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Miller, J.M.; Wijnands, R.A.D.; Wojdowski, P.; Groot, P.J.; Fabian, A.C.; van der Klis, M.; Lewin, W.H.G.

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X-ray Absorption Lines in the Galactic Black Hole Candidate XTE J1650-500

ATEL # 81; [Jon Miller \(MIT\), Rudy Wijnands \(MIT\), Patrick Wojdowski \(MIT\), Paul Groot \(CfA\), Andrew Fabian \(Cambridge\), Michiel van der Klis \(Amsterdam\), and Walter Lewin \(MIT\), on behalf of a larger collaboration](#)

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Password Certification: Rudy Wijnands (rudy@space.mit.edu)

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We report the first convincing detection of narrow features in the grating-resolution X-ray spectrum of a transient low-mass X-ray binary and Galactic black hole candidate. XTE J1650-500 was discovered by Remillard (2001, IAU Circ. 7707) with the All Sky Monitor aboard the Rossi X-ray Timing Explorer (RXTE), and identified as a black hole candidate due to its hard spectrum. Our observations of the source throughout its fall-winter 2001 outburst with the RXTE Proportional Counter Array (PCA) reveal spectra and rapid variability consistent with Galactic systems dynamically constrained to have black hole primaries. Optical observations revealed spectra consistent with a low-mass donor star (Augusteijn, Coe, & Groot 2001, IAU Circ. 7710).

We observed XTE J1650-500 with the Chandra High Energy Transmission Grating Spectrometer (HETGS) twice during the "high/soft" state, at flux levels of approximately 0.40 and 0.25 Crab (1.5-12 keV). Each observation was 30 ksec in duration, and the 0.5-10.0 keV energy spectrum was strongly dominated by a soft thermal component with $kT=0.5-0.7$ keV. A Ne IX resonance line and a transition from an Fe XVIII multiplet are clearly detected in absorption in both spectra, in addition to a myriad of lines of lower intensity which seem to be present. To view a figure illustrating these lines, please see <http://space.mit.edu/~jmm/1650lines.ps>. The expected strength of the Fe L1 edge near the Fe XVIII line is negligible compared to the strength of the line. The neutral Ne K edge from the ISM seen in the spectra is consistent with solar abundances. The spectra were fit locally with power-law continua and the lines were fit with simple Gaussians. The F-statistic probability that the Ne IX R line in the first observation is due to random fluctuations is $P = 7 \text{ E-}3$; for

the Fe XVIII line in the first observation and both lines in the second observation, P is less than $1 \text{ E-}8$.

For a variety of spectral forms incident on a nebula, Kallman & McCray (1982, ApJS, 50, 263) have calculated the temperature at which line features from the irradiated gas will be strongest (assuming a gas in photoionization equilibrium). This work indicates that the Ne IX R and Fe XVIII lines we have observed are likely due to a gas with $\log(T) = 5.0\text{-}5.5 \text{ K}$ -- nearly two orders of magnitude below the inner disk temperature as measured from the dominant thermal continuum spectral component. These lines are resolved, and show small net red-shifts of $140\text{-}300 \text{ +/- } 50 \text{ km/s}$ and FWHM velocity widths between $300\text{-}600 \text{ +/- } 100 \text{ km/s}$. It is possible that these lines represent absorption in an ionized accretion disk atmosphere or accretion disk wind. Previous observations of transient Galactic black holes with low-mass companions with Chandra and XMM-Newton have not clearly revealed line features; in many cases this has been due to limited statistics. The lines we report here (and weaker lines to be reported in detail in forthcoming work) underscore the promise of high-resolution X-ray spectroscopy for revealing the accretion environment in such systems. We acknowledge Harvey Tananbaum and Jean Swank for executing our target-of-opportunity programs, and assistance from the CXC ISIS team.