Pulsar Nulling Quantitative Analysis

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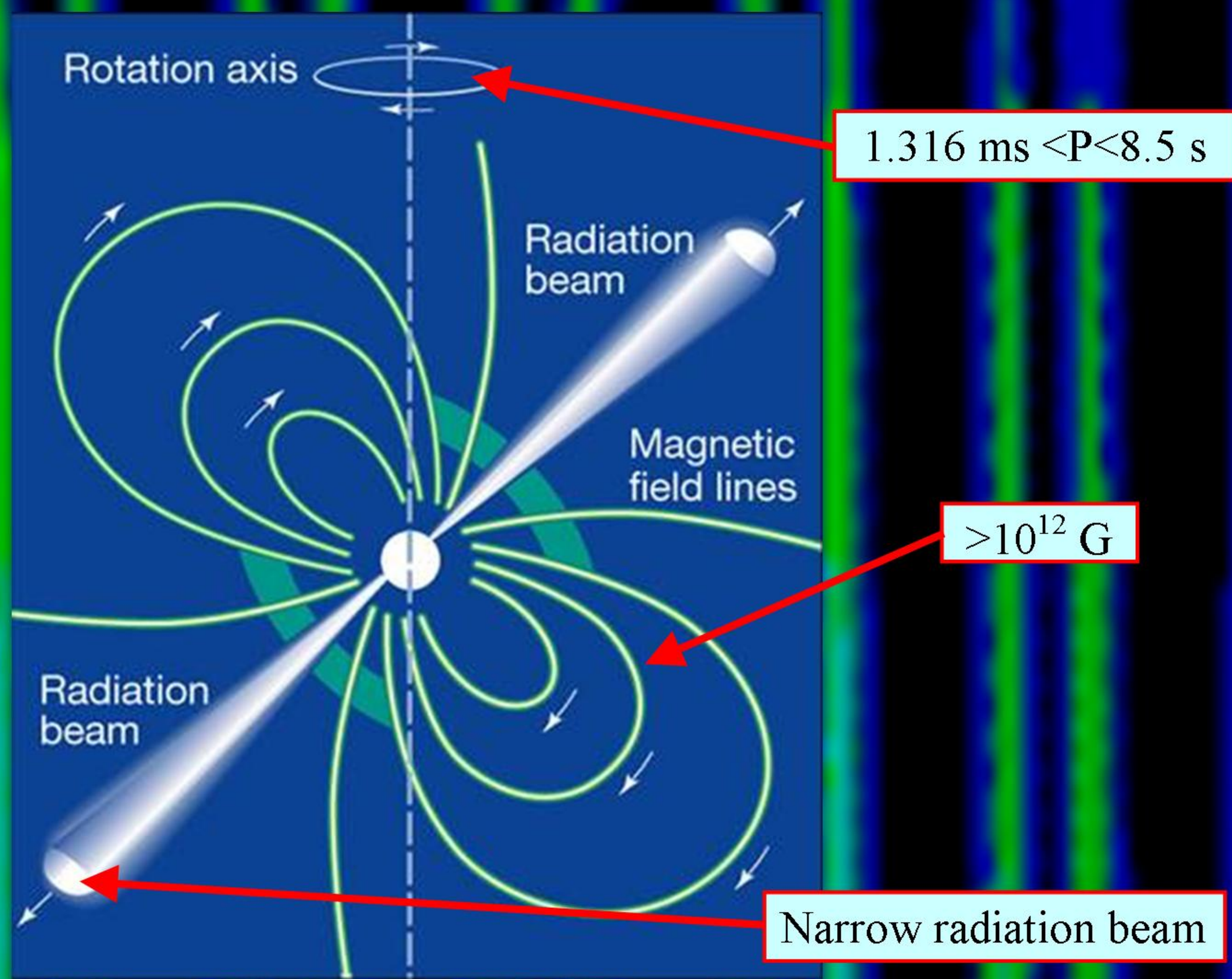
ABSTRACT

Using long sequences of single pulses we have analyzed the nulling behaviour of several pulsars. Each pulsar has been characterized by two "nulling parameters": (a) the "nulling percentage" and (b) the "nulling maximum", which represents the maximum length of consecutive null pulses. These two parameters have been compared to other pulsar parameters. Some interesting correlations have been derived.

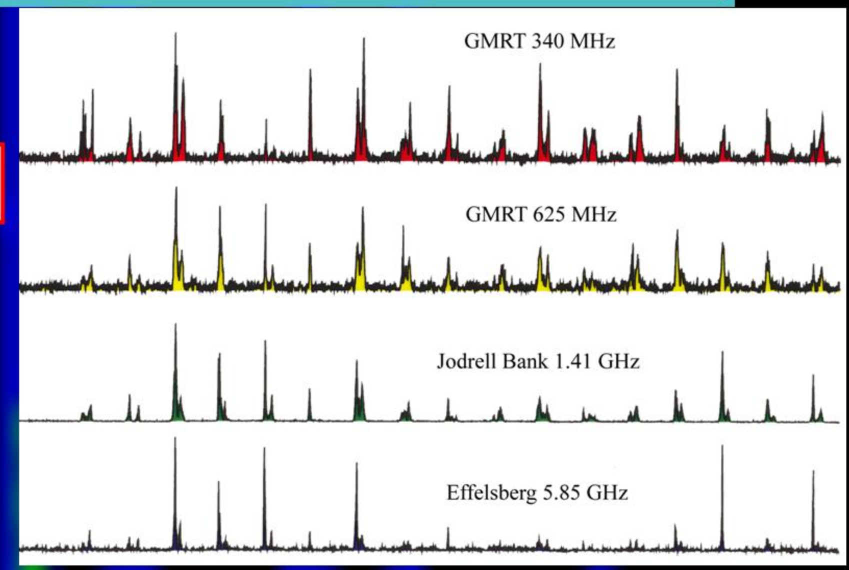
INTRODUCTION

Pulsars are highly magnetized, fast rotating neutron stars, emitting narrow radio pulses along the magnetic axis, often highly polarized. Their magnetic field exceeds 1012 Gauss and their rotating period extends between 1.397 ms (716 Hz) and 8.5 sec. The surface temperature of pulsars is T = 10^6 - 10^7 K and the stellar diameter is about 20 km. Observations have revealed that high frequencies are emitted close to the polar surface and lower frequencies higher up. A few pulsars have been observed in X-rays, γ-rays and optical wavelengths. Already about 1700 pulsars have been detected, mostly in our Galaxy along the galactic plane and a few in the large Magellanic cloud.

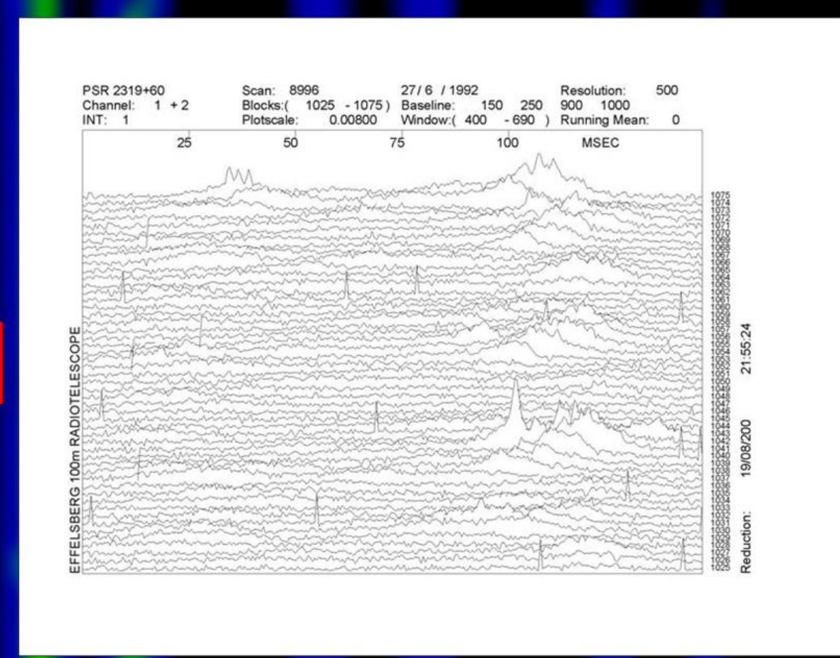
The phenomenon of pulse nulling is a complex process during which the pulsar ceases to radiate for a few up to a few hundred pulses and it was first discovered in PSR 1929+10 by Backer (1970). Each pulsar has completely different nulling characteristics, which change from component to component. Some very important studies have been published that attempt to explain the nulling mechanism and to correlate the pulse nulling with some other pulsar characteristics as the age, period, period derivative and magnetic field, notably Ritchings (1976), Filippenko and Radhakrishnan (1982), Rankin (1986), Biggs (1992), Kazbegi et al. (1996) and van Leeuwen et al. (2003). In this work, we describe the methods and techniques we used for the quantitative analysis of pulsar data and we present some interesting results and correlations for the phenomenon of nulling



The surface temperature is T = 10^6–10^7 K and the stellar diameter is ~ 20 km. High frequencies are emitted close to the polar surface, lower frequencies, higher up. A few pulsars have been observed in X-rays, γ-rays and very few optically.



Single pulses at four different frequencies



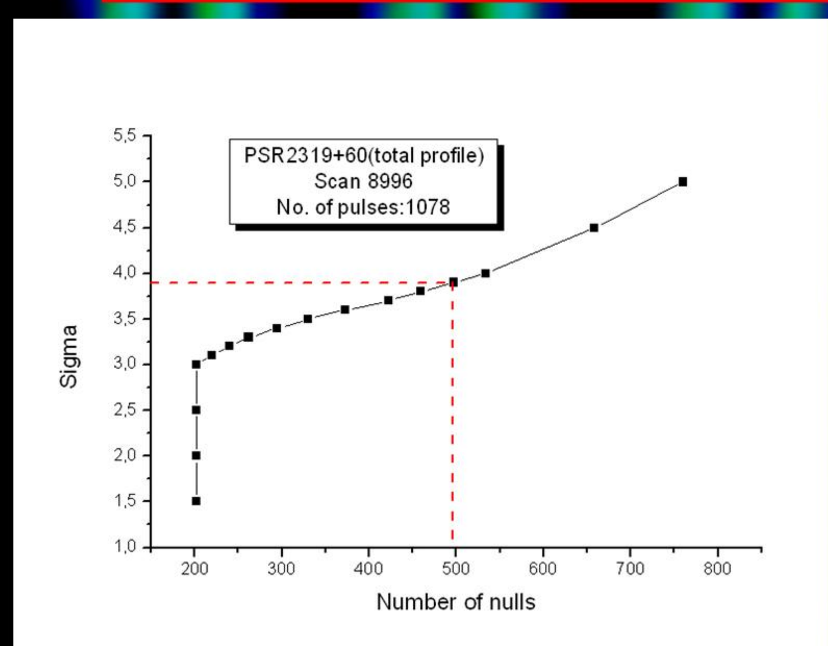
Single pulses showing drifting and nulling

THE OBSERVATIONS

Single pulses from 24 strong pulsars were observed with the 100 m Effelsberg radio telescope of the Max-Planck-Institute for Radio Astronomy, Bonn in 1991-1994. Resolution: A few tens to a few hundreds of μs. Sequences of a few hundred to a few thousand single pulses at 21 cm were analyzed.

PSR0301+19	PSR1706-16
PSR0329+54	PSR1749-28
PSR0450+55	PSR1822-09
PSR0525+21	PSR1933+16
PSR0540+23	PSR1944+17
PSR0628-28	PSR1952+29
PSR0823+26	PSR2016+28
PSR0834+06	PSR2020+28
PSR0950+08	PSR2021+51
PSR1133+16	PSR2217+47
PSR1237+25	PSR2319+60
PSR1642-03	PSR2351+61

DETERMINING THE THRESHOLD FOR A NULL

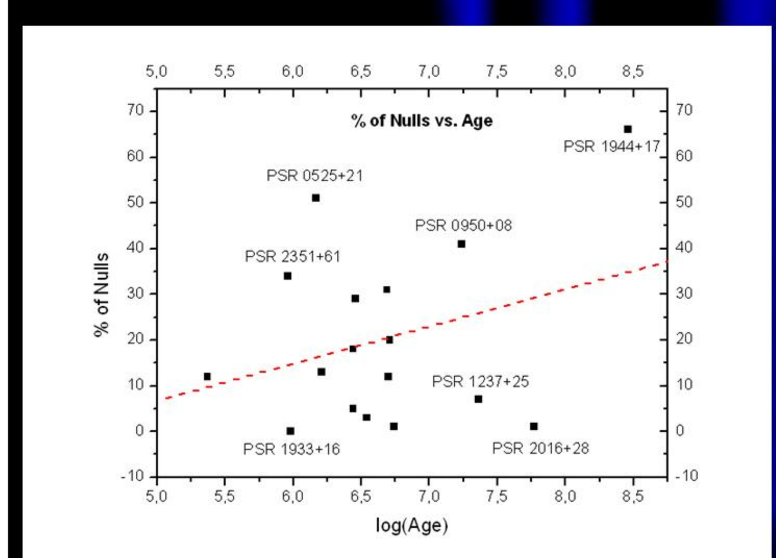


For every single pulse the standard deviation (σ) was calculated outside the integrated profile. If the averaged sum of all points within the integrated profile exceeding 3σ, was found to be below a certain threshold, the single pulse was considered to be a "null".
The threshold was found by comparing the number of "nulls" found at a range of threshold-values between 3σ and 5σ with the number of "nulls" visually counted in a large number of observing runs.

WE DEFINE 2 QUANTITATIVE PULSAR NULL PARMETERS

(a)The percentage (%) of nulls in a long sequence of single pulses, "***nulling percentage***"
(b) The longest sequence of nulls in a long sequence of single pulses, "***nulling maximum***"

ANALYSIS AND RESULTS



Nulling percentage vs. Age

Single Profiles

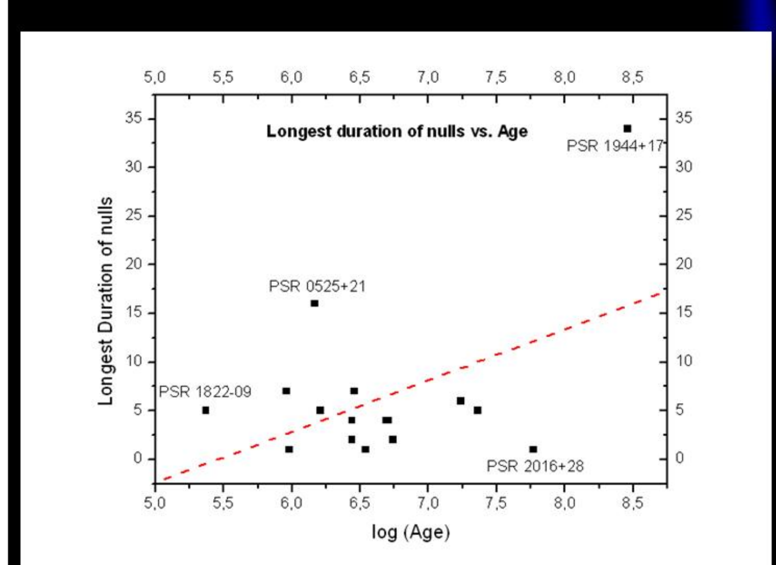
Star	Nulls in total profile
PSR0823+26	31%
PSR0950+08	41%
PSR1642-03	3%
PSR1706-16	13%
PSR1933+16	0%
PSR2016+28	1%

Double Profiles

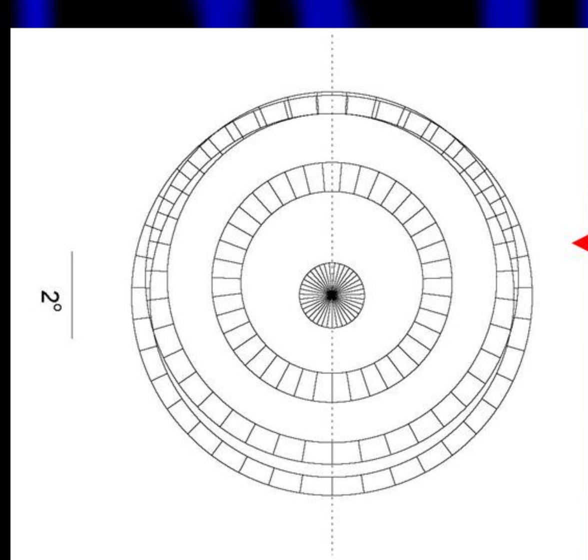
Star	Nulls in total profile	Nulls in C1	C2
PSR0525+21	51%	57%	56%
PSR0628-28	18%	23%	42%
PSR1133+16	12%	16%	23%
PSR1822-09	12%	29%	18%
PSR1944+17	66%	66%	75%
PSR2021+51	5%	15%	10%
PSR2351+61	34%	35%	85%

Multiple Profiles

Star	Nulls in total profile	Nulls in C1	C2	C3	C4	C5
PSR0329+54	1%	42%	8%	2%	14%	12%
PSR1237+25	7%	25%	19%	26%	19%	14%
PSR2020+28	29%	68%	45%	61%	59%	
PSR2319+60	20%	54%	55%	55%		

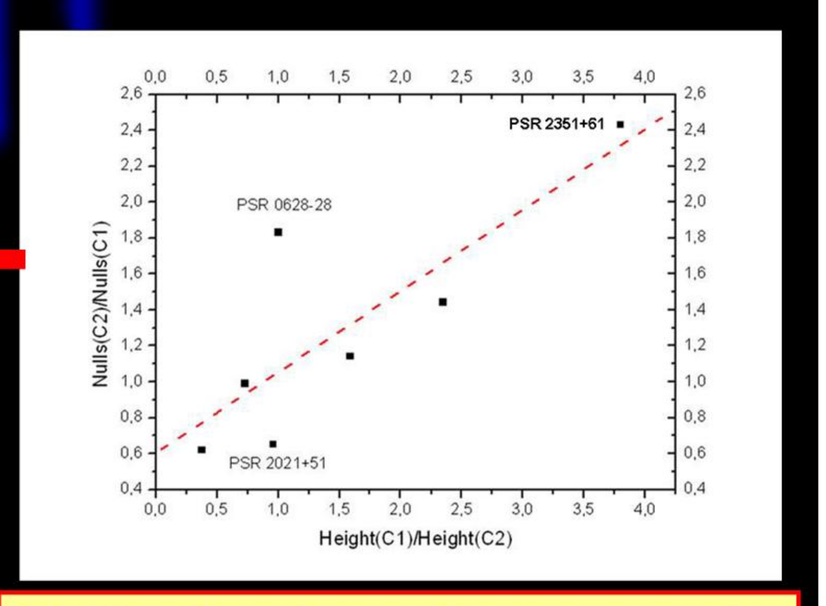


Nulling maximum vs. Age



✓When the component ratio is close to 1, then radiation comes from the same ring
✓When the component ratio is not close to 1, then radiation comes from different rings
This result has been proposed by fluctuation spectra analysis and polarization studies. Now it is confirmed by an independent study, i.e. by studying the nulling properties of pulsars

✓The ratio of the height of components is inversely proportional to the ratio of the nulls in the components
✓Therefore: Individual (single) pulses have more or less equal flux density in all components, but weak components have more nulls



Nulling % ratio vs. Component ratio