T Tauri Stars in the Small Magellanic Cloud

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Abstract. The Small Magellanic Cloud (SMC) is an excellent laboratory to study the formation of solar-mass stars in a low-metallicity environment, similar to the conditions expected in the early phases of galactic evolution. Here we present preliminary results from a search for low-mass pre-main-sequence stars in the SMC based on Hubble Space Telescope archival data. Candidates are selected on the basis of their Hα emission and location in the [(F675W-F814W), F814W] color-magnitude diagram. We discuss characteristics of our candidate T Tauri sample and possible follow up work.

1. Introduction

Young stellar populations often provide the most luminous and prominent stars in galaxies. They trace the ongoing star formation (SF hereafter), and are closely related to its triggering mechanisms. Studies of young stars can help probe chemical enrichment processes of the Universe, and even find local analogs of high redshift systems.

Galactic SF studies take advantage of observations of individual pre-main-sequence (PMS) stars in nearby young clusters and associations. Unfortunately, only the most massive young stars can be observed in external galaxies; while these high-mass stars dominate the light from their host systems, they account for only a fraction of the mass and part of the chemical enrichment. The Magellanic Clouds are the sole exception, offering the possibility to study the formation and early evolution of the most-common low-mass stars at metallicities of only $\sim 1/5$ and $\sim 1/20$ of the solar abundance. The Small Magellanic Cloud (SMC) provides the closest local analog to the conditions in which bulk of the SF at high redshift took place.

Candidate low-mass PMS stars have been detected in the Large Magellanic Cloud (LMC) by Panagia et al. (2000), based on their Hα excess, in the region around Supernova 1987A. They used multi-color photometry to constrain the effective temperatures, to measure the IMF slope, and to study the spatial distribution of high- and low-mass PMS stars. Wichmann et al. (2001) reported the first spectroscopically confirmed extragalactic T Tauri star in the LMC. Their
sample for multi-object spectroscopy was chosen based on the near-infrared excess, and yielded one detection of Hα emission from 19 candidates. The low success rate is somewhat surprising since circumstellar disks are expected to show both infrared excess and accretion signatures in the form of Hα emission. Brandner et al. (2001) relied on the near-infrared excess alone to separate candidate young stars from the underlying populations in the 30 Doradus region of the LMC.

We have commenced a program to select T Tauri candidates in the SMC, in preparation for future spectroscopy. Here we discuss the selection technique, the sample for follow-up optical spectroscopy, and some preliminary results.

2. Field Selection and Data Reduction

The SMC was chosen as a primary target for this work because of its lower metallicity in comparison with the LMC. The relative proximity of the Magellanic Clouds allows us to resolve the stellar populations easily with the WFPC2 on the Hubble Space Telescope (HST). All stars are at roughly same distance, and the Galactic extinction is low (A_B = 0.17 mag; Burstein & Heiles 1982).

We searched the HST/WFPC2 archive for Hα images in the vicinity of clusters in the catalog of Bica & Dutra (2000), ensuring the presence of young stellar population in the fields. We selected the fields with total integration in Hα longer than 1000 sec, and with sufficiently long F675W and F814W exposures. The F675W observations are needed for proper continuum subtraction, and a second broad-band filter is used to construct a color-magnitude diagram (CMD).

A single SMC field near the open cluster Kron 57 (α=1:08:12, δ=−73:14:38, Eq. J2000) satisfies all our criteria. The data were obtained as part of a program to study the extended gas emission (P.I. Garnet, ID 8196). The total integration times (always split in three separate exposures) are 3000, 600, and 1200, in F656N, F675W, and F814W, respectively.

Aperturephotometry was performed on the median-combined images, and was calibrated following the prescription of Holtzman et al. (1995a, 1995b). This procedure is adequate since the field does not suffer from severe crowding.

3. Selection Criteria for PMS Candidates

The PMS candidates were selected on the basis of two criteria. The primary one was a reliable detection of Hα excess emission. We measured all sources in the F656N and F675W images, and obtained their magnitudes. Then, we imposed a condition for “strong” excess, following the example of Panagia et al. (2000): m(F675W) − m(F656N) ≥ 0.3 mag and both measurements are at least 4σ detections, where σ is the IRAF/APPHOT error, obtained with proper gain factors and readout noise for the corresponding WFPC2 chips. The limit above corresponds to Hα equivalent width of about 8 Å or larger (see Biretta 1996 for the HST/WFPC2 filter parameters). The spatial locations of the “strong” Hα emitters are shown in Figure 1 (left).

The secondary condition was the position of the candidates on the [(F675W−F814W), F814W] CMD. It eliminates from the sample bright Be stars with
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Figure 1. Stellar sample. All stars detected in F814W are indicated with small dots, and stars with 4σ Hα excess are solid dots. Left: Spatial distribution. The big circle on WF3 represents the position of Kron 57. Right: Color-magnitude diagram. For each chip are given: number of stars detected in Hα, number of stars with F675W-F814W, and number of stars with 4σ Hα excess.

$m(F656N) \sim 15 - 18$ mag (see also the discussion in Sec. 5 of Panagia et al. 2000). A few such Be stars were detected by Panagia et al. (2000), and we have one in our field, on WF2 (see Figure 1, right). The various sequences on the diagrams are somewhat blurred by the reddening variation and the mixture of stellar populations with different ages and metallicities. The CMD also allows us to exclude some RGB/AGB stars with emission due to extended envelopes and mass loss.

4. Discussion

We have measured a total of 4628 stars in F675W and F814W. Only 1179 of them were detected on the F656N image, and 263 of these passed the “strong” Hα emitter criterion discussed in the previous section. About 10% were classified as Be or RGB/AGB stars, or were excluded as outliers on the CMD, leaving us with ~240 PMS candidates. The “color-color” diagrams [(F675W-F814W),(F675W-F656N)] are shown in Figure 2 (left). The surface density of PMS candidates follows the overall distribution of stars in the field, with an increase toward the center of Kron 57.

The histograms of Hα equivalent width are shown in Figure 2 (right). They resemble closely those for the SN 1987A region (Panagia et al. 2000), and feature no significant differences between Kron 57 and the field, indicating that the latest generation of stars in the cluster and in the field may have formed approximately at the same time, and with a similar IMF. Indeed, the fraction of “strong” Hα emitters is constant within the uncertainties in all chips (5.4-5.9%±0.5% for the WFs; 6.8%±1.7% for the PC). However, this conclusion requires further verification with a larger sample and more colors. The Hα emission properties
of our SMC PMS candidates differ significantly from the Galactic sample (see Figure 5 in Panagia et al. 2000), as do the T Tauri candidates in the vicinity of SN 1987A in the LMC. Most probably, this is due to an age difference between young stars in the Magellanic Clouds and in the Milky Way.

The adopted selection criteria introduce a bias toward (actively accreting) “strong-line” T Tauri stars. This is an unfortunate consequence of the desire to improve the success rate for follow-up spectroscopy. An alternative alleviating this bias is to use the variability of T Tauri stars (Briceño et al. 2001) for candidate selection. It is a time consuming method but the microlensing surveys toward the Magellanic Clouds provide a useful data set (Lamers et al. 1999). Our final PMS sample can still be compared with the subset of Galactic “strong-line” T Tauri stars (e.g. from Briceño et al. 2001) if appropriate constraints are applied to the latter.

5. Results

1. Candidate PMS stars in the SMC are detected for the first time, based on their Hα excess.

2. The locus of selected candidates on the CMD is consistent with them being PMS stars.

3. The distribution of equivalent widths is consistent with that of Panagia et al. (2000) for the PMS candidates in the region around SN 1987A in the LMC. This distribution is different from that for Galactic strong-line T Tauri stars, suggesting a possible age difference.
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