Nulling Pulsars

- Pulsars are massive, rapidly rotating, compact objects that emit electromagnetic radiation from highly magnetized poles
- Roughly 10% of the pulsar population occasionally ceases radio emission for many pulse periods; these are called nulling pulsars (Backer 1970)
- Intrinsinc mechanism for nulling not understood (Gajjar et al. 2012)
- Attempts to correlate nulling fraction (NF) with various measurable/derived parameters disagree:
  - Ritchings (1976) and Wang et al. (2007) claim correlation between nulling fraction and pulsar’s age
  - Biggs (1992) claim stronger correlation between NF and spin period
- Previous measurements of NF were biased, not robust
- More precise & robust measurement of the NF allows for more meaningful correlations
- Goal: tie correlations to understanding of pulsar emission & evolution

Source Selection and Data Reduction

- Focused on 15 pulsars discovered in the Green Bank North Celestial Cap (GBNCC; Stovall et al. 2014) survey that exhibited nulling
- Each pulsar was observed for ~2 hr using the 100-m Robert C. Byrd Green Bank Telescope (GBT)
- Raw data processed by folding the data such that each sub-integration was exactly one pulse, manually removing radio frequency interference
- Produced integrated pulse profiles, manually defined ON/OFF-pulse windows
- Used Kaplan et al. (2018) to create ON/OFF histograms, calculate both a Ritchings (old) and Gaussian Mixture Model (new) NF

Old Method of Analysis

- Ritchings (1976) method defines two regions of the integrated pulse profile: the OFF-pulse window (noise) and the ON-pulse window (signal); see Figure 1a
- ON/OFF intensities are calculated by summing over each pulse and binned into histograms ON, and OFF,.; see Figure 1c
- Trial NFs are chosen until the difference between the ON histogram and the product of the nulling fraction and the OFF histogram equals 0 (Figure 1c)
- Drawbacks: imposes arbitrary histogram binning; assumes negative intensity values from the ON-window are entirely due to nulling
- To limit bias and inaccuracy in the analysis of nulling pulsars, we introduce a new method of analysis—Gaussian Mixture Model (Kaplan et al. 2018)

Gaussian Mixture Model (GMM)

- Uses same ON and OFF pulse windows defined by the Ritchings’ method (Figure 1a)
- Applies Gaussian Mixture Model w/ Markov Chain Monte Carlo (MCMC) to determine more accurate and less biased NF (Figure 1d)
- Allows for negative pulse amplitudes just from noise, even when ON (just low S/N)
- Allows for multiple components: 1 (no nulling), 2 (nulling), 3 (more complex behavior)…; evaluated using Bayesian Information Criteria
- These ON/OFF intensity distributions were then fed into the GMM to determine best-fit parameters with uncertainties (Figure 2)
- Number of components also varied

Results and Conclusions

- Looked at 15 pulsars
- Ritchings method systematically over-estimates the NF, except for J0738-6904 (supported by simulations in Kaplan et al.; see Figure 5)
- 6/15 pulsars analyzed with GMM do not exhibit nulling behavior: best-fit number of components is 1
- In the future will apply broadly to get un-biased view

References


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