The Changing-look Optical Wind of the Flaring X-Ray Transient Swift J1858.6-0814

Muñoz-Darias, T.; Armas Padilla, M.; Jiménez-Ibarra, F.; Panizo-Espinar, G.; Casares, J.; Altamirano, D.; Buisson, D. J. K.; Castro Segura, N.; Cúneo, V. A.; Degenaar, N.; Fogantini, F. A.; Knigge, C.; Mata Sánchez, D.; Özbey Arabaci, M.; Sánchez-Sierras, J.; Torres, M. A. P.; van den Eijnden, J.; Vincentelli, F. M.

DOI
10.3847/2041-8213/ab8381

Publication date
2020

Document Version
Submitted manuscript

Published in
Astrophysical Journal Letters

Citation for published version (APA):
Muñoz-Darias, T., Armas Padilla, M., Jiménez-Ibarra, F., Panizo-Espinar, G., Casares, J., Altamirano, D., Buisson, D. J. K., Castro Segura, N., Cúneo, V. A., Degenaar, N., Fogantini, F. A., Knigge, C., Mata Sánchez, D., Özbey Arabaci, M., Sánchez-Sierras, J., Torres, M. A. P., van den Eijnden, J., & Vincentelli, F. M. (2020). The Changing-look Optical Wind of the Flaring X-Ray Transient Swift J1858.6-0814. Astrophysical Journal Letters, 893(1), [L19]. https://doi.org/10.3847/2041-8213/ab8381
The Changing-look Optical Wind of the Flaring X-ray Transient Swift J1858.6-0814

T. Muñoz-Darias,1, 2 M. Armas Padilla,1, 2 F. Jiménez-Ibarra,1, 2 G. Panizo-Espinar,1, 2 J. Casares,1, 2 D. Altamirano,3 D. J. K. Buisson,3 N. Castro Segura,3 V. A. Cúneo,1, 2 N. Degenaar,4 F. A. Fogantini,5, 6 C. Knigge,3 D. Mata Sánchez,7 M. Özbeý Arabaci,3, 8 J. Sánchez-Sierras,1, 2 M. A. P. Torres,1, 2, 9 J. van den Eijnden,4 and F. M. Vincentelli3

1 Instituto de Astrofísica de Canarias, 38205 La Laguna, Tenerife, Spain
2 Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain
3 Physics & Astronomy, University of Southampton, Southampton, Hampshire SO17 1BJ, UK
4 Anton Pannekoek Institute for Astronomy, University of Amsterdam, Science Park 904, 1098 XH, Amsterdam, the Netherlands
5 Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina
6 Instituto Argentino de Radioastronomía (CCT-La Plata, CONICET; CICPBA), C.C. No. 5, 1894 Villa Elisa, Argentina
7 Jodrell Bank Centre for Astrophysics, Department of Physics and Astronomy, The University of Manchester, M13 9PL, UK
8 Department of Astronomy & Astrophysics, Atatürk University, Erzurum, Turkey
9 SRON, Netherlands Institute for Space Research, Sorbonnelaan 2, NL-3584 CA Utrecht, the Netherlands

(Received March 30, 2020)
Submitted to ApJ Letters

ABSTRACT

We present the discovery of an optical accretion disk wind in the X-ray transient Swift J1858.6-0814. Our 90-spectrum data set, taken with the 10.4m GTC telescope over 8 different epochs and across five months, reveals the presence of conspicuous P-Cyg profiles in He \textsc{i} at 5876 Å and H\textalpha. These features are detected throughout the entire campaign, albeit their intensity and main observational properties are observed to vary on time-scales as short as five minutes. In particular, we observe significant variations in the wind velocity, between a few hundreds and $\sim 2400$ km s\(^{-1}\). In agreement with previous reports, our observations are characterised by the presence of frequent flares, although the relation between the continuum flux variability and the presence/absence of wind features is not evident. The reported high activity of the system at radio waves indicates that the optical wind of Swift J1858.6-0814 is contemporaneous with the radio-jet, as is the case for the handful of X-ray binary transients that have shown so far optical P-Cyg profiles. Finally, we compare our results with those of other sources showing optical accretion disk winds, with emphasis on V404 Cyg and V4641 Sgr, since they also display strong and variable optical wind features as well as similar flaring behaviour.

Keywords: accretion, accretion discs X-rays: binaries stars: black holes stars: winds, outflows

1. INTRODUCTION

In addition to a large variety of accretion-related observables, mostly seen in X-rays (McClintock & Remillard 2006; van der Klis 2006; Belloni et al. 2011), low-mass X-ray binaries (LMXBs) also show a complex outflow phenomenology. This initially included synchrotron radio emission from jets, either in the form of compact sources or discrete ejections (e.g. Mirabel & Rodriguez 1999, Fender et al. 2004), and subsequently X-ray winds of highly ionized material (e.g. Miller et al. 2006, Ponti et al. 2012, Díaz Trigo & Boirin 2016). These outflows can be the dominant source of power released and mass consumed/expelled by the system during some accretion phases (Fender & Muñoz-Darias 2016), and as such represent a fundamental part of the entire accretion process onto stellar-mass black holes (BHs) and neutron stars (NSs).

Furthermore, intense and sensitive spectroscopic campaigns carried out over the last few years have unveiled the presence of optical winds in several BH
transients. P-Cyg profiles have been discovered in V404 Cyg (Muñoz-Darias et al. 2016; Muñoz-Darias et al. 2017; Mata Sánchez et al. 2018; see also Casares et al. 1991 for detections during the 1989 outburst) and MAXI J1820+070 (Muñoz-Darias et al. 2019b), while an archival search showed the presence of conspicuous wind signatures in several outbursts of V4641 Sgr (Muñoz-Darias et al. 2018; see Lindstrom et al. 2005 and Chaty et al. 2003 for earlier reports). In addition, the classical systems GRO J1655-40 and GX 339-4 showed complex emission line profiles (Soria et al. 2000; Rahoui et al. 2014), while the intriguing optical dips of Swift J1858.6-0814 showing that this system displays optical features indicating the presence of an accretion disk wind.

2. OBSERVATIONS AND DATA REDUCTION

We obtained optical spectroscopy using OSIRIS (Cepa et al. 2000) attached to the Gran Telescopio Canarias (GTC) at the Observatorio del Roque de los Muchachos in La Palma, Spain. The target was observed in eight different epochs over a time lapse of five months within March-August 2019. We obtained between 7 and 22 individual spectra per epoch with the grisms R1000B (4200 – 7400 Å) and R2500R (5575 – 7685 Å) depending on the night (see Table 1). This resulted in a total of 90 spectra with a time cadence of ~ five minutes and a velocity resolution of ~ 350 or ~ 160 km s\(^{-1}\) depending on the grism (measured from the FWHM of sky lines; i.e. assuming that resolution is dominated by the 1.0 arcsec slit and not the seeing). Weather conditions were good throughout the campaign, with seeing around ~ 1 arcsec and clear skies. Only epoch-1 was observed on a bright night at high airmass (~ 1.7) due to the very limited visibility window of the target at that time of the year. Across the entire campaign the slit was rotated so to include a brighter field star placed ~ 10 arcsec South-West from the target. In order to carry out a relative flux calibration, spectra from this object were treated in the same way as those of Swift J1858.6-0814. Data were reduced, extracted and wavelength calibrated using IRAF tools, while MOLLY and custom PYTHON routines were used for the analysis. From our g-band acquisition images (typically three per epoch and taken before the spectra) we derive magnitudes in the range 15.4–16.5 across the entire campaign (calibrated against Pan-STARRS).

| Epoch | Observing window (UT) | Grism\(^\dagger\) and exposures | g-band magnitude |
|-------|-----------------------|-------------------------------|-----------------|
| 1     | 24/03 (05:14–05:49)   | LR (7 × 280 s)               | 16.1            |
| 2     | 14/04 (05:30–06:16)   | LR (9 × 280 s)               | 15.4–15.7       |
| 3     | 30/04 (04:32–05:22)   | LR (10 × 280 s)              | 15.9–16.2       |
| 4     | 12/05 (03:36–04:32)   | LR (1 × 280 s) + HR (10 × 280 s) | 15.7–16.4   |
| 5     | 09/06 (03:52–04:48)   | LR (1 × 280 s) + HR (10 × 280 s) | 16.2–16.5       |
| 6     | 01/07 (04:03–04:59)   | LR (1 × 280 s) + HR (10 × 280 s) | 16.2–16.4       |
| 7     | 06/08 (00:00–01:52)   | HR (21 × 280 s) + LR (1 × 280 s) | 16.3            |
| 8     | 18/08 (21:57–22:43)   | HR (9 × 284 s)               | 15.7–16.4       |

\(^\dagger\) LR and HR indicate Lower (~ 350 km s\(^{-1}\)) and Higher (~ 160 km s\(^{-1}\)) Resolution grism (R1000B and R2500R, respectively)

Table 1. Observing log. All the data were taken in 2019.

LR and HR indicate Lower (~ 350 km s\(^{-1}\)) and Higher (~ 160 km s\(^{-1}\)) Resolution grism (R1000B and R2500R, respectively).
3. RESULTS

We focus our analysis on the 5500–7200 Å spectral range covered by both the lower (R1000B) and higher resolution (R2500R) grisms. It includes the emission lines He I at 5876 Å (He I–5876), Hα (6563 Å), He I–6678, as well as He I–7065. The R1000B spectra (epochs 1-7) also include the Bowen blend (mainly N III at 4641 Å) and He II at 4686 Å. These emission lines are detected across epochs 2 to 7, whilst the limited data quality of epoch 1 only allows to study Hα in great detail.

Fig. 1 shows the trailed spectra (top panels) corresponding to He I–5876 (left) and Hα (plus He I–6678; right). Intensity is indicated by a color scale covering from 0.92 (deep blue) to 1.08 (bright yellow) times the continuum level, which was previously normalized. The masked region, containing the Na interstellar doublet in the red wing of He I–5876, is indicated by a green vertical stripe. Bottom-left panel: evolution of the continuum flux (6000–6250 Å) throughout the campaign. Data are represented normalized to the mean value. A zoom-in of epoch 5 (dashed-lined rectangle) is overplotted as an inset, with the orange diamonds corresponding to the spectra with the more conspicuous P-Cyg detections (dashed-lined, orange rectangles in the top panels). Bottom-right panel: Hα excesses diagram for every spectrum with the exception of epoch 1, for which the epoch-averaged spectrum was used. The residuals are given in equivalent width (Å). The grey-shaded and dashed-lined circles indicate the 3σ and 5σ significance contours, respectively (see section 3.2).
By repeating this analysis with slightly different mask configurations we estimate that the normalization process introduces an uncertainty in the continuum level of $\sim 0.3$ percent (i.e. much lower than the $\pm 8$ percent intensity scale used in the trailed spectra). The blue wing of the \hei–5876 emission profile, typically the most sensitive to the presence of optical winds (e.g. Muñoz-Darias et al. 2016), show blue-shifted absorptions in virtually every observing epoch. These absorptions (represented by deep blue traces) make the blue part of the line disappear completely during a large part of the observing campaign. We interpret this as the signature of an accretion disk wind, similar to those previously witnessed in some BH transients.

A closer look at the trailed spectra reveals that the blueshifted \hei–5876 absorptions are more conspicuous...
between epochs 3 and 8, whilst Hα shows them only on epoch-5 and more weakly on epoch-7 (Fig 1, top-right panel). Likewise, He I –6678 behaves in a consistent way with He I –5876, albeit it is significantly less intense than the latter, and therefore any observational feature is expected to be less marked.

Fig 2 (left panel) shows the evolution of He I –5876 using epoch-2 to -8 nightly average spectra. We can distinguish two groups of data by looking at the evolution of the blue wing of the emission profile (i.e. negative velocities). Epochs 3, 5 and 7 (and also 2 to some extent) show standard P-Cyg profile shapes (i.e. blue-shifted absorption and red-shifted emission), with the most conspicuous case (epoch-5) reaching a terminal velocity\(^1\) of 1700 km s\(^{-1}\) and an absorption depth at the core of the profile of 95% the continuum level. An usual approach to determine the terminal velocity in a systematic way is to perform Gaussian fits to the blue-shifted absorption (e.g. Muñoz-Darias et al. 2016). However, in this case the shapes are clearly non-Gaussian and hence the velocity was simply determined by visual inspection. Given the high signal-to-noise ratio of our data, we estimate this to be accurate within \(\sim 100\) km s\(^{-1}\) (see e.g. insets in Fig. 3). The second group of data is formed by epochs 4, 6 and 8. They show odd profiles characterized by a strong and slightly blue-shifted absorption troughs reaching down to 92% the continuum level in some cases (epoch-4 and -8). However, the corresponding epoch-averaged Hα lines are dominated by standard double-peaked profiles during these times (Fig 2; right panel). The combination of a wind-induced blue-shifted absorption at low velocity, together with an underlying double-peaked profile (observed in Hα) offers a viable explanation for the behaviour of He I –5876 during these epochs. Under this interpretation, the emission bumps at \(\sim -500\) km s\(^{-1}\) would be associated with a partial

\(^1\) Throughout the paper, the terminal velocity of the wind is identified as that of the blue-edge of the P-Cyg absorption component. However, we note that this assumption is not always straightforward and is expected to depend on e.g. the physical properties of the ejecta.
absorption (by the wind) of the double-peaked disk component. If this is the case, the blue peak would appear weaker than the red one even when Hα shows the opposite behaviour (e.g. epoch-4). This dimming of the blue emission suggests that even though the blue edge of the absorption indicates wind velocities of just a few hundreds km s$^{-1}$, a higher velocity component is likely present.

It is important to remark that while the Hα profile seems to be unaffected during these low-velocity wind phases, it is clearly asymmetric or even show blue-shifted absorptions during the remaining epochs. As can be seen in the trailed spectra (Fig. 1), the most clear Hα wind detection also occurs on epoch-5. The wind signature is particularly strong in the last three individual spectra of this window (indicated by a dashed-lined, orange rectangle in the trailed spectra), whose averaged spectrum is shown in Fig. 3. Profound P-Cyg profiles are detected in He$^{+}$-5876, and especially Hα with a blue-shifted absorption reaching 90% the continuum level and a blue-edge velocity of $\sim 2400$ km s$^{-1}$. This is larger than $\sim 1700$ km s$^{-1}$ observed in He$^{+}$-5876 (see insets in Fig. 3).

3.1. Continuum flux variability

Given the strong variability observed in the line spectral profiles, we decided to study the evolution of the continuum flux. This was done by dividing each target spectrum by that of the field star included in the slit and subsequently integrating the flux from 6000 to 6250 Å. The bottom-left panel of Fig. 1 presents the light-curve, normalized to the mean value. During the campaign, flux is observed to vary within a factor of 3, with significant variability (factor of 2) observed within each epoch. We do not find a strong correlation between the continuum flux and the properties of the wind features found at different epochs. However, there are two facts worth mentioning. On the one hand, epoch-2, the window with the faintest wind features (He$^{+}$-5876) is the one reaching the highest fluxes. On the other hand, the evolution of epoch-5 (see inset) is affected by the presence of a flare, whose detection is followed by the aforementioned conspicuous wind detections observed in this window (orange dots in the inset). In this regard, we note that even if a similar level of variability is seen in every epoch, this is generally due to fast (non-resolved) flares superposed to a smooth trend, and not to the presence of a single flare as it is the case of epoch-5.

3.2. Search for broad emission line wings

Previous studies have shown that, besides P-Cyg profiles, the presence of broad emission line components can be also associated with the presence of winds. Given its strength, Hα is the best feature to search for the latter. To this end, we have computed the diagnostic diagram developed in Mata Sánchez et al. (2018) for V404 Cyg and subsequently refined in Muñoz-Darias et al. (2019b) for MAXI J1820+070, to which we refer the reader for further details. We performed a Gaussian fit to the Hα line profile masking the innermost part of the line ($-500$ to $500$ km s$^{-1}$ in velocity scale), subtracted the fit from the data, and measured the equivalent width (EW) of the residuals in the blue ($-2000$ to $-1000$ km s$^{-1}$) and red ($1000$ to $2000$ km s$^{-1}$) emission line wings. Significance levels are computed by measuring the $EW$ of the continuum within masks of the same width (i.e. $1000$ km s$^{-1}$) in nearby continuum regions. They show a Gaussian distribution from which significance levels can be derived. The diagram is shown in the bottom-right panel of Fig. 1. In order to increase the signal-to-noise ratio, the seven spectra from epoch-1 were averaged and treated as one. As expected, the entire epoch-5 sits outside the $3\sigma$ contour, with several spectra located well beyond $5\sigma$, within the P-Cyg region of the plot (i.e. negative blue and positive red residuals). Five spectra from epoch-7 also show significant blue-shifted absorptions, as well as two from epoch-6. In addition, there are two spectra sitting on the bottom-left part of the diagram, showing significant blue absorptions ($>5\sigma$). All the above can be considered wind detections based on this method. However, none of these detections present significant red wing residuals (i.e. $\lesssim 0.55$), that is, only the blue-shifted part of the P-Cyg is significantly detected. As a matter of fact, the diagnostic diagram do not show any convincing detection of broad emission line wings (top-right region; $>5\sigma$). Only two epoch-3 observations (out of 84) clearly exceed the $3\sigma$ level (again with non-significant red wing residuals), suggesting that broad emission line components are very weak or not present at all.

4. DISCUSSION

Swift J1858.6-0814 is, after the BH systems V404 Cyg, V4641 Sgr and MAXI J1820+070, the fourth transient LMXB showing optical P-Cyg profiles. Buisson et al. (2020) have recently reported the detection of several X-ray flares consistent with being type I X-ray bursts. If confirmed, this would make Swift J1858.6-0814 the first NS transient showing optical wind signatures, reinforcing the similarities between the outflow phenomenology seen in BH and NS transients (e.g. Ponti et al. 2014 for X-ray winds; Miller-Jones et al. 2010 for jets). In addition, the system has displayed profound, periodic dips/eclipses implying a high inclination and strongly
suggesting a relatively long orbital period of 21.8 hours (Buisson et al. 2020).

As in the previous cases, the emission line that displays the most conspicuous wind signatures is He\textsc{i}-5876. This is also one of the best optical wind markers in massive stars and accreting white dwarfs (e.g., Prinja & Fullerton 1994; Kafka & Honeycutt 2004). Our 90 spectra, taken over eight epochs in a time-lapse of five months, show that the optical wind is active during a large fraction of the time, and continuously detected in our data from (at least) epoch-2 (Figs. 1 and 2). Epoch-5 is arguably the most interesting window, with strong wind signatures in both He\textsc{i}-5876 and H\textsc{o}. The blue-shifted absorptions become particularly conspicuous in the last 3 spectra of this epoch, showing also a significant evolution towards high velocities. The inset in the bottom-left panel of Fig. 1 shows the continuum flux evolution during epoch-5. It can be seen that a flare occurs in the middle of the window. Interestingly, the blue-shifted H\textsc{o} absorption almost disappears during the peak (top-right panel in Fig. 1), while the last 3 spectra (orange dots) correspond to the decay of the flare. This behaviour strongly resembles that of V404 Cyg (e.g. fig. 2 in Muñoz-Darias et al. 2016), which showed the strongest P-Cyg profiles during a low luminosity epoch following a flare. However, the terminal velocity was not observed to vary in that case.

In V404 Cyg, the presence and variability of the P-Cyg profiles was found to be correlated with the ionisation state of the outer disc, which is traced by the relative strength of He \textsc{ii} to H\textsc{β} emission. In particular, the strongest P-Cyg profiles were found at low ionisation; a conclusion that was also supported by the analysis of MAXI J1820+070 (Muñoz-Darias et al. 2019b). Here, we have also computed the flux ratio of He \textsc{ii} to H\textsc{β} (as well as the EWs of He \textsc{ii} and Bowen blend) in the 30 spectra taken with the lower resolution grism. Epoch-2 and -3 show variability within a factor of two, roughly following the evolution of the continuum flux, whilst the single value obtained for epoch-5 is in the lower-end of the sample. However, in the case of the continuum flux variability, we do not find a clear correlation with the presence/absence of wind features. Nevertheless, given the lack of high-cadence coverage in He \textsc{ii} and the similarities between epoch-5 and the behaviour seen in V404 Cyg, we cannot rule out that ionisation effects are a key factor in determining the visibility and properties of the wind.

### Table 2. Transient LMXBs with optical P-Cyg profiles

| Transient     | Period (h) | Inclination (deg) | P-Cyg depth | Terminal velocity (km s\(^{-1}\)) | Outburst     | References       |
|---------------|------------|-------------------|-------------|-----------------------------------|--------------|------------------|
| V404 Cyg      | 155.3      | 60–70             | 30%         | 3000                              | Non-standard | 1,2              |
| V4641 Sgr     | 67.6       | 60–70             | 40%         | 1600 (3000)\(^\dagger\)          | Non-standard | 3,4              |
| Swift J1858.6-0814 | 21.8 (?)   | Dipping/eclipsing | 10%         | 2400                              | Ongoing      | 5, this work     |
| MAXI J1820+070 | 16.9       | 60–81             | 2.5%        | 1800                              | Standard     | 6,7,8            |

\(^{\dagger}\)The maximum P-Cyg terminal velocity is \(\sim 1600\) km s\(^{-1}\). However, broad wings reaching \(\sim 3000\) km s\(^{-1}\) were also observed.

References: (1) Casares & Jonker (2014); (2) Muñoz-Darias et al. (2016); (3) Orosz et al. (2001); (4) Muñoz-Darias et al. (2018); (5) Buisson et al. (2020); (6) Torres et al. (2020); (7) Atri et al. (2020); (8) Muñoz-Darias et al. (2019b)

Table 2 displays the main wind observables as well as some fundamental system parameters of the four transient LMXB with optical P-Cyg detections. As recently discussed in Hare et al. (2020), the strong flaring activity and variable X-ray absorption of Swift J1858.6-0814 (see also Ludlam et al. 2018; Reynolds et al. 2018) resembles the behaviour of V404 Cyg and V4641 Sgr (see e.g. Kimura et al. 2016; Motta et al. 2017; Morningstar et al. 2014; Gallo et al. 2014; Muñoz-Darias et al. 2018). These two objects display non-standard outbursts characterised by sharp rising phases followed by significant luminosity drops and the absence of steady soft states (e.g. Casares et al. 2019 for V404 Cyg). The discovery outburst of Swift J1858.6-0814 is still ongoing and it is beyond the scope of this paper to discuss the outburst evolution. Nevertheless, the source has been active in radio during the entire optical campaign (van den Eijnden et al. to be submitted), which is one of the standard observables associated with BH (and NS to some extent) hard and intermediate states (e.g. Fender & Muñoz-Darias 2016). This is consistent with the behaviour seen in V404 Cyg, V4641 Sgr and MAXI J1820+070.

Table 2 also reports the maximum terminal velocity and blue-absorption depth observed in the four transients with optical P-Cyg detections. These values are likely biased since (among other things) the observing campaigns (e.g. number and frequency of observations) were significantly different and the wind parameters might also change from outburst to outburst. For instance, the 1989 outburst of V404 Cyg is characterised by lower wind velocities than the 2015 event (Mata Sánchez et al. 2018). Nevertheless, the numbers
suggest that, from a purely observational point of view, the wind signatures of Swift J1858.6-0814 are reminiscent but not as extreme as those found in V404 Cyg and V4641 Sgr, while they significantly exceed those of MAXI J1820+070. This last source displayed a regular outburst evolution (e.g. Shidatsu et al. 2019) and has an orbital period of ~17 hours (Torres et al. 2019). A tempting possibility that arises from Table 2 is that larger accretion disks (i.e. ~ long orbital periods) might produce stronger winds, that carry away more mass and/or angular momentum. This could impact on the observed outburst evolution, which at least for the cases of V404 Cyg and V4641 Sgr deviates from the standard patterns typically seen in LMXBs (see e.g. Dunn et al. 2010; Muñoz-Darias et al. 2014 for global studies). Clearly, more observations are required to confirm this speculation. A key system on this matter could be GRS 1915+105 – the BH-LMXB with the longest orbital period (e.g. Corral-Santana et al. 2016) – that have shown some of the best examples of X-ray winds and radio jets (e.g. Neilson & Lee 2009). Although this very extinguished source cannot be observed at optical wavelengths, sensitive, infrared spectroscopy might be able to shed light on this topic.

Finally, it is worth discussing the role of the orbital inclination in the wind detectability, since it has been found to be a key parameter for X-ray winds, which are best seen at high inclination (Ponti et al. 2012; Díaz Trigo & Boirin 2016). Table 2 shows how optical P-Cygs have been only detected in sources with relatively high inclination (~60 deg.; see Higginbottom et al. 2019 for a discussion on the wind geometry and detectability as a function of the line-of-sight). To this list one could add the BH transient Swift J1357.2-0933. This high inclination system has not shown standard P-Cyg profiles, but its characteristic optical dips have been recently found to be associated with broad, blue-shifted absorptions indicating the presence of an outflow (Jiménez-Ibarra et al. 2019b; Charles et al. 2019).

5. CONCLUSIONS

We have detected clear optical features indicating the presence of an accretion disk wind in the X-ray transient Swift J1858.6-0814. The observational properties of the wind are similar to those observed in V404 Cyg and V4641 Sgr. These systems also share other observables with Swift J1858.6-0814, such as the presence of frequent flares and variable X-ray absorption. As it is the case for other LMXBs with optical wind detections, the outflow is contemporaneous with the radio jet. This work provides additional support for systematic and sensitive optical spectroscopic studies of active X-ray binaries in order to unveil the occurrence rate, observational properties and impact of these cold accretion disk winds.

6. ACKNOWLEDGEMENTS

We acknowledge support by the Spanish MINECO under grant AYA2017-83216-P. TMD and MAP acknowledge support via Ramón y Cajal Fellowships RYC-2015-18148 and RYC-2015-17854. MAP is funded by the Juan de la Cierva Fellowship Programme (IJCI-2016-30867). DMS acknowledges support from the ERC under the European Unions Horizon 2020 research and innovation programme (grant agreement No. 715051; Spiders). JvdE and ND are supported by an NWO Vidi grant awarded to ND. FF and DA acknowledge support from the Royal Society International Exchanges The first step for High-Energy Astrophysics relations between Argentina and UK. DA and DJKB acknowledge support from the Royal Society. MOA acknowledges support from the Royal Society through Newton International Fellowship program. N.C.S. acknowledge support by the Science and Technology Facilities Council (STFC), and from STFC grant ST/M001326/1. FMV acknowledges support from STFC under grant ST/R000638/1. Molly software developed by Tom Marsh is acknowledged.

REFERENCES

Atri, P., Miller-Jones, J. C. A., Bahramian, A., et al. 2020, MNRAS, 493, L81, doi: 10.1093/mnrasl/slaa010
Baglio, M. C., Russell, D. M., Pirbhoy, S., et al. 2018, The Astronomer’s Telegram, 12180
Bandyopadhyay, R. M., Shahbaz, T., Charles, P. A., & Naylor, T. 1999, MNRAS, 306, 417, doi: 10.1046/j.1365-8711.1999.02547.x
Belloni, T. M., Motta, S. E., & Muñoz-Darias, T. 2011, Bulletin of the Astronomical Society of India, 39, 409. https://arxiv.org/abs/1109.3388
Buisson, D. J. K., Hare, J., Guver, T., et al. 2020, The Astronomer’s Telegram, 13563, 1
Casares, J., Charles, P. A., Jones, D. H. P., Rutten, R. G. M., & Callanan, P. J. 1991, MNRAS, 250, 712
Casares, J., & Jonker, P. G. 2014, SSRv, 183, 223, doi: 10.1007/s11214-013-0030-6
Casares, J., Muñoz-Darias, T., Mata Sánchez, D., et al. 2019, MNRAS, 488, 1356, doi: 10.1093/mnras/stz1793
The changing-look wind of Swift J1858.6-0814

Cepa, J., Aguilar, M., Escalera, V. G., et al. 2000, in SPIE Conference Series, Vol. 4008, Optical and IR Telescope Instrumentation and Detectors, ed. M. Iye & A. F. Moorwood, 623–631

Charles, P., Matthews, J. H., Buckley, D. A. H., et al. 2019, MNRAS, 489, L47, doi: 10.1093/mnrasl/slz120

Chaty, S., Charles, P. A., Martí, J., et al. 2003, MNRAS, 343, 169, doi: 10.1046/j.1365-8711.2003.06651.x

Corral-Santana, J. M., Casares, J., Muñoz-Darias, T., et al. 2016, A&A, 587, A61, doi: 10.1051/0004-6361/201527130

Corral-Santana, J. M., Casares, J., Muñoz-Darias, T., et al. 2013, Science, 339, 1048, https://arxiv.org/abs/1303.0034

Díaz Trigo, M., & Boirin, L. 2016, Astronomische Nachrichten, 337, 368, doi: 10.1002/asna.201612315

Dunn, R. J. H., Fender, R. P., Körding, E. G., Belloni, T., & Cabanac, C. 2010, MNRAS, 403, 61, doi: 10.1111/j.1365-2966.2010.16114.x

Fender, R. P., Belloni, T. M., & Gallo, E. 2004, MNRAS, 355, 1105, doi: 10.1111/j.1365-2966.2004.08384.x

Gallo, E., Plotkin, R. M., & Jonker, P. G. 2014, MNRAS, 438, L41, doi: 10.1093/mnrasl/slt152

Gehrels, N., Chincarini, G., Giommi, P., et al. 2004, ApJ, 611, 1005, doi: 10.1086/422091

Hare, J., Tomsick, J. A., Buisson, D. J. K., et al. 2020, arXiv e-prints, arXiv:2001.03214, https://arxiv.org/abs/2001.03214

Higginbottom, N., Knigge, C., Long, K. S., Matthews, J. H., & Parkinson, E. J. 2019, MNRAS, 484, 4635, doi: 10.1093/mnras/stz310

Homlan, J., Neilson, J., Allen, J. L., et al. 2016, ApJL, 830, L5, doi: 10.3847/2041-8205/830/1/L5

Jiménez-Ibarra, F., Muñoz-Darias, T., Casares, J., Armas Padilla, M., & Corral-Santana, J. M. 2019a, MNRAS, 489, 3420, doi: 10.1093/mnras/stz2393

Jiménez-Ibarra, F., Muñoz-Darias, T., Armas Padilla, M., et al. 2019b, MNRAS, 484, 2078, doi: 10.1093/mnras/sty3187

Kafka, S., & Honeycutt, R. K. 2004, AJ, 128, 2420, doi: 10.1086/424618

Kimura, M., Isogai, K., Kato, T., et al. 2016, Nature, 529, 54, doi: 10.1038/nature16452

Krimm, H., Barthelmy, S., Cummings, J., et al. 2018, The Astronomer’s Telegram, 12151

Lindstrøm, C., Griffin, J., Kiss, L. L., et al. 2005, MNRAS, 363, 882, doi: 10.1111/j.1365-2966.2005.09483.x

Ludlam, R., Miller, J., Arzoumanian, Z., et al. 2018, The astronomer's telegram, 12158

Mata Sánchez, D., Muñoz-Darias, T., Casares, J., et al. 2018, MNRAS, 481, 2646, doi: 10.1093/mnras/sty2402

McClintock, J. E., & Remillard, R. A. 2006, Black hole binaries, ed. W. H. G. Lewin & M. van der Klis, 157–213, http://adsabs.harvard.edu/abs/2006csxs.book..157M

Miller, J. M., Raymond, J., Fabian, A., et al. 2006, Nature, 441, 953, doi: 10.1038/nature04912

Miller-Jones, J. C. A., Sivakoff, G. R., Altamirano, D., et al. 2010, ApJL, 716, L109, doi: 10.1088/2041-8205/716/2/L109

Mirabel, I. F., & Rodríguez, L. F. 1999, Ann. Rev. Astron. Astrophys., 37, 409, doi: 10.1146/annurev.astro.37.1.409

Morningstar, W. R., Miller, J. M., Reynolds, M. T., & Maitra, D. 2014, ApJL, 786, L20, doi: 10.1088/2041-8205/786/2/L20

Motta, S. E., Kajava, J. J. E., Sánchez-Fernández, C., Giustini, M., & Kuulkers, E. 2017, MNRAS, 468, 981, doi: 10.1093/mnras/stx466

Muñoz-Darias, T., Fender, R. P., Motta, S. E., & Belloni, T. M. 2014, MNRAS, 443, 3270, doi: 10.1093/mnras/stu1334

Muñoz-Darias, T., Casares, J., Mata Sánchez, D., et al. 2016, Nature, 534, 75, doi: 10.1038/nature17446

Muñoz-Darias, T., Jimenez-Ibarra, F., Armas Padilla, M., et al. 2019a, The Astronomer's Telegram, 12881

Muñoz-Darias, T., Torres, M. A. P., & Garcia, M. R. 2018, MNRAS, 479, 3987, doi: 10.1093/mnras/sty1711

Muñoz-Darias, T., Casares, J., Mata Sánchez, D., et al. 2017, MNRAS, 465, L124, doi: 10.1093/mnrasl/slw222

Muñoz-Darias, T., Jiménez-Ibarra, F., Panizzo-Espinar, G., et al. 2019b, ApJL, 879, L4, doi: 10.3847/2041-8213/ab2768

Neilsen, J., & Lee, J. C. 2009, Nature, 458, 481, doi: 10.1038/nature07680

Orósz, J. A., Kuulkers, E., van der Klis, M., et al. 2001, ApJ, 555, 489, doi: 10.1086/321442

Paice, J. A., Gandhi, P., Dhillon, V. S., et al. 2018, The Astronomer’s Telegram, 12197, 1

Ponti, G., Fender, R. P., Begelman, M. C., et al. 2012, MNRAS, 422, L11, doi: 10.1111/j.1745-3933.2012.01224.x

Ponti, G., Muñoz-Darias, T., & Fender, R. P. 2014, MNRAS, 444, 1829, doi: 10.1093/mnras/stu1742

Prinja, R. K., & Fullerton, A. W. 1994, ApJ, 426, 345, doi: 10.1086/174070

Rahoui, F., Coriat, M., & Lee, J. C. 2014, MNRAS, 442, 1610, doi: 10.1093/mnras/stu977
Reynolds, M., Miller, J., Ludlam, R., & Tetarenko, B. 2018, The Astronomer’s Telegram, 12220
Shidatsu, M., Nakahira, S., Murata, K. L., et al. 2019, ApJ, 874, 183, doi: 10.3847/1538-4357/ab09ff
Soria, R., Wu, K., & Hunstead, R. W. 2000, ApJ, 539, 445, doi: 10.1086/309194
Torres, M. A. P., Casares, J., Jiménez-Ibarra, F., et al. 2020, submitted to ApJ, arXiv:2003.02360.
https://arxiv.org/abs/2003.02360
—. 2019, ApJL, 882, L21, doi: 10.3847/2041-8213/ab39df
van der Klis, M. 2006, 39
Vasilopoulos, G., Bailyn, C., & Milburn, J. 2018, The Astronomer’s Telegram, 12164