The Discovery of a Nearby M Dwarf

By O. Shemmer
and
S. Kaspi

School of Physics and Astronomy and the Wise Observatory,
The Raymond and Beverly Sackler Faculty of Exact Sciences,
Tel-Aviv University, Tel-Aviv 69978, Israel

We report the discovery of a nearby M dwarf star, found accidentally while observing the old nova DN Gem at the Wise Observatory. The star is designated 1200-05296925 in the PMM USNO-A1.0 catalogue and its coordinates, calculated for 1997 November 27 are: RA=6 55 05.13 Dec = +32 09 54.1 (Equinox J2000, Epoch J1997.90). Astrometric measurements for the star yielded a yearly proper motion rate of 0.155±0.002 arcseconds in right ascension and negligible yearly proper motion rate in declination. The apparent V magnitude of the star was measured as $m_V=13.87\pm0.16$ mag and spectral identification yielded a spectral type of M3.5Ve±0.5 subclasses. Using relations between spectral type and absolute V magnitude in M dwarfs, we arrive at an absolute magnitude of $M_V=12.3^{+1.2}_{-1.1}$ mag, which corresponds to a distance of $21^{+15}_{-10}$ pc.
Introduction

In the course of monitoring periodic light variations in the old nova DN Gem (nova Gem 1912) at the Wise Observatory, on 1997 April 21, one of the stars (hereafter M dwarf) in the nova’s field seemed to have moved a few arcseconds to the west compared with the nova’s old finding chart. Fig. 1 is part of an image taken on 1997 April 21 to serve as a finding chart. This visual finding was further checked against other images of the nova from previous years taken at the Wise Observatory and a Palomar sky survey plate of the field from 1955. A thorough examination in high proper motions and nearby stars catalogues, including a search through the SIMBAD database yielded no information on this star.

Further examination of DN Gem’s field, resulted in yet another puzzling fact in that the Guide Star Catalogue (hereafter GSC) refers to only one bright object near the position of the M dwarf, whereas there were in fact two bright stars in the images around that position (separated by only a few arcseconds). Checking upon the USNO-A1.0 catalogue resulted also in the appearance of one star at that position, but with the coordinates of the M dwarf. This puzzle was solved by recognizing that the M dwarf was too faint in V magnitude to appear in the GSC catalogue, but appears in the USNO-A1.0 catalogue, and the star about 10 arcseconds due south of the M dwarf appears in the GSC catalogue and not in the USNO-A1.0. The fact that both stars have proper motions above the proper motion standard deviation of the background stars (see below) suggested a possible binary system. However, spectral classification carried out later on, showed that it is highly unlikely that the two stars are physically connected, since the primary object is an M dwarf and the “companion” to its south is a G star (probably a mid type G dwarf, hereafter G star), not entirely classified, but still, having calculated its apparent magnitude, should lie at least several hundreds of parsecs away. We conclude that it is a mere coincidence that both stars, quite near angularly to each other, have proper motions higher than that of the background stars.
Observations and Reductions

The observations were made with the 40" telescope at the Tel-Aviv University Wise Observatory between 1995 and 1997. Photometry and spectroscopy were carried out using the CCD camera and the Faint Object Spectroscopic Camera (FOSC), respectively. Both instruments use a Tektronics 1024×1024 pixel back-illuminated CCD as a detector.

During the spectroscopic observations the spectrograph 10 arcseconds-wide long-slit was aligned at PA=163.3 deg in order to simultaneously include both the M dwarf and the G star in the slit. This way a maximum separation between the two objects spectra is achieved, minimizing the possibility of light from one object contaminating the other. The observation on 1997 November 27 was devoted to photometric calibration of the star’s apparent magnitude using Landolt’s standard star system.

Reduction was carried out in the standard way using the NOAO IRAF daophot package for the photometry and the specred package for the spectroscopy. Since no spectroscopic standards were observed when the spectra of the stars were taken, the spectrum was flux calibrated using the Wise Observatory standard coefficients, which generally do not change significantly from night to night. The spectra extend from 3980 to 7820 Å with a dispersion of 3.8 Å per pixel (about 8 Å resolution).

Astrometry

The exact position and proper motion of the M dwarf was calculated using the IRAF imcoords package. We chose 7 bright stellar candidates in the field of the M dwarf that had their coordinates listed in the PMM USNO-A1.0 catalogue and had no known proper motions. These coordinates were used to calculate the plate solution for each image of the observations and for a reference image extracted from the Palomar Digitised Sky Survey (DSS). Next, the coordinates of the M dwarf and the G star were calculated using the plate solution for each image. The M dwarf coordinates calculated for the image of 1997 November 27 were RA=6 55 05.13 Dec = +32 09 54.1 (Equinox J2000, Epoch J1997.90).

1IRAF (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories, which are operated by AURA, Inc., under cooperative agreement with the National Science Foundation.
The position shifts (hereafter residuals) for each star were then calculated as the (2000) RA & DEC coordinates difference between each image and the DSS image. The standard deviation of the residuals of the 7 background stars is 0.1 arcseconds, which sets a limit to our angular resolution. Results of the astrometric calculations showed that the 7 background stars have negligible residuals in both RA and DEC while the M dwarf has a comparatively large residual in RA, which is $6.6 \pm 0.1$ arcseconds and negligible residual in DEC. The time span between the images of 1955 February 23 (DSS) and 1997 November 27 is 42.76 years, therefore yielding for the M dwarf a yearly proper motion rate of $0.155 \pm 0.002$ arcseconds in RA. This comparatively large proper motion might hint on the proximity of the star. The G star on the other hand, has a proper motion rate in DEC one order of magnitude smaller than the M dwarf proper motion rate in RA, but still about $5\sigma$ above the mean residual of the background stars.

**Photometry**

On the way to verifying the proximity of the M dwarf, we calibrated the star’s magnitude and made corrections for atmospheric extinction. On 1997 November 27 we took exposures of the star with four different filters: B,V,R,I (Johnson) and several fields of Landolt’s standard star system before and after the M dwarf exposures, in different values of the airmass. The standard star fields were chosen to contain several stars with a variety of $B-V$ colours.

Table I lists the resultant apparent magnitudes in different filters. Magnitude values are given within an error of 0.16 mag. By inspection of Table I it is evident that the resultant apparent magnitude of the G star makes it impossible to be nearby, since even late G dwarfs have absolute V magnitudes of the order of 5 mag.

**Spectroscopy**

The key to our conclusion on the proximity of the M dwarf, lies mainly on our spectral identification of the star. By preliminary examination of the spectra we classified the star as an M dwarf and the star to its south as a G star. In the M dwarf spectra (see...
Fig. 2) several features enabled us to make a further sub-classification using the spectral methods given by Kirkpatrick et al. (1991) and by Henry et al. (1994). Among the various features common to M dwarfs, the star’s spectrum also shows emission lines, mainly the Hydrogen Balmer series Hα, Hβ, Hγ and Hδ. According to Joy & Abt (1974) the proportion of stars having emission in the Balmer lines grows with spectral type, in particular for types M3V – M3.5V the ratio of emission line stars among the M dwarfs is 37.5%.

Sub-classification of the M dwarf relied basically on the inspection of existing spectral templates but also on the apparent spectral features to specify the spectral type among the dwarfs. Since our spectrum extends no further to the red than 7820Å, we were not able to specify the spectral type in a more precise manner, since many important features appear in M dwarfs at around 8000Å. In particular we only managed to use 3 out of the 8 ratios cited by Kirkpatrick et al. (1991) to make a cross-identification of the spectral type more precisely. Ratio A, which is the flux ratio between the continuum in the 7020–7050Å band and the CaH band 6960–6990Å was calculated to be of the order of 1.22, suggesting a subclass of M3. Ratio B, which is the flux ratio between the continuum in the 7375–7385Å band and the Ti band 7353–7363Å was calculated to be of the order of 1.07, suggesting a subclass of M4. The ratio of ratio B to ratio A therefore turns out to be 0.877, suggesting a subclass of M3. It should be noted that ratio B is almost constant between M3 and M5 and the B to A ratio is very sensitive to spectral type. It is therefore hard to identify the spectral type using these 3 ratios alone, even though they set a low limiting value of about M2 and a high limit on about M5. However, spectral identification of the discovered M dwarf received strong support both from the spectral templates with the selected spectral features and from the observed colour of $B - V = 1.23$. The fact that the VO bands are very weak or absent in our spectrum ensures us that the star is not considered a late type M dwarf, and the weakness of the CaH $\lambda\lambda 6382,6389$Å bands for instance, or the weakness of the TiO bands around $\lambda 6600$Å prevents it from being a mid to late M dwarf. The weakness or total absence of the BaII line blended with Ti, Fe and Ca bands at $\lambda 6497$Å, makes it more likely an early to mid type M dwarf. Even though the uncertainty in the spectral class still prevails, we establish the spectral type as M3.5,
while it was noted in Henry et al. (1994) that spectral classes of the M dwarfs are in any way uncertain within ±0.5 subclasses.

When analysing the spectrum of the G star we faced more difficulty, since the main spectral features didn’t agree very well with any of the subclasses or with the luminosity classes, see Fig. [3]. Even though, we estimate that the G star is probably a G dwarf, and due to its faintness must lie at least several hundreds of parsecs away.

Summary

We have discovered an M dwarf with a comparatively high rate of proper motion. In order to estimate its proximity, we have used the relation in Henry et al. (1994) between the spectral type of M dwarfs and their absolute V magnitude, where $ST$ is the spectral type:

$$M_V = 0.101(ST)^2 + 0.596(ST) + 8.96 .$$

The absolute V magnitude obtained by equation (1) is within an error of 0.5 mag. Therefore, for an M3.5±0.5 dwarf, we arrive at an absolute V magnitude of $M_V=12.3^{+1.2}_{-1.4}$ mag. Using the apparent V magnitude of the M dwarf given in Table [1] we can finally calculate the distance modulus of the M dwarf to be $\mu = 1.6^{+1.2}_{-1.4}$ which determines a distance of $21^{+15}_{-10}$ pc (neglecting galactic extinction). We conclude that the M dwarf is nearby although it does not appear in the catalogue of nearby stars[6]. Future astrometry, in particular trigonometric parallax measurements, which are too sensitive for the Wise Observatory equipment, may yield a more precise value of the distance to the star.

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Finding chart of the M dwarf. North is up and East is left in this 4.1 X 3.9 arcminutes field.

Table I

| Filter/colour | B   | V   | R   | I   | B − V | V − I |
|---------------|-----|-----|-----|-----|-------|-------|
| M dwarf       | 15.10 | 13.87 | 12.64 | 11.03 | 1.23 | 2.84 |
| G star        | 13.87 | 13.35 | 12.83 | 12.35 | 0.52 | 1.00 |
Spectrum of USNO-A1.0 1200-05296925 identified as an M3.5Ve star. The flux was normalised, according to Kirkpatrick et al. (1991) to the value at the $\lambda 7500\text{Å}$ continuum level, which was $3.41 \times 10^{-14}$ ergs/cm$^2$/sec/Å.
Figure 3

Spectrum of the G star.