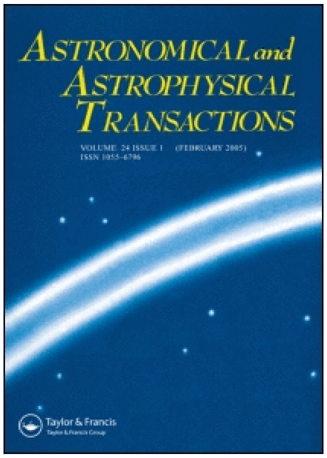

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

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Online Publication Date: 01 November 1995
To cite this Article: Beskin, G. M., Mitronova, S. N., Neizvestny, S. I., Panferova, I. P., Popova, M. Ju., Plokhotnichenko, V. L., Zhuravkov, A. V., Bartolini, C., Guarnieri, A. and Piccioni, A. (1995) 'Optical properties of X-ray nova percei 1992 near maximum', Astronomical & Astrophysical Transactions, 8:4, 297 - 305
To link to this article: DOI: 10.1080/10556799508226946
URL: http://dx.doi.org/10.1080/10556799508226946

Astronomical and Astrophysical Transactions, 1995,
Vol. 8, pp. 297–305
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OPTICAL PROPERTIES OF X-RAY NOVA PERCEI 1992 NEAR MAXIMUM

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(Received June 9, 1993)

We present spectroscopic and photoelectric optical observations of the X-ray Nova GRO J0422+32 = Nova Persei 1992 obtained with a TV spectrum scanner, UBVR photometer and the soft/hardware MANIA complex at the Special Astrophysical Observatory 6 m telescope and with a fast double-head photometer at the Bologna Observatory. In the early phase after its discovery, the spectrum of the object presented a variable continuum with intensity rising blueward and some weak emissions (H, He, N). Photoelectric data show a modulation on a time scale of about 5 h and stochastic flashes, probably of nonthermal origin, on a time scale from 10–20 ms to 200 s. A unique episode of fading of the object was observed on JD 2448986.52.

KEY WORDS X-ray binaries, X-ray novae, black holes

1 INTRODUCTION

Since its discovery, about 20% of the IAU Circulars dealt with the object GRO J0422+32, an X-ray Nova which appeared on the sky on August 5, 1992 and was optically identified ten days later (Paciesas *et al.*, 1992; Castro-Tirado *et al.*, 1992). Several papers on this subject were presented at recent meetings, and this confirms the interest in this object. Shrader *et al.* (1992) point out similarities of GRO J0422+32 with V616 Mon and other low-mass X-ray binaries. According to Kato *et al.* (1992), there are indications of a lower limit for the mass of the compact component of 2.2 solar masses. We will present here some preliminary results of the optical observations which our group has been carrying out.

2 OBSERVATIONS

The observations were carried out on the Russian 6 m telescope at the Special Astrophysical Observatory (SAO) and on the 1.5 m telescope at the Bologna Astronomical Observatory (Italy). The instruments used were a TV spectrum scanner, UBVR photometer and the MANIA (Multichannel Analysis of Nanoseconds Intensity Alterations) registration system with a time resolution of 10^{-7} s (Beskin *et al.*, 1982) on the Russian telescope and a double head fast photometer on the Italian one (Piccioni *et al.*, 1979).

2.1 Spectroscopy

Low dispersion spectra taken on the 6 m telescope between August 31 and September 9, 1992 show a blue, feature-poor continuum; in this period the blue-violet region of the continuum varied considerably on a daily time-scale. This was confirmed by optical photometry, which showed a decreasing of the $U-B$ index. H_β was seen as a broad absorption with a small emission core on September 9 (Figure 1),

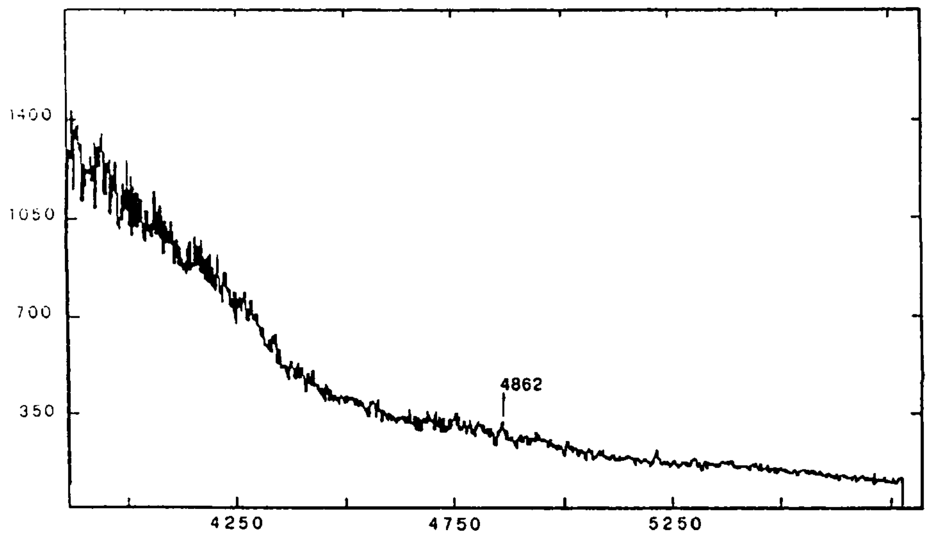

Figure 1 The spectrum of Nova Per on September 9, 1992. A weak H_β emission is present.

but was undetectable on September 4. Several absorption systems appeared in the 3800–4200 Å and 4600–4900 Å ranges. Between December 24 and January 19, 1993 the spectra of GRO J0422+32 were similar to the previous ones. With exception of the weak emission of H_β, H_α, He II 4686 and 5411, NIII 4640, no other emission lines could be clearly detected. The continuum in the spectral region 3900–5200 Å can be described by a power-law with index equal to 2.0–2.2.

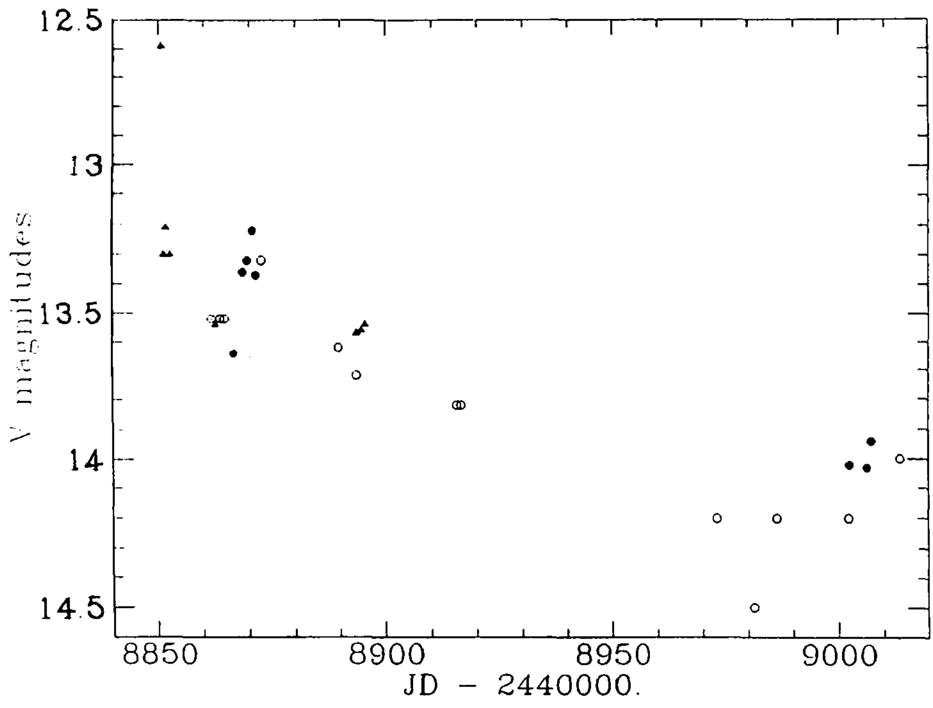

Figure 2 The V optical decay of Nova Per. After the outburst, the curve shows two relative maxima. • refer to the SAO 6 m telescope photometry (this paper); ▲ refer to the photoelectric or CCD photometry; o, to visual estimates. These data were taken from IAU Circulars 5588 (Castro-Tirado *et al.*), 5590, 5632 (Shakhovskoj), 5591 (Schrader *et al.*), 5597, 5613, 5690 (Schmeer), 5606 (Shao), 5690, 5701 (Merlin), and 5701 (Bortle). Visual estimates by Schmeer were artificially increased by 0.62 mag in order to normalize them to a quasi-contemporaneous observation of Shakhovskoj on August 27, 1992 (IAU Circ. 5590). The visual estimate on December 24 was made on the 6 m telescope by eye inspection (because of a cloudy weather, photometry was not possible).

2.2 Photometry

Table 1 reports mean magnitude values in the Johnson UBVR bands obtained on the 6 m telescope. As can be noted, the object was considerably bluer in early September 1992 than in January 1993. Our data and those we were able to collect from the literature are shown in Figure 2. We stress that this material is clearly not homogeneous and affected by short time-scale variabilities; however, it gives an idea about the general optical behavior of the object. In five months its fading was less than one magnitude and the decline was not regular at all; for example, our data show an increase in brightness of the object in all bands (and stronger in U) during the period August 31 – September 4, 1992. Moreover, the light curve shows a third relative maximum occurring about six months after the outburst. This behavior is similar to other X-ray novae which are thought to contain a black hole (Chen *et al.*, 1993). This makes plausible the hypoth-

Table 1. SAO UBVR photometry (Johnson system)

JD	*V*	σ	$B-V$	σ	$U-B$	σ	$V-R$	σ
48866.482	13.64	.03	0.27	.02	−0.26	.03	0.46	.01
48868.492	13.36	.02	0.19	.02	−0.48	.04	0.34	.01
48869.423	13.32	.01	0.21	.01	−0.47	.02	0.32	.01
48870.542	13.22	.01	0.08	.01	−0.52	.02	0.32	.01
48871.419	13.37	.01	0.15	.01	−0.40	.02	0.53	.01
49002.428	14.02	.01	0.26	.02	+0.09	.04	0.47	.02
49006.286	14.03	.05	0.14	.03	−0.04	.03	0.47	.02
49007.260	13.94	.01	0.06	.01	−0.14	.02	0.54	.01

Table 2.

Flash	*Amplitude*		*Duration (ms)*		*(B–R)*	T_b	(10^8 *K)*
No.	*B*	*R*	*Full*	*R.F.*	*mag*	*B*	*R*
127	3.88	2.49	136	40	−0.05	1.5	1.7
154	2.0	2.58	44	20	1.16	3.0	7.0

esis that GRO J0422+32 also belongs to the class of Black Hole X-ray Novae (BHXRNe).

GRO J0422+32 is also variable on shorter time scales. UBVR photometry shows flux and color variations on a time scale of minutes to hours, with an amplitude of 10–20%. Stochastic variability in UBVR bands is present on the time scale of 0.02–100 s with an amplitude of 0.5–4 (in different bands and in different times). For example, Figures 3 and 4 show two short flashes we observed on September 1, 1992, 00 h 33 m UT. Their parameters are reported in Table 2. R. F. denotes the duration of the rising front of the flash. The brightness temperature T_b (in Kelvin) was calculated as

$$T_b = 10^8 t^{-2} f^{-2} D^2 S_m,$$

where t is the duration of rising front in milliseconds, f is the average frequency of observation in units of 10^{15} Hz, D is the distance in kpc, S_m is the flux in mJy. Following Shrader *et al.* (1992), we assumed the distance to GRO J0422+32 of 2.4 kpc and the interstellar extinction $A_v = 1.2$. The resulting estimate of the brightness temperature could be an evidence of nonthermal processes. On the time scale of 10^{-7}–10^{-3} s, variability is absent.

A double head photometer was used for a continuous monitoring of the object on the Bologna 1.5 m telescope on December 27 and 29, 1992 in the V band with 1 s integration time. A period analysis shows significant modulation at 0.208 ± 0.005 days. Figure 5 shows the V light curve folded with this value of the period. The full amplitude is 0.20 mag. Kato *et al.* (1992) and Chevalier and Ilovaisky (1993), who observed the object in different times, found the periods of 0.217 ± 0.001 days

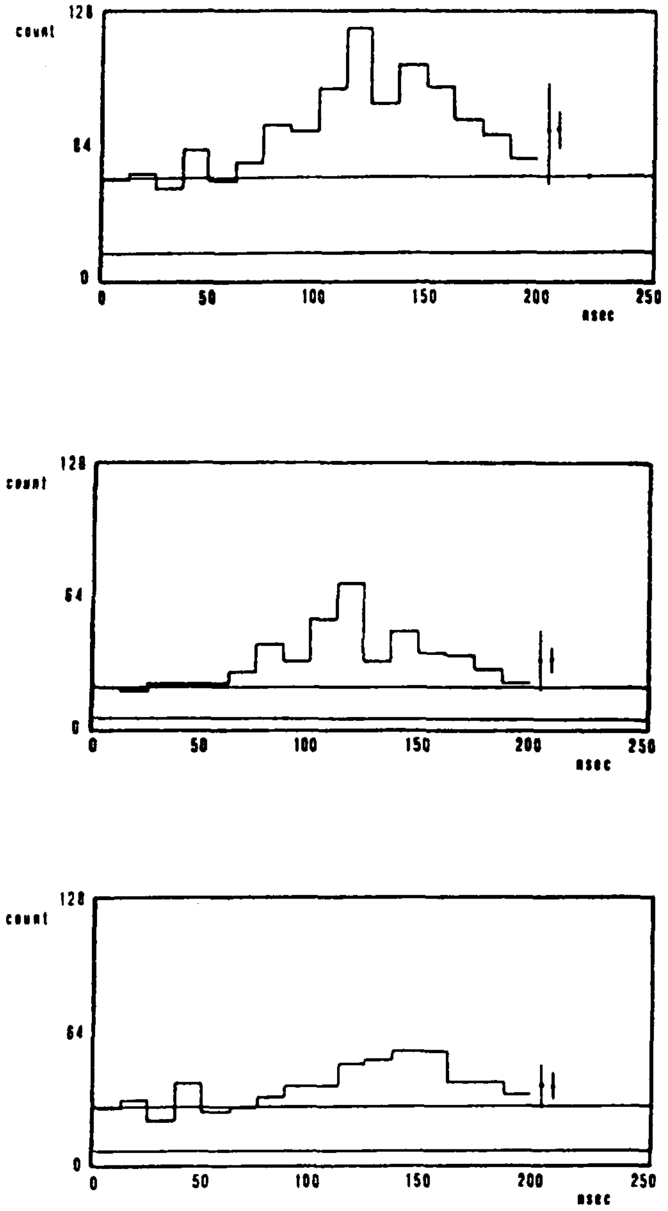

Figure 3 A short flash observed on September 1, 1992. The R, B and B+R light curves are shown from bottom to top, respectively.

and 0.2124 ± 0.0002 days, respectively. Chavalier and Ilovaisky emphasize that the value for the period they found is incompatible with that of Kato *et al.* The same is true for the period we find whose value agrees within errors with the first one. It remains to be clarified if a true period change happened in the system.

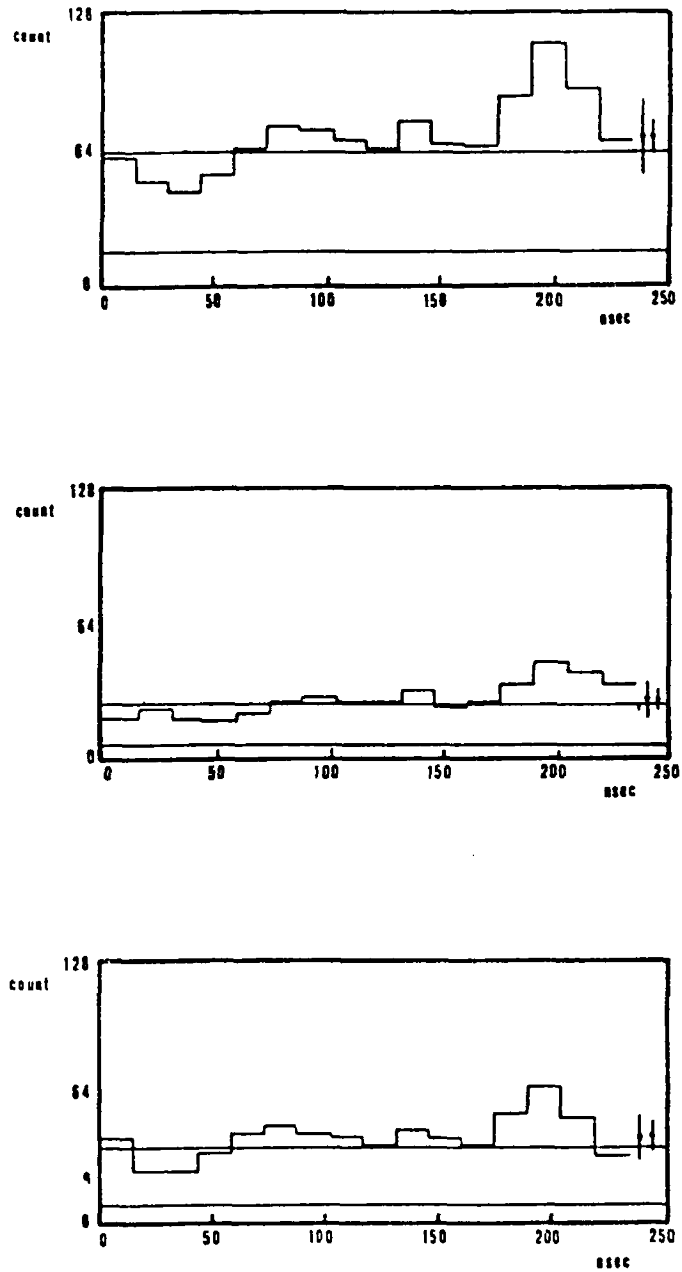

Figure 4 A short flash observed on September 1, 1992. The R, B and B+R curves are shown from bottom to top, respectively.

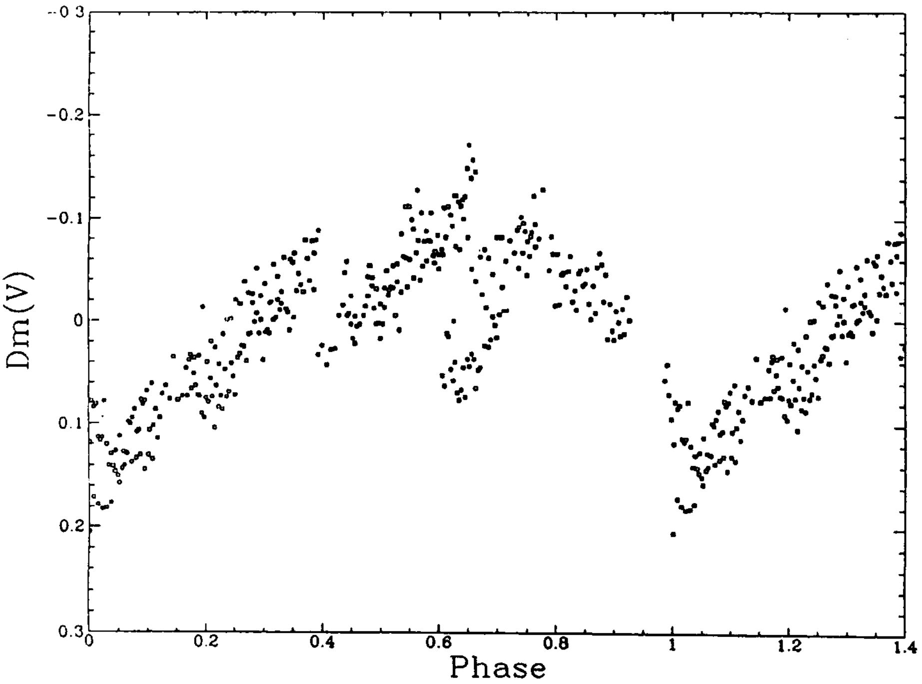

Figure 5 The V light of the (orbital?) modulation folded modulo $0^d.208$, observed at the Bologna Observatory. Each point represents an integration of 100 s.

2.3 The December 10, 1992 episode

We want to briefly describe a very strange episode we observed on the night of December 30, 1992 at the Bologna Observatory, which we have already recorded in IAU Circ. 5690. Two of us (C. B. and A. P.), who had been observing GRO J0422+32 for more than five hours, suddenly recorded a rapid drop of luminosity of the object greater than 3 mag. The fading phase lasted about 20 s, after that the star disappeared into the background of the sky. The light curve of the event is shown in Figure 6, which proves the perfectly regular trend of the comparison star viewed by the second head of the photometer. The night was photometric.

We checked the instruments carefully, and thus we can exclude the possibility of a malfunction of the electronics and mechanics of the photometer or a mechanical drift of one head of the photometer or of the telescope (the comparison star remained centered in its diaphragm). Moreover, the observers visually inspected the field and they recognized the other nearby stars, but they could not detect GRO J0422+32. After an hour and a half the object was still undetectable and the observations were stopped because of its high zenith distance. We do not have any plausible explanation that would attribute this recorded event to observational errors. We will leave any "ad hoc" explanation (eclipse by a cold third body in a wide orbit,

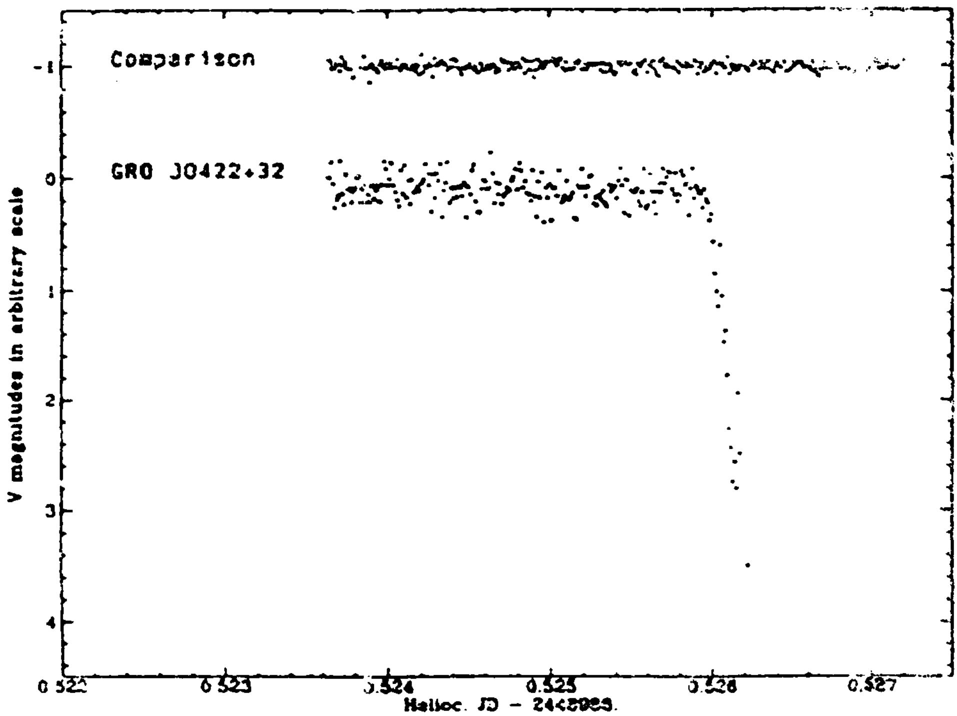

Figure 6 The fading episode observed on December 30, 1992 at the Bologna Observatory.

by a black hole, by a comet of the Oort's cloud, and so on) to the imagination of the theoreticians who will want to believe in the reality of the phenomenon.

3 SOME CONCLUSIONS

GRO J0422+32 appears to be a slow-type nova. Like the X light curve, the optical curve resembles that of V 616 Mon, Nova Mus and GS2000+25 which are promising black-hole candidates. Stochastic variability of the optical flux in the UBVR bands based on the time scales of 0.02 s – minutes is clearly present as well as a regular modulation with a five-hour period. With less certainty we may affirm the existence of short flashes with a duration of some milliseconds. The simultaneous flashes behave differently in different colors. The brightness temperatures of these short phenomena are indicative of nonthermal mechanisms in their emission zones. Optical spectra are similar to those of other X-ray novae, such as Cen X-4, V 616 Mon and Aql X-1. All the mentioned features indicate that GRO J0422+32 could be a member of the class of BHXRNe. However, the outburst X-ray luminosity of GRO J0422+32 is one or two orders of magnitude lower than the luminosity of those sources. If the total energetics of GRO J0422+32 in an outburst was two orders lower than the Eddington energy, it would not be sufficient to produce the ejection of a massive shell. The small optical depth of this non-massive shell permits the observation of the outcoming radiation with the observed characteristics of variability and short flashes.

This research was partially supported by the Italian Ministero per l'Universita'e la Ricerca Scientifica e Tecnologica (MURST) and by "Cosmion" center in the framework of the project "Cosmoparticle Physics".

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