Pulsar Supraluminal Excitation in Supernova Disruption

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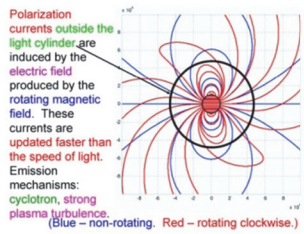
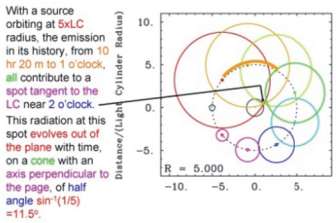
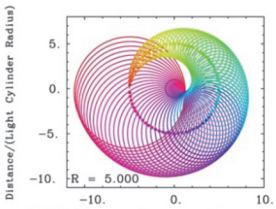
Polarization currents updated faster than c (supraluminally) by rotating, non-aligned, neutron-star magnetospheres, explain the disruption mechanism of supernova progenitors, including the details of SN1987A, gamma-ray bursts, and their afterglows. The directions for which SLIP emission obeys a 1/distance law at great distances are two circles on the sky, perpendicular to, and centered on the rotation axis, with polar angles of arcsin(r/R), where the light cylinder radius, r*Omega=c, and R(>r) is the radius of the polarization current excited at the pulsar rotation frequency, Omega. However, the behavior close to r, is more complicated, involving an offset/obliquity of r(1–r/R), moderating nearby intensities.



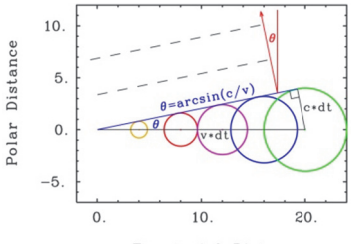
A rotating, magnetized body produces a periodic disturbance, even beyond its light cylinder, which, if there is plasma available, induces polarization currents that are updated faster than the speed of light. The excitation lags one radian for every light cylinder radius.



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



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.



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.

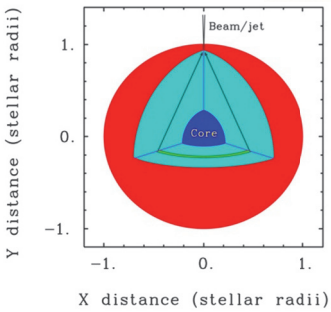
The distance, at time t, between the polarization currents, near $(X,Y,Z)=(0,r_{LC},0)$, but offset by an angle, ϕ, measured clockwise on the circular path of radius R, and the cusp at $(x,r_{LC}^2/R,z)$ can be written, at $\phi=0$, as,

$$\rho(\phi,t) = r_{LC}\{ (ct/r_{LC})^2 - 2ct/r_{LC}\sin\phi + 2(1-\cos\phi) \}^{1/2} .$$

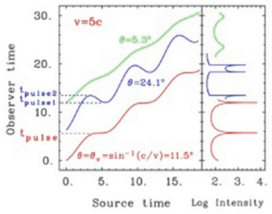
The time delay to this point is: $r(\phi,t)/c, + \phi\, r_{LC}/c$ (due to delay on the polarization current circle). For large distances and small ϕ, this time lag can be written as:

$$r(\phi,t)/c \sim r_{LC}/c\{N + \phi^3/6 + \phi^4/(8N)\};\ \ N == ct/r_{LC} >> 1.$$

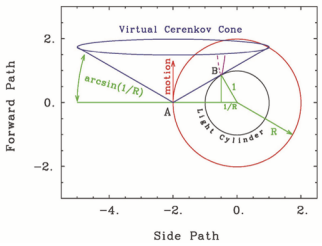
This would produce an infinite response in the favored direction, *even in the time average* (it is the electric and magnetic *fields* that add), as shown in the figure below, were it not for the Y offset of $r - r^2/R$ (1-1/R in units where r_{LC}=1), from the polarization current element. For ϕ=0 and by substituting for Z, and with 1-1/R for Y, ρ can be simplified to: $\rho = RX$. But since $d\rho/dt$=c, then dX/dt=c/R, and this is true even before the cusp forms on the light cylinder, with $0 <= X <= (1-1/R^2)^{1/2}$.



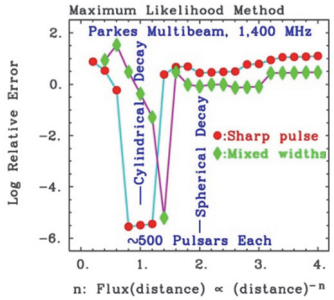
The pulsar remnant in SNe Ia/c transmutes elements through the r-process while driving these (Na, Mg, Ca) in polar jets, even in or near the stellar photosphere. This happens because carbon and oxygen are available there (as they are throughout the rest of the progenitor). SLIP is the only SN model which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



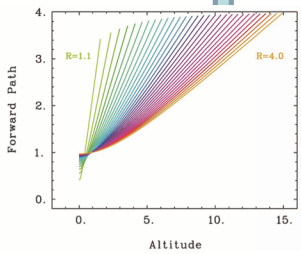
For the lower curve, a time source of finite dimension (1) contributes to a single time (dimension 0) for an observer. Thus the intensity of the pulsations, in the direction represented by this curve (the "cusp" -- polar angle θ_v) only as 1/distance, and this goes on *forever* for the cusp – the further 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.



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.



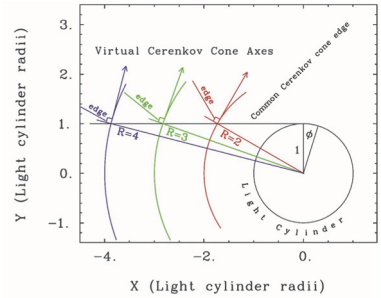
The method of Efstathiou et al. (1988) as applied by Singleton et al. [arXiv:0912.0350] shows that those pulsars in the Parkes Multibeam Survey with sharp pulses (full width half maxima <3% of their periods) dim only as 1/distance, while those with wider pulses are displaced toward distance^{-2} as predicted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



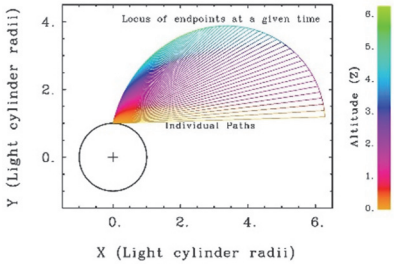
All distances in units of the light cylinder radius, r_{LC}, where $r_{LC}\,\Omega_{pulsar}$= c, and c is the speed of light. Knowing that the path of the cusp will lie on a hyperbola on the *(forward)X - (altitude)Z* plane, with a Y/side-path offset, from the current element, of (1-1/R), with Z=0 and starting at $X=(1-1/R^2)^{1/2}$, we can write the equation:

$$Z = \{R^2-1\}^{1/2}\{X^2 - 1 + \{1/R\}^2\}^{1/2};\ \ X >= \{1-\{1/R\}^2\}^{1/2} .$$

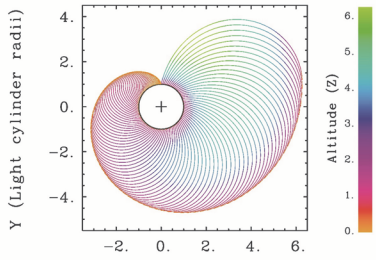
The figure above plots these curves for 30 values of R from 1.1 to 4.0.



Polarization currents from increasingly larger radii contribute to the B field at any given point on the pulsar light cylinder as time progresses, representing larger and larger update velocities, which correspond to wider and wider virtual Cerenkov cones. In turn, the paths of the cusp emanating from the light cylinder point will follow steeper and steeper hyperbolae. For an orthogonal rotator, the polarization currents will be radial.



A single point on the light cylinder (black circle in projection centered on the '+' symbol) gives rise to a whole family of cusp loci as the effect of polarization currents from ever larger radii reach the point. Although the locus of these many points is a curve, each point on this locus is the endpoint of a straight path for a given radius, R. All of these paths begin at Z=0, and then evolve in a given X'-Z plane, where X' is a rotated X axis, and according to the equation, $Z=(R^2-1)^{1/2}(X'^2-1+1/R^2)^{1/2}$. In this plot, the maximum radius for the polarization currents affecting the point on the light is 2π times the light cylinder radius.



The loci of cusps emanating from 100 points, starting at the top and progressing clockwise around the light cylinder, with altitude (Z) coded in color. The maximum radius for the polarization currents is 2π. With plasma out to 100 r_{LC} some 16 generations of these curves would show on the plot. The curves necessarily both begin and end with low altitude (Z). These curves fill out an unbroken surface, and when polarization currents at all altitudes are included, a solid volume. Note that any given point represents a "cusp" with 1/distance law for specific directions which asymptotically trend to the two circles on the sky. These are perpendicular to the neutron star rotation axis, with an angular radius given by *arcsin*(c/v=1/R).

Conclusions

Supernova disruption is an extremely complicated process, driven by supraluminally updated polarization currents, outside of the light cylinder, and caused by the rotating neutron star, in addition to whatever processes occur within the light cylinder. The disruption occurs first at the poles, where the concentration of energy is the highest, and this is the likely cause of the polar beam/jet driven by SN1987A which caused the "Mystery Spot". In addition, material near the poles, just outside of the light cylinder, will be driven tangentially. It is likely this process also produces gamma-ray burst afterglows, which will be found to be 100% pulsed. GRBs themselves are likely to be the interaction of the breakout beam scattering in polar ejecta. Both GRBs and their afterglows are observed across the Universe because each is produced by a supraluminal excitation which obeys a 1/distance law. It is highly unlikely that SNe have been successfully used as standard candles.

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