Appendix to Report of the Committee to Compare the Scientific Cases for Two Gravitational-wave Detector Networks: (AHLV) Australia, Hanford, Livingston, VIRGO; and (HHLV) Two Detectors at Hanford, One at Livingston, and VIRGO

Comparison of the Scientific Cases for Two Networks: (HHJLV) Two Detectors at Hanford, One in Japan, Livingston and VIRGO; and (AHJLV) Australia, Hanford, Japan, Livingston and VIRGO

August 10, 2010

Introduction:

Shortly after the original report was distributed, the Japanese government announced significant though partial support for LCGT, a long baseline interferometric gravitational-wave detector to be placed in the Mozumi mine containing the Kamiokande neutrino detector . The detector will be operated with its test masses and suspensions at cryogenic temperatures. The sensitivity of the detector is projected to be comparable with the Advanced LIGO and VIRGO detectors. The proposed schedule for high sensitivity operation, though not well defined, is planned early in the decade 2020 to 2030 if full funding for the project is made available.

LIGO management requested that the committee formed to make the original study now assess the properties of networks which included the Japanese detector; in particular to make the comparison between HHJLV and AHJLV networks.

As was done for the original report, a group guided by S. Klimenko consisting of Gabriele Vedovato (Padova University) and Marco Drago (Trento University) studied the properties of the two networks for unmodeled sources while another group guided by B. Sathyaprakash consisting of Stephen Fairhurst, and John Veitch (Cardiff University and Ajith Parameswaran and Stephen Privitera (Caltech) studied modeled sources, in particular, binary neutron star coalescences.

Summary of results:

- Adding a fourth detector to the HLV network in either Japan or Australia gives comparable improvements to: the sky coverage, the ability to localize sources and the ability to determine the polarization of the gravitational waves.
- Adding an Australian detector to the HJLV network increases the sensitivity over the sky and significantly increases the fraction of the sky where the angular resolution is 5 square degrees or less
- The orientation of the Australian detector is not as critical in the AHJLV as it is in the AHLV network. In planning the orientation of the Australian detector, it is important to consider the fraction of the time a AHLV network will be functioning as a subset of the AHJLV network.

Study results for unmodeled sources

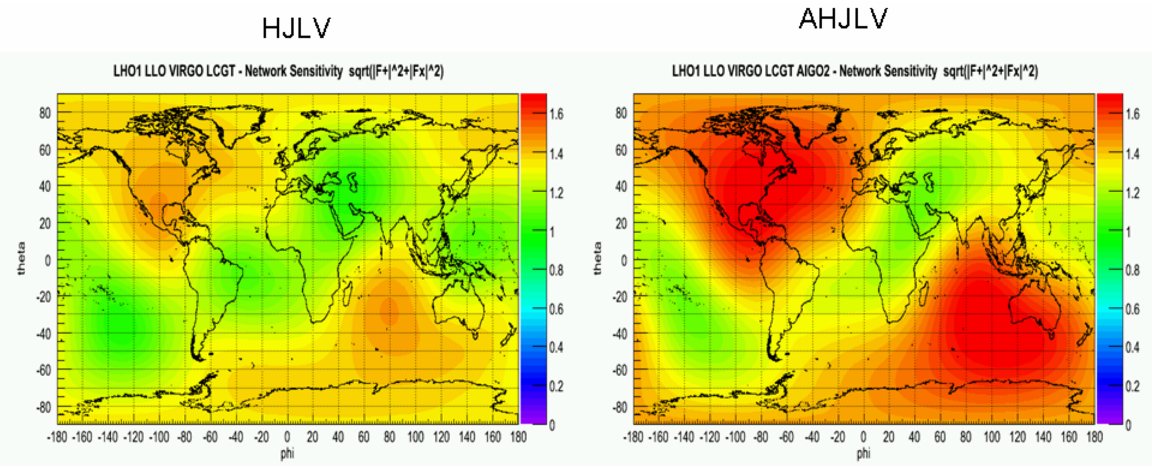

Figure 1A Comparison of network sensitivity over the sky for gravitational waves with equal amplitude at the source. There is a net increase in sensitivity over the sky in the five detector network relative to the four detector network. Compare with **Figure 3** in the main report.

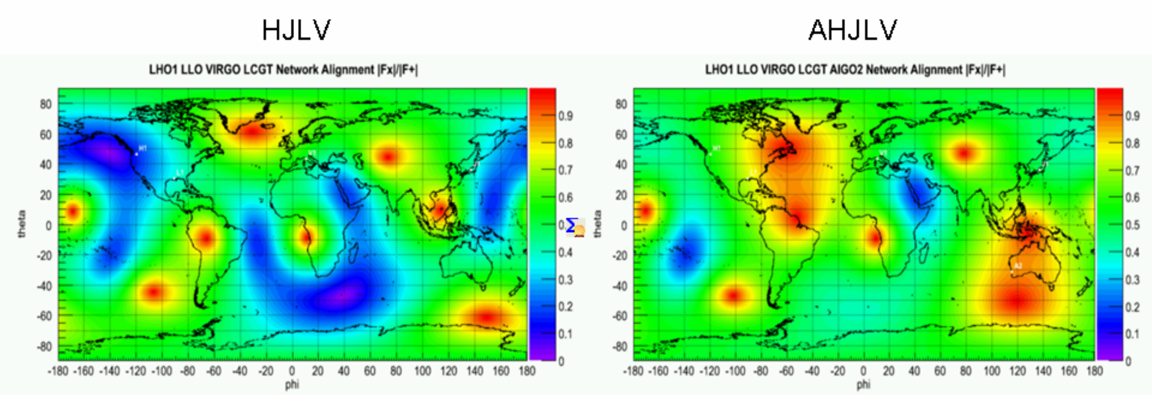

Figure 2A The ability of the networks to determine the polarization components of sources with equal polarization amplitudes at the source which are uniformly distributed over the sky. Fx/F+ estimates the ratio of the SNRs for the two gravitational wave polarizations. Large values indicate that it is possible to determine both polarizations from a source at that location. Blue areas in the map are locations where the polarization is poorly measured. Compare with **Figure 3** in the main report.

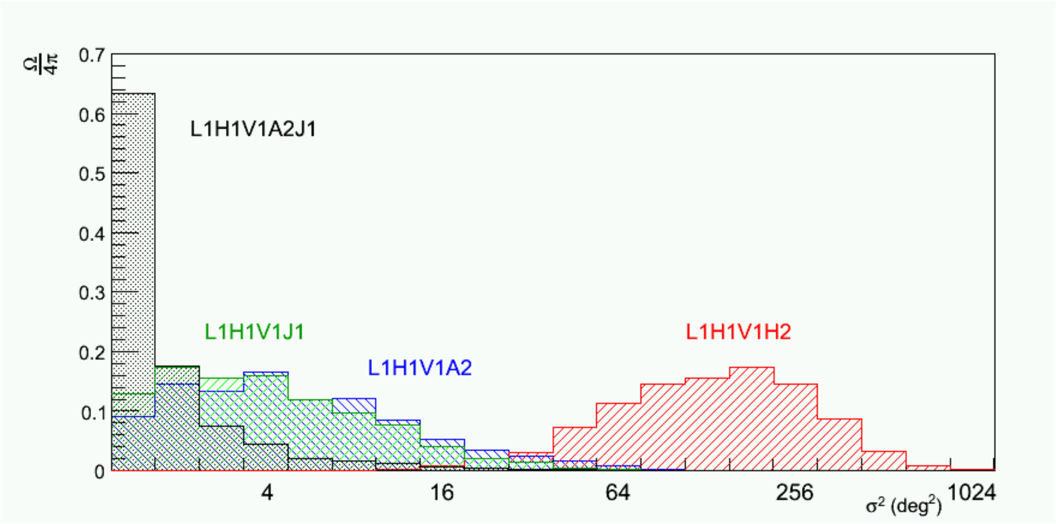

Figure 3A A histogram of the fraction of the sky associated with a 50% confidence angular area error for simulated events with SNR ~ 30. All the networks considered both in the main report and in this appendix are plotted. The red plot shows the distribution for the original advanced LIGO proposal. The blue plot shows the dramatic improvement offered by an Australian detector. The green plot shows the improvement with just a Japanese detector. The improvement is comparable with adding the Australian detector to the original proposal. Finally, the grey plot shows the further improvement with having both a Japanese and an Australian detector in the network. The significant change is the increase in the sky locations with small angular error. The plot was suggested by Lars Bildsten

Results for modeled sources NS/NS coalescences

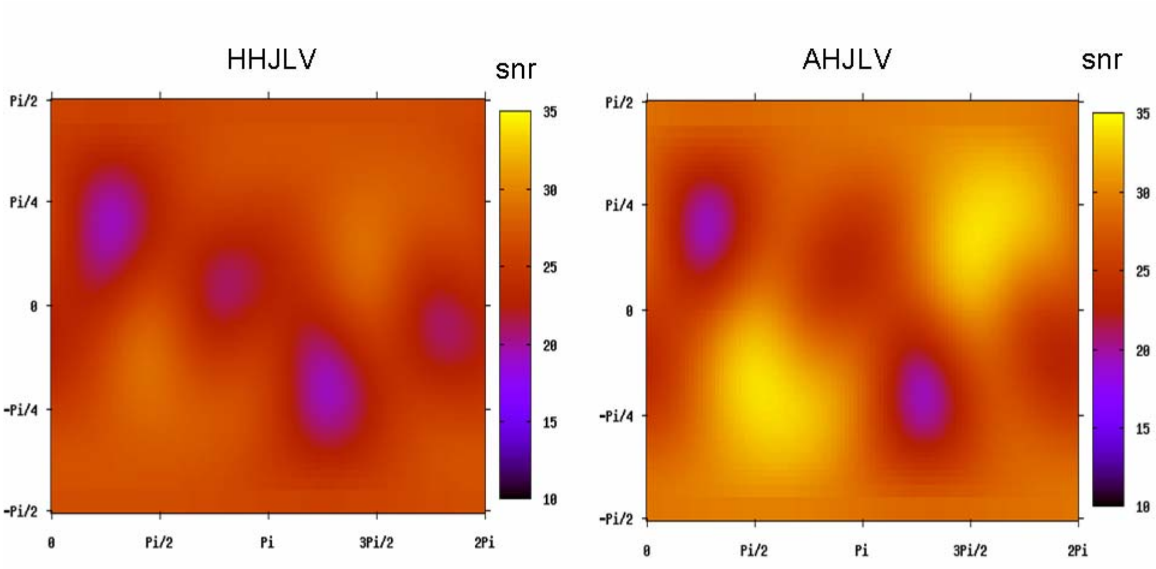

Figure 4A Contour plots of the SNR over the sky for the two networks for optimally oriented NS/NS coalescences situated at a horizon distance of 200 Mpc. The Advanced LIGO detector noise is assumed. Compare with **Figure 2** of the main report

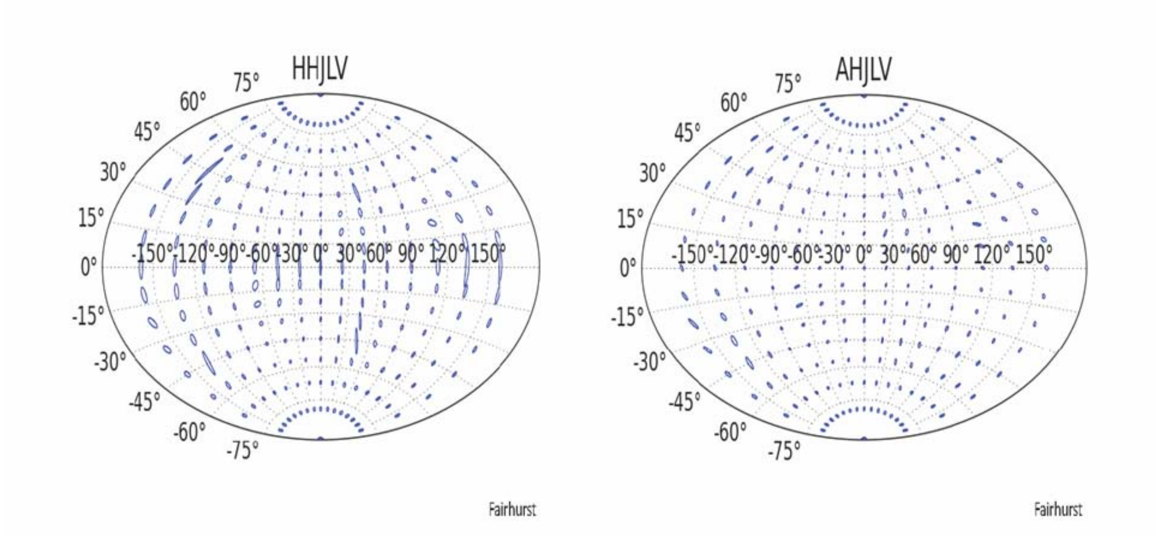

Figure 5A Sky localization for the two networks. The plots show the 90% confidence contours for binary NS/NS coalescences which are optimally oriented and at a horizon distance of 200 Mpc. Compare with **Figure 5** in the main report.

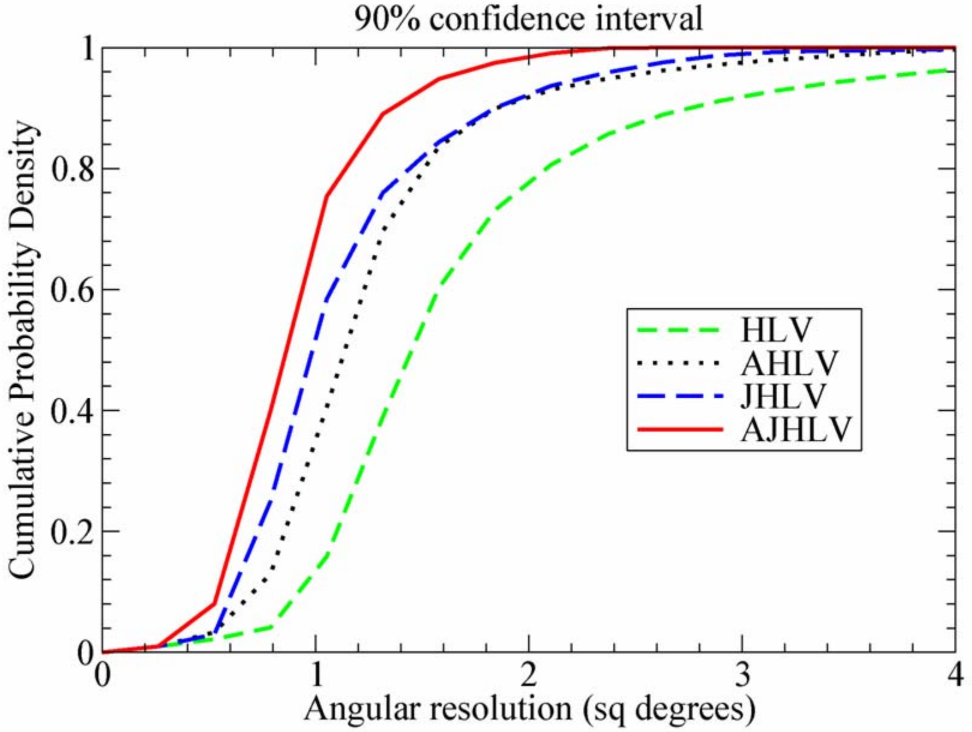

Figure 6A Fraction of the sky for which the angular area error in localizing an optimally oriented NS/NS binary at a horizon distance of 200 Mpc is smaller than the value indicated on the horizontal axis. The values for all the networks considered in both the main report and this appendix are plotted.

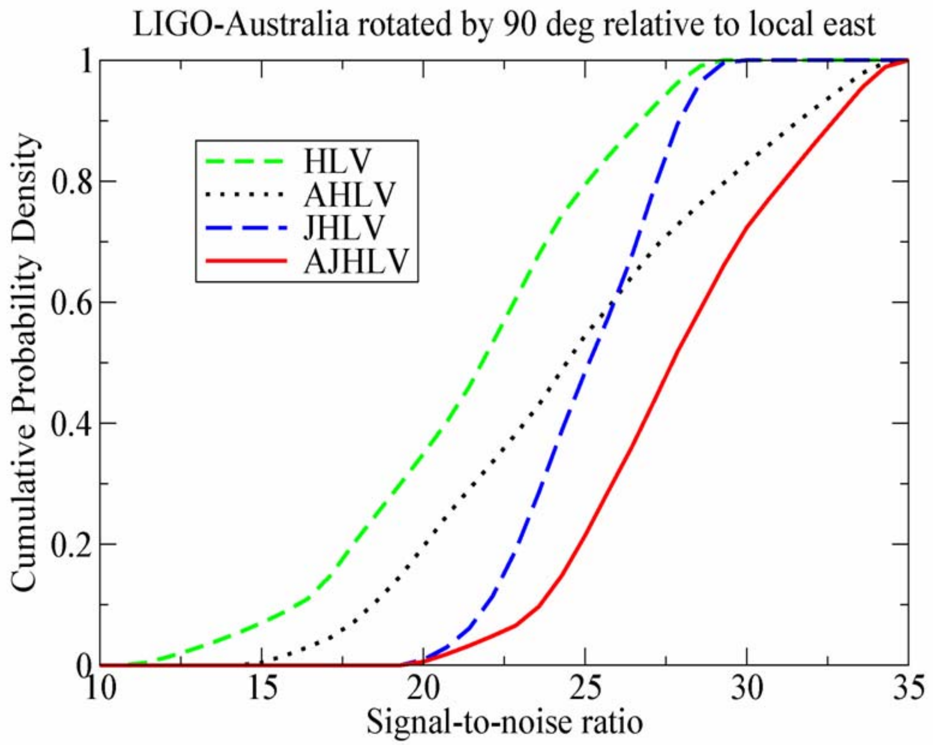

Figure 7A Fraction of the sky for which the SNR of an optimally oriented NS/NS binary at a horizon distance of 200 Mpc is smaller than the value indicated on the horizontal axis. The 90 degrees implies a rotation of the entire detector clockwise (to the east) relative to the initially proposed orientation. Subsequent studies have shown that in a AHJLV, network the rotation of the detector is not a critical factor. The values for all the networks considered in both the main report and this appendix are plotted.

Comparison of the uncertainty in the parameter estimates for the NS/NS coalescences using the two networks will be presented as they become available. The expectation is that, much as with the localization, adding an Australian detector to the HJLV network will help in reducing errors in the parameters.

Coordinates of the vertex of the detectors in the networks (from Google Earth)

A Australia	31^0 20’ 41’’ S	115^0 41’ 48’’ E	
H Hanford	46^0 27’ 16’’ N	119^0 24’ 26’’ W	
J Japan	36^0 16’ 37’’ N	137^0 08’ 29’’ E	(interpolation)
L Livingston	30^0 33’ 48’’ N	90^0 46’ 29’’ W	

V VIRGO	43^0 37’ 54’’ N	10^0 30’ 12’’ E