How good is the clock in X1820-303?

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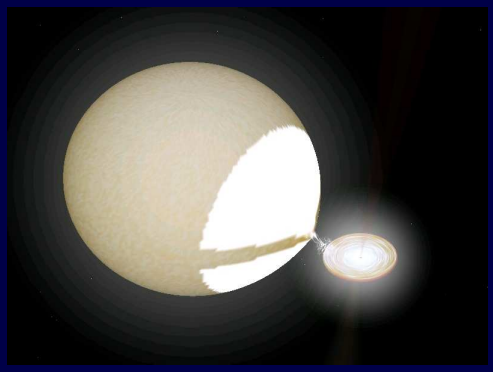
Phil Charles
Silas Laycock
Malcolm Coe

Clarkson et al
2003, MNRAS



The Physics of Ultracompact XRB, KITP

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Ultracompact XRBs, KITP

X1820-303: brief recap

- Ultracompact by any definition:
  - UV period 687.6 ± 2.4s (Anderson et al 1997)
    - Disk rim? (Stella et al 1987) Reprocessing from donor? (aarons & king 1997)
  - X-ray period 685.0144 ± 0.005s (Chou & Grindlay 2001)
    - Stable periodicity: $\dot{P}/P = -5.3 \times 10^{-8}$ yr $^{-1}$
    - ~3% rms amplitude
    - Varying column depth (if high inclination – conflicting models)
  - Bursting LMXB
  - Helium wd donor, $0.06 < M_2 < 0.08\ M_{sol}$
- Evolution:
  - Isolated binary channels (e.g: mass transfer at point of H exhaustion, He star companion, GRW inspiral)
  - Third body capture: red giant or MS followed by CE phase
  - X1820-303 currently the best candidate ultracompact triple

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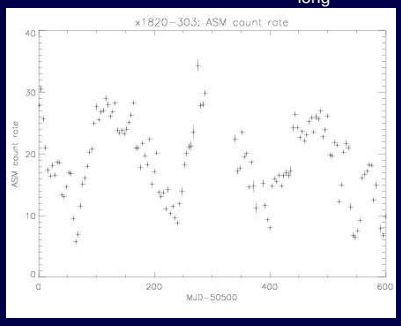
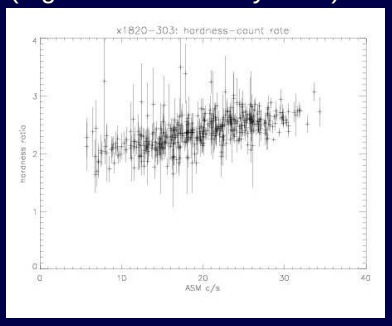
The ~172-day clock

- RXTE/ASM shows P_{long} ~172d (e.g: Chou & Grindlay 2001)





- Anticorrelated with burst state ⇒ mass transfer variation (Stella, Kahn & Grindlay 1984)
- Also present in Ariel 5 dataset (Smale & Lochner 1992)
- Phasing agrees with archival obs to ± 12 days (CG01)

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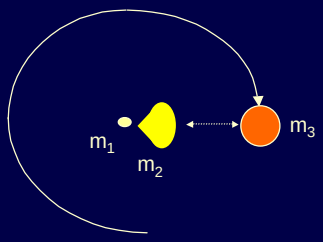
The Triple Model

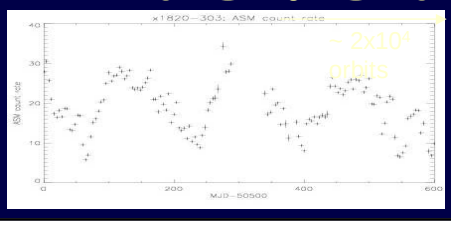
- Passage of third body ⇒ variation of e_{21} ⇒ cycle count rate variation

$$P_{long} = \frac{P_3^2}{P_{21}} f(m_1,m_2,m_3)$$

•m1,m2 well-constrained
•⇒ $P_3(m_3)$ ~ 1 day



~2x10⁴ orbits



•E.g: Mazeh & Shaham 1979; Krymolowski & Mazeh 1999, Ford et al 2000

•Many orbits ⇒ periodicity stable in period and phase

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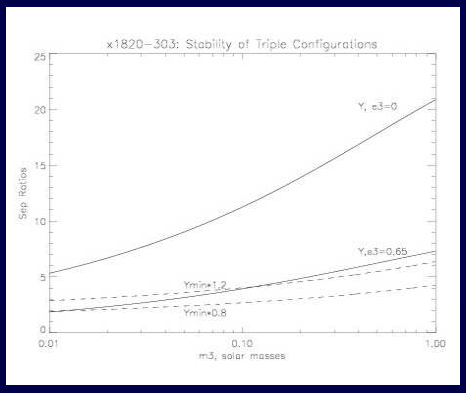
Stability of a hierarchical triple

- Empirical stability criterion (Eggleton & Kiseleva 1995):

$Y > Y_{min}\ (m_1,m_2,m_3)$

$$Y = \frac{a_3(1-e_3)}{a_{21}(1+e_{21})}$$



•Unless $e_3 > 0.65$, triple configuration is stable over 10^4 orbits for all stellar m_3

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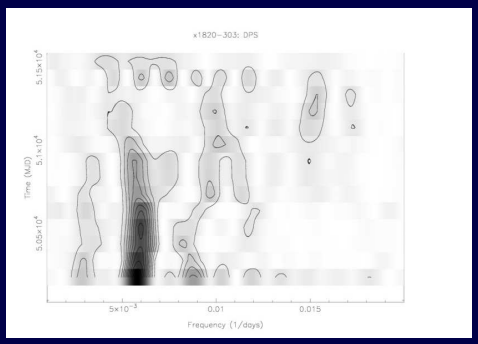
How stable is P_{long}?

- RXTE/ASM 7-year dataset allows time-variability of long periodicities to be traced
- Dynamic Power Spectrum ⇒ P_{long} might be less stable than has been previously thought



RXTE/ASM: random sampling

How significant is this period variation?

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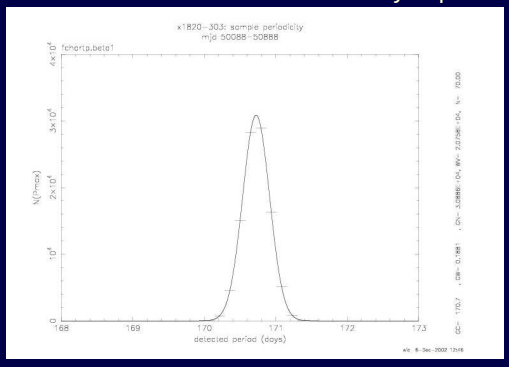
Does P_{long} really vary?

- Compute periodograms of 3 independent data windows

•10^5 simulated datasets: fixed period folds,random sampling
•allows measurement of the accuracy of period detection:



Set	3σ (d)	ΔP_{long}(d)	Significance
1	0.53		
2	1.00		
3	1.97		

$\overline{P_{long}} = 172.97 \pm 0.76$ d

(Historical data give
171.03 ± 0.33 d;
Chou & Grindlay 2001)

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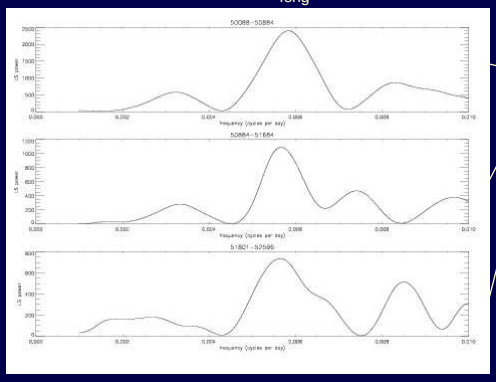
Does P_{long} really vary (2)?

- Compute periodograms of 3 independent data windows

Three independent 800-day windows of the RXTE/ASM dataset show distinct values of P_{long}.



Set	3σ (d)	ΔP_{long}(d)	Significance
1	**0.53**	-1.57	8.7 σ
2	**1.00**	+3.63	11.0 σ
3	**1.97**	-2.07	3.1 σ

$\overline{P_{long}} = 172.97 \pm 0.76$ d

(Historical data give
171.03 ± 0.33 d;
Chou & Grindlay 2001)

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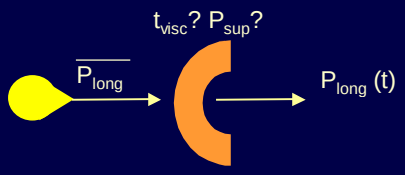
What does this mean for X1820-303? (1)

- Implications for triple system;
  - $\Delta P_{long} \Rightarrow$ >1% change in P_3 if orbital ($P_3 \propto \sqrt{P_{long}}$)
  - *Unless* phase changes not P_3 – but can triple produce this?
- What about disk moderation?
  - •Speculation: internal dissipation variations in disk (e.g: Su Uma) ⇒ mass deposition changes at ns surface



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What does this mean for X1820-303? (2)

- Difficulties with the disk moderation scenario
  - •Speculation: internal dissipation variations in disk (e.g: Su Uma) ⇒ mass deposition changes at ns surface
  - •Problem: in SU Uma systems, Δdiss *not* accompanied by variation in mass throughput
  - •SMC X-1: radiation-driven disk warp ⇒ change in mass throughput? (Clarkson et al 2003 in press)
  - •Warps can generate P_{long} without third body!

Third body unnecessary in this scenario

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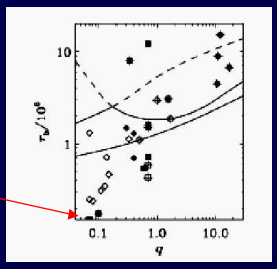
What possibilities are left?

- Superhump scenario has problems:
  - P_{long} 172d ⇒ period difference ~ 30 ms
  - How produce mass transfer rate change?
  - XTEJ1118+480: P_{sup} ~50 days, but P_{orb} 4 hr (Zurita et al 2001)
- Radiation-driven warping not predicted for any ultracompact XRB:



X1820-303

Warping predicted

Warping not predicted

From Ogilvie & Dubus 2001

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What possibilities are left?

- What about other warp mechanisms?
  - Precessing warp ⇒ varying irradiated disk area ⇒ varying mass throughput (composition-dependent)
  - Magnetic warping (Lai 1999, Murray et al 2002)

- Conclusions – interpretations of the changing P_{long}
  (1) Triple – but why the period change?
  (2) The most stable disk variation ever seen…?

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