



Imaging Spotted RS CVn Binaries

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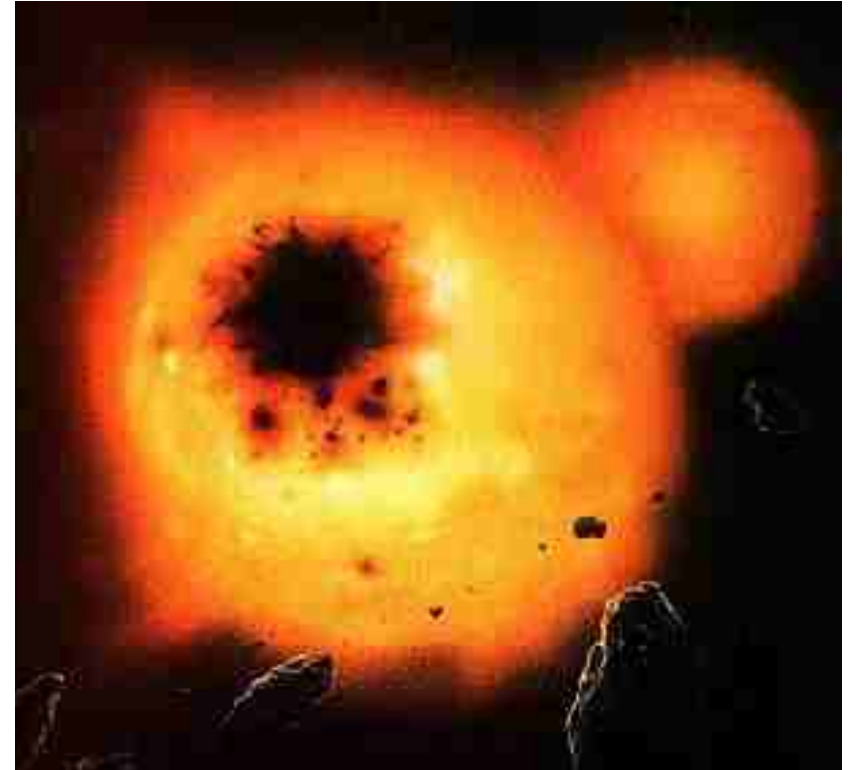
Imaging Spotted Stars with CHARA

- Compare aperture synthesis images with contemporaneous Doppler imaging and light-curve inversion results
- Interferometry from MIRC 6T
- High-resolution spectroscopy from VLT, NOT, STELLA robotic telescope
- Photometry from APT and SMARTS
- RS CVn targets: ζ And and σ Gem



RS CVn Binaries

- Giant or subgiant primary component
- Subgiant or dwarf secondary component
- Exhibit photometric and Ca H and K variability
- Interesting starspot features
 - Polar spots
 - Active longitudes
- Close binaries
 - Short rotation and orbital periods
 - Often tidally-locked
 - No mass transfer



Hall 1976, Berdyugina 2005, Strassmeier 2009

o Dra

- G9III primary
- $T_{\text{eff}} \sim 4430 \text{ K}$
- $P_{\text{rot}} \sim 70 \text{ days}$
- $P_{\text{orb}} \sim 138 \text{ days}$
- Active primary
 - Spot evolution
 - Ca H & K variation
- No direct detections of the companion star

Red Giant
Primary Star
 $R_1 = 25.2 \pm 0.2 R_{\text{sun}}$

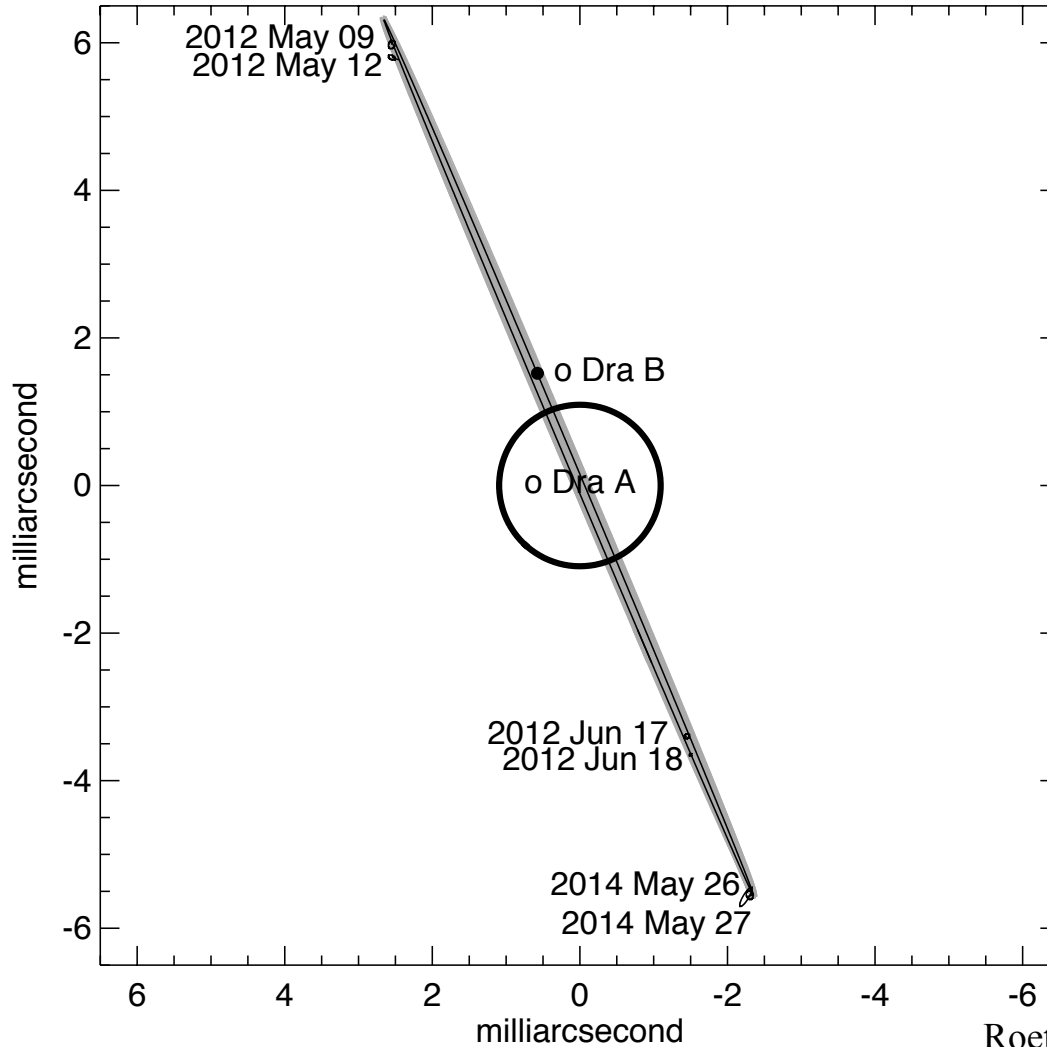


370x fainter than primary



Main sequence
companion

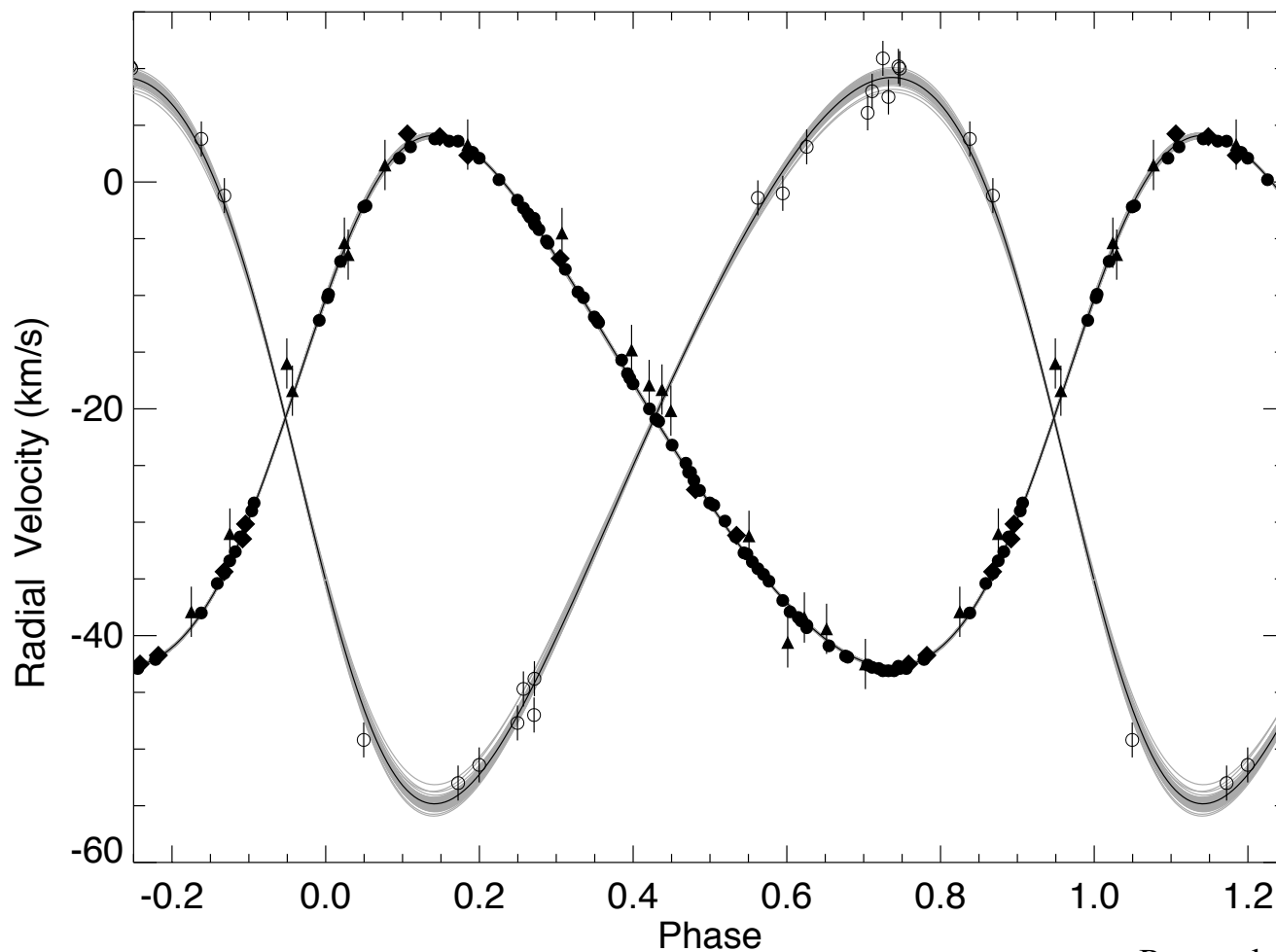
o Dra Orbit



Roettenbacher et al. in prep.

o Dra

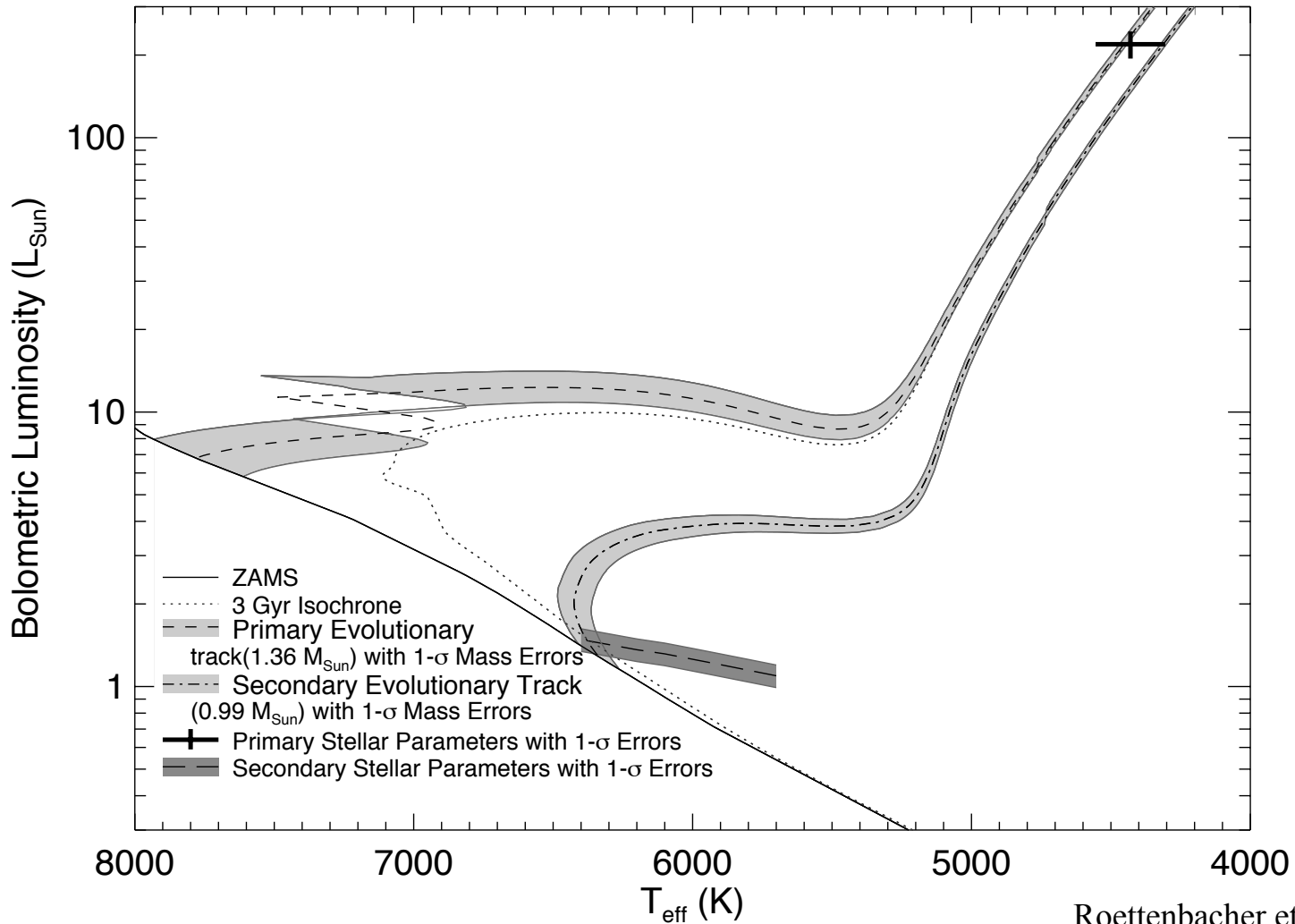
Radial Velocity Curve



Roettenbacher et al. in prep.

o Dra

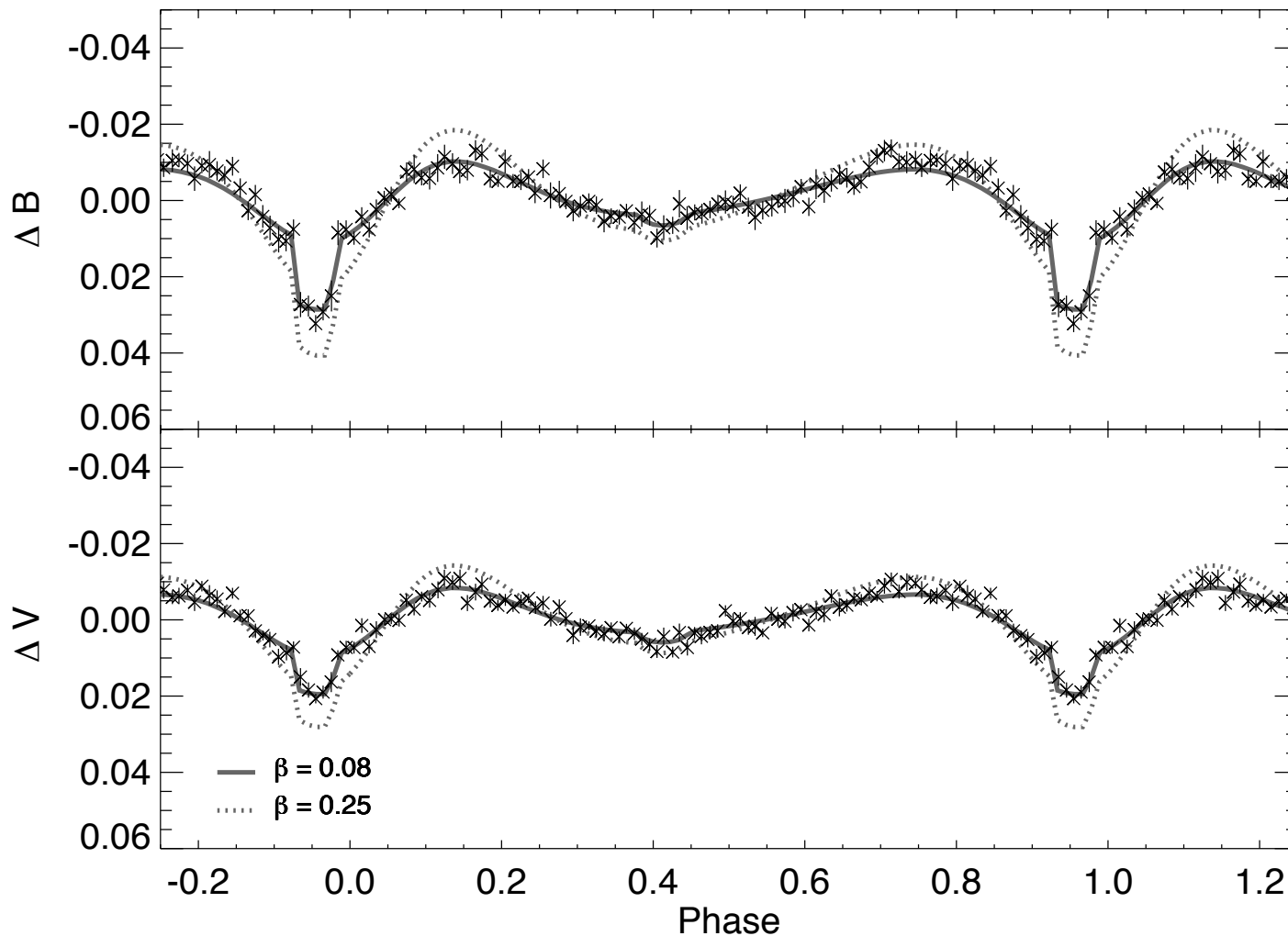
Mass and Evolution



Roettenbacher et al. in prep.

o Dra

Ellipsoidal Variations



Roettenbacher et al. in prep.



o Dra

- $t \sim 3 \pm 0.5$ Gyr
- $M_1 = 1.36 \pm 0.04 M_{\text{sun}}$
- $M_2 = 0.99 \pm 0.02 M_{\text{sun}}$
- $T_1 \sim 4430 \pm 130$ K
- $T_2 \sim 6000 +400/-300$ K
- $R_1 = 25.2 \pm 0.2 R_{\text{sun}}$
- $R_2 = 1.0 \pm 0.1 R_{\text{sun}}$
- Active primary?
 - Ellipsoidal variations
 - Eclipsing

Red Giant
Primary Star
 $R_1 = 25.2 \pm 0.2 R_{\text{sun}}$



370x fainter than primary



Main sequence
companion

σ Gem

- K1III primary
- $T_{\text{eff}} \sim 4530$ K
- $P_{\text{rot}} \sim P_{\text{orb}} \sim 19.6$ days
- Active primary
 - Active longitudes
 - Spot evolution
 - Differential rotation
- No direct detections of the companion star

Main-sequence
Companion

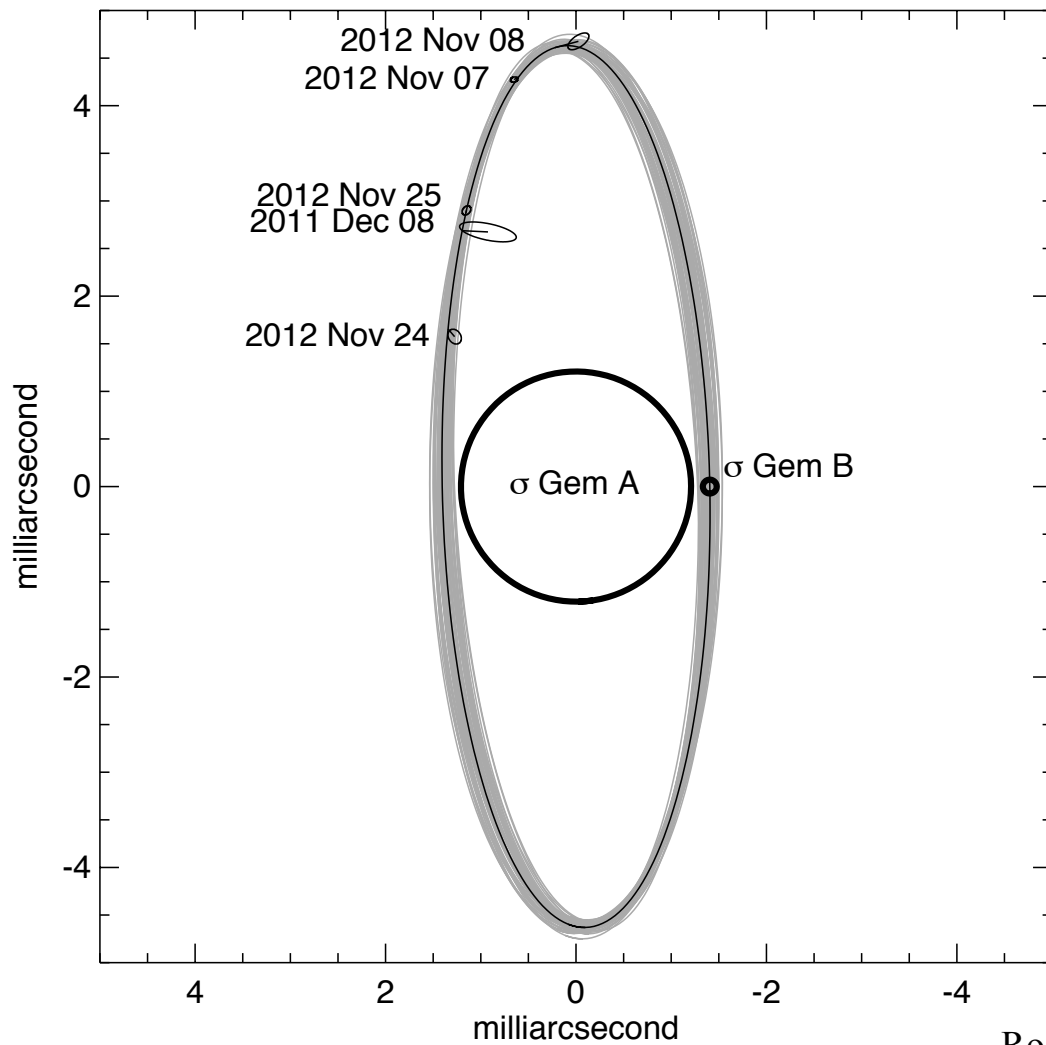
270x fainter than primary



Red Giant
Primary Star
 $R_1 = 10.1 \pm 0.2 R_{\text{sun}}$



σ Gem Orbit



Roettenbacher et al. submitted

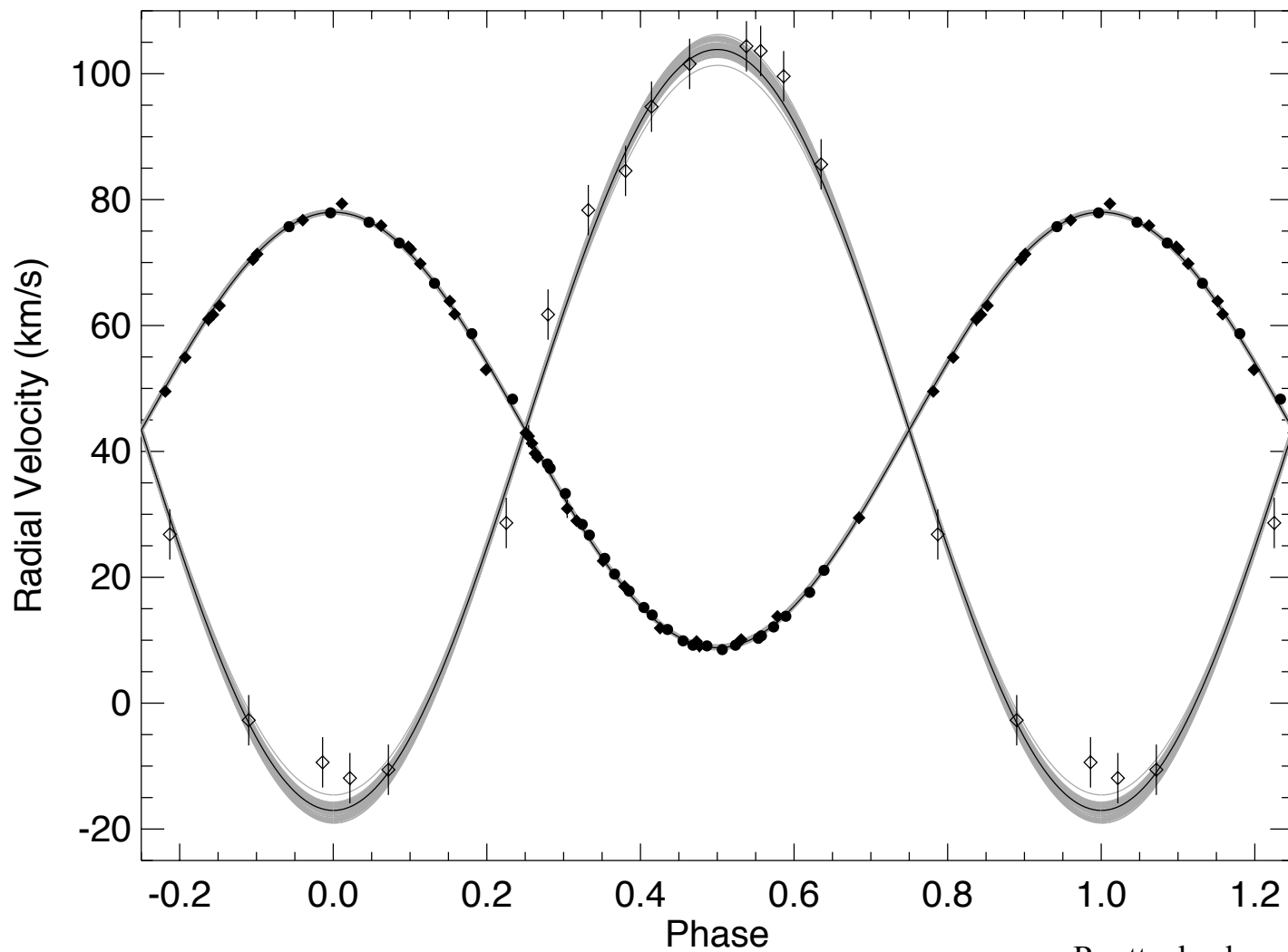


Observatoire de la COTE d'AZUR



σ Gem

Radial Velocity Curve

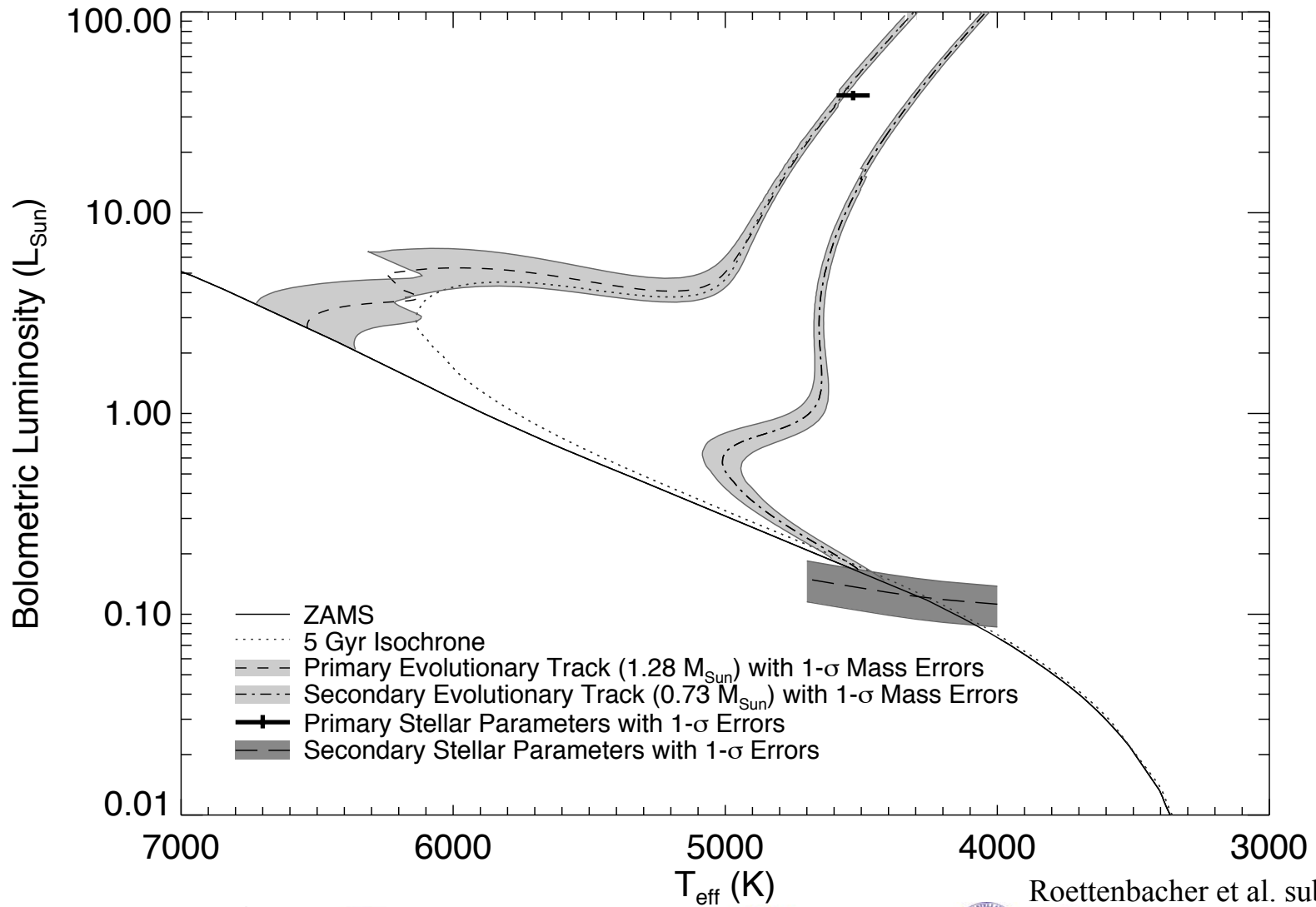


Roettenbacher et al. submitted



σ Gem

Mass and Evolution

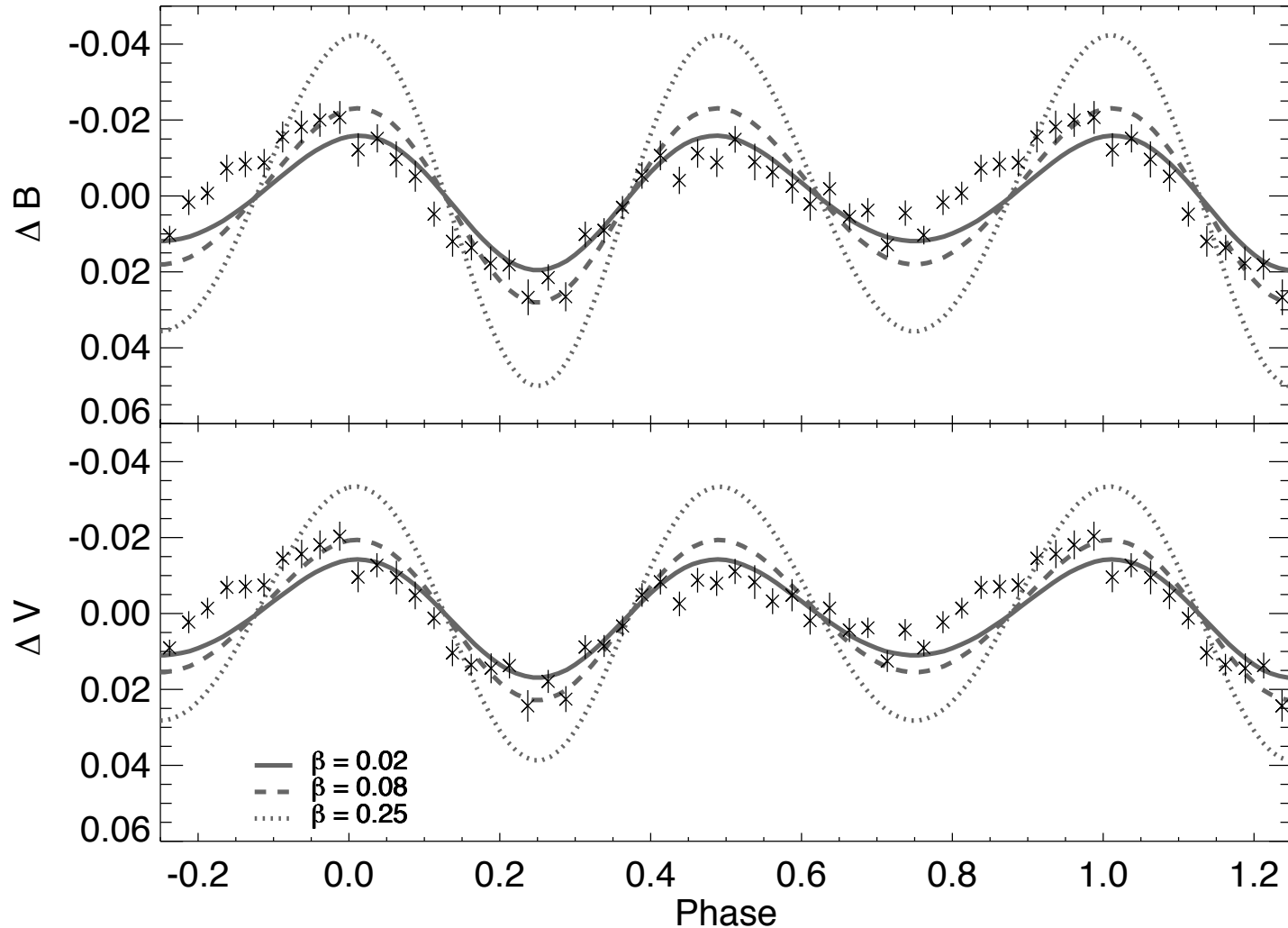


Roettenbacher et al. submitted



σ Gem

Ellipsoidal Variations



Roettenbacher et al. submitted



σ Gem

- $t \sim 5 \pm 1$ Gyr
- $M_1 = 1.28 \pm 0.07 M_{\text{sun}}$
- $M_2 = 0.73 \pm 0.02 M_{\text{sun}}$
- $T_1 \sim 4530 \pm 60$ K
- $T_2 \sim 4300$ K
- $R_1 = 10.1 \pm 0.2 R_{\text{sun}}$
- $R_2 \sim 0.7 R_{\text{sun}}$
- Active primary
 - Large starspots
 - Ellipsoidal variations

Main-sequence
Companion

270x fainter than primary



Red Giant
Primary Star
 $R_1 = 10.1 \pm 0.2 R_{\text{sun}}$



RS CVn Imaging

σ Gem

- Interferometry
 - MIRC (2011, 2012)
- Spectroscopy
 - VLT (2011, 2012)
 - STELLA (2011)
 - NOT (2012)
- Photometry
 - AST (2011, 2012)
 - CTIO (2012)

ζ And

- Interferometry
 - MIRC (2011, 2013)
- Spectroscopy
 - STELLA (2011)
 - VLT (2013)
 - Belgian Mercator (2013)
- Photometry
 - AST (2011, 2013)
 - CTIO (2013)



Preliminary σ Gem Imaging Results



Preliminary σ Gem SIMOI Results

Phase = 0.25

Phase = 0.25



Summary and Future Work

- CHARA/MIRC detected faint main sequence companions
- RS CVns present ellipsoidal variations
- Obtained visual orbit of σ Gem and o Dra
- Image spots with interferometry, spectroscopy, and photometry (σ Gem and ζ And)