Introduction

The emission feature in the core of the Ca II K line is one of the most extensively researched chromospheric lines in the optical spectra of late-type stars. The Ca II K line profile of a red giant exhibits several features (Smith, 1997). These features are designated K1 - the minimum point in the photospheric component of the line; K2 - the double-peaked emission feature caused by the re-absorption of light by the chromosphere and K3 the reversed core of the emission profile (Figure 1). Often the two maxima in the K2 emission are not of equal strength. The asymmetry of these lines is frequently described by the V/R parameter of Wilson (1976). The V/R parameter as described by Wilson (1976) is the ratio of the left peak (K2V) in K2 emission with the right peak (K2R) and can be classified as being <1, 1, or >1 depending on which peak has more intensity. Although the interpretation of this asymmetry can be complicated (Linsky, 1980), an asymmetry of V/R<1 is often considered to be an indication of outflow within the chromospheric region (e.g., Chiu et al. 1977; Stencel, 1978; Drake & Linsky, 1983). Inspection of the Ca II K line of red giants can therefore be used to investigate the onset of mass outflows within their chromospheres.

The most extensive study of the Ca II K emission line among red giants is that of Wilson (1976) who measured the profile widths and V/R asymmetries from Mount Wilson photographic coudé spectra of giants selected from the Bright Star Catalog. An inspection of the Mount Wilson data was conducted by Stencel (1978) and Stencel & Mullan (1980) who concluded that a "dividing line" exists in the H-R diagram, which separates yellow giants with V/R > 1 from late K and M giants with a V/R < 1. V/R ratios of red giants found by Smith (1997), Smith & Shetrone (2000) and Smith & Shetrone (2004) show that Stencel's dividing line is not a rigorous boundary instead more of a transition zone. They found that some giants cooler than a B-V = 1.35 appear to have V/R > 1. Using Arcturus as a model they discuss the possibility that the reason the "dividing line" is not a rigorous boundary is due to its intrinsic stellar variability. Arcturus with a B – V = 1.23 was found to have a variable Ca II K asymmetry with a range of 0.8 ≤ V/R ≤ 1.05 (Gray, 1980). Thus, if Arcturus is typical of other giants near the V/R transition temperature, then such stars might also show temporal variability in their asymmetries. Temporal variations in other stars might account for why some stars do not follow the trend of the "dividing line". However, Smith & Shetrone (2004) also point out that Arcturus is of spectral type K. Thus it might not be representative of any variability of G giants. Our aim is to do a more quantitative study of the V/R ratio of both K and G field red giants whose B-V are close to the "dividing line" to monitor any temporal variability.

For this paper, thirty-one field red giants were monitored using data spanning from July 1998 to August 2007. Fourteen stars previously investigated by Smith and Shetrone (2000) are included in our sample.

Other features in the Ca II K line were also quantified to further understand the origin and behavior of this spectral line. The K2 asymmetry was additionally monitored for the H line to compare our results.

Observations

High Resolution spectra of the Ca II H and K lines have been acquired at McDonald Observatory for a sample of 31 field red giants whose B-V's range from 0.89 – 1.46. The spectra was obtained during various observing runs from November 1998 to August 2007 using both the Sandiford Cassegrain Echelle (CE) spectrometer on the 82” telescope and the 2d-coudé spectrometer on the 107” telescope at McDonald Observatory. Spectra from the 2d-coudé spectrometer were obtained during a three night observing run on 2006 October 30 to September 1 and on August 4, 2007.

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Results

Our sample is made up of 31 field red giants. Of the 31 stars observed, one of the stars is an M giant while the rest are G and K giants. Multiple epochs are available for all 31 stars. Two epochs is the minimum amount of epochs within our sample and correspond to the stars: HD140227, HD1522, HD163770, HD203387, HD205435, HD211391, HD3627, HD85444, HD9138, HD93813. Eight epochs is our maximum corresponding to the star HD156283 (π Her). *The distribution of the mean V/R asymmetry for the K line with respect to spectral type is shown in Table #.* The SIMBAD astronomical database was used to find the spectral types of the stars and their binarity status*. *Figure # shows the distribution of mean V/R's vs. B-V for all 31 giants.* A mean V/R > 1 is more frequent in our sample with 14 giants and a mean V/R < 1 is less frequent with 3 giants. A mean V/R = 1 was assumed for stars whose mean V/R equaled to 1 within ± 0.05. Using this criteria there are 14 giants with a mean V/R = 1. Three of the fourteen giants are stars that are either in a double or multiple system and one of the fourteen is a RSCVn. The M giant in our sample, HD140227, has a mean V/R of 1.05 and thus has been classified to have a V/R = 1. *Figure # shows the the MV , B-V color-magnitude diagram for all 31 giants.* All of the giants whose mean V/R = 1 and whose mean V/R <1 have colors B - V > 1.32. With the exception of 2 stars, giants whose B – V < 1.30 have a mean V/R > 1. The two exceptions to this trend HD168454 a K3 IIIa star and HD175443 a K4 III star have a B-V = 1.38 and B-V = 1.36 respectively. Our results compare to those of Stencel (1978), who found that a Ca II K asymmetry of V/R < 1 becomes dominant among giants of spectral type K4-K5, which corresponds to B-V ≈ 1.3-1.4 (Bessel 1979). If we use either the minimum or maximum V/R's instead of the mean, some of the features of the CMD change while others are still pretty consistent. When the minimum V/R was used it was found that stars that have a V/R ≤ 1 had a color 1.22 < B-V < 1.46. Two out eight stars that have a V/R > 1 have a color 0.89 < B-V < 1.03. Including the two stars the color range is 0.89 < B-V < 1.28. The two giants that do not follow the trend are HD3627 and HD93813. When the maximum V/R was used, giants who have a V/R < 1 have a color 1.36 < B-V < 1.40 and giants with a V/R = 1 have a color 1.33 < B-V < 1.40. Giants with a V/R > 1 have a color 0.89 < B-V < 1.46. The data indicate that the giants that have V/R ≤ 1 lie toward the left of a B – V > 1.22. Whereas, giants whose V/R > 1 are spread out though out the CMD.

To determine quantitatively if there is any variability in the Ca II K line asymmetry, the V/R ratios of the giants were calculated for all available epochs. Data spanning from July 1998 to August 2007 was used for the calculations. Out of the 31 giants, eleven do not show any variability within 1σ error, six do not show any variability within 2σ error and fourteen do not show any variability within 3σ error. Stars that are constant within 3σ error we consider to have variable asymmetries. Six out of the eleven giants that do not show any variability within 1σ, have only two epochs available. Out of the eleven one is a spectroscopic binary and one is the RSCVn. One of the six stars that are constant within 2σ has only two epochs and one of the six is the other spectroscopic binary in our sample. Four of the fourteen that are constant within 3σ only have two epochs and five of the fourteen are stars that are in either a double or multiple system. The two stars HD168454 and HD175443 that were mentioned before that have a mean V/R > 1 but have colors B-V > 1.31 are among the stars that are considered to have variable asymmetries. For the star HD168454 the asymmetry was calculated from 7 epochs spanning almost 3 years. It has a minimum V/R=0.94 and a maximum V/R=1.23 with 4 of the epochs having a V/R > 1. HD168454 is also one of the stars in a multiple system. For the star HD175443 the asymmetry was calculated using 3 epochs spanning also 3 years with two of the epochs having V/R's < 1. It has a minimum V/R=0.98 and a maximum V/R=1.38. Both of their V/R's change from being >1 to < 1. There is the possibility that the V/R's for HD175443 that we calculated are not the absolute minimum that the star can have. Thus, it could be that when the star is at its V/R minimum (V/R <1) it follows the trend set by the 'dividing line' (Stencel, 1978) and when its V/R is at a maximum (V/R > 1) it deviates from this trend. This concept was shown in the color magnitude diagrams above. Because the asymmetry of the Ca II K line can be variable with time the dividing line is not a set relation. Instead it can be considered as a transition zone (Smith & Shetrone, 2004). Smith & Shetrone (2004) using Arcturus as a model proposed the idea of intrinsic stellar variability to explain why the dividing line in an M_V versus B-V CMD might be fuzzy. The Ca II K asymmetry for Arcturus was monitored temporally by Gray (1980), who found that it to be variable with a V/R ranging form 0.8 to 1.05. Thus, Arcturus with a B-V=1.23 follows the dividing line trend when it's at a V/R maximum and deviates from the trend when it's at a minimum. *Table # has a list of all the giants that were found to be variable.*

The Ca II H line is another chromospheric line that can also be characterized by Wilson's (1976) V/R parameter. The H line is less deep than the K line and thus is preferably not used for calculations of the V/R parameter. However, the H line can still be representative of any variability. Thus, to try to verify our results we also measured the V/R parameter for the H line. For some of the stars the V/R for the H line was not calculated due to either low S/N or corruption (i.e. cosmic rays) in the spectral line. It's also important to note that because the H line is less deep than the K line it has a different atmospheric sensitivity. Thus, the V/R values for the H line can possibly deviate by a small amount from the K line values. With this in mind, for the majority of the stars, the mean V/R for the H line within error was found to be higher than the V/R ratios for the K line. *Figure # shows a plot of the V/R values for the K line versus the V/R values for the H line.* A scatter in the values is present in the area between a 0.85 < V/R (K) < 1.15. A linear correlation between the values is observed.

I hesitated to write more about this plot without consulting with you first. I also did not add anything on the plots that Graeme had me do because I haven't heard from you guys about that yet. Feel free to add comments that are pertinent to this discussion.

Other features in the Ca II K line

Other features of interest in the Ca II K line are the width of the K1 feature in the core of the line, the depth of K3 and the width between the K2 peaks. For this paper, the widths between the K2 emission peaks and the depth of the re-absorption have been measured to further study the different features of the Ca II K line. *Figure # shows a plot of depth of K3 versus B-V.* Inspection of the plot shows that there is a minimum depth (z = 0.018) for K3. None of the stars show a depth lower than this. *Please Expand a little on this subject……….* A plot of the K1 width versus K2 width shows a linear correlation. The wider K1 becomes the wider K2 also becomes.

Measurements of the K1 feature have previously been conducted by Wilson and Bappu (1957). By measuring the width of K1 and applying the Wilson-Bappu effect, Wilson and Bappu (1957) derived M_V for the stars in their survey.

Discussion

I left this open because I wanted some feedback from you and Graeme first.