Identifying and correcting sample mix-ups in high-dimensional data

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Attie project

$\sim$500 B6 $\times$ BTBR intercross mice, all ob/ob

Genotypes at 2057 SNPs (Affymetrix arrays)

Gene expression in six tissues (Agilent arrays)

- adipose
- gastrocnemius muscle
- hypothalamus
- pancreatic islets
- kidney
- liver

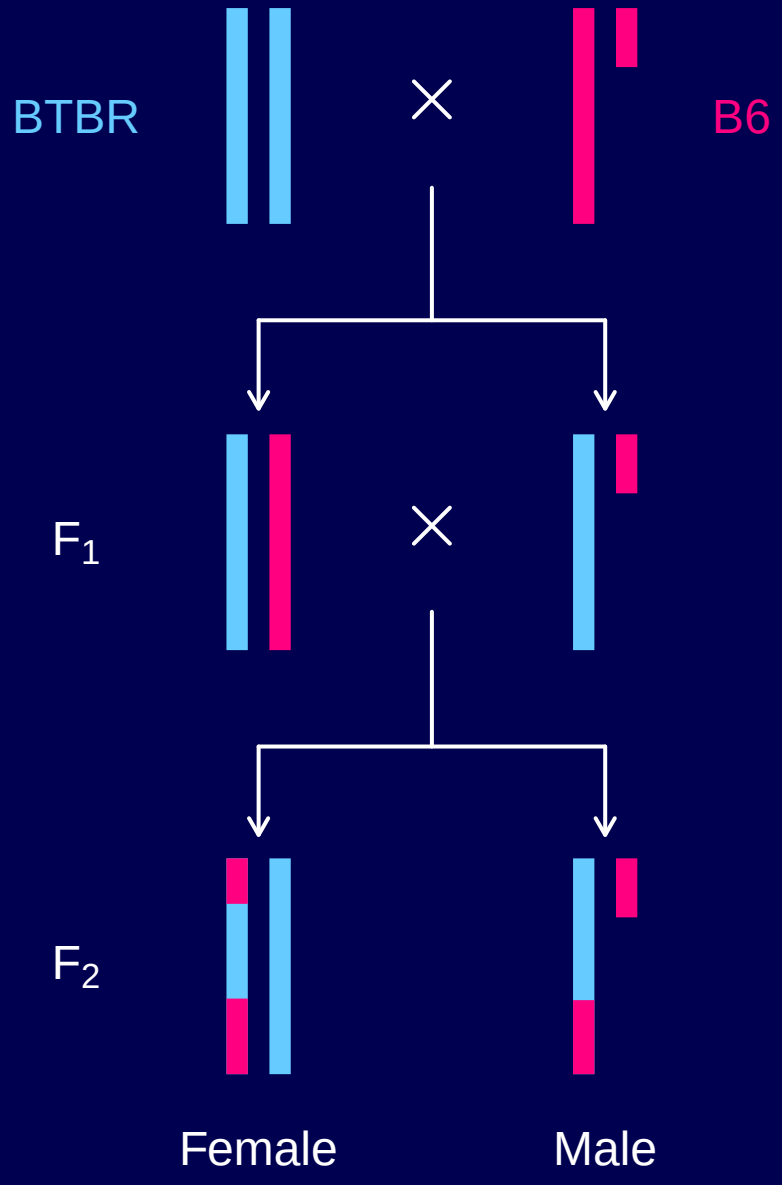
Numerous clinical phenotypes

(e.g., body weight, insulin and glucose levels)

Considerable brain power

Alan Attie, Karl Broman, Aimee Teo Broman, Danielle Greenawalt, Mark Keller, Christina Kendziorski, Amit Kulkarni, Eric Schadt, Brian Yandell, . . .

Sex and the X chr

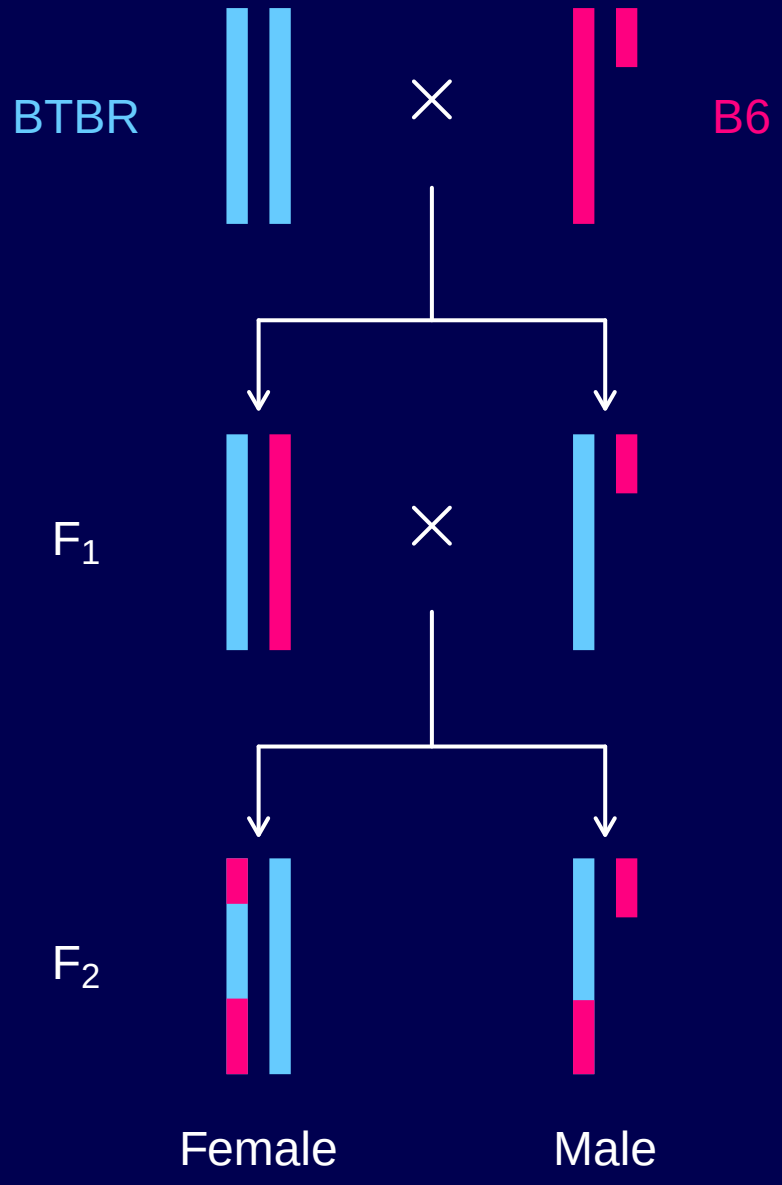


F_2 females: R/R or B/R

F_2 males: hemizygous B or R

Genotype mix-ups

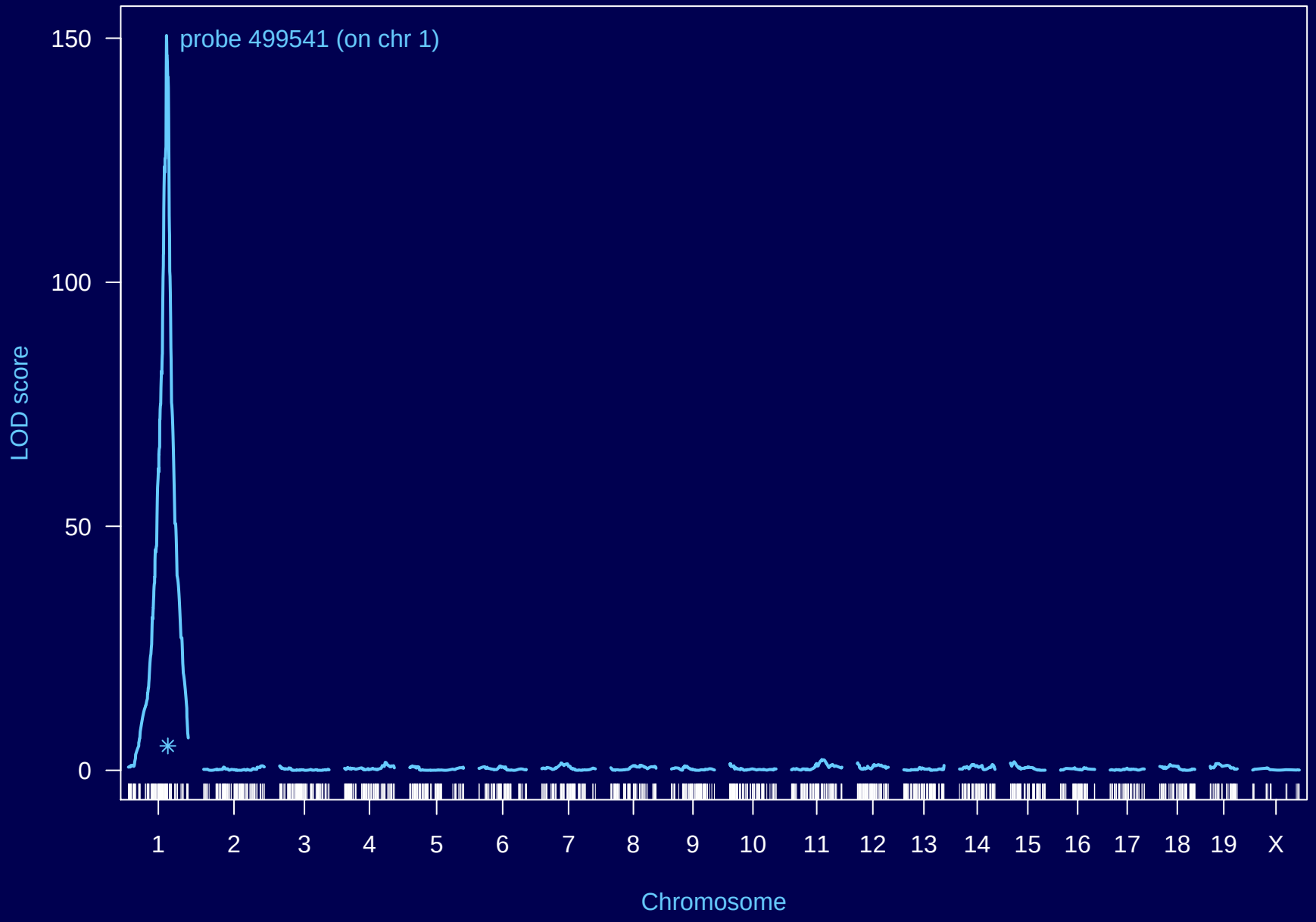
Sex and the X chr



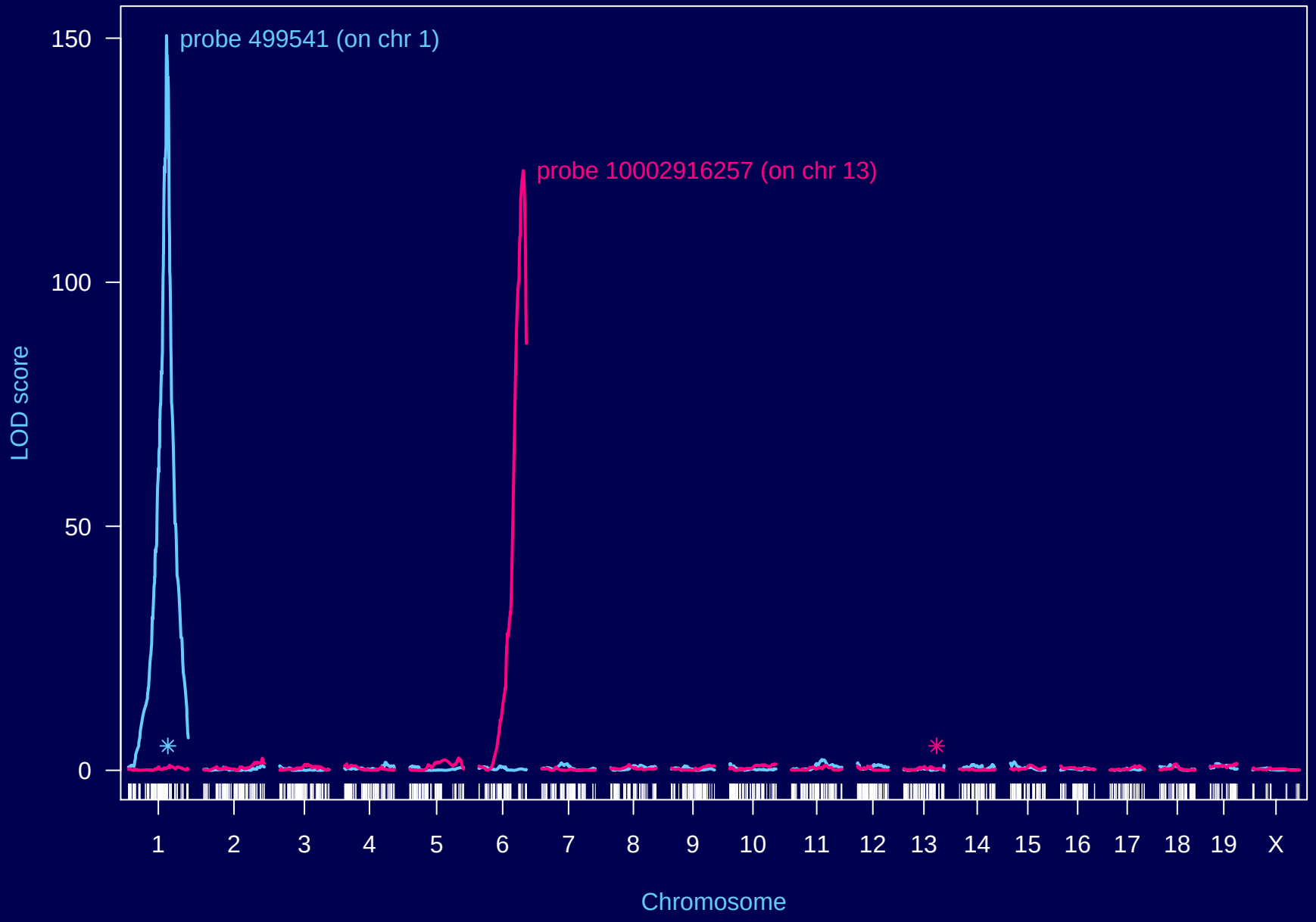
F_2 females: R/R or B/R

F_2 males: hemizygous B or R

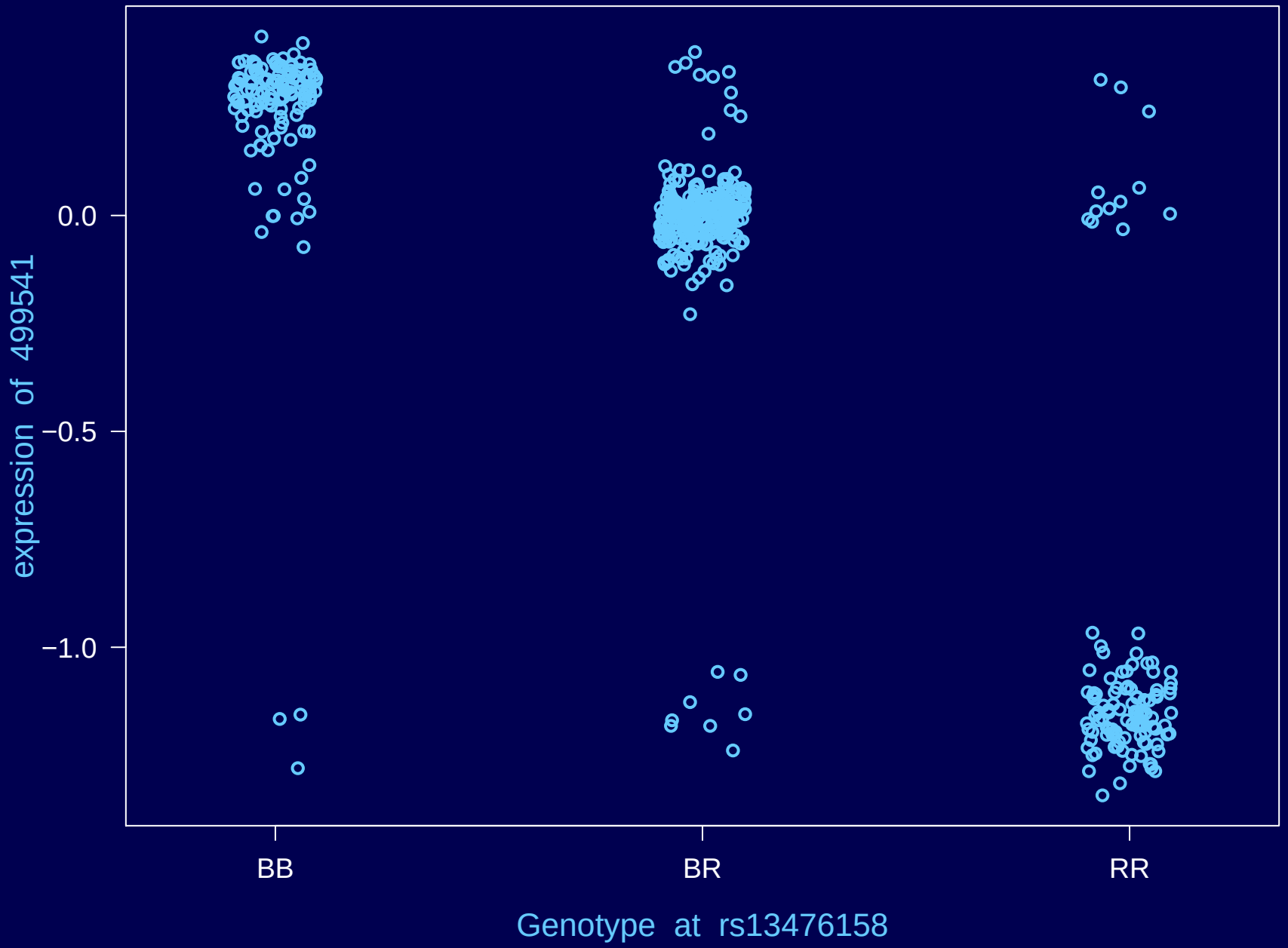
Strong eQTL


probe 499541 (on chr 1)
150
100
50
0
LOD score
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
X
Chromosome

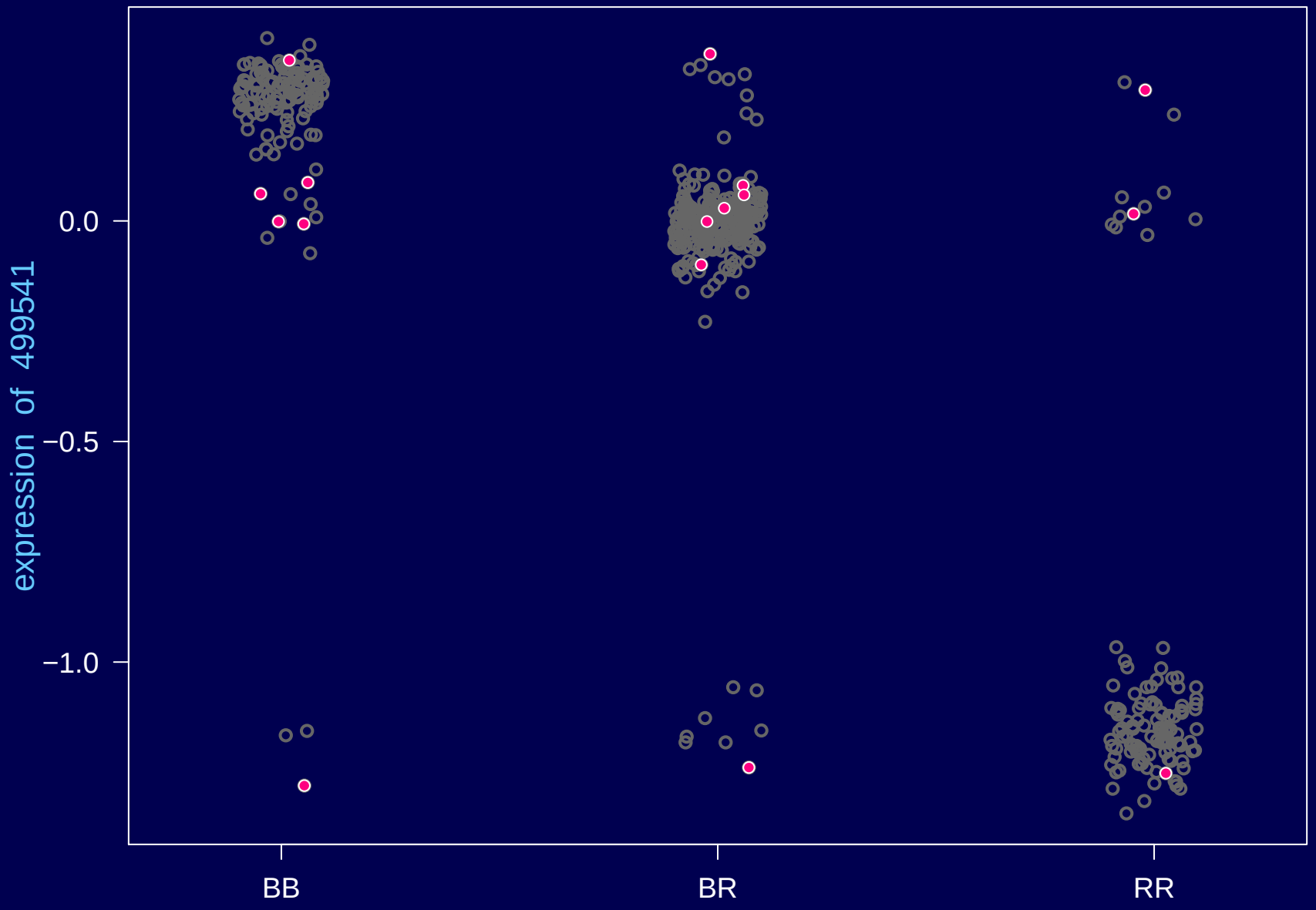
Strong eQTL


probe 499541 (on chr 1)
probe 10002916257 (on chr 13)
150
100
50
0
LOD score
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
X
Chromosome

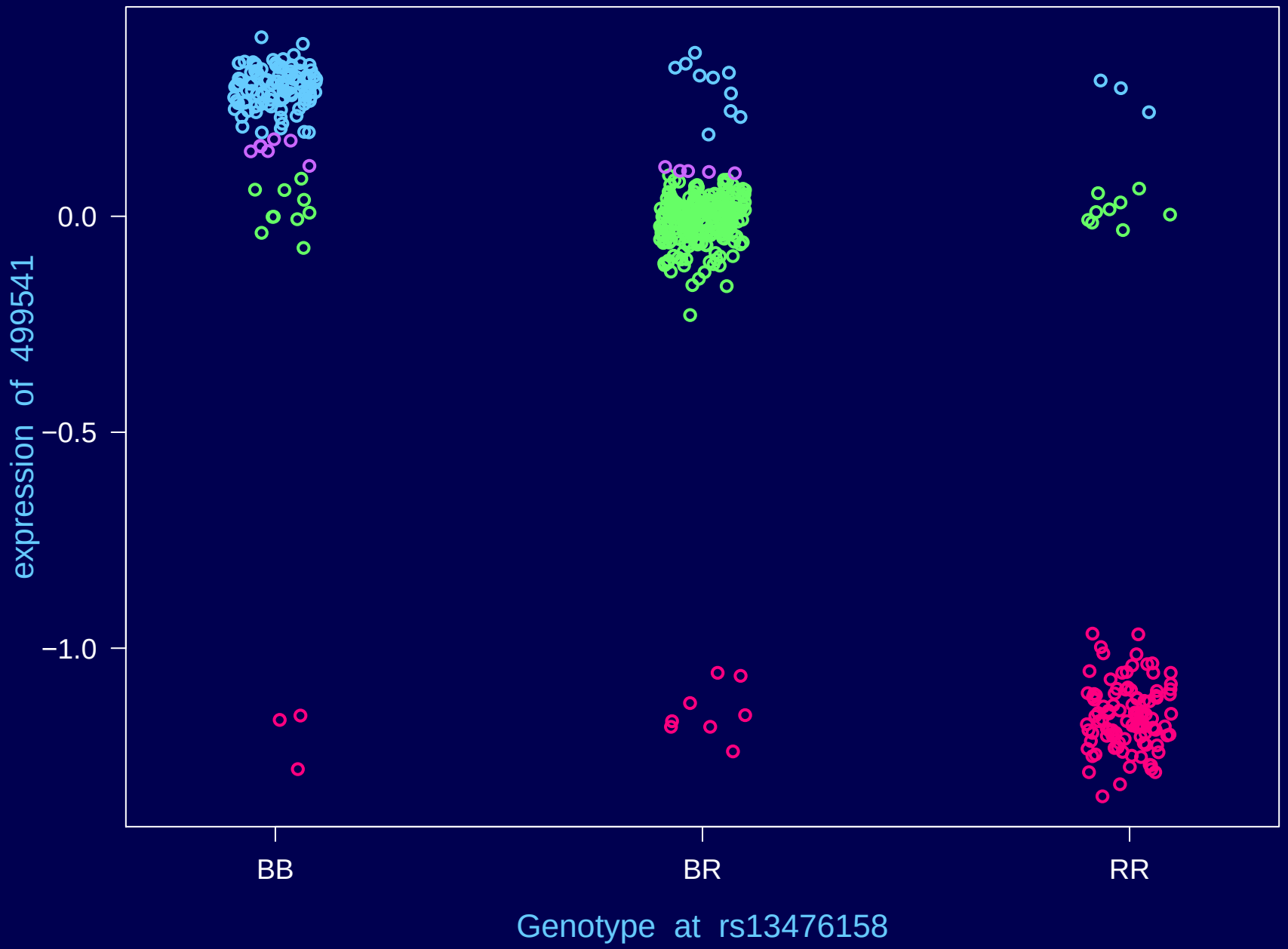
E vs G


0.0
−0.5
−1.0
expression of 499541
BB
BR
RR
Genotype at rs13476158

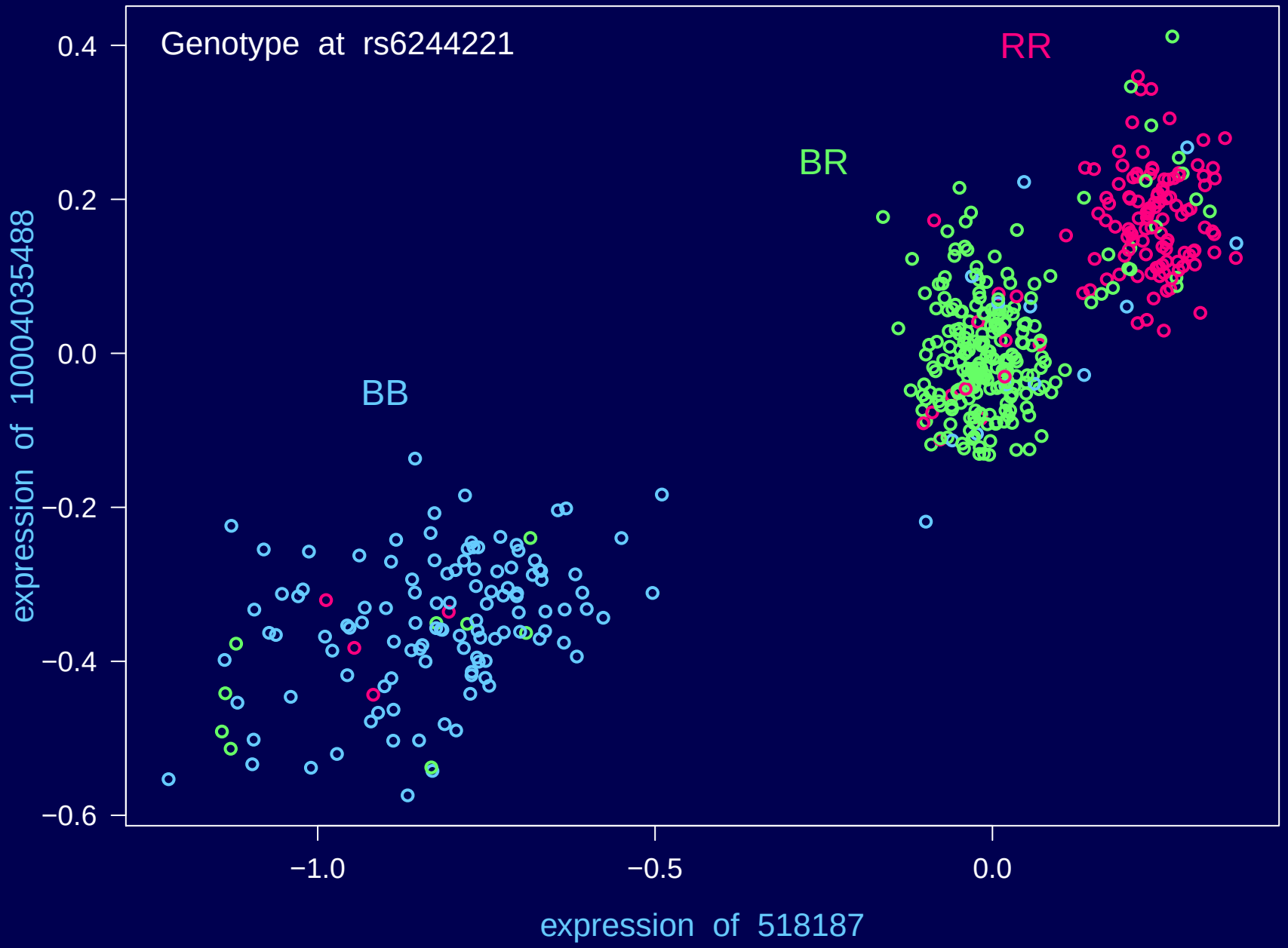
E vs G


0.0
−0.5
−1.0
expression of 499541
BB
BR
RR
Genotype at rs13476158

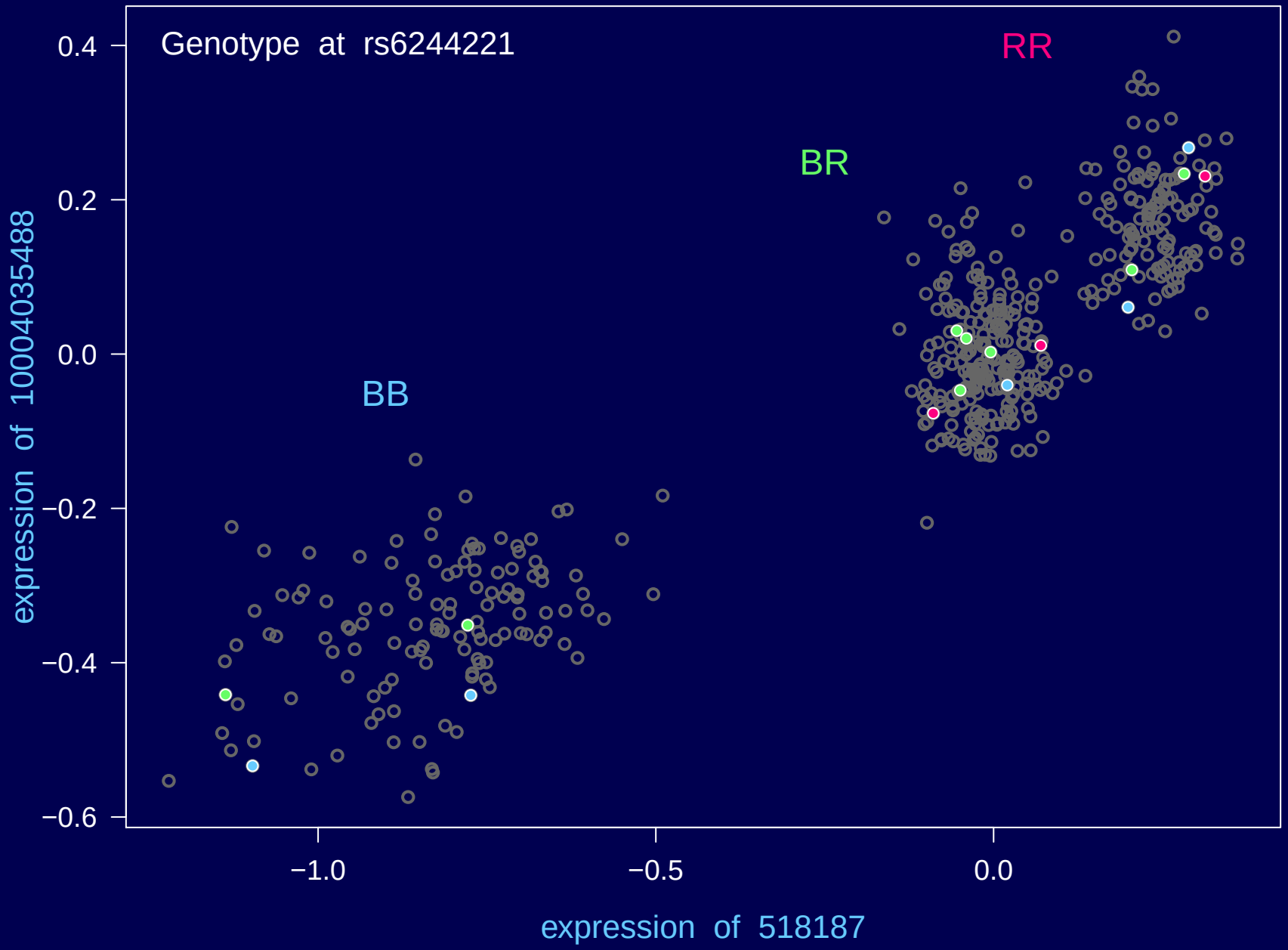
kNN classifier



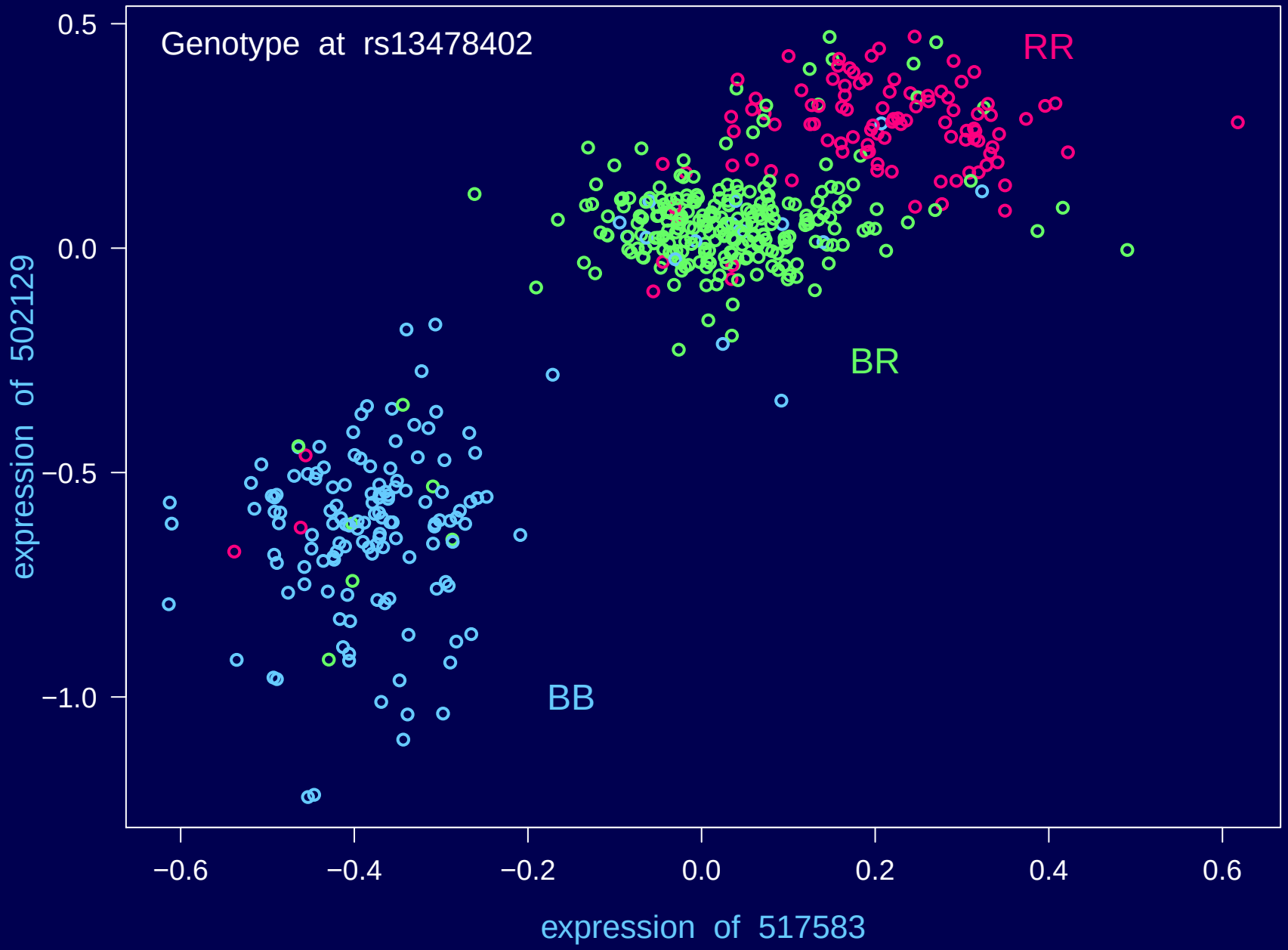
E vs G


Genotype at rs6244221
RR
BR
BB
0.4
0.2
0.0
−0.2
−0.4
−0.6
−1.0
−0.5
0.0
expression of 10004035488
expression of 518187

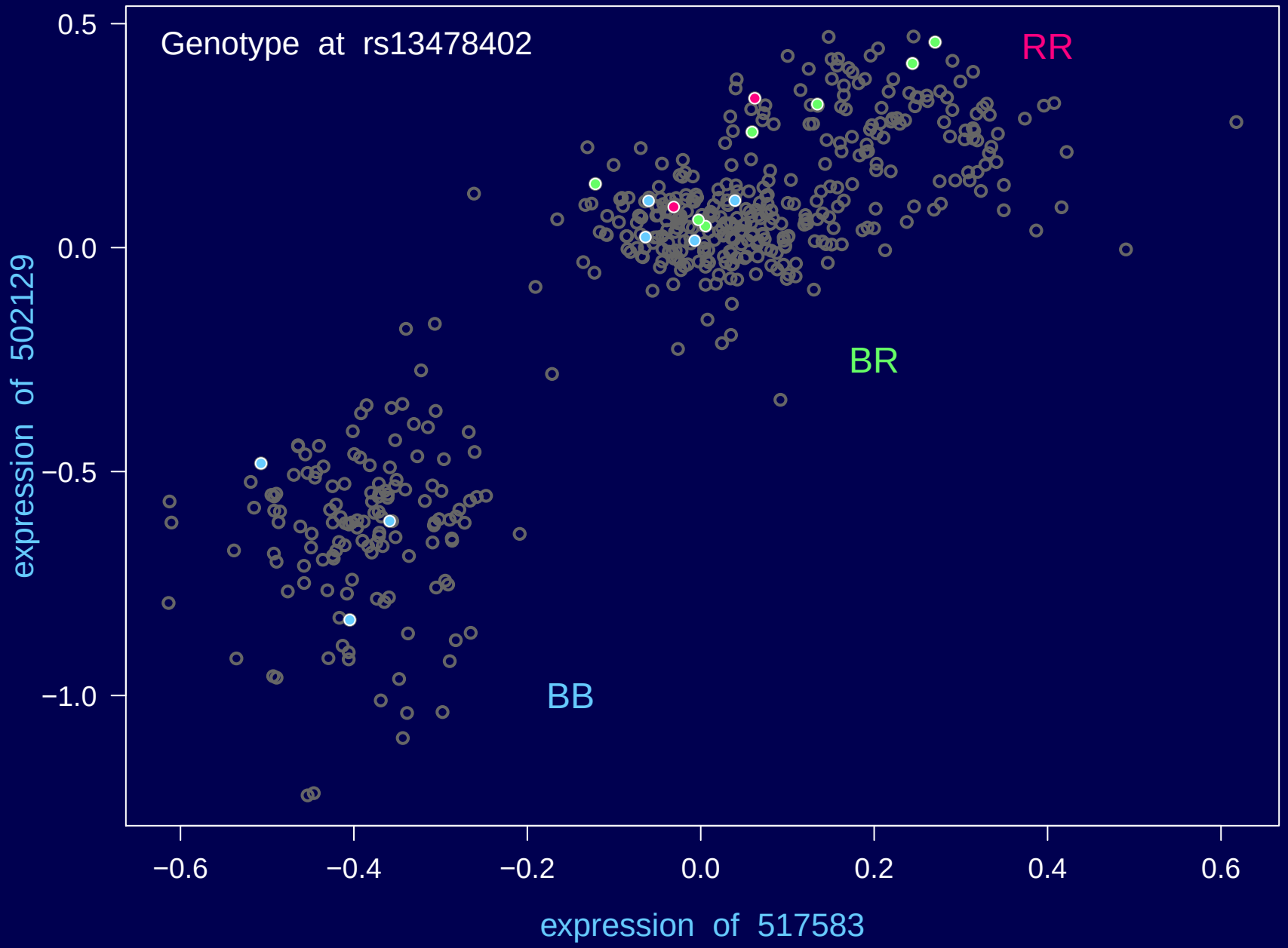
E vs G


Genotype at rs6244221
RR
BR
BB
0.4
0.2
0.0
−0.2
−0.4
−0.6
−1.0
−0.5
0.0
expression of 10004035488
expression of 518187

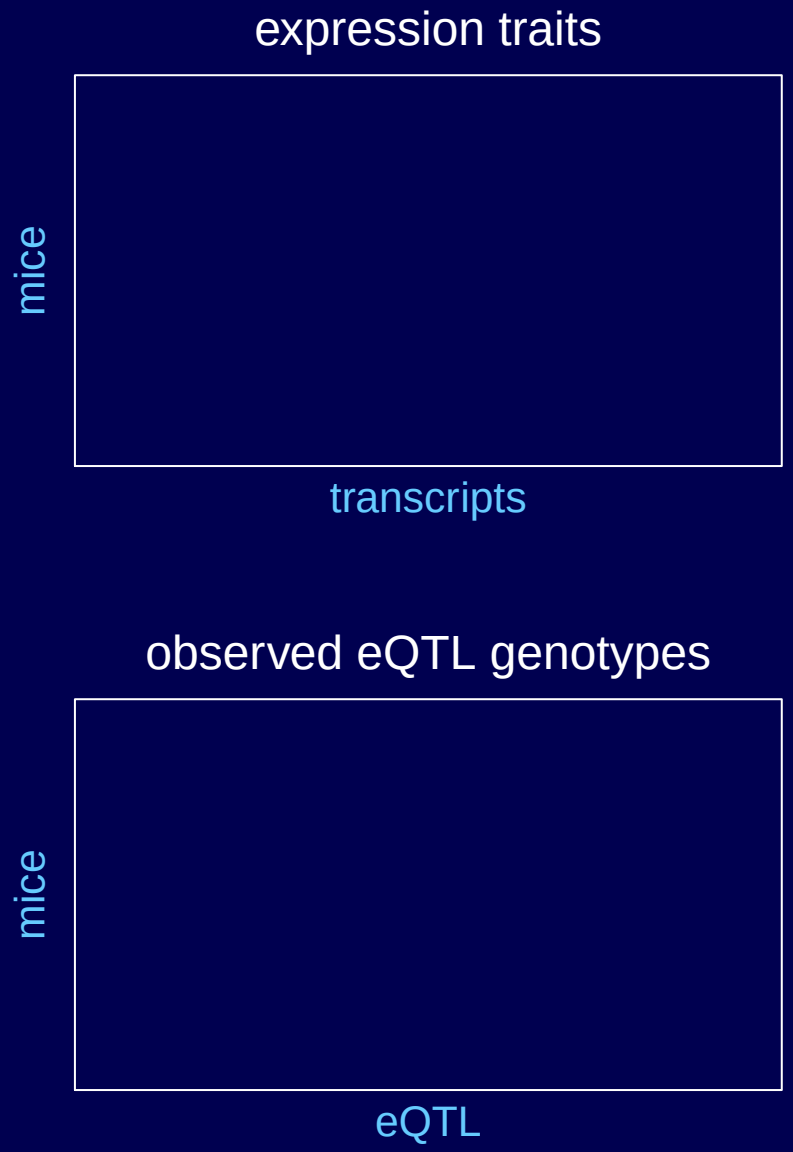
E vs G


Genotype at rs13478402
RR
BR
BB
0.5
0.0
−0.5
−1.0
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
expression of 502129
expression of 517583

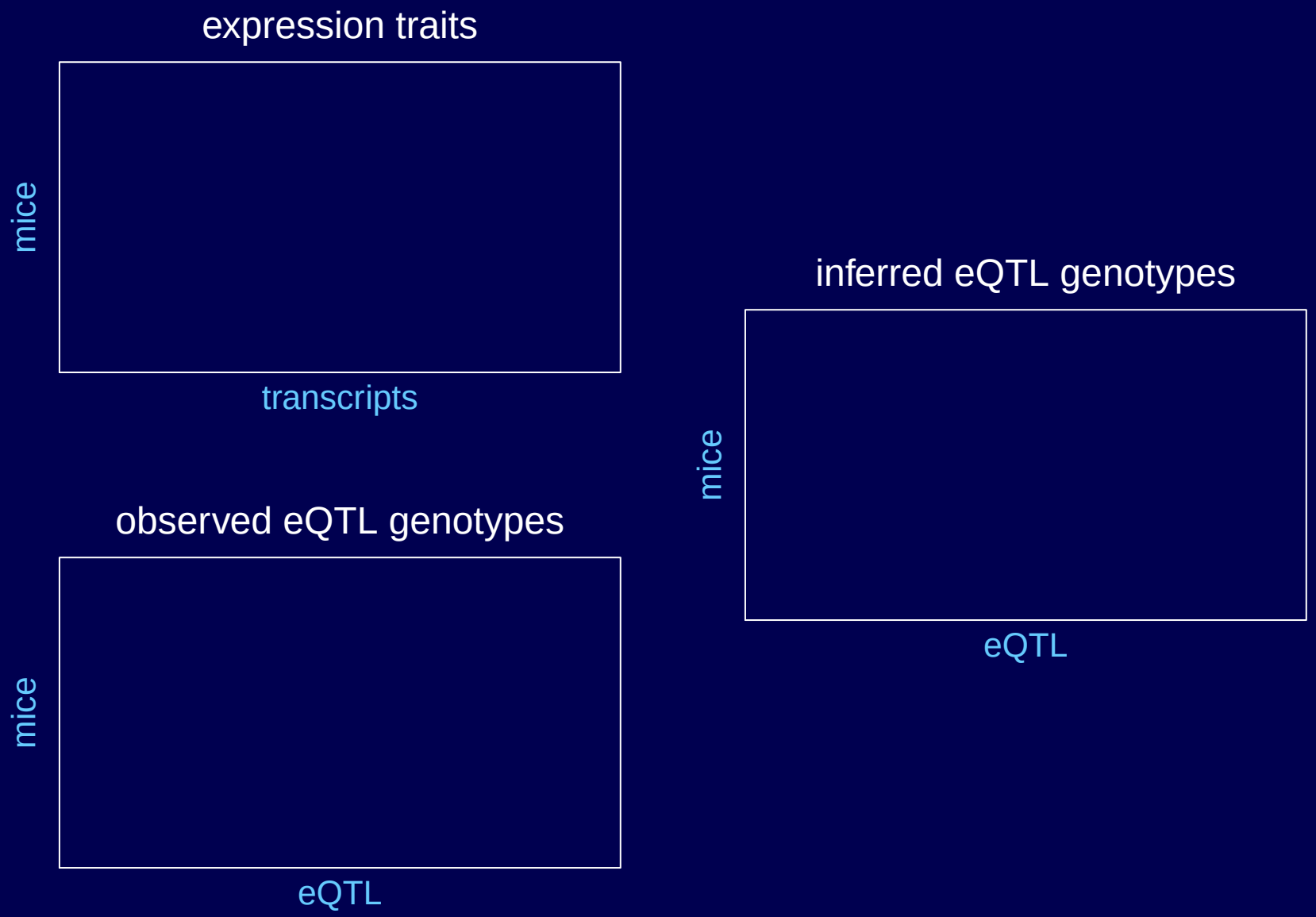
E vs G


Genotype at rs13478402
RR
BR
BB
0.5
0.0
−0.5
−1.0
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
expression of 502129
expression of 517583

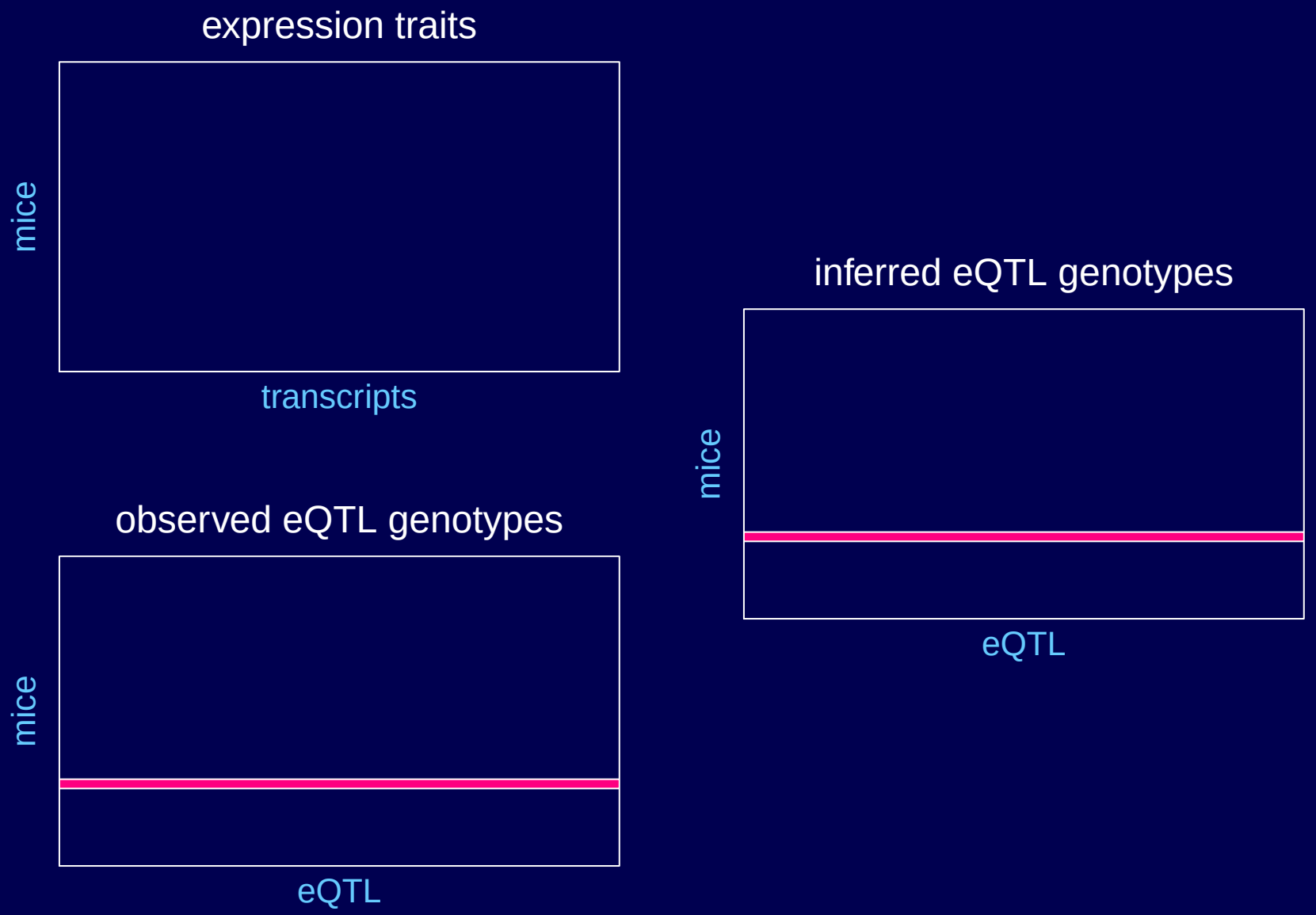
Basic scheme



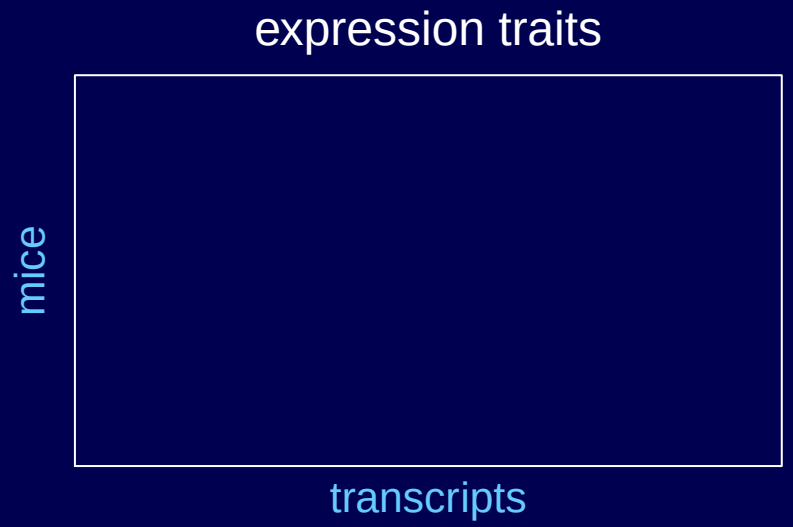
Basic scheme

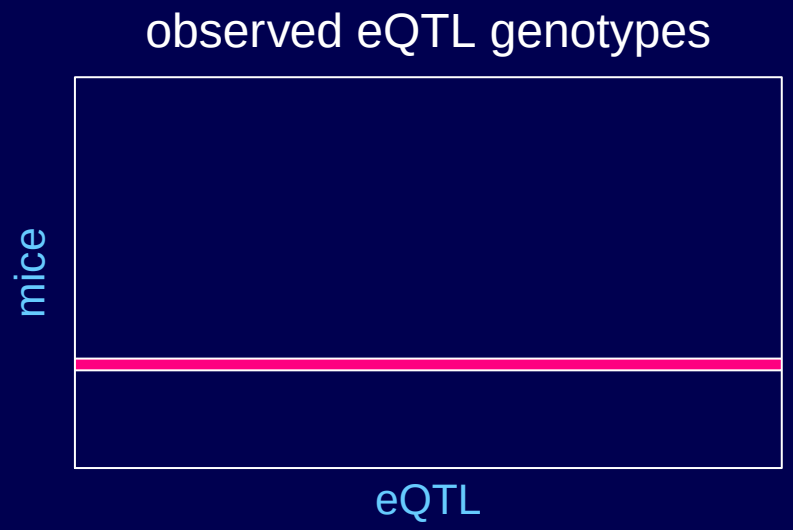


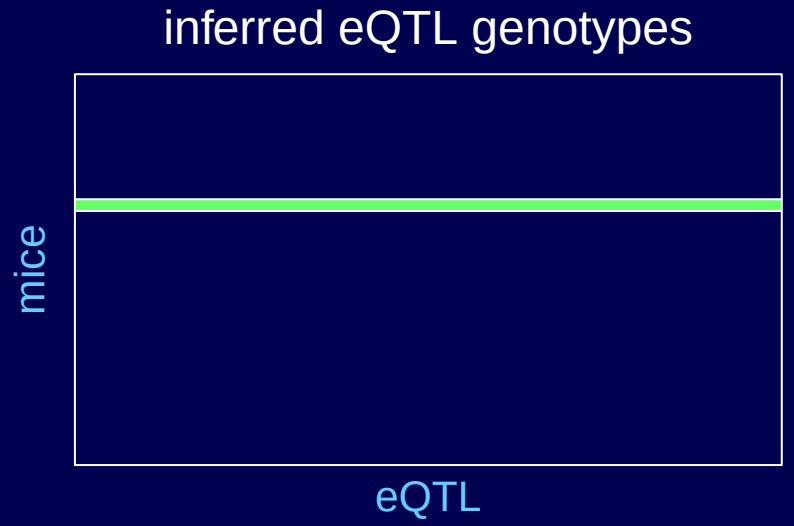
Basic scheme



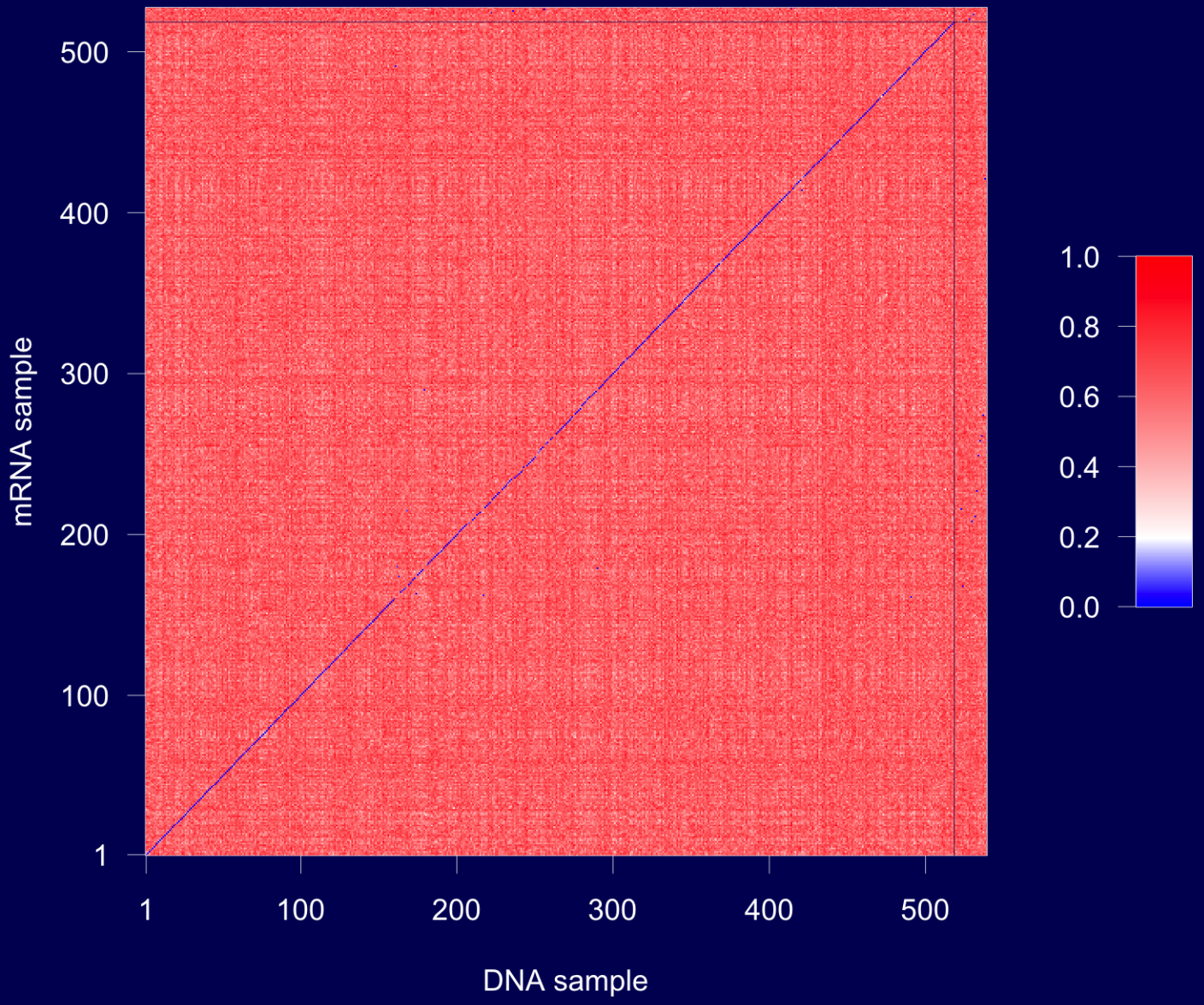
Basic scheme



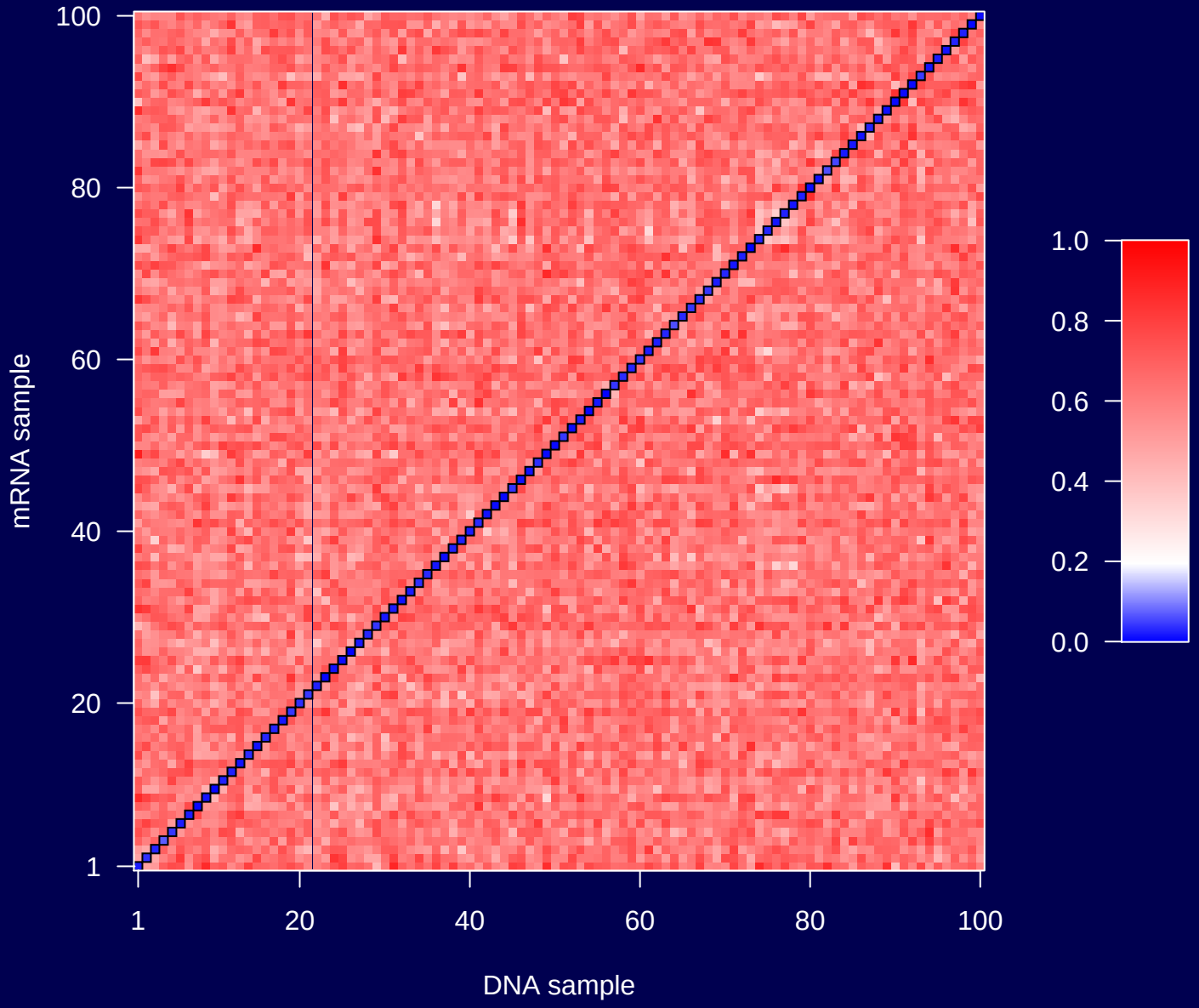




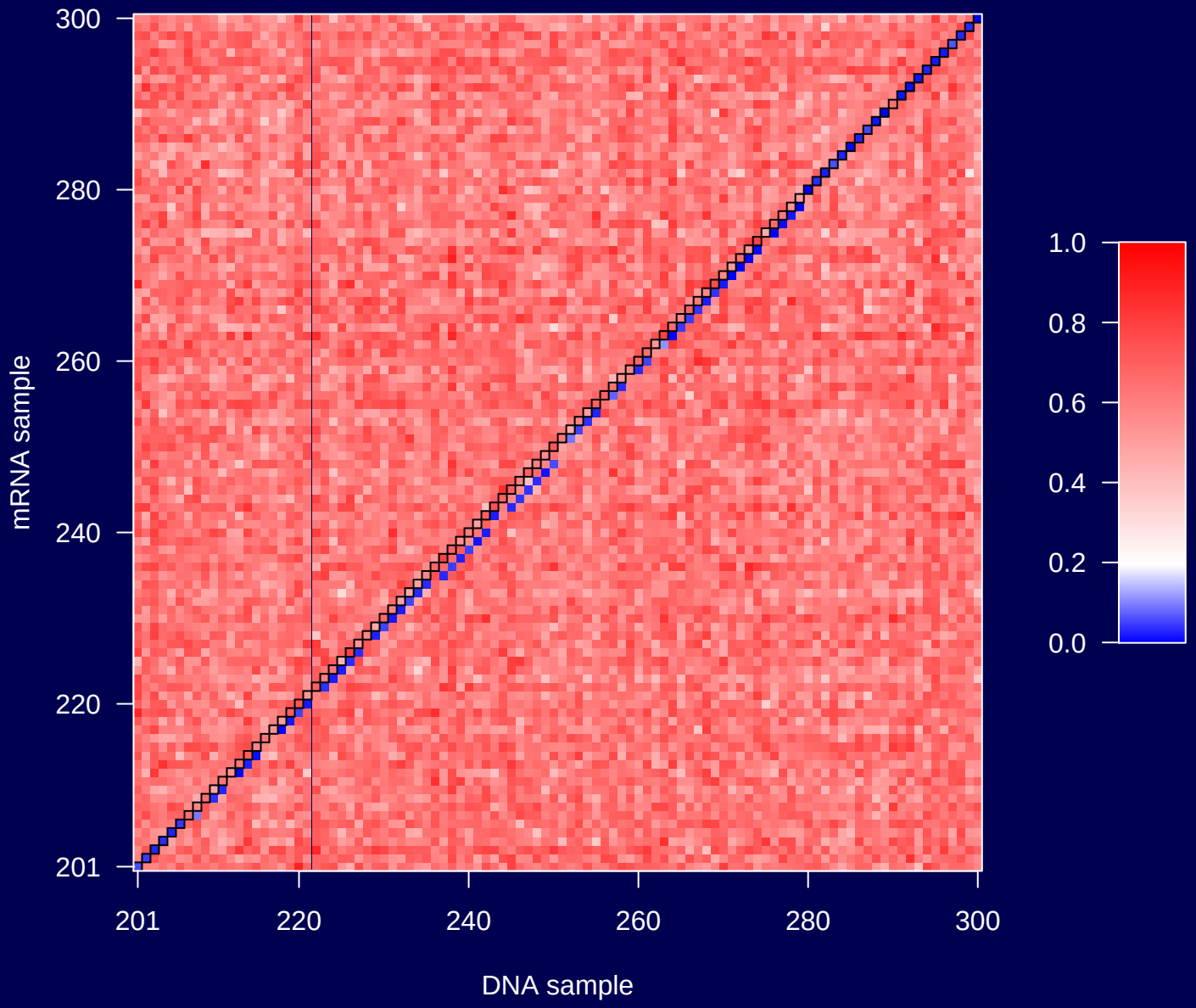
Prop'n mismatches



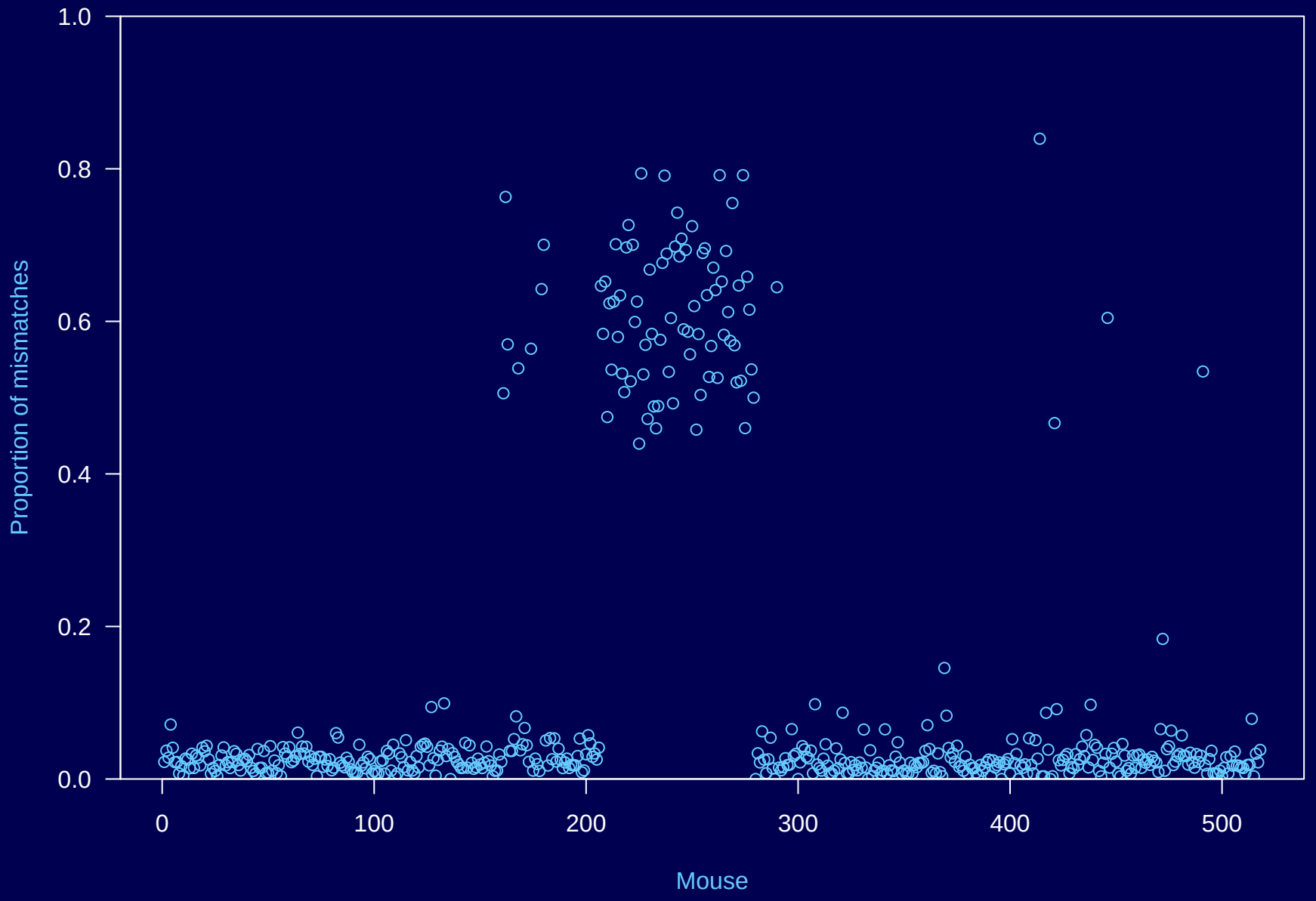
Prop'n mismatches



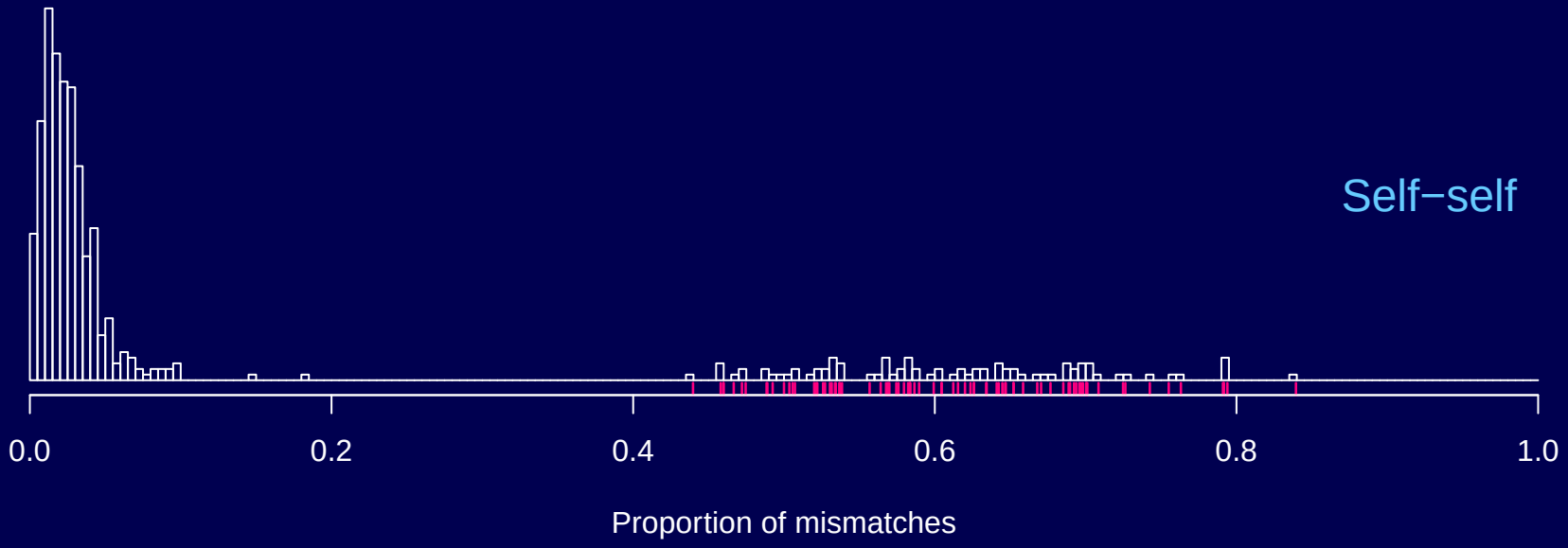
Prop'n mismatches

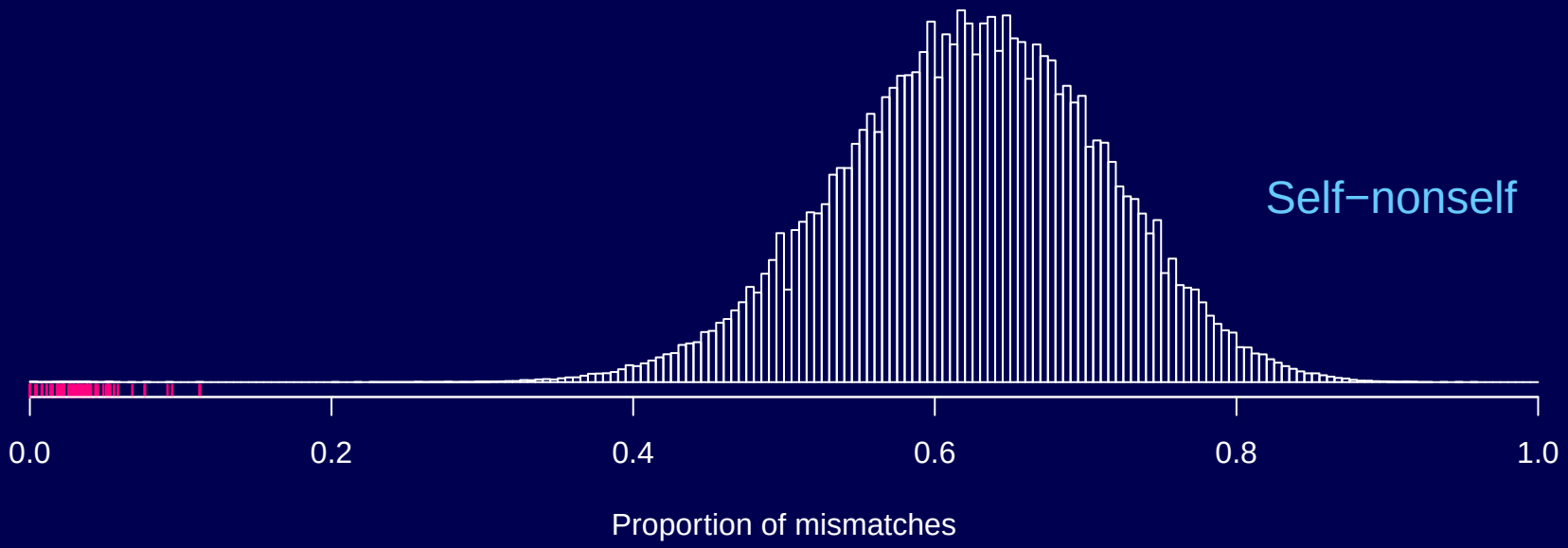


The diagonal

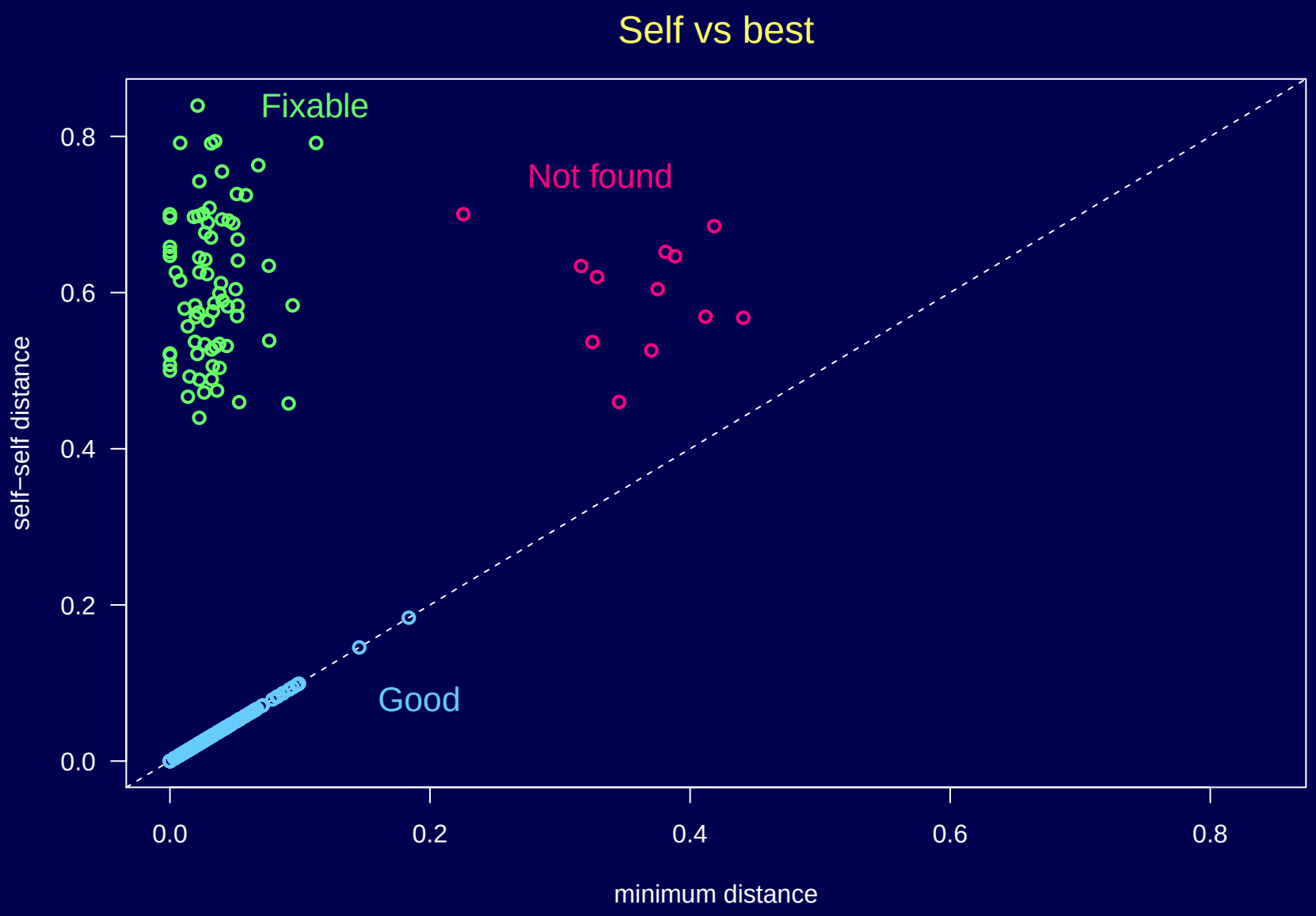


Prop’n mismatches

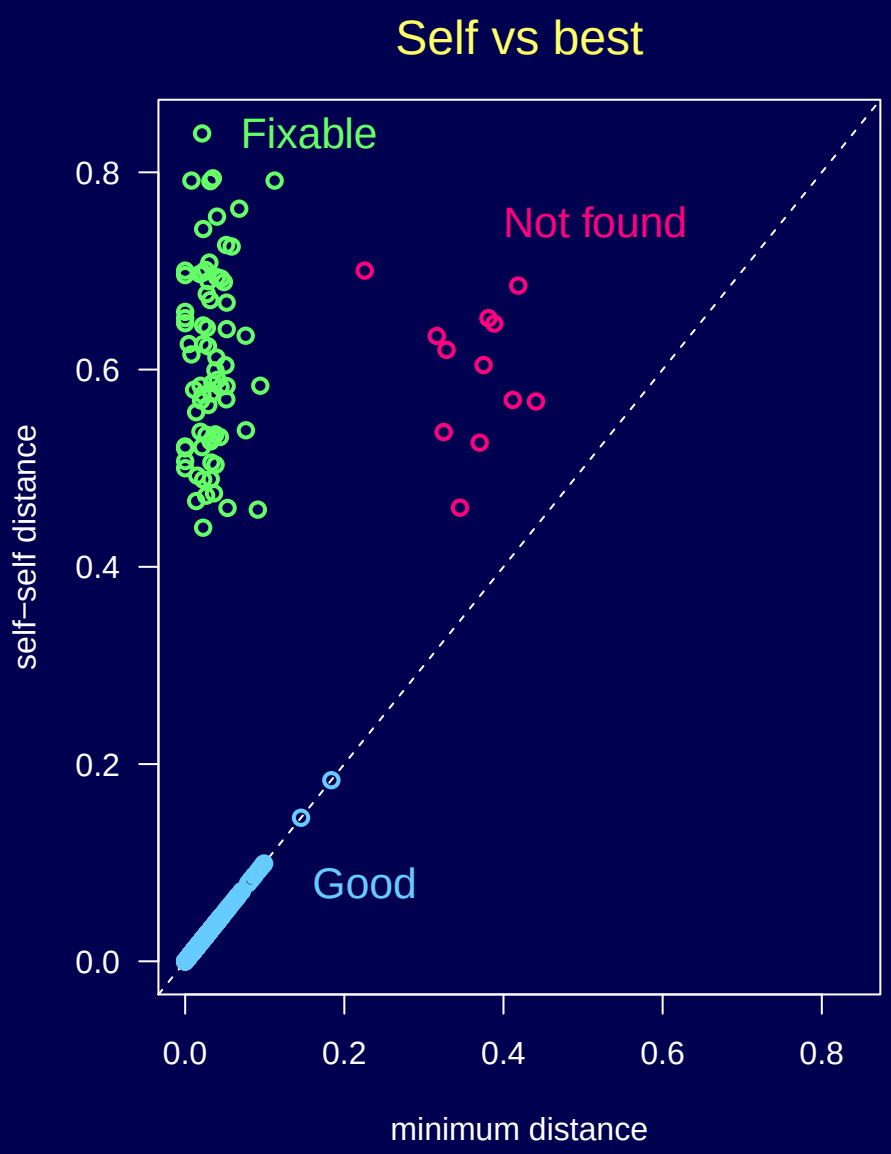


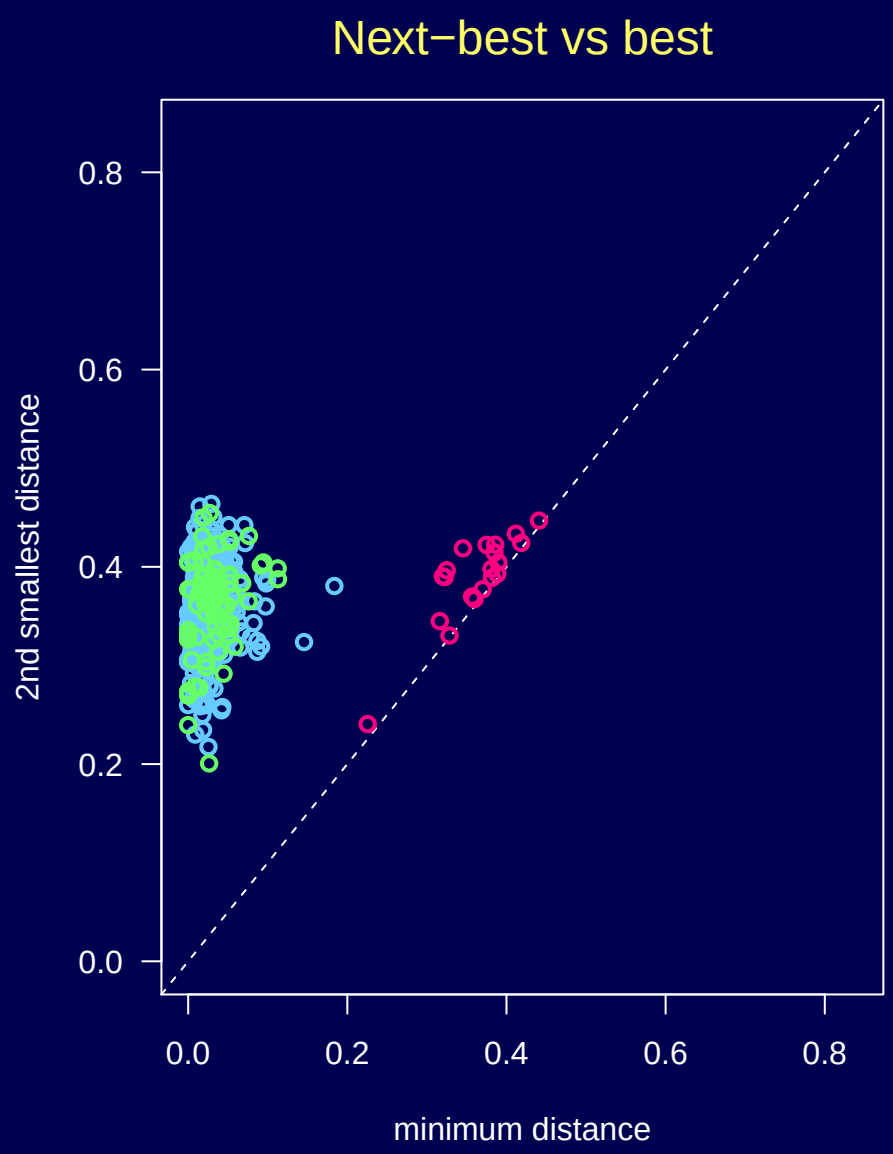


Decisions


Self vs best
Fixable
Not found
Good
self−self distance
minimum distance
0.0
0.2
0.4
0.6
0.8

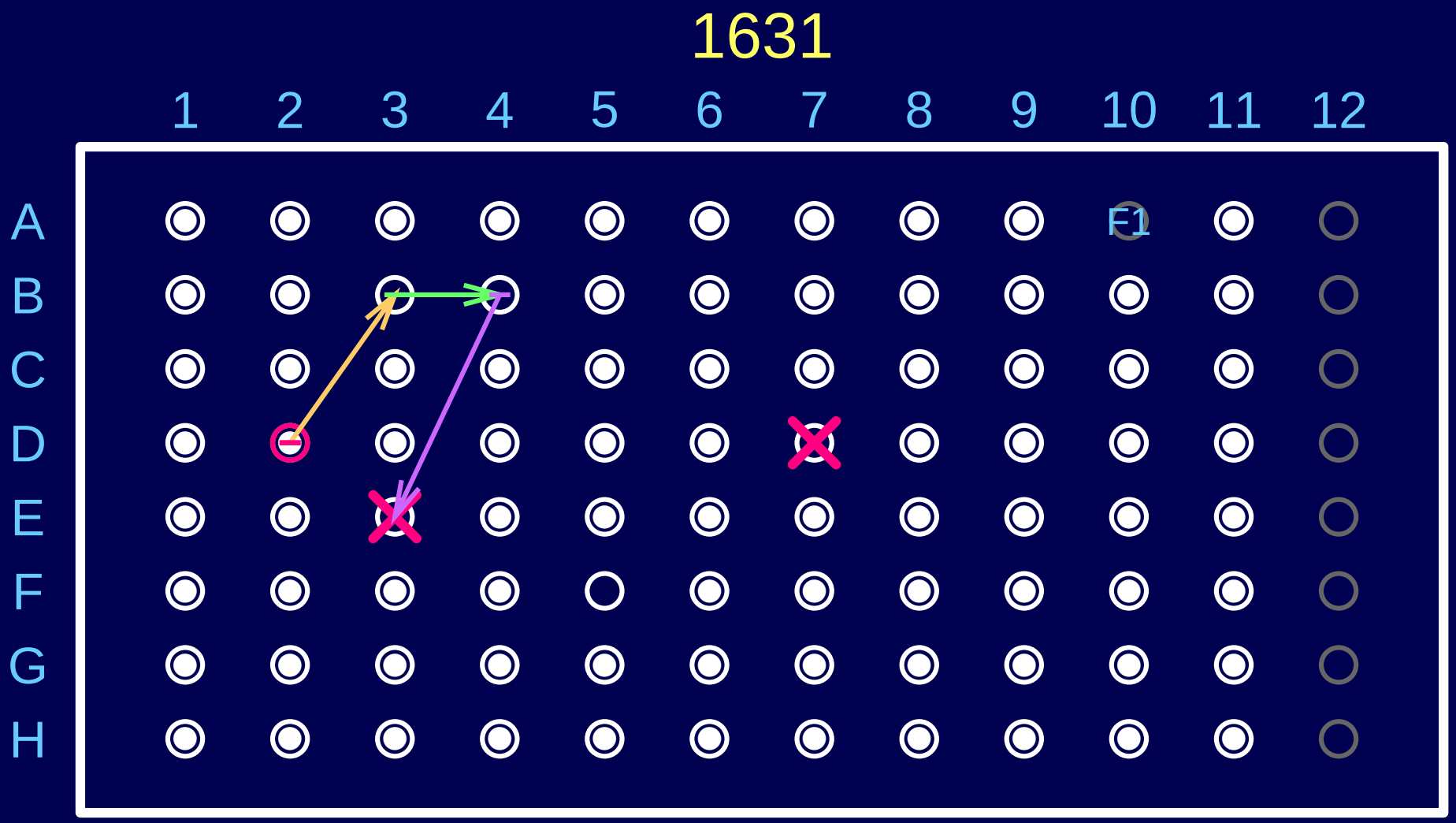
Decisions


Self vs best
Fixable
Not found
Good
self−self distance
minimum distance
0.0
0.2
0.4
0.6
0.8


Next−best vs best
2nd smallest distance
minimum distance
0.0
0.2
0.4
0.6
0.8

Genotype mix-ups

Plate 1631



Plates 1632 and 1630

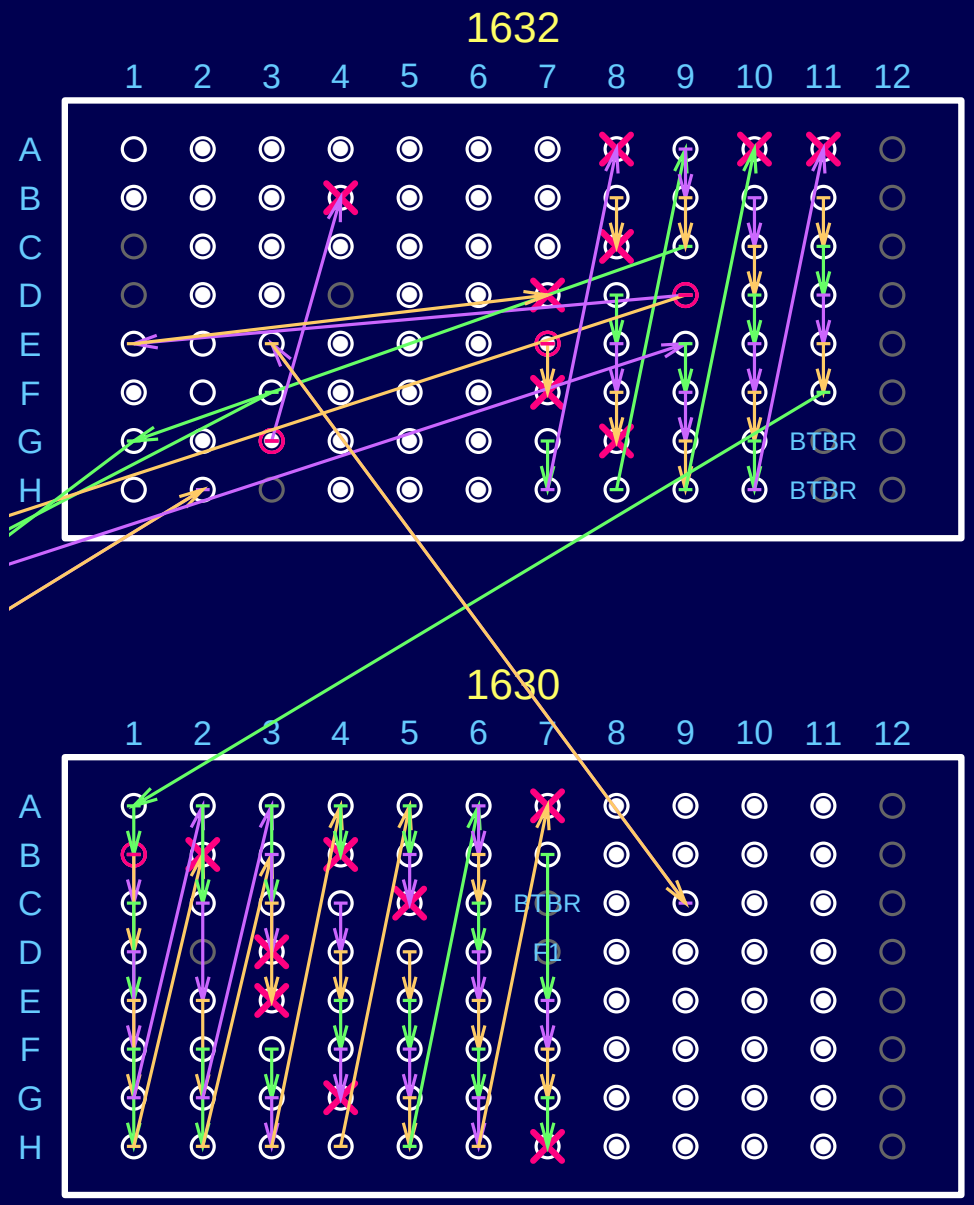
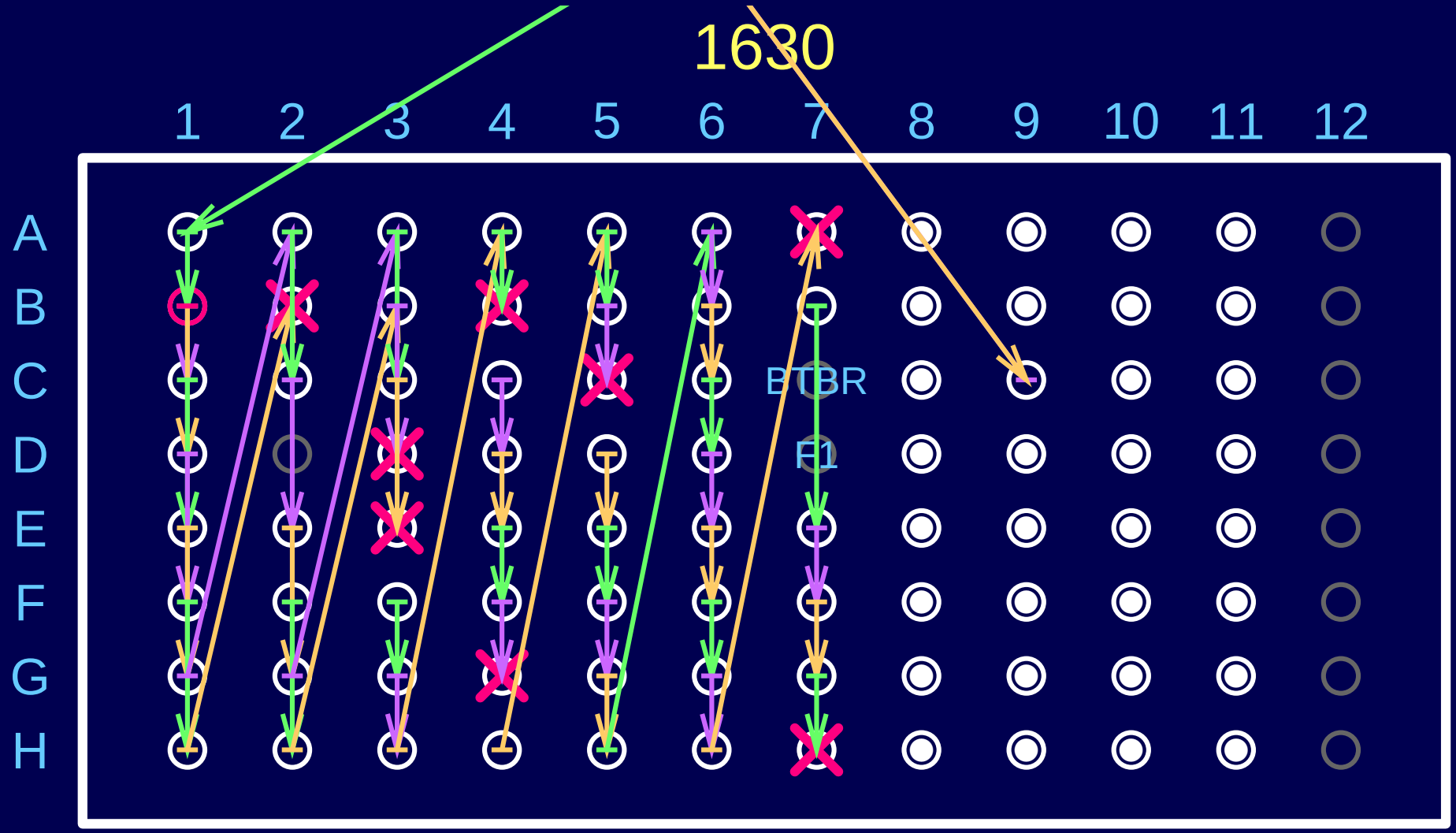


Plate 1630



E vs E


expression in islet
mice
transcripts

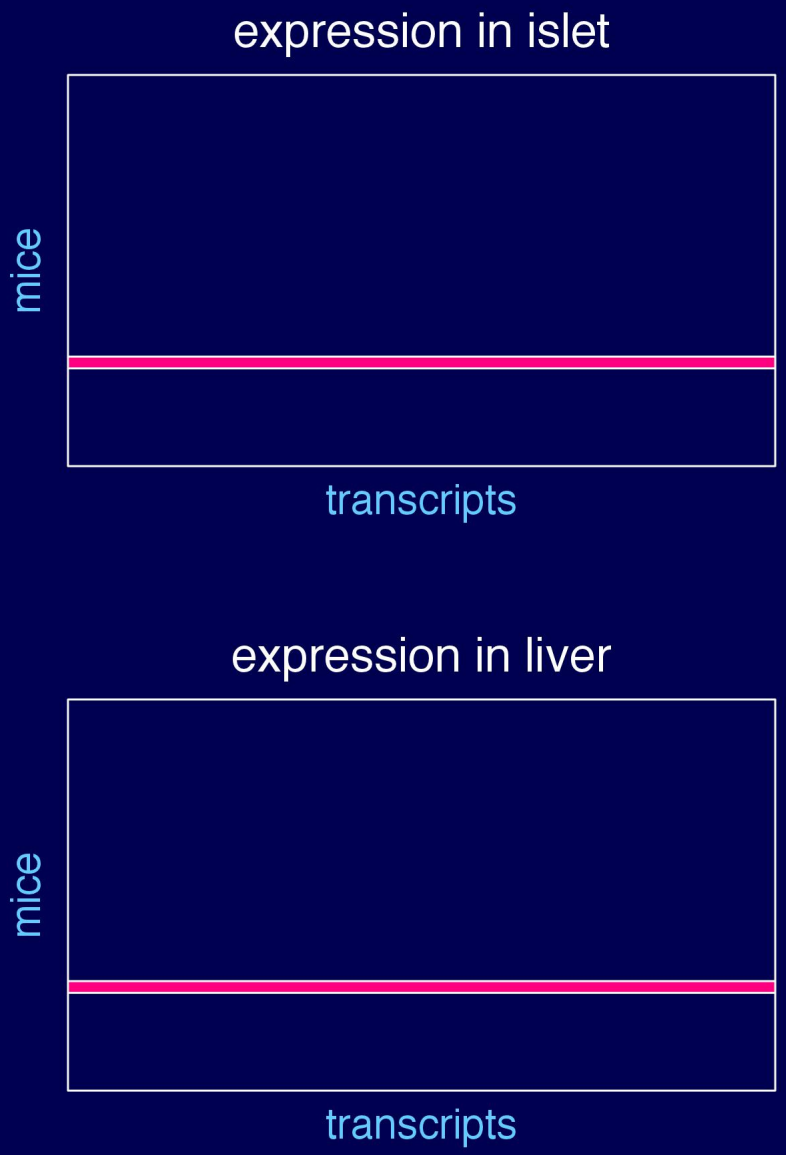

expression in liver
mice
transcripts

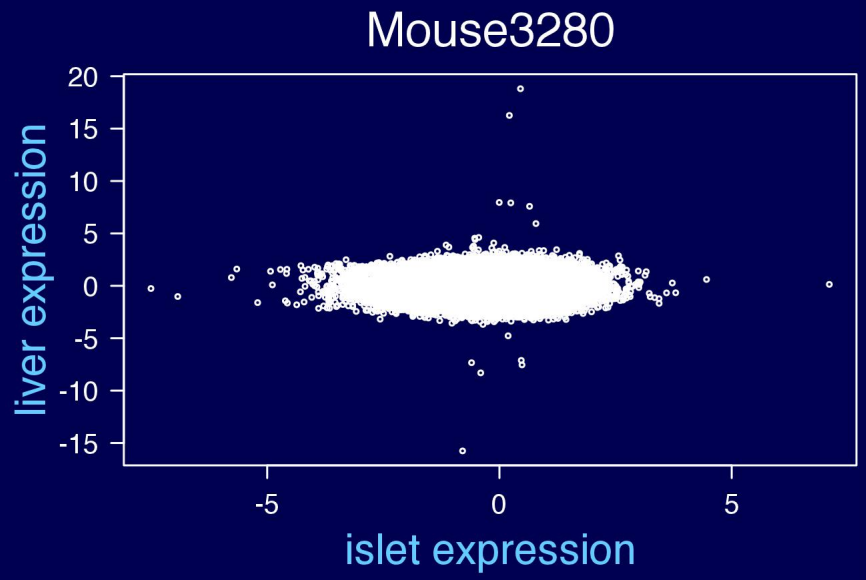
E vs E


expression in islet
mice
transcripts

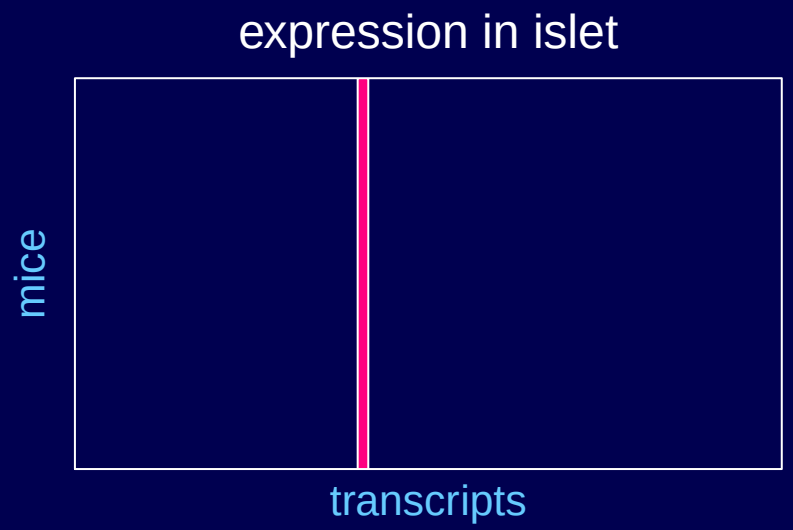

expression in liver
mice
transcripts

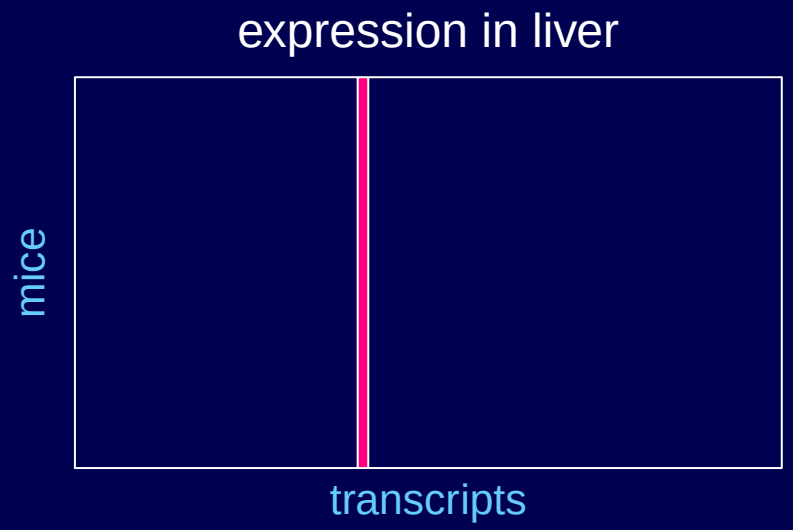
E vs E

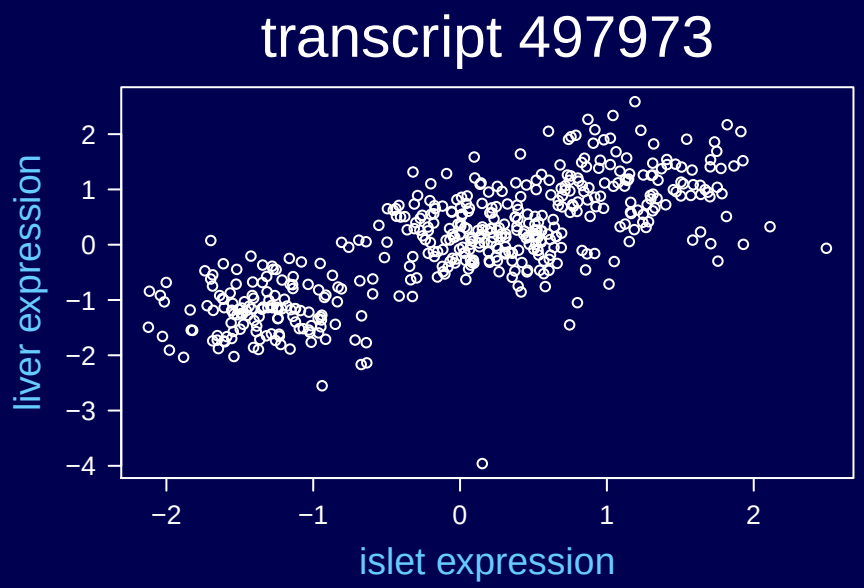

expression in islet
mice
transcripts
expression in liver
mice
transcripts


Mouse3280
liver expression
20
15
10
5
0
-5
-10
-15
-5
0
5
islet expression

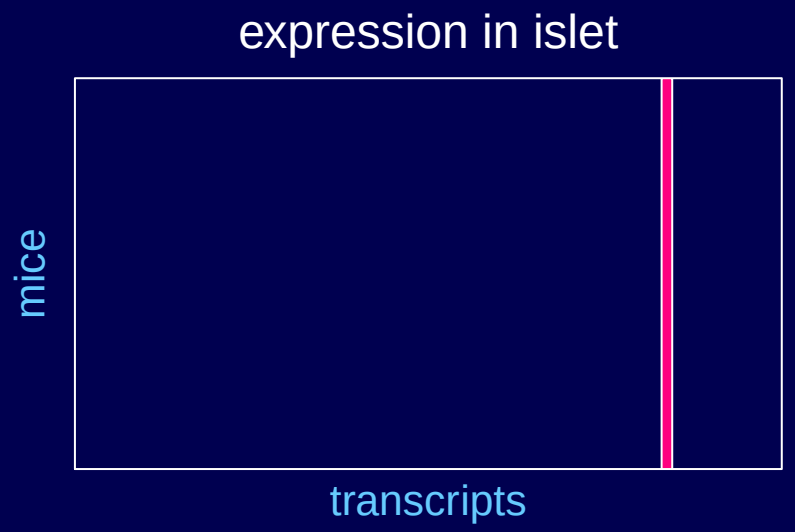
E vs E

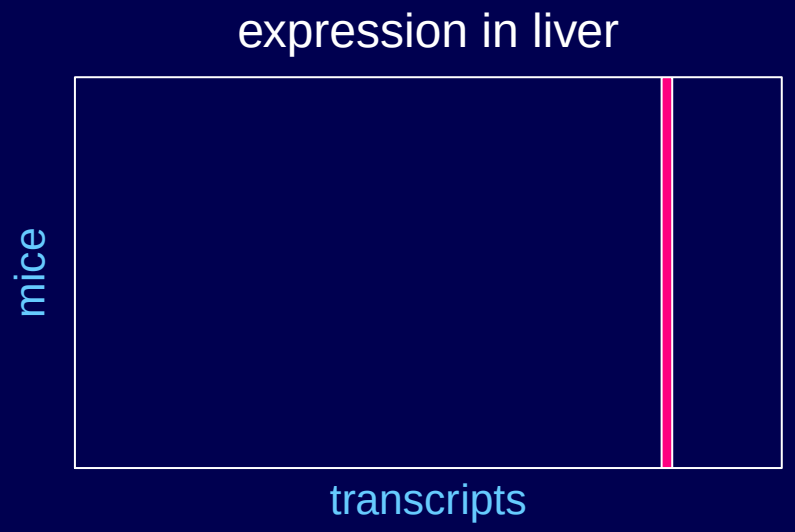

expression in islet
mice
transcripts

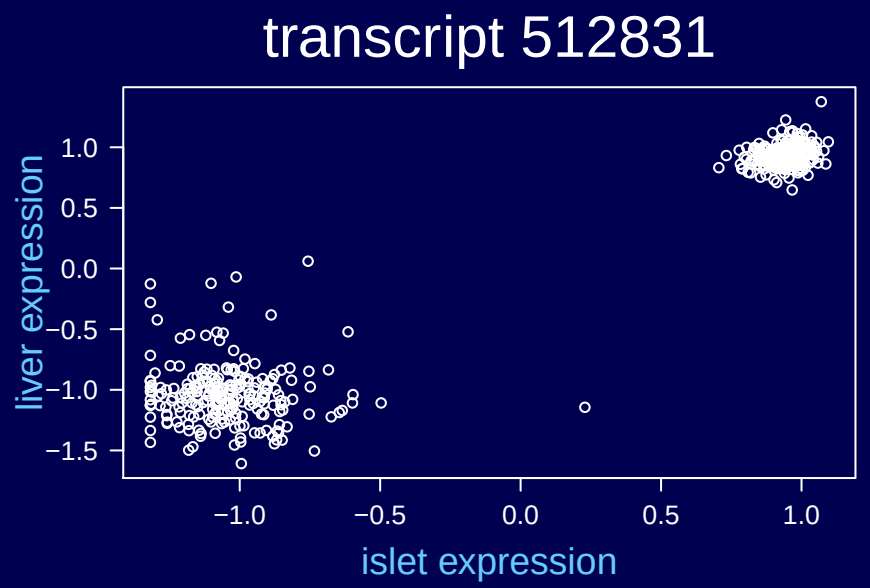

expression in liver
mice
transcripts


transcript 497973
liver expression
islet expression
2
1
0
−1
−2
−3
−4
−2
−1
0
1
2

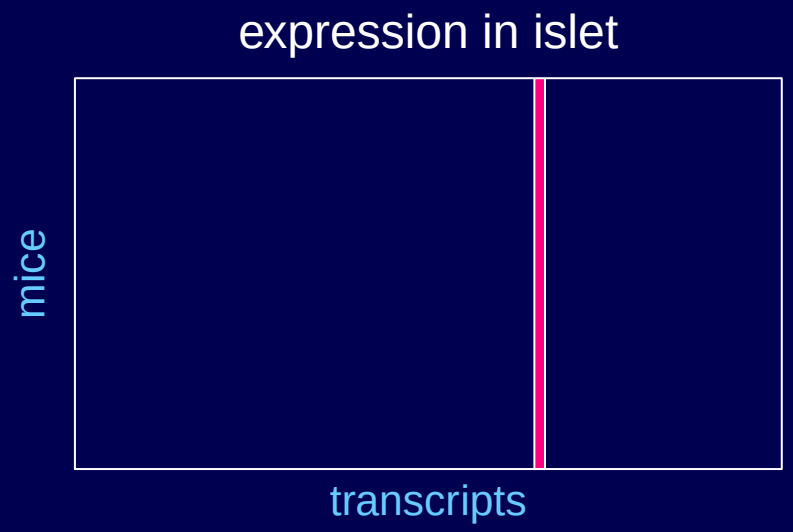
E vs E

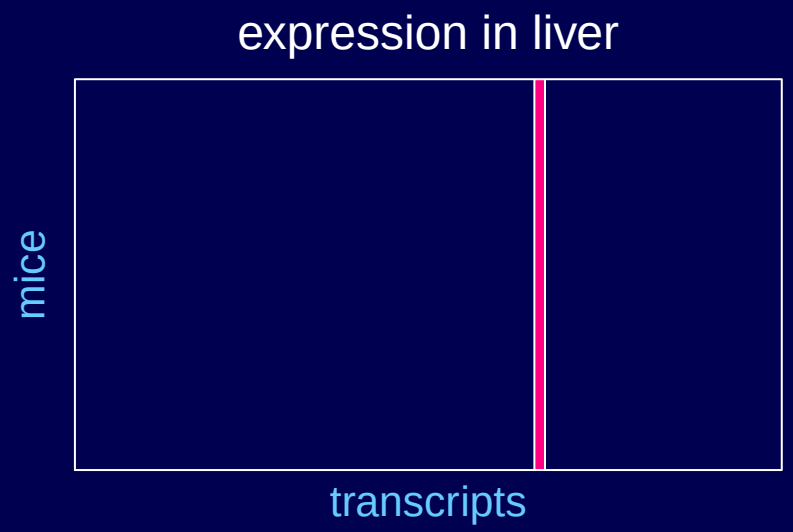

expression in islet
mice
transcripts

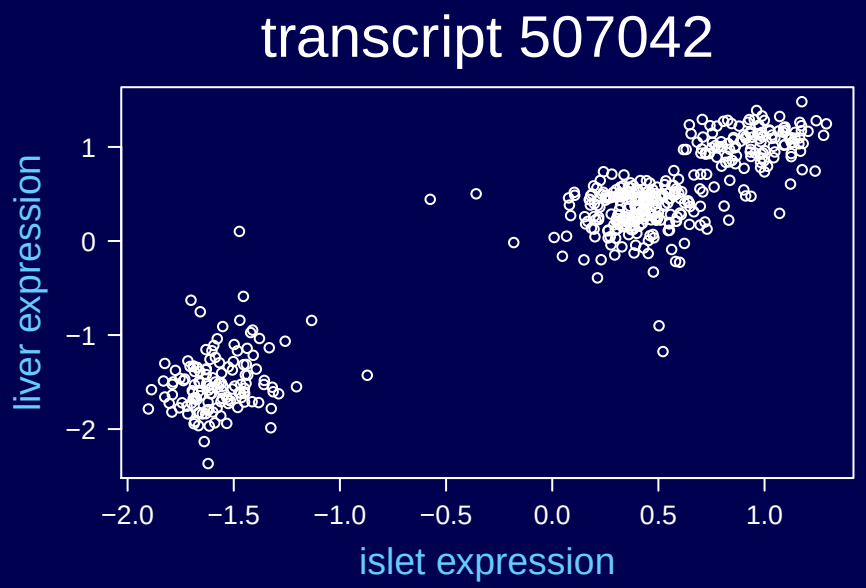

expression in liver
mice
transcripts


transcript 512831
liver expression
1.0
0.5
0.0
−0.5
−1.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
islet expression

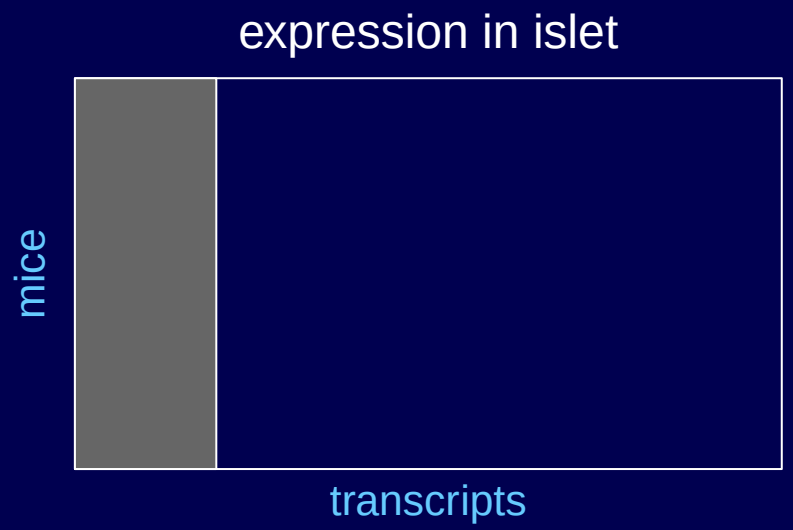
E vs E

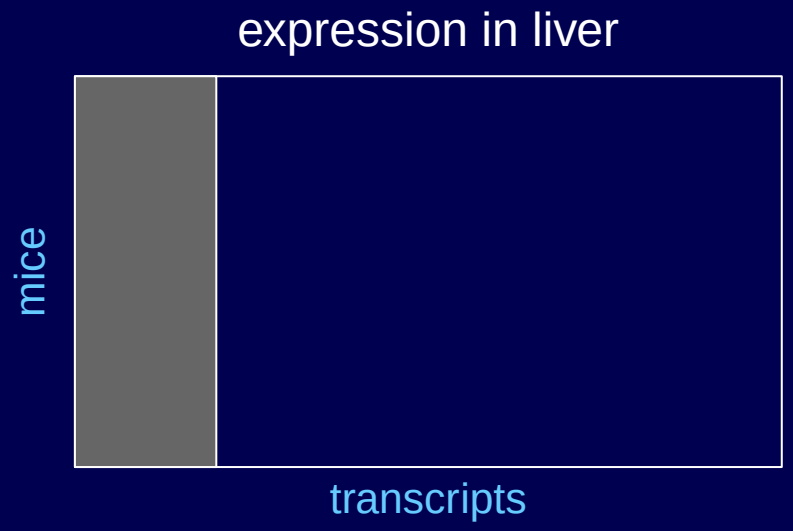

expression in islet
mice
transcripts


expression in liver
mice
transcripts

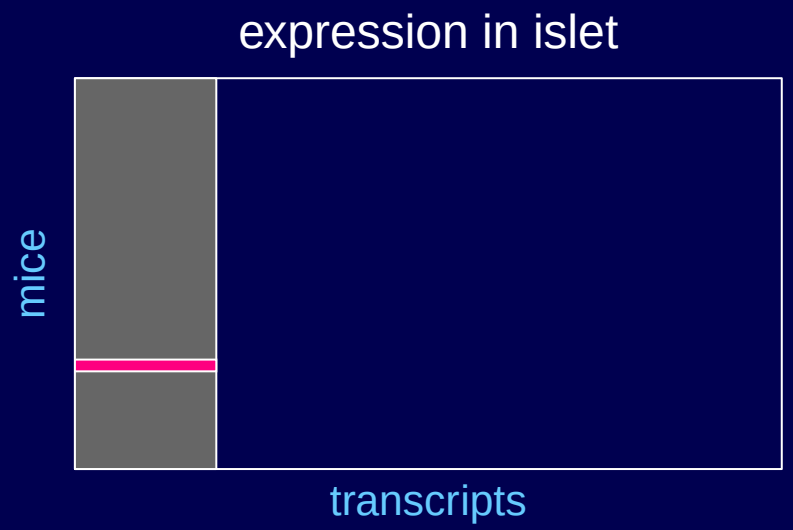

transcript 507042
liver expression
islet expression
1
0
−1
−2
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0

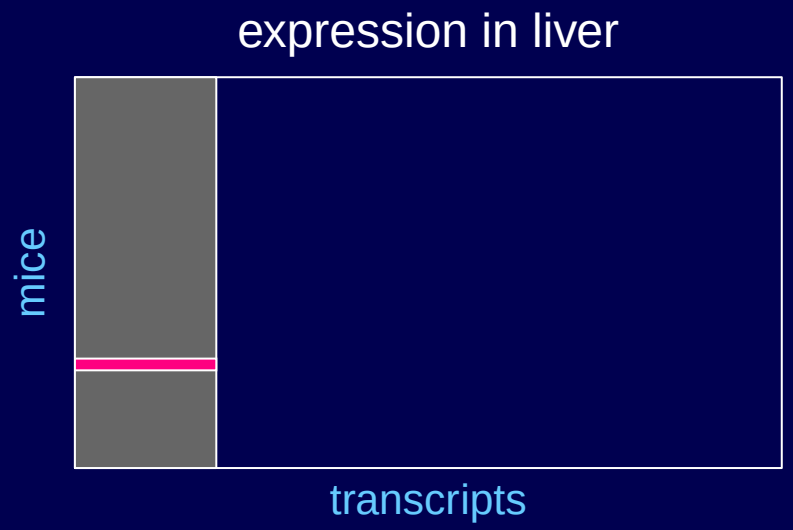
E vs E

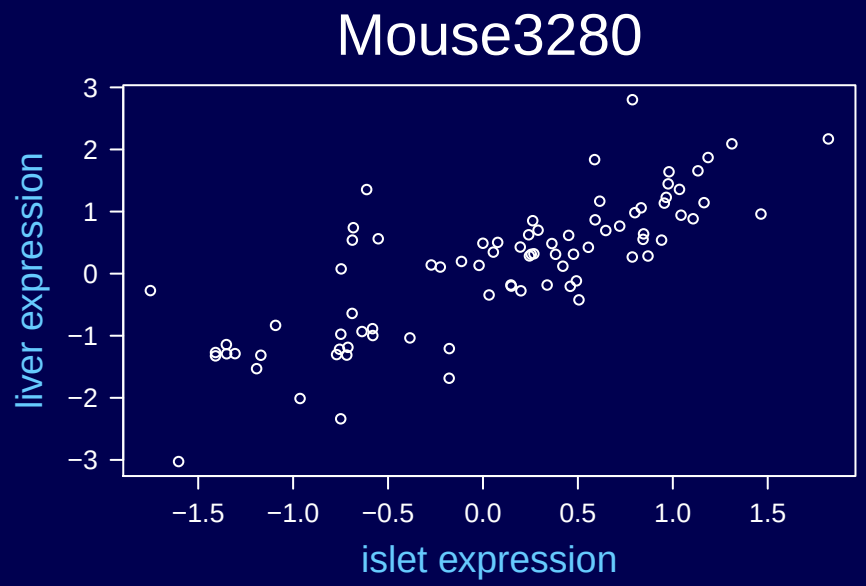

expression in islet
mice
transcripts


expression in liver
mice
transcripts

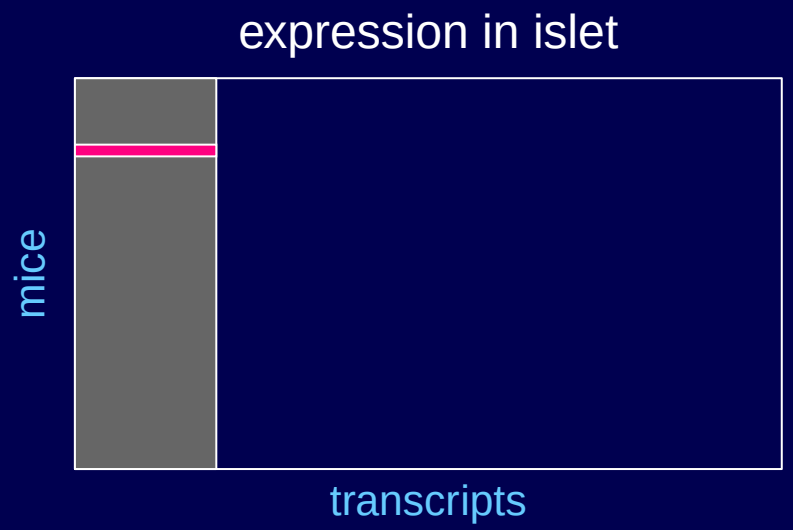
E vs E

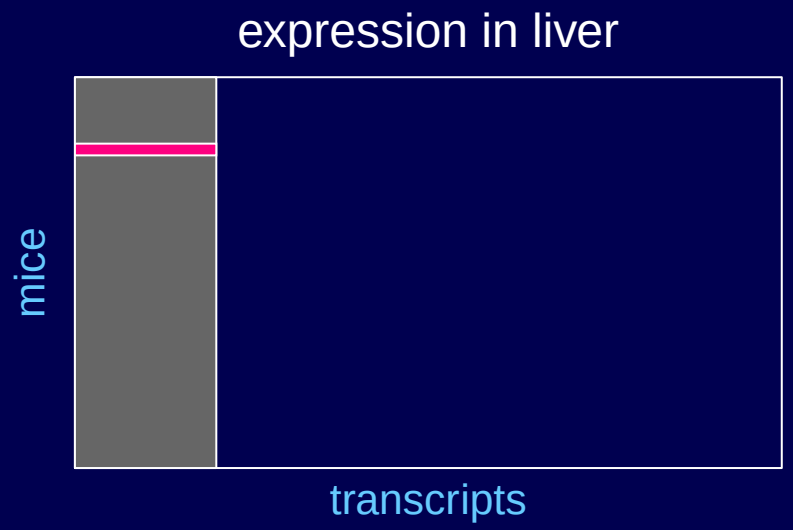

expression in islet
mice
transcripts

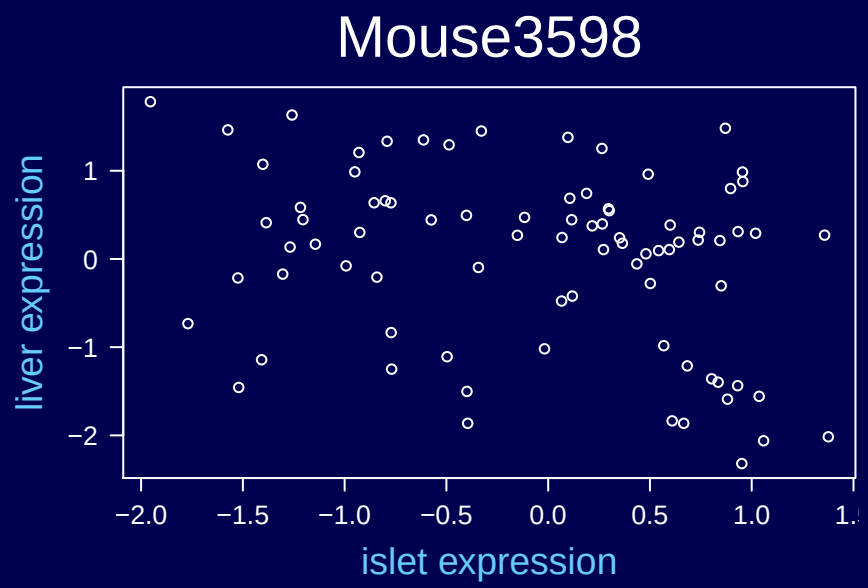

expression in liver
mice
transcripts


Mouse3280
liver expression
islet expression
3
2
1
0
−1
−2
−3
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

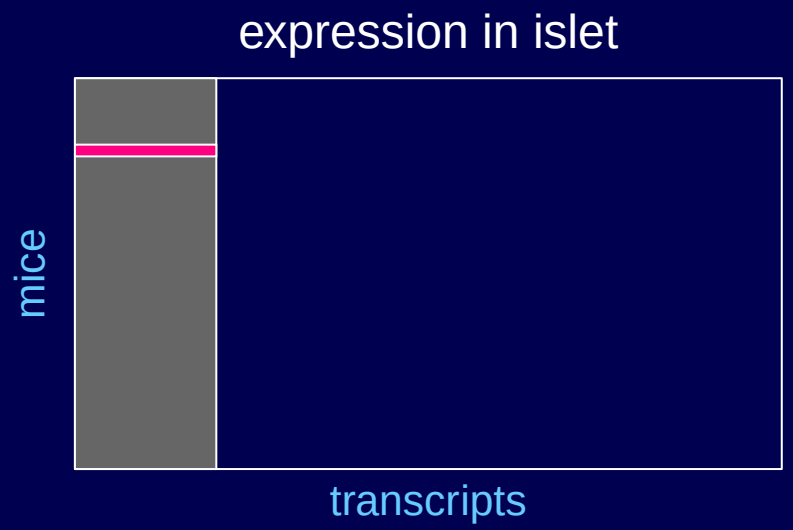
E vs E

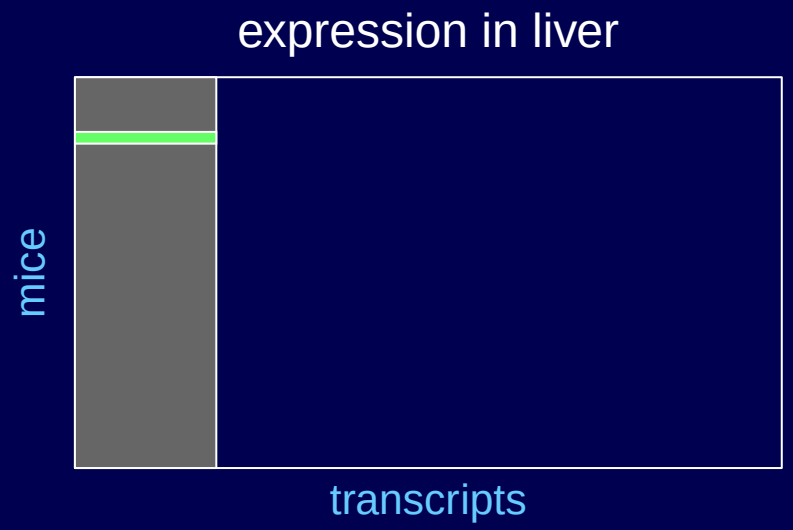

expression in islet
mice
transcripts

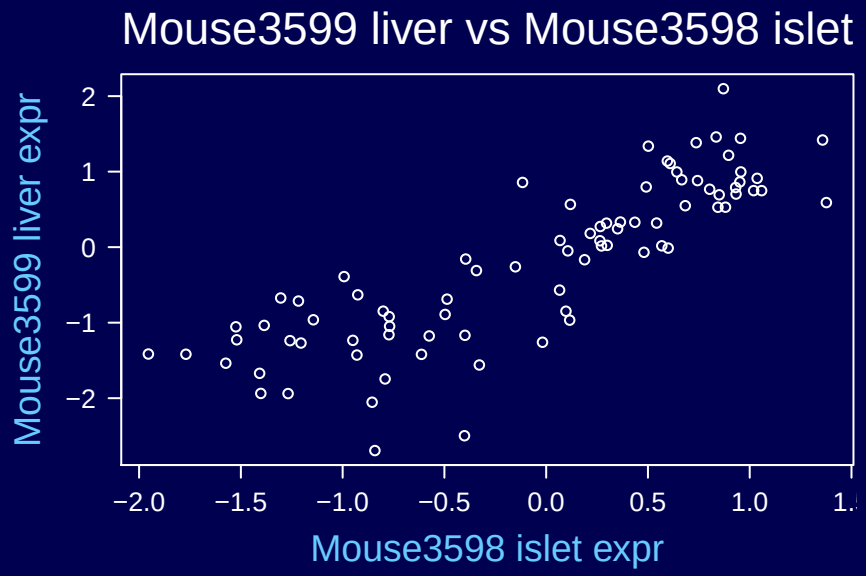

expression in liver
mice
transcripts


Mouse3598
liver expression
1
0
−1
−2
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
islet expression

E vs E

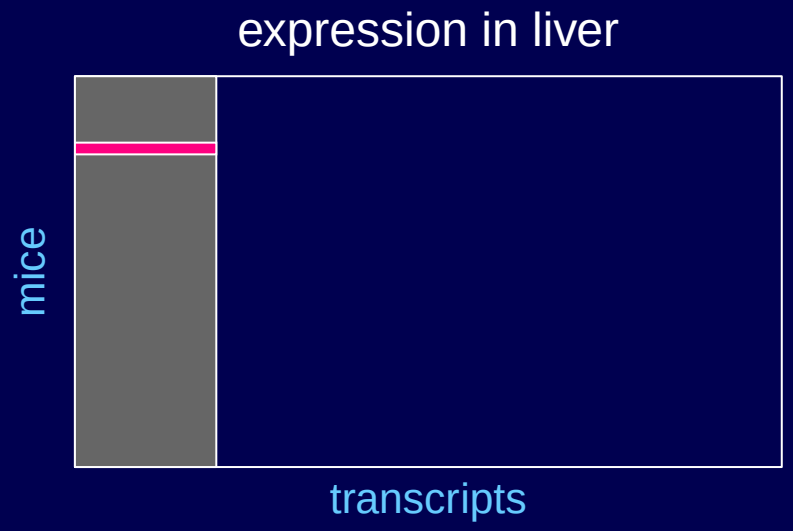

expression in islet
mice
transcripts

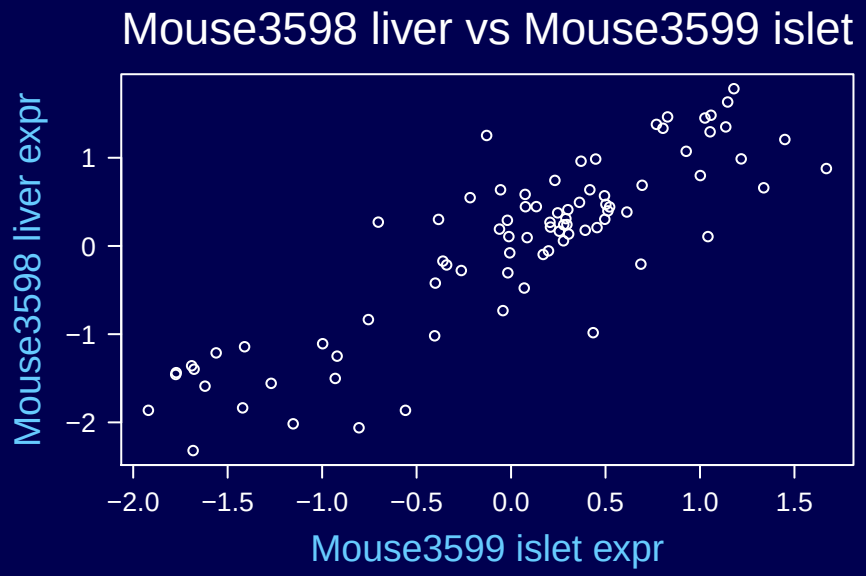

expression in liver
mice
transcripts


Mouse3599 liver vs Mouse3598 islet
Mouse3599 liver expr
2
1
0
−1
−2
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
Mouse3598 islet expr

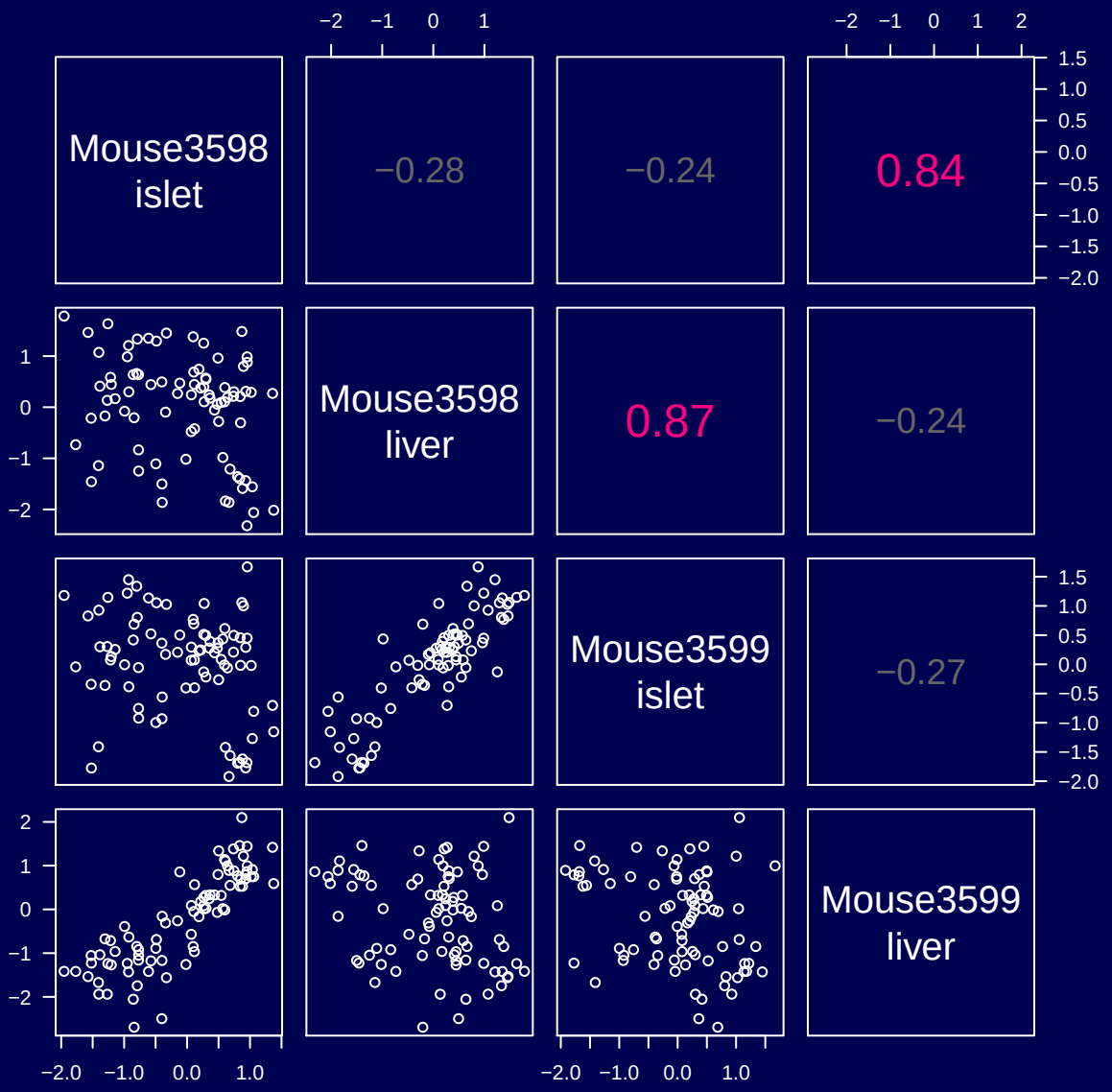
E vs E


expression in islet
mice
transcripts

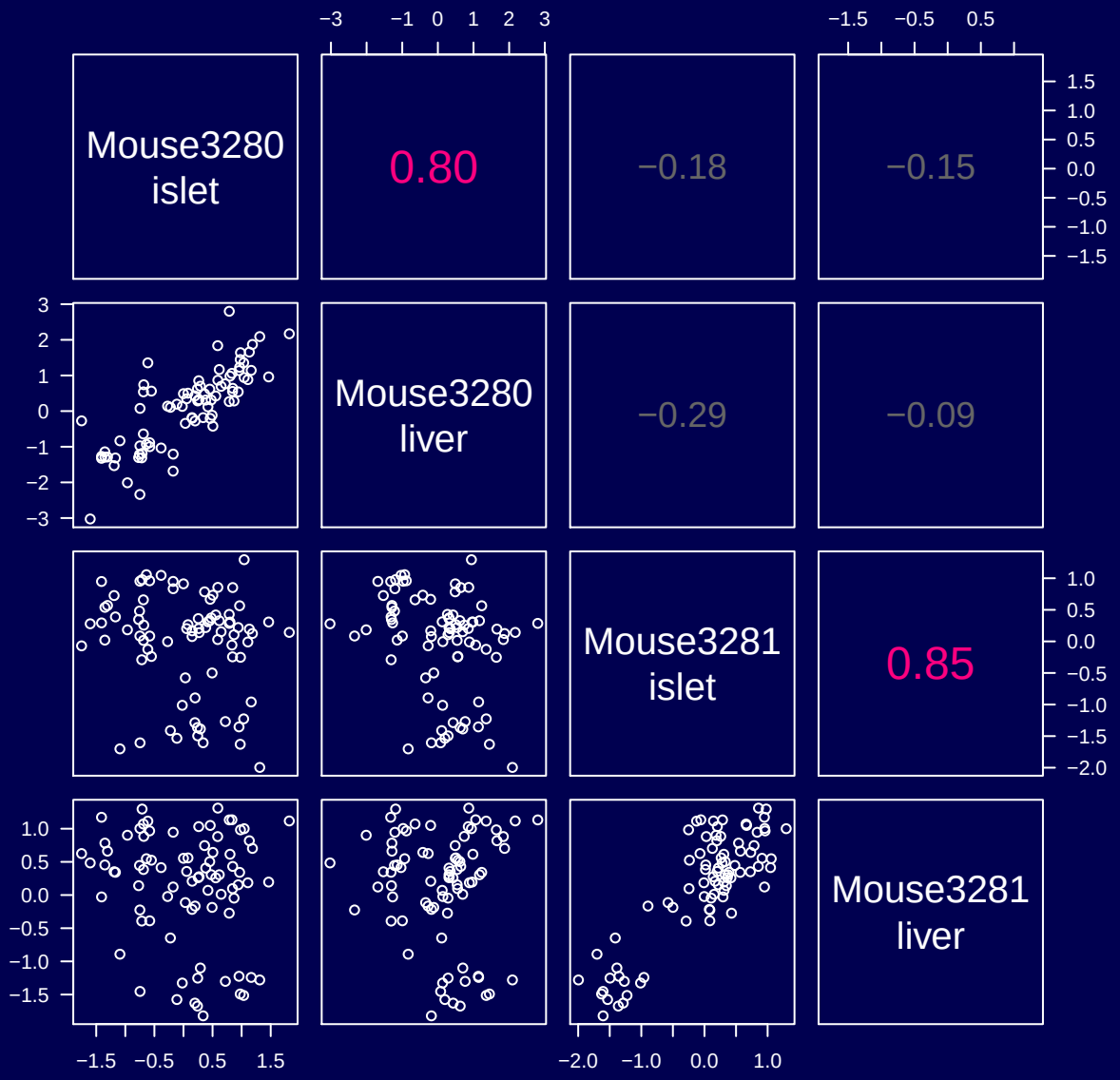

expression in liver
mice
transcripts


Mouse3598 liver vs Mouse3599 islet
Mouse3598 liver expr
Mouse3599 islet expr
1
0
−1
−2
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

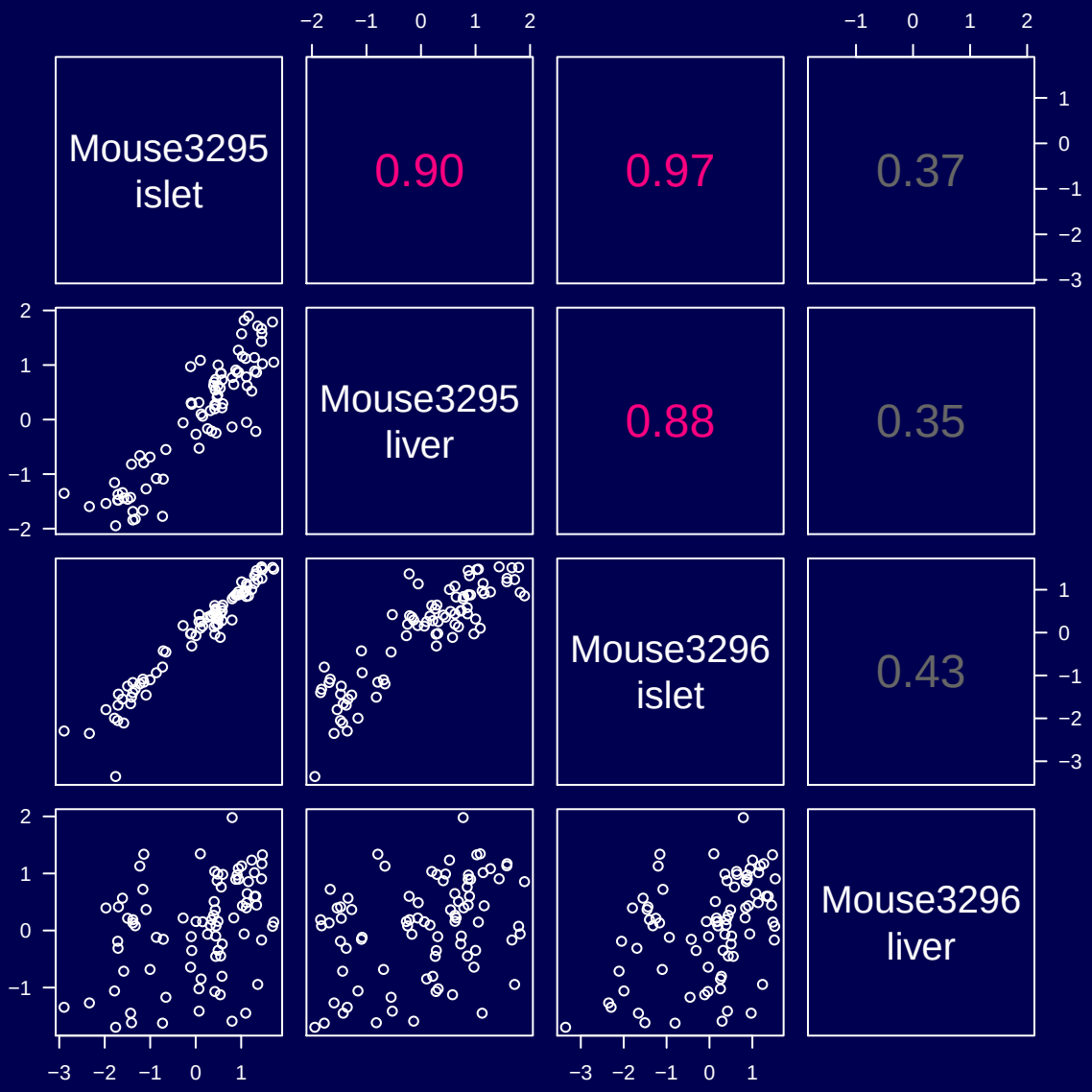
E vs E


Mouse3598 islet
−0.28
−0.24
0.84
Mouse3598 liver
0.87
−0.24
Mouse3599 islet
−0.27
Mouse3599 liver

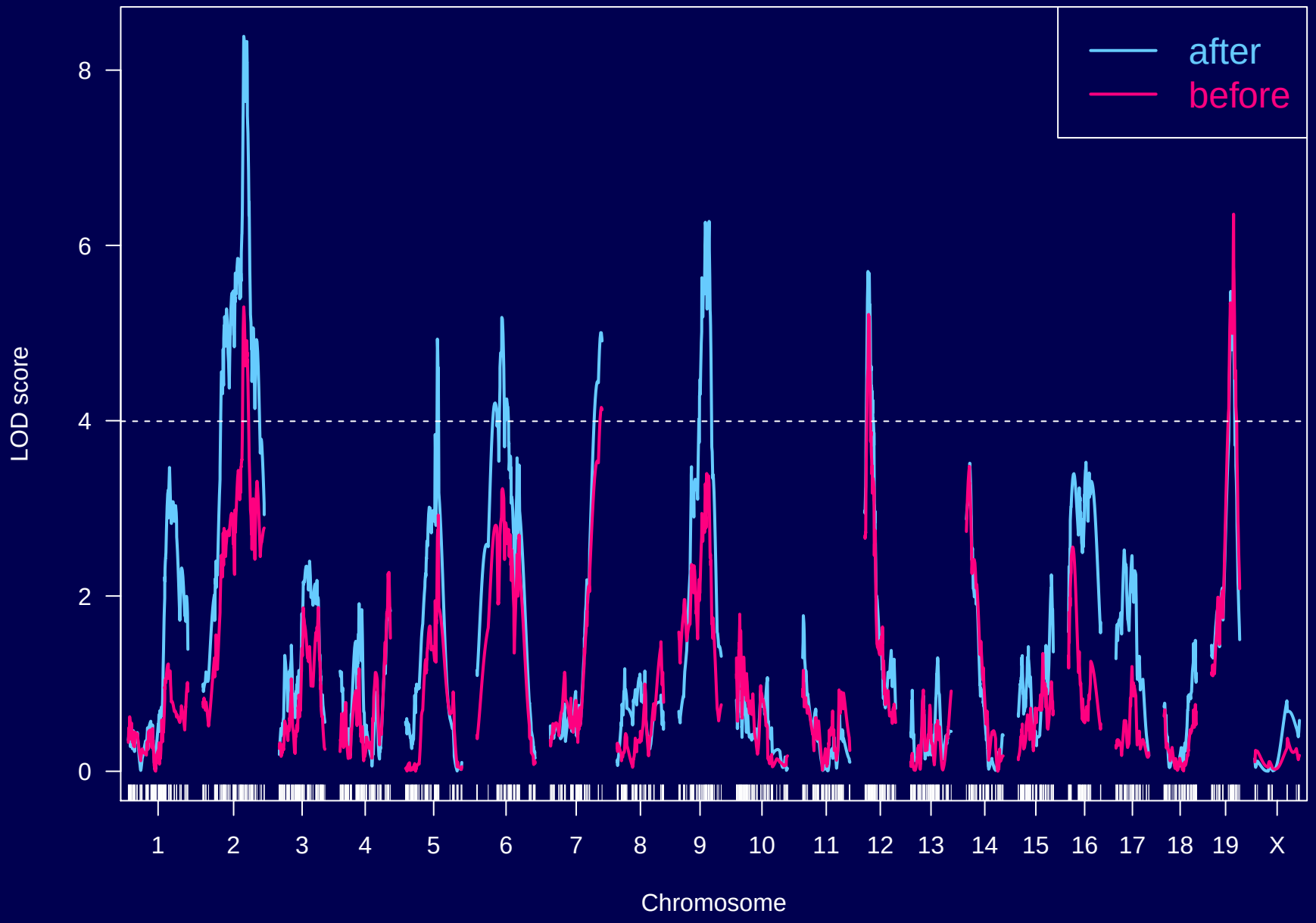
E vs E


Mouse3280 islet
0.80
−0.18
−0.15
Mouse3280 liver
−0.29
−0.09
Mouse3281 islet
0.85
Mouse3281 liver

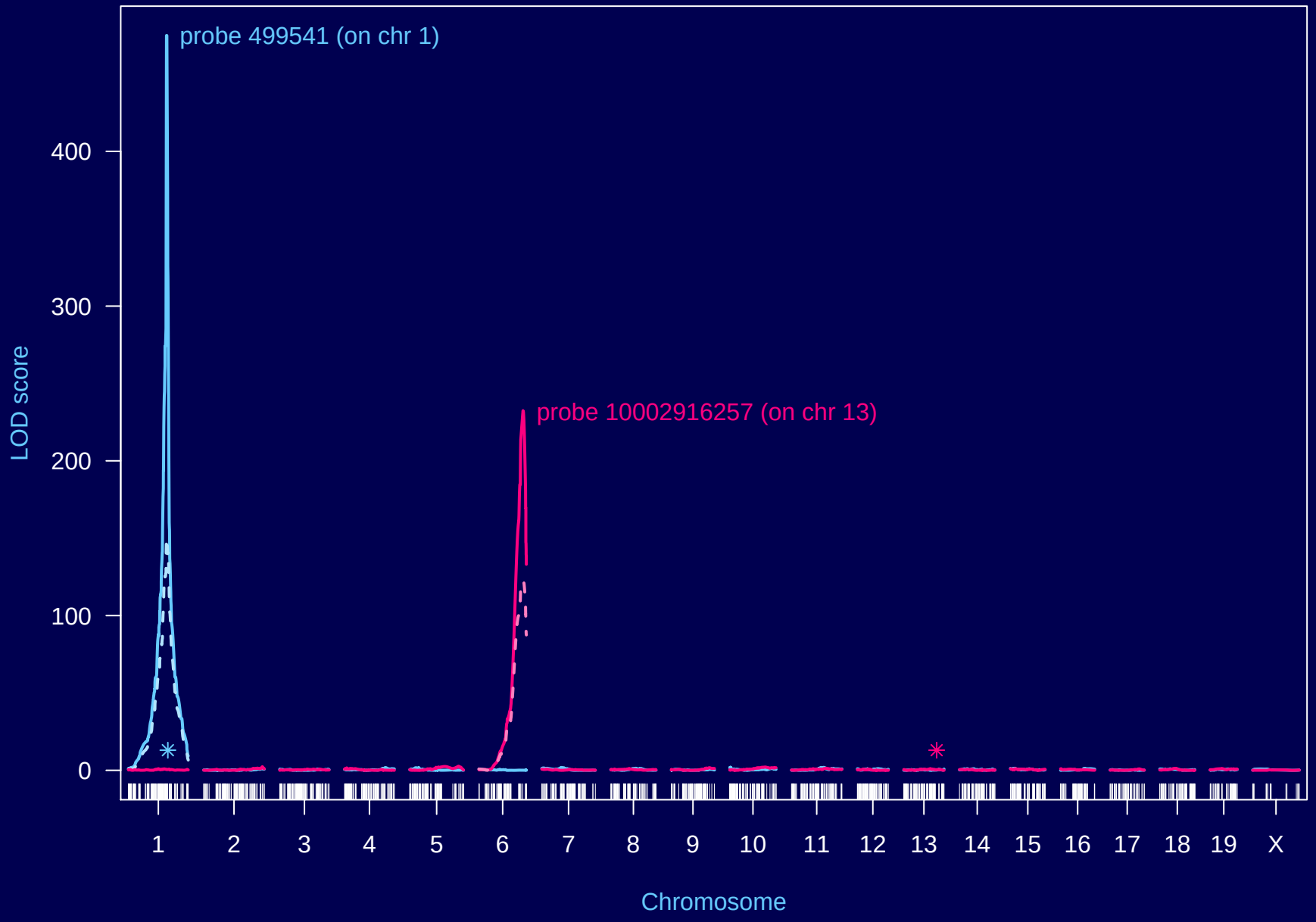
E vs E


Mouse3295 islet
0.90
0.97
0.37
Mouse3295 liver
0.88
0.35
Mouse3296 islet
0.43
Mouse3296 liver

Insulin QTL


after
before
LOD score
0
2
4
6
8
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
X
Chromosome

Strong eQTL


probe 499541 (on chr 1)
probe 10002916257 (on chr 13)
LOD score
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
X
Chromosome

Summary

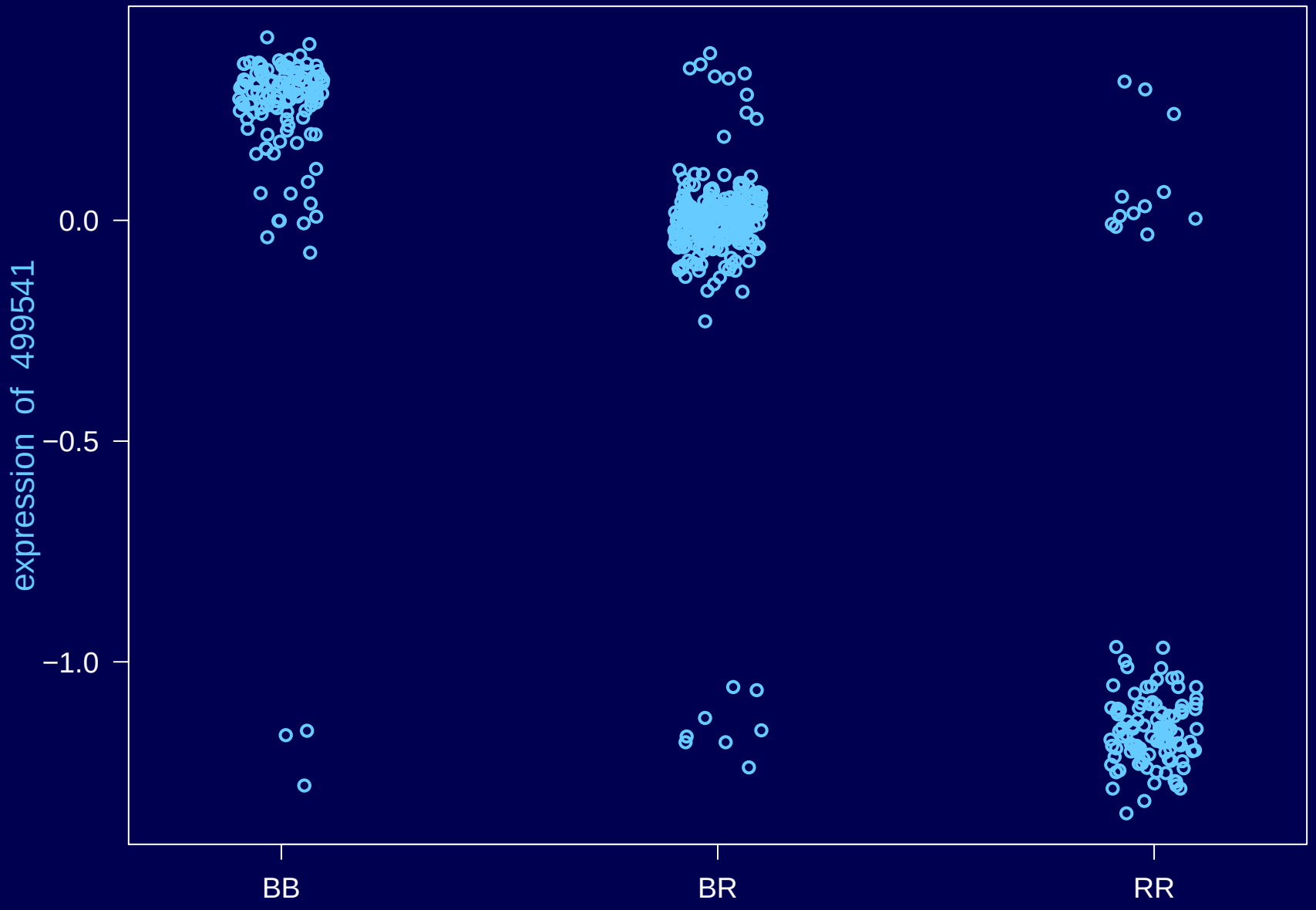
- Sample mix-ups happen
- With eQTL data, we can both identify and correct mix-ups
- There is great value in having expression on multiple tissues
- The general idea here has wide application for high-throughput data
- Related work:
  - Westra et al. (2011) Bioinformatics 27:2104–2111
  - Schadt et al. (2012) Nat Genet 44:603–608
  - Ekstrøm and Feenstra (2012) Stat Appl Genet Mol Biol 3:Article 13
  - Lynch et al. (2012) PLoS ONE 7:e41815

Lessons

- Don’t fully trust anyone
  - Including yourself
- Make lots of plots
  - Don’t rely on summary statistics, like LOD scores
  - Look responses on the original scale
- Follow up all aberrations
- Take your time with data cleaning
  - A month, two months, a year?
- Have a system for keeping track of everything
  - Files, versions of files, analyses, . . .
  - Like a lab notebook

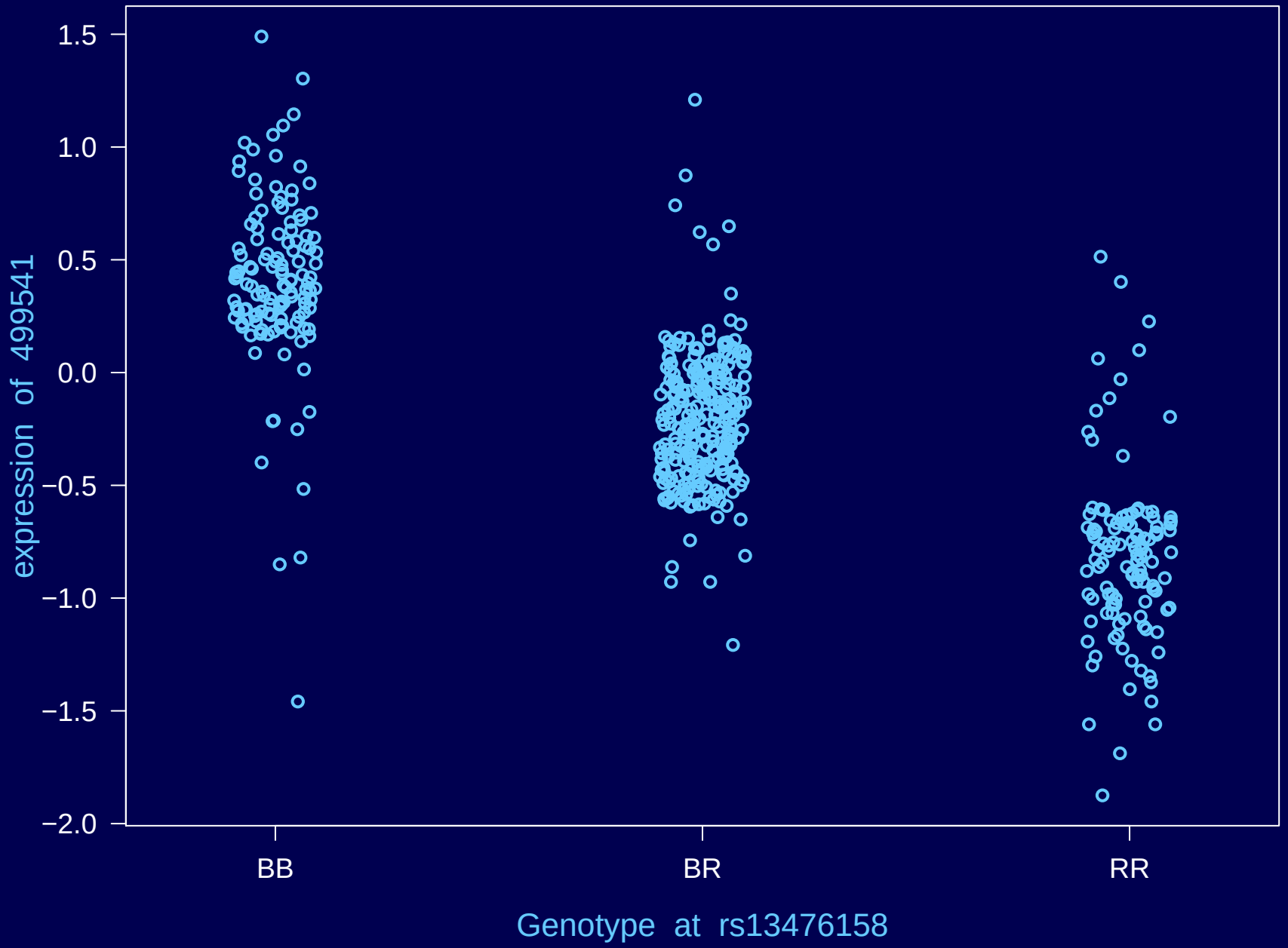
E vs G

original scale



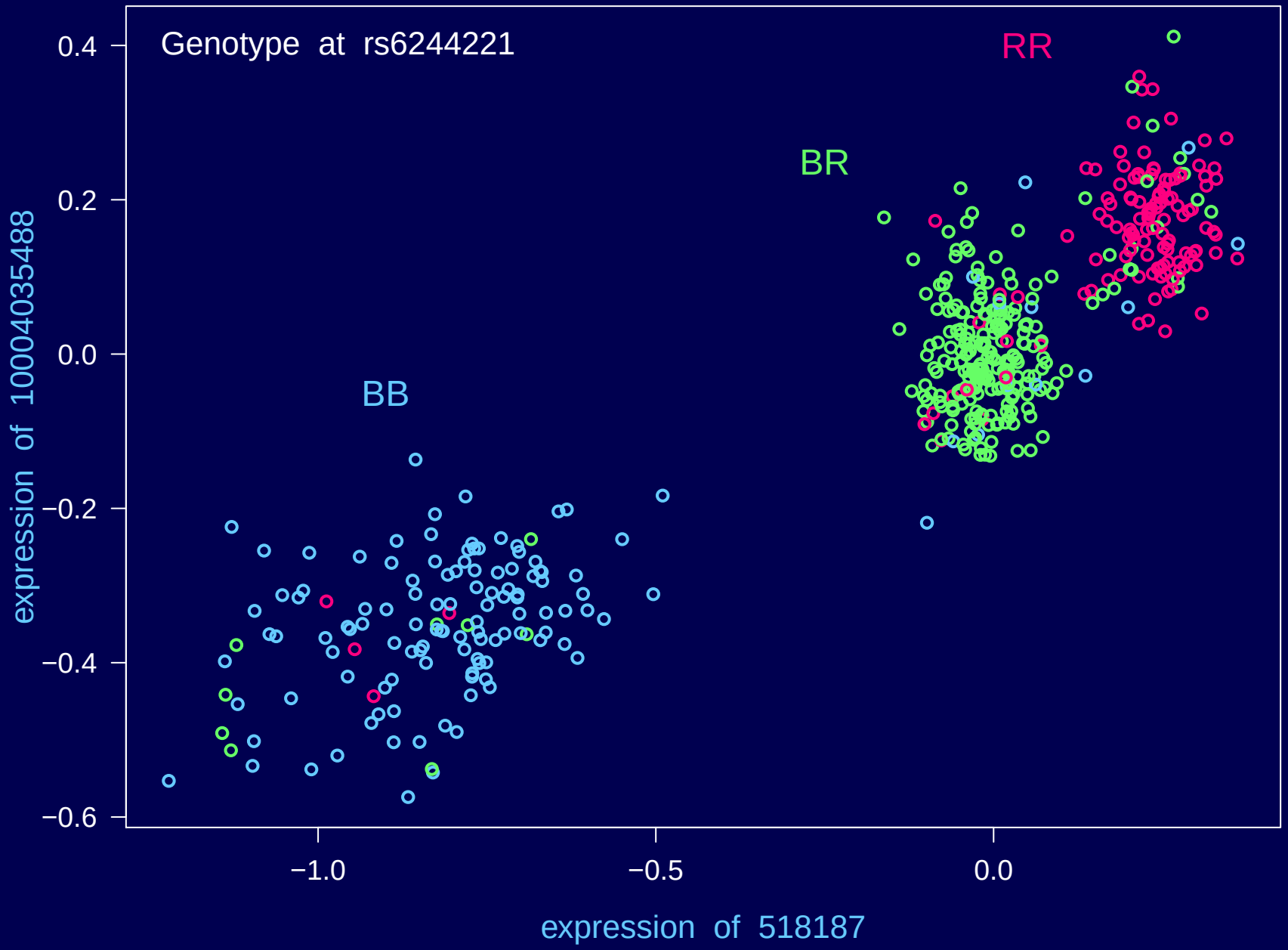
E vs G

transformed scale



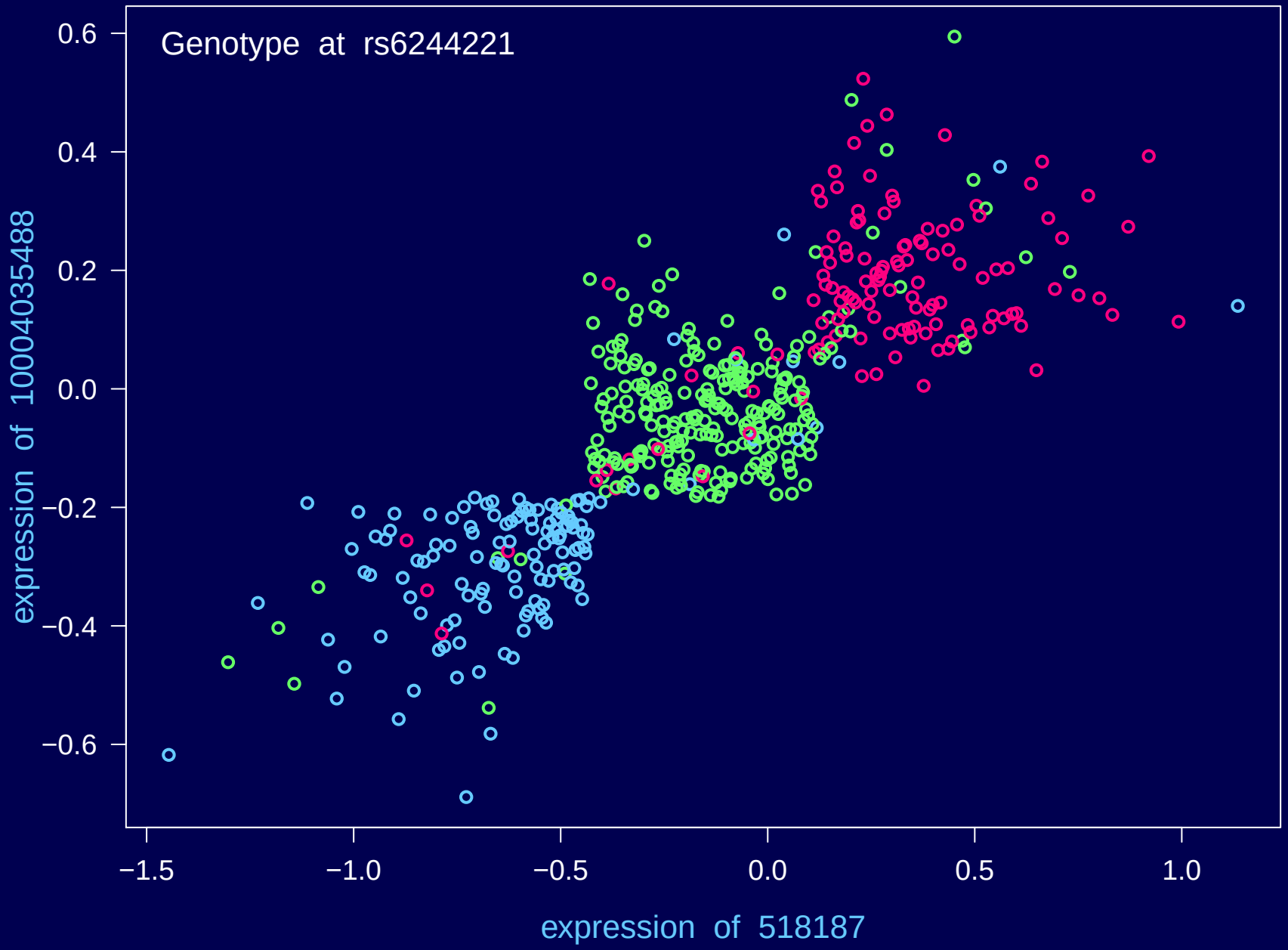
E vs G

original scale



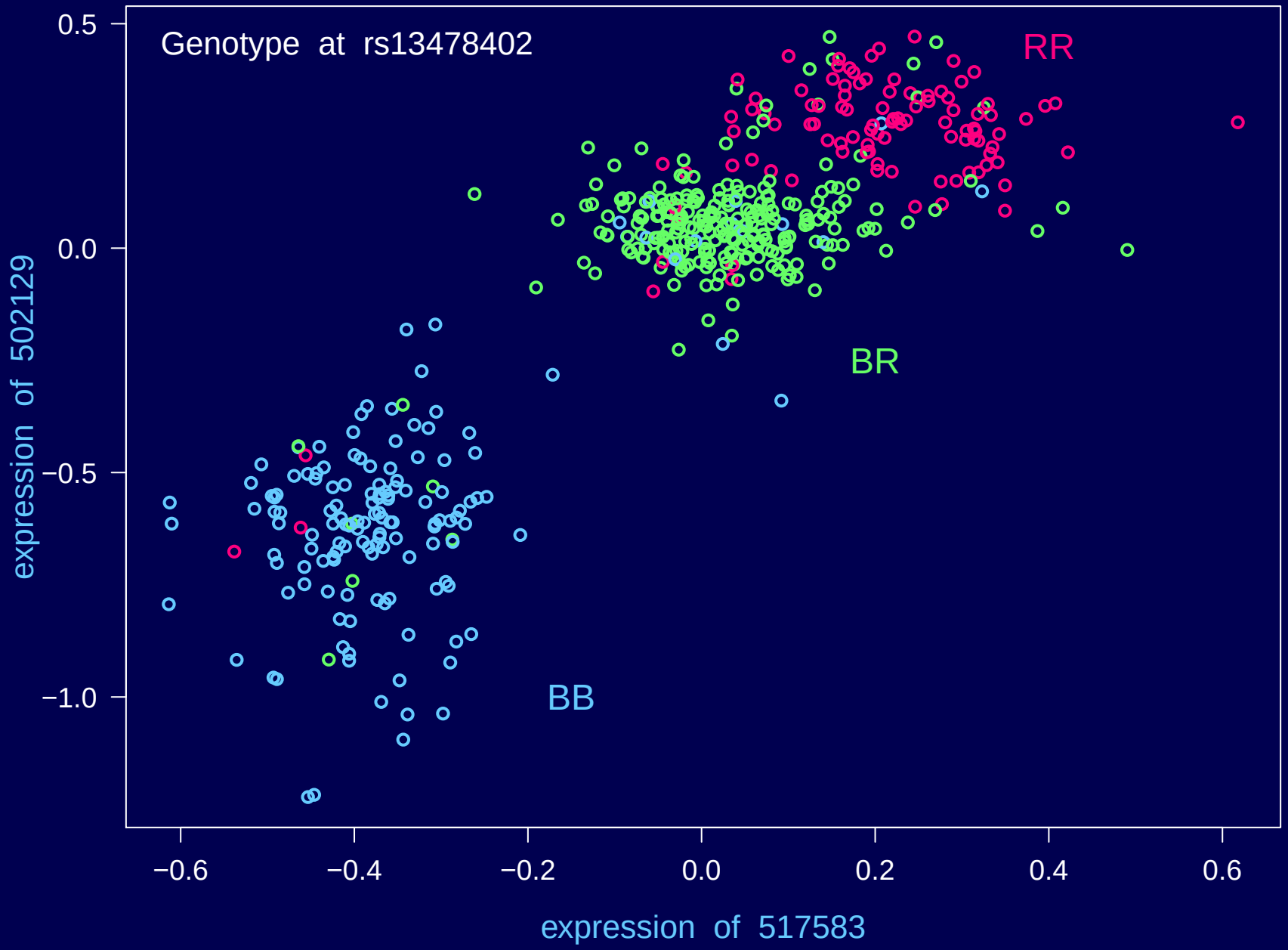
E vs G

transformed scale



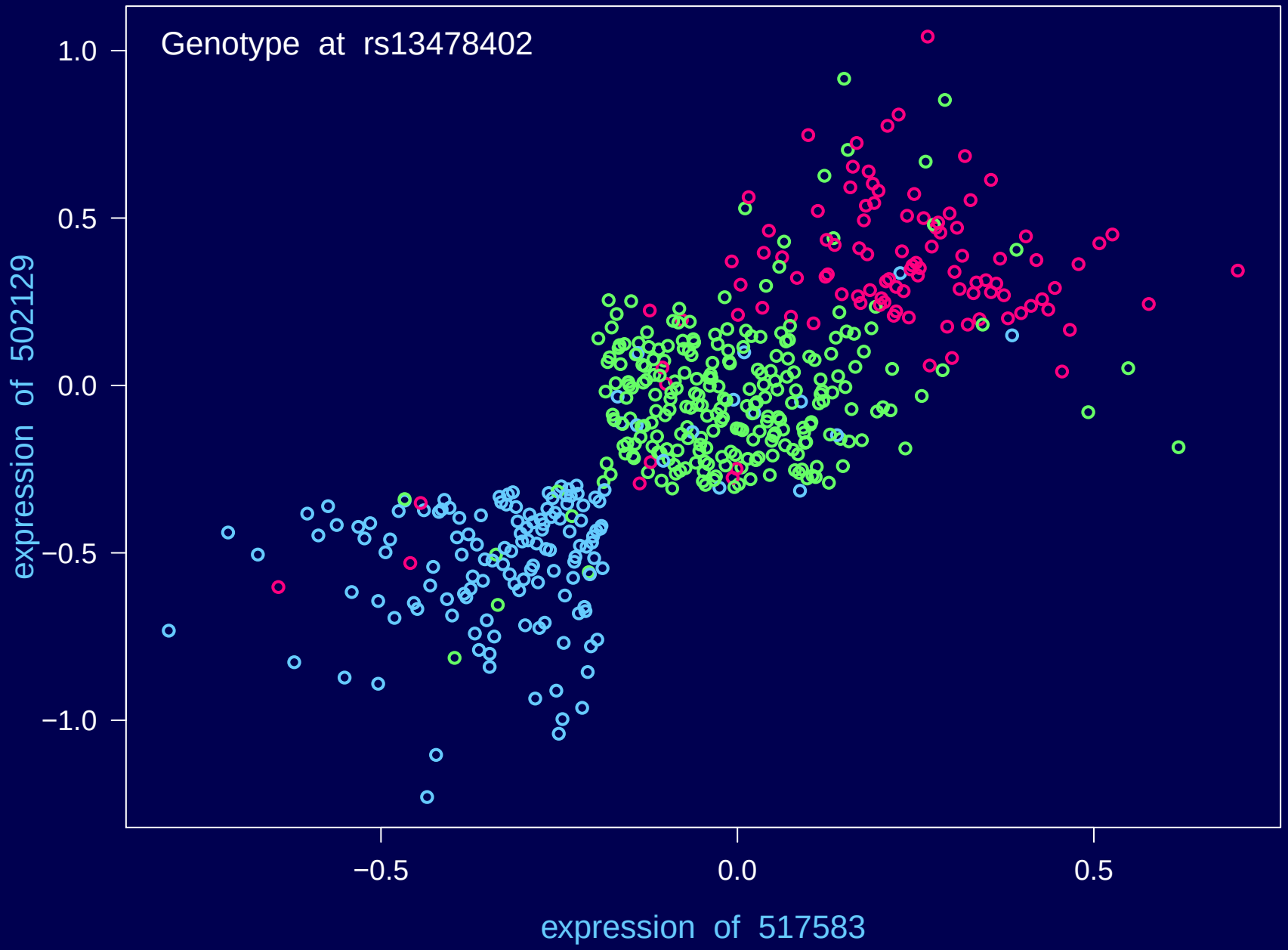
E vs G

original scale



E vs G

transformed scale



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Acknowledgments

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Śaunak Sen	UCSF

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