Why after 50 years is there no consensus on the pulsar radio emission mechanism?

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After nearly five decades there is still no consensus on what the pulsar radio emission mechanism is. There is a proverbial "catch-22": we need to know specific pulsar parameters, including the obliquity angle α, the angle ζ between the line of sight and the rotation axis, and the height of the emission source, in order to constrain the emission mechanism; however, we need to know the emission mechanism in order to use the enormous body of radio data to determine these parameters and to constrain models for pulsar electrodynamics that depend on them. There has been some recent progress: improved constraints on α and ζ by combining radio and high-energy data to [1], and several different arguments pointing to a radio source region at a height above about 10% of the light cylinder radius. Perhaps the strongest indication of the emission mechanism has come from attempts to interpret nanosecond features in the emission from the Crab pulsar [2].

It is convenient to separate possible emission mechanisms into two classes, based on analogy with the two well-established coherent emission mechanisms, electron cyclotron maser emission (ECME) and plasma emission. One class involves accelerated motion (curvature, linear acceleration and free-electron maser emissions) that can lead to emission in vacuo, and in this sense they are analogous to ECME from planets (notably Jupiter's DAM and the Earth's AKR) and from flare stars. I will argue that these mechanisms encounter seemingly insurmountable difficulties in explaining the brightest pulsar radio emission, due to the growth rates being relatively small and the path length for growth being too restricted. The other class is "relativistic plasma emission" (RPE), analogous to plasma emission in solar radio bursts. The defining characteristic is at least two stages in the emission process: growth of plasma waves that cannot escape from the plasma and partial conversion of the energy in these waves into escaping radiation. RPE allows extremely bright emission provided the plasma waves can build up to sufficiently large amplitudes [2]. In most existing versions of RPE the properties of the growing waves do not take account of the dispersive properties of the pulsar plasma, specifically, a one-dimensional pair plasma with a relativistic spread in velocities in a superstrong magnetic field. I will summarize the dispersive properties of such pulsar plasma, and comment on possible ways in which energy can be fed into relevant large-amplitude waves and on the processes through which these might result in RPE.

References

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