Identifying T Tauri Stars using Small Scale Optical Telescopes

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Abstract

Understanding T Tauri stars is essential if we are to more fully understand our own Solar System. Because T Tauri stars are young versions of our Sun, we can better understand our own history by studying these young stellar objects (YSOs). Hα Survey Method to Recognize T Tauri Stars (HαSMRTS), previously known as the Spuck-Butchart-Optical Survey Method, is a simplified method of identifying T Tauri stars using small-scale optical telescopes. However, to date the method has only been used in an attempt to distinguish T Tauri stars from standard stars. Active Galactic Nuclei (AGN) and active M dwarf (dMe) stars emit excess in both infrared and Hα, similar to T Tauri stars, making it likely that objects such as these may contaminate any T Tauri selection method based on infrared and Hα. This study uses observations from the Kitt Peak National Observatory 0.9 meter telescope to further investigate HαSMRTS and its true ability to accurately distinguish T Tauri stars from other objects in space. Contamination by dMe stars is significant; however, a statistical analysis using Precision and Recall indicates a peak accuracy of 90.8% with a Matthews correlation coefficient of +0.74. These results indicate HαSMRTS shows great promise for both professional and amateur astronomers in identifying YSOs, and perhaps could one day lead to a fast and inexpensive all-sky survey and T Tauri star monitoring program.

Introduction

HαSMRTS– (*Butchart 2009*)

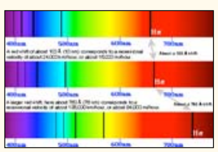
•Successful in distinguishing T Tauri stars from standard stars using simple ratios of Hα, R and I intensity counts

•Based on information that T Tauri stars have significant H-alpha emission

•Target selection could have been improved

•Neither dMe stars nor AGN were included in the study

Both dMe's and AGN have characteristics similar to those of the T Tarui stars which makes significant contamination probable.



Top Figure: This graphic demonstrates how the Hα line will shift as the recessional velocity of the object increases. (image from Red Orbit, 2002)

T Tauri stars – Characteristics

• Young sun like star in the early stages of development
• Large accretion disks
• Bipolar outflow caused by material falling onto the star from the disk
• →Strong Hα emission line
• G, K, or M class star
• →Greater emission at longer λ

Hypothesis

★ Even though dMe stars display a Hα line, these emissions should be significantly stronger in the T Tauri stars as compared to dMe stars.

★ Further, AGN should be distinguishable from T Tauri stars based on their significant cosmological redshift. The Hα line in AGN should be shifted out of the range of the narrowband Hα filter used on the 0.9 meter telescope.

Procedures

★ Targets including AGN, dMe stars, T Tauri stars and standard stars were selected from various publications
★ R exposure time was based on published R or V magnitudes
★ I exposure time was 2 x $R_{exp\ time}$, H-alpha exposure was 10 x $R_{exp\ time}$
★ January 30 through February 2, 2010 observing run
★ Equipment used: WIYN 0.9 M Telescope at KPNO in Tucson, Arizona
★ Used the I-Harris, R-Harris and H-alpha filters
★ Data reduction was completed with MaxIm DL and Pinpoint Astrometry
★ Used the aperture tool in MaxIm DL to measure R, I, and Hα Intensity values
★ Scatter plots were generated in MS Excel
★ Statistical analysis was conducted using Precision and Recall methodology
★ Test image sets were selected and analyzed using the HαSMRTS

Above: View from KPNO 0.9 M Telescope where data was collected for this study.

R filter **I filter** **Hα filter**

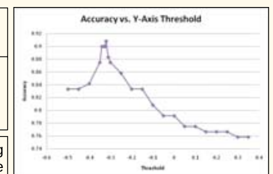
Above: The image displays the aperture tool in MaxIm DL, and the photometry measurements for dMe star *HIP 61413* in the R, I and Hα filters.

$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{((TP+FP)(TP+FN)(TN+FP)(TN+FN))}}$$

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$$

TP – true positive
TN – true negative
FP – false positive
FN – false negative

Above: A statistical analysis was conducted using Precision and Recall methodology to determine Accuracy. Targets are classified as a **true positive (TP) - a confirmed T Tauri star that falls within a set of parameters**, a true negative (TN) - a confirmed non-T Tauri object (e.g. AGN, standard star, dMe star) that falls outside the set of parameters, a false negative (FN) - a confirmed T Tauri star that falls outside the set of parameters, or a false positive (FP) - a confirmed non-T Tauri object (e.g. AGN, standard star, dMe star) that falls inside the set of parameters. The Matthews-correlation coefficient (MCC) is an indicator of prediction capability.

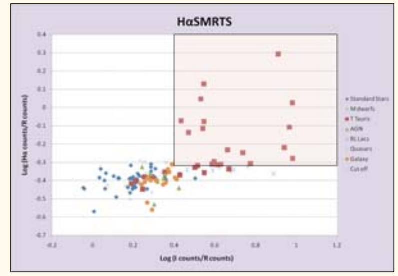


Above: Calculating the accuracy for different threshold values determined the thresholds. An Accuracy vs. X-Axis plot was the basis for holding the x-axis (Log (I counts/R counts)) threshold at 0.4. The accuracy vs. Y-axis Threshold plot above displays a maximum accuracy of 90.8% at a the Y-axis threshold (Log (H counts/ R counts) of -0.32. For this threshold the MCC is 0.74, which emphasizes that the HαSMRTS can be used as a relatively accurate predictor in identifying T Tauri stars.

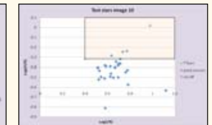
Results

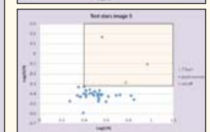
ID	Type	R Intensity counts	I Intensity counts	Hα Intensity counts	Log (I/R)	(Log H/R)
3C 120	AGN	7503	14342	3246	0.281	-0.364
IRAS 04210+0400	AGN	1922	3364	908	0.243	-0.325
MCG +08.15.009	AGN	2223	4961	909	0.349	-0.388

Above: The table was generated in Microsoft Excel and displays a small sample of objects observed in this study and their corresponding intensities in R, I and Hα and the calculated Log ratio values.



Above: The X-Y scatter plot of Log(I-intensity/R-intensity) vs. Log(H-alpha-intensity/R-intensity) displays all targets in the current study including dMe stars, AGN, BL Lacs, Quasars, Galaxies, standard stars and T Tauri stars as well as those standard stars and T Tauri stars from the Butchart study (2009). There is significant contamination from dMe stars, however, at a cut-off of Log(H/R) > -0.32 and Log(I/R) > 0.4, 65.5% of previously known T Tauri stars would have been correctly identified using this method.

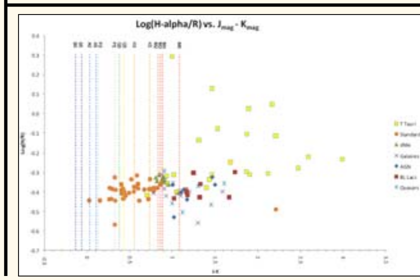




Above: Testing HαSMRTS - Four random test image sets with known T Tauri stars were selected. Point sources were identified by visual inspection of the Hα image. Corresponding targets in the I and R images were measured and data plotted. 93% of known YSO's in the test images were correctly identified.

Conclusions

Based on the evidence in this study, 65.5% of T Tauri stars can be identified using the HαSMRTS with an Accuracy of 90.8%. The Matthews-correlation coefficient of 0.74 indicates a strong correlation between this method and its ability to correctly identify T Tauri candidates. Although there is no single method that can conclusively identify all T Tauri stars, there is strong evidence that supports using the HαSMRTS as a cost-effective tool to initially identify T Tauri star candidates. Observations using additional instrumentation and long-term monitoring programs by the professional and amateur communities could follow to confirm/refute the YSO status of objects discovered using this method.



Future Studies

★ **Left and Right:** Even without the 2MASS data the method works. However J,H,and K data may help to distinguish T Tauri stars from dMe stars, as will the WISE catalogue when available.

★ The INT/WFC Photometric Hα Survey (IPHAS) of the northern Galactic plane has identified 4853 point sources that exhibit strong photometric evidence for Hα emission. This may be a source of data to compare our results to. (Witham et al – 2008)

★ Considering the fact that T Tauri stars have a significantly stronger Ca II line in emission, the contamination of dMe stars may be able to be mitigated by taking a simple ratio of intensities using Ca II and U band filters. Additional observational evidence in Ca II and U is required.