Zeta Pup variability revisited

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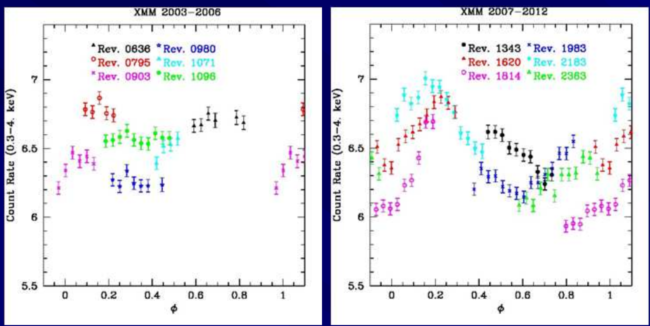
Introduction:

- Massive stars' winds are unstable → shocks, hence stochastically varying X-ray emission
- Previous XMM observations of ζ Pup revealed no stochastic variations beyond noise → many, many clumps in the wind
- They also unveiled some longer-term changes (trends >1d) *(Nazé et al. 2013)*
- Such variations are seen in other O-stars : λCep *(Rauw et al. 2015)*, ξ Per *(Massa et al. 2014)*, ζ Oph *(Oskinova et al. 2001)*
- Similarities exist with the optical/UV variability associated to CIRs (corotating interaction regions)
- A period of 1.78d, possibly associated with the launch of CIRs, was identified for ζ Pup in the optical domain *(Howarth & Stevens 2014, Ramiaramanantsoa et al. 2017)*



Results: *(Nazé et al. 2017, A&A, submitted)*

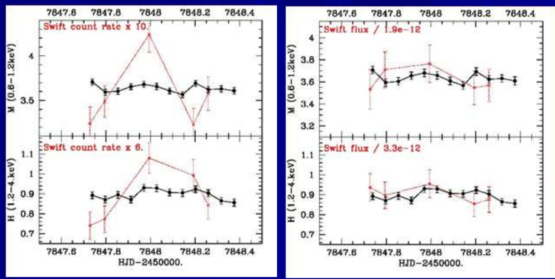
1. Lightcurves
   - Overall amplitude of variations : ~20% peak-to-peak (XMM)
   - Largest in medium energy band (0.6-1.2 keV)
   - Amplitude & shape change from year to year
2. Spectra MIN/MAX
   - Comparison of spectra at extreme brightnesses
   - Moments of RGS lines: compatible within errors
   - Global fits to pn spectra : compatible within errors
   - → Only flux changes !

Data:

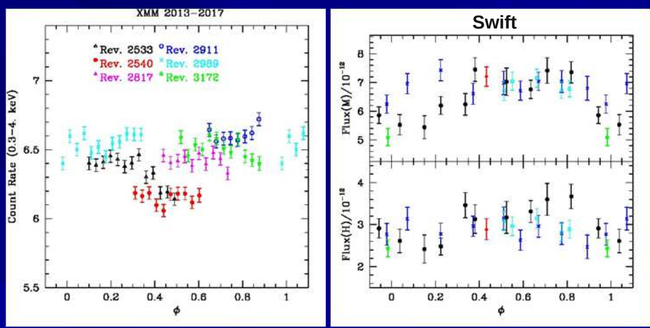
- XMM regular calibrations: pn data in SW mode + thick filter, RGS data, reduced with SAS v15, filtered for flares (& for pattern/flag=0 for pn)
  → lightcurves (5ks bins, SMHT energy bands)
  → spectra @ extreme brightnesses
- Swift dedicated monitorings + calibrations: XRT in WT mode, reduced with heasoft v 6.8, considering only grade=0 & E>0.5keV
  → lightcurves (exposure=1 bin, MH energy bands)
  → spectra (fitted considering energy offsets)

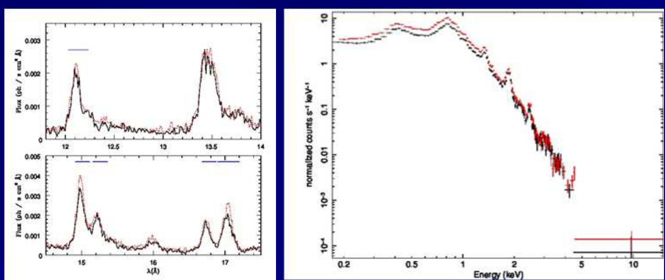
Are Swift data reliable ? Indeed, ζ Pup is very bright → optical loading? Simultaneous observations with XMM in April 2017 show that there are no problem, especially for spectra…

Evolution with time of XMM pn count rate in April 2017 (black points/lines), compared to the simultaneous Swift lightcurves (arbitrary scaled, red crosses/lines) derived from count rates (left) or fluxes resulting from the spectral fitting (right).



XMM and Swift lightcurves, phased with ephemeris from Howarth & Stevens (2014) to simplify comparison



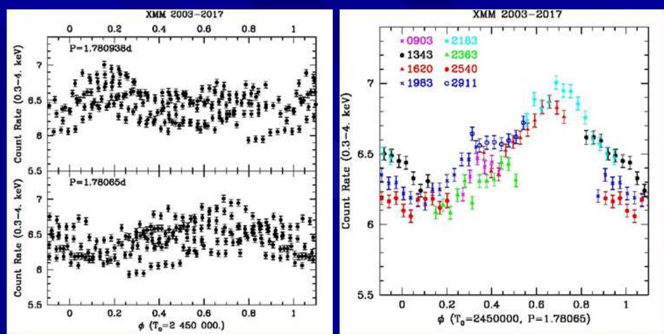


RGS (left, zoom on some lines) and pn (right) spectra taken at minimum (black) and maximum (red) brightnesses: there is no change in spectral shape!

Results:

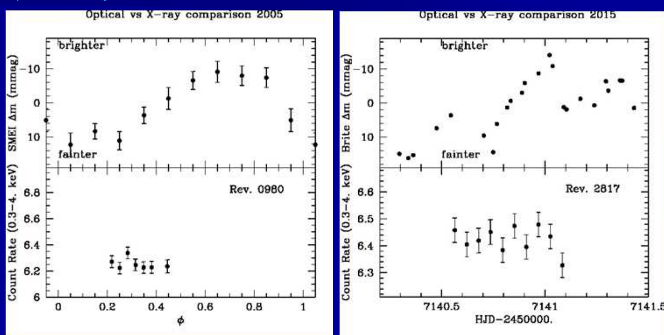
3. Phasing
   - Scatter if all data considered!
   - A subgroup of observations can be combined into a coherent behaviour with P = 1.78 d BUT it's not a continuous group (intercalary observations don't fit!)
4. Correlation with simultaneous optical data
   - SMEI (2004-2006) & BRITE (2015-2017) data available
   - Sometimes it (anti-)correlates, sometimes it doesn't…
   - →No clear link!

Current data unable to securely demonstrate a link between X-rays and CIRs.



XMM data phased with Howarth & Stevens period or a slightly different one (compatible with Ramiaramanantsoa et al. 2017) for all observations (left) or a subgruop of them (right)

Comparison between XMM and optical (SMEI-left, BRITE-right) data taken simultaneously – one can use either the raw optical data (right) or the mean optical cycle at the time (left), which subtracts the stochastic optical variability.



References:

- *Howarth & Stevens 2014, MNRAS, 445, 2878*
- *Massa et al. 2014, MNRAS, 441, 2173*
- *Nazé et al. 2013, ApJ, 763, 143*
- *Oskinova et al. 2001, A&A, 378, L21*
- *Rauw et al. 2015, A&A, 580, A59*
- *Ramiaramanantsoa et al. 2017, MNRAS, submitted*