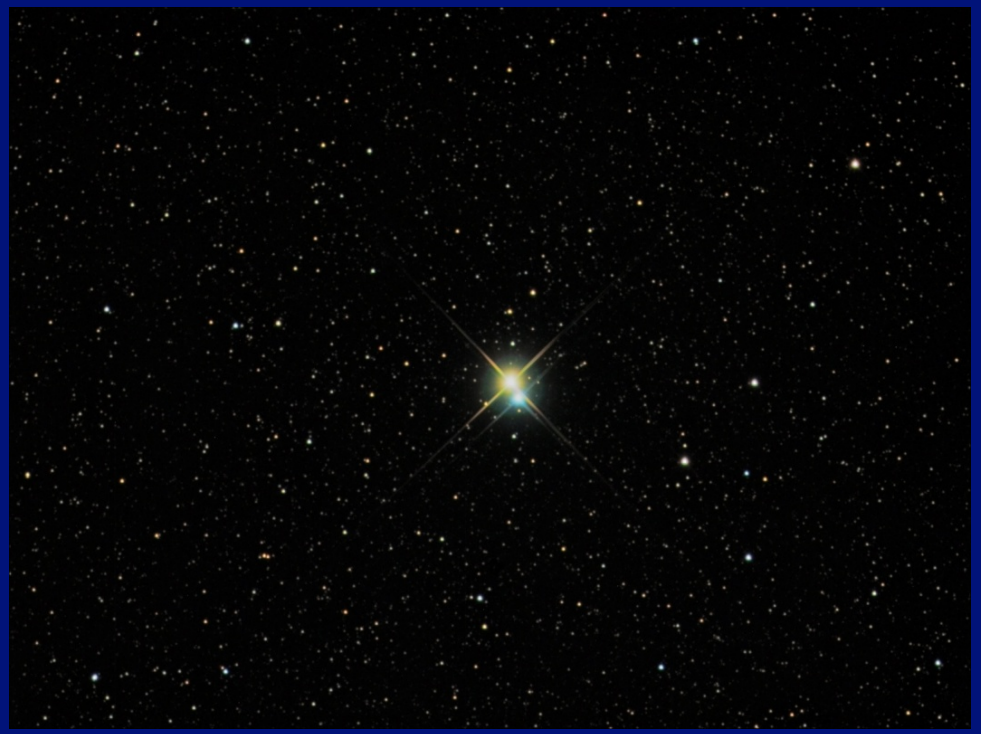
Various Orbital Solutions and Double Star Statistics

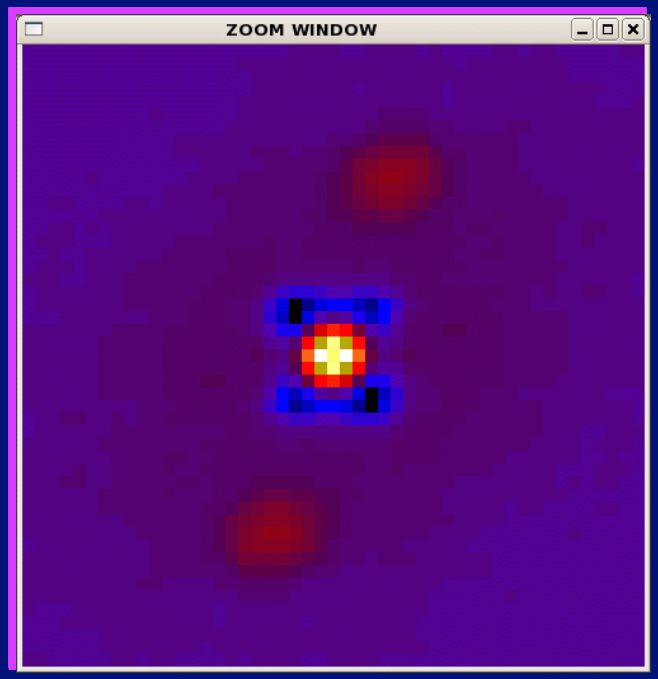
Brian D. Mason

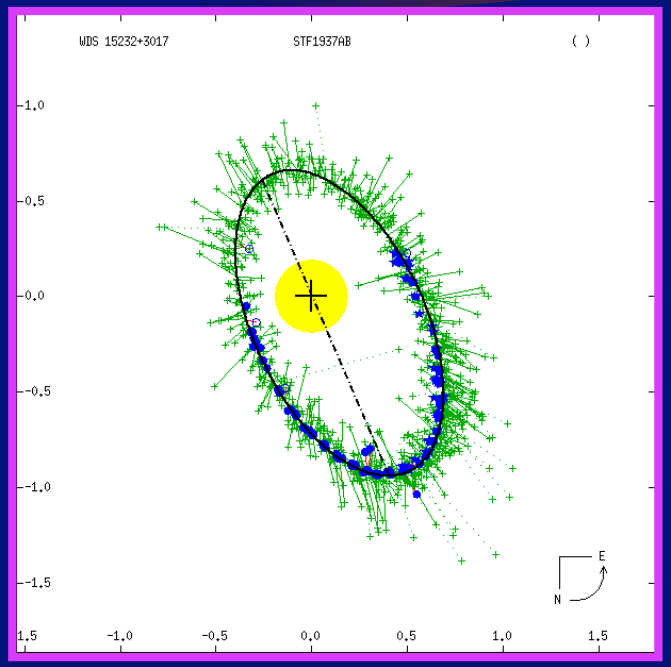
Outline

- USNO speckle observing program: DC and remote
- Improved Orbits
- Premature Solutions
- Double Star Statistics



26″ orbits: h Cor Bor

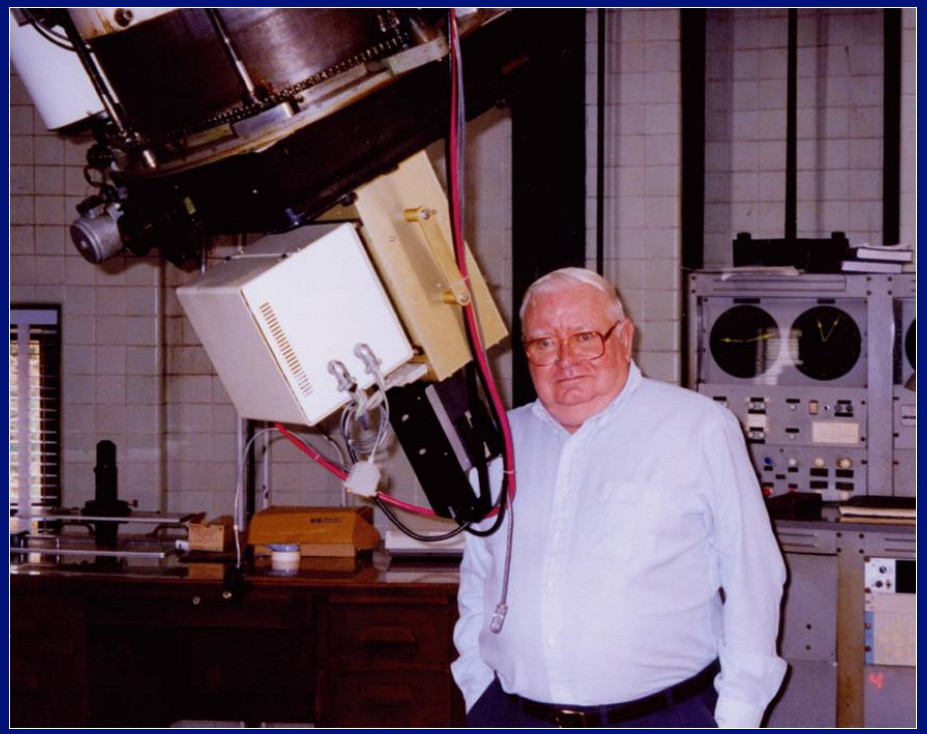




- All observations obtained with USNO 26″ telescope & speckle camera: 1999-2000, 2002-2005, 2009

26″ Speckle Observing

- In 2000 the primary speckle observing program with the USNO 26″ telescope was shifted to “neglected” doubles, these were defined to be either
  - Not observed in 10 or more years or
  - Unconfirmed.
- This definition was adopted by many others and has formed a productive operational observing program.
- 22,737 mean positions with 26″ telescope.



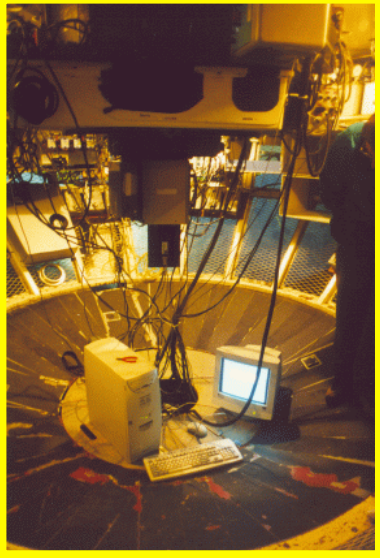
Large Telescope Speckle Observing

These programs have resulted in 3608 observations,

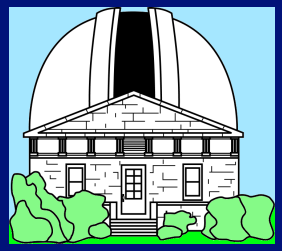
Large telescopes used include the NOFS 61”, the McDonald 82”, the Mt Wilson 100” and the KNPO and CTIO 4m

89 new pairs,

These programs include astrophysically interesting orbit pairs, surveys for new companions, and fainter and southern hemisphere pairs.



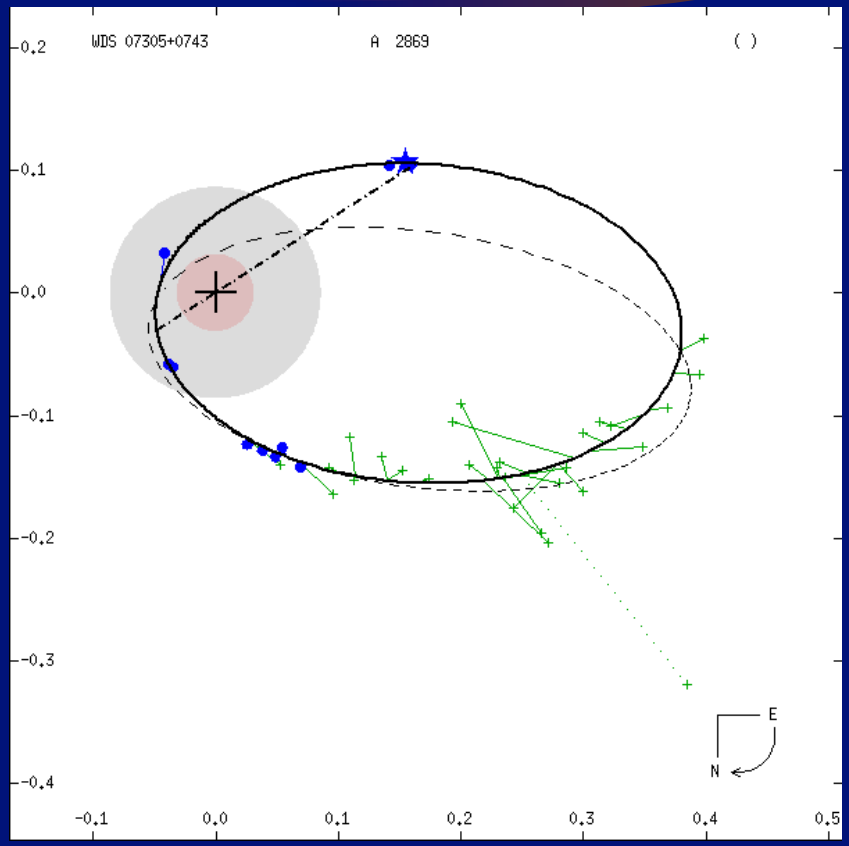
And 260 orbits.

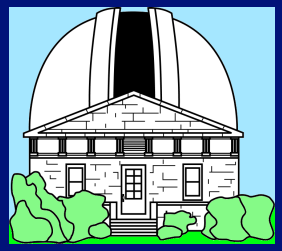


Orbits improved by speckle

- New measures to improve existing orbits.

- Dashed curve is previous orbit.
- Broken line is line of nodes.
- Filled stars = USNO speckle data
- Filled circles = other speckle data
- Large shaded circle = Hipparcos resolution limit
- Small shaded circle = 4m V band speckle resolution limit

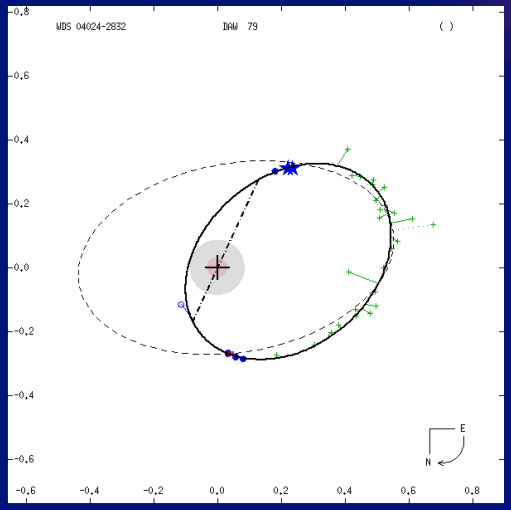


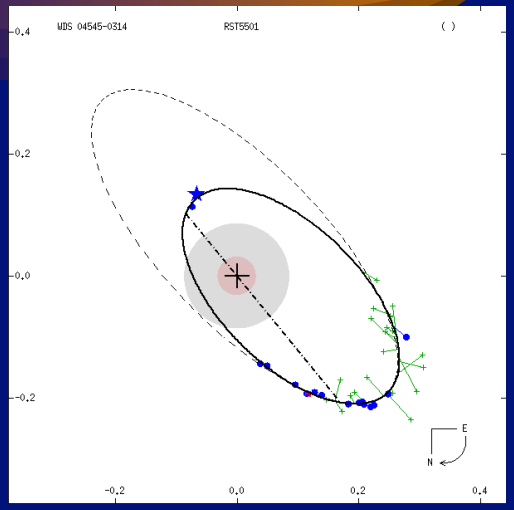


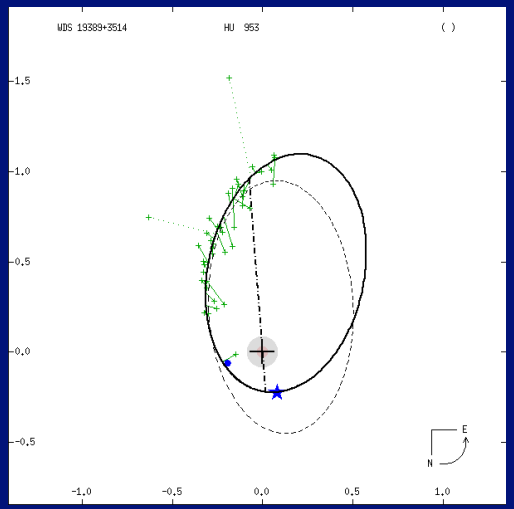
Orbits improved by speckle

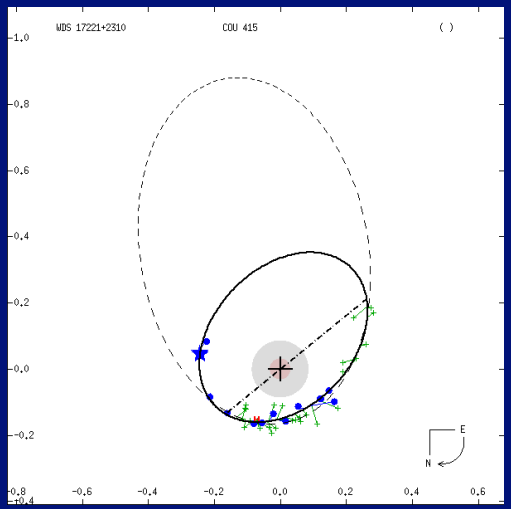
Other improved orbits.

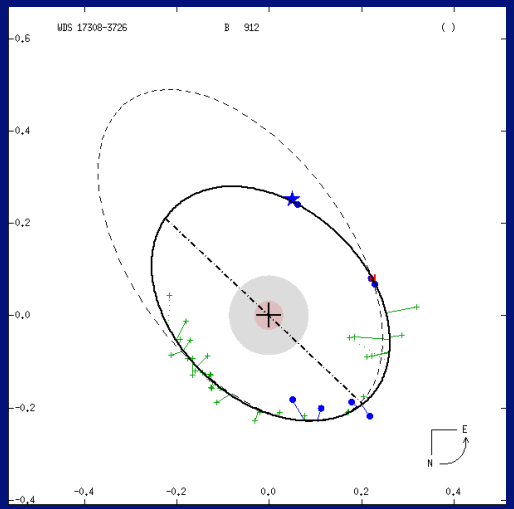
Many other recent contemporaneous speckle measures done in USNO/ Tokovinin collaboration with HRCam at SOAR.

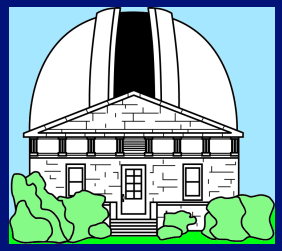






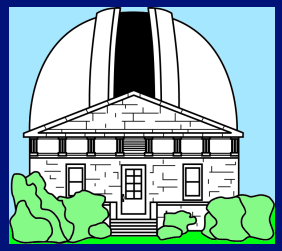






Tweedledum and Tweedledee = HIP 92027

- This is a pair of near identical interferometric pairs discovered by Finsen (FIN 332) in 1953.
- The similarity in brightness, separation and ambiguity led to many issues of misidentification as well as orbital quadrant ambiguities.
- It has been under regular observation by speckle inteferometry since the 1970s, most notably by CHARA and USNO.



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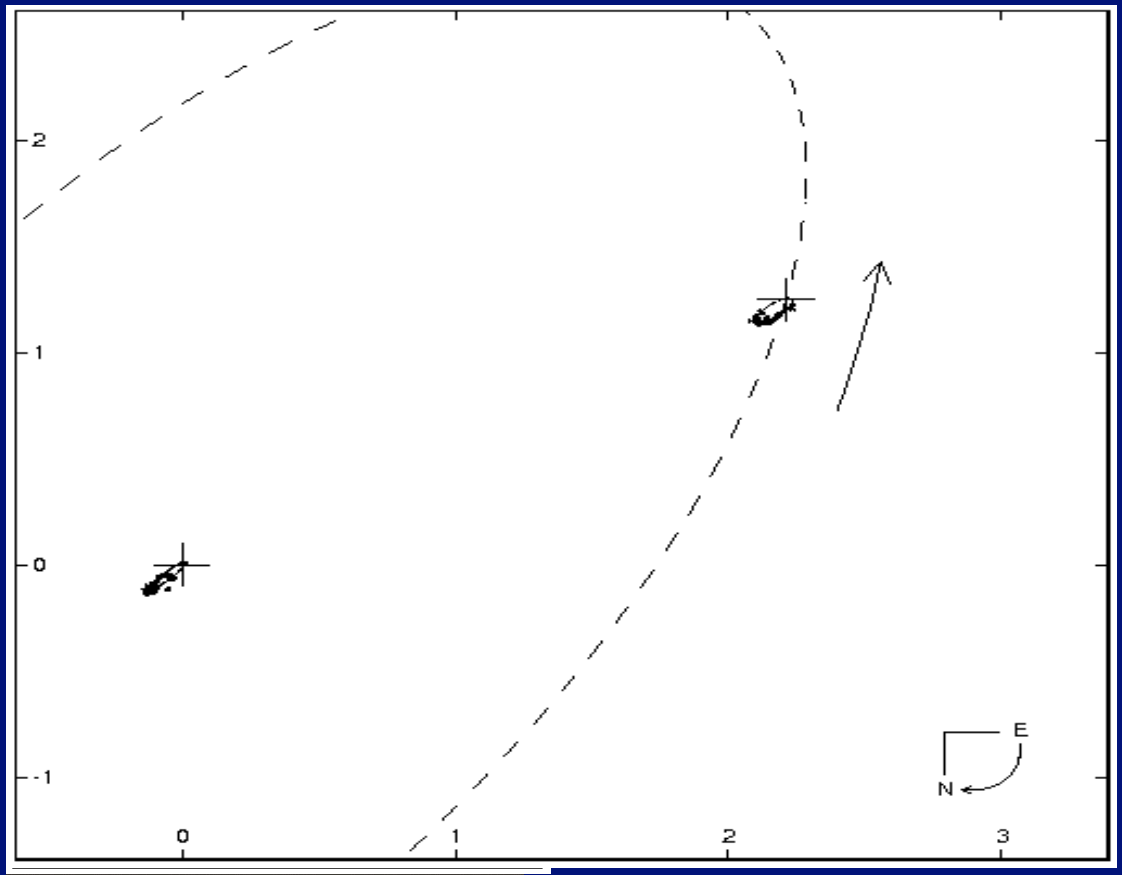

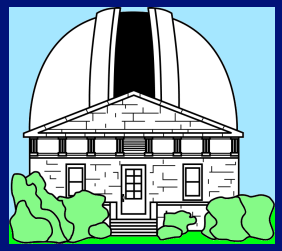

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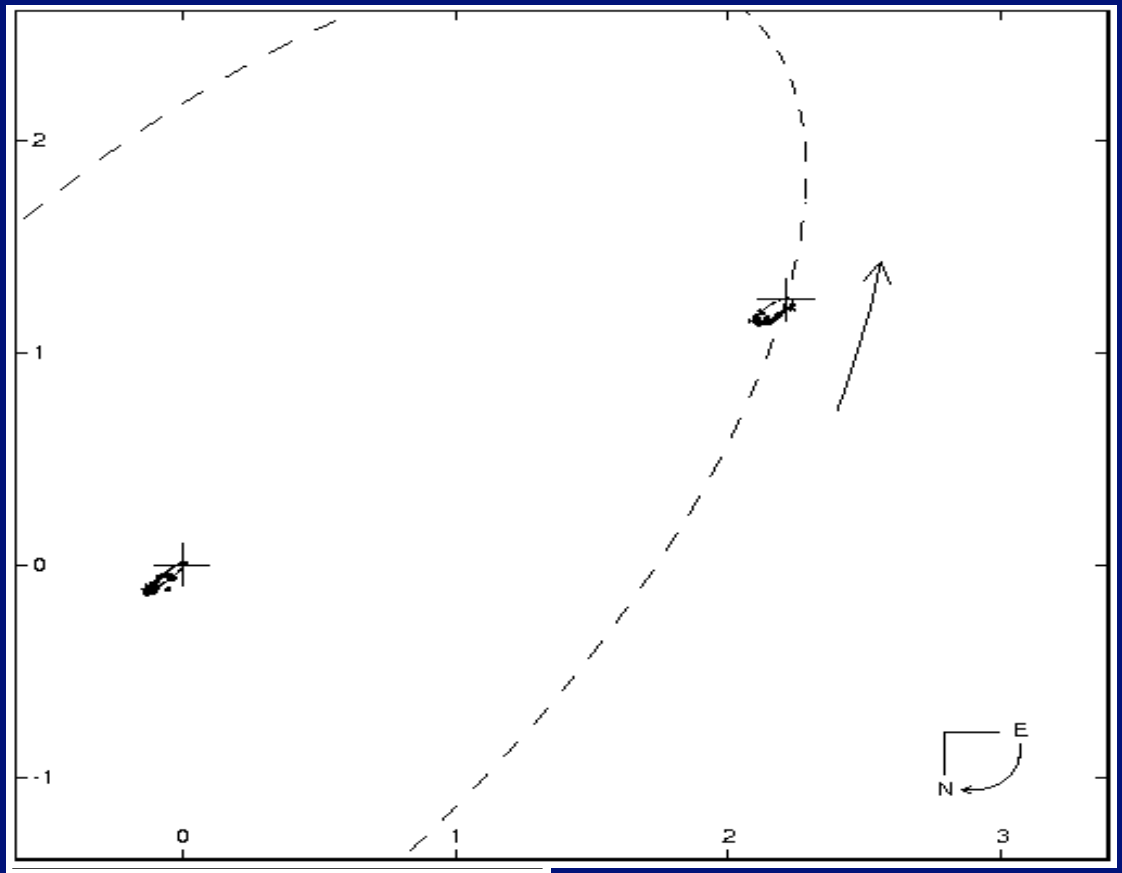
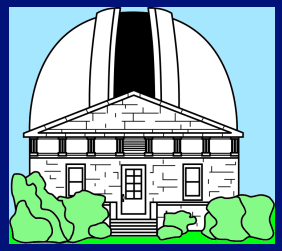


- Continued observation have allowed quadrant and identification issues to be solved and for precise orbits to be determined.
- The pairs have a coplanarity value, f, of 25.2+/-12.2 degrees. According to the Fekel (ApJ 246, 879; 1981) definition they are within 1s of being coplanar.



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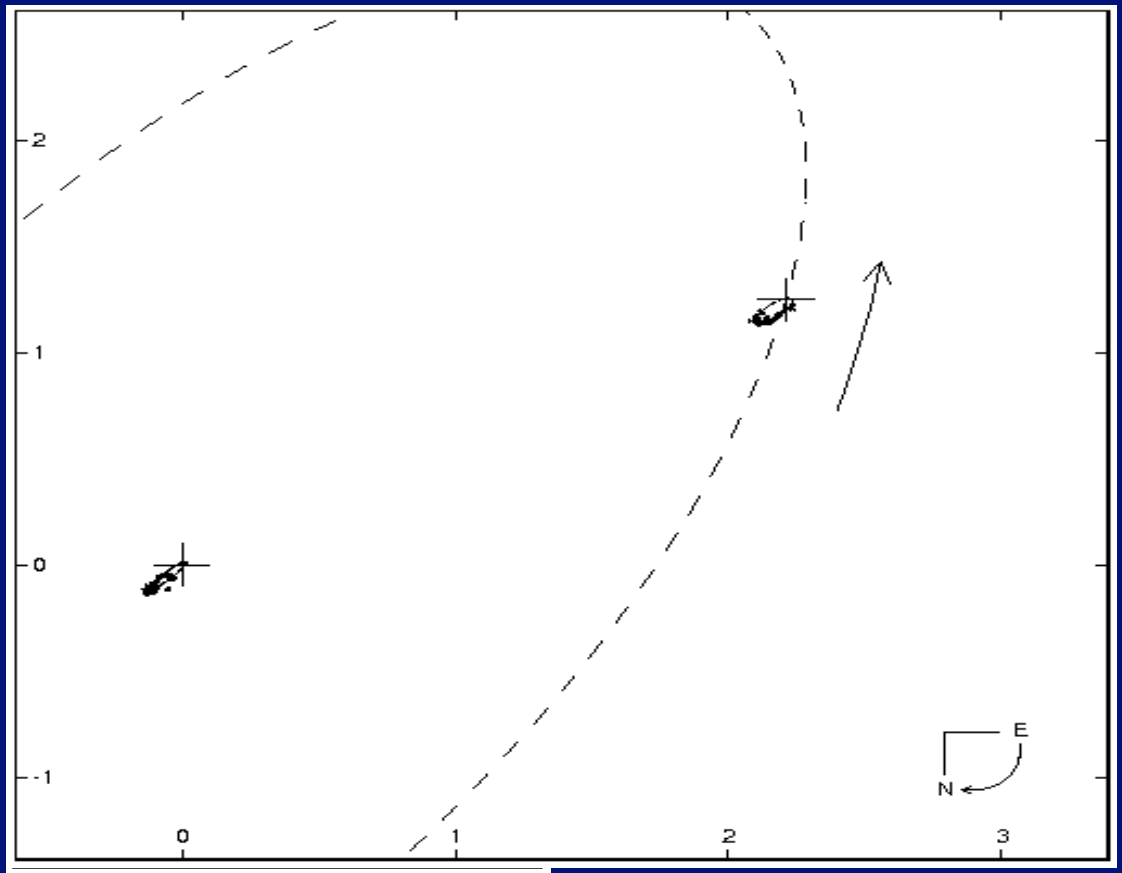

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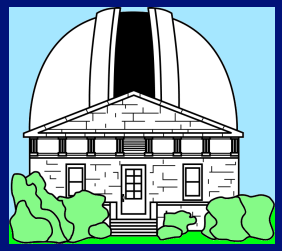

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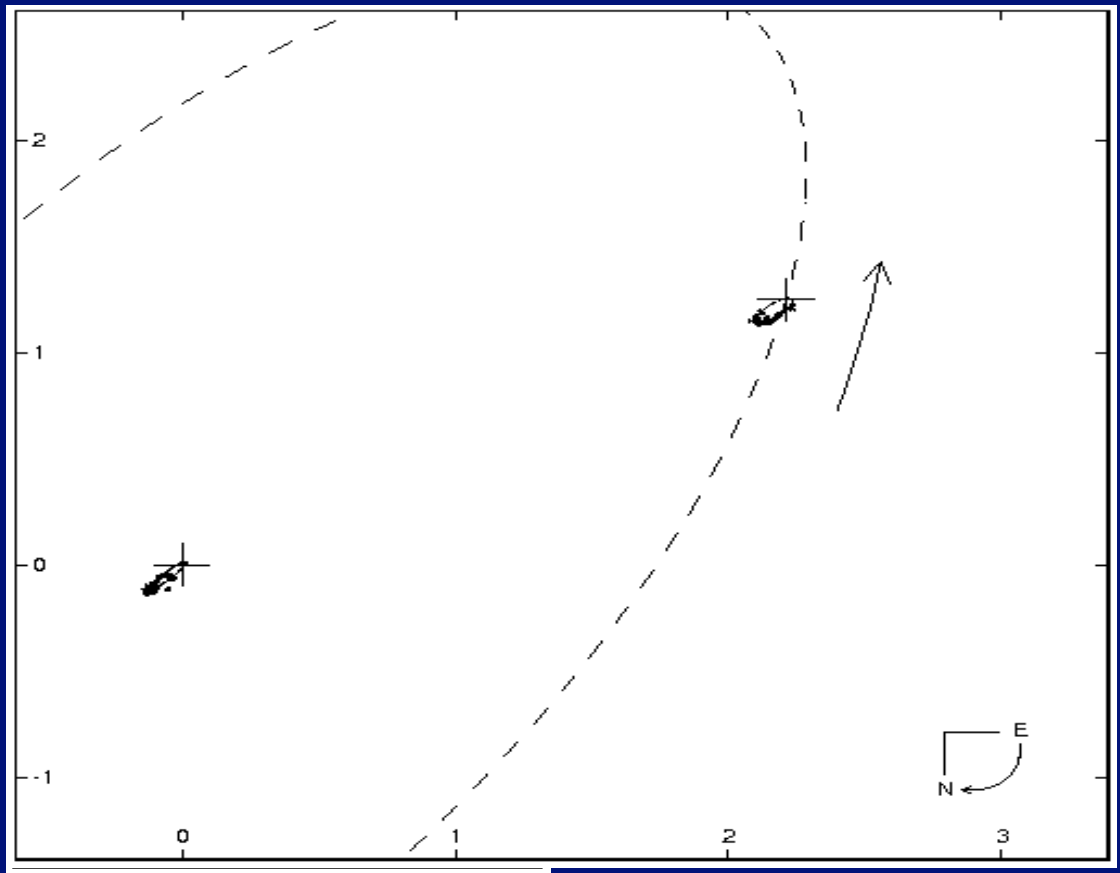

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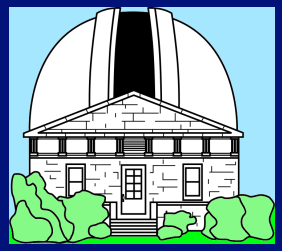
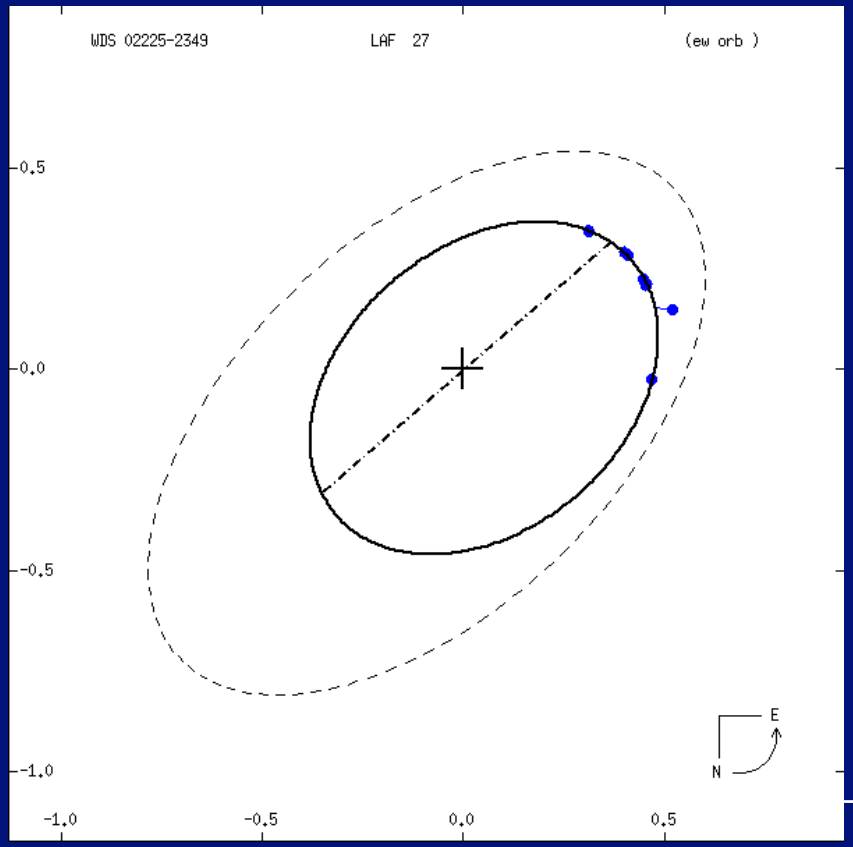
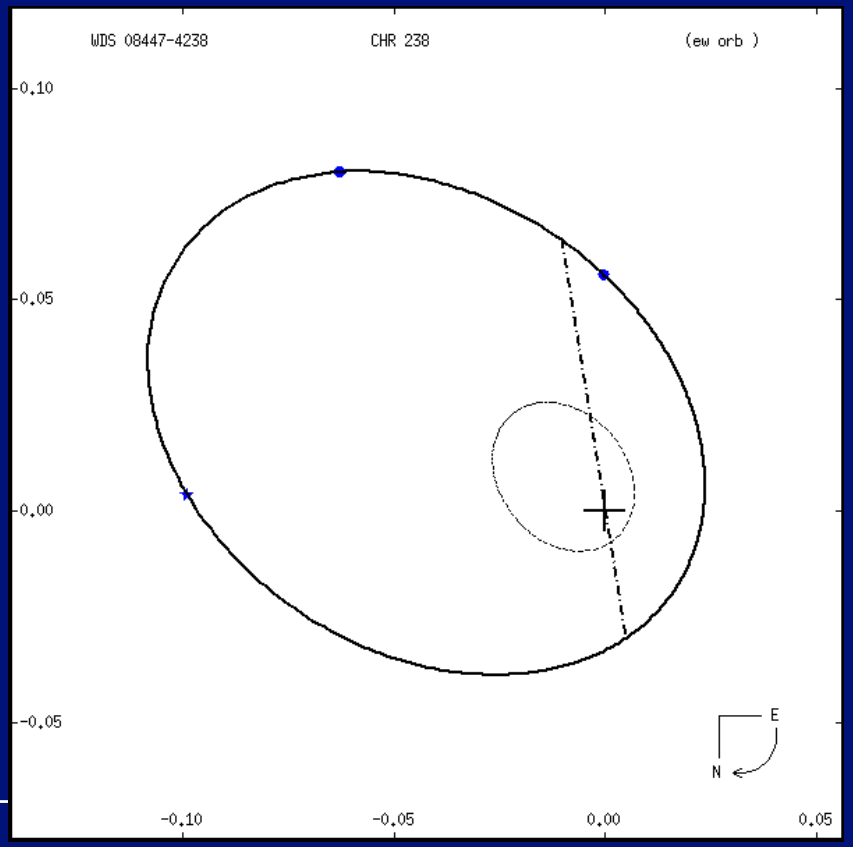
Element	Aa,Ab	Ba,Bb
P	27.03	38.6
a”	0.094	0.105
i	106	117.2
W	136.2	111.8
T	1994.20	1967.9
e	0.79	0.867
w	10	311.2



Resolved orbits of Astrometric Pairs

- These pairs whose orbits were first determined from periodic errors in position and proper motion.
- LAF 27 (k For) was found by fixing P and e to the orbit values. It gives expected masses.
- CHR 238 (HIP 42916) solution independent, but has consistent elements: 815d, e=0.68 (astrometric orbit); 824.7d, e=0.671 (resolved orbit).





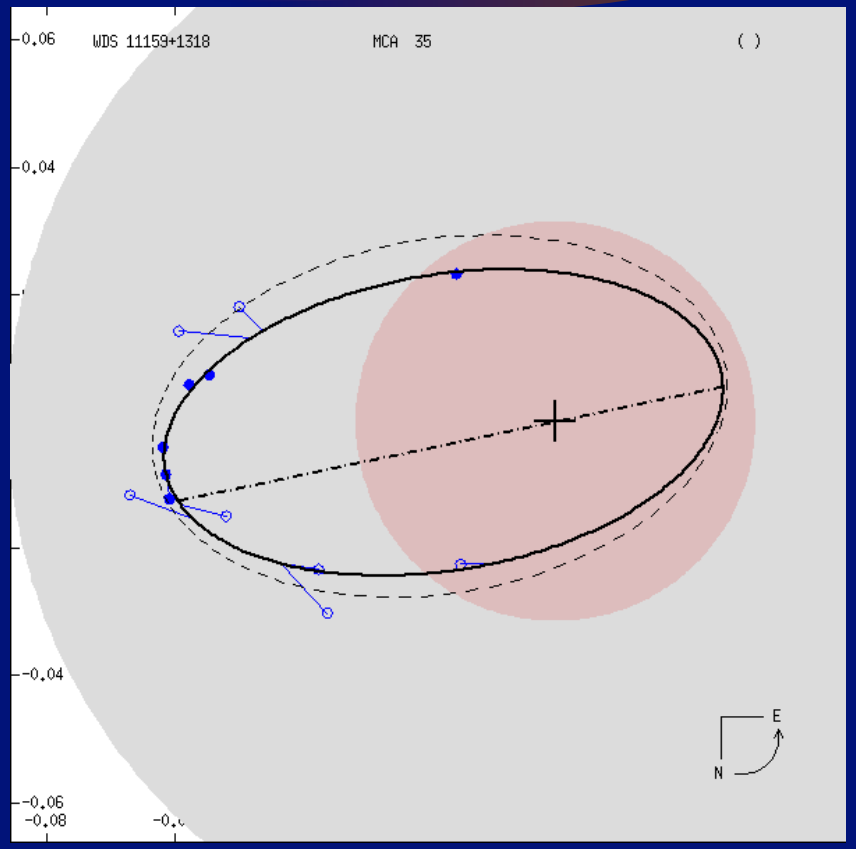
Navy Optical Interferometer

- Six way beam combination is now routinely generating the typical measureables of resolved systems, r and q, making it ideal for combining with historical binary star data, e.g. speckle.

- The Navy Optical Interferometer (NOI) is located on Anderson Mesa, outside Flagstaff in Northern Arizona (USA).
- The current operational baseline allows routine observing to a resolution of 1 mas, ulitmately this capability will be ~200 mas.
- This R to V band instrument has a current limit of V ~ 6. This will be extended significantly when the former Keck Interferometer outrigger telescopes (1.8m) are integrated.

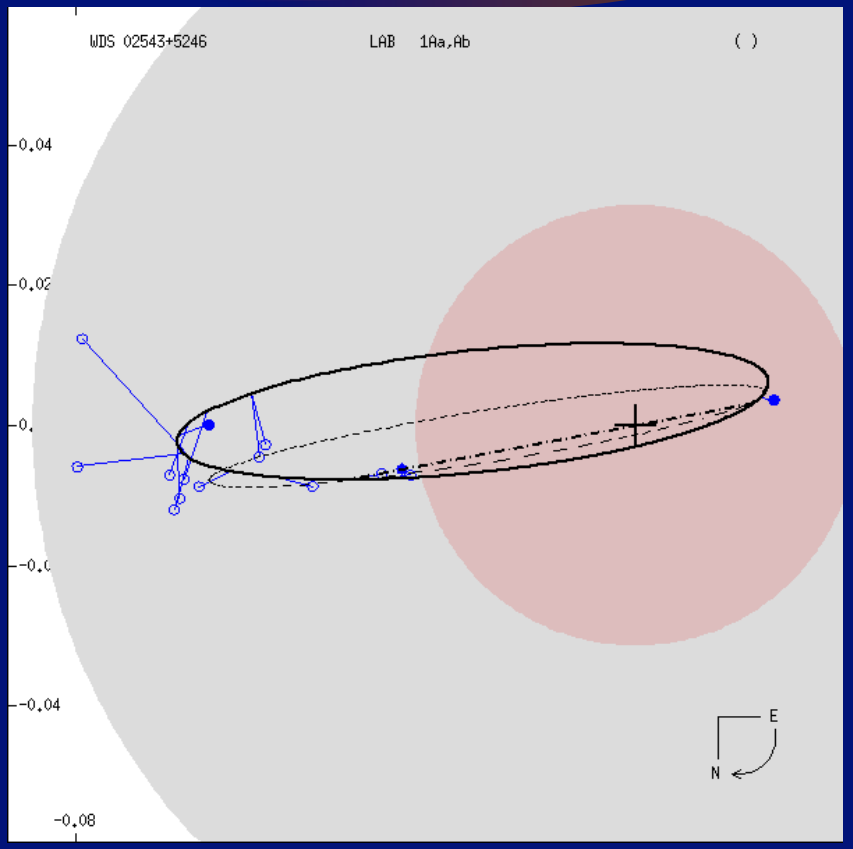
NOI Orbits I: 73 Leo = HIP 55016

- Mason et al. (1997) published combined solution orbits of three hot dwarf cool giant pairs: HR 233, 36 Tau and 73 Leo.
- At right is a new solution based on available relative astrometry and the radial velocities from Griffin (1990).
- Observations of all these objects continues.



NOI Orbits II: t Per = HIP 13531

- Another rarely resolved challenging system is t Per (McAlister 1981). This cool giant hot dwarf pair is ideal for the capabilities of the NOI. The orbit at right is a combined solution of the relative astrometry (including three NOI measures) and the Colacevich (1941) radial velocities.



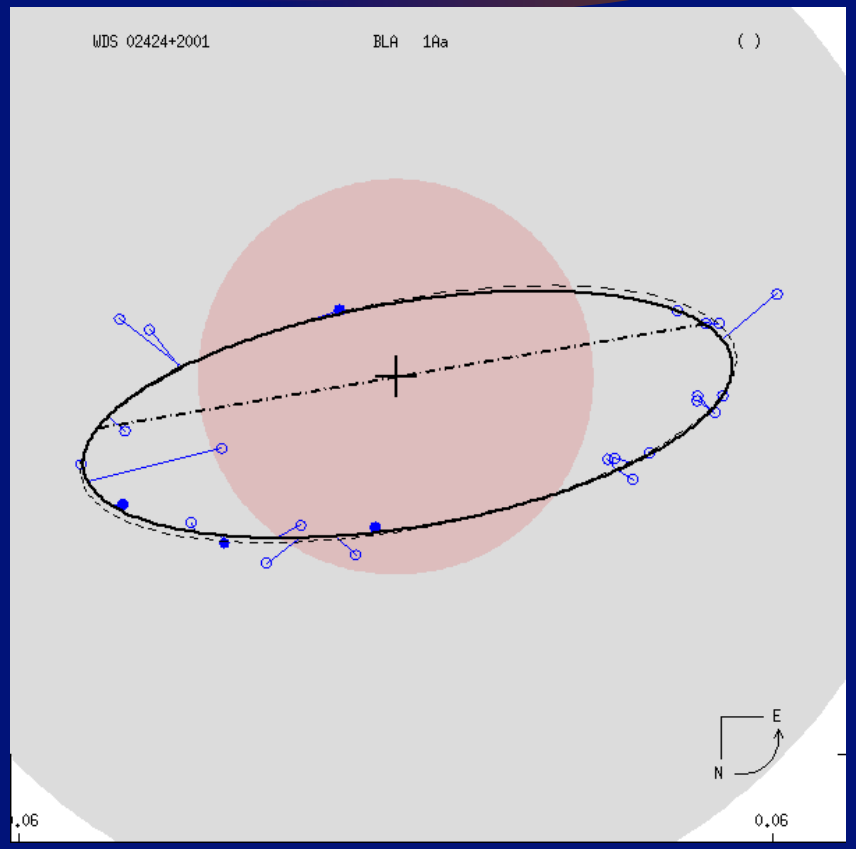
CHARA Array

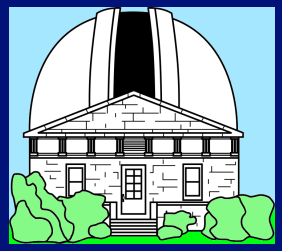
- However, a recent innovation utilizing Separated Fringe Packets (SFP, Farrington et al. AJ 139, 2308; 2010) produces measures of r and q, which can be combined easily with other data.

- The CHARA Array, on Mt. Wilson in California, is an interferometer similar in configuration to the NOI.
- The emphasis on achieving results on the longest baselines in infrared makes this instrument capable of higher resolution than the NOI.
- However, at present most results are pairwise and give the interferometer observables of baseline and visibility.

CHARA Array: m Ari = HIP 12640

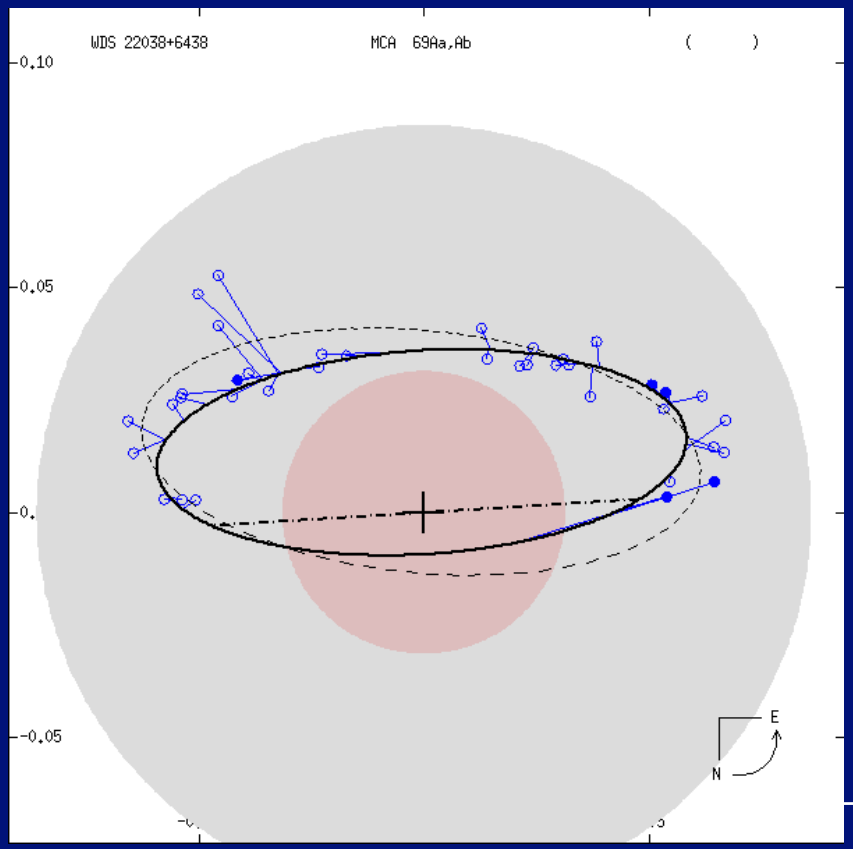
- While the previous orbital solution (Mason 1997) of m Ari is perfectly adequate, these three SFP measures, two in unresolved regions due north and south, significantly reduce the errors.

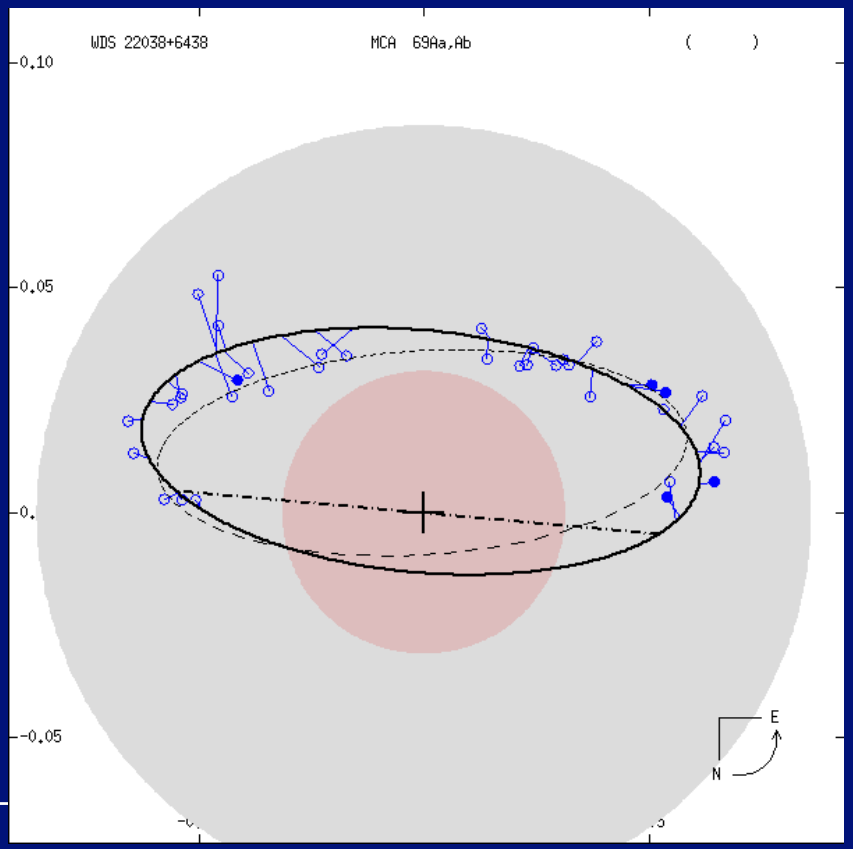




CHARA Array: x Cep = HIP 108917

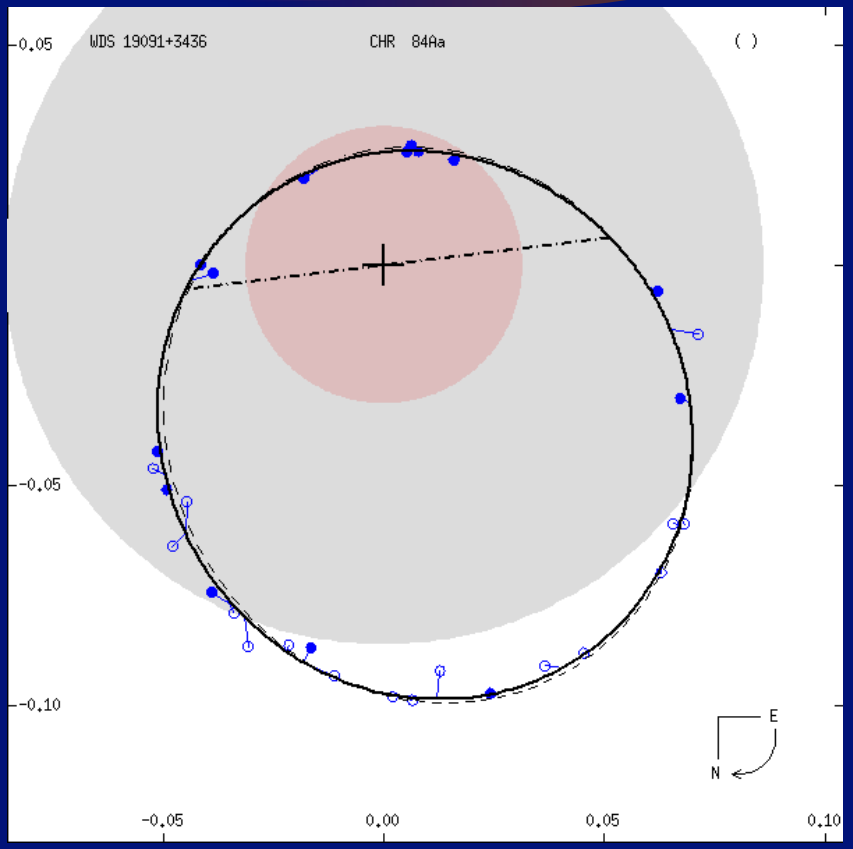
- In the case of x Cep, the superior resolution of long baseline optical interferometry has allowed us to distinguish between two orbits which were previously of approximately the same quality.





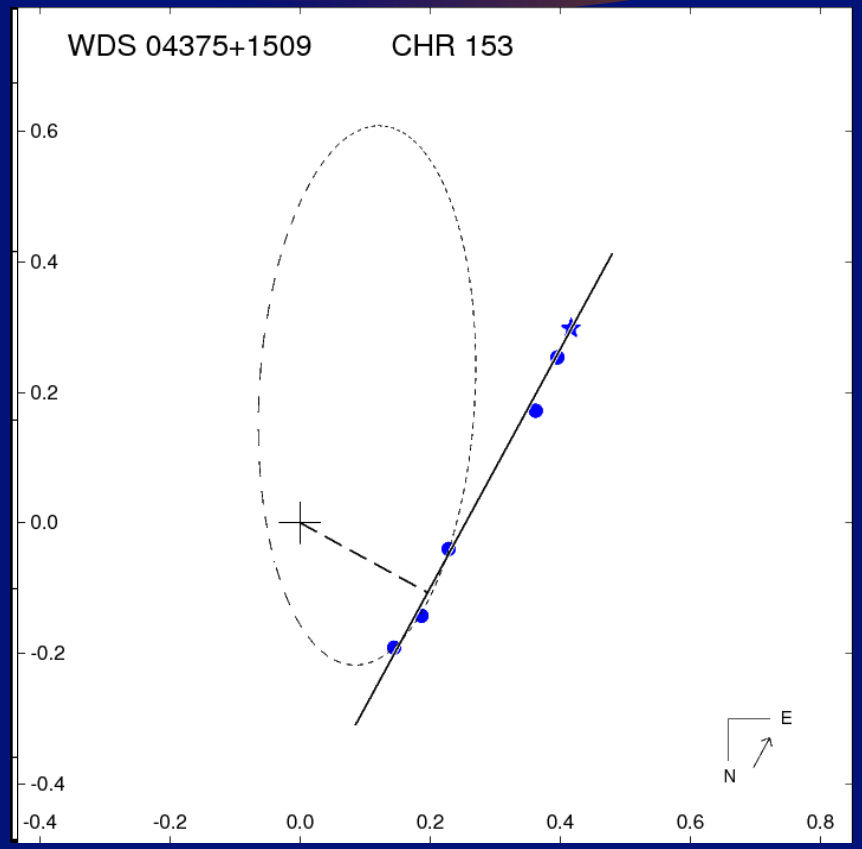
CHARA Array: HD 178911 = HIP 94076

- While the orbit (Tokovinin et al. 2000) of HD 178911 seems superficially adequate, only six relative astrometric measures were available at the time, leading to larger than desired errors [$\mathbf{M_A}$ = 1.07(0.37), $\mathbf{M_B}$ = 0.84(0.29), p = 25(8) mas].
- The significantly greater number of points, most of which are from CHARA SFP, yields combined solution results of $\mathbf{M_A}$ = 0.736(0.049), $\mathbf{M_B}$ = 0.572(0.047), p = 29(2) mas.
- The masses are a the 1s extreme of the earlier solution. The Hipparcos parallax error (p = 19(2) mas) may be due to the orbital motion not being taken into account.



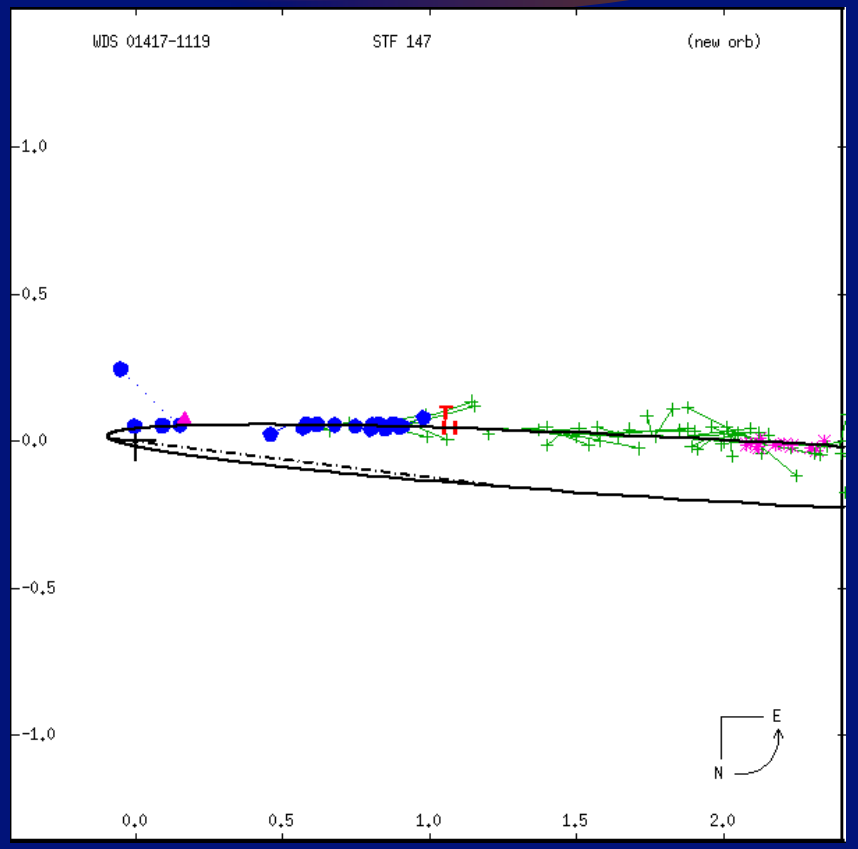
Premature Orbit: CHR 153 = HIP 21543

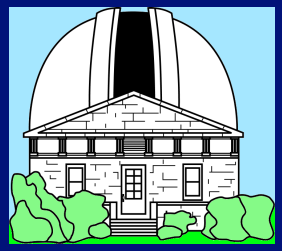
- Orbit determined in 2003 with three data points (72.3-y).
- Subsequent observations in 2005, 2008 and 2010 exhibited a trend in orbit residuals.
- The system is better fit by a linear solution, indicating the pair is likely optical.



Premature Linear Solution: STF 147 = HIP 7916

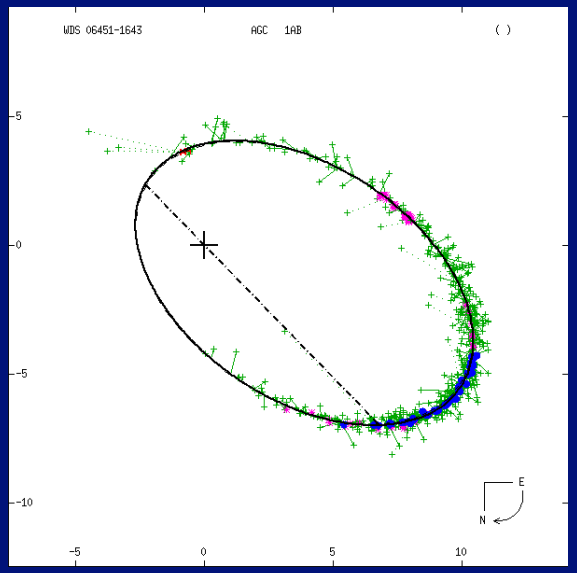
- Solution first determined in Linear Catalog release (2006.5) seemed likely.
- More recent observations have large residual offsets.
- Data seems better fit with an orbit such as this unpublished solution.

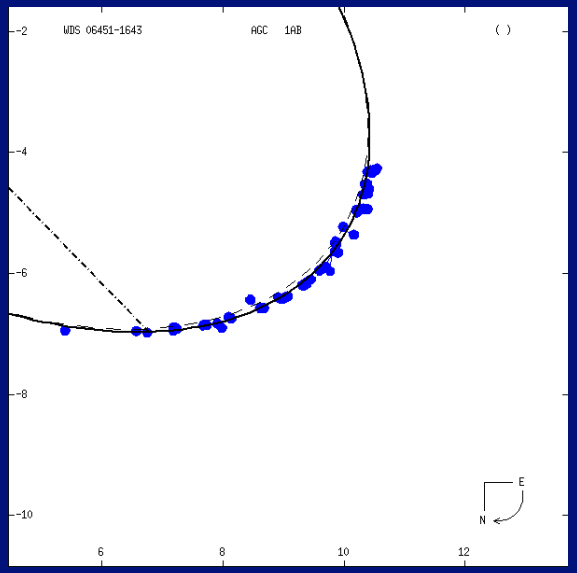


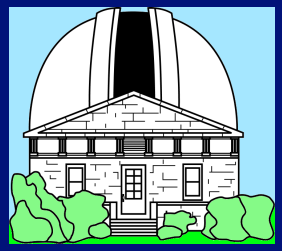


Photographic Data: Sirius

- At the other separation extreme, a cache of photographic plates taken with the USNO double star camera has been digitized and processed, using the method described by Lindenblad (AJ 75, 841; 1970).
- Some 66 plates of Sirius A and B taken between 1970 and 1984 (10% of the total currently available), have been reduced.
- They enable a significant improvement over the current "best" Sirius orbit (van den Bos JO 43, 152; 1960), almost one full revolution later.







Statistics of Double Stars

	N_{sys}	N_{meas}	Mean	N_{orb}	%	N_{lin}	%	No Soln %
Whole catalog	115422	772221	6.69	1653	1.4	1261	1.1	97.5
0.50 < V < 6.00	3596	104334	29.01	301	8.4	152	4.2	87.4
6.01 < V < 12.00	87832	613874	6.99	1312	1.5	1089	1.2	`97.3
12.01 < V < 20.00	23798	52067	2.19	34	0.1	16	0.1	99.8