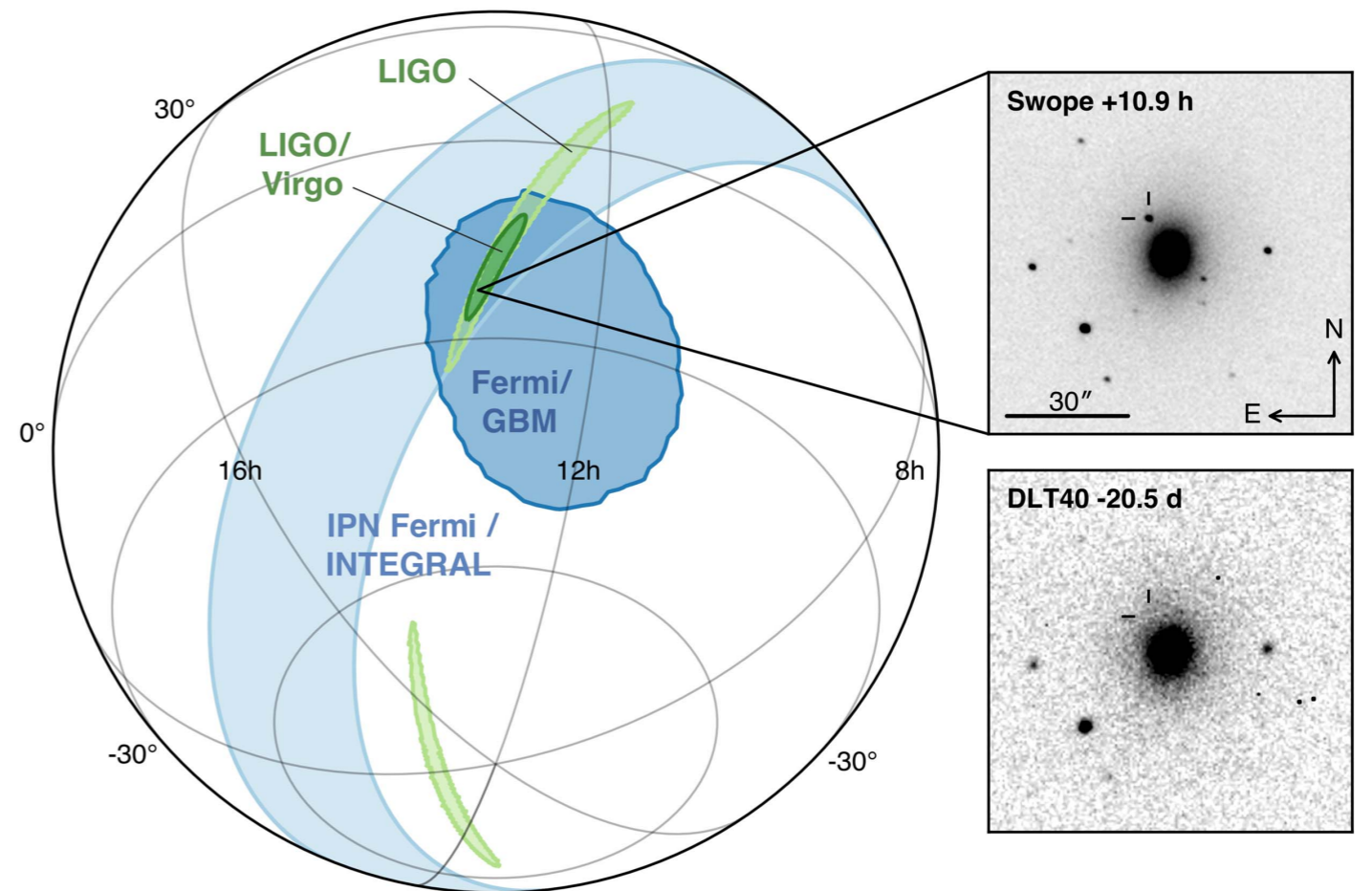
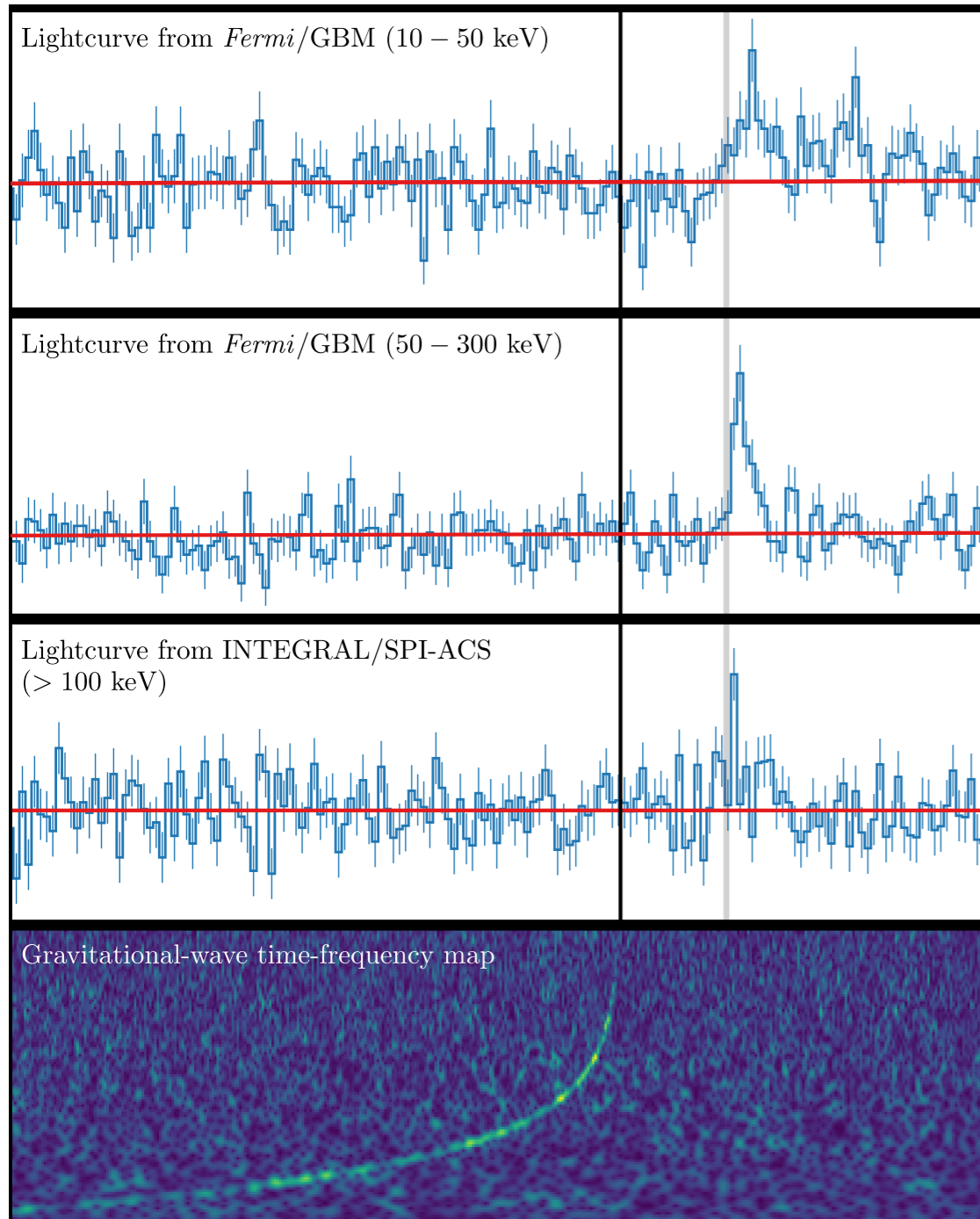


# LIGO, Virgo and KAGRA plans in LSST era of 2022+

Stephen Fairhurst

# GW170817

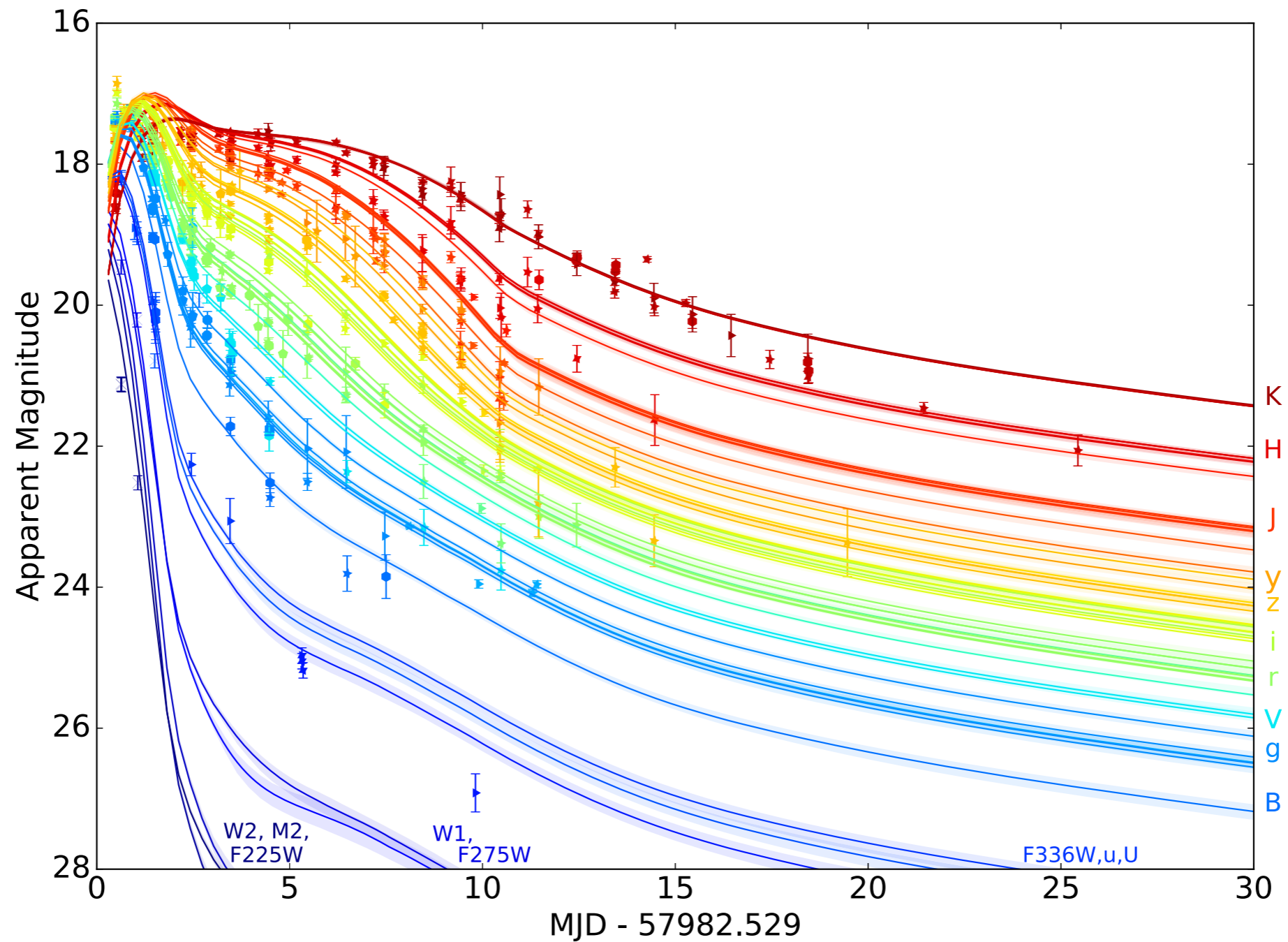


From Abbott et al, “Multi-messenger Observations of a Binary Neutron Star Merger”

Luminosity distance: 40 Mpc

From Abbott et al, “Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A”

# GW170817

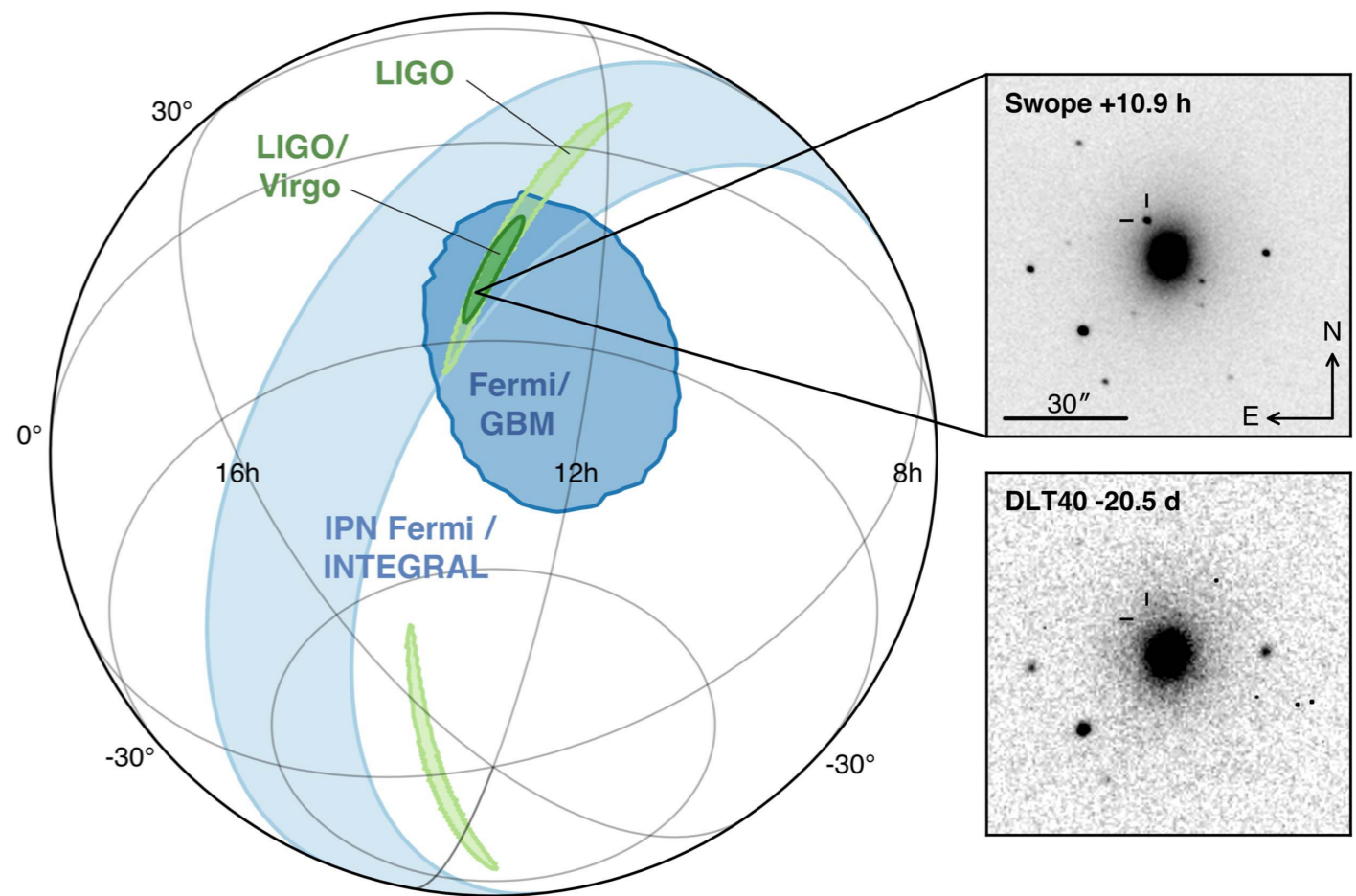
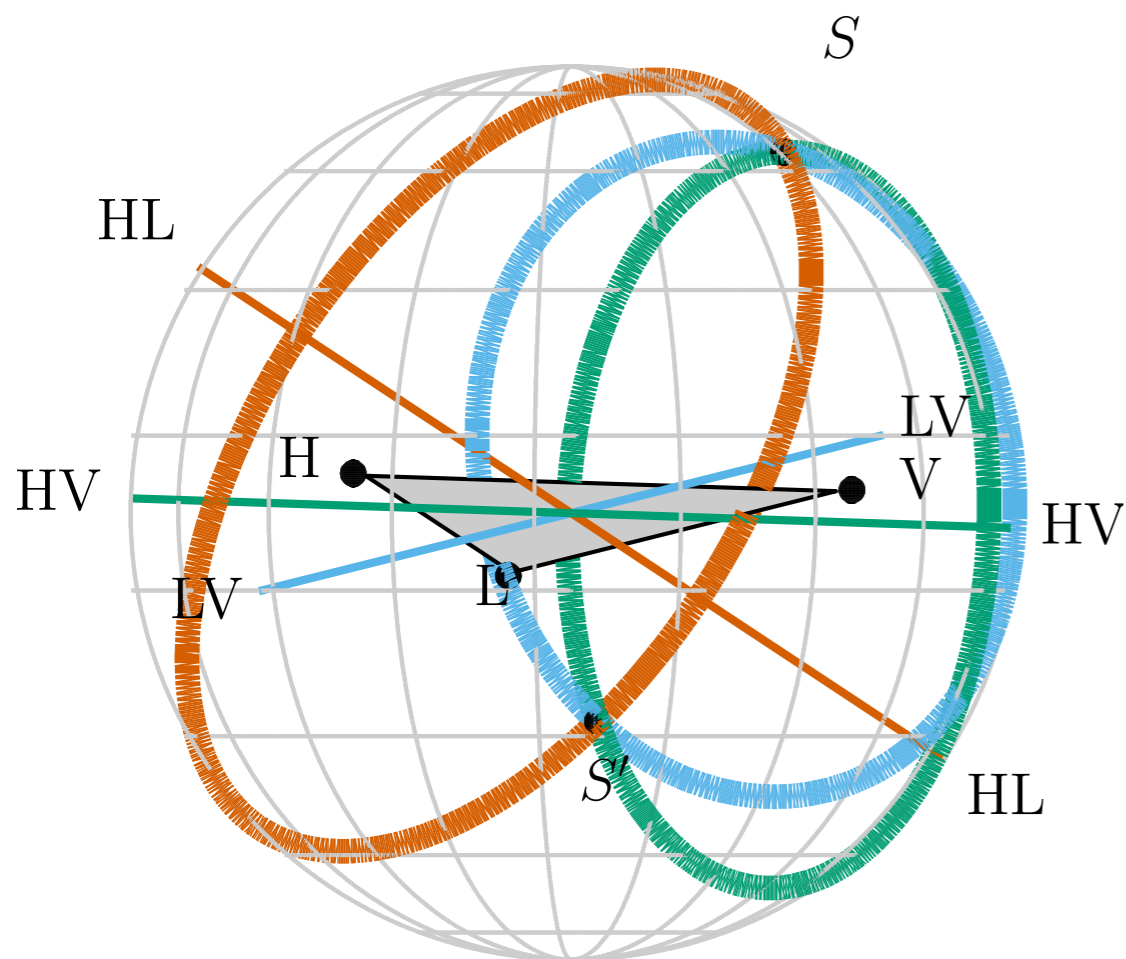


From Villar et al, ApJL 2017

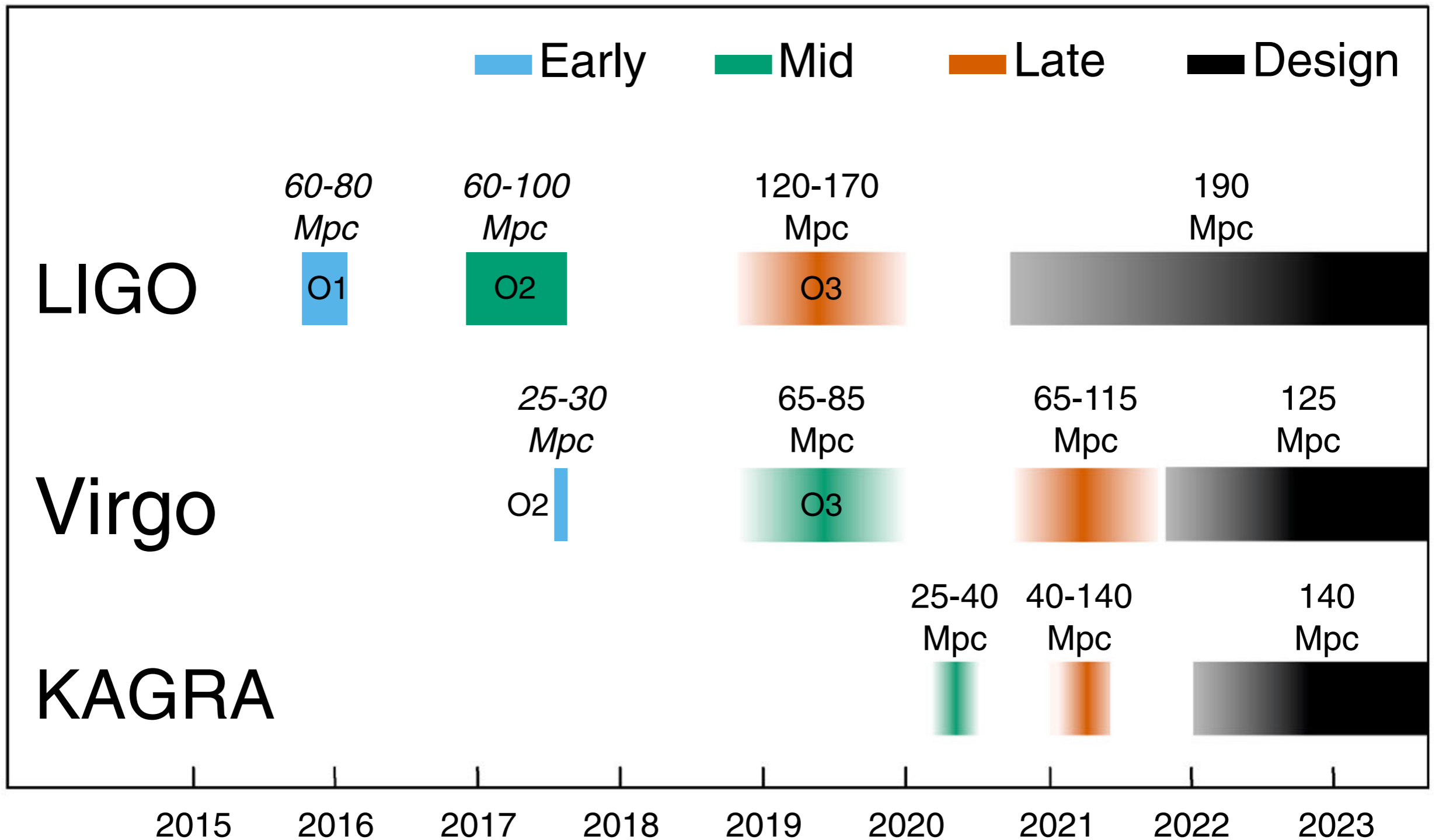
# Science from joint GW-EM observations

- Definitive association of short GRB and kilonova with neutron star mergers (and NS-BH?)
- Understanding the emission as a function of the binary mass and orientation
- Study r-process nucleosynthesis and heavy element formation
- Probe neutron star structure, equation of state of dense nuclear matter
- Hubble constant measurement through independent distance (GW) and redshift (EM) measurement
- Possible unexpected GW transients

# Gravitational wave localisation



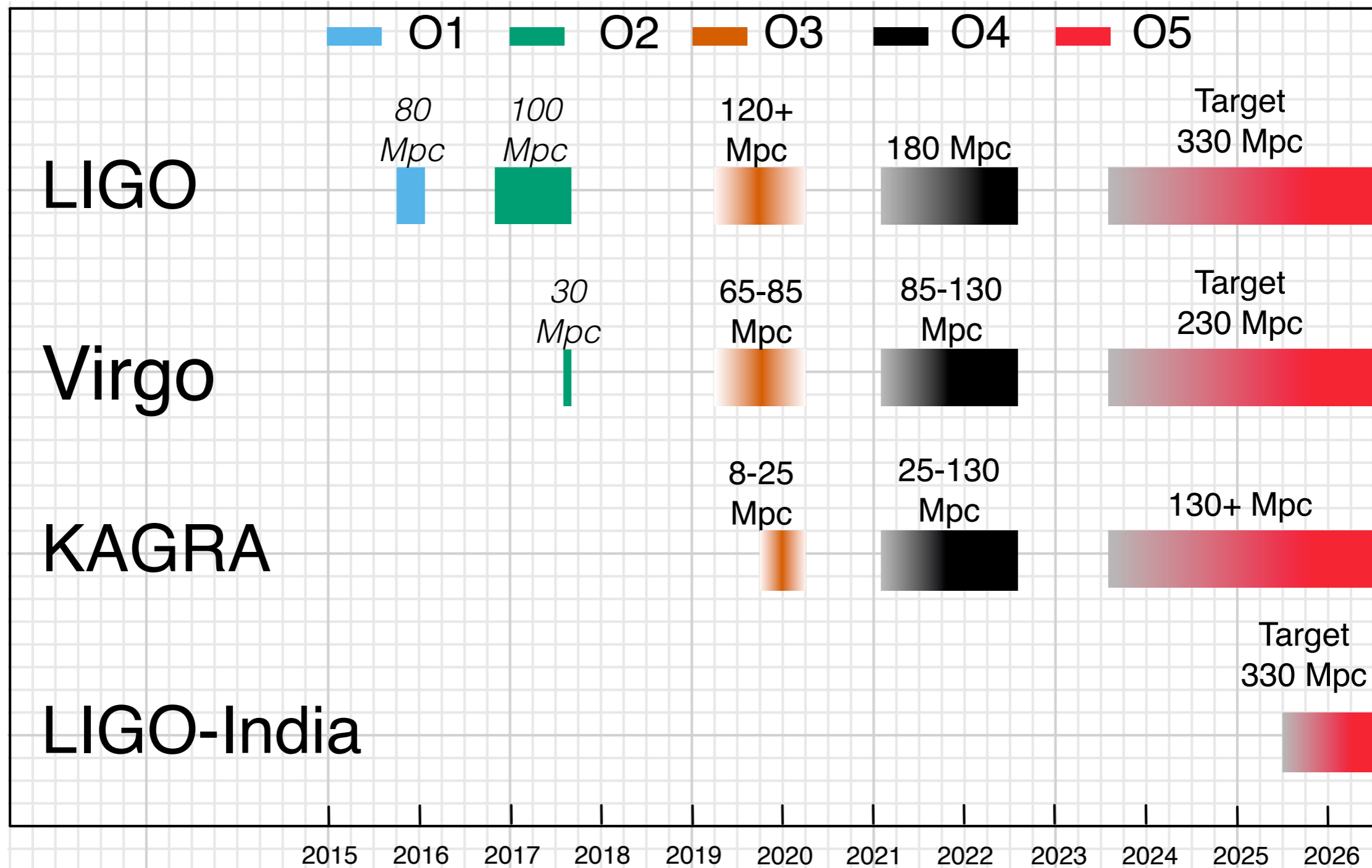
# Sensitivity Evolution



From Abbott et al, arXiv:1304.0670v6

Epoch			2015–2016	2016–2017	2018–2019	2020+	2024+
Planned run duration			4 months	9 months	12 months	(per year)	(per year)
Expected burst range/Mpc	LIGO		40–60	60–75	75–90	105	105
	Virgo		–	20–40	40–50	40–70	80
	KAGRA		–	–	–	–	100
Expected BNS range/Mpc	LIGO		40–80	80–120	120–170	190	190
	Virgo		–	20–65	65–85	65–115	125
	KAGRA		–	–	–	–	140
Achieved BNS range/Mpc	LIGO		60–80	60–100	–	–	–
	Virgo		–	25–30	–	–	–
	KAGRA		–	–	–	–	–
Estimated BNS detections			0.05–1	0.2–4.5	1–50	4–80	11–180
Actual BNS detections			0	1	–	–	–
90% CR	% within	5 deg <sup>2</sup>	< 1	1–5	1–4	3–7	23–30
		20 deg <sup>2</sup>	< 1	7–14	12–21	14–22	65–73
		Median/deg <sup>2</sup>	460–530	230–320	120–180	110–180	9–12
Searched area	% within	5 deg <sup>2</sup>	4–6	15–21	20–26	23–29	62–67
		20 deg <sup>2</sup>	14–17	33–41	42–50	44–52	87–90

# Towards a 5-detector network



From LIGO Decadal Submission, [arXiv:1904.03187](https://arxiv.org/abs/1904.03187)



# O3 alerts

<https://gracedb.ligo.org/>

## GraceDB — Gravitational Wave Candidate Event Database

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Latest — as of 14 May 2019 09:33:58 UTC

Test and MDC events and superevents are not included in the search results by default; see the [query help](#) for information on how to search for events and superevents in those categories.

Query:

Search for: Superevent

Search

UID	Labels	t_start	t_0	t_end	FAR (Hz)	UTC Created
<a href="#">S190513bm</a>	DQOK ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY GCN_PRELIM_SENT	1241816085.736106	1241816086.869141	1241816087.869141	3.734e-13	2019-05-13 20:54:48 UTC
<a href="#">S190512at</a>	DQOK ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY GCN_PRELIM_SENT	1241719651.411441	1241719652.416286	1241719653.518066	1.901e-09	2019-05-12 18:07:42 UTC
<a href="#">S190510g</a>	DQOK ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY GCN_PRELIM_SENT	1241492396.291636	1241492397.291636	1241492398.293185	8.834e-09	2019-05-10 03:00:03 UTC
<a href="#">S190503bf</a>	DQOK PASTRO_READY EMBRIGHT_READY SKYMAP_READY ADVOK GCN_PRELIM_SENT	1240944861.288574	1240944862.412598	1240944863.422852	1.636e-09	2019-05-03 18:54:26 UTC
<a href="#">S190426c</a>	DQOK EMBRIGHT_READY PASTRO_READY SKYMAP_READY ADVOK GCN_PRELIM_SENT PE_READY	1240327332.331668	1240327333.348145	1240327334.353516	1.947e-08	2019-04-26 15:22:15 UTC
<a href="#">S190425z</a>	DQOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY ADVOK	1240215502.011549	1240215503.011549	1240215504.018242	4.538e-13	2019-04-25 08:18:26 UTC
<a href="#">S190421ar</a>	DQOK EMBRIGHT_READY PASTRO_READY SKYMAP_READY GCN_PRELIM_SENT ADVOK PE_READY	1239917953.250977	1239917954.409180	1239917955.409180	1.489e-08	2019-04-21 21:39:16 UTC
<a href="#">S190412m</a>	DQOK SKYMAP_READY PASTRO_READY EMBRIGHT_READY ADVOK GCN_PRELIM_SENT PE_READY	1239082261.146717	1239082262.222168	1239082263.229492	1.683e-27	2019-04-12 05:31:03 UTC
<a href="#">S190408an</a>	DQOK ADVOK SKYMAP_READY PASTRO_READY EMBRIGHT_READY GCN_PRELIM_SENT PE_READY	1238782699.268296	1238782700.287958	1238782701.359863	2.811e-18	2019-04-08 18:18:27 UTC
<a href="#">S190405ar</a>	DQOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY ADVNO	1238515307.863646	1238515308.863646	1238515309.863646	2.141e-04	2019-04-05 16:01:56 UTC

# Example: S190425z

## GraceDB – Gravitational Wave Candidate Event Database

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### Superevent Info

Superevent ID	Category	Labels	FAR (Hz)	FAR (yr <sup>-1</sup> )	t_start	t_0	t_end	UTC Submission time	Links
S190425z	Production	ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK	4.538e-13	1 per 69834 years	1240215502.011549	1240215503.011549	1240215504.018242	2019-04-25 08:18:26 UTC	<a href="#">Data</a>

### Preferred Event Info

Group	Pipeline	Search	Instruments	GPS Time Event time	UTC Submission time
CBC	gstlal	AllSky	L1,V1	1240215503.0171	2019-04-25 08:18:25 UTC

