RECENT STAR FORMATION IN THE LEADING ARM OF THE MAGELLANIC STREAM

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ABSTRACT

Strongly interacting galaxies undergo a short-lived but dramatic phase of evolution characterized by enhanced star formation, tidal tails, bridges and other morphological peculiarities. The nearest example of a pair of interacting galaxies is the Magellanic Clouds, whose dynamical interaction produced the Magellanic Stream, the Bridge and the Leading Arm (LA), giving witness to the recent interaction between the Clouds. However, the interaction of the Clouds with the Milky Way is less well understood. The LA must have a tidal origin, however no purely gravitational model is able to reproduce it well. A hydrodynamical interaction with the gaseous hot halo and disk of the Galaxy is supported by HI observations. Here we show for the first time that young, recently formed stars exist in the LA, indicating that the interaction between the Clouds and our Galaxy is strong enough to trigger star formation in certain regions of the LA.

INTRODUCTION

In a recent study, Casetti-Dinescu et al. (2012) listed 567 OB-type star candidates in a ~7900 deg^2 area encompassing the Magellanic system. The photometric and proper-motion selection was aimed at finding hot (earlier than B5) distant stars with motions consistent with membership in the Magellanic system. In the LA region, three stellar overdensities were found comprising a total of 45 candidates. Here, we have spectroscopically observed 42 of the 45 candidates. Their spatial distribution is shown in Figure 1. Also shown is the HI distribution from the GASS survey (McClure-Griffiths et al. 2009 ; Kalberla et al. 2010) for 150 km/s ≤ RV_{LSR} ≤ 400 km/s. We label the three candidate overdensities as A at $(\Lambda_M,B_M) \sim (15°,-22°)$, B at $(\Lambda_M,B_M) \sim (42°,-8°)$ and C at $(\Lambda_M,B_M) \sim (52°,28°)$. In what follows, we describe the spectroscopic observations and the results.

OBSERVATIONS

Intermediate-resolution spectra were obtained with the IMACS spectrograph on the 6.5m Baade telescope at Las Campanas Observatory. The 1200 l/mm grating at the f/4 camera was employed at first order, with a blaze angle of 17° and 0.75"-wide slit, for a resulting resolution of 1.3 Å in the range 3650 to 5230 Å. The resulting spectra signal-to-noise ratio was higher than 50 for all the targets.

Cross-correlation techniques (IRAF fxcor task), were used to measure heliocentric radial velocities (RVs). In absence of a prior knowledge of the exact temperature and gravity of the targets, the synthetic spectrum of a main-sequence B-type star was adopted as template. The final uncertainty, taking into account the relevant sources of errors, are estimated to be typically 5 km/s for most of the targets. The spectra are also fitted with standard routines to derive the temperature, gravity, surface helium abundance, and, in some cases, rotational velocity.

RESULTS

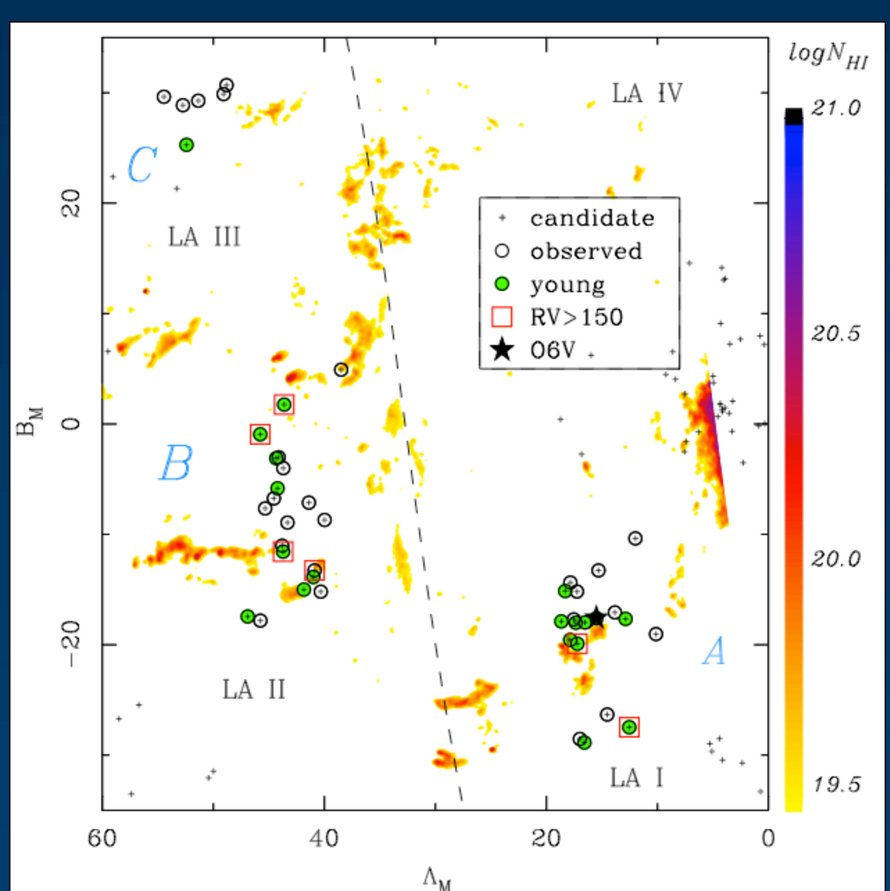

Figure 1. Spatial distribution in Magellanic coordinates of our OB candidates (crosses). The background color map shows the GASS HI density distribution for 150 km/s ≤ RV_{LSR} ≤ 400 km/s, with the main LA branches (Venzmer et al. 2012) indicated. The 42 OB candidates observed spectroscopically are shown with circles. Filled green symbols indicate the young stars, while symbols highlighted with red squares indicate stars with radial velocity RV>150 km/s. The black star symbol represents the most massive, young star in our sample (sp. type O6V). Our three regions of interest (A, B, and C) are also labeled. The dashed line represents the Galactic plane.

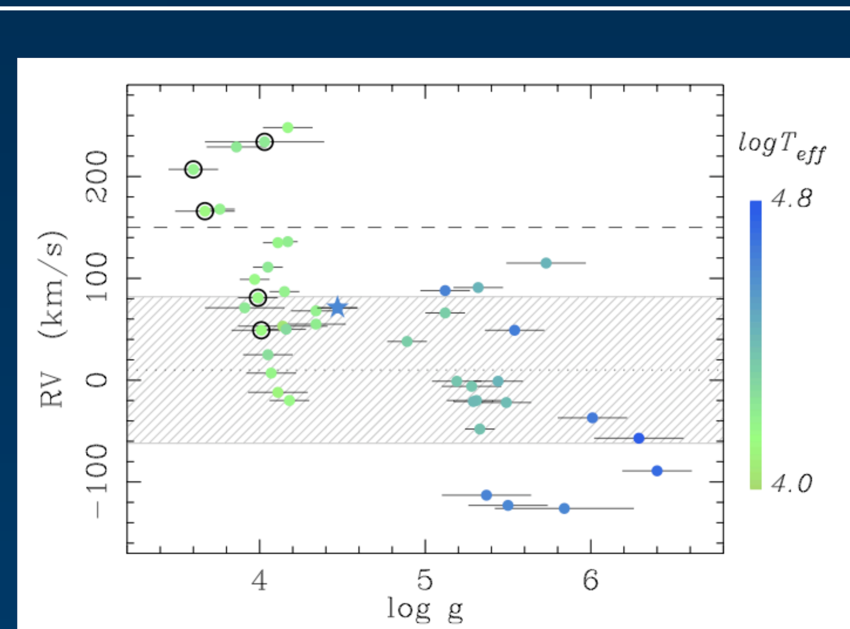

Figure 2. Heliocentric radial velocity as a function of surface gravity for 42 observed stars, color-coded by effective temperature. The mean and ±2σ standard deviations for the Galactic thin+thick disk (Robin et al. 2003) are indicated with a hatched area. The horizontal line at 150 km/s shows the limit for LA RV-member candidates. Fast rotators (v sin(i) > 100 km/s) are highlighted with a black circle. Note the group of six stars with velocities in excess of 150 km/s and log g smaller than ~4.2 dex. Five of these are classified as massive, young stars, and only one as an sdB, primarily on account of its low He abundance. Note also the hot, relatively low log g star at RV ~ 70 km/s (star symbol). This is the earliest spectral-type star found with this surface gravity, and thus is classified as O6V, a massive, young star located at ~40 kpc from the Sun.

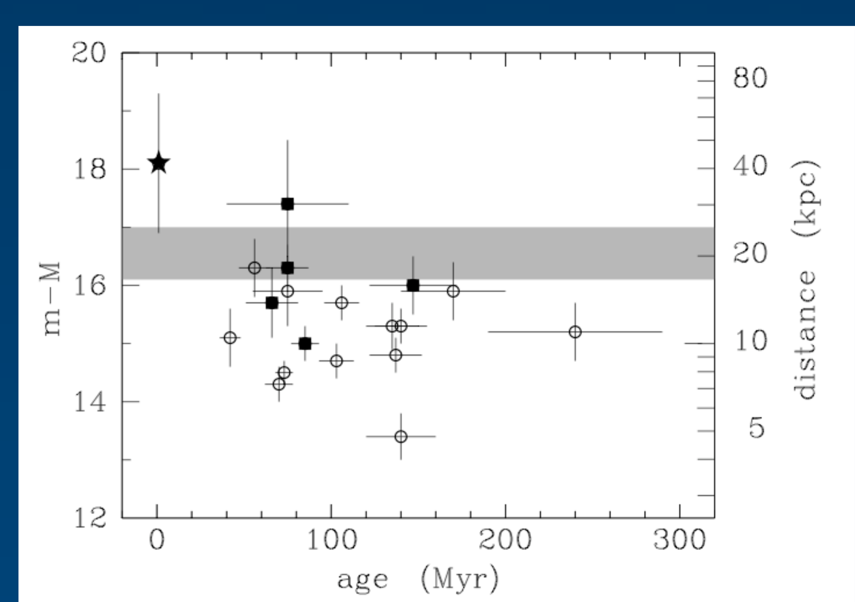

Figure 3. Distances and ages for the young stars. Distance moduli vs. ages are shown for our 19 massive, young stars. The stars with RV > 150 km s−1 are shown with filled squares. The star symbol indicates the O6V star. The gray band represents the kinematical distance of one high velocity cloud member of the LA (McClure-Griffiths et al. 2008); the width of the band corresponds to a 20% error in the distance.

CONCLUSIONS

Our observations establish that conditions were met for recent star formation in the LA material located in the outskirts of the Galactic disk (R ~18 kpc), most likely as a consequence of the interaction between the Galactic disk and portions of the LA. We note that the most distant HI structure associated with the MW disk is a spiral arm at R=18–24 kpc (McClure-Griffiths et al. 2004), while the stellar "edge" of the disk has R~ 14 kpc (e.g., Minniti et al. 2011).

Our findings cast new light on the interaction of the Clouds with the MW, perhaps making a first infall scenario less likely. Whether or not this is the case remains to be established by more complex models, and in light of the lower velocity of the Clouds as indicated by the Vieira et al. (2010), Costa et al. (2009), and Kallivayalil et al. (2013) studies.

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