Astronomy
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Outbursts on normal stars[*]

FH Leo misclassified as a novalike variable

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Abstract. We present high resolution spectroscopy of the common proper motion system FH Leo (components HD 96273 and BD+07 2411B), which has been classified as a novalike variable due to an outburst observed by Hipparcos, and we present and review the available photometry. We show from our spectra that neither star can possibly be a cataclysmic variable, instead they are perfectly normal late-F and early-G stars. We measured their radial velocities and derived the atmospheric fundamental parameters, abundances of several elements including Fe, Ni, Cr, Co, V, Sc, Ti, Ca and Mg, and we derive the age of the system. From our analysis we conclude that the stars do indeed constitute a physical binary. However, the observed outburst cannot be readily explained. We examine several explanations, including pollution with scattered light from Jupiter, binarity, microlensing, background supernovae, interaction with unseen companions and planetary engulfment. While no explanation is fully satisfactory, the scattered light and star-planet interaction scenarios emerge as the least unlikely ones, and we give suggestions for further study.

Key words. stars: abundances – binaries: general – stars: fundamental parameters – planetary systems –
stars: individual: HD 96273 – stars: individual: BD+07 2411B

1. Introduction

FH Leo is a wide visual binary consisting of HD 96273 and BD+07 2411B. The components form a common proper motion (CPM) star pair separated by 8.31″ with 98% probability of being a physical binary according to Halbwachs (1986). The system has been observed with Hipparcos and has been classified as variable and as a probably novalike system (designation NL:) by Kazarovets et al. (1999), based on the outburst appearance of its Hipparcos lightcurve.

This would have been the first cataclysmic variable (CV) found to be part of a multiple star system and its study would have cast light on formation and evolution processes of binary stars. For these reasons we decided to obtain spectra of both components of the system in order to start an investigation into the nature and variability of these objects.

According to SIMBAD it is the brighter northern source, HD 96273, which is the variable star, while Downes et al. (2001) claim that it is not yet clear which of the two stars is actually variable. Also the Hipparcos archive (ESA 1997) lists both HD 96273 and BD+07 2411B under the name HIP 54268,

and indeed both stars were included in the 38″ aperture of the Hipparcos detectors. Hence, it is not clear from the Hipparcos data either on which star the outburst took place. In Sect. 2 we present and review the photometry collected by Hipparcos and by the American Association of Variable Star Observers (AAVSO; Mattei 2004).

Our observations are presented in Sect. 3. The analysis of the two stars is given in Sect. 4, where we show from our spectroscopy that neither HD 96273 nor BD+07 2411B can possibly be CVs; rather they are both perfectly normal late-F and early-G stars. In Sect. 5 we discuss the possible mechanisms that may have caused an outburst on a normal main sequence star. Finally, in Sect. 6 we provide a summary and some concluding remarks concerning further study.

2. The variability of HD 96273 and BD+07 2411B

We have examined the longterm lightcurves, both of the Hipparcos-archive (ESA 1997) and of the AAVSO (Mattei 2004). These reveal a constant brightness from JD 2 447 880 to JD 2 452 437, except for a 0.3^m bright outburst between JD 2 448 624 and JD 244 868. This outburst was observed by Hipparcos and is the actual reason for classifying the system

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[*] Based on observations collected at the La Silla Observatory, ESO (Chile), with the FEROS spectrograph at the 2.20 MPI/ESO telescope.
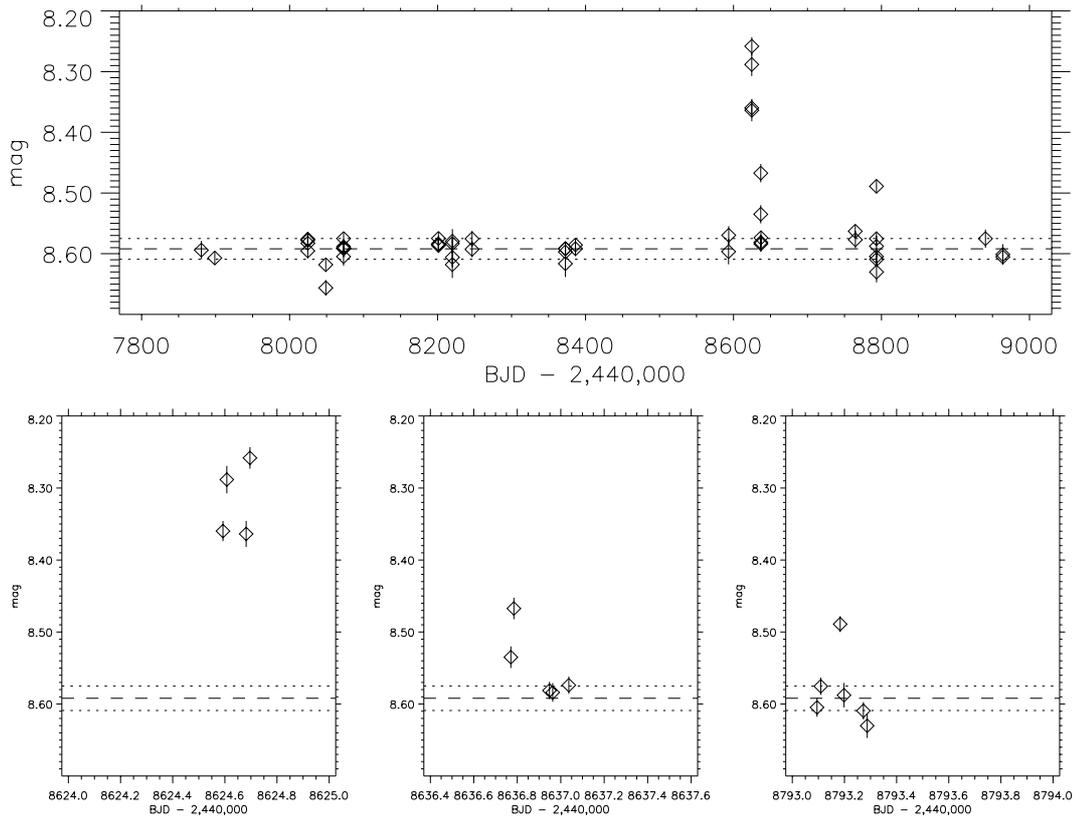
Fig. 1. Full Hipparcos lightcurve for FH Leo. The dashed line is the mean instrumental magnitude (not including the outburst), while the dotted lines are the 1σ standard deviations around the mean. The error bars are Hipparcos intrinsic errors. The lower plots show a zoom-in on the main event (*left and central plot*) and one minor event (*right plot*). Each of the three lower plots cover one day.

as a novalike variable (Kazarovets et al. 1999). The AAVSO lightcurve covers the period JD 2 451 966 to JD 2 452 437, and does not show any signs of outbursts or any other type of variability.

In Fig. 1 we show the Hipparcos data. The rise-time might have been very fast while the decay probably lasted at least 13 days with a possible second event about 170 days later. The data seem to have a very large spread at the two covered intervals on the decay slope (lower left and central plot of Fig. 1). This could indicate a non-constant energy production rate during the outburst, which would require some inhomogeneous region or process. If the system had indeed contained a CV, this short term variation might have been interpreted as flickering in the accretion disk. No obvious explanation exists for the phenomenon occurring in a normal stellar atmosphere, although this does point to very localized phenomena, e.g. clumps of material ingested in the atmosphere causing hot spots or repeated flare-like outbursts.

3. Observations

We have obtained high-resolution ($R \sim 48\,000$) spectra of HD 96273 and BD+07 2411B with the FEROS spectrograph at the ESO/MPI-2.20 m telescope at ESO's La Silla Observatory, Chile on the night of 2004-01-10. Standard data reduction was performed with the FEROS DRS pipeline, which is a MIDAS tool performing bias and flatfield correction, determination of

the wavelength solution, order extraction and wavelength calibration. The spectra cover the range 3800−9000 Å. No spectrophotometric standard was observed during this night.

In Fig. 2 we show the spectra of the two stars, re-binned in order to properly display the usual classification range of 3900−4600 Å, revealing two seemingly normal stars.

4. Analysis

The spectra of the two stars resemble normal late-F to early-G type stars with average rotation rates. There are no emission lines, especially the Ca II H and K lines are devoid of emission cores (see Fig. 3), ruling out the possibility of strong magnetic activity. There are also no indications that either of the stars should be a spectroscopic binary. We can definitively rule out that any of these two stars is a cataclysmic variable, and it is indeed doubtful if they are variable at all.

The spectrum of HD 96273 confirms the old F8 classification in the Henry Draper Catalog, while no classification has yet been published for the fainter companion. Only a *B* magnitude of 10.6 (SIMBAD) and a photographic magnitude of 10.4 (Halbwachs 1986) are listed for BD+07 2411B.

4.1. Atmospheric parameters and abundances

We have conducted a detailed spectral analysis on both stars, determining the fundamental atmospheric parameters
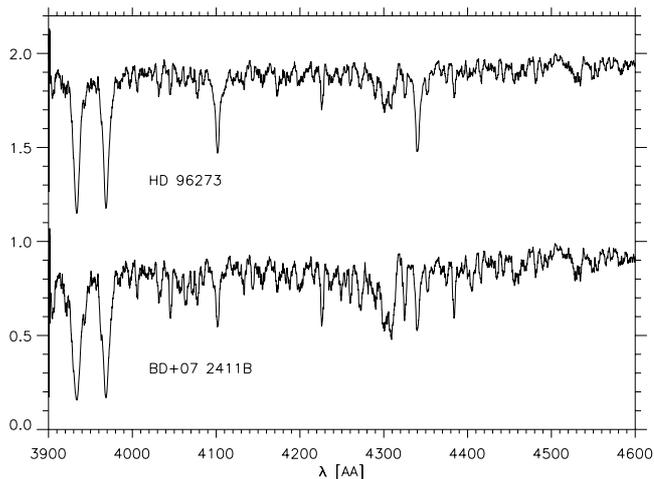
Fig. 2. Part of the spectra of HD 96273 and BD+07 2411B, both re-binned to $R \sim 400$ to simulate classification resolution. The late-F/early-G type classification is obvious. Arbitrary flux units.
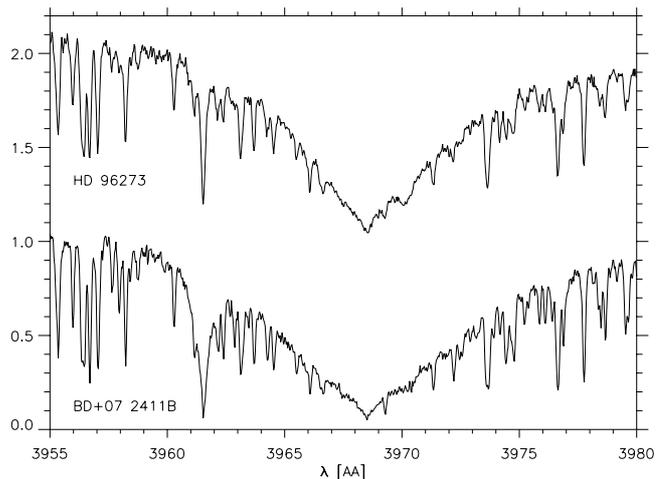
Fig. 3. The Ca II H line in HD 96273 and BD+07 2411B. As can be seen no emission cores are visible, ruling out strong magnetic activity.

through the following steps: measurement of the equivalent widths (*EW*s) of the lines over the full spectral region, determination of a first guess at the basic parameters of the star, calculation of the appropriate model atmosphere, and finally the abundance analysis. The method is the same as employed by Dall et al. (2005, in preparation), which is adopted from the procedures of Morel et al. (2003); Bruntt et al. (2002) and Bruntt et al. (2004).

The first step is the measurement of the *EW*s, which is accomplished using DAOSPEC[1] (Stetson & Pancino 2005, in preparation), which uses an iterative Gaussian fitting and subtraction procedure to fit the lines and the effective continuum. The lines are identified using a list of lines from the VALD database (Kupka et al. 1999; Piskunov et al. 1995), where all lines deeper than 1% of the continuum are included. Different line-lists for different spectral types can be retrieved directly from the database. For our FEROS spectra we used only lines in the region 5000−6800 Å, since for bluer wavelengths the continuum determination becomes uncertain, while beyond 6800 Å the merging of orders and hence the continuum shape proved problematic. Next, an initial estimate of T_{eff} is found using the line depth ratios calibrated by Kovtyukh et al. (2003). A more accurate determination of T_{eff} will be derived later in the process. We adopt $\log g$ and microturbulence parameter ξ_t for a canonical ZAMS star, and assume solar metallicity as our starting point. With this we then calculate the initial model, using the ATLAS9 code adapted for Linux (Kurucz 1993; Sbordone et al. 2004). With the measured *EW*s and the model, the abundances of the Fe-lines are calculated using the WIDTH9 code (Kurucz 1993, modified for PC by V. Tsymbal), and compared line-by-line to Solar abundances, calculated from a high *S/N* solar spectrum obtained with the same instrumental setup, and reduced in the same way as the spectra of HD 96273 and BD+07 2411B. This last step is

crucial to avoid problems due to uncertain gf-values. The parameters of the model used to calculate the solar abundances are T_{eff} = 5778 K, $\log g$ = 4.44, and ξ_t = 1.2 km s^{-1}. Finally, a sigma clipping can be applied to eliminate abundance values deviating e.g. because of errors in the *EW* determination or due to wrong line identifications.

For the initial T_{eff} estimate for BD+07 2411B we used 19 line ratios, which yielded T_{eff} = 5952 ± 107 K. For HD 96273 the line ratios gave a T_{eff} just outside of the valid range of the calibration, hence the initial temperature guess was assumed to be just outside the range at 6150 K.

Now the model parameters (T_{eff}, $\log g$, ξ_t, [Fe/H], and [α/Fe]) are iteratively modified until consistency is reached, defined by the following criteria: (1) that there are no trends of Fe I abundance with *EW*, wavelength or excitation potential; (2) that the abundances derived from Fe I and Fe II are the same; (3) that the derived metallicity and α-element abundances are consistent with the input model.

The final model parameters adopted for the two stars are summarized in Table 1, in the rows marked *(a)*, along with the measured $v \sin i$ and radial velocities (*RV*s). For the determination of the atmospheric parameters of BD+07 2411B we used 327 Fe I and 27 Fe II lines, while for HD 96273 224 Fe I and 24 Fe II lines were in common with the solar spectrum. The *RV*s were derived using DAOSPEC, while $v \sin i$ was measured using synthetic spectra calculated with the SYNTH code (Piskunov 1992; Valenti & Piskunov 1996) as implemented in the VWA software (Bruntt et al. 2002, 2004).

To check our results we conducted an independent analysis following the procedure outlined in Gonzalez & Lambert (1996) and Santos et al. (2004), using the line-list employed by Santos et al., a grid of Kurucz ATLAS9 models, and the 2002 version of the radiative transfer code MOOG (Sneden 1973). The results show that the two methods agree within the errors, with values of T_{eff} = 6493 ± 99 K, $\log g$ = 4.50 ± 0.19, ξ_t = 2.38 ± 0.74 km s^{-1} and [Fe/H] = −0.21 ± 0.10 for HD 96273 and T_{eff} = 5849 ± 54 K, $\log g$ = 4.45 ± 0.19, ξ_t = 1.23 ± 0.13 km s^{-1} and [Fe/H] = −0.22 ± 0.07 for BD+07 2411B (rows marked *(b)* in Table 1).

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[1] DAOSPEC has been written by P. B. Stetson for the Dominion Astrophysical Observatory of the Herzberg Institute of Astrophysics, National Research Council, Canada.

Table 1. The derived parameters for HD 96273 and BD+07 2411B used for the abundance analysis. Note that the values of $v \sin i$ are about equal to the resolution of the spectrograph, hence they must be regarded as upper limits. Letters *(a)* and *(b)* corresponds to the two independent analysis discussed in the text.

Star		T_{eff} [K]	$\log g$	ξ_{t} [km s^{-1}]	$v \sin i$ [km s^{-1}]	RV [km s^{-1}]	[Fe/H]
HD 96273	*(a)*	6450 ± 70	4.26 ± 0.19	2.4 ± 0.2	6.7 ± 0.5	-3.95 ± 0.44	-0.25 ± 0.09
	(b)	6493 ± 99	4.50 ± 0.19	2.38 ± 0.74			-0.21 ± 0.10
BD+07 2411B	*(a)*	5875 ± 55	4.52 ± 0.11	1.4 ± 0.1	5.2 ± 0.5	-3.19 ± 0.37	-0.21 ± 0.07
	(b)	5849 ± 54	4.45 ± 0.13	1.23 ± 0.13			-0.22 ± 0.07
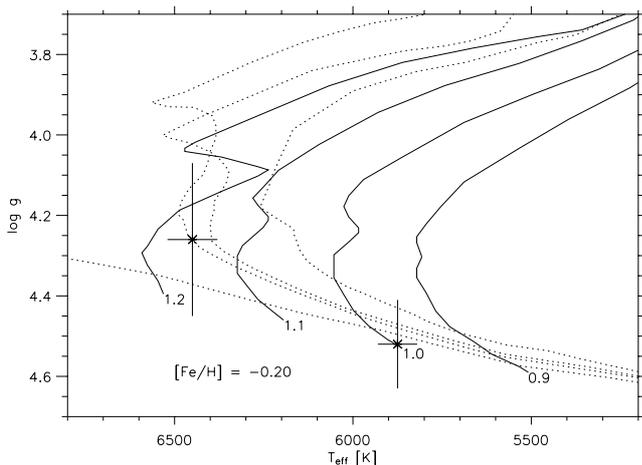
Fig. 4. Evolutionary tracks (solid lines) for metallicity [Fe/H] = -0.20, based on Girardi et al. (2000). Also shown are the isochrones (dotted lines) for 1, 2, 3 and 5 Gyr. The positions of HD 96273 and BD+07 2411B are indicated.

Table 2. The derived abundances ([M/H]) for HD 96273 and BD+07 2411B relative to the measured abundances in a Solar spectrum, or relative to Grevesse & Sauval (1998) (marked by *). The second column for each star lists [M/Fe], i.e. the abundance within the star of each element relative to iron.

Element	HD 96273		BD+07 2411B	
	[M/H]	[M/Fe]	[M/H]	[M/Fe]
Li			+0.87(10) *	1.08
Mg	−0.25(15)	0.00	−0.10(15)	0.11
Ca	−0.17(11)	0.08	−0.15(08)	0.06
Sc	−0.23(10)	0.02	−0.13(08)	0.08
Ti	−0.19(12)	0.06	−0.16(09)	0.05
V	−0.19(14)	0.06	−0.19(11)	0.02
Cr	−0.25(11)	0.00	−0.22(10)	-0.01
Fe	−0.25(10)		−0.21(09)	
Co	−0.24(19)	0.01	−0.20(11)	0.01
Ni	−0.28(13)	-0.03	−0.24(08)	-0.03

The result of both methods agree very well, showing that within the errors the [Fe/H] are the same for the two stars, although there may be hints at a generally slightly higher metallicity in BD+07 2411B.

In Fig. 4 we show the positions of the two stars among evolutionary tracks and isochrones calculated by interpolating in the grid provided by Girardi et al. (2000). From this we estimate an age of ~2 Gyr for HD 96273; an age which within the errors is consistent for BD+07 2411B as well. However, a word of caution must be given regarding the uncertainties in the temperature and metallicity evolution of the models used to compute the isochrones. As demonstrated by Pont & Eyer (2004) the isochrones of Girardi et al. (2000) tend to overestimate the age of the star. Nevertheless, adopting an age estimate of 2 Gyr does not seem unreasonable, and is largely compatible with the lithium age estimate (Sect. 4.2), especially taking into account the error bars.

A detailed abundance analysis of the two stars were then done, using the derived stellar parameters and the corresponding models. In order to minimize systematic errors due to erroneous $\log gf$ values, we have calculated all abundances relative to the Sun on a line-to-line basis where corresponding lines are found, and relative to the values given by Grevesse & Sauval (1998) where the line is not found in the solar spectrum.

The results of the abundance analysis are given in Table 2, with individual abundance determinations discussed in detail below. The abundance errors are estimated by combining the dispersion around the mean with the errors introduced by the uncertainties in T_{eff} and $\log g$.

4.2. The Li abundance

In Fig. 5 we show the $\lambda 6708$ line region for the two stars. For BD+07 2411B we measure *EW*s of the Li doublet at $\lambda\lambda 6707.761, 6707.912$ of 15.9 mÅ and 9.6 mÅ respectively, giving an abundance $A(\text{Li}) = -10.06$. The abundances derived from the two lines differ by only 0.07 dex. The automatic deblending performed by DAOSPEC proved inadequate, and instead we used the IRAF[2] task *splot* for the deblending. Treating the doublet as one single line yields an *EW* of 26.8 mÅ, resulting in an abundance $A(\text{Li}) = -10.01$. We hence adopt $A(\text{Li}) = -10.03$ as a good estimate of the lithium abundance. The dominant error source is the *EW* measurement, and we
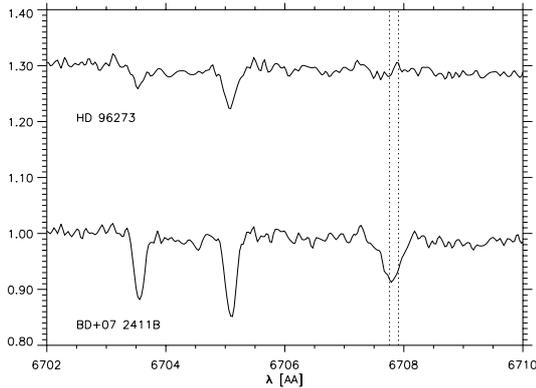
Fig. 5. The region around the Li lines (positions shown by dotted lines).

estimate an error of 0.10 dex. The Li lines in the solar spectrum could not be reliably measured, so we are comparing with the values of Grevesse & Sauval (1998) to get [Li/H] = 0.87.

The Li abundance in HD 96273 cannot be measured since the lines cannot be recognized, as is evident from Fig. 5. If we assume that the λ 6707.761 line could be as strong as 4 mÅ, we estimate an upper limit for the abundance A(Li) $\leq$ −10.2, i.e. at least 0.1−0.2 dex less than for BD+07 2411B.

Is this difference in lithium abundance significant? To address this question we note from several studies of open clusters, that the Li-gap (Boesgaard & Tripicco 1986) is located roughly between 6400−6800 K (e.g. Thorburn et al. 1993; Deliyannis et al. 2000; Jeffries et al. 2002, for Hyades, NGC 752 and NGC 6633 respectively). However, large amounts of star-to-star scatter is generally observed at any given $T_{\rm eff}$ hotter than ~6000 K, the precise temperature limit for the onset of the scatter depending on age. However, lithium depletion and the subsequent development of a Li-gap is not a straightforward relationship with age. In the Hyades (700 ± 50 Myr) no depletion has occurred for stars cooler than 6200 K, while for M 35 (160 ± 20 Myr) depletion is already occurring down to 6000 K (Steinhauer & Deliyannis 2004). For the CPM star pairs investigated by Martín et al. (2002) the situation is even more complex, although most of the systems investigated had comparable Li-abundances. It is believed that the rotational history of the star rather than the current rotation rate, is a determining factor for the amount of depletion. On the cool side of the gap, the Li abundance usually adheres to a more straightforward relation with age, thus the A(Li) of BD+07 2411B is consistent with an age somewhere between M 67 (4.7 Gyr; Pasquini et al. 1997) and NGC 752 (1.8 Gyr; Deliyannis et al. 2000). If the age of the system indeed is several Gyr, as is also suggested by Fig. 4, then it is possible that severe Li-depletion could have occurred in HD 96273 as the star spun down to its current low rotation rate.

4.3. Abundances of the α-elements

The abundances of the electron donor elements Mg, Ca and Ti merit separate comments. In over-active stars these elements are often enhanced with respect to iron, especially for low [Fe/H] stars (Morel et al. 2003; Dall et al. 2005). Hence these elements may act as probes of past or present magnetic activity.

The abundances of calcium was derived using 24 Ca I lines. As can be seen from Table 2 the element is slightly overrepresented in both stars with [Ca/Fe] of 0.08 and 0.06 for HD 96273 and BD+07 2411B respectively.

The magnesium abundances were found using the Mg I λ 5528.405 line, measured by fitting a Voigt profile to the line using *splot*. While we find [Mg/Fe] = 0.11 for BD+07 2411B we do not find any offset to iron for HD 96273.

The titanium abundances were measured using 24 Ti I and 8 Ti II lines for HD 96273 and 45 Ti I and 9 Ti II lines for BD+07 2411B. For both stars titanium is slightly enhanced.

Given the uncertainties on the magnesium abundances, we conclude that the α element enhancement is probably not larger than [α/Fe] = 0.06 for both stars. Whether this enhancement could be due to past magnetic activity is doubtful, especially given the general pattern of enhancements of other elements with respect to iron and keeping in mind the uncertainties on the individual abundances.

### 4.4. A physically bound system

The abundances of the two stars are similar: both are underabundant, and although HD 96273 may be more underabundant than BD+07 2411B, the abundances relative to iron are the same in the two stars, as evident from Table 2, suggesting a common origin and evolution history. Also, taking into account the uncertainties in the models, the small abundance differences may not be real, as discussed in Sect. 4.1.

From the spectra we also derive the radial velocities of the two components using DAOSPEC (Table 1). The relative radial velocity between the two stars is less than 1 km s^{-1}, i.e. a very small velocity shift between HD 96273 and BD+07 2411B, making it even more likely that they indeed constitute a physically bound system.

Using the Hipparcos parallax (ESA 1997) of 8.52 ± 1.73 mas, we find d = 117 pc, and we can reasonably adopt this as the common distance to the system. With a separation of 8$''$, we find a lower limit for the physical separation of 936 AU.

5. What caused the outburst?

Based on our analysis in Sect. 4.1, we rule out the possibility that an outburst occurred in a steady accretion disk of either HD 96273 or BD+07 2411B. While instrumental errors can never be ruled out completely, we note that in general Hipparcos has delivered very accurate and reliable photometry. Also the duration of the event and the gradual fading argues against instrumental errors, since it is unlikely that Hipparcos should have been giving erroneous measurements over a period of about two weeks, without all other measurements during that period being affected. We note that no other star in the vicinity of FH Leo has been flagged variable in the Hipparcos catalog (ESA 1997).
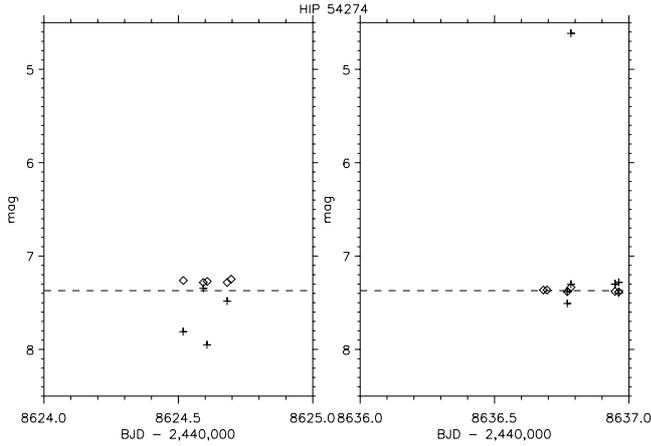
Fig. 6. The Hipparcos lightcurves for HIP 54274 on the dates of the two FH Leo events. +: V_T, ⋄: H. The B_T data are similar to V_T and are not shown for the sake of simplicity. Error bars are about the size of the symbols. The dashed line show the mean magnitude in H.

We see at the present the following possible explanations for the Hipparcos lightcurve:

– Transient background or foreground objects.
– Magnetic interaction with unseen companion.
– A planetary accretion event.
– A microlensing event.

In the following we will discuss these possible scenarios and their likelihood.

5.1. Transient background/foreground objects?

It is in principle possible that the outburst is caused by another object entering directly into the aperture, e.g. a planet, an asteroid or a supernova (SN) in a background galaxy. We estimated the magnitude of this object to be around $B \sim 9.9$ (i.e. even brighter than BD+07 2411B) in order to result in the observed brightening. Neither a SIMBAD search for other objects inside the aperture, nor the FEROS guide camera images reveal any objects that could have caused such a brightening. Moreover, planets (and their satellites) and asteroids would produce an "on-off" effect as they enter and exit the aperture, not a gradual decline, and they would move much too fast to stay within the aperture for the required time. Deep imaging of the region around FH Leo may still reveal a faint distant galaxy, which could have hosted a SN bright enough to offset the Hipparcos photometry, although we deem such a bright SN in an undiscovered galaxy very unlikely.

Another, more likely possibility is that light from a nearby bright planet could have entered the aperture indirectly. During the observed brightening, Jupiter was only ∼6′ away, and it is possible that scattered light somehow may have entered the Hipparcos instruments. To test the likelihood of this hypothesis we examined the Hipparcos lightcurves of close-by stars. On JD 2 448 624.6 (i.e. the time of the main event) Jupiter was at RA = 11:05.5, Dec = +07:07, which is about 6′ away from FH Leo and about the same distance from nearby HIP 54274. The lightcurve of HIP 54274 (Fig. 6) may show a slight
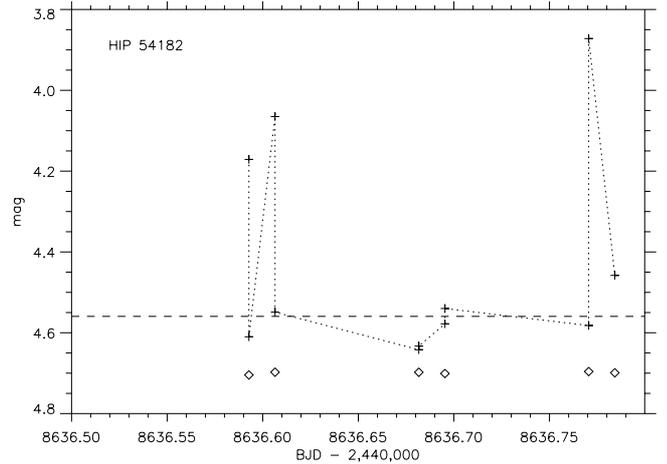
Fig. 7. The Hipparcos lightcurves for HIP 54182 on the date of the second FH Leo event. Symbols as Fig. 6. The dashed line show the mean magnitude in V_T, excluding the three largely deviating points. The V_T data have been offset vertically for clarity, and a dotted line has been drawn to better display the chronology of the data points.

brightening of ∼0.1^m in H at the time of the main event, and shows one spurious data point corresponding to almost 3^m brightening in V_T and B_T at the time of the secondary event, with Jupiter now half a degree away. No brightening in H can be seen at this epoch.

Also at the time of the second event, HIP 54182 located ∼8′ from Jupiter showed a 0.7^m brightening in the V_T filter, while being constant in H and B_T (Fig. 7). This brightening is obviously of spurious nature, since the data points jump up and down with 0.5^m in a few hours. We also checked the lightcurves of HIP 54057 and HIP 54331, both of which at some point were closer than 30′ to Jupiter, but both showed constant lightcurves.

Based on the fact that other Hipparcos lightcurves show similar brightenings, it is quite likely that the apparent outburst of FH Leo may be caused by scattered light from Jupiter. However, the distance from Jupiter is large, and the alleged effect seem to have a random element since not all stars in the area show similar brightenings and not necessarily at the expected time. We note however, that caution is needed in the interpretation of Hipparcos lightcurves, since errors can be larger than what is suggested by the listed error bars.

A quick inspection of the distribution of Hipparcos unsolved variables on the sky, do not suggest a larger concentration near the Ecliptic plane, as would be expected if scattered light were a major source of mistaken variability.

5.2. Magnetic interaction with unseen companion?

It is immediately obvious from the spectra that neither of the stars are over-active. The Ca II H and K lines do not show any emission cores (Fig. 3) and a direct comparison with the FEROS solar spectrum shows that they are both less active than the Sun. Also the infrared Ca triplet shows no signs of emission cores, and none of the Balmer lines show any trace of fill-in emission. The system has also gone undetected by all the high energy satellite missions.

Hence, magnetic activity would need to have been confined to the past, for example induced by some close-in companion in an eccentric orbit, bringing the companion into contact with the star at periastron passage, possibly spurring accretion and disruption of the atmosphere and the magnetic field inducing enhanced magnetic activity. The orbital period would have to be large enough to allow the intermittent magnetic activity to die away completely. As we find no traces of a companion in the spectrum of either star, a neutron star or a giant planet are the most likely assumptions for the companion. The observed high scatter in the Hipparcos light curve during the outburst would then be due to flickering activity in the transient accretion disk or due to continuous rapid flaring activity during the periastron passage.

Chromospheric heating has been discussed by Santos et al. (2003) for HD 192263 and by Shkolnik et al. (2003) for HD 179949. In these cases chromospheric heating occur due to magnetic interaction between the star and a giant planet or brown dwarf in a very close, short period orbit (Saar & Cuntz 2001). A similar mechanism may be at work in the FH Leo system, but possibly only during periastron passage.

Giant planets have been found in very eccentric orbits e.g. HD 80606 (Naef et al. 2001), which harbors a giant planet in a $e = 0.927$ orbit. In such a case the direct cause of the outburst could be a superflare (Rubenstein & Schaefer 2000), where the snapping of field lines during a very close periastron passage could have produced enough energy for the outburst, and temporarily disrupted any remaining field.

Another possibility is a compact companion: this scenario would be similar to an Be/X-ray transient (Negueruela 1998), which due to the lack of wind or disk signatures, would have to be in a very eccentric long-period orbit. However, these transients are known to exist with early type stars, while no such objects have been found with G-type companions, which makes this scenario rather unlikely.

With current instrumentation (i.e. HARPS; Mayor et al. 2003) the detection of even planetary-size companions would be possible, and this possibility should be investigated further.

5.3. Planetary accretion?

Several discussions of possible planetary engulfments have been published recently (Siess & Livio 1999; Sandquist et al. 2002; Israelian et al. 2001, 2003; Retter & Marom 2003). Such an event would leave a "polluted" stellar atmosphere and thus lead to enhanced abundances, especially of the volatiles ^{6}Li, ^{7}Li, ^{9}Be and ^{11}B. Unfortunately, FEROS cannot resolve the ^{6}Li+^{7}Li blend, and it cannot reach the Be lines near the atmospheric UV cutoff.

The amount of energy released in a planetary engulfment process can be estimated as follows: The outburst amplitude of 0.35 mag corresponds to a ratio of energy of 1.38. Assuming solar luminosity for the quiescence star we integrate the energy emitted during the outburst to $\Delta E = 10^{32}$ W. Assuming that all this energy is provided by the gravitational energy $E = G \, M_{star} \, m \, R_{star}^{-1}$ of the accreted material, and taking the solar values for the mass M_{star} and radius R_{star} of the star, we derive

the mass m of the accreted matter $m = 5 \times 10^{20}$ kg, which is about the mass of a large asteroid like Pallas or Vesta.

A scenario where BD+07 2411B accreted a planetary-sized companion could explain both the Hipparcos outbursts, the possible slight overabundances found in BD+07 2411B with respect to HD 96273, and the presence of lithium in BD+07 2411B. One crucial test of this explanation would be to measure the ^{6}Li/^{7}Li isotopic ratio as done by Israelian et al. (2001, 2003), and the abundance of beryllium.

5.4. Microlensing?

The low time resolution and poorly resolved shape of the outburst as well as the absence of color information make it impossible to judge the event as caused by microlensing. However, as the system has high proper motion (-14.04, -61.85) ± (1.81, 1.35) mas/yr, at least the probability for such an event exists. Deep imaging of the region around the system might reveal a faint object in the path of either star which was either lensed or functioned as a lens, and would thus strengthen this interpretation of the brightening. Note though that microlensing would not naturally explain the minor event that occurred 150 days later.

6. Summary

In this paper we have shown that the variable FH Leo cannot possibly be a CV as previously thought. We have found the atmospheric parameters of the two stars in the system and from their derived abundances, RVs and rotation rates, shown them to be perfectly normal main sequence stars.

However, the outburst observed by the Hipparcos satellite remains a mystery. While it may be caused by scattered light entering the instrument from nearby Jupiter, the effect is neither obvious nor reproducible when checking the lightcurves of nearby Hipparcos targets. This analysis showed however, that great care must be exercised when interpreting Hipparcos lightcurves, since deviations much larger than the internal errors can occur. Certainly, it would be worthwhile investigating in detail whether there exist correlations between unsolved Hipparcos variables and the proximity of Solar system objects to the field of view. Our quick inspection did not suggest any correlations though.

The most severe constraints on the possible physical explanations are provided by the lack of activity on either star, which also makes it extremely interesting to determine the proper cause of the outburst: if it was indeed caused by some process involving a very close companion inducing magnetic activity, then we have a unique possibility to gain insight into the time evolution of magnetic phenomena. Hence, the explanations presented in this paper should be assessed: deep imaging of the immediate surroundings of the system could reveal a lensing object or a background galaxy. Accurate radial velocity monitoring with high spectral resolution could reveal any planets or compact companions in orbit around either star, and the combined spectra could provide the high signal-to-noise needed for a measurement of the ^{6}Li/^{7}Li isotopic ratio which is a crucial test for the engulfment scenario.

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