Complementary Approaches to Double and Multiple Star Research,
IAU Colloquium 135, ASP Conference Series, Vol. 32, 1992
Harold A. McAlister and William I. Hartkopf (eds.)

Astrometry and Photometry of Trapezium–Type Multiple Stars[1]

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1. INTRODUCTION

Trapezia systems are defined as multiple stars having three or more components with separation ratios in the range 0.3 to 3. The revival of interest in Trapezia is due to their potential astrophysical significance, as they could originate from a single protostar and be in an expansion stage because of their possible positive energy (see, for example, Bernacca 1988 and references therein). Further decisive advancements in understanding the nature of these systems require data for establishing a list of physically bound systems as well as for the systematic study of their kinematics and energetics. In the present progress report we test three representative cases with the combined exploitation of astrometric, photometric, and spectroscopic data.

2. ASTROMETRIC AND PHOTOMETRIC DATA

Our present effort concentrates on a sample of 58 candidate Trapezia extracted from Salukvadze (1978) and included in a list approved by the European Space Agency as proposal No. 168 for observations with HIPPARCOS. Given the limited capabilities of the satellite to observe bright objects too close together, not all the proposed targets have been retained in the final Input Catalog and typically one component (rarely two) of each system is observed. Thus, to make the most out of the HIPPARCOS observations (absolute parallaxes and proper motions), we began gathering accurate astrometric and photometric (UBVRI) data for the above targets. We have also started gathering spectroscopic observations to improve spectral classification and for precise radial velocity measurements. The sample covers both hemispheres. The GPO astrograph (40-cm refractor, scale $\simeq 52''$/mm) and the 50-cm photometric telescope of the European Southern Observatory in La Silla (Chile) are used to take second epoch plates and the UBVRI photometry in the South. For the North, second epoch plates are being taken with the 38-cm photographic refractor (scale $30''$/mm), and photoelectric photometry is done with the photometer attached at the 40-cm reflector both at Torino Astronomical Observatory. Since last year a multi-channel photometer is available at the 105-cm telescope in Torino and a large format CCD will operate at the same telescope within a few months. First epoch plate material comes from the plate collections of Perth Observatory for the southern targets and

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[1]**Based in part on observations taken at the Europen Southern Observatory (La Silla, Chile) on Dec 1988**

from the Vatican Observatory and Catania Observatory for the northern ones. The photographic plates are digitized using the PDS at ESO Headquarters in Munich, PDS No.2 at the Space Telescope Science Institute (Baltimore), and the MADRAF PDS (University of Wisconsin, Madison).

Plate measurements and derivation of proper motions (a baseline of 80 years or more is usually available) is done using the techniques described in Lattanzi *et al.* (1991). A millisecond–of–arc–per–year (mas/yr) precison is routinely achieved (see below). A standard reduction procedure (performed using the SNOOPY package developed and distributed by ESO) gives photometry of 0.01 mag (rms) for the South and 0.02–0.03 mag for the North.

3. TEST CASES

Findings about three proposed trapezium–type multiple systems (Tr) are reported hereafter. Running numbers are from Salukvadze (1978).

3.1. Tr33

In Figure 1 we show the (relative) proper motions (arrows) in the field of Tr33 (WDS 02434+5529). It is indicated as a 3-component Trapezium system although component C is a close double. Separations (ρ) and position angles (PA) are $\rho_{AB} = 28''.3$, $PA_{AB} = 300°$, and $\rho_{AC} = 66''.6$, $PA_{AC} = 268°$, respectively. Approximate magnitudes are $V_A = 3.9$, $V_B = 7.9$, and $V_C = 9.9$. The primary component is classified as M3Ib-II (HD 17506). The spectral type is presently unknown for the other two components.

The proper motions (average rms error $\simeq$ 1 mas/yr) show component C in a very different apparent kinematical state than A and B, which would indicate that this is only an optical association made of the close visual binary C and the common proper motion pair AB [Note that the physical association of components C1 and C2 is consistent with our proper motions.] However, that is still not enough to conclusively question the physical reality of this trapezium. Indeed, its distance could be such that, assuming the three components are gravitationally bound, the proper motions are the reflection of 'internal' motions due to the mutual interactions. The spectral type of the primary is consistent with a mass of about 20 $\mathcal{M}_\odot$ and a spectroscopic parallax (Schmidt–Kaler 1982) of 200 pc. At this distance (projected) linear separations are $S_{AB} \simeq 0.03$ pc and $S_{AC} \simeq 0.06$ pc, and our proper motions have a 'resolution' of better than 1.5 $\mathrm{km\,s^{-1}}$. The resulting relative tangential velocities are $\Delta V_t(AB) \simeq 8$ $\mathrm{km\,s^{-1}}$ and $\Delta V_t(AC) \simeq 27$ $\mathrm{km\,s^{-1}}$. These velocities are not inconsistent with internal motions driven by interaction with a rather massive star as component A.

It is clear that in this case the HIPPARCOS measurements and further accurate spectroscopic data (classification and radial velocities) are necessary to unravel the nature of this system.

3.2. Tr121

In Figure 2 we show the proper motions in the field of Tr121 (WDS 07019-3438). It is indicated as a 3-component Trapezium system. Component A is a close double ($4''.9$ separation — unresolved on our plates — and $\Delta m = 0.9$).

https://doi.org/10.1017/S0252921100006618 Published online by Cambridge University Press

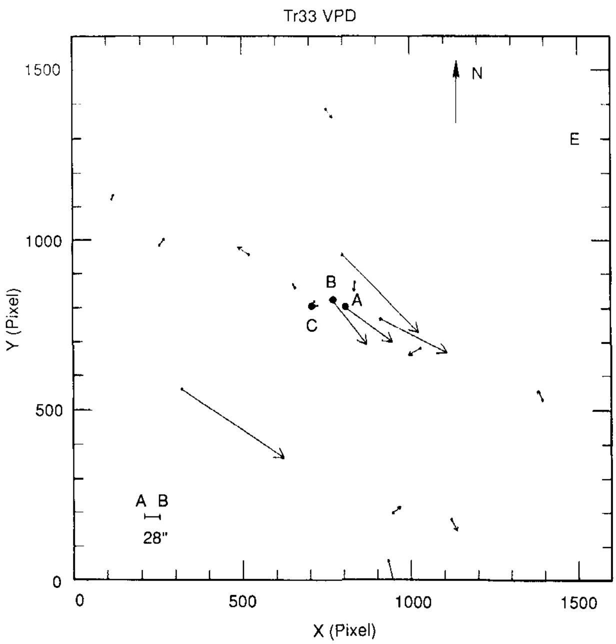

FIGURE 1. **Proper motion distribution in the field of Tr33. Component A has a proper motion of 29 mas/yr, component B of 26 mas/yr, and C (average) of 2 mas/yr.**

Separations and position angles are ρ_{AB} =37″.2, PA_{AB} = 287°, and ρ_{AC} = 38″.7, PA_{AC} =125°, respectively.
Precise magnitudes from our southern photometry are V_A = 6.14 (A1+A2), V_B = 9.74, and V_C = 11.40. The primary component is classified as F2V (HD 53952). There is no spectral type listed for the other two components.

The proper motion average (rms) error is < 1 mas/yr. It is evident that components A and B form a common proper motion pair, the slight deviation of the proper motion of A being probably the result of its larger — 2 mas/yr — error due to the image structure of this close double). Following the same arguments given for Tr33, the spectral type of the primary is consistent with a mass of about 1.5 $\mathcal{M}_\odot$ and a spectroscopic parallax of 40 pc. At this distance linear separations are $S_{AB} \simeq S_{AC} \simeq$0.007 pc, and our proper motions have a 'resolution' of 0.2 km s^{-1}. The resulting relative tangential velocities are $\Delta V_t(AB) \simeq$1.5 km s^{-1} and $\Delta V_t(AC) \simeq$11 km s^{-1}. Again, these velocities are not inconsistent with the internal motions of a gravitationally bound system of low mass stars.

3.3. Tr293

In Figure 3 we show the proper motions in the field of Tr293 (WDS 19301+6306). It is classified as a 3-component Trapezium system. Separations and position angles are ρ_{AB} = 47″.5, PA_{AB} = 279°, and ρ_{AC} = 21″.1, PA_{AC} = 291°, respectively.

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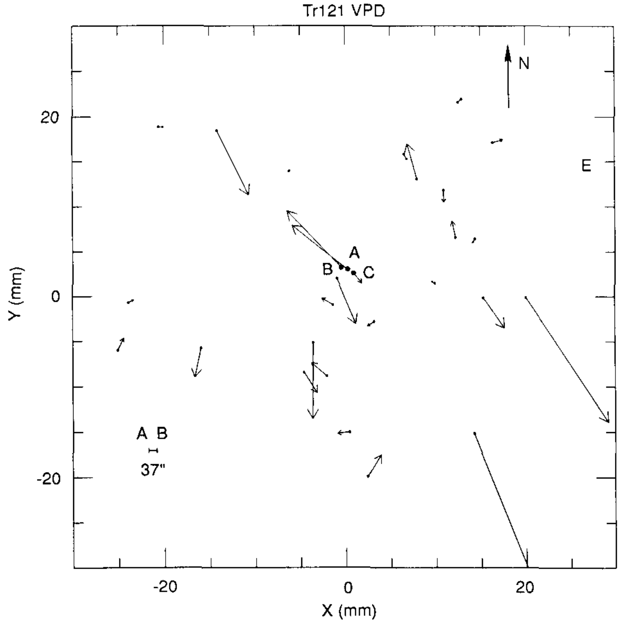

FIGURE 2. Proper motion distribution in the field of Tr121. Proper motions are 50 mas/yr, 55 mas/yr, and 9 mas/yr for components A, B, and C respectively.

This system is somewhat special as all three components are AGK3 stars, and their absolute proper motions have been recently measured during the construction of the AGK3U (Bucciarelli *et al.* 1992). This offers us a unique opportunity to externally check our derivations. The proper motions derived in this study agree in sign and modulus with those listed in the AGK3U within the mean errors of the catalog (6 mas/yr). The largest deviation is 12 mas/yr for the proper motion in the Y-axis of component C. This is a remarkable agreement considering that ours are relative motions and the X,Y axes of our scans are slightly rotated from the North–South and East–West directions.

The AGK3 lists the primary component A as K0 (HD 184563) and component B as A0 (HD 184562). From this, components A and B would be spatially close only if their complete classification is K0III and A0V respectively (some 300 pc from us). [HIPPARCOS is observing both component A and component B of this trapezium.] From standard tables we then derive, after transformations of the AGK3 magnitudes (m_{pg}) into the V system, the magnitudes $V_A = 7.9$, and $V_B = 8.2$. The blue magnitude of component C, which spectral type is unknown, is $B_C = 11.51$. Also, the mass of the primary is $\mathcal{M}_{K0III} \simeq 4\ \mathcal{M}_\odot$ and that of the secondary is $\mathcal{M}_{A0V} \simeq 3\ \mathcal{M}_\odot$.

The proper motion average (rms) error is $\simeq$ 2 mas/yr. At 300 pc separations are $S_{AB} \simeq 0.07$ pc and $S_{AC} \simeq 0.03$ pc, and the proper motions have a resolution of more than 3 km s^{-1}. The resulting relative tangential velocities are $\Delta V_t(AB) \simeq 78$ km s^{-1}, and 54 km s^{-1} for C relative to A.

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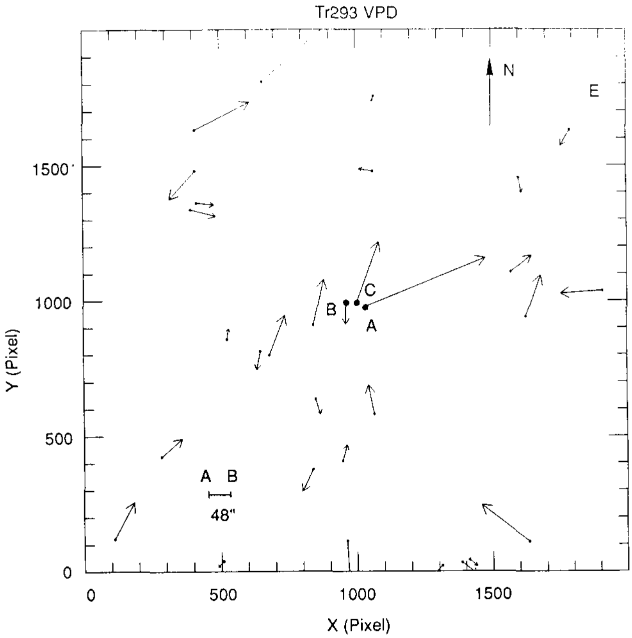

FIGURE 3. Proper motion field in the region of Tr 293. Component A has a proper motion of 51 mas/yr, component B of 7 mas/yr, and C (average) of 25 mas/yr.

4. ACKNOWLEDGMENTS

We would like to thank Dr. C. Anderson, Andrea Schweitzer (Department of Astronomy, University of Wisconsin), and Dr. K. Cudworth for let us use the MADRAF machine and for many helpful advices during the measuring stage. Our appreciation goes to Dr. M. Candy (Perth Observatory) and Father G. Coyne (Vatican Observatory) for lending us their precious material.

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