XMM-Newton observations of the unique binary system HD49798/RXJ0648-4418

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Why a "unique" binary ?

- The only X-ray pulsar with a hot subdwarf companion

  (ROSAT: Israel et al. 1997, ApJ)

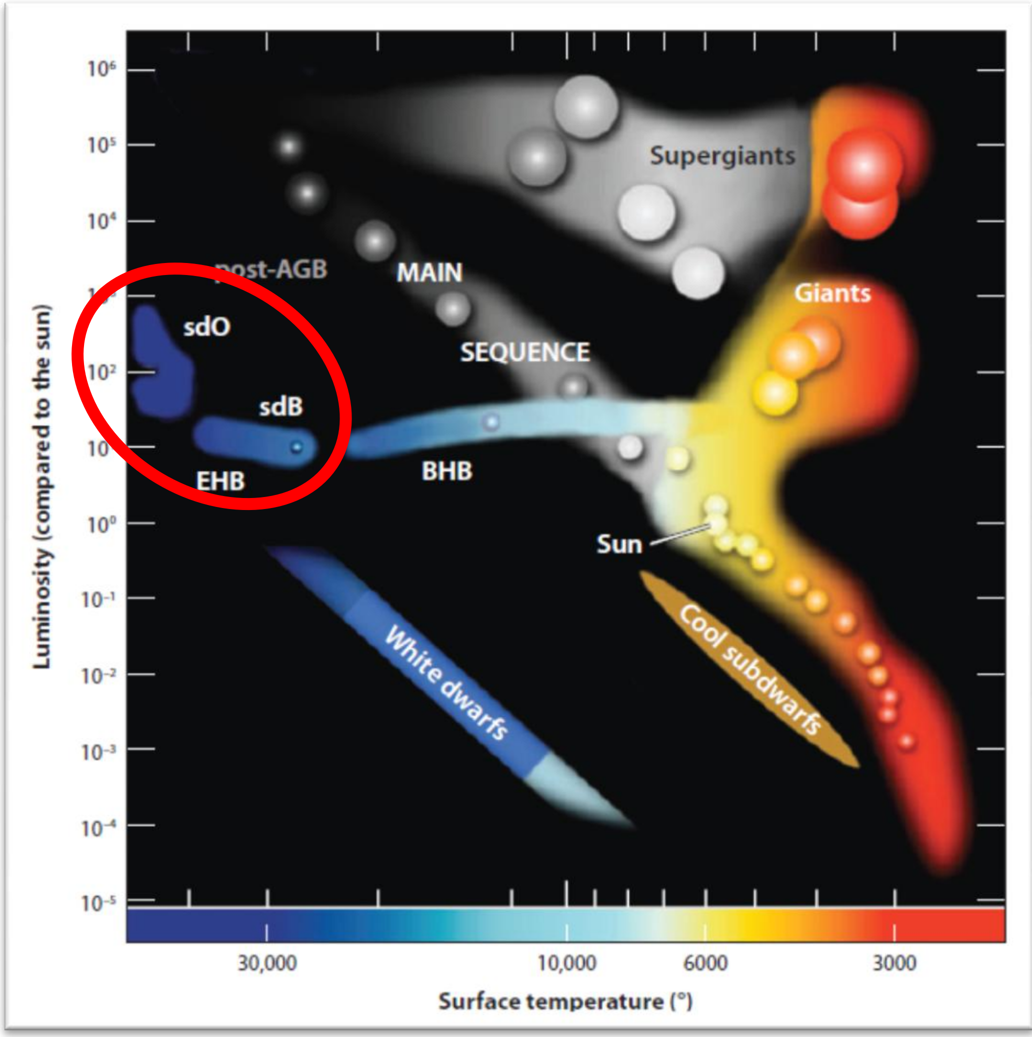
- The pulsar is the fastest spinning - and one of the most massive - white dwarf

  (Mereghetti et al. 2009, Science
  Mereghetti et al. 2011, ApJ)

Hot Sub-Dwarfs

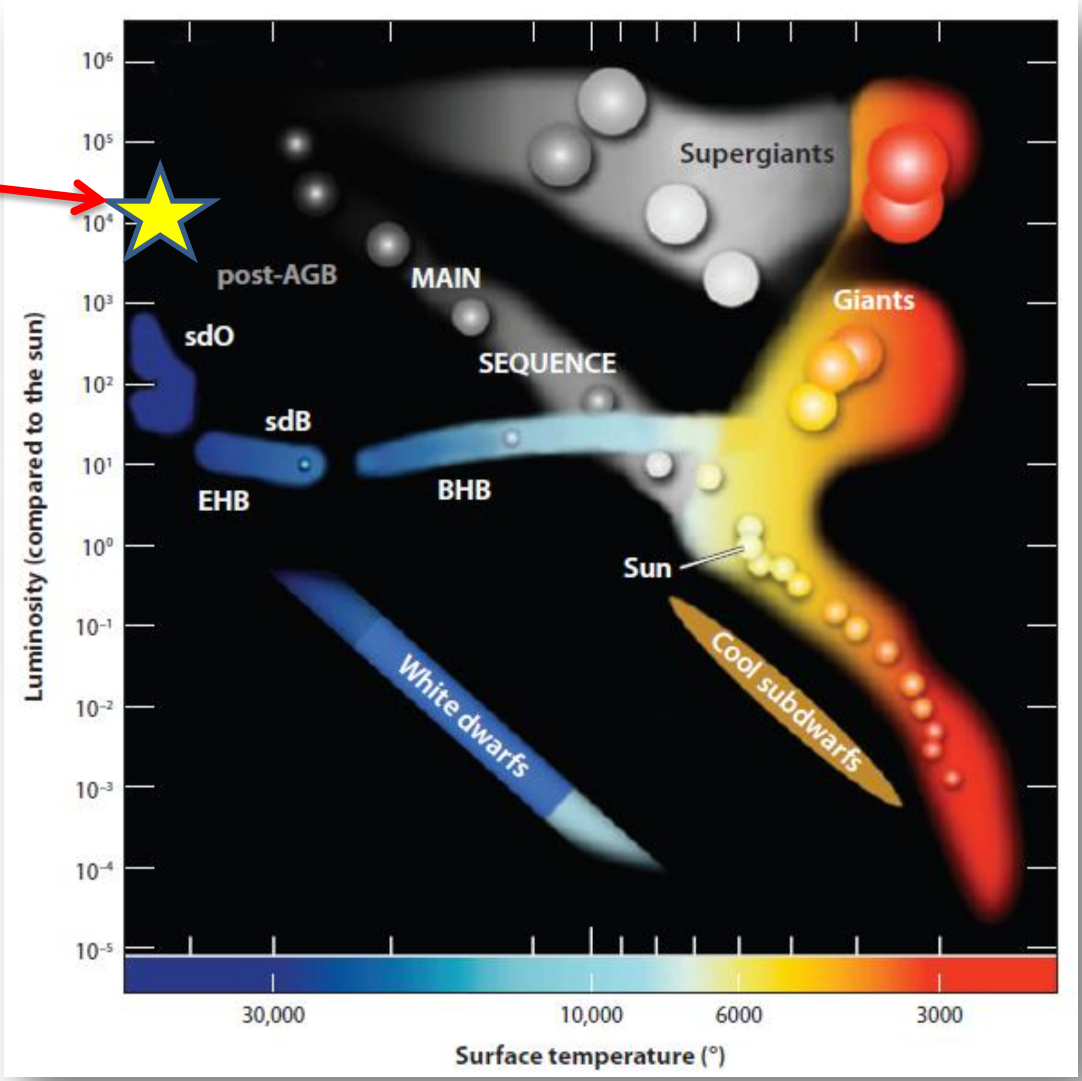
Heber 2009, ARAA

- Low mass He-burning stars with thin H envelope
- Result of evolution involving significant mass loss
- Spectrally classified in
  - sdO   (T>4 10^4 K)
  - sdOB   (3.3 10^4 <T<4 10^4 K)
  - sdB   (2.8 10^4 <T<3.3 10^4 K)
- Many are in binaries



HD 49798: the brightest sdO

T = 47,500 K
L ~ 10^4 L_{sun}
Log g = 4.25



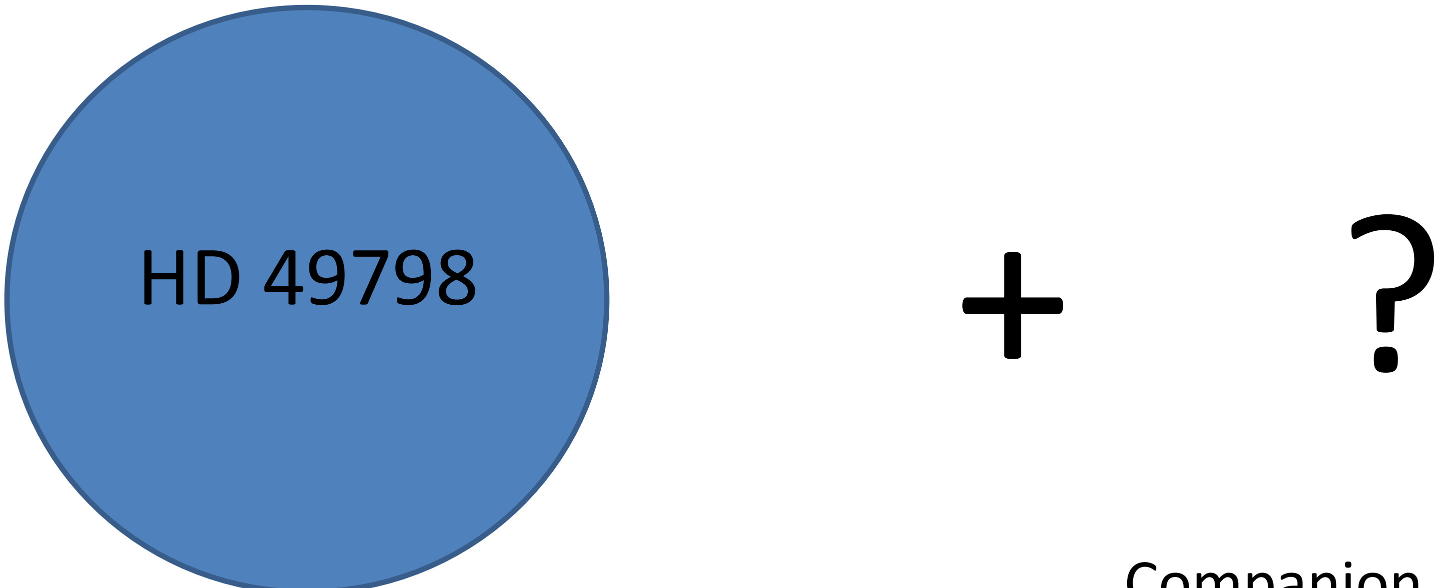
Single-lined spectroscopic binary:

Porb = 1.55 days

d = 650 pc

Thackeray 1970
Kudritzky et al. 1978
Hamann et al. 1981
Bruhweiler et al. 1981
Stickland & Lloyd 1984
Bisscheroux et al. 1997

HD 49798 :
a single-lined spectroscopic binary

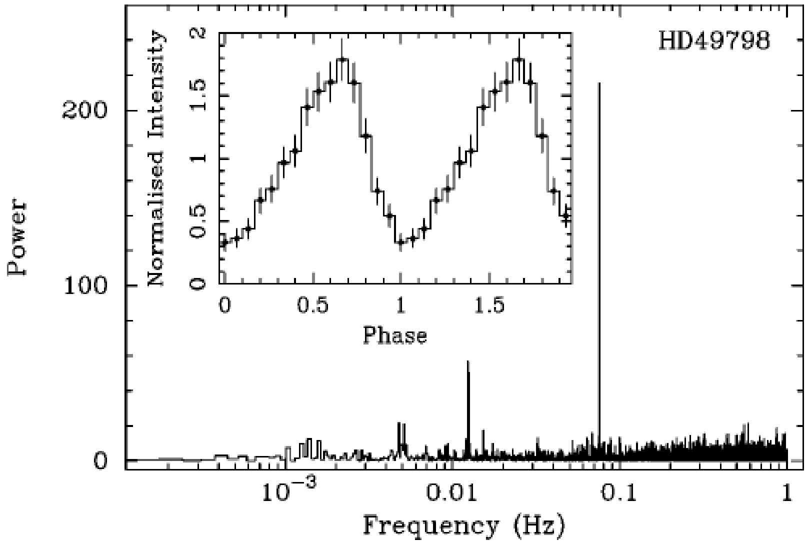


Hot subdwarf
(sdO type)
B = 8 mag

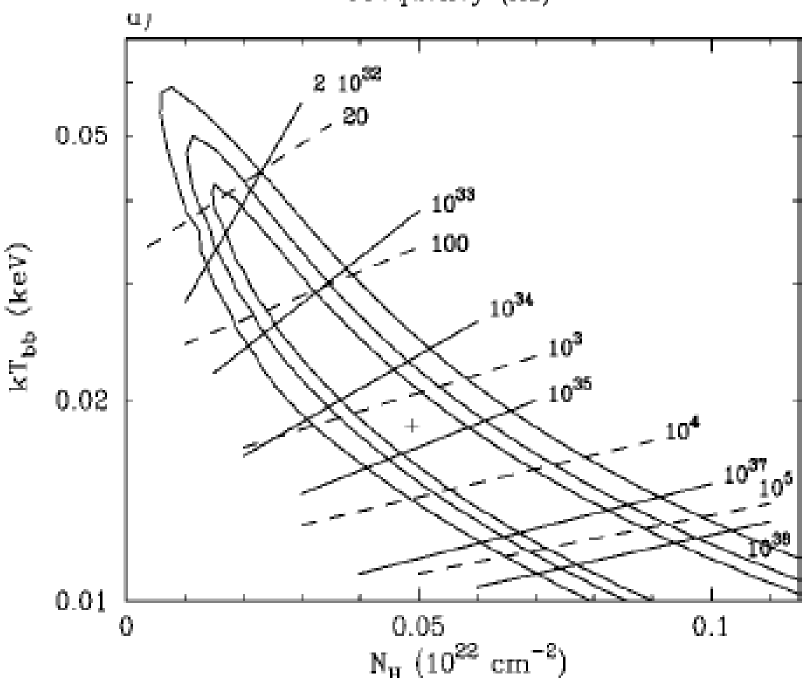
Companion
invisible in
optical / UV data

ROSAT discovery of pulsed soft X-ray emission

(Israel et al. 1997, ApJ)



P=13.2 s → the companion is a **Neutron Star** or a **White Dwarf**



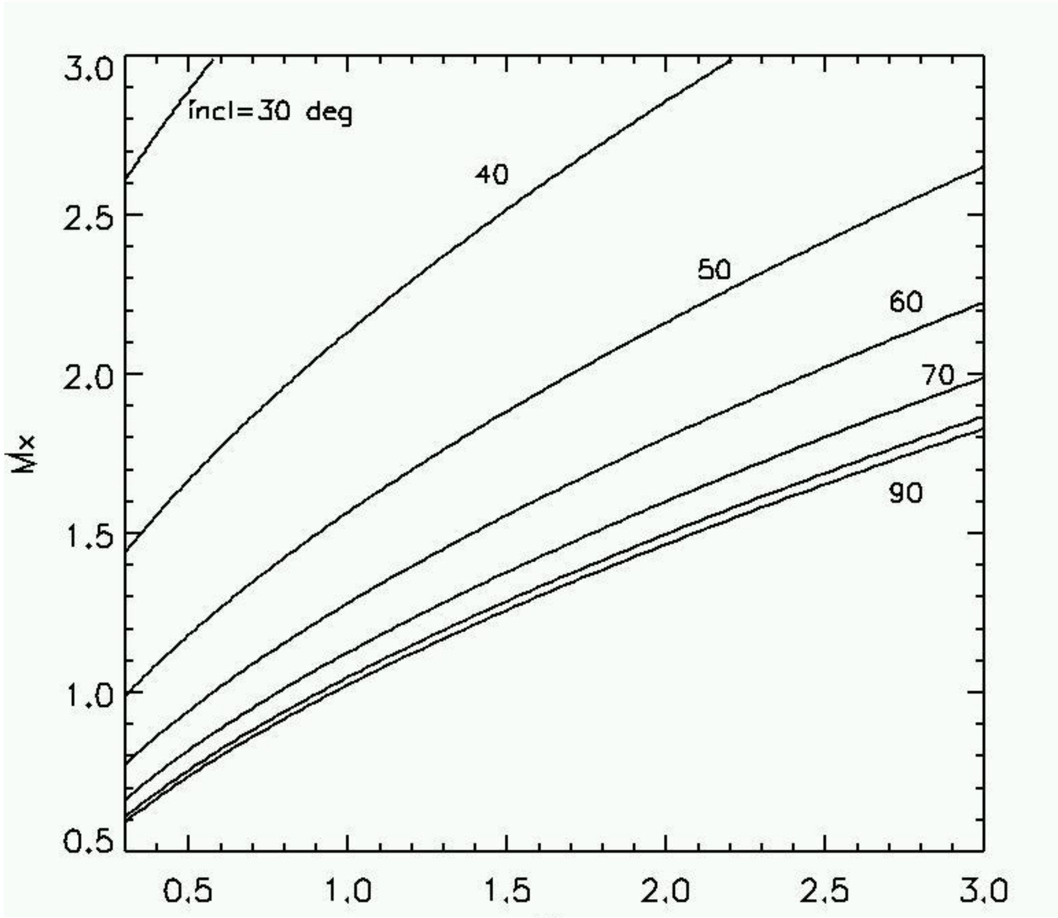
Poorly constrained blackbody spectrum

→ large uncertainty on X-ray luminosity

10^{32} - $>10^{38}$ erg/s

Optical mass function

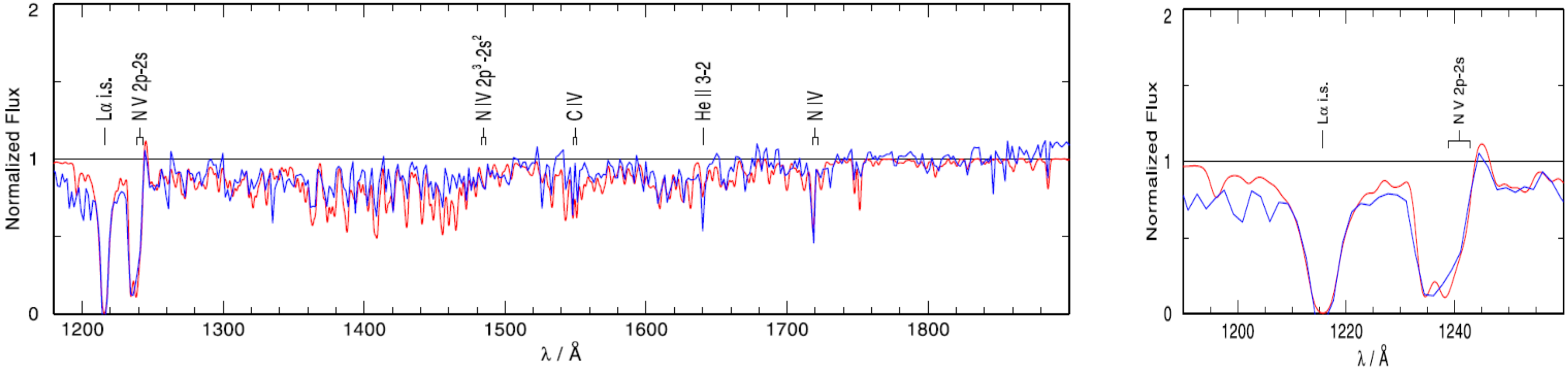
Companion mass
WD or NS ?



HD 49798 mass

Stellar wind from HD49798

UV spectrum of HD 49798 (Hamann 2010)



g. 8 The UV spectrum of the sdO star HD 49798. The IUE observation (*blue continuous line*) is compared to a PoWR model (*red dotted*

Wind from the sdO star with

$V = 1350$ km/s

$\dot{M} = 3\ 10^{-9}\ M_{sun}/yr$

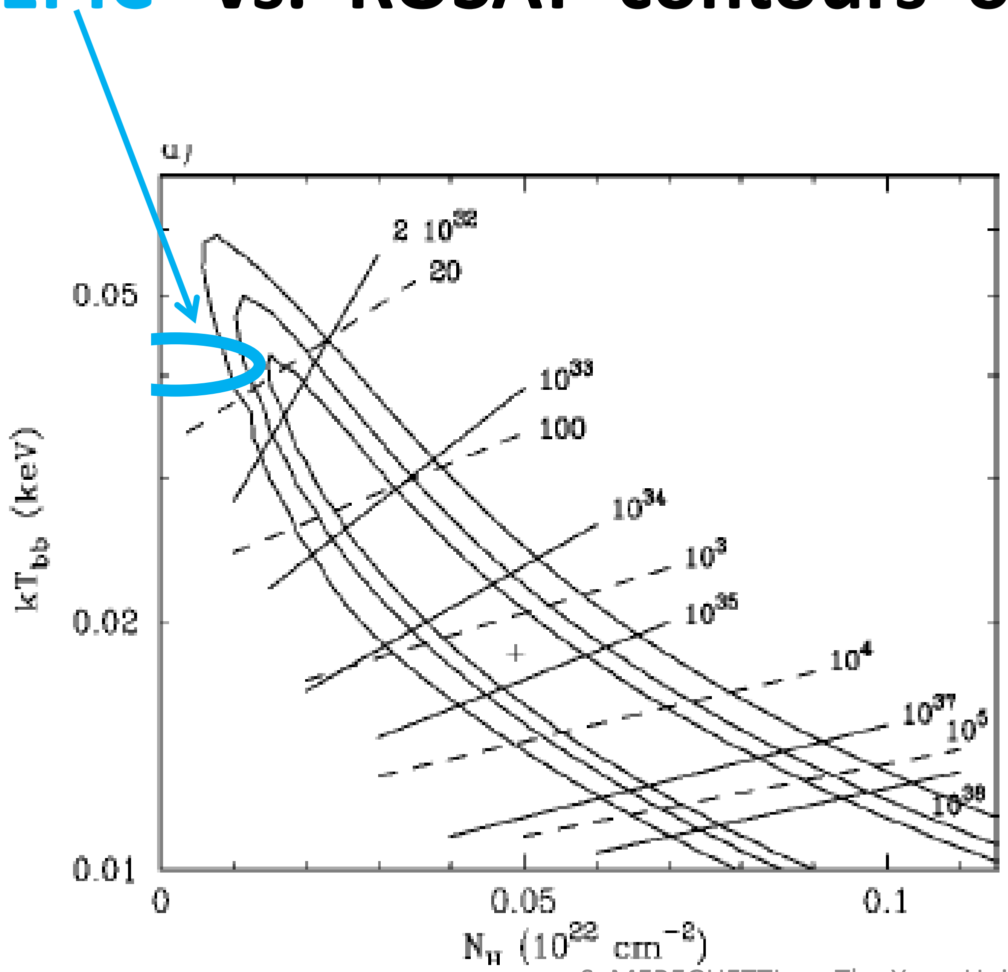
Accretion luminosity:

~ 10^{34} -10^{35} erg/s for NS

~ 10^{31} -10^{32} erg/s for WD

44 ks XMM-Newton observation on May 2008

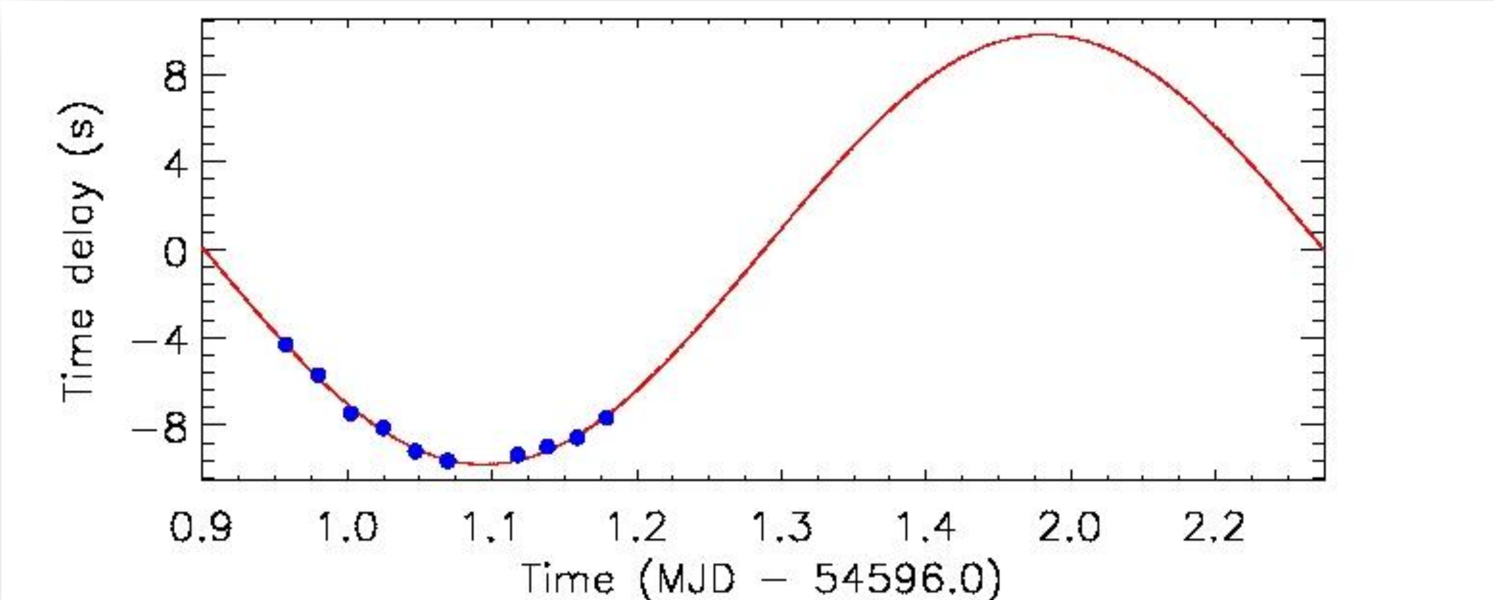
EPIC vs. ROSAT contours of kT-N_H



- kT_{BB} = 40 +/- 2 eV
- $N_H < 10^{20}$ cm^{-2}
- $L_{bol} \sim 10^{32}$ erg/s @ 650 pc

the companion is a White Dwarf

Time delays in X-ray pulses



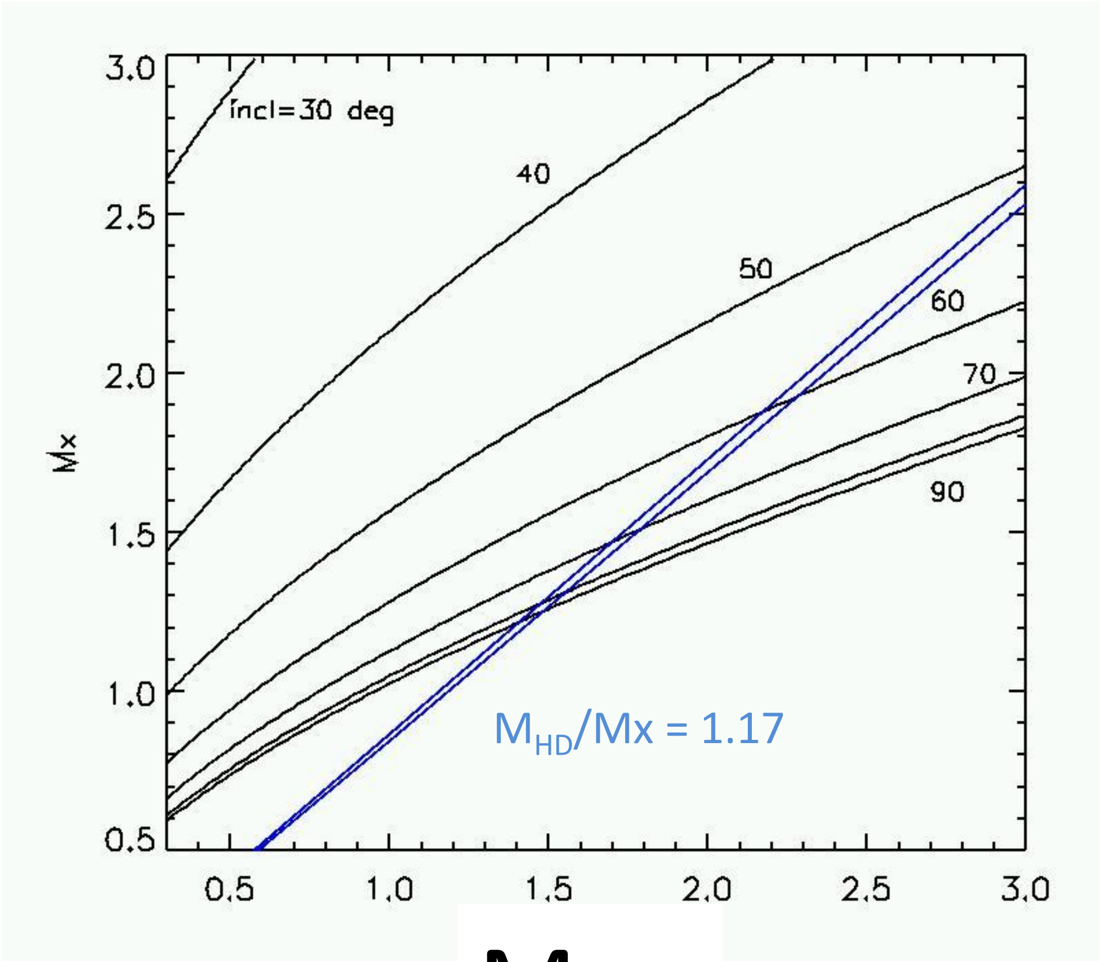
- X-ray projected semi major-axis :

$$A_x \sin i = 9.78 \pm 0.06 \text{ light-sec}$$

+ opt. mass funct. → $q = M_{HD}/M_x = 1.17 \pm 0.01$

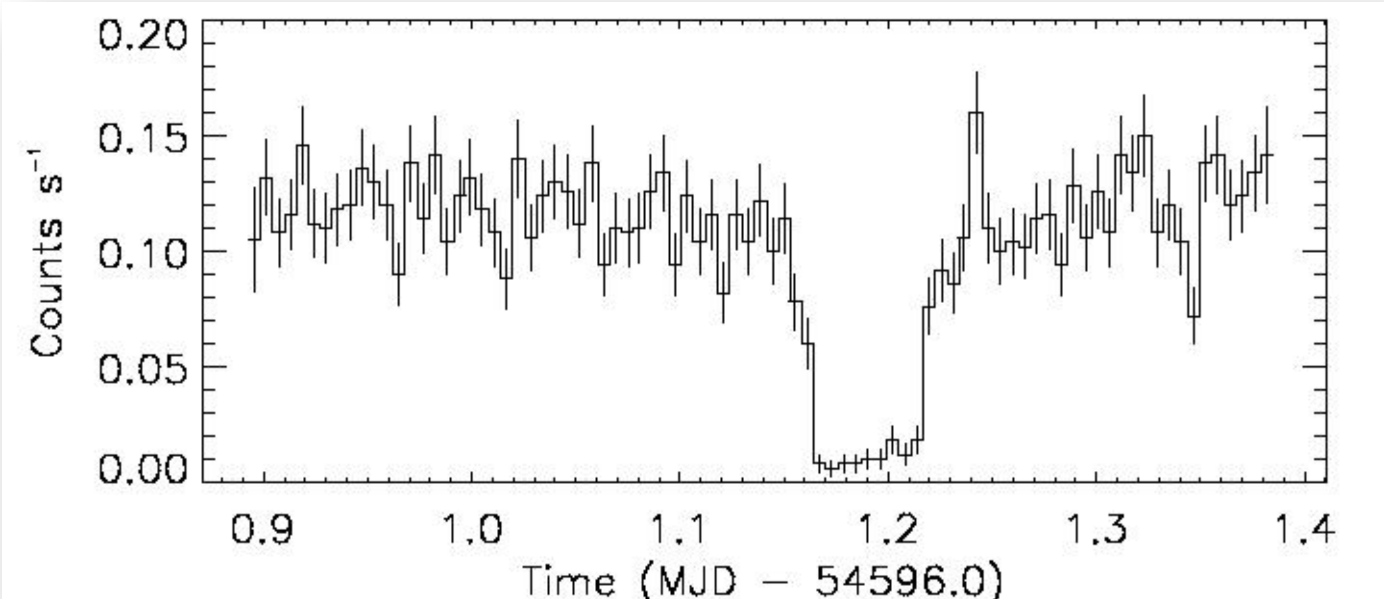
Optical + X-ray mass functions

Mx



M_{HD}

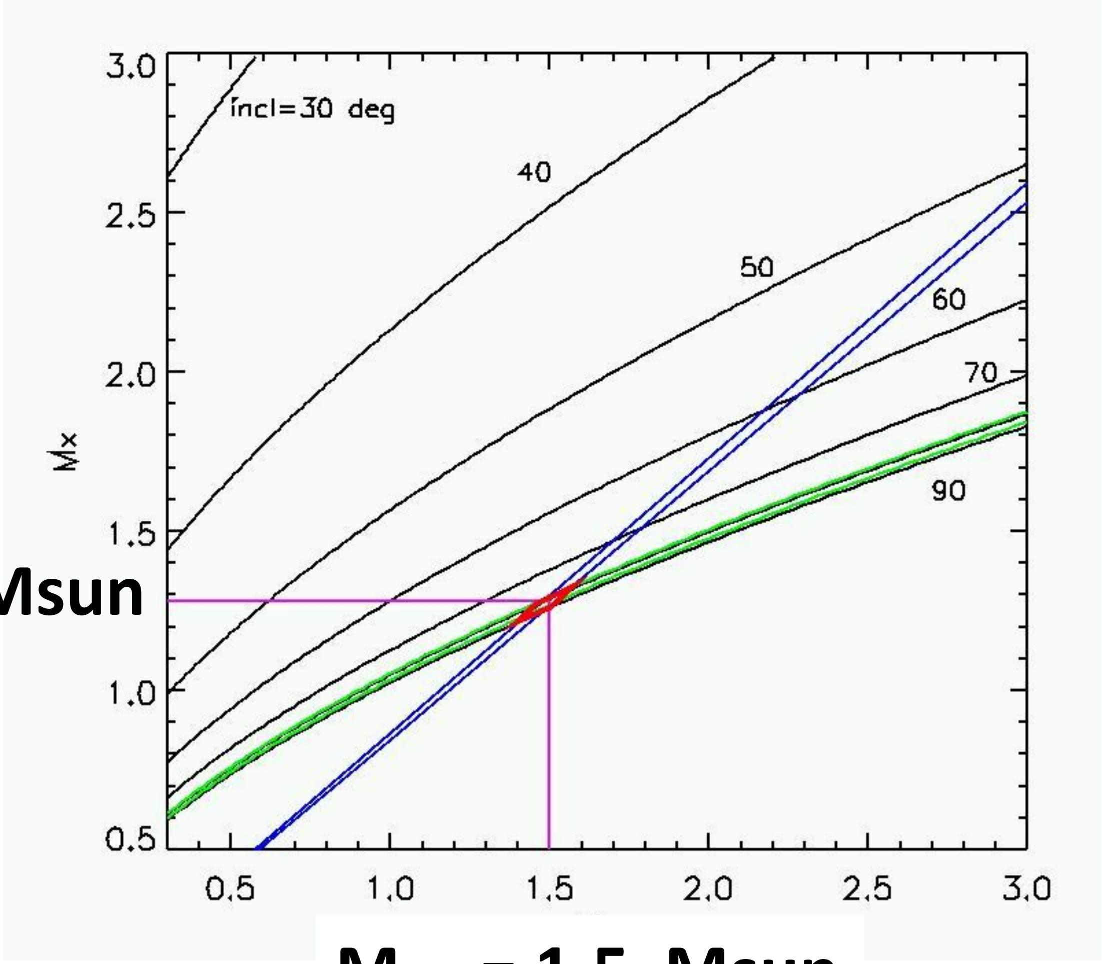
Discovery of X-ray eclipse



$$(R_C/a)^2 = \cos^2 i + \sin^2 i \sin^2 \Theta$$

- Eclipse duration = 1.3 hours
- Radius of HD 49798 = 1.45+/-0.25 Rsun
- → inclination 79—84 degrees

Opt. and X-ray m.f. + inclination

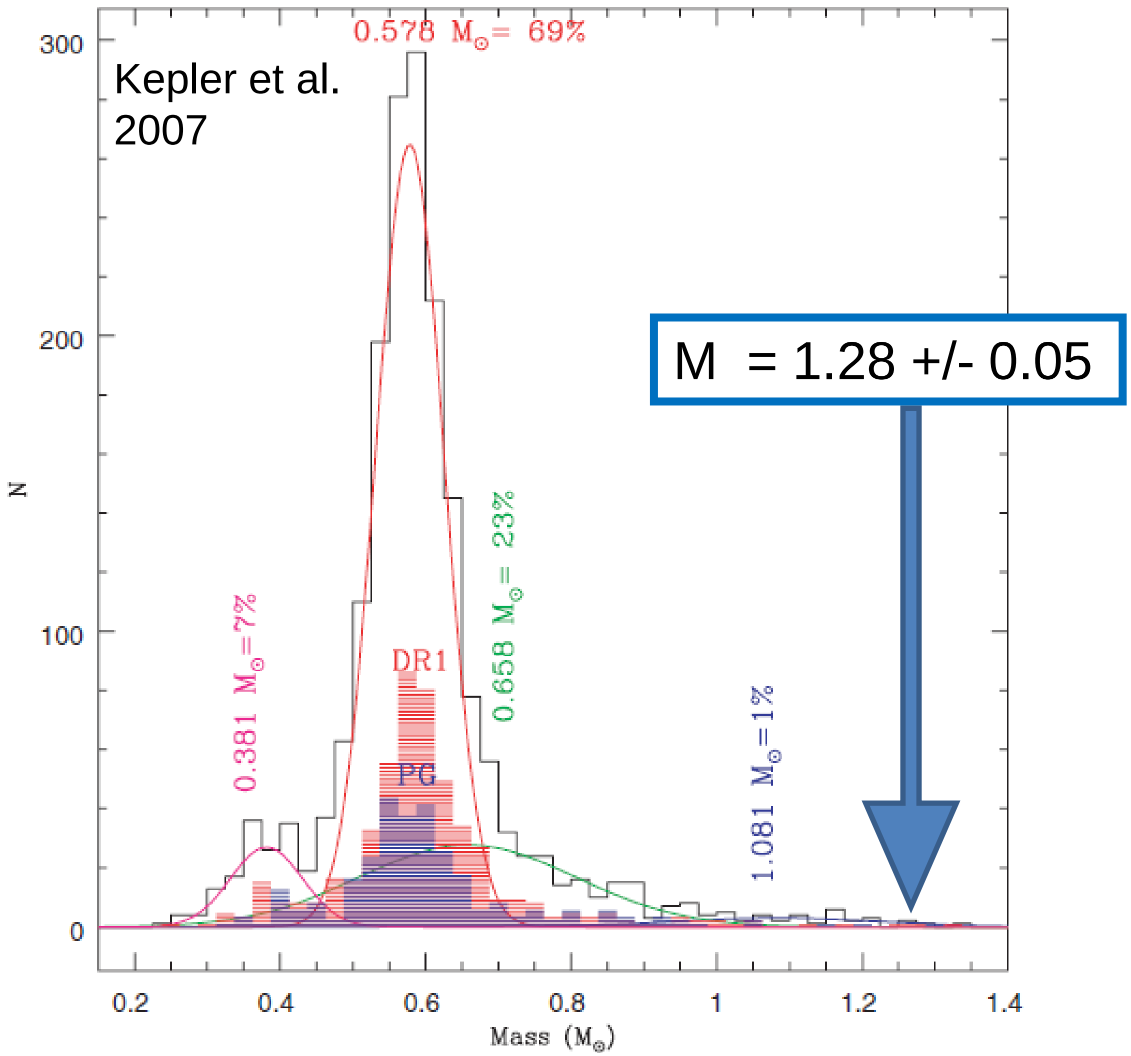


Mx = 1.28 Msun

M_{HD} = 1.5 Msun

The companion of HD 49798 is a very massive WD !

Distribution of WD masses



Direct, dynamical measurement of M

While most WD masses are derived indirectly:

- spectroscopic and photometric methods → L, T, log g → M/R^2
- gravitational redshift → M/R

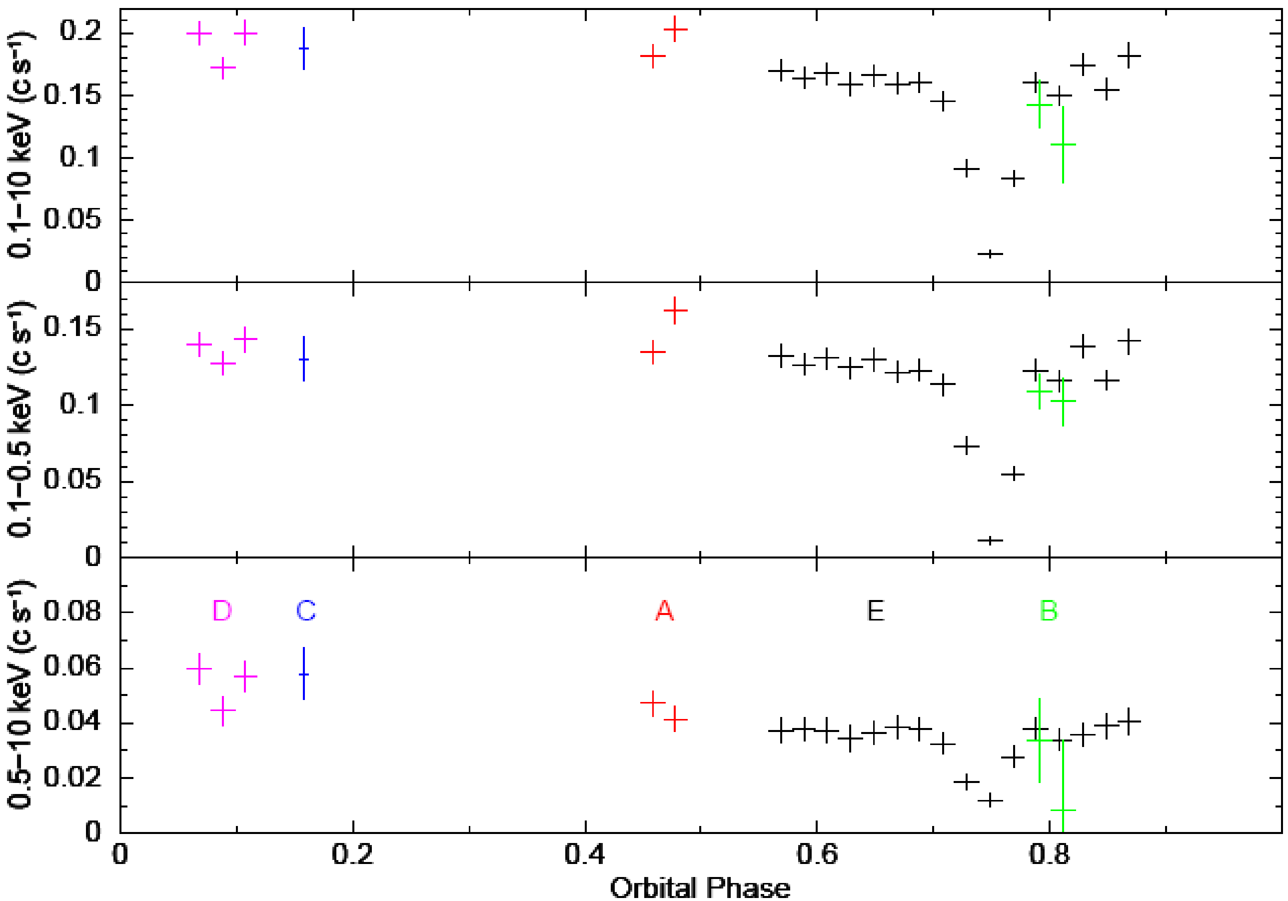
Summary

- Robust, dynamical determination of M > 1.2 Msun for a white dwarf
- Post Common Envelope binary with well determined masses → optimal test-bench for evolutionary models
- The fastest spinning WD (P=13.2 s) → low B to avoid propeller (< few kG)
- Possible future evolution:
  - SN Ia with short delay time or
  - non-recycled millisecond pulsar

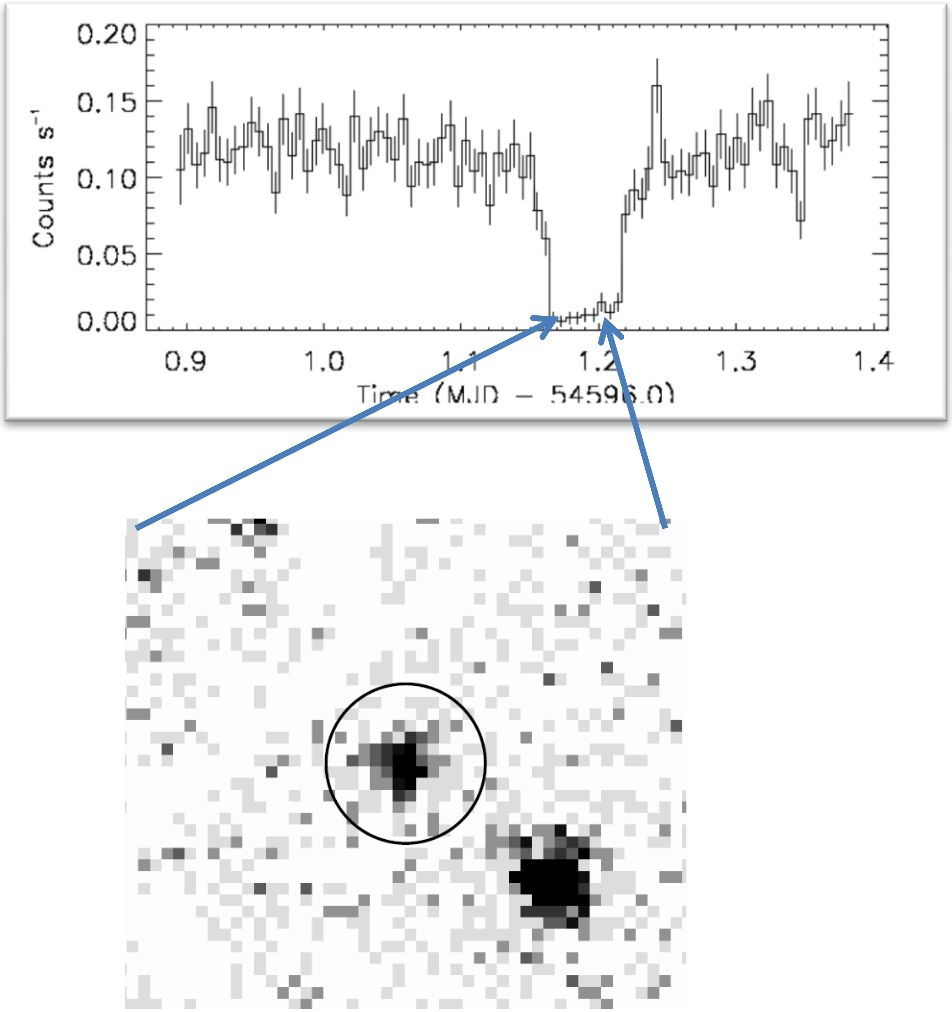
XMM Observations

4 short obs. in 2002 (**A**,**B**,**C**,**D**)
1 long obs. in 2008 (**E**)

EPIC PN



X-rays during eclipse:
emission from the sdO star !



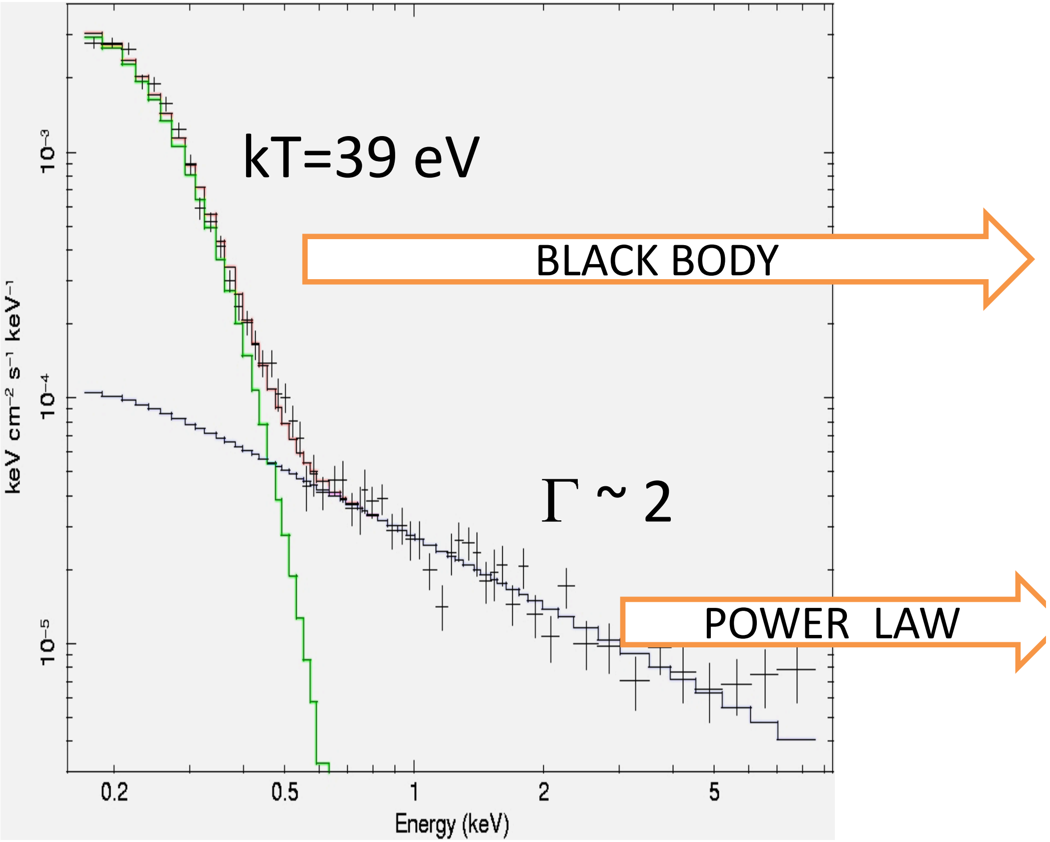
Therm. Bremsstrahlung Spectrum with kT= 0.5 keV

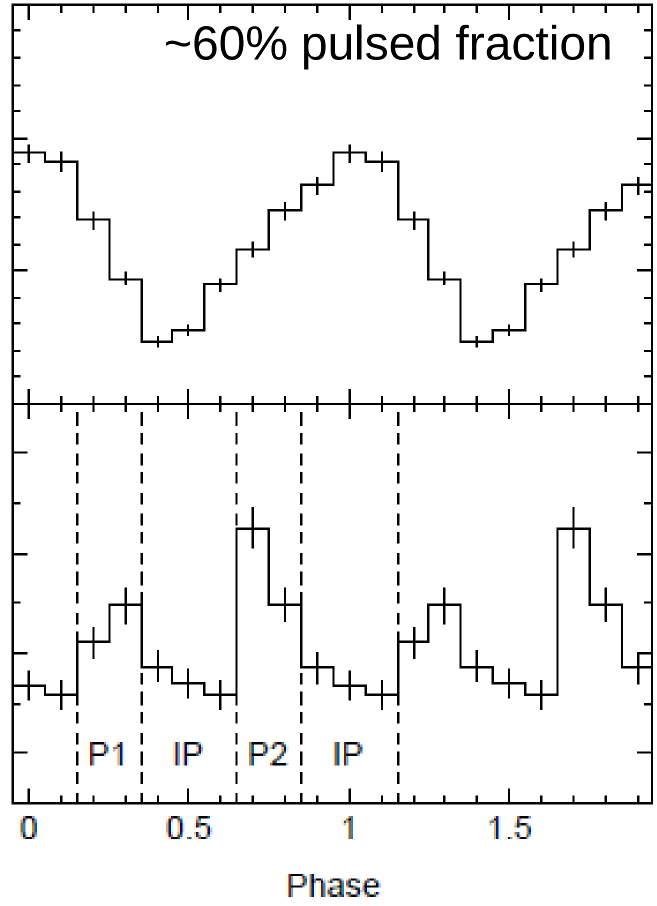
$L_X \approx 2\ 10^{30}$ erg/s

First detection of X-ray emission from a hot subdwarf

$L_X/L_{bol} \approx 10^{-7}$ consistent with O type stars

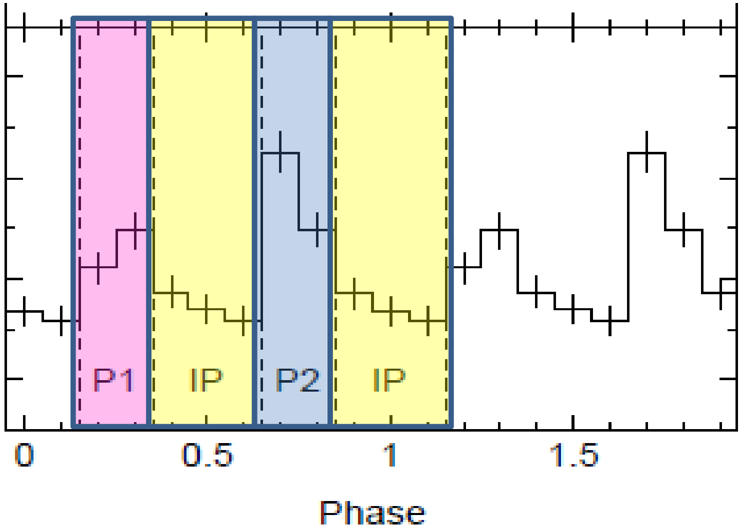
Two components with different spectral and timing properties

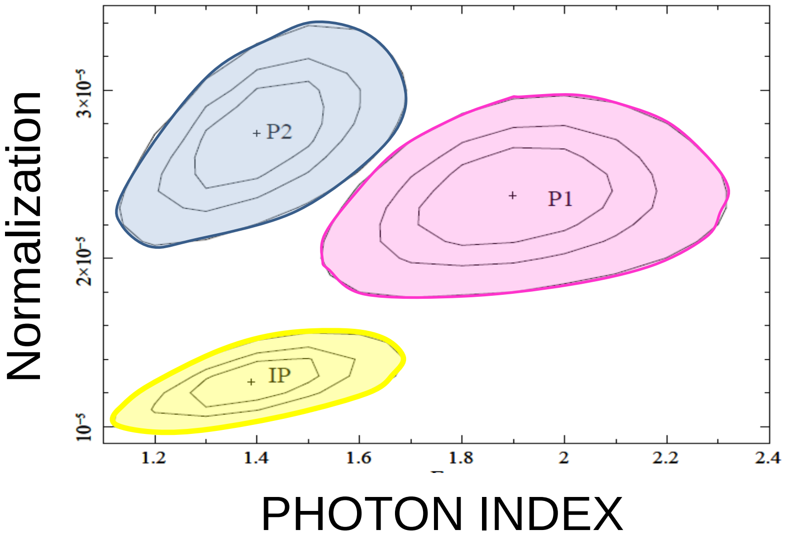




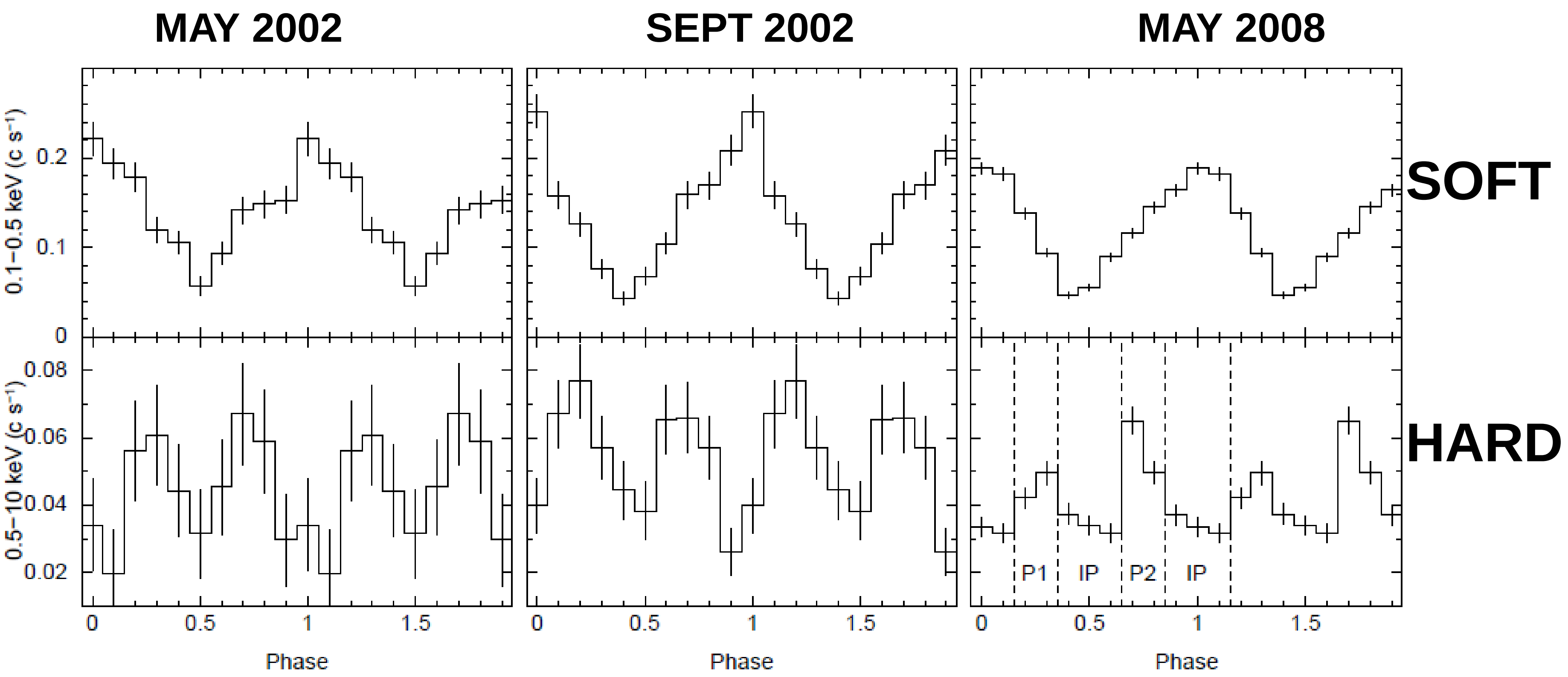
Phase resolved spectroscopy

- Soft component: No temperature variations
- Hard component: First peak is slightly softer

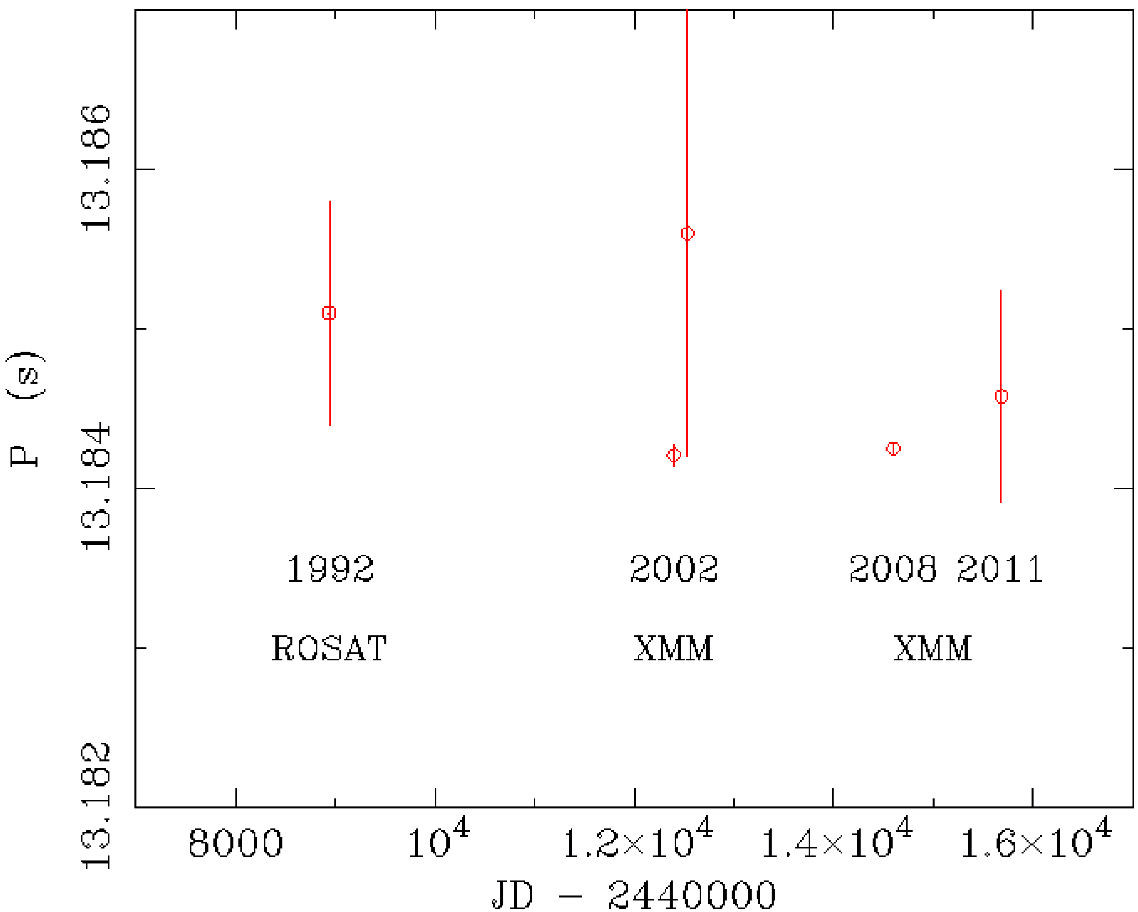




Long term stability of pulse profiles



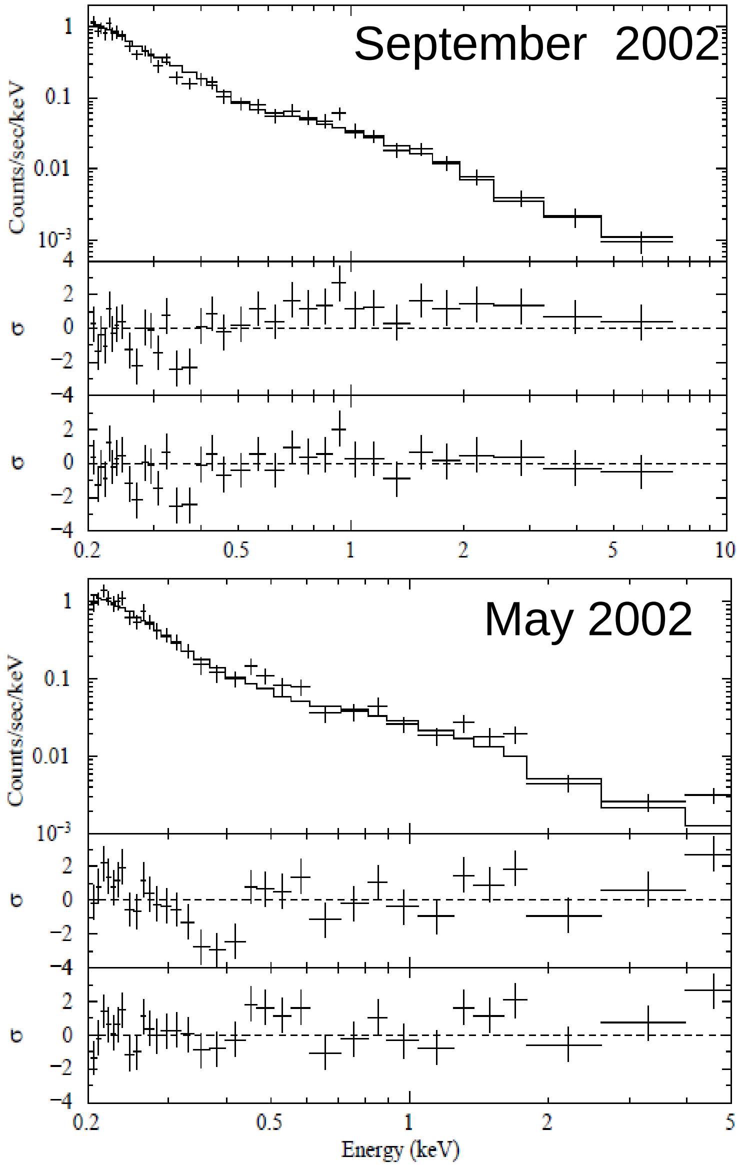
Pulse period evolution



No evidence for significant spin-up or spin-down

$$-5\times10^{-13}\ \mathrm{s\ s^{-1}} < \dot{P} < 9\times10^{-13}\ \mathrm{s\ s^{-1}}$$

Small variations between 2002 and 2008

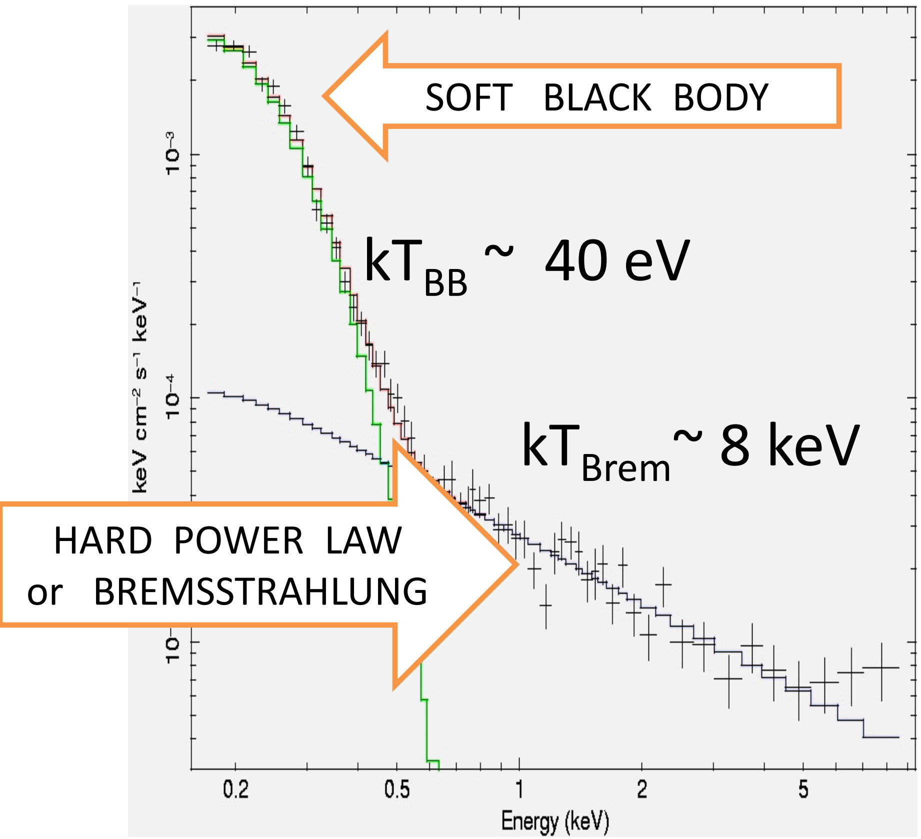


In Sept. 2002
the power law component was
~30% brighter than in 2008

Orbital or long term variability ?

In May 2002
the blackbody temperature
was lower than in 2008
(32 eV wrt 40 eV)

Ratio L_{soft}/L_{hard} ~ 10 as in several magnetic CVs…



….but:

Temperature of hard component lower than expected based on kT-Mass correlation

B < 1 kG wrt ~20—200 MG in polars and ~5—20 MG in Intermediate Polars

Variability properties are different

Accretion is through stellar wind

Conclusions

- X-ray spectral properties are similar to those of Polars and Intermediate Polars
- This is puzzling considering that this system is quite different:
  - accretes from wind and not from Roche-lobe overflow
  - B < few kG rather than several MG
- First X-ray detection of a hot subdwarf → crucial to study X-ray generation in winds of hot stars over a broader parameter space