The NUV Flare Rate of the Galaxy

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Background: Flares from magnetically active M dwarf (dMe) stars produce continuum radiation in the near-ultraviolet (NUV) at wavelengths < 380 nm that increases the flux from the entire star by over 100 times during stellar ``megaflares'' (Kowalski et al. 2010). The large contrast in the NUV also makes flare detection viable down to the low energy ``microflare'' regime (Robinson et al. 1995). The NUV wavelength range is critical for understanding the heating mechanism that produces the white-light continuum, which is the least understood but most energetically important phenomenon in solar and stellar flares. The NUV continuum is also important for characterizing biosignatures in planetary atmospheres around M dwarfs. Models show that the NUV flare continuum affects the non-equilibrium atmospheric chemistry and biosignatures in Earth-like atmospheres around active M dwarfs (Segura et al. 2010, Venot et al. 2016).

The rate of low-to-medium energy flares increases in later M dwarf spectral types (M5-M6s), in part due to the larger `flare visibility' against the background emission and in part due to the higher non-flaring activity fraction for later types (West et al. 2008, Kowalski et al. 2009). Early type (M0-M2s) active M dwarfs produce a larger fraction of their flare energy in high energy flares. However, the flare rates of early-type stars have been determined for one active M0 system (YY Gem) which is an interacting binary (Lacy et al. 1976). Mid type active M dwarfs (M3-M4s) straddle the boundary at which stars become fully convective; they flare frequently and energetically. Recent results from Kepler have shown that there is a continuum of flare frequencies among mid-type active M dwarfs (Hawley et al. 2014), meaning that one star cannot be used as a proxy for the flare properties of a spectral class. We hypothesize that there is a range of non-flaring activity levels (as diagnosed by whether H-alpha is in emission) that can be used as a proxy of the flare frequency. Even inactive M dwarfs (those without H alpha in emission) show other activity indicators and are known to produce flares on occasion (Paulson et al. 2006, Kowalski et al. 2009).

The rate of NUV flares from M dwarfs as a population has previously been characterized as a function of spectral type and activity level from serendipitous observations from the Sloan Digital Sky Survey (SDSS) Stripe 82 (Kowalski et al. 2009). However, the observations sampled a flare once (the observations were obtained once every 2 - 3 days) and thus the flare energy was not well constrained. Also as a result of the cadence, many stars flared only once, and all stars of a given spectral class had to be binned to increase statistics. The red leak in the SDSS u-band limited all flare detections to an increase in flux by a factor of two which resulted in a significant bias for detecting flares on later types. Recently, Gezari et al. (2013) detected 53 flaring M dwarfs in the GALEX Time-Domain Survey (TDS). The GALEX data are better suited than the SDSS data for flare rate studies because there is large flare visibility at all spectral types for the NUV band. We have proposed for APO 3.5m / DIS spectral observations of these stars to determine their non-flaring spectral characteristics so that we can determine the flare frequency distribution of early dMs, the flare frequency of mid-to-late dMs as a function of non-flaring magnetic activity level, and the flare frequency as a function of vertical distance from the Galactic Plane (which is used as a proxy for stellar age).

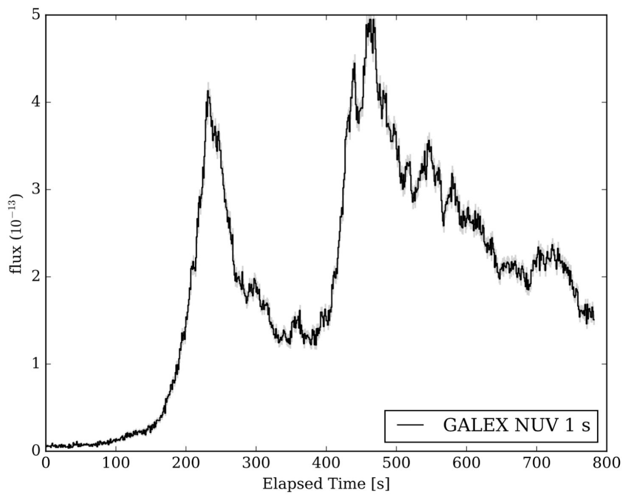

Figure 1 - GALEX NUV Light curve of a large flare on the dM4e star GJ3685A (Robinson et al. 2005).   This is the largest flare in GALEX. We used the gPhoton tool to process the time-tagged data and bin to 1 second.

Project description: The recently released gPhoton tool (Million et al. 2016) will be used to process the time-tagged data of the 53 flare stars from the GALEX TDS to characterize the flare properties (energy, peak luminosity, decay time) on timescales as short as 1-10s. An NUV light curve of the largest flare in GALEX is shown in Figure 1 (Robinson et al. 2005). Using the optical spectra from APO, we will measure the flare frequency as a function of energy, spectral type, non-flaring magnetic activity level as diagnosed by H alpha emission with an equivalent width > 1 Å. The flare rates will be compared to the results from the Sloan Digital Sky Survey. The rates of flare transients in LSST will also be constrained.

NUV/FUV ratios for the peak of all flares will be compared to radiative-hydrodynamic model predictions with the RADYN flare code. The NUV/FUV ratios of the flare in Figure 1 are very large, which is challenging to explain using blackbody-like emission with T~10,000 K that has been used to explain the continuum at longer wavelengths. Thus, we will gain important insight into the the physical origin of the (white-light) continuum emission, which constitutes the majority of the flare radiated energy. The NUV/FUV ratios will also be compared to recent observations of solar flares with IRIS.

References

Gezari, S. et al. 2013 ApJ 766, 60
Hawley, S. et al. 2014 ApJ 797, 121
Kowalski, A. F. et al. 2009 AJ 138, 633

Kowalski, A. F. et al. 2010 ApJ 714L, 98
Lacy, C. et al. 1976, ApJS 30, 85
Million, C. et al. 2016, arXiv 160909492
Paulson, D. et al. 2006, PASP 118, 227
Robinson, R. et al. 2005, ApJ 633, 447
Robinson, R. et al. 1995, ApJ 451, 795
Segura, A. et al. 2010, AsBio 10, 751
Venot, O. et al. 2016 ApJ 830, 77
West, A. et al. 2008 AJ, 135, 785