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ORIGINAL ARTICLE

Photospheric Abundance Peculiarities in RS CVn Binaries

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Abstract We discuss the results of a LTE abundance study of 14 single-lined RS CVn binaries. Increasingly peculiar abundance ratios are observed for the cooler and more active stars in this sample (this is best illustrated in the case of oxygen). This may arise from the existence of large spot groups, departures from LTE much larger than anticipated and/or inadequacies in the Kurucz model atmospheres for these objects.

Keywords Stars: fundamental parameters · Stars: abundances · Stars: activity · Line: formation

1. Observations and analysis

Spectra of 14 single-lined RS CVn binaries (G8-K2 IV-III) were obtained at ESO using the echelle spectrograph FEROS (3600–9200 Å; $R = 48\,000$). Only slow rotators were selected ($v \sin i \lesssim 10\,\mathrm{km\,s^{-1}}$). A control sample made up of 7 single stars of similar spectral type, but with much lower X-ray luminosities was also observed.

The abundances of 13 chemical species were determined using the measured EWs of about 90 carefully-selected spectral lines, along with a set of 1-D line-blanketed LTE Kurucz atmospheric models, as input for the MOOG software. The oscillator strengths were calibrated with a very high-quality FEROS solar spectrum. The effective temperatures and surface gravities were determined from the excitation and ionization equilibrium of the Fe lines, while the

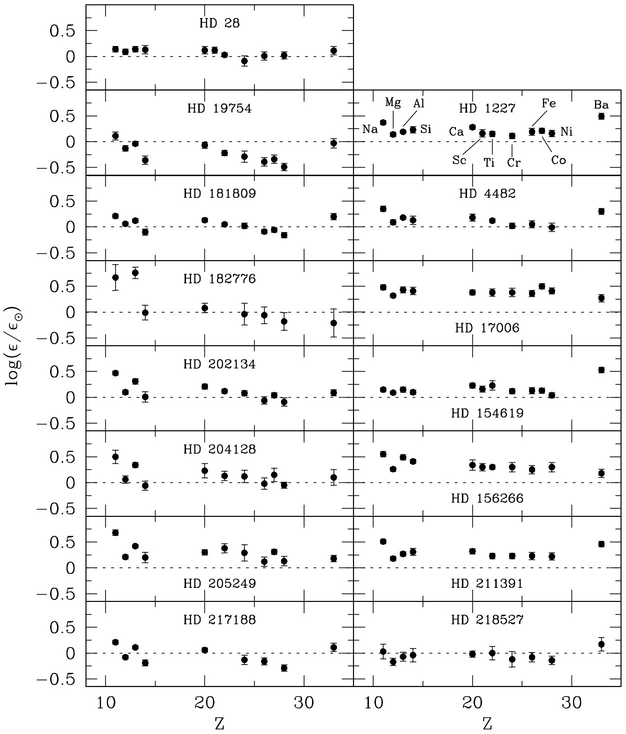

Fig. 1 Abundance patterns of the RS CVn binaries (*left-hand panels*) and the stars in the control sample (*right-hand panels*). The chemical elements are identified in the upper, right-hand panel. The position of barium has been shifted for the sake of clarity to $Z = 33$. The dashed line corresponds to the solar abundance pattern. Adapted from Morel et al. (2004)

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Fig. 2 Abundance ratios as a function of [Fe/H]. The active binaries and stars in the control sample are indicated by filled and open circles, respectively (from Morel et al., 2004). The thick dashed and dotted lines show the characteristic trends of kinematically-selected samples of thin and thick disk stars, respectively (Bensby et al., 2003)

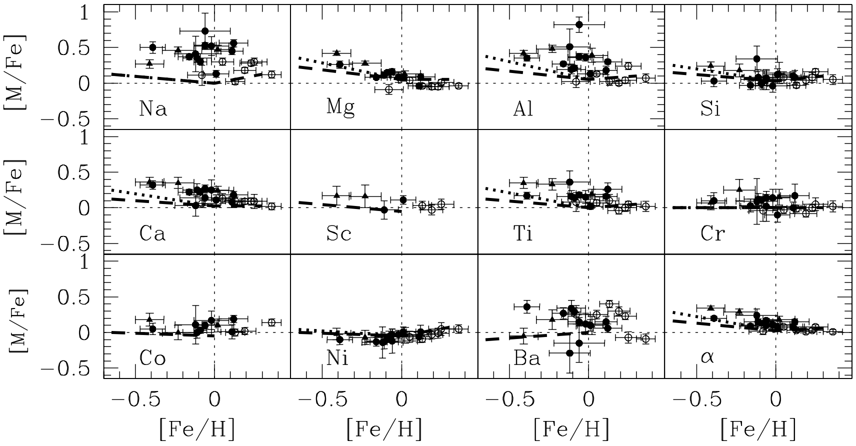
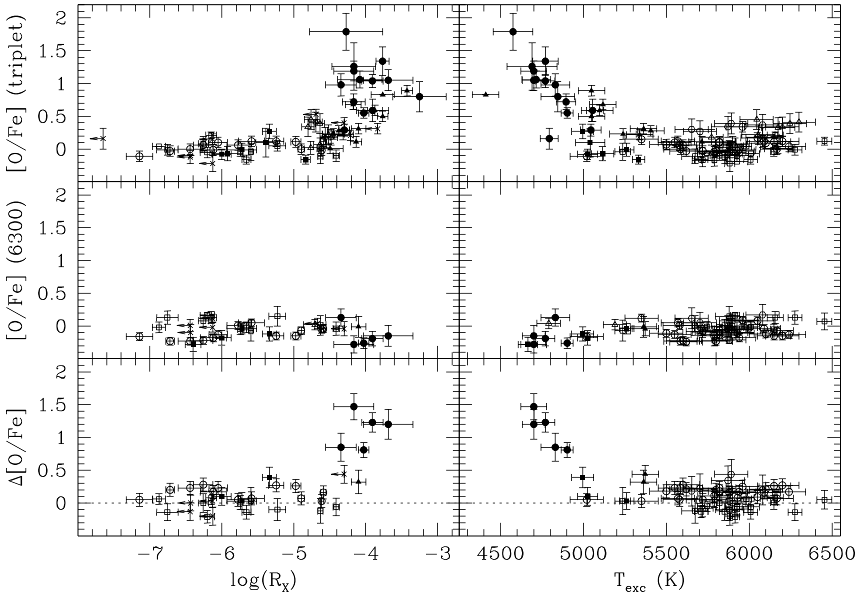


Fig. 3 Oxygen abundances as a function of the activity index, R_X, derived from X-ray data (*left-hand panels*) and the excitation temperature, $T_{\rm exc}$ (*right-hand panels*). The bottom panels show the difference between [O/Fe] yielded by the O I 7774-Å triplet and the [O I] λ6300 line. Filled circles: RS CVn binaries, filled squares: field subgiants (Morel et al., 2003, 2004), filled triangles: Pleiades stars, open triangles: Hyades stars, open circles, squares and hexagons: disk dwarfs (data from the literature). Adapted from Morel and Micela (2004)



microturbulent velocity was derived by requiring the Fe I abundances to be independent of the EWs.

2. Evidence for abundance peculiarities

While the chemical composition of the control stars shows modest departures from a scaled solar abundance pattern, this is generally far to be the case for the RS CVn binaries (compare the left- and right-hand panels of Fig. 1). As can be seen in Fig. 2, the active binaries do not follow the characteristic trends presented by kinematically-selected samples of inactive, FG field dwarfs between the abundance ratios and [Fe/H] (e.g. Al). At a given metallicity, a significant overabundance of several elements is observed in the active stars (see also Katz et al., 2003).

3. Activity and/or temperature effects?

Peculiar abundance ratios are preferentially observed for the cooler and more active objects in our sample. This phenomenon is particularly well illustrated by oxygen (see Fig. 3). In this particular case, the distinct behaviour of the O I triplet and [O I] λ6300 points to unexpectedly large NLTE effects affecting the permitted lines. Although a similar interpretation might apply to other elements, the same analysis carried out on synthetic, composite Kurucz spectra with a varying spot coverage shows that cool spots generally lead to an overestimation of the abundance ratios, in qualitative agreement with the observations. Temperature effects (e.g. inadequacies in the Kurucz models for *K*-type subgiants) may also play a significant role.

4. Conclusion

This first systematic study of the chemical composition of tidally-locked active binaries raises some concerns about the reliability of classical LTE abundance analyses in cool, chromospherically active stars. The combined action of presumably strong NLTE effects, cool spots and inadequate atmospheric models (e.g. which neglect the chromospheric component) may potentially have a significant impact on the final results. These limitations must be kept in mind when comparing the photospheric and coronal abundance patterns of active binaries, for instance (see, e.g. Sanz-Forcada et al., 2004). In a broader context, the chemical peculiarities reported here are strongly reminiscent of recent observations of young open cluster members (e.g. Schuler et al., 2004). It is thus likely that the abundances derived in both classes of objects are affected by similar processes. We expect our forthcoming abundance analysis of a large sample of inactive *K*-type stars to help assessing the relative importance of temperature and activity effects (Morel et al., in preparation).

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