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Is the Sun a Sun-like star?

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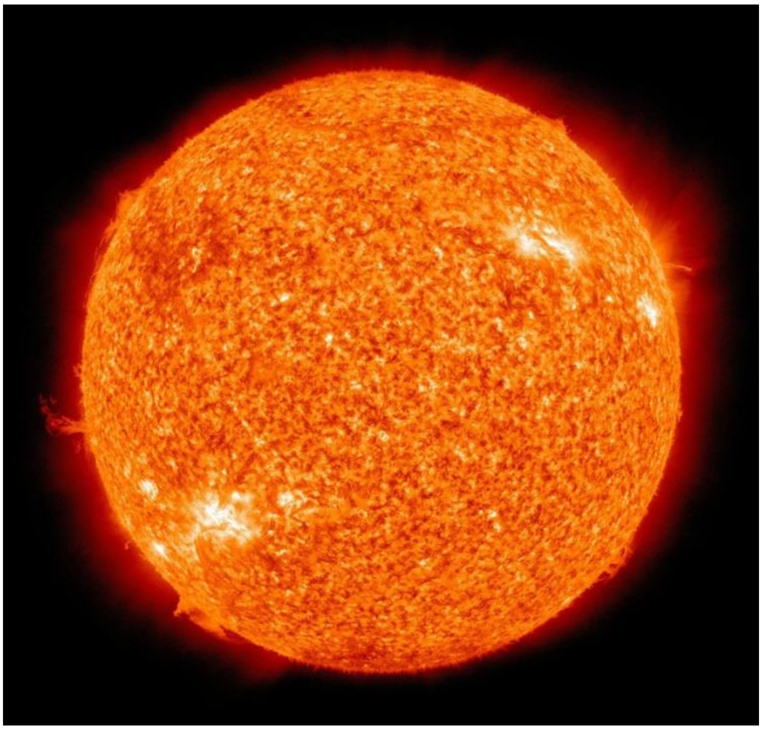
Brightness variability of the Sun and other stars is one of the most intriguing manifestations of their magnetic activity. We compare the Sun's brightness variability to that of its peers and asked how typical it is among other Sun-like stars. Surprisingly, several hundreds of stars that were very similar to the Sun in all parameters still showed much higher brightness variability.



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Is the Sun a Sun-like star? Asking this oxymoronic question might sound strange to most people, but not to astronomers. Comparing the Sun with other stars is a common technique to better understand the Sun and its behavior. Of particular interest here are stars very similar to the Sun, termed as Sun-like stars. In our study, we focus on comparing the variability in the Sun's brightness to that of other Sun-like stars.

For a long time, it was thought that our Sun is an invariable star- even the amount of radiative energy we get from the Sun was termed solar constant! But by the end of the 1970s, space-based measurements have revealed that solar irradiance varies on timescales ranging from seconds to decades. Scientists also observed similar brightness variations in other stars, with different amplitudes and variability patterns. These data initiated solar-stellar comparison studies. Initially, these studies were limited to a few hundreds of stars and relatively low precision due to ground-based measurements, but this situation changed dramatically over the last decade. With the advent of space telescopes – in particular the Kepler mission – stellar brightness variations have been measured for hundreds of thousands of stars. The Gaia space observatory – launched in 2013 – has provided brightness and distance measurements of more than a billion of stars, allowing scientists to identify true Sun-like stars.

We now know that the variability of the Sun and other Sun-like stars has a magnetic origin. The magnetic field is generated inside the star, forming magnetic features such as dark spots and bright faculae on the stellar surface. Since stars spin on their rotation axes, magnetic features constantly rotate in and out of view, which causes the brightness to vary. This brightness variability is well characterized for the Sun. The main goal of our study is to compare the brightness changes that happen in our Sun with that of other Sun-like stars, and to see how common solar variability is.

Sun-like stars are stars with near-solar surface temperature, size, chemical composition, and age. The Kepler telescope monitors the brightness changes of a certain star (i.e. its variability) over a 4-years time span. The changes in brightness turn out to be different from star to star. In some cases, the variability is periodical, induced by the same magnetic features that persist over several rotational cycles. Using this information, we can determine the rotation period of the star. However, most stars show irregular variability - so measuring their rotation period is a difficult task. The reason for this is that the magnetic features (in particular the spots) on these stars do not live long enough to survive one full stellar rotation, resulting in irregular brightness . Interestingly, the Sun also belongs to the class of stars with irregular changes in brightness. Our sample consist of 369 stars with periodical changes in brightness whose measured rotation periods are close to the solar value (roughly 25 days), and 2529 stars with irregular changes in brightness - like the Sun, but with unknown rotation period. These two samples will be called the “periodic” and the “non-periodic” samples in the following, and we will see that their variabilities are very different from each other.

We then compared the variability amplitudes of the periodic and non-periodic stars. We found that the brightness changes of the periodic stars are on average five times higher than in our Sun. The non-periodic stars, however, showed changes in brightness that were similar to those of the Sun. The very existence of the periodic sample is surprising! These stars all have near-solar parameters but they show very regular patterns of the variability, and exhibit much larger variability amplitudes. Since the magnetic activity of the Sun is thought to be determined by the surface temperature and the rotation period, one would expect to find a similar level of magnetic activity (or variability) for the periodic stars.

This result leaves two possible conclusions: First, that there exist (yet unidentified) differences between the Sun and the periodic sample. This explanation would be consistent with the idea proposed by Metcalfe & van Saders (2016,2017) that - at a certain age - Sun-like stars undergo a transition from an active stage, accompanied by large variability amplitudes, to an inactive stage with small variability. In our case, the periodic stars did not yet start such a transition, whereas the non-periodic stars, and in particular also the Sun, currently are in transition, or have already completed it. The second possible explanation is that ALL Sun-like stars can go through epochs of much higher variability than the Sun. While the first explanation is a one-way street from an active past to an inactive future, the second explanation implies that transitioning back and forth is possible and that the Sun could also potentially become much more active in the future! A more active Sun would likely generate larger (or more frequent) high-energetic events such as solar storms, which would also impact the Earth. However, the available data does not allow to decide which explanation is more likely than the other.