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A cannonball star candidate in Canis Minor

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Abstract

We report on the identification of a cannonball star candidate toward the direction of Canis Minor. The star is called PSS 544-7 and it has been selected as a result of a search in SIMBAD at CDS. With uncorrected colors $B - V = 1.58 \pm 0.15$, $V - J = 2.66 \pm 0.14$, $V - K_S = 3.38 \pm 0.23$, $J - H = 0.675 \pm 0.167$, $H - K_S = 0.046 \pm 0.244$, $J - K_S = 0.721 \pm 0.219$, the object exhibits a significant proper motion, 401 ± 13 mas/yr. Based on the object's photometry, we conclude that it is likely a M-dwarf with an unusually high velocity perpendicular to the galactic disk. Its photometric parallax yields a distance estimate of 210 ± 60 pc, a tangential velocity of 399 ± 127 km/s and a W-component >350 km/s. If our interpretation is correct, given its location and kinematic signature, the object is a candidate cannonball star ejected by a star cluster.

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1. Introduction

Stars are not formed isolated but in some type of stellar ensemble or star cluster. Escape from a star cluster is mainly the result of three processes: the first one is the ejection of stars or stellar remnants after a supernova explosion in a binary or higher multiplicity star system, the second one is the ejection of stars after a single close encounter, and the third one is the more gradual process of evaporation. Stars can suffer many weak distant encounters which redistribute their energy according to a Gaussian velocity distribution with the less massive stars having the largest velocities. At this stage, a single distant encounter may eject the star from the cluster. Evaporation is dominant for low-mass stars with the lightest stars tending to escape their parent star cluster first (e.g., Vesperini and Heggie,

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1997; de la Fuente Marcos, 1997a,b; Takahashi and Lee, 2000; de la Fuente Marcos and de la Fuente Marcos, 2000; Baumgardt and Makino, 2003). Numerical simulations indicate that the average escape velocity for low-mass stars in clusters is lower than for massive stars (e.g., see Fig. 7 in de la Fuente Marcos and de la Fuente Marcos, 2000). This trend depends on the cluster richness, with larger star clusters producing faster escapees even for late-type stars. In general, simulations indicate that stars with masses >0.3 $M_{\odot}$ have significantly higher average escape velocities (e.g., de la Fuente Marcos, 1997b). Therefore, stellar dynamics suggests that most of the observed low-mass stars should have relatively low space velocities and that those with the highest velocities should be the result of very strong gravitational interactions within large star clusters. Although it is thought that currently, most of the stars appear to form in small star clusters (e.g., Kroupa, 1995a,b,c; de la Fuente Marcos, 1997b) and that the majority of Galactic open clusters have ages younger than 0.8 Gyr, there is a certain fraction older than the majority (Friel, 1995). The existence of this old population may indicate that larger clusters were overabundant in the past, perhaps as a result of a starburst (de la Fuente Marcos and de la Fuente Marcos, 2004). Therefore, the study of high velocity, low-mass (M-dwarfs), old stars could be another window to the early stages of the evolution of the Milky Way disk. Meylan et al. (1991) discovered two high-velocity stars shot out from the core of the globular cluster 47 Tucanae. The high-velocity stars, by their location and photometry, appear to be cluster members but have radial velocities ($|V_{\rm r}| \sim 35$ km/s) in excess of the cluster escape velocity. These objects were dubbed cannonball stars and they may have been ejected during interactions with hard binaries at the cluster core.

In this paper, we report on the identification of one cannonball star candidate toward the direction of Canis Minor. The star is called PSS 544-7. This paper is organized as follows. In Section 2, we briefly present the data analyzed. Data corrections are discussed in Section 3. A detailed analysis of the data is presented in Section 4. Kinematics is analyzed in Section 5. Finally, in Section 6 we draw some conclusions and suggest further lines of research.

2. Data

PSS 544-7 is a relatively faint ($V = 18.37$) point source located in Canis Minor, Fig. 1 (α(ICRS) = 07 46 27.1, δ(ICRS) = +05 36 41, $l = 214.17$, $b = +14.78$). The object was first identified by Humphreys et al. (1991) during a survey with the 2.1 m telescope at Kitt Peak National Observatory. The photoelectric observations were obtained on 16 nights during four separate observing sessions in 1980 and 1981. For PSS 544-7, they found $B = 19.95 \pm 0.08$ and $V = 18.37 \pm 0.07$, therefore $B - V = 1.58 \pm 0.15$. They also found, $R = 17.15 \pm 0.01$, $V - R = 1.22 \pm 0.08$ and $O = 20.21 \pm 0.17$. These photometric data make it candidate to a low mass main sequence star of spectral type likely in the range M0–M6 (Zombeck, 1990). Its proper motion (from the Automated Stellar Motion Survey, Luyten, 1974, 1979) is relatively important: $\mu_{\alpha} = 117$ mas/yr, $\mu_{\delta} = -149$ mas/yr, with an estimated red magnitude of 18.4, an estimated photographic magnitude of 20.0 and a M spectral type.

The GSC 2.2 Catalogue (STScI, 2001) includes an object, designated N221233214374, located at α(ICRS) = 07 46 26.981, δ(ICRS) = +05 36 41.05, with $R = 17.72 \pm 0.26$ (epoch 1997.187). However, this object appears classified as non-star (class 3).

The USNO-B1.0 Catalog (Monet et al., 2003) includes an object, designated USNO-B1.0 0956-0153014 (epoch 1987.0), at basically the same coordinates (α(ICRS) = 07 46 26.90, δ(ICRS) = +05 36 40.8) with significant proper motion ($\mu_{\alpha} = -354 \pm 12$ mas/yr, $\mu_{\delta} = -188 \pm 5$ mas/yr). This catalogue also gives $R_1 = 19.41$, $B_2 = 19.46$, $R_2 = 17.76$ and an infrared (N) magnitude of 16.66.

Therefore, PSS 544-7 can be clearly identified with USNO-B1.0 0956-0153014. In spite of its low brightness in the blue and visual wavelengths, the USNO-B catalog provides a relatively bright infrared magnitude, 16.66, that suggests a very important infrared excess. The Two Micron All Sky Survey (Skrutskie et al., 1997, 2MASS) offers an opportunity to perform a systematic and unbiased search for unusual objects because it covers in a uniform way the Galactic plane in near infrared wavelengths (J, H and K_S bands) where the extinction is almost 10 times lower than the one