Multi-wavelength CHARA observations of rapid rotators

--- Regulus with non-standard gravity darkening coefficient

Xiao Che, John Monnier
Stellar rotation is important at the beginning and end of stellar life. Why it is overlooked at MS?

- No complete stellar rotation model is available
- Unknown inclination angles
- Most stars rotate slowly
Stellar rotation

- However a large fraction of early type stars show $v_{\text{sin}i} > 100\text{km/s}$ (Abt 1995, 2002)

- Stellar rotation effects (Maeder & Meynet 2000)
  - Distort stellar photosphere shape
    - Maximum $R_{\text{equ}} / R_{\text{pole}}$ could be 1.5 for solid-body rotation
  - Temperature varies across the stellar surface due to gravity darkening
    - $T_{\text{eff}} \propto g^\beta$
      - $\beta = 0.25$ radiative envelopes (Von Zeipel 1924)
      - $\beta = 0.08$ convective envelopes (Lucy 1967)
  - evolution, lifetime, abundance…
Previous interferometric study on rapid rotators

- Previous studies focus on A type stars
- One important result:
  - Non-standard gravity darkening coefficients
    - Average value across the surface?

Regulus --- B7V

Monnier et al. 2007
Zhao et al. 2009
Claret et al. 2000
MIRC observation on Regulus

5 nights of MIRC observation on Regulus with CHARA outer array

<table>
<thead>
<tr>
<th>Target</th>
<th>Obs. Date</th>
<th>Telescopes</th>
<th>Calibrators</th>
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<tbody>
<tr>
<td>α Leo</td>
<td>UT 2008Dec03</td>
<td>S1-E1-W1-W2</td>
<td>θ Leo</td>
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2-D stellar surface model

Temperature:
5. T at the pole
6. Gravity darkening coefficient $\beta$

$$\frac{T}{T_{\text{pole}}} = \left(\frac{g}{g_{\text{pole}}}\right)^\beta$$

Shape:
1. Radius of the pole
2. Angular velocity $\omega$, $\Omega = \frac{\omega}{\omega_{\text{crit}}}$

Orientation:
3. Inclination
4. Position angle

Fully radiative envelope: $\beta = 0.25$ (von Zeipel 1924)
Fully convective envelope: $\beta = 0.08$ (Lucy 1967)
Gravity Darkening Coeffiecient: Regulus

\[ T > 11000\text{K} \]

Fully radiative envelope

von Zeipel’s law

\[ \beta = 0.25 \]

\[ \text{Fraction of critical velocity } \omega \approx 0.96 \]

\[ T_{\text{pole}} = 14520 \text{ K} \quad T_{\text{equ}} = 11010 \]

\[ \alpha \text{ Leo Model} \]

McAlister et al. 2005
Gravity Darkening Coefficient: Regulus

\[ T > 11000K \]

- Fully radiative envelope
- von Zeipel's law
- \( \beta = 0.25 \)

\[ \beta \approx 0.19 \]

von Zeipel's law fails even at hot stars. Fully radiative envelope is impossible for solid-body rotation (Tassoul 2000)
PAVO Observation on Rapid rotator

- Confine gravity darkening coefficient (beta)
  - Higher intensity contrast between poles and equator in visible than in infrared

Beta = 0.188

Beta = 0.25
PAVO Observation on Rapid rotator

PAVO data is slightly better to distinguish models of different beta.
PAVO Observation on Rapid rotator

Observed with W1W2S2
CHARA Collaboration Year-Seven Science Review

Differential rotation

Solid body rotation, w=0.96

Differential rotation,
Pole:  w=0.96
Equ:  w=0.8
Differential rotation

Intensity profile + vsini contour
Stellar images across a line

H-alpha line
VEGA observation: differential rotation vs. solid-body rotation

Visibility and differential phase across Hα line

- **S2S1**
- **S2W2**
- **S1W2**

Solid line: differential rotation
Dotted line: solid-body rotation
VEGA: differential rotation

H-alpha: pressure broadening dominated

• O I triplets: 7772, 7774, 7775 Å. Doppler broadening dominated. Model fitting three lines together.