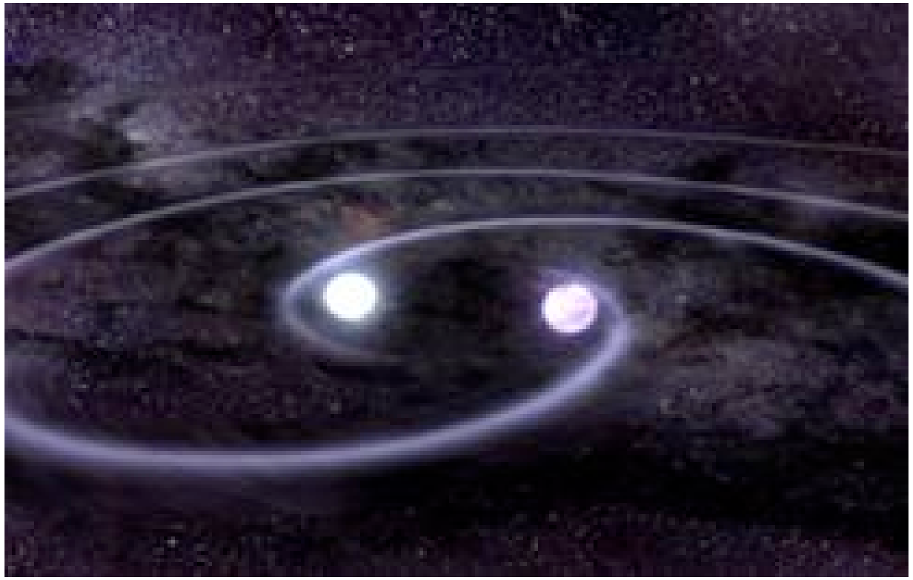
RX J0806+15 and RX J1914+24:

recent results and status



Gavin Ramsay

(Armagh Observatory)

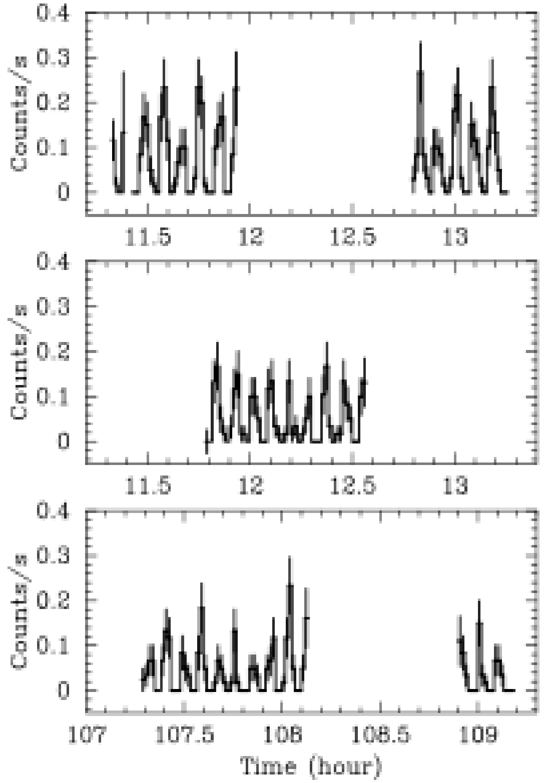
Overview of talk

- Remind you what they are!
- Recent observational work since Nijmegen Meeting.
- Modelling and theoretical work.
- Their current status.

RX J0806+15 (HM Cnc) and RX J1914+24 (V407 Vul)

Both sources discovered as variable sources using the *ROSAT* All-Sky Survey.

RX J1914+24 (Motch et al 1996) - 569 sec
RX J0806+15 (Israel et al 1999) - 321 sec



RX J0806+15: Israel et al (1999)

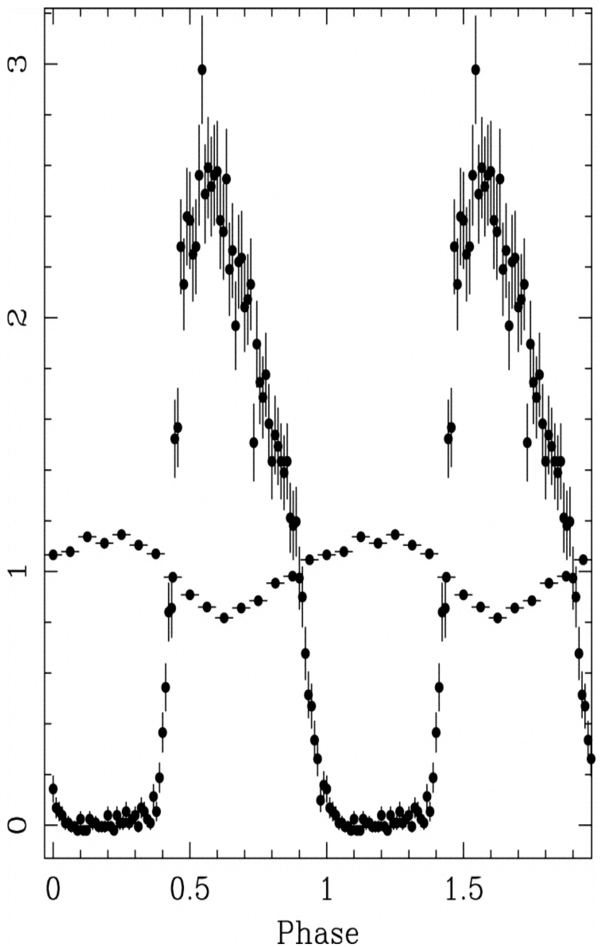
Initially thought that they were Intermediate Polars

Cropper et al (1999) obtained further *ROSAT* observations. Only one period. Proposed double degenerate Polar model.

Discovery of Optical Counterparts -
RX J1914+24 (Ramsay et al 2000)
RX J0806+15 (Ramsay et al 2002, Israel et al 2002)
showed the same period in the optical band.
Close to being anti-phased and no other period.
Interpreted as their ***binary orbital period***.

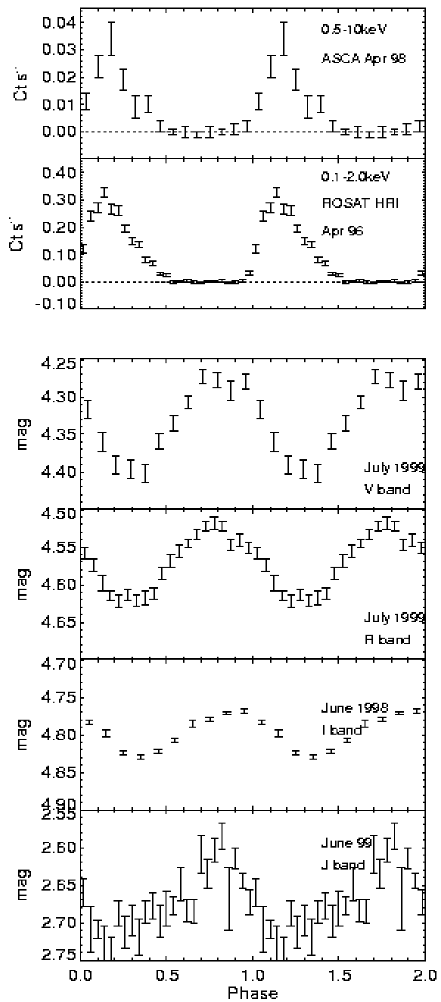
X-ray and optical light curves very similar

RX J0806+15 (321sec)

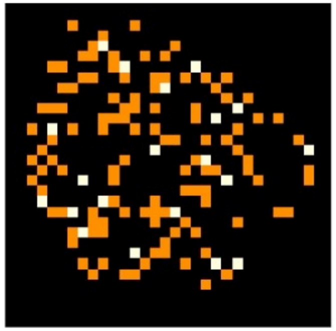


Israel et al (2002)

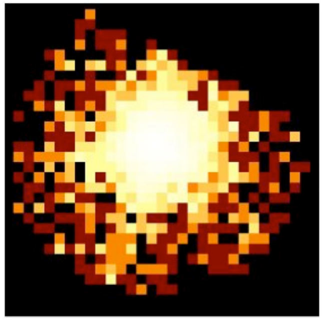
RX J1914+24 - V407 Vul (569sec)



Ramsay et al (2002)

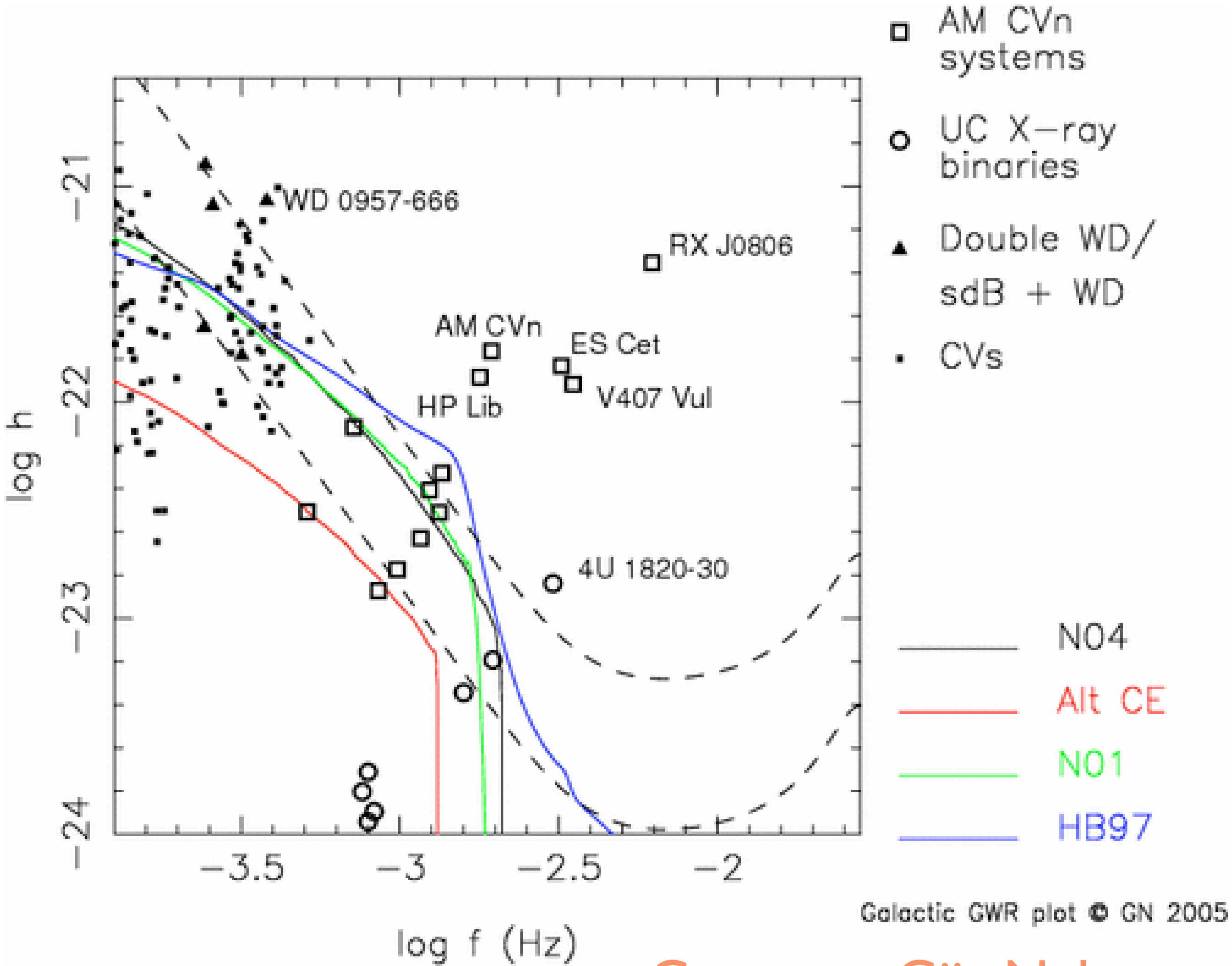


Faint Phase



Bright Phase

Astrophysical significance:

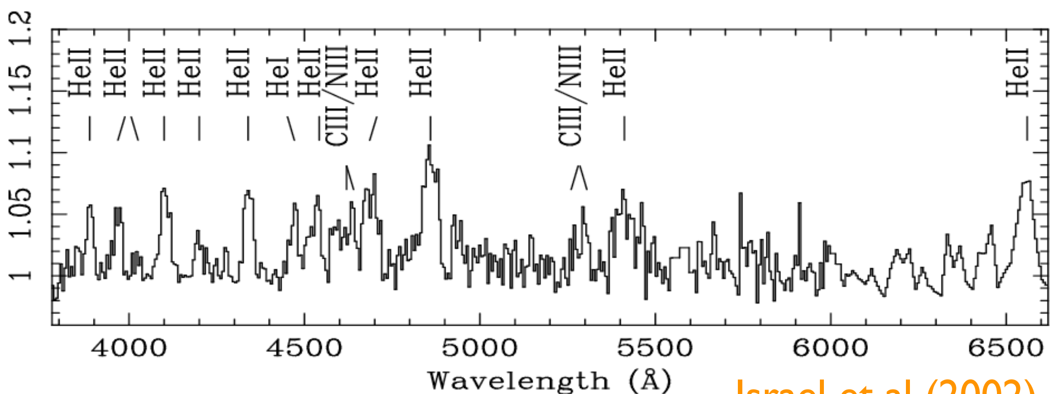


Courtesy: Gijs Nelemans.

If these periods do represent the binary orbital period, then they are predicted to be amongst the first known sources to be detected by LISA.

Optical Spectra - very different!

RX J0806+15 VLT spectrum

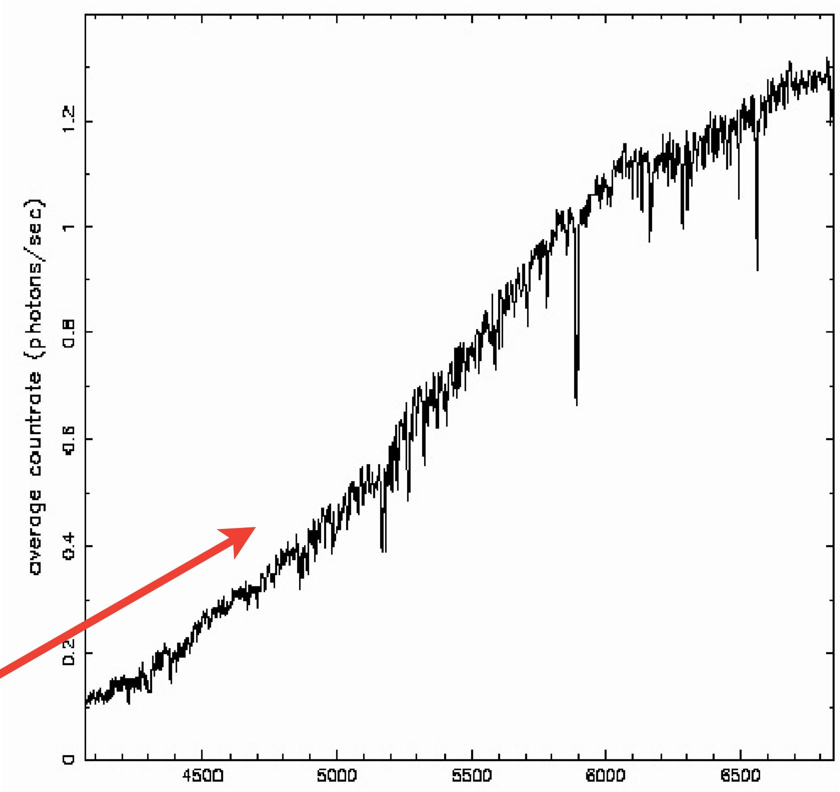


Israel et al (2002)

Weak Helium lines - possibly with a blend of hydrogen (Norton, Haswell & Wynn (2004)?

IR colours not consistent with a single G9 star. Also shows longer term variability in its IR brightness. Multiple spectral components.

RX J1914+24 Gemini spectrum



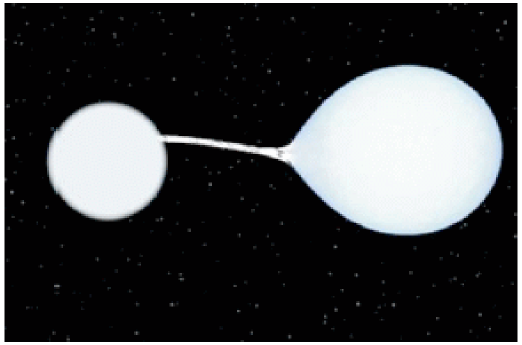
Steeghs et al (2006)

Looks like a G9 star!
Radial velocity limits rule out period < 14 hrs

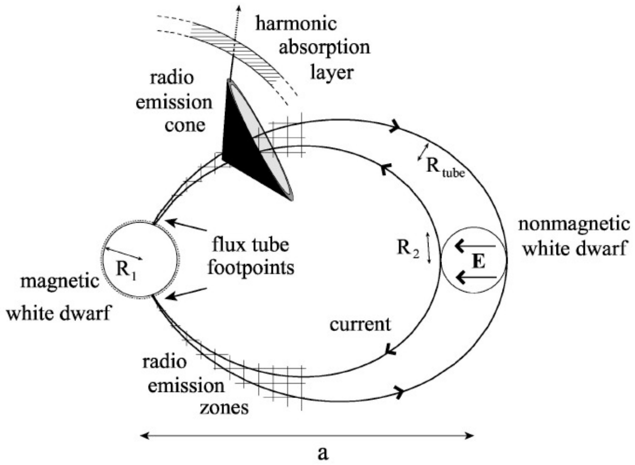
Will come back to both these points.

Proposed models:

Accretion occuring



Accretion **not** occuring



Main competing models are **direct impact model** (Ramsay et al 2002; Marsh & Steeghs 2002) and the **unipolar inductor model** (Wu et al 2002).

Now going on to discuss work done more recently ....

X-ray observations:

Distance to both systems very uncertain.

If RX J1914+24 associated with G9 star, then ~1kpc+ (Steeghs et al 2006).
If primary in RX J0806+15 gives rise to continuum, then assuming Mwd=0.6 solar, then d~2kpc to fit model flux with observed optical (Reinsch et al 2007).

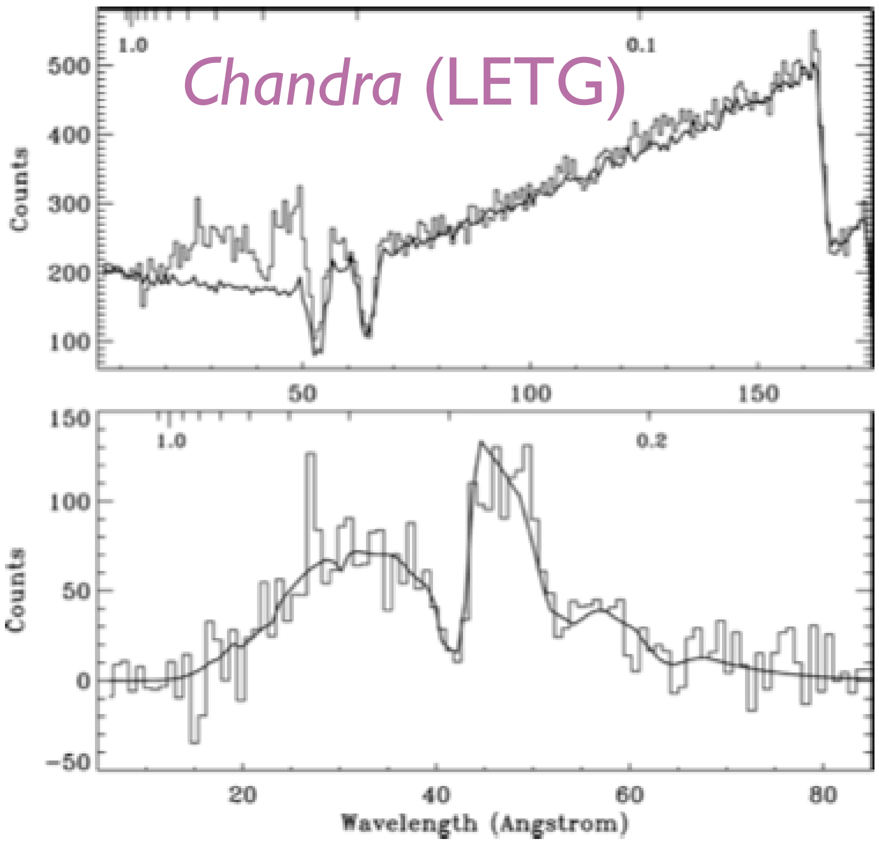
Uncertainty on whether emission model optically thin or thick and distance rather uncertain. In RX J1914+24, Lx was uncertain by 4 orders of magnitude!

Lx allows various models to be tested.

In July 2005 I couldn't work out how to model the X-ray spectrum of RX J1914+24 ...

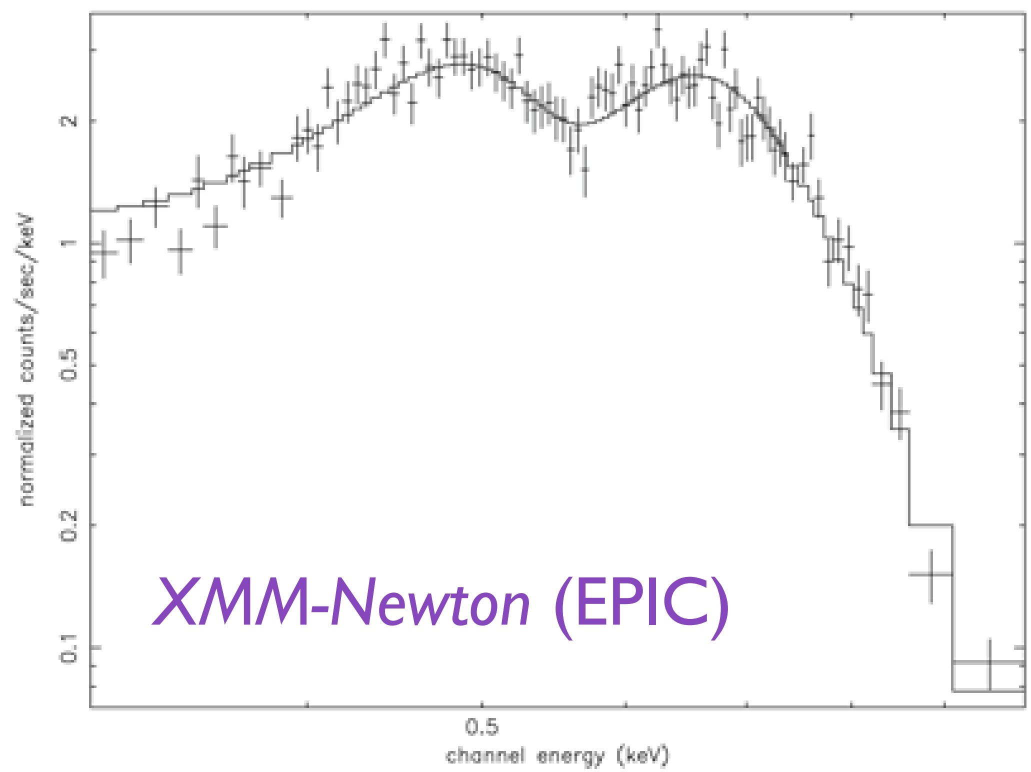
X-ray spectra - soft, but apparently rather different:

RX J0806+15 Strohmayer (2008)



Soft blackbody, kT~65eV
Lx (peak)~3.2e32 erg/s for d=500pc, or 5e33 erg/s for 2kpc
Strohmayer (2008)

RX J1914+24 Ramsay (2008)

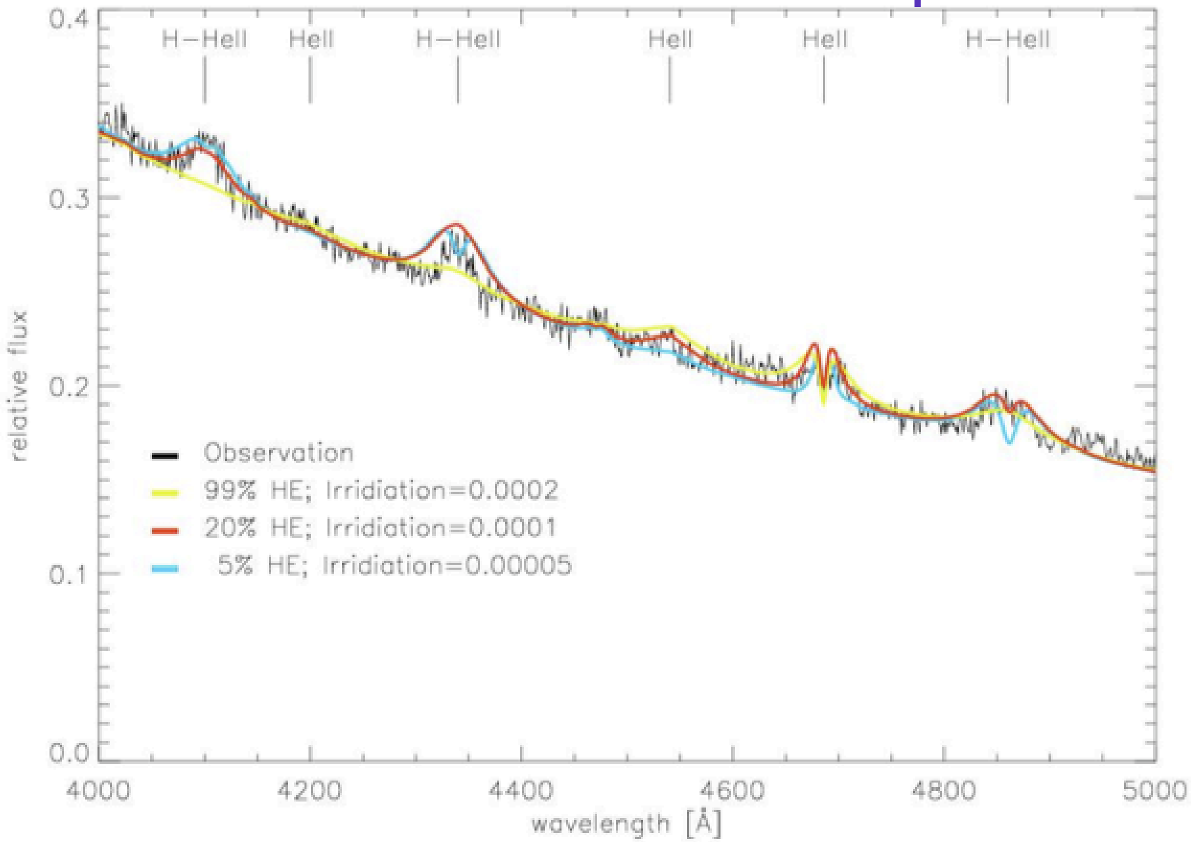


Blackbody (kT~65eV) with absorption component with very non-solar abundance (eg enhanced Neon). For d= 1kpc, Lx~10^34-35 erg/s (Ramsay 2008).

Intrinsically very similar X-ray emission sources.

Optical spectra:

VLT spectrum



Reinsch, Steiper & Dreizler (2007)

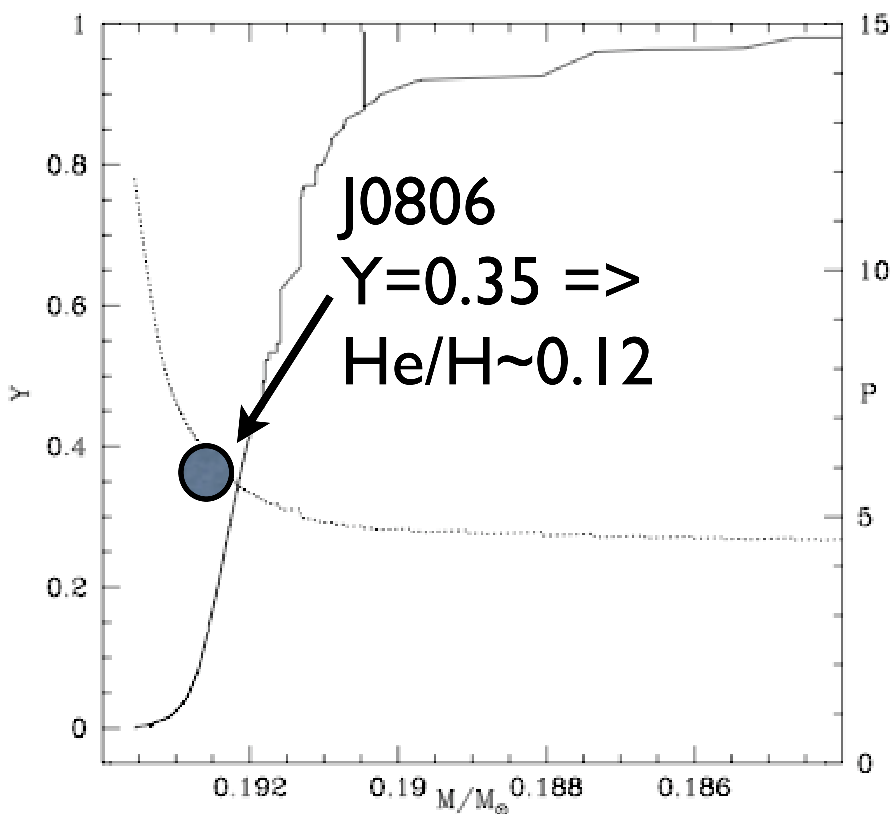
Ratio of odd/even terms of Pickering HeII series suggest hydrogen present. He/H~0.1 by number. log g~6.
Originally thought that this would rule out degenerate donor ....

Composition of donor star

Various models put forward, eg:

D'Antona et al (2006) proposed that J0806+15 had degenerate He white dwarf donor with thick Hydrogen shell burning p-p.

Deloye & Taam (2006) have pure He donor stars. Adding an arbitrary amount of Hydrogen changes their results in qualitative way.

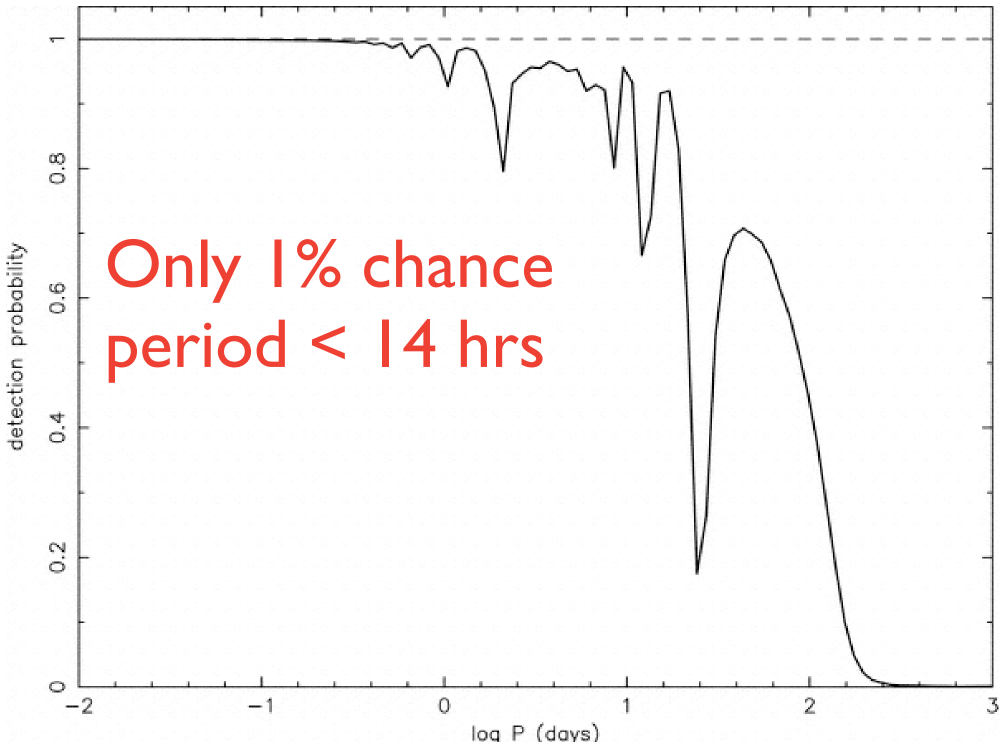


D'Antona et al (2006)

Upshot: Presence of hydrogen in optical spectra not unexpected but cannot distinguish between competing models.

Searching for the origin of the G star in RX J1914+24

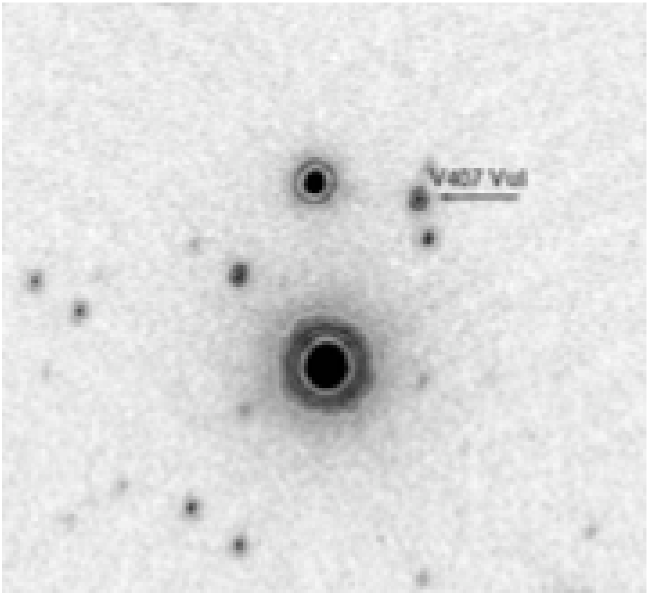
Is it a chance alignment with background star; triple system ...?



Only 1% chance period < 14 hrs

Steeghs et al (2006)

Pulsation Astrometry



Search for variation in position of source as function of 569 sec period (Barros et al 2006).

Barros et al find hint that source which varies on 569 sec period is offset from constant source (G star) by 0.027 arcsec. If in a triple system and d=1kpc, this implies separation of 30AU or 120 yrs. May affect interpretation of changing period ....

Evidence for third body in X-ray light curve?

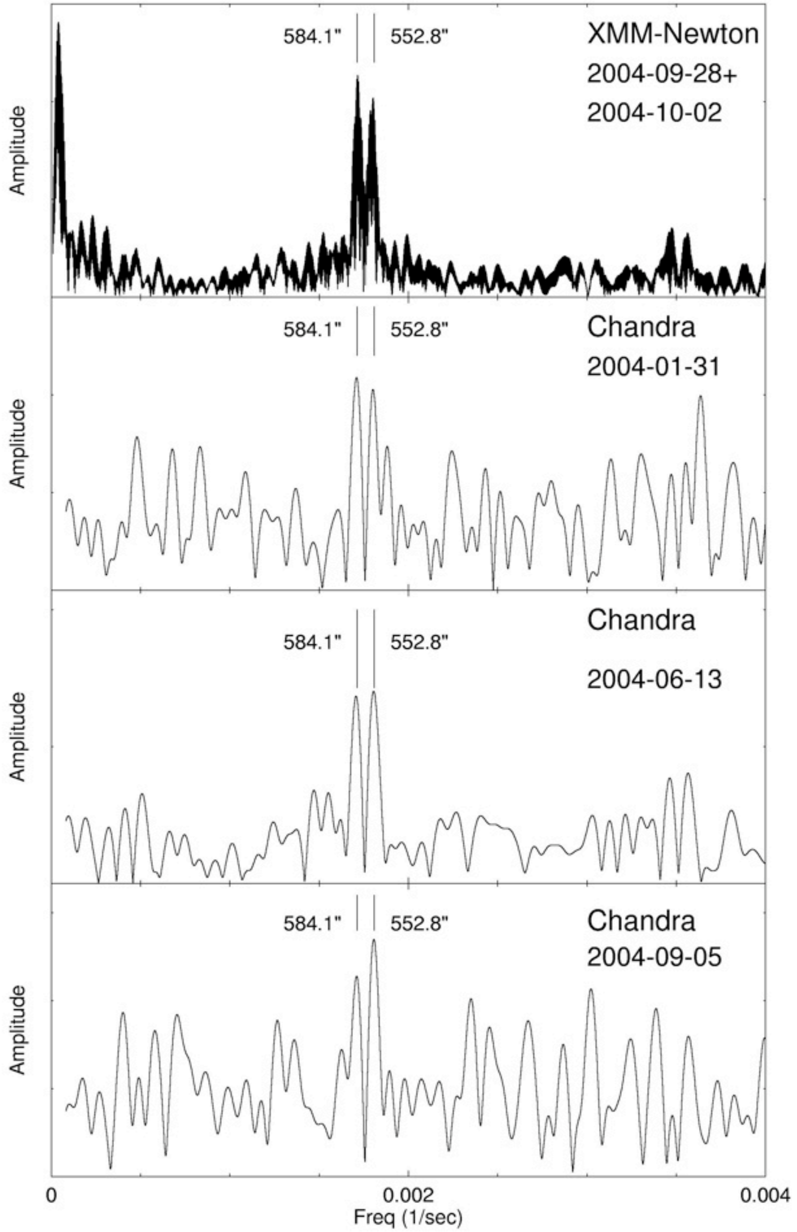
RX J1914+24 observed 4 x with *XMM-Newton* and 9 x with *Chandra*

On 5 occasions evidence for power at 552 and 584 sec [main peak 569 sec]

In case of XMM data in 2004, on both occasions flux increased over duration of observation.

Could be result of beat between the 569 sec period and longer term secular variation, or a period close to 6hrs. Radial Velocity search on Gemini data appear to rule the 6hr period out.

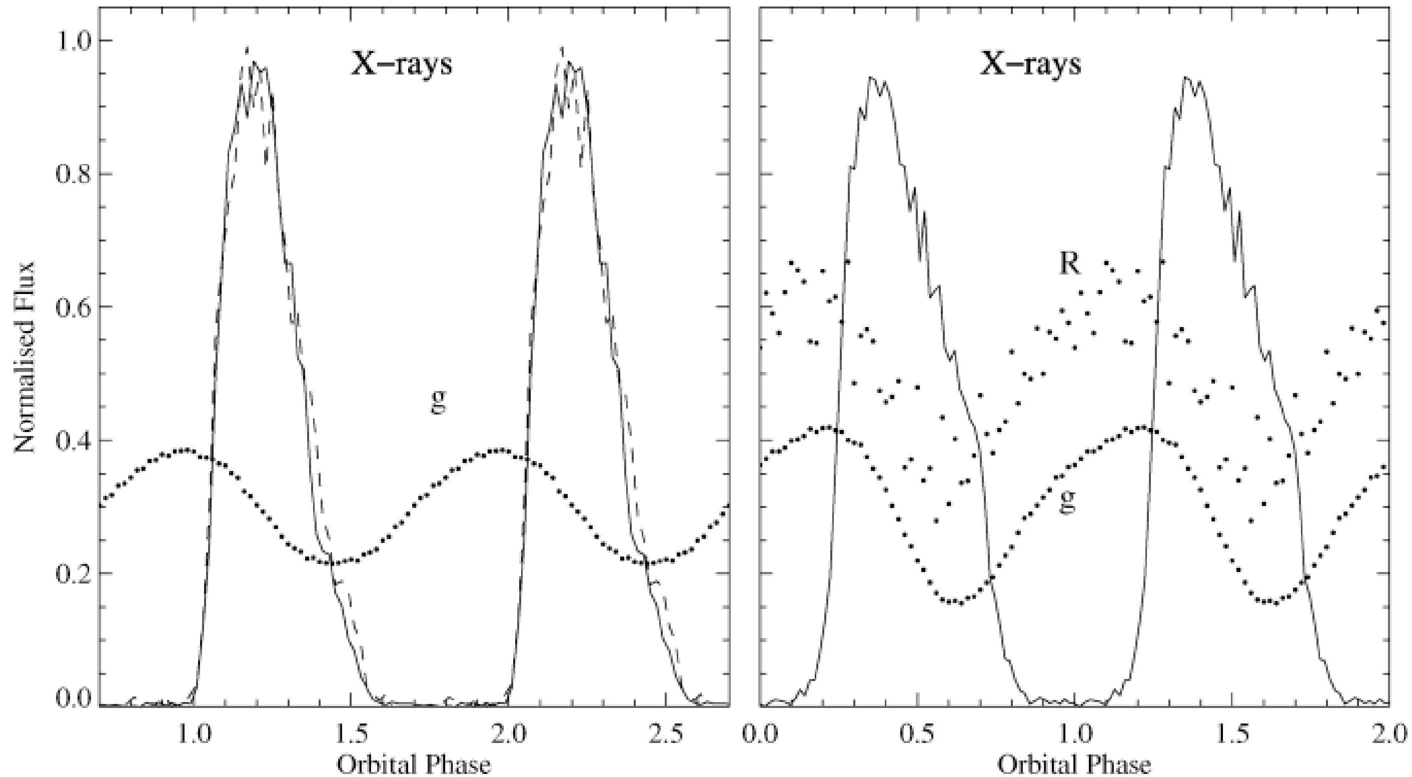
Could this be related to the G9 star?



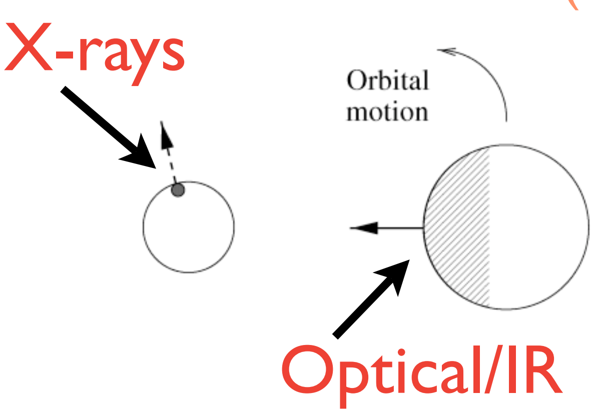
Ramsay, Hakala & Cropper (2006)

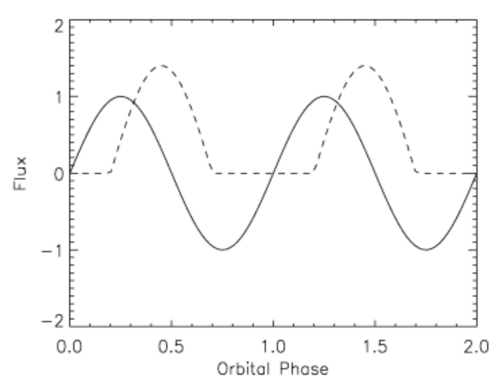
Modelling shift between optical X-ray light curves

RX J1914+24 RX J0806+15



Barros et al (2007)



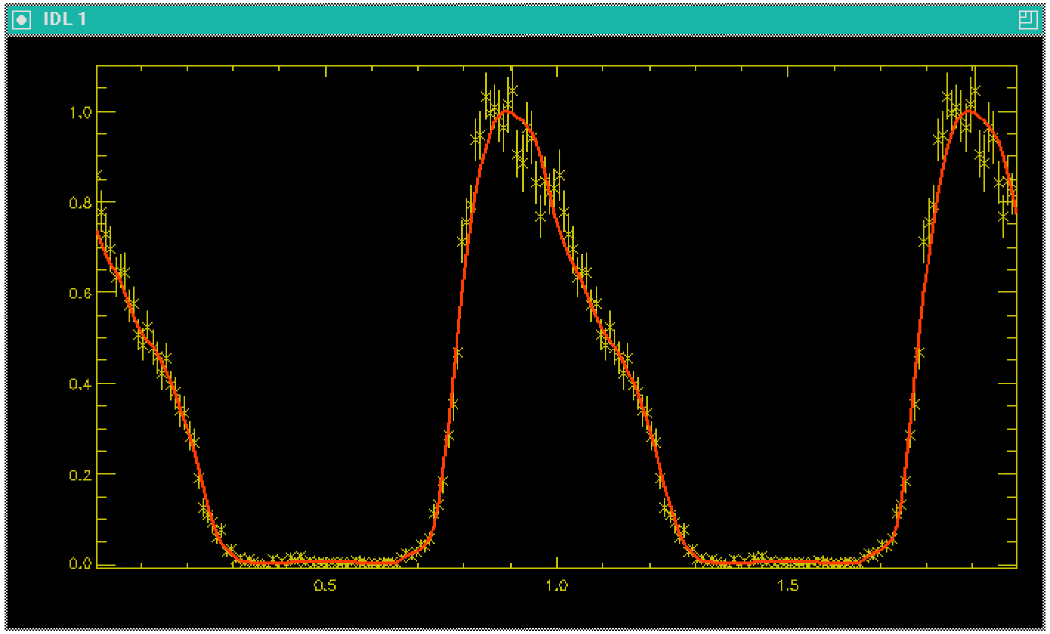


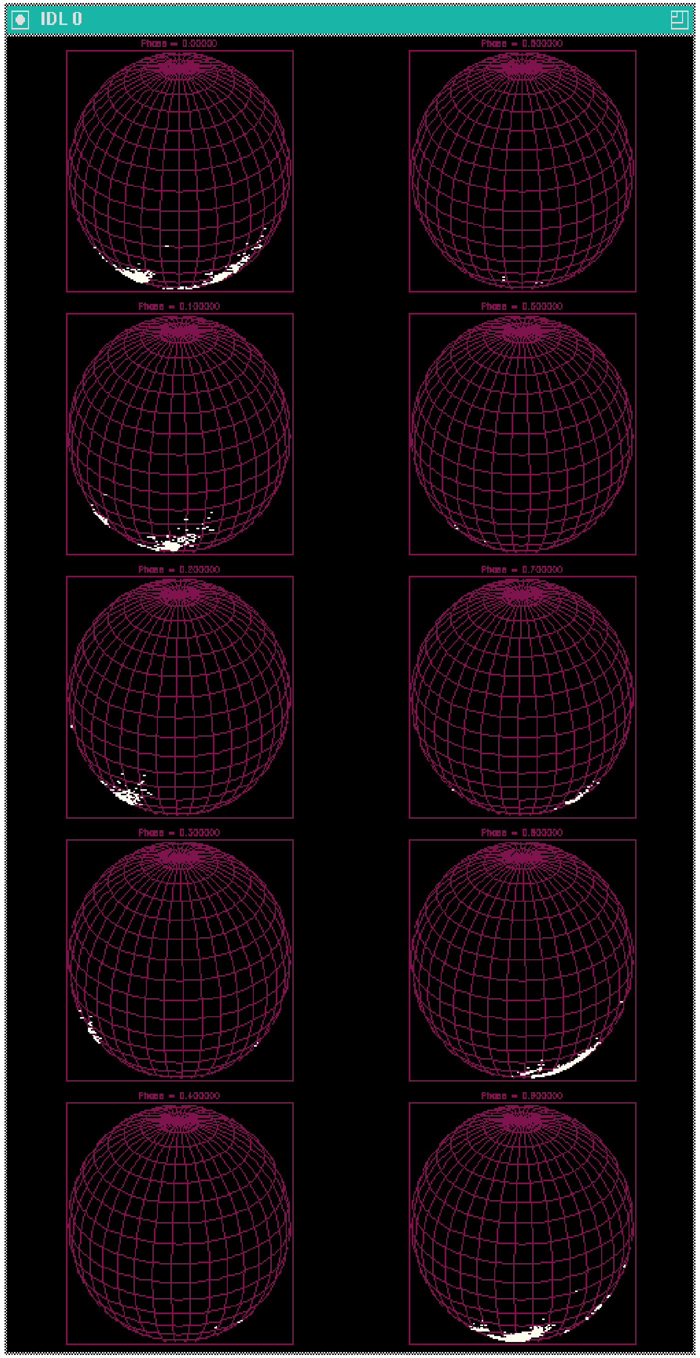
Difficult to model this offset in unipolar - inductor model, although the magnetic field configuation is totally unknown.

Modelling X-ray light curves

Use inversion of X-ray light curve using `fireflies'

- Emission region reconstructed from "optically thick fireflies" i.e. emission points with unit brightness, that are free to move on the WD surface.
- Regularization prefers "compact swarms of flies"
- Swarm size, shape & location optimized by genetic algorithms (by optimising the locations of individual flies).

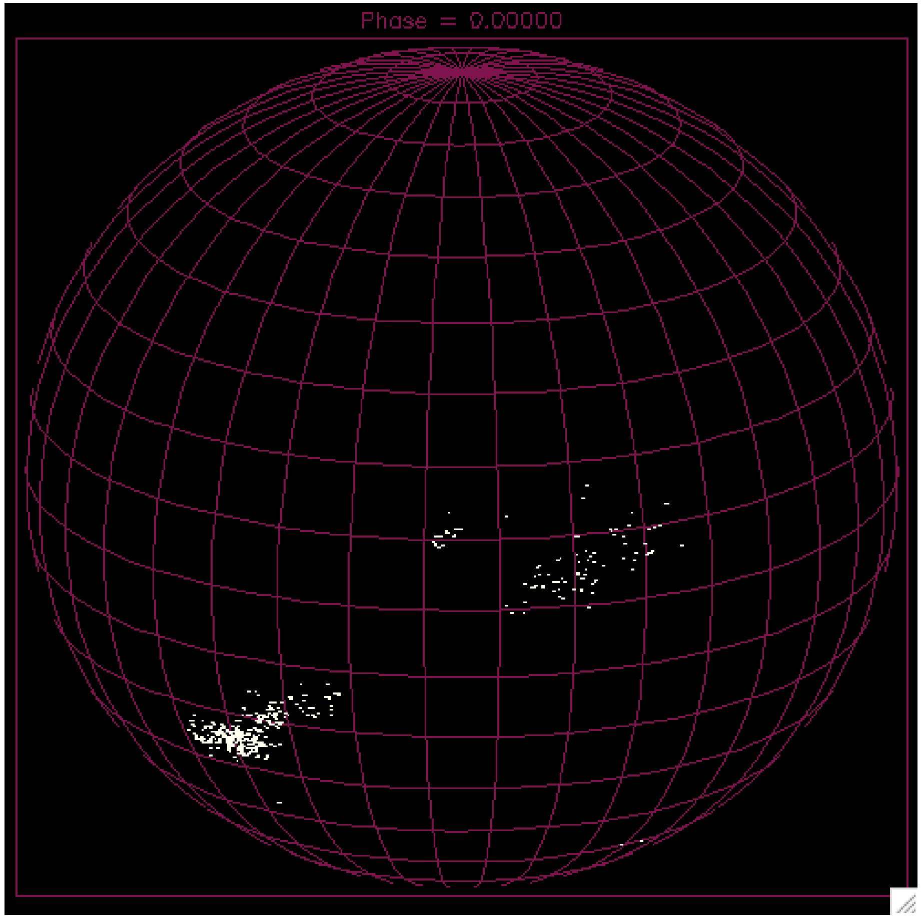




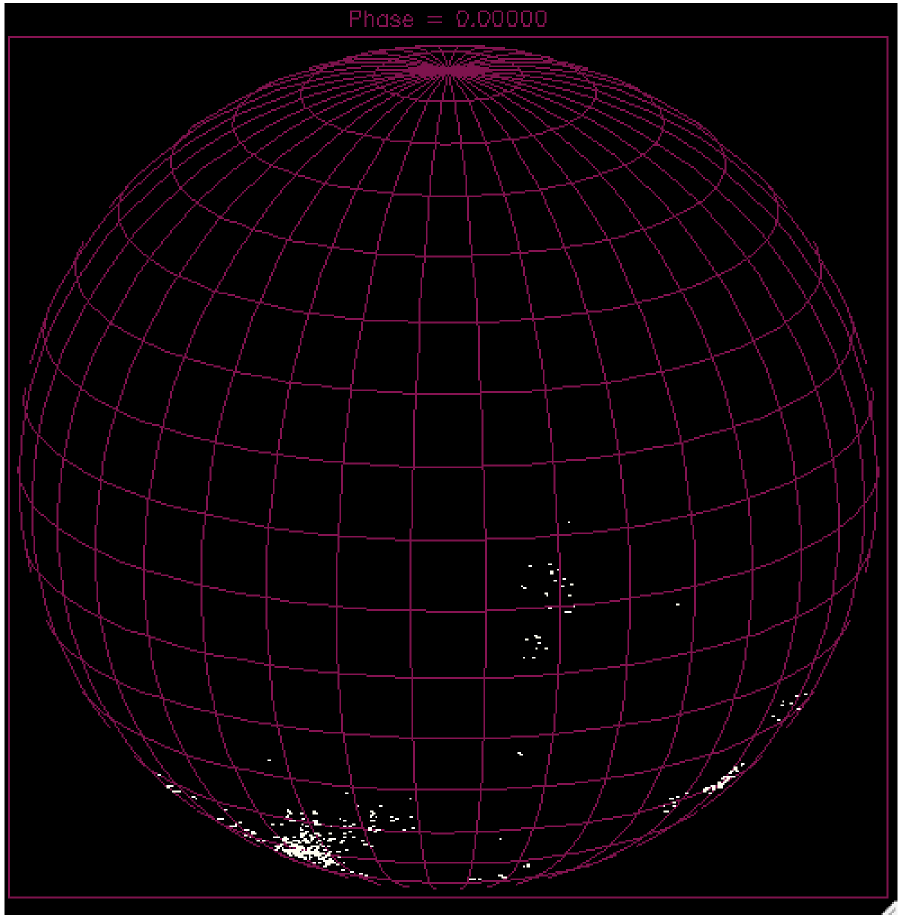
Hakala, Byckling & Ramsay (in prep)

RX J0805+15: *XMM-Newton* data; 0.15-0.5keV

$i = 30$ deg



$i = 60$ deg



Results of firefly modeling:

I. X-ray modulation can be modelled with optically thick emission confined to the surface of the primary without any absorption effects.

II. Both systems have similar emission regions.

III. The results imply two discrete emission regions that are compact, separated from each other by app. 60 degrees and offset from the equator.

IV. The results favour magnetic models over the direct impact scenario.

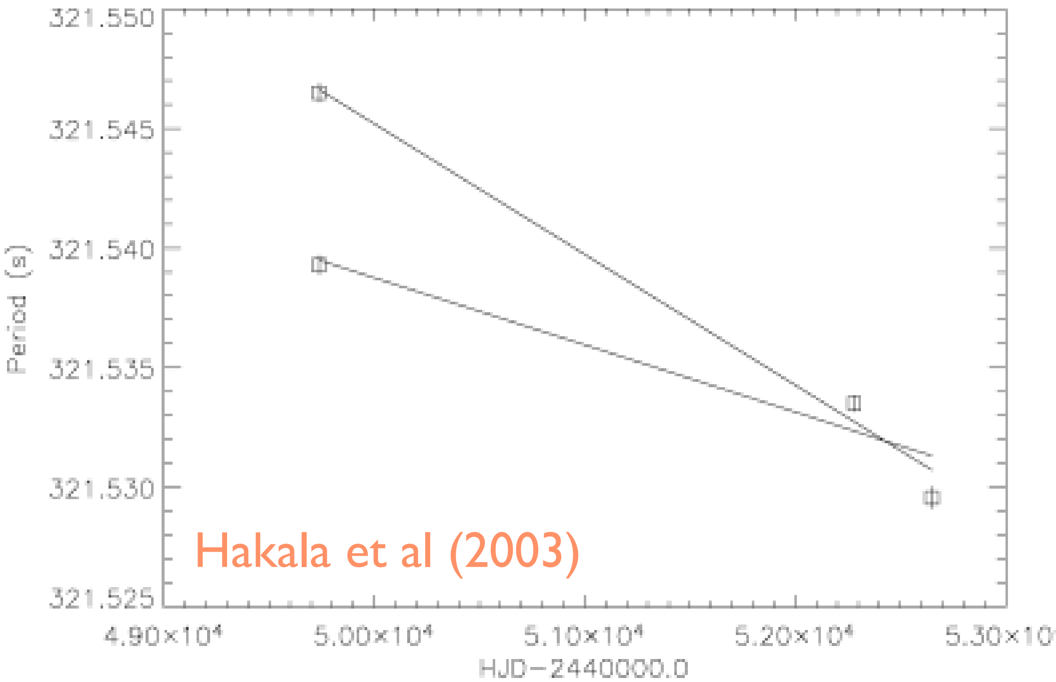
Simulations of direct impact accretion:

Work by Dolence et al (2008) show that predicted size of accretion region is consistent with observations.

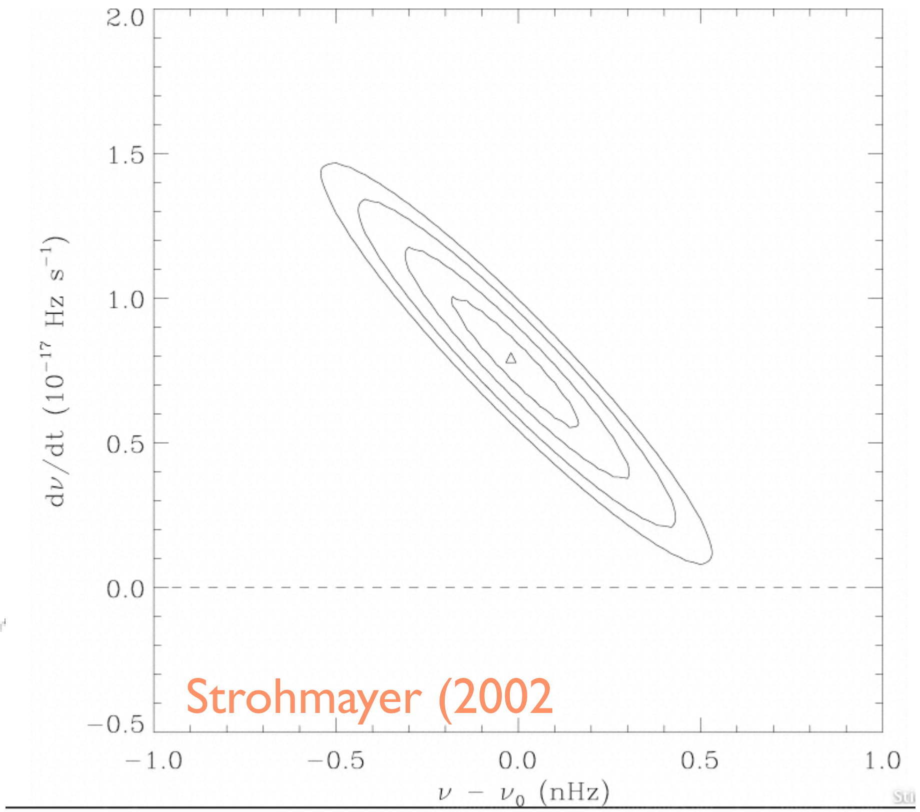
Characterising their orbital evolution

Quite quickly it was found that both systems period is shortening

RX J0806+15



RX J1914+24



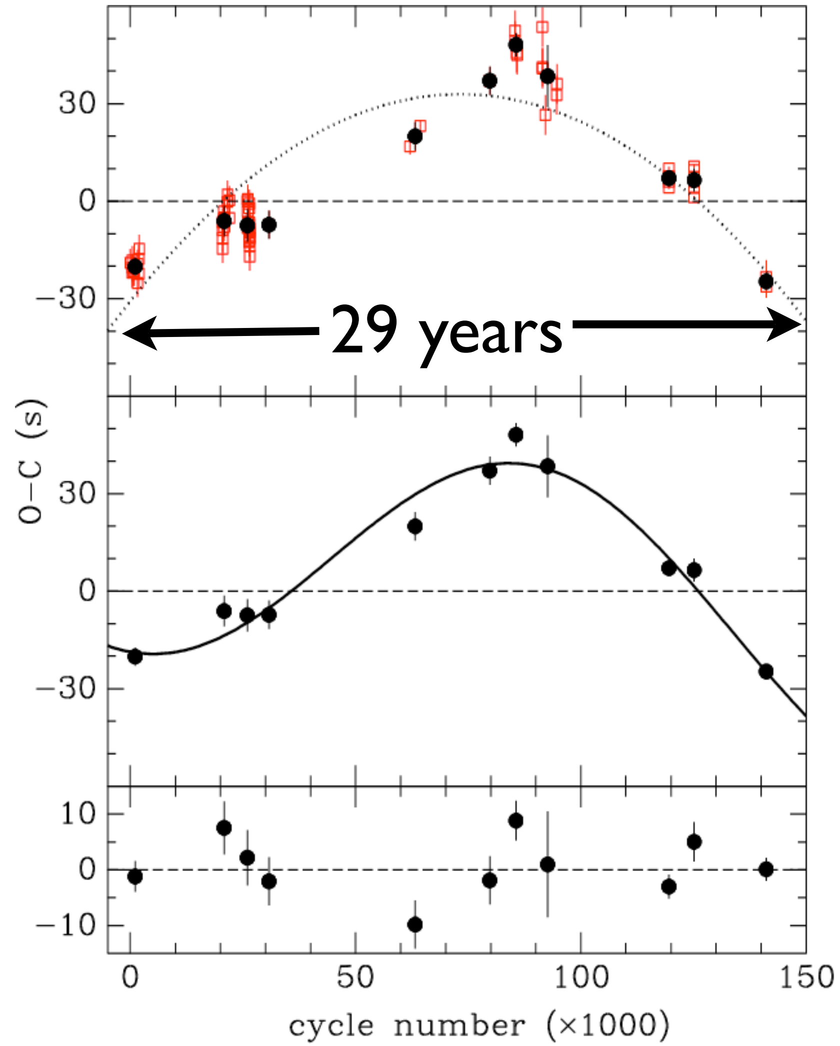
Different techniques give consistent results.

Characterising their orbital evolution

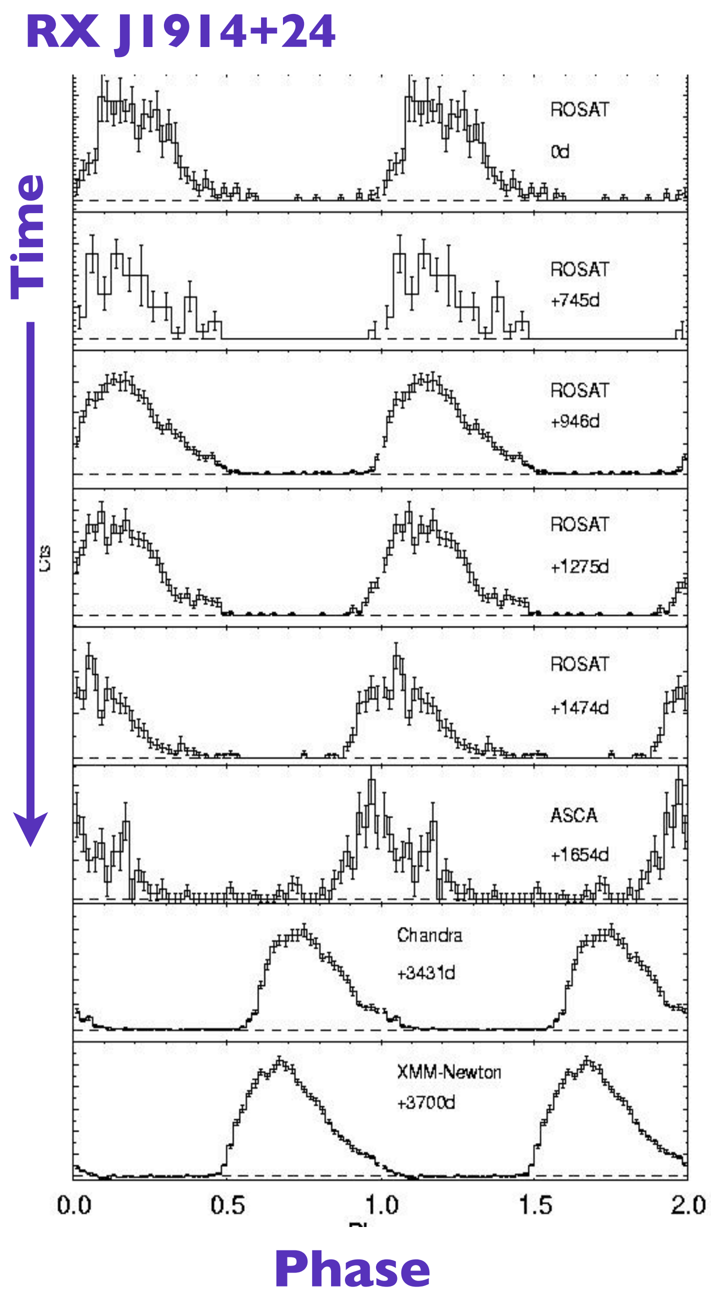
Originally thought that these results ruled out the accretion models since naively thought that in accretion models period would *increase* if fully degenerate donor. HT Cas Borges et al (2008)

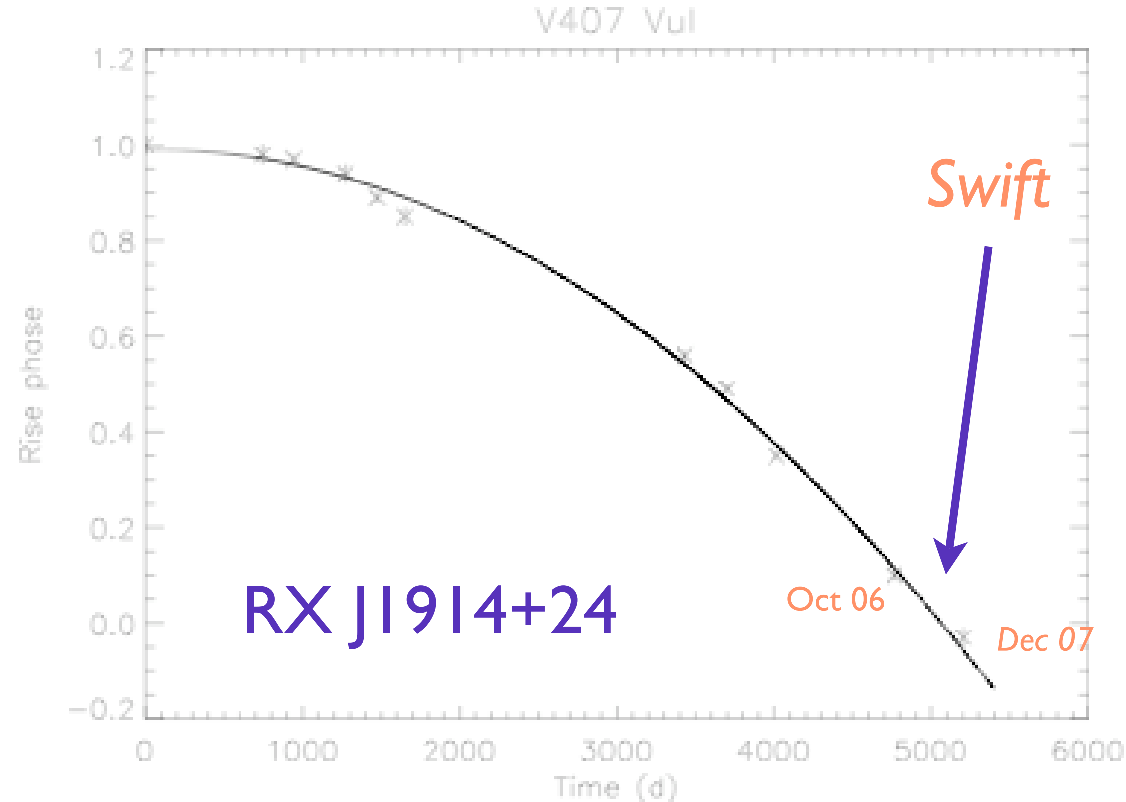
However, if the mass transfer rate can deviate from the equilibrium rate, accretion models will also lead to a *decrease* in the period (Marsh & Nelemans 2005) for a short time.

Other were sceptical that it was a true reflection of orbital period change since evidence of period change is seen in CVs which are not related to orbital period. *However, should see sign of this in 5-10 yrs.*



Characterising their orbital evolution





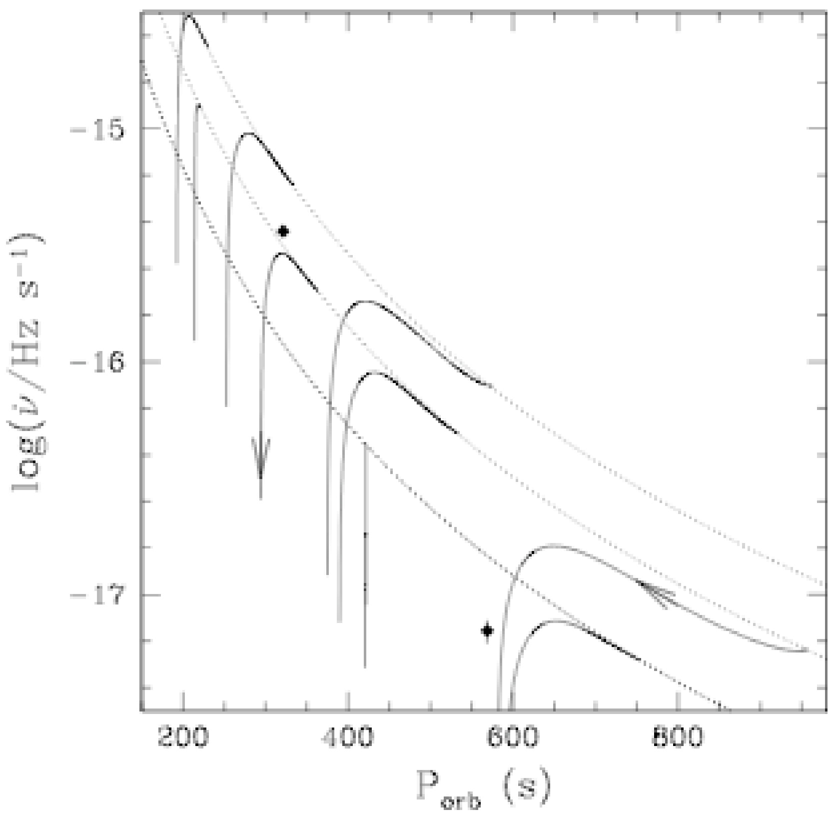
Orbital period decreasing at a constant rate of 1.1+/-0.06e-17 Hz/s = 3.44+/-0.28e-12s/s

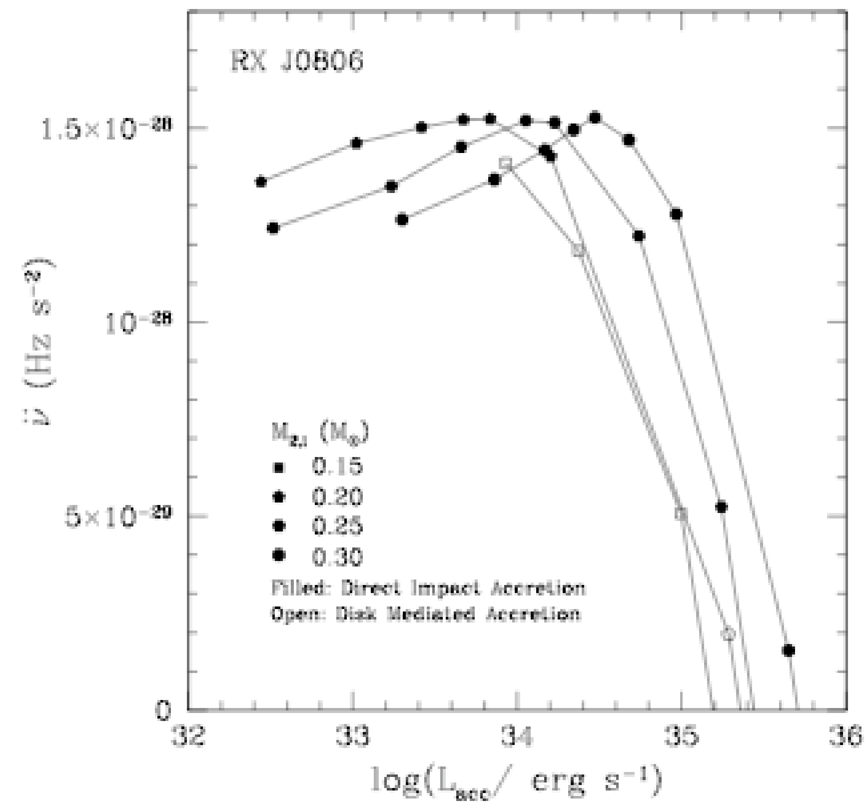
If the G9 star physically associated with X-ray bright source, then this should affect the period over time.

Orbital period of **RX J0806+15** also decreasing - at a rate of 3.4e-16 Hz/s.

Characterising their orbital evolution

Can we use period change to distinguish between models?





Deloye & Taam (2006) predict both the Pdot and Pdotdot assuming direct impact accretion. Show that evidence for Pdotdot term will become visible in ~5-10 yrs for RX J0806+15. Longer for RX J1914+24

=> Continue to monitor period in X-rays, eg further *Swift* time

Characterising their orbital evolution

IF, unipolar induction provides the driving force need to take the spin-orbit coupling into account.

Dall'Osso et al (2006) "... gravitational energy is `converted' into electric energy, powering a continuous flow of currents".

Can only take the spin-down results at face value if spin-orbit coupling is negligible.
Dall'Osso et al (2007):
RX J0806+15 - timing properties differ only slightly from two point masses evolving under GW emission.
RX J1914+24 - measured value of GW emission does not reflect that actual GW emission. *In fact, GW emission much more luminous than expected from Pdot.*

Radio (6cm) observations

VLA observations:

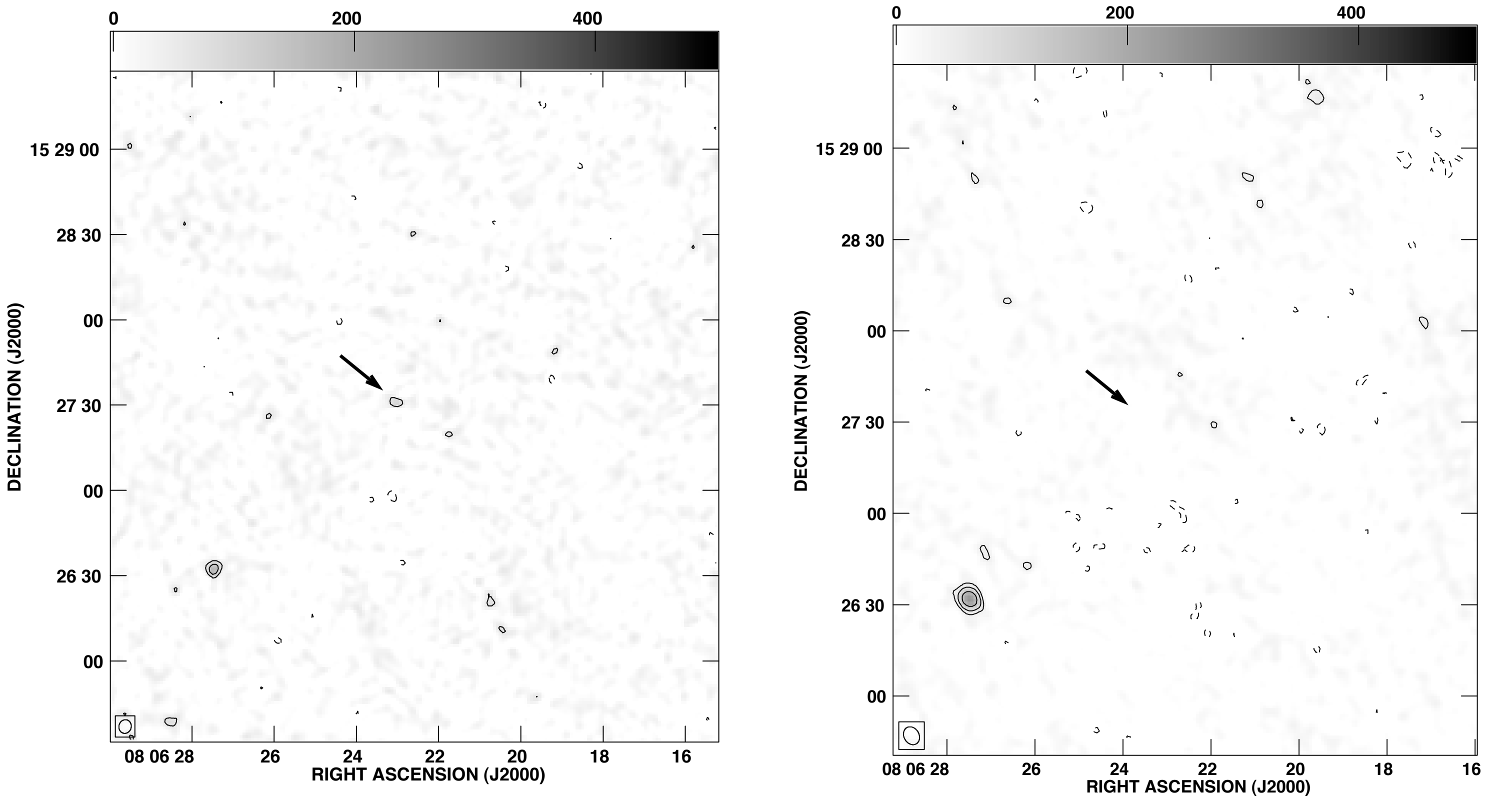
RX J1914+24 => no detection, <42μJy

RX J0806+15 => 26 Sept 2005, 5.8 sig, 99+/-17μJy

=> 29 Dec 2006 <36μJy

RX J0806+15 detected for ~20 mins.

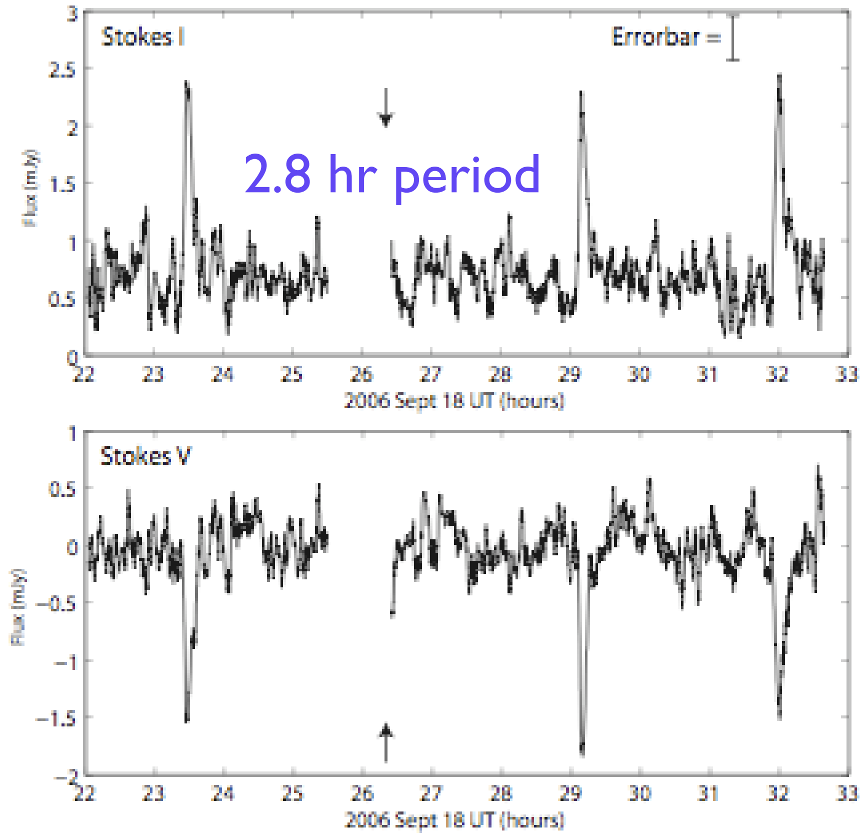
Re-analysis of data shows source clearly polarised.

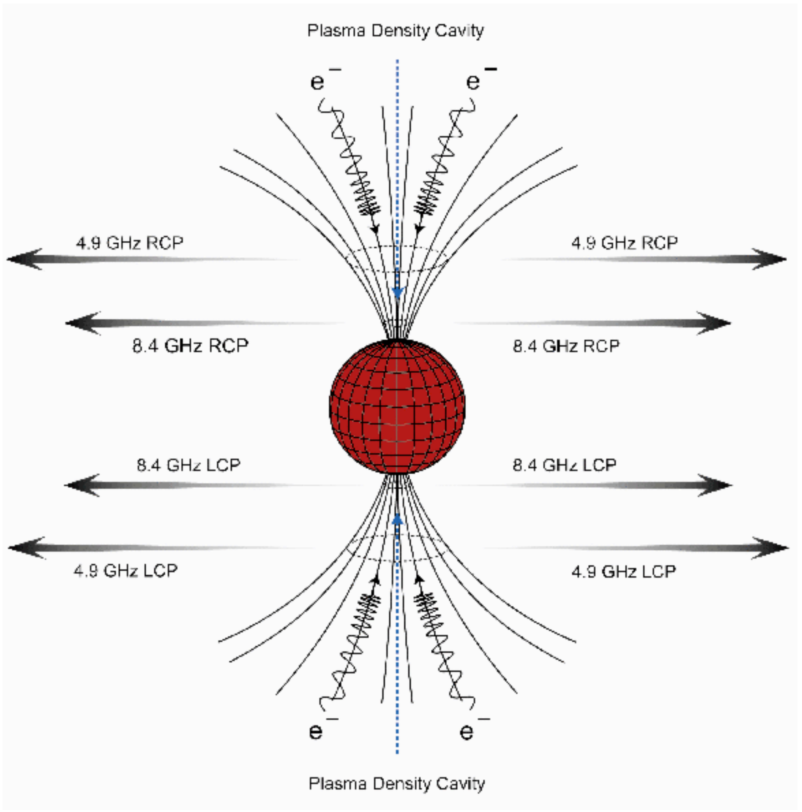


The closeness of the radio source with the optical counterpart of RX J0806+15 (0.3") suggests transient radio emission was detected from RX J0806+15. Brightness temperature >10^18K. Not consistent with non-thermal synchrotron emission, but is with electron-cyclotron maser emission. (Ramsay et al, 2007).

An aside: UI in ultra cool *dwarfs*?

LSR J1835+3254





Hallinan et al (2008)

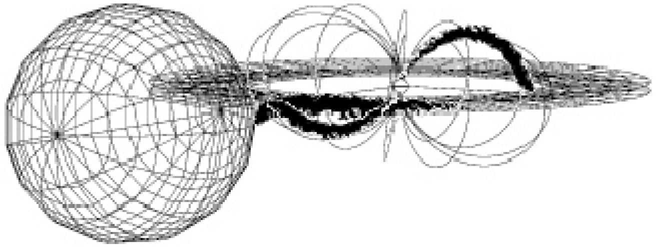
Work by groups in Galway and Armagh have shown that UI powering radio emission in ultra cool dwarfs.

Summary of competing models:

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

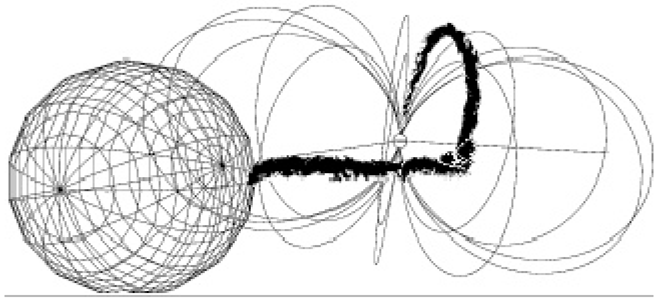
- The periods are the spin period of the white dwarf so the spin up is not a problem.

Problems – lack of strong emission lines. Would expect the secondary to show up as would orbital period unless low inclination. 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 emission lines, polarisation and hard X-rays - although some polars show very little X-ray >2keV. Can't be excluded but regarded as unlikely.

Summary of competing models:

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.

Issues: *Phase relationship between optical and X-rays.*

Lifetime problem not seen to be a problem (Dell'Osso et al)

Luminosity still very uncertain to pin-down energetics well.

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.

Issues: *Location of the X-ray emission sites.*

Long time change in period change - test with few years? (Deloye & Tamm)

Can it predict transient outbursts of polarised radio emission? (Ramsay et al)