MODELING X-RAY PHOTOIONIZED PLASMAS PRODUCED AT THE SANDIA Z-FACILITY

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Abstract. In experiments at the high-power Z-facility at Sandia National Laboratory in Albuquerque, New Mexico, we have been able to produce a low density photoionized laboratory plasma of Fe mixed with NaF. The conditions in the experiment allow a meaningful comparison with X-ray emission from astrophysical sources. The charge state distributions of Fe, Na and F are determined in this plasma using high resolution X-ray spectroscopy. Independent measurements of the density and radiation flux indicate unprecedented values for the ionization parameter $\xi = 20–25 \text{ erg cm s}^{-1}$ under nearly steady-state conditions. First comparisons of the measured charge state distributions with X-ray photoionization models show reasonable agreement, although many questions remain.

Keywords: photoionization, X-ray, spectroscopy

1. Introduction

With the recent launch of the X-ray observatories \textit{Chandra} and \textit{XMM-Newton}, high resolution spectra from numerous photoionized X-ray sources such as X-ray binaries and active galactic nuclei are being obtained. With these instruments we are able for the first time to resolve individual lines in these spectra, and they often contain prominent lines from iron which can be used as diagnostics for the physical conditions in the plasma. However, the analysis of these lines is hampered, amongst other things, by a lack of high quality atomic data and uncertainties in the treatment of the energy balance in optically thick plasmas. As a consequence, we do not know how accurate the results from our modeling codes are. To address this problem, we have set up an experiment to create a near steady-state laboratory X-ray photoionized plasma with observationally constrained physical conditions that are astrophysically relevant. We have produced a low-density plasma of Fe mixed with NaF, and observed absorption and emission spectra of this plasma which will
be used to benchmark existing astrophysical and laboratory modeling codes. These experiments are being combined with an effort to calculate high quality atomic data of relevant iron ions. In Section 2 we briefly describe the experiment and the determination of the physical parameters, while in Section 3 we describe the current status of our modeling effort. Finally, in Section 4 we briefly outline the current status of our atomic data calculations.

2. The Experiment

In experiments at the high-power Z-facility at Sandia National Laboratory in Albuquerque, New Mexico, we have been aiming to produce a low density photoionized laboratory plasma of Fe mixed with NaF. The radiation from the z-pinch is generated by inductively coupling a 20 MA, 100 ns rise time current pulse into a 2 cm diameter wire array, consisting of 300 tightly strung 11.5 \( \mu m \) tungsten wires. The electromagnetic forces drive the wires radially inward onto the central axis, creating a 8 ns FWHM, 120 TW peak power, 165 eV near-blackbody radiation source. The emission from the z-pinch was directly observed by several spectrometers, which allowed us to determine the time-resolved history of the absolute spectral flux of the pinch. The spectrum at peak emission is shown in Figure 1.

Free standing thin (500–750 Å) rectangular foils were suspended in frames and positioned parallel to the z-axis of the pinch at a distance of 1.5–1.6 cm. The foils consisted of a 1.35:1 molar ratio of Fe/NaF and were overcoated on each side with 1000 Å of lexan (C\(_{16}\)H\(_{14}\)O\(_{3}\))\(_n\) to help maintain uniform conditions during heating and expansion. The radiation generated during the 100 ns run-in phase preheats and expands the foil to about 1.5–2 mm. When the wires collide on axis, the resulting

![Figure 1. Z-pinch X-ray spectral emission measured at peak power with an XRD array (histogram), a transmission grating spectrometer (dots), and a PCD array (squares). The peak-normalized 165 eV blackbody fit is also shown.](image-url)