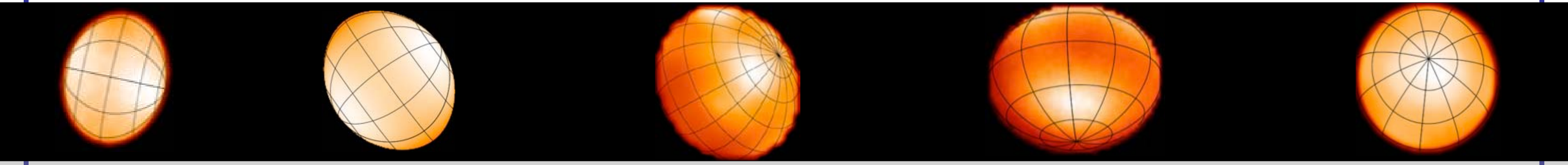
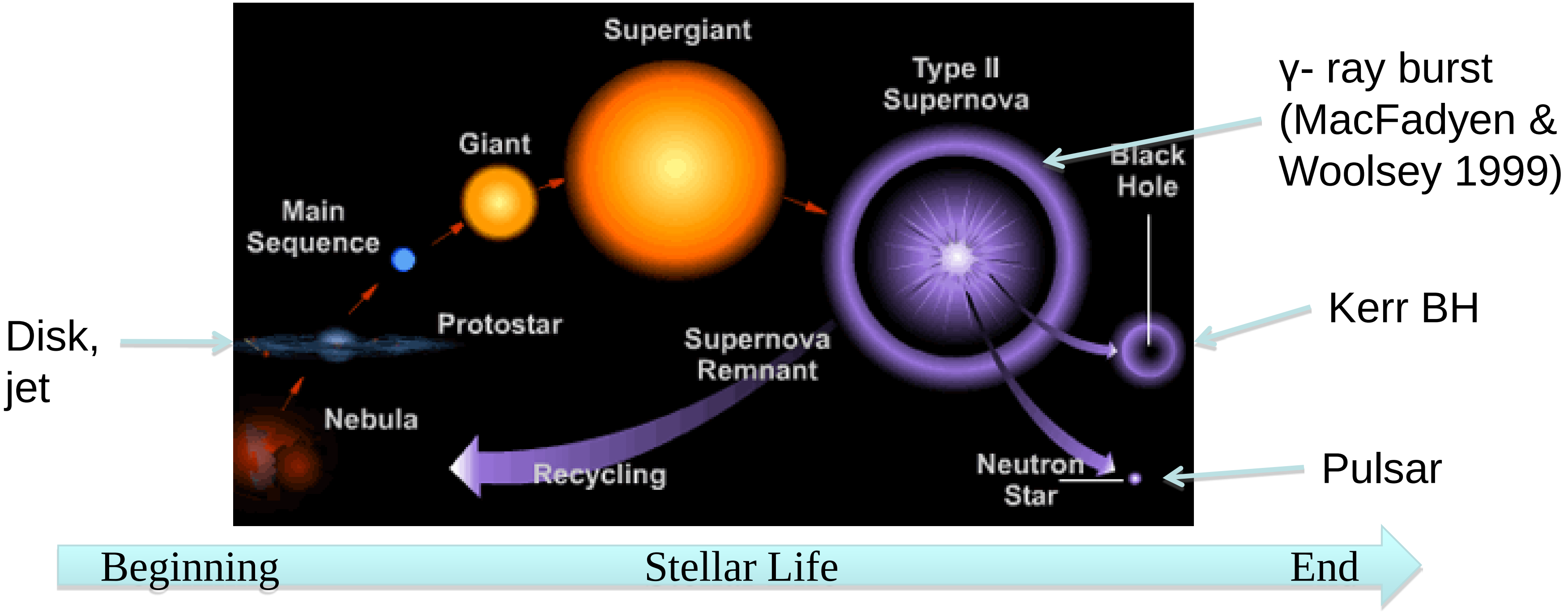
Multi-wavelength CHARA observations of rapid rotators

--- Regulus with non-standard gravity darkening coefficient



Xiao Che, John Monnier

Stellar rotation



γ- ray burst (MacFadyen & Woolsey 1999)

Disk, jet

Kerr BH

Pulsar

Beginning Stellar Life End

- 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 vsini > 100km/s (Abt 1995, 2002)

- Stellar rotation effects (Maeder & Meynet 2000)
  - Distort stellar photosphere shape
    - Maximum R_{equ} / R_{pole} could be 1.5 for solid-body rotation
  - Temperature varies across the stellar surface due to gravity darkening
    - $T_{eff} \propto g^{\beta}$

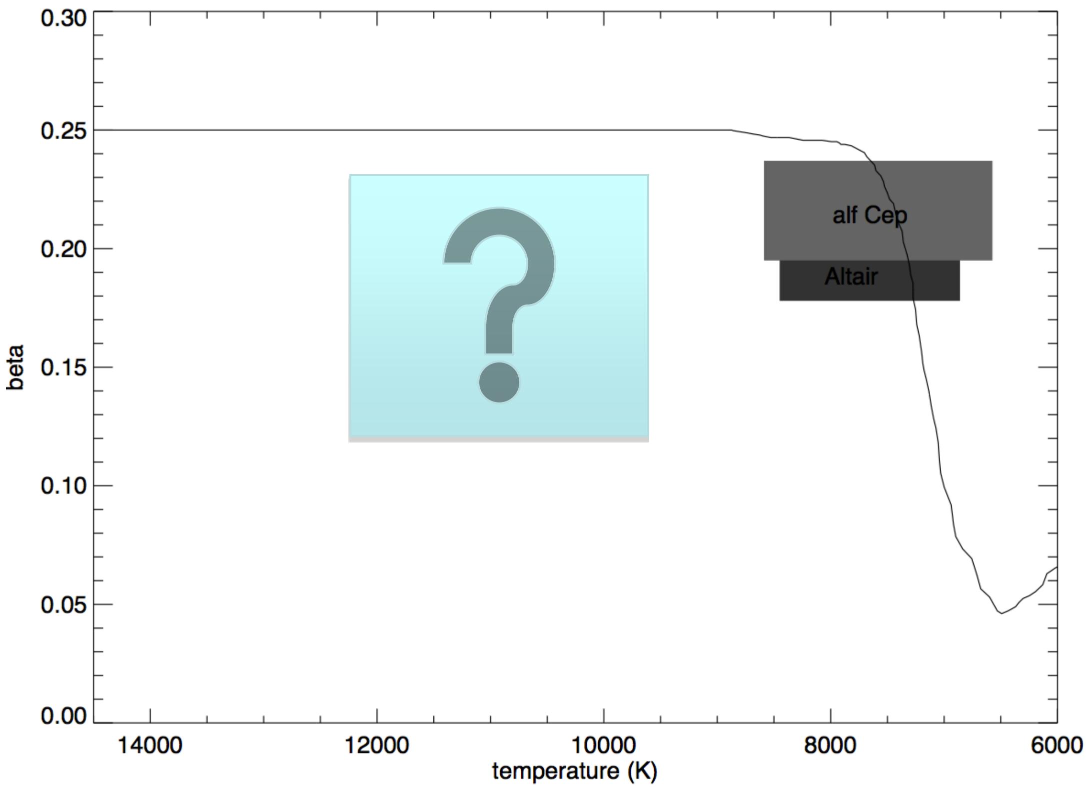
      $\beta = 0.25$ *radiative envelopes (Von Zeipel 1924)*

      $\beta = 0.08$ *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

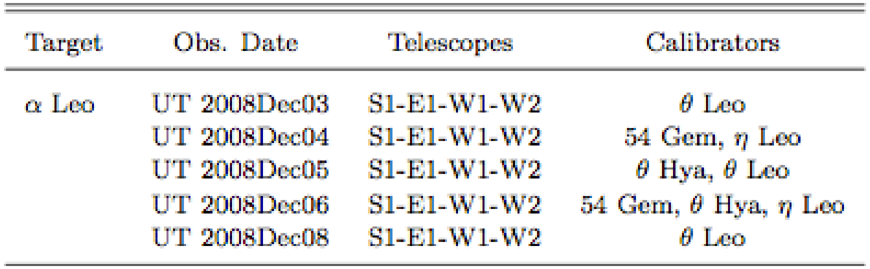


Monnier et al. 2007
Zhao et al. 2009
Claret et al. 2000

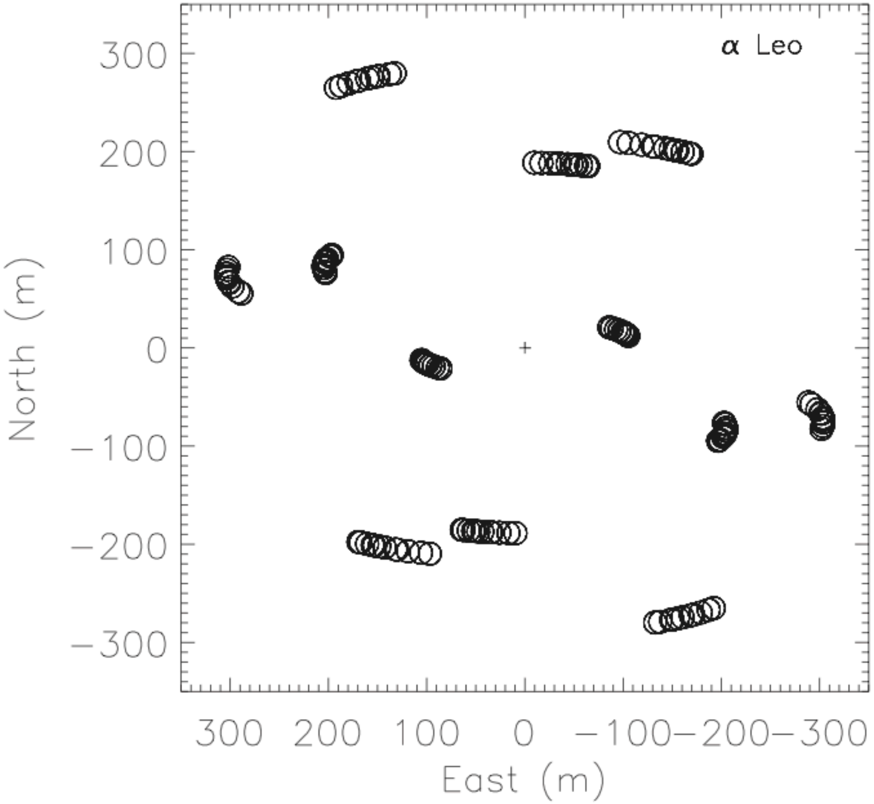
O B A F G K M

MIRC observation on Regulus

5 nights of MIRC observation on Regulus with CHARA outer array



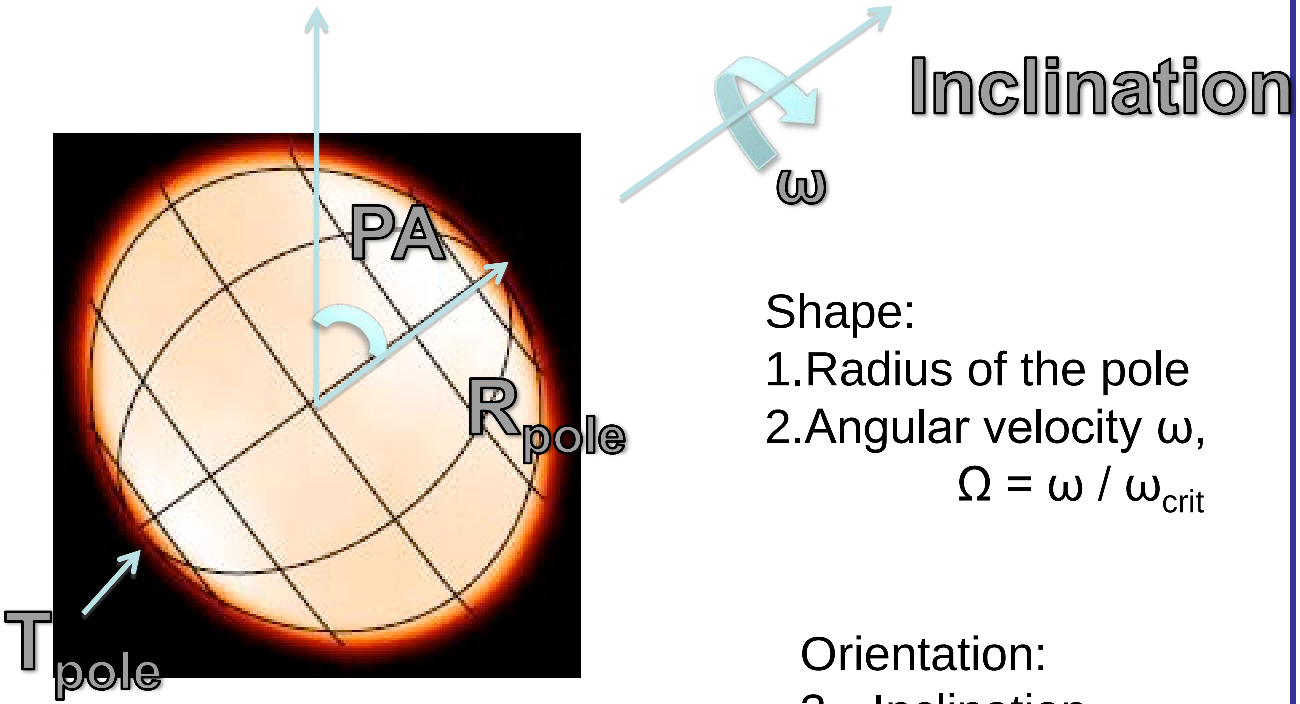
Target	Obs. Date	Telescopes	Calibrators
α Leo	UT 2008Dec03	S1-E1-W1-W2	θ Leo
	UT 2008Dec04	S1-E1-W1-W2	54 Gem, η Leo
	UT 2008Dec05	S1-E1-W1-W2	θ Hya, θ Leo
	UT 2008Dec06	S1-E1-W1-W2	54 Gem, θ Hya, η Leo
	UT 2008Dec08	S1-E1-W1-W2	θ Leo



2-D stellar surface model

Temperature:
5.T at the pole
6.Gravity darkening coefficient β

$$T/T_{pole} = (g/g_{pole})^{\beta}$$



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

Orientation:
3. Inclination
4. Position angle

Fully radiative envelope: β = 0.25 (von Zeipel 1924)
Fully convective envelope: β = 0.08 (Lucy 1967)

Gravity Darkening Coeffiecient: Regulus

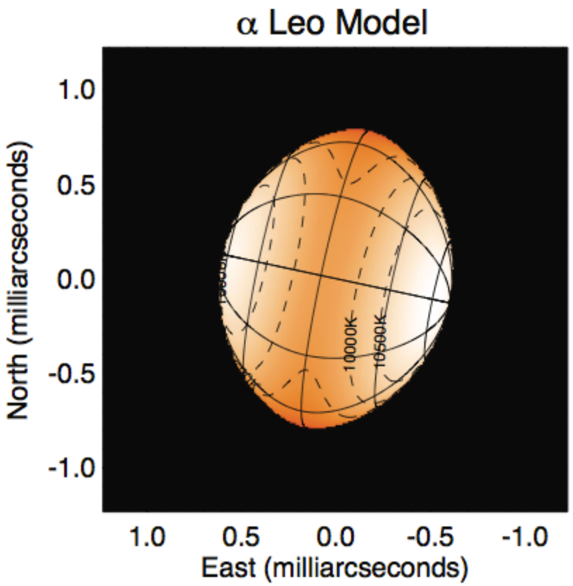
Fraction of critical velocity $\omega \approx 0.96$	
T_{pole} = 14520 K	T_{equ} = 11010

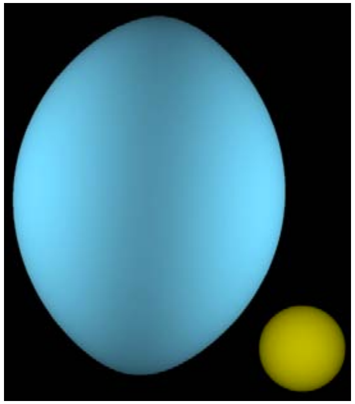
T > 11000K

Fully radiative envelope

von Zeipel's law

β = 0.25 ?





McAlister et al. 2005

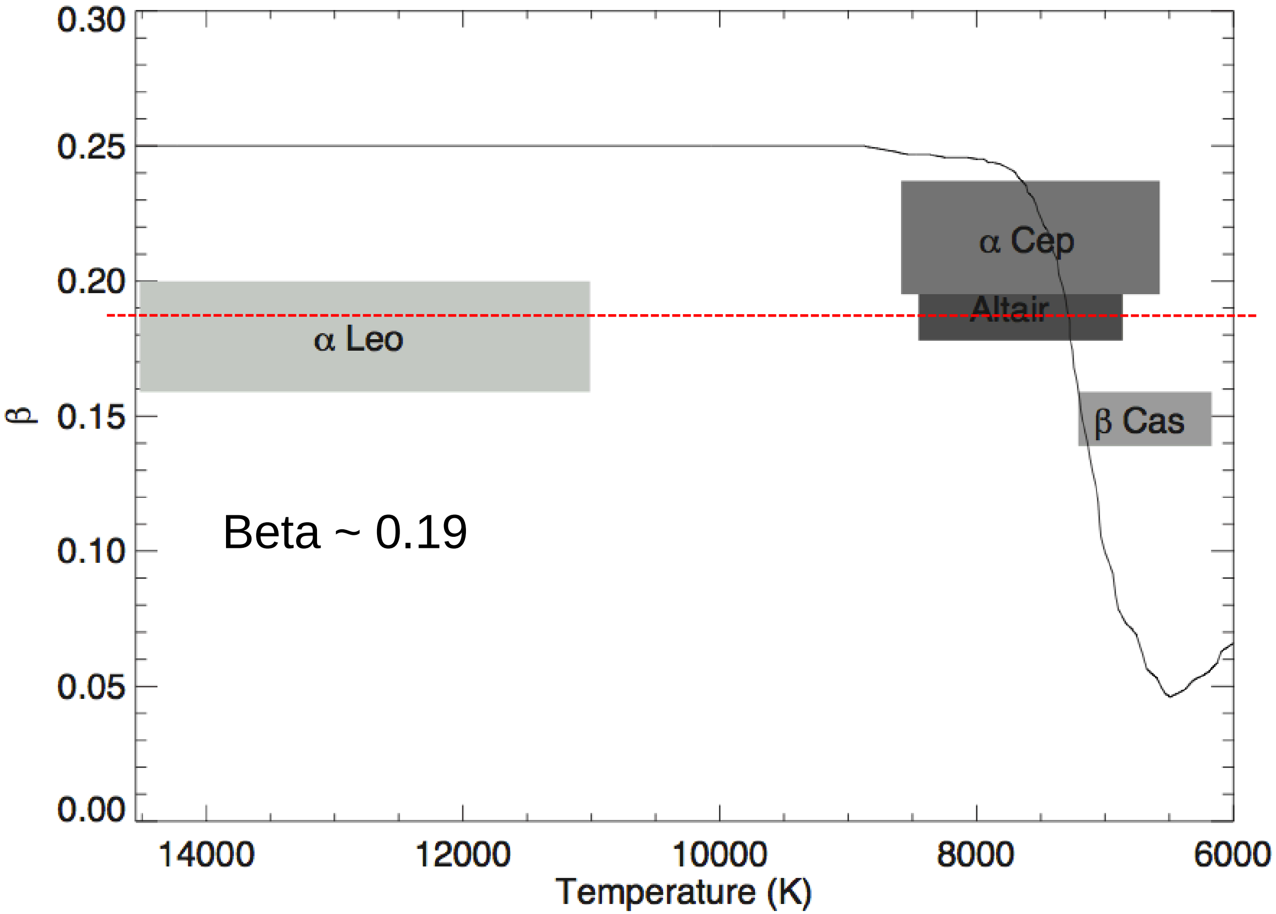
Gravity Darkening Coeffiecient: Regulus

T > 11000K

Fully radiative envelope

von Zeipel’s law

β = 0.25 ?

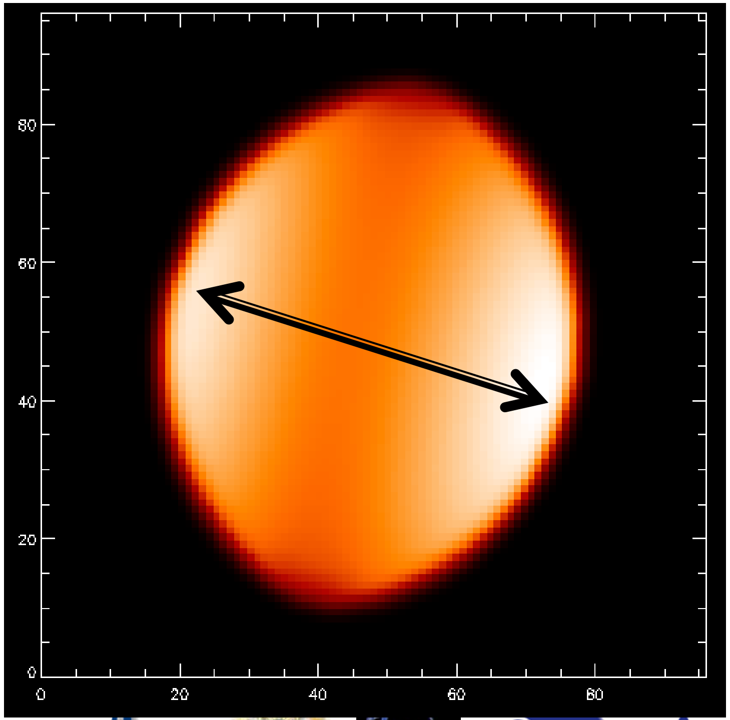


von Zeipel’s law fails even at hot stars. Fully radiative envelope is impossible for solid-body rotation (Tassoul 2000)

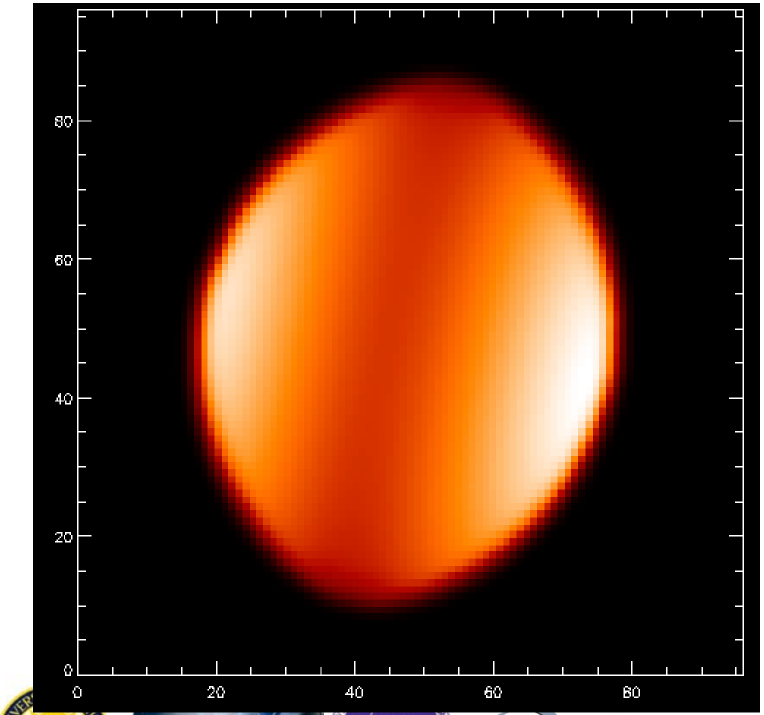
PAVO Observation on Rapid rotator

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

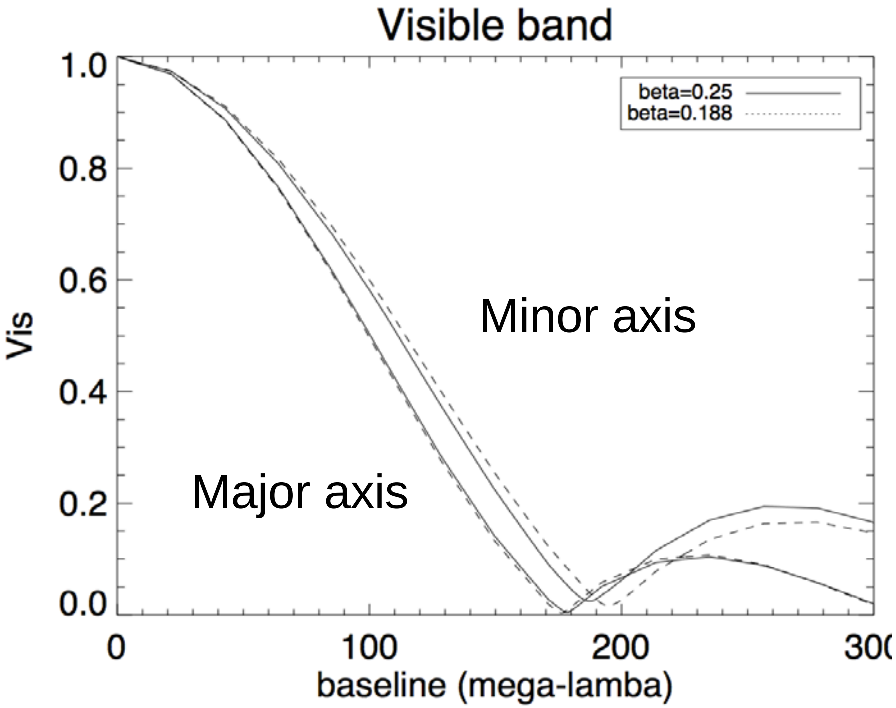
Beta = 0.188

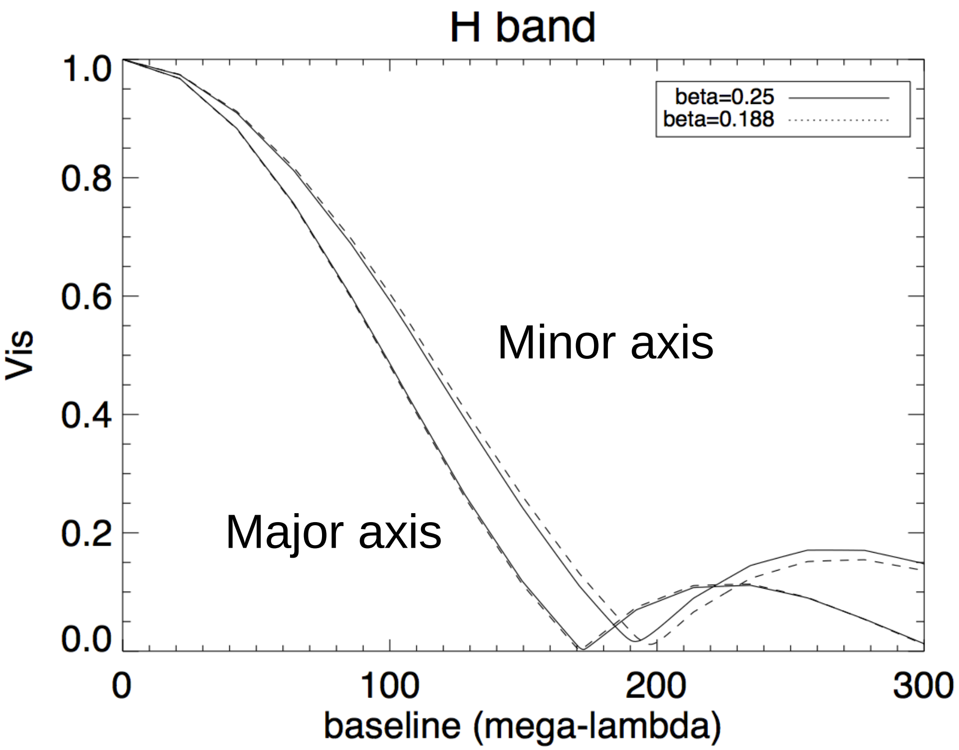


Beta = 0.25



PAVO Observation on Rapid rotator

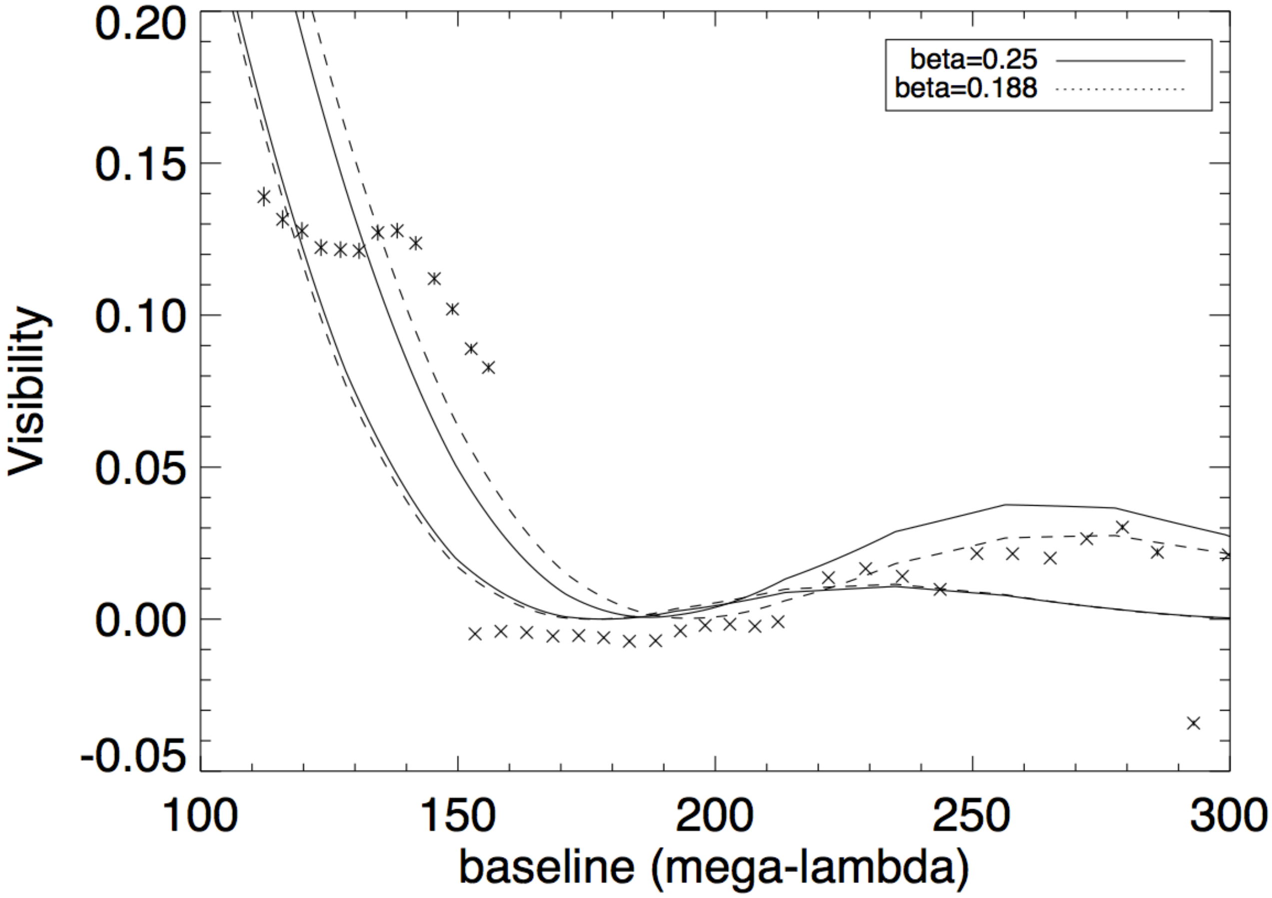




PAVO data is slightly better to distinguish models of different beta.

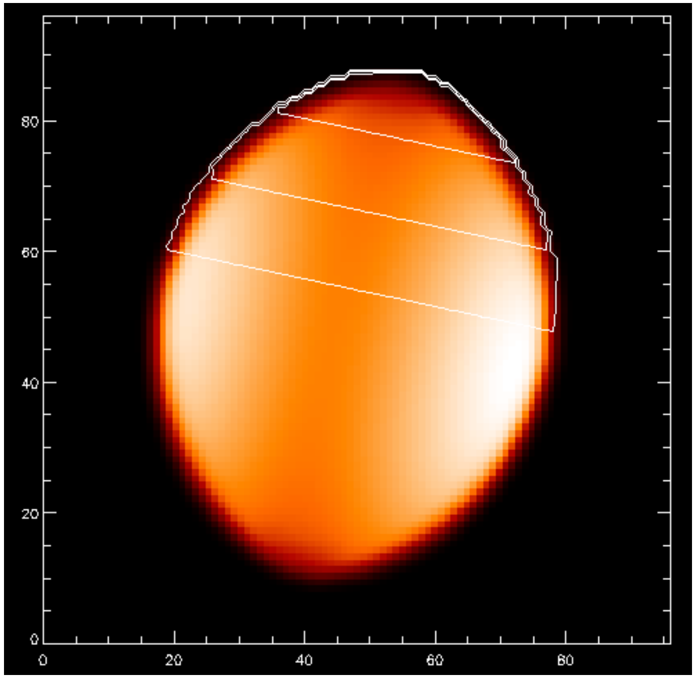
PAVO Observation on Rapid rotator

Observed with
W1W2S2

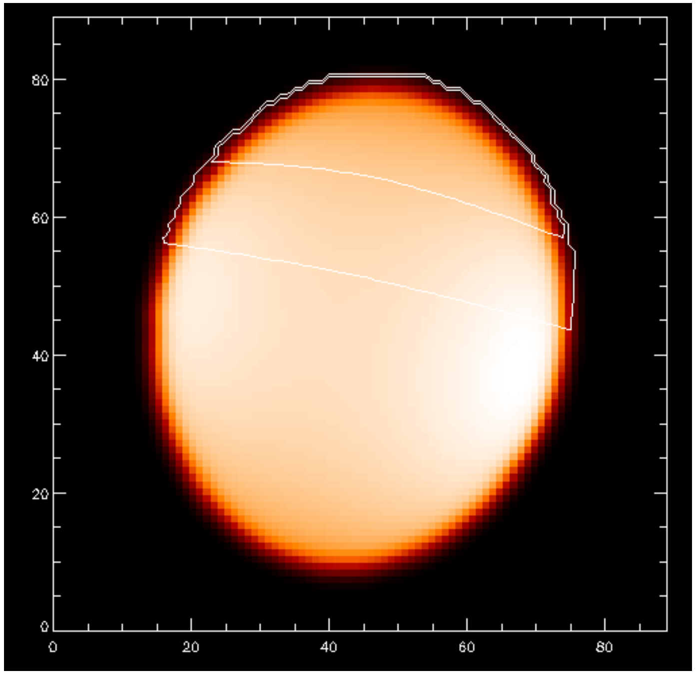


Differential rotation

Intensity profile
+ vsini contour

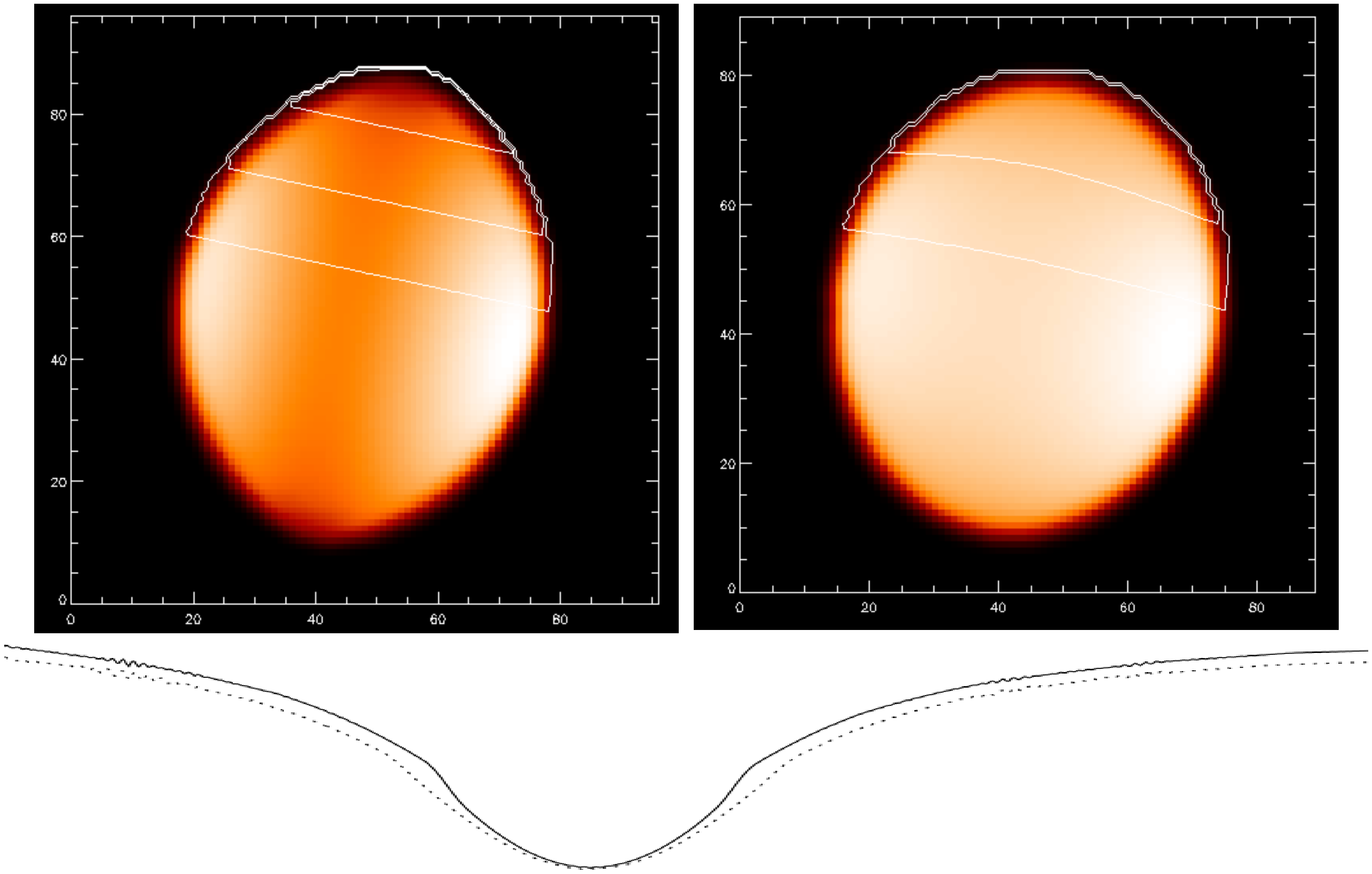


Solid body rotation, w=0.96



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

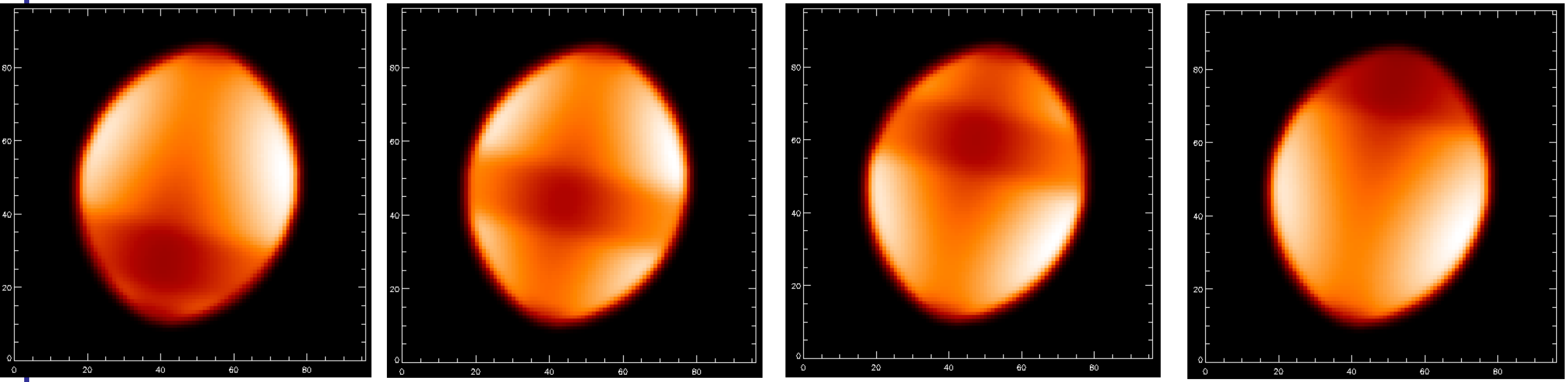
Differential rotation

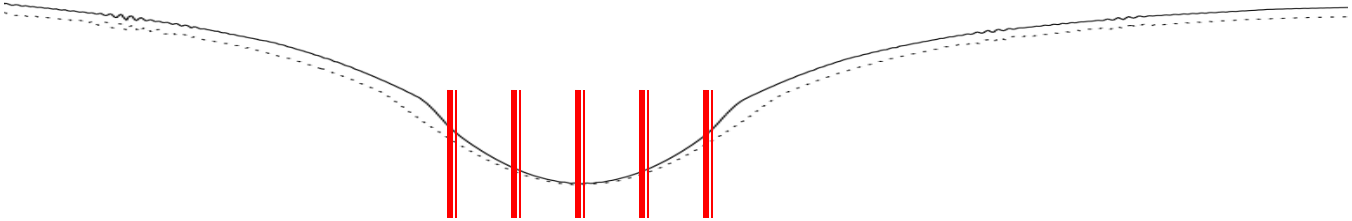


Intensity profile
+ vsini contour

Stellar images across a line

H-alpha line

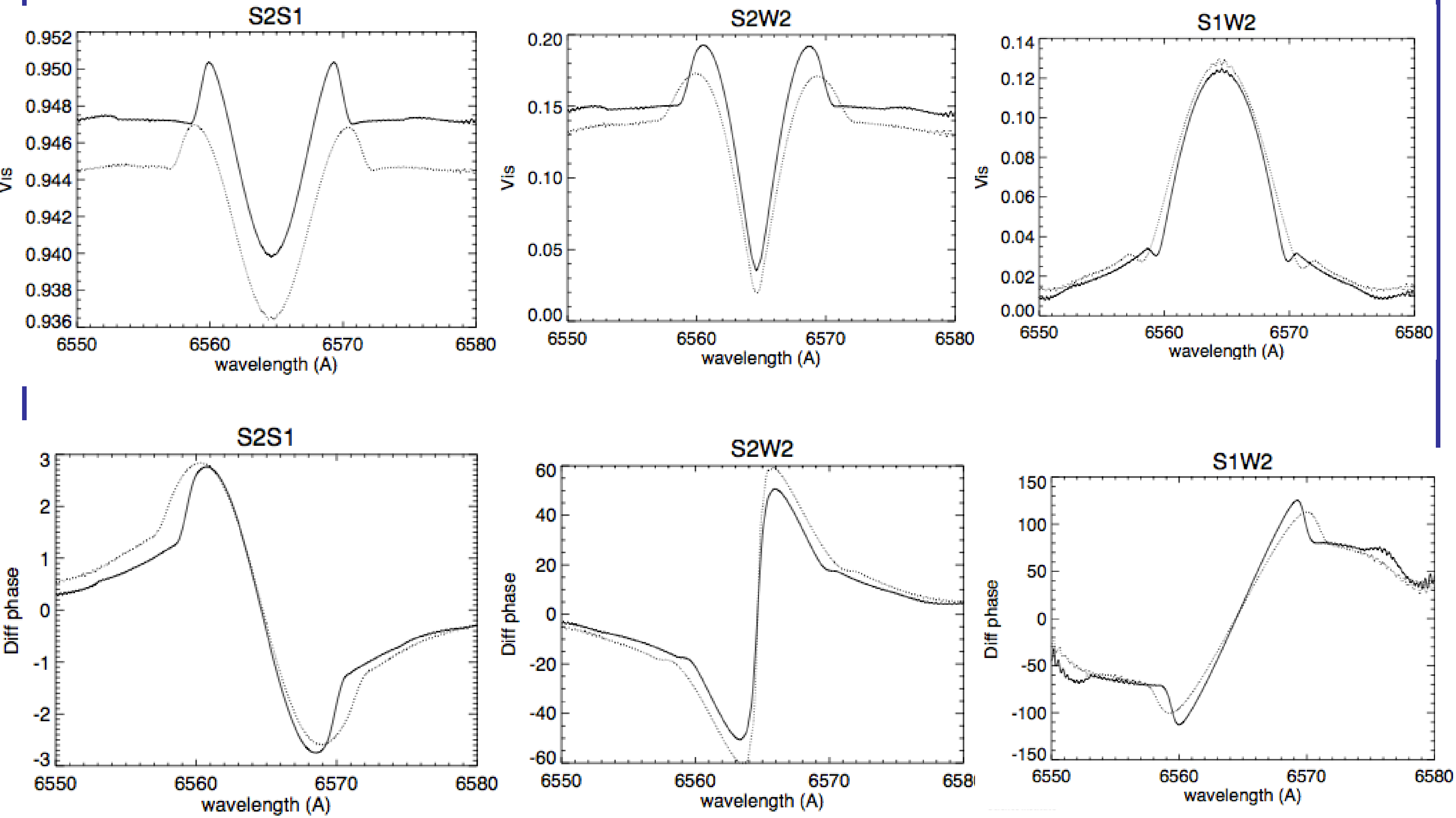




VEGA observation: differential rotation vs. solid-body rotation

Visibility and differential phase across Hα line

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



VEGA: differential rotation

H-alpha: pressure broadening dominated

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