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Astrophysical applications of high resolution laboratory FTS in the visible and ultra-violet

There are a large number of topics in which high resolution and/or high wavelength precision are required in the laboratory data that underwrite observational astrophysics. We consider three cases in which recent FTS data are of relevance.

The first is the stellar chronometer of Butcher (1987) In this case precise relative wavelengths are needed for four weak lines: two lines in the Thorium and Neodymium spectra that form the basis of the chronometer and two lines in the Iron & Nickel spectra that interfere and whose influence must be considered.

It is fundamental to a measurement of the wavelength that the precision of the measurement depends on the signal to noise ratio of the observation and the width of the line (Learner & Thorne, 1988). For the observations considered here, the noise is dominated by the photon noise) and can be minimised by co-adding several interferograms and by using narrow bandwidth optical filters. In the present case a filter of 490 cm^{-1} bandwidth and 40% peak transmission was used. Optimum line width is achieved by using sources with intrinsically narrow lines - low current (10 to 20 mA) Neon hollow cathode lamps - and by matching instrumental resolution to this line width. An instrumental line width one half that of the source is required for maximum signal to noise ratio and was employed for all lines studied except the Thorium line. The majority of the observations were taken using the Chelsea Instruments FT-500 FTS at UKAEA Harwell.

Because the lines being studied are weak a staged calibration procedure was used. Data taken with the low bandwidth filter were used to relate each weak line to a stronger line in the same spectrum. A second set of observations using a much wider filter then linked the strong line to the Neon line at 28937 cm^{-1}, which is of similar strength. One of this set of observations linked the Neon line to the Fe I line at 24709.9345 cm^{-1} which was used to set the data on an absolute scale. The errors of observation are dominated by the first stage, the observation of the weak lines.

The Fe I line proved too weak to observe under the above conditions and recourse was had to a very high current (750 mA) long observation time (1hr 40 min) spectrum taken using the IC FTS. This line can be directly related to the 24709 cm^{-1} FeI line, so Neon line shifts with current or pressure are irrelevant.

The final set of wavelengths with their errors are set out in Table I. Relative errors are relative to Fe I 24709, absolute errors include the uncertainty in the wave number of that line the error analysis includes all uncertainties in line-to-line transfers.

The second problem is concerned with the Pt I & II spectra. A Pt hollow cathode lamp has been developed as a wavelength and intensity standard for the Hubble telescope (Reader et al, 1988). Precise wavelengths depend on observations in the far UV and are influenced by hyperfine structure (Engleman, 1989). Observations with the FTS in the region 1750 - 3000 A show the hfs of many lines. So far the analysis has concentrated on lines relating to the lowest terms in the spectrum; once again a major gain in precision is evident.

The third problem is that of high class absolute wavelengths in Fe I & Fe II. Studies by Dravins et al (1981, 1986) on solar convection have shown that the principal source of error in that type of work is due to uncertainties in the laboratory wavelengths. We have published improved measurements of Fe I in the visible and report here the extension of those measurements to cover the ultra violet. The wavelengths observed with the IC FTS (Harris, 1986) were already known to be on a good relative scale (Johansson, 1988) but were not linked to the longer wavelength work.

In order to minimise photon noise a novel technique using different detectors in the two FTS output beams was employed. This permits simultaneous observation of both UV & visible regions without each being degraded by the photon noise from the other region. We have also made observations, using deliberate misalignments, to show that the Fe I & Fe II wavelengths are stable with respect to changes of illumination. One curiosity of the two detector technique arises from the fact that, due to absorption losses at the beam splitter, the computed phase correction is not of the standard form.

A comparison of the new data with that of Harris and of Learner & Thorne, using strong lines common to overlapping regions of the three spectra shows that the random errors of the calibration are ± 1.8×10^{-9} (typically 7×10^{-5} cm^{-1} or 6μA). We are confident that, using the many strong lines in the three data sets, we can establish UV wavelengths to better than ± 1 mK in Fe I and Fe II covering the region down to 2000 A. This represents a major improvement on older standards (Kaufman & Edlen, 1974; Norlen, 1987).

TABLE 1 WAVELENGTHS OF LINES USED IN THE BUTCHER CHRONOMETER

Element		Relative Error		Abs. Error		
	cm^{-1}	mK	mÅ	mK	mÅ	Å
Th	24873.9780	±0.82	±0.13	±1.3	±0.21	4019.1298
Ni	74.3670	2.0	0.32	2.2	0.36	9.0667
Fe	74.5141	2.5	0.40	2.7	0.43	9.0431
Nd	75.8576	2.7	0.44	2.9	0.47	8.8259

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