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Letter to the Editor

EXOSAT observations of a broad absorption-line quasar: PHL 5200

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SUMMARY:

In our observations of the 45' (FWHM) region centered on a broad absorption-line quasar PHL 5200 performed with the medium energy (ME) and low energy (LE) experiments on board EXOSAT Observatory we have detected X-ray emission in the 2-6 keV energy band. No sources are detected in the 0.05-2.0 keV energy band. These observations have been used to suggest that the quasar rather than a cluster of galaxies or a star in the ME field is the optical counterpart of the 2-6 keV X-ray source. Consistency with the soft X-ray observations made with Einstein Observatory about 5 years prior to the EXOSAT observation requires either a highly variable X-ray source or a higher absorbing column ($\approx 10^{22}$ cm^{-2}) than is needed to explain the EXOSAT observations. A very high minimum column density ($>10^{22}$ cm^{-2}) is needed if the absorption is intrinsic to the quasar. The 4 keV monochromatic luminosity emitted by the quasar is 9.1×10^{28} ergs s^{-1} Hz^{-1}.

Key words: Quasars: PHL 5200 - X-rays.

1. INTRODUCTION:

PHL 5200 is a high redshift ($z = 1.98$; Lynds, 1967; Burbidge, 1968, 1969) broad absorption-line (BAL) quasar (see Turnshek (1984) for characteristics of such quasars) showing very deep and very broad (> 3000 km s^{-1}) absorption profiles in the resonance lines of C IV, S IV, N V and Ly α (Lynds 1967; Scargle, Caroff and Noerdlinger, 1970). A 1° x 1° field centered on the quasar was observed for ≈1000 s with the Imaging Proportional Counter (IPC) on board the Einstein Observatory but no X-ray sources were detected in the 0.4 - 3.5 keV energy band. An upper limit for the X-ray flux from PHL 5200 was reported by Zamorani et al. (1981) based on the IPC observation. In this letter, we present the results of broad-band (0.05-10 keV) observations using the EXOSAT Observatory.

2. OBSERVATIONS AND RESULTS:

The low energy (LE: see de Korte et al. (1981) for a description) and the medium energy (ME: see Turner, Smith and Zimmermann (1981) for a description) experiments on board the EXOSAT Observatory were used to observe PHL 5200 on days 327 and 328 of 1983. The LE experiment consists of a channel multiplier array (CMA) at the focus of a low energy telescope. A 12.4 hours long exposure of a CMA field centered on the quasar was obtained with the LE experiment using the 3000 Å Lexan (3LX) filter, but no X-ray sources were detected in the 0.05 - 2.5 keV energy band. A 3σ upper limit of 1.12×10^{-3} CMA counts s^{-1} is obtained from this observation.

The ME experiment consists of eight proportional counters with a total geometric area of 1500 cm^2 and a square field of view with 45' FWHM. Data from the argon-filled counters, sensitive in the energy range 1-10 keV, were used in our analysis. The quasar PHL 5200 was observed for a total of 14 hours with the ME detectors in the offset mode where four detectors are pointed on the source and the other four detectors are offset by 2° to monitor the background. The aligned and offset detectors were interchanged after 8.5 hours. The data taken during times when a detector showed transient counting rates were excluded giving a useful exposure of 48000s on source. After subtracting the detector background using the data taken by the same detector while offset, a count rate of 0.21 ± 0.027 counts s^{-1} was detected in the 2-6 keV energy

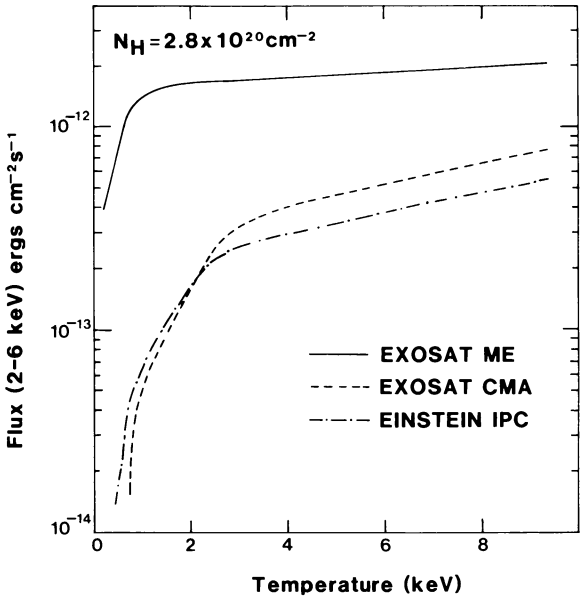

Figure 1. The EXOSAT ME flux and the 3σ upper limits from the EXOSAT CMA and the EXOSAT IPC are plotted as a function of temperature in the case of a thermal bresstrahlung spectrum assuming only the absorption due to our own Galaxy.

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band (pulse height channels 7-24) in each half-array of four detectors. The mode of detection in which the two half arrays of detectors are interchanged midway through the observation makes systematic errors in the background correction largely unimportant and gives confidence in the detection of this weak X-ray source. The source is too weak to derive any spectral information. Using a power law with a photon index (Γ) of 1.7 and correcting for an absorbing column of 2.8 x 10^{20} cm^{-2} (Heiles, 1975) of interstellar matter in the Galaxy, the total observed count rate corresponds to a flux of 1.95 x 10^{-12} ergs s^{-1} cm^{-2} incident on the top of our atmosphere.

The ME field also contains a distant cluster of galaxies - A2446 which is about 20' away from PHL 5200, and a few stars with the brightest one having m_V = 9.42 and spectral type F8. The present data, however, make the association of the ME source with PHL 5200 much more likely than with either of these two possibilities as argued below.

In Figures 1 and 2 the ME flux and the 3σ upper limits from the CMA and IPC (extrapolated to the 2-6 keV band) are plotted as a function of temperature (in the case of a thermal bremsstrahlung spectrum) and photon spectral index (in the case of a power-law spectrum). In both cases only the Galactic absorption is assumed. In the case of a thermal bremsstrahlung spectrum (see Fig. 1) there are no temperatures at which either the CMA or the IPC upper limit becomes consistent with the ME detection. Therefore, if the X-ray emission detected by the ME is due to a thermal process, as in the case where the cluster of galaxies is the counterpart to the X-ray source, the Einstein observation would imply that the source is variable. We can thus rule out the cluster of galaxies as the correct identification for the ME source. A variable thermal source, however, could be identified with a variable star in the ME field. The simultaneous CMA observation, however, requires that the star has an extremely large amount of absorbing matter towards it making it an unlikely candidate for the ME source.

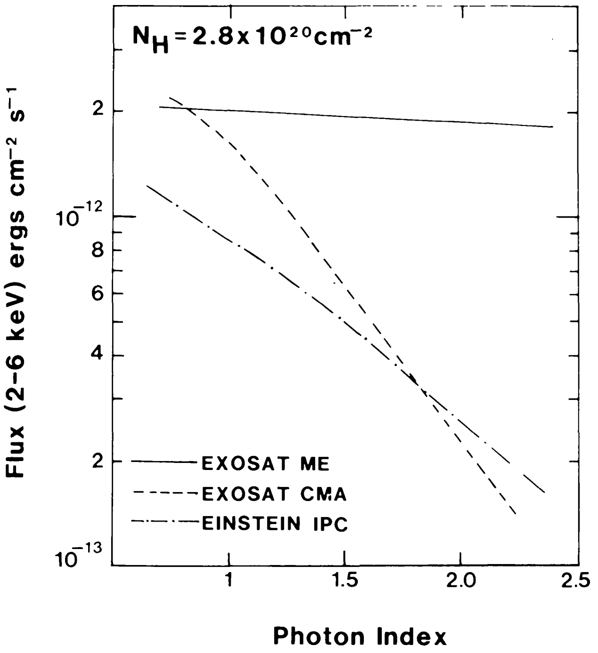

Figure 2. The EXOSAT ME flux and the 3σ upper limits from the EXOSAT CMA and the EINSTEIN IPC are plotted as a function of photon spectral index in case of a power law spectrum asuming only the Galactic absorption.

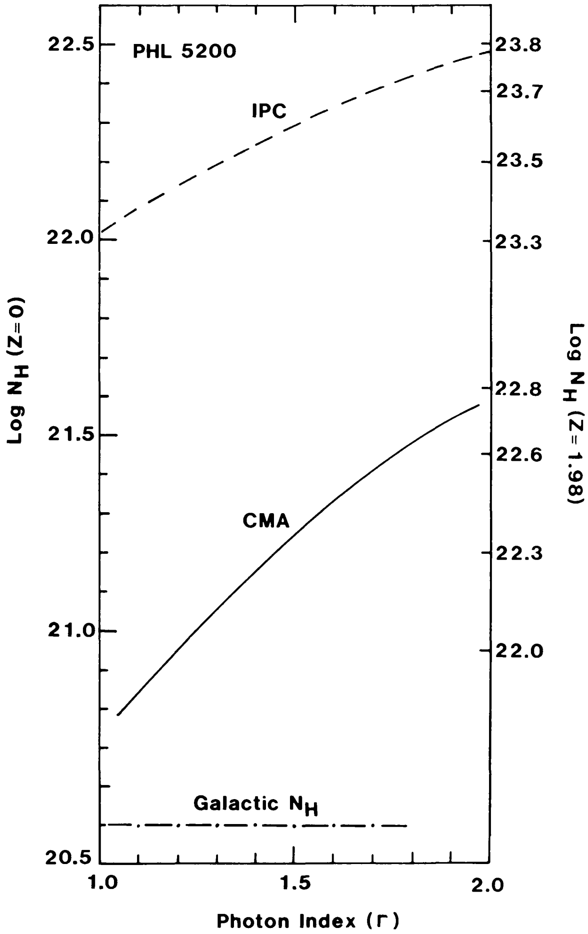

Figure 3. The 3σ lower limits on the equivalent neutral hydrogen column density in the line of sight to the X-ray source in the quasar PHL 5200 as a function of the photon index for the power law source assumed. The left hand scale is for the absorption close to the observer whereas the right-hand scale is for the absorption close to the source. The horizontal line shows the amount of Galactic hydrogen.

The identification of the ME source with PHL 5200 and consistency with the CMA 3σ upper limit requires an extremely flat spectrum (Γ < 1) (see Fig. 2) at odds with the current knowledge on X-ray spectra of quasars (Petre et al. 1984; Elvis, Wilkes and Tananbaum 1985). Alternatively, if we keep the spectral slope of ME source within a more reasonable range of values, then consistency is reached for hydrogen column density values much higher than those attributable to our own Galaxy, implying the presence of intrinsic absorption at the source. Figure 3 shows the minimum column density required if the absorption occurs at redshift, z = 0 (left-hand scale) or if the absorption occurs at the source (right-hand scale) and the redshifts are cosmological. The value of the galactic N_H is also shown for comparison. The 3σ upper limit obtained from the IPC (Zamorani et al., 1981) observation 5 years prior to the EXOSAT observation can similarly be converted to obtain the minimum absorption (Fig. 3) in the line of sight to the ME source. Assuming the source intensity has been the same at the times the two observations were carried out, the IPC observation requires even larger amount of absorption for PHL 5200, else the source is variable.

The monochromatic flux emitted at 4 keV is 1.9 x 10^{-30} ergs cm^{-2} s^{-1} Hz^{-1}. Using a value of 50 km s^{-1} Mpc^{-1} for the Hubble constant, q_0 = 0 and Γ = 1.7, the monochromatic luminosity emitted at 4 keV is 9.1 x 10^{28} ergs s^{-1} Hz^{-1} and the total band luminosity is 9.4 x 10^{46} ergs s^{-1}. The emitted monochromatic luminosity of PHL 5200 at 2500 Å given by Zamorani et al. (1981) is 1.2 x 10^{32} ergs s^{-1} Hz^{-1}. The upper limit for the monochromatic luminosity at 5 GHz has been calculated from the VLA observations (Isobe et al. 1986) of PHL 5200 and is 1.82 x 10^{32} ergs s^{-1} Hz^{-1}. Thus, the nominal power law energy slope between the radio and optical bands is α_{ro} < 0.033, and between the optical and X-ray bands is α_{ox} = 1.2.

3. DISCUSSION:

In an X-ray survey of the quasars carried out with Einstein Observatory by Zamorani et al. (1981) only four out of the nine BAL quasars observed were detected. PHL 5200 was not detected. In light of the data presented here, PHL 5200 is either highly variable or highly absorbed. The minimum column density of 6 x 10^{20} cm^{-2} required by the simultaneous CMA and ME observations (assuming Γ = 1 and that the absorption is due to the matter in our Galaxy or its halo) is about a factor of 2 higher than the value obtained from 21 cm observations of the Galaxy. We are not aware of any other observations which might support a factor 2 discrepancy with the 21 cm measurements. A factor of 10 greater column density is required if the absorption is intrinsic to the source or associated with the high redshift absorption line systems in the quasar. From a study of optical absorption line properties of 14 BAL quasars, Turnshek (1984) derives minimum total column densities of a few times 10^{20} cm^{-2} for the quasars in his sample. These values for total absorption are much smaller than the value required if the X-ray absorption is intrinsic to PHL 5200. It is possible that a similarly large intrinsic absorption in some BAL quasars might be responsible for making them appear faint at low energies and, therefore, undetectable with the soft X-ray detectors such as the IPC.

The measurement of the column density and location of the absorbing gas in the BAL quasars can be very useful for studying the optical and radio characteristics of the gas in the quasars. Bregman (1984) using an upper limit of 10^{22} cm^{-2} for the column density in BAL quasars derived certain properties of the absorbing gas in such systems. Similar properties of the gas but with 10^{22} cm^{-2} as a lower limit apply for PHL 5200. The radio continuum (5 GHz) emission from this quasar is very weak and this may indeed be related to the presence of a very high electron density (> 10^4 cm^{-3}) which corresponds to N_H = 10^{23} cm^{-2} and a continuum source size of 10^{19} cm, i.e, roughly the size of the broad-line cloud region. It is also possible that the absorbing gas clouds are in a highly flattened geometry and that we are viewing the source along such a disk or shell around the continuum source.

Intrinsic absorption like the one suggested by the present data for PHL 5200, has so far been observed in only three other quasars viz., MR 2251-179 (Halpern, 1984), 3C 446 (Garilli and Tagliaferri, 1986) and 1E0104.2 + 3153 (Gioia et al. 1986). More sensitive broad-band X-ray spectroscopic measurements using large X-ray telescopes are needed to confirm the results of the present investigation.

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