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OPTIMUM Hα FILTER COMBINATION FOR PMS STAR SELECTION

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ABSTRACT

We have obtained photometry of stars in NGC 2264 with several combinations of Hα filters and continuum filters. The main purpose of these observations was to determine the best filter combination for selecting low mass member stars in their Pre-Main Sequence (PMS) stage using Hα photometry. A narrow band Hα filter ($\Delta\lambda = 10\AA$) with any combination of continuum filters showed the highest resolution in the Hα photometry.

Key Words : Technique - Photometry, Hα Photometry - PMS stars

I. INTRODUCTION

Assigning membership of low mass PMS stars in young open clusters is of crucial importance in gaining an understanding of star formation processes and stellar formation history (Herbst & Miller 1982; Adams *et al.* 1983). Most earlier works on young open clusters were restricted to the massive stars in the clusters due to the lack of a reliable membership criterion for the low mass stars in the PMS stage (more specifically in the T Tauri stage). Recently Sung et al. (1997, 1998, hereafter SBL1 and SBL2) performed the $UBVRI$ and Hα photometry of two young open clusters (NGC 2264 and NGC 6231) and successfully selected the low mass PMS stars in the ($R-$ Hα) vs ($V-I$) or ($R-$ Hα) vs Johnson Q plane. From their membership criterion for low mass PMS stars, they concluded that low mass star formation was dominant in NGC 2264 (SBL1). On the other hand, SBL2 found only 19 PMS stars and PMS candidates with Hα emission in NGC 6231 and concluded that the formation of low mass stars has been suppressed in the cluster.

In SBL1, they had no definite physical grounds for setting the discriminating level between PMS and normal MS stars. They tentatively selected PMS members with Δ (R - Hα) = $7\sigma_{H\alpha,MS}$ (= $0.^{m}21$), where $\sigma_{H\alpha,MS}$ is the intrinsic scatter of MS stars in ($R-$ Hα) at given ($V-I$) and assigned as PMS candidates those stars with half that level. Later spectroscopic observation of several very weak Hα stars, i.e. stars with small Δ($R-$ Hα) that were not included in the member star list, revealed that these weak line stars also showed weak Hα emission features. This means that the filter combination (standard R filter and medium bandwidth Hα filter with $\Delta\lambda = 55\AA$) used at the Siding Spring Observatory (SSO) was inadequate for the detection of weak Hα emission stars. And it also implies that many weak Hα emission stars could be missed in the membership selection procedure.

The main purpose of this work is to determine the best filter combination for detecting stars with Hα emission by comparing the relative resolution of several filter combinations from images obtained at the Bohyunsan Optical Astronomy Observatory (BOAO) using two Hα filters and two continuum filters. In section II, we will describe the observation and reduction procedures. A simple comparison from the observations will be presented in section III and section IV is the conclusion.

II. OBSERVATIONS AND RESULTS

The observations were made with the 1.8m telescope at the BOAO on 1998, Feb., 16. The seeing was about $1.''6$. The observed area is part of the active star forming region of the young open cluster NGC 2264 ($\alpha = 6^h40^m46^s, \delta = 9°47.'7$, J2000). The filters used in the observations were V, I, two Hα, and two continuum filters. The central wavelengths and the bandwidths of Hα and continuum filters are listed in Table 1. Two sets of exposure times were used in the observation and were listed in Table 1.

The pre-processing including bias subtraction and flat fielding was performed using the NOAO IRAF / CCDRED package. Instrumental magnitudes were obtained using the IRAF version DAOPHOT II (Stetson 1994). The instrumental i and v magnitudes were transformed to the standard V magnitudes and $V-I$ colors using the data in SBL1. Only the zero point differences due to the atmospheric extinction were corrected for the Hα and continuum filters.

Several ($V-I$) vs ($C-$ Hα) diagrams are shown in Fig. 1. We can easily see many Hα emission stars as well as normal MS stars in the diagrams. Each diagram was drawn to the same scale in order to compare the relative resolution of each case. We can see that a narrow band Hα filter with any combination of continuum filters shows better resolution. The scatter of normal MS stars in Fig. 1 (a) & (c) is smaller than that in Fig. 1 (b) & (d).

In Fig. 2 we compare our present result with the previous study by SBL1. The combination of continuum filter and narrow band Hα filter shows about twice

Hα PHOTOMETRY

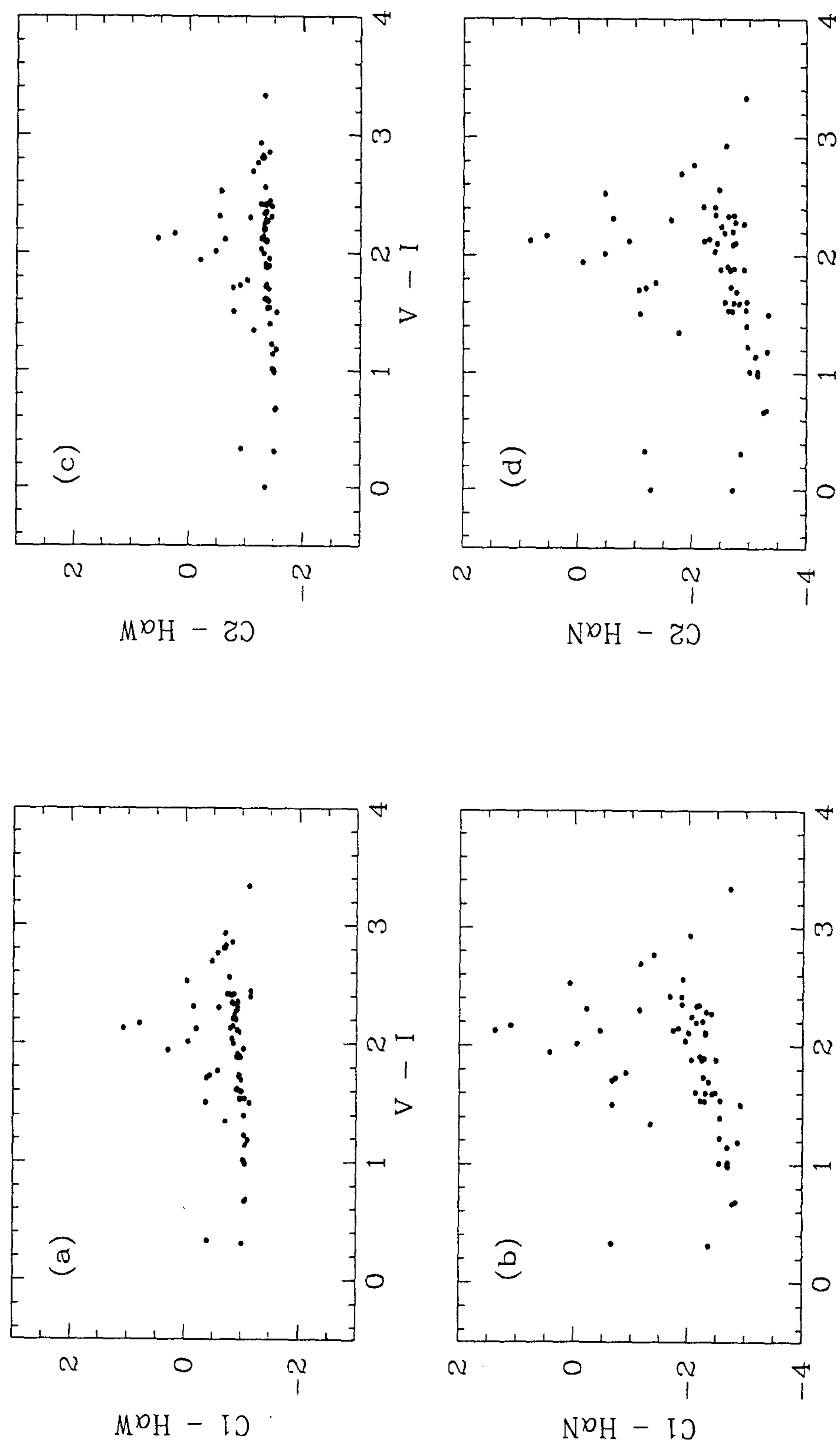

Fig. 1.— (C − HαN) vs (V-I) diagram. All the diagrams are drawan to the same scale.

Table 1. Filter Specification and Exposure Time

Filters	$\lambda_0(\AA)$	$\Delta\lambda(\AA)$	Exposure Time (short)	Exposure Time (long)
V	-	-	$5^s \times 2$	$120^s \times 2$
I	-	-	$5^s \times 2$	$60^s \times 2$
HαN	6563	10	$60^s \times 2$	$1800^s \times 2$
HαW	6570	80	$30^s \times 2$	$600^s \times 2$
C1	6650	80	$10^s \times 2$	$600^s \times 2$
C2	6450	100	$10^s \times 2$	$600^s \times 2$

the resolution of the broad band R and medium band Hα filters which were used in previous studies (SBL1, SBL2). On the other hand, the scatter in the presumed foreground MS stars also increased by about three times the standard deviation.

The $\Delta(C-$ H$\alpha)$ values of the identified stars of each combination of filters against $\Delta(R-$ H$\alpha)$ are plotted in Fig. 3. A narrow band Hα filter with any combination of continuum filters shows about twice the resolution of the previous result, while a wider band Hα filter with any combination of continuum filters shows almost the same resolution as the previous result. A few stars with very weak Hα emission in the previous study by SBL1 showed somewhat stronger Hα emission in the present study. They also show a somewhat larger difference between the filter combinations. This fact implies that many of these PMS stars are variable in Hα emission strength.

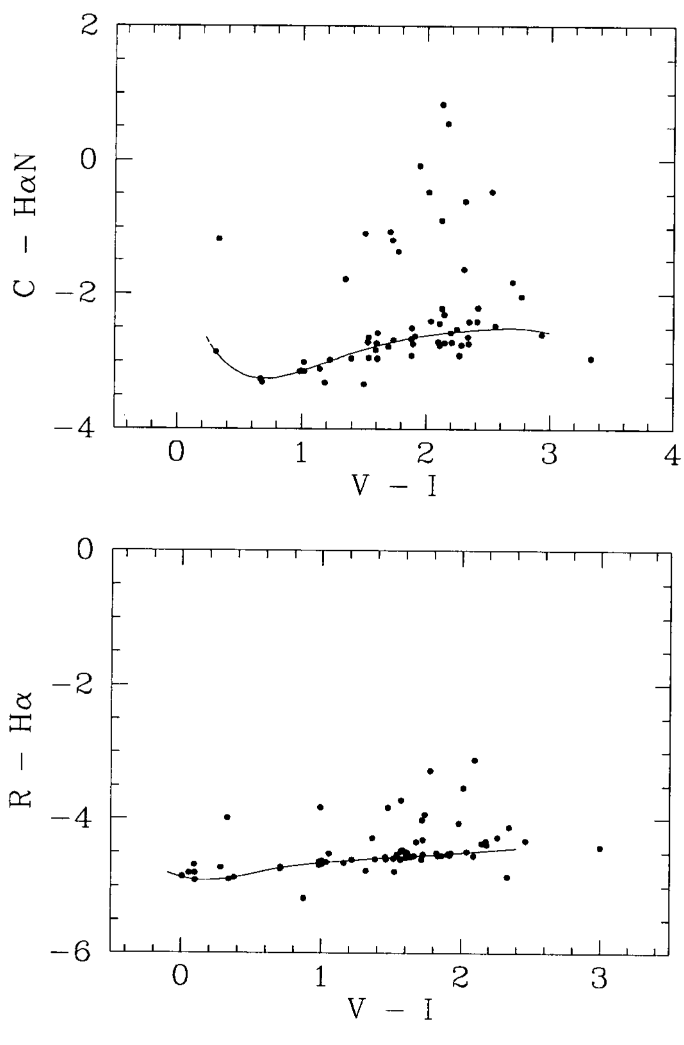

Fig. 2.— The comparison between the present narrow band and the previous broader band Hα measurements. the solid lines are normal relations for MS stars

III. DISCUSSION AND SUMMARY

In SBL1, having no definite physical grounds for setting the discrimination level between PMS stars and normal MS stars an arbitrary level was adopted. Later, spectroscopy revealed that some weak Hα emission stars were omitted in that membership selection. This means that the filter combination used at SSO was inadequate for the detection of weak Hα emission stars. To find more effective filter combination which can be used to detect weak Hα emission stars, we used four combinations of Hα filters (HαN, Hα W, C1, & C2).

In the comparison of each combination of filters, we conclude that a narrow band Hα filter ($\Delta\lambda = 10\AA$) with any combination of continuum filters shows the highest resolution (in absolute scale, i.e. $\Delta(C-$ H$\alpha)_{PMS}$) in the Hα photometry. These combinations of filters show about twice the resolution of R and the medium band Hα filter which was used in previous study (SBL1, SBL2). It seems that the scatter in the MS of ($C-$ HαN) is larger than that of ($R-$ Hα) (σ_{MS} are 0.15 and 0.05 respectively). However the increase in apparent scatter

of ($C-$ HαN) does not imply a degradation in the relative resolution ($\Delta(C-$ H$\alpha)_{PMS}$ / σ_{MS}) of Hα index

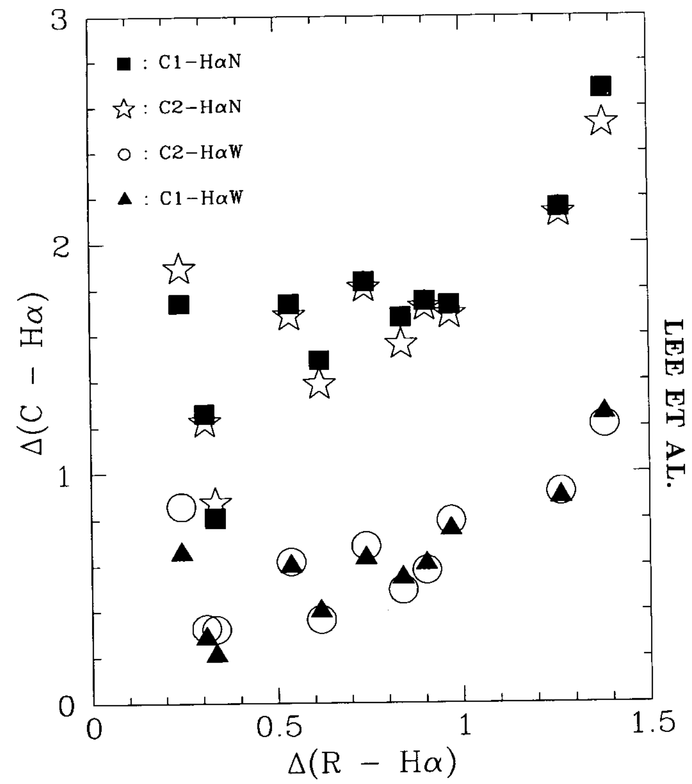

Fig. 3.— $\Delta(C - H\alpha)$ vs $\Delta(R - H\alpha)$diagram for identified stars. $\Delta(C - H\alpha)$=(C - Hα)-(C - Hα)$_{MS}$, $\Delta(R - H\alpha)$=(R - Hα)-(R - Hα)$_{MS}$

because we cannot exclude the possibility that these small $\Delta(C-$ HαN) stars were weak-line T Tauri stars. The increased scatter of the MS stars with the narrow band filters could result from the narrow filter better resolving and thus measuring the Hα absorption line. The increased scatter is probably caused by the line filling in due to rotation or to incipient emission. The broad filter cannot see this as well. Rotation does not change the strength of the line but its shape. The narrow Hα filter sees a shallow line, whereas the wide Hα filter sees most of the line and much less of a change. HαN and continuum observations of normal (non-emission) MS stars are very important and should be performed in the near future.

In addition, most young open clusters and OB associations are heavily obscured by dust in the cloud from which they were formed. The member stars suffer a large amount of differential reddening. Better resolution in the absolute scale of the emission gives better results, especially in the membership selection of low-mass PMS stars in the star forming regions.

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