The enigmatic object A2909AB: double, but not binary

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Abstract

The $0.1''$ classical visual pair A2909AB (HD 21161) is a single star, despite its computed orbit with a period of 11 years. This is evidenced by the speckle non-resolutions at 4.1-m telescope during 11 years, constant radial velocity, and the absolute magnitude corresponding to a single main-sequence star. This object resembles another "ghost" pair A3010, also a single star. We argue that all documented resolutions of these single stars cannot be spurious. The occasional image doubling could instead be caused by a yet unexplored phenomenon. One speckle resolution of A2909AB in 2013.7 is critically examined and found to be reliable.

1 Introduction

In this note, we discuss observations of the visual double star A2909AB and show that it is a single star, not a binary. Yet, several resolutions of this star by visual observers and one speckle resolution cannot be easily dismissed as spurious. If these resolutions are real, the occasional image doubling should be caused by some new, yet unexplored phenomenon. Therefore, the available data merit a close examination.

Cases of visual observers reporting spurious measurements are quite common. If a relibale orbit of the binary system is computed, its past "resolutions" at times when it was too close to be resolved clearly stand out as spurious. Other techniques (e.g lunar occultations and speckle interferometry) also supplied a number of well-documented spurious resolutions, for various reasons that are, mostly, well understood.

However, when a given single star has been resolved repeatedly by different observers, it is unlikely that all those resolutions are spurious. Such is the case of A3010 (WDS 05074+1839, 104 Tau, HD 32923) discussed by Tokovinin (2012). This is a nearby (16 pc) dwarf of spectral type G4V with a constant radial velocity (RV). Speckle monitoring at different telescopes, started at Kitt Peak in 1976.9 and continued at SOAR till 2018, shows the star to be unresolved and certainly invalidates its orbit with a period of 1.1 yr computed by O. Eggen from the visual resolutions. Such objects – single stars occasionaly seen as double – were named "ghosts".

The object of this note is a bright nearby star HIP 15868 (HD 21161, WDS J03244-1539, ADS 2524). Aitken (1918) resolved it for the first time in 1918 into a triplet consisting of the close pair AB at $0.13''$ separation and the distant and faint companion C at $17''$ from AB; the object is designated as A2909. According to the recent astrometry by *Gaia* (Gaia collaboration, 2018), the stars AB and C have common parallaxes, proper motions (PMs), and RVs, and, therefore, form a wide physical binary system. Their parameters are listed in Table 1.

The inner pair AB has been repeatedly measured by visual observers; the last visual resolution of AB was recorded in 1962. The WDS database lists 7 visual resolutions of AB and 6 non-resolutions. The orbit of AB with a period of 11.35 yr was computed by Docobo et al. (2016). The triple system is featured in the Multiple-Star Catalog (Tokovinin, 2018a). Yet, here we present a compelling evidence that the binary AB does not exist and argue that this is yet another case of unexplained "ghost" pairs (Tokovinin, 2012). However, in this case one resolution of AB by speckle interferometry has been reported.

2 Observations of A2090AB at SOAR

Owing to the orbit with a relatively short period, the pair AB has been observed by speckle interferometry at the 4.1-m SOAR telescope 14 times, from 2007.8 to 2019.6. The instrument and data processing are described by Tokovinin (2018b). Only once, in 2013.74, the star was resolved at 140.15°, 0.032″, and $\Delta m = 0.59$ mag. The remaining non-resolutions contradict the orbit by Docobo et al. (2016), which predicts separations from 0.09″ to 0.17″ for the epochs of these observations, while WDS gives $\Delta m = 0$ mag. The SOAR measurement on 2013.74 was used in the orbit calculation and, consequently, it fits the orbit.

We examined all archival speckle data from SOAR and confirmed that they are of adequate quality. Hence, the non-resolutions of A2909AB are reliable and not caused by the poor data. The resolution in 2013.74 merits a special discussion. As usual, two concecutive data cubes, of 400 frames each, were recorded with individual exposure time of 5 ms. The filter y (wavelength 543 nm, bandwidth 22 nm) was used. The zenith distance was 24.2°, and the atmospheric dispersion was corrected in the instrument. The power spectra computed from the two data cubes are similar and show an obvious elongation (Fig. 1). The two objects observed just before, STF 147 and HDS 441, do not have such elongation; the first is used as a reference for deriving the separation, position angle, and Δm of A92909AB.

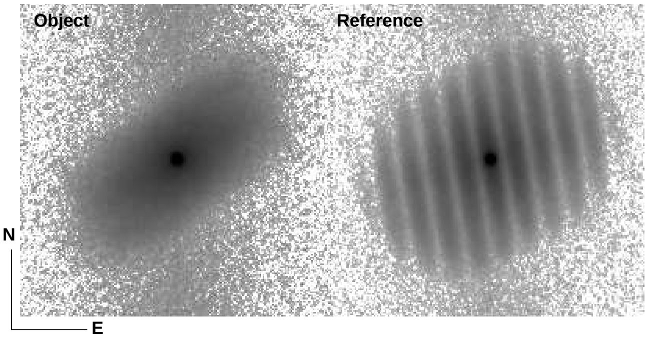

Figure 1: Power spectrum of A2909AB recorded at SOAR in the y filter on 2013.74. It is displayed on the negative logarithmic stretch on the left and is accompanied by the reference spectrum (binary STF 147) on the right, used to derive the position and Δm of A2909AB. Two similar data cubes of the object and reference recorded on the same night are available.

Could the observed elongation of the power spectrum be spurious? It corresponds to the horizontal direction, hence should not be caused by the uncorrected atmospheric dispersion. Moreover, we checked that the prisms were positioned correctly by comparing their settings with preceding and following observations (the prism angles are recorded in the FITS headers). Telescope vibration can blur the speckles as well. The SOAR telescope is known to vibrate occasionally at 50 Hz (Tokovinin, 2018b). However, the short exposure time of 5 ms (1/4 of the vibration period) largely mitigates the elongation caused by vibrations. Furthermore, we do not see such elongation in other objects observed before and after A2909AB. In conclusion, the doubling of A2909AB observed at SOAR on 2013.74 appears to be real, although its instrumental nature cannot be totally ruled out. The non-resolutions on other visits are very secure. The star C, at 17″ from AB, is much fainter than AB and could not be confused with it.

Table 1: Main parameters of A2909AB and A2909C

Parameter	AB	C	Reference
R.A. (J2000)	03:24:24.73	03:24:23.89	Gaia DR2[a]
Dec. (J2000)	−15:39:13.8	−15:39:17.2	Gaia DR2
Parallax (mas)	19.531 ± 0.043	19.673 ± 0.038	Gaia DR2
PM (mas yr^{-1})	221.29, −100.65	218.05, −100.18	Gaia DR2
RV (km s^{-1})	29.98 ±0.15	30.31 ±0.56	Gaia DR2
V (mag)	7.51	12.70	SIMBAD
K (mag)	6.05	8.66	SIMBAD
Sp. type	G1/2V	M0?	SIMBAD

[a] Gaia collaboration (2018)

3 Previous resolutions, orbit, and other data

All 13 visual observations of A2909AB recorded in the WDS database were kindly provided by B. Mason. In 7 cases the pair was measured (separations from $0.12''$ to $0.14''$), in one case only the elongation was noted, and in 5 other visits the pair was unresolved. The pair was also unresolved by *Hipparcos* and by *Gaia* (otherwise *Gaia* would not measure accurate parallax and PM). Comparison between the PMs and positions measured by these satellites shows that the astrometric acceleration does not exceed 0.1 mas yr^{-1} – a stong indication that this star is not a binary.

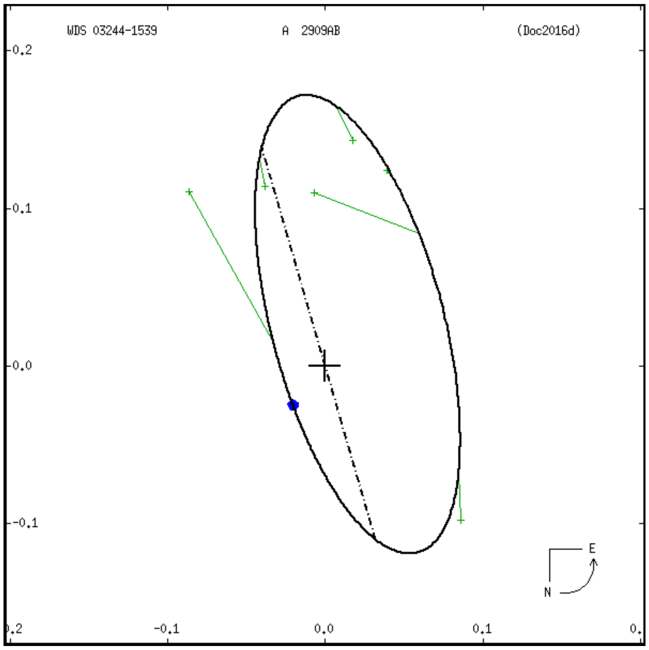

Figure 2: The orbit of A2909AB by Docobo et al. (2016) as represented in the Sixth Orbit Catalog: P = 11.35 yr, e = 0.507, $a = 0.172''$, and i = 71.4°. The SOAR measure is plotted by the blue circle.

The orbit of A2909AB computed by Docobo et al. (2016) is shown in Fig. 2. It is based on the 7 visual measures and on one speckle measure at SOAR, depicted by the blue circle and flipped to $\theta = 320°$. With the *Gaia* parallax, the orbit corresponds to the mass sum of 5.3 $\mathcal{M}_\odot$, while the mass sum estimated from the absolute magnitudes of A and B (as given by the WDS) is 2.05 $\mathcal{M}_\odot$. The orbit is suspicious, despite the grade 3 assigned to it in the Sixth Orbit Catalog (Hartkopf, Mason & Worley, 2001). Although the semimajor axis and period of AB do not quite match the expected mass sum, they are mutually consistent. A pair of solar-type stars of $0.1''$ separation at 50 pc distance should have the period of the order of 10 years. So, the non-resolutions at SOAR during 12 years are highly significant and mean that the star A2909AB is not a binary (incidentally, the wide pair AB,C is a binary).

Believed to be a close binary, this star has attracted attention of other observers. Notably, the survey by Nordström et al. (2004) reports 43 radial velolcity (RV) measurements over a time span of 6676 days (18.3 yr). The mean RV is 29.40 km s^{-1}, the rms scatter is 0.3 km s^{-1}, and the probability that such a scatter is caused by measurement errors (in other words, that the RV is constant) is $P(\chi^2) = 0.83$. *Gaia* measured a similar RV (Table 1). On the other hand, a 10-year binary is expected to have an RV amplitude of ∼15 km s^{-1} multiplied by the inclination factor $\sin i$. This factor is large ($i = 71°$) according to Docobo et al. (2016). So, the constant RV strongly contradicts the claimed binarity of A2909AB. Apparently, this object is being monitored in search of exoplanets using HARPS (Sousa et al., 2011). It has been targeted by several spectroscopic studies of abundance, and none of those mentions double lines.

The photometry and parallax listed in Table 1 place the stars AB and C on the main sequence in the color-magnitude diagram. If AB were a close pair of equal stars, it would be located at 0.75 mag above the main sequence.

4 Discussion

The object A2909AB is a single star occasionally resolved as a double, similarly to A3010. Those two ghosts have several common features. Both are nearby solar-type stars. They were resolved at separations of the order of $0.1''$ with $\Delta m = 0$ (equal components). The position angles appear random (erratic), and the orbits computed from the historic measurements contradict modern speckle non-resolutions. Evidently, these orbits are spurious.

If the occasional image doubling of these stars is (or was) real, what could cause it? Light can be deflected by refraction or by a gravitational field, splitting the image in two or more components. For example, we might envision that the star is surrounded by a thin gaseous disc with a strong vertical density gradient that refracts the rays. If such a disc is on the line of sight, we would see two refracted images of the central star on both sides of the disc. However, deviation of light by a refracting medium or by a gravitational field is usually accompanied by the wave-front curvature and by the corresponding change of the flux. Only a perfect prism deviates the light without affecting the flux, but a prism cannot double the image. Substantial photometric variability of the two ghost binaries discussed here would have been noticed (e.g. by *Hipparcos*). Therefore, the image doubling of ghosts by a hypothetical lens (either refractive or gravitational) located on the line of sight seems unlikely.

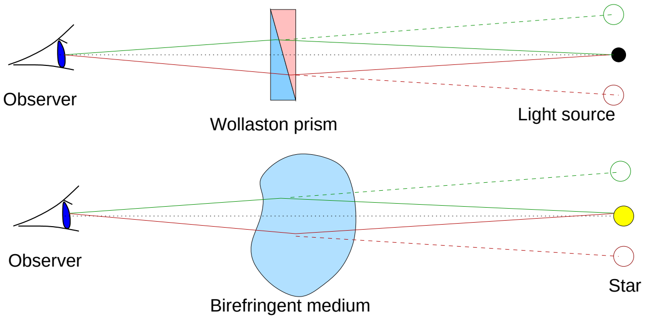

Figure 3: Doubling of the image of a light source caused by the polarizing Wollaston prism (top) and doubling of the image of a star by a hypothetical birefringent cloud (bottom). Green and red lines depict the light rays with different polarizations.

Gravitational waves stretch the image in one direction and compress it in another direction without changing the flux. The amplitude of a gravitational wave needed to split the image by $\sim 0.1''$ (10^{-6} radians) is many orders of magnitude larger than expected from natural sources of gravitational radiation, even if the wave is aligned with the line of sight, amplifying the effect. So, this exotic hypothesis is also unlikely.

If the doubling were caused by a hypothetical polarising medium on the line of sight, there would be no flux variation, and the resulting pair would always have $\Delta m = 0$, as observed. Moreover, the gravity center of the blended image would not be displaced, and there would be no detectable astrometric effect. So, a "Wollaston" prism on the line of sight splitting the light in two linear or circular polarizations could explain the doubling of ghosts. In this case, the two components would be strongly polarized, and this can be verified by speckle polarimetry (Safonov et al., 2019) or by a polarization-dependent displacement of the image photo-center.

Figure 3 illustrates image doubling produced in the laboratory by a Wollaston prism and a similar hypothetical doubling of stellar image that could be produced by a birefringent medium on the line of sight. In the latter case, the linear distance between the polarized images separated by $0.1''$ in angle would be $\sim$5 au if the star is at 50 pc distance. The size of the birefringent cloud should be of the same order or larger. Typical relative velocities of stars in the Galactic disc are $\sim$15 km s^{-1} or $\sim$3 au yr^{-1}. So, a chance alignment between the polarizing cloud and the star could be preserved on a time scale of the order of a year.

We prefer not to speculate on the nature of hypothetical "Wollastons" in the interstellar medium. Note, however, that interstellar scintillation of pulsars reveals the existence of elongated sheets of ionized interstellar gas, presumably shaped by magnetic fields, that deviate and split images of pulsars in the radio domain (Gwinn, 2019).

Despite the facts presented here, the phenomenon of ghosts remains elusive and still needs confirmation. Repeated doubling of a single star recorded by modern speckle interferometers would provide such a confirmation. We continue to revisit the known ghosts A3010 and A2909AB at SOAR in hope of detecting a new doubling. Obviously, ghosts (if they exist) are rare, and the chances of catching a new doubling are small. If the doubling is detected, a polarization test should be made as soon as possible.

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