POLAR CAP RELIEF AND INTEGRATED PULSE STRUCTURE

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Abstract: *An explanation is offered for the complexity and stability of integrated pulse profiles. We propose that the pulse structure arises from surface irregularities at the polar caps, and we indicate how the surface relief affects the number of charges which are released into the magnetosphere and create the observed radio radiation. The electrons produced in the vacuum break-down in the polar gap carry enough energy to continually modify the surface relief of the polar caps, and we suggest one way in which the surface could be modified in a timescale of a million years.*

The integrated pulse profiles of pulsars are observed to be stable over long periods, with the exception of occasional mode changes in some pulsars (Helfand et al. 1975). Their complexity appears to be correlated with age (Taylor and Huguenin, 1971), and some of the older pulsars have profiles with many intensity peaks. To account for these characteristics there must clearly be a stable mechanism for storing somewhere on the pulsars, the information concerning the details of their integrated pulse structure.

We propose that integrated pulse profiles are a reflection of surface irregularities at the polar caps. Variations in the polar cap surface relief would cause corresponding variations in the local electric field. In the model of Ruderman and Sutherland (1975) this electric field accelerates charges, which produce photons by curvature radiation. These photons produce e^+, e^- pairs which by the same process produce more pairs. A given increase in the electric field causes a larger increase in the photon energy, which causes a sharp decrease in the mean free path for pair production in the 'vacuum gap'. This results in a substantial increase in the number of charges produced at the end of the spark discharge, due to multiplication at each step of the avalanche process. In this manner, the surface relief at the polar cap modulates the flow of charges from various parts of the polar cap. Since the charges radiate coherently, the observed radio radiation depends very sensitively upon the number of charges in the radiating current; this is observed as a variation in the mean

W. Sieber and R. Wielebinski (eds.), Pulsars, 173–175.

https://doi.org/10.1017/S0074180900092834 Published online by Cambridge University Press

intensity of the radio radiation as a function of longitude.

While the positrons produced in the gap discharge are released into the magnetosphere, the electrons which carry a similar amount of energy strike the polar cap. The local heating under a spark combined with the electric tension in the polar cap surface can result in a minor deformation in the form of a bump at the position of the spark discharge. Even an increase as small as 10 Å as the result of a spark will lead to surface variations of the order of 10 cm over a time of $\sim 10^6$ years. Height variations of this order can be supported by the surface layers if the base of such hills is of the order of the size of a spark area $\sim 10^3$ cm. Such height variations suffice to produce the observed variations in the integrated pulse profile through the process described in the previous paragraph.

As the building up of hills $\sim$ 10 cm in height from small deformations $\sim$ 10 Å occurs through a random process, complicated relief patterns will be found only in older pulsars, as suggested by the observations (Taylor and Huguenin, 1971). Such patterns will be stable for periods comparable to their creation time, and the number of features likely to be found along a chord through the polar cap is also in reasonable accord with the observations.

A detailed account of this hypothesis has been given by Vivekanand and Radhakrishnan (1980). There we also discuss an alternative possibility, namely variation of the magnetic field within the polar cap region due to the presence of multipole components which may develop in older pulsars (Flowers and Ruderman, 1977). While large intensity variations as a function of longitude can result from such magnetic field variations, the complex structure found in some pulse profiles suggest that polar cap relief is the more likely cause.

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DISCUSSION

WIELEBINSKI: What does your theory predict to happen at different frequencies? Pulse shapes which are "simple" at lower frequencies become quite complex at higher frequencies.

https://doi.org/10.1017/S0074180900092834 Published online by Cambridge University Press

PROSZYNSKI: May I answer this question? The streams of plasma move along tubes of magnetic field lines. Because of the radius-to-frequency mapping, the cones of emission corresponding to different frequencies point in slightly different directions. Therefore it may happen that the observer's line of sight crosses the cone of high-frequency emission but does not cross the cone of low-frequency emission. This is discussed in more detail in my poster paper "On the emission geometry for the magnetic pole models".

STINEBRING: Doesn't the excavation of the surface described by Ruderman present major problems for a random-wolk build-up of these sparking hills?

VIVEKANAND: It would, if such excavation occurs throughout the lifetime of a pulsar; but ^{56}Fe-ionic current could stop beyond the "mature adult" phase, when protons become a major component of ionic current from the pulsar.

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