How to find soon-to-be merging contact binaries?

Ondřej Pejcha

Institute of Theoretical Physics, Prague, Czech Republic

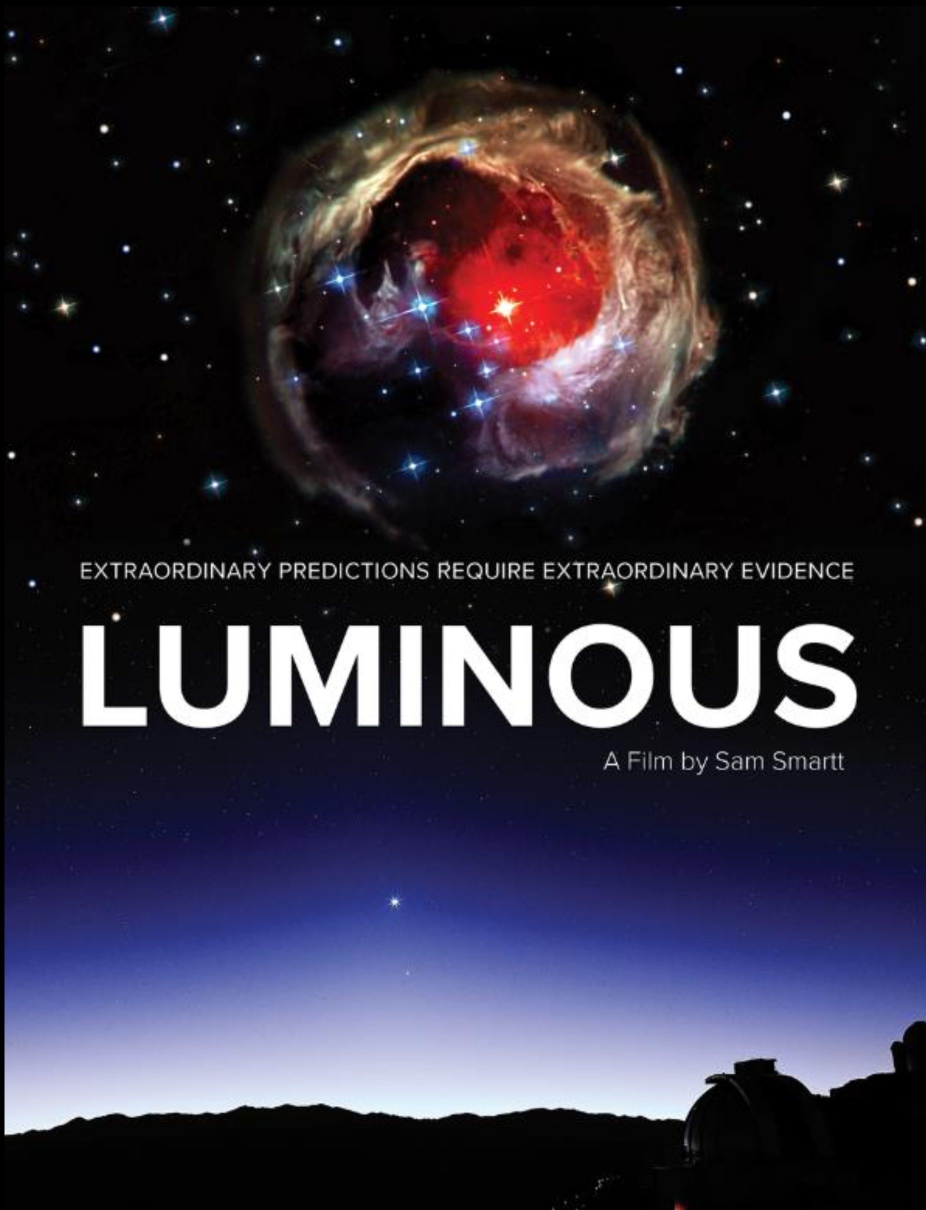
Charles University

GAČR
CZECH SCIENCE FOUNDATION

erc European Research Council

"…a prediction of something completely new, the likes of which have never been seen before."

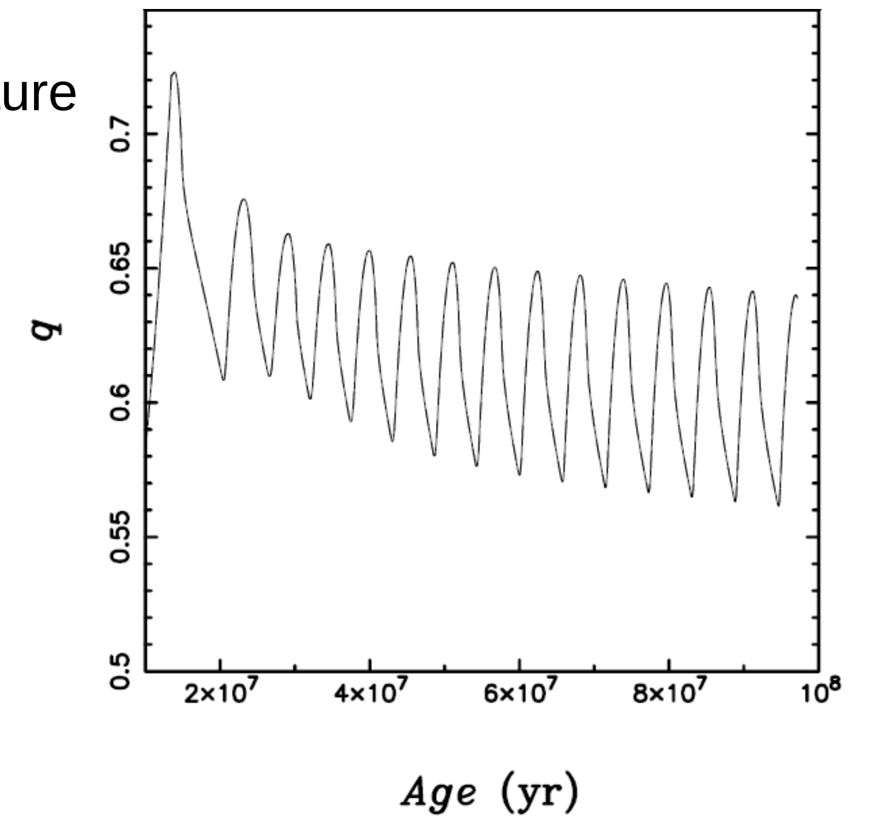
— Owen Gingerich, Professor Emeritus of Astronomy and History of Science, Harvard



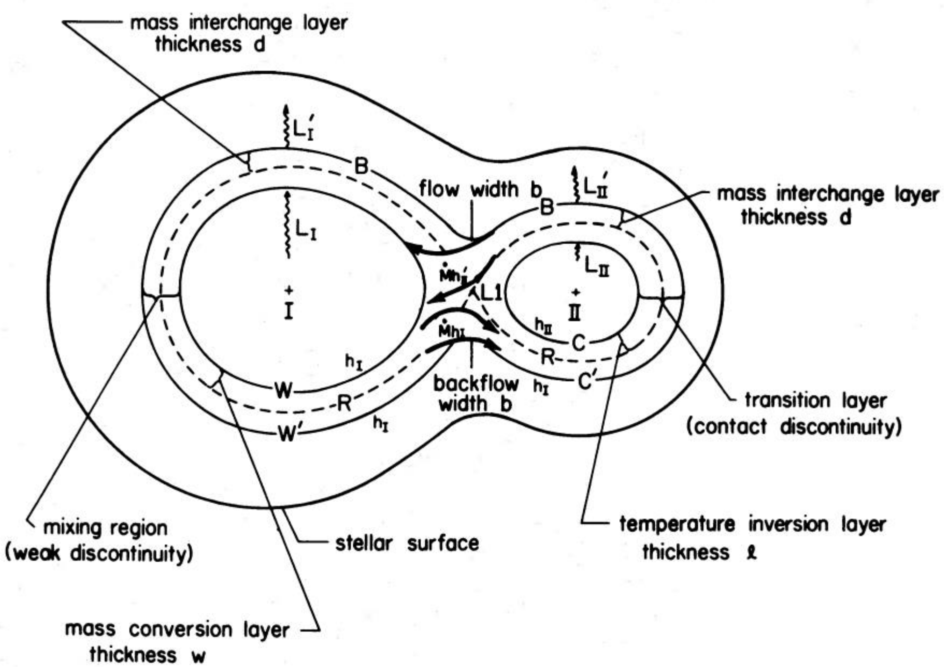
NOW STREAMING!

Contact binaries

- Contact binaries have complicated structure
- Thermal relaxation oscillations
- Evolution to small q

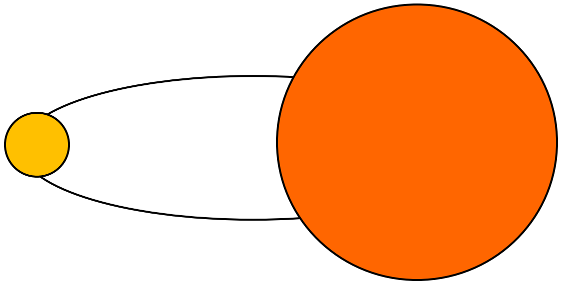


Li et al. (2004)



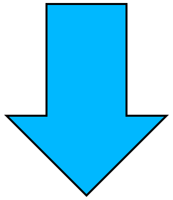
Shu et al. (1979)

Darwin instability



if $L_{spin} > 1/3\ L_{orb} \rightarrow$ tidal instability

(Darwin 1879, Hut 1980)



$q_{crit} \approx 0.1$ for contact binaries

(Rasio 1994)

On what timescale does DI happen?

In the theory of equilibrium tides for nearly circular orbit:

$$\frac{\dot{a}}{a} \propto -\frac{1}{t_{\rm TF}}\left(1-\frac{\Omega}{\omega}\right)$$

Eggleton & Kiseleva-Eggleton (2001):

$$\frac{1}{t_{F1}} = \frac{9}{t_{V1}} \frac{R_1^8}{a^8} \frac{MM_2}{M_1^2} \frac{1}{(1-Q_1)^2} .$$

“ The timescale t_{V1} is of the order of years or decades. ”

↓

For a contact binary (Pejcha 2014):

$$t_{\rm TF} \approx 80 t_{\rm V} \frac{(1+q)^{0.6}}{q^{0.64}} (1-Q_{\rm E})^2$$

Can we see Darwin instability in action?

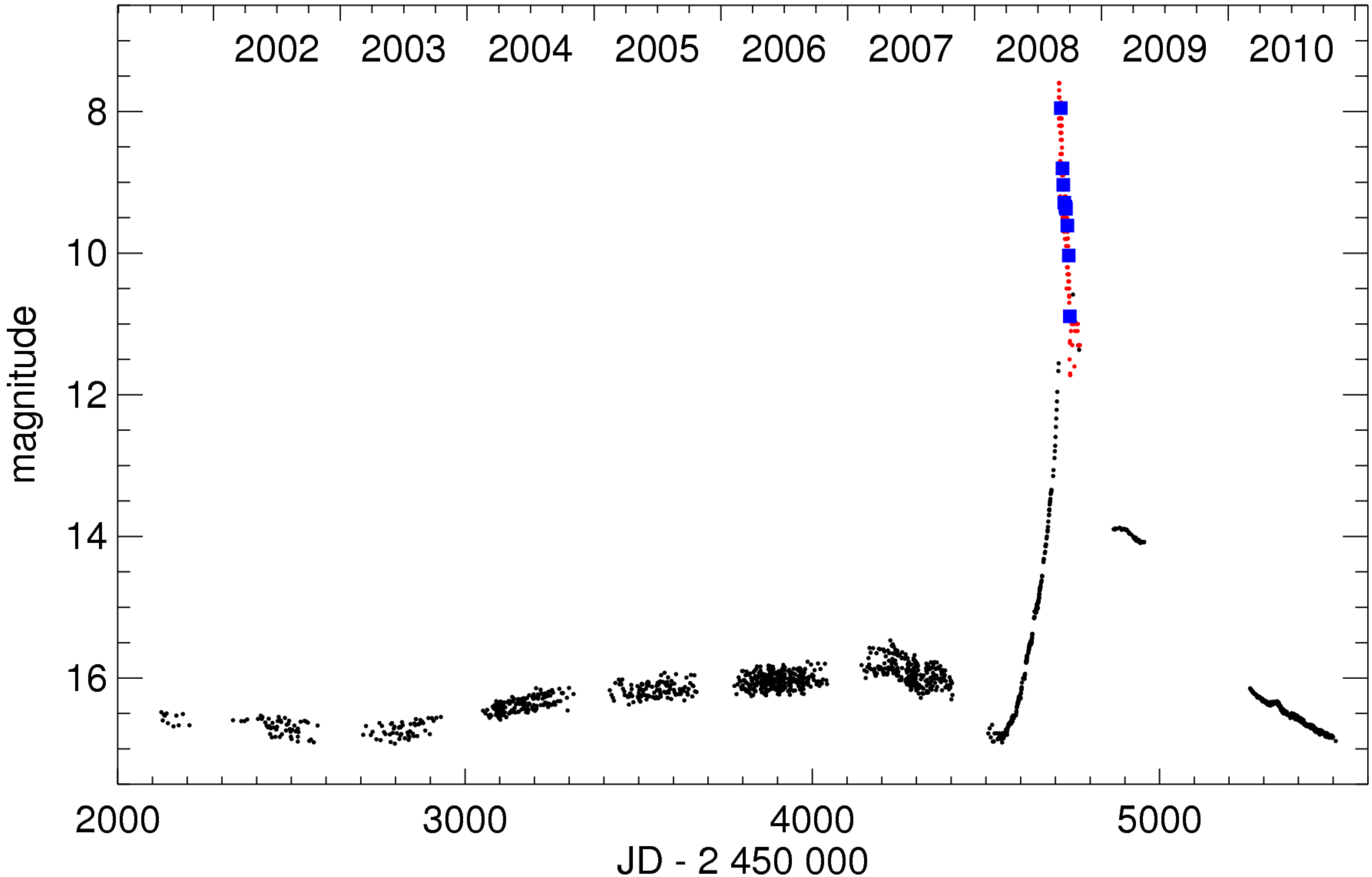
Contact binaries have orbital period change timescales longer than about 10^5 years (consistent with thermal timescale processes)

$$\frac{P}{\dot{P}} \gtrsim 10^5 \text{ years}$$

Pietrukowicz et al. (2017) found one binary with timescale ~10^4 years

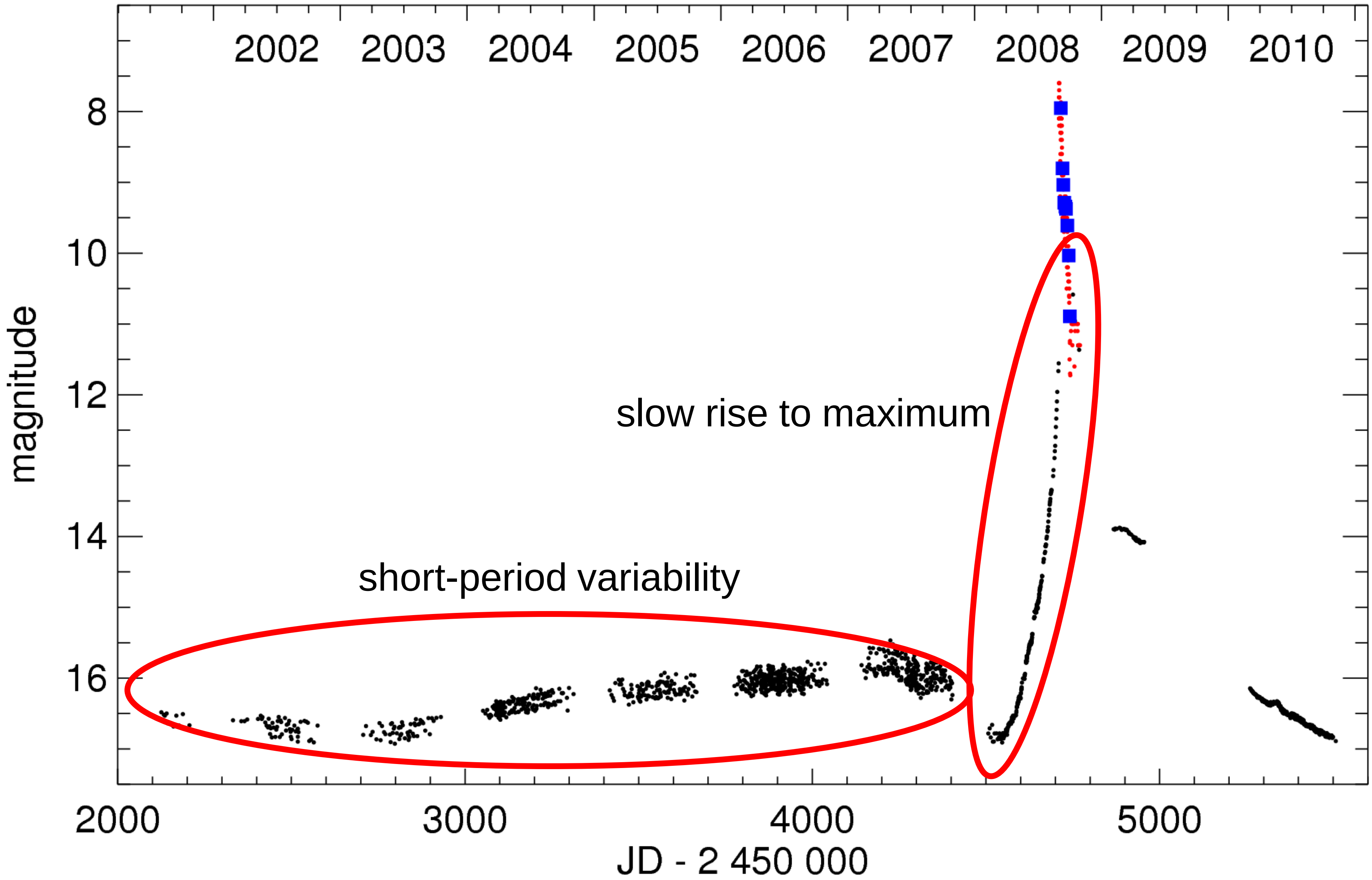
For how long can we see contact binary
with orbital period change timescale $<10^3$ years?

V1309 Sco – light curve



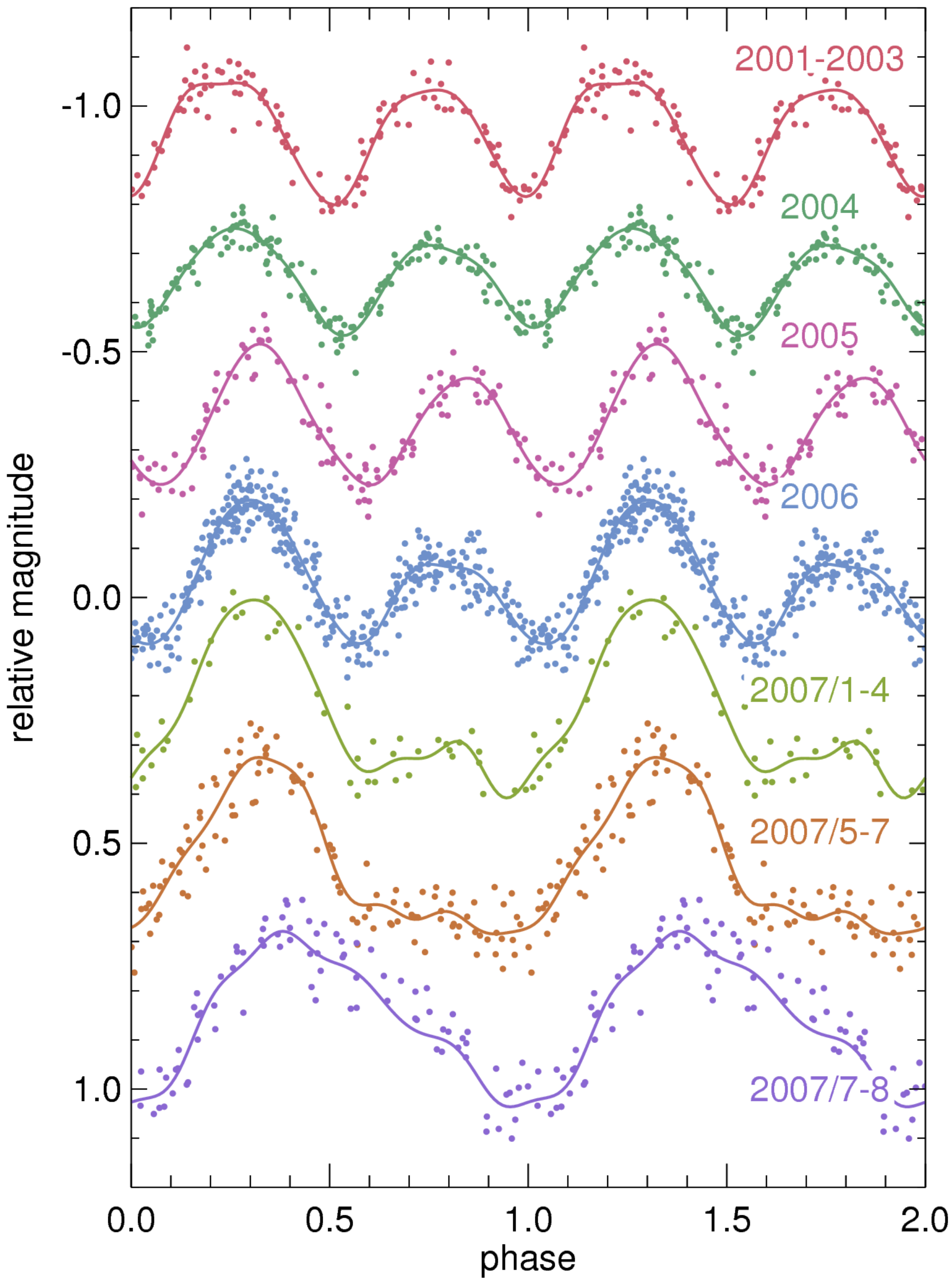
data from OGLE, ASAS, AAVSO (Tylenda et al. 2011)

V1309 Sco – light curve



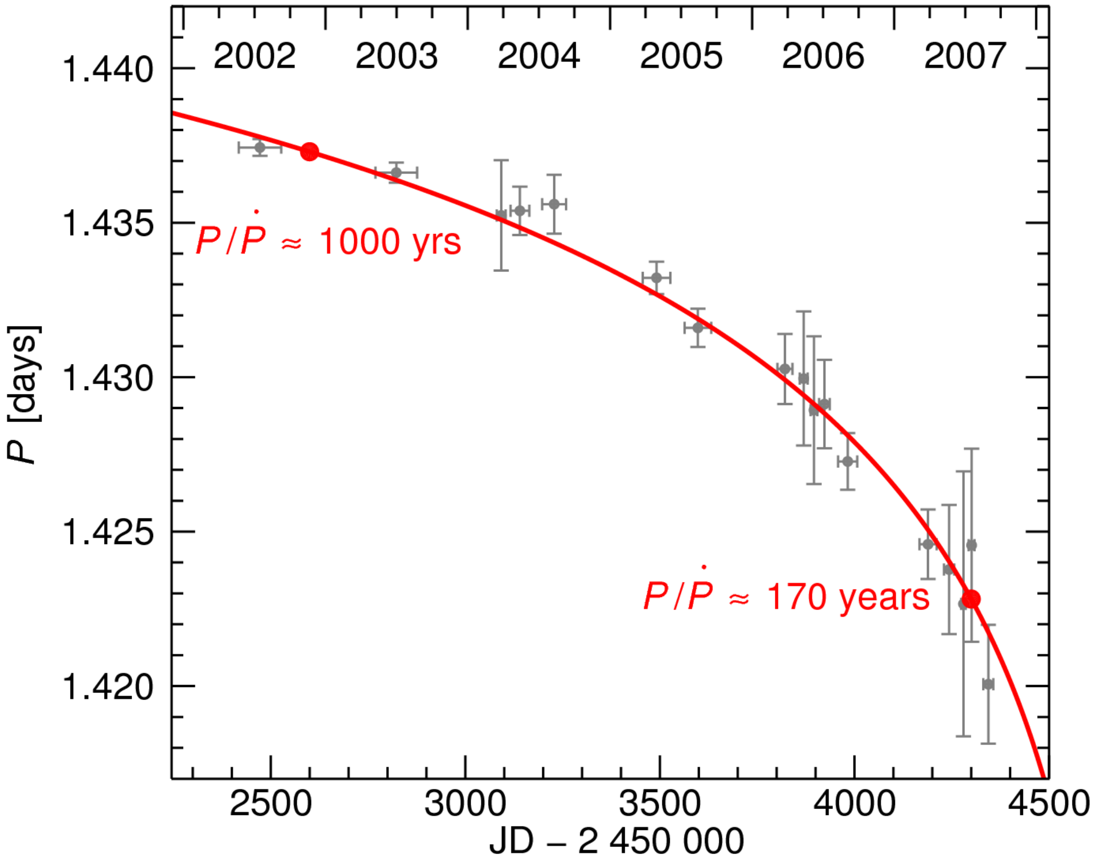
data from OGLE, ASAS, AAVSO (Tylenda et al. 2011)

V1309 Sco – phased light curve



Data from Tylenda et al. (2011)

V1309 Sco – period change



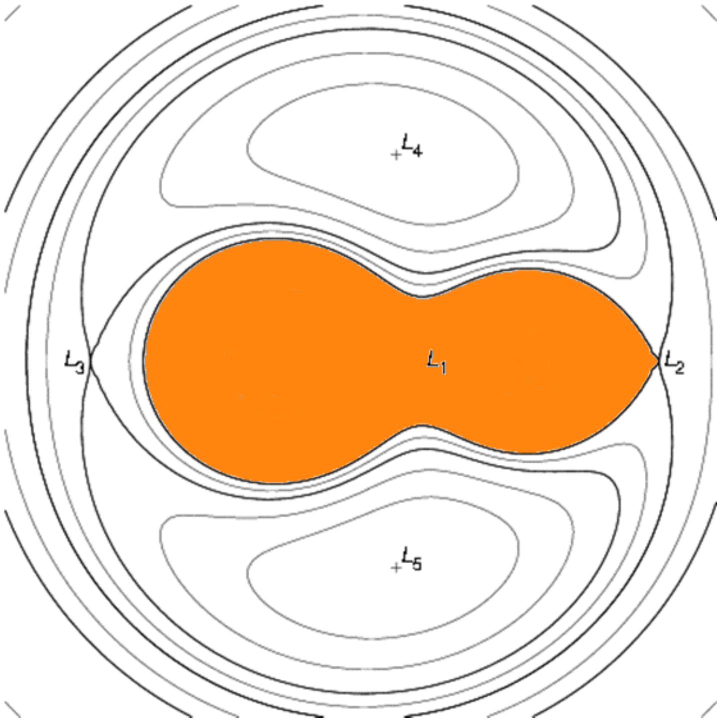
Data from Tylenda et al. (2011)

Period change accelerating

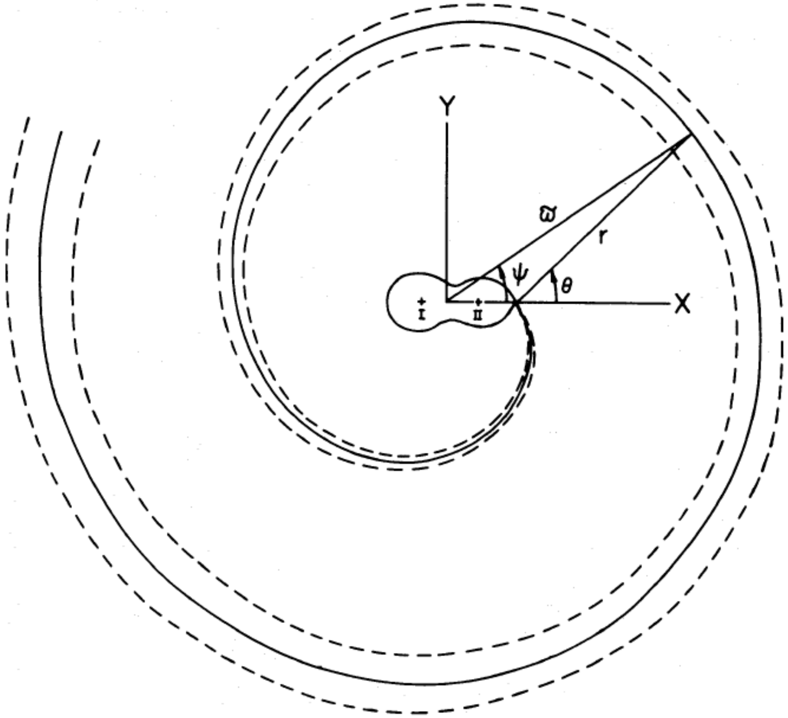
$$\dot{P}/\ddot{P} \sim 2\,\mathrm{years}$$

Much shorter than tidal (~1000 yrs) or thermal timescale (~10^6 yrs), but longer than dynamical (~1 d)

Explaining rapidly accelerating period change



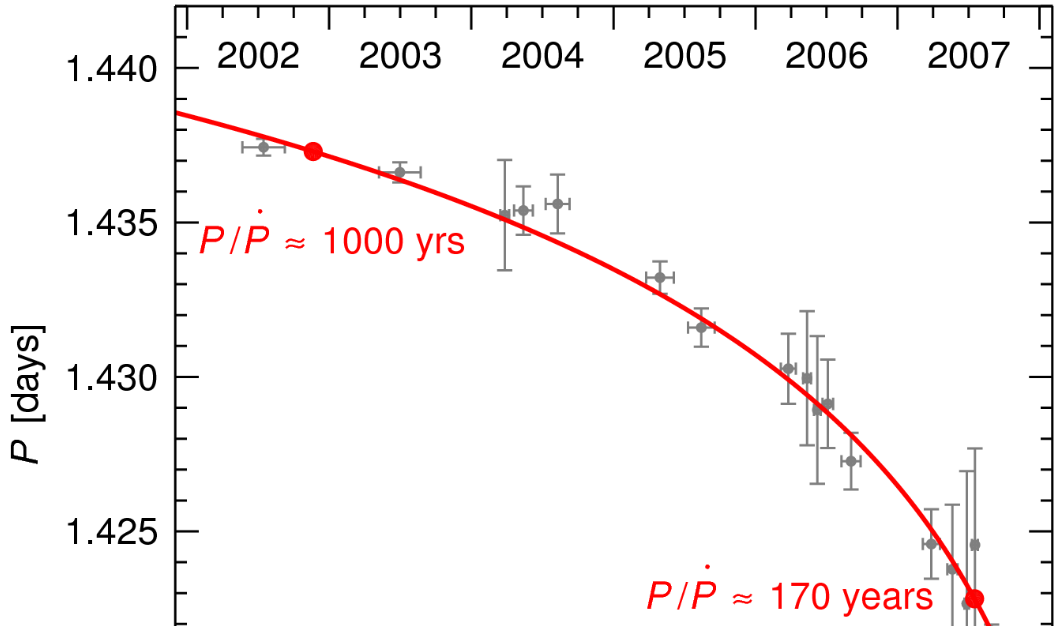
Bhattacharyya (2011)



Shu, Anderson & Lubow (1979)
"garden-sprinkler spiral"

Pejcha (2014), Pejcha et al. (2016a,b, 2017)

V1309 Sco – period change



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The accelerating period decay phase might last only

$$\sim 2 \text{ years} \times \ln\left(\frac{P/\dot{P}_{\text{normal CB}} = 10^5 \text{ years}}{P/\dot{P}_{\text{V1309 Sco}} = 10^2 \text{ years}}\right) \sim 10 \text{ years}$$

How many soon-to-merge CBs can we see?

Estimate 1:

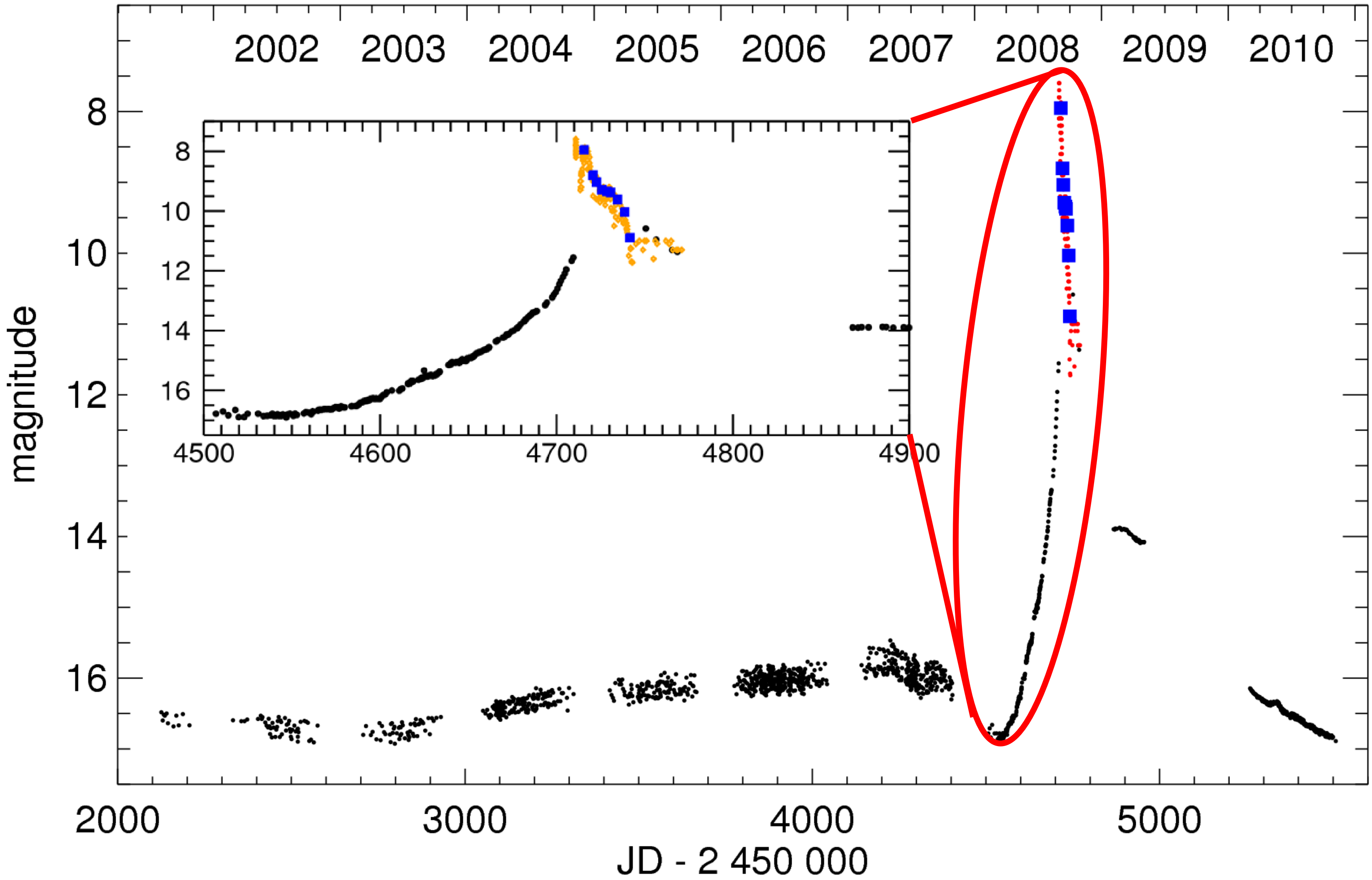
- Typical lifetime of CB: ~10^9 years
- Duration of high Pdot pre-merger phase: ~10 years
- Relative frequency of pre-merger CBs: 10^{-8}
- ~10^{11} stars in the Milky Way
- CB frequency ~ 1/500 (Rucinski 2002) → ~2×10^8 CBs in the Milky Way
- → only ~2 CBs in the Milky Way are currently undergoing high Pdot pre-merger phase

Estimate 2:

- Kochanek et al. (2014): frequency of mergers in Milky Way 0.2 yr^{-1} (many NOT from Darwin instability)
- Duration of high Pdot pre-merger phase: ~10 years
- → only ~2 stars are currently undergoing high Pdot pre-merger phase

⇒ Need to monitor at least half of stars in the Milky Way

How can we identify soon-to-merge binaries?



data from OGLE, ASAS, AAVSO (Tylenda et al. 2011)