

QPPs in XMM flares from 2XMM-Tycho catalogue

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XMM-Newton flares

A&A 581, A28 (2015) DOI: 10.1051/0004-6361/201526217 © ESO 2015 Astronomy Astrophysics

A survey of stellar X-ray flares from the XMM-Newton serendipitous source catalogue: HIPPARCOS-Tycho cool stars^{*,**,***}

J. P. Pye¹, S. Rosen¹, D. Fyfe¹, and A. C. Schröder^{1,2}

- Launched 1999
- Mission extended until end of 2018
- 3 Main Instruments:
 - European Photon Imaging Camera (EPIC)
 - Reflection Grating Spectrometer (RGS)
 - Optical Monitor (OM)





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European Photon Imaging Camera (EPIC)

- Two of the cameras are MOS (Metal Oxide Semi-conductor) CCD arrays.
- EPIC-pn camera.
- Energy range 0.15-15 keV.



- All EPIC CCDs operate in photon counting mode.
 - Register position, arrival time and energies.



2XMM Serendipitous Source Catalogue

- Largest X-ray source catalogue every produced
 - 3491 XMM-Newton EPIC observations made between 2000 February 3 and 2007 March 31.
 - 246897 X-ray source detections which relate to 191870 unique X-ray sources.
- Since extended as 2XMMi, 2XMMi-DR3, 3XMM-DR4.
- OM (optical) data available for some sources.



Pye et al. (2015)

- Tycho-2: HIPPARCOS positions, proper motions & 2-colour photometric data for 2.5million brightest stars in sky.
- Joint 2XMM-Tycho catalogue generated by matching sky positions.
- Automated search for variability in XMM light curves – some of which are flares.
- Flare parameters from XMM light curves for stars in Tycho-2 catalogue.
 - Rise time, fall time, luminosity, energy



XMM-Tycho catalogue

Table 1. Summary of the 2XMM-Tycho survey characteristics.

Quantity	2XMM-Tycho	
-	All	Cool stars
No. of Tycho stars in 2XMM fields	$\sim \! 26000$	~ 19000
No. of 2XMM sources matched with Tycho stars	3042	2357
No. of 2XMM detections matched with Tycho stars	4772	3499
No. of 2XMM sources with light-curves	808	611
No. of detections with light-curves	1393	933
No. of X-ray variable sources/stars	123/120	91/89
No. of variable light-curves	157	118
No. of variable light-curves after quality checking	128	96 ^a
No. of X-ray variable stars after quality checking	85	76 ^a
2XMM summed viewing time (Ms) on Tycho stars:		
for all detected stars ^b	119	87 (82)
for all cool stars with X-ray light-curves		29 (24)
for all stars with X-ray variability ^a		3.9 (1.8)
for all stars with flares ^a		3.0 (1.4)
for all stars with fully-observed flares ^a		2.6 (1.2)
for all stars with flares, $S:N > 10^a$		2.1 (0.62)
for all stars with fully-observed flares, $S:N > 10^a$		1.9 (0.58)

F0 or later

CESA Souther of a

XMM-Tycho catalogue

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F0 or later

Variable sample

• 80% X-ray variable stars show flares

Variability	Sample	Number	Number of	Number of events	
type		of stars	light-curves	Total	Completely
					observed
Flare	CVS	63 (30)	76 (32)	133 (39)	116 (34)
	CLVS	8 (4)	8 (4)	11 (4)	11 (4)
	CVS+CLVS	70 (34)	84 (36)	144 (43)	127 (38)
Trend	CVS	10(1)	11(1)	11(1)	
Gradual	CVS	3 (1)	3 (1)	3 (1)	
	CLVS	1 (0)	2 (0)	2 (0)	
Indeterminate	CVS	6 (5)	6 (5)	6 (5)	
	CLVS	2 (0)	2 (0)	2 (0)	
Poor bgd sub? ^a	CVS	2 (0)	2 (0)	2 (0)	
All	CVS	76 (36)	96 (39)		
	CLVS	11 (4)	12(4)		
	CVS+CLVS	84 (40)	108 (43)		



Examples



0.2



EPIC flux (cts/s)

Some results



Searching for QPPs in XMM flares

- We took a subset of the Tycho-XMM database
 - Those with high S/N and long decay phases.
 - Included examples from previous publications:
 Mitra-Kraev et al. (2005),
 Pandey & Srivastava
 (2009), Srivastava et al.
 (2013).
 - 20 flares in total.





Analysis method

- Followed Pugh et al. (2016)
 - Detrend flare with exponential fit.
 - Wavelet & autocorrelation detrended lightcurve.
 - Fit detrended lightcurve with decaying sinusoid
 - Decay either exponential or Gaussian (Pascoe et al, 2016).
 - Perform global fit of flare lightcurve.
- Also detrended flare with spline.
- Would like to incorporate Chloe's new stats.



Example: HD14716

• F5V star, flare energy=2.483×10³³erg



Example: HD14716





ATMic – Mitra-Kraev et al. (2005)

- Binary, two M4.5Ve stars
- Flare energy = 6.322×10^{32} erg





ATMic – Mitra-Kraev et al. (2005)

- Periodicity of 12.349±0.004min in good agreement with Mitra-Kraev et al. → 12.5min.
- In Cho et al. (2016) with P~8.6 and 13.4min



ξ Boo A – Pandey & Srivastava (2009)

- G8V star, binary with K4 dwarf (period ~151yr).
- Periodicity of 1019s.
- Star in Cho et al. (2016).





ξ Boo A – Pandey & Srivastava (2009)

We find no convincing periodicity (1019s~17min)



Proxima Centauri – Srivastava et al. (2013)

- M6Ve flare star.
- Observed periodicities of 1261s (21min) and 687s (11min).
- In Cho et al. (2016) with period ^(*) 11mins.



Proxima Centauri – Srivastava et al. (2013)

• Again no convincing periodicity observed.



EKDraconis – EPIC-pn

- A young (50Myr) solar analog (G1.5V).
- Flare energy = 3.687×10³³erg, cadence=10s



EKDraconis – MOS-1





EKDraconis – MOS-2





EKDraconis

- Statistically significant peak in all 3 data sets.
- Periods from fits: 79.31±0.03min, 83.59±0.03min, 81.69±0.02min, respectively.
- Periods from wavelets consistent.



EKDraconis – split energy bands

- We split the data into 2 energy bands: 0.2-1keV, and 1-12keV, cadence=100s.
- Consistent results for all 3 detectors.



EKDraconis – split energy bands

 Cross-correlation between energy bands: period~80mins & lag = 3.8min



EKDraconis – split energy bands II

• We split the data into smaller, separated energy bands: 0.5-1keV, 4.5-12keV, cadence=200s.



EKDraconis – split energy bands II

 Cross-correlation between energy bands: Period=83min, lag=9min





Conclusions

- The XMM-Tycho catalogue is a good source for QPP flares.
 - Study needs extending to include all flares in Pye et al (2015) and 3XMM sources.
 - Incorporate Chloe's statistical analysis.
- See QPPs in a flare on EKDra
 - Significant periodicity of ~80mins found.
 - Longer periodicity in higher energy band.
 - Hint of a lag in pulsation?



New project: Kepler-XMM overlap

- 90 sources in Kepler & XMM data.
- 27 classed in Kepler database as 'rotationally variable stars'
- 49 XMM sources observed during Kepler period.
 - 8 likely overlaps i.e. observed at same time.
 - At least 1 flare included in overlap.

