SIMPLE PHOTOELECTRIC ABSORPTION DURING DIPPING IN THE ASCA OBSERVATION OF XB 1916—053

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ABSTRACT

We report results of analysis of the ASCA observation of the low-mass X-ray binary dipping source XB 1916—053 made on 1993 May 2, during which dipping was very deep, so that in the deepest parts of dips, the X-ray intensity in the band 0.5—12.0 keV fell to zero, demonstrating that all emission components were completely removed. The best-fit orbital period of the binary system, determined from the X-ray data, was found to be 3005 ± 10 s. The high-quality ASCA data allowed spectral evolution in dipping to be systematically investigated by spectral analysis in intensity bands covering the full range of dipping from intensities close to zero to nondip values. We have shown that the spectra can be well fitted by the same two-component model previously used to give good explanations of the very different dip sources X1755—338 and X1624—490, consisting of point-source blackbody emission from the neutron star and extended Comptonized emission, probably from the accretion disk corona. In the case of XB 1916—053, we show that all levels of dipping can be fitted using $kT_{bb} = 2.14 ± 0.28$ keV and power-law photon index $\Gamma = 2.42 ± 0.21$, which are the best-fit values for nondip data, together with the corresponding nondip normalizations. Dipping is shown to result from large increases in column density for the pointlike blackbody, combined with the extended power-law component being progressively covered by the absorber, until, in the deepest parts of dips, the partial covering fraction approaches unity. This approach differs radically from the “absorbed-plus-unabsorbed” approach previously used in spectral modeling of XB 1916—053 and similar sources, in which the normalization of the unabsorbed component is allowed to decrease markedly in dipping, behavior that is generally attributed to the effects of electron scattering. Thus, we have shown that spectral evolution in XB 1916—053 can be explained simply in terms of photoelectric absorption and electron scattering in the absorbing region, which shows that little electron scattering is expected in the ASCA energy band.

Subject headings: accretion, accretion disks — binaries: close — scattering — stars: circumstellar matter — stars: individual (XB 1916—053) — X-rays: stars

1. INTRODUCTION

XB 1916—053 is an important member of the class of ~10 low-mass X-ray binary (LMXB) sources that exhibit decreases in X-ray intensity at the orbital period, which are generally accepted as being due to absorption in the bulge in the outer accretion disk, where the flow from the companion impacts on the outer disk (White & Swank 1982). XB 1916—053 is unusual in several respects. It has the shortest orbital period of the dipping sources: 50 minutes (Walter et al. 1982). It has a depth of dipping that is highly variable, at times reaching 100%. The source is also notable for the pointlike blackbody, combined with the extended power-law component being progressively covered by the absorber, until, in the deepest parts of dips, the partial covering fraction approaches unity. This approach differs radically from the “absorbed-plus-unabsorbed” approach previously used in spectral modeling of XB 1916—053 and similar sources, in which the normalization of the unabsorbed component is allowed to decrease markedly in dipping, behavior that is generally attributed to the effects of electron scattering. Thus, we have shown that spectral evolution in XB 1916—053 can be explained simply in terms of photoelectric absorption and electron scattering in the absorbing region, which shows that little electron scattering is expected in the ASCA energy band.

Three EXOSAT observations were made, the results of Smale et al. (1988) showing that the average extent of dipping changed markedly between the observations, as shown by comparing the light curves folded on the X-ray period for the three observations. Spectral analysis showed that nondip data for all three observations was best fitted by a simple power-law model with photon index $\Gamma$ close to 1.80. Dip spectra were selected in intensity bands from all three observations, for which the best fit was a model consisting of two power laws, each with the index fixed at the above value. The column density of the one component could be held at the quiescent value while that of the other component increased strongly in dipping; i.e., there was an absorbed and an unabsorbed term. For the unabsorbed component, the normalization decreased strongly in dipping. This “absorbed-plus-unabsorbed” approach has been used for several of the dip sources: XBT 0748—676 (Parmar et al. 1986), X1254—690 (Courvoisier et al. 1986), and X1624—490 (Jones & Watson 1989). It is clear that the parameters of the source emitting regions cannot change coincidentally with dipping, and the strong decrease in normalization of the unabsorbed component has been attributed to the effects of electron scattering in the absorber (Parmar et al. 1986; Smale et al. 1988); i.e., there is a decrease in flux from the source that is due to scattering and that does not reveal itself as low-energy absorption. More recently, Ginga data on XB 1916—053 has also been fitted by the absorbed-plus-unabsorbed approach (Smale et al. 1992; Yoshida et al. 1999). Yoshida et al. showed that the variation in normalization can be reproduced as absorption by cold matter if electron scattering in the absorber is taken into account.

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XB 1916—053 shows increases in hardness during dip ingress. It was originally expected that all of the dipping sources would show hardening during dipping, because of photoelectric absorption of the X-ray spectrum in the absorbing bulge, which preferentially removes the lower energy X-rays. However, the dip sources do not, in general, comply with this expectation; some sources show a hardening, but some show a marked softening in dipping (e.g., X1624—490; Church & Balucinska-Church 1995), which is totally unexpected in simple physical models, i.e., models with a single emission component. Furthermore, X1755—338 has dipping that is independent of energy in the 1–10 keV band (White et al. 1984).

Several types of spectral models have been used in fitting the dipping sources. The EXOSAT spectra of several dipping sources were fitted by a Comptonization model (White, Stella, & Parmar 1988) represented by a single-component absorbed cutoff power law. Other workers have used two-component models, notably Mitsuda et al. (see, for example, Mitsuda et al. 1984). Apart from this difference in approach, individual dipping sources have generally been fitted by different spectral models. In particular, the absorbed-plus-unabsorbed approach has involved different spectral forms when applied to different sources, i.e., power law plus power law, cutoff power law plus cutoff power law, etc. More recently, Church & Balucinska-Church (1993, 1995) have proposed a two-component or “complex continuum” model that has been able to explain the softening in dipping in X1624—490 and the energy independence of dipping in X1755—338, using the same model. In this model X-ray emission originates as blackbody radiation from the boundary layer at the surface of the neutron star plus power-law emission representing Comptonization in an accretion disk corona (valid at energies much lower than the Comptonization break). In the above sources the model shows that dipping is primarily due to absorption of the point-source blackbody emission, with comparatively little absorption of the extended power-law emission. Whether there is softening, hardening, or energy independence depends mostly on the blackbody temperature. In X1624—490, this is higher than in X1755—338 ($kT_{bb}$ = 1.39 keV, compared to 0.88 keV), so that removal of the blackbody leaves the residual spectrum softer than in nondip emission. The main aim of the present work was to test the complex continuum model in the case of XB 1916—053 using high-quality ASCA data and to test whether this physical model can offer an alternative to the absorbed-plus-unabsorbed approach.

2. RESULTS

The 18 hr observation of XB 1916—053 was made by ASCA on 1993 May 2 (Tanaka, Inoue, & Holt 1994). The quality of the data was very good. We primarily present here the results for the analysis of the GIS2 and GIS3 detector data (see Ohashi et al. 1996), which were screened to remove regions of South Atlantic Anomaly (SAA) passage and to restrict elevation of the source above the limb of the Earth to more than 5°; particle cutoff rigidity to more than 6, angular deviations of the telescope pointing to less than 0.6, and the radiation belt parameter to less than 500. Rise-time discrimination was applied in order to remove detector particle background. Data were preselected from the image to remove the region of the calibration source and outer ring in the image, and source data were taken from a 6° radius circle centered on the source. Various tests were made to determine the best way of subtracting background, and eventually we found that the most reliable background subtraction could be obtained by taking background data from a circular region of radius 8', offset from the center of the image by the same amount as the source region (~2'), diametrically opposite to the source, and containing no visible point sources. This region provided a sufficiently large count for background subtraction, which is important, with a count rate of 0.13 counts s$^{-1}$.

The total observation of XB 1916—053 spanned about 22 orbital cycles. The good data inbetween SAA passage and Earth occultation included parts of about 10 dips. Much of this dip data was very fragmented; however, during the first five orbital cycles observed, complete data were obtained for two orbital cycles. In addition, complete data were obtained from this part of the observation for one more dip. Burst data were contained in the observation but did not remain in GIS data after screening, so they did not affect our spectral analysis.

2.1. Light Curves and Hardness Ratio

Light curves were extracted in various energy bands, and it was found that during part of every dip, the count rate fell to zero in the total band of the GIS detectors from 0.5 to 12.0 keV. The background-subtracted light curve of the GIS2 data is shown in Figure 1, in which the good coverage of three dips in the early part of the observation can be seen, as well as the relatively poor definition of later dips. Interdips between the main dips can also be seen.

A hardness ratio was obtained by dividing the counts per second in the 2.0–12.0 keV band by the counts per second in the 0.5–2.0 keV band; the light curves in these bands and the plot of hardness ratio against time are shown in Figure 2 for one orbital cycle including nondip, interdip, and dip data. Increases in hardness ratio at dip ingress and egress and in interdips can be seen; during deep dipping, when all count rates were very small, the hardness ratio is not well determined. The depth of dipping, defined as the maximum percentage decrease in count rate, was investigated as a function of energy by plotting light curves in several energy bands. In the lower bands (0.5–2.0, 2.0–4.0, and 4.0–6.0 keV), dipping was 100%; in the higher band (6.0–12.0 keV), the depth possibly decreased to 95 ± 5%. Thus, dipping was remarkably deep at all energies, implying an absorber of high column density completely covering all emission regions. In the interdips, dipping was not 100%.

2.2. Light-Curve Folding Analysis

For determining the best-fit X-ray orbital period, we used fast-mode SIS0 data for the whole observation with time resolution of 1 s. The data were folded on trial periods spanning the range 2900–3100 s in order to find the most probable period, from which a best value of 3005 ± 10 s was obtained. In Figure 3 we show the GIS2 light curve from the first five orbital periods in the observation folded on this period (to avoid severe distortion of the folded light curve by adding in data not containing interdips, for example). It is difficult to be certain of the errors attached to this period. The errors of ±10 s represent the range of possible periods around the most likely value in the plot of $\chi^2$ versus period produced by the period searching program, consistent with the scatter of the $\chi^2$ points. However, the period is determined using dip data of variable length, depth, and quality,
and the errors are inevitably larger than in fitting, for example, a coherent oscillation. By folding the data on periods outside the range of the errors above (within $3005 \pm 20$ s), it was found that folded light curves with shapes consistent with the raw light curves could be produced, so the real errors may be somewhat larger than those quoted. Previous values for the X-ray period were determined from EXOSAT data, for example, to be $3015 \pm 17$ s, and from Ginga data to be $3005 \pm 6.6$ s (Smale et al. 1992).

From Figure 3 it can be seen that the main dip lasts 33% of

**Fig. 1.—ASC A GIS2 light curve for the complete 18 hr observation of XB 1916–053 in the 0.5–12.0 keV energy band with 16 s binning**

**Fig. 2.—GIS2 light curves for the third section of data in Fig. 1 (in the 2.0–12.0 and 0.5–2.0 keV energy bands) and the hardness ratio formed by dividing these.**
the orbital cycle, implying an absorbing region that subtends an angle of 120° at the neutron star. The consequence of this is that the absorbing region must be very extended azimuthally and may therefore also be extended in height above the disk. Thus, it might be expected that the depth of dipping can reach 100% as observed, since all emission regions can be covered by the absorber during dips—not only point-source emission from the neutron star, but also extended emission regions. This will be relevant to the spectral modeling discussed below.

2.3. Spectral Evolution in Dipping

The very large depth of dipping in XB 1916—053 during the ASCA observation—the complete coverage of several dips and the high quality of the data—have allowed detailed investigation of spectral evolution in dipping by dividing the data into intensity bins. GIS2 data were divided into bands corresponding to nondip data, 4.0–5.0 counts s⁻¹, and various levels of dipping at 3.0–4.0, 2.0–3.0, 1.0–2.0, and 0.0–1.0 counts s⁻¹, and spectra produced. The corresponding GIS3 data were selected by using the time filters produced when GIS2 data were selected into intensity bands. Because of differences between the detectors, these GIS3 data formed bands that were somewhat different in intensity from the original GIS2 bands. GIS2 and GIS3 spectra were added, systematic errors of 2% added to each channel, and the data regrouped to a minimum of 100 counts per bin. Channels below 0.7 keV and above 10.0 keV were ignored. Response functions and effective areas were used in the spectral fitting as appropriate to the regions from which the data were extracted, and the GIS2 and GIS3 effective area files were combined. Background spectra from GIS2 and GIS3 were combined appropriately. Nondip and dip data were fitted by a number of spectral models, beginning with various simple models such as an absorbed power law, absorbed blackbody, and absorbed bremsstrahlung.

The absorbed power-law model gave a formally acceptable fit to all intensity bands except the lowest intensity band, for which the reduced $\chi^2$ was 2.8. However, the power-law photon index varied between 1.76 in nondip and 0.61 in deep dipping, which is clearly not acceptable physically. The absorbed blackbody could not fit nondip data, giving a $\chi^2$ of 9.9, and the absorbed bremsstrahlung model had $\chi^2$ values in the range 1–4.7 for various intensity bands and $kT$ values varying between 9.4 and 200 keV. Thus, it is clear that simple models cannot be used.

Consequently, we next attempted to fit the kind of two-component model as was used for the sources X1755—33 and X1624—490 (Church & Balucinska-Church 1993, 1995), consisting of a blackbody component associated with the neutron star and a power-law component associated probably with the accretion disk corona. Each component was given its own absorption term, and the model may be represented as $AB_1 \times BB + AB_2 \times PL$. This was related to the appearance of a double-humped shape to the dip spectra, i.e., the apparent existence of an unabsorbed component at lower energies, or soft excess. In the absorbed-plus-unabsorbed approach, the low-energy hump is the unabsorbed component that persists into dipping, even though the higher energy hump is strongly absorbed. As we were unable to fit the two-component model with normalizations fixed at the nondip values, we next fitted the same model with free normalizations. This model gave an acceptable fit to all intensity levels. The normalization of the power-law component decreased by a large factor, and the blackbody column density increased by...
a large amount in dipping. Thus, this is a form of the absorbed-plus-unabsorbed approach that represents a halfway stage between the normal absorbed-plus-unabsorbed approach and our final best-fit modeling below.

An integral part of the complex continuum model is that the source emission parameters cannot change during dipping, and so the normalizations should be held constant. However, during dipping, the count rate falls to zero, and the model must reproduce this. Thus, in this particular source the appropriate form of the complex continuum model to be used must allow for all emission regions to be covered by the absorber, and we therefore applied the model in the following form: $\text{AB}^* \text{BB}^* \text{AG}^* [\text{AB}^* f + (1 - f)]^* \text{PL}$, where AG represents Galactic absorption and $f$ is a partial covering fraction. The blackbody absorption term also includes Galactic absorption, of course; however, we have investigated the best values of column density of the two components as discussed below, and this was done by varying the AG term. With the above spectral model, a good fit was obtained to the nondip data, giving values for the blackbody temperature $kT_{\text{bb}} = 2.14 \pm 0.28$ and power-law index $\Gamma = 2.42 \pm 0.21$. With $kT_{\text{bb}}$, $\Gamma$, and the corresponding normalizations fixed at the best-fit nondip values, very good fits could be obtained to all intensity levels of dip data, with $\chi^2$ being always less than 0.84.

Extensive testing was carried out to determine whether interdips should be included with main dip data. It was found that differences in spectral fitting parameters between dip data and interdip data at the same intensity were generally within 90% confidence errors, although there was some tendency for blackbody column densities to be higher in dips. To obtain better statistics, the final analysis was carried out including all dips and interdips. The best $N_H$ values for the blackbody and power-law components for the nondip spectrum were determined by fixing the AG term in the spectral model at various values and determining $\chi^2$ and the total column density of each component.

When the AG term was fixed at $2 \times 10^{21}$ atoms cm$^{-2}$ (the Stark et al. 1992 value), the blackbody column density became very large: $60 \times 10^{21}$ atoms cm$^{-2}$, with $\chi^2$ equal to 9.0. As the AG term was increased, $\chi^2$ decreased to a value of $\sim 0.78$ when the blackbody and power-law column densities were equal, with a value of $4.75 \times 10^{21}$ atoms cm$^{-2}$. This value is in excess of the Stark et al. value, implying a degree of intrinsic absorption in the source during this observation. Plots of the spectral fitting results as a function of X-ray intensity are shown in Figure 4, and parameter values are given in Table 1.

Figure 5 shows source spectra for nondip, intermediate dip, and deep-dip data, together with the two model components, in order to illustrate how the spectral components of the complex continuum model can successfully model the dipping. It can be seen that there is little evidence for spectral-line features in the nondip data. Because of its relatively high temperature ($kT_{\text{bb}} = 2.14$ keV), the blackbody peaks at $\sim 6.5$ keV, i.e., in the higher energy part of the ASCA spectrum. As this component is pointlike, it is immediately covered by the absorber, and $N_H$ increases by about a factor of 25 as the intensity falls from 4.0–5.0 to 2.0–3.0.

| $I$ (counts s$^{-1}$) | $N_{H(\text{BB})}$ (10$^{22}$ atoms cm$^{-2}$) | $N_{H(\text{PL})}$ | $f$ | $\chi^2$ |
|---------------------|-----------------------------|-----------------|-----|--------|
| 4–5                 | 0.48 ± 0.18                 | 0.48 ± 0.18     | 0.00$^{+0.02}_{-0.00}$ | 0.78  |
| 3–4                 | 4.3 ± 0.6                   | 1.5 ± 0.5       | 0.14 ± 0.04 | 0.84  |
| 2–3                 | 13.8 ± 2.7                  | 2.7 ± 0.5       | 0.37 ± 0.03 | 0.84  |
| 1–2                 | 26.7 ± 12.6                 | 5.4 ± 1.3       | 0.72 ± 0.03 | 0.67  |
| 0–1                 | $>600$                      | 35.6 ± 2.7      | 0.95 ± 0.01 | 0.49  |
Hz. The power law, however, starts with a partial covering fraction of zero and at first suffers little absorption. Thus, as dipping develops, the power law remains as a low-energy peak, while at higher energies, the blackbody is strongly absorbed. In deeper dipping, $N_H$ for the blackbody increases to at least $6000 \times 10^{21}$ atoms cm$^{-2}$, completely removing this component. The partial covering fraction reaches 0.95, $N_H$ for the power law also becomes high at $350 \times 10^{21}$ atoms cm$^{-2}$, and the power law is split between the low-energy hump that is the 5% not covered and the higher energy hump that is covered but not totally absorbed. Finally, the fluxes of both components become zero. Thus, there are no changes in normalization, and the dipping can be explained simply in terms of photoelectric absorption of the point-source blackbody emission from the neutron star, combined with absorption of the extended power-law component by a relatively large absorbing bulge, such that the extended component is progressively covered by the absorber. In this model the "absorbed" part is the blackbody plus the covered part of the power law, and the "unabsorbed" part is the uncovered power law.

3. DISCUSSION

We have demonstrated that the two-component model can describe the spectral evolution in XB 1916−053 well. In this model emission originates as point-source blackbody emission from the neutron star plus extended power-law emission, probably from the accretion disk corona. In the case of XB 1916−053, the source intensity in the 1.0−10.0 keV band often actually becomes zero in the deepest parts of dips. In X1755−338 and X1624−490, dipping was not 100%, and spectral evolution during dips was explained by the two-component model, with dipping being primarily due to absorption of the blackbody (Church and Balucińska-Church 1993, 1995). In the case of XB 1916−053, it was necessary to allow the spectral modeling to take account of the fact that the power-law component must be totally removed in deepest dipping. The modeling that we performed showed that it was not sufficient to use a spectral form $AB^*BB + AB^*PL$; the data could not be fitted by this model with fixed normalizations. It was necessary to allow the extended power-law component in our model to be progressively covered by the absorber; extended emission would not be covered essentially instantaneously, as is the point-source component. With the inclusion of the partial covering term, the two-component model provides very good fits to the spectra.

The fluxes of the blackbody and power-law components in the nondip data in the energy range 1−10 keV are $0.98 \times 10^{-10}$ ergs cm$^{-2}$ s$^{-1}$ and $1.83 \times 10^{-10}$ ergs cm$^{-2}$ s$^{-1}$, respectively, so the blackbody contributes 34% to the total energy flux in this band. In X1755−338 and X1624−490, in which the two-component model showed that dipping was primarily due to absorption of the blackbody, the spectral evolution in dipping is determined by $kT_{bb}$; in X1624−490 $kT_{bb}$ was 1.39 keV, with the blackbody peaking at ~4.5 keV, i.e., it was relatively hard, so the residual power-law spectrum when the blackbody was absorbed was softer. XB 1916−053 has an even higher $kT_{bb}$ of 2.14 keV; however, this does not determine the spectral evolution during dips, since both components are absorbed. The low-energy cutoff of the spectrum is determined by the power-law component, and the hardening observed at dip ingress is clearly simply due to absorption of the low-energy part of the spectrum.

Perhaps the most interesting question is whether we expect electron scattering to be important in the absorbing region producing the dips. In other dip sources in which the...
absorbed-plus-unabsorbed approach was not used, electron scattering was not thought to be important. Electron scattering may take place inXB 1916—053between the source regions and the absorbing bulge in the outer disk, but this will occur in both nondip and dip cases, and so is not relevant. In the absorbing region, we can determine the state of ionization by estimating the ionization parameter $\xi$, using the column density of the point-source blackbody component as a probe of density along a track through the absorbing bulge as dipping develops. Parts of the absorber at different radial positions from the center of the absorber will contribute to the attenuation of the incident radiation as dipping develops, having different lengths along the line of sight. We can write $\xi = L_e/N_H r$, where $L$ is the luminosity, $r$ is radial distance from the source, and the thickness of the absorber along the line of sight is a fraction $\epsilon$ of the accretion disk radius, assumed to fill approximately the Roche lobe of the neutron star. From our best-fit modeling, electron scattering, and we have shown that in the $\epsilon > 0.03$, we get $\xi = 5$, so some elements only can be at most singly ionized.

In both cases described above in which ionization is not complete, the relative importance of photoelectric absorption and electron scattering is given by the ratio $N_H \sigma_{pe}/N_e \sigma_T$, where $\sigma_{pe}$ is the total photoelectric-absorption cross section, $\sigma_T$ is the Thomson-scattering cross section, and $N_e$ is the electron column density. This follows from the dependences of the processes on $\exp - N_H \sigma_{pe}$ and $\exp - N_e \sigma_T$.

For a completely ionized plasma of a medium with solar abundances, the electron density $n_e$ can be calculated to be related to the ion density $n_i$, via $n_i \approx 1.2 n_e$, since elements other than $H$ contribute more than one electron, but with small abundances. Thus, in the above cases $N_H \approx N_e$, and the above ratio is dominated by the ratio of cross sections. At 1 keV, $\sigma_{pe}/\sigma_T \approx 500$; at 4 keV, $\sigma_{pe}/\sigma_T \approx 10$; and at 10 keV, $\sigma_{pe}/\sigma_T \approx 2$. Thus, photoelectric absorption strongly dominates over electron scattering throughout most of the ASCA band. We should also consider how this depends on $N_H$. As the column density increases in deep dipping, corresponding to the central regions of the absorber, at $N_H = 1.5 \times 10^{24}$ atoms cm$^{-2}$, the optical depth for electron scattering becomes unity. However, the product $N_H \sigma_{pe}$ will be $\gg 1$, i.e., the probability of photoelectric absorption is still much higher than that of electron scattering. If incident photons are allowed to be simultaneously absorbed and scattered, in deep dipping, the factor $\exp - N_e \sigma_T$ implies that an appreciable fraction of the radiation that is incident upon the absorber could be scattered. The average column density of $35.6 \times 10^{22}$ atoms cm$^{-2}$ from spectral fitting implies a loss of 20% by scattering, and it could be argued that the spectral model that we have applied should be modified for deep dipping. However, if there is a density gradient in the absorber, with $N_H = 10^{22}$—$10^{23}$ atoms cm$^{-2}$ in the outer layers, the optical depth for absorption will be greater than 1, but for scattering it will be less than 1. Thus, photons will be preferentially removed before they reach the higher density central regions in which scattering would play a part. At 10 keV, this preferential absorption will be much weaker, so that in deepest dipping, electron scattering of the high-energy photons will take place. By this stage of dipping, the blackbody emission is already highly absorbed, leaving flux only in the range just below 10 keV. Thus, our value of $N_H$ for the blackbody in deepest dipping of greater than $600 \times 10^{22}$ atoms cm$^{-2}$ may be an overestimate, as some decrease of normalization may be appropriate for this term, which would imply a smaller $N_H$ value.

Thus, in summary, we have shown that the physical model used by Church & Balucinska-Church to explain the dipping sources X1755—338 and X1624—490 also provides a good explanation for XB 1916—053. In all of these cases, the model can be expressed as point-source blackbody emission plus extended Comptonized emission that is modified by partial covering. For the first two sources, the partial covering fraction $f$ is small, but for XB 1916—053, $f$ becomes large in dipping. Consequently, it is possible to explain the dipping in XB 1916—053 purely in terms of photoelectric absorption in a bulge in the outer accretion disk. There is no need for there to be substantial electron scattering, and we have shown that in the ASCA band, little scattering is, in fact, expected. The explanation of three very different members of the dipping class by the two-component model makes it increasingly likely that it will be able to explain all members of the class.

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