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ROSAT Wide Field Camera EUV observations of cool stars (Invited review)

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Speedy Mic: A young, nearby, extremely fast rotating K Star discovered by the ROSAT/WFC EUV survey

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ROSAT/WFC EUV OBSERVATIONS OF COOL STARS

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ABSTRACT The UK Wide Field Camera on ROSAT has carried out the first-ever all-sky survey in the EUV region. A large number of active cool stars have been detected. The WFC instrument and preliminary overall survey results are briefly described. Examples of the wide variety of active cool star survey observations are presented, including large flares on known dMe flare-stars and the discovery of activity on new dMe, RS CVn and fast-rotating single stars in the solar neighbourhood.

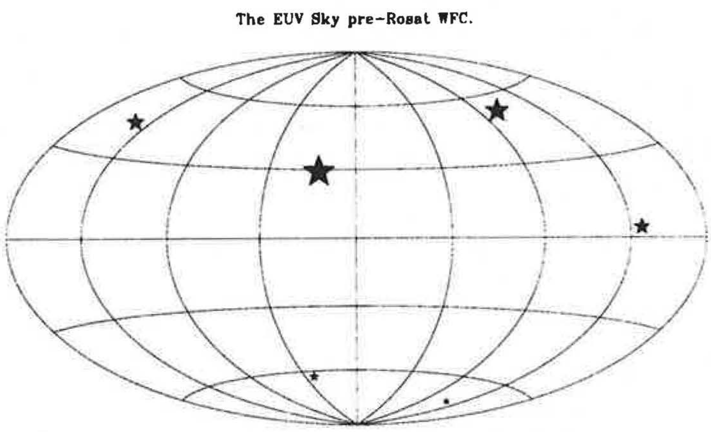
Keywords: Stellar coronae; EUV; flares; sky surveys

INTRODUCTION

The Extreme Ultraviolet (EUV) region has often been referred to as the last great window in the electromagnetic spectrum waiting to be opened on the universe. In the subject area of this workshop, the great importance of observation of EUV emission from plasma in the outer atmospheres of late-type stars has been known for years, from solar observations and modelling (*e.g.* the coronal resonance Fe IX - XIV line emission, temperature and density diagnostics, emission measure distribution studies, continuum emission mechanisms). We strongly expect that radiative energy losses in the EUV region are a very important component of the overall energy balance. Knowledge of the emission measure distribution enables us to start to understand the structure of the atmosphere and consider heating mechanisms – but until ROSAT/WFC there was a gap between $\sim 2 \times 10^5$ and $\sim 2 \times 10^6$ $^\circ K$ in stellar data, between the highest-temperature IUE lines and the temperatures probed by previous X-ray astronomy missions.

Whilst we have known for a long time that this temperature range was crucial, it has been essentially inaccessible to detailed observation, due to a combination of two historical factors: technological barriers and a "fear of the interstellar medium" (because of course the photoelectric absorption by the ISM is crippling in the EUV in high-density directions). Prior to ROSAT we had a closed, shuttered EUV window – with just one or two cracks that had been looked through to give a tantalising glimpse of the EUV universe. Figure 1(a) shows the known EUV sources before ROSAT: a handful of hot white dwarfs and cataclysmic variables, and one active cool star – Proxima Centauri. With the all-sky survey now completed by the UK Wide Field Camera on ROSAT, we have fully opened the window at last. Figure 1(b) shows the resulting EUV sky, with a dramatic increase in numbers of sources detected. These two figures encapsulate the impact of the ROSAT WFC on our knowledge of the EUV sky and stellar EUV sources.

In this review I will briefly describe the WFC instrument, and in particular the wavelength regions covered and the thin-film filters used to select them. Then, concentrating on the all-sky survey results, I will give examples of the EUV sources and their variability, including stars previously known to be active and also some of the exciting new discoveries. Further results from the WFC, including statistical results for cool stars, will be presented by my WFC Consortium colleagues John Pye (Pye *et al.* , Hodgkin & Pye, these proceedings) and Robin Jeffries (Jeffries & Jewel, these proceedings). See also Bromage *et al.* (these proceedings).



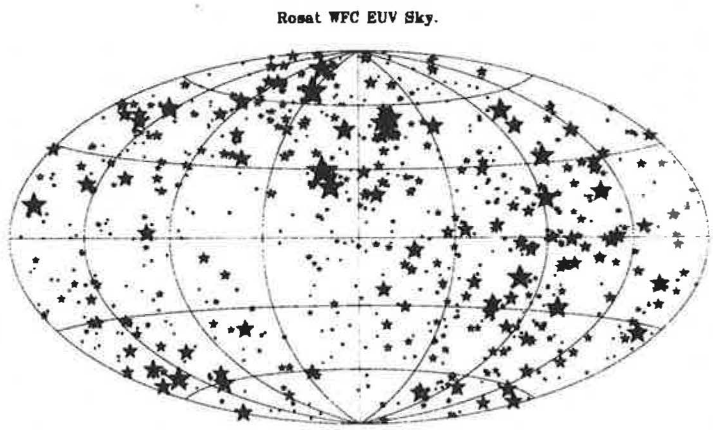


Fig. 1: The known sources in the EUV sky before and after the ROSAT WFC all-sky survey. Note that the sizes of symbols represent the significance of detections in the WFC survey: these are roughly correlated with fluxes, depending on exposure times.

THE WIDE FIELD CAMERA ON ROSAT

Schmitt (these proceedings) has described the ROSAT mission and the soft-X-ray telescope on board. The complementary instrument, performing co-aligned observations during both the survey and pointed phases, is the UK Wide Field Camera. Because of the wider field of view, most areas of the sky were observed in the WFC survey for 5 days, with typical exposure times of 50 seconds every 96-minute orbit. High-ecliptic-latitude areas were covered more deeply, as with the XRT. The WFC (Wells *et al.* , 1990) was built and is operated by a consortium of four UK University groups and the Rutherford Appleton Laboratory; the PI is K.A. Pounds (Leicester). The instrument is shown schematically in Figure 2.

The field of view is 5 degrees diameter, and for the all-sky survey results presented here the spatial resolution was $\sim$ 3 arcmin and absolute positional accuracy of sources is generally between 20 arcsec and 1 arcmin. The instrument consists of a grazing incidence telescope with a set of three nested (co-axial, confocal) Wolter-Schwarzschild Type I gold-coated aluminium mirrors. A focal-plane turret is used to select one of two identical detector assemblies. The detectors are microchannel plates curved to match the optimum focal surface, and with CsI photocathode deposited on the front face to enhance the EUV response. Eight filters are mounted on a wheel in front of the detector.

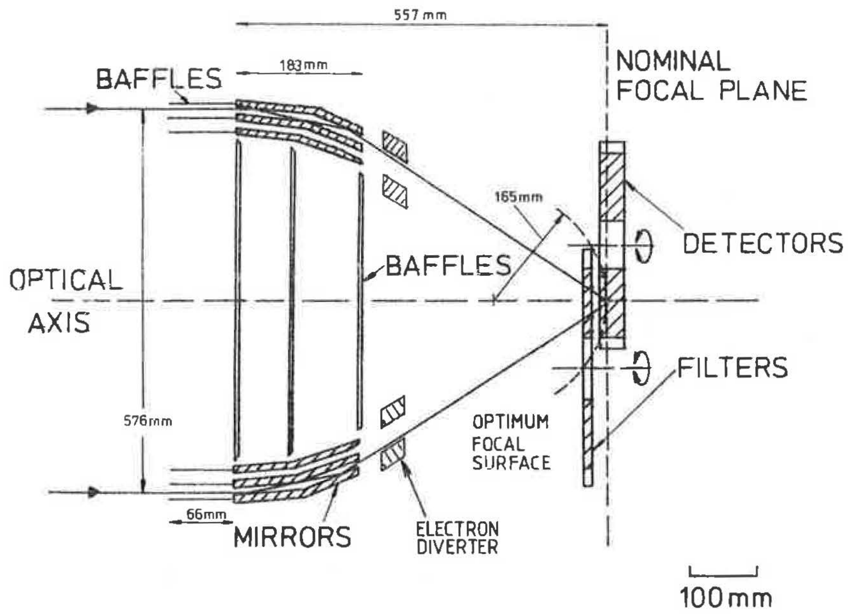


Fig. 2: Wide Field Camera optical path schematic.

The filters (one of the hardware contributions from the Rutherford Appleton Laboratory; see Kent *et al.* 1990) allow broad band photometry to be performed. They are large-area (7 cm diameter) thin-film filters typically 0.5 μm thick, with transmission centred on $\sim \lambda\lambda$ 100, 140, 180 and 600 Å respectively: the first two were used alternately during the all-sky survey, swapping normally once per day.

In addition to selecting bandpasses, the filters are required to suppress the intense geocoronal radiation which would otherwise saturate the detectors, and to suppress UV radiation from hot stars which would otherwise be counted due to the residual UV detector sensitivity. The last requirement implies that the transmission of the survey filters between $L\alpha$ and 2000Å is less than 10^{-8}, a condition that has been met successfully. EUV passband filters are necessarily very thin and therefore fragile, and the design and fabrication of the filters was governed by severe mechanical and optical constraints. The filters are performing exceptionally well in orbit. Details of fabrication, qualification and calibration are described in Kent *et al.* (1990). The main astronomical filters are coated polycarbonate (lexan). Two (S1) lexan/carbon filters (one with a layer of boron carbide for protection against atmospheric oxygen erosion) and two redundant (S2) lexan/beryllium filters were designed for both survey and pointed-phase use: S1a and S2a were used throughout the all-sky survey. In addition, lexan/aluminium (P1) and tin/aluminium (P2) filters provide two further wavelength bands for pointed phase observations. The overall WFC effective-area curves including each filter in turn are shown in Figure 3.

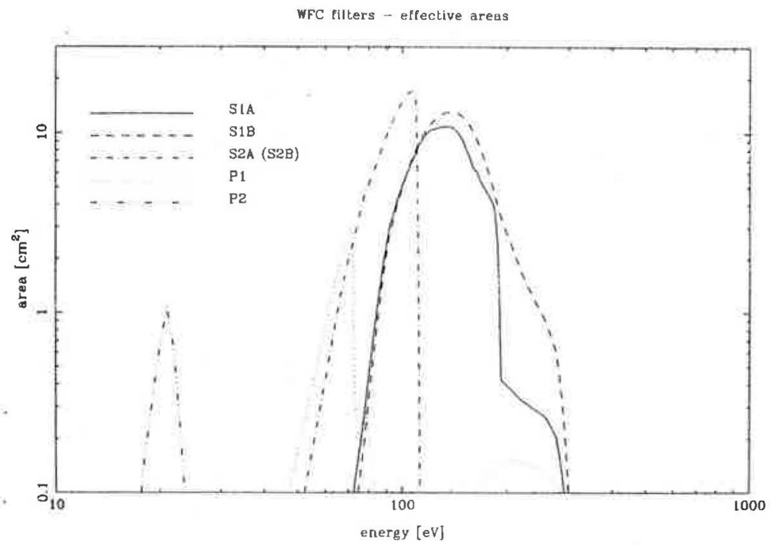


Fig. 3: WFC transmission curves, labelled by filter number.

THE WFC ALL-SKY SURVEY RESULTS

Early in the ROSAT mission, a five-day mini-survey was performed (Pounds *et al.* 1991) and of the 23 identified EUV detections, 15 are coronal sources. This was followed by the all-sky survey, the vast majority of which was completed in the 6-month period from August 1990 onwards. Provisional analysis of all the data is complete and the following summary refers to secure detections from the current stage of analysis: further processing is in hand and is expected to significantly increase the totals.

There are some 700 secure EUV sources so far, of which 250 remain unidentified at present. Identifications via catalogue correlations with known X-ray sources and nearby active stars and hot white dwarfs have been greatly supplemented by an intensive series of optical identification observing campaigns (Mason *et al.* 1991) organised by the WFC Consortium. For coronal sources, an indication of the detection levels is that a 6^m main-sequence active G star with barely detectable Ca II K line emission core at 1 Å resolution is typically also just detected in the WFC survey, whilst active dMe stars are detected down to $\sim 13^m$ in *V*.

Of the $\sim$ 450 identified objects, $\sim$ 10 are Active Galactic Nuclei seen through low-density directions of the interstellar medium, $\sim$ 20 are cataclysmic variables including some exciting new AM Her objects, and $\sim$ 120 are hot white dwarfs — including many of the brightest WFC objects and of which half are new discoveries. Nearly 300 are late type stars, including some 50 identified as RS CVn (evolved) binaries, and 50 dMe stars (of which about half are known to be flare stars).

An example of a pair of fairly close WFC sources is shown in Figure 4. Their separation is 8 arcmin. The softer source (brighter in S2a filter) has now been identified as a new white dwarf, and this filter ratio is typical of such nearby WDs. The somewhat harder source is coincident with a bright double G6 main sequence star, of which one component is optically variable and may be a new RS CVn system.

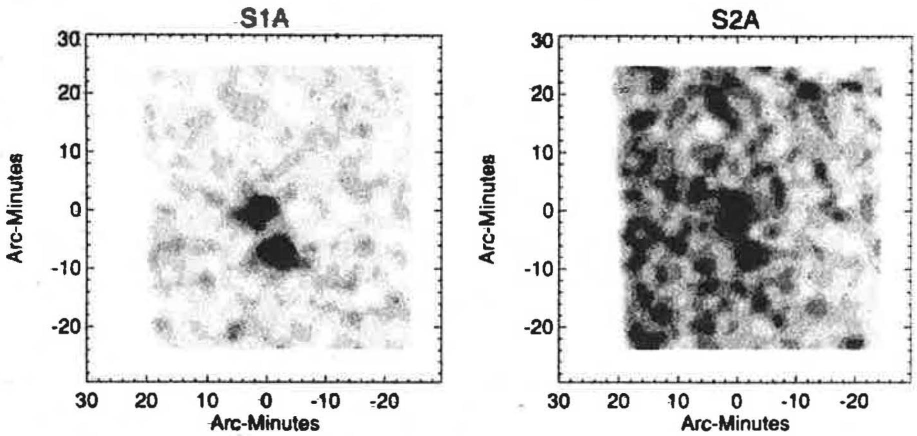


Fig. 4: Example of a pair of close WFC sources illustrating the spatial resolution. The northerly object is a new WD and the other is a coronal source.

For quiescent coronal sources, the WFC filter ratio can be used in conjunction with plasma models to constrain the effective temperature, provided that a reasonably accurate value for the interstellar absorption along the line of sight is known. (*e.g.* Figure 5). More information on the emission measure distribution will be obtainable by combining WFC and XRT data, at least for the ranges of temperature with large emission measure that are tuned to the ROSAT instrument sensitivities; information on low emission-measure ranges will necessarily be more difficult to recover from these broad-band observations. It can be seen from Figure 5 and bearing in mind that most coronal sources with high interstellar columns are too far away to be detectable by the WFC, that coronal sources are expected to have S2/S1 filter ratios between 1 and 2. Finally, it should be noted that it is normally impossible to derive temperature information solely from WFC data on *transient events* during the survey, since the filters were swapped only daily.

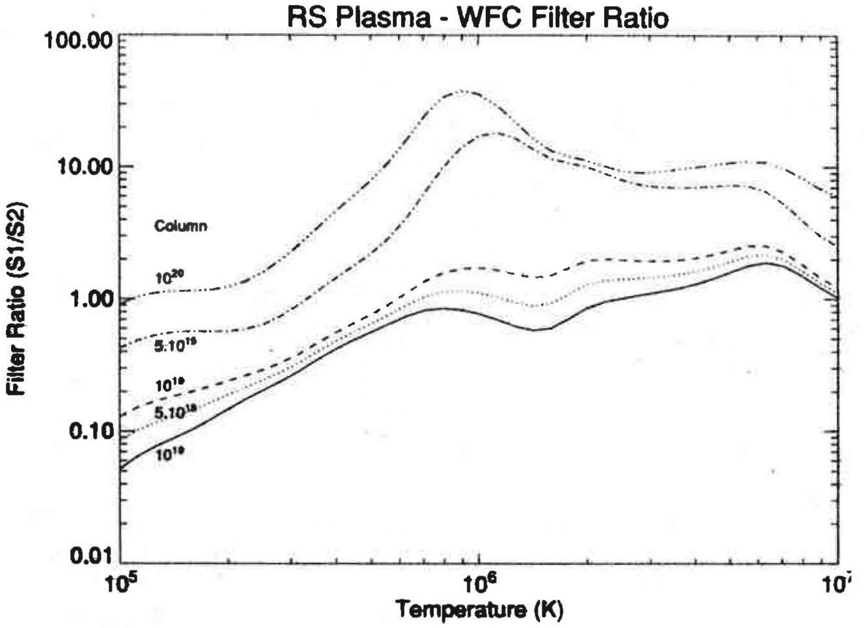


Fig. 5: WFC filter ratio as a function of plasma temperature for single-temperature Raymond-Smith plasma models, and for various values of N_H interstellar hydrogen column density (cm^{-2}).

PREVIOUSLY-KNOWN CORONAL SOURCES: EUV FLARES

The first unambiguous detection of a stellar flare in the EUV — also seen in the ultraviolet (IUE), X-ray (XRT) and optical regions — was recorded by the WFC on 1990 October 1, from the famous double flare star BY Dra. We have already reported the first results from this data set (Barstow *et al.* , 1991). The S2/S1 filter ratio for BY Dra during *quiescence* and a single-temperature model fit yielded $\sim 3 \times 10^6\ {}^\circ K$. The quiescent luminosity and emission measure were 4×10^{28} erg s^{-1} and 2×10^{52} cm^{-3} in the energy range 0.08 - 0.18 keV. The total energy radiated in the EUV *flare* was $\sim 10^{33}$ erg in the S2a filter — a substantial fraction of the total energy released. The EUV and UV (IUE) flare apparently lasted for several hours, and the corresponding XRT flare decay was detectable for nearly 10 hours, making this a particularly long-lasting event for dMe stars.

With only part of the full survey time-series analysed so far, we have also found large EUV flares that occurred on the dMe stars EV Lac (December 17 at ~15:30 UT and December 20 at ~18:00), YY Gem (October 3 at ~10:30) and AU Mic (October 18 at ~19:00). The last is illustrated in Figure 6. The presence of flaring activity in the S1a filter explains the (at first puzzling) anomalous average filter ratio for AU Mic, which was outside the allowable range for coronal models for this star. The first EV Lac flare showed even larger enhancements over quiescent levels, peaking at 1.5 count s^{-1} in the S2a filter, a factor of 20 enhancement. Many of the known shorter-period RS CVn binaries were clearly detected in the survey, and their time variability is now being investigated. For example, an EUV flare has been detected (Barstow & Guinan, private communication) in HR 1099 near the maximum brightness phase in the optical photometric rotational-modulation light curve.

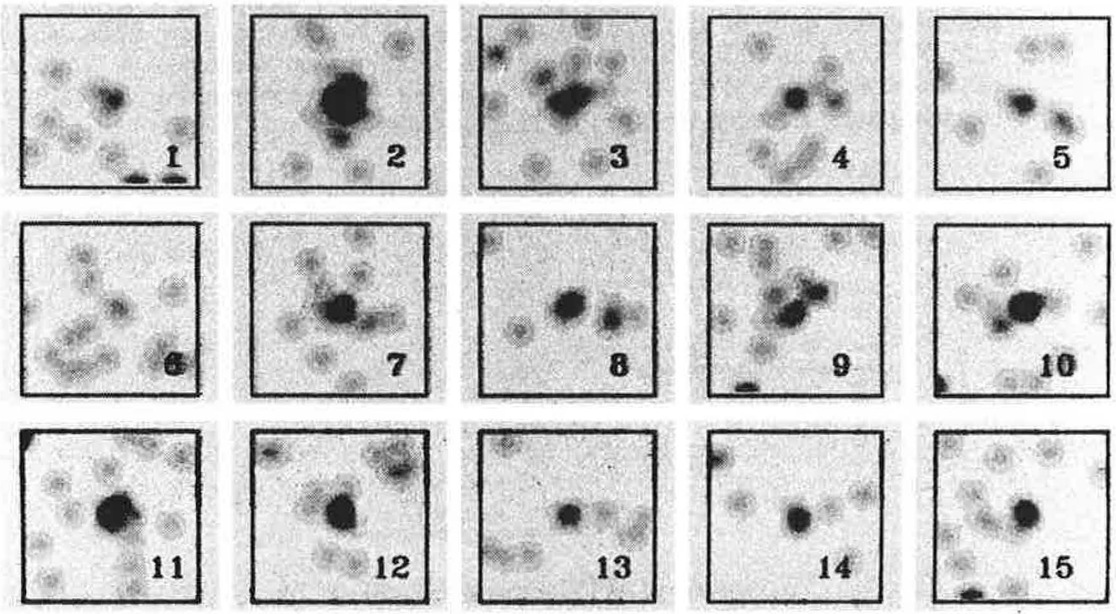


Fig. 6: Time-resolved images of WFC data of the dMe flare star AU Mic, showing EUV (S1 filter) flaring activity. Each frame corresponds to one "snapshot" of ~50 seconds integration, and the frames are for consecutive orbits (separated by 96 minutes) totalling one day's data.

DISCOVERY OF NEW ACTIVE STARS

Many main-sequence F-G-K stars in the solar neighbourhood appear in the WFC survey source list, and a large fraction of these have no previously published record of activity (as evidenced normally by Ca II H and K line emission cores). In our optical identification and follow-up observations, we have confirmed that many of these are indeed chromospherically active, but some reveal nearby dMe companions or nearby WD stars that are the real EUV emitters. The most exciting categories of new discoveries are (a) new dMe flare stars, (b) new RS CVn binaries, and (c) new rapidly-rotating single dwarf stars. In all these cases it is as usual the objects' youth-linked or binary-locked rapid stellar rotation that is assumed to be the key contributing factor (via differential rotation and magnetic fields) to give optical activity and high EUV emission.

An example discovery of a new dMe flare star is shown in Figure 7. This is the WFC source RE0604-34, which had no catalogued counterpart. In the S2a filter observations, a three-orbit flare event occurred on September 12 (labelled section B). Images integrated over the other three labelled time periods show the source was below the WFC sensitivity level at those times, although there is a small positive detection in the averaged S1a filter data. The optical identification search in the WFC error circle yielded a new dMe star with *V* magnitude 13. A similar object with no catalogued counterpart, RE0447-27, and detected only in the S2a filter, proved to be another new dMe, which actually flared serendipitously during optical follow-up spectroscopy, showing enhanced Balmer and Ca II emission including downward-moving (redshifted) chromospheric material in the early stages of the flare.

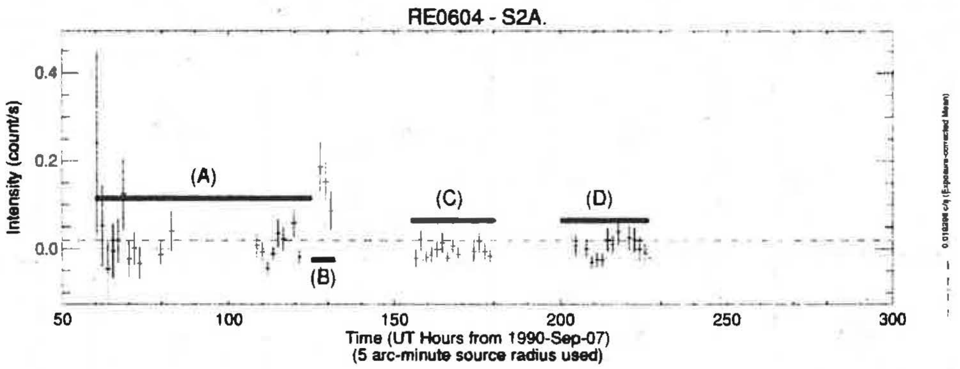
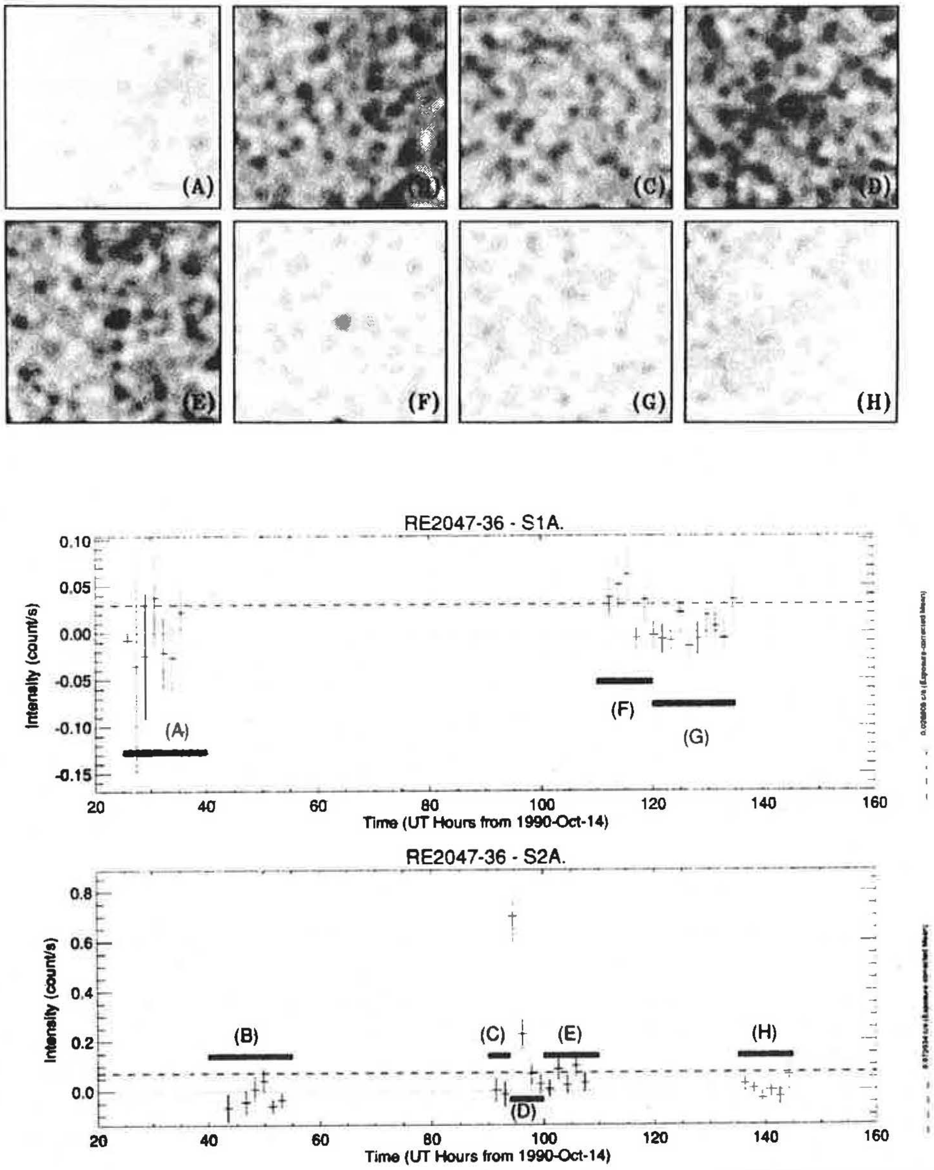


Fig. 7: Time series of WFC survey (S2a filter) observations of the new dMe flare star RE0604-34.

Newly discovered RS CVns include RE0418+23, a double-lined binary with a period of slightly less than 2 days, and RE1603-57, also double-lined with a period of 6 days. The latter is particularly interesting in that it is a G-type 8^m star very close to Iota Normae, a tight cluster of 4^m mid A-type stars in the WFC error circle. We have found on a number of occasions after careful investigation that apparent coincidences of EUV sources with A-type main-sequence stars have proved illusory. In some cases, a faint but very hot white dwarf close-by in the error circle proves to be the EUV-emitter, as with the famous case of Sirius B. In the case of RE1603-57 the EUV source proved to be a coronal late-type active binary rather than the much (optically) brighter A

Fig. 8: Time series and time-resolved image sequence for "Speedy" Mic WFC EUV observations, showing a large flare on this K0V fast rotator.



stars. These results strengthen the existing evidence that these A stars do not possess significant coronae.

Finally, a small number of WFC sources have been identified with young, very fast rotating single K dwarfs, including the well-known example AB Dor. The most spectacular discovery so far is HD 197890 or "Speedy" Mic, in the constellation of Microscopium (Bromage *et al.* , these proceedings). Despite the apparent positional correlation with the HD star, this was at first thought to be a new white dwarf, because of the large average S2a/S1a filter ratio, compared with a normal one of approximately unity for the nearby dMe flare star AT Mic. However, as with AU Mic (see above) which had an apparently irreconcilably *low* S2a/S1a ratio due to flaring in S1a observations, this third Mic source also showed a large flare, this time in S2a. The time series and time-resolved images are shown in Figure 8. Detailed optical follow-up observations proved that this is the fastest single-dwarf rotator known amongst the solar-neighbourhood late-type stars, and is a member of the young Pleiades moving group.

CONCLUDING REMARKS

The WFC instrument is performing excellently and during the all-sky ROSAT survey has produced a wealth of EUV observations of coronal sources. It has opened wide the EUV window on the (relatively nearby) universe. The examples of active star observations presented here are but a small part of this wealth, but have already demonstrated a range of exciting discoveries in this area of astrophysics. We can confidently expect that further analysis of survey data, especially in conjunction with simultaneous XRT observations, further optical and IUE follow-up of the new EUV sources, and indeed the more recent pointed-phase ROSAT WFC observations, will yield more insights into the outer atmospheres of active cool stars.

ACKNOWLEDGEMENTS

The WFC project is supported by the UK Science and Engineering Research Council. The WFC instrument and associated Ground System were developed by a consortium of five UK institutes: the University of Leicester, SERC's Rutherford Appleton Laboratory, the University of Birmingham, the Mullard Space Science Laboratory of University College London, and Imperial College STM London. I would particularly like to thank Barry Kellett (RAL), Robin Jeffries (Birmingham) and Martin Barstow and John Pye (Leicester) for many aspects of help, discussion and collaboration in the analysis and interpretation of data on WFC coronal sources.

REFERENCES

Barstow, M. A., *et al.* 1991, *Nature*, **353**, 635.
Kent, B. J., *et al.* 1990, *Proc. S.P.I.E.*, **1344**, 255.
Mason, K. O., *et al.* 1991, *Vistas in Astronomy*, **34**, 343.
Pounds, K. A., *et al.* 1991, *M.N.R.A.S.*, **253**, 364.
Wells, A., *et al.* 1990, *Proc. S.P.I.E.* **1344**, 230.

SPEEDY MIC: A YOUNG, NEARBY, EXTREMELY FAST ROTATING K STAR DISCOVERED BY THE ROSAT/WFC EUV SURVEY.

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ABSTRACT In October 1990, the ROSAT/WFC all-sky survey detected strong EUV emission from the 9th magnitude K0 star HD197890 in the constellation Microscopium. Prior to ROSAT, this object was not known to be an active-chromosphere star. Most of the EUV emission was contained in a large flare event together with continued activity for about 20 hours. Subsequent optical spectroscopy and photometry have revealed that the star is a single, extremely fast rotator with a photometric period of 8.1 hours. We have nicknamed the star *Speedy Mic.* Kinematic evidence and lithium abundance are consistent with its membership of the very young disk population Local Association (Pleiades group).

Keywords: Stellar coronae; EUV; flares; Local Association

INTRODUCTION

The U.K. Wide Field Camera on board *ROSAT* carried out the first-ever all-sky EUV survey in 1990/91 (Wells *et al.* 1990, Bromage 1991). During this survey, several hundred active late-type stars were detected, including dMe and earlier type active-chromosphere stars and BY Dra, RS CVn and W UMa type binaries.

One of the important classes of EUV emitter, though its members are very rare, is the group of nearby G-K type active stars belonging to the very young disk population Local Association or Pleiades moving group (Innis *et al.* 1986, Anders *et al.* 1991). The stars are most likely to be in a short-lived evolutionary phase following core contraction to the main sequence. In order to study this important phase, it is crucial to discover further nearby members of this group in order to be able to (*inter alia)* investigate rotationally modulated activity in as wide a wavelength range as possible. We report here the discovery of a new member with the fastest rotation found so far.

EUV OBSERVATIONS

The WFC observed the Speedy Mic area from 1990 October 15 to 19. As a result of the survey strategy, the data on a particular source consist of a series of 'snapshots' of about 50 seconds duration separated in time by one ROSAT orbit (1.6 hours) and with the two survey filters (S1 and S2 with energy ranges approximately 0.08 - 0.18 and 0.06 - 0.11 keV respectively) being swapped each day. For the particular coverage including Speedy Mic, for technical reasons a gap of about 35 hours exists on Oct 16-17. The background-subtracted time series of EUV observations is illustrated in the WFC review paper in these proceedings (Bromage 1991).

Outside of the time Oct 17.9 - 19.0, the flux in both filters was largely below the sensitivity of the WFC. However, a large flare occurred in S2 on Oct 17.9 lasting at least 2 orbit-samples and with peak flux at least 20 times the quiescent level. In addition, there was clearly enhanced activity for the next day, up to Oct 19.0 (first in S2 and then in S1 filter observations). Using a distance of 40 parsec (see below) combined with interstellar hydrogen density estimates for this direction, and assuming also that a single smoothly decaying flare was sampled by the WFC snapshots, the total energy emitted was 10^{33} erg within the S2 wavelength range (approximately $\lambda\lambda$ 115 - 180 Å).

The detected source had a positional error circle of 40 arcsec radius and was 10 arcsec from the V = 9.3 mag K0 V star HD197890. We are not aware of any previously published record of activity in this star. If this was indeed the the EUV source that flared, it must be a very active star indeed, and must be either a close binary of the RS CVn type or a fast rotating single star.

OPTICAL SPECTROSCOPY AND PHOTOMETRY

HD 197890 was observed with high dispersion optical spectroscopy covering both Ca H and K and Hα and surrounding spectral regions, at the South African Astronomical Observatory in July and September 1991, and in the red at Mount Stromlo Observatory in July/August 1991. In both cases these observations formed part of a series of optical identifications and follow-ups of a large number of WFC sources, performed by some of the present authors.

The SAAO observations used the 1.9m telescope with image tube spectrograph and RPCS detector, with a spectral resolution of 1 Å at Ca HK. HD 197890 showed by far the broadest K emission line of all stars observed, with a FWHM of 240 ± 40 km s^{-1} after deconvolution from the instrumental profile. Sequences of observations showed no detectable wavelength shifts or other evidence for binarity. A measurement of the Li I λ6708 Å absorption line equivalent width of 220 ± 50 mÅ added to the evidence that this star is a single, young, extremely fast rotating dwarf similar to the well-known AB Dor but even faster.

The Mount Stromlo spectra were taken in the Hα and Na D line region using the echelle spectrograph and an uncoated GEC CCD at the coude focus of the 1.9m telescope. The resolution was 0.2Å . Radial velocities were determined from the Na D profiles using cross-correlation and templates from standard stars. The radial velocity was measured on 11 occasions over 6 days: the average value was -6.5 km s^{-1} with an rms deviation of 2.0 km s^{-1}, and no non-random variations were apparent. We estimate a $v_e \sin i$ value of 120 ± 20 km s^{-1} from these spectra, compared with 70 for AB Dor. The large value of $v_e \sin i$ together with no significant radial velocity variations constitute further strong evidence that the star is single. The Hα profile showed very clear variability from night to night.

Finally, the star was observed on 6 nights during August/September 1991 using the Monash 45 cm telescope for V-band photometry. The differential V magnitude (relative to the average of two comparison stars, whose internal differential was better than 0.01 mag) showed 0.2 mag periodic variations which we attribute to rotational modulation due to large cool spots on the photosphere. A period-search Fourier analysis yielded 8.103 hours.

DISCUSSION AND CONCLUSIONS

The rapid rotation, activity and apparent lithium abundance of Speedy Mic are strongly reminiscent of young active stars like AB Dor. Membership of the kinematic group known as the Local Association (the Pleiades group) has been demonstrated for AB Dor, PZ Tel, V838 Cen and V343 Nor (Innis *et al.* 1986, Anders *et al.* 1991). The total space motion of a Local Association star, V_T, is ~ 30 km s^{-1}. The expected radial velocity of a group member, $V_{radial} = V_T \cos \lambda$, where λ is the angular distance from the convergent point. For Speedy Mic, $V_{radial} = -6$ km s^{-1}, in excellent agreement with the measured value. In addition, limited supporting evidence comes from the proper motion: this is directed to within 25° of the convergent point with a rather large uncertainty. The observed $v_e \sin i$ and photometric period give $R_\star \sin i \sim (0.8 \pm 0.1) R_\odot$, and $\sin i$ must be close to unity or no photometric modulation would be seen. Thus $R_\star$ is consistent with the catalogued spectral type of K0 V and the distance is $\sim$ 40pc.

We conclude that the evidence for membership of Speedy Mic in the Local Association is very strong. The age of the association members is of order 50 to 70 million years. The rapid rotation, and hence activity, is a consequence of the star's youth, as seen in stars like AB Dor, and the Pleiades cluster K dwarfs. The ROSAT/WFC has apparently discovered the fastest known rotator amongst the nearby members identified so far.

ACKNOWLEDGEMENTS

The WFC project is supported by the UK Science and Engineering Research Council. The WFC instrument and associated Ground System were developed by a consortium of five UK institutes: the University of Leicester, SERC's Rutherford Appleton Laboratory, the University of Birmingham, the Mullard Space Science Laboratory of University College London, and Imperial College STM London.

REFERENCES

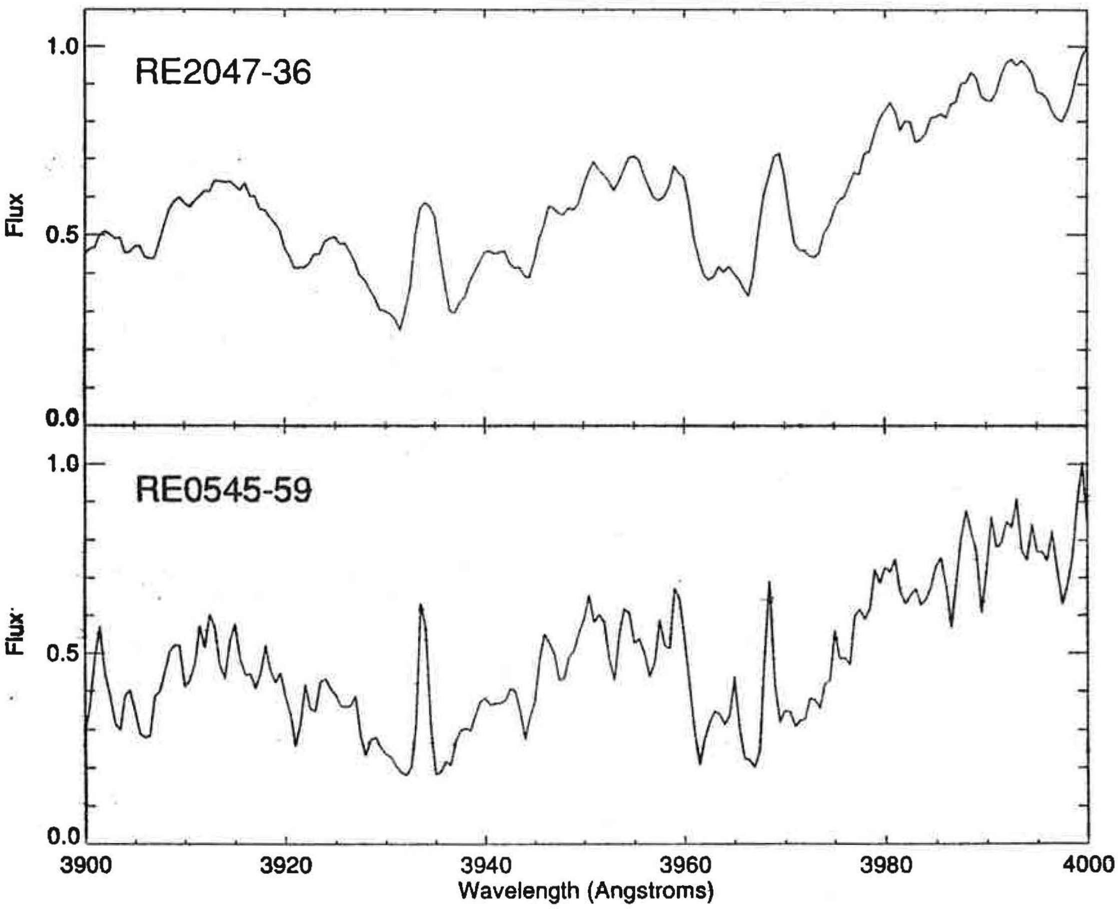
Anders, G. J., *et al.* 1991, *M.N.R.A.S.*, **252** 408.

Bromage, G. E. 1991, in Cool Stars, Stellar Systems, and the Sun, ed. J. Bookbinder & M. Giampapa, *Pub. A.S.P.*, Conf Series, this volume.

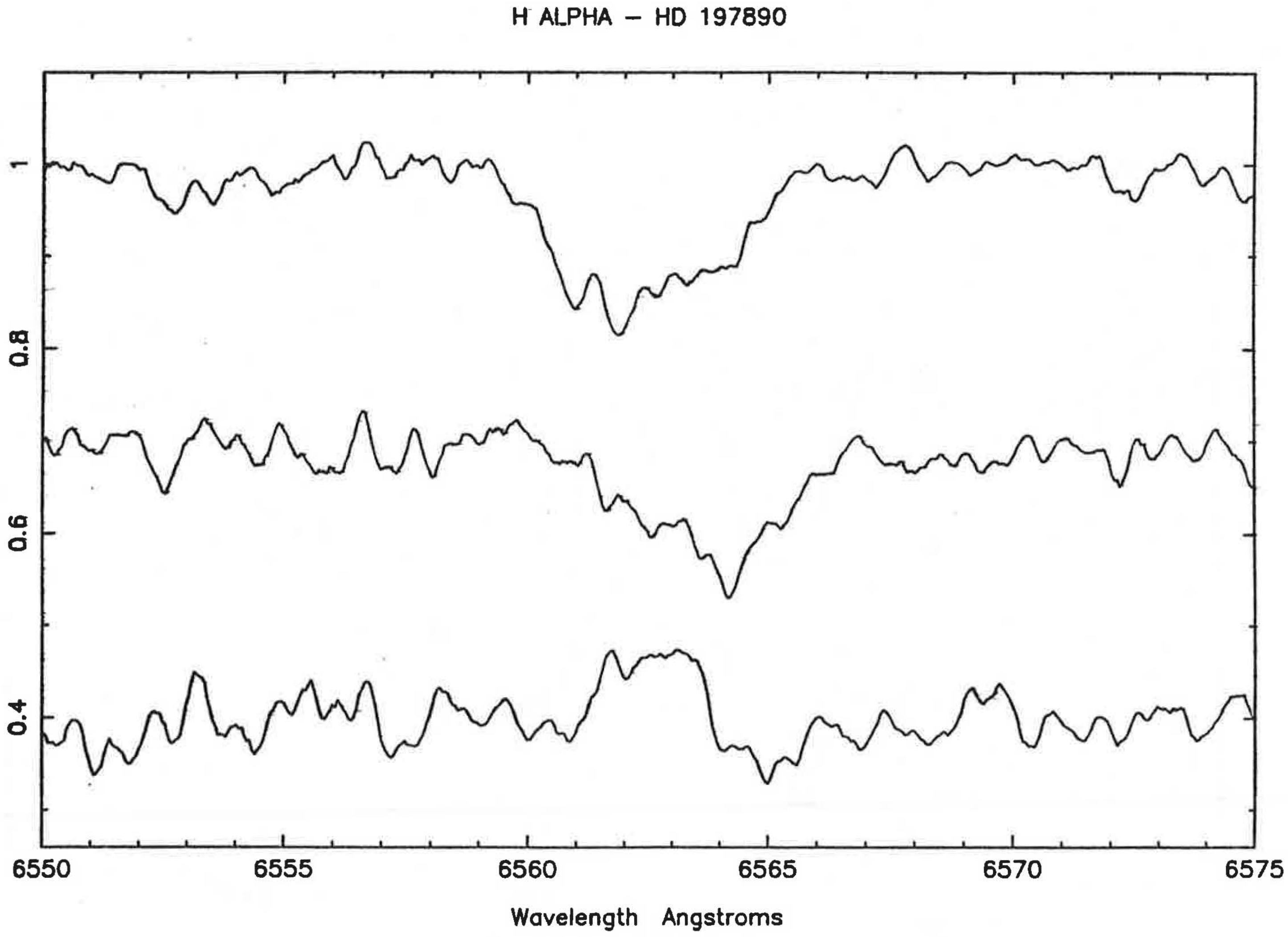
Innis, J. L., *et al.* 1986, *M.N.R.A.S.*, **223** 183.

Wells, A., *et al.* 1990, *Proc. S.P.I.E.* **1344**, 230.

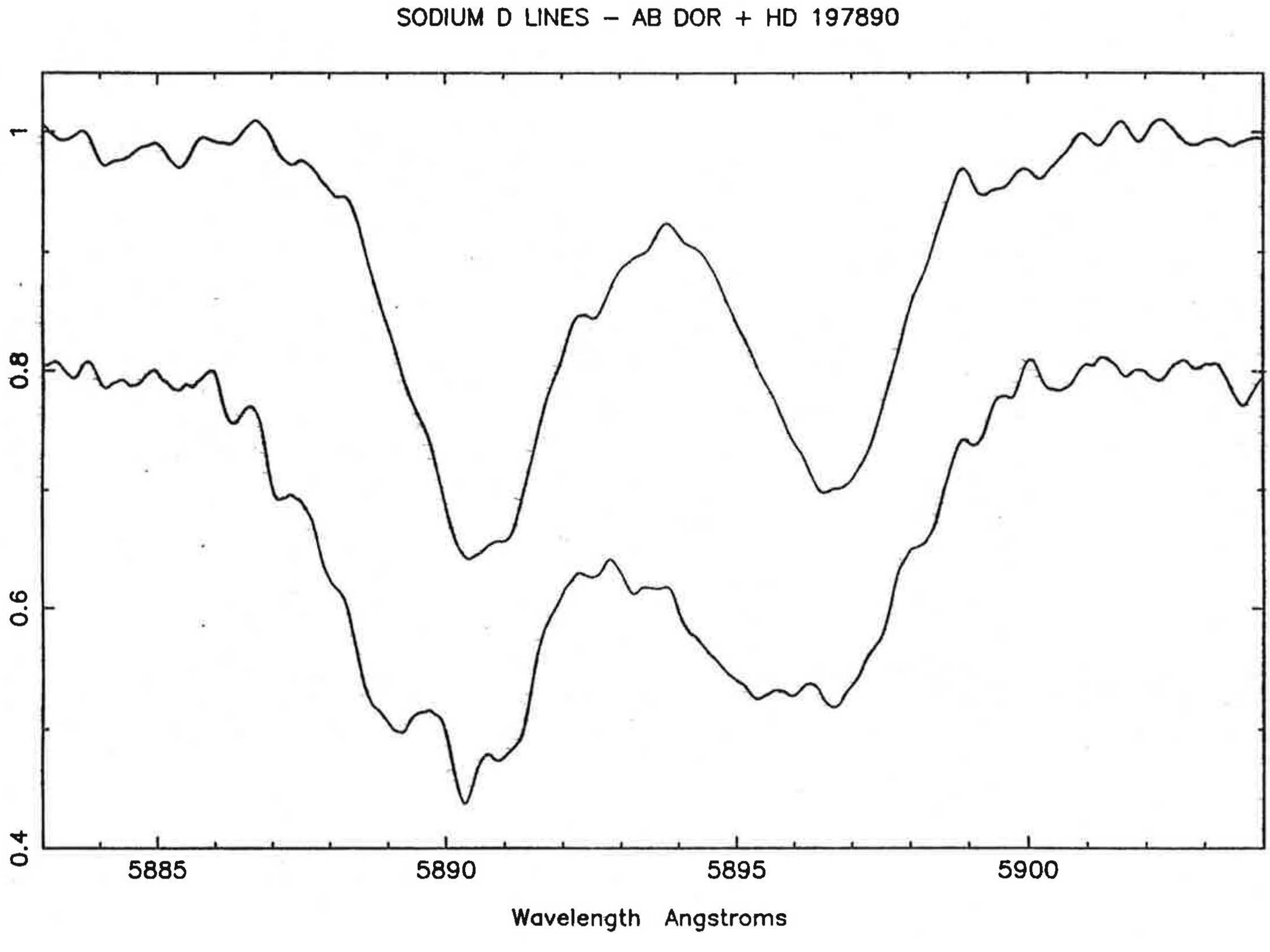
SAAO 1.9m RPCS spectra of Speedy Mic compared with a narrow-lined active chromosphere star at the same instrumental configuration and resolution. The FWHM of the K emission line is 230 km s^{-1} (after deconvolution). There is some evidence for variability in the K line profile from night to night.



Three Hα spectra of Speedy Mic, taken (from top to bottom) on the 26th, 28th and 29th of July 1991. Spectra have been smoothed with a 3 pixel (0.15Å) Gaussian, normalised to a continuum level, and a bias added for display purposes. There is clear variability from night to night.



The sodium D line spectral features from Mt Stromlo observations, for Speedy Mic (bottom) and AB Dor (top, for comparison). Spectra have been smoothed with a 3 pixel (0.15Å) Gaussian, normalised to a continuum level, and a bias added for display purposes. The $v \sin i$ for Speedy Mic is 120 km s^{-1}. The radial velocity measurements showed no evidence for periodicity down to the 2.5 km s^{-1} level.



Optical photometric rotational modulation observations: (a) Differential V magnitude light curve (2 nights data taken 15 nights apart) of HD 197890. (b) Similarly, 2 nights data but taken two weeks later and separated by three days. The deduced rotational modulation period is 8.103 hours.