‘After SDSS-IV’ – Letter of Intent

Disentangling flaring mechanisms across the Herzsprung-Russel diagram and their influence on habitability in planetary systems

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Introduction

On September 1st 1859 the British astronomers R.C. Carrington and R. Hodgson detected the first and largest observed solar flare, while accurately mapping the occurrence of sunspots across the solar surface [1,2]. This is now known as the *Carrington Event*. While the nature of this phenomenon was unknown at that time, nowadays it is generally accepted that solar flares are large explosions in the solar atmosphere and are linked to solar activity cycles. These energetic outbursts are observed when complex magnetic fields reconnect to a lower energy configuration (e.g. [3] and references therein). The magnetic fields responsible for those flares are generated by a dynamo, which requires a sufficiently deep convective envelope in order to operate. The same mechanism is believed to be behind the generation of flares in cool stars of spectral type F-M (e.g. [4,5] and references therein).

Understanding stellar activity is crucial when considering the habitability of a planetary system. While planets may be found in the habitable zone, defined as the region around a star where liquid water can exist, stellar activity may strip away the planetary atmospheres (e.g. [6]). This is especially the case for planets without protective magnetic fields. Stellar activity also leads to an increase in UV radiation, endangering the prospects of life on a promising exoplanet. Therefore special interest is placed on flaring stars with detected exoplanets.

Flares are transient, non-periodic events. Therefore they are difficult to study as the unpredictable nature have made their detection impossible to guarantee during observations. Fortunately, through a continuous study of a specific field on the sky, the *Kepler* mission has granted the opportunity to better understand the high energy flares[1] in cool stars (e.g. [7]).

In the upper part of the *Herzsprung-Russel Diagram (HRD)* only a few flares have been observed. Most of these flares were observed in X-ray but few attempts have been made to explain their nature. In Ap– and Bp–type stars, for example, which have strong large–scale magnetic fields, observed flares may be due to breakout events of magnetically confined stellar winds [8]. Only about 10% of A– and B–type stars are found to be Ap/Bp stars (e.g. [9]), and among those only few have been detected to show flares (e.g. [10]). Recently also ‘normal’ A–type stars were reported to be flaring, however, their nature is still under investigation [11,12,13,14]. In massive binary systems like η Carianae, on the other hand, the flares can arise due to colliding, strong and turbulent stellar winds [15]. Figure 1 illustrates the regions in the HRD where the three mentioned flare mechanisms have been found to operate.

With addition to *Kepler*, the future *TESS* mission (launched in 2017) offers a new opportunity to understand stellar flares. These homogenous observations will for the first time allow to study the occurrence of flares across the **entire** HRD as well as the different mechanisms leading to the flares. In order to do so it is crucial to gather more information on the stars such as their spectral types, binarity and possible circumstellar disks. Additional mechanisms resulting in flares are e.g.: a) Star-disk interactions, where the magnetic fields of the star are connected to a circumstellar disk, b) infalling bodies and c) star-star or star-planet interactions (e.g. [16] and references therein).

[1]Only the most energetic flares are observed in white light.

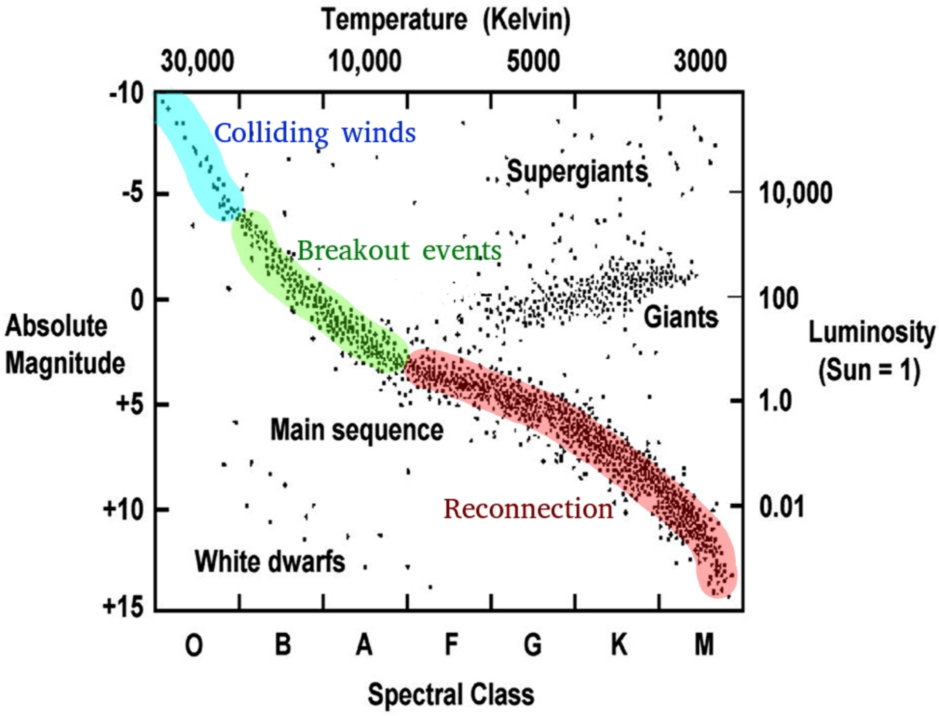

Figure 1: HRD showing where known flare mechanisms may operate. Breakout events may only occur in Ap/Bp stars. Modified from [17].

Science Goal Requirements

This science goal requires follow-up observations on flaring targets identified by the *Kepler*, *K2* and *TESS* missions. The 'After SDSS-IV' facilities are perfect to reach our goal because they allow multi-wavelength observations with different instruments.

The APO spectrographs: For each detected, flaring star we wish to obtain spectra in order to 1) determine their spectral types especially for the faint stars, 2) determine chemical peculiarity (e.g. Ap/Bp stars), and 3) search for emission arising through either chromospheric activity or circumstellar material (CaII H & K, Balmer-lines etc.). For flaring stars with detected exoplanets, we propose to carry out a monitoring programme in which each of those stars are revisited once a month to determine possible stellar activity cycles. This will be done by meassuring the level of emission in the CaII H and K lines and in Hα. A similar monitoring program is proposed for detected, flaring, massive stars relying on possible Hα emission to reach a better understanding of flaring mechanisms in such stars.

The MARVELS spectrograph: To determine the binary fraction of flaring stars and the possibility that such flares may arise from interactions between the stars, we would require observations for all of the detected flaring stars. To reach this goal, we intend to obtain a total of four measurements of each star with a time separation of one month.

The APOGEE-2/APOGEE spectrographs: Near-infrared (NIR) measurements provide information on the presence of 1) a circumstellar disk and/or 2) a cool companion, if an infra-red excess is found. Therefore, in connection to the binarity determination and spectral classification mentioned above, we suggest to obtain one NIR spectrum of each flaring star.

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