First 3D MHD simulation of a massive-star magnetosphere with application to HÎ± emission from Î¸1 Ori C

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We present the first fully 3D MHD simulation for magnetic channeling and confinement of a radiatively driven, massive-star wind. The specific parameters are chosen to represent the prototypical slowly rotating magnetic O star Î¸1 Ori C, for which centrifugal and other dynamical effects of rotation are negligible. The computed global structure in latitude and radius resembles that found in previous 2D simulations, with unimpeded outflow along open field lines near the magnetic poles, and a complex equatorial belt of inner wind trapping by closed loops near the stellar surface, giving way to outflow above the Alfv Ì•en radius. In contrast to this previous 2D work, the 3D simulation described here now also shows how this complex structure fragments in azimuth, forming distinct clumps of closed loop infall within the Alfv Ì•en radius, transitioning in the outer wind to radial spokes of enhanced density with characteristic azimuthal separation of 15 â 20â—¦. Applying these results in a 3D code for line radiative transfer, we show that emission from the associated 3D â€˜dynamical magnetosphereâ€™ matches observed HÎ± emission seen from Î¸1 Ori C, fitting both its dynamic spectrum over rotational phase, as well as the observed level of cycle to cycle stochastic variation. Comparison with previously developed 2D models for Balmer emission from a dynamical magnetosphere generally confirms that time-averaging over 2D snapshots can be a good proxy for the spatial averaging over 3D azimuthal wind structure. Nevertheless, fully 3D simulations will still be needed to model the emission from magnetospheres with non-dipole field components, such as suggested by asymmetric features seen in the HÎ± equivalent-width curve of Î¸1 Ori C.

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