A survey of long-term X-ray variability in cool stars

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X-ray variability in cool stars can be indicative of coronal magnetic field changes and reconfiguration from a variety of phenomena, including flare events (typical timescales of minutes – hours), active-region evolution (hours – days – weeks), rotational modulation (hours – days – weeks), and activity cycles (years – decades). As part of the EXTraS project (Exploring the X-ray transient and variable sky – http://www.extras-fp7.eu/), we have performed a systematic survey of long-term’ X-ray variability using the ~decade-long public database of XMM-Newton observations. We are thus focusing here on timescales from ~a day to ~a decade, using average flux values from individual XMM-Newton observations. Though the resulting sampling is often highly non-uniform in time, the light-curves can provide valuable insights into the magnetic activity outside of shorter-term flaring episodes. We have taken a number of stellar samples and evaluated the statistical properties of the flux distributions, and compared these across, for example spectral type, and with previously-published estimates. We have also examined the potential effects of flare events on the apparent long-term variability estimates. We report here on overall variability distributions and extreme cases, focussing on serendipitously-observed samples (yielding, in some sense an unbiased sample).

Previous stellar X-ray surveys (see e.g. DeWarf+ 2010, ApJ, 722, 343; Robrade+ 2012, A&A, 543, A84; Hoffman+ 2013, ApJ, 759, 145; Sanz-Forcada+ 2013, A&A, 553, L6; review by Güdel 2004, A&ARv, 12, 71) have indicated long-term variability generally <~factor 2 – 3, with a few examples at ~5 – 10. Measured levels of variability have often been dependent on photon-energy band, with emission at higher photon energies more variable than lower energies (i.e. high-temperature material exhibiting more variability than lower-temperatures). In several cases activity cycles have been reported.

Results: example distributions & statistics

Summary of long-term variability from SIMBAD sample

- [R = max_flux / min_flux]
- ~650 F – M stars
- F, G, K stars: median ~1.7 [Fig.2, curve 3]
- M stars: median ~2.6 [Fig.2, curve 4]
- Typical variability amplitude, factor ~2 – 3
- M stars appear to show more variability than F – K (though possible effects of short-term variability not yet fully investigated)
- Short-term variability adds significantly, but does not appear to dominate, the measured long-term variability distributions, increasing the median R by factor <2 (Fig.2). In general, the effects of short-term variability can be separated from the longer-term.
- For a set of non-variable sources, we have determined by simulation that R_median ~1.2 (indicated by the vertical dashed line in Fig.2).
- We see cases where apparent long-term variability is due to short-term flaring and cases where there is no detectable short-term enhancement (Fig.3).
- Potential for statistical studies of activity cycles & active-region evolution (serendipitous data likely too sparse for detection of individual cycle periods)

Results: individual [extreme] cases

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