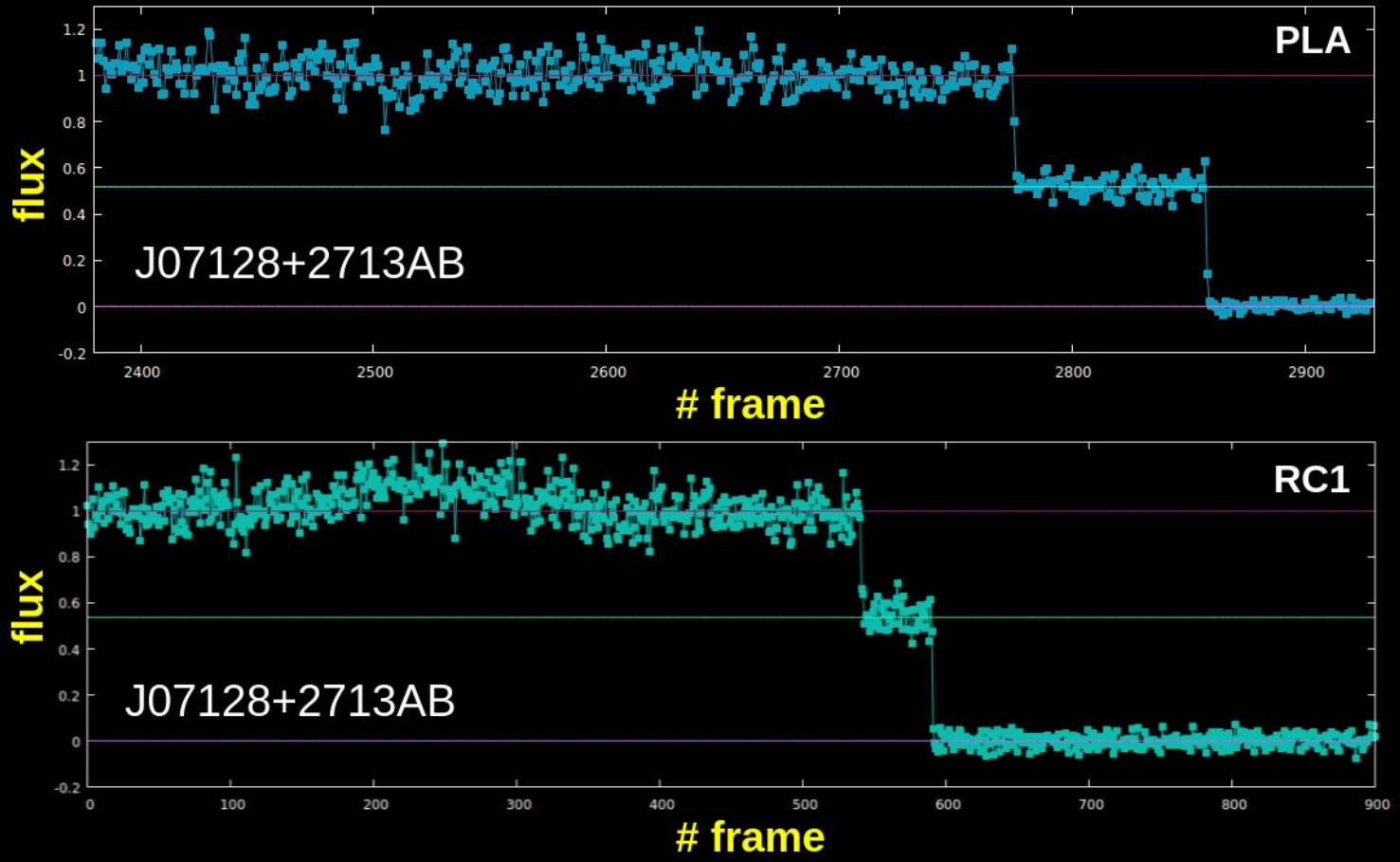
Period (P)	118.35y	± 0.46	**Periastron (T)**	1920.34y	± 0.01	**Semi-major axis (a)**	0.794a ± 0.02
Eccentricity (e)	0.933	± 0.002	**Inclination (i)**	144.7°	± 1.3	**Longitude of periastron (ω)**	259.5° ± 1.9
Node (Ω)	38.5°	± 2.1	**Notes**	n		**Reference**	Sca2015b
Equinox	2000		**Last observation**	2014		**Grade**	2 (1=Definitive, 9=Indet.)

LABEL	THETA	RHO
2000	313.6	1.156
2001	313.2	1.146
2002	312.7	1.135
2003	312.3	1.123
2004	311.8	1.111
2005	311.4	1.099
2006	310.9	1.086
2007	310.4	1.072
2008	309.9	1.058
2009	309.4	1.043
2010	308.9	1.028
2011	308.4	1.011
2012	307.8	0.995
2013	307.2	0.977
2014	306.6	0.959
2015	306.0	0.940
2016	305.3	0.921
2017	304.7	0.900
2018	303.9	0.879
2019	303.2	0.857
2020	302.4	0.834
2021	301.6	0.810
2022	300.7	0.785
2023	299.8	0.759
2024	298.7	0.732
2025	297.6	0.704
2026	296.5	0.674
2027	295.2	0.643
2028	293.7	0.611
2029	292.1	0.576
2030	290.3	0.540
2031	288.2	0.502
2032	285.8	0.461
2033	282.9	0.418
2034	279.3	0.370
2035	274.5	0.319
2036	267.7	0.261
2037	256.7	0.194

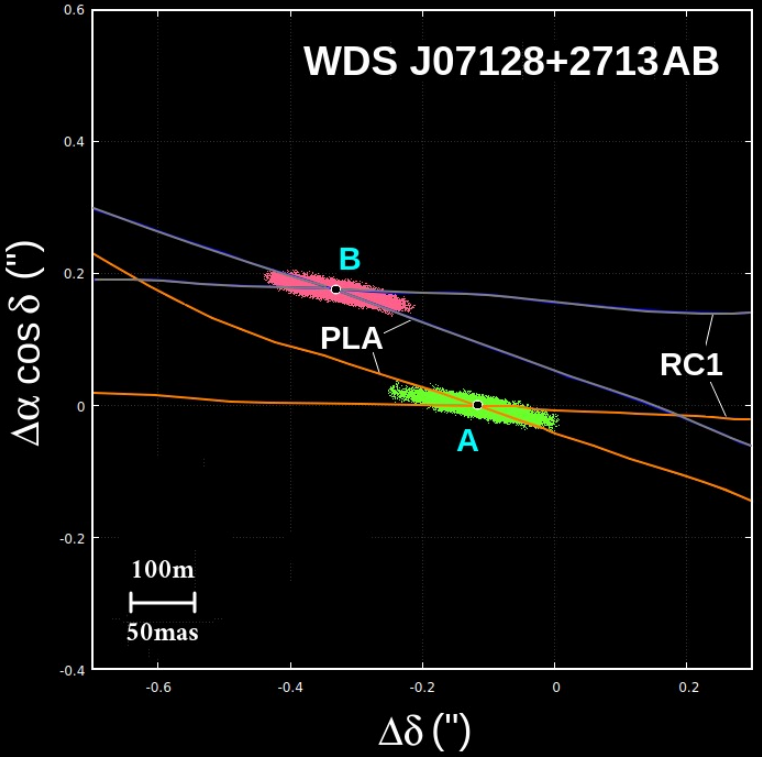


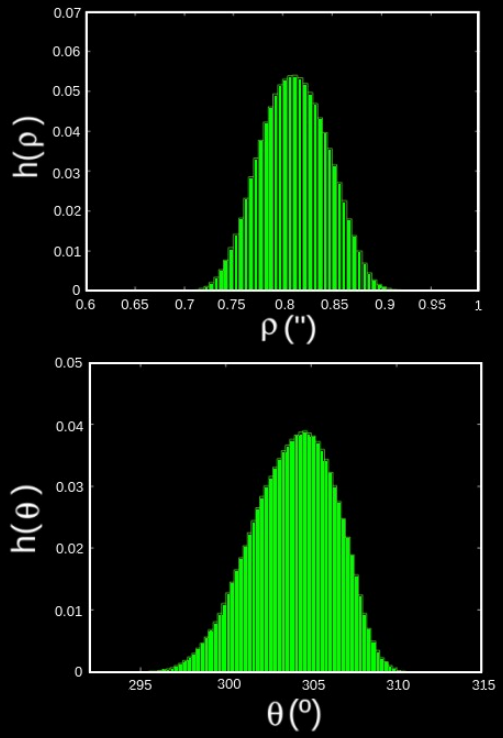
Note: Theta is PA, Rho is Sep. For yearly orbits, data refer to Jan 1st.

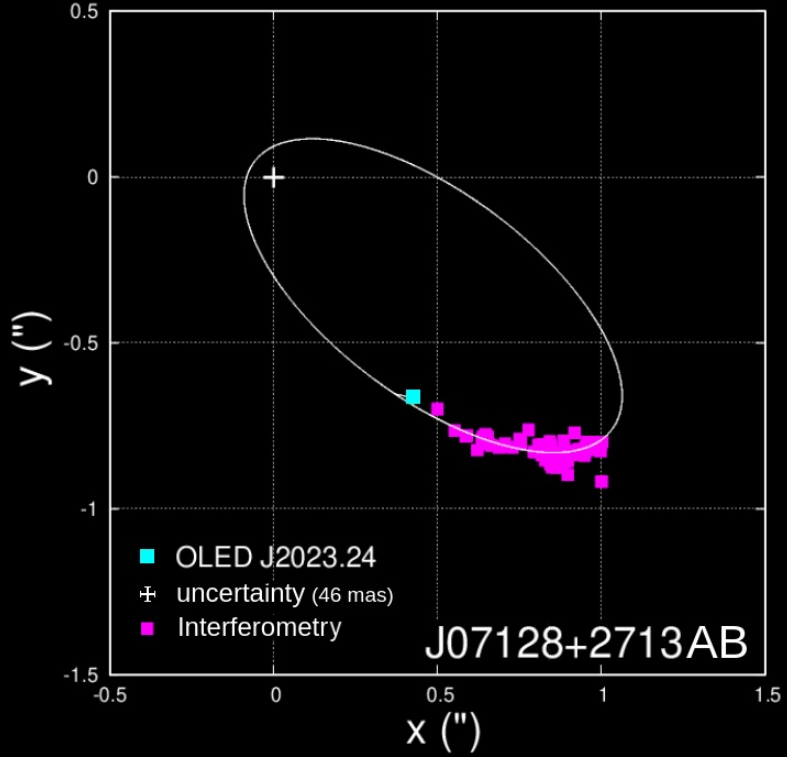
Epoch of observation: J2023.2397



Limb crossing technique







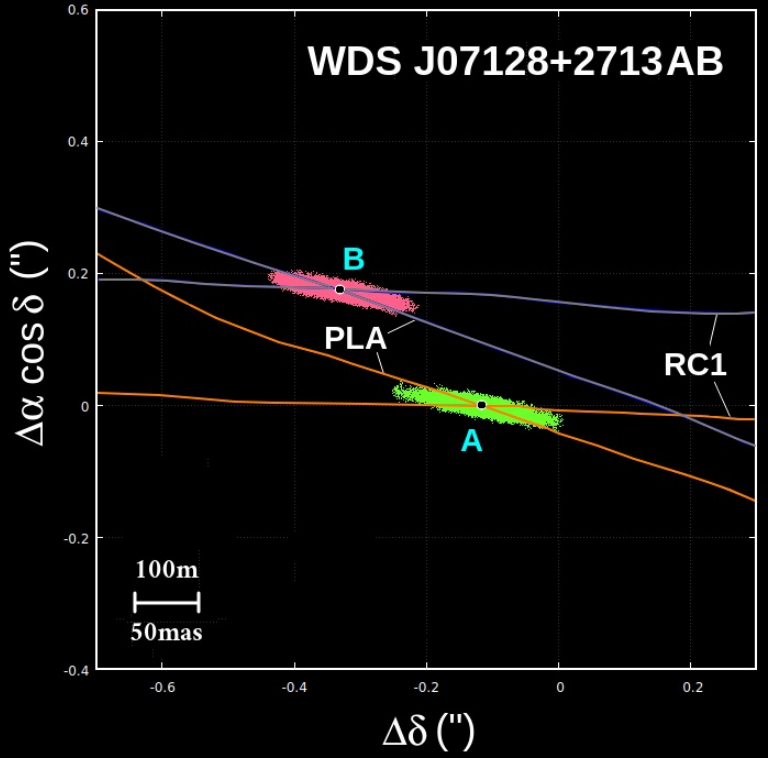
$$\rho = 0.790'' \pm 0.034'', \quad \theta = 302.6^\circ \pm 2.4^\circ \quad (\mathrm{J2023.24})$$

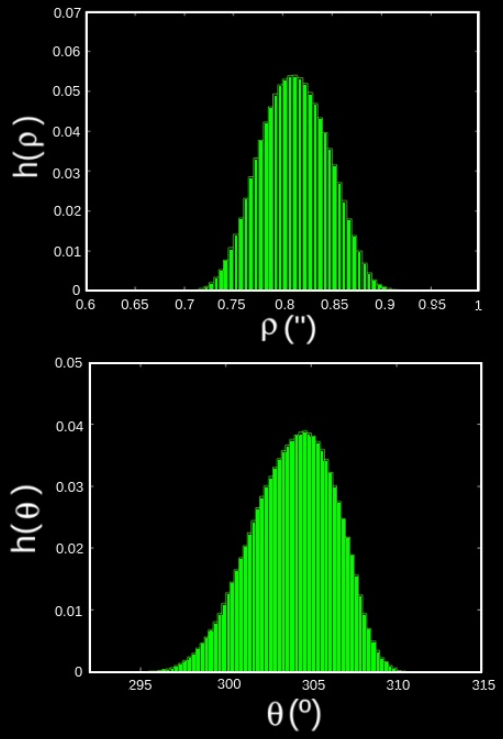
Limb crossing technique

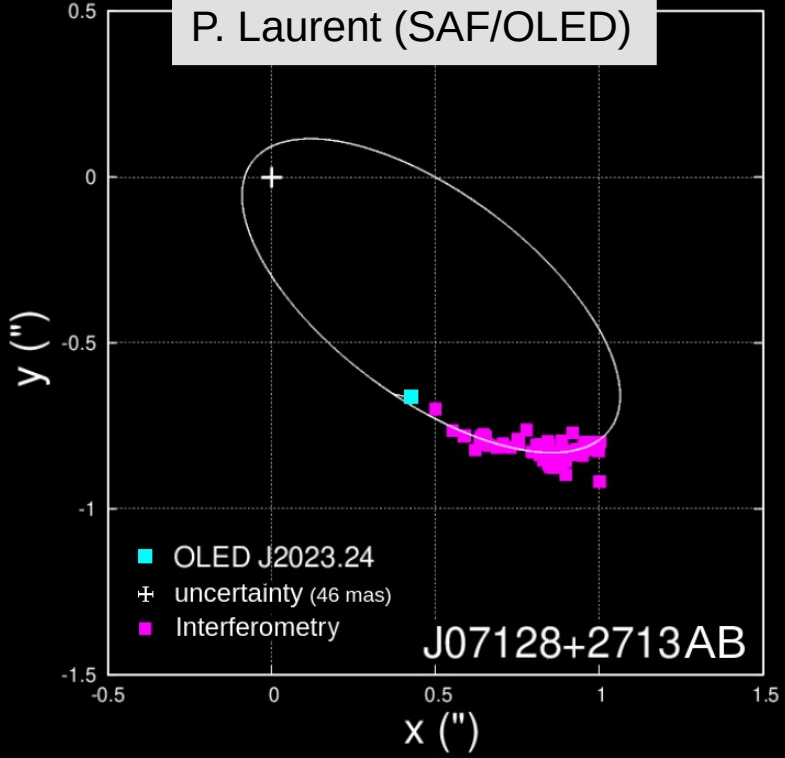
O-C(ρ) = 0.037”

O-C(θ) = 3.1º

P. Laurent (SAF/OLED)







$$\rho = 0.790'' \pm 0.034'', \quad \theta = 302.6^\circ \pm 2.4^\circ \quad (\mathrm{J2023.24})$$

Another example: J01406+0846

01406+0846 TOK 872 (HD 10262)

$01^h\ 40^m\ 34.92^s$ +08° 45' 39.0" P.A. 260.00 sep 0.0 mag 6.60,8.00 Sp F2 dist. 54.7 pc (178.43 l.y.)

Coord 2000	01406+0846	**Discov num**	TOK 872	**Comp**		**Coord arcsec 2000**	01 40 34.92 +08 45 39.0
Date first	2018	**Date last**	2021	**Obs**	5		
Pa first	158	**Pa last**	260.3	**P.A. Now (θ)**	260.3°		
Sep first	0.1	**Sep last**	0.045	**Sep. Now (ρ)**	0.045"		
Mag pri	6.60	**Mag sec**	8.00	**delta mag (ΔM)**	1.4	**Spectral class**	F2 (yellow-white)
Pri motion ra	+068	**Sec motion ra**					
Pri motion dec	+000	**Sec motion dec**					
Notes							

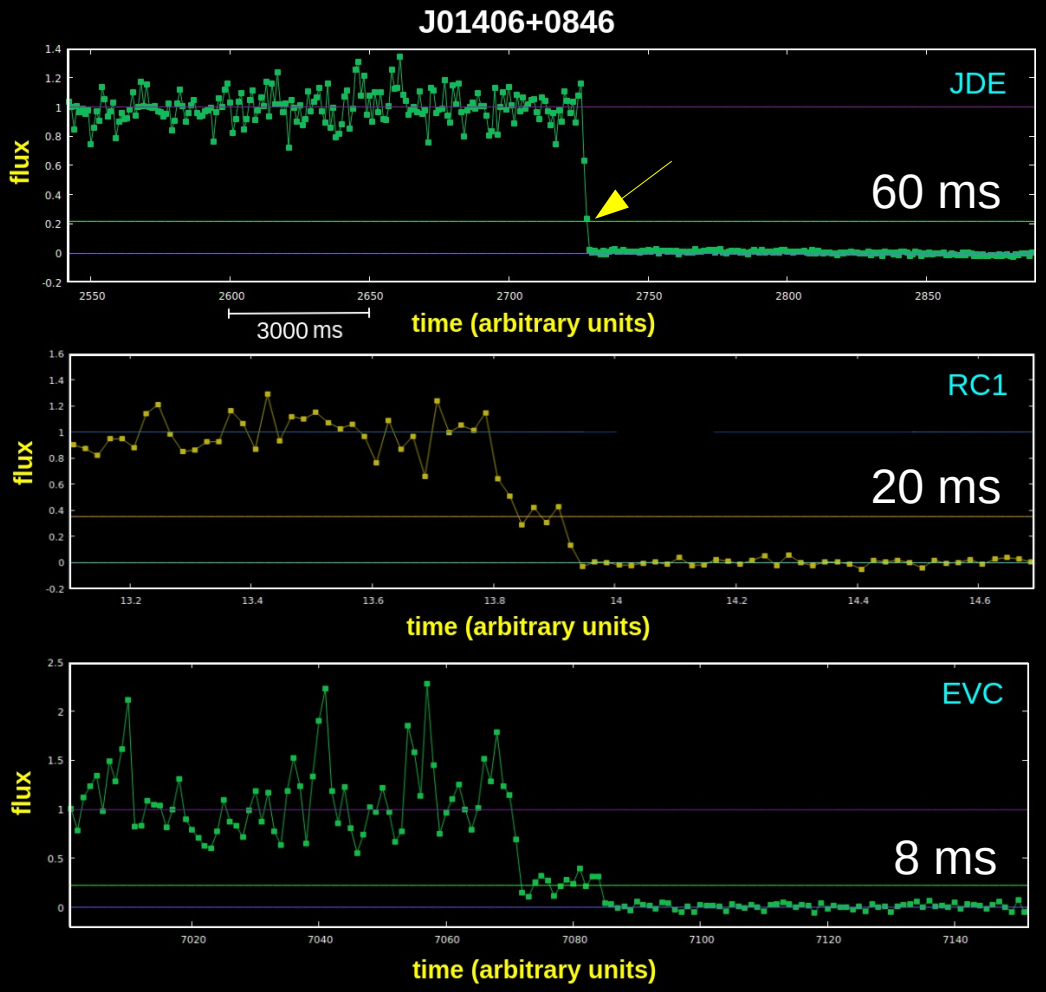
Nature of this double is uncertain.

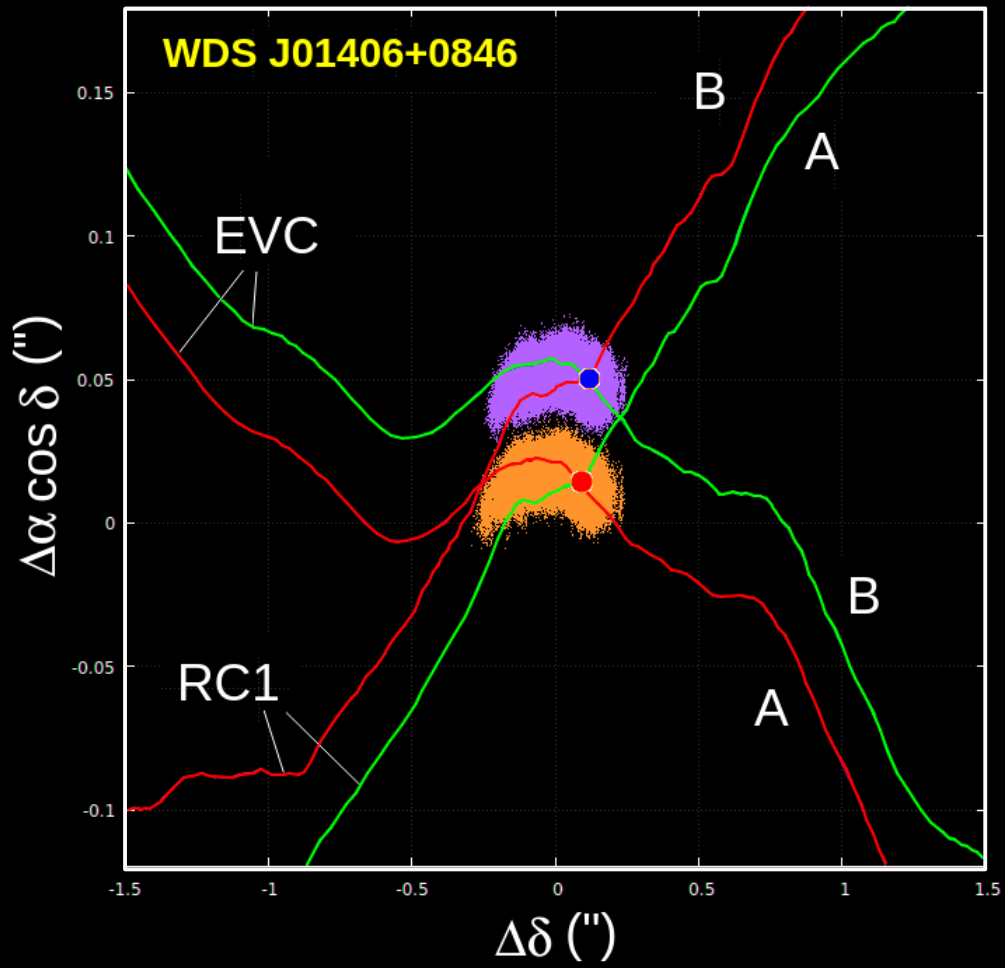
spectroscopic binary

OTHER CATALOGS AND DESIGNATIONS

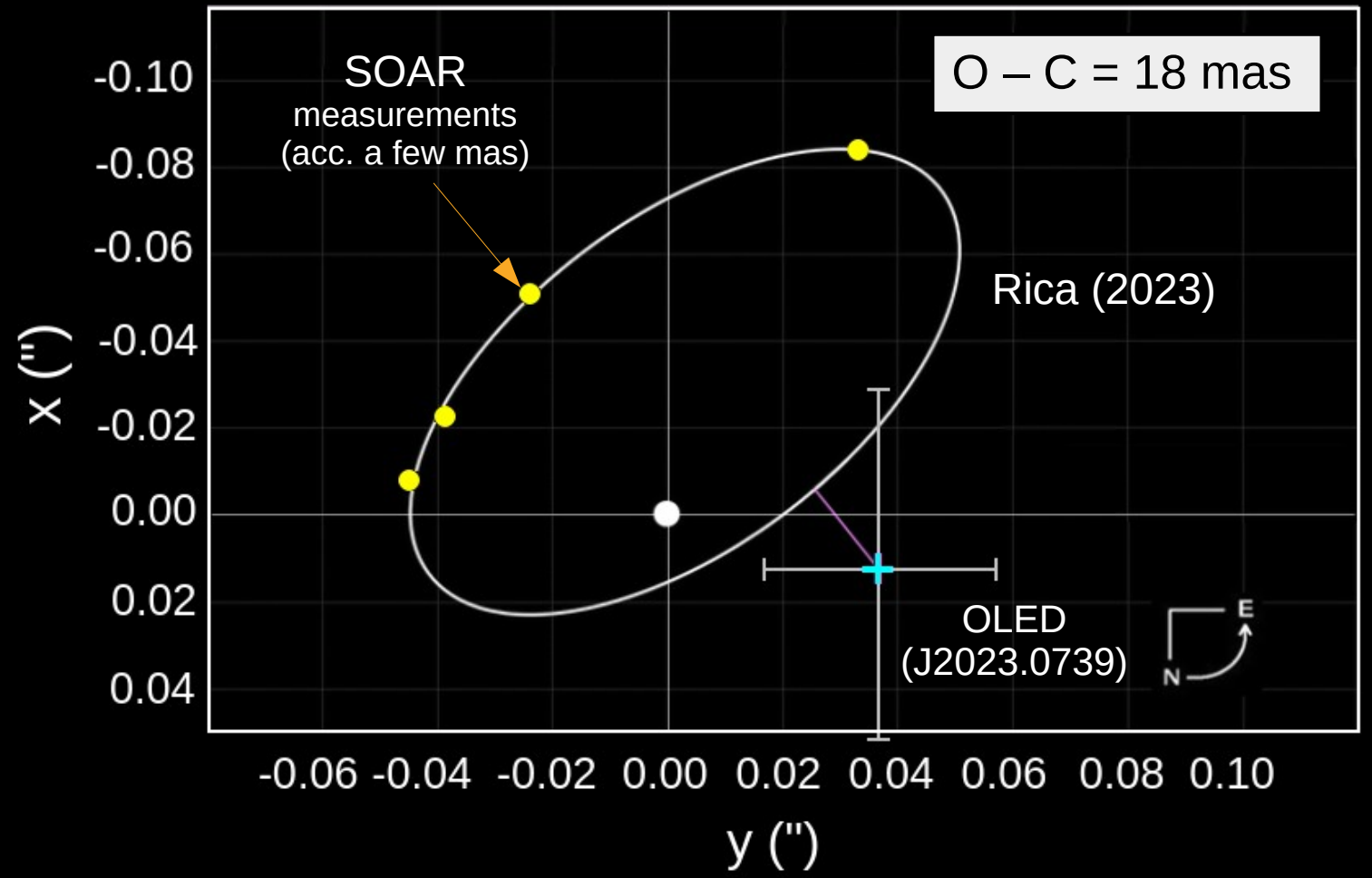
Name	HD 10262	**Constellation**	Pisces	**SAO**	110046	**HIP**	7819
Tycho2	0621-00356-1	**HD**	10262	**GC**	2032	**BD**	BD+08 258
Distance	54.7	**Distance ly**	178.43				

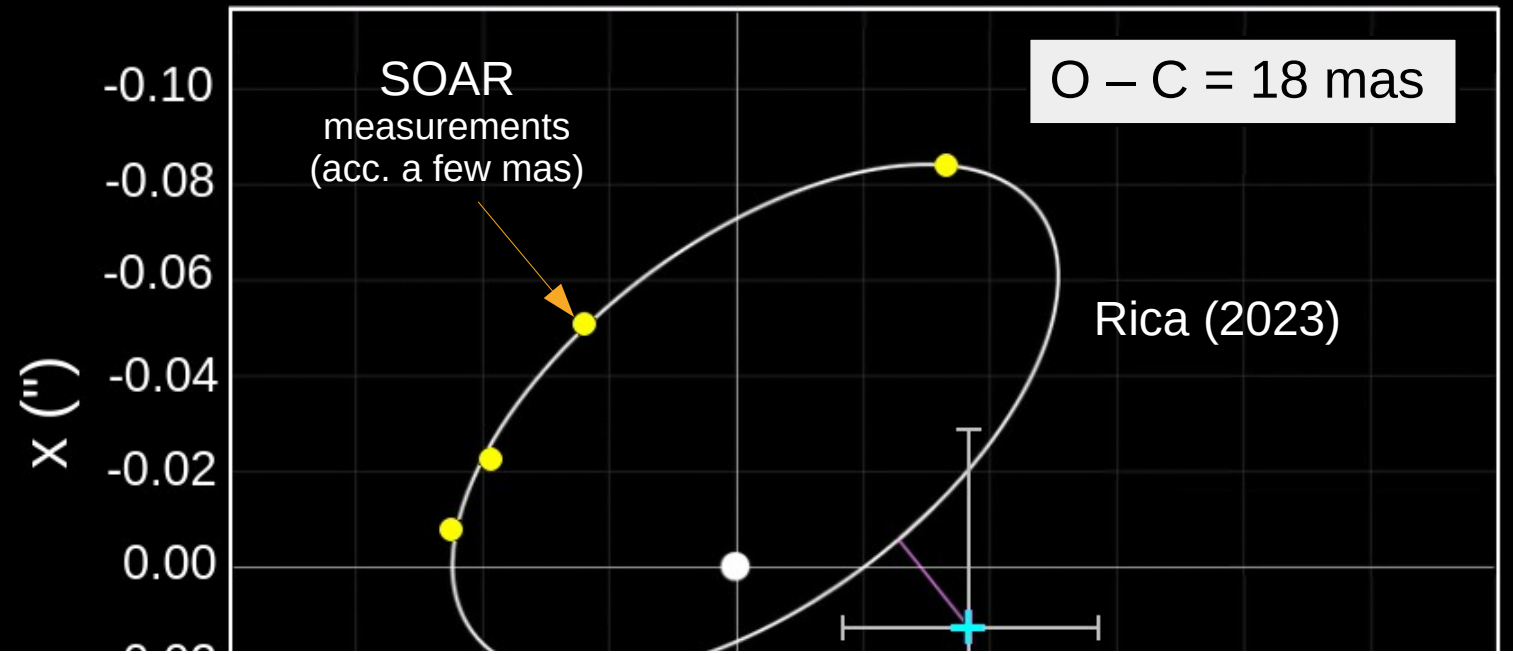
https://www.stelledoppie.it/





ρ = 0.039” ± 0.027”, θ = 71º ± 45º (J2023.073)


SOAR
measurements
(acc. a few mas)
O – C = 18 mas
Rica (2023)
OLED
(J2023.0739)
E
N
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
0.02
0.04
x (")
-0.06 -0.04 -0.02 0.00 0.02 0.04 0.06 0.08 0.10
y (")



	P	T	e	a	i	ω	Ω
Rica (2023)	6.177 y	J2022.851	0.653	0.078″	62.46°	243.62°	131.41°
Tokovinin (2024)	5.979 y	J2022.852	0.710	0.077″	60.30°	245.60°	122.60°

JOA 2023-04

The International Occultation Timing Association's 41st Annual Meeting, 2023 July 15-16 via Zoom Online

Richard Nugent · IOTA · Dripping Springs, Texas · USA · RNugent@wt.net

ABSTRACT: IOTA's 2023 Annual Meeting was held via Zoom online on 2022 July 15-16. Numerous presentations were made by members of the IOTA community worldwide. More than 60 attendees participated in the meeting.

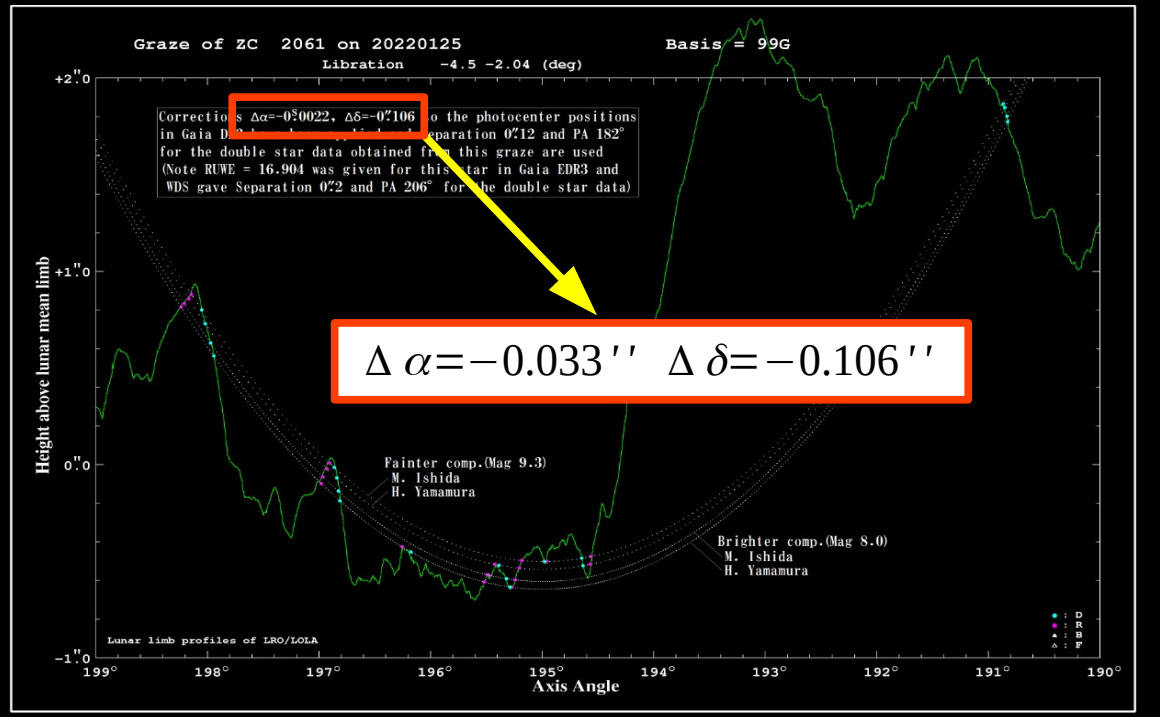


Figure 8. Observations of the graze of ZC 2061 fitted to the lunar limb profile. The graze was observed by M. Ishida and H. Yamamura on 2022 January 25 in Japan.

Sunday 16th July 2022 - Day 2

Technical Sessions

Mitsuru Soma, Vice President for Grazing Occultation Services started the meeting with a talk about "*Lunar Grazing Observations*." M. Soma talked about important results from analyses of observations of lunar grazing occultations from 2021-2023. The ZC 2061 graze on 2022 January 25 was observed by M. Ishida and H. Yamamura in Japan. Their observations clearly showed that the star is double, and the relative positions of the star's components were obtained from their observations (Figure 7). Actually the star's duplicity had already been detected in 2014 by D. Gault and D. Herald in Australia through their lunar occultation observations. It turned out that the newly-obtained results about the relative positions (separation and position angle) are significantly different from those obtained in 2014. The ZC 1049 graze on 2021 September 2 was observed by J. Bourgeois and B. Goffin in Belgium. They found that the star is a new double star. The ZC 709 graze on 2021 September 27 was observed at two stations by B. Gährken in Italy and at one station by M. Turchenko in Russia. B. Gährken also detected the star's companion at his first station. For all of the three events mentioned here it was found that significant corrections to the positions of the stars in *Gaia* DR3 were also required (Figure 8). This demonstrates the importance of observations of lunar grazing occultations not only to find double stars but also to analyse positional errors.

Grazing occultation of J06200+2826 A, B, C

19 August 2006

Observed by members of Agrupación Astronómica de Sabadell

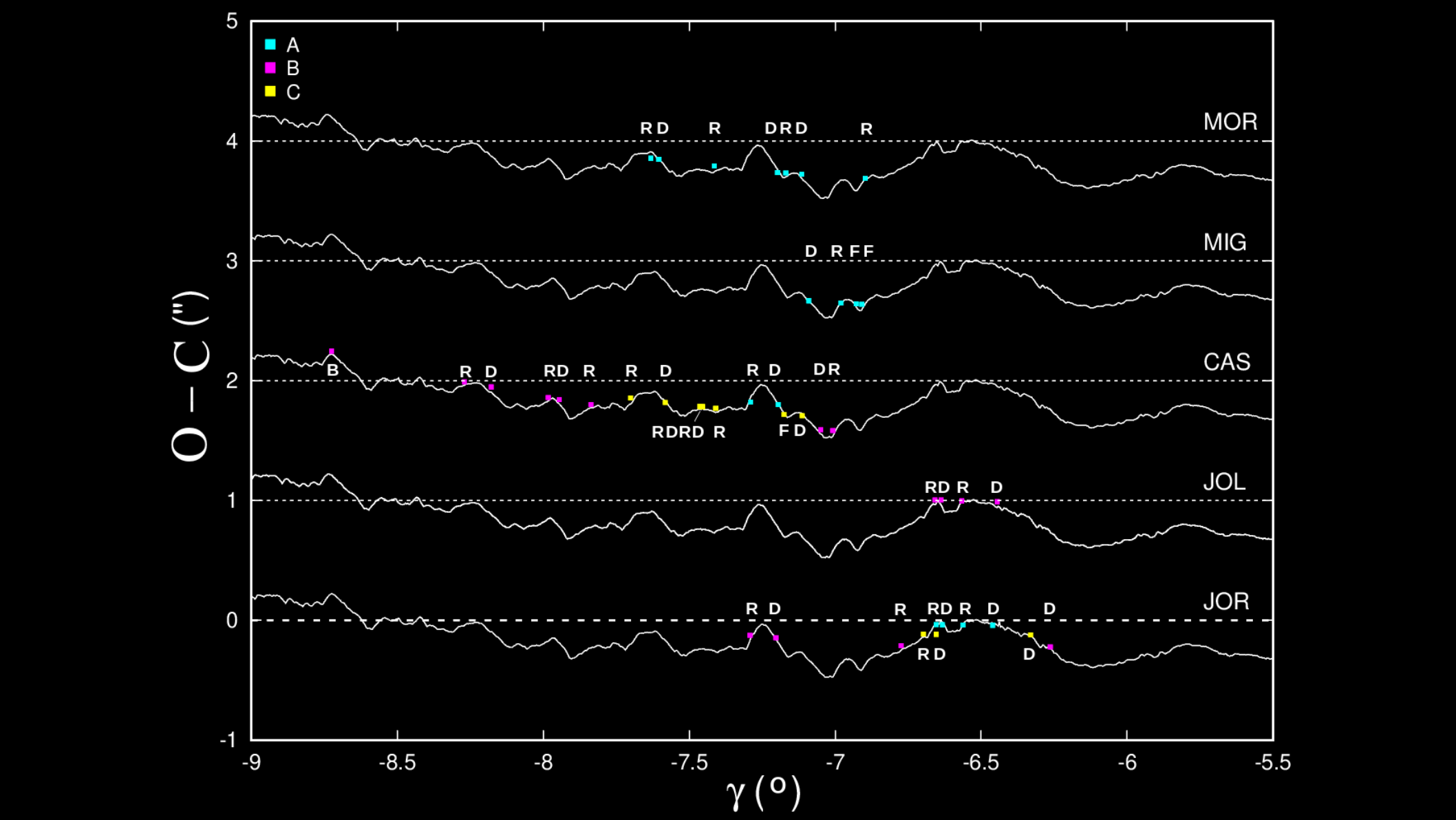
$06^h\ 19^m\ 58.96^s$ +28° 25' 36.6" P.A. 164.00 sep 0.2 mag 8.16,8.35 Sp A6V dist. 132.98 pc (433.78 l.y.)

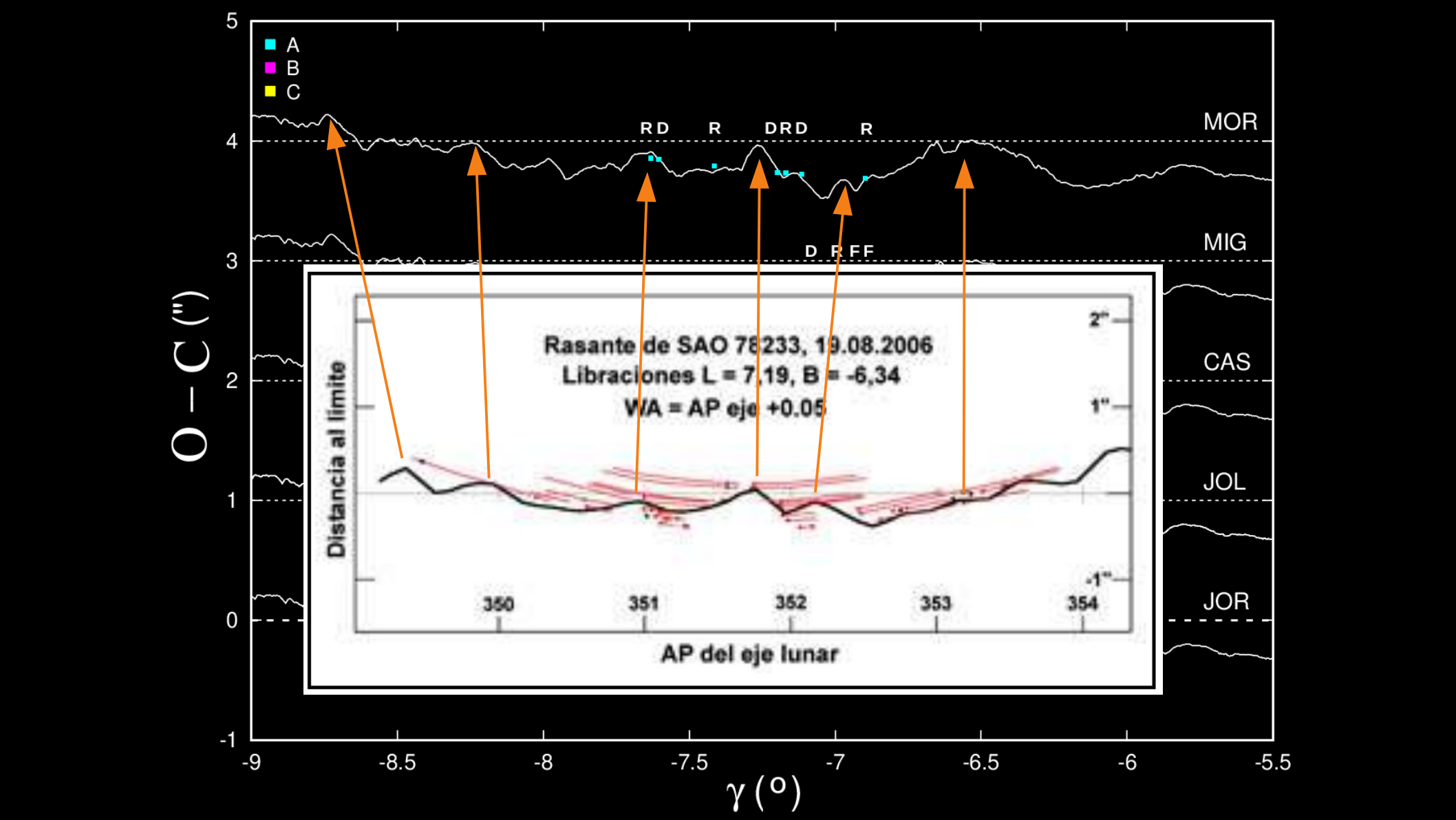
Coord 2000	06200+2826	**Discov num**	BU 895	**Comp**	AB	**Coord arcsec 2000**	06 19 58.96 +28 25 36.6
Date first	1879	**Date last**	2013	**Obs**	104		
Pa first	133	**Pa last**	164.1	**P.A. Now (θ)**	277.5°		
Sep first	0.3	**Sep last**	0.182	**Sep. Now (ρ)**	0.128"		
Mag pri	8.16	**Mag sec**	8.35	**delta mag (ΔM)**	0.19	**Spectral class**	A6V (white)
Pri motion ra	+000	**Sec motion ra**					
Pri motion dec	-039	**Sec motion dec**					
Notes	N O (See Notes, Orbital solution)	**grade 2**					

https://www.stelledoppie.it/

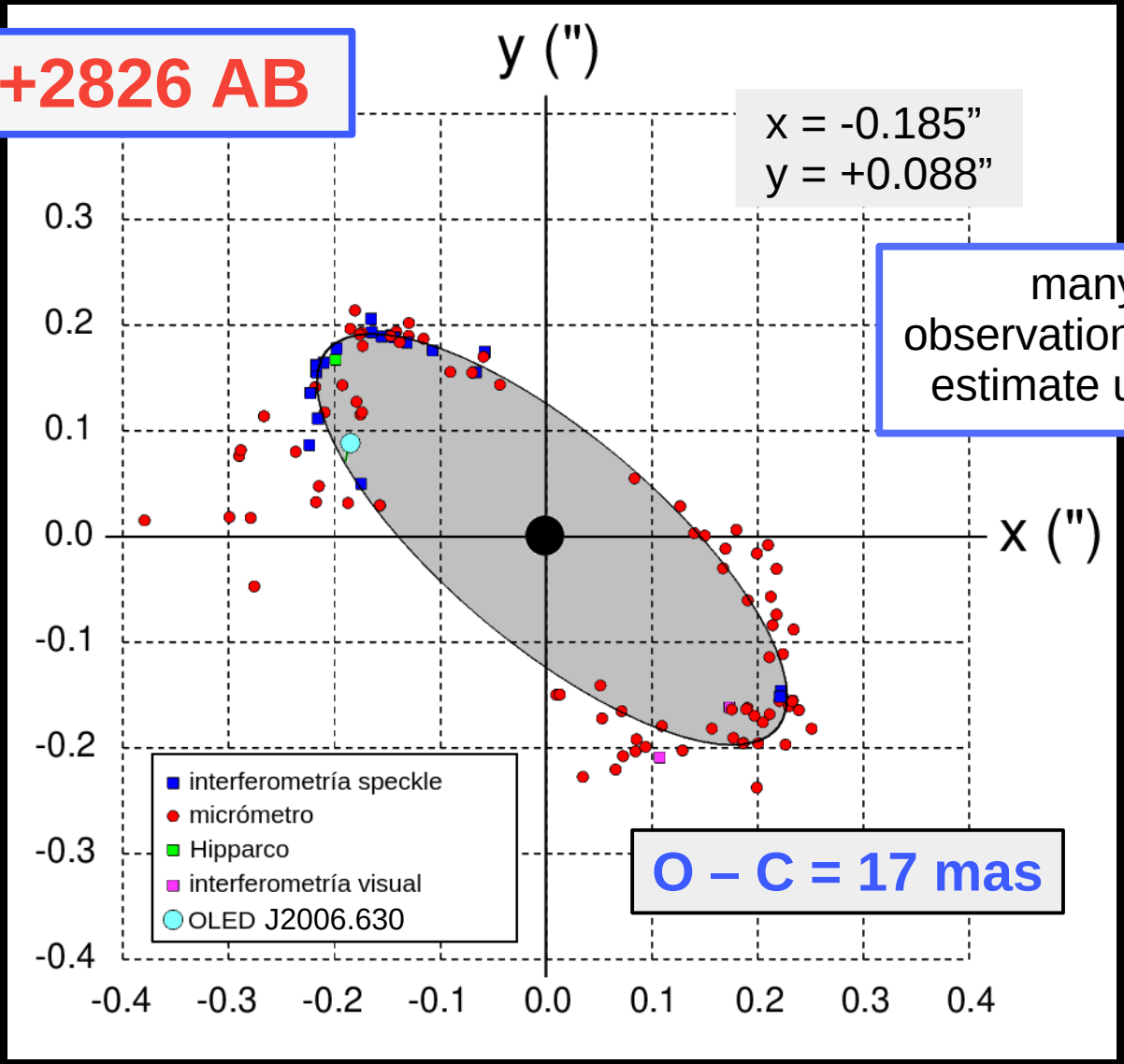
This double is physical.

Acrónimo	Nombre	λ	φ	h
JOL	Joan López y Lluís Xifra	+3° 08′ 26.6″	+42° 01′ 56.3″	5m
JOR	Joan Rovira y Antoni Selva	+2° 08′ 32.2″	+41° 34′ 08.3″	191m
MON	Montse Ribell y Xavier Puig	+2° 05′ 28.3″	+41° 32′ 18.6″	184m
MIG	Miguel Guillén	+2° 04′ 07.0″	+41° 31′ 36.0″	220m
CAS	Carles Schnabel y Antoni Selva	+1° 51′ 13.4″	+41° 25′ 45.4″	220m


A
B
C
MOR
MIG
CAS
JOL
JOR
R D
R
D R D
R
D R F F
B
R D
R D
R
R
D
R D
D R
R D R D R
F D
R D R
D
R D
R
R D R
D
D
R D
D
O − C (")
γ (°)
5
4
3
2
1
0
-1
-9
-8.5
-8
-7.5
-7
-6.5
-6
-5.5


A
B
C
RD
R
DRD
R
D RFF
MOR
MIG
CAS
JOL
JOR
O – C (")
γ (°)
Rasante de SAO 78233, 19.08.2006
Libraciones L = 7,19, B = -6,34
WA = AP eje +0.05
Distancia al límite
AP del eje lunar

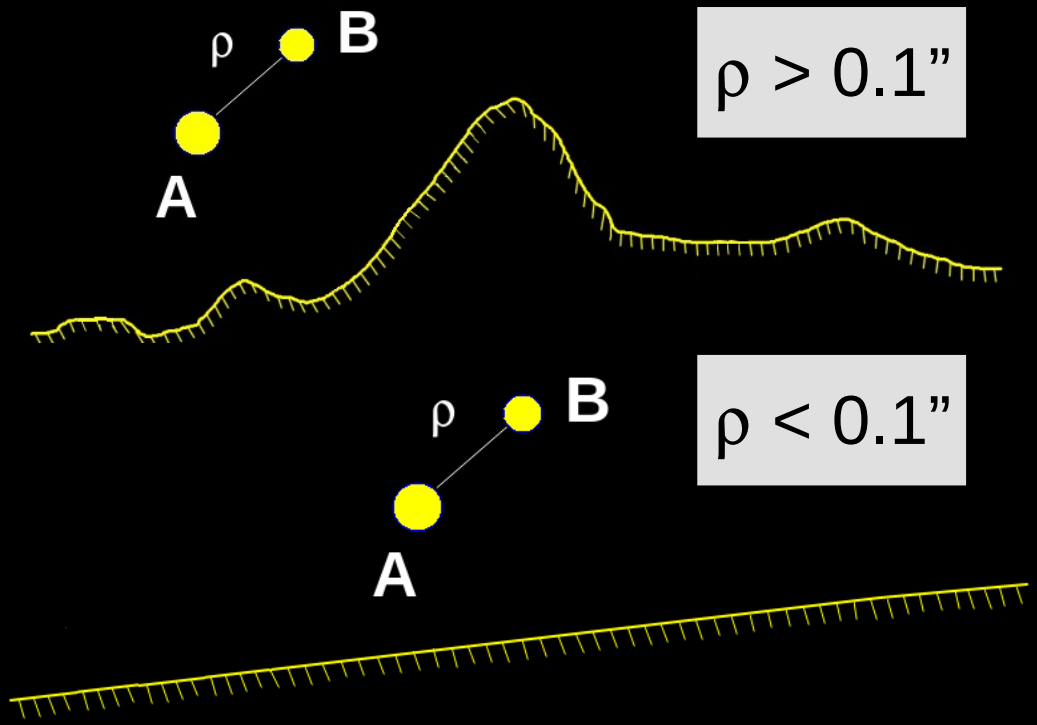
J06200+2826 AB



many visual observations: problem to estimate uncertainties

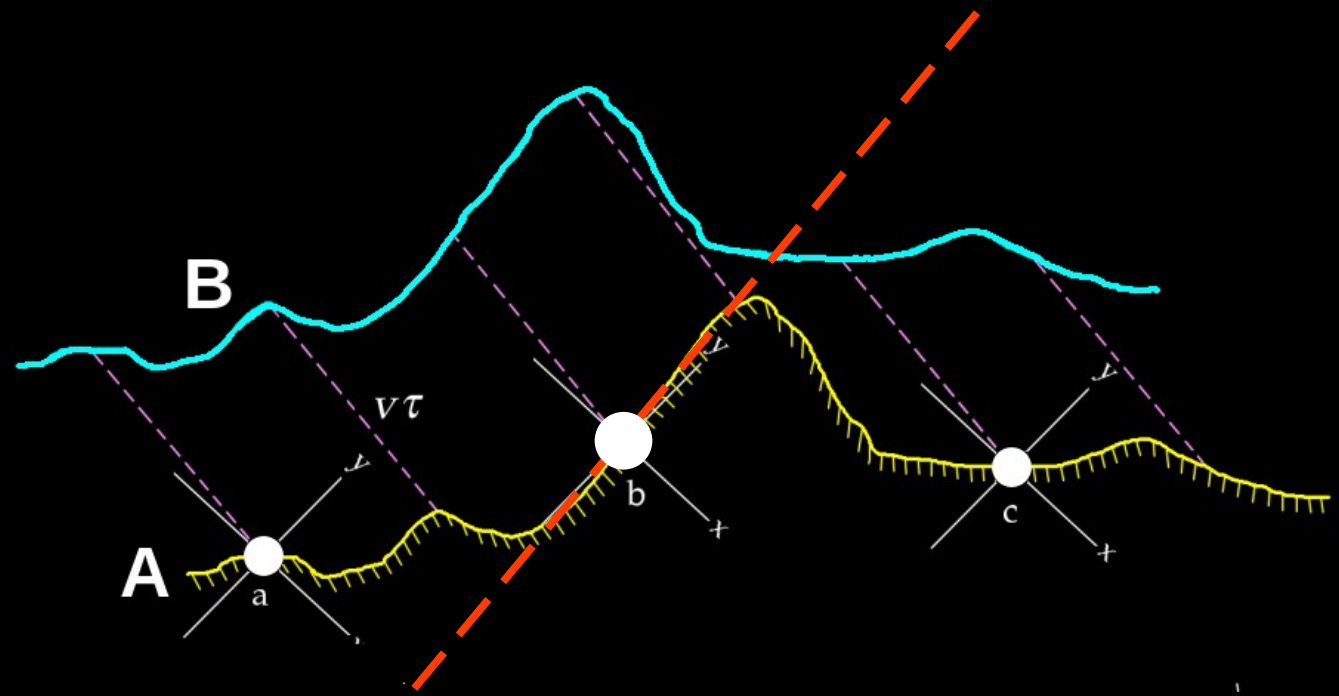
Linear approximation for the lunar limb – Method 2

Can be made when expected separation between components is much less than typical scale of lunar limb roughness



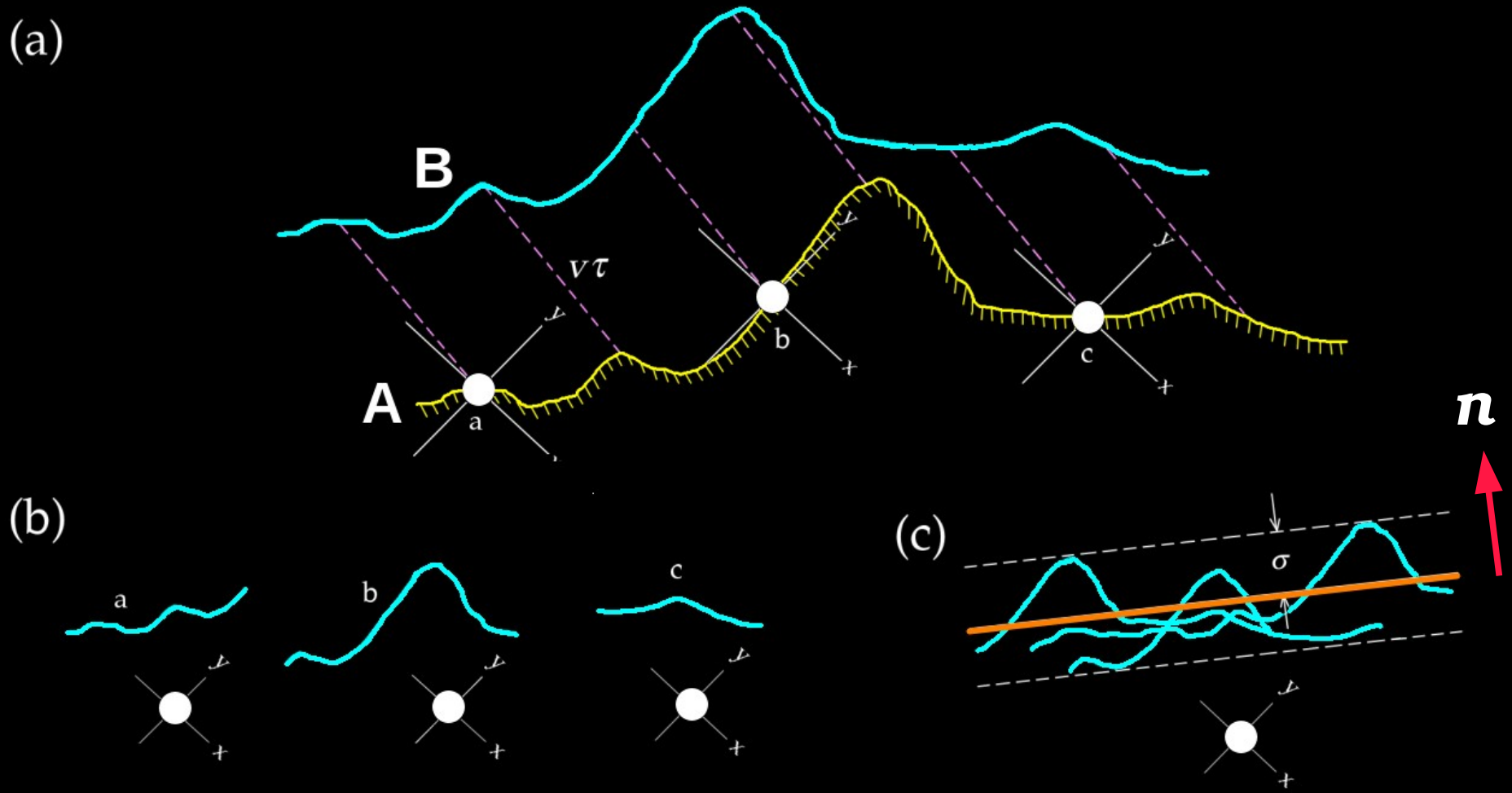
Method 1: general applicability

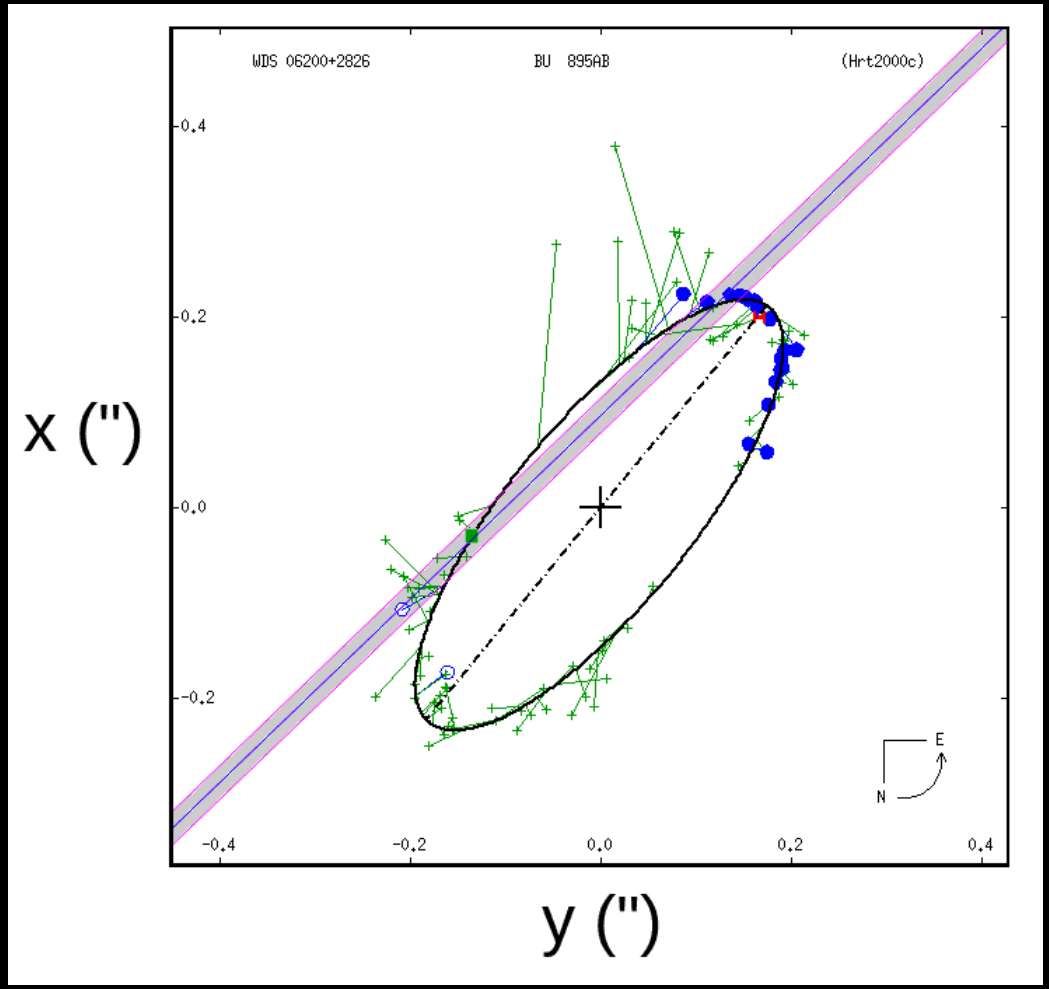
Method 2: good for nonresolved, very close double star; not good in other cases



Using the local slope at the landing point based on the current star ephemeris may lead to incorrect results

1D solutions – possible location of B wrt A

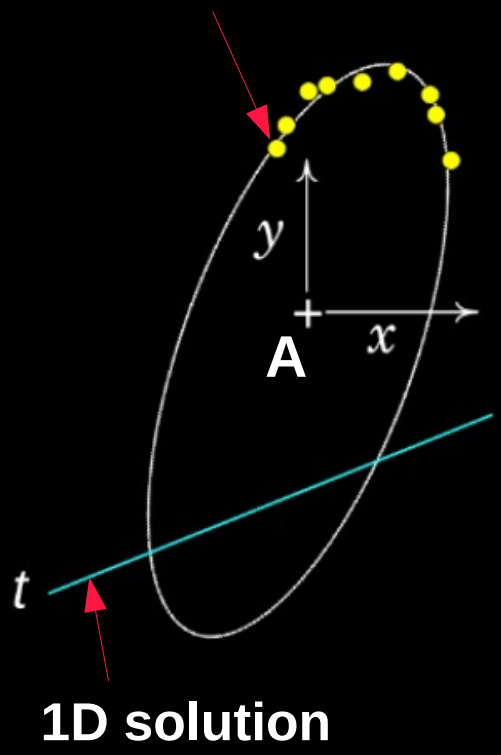


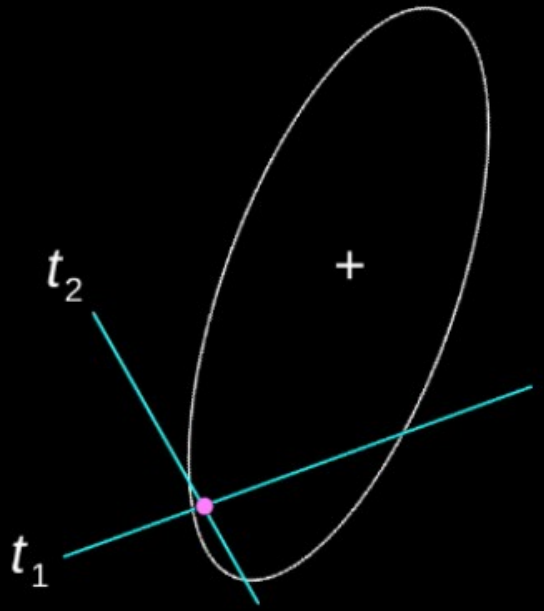

WDS 06200+2826
BU 895AB
(Hrt2000c)
0.4
0.2
0.0
-0.2
-0.4
-0.2
0.0
0.2
0.4
E
N
x (")
y (")

Pairing of 1D solutions – Brian Loader's way

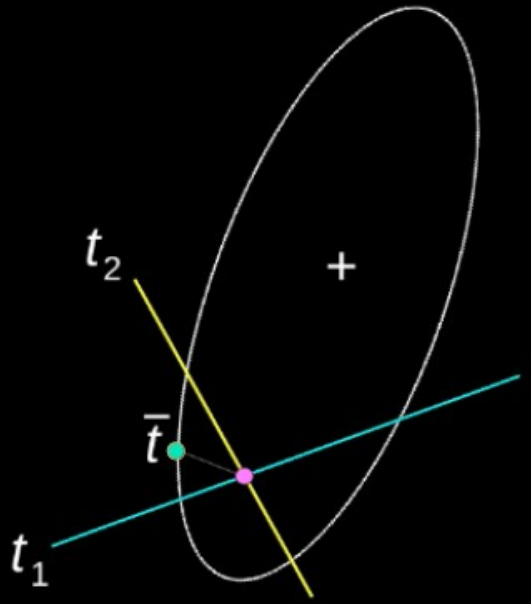
Nather & Evans, Astron. J. **75**, 575 (1970)

Pairing of 2 x 1D → 2D solution





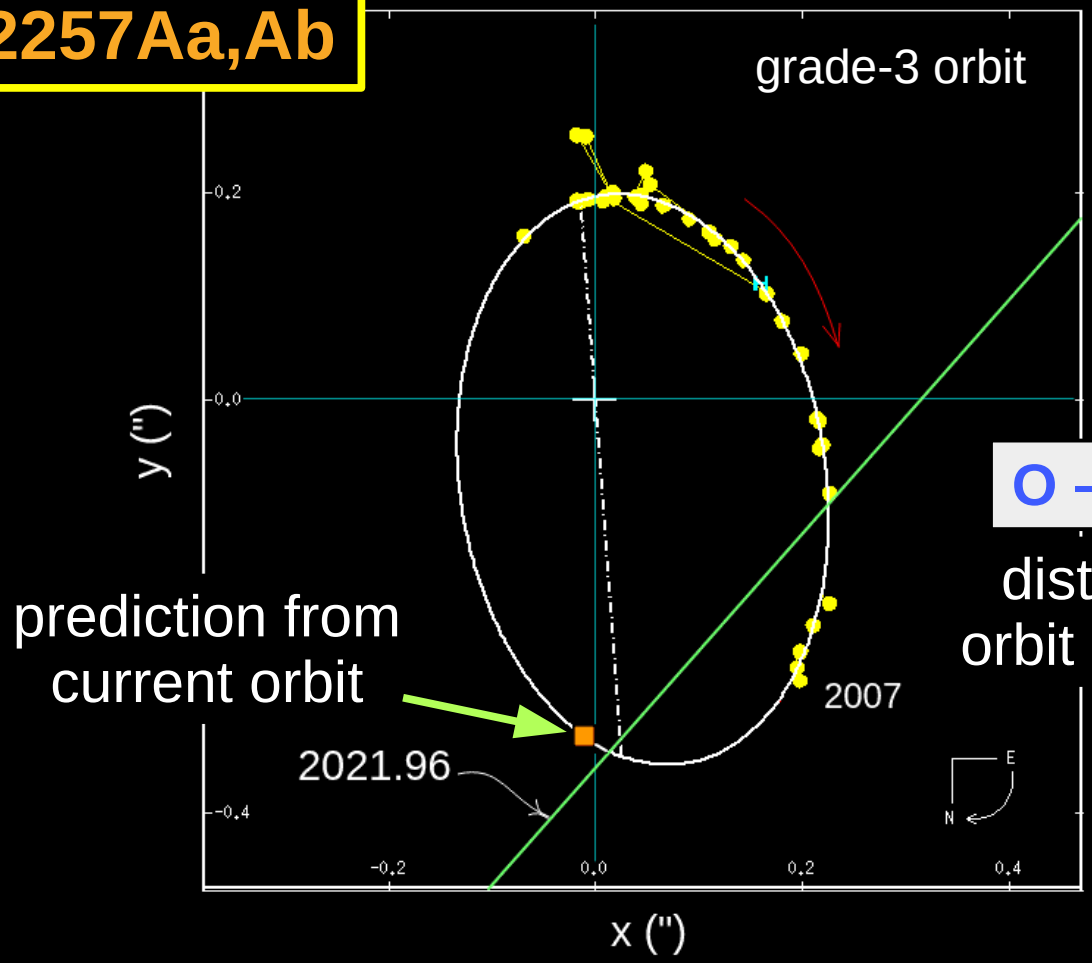
$t_2 - t_1 \ll T$



$t_2 - t_1 \lesssim T$

Orbits of binary stars from lunar occultations, E. Velasco, Journal of Computational Astronomy and Astronomical Computing **1**, 15 (2024)

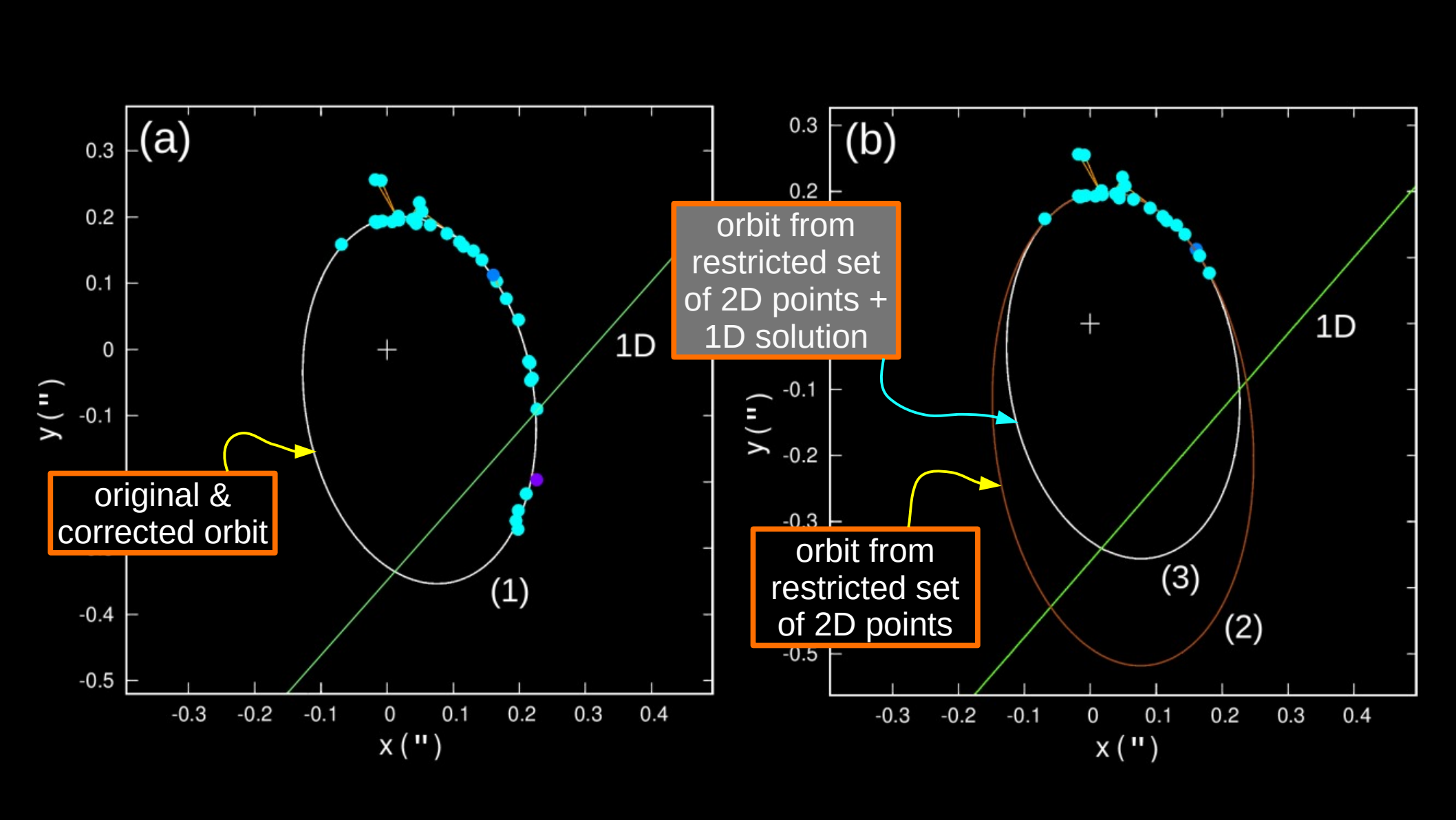
J04422+2257Aa,Ab

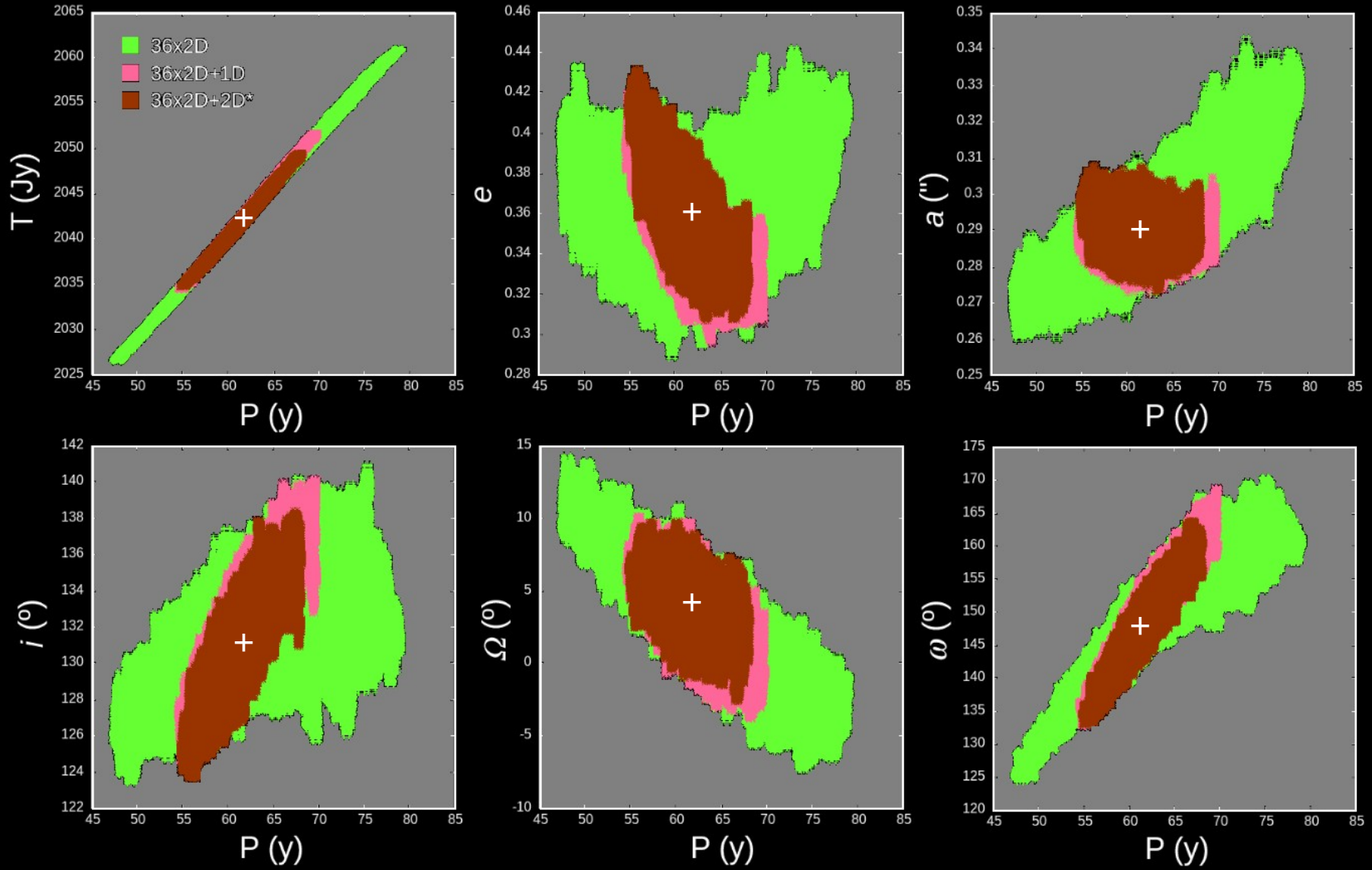


O – C = 27 mas

distance between orbit and 1D solution

prediction from current orbit


(a)
(b)
1D
1D
(1)
(2)
(3)
original & corrected orbit
orbit from restricted set of 2D points + 1D solution
orbit from restricted set of 2D points
x (")
y (")
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4


36x2D
36x2D+1D
36x2D+2D*
T (Jy)
e
a (")
i (º)
Ω (º)
ω (º)
P (y)

https://astro-oled.es/clo1d.html

Federación de Asociaciones Astronómicas de España

AGRUPACIÓN ASTRONÓMICA DE MADRID

Sociedad Española de Astronomía

SOCIÉTÉ ASTRONOMIQUE DE FRANCE

Commission des Étoiles Doubles

CLO1D - Catalogue of Lunar Occultations - 1D solutions

The CLO1D catalogue contains 1D solutions for binary stars extracted from lunar occultation observations. It can be used to analyse new duplicities, confirm suspected ones, and improve orbits of physical binary systems.

The CLO1D catalogue was developed and is maintained by the OLED project, a collaboration between the Agrupación Astronómica de Madrid (AAM) and the Société Astronomique de France (SAE) to observe and analyse double stars by means of lunar occultations.

Note: The current version of CLO1D is v1.0 (April 2024)

Last revised 26 Mar 2024

Federación de Asociaciones Astronómicas de España

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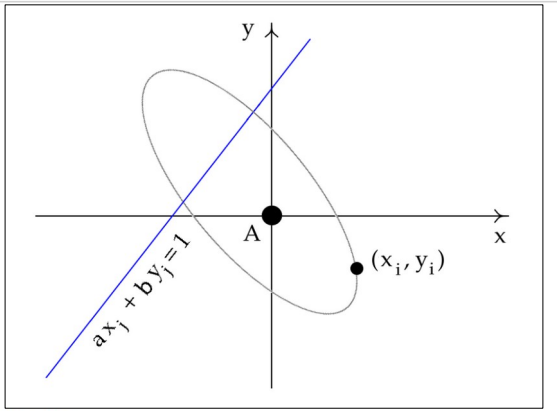
Sociedad Española de Astronomía

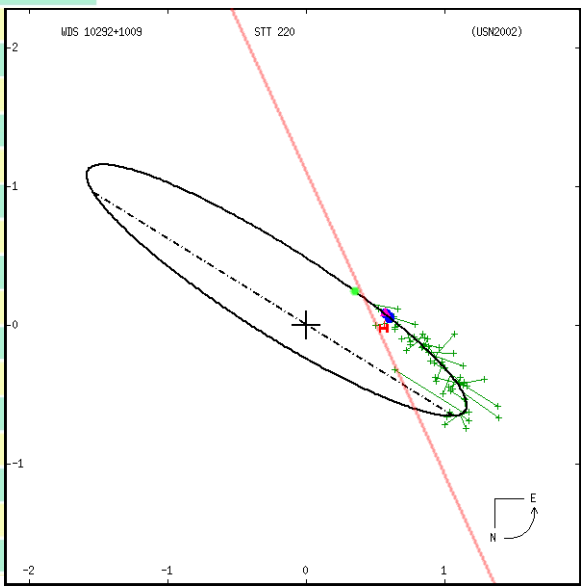
SOCIÉTÉ ASTRONOMIQUE DE FRANCE

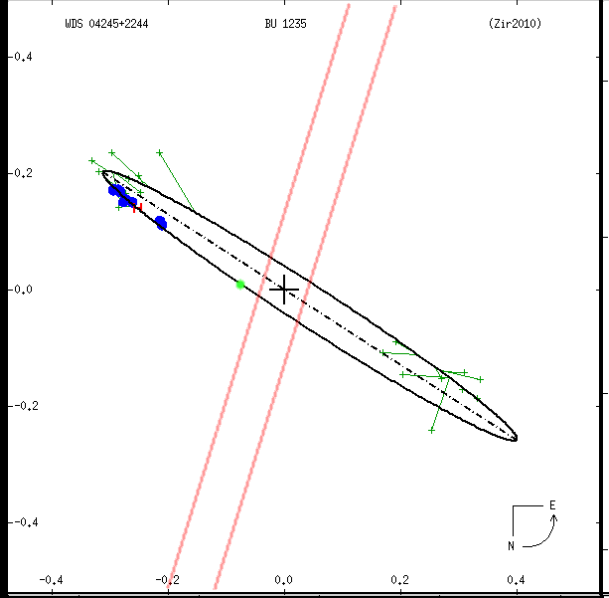
Commission des Étoiles Doubles

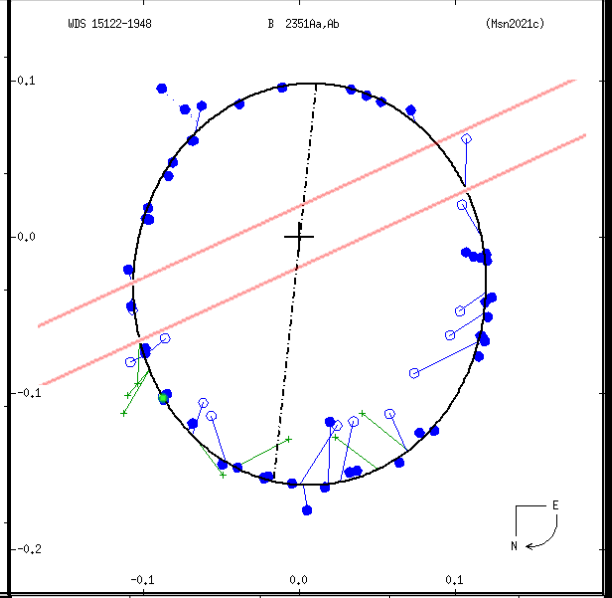


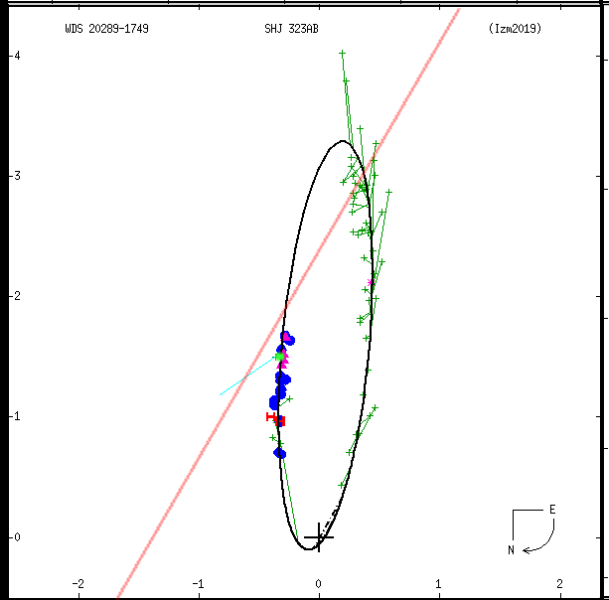
CLO1D catalogue - full version

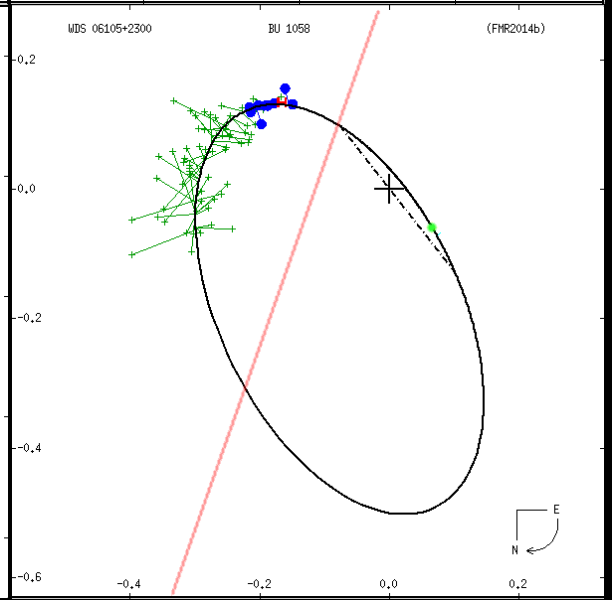
#	Jepoch	a (1/")	b (1/")	σ (")	U	Flag	Notes	WDS/Gaia	Orbit	Analysis
1	2010.005	0.848	-1.243	0.019	0	Y		08444+1555A 2472		
2	2010.015	-0.945	0.839	0.028	0	Y		12161-0728A 144		
3	2010.026					U		15331-2429		
4	2010.064					Y		02463+2105OCC9025		
5	2010.067	2.950	44.562	0.002	0	Y		03437+2339CHR 11Aa,Ab		
6	2010.067	-25.498	62.630	0.002	0	Y		03437+2339CHR 11Aa,Ab		
7	2010.067	-1.118	-0.312	0.020	0	P4		03463+2411BU 536AB	X	
8	2010.067	-0.926	-0.324	0.036	0	P4		03463+2411BU 536AB	X	
9	2010.067	-0.920	-0.343	0.032	0	P4		03463+2411BU 536AB	X	
10	2010.067					Y		03474+2355STF 450		
11	2010.067	-0.995	-0.309	0.027	0	P4		03463+2411BU 536AB		
12	2010.067					Y	1	03475+2406WSI 52Da,Db		
13	2010.067					Y	2	03475+2406WSI 52Da,Db		
14	2010.067					Y	3	03475+2406		
15	2010.067	0.998	1.036	0.010	0	P4		03481+2409COU 80	X	
16	2010.067	5.859	7.173	0.001	0	Y		03486+2411BU 1105		
17	2010.067	8.288	7.230	0.004	0	Y		03486+2411BU 1105		
18	2010.067	5.533	5.655	0.004	0	Y		03486+2411BU 1105		




WDS 04245+2244
BU 1235
(Zir2010)
0.4
0.2
0.0
-0.2
-0.4
-0.4
-0.2
0.0
0.2
0.4
E
N


WDS 15122-1948
B 2351Aa,Ab
(Msn2021c)
0.1
0.0
-0.1
-0.2
-0.1
0.0
0.1
E
N


WDS 20289-1749
SHJ 323AB
(Izm2019)
4
3
2
1
0
-2
-1
0
1
2
E
N


WDS 06105+2300
BU 1058
(FMR2014b)
0.2
0.0
-0.2
-0.4
-0.6
-0.4
-0.2
0.0
0.2
E
N

Accelerated stars

Interest in accelerated stars has grown in the last few years due to their connection with binary systems

- **Kervella et al. Catalogue of PMA (Proper Motion Anomaly)**

A&A 657, A7 (2022)

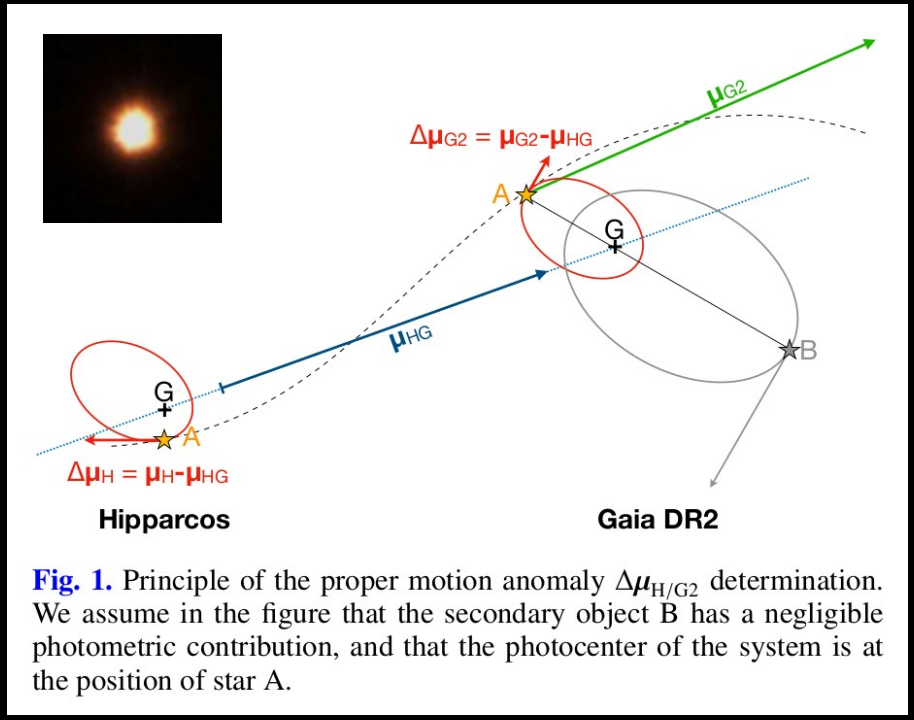


Fig. 1. Principle of the proper motion anomaly $\Delta\mu_{H/G2}$ determination. We assume in the figure that the secondary object B has a negligible photometric contribution, and that the photocenter of the system is at the position of star A.

PMA = difference in proper motion between Hipparcos (J1991.0) and Gaia DR2 (J2015.5), Δt = 24.5 y

$$\dot{\mu} = \frac{\mu_2 - \mu_1}{\Delta t} \quad \text{(acceleration)}$$

Several thousand stars may be suitable for lunar occultation work

- **Halbwachs et al. Gaia DR3 NSS (Non-Single Star) Catalogue**

A&A 674, A9 (2023)

Local (J2016.0) ***accelerations*** are derived from the absolute astrometry of Gaia DR3 during the operation of the satellite

Gaia DR3 position (J2016)

Gaia DR3 proper motion (J2016)

acceleration

$$\alpha(t) = \alpha_0 + \mu_\alpha (t - t_0) + \frac{1}{2}\dot{\mu}_\alpha (t - t_0)^2 + \ldots$$

$$\delta(t) = \delta_0 + \mu_\delta (t - t_0) + \frac{1}{2}\dot{\mu}_\delta (t - t_0)^2 + \ldots$$

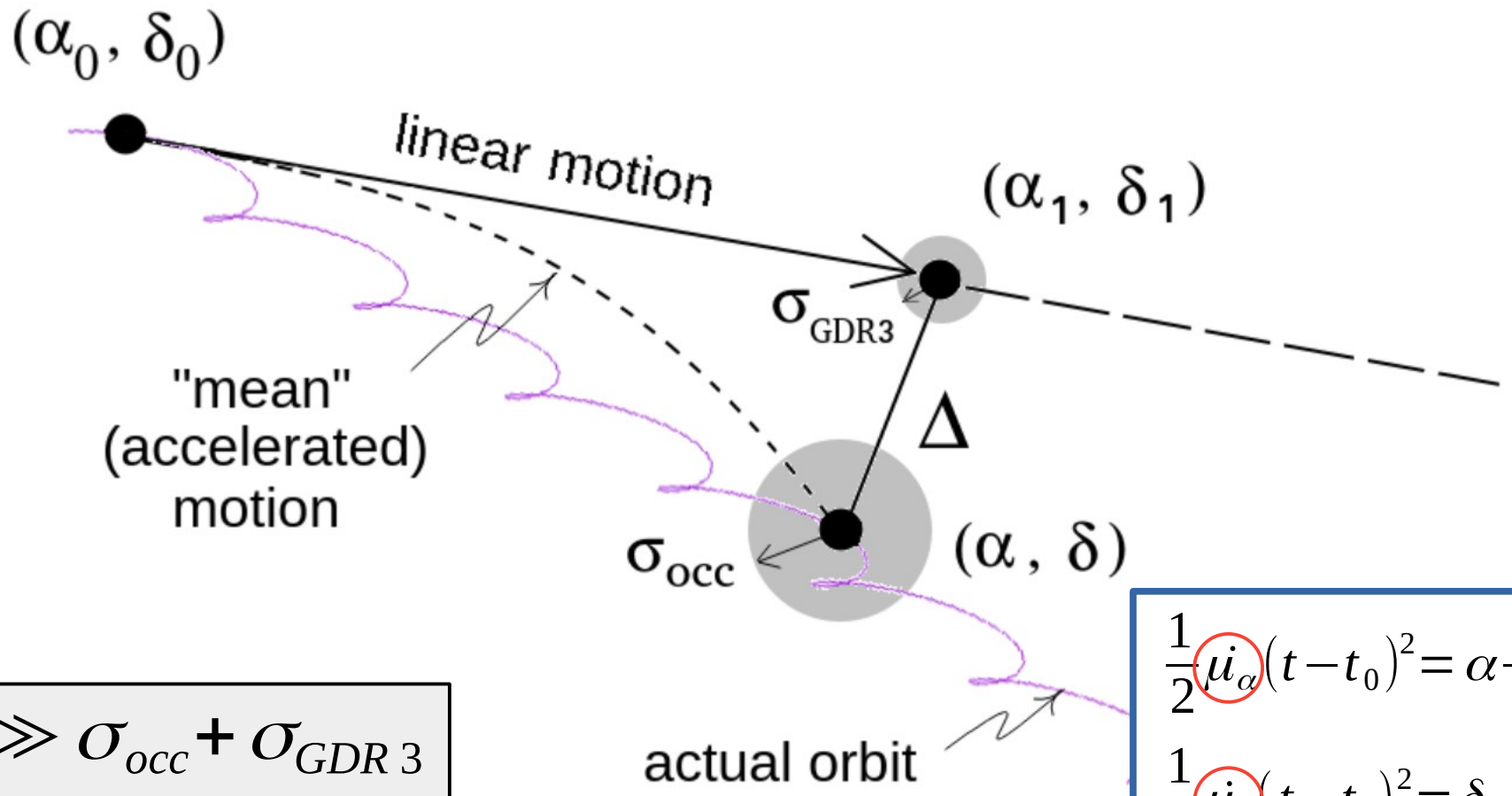
linear extrapolation

The zodiacal subset of the catalogue contains:

- 4166 `accelerated` stars
- 1829 `two-body` stars

of all which can be observed in search for duplicity and/or astrometry

Projection onto the celestial sphere (hypothetical binary star)



$$\Delta \gg \sigma_{occ} + \sigma_{GDR\,3}$$

$$\frac{1}{2}\mu_\alpha (t - t_0)^2 = \alpha - \alpha_1$$

$$\frac{1}{2}\mu_\delta (t - t_0)^2 = \delta - \delta_1$$

Duplicity search in stars of Gaia DR3 NSS catalogue

Data mining in IOTA Herald & Gault (2022) catalogue:

Gaia DR3	a (mas^{-1})	b (mas^{-1})	σ (mas)	ρ_{min} (mas)	Epoch	table
2620074228317782912	-6.280	+73.789	10	13	J2010.42	accelerated
6550735015241285l2	-68.838	+121.750	10	7	J2012.77	accelerated
5925852320591559l8	-28.028	+4.082	10	35	J2015.39	accelerated
2568947762259903616	+75.720	+38.840	6	12	J2020.98	two-body

Gaia DR3 2568947762259903616: two-body table

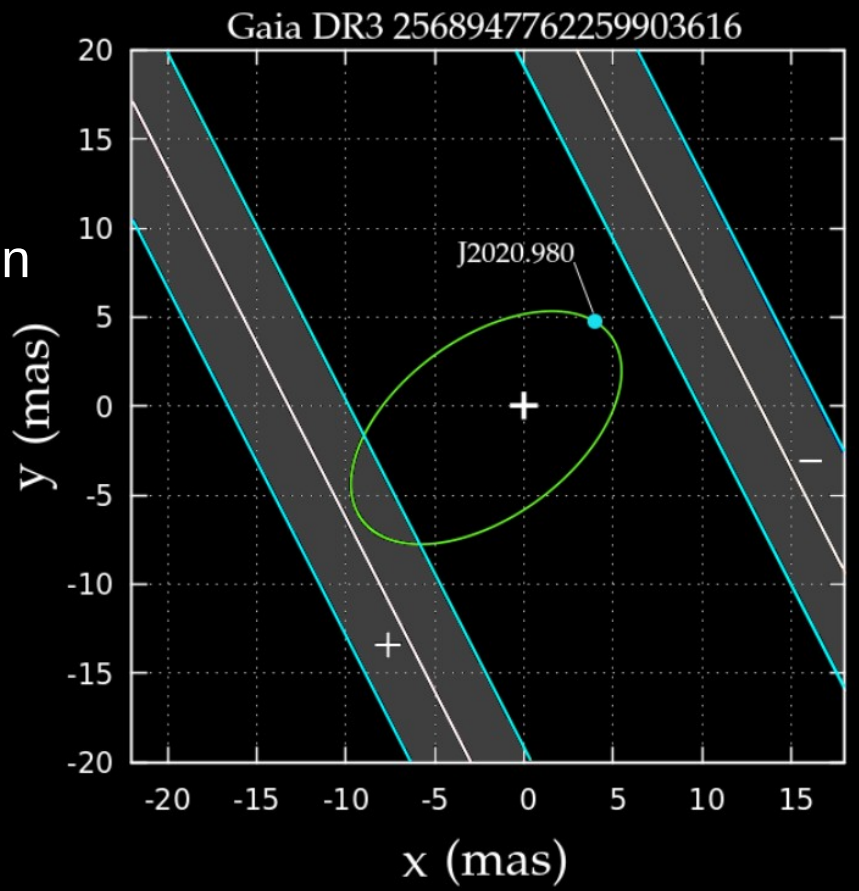
Assuming:

- photocentre at A
- centre of mass is at origin of the orbit
- both stars have the same mass (unlikely)

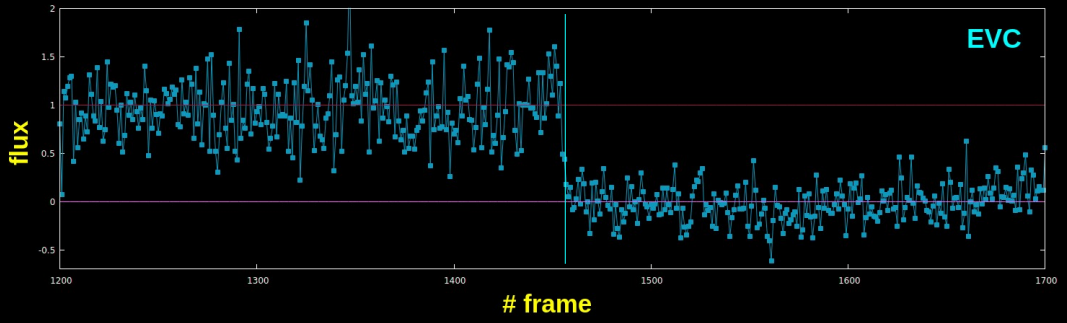
the "–" solution is close to the calculated position

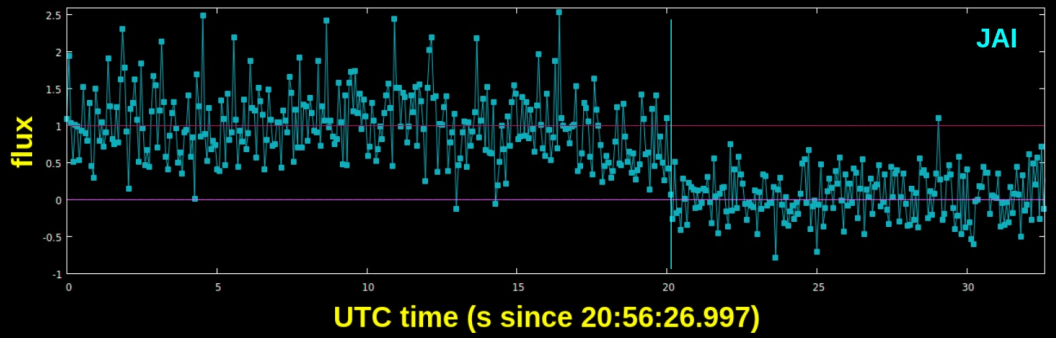
→ astrophysical analysis needed

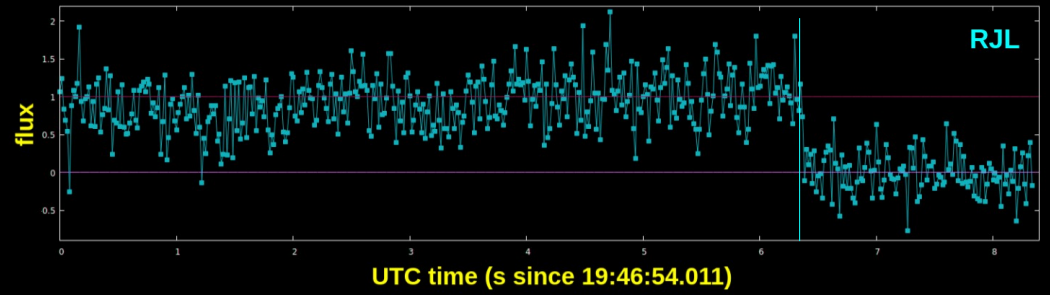
P :	546.247 ± 1.468	(Period in d)
T :	207.384 ± 5.133	(Epoch of periastron since J2016.0 in d)
e :	0.28508 ± 0.01836	(Eccentricity)
A :	-3.718719 ± 0.044182	(mas)
B :	-2.117855 ± 0.168039	(mas)
F :	-0.776131 ± 0.204159	(mas)
G :	$+2.600577 \pm 0.143216$	(mas)



Gaia DR3 2573125047451909376 (PPM 144774)







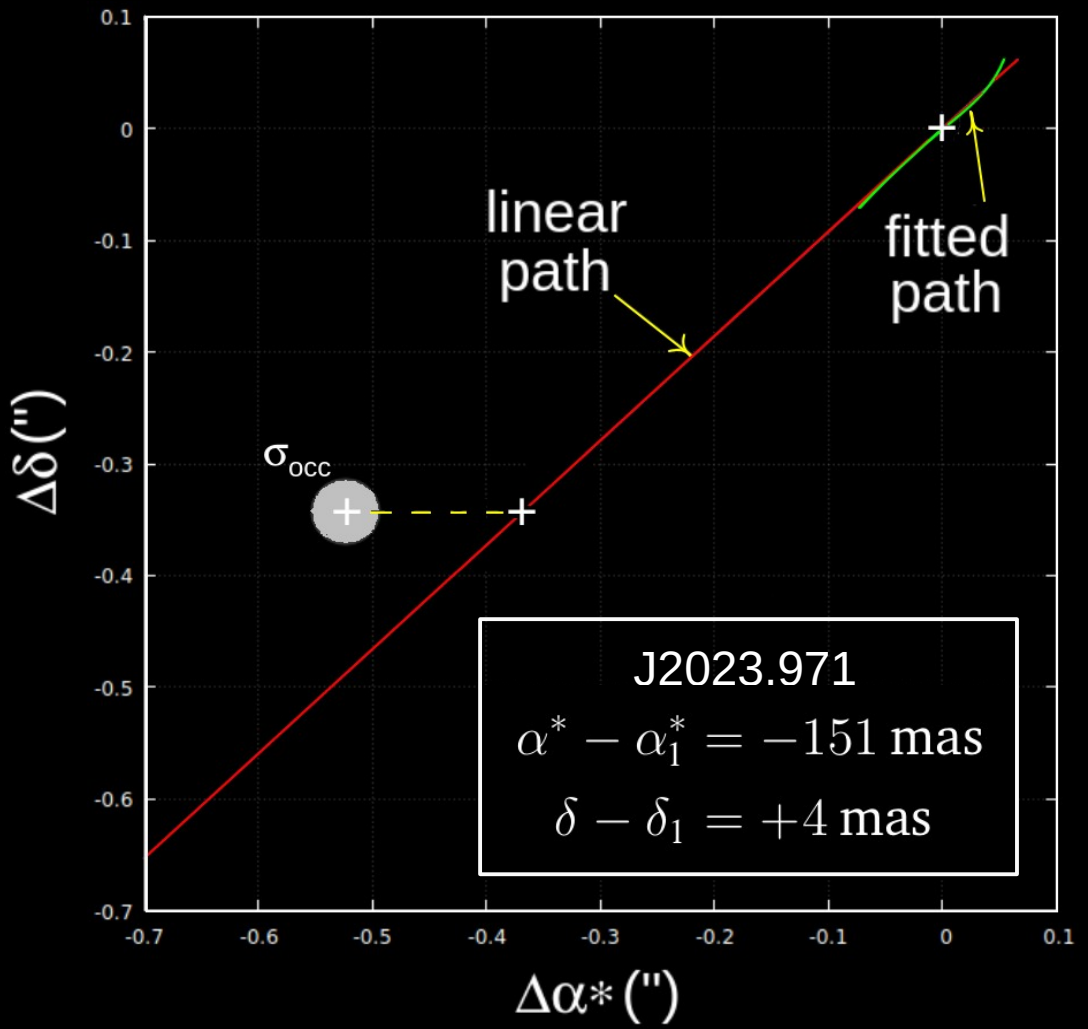
O-C calculated using Gaia DR3 J2016.0 coordinates and linear proper motion:

Station	UTC contact	O−C (mas)
EVC	19:46:46.382	−72
JAI	19:46:08.911	−52
RJL	19:47:00.385	−93
		−72 (average)

The coordinates are optimised using the three observations:

$$S(\alpha,\delta) = \sum_{i=1}^{3} \left[\frac{f(\alpha,\delta;t_i)}{\sigma_i} \right]^2 \rightarrow \min.$$

$$\dot{\mu}_{\alpha*} = -4.8\,\mathrm{mas/y^2}, \qquad \dot{\mu}_{\delta} = +0.1\,\mathrm{mas/y^2}.$$



σ_{occ} = 26 mas

σ_{GDR3} = 2.1 mas (at epoch of observation)

Conclusions

- Number of observations increasing slowly, more observers needed
- Collaboration with or some kind of integration in IOTA efforts
- Not just WDS stars, but other catalogues (e.g. Gaia NSS, Kervella et al., …)
- New catalogues: ***CLO1D*** (1D solutions for orbit determination), future ***High O-C catalogue***
- New avenues in amateur work: high-speed & near-infrared photometry