Stellar Duplicity Discovered During Occultation by Asteroid (709) Fringilla

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Abstract

On 16 January 2025, an occultation of the star UCAC4 644-038283 (Gaia DR3 ID 944967984227916160) by the main-belt asteroid (709) Fringilla revealed the previously unknown binarity of this star. The distance between the two components was determined to be 0.0331" ± 0.0004", the position angle results in 63.3° ± 1.6°.

1. Introduction

In addition to determining important asteroid data such as size and shape, the main goal of observing stellar occultations by asteroids, information about the star can also be obtained, e.g. previously unknown double/multiple stars can be discovered. The Occult4 database (http://www.lunar-occultations.com/iota/occult4.htm) currently lists 173 double stars discovered during asteroidal occultations.

An occultation of the star UCAC4 644-038283 (Gaia DR3 ID 944967984227916160) by the main-belt asteroid (709) Fringilla, which was positively observed by 8 European stations on 16 January 2025, showed target star lightcurve steps in disappearance and reappearance, indicating stellar duplicity. According to the catalogs (Washington Double Star Catalog, Interferometric Catalog, Gaia), the star is not known as a double star. The Occult4 database does not contain any previous occultations of this star.

The observation took place within the framework of the International Occultation Timing Association/European Section (IOTA/ES) (https://iota-es.de/index.html) and the result was recorded with its SODIS (Stellar Occultation Data Input System) portal (https://sodis.iota-es.de).

2. Prediction

The occultation event has been predicted by the 'CentralEurope' feed of Occult Watcher Cloud (https://cloud.occultwatcher.net/event/1476-709-94060-650430-U038283) using Occult4 programme. Table 1 lists data of the occulted star.

Table 1. Occulted star data.

UCAC4	ID	644-038283
Gaia DR3	ID	944967984227916160
	RA (J2000) [h:m:s]	06:37:26.8905
	Dec (J2000) [d:m:s]	+38:41:57.8406
	G-band mean magnitude [mag]	12.69
	RUWE	2.398
	Duplicated source	0

Fig. 1 shows Occult4 generated prediction details and a map (https://astro.kretlow.de/?CORA) with the occultation shadow path and the recording station positions.

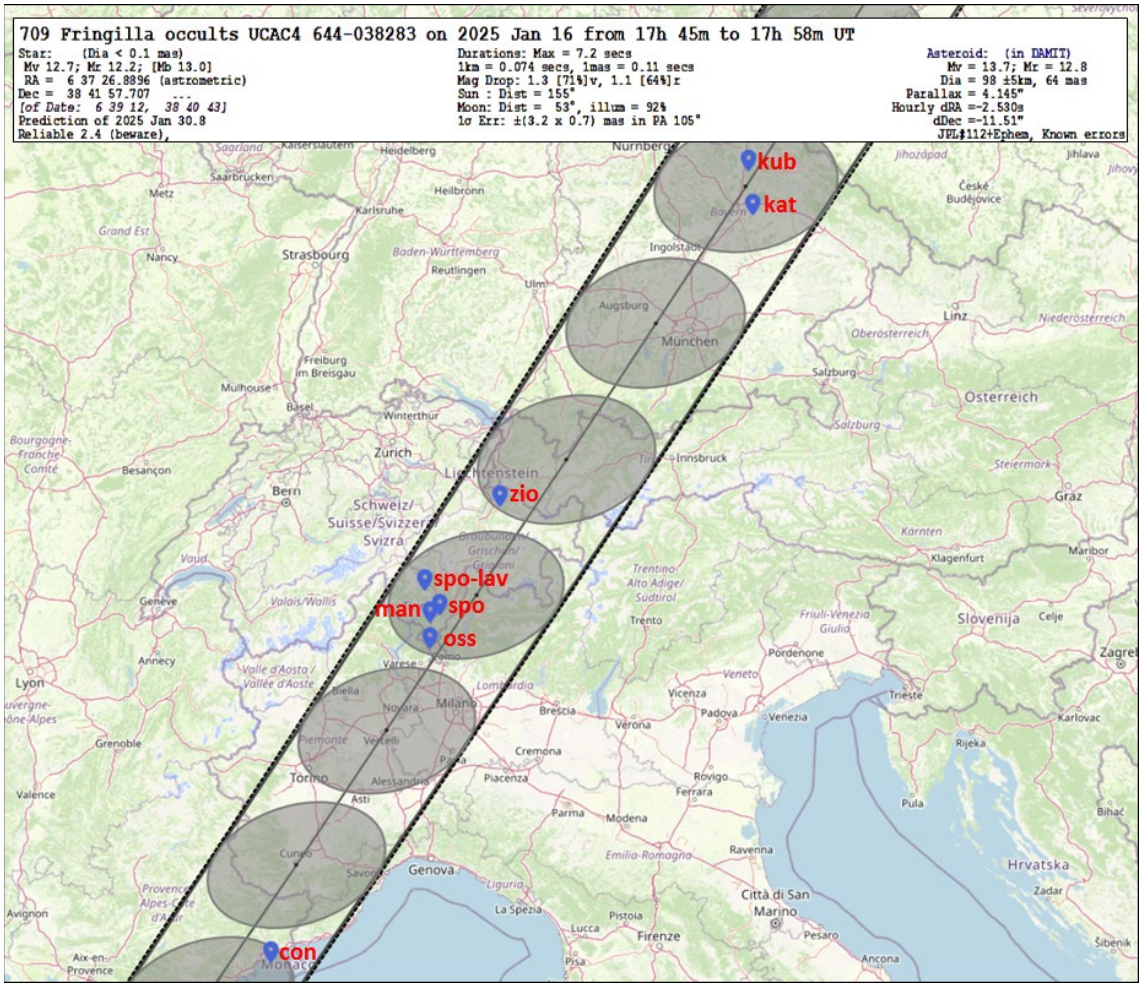

Figure 1: Occultation shadow path with recording stations (see Table 2) and occultation event details of asteroid (709) Fringilla to occult the star UCAC4 644-038283

3. Observations

All stations were using the GPS 1PPS signal for time measurement, resulting in time accuracies in the range of 1 ms (Kamiński et al. 2023). The mirror telescopes had apertures of 200 to 400 mm. The camera types and further details are listed in Table 2.

Table 2. Technical details of the recording stations, CC country code of the country of recording. The analogue camera WAT910HX was always used in conjunction with a Video Time Inserter (VTI), the other digital cameras have built-in GPS shutter controls, *Sensor type: SONY IMX430LLJ-C.

Station	Observer	CC	Mirror telescope aperture [mm]	Camera	Timing source	Rec. format	Exposure time [s]
kub	J. Kubánek, S. Kubánková	DE	200	QHY174M GPS	GPS	SER	0.1
kat	B. Kattentidt	DE	280	DVTI+CAM*	GPS	ADV	0.02
zio	C. Ziolek	CH	356	DVTI+CAM*	GPS	ADV	0.075
spo-lav	S. Sposetti, G. Lavagno	CH	200	WAT910HX	GPS	AVI	0.08
spo	S. Sposetti	CH	420	QHY174M GPS	GPS	ADV	0.08
man	A. Manna	CH	200	WAT910HX	GPS	AVI	0.16
oss	A. Ossola	CH	230	WAT910HX	GPS	AVI	0.32
con	M. Conjat	FR	400	QHY174M GPS	GPS	FITS	0.06

Fig. 2 illustrates the relevant sections of the lightcurves of the target star obtained at the stations.

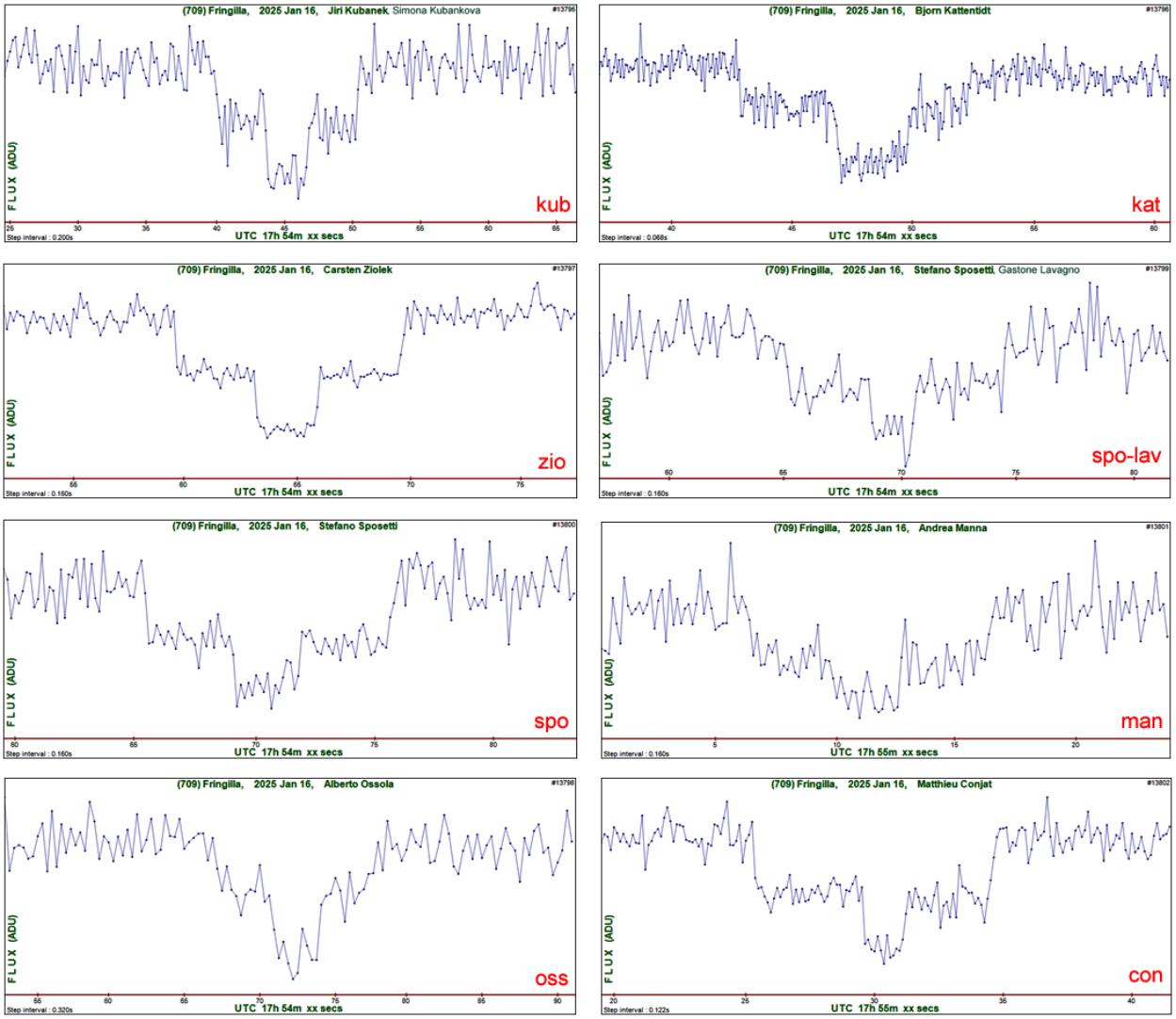

Figure 2: Relevant sections of target star lightcurves showing steps in disappearance and reappearance. Some lightcurves are binned along the x-axis. For the photometry methods used, see Section 4

4. Data reduction

For the photometry of the recordings we used the programme Tangra (http://www.hristopavlov.net/Tangra3/). Only for data from station 'zio' PyMovie (https://pypi.org/project/pymovie/) was applied. We used AOTA, part of the Occult4 software package, to extract the occultation times and the average light levels (Table 3). Fig. 3 shows the reduction for the 'kub' station as an example.

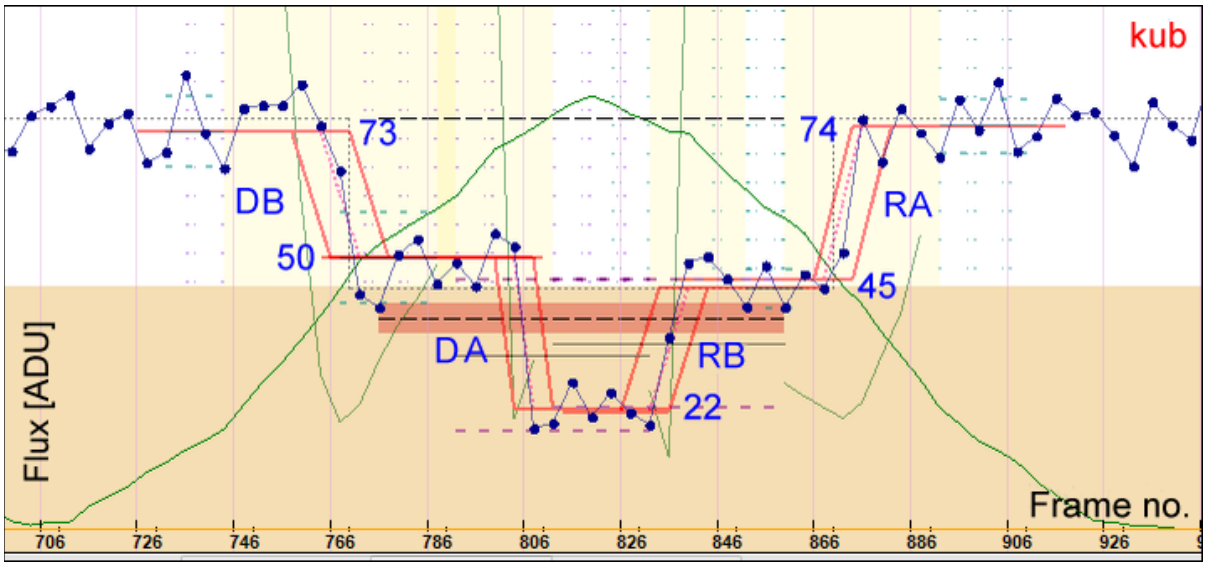

Figure 3: Station 'kub' event times extraction with AOTA, for results see Table 3. A double star main component, B secondary component, D disappearance, R reappearance, the blue numbers give the average light levels in ADU. The light levels and their sequence show that the components are covered in the order B-A-B-A

Table 3. AOTA derived event times and average light levels (compare Fig. 3); A, B stellar components designation, D disappearance, R reappearance, $Delta_{XY}$ light level step in ADU.

Station	DB (UTC) [h:min:s], $Delta_{DB}$ [ADU]	RB (UTC) [h:min:s], $Delta_{RB}$ [ADU]	DA (UTC) [h:min:s], $Delta_{DA}$ [ADU]	RA (UTC) [h:min:s], $Delta_{RA}$ [ADU]
kub	17:54:40.3 ± 0.6, 23	17:54:47.0 ± 0.5, 23	17:54:44.1 ± 0.4, 28	17:54:50.9 ± 0.4, 29
kat	17:54:42.56 ± 0.09, 16	17:54:48.98 ± 0.17, 23	17:54:46.40 ± 0.14, 29	17:54:52.50 ± 0.13, 19
zio	17:54:59.79 ± 0.19, 25	17:55:06.09 ± 0.19, 28	17:55:03.46 ± 0.19, 30	17:55:09.91 ± 0.19, 30
spo-lav	17:55:05.28 ± 0.2, 24	17:55:10.7 ± 0.2, 24	17:55:08.84 ± 0.16, 21	17:55:14.6 ± 0.3, 20
spo	17:55:05.7 ± 0.2, 13	17:55:12.1 ± 0.2, 19	17:55:09.3 ± 0.2, 34	17:55:16.0 ± 0.3, 31
man	17:55:06.4 ± 0.2, 22	17:55:12.7 ± 0.2, 15	17:55:09.8 ± 0.2, 19	17:55:16.5 ± 0.3, 24
oss	17:55:07.2 ± 0.4, 24	17:55:14.2 ± 0.5, 30	17:55:11.4 ± 0.6, 33	17:55:17.9 ± 0.6, 26
con	17:55:25.67 ± 0.15, 24	17:55:31.36 ± 0.18, 20	17:55:29.9 ± 0.2, 24	17:55:34.74 ± 0.15, 28

5. Analysis

For the analysis, we used the corresponding tools from Occult4 in the standard method described in (Herald et al. 2009). Fig. 4 shows the result.

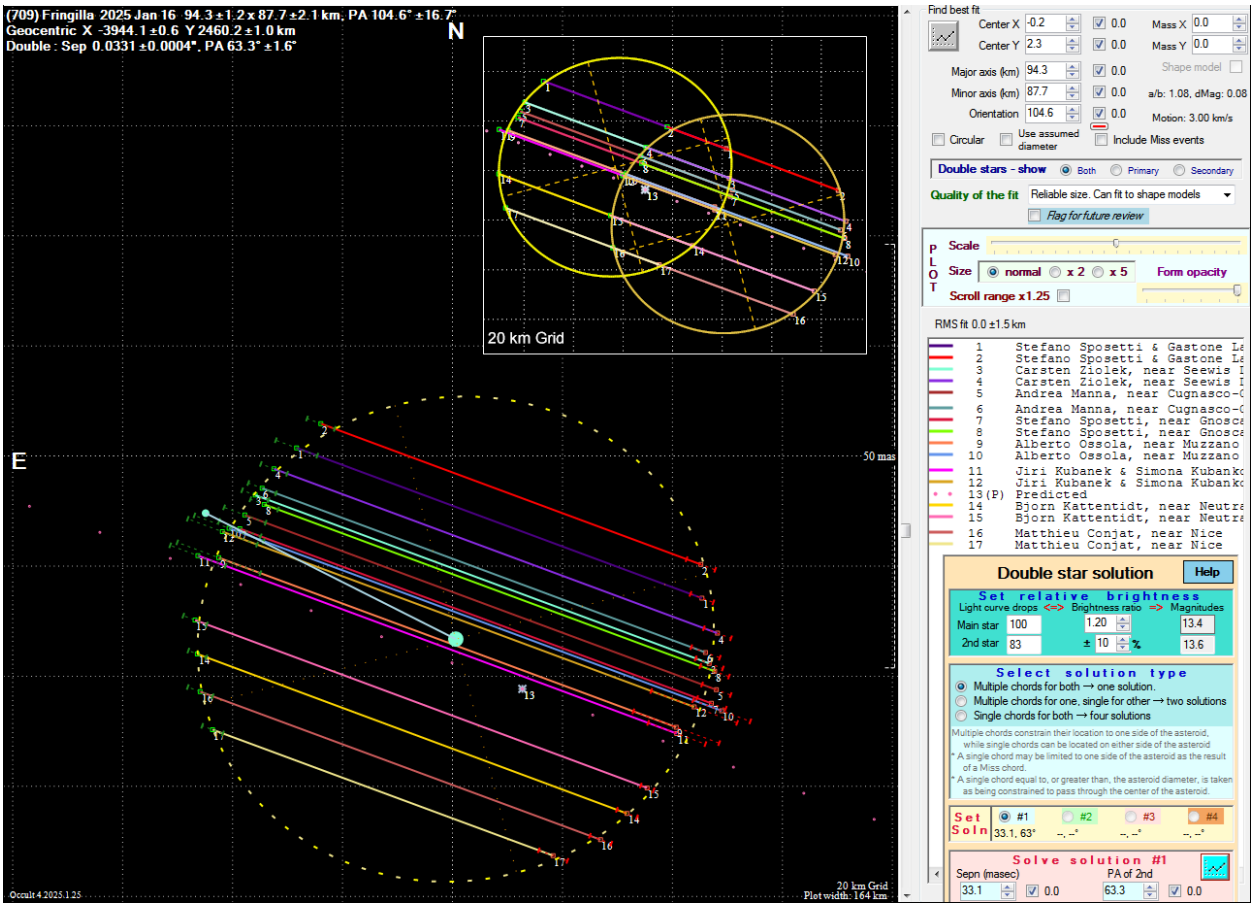

Figure 4: Occult4 double star analysis. The inserted image (not to scale) shows the occultation events of the stellar components not aligned as in the main image

Thanks to the occultation results obtained, the double star solution is not ambiguous (as is often the case with double stars discovered by occultation).

6. Results

The derived binary star solution is listed in Table 4.

Table 4. Double star characteristics (Gaia DR3 ID 944967984227916160).

Double star solution	Separation [mas]	33.1 ± 0.4
	Position angle [°]	63.3 ± 1.6
Estimated component magnitudes	A [mag]	13.4 ± 0.1
	B [mag]	13.6 ± 0.1

Assuming linear camera responses, we estimated the magnitudes of the double star components using the light levels given in Table 3. With Occult4, we determined a brightness of 13.4 ± 0.1 mag for the main component and a brightness of 13.6 ± 0.1 mag for the fainter component (Table 4).

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