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Wind Accretion In Separated Binaries

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In the framework of Euler flows, I present simulations of wind accretion in well separated binaries for three different cases: Cygnus X-3, a high mass X-ray binary (see e.g. Schmutz et al. 1996), ζ Aurigae, a system showing strong atmospheric eclipse effects (see e.g. Griffin et al. 1990), and the generic barium star model of Theuns and Jorissen (1993), which is recomputed here with a different numerical method (a MUSCL-type integrator, incorporated in our AMRCART code). These simulations represent a first, small sample out of the large parameter space of wind accretion in separated binaries (see Table 1).

On the orbital scale, the vorticity of the flow is due to the orbital motion of the stars. It is particularly large for the case where the wind velocity is comparable to the orbital speed of the stars (see Fig. 1). In the vicinity of the accreting star, the vorticity is determined by the accretion process. With two strong vortices above and below the accretor (with respect to the orbital plane), the flow resembles the flow out of a bath tub. On a smaller scale, one finds even more vorticity: The flow is highly turbulent. Such turbulence and the shear flows in the large scale vortices cannot be well captured by an Euler flow model. A next step of improvement would be the use of an appropriate MHD turbulence model. There is yet another problem. The size of the accretor (which in the numerical implementation is always larger than the real object), quantitatively

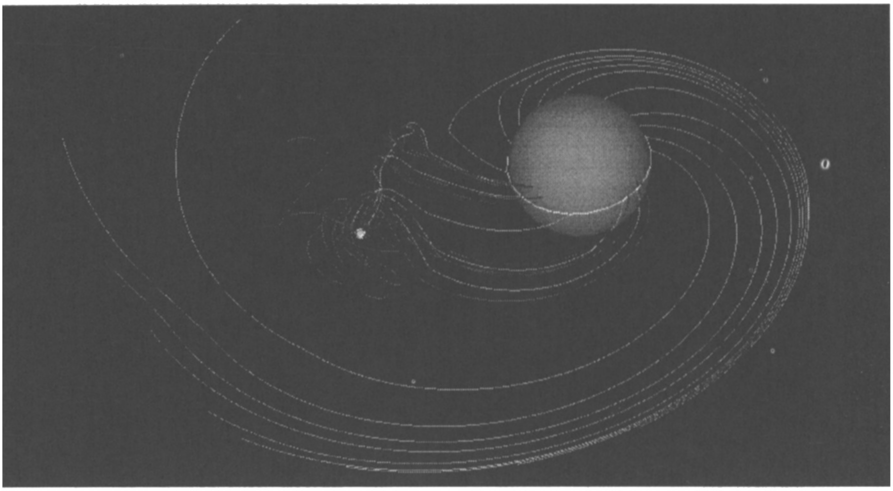

Figure 1. Streamlines of accretion and outflow in the barium star model. Notice the highly turbulent flow in the vicinity of the accretor.

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and qualitatively influences the accretion flow.

Despite these limitations, Euler flow simulations of wind accretion in separated binaries give substantial new insights into the mass-transfer and -outflow in separated binaries. They demonstrate that the Bondi-Hoyle accretion rate is a good measure for the mass transfer rate in binaries with high speed winds. In this case, our results are very similar to those of Ruffert (1996), who investigates non-axisymmetric wind accretion onto a single star. However, if the wind velocity is comparable with the orbital motion, the Bondi-Hoyle rate substantially overestimates the mass transfer rate. Nevertheless, wind accretion can still be very efficient if the mass loss rate of the secondary is high (as e.g. in symbiotics). The orbital motion also essentially determines the accretion of angular momentum, at least in system with circular orbits. There we find unstable accretion and transient rotating accretion cylinder formation rather than a flat classical disk. In the highly eccentric ζ Aurigae, cylinder formation is restricted to Apastron and the direction of rotation is given by the orbital motion.

	Cyg X-3		ζ Aurigae		Barium star model	
period T	4.79 h		972.15 d		895 d	
$a_{min(max)}$	$3.1 \cdot 10^{11}$ cm		$3.95(9.35) \cdot 10^{13}$ cm		$4.5 \cdot 10^{13}$ cm	
ecc. ϵ	0		0.406		0	
donator	WR		K4 Ib		AGB Star	
mass-loss (mlr)	$2.36 \cdot 10^{-5}\ M_\odot/y$		$4 \cdot 10^{-9}\ M_\odot/y$		$1 \cdot 10^{-6}\ M_\odot/y$	
wind vel. v_w	2500 km/s		55 km/s		15 km/s	
accretor	Compact object		B5 V		main sequence	
radius	$\approx 5 \cdot 10^6$ cm		5.1 $R_\odot$		1.0 $R_\odot$	
mass	$\gtrsim 16.9\ M_\odot$		5.4 $M_\odot$		1.5 $M_\odot$	
BH R_A	$7.2 \cdot 10^{10}$ cm		$4.8 \cdot 10^{13}$ cm		$1.8 \cdot 10^{14}$ cm	
R_A/a_{min}	0.23		0.83		4.0	
$v_{donator}/v_w$	645 km/s (0.26)		14 km/s (0.6)		12 km/s (0.8)	
$v_{accretor}/v_w$	480 km/s (0.19)		43 km/s (0.78)		24 km/s (1.60)	
accretion rates						
BH	$2.4 \cdot 10^{-7}\ M_\odot/y$		$1. \cdot 10^{-9}\ M_\odot/y$		$\mathcal{O}(10^{-6})\ M_\odot/y$	
computed	$1.5 \cdot 10^{-7}\ M_\odot/y$		$1.2 \cdot 10^{-10}\ M_\odot/y$		$6 \cdot 10^{-8}\ M_\odot/y$	
% of mlr	0.6 %		3 %		6 %	
% of BH	61 %		8 %		6 %	
angular mom.	spin up		≈ 0		spin up	
drags [dyns]	radial	tang.	radial	tang.	radial	tang.
donator, grav.	+9 (26)	+3 (27)	$+\mathcal{O}(10^{22})$	$+\mathcal{O}(10^{23})$	−7 (25)	+1 (26)
accretor, grav.	−2 (28)	−9 (27)	$-\mathcal{O}(10^{23})$	$-\mathcal{O}(10^{23})$	−2 (26)	−2 (26)
accretor, mom.	−2 (27)	+4 (26)	$-\mathcal{O}(10^{22})$	$+\mathcal{O}(10^{21})$	+4 (25)	+3 (25)

Table 1. Wind accretion of three systems in comparison. *BH:* Bondi-Hoyle, R_A*:* Accretion radius, *mlr:* mass-loss rate.

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