Be star observations with CLASSIC and MIRC

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- John Monnier (U. Michigan)
- Rafael Millan-Gabet (NexSci)
- The CHARA Crew

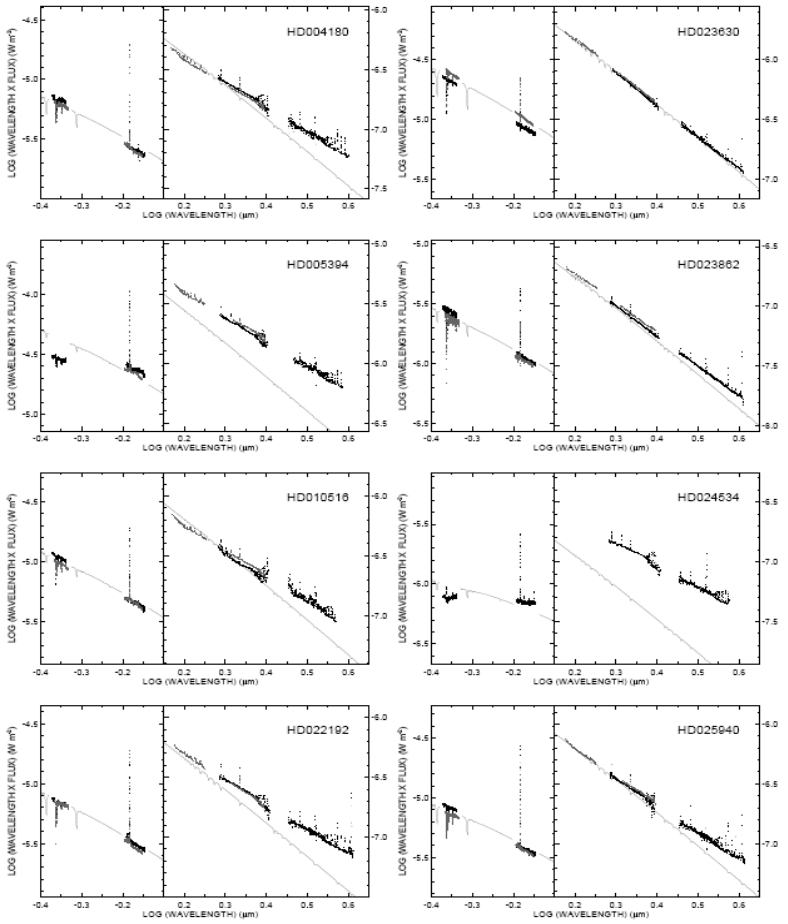
Outline

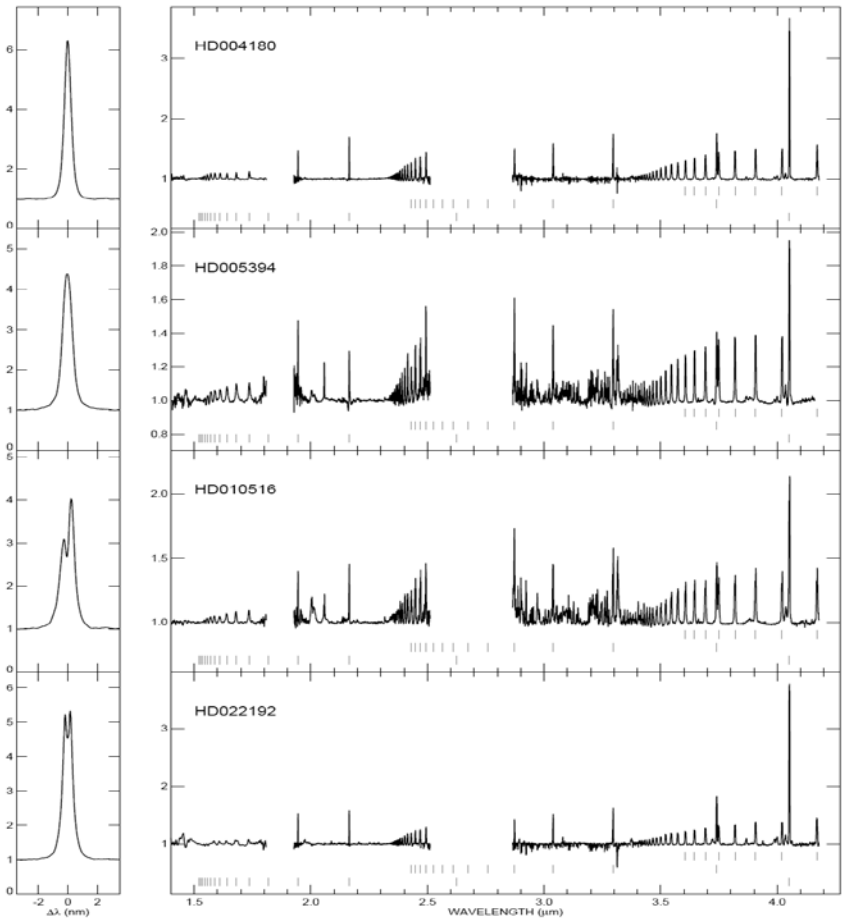
- The status of the project
- Observations of Be Stars with CHARA Classic and MIRC in 2009
- Classic Results
- Delta sco and Chi oph with MIRC
- Fluor observations of Rho cas
- Conclusions and futue work

Thesis project updates

- A survey of 25 Be stars in the *K*- band
- Project started in 2007:
  90% of the project accomplished so far
- The Brighter ones observed with MIRC
- Simultaneous spectroscopic results from Lowell and IRTF published in Touhami et al. 2009
- Predicted Angular Diameters from the emission line equivalent width

SEDs and Spectroscpoic Survey



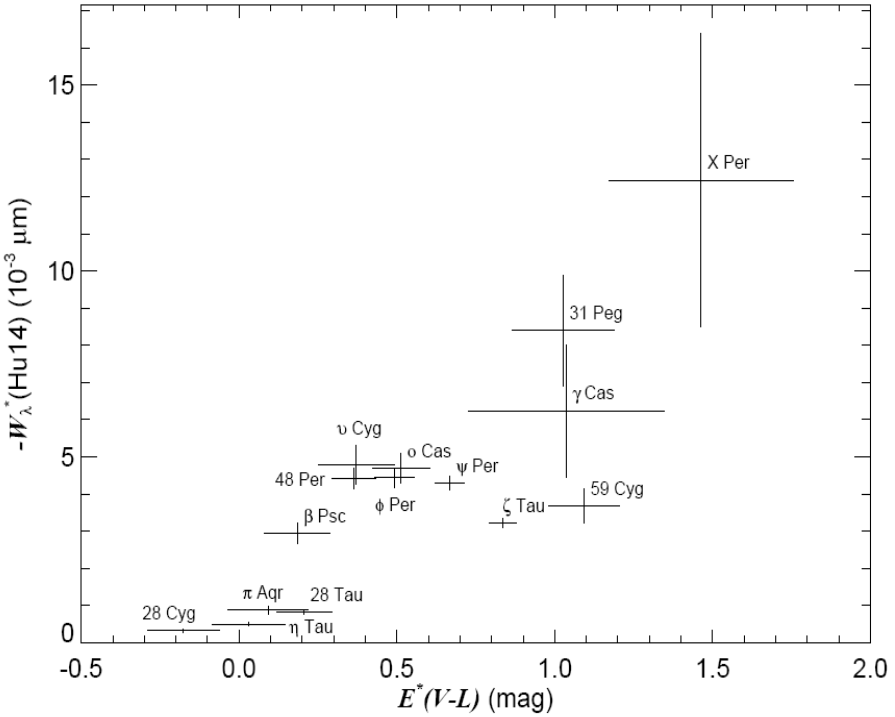


Touhami et al. 2009

EW-IR excess Correlation

Star (1)	Year (2)	$E^\star(V-H)$ (mag) (3)	$E^\star(V-K)$ (mag) (4)	$E^\star(V-L)$ (mag) (5)
HD004180	2006	...	0.15 (9)	0.51 (9)
HD004180	2008	−0.12 (9)	0.10 (9)	...
HD005394	2006	...	0.61 (31)	1.04 (31)
HD005394	2008	0.36 (31)	0.66 (31)	...
HD010516	2006	...	−0.01 (6)	0.49 (6)
HD010516	2008	−0.13 (6)	0.11 (6)	...
HD022192	2006	...	0.30 (4)	0.67 (5)
HD022192	2008	0.09 (5)	0.28 (5)	...
HD023630	2006	...	0.00 (12)	0.03 (12)
HD023630	2008	0.03 (12)	0.05 (12)	...
HD023862	2006	...	0.07 (9)	0.21 (9)
HD023862	2008	0.07 (9)	0.14 (9)	...
HD024534	2006	...	1.01 (29)	1.46 (29)
HD025940	2006	...	0.07 (7)	0.36 (7)
HD025940	2008	−0.01 (7)	0.12 (7)	...
HD037202	2006	...	0.51 (4)	0.84 (4)
HD037202	2008	0.30 (4)	0.52 (4)	...
HD058715	2008	0.08 (4)	0.10 (4)	...
HD191610	2006	...	−0.21 (11)	−0.18 (11)
HD200120	2006	...	0.68 (11)	1.09 (11)

Our sample stars are currently in active states except for Zeta oph and Alcyone

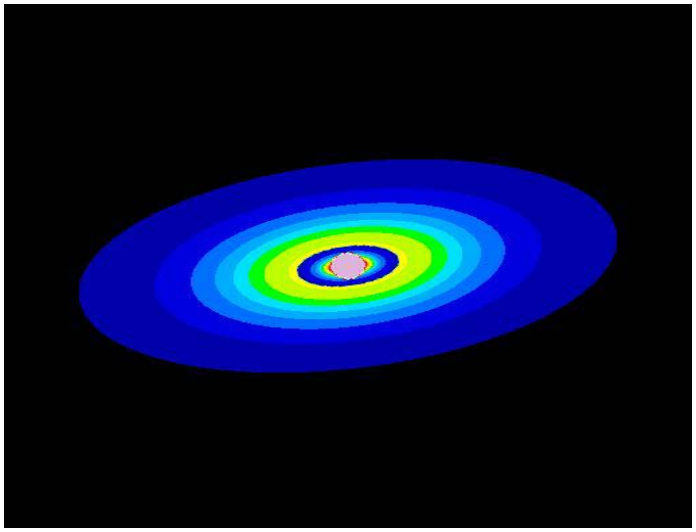


Touhami et al. 2009

Modeling the visibilities: Disk geometry

- Uniform disk star with a set of initial physical parameters: (M_s , R_s, T_{eff} , π,)

$$\begin{cases} \rho(\mathrm{r},\mathrm{z}) = 0 \ , \ r < r_0 \\ \rho(\mathrm{r},\mathrm{z}) = \rho_0 (r/r_o)^{-n} \exp(-1/2(z/H)\text{^}2), \ r > r_0 \end{cases}$$



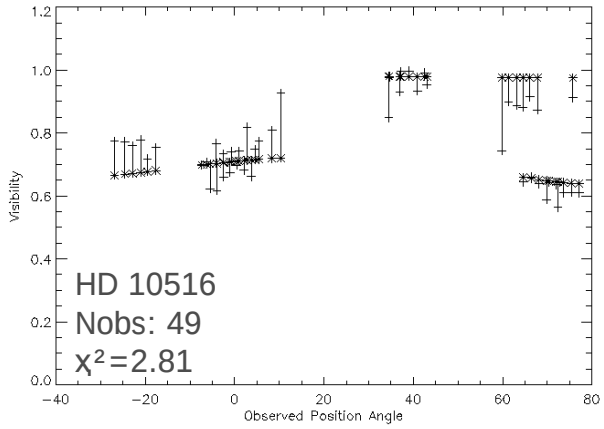
- Temperature profile is distance-dependant

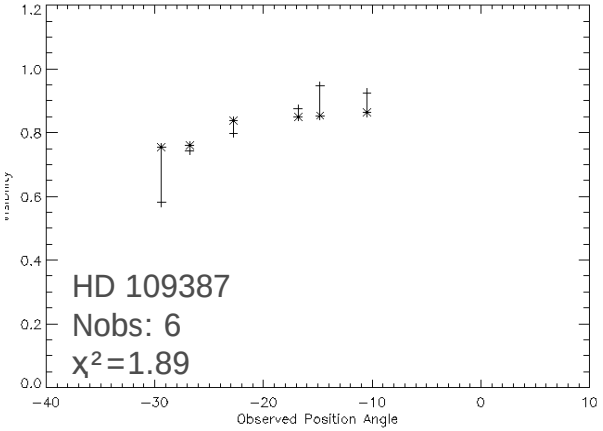
$$T(r) = T_0 (r/r_0)^{-q}$$

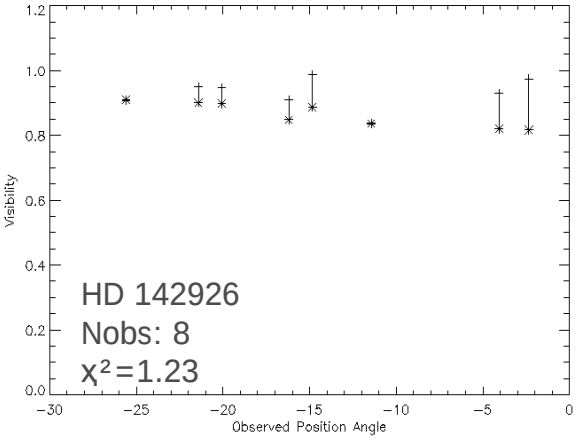
- Considering the free-free and bound-free opacity, the total flux is given by:

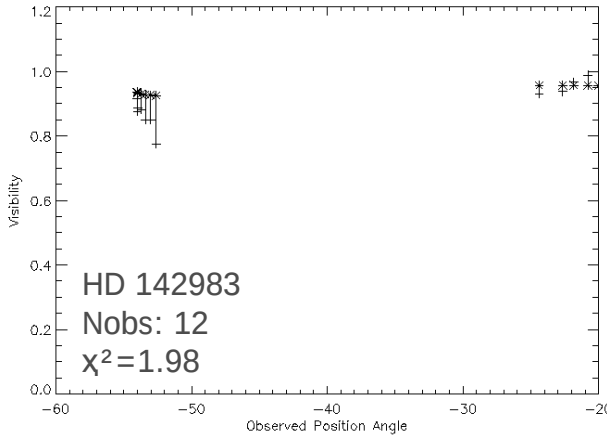
$$F_\nu = \frac{\kappa_\nu}{D^2} \int\int B_\nu(T(r))\, \rho^2(r,z)\, r\, dr\, d\theta\, dz$$

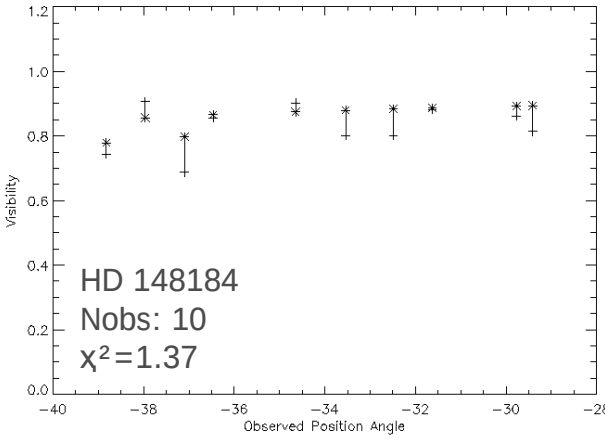
Classic: Results-1

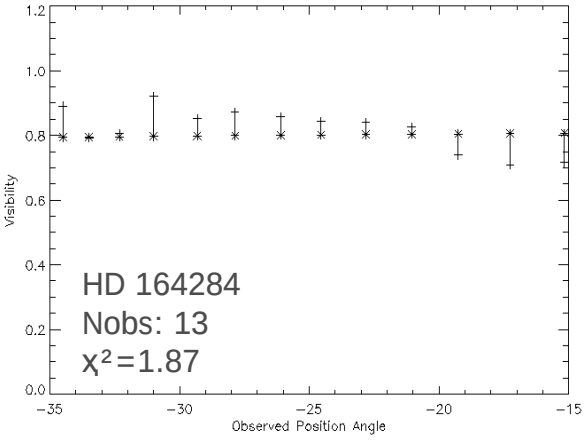




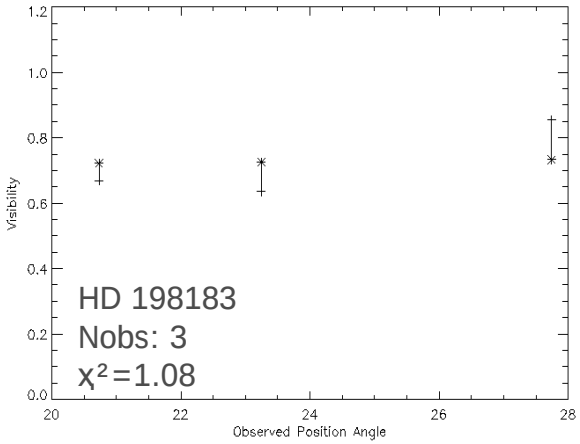


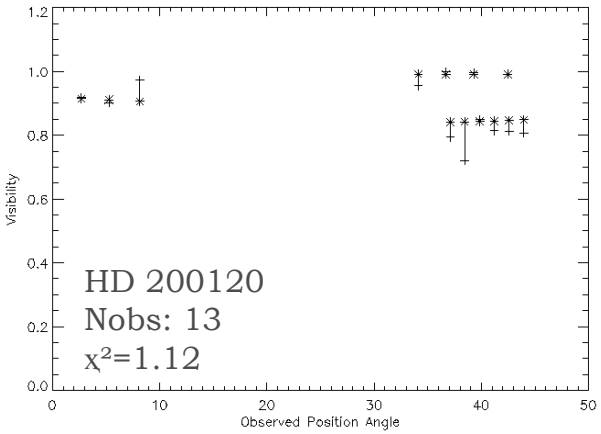


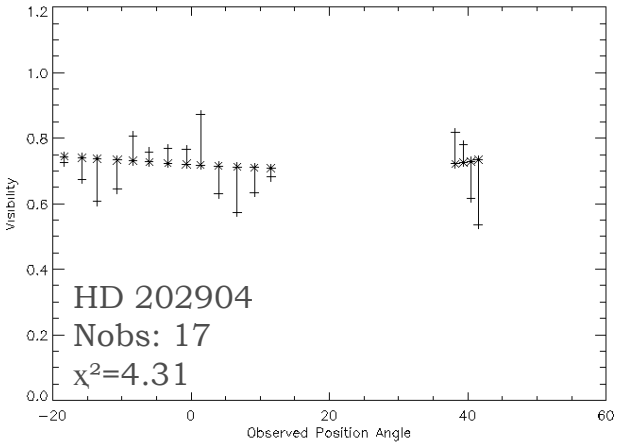


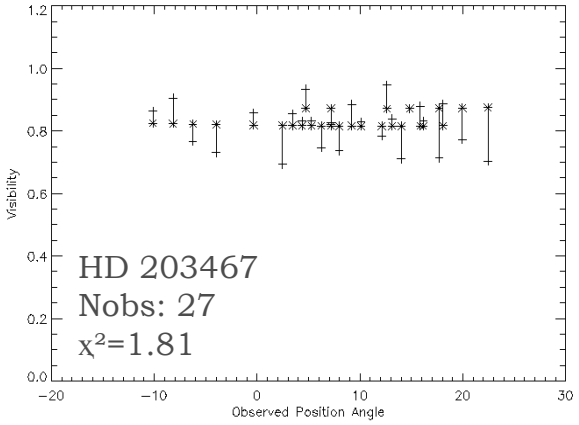


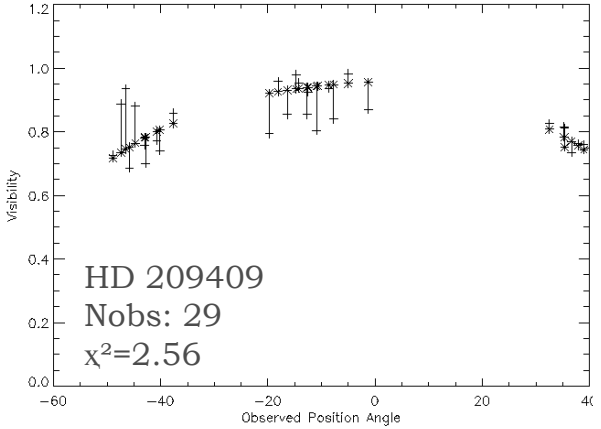
Classic: Results-2

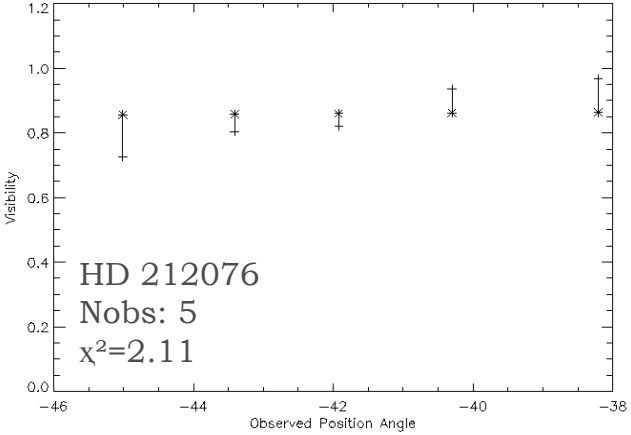




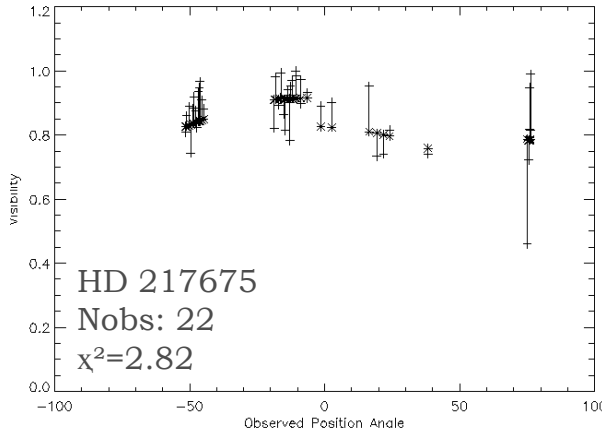


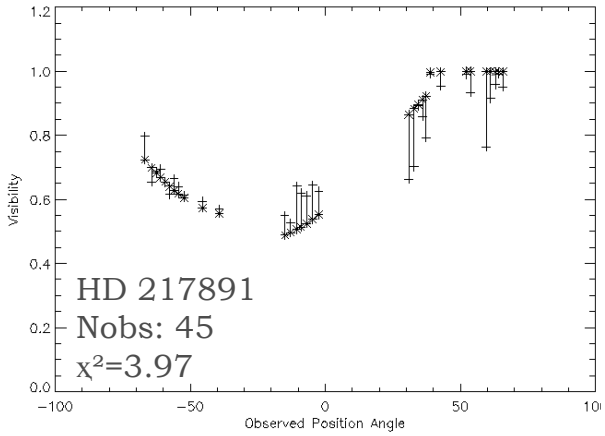


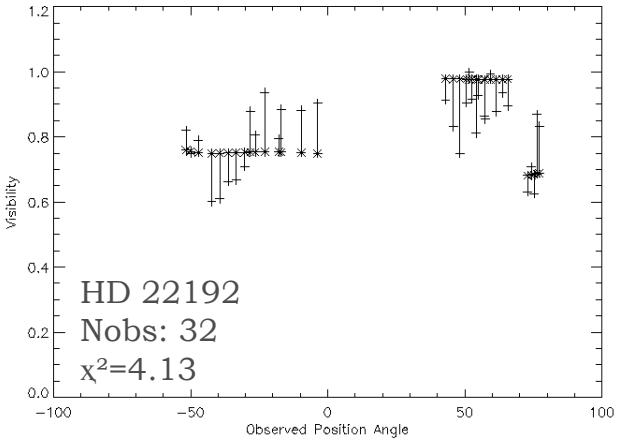


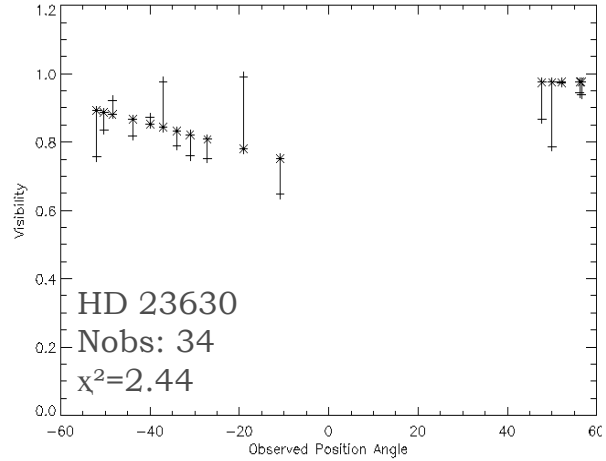


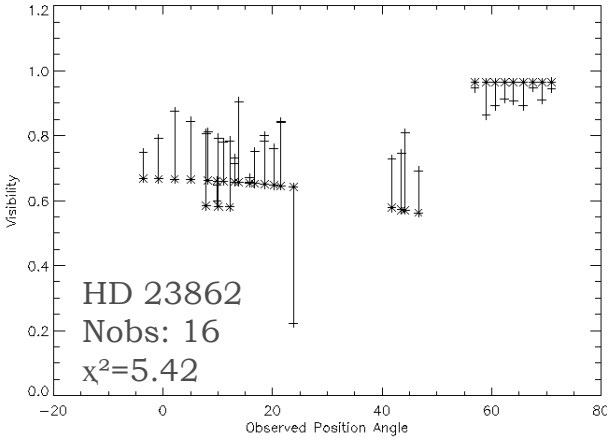
Classic: Results-3

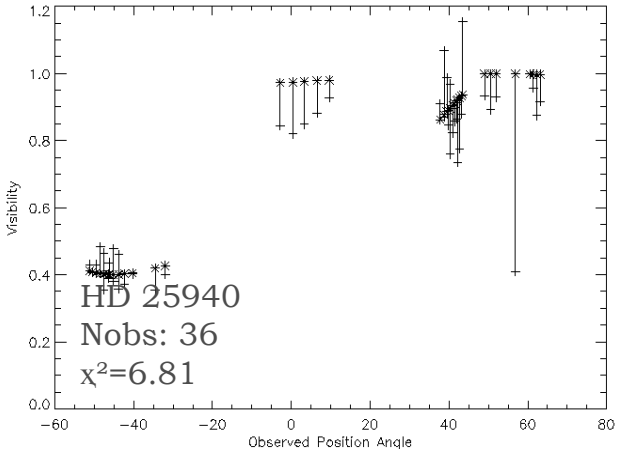






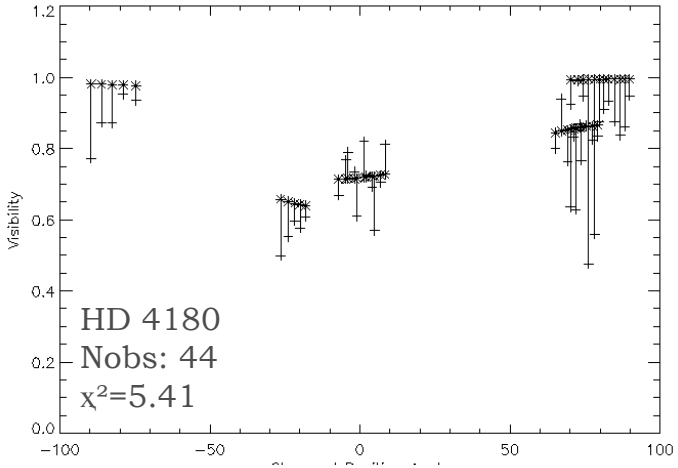


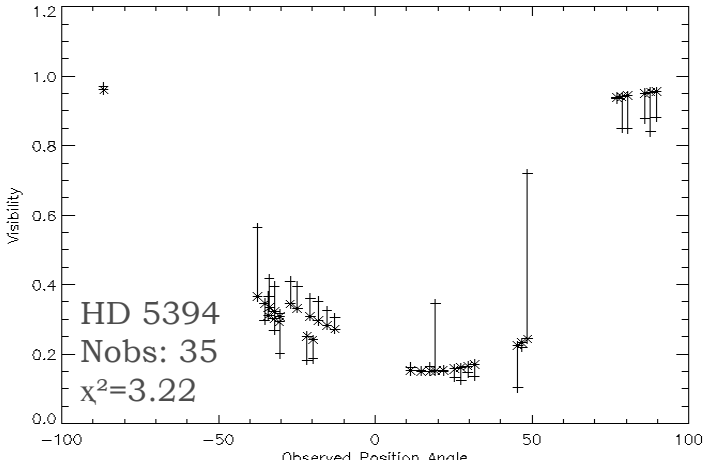


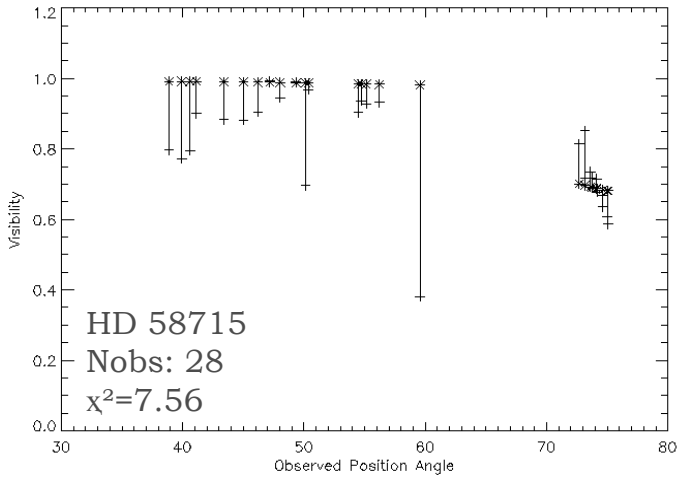


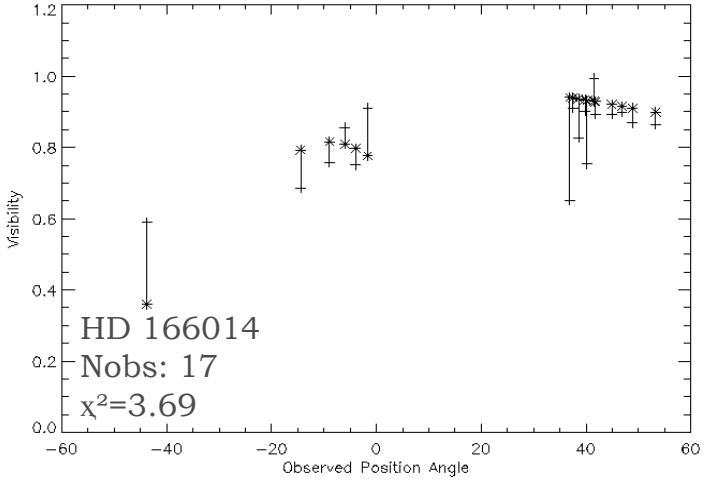
Touhami et al. 2010, in prep

Classic: Results-4







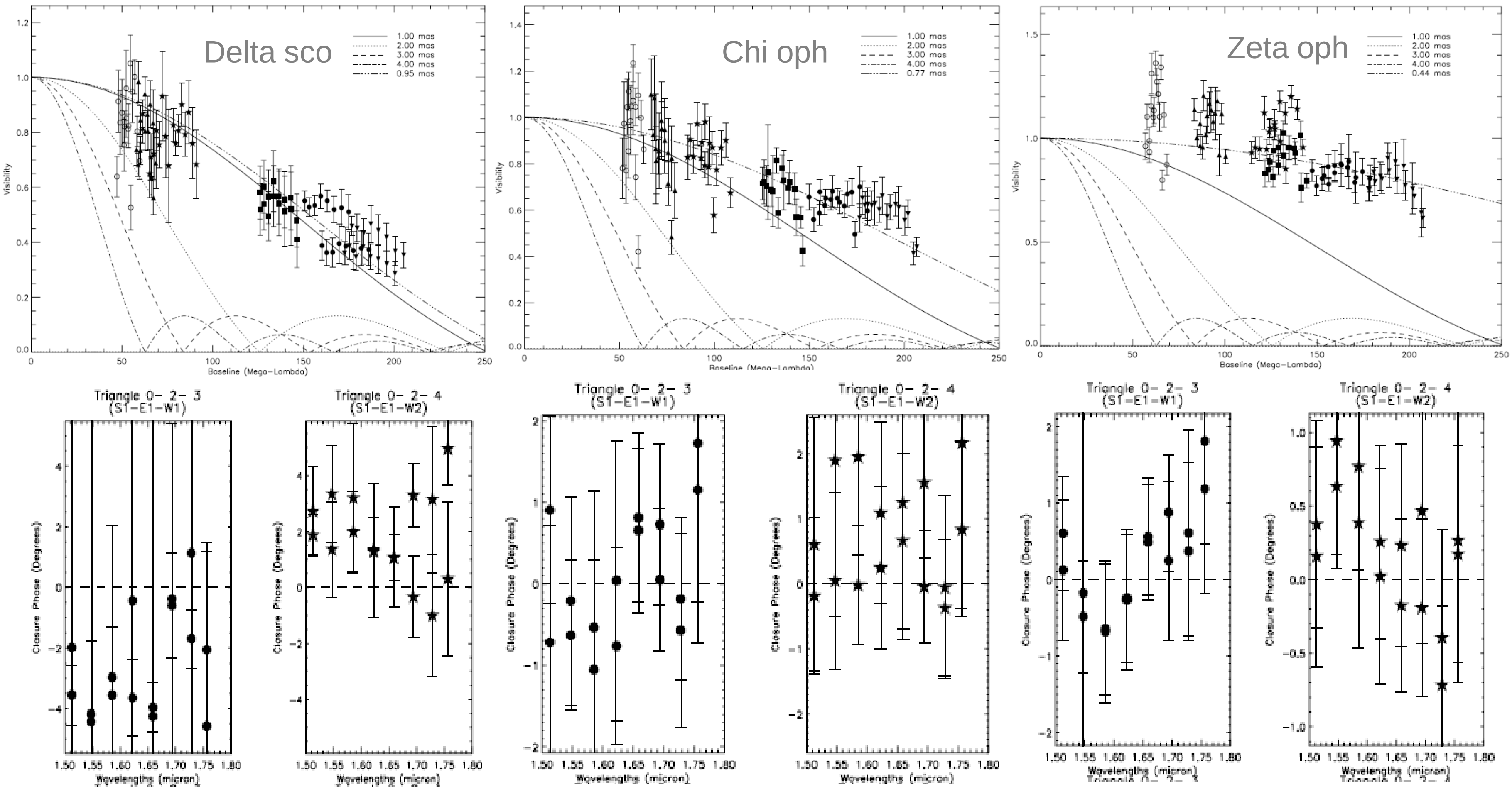


List of observed Be stars

HD	HR	RA(2000)	DEC(2000)	V	R_s	T_eff	WHa	th_d	th_J	Name	Nobs
109387	4787	12 33 28.9	+69 47 17.7	3.88	0.405	14174.	-20.3	3.92	0.72	kapDra	6
138749	5778	15 32 55.8	+31 21 32.9	4.15	0.338	14440.	2.8	1.21	…	the_CrB	2
142926	5938	15 55 30.6	+42 33 58.3	5.74	0.180	12060.	-7.3	1.45	…	4Her	8
142983	5941	15 58 11.4	-14 16 45.7	4.94	0.211	17790.	-24.1	1.88	0.67	48Lib	12
143275	5953	16 00 20.0	-22 37 18.2	2.29	0.484	27000.	-8.0	2.17	…	del Sco	MIRC
148184	6118	16 27 01.4	-18 27 22.5	4.42	0.390	30700.	-37.6	3.17	1.12	chi Oph	MIRC
164284	6712	18 00 15.8	+04 22 07.0	4.64	0.260	21650.	-7.5	1.30	0.74	66Oph	13
166014	6779	18 07 32.6	+28 45 45.0	3.84	0.530	9800.	6.7	2.17	…	omiHer	17
198183	7963	20 47 24.5	+36 29 26.6	4.53	0.340	13925.	4.7	0.99	…	Lam Cyg	3
149757	6175	16 37 09.4	-10 34 02.0	2.56	0.494	28610.	-3.0	1.55	…	Zeta oph	MIRC
200120	8047	20 59 49.5	+47 31 15.4	4.69	0.221	23870.	-12.3	1.22	0.40	59Cyg	13
202904	8146	21 17 55.0	+34 53 48.8	4.32	0.266	20460.	-22.8	2.14	1.26	upsCyg	17
203467	8171	21 19 22.2	+64 52 18.7	5.19	0.200	17087.	-25.4	1.86	0.57	6Cep	27
209409	8402	22 03 18.8	-02 09 19.3	4.70	0.301	12770.	-18.0	3.09	0.94	Omi Aqr	29
212076	8520	22 21 31.0	+12 12 18.7	4.72	0.150	23340.	-23.8	1.12	0.52	31Peg	5
217675	8762	23 01 55.3	+42 19 33.5	3.63	0.480	14140.	4.7	1.36	0.52	OmiAnd	22
217891	8773	23 03 52.6	+03 49 12.2	4.37	0.280	13530.	-11.7	2.31	1.27	betaPsc	45

HD	HR	RA(2000)	DEC(2000)	V	R_s	T_eff	W_Ha	th_d	th_J	Name	Nobs
004180	0193	00 44 43.5	+48 17 03.7	4.43	0.600	14400.	-31.2	7.24	1.89	omiCas	44
005394	0264	00 56 42.5	+60 43 00.3	2.29	0.450	30240.	-32.5	3.43	1.48	gamCas	35
010516	0496	01 43 39.6	+50 41 19.4	4.09	0.264	28760.	-28.8	1.95	0.89	phiPer	49
022192	1087	03 36 29.3	+48 11 33.5	4.25	0.349	16840.	-40.1	4.24	1.00	psiPer	32
023630	1165	03 47 29.0	+24 06 18.5	2.87	0.719	12410.	-2.7	4.67	1.84	Alcyone	34
023862	1180	03 49 11.2	+24 08 12.2	4.96	0.262	12890.	-15.4	2.53	0.75	Pleione	16
024534	1209	03 55 23.1	+31 02 45.0	6.10	0.084	28000.	-24.4	0.58	…	XPer	2
025940	1273	04 08 39.6	+47 42 45.0	3.96	0.387	16720.	-26.6	3.81	1.58	48Per	36
037202	1910	05 37 38.7	+21 08 33.2	3.03	0.430	20050.	-20.2	3.30	0.66	zetaTau	43
058715	2845	07 27 09.0	+08 17 21.5	2.89	0.733	11740.	-1.8	4.86	1.97	betaCMi	28

MIRC observations of Be stars



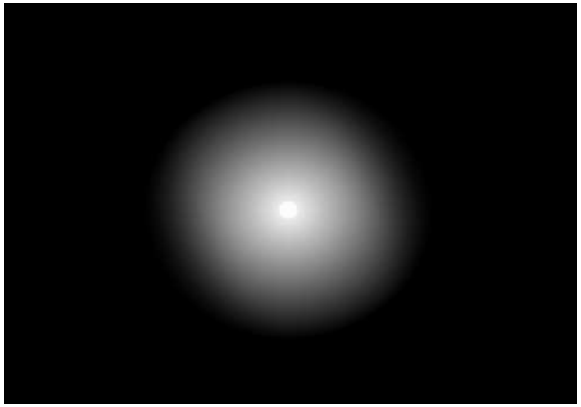
Fluor Observations of Rho Cas

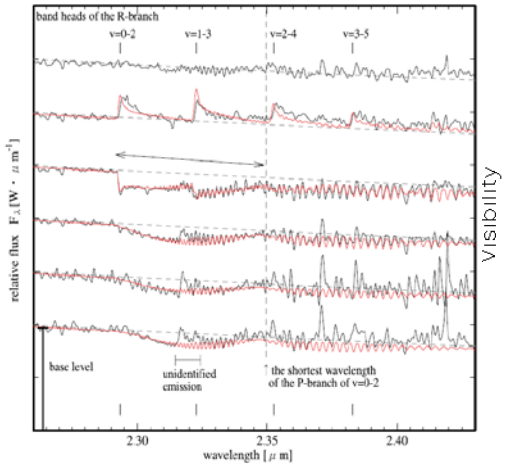
Primary results:

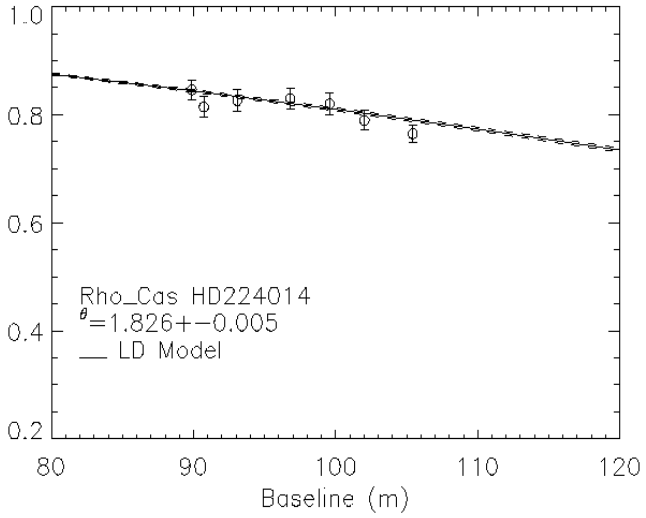
* High presicion estimate for the angular diameter Θ= 1.826 ±0.005 mas

* High IR excess from model matches current observations

* First estimate of the shell density determined at constant effective temperature: 1.17 x 10-¹⁰ g/cm³ consistent with spectroscopic results.







YAMAMURO et al. 2007

Ongoing and Future Work

- Continue the observations to complete the survey: gain in sensitivity with the CLIMB and CHAMP
- Another contemporaneous spectroscopy run for monitoring Be stars from Lowell
- Time evolution of disks: *follow time variations in the visibility measurements to constrain mass loss*
- Finding structures in disks with MIRC: *asymmetries*, *spiral arms*
- Explore signatures of companions

Thank you..