A CHARA Array Survey of Circumstellar Disks Around Nearby Be-type Stars


Surveying Be-Disks

- Rapidly rotating B-stars with ionized disks that produce continuum flux in IR from b-f and f-f emission
- Sample of 24 Be stars: bright, relatively nearby, current Hα emission
- Observations using:
  + Interferometry
    CHARA CLASSIC in the K-band
  + IR Spectrophotometry
    Lowell Obs. / Mimir and IRTF / SPEX
    (Touhami et al. 2010, PASP, 122, 379)
- 563 bracketed observations mainly from 2007 October to 2010 November
- Usually S1/W1 and S1/E1 for better (u,v) coverage
Binary/Multiple Star Corrections

- 14 of 24 Be stars have companions within CHARA FOV
- Normal stars and post-mass transfer remnants
- 9 of 14 are bright enough to affect visibilities
- Developed scheme to correct $V$ based upon sep., PA, $\Delta K$
- Renormalization of $V$ in most cases
**SED UV normalization:**

*stellar angular diameter and NIR flux excess*
**Gaussian Elliptical Model Fits**

- \( V_{tot} = c_p \ V_s + (1 - c_p) \ V_d \)
- Used SED stellar angular diameter (small) for \( V_s \) (\( \approx 1 \))
- Disk visibility as Gaussian for major and minor axes with axial ratio \( r \), position angle \( PA \), and disk FWHM along major axis \( \theta_{maj} \)
- Fraction of Gaussian disk flux falls upon star, so reassigned to the star: corrections for \( c_p \) and \( \theta_{maj} \)
Survey Results:
14 Resolved, 6 Marginal, 4 Unresolved
Survey Results

- Consistency between $K$-band flux excess from SED fits and GE model fits of interferometry

- Inclinations from minor - major axis ratio similar to those estimated from projected rotational broadening of spectral lines (Frémat et al. 2005, A&A, 440, 305)

- Disk normal orientation in sky consistent with linear polarization (corrected for interstellar polarization)

- Ratio of disk radius (half intensity) to stellar radius in range from 1.5 to 10 (mean = 4.4) in $K$-band, about 4 times smaller than for Hα (higher opacity)
**Survey Results**

- Use axial ratio to find $V(\text{equatorial})$ from $V \sin i \div \sin i$

  ➞ most are very rapid rotators

  $< \Omega_{\text{rot}} / \Omega_{\text{crit}} > = 0.95 \pm 0.04$
Table 9. Linear Rotational and Critical Velocities

<table>
<thead>
<tr>
<th>HD Number</th>
<th>( V \sin i ) (km s(^{-1}))</th>
<th>( V_{\text{crit}} ) (km s(^{-1}))</th>
<th>( V_{\text{rot}} ) (km s(^{-1}))</th>
<th>( V_{\text{rot}}/V_{\text{crit}} )</th>
<th>( \Omega_{\text{rot}}/\Omega_{\text{crit}} )</th>
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</thead>
<tbody>
<tr>
<td>HD 004180</td>
<td>208±13</td>
<td>332±21</td>
<td>249±26</td>
<td>0.75±0.09</td>
<td>0.91±0.06</td>
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<tr>
<td>HD 005394</td>
<td>441±27</td>
<td>577±36</td>
<td>599±37</td>
<td>1.04±0.09</td>
<td>≈ 1</td>
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<tr>
<td>HD 010516</td>
<td>462±33</td>
<td>590±42</td>
<td>487±6</td>
<td>0.82±0.06</td>
<td>0.96±0.03</td>
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<tr>
<td>HD 022192</td>
<td>295±15</td>
<td>397±20</td>
<td>310±70</td>
<td>0.78±0.18</td>
<td>0.93±0.11</td>
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<tr>
<td>HD 023630</td>
<td>149±8</td>
<td>274±15</td>
<td>216±20</td>
<td>0.79±0.09</td>
<td>0.94±0.05</td>
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<tr>
<td>HD 025940</td>
<td>220±13</td>
<td>386±21</td>
<td>323±82</td>
<td>0.84±0.22</td>
<td>0.96±0.10</td>
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<tr>
<td>HD 037202</td>
<td>326±7</td>
<td>466±13</td>
<td>333±6</td>
<td>0.71±0.02</td>
<td>0.89±0.02</td>
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<tr>
<td>HD 058715</td>
<td>231±14</td>
<td>380±24</td>
<td>327±91</td>
<td>0.86±0.25</td>
<td>0.97±0.10</td>
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<tr>
<td>HD 142983</td>
<td>407±22</td>
<td>501±28</td>
<td>484±56</td>
<td>0.97±0.12</td>
<td>1.00±0.01</td>
</tr>
<tr>
<td>HD 202904</td>
<td>167±20</td>
<td>468±30</td>
<td>171±7</td>
<td>0.37±0.03</td>
<td>0.52±0.04</td>
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<td>HD 209409</td>
<td>282±20</td>
<td>391±27</td>
<td>288±4</td>
<td>0.74±0.05</td>
<td>0.90±0.04</td>
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<td>HD 217891</td>
<td>100±6</td>
<td>367±24</td>
<td>135±44</td>
<td>0.37±0.12</td>
<td>0.53±0.16</td>
</tr>
</tbody>
</table>
Work Underway

- Draft of papers on physical models for the disks of γ Cas and other Be stars
- Compare disk sizes between $R$–band (PAVO), $H$–band (MIRC), and $K$–band (CLASSIC/CLIMB)
- Use closure phase observations (MIRC, CLIMB) to explore flux asymmetries caused by disk and faint companions (Schaefer et al. 2010, AJ, 140, 1838)
Disk Dynamics: one-armed spiral pattern in ζ Tau

MIRC 6T on ϕ Per
Che et al. 2012 (SPIE, 84450Z)