Serendipitous Detection of Radio Pulses from Evaporating Black Holes, GRBs and Extragalactic Supernova Using SETI@home

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Abstract. There are strong theoretical grounds for the generation of an intense radio pulse of intrinsically short duration during the evaporation of a primordial black hole. Similar emission physics are believed to be associated with Gamma Ray Bursts and certain supernova. Here we outline a program underway to mine the 50 Tbyte SETI@home Data Archive for serendipitous detections of such events.

1 Introduction

Rees (1977)[1] first suggested that during the evaporation of a primordial black hole (PBH), the pair produced e^+/e^- 'shell' expanding into an ambient interstellar magnetic field would generate an electromagnetic pulse of duration $1/\nu$ sec, with ν the 'peak' frequency of the synchrotron emission. Here $\nu \sim \frac{\gamma^2 c}{r_{max}}$, γ the Lorentz factor of the blastfront and r_{max} the size of the fireball when the energy of the swept up field finally decelerates it. Similar physics is applicable to certain classes of supernova, and that of a Gamma Ray Burst. The emission is expected to peak in the radio regime at flux densities within the range of existing observational facilities. Intervening interstellar/intergalactic plasma would disperse such pulses. For evaporating PBH within the galactic halo, the Taylor & Cordes [2] galactic electron density model allows one to compute the dispersion measure (DM) as a function of distance & (l, b), and so de-disperse & recover the original pulse signal. Typical values range from 5 to 30 cm^{-3} pc (from about 0.5 kpc to 40 kpc), increasing near the arms, with 5 to 250 pc cm^{-3}. For extragalactic GRBs & supernovae events, the DM is a function of the Hubble constant, the deceleration parameter, the mass of baryonic intergalactic matter and the distance to the source object in question [3]. Thus for GRB 970228 ($z \sim 0.7$), $\rightarrow$ DM $\sim$ 420. Critically, computation of the DM for a GRB of known z would allow one to invert the DM relationship to constrain the other cosmologically relevant parameters. Such pulse events are however sporadic, random occurrences and their detection requires receiver systems that operate at the highest temporal resolution yet guarantee high sensitivity. UC Berkeley's SETI@home receiver system is located at the 305m Arecibo radiotelescope in Puerto Rico observing in a 'piggyback' fashion, operating at 1.4 GHz with a bandwidth of 2.5 MHz.

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Its 4 year programme will sample ~ 25% of the sky, re-visiting on average 3 times each location within its 0.1 degree beam. Whilst better known via the SETI@home screensaver initiative, the data archive provides tremendous opportunities for collateral research, such as the production of a unique spectral map of galactic HI [4], and to search for existing and undiscovered pulsars. We propose to analyse the entire dataset for evidence of dispersed pulses of intrinsically short duration consistent with an astrophysical origin as outlined above.

2 Mining the SETI@home Archive

Time domain data is obtained in the following manner: a 30 MHz band from the receiver is converted to baseband using a pair of mixers and low pass filters. The resulting complex signal is digitized and then filtered to 2.5MHz using a pair of 192 tap FIR filters in the SERENDIP IV instrument [5]. One bit samples are recorded on 35 GByte DLT tapes (one bit real and one bit imaginary per complex sample). These tapes are shipped to Berkeley and form the SETI@home Data Archive. The pulse search algorithm under active development involves use of a coherent de-dispersion and thresholding technique, with the latter typically set at between 15 - 20 σ. Each set of raw 1-bit data is converted to complex floating point, a 2k chunk is FFT'd, multiplied by a chirp function encapsulating a specific DM, the inverse FFT obtained and the time series thresholded accordingly. The process is repeated for a range of DM values, and then on to the next 2k chunk. At a sample rate of 2.5 MHz, each 2k chunk represents 0.8 msec of data, and overlapping is done for completeness. Chunks in excess of 0.8 msec will be required for accurate de-dispersion in the case of extragalactic sources We estimate that to analyse the 3 years worth of data to date in real time would require a computational throughput of ~ 500 GFLOPS/sec. As such the problem is eminently parallel in nature, and a distributed approach similar to the SETI@home screensaver system is a likely solution, although more specific distributed computing paradigms are under examination, such as Grid and BOINC[1]. Such an optimised search algorithm could be of some relevance as regards a 'real time' or pipeline application in the next generation of radio telescope facilities, such as SKA and the ATA.

References

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