

# Double white dwarfs and AM CVn systems

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# Outline

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- ▶ Introduction: why bother?
- ▶ Double white dwarfs
  - ▶ Formation, expected Galactic population
  - ▶ Observations, now and future
  - ▶ Further evolution: gravitational wave sources
- ▶ Double white dwarf mergers
  - ▶ SNIa progenitors?
  - ▶ Many more possibilities: study related objects
- ▶ Non-mergers: AM CVn systems
  - ▶ Direct impact, Novae, Ia SN
  - ▶ Population and Gravitational wave sources
- ▶ Conclusion and Outlook

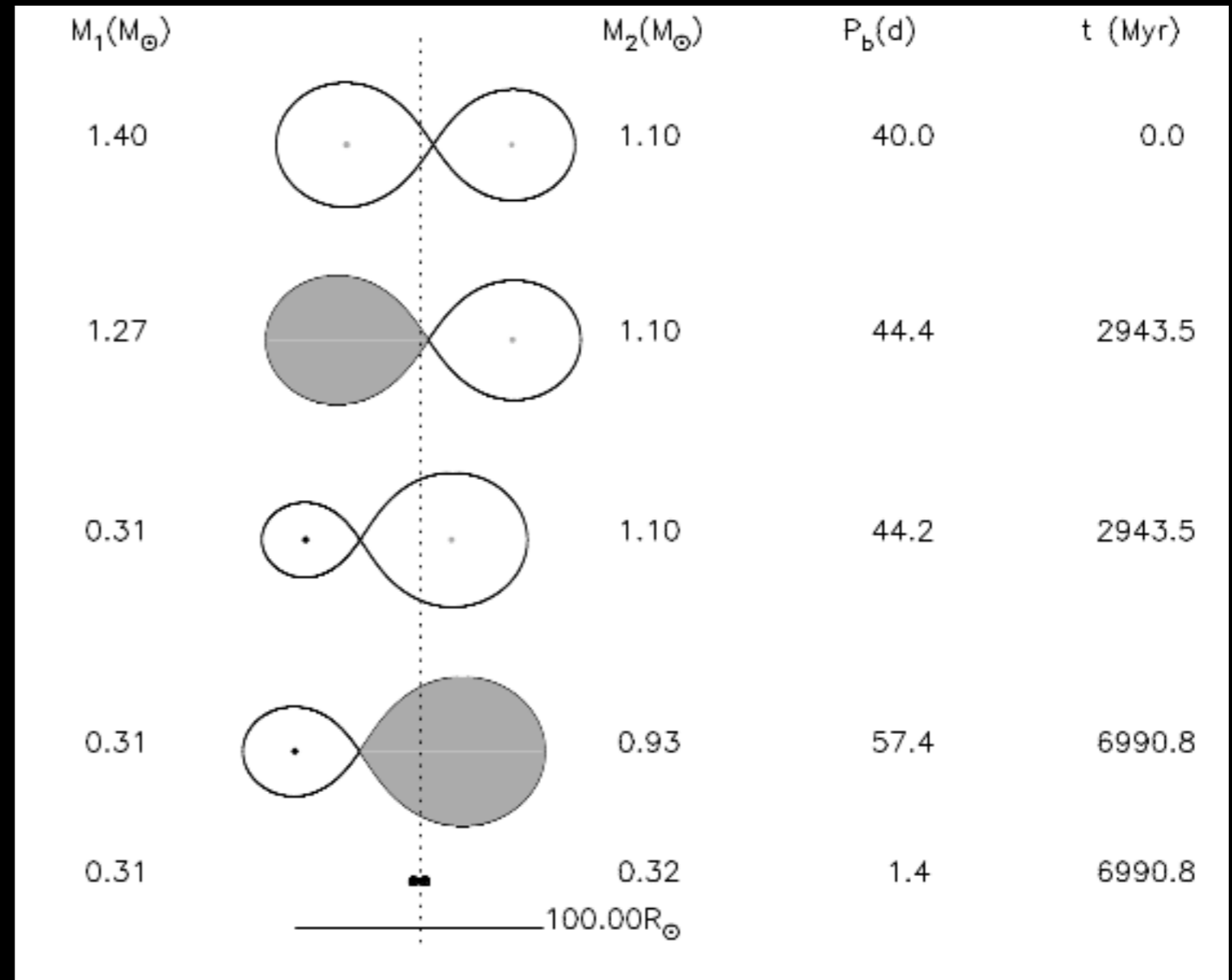
# Introduction: why bother

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- ▶ Double white dwarfs: remnants of (many) low-mass stars
- ▶ Understanding stellar evolution and binary interaction
  - ▶ Common products, yet poorly understood (common envelope)
- ▶ Dominant low-frequency gravitational wave sources
- ▶ Interesting tidal interaction (internal structure WD)
- ▶ Mergers
  - ▶ Possible SNIa progenitors, but much more!
- ▶ Mass transfer between WD (AM CVn stars)
  - ▶ Peculiar accretion, He Novae, .Ia SN
  - ▶ LISA verification binaries

# Double white dwarfs

- ▶ Theoretically predicted 1970s
- ▶ First one found in 1980s
- ▶ Typical formation



- ▶ ... i.e. low-mass WD

Nelemans et al. 2001

# Binary population synthesis

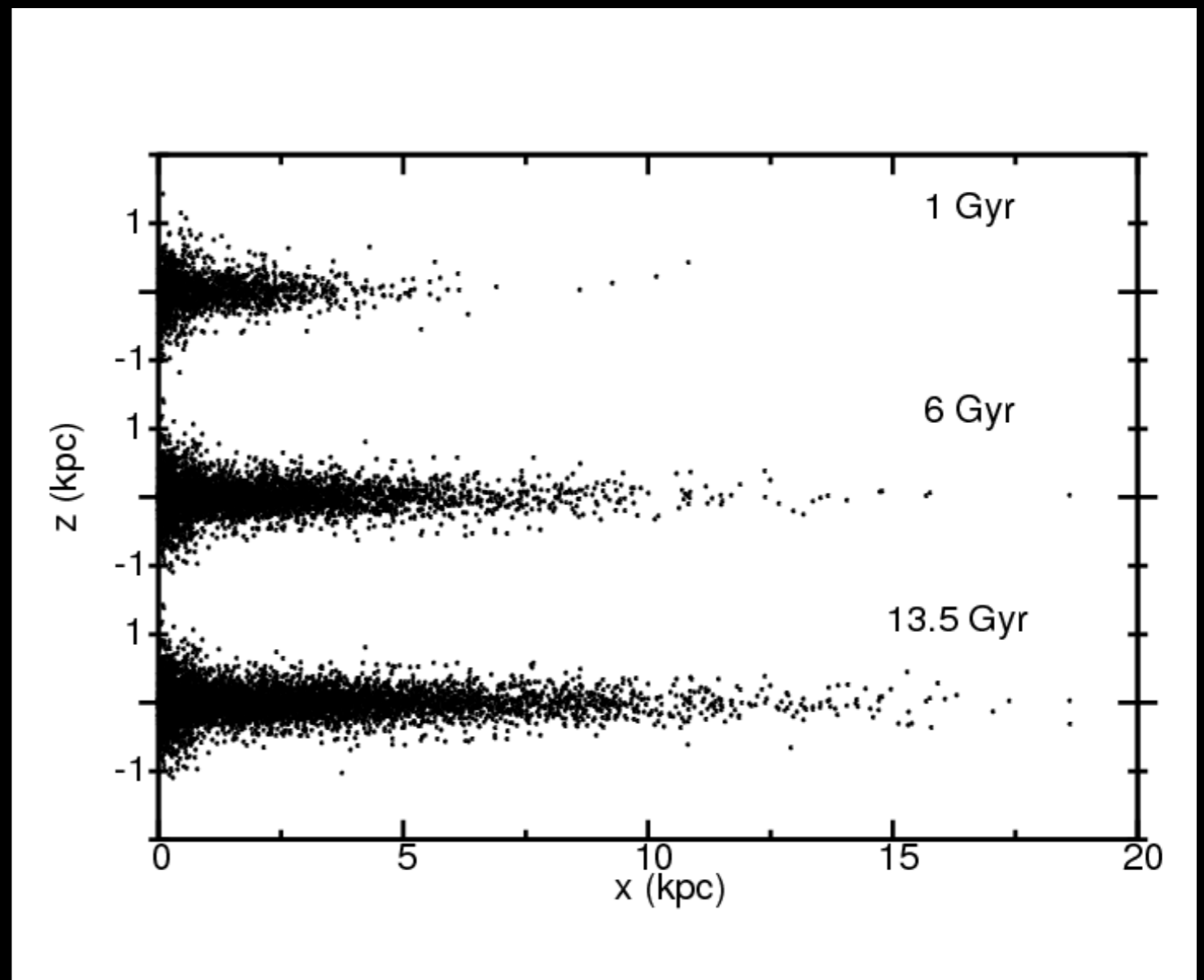
- Recipes for stellar and binary evolution (rapid)

Portegies Zwart & Verbunt, 1996  
Nelemans et al. 2001

- Model for initial distributions (M,m/M,P)

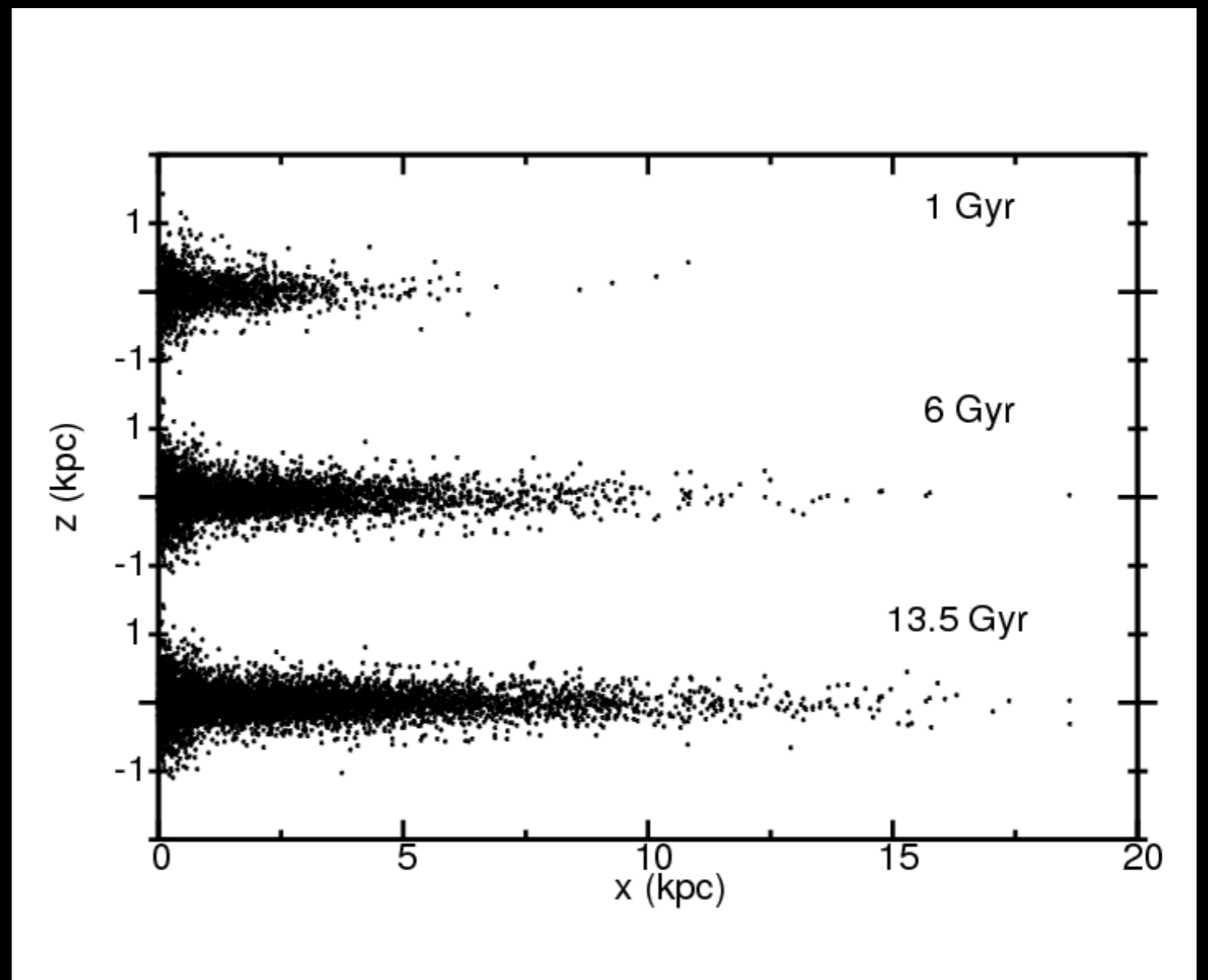
- Model for the star formation history

Nelemans et al. 2004 based on  
Boissier & Prantzos 1999



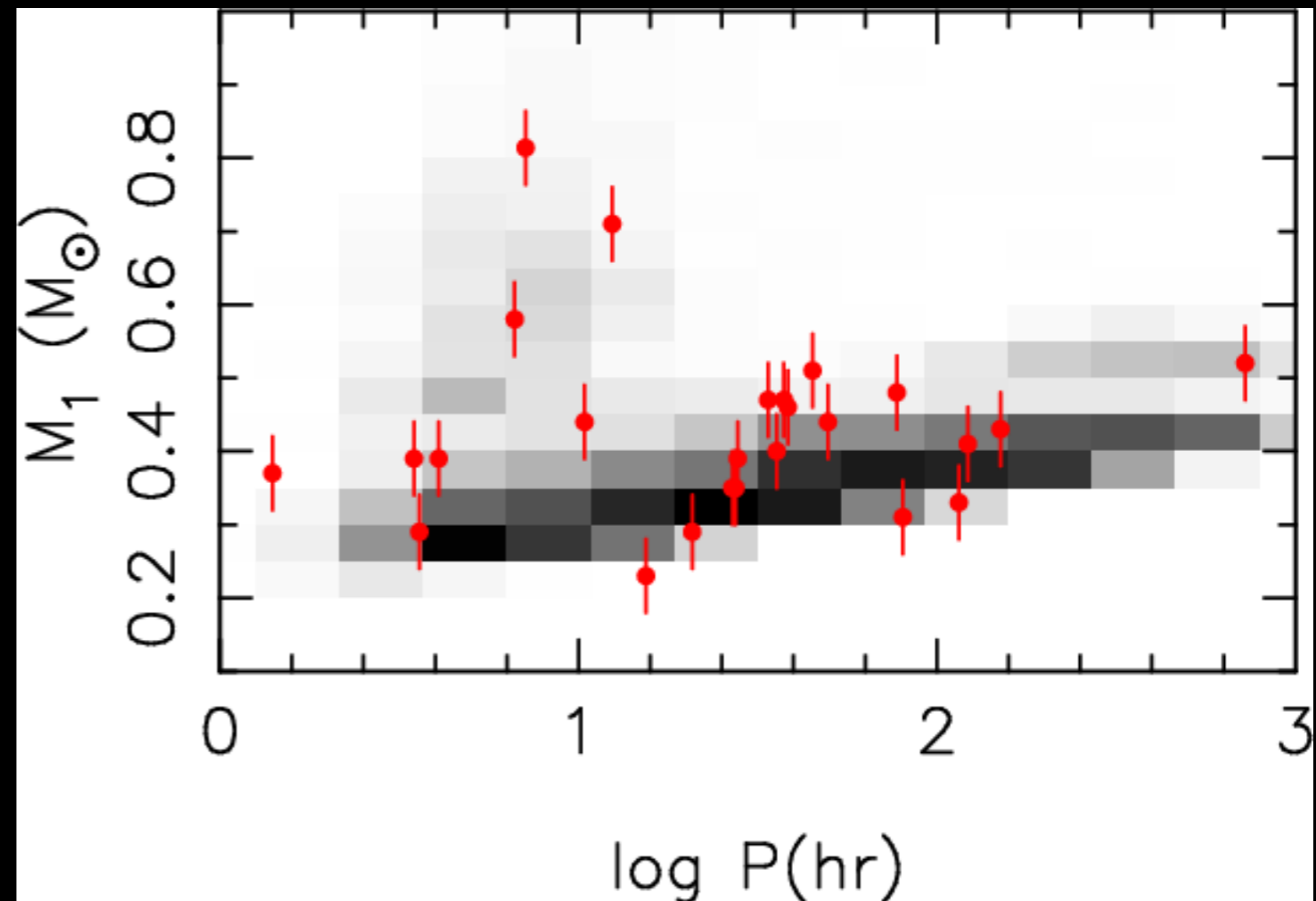
# Binary population synthesis

- Common envelope, stellar wind...
- Model for initial distributions?
  - ▶ Galactic model and reddening
    - ▶ Schlegel et al dust map



# Expected population of double white dwarfs

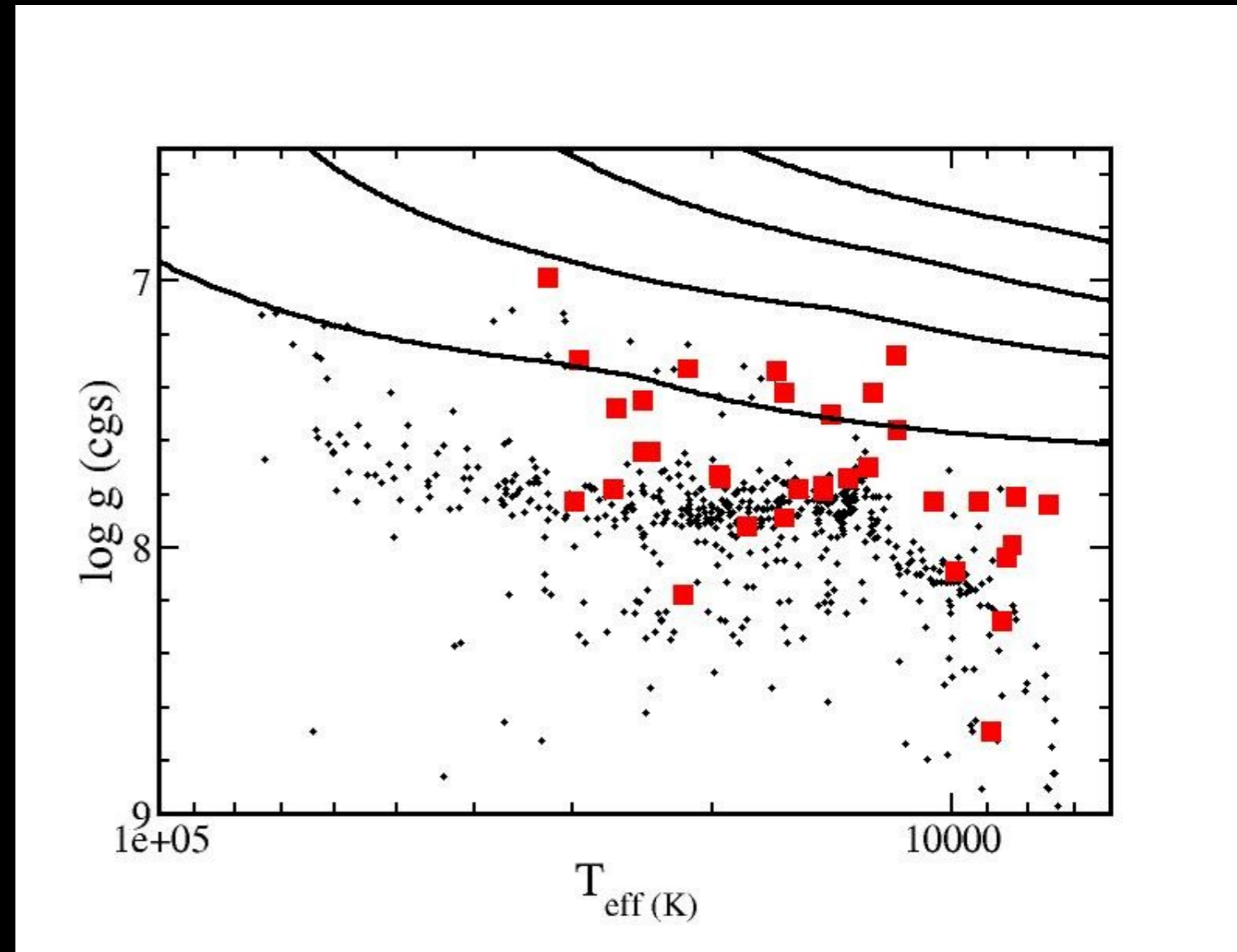
- ▶ Total number: 100 million
- ▶ Birth rate: 1/50 years
- ▶ Merger rate: 1/125 years
- ▶ Including selection effects
- ▶ Compare to observations
- ▶ Reasonable agreement



Nelemans et al. 2001a,b, 2005

# Observations: SPY survey

- ▶ PI Napiwotzki
- ▶ 611 WD with 2 spectra
- ▶ Search for RV variation
- ▶ 34 certain binaries
- ▶ Less than previously thought
- ▶ 7 periods derived
- ▶ Many interesting other objects
- ▶ Also many single He WD
- ▶ Planetary interactions?





# Future observational work

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- ▶ Finish SPY sample....
- ▶ Exploit SDSS (SWARMS Survey, GN, TRM work)
- ▶ New possibilities from massive photometry
  - ▶ GAIA (launch 2012)
  - ▶ Variability surveys (RATS, OmegaWhite, LSST, Pan-Starrs, SkyMapper?..)

# Galactic populations: RATS & OmegaWhite

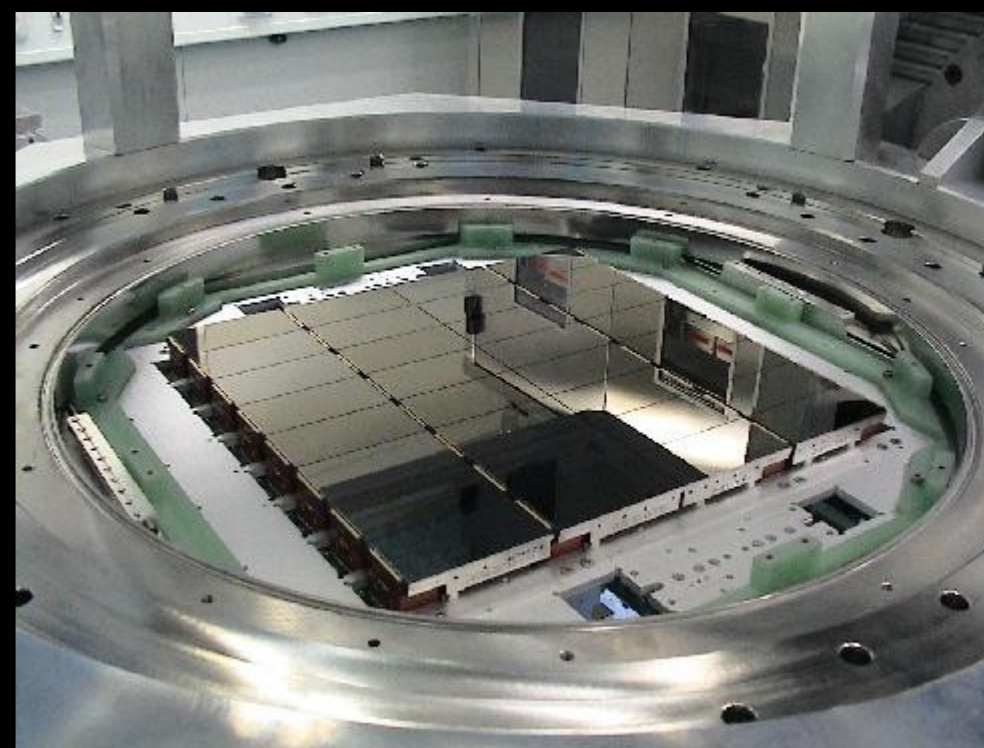
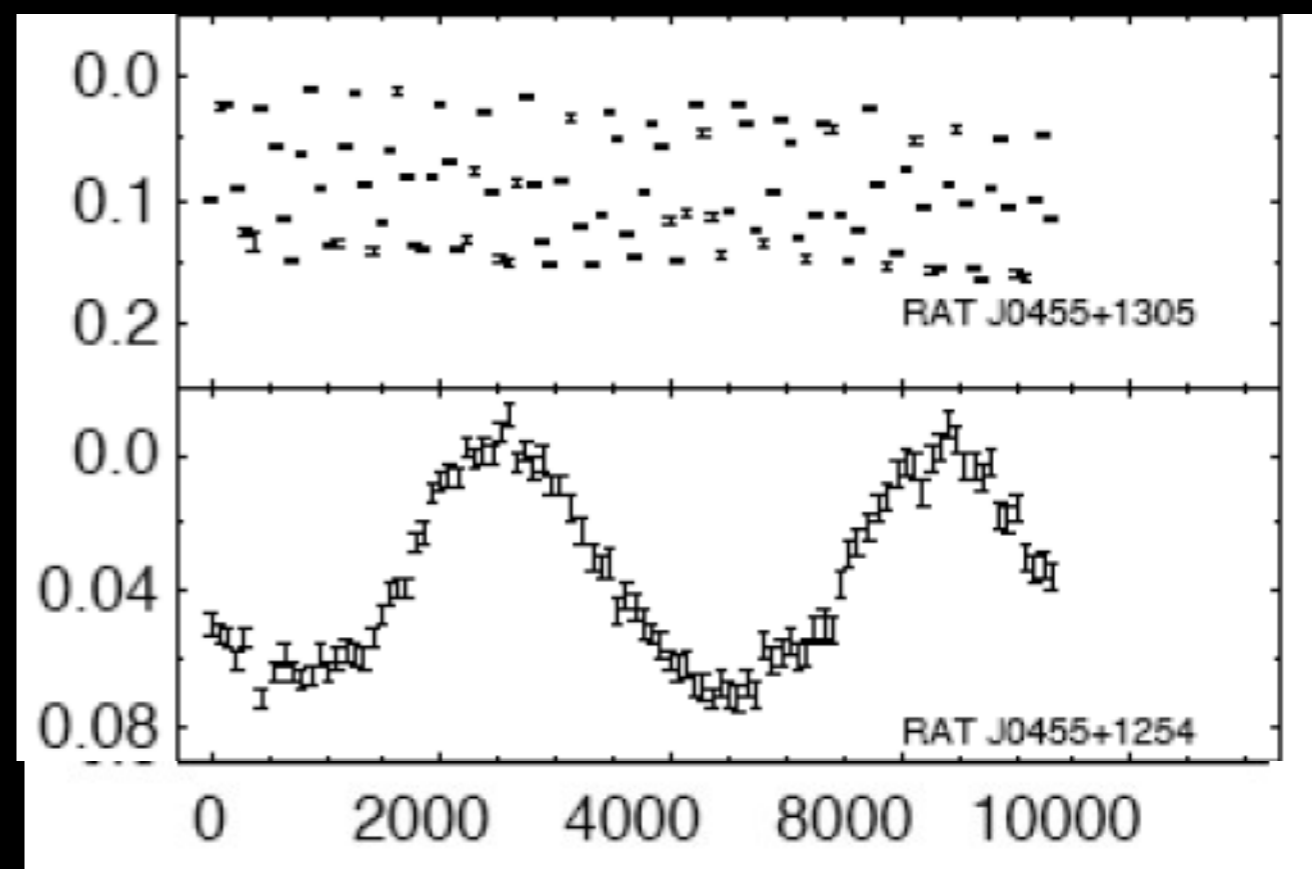
## ▶ RATS (Ramsay)

- ▶ Survey short timescales with wide field camera's on 2m class telescopes
- ▶ Happening NOW

## ▶ OmegaWhite (Groot)

- ▶ Survey short timescales with OmegaCam on VST (hopefully....)
- ▶ Start 2009 (?)

## ▶ Many new systems!

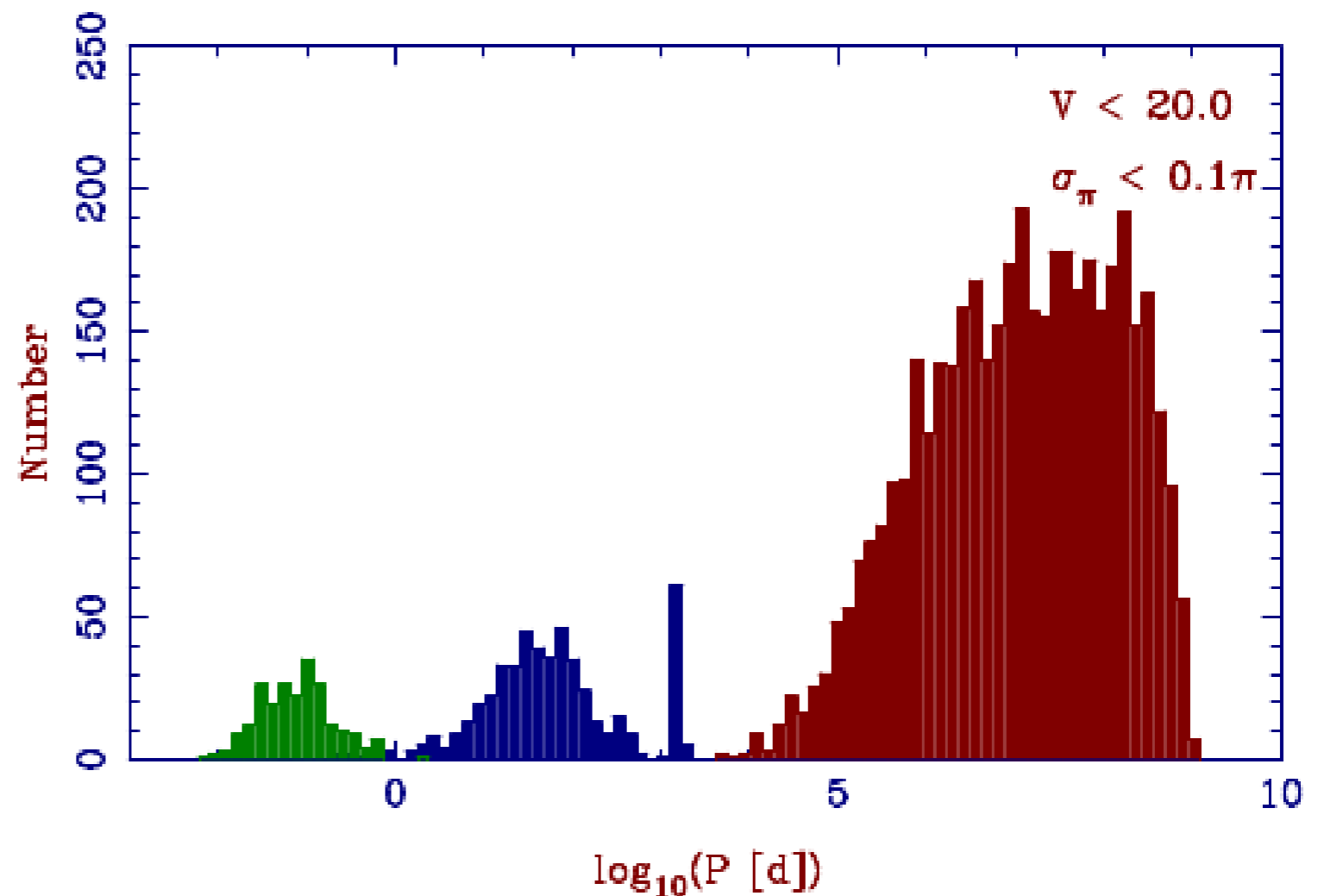


# GAIA

4300 resolved pairs, of interest for tests of IMF relation & cooling models.

500 astrometric binaries, periods peaking at 30 d probing a largely unknown region of parameter space.

230 eclipsing DWDs, periods from  $10^{-2}$  to 1 day, cf none known today.



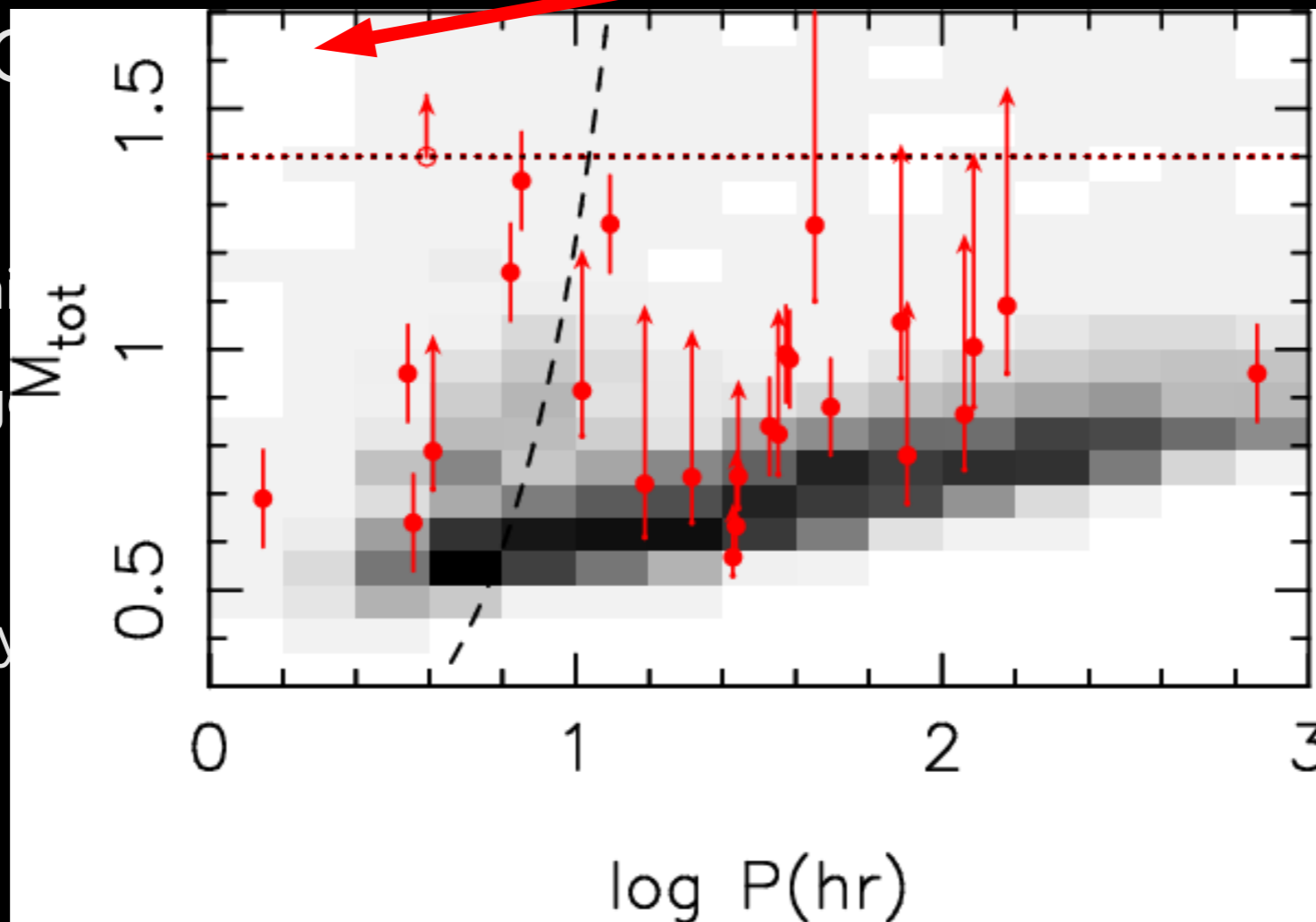
eclipsing, astrometric, resolved pairs

# Double white dwarf mergers

- ▶ Type Ia supernova progenitors?
  - ▶ Rates promising (but maybe too few [Maoz])
  - ▶ Short as well as long delays
  - ▶ Rapid accretion more likely to produce AIC and NS?
  - ▶ No real convincing case seen yet (V458 Vul?), few “close” ones

## ▶ WARNING

- ▶ Should be
- ▶ Double wh
- ▶ Single deg
- ▶ (recurrent)
- ▶ Possible sy
- ▶  $M_{WD}$  from

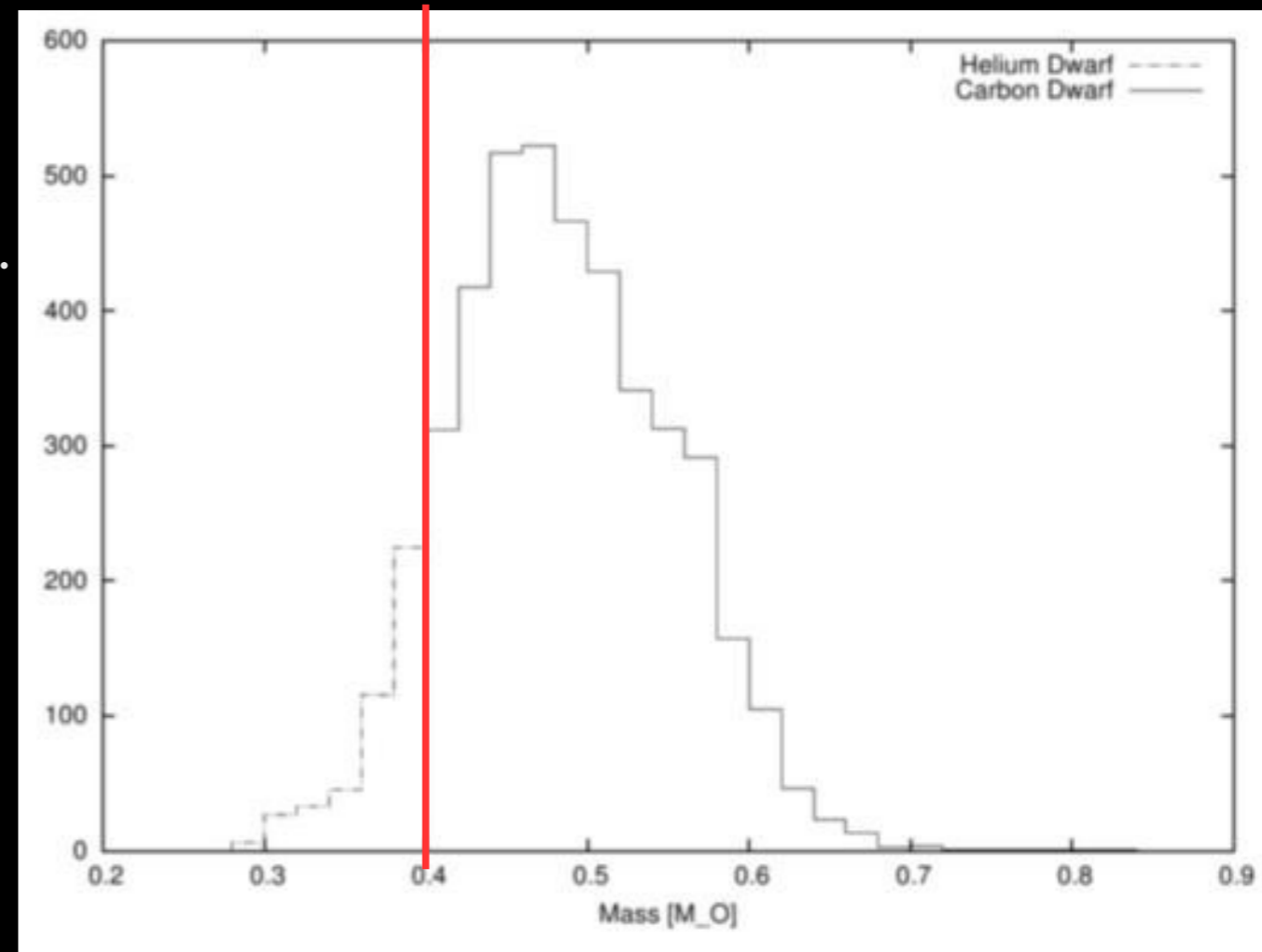


progenitors

max > 1 Mpc!

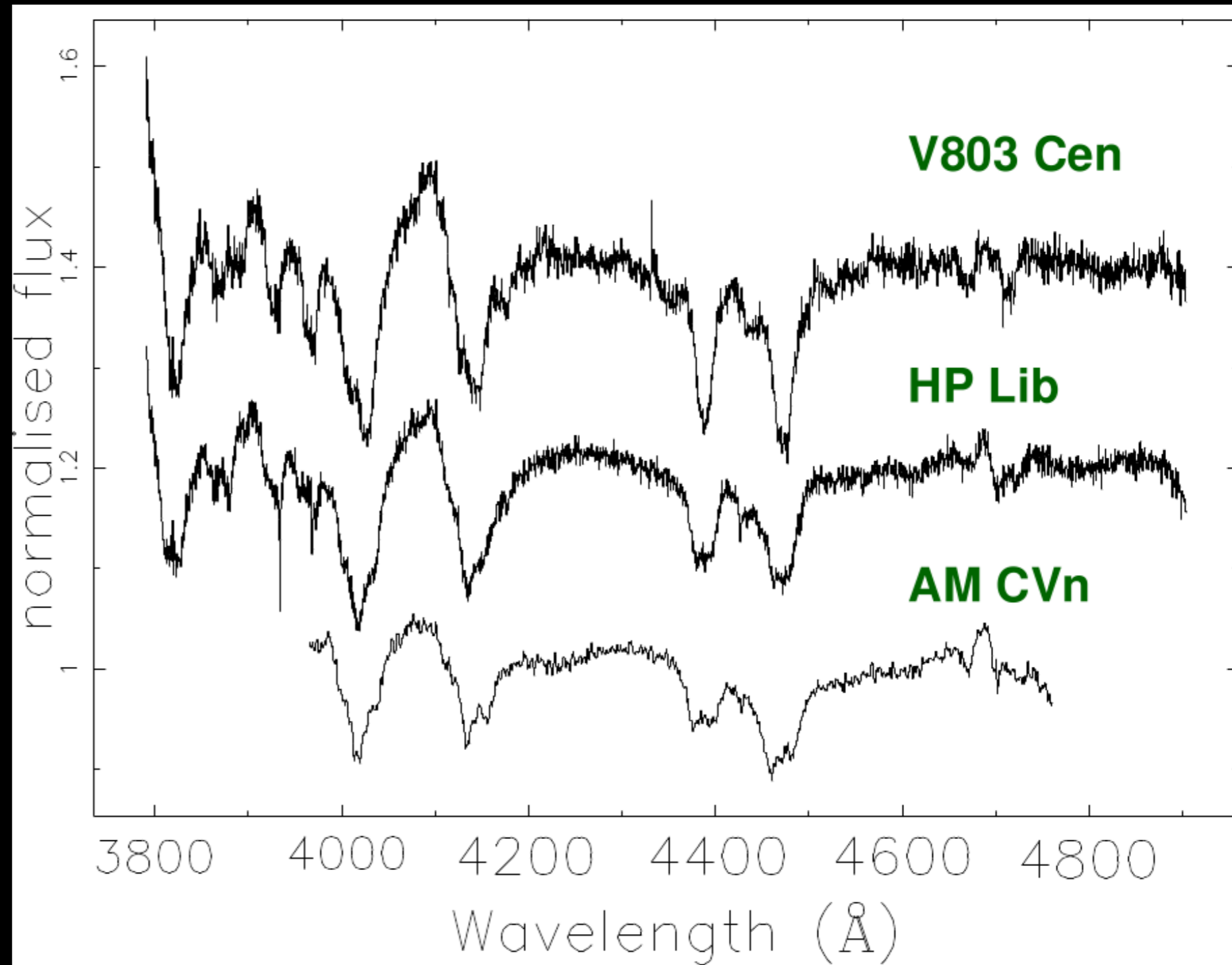
# Double white dwarf mergers (next 2 talks)

- ▶ Around 90% of mergers will certainly not be SNIa...
- ▶ Some bright and easy(er) to study
- ▶ Many low(er)-mass mergers
  - ▶ He + He  
→ single He WD, subdwarf B stars...
  - ▶ He + CO  
→ R CrB stars/extreme He stars
  - ▶ CO + CO  
→ Accretion induced collapse
- ▶ Single He/sdB connection with planetary companions



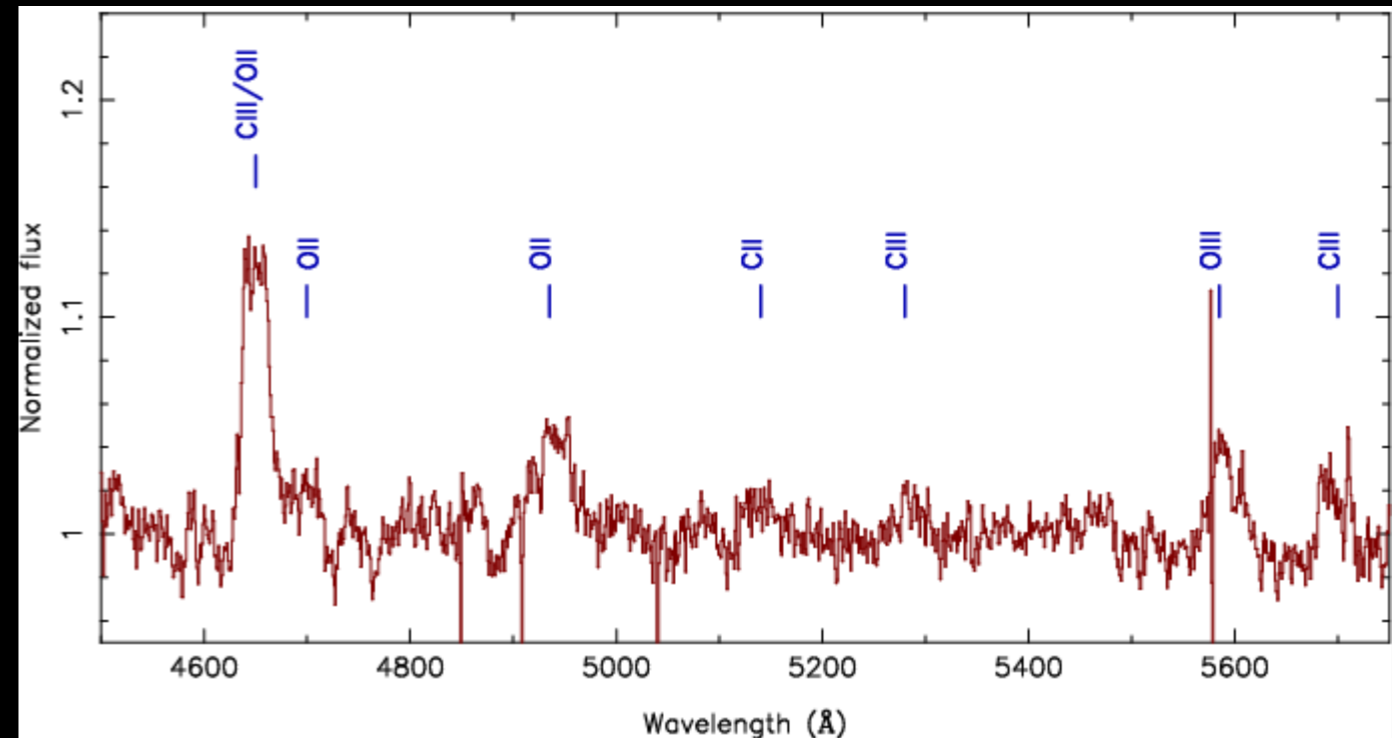
# Non-mergers: AM CVn stars

- ▶ Short period variables
- ▶ He dominated spectra
- ▶ Different formation channels



# Cousins: Ultra-compact X-ray sources

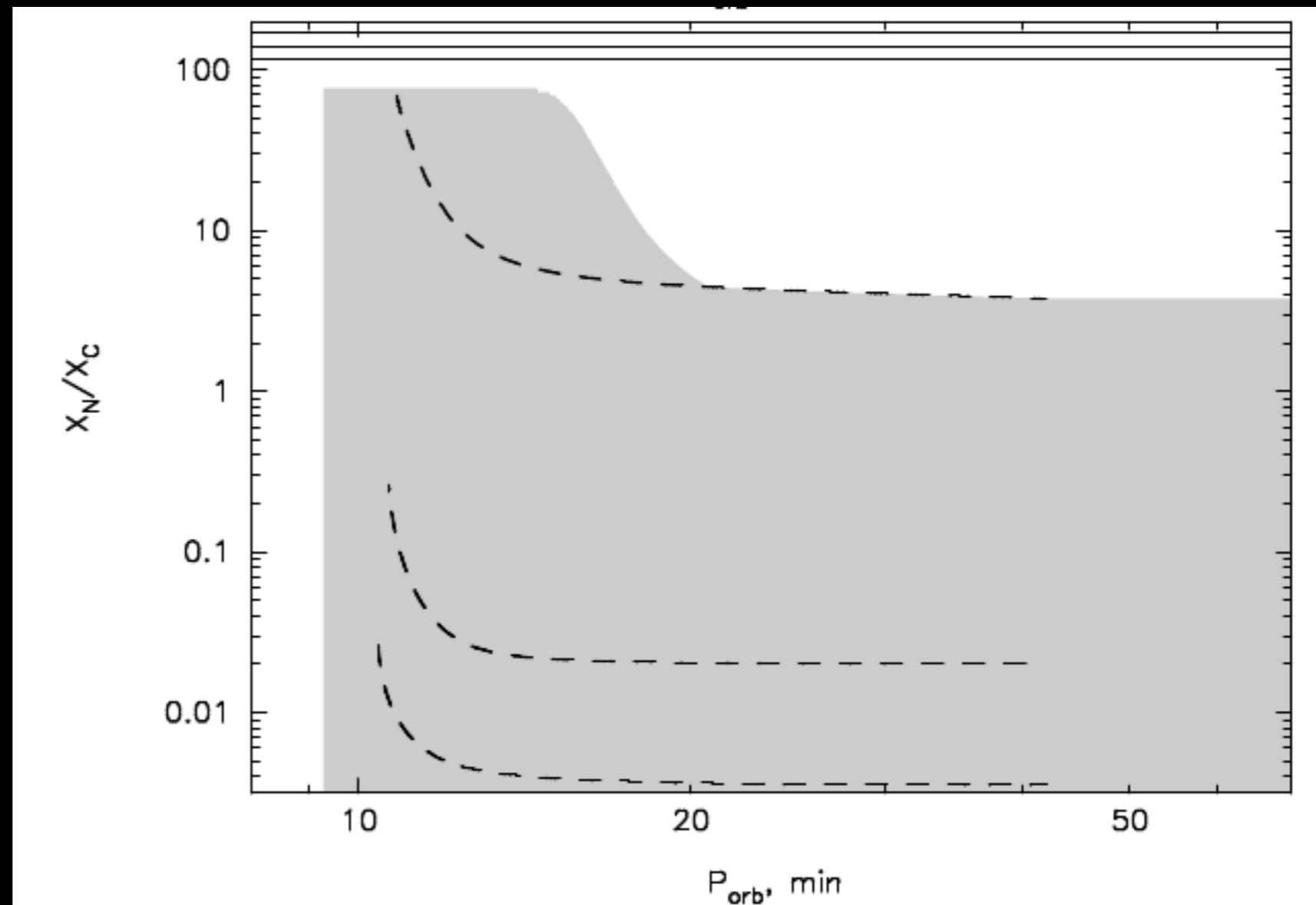
- ▶ Replace accreting WD with neutron star
- ▶ Similar formation channels
- ▶ Optical spectra very different (irradiation)
- ▶ Donors often C/O rich
- ▶ Nova equivalent: X-ray bursts (some confusing results)



Nelemans et al 2004, 2006, Werner et al 2006

# Donor abundances: distinguish formation

- ▶ N to C ratio
- ▶ He WD donors have  $N/C > 100$
- ▶ CO WD donors have  $N/C < 1e-4$
- ▶ He star donors have  $80 > N/C > 1e-3$
- ▶ “Evolved” CV probably rare and mostly show some H





# Direct impact, He Novae, .Ia SN

- ▶ Early phase: direct impact

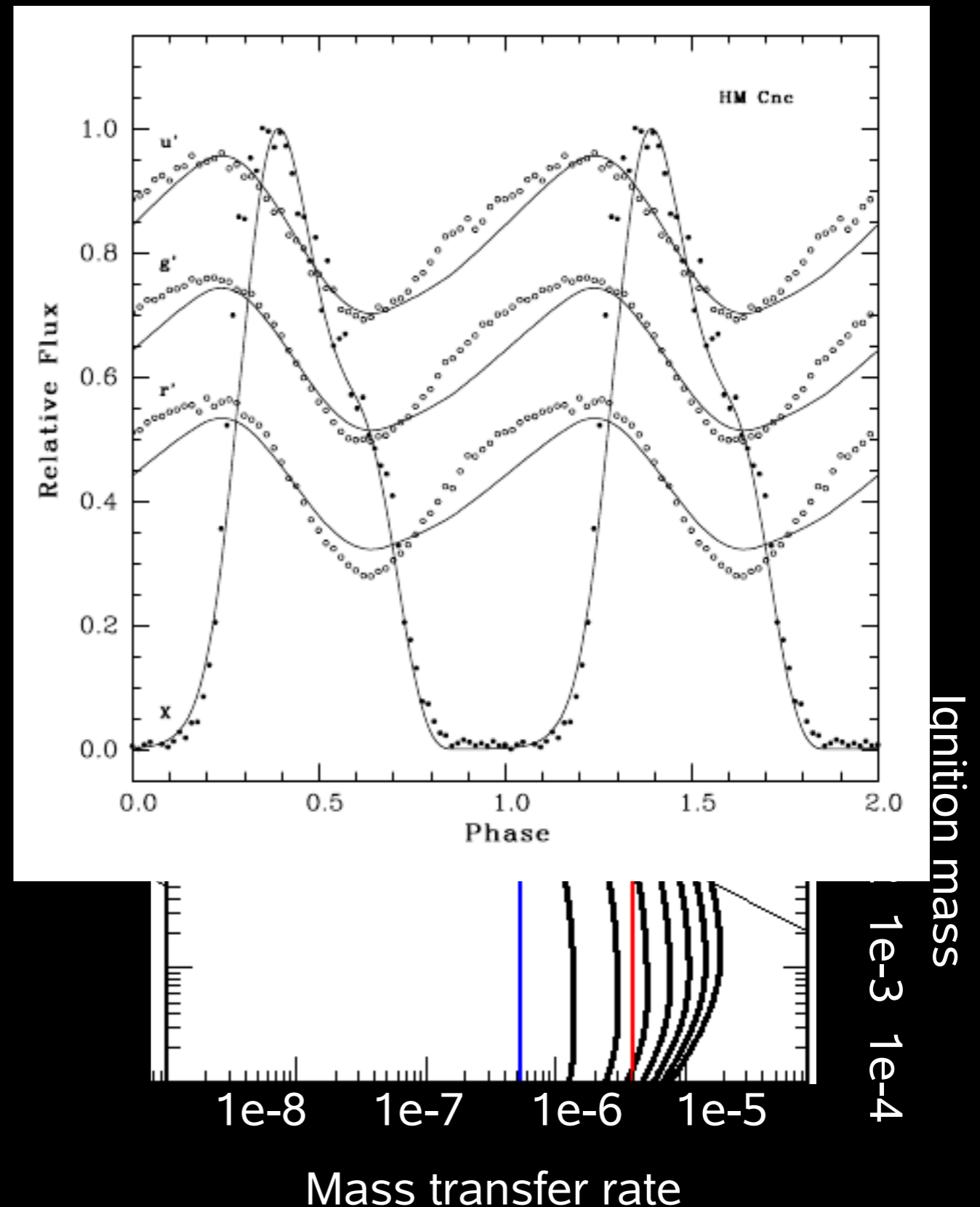
- ▶ Algol like geometry
- ▶ Matches light curves 2 observed systems

Marsh & Steeghs 2002, Wood 2009

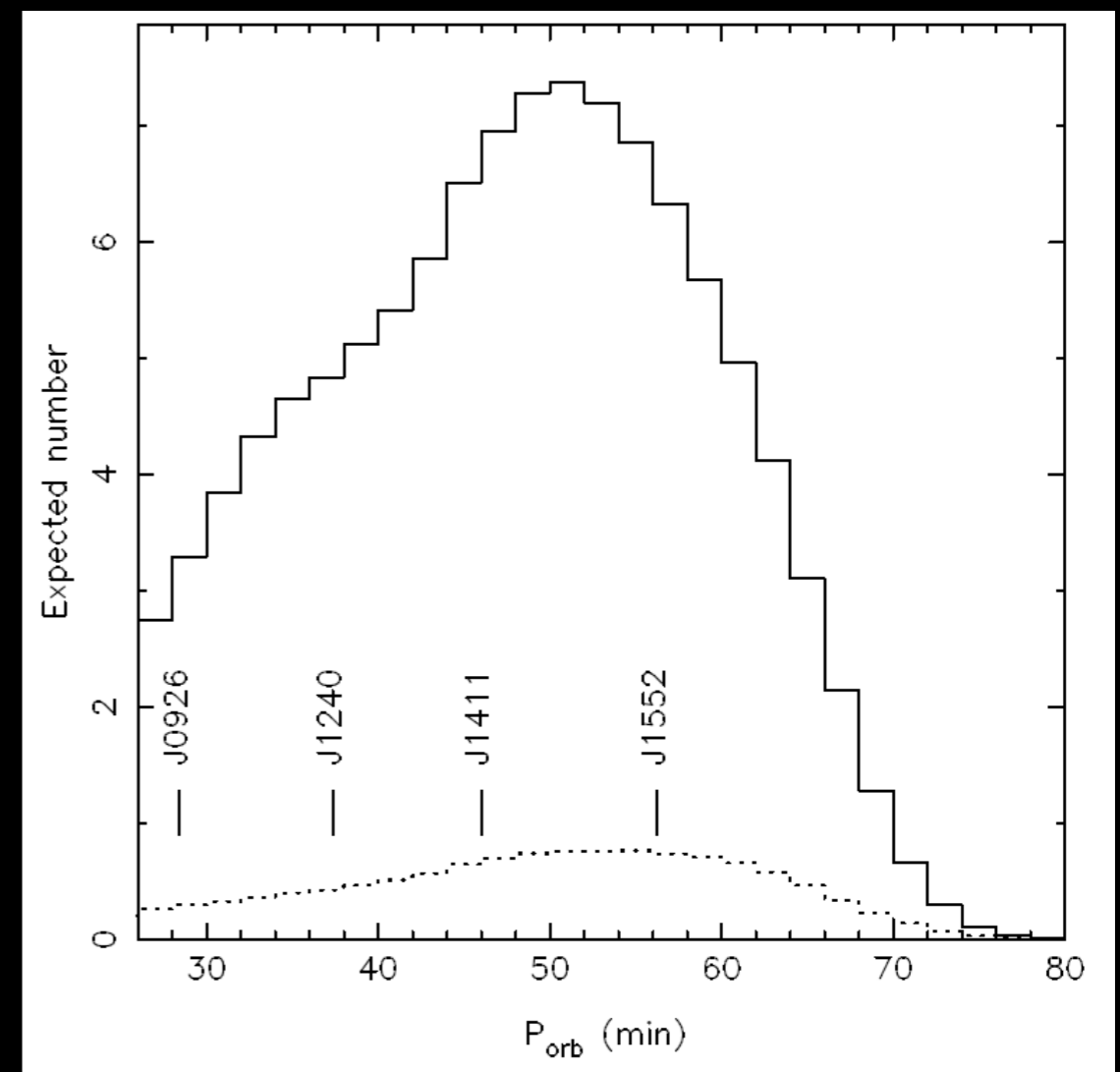
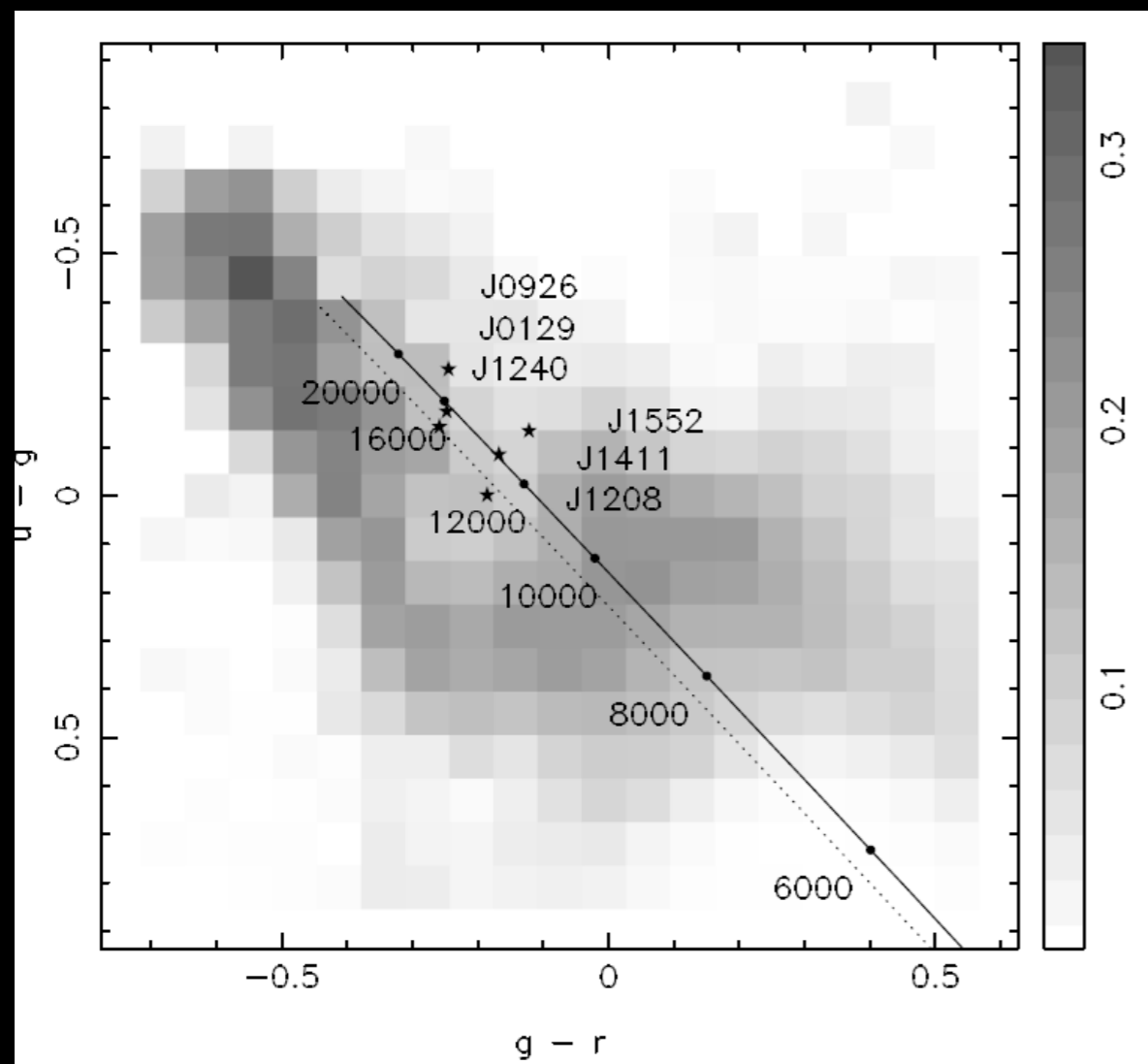
- ▶ He accretion onto CO WD  
→ He Novae

- ▶ Rare but powerful
- ▶ Different physics
- ▶ .Ia faint thermonuclear SN

Bildsten, Shen etc.



# Galactic populations: SDSS

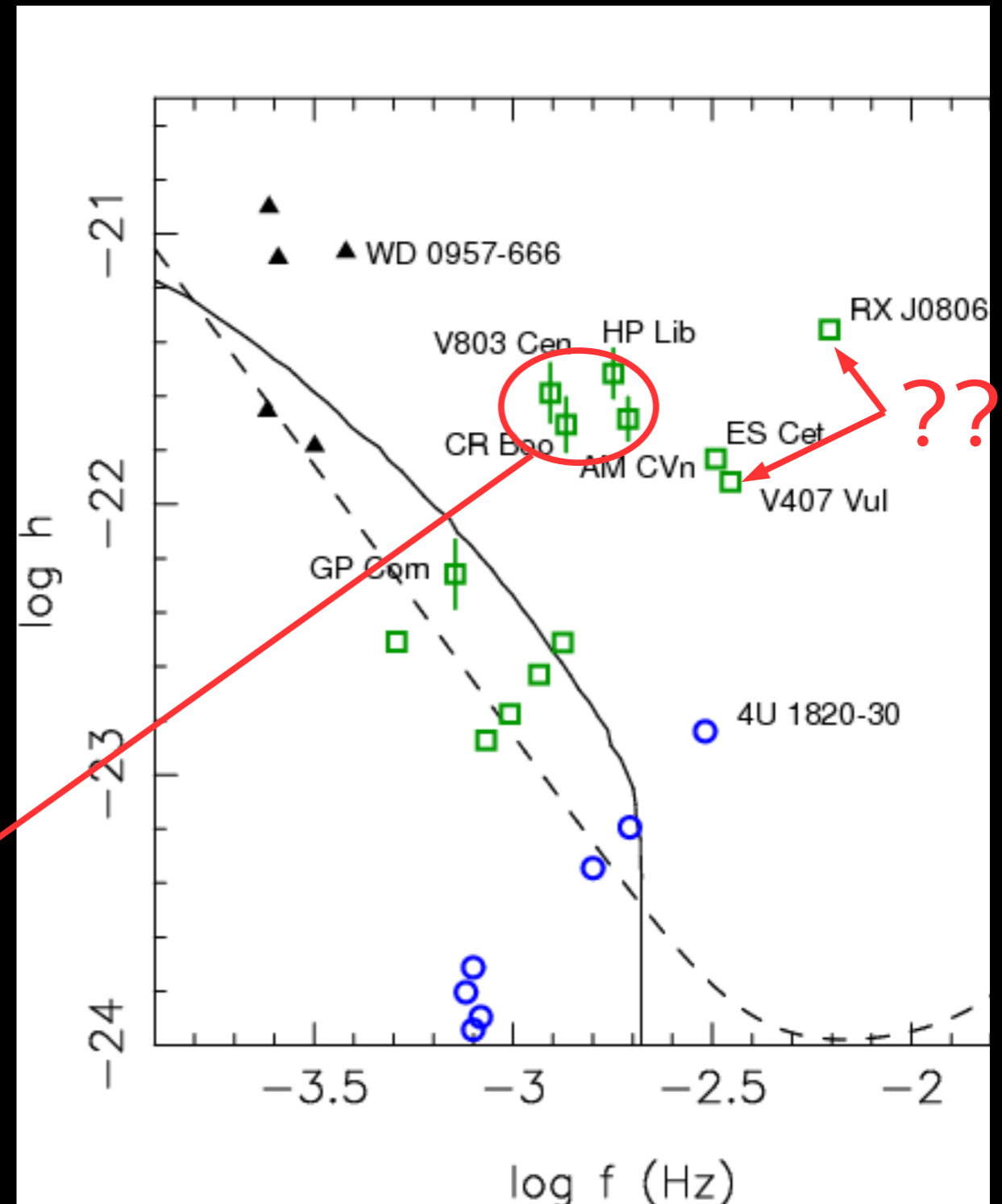


- ▶ Detailed study of AM CVn stars in SDSS
  - ▶ Not as many as hoped/predicted (by > factor 10!)

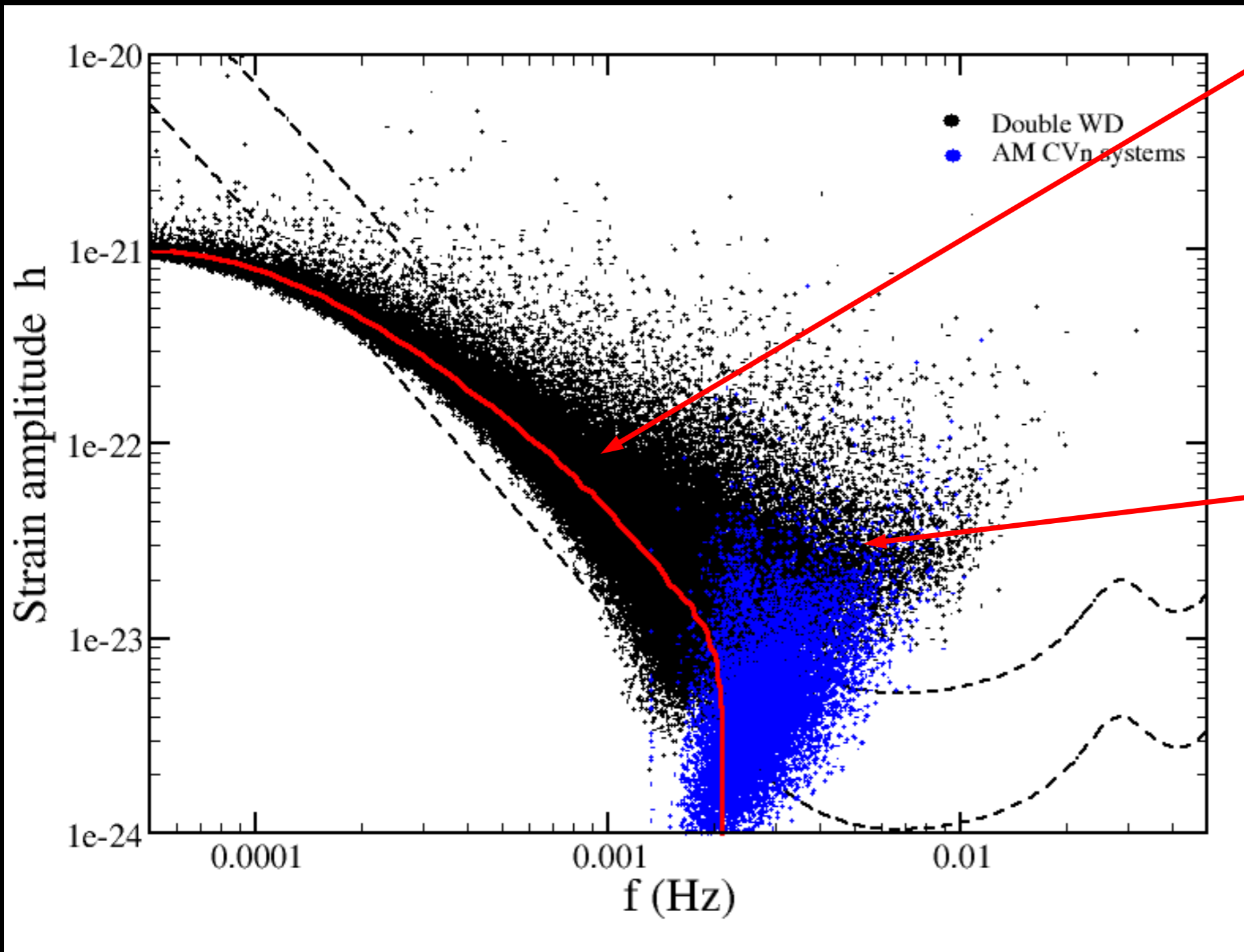
Roelofs et al. 2007, MNRAS

# Gravitational waves: LISA: verification sources

- ▶ Five AM CVn systems
- ▶ Parallax from HST FGS
- ▶ VLT resolved spectroscopy reveals structure in disc and sometimes the accreting star
  - ▶ can use to constrain masses
- ▶ Together with distances gives estimate gravitational wave signature!
  - ▶ LISA Verification sources



# Gravitational waves from double white dwarfs



Unresolved  
double WD  
background

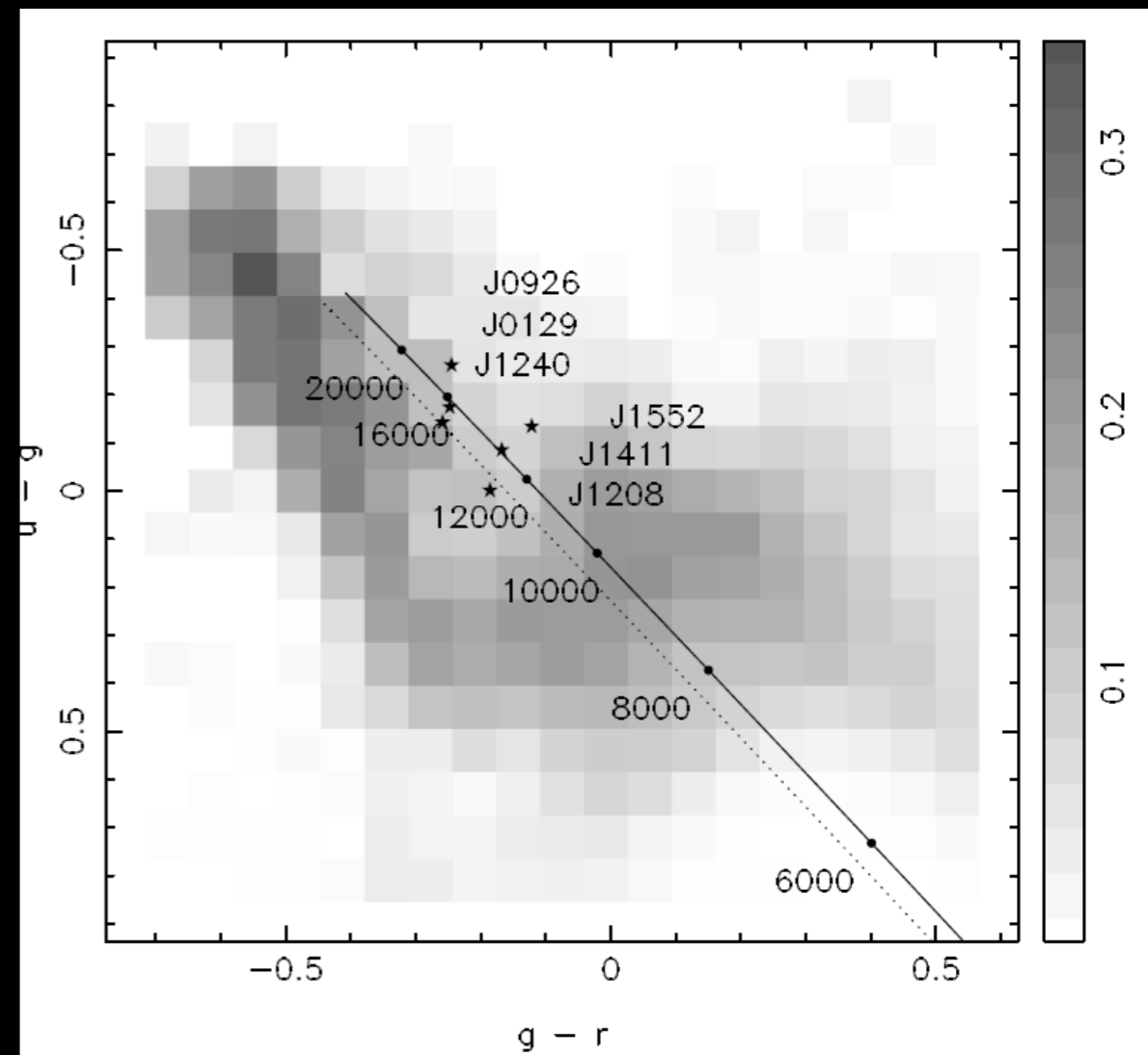
Above and at  
high  $f$  systems  
resolved:  $\sim 10,000$   
of both double  
WD and  
AM CVns

Nelemans et al. 2004

(too many  
AM CVn systems)

# Mining SDSS for new AM CVn systems

- ▶ Complete spectroscopic survey in colour-selected sample (Roelofs, Groot)
- ▶ ~1500 objects, should contain another ~40 AM CVns
- ▶ Currently several 100 observed (VLT, NOT, WHT...)
- ▶ 5 New systems found
- ▶ Current number of AM CVn systems 28



# Outlook

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- ▶ Detailed evolutionary calculations AM CVn stars
- ▶ Detailed He Nova calculations
- ▶ New observations to find more systems
- ▶ Better (= more direct) comparison population models and observations
- ▶ Study (model) related populations simultaneously

# Conclusions

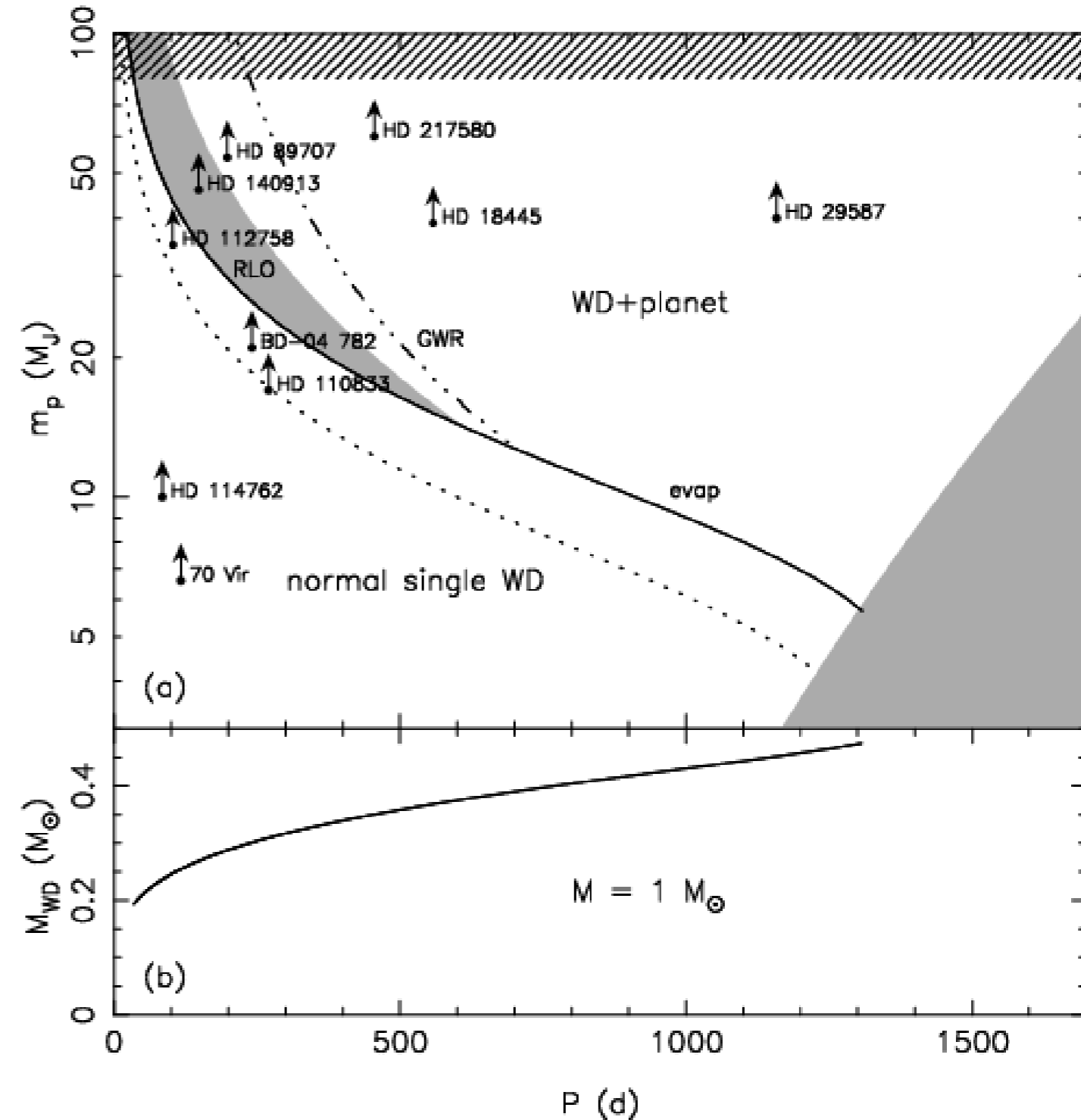
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- ▶ Double WD rates fairly well determined
- ▶ Rich zoo of merger products and non-mergers
- ▶ Important to look at related objects as may be easier to study
- ▶ Current and new surveys look very promising
- ▶ GAIA: many eclipsing double WD
- ▶ AM CVn systems very rare (i.e. more mergers)
- ▶ New systems are found in SDSS
- ▶ Double WD and AM CVn stars most promising low-frequency GWR sources

# Formation of single He WD

- ▶ He white dwarf merger
- ▶ RG enhanced wind
  - ▶ Ad hoc....
- ▶ Planet/brown dwarf
  - ▶ Companion survives
  - ▶ Companion just evaporates

Soker et al.



Nelemans & Tauris 1998