Accretion Phenomena and Related Outflows, IAU Colloquium 163
ASP Conference Series, Vol. 121, 1997
D.T. Wickramasinghe, L. Ferrario, and G.V. Bicknell, eds.

3-D Hydrodynamic Simulation of Accretion Disk Formation in LMC-X4

Michael P. Owen and John M. Blondin

Dept. of Physics, NCSU, Raleigh, NC 27695-8202

1. Summary

We present preliminary results of a time-dependent, three-dimensional hydrodynamic simulation of LMC-X4, an HMXB known to be undergoing RLOF. The simulation is initialized with the collapsed companion embedded in the undisturbed primary wind. The primary is in contact with the Roche surface, although no tidal stream or accretion disk is initialed; they are allowed to form independently.

Several features of general interest to disk-fed HMXBs are apparent in the simulation. First, the primary immediately develops a compressed-wind disk in the orbital plane. This may be a natural result in most disk-fed HMXBs. For a circularized system in an orbit close enough for RLOF to take place, we may expect the primary to be in corotation. The surface velocity may then be a significant fraction of the breakup velocity, leading to a compressed-wind disk.

A steady state tidal stream quickly develops, forming an accretion disk ($r_{\rm disk} \approx \frac{1}{2} r_{Roche}$) which rapidly ($\approx P_{\rm orbital}$) becomes quasi-static. We find that tidal forces are sufficient to tear apart the in falling stream and "fill" in the disk. Once the disk has formed and entered a quasi-steady state, we find that the tidal stream is approximately twice the disk thickness at the impact site. The tidal stream flows over the disk (without "splash") and merges with the Keplerian flow on the far side near the accretor ($\approx \frac{1}{4} r_{\rm disk}$). Strong spiral shocks in the disk (much stronger than is observed in 2D simulations) which are capable of efficiently transporting angular momentum outward and mass inward to a radius of 10^{10} cm ($\approx 0.1 r_{\rm disk}$), may be powered by the stream impact. The simulation sustains a self-consistent $L_{\rm x}$ of order the Eddington luminosity, in good qualitative agreement with observation.

The disk shows a Gaussian density profile in height, as expected on simple theoretical grounds. However, the scale height at the rear of the disk (away from the primary) is larger than expected; i.e. the disk bulges at the rear. This may be a Bernoulli effect as the fast wind flows across the disk surface. The disk itself is non-circular and offset from the accretor slightly. Both of these effects are most likely due to the strong primary wind impacting the leading edge of the disk, which ablates large amounts of material into the disk's "wind wake".

Finally, a powerful thermally driven wind is driven from the inner edge of the accretion disk, excited by X-ray irradiation. This wind forms a bipolar outflow from the accretor and has a terminal velocity comparable to that of the primary wind. Interestingly, this wind strikes the primary surface and completely suppresses any X-ray irradiation thermal wind that may try to form there.

https://doi.org/10.1017/S0252921100043943 Published online by Cambridge University Press