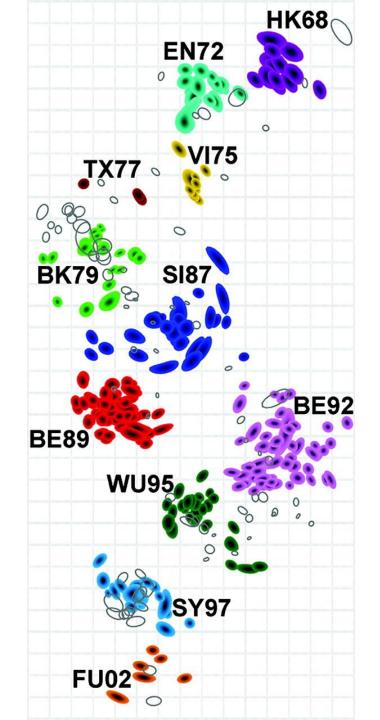
Introduction to antigenic cartography

August 2024

Antonia Netzl (she/her) an604@cam.ac.uk
PhD student, Centre for Pathogen Evolution, University of Cambridge

Antigenic data

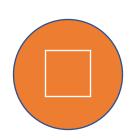
	STRAIN DESIGNATION						REFERENC	E FERRET AN	TISERA							
	3 TRAIN DESIGNATION		Date	Α	В	С	D	E	F	G	н	- 1	J	К	L	М
FFFRENC	E ANTIGENS	CDC ID#	collected	WY/03	WEL/01	CA/7	CA/7	VIC/500	SN/37	WI/19	NY/55	NY/55	HK/4593	NH/14	HK/2831	MS/
	- THE COLUMN TO	0001011	Concecco	REASS	1120 01	G/ 1,7 /	REASS	110,000	REASS	111,710	1117.55	REASS	180 1000	10011	NEW	NE)
1 WY	A/WYOMING/03/2003 X-147	2003715730	REASS	1280	80	160	320	320	40	80	80	40	80	320	40	16
2 NZ	A/WELLINGTON/01/2004	2004729358	1/26/04	160	1280	640	1280	640	30	160	320	160	640	640	160	64
3 CA	A/CALIFORNIA/07/04	2005705486	9/16/04	160	160	640	2560	1280	320	320	320	160	640	640	160	32
4 CA	A/CA/07/04 x PR/8 CDC	2005712034	REASS	320	320	1280	2560	2560	640	640	1280	320	1280	1280	160	12
5 AS	A/VICTORIA/500/2004	2005707652	8/13/04	160	160	320	1280	640	80	160	160	80	320	320	80	32
6 AS	A/SINGAPORE/37/2004 IVR-140	2005707637	REASS	160	160	640	1280	640	640	1280	640	160	640	640	80	32
7 WI	A/WISCONSIN/19/2004	2005705540	11/6/04	160	320	1280	2560	640	320	1280	1280	160	640	640	160	64
8 NY	A/NEW YORK/55/2004	2005705561	1] (20 (04						222			222				64
9 NY	A/NY/55/04 A/PR/8/34 X-157	2005711905										_				12
10 HK	A/HONG KONG/4593/04	2005710182	10	·cc	•	_ 1 _	1 -	• .				1				64
11 NH	A/NEW HAMPSHIRE/14/04	2005710231	12	ITT		IIТ	TC	1 Ir	ΊΤΩ	rn	ДΤ					64
12 HK	A/HONG KONG/2831/05	2005743649			こしし	4 I L	U) ir	こして	i N	てし		7			16
13 MS	A/MISSISSIPPI/5/04	2005707679	12			_				ľ		_				64
EST ANT	IGENS	REPEATS		_	~~	_ :		car	+~	~ 4	.	h,				
14 TH	02-504942 ORIGINAL	2005707539	— a	MIJIN	86	? /]]	\mathbf{C}	dali	LO	212	10	M	d S			64
15 TH	02-504957 ORIGINAL	2005707540			0		_ '			Ο.,	- P	7		-		64
16 TH	02-505107 ORIGINAL	2005707542			_					_	_	_				32
17 MS	05020500027 ORIGINAL	2005712779	2/			_	•	•	_		_	_	•			64
I/ IMIS							_		_				_			
		2005714223	1/2	2	100	^+ :			+^ '		· ^ +	^+		lack		32
18 UR 19 DJ	A/KHABAROVSK/9/05 2004914389		1/2	60	me	eti	ric	ın	tei	rpr	'et	at	101	1		
18 UR	A/KHABAROVSK/9/05	2005714223	1/2 12/1 1/2 S	eo	me	eti	ric	in	te	rpr	et	at	101	1		64
18 UR 19 DJ	A/KHABAROVSK/9/05 2004914389	2005714223 2005714244	1/2 12/1 1/2 1/2	eo	me	eti	ric	ın	te	rpr	et	at	101	1		64 64
18 UR 19 DJ 20 DJ	A/KHABAROVSK/9/05 2004914389 2005900911	2005714223 2005714244 2005714283	1/2	eo	me	eti	ric	ın	te	rpr	et	at	101	1		64 64
18 UR 19 DJ 20 DJ 21 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992	2005714223 2005714244 2005714283 2005714289	1/4	eo	me	eti	ric	ın	te	rpr	et	at	101	1		64 64 32
18 UR 19 DJ 20 DJ 21 DJ 22 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307	2005714223 2005714244 2005714283 2005714289 2005714306	1/2	eo	me	eti	ric	ın	te	rpr	et	at	101	1		64 64 32 121
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901309	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307	1/2 2/	2560	640	2560	ric	5120	te l	1 P 1	'et	at	5120	5120	640	64 64 32 12
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901309 2005901315	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308	1/2 1/2 2/ 2/ 2/							•					640 320	64 64 32 123 123 513
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901309 2005901315 2005901330	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309	1/2 1/2 2/ 2/ 2/ 2/4/2005	2560	640	2560	5120	5120	2560	2560	2560	640	5120	5120		64 64 32 123 123 512 256
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901309 2005901315 2005901330 2005902082	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714309	1/2 1/2 2/ 2/ 2/4/2005 2/12/2005	2560 320	640 640	2560 1280	5120 2560	5120 2560	2560 1280	2560 1280	2560 1280	640 320	5120 2560	5120 2560	320	644 64 32 128 512 256
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005901330 2005902082 2005902100	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335	1/2 1/2 2/ 2/ 2/ 2/4/2005 2/12/2005 2/14/2005	2560 320 640	640 640 320	2560 1280 1280	5120 2560 5120	5120 2560 2560	2560 1280 640	2560 1280 1280	2560 1280 2560	640 320 320	5120 2560 2560	5120 2560 1280	320 320	644 644 322 123 512 250 123 64
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901309 2005901315 2005901315 2005902082 2005902082 2005902100 2005902111	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714335	1/2 2/ 2/ 2/ 2/4/2005 2/12/2005 2/14/2005 2/24/2005	2560 320 640 320	640 640 320 160	2560 1280 1280 640	5120 2560 5120 2560	5120 2560 2560 2560	2560 1280 640 640	2560 1280 1280 640	2560 1280 2560 640	640 320 320 320	5120 2560 2560 640	5120 2560 1280 1280	320 320 160	644 644 32 123 512 512 512 64 64
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490730	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740130	1/2 1/2 2/ 2/ 2/ 2/4/2005 2/12/2005 2/14/2005 2/24/2005 6/22/2005	2560 320 640 320 320	640 640 320 160	2560 1280 1280 640 640	5120 2560 5120 2560 2560	5120 2560 2560 2560 2560 1280	2560 1280 640 640 640	2560 1280 1280 640 640	2560 1280 2560 640 1280	640 320 320 320 320 160	5120 2560 2560 640 1280	5120 2560 1280 1280 640	320 320 160 160	644 644 32 123 51; 256 123 64 64 16
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490728	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740130 2005740130	1/2 2/ 2/ 2/ 2/ 2/ 2/2/2005 2/12/2005 2/14/2005 2/24/2005 6/22/2005 6/21/2005	2560 320 640 320 320 320	640 640 320 160 160 80	2560 1280 1280 640 640 160	5120 2560 5120 2560 2560 2560 640	5120 2560 2560 2560 2560 1280 160	2560 1280 640 640 640 80	2560 1280 1280 640 640 40	2560 1280 2560 640 1280 80	640 320 320 320 320 160 80	5120 2560 2560 640 1280 80	5120 2560 1280 1280 640 160	320 320 160 160	64 64 32 123 512 256 123 64 64 16
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 31 PN	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902130 2005902111 490730 490730 490714	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740131 2005740131	1/2 2/ 2/ 2/ 2/ 2/ 2/2/2005 2/12/2005 2/14/2005 2/24/2005 6/22/2005 6/21/2005 6/18/2005	2560 320 640 320 320 320 20 320	640 640 320 160 160 80 320	2560 1280 1280 640 640 160 1280	5120 2560 5120 2560 2560 640 5120	5120 2560 2560 2560 1280 160 2560	2560 1280 640 640 640 80 1280	2560 1280 1280 640 640 40 1280	2560 1280 2560 640 1280 80 1280	640 320 320 320 160 80 320	5120 2560 2560 640 1280 80	5120 2560 1280 1280 640 160 2560	320 320 160 160 160 320	644 644 32 123 512 512 644 644 166 123
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 28 DJ 29 PN 30 PN 31 PN 32 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901315 2005902100 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714309 2005714309 2005714334 2005714335 2005714336 2005740130 2005740131 2005740131 2005740131	1/2 2/ 2/ 2/ 2/ 2/4/2005 2/12/2005 2/14/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005	2560 320 640 320 320 20 320 160	640 640 320 160 160 80 320 40	2560 1280 1280 640 640 160 1280 320	5120 2560 5120 2560 2560 640 5120 320	5120 2560 2560 2560 1280 160 2560 80	2560 1280 640 640 640 80 1280 80	2560 1280 1280 640 640 40 1280	2560 1280 2560 640 1280 80 1280 160	640 320 320 320 160 80 320 80	5120 2560 2560 640 1280 80 1280	5120 2560 1280 1280 640 160 2560	320 320 160 160 160 320 80	644 644 32 123 513 256 644 644 166 123 846
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 31 PN 32 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740131 2005740131 2005740131 2005740144 2005740147	2/2 2/2 2/2 2/2 2/2 2/12/2005 2/14/2005 2/24/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 2/1/2005	2560 320 640 320 320 20 320 160 640	640 640 320 160 160 80 320 40 320	2560 1280 1280 640 640 160 1280 320 640	5120 2560 5120 2560 2560 640 5120 320 2560	5120 2560 2560 2560 1280 160 2560 80 640	2560 1280 640 640 640 80 1280	2560 1280 1280 640 640 40 1280 80 640	2560 1280 2560 640 1280 80 1280 160 640	640 320 320 320 160 80 320 80 640	5120 2560 2560 640 1280 80 1280 160	5120 2560 1280 1280 640 160 2560 160	320 320 160 160 160 320 80 320	644 644 644 125 125 126 644 166 126 644 32
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 31 PN 31 UR 33 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05 A/OMSK/23/04	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740130 2005740131 2005740144 2005740147 2005740149	1/2 2/ 2/ 2/ 2/ 2/ 2/2/2005 2/12/2005 2/14/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 1/14/2005 1/120/2004	2560 320 640 320 320 20 320 160 640 160	640 640 320 160 160 80 320 40 320 160	2560 1280 1280 640 640 160 1280 320 640 320	5120 2560 5120 2560 2560 640 5120 2560 640	5120 2560 2560 2560 1280 160 2560 80 640	2560 1280 640 640 80 1280 80 1280	2560 1280 1280 640 640 40 1280 80 640 40	2560 1280 2560 640 1280 80 1280 1260 640 80	640 320 320 320 160 80 320 80 640	5120 2560 2560 640 1280 80 1280 160 1280	5120 2560 1280 1280 640 160 2560 160 2560	320 320 160 160 160 320 80 320	644 644 644 123 513 253 124 644 164 124 84 644 32 32
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 31 PN 32 UR 33 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902110 490730 490730 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05 A/OMSK/23/04 A/VLADIMIR/37/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714309 2005714309 2005714334 2005714335 2005714336 2005740130 2005740131 2005740144 2005740149 2005740149 2005740150 2005740150	2/4/2005 2/12/2005 2/12/2005 2/14/2005 2/14/2005 2/24/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 2/1/2005 1/20/2004 2/17/2005	2560 320 640 320 320 20 320 160 640 160	640 640 320 160 80 320 40 320 160 80	2560 1280 1280 640 640 160 1280 320 640 320 320	5120 2560 5120 2560 2560 640 5120 320 640 640	5120 2560 2560 2560 2560 160 2560 80 640 640 320	2560 1280 640 640 80 1280 80 1280 80 160 80	2560 1280 1280 640 640 40 1280 80 640 40 320	2560 1280 2560 640 1280 80 1280 160 640 80 320	640 320 320 320 160 80 320 80 640 80	5120 2560 2560 640 1280 80 1280 160 1280 160 320	5120 2560 1280 1280 640 160 2560 160 2560 160 320	320 320 160 160 160 320 80 320 160	644 644 32 12 12 12 12 12 12 12 12 12 12 12 12 12
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 24 DJ 25 DJ 26 DJ 27 DJ 27 DJ 28 DJ 29 PN 30 PN 31 PN 32 UR 33 UR 33 UR 35 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901315 2005902100 2005902100 2005902111 490730 490728 490714 A/EKATEINBURG/1/05 A/YAROSLAVL/13/05 A/VAROSLAVL/13/05 A/VARBAROVSK/51/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714309 2005714309 2005714334 2005714335 2005714336 2005740130 2005740130 2005740131 2005740147 2005740147 2005740149 2005740150	2/2 2/2 2/2 2/2 2/2/2005 2/12/2005 2/14/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 2/1/2005 1/20/2004 2/17/2005 3/5/2005	2560 320 640 320 320 20 320 160 640 160 5	640 640 320 160 160 80 320 40 320 160 80 5	2560 1280 1280 640 640 160 1280 320 640 320 320 5	5120 2560 5120 2560 2560 640 5120 320 2560 640 640 5	5120 2560 2560 2560 1280 160 2560 80 640 640 5	2560 1280 640 640 80 1280 1280 160 80 5	2560 1280 1280 640 640 40 1280 80 640 40 320 5	2560 1280 2560 640 1280 80 1280 160 640 80 320 5	640 320 320 320 160 80 320 80 640 80 160 5	5120 2560 2560 640 1280 80 160 1280 160 1280 160 5	5120 2560 1280 1280 640 160 2560 160 2560 160 320 5	320 320 160 160 160 320 80 320 160 160 5	644 644 322 5112 5112 644 644 322 322 532 322 322 322 322 322 322 322
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 27 DJ 28 DJ 29 PN 30 PN 31 UR 33 UR 34 UR 35 UR 36 UR 36 UR 37 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490730 490728 490714 A/YAROSLAVL/13/05 A/YAROSLAVL/13/05 A/OMSK/23/04 A/VLADIMIR/37/05 A/KHABAROVSK/51/05 A/TOMSK/27/04	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005740130 2005740130 2005740131 2005740132 2005740144 2005740147 2005740149 2005740150 2005740151 2005740151	1/2 2/ 2/ 2/ 2/ 2/ 2/ 2/12/2005 2/14/2005 2/24/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 2/1/2005 1/20/2004 2/17/2005 1/7/2005	2560 320 640 320 20 320 160 640 160 160 5	640 640 320 160 80 320 40 320 160 80 5	2560 1280 1280 640 640 1280 320 640 320 320 5	5120 2560 5120 2560 2560 640 320 2560 640 640 5 5	5120 2560 2560 2560 1280 160 2560 640 640 320 5	2560 1280 640 640 80 1280 1280 160 80 5	2560 1280 1280 640 40 1280 80 640 40 320 5	2560 1280 2560 1280 80 1280 80 1280 640 80 320 5	640 320 320 320 160 80 640 80 640 5	5120 2560 2560 640 1280 80 1280 160 1280 160 320 5	5120 2560 1280 1280 640 160 2560 160 2560 160 320 5	320 320 160 160 320 80 320 160 160 5	644 644 644 322 122 511 255 126 644 166 323 323 44
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 28 DJ 29 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 DJ 29 DJ 20 DJ	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05 A/OMSK/23/04 A/VLADIMIR/37/05 A/KABAROVSK/51/05 A/TOMSK/27/04 A/HONG KONG/4421/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740130 2005740131 2005740144 2005740147 2005740149 2005740150 2005740150 2005740151 2005740153 2005740153	1/2 2/ 2/ 2/ 2/ 2/ 2/ 2/2/2005 2/14/2005 2/14/2005 6/21/2005 6/21/2005 6/18/2005 1/14/2005 1/20/2004 2/17/2005 3/5/2005 1/7/2004 6/8/2005	2560 320 640 320 20 320 20 320 160 160 160 5	640 640 320 160 80 320 40 320 160 80 5	2560 1280 1280 640 160 1280 320 640 320 320 5 160	5120 2560 5120 2560 640 5120 320 640 640 5 5 320 160	5120 2560 2560 2560 1280 160 2560 80 640 640 320 5	2560 1280 640 640 80 1280 80 1280 80 5 80 40	2560 1280 1280 640 40 1280 80 6440 40 320 5 40 40	2560 1280 2560 640 80 1280 160 640 80 320 5 80	640 320 320 320 160 80 320 80 640 80 160 5	5120 2560 2560 640 1280 80 1280 160 320 5 80 80	5120 2560 1280 1280 640 160 2560 160 320 5 160 160	320 320 160 160 320 80 320 160 160 5 80	644 644 322 122 511 255 122 644 166 122 84 32 32 32 44
18 UR 19 DJ 20 DJ 21 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 27 DJ 28 DJ 27 DJ 28 DJ 29 PN 30 PN 30 UR 30 UR 30 UR 30 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901307 2005901315 2005901315 2005902100 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05 A/VADIMIR/37/05 A/KHABAROVSK/51/05 A/TAMSK/23/04 A/TAMSK/23/04 A/HONG KONG/4281/05 A/HONG KONG/4281/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714309 2005714334 2005714335 2005714335 2005714335 2005740130 2005740131 2005740132 2005740144 2005740147 2005740150 2005740150 2005740150 2005740153 2005740153 2005740176 2005740177 2005740177	2/4/2005 2/4/2005 2/12/2005 2/12/2005 2/14/2005 2/14/2005 6/21/2005 6/21/2005 6/18/2005 1/14/2005 2/1/2005 1/20/2004 2/17/2005 3/5/2005 1/7/2005 6/8/2005 6/16/2005	2560 320 640 320 320 20 320 160 640 160 5 160 80	640 640 320 160 80 320 40 320 160 80 5	2560 1280 1280 640 160 1280 320 640 320 320 5 160 80	5120 2560 5120 2560 2560 2560 320 2560 640 5 320 5 320 640 5 320 640 5	5120 2560 2560 2560 1280 160 2560 80 640 320 5 320 20 20	2560 1280 640 640 80 1280 1280 80 5 80 40	2560 1280 640 640 40 1280 80 640 40 320 5 40 40	2560 1280 2560 640 1280 80 160 640 80 320 5 80 160 640	640 320 320 160 80 80 640 80 5 80 80 80 80	5120 2560 2560 640 1280 80 1280 160 1280 160 320 5 80 80 40	5120 2560 1280 1280 160 2560 160 2560 160 320 5 160 80	320 320 160 160 160 320 80 320 160 160 5	644 644 322 122 511 255 122 644 166 122 864 322 322 444 88
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 22 DJ 22 DJ 22 DJ 22 DJ 22 DJ 23 DJ 24 DJ 26 DJ 27 DJ 28 DJ 28 DJ 28 DJ 28 DJ 28 DJ 31 PN 33 UR 33 UR 34 UR 35 UR 36 UR 37 UR 38 HK 37 UR	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901309 2005901315 2005902082 2005902100 2005902111 490730 490728 490714 A/EAATERINBURG/1/05 A/YAROSLAVL/13/05 A/OMSK/23/04 A/VLADIMIR/37/05 A/KHABAROVSK/51/05 A/TOMSK/27/04 A/HONG KONG/4281/05 A/HONG KONG/4281/05 A/HONG KONG/4281/05 A/HONG KONG/421/05 A/HONG KONG/421/05	2005714223 2005714224 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005740130 2005740130 2005740131 2005740132 2005740144 2005740149 2005740150 2005740150 2005740150 2005740176 2005740177 2005740177 2005740179 2005740179	1/2 2/ 2/ 2/ 2/ 2/ 2/ 2/12/2005 2/14/2005 2/24/2005 6/21/2005 6/18/2005 6/18/2005 1/14/2005 2/1/2005 1/20/2004 2/17/2005 1/7/2005 6/8/2005 6/16/2005 6/16/2005 6/16/2005 6/14/2005	2560 320 640 320 20 320 20 320 160 640 160 160 80 40 40	640 640 320 160 80 320 160 40 320 160 80 5 160 20 20	2560 1280 1280 640 640 160 1280 320 640 320 5 160 160 80 320 40	5120 2560 5120 2560 2560 640 5120 320 2560 640 640 5 320 160 160 40	5120 2560 2560 1280 160 2560 640 640 320 5 320 20 20 20	2560 1280 640 640 80 1280 1280 160 80 5 80 40 40	2560 1280 1280 640 640 40 1280 640 40 320 40 40 40 40 80	2560 1280 2560 640 1280 80 1280 640 80 320 5 80 160 40	640 320 320 320 160 80 320 640 80 640 80 160 80 80 80 40	5120 2560 2560 640 1280 80 1280 160 1280 160 320 5 80 80 40 160 40	5120 2560 1280 640 160 2560 160 320 5 160 160 320 20	320 320 160 160 160 320 320 160 160 160 160 160 160 160 160	644 644 323 122 511 255 644 166 322 322 323 44 44 88
88 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 26 DJ 27 DJ 28 DJ 28 DJ 29 PN 31 PN 33 UR 34 UR 35 UR 36 UR 37 UR 38 HK 39 HK	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901315 2005901330 2005902102 2005902100 2005902111 490730 490728 490714 A/YAROSLAVL/13/05 A/YAROSLAVL/13/05 A/VABJAROVSK/51/05 A/KHABAROVSK/51/05 A/TOMSK/23/04 A/HOMG KOMG/4421/05 A/HOMG KOMG/4241/05 A/HOMG KOMG/4241/05	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714309 2005714334 2005714335 2005714335 2005714335 2005740130 2005740131 2005740132 2005740144 2005740147 2005740150 2005740150 2005740150 2005740153 2005740153 2005740176 2005740177 2005740177	2/4/2005 2/4/2005 2/12/2005 2/14/2005 2/14/2005 6/21/2005 6/21/2005 6/21/2005 6/18/2005 1/14/2005 1/14/2005 1/20/2004 2/17/2005 1/7/2004 6/8/2005 6/16/2005 6/16/2005	2560 320 640 320 320 320 320 160 640 160 5 160 80	640 640 320 160 80 320 160 80 5 160 20 20	2560 1280 1280 1640 640 160 1280 320 640 320 5 160 160 80 320	5120 2560 5120 2560 640 5120 320 640 640 5 320 160 160 40	5120 2560 2560 2560 1280 160 2560 80 640 640 320 5 320 20 80 20 80	2560 1280 640 640 80 1280 160 80 5 80 40 40	2560 1280 1280 640 640 40 1280 640 40 320 5 40 40 40 20	2560 1280 2560 640 80 1280 6640 80 320 5 80 160 40 40 80	640 320 320 320 160 80 320 80 160 5 80 80 80 80 80 80 80 80 80 80 80 80 80	5120 2560 2560 640 1280 80 1280 160 320 5 80 40 160 40 160	5120 2560 1280 640 160 2560 160 2560 160 320 5 160 160 80 320	320 320 160 160 160 320 80 320 160 160 5 80 160 160 40 40	644 644 322 511 255 122 644 644 322 322 44 48 88 88
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 31 UR 33 UR 34 UR 35 UR 36 UR 37 UR 38 HK 40 HK 40 HK	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901307 2005901315 2005901315 2005902100 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05 A/OMSK/23/04 A/VLADIMIR/37/05 A/KHABAROVSK/51/05 A/TOMSK/27/04 A/HONG KONG/421/05 A/HONG KONG/421/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/42607/05 2005904864 2005906943	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740130 2005740131 2005740147 2005740147 2005740151 2005740151 2005740153 2005740177 2005740179 2005740177 2005740179 2005740179 2005740179 2005740177 2005740179	1/2 2/ 2/ 2/ 2/ 2/ 2/ 2/2/2005 2/12/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 1/120/2004 2/17/2005 3/5/2005 1/7/2004 6/8/2005 6/16/2005 6/16/2005 6/14/2005	2560 320 640 320 320 320 320 160 640 160 5 160 80 40 80 40 80	640 640 320 160 160 80 320 160 80 5 160 20 40 10 20 20	2560 1280 640 640 1280 640 1280 320 640 320 5 160 160 80 320 40	5120 2560 5120 2560 2560 2560 640 5 320 2560 640 5 320 160 160 40	5120 2560 2560 2560 1280 160 2560 80 640 320 5 320 20 20 80 20	2560 1280 640 640 80 1280 1580 160 80 5 80 40 40 80 10 40	2560 1280 640 640 40 1280 80 640 40 320 5 40 40 40 40 40 40 40 40 40 80 40 40 40 40 40 40 40 40 40 40 40 40 40	2560 1280 2560 640 1280 80 1280 160 640 80 5 80 160 40 40 80 80 80	640 320 320 160 80 640 80 5 80 640 80 160 40 80 80 80	5120 2560 2560 640 1280 80 160 1280 160 320 5 80 40 160 40 160	5120 2560 1280 640 160 2560 160 2560 160 320 5 160 80 320 20 160 80	320 320 160 160 160 320 80 320 160 160 5 80 160 40 40 80 80	644 644 644 322 122 551 255 126 644 166 322 322 323 444 448 881 1168 881 444
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 22 DJ 22 DJ 22 DJ 22 DJ 22 DJ 23 DJ 24 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 30 PN 31 UR 33 UR 34 UR 35 UR 36 UR 37 UR 38 HK 41 HK 41 HK 42 EG	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901307 2005901315 2005901330 2005902082 2005902100 2005902111 490730 490728 490714 A/YAROSLAVL/13/05 A/YAROSLAVL/13/05 A/YAROSLAVL/13/05 A/YAROSLAVL/13/05 A/KHABAROVSK/51/05 A/TOMSK/23/04 A/HONG KONG/4421/05 A/HONG KONG/421/05 A/HONG KONG/420/05	2005714223 2005714224 2005714283 2005714289 2005714306 2005714307 2005714309 2005714334 2005714335 2005714335 2005740130 2005740131 2005740131 2005740144 2005740149 2005740150 2005740150 2005740177 2005740179 2005740181 2005740179 2005740181 2005740179 2005740181 2005740179 2005740181 2005740179 2005740181 2005740179 2005740170 20057401719 20057401719 20057401704 20057401704 20057401704 20057401719	2/4/2005 2/4/2005 2/12/2005 2/14/2005 2/14/2005 6/21/2005 6/21/2005 6/18/2005 1/14/2005 1/14/2005 1/16/2005 1/16/2005 6/16/2005 6/16/2005 6/14/2005 4/20/2005	2560 320 640 320 320 320 320 160 640 160 5 160 80 40 40 80 40 80 80 320	640 640 320 160 80 320 160 80 5 160 20 20 40 10 20 20 20 160	2560 1280 1280 1280 640 640 160 320 640 320 5 160 160 80 40 160 640	5120 2560 5120 2560 2560 640 5120 2560 640 5 320 160 160 40 160 40 160 640	5120 2560 2560 1280 160 2560 80 640 640 320 5 320 20 80 20 80 10 320	2560 1280 640 640 80 1280 160 80 5 80 40 40 40 40 20 160	2560 1280 1280 1280 640 40 1280 80 640 40 320 5 40 40 40 40 40 40 40 40 40 40 40 40 40	2560 1280 2560 640 1280 80 1280 640 80 320 5 80 160 40 40 80 80 320	640 320 320 320 160 80 320 640 80 640 5 80 80 80 40 80 80 80 80 80 80	5120 2560 2560 640 1280 80 1280 160 1280 160 320 5 80 80 40 160 40 160 320	5120 2560 1280 640 160 2560 160 320 5 160 160 80 20 160 80 80 640	320 320 320 160 160 320 320 160 160 5 80 160 640 40 80 80 160	322 644 644 322 122 51,2 51,2 51,2 644 644 644 88 88 44 44 32 32 48 48 44 44 32
18 UR 19 DJ 20 DJ 21 DJ 22 DJ 23 DJ 24 DJ 25 DJ 26 DJ 27 DJ 28 DJ 29 PN 30 PN 31 UR 33 UR 34 UR 35 UR 36 UR 37 UR 38 HK 40 HK 40 HK	A/KHABAROVSK/9/05 2004914389 2005900911 2005900992 2005901307 2005901307 2005901315 2005901315 2005902100 2005902100 2005902111 490730 490728 490714 A/EKATERINBURG/1/05 A/YAROSLAVL/13/05 A/OMSK/23/04 A/VLADIMIR/37/05 A/KHABAROVSK/51/05 A/TOMSK/27/04 A/HONG KONG/421/05 A/HONG KONG/421/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/4241/05 A/HONG KONG/42607/05 2005904864 2005906943	2005714223 2005714244 2005714283 2005714289 2005714306 2005714307 2005714308 2005714309 2005714334 2005714335 2005714336 2005740130 2005740131 2005740147 2005740147 2005740151 2005740151 2005740153 2005740177 2005740179 2005740177 2005740179 2005740179 2005740179 2005740177 2005740179	1/2 2/ 2/ 2/ 2/ 2/ 2/ 2/2/2005 2/12/2005 6/22/2005 6/21/2005 6/18/2005 1/14/2005 1/120/2004 2/17/2005 3/5/2005 1/7/2004 6/8/2005 6/16/2005 6/16/2005 6/14/2005	2560 320 640 320 320 320 320 160 640 160 5 160 80 40 80 40 80	640 640 320 160 160 80 320 160 80 5 160 20 40 10 20 20	2560 1280 640 640 1280 640 1280 320 640 320 5 160 160 80 320 40	5120 2560 5120 2560 2560 2560 640 5 320 2560 640 5 320 160 160 40	5120 2560 2560 2560 1280 160 2560 80 640 320 5 320 20 20 80 20	2560 1280 640 640 80 1280 1580 160 80 5 80 40 40 80 10 40	2560 1280 640 640 40 1280 80 640 40 320 5 40 40 40 40 40 40 40 40 40 80 40 40 40 40 40 40 40 40 40 40 40 40 40	2560 1280 2560 640 1280 80 1280 160 640 80 5 80 160 40 40 80 80 80	640 320 320 160 80 640 80 5 80 640 80 160 40 80 80 80	5120 2560 2560 640 1280 80 160 1280 160 320 5 80 40 160 40 160	5120 2560 1280 640 160 2560 160 2560 160 320 5 160 80 320 20 160 80	320 320 160 160 160 320 80 320 160 160 5 80 160 40 40 80 80	644 644 644 644 644 644 644 644 644 644



Antigenic cartography visualizes multi-dimensional titer data in lower dimensions

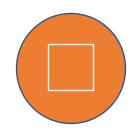
Antigenic map of influenza H3N2 from 1968 –
 2002 by Smith et al *Science* 305, 371-376, 2004

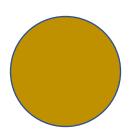
	Antigen 1	Antigen 2	Antigen 3	Antigen 4
Titer	160	40	80	40
Log2(Titer/10)	4	2	3	2
Log2(maxTiter/10) – Log2(Titer/10)	4 - 4 = 0	4 -2 = 2	4 – 3 = 1	4 -2 = 2
Fold change (FC) from max titer	160/160 = 1	160/40 = 4	160/80 = 2	160/40 = 4
Log2(FC)	0	2	1	2





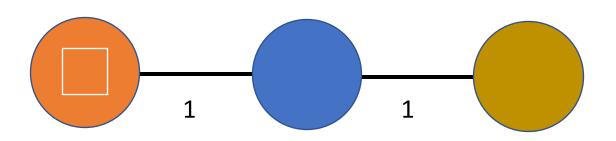
	Antigen 1	Antigen 2	Antigen 3	Antigen 4
Titer	160	40	80	40
Log2(Titer/10)	4	2	3	2
Log2(maxTiter/10) – Log2(Titer/10)	4 - 4 = 0	4 -2 = 2	4 – 3 = 1	4 -2 = 2
Fold change (FC) from max titer	160/160 = 1	160/40 = 4	160/80 = 2	160/40 = 4
Log2(FC)	0	2	1	2







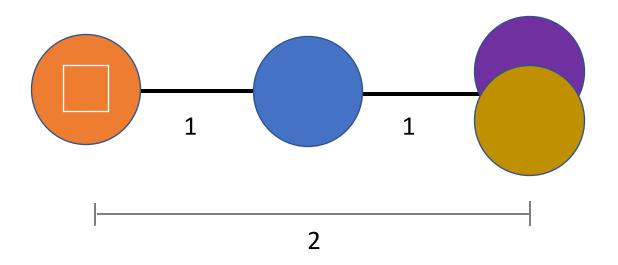
	Antigen 1	Antigen 2	Antigen 3	Antigen 4
Titer	160	40	80	40
Log2(Titer/10)	4	2	3	2
Log2(maxTiter/10) – Log2(Titer/10)	4 - 4 = 0	4 -2 = 2	4 – 3 = 1	4 -2 = 2
Fold change (FC) from max titer	160/160 = 1	160/40 = 4	160/80 = 2	160/40 = 4
Log2(FC)	0	2	1	2





2

	Antigen 1	Antigen 2	Antigen 3	Antigen 4
Titer	160	40	80	40
Log2(Titer/10)	4	2	3	2
Log2(maxTiter/10) – Log2(Titer/10)	4 - 4 = 0	4 -2 = 2	4 – 3 = 1	4 -2 = 2
Fold change (FC) from max titer	160/160 = 1	160/40 = 4	160/80 = 2	160/40 = 4
Log2(FC)	0	2	1	2





	Sample 1	Sample 2
Antigen 1	160	160
Antigen 2	40	80
Antigen 3	80	320
Antigen 4	40	160

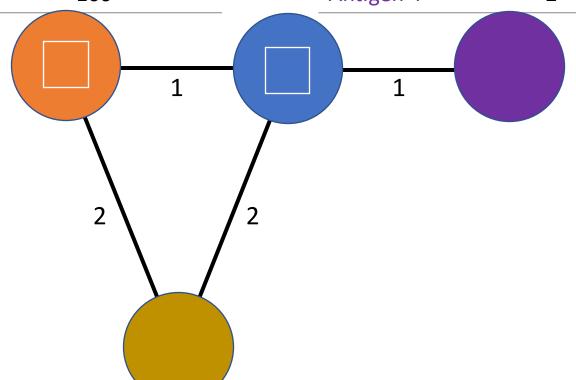


	Sample 1	Sample 2
Antigen 1	160	160
Antigen 2	40	80
Antigen 3	80	320
Antigen 4	40	160

Serum

Antigen

	Sample 1	Sample 2
Antigen 1	0	1
Antigen 2	2	2
Antigen 3	1	0
Antigen 4	2	1



	Sample 1	Sample 2	•••	Sample n
Antigen 1	Titer _{1,1}	Titer _{1,2}		Titer _{1,n}
Antigen 2	Titer _{2,1}	Titer _{2,2}		Titer _{2,n}
Antigen i	Titer _{i,1}	Titer _{i,2}		Titer _{i,n}

Log2 transform calculate distances

Table with target distances D

Optimize map distances d for each serum, antigen pair Minimize map stress $s = \sum_{i,n} (D_{i,n} - d_{i,n})^2$

Antigenic map

Key Points

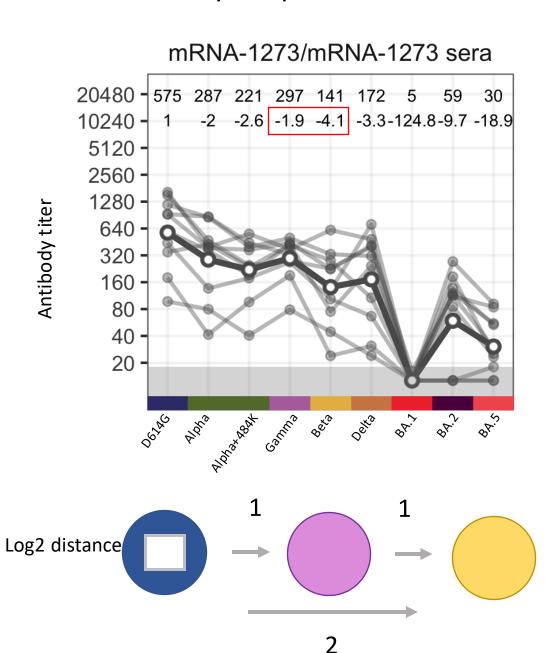
- Antigenic cartography is a geometric interpretation of neutralization data
- Map distance corresponds to neutralization titers
- Variants that elicit the same titers in the same sera are close together in map, and vice versa
- Different serum types are necessary to resolve different areas of antigenic space
- Map distance reflects antigenic relationship

What about multiple exposures?

From antigenic maps to antibody landscapes

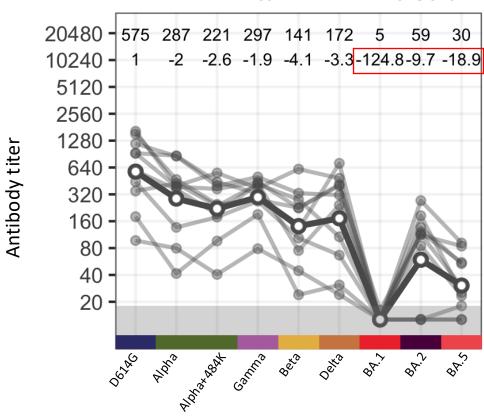
The data used in the next section is from the publication by Rössler, Netzl, et al. (2022) DOI: 10.1038/s41467-022-35312-3

Secondary exposures overshadow underlying relationships

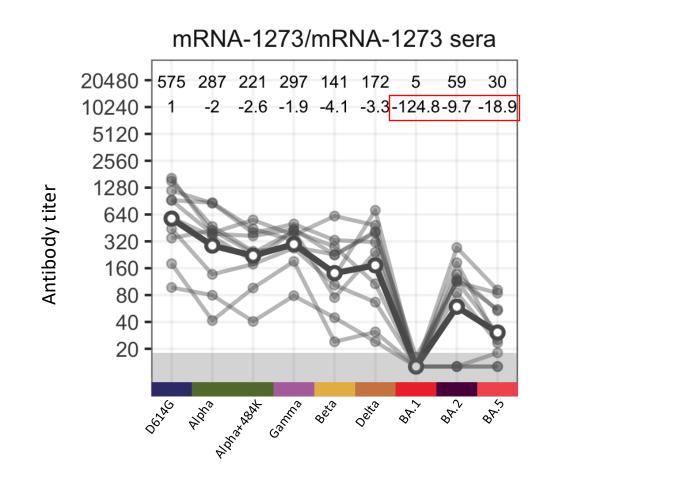


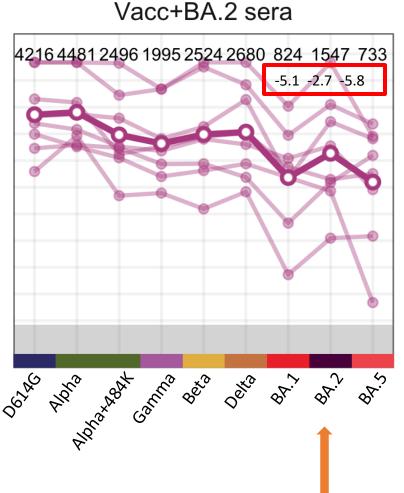
Secondary exposures overshadow underlying relationships



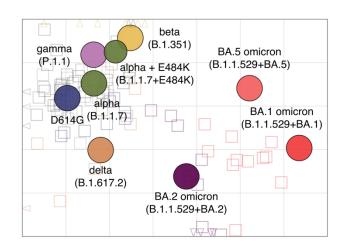


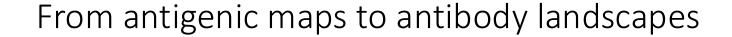
Secondary exposures overshadow underlying relationships

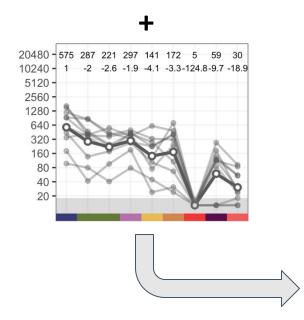


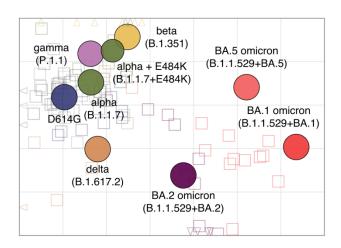


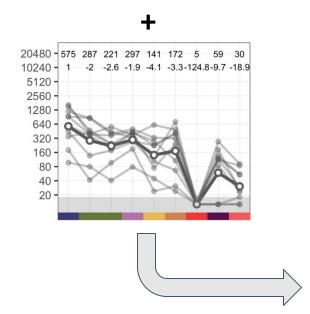
Multiple (distinct) exposures increase cross-neutralization and therefore decrease antigenic distance (log2 fold changes). It is not, however, the variants' antigenic properties that change with multiple exposures but the antibody composition in the serum \rightarrow Antibody landscapes on top of a single exposure serum map



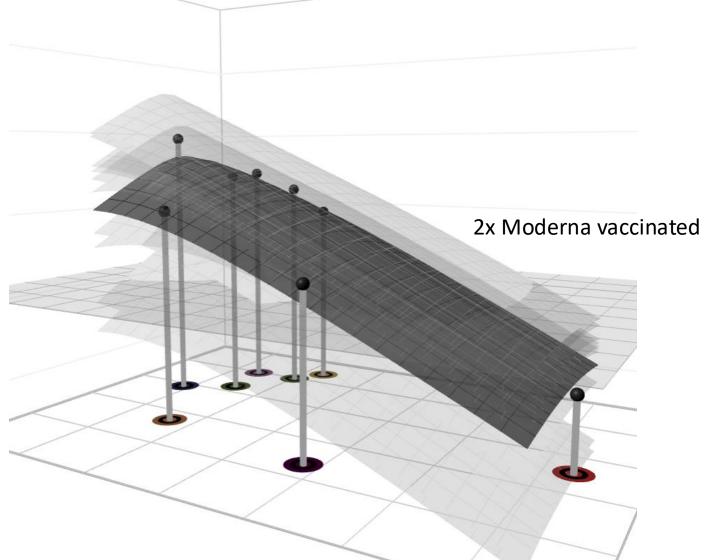


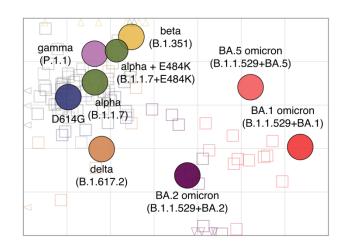






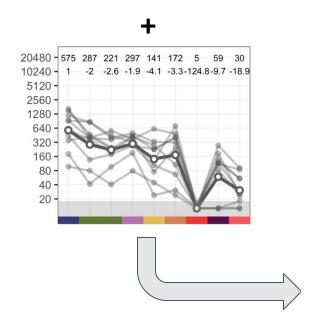
From antigenic maps to antibody landscapes

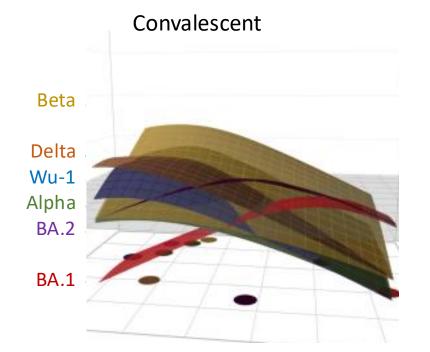


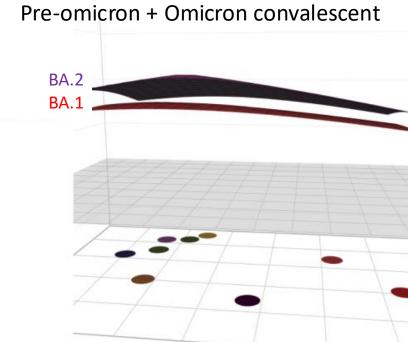


From antigenic maps to antibody landscapes

Multiple (distant) exposures broaden immune profiles







Key Points

- Multiple exposures broaden immune response and decrease titer fold changes
- Multiple exposures change the neutralizing properties of the serum, not the antigenic properties of the variants
- Antibody landscapes show neutralization titers across a mapped antigenic space
- Antibody landscapes show how serum properties change over time without changing the antigenic relationships of mapped variants

References

- Antigenic cartography: Smith et al., Science (2004) DOI: 10.1126/science.1097211
- Antibody landscapes: Fonville et al., Science (2014) DOI: 10.1126/science.1256427
- Racmacs R package for map making: Wilks S (2023). *Racmacs: Antigenic Cartography Macros*. R package version 1.2.9, https://github.com/acorg/Racmacs/, https://acorg.github.io/Racmacs/.
- Antibody landscapes R package: Wilks S (2021). _ablandscapes: Making Antibody landscapes Using R_. R package version 1.1.0,
 https://github.com/acorg/ablandscapes.
- Map diagnostics in supplementary material of these publications:

Rössler, A., Nat Commun 13, 7701 (2022). https://doi.org/10.1038/s41467-022-35312-3
Rössler, A., Nat Commun 14, 5224 (2023). https://doi.org/10.1038/s41467-023-41049-4