The nature of the 10min binary RX J1914+24

Gavin Ramsay
Mark Cropper
Kinwah Wu
Mullard Space Science Lab,
University College London, UK
Pasi Hakala
University Helsinki, Finland

UCL MSSL

Structure:

1. **Context**
2. **Observational Characteristics**
3. **Possible models**
4. **Gravitational radiation**
5. **Summary**

Context

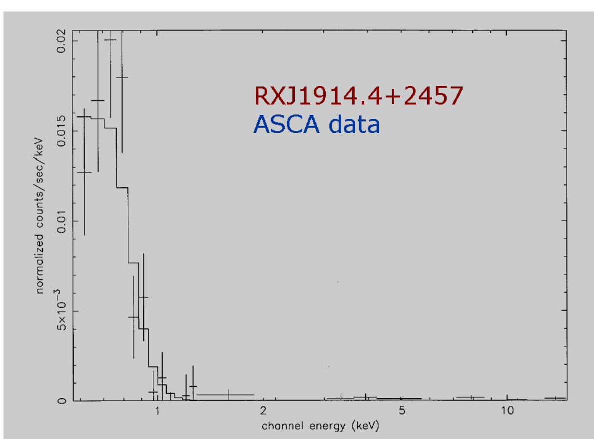
- **3 systems with binary periods <10 min**

RXJ1914.4+2457 (V407 Vul)	9.5 min	Cropper et al (1998)
RXJ0806.3+1527	5.4 min	Ramsay, Hakala & Cropper (2002) Israel et al (2002)
KUV01584–0939 (ES Cet)	10.3 min	Warner & Woudt (2002)

- **Initial discovery of V407 Vul discovered in *ROSAT* surveys by Motch et al (1996); identified as a "soft IP"**
- **Initial discovery of RXJ0806.3+1527 was in Israel et al (1999) and Beuermann et al (1999); identified as an IP**
- **Initial discovery of ES Cet in *Kiso Schmidt UV Survey* (Kondo, Noguchi & Maehara 1984). Has double peaked emission so has a disk.**

Observational Characteristics (1)

Absence of Hard X-ray emission

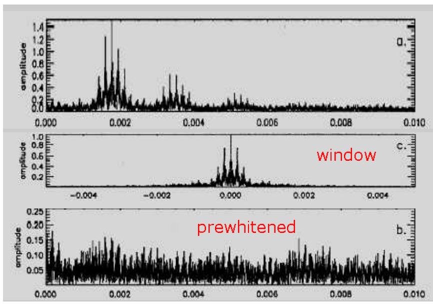


Ramsay et al (2000)

Observational Characteristics (2)

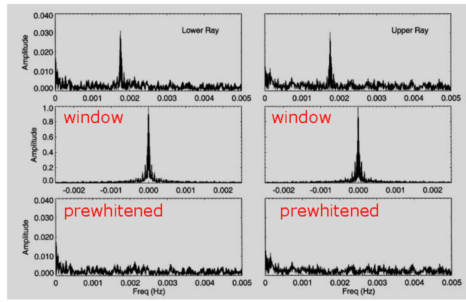
Only one period in power spectra; if this is the orbital period then the secondary has to be degenerate

RXJ1914.4+2457



ROSAT HRI data

Cropper et al (1998)

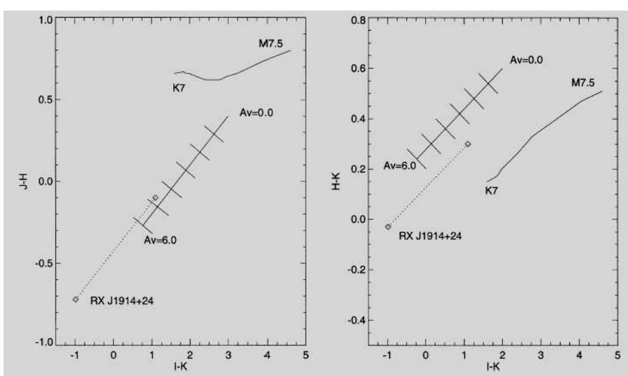


NOT optical data

Ramsay et al (2000)

Observational Characteristics (3)

Optical Colours



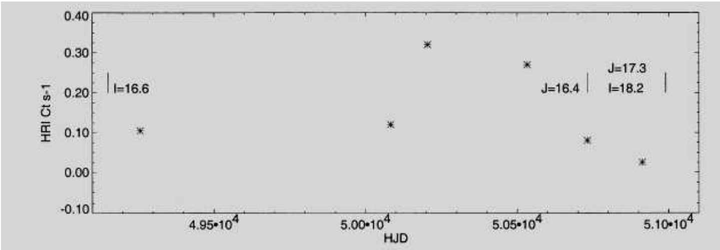
RXJ1914.4+2457

Ramsay et al (2000)

- **No evidence for a late main-sequence secondary star**
- **Spectral flux distribution in optical is that of a hot (tens of kKelvin) black body**

Observational Characteristics (4)

- **Source is not constant in X-ray or optical/IR ⇒ most likely some sort of accretion or similar mechanism**

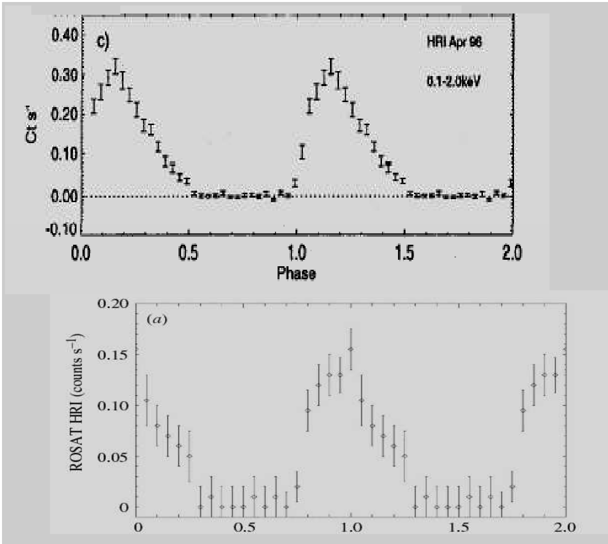


Long-term light-curve: RXJ1914.4+2457

Ramsay et al (2000)

Observational Characteristics (5)

- **X-ray light curve shows sharp rise to maximum and slower decline**
- **X-rays essentially "off" for ~50% of the cycle ⇒ small emission region**
- **RXJ1914.4+2457 and RXJ0806.3+1527 X-ray light curves are almost identical**

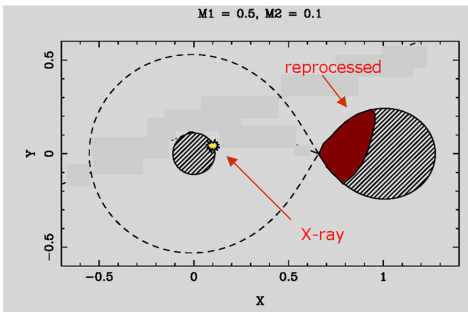


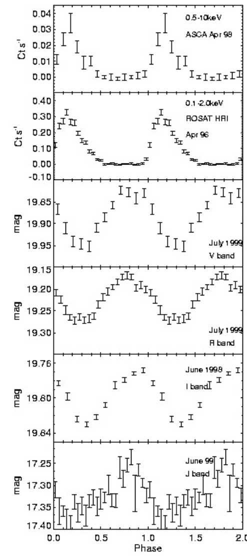
Top: RXJ1914.4+2457
Bottom: RXJ0806.2+1527

Cropper et al (1998)
Burwitz & Reinsch (2000)

Observational Characteristics (6)

- **Phasing of X-ray and optical/IR light curves argues against a single star**
- **Simplest explanation is a reprocessing source in a binary system where the X-rays from the primary are reprocessed from the secondary**



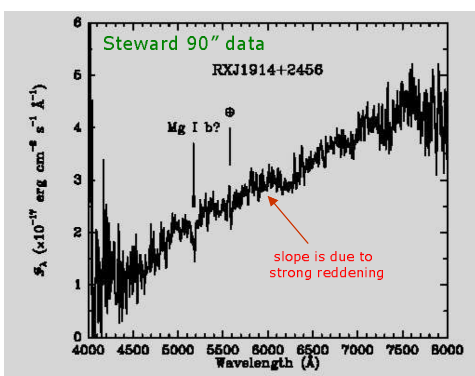


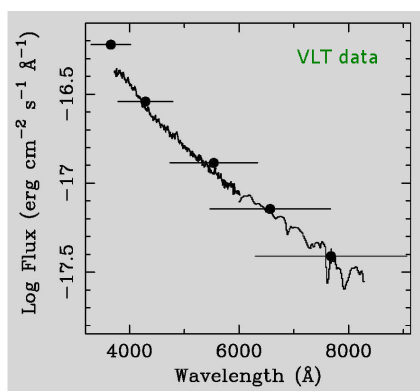
RXJ1914.4+2457

Ramsay et al (2002)

Observational Characteristics (7)

- **Absence of strong emission lines typically seen in IPs and other accreting systems**





Left: RXJ1914.4+2457 — Ramsay et al (2002)
Right: RXJ0806.2+1527 — Israel et al (2002)

Possible Models

- **Four models exist for these systems**

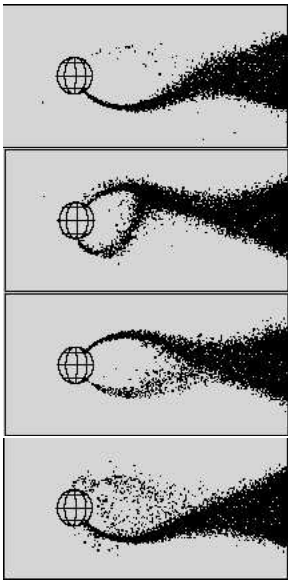
a) Intermediate Polar	Motch et al (1996) Norton et al (2002)
b) Double Degenerate Polar	Cropper et al (1998)
c) Double Degenerate Algol	Marsh & Steeghs (2002) Ramsay et al (2002)
d) Electric Star	Wu et al (2002)

- **Of these models, three involve magnetic fields**
- **Neutron star models are ruled out because of the absence of a hard tail of X-ray emission; also they need to be extremely close (too close for the observed level of reddening)**

Model 1: IP

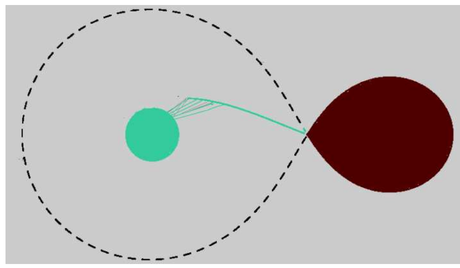
- **Initial IP model from Motch et al (1996) dismissed by Cropper et al (1998) on grounds of light curve shape (off for 50% of the cycle)**
- **Idea of pole switching was entertained, but considered unlikely because of travel time considerations**
- **Model resuscitated by Norton et al (2002) for a face on system**
- **Detailed calculations using SPH indicated that the pole switching could produce the observed sharp rise in the lightcurve and the duty cycle of 50%**

Norton et al (2002)



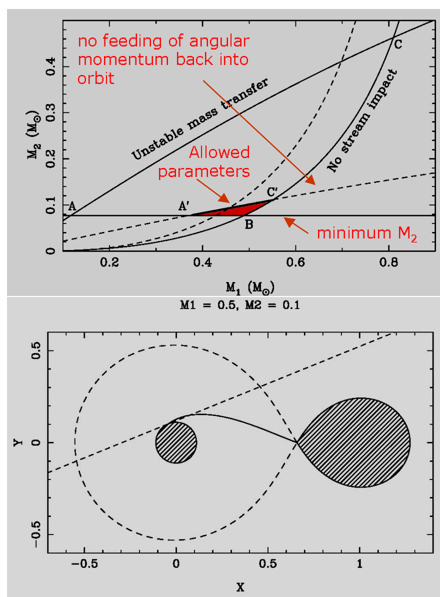
Model 2: DD Polar

- Initially introduced by Cropper et al (1998) to explain light curve in RXJ1914.4+2457.
- Successfully predicted (in Ramsay et al 2000):
  a) absence of hard component
  b) absence of spectral signature of secondary
- Absence of polarisation and lack of emission lines from a stream seen as a possible difficulty (Ramsay et al 2002)
- Model is still viable if:
  a) magnetic field is low enough to channel flow but not for polarisation in optical band and
  b) stream is very narrow



Model 3: DD Algol

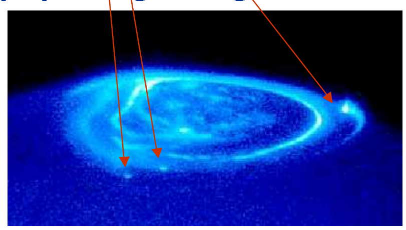
- Introduced independently by Marsh & Steeghs (2002) and Ramsay et al (2002)
- Direct stream impact onto primary because of small dimensions of binary separation compared to R_{WD}
- Conclusions depended on where one was coming from:
  - for a relatively narrow range of parameters the model was viable (Marsh & Steeghs 2002)
  - model was difficult to make it work because it required a particularly narrow range of parameters (Ramsay et al 2002)



Marsh & Steeghs (2002)

Model 4: Electric Star

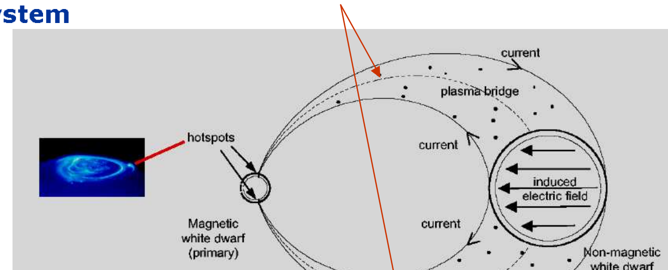
- Model introduced by Wu et al (2002) to deal with absence of polarisation and emission lines in RXJ1914.4+2457
- Scaled-up version of Jupiter-moon interactions heating Jupiter's atmosphere at footpoints of magnetic field lines threading moon, BUT:
  a) energy release boosted by stronger magnetic field
  b) shorter period
  c) secondary larger than a moon
- Up to 10^{36} ergs/s available (depending on degree of asynchronism)
- Star shines by electrical resistive heating: new mechanism after
  1. nuclear fusion
  2. accretion
  3. magnetic (magnetars)

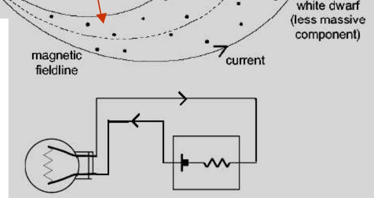


HST image (NASA)

Model 4: Electric Star (ctd)

- Conductor (secondary) moving in magnetic field of primary has EMF induced across it (as in any generator)
- EMF drives a current in 2 circuits if low density plasma in system





- Emission takes place from two small hotspots at the base of the field lines on primary

Wu et al (2002)

Further thoughts: ES Model

- ES model suffers from being 'unconventional' but nevertheless:
  - a) provides the best interpretation of the data
  - b) evidently works in astrophysical systems (Jupiter)
- Predicts the right shape of X-ray light curve (retrograde spin on primary WD)
- Lifetime of the system is ~10^6 years, short but not particularly short – NOTE: the 10^3 years quoted by Marsh & Steeghs (2002) is a misinterpretation of the text in Wu et al (2002)
- It is an expected end point for double WD pairs if one has a modest (<1MG) field; secondary is not necessarily in contact with Roche Lobe – expect many of these systems?

Model Comparison

	IP	DD Polar	DD Algol	Electric Star (ES)
Absence of Hard X-rays	x	√	√	√
Only one modulation period	x	√	√	√
Optical-IR colours	x	√	√	√
Phasing of X-ray and Optical	~	√	~	√
Shape of X-ray modulation	√	√	√	√
Absence of Polarisation	√	~	√	√
Absence of H	x	√	√	√
Absence of strong emission lines	x	~	~	√
Long-term variability	√	√	√	√

- On current knowledge, only strongly ruled out model is the IP, mainly because of lack of photometric evidence for secondary

  ⇒ perhaps consider DD IP?

Gravitational Radiation

- Ultra-short period binaries are expected to be strong sources of gravitational radiation. These will be the calibrators for LISA

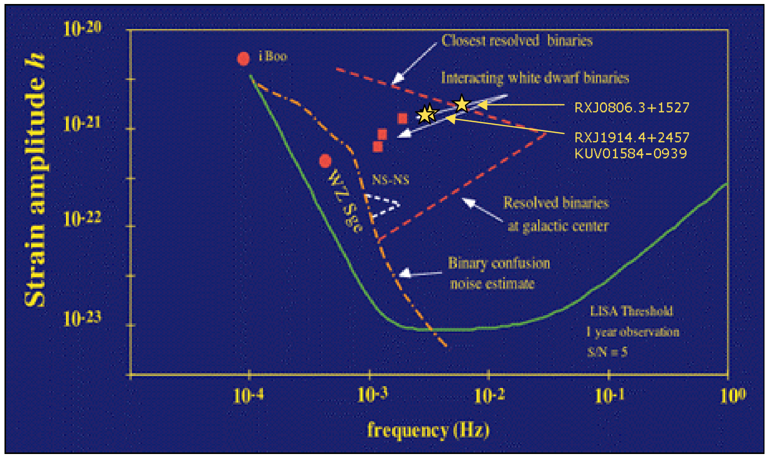


Figure from NASA/JPL; strain from Nelemans et al (2001)

Summary

- Pretty certain that the periods seen in these systems are indeed the orbital periods ⇒ these really are ultra-short period binaries
- Three models still viable: DD Polar, DD Algol and ES; need phase-resolved optical spectroscopy to make further progress and also X-ray/optical phasing
- Electric Star model should not be viewed too skeptically but perhaps some further indications are required
- Amongst the first sources to be detected by LISA