Benchmark Testing and Optimized Processing of a Pulsar Survey in the Large Magellanic Cloud
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Background
- Neutron stars are the ultra dense cores that are left over from supernova explosions of high mass stars.
- Neutron stars are the most physically extreme stars in the universe with high densities and some of the strongest magnetic fields.
- Neutron stars can also spin incredibly fast with periods as fast as 1.4 milliseconds.
- A neutron star is a pulsar if the magnetic pole of the star points toward Earth as the star goes through its rotational cycle.
- This is known as the “Lighthouse Effect” where the star emits radio waves in a beam along the magnetic poles as it spins.
- Viewing this type of Neutron Star from Earth you would see periodic pulses of light, hence the name “pulsar.”
- Pulsars can be used as extreme physics laboratories due to high densities, strong magnetic fields, high temperatures and relativistic surface velocities. Conditions impossible to create on this earth.
- The periodicity of the pulsar signals is also useful in establishing astronomical ephemeris and detecting gravitational waves.

Abstract
- The large concentration of x-ray sources and the high density of stellar activity make the Large Magellanic Cloud a good survey target for pulsars.
- Pulsar surveys require very long processing times due to the large amount of raw data produced by the observations.
- The initial set of observations done at the Parkes Radio Telescope included the first 20% of the total survey.
- Each data file contains roughly 33Gb of data acquired in 2.4 hours of integration time.
- This large amount of data is needed to detect weak pulsars, an essential component of an extragalactic survey such as this one.
- This project goal was to first run benchmark tests to optimize processing times and sensitivity using different search parameters.
- After completing the benchmark tests, the trends were analyzed and a final set of parameters was chosen to use in processing the full data set.
- Once the full data set was analyzed the chosen processing parameters were reevaluated based on the search results.

Method
- Pulsar data is comprised of a series of samples gathered over the period of observation.
- Each sample contains information about the average flux density over the sample time.
- An 8400 second observation made up of 64µs samples gives over 100 million data points.
- We are using SIGPROC 4.3 a widely used pulsar-processing program to process the raw data.
- The program folds the raw data onto itself at different periods to see if a signal is amplified over the observation length.
- We are allowed to specify certain parameters for this search with a wide range of variability.
- Over 80 trials were run with different parameters on a single beam. Trials were run in sets with only one changing parameter to show how each parameter affected the processing time.

The Large Magellanic Cloud
- At 150,000 ly away this irregular galaxy is the third closest galaxy to the Milky Way and is the fourth largest galaxy in our local group.
- Due to its high concentration of interesting x-ray sources the LMC is a good target for a pulsar survey.

Processing Parameters
- Observation length
  We can take any fraction of the full observation to process. Reducing the length decreases processing time but also reduces signal strength.
- Sample length
  Any multiple of the virgin sample length of 64µs. increasing the sample length reduces processing time but also time resolution.
- DM range
  We can set any DM range to search. Smaller search ranges greatly reduce processing times but limit the range of distances to which we are sensitive.
- Maximum Acceleration
  We can allow the search to span many possible orbital accelerations. A wider range takes longer to process but can find highly accelerated binary systems.
- Period Resolution
  We can specify a minimum period resolution to find pulsars with fast periods at the cost of longer processing times.

Setting the S/N ratio weeds out any candidate with a lower S/N. Higher S/N ratios take less time to process but we could miss weaker candidates.

Benchmark Results
- The first set (Figure 1) tested how changing the sizes of the DM range affected searching times.
- The second set (Figure 2) tested how changing the lowest period resolution affected the searching time for data sets of a 10 minute observation at a maximum acceleration of 22.7 m/s and DM range from 0-50 with sample rates at 64µs, 128µs and 256µs.
- The third set (Figure 3) shows how changing the maximum acceleration affected searching time. The searching time increases linearly as you step up through the normal range of accelerations.

Conclusion
- From the data gathered we chose the parameters shown in table 1. This allowed for a processing time of about 24 hours per beam, which would be reasonable to complete in a 10-week period.
- This search produced over 26,000 candidates, which were individually classified. After an initial round of classification 49 candidates were chosen for further investigation. Of these, all turned out to be RFI after a focused search.
- We feel as though the reason for these negative results is because the low integration time is decreasing the signal strength to a point where a real pulsar would have had a S/N value under 8, which would have caused it to be excluded.
- Further investigation was conducted by searching for known pulsars in the data using the same search parameters. Candidates resulting from this targeted search where too weak to have been picked up initially.
- A future investigation is being planned to find the limits of this processing technique to find the boundary.

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