LMXB‘s
Low Mass X-ray Binaries

Sebastian Ihle

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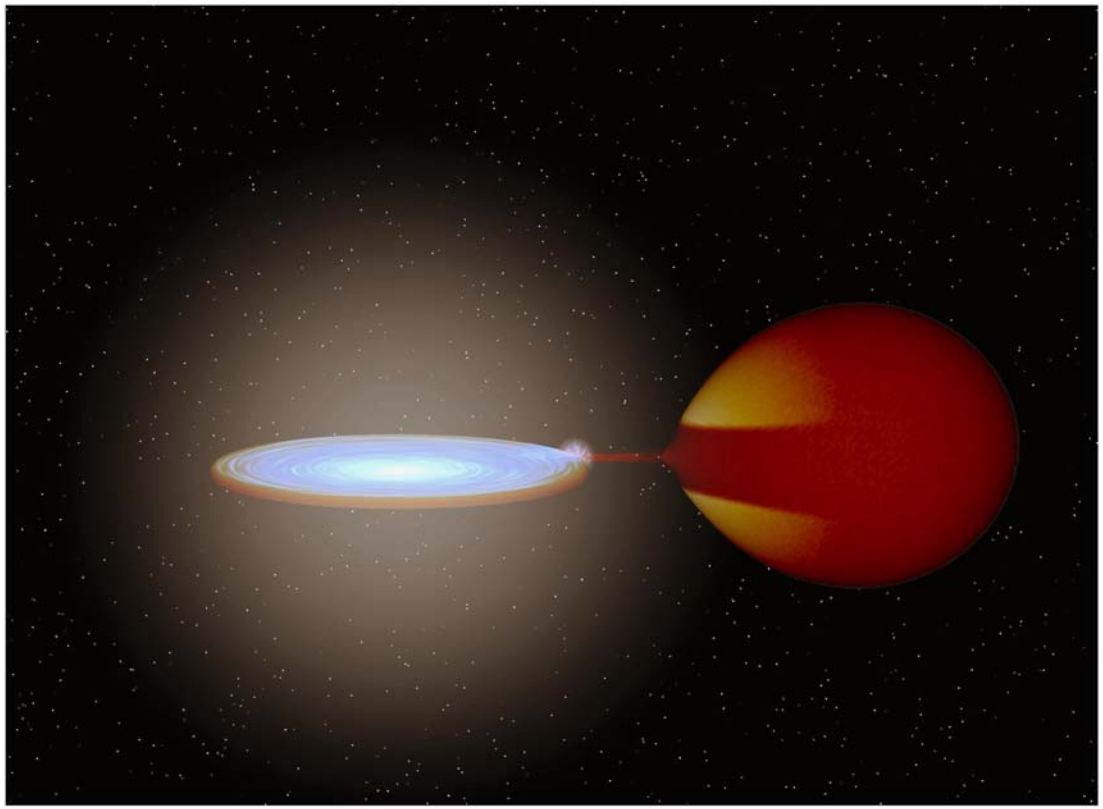
Topics

- Classification of LMXB‘s
- Properties of LMXB‘s
- Formation of LMXB‘s
- Observations of LMXB’s
- Millisecond pulsar as final stages of LMXB‘s
- Literature

Classification of LMXB‘s

A compact object (neutron star or black hole) and a companion (a star or white dwarf) with lower mass



Properties of LMXB‘s

- 150 known LMXB‘s (2001):
  - 130 in milk way, 13 in globular clusters, 2 in LMC
  - 63 are X-ray bursters
  - 75 transient (not always observable)
  - 11 with a black hole (& 8 possible candidates)
- Luminosity typically 250 to 25000 $L_\odot$

Very bright objects and X-Rays very penetrating

$\Rightarrow$ Almost all constant bright objects known

Properties of LMXB‘s

- Luminosity and accretion rate
  - Typically:

$$L_{LMXB} \approx 10^{36} - 10^{38} ergs^{-1} \hat{=} \dot{M} \approx (10^{-10} - 10^{-8}) \frac{M_\odot}{a} R \left(\frac{M_{NS}}{1{,}4 M_\odot}\right)^{-1}$$

- X-ray spectra: soft ($kT \leq 10keV$)
- Accretion process: Roche-lobe overflow
- Orbital periods: from 11 minutes to 17 days

Formation of LMXB‘s

- Direct: Birth as binary system

  More massive star $\Rightarrow$ compact object

  Less massive star fills Roche radius

  $\Rightarrow$ mass-transfer $\Rightarrow$ LMXB
- Capture: Birth of more massive star alone $\Rightarrow$ compact object

  Close encounter $\Rightarrow$ capture of second star

  High star density $\Rightarrow$ happens almost only in globular clusters

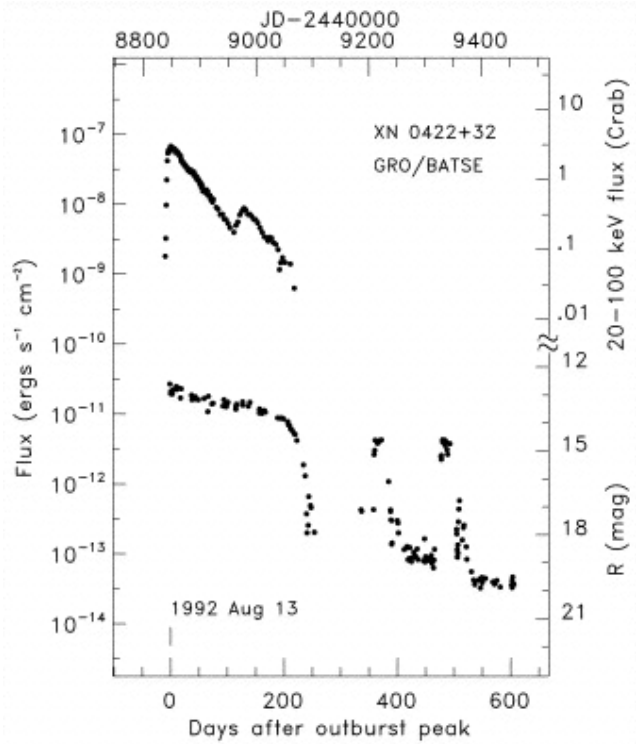
Observations of LMXB‘s

How is an X-ray source identified as LMXB?

Easy Possibility:

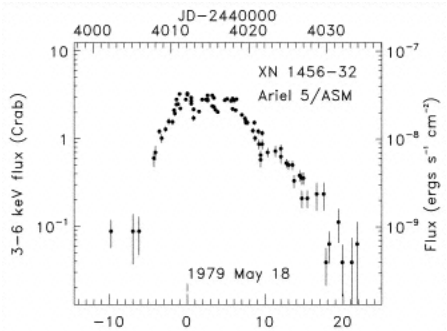
Source is transient

⇒ Identification with light curve



V518 Per

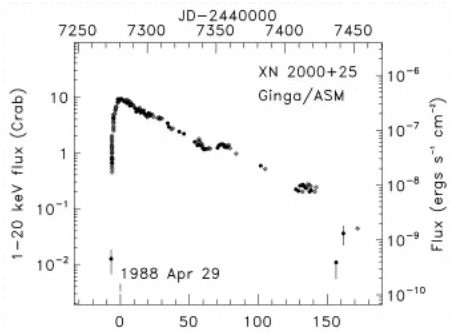
Black hole LMXB



V882 Cen

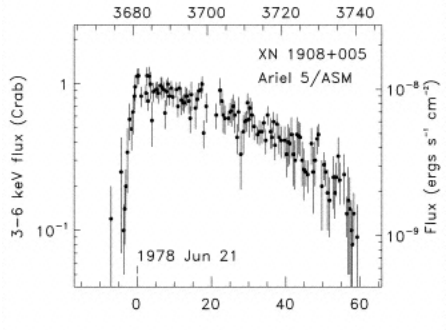
NS LMXB

Typ I X-ray-bursts



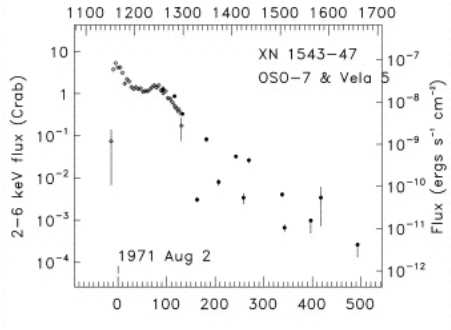
QZ Vul

BH LMXB



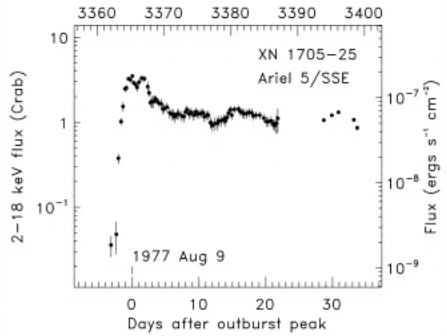
V1333 Aql

NS LMXB



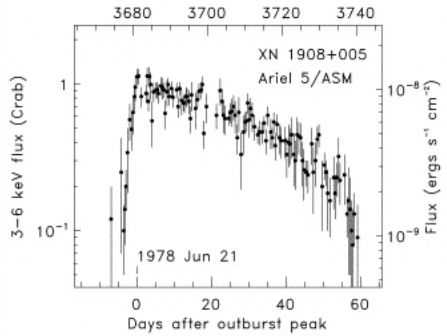
IL Lup

BH LMXB



V2107 Oph

BH LMXB



V1333 Aql

NS LMXB

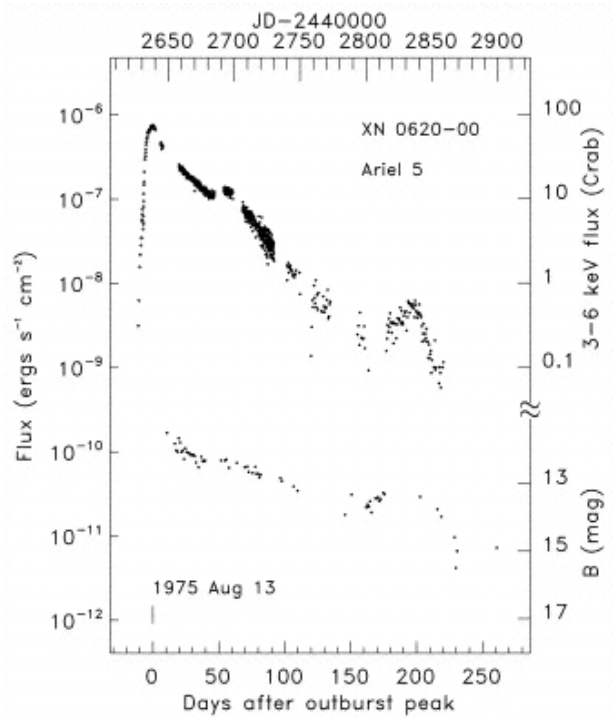
Typ I X-ray-bursts

Observations of LMXB‘s

Mechanism of the bursts:

Accretion disk has two states:

- cold: matter-flux into disk greater than out of the disk; does not radiate x-rays
- hot: matter-flux into disk lower than onto the compact object; bright in x-rays



V616 Mon

BH LMXB

Observations of LMXB's

Other Possibilities of identification:

- Optical Observation of the X-ray-source and determination of the masses of the objects also only possible for transient sources
- X-rays: soft (LMXB) or hard (HMXB)

  But not always clearly distinguishable

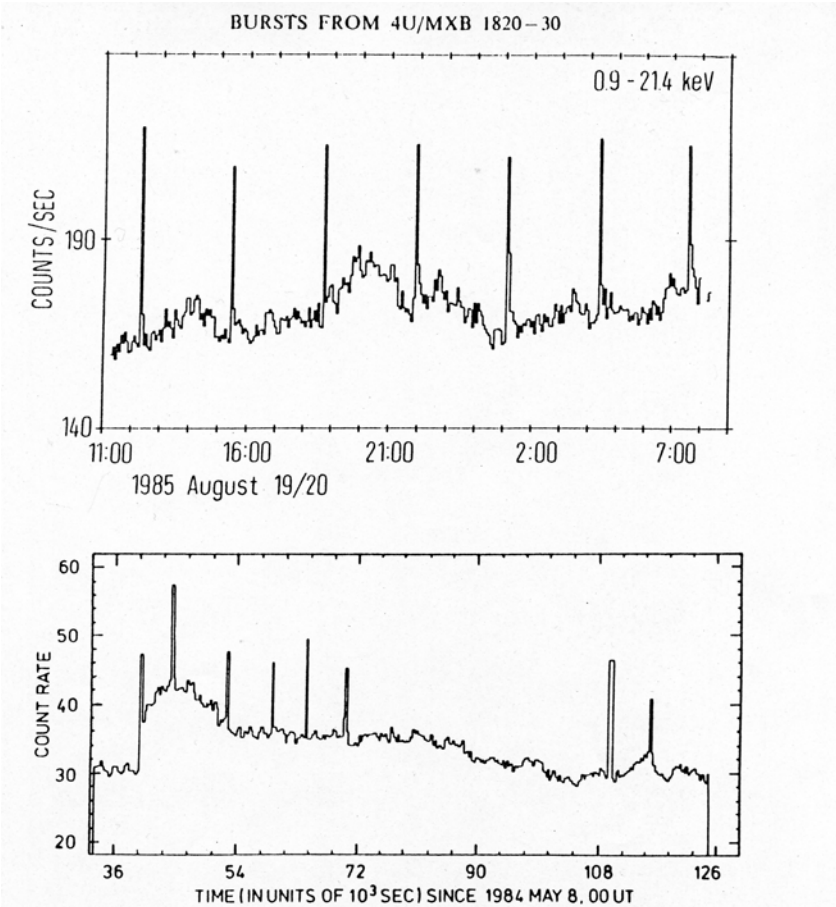


Fig. 3.14. (a) Example of a very regular burst recurrence pattern, observed for 1820–303 (from Haberl *et al.* 1987). (b) Irregular burst recurrence, observed from 1636–536 (from Sztajno *et al.* 1985).

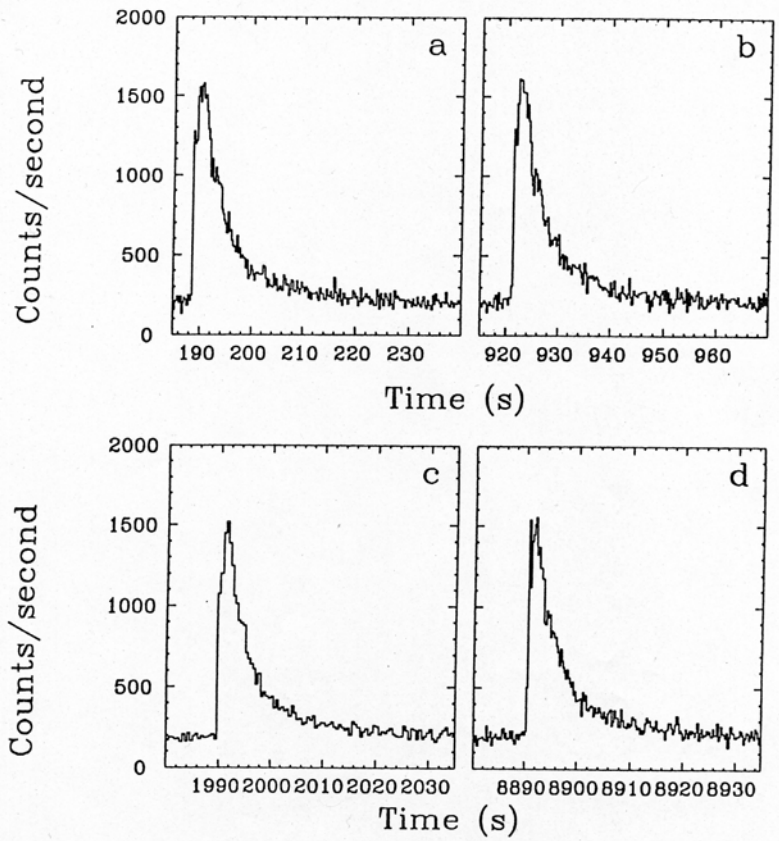


Fig. 3.2. Profiles of four of seven bursts observed from 1820–303 with EXOSAT in the ~1–20 keV band during a 20 hour observation on August 19/20, 1985. The counting rates have not been dead-time corrected. The horizontal axes represent time in seconds. The burst start times are: Aug. 19, UT 12:16:23 (a), Aug. 19, UT 18:42:52 (b), Aug. 19, UT 15:26:52 (c), and Aug. 19, UT 21:55:28 (d). The profiles of all seven bursts were very similar (courtesy T. Oosterbroek).

Observations of LMXB's: X-ray bursters

Two Types of bursts:

- Type I: thermonuclear explosion of He on the neutron star
- Type II: instabilities of accretion flow onto the neutron star

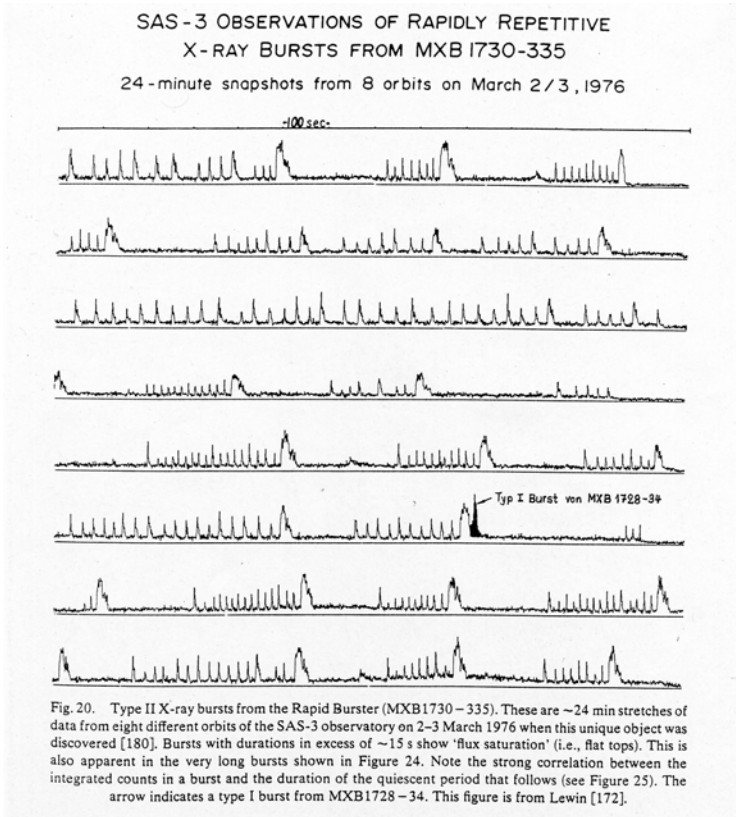
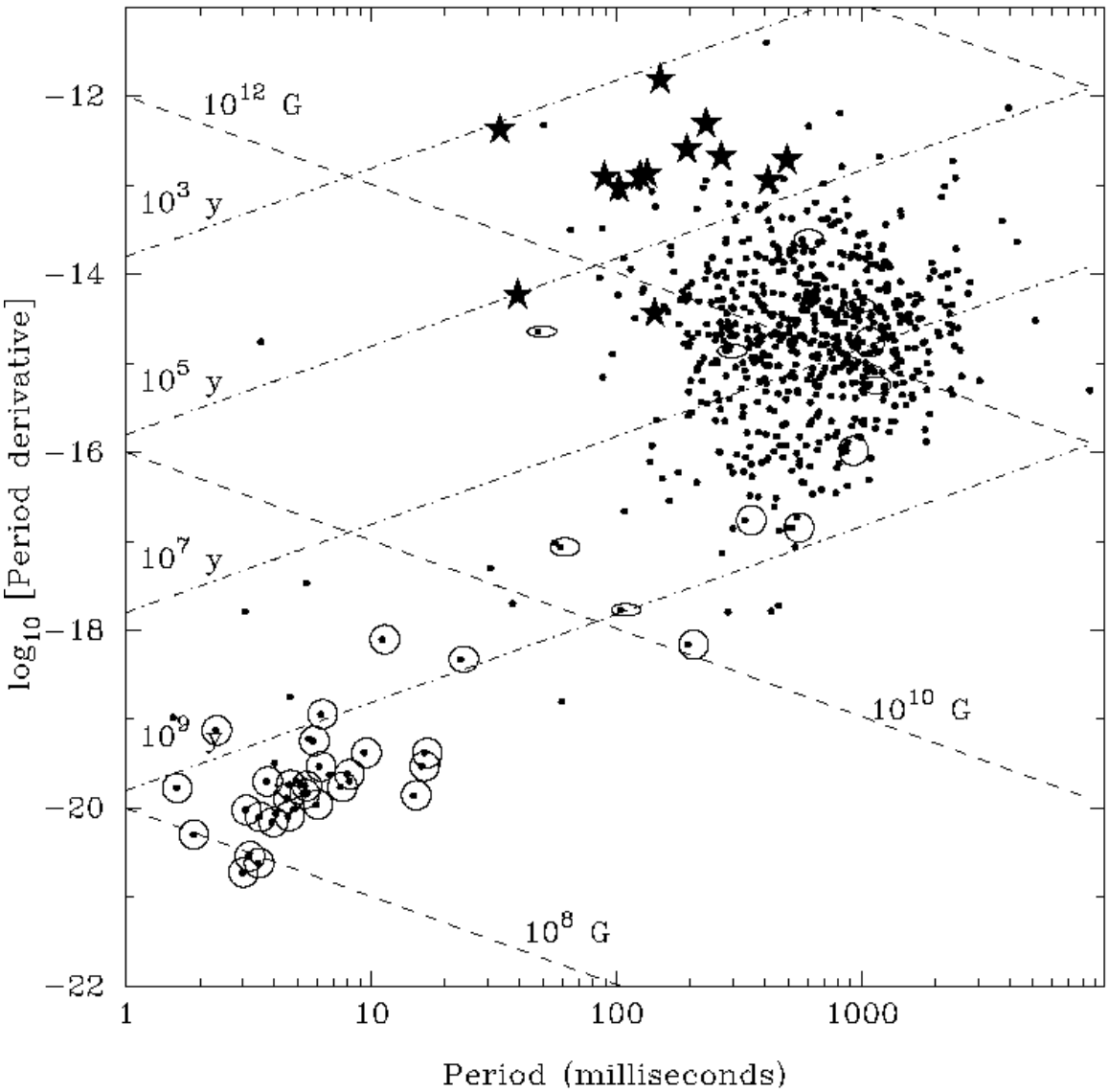


Fig. 20. Type II X-ray bursts from the Rapid Burster (MXB1730−335). These are ~24 min stretches of data from eight different orbits of the SAS-3 observatory on 2–3 March 1976 when this unique object was discovered [180]. Bursts with durations in excess of ~15 s show 'flux saturation' (i.e., flat tops). This is also apparent in the very long bursts shown in Figure 24. Note the strong correlation between the integrated counts in a burst and the duration of the quiescent period that follows (see Figure 25). The arrow indicates a type I burst from MXB1728−34. This figure is from Lewin [172].

Millisecond pulsars as final stages of LMXB‘s

- Pulsation Periods: ≥ 1.6 ms
- Period of normal Pulsars decrease with age $\Rightarrow$ first assumption: very young pulsars
- Young pulsars should have strong magnetic fields; but measured magnetic field of millisecond pulsars very weak: apparent inconsistency
- Solution: millisecond pulsars are very old “recycled” neutron stars


10^{12} G
10^{3} y
10^{5} y
10^{7} y
10^{9} y
10^{10} G
10^{8} G
−12
−14
−16
−18
−20
−22
$\log_{10}$ [Period derivative]
1
10
100
1000
Period (milliseconds)

Millisecond pulsars as final stages of LMXB‘s

- Neutron star born $\Rightarrow$ normal pulsar

  Distance too big for mass transfer
- Magnetic field and pulsation period decrease with age $\Rightarrow$ invisible as pulsar
- LMXB $\Rightarrow$ mass transfer

Millisecond pulsars as final stages of LMXB‘s

- Transferred mass $\Rightarrow$ angular momentum “spins up” neutron star
- Rotation period ~ milliseconds
- Equilibrium between spinning up and slowing down
- Stop of mass-transfer $\Rightarrow$ visible as millisecond pulsar

Literature

- Sterne und Weltraum, 7-8/1989, Max Camenzind, Millisekundenpulsare
- Scientific American, November 1993, Edward P.J. van der Heuvel and Jan van Paradijs, X-ray Binaries
- Scientific American, 1987, Jacob Shaham, The Oldest Pulsars in the Universe
- Sky & Telescope, April 1995, Victoria M. Kaspi, Millisecond Pulsars: Timekeepers of the Cosmos

Literature

- Astro-ph/030456 v1, 20 Mar 2003, T. M. Tauris and E. P. J. van den Heuvel, Formation and Evolution of Compact Stellar X-ray Sources
- Astro-ph/0308020 v2, 24 Oct 2003, P. A. Charles and M. J. Coe, Optical, Ultraviolet and Infrared Observations of X-ray Binaries
- Private Conversations with H. Ritter