Accretion mode changes in QS Tel (RE 1938 − 461): EUVE, ROSAT and optical observations


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ABSTRACT
Pointed EUVE and ROSAT observations of the AM Her type binary QS Tel (RE 1938 − 461) are reported, together with complementary contemporaneous optical measurements. The EUVE data reveal a double-peaked orbital light curve, dramatically different from the 'bright−faint' morphology seen during the ROSAT WFC survey discovery observations, indicating that two accretion sites were active. A deep dip is present during one of the EUVE flux maxima and probably arises from occultation of the emission site by the accretion flow rather than via an eclipse by the companion star. This dip, which does not appear to be accompanied by significant spectral hardening, possesses a slow (∼300 s) ingress but much more rapid (∼40 s) egress. Both ingress and a restricted phase interval near mid-dip are affected by strong flare-like activity. Blackbody representation of the EUVE spectra yields a low emission temperature (∼15 eV). The inferred estimates of the soft component flux point to a large soft/hard component flux ratio (∼15). However, we also find tentative evidence of an ionization edge at 85 Å and absorption lines at 98 and 116 Å, possibly due to Ne VI, Ne VIII and Ne VII respectively. Contemporaneous optical photometry shows the light curve to vary substantially over 3 d but, where we have simultaneity, there is no significant correlation between the optical and EUV fluxes. During the earlier ROSAT pointed observation, the source was in a single-pole mode but the intensity of the bright interval had declined by a factor ∼5 relative to the survey observation. A counterpart to the EUVE dip was seen in both the WFC and PSPC bands during the bright interval, the WFC event being similar in morphology to the EUVE dip and more protracted than the PSPC dip. Quasi-simultaneous V- and J-band photometry shows a broad dip centred on the X-ray event, with greater depth at red wavelengths. A hard spectral component is detected in the ROSAT spectrum. This collection of observations highlights the variable behaviour of QS Tel but also provides a rather clean, simple example of a change of accretion mode in an AM Her system. We consider the implications of this result and also discuss the nature of the accretion flow.

Key words: accretion, accretion discs – binaries: close – stars: individual: QS Tel (RE 1938 − 461) – novae, cataclysmic variables – X-rays: stars.
1 INTRODUCTION

Membership of the AM Her (polar) magnetic subgroup of the cataclysmic variables (CVs) has expanded rapidly in recent years, not least as a result of the ROSAT X-ray/EUV mission. These binaries comprise a low-mass star transfering material to a strongly magnetic ($B \sim 10^7$ G), essentially synchronously rotating white dwarf. The inflow is eventually collimated by the magnetic field, leading to quasi-radial accretion on to a restricted area of the surface of the white dwarf where the infall energy is liberated, principally in the EUV and X-rays and as optical/IR cyclotron radiation (see Cropper 1990 for a review of AM Her stars).

At a peak count rate of about 1 count s$^{-1}$ in both the 65–140 Å (S1A) and 112–200 Å (S2B) Wide-Field-Camera (WFC) bands, QS Tel (RE 1938–461) was one of the brightest objects discovered during the ROSAT EUV WFC survey (Pounds et al. 1993; Pye et al. 1995), conducted between 1990 June and 1991 January, prior to the pointed phase of the mission (for a description of the WFC, see Wells et al. 1990). Its independent discovery in the PSPC survey data was reported by Beuermann & Thomas (1993). Subsequent optical photometry and spectroscopy identified QS Tel as a polar (Buckley et al. 1993), one of seven discovered by the WFC. As a group, these seven systems were found to exhibit unusually large EUV/optical flux ratios compared to the majority of the previously known AM Her stars, and it was suspected that they would also possess rather weak hard X-ray fluxes (see Watson 1993), a view perhaps supported by a later Ginga observation of QS Tel which yielded only an upper limit on the hard emission (Buckley et al. 1993). On this basis, it was suggested that their accretion flows may be primarily composed of discrete blobs (Watson 1993, and references therein). In addition to its EUV brightness, QS Tel was of particular interest for two reasons. First, its orbital period of 2.33 h lies unambiguously within the CV period gap (see, e.g., Cropper 1990), the continuation of accretion perhaps suggesting that it was born there (Buckley et al. 1993), though see also Wickramasinghe & Wu (1994). Secondly, its WFC (EUV) (Buckley et al. 1993) and PSPC (X-ray) (Beuermann & Thomas 1993; Schwote et al. 1995) survey light curves indicated a simple accretion geometry involving inflow predominantly on to a single pole which passed out of view behind the white dwarf for about 50 to 60 per cent of the orbital cycle. Optical spectropolarimetry of QS Tel in a low state (Ferrario et al. 1994) suggested a magnetic field of 56 MG, whilst a later, brighter state spectroscopic study by Schwote et al. (1995) revealed evidence of cyclotron emission from two poles, one of which possesses the largest field strength (~ 80 MG) yet measured in a polar system. QS Tel was also observed by the Extreme Ultra-Violet Explorer (EUVE) during the performance verification phase of the mission (Warren et al. 1993), but the source was found in a deep low state (as was the case three weeks later when observed optically by Ferrario et al. 1994), its EUV light curve being dominated by two flare events, and no orbital variability could be discerned. It was much brighter (by a factor ~ 50) when scanned, about 90 d later, during the EUVE survey (Bowyer et al. 1994; Malina et al. 1994).

We have since secured, and present here, pointed EUVE and ROSAT observations of QS Tel, which reveal an intriguing array of accretion modes and new information on the emission regions and the accretion flow. We also present the results of coordinated optical observations obtained to complement the separate ROSAT and EUVE runs. For reference, and interesting and tabular representations of the observational data base on QS Tel and the data presented in this paper can be found in Fig. 11 and Table 1.

2 OBSERVATIONS

2.1 Extreme Ultra-Violet Explorer (EUVE)

QS Tel was the target of two pointed EUVE observations. The first, originally planned as a single visit, began on 1993

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August 16 at about 03:48 UT, but was interrupted by a target-of-opportunity (TOO) pointing (at SS Cyg) after about 21 h. During this time, about 29 ks of on-source exposure were recorded. As compensation, a second observation was scheduled, commencing on 1993 October 6 at about 07:54 UT and spanning an interval of about 3.8 d with a total about 21 h. During this time, about 29 ks of on-source expo-
samples the wavelength range between 70 and 760 Å by the use of separate gratings which yield approximate subdivided into short (SW; 70-190 Å), medium (MW; 140-380 Å) and long (LW; 280-760 Å) wavelength regions by the use of separate gratings which yield approximate mean spectral resolutions of 0.5, 1.0 and 2.0 Å in the SW, MW and LW ranges respectively, but with roughly a factor of 2 variation in the resolution across each separate range. The source was also observed simultaneously by the deep survey (DS) imaging instrument which effectively provides photometric information over the 70-360 Å bandpass – a description of the EUVE instrumentation can be found in Bowyer & Malina (1991), whilst an update on the instru-
mental performance is presented in the EUVE Guest Observer Program Handbook (1994). QS Tel was promi-
inent in both the SW and DS instruments, but was not signi-
ficantly detected in the MW or LW spectrometers, primarily due to the effects of absorption by interstellar (and possibly local) gas.

The EUVE analysis presented here has mainly made use of the event files supplied by the EUVE guest observer centre (EGO) at the Centre for EUV Astrophysics (CEA) in Berkeley, rather than the auto-reduced products produced by the initial pipeline processing at the EGO. The spectrometer data were screened (using time filters based on the housekeeping data) to exclude periods of Earth occultation and intervals of high background such as during satellite passage through the SAA. Our spectral and tem-
poral reduction has been performed via the NOAA software package IRAF. Whilst the initial images provided by the EGO showed a characteristic curvature of the spectrum in detector coordinates, for the second observation we have been able to exploit data that was subsequently reprocessed by the EGO in which the spectrum has been straightened. In extracting spectra and time-series, we utilized a rectangular source cell whose length included almost the full range in the dispersion direction and whose width was chosen (~17 pixel) to enclose essentially the entire source in the spatial direction. To quantify and remove the background contami-
nation, a region five times wider than the source cell was selected, located close to, but outside the limits of the source box. In constructing spectra, we have incorporated background statistics via information derived from this background region.

The DS data were provided in the form of two event files, one for a pre-defined annular background zone and the other for the source area. The source was offset from the centre of the field to minimize the effects of the detector dead-spot, a procedure now routinely employed since the calibration observation of HZ 43 which originally produced the dead-spot. Background-subtracted time-series were extracted by simply removing an appropriate scalar multiple (0.2) of the background series from that of the source. A small amount of data from both the SW and DS observa-
tions, recorded when the satellite was pointing close to the Earth horizon (i.e., when the source may have been subject to attenuation in the Earth’s atmosphere and/or higher background flux levels), have been discarded. This was achieved by folding the data on the satellite period and excluding data in the transitions between the satellite’s ‘day’ and ‘night’ intervals. No ‘daytime’ data were used. We point out here that, unless otherwise stated, the DS data (primarily the light curves) presented in this paper are not corrected for Primbsching, deadtime or dead-spot effects (see, e.g., the EUVE Guest Observer Data Products Guide 1995), since the corrections are approximately constant throughout the duration of each observation – profile com-
parisons are thus reliable. We also note that the absolute DS count rates are subject to a ±15 per cent uncertainty which dominates over Poisson statistics, due primarily to the uncertainty in the dead-spot correction factor.

2.2 Optical

Owing to the highly variable nature of QS Tel, attempts were made to organize quasi-simultaneous optical coverage of the star with the scheduled EUVE run. In the event, due to the interruption by the TOO observation, little simulta-
neity was actually achieved. Nevertheless, photometric and spectroscopic measurements were made over a span of 3 d at the end of the first EUVE observation.

Two sets of UBV photometric measurements were secured with the single-channel STAP photoelectric photometer on the 1-m telescope of the South African Astronomical Observatory (SAAO) on the night of 1993 August 16/17. Integrations of 30 s (for U and B) and 60 s (for V) were used. The two sets of exposures were separated by a series of corresponding background measurements, the entire sequence being completed within 7 min. The first set recorded \( V = 15.702, B - V = 0.015 \) and \( U - B = -1.203 \), whilst the second found \( V = 15.412, B - V = 0.032 \) and \( U - B = -1.192 \). QS Tel was thus in its bright state [verified by B-band photometry taken on the following night (Schwope et al. 1995)], comparable to that when observed by Buckley et al. (1993) and much brighter than during spectropolarimetric observations performed in 1992 July (Ferrario et al. 1994), when it was languishing around \( V = 17.2 \).

On the same night, immediately following the second set of UBV measurements, a fast photometric time-series was obtained in white light using the same instrumentation. The data stream spanned an interval of 2.9 h with individual integrations of 10 s. Background subtraction was facilitated via measurements of the sky made intermittently (typically every 15-20 min) during the observation. This light curve overlaps the second and third to last on-source windows of the first EUVE run.

In addition, we were able to secure further fast photo-
metric observations of QS Tel on August 20 from the Cerro Tololo Inter-American Observatory (CTIO) in Chile. These data were taken with the 1.0-m telescope using the Auto-
mated Single Channel Aperture Photometer operated with a Hamamatsu R943-02 photomultiplier tube and a Johnson \( B \) filter. The observation began at about 0h UT and lasted for 7.6 h, consisting of a stream of 10-s integrations. The sky contribution was removed by subtracting a smooth function
fit to sky observations, which were obtained regularly over the course of the night. Flux calibration was accomplished via reference to a comparison star located a few arcmin away from QS Tel. This star was monitored throughout the night to correct for airmass effects. The $B$-band flux of the comparison star was determined from all-sky photometry using Landolt (1992) standard stars. The resulting uncertainty in the flux of QS Tel in each 10-s bin is typically about 5 per cent. During the CTIO observation, QS Tel varied away from QS Tel. This star was monitored throughout the run. Data were taken on the 1-m telescope at the SAAO on the night of 1992 October 13 (i.e., approximately a year prior to the second $EUVE$ observation), starting at about 06:35 UT (see PfefJer- mann et al. 1986 for a description of the $ROSAT$ satellite and instrumentation). The observation spanned 2.9 d with an effective on-source exposure of 22.6 ks in the PSPC X-ray detector, divided between 19 observation slots, ranging in length between 5 and 55 min. The source was also visible in the co-aligned EUV Wide Field Camera, where the exposure time amounted to 24.5 ks. The PSPC observations were performed with the filter in the open position and with the source placed 40 arcmin off-axis (to minimize the well-known periodic obscuration effects by the PSPC window support wires at the 400-s spacecraft wobble period). The $S2B$ (112–200 $\AA$) filter was employed throughout with the WFC. Data from both instruments during periods of SAA passage (when the high-voltage supplies are switched off) and Earth occultations were excluded from the data train as part of the standard SASS processing of $ROSAT$ data.

### 2.4 Optical observations for $ROSAT$

Quasi-simultaneous optical CCD photometry was secured to complement the $ROSAT$ run. Data were taken on the 1-m telescope at the SAAO on the night of 1992 October 13/14 using the UCL CCD camera employing the RCA chip. Time-series observations spanning approximately 3.3 h were obtained in $V$ and $I_c$ bands with integration times of 100 s in $V$ and 80 s in $I_c$, exposures being obtained alternately in each band. The data were reduced in the standard manner (flat-fielded, bias- and pre-flash-corrected) and PSF-fit magnitudes were derived for QS Tel and several frame standards using the $DOPHOT$ package (Mateo & Schecter 1989). The optical observations overlap one $ROSAT$ on-source window.

### 3 EUVE RESULTS

#### 3.1 EUVE light curves

Light curves of QS Tel, accumulated into 10-s bins, were derived from both $EUVE$ SW spectrometer observations, following the approach outlined in Section 2.1. The source was detected at a mean SW count rate of $0.197 \pm 0.004$ count s$^{-1}$ in the first observation and $0.224 \pm 0.002$ count s$^{-1}$ during the second. The mean raw count rate in the DS instrument during the second observation was $1.497 \pm 0.005$ count s$^{-1}$. Applying corrections to account for Primbschingi-deadtime ($\approx 1.09$) and the dead-spot effects ($\approx 2.3$) yields an absolute DS instrument count rate of $3.9 \pm 0.7$ count s$^{-1}$ which represents a $\approx 650$-fold increase in brightness over the non-flaring level measured during the on-orbit calibration (IOC) (performance verification phase) $EUVE$ observations reported by Warren et al. (1993) when the source was clearly in a low state. The SW data, further grouped into 60-s bins, are displayed in Fig. 1. The data gaps represent the day portion (about two-thirds) of the satellite's orbit when the Earth's outer atmosphere is bright in the $EUVE$ (the $EUVE$ satellite is in a 96-min, low-Earth orbit). Long-term ($\approx 1-2$ d) flux variations of up to $\approx 70$ per cent about the mean appear to be present during the second observation, but some of this is due to the way in which the satellite samples intrinsic source variations occurring on the binary period (see below).

An $L$-statistic periodogram (Davies 1990) of the data showed it to be modulated on the previously identified orbital period of 0.0972 d (Buckley et al. 1993; Schwope et al. 1995). The two $EUVE$ time-series were subsequently folded, separately, into 50 orbital phase bins using the linear optical spectroscopic ephemeris of Schwope et al. (1995) (their equation 2), which we use throughout this paper. The period of the ephemeris is 8396.96 s. Note that phase zero marks the blue-to-red crossing point in the radial velocity curve of the narrow component in the optical emission lines which they associate with the secondary star, thus locating that star at inferior conjunction at this time. Note also that Schwope et al. (1995) presented marginal evidence for the need of a quadratic term in the ephemeris. None of our $EUVE$ or optical data provide any useful additional constraints on this issue, however, not least because the difference between the linear and quadratic ephemerides amounts to no more than 0.025 in phase over the baseline between our observations and those of Schwope et al. The resulting $EUVE$ orbital light curves of QS Tel are displayed in Fig. 2. The flux profile for the second observation, derived from the DS instrument (which has approximately 8 times greater effective sensitivity than the SW spectrometer, even including the effect of the dead-spot), is shown in Fig. 3, again folded into 50 bins per cycle. It is evident that the overall profile from both $EUVE$ observation epochs is essentially similar, exhibiting two key features. First, the morphology of the underlying orbital modulation is double-peaked, with maxima arriving at about phases 0.6 and 1.1 (hereafter referred to as the secondary and primary maxima...
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Figure 1. The top panel shows the SW light curve of QS Tel obtained from the first (August 16) EUVE observation. The lower panel shows the time-series of the longer, second observation, starting on October 6. In both cases the data have been grouped into 60-s bins. Data gaps arise from detector switch-offs during the daylight part of the satellite orbit. Horizontal bars indicate the binary period.

Figure 2. Top panels show the mean EUVE SW light curves of the first (left column) and second (right column) observations of QS Tel, folded into 50 phase bins using the orbital period of Schwope et al. (1995). The dashed lines delineate the phase range that corresponds to the bright interval observed during the ROSAT WFC survey observations. The lower panels display the corresponding EUV-band hardness-ratio curves (defined by the ratio of the count rates in the 75–105 and 105–180 Å bands).

respectively). Secondly, the primary peak appearing in the phase range 0.85–1.35, is punctured, on its ascending side, by a deep dip which lasts about 0.1 in phase. Whilst differences exist between the two light curves, such as the fact that the secondary maximum (centred at about phase 0.55) observed during the second observation is more pronounced than during the first, the overall level of compatibility is good. The double-peaked profile of the EUVE data contrasts sharply with both the WFC EUV (Buckley et al. 1993) and PSPC X-ray (Beuermann & Thomas 1993) ROSAT survey observations of QS Tel in which the orbital light curve displayed simple bright and faint intervals lasting about 0.4 and 0.6 in phase respectively, with the flux during the faint interval attaining an essentially constant, very weak (but non-zero) level in the PSPC and both WFC survey filters. It should be noted that the bandpass of the EUVE
Figure 3. From top to bottom: The ROSAT WFC survey (S1A) light curve of QS Tel (for comparison); the mean EUVE Deep Survey instrument light curve from the second observation; the SAAO white light photometric light curve, binned into 60-s bins but plotted unfolded; the CTIO data, binned into 60-s bins - the data, which comprise a near-continuous span of just over 3 cycles, have not been phase-folded but have been divided into two sections, distinguished by the solid and dashed curves, and overlayed to emphasize the cycle-to-cycle variability; the radial velocity curve of the core component of the emission lines – the Hβ and Hα measurements are depicted by squares and crosses respectively, whilst the solid curve represents the sinusoidal velocity curve that best fits the data, excluding the points between phases 0.11 and 0.19; the radial velocity curve of the broad-emission-line component – the symbols are as for the preceding panel, and the solid curve is the best-fitting sinusoid to all the data.

SW spectrometer encompasses those of both the S1A and S2B WFC filters, providing added legitimacy to the comparison. The simple 'bright–faint' mode witnessed during the ROSAT survey is seen in the light curves of several polars (e.g., UZ For, Osborne et al. 1988; DP Leo, Biermann et al. 1985) and is interpreted in terms of a single, compact active accreting pole which rotates out of view behind the white dwarf during the faint interval. Using the orbital ephemeris of Schwopes et al. (1995) to compare the EUVE and WFC survey observations directly, we find that the centroid of the single maximum in the WFC survey data (estimated HJD = 244 8160.408; Buckley et al. 1993) arrives at phase 0.02 ± 0.02, the WFC bright interval spanning the phase range ~ 0.83–1.23, as indicated by the dashed lines in Fig. 2: the phase uncertainty between the ROSAT survey and EUVE observation epochs arising from the period of the ephemeris alone is ~ 0.02. The primary maximum in the EUVE data may be slightly broader (by up to 0.1 in phase) than that of the WFC survey data and there may also be an accompanying shift of up to about 0.1 in phase. Nevertheless, we conclude that the primary maximum seen in the EUVE light curves is associated with an emission site that is located at approximately the same longitude as that observed during the ROSAT survey observations. The
secondary flux maximum observed in the EUVE data is then most readily interpreted as arising from previously unobserved accretion activity at a second site, located approximately opposite the primary pole in azimuth. In the absence of polarimetry, we cannot conclusively establish whether the two sites are located around the same magnetic pole or, perhaps more naturally, in diametrically opposite hemispheres (see also discussion in Section 5.1). The presence of a second pole has been inferred previously via the detection of its cyclotron flux (Schwope et al. 1995). However, these EUVE observations provide the first direct evidence of substantial accretion on to a second accretion site.

An initial investigation of potential phase-dependent EUV spectral variability in QS Tel was conducted via a study of the hardness ratio. Light curves, folded into 20 phase bins according to the ephemeris of Schwope et al. (1995) adopted above, were extracted from the 75–105 Å (0.118–0.165 keV – hard) and 105–180 Å (0.069–0.118 keV – soft) ranges, chosen to achieve a mean ratio of about unity. The orbital behaviour of the resulting hard/soft flux ratio for each EUVE observation is presented in the lower panels of Fig. 2. Disregarding the dip, which we will discuss shortly, the curve from the second observation shows a distinct modulation with the emission hardening during the two flux peaks, most markedly during the secondary maximum. The hardness-ratio variation in the first, shorter observation is noisier than, but consistent with that from the second run.

In Fig. 4, we show the region of the folded light curve from the second EUVE observation, centred on the dip feature, but with the data now folded into 200 bins to

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**Figure 4.** The mean EUVE light curve of QS Tel, folded into 200 bins/cycle, but focusing on the deep orbital dip. The panels show, from top to bottom: the mean profile derived from the SW data; the same but for the Deep Survey instrument (note that here the errors show the rms scatter of the data in each phase bin); the 75–105 Å (hard) band SW light curve; the 105–180 Å (soft) band profile; the hardness ratio formed from the curves in the two preceeding panels. The ratio in the interval 0.01–0.10 is shown as a single bar representing the mean in this range, since the individual bins are dominated by noise.
enhance the temporal resolution (the data from the separate observations are essentially in agreement within the uncertainties). The dip was not recognized in the WFC survey light curves presented by Buckley et al. (1993). The EUVE dip, spanning the phase range ~0.97–1.1 in Fig. 4, maps to the interval 0.95–1.08 ± 0.02 in Fig. 8 of Buckley et al. (1993). Although the light curve of QS Tel was sparsely sampled during the WFC survey, the points at phase 1.04 (S1A panel) and 1.05 (S2A panel) of their Fig. 8 might conceivably have fallen within the dip if it maintained its phase and width, but there is little evidence that either point lies inside a deep trough. The dip in the EUVE data, whose total duration is 0.13 in phase, possesses a resolved ingress lasting about 0.04 in phase (330 s) but a barely resolved egress which occurs within about 0.005 in phase (40 s). The DS instrument data from the long second EUVE run, shown in the second panel of Fig. 4, demonstrate that the remaining flux during dip minimum (phase 0.01–0.10) is predominantly concentrated in the phase interval between 0.04 and 0.08, where the mean flux is about 21 per cent of the underlying variation. In the two phase intervals adjacent to this enhancement (i.e., between phases 0.01–0.035 and 0.08–0.10), the flux is much weaker, representing about 2 and 6 per cent of the out of dip flux respectively. In fact, the signal-to-noise ratio (S/N) of the DS data allows us to examine the individual dips in some detail. Fig. 5 displays the DS light curve for each dip at 10-s resolution. In confirming that there is a tendency for the residual flux to occur over a limited phase range, these data strongly suggest that it arises primarily from flare-like events rather than persistent emission (see, in particular, panels 2a, 3a, 4b, 6b and 14b). Flare-like phenomena also appear to contribute signi-

![Graph showing individual dips in QS Tel observed by the Deep Survey instrument during the first (1a–5a) and second (1b–17b) EUVE runs. Data are plotted at 10-s resolution. The right and leftmost dashed lines delineate the end of ingress and mid-egress as determined from the average DS dip light curve from the second observation.](http://mnras.oxfordjournals.org/)


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significantly to the mean ingress profile (e.g., panels 2b, 4b and 12b), making it difficult to establish the intrinsic underlying ingress profile. It may be that this behaviour during ingress is a manifestation of changes in the width of the dip, caused, for example, by changes in the breadth of an occulting body such as the accretion flow. In contrast, the DS data highlight an apparently much more tightly constrained egress to the dip. All six EUVE windows from the second observation that fully sample the egress interval (i.e., ignoring panel 5b) exhibit an abrupt rise near phase 0.10 which lasts \( \leq 0.40 \) s. Although five dips were sampled by the DS instrument during the first observation, the ingress was observed only once and the interval between phases 0.98 and 1.01 was not covered at all. Two points concerning the dips from the first observation are worth highlighting. First, there is pronounced activity during the 1.08–1.10 phase interval in the dip shown in panel 3a, giving rise to an unusually complex egress shape. Secondly, there is a suggestion that the dip egress wanders more in phase (for example, compare panels 2a and 5a), although the mean egress profile closely matches that from the second observation.

In an attempt to probe spectral evolution through the dip, we computed the hardness ratio (as defined above) as a function of dip phase, again folding the data into 200 phase bins per cycle. The SW spectrometer light curves in the two energy-resolved bands, together with the resulting hardness ratio, are shown in the lower panels of Fig. 4. The hardness ratio during the 0.98–1.01 phase interval is 0.92 ± 0.19 which, when compared with that (0.84 ± 0.08) of the immediate pre-dip (0.90–0.97) phase interval, indicates that there is no significant hardness ratio variation during dip ingress. If, for example, the flux decline during ingress arises from increasing photoelectric absorption in the accretion flow as its leading edge covers the EUV emission site (see Section 5.3), one can estimate the absorbing column required of a cold, homogeneous medium to produce the observed reduction in flux and the effect this absorption would have on the hardness ratio. Adopting the spectral parameters (see Section 3.2) pertaining to the blackbody model that best fits the spectrum of the primary maximum (excluding the dip), we find that an additional column of \( 1.8 \times 10^{19} \) cm\(^{-2}\) is required to depress the flux by 50 per cent (appropriate to mid-ingress). This predicts a hardness ratio of 1.38, which is significantly higher than observed. Allowing for the fact that the column is changing continuously through the ingress time-scale when predicting the mean ratio does not improve the situation, and it is unlikely that the picture would be clearer were we to account for cycle-to-cycle variations. The assumption that hydrogen in the accretion flow is ionized [as might be the case if the absorbing material has a temperature of \((1-2) \times 10^6 \) K], so that the opacity of the absorber (in the EUVE band) is essentially dominated by helium, also makes only a modest difference to the predicted ratio.

We also examined the data during dip minimum for evidence of spectral changes. In the context of the stream occultation hypothesis, photoelectric absorption would be greater around the time of minimum light due to the larger path-length and possibly higher density when viewing the source through the core of the stream. The mean hardness ratio during dip minimum, i.e., over the phase range 0.01–0.09, is 1.25 ± 0.47 and is represented by a single point spanning this interval in Fig. 4, since the individual (42-s) bins are dominated by noise (the corresponding measurement from the first observation is 0.41 ± 0.46). However, as noted earlier, the emission during dip minimum is not constant but dominated by flare-like events, concentrated between phases 0.04 and 0.08. In the phase interval 0.01–0.035 the residual flux is too weak to constrain the hardness ratio usefully although, following the approach above, we would expect a ratio \( > 6 \) if the flux were simply being extinguished by a cold absorber. In the range 0.08–0.10 we measure a ratio of 0.2 ± 0.3, whereas we might anticipate a value of about 4.7. If we assume that the dip profile arises solely from flux transmitted through a uniform stream, one then has to attribute the residual flare-like emission between phases 0.04 and 0.08 to intrinsic flaring behaviour at the emission site. In this case, since we are presumably looking through the core of the stream at this time, one would expect the emission to be characterized by a large hardness ratio, comparable to or greater than that predicted for the 0.01–0.035 phase range. However, the measured ratio in the 0.04–0.08 phase interval is 2.1 ± 1.0. In fact, we were able to explore this scenario more carefully by studying the properties of two strong flares (i.e., where we can exploit the improved S/N ratio), which circumvents the problems associated with averaging over cycle-to-cycle variations. The mid-dip flare shown in panel 4b of Fig. 5 (phase 0.06–0.076) yielded a hardness ratio of 0.9 ± 0.3. Similarly, the flare seen in late ingress (panel 12b) (phase 0.99–1.01) has a mean hardness ratio of 0.8 ± 0.3. Thus we find no convincing evidence that the dip is caused principally by photoelectric absorption. If, on the other hand, the flaring represents the effects of leakage through an inhomogeneous (blobby) stream in which the blobs are essentially totally opaque to EUV radiation, the ratio could approach unity, depending on the column density due to any tenuous interblob material.

Finally, we point out that the weak residual emission observed between phases 0.01–0.035 and 0.08–0.10 might, in principle, arise from a second emission site with the flux from the primary emission region perhaps being totally extinguished (in both EUVE spectral bands defined above) by a large (\( > 10^{20} \) cm\(^{-2}\)) absorbing column. A conceivable origin for such a separate emission site might be the secondary star. To test this, we synthesized a two-component spectrum \( (kT_1 \sim 2 \times 10^6 \) K and \( kT_2 \sim 1.1 \times 10^6 \) K with comparable volume emission measures), employing the coronal emission model of Mewe, Gronenschild & van den Oord (1985). However, adopting a line-of-sight absorbing column density, \( N_{\text{H}}=0 \), and normalizing the spectrum to match the observed EUVE count rate in the 0.01–0.035 phase interval, where the weakest signal remains, yields a lower limit on the 0.1–3.5 keV luminosity of about \( 2 \times 10^{30} \) erg s\(^{-1}\) for a distance of 190 pc (Schwope et al. 1995). This is more than an order of magnitude larger than found for isolated late- (M-) type stars (e.g. Barbera et al. 1993; see also Schmitt, Fleming & Giampapa 1995) and is comparable to the upper limit applicable to RS CVn systems (e.g. Dempsey et al. 1993), so it is unlikely that the residual emission arises predominantly from the secondary star. It is worth noting that Sohl, Watson & Rosen (1995) have recently found that the residual X-ray flux observed during the minimum of the eclipse in the AM Her star,
REJ 2107−05 (HU Aqr), is broadly consistent with what might be expected for coronal emission from an isolated M star, suggesting, if correctly attributed, that coronal activity on the secondaries in CVs is probably no greater than that in the single-star case.

3.2 The EUVE spectra

The high spectral resolution of the EUVE spectrometers allows us to examine the hitherto poorly defined spectral distribution of QS Tel in the EUV, and to search for possible spectral features which might give clues to the conditions in the emission region. We began by accumulating a mean spectrum for each of the two EUVE runs in the range 75−190 Å. Since the data were not taken in dithered mode, we allowed for the effects of Fixed Pattern Noise (FPN) [a modulation of the signal on the detector with a spatial scale ~ 17 pixels (1.2 Å) – see Vallerga et al. 1991; EUVE Guest observer Center User Guide 1993], by adding 20 per cent systematic errors, in quadrature, to the data in each bin, this being the typical level of modulation arising from FPN. The data were then grouped so as to achieve a minimum of 100 counts in each output bin. The spectra were initially fitted with a simple blackbody emission model to quantify the overall spectral distribution. The best fit to the data from the second observation was obtained for a temperature of 14.8 ± 0.6 eV and an absorbing column of (4.4 ± 0.3) × 10^{19} cm^{-2} which yielded χ^2 = 1.060, ν = 139 degrees of freedom (without systematics, the fit gives χ^2 = 1.577). It should also be noted that if we try to average out the FPN effects by combining 17 pixels per output bin rather than adding systematics, the fit parameters remain essentially unchanged, but the reduced χ^2 is 1.903 for 94 degrees of freedom. The large χ^2 here is dominated by the contribution of data in the 90−120 Å range, which shows apparently systematic departures from the model (see below) and suggests that the incorporation of 20 per cent systematics (above) to minimize FPN effects may be overly conservative. The blackbody model fit, together with the data binned into 17 pixels per output bin for clarity, are shown in Fig. 6. The best-fitting column and temperature from the separate EUVE observations are consistent within errors. The temperature is significantly lower than that derived from fits to the ROSAT data (see Section 4.2) and gives rise to a large inferred bolometric flux (uncorrected for viewing angle) of 1.1 × 10^{-9} erg s^{-1} cm^{-2} for the soft component (see Section 5.2). However, closer inspection of the mean spectrum hints at the presence of absorption features, particularly near 85, 98 and 116 Å. To simply quantify these, we added an edge and two Gaussian line structures to the blackbody model. The fit then yields a column of 4.3 × 10^{19} cm^{-2} and a temperature of 15.3 eV (χ^2 = 0.94 for 133 degrees of freedom) with an inferred bolometric flux of 9.4 × 10^{-10} erg s^{-1} cm^{-2}.

The edge occurs at 85.5 ± 1.2 Å and has an optical depth of 0.15 ± 0.1, whilst the centroid wavelengths of the two lines are 98.3 ± 0.3 and 116.1 ± 0.4 Å.

To investigate the line features in more detail, we examined the unbinned data (Δλ ~ 0.07 Å), although we point out that the spectral resolution is ~ 0.5−1 Å. The section of the spectrum between 75 and 125 Å from the second observation is shown in the inset panel in Fig. 6. The fluxes at the minima of the 98- and 116-Å troughs represent a reduction of about 30 and 25 per cent relative to the fitted continuum respectively. Relative to the local data, the 98-Å
feature may be as deep as 40 per cent and certainly exceeds the level of modulation expected from FPN. Moreover, we note that there are several other potential features in the more coarsely binned data shown in Fig. 6 such as the ‘dome’ of emission surrounding the 98-Å dip and the broad trough between 102 and 106 Å (or, conversely, the peak at 108 Å). Nevertheless, despite the apparent visibility of these features, in the absence of data taken in dithered mode and of generally superior S/N ratio, we advise caution in their interpretation.

The presence of spectral features is not unexpected, however, since the soft EUV/X-ray component in polars is thought to originate from a heated region of the white dwarf’s atmosphere in the vicinity of the accretion site, the outwardly bound continuum flux having to traverse layers of the atmosphere which are not fully ionized. This region may be heated by reprocessing of any hard X-ray flux from a putative column above the stellar surface or by direct energy deposition by blobs. In the context of our present EUVE spectrum of QS Tel and the features tentatively identified there, it is interesting to note that the 85-Å edge and 98-Å line structures (perhaps associated with Ne vii and Ne viii respectively) were probably seen in the EUVE SW spectrum of the prototypical polar, AM Her (Paerels et al. 1996), where better S/N was achieved than for QS Tel. The 116-Å feature observed in QS Tel may correspond to an Ne vii bound–bound transition (2s2p→2s3d). Evidence of other absorption edges have previously been claimed in EXOSAT transmission grating spectrometer (TGS) data on AM Her (Paerels, Heise & van Teeseling 1994), indicating that absorption in the heated atmosphere of the white dwarf is important. The modest S/N ratio of the spectrum of QS Tel prevents us from establishing whether there are features present at other, coupled wavelengths to those of the features ‘identified’ (i.e., anticipated Ne vii, Ne viii or Ne ix transitions as those noted by Paerels et al. 1996). We do not see clear evidence of the absorption edge due to O vi at 98 Å which, it was suggested, may be present in the EUVE spectrum of VV Pup (Vennes et al. 1995). Nevertheless, the structure in the 90–120 Å region may reflect the presence of unrecognized atmospheric absorption features, in which case a comprehensive modelling analysis employing realistic, self-consistent white dwarf atmosphere models is demanded.

To investigate the orbitally dependent spectral variations suggested by the hardness-ratio study (Section 3.1) (e.g., to assess whether the two emitting regions are characterized by different effective temperatures), phase-resolved spectra sampling the two maxima and one of the minima were extracted. The secondary maximum was defined between phases 0.47 and 0.70, the primary maximum between phases 0.93 and 1.26 with data in the dip, defined between phases 0.98 and 1.11, excluded in the latter case. The spectrum covering the minimum of the underlying modulation includes the phase interval 0.26–0.47. Again, blackbody models were fitted to the phase-resolved data. Whilst, due to the likely presence of absorption features, we do not expect this model to be an appropriate description of the spectra in detail, it serves as a useful means of assessing differences between the spectra. The results for the best-fitting model to the primary and secondary maxima are displayed in Fig. 7, where we show the 68, 90 and 99.7 per cent confidence contours in the $N_H$–$kT$ plane. These contours are conservative, since without systematics the fits are poor ($\chi^2 \sim 1.7$) and we have added $\sim 30$ per cent systematics to normalize the reduced $\chi^2$ to unity before determining confidence bounds. The 68 per cent confidence contours for the two flux maxima do not overlap, suggesting that the two poles do not present the same observed spectrum. However, we are unable to establish whether it is the temperature, the column or both which differ. The spectrum from the flux minimum between phases 0.26 and 0.47 is even less well constrained, although there is a less than 1 per cent probability that it is consistent with that of the second pole (for clarity, contours for the fit to the data in the minimum are not shown in Fig. 7).

### 3.3 Contemporaneous optical photometry for EUVE

The white light SAAO photometry, obtained partially simultaneously with EUVE on August 16/17, and the B-band CTIO data taken 3 d later, were translated to phase and are

![Figure 7](http://mnras.oxfordjournals.org/)

**Figure 7.** 68, 90 and 99.7 per cent confidence contours in the $kT$–$N_H$ plane for the blackbody model fits to the EUVE spectra of QS Tel taken from the primary maximum (dashed contours) and the secondary maximum (solid contours).
incorporated in Fig. 3. The SAAO light curve, which spans about 1.25 binary cycles and overlaps the third and second to last windows of the first EUVE run, shows an asymmetric, ramp-like profile, varying by about 30 per cent from peak to trough of the smoothed curve. It also contains several narrow dips and flares. The SAAO curve shows no obvious correlation with that recorded in the EUV band. The deepest of the narrow dips in the optical band has its apparent minimum at about phase 0.02, close to, but not coincident with the mid-point of the dip in the EUV band. This optical dip, which has a width of about 0.08 in phase and a depth of ~30 per cent, then ends abruptly, arising into what may be a large flare within about 180 s. If the feature at phase 1.07 in the SAAO light curve is indeed a flare, the underlying dip profile may more closely match the EUVE event in phase, although the optical dip also appears to start about 0.02 earlier in phase. Nevertheless, with only one orbital cycle covered by the SAAO data, it is unclear whether the overall profile is representative of the mean light curve, and whether the optical dip is a true counterpart to the EUV feature or simply a stochastic change in the emitted flux. The B-band light curve, obtained from ESO (see Schwope et al. 1995) within 24 h of our SAAO data, shows a different orbital profile but contains no evidence of a narrow, systematic dip centred between phases 1.0 and 1.1.

This uncertainty is compounded by the CTIO observations which, though obtained only 30 binary cycles after the SAAO time-series, and spanning 3.25 binary cycles, seems to display a distinctly different shape. The light curve shows several prominent examples of flaring which may be significantly distorting the appearance of the underlying profile. There is a weak, possibly double-peaked modulation of the light curve, but it is apparently uncorrelated with the EUVE data. In view of the limited SAAO time-series and the marked morphological changes noted in the CTIO data taken so soon afterwards, we are unable to draw definitive conclusions about any orbital relationship between the EUV and optical fluxes from these data. However, we emphasize that the optical and EUV fluxes need not exhibit coordinated behaviour, since they are probably formed predominantly in separate regions which are subject to physically and geometrically different orbital effects. As a comparison, it may be worth noting that the optical light curve of V834 Cen has been observed to change from a double-peaked to a ramp-like morphology (Cropper, Menzies & Tapia 1986).

To test for non-periodic, but sympathetic, behaviour between the EUV and optical light curves, we also conducted a cross-correlation analysis on the 3500 s of data (essentially two EUVE windows) where we have simultaneous EUVE and SAAO optical coverage, both time-series being binned at 60 s resolution. Employing the discrete cross-correlation algorithm of Edelson & Krolik (1988), which computes a correlation coefficient, \( \phi_c \), as a function of temporal shift, \( \Delta t \), between the two light curves, we find no evidence for significantly correlated behaviour (\( |\phi_c| < 0.53 \)) in the range \(-0.05 < \Delta t < +0.05 \) d.

### 3.4 Radial velocity motion

The ANU spectroscopy of QS Tel was obtained within two days of the first EUVE observation. Having already demonstrated that the source is highly variable at optical wavelengths on time-scales of this order, the spectroscopy provides an important contribution, because the radial velocity curves of most polars tend to be rather stable and do not generally appear to be affected by luminosity changes in the system. To investigate the emission-line behaviour in the ANU data, trailed images were constructed in each line by phase-folding the separate spectra into 20 bins — note that six phase bins were only filled by data from the first night whilst another three were not covered at all. The grey-scale images (not shown) manifested clear radial velocity and line flux modulations, showing at least two prominent components within the line profile.

The phase-resolved H\( \beta \) line shapes are presented in Fig. 8. Each line can be readily decomposed into a broad component and a (usually) strong, narrower core component. We point out here that despite the good spectral resolution of our data, perhaps due to the modest S/N achieved in this limited data set and the lack of complete phase coverage, we are generally unable to distinguish the narrow component, which Schwope et al. (1995) associated with the secondary star, from the bright, high-velocity component (HVC) (see also Buckley et al. 1993). In two adjacent phase bins (phases 0.525 and 0.575), however, there is a third, weak, narrow peak on the red side of the central maximum which may be the narrow component. Despite the fact that the narrow component should be moving to blueshifted velocities at this time according to the ephemeris of Schwope et al. (if it is indeed the narrow component), it may be visible at this phase because it is well separated from the HVC which is then near maximum redshift. Nevertheless, given our general inability to isolate the narrow component, for consistency in determining the radial velocity motion of the line components, we have fitted a simple analytic function to the spectrum from each slice of the image. This comprised a single broad Gaussian feature and a narrower (core) component which encompasses the unresolved narrow and HVC subcomponents — the radial velocity curve of the core thus representing the combined motion of these two constituents. Formal 68 per cent uncertainties on our velocity measurements were derived using (conservatively) four parameters of interest, although in some cases formal limits could not be obtained from the fitting, and these errors were then estimated by eye. The resulting radial velocity curves for the core (FWHM ~ 7 Å) component and broad (FWHM ~ 20 Å) components are shown in the lower two panels of Fig. 3. The core component shows an apparently significant positive departure between phases 0.11 and 0.19 from the smooth modulation defined by the remaining points. This is probably associated with the rapid velocity excursion noted previously by both Buckley et al. (1993) and Schwope et al. (1995), which is due to the contribution of the HVC which is near maximum redshift at this time. A sinusoidal fit to the remaining points yields a semi-amplitude of \( 106 \pm 28 \) km s\(^{-1}\), a barycentrically corrected mean velocity of \( 69 \pm 17 \) km s\(^{-1}\) and a blue-to-red crossing phase of 0.87 ± 0.03, although we stress again that this represents the mean motion of the unresolved narrow and HVC components. A fit to all the data comprising the broad component velocity curve gives an amplitude of \( 429 \pm 53 \) km s\(^{-1}\), a mean velocity relative to the Solar system barycentre of \( 61 \pm 37 \) km s\(^{-1}\), and a blue-to-red crossing phase of...
0.80 ± 0.02. This latter component is therefore at maximum redshift at phase 0.05 [similar to that (~0.03) implied by fig. 17 of Buckley et al. (1993) once referenced to the ephemeris of Schwope et al. (1995)], the approximate mid-point of the dip in the EUV light curve. It should also be noted that at about this time, the lines show a marked decline in intensity although this flux minimum lasts longer (0.0–0.2) than the EUV event. There may also be evidence of a decrease in brightness of the core component about half a cycle later, around phase 0.6–0.7. Finally, it should be borne in mind that the phase convention adopted refers to the blue-to-red crossing point of the narrow component in the data of Schwope et al. If this component originates on the secondary star, the epoch marks inferior conjunction of that star. That this apparently occurs prior to inferior conjunction of the accretion flow would suggest that the stream lags the secondary star, in contrast to the conventional picture in which, due to the Coriolis force, the stream leads the secondary. This may in part indicate that the uncertainty on the phasing of the narrow component is greater than currently acknowledged.

4 ROSAT RESULTS

4.1 PSPC light curve

The ROSAT pointed phase observations of QS Tel were obtained approximately one year prior to the longer of the two EUVE pointings. The orbital PSPC light curve, folded into 256 bins using the ephemeris adopted above, is shown in Fig. 9. The mean measured PSPC (0.1–2.5 keV) count

![Figure 8](http://mnras.oxfordjournals.org/)

Figure 8. The sequence of 20 orbitally phase-folded spectra of QS Tel obtained at the ANU telescope (1993 August 17/18 and 18/19). The lines consist of a broad component and a narrower core component which comprises the generally unresolved narrow feature from the secondary star and the HVC (Schwope et al. 1995). The narrow component may be visible on the red side of the core at phases 0.525 and 0.575.
Figure 9. From top to bottom: the mean 0.1–2.5 keV ROSAT PSPC orbital light curve of QS Tel from the pointed observation, binned into 100 channels, showing that the source was in its single-pole accretion mode. The flux is dominated by the soft spectral component. The inset shows three separate sections of data (identified by different symbols) which sample the narrow PSPC dip; the 0.5–2.0 keV band PSPC data (sampling the hard spectral component in QS Tel); the hardness ratio, in 50 bins/cycle, of the (0.2–0.5)/(0.1–0.2) keV bands (subsampling the soft component); the WFC S2B light curve binned into 30 bins/cycle. The inset shows the data from the dip which was fully covered.

The rate is $1.53 \pm 0.03$ count s$^{-1}$, substantially lower than the mean flux of 8.9 count s$^{-1}$ detected during the PSPC survey (i.e., taken at the same time as the WFC survey data). It should be pointed out here that the modest exposure and the sampling of the binary light curve by ROSAT during the pointed observation was such that about 27 per cent of the orbital cycle was covered only once (phases 0.65–0.8 and 0.98–1.1) and much of the remainder only twice, hence the somewhat erratic appearance of the folded light curve (flickering and cycle-to-cycle variability is not generally averaged out). That said, it is immediately obvious that the underlying morphology of the PSPC data is very different from that of the EUVE data presented in Section 3.1, showing essentially a single maximum between phases 0.8 and 1.3 and a fainter, but distinctly non-zero minimum over the remainder of the cycle, where the flux drops to about 30–40 per cent of its average bright phase level (in comparison, the corresponding ratio measured from the PSPC survey data was only about 5 per cent). It should be emphasized here, however, that in comparison with the PSPC survey light curve, it is the flux level during the bright phase that has declined (by a factor of about 5–6), whereas the mean level of the faint interval is, in fact, little changed. This suggests that the accretion rate was substantially lower during the pointed observation. Relative to the primary maximum of the EUVE light curve, the bright interval in the PSPC data may be slightly shifted (earlier by $\pm 0.1$ in phase), although this might be partly influenced by the difficulty in judging exactly where the bright phase begins and ends, due to both the greater apparent asymmetry of the profile in the PSPC data and the presence of strong flaring activity.

The PSPC data in Fig. 9 also contains a deep, narrow dip between phases 1.09 and 1.115 during the bright interval. This dip, displayed on an expanded scale in the inset panel,
was incompletely sampled by the PSPC. However, our confidence in its reality is strengthened by the fact that the ingress was observed at the end of one ROSAT on-source window, whilst the egress was covered at the start of a later ROSAT window (and therefore a different binary cycle). This view is underpinned by the fact that on the linear ephemeris of Schwolle et al. (1995) adopted previously, the dip occurs during the same phase interval as the EUVE event. In fact, the egress observed in the PSPC time-series arrives within about 90 s (0.01 in phase) of that observed in the EUVE light curve and the phasing may be consistent, given the uncertainties on the ephemeris (0.006 in phase due to the period alone) and the measurement of the epoch of egress in each data set. We find no convincing sign that the PSPC flux over the 0.98–1.08 phase interval (i.e., corresponding to the ingress and mid-dip of the EUVE data) is significantly depressed relative to the local out-of-dip level although, due to the poor sampling of the light curve by ROSAT (including a data gap between phases 1.01 and 1.04), the underlying flux profile is not well defined.

The ROSAT data have been divided into three energy bands covering the 0.1–0.2, 0.2–0.5 and 0.5–2 keV bands. The first two ranges subdivide the soft spectral component, whilst the latter monitors the low-energy domain of the harder component (see Section 4.2). The orbitally folded light curve of the hardest band is shown in Fig. 9, together with the hardness ratio formed from the 0.2–0.5 and 0.1–0.2 keV bands. The hardness ratio, whilst noisy, shows no systematic variation through the cycle. We are also unable to discern any intensity variation in the hard spectral component (0.5 < E < 2.5 keV), measuring fluxes of 0.039 ± 0.004 between phases 0.8 and 1.35 and 0.034 ± 0.004 in the phase interval 0.35–0.8 respectively. The narrow dip cannot be recognized in the hard band light curve either, perhaps due to the poor S/N ratio of the data.

4.1.1 WFC light curve

In addition to the PSPC, QS Tel was generally simultaneously visible to the ROSAT WFC. The average WFC count rate was 0.11 ± 0.01 count s⁻¹ in the S2B filter, after correction (by a factor of 5.4) for the diminished detector sensitivity arising from the satellite’s catastrophic loss of attitude control in 1991 January. This compares with the mean level of 0.30 ± 0.02 count s⁻¹ recorded in the S2A filter (which has essentially the same response curve) during the WFC survey (Buckley et al. 1993; Pounds et al. 1993). Thus the WFC data confirm the PSPC results in indicating that the source was much fainter during the pointed observation, a conclusion reinforced by the EUVE survey scans of the source that partially overlapped the ROSAT pointed observation (Bowyer et al. 1994; Malina et al. 1994 – see Fig. 11 and Table 1). The orbitally folded WFC light curve is shown in Fig. 9, subdivided into 30 bins per cycle. The overall WFC profile is similar to that seen by the PSPC, showing a bright interval lasting ~0.5 in phase, and a faint period when the emission level declines to about 30–40 per cent of that at the peak of the curve. As with the PSPC data, it is the intensity of the bright phase that has changed substantially since the survey observation. The mean flux during the faint phase is only about a factor 1.7 down, whereas the bright-phase emission is reduced by a factor of 5. We are not able to detect any significant orbital variation in the ratio of the PSPC (0.1–2.5 keV) and WFC (S2B) fluxes, the mean ratio in the bright and faint intervals being 13.3 ± 1.5 and 15.8 ± 2.6 respectively.

Also prominent in the WFC light curve of Fig. 9 is a dip, centred at about phase 1.05, which was sampled completely by one WFC window and partially during a further four – note that during the fully sampled dip, data from the PSPC were rejected by the SASS processing, so there is no PSPC coverage of that event. The data from the completely sampled dip are shown in greater detail in the inset panel. In comparison with the PSPC event, the data suggest that the WFC dip may be broader, beginning at about phase 0.98, but ending rapidly at essentially the same phase as the egress of the PSPC feature. Indeed, the WFC dip may possess a basically similar morphology to the EUVE dip, displaying a gradual ingress (whose duration is difficult to determine due to the low S/N of the data), a minimum lasting until phase 1.10, and an abrupt egress that probably lasts less than 100 s.

4.2 ROSAT spectral analysis

Given our inability to detect significant spectral changes via the hardness ratios for bands within the PSPC energy range or between the PSPC and WFC, we have simply extracted a mean PSPC (0.1–2.5 keV) spectrum. The data, supplemented by a corresponding point from the WFC (S2B filter), were initially fitted with a simple blackbody model, subject to a single absorbing column. This model, however, is not acceptable, yielding a reduced χ² of 4.11 for 30 degrees of freedom. Incorporating an additional bremsstrahlung source, subject to the same absorbing column, significantly improved the fit (χ² = 1.16 for ν = 28 degrees of freedom), although it was necessary to fix the bremsstrahlung temperature (we adopted a value of 10 keV) since the true temperature, which is certainly greater than a few keV, cannot be constrained by fits to the high-energy domain of the PSPC band. The best fit gave a soft component temperature of 20.5 ± 1.5 eV and a column of 3.3 ± 0.7 × 10¹⁹ cm⁻² with χ² = 1.115 for ν = 30 (90 per cent confidence uncertainties), yielding a bolometric flux of 4.3 × 10⁻¹¹ erg s⁻¹ cm⁻² for the soft spectral component. The corresponding hard component bolometric flux is 1.5 × 10⁻¹² erg s⁻¹ cm⁻², with an estimated upper bound (assuming a temperature of 30 keV) of 3.1 × 10⁻¹¹ erg s⁻¹ cm⁻². The blackbody temperature is slightly (but significantly) higher than that derived from the EUVE data (Section 3.2), partially explaining the lower inferred bolometric luminosity. If the temperature is fixed at that derived from the EUVE data (15 eV), the implied bolometric flux climbs to 4.5 × 10⁻¹⁰ erg s⁻¹ cm⁻², but the fit is unacceptable (χ² = 3.68 for ν = 31), displaying systematic deviations from the data. The higher temperature from the ROSAT data may in part reflect the fact that the blackbody model provides an inadequate description of the photospheric emission region, although this is probably not a major factor in explaining the difference here, since the spectral domain sampled by the EUVE SW spectrometer is essentially fully covered, albeit at much lower resolution, by the PSPC/WFC combination. However, since the ROSAT and EUVE observations were so widely separated in time.


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and are clearly snapshots of the system in different luminosity states, with quite plausibly different temperatures, we refrain from commenting further on this result.

4.3 Contemporaneous optical photometry for ROSAT

Quasi-simultaneous optical V- and I-band photometry was obtained from the SAAO to augment the ROSAT pointed observation. The orbitally folded light curve for each band is shown in Fig. 10, without binning. The optical observation covered about 1.5 cycles, sampling the phase interval 0.98–1.44 twice; in fact, the second cycle covers the interval when the PSPC observed the dip ingress. Evidence of cycle-to-cycle variability between the two cycles is highlighted by the different symbols employed. Nevertheless, the key features seem to be repeatable. In the V band, the curve can be characterized by a roughly flat-topped bright interval spanning the phase interval 0.9–1.4, and a fainter period between phases 0.5 and 0.85 when the star fades by about 0.4 mag (31 per cent in flux) on average. There is some evidence, most notably, but perhaps coincidentally, during the cycle in which the PSPC dip was observed, of a dip in the V-band flux centred near phase 1.1 when the flux declines by about 0.17 mag (14 per cent). While the V-band minimum is replicated at red wavelengths, the bright interval is replaced by a double-peaked morphology with peaks centred near phases 0.9 and 1.35 in the red. The intervening trough, seen in both optical cycles, reaches a minimum near phase 1.1 (the phase of egress of the PSPC dip) and, at its deepest, is fainter than the adjacent bright peak, by about 0.4 mag (31 per cent). The phases of the two maxima match reasonably well with those in the I-band data presented by Ferrario et al. (1994), where they were interpreted as representing the two quadrature points in the ellipsoidal modulation of the

Figure 10. The V-(top panel) and I-(lower panel) band SAAO data taken contemporaneously with the ROSAT pointed observation. The data are folded but not binned. Where there is phase overlap (between phases 0.98 and 1.45) the separate cycles are depicted by different symbols.
secondary star. In those observations (1992 July), the star was about 0.75 mag (50 per cent) fainter in $V$ than in the observations presented here.

5 DISCUSSION

The EUVE, ROSAT, and optical observations presented in this paper reveal several important new properties of QS Tel which can impact on our understanding of the accretion process in AM Her stars. We discuss these below. For reference, Table 1 presents a catalogue of the observations of QS Tel, including our own data and previous studies. The same data are displayed graphically in Fig. 11.

5.1 Changes in the accretion geometry

The EUVE observations signal a dramatic alteration in the morphology of the EUV light curve since the ROSAT survey observations. The presence of two maxima, separated by about half a cycle, favours an interpretation in which a change of the accretion geometry has led to material being able to feed a second accretion site. The evidence of spectral hardening during the EUVE flux maxima argues against the idea of a single region in which the troughs of the double-peaked modulation arise from absorption effects. Whilst the limited quantity and sampling of the ROSAT survey data means that the duration of the bright phase at that time cannot be accurately determined, it appears that it lasted for no more than about 50 per cent of the cycle, suggesting that the emission site at that epoch was located in the white dwarf's lower hemisphere. During the EUVE observation (and indeed the ROSAT pointed run), the presence of the dip in the primary maximum, which is almost certainly due to stream occultation, indicates that material was being lifted out of the plane to feed an accretion region in the upper hemisphere of the white dwarf. Although it is not the only scenario, it seems likely that this is the source of the primary maximum in the EUVE light curve (and perhaps of the single maximum in the ROSAT pointed run). The location of the second accretion site, however, is unclear. It could, for example, be associated with the other (lower) pole of a dipolar field configuration, or both it and the primary emission site may be located around the same magnetic pole. This issue cannot be unambiguously resolved without polarization information.

Alterations in the soft and/or hard X-ray light curves of some polars have been recorded previously (e.g., AM Her, Heise et al. 1985; QQ Vul, Osborne et al. 1987; V834 Cen, Osborne, Cropper & Cristiani 1987; BL Hyi, Beuermann et al. 1985, Singh, Agrawal & Reigler 1984; BY Cam, Ishida et al. 1991, and references therein; RXJ 1940-1025, Watson et al. 1995, Stavroyiannopoulos, private communication). In the latter two cases, the changes can probably be ascribed to the fact that the white dwarf (and its magnetic field) rotates slightly asynchronously with respect to the stream of material emanating from the companion star and is therefore undergoing a continuous change of its accretion geometry. In AM Her, QQ Vul and V834 Cen the explanation remains unclear, since they are believed to be synchronous systems, but the simplest interpretation of the so-called

![Figure 11](https://via.placeholder.com/150.png?text=Figure+11.+Graphical+representation+of+the+long+term+EUV+and+optical+variability+of+QS+Tel.+The+left+axis+shows+the+DS+instrument+count+rate+scale,+whilst+the+right+axis+calibrates+the+optical+flux.+Mean+EUVE+measurements+are+shown+as+squares,+linked+by+the+solid+line.+ROSAT+values+are+equivalent+fluxes+expected+in+the+DS+instrument+(see+Table+1+for+an+explanation)+and+are+depicted+by+stars,+joined+by+the+dashed+line.+The+optical+data+are+indicated+by+crossed+circles,+connected+by+the+dotted+line.+Note+that+the+lines+are+shown+simply+to+guide+the+eye+between+observations+performed+in+the+same+bond+-+substantial,+unobserved+variability+may+well+have+occurred+at+epochs+between+adjacent+plotted+points.+The+dot-dashed+line+marks+the+zero+level+for+the+EUVE+fluxes.)
Asynchronism in QS Tel, one might conceivably anticipate that some future observations may witness the system accreting predominantly on to the second site.

The alternative scenario, greater penetration of the magnetosphere by the gas stream, depends on a number of factors. If the infalling material is largely homogeneous, an increase in its density and therefore ram pressure \( (\rho v^2) \) leads to compression of the effective magnetospheric radius \( R_{\text{mag}} \propto M^{-2/3} \). If, on the other hand, the stream is primarily composed of blobs, the key factor is the time-scale on which blobs lose energy and angular momentum to the magnetic field which is directly related to the blob density. Hence, if the density increases (a possible consequence of an enhanced mass transfer rate), the blobs can persist for longer and travel further within the magnetosphere before the material is forced to follow the field lines. Finally, possible changes in the efficiency of the instabilities (e.g., Rayleigh–Taylor/Kelvin–Helmholz) that regulate the homogeneity of the flow as it enters the magnetosphere, and the rate at which blobs within it are stripped of material, can alter the depth to which such entities can sink.

To gauge the relative changes of accretion rate between observations, we extrapolated the spectrum measured from the ROSAT pointed observation to the EUVE SW band and then, assuming the temperature and column to be unchanged, scaled this to account for the higher PSPC count rate observed during the ROSAT survey. This underpredicts the observed EUVE SW count rate by a factor \( \sim 2 \) when one allows for the fact that two regions were accreting during the EUVE observation. If, instead, one compares the bolometric soft component flux inferred from the EUVE spectrum and that from the pointed ROSAT observation, again appropriately scaled, the brightening factor may be as large as 5. Thus the accretion rate at the time of the EUVE run may have been \( 2-5 \) times higher than at the epoch of the ROSAT survey. For the homogeneous case described above, such a change would result in only an \( 18-37 \) per cent contraction in the magnetospheric radius so that, if this permits material to reach field lines that feed the second pole, such access is relatively sensitive to the accretion rate in QS Tel. However, it seems unlikely that a route to the second pole would be possible in any realistic dipole configuration based on this level of constriction, even if the dipole is not centred in the white dwarf.

To test and illustrate the effects of enhanced accretion in the case of a structured stream (composed of blobs), we performed simple simulations based on the treatment of King (1993) and Wynn & King (1995). Although many of the geometrical and dynamical parameters of QS Tel are poorly known, we adopted a field strength of a few \( 10^7 \) G, a dipole colatitude and longitude (relative to the line of centres) of 60° and 10° respectively, and white dwarf and companion star masses of 0.6 and 0.3 M\(_\odot\) respectively. The time-scale on which blobs of density \( \rho_b \) and length \( l_b \) exchange energy and angular momentum with the field is \( t_{\text{mag}} \sim c_A \rho_b l_b B^{-2} \), where \( c_A \) is the Alfvén velocity (see Hamer, King & Lasota 1986, and references therein). Since this time-scale is related to the density and size of the blob, the effect of an increase in \( M \) requires a knowledge of how such a change affects the blob formation mechanism, and hence \( \rho_b \) and \( l_b \). The blob formation process has yet to be securely identified, but to gain some insight into possible effects on
the blob parameters, we consider the L1 point oscillation model proposed by King (1989) in which photoionization of the L1 region leads to compressions and rarefactions in the gas which may ‘chop’ the gas into blobs. In such a model, changes in accretion rate might, to first approximation, be expected to produce a roughly linear increase in the blob density. The relation, $M \propto \rho_b$, then suggests that the blob lifetime, $t_{\text{reg}}$, also scales with $M$. Under these circumstances, our simulations show that it is possible for blobs to accrete to a pole on the far side of the white dwarf if $M$ increases by $\sim 5$; thus blob penetration of the magnetosphere may offer an explanation of the geometry changes seen in QS Tel. If so, a number of implications follow. Any realistic blob formation mechanism would probably produce a spectrum of blob parameters. If, at high accretion rates, the densest blobs can survive long enough to reach the secondary pole, the less dense blobs are likely to accrete predominantly at the primary pole facing the companion star. This pole would also sweep up most of any tenuous interblob material, and we would thus expect the primary pole to be a stronger emitter of hard X-rays, produced by material that shocks at low optical depths in the atmosphere of the white dwarf and/or above the surface. The clear phase shift observed between the hard and soft X-ray light curves of QQ Vul (Beardmore et al. 1995) might be a manifestation of this separated hard and soft pole picture. In the case of QS Tel, the lack of medium-energy X-ray data to complement our high-state EUVE observations means that we are currently unable to test this hypothesis, but future monitoring observations of the system may provide further insights into the cause of the geometry changes in polars.

One potentially puzzling aspect of our observations pertains to the optical emission-line profiles. The spectroscopic data show that the broad component of the lines is maximally redshifted near the time of the EUVE dip. The core component, which is dominated by the contribution from the bright HVC, reaches maximum redshift about 0.07 later in phase, approximately coinciding with the time of maximum EUV flux from the primary emission site. Thus we appear to have two components of the line, which trace the motion of material falling towards the primary site. The narrow component, largely unrecognizable in our data, is believed to track the motion of the companion star. Yet, if we postulate that the secondary EUV flux maximum arises from accretion at a second pole that is in the opposite hemisphere to the primary pole, it seems perhaps surprising that there is no sign of a second accretion flow, manifesting itself via at least a fourth emission-line component, whose radial velocity motion is modulated approximately in antiphase to the broad and HVC components. The emission-line components present in our bright-state spectroscopy (when the system was almost certainly accreting at two sites) appear to be the same as those observed by Schweppe et al. (1995) when it was in an intermediate state optically, but showed evidence of cyclotron emission from two poles -- recall that their data were obtained only 17 d prior to the ROSAT pointed observation which found the star accreting, rather weakly, on to a single pole. It may be that the accretion flow on to the second pole is not a strong source of optical emission lines although, given the apparently similar characteristics of the two poles in the EUVE data, it is unclear why this should be so. Alternatively, the lack of line emission from two streams may support the notion that both accretion sites are located around the same magnetic pole, the stream perhaps dividing but feeding both sites from a broadly similar direction.

5.2 The spectrum

The brightness of QS Tel makes it one of the few known AM Her systems for which we can reasonably hope to exploit EUVE data to search for spectral features arising from the heated white dwarf photosphere in the vicinity of the accretion region. As noted in Section 3.2, we may be seeing signs of both an ionization edge and possible absorption lines in the EUVE spectrum of the star. The EUVE spectrum of QS Tel can be compared with those published for AM Her (Paerels et al. 1996) and VV Pup (Vennes et al. 1995). Both the edge at 85 Å and the 98 Å absorption line in QS Tel apparently have counterparts in AM Her, whose inferred temperature (25 eV) is somewhat higher than in QS Tel (15 eV). It is perhaps surprising that Paerels et al. (1996) saw no sign of the apparently strong (possibly Ne viii) feature near 116 Å which we observe in QS Tel. Paerels et al. (1996) highlighted a number of odd properties of the spectrum of AM Her, which they argued could be the signature of hard X-ray irradiation of the surface emission site. These included (a) the unexpected presence of the Ne viii line, given the low inferred continuum temperature, (b) the presence of both Ne vi and Ne viii, which suggests that the temperature gradient of the region may be lower than anticipated for an unilluminated area, (c) the apparent absence of the anticipated O vii edge at 98 Å, and (d) tentative evidence of limb brightening when the emission region appears over the limb of the white dwarf. The first three points apply equally to QS Tel. Weak evidence of the O vii edges has been claimed in the EUVE spectrum of VV Pup (Vennes et al. 1995). Clearly, our understanding of the emission site in AM Her stars demands a substantial step forward in the atmospheric modeling, including the effects of both possible X-ray irradiation from the putative hard X-ray column above the surface (for which some development has taken place (van Teeseling, Heise & Paerels 1994)) and the non-LTE effects arising from the intrinsic high temperature of the region.

In the absence of a comprehensive model, we use the crude information derived from our simple spectral fits to glean some information on the characteristics of the emission regions in QS Tel. From the separate blackbody fits to the spectra of the primary and secondary flux maxima, the inferred bolometric luminosities of each pole, assuming a distance of 190 pc (Schwope et al. 1995) and ignoring the unknown sec θ projection factor correction, are similar at about $3.5 \times 10^{33}$ erg s$^{-1}$. Since this is emitted from an area, $4\pi R_{\text{WD}}^2 f_{\text{acc}}$, where $f_{\text{acc}}$ is the fractional area (appropriate to each pole), characterized by a temperature of 15 eV, and $R_{\text{WD}}$ is the white dwarf radius (taken as $8 \times 10^8$ cm), we obtain values of $f_{\text{acc}}$ of 0.008 at each polar region. Allowing for the presence of possible edges and lines leads to an inferred flux that is about 25 percent lower and a corresponding reduction in emitting area. This area is approximately two orders of magnitude greater than obtained by Schweppe et al. (1995) based on the ROSAT survey data and an assumed temperature of 25 eV -- the fractional accreting...
area inferred from the ROSAT pointed data is very similar to that deduced by Schwope et al. The smaller area inferred from the ROSAT data can in part be attributed to the higher temperature adopted by Schwope et al., which leads to a lower inferred bolometric luminosity and to a higher emissivity per unit area (\(\alpha T^4\)), both of which decrease the required emitting area. Moreover, the source was probably intrinsically less luminous, again diminishing the size of the region needed to radiate the energy.

We do not have measurements of the hard X-ray component or cyclotron fluxes at the time of the EUVE observation. However, we can make estimates, assuming that these components scale with the soft component flux (which we acknowledge need not necessarily be the case). We scaled the likely upper limit for the hard component flux (\(\sim 3 \times 10^{-12}\) erg s\(^{-1}\) cm\(^{-2}\)) derived from the bright phase spectrum of the pointed ROSAT observation by a factor of 25 (probably an upper bound on the brightening of the soft X-ray component between the ROSAT pointed run and the EUVE observations). This was then combined with the estimated bolometric cyclotron flux obtained by Schwope et al. (1995), multiplied by the same factor in an attempt to account for overall luminosity differences since their cyclotron measurements were made within two weeks of the ROSAT pointed observation. This then yields a ratio, \(f_{\text{soft}}/f_{\text{hard}}\), of 15, where \(f_{\text{soft}}\) is the soft component flux inferred for each emission site in the EUVE data. Thus QS Tel exhibits a large soft excess, at least qualitatively consistent with the magnetic field/soft excess relationship uncovered by Beuermann & Schwope (1994) (see also Ramsay et al. 1994).

### 5.3 The narrow dip

The properties of the narrow orbital dip discovered in both the EUVE and ROSAT pointed observations of QS Tel are complex. Nevertheless, it may eventually provide important information on the nature of the accretion flow.

A dip in the X-ray/EUV light curve of AM Her stars can arise in three ways. These are (1) an eclipse of the emission site by the companion star, (2) occultation of the same region by the accretion flow between the stars, or (3) the presence of two separated emission sites around the primary pole. We consider only the first two options here. This is partly because it is hard to envisage a geometry for the third option which could produce the rapid dip transitions. At the same time, we know from the radial velocity motion that both the secondary star and the accretion flow are near inferior conjunction at the time of the dip, and are thus potential candidates to explain the event by obscuration.

The scenario of an eclipse by the secondary star, whether to explain all or even part of the dip, is eliminated because, as mentioned before, an eclipse in which the white dwarf, its emission region and presumably the cyclotron emitting region near its surface are hidden, would produce a significant optical eclipse which is not observed. It is also worth noting that in accounting for previous polarimetric data (Ferrario et al. 1994) and spectroscopic observations (Schwope et al. 1995), an inclination of \(\leq 60^\circ\) has been inferred (though see Section 5.3.1) which precludes an eclipse. Finally, the duration of the dip egress in QS Tel is 30–40 s, which is much longer than the firm upper limit of 5 s imposed by the EUVE data covering the eclipse egress in UZ For (Warren, Sirk & Vallerga 1995) and the \(\approx 7\)-s upper limit measured from the ROSAT HRI observation of the eclipse egress in RE 2107−05 (K. Sohl, private communication).

We are then left with the hypothesis that stream occultation alone accounts for the dip. However, we have presented evidence in Section 3.1 that the dip does not appear to be accompanied by any strong spectral changes (at least in the EUVE observation), suggesting that photoelectric absorption is not the dominant process. The two most likely alternative mechanisms affecting the EUV continuum flux are electron scattering or partial covering. To explain the deepest parts of the dip by electron scattering demands a column of \(6 \times 10^{24}\) cm\(^{-2}\) (\(\tau_\text{e} \sim 4\)). As an example, if this were achieved by looking perpendicularly through material travelling at 500 km s\(^{-1}\) in a cylindrical flow of radius 10\(^6\) cm, the implied accretion rate would be \(~ 8 \times 10^{16}\) g s\(^{-1}\) which is a factor \(~ 3\) greater than that inferred from the luminosity of the soft spectral component alone (assuming a distance of 190 pc (Schwope et al. 1995) and a white dwarf mass of 0.7\(M_\odot\)). The required accretion rate increases if one looks through a broader stream or through material moving at greater velocities, but could be decreased if the line of sight is not perpendicular to the flow. It should be noted here that the reduction in flux due to electron scattering alone would be energy-independent. However, unless the gas was significantly ionized, i.e., a warm absorber (due to a high temperature and/or strong photoionization, both of which could only occur very close to the white dwarf), heavy elements (e.g., C, N and O) would still retain their inner electrons, so that photoelectric effects would overwhelm electron scattering in absorbing \(~ 1\)-keV photons. In other words, if the reduction in the EUV flux could be attributed to electron scattering alone (i.e., if hydrogen and helium were largely ionized), the \(~ 1\)-keV photons would suffer at least this level of absorption and maybe more, depending on the level of ionization of the heavier elements in the gas. In the absence of such low-energy X-ray data to accompany the EUVE observations, however, we are unable to test this hypothesis here. The alternative mechanism, namely obscuration by an inflow composed of dense blobs, is attractive for several reasons. First, blobs that are opaque to EUV radiation will reduce the transmitted flux due to geometric obscuration without introducing any accompanying energy dependence, as apparently observed in the EUVE data. Secondly, the flaring activity during the dip might then be associated with times when, due to statistical chance, the source is not entirely covered by blobs. Thirdly, such a picture fits qualitatively with the blob models preferred by Kuiper & Pringle (1982) and Frank, King & Lasota (1988) to explain the soft X-ray excess seen in several AM Her stars. Such models have also been considered appropriate to explain some of the optical properties of polars (e.g., RXJ 1940−1025; Watson et al. 1995). In QS Tel the apparent existence of a strong soft X-ray excess, together with the changes in the accretion geometry which may best be explained by greater penetration of the magnetosphere by dense blobs, might corroborate the picture of a blob-dominated flow in this system.
A complication which applies here concerns the ROSAT pointed observation of the dip. If the blobs are opaque to both the EUV and soft X-ray emission, the partial covering effects would be the same in both bands. Yet in Section 4.1.1 we drew attention to the fact that the breadth of the WFC dip may be similar to the EUVE event and thus much broader than the quasi-simultaneously measured PSPC dip. This would suggest that, in contrast to the broader than the quasi-simultaneously measured PSPC dip.

5.3.1 Geometry

Two points emerge from these observations regarding the accretion geometry in QS Tel. First, we find that the two EUV-emitting regions are located about 180° apart in azimuth, contrasting with the conclusions drawn by Schwope et al. (1995) from their optical data. Secondly, if the presence of the narrow dip does reflect the occultation of an emission site in the upper hemisphere by the accretion flow, it implies that \( \alpha > \beta + \alpha \), where \( \alpha \) is the inclination, \( \beta \) the magnetic colatitude of the site, and \( \alpha \) is the angular offset of the accretion site from the magnetic pole – it is expected that \( \alpha \neq 0 \), because the material connects to the field at a finite distance from the white dwarf. Based on their radial velocity data, Schwope et al. (1995) argued that the system inclination is probably less than 50°. In this case, the above constraint suggests that the primary emission region would barely, if at all, disappear from view during the rotation cycle (since \( \alpha + \beta + \alpha \leq 100° \)), in conflict with the fact that it is only visible for about 50 per cent of the cycle. This argument ignores the fact that the stream has a finite width. The constraint might also be circumvented if the dip arises from obscuration by a spatially extended accumulation of material such as might form in a putative stagnation region where the inflow begins to interact strongly with the magnetosphere (see, e.g., Warren, Sirk & Vallerga 1995). Nevertheless, this complication is probably most relevant in more highly inclined systems (e.g., where an eclipse is clearly present) such as UZ For, for which it was raised by those authors. At present, we thus concur with the view of Ferrario et al. (1994) that the binary inclination of QS Tel is probably quite high (\( i > 50° \)), although the lack of an obvious optical eclipse also suggests \( i \leq 75° \).

6 CONCLUSIONS

Comprehensive EUVE, ROSAT and optical observations of QS Tel have been presented. EUVE witnessed the source accreting strongly on to two regions, in contrast to both the earlier survey and pointed ROSAT observations when only one site was active. It is not clear, however, whether the two regions lie around the same magnetic pole or, for example, around opposite poles of a dipolar field structure. The two-site accretion mode may be related to the high inferred accretion rate pertaining at the time of the EUVE observation, although it seems unlikely that magnetospheric compression by a homogeneous stream could permit access to a second pole that is located in the opposite hemisphere to the primary pole. An accretion flow composed of blobs which can penetrate deeper into the magnetosphere may offer a more plausible explanation. A deep dip is observed during the persistent flux maximum. Its profile is complex and is probably produced by stream occultation rather than by an eclipse. Contemporaneous radial velocity data support the notion that the accretion flow is crossing the line of sight to the emission region around the time of the dip. However, the dip exhibits apparently different spectral properties in the EUVE and ROSAT observations, making it difficult to reach a conclusion about the absorbing mechanism. The mean EUVE spectrum, simply characterized by a 15-eV blackbody, probably contains absorption features due to Ne vi, Ne vii and Ne viii, but little sign of an expected O vi edge. If confirmed by higher quality EUV spectra, this raises awkward questions, already noted in AM Her, about the structure and heating mechanism in the emission region. Contemporaneous optical photometry of QS Tel shows the light curve to be variable on time-scales of days. While the observational (particularly X-ray/EUV) data base on QS Tel is still very limited, there is some evidence that this system undergoes relatively frequent changes of its accretion geometry. If this is so, and not due to asynchronism, QS Tel may offer an excellent opportunity to investigate and pin down the mechanism(s) behind mass-transfer-rate-induced changes of accretion geometry in polar systems.

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