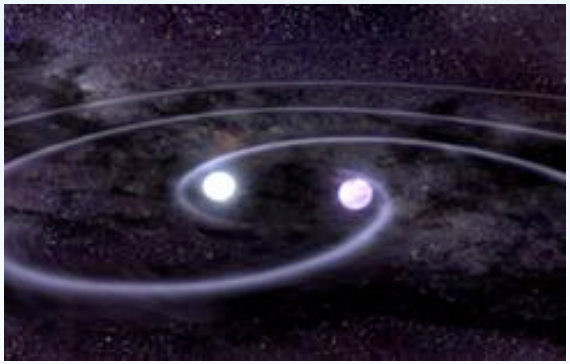
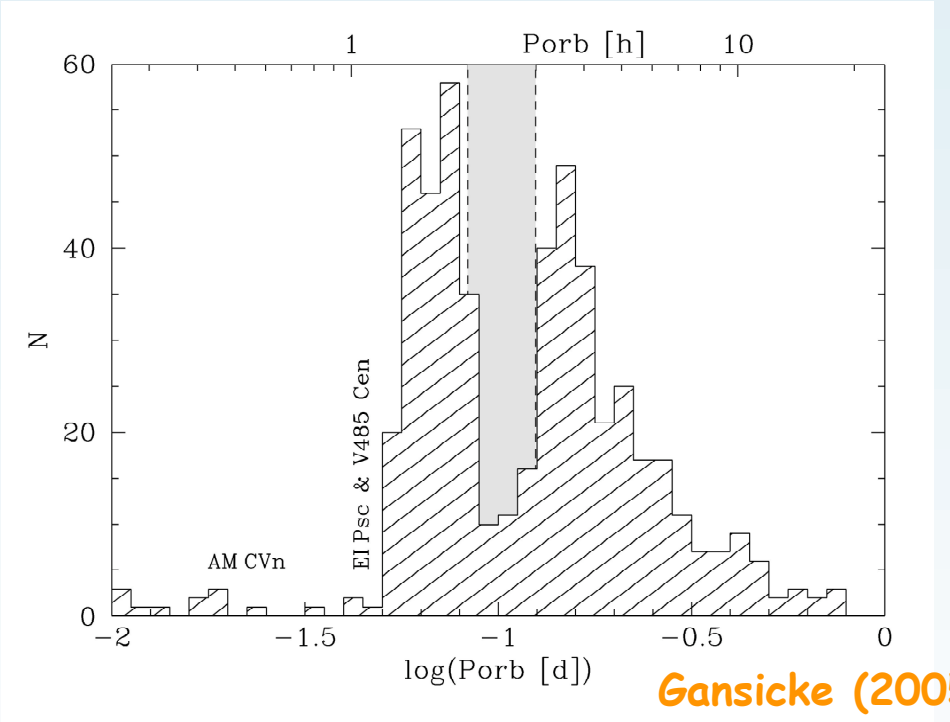
Ultra-Compact Binaries

Gavin Ramsay (MSSL-UCL)



Pasi Hakala (Turku), Danny Steeghs (CfA), Tom Marsh (Warwick),
Gijs Nelemans (Nijmegen), Paul Groot (Nijmegen),
Kinwah Wu (MSSL), Mark Cropper (MSSL)

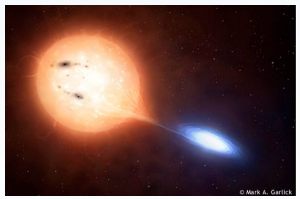
What are `Ultra-Compact' Binaries? aka `AM CVn' stars



Gansicke (2005)

Accreting binaries with white dwarf primaries and main sequence secondaries have binary orbital periods greater than 80 mins. For shorter period systems the secondary must have degenerate or semi-degenerate. eg white dwarf - white dwarf binaries.

How compact are these binaries?



Cataclysmic Variable
with Porb~2hrs

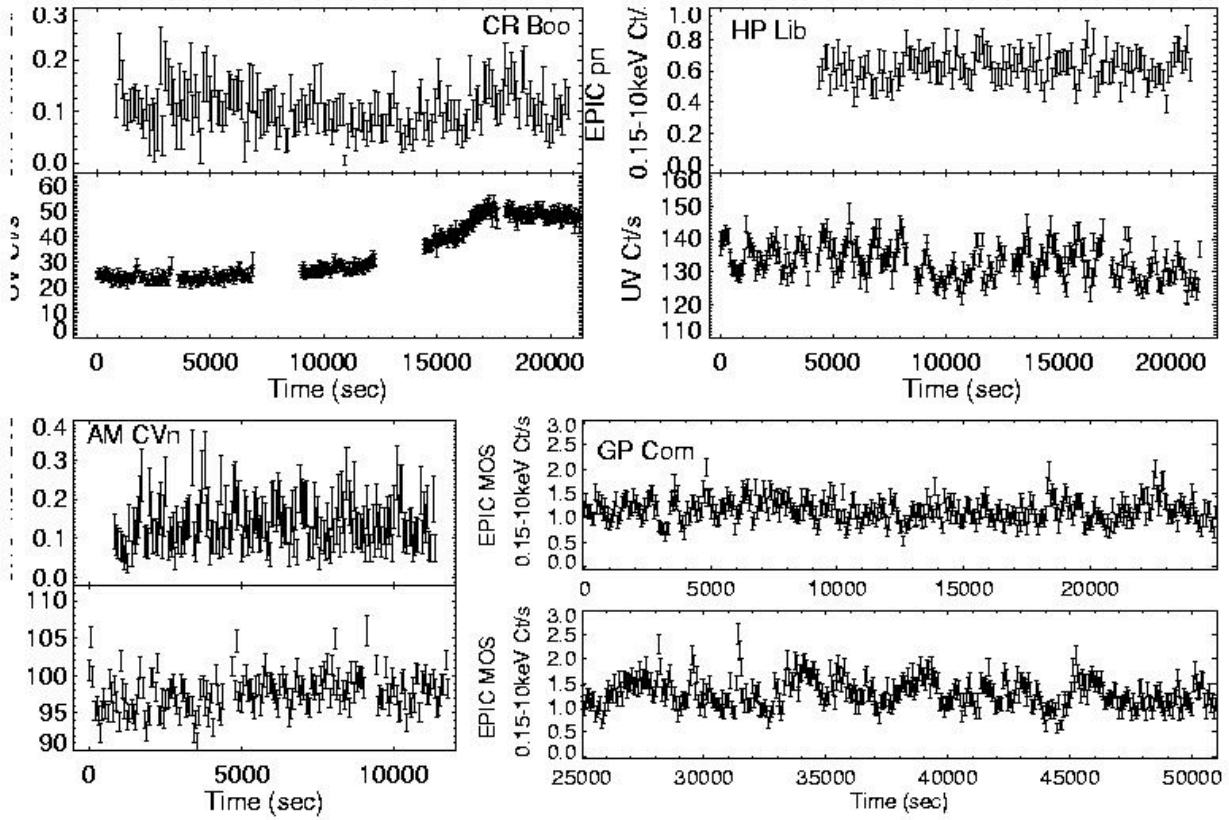
UCB with Porb~10min
RX J1914+24

UCB with Porb~5min
RX J0806+15

What is their astrophysical significance?

- They are predicted to be strong sources of gravitational radiation and be the first know sources detected using LISA.
- Their space density is a sensitive test of binary and population synthesis models.
- Currently less than 20 systems known - significantly less than predicted.

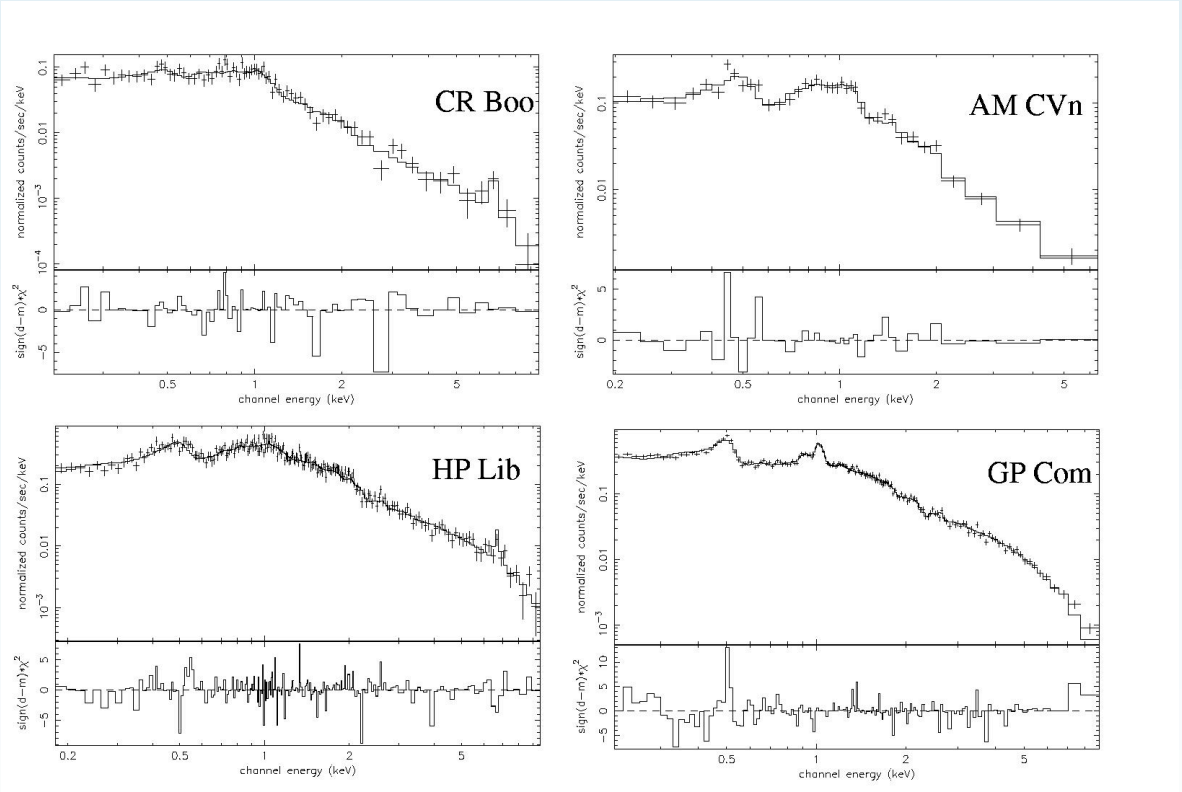
The *XMM-Newton* view of UCBs: I



XMM-Newton observations show they have wide range of UV modulation characteristics and no evidence of any periods in X-ray data. A surprise!

Ramsay et al (2005)

The *XMM-Newton* view of UCBs: II

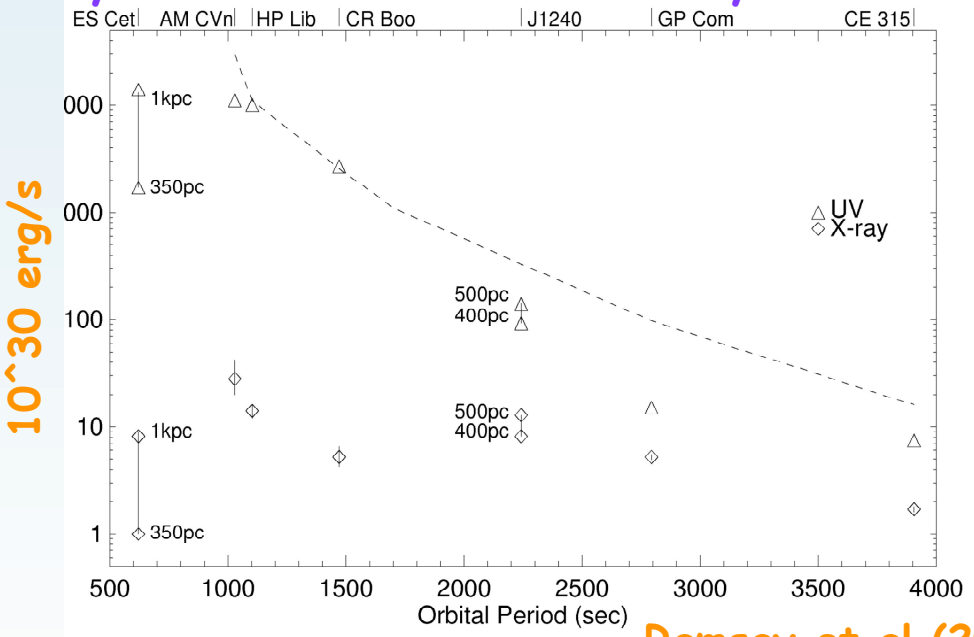


Ramsay et al (2005)

These spectra are be modelled using multi-temperature thermal models with highly non-solar abundances - with typically large amount of nitrogen required to get good fits.

The *XMM-Newton* view of UCBs: III

Prior to *XMM-Newton* it was thought most of the accretion luminosity would be emitted in X-rays.

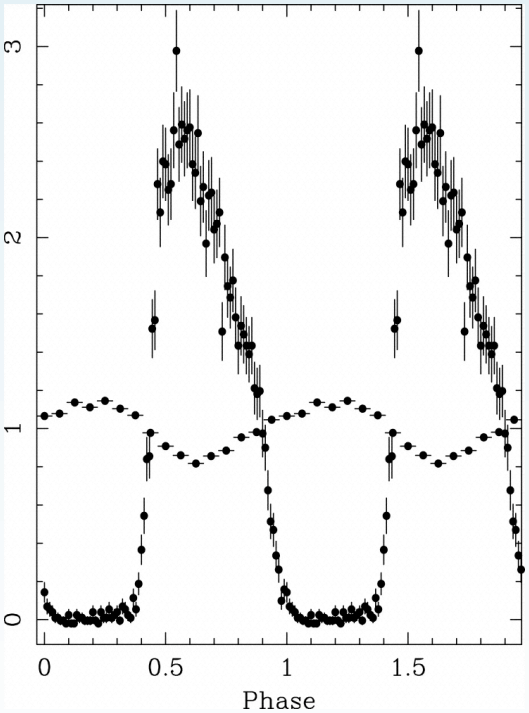


Ramsay et al (2006)

HST parallax programme allowed accurate distances for many systems. We find that most of accretion luminosity emitted in UV and is in good agreement with predictions. This is first time that these predictions have been verified by observations. Suggests that UV band a good place to discover new systems.

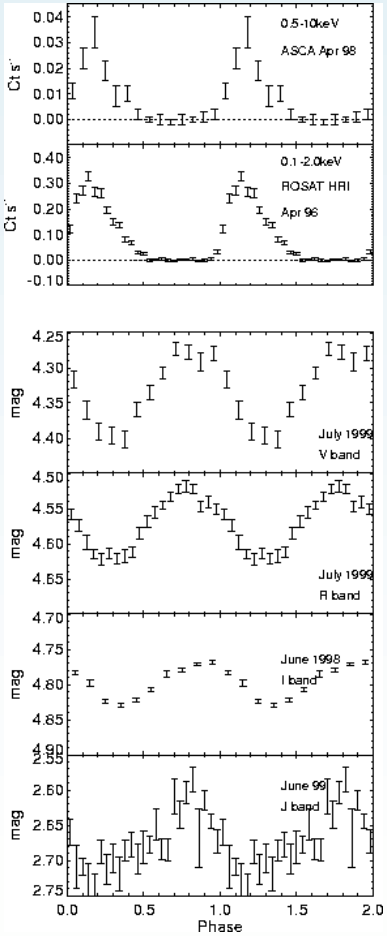
The candidate systems RX J0806+15 and RX J1914+24

RX J0806+15 (321sec)



Israel et al (2002)

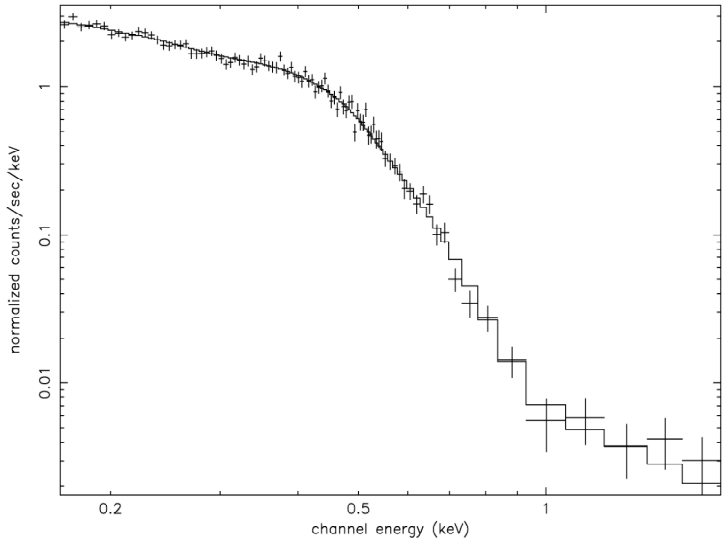
RX J1914+24 - V407 Vul (569sec)



Ramsay et al (2002)

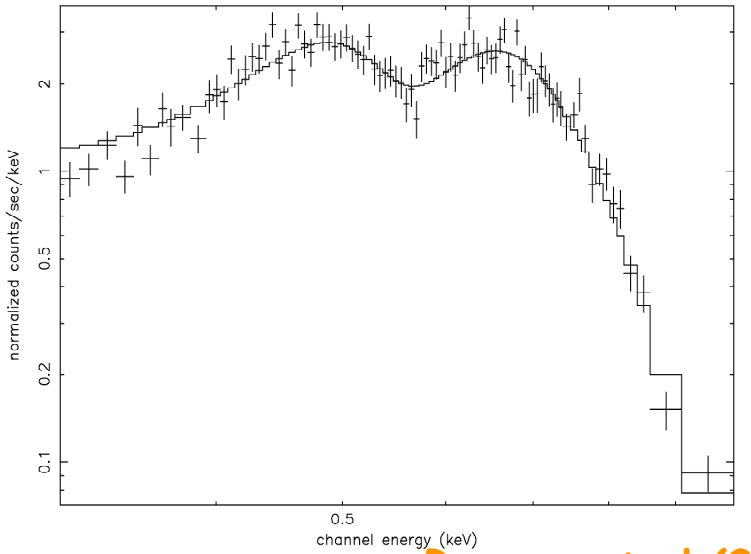
XMM-Newton spectra:

RX J0806+15



Soft blackbody, kT~60eV
Lx~1e32 erg/s for d=500pc

RX J1914+24



Ramsay et al (2006)

Thermal plasma model T~0.2keV
with highly non-solar abundances
plus edge at 0.83keV.
Lx~1e33 erg/s for d=1kpc

Characterising their orbital evolution

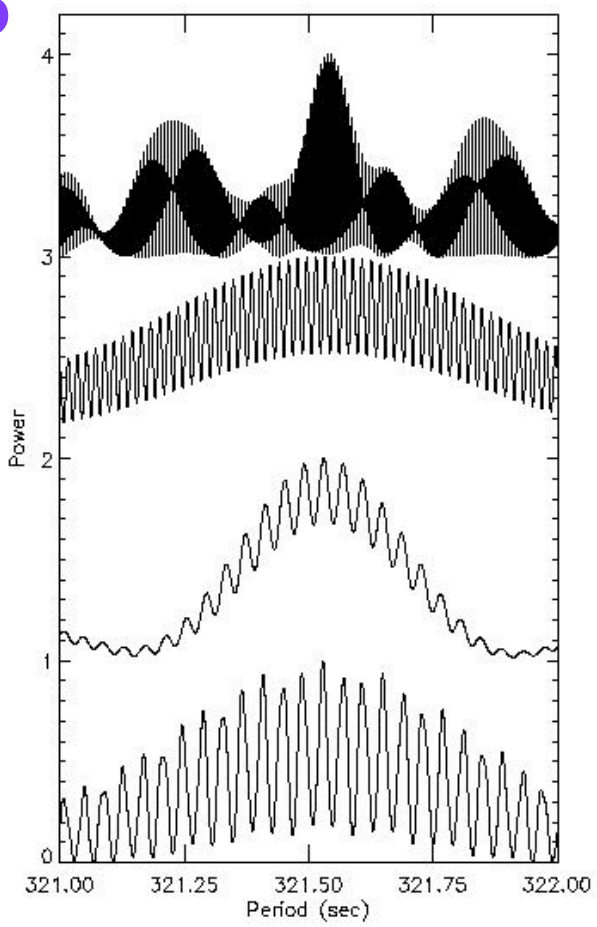
RX J0806+15

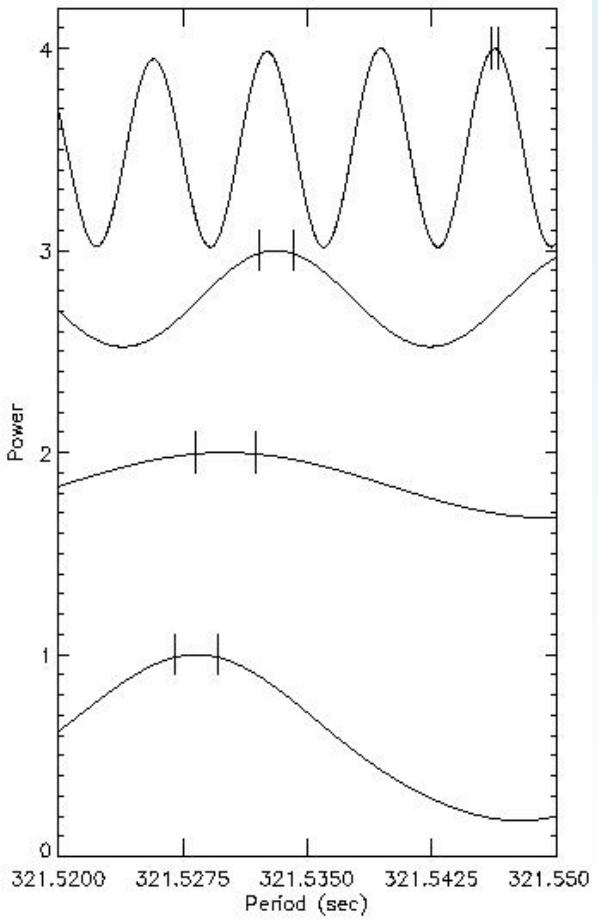
ROSAT
1994-1995

VLT+NOT
2001-2002

NOT
2003

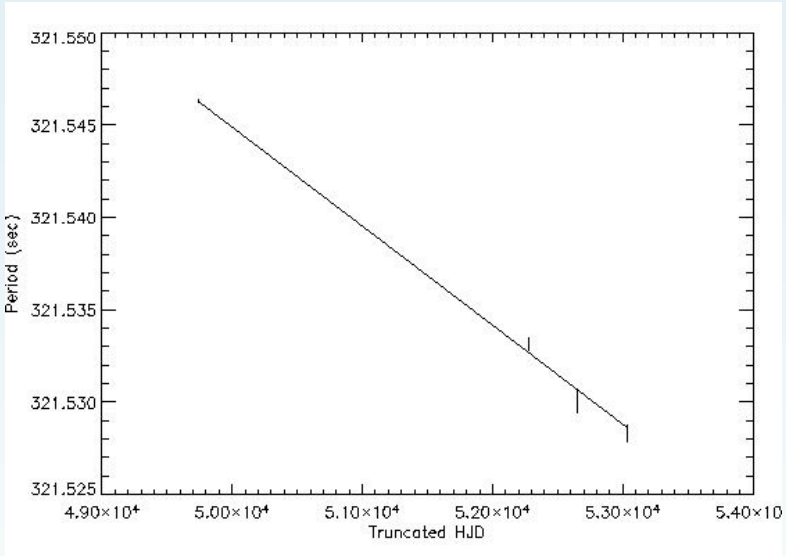
INT+NOT
2003-2004





Hakala, Ramsay & Byckling (2004)

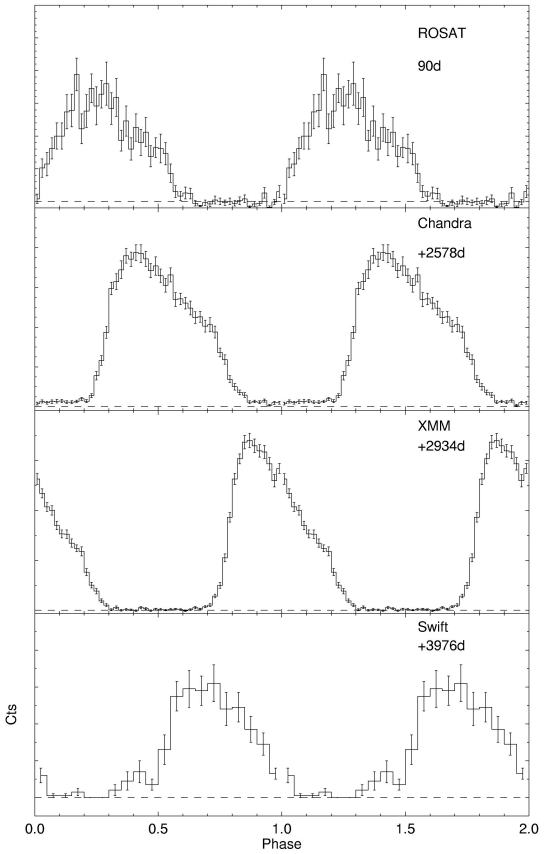
RX J0806+15

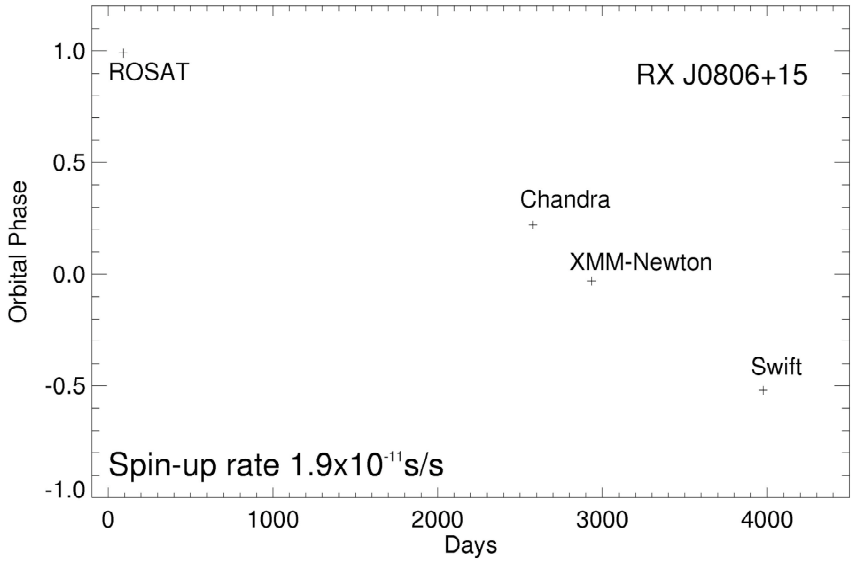


Hakala, Ramsay & Byckling (2004)

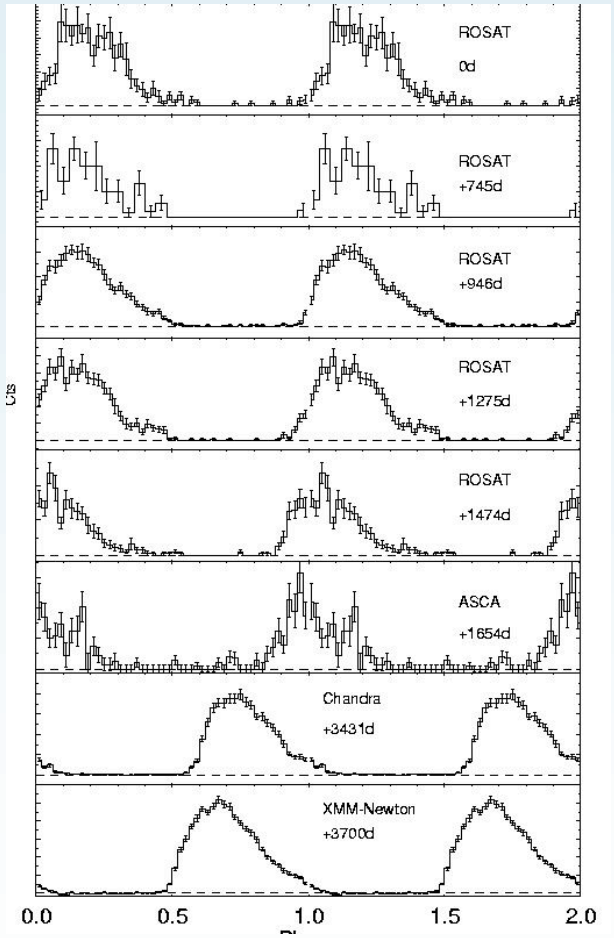
Spinning up at a rate of 1.9x10-11 s/s

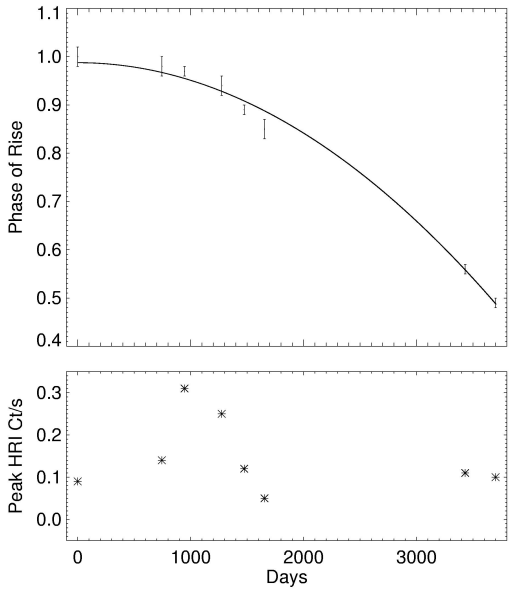
Spin up in RX J0806+15 (II):





RX J1914+24

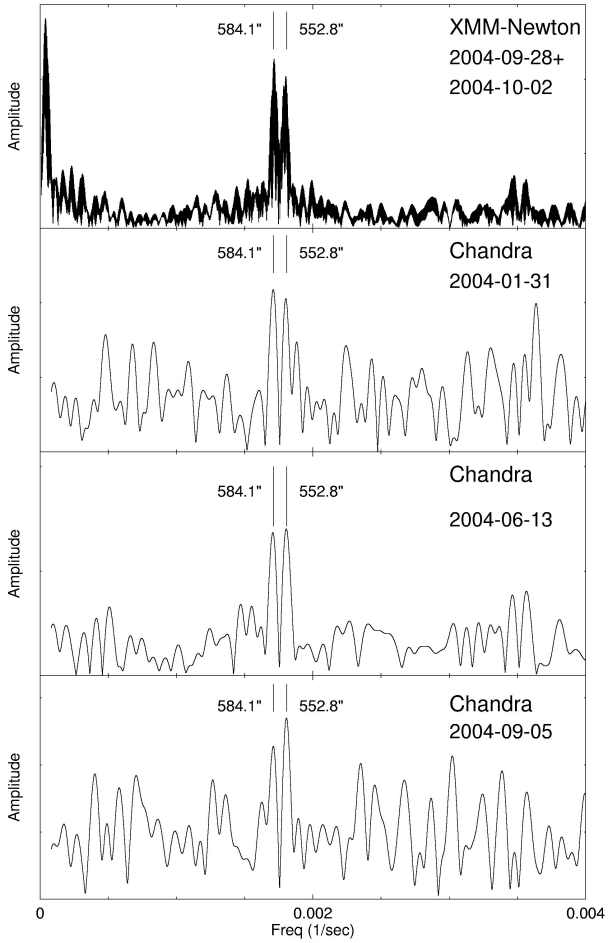




Ramsay et al (2005)

Spinning up at a rate of 3.2e-12 s/s

More periods in RX J1914+24?

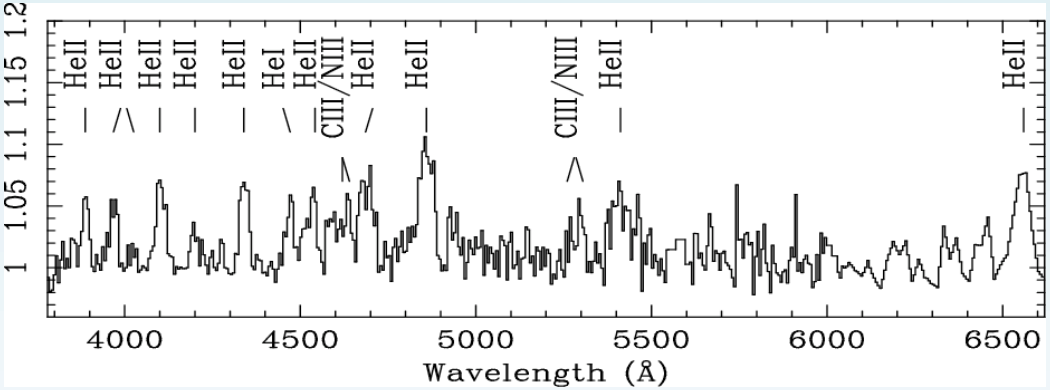


Previously known that the long term X-ray flux varied (Ramsay et al 2000)

Now find evidence for power at 556 and 585 sec at some epochs. Not clear if this is due to beat between the dominant period at 569 sec and a longer period or secular variations (Ramsay et al 2006).

Optical Spectra - very different!

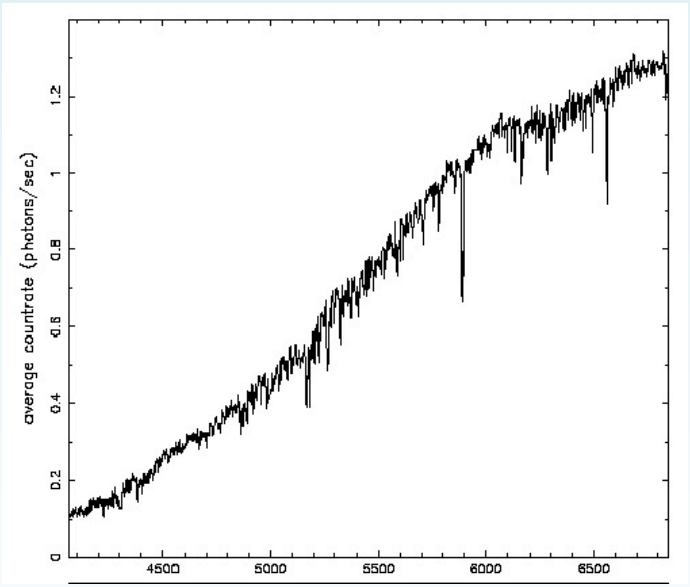
RX J0806+15



Israel et al (2002)

Weak Helium lines

RX J1914+24



Steeghs et al (2006)

Looks like a G star.
Radial velocity limits rule out period < 14 hrs

- A triple system?
- A chance line-of-sight?

Radio (6cm) observations of UCBs

VLA observations:

RX J1914+24 => no detection, 75μm/beam

RX J0806+15 => 5sig detection 0.1mJy

ATCA observations:

ES Cet (10.3min) => no detection, 24μm/beam

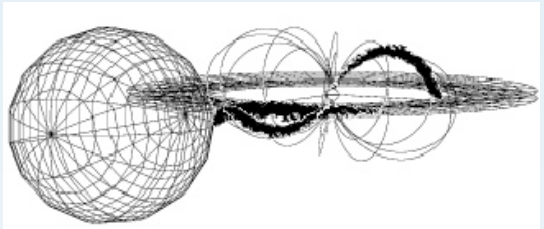
Further observations of RX J0806+15 planned. Significance of these observations will be explained shortly!

Models put forward to account for these observations

An intermediate polar: (Norton, Haswell & Wynn (2004)

- The periods are the spin period of the white dwarf so the spin up is not a problem.

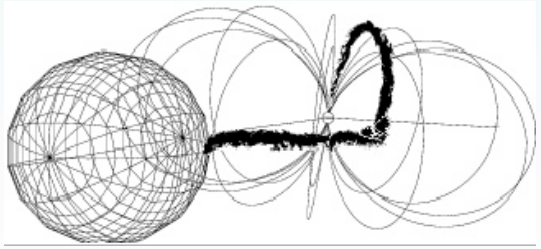
Problems – lack of strong optical emission lines. Would expect the secondary to show up. Could be a double degenerate IP. Regarded as unlikely.



A double degenerate polar: (Cropper et al 1998).

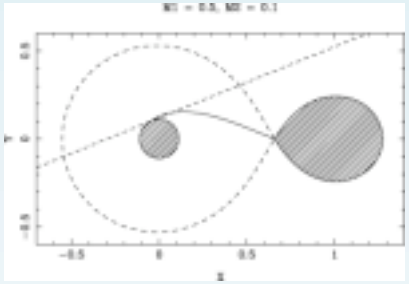
- A strongly magnetic accreting white dwarf. Its spin period is locked with the binary orbital period.

Problems – lack of strong optical emission lines, polarisation and hard X-rays. Can't be excluded but regarded as unlikely.



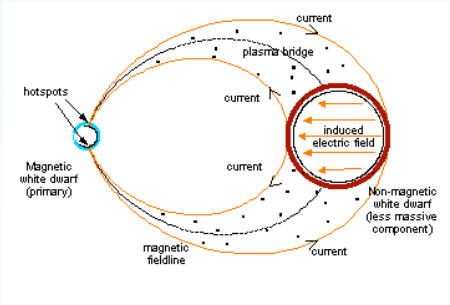
Direct impact model: Marsh & Steeghs (2002), Ramsay et al (2002)

A double degenerate system where the accretion stream impacts the accreting white dwarf directly. Would expect optical emission lines. In M&S interpretation the optical emission is from cooling X-ray tail. Works in relatively narrow parameter range.

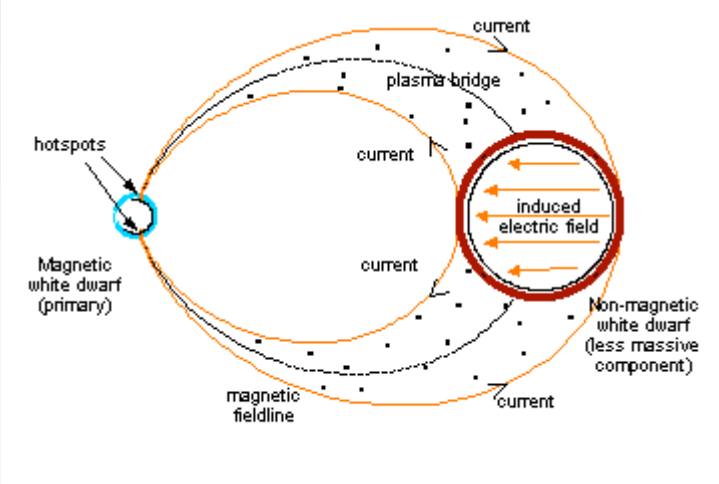


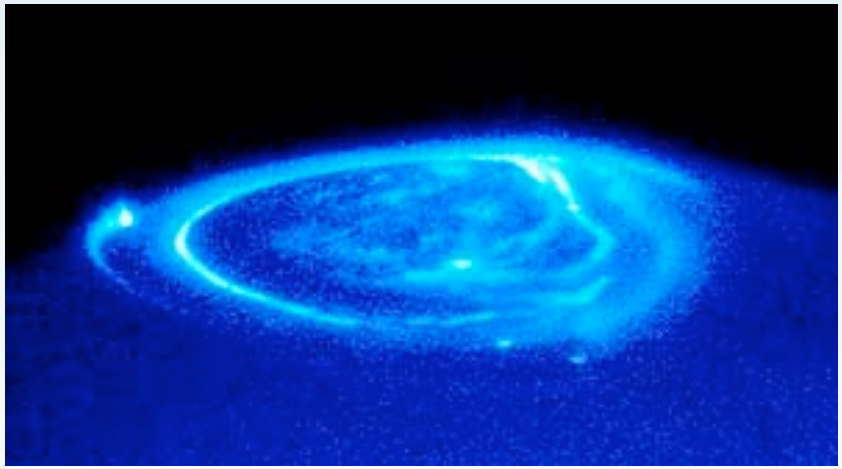
Unipolar inductor or electric star model: Wu et al (2002)

A double degenerate system in which a non-magnetic white dwarf transverses the magnetic field of a magnetic white dwarf causing large currents to be driven causing heating of the white dwarf. Strongly circularly polarised radio emission predicted.



More on unipolar-inductor model:



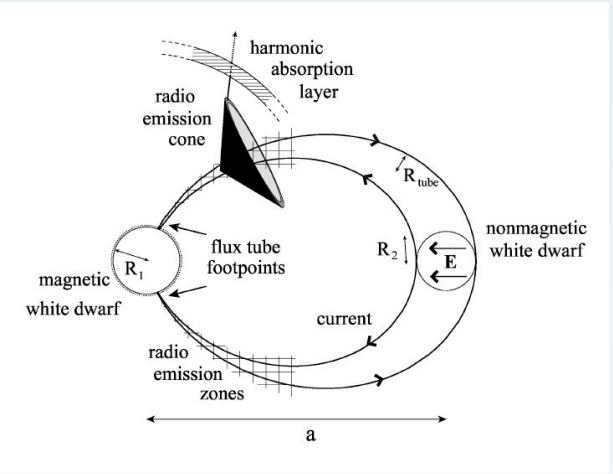


Sounds far fetched by it has been seen on Jupiter!

Can see tracks where satellites magnetic field lines enter atmosphere of Jupiter.

Status of RX J0806+15 and RX J1914+24

The weak detection of radio emission in RX J0806+15 is consistent with UI but the non detection in RX J1914+24 suggest that it is less likely that UI powers this system.



This is a similar conclusion to that reached by Willes, Wu & Ramsay (2006) and Dall'Osso, Israel & Stella (2006) who take the observed spin-up rates and use the UI model to predict their luminosities and lifetimes.

Conclusion: RX J0806+15 candidate for UI system.
RX J1914+24 an odd triple system?