Spectral synthesis analysis and radial velocity study of the northern F-, G-, and K-type flare-stars

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ABSTRACT

In this publication we present a study of the general physical, chemical properties and radial velocity monitoring of young active stars. We derive temperatures, \(\log g\), [\(\text{Fe}/\text{H}\)], \(v\sin i\), and \(R_{\text{spec}}\) values for eight stars. The detailed analysis reveals that the stars are not as homogeneous in their premier physical parameters as well as in the age distribution. In 4/5 we found a periodic radial velocity signal which originates in surface features the fifth is surprisingly inactive and shows little variation.

Key words: stars: abundance, activity, atmospheres, rotation; individual: HIP 1803, HIP 18512A, HIP 26779, EK Dra, HIP 73555, HIP 98698, HN Peg, HIP 114385

1 INTRODUCTION

Ten years ago the first extra solar planet was discovered around 51 Peg (Mayor & Queloz 1995) and today we know of more than 160 planets discovered with radial velocity (RV) measurements. Previous RV planet search programs have concentrated on old and inactive stars. It is now generally believed that the orbits of planetary systems change in time. This is of crucial importance for the formation of planets and the evolution of extra solar planetary systems (e.g. Weidenschilling & Marzari 1996; Alibert et al. 2005). Therefore it is necessary to study the orbits of young extrasolar planets and compare them to old ones. We therefore monitor the RV of 40 young stars at the Thüringer Landessternwarte (TLS) and 80 young stars with HARPS at 3.6 m telescope at ESO/La Silla.

Young stars are active and one source for active stars within 100 pc is the catalogue of flare stars published by Gershberg et al. (1999). In this paper we discuss the G- and K-stars in this catalogue of the northern hemisphere. We present the results of the spectral synthesis analysis performed to derive the stellar parameters, to compare these to the results achieved by other groups, and to put the stars into a general picture, e.g. identify the stellar association the stars origin from. We present here the results of the RV measurement of five stars. The remaining three were too faint and too far south from the TLS to measure a sufficient amount of RV data points.

The publication is organised as follows: A short description of the analysing methods is followed by the results of this analysis for the individual stars, followed by an overview of the RV monitoring and the findings, followed by a discussion and conclusions.

2 DATA REDUCTION AND SPECTRAL SYNTHESIS ANALYSIS

We observed the northern flare star sample 2000-2001 from Calar Alto using the high resolution échelle spectrograph FOCES (Pfeiffer et al. 1998) mounted on the 2.2 m telescope. Data reduction and analysis was carried out using the reduction pipeline written in IDL especially for this fibre coupled spectrograph.

For the spectral synthesis analysis we used the model atmospheres MAFAGS. For a detailed description of the methods see Fuhrmann et al. (1997). Grupp (2004) has extended the program but has also given a detailed description of the state of the art of the model atmosphere code MAFAGS. A number of eight stars of the northern Gershberg sample were analysed in total. As described in Fuhrmann et al. (1997) we deduce the effective temperature from the Balmer line wings, the surface gravity from the iron ionisation equilibrium and the wings of the Mg I\(\beta\) lines. The analysis is performed strictly relative to the Sun.
2.1 Analysis of individual stars

In this paper we want to treat each star individually because, as we will see later, some stars have very individual features. We have summarized our analysis in Tab. In addition to our analysis we have listed log \((L_\nu/L_{bol})\) in Tab. for each star which is a measure of the stellar activity (see e.g. Stelzer et al. 2002). The X-ray luminosity was calculated from the ROSAT PSPC count rates listed in the ROSAT bright and faint source catalogs (Voges et al. 1999, 2000) and converting it to a X-ray luminosity using an energy conversion factor of \(\log(\text{ecf}) = 11\). For each object we will also discuss the results of other authors using narrow-band photometry or spectral synthesis analysis.

2.1.1 HIP 1803, [GKL99] 15, HD 1835, BE Cet

HIP 1803 is a well known G-type star at a distance of 20.39 ± 0.38 pc and as often referred to is a young solar twin. The age estimates are ~ 600 Myrs which are confirmed by the fact that it is a Hyades super-cluster member (Montes et al. 2001). From the space motion Montes et al. (2001) concludes that HIP 1803 is a member of the Hyades Super Cluster. Gaidos et al. (2000) give kinematic measurements of \((U/V/W)_{\text{LSR}} = (-26.7 \pm 0.7/ -3.3 \pm 0.3/7.1 \pm 0.1)\) km s\(^{-1}\) and Mishenina et al. (2001) of \((U/V/W)_{\sun} = (-35.7/ -14.7/ -0.2)\) km s\(^{-1}\) with respect to the Sun \((U, V, W)\) is defined to be positive in the Galactic anti-centric direction, and the adopted solar motion with respect to the LSR is \((U, V, W) = (-10.2, +5.2, +7.2)\) km s\(^{-1}\).

The star has a distant companion at a separation of 3860 AU and \(\Delta V = 6.1\) mag with the name BD -13 60B. Favata et al. (1997) find a lithium equivalent width of \(W(\text{Li}) = 76 \text{mA}\) and an abundance of \(\log N(\text{Li}) = 2.46\) at a temperature of \(T_{\text{eff}} = 5732\) K. They consider the star kinematically young. Longterm photometric monitoring of HIP 1803 from Catispota (1992) and \(v \sin i\) from Pasquini & Pallavicini (1991) lead to a radius of 1.06\(R_\sun\) at \(i\) close to 90°.

The star was also target for the search of a debris disc (Greaves et al. 2004) but no disc could be detected at 850\(\mu\)m with a flux limit of 2\(\sigma\) (2\(m\)Jy) corresponding to a total of 0.02\(M_\odot\) of dust per star.

The FOCES spectra were observed on Dec 01 2001 with a signal-to-noise ratio of 250. We measure a lithium EW of 72.5 mA which transforms to a lithium abundance of \(\log N(\text{Li}) = 2.30\), and the core of \(\text{H} \alpha\) is filled-in to a level of 5%. Also the cores of calcium H&K-lines are filled. All in all the star is quite active. The magnetically sensitive iron line at 6173 Å is asymmetric which lead to the conclusion that there is a strong magnetic field on the surface. Our spectral synthesis leads to the stellar parameters listed in Tab. The difference between the predicted spectroscopic distance and the parallax measurement of Hipparcos (Hipparcos, ESA 1997) is only 2.8%.

Gaidos et al. (2000) have measured a rotation period of 7.81 ± 0.01 days. Using our estimate of the radius and the \(v \sin i = 6.39 \text{km s}^{-1}\) we estimate an inclination of 0.054° and \(v \sin i = 6675 \text{m s}^{-1}\).

2.1.2 HIP 18512, [GKL99] 104, HD 24916 A

Relying on kinematic data, Madsen et al. 2002 and Montes et al. 2001 list HIP 18512 as a member of the Ursa Major association. They estimate a parallax \(\pi = 63.3 \pm 2.0\) mas and measured by Hipparcos of \(\pi = 63.41 \pm 2.0\) mas, respectively. Favata et al. (1997) estimated a temperature of \(T_{\text{eff}} = 4394\) K and they measured lithium equivalent width of \(W(\text{Li}) = 4\) mA and an abundance of \(\log N(\text{Li}) = -0.55\). They consider the star kinematically young.

The results of our analysis of the FOCES spectra observed Dec 01 2001 and with a SNR of 300 give the parameters: \(T_{\text{eff}} \sim 4600 \pm 100\), \([F_{c}/H] = 0.03 \pm 0.07\), \(\log g = 4.60 \pm 0.10\). We do not detect a trace of the lithium absorption line at 6707 Å.

2.1.3 HIP 26779, [GKL99] 145, HD 37394

The space motion derived by Gaidos 1998 show that the star is a member of the local association. The stellar parameters they derive are \(T_{\text{eff}} = 5200\) K, \(W(\text{Li}) = 1.3 \pm 3.2\) mA which lead to a lithium abundance of \(\log N(\text{Li}) = 0.03\pm0.03\), \(v \sin i = 4.0 \text{km s}^{-1}\) and an inclination range \(i = 45° - 90°\). Analysing the FOCES spectra, we get a very good agreement of the spectroscopic distance with the Hipparcos distance of only 0.5%.

2.1.4 EK Dra, HIP 71631, HD 129333, [GKL99] 306

EK Dra is an interesting young binary where it is possible to solve the Keplerian orbit and derive the true masses König et al. 2001. The masses of the two stars are 0.90 \pm 0.10\(M_\odot\) and 0.50 \pm 0.10\(M_\odot\), respectively.

We also performed a spectral synthesis analysis in course of that publication. The results are summarised in Tab. As mentioned in König et al. 2003, EK Dra has a large overabundance. The measured lithium equivalent width in the observed spectrum is 190 ± 10 mA. Modelling the lithium line this leads to a lithium contents of \(\log N(\text{Li}) = 3.30 \pm 0.05\).

2.1.5 HIP 73555, [GKL99] 312, HD 133208

The recent classification in the SIMBAD database list it as G8IIIa which would mean that it is a post-main-sequence subgiant. Since the star was listed in the catalogue it was observed with high resolution spectroscopy using the FOCES instrument at Calar Alto in Feb. 13th 2001.

The spectral synthesis analysis reveal the nature of the star as a subgiant given the estimated \(\log g\) using the \(Fe I/Fe II\) and \(Fe/Mg\) ionisation equilibrium.

Placing the star into an Herzsprung-Russell diagram (see Fig. 1) using post-main-sequence tracks of Schaller et al. (1992) we estimate the mass of 3.4 \pm 0.2\(M_\odot\) and an age of 240 Myrs. This would imply that it is still a young star, but because of its higher mass the evolution time scales are smaller and yet it has reached the post-main-sequence. Calculating a spectroscopic parallax and comparing it with the Hipparcos parallax the difference is 3.6%. The kinematics of this star reveal a space velocity of \((U/V/W) = (6.6/ -17.1/ -1.2)\) km s\(^{-1}\). This is consistent with the Pleiades, α Per, IC 2602, and Coma Berenice.
Spectral synthesis analysis and radial velocity study of the northern F-, G-, and K-type flare-stars

Table 1. Spectral parameters of the flare-stars derived by spectral synthesis analysis. log(L_X/L_bol) is a measure for the activity of the stars.

| name          | T_eff [K] | M [M_☉] | log g    | [Fe/H]  | M_V [mag] | M_bol [mag] | v sin i [km s⁻¹] | R_spect [R_☉] | P_rot [days] | log(L_X/L_bol) |
|---------------|-----------|---------|----------|---------|-----------|-------------|-----------------|---------------|-------------|----------------|
| HIP 1803      | 5740 ± 70 | 1.0     | 4.34 ± 0.10 | +0.14 ± 0.07 | 4.59       | 4.71        | 6.39 ± 1.00     | 1.03 ± 0.03   | ~14         | -4.49 ± 0.11  |
| HIP 18512A    | 4600 ± 100 | 0.7     | 4.60 ± 0.20 | -0.03 ± 0.15 | 8.06       | 6.53        | 2.10 ± 2.00     | 0.69 ± 0.03   | 3.82 ± 0.12  |
| HIP 26779     | 5260 ± 70  | 0.9     | 4.50 ± 0.10 | +0.09 ± 0.07 | 6.12       | 5.43        | 3.10 ± 1.00     | 0.88 ± 0.02   | ~14         | -4.53 ± 0.11  |
| EK Dra        | 5700 ± 70  | 0.9     | 4.37 ± 0.10 | -0.16 ± 0.07 | 7.60       | 4.79        | 16.50 ± 1.00    | 1.00 ± 0.02   | 2.76 ± 0.005 | -3.48 ± 0.09  |
| HIP 73555     | 4990 ± 70  | 3.4     | 2.40 ± 0.10 | +0.01 ± 0.07 | 3.51       | -0.96       | 4.10 ± 1.00     | 18.5 ± 0.5    | 200 ± 15     | -6.56 ± 0.21  |
| HIP 98698     | 4730 ± 70  | 0.8     | 4.60 ± 0.10 | -0.04 ± 0.07 | 7.47       | 6.39        | 2.50 ± 1.00     | 0.70 ± 0.02   | -4.82 ± 0.20 |                |
| HN Peg        | 5950 ± 70  | 1.0     | 4.35 ± 0.10 | +0.07 ± 0.07 | 5.94       | 4.51        | 9.90 ± 1.00     | 1.05 ± 0.02   | multiple     | -4.32 ± 0.11  |
| HIP 114385    | 5830 ± 70  | 1.1     | 4.38 ± 0.10 | +0.08 ± 0.07 | 7.11       | 4.65        | 6.10 ± 1.00     | 1.02 ± 0.02   | 2.95 ± 0.05  | -3.37 ± 0.13  |

Table 2. Spectral parameters of HIP 1803 derived using the spectral synthesis analysis methods described before (first row of the table). The last ten rows summarise the work of the other authors, where most of the data was compiled by Cayrel de Strobel et al. (1997) from several sources. Malagnini et al. (2000) has listed the same stars in their work. The spectral parameters were used to calculate the spectroscopic distance and compare to the Hipparcos distance to investigate the accuracy of the analysis.

| T_eff [K] | log g   | [Fe/H] [dex] | M_V [mag] | M_bol [mag] | d_HIP [pc] | d_spec [pc] | Reference       |
|-----------|---------|--------------|-----------|-------------|------------|------------|----------------|
| 5740 ± 70 | 4.37 ± 0.10 | 0.13 ± 0.07 | 6.39       | 4.65        | 20.39      | 20.95      | this work       |
| 5771      | 4.44     | 0.15         | 4.81       | 21.5        | G          |            | Katz 2003      |
| 5675 ± 60 | 4.31 ± 0.12 | 0.17 ± 0.05 | 4.56       | 21.1        | M, C       |            | Gaidos & Gonzalez 2002 |
| 5860      | 4.4      | -0.09        | 4.65       | 18.4        | M, C       |            | Malagnini et al. 2000 |
| 5860      | 4.4      | 0.28         | 5.65       | 21.2        | M, C       |            | Cayrel de Strobel et al. 1997 |
| 5793      | 4.6      | 0.24         | 5.20       | 16.4        | M, C       |            | Glushneva et al. 2004 |
| 5793      | 4.5      | 0.2          | 4.95       | 18.4        | M, C       |            | Abia et al. 1984  |
| 5673      | 4.22     | -0.01        | 4.34       | 24.0        | M, C       |            | Glushneva et al. 2004 |
| 5781      | 4.40     |              | 4.69       | 20.7        | A          |            |                 |
| 5800      | 4.60     | 0.24         | 4.69       | 20.7        | A          |            |                 |

Figure 1. Schaller et al. (1992) post-main-sequence tracks and age-marks. Indicated with a * is the position of HIP 73555.

moving groups, which are summarised as the local association. Since the local association is a conglomerate of comoving groups with different ages, the age estimated from the post-main-sequence tracks of Schaller et al. (1992) cannot be confirmed or disproved.

For the subgiant HIP 73555 radius measurement are available and listed in Richichi & Percheron (2002) and references therein. By interferometry they measure a diameter of 2.99 ± 0.01 mas with a parallax of π = 14.91 ± 0.57 mas this leads to a diameter of D = 43.0 ± 2.0 R_☉, or radius R = 21.5 ± 1.0 R_☉. Our measured temperature can be used to predict a radius: 18.5 ± 0.5 R_☉. The radius predictions are in agreement, so we are confident that our measured effective temperature is reasonable.

2.1.6 HIP 98698, HD 19007, [GKL99] 381

HIP 98698 was observed May 24 2002 from Calar Alto with FOCES. The spectrum of the star shows a young main-sequence star with a temperature of 4720 ± 80 K. The surface gravity (log g = 4.60 ± 0.10) and the iron abundance is [Fe/H] = −0.04 ± 0.07.

2.1.7 HN Peg, HIP 107350, HD 260680, [GKL99] 410

HN Peg was observed from Calar Alto using the FOCES spectrograph in Nov. 29 2001. What guides the eye in this spectrum is the strong lithium absorption feature, the filling-in of Hα of about 10% and the line-broadening due to the high projected rotational velocity v sin i. The activity
level namely the line-filling would support an age of 100-300 Myrs. Chen et al. [2001] studied the lithium abundance: \( EW(\text{Li}) = 109.5 \text{ mÅ} \) which transforms to an abundance of \( \log N(\text{Li}) = 2.73 \) derived by non-LTE calculations. The space velocity is \( (U/V/W) = (5.1/ -16.4/3.1) \text{ km s}^{-1} \). The stars is a member of the local association.

The spectral synthesis analysis reveals a star close to the main-sequence on the zero-age main-sequence (ZAMS). The measured lithium equivalent width in the observed spectrum is \( 100.8 \pm 0.8 \text{ mÅ} \). Modelling the lithium line this leads to a lithium content of \( \log N(\text{Li}) = +2.81 \pm 0.09 \). Thus, like EK Dra, HN Peg also has a large overabundance of lithium. The stellar parameters are listed in Tab. 1.

2.1.8 HIP 114385, HD 218739 and HIP 114379, [GKL99] 440, HD 218738

The stars HIP 114385 and HIP 114379 A&B form a triple system where HIP 114385 and HIP 114379 from a visible binary system and HIP 114379 A&B is a spectroscopic and adaptiv optics (AO) binary. HIP 114385 and HIP 114379 are located at the same distance at \( 34.06 \pm 2.31 \text{ mas} \) and \( 39.56 \pm 7.67 \text{ mas} \) respectively. They are comoving. Note the big error in the parallax measurement of Hipparcos. For HIP 114379 this clearly shows that the companion disturbed the precision of the parallax measurement. But also the stray light from HIP 114379 (\( \pi = 39.56 \pm 7.67 \text{ mas} \)) disturbed the parallax measurement of HIP 114385 (\( \pi = 34.06 \pm 2.31 \text{ mas} \)) which can be noticed by the relative big error.

For HIP 114379 the following data is available from the catalogue of nearby star metallicities (Zakhozhaj & Shaparenko [1999]) obtained from photometric UBV data (\( \pi = 28.7 \text{ mas}, [Fe/H] = -0.30 \)). This result must be regarded with care because the star is a binary and the data has not been corrected for this.

For the visual companion (HIP 114385) no data from that catalogue is available. We measure the metallicity of the companion star to be \( [Fe/H] = 0.08 \pm 0.07 \), much higher than its companion. It is not clear, why the companion should have a different metallicity. We can only guess that the metallicity determined by photometry is not correct.

Its lithium is already burned which makes the star older than the Pleiades, but its activity indicate an age similar to the Ursa Major cluster.

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### Table 3. Spectral parameters of HIP 73555 derived using the spectral synthesis analysis methods described before (first row of the table). The last three rows summarise the work of the other authors. The spectral parameters were used to calculate the spectroscopic distance and compare to the Hipparcos distance to investigate the accuracy of the analysis.

| Reference | \( T_{\text{eff}} \) [K] | log g | \([Fe/H]\) [dex] | \( M_V \) [mag] | \( M_{\text{bol}} \) [mag] | \( d_{\text{HIP}} \) [pc] | \( d_{\text{spec}} \) [pc] | \( R_{\text{measured}} \) [R\(_{\odot}\)] | \( R(T_{\text{eff}}) \) [R\(_{\odot}\)] |
|-----------|----------------|-------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| this work | 4990 \pm 70 | 2.40 \pm 0.10 | 0.01 \pm 0.07 | 3.51 | -0.96 | 67.7 | 69.5 | 21.5 \pm 1.0 | 18.5 \pm 0.5 |
| B         | 5000          | 2.00  | -0.07         | 0.47 | -1.24 | 75   | 9.0  |                 |                 |
| McW       | 5150          | 3.06  | -0.13 \pm 0.10 | 0.47 | -1.24 | 75   | 9.0  |                 |                 |
| B&G       | 4929          | 2.30  | 0.04          | -1.24 | 75   |                 |                 |                 |                 |

K: this work, B: Brown et al. [1981], McW: Mc William [1990], B&G: Bell & Gustafsson [1990]

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### Figure 2. Hipparcos distance versus spectroscopic distance of the flare-stars. Underlayed in gray is the average errorbar of the Hipparcos parallax measurements. The lines marking the 15% level correspond to a 2σ confidence level.

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### 3 TLS RADIAL VELOCITY MONITORING

The radial velocity (RV) search program of young and active stars of the TLS described by Hatzes et al. [2003]. For this program we use the 2-m-Alfred Jensch telescope of the TLS at Tautenburg which is equipped with an échelle spectrograph with resolving power of \( \Delta \lambda/\lambda = 67000 \). During...
the observations an iodine absorption cell is placed in the optical light path in front of the spectrographs slit. The resulting iodine absorption spectrum is then superposed on top of the stellar spectrum providing a stable wavelength reference against which the stellar RV are measured. In the first step, the spectra are bias-subtracted, flat-fielded, and extracted using standard IRAF routines.

In the second step the RVs are calculated by modelling the observed spectra with a high signal-to-noise ratio template of the star (without iodine) and a scan of our iodine cell taken at very high resolution with the Fourier Transform Spectrometer of the McMath-Pierce telescope at Kitt Peak. The latter enables us to compute the relative velocity shift between stellar and iodine absorption lines as well as to model the temporal and spatial variations of the instrumental profile. See Valenti, Butler &Marcy (1993) and Butler et al. (1996) for a description of the principles behind this technique. RV measurements have been made at TLS since 2001 and these show that we can achieve a routine RV precision of \( \approx 3 \text{ m} \text{s}^{-1} \).

### 3.1 HIP 26779, [GKL99] 145, HD 37394

Gaidos (1998) give a rotation period of 11.02 \( \pm \) 0.05 days derived using the Ca H & K activity indicator with a constant RV. Montes et al. (2001) show that the star is a member of the local association (Pleiades, \( \alpha \) Per, M34, \( \delta \) Lyr, NGC 2516, IC2602) and it has an age between 20-150 Myr, thus it is relatively young and we therefore expect a high level of activity but observe a rather modest level (see Fig. 3): the variance is only 11.8 m s\(^{-1} \) which should be compared to the average error of the measurement of 7.2 m s\(^{-1} \). We explain this by the relatively slow rotation which is indicated by the long rotation period and \( v \sin i \). Despite the low amplitude we find a possible period of about 14 days of the RV-variations.

### 3.2 HIP 73555

The subgiant HIP 73555 is an interesting testcase for RV measurements, because as mentioned above there are interferometric radius measurements available. As mentioned above the radius is \( R = 21.5 \pm 1.0 \text{R}_\odot \). From the spectra we determined a \( v \sin i \) of 4.10 \( \pm \) 1.0 km s\(^{-1} \) (Tab. 1). We observed the star for three years, and obtained 42 RV measurements. In this data, we find a sinusoidal variation with a period of 200 \( \pm \) 15 days and a semi-amplitude of about 10 m s\(^{-1} \) (see Fig. 3). The obvious explanation of this variation is simply the presence of stellar surface features in conjunction with the rotation of the star. Under this assumption, we calculate an inclination of 28 \( \pm \) 6°.

### 3.3 HN Peg

In the Lick planet search (Cumming et al. 1999) HN Peg was observed with a precision of \( \sim 5 \text{ m} \text{s}^{-1} \), but no significant RV variations were detected. However, we find sinusoidal variations (see Fig. 3) with a period of 4.38 \( \pm \) 0.15 days and a semi-amplitude of 30 m s\(^{-1} \) which we explain by surface features which are common for a young star. In addition to this we find less significant sinusoidal periods: 5.12 \( \pm \) 0.15 days, 4.94 \( \pm \) 0.15 days, and 4.69 \( \pm \) 0.15 days as shown in the periodogram in Fig. 4.

This strange behaviour agrees well with the results of the photometric monitoring in the years 1992-1998 of You & Duemmler (2002). They detect a period of 5.1348 \( \pm \) 0.0095 days which was seen throughout their entire observing time and additional periods in the range between 4.4 and 4.8 days. They explain this with the activity cycle of the star in conjunction with differential rotation.

Donahue et al. (1996) monitored the flux-variations of Ca H & K of HN Peg for 12 years, and find periods in the range between 4.57 to 5.30 days. Additionally Frasca et al. (2000) measured periodic H\alpha and Ca H & K flux variations, and variations in the Strömgren photometry with a period of 4.74 days.

Thus, with the RV-measurements we find the same periods again, as in the photometric data, as well as in the line-flux variations of the H\alpha and Ca H & K.
Figure 5. RV measurements of HN Peg in the years 2001, 2002, and 2003 at the TLS. The RV variation seen are caused by surface features and the period of those variations is that of the rotation period of the star.

Figure 6. Periodogram of the RV measurements of HN Peg. We find several possible periods.

3.4 HIP 114385

We monitored the star in 2001-2003 and it showed periodic RV variation of $2.95 \pm 0.05$ days and a semi-amplitude of about $20 \text{ m s}^{-1}$ (Fig. 7). An analysis of the photometric measurements carried out by Hipparcos shows also the same period of $2.95 \pm 0.05$ days. Fig. 8 shows the periodogram of the photometric data compared to our RV measurements. The Fig. 9 shows the phase-folded light-curve. We conclude that the RV variations are caused by surface features.

4 DISCUSSIONS

HIP 1803 is a member of the Hyades supercluster. All spectroscopic signatures confirm that the star is ZAMS. For HIP 1803 the newly derived spectral parameters differ quite a lot for older estimates. Regarding the difference between the spectroscopic distance and the parallax measurement of Hipparcos we are confident that our estimates are reliable.
HIP 18512 A is a member of the Ursa Major association. The kinematics, the lithium abundance, as well as the $[Fe/H]$, and the $v\sin i$ support this conclusion.

HIP 26779 is a young star. The lithium in the atmosphere as well as its membership to the local association support the young age. But we are not able to give a definite answer to how old this star really is. We can exclude a planetary companion with a mass $\geq 0.11\, M_{\text{Jupiter}}$ with a period $\leq 10$ days.

EK Dra is a binary with an orbital period of $45 \pm 5$ yrs. It is one of the young stars where the true masses can be derived using only Keplers laws. The masses are $0.9 \pm 0.1\, M_\odot$ and $0.5 \pm 0.1\, M_\odot$ respectively (König et al. 2003). Our spectral synthesis analysis confirms the mass of the primary. The light contribution of the secondary to the spectrum of the primary is negligible so that the analysis is not affected. We can exclude a planetary companion with a mass $\geq 1.0\, M_{\text{Jupiter}}$ with a period $\leq 10$ days.

HIP 73555 is a young post-main-sequence giant and not a pre-main-sequence star. Therefore it should not be listed in the Gershberg et al. (1990) catalogue. The conclusions for this star is: it is a young post-main-sequence star with only 240 Myrs but due to its mass it has already evolved past the main-sequence and thus does not belong to this sample. But since the star is relatively young it might anyway be interesting to search for planets in its vicinity. For this star, we can exclude a planet with a mass of more than $0.6\, M_{\text{Jupiter}}$ with a period of less than 200 days ($\sim$ one AU).

The other stars are all ZAMS stars. The flare activity is probably related to the differential rotation and the magnetic field of the star. Though the spot coverage of EK Dra is about $1/3$ of the visible surface at some phases of rotation and activity, these kind spots are not known on the surface of the Sun.

On the other flare stars analysed on course of this work we realise that the Hα cores are often filled-in and that the temperature estimated from Hα is if the core is filled by more than 10% 20-40 K lower than the Hβ temperature. In those cases we give priority to the Hβ temperature. Especially as the example of EK Dra shows due to the flaring activity and stellar spots on the surface.

The lithium abundance of HN Peg and EK Dra exceeds the lithium abundance of other G-type stars, even for their young age. It is interesting to note that the two stars with the lithium overabundance are also the most active stars of our sample. It is well known that active, late type stars have an overabundance of lithium (Morel et al. 2004). We thus speculate that in this star lithium is generated during flare events (Ramaty et al. 2000). HN Peg and EK Dra do not show other peculiarities in its spectrum. They are otherwise typical ZAMS stars. We can exclude a planetary companion with a mass $\geq 0.4\, M_{\text{Jupiter}}$ with a period $\leq 10$ days around HN Peg.

HIP 114385 and HIP 114376 A&B The stars form a hierarchical triple system. The spectroscopic and AO binary HIP 114376 A&B is the star appearing in the flare star catalogue. Maybe the binarity triggers the activity. We cannot analyse the binary but the analysis of the companion is possible and we can then assume a common formation scenario and thus the same age, and metallicity.

As a general remark we conclude that all these stars are ZAMS stars making the older than previously suspected by having only the information about the flaring activity. Due to their proximity to the sun they are all good targets for direct imaging searches for planets which are already ongoing. RV monitoring for the planet search are challenging as the example of EK Dra shows due to the flaring activity and stellar spots on the surface.

5 CONCLUSION

The stars all have about solar metallicity. It is interesting to note the two most active stars of this sample have an overabundance of lithium. We deduce a mean $v\sin i = 6.0 \pm 4.6\, \text{km s}^{-1}$ of our sample stars. In all monitored stars we detect periodic RV variations. The semi-amplitude is typically $20\, \text{m s}^{-1}$. This corresponds to the activity level seen in the RV amplitude of ε Eri (Hatzes et al. 2000). Around this star it was possible to detect a planet of $m\sin i = 0.86\, M_{\text{Jupiter}}$ which caused a semi-amplitude of $19\, \text{m s}^{-1}$, an eccentricity of $0.608 \pm 0.041$, a semimajor axis of $3.4\, \text{AU}$ and a period of $2502.1 \pm 20.1$ days (Hatzes et al. 2000). For HIP 26779, EK Dra, HIP 73555, HN Peg, HIP 114385 we can exclude 51 Peg like planets: Our upper limits are 0.11, 1.0, 0.6, 0.4 $M_{\text{Jupiter}}$ respectively.

ACKNOWLEDGEMENTS

This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France. B.K. wishes to thank Klaus Fuhrmann for the discussions. We acknowledge the help of Ana Bedalov and Matthias Ammler with some of the observations and the technical support of the staff of the Alfred Jensch telescope. The analysis of some of the data was carried out as part of B.K.s PhD thesis at the Max-Planck-Institut für extraterrestrische Physik in Garching. We wish to thank the referee R.E. Gershberg for his comments to improve the work and for further suggestions how to continue this work succesfully.

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