LETTERS TO NATURE

Infall of Matter into Galaxies

THE concept discussed by R. B. Larson¹ that infall of matter into galaxies from their coronae or from intergalactic space may play an important role in the structure and evolution of galaxies and their nuclei was clearly anticipated in a paper presented in 1963 at the Canberra-Sydney IAU Symposium on the Galaxy and the Magellanic Clouds². I wrote then "It is tempting to regard such nuclei (of galaxies) as the foci of convergence, or injection points of the infalling gas from the galactic corona. . . . The motion may be visualized as a double vortex funnelling coronal matter toward the nucleus. The infalling of the gas need not be limited to the nuclear region, but may occur with progressively reduced intensity (both as to density and velocity) at increasing distances from the centre. Possibly the low-intensity components of the 21-cm line observed in high galactic latitudes at predominantly negative velocities are, at least in part, evidence for the postulated circulation"².

I speculated (as Larson does) that such gas vortices might provide a source of energy and excitation mechanism for line emission in some galactic nuclei. Further on I added "In general it may be presumed that magnetic forces will effectively prevent actual collision or limit its extent, and that most of the gas will be sharply deflected in two streams (recombining to neutral upon reaching the higher density in the galactic plane) flowing in opposite directions away from the nucleus. If so, a permanent flow régime will be set up along the bar under the constant pressure of the infalling coronal gas".

Finally I pointed out that "Because most of the interstellar gas injected into the system will be eventually removed by star formation, only a small fraction at best might be involved in a closed-circuit or recirculating flow pattern; rather one might postulate that the influx of gas from the corona required to maintain a steady centrifugal flow along the bar and into the arms is supplied and driven by the condensation of primordial intergalactic gas . . .".

In support of such views I quoted the preliminary evidence for gas streaming along the bars of spirals⁴ which was later confirmed by our detailed analysis of internal motions in NGC 4027⁵. (Incidentally these studies show that gas is flowing outward along the bars, not inward as assumed by Larson.)

It would seem that the time has come seriously to consider systematically the various possible interactions between galaxies and intergalactic matter and I hope that the Larson paper will contribute to renewed awareness of this problem.

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¹ Larson, R. B., *Nature*, **236**, 21 (1972).

² de Vaucouleurs, G., in *The Galaxy and the Magellanic Clouds* (edit. by Kerr, F. J., and Rodgers, A. W.), IAU Symp. 20, 195 (Canberra, 1964).

³ de Vaucouleurs, G., in *The Galaxy and the Magellanic Clouds* (edit. by Kerr, F. J., and Rodgers, A. W.), IAU Symp. 20, 297 (Canberra, 1964).

⁴ de Vaucouleurs, G., in *The Galaxy and the Magellanic Clouds* (edit. by Kerr, F. J., and Rodgers, A. W.), IAU Symp. 20, 269 (Canberra, 1964).

⁵ de Vaucouleurs, G., de Vaucouleurs, A., and Freeman, K., *Mon. Not. Roy. Astron. Soc.*, **139**, 425 (1968).

Pulsar Glitches and the Metastability of the Superfluid Core

PACKARD¹ has suggested that the glitches in the Crab and Vela pulsars may be caused by transitions between metastable flow states in the superfluid interior of the neutron star. If ΔL_t is the amount of angular momentum lost by the fluid core during the transition, then the fractional increase of angular velocity of the crust would be given by

$$\frac{\Delta\omega}{\omega} = \left(\frac{I_t}{I_c}\right) \frac{\Delta L_t}{L_t} \quad (1)$$

where I_t , I_c are the moments of the superfluid core and the crust respectively and L_t is the total angular momentum of the superfluid core.

We find that this model together with the observed rates of slowdown and the time intervals between the glitches in the two pulsars leads to too small a mass for the Crab pulsar.

The glitches observed in the Crab²⁻⁵ and the Vela⁶⁻⁸ pulsars did not differ from each other in order of magnitude and occurred at regular intervals. If only a fraction of the angular momentum excess is released during a glitch then there will be an accumulation of excess angular momentum in the core and subsequent glitches will either be larger in magnitude or more frequent—there is no experimental indication for that. We therefore assume that at each glitch the core loses the entire angular momentum excess and the pulsar rotates like a rigid body. The experiments of Reppy and Lane⁹ also seem to indicate that in transitions from a metastable state to a state of equilibrium, intermediate metastable states, if any, have small lifetimes.

If ω_1 and ω_2 are the angular velocities of the crust of the pulsar just after the first glitch and just before the second glitch respectively, then the excess angular momentum of the fluid core just before the second glitch is

$$I_t(\omega_1 - \omega_2) = I_t \delta\omega$$

where $\delta\omega \equiv (\omega_1 - \omega_2)$ is the amount of slowdown of the crust between two glitches. We make $\Delta\omega$ the increase of angular velocity in a single glitch as shown in Fig. 1. If the star again rotates like a solid body after the glitch, then from the conservation of angular momentum we have

$$I_c \Delta\omega = I_t (\delta\omega - \Delta\omega)$$

Hence

$$\frac{\Delta\omega}{\omega} = \frac{I_t}{I_c} \left(\frac{\delta\omega}{\omega} - \frac{\Delta\omega}{\omega} \right) \quad (2)$$

The rate of slowdown of the crust $\frac{1}{\omega} \frac{\delta\omega}{\delta t}$ was found to be

$\frac{1}{2,400}$ per year for the Crab pulsar and $\frac{1}{24,000}$ per year for the Vela pulsar¹⁰.

The second glitch of the Vela pulsar occurred about 2.5 years after the first. So

$$\frac{\delta\omega}{\omega} \approx 10^{-4}$$

Further, the glitch observed was

$$\frac{\Delta\omega}{\omega} \approx 2 \times 10^{-6}$$