WASP Observations of the Short-Term Variability in the Black Hole Binary A0620-00

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Abstract

The variability of the accretion flow of black holes can be used to probe the accretion flow's properties. Using Hale+WASP observations, we report on the short-term variability of the non-stellar emission from A0620-00. There appears to be quasi-periodic variability on timescales of 30-40 minutes at orbital phases $0.4 < \theta < 0.7$, but not $\theta < 0.4$. Understanding this dependence on phase will yield insights into quiescent black holes and their accretion flow model.

Introduction

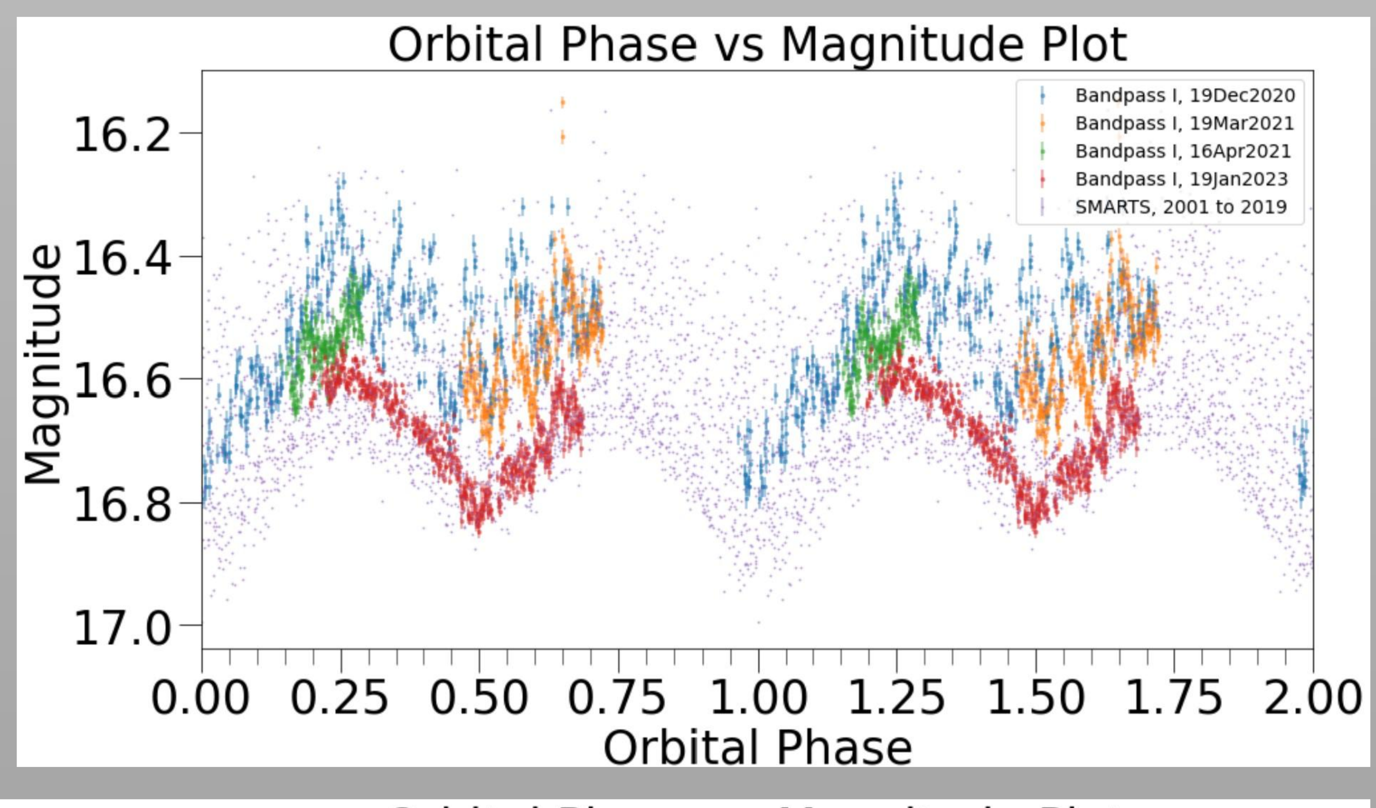
Black holes, as enigmatic entities, have captivated both the general public and the academic community. We are studying the transient black hole X-ray binary (BHXB) A0620-00, which is currently in quiescence. As one of the closest stellar-mass black holes to Earth, A0620-00 has been the subject of many studies since its discovery in 1975. In quiescence, the accretion disk emission from A0620-00 varies at all timescales, from hours to years [1,2], and exhibits an ADAF-like state. In outburst, A0620-00 exhibited a fast rise in luminosity followed by a much longer exponential decline and varied on millisecond-timescales [3].

However, minute-timescale variability remains unexplored for all wavelength regimes in A0620-00, and for quiescent black hole binaries more generally. In order to understand accretion during quiescence, we have investigated the variability of A0620-00 on minute-timescales in the optical/IR regime.

Methodology

Using the WASP instrument on the 5.1-m Hale telescope at Palomar Observatory, we have obtained data for four partial orbits of A0620-00. Exposure times were 10s in the I band. Combined with readout and overhead time, one observation was taken every 25 seconds, providing the necessary resolution for studying minute-scale phenomena. Observations were taken on Dec. 19 2020, Mar. 19 2021, Apr. 16 2021, and Jan. 19 2023. The time gaps between these dates enabled us to study the distinct substates of quiescence displayed by the source. In order to have a reference for the different substates of quiescence, we overlaid the WASP data on top of our 18 year-long SMARTS dataset of A0620-00, which contains observations of the system during various substates of quiescence.

To analyze the acquired data, we used traditional time-domain analysis techniques on the non-stellar emission component of A0620-00, such as graphing multiple types of periodograms and autocorrelations.



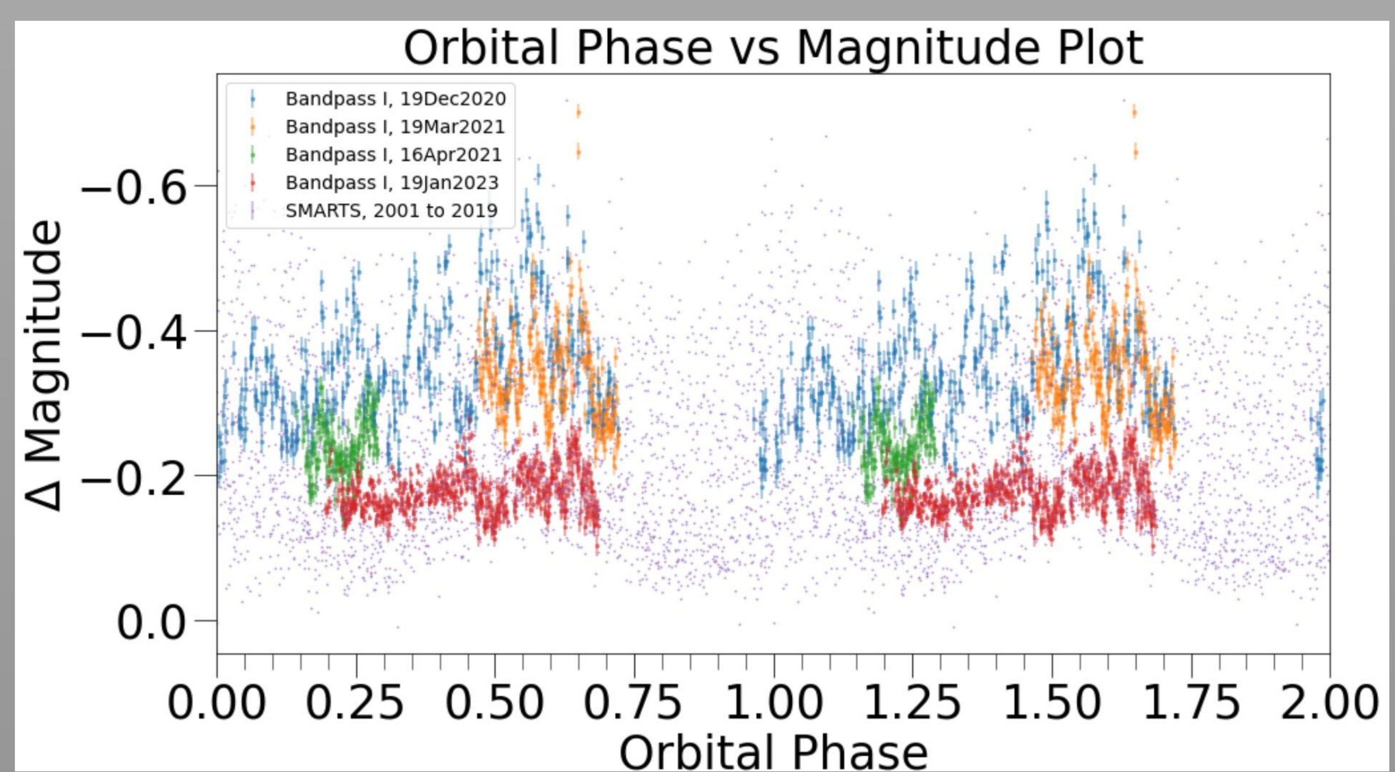


Fig. 1: Light curve of A0620-00 with (top) stellar emission included and (bottom) stellar emission subtracted.

Results

Our data contains observations of A0620-00 from orbital phases 0.00-0.75 and 0.98-1.00 (the missing phases 0.75-0.98 were lost due to poor observng conditions). The amplitude of the variability at phases $0.4 \leq \theta \leq 0.7$ is much higher than that at $\theta \leq 0.4$ for the non-stellar emission, indicating quasi-periodic variability in the system, but only for the former phases. Autocorrelations and periodograms suggest that this quasi-periodic variability is on timescales of ~30-40 minutes.

The accretion luminosity for the Jan. 19 2023 data is significantly lower than that of the other three nights, matching the lower end of the SMARTS dataset.

Conclusions

The non-stellar quasi-periodic variability dependence on phase could indicate the spatial location of a hotspot on the accretion disk or the preferred orientation of a jet. Since the existing data is sparse and missing some orbital phases, we hope to obtain new observations to confirm the spatial distribution, and thus nature, of the variability.

The lower accretion luminosity in the Jan. 19 2023 data compared to the other three nights indicates a switch from the active substate of quiescence to the passive substate.

References

[1] Cantrell et al. 2008, ApJL, 673, 159.
[2] Dincer et al. 2018, ApJ, 852, 4.
[3] Esin et al. 1999, ApJ, 532, 1069.