The RRAT trap: Localizing RRATs using ALPACA

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Justification

Neutron stars are dense cores of dead stars and have been vital probes of extreme physics with innumerable other applications since their discovery more than 50 years ago (Hewish et al., 1968). While most of these sources are detected as radio pulsating stars or pulsars, a large diversity in their emission is observed in the general population. Most radio pulsars are stable emitters, releasing radio emission at every rotation. In 2006, a new class of radio emitting neutron stars was discovered that were characterised by extremely intermittent bright radio pulses with large stretches of radio silence (McLaughlin et al., 2006). These so-called 'Rotating RAdio Transients'(RRATs) emit bright pulses that are periodic as one would expect from a spinning neutron star but unlike a pulsar, they are extremely sporadic, suggesting a different evolutionary stage of a neutron star compared to the general population. A few of these sources have multi-wavelength counterparts (McLaughlin et al., 2007) suggesting that they are more energetic than their radio pulsar counterparts. Most of the RRATs so far have only been found by single dish telescope on account of their large Field of View (FoV) but by the same virtue, are not well localised as it requires significant amount of telescope time to perform gridded observations in order to localise them. At the same time, it is incredibly important to localise RRATs as removing the location uncertainty is essential for radio timing experiments of radio loud neutron stars (Verbiest et al., 2021). By timing these RRATs, one can gain valuable knowledge not only about the mysterious emission mechanism but also the interior of the star itself. Here, we propose to use the ALPACA Phased Array Feed (PAF) on the Green Bank Telescope (GBT) to observe a sample of 10 RRATs in order to achieve the following scientific goals:

- **Localise the RRATs to a precision of a few arc-seconds in order to enable timing studies and multi-wavelength follow-up**
- **Study a large sample single pulses from them with the excellent sensitivity of the Green bank telescope**

Proposal

Typically, after discovering an RRAT, single dishes are unable to localise them due to the large FoV. The only way to localise them accurately to enable interferometric observations and other multi-wavelength follow-up is to perform gridded observations of the localisation region. This takes up a lot of telescope time and resources. This is where a PAF is advantageous. It combines the excellent sensitivity of the GBT and the ability to form over-sampled beams on the sky such that we can obtain a grid in the localisation region within a single observation. Thus, the RRAT can be localised to a precision much better than the FWHM of the single GBT beam by triangulating the location using detection in multiple over-sampled beams that overlap at the 90% power level. Hence, we request to perform a single epoch observation of 10 RRATs that have not been localised to reasonable precision ($<$1 arc-minute). We request for two hours on each RRAT in order to account for the variation in the burst rate such that we are guaranteed at least a few detections above the sensitivity of the GBT. Accounting for 15 minutes of overheads, we request for a total of 22.5 hours for this observing campaign. This experiment will result in a significant increase in the sample of localised RRATs and enable further timing and multi-wavelength follow-up which is vital to probe unanswered questions about the fundamental workings of these objects.

References

Hewish A., Bell S. J., Pilkington J. D. H., Scott P. F., Collins R. A., 1968, , 217, 709
McLaughlin M. A., et al., 2006, , 439, 817
McLaughlin M. A., et al., 2007, , 670, 1307
Verbiest J. P. W., Oslowski S., Burke-Spolaor S., 2021, arXiv e-prints, p. arXiv:2101.10081