The Effect of Pulsar Timing Noise and Glitches on Timing Analysis for Ground Based Telescopes Observation

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Abstract

Pulsed emission from a number of gamma-ray pulsars is expected to be detectable with next generation ground-based gamma-ray telescopes such as MAGIC and possibly H.E.S.S. within a few hours of observations. The sensitivity is however not sufficient to enable a detection within a few seconds as reached by radio surveys. In some cases we may be fortunate to do a period search given a few hours' data, but if the signal is marginal, the correct period parameters must be known to allow a folding of the gamma-ray arrival times. The residual phases are then subjected to a test for uniformity from which the significance of a signal can be assessed. If contemporary radio parameters are not available, we have to extrapolate archival radio parameters to the observation time in question. Such an extrapolation must then be accurate enough to avoid significant pulse smearing.

The pulsar ephemerides from the archival data of HartRAO and Princeton (between 1989 and 1998) provide an excellent opportunity to study the accuracy of extrapolations of such ephemerides to the present moment, if an appropriate time shift is introduced. The aim of this study is to investigate the smear in the gamma-ray pulse profile during a single night of observations.

1. Introduction

A new generation of Imaging Atmospheric Cherenkov Telescopes [3,4] such as MAGIC [2,5] attempts to cover the energy range between 10 GeV and 1 TeV with improved sensitivities. The so-called imaging method is applied to reject the high background of charged cosmic rays.

However at very low energies, around 10-30 GeV, the Cherenkov light yield may be too faint to produce good images of extensive air showers.

Without the gamma/hadron discrimination capabilities provided by imaging, the background of cosmic-ray initiated showers becomes a serious problem, both because of its magnitude and because of the difficulty to estimate accurately

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its contribution to the observed rate of events.

However, in observing periodic sources such as pulsars, a timing analysis may in part overcome these difficulties. We present an analysis of the effect of pulsar timing noise by using extrapolated ephemerides from radio observation to the γ-pulsar candidates online observation.For our studies, the HartRAO data base provided ephemerides for 5 pulsars and 43 were selected from Princeton data base. The long duration of these data bases allow us to study the effect of timing noise when attempting to extrapolate ephemerides in the absence of contemporary radio observations.

2. Method: Testing the extrapolation of the ephemeris

Assuming that MAGIC will be fully operational in 2003, and assuming a typical run of 6 hours per night, the question remains if it is possible to extrapolate radio parameters derived around 1997 to an observation period during 2003. This implies a data gap of six years and to answer this question, data from 1990 to 1992 are used to predict the pulsar period during 1997. The predicted minus observed frequency for 1997 then gives us an indication of the accuracy of extrapolation. Thus, assuming that there are no observations between 1997 (that is the last year with pulsar observation given the present catalogues), and 2003, we need to extrapolate over a period of 6 years to give the predicted frequency:

$$\nu_{\mathrm{extrap}} = \nu_o + \dot{\nu}(t - t_o) + \frac{1}{2}\ddot{\nu}^2(t - t_o)^2 \tag{1}$$

where t_o is the reference time and t the time corresponding to the observations in question. The difference between the true frequency ν(t) at the present epoch t, given a typical observation period of T=6 hours for ground based γ-ray observations, and the extrapolated frequency defines the phase smear for the γ-ray pulse profile:

$$\Delta = (\nu - \nu_{\mathrm{extrap}}) \cdot T, \tag{2}$$

The phase smear Δ must be much smaller than 1 to conserve periodicity, whereas complete phase smear is achieved if $\Delta \geq 1$.

3. Results

Given the large combined data base of timing data provided by Princeton and HartRAO, we can make a statistical study of the accuracy of extrapolating timing solutions in general. The effect of Glitches will be implicitly included in these studies.

For each pulsar we arbitrarily adopt a reference time interval of (t-t_o)=10^3 days, close to the length of our shortest data span. Fig. 1 shows the correlation

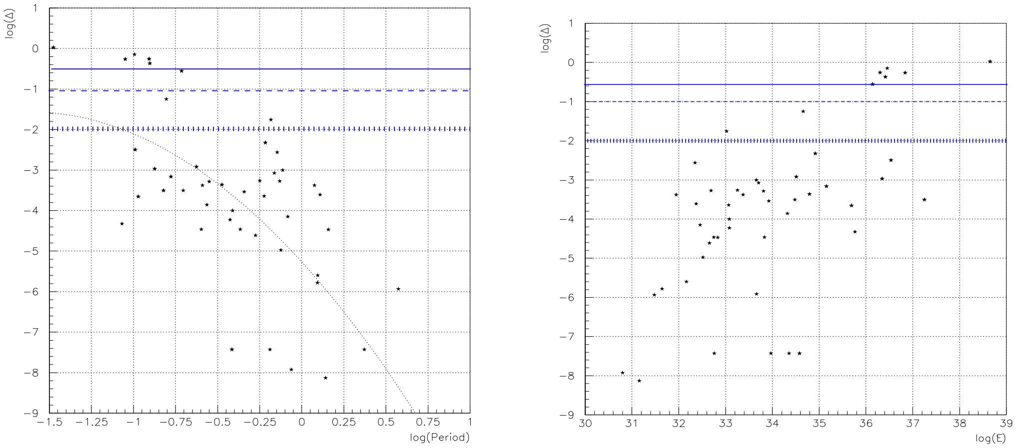

Fig. 1. On the left: (a) Δ vs. the log of the Period. On the right: (b)The smear in the phase, Δ, in units of IFS (Independent Fourier Spacing), plotted as a function of the spindown power

found between the period of the pulsar and the spindown power= $4\pi^2 I\dot{P}/P^3$. A correlation with the period of the pulsar was found as well.

The horizontal solid line in the figure marks the condition where the period is completely destroyed, the dashed line marks the limit to resolve broad peaks, and a sharp peak will be destroyed above the dotted line. Therefore, depending of the pulse duty cycle of the pulsar radiation we can impose any of these constraints.

An attempt was made to relate Δ with the radio activity parameter [1]. It was hoped to get a linear fit since both of them are a measure of the amount of timing noise. Nevertheless, we found no correlation between the two parameters. Next is to determinate for how long we can integrate the signal without losing the periodicity. Fig. 2 shows the number of hours needed, allowing for a smear in the phase of 1% (dots) and of 10% (crosses). The two horizontal lines mark 6, 48 hours and 2 weeks (the typical duration of a observation shift) respectively. The number of hours is calculated from the expression (2) for again a reference time interval of (t-t_o)=2.7 years. It is remarkable that for some pulsars with lower spindown power, the stability of the period is good enough to allow the folding with the extrapolated ephemerides during T=10^6 hours.

4. Discussion and conclusions

As a conclusion of these studies, it is clear that it is possible to extrapolate the radio parameters of most radio pulsars over several years.

For a given period or spindown power we can easily discern if the extrap-

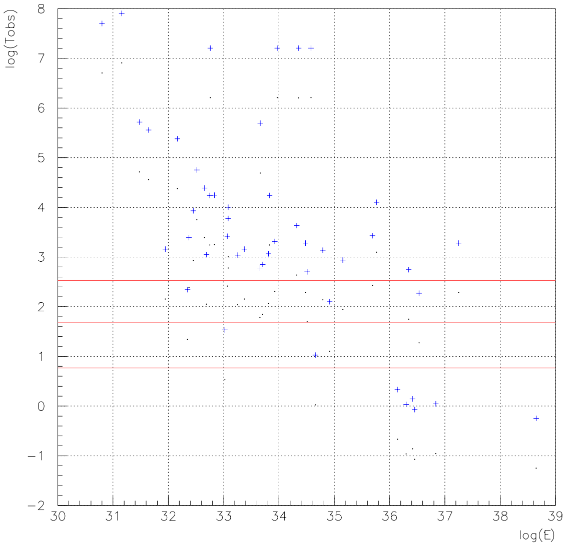

Fig. 2. The log of the maximum integration time in hours, allowing a smear in the phase of 1% (dots) and 10% (crosses) vs. the spindown power. The horizontal red line on the top marks the limit of 24 hours, and the one on bottom the limits at 6 hours.

olation of the ephemerides are valid and for how long is it possible to use them. Therefore, allowing for a smear in the phase of 1%, for T=6 hours we could extrapolate the ephemerides for 83% of 48 pulsars. For T=48 hours it would be possible to use the extrapolations for 77%, and for T=2 weeks, 42% of the total number of studied pulsars could be analyzed without contemporary radio observations.

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5. References

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