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STARS SUSPICIOUS OF BRIGHT SPOTS[1]

M. ZBORIL

Tomášikova 43, Poprad, 058 01, Slovakia

E–mail: zboril@astro.sk

Abstract. This contribution summarizes gross results of studies related to dark, cool spots often presented in a late-type star atmosphere. Methods capable to reveal spots in the stellar photosphere are briefly mentioned as well as main results describing spot properties. Subsequently, current status in bright spots investigations is presented and further progress discussed.

1. INTRODUCTION

Generally, the background to explain the presence of spots on stellar surface, typically in the upper part of stellar photosphere, comes from the magneto-hydrodynamical equations solutions which are able to explain rising, the existence, and behaviour of magnetic flux tubes beneath the stellar photosphere (e.g. Thomas and Weiss 1999). Yet, to measure and to understand the properties of spots associated with flux tubes took some time and now we are in a position to make some inter-comparisons with the Sun, specifically with sunspots. There are available sunspots records over many decades enable us to study sunspots properties such as spot area, location and lifetime and make considerations about solar magnetic activity. At present, the same goes for stars, specifically late-type stars. However, recently the question has been raised about the presence and properties of bright spots in the stellar atmosphere as an analogue to cool, dark spots already studied in detail on some stars. Current status in studies of this type of spots is outlined and future progress sketched in this contribution.

2. METHODS

In an effort to study and understand stellar spots some methods have been developed in time. First of all, it is the photometry which contributed and it is certainly interesting fact that perhaps first realistic proof about cool spots in the stellar atmosphere came from eclipsing binaries light curves analysis some time ago (Hall 1972). Depending on quality and shape of the light curve, some spot information can occasionally be retrieved from the light curve of a single star. Mapping HR 1099 star using the Doppler imaging method introduces this technique to cool star work in 1983 and roughly at the same time (e.g. Ramsey and Nations 1980) molecular bands were used

[1] Astronomical Institute, Tatranská Lomnica, 059 60, Slovakia

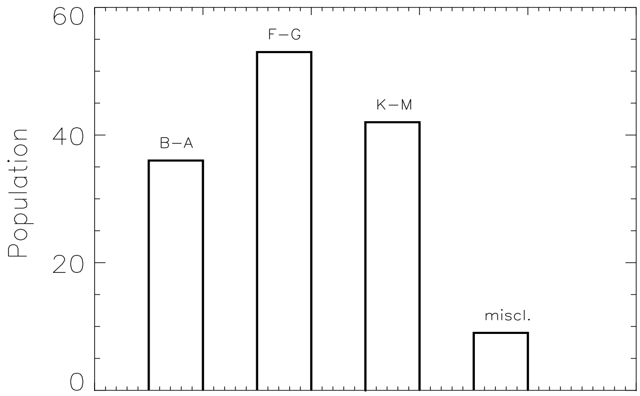

Figure 1: Spectral type population in the catalogue (present version).

to estimate basic spot parameters such as the temperature and total surface area. The technique line-depth-ratio (LDR) uses basically various temperature sensitive spectral transitions and is often combined with results from photometry (the light curve). The Least-square-deconvolution method (LSD) reduces noise and improves S/N ratio and there are estimates available that one can use 120cm telescope when applying this method instead of 4m telescope. Furthermore, an optical interferometry method has started. Due to the atmosphere properties it was almost impossible to start with the optical region and first interferometer operating in the optical regions should have the resolution of 10 - 20 elements across the stellar disk. In 1936 A. Einstein dealt with the idea of stellar light changes if massive object is in the light of sight of distant source of light (micro-lensing effect). He derived the formula for typical brightening and typical light curve of distant light source. However, the probability to detect such an event is low, in 1986 B. Paczynski estimated this probability as 1:1 000 000. There are currently about 100 candidates per year for this effect, and 2-3 candidates only with spots in the stellar atmosphere suitable for study. In practice, some methods are used individually (e.g. Doppler imaging) but encouragingly enough, some of them are also used in a combination.

3. STARSPOTS

3. 1. COOL, DARK SPOTS

These methods have been used for several decades and brought many respectful results. First of all, it is worth noting that dark spots in stellar atmosphere were detected on a variety of objects. They were detected in T Tauri stars, solar type stars, W UMa, Algols, RS CVn and BY Dra type stars, red giants and dwarfs, white and brown dwarfs and reportedly in a neutron star. The 'spot' phenomenon is now common across the HR diagram, studying bright spots in stellar atmosphere may offer some more results. But gross results on dark, cool spots first.

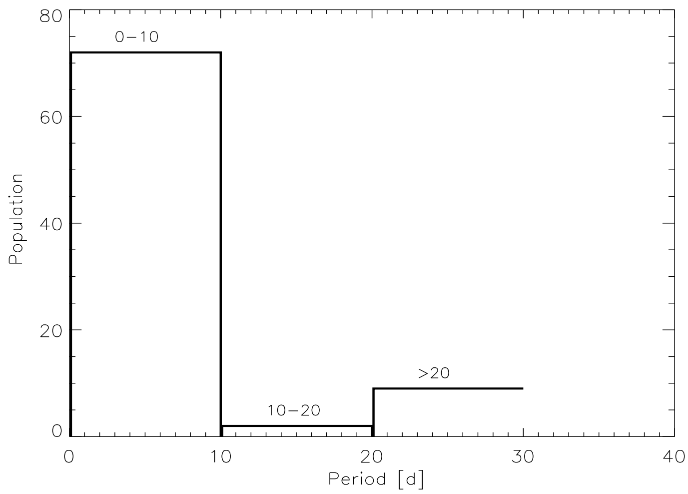

Figure 2: Periods distribution for stars in the catalogue.

3. 2. SOME RESULTS

The aforementioned techniques certainly brought original observational results and contributed significantly to the plasma physical properties as described and predicted by the magneto-hydrodynamical equations. Basically, it was found that cool spots in stellar atmosphere were cooler, larger, have larger life- time and also magnetic fields were larger when compared to the Sun. That goes for main spot properties and in broader context additional results include:

- variable max. brightness of stars (long-term trend)
- presence of polar caps on stars
- detection of magnetic cycles
- detection of spot positions (including butterfly diagram construction)
- detection of stellar differential rotation.

3. 3. BRIGHT SPOTS

This valuable results are not the end of stellar spots story and at present scientific effort in this field certainly includes mapping environment around stars, the resolution and mapping stellar magnetic fields (size, location, orientation etc.) and the opposite of dark spots, i.e. bright active regions/spots. The latter has been recognized mainly in stellar colour indexes, occasionally from eclipsing binaries light curve analyzes, and rarely still on images produced by using the Doppler imaging method. According to the catalogue recently constructed (Zboril 2009), the stars suspicious of bright spots are numerous, bright spots were indicated on a variety of spectral type, singles and binaries. Physically, it is easy to understand bright spots presented in young T Tauri star, these stars are believed to produce large magnetic fields as they are young and generate interesting flux tubes associated with bright spots (perhaps including dark spots as well). It also may be tentatively concluded about detection of bright spots in close (eclipsing) binaries as the systems are dynamic and existing magnetic flux tubes are subject of various competitive forces in these systems. For example, around 30% binaries in the catalogue have bright spots located near Roche point (neck-zone). Of these systems, those binaries where bright spots swap (from one stellar component to other) or bright spot/region swap to dark spot in time, are notably valuable physical laboratory. But presence of bright spots/regions on other type stars (e.g. single solar type stars) may not be so trivial to understand though plages are typical candidate for an explanation. Fig. 1 displays the histogram of spectral type population in the catalogue and Fig. 2 offers the periods distribution for stars in the catalogue.

4. CONCLUSIONS

After several decades of dark, cool spots investigations new and inquisitive view to stellar spots problems emerged: it may go for the properties of stellar magnetic fields (e.g. Donati 1996, Piskunov 2002), chromospherically active late-type stars in particular, and for the question about the reality and properties of bright active regions/spots presented in stellar atmosphere. The latter may evolve in time assuming the following steps:

i./ detailed spots study of close binaries
ii./ dtto for young T Tauri stars
iii./ dtto for single solar type stars
iv./ new version of the catalogue

Of the methods, Doppler imaging seems to be the most reliable and it is hoped that some observational data will be obtained for Zeeman-Doppler imaging method as well (applied to T Tauri stars for example). New version of the catalogue should critically evaluate colour excesses of stars in the present version of the catalogue and enlarge data for binaries (periodicities, binary elements, activity indicators, etc.). Present version of the catalogue is available at *http://www.astro.sk/ zboril/catalogue/catalog.html*.

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