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Pulsar Searches at Effelsberg — Past, Present & Future

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Abstract. It is fair to say that pulsar searches with the 100-m Effelsberg telescope have had something of a checkered history — after all, for many years, this was the largest radio telescope in the world never to have found a pulsar! This situation has, happily, changed. In this review we summarize recent discoveries of weak pulsars along the Galactic plane, give a progress report on a survey for highly dispersed pulsars in the Galactic centre and, in the spirit of this meeting, speculate on what should be a bright future for pulsar searches with this instrument.

1. Early Pulsar Searches at Effelsberg

With its large collecting area and low-temperature receivers, the 100-m telescope at Effelsberg is certainly a prime instrument for pulsar observations in the Northern hemisphere. Undoubtably the main reason for not finding pulsars in the early years was the lack of time allocated for searching, with the telescope being heavily in demand by other users. Some search projects were initiated during the 1970s, however, the most significant effort being a targeted search at 21 cm carried out by Seiradakis & Graham (1980). The list of 44 targets included 20 supernova remnants and 15 globular clusters. The search system at the time achieved sensitivity to pulsed signals with periods in the range 0.3 to 3 s as weak as 2 mJy. Interestingly, this was probably one of the first attempts to find pulsars in globular clusters.

Looking back at the source list of Seiradakis & Graham, it is interesting to note that they narrowly missed out on finding the 289-ms pulsar B1745−20 in the globular cluster NGC 6440 — eventually discovered by Manchester et al. (1989). Seiradakis & Graham would certainly have discovered the relatively bright 549-ms pulsar J0215+6218 (Lorimer, Lyne & Camilo 1998) had the supernova remnant that it sits within (G132.7+1.3) been compact enough to have been included in their source list. Either of these discoveries would, surely, have sparked a revolution in the use of Effelsberg as a pulsar searching instrument. As it was, pulsar observations with the telescope since that time have largely taken advantage of the excellent performance of the instrument at frequencies up to 40 GHz (see e.g. the contribution by Wielebinski in this volume).

2. The 21-cm Galactic Plane Pulsar Survey

Following the early announcements of pulsar discoveries by the Parkes multi-beam survey (Camilo et al. 1997; see also contributions by Camilo and Manchester in these proceedings) we decided, along with our colleagues in Bonn, that a search of the northern Galactic plane at Effelsberg would be a worthwhile and fruitful use of telescope time. The search capabilities of the instrument during the summer of 1998 were somewhat limited — only one 21-cm beam with 16 MHz bandwidth (4×4 MHz frequency channels!) in each of two polarizations were available at that time.

In spite of these limitations, the large forward gain (1.5 K/Jy) and relatively low system temperature of the receiver (30 K) meant that we could achieve a sensitivity to long-period pulsars of around 0.3 mJy in a 36-min integration — only a factor of 2 worse than that obtainable at Parkes. With this system we embarked on a survey of a 2-deg^2 patch of the northern Galactic plane defined by $28° < l < 30°$; $|b| < 0.5°$. The interested reader is referred to Lorimer et al. (2000) for gory details of this experiment. In brief, seven pulsars were detected, four of which were previously unknown. Figs. 1/2 and Table 1 summarize these results. The new pulsars are relatively weak (sub-mJy), high dispersion measure objects.

PSR	J1841–0345	J1842–0415	J1844–0310	J1845–0316
R. A. (J2000)	$18^h41^m37^s$	$18^h42^m11^s$	$18^h44^m45^s$	$18^h45^m53^s$
Decl. (J2000)	$-03°45'23''$	$-04°15'39''$	$-03°11'51''$	$-03°16'53''$
Period (sec)	*0.2040665*	*0.5266813*	*0.5250487*	*0.2076355*
Epoch (MJD)	51330	51070	51350	51350
$\dot{P}(10^{-15})$	59	22	10	9
DM (cm^{-3} pc)	170	167	908	500
S_{1400} (mJy)	0.9	0.5	0.6	0.6
τ_c (kyr)	55	380	824	371
B (10^{12} G)	3.5	3.4	2.3	1.4

Table 1. Observed and derived parameters of the new pulsars.

The astute reader will, by now, have noticed a striking similarity between the periods of PSRs J1842–0415, and J1844–0310, and, to a lesser extent, PSRs J1845–0316, and J1841–0345. It is left as an exercise to show that the *a-priori* probability of finding pulsars with such similar periods is vanishingly small! This unexpected result initially gave us some cause for concern that the "signals" we had detected were indeed pulsars. However, having thoroughly investigated each source, we are confident that this is nothing more than a bizarre coincidence. In particular, regular timing measurements carried out over the past year show that each pulsar has a distinct set of spin-down parameters. Perhaps the most interesting new discovery is the 204-ms pulsar J1841–0345, which based on its period and period derivative has a characteristic age of about 55 kyr. Presently, no known supernova remnant is associated with this young neutron star.

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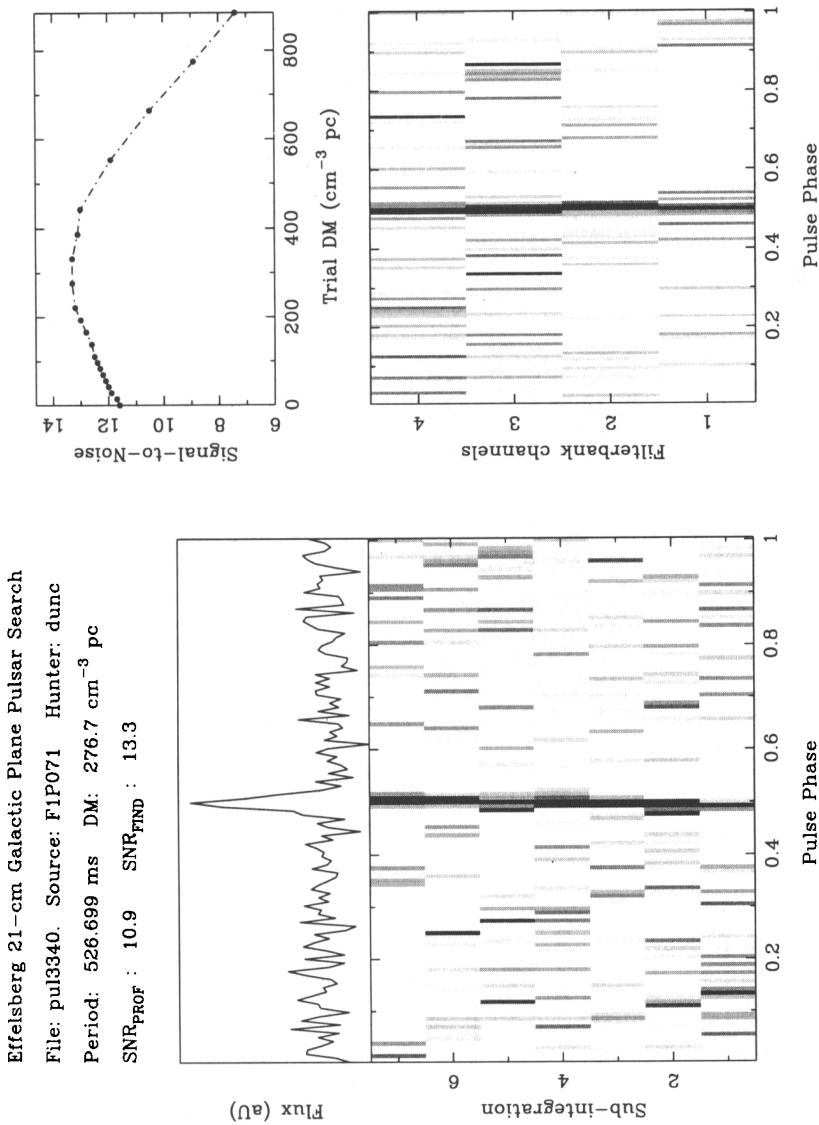

Figure 1. Search output for J1842-0415, — the first Effelsberg pulsar!

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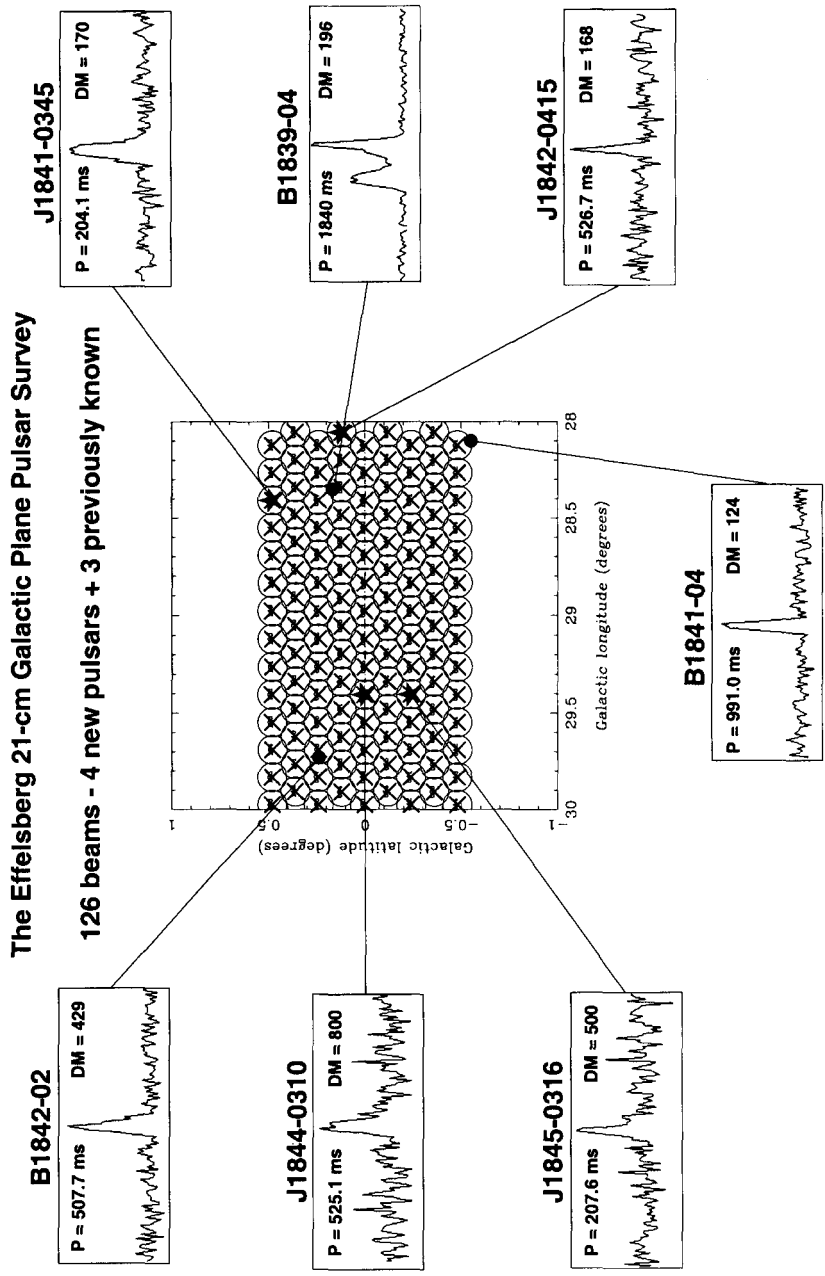

Figure 2. The searched area and pulsar detections in the 21-cm survey.

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3. The 6-cm Galactic Centre Pulsar Survey

Whilst the aforementioned discoveries of the 21-cm survey would have allowed us to obtain more time from the Effelsberg TAC to expand the survey region, the announcement that the Parkes multibeam search was being extended out to $l = 50°$ (Lyne et al. 1999) made us re-think our search strategy to cover a different region of parameter space.

A project actively being undertaken in this regard is the 5-GHz (6-cm) search of the Galactic centre region reported in detail by Kramer et al. elsewhere in these proceedings. In brief, the survey aims to find highly dispersed pulsars in the Galactic centre which are presently rendered "invisible" to lower frequency surveys by to the deleterious effects of interstellar scattering. As discussed by Camilo in these proceedings, several of the pulsars discovered in the Parkes multibeam survey have severely scatter broadened pulse profiles at 21-cm. Given the potentially large amount of scattering material in the Galactic centre, high frequency surveys are certainly required to pluck out pulsars that must certainly reside in this very exciting area of our Galaxy.

Effelsberg is presently the most sensitive telescope in the world capable of observing at 6 cm; a natural goal for a long time has therefore been to search a ~ 1 deg^2 box around the Galactic centre. The new wide-band dual-beam 6-cm search system reported by Kramer et al. in these proceedings has now been commissioned and is achieving a sensitivity of 0.1 mJy on the sky. For typical pulsar spectral indices between -1 and -2, this translates to a sensitivity between 0.3–1.2 mJy at 21 cm and should allow us, for the first time, to probe the population of pulsars in the inner Galaxy. In particular, the sensitivity of this survey as a function of dispersion measure surpasses any other present search system at lower frequencies.

4. Future Goals and Directions

Looking ahead to the future, we now briefly outline some possible search strategies ideally suited to Effelsberg, or indeed any other 100-m class telescope in the Northern hemisphere for that matter!

4.1. A targeted search of dispersed regions at 6 cm

Despite its good sensitivity, the dual-beam 6-cm search outlined above is unlikely to be profitably used in large-area searches of the Galactic plane simply because each beam width is only 2.5 arcmin. There are however a number of interesting targets requiring relatively few telescope pointings where we might reasonably expect to find a highly dispersed pulsar. These include Wolf Rayet stars, HII regions and distant supernova remnants.

4.2. Searches using the I-EBPP

Whilst the 4-MHz channel bandwidths of the 21-cm filterbank used in the Galactic plane survey are adequate to detect long-period pulsars with relatively high dispersion measures, they are virtually useless when searching for millisecond and short-period pulsars with dispersion measures $\gtrsim 20$ cm^{-3} pc. To maintain

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sensitivity to such objects, a filterbank with much finer channelization is required. It was this factor that motivated the purchase of a filterbank designed by Don Backer at UC Berkeley. The I-EBPP (the **I**ncoherent part of the **E**ffelsberg-**B**erkeley-**P**ulsar-**P**rocessor), will provide rapid sampling of bandwidths of up to 100 MHz and frequency resolutions as good as 125 kHz. Final stages of I-EBPP installation were in progress during this meeting and it is hoped that, by the time these proceedings appear in print, the system will be taking data as both a search machine, and a single pulse polarimeter.

One of the immediate scientific goals of a search with the I-EBPP would be to target a number of globular clusters at 21 cm. This is motivated in part by the remarkable spate of discoveries in 47 Tucanae using the 21-cm system at Parkes (Camilo et al. 2000; see also contribution by Freire et al. in these proceedings), and also the significant improvements in sensitivity over previous cluster searches (e.g. Biggs & Lyne 1996). The long integration times possible for many clusters would naturally lend themselves to the new binary search techniques described by Ransom elsewhere in this volume. Another worthy project using Effelsberg and the I-EBPP would be to undertake a large-area survey of the Galactic plane at 2.3 GHz (11 cm). The aim of this configuration is to use the higher frequency to dig deeper into regions along spiral arms where one might expect enhanced scattering which would hamper detections at e.g. 21 cm.

In summary, the prospects for future searches with at Effelsberg are most promising. The unique frequency coverage and sensitivity of the telescope mean that it could play a valuable role in our understanding of the pulsar population in the inner Galaxy, and also in globular clusters.

Acknowledgments. Finally finding pulsars with the Effelsberg telescope (and thus winning a bet or two in the process!) has been a team effort and it is a great pleasure to acknowledge the significant roles played by colleagues: Axel Jessner, Peter Müller, Berndt Klein, Norbert Wex, Christoph Lange, Jiannis Seiradakis and Richard Wielebinski, all of whom have in various ways been instrumental in getting the search system at Effelsberg going in recent years. We are also indebted to the dedicated telescope operators who have helped us to collect search data at all hours of the night during the 21-cm survey.

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