

# O3 simulation

*with GPU-accelerated  
CBC Parameter Estimation (G.P.E.)*

S. Haino / Academia Sinica

# Acknowledgements

Special Thanks to:

- Narikawa-san (ICRR)  
Sharing information and suggestions
- Prof. Ting-Wai Chiu (NTNU/ASIoP)  
GPU developments and his GPU farm supports
- Academia Sinica Grid Center (ASGC)  
GPU farm and computing supports

# Simulation conditions

- Software: GPU-accelerated Parameter Estimation (GPE) based on nested sampling algorithm
  - *JGW-G1807674-v2*
- Signal injection: NS-NS (1.5-1.25) at 40 Mpc  
TaylorF2 waveform (no-spin, no-tidal)
- Sensitivity curves from :
  - *arXiv:1304.0670 (LRR 19,1)* for LIGO/Virgo
  - *JGW-T1707556-v2 (Y.Enomoto)* for KAGRA

# Sensitivity scenarios

	LIGO <sup>*1</sup>	Virgo <sup>*1</sup>	KAGRA <sup>*2</sup>
Case 1	Late Low (116 Mpc)	Mid. Low (62.9 Mpc)	O3-40 (42.3 Mpc)
Case 2	Late Low (116 Mpc)	Late Low (83.1 Mpc)	O3-40 (42.3 Mpc)
Case 3	Late Low (116 Mpc)	Late Low (83.1 Mpc)	O3-20 <sup>*3</sup> (20.1 Mpc)
Case 4	Late Low (116 Mpc)	Late Low (83.1 Mpc)	O3-10 (9.5 Mpc)

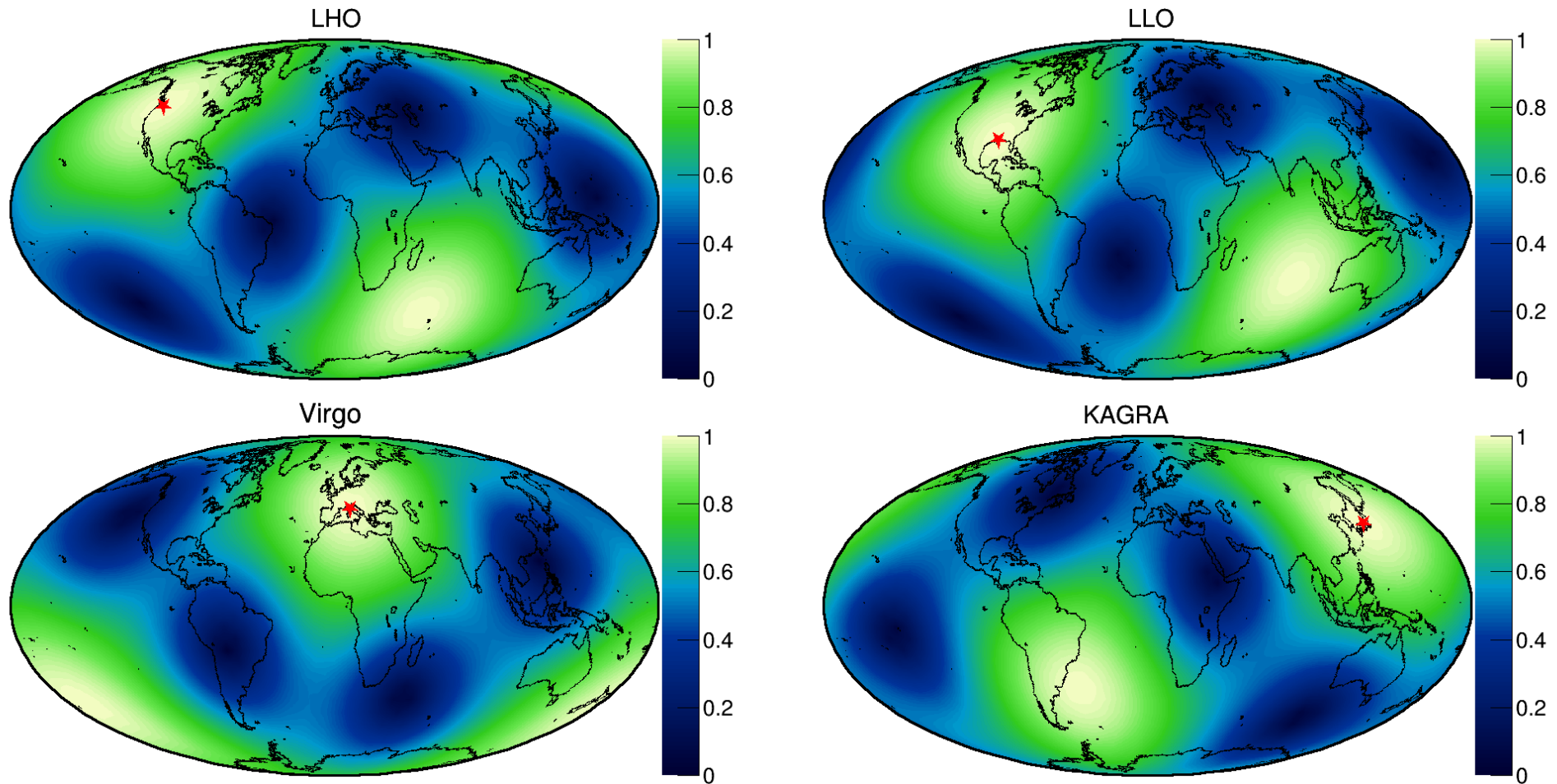
<sup>\*1</sup> Sensitivity data from *arXiv:1304.0670 (LRR 19,1)*

<sup>\*2</sup> Sensitivity data by *Y.Enomoto JGW-T1707556-v2*

<sup>\*3</sup> Sensitivity data interpolated *JGW-T1707556-v2*

# Detector antenna patterns

$$\text{Sqrt}(F_p^2 + F_x^2)$$



# Simulation conditions

Injected with 15,360 (= 192 x 5 x 4 x 4) conditions:

- 192 (Longitudes and Latitudes – *Heaplix* uniform)
- 5 Polarization angles ( $\psi = 0, 0.2\pi, 0.4\pi, 0.6\pi, 0.8\pi$ )
- 4 Inclination angles ( $\theta_{JN} = -30^\circ, -42^\circ, 42^\circ, 30^\circ$ )
- 4 sensitivity scenarios

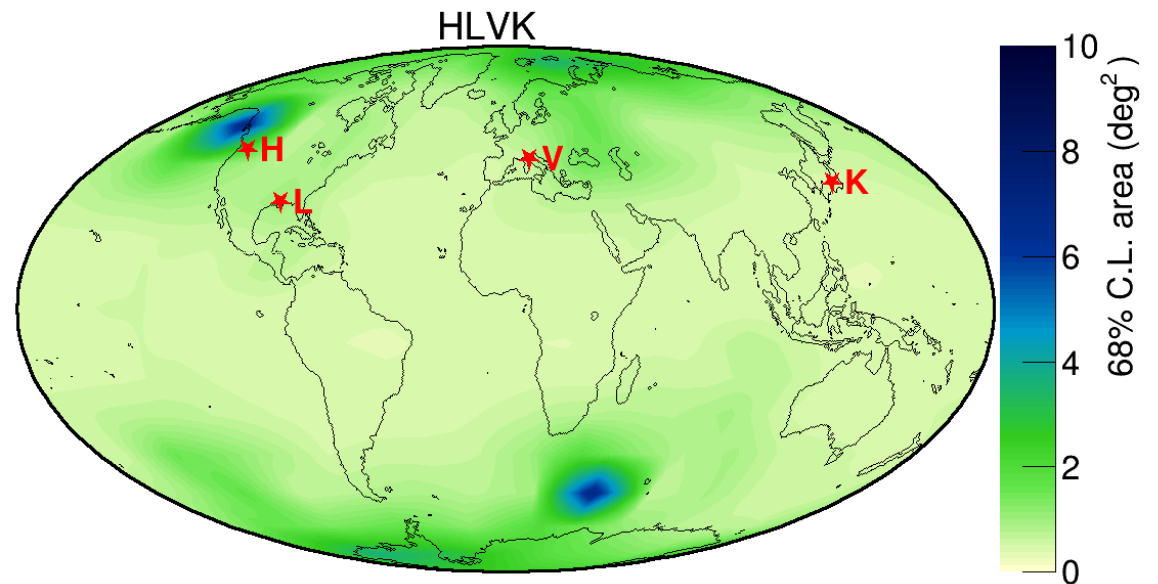
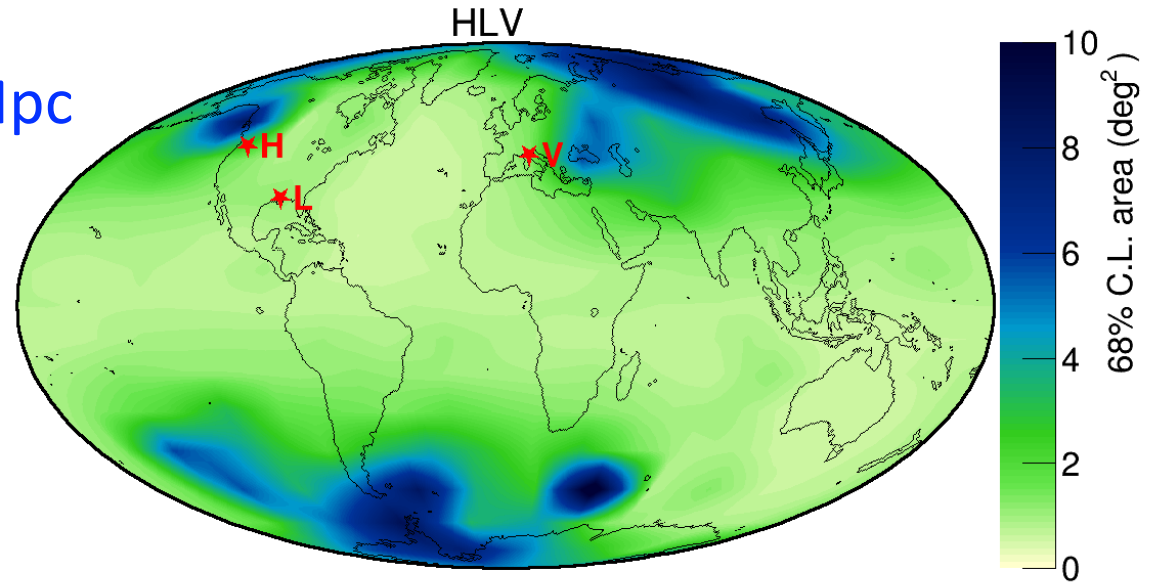
*computation time for each simulation is ~6 min.*

*(with GeForce™ GTX 1080 Ti)*

# Sky confidence area comparison

Case 1: LVK= 120, 60, 40 Mpc

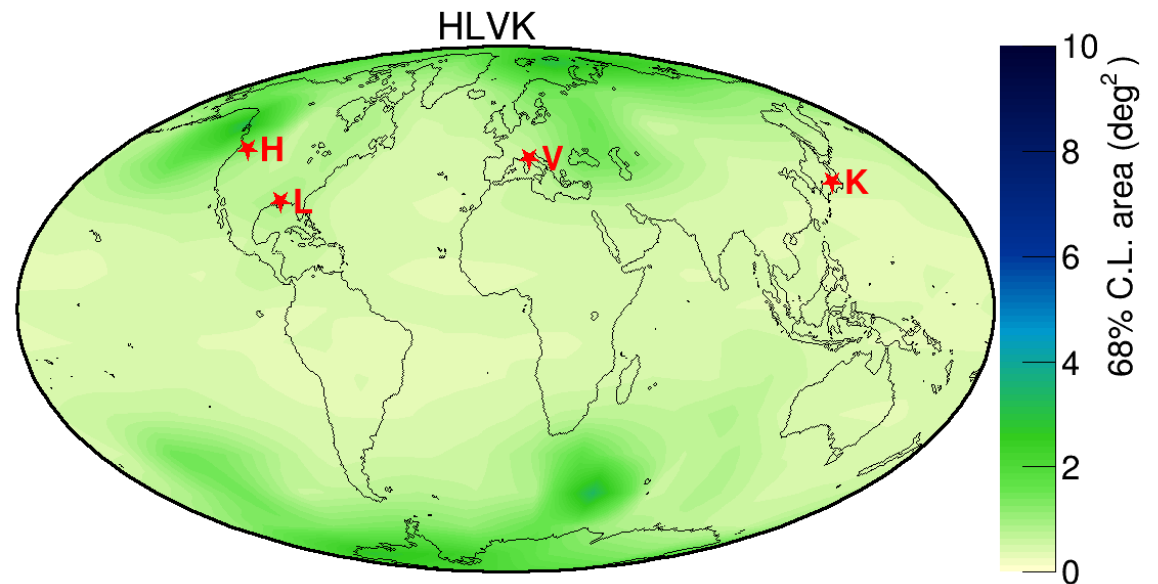
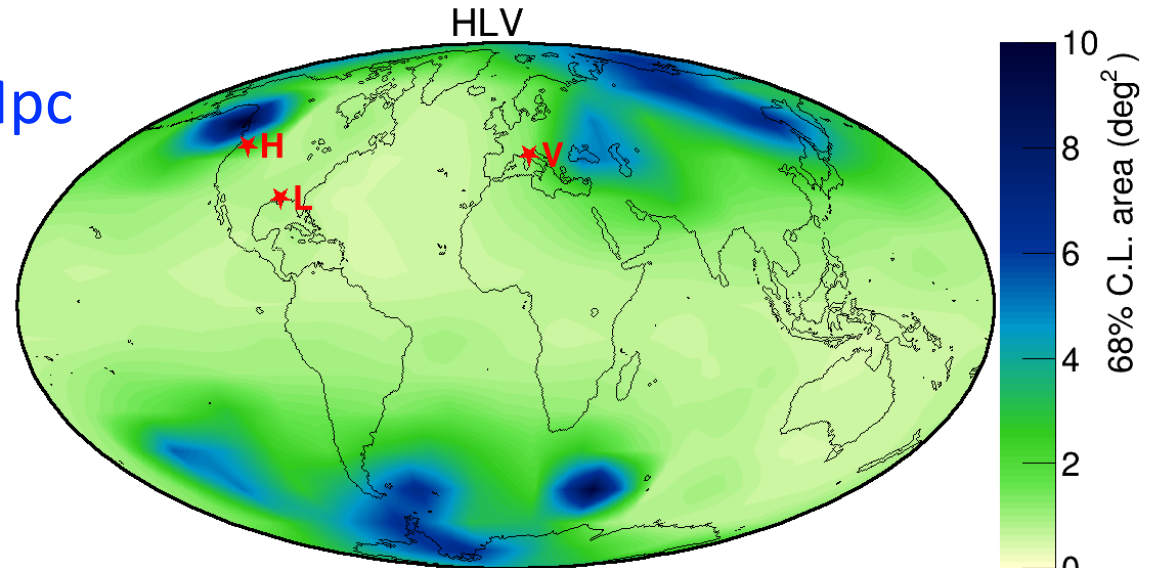
$$\psi = 0.6\pi \theta_{\text{JN}} = 42^\circ$$



# Sky confidence area comparison

Case 1: LVK= 120, 80, 40 Mpc

$$\psi = 0.6\pi \theta_{\text{JN}} = 42^\circ$$

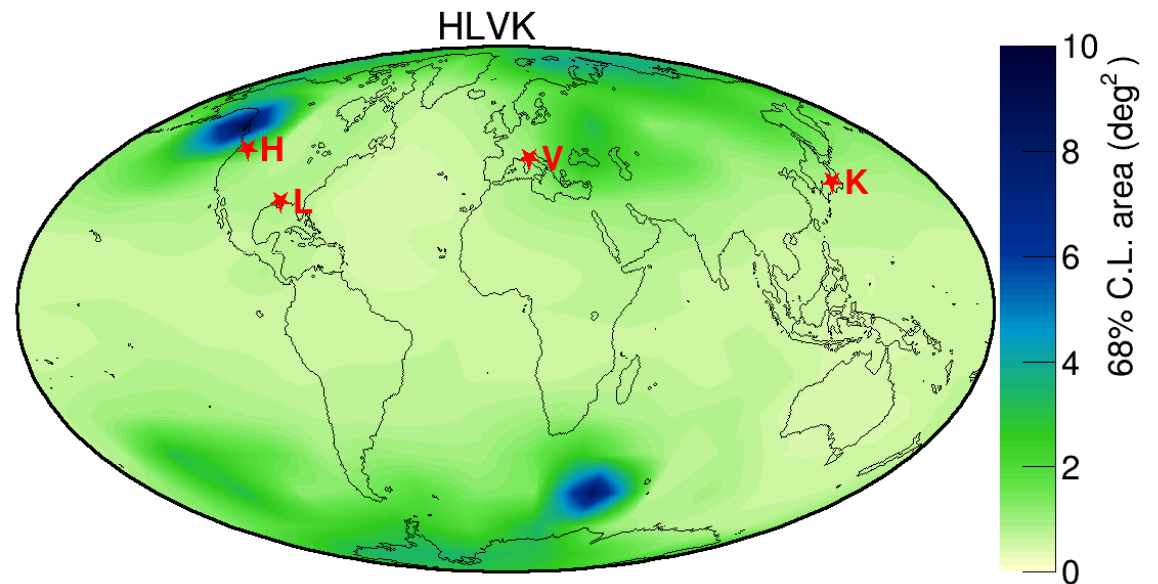
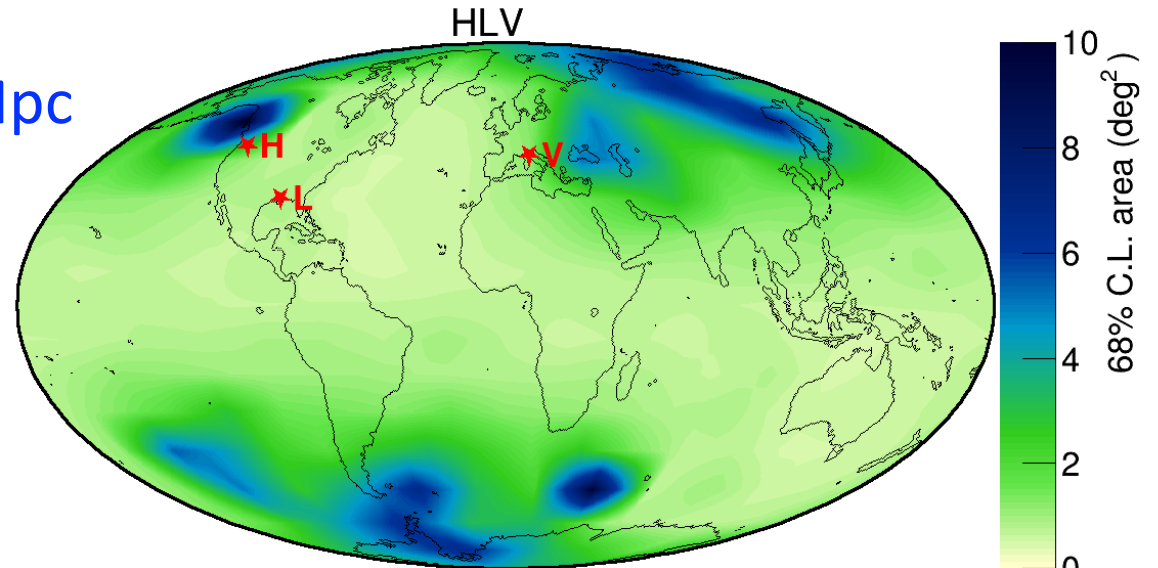




# Sky confidence area comparison

Case 1: LVK= 120, 80, 20 Mpc

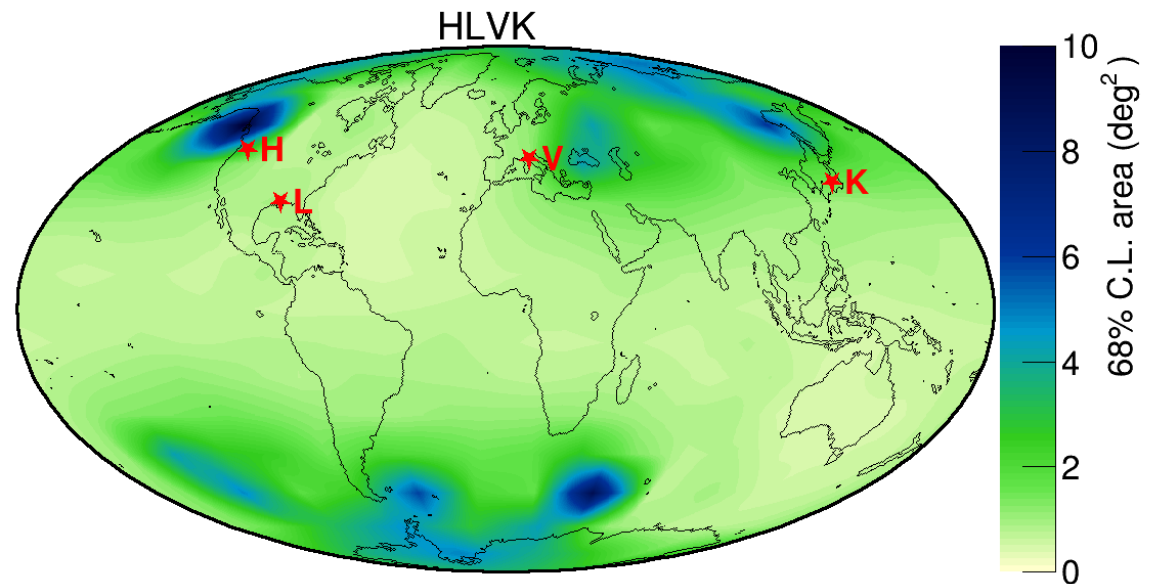
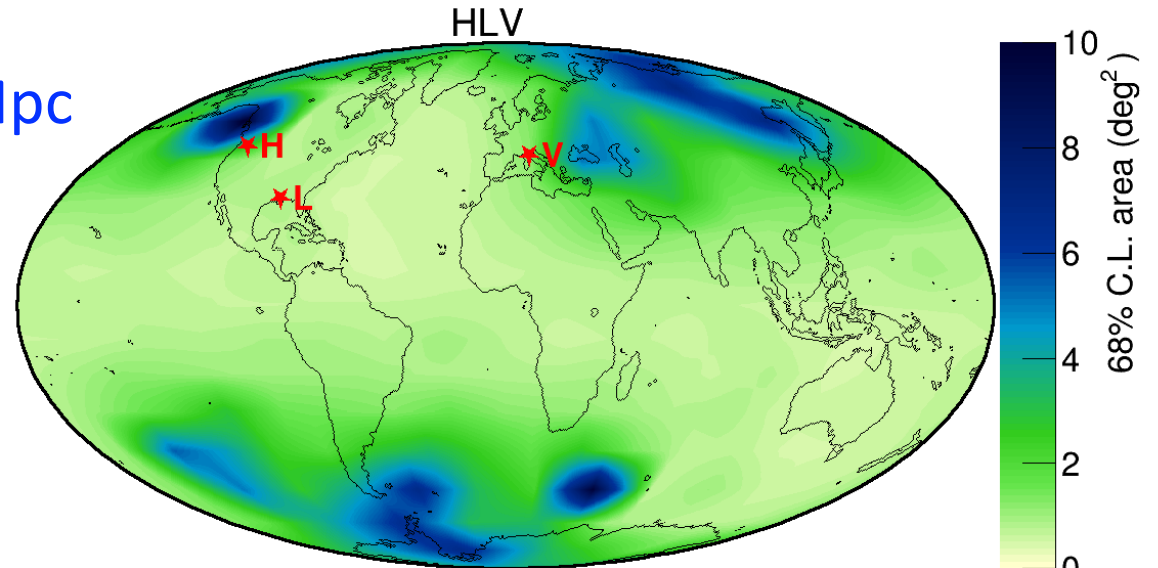
$$\psi = 0.6\pi \theta_{\text{JN}} = 42^\circ$$



# Sky confidence area comparison

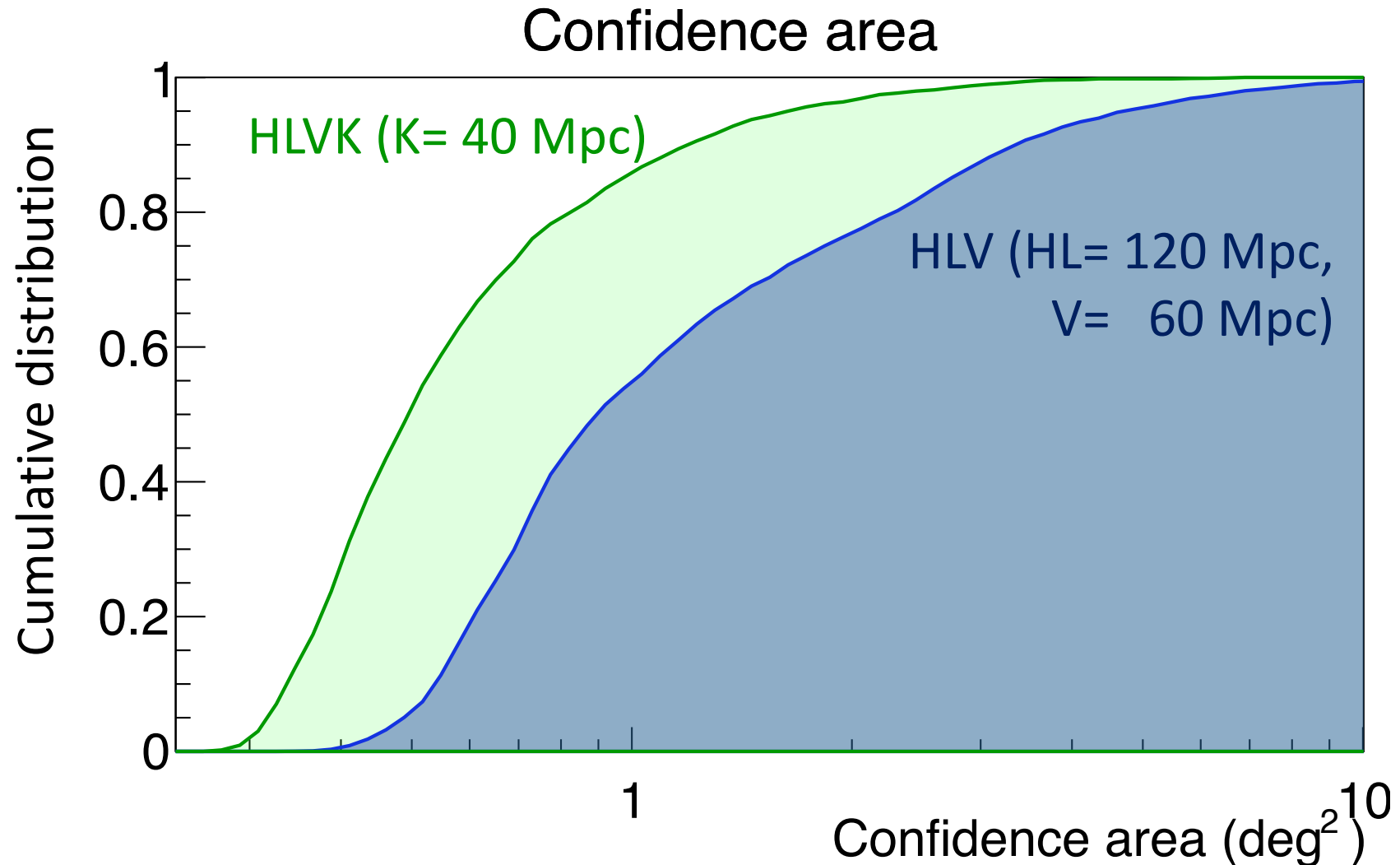
Case 1: LVK= 120, 80, 10 Mpc

$$\psi = 0.6\pi \theta_{\text{JN}} = 42^\circ$$



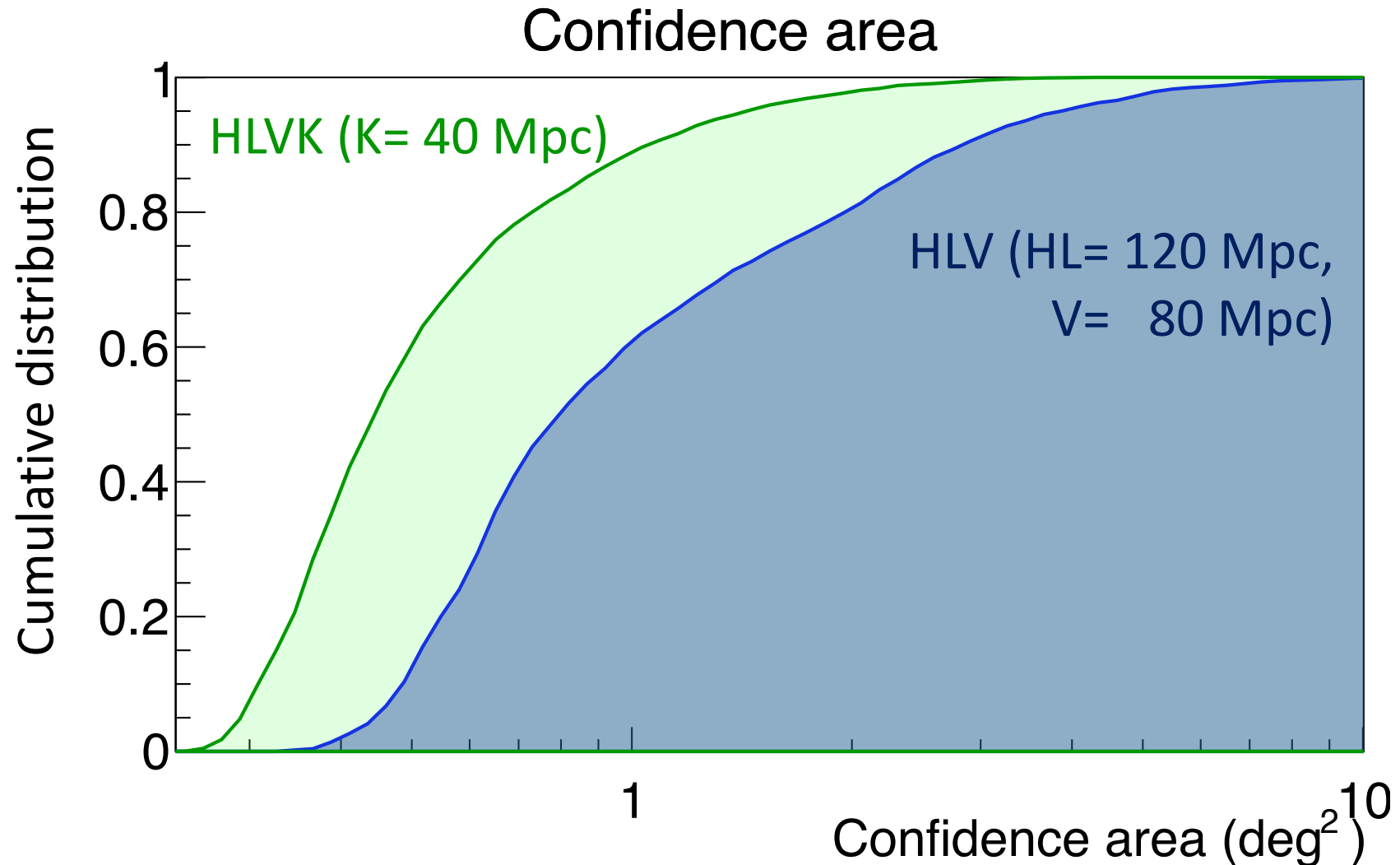
# Sky confidence area summary

Averaged over 3840 cases (192 long./lat. 5  $\psi$ , 4  $\theta_{JN}$ )



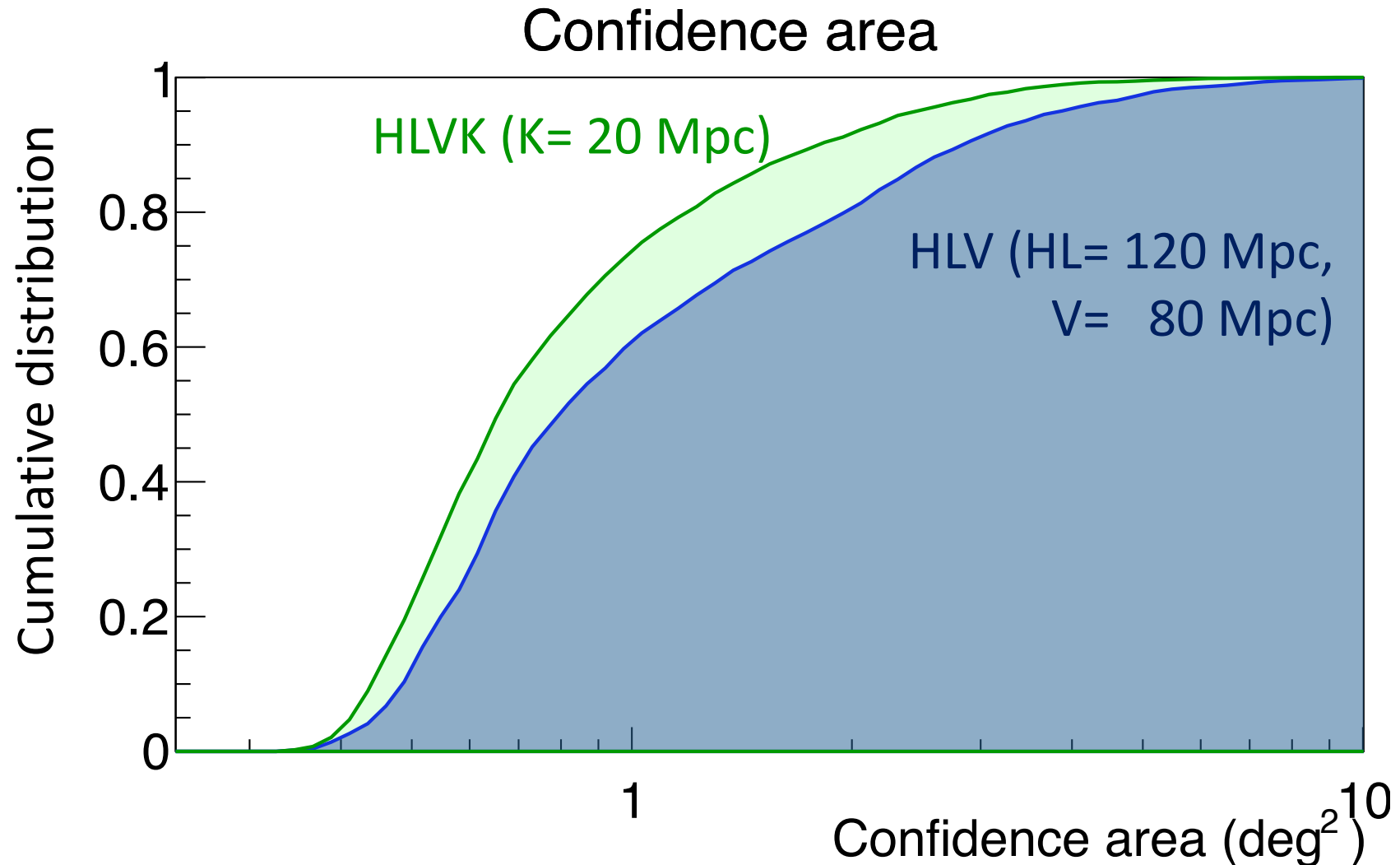
# Sky confidence area summary

Averaged over 3840 cases (192 long./lat. 5  $\psi$ , 4  $\theta_{JN}$ )



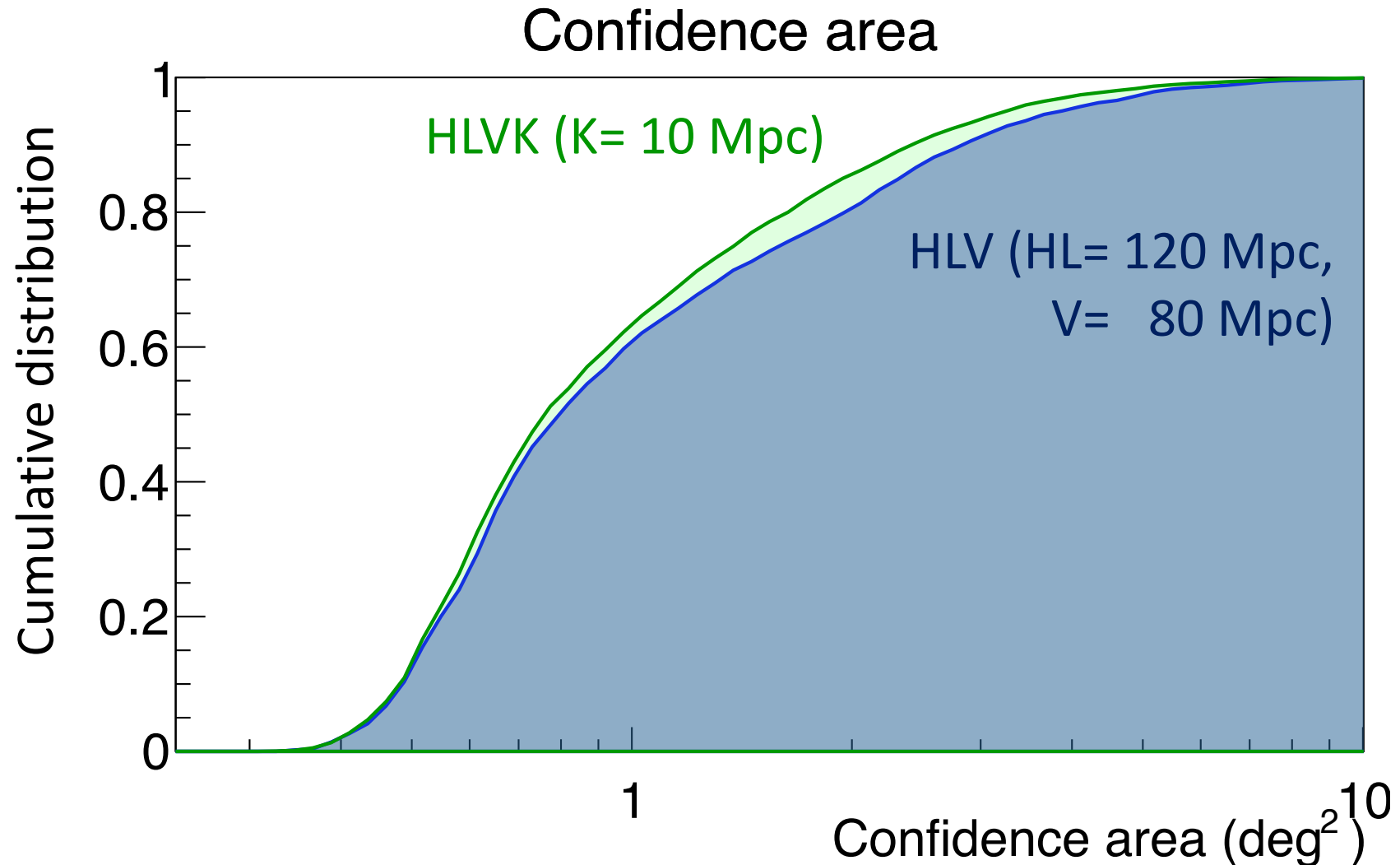
# Sky confidence area summary

Averaged over 3840 cases (192 long./lat. 5  $\psi$ , 4  $\theta_{JN}$ )



# Sky confidence area summary

Averaged over 3840 cases (192 long./lat. 5  $\psi$ , 4  $\theta_{JN}$ )





# Comparison (KAGRA 40 Mpc)

Based on Narikawa-san's list: TF2\_15BNS125\_40Mpc\_i30deg.xml

Event #	SNR(H)		SNR(L)		SNR(V)		SNR(K)		Network	
	TN	SH	TN	SN	TN	SN	TN	SN	TN	SN
10	42.2	42.2	43.2	43.2	9.2	9.2	7.8	7.8	61.6	61.6

Ev. #	$\Delta\Omega$ (HL)		$\Delta\Omega$ (HLV)		$\Delta\Omega$ (HLK)		$\Delta\Omega$ (HVK)		$\Delta\Omega$ (LVK)		$\Delta\Omega$ (HLVK)	
	TN	SH	TN	SN	TN	SN	TN	SN	TN	SN	TN	SN
10	167	144	5.5	5.9	25.5	27.1	8.1	9.3	6.9	6.6	5.3	5.6

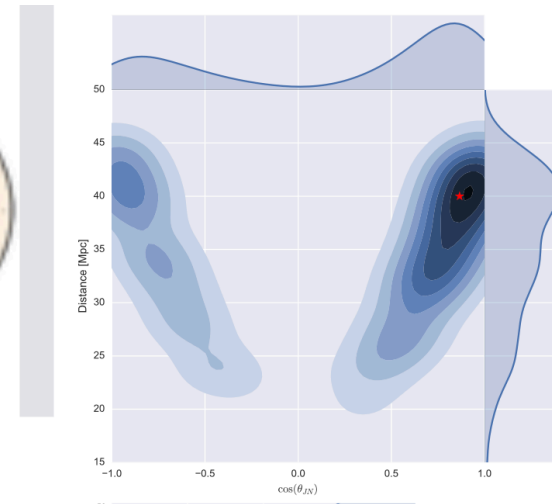
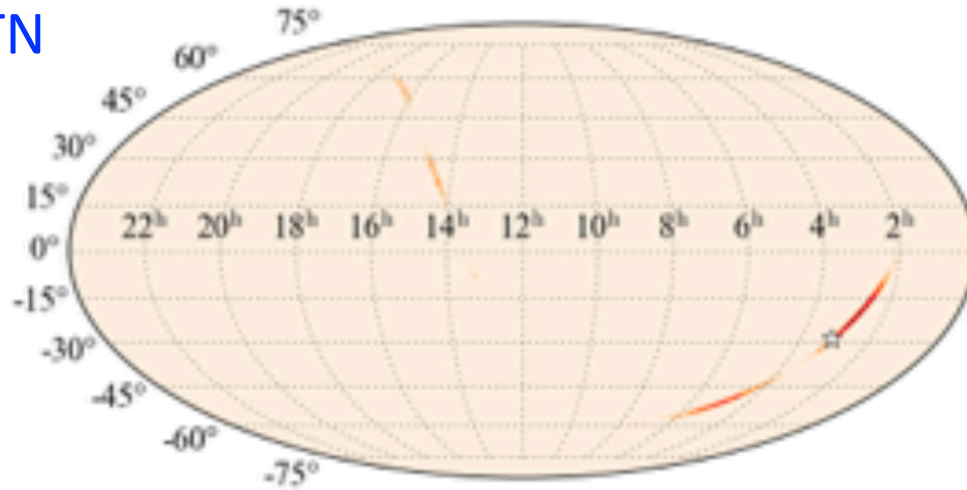
Agreements between TN and SH results



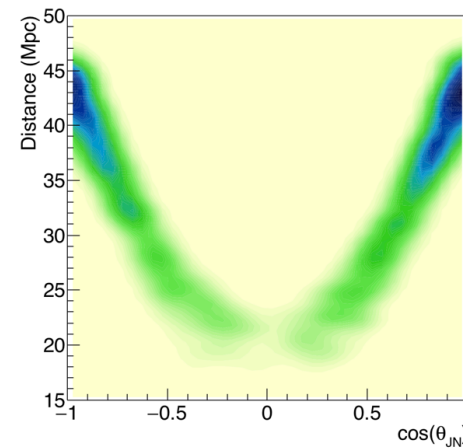
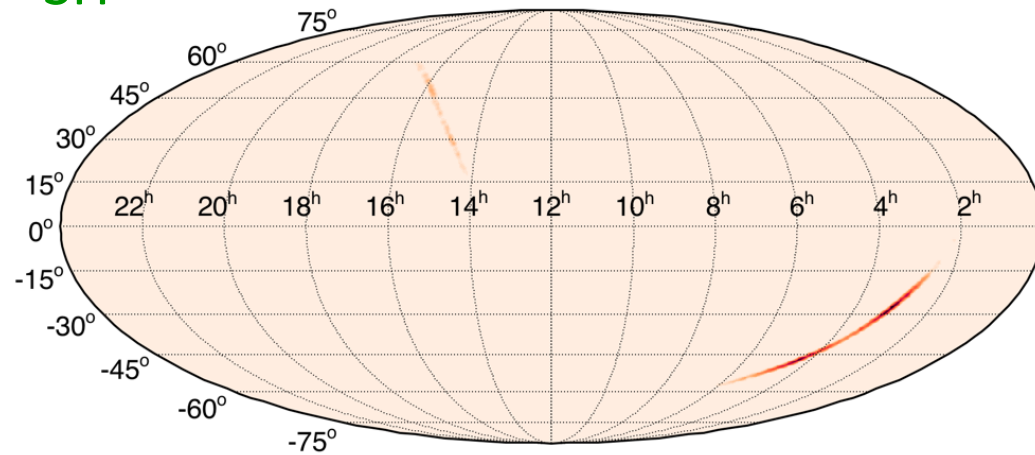
# Comparison

Event #10 <HL>  $\Delta\Omega = 167$  (TN), 144 (SH)  $\text{deg}^2$

TN



SH



# Injected signals

Based on Narikawa-san's list: TF2\_15BNS125\_40Mpc\_i30deg.xml

Event #	SNR(H)		SNR(L)		SNR(V)		SNR(K)		Network	
	TN	SH	TN	SN	TN	SN	TN	SN	TN	SN
2	19.4	19.4	26.2	26.2	2.7	2.7	3.5	3.5	32.9	32.9
271	25.2	25.2	8.8	8.8	12.4	12.4	3.4	3.4	29.7	29.7
287	16.3	16.3	18.1	18.1	7.5	7.5	3.6	3.6	25.7	25.7
294	27.5	27.4	15.4	15.4	12.0	12.0	3.5	3.5	33.9	33.9
300	20.1	20.1	12.9	12.9	10.7	10.7	3.6	3.6	26.4	26.4
306	18.1	18.1	16.8	16.8	8.8	8.8	3.7	3.7	26.5	26.4
320	21.9	21.9	17.0	17.0	10.2	10.2	3.7	3.7	29.8	29.8

# 90 % C.L. area

Based on Narikawa-san's list: TF2\_15BNS125\_40Mpc\_i30deg.xml

Ev. #	$\Delta\Omega$ (HL)		$\Delta\Omega$ (HLV)		$\Delta\Omega$ (HLK)		$\Delta\Omega$ (HVK)		$\Delta\Omega$ (LVK)		$\Delta\Omega$ (HLVK)	
	TN	SH	TN	SN	TN	SN	TN	SN	TN	SN	TN	SN
2	101	95	30	33	50	64	308	2520	35	410	19	27
271	314	83	41	17	163	33	26	12		14	26	11
287	564	52	64	20	282	47		68	443	106	44	15
294	336	101	46	20	116	36	164	13		44	27	9.5
300	372	64	55	18	158	26	260	12		15	38	10
306	413	125	53	27	162	49	612	13	702	11	32	11
320	321	109	50	23	194	51	464	15	720	16	25	12

# Issues to be checked

- Confidence area depends on the smoothing of Healpix map (--skyres)  
Too big values (--skyres=0.5~1) result in worsening of the confidence area particularly for >2 detectors
- The consistency of results between TN and SH should be checked