ABSTRACT & INTRODUCTION

IUE-ULDA Access Guide to Chromospherically Active Binary Stars

Abstract

Background information is provided on both low and high dispersion IUE spectra of chromospherically active late-type binaries, that have been taken until the end of 1992, in order to foster an optimum usage of the IUE archive. Physical information on all systems, arranged by binary star name, together with characteristics of the individual exposures, the position of the observations in the orbital light curve, an average low resolution ultraviolet spectrum, and, whenever available, the shape of the MgII feature at 2800 Åin high resolution, are given.

Introduction

It is a well-know fact that many late-type cool stars (later than F5) show indications of solar-like magnetic activity, such as photospheric spots, chromospheric emission, coronal x-ray and radio emission, as well as flare activity (see e.g. Guinan and Giménez, 1993). Apart from very young stellar objects, such as T Tauri stars and related pre-main sequence stars, those with the highest activity levels are close binary systems with cool, G- to M-type components. Otherwise, the majority of solar-like stars in the Sun's neighbourhood are relatively old and have activity levels comparable to that of our Sun.

Observationally, active late-type binaries typically show emission cores in the H and K CaII resonance lines, as well as in the Hα line that can be hundreds of times stronger than those in the Sun, a characteristic which is generally considered to be an indicator of chromospheric activity (see, e.g., Rodonó, 1992). These binary systems are also strong coronal x-ray sources, having x-ray luminosities on the order of 10^2 to 10^4 times that of the quiet Sun. Moreover, they often show migrating waves in their light curves which are interpreted as being caused by huge, cool star spots or groups of them. The explanation of these photometric, wave-like anomalies by means of the "spot" hypothesis, which was first introduced by Kron (1947), and later developed by Hall (1972) and Torres and Ferraz-Mello (1973), allowed the explanation of a large range of peculiarities displayed by these stars in terms of some kind of enhanced solar activity. The spots produce periodic variations in the light curve which permit a determination of the star's rotational period and of the size of the star's surface area covered by them. It turns out that the coverage in active binary stars can be on the order of some 20% of their surface area, in contrast to the active Sun for which a coverage of less than some 0.2% is observed. The photospheric activity is generally accompanied by the presence of an active chromosphere, as detected through the above-mentioned emission cores; and the level of both activities is found to be correlated. A similar correlation has also exists between the anomalous behaviour of the Strömgren intermediate-band uvby colour indices and the photometric peculiarities of active stars (Giménez et al., 1991). In addition, large energetic flare-like events, the most remarkable phenomena of stellar activity, have been reported for many chromospherically active binaries (Catalano, 1990).

The currently accepted general picture of the nature of active late-type binaries is based on the emergence of magnetic flux tubes producing active regions in analogy to those in the Sun with spots, active chromospheres, and coronae. The combination of deep convective envelopes with magnetic fields and forced stellar rotation lies at the origin of this kind of stellar activity. In fact, due to the strong tidal interaction in these binaries, the stars are usually forced to rotate relatively rapidly and typically their rotational periods are synchronized with their orbital periods. The strength of the indicators is expected to increase as a function of stellar rotation and of the depth of the convective envelope.

Chromospherically active binaries are generally classified under such group names as RS CVn, BY Dra, W UMa, and related systems. A similar kind of stellar activity is also probably present in Algol-type binaries and in the secondaries of cataclysmic variables, but in these cases it is more difficult to study because of the relative brightness of the hotter component. Also, in these systems the cooler, active component is in contact with its Roche lobe which might change its physical properties or observable characteristics. Furthermore, mass loss and mass transfer frequently produce light variations and spectroscopic features which veil the traces of the cool component in the overall observational picture. Similar effects are likely to be at work in W UMa-type binaries where both components fill their respective Roche lobes.

IUE observations of late-type active binaries

The increase in the available information on the ultraviolet and x-ray spectral regions obtained by means of space observatories has confirmed the general picture of active binaries and added a wealth of new information. Late-type stars in the ultraviolet do not have continuum fluxes dominating the spectrum and, thus, the emission lines appear clearly with a much better contrast than in hotter stars. This is one of the reasons why chromospherically active binaries have received much attention from observers using UV and x-ray astronomical satellites (Rodonó, 1993). In fact, ultraviolet observations of this kind of binaries have proven to be extremely rewarding concerning the quantitative evaluation of the level of stellar activity, the presence of flares, variations with orbital phase, and secular changes due to long-period activity cycles.

As mentioned above, one of the hallmarks of RS CVn, BY Dra, and related stars is their strong CaII H and K emission. Following the solar analog, these emissions are identified with enhanced chromospheric emission from plage-like regions and the chromospheric network. Therefore, emission lines which originate in the same stellar region as the CaII resonance lines but lie at ultraviolet wavelengths (as a large number of them do) should be observable with a better contrast with respect to the continuum flux. The most interesting lines in this context are the chromospheric emission features of MgII h and k at 2800 Å and the transition region line emissions of NV at 1240 Å, SiII at 1400 Å, and CIV at 1550 Å. Moreover, the study of the HeII feature at 1640 Å may provide some information on the physical conditions of stellar coronae. Numerous observations of active stars with the International Ultraviolet Explorer (IUE) satellite since 1978 confirmed these expectations and have indeed led to an explosion of information on the chromospheric and transition regions. The interested reader may find some discussions on the current picture of chromospherically active stars, as derived from IUE observations, in recent review papers (e.g., Rodonó, 1986; Zwaan, 1986; Jordan and Linsky, 1987; Linsky, 1988 and 1990; Ramsey, 1990; Guinan, 1990).

Definition of binary systems included in our catalogue

The first thing to be established is what kind of stars, in the context of the catalogue at hand, we consider chromospherically active late-type binaries. In general, we accept as such any kind of close binaries in a detached, or marginally semidetached, configuration with strong chromospheric activity. These are mainly the RS CVn binaries, first defined as a group by Hall (1976), and the BY Dra systems, defined by Bopp and Feckel (1977). RS CVn binaries are systems whose stellar components are dwarfs subgiants and giants of spectral type F to K. A full description of the main characteristics presented by them is given by Hall (1981). On the other hand, in BY Dra stars always at least one component is of type dK or dM. Both groups are clearly identified by strong chromospheric activity and the presence of large spotted regions. Active late-type binaries of the RS CVn type, with essentially detached components, are the subject of an intense research at different wavelength ranges because of their suitability as a primary source of information on the physical mechanisms responsible for coronal and chromospheric activity, their evolution, and their dependence on stellar convection, rotation, and magnetic fields. In fact, detached double-lined eclipsing binaries are the only known way to determine accurate absolute stellar dimensions and, thus, provide the only reliable way for a detailed comparison between observed stellar parameters and theoretical predictions of their structure and of evolutionary models. Detailed discussions on these topics are given by Byrne and Rodonó (1983) and Hartmann and Noyes (1987).

W UMa-type binaries, which show clear evidence of chromospheric activity (see, e.g., Rucinski, 1993) were excluded from the catalogue, as well as binaries containing M-giants or single stars with chromospheric activity like FK Comae stars and T Tauri stars.

This is basically the same definition as adopted by Strassmeier et al. (1989, 1993) in their catalogue of chromospherically active binary stars. Therefore, we have taken this catalogue as the input data base for the selection of systems to be included in our compilation of the IUE archives information. Details about the adopted selection criteria are given in Strassmeier et al. (1988).

The catalogue

The name list searched is that given in Strassmeier et al. (1993). All stars in this catalogue which have entries in the IUE Data Base were included in our catalogue. In total, 127 late-type active binaries have been observed with IUE Satellite until the end of 1992. For these targets a total of 2569 spectra, 1227 in the short wavelength range and 1343 in the long one, have been obtained, 1075 of them in high resolution.

In order to facilitate work with this catalogue, for each system we start out by providing a list of general information on physical parameters and properties of the emitted flux and, if they exist, references to important recent papers on observational aspects of the specific target in question. This then is followed by a list of details on the available IUE observations. And finally for each system one page with actual plots of observations is given. In the following we provide a detailed description of the various entries.

a) A list of general information:

Name: As primary name the variable star name of the system, as given in the General Catalogue of Variable Stars by Kholopov (1985), is used and the targets are arranged in this order. In cases where no such name exists, they are listed by HD number at the end of the catalogue.

Alternative names: A list of aliasses in use are given in order to help the user identify the targets. Names from the Henry Draper catalogue (HD number), the Smithsonian Astrophysical Observatory catalogue (SAO number), the HR number from the Bright Star catalogue, the bright star name, and the Durchmusterung catalogues (BD or CD/CPD numbers) were included, when available. A list of cross references in all possible permutations is provided at the end of the catalogue.

Coordinates: Right ascension and declination of the star are given for the 2000.0 epoch.

System parameters: Several parameters relevant for the understanding of the main UV characteristics are taken directly from Strassmeier et al. (1993) where references to the original papers and selection criteria are given. These parameters are the orbital period and time of conjunction (T_0)[1]; the type of binary, the eccentricity, the stellar masses, radii, spectral types, and the distance, whenever available.

activity parameters: Likewise, from the catalogue of Strassmeier et al. we adopted some parameters describing the state of activity of each system. These are the photometric period, the amplitude of brightness variations in the V band, the x-ray luminosity, the CaII index, the strength of the $H\alpha$ emission, and the radio flux density. As one additional parameter we measured the MgII index from the IUE observations. It is based on the definition by Fanelli et al. (1990) as the ratio between the flux measured in the unbinned data in the band $2800 \pm 20\AA$ and the continuum flux defined as a linear interpolation between the flux values at 2650 ± 50Å and 2950 ± 50Å. For measurements based on low resolution data (the spectra incorporated in the average spectrum as displayed) the corresponding MgII index is given in square brackets; values determined form the high resolution spectrum in the plot (below) are given without brackets.

Photometric parameters: Only Johnson's UBV photometry was taken from the catalogue of Strassmeier et al. (1993). Strömgren uvby colours were taken, when available, from Giménez et al. (1991). Otherwise, data from Hauck and Mermilliod (1990, 1980), Olsen (1993), and Schuster et al (1993) were adopted. ROSAT measurements in the EUV were taken from Pounds et al. (1993). Preliminary data from the EUVE survey were taken from

[1] The same comments apply as in Strassmeier et al. (1993) (preface to Table 4), where the letters 's', 'p', and 't', written as addition to 'Min I', specify which component is behind at time T_0. The symbol '{...}' denotes the binary in a triple system.

Bowyer et al. (1994). The infrared information from IRAS was taken from Simbad and Gezari et al. (1987); from this latter reference we also took approximate fluxes using their notation '0' and '1' for the ranges 0.5 - 5 Jy and 5 - 50 Jy, respectively. UV continuum fluxes are determined from the low resolution IUE images as given in the plots. These colours were measured from the unbinned data in the wavelength ranges: 1450 ± 30Å, 2650 ± 50Å and 2950 ± 50Å. In cases where no low resolution long wavelength spectrum is available, the long wavelength continuum fluxes are taken from the one high resolution spectrum also displayed in the plot, otherwise determined in the same way (same code, same wavelength range) as in the case of the low resolution spectra; for clarity they are given in square brackets.

A list of additional references: In the spirit of providing comprehensive background information to all systems, we found it necessary to also quote papers devoted to the system, e.g., if a global picture of the structure and activity behaviour is discussed or if the activity behaviour is further analysed from an observational point of view. Only papers published during the last 10 years have been considered. References to the sources of individual parameters are given by Strassmeier et al. (1993) and additional information and further data may be extracted from papers included in the discussion of large data sets given at the end of this introduction.

b) A list of available IUE spectra:

A list of all the available IUE spectra is given, taken from the VILSPA Data Base which is meant to be complete for spectra taken until the end of 1992. Only large aperture spectra are considered, since spectra taken in the small aperture cannot be calibrated. On the other hand, no FES images have been included since, for RS CVn and related binaries, they do not contain scientifically useful information.

The tables contain the following information:

column 1: Sequential identification number of individual observations.

column 2: Camera identification (LWR: Long Wavelength Redundant camera, LWP: Long Wavelength Primary camera, SWP: Short Wavelength Primary camera).

column 3: Image number in the IUE Data Base.

column 4: Resolution (H: high 1-3 10^4, L: low, 1-3 10^2).

column 5: Displayed spectra (those low resolution images which together form the average spectrum as displayed for each system, as well as the high resolution one whose MgII profile is plotted, are marked with an asterisk in this column).

column 6: Day at the beginning of the observation (yy.mm.dd).

column 7: Time of the beginning of the exposure (hh:mm:ss).

column 8: Julian Date at the beginning of the exposure, corresponding to the previous 3 columns, given as JD-2440000.

column 9: Exposure time for the spectrum (mmm.mm).

column 10: Optical stellar magnitude derived from the FES counts and mode using the calibration formula as given by Stickland (1980) for measurements taken at the old reference point (-16, -208), i.e. at GSFC before 22.1.90 or at VILSPA until 23.7.90. The calibration provided by Pérez (1991) was used for measurements taken at the new reference point (-144, 176) thereafter. From 10.11.92 onwards, due to the occurrence of the streak light, no calibration of FES measurements is possible any longer. If available, the B-V index was taken from Strassmeier et al. (1993) (the value given in the previous section); if not known, it was defined as 0.

column 11: Orbital phase at the beginning of the exposure, using values of previous columns and the ephemeris in the previous section. Two digits only are given, so that no significant difference exists between values derived from JD and HJD. In cases where no ephemeris is known, the time of the first IUE observation was taken as zero time and relative phases calculated on the basis of the orbital period only; values derived in this way are given in square brackets.

column 12: Same as column 11 for the end of the exposure. FES magnitudes and orbital phases are used to plot the coverage light curves (see next section).

column 13: Number of cycles elapsed since the ephemeris T_0 as given by Strassmeier et al (1993) and quoted in the table of system parameters. This number allows an estimate of the accuracy of the given orbital phases.

column 14: Quality given by the observer according to standard codes adopted for the description of IUE images. Keys to this can be found in the preface to the IUE merged log.

c) Plots of observation:

Top figure: Average ultraviolet spectrum of the system, using low resolution data, displayed in 5 Å bins. Whenever necessary, a small insert shows the far UV region on a larger scale. Nevertheless it should be noted that in particular the line fluxes can vary considerably between spectra of the same system taken at different epochs. Crosses at the upper margin of the plot indicate that the flux value at this wavelength of (at least) one of the spectra in the average has a problem (the ε value is different from zero) and, thus, that some caution should be exercised when interpreting these data and that the original spectra should be consulted for details.

Lower right figure: Plot of the MgII 2800 Å region observed in high resolution. The selected image was put, for plotting purposes, into bins of approximately 0.2 A width. As in the plots of the low resolution spectra, crosses mark some problem in the data.

Lower left figure: Light curve of the systems derived from the FES magnitudes, calculated as described above, in the form of bars at the level of the FES magnitude, ranging from the orbital phase at the beginning of each exposure to its end. This plot shows a rough shape of the photometric variations in the optical together with the available coverage of the orbit with ultraviolet data. For systems with no known ephemeris, the time of the first IUE observation was taken as zero time and relative phases were computed on the basis of this (see column 11 of the table of observations).

Whenever a sufficiently large number of spectra of the same system exist to permit any choice in what data to display, the selection as indicated in the list of the previous section with an asterisk (*) in column 5, was done in the following way:
a) no overexposures were accepted, except for the long-wavelength part of the SWP in case no LWP/R was available, or longward of MgII;
b) no overexposures in the MgII features were accepted;
c) preferentially, orbital phases near 0.25 or 0.75 were used, especially in the case of eclipsing systems; eclipse observation were avoided by all means;
d) if possible, spectra without exposure code were avoided;
e) for unknown reasons, some spectra could not be found in ULDA and, therefore, were not used in the averages.

d) Acknowledgements:

We are indebted to Dr. Strassmeier for providing us with the chromospherically active binary stars catalogue in electronic format. We have made use of the VILSPA facilities to retrieve lists of IUE images from the data base and to extract low resolution IUE images from ULDA. Moreover, the Regional Data Analysis Facility at GSFC was used to obtain the high resolution images and a few low resolution spectra that for some reason are missing in ULDA. Finally, we gratefully acknowledge that this research has made use of the Simbad database, operated at CDS, Strasbourg, France.

e) References:

Bopp, B.W., Fekel, F.C.: 1977, *Astronom. J.* **82**, 490

Bowyer, S., Lieu, R., Lampton, M., Lewis, J., Wu, X., Drake, J.J., Malina, R.F.: 1994, *Astrophys. J. Suppl.* **93**, 569

Byrne, P.D., Rodonó, M.: 1983, (eds.) in *Activity in Red Dwarf Stars*, Reidel, Dordrecht/Holland

Catalano, S.: 1990, in *Active Close Binaries* (edit. C. Ibanoğlu), Kluwer, Dordrecht/Holland, p. 411

Fanelli, M.N., O'Connell, R.W., Burstein, D., Wu, C.-C.: 1990, *Astrophys. J.* **364**, 272

Gezari, D.Y., Schmitz, M., Mead, J.M.: 1987, NASA RP 1196

Giménez, A., Reglero, V., de Castro, E., Fernandez-Figueroa, M.J.: 1991, *Astron. & Astrophys.* **248**, 563

Guinan, E.F.: 1990, in *Evolution in Astrophysics: IUE Astronomy in the Era of New Space Missions* (edit. E.J. Rolfe), ESA SP-310, 383

Guinan, E.F., Giménez, A.: 1993, in *The Realm of Interacting Binary Stars*, (eds. J. Sahade et al.), Kluwer, Dordrecht/Holland, p. 51

Hall, D.S.: 1972, *Publ. Astron. Soc. Pac.* **84**, 323

Hall, D.S.: 1976, in *Multiple Periodic Phenomena in Variable Stars*, IAU Colloq. 29 (edit. W.S. Fitch), Reidel, Dordrecht/Holland

Hall, D.S.: 1981, in *Solar Phenomena in Stars and Stellar Systems* (eds. R.M. Bonnet and A.K. Dupree), Reidel, Dordrecht/Holland, p. 431

Hartmann, L.W., Noyes, R.W.: 1987, *Ann. Rev. Astron. & Astrophys.* **25**, 443

Hauck, B., Mermilliod, M.: 1980, *Astron. & Astrophys. Suppl.* **40**, 1

Hauck, B., Mermilliod, M.: 1990, *Astron. & Astrophys. Suppl.* **86**, 107

Jordan, C., Linsky, J.L.: 1987, in *Exploring the Universe with the IUE Satellite* (eds. Y. Kondo et al.), Reidel, Dordrecht, p. 259

Kholopov, P.N.: 1985, *General Catalogue of Variable Stars*, Nauka Publ. House, Moscow

Kron, G.E.: 1947, *Publ. Astron. Soc. Pac.* **59**, 261

Linsky, J.L.: 1988, in *Multiwavelength Astrophysics* (edit. F. Córdova), Cambridge Univ. Press, Cambridge, p. 49

Linsky, J.L.: 1990, in *Active Close Binaries* (edit. C. Ibanoğlu), Kluwer, Dordrecht/Holland, p. 747

Olsen, E.H.: 1993,

Astron. & Astrophys. Suppl. **102**, 89

Pérez, M.: 1991, ESA IUE Newsletter, 38, 27

Pounds, K.A., Allan, D.J., Barber, C., Barstow, M.A., Bertram, D., et al.: 1993, *Mon. Not. R. Astr. Soc.* **260**, 77

Ramsey, L.W.: 1990, in *6th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun* (edit. G. Wallerstein), ASP Conf. Series, 9, p. 171

Rodonó, M.: 1986, in *Cool Stars, Stellar Systems, and the Sun* (eds. M. Zeilik and D.M. Gibson), Springer-Verlag, Berlin, p. 475

Rodonó, M.: 1992, in *Evolutionary Processes in Interacting Binary Stars* (eds. Y. Kondo et al.), Kluwer, Dordrecht/Holland, p. 71

Rodonó, M.: 1993, *Mem. Soc. Astron. Ital.* **64**, 287

Rucinski, S.: 1973, in *The Realm of Interacting Binary Stars*, (eds. J. Sahade et al.), Kluwer, Dordrecht/Holland, p. 111

Schuster, W.J., Parrao, L., Contreras Martínez, M.E.: 1993, *Astron. & Astrophys. Suppl.* **97**, 951

Stickland, D.J.: 1980, ESA IUE Newsletter 5, 30

Strassmeier, K.G., Hall, D.S., Feckel, F.C., Scheck, M.: 1993, *Astron. & Astrophys. Suppl.* **100**, 173

Strassmeier, K.G., Hall, D.S., Zeilik, M., Nelson, E., Eker, Z., Feckel, F.C.: 1988, *Astron. & Astrophys. Suppl.* **72**, 291

Torres, C.A.O., Ferraz Mello, S.: 1973, *Astron. & Astrophys.* **27**, 231

Zwaan, C.: 1986, in *Cool Stars, Stellar Systems, and the Sun* (eds. M. Zeilik and D.M. Gibson), Lecture Notes in Physics, vol. 254, p. 19

Additional references of compilations of data published during the past 10 years

Altenhoff W.J., Thum C., Wendker H.J.: 1994, *Astron. & Astrophys.* **281**, 161, *Radio emission from stars: a survey at 250 GHz.*

Balona L.A.: 1987, *South. Afr. Astron. Obs. Circ.* **11**, 1, *Radial velocities of calcium emission stars. I. Observations at Sutherland.*

Bedford D.K., Elliott K.H., Eyles C.J.: 1985, *Space Sci. Rev.* **40**, 51, *X-ray observations of active chromosphere stars.*

Berrios M.L.: 1993, *Rev. Mex.* **26**, 107, *Southern RS CVn systems UBVRI photometry.*

Bopp B.W.: 1984, *Astrophys. J. Suppl.* **54**, 387, *CaII emission surface fluxes in active chromosphere stars.*

Budding E., Zeilik M.: 1987, *Astrophys. J.* **319**, 827, *An analysis of the light curves of short-period RS Canum Venaticorum star: starspots and fundamental properties.*

Busso M., Scaltriti F., Persi P., Ferrari-Toniolo M., Origlia L.: 1988, *Mon. Not. R. Astr. Soc.* **234**, 445, *IR Excesses of RS CVn-type binaries from IRAS observations.*

Caillault J.P., Drake S., Florkowski D.: 1988, *Astronom. J.* **95**, 887, *A VLA survey of BY Draconis variables.*

Chugainov P.F., Lovkaya M.N.: 1989, *Astrofizika* **30**, 243, *Infrared excess for BY Dra-type stars from the IRAS data.*

Cutispoto G.: 1990, *Astron. & Astrophys. Suppl.* **84**, 397, *UBVRI observations of southern hemisphere active star.*

Cutispoto G.: 1991, *Astron. & Astrophys. Suppl.* **89**, 435, *UBVRI observations of southern hemisphere active stars. II. 1987 data.*

Cutispoto G.: 1992, *Astron. & Astrophys. Suppl.* **95**, 397, *Long-term monitoring of active stars. II. UBV(RI)c at ESO during January-March 1989.*

Dempsey R.C., Linsky J.L., Fleming T.A., Schmitt J.H.M.M.: 1993, *Astrophys. J. Suppl.* **86**, 599, *The ROSAT all-sky survey of active binary coronae. I. Quiescent fluxes for the RS Canum Venaticorum systems.*

Dempsey R.C., Linsky J.L., Schmitt J.H.M.M., Fleming T.A.: 1993, *Astrophys. J.* **413**, 333, *The ROSAT all-sky survey of active binary coronae. II. Coronal temperatures of the RS Canum Venaticorum systems.*

Drake S.A., Simon T., Linsky J.L.: 1986, *Astronom. J.* **91**, 1229, *A 6 centimeter radio survey of short-period active binary stars.*

Drake S.A., Simon T., Linsky J.L.: 1989, *Astrophys. J. Suppl.* **71**, 905, *A survey of the radio continuum emission of RS Canum Venaticorum and related active binary systems.*

Drake S.A., Simon T., Linsky J.L.: 1992, *Astrophys. J. Suppl.* **82**, 311, *Radio continuum and x-ray properties of the coronae of RS Canum Venaticorum and related active binary systems.*

Eker Z.: 1992, *Astrophys. J. Suppl.* **79**, 481, *Kinematics and age of RS Canum Venaticorum and BY Draconis stars.*

Estalella R., Paredes J.M., Rius A., Marti J., Peracaula M.: 1993, *Astron. & Astrophys.* **268**, 178, *Radio emission from RS CVn stars, Algol and LSI +61 303.*

Evans T.L., Koen M.C.J.: 1987, *South Afr. Astron. Obs. Circ.* **11**, 21, *UBV(RI)c photometry for CaII emission stars. I. Observations at Sutherland.*

Fekel F.C., Moffett T.J., Henry G.W.: 1986, *Astrophys. J. Suppl.* **60**, 551, *A survey of chromospherically active stars.*

Fernandez-Figueroa M.J., Sedano J.L., de Castro E.: 1986, *Astron. & Astrophys.* **169**, 237, *The Mg II emission in a sample of regular-period RS CVn systems.*

Gimenez A., Reglero V., de Castro E., Fernandez-Figueroa M.J.: 1991, *Astron. & Astrophys.* **248**, 563, *A uvby-beta survey of northern-hemisphere active binaries. II. the m1 deficiency.*

Haggkvist L., Oja T.: 1987, *Astron. & Astrophys. Suppl.* **68**, 259, *Narrow-band photometry of late-type stars. II..*

Hall D.S.: 1990, *Astronom. J.* **100**, 554, *Masses and radii for thirteen chromospherically active ellipsoidal variables.*

Hall D.S., Ramsey L.W.: 1992, *Astronom. J.* **104**, 1942, *Eclipse observations of RS CVn binaries. I. A survey for extended matter.*

Henry G.W., Hall D.S.: 1989, *Bull. Am. Astr. Soc.* **21**, 1149, *Masses and radii for 12 ellipsoidal RS CVn binaries.*

Herbst W., Miller J.R.: 1989, *Astronom. J.* **97**, 891, *H-alpha photometry of dwarf K and M stars: chromospheric activity.*

Huenemoerder D.P., Ramsey L.W.: 1985, *Bull. Am. Astr. Soc.* **16**, 912, *Balmer decrements in active chromosphere stars.*

Huisong T., Xuefu L.: 1987, *Astron. & Astrophys.* **172**, 74, *Measurements and study of rotational velocities in RS CVn stars systems.*

Katsova M.M., Tsikoudi V.: 1992, *Astrophys. J. Letters* **402**, L9, *The far-infrared and x-ray radiation of active late-type stars: suggestions for strong spottedness.*

Koch R.H.: 1990, *Bull. Inf. Centre Donnees Stellaires* **38**, 175, *Close binaries observed polarimetrically.*

Liu X.F., Li A., Huang H., Lu F.J.: 1993, *Astrophys. and Space Science* **205**, 359, *New H-alpha survey of chromospherically active binaries.*

Liu X.F., Tan H.S.: 1986, *Acta Astron. Sin.* **27**, 259, *Observations and study of polarization for 31 RS CVn stars.*

Liu X.F., Tan H.S.: 1987, *Acta Astron. Sin.* **28**, 139, *Observations and study of polarization for 30 RS CVn stars.*

Liu X.F., Zhao G., Tan H.S.: 1993, *Chin. Astron.* **17**, 51, *Lithium abundance and activity for 57 RS CVn systems.*

Majer P., Schmitt J.H.M.M., Golub L., Harnden F.R., Rosner R.: 1986, *Astrophys. J.* **300**, 360, *X-ray spectra and the rotation activity connection of RS Canum Venaticorum binaries.*

Morris D.H., Mutel R.L.: 1988, *Astronom. J.* **95**, 204, *Radio emission from RS CVn binaries. III. A VLA survey of 103 systems.*

Mutel R.L., Lestrade J.F.: 1985, *Astronom. J.* **90**, 493, *Radio emission from RS CVn binaries. I. VLB survey and period-radio luminosity relationship.*

Pallavicini R., Monsignori-Fossi B.C., Landini M., Schmitt J.H.M.M.: 1988, *Astron. & Astrophys.* **191**, 109, *Stellar coronae with EXOSAT: broad-band spectroscopy of nearby coronal sources.*

Pallavicini R., Randich S., Giampapa M.S.: 1992, *Astron. & Astrophys.* **253**, 185, *Lithium in RS CVn binaries and related chromospherically active stars. I. Observational results.*

Pallavicini R., Tagliaferri G., Stella L.: 1990, *Astron. & Astrophys.* **228**, 403, *X-ray emission from solar neighbourhood flare stars: a comprehensive survey of EXOSAT results.*

Pasquini L., Schmitt J.H.M.M., Pallavicini R.: 1989, *Astron. & Astrophys.* **226**, 225, *X-ray spectroscopy of RS CVn stars with EXOSAT.*

Pounds, K.A., Allan, D.J., Barber, C., Barstow, M.A., Bertram, D., et al.: 1993, *Mon. Not. R. Astr. Soc.* **260**, 77, *The ROSAT Wide Field Camera all-sky survey of extreme-ultraviolet sources. I. The bright source catalogue.*

Randich S., Gratton R.,, Pallavicini R.: 1993, *Astron. & Astrophys.* **273**, 194, *Lithium in RS CVn binaries and related chromospherically active stars. II. Spectrum synthesis analysis.*

Reglero V., Giménez A., de Castro E., Fernandez-Figueroa M.J.: 1987, *Astron. & Astrophys. Suppl.* **71**, 421, *A uvby beta survey of northern-hemisphere active binaries. I. The observations.*

Scaltriti F., Piirola V., Coyne G.V., Koch R.H., Elias N.M., Holenstein B.D.: 1993, *Astron. & Astrophys. Suppl.* **102**, 343, *UBVRI linear and circular polarization of RS CVn type binaries.*

Slee O.B., Nelson G.J., Stewart R.T., Wright A.E., Innis J.L., Ryan S.G., Vaughan A.E.: 1987, *Mon. Not. R. Astr. Soc.* **229**, 659, *A microwave survey of southern active stars.*

Slee O.B., Stewart R.T., Nelson G.J., Wright A.E., Dulk G.A., Bastian T.S, McKean M.: 1988, *Astrophys. Lett.* **27**, 247, *Microwave spectra and polarization of active stars.*

Schmitt J.H.M.M., Collura A., Sciortino S., Vaiana G.S., Harnden F.R., Rosner R.: 1990, *Astrophys. J.* **365**, 704, *Einstein Observatory coronal temperatures of late-type stars.*

Soderblom D.R.: 1990, *Astronom. J.* **100**, 204, *Kinematics of chromospherically active late-type dwarfs in the solar neighbourhood.*

Stewart R.T., Slee O.B., Nelson G.J., Wright A.E., Jauncey D.L., Large M.I., Bunton J.D., Peters W.L.: 1987, *Lecture Notes in Physics* **291**, 95, *Results of a southern radio survey of active chromosphere stars.*

Strassmeier K.G., Fekel F.C., Bopp B.W., Dempsey R.C., Henry G.W.: 1990, *Astrophys. J. Suppl.* **72**, 191, *Chromospheric Ca II H and K and H alpha emission in single and binary stars of spectral types F6-M2.*

Strassmeier K.G., Hall D.S.: 1988, *Astrophys. J. Suppl.* **67**, 439, *Photometric variability in chromospherically active stars. I. The constant stars.*

Strassmeier K.G., Hall D.S., Boyd L.J., Genet R.M.: 1989, *Astrophys. J. Suppl.* **69**, 141, *Photometric variability in chromospherically active stars. III. The binary stars.*

Tan H.S., Liu X.F.: 1986, *Acta Astron. Sin.* **27**, 130, *Rotational measurements and study for RS CVn stars.*

Tan H.S., Wang X.H., Pan K.K.: 1991, *Chinese Astron.* **15**, 461, *The non-synchronous systems among RS CVn stars.*

Tsikoudi V.: 1990, *Astrophys. J. Suppl.* **170**, 69, *IRAS observations of solar-like stars.*

Verma R.P., Iyengar K.V.K., Rengarajan T.N.: 1987, *Astron. & Astrophys.* **177**, 346, *IRAS observations of RS CVn systems.*

Wangt G., Hu J.Y., Qian Zh.Y., Zhou X.: 1987, *Acta Astrophs. Sin.* **7**, 255, *Infrared radiation of RS CVn systems.*