Mass loss in PSR 1957+20

SIR—Although the precise mechanism of the eclipses in the binary system containing pulsar PSR 1957+20 is still unclear¹⁻⁵, it is generally agreed¹⁻⁴ that the $\sim 0.02M_{\odot}$ companion¹ in circular orbit ($e < 0.0002$) (ref. 2) is losing mass. Measurement of the mass-loss rate of this very light companion can provide a critical test of theories of this millisecond pulsar as well as the theory of millisecond pulsar evolution^{3,4,6,7}. As pointed out by Kluzniak *et al.*³, the mass loss need not lead to a significant change of the orbital period, P_{orb} , if the ratio of the specific angular momentum lost to the specific angular momentum of the companion star, k , is close to unity, because

$$\dot{P}_{\text{orb}}/P_{\text{orb}} = 2(k-1)\dot{m}_c/m_c \quad (1)$$

where m_c is the mass of the companion. Here we point out that if the change in speed of the neutron star, v_1 , another observable quantity, were measured, then the mass-loss rate could be deduced as

$$\frac{\dot{m}_c}{m_c} = \frac{\dot{v}_1}{v_1} + \frac{1}{3} \frac{\dot{P}_{\text{orb}}}{P_{\text{orb}}} = \frac{\dot{a}_1}{a_1} - \frac{2}{3} \frac{\dot{P}_{\text{orb}}}{P_{\text{orb}}} \quad (2)$$

where a is the semimajor axis.

Equation (2) is model independent. Therefore, observational determination of mass-loss rate can be made by measuring v_1 and P_{orb} as well as their time derivatives.

From theoretical arguments, if the evaporation of the companion is fast enough to explain the original solitary millisecond pulsar PSR 1937+214, $\dot{m}_c/\dot{m}_c < 10^8$ yr is needed. Six months of data on PSR 1957+20 gives $3\dot{P}_{\text{orb}}/P_{\text{orb}} > 10^7$ yr (ref. 2), while $v_1/\dot{v}_1$ is easily measured from the Doppler shift of the pulse period. Within five years, we would probably reach the limit of theoretical interest even if $\dot{P}_{\text{orb}}/P_{\text{orb}}$ is the dominant term.

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1. Fruchter, A.S., Stinebring, D.R. & Taylor, J.H. *Nature* **333**, 227 (1988).
2. Fruchter, A.S. *thesis* (Princeton Univ, 1989).
3. Kluzniak, W., Ruderman, M., Shaham, J. & Tavani, M. *Nature* **334**, 225 (1988).
4. Phinney, E.S., Evans, C.R., Blandford, R.D. & Kulkarni, S.R. *Nature* **333**, 832 (1988).
5. Michel, F.C. *Nature* **337**, 236 (1988).
6. Ruderman, M., Shaham, J. & Tavani, M. *Astrophys. J.* **336**, 507 (1989).
7. Kulkarni, S.R. & Narayan, R. *Astrophys. J.* **335**, 755 (1988).

Kinematics of the Alpine arc

SIR—Platt *et al.*¹ provide a compilation of kinematic data for the Alpine arc which will find far wider use than their particular purpose of establishing the independence of the Adria plate from both the European and African plates. They stress that "we have included only data for which we could find good evidence of age". Their ages are out of date, however, in that they have not taken account of some recent research or of changes in stratigraphic correlations. This is most clearly the case in the south-west Alps, where they have allocated all their south-west-directed motions in the external zones and in the nappes of Embrunais-Ubaye (their arrows 37, 40, 45, 46, 47, 49–51) to ages that are post-Eocene.

A principally sedimentological study² in an area between the Embrunais-Ubaye nappes and the Provençale platform found south-west-directed thrusts that had cut the surface during deposition of calcaire nummulitique (Eocene). The study shows that south-west-directed thrusting constrains the geometry of the Grès d'Annot basin (Eocene). Most thrusts in the upper parts of the external zone succession, and many in the sub-Briançonnais of the lower Embrunais-Ubaye nappes³ are folded by structures that formed during nappe emplacement^{3,4}. The hypothesis that the nappe loading caused the thrusts in the external zone

beneath and which has generally been accepted as a basis for structural correlation, is therefore not valid and an earlier (Eocene) age for much of the thrusting is established.

It is also necessary to reinterpret ages in the literature. Many biostratigraphic zones were once considered of Oligocene age, but are now firmly established as Eocene (see ref. 5, for example). Whereas the shift of the zonal scheme has been 'absorbed' relatively easily, many early attributions of Oligocene age to structural events persist in the structural geology literature. The emplacement of the lower Embrunais-Ubaye nappes is important in structural correlation and is well constrained stratigraphically.

Referring to the nannoplanktonic (NP) zonal scheme, the topmost beds of the Grès d'Annot are NP 19–20 (Muller, cited in ref. 5). The nappes override these beds, after deposition of an olistostrome⁶, but were uplifted, subjected to subaerial erosion, and become the source of the sediment near the base of zone NP 22 at Barrême⁷. Emplacement was therefore within a time window corresponding to zones NP 20 and NP 21. If we now accept the zonal boundary NP 21–22 as the Eocene/Oligocene boundary (as for example p. 393 of ref. 5), the nappe emplacement and all associated structures must be of Eocene, not Oligocene, age.

The pitfalls of structural correlation in the Embrunais-Ubaye region are discussed elsewhere⁸. Readers of Platt *et al.*¹ are

advised that these amended ages do not invalidate the general time-divisions of their Figs 1 and 2 but that, in the south-west Alps and possibly elsewhere, some of the data which they have treated as post-Eocene may be of Eocene age. In any event, their data set is misleading in that it does not indicate the scale and complexity of Eocene Alpine tectonics which, in the south-west Alps at least, was dominated by southwestward displacements⁸.

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PLATT REPLIES—The evidence cited by Fry (unpublished when we wrote our paper¹) for a late Eocene onset of deformation in the external zone of the south-west Alps is of considerable interest, as precise timing of the beginning of deformation in different parts of the Alps should help constrain the rate of convergence. The main evolution of the thrust belt in this region, however, is clearly post-Eocene: Grès d'Annot and flysch of Priabonian (late Eocene) age are imbricated in the thrust sheets; and in the Digne and Nice arcs, Triassic rocks have been thrust over sediments of late Miocene to Pliocene age.

The presence of detritus derived from the Embrunais-Ubaye nappes in late Eocene sediments is not a valid constraint on the timing of external-zone deformation. These nappes, which form part of the internal zone, had been incorporated into the Alpine orogenic wedge and could have been subject to erosion by late Eocene time: kinematic data reflecting this deformation are shown on our map (data sets 41, 42 and 44 in Fig. 1 of ref. 1) and generally trend west or north-west. The accretion of external-zone rocks beneath these nappes occurred later and caused folding, reimbrication and back-thrusting in the older parts of the wedge (data sets 43, 45 and 46): these structures are generally associated with north-east-south-west-directed kinematic indicators, parallel to those associated with the co-eval south-west-directed thrusting in the external zones (data sets 37, 47 and 49).

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1. Platt, J.P., Behrmann, J. H., Cunningham, P. C., Dewey, J. F., Helman, M., Parish, M., Shepley, M. G., Wallis, S. & Weston, P. J. *Nature* **337**, 158–161 (1989).
2. Apps, G. *thesis*, Univ. Liverpool (1987).
3. Lawson, K.D. *thesis*, Univ. Coll. Swansea (1987).
4. Kerckhove, C. *Géol. alpine* **45**, 5–204 (1969).
5. Cavellier, C. (coord.) *et al. Paléogène en Synthèse géologique du Sud-Est de la France. Mémoire BRGM* 125 (1984).
6. Kerckhove, C. C. r. *hebd. Séance. Acad. Sci., Paris* **259**, 4742–4745 (1964).
7. Bodelle, J. *thesis*, Univ. Nice (1971).
8. Fry, N. *Geol. Soc. Lond., Spec. Publ.* **45**, 83–109 (1989).