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Spectroscopic Monitoring of PMS and Vega-type stars

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EXPORT

Abstract. High and intermediate resolution spectroscopy of pre-main sequence (PMS) and Vega-type stars was the main contribution to the EXPORT observing project. Roughly 80 stars were observed at intermediate resolution while high resolution spectra were obtained for about 50 objects. A major characteristic of the data relies on the spectroscopic monitoring, the monitoring time scales of hours, days and months for many of the observed stars. Details of these observations and few examples of our results are presented in this contribution.

1. Introduction

Planets are thought to be an end product of the evolutionary process departing from the protostellar disks associated with protostars. In such scenario, the dissipation time scale for the disk or circumstellar (CS) material, must be overruled by the protoplanetary formation time scale. A first step leading to planets thus must be the formation of large solid bodies. The formation and evolution of protoplanetary disks and the study of planetesimals, as possible planet precursors, motivated the EXPORT project (Eiroa et al., this volume) to obtain intensive observational attention to PMS and Vega-type stars. Clues for these objects to be of importance for (proto-) planetary system formation are the different observational results for PMS and MS stars that have been interpreted in terms of circumstellar disks harbouring solid bodies (Grady et al. 2000, Lagrange, Backman, & Artymowicz 2000). A more specific example is β Pic, which is the best studied case of a MS star with a dust and gas disk, where transient absorption components in the spectral lines of several chemical species could be explained in terms of kilometer size solid bodies acting as star grazers, also known as the falling evaporating bodies (FEB) hypothesis (e.g. Beust et al. 1998 and references therein). In addition, a significant fraction of PMS stars show β Pic-like spectroscopic events. It has been suggested that these stars, whose best studied member is UX Ori, are β Pic system progenitors.

The EXPORT spectroscopic monitoring programme aimed to study the variable gaseous circumstellar activity in different time scales of stars of different evolutionary ages. High-resolution spectroscopy allows us to analyze the kinematics of transient spectroscopic gaseous events in detail, while intermediate-resolution spectroscopy provides better time resolution plus the possibility of observing faint objects. It is important to point out that these observations were complemented with simultaneous optical photo- & polarimetry and near-IR photometry. With such a unique data-set information on possible simultaneous changes or correlations in the gaseous and dusty structures of circumstellar disks can be achieved

2. EXPORT spectroscopic observations

2.1. Intermediate resolution

Intermediate resolution spectra were taken with the 2.5 m Isaac Newton Telescope (INT) equipped with the intermediate dispersion spectrograph (IDS). Observations were carried out during 16 nights distributed in four observing runs, approximately four nights per run, in May 1998, July 1998, October 1998 and January 1999. This distribution allowed us to obtain long-term (months) and short-term (hours, days) spectroscopic monitoring. The quality of the nights was good, even photometrically. Spectra of many stars were obtained during each single night when observable.

Two different instrumental setups were used. An EEV CCD was used in May 1998; the spectral range covered from 5854 Å to 6728 Å, with a resolution of $\Delta\lambda \sim 0.707$ Å per pixel and a resolving power ~4500 at 6300 Å. An upgraded EEV CCD was used during the other three observing runs. Now the wavelength range covered 5712 to 6812 Å, the resolution was $\Delta\lambda \sim 0.474$ Å per pixel and the resolving power ~6600 at 6300 Å. The slit width was always set on 1.0 arcsecond.

During our observations 81 stars were observed for wich 507 individual spectra were collected. Table 1 lists the observations and the number of spectra obtained per object. Exposure times ranged from one minute for the brightest objects, e.g. HR 10, V = 6.23 mag, and resulted in a signal to noise ratio (SNR) ~ 280, to half an hour for the faintest, e.g. VY Mon, V ~ 14.0 mag, SNR ~ 95. Figure 1 presents an histogram of the number of exposures per star in our sample. Around 50 % of the stars were observed at least 8 times, while only 11 out of the 81 stars were observed only once; the later ones are those apparently showing 'pure' photospheric spectra.

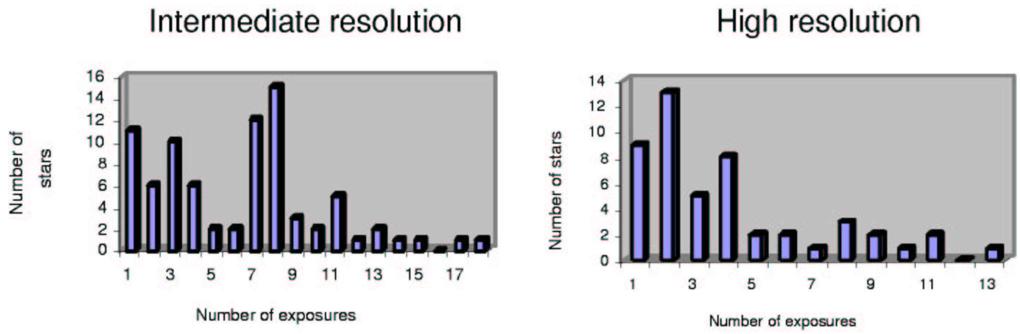

Figure 1. Number of observations per star

2.2. High resolution

High-resolution spectra were obtained at the 4.2 m William Herschell Telescope (WHT) equipped whith the Utrecht echelle spectrograph (UES). In this case, the overall observing time consisted of 12 nights distributed in the same runs as the INT observations: two nights in May and October 1998 and four nights in July 1998 and January 1999. In the May and October runs four nights were fully dedicated to observe 51 Peg and τ Bootis (see the contribution by Harris et al. in this volume)

UES was set to provide a wavelength coverage from 3800 to 5900 Å, a spectral resolution of 49000 and a slit width of 1.15 arcseconds projected on the sky. The achieved data set extend to 198 spectra for 49 stars. The observed objects and the number of UES spectra obtained are shown in Table 1. Integration times range from 10 minutes for the brightest objects (e.g. HR 10, V = 6.23 mag, SNR $\sim$ 2400) to 45 minutes for the faintest (e.g. VV Ser, V $\sim$ 11.9 mag, SNR $\sim$ 14). The histogram of the number of UES spectra per star is also displayed in Figure 1. In this case, the frequency of observations per star is considerably lower than in the case of the INT spectra, due to the exposure times needed to obtain good quality UES spectra. Nevertheles, the most interesting objects, as indicated by the INT observations, were observed as frequently as possible.

3. Observational results

The sample selection contained 81 objects of different masses and ages. 57 % of them are PMS stars and 43 % are considered MS stars. PMS stars consist of HAeBe, HAeBe/ZAMS, T Tauri and UXOR stars. UXORs are a subgroup of HAe stars and T Tauri stars which share photometric and spectroscopic characteristics with the prototype of the class: UX Ori. We have singled them out because it has been suggested that UXORs could be the progenitors of Vega-type/β Pic systems. The MS group consists of Vega-type stars, A-shell stars and post-Tauri (PTT) stars. PTT stars were taken from Lindroos's list (Lindroos 1986) of visual binaries composed of an early spectral type star (primary) and a late type star thought to be in the PTT phase. Because of the MS like photospheric spectra of these stars, we introduce this group into the MS stellar

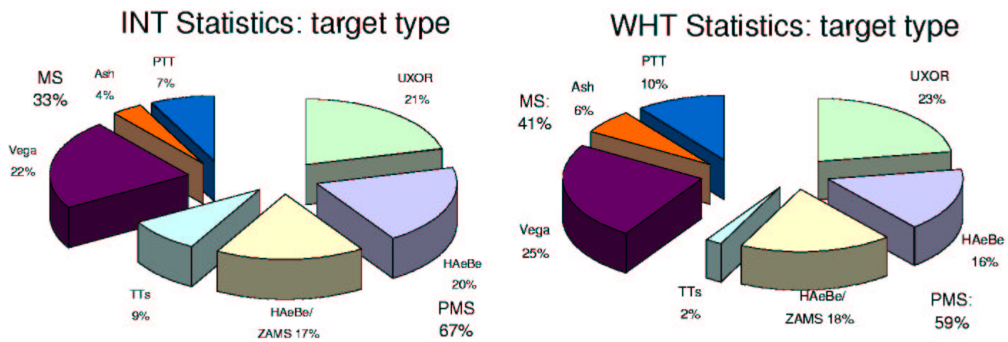

Figure 2. Statistics of target types

sample, though few of the secondaries show LiI absorption - which is an indication of youth. Figure 2 shows the statistics of the observed stars of each group with both INT and WHT data. Only one T Tauri was observed with the WHT because of the faintness of the selected stars of this subgroup.

One of the main aims of the observations is to monitor transient events that could be indicative for the presence of orbiting solid bodies in the circumstellar dust disks. Our spectra show the presence of blue- and red-shifted aborption components in several lines of many of the stars observed for the PMS and Vega-type nature. Some examples are shown in other EXPORT contributions in this volume. As illustrative examples we show the results on XY Per E and UX Ori. XY Per E was observed in three different runs, while UX Ori was observed in two. Figure 3 shows the CaII K and Hβ line profiles as observed with the WHT during those dates. The spectra in Figure 3 show remarkable changes in time scales of hours, days and months and they demonstrate the feasiblity of a detailed monitoring of the evolution of transient events in terms of their kinematics and strength.

Finally, it is well known that Hα emission is a good indicator of the presence of gas in the circumstellar environment. In the case of the PMS group most of the stars show, as expected, Hα in emission and for 79% of these objects the line is clearly strongly variable. Only in three cases of the HAeBe/ZAMS subgroup Hα is pure absorption, though with a complex profile, HD 158352, HD 199143 and HD 203024. In the MS group only three stars show Hα emission: 51 Oph, HR 1847B and HD 34700.

References

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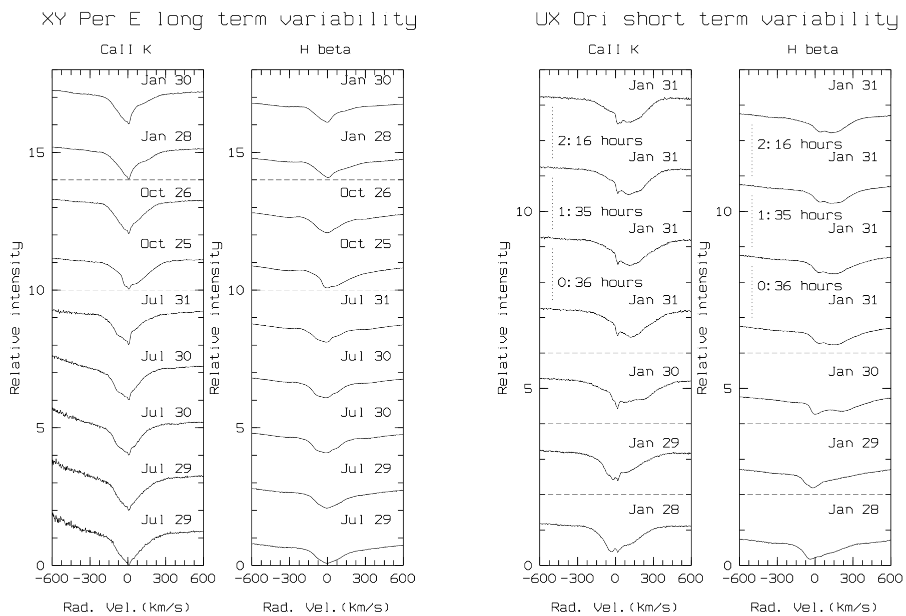

Figure 3. Examples of long and short term variations. The interval in hours between consecutive exposures is shown for the UX Ori short term variations in January 31st 1999

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Table 1. List of observed stars. The number of high and intermediate resolution exposures is given

Name	Type	# WHT	# INT	Name	Type	# WHT	# INT
17 Sex	Ash	4	3	HR 26	PTT	2	2
24 CVn	Ash	4	3	HR 26-B	PTT	-	2
49 Cet	Vega	2	4	HR 419	PTT	1	-
51 Oph	Vega	8	8	HR 1847	Vega	-	7
AS 442	HAeBe	-	5	HR 1847-B	Vega	-	7
BD+31 643	Vega	5	8	HR 2174	Vega	1	7
BD+31 643-B	Vega	-	2	HR 2174-B	Vega	-	2
BF Ori	UXOR	4	9	HR 4757	PTT	3	4
BH Cep	HAeBe	8	17	HR 4757-B	PTT	2	4
BO Cep	T Tauri	-	13	HR 5422	PTT	2	4
BM And	T Tauri	-	11	HR 5422-B	PTT	-	4
CO Ori	UXOR	3	8	HR 9043	Vega	2	2
CQ Tau	UXOR	1	8	KK Oph	UXOR	5	10
CW Tau	T Tauri	-	7	KK Oph-B	UXOR	-	3
DK Tau	UXOR	-	7	λ Boo	Vega	13	8
DK Tau-B	UXOR	-	1	LkHα 200	T Tauri	-	6
DR Tau	UXOR	2	8	LkHα 234	HAeBe	-	9
HD 23362	Vega	1	1	LkHα 262	T Tauri	-	4
HD 23680	Vega	-	1	LkHα 262-B	T Tauri	-	2
HD 31293	HAeBe	1	-	MWC 297	HAeBe/ZAMS	-	1
HD 31648	HAeBe/ZAMS	4	7	NV Ori	HAeBe	1	8
HD 34282	HAeBe/ZAMS	2	8	PX Vul	HAeBe	-	9
HD 34700	Vega	2	7	R Mon	HAeBe	-	3
HD 58647	HAeBe/ZAMS	3	3	RR Tau	UXOR	3	8
HD 109085	Vega	4	7	RY Ori	T Tauri	1	7
HD 123160	Vega	6	8	RY Tau	UXOR	4	7
HD 141569	HAeBe/ZAMS	11	10	SV Cep	HAeBe	7	14
HD 142666	HAeBe/ZAMS	6	12	T Ori	UXOR	1	7
HD 142764	Vega	2	6	UX Ori	UXOR	10	15
HD 144432	HAeBe/ZAMS	4	11	UX Ori-N	UXOR	-	1
HD 150193	HAeBe	-	3	V1685 Cyg	HAeBe	-	1
HD 158352	HAeBe/ZAMS	-	5	V1685 Cyg-B	HAeBe	-	1
HD 163296	HAeBe/ZAMS	9	11	V1686 Cyg	UXOR	-	8
HD 179218	HAeBe/ZAMS	-	3	V346 Ori	HAeBe	-	8
HD 190073	HAeBe/ZAMS	2	8	V350 Ori	UXOR	-	7
HD 199143	HAeBe/ZAMS	2	8	VV Ser	HAeBe	11	18
HD 203024	HAeBe/ZAMS	-	1	VX Cas	HAeBe	3	11
HD 203024-B	HAeBe/ZAMS	-	1	VX Cas-B	HAeBe	-	1
HD 233517	Vega	4	3	VY Mon	HAeBe	-	3
HD 233517-B	Vega	-	1	WW Vul	UXOR	8	13
HK Ori	UXOR	1	8	XY Per E	HAeBe	9	11
HR 10	Ash	2	3	Z CMa	HAeBe	2	-