Modelling Brightness Variability of Sun-Like Stars

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Cool Stars 20

Fundamental Properties of Cool Stars

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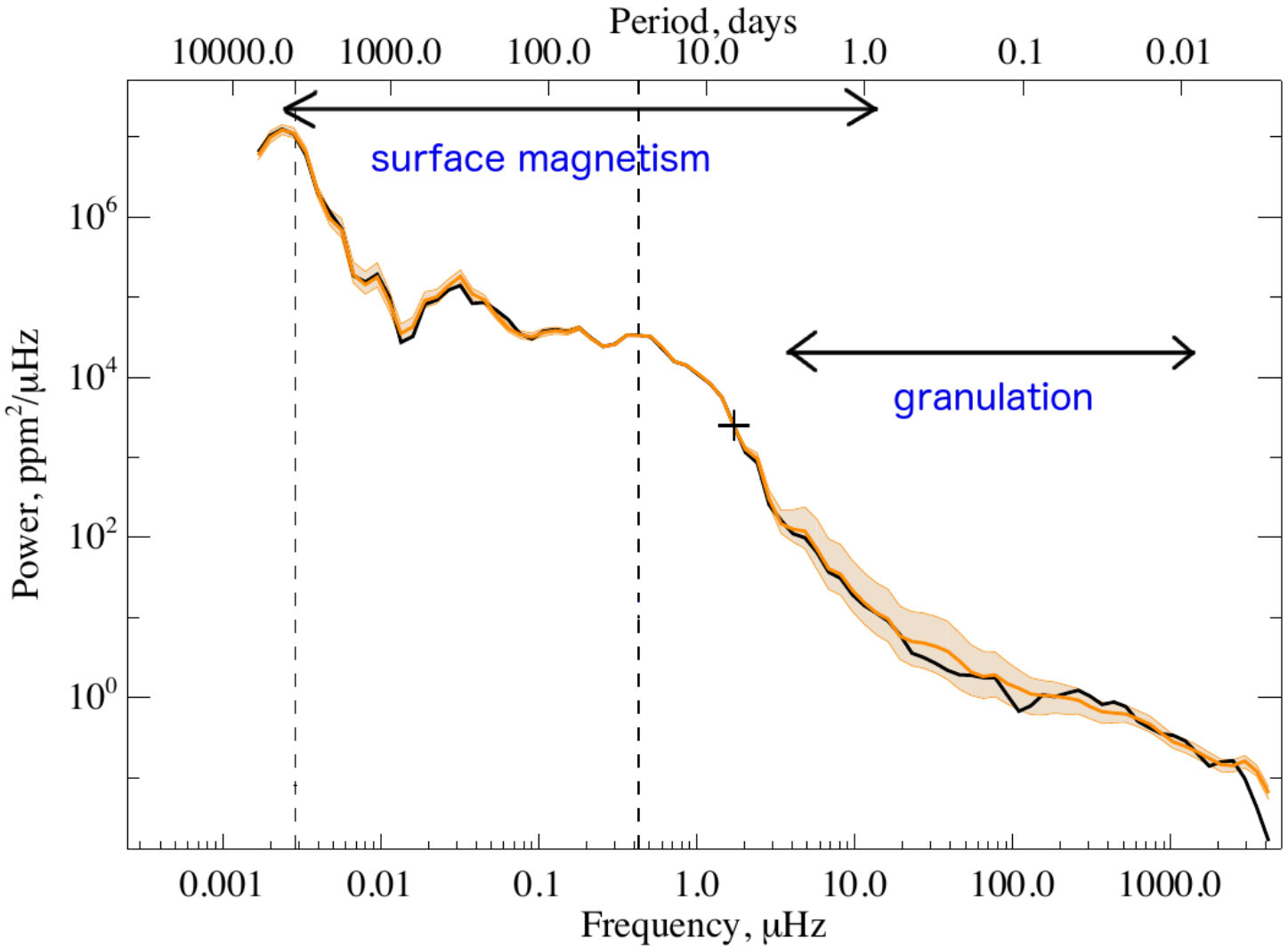
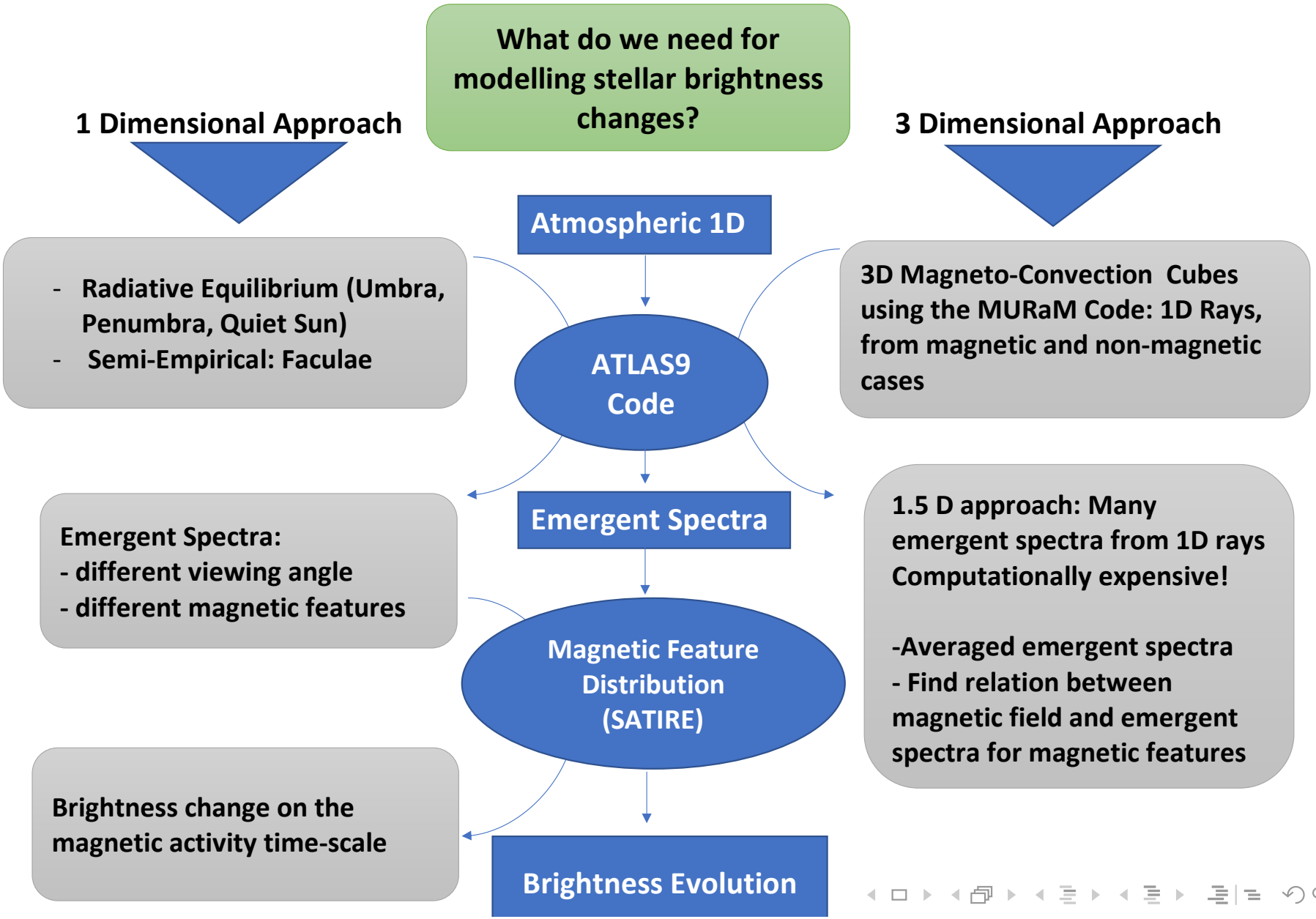
- Time-scales $<$ a day: convection and oscillations [Seleznyov et al. 2011]
- Time-scales $>$ a day: caused by surface magnetic fields [Ermolli et al. 2013, Solanki et al. 2013]

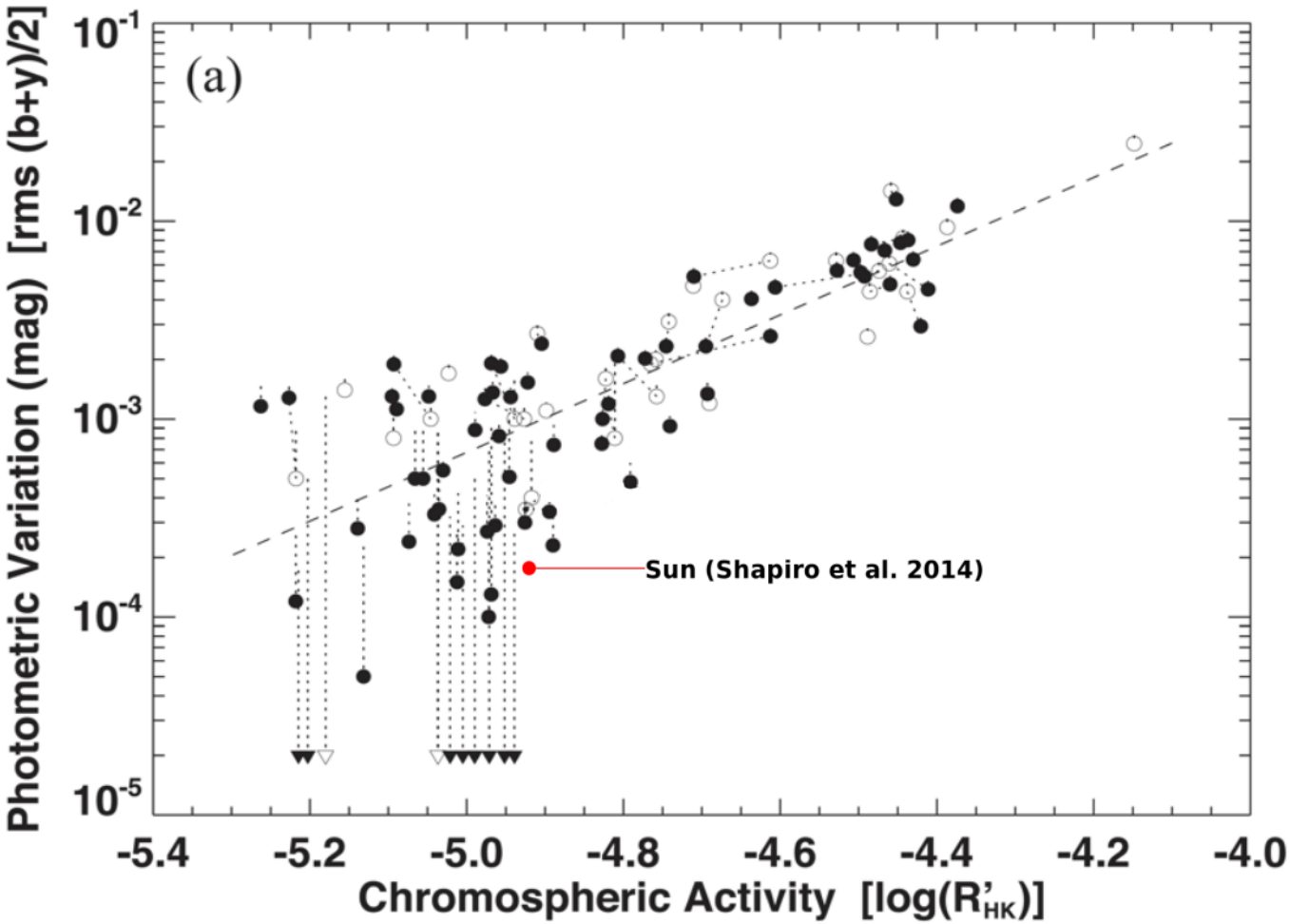


How to Model Stellar Brightness Variability



Observed Long-Term Brightness Variations of Sun-like Stars

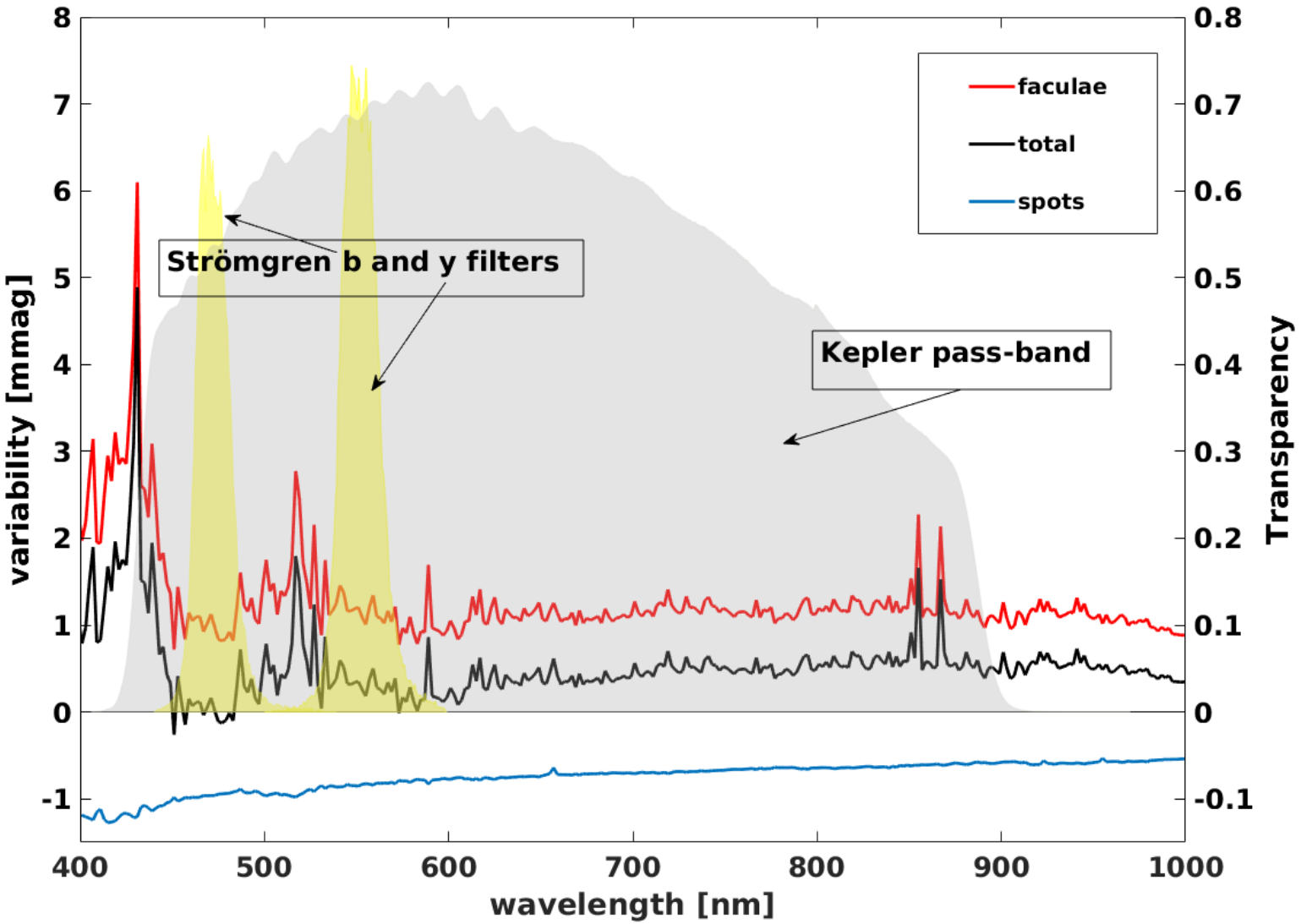
Mount Wilson Observatory [Wilson 1968, Wilson 1978]; Lowell Observatory Lockwood et al. 1992], Fairborn Observatory [Hall et al. 2009]; Kepler mission [Borucki et al. 2010]



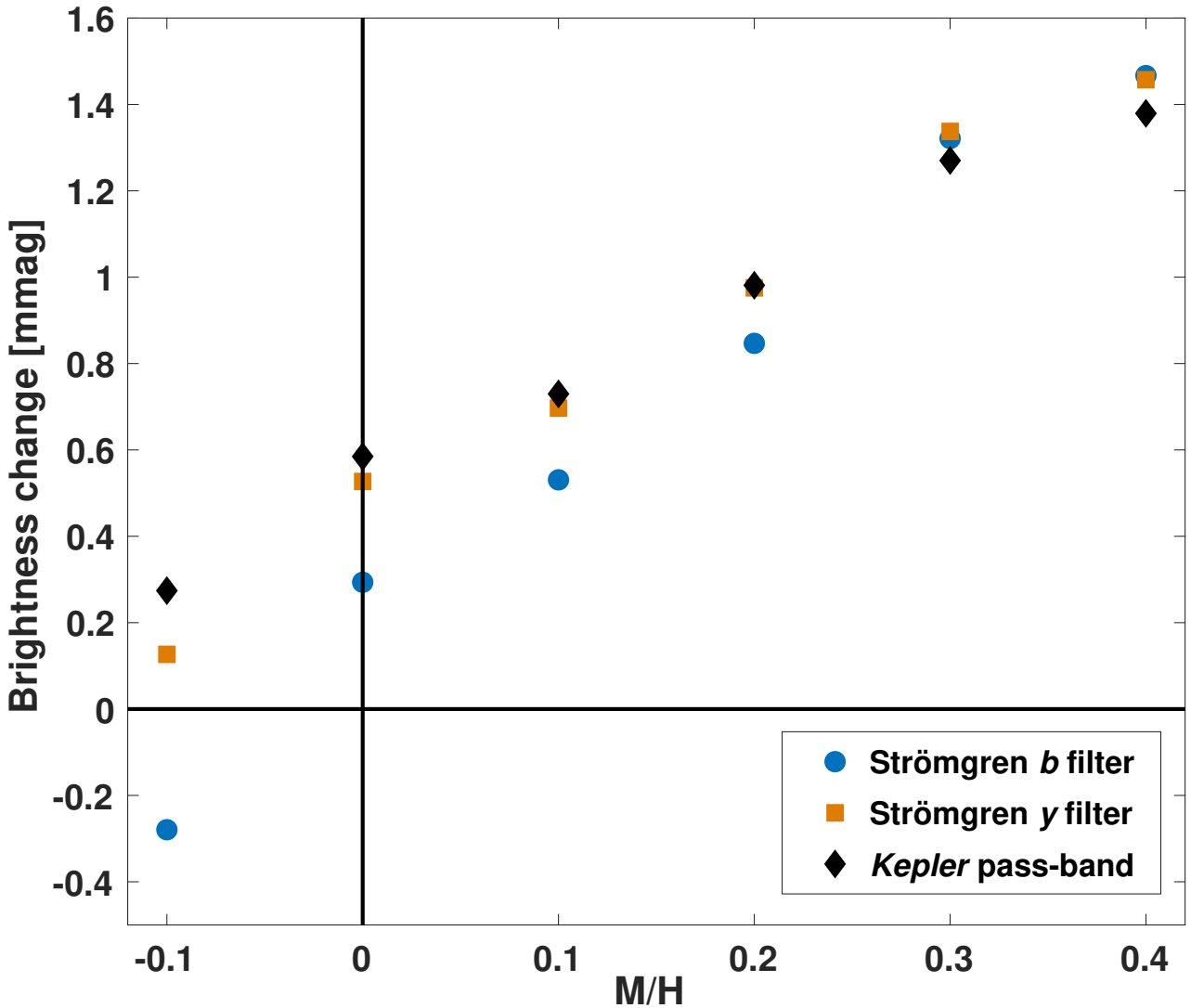
72 primarily main-sequence Sun-like stars; Figure from Radick et al. (2018). Solar photometric variability calculated with SATIRE model

Stellar Brightness Variability using SATIRE model

- Delicate balance between faculae and spot contribution
- Spot: smooth not much contribution from Fraunhofer lines

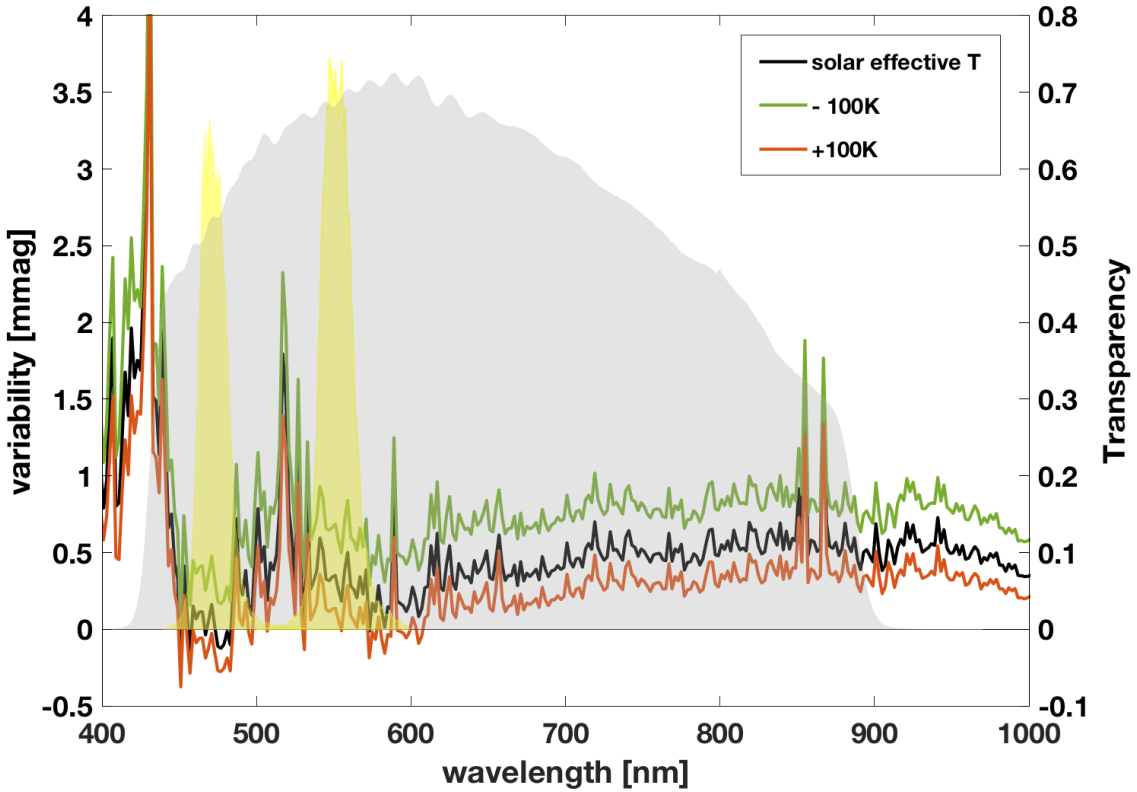


Effect of Metallicity on Stellar Brightness Change (1D model)



- Dependence of brightness change integrated over Strömgren *b* and *y* filters and Kepler pass-band
- Observed activity and greater brightness change of the solar analoge HD 173701 can be explained (Karoff et al. 2018).

Effect of Small Effective Temperature Deviations (1D model)

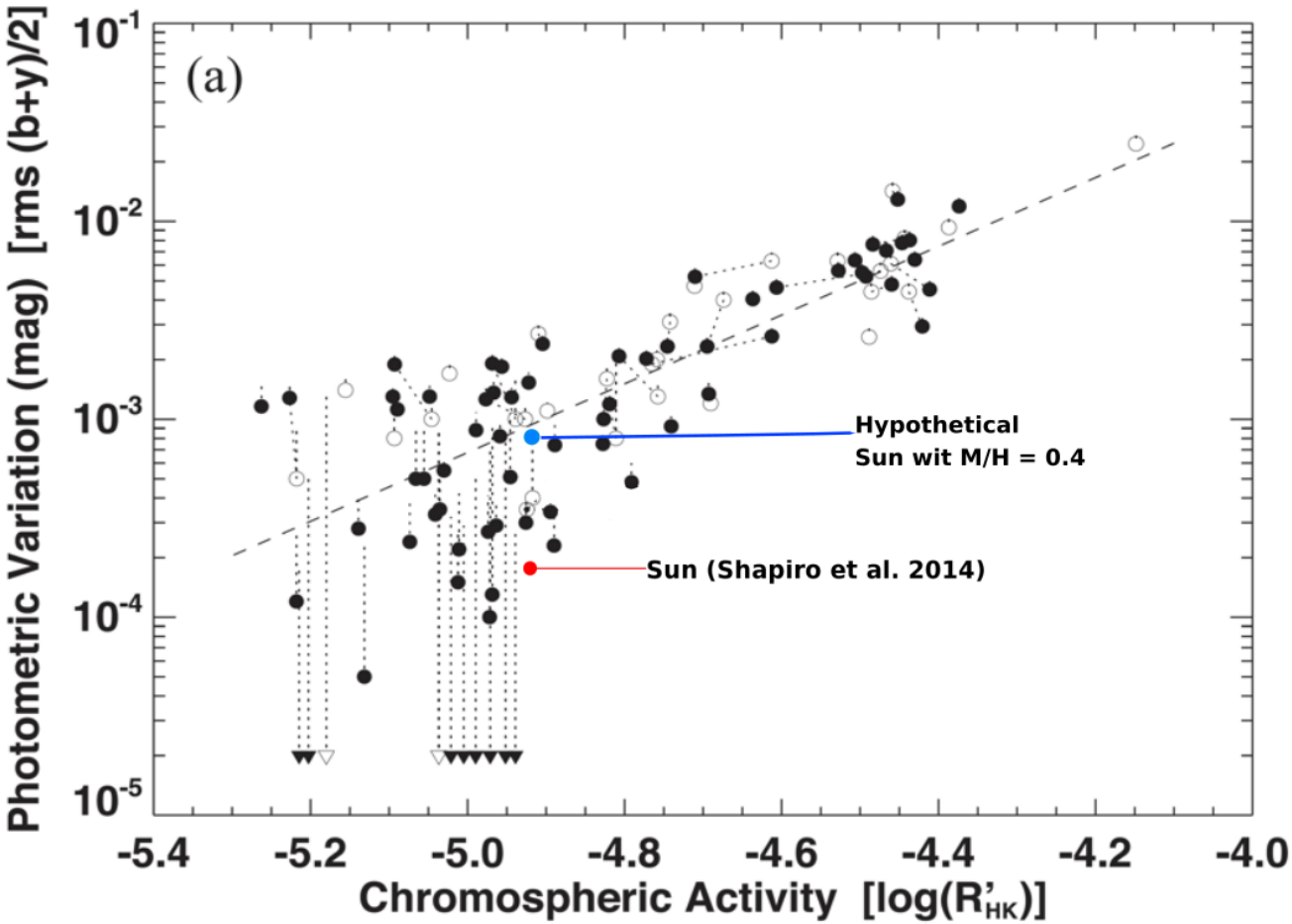


- Small T_{eff} changes of $\pm$100 K, which is of the order of measurment accuracy
  (Pinsonneault et al. 2012)
- Drop in effective temperature - spot dominated brightness changes
- Note, 1-D models do not capture geometric effects, e.g. from hot faculae walls

More detailed investigation including the effect of effective temperature and inclination will be soon available (Witzke, V. et al., submitted to A & A)

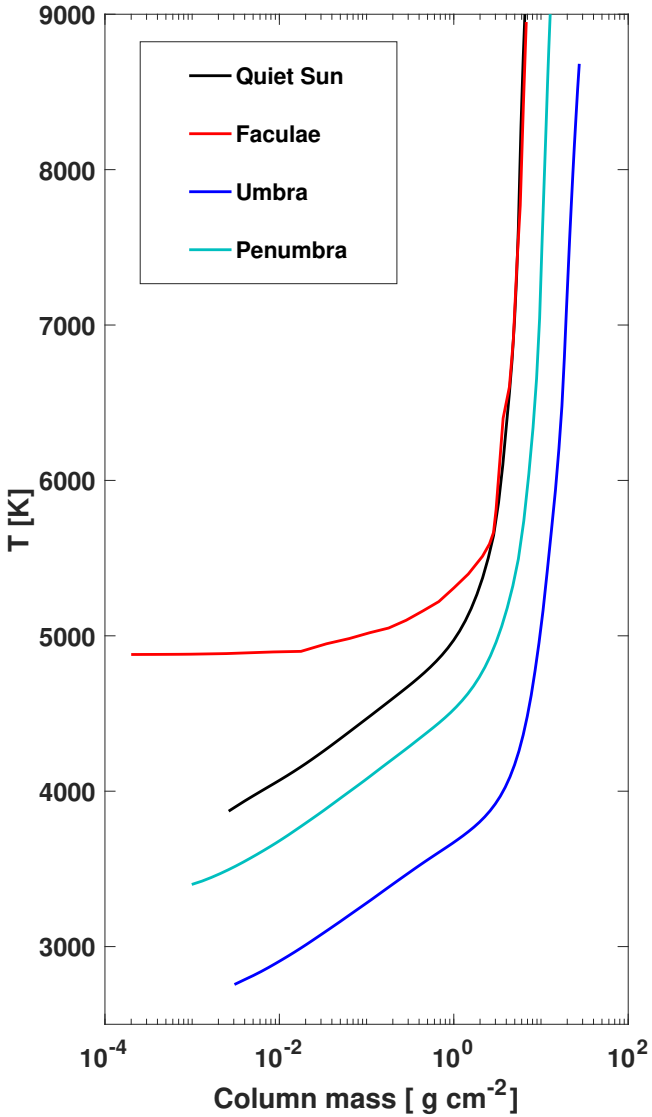
Placing a hypothetical Sun with M/H = 0.4

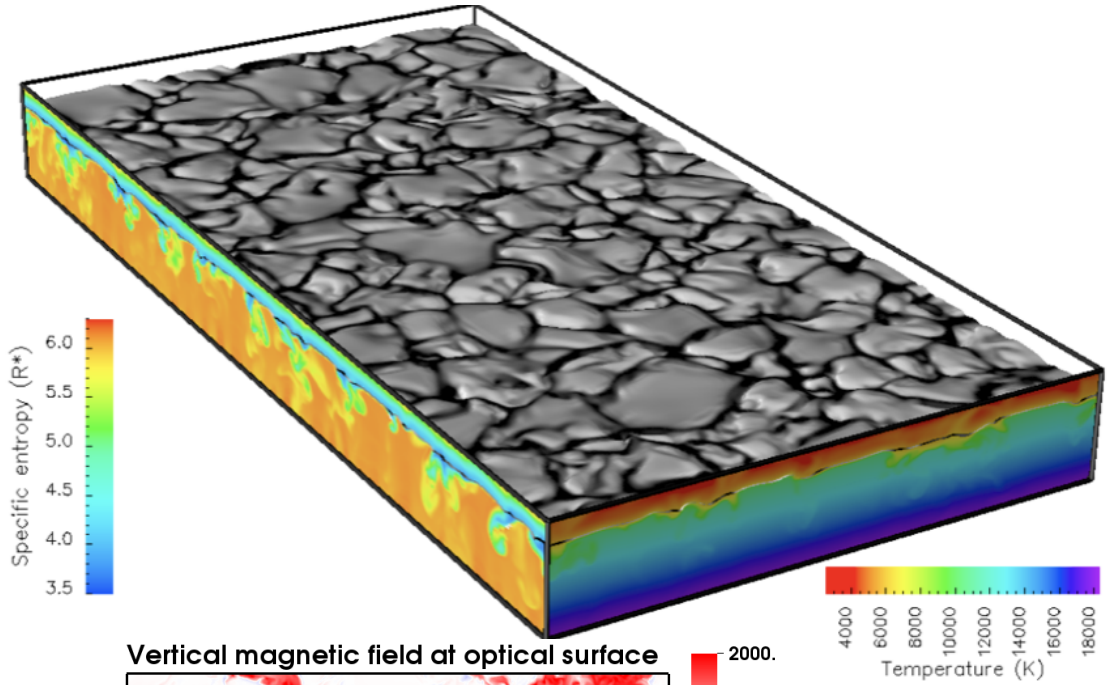
The solar fundamental parameters are close to a local minimum for the brightness changes on the magnetic activity time-scale

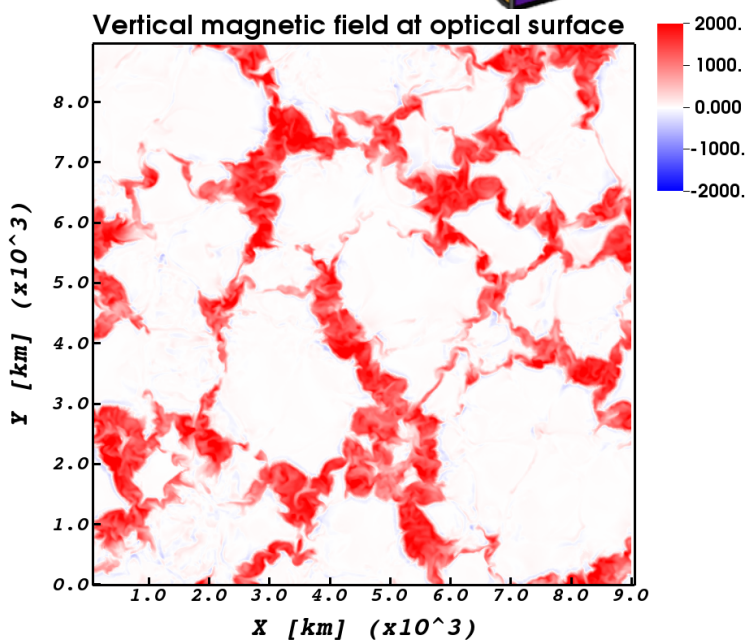


72 primarily main-sequence Sun-like stars; Figure from Radick et al. (2018). Solar photometric variability calculated with SATIRE model

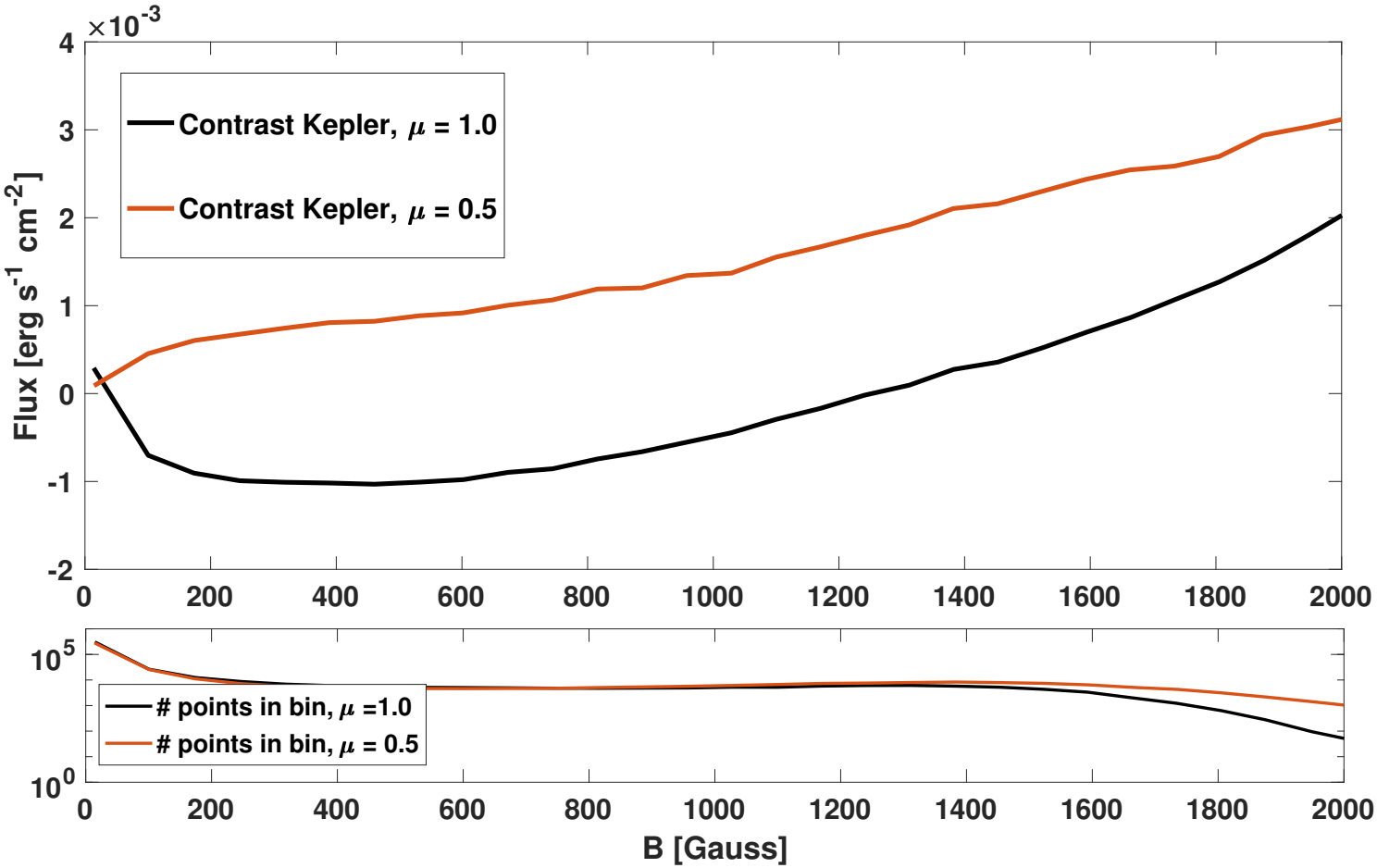
1D atmospheric structure versus 3D MURaM Cubes





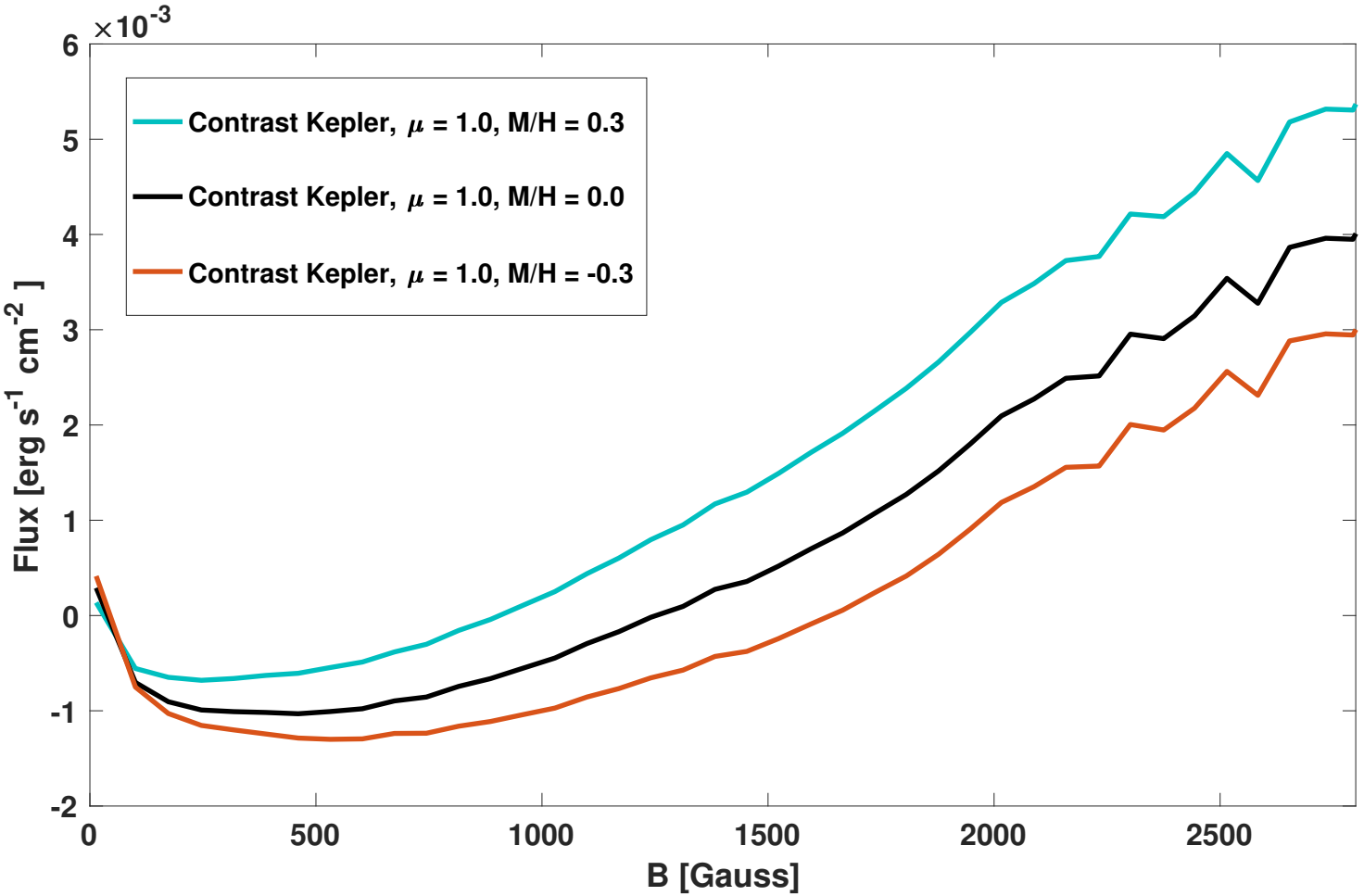


Contrast dependence on viewing angle:



Relation between the vertical magnetic field and Intensity

Effect of Fraunhofer lines on the contrast:



Contrasts in Kepler passband increase gradually with metallicity

Main results:

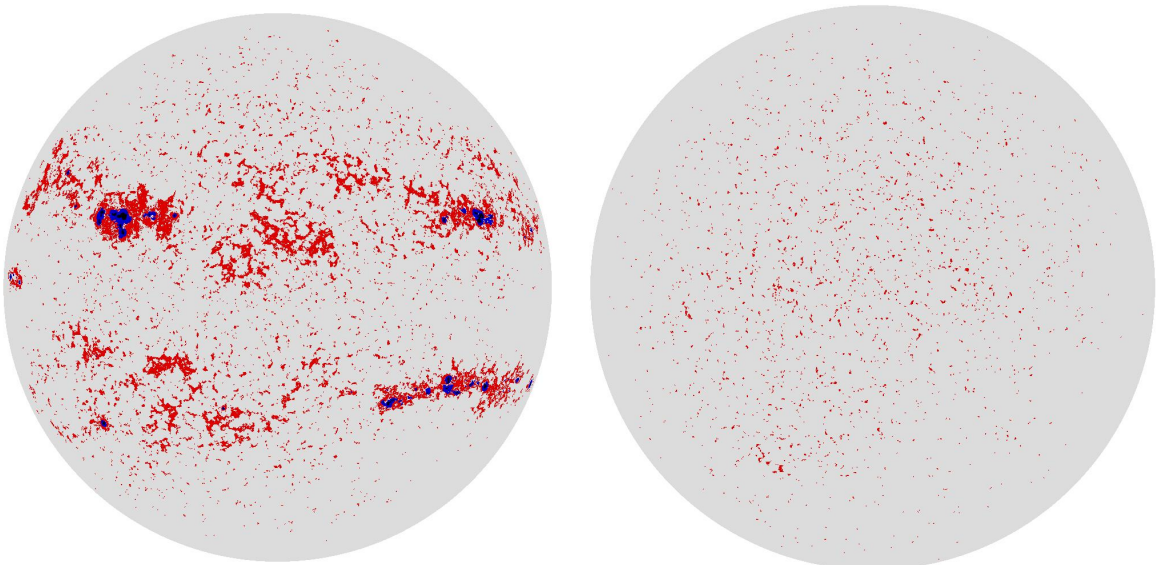
- The solar fundamental parameters are close to a local minimum for the brightness changes on the magnetic activity time-scale (Witzke, V. et al., submitted to A & A)
- First preliminary results using 1.5D approach confirm a higher faculae contrast in the Kepler passband for M/H = 0.3 and lower contrasts for M/H = -0.3

Future steps:

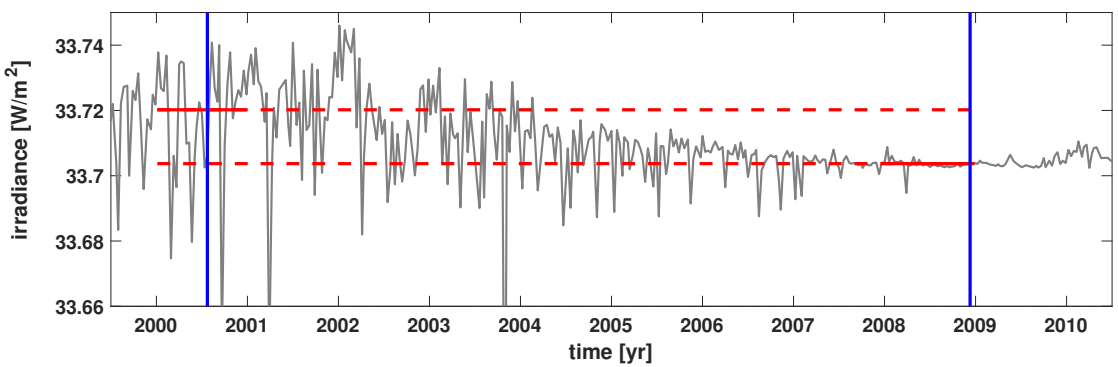
- Finalising 3D MHD investigations for a more realistic modelling
- Comparison of stars for which extended and detailed measurements exist, so far only for the solar analoge HD 173701 (Karoff et al. 2018).
- Large sample of stars, for example from Kepler full-frame images

Thank you for your attention!

- 11-years solar cycle driven by magnetic activity; phenomena are spots and faculae



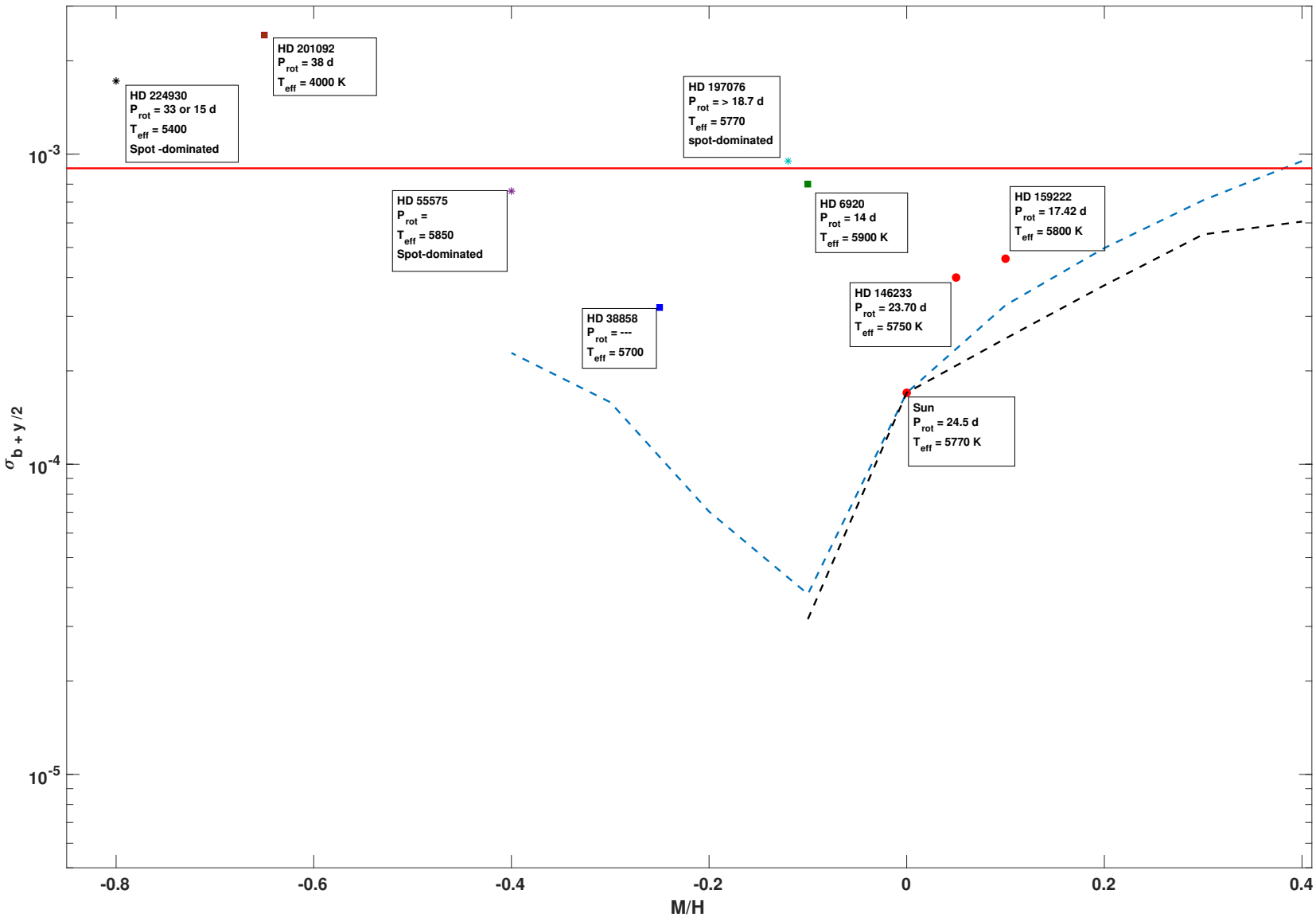
Solar magnetic feature's distribution (1th of July, 2000 & 1st of Dec, 2008)



Solar brightness in Strömgren *b* filter; blue lines are the time point of the two upper plots

$$F(\lambda) = F_Q(\lambda) + F_m(\lambda),$$

- Corresponding to the amplitude of solar cycle 23
- Uses solar magnetic feature distribution


HD 224930
P rot = 33 or 15 d
T eff = 5400
Spot -dominated
HD 201092
P rot = 38 d
T eff = 4000 K
HD 197076
P rot = > 18.7 d
T eff = 5770
spot-dominated
HD 55575
P rot =
T eff = 5850
Spot-dominated
HD 6920
P rot = 14 d
T eff = 5900 K
HD 159222
P rot = 17.42 d
T eff = 5800 K
HD 146233
P rot = 23.70 d
T eff = 5750 K
HD 38858
P rot = ---
T eff = 5700
Sun
P rot = 24.5 d
T eff = 5770 K
10-3
10-4
10-5
σb + y /2
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
M/H