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The line-profile variable $\lambda$ Scorpii is a spectroscopic triple system

K. De Mey$^1$, C. Aerts$^1$**, C. Waelkens$^1$, S.R. Cranmer$^2$, C. Schrijvers$^3$, J.H. Telting$^4$, K. Daems$^{1,***}$, and G. Meeus$^1$

$^1$Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Celestijnenlaan 200B, B-3001 Heverlee, Belgium
$^2$Smithsonian Astrophysical Observatory, 60 Garden Street, MS 50, Cambridge, MA 02138, USA
$^3$Astronomical Institute Anton Pannekoek, University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands
$^4$Netherlands Foundation for Research in Astronomy, Isaac Newton Group of Telescopes, Apartado 321, E-38780 Santa Cruz de La Palma, Spain

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Abstract. An analysis of 278 spectra of the line-profile variable $\lambda$ Scorpii leads to the following conclusions.

$\lambda$ Sco is the primary of a binary system. The radial-velocity variations have a peak-to-peak amplitude of $\sim 60$ km/s and an orbital period of 5.995 days. The orbit is not circular but has an eccentricity of 0.29. The $5^{a} 959$-binary system probably moves in orbit with another distant, as yet unknown third star.

By means of three five-hour time series of high-resolution spectra, the oscillations of the rapidly rotating $\beta$ Cephei-type main component are investigated. Line-profile variations, which reveal travelling subfeatures across the lines, are discovered. $\lambda$ Sco is so far one of the very few $\beta$ Cephei stars in which such a moving-bump phenomenon is detected. Radial-velocity variations are derived from the data and analysed to reveal a main oscillation frequency near $4.66$ cycles day$^{-1}$, and some more candidate frequencies. $\lambda$ Sco is a non-radially pulsating $\beta$ Cephei star which rotates supersynchronously.

The characteristics of $\lambda$ Sco and the $\zeta$ Oph stars are briefly addressed. Despite the common line-profile behaviour, spectral type, and $v \sin i$, we find no evidence of circumstellar material around $\lambda$ Sco.

Key words: stars: binaries: spectroscopic – stars: oscillations – stars: individual: $\lambda$ Scorpii – line: profiles

1. Introduction

The star $\lambda$ Scorpii (HD158926, SAO208954, 35 Sco, Shaula, HR 6527, $\alpha_{1950} = 17^h 30^m 12.6^s$, $\delta_{1950} = -37^\circ 04' 09''$) is a bright variable star ($V = 1.59-1.65$) located in the Sco-Cen association and is classified in the Bright Star Catalogue (Hoffleit 1982) as a triple system with AC-components B2IV+B. $\lambda$ Sco was first reported to be a spectroscopic binary by Slipher (1903) and he derived an orbital period of $5^{a} 6.6$ from 11 velocity observations. Lomb and Shobbrook (1975) used the mean velocities of 46 spectrograms of $\lambda$ Sco to determine the orbital period. They found a period near 10 days. Lesh (1978) determined a binary period of 10.16 days. $\lambda$ Sco was found also to be a visual binary, from interferometric techniques by Hanbury Brown et al. (1974). The system is composed of two stars of approximately equal brightness and the same colour.

The intrinsic variability of $\lambda$ Scorpii was reported by Lomb and Shobbrook (1972, 1975), who classified $\lambda$ Sco as a $\beta$ Cephei variable. Their classification was mainly based on their photometric observations made from 1969 until 1973 and on radial velocities measured from spectrograms obtained during 1969 and 1970. An analysis of the V magnitudes revealed photometric variations which arose from a superposition of 3 periodic phenomena with periods of $0^d 2137015$, $0^d 10685075$, and 10 days. Watson (1988) reported a radial mode for $\lambda$ Sco interpreting observed flux changes. No study of line-profile variations has been published so far.

Lomb and Shobbrook (1975) estimated the following parameters for the B1.5IV main component star: $R = 9 \pm 1$ R$_\odot$, $T_{\text{eff}} = 23500$ K, $g = 3.5$, Heynderickx et al. (1994) calculated physical parameters for $\beta$ Cephei variables using a calibration of both the Strömgren and the Geneva photometric system. They derived $T_{\text{eff}} = 4326$, $g = 3.768$, $M/M_\odot = 10.81$, $M_{\text{bol}} = -5.15$, and log $T_{\text{eff}} = 4.364$, $g = 3.755$, $M/M_\odot = 10.50$, $M_{\text{bol}} = -5.53$ respectively. This leads to a radius for $\lambda$ Sco of some 7 R$_\odot$.

Different values for $v \sin i$ have been reported in the literature: 163 km/s (Bright Star Catalogue, Hoffleit 1982), 120 km/s (Watson 1971), 250 km/s (Buscombe 1969), 157 km/s (Stoeckley et al. 1987). The latter made also an estimate of the inclination ($i = 37^\circ$) comparing measured line profiles with calculated line profiles based upon solid body and differentially rotating, gravity darkened Roche model stars.

The possible close-binary nature of $\lambda$ Sco is certainly of interest in relation with the pulsations that are reported for this star. On the one hand, Waelkens & Rufener (1983) found that no $\beta$ Cephei-type pulsations occur in binaries with periods less...
than four days; on the other hand, several authors (e.g. Mathias et al. 1991, Aerts et al. 1997) have found that the pulsations of binary \( \beta \) Cephei stars with orbital periods in the range of days as well as years are affected or even modulated by the orbital motion. The study of \( \beta \) Cephei stars in close binaries is therefore interesting in the more general context of forced oscillations in stars.

Until now, few radial-velocity measurements of \( \lambda \) Sco have been published and some ambiguity about the true value of the orbital period remains. The present paper is dedicated to a detailed study of the binary system \( \lambda \) Scorpii. The plan of the paper is as follows. In Sect. 2 we describe and tabulate our spectroscopic observations and data reduction. The time-series analysis is discussed in Sect. 3. We present the details of the computation of the elements of the short orbit in Sect. 4. Sect. 5 is devoted to a preliminary analysis of the line-profile variations (LPV) of the primary of \( \lambda \) Sco. In Sect. 6 we compare \( \lambda \) Sco with the \( \zeta \) Oph stars. Finally, we discuss our findings in Sect. 7.

### 3. Time series analysis

We collected the 278 radial velocities determined from the spectra of 1988, 1995, and 1996 for the time series analysis. A plot of the data versus the time (Fig. 1) reveals that the variations show three different time scales:

- long-term seasonal variations,
- medium-term variations with a characteristic time-scale of a few days,
- fast variations on a time-scale of a few hours.

After we convinced ourselves of the reality of the orbital radial-velocity variations, we first checked whether the conclusion of Lomb and Shobbrook (1975), namely that the radial velocity of \( \lambda \) Sco varies on a time-scale of about 10 days, remains valid. It is clear that this medium-term variation is not the only one that is present since the line-profile variations occur on a much shorter time-scale. Moreover, the gamma-velocity varies significantly from season to season. The presence of a long-term periodic behaviour is indicated by the different gamma-velocities: \( v_\gamma \sim 34 \mathrm{km/s} \) in 1988, \( v_\gamma \sim -10 \mathrm{km/s} \) in June 1995 and \( v_\gamma = 18.6 \mathrm{km/s} \) in 1996. To analyse the long-term periodic behaviour, we need to collect more data that are better spread in time. The time spread of our data is not sufficient to determine a period for these seasonal variations and thus to remove this long-term effect. For this reason, we used only the 1996 data to study the medium-term variations since these data are best spread in time for our purpose.

A first period analysis of the individual data sets shows that a period close to 6 days is apparent in the data of 1996. This period is dominant in the data of April 1996, when we sampled during 7 subsequent nights. We then performed a period analysis of all the radial-velocity measurements of the 1996 data using the PDM-method of Stellingwerf (1978). It seems that a period of \( 5^d \ 959 \) offers the lowest residual rms error of 5.7 km/s. The earlier found period of 10 days does not fit our data at all. Using shorter 1996-datasubsets, we also find the same period of 5.959

<table>
<thead>
<tr>
<th>Year-month</th>
<th>observer</th>
<th>N</th>
<th>S/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1988</td>
<td>C. Waelkens</td>
<td>12</td>
<td>400-600</td>
</tr>
<tr>
<td>June 1995</td>
<td>C. Aerts</td>
<td>191</td>
<td>350</td>
</tr>
<tr>
<td>September 95</td>
<td>J. Telting</td>
<td>11</td>
<td>500-600</td>
</tr>
<tr>
<td>March 96</td>
<td>G. Meeus</td>
<td>13</td>
<td>350</td>
</tr>
<tr>
<td>April 96</td>
<td>G. Meeus</td>
<td>14</td>
<td>350</td>
</tr>
<tr>
<td>April 96</td>
<td>C. Schrijvers</td>
<td>13</td>
<td>400</td>
</tr>
<tr>
<td>May 96</td>
<td>G. Meeus</td>
<td>2</td>
<td>350</td>
</tr>
<tr>
<td>June 96</td>
<td>K. Daems</td>
<td>10</td>
<td>150-200</td>
</tr>
<tr>
<td>July 96</td>
<td>C. Aerts</td>
<td>12</td>
<td>300-450</td>
</tr>
</tbody>
</table>
days. In Fig. 2 we show the $\theta$-statistics of Stellingwerf’s (1978) PDM period search for the 1996 radial-velocity data.

We conclude that the stellar radial velocity of $\lambda$ Sco varies with a period of 5.959 days, which is a binary period different from the one found by Lomb and Shobbrook (1975).

4. Basic orbital elements of $\lambda$ Sco

For the determination of the orbital parameters of the Aab system, we have adopted the orbital period of $P = 5^{d}.959$. In Fig. 3 we show the 1996 radial-velocity data folded with this period. We calculated an orbital solution through these radial velocities using the method of Lehmann-Filhés. The result is satisfactory,
especially if one takes into account that the radial velocities are influenced by the strong line-profile variations.

We list in Table 3 our final orbital elements and their standard deviations for λ Scorpii in 1996. $P$ is the period of the orbit, $v_\gamma$ the $\gamma$-velocity, $K$ is the amplitude of the velocity curve, $\sigma$ is the root mean square deviation from the mean curve, $\tau$ the phase of periastron passage and $\omega$ the angular distance of periastron. The julian date $E_0$ corresponds to the first data point of 1995. The amplitude $K$ together with the orbital period, implies a mass function of 0.0188 $M_\odot$. The theoretical velocity curve computed with the orbital elements listed in Table 3 is also shown on Fig. 3. The data taken in 1988 and 1995 are not in conflict with the solution presented in Table 3. It is possible to bring all datasets (1988, 1995, 1996) to fair agreement, allowing for different gamma velocities.

5. Line-profile variations

We now turn to the description of the line-profile variations. We base our study on the observations obtained in June 1995, when a large set of data was obtained specifically with this aim. Unfortunately, due to bad weather, we did not obtain a good orbital coverage.
Table 3. Orbital elements of the binary determined with the Lehmann-Filhés method.

<table>
<thead>
<tr>
<th>Element</th>
<th>( \lambda ) Sco</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P ) (days)</td>
<td>5.959</td>
</tr>
<tr>
<td>( v_\alpha ) (km/s)</td>
<td>18.6 ( \pm ) 0.8</td>
</tr>
<tr>
<td>( K ) (km/s)</td>
<td>31 ( \pm ) 1</td>
</tr>
<tr>
<td>( E_0 ) (HJD)</td>
<td>2449876.646</td>
</tr>
<tr>
<td>( \sigma ) (km/s)</td>
<td>8.3</td>
</tr>
<tr>
<td>( e )</td>
<td>0.29 ( \pm ) 0.04</td>
</tr>
<tr>
<td>( a \sin i ) (a.u.)</td>
<td>0.016</td>
</tr>
<tr>
<td>( \tau )</td>
<td>0.425 ( \pm ) 0.003</td>
</tr>
<tr>
<td>( \omega ) (degrees)</td>
<td>67 ( \pm ) 9</td>
</tr>
<tr>
<td>( f(m) ) (M( \odot ))</td>
<td>0.016</td>
</tr>
</tbody>
</table>

5.1. Global behaviour

A sensitive indication of line-profile variations is provided by the absolute mean deviation of the residuals (i.e., the sum of the absolute values of the residual variations, normalised by the number of spectra in the series) (Walker 1991):

\[
\sigma_a = \frac{1}{n} \sum_{i=1}^{n} |\nu_i - \nu|,
\]

where \( \nu \) stands for a wavelength, \( n \) is the number of spectra and \( \nu_i \), \( \nu_i \) are the intensities at the wavelength \( \nu \) in the mean and individual spectra respectively. The parameter \( \sigma_a \) is a sensitive test for line variability and the presence of rapidly-moving sub-features in long spectral series.

In Fig. 4 we illustrate the mean deviation for the time series obtained in 1995 for the lines in the selected spectral region. The inverted mean spectrum is superimposed for comparison. The depth of the strongest line of the Si III triplet has been normalised to coincide with the maximum of the mean deviation. Note that the increased amplitude due to variations is confined to within the rotationally broadened profiles. The continuum on either side of the profile shows a flat mean deviation curve, which allows us to estimate the noise level. Fig. 4 indicates an amplitude of the line-profile variations that is approximately 3 times the noise level, and which extends also to the line wings. In the following, we concentrate on the behaviour of the \( \lambda 4567 \) line, which is not the strongest line, since, due to vignetting, we lost some information in the \( \lambda 4553 \) line on June 7, 1995.

A gray-scale display (Fig. 5) of the behaviour of the Si III-4567 line in \( \lambda \) Sco during the 3 nights June 7-8, 10-11, 11-12 of 1995 shows the variations within the line profiles. We subtracted the nightly averages from the individual profiles. These residuals have been combined into 2-dimensional gray-scale pictures. Individual observations are represented by shades of gray that are proportional to the residual flux and stacked in order of time. The line asymmetry varies continuously on a time-scale of hours. Small sub-features travelling from blue to red are clearly seen. Moving bumps have only very rarely been reported in \( \beta \) Cephei stars. Another example of their appearance in a \( \beta \) Cephei star is for the star \( \kappa \) Sco (Aerts et al. 1989). This star will be the subject of a forthcoming paper.

5.2. Period analysis

To split the fast and medium-term variations, we prewhitened the data with the binary period. This separation of the two kinds of variations is only a crude correction because \( v_\gamma \)-changes from season to season appear as well, but we are unable to correct for this long-term variability. We therefore perform period determinations in the large frequency range of 0 to 25 c/d.

We used different diagnostics to study the fast periodic variations in the line profiles. We searched for periods on either the moments of the absorption lines (Aerts et al. 1992) or on the intensity variations as a function of position in the line profile (Gies & Kullavanijaya 1988, Schrijvers et al. 1997).

The first set of diagnostics consists of the equivalent width, full width at half maximum (FWHM), first, second, and third moment of the Si III 4567 A line. There is some uncertainty on these parameters since the problems of the normalisation and the noise of the spectra do not allow a clear determination of the line wings. Moreover, the scatter in the radial velocity is large because of the moving sub-features and the total asymmetry of the profiles.

We performed a PDM analysis on these parameters with frequency steps of \( 10^{-3} \) c/d, 10 bins and 2 covers. On the same parameters we also performed another Fourier-based technique, for which the Fourier spectrum is cleaned by means of the window function. We show the clean periodograms of the moments (calculated form the Si III 4567 A line) on Fig. 6. The analysis of these parameters confirms the presence of one dominant frequency of \( f_1=4.66 \) c/d close to the photometric frequency of 4.67942 c/d. The same frequency was recovered after applying the frequency searches on the moments of the Si III 4547 A line.

To check whether \( f_1 \) is also present in the individual seasons, we repeated the procedure on the individual prewhitened data sets separately. We encountered the same frequency. In Fig. 7...
Fig. 5. Variability of Si III 4567 Å in λ Sco on June 1995 (HJD from bottom to top). The wavelength coverage is from 4562 to 4571 Å. Shown are the residuals with respect to the mean profile. Black (white) denotes local flux deficiencies (excesses). Left panel: June 7, central panel: June 10, right panel: June 11.

Fig. 6. The CLEANED periodograms of the equivalent width, Full width at half maximum, and the velocity moments of the Si III 4567 line. One can see a dominant frequency of 4.66 c/d.

we show phase diagrams with respect to $f_1$ for the different parameters. We note that $f_1$ is not recovered in the equivalent width variations.

When the variation with $f_1$ is prewhitened from the data and the residuals are analysed for a second periodicity, we find some more frequencies, but the data are not numerous enough for an unambiguous judgement.

The CLEAN method was further applied on the second diagnostics, i.e. the intensity variations as a function of the position in the line profiles. We show the result in the periodogram in Fig. 8. We notice discrete patches of power in the periodogram, some of which extend across the whole line profile. The intensity variations occur on a time-scale comparable with the period that Lomb and Shobbrook (1975) found using photometry. We summed the detected power of the periodogram of the variation across the lines to a one dimensional periodogram and compared this with the periodogram determined with the first method. We again find the frequency $f_1$.

5.3. Determination of the velocity parameters

$\lambda$ Sco is situated in the $\beta$ Cephei-instability strip. The fact that we recover the short period of 5.15 hours in our spectroscopic data is indeed an indication that we are dealing with pulsation. The frequency $2f_1$ is not found in $\langle v^2 \rangle$, while $2f_1$ is clearly present in $\langle v^3 \rangle$ (see Fig. 6). This points towards the presence of a non-axisymmetric mode (De Pauw et al. 1993). The large FWHM variation with $f_1$ and the observed moving subfeatures support this finding. The lack of $f_1$ in the EW indicates small temperature variations, which is consistent with the small pho-
Fig. 7. A phase diagram of the different parameters for the frequency $f_1 = 4.66$ c/d. The full line is the fit, while the dots represent the observations.

tometric amplitude of 11 mmag (Lomb and Shobbrook 1975). All these findings lead to the conclusion that the main mode of $\lambda$ Sco is non-radial, in contradiction to the finding of Watson (1988).

The scatter in the moments is too large to attempt a more thorough mode identification of the pulsation with frequency $f_1$. As already mentioned, this scatter is partly due to normalisation problems which makes the determination of the wings of the profiles uncertain. A second cause of the scatter is the presence of other modes.

We conclude that the asymmetric line-profile variations and their moments and FWHM points towards the presence of a non-axisymmetric main pulsation mode. We find indications of the presence of more pulsation modes, but we need much longer series of observations to disentangle the complete pulsational behaviour.

An estimation for $v \sin i$ was determined from a line profile which was close to the pulsation-phase where the radial velocity changes its sign. The pulsation does not contribute to the line width at that phase. Taking into account that the intrinsic broadening is of the order of 20 km/s for the temperature of $\lambda$ Sco, we find a value for $v \sin i$ of 145 km/s. When we calculate the synchronous orbital rotation velocity $v_{\text{syn}}$, we find a value of 76 km/s, respectively 59 km/s depending on the radius being used ($9 R_\odot$, respectively $7 R_\odot$). This is an upper limit for $v_{\text{syn}} \sin i$. From these results we can conclude that $\lambda$ Sco is rotating supersynchronously.

6. A link with the $\zeta$ Oph stars?

The detection of moving subfeatures in the short-term line-profile variations of some Be stars (the so-called $\zeta$ Oph stars, see Balona 1990) has laid to the suggestion that these stars are non-radial pulsators. Some examples of these stars with spectral types comparable to $\lambda$ Sco are $\mu$ Cen ($v \sin i = 155$ km/s, Baade 1984), $\eta$ Cen ($v \sin i = 350$ km/s, Stefl et al. 1994), and DX Eri ($v \sin i = 180$ km/s, Stefl & Balona 1995). It has been claimed that the presence of the Be phenomenon is linked with the pulsational properties of Be stars (e.g. Grady et al. 1987). If non-radial pulsations are a major clue to the understanding of the Be phenomenon, then the question arises what the physical differences are between Be stars and rapidly-rotating pulsating
“normal” B stars. The results described in the previous sections show that the moving-bump phenomenon in early-type stars is not uniquely connected to the ζ Oph stars. In view of the line-profile behaviour common to the latter and the confirmed pulsator λ Sco it is worthwhile to compare their other properties.

The most characteristic features of Be stars are their circumstellar material, which gives rise to the Hα emission and small infrared excesses, and the presence of bluewards shifted resonance lines of C IV and Si IV in the UV. We have obtained a Hα profile for λ Sco showing that this line is in absorption, consistent with the finding of Ebbets (1982). Despite their Be nature, all three ζ Oph examples mentioned above also experienced non-emission phases: μ Cen has shown evidence of a period with almost pure Hα absorption in 1977/78 (Dachs et al. 1981), Feinstein (1974) and Slettebak et al. (1975) reported the absence of Balmer emission for η Cen in the seventies, and DX Eri showed no Hβ emission in 1985-6 (Mennickent & Vogt 1988). IRAS has made reliable detections of λ Sco at 12 and 25 μm. We have compared the observed fluxes with models (Kurucz 1979) for a star with λ Sco’s temperature and gravity and find no infrared excess at both wavelengths. Thus there is no observational evidence of the presence of circumstellar matter around λ Sco on the basis of Hα and the infrared flux. The three ζ Oph stars do have IR excesses at 12 μm, albeit very small ones (Coté & Waters 1987).

The wind compressed disc (WCD) model (Bjorkman & Cassinelli 1993) predicts the formation of a thin disc in the equatorial region of a rapidly-rotating star that has a radiation-driven stellar wind. Although the same radiation force is expected for λ Sco and some ζ Oph stars, it was observationally found that the wind in the latter is much stronger (Prinja 1990). In order to study if the WCD model predicts a disk around λ Sco, we implemented the numerical kinematic model of Bjorkman & Cassinelli (see also Cranmer & Owocki 1995; Ignace et al. 1996) for a radiation-driven stellar wind with wind parameters found in the literature (see Cassinelli et al. 1994). We used an equatorial rotation velocity of 200 km/s to compute a 2-dimensional wind compression model (Cranmer & Owocki, 1995). Our main result is that the rotation velocity is far too small to create a significant equatorial disk. There are virtually no streamlines attempting to cross the equator, and we find only a small (factor-of-two) increase in density at the equator. We briefly mention here that the formation of a disk by the classical WCD model has recently been seriously called into question when the winds are driven by radiation forces (Owocki et al. 1996).

Our theoretical result based on the classical WCD model is in agreement with the observation of Grady et al. (1987) that Be stars with v sin i smaller than 150 km/s have resonance lines indistinguishable from those seen in normal B stars. They studied the C IV, Si IV and Si III line of λ Sco and did not detect wind variability in any of these lines. They also note, however, that the C IV line of η Cen is very similar to that of e.g. λ Sco (or any other β Cephei star), despite its much higher rotation velocity.

We conclude that both theory and observation points towards the absence of circumstellar matter for λ Sco. Its line-profile behaviour is comparable to the one of the ζ Oph stars, albeit that the latter have slightly longer periods. Something must distinguish λ Sco from the ζ Oph stars and this something clearly allows them to occupy the same region in the HR diagram and even to have the same v sin i.

7. Discussion

High spectral resolution and high S/N ratio spectroscopy of λ Scorpii allowed us to derive the orbital elements of this binary. We detected rapid variations of the profiles of the lines of the main component and report the discovery of moving subfeatures from blue to red across the profiles. We determined the main physical period that controls the line-profile variations and showed that they cannot be caused by a radial pulsation but instead must be the result of a non-radial mode. We have found evidence that more modes are active in this β Cephei star.

An intriguing peculiarity of λ Sco is its supersynchronization. Most close detached binaries with B-type primaries have a synchronous rotation period. The λ Sco binary system bears some similarity to Spica. The two components of Spica move around each other in a short-period (P=4.01545 days) eccentric orbit (e=0.146). Using i = 37° (Stoeckley et al. 1987) for λ Sco, we find a ratio of the orbital period (5.959 days) to the rotation period (1.47 days) of ±4, which may imply a 4:1 resonance of the rotation rate and the orbital rate as compared to the 2:1 spin-orbit coupling of Spica (Smith 1985). A few other systems which might have such a coupling are QX Car : 2:1 (Andersen et al. 1983), AR Cas : 3:1 (Giuricin et al. 1984), and η Ori : 4:1 (De Mey et al. 1996). In all these cases it is difficult to definitely make conclusions on the resonance with the orbital period because sin i is not (well) determined.

The evolutionary age of the primary component star in the λ Sco system can be derived adopting the models by Maeder & Meynet (1988). The age was obtained by comparing evolutionary tracks for the observed stellar Teff and luminosity. We found λ Sco to be situated in the neighbourhood of the track of a star with an initial mass of 9 Msun, still in the nuclear burning phase. From the models we derived an age between 2 and 2.8 times 10^7 year. It is impossible in our case to determine synchronization and circularization times, due to a lack of parameters needed for these calculations. We must also remark here that the theoretical value for synchronization time is only applicable to static stars (Tassoul & Tassoul 1990). Any sizeable changes in the radii act against synchronization.

The supersynchronous system λ Sco is not unique among detached binaries with upper-main-sequence primaries (Spica, QX Car, AR Cas, η Ori). An interesting point to mention is that λ Sco is situated in the center of the theoretical instability domain for the β Cephei stars (Moskalik 1995) but close to the domain of the g-modes. g-modes can also be excited in β Cephei stars (Dziembowski 1993) but they are not commonly observed in these stars, although some possible cases have been reported (Waelkens & Heynderickx 1989, Aerts et al. 1994, De Mey et al. 1996). The pulsation frequency of 4.66 c/d has a corresponding Q value of 0.0374 days. The lack of other pulsation frequencies...
does not allow us to infer if the main mode has a p- or g-character based on frequency differences or ratios.

The question is also whether the rotation or the binarity is responsible for exciting the mode with frequency 4.66 c/d. We do not have enough data to pass a judgement on this. Single stars are able to select single modes with a period comparable to their rotational period. It is possible that rotation offers the potential of coupling driving energy to any of a number of modal frequencies (Osaki 1974) and that the tides ultimately select which of these modes are driven in close binaries. The role of rotation in the β Cephei phenomenon has not yet been determined. A high rotation does seem to decrease the amplitude of the pulsation (Jakate 1979, Waelkens 1991).

Altogether, λ Sco is an astrophysically interesting binary system. It remains to be studied to which extent the binary nature is related to the observed line-profile variations. A refined value of the pulsation periods and the inclination angle will show whether a resonant behaviour exists between the pulsation, the rotation, and the eccentric orbit.

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