§15. Non-Equilibrium Plasma Diagnostics of Solar Coronal Plasma Verified by Large Helical Device (LHD)

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EUV Imaging Spectrometer (EIS) on board Hinode is observing numerous emission lines from iron ions at various ionization stages for pinning down the mechanism of coronal heating via its spectroscopic observations. Atomic models and their atomic parameters used in these models for solar application could be improved through the experiment of the Large Helical Device (LHD). Independent measurements of plasma temperatures and densities restrict the other plasma parameters in the atomic models in case of the laboratory experiments, which would result to improve the accuracy of these models. The improved models verified by the laboratory experiments will develop new research area in the physics of solar transition region and the mechanisms of chromospheric and coronal heating [1].

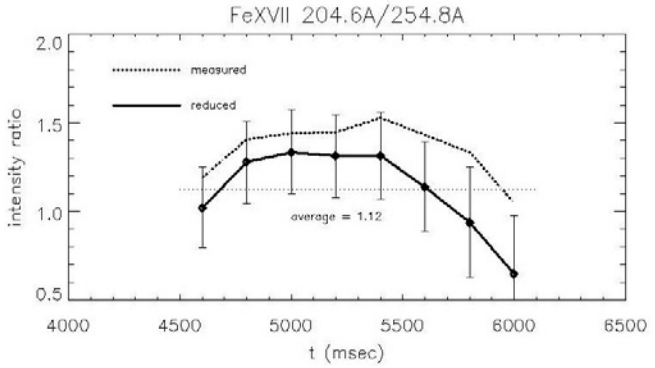

Fig. 1. Intensity line branching ratio of FeXVII λ204.65/λ254.87 measured in LHD TESPEL experiment (No. 107802). The figure shows that the ratio is close to the theoretical value.

EIS has been observing FeXVII lines formed in the core (high-temperature) region of active regions. Ne-sequence iron ions, FeXVII, are formed around the temperature of log $T_e \sim 6.7$, which nearly corresponds to the maximum temperature reached in solar active regions. EIS has detected several weak FeXVII emission lines appearing in its observing wavelengths (170 - 210 Å, 250 - 290 Å), and they are identified as those from the transitions between $2p^5$ 3s/3p - $2p^5$ 3p/3d. The observed line intensity ratios among them are compared with our theoretical calculations. We found that many of them were blended by lower-temperature weak coronal lines, and that the branching ratio of the $2p^53p\ ^3S_0$ level to the $2p^53s$ levels was wrong roughly by a factor of 2 [2].

The intensity ratios of these lines are for the first time successfully measured in LHD at NIFS (see Fig. 1). EUV

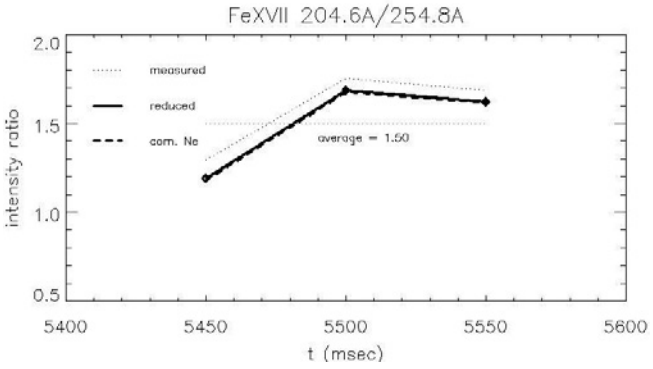

Fig. 2. The same figure for the shot No. 13596, which suffered from more severe blends of cool iron lines of FeXII and XIII.

spectra were taken by injecting the iron TESPELs (Tracer Encapsulated Solid Pellets) into LHD. An Al filter properly blocked the contribution of the emission lines in the 2nd order wavelengths, and relatively cool plasma of $T_e \sim$ 700eV was created by the NBI control. The analysis reveals that the intensity ratios of FeXVII λ 204.6 Å / λ 254.8 Å are less than 1.4 (See Fig. 1). These line ratios could closely reach the theoretical value of ~ 1, if the contributions of FeXIII lines blending is considered in the FeXVII λ 204.6 Å line.

The same line branching ratio was also measured in the LHD experiment conducted in autumn 2012 (See Fig. 2). This time, stronger blends of FeXII and XIII lines near the FeXVII lines were observed and we could not properly estimate the branching ratio, although it still has systematic discrepancy with the solar values observed by EIS. This fact suggests that the in-flight calibration and its degradation since the launch should be revisited.

The next Japanese solar mission (nick-named as "Solar-C") has been kicked-off for conceptual study. A candidate payload (EUVST) for UV/EUV spectroscopic observation will have a capability of observing solar atmospheres in a wider temperature range with higher sensitivity. Diagnostic capability of density sensitive line ratios in higher temperatures above $T_e \sim 10^7$ K will be of interest and the scientific target for next cross validation of atomic models and parameters.

1) Watanabe, T. et al.: 2013, "Evaluation of Spectroscopic Modeling for Iron Ions and Study on Non-Equilibrium Ionization Phenomena for Solar and LHD Plasmas," in Proc. ITC22, PFR in press.
2) Watanabe, T. et al.: 2012, "EUV FeXVII Emission Line Branching Ratio," in 2012 ICAMDATA-8 (Gaithersburg, US).