Star spots and their impact on observable stellar properties

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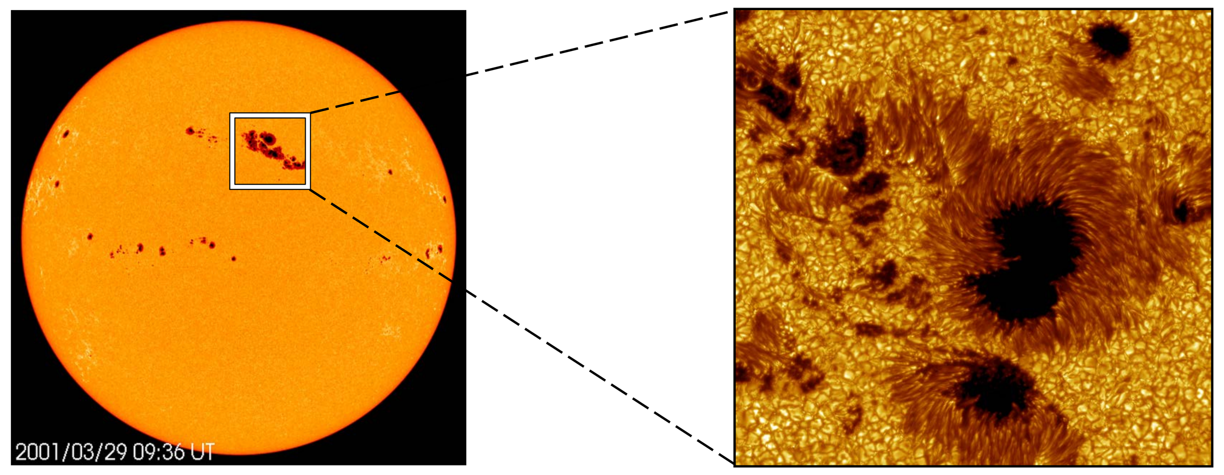
Star spots: Why they matter

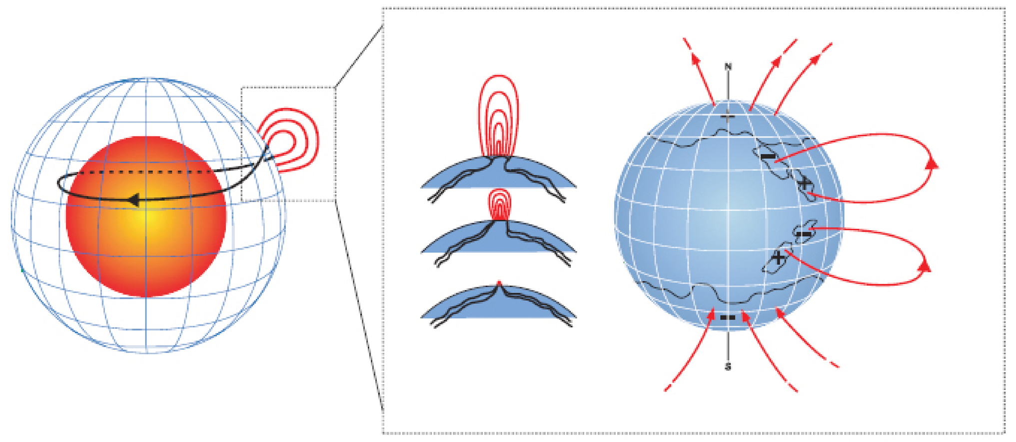


Star spots are areas on a star's optical surface that are cooler than the surrounding ambient surface due to the hinderance of convection by magnetic fields. We test how the presence, surface coverage fraction, and temperature contrast of star spots affect a star's position in multiple color-magnitude diagrams. Using a phenomenological model for the impact of spots on stellar structure, we investigate changes in stars' color, temperature, and brightness and their correlation to spot properties assuming different energy redistribution mechanisms. Our tests have the potential to delineate between different theoretical models of star spot formation, which will lead to better a understanding of star spot physics and how spots affect stars' observable properties.

Formation of Star spots: Where are the roots?

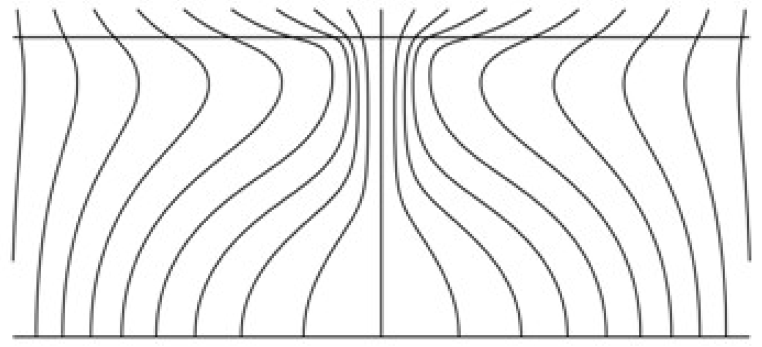
The location of the spot's base within the convection zone and the physical processes that lead to their formation drive two different and opposing theories on the formation of star spots.

Deep within the convection, near the solar tachocline, the base of the star spot is located below the super-adiabatic layer.



Dikpati & Gilman (2007)

Near the solar surface, the base of the star spot is located near the super-adiabatic layer.



Kitchatinov & Mazur (2000)

Potential influence on the classification of stars

If assuming the star prefers thermal equilibrium, the presence of a spot can lead to changes in the star's structure. Cooling of the heated plasma in the flux tube coupled with the hindered heated plasma underneath, will lead to the restructuring of the star to regain equilibrium. If the block is released quickly, little to no change may occur. On a longer timescale, the star may restructure changing the radius, the temperature, and/or the luminosity. Given the uncertainties of the origin within the convection zone, the effects on stellar properties is the focus. Looking into the changes in stellar properties, we can glean the effects of the spots and this can allow for more precise classification of stars with respect to potential color magnitude changes.

Experiments viewing the changes in stellar properties

We parametrize the influence of spots on stellar structure using a simple toy model to capture how properties of a star could react to the presence of spots.

$$\mathcal{L} = \xi \varphi^4 \left[1 - \varrho \left(1 - \varpi^4\right)\right]$$

Luminosity ratio — Surface area ratio — Photospheric temperature ratio — spot areal coverage — spot temperature contrast

Short Timescale: Change in Luminosity

On a short timescale, we assume spots do not exist long enough to grossly affect the star's radius or photospheric temperature. Spots only cause a temporary decrease in luminosity.

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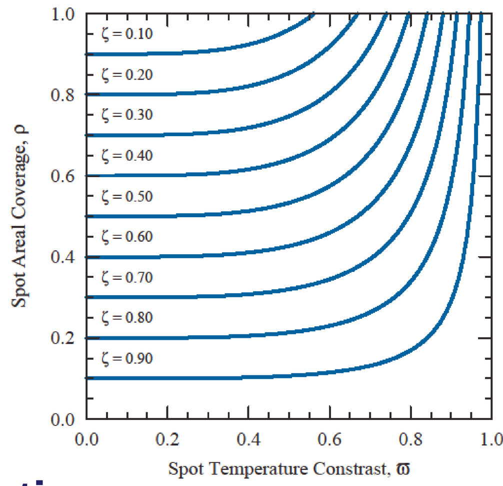
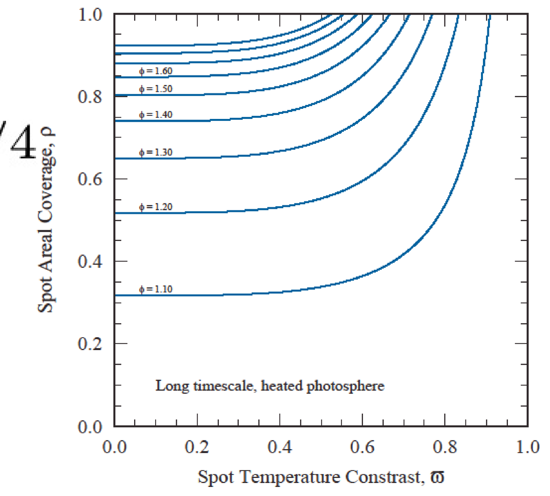
$$\mathcal{L} = 1 - \varrho \left(1 - \varpi^4\right)$$



Long Timescale: Photospheric Heating

Presence of spots for an extended period of time may lead to changes in stellar properties. One hypothesis is that flux blocked by spots acts to heat the ambient photosphere.

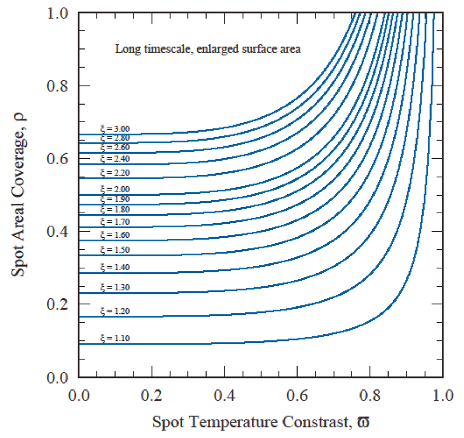
$$\varphi = \left[1 - \varrho \left(1 - \varpi^4\right)\right]^{-1/4}$$



Long timescale: Enlarged Radius

A second hypothesis is that the blocked flux will be re-emitted after the star restructures by growing larger to allow for more flux to escape.

$$\xi = \left[1 - \varrho \left(1 - \varpi^4\right)\right]^{-1}$$

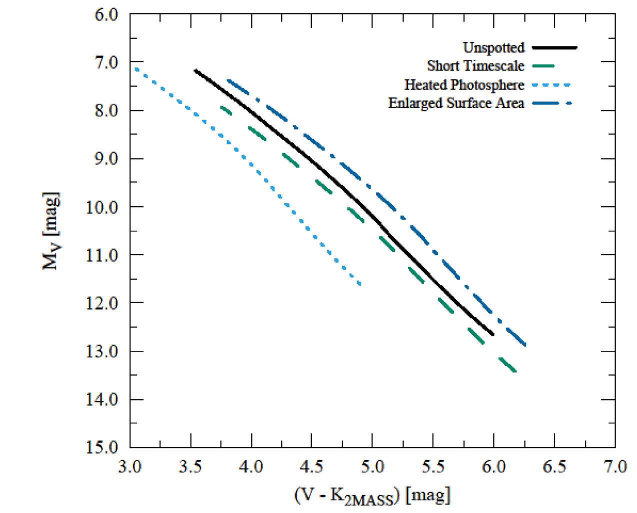


Taking into consideration the uncertainty of star spot formation, we focus on a bottom up approach. When introducing known spot properties into current stellar models, what is the outcome? What spot properties impact stellar properties more than others? Filtering through changes the data proposes, we can glean an understanding about the effects of star spots. This will lead to a better knowledge of star spot physics, their formation, and their effects on stars.

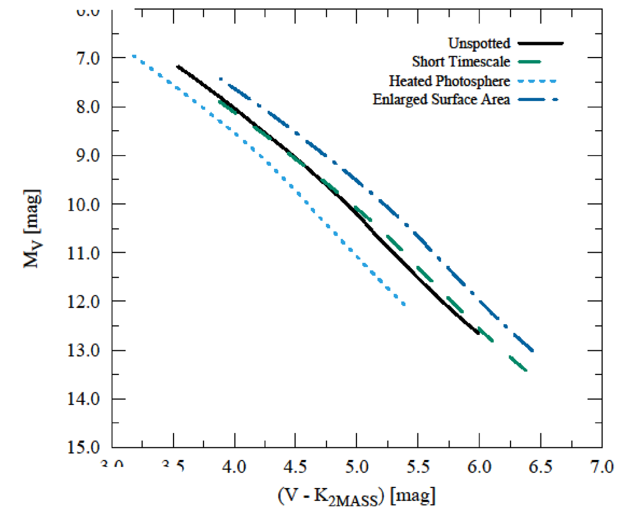
Results and the continuation of Exploration

Spot Properties: the battle to drive more change

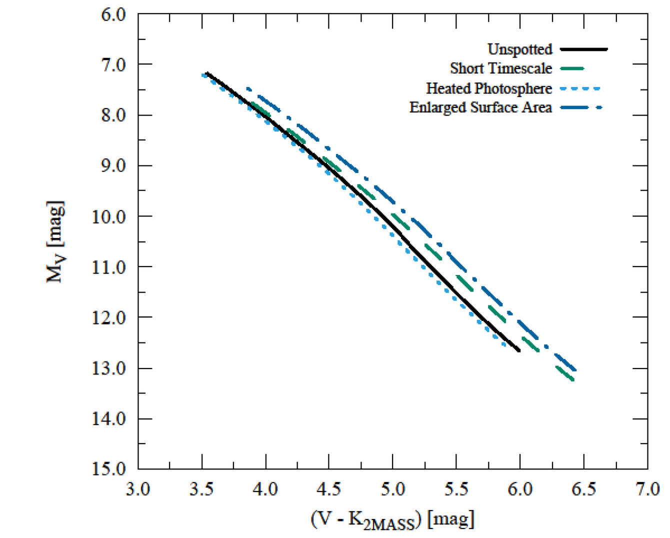
When looking at spot properties such as the temperature contrast with respect to the photospheric temperature and the radius ratio with respect to the radius of the star, we can see there is a trend that follows.



- Parameters: Spot temperature contrast is .6 and spot coverage ratio is .5
- Short timescale: there is a decrease in magnitude and a change in color toward red.
- Long timescale: Heated photosphere there is large shift in magnitude and a large shift in color toward blue.
- Long Timescale: Enlarged Radius: There is a slight decrease in magnitude and a shift in color toward the red.



- Parameters: Spot temperature contrast is .75 and spot coverage ratio is .5
- Short timescales there is a decrease in magnitude and a change in color toward red.
- Long timescale: Heated photosphere: there is an increase in magnitude and a change in color toward blue.
- Long timescale: Enlarged radius: there is a decrease in magnitude and a shift in color toward red.



- Parameters: spot temperature contrast is .9 and spot coverage ratio is .5
- Short timescale there is a decrease in magnitude and a slight change in color to the red.
- Long timescale: Heated photosphere there is little to no change with respect to the unspotted star
- Long timescale: Enlarged radius there is a slight decrease in magnitude and a larger shift in color toward red.

Conclusions and continued research

There is a trend of decreased V-band magnitude and a shift in color to the red with short timescale model and the long timescale model with an enlarged radius. In these scenarios, the spot temperature contrast outweighs the spot coverage ratio. However, the long timescale model with a heated photosphere shifts colors toward the blue and introduces an increase in V-band magnitude. In this case, both the spot temperature contrast and the spot coverage ratio play a significant role.

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