Pulsar Supraluminal Excitation – the Near Field

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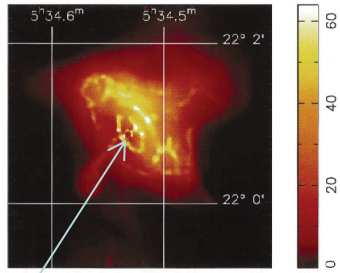
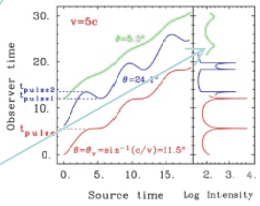
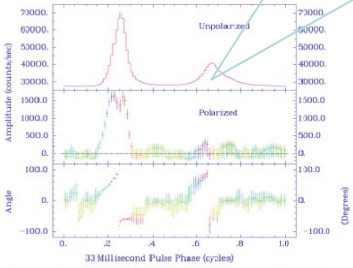
The mechanism of polarization currents excited supraluminally (updated faster than c) by rotating neutron star magnetospheres (SLIP) can be used to explain the pulse profiles of the young, high energy, rotation-powered pulsars, not to mention how supernova progenitors are disrupted, including the details of SN 1987A, and gamma-ray bursts and their afterglows are produced. The directions for which SLIP emission is strongest (obeys a 1/distance intensity law) are two circles on the sky, perpendicular to, and centered on the rotation axis, with polar angles of $\arcsin(R_{LC}/R)$, where $\Omega R_{LC} = c$, and $R(>R_{LC})$ is the radius (as projected onto the plane of rotation) of the polarization current excited at the pulsar rotation frequency, Ω. In a landmark observation of the Crab pulsar from Arecibo, Hankins & Eilek (2007) observed the spectral bands exactly as predicted by SLIP in the interpulse of the Crab pulsar, for the geometry as measured by Wiesskopf et al. (2012), where the preferred direction, for emission from plasma just outside of the light cylinder (0.209% beyond the light cylinder radius – 1.00209 R_{LC}) is 4.5° out of the rotational plane, while the Earth is 29° out. However, the effect was not observed in the Crab's main pulse, which, unlike the interpulse, is sharp enough to indicate it is seen from Earth in a direction where the SLIP 1/distance law operates, which would correspond to plasma at 1.1435 R_{LC}. This is such a small difference that there is no way the lead/lag between the main and interpulse of 0.41/0.59 cycles can be explained by SLIP emission on the equator (a lag of 0.14335-0.00309= 0.14026 cycles), or even from the wind driven on the 4.5° cone. Thus there is the possibility that 2nd ary supraluminal excitations occur well out of the rotational plane, or that vertical shear structure in the magnetic field, or both, account for the phase difference.



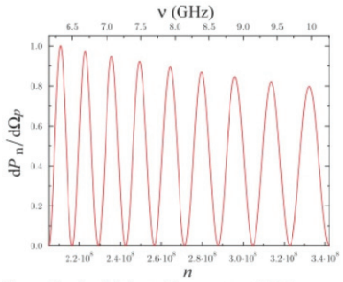
The Crab's rotational axis is 25° out of the plane of the sky. We observe the interpulse well away from the favored direction for plasma just outside the light cylinder (~equatorial). Thus its pulse profile is similar to the green upper curve, confirming SLIP again.



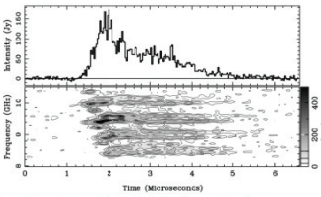
For the lower curve, a time source of finite dimension (1) contributes to a single time (dimension 0) for an observer. Thus the intensity of the pulsations, in the direction represented by this curve (the "cusp" -- polar angle θ_0) only as 1/distance, and this goes on *forever* for the cusp – the further away the observer, the more source contributes to the signal. For observers at larger polar angles, as for the middle curve, two still narrow peaks are observed in the pulse profile, and the intensity drops with the usual 1/distance^2 law. At smaller polar angles (top curve), the pulse profile consists of only a broad, weak, single peak.



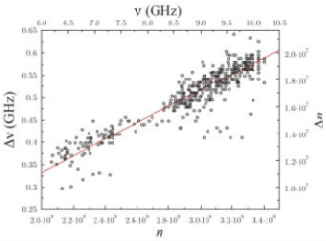
(Top) The optical pulse profile of the Crab Pulsar. (Middle) The polarized pulse profile. (Bottom) The polarization angle of the pulse profile. The spectrum of a giant radio interpulse sub-pulse shows the bands predicted by SLIP (see below).



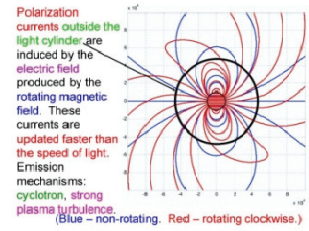
The predicted oscillations of the spectrum of SLIP emission for $\omega/(2\pi) = 30.3$ Hz and $\Omega/\omega \sim 1.9 \times 10^4$. The actual spectrum shown below is identical to this.



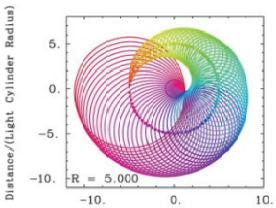
A radio spectrum of a typical giant interpulse, from Hankins & Eilek 2007, shows the bands predicted by SLIP. Giant pulses in the main peak do not show these bands, thus the Crab's pulse and interpulse have different origins. The interpulse is consistent with a view closer to the rotational axis than the optimum angle given by $\arcsin(c/v)$, as given by the upper pulse profile of the three shown in a previous frame, and the orientation given by the Crab pulsar movie of Hester et al., 2002, shown in another frame to follow.



The predicted oscillations of the spectrum of the emission for $w/(2p) = 30.3$ Hz and $W/w \sim 1.9 \times 104$, have the same spacing as those of the emission bands in the observed spectrum of the Crab pulsar (Hankins & Eilek 2007).



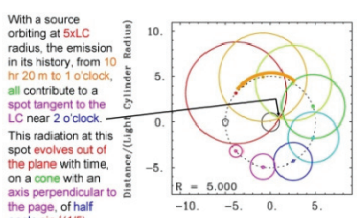
A rotating, magnetized body produces a periodic disturbance, even beyond its light cylinder, which, if there is plasma available, induces polarization currents that are updated faster than the speed of light. The excitation lags one radian for every light cylinder radius.



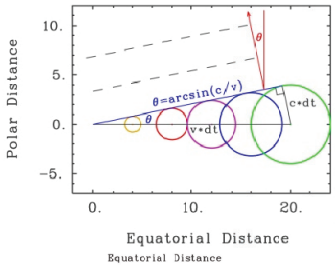
A polarization current source, rotating counterclockwise at 5 times the light cylinder radius, starting just >180°, and ending at just <180°, produces a pattern of emission (Huygens wavelets as colored circles) which is initially focused on its light cylinder (inner circle) just <360°, and then progresses out of the plane with time (see next). The range of sources (dots), contributing to the cusp, runs from red through magenta to blue (180° to 320°), a *third* of an entire revolution.

With a source orbiting at 5xLC radius, the emission in its history, from 10 hr 20 m to 1 o'clock, all contribute to a spot tangent to the LC near 2 o'clock.

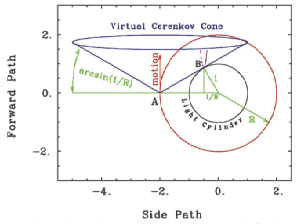
This radiation at this spot evolves out of the plane with time, on a cone with an axis perpendicular to the page, of half angle $\sin^{-1}(1/5) = 11.5°$.



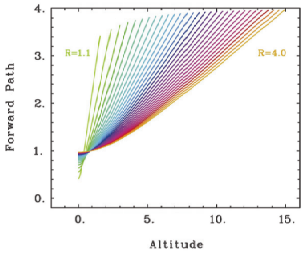
The angular advance from the radiating source to the focus can be explained by considering the geometry as shown below.



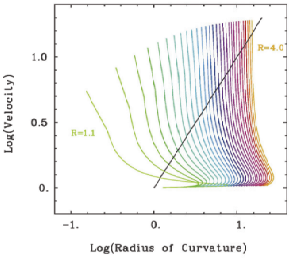
Huygens' wavelets of a supraluminal disturbance (v=5c) propagating from right to left form two fronts, each with a polar angle of arcsin(c/v). Emission in these directions (two circles on the sky) decays only as 1/distance.



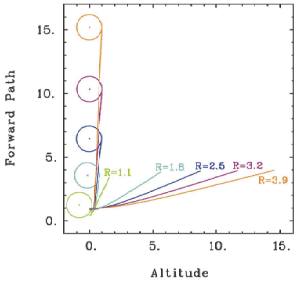
Upward supraluminal motion, at R times the speed of light, of an excitation at point A (red arrow) is seen to be exactly at the speed of light on a virtual Cerenkov cone (virtually slightly rotated for clarity) of half angle, 90° – arcsin 1/R. The acceleration of the excitation toward the center of the light cylinder due to its curving motion breaks the degeneracy of the cone so that the focus occurs on only the one spot, at point B. This focus then immediately splits into/out of the plane to travel along the surface of the cone at constant side path, becoming a hyperbola (magenta), asymptotically approaching the cone angle at large distance.



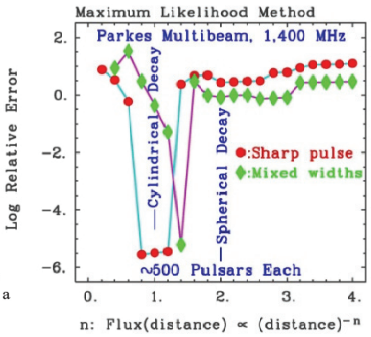
The gain in altitude is greater for the larger radii, as is the offset of the initial focused beam. The plotted radii (R) run from 1.1 to 4.0, and the forward paths run from 0.005 to 3.0, plus the initial offsets (visible at the lower left).



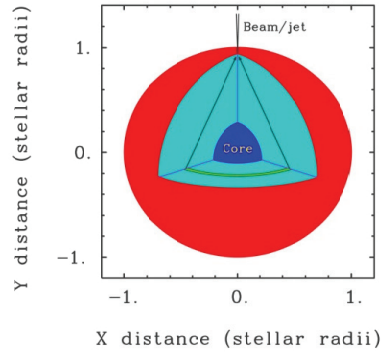
The logs of the velocities on the hyperbolae are plotted against the logs of the radii of curvature at the points where the velocities were interpolated. The black line intersects the curves where such velocities are equal to the radii of curvature, and thus a situation similar to the rotational excitation exists. The extreme deceleration of the velocities on their paths will be a complication, and more calculations are needed to determine the exact effect.



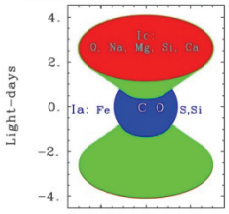
The virtual "light cylinders" of these supraluminal excitations on the virtual Cerenkov cones are plotted along with the initial vectors tangent to them for 5 R's within the 1.1 to 4.0 range. Another set of cylinders will exist for the opposite altitudes. Is one of these the source of the Crab's main pulse? Possibly. New virtual Cerenkov cones will rise out of this plane (along the Side Path direction), and some of these will overlap R=1.1433. Again, more calculations are needed.



The method of Efstathiou et al. (1988) as applied by Singleton et al. [arXiv:0912.0350] shows that those pulsars in the Parkes Multibeam Survey with sharp pulses (full width half maxima <3% of their periods) dim only as 1/distance, while those with wider pulses are displaced toward distance^{-2} as predicted by SLIP.



The pulsar remnant in SNe Ia/c transmutes elements through the r-process while driving these (Na, Mg, Ca) in polar jets, even in or near the stellar photosphere. This happens because carbon and oxygen are available there (as they are throughout the rest of the progenitor). SLIP is the only SN model which accounts for the lines of r-process elements observed even in very early spectra of SNe Ic.



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Conclusions

There *are* secondary focused beams in SLIP emission, but it is not yet clear if these are still strong enough, and high enough in altitude, while still at 1.14 light cylinder radii to explain the 0.41 cycle phase advance of the Crab's main pulse from its interpulse. However, the effect certainly exists. More calculations will be necessary to settle the many questions remaining.

One implication of the operation of the SLIP mechanism in supernova disruption includes the discrediting of Dark Energy as the source of the apparent anomalous dimming of distant supernovae – the real cause being an unrepresentatively overluminous local sample. Without a detailed understanding of SLIP's role in the disruption mechanism, which at present does not exist, Type Ia, or any other type of SNe, cannot be used as standard candles.

Other supraluminal excitation geometries, such as a linearly accelerating supraluminal excitation, can explain outbursts of quasars, and gamma-ray bursts. The inverted distance law for certain directions is common to such excitations, so much so that most, or even all, transient events in the distant Universe are the result of one supraluminal excitation or another.

See: http://www.hindawi.com/journals/aa/2012/898907

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