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Laboratory measurements of the x-ray line emission from neon-like Fe XVII

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ABSTRACT

We have conducted a systematic study of the dominant x-ray line emission from Fe XVII. These studies include relative line intensities in the optically thin limit, intensities in the presence of radiation from satellite lines from lower charge states of iron, and the absolute excitation cross sections of some of the strongest lines. These measurements were conducted at the Lawrence Livermore National Laboratory electron beam ion trap facility using crystal spectrometers and a NASA-Goddard Space Flight Center microcalorimeter array.

1. Introduction

The x-ray line emission from neon-like Fe XVII has been observed in several astrophysical sources such as the corona of the Sun, other stellar coronae, and elliptical galaxies. Because they create a distinct spectral signature and are present over a large temperature range, Fe XVII x-ray lines are prime diagnostic candidates. To help uncover the diagnostic potential of these lines and understand Fe XVII line emission observed in both celestial and laboratory sources, we have used the LLNL electron beam ion trap facility in conjunction with crystal spectrometers and a microcalorimeter to conduct a study of the Fe XVII line emission under well-controlled laboratory conditions. Here we give a brief overview of some of the experimental results focussed on measuring the intensities of the resonance and intercombination lines, located at λ=15.01 Å and 15.26 Å, and known as 3C and 3D, respectively.

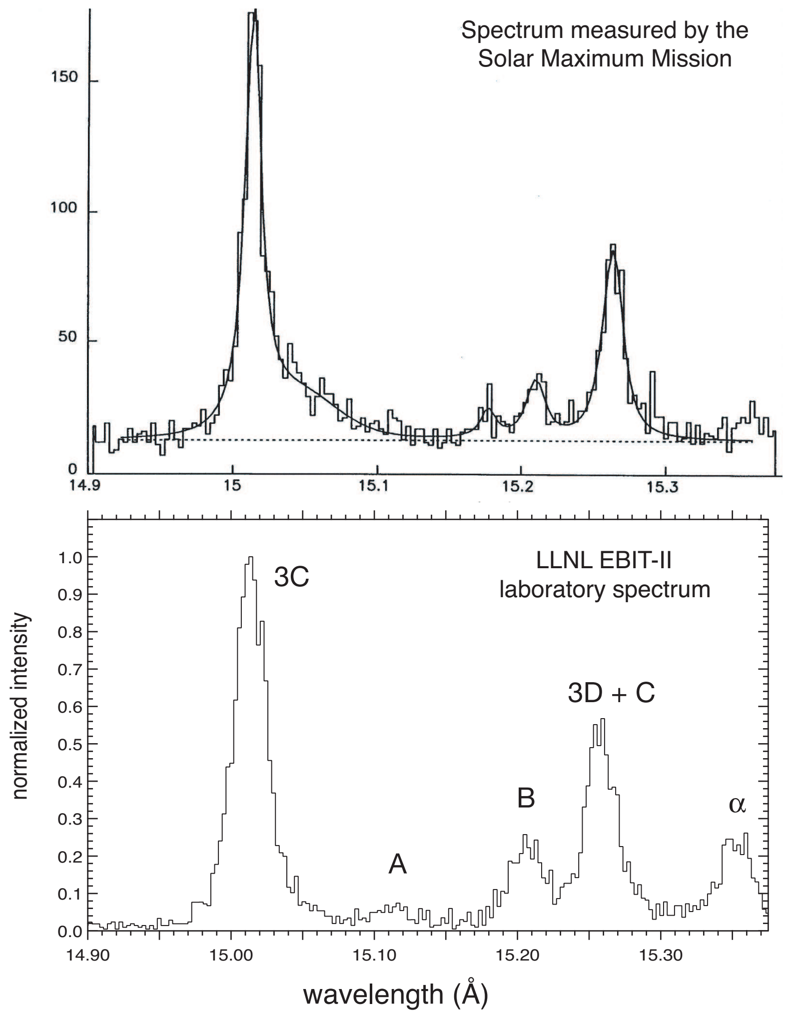

Fig. 1.— (top) Spectrum emitted from a quiescent active region of the Sun and measured by the Solar Maximum Mission (Brickhouse & Schmelz 2006). (bottom) Spectrum measured using a crystal spectrometer and the LLNL EBIT-II (Brown et al. 2001) where the relative abundance of Fe XVI to Fe XVII ions is ∼1. The lines are 3C and 3D from Fe XVII, A, B, and C from Fe XVI, and α from Fe XV.

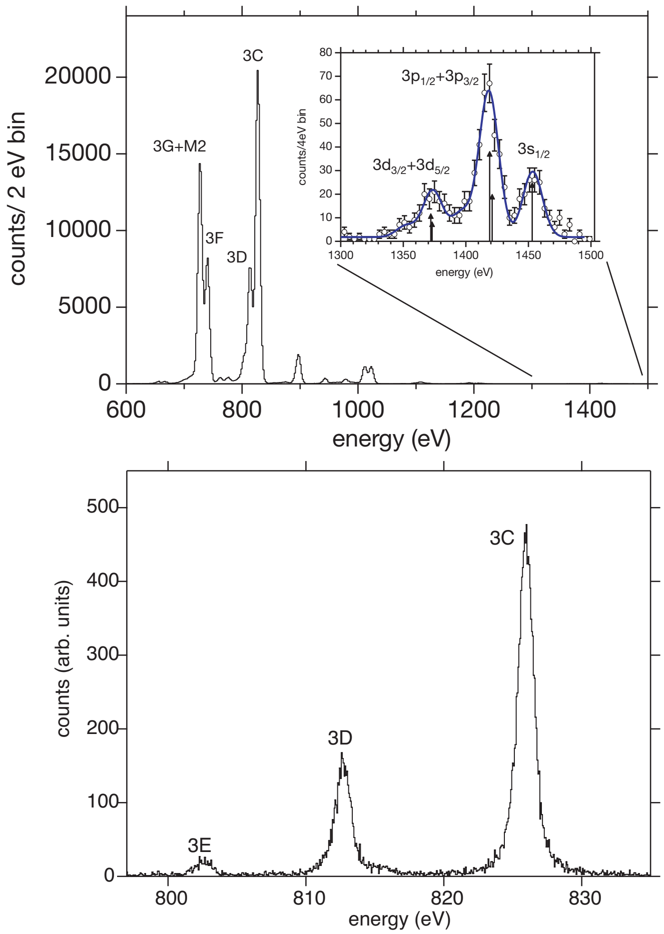

Fig. 2.— (top)Spectrum of Fe XVII measured by the NASA/GSFC 6 × 6 microcalorimeter array. The insert shows a close up of the energy range containing the emission from radiative recombination. (bottom) Fe XVII spectrum measured with a crystal spectrometer in concert with the microcalorimeter spectrum.

2. Measurements

The relative intensity of lines 3C and 3D measured in the Solar corona is significantly less than many predictions. At first, resonant scattering of line 3C was believed to be the source of the discrepancy, and many took advantage of this to infer line 3C's opacity. Measurements by our group (Brown et al., 1998) showed that the relative line intensity in the optically thin limit is less than the theoretical predictions, and in many cases, invoking resonant scattering was not necessary. However, some Solar ratios were still much lower than the laboratory value. Further study by our group found that the lower ratios observed in the Sun could be reproduced in the laboratory when, in addition to the Fe XVII ions, a significant amount of Fe XVI ions are also present (Brown et al. 2001). In this case, an Fe XVI line produced by inner-shell excitation coincides with the Fe XVII intercombination line 3D. The additional flux added to the 3D feature reduces the apparent ratio, I_{3C}/I_{3D}. A recent study by Brickhouse &Schmelz (2006) revisited spectra measured from the Sun and found distinct line emission from Fe XVI. They concluded that the low values for I_{3C}/I_{3D} were explained by the Fe XVI line coincidence. Invoking resonant scattering was not necessary. A comparison of the laboratory spectrum with the spectrum measured from the Sun is given in figure 1.

To provide a more stringent test of theory, we continued our study of 3C and 3D by measuring each line's absolute excitation cross section, as opposed to relative excitation cross sections. The cross sections are brought to an absolute scale by measuring the photon emission from the direct excitation and radiative recombination simultaneously, and then normalizing to the well-known cross sections for radiative recombination. The spectrum including both the RR and direct excitation was measured using the broad-band NASA/GSFC x-ray microcalorimeter. To verify that no blending occurs we also measure the 3C and 3D line emission with a high resolution crystal spectrometer. Figure 2 shows the measured spectra. When comparing to theory, we find that in the case of the line 3C, the predicted cross section is significantly larger than the measurement (Brown, et al. 2006). The lower cross section for 3C helps resolve the puzzling observations by Xu et al. (2002) and Behar et al. (2001) who in their study of NGC 4656 and Capella, respectively, found that consistent results were obtained only if they normalized their spectrum to 3D not to 3C. We also note that recent theoretical calculations have reproduced some of the relative intensities measured in the laboratory and celestial sources (Loch et al 2006). However, owing to the fact that significant differences have been found when comparing absolute cross sections and that, in some physical regimes the relative intensities also do not agree, further study is required.

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