Clumped stellar winds in supergiant high-mass X-ray binaries: X-ray variability and photoionization

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The clumping of massive star winds is an established paradigm, which is confirmed by multiple lines of evidence and is supported by stellar wind theory. The purpose of this paper is to bridge the gap between detailed models of inhomogeneous stellar winds in single stars and the phenomenological description of donor winds in supergiant high-mass X-ray binaries (HMXBs). We use the results from time-dependent hydrodynamical models of the instability in the line-driven wind of a massive supergiant star to derive the time-dependent accretion rate on to a compact object in the Bondiâ€"Hoyleâ€"Lyttleton approximation. The strong density and velocity fluctuations in the wind result in strong variability of the synthetic X-ray light curves. The model predicts a large-scale X-ray variability, up to eight orders of magnitude, on relatively short time-scales. The apparent lack of evidence for such strong variability in the observed HMXBs indicates that the details of the accretion process act to reduce the variability resulting from the stellar wind velocity and density jumps.

We study the absorption of X-rays in the clumped stellar wind by means of a two-dimensional stochastic wind model. The monochromatic absorption in the cool stellar wind, depending on the orbital phase, is computed for realistic stellar wind opacity. We find that the absorption of X-rays changes strongly at different orbital phases. The degree of the variability resulting from the absorption in the wind depends on the shape of the wind clumps, and this is stronger for oblate clumps.

We address the photoionization in the clumped wind, and we show that the degree of ionization is affected by the wind clumping. We derive a correction factor for the photoionization parameter, and we show that the photoionization parameter is reduced by a factor inline image compared to the smooth wind models with the same mass-loss rate, where inline image is the wind inhomogeneity parameter. We conclude that wind clumping must also be taken into account when comparing the observed and model spectra of the photoionized stellar wind.

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