Gemini H-band Spectroscopy of the Galactic Microquasar GRS 1915+105

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Abstract

Since its discovery in 1994 (Castro-Tirado 1994) GRS 1915+105 has become one of the most intensely studied of all the X-ray binaries in the Galaxy. This Galactic microquasar system is unique in that it has remained in outburst for the past 20 years: furthermore, initial measurements suggested a relatively high black hole mass of 14±4M$_\odot$ (Greiner et al. 2001), outside the predicted mass range for such transients (Fryer et al. 2001, Ozel et al. 2010). Here we present new Gemini H-band observations, and discuss the degree to which they can be used to refine the black hole mass in comparison to more recent estimates (Steeghs et al 2013). In addition, previous work found phase dependent emission of the CO bandheads in the K-band (Hurley et al 2013), and we present evidence of double peaked emission lines, indicative of ongoing mass transfer via the accretion disk.

Introduction

Black hole X-ray transients are binary systems in which a low mass star transfers material onto its compact object companion. GRS1915+105 is perhaps one of the most studied of such systems as many of its properties are very unusual. Since it was discovered in the early 1990s it has remained in outburst while other systems of this type tend to return to quiescence within a year (Steeghs et al. 2013). The first mass estimate of the black hole was 14±4M$_\odot$ (Greiner et al. 2001b), indicating it to be one of the most massive black holes of its class in the Galaxy, albeit with a large error. As a microquasar the main feature of GRS1915+105 is the relativistic jet, which is thought to be powered by the spin of the black hole which has been measured to be at near maximum rate (Narayan et al. 2012). Due to the high optical extinction, $A_v \approx 20$ mag (Chapuis et al. 2004), observations in the IR have proven vital (Greiner et al. 2001a,b, Hurley et al, 2013, Steeghs et al. 2013). Here we present analysis of H-band spectra, whose atomic absorption features are expected to be narrower than the molecular ones used in the original radial velocity studies of Greiner et al. (2001a,b), in the hope it will lead to a more accurate mass function.

Observations and Data Reduction

The data presented here were obtained using the Gemini North Near-Infrared Integral Field Spectrometer (NIFS). A total of seven observations were carried out in 2013 and combined with three exisiting NIFS spectra taken in 2010. Together these ten spectra cover the entire orbital period of the system. NIFS provides spectroscopy with a 3.0" x 3.0" field of view and H-band resolution of ∼5000. The data were reduced using the IRAF[a] Gemini package in conjunction with the reduction scripts provided by Gemini[b] for baseline calibration, telluric correction and science reduction. The baseline calibration makes the flat field and bad pixel mask, wavelength calibrates the arcs and determines the spatial and spectral distortion in the Ronchi flat. Telluric correction was achieved by observing the A0V standard star HD 182761 before and after science runs. This star first had to be corrected for the presence of Hydrogen recombination lines before being divided into the science data. Finally, the science reduction script flat fields, sky and dark subtracts, telluric corrects and wavelength calibrates the science data. The data were then exported to MOLLY[c] for analysis where they were rebinned to a common velocity scale and cross correlated against a KI III template star HD 83240, taken from the high resolution catelogue of Lebzelter et al. (2012).

[a]IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation

[b]http://www.gemini.edu/sciops/instruments/nifs/data-format-and-reduction

[c]http://www2.warwick.ac.uk/fac/sci/physics/research/astro/people/marsh/software

Date (UT)	No. of Exp	Total (s)	Phase
2010 Jun 29	24 x 180	4320	0.5888
2010 Jul 06	24 x 180	4320	0.7959
2010 Jul 13	24 x 180	4320	0.002428
2013 Jun 22	18 x 120	2160	0.7601
2013 Jun 30	18 x 120	2160	0.9937
2013 Jul 01	15 x 120	1800	0.02317
2013 Jul 03	18 x 120	2160	0.8575
2013 Jul 05	9 x 120	1080	0.1445
2013 Jul 15	16 x 120	1920	0.4389
2013 Jul 18	18 x 120	2160	0.5254

Results

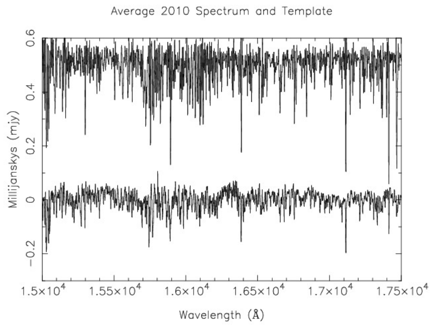

FIGURE 1: TOP: THE HIGH RESOLUTION KI III TEMPLATE SPECTRUM OF LEBZELTER USED TO CROSS CORRELATE THE 2010 SPECTRA. BOTTOM: THE AVERAGE SPECTRUM OF THE 2010 DATA. WE NOTE THE ABSENCE OF EMISSION LINES WHICH ARE SEEN IN THE 2013 DATA.

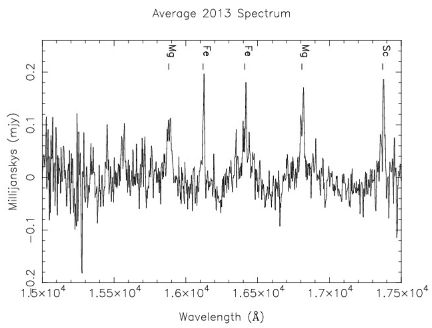

FIGURE 2: THE AVERAGE SPECTRUM OF THE 2013 DATA. WE NOTICE THE STARK DIFFERENCE BETWEEN THIS AND THE 2010 DATA: HERE THE SPECTRA ARE DOMINATED BY EMISSION LINES RATHER THAN THE ABSORPTION LINES SEEN IN THE 2010 SPECTRA.

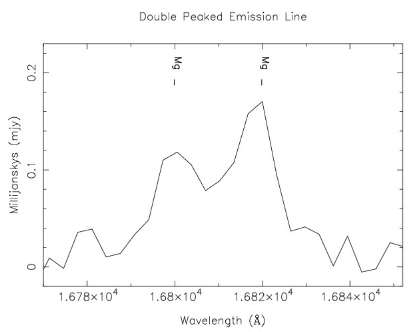

FIGURE 3: ZOOMING IN ON FIG. 2 WE SEE THE DOUBLE PEAKED NATURE OF THE EMISSION LINES AT ∼16800Å SUGGESTING THE EMISSION IS FROM THE ACCRETION DISK.

Discussion

The most obvious thing to note here is that our three spectra taken in 2010 exhibit only absorption lines. This can be seen in Figure 1 where the spectra were cross correlated with the template star HD 83420 from the high resolution catelogue of Lebzelter et al. (2012) and then averaged.
Figure 2 shows the averaged spectrum of the 2013 data. Here the spectrum is dominated by emission lines although we do see some absorption features. Figure 3 zooms in on the wavelength range of 16750Å to 16875Å of Figure 2 to show the emission lines more clearly. It is here that we can clearly see the double peaked nature of the emission lines, indicating that, even in the H-band, the accretion disk can still contaminate the observed flux.
Work carried out by Hurley et al. (2013) found phase dependent emission in the K-band. The CO bandheads were seen in emission between phases 0.15 and 0.35 while they were in absorption between phases 0.65 and 0.85. However there is no such phase dependence in our H-band data suggesting a different source of emission in comparison to that observed by Hurley et al. (2013) .

Conclusions and Future Work

Further analysis is needed to confirm the source of the emission seen in the 2013 data is the accretion disk. We also need to account for the difference observed between the 2010 and 2013 datasets. Finally, we need to investigate the 2013 data in more detail to see if the expected radial velocity variation is present in the data.

References

Castro-Tirado, A. J., Brandt, S., Lund, N., Lapshov, I., Sunyaev, R., Shlyapnikov, A. A., Guziy, S., Pavlenko, E. P., 1994, ApJS, 92, 469

Chapuis, C., Corbel, S., 2004, A&A, 414, 659

Done, C., Wardzinski, G., Gierlinsky, M., 2004, MNRAS, 349, 393

Fryer, C. L., Kalogera, V., 2001, ApJ, 554, 548

Greiner, J., Cuby, J., McCaughrean, M., Castro-Tirado, A., Mennickent, R. 2001a, A&A, 373, L37

Greiner, J., Cuby, J., McCaughrean, M. 2001b, Nature, 414, 522

Hurley, J. D., Callanan, J. P., Elebert, P., Reynolds, T. M., 2013, MNRAS, 430, 1832-1838

Lebzerlter, T., et al., 2012, A&A, 539, A109

Narayan, R., McClintock, E. J., 2012, MNRAS, 419, 69

Ozel, F., Psaltis, D., Narayan, R., McClintock, E. J., 2010, ApJ, 825, 1918

Steeghs, D., McClintock, E. J., Parsons, G. S., Reid, J. M., Littlefair, S., Dhillon, S. V., 2013, ApJ, 768, 185

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