Experiments in the Relationship between Stellar Spectral Type and Starspots

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Abstract:

The tendency of stars to develop starspots (dark, cool blemishes on the surface of the star caused by the twisting of magnetic flux tubes) is a useful resource in determining certain properties of a star. The relationship between strong x-ray magnetic fields and starspots was studied to determine which spectral type of star is more likely to feature starspots. By determining the number of BY variables, stars known to have starspots, per a certain spectral type, which was done using an X-ray master catalog and a variable star catalog, the spectral type of star most prone to starspots was determined. Accounting for experimental errors, the final results supported the hypothesis, which was that stars of higher mass, spectral types K and M, would have a higher tendency to exhibit starspots due to higher magnetic activity in their convective envelope.

Introduction:

In the study of stellar bodies, it is undeniably necessary to give particular attention to the phenomena of starspots. According to the Wilson Effect, starspots are visible depressions in the star's surface, formed by the twisting of magnetic flux tubes in the convective envelope of the star (Wikipedia). These magnetic flux tubes puncture the envelope, halting convective transfer of energy and resulting in a dark, cool region of intense magnetic activity (Russell). It is these regions that have been dubbed starspots. Starspots are widely used to calculate the rotation rate of a stellar body; close observation of starspots has revealed surprising and key evidence of differential rotation among various longitudes of a star (Britt). Further analysis has proven that stars are in fact fluid bodies, an important discovery regarding their composition (Wikipedia). Because starspots can provide such a window to future discoveries, it is advantageous to know which spectral type of star is more likely to feature these phenomena. Studies of a star in this spectral type will automatically have a potential focus of research and observation that almost promises further understanding of that star and stars similar to it.

The twisting of magnetic fields, which occurs if a star features a convective envelope, creates x-rays. Stars of greater mass generally replace some, if not all, of a convective envelope with a radiative envelope, suggesting that they are not prone to the distortion of magnetic flux tubes which creates starspots (Darling). Therefore, it is reasonable to assume that a star which features starspots is also an x-ray emission source. However, there are other reasons why a star might emit x-rays, such as the collapsing of accretion discs (Longair). A star that actually exhibits starspots will also vary in brightness, due to the apparent darkness created by the cooler regions (Russell). It is thus prudent to cross-reference a list of x-ray emission sources of a certain spectral type with a variable star catalogue. However, only a certain type of variable star suggests starspots. BY variables are categorized by a non-uniformity in the surface, such as starspots, as the star rotates. Thus, this type of star is most pertinent to this line of research and deserves particular attention.

Purpose:

The purpose of this experiment is to determine which spectral type of stellar x-ray emission source is more likely to exhibit starspots.

Hypothesis:

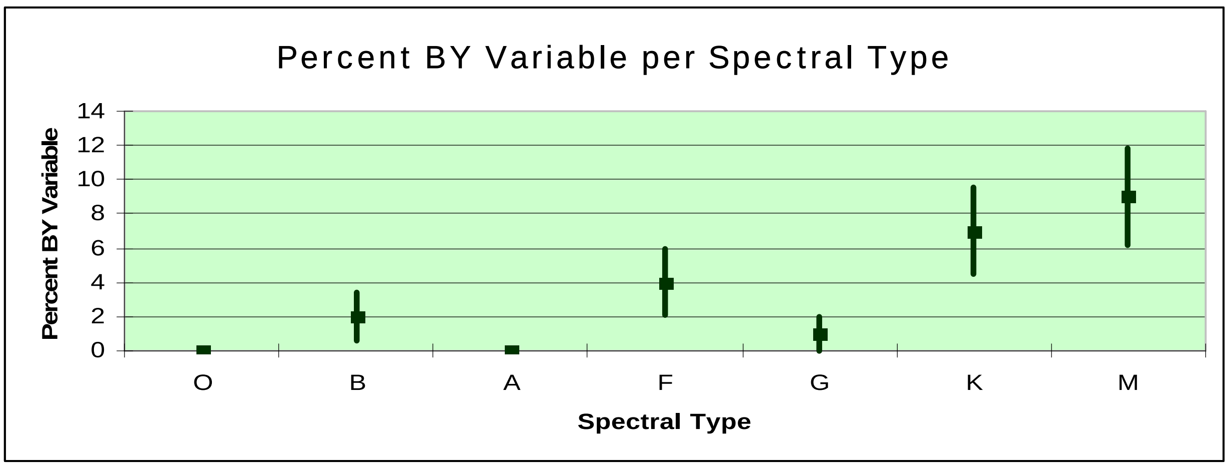
If stars of lower mass (spectral types closer to K and M) are tested against stars of greater mass (spectral types closer to O and B), it will be found that the lower mass stars, particularly type M, will yield greater potential for star spots due to their intense convective magnetic activity relative to stars of greater mass.

Method:

A list of x-ray emission sources from the X-Ray Master Catalog[1] was organized by spectral type (High Energy). A sample of 100 stars in each type was narrowed by cross-examination with the GCVS Variable Star Catalogue, eliminating all the x-ray emission sources that were not of the BY variable type (Samus). To do this, the each x-ray source was searched for in the variable star catalog by their coordinates, with a search radius of 120 arcseconds to account for possible imprecision in location. Then the ratios between the number of BY variable stars per a specific spectral type and the number of x-ray emission stars in the sample for that spectral type were recorded.

Results:

The results for this experiment are exhibited in the following graph:



1 The X-Ray Master Catalog is a compilation of entries from the following databases: XRBCAT, HMXBCAT, MAGHMXBCAT, LMXBCAT, ULXRBCAT, BAXGALCLUS, A2PIC, HEAO, 1 A4, EMSS, HRICFA, HRIDEEP, IPC, IPCDEEP, IPCOSTARS, IPCSLEW, LMCXRAY, SMCXRAY, IPCULTSOFT, EXSS, EINSTEIN2E, EINOPSLGAL, EINGALCAT, EINGALCLUS, CMA, EXOHGLS, RASSBSC, ROSATSRC, WGACAT, RBS, LMCHRIXRAY, SMCROSXRY2, ROSPSPC, RASSHGSOFT, RASSFSC, CHASFRXRAY, LMCROSXRAY, SMCROSXRAY, RASSCNS3, ROSHRI, ORIONXRAY, RASSWD, RASSOB, M31ROSXRAY, RASSDWARF, ROSATRLQ, ROSATRQQ, RASSGIANT, DXRBS, PLEIADXRAY, BMWHRICAT, REFLEX, RASSNORSAM, HRASSCAT, RIXOS, NORAS, RASSDSSAGN, RASSEBCS, ROSGALCLUS, RBSCNVSS, ROSNEPAGN, ASCAGIS, ASCASIS, TARTARUS, ASCAGPS, ASCALSS, SAX2TO10, CHANDFN2MS, CHANDFS1MS, CHANSEXSI, CLASXS, M31CXOXRAY, M33CXOXRAY, HANEXTDFS, XMMSSC, XMMGPS, M31XMMXRAY, M33XMMXRAY, XMMCFRSCAT, XMDSVVDS4, and XTEASSCAT

In this graph, it is evident that the spectral type M exhibited the highest number of BY variable stars, with spectral type K following in second. Spectral types F, B, and G contained lower numbers of BY variables respectively, and spectral types O and A contained none.

Discussion:

The results clearly show that lower mass stars are more prone to starspots, thus supporting the hypothesis. Lower mass stars demonstrate a greater magnetic activity in the convective envelope, a layer which dissipates as mass among stars increases (Darling). However, deviations from the hypothesis occur with study of the results from other spectral types, especially B, A, and G. Per the hypothesis and other known features of trends among spectral types, the number of BY variable stars was expected to gradually increase from O to M. However, this trend was not the case in the aforementioned spectral types. This surprising result could be due to experimental error. While the sample was a sizeable portion of the known x-ray emission stars, it cannot be avoided that any sample size, unless it is that which includes every star in the available data, will not be an entirely accurate representation of the greater database. It could be that, by coincidence, the stars chosen were tended to be or not be of the BY type, thus giving a skewed idea of the spectral type. It is also possible that the variation in brightness due to starspots, especially in already faint spectral types K and M, was so small that it was not recorded in the variable star catalog. This would result in these types being underrepresented, again skewing the results. To account for these potential errors, uncertainty was calculated for each spectral type.

To further this experiment, the next step would be to obtain data from a larger sample size. Several variable star catalogs could be used to prevent underrepresentation due to undetected BY variables. As mentioned before, starspots are key to understanding the movement and composition of stellar bodies. With these results, later experimenters will know whether or not a particular star is likely to have starspots, an intrinsic potential study point that promises certain key answers about the star in question. Analysis of starspots can easily yield the rotation rate of a studied star by recording their movement. The results of this experiment can be used in subsidiary experiments of that nature.

Conclusion:

The hypothesis, which was that spectral type M would have the highest tendency to exhibit starspots, was supported by the final result of this experiment. Also, the expectation that there would be an overall upward trend in number of BY variables as stellar mass increased was generally fulfilled.

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