Identification of the donor in GRS 1915+105

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Abstract. We report on the results of medium-resolution spectroscopy of GRS 1915+105 in the H and K band using the 8m VLT at ESO. We clearly identify absorption bandheads from ^{12}CO and ^{13}CO. Together with other features this results in a classification of the donor as a K-M III star.

Keywords: X-ray binary, GRS 1915+105, infrared observations

1. Introduction

GRS 1915+105 (Castro-Tirado et al. 1994) is the prototypical microquasar, a galactic X-ray binary ejecting plasma clouds at v≈0.95–0.98 c (Mirabel & Rodriguez 1994). It exhibits unique X-ray variability patterns (Greiner et al. 1996) which have been interpreted as instabilities leading to an infall of parts of the inner accretion disk (Belloni et al. 1997). It is therefore of great importance to know some details about the system components in order to understand the conditions which lead to these unique characteristics.

2. Observations and Results

We obtained H and K band infrared spectroscopy of GRS 1915+105 with the aim of searching for absorption signatures due to the donor. Since GRS 1915+105 is a strongly variable infrared source, believed to predominantly caused by synchrotron emission of ejected material (Eikenberry et al. 2000, Greiner et al. 2001), this required high signal-to-noise as well as good spectral resolution in order to beat the strong veiling. We therefore used the infrared spectrometer ISAAC on the 8m VLT Antu telescope on Paranal (ESO, Chile).

The short wavelength (0.9–2.5 μm) arm of ISAAC is equipped with a 1024×1024 pixel Rockwell HgCdTe array with an image scale of

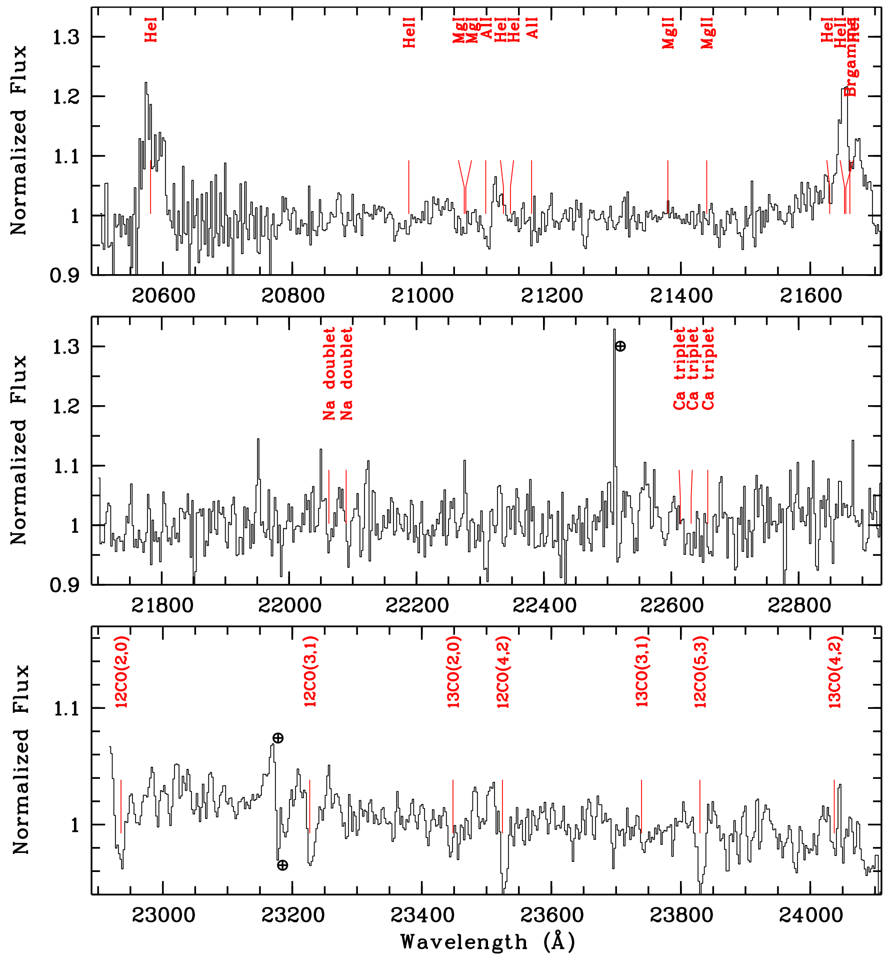

Figure 1. Spectrum of GRS 1915+105 in the K band. The top two panels correspond to 3000 sec exposure, while the bottom panel shows a sum of 4 images with 2000 sec exposure each. All spectra were rebinned by a factor of 2.

0.″147/pixel. Using the grating with the highest possible spectral resolution (∼3000 for a 1″ slit) yields 0.8Å/pixel in the H band and 1.2Å/pixel in the K band. Observations were performed in 1 (2) adjacent H bands, and 2 (3) adjacent K bands on 20/21 July 1999 (24/25 July 2000).

Science exposures consisted of several 250–300 sec individual exposures which were dithered along the slit by ±30″. In order to correct for atmospheric absorption, the nearby star HD 179913 (A0 V) was observed either before or after each science exposure. The initial data reduction steps like debiasing, flatfielding and co-adding were performed within the *Eclipse* package (Devillard 2000). The extraction and wavelength calibration was done using an optimal extraction routine within the MIDAS package.

The spectra of the 3 grating settings covering the K band are shown in Fig. 1. The top panel shows the strong emission lines of Br γ and He I known already from previous low-resolution spectroscopy (Castro-Tirado et al. 1996). In addition, we find for the first time several absorption lines which allow us to roughly identify the donor in GRS 1915+105. The lower panel clearly shows ^{12}CO absorption band heads characteristic of a low temperature ($T < 7000$ K) star (e.g. Kleinmann & Hall 1986). Though weak, we also identify the ^{13}CO (2,0) and ^{13}CO (3,1) transitions, indicating a luminosity class III or brighter (e.g. Wallace & Hinkle 1997). We also identify the Na doublet (2.20624/2.20897 μm), and possibly the Ca triplet (2.26141/2.26311/2.26573 μm), Al I (2.10988 μm) and the Mg I doublet (2.10655/2.10680 μm) in absorption. Note that the CN doublet (2.0910/2.0960 μm), which in supergiants is more prominent than Al/Mg, is not detected. Thus, we conclude that the donor in GRS 1915+105 is a late-type K-M giant.

We have tried to confirm the luminosity class more quantitatively by using the veiling-independent indicator

$r = \log[EW(^{12}\mathrm{CO}(2,0))/(EW(\mathrm{Na}) + EW(\mathrm{Ca}))]$

(Ramírez et al. 1997). Because of the low significance of the Ca triplet our measurement has a large error: $r = 0.25 \pm 0.20$. This value falls in between the ranges covered by dwarfs ($-0.2 \lesssim r \lesssim 0.0$) and giants ($0.4 \lesssim r \lesssim 0.6$) (Ramírez et al. 1997). The ratio of equivalent widths of ^{12}CO to ^{13}CO which depends on luminosity class (Campbell et al. 1990), has been measured for the seven transitions covered (lower panel of Fig. 1) to $\sim 3 \pm 1$, again supporting a giant classification.

Unfortunately, the H band spectra are of too low S/N ratio to detect OH or CO, thus not allowing us to use the veiling-independent temperature/luminosity discriminants as proposed by Meyer et al. (1998). However, the veiling was roughly determined by comparison of our flux-calibrated 2.35 μm spectrum of GRS 1915+105 with that of a K2 III standard star, observed with the same settings. We adopted a 13 mag flat continuum and added the K2 III star spectrum scaled to a brightness in the range 13.5–17.5 mag (Fig. 2). A comparison with the GRS 1915+105 spectrum gives a (not extinction-corrected) magnitude of K = 14.5–15.0 mag for the donor. With a distance of $\sim$11 kpc and a $A_{\mathrm{K}} = 3$ mag extinction correction this implies an absolute magnitude of $M_{\mathrm{K}} = -2...-3$ mag, consistent with the giant classification.

This identification of the donor of GRS 1915+105 as a K-M giant implies a rather narrow mass range of 1.0–1.5 $M_{\odot}$. Typical spherical mass-loss rates of such stars are much too low to sustain the high accretion luminosity of GRS 1915+105 via accretion from the donor's stellar wind. We therefore suggest (not too surprisingly) that accretion should occur via Roche lobe overflow. We finally note that while our

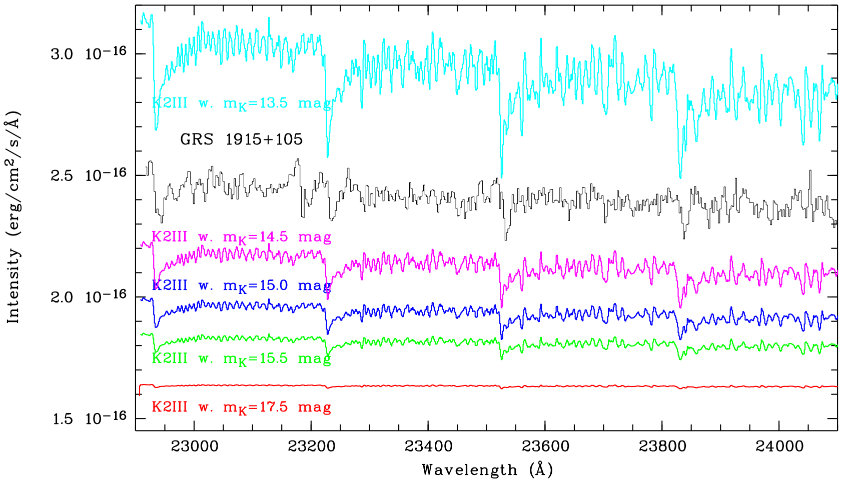

Figure 2. Spectrum of GRS 1915+105 in the 2.3–2.4 μm range (second from top, not extinction-corrected), compared to the spectrum of the K2III star HD 202135 scaled to different magnitudes (as marked on each spectrum) which is veiled by a 13 mag flat continuum. This implies that the donor of GRS 1915+105 has a magnitude of 14.5–15 mag prior to extinction correction.

identification contradicts the findings of Martí et al. (2000) who argue for a massive OB-type companion, it is consistent with the constraints derived by Eikenberry et al. (2001).

The presence of clear donor absorption features will now allow a period search as well as a determination of the mass of the compact object using radial velocity measurements of the donor.

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