Pulsar Astronomy — 2000 and Beyond
ASP Conference Series, Vol. 202, 2000
M. Kramer, N. Wex, and R. Wielebinski, eds.

Kilohertz QPOs and general-relativistic orbital motion—a maximum likelihood test

Tomasz Bulik

Nicolaus Copernicus Astronomical Center, Bartycka 18, 00716 Warsaw, Poland

Abstract. Using the maximum likelihood method we show that the observed distribution of maximum frequencies of kilohertz quasi periodic oscillations (QPOs) in LMXBs agrees with the frequencies of orbital motion in the marginally stable orbit around compact objects with masses chosen randomly from some interval, which we find to be $(1.55\,M_\odot, 2.40\,M_\odot)$ at the 99% confidence level. As this remarkable agreement with the expected mass range of neutron stars in LMXBs demonstrates, the assumption that the maximum-frequency QPOs occur in the marginally stable orbit is consistent with the current data set.

1. Introduction

Kilohertz Quasi Periodic Oscillations (QPO) have been discovered in 1996 by Rossi XTE, in observations of Sco X-1, and 4U1728-34 (Strohmayer, Zhang and Swank 1996; van der Klis etal 1996)). Zhang etal. (1998) noted that the QPO frequency is correlated with the count rate in 4U1820-30, and that this correlation ceases when the QPO frequency reaches ≈ 1.06 kHz. They interpreted it as evidence for orbital motion in marginally stable orbit. If the highest QPO frequency is interpreted as the orbital motion around the compact object, than it is natural to expect that there is a highest frequency to be observed, the orbital frequency at the marginally stable orbit (Kluźniak, Michelson, Wagoner 1990). Assuming that this is the case we find the mass range of the central objects.

2. The data

Kilohertz QPOs in steady emission have been observed from fourteen sources. Here we present an analysis of a subset of these observations, and we have excluded four sources for which there are serious doubts that we have observe the maximum frequency [for a discussion see Bulik, Kluźniak and Zhang 2000)]. The data set used includes the following sources listed with the respective kHz QPO frequencies in parentheses: 4U 1636-536 (1220), KS 1731-260 (1207), 4U 1702-43 (1156), 4U 1728-34 (1150), 4U 1735-44 (1149), 4U 0614+09 (1145), Sco X-1 (1130), 4U 1608-52 (1125), X 2123-058 (1123), GX 17+2 (1087), 4U 1820-30 (1066), and Cyg X-2 (1020).

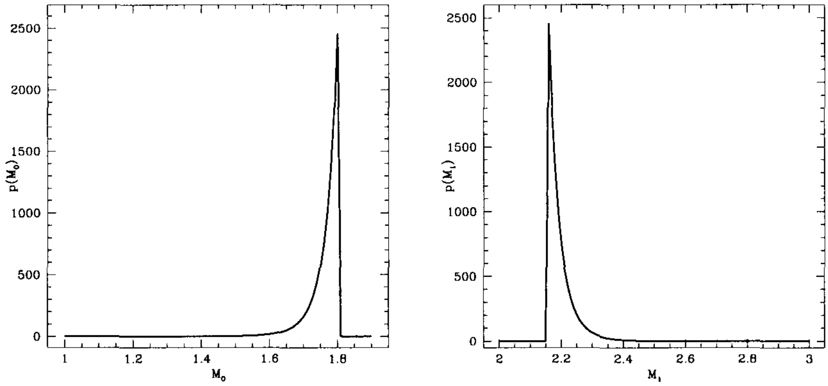

Figure 1. The left panel shows the probability density of the lower mass interval limit M_0 and the right panel shows the probability density of the upper mass interval limit M_1.

3. Results

We assume that the masses of central compact objects are distributed uniformly in the interval between M_0 and M_1. The probability density for detecting a frequency f is

$$p(f) = \begin{cases} 2198 f^{-2}(M_1 - M_0)^{-1}, & \text{if } \frac{2198}{M_1} < f < \frac{2198}{M_0}. \\ 0 & \text{elsewhere} \end{cases} \quad (1)$$

We use this probability to calculate the likelihood of the data given a model described by the two parameters: the lower and upper mass limit. We present the resulting probability distributions of M_0 and M_1 in Figure 1.

We that the masses of the compact objects have to be in the range between $1.55 M_\odot$ and $2.40 M_\odot$ at the 99% confidence level. Thus we extend the results of Zhang Strohmayer and Swank (1998) to the whole data set. Note that we have made no assumption about the nature of the compact objects, yet we find a range of masses remarkably close to the one expected for neutron stars.

Acnowlegdements. This reasearch was supported by the KBN grant 2P03D02117.

References

Bulik, T., Kluźniak, W., Zhang, W., 2000, A&A, submitted

Strohmayer, T., Zhang, W., and Swank, J., 1996, IAU Circ., 6320, 1

van der Klis, M., etal., 1996, IAU Circ., 6319, 1

Kluźniak, W., Michelson, P., Wagoner R., 1990, ApJ, 358, 538

Zhang, W., etal., 1998, ApJ, 500, L171

Zhang, W., Strohmayer, T. E., and Swank, J. H., 1997, ApJ, 482, L167