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Title	Keck infrared observations of GRO J0422+32 in quiescence
Authors	Reynolds, Mark T.;Callanan, Paul J.;Filippenko, Alexei V.
Publication date	2007
Original Citation	Reynolds, M. T., Callanan, P. J. and Filippenko, A. V. (2007) 'Keck infrared observations of GRO J0422+32 in quiescence', Monthly Notices of the Royal Astronomical Society, 374(2), pp. 657-663. doi: 10.1111/j.1365-2966.2006.11180.x
Type of publication	Article (peer-reviewed)
Link to publisher's version	https://academic.oup.com/mnras/article-lookup/doi/10.1111/j.1365-2966.2006.11180.x - 10.1111/j.1365-2966.2006.11180.x
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Download date	2026-09-17 04:33:40
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Mon. Not. R. Astron. Soc. **374,** 657–663 (2007) doi:10.1111/j.1365-2966.2006.11180.x

Keck infrared observations of GRO J0422+32 in quiescence

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Accepted 2006 October 9. Received 2006 October 9; in original form 2006 August 19

ABSTRACT

We present Keck *K*-band photometry and low-resolution *H*- and *K*-band spectroscopy of the X-ray nova GRO J0422+32 obtained while the system was in the quiescent state. No clear ellipsoidal modulation is present in the light curve, which is instead dominated by a strong flickering component. In the *K* band, we observe strong Brγ emission, with an equivalent width of 38 ± 5 Å. From this, we conclude that the accretion disc is the most likely source of the observed photometric contamination, and that previous infrared-based attempts to constrain the mass of the putative black hole in this system are prone to considerable uncertainty. We finally proceed to show how it is possible to place meaningful constraints on some of the binary parameters of this system, even in the presence of a relatively high level of contamination from the disc.

Key words: stars: individual: GRO J0422+32 – X-rays: binaries.

1 INTRODUCTION

Low-mass X-ray binaries (LMXBs) are systems in which a degenerate primary, typically a neutron star or black hole, accretes from a low-mass ($M_2 < 1$ M$_\odot$), late-type companion (secondary) star. X-ray novae (XRNe) form a subset of the LMXBs: these are transient systems which undergo periods of greatly enhanced emission, by factors of as much as $\sim 10^6$ or greater, before returning to quiescence over a time-scale of months. However, for many of these systems, as they return to quiescence, the secondary (typically of K or M type) begins to make a significant contribution to the optical flux of the system. Observations of the secondary in this state are the most reliable means for determining the mass of the compact object. Thus far, 20 systems have been dynamically confirmed as having a probable black hole primary; of these, three are persistent sources while the other 17 are XRNe (Casares 2005); see Tanaka & Shibazaki (1996) for a thorough review of XRNe and McClintock & Remillard (2006) for a more recent review of black hole binaries.

GRO J0422+32 was first detected by the *Compton Gamma Ray Observatory* (*GRO*) in 1992 August by Paciesas et al. (1992). The optical counterpart was identified soon thereafter and found to have $V \approx 13$ mag (Castro-Tirado et al. 1993). The retreat to quiescence was punctuated by three further mini-outbursts of approximately 4 mag each (Harmon, Fishman & Paciesas 1992; Filippenko, Matheson & Ho 1993; Zhao et al. 1993). By 1994 September, the system was deemed to have returned to quiescence (Zhao et al. 1994), with $V \approx 22.4$ mag, over 2 yr after the initial outburst. In total the luminosity increased by over 9 mag in V, making GRO J0422+32 the highest-amplitude XRN observed to date. Castro-Tirado et al. (1993) searched archival plates and found no indication of any previous outburst from this system since at least 1923.

Previous attempts to determine the mass of the compact object in this system have been made by Filippenko, Matheson & Ho (1995), Casares et al. (1995) and Webb et al. (2000); through optical observations, they determined the mass of the primary to be $M_x = 3.57 \pm 0.34$ M$_\odot$, 2.5 M$_\odot$ $< M_x <$ 5 M$_\odot$ and $M_x > 2.2$ M$_\odot$, respectively. Recent work in the infrared (IR) by Gelino & Harrison (2003) has led to a value of $M_x = 3.97 \pm 0.95$ M$_\odot$; however, negligible contamination arising from the accretion disc was assumed. The observations we describe here were undertaken in an effort to constrain the IR contamination due to the accretion disc, and hence to determine the reliability of the current mass estimate for this black hole candidate.

2 DATA

IR photometry and spectroscopy were undertaken using the Near-Infrared Camera (NIRC; Matthews & Soifer 1994) at the f/25 forward Cassegrain port of the Keck-I 10-m telescope. NIRC is a 256 × 256 pixel InSb array with an angular scale of 0.15 arcsec pixel^{-1}. Low-resolution spectra were obtained using a grism ($R \approx 120$) and the *HK* filter, which covers the standard *H* and *K* bands.

2.1 Photometry

Photometry of GRO J0422+32 was undertaken on the night of 1997 November 9 UT. The system was observed in the *K* band for a full orbital cycle of ∼5.1 h. Conditions were excellent throughout the night, with seeing no worse than 0.45 arcsec at any time. Individual exposure times were 4 s, with 30 co-adds per image (i.e. 2-min

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Table 1. NIRC observation log.

JD[a]	Seeing (arcsec)	Exp. time (s)	ϕ^b	Apparent K-band mag[c]
245 0762.919 954 13	0.40	1080	0.528	17.344 ± 0.014
245 0762.936 190 41	0.35	1080	0.605	17.389 ± 0.010
245 0762.955 001 79	0.35	1080	0.693	17.364 ± 0.015
245 0762.973 924 75	0.30	1080	0.783	17.397 ± 0.014
245 0762.989 451 41	0.30	1080	0.856	17.452 ± 0.015
245 0762.004 936 42	0.30	1080	0.929	17.406 ± 0.015
245 0763.020 459 06	0.30	1080	0.002	17.368 ± 0.015
245 0763.036 884 40	0.30	1080	0.079	17.311 ± 0.015
245 0763.053 828 48	0.30	1080	0.159	17.282 ± 0.015
245 0763.069 806 07	0.35	1080	0.234	17.345 ± 0.014
245 0763.085 373 09	0.40	1080	0.309	17.345 ± 0.015
245 0763.103 997 60	0.40	1080	0.392	17.389 ± 0.015
245 0763.118 578 11	0.45	1080	0.464	17.298 ± 0.023
245 1085.993 422 59	0.35	1080	0.310	17.264 ± 0.093

[a]Exposure time consists of nine 2-min exposures; JD is at the mid-point.
[b]$T_0 = 245\,0274.4156$, $P = 0.212\,1600$ d.
[c]Magnitudes correspond to those of the binned light curve; see Fig. 2.

exposure per image). The telescope pointing was dithered (using a 3 × 3 grid) to allow for accurate subtraction of the IR background; see Table 1 for a log of observations. A single nine-image grid of observations of similar duration was also taken nearly a year later (1998 September 28 UT), contemporaneously with the spectroscopy (see below).

2.1.1 Data reduction

The data were dark-current subtracted, flat-fielded, background subtracted and combined using standard IRAF routines.[1] Photometry of GRO J0422+32 and a number of nearby stars was carried out using the profile-fitting task DAOPHOT (Stetson 1987). The standard stars FS12 and FS16[2] (Casali & Hawarden 1992) were also observed to allow accurate calibration of the target frames. The magnitudes were cross-checked using the bright star to the north (2MASS J042142.57+325449.5), which is visible in the Two-Micron All-Sky Survey (2MASS)[3] field of GRO J0422+32. We display one of our frames in Fig. 1. The resulting light curve was then phased to the ephemeris of Webb et al. (2000). As our data were taken ∼125 d after the ephemeris of Webb et al. (2000), any errors will be minimal.

We find that our magnitudes are in agreement with those of Gelino & Harrison (2003), confirming that our observations were indeed taken in quiescence. It is apparent from our images that there is a line-of-sight star to the north-west, lying approximately 2.6 arcsec from GRO J0422+32, which may have been unresolved in previous observations of the system (see Fig. 1). Profile fitting was carried out on this star simultaneously with our target star, GRO J0422+32. We find this star to have a mean magnitude of 19.62 ± 0.06, which was constant over the course of our observations.

[1] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.
[2] http://www2.keck.hawaii.edu/inst/nirc/UKIRTstds.html
[3] The 2MASS is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, California Institute of Technology, funded by NASA and the National Science Foundation.

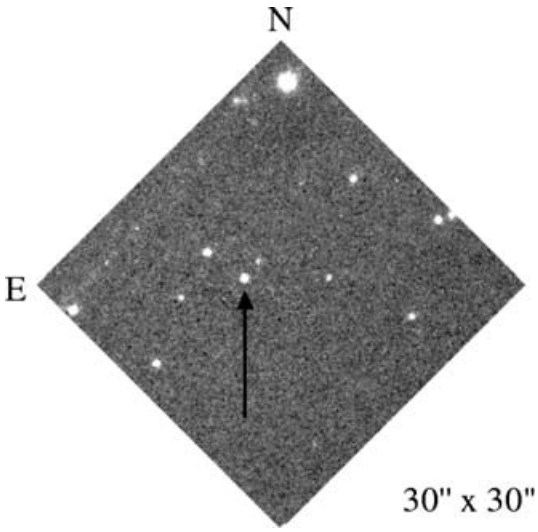

Figure 1. The NIRC GRO J0422+32 field. The black arrow indicates the position of GRO J0422+32. The exposure time was 2 min.

The photometric accuracy of our GRO J0422+32 light curve (2-min resolution) was determined by applying a linear fit to the light curve of the star to the northeast (Fig. 1), of comparable magnitude to GRO J0422+32, which was assumed to be constant during the course of our observations. The uncertainty was then taken to be the rms deviation from this linear fit and was measured to be 0.024 mag.

The 1998 observation was reduced in a manner identical to that described above. When phased and calibrated similarly to the previous epochs data, the magnitude was found to be consistent. This confirms that the system was in a quiescent state similar to that detected the previous year. The resulting light curve is shown in Fig. 2.

2.2 Spectroscopy

We obtained a number of low-resolution NIRC spectra of GRO J0422+32 on the night of 1998 September 28 UT. The *HK* filter

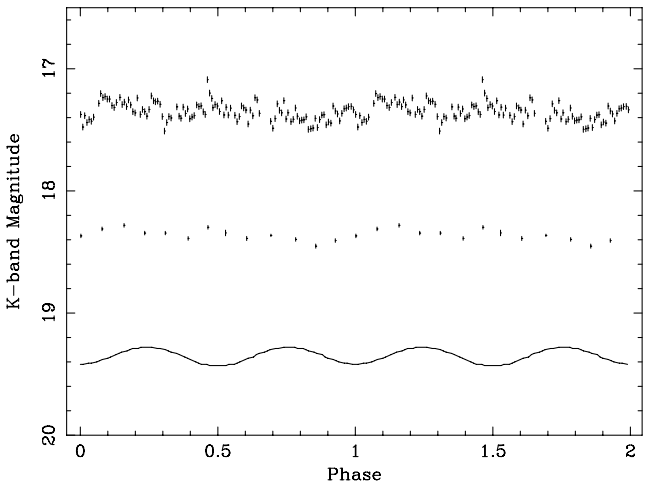

Figure 2. The NIRC *K*-band light curve of GRO J0422+32. The top light curve is the 2-min resolution *K*-band light curve. We plot this binned to a resolution of 18 min in the middle. As a comparison, the best-fitting model of Gelino & Harrison (2003) is plotted below. The unbinned light curve is accurately calibrated, while the middle and bottom light curves are shifted downwards by 1 and 2 mag (respectively) for clarity.

was used (1.40–2.53 μm) in conjunction with the gr120 grism and a 0.67-arcsec slit, giving a resolution $R \approx 120$. Observing conditions were once again excellent, with seeing as good as 0.30 arcsec, for the majority of the observations. The system was observed from orbital phase 0.36 to 0.78. Individual exposure times were 200 s, dithered to five positions along the slit. In total, 30 spectra of the system were acquired.

2.2.1 Data reduction

The one-dimensional spectra were extracted in the standard manner using IRAF. Of the 30 exposures, 28 contained useful spectra. Spectra of the G0V stars BS8455 and BS1789 were also taken to aid with the removal of telluric features. No arc spectra were taken due to the availability of a known calibration, which was obtained from the NIRC online manual.[4]

The GRO J0422+32 and G0V star spectra were normalized using a low-order spline. The region surrounding the Brγ feature in the G0V spectrum was masked and the GRO J0422+32 spectra were then divided by the G0V spectra to remove the telluric features. The resulting spectra were median combined so as to negate the effect of cosmic-ray hits and other spurious effects, while at the same time maximizing the available signal-to-noise ratio (S/N).

No significant features were detected in the resulting *H*-band spectrum. In the *K* band, we observe strong Brγ emission, which we display in Fig. 3. The EW of the Brγ feature was measured to be 38 ± 5 Å.

3 ANALYSIS

3.1 Colour

We calculated the $H - K$ colour index of the system from our spectra. This was achieved by fitting a polynomial to the continuum of the individual *H*- and *K*-band spectra and then integrating the flux across the respective passband. The median colour was found to be

[4] http://www2.keck.hawaii.edu/inst/nirc/

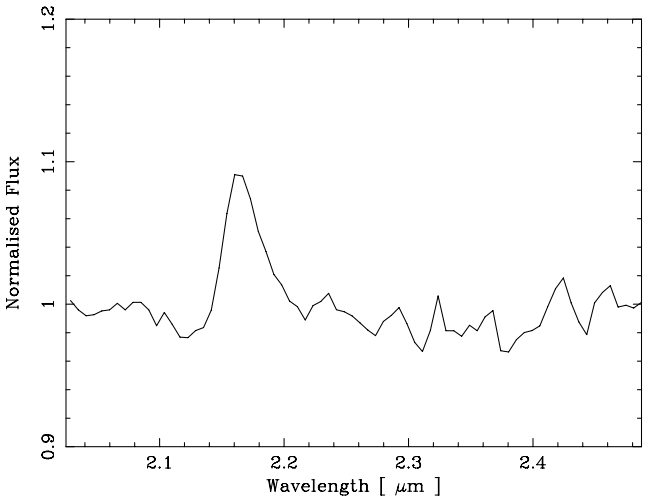

Figure 3. The NIRC *K*-band spectrum of GRO J0422+32.

$H - K = 0.02 \pm 0.01$ mag, where the error is the rms deviation of the data. Correcting for interstellar extinction using a value of $E(B - V) = 0.3 \pm 0.1$ mag (Beekman et al. 1997) for the colour excess leads to an extinction-corrected colour of $(H - K)_0 = 0.07 \pm 0.08$ mag, which equates to spectral types in the range ∼B5 to ∼K7 (Cox 2000). This is somewhat earlier than the expected spectral type of ∼M2 estimated by Filippenko et al. (1995), although the uncertainties are large.

3.2 Power density spectrum

It is immediately apparent in the 2-min resolution light curve (Fig. 2) that any ellipsoidal modulation in the data is masked by a strong flickering component. In an attempt to decouple the ellipsoidal variation of the secondary star from the flickering component, we followed the method of Zurita, Casares & Shahbaz (2003). As the data sampling was not uniform, a Lomb–Scargle periodogram (Scargle 1982) of the 2-min resolution data was calculated. A significant signal (∼5σ) is detected at a period ∼2.5 h, similar to half the orbital period.

The amplitude of the modulation at this period is only 0.03 mag. However, as can be clearly observed from the binned (18-min resolution data; Fig. 2), this variation cannot be ellipsoidal in origin: the minima for this modulation occur at phases ∼0.3 and 0.8 and not at phases 0.0 and 0.5 as would be expected for an ellipsoidal modulation. This phase shift is much greater than the error in calculating the orbital phase from the known ephemeris of Webb et al. (2000). Hence, we can use our data to place a conservative upper limit of 0.03 mag on the amplitude of any ellipsoidal variation present in our data.

In an attempt to characterize the shorter time-scale variability present in our light curve, we computed the power density spectrum (PDS). A power-law fit to our data of the form $f(x) \propto x^{\beta}$ yielded a power-law index $\beta \approx -0.9$: see Fig. 4. This is consistent with the variability time-scales observed in the optical in both A0620−00 and GRO J0422+32 by Zurita et al. (2003), who measured significant variability on time-scales of up to 90 min.

4 DISCUSSION

In the *JHK* photometry of Gelino & Harrison (2003), an ellipsoidal modulation is present in both sets of *K*-band observations (from

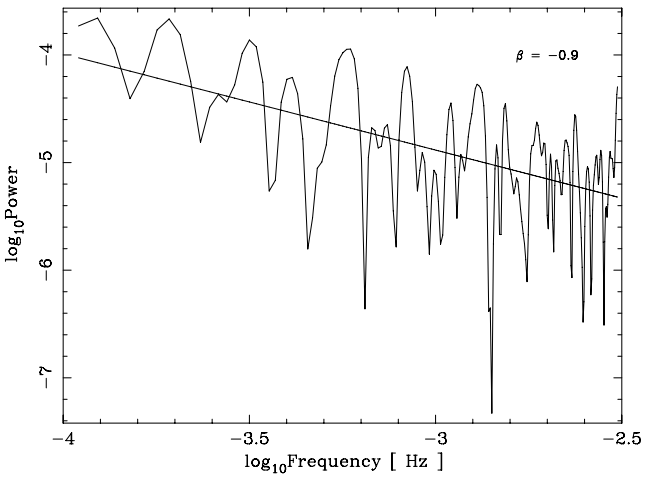

Figure 4. The IR power spectrum of GRO J0422+32. The solid line indicates the best power-law fit to the data.

2000 and 2003). By contrast, our unbinned light curve (resolution ∼2 min), while showing rapid variability, appears to display little evidence of an ellipsoidal modulation. Binning the data to ∼18-min resolution (this is equal to the duration of our 3 × 3 dither pattern and comparable to that of Gelino & Harrison 2003), gives rise to a modulation that, although superficially ellipsoidal in nature, clearly is not (see Section 3.2). Curry, Bailyn & Buxton (2003) observed this system in 2002 with the 3.5-m WIYN telescope, they also report a modulation on a ∼5-h period that is not ellipsoidal in nature. It is unclear why our results differ from those of Gelino & Harrison (2003), especially as the mean *K*-band magnitude we measure is consistent with theirs (and hence there cannot have been a significant change in the overall contribution of the flux from the disc to the light curve) but it may be that their *K*-band modulation is similar to the one we observe, but coincidentally at a phase that made it appear ellipsoidal in origin.

In any case, we now discuss the likely sources of the light curve we observe: (i) spots on the M-type secondary star, (ii) contamination originating in a radio jet and/or (iii) contamination from the quiescent accretion disc.

4.1 Spots on the M-type secondary

Deviations from a pure ellipsoidal modulation have sometimes been attributed to the presence of spots on the rapidly rotating secondary star (Chevalier & Ilovaisky 1993; Khruzina & Cherepashchuk 1995; Gelino, Harrison & Orosz 2001). We searched the literature in an attempt to find examples of M-type dwarfs containing spots, but the number of candidate systems is few, given that we require a rapidly rotating companion: $v_{\rm rot} \sin(i)$ for GRO J0422+32 is close to 90 km s^{-1} (Harlaftis et al. 1999). The two best candidates are the isolated M1 stars HK Aqr and RE 1816+541, with rotational velocities of ∼70 and ∼60 km s^{-1}, respectively.

Detailed *V*-band light curves of HK Aqr (Young et al. 1990) show a ∼0.09-mag modulation due to spots. However, this modulation appears to be quite uniform and smooth, in contrast to the rapid variability which we observe in GRO J0422+32. Indeed, recent Doppler images (Barnes & Collier Cameron 2001) reveal the presence of a large number of star spots on the surface of these rapidly rotating M-type stars even though the observed variability is quite low. Hence, we do not believe that star spots offer a satisfactory explanation for the observed rapid variability of GRO J0422+32 in the IR.

4.2 Contamination from a jet

In recent years, evidence has emerged that the synchrotron flux from a radio jet could be contributing to the flux emitted at other wavelengths, in particular the IR and optical (Fender 2001). IR contamination, which has been attributed to a jet, has been observed in the halo black hole candidate XTE J1118+480 during outburst (Hynes et al. 2000). Fender, Gallo & Jonker (2003) claim that all black hole X-ray binaries (XRBs) will become jet dominated in the quiescent state. To date emission from a radio jet in quiescence has been detected for two XRBs, V404 Cyg (GS 2023+338; Gallo, Fender & Hynes 2005) and A0620−00 (Gallo et al. 2006). The observation of A0620 is the more pertinent here due to the similarity of its orbital period (7.8 h) and quiescent X-ray luminosity (3×10^{30} erg s^{-1}) compared to those of GRO J0422+32 (5.1 h and 8×10^{30} erg s^{-1}, respectively). However, recent *Spitzer* observations (Muno & Mauerhan 2006) do not appear to be consistent with emission from the jet in A0620−00 longwards of 8 μm: shortwards of 8 μm Muno & Mauerhan (2006) argue that the emission appears to be consistent with that originating from an optically thick blackbody and not the photosphere of the secondary star. Hence, by analogy with A0620−00, we think it unlikely that the flux we observe in the case of GRO J0422+32 originates in a jet.

4.3 Contamination from the accretion disc

4.3.1 Photometric constraints

Previous estimates of the fractional contribution of the accretion disc to the total flux range from ∼60 per cent (Filippenko et al. 1995) to as little as 20 per cent (Callanan et al. 1996) in the *R* band. In a subsequent reanalysis of the data from Filippenko et al. (1995), Harlaftis et al. (1999) measured the flux from the accretion disc to contribute ∼40 per cent of the total optical flux in quiescence. Similarly, Webb et al. (2000) measured the contamination from the accretion disc to be ∼60 per cent in the *I* band. These measurements hint at an increasing level of contamination at longer wavelengths, although the different template stars used in the respective analyses (M2 versus M4) limit the conclusions that can be made.

In their analysis of GRO J0422+32, Gelino & Harrison (2003) assumed a negligible contribution from the accretion disc in the *K* band. To check this assumption, we have used the ELC light-curve modelling code (Orosz & Hauschildt 2000) to model the flux from an accretion disc, assuming a temperature profile of the form $T(r) \propto T_{\rm inner}(r/r_{\rm inner})^{\xi}$, with ξ chosen so as to ensure a steady state disc, and an outer disc radius of ∼0.55 R_L (these values being consistent with observations of the quiescent disc in the XRNe A0620−00 and XTE J1118+480; Marsh, Robinson & Wood 1994; McClintock, Horne & Remillard 1995; McClintock et al. 2003). We calculate that for any value of the accretion disc contribution to the total flux in the *R* band, the fractional contribution of the accretion disc flux to the *K* band is similar, if not greater. This is in contrast to the canonical picture where the flux from the disc falls off as we venture towards the IR. The contributions from the accretion disc measured in the *R* and *I* band in the case of GRO J0422+32 agree with this simple model and hence we would expect a similar level of contamination in the *K* band. This result is dependent on the inclination of the system, as the flux from the accretion disc relative to that from the secondary increases with lower inclination.

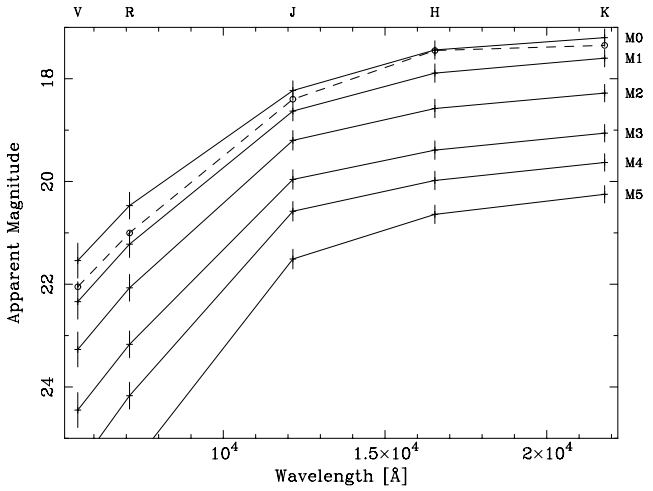

Figure 5. *VRJHK* SED of various M-type stars and GRO J0422+32 (dashed line).

In Fig. 5, we plot the *VRJHK* spectral energy distribution (SED) for various M-type secondary stars along with that of GRO J0422+32. A distance of 2.6 ± 0.2 kpc and a reddening of $E(B-V) = 0.3 \pm 0.1$ have been assumed (from Jonker & Nelemans 2004). The absolute *V*-band magnitudes and the various colour relations of the M-type stars are taken from Leggett (1992). The dashed line indicates the observed SED of GRO J0422+32. The error bars account for both the uncertainty in the reddening and the distance values quoted above. The observed colours are broadly consistent with a spectral type of M1, and suggest a disc contribution in the *K* band of no more that ∼0.3 mag (albeit at the 1σ level). This value would be consistent with that observed in the *R* band, as expected from the modelling discussed above. Alternatively, if there existed a cool optically thick component to the accretion disc (as might be expected theoretically – see Hynes, Robinson & Bitner 2005), a contribution from a radio jet (see Section 4.2), or some form of circumbinary disc (Muno & Mauerhan 2006), any of these contributions could lead to a flatter SED than might otherwise be expected.

A spectral type of M1 is consistent with previous spectral-type determinations (Casares et al. 1995; Filippenko et al. 1995; Gelino & Harrison 2003), with the exception of Webb et al. (2000) who measured a spectral type between M4 and M5. To reconcile the latter spectral type with the observed SED would require that the distance estimate used above is significantly in error, or a *K*-band contamination from the accretion disc of ∼3 mag (which we also regard as unlikely).

4.3.2 Spectroscopic measurements

The Brγ feature at 2.16 μm, with an equivalent width of ∼38 Å, dominates the *K*-band spectrum of GRO J0422+32. No other spectral lines are visible in either the *H* or the *K* bands. We also note the absence of the CO bandheads from the companion star in this spectrum, although it is possible that they are simply unresolved.

Previous observations of LMXBs support the conclusion that the presence of strong Brγ emission is due to contamination by the accretion disc. IR spectroscopy of a sample of persistently bright neutron star LMXB (Bandyopadhyay et al. 1999, 1997; Bandyopadhyay, Shahbaz & Charles 2003) revealed the presence of Brγ emission. In the sources with the strongest emission (Sco X-1, Sco X-2, GX 5-1), the presence of a large Brγ feature (EW ∼23, 29, 45 Å) was accompanied by the absence of the CO bandheads or any other spectral features due to the secondary star. In contrast, in the sources with lower levels of Brγ emission (GX 1+4, GX 13+1, EW ∼10 Å, 5 Å), the CO bandheads and other lines due to the secondary star were detected.

Previous quiescent IR observation of the XRNe V404 Cyg and A0620−00 (Shahbaz et al. 1996; Shahbaz, Bandyopadhyay & Charles 1999) also reveal the presence of Brγ emission. In V404 Cyg, the equivalent width of the Brγ line was measured to be only 2.9 Å. In this case, the CO bandheads from the secondary star were also detected. The Brγ line was detected with an EW ∼15 Å in A0620−00. In this case, the CO bandheads were only marginally detected (the S/N of the spectrum was very low). Using these spectra, the authors measured the IR contamination from the accretion disc to be $\leqslant$14 and 27 per cent, respectively. Recent IR spectroscopy of A0620−00 by Harrison et al. (2006) supports the measurement of excess *K*-band flux in this system.

In summary, our data, both spectroscopic and photometric, strongly suggest a significant contribution to the *K*-band flux of GRO J0422+32 from the accretion disc. As previously discussed, these observations are not the first to observe 'flickering' in the light curve of a quiescent XRN: Hynes et al. (2003) obtained fast photometry of the XRNe A0620−00, Nova Mus 1991 and MM Vel in the optical and detected rapid variability similar to that reported here. Zurita et al. (2003) obtained fast photometry of five XRNe including GRO J0422+32; significant variability was found, superposed on the ellipsoidal variations. We note that of the five XRNe observed optically (V404 Cyg, A0620−00, GRO J0422+32, GS 2000+25 and Cen X-4), the largest amplitude variability was observed in the light curve of GRO J0422+32. Zurita et al. (2003) contend that the observed optical flaring originates in the accretion disc and not as chromospheric activity from the secondary. Our observations are the first to show this kind of flickering variability in the *K* band, where such contamination had previously been thought to be minimal for quiescent XRNe.

4.4 Mass of the compact object

As demonstrated above, there is no clear ellipsoidal modulation present in our *K*-band data. However, for a given accretion disc contamination level in the *K* band, we can still hope to constrain the mass ratio q, and orbital inclination, i, as follows. First, we assume that the true ellipsoidal modulation has an amplitude less than the 0.03-mag variation discussed in Section 3.2.

Assuming that the excess flux from the accretion disc contributes approximately 30 per cent of the flux in the *K* band (see Section 4.3.1), an intrinsic ellipsoidal modulation of 0.04 mag would be reduced to the 0.03-mag variation limit above. In Fig. 6, we display the q versus i plot for GRO J0422+32: the dotted line indicates the best fit to a 0.04-mag modulation. We can represent the ellipsoidal modulation by a single amplitude because, at these relatively low inclinations, the depth of the minima at phases 0.0 and 0.5 are very similar.

As this line represents an upper limit to any ellipsoidal modulation present, allowed values of q and i are constrained to lie to the right of and below this line. By combining this with the limit from the radial velocity measurements (assuming a secondary mass of 0.45 $M_\odot$), as delineated by the solid line, we can constrain q and i as follows: $i < 30^\circ$ and $q > 23$. Note that the inclination constraint is an upper limit because we have only an upper limit on the amplitude of the ellipsoidal modulation. The latter yields a lower limit to the compact

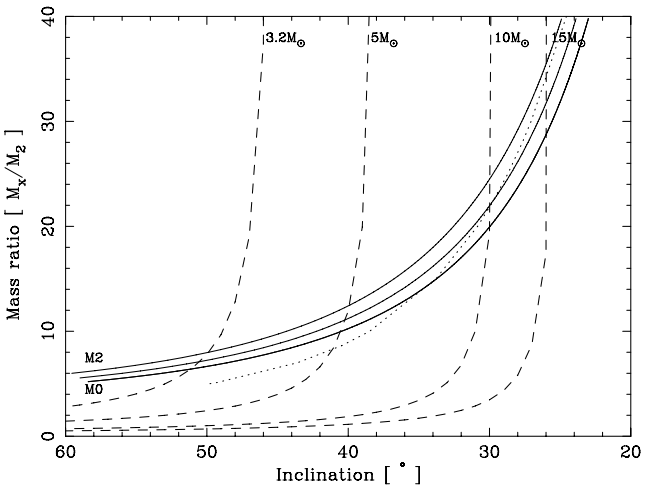

Figure 6. Mass ratio inclination plot for GRO J0422+32. The dashed lines indicate lines of constant primary mass. The solid lines indicate lines of constant mass appropriate for M0-, M1- and M2-type secondaries. The dotted line indicates the best fit q, i pairs for a 0.04 amplitude sine wave.

object mass of $\sim$10.4 $M_\odot$. This is in contrast to the inclination of $45^\circ \pm 2^\circ$ ($M_x = 3.97 \pm 0.95$ $M_\odot$) obtained by Gelino & Harrison (2003), bearing in mind that the uncertainties discussed earlier.

5 CONCLUSIONS

The *K*-band properties of GRO J0422+32 are consistent with a flux contaminated by the emission from the accretion disc, and not solely from the secondary as previously supposed.

Previous authors have assumed negligible contamination of the IR flux of quiescent XRNe by the accretion disc, and hence that the ellipsoidal modulation and black hole mass could be most accurately measured in the IR (in comparison to the optical). This conclusion was generally based on an extrapolation of the contamination from the optical to longer wavelengths (see Haswell 1996). Our data show that this is apparently an invalid assumption in the case of GRO J0422+32.

Our observations are the first to detect flickering from a quiescent XRN accretion disc in the *K* band, most likely because of the superior S/N obtainable with the 10-m Keck telescope compared with the smaller telescopes from which similar measurements have been previously obtained. However, it is also possible that the *K*-band flickering is present because GRO J0422+32 is a relatively low inclination system: in this case, if the source of the flickering is located in the inner disc, then the flickering would be more easily observable in a low inclination system such as GRO J0422+32 in comparison to other (higher inclination) quiescent XRNe.

In light of the observations discussed in this paper, it is clear that higher time resolution photometry or higher S/N spectroscopic observations of other XRNe in the IR are required to better constrain the contribution of the accretion disc at these wavelengths, and to determine the degree to which IR ellipsoidal variability measurements can be used to reliably constrain the mass of black holes in quiescent XRNe. Flickering of the amplitude reported here (0.2 mag) would have a significant effect on even the highest amplitude ellipsoidal variation ($\sim$0.3 mag: see for example the case of GRO J1655−40 discussed by Greene, Orosz & Bailyn 2001). Even when such contamination is significant, however, it may still be possible to extract useful limits on system parameters, as long as the degree of such contamination can be quantified (e.g. spectroscopically), as we have discussed here.

ACKNOWLEDGMENTS

This research made use of the SIMBAD data base, operated at CDS, Strasbourg, France, and NASA's Astrophysics Data System. The data presented herein were obtained at the W. M. Keck Observatory, which is operated as a scientific partnership among the California Institute of Technology, the University of California and the National Aeronautics and Space Administration. The observatory was made possible by the generous financial support of the W. M. Keck Foundation. AVF is grateful for support from NSF grant AST-0307894. MTR and PJC acknowledge financial support from Science Foundation, Ireland. We thank an anonymous referee for useful comments which improved the quality of this paper.

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