Section 2.3

Hipparcos Catalogue: Double and Multiple Systems Annex

2.3. Hipparcos Catalogue: Double and Multiple Systems Annex (DMSA)

2.3.1. Overview of the DMSA

The main Hipparcos Catalogue (Volumes 5–9) contains the principal astrometric and photometric results on all stellar objects observed with the satellite. For the majority of apparently single objects this adequately summarises the Hipparcos observations in terms of the standard astrometric single-star model, represented by the five parameters α, δ, π, $\mu_{\alpha*}$, μ_δ (see Section 1.2.8).

For a number of double and multiple stars the single-star model was not sufficient to represent the observations to within their intrinsic uncertainties, and more complex models, involving additional parameters, had to be used. The complementary information derived from these solutions are given in Volume 10 of the Hipparcos Catalogue, containing the Double and Multiple Systems Annex (DMSA).

The models (or solutions) used for the manifestly or suspected non-single stars are of five different kinds. Accordingly, the DMSA is divided into the five parts:

DMSA/C: Component solutions
DMSA/G: Acceleration solutions
DMSA/O: Orbital solutions
DMSA/V: 'VIM' (variability-induced movers) solutions
DMSA/X: Stochastic solutions

The various models are briefly explained below, and in some detail in the following sections. In the printed catalogue, the fields (or columns) are identified by numbers shown in the column header on every page. To avoid confusion between the different parts of the DMSA these fields are normally referenced by letters DC, DG, DO, DV and DX followed by the number in the column header.

Component Solutions: The component solutions in DMSA/C comprise resolved systems in which the individual components were modelled similarly to the single stars, using, for each component, five astrometric parameters and a magnitude. Clearly this applies to 'optical' double stars, but also to long-period binary and multiple systems, where the configuration of components remains approximately fixed over the observing interval, or where the relative motions can be represented as linear functions of time (i.e. by assigning different absolute proper motions to the different components). The layout of this information in the printed DMSA/C mirrors the corresponding columns of the main catalogue, except that the data are given for each component.

Acceleration Solutions: DMSA/G lists apparently single (unresolved) stars, for which the motion appears to be significantly non-linear. They are probably 'astrometric binaries': either too close to be resolved ($\varrho \lesssim 0.1$ arcsec), or with a companion too faint to be seen by Hipparcos. If an orbital solution can be obtained, usually with the help of ground-based data, then the result is given in DMSA/O. In DMSA/G only those (long-period) astrometric binaries are included for which the motion of the photocentre, as observed by Hipparcos, could be adequately described by quadratic or cubic polynomials in time. DMSA/G contains the non-linear terms of their motions. (The 'G', as well as the designations g and $\dot{g}$ chosen for the acceleration terms, derive from the word 'gravity'.)

Orbital Solutions: DMSA/O contains results for orbital binaries where the Hipparcos observations could be used to determine some or all of the elements of the *absolute* Keplerian orbit of the system's photocentre. These solutions often involve ground-based data for the determination of certain orbital elements (such as the period), and the sometimes complex interdependence of space and ground-based data cannot easily be specified in compact form. Therefore, only the main results of the orbital solutions are given in a simple tabular form, while detailed discussions of the individual systems will be published separately.

VIM Solutions: 'Variability-Induced Movers', or VIMs, are unresolved binaries in which one of the components is variable. The photocentre of such a system shows a specific motion on the sky, coupled to the system's total brightness variation. Specification of the variability-induced motion requires two additional parameters that can be determined together with the normal five astrometric parameters used for single stars. DMSA/V contains the additional parameters and reference data describing the VIMs.

Stochastic Solutions: DMSA/X finally lists the objects for which no solution of the previous types could be found in reasonable agreement with the standard errors of the Hipparcos observations. These objects could be double or multiple stars of unknown characteristics, or short-period astrometric binaries for which the displacement of the photocentre from the assumed linear motion of the centre of mass mimics a random scatter among the individual observations. In this case a stochastic model was adopted for the deviations from a linear motion, by postulating the presence of a non-zero physical scatter in excess of the measurement noise. DMSA/X lists the excess scatter or 'cosmic error' of these objects, the 'X' symbolising its unknown origin.

G, V and X type solutions are new classifications of astrometric phenomena, made possible by the specific observational capabilities of Hipparcos. In particular the high positional accuracy obtained in numerous individual observations spread over a relatively short time interval (few years) enables the detection of small deviations from the expected uniform motion of an apparently single star. Such deviations are most likely manifestations of the binary nature of the star, and as such belong in the DMSA of the Hipparcos Catalogue.

The relations between the astrometric parameters given in the main catalogue and the additional information in the G, O and V parts of the DMSA are further illustrated in Figures 2.3.1–3. In these, the motion according to the five astrometric parameters in the main catalogue is represented by the dashed line, while the solid curves describe the superposed non-linear motions of the photocentre as represented by the additional parameters in the DMSA.

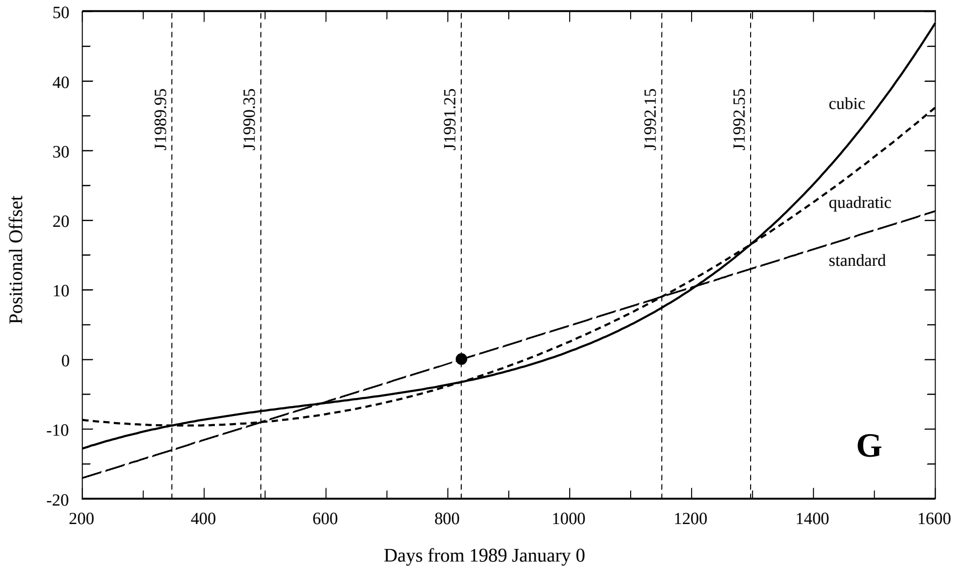

Figure 2.3.1. *Schematic representation of the barycentric position of the photocentre, as a function of time, in a 'G' type (acceleration) solution. The curves marked 'quadratic' and 'cubic' illustrate the positional offset in one coordinate (e.g. right ascension) for a solution including the g terms (quadratic), and g and $\dot{g}$ terms (cubic). The dashed line marked 'standard' represents the offset for the standard model (Section 1.2.8) using only the five astrometric parameters given in the main catalogue. The heavy dot, in particular, corresponds to the position at the catalogue epoch J1991.25 as given in Field H8 or H9 of the main catalogue, and the slope of the dashed line corresponds to the proper motion in Field H12 or H13. Note that these parameters approximately describe the mean motion over the mission interval, rather than the instantaneous motion at 1991.25. See Section 2.3.3 for the significance of the epochs J1989.95, J1990.35, J1992.15 and J1992.55.*

Combinations of the five models C, G, O, V and X could well be envisaged, but for reasons of logistics no overlap has been allowed between the five parts of the DMSA. A given HIP entry consequently occurs in at most one of them, as specified by the flag (C, G, O, V or X) in Field H59 of the main catalogue. An alternative interpretation of the object may nevertheless be indicated among the Notes. (The presence of a note is flagged in Field H70 of the main catalogue and in the corresponding field of the DMSA: DC6, DG12, DO17, DV12, or DX4.)

The decision as to which model to adopt for an object is made according to the following list of priorities:

1. Component solutions
2. Orbital solutions
3. VIM solutions
4. Acceleration solutions
5. Stochastic solutions
6. Single-star solutions
7. Invalid solutions (not retained in the published catalogue)

That is, a component solution, if significant and of acceptable quality, takes precedence over an orbital solution of the same HIP entry, etc. This particular order of priorities is

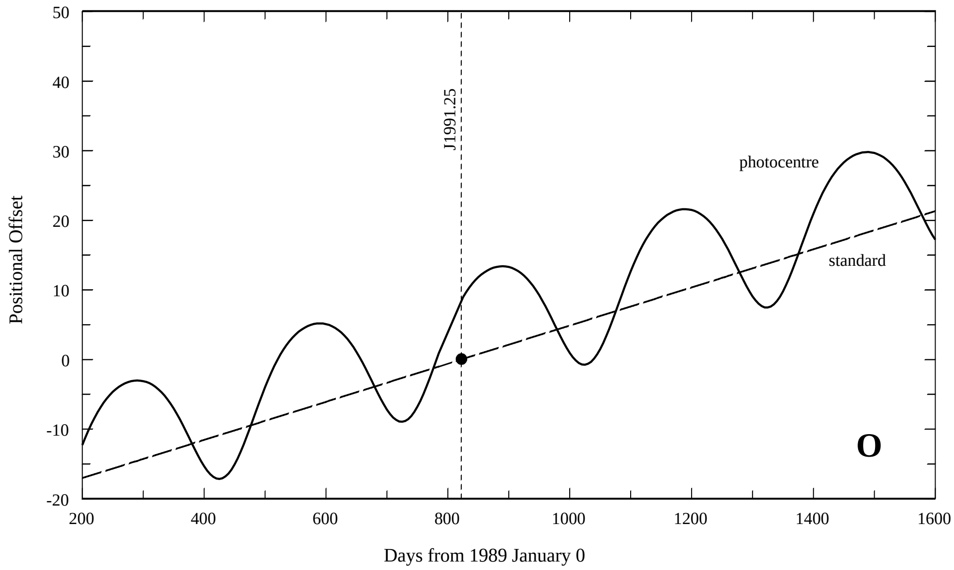

Figure 2.3.2. *This figure illustrates the motions of the photocentre (solid curve) and centre of mass (dashed line) in an 'O' type (orbital) solution. The main catalogue gives, in this case, the astrometric parameters for the centre of mass.*

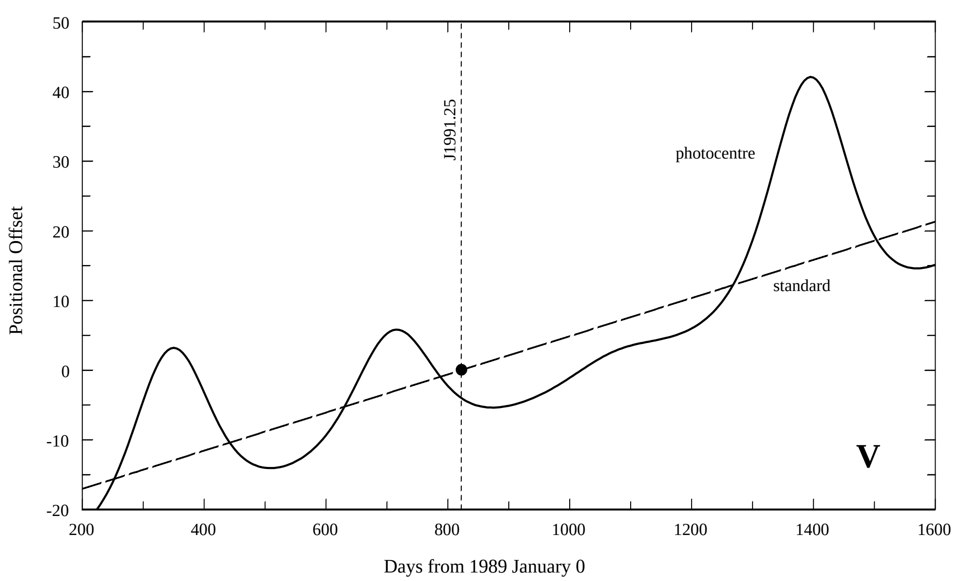

Figure 2.3.3. *For a 'Variability-Induced Mover' (VIM) the photocentre (solid curve) describes an oscillating motion between the binary components in phase with the variations of the total luminosity of the system. The dashed line, corresponding to the astrometric parameters in the main catalogue, gives the hypothetical motion of the photocentre, had the total magnitude been constant and equal to the reference magnitude in Field DV2.*

mainly based on practical considerations in the complex task of assembling the DMSA from several different processes; there is consequently no guarantee that the best solution was invariably selected for each object, although in general the classification was unproblematic. It should be noted however that the adopted criteria for accepting or rejecting a particular kind of solution are always to some extent arbitrary, and could greatly affect the number of objects in each category.

In practice, for the entries remaining after the resolved double and multiple stars (part C), orbital astrometric binaries (part O), and VIMs (part V) had been selected, the choice between the G solutions (7-parameter, g; or 9-parameter, $\dot{g}$) and X solutions was made as follows, depending on the rejection (outlier) rate F1 and the goodness-of-fit F2 (as described in further detail in subsequent sections):

– the 9-parameter solution was chosen if significant ($F_{\dot{g}} > 3.44$), if the goodness-of-fit F2 < 4, if F1 < 7 per cent, and if the 7-parameter solution would otherwise have been accepted (the resulting g terms may or may not be significant);

– the 7-parameter solution was chosen if significant ($F_g > 3.44$), if the goodness-of-fit F2 < 4, and if F1 < 7 per cent;

– the X solution was chosen if significant (cosmic error > 5σ) or if the 5-parameter solution would give F1 > 20 per cent; the X solution was however rejected if the associated cosmic error exceeded 100 mas;

– otherwise the 5-parameter solution was chosen.

For a few hundred stars no sensible solution could be found according to this scheme. In a stochastic solution they would have had an unphysically large cosmic error, while in a standard 5-parameter solution most of the observations would have been rejected. These are most likely strongly affected by unresolved grid-step errors, in which case neither solution would be useful. No astrometric data is provided for these objects.

Field H59 is the pointer from the main catalogue to the relevant part of the DMSA. The detailed information in parts G, O, V and X of the DMSA is given under the corresponding HIP number. In contrast, the data in DMSA/C are given according to the CCDM numbers (see Section 1.4.4) and component identifiers (a single letter). The reason for this is that the HIP number of systems in part C has no simple relation to the double and multiple systems or their components: a given HIP number may correspond to several components, while a given double or multiple system may contain components with different HIP numbers. The entry point to DMSA/C is thus provided by the CCDM identifier given in Field H55 of the main catalogue.

Although the DMSA (together with the main catalogue) provides the full details of the solutions for the non-single object models, the main astrometric and photometric parameters are always given in the main catalogue. These data must then be interpreted with some caution, as they are necessarily incomplete. For example, the position and proper motion given in the main catalogue may refer to a particular component of a resolved binary, to the photocentre or centre of mass of the system, or to the mean motion of the system over the Hipparcos mission. The flags in Fields H10 and H57–60 must be consulted to ensure proper interpretation of the main astrometric data; similarly Fields H36, H43 and H48 must be consulted for the main photometric data.

2.3.2. DMSA/C: Component Solutions

The Component Solutions part of the DMSA (DMSA/C) contains the Hipparcos results on double and multiple stars resolved into distinct components, whose motions can be described, to the precision of the observations, as linear functions of time. This latter condition is generally met for systems having orbital periods longer than several times the length of the observing interval (3.3 years), and applies to the majority of systems resolved by the Hipparcos instrument. General considerations related to the observation and classification of double and multiple systems are given in Section 1.4.

While all other parts of the Hipparcos Catalogue are organised according to the HIP numbers, the unique entry point to DMSA/C is the CCDM identifier of the double or multiple system. This choice was motivated by the fact that, in many cases, two or more different HIP entries had to be treated together in the double-star analysis (typically this applies to systems with a separation between 10 and 30 arcsec, and referred to as 'two-pointing' or 'three-pointing' systems). For a given CCDM number the different components are uniquely identified by letters (A, B, ...). A given component is always associated with a single HIP number, namely that under which it was observed by the Hipparcos satellite; the reverse relation is however not unique: several components (within a radius of up to 15–20 arcsec) may be associated with the same HIP number.

Each line in the printed DMSA/C corresponds to a single component, as seen by Hipparcos. The system and component identifiers are given in Fields DC1 and DC7, respectively, while the HIP number under which the component was observed is given in Field DC8.

While the system and component identifiers uniquely define each component under consideration, a further identifier is needed to specify which components were jointly considered in a solution for their astrometric and photometric parameters. Normally a double or multiple star solution may be confined to the components within a radius of approximately 30 arcsec from the main star of each HIP entry; more distant companions or field stars can usually be ignored. Since many systems in the CCDM catalogue are much larger than this, it may happen that two independent solutions (involving different sets of components) are made under the same CCDM number. The solution identifier 'S' in Field DC2 was introduced to distinguish between such solutions. It can be regarded as a division of the whole system (as defined by a single CCDM number) into subsystems suitable for the special double and multiple star reduction. A well-known example is the multiple system ϵ Lyr (CCDM 18443+3938), which in the Hipparcos reductions was treated as two independent double stars; in DMSA/C the results are listed under S = 1 for components A and B, and under S = 2 for C and D.

For the user's convenience certain *relative* astrometric information is added in relevant cases (Fields DC25–29): the position angle and separation of one component relative to another and the rate of change of these angles. These data are uniquely derived from the absolute astrometric information in the preceding fields and rounded according to their uncertainties. When an entry contains precisely two components, summary data (including position angle, separation and magnitude difference) are given in the main catalogue, Fields H62–67. Again, these are uniquely derived from the absolute data contained in DMSA/C.

The DMSA/C contains the results of 12 195 solutions, of which 12 005 are double star solutions, 182 triple star solutions, and 8 quadruple star solutions. The total number of components, therefore, is $12\,005 \times 2 + 182 \times 3 + 8 \times 4 = 24\,588$; the number of different HIP entries concerned is 13 211.

The contents of the printed DMSA/C are described in detail below. Further details on the machine-readable version are given in Section 2.3.7, in particular Table 2.3.2.

Field DC1: System Identifier

Field DC1: CCDM number

The Catalogue of Components of Double and Multiple Stars (CCDM), described in Section 1.4.4, provides the principal cross-reference to information on double and multiple systems. In DMSA/C the CCDM number is used as the unique entry to the Hipparcos results on resolved components of double and multiple systems. For previously uncatalogued systems new CCDM identifiers were constructed according to the conventions of the CCDM Catalogue, and the newly-constructed identifiers have been included within the CCDM data base.

The CCDM identifier is based on the approximate equatorial coordinates of the system at epoch and equinox J2000.0, rounded to the nearest 0.1^{m} in α and 1 arcmin in δ (but taking into account other systems in order to guarantee the uniqueness of the identifier). System identifiers already included in the CCDM before the construction of the Hipparcos Catalogue have not been changed.

Fields DC2–6: Solution Details

Field DC2: Solution identifier, S

This field contains a digit (S = 1, 2, ...) identifying different solutions pertaining to the same CCDM number in Field DC1. More than one solution may occur if the system was split up into different parts (regions) subject to separate solutions. This field is related to the 'two-pointing' and 'three-pointing' systems (F, I, L, or P in Field H60) where components having more than one HIP identifier have the same CCDM number (Field DC1 and H55) and the same solution identifier.

The number of solutions for the system is given in the header record of the machine-readable DMSA/C as N_{S}. There are 12 157 systems with $N_{\mathrm{S}} = 1$, 19 with $N_{\mathrm{S}} = 2$ and none with $N_{\mathrm{S}} \geq 3$, resulting in $12\,157 + 2 \times 19 = 12\,195$ solutions in total.

Field DC3: Type of solution

This field provides a summary of the type of double or multiple star solution, and has the following meaning:

- F : fixed double or multiple system: the components are assumed to have identical proper motions and parallaxes;
- I : individual parallaxes and linear (relative) motion (possible optical double star);
- L : linear double or multiple system: the components may have different proper motions, but curved motions are not considered, and the components are assumed to have the same parallax.

The following table summarises what the different solution types imply in terms of constraints and the total number of estimated parameters.

Summary of the properties of the various solution types in terms of constraints among the parallaxes and absolute proper motions of the different components of a system, and the total number of estimated parameters in the solution, including the magnitude of the component (N_P). N_C is the number of components.

Solution Type	Constraints	Number of Parameters
F	same π, $\mu_{\alpha*}$, μ_δ	$3 + 3N_C$
I	no constraint	$6N_C$
L	same π	$1 + 5N_C$

Field DC4: Source of solution

Most solutions are obtained by combining the results from the two data reduction consortia (FAST and NDAC), while some originate from one consortium only:

C : combined FAST+NDAC solution;
F : solution taken from the FAST Consortium only;
N : solution taken from the NDAC Consortium only.

Field DC5: Quality of solution

This provides an indication of the reliability of the double or multiple star solution on a scale from A to D. The quality flag was computed according to the availability, mutual agreement and estimated quality (first/second class) of the individual FAST and NDAC solutions. This was done regardless of whether the adopted solution agreed with ground-based data as given, for instance, in the Hipparcos Input Catalogue. Cases of severe disagreement are instead indicated in a note (see Field DC6). The quality flags can be understood as follows:

A : 'good', or reliable solution: this solution was obtained by combining two first-class solutions in good mutual agreement;
B : 'fair', or moderately reliable solution: based on only one first-class solution, or a combination of a first-class and a second-class solution in mutual agreement;
C : 'poor', or less reliable solution: based on only one second-class solution, or a combination of two second-class solutions in mutual agreement;
D : 'uncertain' solution: this flag is a warning that FAST and NDAC found distinctly different solutions and that a choice between them had to be made according to certain criteria. The source of the retained solution is given in Field DC4. The main parameters (ΔHp, θ, ϱ) of the rejected solution are given among the Notes at the end of the volume (see Field DC6).

Field DC6: Flag indicating a note

Notes are included at the end of the relevant volumes: Volumes 5–9 for general notes, Volume 10 for double and multiple systems, and Volume 11 for photometric notes (see Field H70 for explanation of the Notes system). The flag has the following meaning:
D : double and multiple systems note only;
G : general note only;
P : photometric (including variability notes) only;
W : 'D' + 'P' only;
X : 'G' + 'D' only;
Y : 'G' + 'P' only;
Z : 'G' + 'D' + 'P'.

Fields DC7–8: Component Identifiers

Field DC7: Component identifier

This field contains a single letter (A, B, C, ...) designating the component of the double or multiple system considered in subsequent fields. 'A' designates the primary, usually the brightest component; 'B' the secondary, usually the second brightest component; etc. An effort has been made to use the same component designations as in the CCDM catalogue for systems already known from ground-based observations, while new designations have been assigned to the newly discovered components.

What is referred to here as a component is the smallest entity considered in the published Hipparcos solution. It can in reality consist of more than one star, in which case the given position refers to the photocentre of the unresolved object in the passband of the *Hp* magnitude. In such cases the single-letter identifier given here may in other catalogues designate just one of the unresolved components. Thus, a known triple star ABC may be given as a double star with component identifiers A and C, although the A component may actually be the photocentre of A and B.

Close binaries with a small magnitude difference sometimes present an ambiguity in the component identification caused by possible orbital motion since the (often old) ground-based identification. In doubtful cases such binaries are given the component designations A and S. The system AS could thus be interpreted as either AB or BA.

The total number of (resolved) components in the solution is given in the machine-readable DMSA/C as N_C. There are 12005 solutions with $N_C = 2$, 182 with $N_C = 3$ and 8 with $N_C = 4$.

Field DC8: Hipparcos Catalogue identifier

This field gives the HIP number under which the component was observed.

Components confined to the roughly 30 arcsec diameter sensitive area of the primary detector were usually observed under the same HIP number. If two components with not too unequal magnitudes were known *a priori* in the Hipparcos Input Catalogue (HIC) to be within 10–30 arcsec of each other, they were considered as individual targets and given separate HIC numbers; this numbering is retained in the Hipparcos Catalogue.

A given HIP number cannot occur under more than one system identifier (Field DC1). The CCDM number, if any, for a given HIP number is found in Field H55 of the main catalogue.

Fields DC9–14: Component Photometric Data

Field DC9: Magnitude of component in the Hipparcos photometric system, Hp

Field DC10: Standard error of the Hp magnitude, σ_{Hp} (mag)

These fields give the magnitude of the component in the broad-band Hp photometric system, as derived from the astrometric and photometric processing, with its estimated standard error. For variable stars the magnitude should be understood as a median value, and the standard error includes a contribution from the variability.

Field DC11: Magnitude of component in the Tycho photometric system, B_T

Field DC12: Standard error of the B_T magnitude, σ_{B_T} (mag)

Field DC13: Magnitude of component in the Tycho photometric system, V_T

Field DC14: Standard error of the V_T magnitude, σ_{V_T} (mag)

Fields DC11–14 give, when available, the (corrected or 'de-censored') mean B_T and V_T magnitudes and standard errors of the component as derived in the Tycho data analysis (see Section 2.2 for details). Blank fields indicate that no component data were available from the Tycho data analysis. This usually means either that the component was too faint ($\gtrsim$ 11 mag), or that it could not be separated from another component ($\varrho \lesssim$ 2 arcsec).

Fields DC15–19: Component Astrometric Data

Fields DC15–16: Equatorial coordinates at the epoch J1991.25, α and δ (deg)

Field DC17: Trigonometric parallax, π (mas)

Fields DC18–19: Proper motion, $\mu_{\alpha*}$ and μ_δ (mas/yr)

The position (α, δ) and the proper motion components in right ascension, $\mu_{\alpha*} = \mu_\alpha \cos\delta$, and declination, μ_δ, refer to the epoch J1991.25 and are given with respect to the reference system of ICRS. The proper motion is expressed in milliarcsec per Julian year (mas/yr).

Fields DC20–24: Standard Errors of Component Astrometry

Fields DC20–21: Standard errors of the position at the epoch J1991.25, $\sigma_{\alpha*}$ and σ_δ (mas)

The standard error in right ascension is given as a great-circle measure, $\sigma_{\alpha*} = \sigma_\alpha \cos\delta$.

Field DC22: Standard error of the trigonometric parallax, σ_π (mas)

Fields DC23–24: Standard errors of the proper motion at the epoch J1991.25, $\sigma_{\mu_{\alpha*}}$ and σ_{μ_δ} (mas/yr)

Fields DC25–29: Relative Astrometry

The relative astrometric data given in Fields DC25–29 are computed from the data in Fields DC15–19 for the relevant components. Fields DC26–29 may be of truncated precision compared to the absolute data, and no standard errors are given. They are provided merely as a convenient way to form an overview of the geometry of a system and of the relative motions of the components. All relative data refer to the catalogue epoch, J1991.25.

Fields DC25–29 are blank for the first component in a solution. Fields DC28–29 are blank also for the other component(s) of a fixed solution (type F in Field DC3), where $d\theta/dt = 0$ and $d\varrho/dt = 0$ are enforced by the solution process.

Field DC25: Reference component for the data in Fields DC26–29

This field designates the reference component for the relative data of the current component (Field DC7).

Fields DC26–27: Position angle and separation, θ (deg) and ϱ (arcsec)

The position angle, θ, of the current component (Field DC7) relative to the reference component (Field DC25) is measured counterclockwise, as seen on the sky, from the $+\delta$ direction.

Fields DC28–29: Rate of change of position angle and separation, $d\theta/dt$ (deg/yr) and $d\varrho/dt$ (arcsec/yr)

These data are given only for solutions of type L and I (see Field DC3).

Charts of Double and Multiple Systems

All systems in DMSA/C are graphically depicted at the bottom of the printed page on which the data appear. Each chart is labelled, immediately below its frame, with the CCDM number of the system (from Field DC1), the solution identifier (Field DC2) if there is more than one solution for the system, and the scale of the chart expressed as the side length in arcsec.

The orientation of the charts is such that right ascension increases towards the left and declination towards the top. Component identifiers are shown as appropriate.

2.3.3. DMSA/G: Acceleration Solutions

For some apparently single (unresolved) stars it was found that the observed motion on the sky could not be properly modelled by the standard five astrometric parameters, while an acceptable solution was obtained by adding acceleration terms to the model. These objects are probably astrometric binaries with periods above some 10 years, so that the photocentric motion over the Hipparcos observation interval (roughly 1990.0–1993.2) is adequately represented by a quadratic or cubic polynomial in time. DMSA/G gives the non-linear (acceleration, or higher-order) terms for these objects.

The acceleration models are polynomial extensions of the single-star model with five astrometric parameters (α, δ, π, $\mu_{\alpha*}$, μ_δ). The additional parameters are the accelerations in right ascension and declination, or approximately $g_{\alpha*} = \mathrm{d}\mu_{\alpha*}/\mathrm{d}t$, $g_\delta = \mathrm{d}\mu_\delta/\mathrm{d}t$; and in some cases also the second derivatives of the proper motions, or approximately $\dot{g}_{\alpha*} = \mathrm{d}^2\mu_{\alpha*}/\mathrm{d}t^2$, $\dot{g}_\delta = \mathrm{d}^2\mu_\delta/\mathrm{d}t^2$. A stricter definition is given below.

Using a polynomial model for the motion is, from a physical viewpoint, a very unsatisfactory substitute for a complete orbital model. Probably it is still the most practical and compact representation of the Hipparcos measurements of astrometric binaries following an otherwise unknown, long-period orbit. The polynomial fit must however *never* be used to extrapolate the motion significantly outside the observation interval. Since the extrapolation of stellar positions by means of observed proper motions is nevertheless a legitimate use of the catalogue, a special provision has been made to somewhat reduce the risk of this procedure. Basically, the main catalogue (Fields H8–9 and H12–13) gives the best *linear* approximation of the motion over the observation interval, while DMSA/G gives the non-linear deviation from that motion. The recommended procedure for extrapolating to distant epochs is to rely entirely on the parameters in the main catalogue, thus ignoring the acceleration terms. While this may still lead to considerable errors in the presence of actual accelerations, it is obviously safer than the use of polynomial models.

The acceleration terms are defined in terms of local rectangular coordinates (ξ, η) valid in a small area around the object; cf. Section 1.2.9 and Figure 1.2.3. (ξ and η are positional offsets in the directions of $+\alpha$ and $+\delta$, respectively, from a fixed reference position; i.e. $\xi \simeq \Delta\alpha\cos\delta$, $\eta \simeq \Delta\delta$.) The model for the accelerated motion is:

$$\begin{aligned}\xi(t) &= \xi_{\rm S}(t) + \tfrac{1}{2}(t^2 - a)g_{\alpha*} + \tfrac{1}{6}(t^2 - b)t\dot{g}_{\alpha*}\\ \eta(t) &= \eta_{\rm S}(t) + \tfrac{1}{2}(t^2 - a)g_\delta + \tfrac{1}{6}(t^2 - b)t\dot{g}_\delta\end{aligned} \qquad [2.3.1]$$

where the time t is reckoned from the catalogue epoch J1991.25. Here, $\xi_{\rm S}(t)$ and $\eta_{\rm S}(t)$ give the motion according to the standard single-star model described in Section 1.2.8; this is specified by the five astrometric parameters given in Fields H8–13 of the main catalogue. a and b are the fixed constants:

$$a = 0.81\ \mathrm{yr}^2\,, \quad b = 1.69\ \mathrm{yr}^2 \qquad [2.3.2]$$

introduced in order to make the g and $\dot{g}$ terms approximately orthogonal to the position and proper motion terms implicit in $\xi_{\rm S}(t)$ and $\eta_{\rm S}(t)$. As a consequence, the position and proper motion given in the main catalogue represent the mean position and mean proper motion over the observation interval, rather than the instantaneous position and proper motion at epoch J1991.25 according to the fitted acceleration model.

The g terms vanish precisely at the two epochs J1990.35 and J1992.15 ($t = \pm\sqrt{a}$) while the $\dot{g}$ terms vanish at J1989.95, J1991.25 and J1992.55 ($t = 0, \pm\sqrt{b}$). This permits the following interpretation of the position and proper motion parameters in the main catalogue in terms of the fitted quadratic or cubic motion: the position in Fields H8–9 is the mid-point of the fitted locations at J1990.35 and J1992.15, and the proper motion in Fields H12–13 is the mean annual motion between the fitted locations at J1989.95 and J1992.55 (see Figure 2.3.1).

Note that any contribution from the secular acceleration (a geometrical effect due to the star's radial velocity; see Section 1.2.8) is included in the definition of $\xi_S(t)$ and $\eta_S(t)$, at least if it would exceed 0.1 mas during the mission. The g and $\dot{g}$ terms, when significant, therefore represent a true physical action on the object.

The g and $\dot{g}$ terms were initially estimated for all stars, but depending on their statistical significance, the finally adopted solution was constrained to $n = 5$, 7 or 9 parameters. This corresponds, respectively, to the standard astrometric model (with no entry in DMSA/G), the quadratic, and the cubic model. The first five parameters are given in Fields H8–13 of the main Hipparcos Catalogue, while the additional quadratic and cubic terms are given in Fields DG2–3 and DG7–8. The standard errors of all n parameters are also given in the printed catalogue (Fields H14–18, DG4–5 and DG9–10).

The significance of the g and $\dot{g}$ terms was determined by means of the statistics F_g and $F_{\dot{g}}$ given (in significant cases) in Fields DG6 and DG11. They are defined by:

$$F_g^2 = (\, g_{\alpha*} \quad g_\delta \,) \begin{pmatrix} \sigma^2_{g_{\alpha*}} & \rho_g \sigma_{g_{\alpha*}} \sigma_{g_\delta} \\ \rho_g \sigma_{g_{\alpha*}} \sigma_{g_\delta} & \sigma^2_{g_\delta} \end{pmatrix}^{-1} \begin{pmatrix} g_{\alpha*} \\ g_\delta \end{pmatrix} \qquad [2.3.3]$$

and:

$$F_{\dot{g}}^2 = (\, \dot{g}_{\alpha*} \quad \dot{g}_\delta \,) \begin{pmatrix} \sigma^2_{\dot{g}_{\alpha*}} & \rho_{\dot{g}} \sigma_{\dot{g}_{\alpha*}} \sigma_{\dot{g}_\delta} \\ \rho_{\dot{g}} \sigma_{\dot{g}_{\alpha*}} \sigma_{\dot{g}_\delta} & \sigma^2_{\dot{g}_\delta} \end{pmatrix}^{-1} \begin{pmatrix} \dot{g}_{\alpha*} \\ \dot{g}_\delta \end{pmatrix} \qquad [2.3.4]$$

where $\sigma_{g_{\alpha*}}$, σ_{g_δ}, $\sigma_{\dot{g}_{\alpha*}}$ and $\sigma_{\dot{g}_\delta}$ are the standard errors of the g and $\dot{g}$ terms (Fields DG4–5 and DG9–10), ρ_g is the correlation coefficient between $g_{\alpha*}$ and g_δ, and $\rho_{\dot{g}}$ the correlation coefficient between $\dot{g}_{\alpha*}$ and $\dot{g}_\delta$. (These two correlation coefficients are not given in the printed catalogue, but are contained in the machine-readable file as the 21st and 36th coefficients, ρ_{21} and ρ_{36}, respectively; see Table 2.3.3.)

In the absence of real accelerations, the g and $\dot{g}$ terms are expected to be random variables, following a centred multivariate normal distribution with the given standard deviations and correlations. In this case F_g^2 and $F_{\dot{g}}^2$ each follow the χ^2 distribution with two degrees of freedom. The probability that $F_g > x$ is then given by $\exp(-\frac{1}{2}x^2)$, and similarly for $F_{\dot{g}}$. The g terms were considered to be significant if $F_g > 3.44$, and the $\dot{g}$ terms were considered to be significant if $F_{\dot{g}} > 3.44$. This gives the same level of significance (0.27 per cent) as the two-sided 3σ criterion for a normal distribution.

The quadratic model ($n = 7$) was adopted if a seven-parameter fit resulted in significant g terms ($F_g > 3.44$) and an acceptable goodness-of-fit (F2 < 4 in Field H30) with a reasonable rejection rate (F1 < 7 per cent). If, however, the addition of the $\dot{g}$ terms produced a significant solution ($F_{\dot{g}} > 3.44$), then the cubic model ($n = 9$) was instead adopted.

The fields of the printed DMSA/G are described below. Further details on the machine-readable version are given in Section 2.3.7, in particular Table 2.3.3.

Field DG1: Identifier

Field DG1: Hipparcos Catalogue identifier

This field gives the HIP number under which the object was observed.

Fields DG2–6: Acceleration of Photocentre

Fields DG2–3: Components in right ascension and declination of the apparent acceleration of the photocentre at epoch J1991.25, $g_{\alpha*}$ and g_δ (mas/yr^2)

Fields DG4–5: Standard errors of the acceleration terms, $\sigma_{g_{\alpha*}}$ and σ_{g_δ} (mas/yr^2)

The acceleration (g) terms describe the quadratic deviation of the path of the photocentre on the sky from the motion predicted for a single star. They may be interpreted as the rates of change of the proper motion components, $g_{\alpha*} = \mathrm{d}\mu_{\alpha*}/\mathrm{d}t$ and $g_\delta = \mathrm{d}\mu_\delta/\mathrm{d}t$, after correction for the perspective acceleration (see the preceding discussion).

Field DG6: Statistic for the significance of the acceleration terms, F_g

The quadratic model is only adopted if the g terms are significant, i.e. $F_g > 3.44$; see Equation 2.3.3.

Fields DG7–11: Third-Order Motion of Photocentre

Fields DG7–8: Components in right ascension and declination of the rate of change of the apparent acceleration of the photocentre, $\dot{g}_{\alpha*}$ and $\dot{g}_\delta$ (mas/yr^3)

Fields DG9–10: Standard errors of the $\dot{g}$ terms, $\sigma_{\dot{g}_{\alpha*}}$ and $\sigma_{\dot{g}_\delta}$ (mas/yr^3)

Together with the g terms, the $\dot{g}$ terms describe the deviation of the path of the photocentre on the sky from the linear motion predicted for a single star. The $\dot{g}$ terms express a linear variation with time of the acceleration (g) terms, with DG2–3 being the instantaneous accelerations at epoch J1991.25.

Field DG11: Statistic for the significance of the $\dot{g}$ terms, $F_{\dot{g}}$

The third-order (cubic) model is only adopted if the $\dot{g}$ terms are significant, i.e. $F_{\dot{g}} > 3.44$; see Equation 2.3.4.

Fields DG7–11 are blank unless a solution was found with significant cubic terms ($F_{\dot{g}} > 3.44$).

Fields DG12: Notes

Field DG12: Flag indicating a note

Notes are included at the end of the relevant volumes: Volumes 5–9 for general notes, Volume 10 for double and multiple systems notes, and Volume 11 for photometric notes (see Field H70 for explanation of the Notes system). The flag has the following meaning:

D : double and multiple systems note only;
G : general note only;
P : photometric (including variability notes) only;
W : 'D' + 'P' only;
X : 'G' + 'D' only;
Y : 'G' + 'P' only;
Z : 'G' + 'D' + 'P'.

2.3.4. DMSA/O: Orbital Solutions

The astrometric solution for the systems described in DMSA/O is the superposition of two models (see Figure 2.3.2):

1. a model for the uniform space motion of the centre of mass: this is described by the same five parameters as used for a single star (α, δ, π, $\mu_{\alpha*}$, μ_δ);
2. a model for the orbital motion of the photocentre around the centre of mass: this assumes a Keplerian orbit and is consequently fully specified by seven orbital elements (P, T, a_0, e, ω, i, Ω).

The astrometric parameters for the centre of mass are given in the main catalogue (as indicated by '+' in Field H10), while the results for the orbital elements are given in DMSA/O. It was not always possible to determine all seven orbital elements uniquely from the Hipparcos data. In many cases some of the elements (and in a few cases all the orbital elements) were adopted from the literature; these are indicated by the presence of a reference number in Field DO16 and by blanks in Fields DO9–15 for the standard errors of the adopted elements. In other cases where no published orbit was used, and where Field DO16 is consequently blank, it was nevertheless necessary to constrain the solution by assuming a circular orbit ($e = \omega = 0$); in these cases Fields DO12–13 are blank. The status of each parameter—estimated or constrained—is thus consistently flagged by the presence or absence of numerical data in Fields DO9–15, and also by Field DOM1 in the machine-readable DMSA/O (Table 2.3.4a).

The elements given in DMSA/O are the classical ones normally used to describe binary orbits from visual and spectroscopic observations (see, e.g. L. Binnendijk, 1960, *Properties of Double Stars*, Philadelphia, and A.H. Batten, 1973, *Binary and Multiple Systems of Stars*, Oxford). Note however that the present elements always describe the *absolute* orbit of the photocentre with respect to the mass centre of the binary, whereas ground-based observations usually give the *relative* orbit of the secondary with respect to the primary star.

The definition of each element is contained in the descriptions of Fields DO2–8. For convenience the complete formulae to compute the positional offset of the photocentre with respect to the centre of mass are given below. The offset is expressed in the local rectangular coordinates (ξ, η), cf. Section 1.2.9 and Figure 1.2.3. (ξ and η are positional offsets in the directions of $+\alpha$ and $+\delta$, respectively, from a fixed reference position; i.e. $\xi \simeq \Delta\alpha\cos\delta$, $\eta \simeq \Delta\delta$.) With $\xi_{\rm s}(t)$, $\eta_{\rm s}(t)$ representing the motion of the centre of mass as described by the five astrometric parameters (Fields H8–13 of the main Hipparcos Catalogue) in terms of the standard model discussed in Section 1.2.8, the motion of the photocentre is given by:

$$\xi(t) = \xi_{\rm s}(t) + B\,X(t) + G\,Y(t)\,, \quad \eta(t) = \eta_{\rm s}(t) + A\,X(t) + F\,Y(t) \qquad [2.3.5]$$

where A, B, F, G are the Thiele-Innes elements:

$$\begin{aligned} A &= a_0(+\cos\omega\cos\Omega - \sin\omega\sin\Omega\cos i) \\ B &= a_0(+\cos\omega\sin\Omega + \sin\omega\cos\Omega\cos i) \\ F &= a_0(-\sin\omega\cos\Omega - \cos\omega\sin\Omega\cos i) \\ G &= a_0(-\sin\omega\sin\Omega + \cos\omega\cos\Omega\cos i) \end{aligned} \qquad [2.3.6]$$

(expressed in mas), and (X, Y) the time-dependent dimensionless coordinates in the orbital plane:

$$X(t) = \cos E - e\,, \quad Y(t) = (1-e^2)^{1/2}\sin E \qquad [2.3.7]$$

The eccentric anomaly, E, is obtained from Kepler's equation:

$$\frac{2\pi}{P}(t - T) = E - e \sin E \qquad [2.3.8]$$

The fields of the printed DMSA/O are described below. Further details on the machine-readable version are given in Section 2.3.7, in particular Table 2.3.4.

Field DO1: Identifier

Field DO1: Hipparcos Catalogue identifier

This field gives the HIP number under which the binary was observed.

Fields DO2–8: Orbital Elements of the Photocentre

Field DO2: Orbital period, P (days)

This is the time interval in days between successive periastron passages (cf. Field DO3).

Field DO3: Time of periastron passage, T (days)

This is the date when the photocentre is closest to the centre of mass in the orbital plane. This is equivalent to the closest approach of the stellar components, so that the event may be called 'periastron passage' without ambiguity. The date is expressed in days from JD2 440 000.0(TT).

Field DO4: Semi-major axis of photocentre orbit, a_0 (mas)

This is the semi-major axis of the absolute orbit of the photocentre, as measured in the orbital plane.

Field DO5: Eccentricity, e

This is the eccentricity of the true orbit. $0 \le e < 1$.

Field DO6: Argument of periastron, ω (deg)

This is the angle in the orbital plane from the line of nodes to the major axis. It is measured from the nodal point (Ω in Field DO8) to the periastron in the direction of motion. $0 \le \omega < 360°$.

Field DO7: Inclination, i (deg)

This is the inclination of the orbital plane to the tangent plane of the sky. It is taken to be in the first quadrant if the apparent motion is direct (counter-clockwise) and in the second quadrant for retrograde (clockwise) apparent motion. $0 \le i \le 180°$.

Field DO8: Position angle of the node, Ω (deg)

This is the position angle (measured counterclockwise, as seen on the sky, from the $+\delta$ direction) of the line of nodes, or the intersection of the orbital and tangent planes. If the radial motion of the components is known from spectroscopic studies, then Ω should give the position angle of the *ascending node*, at which the primary star crosses the tangent plane while receding from the observer. In the absence of spectroscopic information Ω refers to the node with the smallest positive position angle (which may then actually be the descending node). This ambiguity has no effect on the calculation of the positional offset on the sky. $0 \leq \Omega < 360°$.

Fields DO9–15: Standard Errors

Field DO9: Standard error of P (days)

Field DO10: Standard error of T (days)

Field DO11: Standard error of a_0 (mas)

Field DO12: Standard error of e

Field DO13: Standard error of ω (deg)

Field DO14: Standard error of i (deg)

Field DO15: Standard error of Ω (deg)

These fields contain the standard errors of each element of the photocentre determined or improved by the Hipparcos observations. A blank field signifies either that the corresponding element was adopted from the literature (in which case a reference number is given in Field DO16), or that the element was otherwise constrained in the solution (viz. by assuming a circular orbit, $e = \omega = 0$).

Fields DO16–17: References and Notes

Field DO16: Reference number

This number points to the references to adopted ground-based orbital elements given at the end of DMSA/O. This field is blank when no ground-based orbit exists, or when the orbital elements were determined without regard to any previous determination.

Field DO17: Flag indicating a note

Notes are included at the end of the relevant volumes: Volumes 5–9 for general notes, Volume 10 for double and multiple systems notes, and Volume 11 for photometric notes (see Field H70 for explanation of the Notes system). The flag has the following meaning:

D : double and multiple systems note only;
G : general note only;
P : photometric (including variability notes) only;
W : 'D' + 'P' only;
X : 'G' + 'D' only;
Y : 'G' + 'P' only;
Z : 'G' + 'D' + 'P'.

2.3.5. DMSA/V: VIM Solutions

The photocentre of an unresolved binary, in which one component is a variable star, shows a specific motion on the sky, coupled to the variation in the total brightness of the system. Such an object is called a 'Variability-Induced Mover', abbreviated as VIM. The detailed theory of VIMs is described elsewhere (R. Wielen, 1996, *Astronomy & Astrophysics*, 314, 679). Only a concise description is given here.

The variable star is called V; the other star C is assumed to have the (unknown) constant magnitude Hp_C. The total magnitude of the system at time t, observed by Hipparcos, is $Hp_{\rm tot}(t)$. The (unknown) angular separation between the two stars is ϱ. The equatorial components of ϱ are called $d_{\alpha*} = \varrho \sin\theta_C$ and $d_\delta = \varrho\cos\theta_C$, where θ_C is the position angle of C with respect to V. It is assumed that the relative geometry of the double star, defined by ϱ and θ_C, does not change significantly over the observational period of Hipparcos (3.3 years). This is probably a good approximation for most of the VIMs found by Hipparcos.

If the system had always the same total brightness, then the photocentre would be fixed with respect to the two components, and hence with respect to the centre of mass of the system; consequently the photocentre would move like a single star and could be described by the usual five astrometric parameters. Such an (unresolved) object would not be recognised as a binary by Hipparcos, and indeed many of the 'single' stars in the Hipparcos Catalogue may be of this kind.

If one of the components is variable, the photocentre is not fixed with respect to the centre of mass but moves back and forth on the line joining the two components. In order to apply the five astrometric parameters to such a VIM, a 'reference magnitude' $Hp_{\rm ref}$ is chosen for the object, and the 'reference point' of the system is defined as the position of the photocentre when the total magnitude equals $Hp_{\rm ref}$. The choice of reference magnitude is arbitrary in principle, but should be close to the mean magnitude of the system for practical reasons. Clearly the reference point moves like a single star and can be described by the standard astrometric model (Section 1.2.8) in terms of the five parameters α, δ, π, $\mu_{\alpha*}$ and μ_δ. These are given in the main Hipparcos Catalogue as for a single star (Fields H8–13). The variability-induced motion, specified by the two parameters $D_{\alpha*}$ and D_δ together with the light curve, is superposed on the standard model, giving the observed motion of the photocentre (see Figure 2.3.3).

The DMSA/V gives the estimates of $D_{\alpha*}$ and D_δ, for a specified reference magnitude, together with their standard errors. The machine-readable DMSA/V additionally provides the complete set of correlation coefficients among the seven estimated parameters. Three more quantities, derived from the above parameters, are given in the DMSA/V. These are the position angle θ_C of the constant star with respect to the variable star; a lower limit $\varrho_{\rm min}$ on their separation; and the approximate size $d_{\rm var}$ of the VIM effect. Finally the statistical significance of the solution, F_D, is also given.

The additional variability-induced motion can be expressed as small offsets in the local rectangular coordinates (ξ,η); cf. Section 1.2.9 and Figure 1.2.3. With $\xi_S(t)$, $\eta_S(t)$ representing the motion of the reference point, as defined by the five astrometric parameters in the main Hipparcos Catalogue, and Hp_C the Hp magnitude of component C, the motion of the actual photocentre is found to be:

$$\begin{aligned}\xi(t) &= \xi_S(t) + \left(10^{-0.4(Hp_C - Hp_{\rm tot}(t))} - 10^{-0.4(Hp_C - Hp_{\rm ref})}\right) d_{\alpha*}\\ \eta(t) &= \eta_S(t) + \left(10^{-0.4(Hp_C - Hp_{\rm tot}(t))} - 10^{-0.4(Hp_C - Hp_{\rm ref})}\right) d_\delta\end{aligned} \qquad [2.3.9]$$

This depends on the three unknowns $d_{\alpha*}$, d_δ and $Hp_{\rm C}$, which however cannot be separated by observing only the photocentre. Introducing:

$$\begin{aligned} D_{\alpha*} &= 10^{-0.4(Hp_{\rm C}-Hp_{\rm ref})} d_{\alpha*} \\ D_\delta &= 10^{-0.4(Hp_{\rm C}-Hp_{\rm ref})} d_\delta \end{aligned} \qquad [2.3.10]$$

the motion of the photocentre can be written:

$$\begin{aligned} \xi(t) &= \xi_{\rm s}(t) + \left(10^{0.4(Hp_{\rm tot}(t)-Hp_{\rm ref})} - 1\right) D_{\alpha*} \\ \eta(t) &= \eta_{\rm s}(t) + \left(10^{0.4(Hp_{\rm tot}(t)-Hp_{\rm ref})} - 1\right) D_\delta \end{aligned} \qquad [2.3.11]$$

Since $Hp_{\rm tot}(t)$ is known, and $Hp_{\rm ref}$ is an adopted value, $D_{\alpha*}$ and D_δ (measured in mas) can be obtained in a simultaneous least-squares solution together with the five standard astrometric parameters. The full solution is therefore a seven-parameter solution.

Because $Hp_{\rm C}$ is unknown, it is not possible to derive the separation ϱ of a VIM. However, a lower limit can be computed, since obviously $Hp_{\rm C} \geq Hp_{\rm tot,\,min}$, the total magnitude of the system at its minimum luminosity:

$$\varrho \geq \varrho_{\rm min} = 10^{0.4(Hp_{\rm tot,\,min}-Hp_{\rm ref})}(D^2_{\alpha*} + D^2_\delta)^{1/2} \qquad [2.3.12]$$

To determine this value, the faintest magnitude actually observed by Hipparcos has been used. For some Mira stars and other objects a larger $\varrho_{\rm min}$ could be derived by using fainter ground-based values of $Hp_{\rm tot,\,min}$.

The size of the VIM effect is indicated by the total displacement of the photocentre between the (observed) minimum and maximum luminosity:

$$d_{\rm var} = \left(10^{0.4(Hp_{\rm tot,\,min}-Hp_{\rm ref})} - 10^{0.4(Hp_{\rm tot,\,max}-Hp_{\rm ref})}\right)(D^2_{\alpha*} + D^2_\delta)^{1/2} \qquad [2.3.13]$$

The significance of the VIM solution is determined by means of the statistic F_D defined in analogy with F_g and $F_{\dot g}$ (Fields DG6 and DG11):

$$F_D^2 = (\,D_{\alpha*} \quad D_\delta\,) \begin{pmatrix} \sigma^2_{D_{\alpha*}} & \rho_D\sigma_{D_{\alpha*}}\sigma_{D_\delta} \\ \rho_D\sigma_{D_{\alpha*}}\sigma_{D_\delta} & \sigma^2_{D_\delta} \end{pmatrix}^{-1} \begin{pmatrix} D_{\alpha*} \\ D_\delta \end{pmatrix} \qquad [2.3.14]$$

where ρ_D is the correlation coefficient between $D_{\alpha*}$ and D_δ (this correlation is only given in the machine-readable DMSA/V; see Table 2.3.5). An object is accepted as a VIM, if $F_D > 2.15$. This corresponds to a 10 per cent probability of wrongly accepting an object as a VIM. The adopted limit for F_D (2.15) is smaller than for F_g and $F_{\dot g}$ (3.44), since the warning on the possible binary nature of the variable star is considered to be important even for less certain cases.

As previously explained, the positional parameters α and δ given in Fields H8–9 refer to the reference point, and are valid for the chosen reference brightness $Hp_{\rm ref}$ of the object. The corresponding parameters for the variable star itself are given by $\alpha_{\rm V} = \alpha - D_{\alpha*}\sec\delta$ and $\delta_{\rm V} = \delta - D_\delta$. The position of the constant star cannot be derived. Due to the assumption of ϱ and $\theta_{\rm C}$ being fixed, the given proper motion of the reference point (Fields H12–13) is identical to the proper motions of the centre of mass, of the constant star, and of the variable star.

The fields of the printed DMSA/V are described below. Further details on the machine-readable version are given in Section 2.3.7, in particular Table 2.3.5.

Fields DV1–2: Identifier and Reference Magnitude

Field DV1: Hipparcos Catalogue identifier

This field gives the HIP number under which the object was observed.

Field DV2: Adopted reference magnitude for the object, $Hp_{\rm ref}$

The reference magnitude is freely chosen and defines the reference point for the object. The positional parameters α and δ (Fields H8–9 of the main Hipparcos Catalogue) and the VIM elements $D_{\alpha*}$ and D_δ (Fields DV3–4) depend on the chosen $Hp_{\rm ref}$. Fields DV7–11, on the other hand, do not depend on $Hp_{\rm ref}$.

Fields DV3–6: Elements of the VIM

Fields DV3–4: Elements of the variability-induced motion in right ascension, $D_{\alpha*}$, and declination, D_δ, in mas, valid for the reference magnitude $Hp_{\rm ref}$ (Field DV2)

Fields DV5–6: Standard errors of the VIM elements in right ascension, $\sigma_{D_{\alpha*}}$, and declination, σ_{D_δ}, in mas

Field DV7: Statistic for the significance of the detection of the variability-induced motion, F_D

See Equation 2.3.14 for the definition of F_D. The VIM solution is only accepted if $F_D > 2.15$.

Fields DV8–11: Derived Quantities

Field DV8: Position angle $\theta_{\rm C}$ of the constant component of the binary with respect to the variable component, in degrees

The position angle is measured counterclockwise, as seen on the sky, from the $+\delta$ direction. It is derived from $D_{\alpha*}$ and D_δ given in Fields DV3–4.

Field DV9: Standard error $\sigma_{\theta_{\rm C}}$ of the position angle, in degrees

Field DV10: Lower limit for the separation of the binary, $\varrho_{\rm min}$, in mas

From the Hipparcos observations only this lower limit for the separation can be derived.

Field DV11: Displacement of photocentre between the minimum and maximum luminosity of the system, $d_{\rm var}$, in mas

This quantity is provided as an indication of the size of the VIM effect.

Field DV12: Notes

Field DV12: Flag indicating a note

Notes are included at the end of the relevant volumes: Volumes 5–9 for general notes, Volume 10 for double and multiple systems notes, and Volume 11 for photometric notes (see Field H70 for explanation of the Notes system). The flag has the following meaning:

D : double and multiple systems note only;
G : general note only;
P : photometric (including variability notes) only;
W : ‘D’ + ‘P’ only;
X : ‘G’ + ‘D’ only;
Y : ‘G’ + ‘P’ only;
Z : ‘G’ + ‘D’ + ‘P’.

2.3.6. DMSA/X: Stochastic Solutions

For some unresolved stars it was not possible to find an acceptable single or double star solution in reasonable agreement with the statistical uncertainties (standard errors) assigned to the individual measurements. These objects could for instance be astrometric binaries with relatively short periods (< 3 years), for which a simple polynomial model was clearly inadequate, while the space data alone did not allow a full orbital solution. In the individual measurements, the displacement of the photocentre from an assumed linear motion of the centre of mass thus appears like a random scatter in excess of the measurement noise.

Lacking an acceptable deterministic model for such objects, a reasonable treatment would be to assume a stochastic model for the photocentric displacements superposed on a uniform motion of the centre of mass. Practically, the stochastic model is implemented by quadratically adding a certain amount ϵ to the standard errors of all the observations of the object, thereby reducing their statistical weights in the least-squares determination of the single-star parameters. The size of ϵ for a given object is adjusted to bring the modified weights in statistical agreement with the residuals of the fit, taking into account that occasional outliers could still exist. As a consequence, the standard errors in the main catalogue (Fields H14–18) fully reflect the increased uncertainty of the solution. Furthermore, the rms residual (or 'unit weight error') for the X solutions is, by construction, exactly equal to 1, resulting in a goodness-of-fit statistic F2 (see the description for Field H30) close to zero. This statistic is normally given in Field H30 of the main catalogue, which however is left blank for the X solutions. In this way the user should avoid the false impression that the five-parameter model provides an excellent fit to the observations.

The quantity ϵ may be referred to as the 'cosmic error' of the (suspected) astrometric binary. To the extent that the cosmic error actually represents a physical scatter in excess of the measurement noise, its value provides an order-of-magnitude estimate of the size of the orbit of the photocentre, and may consequently be of considerable astrophysical interest. The adopted quantities ϵ are given in DMSA/X, while the corresponding single-star parameters describing the mean motion of the object are given in the main catalogue.

It should be noted that the stochastic model is applied only to objects where other models fail and a forced application of the single-star model would lead to the rejection of a significant fraction of the data, or where the cosmic error is highly significant. For instance, if an acceptable fit can be obtained by rejecting only a few data points, then that method is generally preferred to the stochastic model. The quality of such a fit is generally specified by the percentage of rejected observations (F1) and the resulting goodness-of-fit statistic (F2), as given in the main catalogue (Fields H29 and H30, respectively).

In cases where there is in fact an unmodelled scatter above the measurement noise, the stochastic model has however two important advantages over the standard single-star solution with rejection of outliers: firstly, it avoids the rather arbitrary designation of some measurements as outliers, while others retain their full weight; in this way, the stochastic model often produces more realistic values of the astrometric parameters. Secondly, the weight reduction causes the standard errors of the estimated single-star parameters to become larger, reflecting the actual scatter of the observations, and hence being more realistic.

The stochastic model can also be regarded as a kind of robust estimation. However, in contrast to most standard robust techniques, which are designed to deal for instance with strongly non-Gaussian tails of the error distribution, the present model assumes a fairly uniform contribution of the excess scatter to all the observations (while exceptional outliers are still rejected). Moreover, it provides a direct estimate of the excess scatter, or cosmic error, and assigns a possible physical significance to it.

The fields of the printed DMSA/X are described below. Further details on the machine-readable version are given in Section 2.3.7, in particular Table 2.3.6.

Field DX1: Identifier

Field DX1: Hipparcos Catalogue identifier

This field gives the HIP number under which the object was observed.

Fields DX2–3: Cosmic Error

Field DX2: Cosmic error, ϵ (mas)

This field gives the excess rms observational noise. The astrometric data in Fields H8–30 have been derived from one-dimensional measurements (abscissae) after their *a priori* standard errors were modified according to the formula:

$$\sigma_{\text{absc, adopted}} = \sqrt{\sigma^2_{\text{absc, } a\ priori} + \epsilon^2} \qquad [2.3.15]$$

Field DX3: Estimated standard error of the cosmic error, σ_ϵ (mas)

Field DX4: Notes

Field DX4: Flag indicating a note

Notes are included at the end of the relevant volumes: Volumes 5–9 for general notes, Volume 10 for double and multiple systems notes, and Volume 11 for photometric notes (see Field H70 for explanation of the Notes system). The flag has the following meaning:

D : double and multiple systems note only;
G : general note only;
P : photometric (including variability notes) only;
W : 'D' + 'P' only;
X : 'G' + 'D' only;
Y : 'G' + 'P' only;
Z : 'G' + 'D' + 'P'.

2.3.7. The Machine-Readable DMSA

The machine-readable version of the DMSA contains strictly the same data as the printed version, plus information on the statistical correlations among the estimated parameters. Further fields have been added to facilitate the automatic interpretation of the files. Tables 2.3.1–6 summarise the contents of the machine-readable files.

The correlation coefficients among the five astrometric parameters α, δ, π, $\mu_{\alpha*}$ and μ_δ are given in the main catalogue (Fields H19–28) rounded to the nearest per cent. The DMSA contains the results of the fitting of more complex models to the observations, involving the statistical estimation of additional parameters or unknowns. The machine-readable DMSA provides the complete set of correlations for these model fits, including (for convenience) the correlations already specified in the main catalogue. The main reason for systematically providing correlations in DMSA is to allow a correct derivation of the standard errors of transformed quantities such as space velocities in galactic coordinates.

Coding of correlation coefficients in DMSA: The estimation of the astrometric parameters for single stars is usually well conditioned, resulting in small or moderate correlations, for which values percentage values (as given in the main catalogue) are generally sufficient.

The situation is often rather different in the estimation problems connected with double and multiple stars, astrometric binaries and orbital systems: some of the estimated parameters may exhibit a very high degree of (positive or negative) correlation. Correlation coefficients (ρ) of ±0.999 or even ±0.9999 are not uncommon, for instance between the component magnitudes of a close binary. In such cases a correlation coefficient rounded to the nearest per cent would lead to unacceptable errors in the calculation of the standard errors of transformed quantities. A special coding was therefore adopted for the correlation coefficients in the machine-readable DMSA, using a non-linear mapping of $-1 \le \rho \le +1$ onto the integers $-99 \le I \le 999$. This mapping is given by:

$$I = \mathrm{round}\,(450.0 + 349.5 \times \arcsin\rho) \qquad [2.3.16]$$

where round() represents rounding to the nearest integer. The inverse mapping (decoding) is given by:

$$\rho = \sin((I - 450.0)/349.5) \qquad [2.3.17]$$

where the argument of the sine function is expressed in radians. The number 349.5 should be regarded as exact: it is adopted as a convenient approximation to $(999+99)/\pi$. The numerically largest correlations that are distinct from unity in this coding are $\rho = \pm0.9999960$.

Sequence of correlation coefficients: In a solution with N parameters, $N(N-1)/2$ correlation coefficients must be specified, corresponding to the triangular part of the (symmetric) correlation matrix above or below the main diagonal. These coefficients are always given in a fixed sequence, corresponding to the columns of the upper-triangular matrix or, equivalently, the rows of the lower-triangular matrix; the order of reading is top to bottom and left to right.

The number of parameters varies between the different solution types depending on the specific models used. For DMSA/C and DMSA/O the situation is further complicated by constraints among the parameters: in the component solutions this means, for instance, that the two components in an F or L type binary solution are assumed to have the same parallax. Similarly, in the orbital solutions, certain elements may be constrained to their values from ground-based orbit determinations, and consequently not estimated from the Hipparcos data. In order to avoid unnecessarily complex and variable data structures, the correlations among all of the model parameters are given in the machine-readable files. This allows the use of a fixed sequence for the parameters, and hence also for the correlation coefficients. The required distinction between the separately estimated (or 'active') parameters, and the constrained (or 'passive') ones is provided by an array of status flags, one for each parameter. The status flag is 1 if the parameter is active, otherwise 0. A non-redundant set of parameters and the corresponding correlation matrix can thus be constructed from the full set given in the files by deleting parameters with status flag 0 as well as the corresponding rows and columns of the correlation matrix.

The correlation coefficients are placed at the end of the data record, following the fields of the printed DMSA. However, for DMSA/C a slightly different arrangement was necessary because of the variable number of components. For each component there are six parameters (Hp, α, δ, π, $\mu_{\alpha*}$, μ_δ), so the number of parameters in the solution ranges from 12 to 24 and the number of correlation coefficients from 66 to 276. Choosing a record length to accommodate the actual maximum number of coefficients would be highly impractical. Instead, at most 66 coefficients are given in a record, which suffices for the vast majority of objects, but there may be up to five such records for a given solution. In DMSA/C there are consequently two record types: component records and correlation records. They are distinguished by the word 'COMP' and 'CORR', respectively, in Field DCM5. The first 32 bytes are identical in each record of a solution. The component records correspond to the lines of the printed DMSA/C.

Table 2.3.1. Overview of the machine-readable DMSA

This table summarises the files constituting the machine-readable DMSA
The file names are given in Section 2.11.2

Part of DMSA	Record length (bytes)	Number of records	Format description
C	238	37179	Table 2.3.2
G	195	2622	Table 2.3.3
O (data)	337	235	Table 2.3.4a
O (references)	80	118	Table 2.3.4b
V	144	288	Table 2.3.5
X	22	1561	Table 2.3.6

Table 2.3.2a. The Machine-Readable DMSA/C: Component Record

Fields designated DCM... appear only in the machine-readable catalogue

Field	Bytes	Format	Description
DC1	1–11	A10,X	System identifier (CCDM number)
DC2	12–13	I1,X	Solution identifier, S (1 to N_S)
DC3	14–15	A1,X	Type of solution (F, I, L)
DC4	16–17	A1,X	Source of solution (C, F, N)
DC5	18–19	A1,X	Quality of solution (A, B, C, D)
DC6	20–21	A1,X	Flag indicating a note at the end of relevant volume
DCM1	22–23	I1,X	Number of solutions pertaining to the system, N_S
DCM2	24–26	I2,X	Number of components in this solution, N_C
DCM3	27–29	I2,X	Number of free parameters in this solution, N_P
DCM4	30–32	I2,X	Number of correlation records in this solution, N_R
DCM5	33–37	A4,X	This field contains the word 'COMP'
DCM6	38–40	I2,X	Sequential component number in this solution (1 to N_C)
DC7	41–42	A1,X	Component identifier (A, B, C, ...)
DC8	43–49	I6,X	Hipparcos Catalogue (HIP) identifier
DC9	50–56	F6.3,X	Magnitude of component, Hp (mag)
DC10	57–62	F5.3,X	Standard error of Hp magnitude, σ_{Hp} (mag)
DC11	63–69	F6.3,X †	Magnitude of component, B_T (mag)
DC12	70–75	F5.3,X †	Standard error of B_T magnitude, σ_{B_T} (mag)
DC13	76–82	F6.3,X †	Magnitude of component, V_T (mag)
DC14	83–88	F5.3,X †	Standard error of V_T magnitude, σ_{V_T} (mag)
DC15	89–101	F12.8,X	Right ascension, α (deg)
DC16	102–114	F12.8,X	Declination, δ (deg)
DC17	115–122	F7.2,X	Trigonometric parallax, π (mas)
DC18	123–131	F8.2,X	Proper motion in right ascension, $\mu_{\alpha*}$ (mas/yr)
DC19	132–140	F8.2,X	Proper motion in declination, μ_δ (mas/yr)
DC20	141–147	F6.2,X	Standard error of α, $\sigma_{\alpha*}$ (mas)
DC21	148–154	F6.2,X	Standard error of δ, σ_δ (mas)
DC22	155–161	F6.2,X	Standard error of π, σ_π (mas)
DC23	162–168	F6.2,X	Standard error of $\mu_{\alpha*}$, $\sigma_{\mu_{\alpha*}}$ (mas/yr)
DC24	169–175	F6.2,X	Standard error of μ_δ, σ_{μ_δ} (mas/yr)
DC25	176–177	A1,X	Reference component for the data in Fields DC26–29
DC26	178–185	F7.3,X †	Position angle relative to reference component, θ (deg)
DC27	186–194	F8.3,X †	Separation from reference component, ϱ (arcsec)
DC28	195–203	F8.3,X †	Rate of change of θ, $\mathrm{d}\theta/\mathrm{d}t$ (deg/yr)
DC29	204–210	F6.3,X †	Rate of change of ϱ, $\mathrm{d}\varrho/\mathrm{d}t$ (arcsec/yr)
DCM7	211–213	I2,X ‡	Sequential record number for the reference component in Field DC25
DCM8	214–238	6I1,19X	Status flags for Hp, α, δ, π, $\mu_{\alpha*}$ and μ_δ: 1 = estimated 0 = constrained to the value for the first component

† blank if undefined ‡ set to zero if Field DC25 is blank

Table 2.3.2b. The Machine-Readable DMSA/C: Correlation Record

Fields designated DCM... appear only in the machine-readable catalogue
Bytes 1–32 are copied from the corresponding component records

Field	Bytes	Format	Description
DC1	1–11	A10,X	System identifier (CCDM number)
DC2	12–13	I1,X	Solution identifier, S (1 to N_S)
DC3	14–15	A1,X	Type of solution (F, I, L)
DC4	16–17	A1,X	Source of solution (C, F, N)
DC5	18–19	A1,X	Quality of solution (A, B, C, D)
DC6	20–21	A1,X	Flag indicating a note
DCM1	22–23	I1,X	Number of solutions pertaining to the system, N_S
DCM2	24–26	I2,X	Number of components in this solution, N_C
DCM3	27–29	I2,X	Number of free parameters in this solution, N_P
DCM4	30–32	I2,X	Number of correlation records in this solution, N_R
DCM5	33–37	A4,X	This field contains the word 'CORR'
DCM6	38–40	I2,X	Sequential number of this correlation record (1 to N_R)
DCM9	41–238	66I3 ‡	Up to 66 correlation coefficients in a non-linear coding

† blank if undefined ‡ trailing undefined values are blank

The correlation records contain the correlation coefficients among the maximum set of $6N_C$ parameters (i.e. Hp_i, α_i, δ_i, π_i, $\mu_{\alpha*i}$, $\mu_{\delta i}$ for each component, $i = 1, \ldots, N_C$). The number of correlation coefficients is $6N_C(6N_C - 1)/2 = 66$, 153, and 276 for $N_C = 2$, 3, and 4. A correlation record contains up to 66 coefficients; thus respectively 1, 3 and 5 records are needed for a double, triple or quadruple star. The order of the correlation coefficients is indicated by the table below. They are coded as integers between −99 and 999 using the arcsine transformation (Equation 2.3.16).

Depending on the solution type (Field DC3) some of the parameters may be common for the components, in which case the correlation coefficients are replicated for the respective parameters. For instance, a double star solution of type L implies that $\pi_2 = \pi_1$; then $\rho_{37} = \rho_4$, $\rho_{38} = \rho_5$, $\rho_{39} = \rho_6$, $\rho_{40} = 1$, etc. The subset of 'active' (free, or non-redundant) parameters ($N_P \le 6N_C$) is defined by the status flags in Field DCM8 of the component records.

	Hp_1	α_1	δ_1	π_1	$\mu_{\alpha*1}$	$\mu_{\delta 1}$	Hp_2	α_2	δ_2	π_2	$\mu_{\alpha*2}$	$\mu_{\delta 2}$	Hp_3	$\ldots$
Hp_1	1	ρ_1	ρ_2	ρ_4	ρ_7	ρ_{11}	ρ_{16}	ρ_{22}	ρ_{29}	ρ_{37}	ρ_{46}	ρ_{56}	ρ_{67}	$\cdots$
α_1	ρ_1	1	ρ_3	ρ_5	ρ_8	ρ_{12}	ρ_{17}	ρ_{23}	ρ_{30}	ρ_{38}	ρ_{47}	ρ_{57}	ρ_{68}	$\cdots$
δ_1	ρ_2	ρ_3	1	ρ_6	ρ_9	ρ_{13}	ρ_{18}	ρ_{24}	ρ_{31}	ρ_{39}	ρ_{48}	ρ_{58}	ρ_{69}	$\cdots$
π_1	ρ_4	ρ_5	ρ_6	1	ρ_{10}	ρ_{14}	ρ_{19}	ρ_{25}	ρ_{32}	ρ_{40}	ρ_{49}	ρ_{59}	ρ_{70}	$\cdots$
$\mu_{\alpha*1}$	ρ_7	ρ_8	ρ_9	ρ_{10}	1	ρ_{15}	ρ_{20}	ρ_{26}	ρ_{33}	ρ_{41}	ρ_{50}	ρ_{60}	ρ_{71}	$\cdots$
$\mu_{\delta 1}$	ρ_{11}	ρ_{12}	ρ_{13}	ρ_{14}	ρ_{15}	1	ρ_{21}	ρ_{27}	ρ_{34}	ρ_{42}	ρ_{51}	ρ_{61}	ρ_{72}	$\cdots$
Hp_2	ρ_{16}	ρ_{17}	ρ_{18}	ρ_{19}	ρ_{20}	ρ_{21}	1	ρ_{28}	ρ_{35}	ρ_{43}	ρ_{52}	ρ_{62}	ρ_{73}	$\cdots$
α_2	ρ_{22}	ρ_{23}	ρ_{24}	ρ_{25}	ρ_{26}	ρ_{27}	ρ_{28}	1	ρ_{36}	ρ_{44}	ρ_{53}	ρ_{63}	ρ_{74}	$\cdots$
δ_2	ρ_{29}	ρ_{30}	ρ_{31}	ρ_{32}	ρ_{33}	ρ_{34}	ρ_{35}	ρ_{36}	1	ρ_{45}	ρ_{54}	ρ_{64}	ρ_{75}	$\cdots$
π_2	ρ_{37}	ρ_{38}	ρ_{39}	ρ_{40}	ρ_{41}	ρ_{42}	ρ_{43}	ρ_{44}	ρ_{45}	1	ρ_{55}	ρ_{65}	ρ_{76}	$\cdots$
$\mu_{\alpha*2}$	ρ_{46}	ρ_{47}	ρ_{48}	ρ_{49}	ρ_{50}	ρ_{51}	ρ_{52}	ρ_{53}	ρ_{54}	ρ_{55}	1	ρ_{66}	ρ_{77}	$\cdots$
$\mu_{\delta 2}$	ρ_{56}	ρ_{57}	ρ_{58}	ρ_{59}	ρ_{60}	ρ_{61}	ρ_{62}	ρ_{63}	ρ_{64}	ρ_{65}	ρ_{66}	1	ρ_{78}	$\cdots$
Hp_3	ρ_{67}	ρ_{68}	ρ_{69}	ρ_{70}	ρ_{71}	ρ_{72}	ρ_{73}	ρ_{74}	ρ_{75}	ρ_{76}	ρ_{77}	ρ_{78}	1	$\cdots$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	

Table 2.3.3. The Machine-Readable DMSA/G

Fields designated DGM... appear only in the machine-readable catalogue

Field	Bytes	Format	Description
DG1	1–7	I6,X	Hipparcos Catalogue (HIP) identifier
DG2	8–15	F7.2,X	$g_{\alpha*} = \mathrm{d}\mu_{\alpha*}/\mathrm{d}t$ at J1991.25 (mas/yr^2)
DG3	16–23	F7.2,X	$g_\delta = \mathrm{d}\mu_\delta/\mathrm{d}t$ at J1991.25 (mas/yr^2)
DG4	24–31	F7.2,X	Standard error of $g_{\alpha*}$, $\sigma_{g_{\alpha*}}$ (mas/yr^2)
DG5	32–39	F7.2,X	Standard error of g_δ, σ_{g_δ} (mas/yr^2)
DG6	40–45	F5.2,X	Significance of the g terms, F_g
DG7	46–53	F7.2,X †	$\dot{g}_{\alpha*} = \mathrm{d}^2\mu_{\alpha*}/\mathrm{d}t^2$ at J1991.25 (mas/yr^3)
DG8	54–61	F7.2,X †	$\dot{g}_\delta = \mathrm{d}^2\mu_\delta/\mathrm{d}t^2$ at J1991.25 (mas/yr^3)
DG9	62–69	F7.2,X †	Standard error of $\dot{g}_{\alpha*}$, $\sigma_{\dot{g}_{\alpha*}}$ (mas/yr^3)
DG10	70–77	F7.2,X †	Standard error of $\dot{g}_\delta$, $\sigma_{\dot{g}_\delta}$ (mas/yr^3)
DG11	78–83	F5.2,X †	Significance of the $\dot{g}$ terms, $F_{\dot{g}}$
DG12	84–85	A1,X	Flag indicating a note at the end of relevant volume
DGM1	86–87	I1,X	Number of astrometric parameters, $n = 7$ or 9
DGM2	88–195	36I3 †	(Up to) 36 correlation coefficients in a non-linear coding

† blank for undefined values

The complete set of $n(n-1)/2$ correlation coefficients (where $n = 7$ for a quadratic and $n = 9$ for a cubic model of the photocentric motion) is given in the order indicated by the following table:

	α	δ	π	$\mu_{\alpha*}$	μ_δ	$g_{\alpha*}$	g_δ	$\dot{g}_{\alpha*}$	$\dot{g}_\delta$
α	1	ρ_1	ρ_2	ρ_4	ρ_7	ρ_{11}	ρ_{16}	ρ_{22}	ρ_{29}
δ	ρ_1	1	ρ_3	ρ_5	ρ_8	ρ_{12}	ρ_{17}	ρ_{23}	ρ_{30}
π	ρ_2	ρ_3	1	ρ_6	ρ_9	ρ_{13}	ρ_{18}	ρ_{24}	ρ_{31}
$\mu_{\alpha*}$	ρ_4	ρ_5	ρ_6	1	ρ_{10}	ρ_{14}	ρ_{19}	ρ_{25}	ρ_{32}
μ_δ	ρ_7	ρ_8	ρ_9	ρ_{10}	1	ρ_{15}	ρ_{20}	ρ_{26}	ρ_{33}
$g_{\alpha*}$	ρ_{11}	ρ_{12}	ρ_{13}	ρ_{14}	ρ_{15}	1	ρ_{21}	ρ_{27}	ρ_{34}
g_δ	ρ_{16}	ρ_{17}	ρ_{18}	ρ_{19}	ρ_{20}	ρ_{21}	1	ρ_{28}	ρ_{35}
$\dot{g}_{\alpha*}$	ρ_{22}	ρ_{23}	ρ_{24}	ρ_{25}	ρ_{26}	ρ_{27}	ρ_{28}	1	ρ_{36}
$\dot{g}_\delta$	ρ_{29}	ρ_{30}	ρ_{31}	ρ_{32}	ρ_{33}	ρ_{34}	ρ_{35}	ρ_{36}	1

ρ_{22} to ρ_{36} are blank if $n = 7$. All correlation coefficients are coded as integers between −99 and 999 using the arcsine transformation (Equation 2.3.16). Note that ρ_1 to ρ_{10} are also given, to the nearest percentages, in the main catalogue (Fields H19–28).

Table 2.3.4a. The Machine-Readable DMSA/O (Data)

Fields designated DOM... appear only in the machine-readable catalogue

Field	Bytes	Format	Description
DO1	1–7	I6,X	Hipparcos Catalogue (HIP) identifier
DO2	8–18	F10.4,X	Orbital period, P (days)
DO3	19–30	F11.4,X	Time of periastron passage, T (days from JD2 440 000.0)
DO4	31–39	F8.2,X	Semi-major axis of photocentre orbit, a_0 (mas)
DO5	40–46	F6.4,X	Eccentricity, e
DO6	47–53	F6.2,X	Argument of periastron, ω (deg)
DO7	54–60	F6.2,X	Inclination, i (deg)
DO8	61–67	F6.2,X	Position angle of the node, Ω (deg)
DO9	68–76	F8.4,X †	Standard error of P (days)
DO10	77–86	F9.4,X †	Standard error of T (days)
DO11	87–92	F5.2,X †	Standard error of a_0 (mas)
DO12	93–99	F6.4,X †	Standard error of e
DO13	100–106	F6.2,X †	Standard error of ω (deg)
DO14	107–113	F6.2,X †	Standard error of i (deg)
DO15	114–120	F6.2,X †	Standard error of Ω (deg)
DO16	121–124	I3,X	Reference to the literature for the orbital parameters
DO17	125–126	A1,X	Flag indicating a note at the end of relevant volume
DOM1	127–139	12I1,X	Status flags for the 12 astrometric and orbital parameters taken in the order indicated below (1 = estimated, 0 = not estimated)
DOM2	140–337	66I3	66 correlation coefficients in a non-linear coding

† blank if the element is not estimated but assumed or adopted from the literature (status 0 in Field DOM1)

The order of the correlation coefficients in Field DOM2 is indicated by the table below. Correlation coefficients which are undefined (corresponding to blanks in the standard error Fields DO9–15, and a status flag = 0 in Field DOM1) are set to zero. The table also indicates the order of the 12 astrometric and orbital parameters relevant for the status flags. All correlation coefficients are coded as integers between −99 and 999 using the arcsine transformation (Equation 2.3.16); undefined values are thus coded as 450. Note that ρ_1 to ρ_{10} are also given, to the nearest percentages, in the main catalogue (Fields H19–28).

	α	δ	π	$\mu_{\alpha*}$	μ_δ	P	T	a_0	e	ω	i	Ω
α	1	ρ_1	ρ_2	ρ_4	ρ_7	ρ_{11}	ρ_{16}	ρ_{22}	ρ_{29}	ρ_{37}	ρ_{46}	ρ_{56}
δ	ρ_1	1	ρ_3	ρ_5	ρ_8	ρ_{12}	ρ_{17}	ρ_{23}	ρ_{30}	ρ_{38}	ρ_{47}	ρ_{57}
π	ρ_2	ρ_3	1	ρ_6	ρ_9	ρ_{13}	ρ_{18}	ρ_{24}	ρ_{31}	ρ_{39}	ρ_{48}	ρ_{58}
$\mu_{\alpha*}$	ρ_4	ρ_5	ρ_6	1	ρ_{10}	ρ_{14}	ρ_{19}	ρ_{25}	ρ_{32}	ρ_{40}	ρ_{49}	ρ_{59}
μ_δ	ρ_7	ρ_8	ρ_9	ρ_{10}	1	ρ_{15}	ρ_{20}	ρ_{26}	ρ_{33}	ρ_{41}	ρ_{50}	ρ_{60}
P	ρ_{11}	ρ_{12}	ρ_{13}	ρ_{14}	ρ_{15}	1	ρ_{21}	ρ_{27}	ρ_{34}	ρ_{42}	ρ_{51}	ρ_{61}
T	ρ_{16}	ρ_{17}	ρ_{18}	ρ_{19}	ρ_{20}	ρ_{21}	1	ρ_{28}	ρ_{35}	ρ_{43}	ρ_{52}	ρ_{62}
a_0	ρ_{22}	ρ_{23}	ρ_{24}	ρ_{25}	ρ_{26}	ρ_{27}	ρ_{28}	1	ρ_{36}	ρ_{44}	ρ_{53}	ρ_{63}
e	ρ_{29}	ρ_{30}	ρ_{31}	ρ_{32}	ρ_{33}	ρ_{34}	ρ_{35}	ρ_{36}	1	ρ_{45}	ρ_{54}	ρ_{64}
ω	ρ_{37}	ρ_{38}	ρ_{39}	ρ_{40}	ρ_{41}	ρ_{42}	ρ_{43}	ρ_{44}	ρ_{45}	1	ρ_{55}	ρ_{65}
i	ρ_{46}	ρ_{47}	ρ_{48}	ρ_{49}	ρ_{50}	ρ_{51}	ρ_{52}	ρ_{53}	ρ_{54}	ρ_{55}	1	ρ_{66}
Ω	ρ_{56}	ρ_{57}	ρ_{58}	ρ_{59}	ρ_{60}	ρ_{61}	ρ_{62}	ρ_{63}	ρ_{64}	ρ_{65}	ρ_{66}	1

Table 2.3.4b. References to DMSA/O

This file is an alphabetical list of references to the literature for orbital elements adopted in the orbital solutions or used as starting values for the solution. The references are numbered sequentially, with Field DO16 in Table 2.3.4a pointing to the relevant reference. Each reference consists of up to nine lines of text, with a maximum of 72 characters in each line.

Fields designated DOM... appear only in the machine-readable catalogue

Field	Bytes	Format	Description
DO16	1–4	I3,X	Reference number from Field DO16
DOM3	5–6	I1,X	Number of records (N) under this reference number
DOM4	7–8	I1,X	Sequential number (1 to N) of this record
DOM5	9–80	A72	Text

Table 2.3.5. The Machine-Readable DMSA/V

Fields designated DVM... appear only in the machine-readable catalogue

Field	Bytes	Format	Description
DV1	1–7	I6,X	Hipparcos Catalogue (HIP) identifier
DV2	8–13	F5.2,X	Adopted reference magnitude, $Hp_{\rm ref}$ (mag)
DV3	14–21	F7.2,X	VIM element in right ascension, $D_{\alpha*}$ (mas)
DV4	22–29	F7.2,X	VIM element in declination, D_δ (mas)
DV5	30–37	F7.2,X	Standard error of $D_{\alpha*}$, $\sigma_{D_{\alpha*}}$ (mas)
DV6	38–45	F7.2,X	Standard error of D_δ, σ_{D_δ} (mas)
DV7	46–51	F5.2,X	Significance of the VIM elements, F_D
DV8	52–58	F6.2,X	Position angle of the constant component, $\theta_{\rm C}$ (deg)
DV9	59–65	F6.2,X	Standard error of the position angle, $\sigma_{\theta_{\rm C}}$ (deg)
DV10	66–72	F6.1,X	Lower limit for the separation of the binary, $\varrho_{\rm min}$ (mas)
DV11	73–79	F6.1,X	Displacement of photocentre between maximum and minimum luminosity, $d_{\rm var}$ (mas)
DV12	80–81	A1,X	Flag indicating a note at the end of relevant volume
DVM1	82–144	21I3	21 correlation coefficients in a non-linear coding

The correlation coefficients in Field DVM1 are given in the sequence indicated by the following table:

	α	δ	π	$\mu_{\alpha*}$	μ_δ	$D_{\alpha*}$	D_δ
α	1	ρ_1	ρ_2	ρ_4	ρ_7	ρ_{11}	ρ_{16}
δ	ρ_1	1	ρ_3	ρ_5	ρ_8	ρ_{12}	ρ_{17}
π	ρ_2	ρ_3	1	ρ_6	ρ_9	ρ_{13}	ρ_{18}
$\mu_{\alpha*}$	ρ_4	ρ_5	ρ_6	1	ρ_{10}	ρ_{14}	ρ_{19}
μ_δ	ρ_7	ρ_8	ρ_9	ρ_{10}	1	ρ_{15}	ρ_{20}
$D_{\alpha*}$	ρ_{11}	ρ_{12}	ρ_{13}	ρ_{14}	ρ_{15}	1	ρ_{21}
D_δ	ρ_{16}	ρ_{17}	ρ_{18}	ρ_{19}	ρ_{20}	ρ_{21}	1

All correlation coefficients are coded as integers between −99 and 999 using the arcsine transformation (Equation 2.3.16). Note that ρ_1 to ρ_{10} are also given, to the nearest percentages, in the main catalogue (Fields H19–28).

Table 2.3.6. The Machine-Readable DMSA/X

Field	Bytes	Format	Description
DX1	1–7	I6,X	Hipparcos Catalogue (HIP) identifier
DX2	8–14	F6.2,X	Cosmic error, ϵ (mas)
DX3	15–21	F6.2,X	Standard error of ϵ, σ_ϵ (mas)
DX4	22	A1	Flag indicating a note at the end of relevant volume