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Bistable Profile Illumination in Pulsars B0919+06 & B1859+07

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ABSTRACT
Unusual single-pulse behaviour has been identified in two pulsars, B0919+06 and B1859+07. Both stars normally emit bright subpulses in a region near the trailing edge of their profile. However, they occasionally undergo "events", whereby the emission longitude gradually decreases by about their profile width, remains in this position for typically several tens of pulses, and then gradually returns over a few pulses to the usual longitude. The effect bears some resemblance to a profile "mode change", but here the effect is gradual and episodic. On close inspection, the separate profiles of the normal and "event" in each pulsar emission reveal a broad and complex structure—but one which may be understood in terms of the geometry of a conical beam. Possibly the effect entails an extreme example of variable "absorption" within the magnetosphere, as suspected in other pulsars. Alternatively, it may be caused by intrinsic changes in the emission within the pulsar's beam.

Key words: stars: pulsars: B0919+06, B1859+07 –polarisation – radiation mechanisms: non-thermal

1 INTRODUCTION

Pulsar emission phenomena have proved to be a rich area of study, and have often provided needed insights for theory building. The "classical" six such phenomena, drifting subpulses, nulling, profile mode changing, microstructure, polarization modes and "absorption" are well known, and several further well defined behaviours have been identified in recent years.

We describe below a further possible phenomenon which is difficult to categorise under the classsical terms. It was found in two little-studied pulsars in the course of analysing sensitive new Arecibo polarimetric pulse-sequence (hereafter PS) observations. The two stars, B0919+06 and B1859+07, both exhibit highly asymmetric average profiles with a long leading region of weak emission culminating in a bright "component" with a sharp trailing edge. What attracted our attention was that their bright subpulses, usually found in the trailing region, occasionally moved progressively to near the leading profile edge for several score pulses and then progressively back again. In one of the pulsars the effect sometimes seems to recur in a near-periodic fashion. This behaviour — which we simply denote as an "emission shift" — is not a subpulse drift in the usual sense since it does not consist of repeating subpulse bands, but nor is it exactly like a conventional profile mode change, which tends to be sudden and accomplished within a rotation period.

As also with conventional mode-changing, this unusual behaviour is difficult to understand in theoretical terms. In particular, it is not an effect easily visualized in terms of a rotating subbeam "carousel" system. We argue the effect may be related to the potentially important property of "absorption", or alternatively to some "Christmas lights" phenomenon, whereby different sources within the profile window take turns to illumine at different times. Here a preliminary study of the phenomenon is presented so that pulsar investigators may become aware of it. §2 describes our observations, §3 & 4 examine the phenomenon from the perspectives of individual pulses and average profile, respectively. §5 & 7 assess the implied emission geometries of the two stars, §7 considers possible explanations and §8 summarizes the results.

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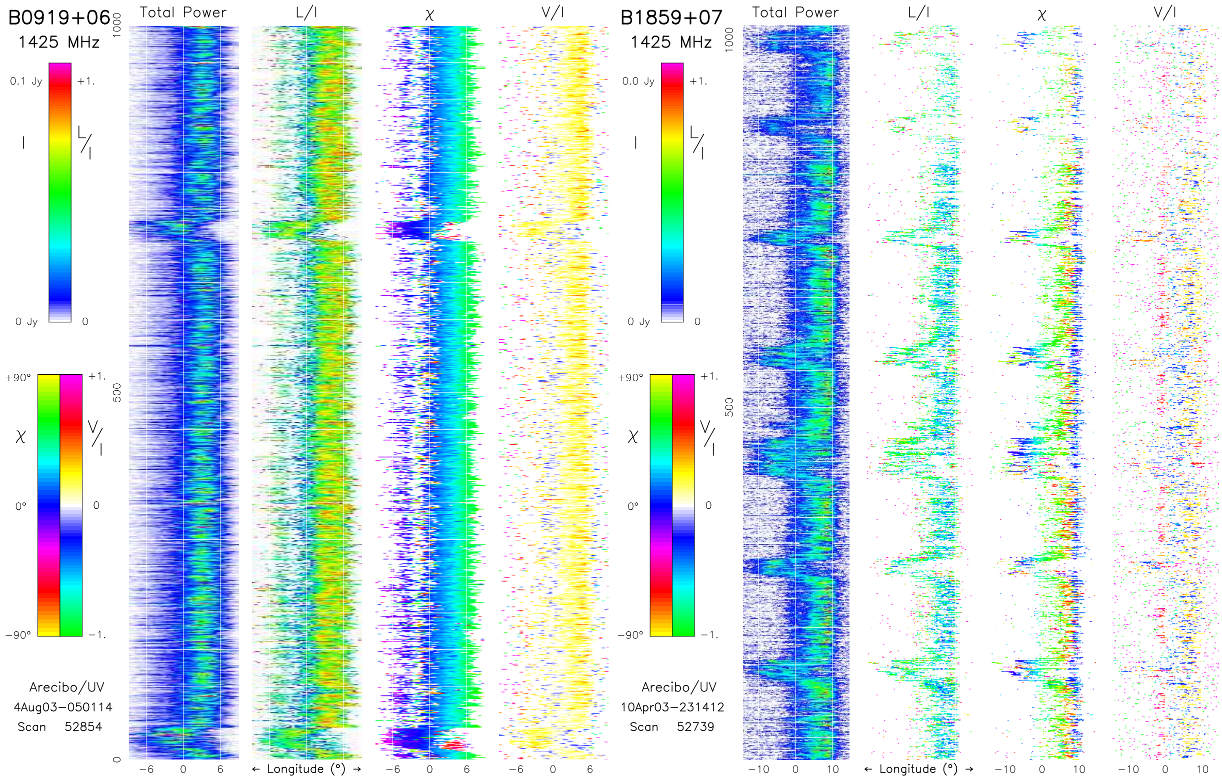

Figure 1. Pulse-sequence polarization displays showing the "emission shift" effect. Two such events are seen in the B0919+06 sequence (left) and some seven in the B1859+07 (right) display. In both cases the onset and return usually occurs over a duration of a few pulses with bright subpulses appearing to shift from the usual emission pattern to an earlier phase. Both panels display a 1000-pulse sequence. The total power I, fractional linear L/I, χ (=PA), and fractional circular polarization V/I are colour-coded in each of the respective four columns according to their respective scales at the left of the diagram. The latter three columns are plotted only when a given sample falls above a 2-sigma noise threshold.

Table 1. Available Observations

Frequency (MHz)	MJD	Resolution (°)	pulses	events
B0919+06				
1404	44857	0.42	3582	2
1404	44859	0.84	1886	none
1400	52854	0.43	1115	2
327	52916	0.43	4180	1
B1859+07				
1400	52739	0.64	1021	6
1400	53372	0.64	2096	8-10

2 OBSERVATIONS

The observations used in our analyses were made using the 305-m Arecibo Telescope in Puerto Rico. The primary L and P-band polarized PSs were acquired using the upgraded instrument together with the Wideband Arecibo Pulsar Processor (WAPP[1]) between 2003 July and early 2005 The ACFs and CCFs of the channel voltages produced by receivers connected to orthogonal linearly polarized feeds[2] were 3-level sampled. Upon Fourier transforming, up to 256 channels were synthesized across a 100- (L) or 25-MHz (P) bandpass with a sampling time of roughly a milliperiod, providing overall resolutions well less than 1° longitude. The Stokes parameters have been corrected for dispersion, interstellar Faraday rotation, and various instrumental polarization effects. The L-band observations usually recorded four 100-MHz channels centred at 1275, 1425, 1525 and 1625 MHz, and the lower three of these were added together appropriately for greater sensitivity. Older Arecibo observations at 1400 MHz (Stinebring *et al.* 1984) were used for comparison as detailed in Table 1.

3 THE PULSE SEQUENCES

3.1 Modulation of the pulse intensity

Figure 1 displays two 1000-pulse sequences (hereafter PSs), one of B0919+06 (left) and the other of B1859+07 (right). Both exhibit episodes in which the emission

[1] http://www.naic.edu/∼wapp

[2] A quadrature hybrid was inserted between the feed and receivers of the P-band system on 11 October 2004, making it thereafter an orthogonal circular system.

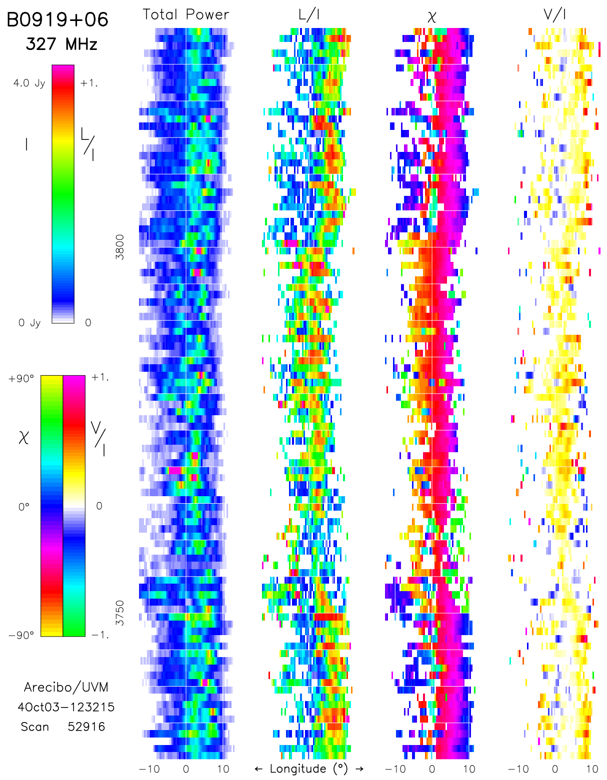

Figure 2. Pulse-sequence polarization display showing a "shift" effect in B0919+06 at 327 MHz as in Fig. 1. Here only a 200-pulse sequence is depicted. The event begins about pulse 3750 and extends to pulse 3810.

moves sharply to earlier phases, leaving the usual region of bright subpulses almost empty. Two such "events" are seen in B0919+06 and some seven in B1859+07. In both stars the emission moves earlier by an amount which is of the scale of the profile width. Each event a) commences and exhibits an orderly shift, over a few pulses, of bright emission toward earlier longitude, b) remains in this state for up to some 20 or so pulses, and c) then gradually returns over a few pulses to the usual configuration and phase of emission. In B0919+06, these events are rather rare—typically one in several thousand pulses—which may be one reason why they have not been reported earlier. In B1859+07, however, they typically occur every 1–2 hundred pulses, and in Fig. 1 they even appear quasi-periodic, though much less so in the MJD 53372 observation (not shown).

In total power (I, column 1), the events almost resemble an effect which could be produced by an instrumental timing fault—possibly a further reason why they have not been noted earlier. They can be seen more clearly in the polarization data of the displays (columns 2–4), in part because the linear (L/I) and circular (V/I) Stokes parameters are plotted only when they exceed a noise threshold. This 2-sigma threshold is shown as a narrow white bar on the I-L/I color bar, but it can only be seen on the B1859+07 bar at about the 5% level because in B0919+06 the signal-to-noise ratio (hereafter S/N) is so high that it disappears into the white region just above zero intensity.

3.2 Modulation of the single pulse polarisation

Close inspection of the third columns of Figure 1 shows that during events the pulses in both pulsars change their linear polarization angles (χ, hereafter PA) in a systematic way. In B0919+06, the PA rotates smoothly from green (+60°) on the trailing edge through cyan (+30°) to almost blue (+15°) on the leading edge of the usual profile, but during an event the PA reaches full purple (−15°). Similarly, in B1859+07, a region of smooth PA rotation begins with near orange (−75°) then rotates through green (+60°) to cyan (+30°) and even blue (0°) during an event. Also of possible significance is a PA jump on the trailing edge to blue (0°).

In B0919+06's normal emission pattern note that there is a region of enhanced linear polarization (L/I) between about –3 and –5° longitude and further that during the two events bright subpulses extend well in advance of –6°. Note also that the region of reduced linear polarization on the leading edge of the normal pattern—which we have taken as the longitude origin—also tends to occur on the trailing side of the event pattern. And both the trailing part of the normal pattern and leading side of the events show some weak negative circular polarization. B1859+07's circular polarization (V/I) is more interesting: we see consistent weak positive at about –2°and a suggestion of weak negative circular around +2°longitude.

3.3 Single pulses from B0919+06 at 327 MHz

Figure 2 shows a time-expanded 200-pulse view of the one event encountered in our only 327-MHz observation of B0919+06 on MJD 52916. At this lower frequency the overall profile width is larger but, surprisingly, the event is less dramatic. In fact it is hardly discernible in total power, but in the linear and even circular polarization (second and fourth columns) we see that the band of highly linearly polarized subpulses moves sharply to earlier longitudes following pulse number 3750 and remains in this configuration until pulse 3810. However, as at the higher frequency, the PA (χ) values during the event exhibit a smooth rotation toward the yellow-orange angle (−80°) from the blue-magenta-red (0 to −60°), a range that is also characteristic of the *un*disturbed emission pattern.

4 AVERAGE PROFILE & MODULATION PROPERTIES

Let us now try to understand the emission shifts further by constructing sets of total (bold) and partial average (lighter curves) profiles. These are shown in Figures 3 for B0919+06 and 4 for B1859+07. The top panels give the total intensity (solid curves), total linear polarization (dashed lines) and circular polarization (dotted lines). The lower panels show the total PA distribution of samples having angle errors less than 3° as well as average PA curves of the total (bold) and partial (lighter) averages.

The asymmetric total profiles of B0919+06 are well known from Stinebring *et al.* (1984) and Blaskiewicz *et*

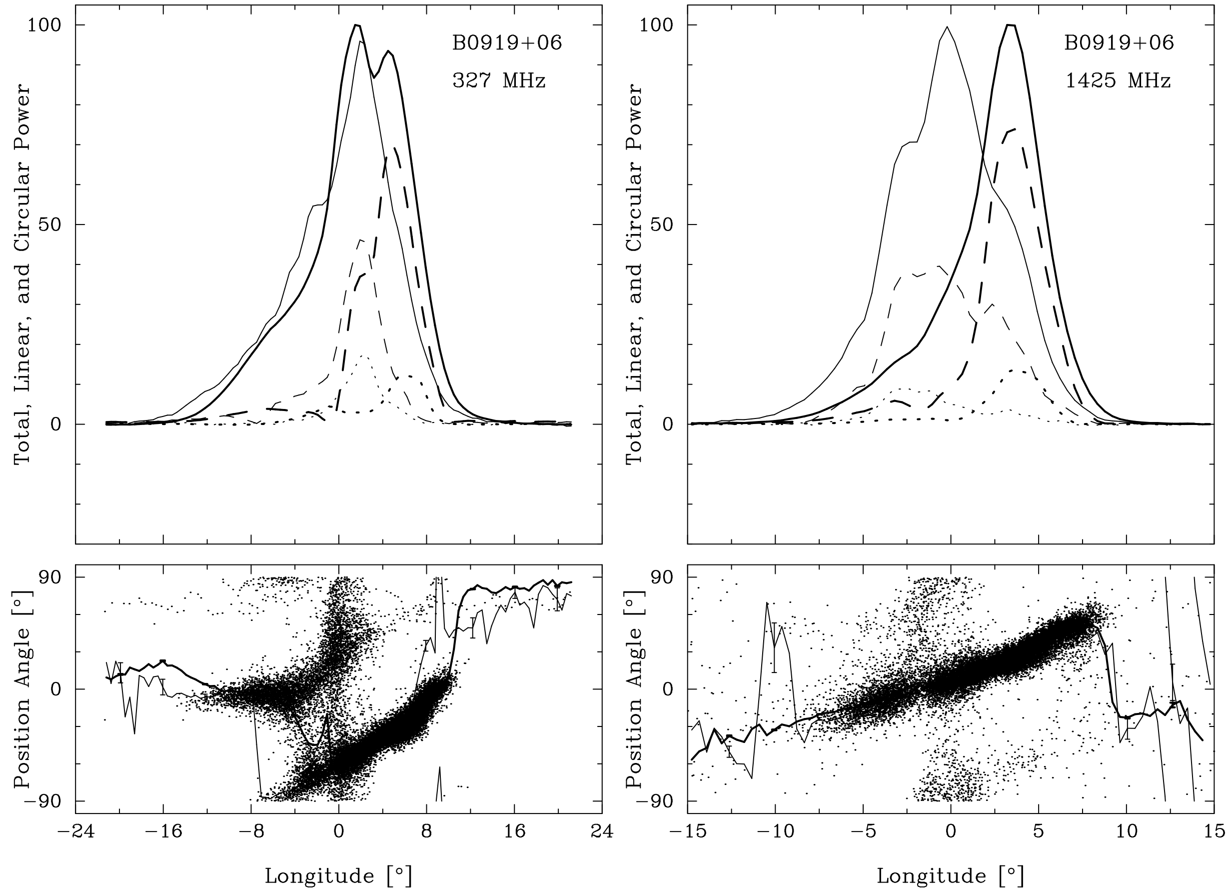

Figure 3. Total (bold) and partial average (lighter curves) profiles of B0919+06 at 327 MHz on MJD 52916 (left) and 1400 MHz on MJD 52854 (right) in the upper panels. Solid curves are the total intensity (Stokes I), dashed the total linear (Stokes L), and dotted the circular polarization (Stokes V). The lower panels give PA histograms corresponding to the total profile of those samples having PA errors smaller than 3° as well as the average PA curves for both the total and partial profiles. The total profiles are very asymmetric with gradual leading and sharp trailing edges. The partial averages include only those pulses associated with the "events" in the respective PSs. Note the markedly different profile forms but highly similar PA behavior.

al. (1991), and even in the latter it was understood that the single bright peak at 21 cms aligns with the trailing component at 430 MHz, probably owing to the work of Phillips & Wolszczan (1991). Fig. 3 shows us that the star's profiles (bold curves) have three main components at both frequencies. At 327 MHz (left diagram) the center and trailing components are almost equally bright with the leading one much less so. During an event, however (lighter curves), the leading component brightens up, the central one remains almost unchanged, and the trailing feature's intensity drops to half or less. Note that the strong linear polarization under the trailing feature simply disappears during the event. Then we see a polarized feature associated with the central component, a leading-edge extension of the region of smooth PA rotation, and indeed a poorly defined linear PA in the region under the trailing component.

A similar, but more dramatic behavior is seen at 1400 MHz in the right-hand display (Note the finer longitude scale). Here the total profile asymmetry is so extreme that we see little apart from the trailing component. The central feature is visible in neither the total power nor the linear polarization, and the leading component shows only as a small bump in both. During the events, however, (lighter curves) the profile position shifts markedly earlier, and the three main components are in clear evidence. The leading component is again much brighter, the central feature now as bright as the usual trailing feature, and the latter's intensity now again reduced to half or so. We also see that the PA traverses of the total and event profiles track each other closely. Finally, recall that the events in this pulsar are rather rare as shown in Table 1, so that the partial averages at 327 and 1400 MHz are comprised of only some 36 and 77 pulses, respectively.

Figure 4 gives a further set of total and "event" partial average profiles for the two observations of B1859+07 at 1400 MHz on MJDs 52739 and 53372. This star's two total average profiles (bold curves) are also very asymmetric with long gradual leading regions and sharp trailing edges. Both observations also show several weak features which may be evidence of underlying component structure. Then, during the events—which are considerably more frequent in this pulsar—the profiles (lighter curves) become more nearly symmetric.

While the total profiles do not exhibit any recognizable profile form, the partial averages are much more

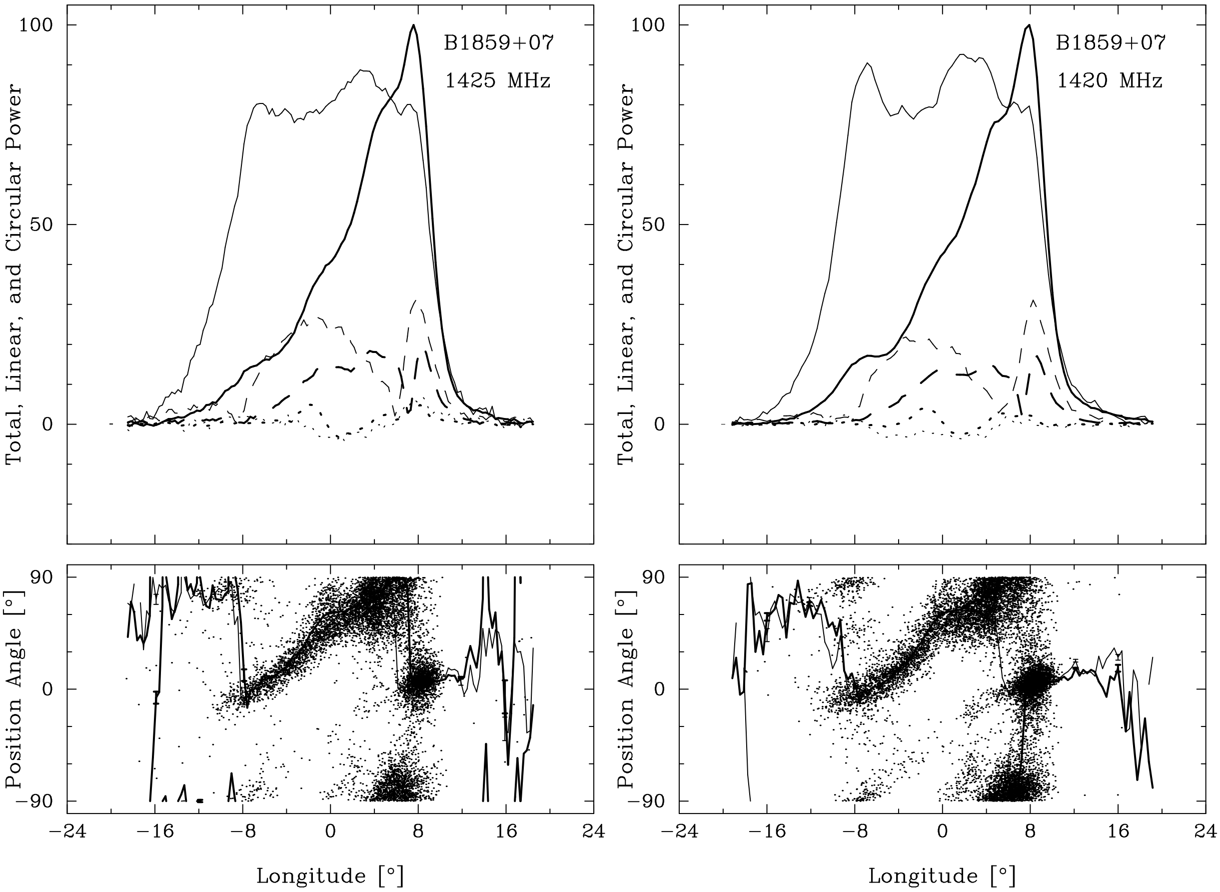

Figure 4. Total (bold) and partial average (lighter curves) profiles of B1859+07 at 1400 MHz on MJD 52739 (left) and 53372 (right) as in Fig. 3. Here the partial averages are scaled up by a factor of 1.5 for easier comparison with the total profiles. The lower panels give PA histograms of those samples having PA errors smaller than 3° as well as the average PA curves for both the total and partial profiles. The total profiles are again asymmetric with gradual leading and sharp trailing edges, whereas the partial averages including only the event pulses are nearly symmetric. Again note the markedly different profile forms but highly similar PA behavior.

interesting. Notice first the tripartite form of the total linear polarization L: we see a trailing feature aligned with the usual bright narrow total-power trailing component at about $+9°$ longitude, then a broad central "hump" between about -8 and $+7°$, and finally a leading feature around -10°. The latter's linear power is small, but note in the lower panel that two different populations of bright polarized subpulse samples contribute to the power in this leading-edge region—one at a PA of roughly -10° and the other at some +80°—contributing to the nearly complete depolarization on the leading edge of the partial profile. We can also see that this polarization-modal behavior on the leading edge mirrors that on the trailing edge, which there has primary polarization-mode power at about +90° immediately followed by secondary polarization-mode power at about 0°. Such adjacent configurations of modal power—producing 90° PA "flips" and linear polarization "nulls"—are most often seen on the outside edges of conal beams (Rankin & Ramachandran 2003). Thus, they seem to mark the sightline crossings of the outer conal beam edge and indicate that even this extremely asymmetric profile is produced in substantial part by a full traverse through a conal emission beam. Again, it is worth noting that the PA distribution reflects the properties of the total profile, but of course emission at longitudes earlier that about -5° only occurs during the "events" as can readily be seen in the right-hand panel of Fig. 1.

Moreover, we see weak antisymmetric circular polarization in the total profiles about the longitude of the origin, and while it is only a few percent positive (near -2°) and negative (near +2°) it is produced by a population of highly circularly polarized subpulses as can again be seen in the righthand panel of Fig. 1. This in turn suggests some core activity in the center part of the profile and argues that overall we should regard the star's profile as reflecting emission from both a core and a cone.

Finally, Weltevrede *et al.* (2006) include both stars in their survey of pulse modulation characteristics. In the case of B0919+06, not surprisingly, they find evidence of a weak modulation with a P_3 of 50 P_1 or more. Also in the case of B1859+07 their fluctuation spectra show a low frequency excess.

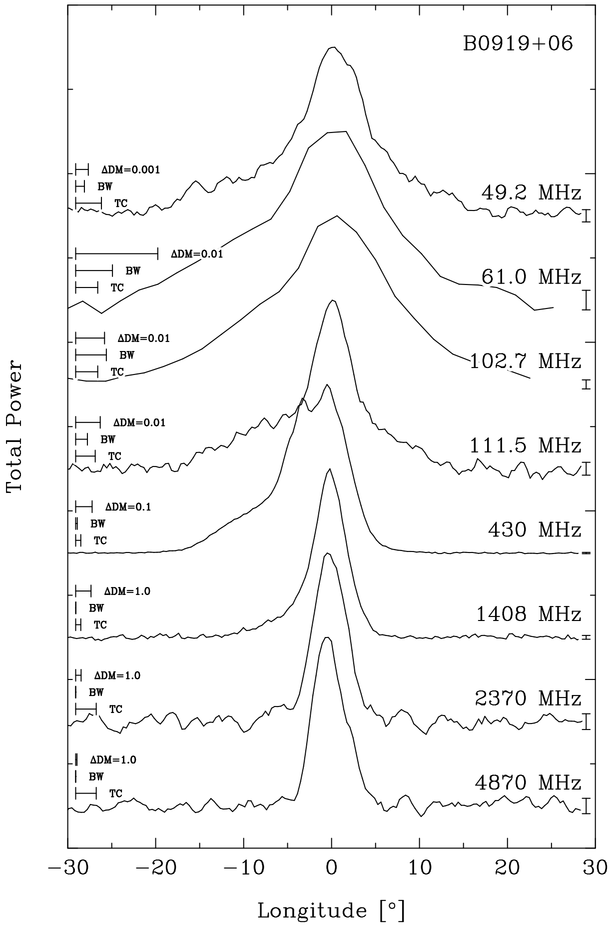

Figure 5. Time-aligned average profiles of B0919+06 between 49 and 4870 MHz. All were recorded using the Arecibo Observatory except those at 61 and 103 MHz, which were acquired at the Pushchino Radio Astronomy Observatory. Bars indicating the instrumental resolutions are given at the left of the diagram. From Hankins & Rankin (2006).

5 B0919+06 PROFILE GEOMETRY

Pulsar B0919+06 is bright over a very large spectral range and has thus been well observed both at very high and very low frequencies. At 21 cms and above, its profile exhibits only a single component—the one we have identified as its trailing component—as we have seen in Fig. 3 (right). Then, in a range including 300–500 MHz, it shows two components (*e.g.*, Fig.3 left), spaced by about 3°. At all lower frequencies the resolution has been such that these two features apparently merge into one broad feature. The entire sweep of this star's profile evolution can be seen in Figure 5, where a set of high quality total power profiles have been time-aligned over a frequency range from 50 to 5000 MHz (from Hankins & Rankin 2006).

Of course, these profiles should not have been aligned as they are: The star's profiles are basically three-componented, so the middle (probably core) feature would provide a better alignment point. This would shift the longitude origin some 4° earlier—near the leading peak of the 430-MHz profile—so that the second peak as well as the higher frequency profile peaks align as a trailing conal component. Then, the time-alignment of the 100-MHz and lower profiles seems to indicate that they too are dominated by this trailing component, and in no other profile do we clearly see the central component.

Quality polarimetry is available for B0919+06 at many frequencies from a number of different instruments. In addition to Blaskiewicz *et al.* and Hankins & Rankin above, Gould & Lyne (1998), von Hoensbroech & Xilouris (1997), Rankin *et al.* (1989), Stinebring *et al.* (1984), Suleymanova *et al.* (1988) and Weisberg *et al.* (1999) have published profiles between 60 MHz and 5 GHz. Unfortunately, most of this work gives little insight into the leading "ramp" region of most interest to us here.

Another hint may come from the size of the triangular "ramp" on the profile leading edges. We first see evidence of this in the asymmetry of the 1408-MHz profile, which we know from the above discussion is associated with the "events" and therefore with activity in the earlier components. Here, its overall scale (see also Fig. 3) is hardly 10°, but from 430 MHz down it appears to have a nearly constant extent of about twice this.

The nearly symmetrical triangular "ramp" on this star's trailing edge at low frequencies is no less strange. We see no hint of it in our 327-MHz profile, but at 111 MHz, it is a significant feature. Nor can this be attributed to scattering; Phillips & Wolszczan (1992) have shown that scattering dominates the star's profile at 25 MHz, but appears to distort it little at 50 MHz. Moreover, the available polarimetry at low frequencies (Suleymanova *et al.* 1988; Hankins & Rankin 2006) suggest that the triangular "ramps" are highly linearly polarized at an angle rotating about $+9°/°$ over the entire profile. These triangular low frequency features—not really components—are quite unusual and deserve further study.

Finally, returning to Fig. 3 the partial profiles provide further indications of the profile's structure, but not enough to significantly improve the geometrical models in Paper VIb. Slightly revising the values there (see Table 5), a putative core width of some 4.7°, 1-GHz profile width of about 10°, and a PA rate of $+9°/°$ indicate an inner cone geometry with magnetic latitude and sightline impact angles of 53 and 5.1°, respectively, and a sightline cut some 25% inward of the outside conal 3-db edge. This may be compatible with the apparent lack of conal spreading at very low frequency.

6 B1859+07 PROFILE GEOMETRY

A more limited record of published observations is available for B1859+07, in part because its relatively short period (0.644 s) combined with a large dispersion measure (253 pc/cm^3) makes it difficult to observe at lower frequencies. Polarimetric observations have been published only by Gould & Lyne (1998) and Weisberg *et al.* (2004).[3] Both show single profiles with a slow rise and

[3] Both observations show anomalies at lower frequencies: The former's 300-MHz profile is poorly resolved and defined polarimetrically; whereas the latter authors were unable to detect significant linear polarization.

steep trailing edge. The average-profile width increases with decreasing frequency; its half-power dimension is hardly 10° around 21 cm and may be as much as 20° in the 400-MHz region.

At no frequency does the star exhibit much fractional linear linear polarization, 20% at most. Gould & Lyne's 1408-MHz profile resembles those in Fig. 4 in both form and fractional linear; even the PA seems to show both the leading ramp and abrupt −90° "jump". The PA rate is about +6°/°, and, as we had observed above, the clear "patches" of modal polarization on the edges of the event partial profile, together with the evidence for low frequency spreading, have the pattern of an outer cone. Moreover, the emission near the center of the profile suggests core activity—and altogether argues that the underlying emission pattern is that of a triple (**T**) or possibly a five-component (**M**) geometry.

We can then compute the basic emission geometry as above using the procedures outlined in Rankin (1993b) for Table 5 of that reference. Estimating the outside (conal) half-power 1-GHz width of the profile as 20° from the "event" profiles in Fig. 4, we find that the star has an outer cone geometry with α and β some 31° and 4.8°, respectively. Interestingly, this geometry also implies a core width of 6.0°, and while we are not able to measure this width accurately from the profiles, we can get some indication of its value from the circularly polarized power in individual pulses referred to above. If we measure the typical separation between the respective leading positively and weaker trailing negatively circularly polarized subpulses associated with the core emission in Fig. 1 (*e.g.* near pulse 150 or 650), the interval is clearly a few degrees. In total power the central feature in the "event" partial profiles of Fig. 4 appears quite broad, but could also be comprised of several merged components (if intrinsically a double cone **M** profile).

7 HOW ARE "EVENTS" TO BE UNDERSTOOD?

Since first noting the emission-shift phenomenon we have tried to understand its character and causes. We considered, for instance, whether it might be caused by a displacement of the emitting region to a higher altitude within the polar flux tube. This idea seems appealing given the gradual nature of the event onsets and returns. However, it turns out that the displacements required are too large in terms of vertical height in the magnetosphere. In both pulsars the magnitude of the shift is about 15°, and interpreted in terms of light-travel-time would correspond to a vertical displacement about one quarter of the light-cylinder radius (5,500 km in the case of B0919+06 and 8,000 km for B1859+07). These figures greatly exceed the height above the neutron star's surface within which the radio emission is widely believed to originate, and must be considered implausible. Furthermore, we have demonstrated in both pulsars a consistency with the picture of a single shared emission cone for both normal and shifted emission, based on the continuous PA change across the profile. A sudden increase in emission altitude would surely lead to an abrupt change to some new PA pattern and a dramatic widening of the total emission cone, and neither of these features is observed.

Rather, on closer inspection, the usual profile of either star seems to reflect an incomplete illumination of the full geometric traverse of the sightline through the emission cone. During the events, the situation is very different: here the partial profiles have recognizable forms, dimensions, component structures and even sensible classifications (*e.g.*, Rankin 1983a). In both cases, the usual total profile is unusually asymmetric, but the partial profiles of the events have the usual and familiar level of overall conal symmetry. Similarly with the PA behaviour, especially of B1859+07: the PA histograms suggest a complete profile with modal power on both edges, but this power is only observed on the leading edge during events.

Given these circumstances, we wondered whether the events could be constructively viewed as a kind of profile mode change. Certainly we do see a good deal of evidence for more or less asymmetric profile illumination in the different modes of a many pulsars. What distinguishes the present phenomenon, though, is its gradual character: usually we see that pulsars take no more than one or two pulses to go from the normal emission pattern to a new mode—indeed, most mode changes seem to occur within a single pulse. We can think of no good case of a gradual mode-change onset.[4] A recognizable reconfiguration of the emission pattern within about a single stellar rotation is thus usually implied in a "mode change".

If the "events" are not a form of conventional mode change (or even if they are), we have seen above that in both pulsars they entail a change in the emission pattern, from one which is concentrated "late" on the trailing edge of the profile—that is well past the probable longitude of the magnetic axis—to one which strongly favors a region earlier than the zero longitude. Such a configuration is very suggestive of the problematic "absorption" phenomenon first identified in pulsar B0809+74 (Bartel *et al.*; Bartel 1981), but now identified in a number of situations (*e.g.*, Rankin 1983b). Indeed, in the current context "absorption" provides an interesting model: if one looks carefully again at Fig. 1, it *does* appear that the leading part of the emission pattern is usually obscured, but during an "event" it is rather the trailing part which is obscured.

Evidence in other pulsar contexts does indeed suggest that a partial or complete blockage of the radiation from either the leading of trailing side of the magnetic axis longitude does occur. The most interesting recent evidence about the phenomenon comes from studies of the drifting-subpulse patterns of pulsars B0943+10 (Deshpande & Rankin 1999, 2001; Rankin *et al.* 2003; Rankin & Suleymanova 2006) and B0809+74 (Rankin *et al.* 2005; 2006a,b), where the rotating-subbeam "carousel" is usually visible only at longitudes later and earlier than the central longitude, respectively. Fascinatingly, however, this is not always the case: in B0809+74 the "absorption" characteristics are frequency dependent and possi-

[4] We do have some evidence for a gradual as well as sharp character to mode changes in pulsar B0943+10 (Suleymanova *et al.* 1998; see also Rankin & Suleymanova 2006)

bly are in some cases specific to one polarization mode. In B0943+10 recent studies show that the "absorption" properties can change very slowly; the profile changes entailed in a transition from its Q to B emission mode take the order of an hour to completely change from favouring emission prior to the central longitude to nearly precluding it.

We have, however, cautiously maintained inverted commas around the word "absorption" since the presence of an absorbing agent between ourselves and the source may not be the only interpretation for the emission shifts in B0919+06 and B1850+07. We might equally suppose that different regions of the open emission cone defined by the profile structure illumine at different times, in the manner of "Christmas lights", so that the emission flips from one side of the magnetic axis to the other. However, both explanations demand dynamic, irregular changes in the pulsars' magnetospheres—whether in the absorbing or emitting material—for which no model has yet appeared, and there would seem to be no observational way to distinguish between the two hypotheses.

An interesting point is that in both B0919+06 and B1859+07 the "events" shift the emission earlier. Other prominent instances of "absorption" show no such bias: as noted above, B0943+10's effect usually curtails emission after the central longitude, whereas just the opposite is true for B0809+74. Thus, we might speculate that there might be other pulsars which could usually emit early and then throw their emission later during "events". Indeed, a very similar effect is seen in B2034+19, but in that case the changes are quick, bounded by nulls and are easily classed under the "mode-change" rubric (Redman 2006). It is also possible that in some stars the "events" occur much more frequently so that they are seen merely as chaotic subpulse modulation; pulsar B1604–00 may provide such an instance (*e.g.*, Rankin 1988).

Taking the pulsars B0919+06, B1859+07 and B1604-00 as the most convincing exemplars of the emission shift phenomenon, we attempted to find some common features among their basic physical parameters. However, their spin-down ages give no clue: they range from the "middle-aged" B0919+06 at 0.5 Myr to B1604-00 at 20 Myr. Much the same is true of their inferred surface magnetic fields and their corresponding light-cylinder values. The only possible hint is that their rotation periods are fairly close to one another (0.43, 0.64 and 0.43 s respectively) and somewhat shorter than the average for the general population of "slow" pulsars. Physically, this may suggest that the observed *gradual* emission shift requires an intermediate-size light-cylinder for its operation.

8 SUMMARY

We identify what may be a new aspect of pulsar behavior wherein the emission usually comes from a trailing region of the profile, but then occasionally shifts earlier over a few pulses to illuminate the leading part of the profile for some 20–50 pulses, and then shifts back again over a few pulses. Both B0919+06 and B1859+07 exhibit the effect, the former perhaps once in 2000 pulses and the latter about 10 times more often.

Both stars exhibit asymmetric single profiles which defy ready classification, though in the case of B0919+06 enough structure has been discerned to suggest that it has three main components (Rankin 1993b). However, when partial profiles are constructed only of the pulses framing the "events", more recognizable profile forms are found—and in both cases we have been able to identify some of the underlying component structure and work out their probable basic emission geometry. It is interesting that B0919+06 is among the stars thought by Lyne & Manchester (1988) to represent a class of "partial cones"—and indeed we certainly find that this classification is appropriate, given that only during its "events" is the leading part of its cone illuminated. It will be interesting to see if other pulsars with asymmetric single profiles thus classified by Lyne & Manchester also exhibit similar "events"—and whether other stars exhibiting the effect will be found to throw their emission later rather than earlier.

Our primary interest in these pulsars and their behaviour, however, lies in the possibility that the "events" represent an example of the profile "absorption" effect. In both it is possible to interpret the emission shift as if emission in the leading part of the profile is normally obscured and then, for brief intervals, the obscuration shifts to the trailing part of the star's profiles. "Absorption" appears to exhibit this sort of asymmetry about the longitude of the magnetic axis in other pulsars, and it also exhibits a gradual onset in some other instances. Nevertheless, we cannot rule out that the effect might represent an intrinsic relocation of the emission sources within the defined emission cone, so that the emitting zone appears to shift laterally as different regions switch on and off. Clearly, we do not yet understand physically the origin of this phenomenon, but the starting point must be define its observational characteristics.

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