Re-calibration of SOAR speckle data

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Version: 2
Date: Feb 1, 2016
File: prj/speckle/doc/SAM16/recalibration/recal.tex

1 Introduction

Accurate calibration of speckle interferometry is not an easy task. The field of view is normally small, so the established astrometric standards like globular clusters or Orion Trapezium are not useful. Orbits of binary stars are normally less accurate than the data, so their use for calibration does more harm than good. Only orbits based on long-baseline interferometry, with accuracy exceeding speckle, can be used as calibrators, but those binaries are mostly quite close. On the other hand, wide binaries with separation above 1 arcsec should be used as calibrators because they allow measurement of scale and angle offset with higher accuracy, compared to the close pairs.

Absolute (i.e. independent of standards) calibration of speckle instruments has been done in the past. A two-slit mask placed in front of the telescope and an interference filter with well-known transmission allow such calibration, provided that the mask orientation is tied to the parallactic angle and that the mask is in the pupil and not in other place, where an additional scale factor must be accurately determined. At SOAR, absolute calibration has been done in 2009 using laser interference fringes and atmospheric dispersion to ascertain the angle. More recently, the SOAR HRCam has been tied astrometrically to the SOAR CCD imager (SAMI) with a $3'$ field. This relation is established by moving the point source in the focal plane and measuring its pixel coordinates in both instruments. Distortion in SAMI images is removed and they are calibrated astrometrically against 2MASS or other catalogs, providing orientation and pixel scale for SAMI and, hence, for HRCam.

Most runs of HRCAM were not accompanied by absolute calibration, however. Some (e.g. in 2012) used only the internal point-source calibration, relying on correct orientation and stable focus provided by the telescope. Short runs of only a few hours were not calibrated independently and "borrowed" calibration parameters from previous or posterior runs.

Fortunately, in every run several wide binaries were always observed with the idea to use them for calibration *post factum* when their motion is accurately determined by other means. Such "anchor" binaries can be also used to test the internal consistency of the full HRCam data set. Systematic errors were evident (Fig. 1).

The first step in this direction was taken in 2014, see the SOAR2014 paper. A set of 41 binaries wider than $0.5''$ without known subsystems, each observed in at least 4 runs, was selected. The motion in θ and ρ was approximated by linear functions of time. Then for each run deviations of the observed subset of calibrators from their linear ephemeris were median-averaged to determine systematic corrections for this run. After applying these corrections, the linear models were updated, new run corrections were found, etc. After several iterations the process converged. The resulting typical rms differences between models and calibrated data were 0.1° in angle and 1.9 mas in separation.

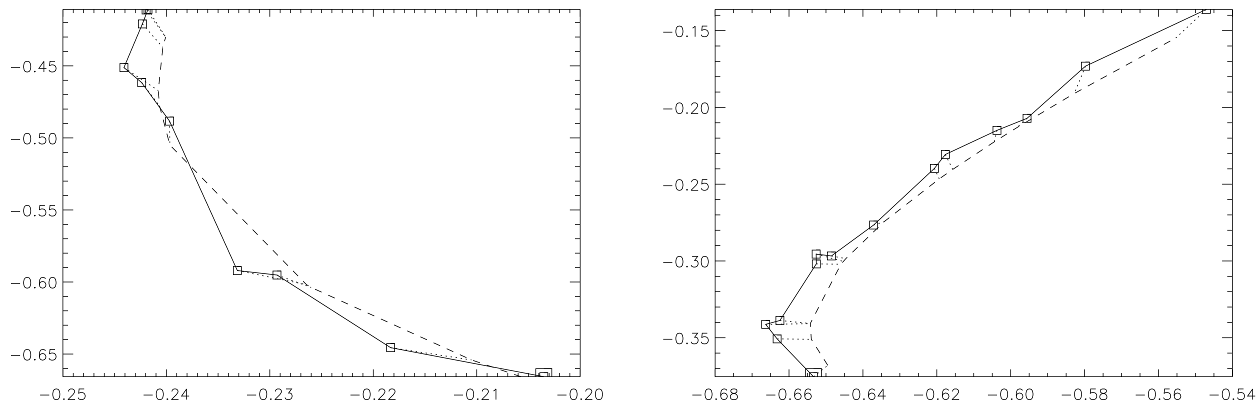

Figure 1: Speckle data before recalibration. Left: JC 8 AB (03124-4425), right: HJ 1399 (06003-3102). Scale in arcseconds, North up, East left, primary at (0,0). In each plot, squares connected by full line are the measurements, dashed line is the current orbit, dotted lines connect measurements to predicted positions.

Here this procedure is repeated with a few modifications, resulting in more robust estimation of the calibration parameters. I now included calibrators observed in only 3 runs and modeled the motion of orbital binaries more accurately. The set of calibrators is thus extended. They are by no means an ideal set, but rather *the* random set that happens to have adequate observations with HRCam.

It should be noted that a systematic error in scale or orientation common to all runs would remain undetected by this self-calibration procedure.

2 Modified calibration procedure

The new procedure is implemented in the code `recalib3.pro` which contains several programs. It should be launched from the main directory, where all necessary binary files such as `allruns.idl` are found. Recalibration is described step by step in the following.

1. The preliminary list of calibrators `recalib3.txt` is formed by `getstars`. Criteria: minimum average separation $0.5''$, data in no less than 3 runs. The list also contains HIP numbers and flags if orbits are known.

2. In the edited version `recalib3a.txt` many entries are eliminated (commented out) because they contain resolved subsystems. This is done by examination of all data on each system. Note that for some calibrators the sub-systems listed in the WDS (e.g. FIN 317 Aa,Ab in 09125-4337) are not confirmed at SOAR, and those are retained as simple binaries. A few pairs are removed because of their large Δm, hence large measurement errors. Nevertheless, the new list counted 73 calibrators with a total of 418 observations, or 5.7 runs per calibrator on average.

3. The structure `recalib` is created by `getrecalib` by reading the edited file. Its elements are:

```
el0 = {wds:'',name:'',hip:0L,rho:0.0,dm:0.0,nruns:0,type:1,el:dblarr(10),rmstheta:0.,rmsrho:0.
```

The type defines the nature of the data. Type 1 is the linear motion, in which case the first 5 elements of the array are $(t_0, \theta_0, \dot{\theta}, \rho_0, \dot{\rho})$. Type 2 are orbital pairs, where the first 7 numbers are orbital elements $(P, T, e, a, \Omega, \omega, i)$.

4. Collect measurements of all calibrators using `getobs`. It creates the structure `dat`, saved in `recaldat.idl`, with elements:

```
el0 = {name:'',irun:-1,t:0.0,theta:0.0,rho:0.0}
```

Several measurements in one run are averaged, without regards of filters. The Δm parameter is also average over all filters.

5. Add measurements from *Hipparcos* using `gethipdat`. Some pairs with HIP numbers do not have such measurements, being unresolved by *Hipparcos*.

6. Fit linear elements to binaries of type 1 with `fitlin` procedure. It takes the name of the star as input and returns the parameters and the rms residuals. Its keywords are /iterate (correct for run systematics before fitting), /nohip (do not use HIP point in the fitting), /save (put the results and rms residuals into `recalib`, /runname (read run corrections from another file, rather that default). In the first pass of fitting, the run corrections determined in 2014 were used. The procedure `alllin` fits all linear elements. In most cases I ignored the HIP point, as it is spaced too far in time from the HRCam data set and increases the residuals because of the non-linear orbital motion. The HIP datum is used only for some calibrators with just 3 HRCam points and slow motion.

7. Collect orbital elements from VB6 using `getorbit`. It selects data from VB6 matching both WDS and object name. If no or several matches are found, the selection is done manually for this object.

8. Updating the orbits. The procedure `allinp` creates for each type-2 binary the file NAME.inp in the sub-directory `orb` that lists orbital elements and data (only HIP and HRCAM, extracted from `dat`) in a format suitable for the `orbit` program. The HRCAM data are corrected for the run systematics, but uncorrected for precession in angle. By default, all elements except (T, a, Ω) are fixed. Using `orbit`, I adjusted the 3 free elements to match the data. HRCAM data have a weight 25 times larger than HIP, according to the square ratio of respective measurement errors. In some cases, I also fitted ω and/or i to reach reasonably small residuals of a few mas. When even this failed, a more thorough revision of some orbits was attempted [Give list]. It should be stressed that the adjusted orbits serve only as good approximations of the HRCAM data, regardless of their quality in other aspects. Figure 2 gives two examples.

The HIP measure of STF 186 was flipped. The orbits of 22451-0240 (A 2696 BC) and 23171-1349 (BU 182 AB) could not be adjusted to give reasonably small residuals, so linear fits were done instead. Overall, there are 50 calibrators of type 2 (orbital) and 23 of type 1 (linear). However, 01361-2954 (HJ 3447) is removed from calibrators owing to large residuals. Apparently it contains a subsystem.

9. Ingest the updated orbits into `recalib` using `allorbit`. It simply reads the new elements from the NAME.out files and replaces them. The orbit adjustment can then be repeated by creating a new set of *.inp files that use better corrections for the runs.

10. Examine all data using `plotstar`. It plots the run-corrected observations and their models, either linear or orbital. The procedure `ephstar` computes the latter, given type and elements. The keyword /save allows to update the residuals in `recalib`. The `allplot` plots all stars in the list sequentially, with a stop to examine the plot.

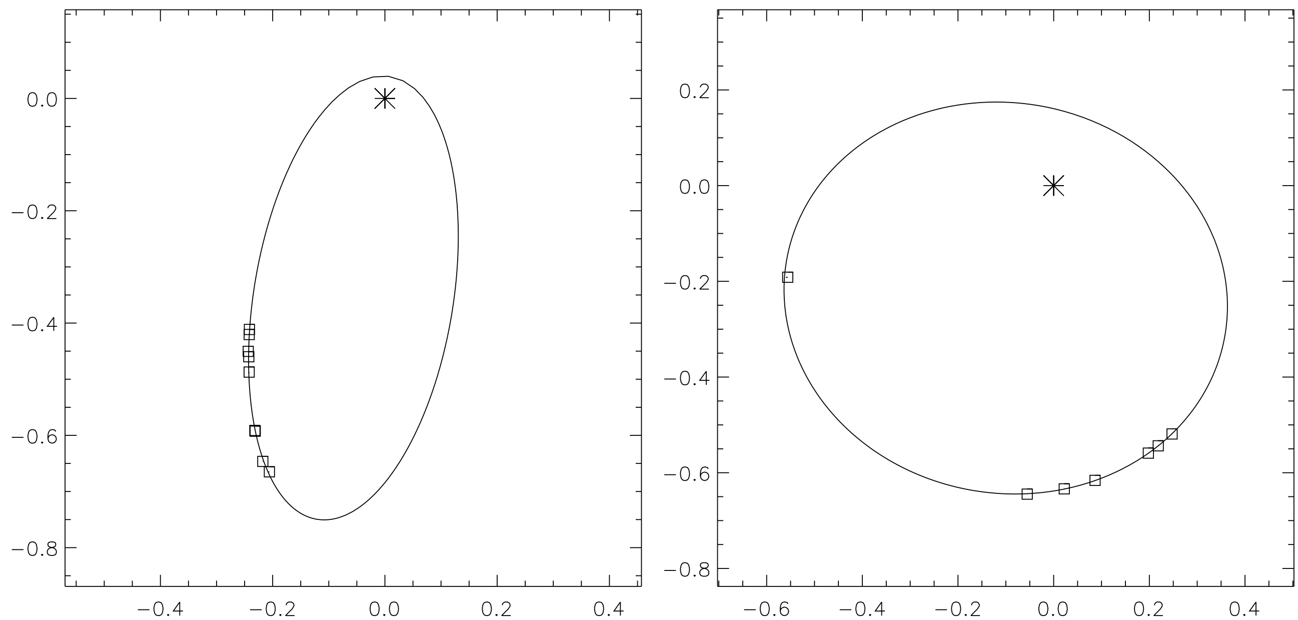

Figure 2: Adjusted orbits. Left: JC 8 AB, $P = 45.2\,\mathrm{yr}$, rms 0.8/1.3 mas. Right: HDS 2412 Aa,Ab, $P = 41.3\,\mathrm{yr}$, rms 0.7/0.6 mas.

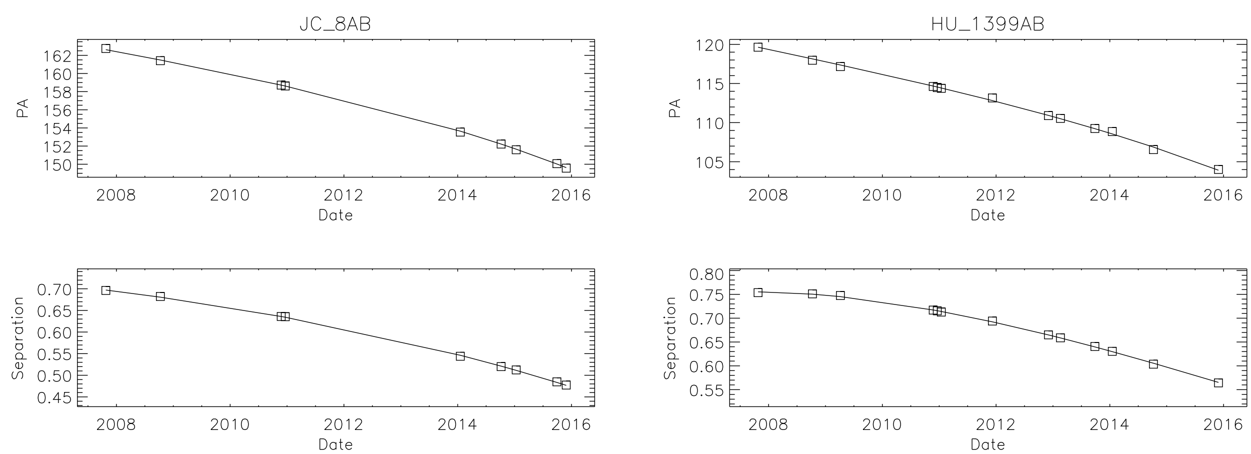

Figure 3: Comparison between data and models for two orbital binaries. Left: JC 8 AB, 0.8/1.3mas tangential/radial residuals, right: HU 1399 AB, 2.3/1.2 mas residuals.

Figure 3 gives examples of the plots for orbital binaries. Figure 4 shows HJ 3447 with large residuals (possibly undetected subsystem) and a linear model for B 1491. Overall, the rms residuals in tangential and radial directions are similar, with median values of 1.85 and 1.35 mas, respectively.

11. Iterate. The procedure `fitruns` re-computes the run corrections using observations and the models currently stored in `recalib`. The results are saved in the binary file `runs3.idl`. It contains the

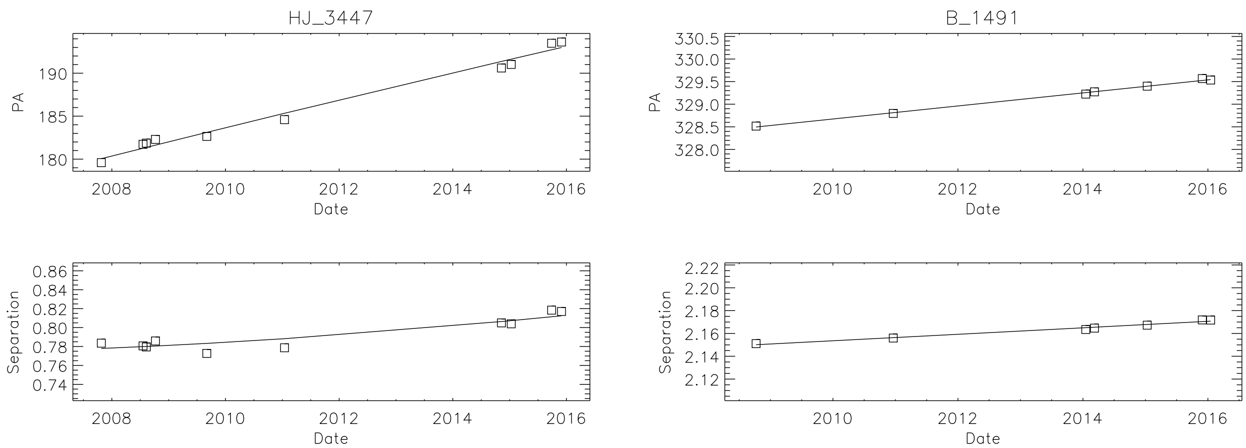

Figure 4: Comparison between data and models. Left: HJ 3447 with large residuals of 9.1/6.3 mas apparently caused by wobble, right: B 1491 with a good linear model, 1.6/1.3 mas.

array `runs[nruns,3]` where for each run the $\Delta\theta$, scale factor, and number of calibrators are stored, and the file `eruns[nruns,2]` with rms residuals in θ (degrees) and ρ (arcsec). The array `yrmin` is also saved with the beginning dates of each run, to facilitate the recalibration. The $\Delta\theta$ and scale have the sense of (O-C), so to correct for the run systematics they need to be applied in reverse (subtract and divide).

After the first determination of the elements, I iterated for the second time. The residuals decreased somewhat. No further iterations were made.

12. Listing of results and additional services.

`liststars` produces list of all calibrators `liststars3.txt`.

`listruns` creates `listruns3.txt` with calibrations of the runs.

`listpar` produces `linpar.txt` with linear elements and `orbpar.txt` with orbital elements.

`biascor` is a procedure to apply run corrections to a set of observations. The run data are read at the first call and kept in the common block for subsequent calls. The procedure `corrrun` uses this utility to remove systematics from any observing run. The corrected data are saved in a file with .corr added to the name, e.g. `obsres.idl.corr`.

`checkrun` finds calibrators in the given run and determines run corrections. It is useful for calibration of future runs.

3 Results

Figure 5 plots the systematic offsets found here. The scale is mostly within 0.2% from one, with the largest correction of -0.5% for the run 26 (2014.85, replacement detector and different lens in the camera). The largest offsets in angle are $+0.6°$ for the run 20 (2013.47, poor calibration) and $-0.4°$ for run 15 (2012.83). The runs 10 and 19 remain without calibrators; however, they contain only a small number of measurements. The median values of the run corrections in absolute value are $0.13°$ in angle and 0.1% for the scale. They are very similar to the medians of the rms scatters within each

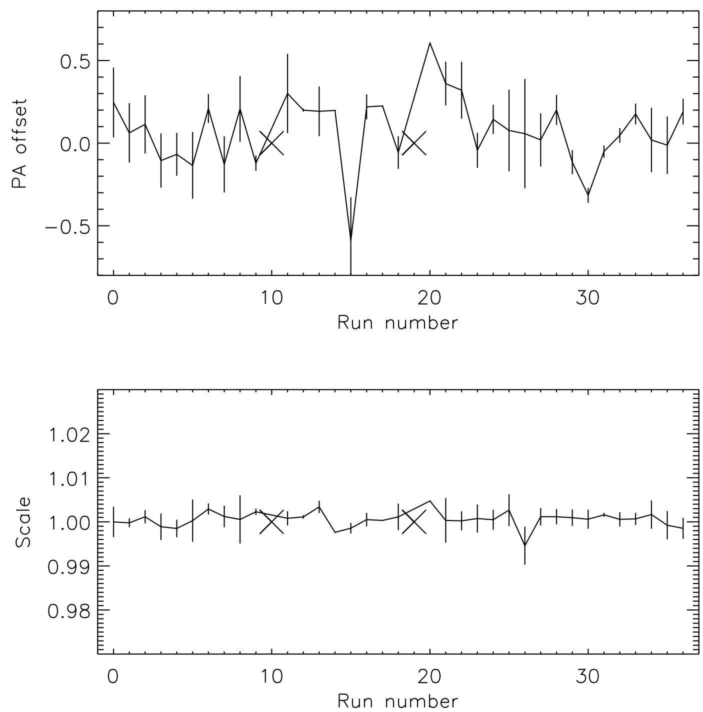

Figure 5: Calibration parameters found here. The vertical lines show rms scatter for each run (not the error of the mean). Two runs without calibrators are marked by crosses.

run, 0.105° and 0.18%, respectively. This tells us that no further improvement in calibration accuracy is expected from continued iterations.

The rms residuals of calibrators in the radial and tangential directions are similar, with median values of 1.35 and 1.85 mas, respectively. For a typical 1″ binary, the 2-mas tangential error corresponds to 0.11°. However, some stars have larger residuals. HJ 3447 suggests a wobble caused by unrecognized subsystem, so it was removed from the calibrator set (Fig. 4). In some other cases one slightly deviant measure causes the large rms residuals.

As an example, I applied the recalibration corrections to all data of 2015 (runs 28 to 35). These runs were already checked vs. linear calibrators defined in 2014. Still, non-negligible corrections of +0.20° and −0.32° are found for the runs 28 and 30 (2015.10 and 2015.25), while the corrections in scale are all under 0.2%. Before correction, the calibrators had rms residuals of 0.11° and 0.26% for the 2015 data. After correction, the residuals decreased to 0.067° and 0.23%.

Corrections of systematics have only a tiny effect on the close binaries. For wide pairs, however, they help to determine more accurate orbital elements and to study deviations caused by subsystems. Such deviations with a period on the order of 10 yrs were found here for 01361-2954 (HJ 3447), known also as τ Scl, HR 462 ($V = 5.69$, sp. type F2, parallax 14.42 mas). Its orbit with $P = 1500$ yr is based only on a short observed arc, so it is not reliable. The system might belong to the Hyades supercluster according to O. Eggen.

4 Lists

The list of calibrators and resulting rms residuals (in mas), calibrators3.txt. Remarks in the last columns indicate dates single deviant measures or other reasons of rms residuals exceeding 4 mas.

WDS	Name	HIP	Nruns	Rho	dm	type	rmstheta	rmsrho	Rem
00522-2237	STN_3AB	4072	6	1.99	0.87	1	2.3	2.0	
01084-5515	RST1205AB	5348	10	0.56	2.80	2	0.6	0.7	
01262-6751	DON_17	6703	7	1.34	1.05	2	0.8	3.1	
01361-2954	HJ_3447	7463	10	0.79	1.36	2	9.1	6.3	wobble,removed
01559+0151	STF_186	8998	4	0.76	0.52	2	2.1	0.8	
02039-4525	RST2272	9642	8	1.46	4.68	2	2.6	2.9	
02232-2952	BU_738	11131	4	1.96	0.36	2	12.1	2.9	2014.7?
02332-5156	HDS_333	11877	7	0.60	1.71	1	1.9	6.7	curvature
02460-0457	BU_83	12912	8	0.97	1.96	2	2.6	3.2	
03124-4425	JC_8AB	14913	9	0.54	0.76	2	0.8	1.3	
03236-4005	I_468	15799	7	2.54	3.05	2	7.9	5.3	2014.7?
04021-3429	BU_1004AB	18824	7	1.16	0.67	2	2.2	2.4	
04257-0214	BU_403	20673	5	0.97	1.56	1	1.0	1.3	
04518+1339	BU_552AB	22607	5	0.75	2.12	2	6.1	4.7	2014.8?
04584-0344	HDS_644	23116	3	0.63	2.60	1	0.7	0.3	
04590-1623	BU_314AB	23166	7	0.83	1.62	2	1.4	0.8	
05019-7638	RST2368	23413	3	0.80	2.33	1	0.9	0.6	
05079+0830	STT_98	23879	6	0.89	0.93	2	2.1	2.8	
05417-0254	BU_1052	26820	3	0.62	1.08	2	0.3	1.0	
05508-2907	B_1491	27609	7	2.17	2.42	1	1.6	1.3	
06003-3102	HU_1399AB	28442	13	0.71	0.94	2	2.3	1.2	
06048-4828	DUN_23	28796	11	2.61	0.42	2	9.5	4.8	2012.8?
06274-2544	B_114	30733	4	0.65	0.35	2	1.7	3.2	
06298-5014	R_65AB	30953	3	0.57	0.40	2	1.7	0.5	
06425-4234	I_283	32111	9	2.35	2.54	1	2.0	1.0	
07123-4030	HDS1001	34802	3	0.70	4.29	1	1.9	1.2	
07294-1500	STF1104AB	36395	11	1.82	1.28	2	4.6	3.4	
07448-3344	STN9001	37781	8	1.08	0.08	1	2.2	0.6	
07479-1212	STF1146	38048	9	1.10	1.68	2	1.2	0.9	
07518-1354	BU_101	38382	6	0.51	0.95	2	0.8	0.7	
08221-4059	HJ_4087AB	41006	8	1.45	0.45	2	4.6	0.9	2014.0?
08563-3707	RST2593	43880	6	0.93	3.70	2	3.0	0.9	
08574-5140	HDS1297	43983	4	0.61	2.48	1	1.2	2.6	
09125-4337	HJ_4188AB	45189	9	2.89	0.84	1	4.3	2.7	2014.0?
09149+0427	HEI_350	45383	4	0.75	2.39	2	0.7	4.4	
09193-5856	HDS1342	45726	3	1.03	4.17	1	0.4	0.7	
09285+0903	STF1356	46454	6	0.82	0.94	2	0.7	0.7	
09307-4028	COP_1	46651	4	0.97	1.33	2	2.4	0.5	
09313-1329	KUI_41	46706	4	0.71	0.28	2	1.1	1.0	
09488-5237	B_1663	48133	7	1.11	2.73	1	1.2	0.6	
10062-4722	I_173	49485	3	0.97	1.83	2	1.9	2.7	
10217-0946	BU_25	50747	9	1.57	0.67	2	6.3	10.4	wobble?
10311-2411	B_201AB	51501	7	1.98	3.72	1	4.6	1.9	large dm?
10361-2641	BU_411	51885	7	1.33	1.13	2	3.8	1.5	

10375-0932	RST3708	0	8	0.51	1.37	2	0.5	1.0	
10426+0335	A_2768	52401	8	0.62	1.63	2	2.0	0.8	
10444-6000	HDS1534Aa,Ab	52526	3	1.01	4.05	1	1.0	2.9	
12036-3901	SEE_143	58799	4	0.57	0.61	2	1.1	2.3	
13501-4451	DON_624	67527	3	1.05	3.13	1	0.8	0.7	
13520-3137	BU_343	67696	5	0.67	1.15	2	0.7	1.3	
13535-3540	HWE_28AB	67819	4	1.01	0.06	2	3.5	0.2	
15234-5919	HJ_4757	75323	3	0.82	0.81	2	3.0	1.6	
15351-4110	HJ_4786	76297	4	0.81	0.43	2	0.4	1.4	
15462-2804	BU_620AB	77235	5	0.63	0.59	1	0.8	0.5	
17031-5314	HDS2412Aa,Ab	83431	6	0.59	2.82	2	0.7	0.6	
17104-1544	BU_1118AB	84012	3	0.59	0.63	2	0.7	1.1	
17190-3459	MLO_4AB	84709	4	1.43	1.23	2	2.0	1.5	
17202-7003	I_104	84827	3	0.65	2.35	1	1.9	1.0	
18031-0811	STF2262AB	88404	3	1.61	0.72	2	1.3	2.8	
18096+0400	STF2281AB	88964	3	0.71	1.48	2	2.7	1.3	
18191-3509	OL_18	89766	8	0.93	0.48	1	1.4	1.8	
18250-0135	AC_11	90253	3	0.91	0.88	2	3.4	2.0	
19064-3704	HJ_5084	93825	4	1.34	0.11	2	2.0	1.2	
20401-2852	SEE_423AB	0	5	1.17	1.52	1	2.5	2.7	
20514-0538	STF2729AB	102945	6	0.85	1.28	2	1.1	1.9	
22152-0535	A_2599	109874	4	0.70	2.24	1	0.8	0.8	
22266-1645	SHJ_345AB	110778	4	1.34	0.23	2	6.6	3.0	needs data
22451-0240	A_2696BC	112325	5	0.62	0.97	1	0.8	1.0	
22478-0414	STF2944AB	112559	9	1.88	0.33	2	3.0	2.3	
22552-0459	BU_178	113184	3	0.65	2.25	2	0.4	2.5	
23100-4252	DON1042	114382	3	0.68	3.14	2	1.3	0.3	
23171-1349	BU_182AB	114962	6	0.77	0.67	1	0.6	1.4	
23357-2729	SEE_492AB	116436	5	0.65	1.57	2	1.7	5.2	

Calibration parameters of the runs, listruns3.txt.

N	Date	Ncal	Theta	Scale	rms_t	rms_sc	par-file
0	2007.81	6	0.246	1.000	0.211	0.003	soar07.par
1	2008.54	10	0.062	1.000	0.180	0.001	blanco.par
2	2008.60	10	0.114	1.001	0.176	0.001	soar08a.par
3	2008.77	35	-0.096	0.999	0.168	0.003	soar08b.par
4	2009.26	37	-0.060	0.998	0.135	0.002	soar09.par
5	2009.67	11	-0.135	1.000	0.203	0.005	sam.par
6	2010.89	8	0.210	1.003	0.087	0.001	sam10.par
7	2010.96	24	-0.113	1.001	0.180	0.002	sam10a.par
8	2011.04	16	0.208	1.001	0.200	0.006	sam10b.par
9	2011.29	2	-0.121	1.002	0.057	0.001	sam11a.par
10	2011.36	0	0.000	1.000	0.000	0.000	sam11b.par
11	2011.93	7	0.314	1.001	0.240	0.002	sam12a.par
12	2012.10	2	0.200	1.001	0.009	0.000	sam12b.par
13	2012.18	4	0.193	1.003	0.158	0.002	sam12c.par
14	2012.35	1	0.198	0.998	0.000	0.000	sam12d.par
15	2012.83	3	-0.422	0.999	0.288	0.002	sam12e.par
16	2012.92	13	0.219	1.001	0.074	0.002	sam12f.par

17	2013.08	1	0.225	1.000	0.000	0.000	sam13a.par
18	2013.13	21	-0.062	1.001	0.097	0.003	sam13b.par
19	2013.24	0	0.000	1.000	0.000	0.000	sam13c.par
20	2013.47	1	0.606	1.005	0.000	0.000	sam13d.par
21	2013.73	8	0.348	1.000	0.130	0.005	sam13e.par
22	2014.04	20	0.320	1.000	0.169	0.002	sam14a.par
23	2014.18	10	-0.043	1.001	0.106	0.003	sam14b.par
24	2014.30	14	0.130	1.000	0.088	0.002	sam14c.par
25	2014.76	17	0.077	1.003	0.246	0.004	sam14d.par
26	2014.85	10	0.063	0.995	0.337	0.004	sam14e.par
27	2015.03	21	-0.008	1.001	0.167	0.002	sam15a.par
28	2015.10	4	0.201	1.001	0.090	0.002	sam15b.par
29	2015.17	12	-0.147	1.001	0.081	0.002	sam15c.par
30	2015.25	6	-0.316	1.001	0.049	0.002	sam15d.par
31	2015.33	7	-0.050	1.001	0.058	0.000	sam15e.par
32	2015.50	8	0.045	1.000	0.048	0.002	sam15f.par
33	2015.54	4	0.162	1.000	0.067	0.001	sam15g.par
34	2015.74	18	0.008	1.002	0.198	0.003	sam15h.par
35	2015.91	34	-0.039	0.999	0.179	0.003	sam15i.par
36	2016.04	16	0.179	0.998	0.089	0.002	sam16a.par

List of orbital elements orbpar.txt.

WDS	Name	P	T	e	a	W	w	i
01084-5515	RST1205AB	210.370	2110.73	0.3480	0.7153	10.54	271.88	55.59
01262-6751	DON_17	1512.000	1939.59	0.9000	2.5233	159.36	344.00	37.00
01361-2954	HJ_3447	1503.580	2040.16	0.6040	3.0511	67.94	140.20	55.60
01559+0151	STF_186	165.720	1891.52	0.7260	1.0001	218.96	40.20	72.40
02039-4525	RST2272	549.830	2094.89	0.6710	3.7766	281.47	59.55	74.20
02232-2952	BU_738	560.000	1952.62	0.7550	2.2287	30.43	32.00	95.60
02460-0457	BU_83	716.260	2420.26	0.6767	2.1486	148.60	287.62	101.40
03124-4425	JC_8AB	45.200	1977.10	0.9000	0.4104	109.86	118.00	165.00
03236-4005	I_468	237.680	1973.54	0.5050	2.6451	321.84	30.90	41.60
04021-3429	BU_1004AB	410.000	2061.04	0.3188	1.4546	94.83	114.61	160.20
04518+1339	BU_552AB	95.200	1982.47	0.5763	0.7324	147.69	309.39	48.00
04590-1623	BU_314AB	55.000	1980.56	0.9225	0.4483	140.96	-0.54	118.00
05079+0830	STT_98	197.450	1975.97	0.1750	0.9919	89.40	62.80	142.80
05417-0254	BU_1052	191.900	2083.78	0.1260	0.5944	182.79	127.03	99.30
06003-3102	HU_1399AB	67.450	1998.66	0.5160	0.9984	126.70	282.58	101.20
06048-4828	DUN_23	915.000	2012.08	0.4270	4.5725	124.68	2.00	63.60
06274-2544	B_114	59.660	1978.02	0.5410	0.4338	153.86	26.69	19.80
06298-5014	R_65AB	53.130	1969.54	0.9770	0.6310	139.95	67.10	121.50
07294-1500	STF1104AB	729.000	2037.18	0.1420	2.5253	157.91	258.67	38.10
07479-1212	STF1146	454.924	2100.04	0.5438	2.2744	23.36	201.03	108.88
07518-1354	BU_101	23.330	1985.95	0.7647	0.6224	282.59	253.64	80.82
08221-4059	HJ_4087AB	880.000	1830.07	0.6350	2.7917	130.65	113.30	111.70
08563-3707	RST2593	159.720	2056.67	0.2150	0.9716	197.44	351.60	143.30
09149+0427	HEI_350	198.560	2002.66	0.5740	1.8015	74.15	344.70	122.20
09285+0903	STF1356	117.971	1959.75	0.5619	0.8733	326.51	302.54	65.35
09307-4028	COP_1	33.950	1969.84	0.4330	0.7973	289.17	44.30	58.00

09313-1329	KUI_41	18.928	2001.95	0.2972	0.6412	233.59	108.79	142.39
10062-4722	I_173	202.700	1923.10	0.6670	0.5872	11.06	180.50	41.90
10217-0946	BU_25	817.000	2284.51	0.0000	1.8714	5.09	0.00	141.20
10361-2641	BU_411	158.500	1948.61	0.7590	0.8772	149.61	43.20	127.70
10375-0932	RST3708	154.810	1981.42	0.4570	0.4687	171.27	61.95	54.60
10426+0335	A_2768	81.660	1976.45	0.5500	0.4015	57.75	354.90	140.10
12036-3901	SEE_143	111.000	1913.47	0.5790	0.6678	209.38	285.40	155.30
13520-3137	BU_343	280.000	1995.81	0.6560	1.1363	183.38	238.33	133.43
13535-3540	HWE_28AB	373.000	1959.33	0.7750	1.5307	112.44	90.70	74.20
15234-5919	HJ_4757	258.000	2079.47	0.9310	2.5758	113.10	264.90	100.40
15351-4110	HJ_4786	190.000	1900.73	0.5100	0.6111	93.23	323.34	95.00
17031-5314	HDS2412Aa,Ab	41.320	1999.59	0.6220	0.5915	72.80	94.10	133.80
17104-1544	BU_1118AB	87.580	2024.12	0.9500	1.4210	38.89	274.80	95.20
17190-3459	MLO_4AB	42.150	1976.02	0.5800	1.8131	311.12	247.68	128.00
18031-0811	STF2262AB	257.000	1833.10	0.7700	1.3376	62.16	42.00	52.00
18096+0400	STF2281AB	294.000	1911.29	0.6100	1.1622	73.73	307.00	103.00
18250-0135	AC_11	248.000	1882.36	0.3800	0.6587	174.88	0.00	93.60
19064-3704	HJ_5084	121.760	1999.43	0.3200	1.8927	50.01	344.63	146.35
20514-0538	STF2729AB	199.800	1906.85	0.5444	0.8813	170.32	57.22	65.15
22266-1645	SHJ_345AB	3500.000	2022.97	0.9000	14.6835	299.63	148.12	43.49
22478-0414	STF2944AB	1160.280	2075.72	0.7550	4.4554	-6.50	46.86	47.76
22552-0459	BU_178	96.480	1956.27	0.6430	0.4257	140.68	375.53	85.70
23100-4252	DON1042	98.270	1994.83	0.5530	0.8026	231.96	124.00	39.70
23357-2729	SEE_492AB	77.050	1974.32	0.5060	0.5977	81.54	113.02	47.50

List of linear elements linpar.txt.

WDS	Name	t0	theta0	dtheta	rho0	drho
00522-2237	STN_3AB	2012.963	242.520	-0.205	1.9855	0.0011
02332-5156	HDS_333	2013.570	246.992	1.465	0.5994	-0.0058
04257-0214	BU_403	2012.672	83.861	-0.243	0.9722	-0.0113
04584-0344	HDS_644	2012.616	159.374	2.350	0.6164	0.0081
05019-7638	RST2368	2011.884	149.388	0.692	0.7985	0.0030
05508-2907	B_1491	2013.564	329.188	0.144	2.1637	0.0028
06425-4234	I_283	2013.485	193.745	0.188	2.3518	-0.0008
07123-4030	HDS1001	2012.944	270.169	1.223	0.6783	-0.0084
07448-3344	STN9001	2013.635	29.701	0.797	1.0872	-0.0145
08574-5140	HDS1297	2012.170	102.769	0.351	0.5869	-0.0174
09125-4337	HJ_4188AB	2013.898	280.668	0.057	2.8873	0.0045
09193-5856	HDS1342	2012.146	165.597	-0.495	1.0178	0.0063
09488-5237	B_1663	2013.542	331.998	-0.765	1.1152	0.0179
10311-2411	B_201AB	2012.930	67.897	0.121	1.9790	0.0031
10444-6000	HDS1534Aa,Ab	2011.542	325.494	0.049	1.0119	0.0000
13501-4451	DON_624	2012.232	117.259	-0.629	1.0617	-0.0117
15462-2804	BU_620AB	2012.240	173.382	0.167	0.6304	0.0028
17202-7003	I_104	2012.968	127.275	-0.029	0.6689	-0.0108
18191-3509	OL_18	2013.652	294.314	0.301	0.8871	0.0268
20401-2852	SEE_423AB	2011.715	38.663	0.155	1.1713	0.0044
22152-0535	A_2599	2012.724	279.926	0.042	0.6986	0.0002
22451-0240	A_2696BC	2015.500	74.758	-0.887	0.6171	0.0000
23171-1349	BU_182AB	2012.849	227.182	0.097	0.7728	-0.0033