Max Planck Institute for extraterrestrial Physics

Fully Resolved Optical Polarization of the Crab Pulsar

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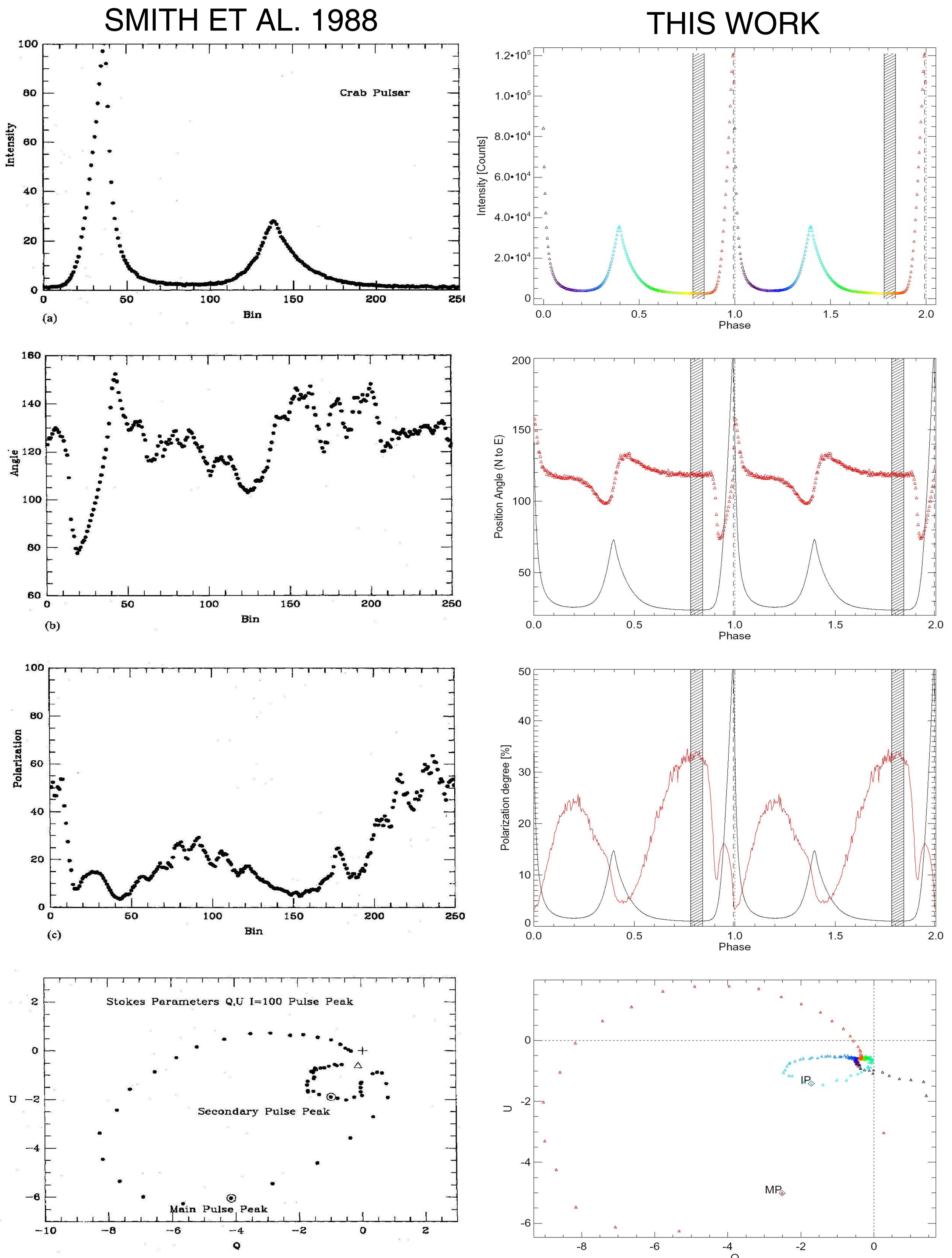
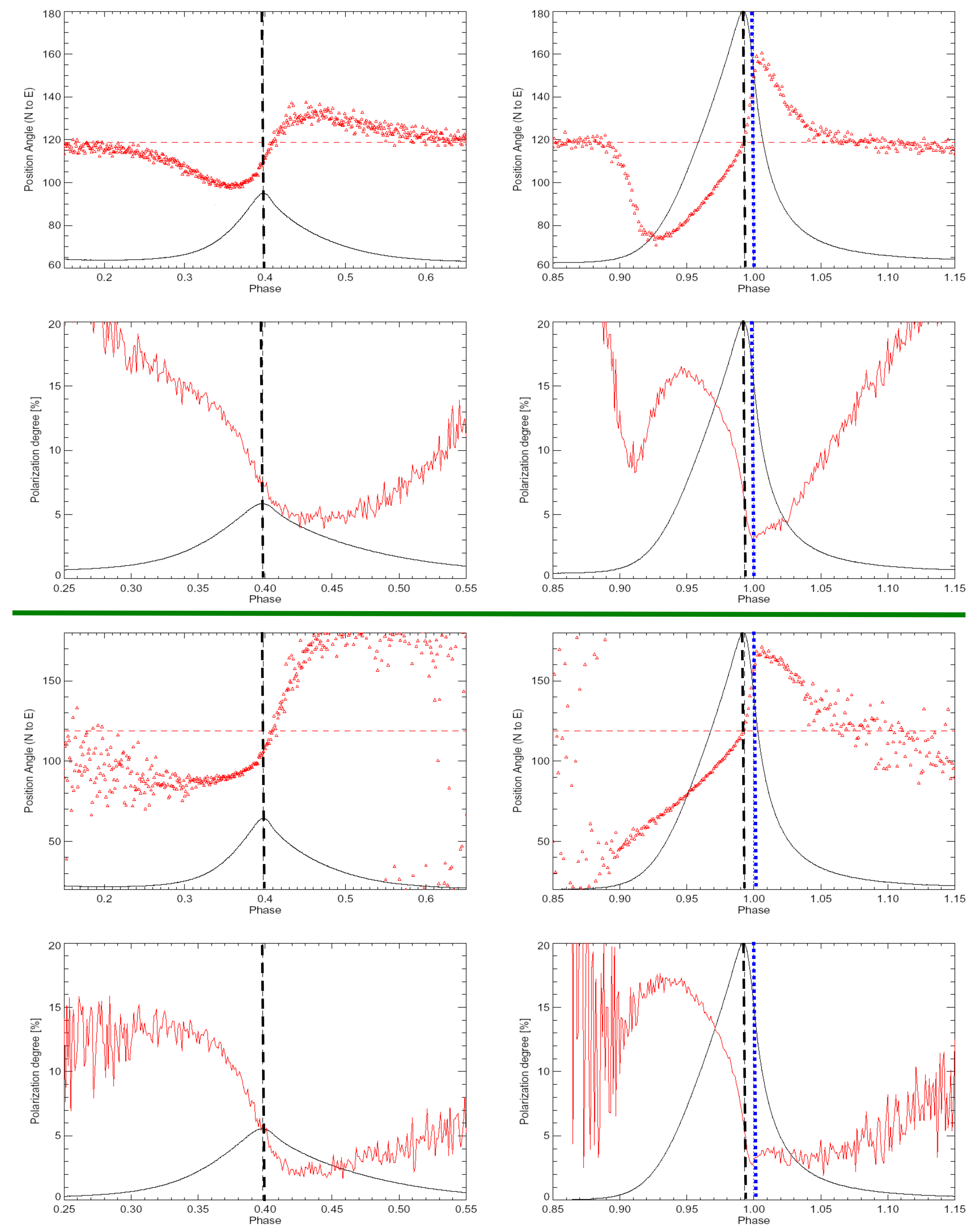
We present the optical polarization of the Crab pulsar and its environment based on ~14 hours (selected out of 25 hours) of observations with the high-speed photo-polarimeter OPTIMA at the 2.5 m Nordic Optical Telescope (NOT). Time resolution as short as 10 μsec and high statistics allow the derivation of details in the degree and angle of linear polarization never before resolved. The phase resolved optical polarization shows surprising correlations ('bends') in the degree and angle of polarization with the phase structure at radio wavelengths. This subtle connection between presumed coherent and non-coherent emissions, which have also been detected between the giant radio pulses and the optical intensity of Crab [8], will require more elaborate theoretical models than those currently available in the literature (e.g. [1,2,6,7]). The cases of polarized pulsars (and e.g. blazars) show that mapping optical polarization could serve as a tool to identify counterparts for unidentified GLAST sources.

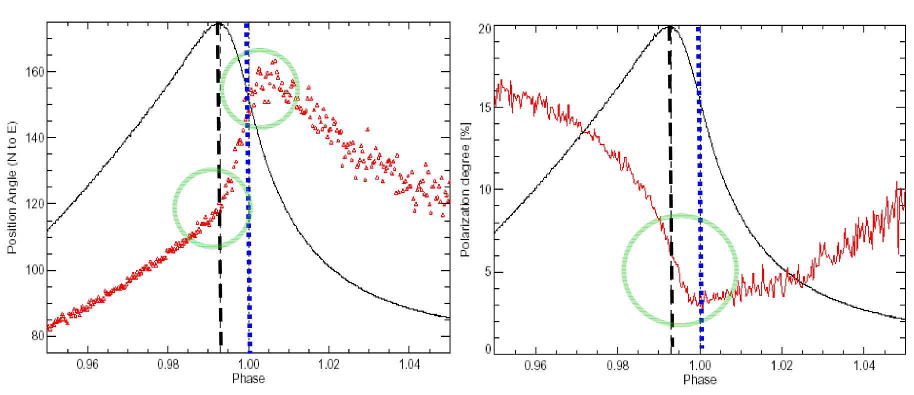


Comparison of the results obtained by Smith et al. 1988 (left) and this work (right). From top to bottom; the intensity, position angle, polarization degree, and the Stokes parameters Q, U plotted as a vector diagram as a function of the pulsar phase. There are 250 bins per cycle in both cases, the only difference is that for clarity we show two periods. As a DC component Smith et al. took 50 out of 250 bins, whereas we took only 7% of the rotational period (phase range: 0.78-0.84 indicated by a dashed region).



Polarization characteristics, θ and p for both Crab pulsar peaks; left and right column is for the IP and MP, respectively. The upper two rows show the polarization before DC (θ=118.9°, p=33%) subtraction, the lower two rows after this subtraction. Black dashed lines indicates the optical maximum phases of the peaks, blue dotted line indicates the peak radio phase. Red dashed horizontal line shows the θ_{DC}=118.9°. For clarity the optical light curve of the Crab pulsar is over plotted (black solid-line).

θ and p zoomed to phase range 0.95-1.05



The optical emission from the Crab pulsar is highly polarised, especially in the bridge and the 'off-pulse' phases. The θ and p of linear polarisation as a function of rotation phase show well determined properties:

a) the polarisation characteristics of both, the MP and the IP, components are very similar,
b) the polarisation degree is minimal at the phases of maximum radio intensity; therefore, it is NOT aligned with the optical peaks,
c) there is a well defined bump in polarisation degree on the rising flank of MP,
d) there is an indication of such a bump also for IP (especially after the DC subtraction),
e) the polarisation angle swings through a large angle in both peaks: after subtraction of an assumed constant polarisation component, the angle swing is 130° and 100° for MP and IP, respectively.

Theoretical models, like the two-pole caustic model [1] or the striped pulsar wind model [6] are able to reproduce (qualitatively, at least) some of these properties, e.g. (a) and (e). However, full explanation of the properties (a) to (e) will require more detailed models to be developed. Detailed presentation and discussion of these results will be given elsewhere (Słowikowska et al. in preparation).

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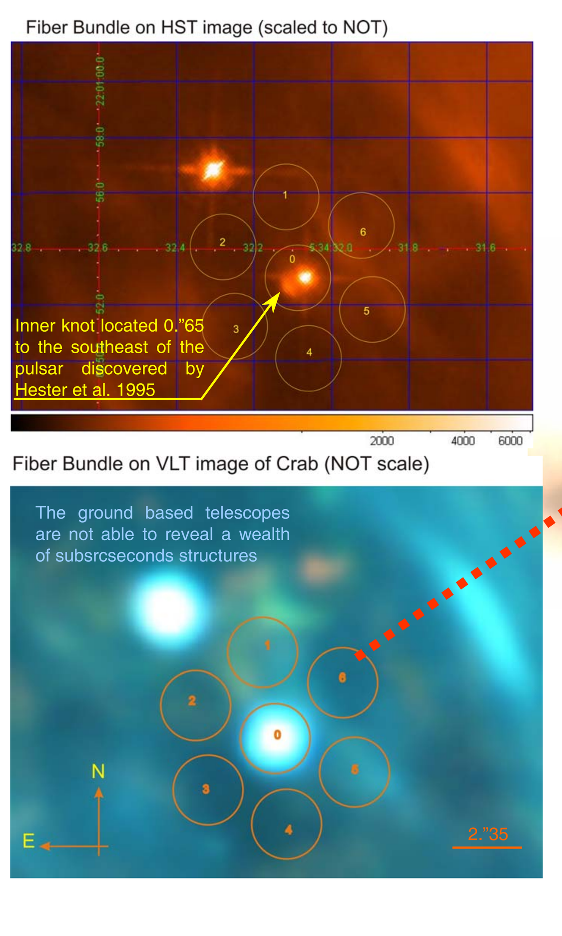
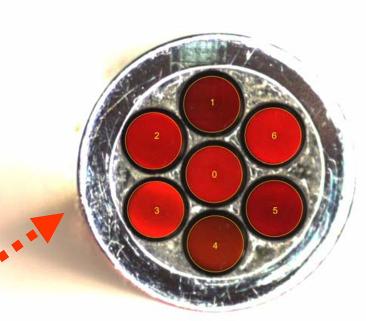
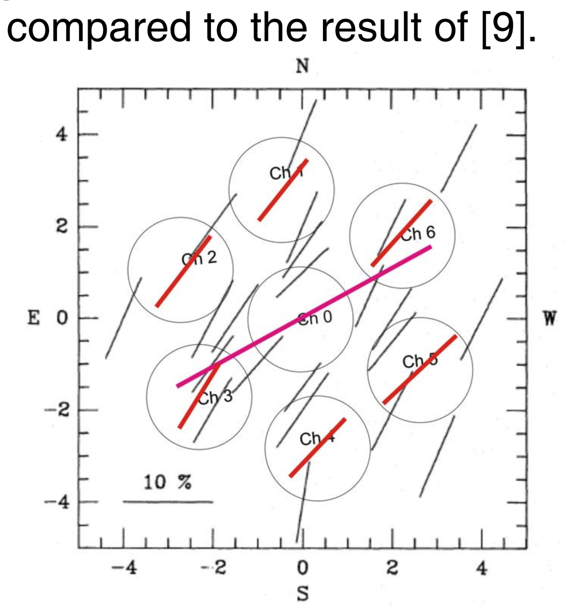


Fiber pick-up [4, 5] and projection on the inner part of the Crab nebula; the nebular polarization was derived during the phase of pulsar minimum (0.78-0.84) and is compared to the result of [9].

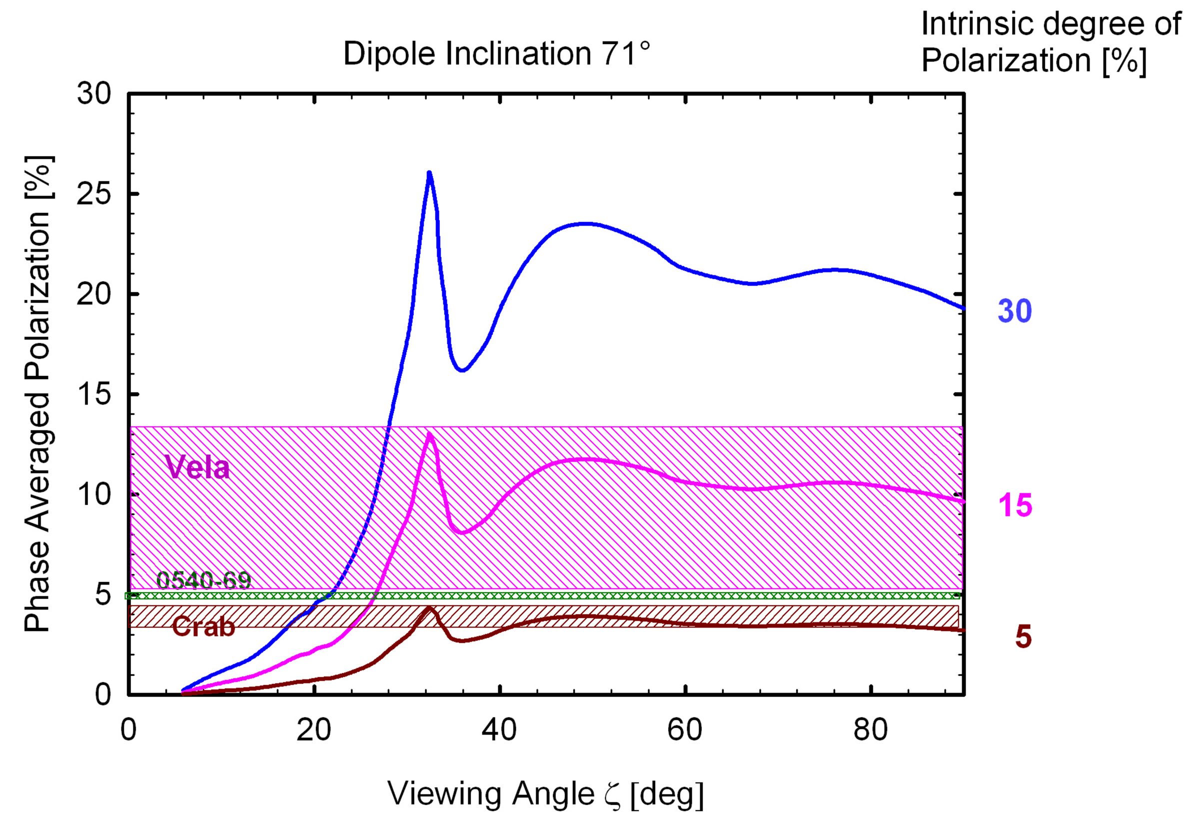




A rotating polarization filter covered the complete aperture and was binned into 180 phase bins (linear polarizers). Data analysis followed the method introduced by [10] using *'The Case of n Polarizers'*.

Phase averaged polarization of optical Pulsars:

Pulsars and other high-energy sources are expected to show polarization since their emission characteristics are often highly anisotropic. The figure ([11] and Dyks private comm.)shows the phase averaged polarization for a simplified outer gap model ([1]) for different viewing angles and intrinsic degrees of polarization and the observed polarization of the brightest optical pulsars. Detection of polarized objects in the field of unidentified γ-ray sources could be a valuable tracer to aid identification.



References

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[4] Kanbach et al., SPIE 4841, 2003; [5] Kanbach et al., AIP Conf. Proc. 801, 306, 2005; [6] Pétri & Kirk, ApJ 627, 37, 2005;
[7] Romani & Yadigaroglu, ApJ 438, 314, 1995; [8] Shearer et al., Science 301, 493, 2003; [9] Smith et al., MNRAS 233, 305, 1988;
[10] Sparks & Axon, PASP 111, 1298, 1999; (11) Mignani et al.. A&A accepted, 2007,

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