Low mass X-ray binaries (LMXB)

An overview

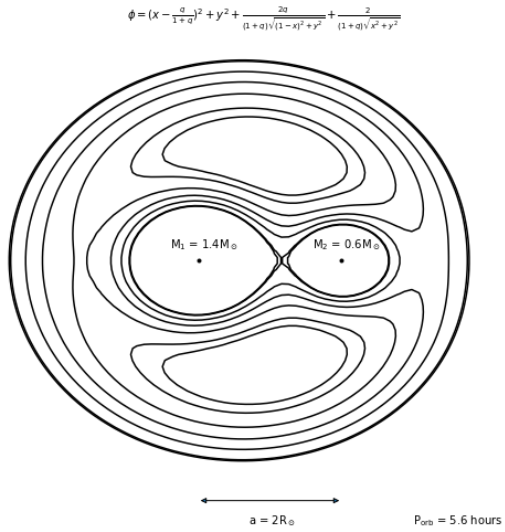
Joona Rautiainen

December 9, 2020

Contents

General Properties

- Accretor: Low magnetic field NS or BH
- X-ray spectra: $kT \leq 10\mathrm{keV}$ (soft)
- Accretion via Roche-lobe overflow - Semi-detached
- Type time variability: Very few pulsars, often X-ray burst
- Accretion timescale: $10^7 - 10^9$
- Distribution: Galactic center and around the plane (globular clusters)
- Stellar population: Age $> 10^9$
- Secondary star: low mass $\leq 1\mathrm{M}_\odot$, faint $M_\mathrm{V} \approx 2$, $L_\mathrm{optical}/L_\mathrm{x-ray} \ll 0.1$
- Periods 11 min to 17 days



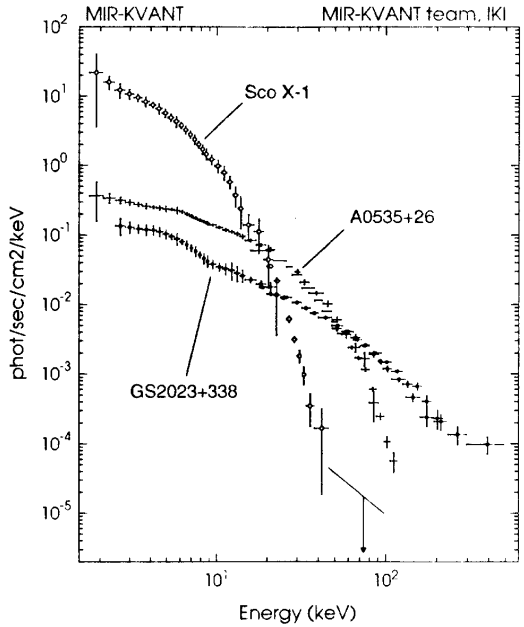
Primaries

Neutron star

- Burst
- Low magnetic field $< 10^{11}$G (10^{9}G)
- Mass $1.4\mathrm{M}_{\odot}$, $M < 3\mathrm{M}_{\odot}$

Black hole

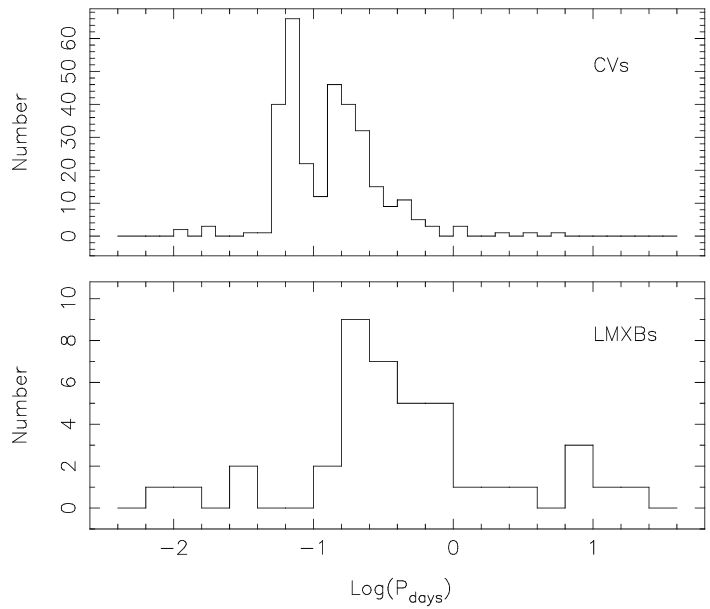
- No burst (Still low mass soft X-ray transients)
- No pulsars
- M 3 - 15 $\mathrm{M}_{\odot}$



van Paradijs 1998

On Secondaries

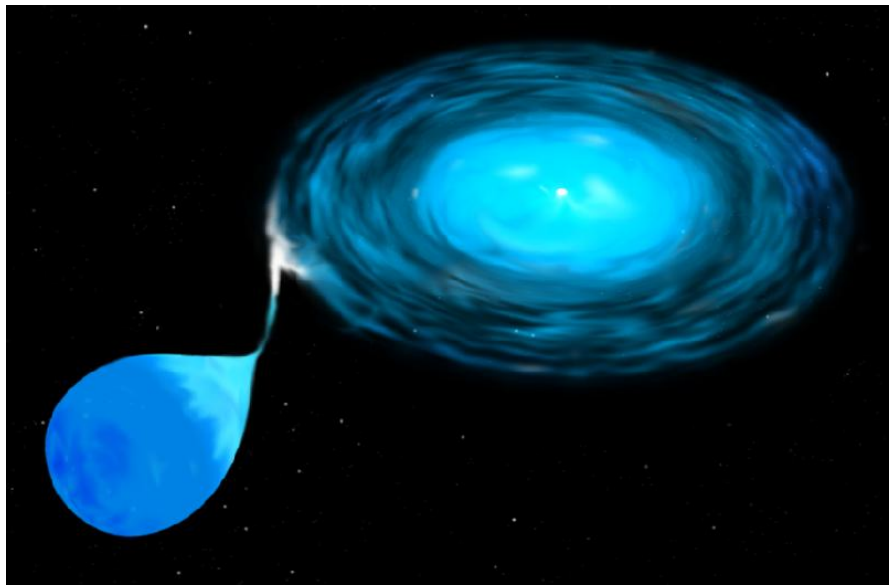
- Mass $\leq 1 M_{\odot}$
- Wide range of periods - wide range of evolution stages
- MS
- Giant
- WD



van Paradijs 1998

Accretion

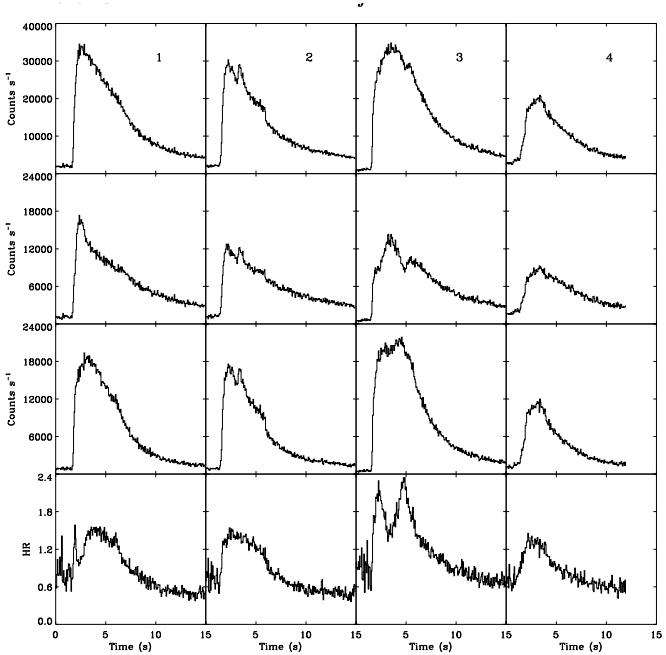
- Accretion mainly via accretion disk
- Accretion rates 10^{-11} - $10^{-8} \frac{\mathrm{M}_\odot}{\mathrm{yr}}$ restricted by the Eddington limit
- Accretion disk sizes vary from tens of km (R_N) to few $R_\odot$
- Temperature profiles follow the $T_{\mathrm{eff}} \propto R^{-3/4}$ or $T_{\mathrm{eff}} \propto R^{-3/7}$
- Optical spectra can be dominated by X-ray reprocessing $L_{\mathrm{V}} \propto L_{\mathrm{x}}^{1/2} P^{2/3}$
- In case of neutron star BB can be modified by electron scattering



Wikipedia Commons

X-ray

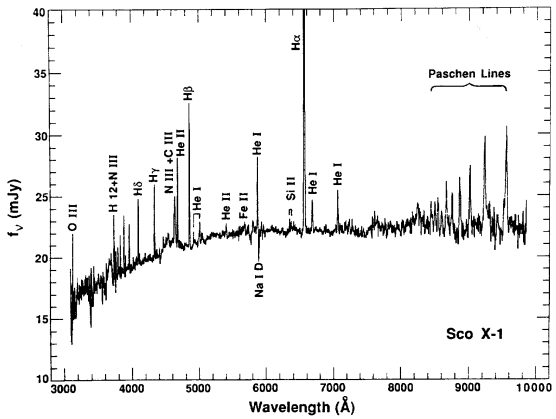
- Orbital periods (eclipses and "dips")
- X-ray Type I burst (10 - 100)s
- Expansion and shrinking of the photos sphere
- Often no pulsation - "weak" magnetic field (no synchrotron absorption)
- BB fit to determine radii of NS $R \propto \left(\frac{T_{\mathrm{e}}^4}{L_{\mathrm{bol}}}\right)^{1/2}$
- EoS



Strohmayer and Bildsten 2003

Optical

- Orbital periods (Brightness variations)
- Radial velocity changes in disk emission lines
- Occasionally absorption lines in the secondary
- Hα, H$_\beta$, He II λ4686 and C III - N IIIλ4630 – 50
- Heavy element abundance in the accreted matter



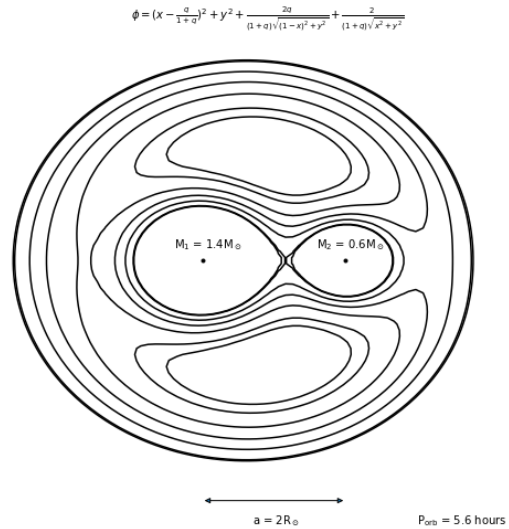
van Paradijs 1998

Binary evolution

- $$R_L = a\frac{0.49q^{-2/3}}{0.6q^{-2/3} + \ln\left(1 + q^{-1/3}\right)}$$

- $$\frac{\dot{a}}{a} = 2\frac{\dot{J}_{\rm orb}}{J_{\rm orb}} - 2\frac{\dot{M}_1}{M_1} - 2\frac{\dot{M}_2}{M_2} + \frac{\dot{M}_1 + \dot{M}_2}{M}$$

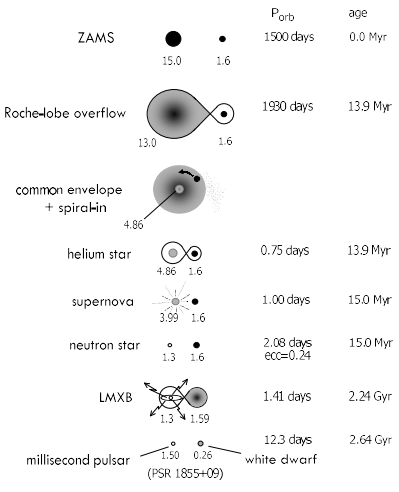
- $$\frac{\dot{J}_{\rm orb}}{J_{\rm orb}} = \frac{\dot{J}_{\rm GR}}{J_{\rm orb}} + \frac{\dot{J}_{\rm MB}}{J_{\rm orb}} + \frac{\dot{J}_{\rm TS}}{J_{\rm orb}} + \frac{\dot{J}_{\rm ML}}{J_{\rm orb}}$$



- MB and GR for initial $P_{\rm orb} < 2$ days
- Thermonuclear evolution for $P_{\rm orb} > 2$ days

ZAMS to binary millisecond pulsars

- Thought to evolve from LMXB (Spun up due to accretion)
- Millisecond burst oscillations
- Accreting millisecond X-ray pulsars



Tauris and van den Heuvel 2006

Thank you for your time, any questions?

References

Walter H. G. Lewin, Jan van Paradijs, and Ronald E. Taam. X-Ray Bursts. , 62(3-4):223–389, September 1993. doi: 10.1007/BF00196124.

Ph. Podsiadlowski, S. Rappaport, and E. D. Pfahl. Evolutionary sequences for low- and intermediate-mass x-ray binaries. *The Astrophysical Journal*, 565(2): 1107–1133, feb 2002. doi: 10.1086/324686. URL `https://doi.org/10.1086%2F324686`.

Tod Strohmayer and Lars Bildsten. New Views of Thermonuclear Bursts. *arXiv e-prints*, art. astro-ph/0301544, January 2003.

T. M. Tauris and E. P. J. van den Heuvel. *Formation and evolution of compact stellar X-ray sources*, volume 39, pages 623–665. 2006.

J. van Paradijs. Neutron Stars and Black Holes in X-Ray Binaries. In R. Buccheri, J. van Paradijs, and A. Alpar, editors, *The Many Faces of Neutron Stars.*, volume 515 of *NATO Advanced Study Institute (ASI) Series C*, page 279, January 1998.

F. Verbunt and C. Zwaan. Magnetic braking in low-mass X-ray binaries. , 100:L7–L9, July 1981.

Frank Verbunt. Observations of accretion disks in X-ray binaries. *arXiv e-prints*, art. astro-ph/9809028, September 1998.