# Differential rotation in two RS CVn-systems: σ Gem and ζ And

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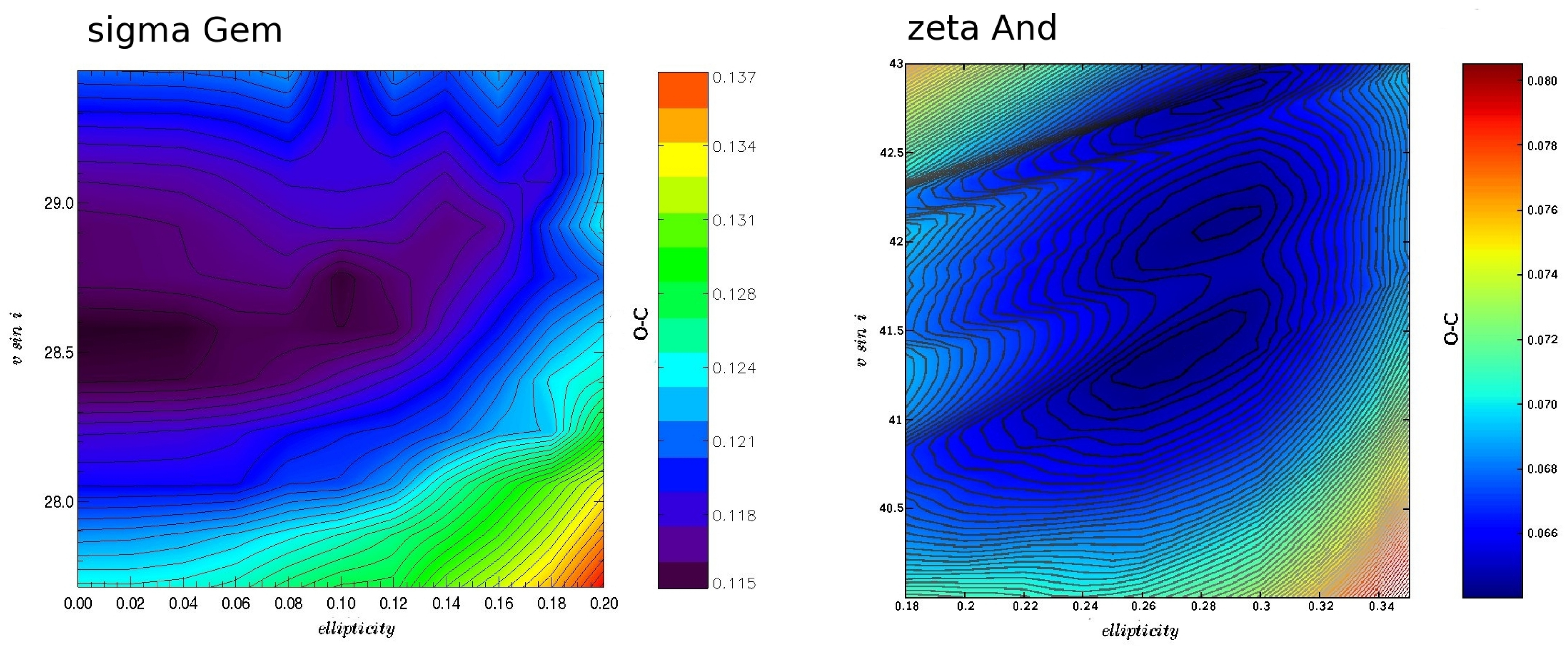
**The differentially rotating convective envelope is an indispensable element of the magnetic dynamo working in RS CVn-systems. Tidal coupling is responsible for maintaining fast rotation, and so the observed high level of magnetic activity. In this work we compare some physical properties of two well known RS CVn-type binaries, the long-period system σ Gem and the ellipsoidal variable ζ And, to understand how differential rotation could be affected by tidal forces in such close binaries.**

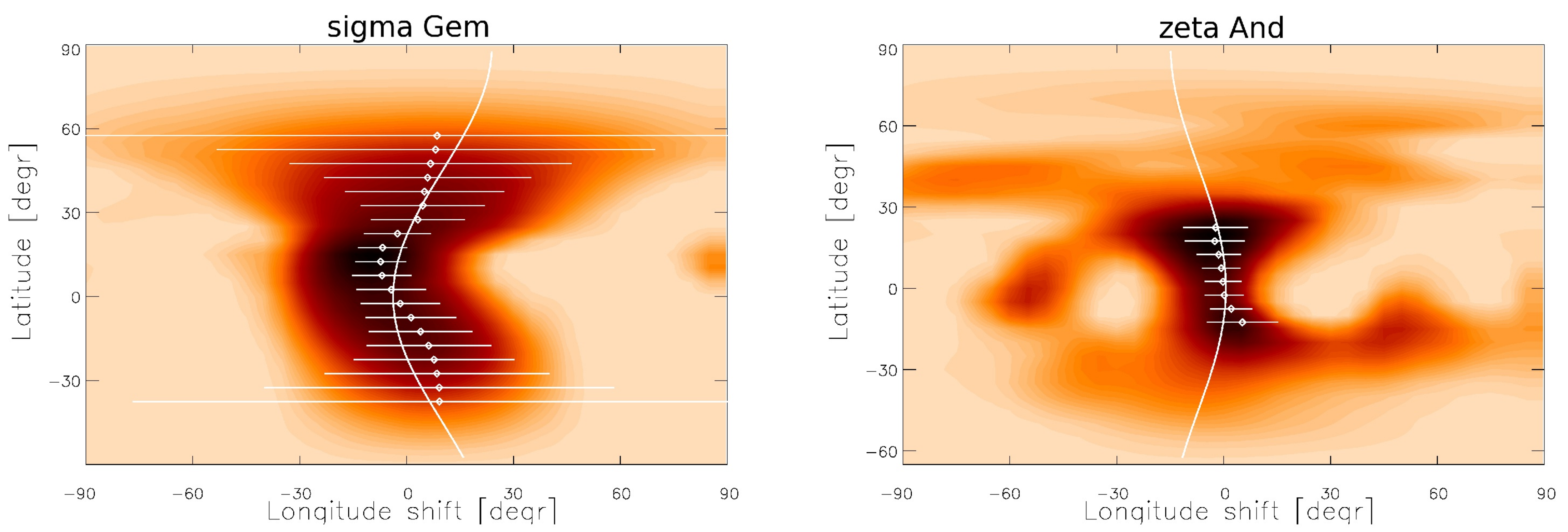
## Measuring gravitational distortion

From our extended DI code TempMap$_\varepsilon$ we determine the gravitational distortion (see Kővári et al. 2007a). The distortion is parameterized by $\varepsilon=(1-(a/b)^2)^{0.5}$, where $a$ and $b$ are the long and short radii, respectively, of a rotational ellipsoid, that is elongated towards the secondary star. Scanning through a meaningful part of the ($\varepsilon-v\sin i$) parameter plane, while all other parameters are held constant in the Doppler imaging process, yields the likely best estimate when the $\chi^2$ of the line-profile fits reaches a minimum. This way for σ Gem we get $\varepsilon<0.12$, while in the case of ζ And the O-C plot suggests $\varepsilon=0.27\pm0.02$.




## Measuring surface differential rotation by the means of time-series Doppler Imaging

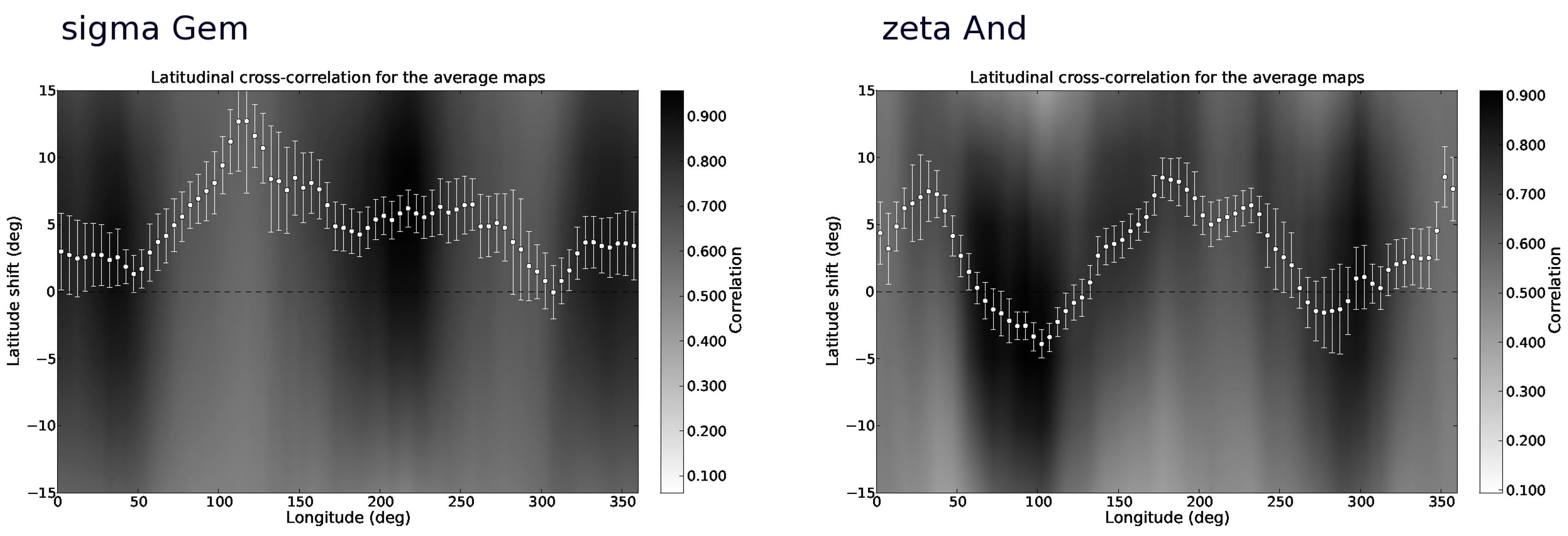
We employ the method called ACCORD (acronym from 'Average Cross-CORrelation of consecutive Doppler images') which is based on averaging cross-correlation function (ccf) maps of subsequent Doppler images in a way to enhance the DR pattern in the ccf maps, while suppressing the unwanted effect of stochastic spot changes (see Kővári et al. 2004, 2007a, 2007b, 2009 for details). Our time-series data obtained during a 70-night long observing run at NSO in 1996/97. From that we reconstruct 34 and 36 time-series Doppler images for σ Gem and for ζ And, respectively.



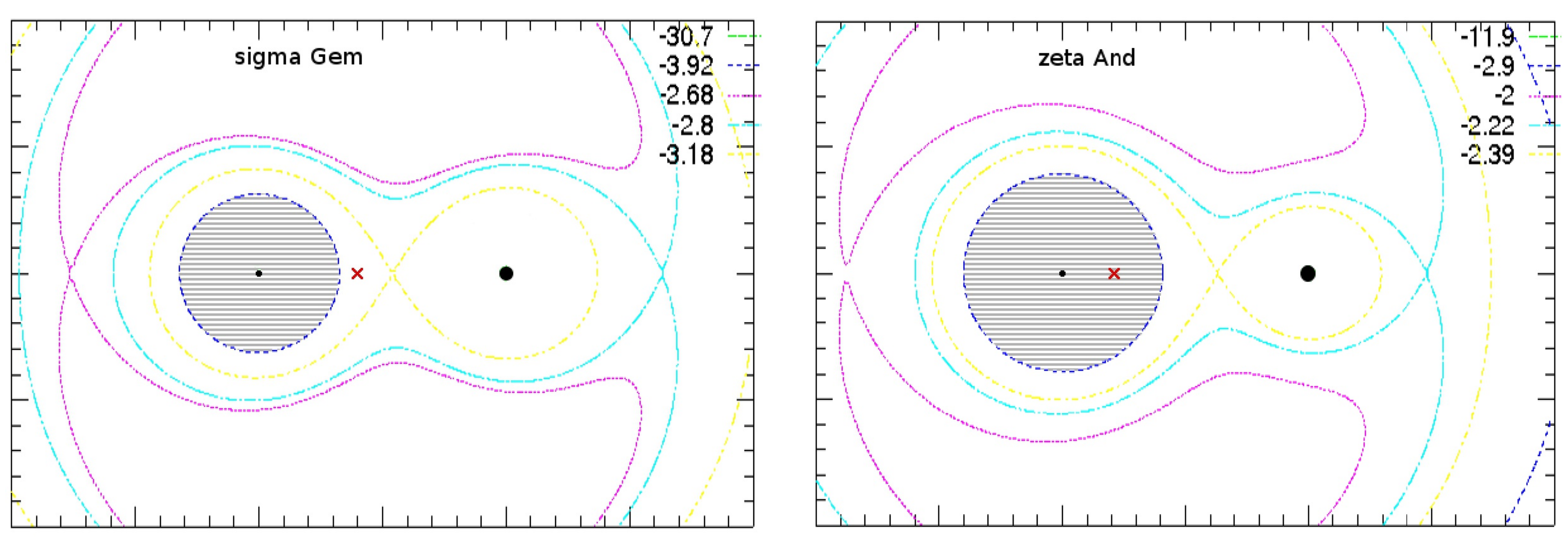

Applying ACCORD for σ Gem yields equatorial deceleration, i.e. anti-solar-type DR with an average surface shear of $\alpha = -0.07\pm0.026$. In the case of ζ And, we get solar-type DR with a surface shear of $\alpha = +0.05\pm0.02$ (Kővári et al. 2007a). This value is consistent with our new result of $\alpha \approx +0.053$ derived from new ζ And data (Kővári et al. in prep.).

## Meridional flows

Meridional motion of surface features can also be quantified by ACCORD (for a detailed description see Kővári et al 2007a,b). For σ Gem we find a joint poleward migration trend of 4.0±0.2° per rotation cycle. This result is consistent with the theoretical work by Kitchatinov & Rüdiger (2004), who predicted a meridional flow of at least this strength for a star performing anti-solar-type DR. As against, however, on ζ And, which performs solar-type DR, no sign of such a strong joint motion is seen.




## Distortion vs. differential rotation




The center of gravity (red cross) is outside the limb of the giant component in σ Gem, but lies well within the giant star in ζ And. This difference may reshape the DR inside the convective bulk, which can explain the observed differences. Using Scharlemann's (1981, 1982) theoretical calculations, the corotating latitude (i.e., the latitude of the differentially rotating component that rotates synchronously with the system) $\beta_{cor}$ is ≈20° for σ Gem, which is near the value of 22° derived from ACCORD. However, the more distorted ζ And with synchronized equatorial belt ($\beta_{cor}$≈10° from ACCORD) performs a different subsurface scenario. Observations showed the existence of spots concentrating at quadrature positions in ζ And (e.g. Kővári et al. 2007a, Korhonen et al. 2010). Holzwarth & Schüssler (2000, 2002) showed that the tidal forces and the distortion of the active component in an RS CVn-type binary can explain the emergence of magnetic flux at preferred longitudes. Likewise, the deformation could also account for the disparate DR laws obtained for the two stars.

## References

Holzwarth, V., & Schüssler, M. 2000, Astron. Nachr. 321, 175
Holzwarth, V., & Schüssler, M. 2002, Astron. Nachr. 323, 399
Kitchatinov, L.L., & Rüdiger, G. 2004, Astron. Nachr. 325, 496
Korhonen, H., Wittkowski, M., Kővári, Zs., et al. 2010, A&A 515, A14
Kővári, Zs., Strassmeier, K.G., Granzer, T., et al. 2004, A&A 417, 1047
Kővári, Zs., Bartus, J., Strassmeier, K.G., et al. 2007a, A&A 463, 1071
Kővári, Zs., Bartus, J., Strassmeier, K.G., et al. 2007b, A&A 474, 165
Kővári, Zs., Washüttl, A., Foing, B.H., et al. 2009, AIP Conf. Ser., Vol 1094, p676
Scharlemann, E.T. 1981, ApJ 246, 292
Scharlemann, E.T. 1982, ApJ 253, 298

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