Activity and Variability in M Dwarfs
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Introduction
We investigate the connection between activity and variability in a large sample of M Dwarfs for which we have approximately 75 repeat observations. We used 9 years of five-band photometric data for over 25,000 spectroskopically observed M dwarfs in the Sloan Digital Sky Survey (SDSS) Stripe B2.

Activity:
We use H-alpha emission as the indicator for magnetic activity strength. At $\lambda = 6562.8$ Å, this line is caused by the ionization and recombination of hydrogen in a star’s chromosphere.

Variability:
As stars rotate, their magnetic fields twist and cause disturbances on the surface. These spots are cooler than the surrounding surface, which results in varying brightness. A star’s light curve will reflect the changes in magnitude, and we use the Median Absolute Deviation (MAD) to quantify this.

Statistics
MAD depends only on the median, which is necessary as we expect outliers in our data in the form of flare events.

$$\text{MAD} = \text{median}(\{x_i - \text{median}(x_i)\})$$

In Figure 1, a sample light curve for an M0 star is plotted, with the MAD calculation shown visually. This star has a trend of long term variability, while we are more interested in short term variation.

To account for the long-term variability, we took the average of each year’s MAD values to represent short term variation in each M dwarf’s variation.

Data and Analysis
Using the $g$ and $r$ band to increase the contrast between the surface and the spots on the star, we plot the equivalent width of the H-alpha emission (EWHA) against the AVG MAD for each star in a given spectral type. We find that for early spectral types (M0-M2), stars with high levels of activity show larger amounts of variability. These results are shown in Figure 2. In the binned graph, we also plot the variation of the inactive stars for comparison. For the mid-type M dwarfs (M3-M5), we find that as the magnetic activity increases, the variability decreases. The results are shown below in Figure 3.

Methods
We make five significant cuts to obtain statistically significant results in our sample. These cuts are:

- **noise** – We require the MAD and the standard deviation of the brightness to be greater than the median error of each measurement.
- **activity** – Stars are classified as active or inactive based on our criteria, or removed altogether from the sample if neither description fits.
- **limiting magnitude** – SDSS has a limiting magnitude of 22.2 for both the $g$ and $r$ bands.
- **number of observations** – Each star needed to have at least 20 photometric observations.
- **2nd noise cut** – We required both the MAD and the Average MAD to be greater than the median error of each brightness measurement.

Discussion
Our results show in mid-type M dwarfs, as activity increases the variability decreases. This is important for possible exoplanet transits, where the decrease in brightness would be significantly smaller than spot variation. We also find that early-type M dwarfs show a larger fraction of possible activity cycles, where their variability changes during the 9 years of observations.

Acknowledgement
This project was sponsored by the Department of Astronomy at Boston University and funded by a grant from the National Science Foundation [NSF].