MASS TRANSFER AND EVOLUTION IN LONG-PERIOD BINARY SYSTEMS

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In the earliest studies of close binary evolution (Paczynski 1967; Kippenhahn, Kohl, and Weigert 1967; Plavec, et al. 1968), it was assumed that the total mass and orbital angular momentum of a binary system are conserved during mass transfer. This assumption of convenience actually succeeds quite well in producing model post-mass-transfer binaries which closely resemble classical Algol-type systems, and helium-star binaries such as KS Per and υ Sgr as well (Plavec 1973; Schönberner and Drilling 1983). Among longer-period interacting binaries, however, there are strong reasons to believe that these simple assumptions break down. For example, it is well-known that single stars may lose a very substantial fraction of their mass in a stellar wind during ascent of the giant and asymptotic-giant branches (e.g., Kudritzki and Reimers 1978). In addition, many highly-evolved short-period binaries, such as the cataclysmic variables, appear to owe their origins to very long-period progenitors (Paczynski 1976; Ritter 1976; Webbink 1976). These latter systems evidently evolved through a common envelope phase (Paczynski 1976; Meyer and Meyer-Hofmeister 1979), in which the giant progenitor of the present white dwarf devoured its companion star, and ultimately was divested of its envelope by the release of orbital energy as that companion spiralled toward its core.

Theoretically, there appear to be at least two sets of circumstances in which common envelope evolution is likely to occur. In the first, the combined spin moments of inertia of the two stars are so large that the equilibrium state of synchronous rotation is secularly unstable (Darwin 1879; Counselman 1973), and the orbital angular momentum of the system is absorbed into rotation of one (or both) of its components. In the second, the adiabatic response of a lobe-filling star to loss of mass will not permit it to remain within its Roche lobe (Paczynski, Ziołkowski, and Żytkow 1969), and it engulfs its companion soon after the onset of mass transfer. Such a situation readily develops if the lobe-filling star has a deep convective envelope (Paczynski and Sienkiewicz 1972), and should therefore be prevalent among long-period interacting binaries, particularly those of low mass.

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The classical Algol systems show clear evidence of the bifurcation between courses of evolution which involve dramatic losses of mass and angular momentum and those which are approximately conservative of these quantities: Their distribution in mass and angular momentum shows a nearly total absence of systems in which the original primary component had reached the giant branch prior to mass exchange (Giuricin, Mardirossian, and Mezzetti 1983; Webbink 1986). The missing systems are just those expected to evolve to a common envelope state by the second mechanism described above.

At longer orbital periods, however, the division between these courses of evolution is not so easily identified. Examples may be found among symbiotic stars (e.g., Gallagher, et al. 1979; Kenyon and Webbink 1984) and barium stars (Böhm-Vitense 1980; Webbink 1986) of systems which have survived evolution of one component to the degenerate state, at orbital periods too short to have avoided mass transfer, but too long to have suffered the large-scale losses of angular momentum associated with common envelope evolution. How they have done so is not yet fully understood theoretically, but they probably owe their existence to the stabilizing effects of mass loss from the primary star in a stellar wind prior to mass exchange (e.g., Eggleton 1985), and to the moderating effect of a relatively large core mass on the adiabatic response of that star to mass loss (Hjellming and Webbink 1985).

While the general properties of Algol binaries agree qualitatively very well with the current status of close binary evolutionary theory, the difficulty in understanding the existence of certain long-period binaries, symbiotic stars and barium stars among them, illustrates the inadequacy of theory in this extreme.

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REFERENCES

Böhm-Vitense, E. 1980, Astrophys. J. (Letters), 239, L79.
Couselman, C.C., III 1973, Astrophys. J., 180, 307.
Darwin, G.H. 1879, Proc. R. Soc. London, 29, 168.
Eggleton, P.P. 1985, paper presented at the NATO Advanced Research Workshop on "Evolution of Galactic X-Ray Binaries," Tegernsee, FRG.
Gallagher, J.S., Holm, A.V., Anderson, C.M., and Webbink, R.F. 1979, Astrophys. J., 229, 994.
Giuricin, G., Mardirossian, F., and Mezzetti, M. 1983, Astrophys. J. Suppl., 52, 35.
Hjellming, M.S., and Webbink, R.F. 1985, Bull. Am. Astr. Soc., 17, 840.
Kenyon, S.J., and Webbink, R.F. 1984, Astrophys. J., 279, 252.
Kippenhahn, R., Kohl, K., and Weigert, A. 1967, Z. Astrophys., 66, 58.
Kudritzki, R.D., and Reimers, D. 1978, Astr. Astrophys., 70, 227.
Meyer, F., and Meyer-Hofmeister, E. 1979, Astr. Astrophys., 78, 167.
Paczynski, B. 1967, Acta Astr., 17, 193.

Paczynski, B. 1976, in IAU Symposium No. 73, Structure and Evolution of Close Binary Systems, ed. P. Eggleton, S. Mitton, and J. Whelan (Dordrecht: Reidel), p. 75.
Paczynski, B., and Sienkiewicz, R. 1972, Acta Astr., 22, 73.
Paczynski, B., Ziołkowski, J., and Żytkow, A. 1969, in Mass Loss from Stars, ed. M. Hack (Dordrecht: Reidel), p. 237.
Plavec, M. 1973, in IAU Symposium No. 51, Extended Atmospheres and Circumstellar Matter in Spectroscopic Binary Systems, ed. A.H. Batten (Dordrecht: Reidel), p. 216.
Plavec, M., Křiž, S., Harmanec, P., and Horn, J. 1968, Bull. Astr. Inst. Czechoslovakia, 19, 24.
Ritter, H. 1976, Monthly Notices R. Astr. Soc., 175, 279.
Schönberner, D., and Drilling, J.S. 1983, Astrophys. J., 268, 225.
Webbink, R.F. 1976, Astrophys. J., 209, 829.
Webbink, R.F. 1986, in Critical Observations vs. Physical Models of Close Binary Systems, ed. K.-C. Leung and D.-S. Zhai (New York: Gordon and Breach), in press.

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