Contrib. Astron. Obs. Skalnaté Pleso **55/3**, 484 – 486, (2025)
https://doi.org/10.31577/caosp.2025.55.3.484

Kinematic solutions in the Washington Double Star catalog: adding 169,000 orbits to the Visual Orbit catalog

R.A. Matson[1], **B.D. Mason**[1] **and S. Stepanoff**[1,2]

[1] *U.S. Naval Observatory, 3450 Massachusetts Avenue NW, Washington, D.C. 20392, USA (E-mail: rachel.a.matson2.civ@us.navy.mil)*

[2] *Georgia Institute of Technology, North Avenue, Atlanta, GA 30332, USA*

Received: November 15, 2024; Accepted: January 3, 2025

Abstract. The Washington Double Star catalogs, maintained by the US Naval Observatory, are the world's principal database of astrometric double and multiple star information. Double stars showing significant relative motion are catalogued in the Sixth Catalog of Orbits of Visual Binary Stars (ORB6), a compilation of visual and astrometric orbits of more than 3500 binaries, and the Second Catalog of Rectilinear Elements (LIN2). The current status of each catalog and ongoing work to produce a new orbit catalog incorporating the ∼160,000 astrometric obits from Gaia DR3 are presented.

Key words: binary stars – multiple stars

1. Introduction

The US Naval Observatory (USNO) double star catalogs include kinematic solutions for stars showing significant relative motion. The Sixth Catalog of Orbits of Visual Binary stars[1] (ORB6; Hartkopf et al., 2001) is part of a series of compilations of visual binary star orbits begun in the 1930's. The Second Catalog of Rectilinear Elements[2] (LIN2) provides linear fits for pairs of stars whose motion does not appear to be Keplerian. LIN2 was most recently updated in July 2024 and contains linear fits for 1,288 pairs.

2. The Sixth Catalog of Orbits of visual binary stars

ORB6 currently contains 3,655 orbits of 3,539 systems and is updated regularly using orbits published in the literature. The catalog provides the J2000 coordinates, Washington Double Star (WDS; Mason et al., 2001) designation, orbital elements, grades, notes, and references, as well as additional parameters

[1]https://crf.usno.navy.mil/wds-orb6
[2]https://crf.usno.navy.mil/wds-lin2

and ephemerides for each system. Each orbit is graded from 1 (definitive) to 5 (tentative) based on the orbital coverage, weighted rms residuals, and number of revolutions observed. While primarily made up of visual orbits, the catalog also contains ∼40 incomplete (grade 7), ∼20 interferometric (grade 8), and ∼500 astrometric (grade 9) orbits.

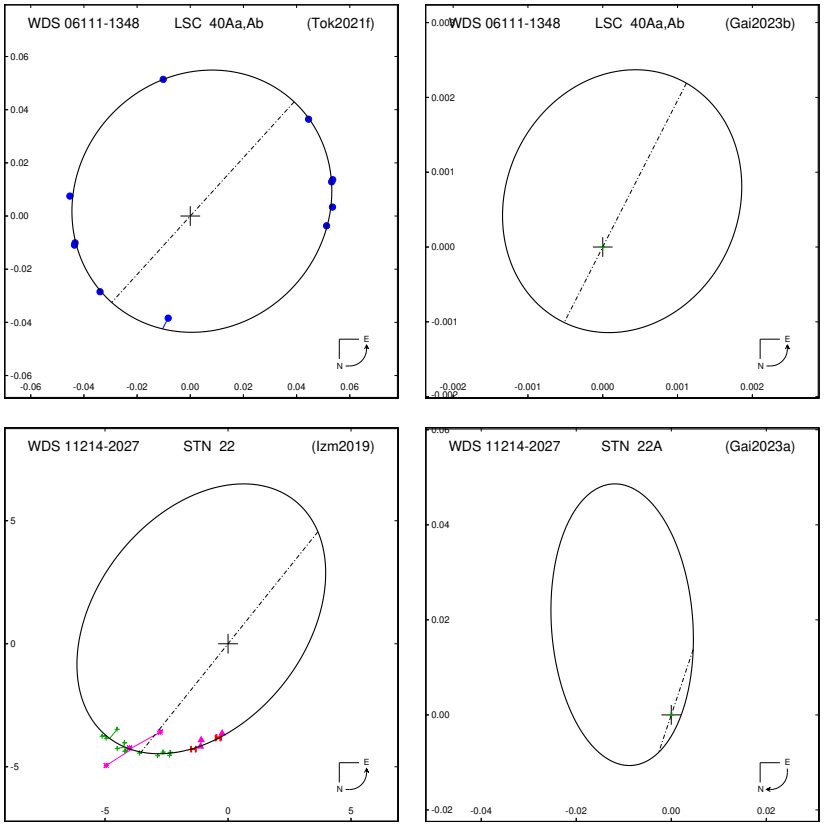

Figure 1. Examples of common (top) and hierarchical (bottom) systems from ORB6 (left) and Gaia DR3 (right). Visual observations are color-coded by technique (blue = speckle, green = micrometry, pink = space-based, red = CCD).

3. The Seventh Catalog of Orbits of visual binary stars

Gaia DR3 (Gaia Collaboration et al., 2023) includes a catalog of non-single-stars with astrometric orbital solutions for approximately 169,000 binary stars (Halbwachs et al., 2023; Holl et al., 2023). As a majority of the DR3 astrometric orbits have periods less than 1000 days, ORB6 serves as an overlapping and

complementary sample. We are therefore working on a new version of the orbit catalog (ORB7) that will include DR3 astrometric orbits, enabling comparisons between orbits and the identification of hierarchical systems.

We performed a crossmatch between ORB6+WDS and the DR3 astrometric orbits, then split the existing orbit catalog by visual vs. astrometric orbits. Preliminary grades were determined for DR3 astrometric orbits (9.1 – 9.9) based on the orbit significance, efficiency, and number of observations. Verification of the 34 (1800) tentative matches between ORB6 (WDS) and DR3 astrometric orbits is currently underway. The names and Campbell orbital elements for an example common (WDS 06111-1348) and possible hierarchical system (WDS 11214-2027) are provided in Table 1 and the orbits are shown in Figure 1.

Table 1. Orbital elements of common systems in ORB6 and Gaia DR3

Name	P (y)	a ($''$)	i ($^\circ$)	Ω ($^\circ$)	T (y)	e	ω ($^\circ$)	Grade
WDS 06111-1348 Aa,Ab	2.5	0.051	21.1	137.7	2020.0	0.14	184.6	2.2
DR3 2994437527894182272	2.2	0.002	21.6	152.9	2015.2	0.37	184.4	9.5
WDS 11214-2027 AB	1028.1	6.532	49.3	141.3	2072.5	0.35	267.2	5.4
DR3 3545469496823737856	13.4	0.054	110.2	161.5	2016.6	0.90	107.7	9.5

For Gaia DR3 orbits, a$''$ is the semi-major axis of the photocentric orbit (a_0).

References

Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al., Gaia Data Release 3. Summary of the content and survey properties. 2023, *Astronomy and Astrophysics*, **674**, A1, DOI:10.1051/0004-6361/202243940

Halbwachs, J.-L., Pourbaix, D., Arenou, F., et al., Gaia Data Release 3. Astrometric binary star processing. 2023, *Astronomy and Astrophysics*, **674**, A9, DOI:10.1051/0004-6361/202243969

Hartkopf, W. I., Mason, B. D., & Worley, C. E., The 2001 US Naval Observatory Double Star CD-ROM. II. The Fifth Catalog of Orbits of Visual Binary Stars. 2001, *Astronomical Journal*, **122**, 3472, DOI:10.1086/323921

Holl, B., Sozzetti, A., Sahlmann, J., et al., Gaia Data Release 3. Astrometric orbit determination with Markov chain Monte Carlo and genetic algorithms: Systems with stellar, sub-stellar, and planetary mass companions. 2023, *Astronomy and Astrophysics*, **674**, A10, DOI:10.1051/0004-6361/202244161

Mason, B. D., Wycoff, G. L., Hartkopf, W. I., Douglass, G. G., & Worley, C. E., The 2001 US Naval Observatory Double Star CD-ROM. I. The Washington Double Star Catalog. 2001, *Astronomical Journal*, **122**, 3466, DOI:10.1086/323920