

Exploración espectroscópica de estrellas frías aisladas miembros de grupos de movimiento jóvenes



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Resumen

En esta contribución se describe la exploración espectroscópica de alta resolución que estamos llevando a cabo para estrellas aisladas de los últimos tipos, identificadas en nuestros anteriores estudios como posibles miembros de grupos cinemáticos jóvenes: (Asociación Local (20 - 150 Myr), Ursa Major (300 Myr), Híades (600 Myr), IC 2391 (35 Myr) y Castor (200 Myr)). Las observaciones espectroscópicas se han realizado durante diez campañas de observación entre 1999 y 2002 utilizando diferentes espectrógrafos "echelle": FOCES en el telescopio de 2.2m CAHA, Almería), SOFIN en el Nordic Optical Telescope (NOT) (La Palma), MUSICOS en el Isaac Newton Telescope (INT) (La Palma), y SARG en el Telescopio Nazionale Galileo (TNG) (La Palma). Hasta ahora se han observado un total de 150 estrellas. Nuestro objetivo principal es analizar con más detalle la pertenencia de estas estrellas a los diferentes grupos cinemáticos estelares.

Por una parte, se ha comprobado su pertenencia cinemática calculando las componentes de velocidad galácticas (U, V, W) utilizando para ello las velocidades radiales determinadas en nuestros espectros por correlación cruzada con estrellas estándares de velocidad radial. Por otra parte, se han utilizado métodos de determinación de edades característicos de estrellas frías tales como el nivel de actividad cromosférica y la línea de absorción del litio. Además, se están utilizando estos espectros para determinar otros parámetros estelares fundamentales de estas estrellas como el tipo espectral, clase de luminosidad, velocidad de rotación ($v \sin i$), y abundancias químicas. Para las estrellas más activas de la muestra se han realizado espectros durante varias campañas de observación con el fin de analizar en detalle la modulación rotacional de la actividad fotosférica y cromosférica.

Introduction

Stellar kinematic groups (SKG), (Superclusters (SC) and Moving groups (MG) are kinematic coherent groups of stars (Eggen 1994) that could share a common origin. In our previous work (Montes et al. 2001, MNRAS, in press, Paper I) we have compiled a sample of late-type stars possible members of the youngest and best documented MG:

- Local Association (Pleiades moving group 20 - 150 Myrs), (La Palma, Observatorio de la Armada)
- Ursa Major group (300 Myrs)
- Hyades supercluster (600 Myrs)
- Ursa Major group (Sirius supercluster, 300 Myrs)
- Hyades supercluster (600 Myrs)

Stars have been selected from previously established members of SKG from photometric and kinematic properties, as well as from new candidates based on other criteria as their level of chromospheric activity, rotation rate and lithium abundance. In Fig. 1 we represent the (U, V) and (W, V) planes (Boettingler diagram) for this sample of stars.

In order to better establish the membership of these candidate stars to the different young SKG we have started a program of high resolution echelle spectroscopic observations. The spectroscopic analysis of these stars allow us to obtain a better determination of their radial velocity, lithium ($\lambda 6707.8 \text{ \AA}$) equivalent width, rotational velocity and the level of chromospheric activity. We will use all these new data to study in detail the kinematic (Galactic space motions (U, V, W)) of these stars, apply age-dating methods for late-type stars, and in this way analyse in more detail the membership of these stars to the different SKG.

We present here the results of our first spectroscopy studies of a sample of single late-type stars selected by us in Paper I as young disks stars or possible member of some of the young SKG above mentioned.

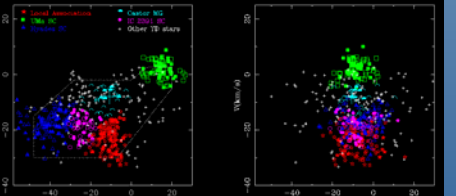
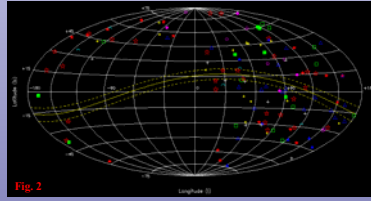


Fig. 1. Boettingler diagram for the late-type stars selected in our previous study (Montes et al. 2001) as young disks stars or possible members of the Local Association, Hyades, Ursa Major, IC 2391 and Castor MGs.

Observations

A total of 150 stars have been observed until now. The Distribution of the sample in Galactic coordinates (l, b) is plotted in Fig. 2 (symbols are as in Fig. 1).



The spectroscopic observations (high resolution echelle spectra) of the stars analysed in this work were obtained during twelve observing runs (from 1999 to 2002):

Observing run:	Wavelength range:	Spectral resolution:
• 2.2m-FOCES (24-29 July 1999)	3910 - 9075 \AA	0.09 - 0.26 \AA
• 2.2m-FOCES (21-24 September 2001)	3510 - 10700 \AA	0.08 - 0.35 \AA
• 2.2m-FOCES (22-25 April 2002)	3510 - 10700 \AA	0.08 - 0.35 \AA
• 2.2m-FOCES (01-06 July 2002)	3510 - 10700 \AA	0.08 - 0.35 \AA
• INT-MUSICOS (18-22 January 2000)	4430 - 10225 \AA	0.16 - 0.30 \AA
• INT-MUSICOS (5-11 August 2000)	4430 - 10225 \AA	0.16 - 0.30 \AA
• 2.5 m Isaac Newton Telescope, ESA-MUSICOS spectrograph		
• INT-IDS (2-5 April 2001)	3554 - 5176 \AA	0.48 \AA
• Intermediate Dispersion Spectrograph (La Palma, Spain)		
• NOT-SOFIN (26-27 November 1999)	3525 - 10425 \AA	0.14 - 0.32 \AA
• NOT-SOFIN (10-13 November 2000)	3525 - 10425 \AA	0.14 - 0.32 \AA
• NOT-SOFIN (21-29 August 2002)	3525 - 10200 \AA	0.02 - 0.05 \AA
• 2.56 m Nordic Optical Telescope, Soviet Finnish High Resolution Echelle Spectrograph (La Palma, Spain)		
• TNG-SARG (10-11 October 2001)	4960 - 10110 \AA	0.08 - 0.17 \AA
• 3.5 m Telescopio Nazionale Galileo, Spectrografo di Alta Risoluzione Galileo (La Palma, Spain)		
• HET-HRS (19 Dec 2001 - 28 Feb 2002)	5040 - 8775 \AA	0.15 - 0.28 \AA
• 9.2 m Hobby-Eberly Telescope, High Resolution Spectrograph (McDonald Observatory in Texas, USA)		

Radial Velocities & Space Motions

Heliocentric radial velocities have been determined by using the cross-correlation technique. The spectra of the program stars were cross-correlated order by order, using the routine FXCOR in IRAF, against spectra of radial velocity standards of similar spectral types. The velocity is derived from the position of the cross-correlation peak. The orders including chromospheric features and prominent telluric lines were excluded when determining the mean velocity. Uncertainties in the derived velocities have been estimated from the width of the cross-correlation peak and the inter-order agreement in the derived velocities. In Table 1 we list the obtained heliocentric radial velocities (V_{hel}) and their associated errors (σ_v) for each spectrum.

We have used these radial velocities together with precise measurements of proper motions and parallaxes taken from Hipparcos and Tycho-2 Catalogs, to calculate Galactic space-velocity components (U, V, W) in a right-handed coordinated system (positive in the directions of the Galactic center, Galactic rotation, and the North Galactic Pole, respectively). We have modified the procedures in Johnson & Soderblom (1987) to calculate U, V, W, and their associated errors. The original algorithm is adapted here to epoch J2000 coordinates in the International Celestial Reference System (ICRS). The uncertainties of the velocity components have been obtained using the full covariance matrix. We have used the correlation coefficients provided by Hipparcos (ESA 1997). The (U, V) and (W, V) planes (Boettingler diagram) are plotted in Fig. 3.

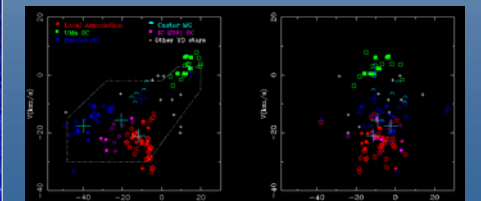


Fig. 3. As Fig. 1 for the late-type stars included in this spectroscopic survey

The Li I $\lambda 6707.8 \text{ \AA}$ line

The resonance doublet of Li I at 6707.8 \AA is an important diagnostic of age in late-type stars since it is destroyed easily by thermonuclear reactions in the stellar interior. This line is included in our echelle spectra (Fig. 4) in all the observing runs. At this spectral resolution and with the rotational velocity ($v \sin i > 8 \text{ km s}^{-1}$) of the observed stars the Li I line is blended with the nearby Fe I 6707.41 \AA line. We have corrected the total measured equivalent width, EW(Li I+Fe I), by subtracting the EW of Fe I calculated from the empirical relationship with (B-V) given by Soderblom et al. (1990). The obtained values are given in Table 1 and plotted in the EW(Li I) vs. spectral type diagram (Fig. 5).

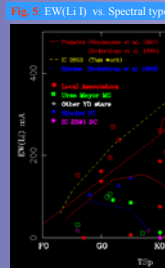
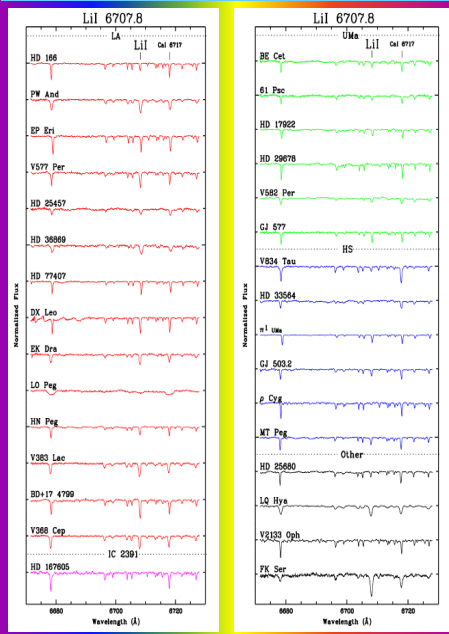


Fig. 4. Spectra in the Li I $\lambda 6707.8 \text{ \AA}$ line region for stars of the sample with significant EW(Li I).



In order to obtain an estimate of the ages of our stars we compare their EW(Li I) with those of stars in well known young open clusters of different ages. In Fig. 5 we have overlaid the upper and lower envelopes of the Li I EW in IC 2602 (10-35 Myr), Pleiades (78-125 Myr) and Hyades (600 Myr) clusters. For the Pleiades we adopt the upper envelope determined by Neuhäuser et al. (1997) and the lower envelope given by Soderblom et al. (1993). In the case of IC 2602 we have not adopted the upper envelope given by Neuhäuser et al. (1997) because they have used EW(Li I) not corrected from the EW(Fe I) and we have determined a new upper envelope with corrected EW(Li I) and using, in addition, new data provided by Randich et al. (2001). Finally for the Hyades we have used the upper envelope adopted by Soderblom et al. (1993).

Table 1. Observed stars and measured V_{hel} , $v \sin i$, EW(Li I)

Name	T_{eff}	N° Obs.	$v \sin i$ (km s $^{-1}$)	$V_{hel} \pm \sigma_v$ (km s $^{-1}$)	EW(Li I) (mÅ)
LA					
HD 166	K0 V	2	6.54	-	56
PW And	K2 V	11	24.80	-10.79 \pm 0.40	273
47 Cnc	F9 V	1	55.08	-19.25 \pm 1.71	-
EP Eri	K2 V	3	13.08	17.27 \pm 0.10	211
V377 Per	K2 V	1	<4.9	-	236
GJ 211	K1 V	1	-	0.28 \pm 0.17	36
HD 25457	F8 V	1	23.46	15.30 \pm 0.45	132
HD 25665	G5 V	1	18.29	-13.30 \pm 0.10	7
HD 26869	G3 V	1	27.34	-	238
HD 27407	G0 V	2	-	4.43 \pm 0.17	162
DX Leo	K0 V	4	-	8.13 \pm 0.08	186
EK Dra	G1 V	2	-	-20.64 \pm 0.23	195
GJ 417 A	M0 V	1	13.85	-6.29 \pm 0.45	-
HD 169394	K7 V	1	18.73	-31.34 \pm 0.34	0
V889 Her	G2 V	1	45.50	-19.66 \pm 0.46	270
LO Peg	K5 V	3	5.70	-19.27 \pm 1.00	244
HR Peg	G9 V	3	13.47	-16.53 \pm 0.10	117
V383 Lac	K1 V	14	21.95	-19.74 \pm 0.09	258
HD 17 4799	K0 V/IV	2	12.74	-16.77 \pm 0.12	200
v Ag	F7 V	1	4.2	-6.34 \pm 0.36	0
V306 Cep	K1 V	10	19.66	-16.67 \pm 0.11	208
GJ 588	K5 V	2	9.07	5.09 \pm 0.10	0
IC 2391					
HD 17390	K2 IV	1	<7.9	-	177
SI Aps	F8 V	1	3.54	-	18
V104	F8 V	1	21.65	-	18
GJ 2706	K0 V	1	-	-2.60 \pm 0.21	1
HD 167805	K2 V	2	12.78	-13.84 \pm 0.09	32
HD 203631	K0 V	1	6.27	-12.41 \pm 0.10	0

Name	T_{eff}	N° Obs.	$v \sin i$ (km s $^{-1}$)	$V_{hel} \pm \sigma_v$ (km s $^{-1}$)	EW(Li I) (mÅ)
UMA					
46 Pic	G7 V	1	<0.6	3.66 \pm 0.13	11
HD 26919	K4 V	1	8.09	-	16
V84 Tau	K3 V	1	3.2	0.27 \pm 0.10	60
V1386 Ori	K0 V	1	11.06	-	13
HD 20504	F8 V	1	18.20	-	32
σ UMa	G1.5 V	3	-	-14.45 \pm 0.13	106
GJ 2032	G2 V	1	-	-9.26 \pm 0.28	32
ρ Crv	G5 III	1	3.36	-	85
MT Peg	G1 V	1	5.08	-	99
HS					
BU Cnc	G3 V	2	>7.2	-4.50 \pm 0.21	127
GJ Pnc	F8 V	1	14.01	-2.14 \pm 0.09	105
HD 17922	F3 V	1	11.48	-	94
HD 28278	K0 V	1	3.2	-	306
V382 Per	F7 V	1	17.58	-	95
HD 7317	K1 III	1	5.34	-	4
GJ 227	G5 V	3	-	-6.48 \pm 0.10	145
HD 20550	K2 V	1	<4.9	-	0
Other YD stars					
GJ 13 A	M1.5 V	1	6.50	9.98 \pm 0.29	-
HD 25880	G5 V	1	-	-	07
LQ Hy	K2 V	5	-28.84	7.58 \pm 0.24	244
V1152 Oph	K2 V	1	8.74	-12.80 \pm 0.07	34
FR Ser	K5 V	1	13.69	-0.09 \pm 0.25	244
GJ 725 A	M3 V	2	6.72	-1.06 \pm 0.46	-
GJ 725 B	M3.5 V	2	0.60	0.42 \pm 0.49	-

Rotational Velocities ($v \sin i$)

We have determined the rotational velocities ($v \sin i$) of our star sample by using the cross-correlation technique. The spectrum of the program star is cross-correlated against the spectrum of a template star (a slowly rotating star of similar spectral type) and the width of the cross-correlation function determined. The calibration of this width to yield an estimate of $v \sin i$ is determined by cross-correlating artificially broadened spectra of the template star for a range of $v \sin i$ with the template star spectrum. We have tested this method with stars of known rotational velocity obtaining a good agreement. The $v \sin i$ we have measured for our star sample are given in Table 1.

Chromospheric activity indicators

Ca II H & K, H α , H β , H γ , H δ , He I $\lambda 6678$, H α , and Ca II IRT

The echelle spectra analysed in this work allow us to study the behaviour of the different optical chromospheric activity indicators from the Ca II H & K to the Ca II IRT lines, formed at different atmospheric heights. The chromospheric contribution in these features has been determined using the spectral subtraction technique described in detail by Montes et al. (1995; 1997; 1998). The synthesized spectrum was constructed using the program STARMOD developed at Penn State (Barden 1985). The inactive stars used as reference stars in the spectral subtraction were observed during the same observing run as the active stars.

Representative spectra in the H α and Ca II IRT ($\lambda 8498, \lambda 8542$) line regions of some of the stars of the sample have been plotted in Figs. 6. For each star we have plotted the observed spectrum (solid-line) and the synthesized spectrum (dashed-line) in the left panel and the subtracted spectrum (dotted line) in the right panel.

Fig. 6. Spectra in the H α and Ca II IRT lines region of some of the stars of the sample.

