

### **bc-GenExMiner 3.0: new mining module computes breast cancer gene-expression correlation analyses**

Pascal Jézéquel, Jean-Sébastien Frénel, Loïc Campion, Catherine Guérin-Charbonnel, Wilfried Gouraud, Gabriel Ricolleau, Mario Campone

Supplementary Method:

#### **Multi-correlation score (MCS) calculation (eigenvalue decomposition)**

Given a matrix  $M$ , an eigenvalue is a scalar  $\lambda$  such that  $Mu = \lambda u$  for some non-zero vector  $u$ , which is called an eigenvector. As the correlation matrix  $C$  of a given set of genes is diagonalizable, we can find a matrix  $U$  of linearly independent eigenvectors such that  $C = U\Lambda U^{-1}$ , where  $U$  is the matrix of eigenvectors and  $\Lambda$  is a diagonal matrix whose diagonal elements are the different eigenvalues. Each eigenvalue is equal to the variance explained by the corresponding eigenvector. As the eigenvectors are linearly independent, taking the largest eigenvalue permits to quantify the variance that is the most important within the data, and when divided by the sum of all eigenvalues and multiply by 100 to get the multi-correlation score, to know the proportion of this “information” compared to the whole “information” contained in the data.

**Supplementary Table 1** Screening of continuous clusters of correlated ( $r \geq 0.30$  and  $p \leq 0.05$ ) co-expressed genes ( $n \geq 3$ ) based on Bunes results as input genes by means of bc-GenExMiner v3.0 gene expression correlation analysis by chromosomal location [15]

N <sup>oa</sup>	Cytoband	Molecular subtype	bc-GenExMiner continuous cluster of correlated co-expressed genes		MCS <sup>b</sup> (%)
			No.	genes	
1	17q12-q21	All patients	7	<i>STARD3, TCAP, PNMT, PGAP3, ERBB2, C17orf37, GRB7</i>	59.84
		All patients	3	<i>FBXL20, MED1, CDK12</i>	78.06
		HER2			83.53
		luminal A			60.34
		luminal B			68.43
		All patients	7	<i>MED24, THRA, NR1D1, MSL1, CASC3, RAPGEFL1, WIPF2</i>	54.33
		HER2			59.97
		HER2	8	<i>MED24, THRA, NR1D1, MSL1, CASC3, RAPGEFL1, WIPF2, CDC6</i>	58.05
		All patients	7	<i>SOCS7, ARHGAP23, SRCINI, C17orf96, MLLT6, CISD3, PCGF2</i>	58.11
		HER2	5	<i>SRCINI, C17orf96, MLLT6, CISD3, PCGF2</i>	76.67
		Luminal B	3	<i>LOC100287808, PSMB3, PIP4K2B</i>	71.99
		All patients	3	<i>PSMB3, PIP4K2B, CWC25</i>	70.52
		HER2			90.65
		Luminal B	3	<i>SYNRG, DDX52, HNF1B</i>	60.89
		All patients	4	<i>TADA2A, DUSP14, SYNRG, DDX52</i>	56.36
		HER2			68.94
		Luminal B	3	<i>ARL4D, DHX8, RPL19</i>	62.50
		All patients	3	<i>GSDMB, ORMDL3, PSMD3</i>	71.50
		HER2			68.85
		2	17q11-q12	All patients	6
HER2					80.20
Basal-like	4			<i>TRAF4, C17orf63, ERAL1, FLOT2</i>	53.87
Luminal B					70.20
Luminal A	3			<i>ERAL1, FLOT2, DHRS13</i>	61.04
All patients	5			<i>SPAG5, SGK494, KIAA0100, SDF2, SUPT6H</i>	58.85
Basal-like	3			<i>KIAA0100, SDF2, SUPT6H</i>	69.66
HER2					90.45
Luminal B					68.79
All patients	5			<i>TMEM97, IFT20, TNFAIP1, POLDIP2, TMEM199</i>	61.17
Basal-like					55.78
HER2	4			<i>TMEM97, IFT20, TNFAIP1, POLDIP2</i>	81.07
Luminal B	4			<i>IFT20, TNFAIP1, POLDIP2, TMEM199</i>	66.58
Basal-like, HER2	3			<i>BLMH, CPD, GOSR1</i>	56.55
All patients	3			<i>TMEM199, SARM1, SLC46A1</i>	68.42
HER2					58.26
3	8q24			All patients	7
		basal-like			64.15
		HER2	4	<i>FBXL6, GPR172A, ADCK5, CPSF1</i>	70.30
		Luminal A			50.46
		Luminal B			72.15
		HER2	4	<i>CPSF1, SLC39A4, VPS28, CYHR1</i>	61.90
		All patients	7	<i>GRINA, OPLAH, EXOSC4, GPAAL, CYC1, SHARPIN, MAF1</i>	59.64
		Luminal B			78.04
		Basal-like	6	<i>GRINA, OPLAH, EXOSC4, GPAAL, CYC1, SHARPIN</i>	61.34
		HER2	5	<i>EXOSC4, GPAAL, CYC1, SHARPIN, MAF1</i>	68.28
		Luminal A	4	<i>EXOSC4, GPAAL, CYC1, SHARPIN</i>	59.72
		All patients	5	<i>ZNF707, MAPK15, FAM83H, SCRIB, PUF60</i>	59.48
		Basal-like	4	<i>FAM83H, SCRIB, PUF60, NRBP2</i>	65.45
		HER2	3	<i>FAM83H, SCRIB, PUF60</i>	77.83
		Luminal A			65.77
		Luminal B	5	<i>FAM83H, SCRIB, PUF60, NRBP2, PLEC</i>	68.82
		All patients	5	<i>MFSD3, RECQL4, LRRC14, C8orf82, ARHGAP39</i>	57.25
		Basal-like	3	<i>RECQL4, LRRC14, C8orf82</i>	60.14
		Luminal B	4	<i>RECQL4, LRRC14, C8orf82, ARHGAP39</i>	68.71
		All patients	10	<i>C8orf51, RHPN1, ZC3H3, GSDMD, C8orf73, NAPRT1, EEF1D, TIGD5, PYCRL, TSTA3</i>	49.02
		Basal-like	4	<i>EEF1D, TIGD5, PYCRL, TSTA3</i>	55.80
		Luminal B	4	<i>TIGD5, PYCRL, TSTA3, ZNF623</i>	64.65
		All patients	7	<i>ZNF517, ZNF7, COMMD5, ZNF250, ZNF16, ZNF252, C8orf33</i>	56.16
		Basal-like	6	<i>ZNF7, COMMD5, ZNF250, ZNF16, ZNF252, C8orf33</i>	63.65
		HER2	4	<i>ZNF7, COMMD5, ZNF250, ZNF16</i>	73.41
		Luminal B			79.67
		Luminal A	3	<i>COMMD5, ZNF250, ZNF16</i>	56.09

4	6p21	All patients	10	<i>MAPK15, FAM83H, SCRIB, PUF60, NRBP2, PLEC, PARP10, GRINA, OPLAH, EXOSC4</i>	54.45		
		Basal-like	6	<i>GRINA, OPLAH, EXOSC4, GPAAI, CYC1, SHARPIN</i>	61.34		
		HER2	5	<i>EXOSC4, GPAAI, CYC1, SHARPIN, MAF1</i>	68.28		
		Luminal A	4	<i>EXOSC4, GPAAI, CYC1, SHARPIN</i>	59.72		
		Luminal B	7	<i>GRINA, OPLAH, EXOSC4, GPAAI, CYC1, SHARPIN, MAF1</i>	78.04		
		All patients	4	<i>HLA-DOB, TAP2, PSMB8, TAP1</i>	59.93		
		Basal-like	9	<i>HLA-DOB, TAP2, PSMB8, TAP1, HLA-DRB1, PSMB9, HLA-DQB1, HLA-DMB, HLA-DMA</i>	68.48		
		All patients	7	<i>PSMB8, TAP1, HLA-DRB1, PSMB9, HLA-DQB1, HLA-DMB, HLA-DMA</i>	65.73		
		HER2			66.42		
		Luminal B	5	<i>PSMB8, TAP1, HLA-DRB1, PSMB9, HLA-DQB1</i>	65.77		
Basal-like	4	<i>HLA-DRA, HLA-DQA1, HLA-DRB6, HLA-DOB</i>	60.39				
All patients	4	<i>HLA-DQB2, HLA-DPA1, HLA-DPB1, HLA-DPB2</i>	60.91				
Basal-like	3	<i>HLA-DQB2, HLA-DPA1, HLA-DPB1</i>	63.85				
HER2			68.96				
Luminal B	4	<i>HLA-DOA, HLA-DQB2, HLA-DPA1, HLA-DPB1</i>	61.76				
All patients	3	<i>HLA-DOA, HLA-DQB2, HLA-DPA1</i>	59.30				
All patients	3	<i>HSD17B8, RING1, VPS52</i>	58.70				
All patients	4	<i>PRICKLE4, USP49, MED20, BYSL</i>	52.47				
5	17q24-q25	All patients	7	<i>SUMO2, NUP85, GGA3, MRPS7, MIF4GD, SLC25A19, GRB2</i>	53.47		
		Basal-like	3	<i>NUP85, GGA3, MRPS7</i>	61.04		
		HER2	12	<i>CDR2L, ICT1, ATP5H, KCTD2, SLC16A5, ARMC7, NT5C, HNI, SUMO2, NUP85, GGA3, MRPS7</i>	74.89		
		Luminal B	3	<i>NUP85, GGA3, MRPS7</i>	68.95		
		HER2	4	<i>SAP30BP, ITGB4, GALK1, H3F3B</i>	67.43		
		All patients	4	<i>ARL16, HGS, MRPL12, SLC25A10</i>	65.17		
		Basal-like			62.98		
		HER2	3	<i>HGS, MRPL12, SLC25A10</i>	73.10		
		Luminal A			58.43		
		Luminal B			69.81		
		All patients	5	<i>ARMC7, NT5C, HNI, SUMO2, NUP85</i>	53.89		
		Basal-like	3	<i>HNI, SUMO2, NUP85</i>	71.29		
		HER2	10	<i>C17orf28, CDR2L, ICT1, ATP5H, KCTD2, SLC16A5, ARMC7, NT5C, HNI, SUMO2</i>	76.06		
		HER2	4	<i>SAP30BP, ITGB4, GALK1, H3F3B</i>	67.43		
		All patients	3	<i>SIRT7, PCYT2, MAFG</i>	63.88		
		HER2			66.05		
		Basal-like	4	<i>SIRT7, PCYT2, MAFG, PYCR1</i>	55.43		
		All patients	8	<i>ASPSCR1, STRA13, LRRC45, RAC3, DCXR, RFNG, GPSI, DUS1L</i>	55.40		
		Basal-like	5	<i>ASPSCR1, STRA13, LRRC45, RAC3, DCXR</i>	57.41		
		HER2			71.89		
		All patients	4	<i>KIAA0195, CASKIN2, TSEN54, LLGL2</i>	58.62		
		HER2	6	<i>SLC25A19, GRB2, KIAA0195, CASKIN2, TSEN54, LLGL2</i>	69.04		
		Luminal B	4	<i>SLC25A19, GRB2, KIAA0195, CASKIN2</i>	58.89		
		Basal-like	3	<i>CASKIN2, TSEN54, LLGL2</i>	56.87		
		HER2	3	<i>RECQL5, SAP30BP, ITGB4</i>	67.00		
		Basal-like	4	<i>LLGL2, MYO15B, RECQL5, SAP30BP</i>	36.39		
		All patients	4	<i>ARL16, HGS, MRPL12, SLC25A10</i>	65.17		
		Basal-like			62.98		
		All patients	4	<i>P4HB, ARHGDI1, ANAPC11, THOC4</i>	58.47		
		Basal-like			67.44		
		HER2			66.34		
		Luminal B			67.01		
		6	11q12-q13	All patients	3	<i>MRPL49, SYVN1, CAPN1</i>	61.39
				All patients	3	<i>DPF2, TIGD3, SLC25A45</i>	57.45
				HER2	3	<i>POLA2, CDC42EP2, DPF2</i>	61.86
				All patients	5	<i>MAP3K11, PCNXL3, SIPA1, RELA, KAT5</i>	49.49
Luminal B	3			<i>SCYL1, LTBP3, SSSCA1</i>	65.63		
HER2	3			<i>PACSI, EEFIG, TUT1</i>	56.61		
All patients	5			<i>KLC2, RAB1B, CNIH2, YIF1A, TMEM151A</i>	51.89		
All patients	3			<i>ADAM15, EFNA4, EFNA3</i>	55.87		
7	1q21-q22	HER2			57.33		
		Basal-like	3	<i>DCST2, DCST1, ADAM15</i>	77.24		
		HER2	4	<i>PYGO2, SHC1, CKS1B, FLAD1</i>	62.77		
		Luminal B	3	<i>SHC1, CKS1B, FLAD1</i>	56.03		
		All patients	4	<i>FAM189B, SCAMP3, CLK2, HCN3</i>	53.88		
		Basal-like	3	<i>FAM189B, SCAMP3, CLK2</i>	61.79		
		HER2			70.37		
		Luminal B			57.88		
		Luminal A	4	<i>GBA, FAM189B, SCAMP3, CLK2</i>	59.26		
		All patients	4	<i>MSTO1, YY1API, DAP3, GON4L</i>	56.76		

		Luminal A			60.28
		Basal-like	3	<i>MSTO1, YY1API, DAP3</i>	61.02
		HER2	3	<i>YY1API, DAP3, GON4L</i>	62.06
		HER2	3	<i>EFNA1, DPM3, KRTCAP2</i>	75.10
		Luminal B	3	<i>EFNA4, EFNA3, EFNA1</i>	60.82
		All patients	3	<i>FDPS, C1orf104, RUSC1</i>	62.80
		All patients	4	<i>PMVK, PBXIP1, PYGO2, SHC1</i>	53.01
		HER2			63.50
		All patients	4	<i>PSMD4, ZNF687, PI4KB, RFX5</i>	55.46
		Basal-like	3	<i>PSMD4, ZNF687, PI4KB</i>	65.80
		Luminal A			62.74
		HER2	4	<i>VPS72, PIP5K1A, PSMD4, ZNF687</i>	61.68
		All patients	4	<i>POGZ, CGN, TUFT1, SNX27</i>	54.66
		HER2	3	<i>POGZ, CGN, TUFT1</i>	60.47
		Luminal A			57.96
8	17q21-q23	All patients	6	<i>DHX40, CLTC, PTRH2, TMEM49, TUBD1, RPS6KB1</i>	57.10
		Basal-like	3	<i>CLTC, PTRH2, TMEM49</i>	67.49
		HER2	8	<i>DHX40, CLTC, PTRH2, TMEM49, TUBD1, RPS6KB1, RNFT1, HEATR6</i>	63.26
		Luminal B	3	<i>DHX40, CLTC, PTRH2</i>	67.75
		HER2	7	<i>CLTC, PTRH2, TMEM49, TUBD1, RPS6KB1, RNFT1, HEATR6</i>	65.25
		Luminal B	4	<i>TUBD1, RPS6KB1, RNFT1, HEATR6</i>	64.25
		All patients	6	<i>DHX40, CLTC, PTRH2, TMEM49, TUBD1, RPS6KB1</i>	57.10
		HER2	3	<i>ACSF2, CHAD, RSAD1</i>	68.80
		HER2	4	<i>TOB1, SPAG9, NME1, NME1-NME2</i>	80.08
9	10p11-p12	All patients	5	<i>UPF2, DHTKD1, SEC61A2, NUDT5, CDC123</i>	54.49
		Luminal B	4	<i>DHTKD1, SEC61A2, NUDT5, CDC123</i>	70.75
		Basal-like	3	<i>RPP38, NMT2, FAM171A1</i>	63.28
		All patients	3	<i>SEPHS1, BEND7, PRPF18</i>	58.75
		Basal-like			59.21
		All patients		<i>UPF2, DHTKD1, SEC61A2, NUDT5, CDC123</i>	54.49
		Basal-like	3	<i>UPF2, DHTKD1, SEC61A2</i>	56.64
		Basal-like	3	<i>HSPA14, SUV39H2, DCLRE1C</i>	61.03
		Luminal B			59.58
		HER2	3	<i>FAM188A, PTER, RSU1</i>	60.35
10	19q13	All patients	7	<i>ZNF579, FIZ1, ZNF524, ZNF784, ZNF580, ZNF581, CCDC106</i>	55.38
		Basal-like	3	<i>TMEM190, RPL28, UBE2S</i>	67.80
		All patients	5	<i>UBE2S, SHISA7, ISOC2, ZNF628, NAT14</i>	52.11
		All patients	5	<i>ZNF416, ZIK1, ZNF530, ZNF134, ZNF211</i>	52.07
		Luminal B	3	<i>ZNF530, ZNF134, ZNF211</i>	64.13
		All patients	3	<i>ZNF135, ZSCAN18, ZNF329</i>	64.68
		Basal-like			68.76
		HER2			63.09
		Luminal A			66.84
		Luminal B			64.25
		All patients	4	<i>ZSCAN18, ZNF329, ZNF274, ZNF544</i>	53.90
		Basal-like	3	<i>ZSCAN18, ZNF329, ZNF274</i>	62.66
		Luminal B	3	<i>ZNF132, KIR2DS3, KIR2DS2</i>	52.62
		Basal-like	3	<i>ZBTB45, TRIM28, CHMP2A</i>	65.47
		Luminal B			68.11
11	16p13	All patients	3	<i>SNHG9, NTHL1, TSC2</i>	61.31
		All patients	3	<i>SLC9A3R2, SNHG9, NTHL1</i>	60.39
		All patients	3	<i>NME4, DECR2, RAB11FIP3</i>	62.89
		Luminal A			58.69
		Basal-like	3	<i>DECR2, RAB11FIP3, SOLH</i>	54.33
		All patients	4	<i>RAB11FIP3, SOLH, PIGO, RAB40C</i>	51.38
		Luminal A	3	<i>SOLH, PIGO, RAB40C</i>	61.04
		All patients	8	<i>FAM195A, WDR90, RHOT2, RHBDL1, STUB1, JMJD8, WDR24, FBXL16</i>	55.12
		Basal-like	3	<i>FAM195A, WDR90, RHOT2</i>	67.21
		Luminal A			65.90
		Luminal B	3	<i>RHOT2, RHBDL1, STUB1</i>	67.55
		All patients	3	<i>CCDC154, CLCN7, TELO2</i>	65.70
		All patients	3	<i>SNHG9, NTHL1, TSC2</i>	61.31
12	8p11-q13	All patients	5	<i>LSM1, BAG4, DDHD2, PPAPDC1B, WHSC1L1</i>	64.14
		Basal-like			63.11
		HER2			71.50
		Luminal B			86.70
		All patients	3	<i>FGFR1, TACCI, PLEKHA2</i>	56.21
		All patients	3	<i>GTF2E2, GSR, UBXN8</i>	58.00
		HER2	4	<i>GTF2E2, GSR, UBXN8, PPP2CB</i>	56.09
		Luminal B	7	<i>LEPROTL1, DCTN6, RBPMS, GTF2E2, GSR, UBXN8, PPP2CB</i>	66.10
13	19p13	All patients	5	<i>GCDH, SYCE2, FARSA, CALR, RAD23A</i>	53.34
		Basal-like	4	<i>FARSA, CALR, RAD23A, GADD45GIP1</i>	59.02

		Luminal B			57.17
		Luminal A	3	<i>FARSA, CALR, RAD23A</i>	62.97
		All patients	4	<i>FDX1L, RAVER1, ICAM3, TYK2</i>	56.36
		All patients	5	<i>CARM1, YIPF2, C19orf52, SMARCA4, LOC147727</i>	51.63
		Basal-like	4	<i>CARM1, YIPF2, C19orf52, SMARCA4</i>	59.77
		HER2	3	<i>TMED1, CARM1, YIPF2</i>	55.65
		Luminal B			64.19
		All patients	4	<i>DHPS, FBXW9, TNPO2, C19orf43</i>	59.03
		Basal-like	3	<i>WDR83, DHPS, FBXW9</i>	71.77
14	1q42-q44	All patients	4	<i>NUP133, ABCB10, TAF5L, URB2</i>	54.39
		Basal-like			59.05
		All patients	3	<i>TBCE, B3GALNT2, FAM72A</i>	67.48
		Basal-like			62.60
		HER2	3	<i>GGPS1, TBCE, B3GALNT2</i>	60.64
		Luminal B			70.81
		All patients	4	<i>ARF1, C1orf35, MRPL55, GUK1</i>	58.40
		Basal-like			57.22
		All patients	3	<i>RHOU, RAB4A, C1orf96</i>	57.49
		Luminal A			62.57
		All patients	6	<i>C1orf131, GNPAT, EXOC8, C1orf124, EGLN1, TSNAX</i>	55.14
		Basal-like	4	<i>C1orf131, GNPAT, EXOC8, C1orf124</i>	68.04
		Luminal B			71.47
		Luminal A	5	<i>C1orf131, GNPAT, EXOC8, C1orf124, EGLN1</i>	57.94
15	16q11-q13	All patients	6	<i>MT1A, MT1B, MT1F, MT1G, MT1H, MT1X</i>	62.75
		Luminal A			76.39
		Basal-like	8	<i>MT2A, MT1M, MT1A, MT1B, MT1F, MT1G, MT1H, MT1X</i>	70.68
		HER2	3	<i>MT1F, MT1G, MT1H</i>	77.14
		Luminal B	4	<i>MT1F, MT1G, MT1H, MT1X</i>	71.87
		All patients	3	<i>MT1H, MT1X, NUP93</i>	64.71
		Luminal A	3	<i>NUDT21, OGFOD1, BBS2</i>	64.44
		Luminal B			75.91
		All patients	4	<i>CPNE2, FAM192A, RSPRY1, ARL2BP</i>	53.95
		Luminal B	3	<i>FAM192A, RSPRY1, ARL2BP</i>	76.68
16	16q21-q24	All patients	5	<i>NOB1, WWP2, PDPR, EXOSC6, AARS</i>	49.87
		All patients	4	<i>FUK, COG4, SF3B3, IL34</i>	58.44
		Basal-like	3	<i>FUK, COG4, SF3B3</i>	61.58
		Luminal A			63.03
		Luminal B			65.08
		All patients	3	<i>VPS4A, NIP7, TMED6</i>	57.13
		All patients	7	<i>RLTPR, ACD, PARD6A, C16orf48, C16orf86, GFOD2, RANBP10</i>	51.69
		Basal-like	3	<i>THAP11, NUTF2, EDC4</i>	57.63
		Luminal B			64.69
		All patients	3	<i>DDX28, DUS2L, NFATC3</i>	57.94
17	6p21-p22	All patients	4	<i>BTN3A2, BTN2A2, BTN3A1, BTN3A3</i>	63.22
		Basal-like			74.94
		HER2			65.95
		Luminal A			55.79
		Luminal A	3	<i>BTN3A2, BTN2A2, BTN3A1</i>	62.75
		All patients	6	<i>C6orf136, DHX16, KIAA1949, NRM, MDC1, TUBB</i>	55.39
		Basal-like	3	<i>MRPS18B, C6orf136, DHX16</i>	72.44
		HER2	3	<i>HIST1H2BD, HIST1H2BE, HIST1H4D</i>	68.75
		All patients	3	<i>HIST1H3D, HIST1H2AD, HIST1H2BF</i>	67.40
		Basal-like			73.73
		Luminal A			74.45
		Luminal B			74.40
		All patients	5	<i>HIST1H2AD, HIST1H2BF, HIST1H4E, HIST1H2BG, HIST1H2AE</i>	65.05
		HER2			67.52
		Basal-like	4	<i>HIST1H2AD, HIST1H2BF, HIST1H4E, HIST1H2BG</i>	64.89
		HER2	3	<i>HIST1H2BG, HIST1H2AE, HIST1H3E</i>	68.63
		All patients	4	<i>HIST1H2BH, HIST1H3G, HIST1H2BI, HIST1H4H</i>	64.34
		Basal-like			60.20
		HER2			69.29
		Luminal A			60.81
18	11q13-q14	All patients	4	<i>NDUFC2, ALG8, KCTD21, LOC100287896</i>	65.37
		Luminal B	3	<i>NDUFC2, ALG8, KCTD21</i>	85.43
		All patients	5	<i>PAK1, AQP11, CLNS1A, RSF1, C11orf67</i>	64.33
		Luminal B			74.46
		HER2	3	<i>CLNS1A, RSF1, C11orf67</i>	84.24
		Luminal A			62.95
		All patients	3	<i>USP35, GAB2, NARS2</i>	67.11
		Luminal A			59.57
		Luminal B			81.35

		Luminal A	3	<i>PRCP, C11orf82, RAB30</i>	47.99		
		All patients	3	<i>OR7E126P, MAP6, MOGAT2</i>	60.79		
19	1p32-p35	All patients	3	<i>IPO13, ATP6V0B, B4GALT2</i>	58.45		
		Basal-like	4	<i>DPH2, IPO13, ATP6V0B, B4GALT2</i>	53.90		
		Basal-like	3	<i>EIF2B3, HECTD3, UROD</i>	56.72		
		HER2	3	<i>PRDX1, AKR1A1, NASP</i>	61.19		
		All patients	3	<i>DMAP1, ERI3, RNF220</i>	59.11		
		Basal-like			61.91		
		Luminal B			62.15		
		All patients	3	<i>INPP5B, LOC100128093, SF3A3</i>	59.11		
20	19q13	All patients	4	<i>SCAF1, IRF3, BCL2L12, PRMT1</i>	57.03		
		Basal-like	3	<i>IRF3, BCL2L12, PRMT1</i>	66.60		
		Luminal B			77.90		
		All patients	3	<i>NOSIP, PRRG2, PRR12</i>	58.27		
		Luminal B			65.38		
		All patients	5	<i>MED25, DKFZP434J0226, PTOV1, PNKP, AKT1S1</i>	54.13		
		Luminal A	3	<i>DKFZp434J0226, PTOV1, PNKP</i>	61.32		
		Luminal B	3	<i>PTOV1, PNKP, AKT1S1</i>	70.23		
		Luminal B	3	<i>YRK3, ZNF473, MYH14</i>	71.39		
		21	19q13	All patients	3	<i>ZNF383, HKR1, ZNF527</i>	61.05
All patients	3			<i>WDR87, SIPA1L3, DPF1</i>	59.42		
All patients	3			<i>PSMD8, GGN, FAM98C</i>	58.38		
HER2	3			<i>ACTN4, CAPN12, LGALS7</i>	68.01		
22	3p21	Luminal B	3	<i>GPX1, RHOA, TCTA</i>	55.52		
		All patients	7	<i>P4HTM, WDR6, DALRD3, NDUFAF3, IMPDH2, QRICHI, QARS</i>	50.05		
		HER2	3	<i>IMPDH2, QRICHI, QARS</i>	62.24		
		All patients	3	<i>QARS, USP19, LAMB2</i>	58.44		
23	16p11-p13	All patient	3	<i>BCKDK, MYST1, PRSS8</i>	63.11		
		Luminal A			72.57		
		Luminal B			68.34		
		Luminal A	3	<i>FUS, PYCARD, PYDC1</i>	65.44		
		All patients	3	<i>FBXL19, ORA13, SETD1A</i>	65.50		
		All patients	7	<i>PRR14, FBRS, SRCAP, PHKG2, C16orf93, RNF40, ZNF629</i>	54.88		
		Luminal A	4	<i>PRR14, FBRS, SRCAP, PHKG2</i>	63.22		
		Luminal A	4	<i>PHKG2, C16orf93, RNF40, ZNF629</i>	61.39		
		Luminal B	3	<i>PRR14, FBRS, SRCAP</i>	65.51		
		All patients	5	<i>BOLA2, SULT1A3, LOC595101, CD2BP2, TBC1D10B</i>	51.47		
		All patients	5	<i>ZNF768, ZNF747, ZNF764, ZNF688, ZNF785</i>	55.52		
		24	14q13-q21	Luminal B	3	<i>KLHDC2, SDCCAG1, ARF6</i>	60.88
				All patients	3	<i>SOS2, L2HGDH, ATP5S</i>	54.12
All patients	3			<i>RPL36AL, MGAT2, C14orf104</i>	57.30		
HER2					56.13		
Basal-like	3			<i>PPIL5, RPL36AL, MGAT2</i>	61.89		
All patients	3			<i>MAP4K5, AT1L1, SAV1</i>	60.16		
All patient	3			<i>FAM179B, PRPF39, FKBP3</i>	60.88		
Basal-like					59.81		
Luminal B					65.65		
Luminal B	3			<i>KLHL28, FAM179B, PRPF39</i>	72.22		
25	12q13-q15	HER2	3	<i>YEATS4, FRS2, CCT2</i>	66.61		
		Luminal B			73.98		
		All patients	4	<i>MDM1, RAP1B, NUP107, SLC35E3</i>	57.47		
		HER2			75.43		
		Luminal A	3	<i>MDM1, RAP1B, NUP107</i>	58.61		
		All patients	3	<i>NUP107, SLC35E3, MDM2</i>	57.57		
		HER2	4	<i>RAP1B, NUP107, SLC35E3, MDM2</i>	66.94		
		Luminal B			75.13		
26	6q16-q21	All patients	7	<i>ATG5, AIM1, RTN4IP1, QRSL1, C6orf203, BEND3, PDSS2</i>	51.52		
		Basal-like	4	<i>ATG5, AIM1, RTN4IP1, QRSL1</i>	59.51		
		HER2	4	<i>AIM1, RTN4IP1, QRSL1, C6orf203</i>	69.08		
		Luminal B	3	<i>ATG5, AIM1, RTN4IP1</i>	69.82		
		Luminal A	3	<i>RTN4IP1, QRSL1, C6orf203</i>	57.74		
		HER2	3	<i>SMPD2, MICAL1, ZBTB24</i>	62.37		
		Luminal B			71.04		
		Luminal B	3	<i>WASF1, CDC40, DDO</i>	57.97		
		All patients	6	<i>RAD54B, KIAA1429, ESRP1, DPY19L4, INTS8, CCNE2</i>	57.87		
27	8q21-23	Basal-like	3	<i>RAD54B, KIAA1429, ESRP1</i>	65.96		
		Basal-like	4	<i>KIAA1429, ESRP1, DPY19L4, INTS8</i>	55.24		
		Luminal B			72.40		
		HER2	5	<i>RAD54B, KIAA1429, ESRP1, DPY19L4, INTS8</i>	68.10		
		HER2	7	<i>ESRP1, DPY19L4, INTS8, CCNE2, TP53INP1, C8orf38, PLEKHF2</i>	61.95		
		All patients	3	<i>UQCRB, MTERFD1, PTDSSI</i>	67.67		
		Basal-like			69.88		

		HER2			72.53
		Luminal A			56.98
		Luminal B			74.31
		Luminal A	3	<i>SDC2, PGCP, TSPYL5</i>	60.86
		Luminal B	4	<i>MTERFD1, PTDSSI, SDC2, PGCP</i>	64.49
		Basal-like	3	<i>TSPYL5, MTDH, LAPTM4B</i>	59.82
		Luminal B	3	<i>MTDH, LAPTM4B, MATN2</i>	60.76
		All patients	3	<i>FBXO43, POLR2K, SPAG1</i>	56.99
		HER2	4	<i>POLR2K, SPAG1, RNF19A, ANKRD46</i>	63.19
28	3q26-q27	All patients	3	<i>DVL3, AP2MI, ABCF3</i>	54.60
		Basal-like	4	<i>EIF2B5, DVL3, AP2MI, ABCF3</i>	52.75
		Basal-like	3	<i>PSMD2, EIF4G1, FAM131A</i>	63.68
		Luminal B			62.97
29	11p11-p13	Basal-like	3	<i>APIP, PDHX, CD44</i>	66.50
		Luminal B	3	<i>FJX1, TRIM44, LDLRAD3</i>	69.21
		Luminal B	3	<i>CAPRINI, NAT10, ABTB2</i>	62.31
		Basal-like	3	<i>TRIM44, LDLRAD3, COMMD9</i>	63.38
		Luminal B			65.13
30	19p11-p13	All patients	5	<i>LASS1, COPE, DDX49, HOMER3, ARMC6</i>	51.35
		Basal-like	4	<i>COPE, DDX49, HOMER3, ARMC6</i>	59.16
		All patients	3	<i>TMEM161A, RFXANK, NR2C2AP</i>	67.26
		Basal-like			77.37
		Luminal A			56.15
		All patients	3	<i>C19orf50, UBA52, C19orf60</i>	59.75
31	20q13	All patients	4	<i>OSBPL2, ADRM1, LAMA5, LOC100287547</i>	53.01
		HER2	3	<i>OSBPL2, ADRM1, LAMA5</i>	57.59
		Luminal B	3	<i>SYCP2, PPP1R3D, C20orf177</i>	68.54
		All patients	3	<i>TCFL5, DIDO1, C20orf11</i>	61.26
		Luminal B			62.65
32	9q33-q34	Luminal B	3	<i>GAPVD1, MAPKAP1, PBX3</i>	56.09
		HER2	3	<i>LMX1B, ZBTB43, ZBTB34</i>	82.42
		All patients	3	<i>TTC16, TOR2A, SH2D3C</i>	56.53

a: Bunes order of frequency; b: multi-correlation score

**Supplementary Table 2** Screening of continuous clusters of correlated ( $r \geq 0.30$  and  $p \leq 0.05$ ) co-expressed genes ( $n \geq 2$ ) according to ER status of genes overexpressed in gained regions based on Han's results as input genes by means of bc-GenExMiner v3.0 gene expression correlation analysis by chromosomal location [21]

Cytoband	Input gene	Test results			ER- specificity
		ER <sup>-</sup> cluster	ER <sup>+</sup> cluster	Basal-like cluster	
9p24.3-p21.1	<i>KANK1</i>	<i>KANK1, DMRT1, DMRT3, DMRT2</i> <b>MCS<sup>p</sup> = 46.7</b>	<i>DOCK8, KANK1, DMRT1, DMRT3, DMRT2</i> <b>MCS = 52.5</b>	No cluster	Discordant
	<i>KIAA0020</i>	Discontinuous		Discontinuous	Tendency
	<i>RCL1</i>	<i>PPAPDC2, CDC37LI, AK3, RCL1, JAK2</i> <b>MCS = 55.3</b>	<i>PPAPDC2, CDC37LI, AK3, RCL1</i> <b>MCS = 54</b>	<i>PPAPDC2, CDC37LI, AK3, RCL1</i>	Yes
	<i>UHRF2</i>	No cluster	No cluster	Discontinuous	No
	<i>GLDC</i>	No cluster	No cluster	No cluster	No
	<i>KDM4C</i>	No cluster	No cluster	Discontinuous	No
	<i>C9orf123</i>	Discontinuous		Discontinuous	Tendency
	<i>NFIB</i>	<i>MPDZ, NFIB, ZDHHC21</i> <b>MCS = 58.8</b>	<i>MPDZ, NFIB</i> <b>MCS = 57.8</b>	<i>MPDZ, NFIB, ZDHHC21</i>	Yes
	<i>PSIP1</i>	<i>TTC39B, SNAPC3, PSIP1, C9orf93</i> <b>MCS = 60.4</b>	<i>TTC39B, SNAPC3, PSIP1, C9orf93</i> <b>MCS = 61</b>	<i>TTC39B, SNAPC3, PSIP1</i>	Discordant
	<i>PLIN2</i>	No cluster	No cluster	No cluster	No
	<i>RPS6</i>	No cluster	No cluster	No cluster	No
	<i>MTAP</i>	No cluster	No cluster	No cluster	No
	<i>PLAA</i>	<i>TUSC1, C9orf82, PLAA</i> <b>MCS = 66.7</b>	<i>TUSC1, C9orf82, PLAA</i> <b>MCS = 62.7</b>	<i>TUSC1, C9orf82, PLAA</i>	Yes
	<i>MOBK2B</i>	<i>C9orf11, MOBK2B, IFNK</i> <b>MCS = 63.1</b>	<i>C9orf11, MOBK2B</i> <b>MCS = 56.8</b>	No cluster	Yes
	<i>CNTLN</i>	No cluster	No cluster	No cluster	No
<i>HAUS6</i>	Discontinuous		Discontinuous	Tendency	
<i>CDKN2A</i>	<i>CDKN2A, CDKN2B</i> <b>MCS = 52.4</b>	<i>CDKN2A, CDKN2B, DMRTA1</i> <b>MCS = 54.1</b>	<i>CDKN2A, CDKN2B</i>	Discordant	
10p15.3-p14	<i>GTPBP4</i>	<i>LARP4B, GTPBP4, IDI2</i> <b>MCS = 52</b>	<i>LARP4B, GTPBP4, IDI2, IDI1</i> <b>MCS = 54.7</b>	<i>LARP4B, GTPBP4, IDI2</i>	Discordant
	<i>PFKP</i>	Discontinuous			Tendency
	<i>IL15RA</i>	<i>IL15RA, IL2RA</i> <b>MCS = 49.7</b>	<i>ANKRD16, FBXO18, IL15RA, IL2RA</i> <b>MCS = 50.2</b>	<i>IL15RA, IL2RA</i>	Discordant
	<i>RBM17</i>	No cluster	No cluster	No cluster	No
	<i>CELF2</i>	No cluster <b>MCS = 64</b>	<i>SFTA1P, LOC254312, CELF2</i> <b>MCS = 59</b>	No cluster	Yes
	<i>NUDT5</i>	<i>UPF2, DHTKD1, SEC61A2, NUDT5, CDC123</i> <b>MCS = 55.6</b>	<i>UPF2, DHTKD1, SEC61A2, NUDT5, CDC123</i> <b>MCS = 53.6</b>	Discontinuous	Yes
	<i>IDI1</i>	No cluster <b>MCS = 52</b>	<i>LARP4B, GTPBP4, IDI2, IDI1</i> <b>MCS = 54.7</b>	No cluster	Discordant
	<i>WDR37</i>	No cluster	No cluster	No cluster	No
	<i>CALML5</i>	No cluster	No cluster	No cluster	No
	<i>GDI2</i>	<i>C10orf18, GDI2</i> <b>MCS = 67.7</b>	No cluster <b>MCS = 61.5</b>	<i>C10orf18, GDI2, FBXO18</i>	Yes
	<i>KIN</i>	<i>KIN, ATP5C1, TAF3</i> <b>MCS = 64.9</b>	<i>KIN, ATP5C1</i> <b>MCS = 55.1</b>	<i>KIN, ATP5C1</i>	Yes
<i>USP6NL</i>	<i>USP6NL, ECHDC3, C10orf47</i> <b>MCS = 61</b>	No cluster <b>MCS = 55.9</b>	<i>USP6NL, ECHDC3</i>	Yes	
12p13.33-p13.31	<i>CCDC77</i>	<i>KDM5A, CCDC77</i> <b>MCS = 83.6</b>	<i>KDM5A, CCDC77</i> <b>MCS = 73.3</b>	<i>KDM5A, CCDC77, B4GALNT3</i>	Yes
	<i>NINJ2</i>	<i>NINJ2, LOC100049716</i> <b>MCS = 71.3</b>	No cluster <b>MCS = 63.8</b>	<i>NINJ2, LOC100049716, WNK1</i>	Yes
	<i>WNT5B</i>	No cluster	No cluster	<i>FBXL14, WNT5B</i>	No
	<i>FOXMI</i>	<i>FOXMI, C12orf32, TULP3, TEAD4</i> <b>MCS = 61.7</b>	<i>FOXMI, C12orf32</i> <b>MCS = 54.4</b>	<i>FOXMI, C12orf32, TULP3, TEAD4</i>	Yes
	<i>C12orf4</i>	<i>C12orf4, RAD51API, DYRK4</i> <b>MCS = 62.9</b>	<i>C12orf4, RAD51API</i> <b>MCS = 54.3</b>	<i>C12orf4, RAD51API, DYRK4</i>	Yes
	<i>NDUFA9</i>	No cluster	No cluster	No cluster	No
13q31.3-q34	<i>DZIP1</i>	No cluster	No cluster	No cluster	No
	<i>RAP2A</i>	<i>MBNL2, RAP2A, IPO5</i> <b>MCS = 61.3</b>	<i>RAP2A, IPO5</i> <b>MCS = 56.6</b>	<i>MBNL2, RAP2A, IPO5, FARP1, STK24</i>	Yes
	<i>TNFSF13B</i>	<i>TNFSF13B, SP3P</i>	No cluster	No cluster	Yes



		<b>MCS = 64.8</b>			
	<i>ANKRD10</i>	<i>CARKD, CARS2, INGI, ANKRD10, ARHGEF7, C13orf16</i> <b>MCS = 50.6</b>	<i>CARKD, CARS2, INGI, ANKRD10, ARHGEF7, C13orf16</i> <b>MCS = 50.8</b>	<i>CARKD, CARS2, INGI, ANKRD10, ARHGEF7</i>	Discordant
	<i>GPR180</i>	<i>TGDS, GPR180</i> <b>MCS = 67.6</b>	<i>TGDS, GPR180</i> <b>MCS = 74.8</b>	<i>TGDS, GPR180</i>	Discordant
	<i>CLYBL</i>	No cluster <b>MCS = 60.2</b>	<i>TM9SF2, CLYBL</i> <b>MCS = 67.6</b>	Discontinuous	Discordant
18q12.1-12.2	<i>DSC2</i>	<i>DSC3, DSC2</i> <b>MCS = 73</b>	<i>DSC3, DSC2</i> <b>MCS = 66.5</b>	<i>DSC3, DCS2</i>	Yes
	<i>DSG2</i>	<i>DSG3, DSG2</i> <b>MCS = 66.1</b>	No cluster <b>MCS = 60.8</b>	<i>DSG3, DSG2</i>	Yes
	<i>RNF138</i>	No cluster	No cluster	No cluster	No
	<i>MAPRE2</i>	No cluster	No cluster	No cluster	No
18q21.33-q23	<i>SERPINB5</i>	No cluster	No cluster	No cluster	No
	<i>MBP</i>	No cluster	No cluster	No cluster	No
	<i>NFATC1</i>	No cluster <b>MCS = 60.6</b>	<i>ATP9B, NFATC1</i> <b>MCS = 65.6</b>	No cluster	Discordant
	<i>CDH19</i>	No cluster	No cluster	No cluster	No
	<i>PQLC1</i>	<i>PQLC1, FLJ37638</i> <b>MCS = 74.6</b>	<i>PQLC1, FLJ37638</i> <b>MCS = 73.4</b>	Discontinuous	Yes
21q22.3	<i>WDR4</i>	No cluster	No cluster	No cluster	No
	<i>CBS</i>	<i>CBS, U2AF1</i> <b>MCS = 67.1</b>	No cluster <b>MCS = 61.8</b>	<i>CBS, U2AF1</i>	Yes
	<i>PDXK</i>	<i>RRP1B, PDXK, CSTB, RRP1</i> <b>MCS = 62.6</b>	<i>RRP1B, PDXK</i> <b>MCS = 50.9</b>	<i>RRP1B, PDXK, CSTB, RRP1</i>	Yes
	<i>C21orf70</i>	No cluster	No cluster	No cluster	No
	<i>SI00B</i>	No cluster	No cluster	<i>SI00B, PRMT2</i>	No
	<i>TMPRSS3</i>	No cluster	No cluster	No cluster	No
	<i>PDE9A</i>	No cluster	No cluster	No cluster	No
	<i>AGPAT3</i>	No cluster	No cluster	<i>RRP1, AGPAT3</i>	No
	<i>SUMO3</i>	<i>UBE2G2, SUMO3</i> <b>MCS = 66.2</b>	<i>UBE2G2, SUMO3</i> <b>(MCS = 65.7)</b>	<i>UBE2G2, SUMO3, PTTG1IP</i>	Yes
	<i>SUMO3</i>	<i>SUMO3, PTTG1IP</i> <b>MCS = 75.1</b>	<i>SUMO3, PTTG1IP</i> <b>MCS = 73.2</b>	<i>UBE2G2, SUMO3, PTTG1IP</i>	Yes

a: oestrogen receptor; b: multi-correlation score

Supplementary Figure 1: Level of expression genes belonging to *ESR1* cluster (*RMND1*, *C6orf211*, *C6orf97*, *ESR1*) in breast cancer patients according to oestrogen receptor (ER) status, based on bcGenExMiner v3.0 data.

