MACHO photometry of two Large Magellanic Cloud Be X-ray transients, EXO 0531–66 and H 0544–665

K. E. McGowan1,2* and P. A. Charles2,3
1Los Alamos National Laboratory, Los Alamos, NM 87545, USA
2Department of Physics, University of Oxford, Oxford OX1 3RH
3Department of Physics & Astronomy, University of Southampton, Southampton SO17 1BJ

Accepted 2002 May 10. Received 2002 May 8; in original form 2002 January 18

ABSTRACT
Long-term variations are well-known in Be X-ray binaries, and are attributed to non-orbital changes in the structure of the Be circumstellar (equatorial) disc. However, the time-scales involved are so long (tens of days to years) that systematic studies have been very restricted. The ∼8-yr MACHO monitoring of the Large Magellanic Cloud (LMC) therefore presents an ideal opportunity to undertake such studies of Be X-ray systems that lie within the monitored fields. Here we present MACHO observations of two LMC Be X-ray transients, EXO 0531–66 and H 0544–665, the light curves of which show substantial (∼0.5 mag) long-term variations. However, our analysis shows little evidence for any periodic phenomena in the light curves of either source. We find an upper limit for detection of a short (1–100 d) periodicity in the V- and R-band light curves of EXO 0531–66 of 0.041 mag and 0.047 mag semi-amplitude, respectively. The upper limits for the V- and R-band data of H 0544–665 are 0.054 mag and 0.075 mag semi-amplitude, respectively. Both EXO 0531–66 and H 0544–665 become redder as they brighten, possibly due to variations in the structure of the equatorial disc around the Be star. Spectra of both sources show Hα emission; for EXO 0531–66 we find the emission varies over time, thereby confirming its optical identification.

Key words: binaries: close – stars: individual: EXO 0531–66 – stars: individual: H 0544–665 – X-rays: stars.

1 INTRODUCTION
High-mass X-ray binaries (HMXBs) generally fall into two subgroups, supergiant HMXBs and Be X-ray binaries (Be/XRBs). The companion star in a Be/XRB is a Be (or Oe) star, with a typical mass of ∼10–20 M⊙. A Be star is defined as a non-supergiant early-type star which has at some time shown Hα emission. This Balmer emission, along with a significant infrared excess, is believed to originate from circumstellar material which forms an equatorial disc around the Be star. The Be star significantly underfills its Roche lobe, but is thought to be rapidly rotating to explain the equatorial disc (Slettebak 1987). The orbital periods are long, ranging from ∼15 d to years.

The light curves of Be/XRBs, and isolated Be stars, display non-orbital long-term modulations which vary on time-scales of tens of days to years. The modulations are thought to be due to a phase of matter ejection from the star, the Be phenomenon (Slettebak 1987). Owing to the time-scales involved it is difficult to study these long-term modulations using normal observing programmes. Hence, the observations obtained by the MACHO project provide a data base from which to investigate such systems.

In a previous paper (Alcock et al. 2001) we studied ∼5 yr of MACHO observations of the Be X-ray transient (Be/XRT) A 0538–66. The analysis revealed a long-term modulation of 421 d, together with the previously known 16.6-d orbital period. We attributed this long-term period to the formation and depletion of the equatorial disc surrounding the Be star.

These results motivated us to search for long and short term periodicities in other Be/XRTs. In this paper we present analysis of the MACHO light curves of two other Be/XRTs, EXO 0531–66 and H 0544–665.

2 MACHO OBSERVATIONS
The MACHO project monitored the LMC from 1992 July to 1999 December, with the primary aim of detecting gravitational microlensing of constituent LMC stars by intervening dark matter. The observations were made using the 1.27 m telescope at Mount Stromlo Observatory, Australia. A dichroic beam-splitter and filters provide simultaneous CCD photometry in two passbands, a ‘red’ band (∼6300–7600 Å) and a ‘blue’ band (∼4500–6300 Å). The
latter filter is a broader version of the Johnson V passband (see Alcock et al. 1995a, 1999, for further details). The ‘blue’ and ‘red’ magnitudes were transformed to Johnson V and Kron–Cousins R respectively, using the absolute calibrations of the MACHO fields.

The images were reduced with the standard MACHO photometry code SODOPHOT, based on point-spread function fitting and differential photometry relative to bright neighbouring stars. Further details of the instrumental set-up and data processing may be found in Alcock et al. (1995b, 1999), Marshall et al. (1994) and Stubbs et al. (1993), and we note that the MACHO data base is now in the public domain (Allsman & Axelrod 2001).

3 EXO 0531–66

EXO 0531–66 was discovered in 1983 during observations of the LMC X–4 region with EXOSAT (Pakull et al. 1985). It was only seen for a month at the end of 1983 (Pietsch, Rosso & Dennerl 1989), and had not been seen in the Einstein survey of the LMC (Long, Helfand & Grabelsky 1981). The source was detected again in 1985 with the SL2-XRT experiment on the Spacelab2 mission (Hanson et al. 1989). The lack of detection of the source in EXOSAT observations made between 1983 and 1985 indicates that EXO 0531–66 is a recurrent transient.

The proposed optical counterpart (Haberl, Dennerl & Pietsch 1995) is a Be star, which is the northern component of a close double. During a 4-yr observing programme of EXO 0531–66 with ROSAT, a strong outburst was detected in 1993 which lasted more than two months (Haberl et al. 1995). The intensity of this outburst was comparable to that seen by EXOSAT in 1983, and a 13.7-s pulsation period was detected (Dennerl, Haberl & Pietsch 1996; Burderi et al. 1998), indicating that EXO 0531–66 is a Be–neutron star binary.

Haberl et al. (1995) suggested that the observed outbursts were consistent with being caused by the periastron passage of the neutron star in a Be/XRB with an orbital period of 600–700 d. However, they could not rule out that the outbursts occur irregularly during a phase of increased matter ejection from the Be star. Dennerl et al. (1996) constrained the orbital period to lie in the range of 4–70 d, assuming that the rate of period change of the pulse period was predominantly caused by Doppler shifts. They found an orbital solution with $P_{\text{orb}} = 25.4$ d, $e \sim 0.1$ and $i \sim 50^\circ$, for an assumed mass for the compact object of 1.4 M$_\odot$, and 15 M$_\odot$ for the Be star companion.

The identification of the optical counterpart remains uncertain as both the northern and southern stars in the close (~4 arcsec) double are early-type stars. Based solely on the X-ray error circle (9 arcsec), either star could be the optical counterpart. Stevens, Coe & Buckley (1999) obtained a spectrum of the northern component which confirmed the presence of Hβ emission. A low-resolution spectrum taken two nights later shows Hβ also in emission. No spectrum has been taken of the southern component.

We searched the MACHO data base for sources within a 9 arcsec radius of the X-ray position. We find that the only source which displays long-term variations typical of a Be star is the previously proposed optical counterpart, the northern component of the double.

3.1 Light curve

We show in Fig. 1 the ‘blue’ and ‘red’ photometry of the northern star proposed as the optical counterpart of EXO 0531–66, from 1993 January 19 to 1999 December 30. During three consecutive observations of EXO 0531–66, between 1993 March and May, Haberl et al. (1995) found the source to be X-ray active. The maximum observed count rate occurred on 1993 April 27 and was found to correspond to $2.0 \times 10^{38}$ erg s$^{-1}$ in the ROSAT band (0.1–2.4 keV) for $d = 50$ kpc. The times of the three observations taken during the extended outburst are marked on Fig. 1. Unfortunately, the MACHO project did not obtain observations of the source on these exact dates.

![Figure 1](https://example.com/f1.png)

**Figure 1.** The MACHO light curves in blue (top panel) and red (bottom panel) filters of the proposed optical counterpart of EXO 0531–66, which is the northern component of a close double. The V and R magnitudes have been calculated using the absolute calibrations of the MACHO fields. The three arrows near day 100 in the top and bottom panels indicate the observations taken during the X-ray outburst in 1993 (Haberl et al. 1995), the time of peak X-ray luminosity is indicated by the middle arrow in each case. The arrow near day 1500 in the top and bottom panels indicates the time of the X-ray outburst observed by Burderi et al. (1998).
However, observations were made near to these times and the light curve shows a slight brightening of the source which could indicate an optical response to the X-ray outburst.

Burderi et al. (1998) observed EXO 0531–66 on 1997 March 13–15 with BeppoSAX (also marked on Fig. 1). The estimated X-ray luminosity at the time of observation, converted into the ROSAT band (0.1–2.4 keV), was $\sim 2.3 \times 10^{36}$ erg s$^{-1}$. This value is close to the luminosity of the outburst measured by Haberl et al. (1995). In a low state the source is found to have a luminosity of $\lesssim 10^{35}$ erg s$^{-1}$ (Haberl et al. 1995). Burderi et al. (1998) concluded that the source was in outburst at the time of their observation. During the $\sim 2$-d observation the light curve of EXO 0531–66 in the medium energy band (1.0–10.5 keV) was relatively flat, but with random fluctuations up to a factor of $\sim 2$ on time-scales of 30 s. The low-energy light curve (0.1–1.8 keV) displayed flaring episodes which were also observed in the high-energy light curve (15–60 keV). The $V$- and $R$-band light curves show a slight brightening of the source at the time of the outburst reported by Burderi et al. (1998), this could be related to the X-ray activity.

3.2 Period analysis

Haberl et al. (1995) suggested that the orbital period for EXO 0531–66 was in the range of 600–700 d. However, Dennerl et al. (1996) proposed a much shorter period in the range of 4–70 d, with a preferred value of 25.4 d. To investigate variability on these time-scales we performed a period search of the $V$- and $R$-band data sets over frequency range $6.67 \times 10^{-4}$–1.0 cycle d$^{-1}$, with a resolution of $1.25 \times 10^{-4}$ cycle d$^{-1}$. Before the temporal analysis was performed we detrended the data by subtracting a linear fit. We searched for periodicities in the light curves using a Lomb–Scargle (LS) periodogram (Lomb 1976; Scargle 1982) and a phase dispersion minimization (PDM) periodogram (see Stellingwerf 1978).

We show in Fig. 2 the period searches of the $V$-band light curve of EXO 0531–66, the results for the $R$-band data were similar. The largest peaks in the LS and PDM periodograms occur at $\sim 1200$ d and $\sim 600$ d. We folded both data sets on these periods. The folded light curves indicated that the $\sim 600$ d peak is a harmonic of the $\sim 1200$ d peak. We note that the value of 1200 d is close to half the length of the data. The light curves of EXO 0531–66 are dominated by the maxima at MJD 2449500 and MJD 2450750. Therefore, the $1200$-d peak is most likely due to the non-periodic variations characteristic of Be stars, rather than a true periodicity.

We find no evidence for any short-term (1–100 d) periodicities in the light curves of EXO 0531–66. The peaks at 1 d in the LS and PDM periodograms are probably caused by the sampling of the data sets. We find an upper limit of 0.041 mag semi-amplitude for the presence of any short-term periodicity in the $V$-band data, and 0.047 mag for the $R$-band data.

4 H 0544–665

H 0544–665 was discovered with the HEAO-1 scanning modulation collimator by Johnston, Bradt & Doxsey (1979). The brightest star in the error region was found to have a magnitude of $B \sim 16$ (star 1 in fig. 6 of Johnston, Bradt & Doxsey (1979), and was later found to be variable (Thorstensen & Charles 1980). van der Klis et al. (1983) found that the star was variable on a time-scale of weeks and determined a spectral type of BO-1 V. By plotting $V$ as a function of $B - V$, van der Klis et al. (1983) found a colour–magnitude correlation in which the star becomes redder as it brightens. This is typical of Be stars, where the variability is due to variations in the circumstellar disc. Coe et al. (1997) suggested that, owing to the lack of IR emission from the candidate proposed by van der Klis et al. (1983), another star was the optical counterpart (Star 22 in Coe et al. 1997). However, the Be nature of star 1 of Johnston et al. (1979) was subsequently confirmed by Stevens et al. (1999) from spectra of the source in which double peaked H$\alpha$ and weak H$\beta$ emission is evident. They therefore concluded that this star is the optical counterpart of H 0544–665.

4.1 Light curve

Fig. 3 shows the MACHO project observations of H 0544–665 taken during the period 1993 January 19 to 1997 January 30. The
Figure 3. The optical light curves in blue (top panel) and red (bottom panel) filters of H 0544–665 from MACHO project observations. The V and R magnitudes have been calculated using the absolute calibrations of the MACHO fields.

4.2 Period analysis

We detrended the V- and R-band data of H 0544–665 by subtracting a linear fit. We then searched for periodicities in the detrended light curves. The temporal analysis was performed over a frequency range of $1.43 \times 10^{-3} - 1.0$ cycle d$^{-1}$, with a resolution of $1.25 \times 10^{-4}$ cycle d$^{-1}$.

The LS and PDM periodograms for the R-band data are shown in Fig. 4. The results for the V-band data were less significant. There is one LS peak which lies above the 99 per cent confidence level, however, it is not significant at the 99.9 per cent level. We conclude that there are no significant periodicities present in the light curves of H 0544–665. We determine an upper limit for detection of any short-term (1–100 d) periodicity in the V-band light curve of 0.054 mag semi-amplitude, and 0.075 mag semi-amplitude for the R-band light curve of H 0544–665.

5 COLOUR VARIATIONS

We constructed V/(V – R) diagrams for EXO 0531–66 and H 0544–665 to investigate the changes in colour as the brightness of the sources vary. From Fig. 5 we can see that as EXO 0531–66 and H 0544–665 brighten their colour becomes redder. This confirms the colour–magnitude correlation found for H 0544–665 by van der Klis et al. (1983). This indicates that the variations in the light curves are likely to be caused by variations in the structure of the equatorial disc around the Be star. This is a result of the disc being redder in $B - V$ (i.e. cooler) than the Be star (Janot-Pacheco, Motch & Mouchet 1987). Thus, the formation of the equatorial disc will increase the optical brightness of the system by the addition of red light, or it will make the system appear fainter by masking the Be star, behaviour that is dependent on the inclination of the system.

6 SPECTROSCOPY

Spectra of the northern component of the double proposed as the optical counterpart of EXO 0531–66 were obtained on the nights of 1998 December 9 and 1998 December 14, using the 1.9-m telescope at SAAO. The detector was a SITe CCD attached to the Grating Spectrograph, using a 1200 line mm$^{-1}$ grating, giving a resolution of 1 Å. Two 900-s exposure spectra of the source were obtained on both nights, together with Cu–Ar arc spectra for wavelength calibration and dome flats. Spectra of H 0544–665 (Star 1 of Johnston et al. 1979) were obtained on the nights of 1998 December 11 and 1998 December 12, exactly as for EXO 0531–66.

The spectra were reduced using IRAF in a completely standard way. The one-dimensional spectra were extracted from the two-dimensional image using a FWHM aperture to ensure optimum signal-to-noise ratio. As no flux standards were observed, the spectra are presented in raw counts only.

6.1 EXO 0531–66

The summed spectra of EXO 0531–66 for each night are shown in Fig. 6 and confirm the presence of Hα emission as seen by Stevens et al. (1999). It is clear that the Hα emission profile is changing with time, as shown by the factor $\sim 2.3$ increase in flux from the first night to the second. Balmer emission in the spectra of Be/XRBs is believed to originate in the circumstellar material disc around the Be star (Stevens et al. 1999). The variations in Hα we observe are most likely due to variations in this disc.

6.2 H 0544–665

Due to the poorer quality of the spectra of H 0544–665 we summed all four spectra in order to increase the signal-to-noise (Fig. 7). Hα emission is evident in the combined spectrum, again confirming the results of Stevens et al. (1999).
Figure 4. PDM (top) and LS periodograms (bottom) for the R-band data of H 0544–665, frequency range and resolution are $1.43 \times 10^{-3}$–1.0 cycle d$^{-1}$ and $1.25 \times 10^{-4}$ cycle d$^{-1}$, respectively. The dotted line is the 99 per cent confidence level, the dashed line is the 99.9 per cent confidence level.

Figure 5. $V$ versus $V-R$ plot for EXO 0531–66 (top panel) and H 0544–665 (bottom panel). Note that both sources get redder as they get brighter.

7 DISCUSSION

To investigate the origins of the brightness variations that we observe in EXO 0531–66 and H 0544–665 it is instructive to consider another Be/XRT, A0535+26. This source has been extensively studied since its discovery in 1975 (Coe et al. 1975; Rosenberg et al. 1975).

The system contains a neutron star with a 104-s spin period in an elliptical orbit of period $\sim$110.3 d around its O9.7 IIIe companion (Priedhorsky & Terrell 1983; Nagase 1989).

Clark et al. (1999, hereafter C99) analysed 15 yr of optical photometry of A0535+26 and compared the variability found with that of the X-ray data taken with BATSE over the same period. As the neutron star accretes material from the circumstellar disc around the Be star, a study of the long-term variability of the envelope can help in the understanding of the source's X-ray behaviour. A0535+26 was found to be highly variable in the optical over the 15-yr period.

C99 performed period searches of the long-term optical light curve of A0535+26. The analysis failed to find any evidence for modulation of the circumstellar envelope at the orbital period identified from the X-ray light curve. However, periods of $\sim$1400, $\sim$470 and $\sim$103 d were found in the optical light curve, but their cause and whether they are coherent over time is unclear. C99 suggest that these changes in the optical light curve are due to the variability in the emission measure of an optically thin circumstellar envelope emitting via free–free and bound-free emission mechanisms. As there was no evidence for optical modulation at the orbital period, C99 concluded that it is unlikely that the periastron passage of the neutron star affects the mass-loss rate from the optical companion. We note however that Hutchings (1984) found that the H$\beta$ emission from A0535+26 was modulated on the 111-d period.

We find little evidence for any periodicities in the light curves of EXO 0531–66 and H 0544–665. The orbital periods of Be/XRTs are usually determined from the recurrence period of outbursts, particularly in X-rays. We found a stable period of 421 d for A0538–66 (see Alcock et al. 2001) which we suggest is related to the formation and depletion of the equatorial disc around the Be star, and is certainly
not orbital in origin. However, the long-term modulations we observe in the optical light curves of EXO 0531–66 and H 0544–665 are most likely due to non-periodic variations characteristic of Be stars. If stable long-term variations are present in the light curves of EXO 0531–66 and H 0544–665, they are occurring on much longer time-scales than presented here.

If it is assumed that the orbital plane of the neutron star and the equatorial plane of the Be star are coincident, then when the neutron star passes through the dense material close to the Be star at periastron, an X-ray flare should be observed. C99 tested this model using their simultaneous optical and X-ray data of A0535+26. If the neutron star is accreting directly from the outflowing circumstellar disc material, the optical and X-ray light curves should be strongly correlated.

C99 did not find any positive correlation between the optical and X-ray data, and concluded that this indicates that the neutron star is not accreting directly from the stellar wind. C99 found that the X-ray outbursts seemed to occur after a period in which the optical light curve was seen to fade. This anti-correlation could represent a discrete episode of disc-loss which occurs radially, the interaction of the neutron star with this material then triggers the X-ray emission. They also observed a case in which an optical outburst was observed with no accompanying X-ray outburst. We find a slight brightening in the optical light curve of EXO 0531–66 at times of recorded
X-ray outburst (see Fig. 1; Haberl et al. 1995; Burderi et al. 1998). The lack of a strong correlation between the optical and X-ray data could be related to the low optical to X-ray luminosities observed for the sources.

Janot-Pacheco et al. (1987) showed that changes in the emission from the circumstellar disc lead to a correlation between \( V \) and \( (B - V) \) for A0535+26. C99 confirmed that a correlation exists where the system becomes redder as it brightens, owing to a greater contribution from the cooler disc. We find the same correlation for the MACHO data of EXO 0531–66 and H 0544–665. However, another LMC Be/XRT we have studied, A0538–66, becomes redder as it fades (see Alcock et al. 2001). As the \( V/(B - V) \) correlation is dependent on the inclination of the system, this suggests that we are viewing A0535+26, EXO 0531–66 and H 0544–665 at lower inclinations than A0538–66 (see McGowan & Charles 2002).

Clark et al. (1998) investigated the long-term variability of optical spectroscopy of A0535+26. The profile and equivalent width of the H\( \alpha \) emission line were found to vary considerably over the 7-yr period of study. It varied between a single-peaked and double-peaked or asymmetric structure, and the relative intensities of the symmetric and asymmetric profiles varied over time. The asymmetries were characterized by an additional feature in the blue or red shoulder, which was sometimes displaced far enough from the rest wavelength to appear as a separate peak. Clark et al. (1998) conclude that the variability in the H\( \alpha \) line reflects the changes occurring in the circumstellar envelope, and suggest that the asymmetries observed in the profile are due to the envelope being asymmetric in geometry or density.

8 Conclusions

We can confirm the optical identification of EXO 0531–66 with the northern component of the close double from the variability in the light curve, and the H\( \alpha \) emission that is observed in the spectra. The variability in the emission may be due to changes occurring in the circumstellar envelope as for A0535+26 (Clark et al. 1998). Our H 0544–665 spectrum also shows H\( \alpha \) emission, but more spectra are required in order to investigate its variability.

Haberl et al. (1995) proposed an orbital period for EXO 0531–66 of 600–700 d. Dennerl et al. (1996) proposed a much shorter period for the source in the range of 4–70 d. We find no variability on these time-scales in the MACHO data. We find that the upper limits for a short-term (1–100 d) periodic modulation to be detected in the H\( \alpha \)- and \( R \)-band light curves of EXO 0531–66 are 0.041 mag and 0.047 mag, respectively, and 0.054 mag and 0.075 mag, respectively, for H 0544–665.

The colour changes for A0535+26, EXO 0531–66 and H 0544–665 are consistent with the systems becoming redder as they brighten owing to the greater contribution from the cooler equatorial disc (Janot-Pacheco et al. 1987). This provides evidence that we are observing the systems at a lower inclination than A0538–66 (see McGowan & Charles 2002). We detected the orbital period in the optical light curve of A0538–66 (see Alcock et al. 2001) which is also seen in X-rays. C99 find no evidence for modulation of the optical light curve of A0535+26 on the X-ray-determined orbital period. Hence, the system inclination may determine whether the orbital period of a Be system is detectable optically, and therefore we may only be able to detect those of EXO 0531–66 and H 0544–665 in X-rays. However, the detection of the orbital period in both optical and X-rays for A0538–66 may be connected to its short orbital period (16.6 d). If this is true, it suggests that the orbital periods for EXO 0531–66 and H 0544–665 are both longer than \( \sim 20 \) d.

Acknowledgments

We thank Thebe Medupe for generously obtaining the optical spectra with the SAAO 1.9-m telescope. This paper utilizes public domain data obtained by the MACHO project, jointly funded by the US Department of Energy through the University of California, Lawrence Livermore National Laboratory under contract No. 7405-Eng-48, by the National Science Foundation through the Center for Particle Astrophysics of the University of California under cooperative agreement AST-8809616, and by the Mount Stromlo and Siding Spring Observatory, part of the Australian National University.

References

Alcock C. et al., 1995a, Phys. Rev. Lett., 74, 2867
Alcock C. et al., 1995b, ApJ, 445, 133
Alcock C. et al., 1999, PASP, 111, 1539
Alcock C. et al., 2001, MNRAS, 321, 678
Allsman R. A., Axelrod T. S., 2001, astro-ph/0108444
Burderi L., Di Salvo T., Robba N. R., del Sordo S., Santangelo A., Segreto A., 1998, ApJ, 498, 831
Clark J. S. et al., 1998, MNRAS, 294, 165
Clark J. S. et al., 1999, MNRAS, 302, 167 (C99)
Coe M. J., Carpenter G. F., Engel A. R., Quenby J. J., 1975, Nat, 256, 630
Coe M. J., Buckley D. A. H., Fabregat J., Steele L. A., Still M. D.,Torrejon J. M., 1997, A&A, 126, 237
Dennerl K., Haberl F., Pietsch W., 1996, in Zimmermann H. U., Trümper J., Yorke H., eds, Proc. on Röntgenstrahlung from the Universe, MPE Report 263. MPE, Garching, p. 131
Haberl F., Dennerl K., Pietsch W., 1995, A&A, 302, L1
Hanson C. G., Skinner G. K., Eyles C. J., Willmore A. P., 1989, MNRAS, 240, 1
Hutchings J. B., 1984, PASP, 96, 312
Janot-Pacheco E., Motch C., Mouchet M., 1987, A&A, 177, 91
Johnston M. D., Bradt H. V., Doychey R. E., 1979, ApJ, 233, 514
Lomb N. R., 1976, Ap&SS, 39, 447
Long K. S., Helfand D. J., Grabelsky D. A., 1981, ApJ, 248, 925
McGowan K. E., Charles P. A., 2002, MNRAS, submitted
Marshall S. et al., 1994, in MacGillivray H. T., et al., eds, Proc. IAU Symp. 161, Astronomy from Wide-field Imaging. Kluwer, Dordrecht, p. 67
Nagase F., 1989, PASP, 41, 1
Pallier M., Brunner H., Staubert A., Pietsch W., Beuermann K., 1985, Space Sci. Rev., 40, 379
Pietsch W., Rosso C., Dennerl K., 1989, in Proc. 23rd ESLAB Symp., Two Topics in X-Ray Astronomy, Vol. 1, p. 573
Priedhorsky W. C., Terrell J., 1983, Nat, 303, 681
Rosenberg F. D., Eyles C. J., Skinner C. G., Willmore A. P., 1975, Nat, 256, 631
Scargle J. D., 1982, ApJ, 263, 835
Slettebak A., 1987, in Slettebak A., Snow T. P., eds, Proc. IAU Symp. 92, Physics of Be Stars. Boulder, Colorado, p. 24
Stellingwerf R. F., 1978, ApJ, 224, 953
Stevens J. B., Cooke M. J., Buckley D. A. H., 1999, MNRAS, 309, 421
Stubbs C. W. et al., 1993, in Blouke M., ed., Proc. SPIE 1900, Charge-coupled Devices and Solid-State Optical Sensors III. SPIE, Bellingham, p. 192
Thorsten J. R., Charles P. A., 1980, IAU Circ. 3449
van der Klis M., van Paradijs J., Charles P. A., Thorsten J. R., Tuohy L., Elson J., 1983, MNRAS, 203, 279

This paper has been typeset from a TeX/XeTeX file prepared by the author.