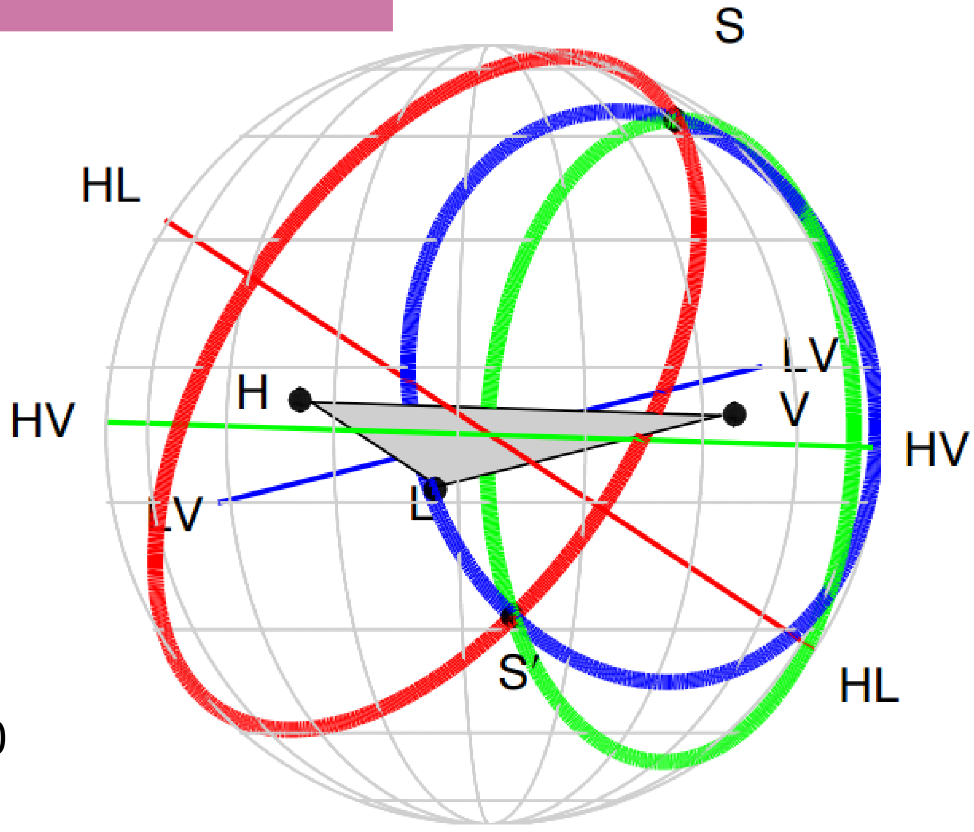
Updating the Observing Scenario

23 April 2015

Workshop on the LIGO–Virgo Electromagnetic follow-up program
Cascina, European Gravitational Observatory
DCC LIGO-G1500514

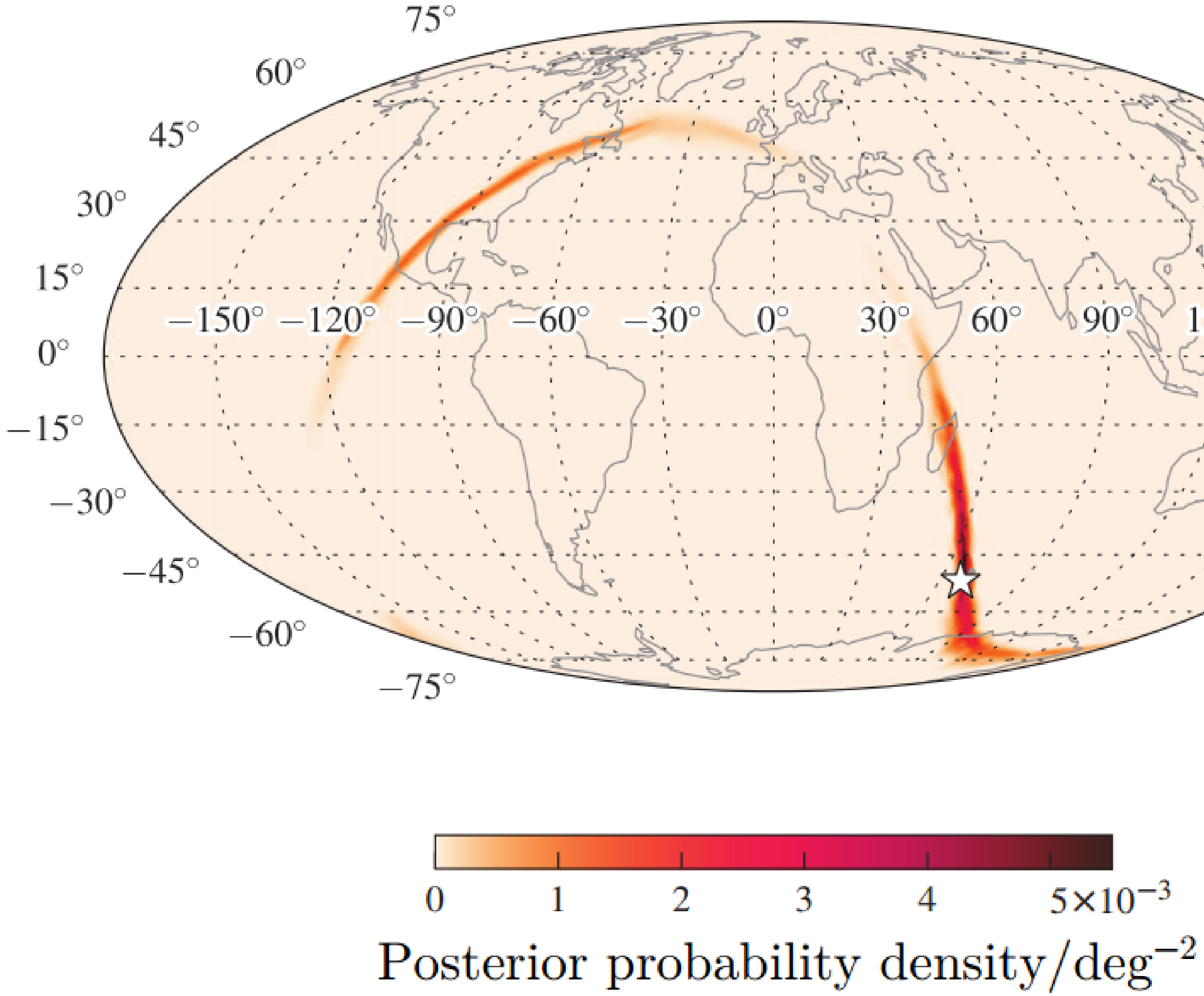
Timing triangulation

- Gives a good, intuitive picture of sky localization
- Is overly pessimistic (arXiv:1310.7454)
- Is not what we will use in O1



Credit: arXiv:1304.0670

We can do better using parameter-estimation algorithms



www.ligo.org/scientists/first2years/

Credit: arXiv:1411.6934

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The First Two Years of Electromagnetic Follow-Up with Advanced LIGO and Virgo

Leo P. Singer, Larry R. Price, Ben Farr, Alex L. Urban, Chris Pankow, Salvatore Vitale, John Veitch, Will M. Farr, Chad Hanna, Kipp Cannon, Tom Downes, Philip Graff, Carl-Johan Haster, Ilya Mandel, Trevor Sidery, Alberto Vecchio

(Submitted on 22 Apr 2014 (v1), last revised 22 Oct 2014 (this version, v5))

Accepted

arXiv.org > astro-ph > arXiv:1411.6934

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Astrophysics > High Energy Astrophysical Phenomena

Parameter estimation for binary neutron-star coalescences with realistic noise during the Advanced LIGO era

Christopher P. L. Berry, Ilya Mandel, Hannah Middleton, Leo P. Singer, Alex L. Urban, Alberto Vecchio, Salvatore Vitale, Kipp Cannon, Ben Farr, Will M. Farr, Philip B. Graff, Chad Hanna, Carl-Johan Haster, Satya Mohapatra, Chris Pankow, Larry R. Price, Trevor Sidery, John Veitch

(Submitted on 25 Nov 2014)

Burst

Published

arXiv.org > astro-ph > arXiv:1409.2435

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Astrophysics > High Energy Astrophysical Phenomena

Localization of short duration gravitational-wave transients with the early advanced LIGO and Virgo detectors

Reed Essick, Salvatore Vitale, Erik Katsavounidis, Gabriele Vedovato, Sergey Klimenko

(Submitted on 8 Sep 2014 (v1), last revised 16 Dec 2014 (this version, v2))

Data release | 2015, HL | 2016, HLV | new 2015, recoloured | Show/hide columns

The First Two Years of Electromagnetic Follow-Up with Advanced LIGO and Virgo

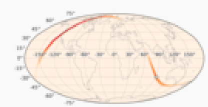
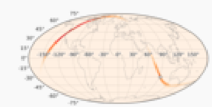
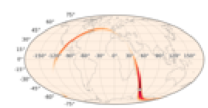
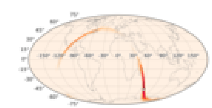
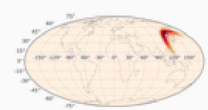
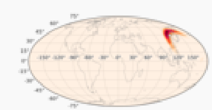
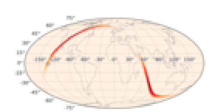
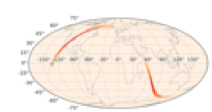
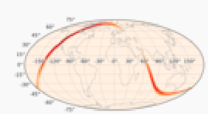
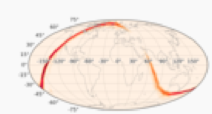
Singer et al. 2014 arXiv:1404.5623 | Berry et al. 2015 arXiv:1411.6934

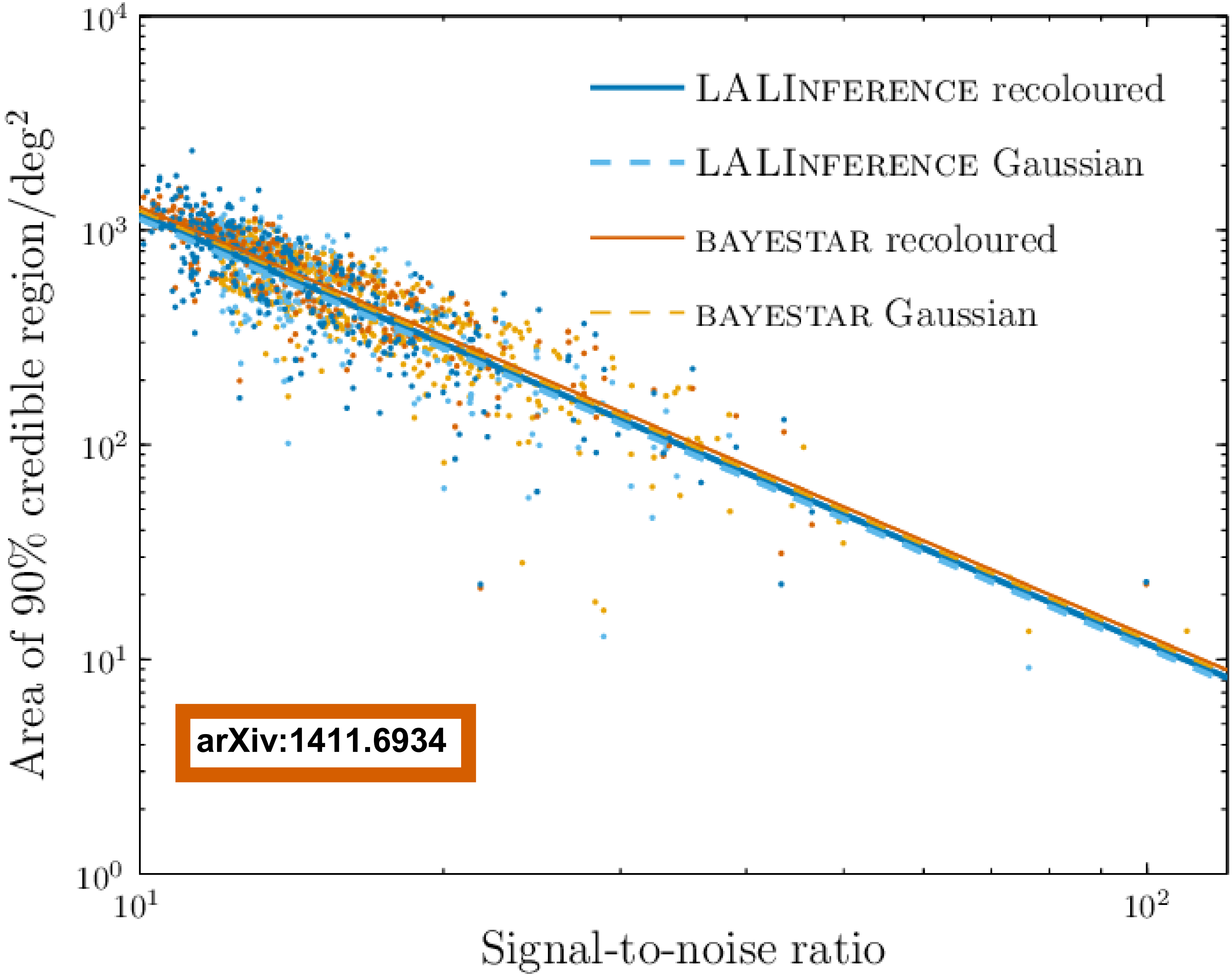
www.ligo.org/scientists/first2years

This web page | additional online | related to the pa | Two Years of El | Follow-Up with | and Virgo" and | paper "Paramet | for Binary Neutr | Coalescences v

Data release | 2015, HL | 2016, HLV | new 2015, recoloured | Show/hide columns

Catalog of simulated events and sky maps for two-detector, HL, 2015 configuration. This is the same configuration as the 2015 tab, except that the simulated detector noise is data from initial LIGO's sixth science run, recoloured (filtered) to have the same PSD as the early Advanced LIGO configuration. See also ASCII tables of simulated signals, detections, and parameter-estimation accuracies in Machine Readable Table format.

event ID	sim ID	network	SNR			BAYESTAR			LALINFERENCE_NEST			sky maps	
			net	H	L	50%	90%	searched	50%	90%	searched	BAYESTAR	LALINFERENCE_NEST
4532	899	HL	13.9	10.1	9.5	180	750	190	170	790	150		
4572	1243	HL	13.2	10.0	8.7	230	830	45	200	920	33		
4618	1768	HL	10.8	8.0	7.3	160	540	220	130	440	280		
4647	1964	HL	12.4	8.6	9.0	260	890	1200	190	780	780		
4711	2704	HL	10.7	8.0	7.1	370	1200	300	450	1600	520		



LALInference recoloured
LALInference Gaussian
BAYESTAR recoloured
BAYESTAR Gaussian
arXiv:1411.6934
Area of 90% credible region/deg^2
Signal-to-noise ratio
10^0
10^1
10^2
10^3
10^4
10^1
10^2

Table 1: Summary of a plausible observing schedule, expected sensitivities, and source localization with the advanced LIGO and Virgo detectors, which will be strongly dependent on the detectors' commissioning progress. The burst ranges assume standard-candle emission of $10^{-2}\,M_{\odot}c^2$ in GWs at 150 Hz and scale as $E_{\rm GW}^{1/2}$. The burst and binary neutron star (BNS) ranges and the BNS localizations reflect the uncertainty in the detector noise spectra shown in Figure 1. Differences in the shape of the detector noise curves and also relative sensitivities between detectors have an effect on the localization areas. The BNS detection numbers also account for the uncertainty in the BNS source rate density [1], and are computed assuming a false alarm rate of $10^{-2}\,{\rm yr}^{-1}$. Burst localizations are expected to be broadly similar to those for BNS systems, but will vary depending on the signal bandwidth. Localization and detection numbers assume an 80% duty cycle for each instrument.

Epoch	Estimated Run Duration	$E_{\rm GW} = 10^{-2}\,M_{\odot}c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
		LIGO	Virgo	LIGO	Virgo		5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016 – 2017	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017 – 2018	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

Table 1: Summary of a plausible observing schedule, expected sensitivities, and source localization with the advanced LIGO and Virgo detectors, which will be strongly dependent on the detectors' commissioning progress. The burst ranges assume standard-candle emission of $10^{-2} M_{\odot}c^2$ in GWs at 150 Hz and scale as $E_{\mathrm{GW}}^{1/2}$. The binary neutron star (BNS) localizations is characterised by the size of the 90% credible region (CR) and the searched area. For 2015 and 2016–2017, these have been calculated from parameter estimation studies [2, 5]. The CRs for subsequent periods are estimated from timing triangulation (highlighted by italics), which is known to provide estimates on average a factor of ~ 4 too large [4, 2] for a three-detector network. Both ranges as well as the BNS timing-triangulation localizations reflect the uncertainty in the detector noise spectra shown in Figure 1. Differences in the shape of the detector noise curves and also relative sensitivities between detectors have an effect on the localization areas. The BNS detection numbers also account for the uncertainty in the BNS source rate density [1]. BNS detection numbers and sky localization estimates are computed assuming an SNR greater than 12. Burst localizations are expected to be broadly similar to those derived from timing triangulation, but will vary depending on the signal bandwidth; the median burst searched area (with a FAR of ~ 1 yr^{-1}) may be a factor of ~ 2–3 larger than the values quoted for BNS signals [3]. Localization and detection numbers assume an 80% duty cycle for each instrument.

Epoch			2015	2016 – 2017	2017 – 2018	2019+	2022+ (India)
Estimated run duration			3 months	6 months	9 months	(per year)	(per year)
Burst range/Mpc		LIGO	40 – 60	60 – 75	75 – 90	105	105
		Virgo	—	20 – 40	40 – 50	40 – 80	80
BNS range/Mpc		LIGO	40 – 80	80 – 120	120 – 170	200	200
		Virgo	—	20 – 60	60 – 85	65 – 130	130
BNS detections			0.0004 – 3	0.006 – 20	0.04 – 100	0.2 – 200	0.4 – 400
90% CR	% within	5 deg^2	< 1	2	*1 – 2*	*3 – 8*	*17*
		20 deg^2	< 1	14	*10 – 12*	*8 – 28*	*48*
	median/deg^2		481	235	—	—	—
searched area	% within	5 deg^2	6	20	—	—	—
		20 deg^2	16	44	—	—	—
	median/deg^2		88	29	—	—	—

Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories

LIGO Scientific Collaboration, Virgo Collaboration: J. Aasi, J. Abadie, B. P. Abbott, R. Abbott, T. D. Abbott, M. Abernathy, T. Accadia, F. Acernese, C. Adams, T. Adams, P. Addesso, R. X. Adhikari, C. Affeldt, M. Agathos, O. D. Aguiar, P. Ajith, B. Allen, A. Allocca, E. Amador Ceron, D. Amariutei, S. B. Anderson, W. G. Anderson, K. Arai, M. C. Araya, C. Arceneaux, S. Ast, S. M. Aston, P. Astone, D. Atkinson, P. Aufmuth, C. Aulbert, L. Austin, B. E. Aylott, S. Babak, P. Baker, G. Ballardin, S. Ballmer, Y. Bao, J. C. Barayoga, D. Barker, F. Barone, B. Barr, L. Barsotti, M. Barsuglia, M. A. Barton, I. Bartos, R. Bassiri, M. Bastarrika, A. Basti, J. Batch, J. Bauchrowitz, Th. S. Bauer, M. Bebronne, B. Behnke, M. Bejger, M.G. Beker, A. S. Bell, C. Bell, G. Bergmann, J. M. Berliner, A. Bertolini, et al. (775 additional authors not shown)

(Submitted on 2 Apr 2013)

We present a possible observing scenario for the Advanced LIGO and Advanced Virgo gravitational wave detectors over the next decade, with the intention of providing information to the astronomy community to facilitate planning for multi-messenger astronomy with gravitational waves. We determine the expected sensitivity of the network to transient gravitational-wave signals, and study the capability of the network to determine the sky location of the source. For concreteness, we focus primarily on gravitational-wave signals from the inspiral of binary neutron star (BNS) systems, as the source considered likely to be the most common for detection and also promising for multimessenger astronomy. We find that confident detections will likely require at least 2 detectors operating with BNS sensitive ranges of at least 100 Mpc, while ranges approaching 200 Mpc