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Research Note

On the purity of Be II measurements

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Abstract. The presence of broad absorption features of telluric ozone close to the Be II doublet seems to have been ignored in the literature. Actually, for objects with small or negative velocities the Be II lines are not affected by ozone absorption; however, for objects with high positive velocities (as are found in some globular cluster members and Population II objects) the stellar Be II lines will be red-shifted onto the flanks of a nearby ozone feature to an extent that could have a significant impact on accurate calculations of stellar Be abundances.

Key words. atmospheric effects – methods: observational – techniques: miscellaneous

The near UV, once a relatively easy domain for photographic stellar spectroscopy, has been somewhat out of favour for CCD observing. The need to tackle problems whose solutions lie more towards the red has removed still further the ability of most spectrographs to make efficient observations at wavelengths much below ~λ3600 Å. However, one astrophysical problem, namely the detection and measurement of beryllium – whose only accessible lines of any strength occur in the ground-state pair of Be II near λ 3130 Å – depends upon efficient access to the near uv, and requires suitable optics and a uv-sensitive CCD.

The region of the Be II lines is cluttered, and not only with features of stellar origin. The Earth's atmosphere causes significant quasi-continuous "extinction" which, while affording the Earth a protection against harmful solar uv radiation, does also raise problems for stellar spectroscopy. The chief components of atmospheric extinction are Rayleigh (small-particle) scattering and stratospheric ozone (O_3) absorption. The former is a continuum that follows a λ^{-4} law, and therefore does not noticeably affect the measurement or synthesis of stellar spectra since the latter are treated *relatively* to the stellar continuum. The uv ozone absorption occurs in two forms: the Hartley bands (an extremely intense absorption from ~λ 2400–3000 Å) and a much weaker system, the Huggins bands, from ~λ 3000–3400 Å.

For nearly a century telluric O_3 absorption has been measured from the Huggins bands as seen against the solar spectrum, and interpreted with the help of laboratory O_3 absorption coefficients determined first by Ny & Choong (1933) and then by Vigroux (1953, 1967) and by Bass & Paur (1984); recent high-resolution laboratory sources also include the cross-sections measurements by Yoshino et al. (1988) and by Burrows et al. (1999). However, the impact of the Huggins bands on ground-based uv stellar spectroscopy does not appear to have been studied rigorously except in absolute photometry – e.g. Chalonge & Divan (1952) and references therein. This note examines the nature and size of one possible effect of the Huggins bands in stellar abundance work.

The Huggins O_3 features are ~15–20 Å broad, and near λ 3130 Å they are only ~10% deep. Some band structure is visible; many of the features are clearly blends of two or three components. The appearance of the Huggins bands is illustrated in Fig. 1, which shows a somewhat compressed spectrum of Vega derived from a photographic exposure made at the coudé focus of the Mount Wilson 100-inch telescope in 1977 June at a reciprocal dispersion of ~0.75 Å mm^{-1}. The smooth line is an "absorption" spectrum of O_3 derived from the Yoshino et al. (1988) cross-sections, and has been displaced downwards by 40% in the figure for clarity. The close correspondence between the two spectra fully confirms O_3 as the identity of the broad dips in the stellar spectrum.

Figure 2 takes a closer look at the Be II region. Both panels show the same spectrum of Vega and compare it to the same laboratory spectrum of O_3 drawn in Fig. 1. In Fig. 2a the wavelength rest-frame of the star is the same as that of the laboratory, whereas in Fig. 2b the stellar spectrum has been red-shifted by +200 km s^{-1} relative to the laboratory spectrum. The arrows

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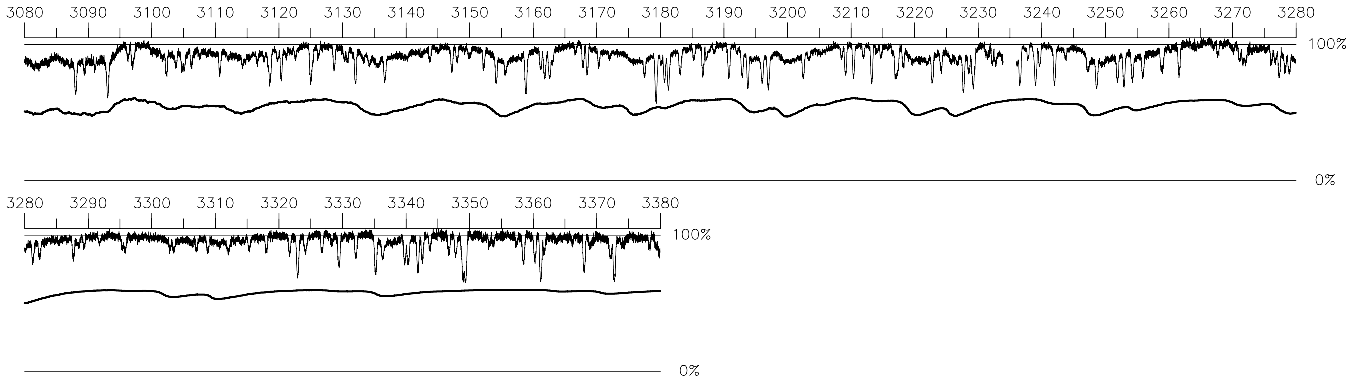

Fig. 1. The uv region of the spectrum of Vega observed from the ground; the dips due to O_3 absorption are clearly visible. The smooth line (which has been displaced downwards by 40% for clarity) is an absorption spectrum of O_3 derived from laboratory cross-sections by Yoshino et al. (1988).

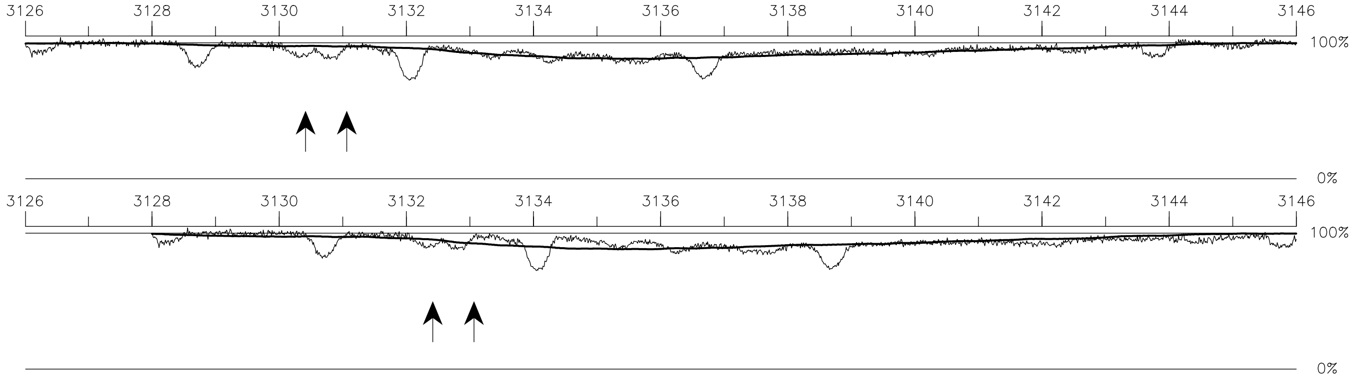

Fig. 2. The location of the Be II doublet in relation to absorption by telluric O_3. **a)** The spectrum of Vega as observed, in the laboratory rest-frame; **b)** the same spectrum of Vega, red-shifted by 2 Å (~200 km s^{-1}). The arrows mark the stellar wavelengths of the Be II doublet. The smooth line in both plots is the same spectrum of O_3 as in Fig. 1. The vertical scale is the same as in Fig. 1.

indicate the locations of the Be II lines in the two versions of the Vega spectrum.

For a star whose radial velocity (RV) is even several 100 km s^{-1} negative, or up to a few tens of km s^{-1} positive, the Be II lines are scarcely contaminated with O_3 absorption (Fig. 2a). However, the effect of O_3 absorption encroaches increasingly as the RV exceeds about +100 km s^{-1} (Fig. 2b). The impact of the O_3 absorption can therefore be significant for high-velocity objects such as Population II stars and some globular clusters for which there is considerable interest in determining stellar ages by means of the Be II chronometer, e.g. Pasquini et al. (2004). Because the nearby O_3 feature is fairly smooth, measurements of the equivalent widths of the Be II lines in highly red-shifted, metal-poor objects will probably not be compromised since they are referred to the nearby stellar continuum, but simulated model spectra *will* need to take O_3 absorption into account. Ignoring the contribution of O_3 to the continuum near the Be II blends in such red-shifted stars could result in over-estimates of the Be abundance and corresponding under-estimates of the stellar ages. The Be II lines are not intrinsically of equal strength, and because the weaker of the pair is at the longer wavelength the presence of O_3 absorption will tend to accentuate that inequality.

Even if the magnitude of the effect described above proves to be small – perhaps only a few percent – the very high quality of the spectra that can routinely be obtained even on faint objects requires that it be taken into account in stars of high redshift in order to avoid systematic errors. The objects in which Be can normally be detected, and in which it is most widely measured – e.g. Boesgaard (2001) – are F-G dwarfs. Metal-poor objects such as those studied by Pasquini et al. (2004) display as much continuum as an early A dwarf, but the F-G dwarfs (other than very metal poor ones) have rather rich spectra in which the stellar continuum is difficult to locate, and Be abundance analyses in such cases are likely to assume that the stellar continuum is locally flat for tens (or more) of Å.

Other stellar abundance work that relies on measurements of uv features shortward of about λ 3350 Å could also be contaminated by O_3 absorption. All spectrum syntheses, *regardless of whether the stellar continuum can be discerned in the observations*, should therefore take into account the presence of at least the stronger Huggins O_3 features.

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