Title: Star Formation Studies with the Sloan Digital Sky Survey

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Abstract. The determination of timescales associated with planetary formation and circumstellar disk evolution requires large samples of stars having diverse environments and ages. Such a sample can be obtained using the Sloan Digital Sky Survey (York et al. 2000) as it is systematically mapping one-quarter of the entire sky providing photometric data on over 100 million objects in five passbands (Gunn et al. 1998, Fukugita et al. 1996).

Pre main sequence stars have distinct colors in the SDSS u'g'r'i'z' photometric system as a consequence of their late-type photospheres and strong UV excess driven by the magnetospheric accretion shock. SDSS observations of known Orion population emission line stars cataloged by the Kiso objective prism survey reveal a color-based signature that correlates well with the Hα emission line strength.

As the excess emission is a direct consequence of the presence of a circumstellar disk we can constraint the duration of the planetary formation process by determining the age of the young star. Follow-on observations of SDSS T Tauri candidates have begun at the Astrophysical Research Consortium's 3.5 meter telescope using medium resolution (R = 5000) spectroscopy. The aim is to place these objects on theoretical evolutionary tracks using spectral indicators for effective temperature and surface gravity and to create a catalog for future studies including a circumstellar disk census.

1. Introduction

The SDSS complements the ROSAT All-Sky Survey (RASS) in its ability to detect actively accreting young stars. While the SDSS T Tauri survey will also include chromospherically active low-mass stars, it can detect Classical T Tauris at 6 magnitudes fainter than the corresponding RASS limit. A recent analysis of RASS observations in the Tucanae association by Stelzer & Neuhauser (2000) shows the RASS sensitivity limit at 45 parsecs is $2 \times 10^{28}$ erg/s. This places the detection limit for analogs of TW Hydrae, the canonical isolated Classical T Tauri ($M_V = 7.3, L_x = 11.5 \times 10^{29}$ erg/s), at 340 parsecs, or $V = 15$. 
2. Primary Selection

The Wiramihardja et al. (1989) objective prism survey of stars located in the Orion complex provides the estimated Hα emission strength on a numerical scale between 1 (very weak) and 5 (very strong). We examined the correlation of this index with the stellar locus parameters of Fan (1999) and defined \( e = 0.33 \times c_1 - 0.94 \times c_3 \).

The coefficients for \( c_1 \) and \( c_3 \) were chosen to have a unit basis vector, and to produce a parameter that was reddening independent under \( [A_u, A_g, A_r, A_i, A_z] = [1.87, 1.38, 1, 0.76, 0.54] \times A_r \). This latter point was important for target selection since the stellar locus would otherwise move into the search space in regions known to have \( A_V \) of 1 to 2.

The strongly emitting stars were closer to the stellar locus in the r-i and i-z colors since these colors are the least affected by the veiling, or excess continuum. The resulting primary selection is \((r-i) > 0.3 \) AND \((i-z) > 0.25 \) AND \( e < -0.2 \). Orion population stars having weak Hα emission were indistinguishable from the stellar locus in all colors.

3. M dwarf/White dwarf Pairs

Examination of candidate SDSS spectra indicated that M dwarf/White dwarf binaries were a major source of contamination. Comparison with the Orion emission line stars and a sample of 39 spectrally identified M dwarf/White dwarf binaries showed that the g-r values for the Orion stars are generally higher (redder), since the T Tauri accretion signature peaks farther into the UV.

The secondary selection aimed at removing the white dwarf binaries is \((g-r) > 1.1 \) OR \((g-r) - 0.45 \times (u-g) > 0.7 \). This criterion errors on the conservative side, since we see overlap in the region near \((u-g, g-r) = (1.0, 0.6)\).

4. Characterization of Candidates

Spectroscopic examination of candidates are under way using the Astrophysical Research Consortium and Calar Alto 3.5 meter telescopes for characterization of the Balmer line emission generated by the accretion process, computation of the CaH and TiO spectral indices, and possible Lithium detection. These observations will allow verification of the accretion signature and placement of the T Tauris upon theoretical evolutionary tracks thus establishing a catalog of circumstellar disk presence as a function of age and spectral type.

The CaH and TiO spectral indices can be used to estimate the surface gravity of the young star. Using the Grenoble model server of Siess (2000) we see an increase of log \( g \) by 0.6 to 0.8 dex between the ages of 1 Myr to 10 Myr for low mass stars with the steepest rate of contraction occurring within the first 5 Myr. This provides a good match to the expected timescale for loss of the circumstellar accretion disk.

Early attempts using narrow band photometry (Mould & Wallis 1977) yielded qualitative results while recent approaches used in the star formation community rely upon echelle spectroscopy (Piorno Schiavon, Batalha, & Bar-
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buy 1995). We adopt the method of Kirkpatrick et al. (1991) for determination of the spectral indices.

The Li I absorption signature is a commonly used indicator for youth although the rate of depletion is dependent upon the core temperature, lifetime of the convective zone, and rotation speeds (Duncan & Rebull 1996).

Additional follow-on observations planned include spectroscopic study of fainter targets using 8 to 10 meter class facilities and detailed circumstellar disk surveys using multi-band IR photometry.

5. Summary

Study of SDSS photometric data reveal a color signature for young stars having moderate to very strong Hα emission. While there is some confusion with M dwarf/White dwarf pairs, the objects within this color space appear to be either pre main sequence stars or chromospherically active low mass stars.

References


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