The 2017 Outburst of Swift J1357.2-0933: Variable period blue dips with a hot, dense HeII wind


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Abstract

Quasi-simultaneous optical (ULTRACAM/NTT, SALT), X-ray (NuSTAR, XRT/Swift) and radio (ATCA) observations of the short period, high luminosity LMXB transient, Swift J1357.2-0933 during its 2017 outburst have revealed remarkable additional properties. In addition to confirming the variable frequency optical dipping seen during its 2011 discovery outburst, we also find: (1) the dip shapes is consistent with partial disc occultations, (2) the source becomes significantly bluer during these dips, indicating an unusual geometry compared to other LMXB dips, (3) there is no X-ray response to the optical dips, (4) HeII and Balmer absorption is present only during the dips, and is blue-shifted by ~500 km s⁻¹. These spectral features imply a very hot (T ~ 45000 K) dense (n ~ 10^10 cm⁻³) outflow driven by a central L ~ 10^{37} erg s⁻¹. Its periodicity implies a very high orbital inclination and a warped inner disc structure that moves out during the outburst. This is also consistent with its low observed F / F_o, max, implying that it is an Accretion Disc Corona (ADC) source, and not a VFXT (very faint X-ray transient).

This poster represents a summary of results presented in Paice et al 2019 (MNRAS 488, 512; P19) and Charles et al 2019 (MNRAS on press; Ch19) - all figures are taken from these papers.

Introduction to Swift J1357.2-0933

- XRT discovered by Swift BAT in 2011
- high inclination (i > 90°)
- initially thought d ~ 1 Mpc -> VFXT with L ~ 10^{35} erg s⁻¹, ruled out by lack of donor features in quiescence
- key feature: Comal-Santana et al. 2013 (A&A 567, A61; CS13) discovered fast (minutes) optical dipping whose period changed as the outburst progressed
- dips interpreted as CS13 as structure in inner disc (“island”) that moved out as outburst progressed (P_{out} = Keplerian P at that radius), hence high inclination
- CS13 found P_{out} ~ 2.5 h from Hb outburst spectroscopy, consistent with BH object (M ~ 10^6) and very low mass donor

2017 X-ray and Optical Variability

Figure 1: Dip frequency evolution of the 2011 (black) and 2017 (blue, red, SALT, ULTRACAM/NTT) outbursts. Fits areparable (see CS13, P19).

Figure 2: Timeline of Swift J1357.2-0933 2017 outburst with red lines marking key observation dates (1-SALT-XNSTAR; 2-SALT+Swift+ATCA; 3-ULTRACAM+NuSTAR+SALT). From P19

Figure 3: ULTRACAM (top) and NuSTAR (bottom) simultaneous (off-axis) spectra from 2017 Jun 1011. Optical dips have been binned with a moving average function to better show the long term trends. Note the numerous dips that occur throughout the lightcurve in optical, and the lack of any distinct dips in the X-rays. From P19.

Figure 4: X-ray (NuSTAR) and optical (ULTRACAM; g', r', g) PSDs of J1357. Note the optical peak at ~3 ms (the dip frequency) and the absence of any X-ray peak. From P19.

Figure 5: ULTRACAM colour-magnitude diagram which shows how blue the (same) dip points are, moving orthogonally to that expected for blue obscuration (red dashed lines). The solid green line is the g' median level. From P19

Conclusions

- J1357 has 2 unique properties (variable P dipping, HeII absorption) amongst all LMXBs
- dips are blue, requiring multiple emitting components of differing colours, e.g. recessed disc or jet
- the strong, absorption-line-only, hot, dense wind implies a very high orbital inclination
- wind requires high L_\alpha, hence it must be an ADC and at a distance ≥ 6 kpc

SALT time-resolved spectra reveal hot, dense, outflowing wind

Figure 6: SALT time-series spectra of J1357 on 2017 Jul 21, when the dip period was ~50s. Note the strong HeII 1640Å and Hβ variations associated with the dip frequency. From Ch19.

Figure 7: Hβ and HII profiles from mean of four SALT R55 spectra of J1357.2 when these features were strongest on 2017 Jul 21. Gaussian fits are shown, and velocities are relative to rest wavelength, demonstrating the ~600 km s⁻¹ outflow. From Ch19

Figure 8: Continuum normalised model spectra, calculated with full radiation transfer and in the pure absorption limit, compared to (bottom) R55 spectrum. We show three models that produced obvious and/or Balmer absorption lines: Model A (L_\text{bol} = 10^{37} erg s⁻¹, \beta = 3, \alpha = 5), Model B (L_\text{bol} = 10^{37} erg s⁻¹, \beta = 0, \alpha = 5), and Model C (L_\text{bol} = 10^{37} erg s⁻¹, \beta = 3, \alpha = 5.3). From Ch19

Acknowledgements

See P19 and Ch19 for full details of the extensive observatory facilities utilised in these studies.