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Donor stars in short period CVs

Wild Stars in the Old West, Tucson

16th March 2009

The period bounce problem

- 70% of CVs should have passed period minimum (Kolb 1993)
- A handful of plausible candidates exist
  e.g.
  GD 552 - Unda-Sanzana et al 2008, Patterson, Thorstensen & Kemp 2005
  RXJ 1050-14 - Mennickent et al 2001, PTK 2005)
  Superhumpers? (Patterson et al 2005)
- But not one *definite* period bouncer...

'...as recently as the 2004 Strasbourg meeting, Tom Marsh turned to the audience and asked: "Does anyone know the *names* of these stars?"...and was answered by silence' - Patterson (2009; submitted)

The solution

- Period bounce CVs are *faint;* deeper surveys are needed (Pretorius et al 2007)
- Major advance with SDSS CV Survey
  (Szkody et al 2002, Szkody et al 2003, Szkody et al 2004, Szkody et al...)
- SDSS turned up plenty of faint, short period CVs (see Tuesday talk by Gänsicke), but we still need donor masses, and donors are too faint to detect...

Photometric mass determination

- First applied by Wood et al (1986); component masses from eclipse
- Assumptions!
  - Donor fills Roche Lobe
  - Bright spot lies along free-fall gas stream trajectory ⇒ q
    - *not* necessarily where stream hits disc
  - White dwarf follows theoretical mass-radius relationship ⇒ M_w
  - [We see light from whole surface of white dwarf]

Those pesky assumptions

- Donor fills Roche Lobe ✔
- Bright spot lies along free-fall gas stream trajectory ✘
- White dwarf follows theoretical mass-radius relationship ✘
- [We see light from whole surface of white dwarf] ✘

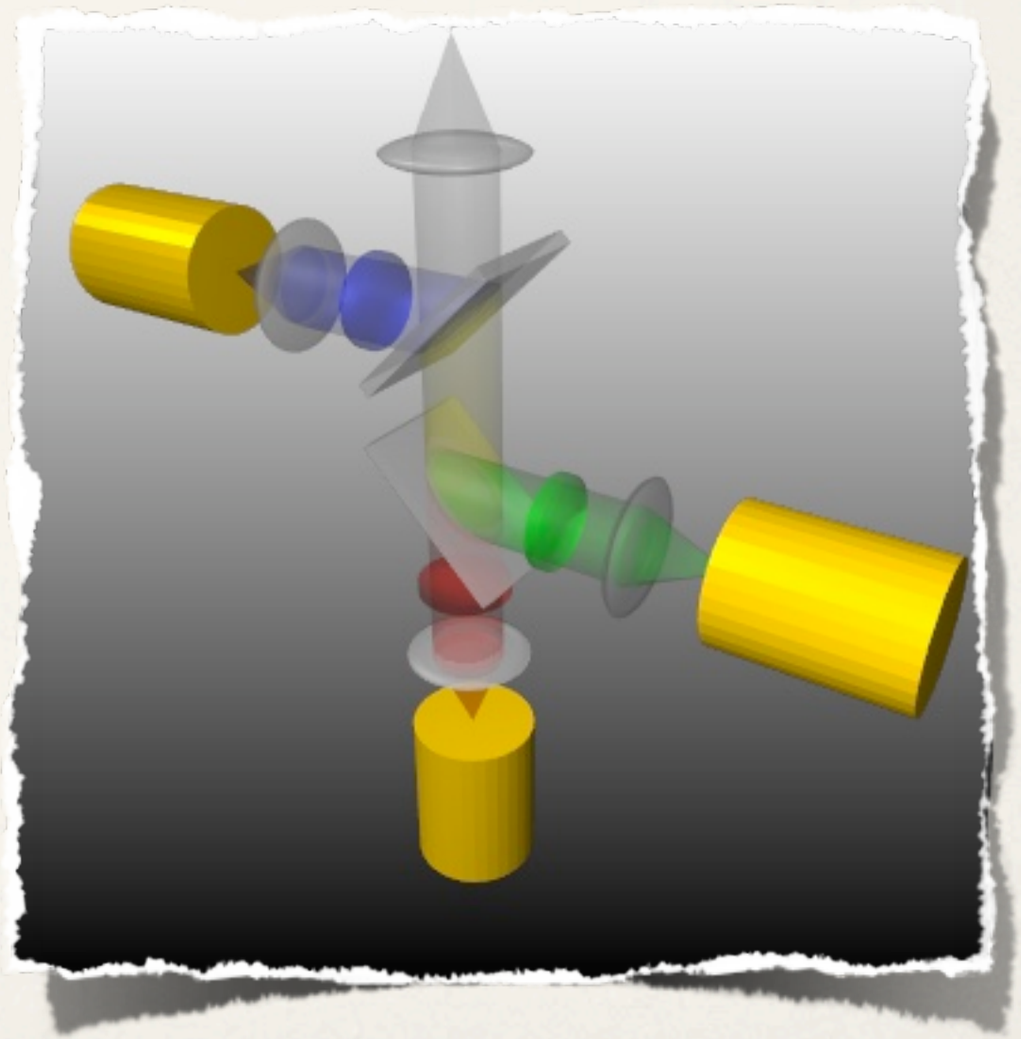
Independent tests of method

- Compare photometric q_{phot} with purely spectroscopic q_{spec}
- Agreement within 1σ (V2051 Oph, EX Dra - Feline et al 2005)
- But 1σ = 0.05, so claimed precisions in q_{phot} of 0.002-0.003 *untested*
- IP Peg (Marsh Poster, this conference) c.f. K_2 from Roche Tomography (Watson et al 2003):

  $\Delta K_2 \approx 12 \pm 12$ kms^{-1}
- SDSS 1433 (Tulloch Poster, this conference) c.f. Littlefair et al (2008)

The role of ULTRACAM

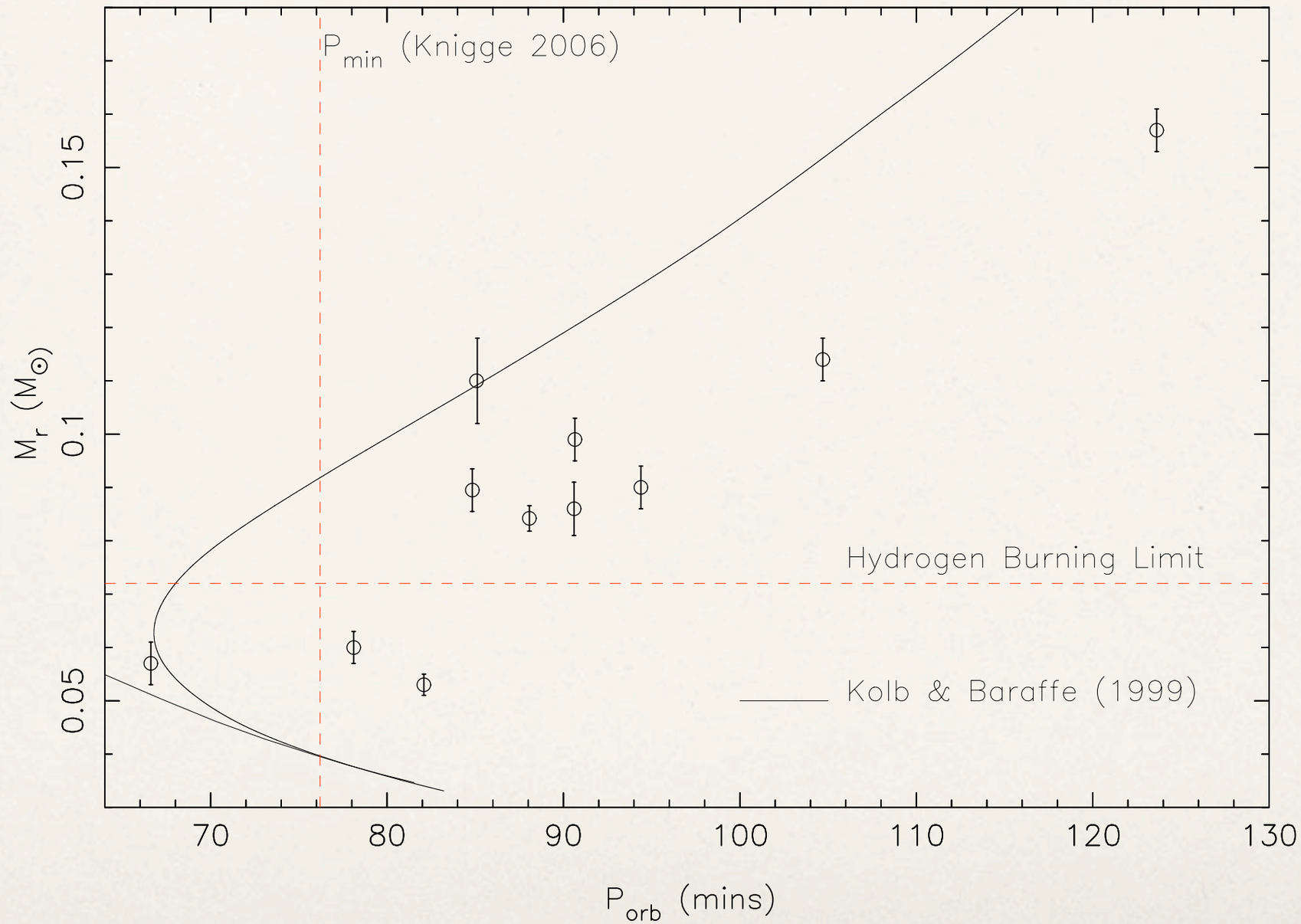
- Requirements:
  - time resolution ~3s
  - simultaneous multi-colour
- for g'~19 (out of eclipse)!
- This talk is thanks to ULTRACAM!



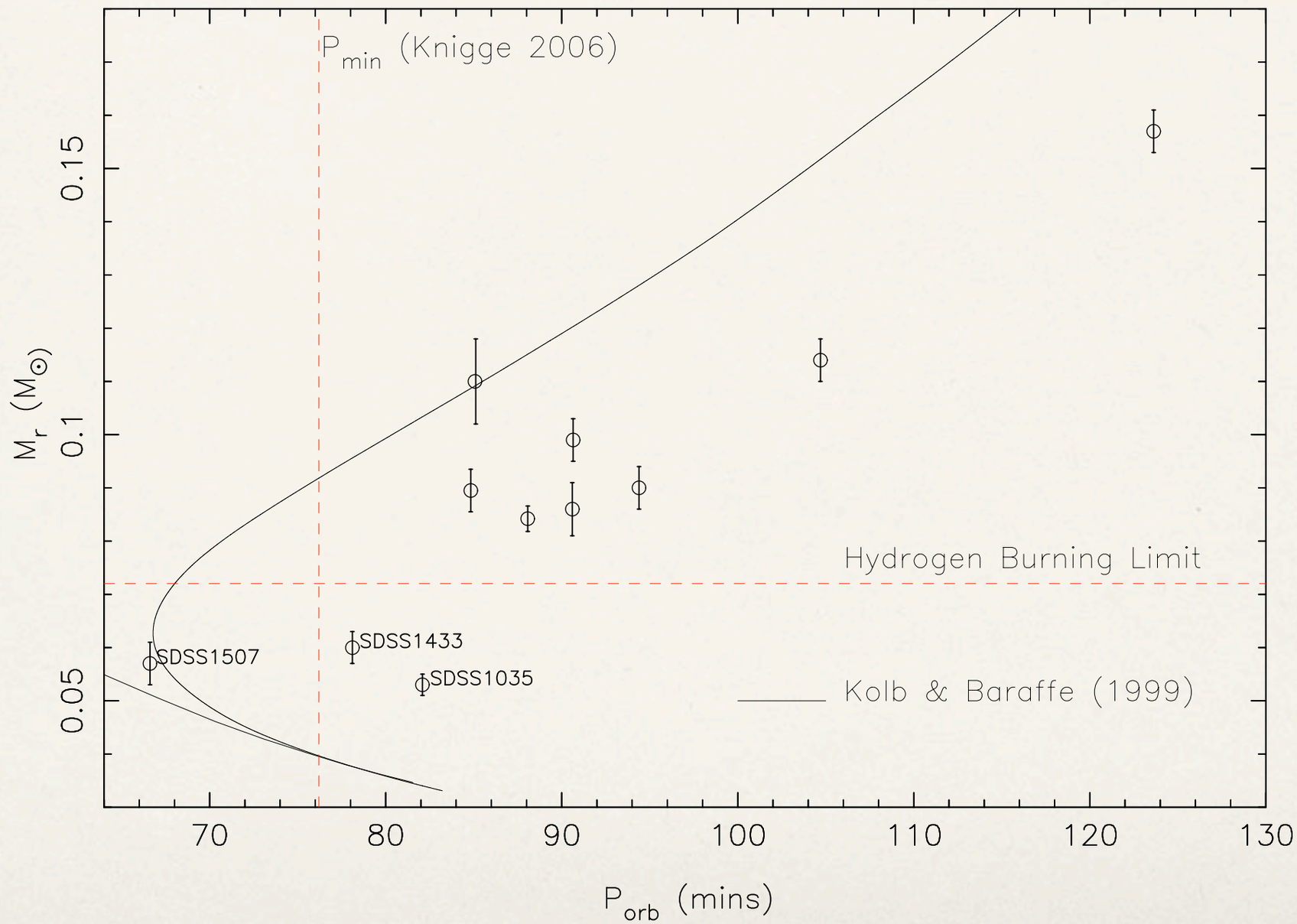
Results

- New analysis using Markov-Chain Monte-Carlo method
  - more robust parameter estimates and errors
- Present re-analysis of CVs from Littlefair et al (2008, 2006a,b) & Feline et al (2004a,b)
- Masses (and errors!) confirmed with two exceptions
  - OU Vir: slightly lower mass (old mass used timing method)
  - SDSS J1501: mass ratio, q, not well constrained - needs more data

Results - Donor star masses

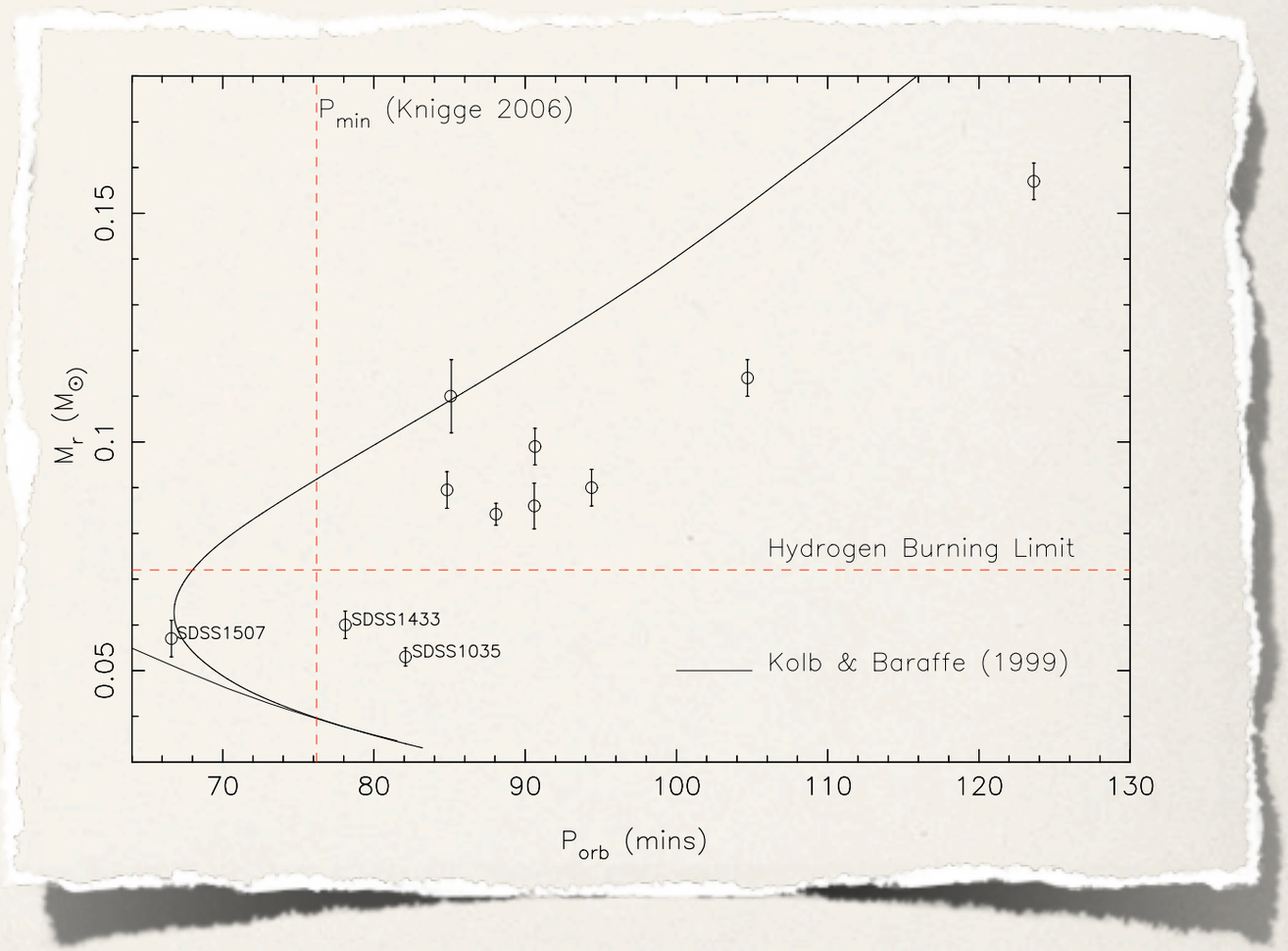


We know their names...



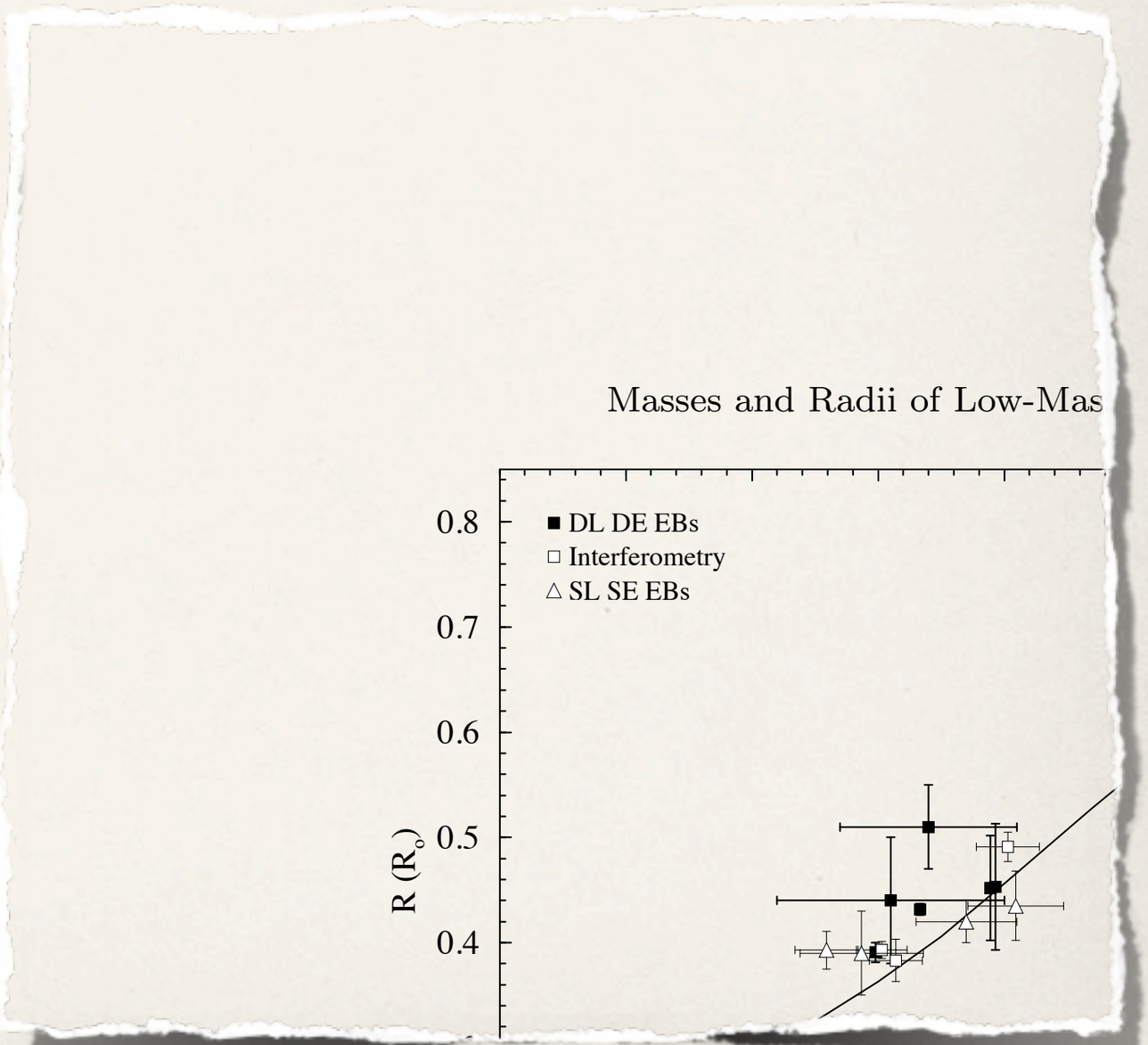
Results - Donor star masses

- Not a good fit - not news
  - P_{min} problem told us this for years (e.g. Patterson 1998, Barker & Kolb 2003)
  - Superhumpers tell the same story (Patterson et al 2005; Knigge 2006)
  - Donor Stars are *too large*
- Why?



Stellar Models?

- We know radii of low-mass eclipsing binaries are also too large (e.g. Ribas 2006)
- Also seen in single M-dwarfs (Cassagrande, Flynn & Bessel 2008)
- Missing opacity (CFB 2008)?
- Magnetism (Chabrier et al 2007)?

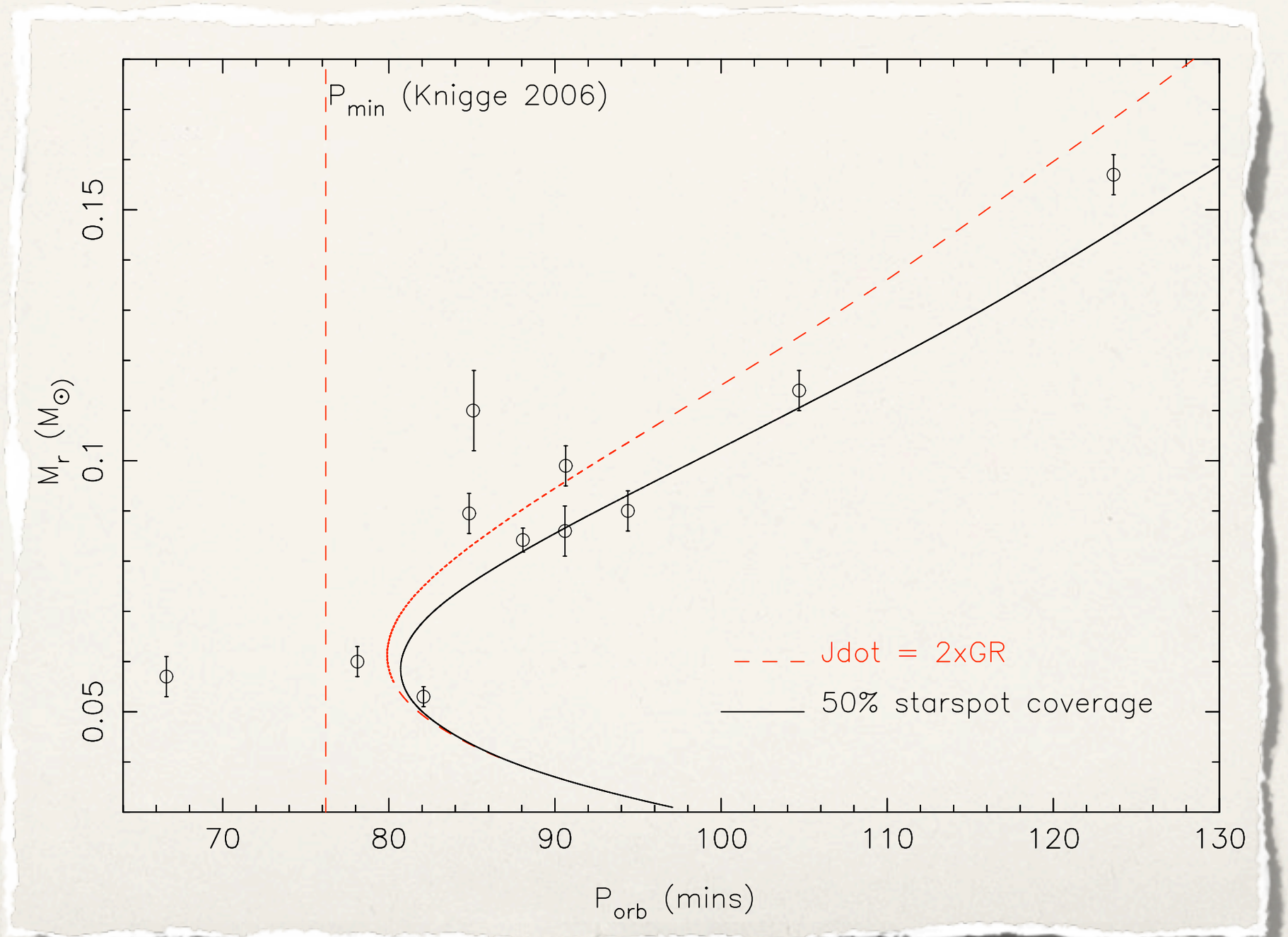


Ribas (2006)

Angular Momentum Loss?

- AML below the period gap is assumed to be solely GR
- Faster AML/accretion drives donor from thermal equilibrium ⇒ larger donor
- Observations of single stars show *magnetic wind braking* still present in low mass stars AND brown dwarfs (Reiners & Basri 2008)
- is it comparable to AML from GR?

Starspots or AML?



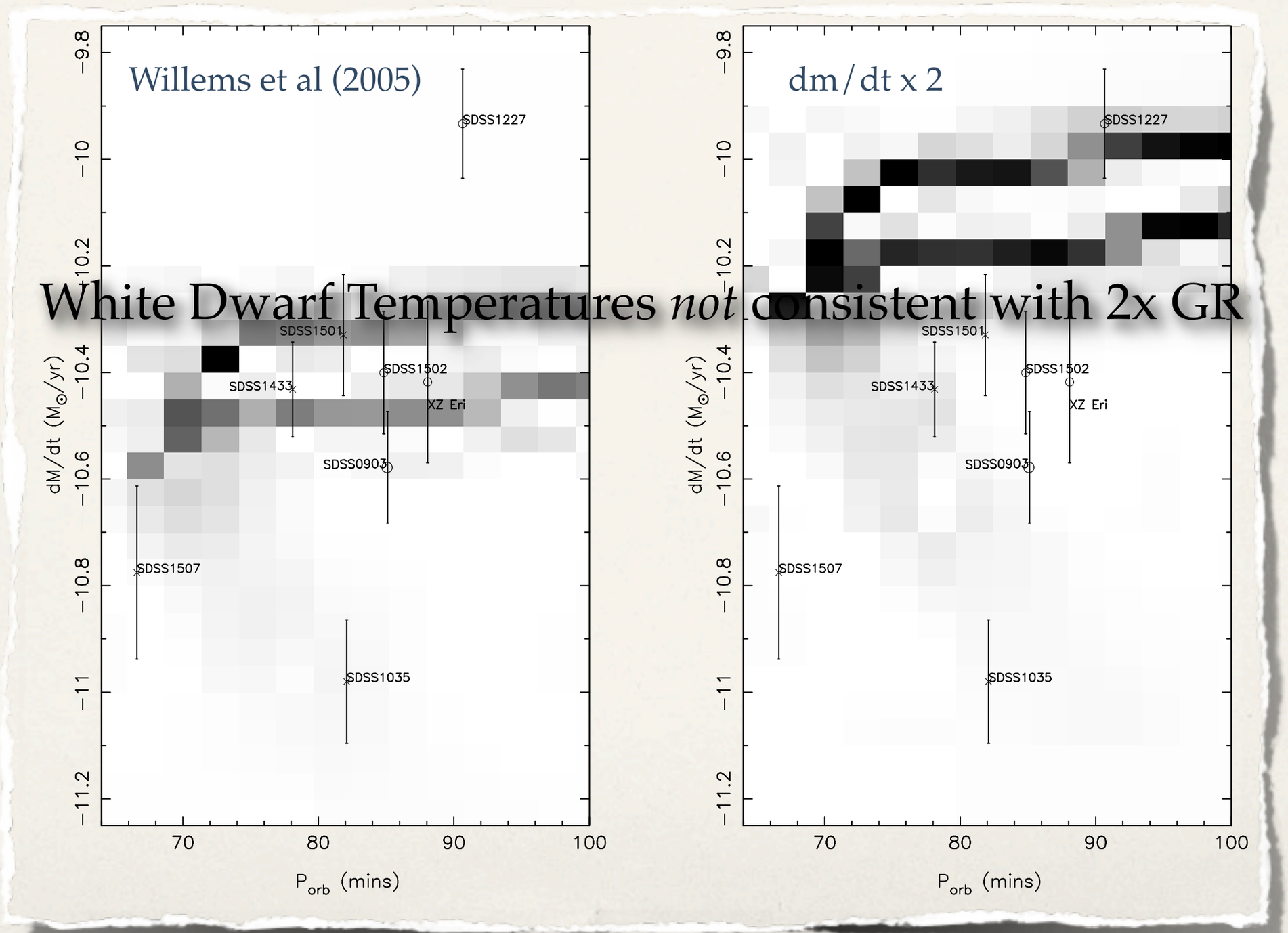
Starspots or AML?

- Decent estimate of long term AML rate from white dwarf temperature

  (see talk by Dean Townsley after lunch)

- We get temperature for WD from u′g′r′ colours of white dwarf eclipse!

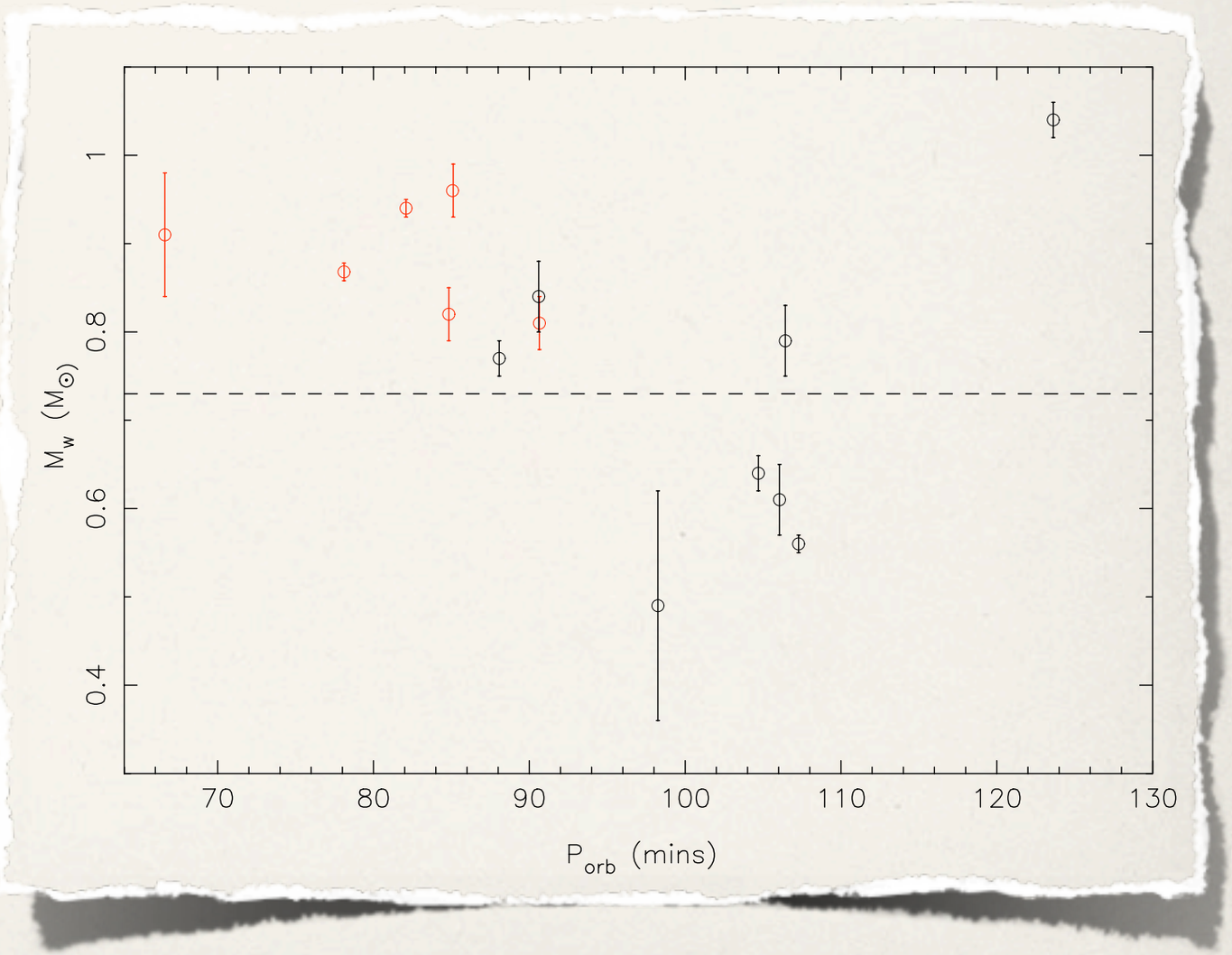
Angular Momentum Loss?



White Dwarf Temperatures *not* consistent with 2x GR

Aside: white dwarf masses

- All of our white dwarf masses are >0.8M$_\odot$
- Not a selection effect
- 40-80% of short period CVs should have Helium WDs (Willems et al 2005)
- None in our sample (see talk by Lars Bildsten, Tues)



Conclusions

- Mining of SDSS for CVs has been major breakthrough
- Photometric mass determination works, and shows that SDSS CVs contain period bouncers in significant numbers (good news!)*
- Masses and radii poorly fit by models (not news!)
- White dwarf temperatures suggest this is *not* enhanced AML (definitely news!)
- Urgently need independent confirmation of AML loss rates

*for theorists