Inverse Population Synthesis: Searching for the Origins

K. X. Van[1], N. Ivanova[1]
[1] University of Alberta, Edmonton, AB, T6G 2R3, Canada

UNIVERSITY OF ALBERTA

The formation of neutron star low-mass X-ray binaries is an ongoing challenge in stellar evolution. Neutron star low-mass X-ray binaries are systems containing a neutron star accreting material from a donor where the mass transfer is driven by magnetic braking. There are significant discrepancies between the observed mass transfer rates and the theoretically predicted values, in some cases differing up to an order of magnitude. Using the MESA stellar evolution code we tested modified magnetic braking which scales the default "Skumanich" prescription and a "Reville" prescription. Using these different magnetic braking prescriptions we can produce the observed mass transfer rates at the detected mass ratio and orbital period. Using the simulated results we can work backwards and show the possible progenitors to a given observed low-mass X-ray binary. We present for the first time, possible progenitor systems of a given group of observed low-mass X-ray binaries.

INTRODUCTION

Mass transfer in binary systems results in emitted radiation which is one of the main ways we can observe binary systems. The number of well observed, persistent binaries is very limited[1,3,6].

Using MESA[5], we ran a large grid of donor masses and periods to simulate binary systems. We apply two different magnetic braking prescriptions to our simulations to produce the models. We compare these simulated systems to observed binaries to determine possible progenitors of observed persistent LMXBs.

MAGNETIC BRAKING PRESCRIPTION

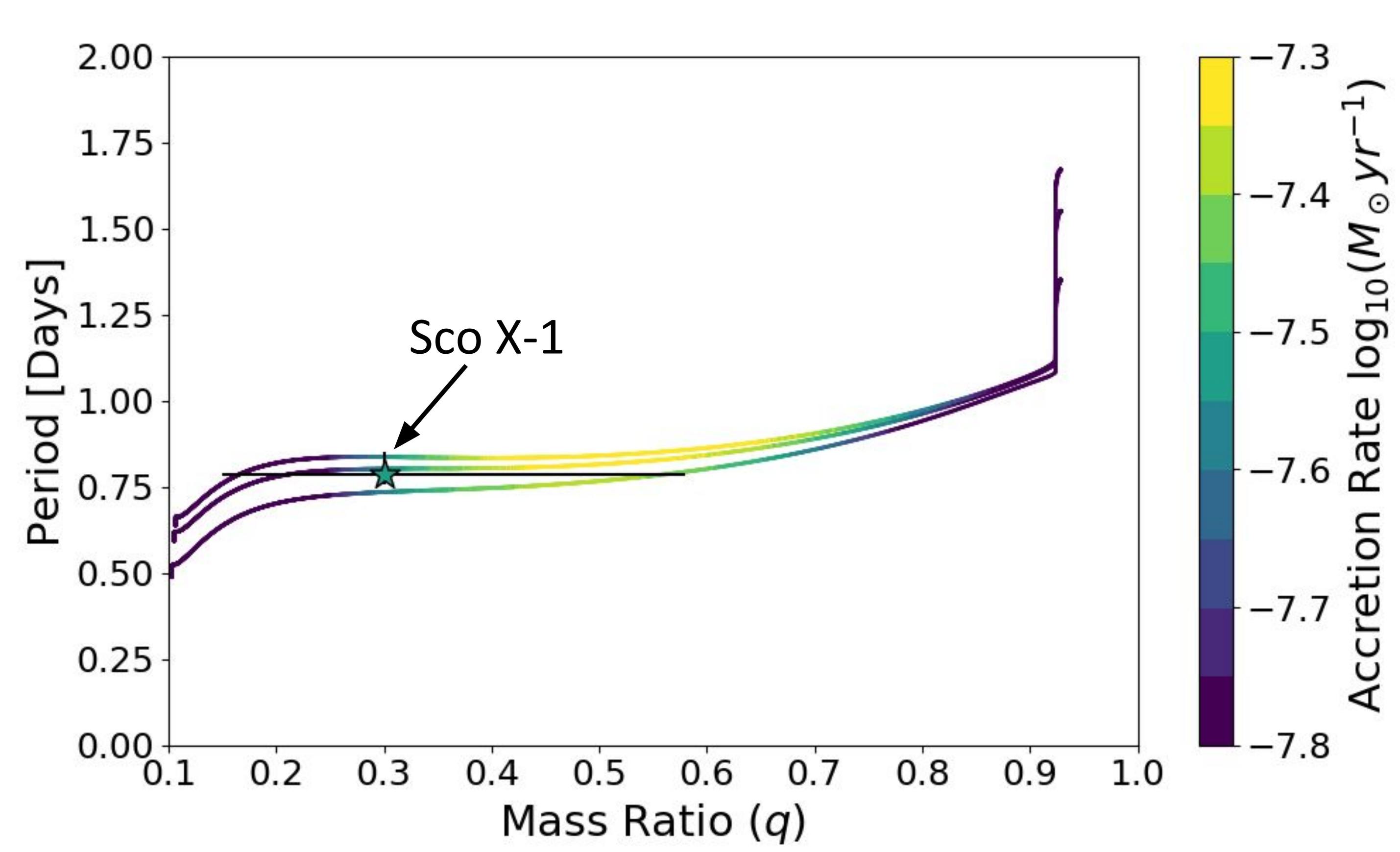
Stellar simulation codes use a default magnetic braking scheme known as the "Skumanich" prescription[7]:

$$\dot{J}_{\rm Sk} = -3.8\times10^{-30} M_{\rm d} R_\odot^4 \left(\frac{R_{\rm d}}{R_\odot}\right)^{\gamma_{\rm mb}} \Omega^3 {\rm dyne\ cm}$$

The Skumanich magnetic braking scheme cannot reproduce many observed LMXBs[1,2,8]. We derive an improved scheme using physics by accounting for the wind, turnover time, and escape velocity[8]:

$$\dot{J}_{\rm rev} \simeq -\frac{2}{3}\Omega \dot{M}_{\rm W} R^2 \left(\frac{B_\odot^4 \Omega^4 \tau_{\rm conv}^4 R^4}{\dot{M}_{\rm W}^2 \Omega_\odot^4 \tau_{\odot,\rm conv}^4} \frac{1}{v_{\rm esc}^2 + \frac{2\Omega^2 R^2}{K_2^2}} \right)^{2/3}$$

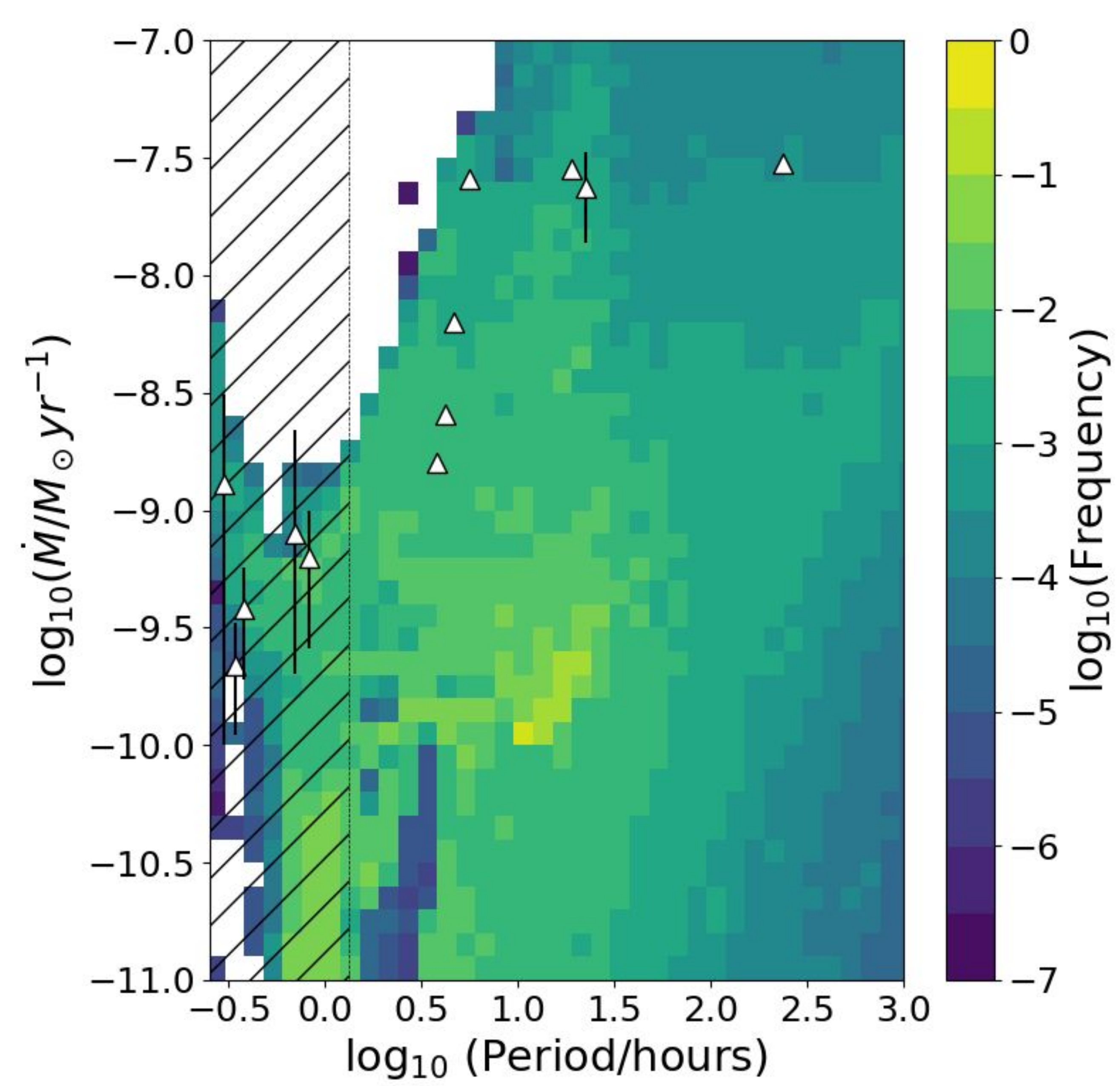
The derived scheme can reproduce Sco X-1 whereas the default cannot[4].



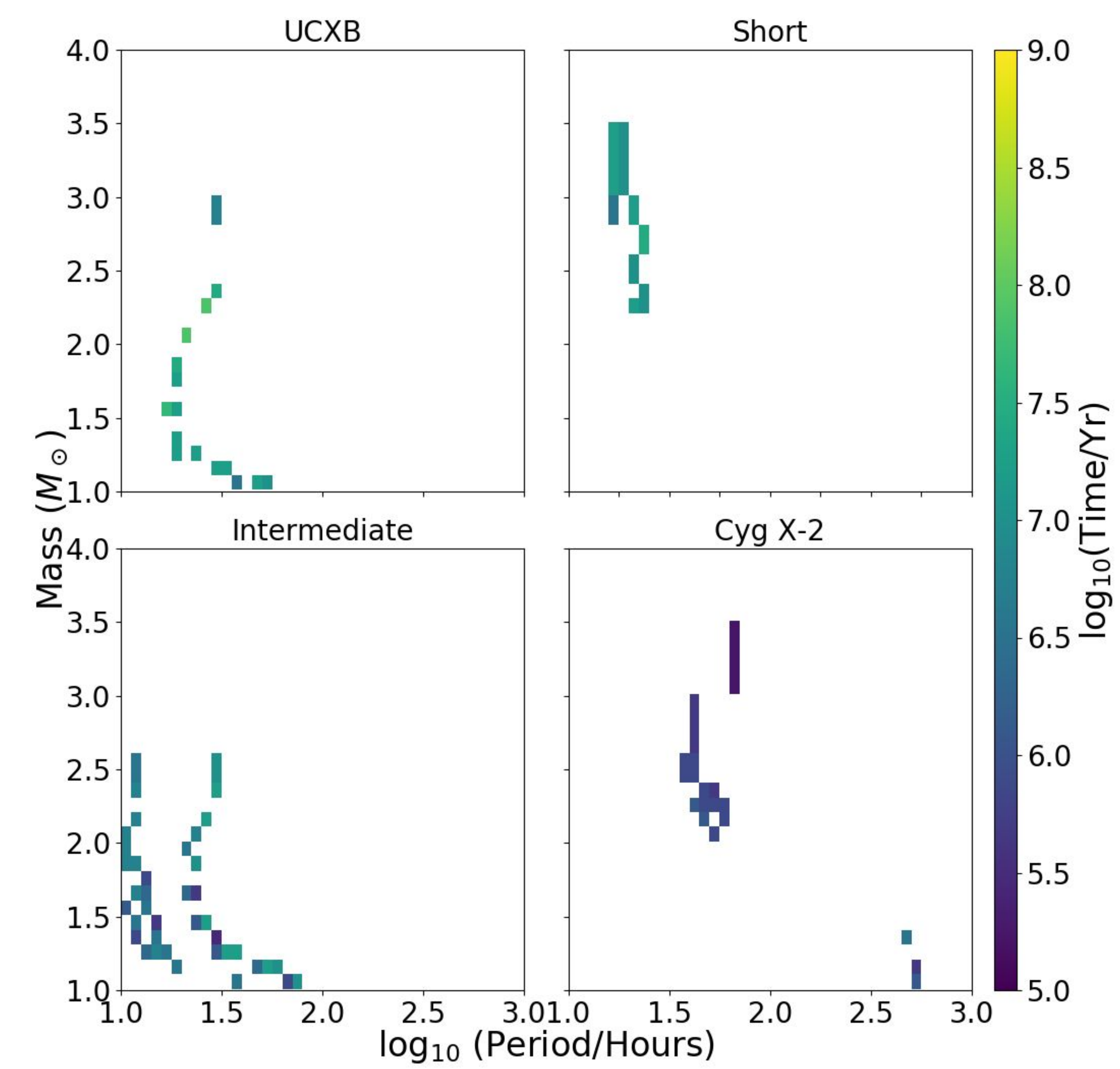
OBSERVED SYSTEMS & 2D COMPARISON

System Name	Period [hr]	$\log_{10}(P)$	q	$\log_{10}(\dot{M}_a)$
UCXB				
4U 0513-40	0.28	[-0.57, -0.52]	[0.01, 0.06]	[-9.2, -8.6]
2S 0918-549	0.29	[-0.56, -0.51]	[0.01, 0.06]	[-9.8, -8.6]
4U 1543-624	0.30	[-0.54, -0.49]	[0.01, 0.06]	[-9.1, -8.6]
4U 1850-087	0.34	[-0.48, -0.43]	[0.01, 0.06]	[-10.0, -8.4]
M15 X-2	0.38	[-0.44, -0.39]	[0.01, 0.06]	[-9.7, -9.1]
4U 1626-67	0.70	[-0.17, -0.12]	[0.01, 0.06]	[-9.7, -8.6]
4U 1916-053	0.83	[-0.10, -0.05]	[0.03, 0.08]	[-9.6, -8.9]
Short				
4U 1636-536	3.79	[0.56, 0.61]	[0.15, 0.40]	[-9.1, -8.6]
GX 9+9	4.20	[0.60, 0.65]	[0.20, 0.33]	[-8.7, -8.2]
4U 1735-444	4.65	[0.65, 0.70]	[0.29, 0.48]	[-8.4, -7.9]
2A 1822-371	5.57	[0.73, 0.78]	[0.26, 0.36]	[-7.8, -7.3]
Intermediate				
Sco X-1	18.90	[1.26, 1.31]	[0.15, 0.58]	[-7.8, -7.3]
GX 349+2	22.50	[1.33, 1.38]	[0.39, 0.65]	[-8.0, -7.3]
Cyg X-2	236.27	[2.35, 2.40]	[0.25, 0.53]	[-7.7, -7.2]

Comparing observed and simulated systems in the period-mass transfer rate all observed systems are reproducible with the derived magnetic braking scheme.



PROGENITOR SEARCH



The derived magnetic braking scheme found possible progenitors to all of the observed persistent LMXBs.

References

[1] Heinke C. O., Ivanova N., Engel M. C., Pavlovskii K., Sivakoff G. R., Cartwright T. F., Gladstone J. C., 2013, ApJ, 768, 184
[2] Justham, S., Rappaport, S., & Podsiadlowski, P. 2006, MNRAS, 366, 1415
[3] Liu Q. Z., van Paradijs J., van den Heuvel E. P. J., 2007, A&A, 469, 807
[4] Pavlovskii K., Ivanova N., 2016, MNRAS, 456, 263
[5] Paxton B., et al., 2019, arXiv e-prints, p. arXiv:1903.01426
[6] Podsiadlowski P., Rappaport S., Pfahl E. D., 2002, ApJ, 565, 1107
[7] Rappaport S., Verbunt F., Joss P. C., 1983, ApJ, 275, 713
[8] Réville V., Brun A. S., Matt S. P., Strugarek A., Pinto R. F., 2015, ApJ, 798, 116

Contact

Kvan@ualberta.ca
https://kvan1231.github.io/