PULSAR ACTIVITY AND SUPERNOVA REMNANT MORPHOLOGY

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Abstract: *We use the recently introduced concept of a "window" of magnetic field strengths in which pulsars can be active to explain the variation in morphology of supernova remnants. Neutron stars created with field strengths of a value permitting pulsar activity result in particle production and Crab-like centrally concentrated remnants. Other field values lead to strong magnetic dipole radiation and consequent shell formation, e.g., Cas A.*

It has been argued recently that only those neutron stars whose surface magnetic fields lie within a small range will be active as pulsars (Radhakrishnan, 1980; Shukre and Radhakrishnan, 1980). This implies that those neutron stars which are created with fields outside the window will not have a particle outflow from them and can only put out magnetic dipole radiation. We wish to suggest that these two forms of behaviour are responsible for the creation of the two types of supernova remnants found in the galaxy; we assume that a neutron star is formed in every supernova event.

Observations of supernova remnants seem to indicate that they come in two distinct forms, (a) those with filled centres, and (b) those with well defined shells and a hollow interior. Those neutron stars which are active as pulsars produce centrally filled remnants such as the Crab and 3C58, of which about 10 are known so far. The remainder of the 120 or so remnants which have been catalogued are of the shell variety with hollow centres, of which Tycho, Kepler and Cas A are the classic examples. We attribute the form of the shell remnants to the presence in every one of them of a neutron star that is not operative as a pulsar. There is no central nebulosity because no particles are emitted. However, the dipole radiation into which all of the loss in rotational energy is converted is effective in creating the observed shells. The pressure of the radiation acts like a piston on the mantle of the star and accelerates it to high velocities as suggested by Ostriker and Gunn (1971). Multiple reflections in the cavity will render the pressure isotropic and produce spherical shells such as are observed.

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According to the picture sketched above there are active pulsars in about 10 supernova remnants of which only two, the Crab and Vela X, have been detected. Among the factors, some or all of which contribute to the non-detection of pulsars in the remaining filled remnants are: (1) beaming, (2) low flux density and (3) a large dispersion measure. This argument is invoked only for a handful of filled remnants and not, as is often done, for all of the more than a hundred known shell type SNRs. The absence of pulsars in these shell type remnants follows naturally from our hypothesis. The absence of nebulosities around the other 300 or so known pulsars is also understood because of the limited lifetime of the nebulae created by pulsars soon after they are born (Weiler and Panagia, 1978).

The ratio of the number of filled remnants to shell remnants known is approximately the same as the ratio of their expected lifetimes. We conclude therefore that half of all neutron stars that are created function as pulsars, taking no account of those that may 'turn on' as pulsars in later life; it is conceivable that this may happen due to decay of the magnetic field. Thus it is seen that if any serious discrepancy is claimed to exist between the birth rate of pulsars and the occurrence rate of SN, it will be affected by our hypothesis only marginally. If the discrepancy is real, and large, another explanation will have to be sought, e.g., by the formation of neutron stars from white dwarfs - see for example the recent discussion by Shklovskii (1978).

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DISCUSSION

KUNDT: What is your objection to the conjecture that all kelifons (= shell-type remnants) contain a binary neutron star?

RADHAKRISHNAN: No objection as long as these neutron stars do not function as pulsars. In other words they must put out only low frequency dipole radiation but not relativistic particles. I do not see how the pressure of a companion star can be responsible for such a behaviour.

BLANDFORD: In the case of shell sources, would you expect any radio emission from externally accelerated electrons radiating in the low frequency waves?

RADHAKRISHNAN: If there is such emission, I would expect it to be close to the inner boundary of the shell.

GOSS: Would you like to comment on the case of MSH 15-56 or G326.3-1.8? This is a combination of a shell remnant and a filled-centre.

RADHAKRISHNAN: Not as yet. We are thinking about it.

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