GRAVITY Astrometry of the Young Triple Star TWA5

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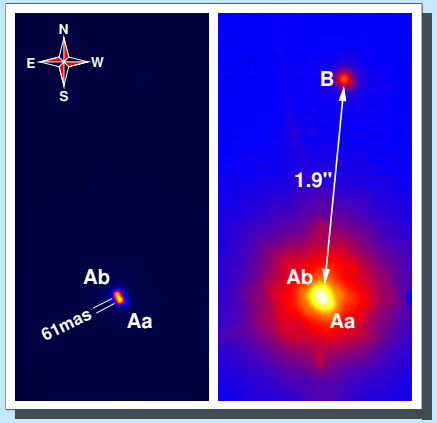
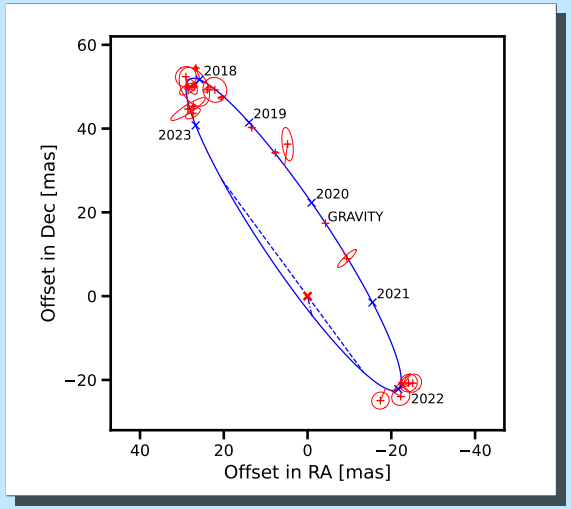
Introduction

TWA 5 is one of the 5 original members of the TW Hydrae association.
It consists of three components: a pair of low-mass stars, **TWA 5Aa-Ab**, and a brown dwarf companion, **TWA 5B**.
TWA 5Aa-Ab had a separation of 55 mas when it was discovered in 2000, while TWA 5B is located about 2 arcsec away. In Köhler et al. (2013, A&A 558, A80), we presented an orbit fit for TWA 5Aa-Ab with a period of ∼6 years. We also used TWA 5B as astrometric reference to solve for the individual orbits of Aa and Ab. This allowed us to estimate the mass ratio of Aa and Ab.
The configuration of the triple makes it an ideal target for GRAVITY. It can measure the visibility of the inner binary, and simultaneously obtain the astrometry of the third component. Furthermore, most of the inner binary's orbit can only be resolved by long-baseline interferometry.
We obtained two observations of TWA 5 with GRAVITY in March 2020.



Left: Image of TWA 5 taken with NACO in Jan 2012.
Both panels show the same image, on the left with a linear scale, on the right with a logarithmic scale to unveil the low-mass companion TWA 5B.

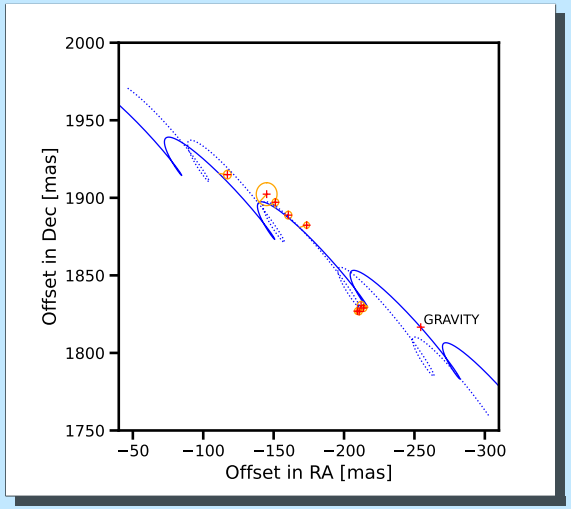
The orbit of TWA Aa-Ab



The orbit of TWA Ab around component Aa.
Observed positions are marked by their error ellipses. Most of them were measured by Keck or NACO, the new GRAVITY point in 2020 is indicated. Its error ellipse is much smaller than the symbol size. The dash-dotted line indicates the line of nodes, the solid line the periastron. Crosses mark the positions at the beginning of the years 2016 to 2023.

Semi-major axis: 3.27 ± 0.14 AU
Period: 6.03 ± 0.01 years
Eccentricity: 0.77 ± 0.03
Binary Mass M_{Aa+Ab}: $0.96 \pm 0.12\,M_\odot$

The motion of TWA 5 B around Aa



The motion of TWA 5B relative to A.
Observed positions are marked by their error ellipses. The solid line shows the motion of B relative to Aa, i.e. the combination of the orbit of B around the center of mass, and the motion of the center of mass relative to Aa. The dotted line is the old result of fitting the orbits to NACO data, without the new point by GRAVITY.

Semi-major axis: 170 ± 24 AU
Period: 2160 ± 520 years
Eccentricity: 0.4 ± 0.2
Mass ratio M_{Ab}/M_{Aa}: 0.85 ± 0.11

Results

From the binary mass and the mass ratio, we obtain the individual masses of the binary components:

M_{Aa}: $0.518 \pm 0.077\,M_\odot$
M_{Ab}: $0.442 \pm 0.068\,M_\odot$

Our data reduction is based on algorithms originally developed for the PRIMA instrument. We are still working on our understanding of the GRAVITY instrument and how to do astrometry with it. Therefore these results are only preliminary.

Unfortunately, our second GRAVITY observation of TWA 5 in February 2022 turned out to be unusable because of instrumental issues.

Outlook

Despite the difficult data reduction, GRAVITY has already shown to give astrometric measurements an order of magnitude more precise than NACO.

GRAVITY has the potential to become a great tool for orbital monitoring of binary and triple systems. This will allow mass determinations of close binary systems within relatively short timescales.

The unique advantage of GRAVITY is that we can use triples to determine individual masses of the components. This greatly simplifies the comparison with stellar evolutionary models.