Research Note

First HST/FOC images of the low mass companion of the astrometric binary Gliese 623*

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Abstract. We have resolved the astrometric binary Gliese 623 into two components, by direct imaging in the visible band, with the COSTAR corrected FOC. The images clearly show the faint companion Gliese 623B, with a derived absolute magnitude of $M_V = 16.17 \pm 0.10$, at a distance of 0.33" from the primary (namely at 2.51 AU, assuming a parallax of $\pi = 0".132$, i.e. a distance of 7.6 pc). From the mass–luminosity relationship of Henry and McCarthy (1993), the photometric mass of the secondary is 0.098 solar masses.

Key words: stars: binaries: visual – stars: brown dwarf – stars: Gliese 623

1. Introduction

The faint end of the stellar mass-luminosity function is still poorly defined and understood. A discussion of the pre–HST situation is contained for instance in Henry and McCarthy (1993). Accurate mass determinations at this low end are crucial to answer the fundamental question as to whether masses around 0.1 solar masses or slightly lower mark indeed the end of the stellar mass function. This is a problem whose answer can shed light on general issues such as that of the origin and nature of dark matter. The HST is rapidly changing the observational situation, with the recent discovery of Very Low Mass stars and even Brown Dwarfs (see for instance Golimowski et al., 1995). Here we wish to report the successful imaging in the visible of the low mass component of the astrometric system Gliese 623. Indeed, several Very Low Mass stars and Brown Dwarfs candidates are known from astrometric observations which observed for decades the celestial path of a number of nearby low mass M stars, and in a few cases successfully detected small perturbations indicative of the presence of an associated low mass companion. Among these is Gliese 623, whose duplicity was first suspected by Lippincott and Borgman (1978), who found for the companion a period of $\approx 3.7$ yrs. This result was subsequently confirmed by both speckle interferometric observations of the companion (McCarthy 1986, McCarthy & Henry 1987) and radial velocity measurements (Marcy et al. 1986; Marcy & Moore 1989). Gliese 623 parallax, as given in the Hipparcos Input Catalogue (Turon et al., 1992), is $0.132 \pm 0.007$ arcseconds (distance 7.6 pc, distance modulus $-0.603$), its spectral type is M2.5V (Henry, Kirkpatrick, & Simon 1994), its apparent visual mag $V=10.3$ (Henry & McCarthy 1993), its radial velocity -28.6 Km/sec (Leggett 1992). McCarthy and Henry (1987) derived, from 1D IR speckle observations of the two components, masses of 0.51 and 0.11 $M_\odot$ for the primary (consistent with a normal main sequence M3 star), and the secondary, respectively. From additional infrared speckle work, Henry & McCarthy (1993) confirmed these numbers which are, however, at variance with determinations stemming from photometry and standard Population I main-sequence relations, which attributed 0.3 $M_\odot$ to the primary, and not more than 0.08 $M_\odot$ (at the $1 \sigma$ level) to the companion (Marcy & Moore 1989). On the other hand the slope of the Mass–Luminosity relation at these faint magnitudes is very steep. Therefore, small photometric errors translate into large mass uncertainties.

* Based on observations with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by AURA, Inc. under NASA Contract NAS 5-26555
can be at most of ±1 pixel, namely 0′′.015. The center of the secondary was more easily measured, and the error associated with its position is much smaller, not more than two tenths of a pixel. The distance is therefore 0″.33 ± 0.02. The position angle was determined by composing the information on the relative distance of the two stars with the orientation of the FOC image on the sky (the y image axis had a PA = 113.3° at the time of the observation), and resulted to be 7.0°, with an indetermination of ±2.6°. This uncertainty is compatible with the difference resulting from the comparison of the position angles obtained from the two separate images.

Aperture photometry of both stars was performed using the IRAF package digi phot. apphot on the second image taken, corrected by the HST pipeline for geometric distortions of the FOC detector and flat field. Details on the technique are described in De Marchi et al. (1993). After examining the profile of the two stars in the image, we selected the aperture sizes for the core and the background annulus, namely a radius of 3 pixels for the core, and annulus between 3.5 and 6 pixels for the background subtraction.

The aperture correction was derived by using a standard PSF (taken during SMOV with the F486N filter of the standard star BPM16274, background subtracted) to measure the fraction of the total light contained in the core aperture and in the background annulus. By using the imexamine package we measured that our selected core aperture contained 59.2% of the total source light, while the background annulus contained 10.0% of the total light. These measured values compare well to 61.0% for the aperture with 3 pixel radius and 13.0% for the annulus as given in the FOC Instrument Handbook (Nota et al. 1994). The overall aperture correction results to be 54.6%. Scaling appropriately the measured flux for the aperture correction, we derived for Gliese 623B a total of 8809 cts in 900 sec, corresponding to a count rate of 9.78 cts/sec.

We then used SYNPHOT to determine the V magnitude of the late M-type star which would have produced such a count rate in the F486N filter. Calculations show that later than M1 the result is independent, within few hundredths of magnitude, of the spectral type adopted. The following correction can be applied:

\[ V = m_{F486N} - 0.34 \]  

(1)

The result is \( m_{F486N} = 15.91 \), \( V = 15.57 \). At the adopted distance modulus \( m - M = -0.603 \), the absolute visual magnitude is then \( M_V = 16.17 \), with an estimated error of ±0.1 as discussed in the following paragraph.

3. Discussion and conclusions

Our measured magnitude is in reasonably good agreement with the value derived by Henry and McCarthy (1993) of 16.67 ± 0.7. This value had been extrapolated from their IR photometry, using a IR-visible relation derived analyzing a sample of 53 nearby single red dwarfs. Although formally consistent with the derived V magnitude, our measurements are affected by a much smaller error, unless the spectral characteristics of Gliese 623B
are very different from that of M-type stars. The overall uncertainty associated with our derived absolute magnitude is given by the composition of three independent effects: 1) the statistical error on the photometric measurement, which is Poissonian (\( \approx 1\% \)), 2) the accuracy on the photometric calibration at the wavelength of the observation (\( \approx 7\% \)), 3) the uncertainty on the transformation between the F486N and V filters (less than 2\%, as we are considering two adjacent bandpasses). The latter is so small because the transformation is insensitive to spectral changes for stars later than M1 as already stated.

On the other hand, Henry and McCarthy's resulting V magnitude for Gliese 623B is affected by an error which is much larger: the K magnitude of Gliese 623B is in the region of their relation where a larger uncertainty is associated with the assumption that the objects fixing the calibration are indeed single. Henry and McCarthy provide also a mass-luminosity relation, which they empirically derive by comparing magnitudes and masses (astrometrically determined) for a sample of 37 nearby intermediate disk age stars. We use this relation to convert the luminosity for Gliese 623B into a mass, and obtain \( m = 0.098 M_\odot \pm 0.001 \), where the quoted uncertainty comes entirely from the photometry (i.e. the M-L relation is assumed not to be affected by statistical uncertainty). Our value for the mass is formally smaller than the mass obtained by Henry and McCarthy (0.114) on the basis of astrometry alone, although consistent with their quoted error (0.042).

Further work is in progress to analyse the astrometric data and derive a dynamical mass for the system.

References