Observing transients with SKA and future generation gravitational wave detectors

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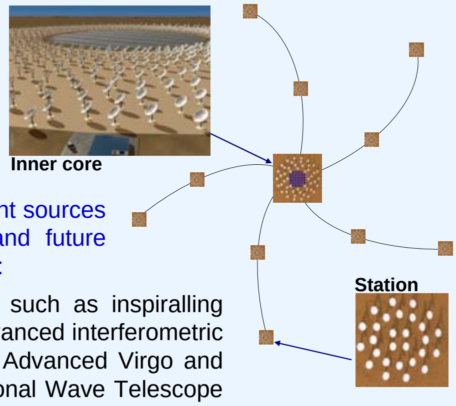
Introduction

The Square Kilometre Array (SKA) is a project to design and build a radio telescope with an effective collecting area of one square kilometre (fully operation ca. 2020). It will have an instantaneous field of view of at least one square degree and have the capability to both survey the sky and perform follow-up observations of individual objects with high angular and time resolution. The key scientific goals of this project include detecting and observing stars and galaxies from the very early phases of the universe, timing pulsars to probe strong field gravity and searching for Earth-sized planets in proto-planetary disks. Australia and South Africa have been short-listed as possible locations for the SKA.

Figure 1: Square Kilometre Array (SKA). Credit: Richard Schilizzi



Here, we consider two potential transient sources for joint observation between SKA and future generation gravitational wave detectors:

- coalescing binary compact objects, such as inspiralling neutron stars, in conjunction with advanced interferometric detectors such as Advanced LIGO, Advanced Virgo and the Large Scale Cryogenic Gravitational Wave Telescope (LCGT)
- glitches in pulsar timing, in conjunction with advanced interferometric detectors as well as next generation resonant-mass detectors such as DUAL or spherical resonant-mass detectors.

Figure 2: The Advanced LIGO and Advanced Virgo detectors will be upgrades of the detectors at their existing sites. Mini-Grail is a spherical detector in Leiden, Netherlands.

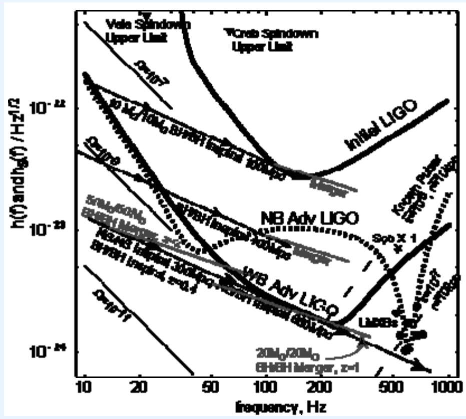


Figure 3: Expected sensitivity of Advanced LIGO. The projected range for 1.4-1.4 $M_\odot$ binary neutron stars is 300 Mpc. Credit: Kip Thorne, http://www.ligo.caltech.edu/advLIGO/

Coalescing binary compact objects

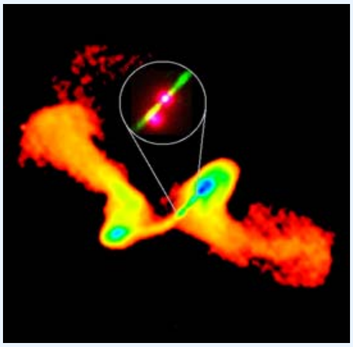


Figure 4: Radio image of NGC326. Expanded radio image shows the jets have changed directions, possibly caused by black holes merging. Credit: National Radio Astronomy Observatory / AUI, observers Murgia et al. STScI

For coalescing binary compact objects, external triggers from gravitational wave detectors pre-define the location of an expected radio burst. Data from an Advanced LIGO and/or Virgo network can be used to generate an error box on the sky containing a close (< 300 Mpc) binary neutron star inspiral and plunge. The SKA can then perform a rapid-response search of this error box.

A 1.4-1.4 $M_\odot$ binary neutron stars entering the Advanced LIGO band at 10 Hz is expected to be in-band for ~1000 s. The gravitational wave signal for a 1.4 $M_\odot$ neutron star inspiralling into a 10 $M_\odot$ black hole would be in-band for ~200 s. We could detect the gravitational wave signal tens to hundreds of seconds before coalescence to exchange trigger data between the sites, identify the coincident event, triangulate its position, communicate the information to SKA and have the SKA respond.

Gravitational waves associated with pulsar glitches

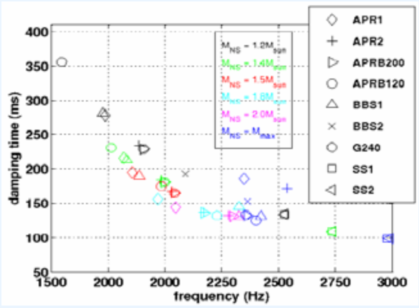


Figure 6: Expected frequency and damping time of gravitational wave ring-down signal for different equation of states. (gr-qc/0703138)

Sudden changes in the rotation rates of some radio pulsars have been observed. These pulsar "glitches" are thought to be caused by a sudden decoupling of the neutron star's crust from its superfluid interior (for older pulsars) or a rearrangement of the star's solid crust (for younger pulsars). The normal modes of the neutron star are excited and a gravitational wave ring-down signal is expected to be observed in association with the pulsar glitch.

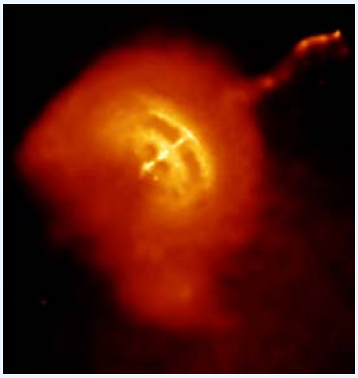


Figure 5. Vela pulsar. Credit: NASA/Chandra X-ray telescope

While pulsar glitches can be clearly seen in radio timing data, the gravitational wave signal is very weak. Accurate timing of the pulsar glitch, to about 1 minute (currently >10 minutes), will significantly reduce the false alarm rate and, thus, improve the chances of observing the gravitational wave signal. To achieve this timing accuracy, the SKA can constantly monitor selected "glitchy" pulsars with the aperture array. The ring-down signals can be searched for using matched filtering techniques (see talk by L. Goggin, Friday in session M5b) or a Bayesian Evidence-based approach (see poster by J. Clark).

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