Stellar magnetic activity, Spring 2024
Models for exercises I

1. Using the formula suggested by Noyes et al. (1984; SMA Lecture 2, slide 6), estimate the convective turnover time for the Sun and AU Mic. Are these estimates resonable?

   The formula suggested by Noyes et al. (1984) to estimate the convective turnover time uses the parameter $x = 1 - (B - V)$:

   $$\log \tau_c = 1.362 - 0.166x + 0.025X^2 - 5.323x^3, x > 0$$
   $$\log \tau_c = 1.362 - 0.14x, x < 0$$

   For the Sun $(B - V) \approx 0.656$ and for AU Mic $(B - V) \approx 10.05 - 8.627 = 1.423$ (sources: Gray 1992; Simbad).

   For the Sun ($x = 1 - 0.656 = 0.344 > 0$) we get

   $$\log \tau_c = 1.362 - 0.166 \cdot 0.344 + 0.025 \cdot 0.344^2 - 5.323 \cdot 0.344^3$$
   $$\Rightarrow \tau_c \approx \underline{12.4\text{d}}.$$

   For Au Mic we get ($x = 1 - 1.423 = -0.423 > 0$) we get

   $$\log \tau_c = 1.362 - 0.14 \cdot (-0.423)$$
   $$\Rightarrow \tau_c \approx \underline{26.4\text{d}}.$$

   Both estimates are reasonable. For the Sun $\tau_c \approx 25$ d at the bottom and $\tau_c < 1$d at the top of the convection zone. The value used for calculating the Rossby number should be midway between these extremes. AU Mic has a spectral class of M1V $\Rightarrow$ τ_c should be larger than the solar value.

2. Estimate how many stars belong to these classes of magnetically active stars:

   - RS CVn -stars
   - BY Dra -stars
   - FK Com-stars

   Searching Simbad gives:

   - RS CVn -stars (otype='RS*'): <u>2179</u>
   - BY Dra -stars (otype='BY*'): <u>1161</u>

   One can also use estimates by Chen et al. (2020), which give considerably higher numbers of candidates.

   For FK Com -stars there is no 'otype' specified in Simbad. But searching literature reveals that there are only three clear cases: FK Comae, V1794 Cyg and YY Men. In addition, there are ~ 10 known candidates for this class.

   The reason for the low number of FK Com -type stars is, that they (probably) represent a transient state after the merger of W UMa binaries. BY Dra -type stars are young late-type stars and therefore much more abundant. RS CVn stars are close binaries, with an evolved late-type star as the primary component. The close binary causes synchronized rotation, so magnetic breaking is insufficient. Many of them are subgiants or giants and thus have absolute magnitudes considerably higher than their main sequence progenitors, so they are visible from larger distances. In reality there should be more BY Dra -type than RS CVn -type stars. But because the latter are in general brighter, there are more of these in the Simbad-database.

3. Does the Sun have persistent active longitudes?

   Check the articles listed below:
   - Berdyugina & Usoskin, 2003, A&A 405, 1121
   - Pelt et al., 2005, A&A 429, 1093

   What is the major reason complicating this question and why do you think they have obtained different results?

   The solar surface differential rotation is the main complicating factor in this analysis, as spot groups on different latitudes will rotate with different angular velocities.

   Berdyugina & Usoskin (2003; BD) report a century persistence of two active longitudes on the Sun. The analysis was based on daily data on sunspot group locations and areas covering 11 full solar cycles. The methods applied to the Sun was similar to that used for active stars, but took into account differential rotation.

   Pelt et al. (2004; PTB) applied the (assumed) procedure by BD on randomly generated data. By assuming "somewhat" persistent active regions, they were able to simulate a similar bimodal distribution as presented by BD. They reported three reasons for the bimodal distribution:

   - The phase jumps introduced in the analysis of BD improving the continuity of the active region migration path.
   - The requirement of a minimal distance in phase $\Delta\phi$ to mimicing stellar ligh-curves.
   - The fact that active regions are persistant over a times exceeding the Carrington rotation period.

   However, PTB conclude that their "simulation analysis does not rule out that in principle there can be certain persistent phenomena in sunspot longitude distributions". The reason why BD and PTB arrive at different interpretations would be disagreement between what constitutes a statistically significant result.