Disks, Planetesimals and Planets
ASP Conference Series, Vol. 3×10^8, *2000*
Garzon, Eiroa, de Winter, Mahoney eds.

Optical photo-polarimetry and near-IR photometry of Pre-Main Sequence and Main Sequence objects

René D. Oudmaijer

Department of Physics and Astronomy, E C Stoner Building, Leeds LS2 9JT, UK

J.K. Davies

Joint Astronomy Centre, 660 N. A'ohoku Place, University Park, Hilo, Hawaii 96720, USA

C. Eiroa & J. Palacios

Dpto. Fisica Teorica, Facultad de Ciencias, Universidad Autonoma de Madrid, 28049 Cantoblanco. Madrid, Spain

F. Garzon

Instituto de Astrofisica de Canarias, C/ Via Lactea s/n 38200 La Laguna, Tenerife, Spain

D. de Winter

TNO/TPD-Space Instrumentation, Stieltjesweg 1, PO Box 155, 2600 AD Delft, The Netherlands

The EXPORT team

Abstract.
This contribution discusses the optical *UBVRI* broadband photo-polarimetry of the EXPORT sample obtained at the 2.5m Nordic Optical Telescope and the near-infrared *JHK* photometry obtained at the 1.5 m Carlos Sanchez Telescope of the EXPORT sample. The data, consisting of multi-epoch photo-polarimetry of more than 70 pre-main-sequence and main-sequence stars, comprises the largest set of its kind.

1. Introduction

One of the main projects within the EXPORT proposal concerned the study of the circumstellar gas and dust around pre-main-sequence (PMS) and main-sequence (MS) objects thought to be accompanied by planets, or by planets in the process of formation (see Eiroa et al, these proceedings). The data concerned are semi-simultaneous spectroscopy, photometry and polarimetry. Simplistically, the former data probe the gas closest to the stars, while the photo-polarimetry probes gas and dust further out from the stars.

Although studies of individual objects have been carried out in the recent past, a large sample of objects has not been studied in a systematic and statistical manner. This is mainly due to the large amounts of telescope time needed. Rectifying this omission was made possible by the allocation of the La Palma International Time to the EXPORT project. This contribution discusses the optical photo-polarimetric and near-infrared (NIR) photometric data acquisition, details of the spectroscopic effort are found in Mora et al (these proceedings).

The use of these data is twofold. In the first place, the data can be used to flux calibrate the spectroscopic data. This enables both changes in emission line equivalent width and energy output to be traced. Secondly, combined polarimetry and photometry can reveal a great deal about the geometry of the circumstellar material. Stellar light that is scattered off circumstellar dust grains will result in the light being polarized. In the case of spherically symmetric shells, or face-on circular disks, no net polarization will be observed as all polarization vectors cancel each other out. On the other hand, in the case of a deviation from circular symmetry on the sky, a net polarization will be observed (see also Grinin, these proceedings). However it is hard to decide, based on single epoch polarimetry, whether a polarized object has a disk-like dust configuration. This is because the separation between interstellar and circumstellar polarization is not trivial. A comparison with the so-called Serkowski law, which describes the normal behaviour of interstellar polarization has to be done, but this method is not always conclusive. Multi-epoch polarimetry can resolve this question quite straightforwardly. Any variations in polarization must be due to circumstellar effects, because interstellar dust clouds are not expected to vary within the epochs under consideration.

Polarimetric variability has been observed in several intermediate mass PMS stars, and is commonly referred to as the 'UX Ori' phenomenon (Grinin et al 1994). As an aside, the fact that the dust-polarization of the UXOR's is variable, implies that the stars are surrounded by flattened dust structures. Interestingly, this could have settled the question whether the intermediate mass Herbig Ae/Be PMS objects are surrounded by disks or not, long ago. Instead a long debate over this issue has ensued (see e.g. Pezzuto et al 1997, Oudmaijer & Drew 1999 for overviews).

2. Observations and data reduction

The optical data were obtained using the TurPol photo-polarimeter mounted on the 2.5m Nordic Optical Telescope (NOT), La Palma, Spain. This instrument observes the light through a diaphragm, then, using a beam-splitter, the *UBVRI* photons are recorded simultaneously on photo-multipliers. Approximately 50% of the 16 observing nights, during 4 epochs in May, July & October 1998 and January 1999, were photometric. Almost 70 targets were observed altogether, most of the objects more than 4 times in 2 epochs. The target acquisition was guided by the progress of the INT spectroscopy to ensure near-simultaneity. The photometry is accurate to within 0.03 mag, an error which is dominated by systematic effects rather than photon shot noise, as on average millions of photons were recorded to reach an accuracy of 0.05 - 0.10 % in V band polarization.

The NIR photometry was obtained during the same observing epochs as the NOT observations. In the May and October runs a NIR photometer was used, while in July and January a NIR camera was used. 60 objects were observed during 13 nights which were at least partly photometric. The resulting accuracies were about 0.05 mag.

3. Results

3.1. Near-infrared photometry

Of the 60 objects that were observed, 42 were PMS stars, massive Herbig Ae/Be stars and intermediate mass T Tau stars. The remainder were stars beyond that phase: A-B type main-sequence, (Vega-type) objects and naked post-T Tau stars. The major results are discussed in a poster (see Eiroa, these proceedings). Analysis of this data-set is still in progress, but the global characteristics of the sample can be summarized as follows: The majority of the 'evolved' objects do not show evidence for circumstellar (hot) dust in the NIR bands, their spectral energy distributions up to 2 μm are still photospheric. In contrast, the majority of the PMS objects show excess emission, due to hot dust. Half of these latter objects are photometrically variable.

3.2. Optical photo-polarimetry

The main global property that we discuss here is the presence of polarimetric variability - which confirms the presence of a flattened structure around the objects. The presence of variability was investigated in the data using relatively simple statistical methods. The main result for the more than 15 Vega-type objects is that these systems are hardly polarized at all, and are not variable to within the errorbars.

The 15 objects that were classified as UXOR's all showed significant variability, both on short (days) and long (months) timescales. This was not necessarily unexpected as UXOR's by definition show this type of variability.

Interestingly, around half of the remaining Herbig Ae/Be stars do show variability, albeit of mostly lower amplitudes. In most cases, the polarimetry is anti-correlated with the photometry: the objects show larger polarization when they are fainter. This is generally interpreted in terms of a-spherically distributed dust clouds orbiting the star. These give rise to more extinction in the line-of-sight, while the scattered light will not be blocked. This results in an increase of its relative contribution to the total observed light, giving rise to larger polarization (e.g. Grinin et al 1994).

Arguably, the distinction between 'UXORs' (Herbig Ae/Be stars showing large variations in photometry and polarization) and Herbig Ae/Be stars becomes less pronounced based on results like these. Indeed, this large data-set indicates that the majority of the observed Herbig Ae/Be stars show evidence for non-spherical envelopes. Although there may have been a certain personal bias in the selection of the targets, it should be noted that most of the observable (northern) known Herbig Ae/Be stars have been observed in this project. Considering that the number of Herbig Ae/Be stars only number about one hundred (Thé et al 1994), we speculate at this point that perhaps *all* massive PMS objects have a-spherical structures. This is in line with the random orientations of any disks in the line of sight. If the disks are circular, then those disks oriented face-on would not show any polarization/polarization variability. Inclined disks would give detectable polarizations. Of course, we need to analyze the data further, but such a conclusion, albeit tentative, illustrates the importance of observing a large sample of PMS stars to be able to reach general conclusions on the properties of this evasive class of object.

References

Grinin V.P. et al 1994, A&A 292, 165
Oudmaijer R.D. & Drew J.E. 1999, MNRAS 305, 166
Pezzuto S. et al 1997, ApJ 485, 290
Thé et al 1994, A&AS 104, 315