Solar and Stellar Flares and their Connection

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HEADLINE SUMMARY:

In this poster, we look at the solar-stellar flare connection. Firstly, detailed observations of a confined solar flare event from SST along with a 3D MHD simulation are used to understand the trigger mechanism and kinematics. These results are used to provide insights into large scale flare events observed on other solar-type stars from TESS observations.

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1. INTRODUCTION

Solar flares are extremely powerful events and are observed across the entire electromagnetic spectrum, possessing energy outputs of up to 10^{32} erg (Fletcher et al. 2011). Stellar flares have been observed on stars similar to and less massive than the Sun over many decades with energies exceeding 10^{33} erg (e.g. Schaefer et al. 2000). Known as 'superflares' these large outbursts can have severe consequences for any orbiting planets atmosphere. The lack of detailed spatial and temporal stellar flare observations poses an issue in the community. Therefore, we should look to the Sun to provide these details.

2. SOLAR FLARE SUNSPOT CONNECTION

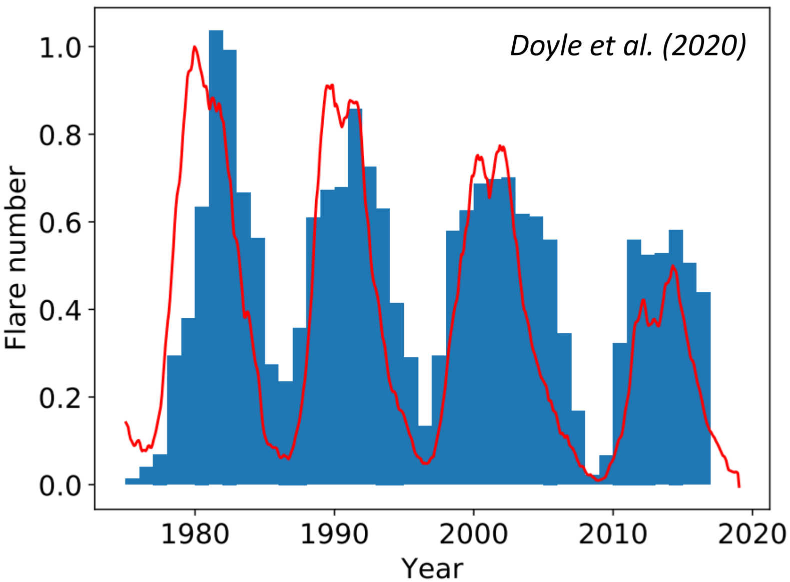


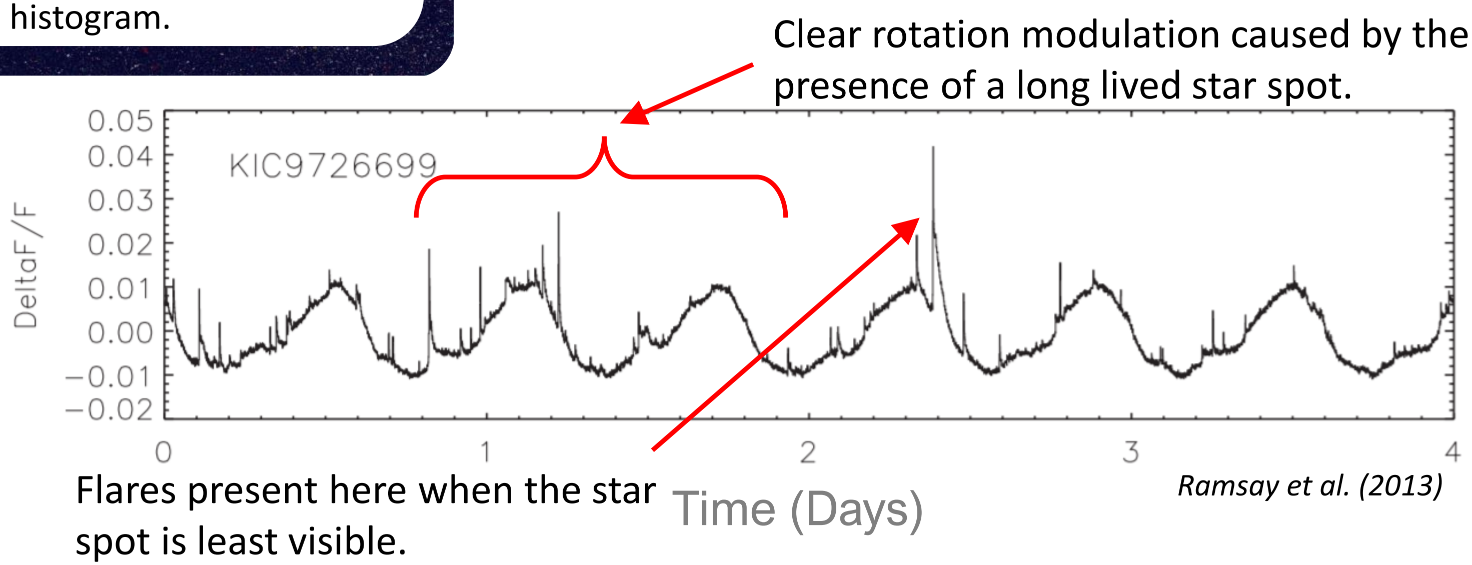
Figure 1: Historic data of solar flares and sunspots, where the sunspot number in the red solid line and the flare number is the blue histogram.

There is a well established correlation between solar flares and sunspots on the Sun which dates back to the 1930s. It is generally accepted that these phenomena are closely related, see Figure 1.

3. STELLAR FLARE STARSPOT CONNECTION

Figure 2 shows rotational modulation produced due to the presence of a starspot on the disk of the star moving in and out of view. Here it is important to notice flares are present throughout the lightcurve and are not solely seen when the spot is most visible. This comes as a surprise as it contradicts what we believe is true from observations of the Sun.

Figure 2: A section of the short cadence Kepler lightcurve of GJ 1243, a highly active M4 star. This is an example which shows there is flaring activity present across all rotational phases despite the presence of clear rotational modulation.



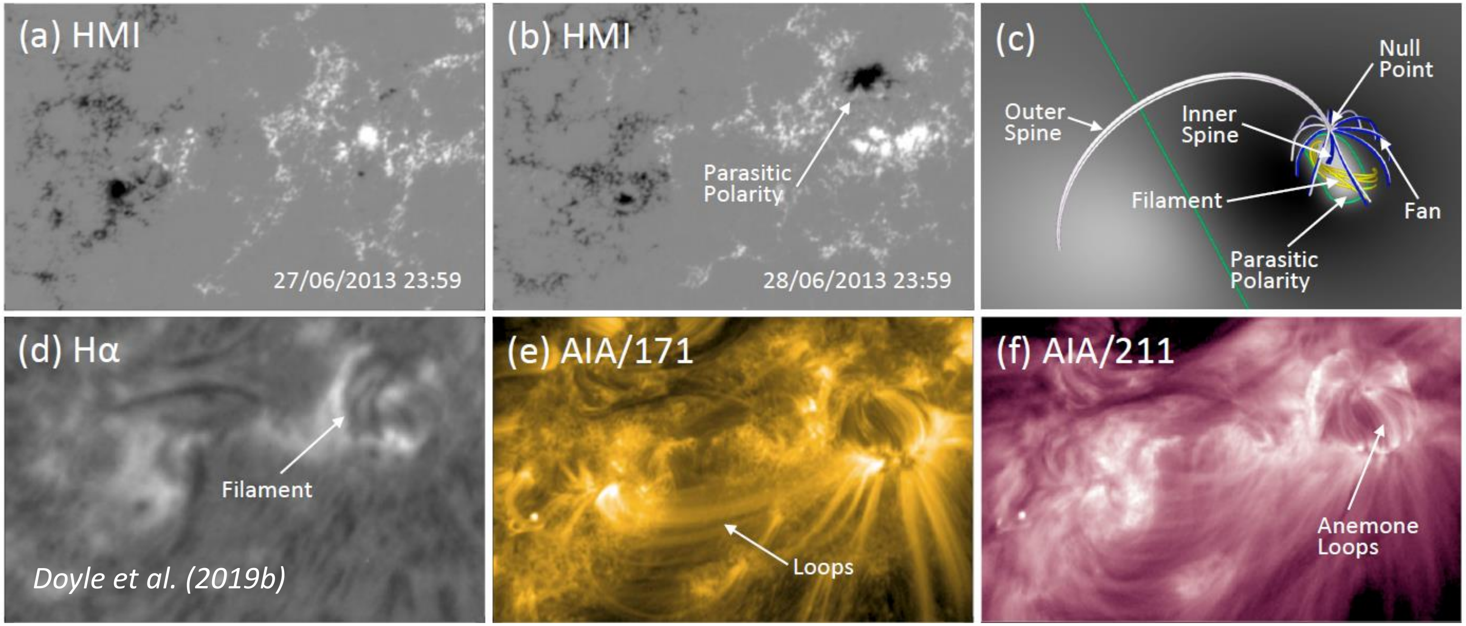


Figure 3: This selection of images shows the active region in multi-wavelengths from GONG, AIA and HMI. Panel (a) and (b) show the HMI magnetogram before and after the parasitic polarity appears, (c) shows the pre-are magnetic field within the simulation and (d) - (f) shows the region after the parasitic polarity appears in Hα, AIA 171Å and AIA 211Å.

4. SOLAR FLARE STUDY

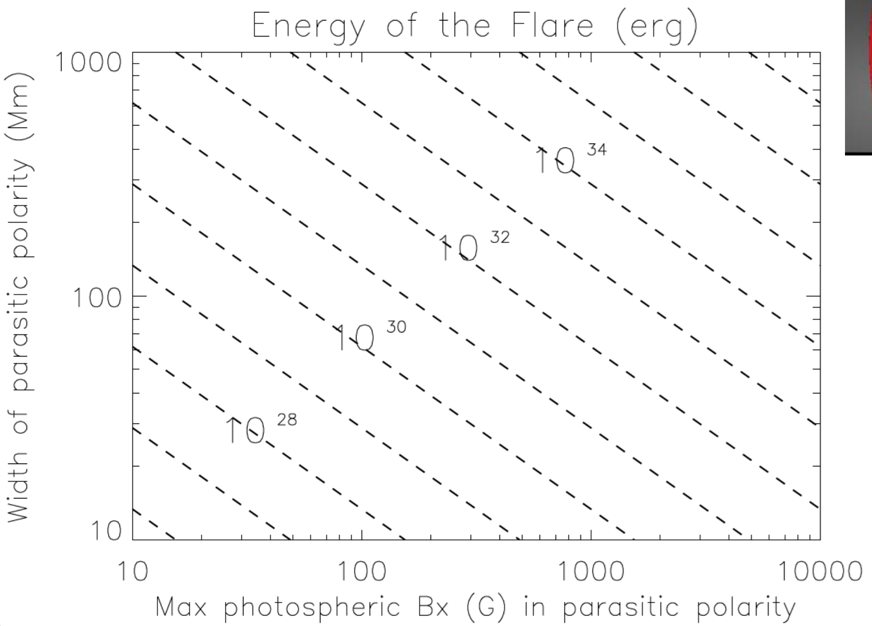
Utilising high cadence, Hα observations of a filament eruption and jet made using the CRISP spectro-polarimeter mounted on the SST allowed for the construction of velocity maps of the event, providing details on the kinematics. The observations were contrasted with a 3D MHD simulation of a breakout jet in a closed-field background (similar to Wyper et al. 2017) and a close qualitative agreement was found. We conclude that the breakout model can not only be applied to CMEs and jets but flares also.

5. STELLAR FLARE STUDY

- 209 solar-type stars between F7 – K2 (Doyle et al. 2020).
- Total of 1980 flares ranging in energy from 10^{31} – 10^{36} erg.

Main Result:
No correlation between flares and starspots found, suggesting flares are randomly distributed and do not coincide with starspot producing modulation.

Figure 4: A scale up of the solar 3D MHD simulation. The x-axis represents the field strength of the parasitic polarity and the y-axis the size of the parasitic polarity. The dashed lines are the varying output energies of the flare.



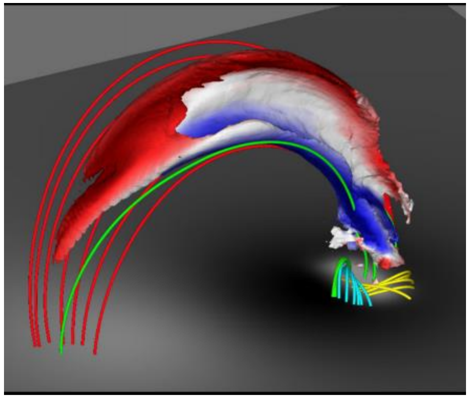


Figure 5: The 3D MHD simulation of the eruption with an isosurface of velocity to show the jet.

6. MODEL SCALE-UP

Could this solar model be capable of producing much larger flares? This could shed some light on the origin of the stellar flares. To compare the observations of stellar and solar flares the 3D MHD simulation was scaled up to see how it would produce flares of greater energies, like the ones observed in solar-type stars. This scale up can be seen in Figure 4 which shows the conditions needed in both the magnetic strength and size of the parasitic polarity in order to produce flares of greater energies.

7. CONCLUSION

Producing a flare of energy 10^{34} erg would require a parasitic polarity of size 200Mm and field strength 2kG. In terms of the Sun, the field strength of 2kG would be possible as sunspots tend to be in the region of 1kG - 4kG, however, a sunspot which is a third of the solar disk is extremely unlikely. This shows there needs to be more collaborations between solar and stellar models to explain the origin of superflares in more detail.

References:

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