Practical application of cyclic spectroscopy to pulsar signals

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Precision pulsar timing observations are subject to many effects from the interstellar medium (ISM) which corrupt the signal and reduce the achievable timing precision. The largest effect, dispersion, is now routinely corrected for using the technique of coherent dedispersion, where a digital filter is used to invert the linear transfer function of the interstellar medium. Inhomogeneities in the ISM give rise to more subtle corruption in the form of scattering and scintillation. Much research has been done to study and characterize these effects with the hope of mitigating them. These effects span a wide range of time and frequency scales. The trade off between time and frequency resolution inherent in traditional spectral analysis reduces the amount of information about the perturbations which can be obtained using this method.

Cyclic spectroscopy is a promising new technique for studying and mitigating the effects of the interstellar medium on pulsar signals. This technique takes advantage of the periodic nature of pulsar signals to improve the time-frequency resolution of perturbative features in the ISM. It also preserves phase information about the transfer function of the scattering medium which is lost in intensity spectra.

The Interstellar Medium Mitigation group of the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) collaboration has undertaken extensive studies to determine the potential benefits of cyclic spectroscopy for precision pulsar timing. These efforts include simulations and analyses to determine which pulsars will benefit from the technique and efforts to enable routine use of the technique during pulsar observations by accelerating the computation and reducing the data volumes that must be recorded to disk. To form the complete cyclic spectrum, baseband signals from overlapping filterbank channels are required, which increases the computational demand over a traditional coherent pulsar spectrometer.

We have implemented an FPGA-based digital filterbank front-end which feeds data to a cluster of GPU based processing nodes to compute the cyclic spectrum in real time. Our initial results demonstrate that observing with cyclic spectroscopy in real time is practical over the full bandwidth of modern receivers used for pulsar observing. We will discuss the cyclic spectroscopy technique, details of the implementation and application, and initial results from this instrument.