Multiwavelength Analysis of Be Star Circumstellar Disks

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Physical Model of The K-band Visibility

- Uniform disk star with a set of initial physical parameters: (M_s , R_s , T_{eff} , π)
- Disk geometry (Hummel & Vrancken 2000)

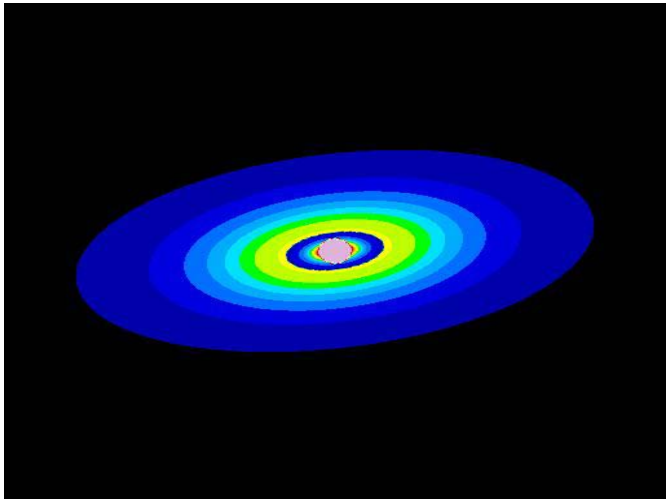
$$\begin{cases} \rho(\mathrm{r,z}) = 0 \ , \ r < r_0 \\ \rho(\mathrm{r,z}) = \rho_0 (r / r_o)^{-n} \exp(-1/2(z/H)^\wedge 2), \ r > r_0 \end{cases}$$

r_0 = inner disk radius (R_0)
ρ_0 = base density (g cm^{-3})
n = radial density exponent
$H(R) = R^{3/2}\, C_s \,/\, V_K$ = disk scale height

- Observer parameters:

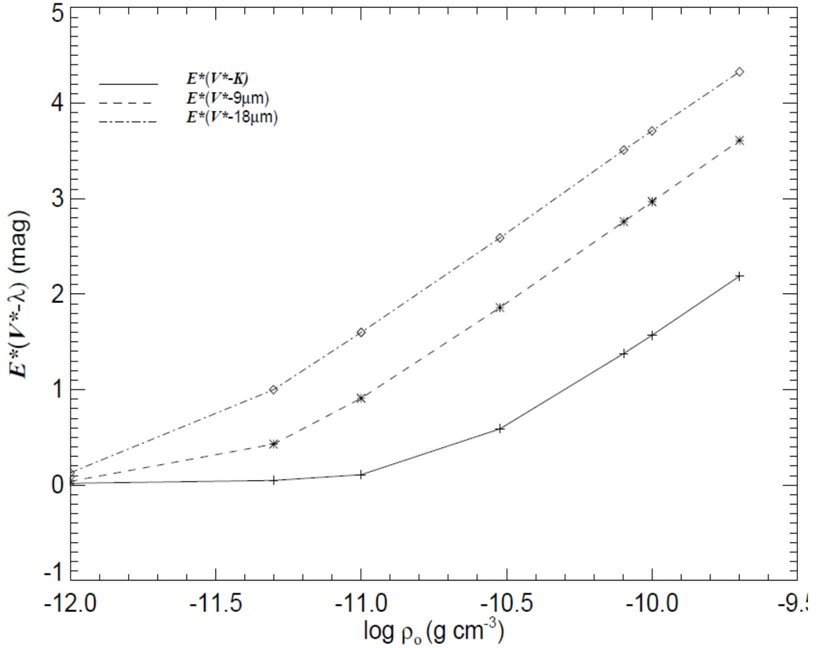
i = inclination of disk normal
α = position angle

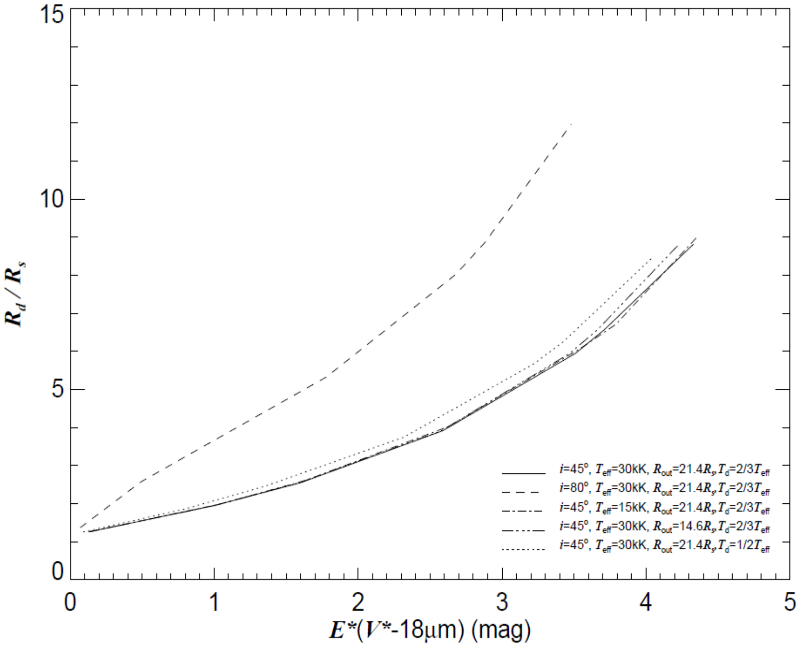
- Output: Physical infrared images, Model visibility, and infrared excess



Multiwavelength Disk Densities and Sizes

- The optically thick-thin boundary of the disk and the excess flux increase at longer wavelengths.
- As the disk inclination increases, the excess emission decreases and the apparent size of the disk increases.
- Cooler Be stars show the same excesses and apparent sizes because of the temperature dependence of the optical depth coefficient

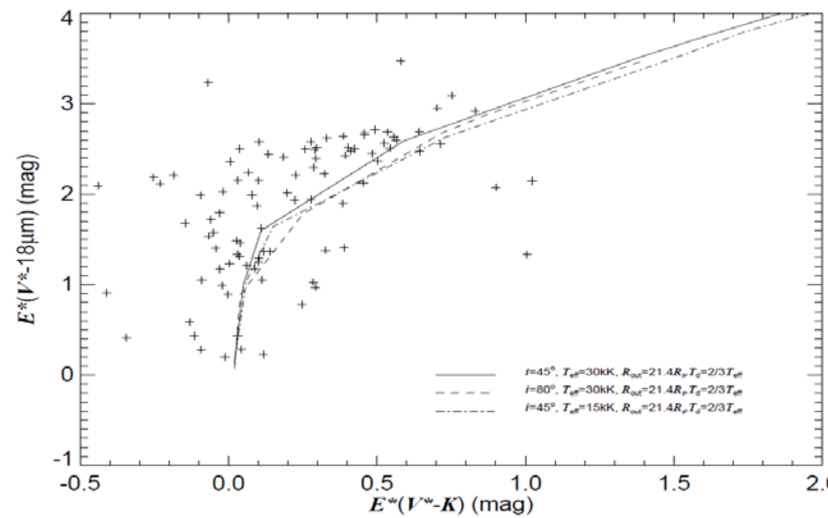


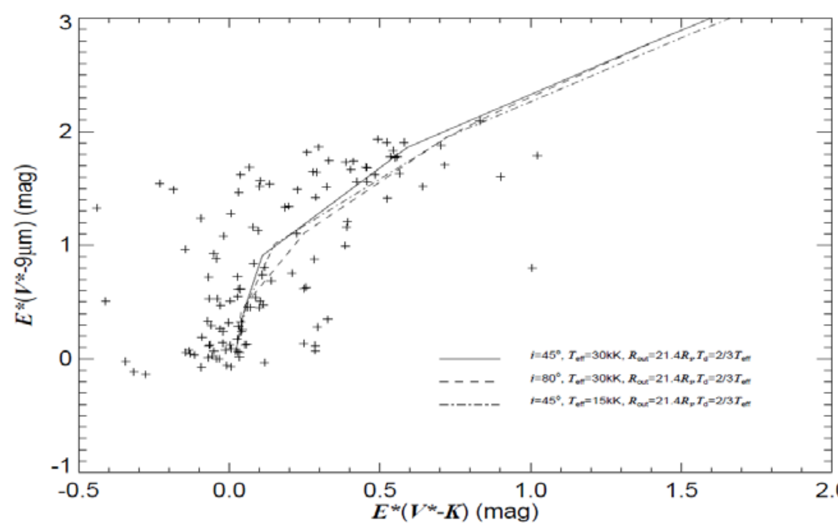


Excesses at 9 and 18 microns

- Comparison between our model excesses at 9 and 18 micron versus the excess in the K-band with the recent AKARI/IRC mid-infrared all-sky survey.

- At the high density limit, the disk flux dominates over the stellar flux and the system colors are due to the disk, and the color-color excess diagrams show a linear shape





Evolutionary Status of Be stars

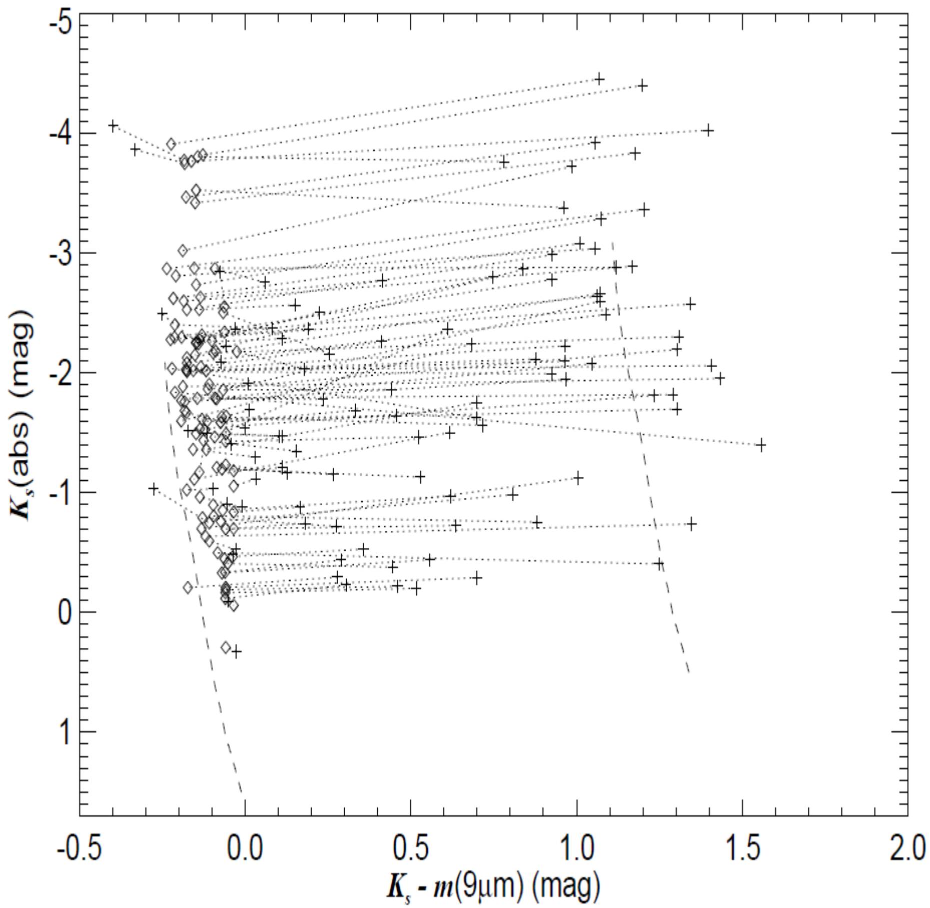
- The absolute Ks magnitude versus the interstellar-reddening-corrected color excess at 9 micron

- The left dotted line is the zero age main sequance from the theoretical tracks (Lejeune & Schaerer 2001)

- The asymptotic form of the excess in the dense disk case is found to be:

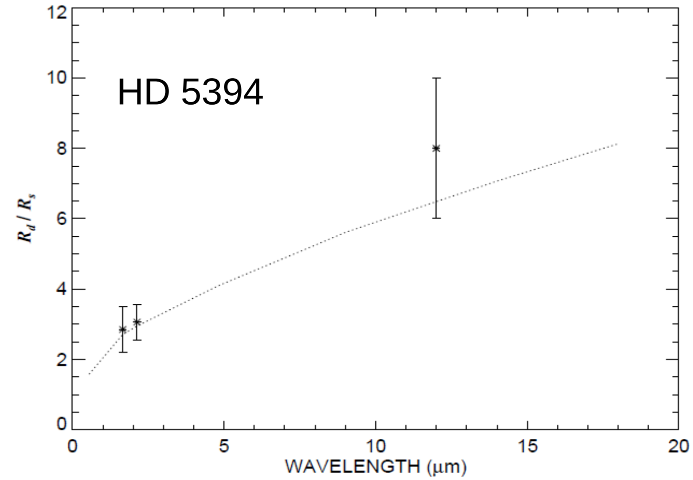
$$E^{\star}(V^{\star} - 9\ \mu\mathrm{m}) \approx E^{\star}(V^{\star} - K_s) + 1.35$$

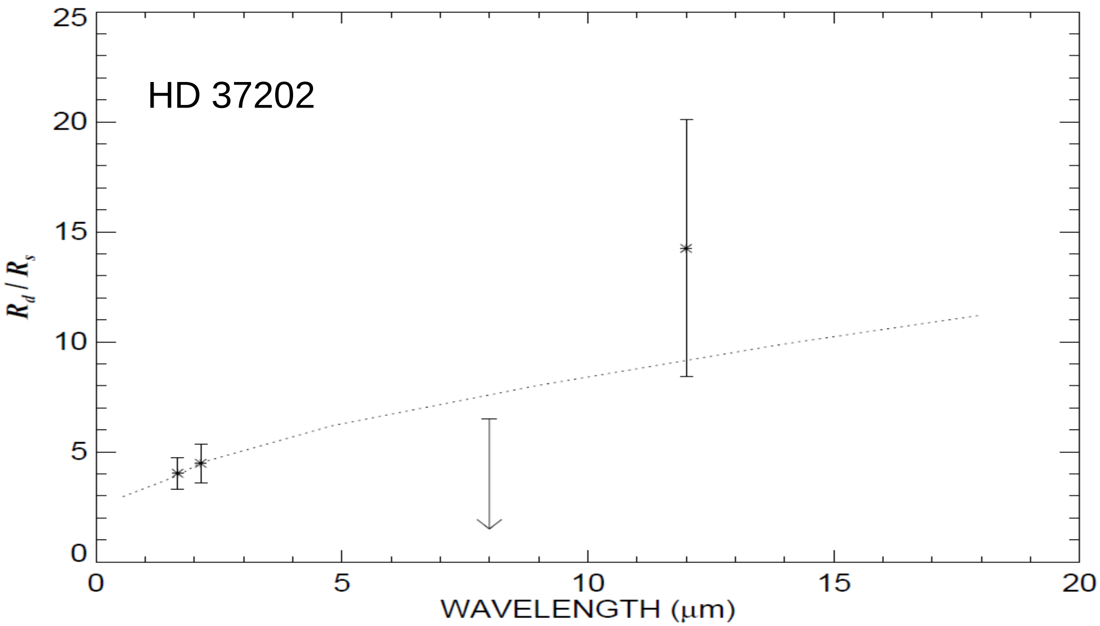
- Be stars range in color excess between the “no disk” and the “strong disk’ cases

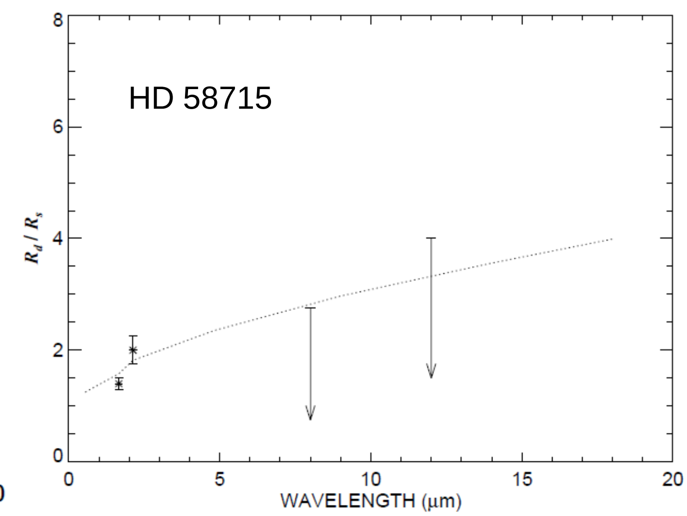


Disk Size versus wavelength

- The apparent disk sizes at different wavebands for Zeta Tau, Beta CMi, and Gamma Cas
- Model predictions are consistent with CHARA/MIRC, CHARA/Classic, and VLTI/MIDI 8 and 12 micron observations







CHARA Array Observations

- A survey of 25 bright Be stars in the *K*- band to determine size and orientation of disks.
- Project started in 2007 and reached the completion stage in Fall 2010
- The circumstellar disks of Be stars were resolved with the long baselines of the CHARA array (using the Classic, FLUOR, and MIRC Beam Combiners)

Survey Results

Star Name	F_t/F_0	inc (degrees)	PA (degrees)	R_d/R_s	$E(V-K)$ (mag)	V_{rot} (km/s)
HD 004180	2.09	$45^o \pm 7^o$	$83^o \pm 7^o$	2.06	0.83	313 ± 48
HD 005394	2.11	$57^o \pm 5^o$	$113^o \pm 8^o$	3.77	0.81	525 ± 31
HD 010516	2.27	$8^o \pm 5^o$	$36^o \pm 4^o$	1.54	0.89	397 ± 53
HD 022192	1.42	$89^o \pm 7^o$	$51^o \pm 3^o$	3.79	0.37	295 ± 23
HD 023630	1.08	$79^o \pm 9^o$	$358^o \pm 17^o$	1.69	0.08	176 ± 19
HD 023862	2.71	$71^o \pm 5^o$	$126^o \pm 11^o$	3.05	1.08	233 ± 18
HD 025940	1.57	$51^o \pm 8^o$	$181^o \pm 13^o$	1.45	0.49	283 ± 15
HD 037202	1.60	$87^o \pm 3^o$	$41^o \pm 5^o$	4.75	0.51	320 ± 11
HD 058715	1.41	$55^o \pm 7^o$	$27^o \pm 7^o$	1.44	0.40	282 ± 12
HD 109387	1.52	$76^o \pm 3^o$	$24^o \pm 8^o$	1.83	0.45	215 ± 12
HD 138749	1.17	$93^o \pm 5^o$	$207^o \pm 13^o$	1.17	0.17	327 ± 17
HD 142926	1.45	$68^o \pm 3^o$	$94^o \pm 10^o$	1.98	0.39	364 ± 16
HD 142983	1.89	$64^o \pm 5^o$	$115^o \pm 5^o$	2.11	0.69	453 ± 23
HD 148184	2.61	$18^o \pm 6^o$	$164^o \pm 9^o$	1.64	1.04	488 ± 19
HD 164284	2.07	$81^o \pm 7^o$	$93^o \pm 11^o$	3.60	0.79	291 ± 15
HD 166014	3.56	$79^o \pm 6^o$	$8^o \pm 6^o$	4.94	1.37	168 ± 13
HD 198193	7.84	$12^o \pm 5^o$	$88^o \pm 7^o$	2.97	2.23	339 ± 21
HD 200120	1.87	$69^o \pm 4^o$	$133^o \pm 5^o$	2.28	0.68	414 ± 24
HD 202904	1.88	$47^o \pm 5^o$	$93^o \pm 6^o$	2.73	0.68	295 ± 15
HD 203467	3.24	$39^o \pm 8^o$	$122^o \pm 6^o$	2.64	1.27	262 ± 13
HD 209409	1.48	$79^o \pm 3^o$	$163^o \pm 14^o$	2.18	0.42	287 ± 10
HD 212076	1.81	$71^o \pm 8^o$	$51^o \pm 7^o$	2.39	0.64	109 ± 12
HD 217675	1.32	$85^o \pm 3^o$	$107^o \pm 5^o$	3.58	0.30	290 ± 11
HD 217891	1.30	$13^o \pm 6^o$	$79^o \pm 6^o$	1.24	0.28	445 ± 27

Touhami et al. in prep

Thesis project updates

- A survey of 25 Be stars in the *K*- band:
  Project completed in Fall 2010 (Touhami et al., in prep)

- The Brighter Be stars observed with MIRC
- Optical Observations with PAVO + Modeling - - In progess
- Multiwavelength disk analysis (Touhami et al. 2011, ApJ, 729, 17)
- Simultaneous spectroscopic results from Lowell and IRTF published (Touhami et al. 2010, PASP, 122, 379)

Summary

- The circumstellar disks around Be stars are routinely resolved by interferometers
- Interferometric observations have the potential of placing fundamental constraints on the current theories/models
- Contemporaneous Spectroscopy measurements constrain disk temperature
- The disk sizes determined at different wavelengths are consistent with model predictions
- Using inclination with vsini, the actual rotational velocity of the central star is found to be close to critical
- Signatures of companions

Thank you..