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Accurate VUV laboratory measurements of Fe III transitions for astrophysical applications

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ABSTRACT

We report preliminary measurements of Fe III spectra in the 1150 to 2500 Å wavelength interval. Spectra have been recorded with an iron-neon Penning discharge lamp (PDL) between 1600 and 2500Å at Imperial College (IC) using high resolution Fourier (FT) transform spectroscopy. These FT spectrometer measurements were extended beyond 1600Å to 1150Å using high-resolution grating spectroscopy at the National Institute of Standards and Technology (NIST). These recorded spectra represent the first radiometrically calibrated measurements of a doubly-ionized iron–group element spectrum combining the techniques of vacuum ultraviolet FT and grating spectroscopy. The spectral range of the new laboratory measurements corresponds to recent *HST*/STIS observations of sharp-lined B stars and of Eta Carinae. The new improved atomic data can be applied to abundance studies and diagnostics of astrophysical plasmas.

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1. Introduction

The disentangling of complex astrophysical spectra to reveal important information is crucially dependent upon a detailed and precise knowledge of each species present. Atomic spectral data of the iron–group elements (Ti, V, Cr, Mn, Fe, Co, Ni) have a major impact on stellar abundance investigations. Doubly ionized species dominate hot star spectra, however the current laboratory atomic database for those ions is inadequate limiting stellar analyses. In particular, there are no laboratory determined oscillator strengths for any of the doubly ionized iron-group elements (including Fe III) in the vacuum UV (VUV, $\lambda < 2000$Å). The lack of accurate atomic data is the major source of uncertainty in the interpretation of expensively acquired stellar spectra and without new intensity calibrated laboratory measurements future astrophysical analysis will be severely restricted.

Knowledge of elemental abundances in stellar photospheres provides information on the chemical evolution of our galaxy and its neighbors, allowing validity checks of theoretical calculations of stellar nucleosynthesis. Hot stars, such as B type stars, provide insight into the recent enhancements of the moderate–heavy elements as they display the current chemical state of the region of the galaxy in which they reside. Knowledge of the abundance of Fe group elements is especially important, since these species are synthesized late in the life of a star. Sofia, U.J. & Meyer, D.M. (2001) suggest that, in general, B stars are depleted in most elements with respect to the interstellar medium. However the theory may just be an artefact of poor atomic data used in the model atmospheres.

Eta Carinae (η Car) has been of great interest since the nineteenth century when it briefly became the second brightest star in the sky. *HST*/STIS observations of η Car have revealed much information about this variable star including the presence of a number of dense condensations, the "Weigelt blobs". Of particular interest to our current research is the pumping effect of H I Ly α on Fe III.

An intensity anomaly can be observed in the 1914Å vs 1926Å transitions in figure 1a. The upper level involved in the 1914Å transition ($3d^5$ (^{6}S) 4p $^7P_3$) is being preferentially pumped by the H Ly α line, as discussed by Johansson S., et al. (2000). However, there are no currently available experimental oscillator strengths for the UV34 multiplet. Our high resolution FT spectroscopy measurements (Smith, P.L., Pickering, J.C., & Thorne, A.P. 2002) given in figure 1(b) do not exhibit an intensity anomaly and oscillator strengths will be determined for these transitions to experimentally confirm the pumping mechanism.

2. Laboratory Measurements

Recent advances in laboratory techniques, including the use of Image Plates (IP), have allowed, for the first time, accurate intensity calibration of grating spectra below H I Ly α (λ $<$ 1210Å). Image plates, which were originally developed for soft x–ray medical diagnostics,

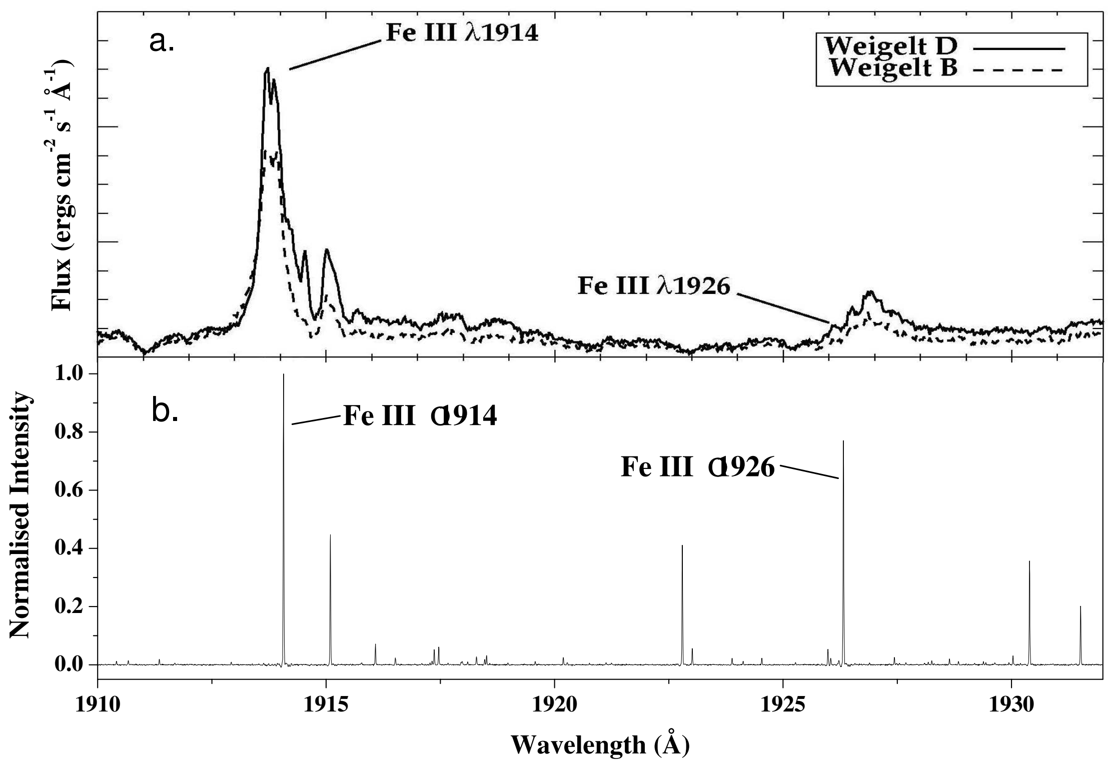

Fig. 1.— (a) *HST*/STIS observations of Weigelt D, see Nielsen et al. and Gull & Nielsen in these proceedings. (b) Fe III spectra recorded by the IC VUV FT spectrometer.

have similar or better sensitivity than other detectors for wavelengths below 2300Å (Reader, J., Sansonetti, C.J., & Deslattes, R.D. 2000). In addition, phosphor image plates have a linear intensity response with a dynamic range of at least 10000. Using a deuterium standard lamp to provided a radiometric calibration of the spectra, branching fractions can be determined to the short wavelength limit of $\lambda > 1150$Å.

Intensity calibrated Fe III spectra have been recorded on the IC VUV FTS over the wavelength range 1600 to 2500Å. In addition, Fe III spectra have been recorded over the wavelength range 1150 to 2500Å on the NIST Normal Incidence Vacuum grating Spectrograph (NIVS). The high resolution FT spectrometer spectra provide an excellent comparison to the NIVS spectra and the intensity calibration of both measurements can be verified over a broad spectral range. The light source used for the Fe III measurements is the Penning discharge lamp (PDL) (Heise, C., et al. 1994). The PDL is the ideal source for the measurements as it combines intensity stability and low to zero field plasma conditions. The Fe III emission spectra are intensity calibrated using two radiometric standard deuterium lamps at

IC and NIST. Taking the ratio of the calibrated line intensities yields branching fractions, which when combined with energy level lifetime values yield oscillator strengths.

3. Conclusion

We have carried out measurements on the IC VUV high resolution FT spectrometer and the NIST NIVS to record spectra of Fe III from 1150 to 2500Å. The source for both NIST and IC measurements was an iron–neon Penning discharge lamp. Using phosphor image plates to record the Fe III spectra on the NIST NIVS and using a deuterium intensity standard lamp we have measured the first ever intensity calibrated Fe III spectra in the wavelength range 1150 to 1600 Å. Preliminary branching ratio measurements for the Fe III transitions from the $3d^5$ (^{6}S) 4p ^7P_j levels have been determined and this work is in progress. Additional lifetime measurements for the $3d^5$ (^{6}S) 4p ^7P_j levels are also underway. Future work will include extending the wavelength range of the intensity calibration to $\lambda < 1150$Å and the measurement of other doubly ionized species of astrophysical interest will be investigated.

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