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Large Scale Variability Surveys from Venezuela: Orion OB1 and beyond

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Abstract. We present our scheme and initial results for variability surveys spanning hundreds of square degrees near the celestial equator, carried out with an 8k x 8k CCD Mosaic Camera optimized for drift-scanning, installed on the 1m Schmidt telescope at the Venezuela National Astronomical Observatory. In the Orion OB1 association, one of the nearest and most active regions of star formation, we are conducting a 120 sqr.deg. VRIHα survey to map the low mass young stellar population in this region. The absence of dust and gas around the young stars in the $\sim$ 10 Myr Ori OB 1a sub-association suggests that star formation is a rapid process, and that molecular clouds do not last more than a few million years after the first stars are born. The lack of accretion indicators or near IR emission from inner dusty disks among stars in Ori OB 1a suggests that significant disk dissipation has occurred in a few Myr, possibly due to the coagulation/agglomeration of dust particles into larger bodies like planetesimals or planets. The results of our variability surveys will be made available through a massive database equipped with web-based data mining tools, as part of the effort leading to the International Virtual Observatory.

Key words. Stars: formation – Stars: low-mass – Stars: oscillations

1. Introduction

In recent years variability has been recognized as a powerful tool to investigate a wide range of astrophysical phenomena. The study of the initial stages in the evolution of stellar and planetary systems is one of the areas in which new horizons are being revealed through the use of variability as a tool to search for young stellar populations in the Galaxy.

Our understanding of the formation of low-mass stars and planets has undergone major advances during the last decade. Dusty disks surrounding young stars, in addition to the burgeoning number of extra solar planets indicate that protoplanetary disks are a common outcome of the star formation process. Evidence is also accumulating in support of a picture of star formation as a rapid process (Hartmann 2001; Briceño

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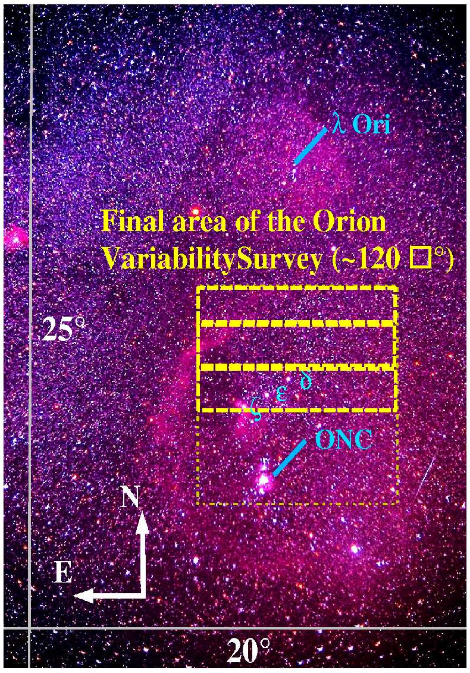

Fig. 1. Image of Orion showing the total survey area of 120 sqr.deg. (large dashed-lined box). The first strip, passing over the three Orion belt stars is indicated by thick dashed lines. Two additional strips covering the northern part of our survey have also been completed, for a total of $\sim$ 80 sqr.deg. The Orion Nebula Cluster (ONC) and the bubble around the star λ Orionis are clearly seen.

et al. 2001). However, despite significant progress, little is known about star/planet formation in the vast areas spanned by nearby OB associations like Orion OB1, were thousands of young ($\lesssim$ 15 Myr), low-mass ($\lesssim 1\ M_\odot$) stars are expected to exist but remain undetected yet. Existing optical/IR studies have concentrated mostly on small regions such as the Orion Nebula Cluster (ONC; e.g., Hillenbrand 1997) and the surroundings of the star σ Ori (Walter et al. 1998); a few large scale studies (Wiramihardja et al. 1991; Alcalá et al. 1996) have been done but did not find the more spread out, slightly older lower mass young stars. Only by identifying and studying somewhat older ($\sim$ 10 Myr), low-mass stars in widely spread stellar populations, can we address fundamental questions like the time scale for the coagulation of dust grains into into larger bodies such as planets, and the lifetimes of molecular clouds. But older stellar populations are difficult to find because they are widely spread on the sky; their natal dark, dusty molecular clouds have dispersed and so no longer serve as markers of their positions.

In order to find, map and study populations of young, low mass stars spanning a range of ages and environments, we are carrying out a long-term optical variability survey over $\sim$ 120 sqr.deg. in the Orion OB1 Association ($d \sim 400$ pc). Young, low mass stars have long been known to vary their brightness by up to a few magnitudes (e.g. Herbst 1986). However, only now has variability been used as a technique to pick out these objects among field stars. The survey area (Fig.1) includes young regions of star formation like the Orion Nebula Cluster (ONC; $\lesssim$ 1 Myr), the Ori 1b sub-association (the Orion Belt region, $\sim$ 2 Myr; Warren & Hesser [1977]; Brown et al. [1994]), and older regions devoid of molecular gas like the Ori 1a sub-association ($\sim$ 11 Myr old).

2. The Variability Survey

The large scale, VRIHα, multi-epoch survey is being carried out using an 8000×8000 pixel CCD Mosaic Camera (Baltay et al. 2002) installed on the 1.0/1.5m Schmidt telescope at The National Astronomical Observatory of Venezuela at Llano del Hato, in the Venezuelan Andes (8°47′ N, 3610 m elevation). The 16 2048×2048 UV-enhanced, front illuminated, Loral CCD chips are set in a 4x4 array, yielding a scale of 1.02" per pixel and a field of view of $2.3° \times 2.3°$. The camera is optimized for drift-scanning in the range $-6° \leq \delta \leq +6°$. This procedure generates a continuous strip (or "scan") of the sky, 2.3° wide;

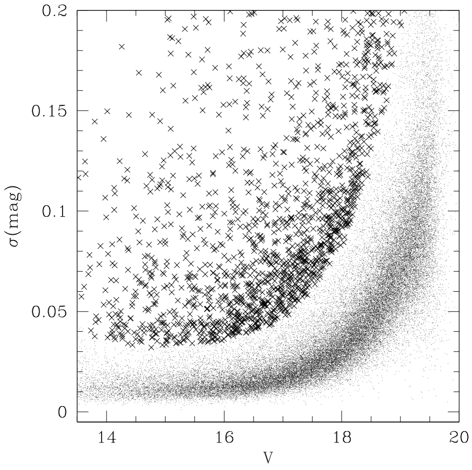

Fig. 2. The 1 σ dispersion in the magnitudes in a dataset of 16 scans over the Orion region. Crosses indicate stars selected as variable using our χ^2 test. Most stars ($\gtrsim$ 96%) are non-variable (dots).

conversely, one can survey the sky at a rate of 34.5 $sqr.deg./hr/filter$, down to $V_{lim} = 19.7$ ($S/N = 10$). The raw images are processed with a specially developed automated software pipeline (Baltay et al. 2002) that produces object catalogs containing IDs, accurate positions ($\pm 0.2''$), and instrumental magnitudes.

We have developed tools for identifying variable stars using differential photometry. With a χ^2 test and assuming a Gaussian distribution for the errors, we consider variable only those objects for which the probability that the observed distribution is a result of the random errors is $< 0.01\%$. The minimum amplitude we can detect at a 99.99% confidence level is $\Delta V \sim 0.07$ magnitudes at $V \sim 16$ and $\Delta V \sim 0.4$ magnitudes at $V \sim 19$. The value of variability for picking out young stars is shown in Fig.3. Follow up spectra of a large number of candidate young stars indicate that our selection technique is very efficient: roughly 50-60% of our candidates turn out to be young, low mass stars.

3. Results in Orion

There is a clear correlation between the spatial distribution of the newly identified young stars and their ages, in the sense that the younger stars concentrate towards the OB 1b sub-association, an area where significant amounts of gas and dust are still present (Fig.1). In contrast, the older (~ 10 Myr) stars are spread over a much wider area in the Ori OB 1a region, mostly devoid of gas and dust. This suggests that molecular clouds dissipate within only a few Myr after the first stars form. We have extracted JHK_s magnitudes for each star from the 2MASS database. We find that the stars that exhibit near IR excesses are located only in the Ori OB 1b area, whereas stars in Ori OB 1a show no near IR excess emission. This implies that the inner disks surrounding young stars dissipate in less than 10 Myr, either through accretion of material onto the central star or by coagulation/agglomeration onto larger bodies like planetesimals and planets, a result that places important constraints on theories of planet formation (see Briceño et al. 2001 for details).

4. The Equatorial Variability Survey

The exciting results in Orion, and those presented in this same conference by A.K. Vivas, have prompted us to initiate a Variability Survey near the Celestial Equator. We have now accumulated 3 years of data for a strip centered at $\delta = -1^o$, covering almost all RA around the sky. Presently we are scanning a new strip centered at $\delta = -3^o$, which we plan to observe repeatedly during the next 2 yrs. The temporal sampling is dictated by the number of nights available for our project, usually 8-10 nights/month, and the weather. Using the YALO telescope we have obtained data of selected fields located along our survey strips, in order to perform the photometric calibration of the data.

In collaboration with E.A. Ponsot, a Systems Engineer with ample expertise in

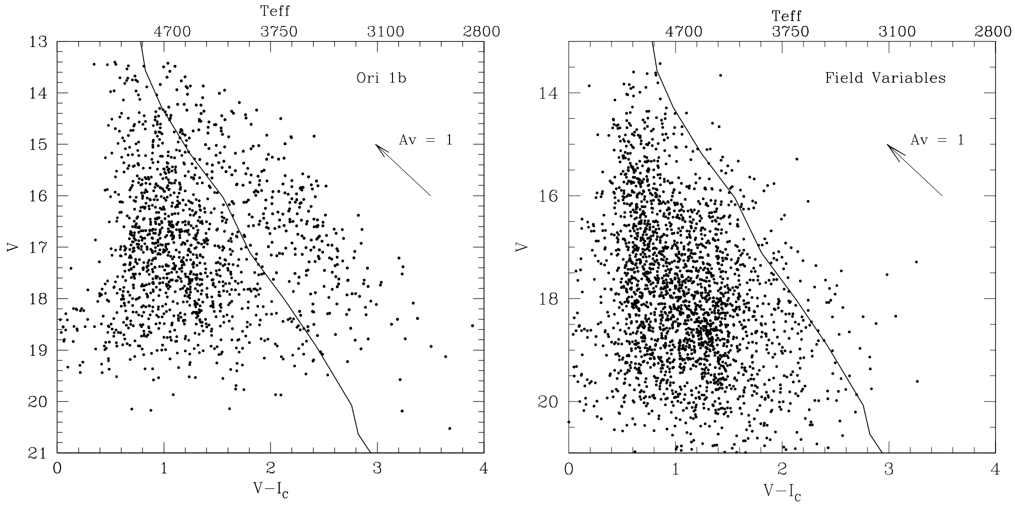

Fig. 3. V vs. (V-I) diagram for different samples. Left panel: all **variables** in Ori 1b; Right panel: all variables in a control field off Orion. Solid line: ZAMS. Pre-main sequence variables are clearly separated from the background. They do not show in the control fields, stressing the value of variability over photometry alone to pick up pre-main sequence candidates.

databases at Universidad de los Andes, Mérida, Venezuela, we are developing a variability database from the data collected in our surveys, together with web-based tools to mine the data. We have obtained a grant from the Fondo Nacional para la Ciencia y la Tecnología (FONACYT) of Venezuela, to fund the database, the hardware, and the software development efforts. We have now a dedicated multi-processor server with large disk space to process the data and host the database, and expect to release an initial version of the database to the astronomical community by the end of 2003.

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