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***Perspective***

# X-Ray Polarimetry of the Crab Pulsar and its Nebula Astrophysical Systems

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**INTRODUCTION:** The first phase- and space-resolved soft x-ray polarised observation of the crab psr and pwn. Our results show that the total polarisation of the pulsed signal is negligible. The consistency with optical polarisation measure is marginal. Only the core of the main peak was found to be significantly polarised. Marginal evidence for polarisation, below 3σ, in other phase bins is also reported. The low average polarization is in contrast with the vast majority of the existing psr models which typically predict polarisation fraction in the pulsed emission of 40-80%.

**DESCRIPTION:** The model polarisation is generally especially high in the b region. The peaks which are believed to be caustics are typically de-polarised via rapid sweeps. In contrast we find our highest pd in the core. Moreover a simple pa swing does not seem capable by itself to explain the presence of a highly polarized core surrounded by low polarization wings, unless the pa swings much faster than in optical. Intrinsic depolarization is most likely required. Analytical striped-wind emission models suggest possible lower polarization in B, but also predict a fully unpolarized. However recent models, focused on emission in the wind and outer magnetosphere, based on numerical magnetospheric solution have shown that the polarization signatures are highly sensitive to the location and geometry of the emission region. Low integrated polarization suggests that the emission region should be close to or beyond the light cylinder. However, none of the current models include important physical ingredients micro-turbulence, which is likely present in the wind current sheet, and could lead to significative depolarization, short time-scale variability which manifests as timing noise and could lead to potential depolarization for long time integration. The spatially resolved pd reaches a maximum of 46-50%. This is about two times larger than expected from simple predictions based on synchrotron turbulent modelling of the crab torus and inner ring luminosity profiles, calibrated on the results. More sophisticate 3d models lacking however micro-turbulence can give pd close to the theoretical maximum with higher values typically in the south-west region, but in general the prediction is for polarised patterns quite symmetric with respect to the nebular axis, unlike what was found. This suggests that the level and development of turbulence within the nebula, is not as strong as predicted and much patchier in its spatial distribution. While the lower level of polarization close to the center of the pawn is easily explained by summed emission from a wide range of pa in the central resolution elements, the increase of the pd with distance at the rim of the torus suggests the presence of a highly ordered magnetic layer at the edge of the torus itself the ratio of the energy in the turbulent versus ordered magnetic field components should be about a factor smaller than in the core of the torus. This differs from what is seen in optical where higher polarization is found in inner features, suggesting that optical and x-ray emitting particles might be accelerated in different locations and sample different regions of the nebula as previously suggested. The fact that the pd which depends on the ratio of magnetic energy in the turbulent to ordered components is far more asymmetric, with respect to the nebular axis, than the intensity which depends on the total turbulent plus ordered magnetic energy density suggests that the level of turbulence anti-correlates with the strength of the ordered component of the magnetic field. This is what one would expect if turbulence was driven by the growth of instabilities, like rayleigh-taylor, which are suppressed by stronger fields. If this is correct we should expect that more highly polarized turbulent systems should show stronger toroidal patterns with smaller degree of rayleigh-taylor induced patchy de-polarisation and intensity enhancement the recent ixpe observation, submitted to Nature.

**CONCLUSION:** The polarisation results indicate that present modeling lacks physical ingredients needed to explain the low pulsar polarisation seen at most phases. The substantial spatial variation of the pd in the nebula also indicates that effects are missing even in the most advanced relativistic magnetohydrodynamical models, mhd turbulence seems likely to be important in both cases.