## DATA FROM THE WASHINGTON DOUBLE STAR CATALOGS (WDS)

## U.S. NAVAL OBSERVATORY WASHINGTON D.C. 20392

As a result of numerous changes in software and hardware, as well as the addition of new catalogs, information is now provided in a somewhat different format. It is hoped that this presentation is clearer; if it is in any way confusing, or there are omissions, please let us know.

The WDS (and associated catalogs) are at present in a state of flux. At this point the following things have been done :

General comments:

- 1. Data from all catalogs are referenced to a single note file and single reference file.
- 2. To facilitate those of you who make data requests on a regular basis I've added a "version number" to the top line so that it is known when this file is modified. Typically a user can just check these numbered notes and look for new ones.
- 3. Explanatory material from the WDS "intro.doc" added to this file, so that all explanatory WDS material is in a single file.

WDS summary lines:

- 1. Arcsecond precise coordinates have been provided when available.
- 2. Secondary proper motions have been provided when available .
- 3. Duplicate discovery designations have been removed. Some numbers had been used more than once erroneously. In addition, some discovery designations were given unfortunate additional designations ("1/2", "a", and even the Struves' use of "App"). Some numbers were repeated due to the discoverer having more than one list (Herschel lists I-VI and N come to mind). To make the WDS discovery designation more clear all of these duplicate designations have been corrected.
- 4. The magnitude information in the WDS is a hodge-podge of data. Many systems with entries in the delta-m catalog inexplicably had little or no magnitude information available. These have been updated to be as consistent as possible, taking Tycho V magnitudes when available.
- 5. X codes have been added in column 109 of the summary line when the pair is questionable. Generally these are unconfirmed systems, which pairs may represent positional typos in the original publication (thus we're looking in the wrong location), optical doubles which have changed greatly in separation and/or angle due to radically different proper motions, plate errors, or may simply be not at the magnitude, separation, etc., where the first measure was added (too

faint, too close, etc.). We would certainly like to know about circumstances where you have found or have ascertained the mystery behind these pairs.

- 6. The format of the WDS summary lines was changed slightly:
  - a. The column for number of measures has been increased to four digits. Therefore, the 607 systems which previously had "99" measures (indicating N greater than or equal to this number) now have the actual number of measures. Ten systems have more than 1000 measures, with the largest being 70 Ophiuchus with 1640.
  - b. The secondary proper motion, formerly at the end of each record, has been moved next to the primary proper motion.
  - c. An additional notes column has been added. The actual notes codes have not changed, however, many cases have been found where a note has either been not included or put in the notes file. Adding the additional column will eventually decrease the size of the notes file.
  - d. Precisions of coordinate have been improved by an order of magnitude in each digit, i.e., tenths of a second of arc and hundredths of a second of time. Nearly 99% of the pairs in the WDS now have coordinates to this precision.
  - e. Spaces and decimals have been added where appropriate, for consistency and to improve readability.
- 7. The p code has been removed from the summary line codes in columns 108-111. This code referred to "Coordinates and proper motions from ACRS, PPM, IRS, FK5 catalogs".
- 8. Ambiguities with "P" coded proper motion (10x larger than listed) have been corrected.
- 9. Identification of pairs that could be physical or are certainly not physical are flagged, using one of several codes. See the list of summary catalog codes below. As of 2009.5 these were 2894 pairs with physical codes and 1552 with optical codes; this represents 2.77% and 1.49%, respectively, of the entire catalog. True natures of the vast majority of systems in the WDS are still undetermined.
- 10. At present the Durchmusterung catalogs (BD, CD, CPD) are still used as the primary cross-reference (in addition to the precise coordinates). It is anticipated that once it is complete, the more modern and deeper all-sky UCAC4 may be used in this role; alternatively, some combination of catalogs (Hipparcos, Tycho2, UCAC4, etc.) may be used for pairs of different magnitudes. In any event, a historical WDS <-> DD <-> BD cross reference will be available on the WDS website.
- 11. The procedure for updating first and last measures has been simplified somewhat. Typically the first and last measures refer only to "full" measures (measures which include date + theta + rho); the number of measures (nmeas) counts only those full measures. A small number of pairs have only "partial" measures (measures lacking one or more of the three quantities). Therefore, if nmeas = 0, the first and last partial measure are listed; any missing value is given as "-1".

WDS data lines:

- The codes to the WDS data lines (columns 125 and 126) have been updated. Many codes have been removed, in favor of additional information included with the measures (for example, the "D" code, indicating that the separation is an upper limit, has been replaced with a "<" preceding rho). See the data line format table below.</li>
- Non-numeric position angles (N, NP, SF, etc.), have been converted to the nearest numeric position angle and a code (L) has been added indicating the change.plate
- 3. Measures which are likely to be in error, but cannot be corrected (code "X") are not included in the ensemble of data points for the summary line. Incomplete data (missing date, position angle and/or separation) are also not included in the summary line.
- 4. Our updating of measures, orbits, and discoveries continues.
- 5. Method files for all USNO double star catalogs have been combined. The new 1- and 2-letter codes (see below) provide considerably more detailed information about the technique than previously possible.
- 6. We are in the midst of correcting many errors in the WDS. This task included examining all measures containing old codes G, H, I, and J as well as large outliers in orbit or linear motion calculations. In most cases, this involves going back to the original reference and examining the observation to determine what errors can be ascertained (often a misidentification or a typo) and corrected. We have gone from these four codes to a more generic code "N" (corrected) or "X" (not corrected, while retaining the "I" (identification questionable) code. Code "X" data are not included in the summary line.
- 7. Sometimes you will find that the reference is listed as "unpublished". If you use such data, as a common courtesy dictates that you obtain the permission of the author if possible. This permission is implicitly given by us by inclusion of our own unpublished measures in the data base. Also, if you make use of data supplied by us, we would appreciate an acknowledgement in your published report or paper.

## Associated catalogs:

- Data requests now include orbital information, ephemerides, and figures illustrating the orbits and all measures, all from the Sixth Orbit Catalog. See http://ad.usno.navy.mil/wds/orb6.html for more information.
- 2. Linear solutions from the "Linear Elements Catalog" <http://ad.usno.navy.mil/wds/lin1.html> as well as associated ephemeris and figures are now provided with data requests as well.
- 3. Data from the delta-m catalog (previously unavailable) are included in data requests. This is from the new, 3rd magnitude difference catalog, over 200% larger than the first magnitude difference catalog. See http://ad.usno.navy.mil/wds/dm3.html for more information.
- 4. The Fourth Interferometric Catalog is not currently checked by this program. However, virtually all relevant information from this catalog has been incorporated into the WDS database during the most

recent reformat efforts. WDS technique codes were expanded to two characters in order to more complete technique descriptions in the Interferometric Catalog.

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Cross-reference (columns 99-106):

Durchmusterung number of the object in the system used by the Henry Draper Catalogue:

Bonn from +89 degrees to -22 degrees inclusive, Cordoba from -23 degrees to -51 degrees inclusive, Cape Photographic from -52 degrees to -89 degrees inclusive.

When a star is not contained in the Durchmusterung proper to its declination zone, but is contained in another Durchmusterung, this is so indicated in the Notes. Other components having different Durchmusterung numbers are also indicated in the Notes.

Note that the DM designation for Aa,Ab and other subcomponents of A as well as AB and simple binaries (i.e., no component designation) we give the appropriate cross-reference for the A component.

For other pairs in multiple systems, AC, AD, AB,C, or even BC, we give the cross-reference of the secondary of that pairing (i.e., for the above, C, D, C and C).

WDS SUMMARY CATALOG - note flags (columns 108-111):

- B Summary line gives blue (Johnson U or B, blue photographic, etc.) magnitudes
- C Orbit and Linear solution. A published orbit exists and this system has a Linear Solution as well. A "C" code, then, indicates both an "O" and an "L" code.
- I Identification uncertain. Match of object at precise position with WDS pair may or may not be correct. Currently under examination.
- K Summary line gives K-band or other infrared (>1 micron) magnitudes
- L Linear solution. Linear elements for this pair have been determined.
- M Magnitude modified. Magnitudes have been corrected to the Tycho-V scale based on other systems measured by the discoverer and Tycho.
- N Notes found in wdsnot.memo of the WDS.
- O Orbit, briefly described in WDSNOT MEMO and has entry in Orbit Catalog
- P 100 year proper motion in right ascension and declination.
- R Summary line gives red (Johnson R or I, red photographic, etc.) magnitudes.
- S Statistically different parallax and proper motion indicates that this pair is non-physical.

- T Statistically the same parallax within the errors and similar proper motion or other technique indicates that this pair is physical.
- U Proper motion or other technique indicates that this pair is non-physical.
- V Proper motion or other technique indicates that this pair is physical.
- W System has additional components and/or measures in the WDS Supplement (WDSS) catalog.
- X A "Dubious Double" (or "Bogus Binary"). This pair may represent a positional typo in the original publication (so we're looking in the wrong location), an optical double disappearing due to radically different proper motions, a plate flaw, or simply a pair not at a magnitude, separation, etc., sufficiently similar to those noted when the first measure was added (making it too faint, too close, etc.). We would certainly like to know about any circumstances where you have found or have ascertained the mystery behind these pairs.
- Y Statistically different parallax for the components indicates they are non-physical.
- Z Statistically the same parallax within the errors would indicate the components are physical.

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WDS OBSERVATION CATALOG: data line format

The format of the WDS data lines was greatly expanded May/June 2012, in order to accomodate more precise astrometry and photometry, as well as formal astrometric and photometric errors and filter information. During the process many old observation codes were eliminated, often by including additional information with the measure itself (for example, the "D" code, indicating that the separation is an upper limit, has been replaced with a "<" preceding rho). The new format is described below (note that in all cases the number of decimal places quoted in the catalog indicates the published precision):

term	columns	format	description
date	008-017	f10.5	Observation date, in years.
tflag	019-019	a1	Flag for theta (position angle) measure. Flags include:
			: = uncertain/estimated (old code U)
			L = originally published as nf, sp, etc.
			Q = quadrant flipped 180deg from published value
			<pre>V = measure is vector separation along this angle vector</pre>
theta	020-026	f7.3	position angle, in degrees
terr	028-033	f6.3	published formal theta error, in degrees
rflag	035-035	al	Flag for separation (rho). Flags include:
U U			: = uncertain/estimated(old code U)
			<pre>&lt; = separation is less than quoted value   (old code D)</pre>
			D = separation is in degrees (old code H)
			E = pair elongated

			<pre>G = Hipparcos non-component double star solution (acceleration solution: apparently single, but with significant non-linear motion)</pre>
			M = separation is in arcminutes (old code C)
			<pre>m = separation is in milliarcseconds (old code A)</pre>
			<pre>0 = Hipparcos non-component double star solution (orbit solution: astrometric pair with orbital</pre>
			P = nain necolved but no concation given
			S = Hipppncos "suspected pop-single" stap
			(large scatter in single-star solution)
			U = nair unresolved/single (old code S)
			V = Hipparcos non-component double star solution
			(variability-induced mover: unresolved pair
			where one componeent is variable)
			X = Hipparcos non-component double star solution
			(stochastic solution: Hipparcos unable to get
			acceptable single- or double-star solution)
rho	036-044	f9.5	separation, in arcseconds (unless indicated
			otherwise by rflag)
reflag	046-046	al	Flag for separation error. Flags include:
			> = error is lower limit to true value
			<pre>&lt; = error is upper limit to true value </pre>
	047 052		P, F, G, V = quality flags (poor, fair, etc.)
rerr mflog1	047-053	T/.5	separation error, in same units as rho
mtragr	600-600	ат	primary magnitude flag. Flags include:
			y = nrimary is variable
mag1	956-961	f6.3	primary magnitude, in mag
mleflag	062-062	a1	primary magnitude error flag. Flags include:
			> = error is lower limit to true value
			< = error is upper limit to true value
mlerr	063-067	f5.3	primary magnitude error, in mag
mflag2	069-069	a1	secondary magnitude flag. Flags include:
-			> = magnitude is lower limit to true value
			f = star is too faint (old code F)
			s = mag2 is a magnitude rather than magnitude
			difference (only used if mag1 is blank;
			old code W)
2	070 075	66.2	v = secondary is variable (old code V)
mag2	0/0-0/5	t6.3	secondary magnitude, in mag. If magi is blank,
m2oflog	076 076	<b>5</b> 1	magz is the magnitude difference.
mzeriag	0/0-0/0	aı	Secondary magnitude enforminag. Flags include. $\lambda = \text{encor}$ is lower limit to true value
			$\zeta = \text{error is upper limit to true value}$
m2err	077-081	f5.3	secondary magnitude error. in mag
filter	083-090	2a4	filter effective wavelength and FWHM. in nm
fflag	091-091	al	filter flag. Flags include:
U			? = filter information is uncertain
			: = filter information is approximate

			<pre>a = value is average of multiple filters. Filter columns now include the mean wavelength and sigma of the filters averaged.</pre>
			B = blue filter
			<pre>c = filter effective wavelength and FWHM are in centimeters</pre>
			<pre>f = magnitudes are model-fit values rather than aperture magnitudes (relevant only to UCAC4 measures)</pre>
			K = IR filter
			<pre>M = filter effective wavelength and FWHM are in meters</pre>
			<pre>m = filter effective wavelength and FWHM are in millimeters</pre>
			n = no filter used
			R = red filter
			<pre>u = filter effective wavelength and FWHM are in microns</pre>
			X = X-ray band
tel	093-097	f5.1	telescope aperture, in meters
teflag	098-098	al	<pre>telescope aperture flag. Flags include: a = average of multiple telescopes (old code M) k = multiple aperture telescope, baseline in km</pre>
nn	100-101	i2	number of nights averaged into mean measure
ref	103-110	a8	reference code
tech	112-113	a2	technique code. See table below.
codes	115-116	2a1	additional codes. See table below.
d.e. note	117-117	a1	data entry note. See table below.

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WDS OBSERVATION CATALOG: technique or method (data lines, columns 112-113)

These same technique codes are now used for all our catalogs; the table below also lists the old codes used in the WDS and Interferometric Catalog, prior to the most recent reformat.

new	old	description
A Aa Ac	U Uch	<pre>= adaptive optics = adaptive optics with apodizing phase plate = CHARA adaptive optics</pre>
Ad	Usd	= adaptive optics spectral deconvolution technique
Ag	Ula	= laser-guided AO
Al	Usi	= adaptive optics imaging, keeping only selected images
		("lucky imaging")
Am	Uam	= adaptive optics with aperture mask
Ao	Uco	= adaptive optics coronagraph
As	Uds	= AO + dark speckle coronagraph

Aw	Ucw	=	adaptive optics with coronagraph and "well-corrected subaperture"
С	F	=	CCD or other two-dimensional electronic imaging
Ca	W	=	Area scanner
Cc	Fic	=	IR coronagraph
Ce	L	=	Electronographic camera
Cg		=	imaging using Gaussian aperture pupil mask
Ci	Fir	=	IR direct imaging
C1	Fsi	=	<pre>short-exposure CCD imaging, keeping only selected images ("lucky imaging")</pre>
Ср	Fip	=	IR imaging polarimetry
Ċs	Fss	=	IR one-dimensional slit scanning
Cu	F	=	USNO CCD imaging (speckle-style reduction)
Cv		=	CCD imaging (speckle-style reduction)
D	D	=	Heliometer
Е	Е	=	Wide-field CCD or other two-dimensional electronic imaging
E2	E2m	=	2MASS (Two Micron All-Sky Survey)
Ed	Ede	=	DENIS (Deep Near-Infrared Survey)
Ek	Euk	=	UKIDSS (UKIRT Infrared Deep Sky Survey)
Ер		=	PPMX, PPMXL
Er		=	USNO URAT
Es	Esd	=	SDSS (Sloan Digital Sky Survey)
Eu	Eu3	=	UCAC3
Eu	Eu4	=	UCAC4
Еy		=	Yale SPM (Southern Proper Motion) Survey
Н	Т	=	Hipparcos/Tycho, HST, Spitzer, or other space-based technique
Н	Q	=	Hipparcos/Tycho, HST, Spitzer, or other space-based technique
На	Qac	=	HST + ACS
Hc	Ech	=	Chandra
He	Eei	=	Einstein
Hf	Q+g	=	HST + Fine Guidance Sensor
нg		=	Gala
HN	i np	=	Hipparcos
	Qir	=	Spitzer Space Telescope + IRAC (Intrared Array Camera)
HK	0	=	Repier Spitzon Space Telescone + MIDS (Multiband Imaging Destemator
пш	Quit	=	for Spitzen Space reference + MIPS (Multibanu imaging Photometer
Ц'n	Oni	_	HST , NICMOS IP dinact imaging
		_	HST + Faint Object Campa
ПU Цр	Q10 Onc	_	HST + HEDC2 Dianotany Camona
пр цэ	Qpc	_	UST + MEC2
Нс	∩c+	_	
H+	τtν	_	Tycho
Hw	Owi	=	WISE (Wide-field Infrared Survey Explorer) satellite (IR
	£=		imaging)
Hx	Qsx	=	Spitzer Space Telescope + SpeX spectrometer and slit-viewing

Hz		=	camera XMM Newton satellite
I	Р	=	interferometric technique
Ig	Pgi	=	phase grating interferometer
Im	Pmi	=	Michelson interferometer
J	] 7	=	visual interferometer
JW	JIIIW	=	(Anderson, Merrill)
Jp	Јре	=	Mount Wilson 20-foot beam interferometer (Pease)
К	К	=	long-baseline visual/IR/radio interferometer
К2	Kce	=	CERGA 2-telescope interferometer
Ка		=	ALMA array
Kb	Kbi	=	BIMA
Кс	Kch	=	CHARA Array
Kd		=	Plateau de Bure array
Ke	Kev	=	European VLBI network
Κf	Kcs	=	CHARA Array (separated fringe packet data)
Kg	Kgl	=	global VLBI array
Ki	Kio	=	IOTA
Kk	Kki	=	Keck interferometer
K1	Kvl	=	VLA
ΚI	Kvb	=	VLBA
Km	Km3	=	Mark III
Kn	кпр	=	NPOI/NOI [Navy (Prototype) Optical Interferometer]
кр	крт	=	PII (Palomar Testbed Interterometer)
Kr	кар	=	radio/ik aperture synthesis technique
KS V	KSU	=	SUSI (Sydney University Stellar Interferometer)
KU KV	кри Кур	_	
ΓV	кvа	-	VLII/AMDER
М	А	=	micrometry technique
Ма	А	=	micrometer with refractor
Mb	В	=	micrometer with reflector
Мс	C	=	Comparison image micrometer
Md	N	=	Visual measures with a double-image micrometer
Mg	Μ	=	Microguide eyepiece
Mr	R	=	RGO use of micrometer plus comparison image micrometer on same star
0	0	=	occultation
0	0cc	=	occultation
Р	G	=	photographic technique
Pa	G	=	photographic, with astrograph
Pb	~	=	USNU-B photographic, with multiple astrographs
PC	Gac	=	Astrographic Catalog
Ре	G	=	ESU Schmidt astrograph

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Pk Gag = AGK Catalog
            = photographic, with medium or long-focus technique or with
   Po H
              ocular enlargement
   Pp Gp1 = Palomar Observatory Sky Survey (POSS-I)
              1948-1958, 48in/1.2m Schmidt
   Pp Gp2 = Palomar Observatory Sky Survey (POSS-II)
              1985-1999, 48in/1.2m Schmidt
   Pu Guk = UK Schmidt Southern Survey
              1974-1987, 48in/1.2m Schmidt
   S
       Spe = speckle interferometric technique
   Sa Sam = aperture masking technique (MAPPIT, etc.)
   Sb Sbi = bispectrum speckle interferometric technique
   Sc Sch = CHARA speckle
   Si Sir = IR speckle
   Sp Spo = speckle polarimetry
   Ss Ssa = shift-and-add technique
   St
            = Tokovinin "hrcam"
   Su Sus = USNO speckle
   Т
       М
            = Transit circle / Meridian circle
            = "Eyepiece micrometer" transit/chronometric technique
   Tm I
   V
            = visual estimate
   Х
            = spectroscopic technique
   Xg X
            = Visual estimate made with an objective grating
   Xh Zhr = high-resolution spectroscopy
   X1 Zlr = low-resolution spectroscopy
   Xr Zre = resolved spectroscopy
   Xs Zsp = spectrophotometry
   Z
       Ζ
           = photometric technique
       Zpt = photometer
   Ζ
           = CCD photometry
   Zc
   Zd V = Photocell with diaphragm in focal plane
   Zp Z = Visual photometry with a double-image or polarizing photometer
            = Wedge photometer
   Zw Y
Additional codes for references:
      lin = solution in Rectilinear Elements Catalog
      not = paper referenced in Notes file
      orb = orbit information in Sixth Orbit Catalog
WDS OBSERVATION CATALOG: codes (data lines, columns 115-116)
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D Thought to be reliable magnitudes / magnitude difference

F G	Too faint, not seen, or not located This measure is not in the published paper but is a vector combination of measured pairs by this author for a pair already in the WDS.						
т	Identification, or question about such						
L	Original PA given as n, nf, f, sf, s, sp, p, or np (n = north, s = south, f = following, p = preceeding), and converted to 0, 45, 90, 135, 180, 225, 270, or 315, respectively. Also, a PA given as e (east) or w (west) is converted to 90 or 270 respectively. The PA is assumed accurate only to the nearest quadrant (i.e., +/- 45 deg).						
M N	Mean of multiple measures of same photographic plate or CCD. Identification or position error, or misprint in publication	n, corrected.					
0	Optical						
P	Corrected by author						
V	No. of nights varies 50% or more between angle and separation In this case, N = [(Npa + Nsep) / 2], rounding down.	n measures					
Х	Identification error, position error, or misprint in publicat corrected. Code "X" data are not included in summary lines. also used to indicate measures superceded by later reductions	tion, NOT The X code is s of the same					
	data (for example, reprocessing of Astrographic Catalog data	for the WFC).					
Z	Measurer other than author(s)	,					
WDS 0 1 2 3 4 5 6 7 7 A 1 cor	S OBSERVATION CATALOG: data entry notes (data lines, column 1: Pre-IDS measure added by Burnham, Aitken, etc. Post-IDS measure added by Lick Observatory Post-IDS measure added by USNO Measure prior to Lick punch-card collection, added by USNO Post WDS (1984.0) measure added by USNO Post WDS (1996.0) measure added by USNO Post WDS (2001.0) measure added by USNO Post WDS (2006.5) measure added by USNO total of 1,192,565 data lines of 120,005 systems of which 858 mplete astrometric measures (T,pa,sep).	N=161,240 N= 14,858 N= 75,575 N=132,903 N= 65,250 N= 63,271 N=170,862 N=508,606					
===							
SIX	<pre>(TH ORBIT CATALOG - elements:</pre>						
Р	= Period of revolution						
pf.	lag = units of period (c = centuries, d = days, h = hours, y =	= vears)					
a	= Semimajor axis of orbit	, ,					
af:	<pre>lag = units of semimajor axis (a = arcsec, m = milliarcsec, M u = microarcsec)</pre>	= arcminutes,					
i Noc	<pre>u = microarcsec) = inclination, angle between plane of the sky and plane of the orbit, 0-180 degrees. The motion is direct (i.e., in direction of increasing position angles) if i &lt; 90 and retrograde if i &gt; 90. Node = Position angle of the line of intersection between the plane of the</pre>						

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orbit and plane of the sky, in degrees.
T = epoch of periastron passage
tflag = units of T (y = years, d = MJD)
e = orbital eccentricity
omega = longitude of persiastron, in degrees
G = orbit grade (1 = definitive, 2 = good, 3 = reliable, 4 = preliminary,
5 = indeterminate, 9 = unknown). The grading procedure is described
in the introduction to the Sixth Catalog
(see http://ad.usno.navy.mil/ad/wds/int6.html).
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Notes : In some cases more than one orbit will be provided. Cases like this fall into one of two categories:

- 1. More than one binary in a multiple system has an orbit calculated.
- 2. While the orbit grading algorithm grades orbits objectively on many categories, they sometimes can achieve approximately the same grade and the decision as to which orbit is better may be ambiguous. As a rule of thumb, following the time-honored precepts of van den Bos and Worley, and asking the question "Is this Orbit Really Necessary?" (see, for example, PASP, 74, 297; 1962 ), we answer in the negative, and retain the earlier orbit. However, there still remain cases where the orbits can be sufficiently different but ambiguous (for example, solutions with different quadrants selected for small magnitude difference systems). In this case, more than one orbit may be retained.
- 3. A grade 8 or 9 orbit (which was not provided in Worley & Heintz) is given when it is not possible to evaluate the orbit as no "classical double star" data are available.

Interferometric orbits based solely on visibility data (i.e., no rho and theta provided) are given a grade of 8. Were complete data available these orbits (usually combined solutions with spectroscopic data) would undoubtedly have a very good grade.

Astrometric orbits (derived from photocenter vs. barycenter shifts) are given a grade of 9. When resolved, systems of this type typically show rather large differences between the elements computed astrometrically and those based on differential measures. Further, the grades are only based on available visual double star

data. If the solution to an orbit is based on a combined solution (e.g., with spectroscopic information), certain elements are certainly known better. Utilizers of the data are encouraged to thoroughly scan the "notes" section.

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SIXTH ORBIT CATALOG - ephemerides:

Each orbit above is provided with an ephemeris for the next five years. While many orbits may be of poor quality, short-term ephemerides are often quite good.

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## SIXTH ORBIT CATALOG - figures:

In all orbit figures in this catalog, green plus signs indicate visual (micrometric) observations, violet asterisks photographic measures, and blue symbols various interferometric techniques (open circles, filled circles, and filled squares for eyepiece interferometry, speckle or other single-aperture techniques, and multi-aperture techniques, respectively). Finally, a red "H" or "T" indicates a measure from Hipparcos or Tycho. The dot-dash line indicates the line of nodes. Scales are in arcseconds, and the curved arrow at lower right indicates the direction of orbital motion.

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RECTILINEAR ELEMENTS CATALOG - elements:

The elements are defined by linear relationships relative to the closest approach

x = -sin(theta) \* rho
y = cos(theta) \* rho

and let (x0,y0,t0) or (rho0,theta0,t0) define the relative location and time of closest approach

Solve for:

x = xa \* (t-t0) + x0y = ya \* (t-t0) + y0

A standard weighted least squares fit is made, with weights of individual measures determined using the technique outlined in the Sixth Catalog of Orbits of Visual Binary Stars. RMS errors determine the errors of these parameters.

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RECTILINEAR ELEMENTS CATALOG - ephemerides:

Ephemerides for years 2010-2035 are provided with the elemental errors propagated into the rho and theta relative position.

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RECTILINEAR ELEMENTS CATALOG - figures:

Figures are also provided for each system, and are linked from the main catalog by the letter "P" in one of the righthand columns. The figures include all measures in the WDS, as well as the linear fits whose elements are given in the main catalog (shown as a solid black line). Individual measures in these figures are color-coded as in the Orbit Catalog; green, blue, and purple indicate micrometric, interferometric, and photographic measures, respectively, while a red "H" or "T" indicates a measure from Hipparcos or Tycho. Measures are connected to their predicted locations by "O-C" lines; measures given zero weight are indicates by dotted O-C's.

For those pairs with two sets of proper motions in the WDS, a red line indicates the differential proper motion predicted by these values. Since most of these proper motions are from the Hipparcos or Tycho-2 catalogs, the red lines intersect the least-squares fit to the data at the Hipparcos epoch of 1991.25. The lengths of both the black and red lines correspond to a similar range of dates (usually roughly corresponding to the range of observation dates, unless T0 falls outside that range).

WDS SUPPLEMENT CATALOG :

Format for the summary lines are as follows:

01	001-014	a14		WDSS identifier
02	016-018	a3		Component identifier
03	025-028	i4		dates of first/last observation
04	030-032	i3		Number of astrometric observations
05	034-036	i3	deg	First/last position angle
06	038-043	f6.2	arcsec	First/last separation (arcseconds or as
				noted)
07	044-044	a1		<pre>Flag for separation units     m = mas</pre>
				M = arcminutes
				D = degrees
08	046-050	f5.2	mag	Primary/secondary visual magnitudes (Johnson V or similar, or as noted)
09	051-051	a1		Flag for filter
				b = blue
				r = red
				g = SDSS g
10	053-057	f5.2	mag	Primary/secondary infrared magnitudes (K-band or similar, or as noted)
11	058-058	a1		Flag for filter
				h = H-band
				j = J-band
12	060-064	a5		Spectral type of primary/secondary
13	066-081	2f8.2	mas/y	Proper motion (RA and DEC) of
				primary/secondary
14	083-089	f7.2	mas	Parallax of primary/secondary
15	091-114	a24		Alternate name for primary/secondary
16	116-117	2a1		Note flags:
				C = pair has both orbit and linear
				solutions, uncertain which is correct
				L = pair has rectilinear solution in

Linear Elements Catalog N = see note in notes file 0 = pair has orbital solution in the Sixth Orbit Catalog U = pair is optical, based on parallax, proper motion, or other factors V = pair is physical, based on parallax, proper motion, or other factors X = pair is bogus (due to error in published coordinates, plate flaw identified as star, or other problem) Coordinates (J2000) of primary/secondary 17 119-136 Right ascention 2i2,f5.2 hhmmss.ss Declination a1,2i2,f4.1 +ddmmss.s 18 138-147 a10 Designation in main WDS catalog 19 149-155 a7 Discoverer designation in main WDS catalog Component designation in main WDS catalog 20 156-160 a5 Format for measurement lines are as follows: 01 001-014 a14 WDSS identifier 02 017-023 a7 Component pair identifier 03 025-034 f10.5 Date of observation (Julian epoch) Position angle flag 04 036-036 a1 : = value is uncertain/estimated L = originally published as nf, sp, etc. q = quadrant has been flipped 180deg from published value V = measure is a vector separation along this angle vector 05 037-043 f7.3 deg Position angle 06 045-050 f6.3 Position angle error deg Separation flag 07 052-052 a1 : = value is uncertain/estimated < = separation is less than quoted value E = pair elongated U = pair unresolved/single G,O,S,V,X = Hipparcos non-component double star solutions or suspected non-single R = pair resolved but no separation give D = separation is in degrees M = separation is in arcminutes m = separation is in milliarcseconds 08 053-061 f9.5 Separation (arcseconds or as noted by arcsec separation flag) Separation error flag 09 063-063 a1 P, F, G, V = quality (poor, fair, etc.)

				<pre>&gt; = error is lower limit to true value &lt; = error is upper limit to true value</pre>
10	064-070	f7.5	arcsec	Separation error (same units as separation)
11	072-072	a1		Primary magnitude flag
				<pre>&gt; = mag is lower limit to true value</pre>
				v = primary is variable
12	073-078	f6.3	mag	Primary magnitude
13	079-079	a1	-	Primary magnitude error flag
				> = error is lower limit to true value
				< = error is upper limit to true value
14	080-084	f5.3	mag	Primary magnitude error
15	086-086	al	C	Secondary magnitude flag
				> = mag is lower limit to true value
				s = magnitude rather than magnitude
				difference (only used if primary
				magnitude field is blank)
				f = star is too faint
				v = secondary is variable
16	087-092	f6.3	mag	Secondary magnitude, or magnitude
			0	difference if primary magnitude field is
				blank
17	093-093	a1		Secondary magnitude error flag
				> = error is lower limit to true value
				<pre>&lt; = error is upper limit to true value</pre>
18	094-098	f5.3	mag	Secondary magnitude error
19	100-107	2i4	nm	Filter effective wavelength and FWHM
		or 2f4.1		Ũ
20	108-108	a1		Filter flag
				a = value is average of multiple filters
				u = wavelength is in microns
				<pre>m = wavelength is in mm</pre>
				c = wavelength is in cm
				M = wavelength is in meters
				B = blue filter (effective
				wavelength/FWHM values unknown)
				<pre>K = IR filter (effective wavelength/FWHM</pre>
				values unknown)
				R = red filter (effective wavelength/FWHM
				values unknown)
				X = X-ray band (effective wavelength/FWHM
				values unknown)
				n = no filter used
				? = filter information is uncertain
				: =filter information is approximate
24	110 111	<b>CF A</b>		
21	110-114	T5.1	m	Telescope aperture
22	112-112	ат		rerescope aperture trag
				a = average of multiple telescopes
				κ = multiple aperture telescope, baseline

23	117-118	i2	Number of	nights averaged into mean measure
24	120-127	a7	Reference	<pre>code (see file wdsref.memo)</pre>
25	129-130	a2	Technique	code (same as WDS above)

WDS REFERENCES: column description

- 01 3-character discover designation
- 02 8-character reference code
- 03 Codes for observation techniques, orbits, linear fits, notes in reference
- 04 Flag for epoch of measurement dates in reference (double star measures were traditionally published with dates given as Besselian epoch, but these are gradually being converted to Julian epoch, as recommended by the IAU).
  - = either the paper contains no measures or the measurement dates are of insufficient precision to be of concern (differences between Besselian and Julian epoch are at the 0.001-year level)
  - j = dates either published as or converted to Julian epoch
  - u = epoch unknown (not mentioned in paper)

w = all measures are of wide (>10") pairs; the epoch is of no consequence
? = paper not yet reexamined to determine epoch

We would welcome any information you might have concerning those references with "u" or "?" epoch flags.

- 05 Authors and reference
- 06 Bibcode if available

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