# The X-ray eclipse of the dwarf nova HT CAS observed by the *XMM*-Newton satellite: spectral and timing analysis

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## 1. Introduction

Cataclysmic variables (CVs) are binary systems that consist of a white dwarf (called primary star) gravitationally interacting with a secondary object that is losing mass. The two stars interact by means of the formation of a Roche-lobe, but the details of the accretion mechanism depend upon several parameters, the most important of which is the intensity of the magnetic field. Depending on the intensity of the WD magnetic field, CVs are classified as: (i) non-magnetic systems, which have a very weak field ($\lesssim$0.1 MG) in which an accretion disk forms around the compact object; (ii) intermediate polars (with magnetic field in the range 0.1-10 MG), where the accretion disk is disrupted in the vicinity of the WD; or (iii) polars (highly magnetized systems, $\gtrsim$10 MG), where the accretion occurs primarily by means of a mass stream. For a detailed description of the main properties of CVs, we refer to [1]. Given the low luminosity of these systems, *XMM*-Newton is remarkably well suited to their study because of its large effective area and the possibility of observing the source simultaneously in the optical band with the optical monitor (OM). A CV candidate that is one of the easiest to study and constrain the size of the X-ray emitting region, is the dwarf nova HT Cas. As for many other CVs, HT Cas is a short period binary system ($P_{orb} \simeq 1.77$ h, [2]), close to the lower edge of the period gap at $\sim 2.5$ h. The system is characterized by a visual magnitude of $\sim 16.4$ during its quiescent state, relatively rare outbursts, and white dwarf eclipses well observed in several optical campaigns. We present a $\sim 45$ ks *XMM*-Newton observation of the dwarf nova HT Cas, and discuss a detailed spectral and timing analysis conducted on data collected by the EPIC cameras and the OM telescope. The EPIC source spectra were extracted in a circular region centered on the nominal position of HT Cas in the three EPIC cameras (extraction circles with radius $\simeq 60''$), while the background spectra were accumulated in circular regions on the same chip and, where possible, at the same vertical location. The net count rates of the source in the two MOS and PN cameras are $\simeq 0.33$ count s$^{-1}$, $\simeq 0.36$ count s$^{-1}$, and $\simeq 1.00$ count s$^{-1}$. The resulting spectra were rebinned to have at least 25 counts per energy bin, and imported into XSPEC (version 12.4.0) for spectral fitting. A single temperature thermal plasma model with absorption by neutral gas (MEKAL and WABS models in XSPEC) gave a fit (with all the parameters free to vary) with $\chi^2_\nu = 1.3$ (549 d.o.f.), for a temperature $kT = 7.14 \pm 0.23$ keV and hydrogen column density $N_H = (1.44 \pm 0.04) \times 10^{21}$ cm$^{-2}$; the normalization of this component is $N = (2.40 \pm 0.02) \times 10^{-3}$. We note that the temperature derived for this model is lower than that ($10.1 \pm 1.5$ keV) estimated by using the ASCA data [3]. All the errors in this work are quoted at the 90% confidence level, unless otherwise stated. Given that this model underestimates the flux below 0.3 keV, a low temperature black-body component is added to obtain an acceptable fit of $\chi^2_\nu = 1.21$ (547 d.o.f.), yielding a temperature of $kT_1 = 6.89 \pm 0.23$ keV, for the MEKAL component, and $kT_2 = 30^{+8}_{-6}$ eV, for the soft black-body component. The normalizations of the two components are $N_1 = (2.45 \pm 0.03) \times 10^{-3}$ and $N_2 = (7^{+20}_{-5}) \times 10^{-4}$, respectively. Given the very large uncertainty in the normalisation of the black-body component, it should be considered as an upper limit. The spectrum shows a strong emission line (iron K$\alpha$ transition) at 6.7 keV, which was well produced by the adopted plasma model. The fitted hydrogen column density is $N_H = (1.6 \pm 0.1) \times 10^{21}$ cm$^{-2}$. We also emphasize that the column density derived from our fit is remarkably lower than that measured by using the ASCA data ($n_H \simeq 3.3 \times 10^{21}$ cm$^{-2}$, [3]). Hence, the ASCA spectrum may be affected by self-absorption at low energies that we do not see in the *XMM*-Newton data. However, various column densities have been measured, such as $1.8 \times 10^{20}$ cm$^{-2}$ [4] and $6 \times 10^{20}$ cm$^{-2}$ [5]. As discussed by [4], in the quiescent state a fraction of the flux coming from the white dwarf, as well as from the boundary layer, may be obscured by the edge of the disk. If the obscuration does not occur during the low flux state, the column density will be lower. In Fig. 1, we show the MOS 1, MOS 2, and PN spectra ($0.2 - 9$ keV) for the source, the irrespective best fit model (solid lines), and the individual model components (dashed lines). The total absorbed flux in the 0.2-9 keV band is $F^{\rm Abs}_{0.2-9} = (4.1 \pm 0.1) \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$, the respective contributions of the MEKAL and black-body components being $F^{Mek}_{0.2-9} = (4.05 \pm 0.05) \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ and $F^{BB}_{0.2-9} = (2.2^{+6.2}_{-1.5}) \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$. We note that the measured *XMM*-Newton flux in the $0.1-1.2$ keV band is a factor $\sim 3$ higher than the corresponding flux measured by [4]. Therefore, our observations indicate that we are studying the normal quiescent state of HT Cas, and not a very low flux state. Neglecting the black-body component, for a optically thin spectrum at $kT \simeq 6.89$ keV the observed 0.2-9.0 keV band flux corrected for the absorption is $F^{\rm Cor}_{0.2-9} = (5.0 \pm 0.1) \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$. By using Xspec, it is straightforward to estimate a bolometric correction factor of $\simeq 30\%$, therefore the unabsorbed bolometric flux turns out to be $F^{\rm Bol} = (6.5 \pm 0.1) \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$. Consequently, for an estimated distance of 131 pc (see [6]), the luminosity of HT Cas is $(1.33 \pm 0.02) \times 10^{31}$ erg s$^{-1}$. Light curves of the source were extracted from the original event list files to avoid introducing gaps that can induce artifacts in the timing analysis. We applied a solar system barycentric correction so that the event times are in barycentric dynamical time instead of spacecraft time. For all the three EPIC cameras, we used a circular apertures of radius $\simeq 60''$ centered on HT Cas. The background light curves were extracted from the same CCD, scaled to the extraction area and subtracted from the source light curves. To increase the signal-to-noise ratio, the background-corrected light curves were combined. In Fig.1, we show the EPIC light curve folded using the [2] linear ephemeris period and zoomed around phase 0. We remind the reader that the time axis shows barycenter-corrected times. The folded light curve was used to determine the contact points of the eclipse via a Levenberg-Marquardt least squares fit to the data, restricted around the central eclipse, yielding values of $\phi_1 = -0.0266 \pm 0.0005$, $\phi_2 = -0.0189 \pm 0.0012$, $\phi_3 = 0.0207 \pm 0.0005$, and $\phi_4 = 0.0284 \pm 0.0012$, with a reduced $\chi^2 = 1.5$ (314 d.o.f.). In the time domain, the ingress/egress and total occultation time scales of the X-ray light curve of HT Cas are $49.2 \pm 9.9$ s, and $298.9 \pm 8.9$ s, respectively. Thus, the X-ray emitting region size is $r_X = (0.0117 \pm 0.0004)$ R$_\odot$, to be compared with the white dwarf optical radius $r \simeq 0.0118$ R$_\odot$, i.e. a tight constrain on the origin locus of X-rays in HT Cas has been obtained. We address the reader to the original paper ([7]) for further details on the analysis.

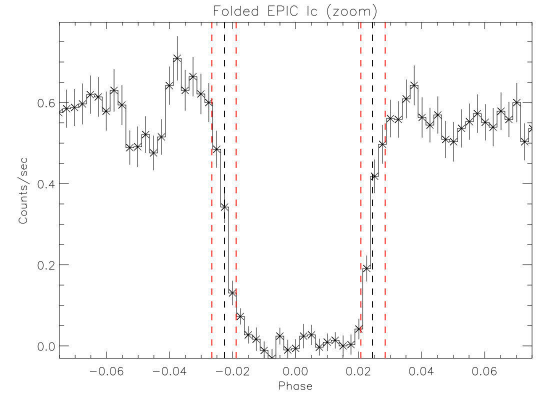


Figure 1. The X-ray folded light curve around the eclipse. See text for details about the method used to determine the eclipse contact points.

## REFERENCES


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