Supplementary Figures

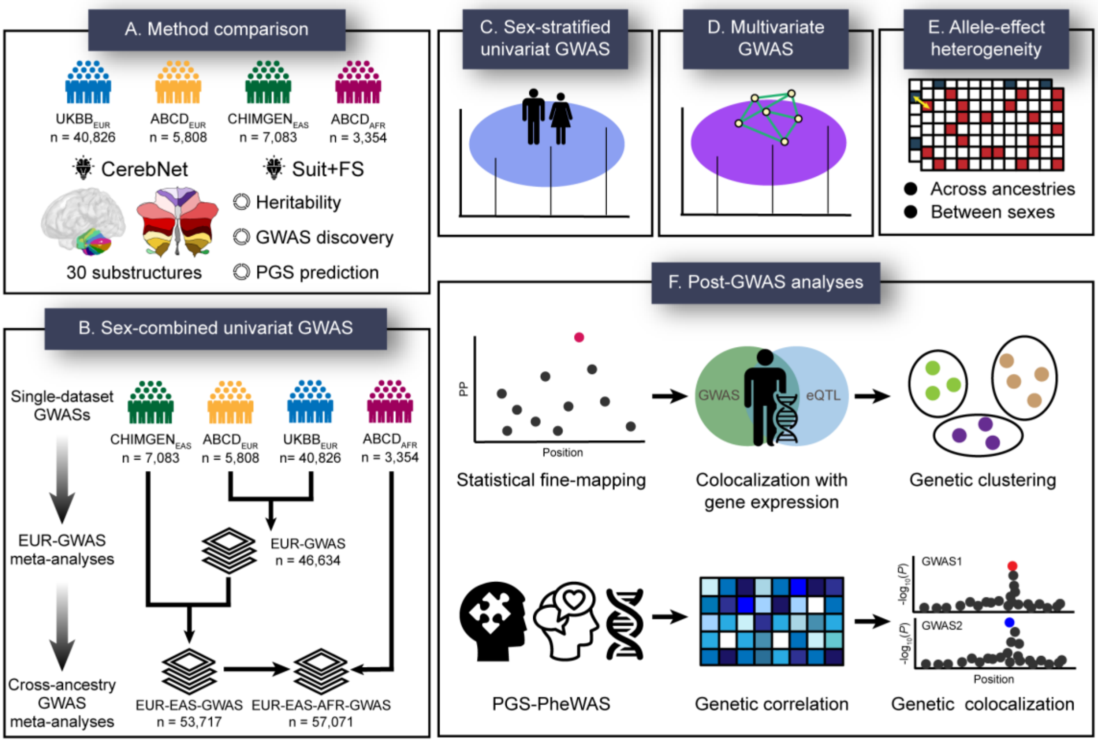


Fig. S1 | A schematic summary of study design. This study includes four independent subgroups with raw genetic and neuroimaging data (UKBB_{EUR}, ABCD_{EUR}, $\text{CHIMGEN}_{\text{EAS}}$, and ABCD_{AFR}). (**A**) To compare the cerebellar segmentation methods, we calculate the volumes of 30 cerebellar substructures using CerebNet and SUIT+FS, and we evaluate their differences in heritability estimation, GWAS discovery, and PGS prediction. (**B**) In the sex-combined univariate analyses, we further include total cerebellar volume as a trait and perform GWASs for the 31 cerebellar volumetric traits across the four subgroups, respectively. We also conduct one EUR-GWAS and two cross-ancestry (EUR-EAS and EUR-EAS-AFR) GWAS meta-analyses. (**C**) In the sex-stratified univariate analyses, we repeat the seven sets of GWASs in males and females, respectively. (**D**) Multivariate GWASs are performed in both sex-combined and sex-stratified populations. (**E**) We identify allelic-effect heterogeneity across ancestries based on sex-combined EUR-GWASs, CHIMGEN$_{\text{EAS}}$-GWASs, and ABCD$_{\text{AFR}}$-GWASs, while we detect allelic-effect heterogeneity between sexes based on sex-stratified EUR-GWASs, CHIMGEN$_{\text{EAS}}$-GWASs, and ABCD$_{\text{AFR}}$-GWASs. (**F**) The post-GWAS analyses include statistical fine-mapping, genetic colocalization with cerebellar gene expression, genetic clustering for cerebellar subregions, PGS-PheWAS, and genetic correlation and colocalization with neuropsychiatric disorders. Abbreviations: ABCD, the Adolescent Brain Cognitive Development study; AFR, African ancestry; CHIMGEN, the Chinese Imaging Genetics study; EAS, East Asian ancestry; EUR, European ancestry; FS, FreeSurfer; GWAS, genome-wide association study; PGS, polygenic score; PheWAS, phenome-wide association study; SUIT, spatially unbiased infra-tentorial; FS, FreeSurfer; UKBB, the UK Biobank study.

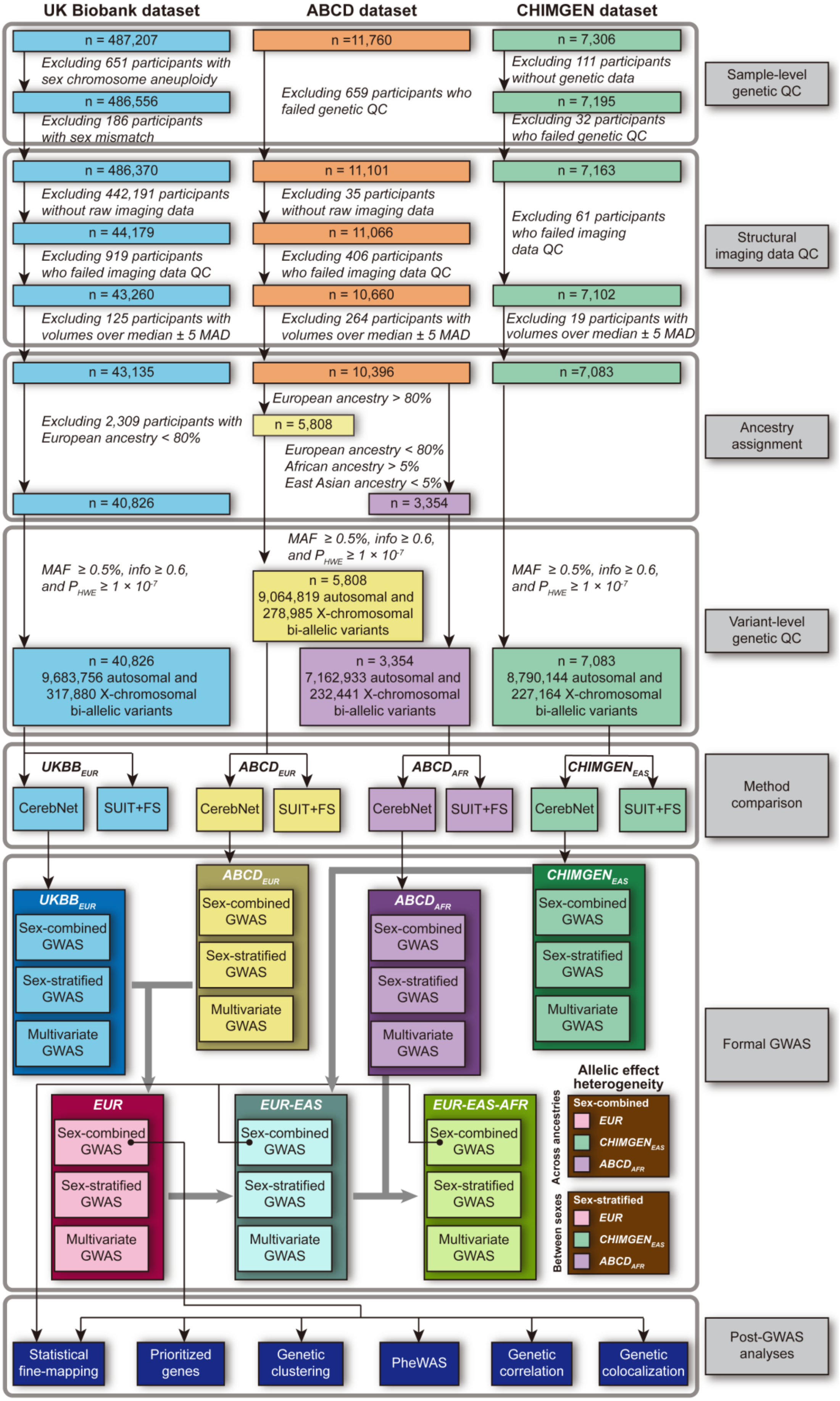
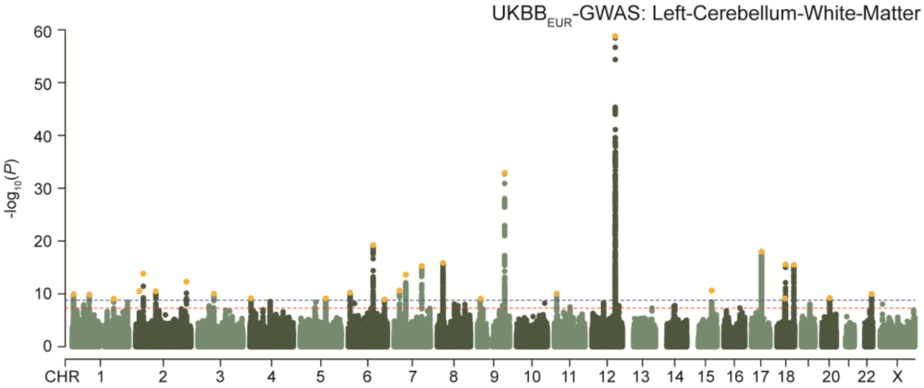
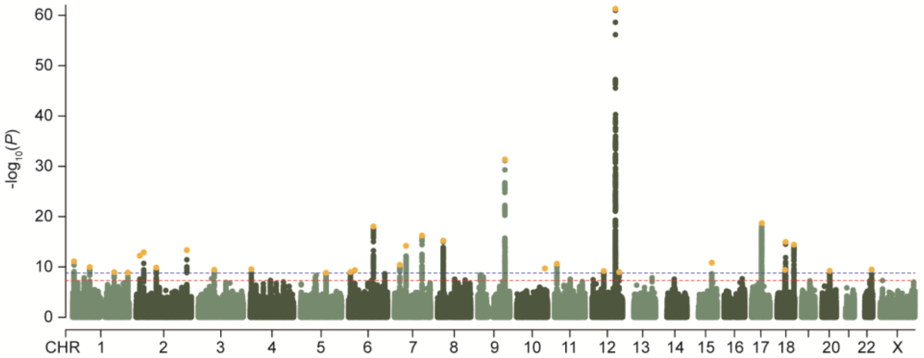

UK Biobank dataset
ABCD dataset
CHIMGEN dataset
n = 487,207
Excluding 651 participants with sex chromosome aneuploidy
n = 486,556
Excluding 186 participants with sex mismatch
n =11,760
Excluding 659 participants who failed genetic QC
n = 7,306
Excluding 111 participants without genetic data
n = 7,195
Excluding 32 participants who failed genetic QC
Sample-level genetic QC
n = 486,370
Excluding 442,191 participants without raw imaging data
n = 44,179
Excluding 919 participants who failed imaging data QC
n = 43,260
Excluding 125 participants with volumes over median ± 5 MAD
n = 11,101
Excluding 35 participants without raw imaging data
n = 11,066
Excluding 406 participants who failed imaging data QC
n = 10,660
Excluding 264 participants with volumes over median ± 5 MAD
n = 7,163
Excluding 61 participants who failed imaging data QC
n = 7,102
Excluding 19 participants with volumes over median ± 5 MAD
Structural imaging data QC
n = 43,135
Excluding 2,309 participants with European ancestry < 80%
n = 40,826
n = 10,396
European ancestry > 80%
n = 5,808
European ancestry < 80%
African ancestry > 5%
East Asian ancestry < 5%
n = 3,354
n =7,083
Ancestry assignment
MAF ≥ 0.5%, info ≥ 0.6, and $P_{HWE} \geq 1 \times 10^{-7}$
MAF ≥ 0.5%, info ≥ 0.6, and $P_{HWE} \geq 1 \times 10^{-7}$
MAF ≥ 0.5%, info ≥ 0.6, and $P_{HWE} \geq 1 \times 10^{-7}$
n = 5,808
9,064,819 autosomal and 278,985 X-chromosomal bi-allelic variants
n = 40,826
9,683,756 autosomal and 317,880 X-chromosomal bi-allelic variants
n = 3,354
7,162,933 autosomal and 232,441 X-chromosomal bi-allelic variants
n = 7,083
8,790,144 autosomal and 227,164 X-chromosomal bi-allelic variants
Variant-level genetic QC
$UKBB_{EUR}$
$ABCD_{EUR}$
$ABCD_{AFR}$
$CHIMGEN_{EAS}$
CerebNet
SUIT+FS
CerebNet
SUIT+FS
CerebNet
SUIT+FS
CerebNet
SUIT+FS
Method comparison
$UKBB_{EUR}$
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
$ABCD_{EUR}$
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
$ABCD_{AFR}$
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
$CHIMGEN_{EAS}$
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
EUR
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
EUR-EAS
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
EUR-EAS-AFR
Sex-combined GWAS
Sex-stratified GWAS
Multivariate GWAS
Allelic effect heterogeneity
Across ancestries
Sex-combined
EUR
$CHIMGEN_{EAS}$
$ABCD_{AFR}$
Between sexes
Sex-stratified
EUR
$CHIMGEN_{EAS}$
$ABCD_{AFR}$
Formal GWAS
Statistical fine-mapping
Prioritized genes
Genetic clustering
PheWAS
Genetic correlation
Genetic colocalization
Post-GWAS analyses

Fig. S2 | Participant selection, quality control, and analysis workflow. Abbreviations: ABCD, the Adolescent Brain Cognitive Development study; AFR, African ancestry; CHIMGEN, the Chinese Imaging Genetics study; EAS, East Asian ancestry; EUR, European ancestry; FS, FreeSurfer; GWAS, genome-wide association study; HWE, Hardy-Weinberg equilibrium; info, imputation information score; MAD, median absolute deviation; MAF, minor allele frequency; PheWAS, phenome-wide association study; QC, quality control; SUIT, spatially unbiased infra-tentorial; UKBB, the UK Biobank study.

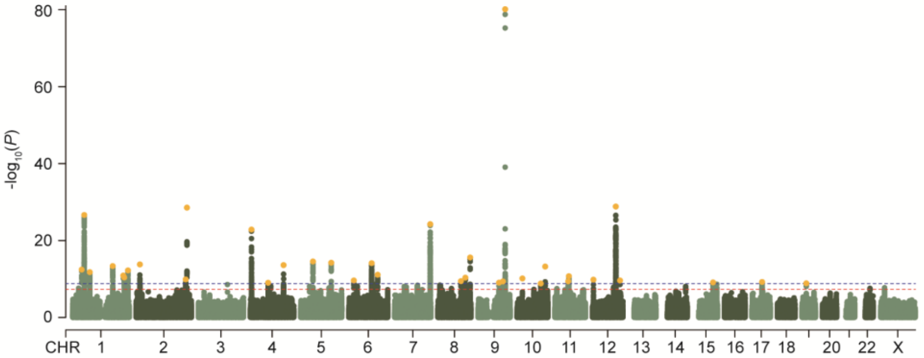
UKBB$_{EUR}$-GWAS: Left-Cerebellum-White-Matter



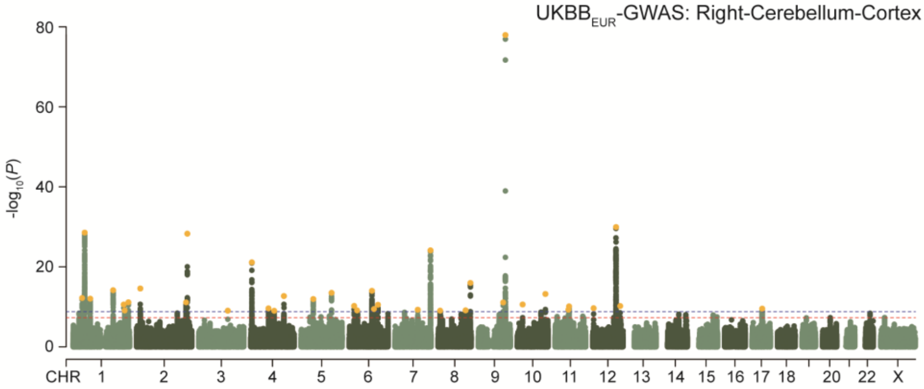
UKBB$_{EUR}$-GWAS: Right-Cerebellum-White-Matter

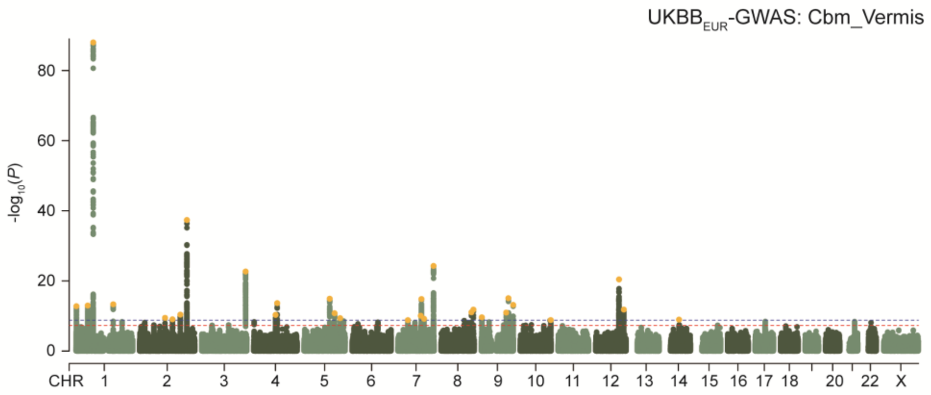


UKBB$_{EUR}$-GWAS: Left-Cerebellum-Cortex

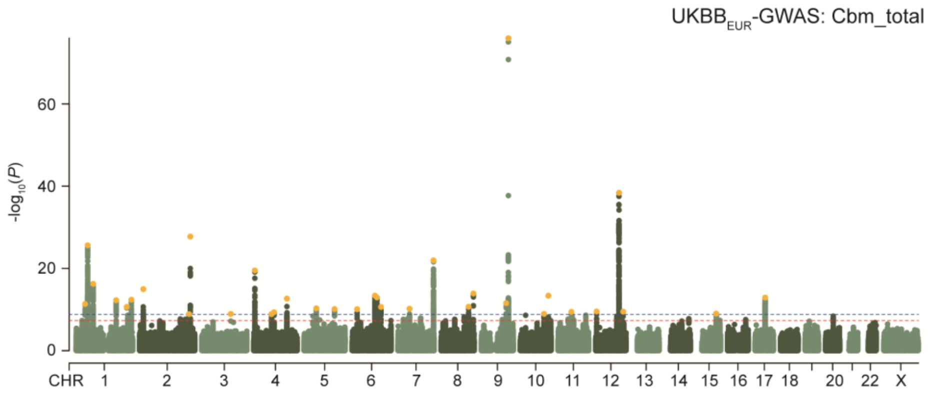


UKBB$_{EUR}$-GWAS: Right-Cerebellum-Cortex

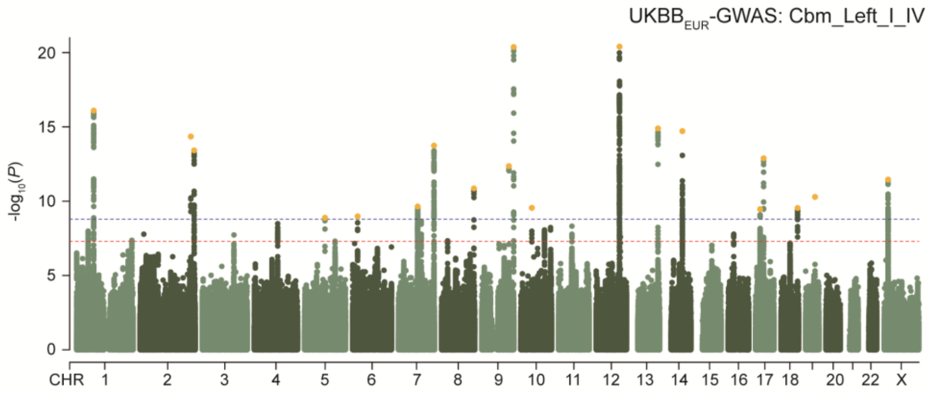




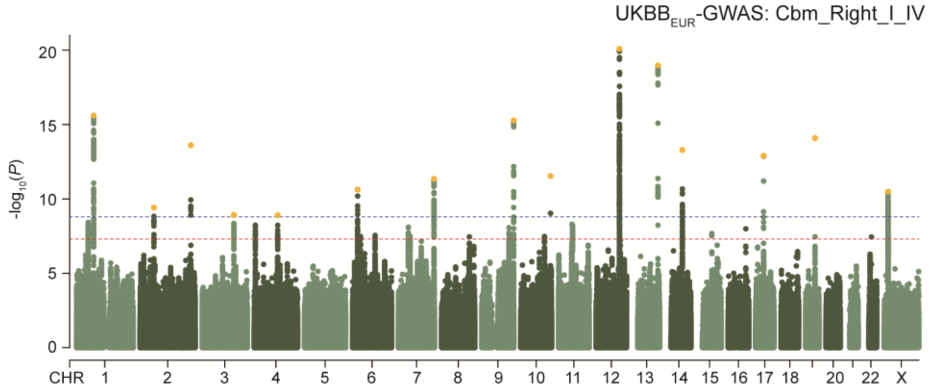
UKBB$_{EUR}$-GWAS: Cbm_Vermis



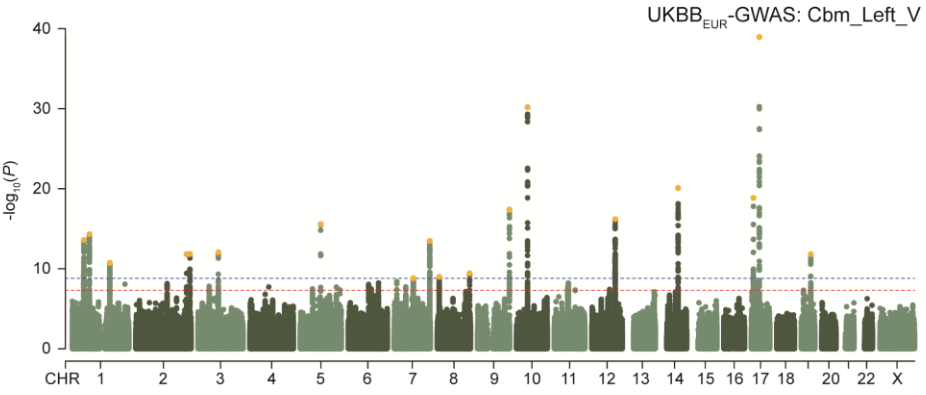
UKBB$_{EUR}$-GWAS: Cbm_total

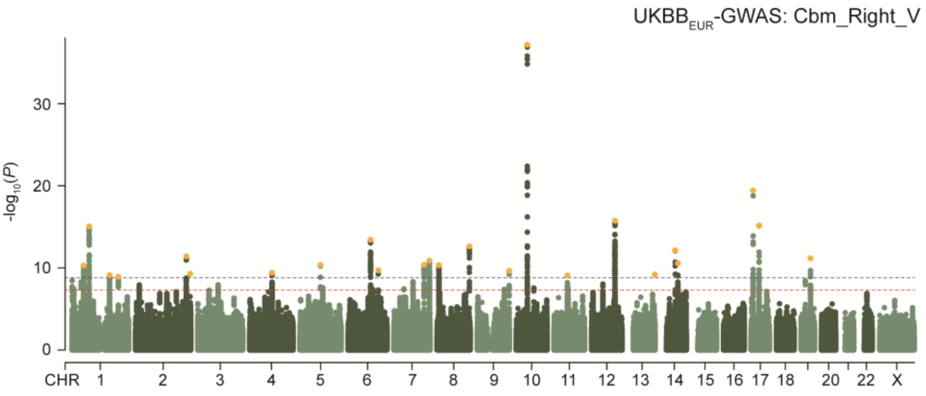


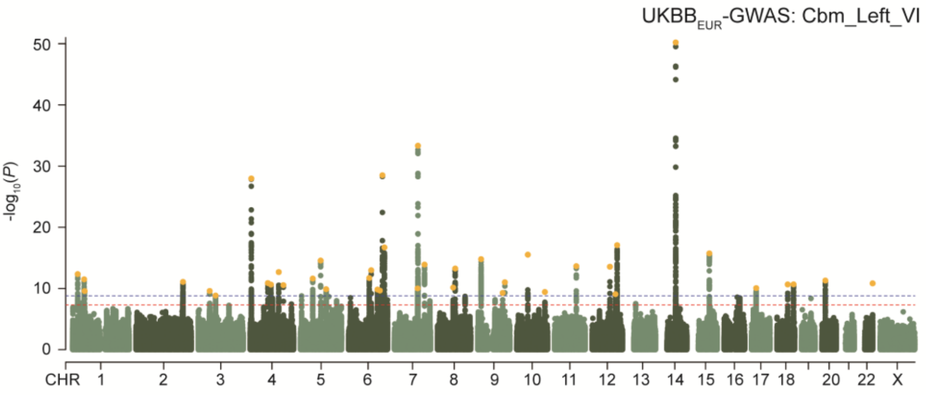
UKBB$_{EUR}$-GWAS: Cbm_Left_I_IV

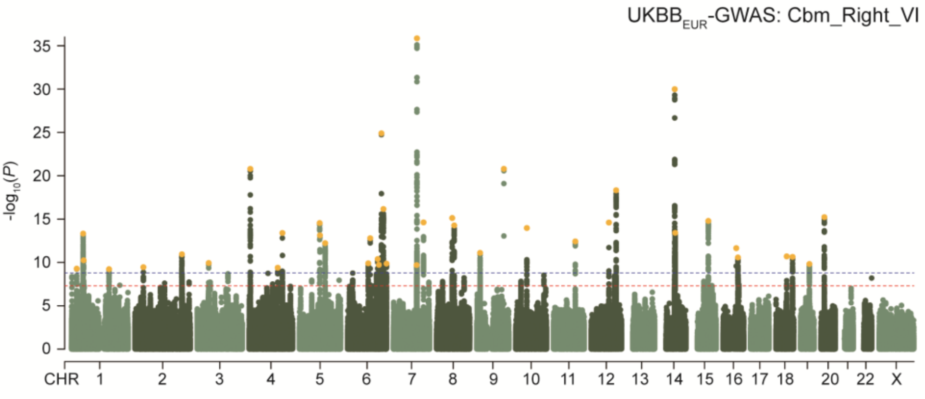


UKBB$_{EUR}$-GWAS: Cbm_Right_I_IV

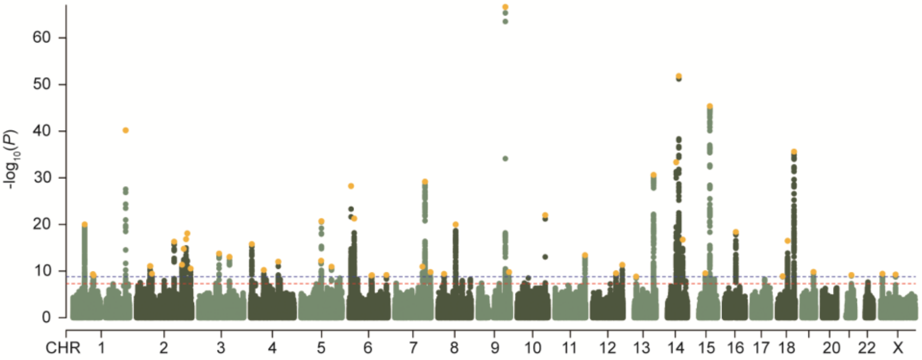

UKBB$_{EUR}$-GWAS: Cbm_Left_V


UKBB$_{EUR}$-GWAS: Cbm_Right_V

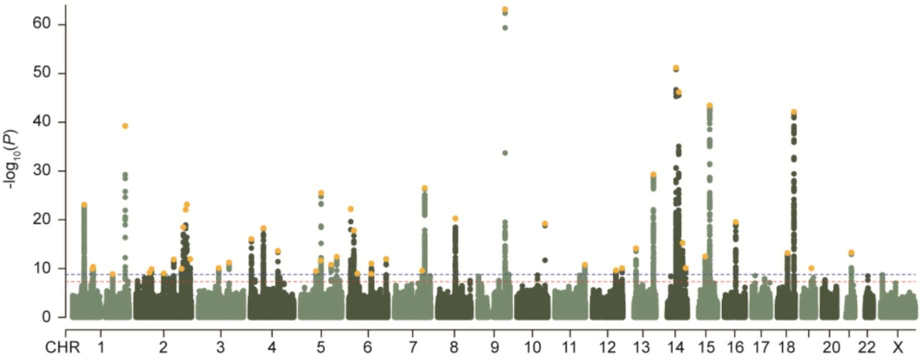

UKBB$_{EUR}$-GWAS: Cbm_Left_VI


UKBB$_{EUR}$-GWAS: Cbm_Right_VI

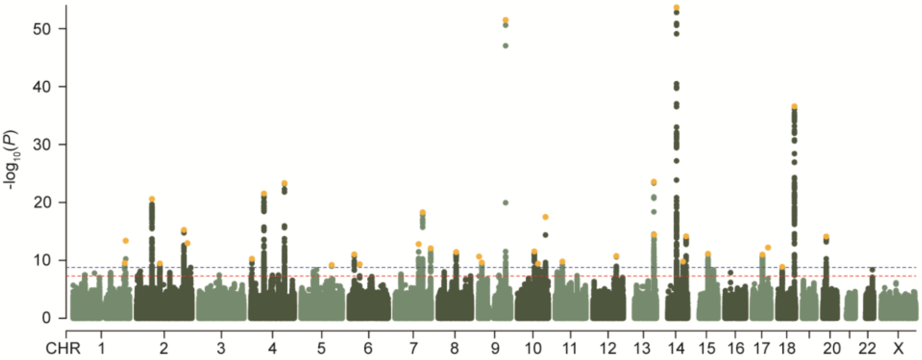
UKBB$_{EUR}$-GWAS: Cbm_Left_CrusI



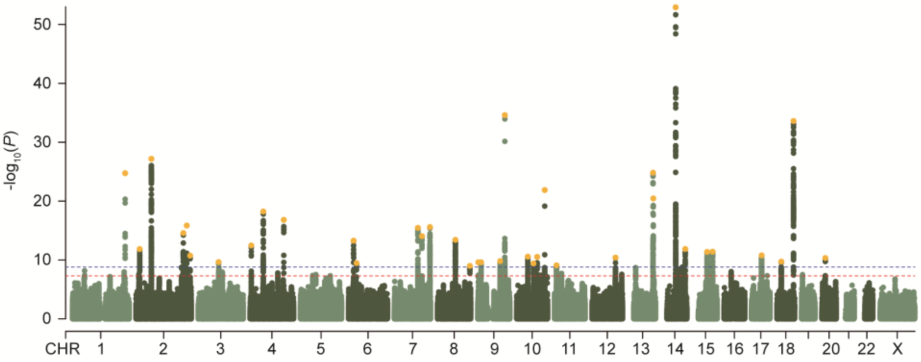
UKBB$_{EUR}$-GWAS: Cbm_Right_CrusI



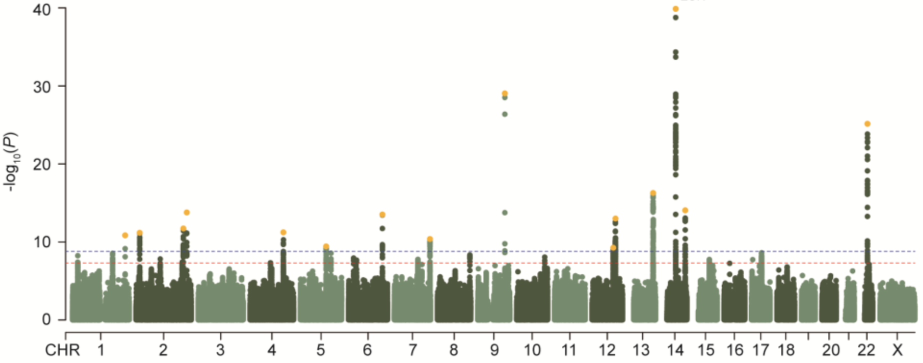
UKBB$_{EUR}$-GWAS: Cbm_Left_CrusII



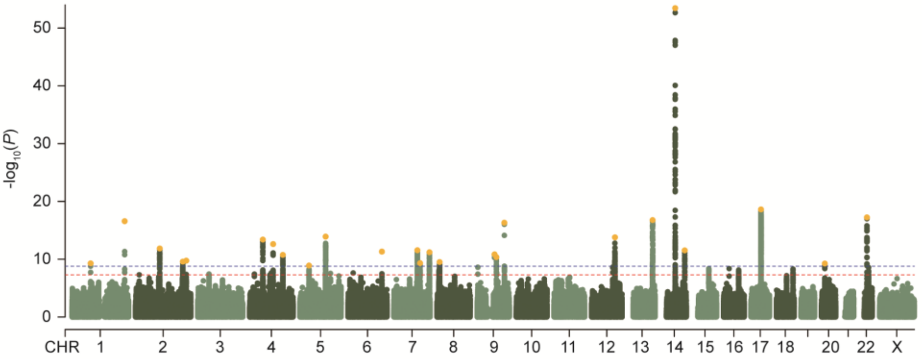
UKBB$_{EUR}$-GWAS: Cbm_Right_CrusII



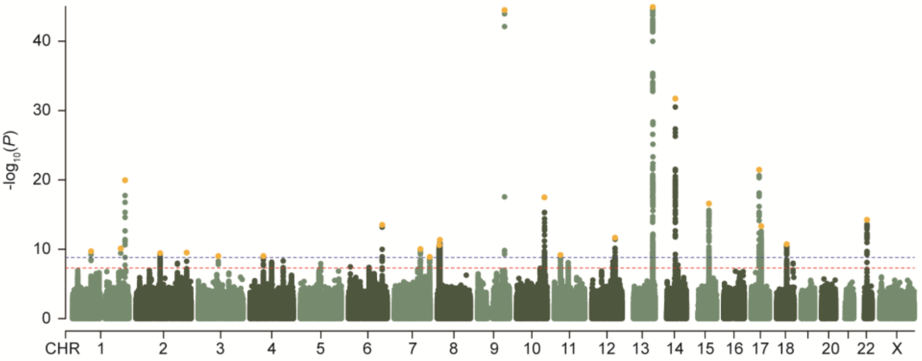
UKBB$_{EUR}$-GWAS: Cbm_Left_VIIb



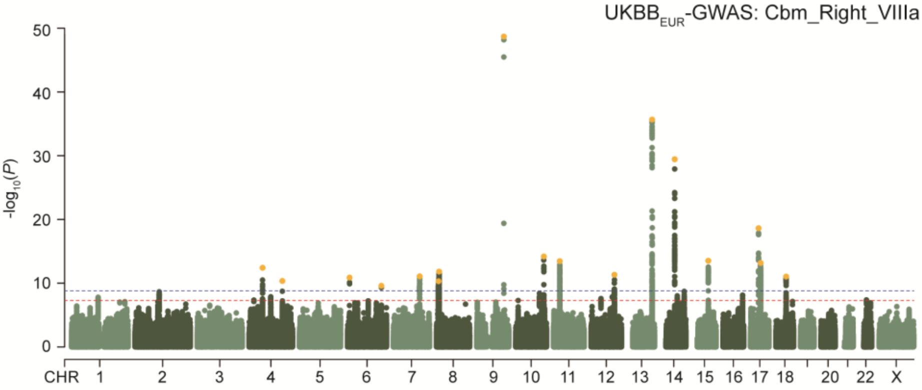
UKBB$_{EUR}$-GWAS: Cbm_Right_VIIb

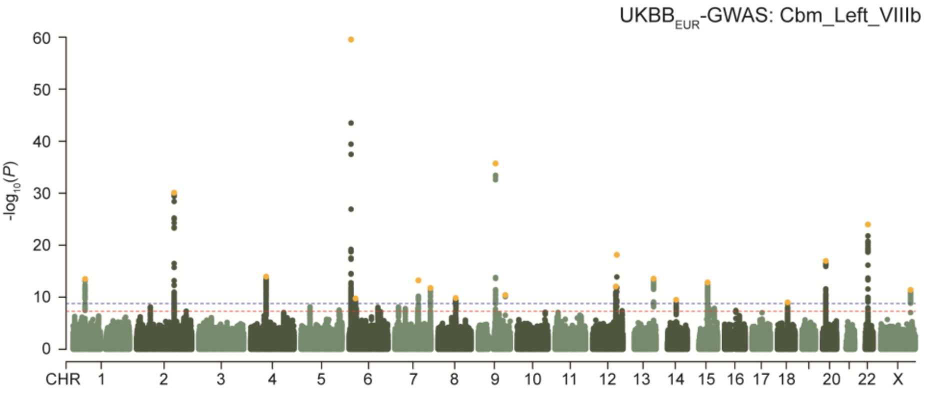


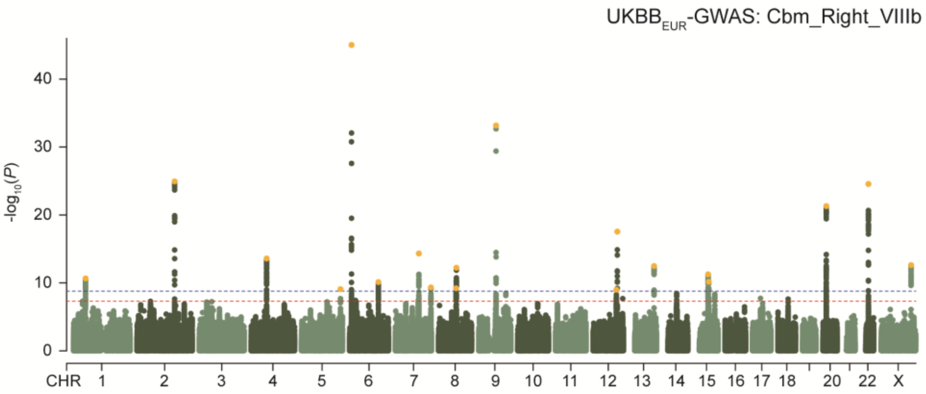
UKBB$_{EUR}$-GWAS: Cbm_Left_VIIIa

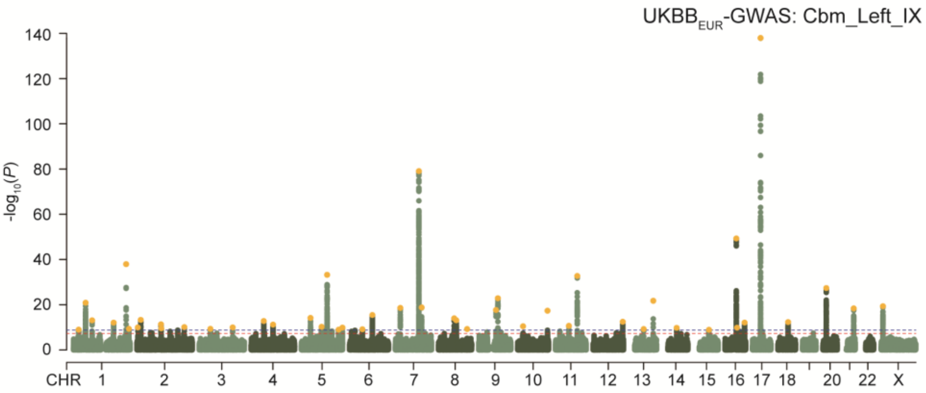


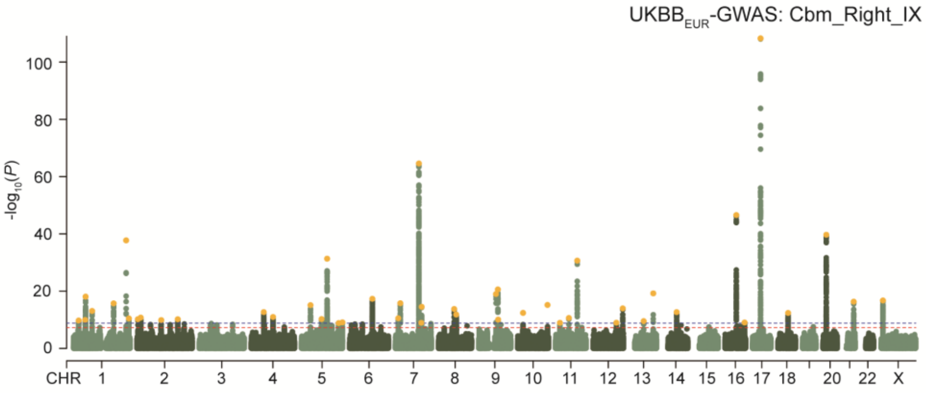
UKBB$_{EUR}$-GWAS: Cbm_Right_VIIIa

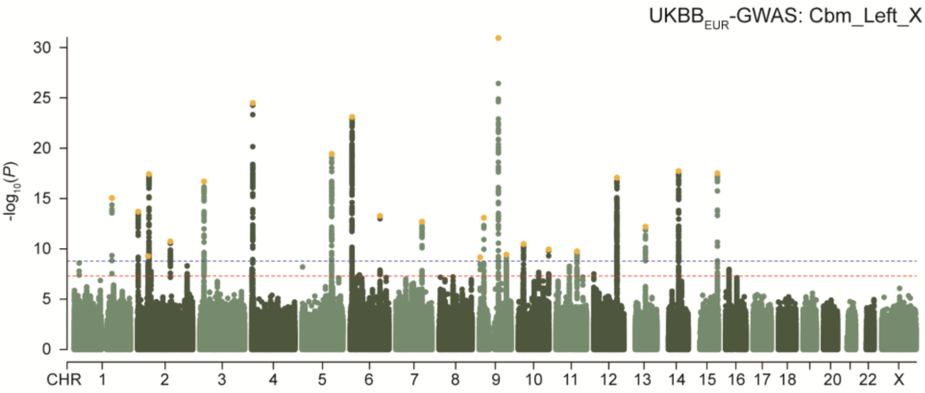



UKBB$_{EUR}$-GWAS: Cbm_Left_VIIIb
60
50
40
30
20
10
0
-log$_{10}$(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

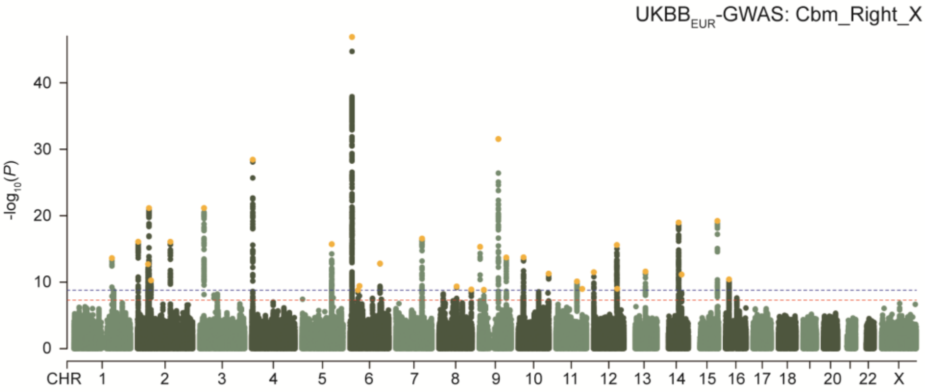

UKBB$_{EUR}$-GWAS: Cbm_Right_VIIIb
40
30
20
10
0
-log$_{10}$(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


UKBB$_{EUR}$-GWAS: Cbm_Left_IX
140
120
100
80
60
40
20
0
-log$_{10}$(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


UKBB$_{EUR}$-GWAS: Cbm_Right_IX
100
80
60
40
20
0
-log$_{10}$(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X



UKBB$_{EUR}$-GWAS: Cbm_Left_X



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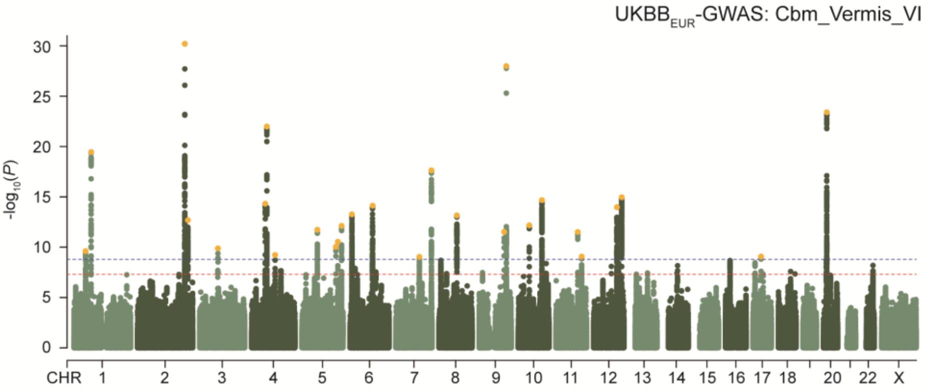
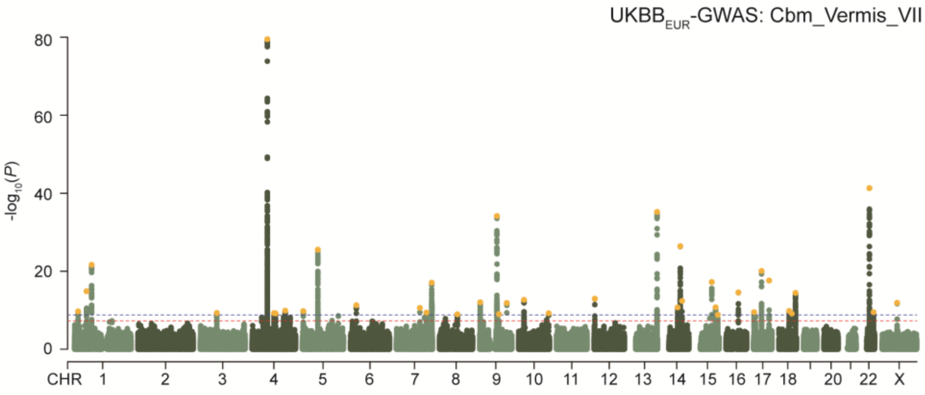


UKBB$_{EUR}$-GWAS: Cbm_Vermis_VI



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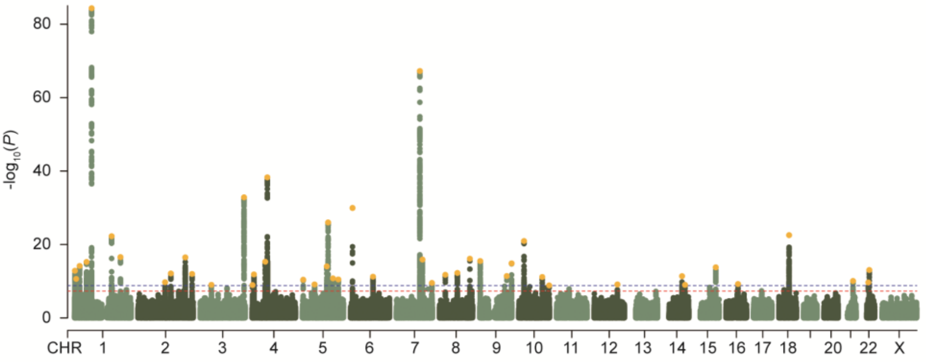
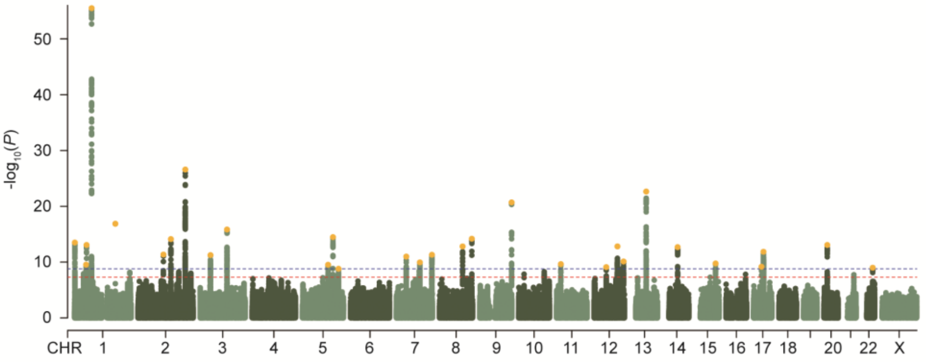


UKBB$_{EUR}$-GWAS: Cbm_Vermis_VIII



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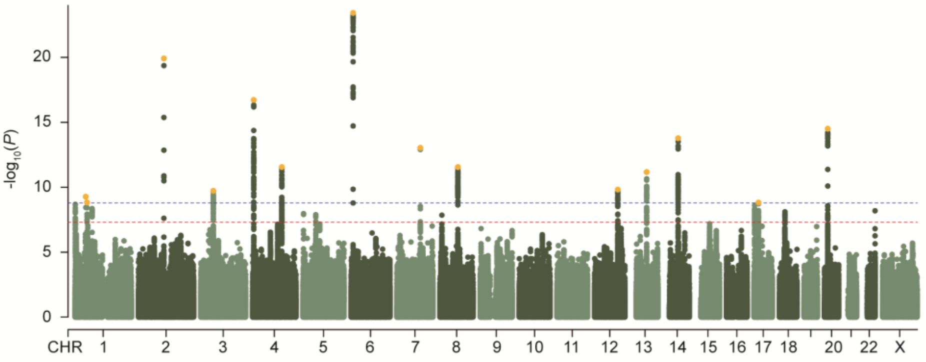
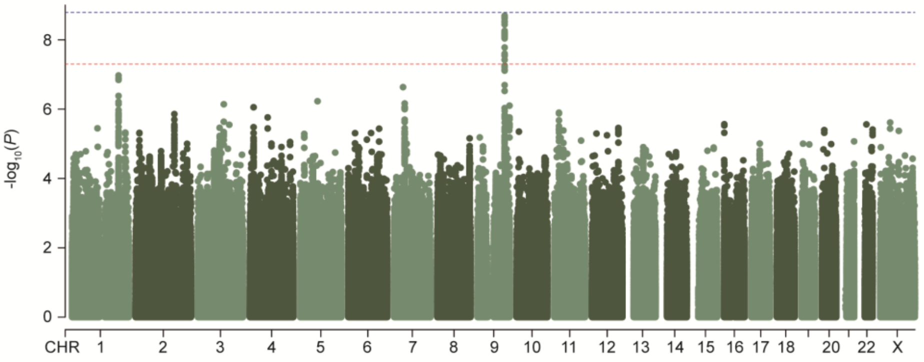
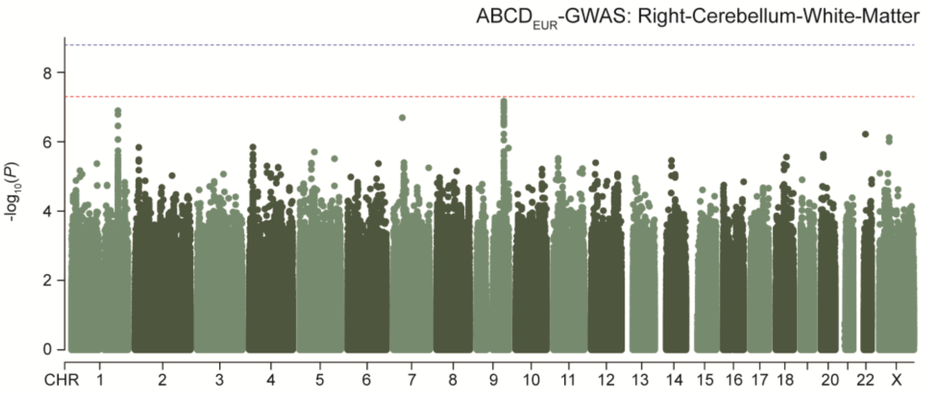


UKBB$_{EUR}$-GWAS: Cbm_Vermis_X



ABCD$_{EUR}$-GWAS: Left-Cerebellum-White-Matter


ABCD$_{EUR}$-GWAS: Right-Cerebellum-White-Matter
-log$_{10}$(P)
0
2
4
6
8
CHR
1
2
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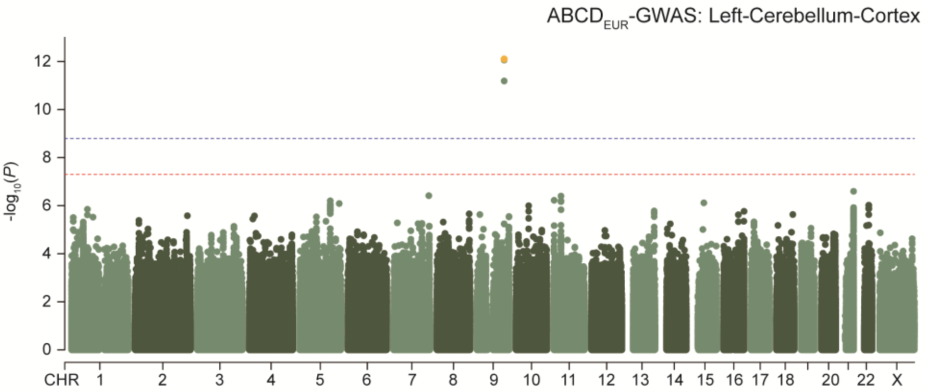
22
X


ABCD$_{EUR}$-GWAS: Left-Cerebellum-Cortex
-log$_{10}$(P)
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2
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12
CHR
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20
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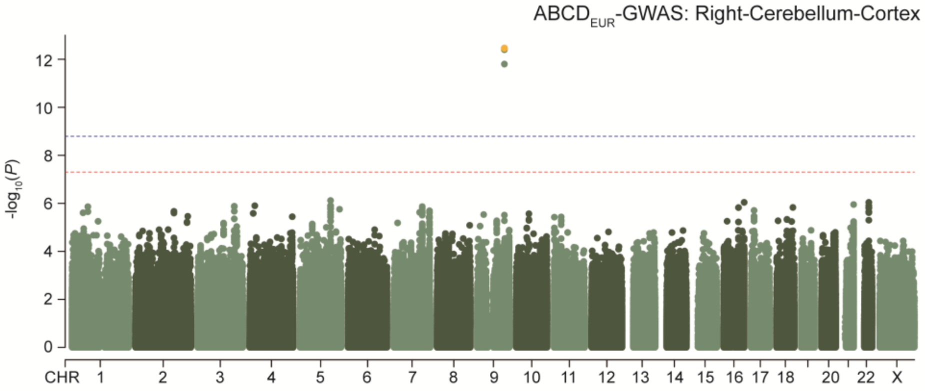
ABCD$_{EUR}$-GWAS: Right-Cerebellum-Cortex
-log$_{10}$(P)
0
2
4
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8
10
12
CHR
1
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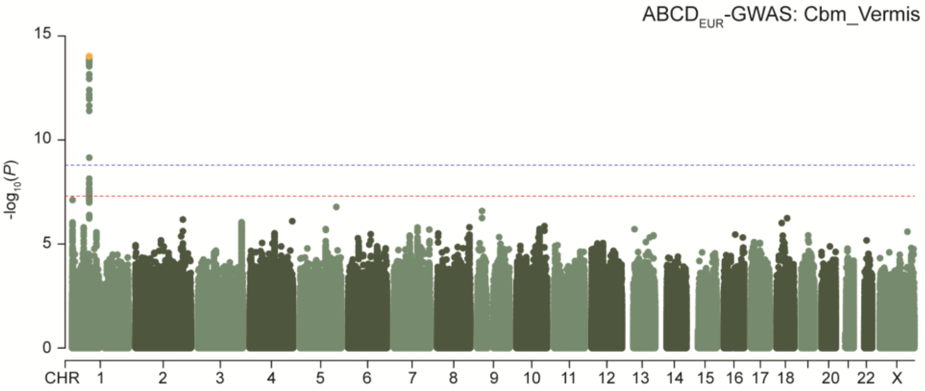
ABCD$_{EUR}$-GWAS: Cbm_Vermis
-log$_{10}$(P)
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5
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CHR
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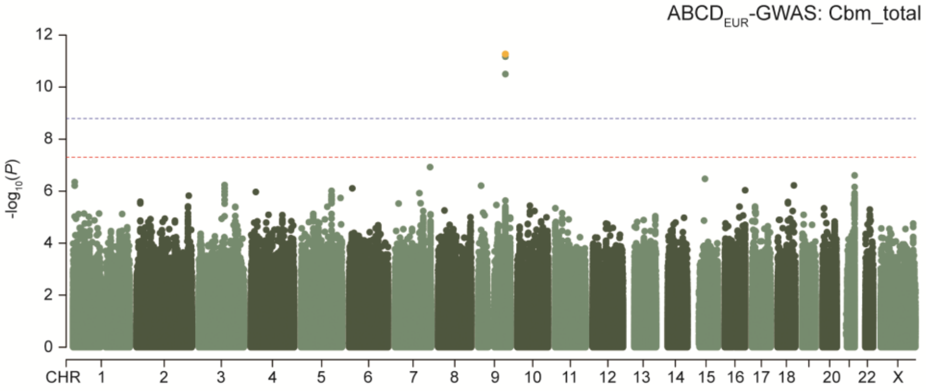
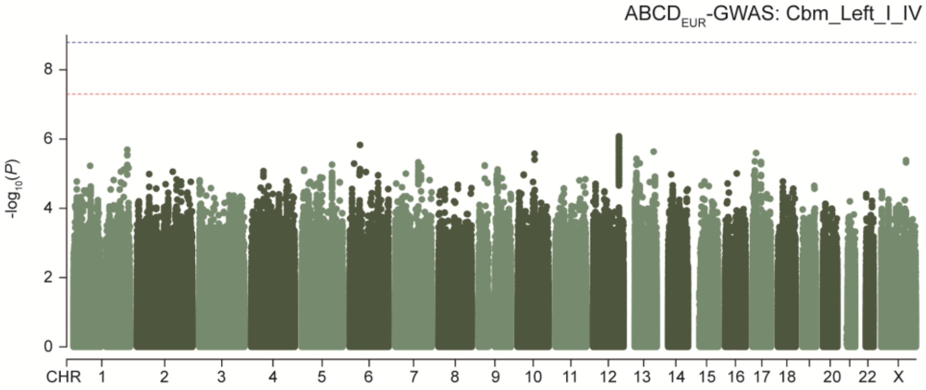
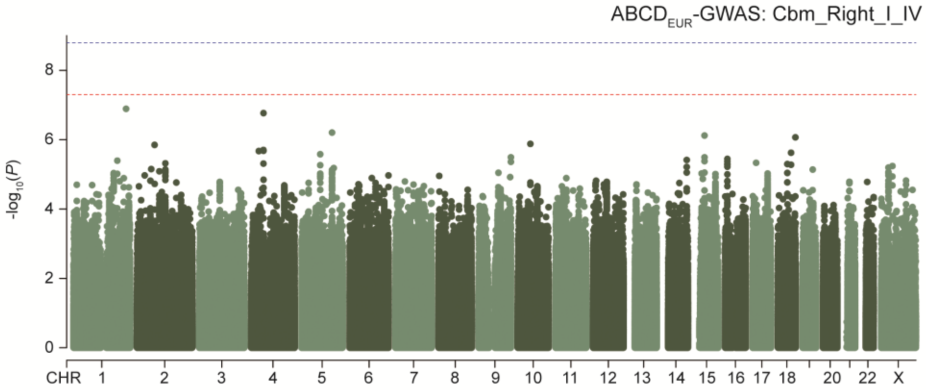

ABCD$_{EUR}$-GWAS: Cbm_total


ABCD$_{EUR}$-GWAS: Cbm_Left_I_IV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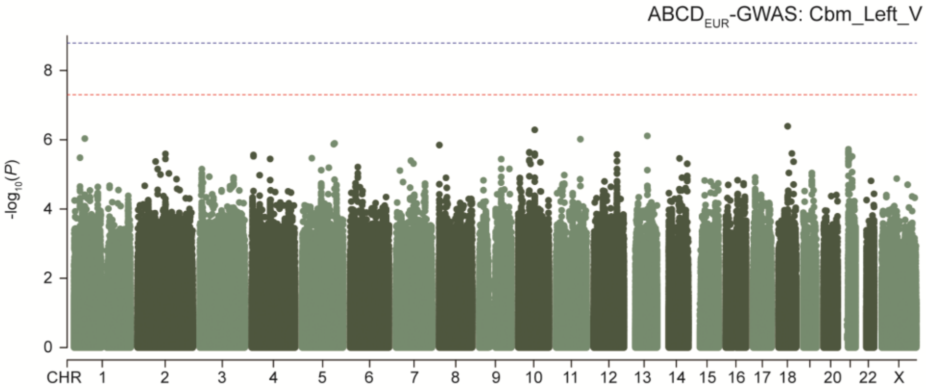
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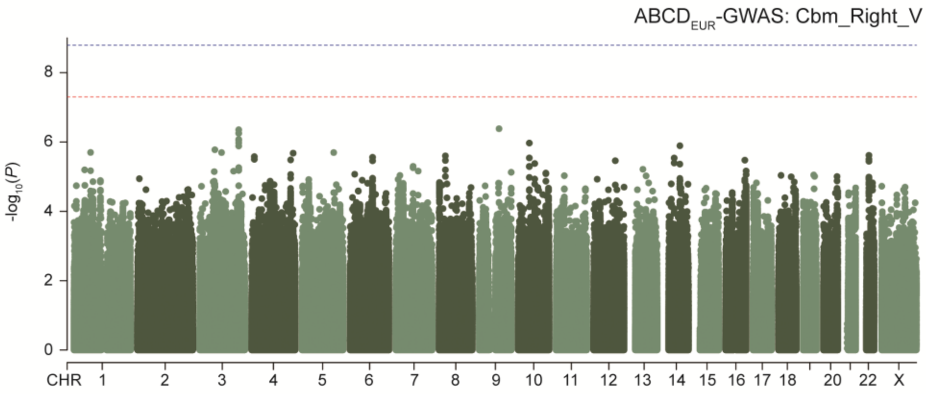
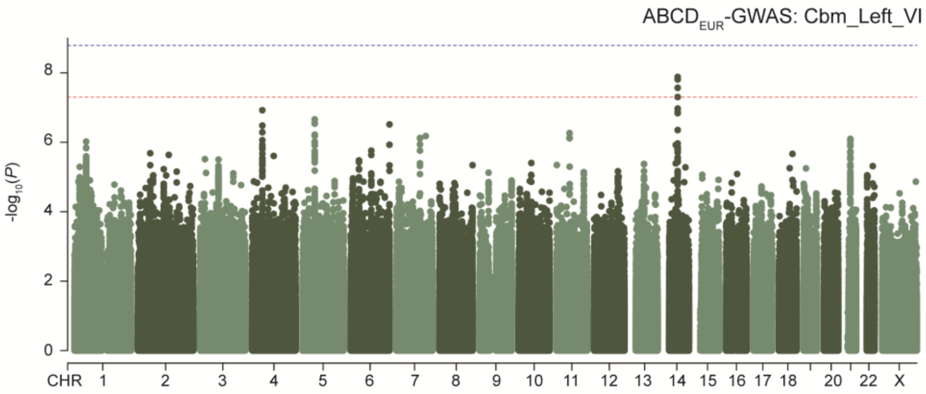
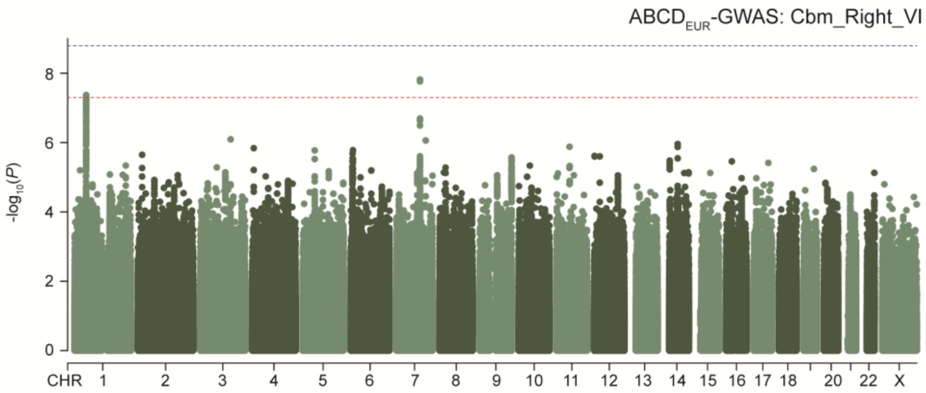


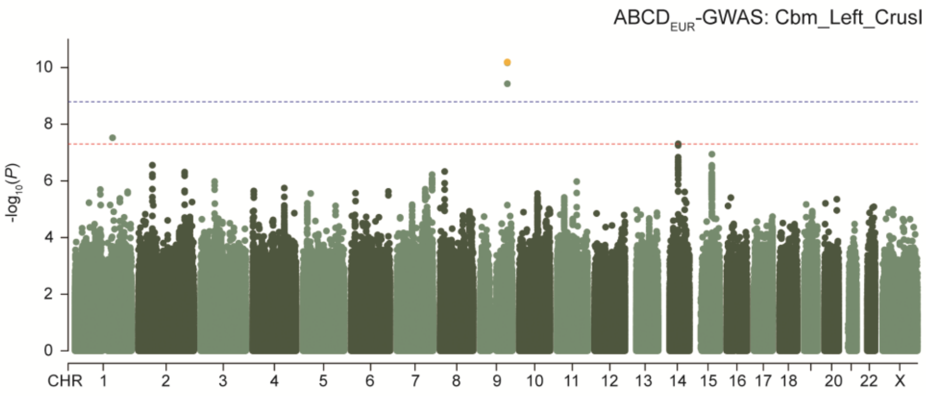
ABCD$_{EUR}$-GWAS: Cbm_Right_V



ABCD$_{EUR}$-GWAS: Cbm_Left_VI

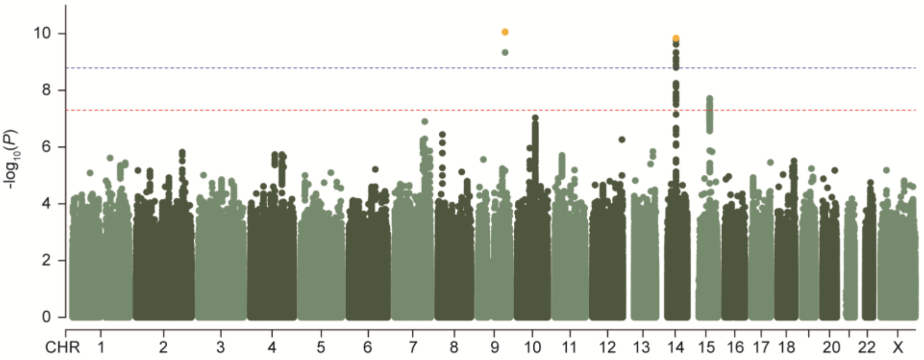


ABCD$_{EUR}$-GWAS: Cbm_Right_VI

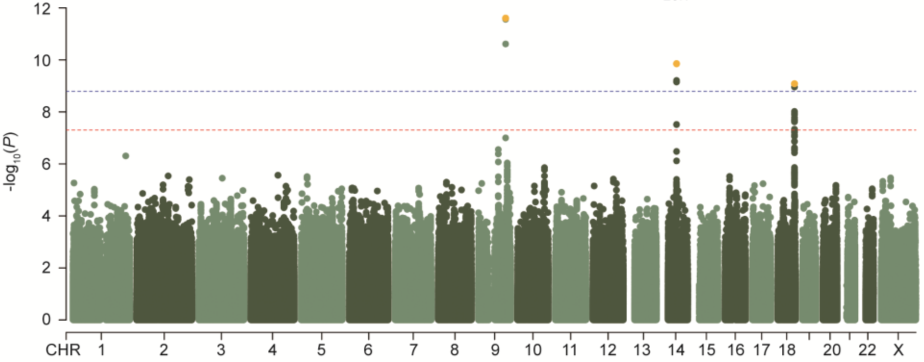


ABCD$_{EUR}$-GWAS: Cbm_Left_CrusI

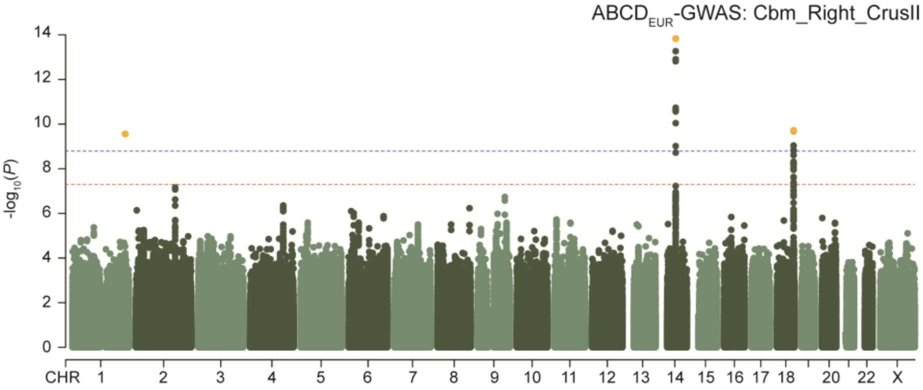
ABCD$_{EUR}$-GWAS: Cbm_Right_CrusI



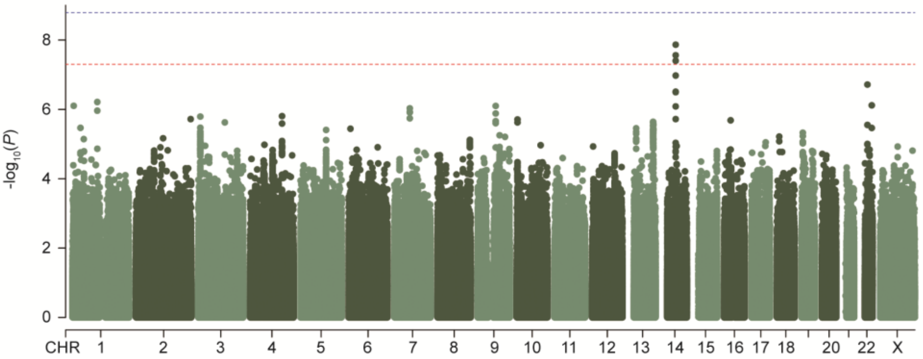
ABCD$_{EUR}$-GWAS: Cbm_Left_CrusII

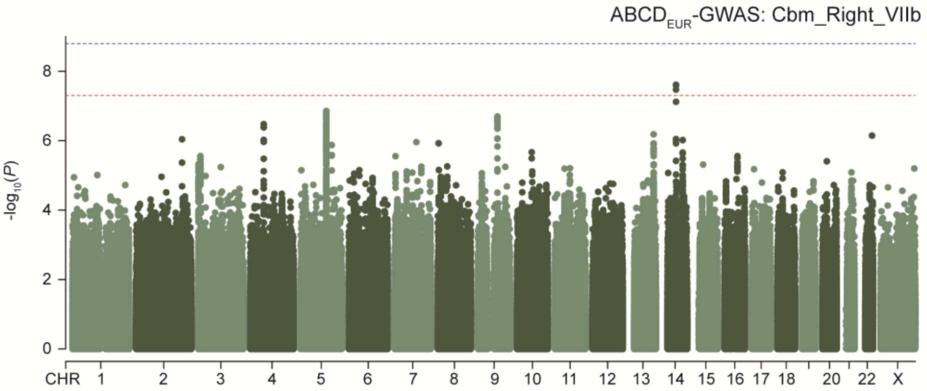


ABCD$_{EUR}$-GWAS: Cbm_Right_CrusII



ABCD$_{EUR}$-GWAS: Cbm_Left_VIIb

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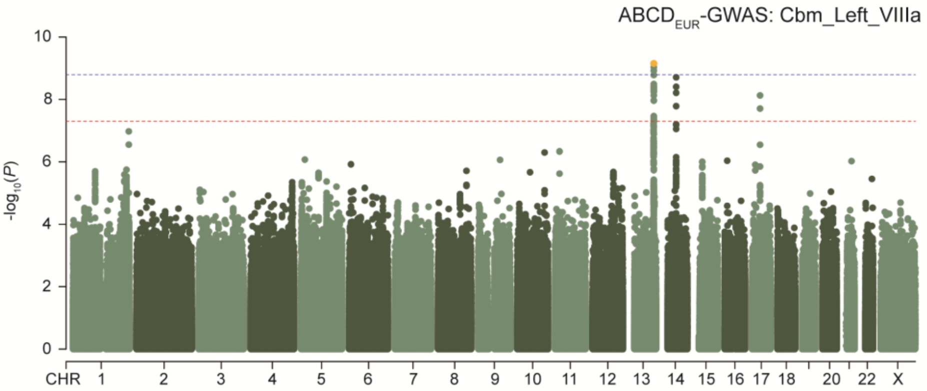
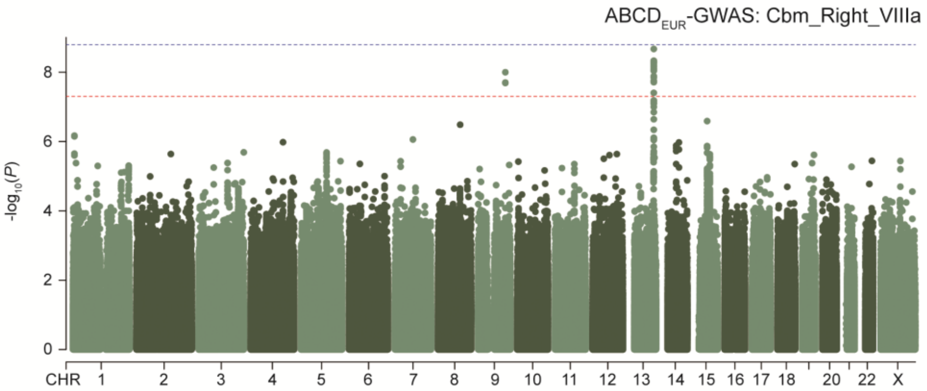

ABCD$_{EUR}$-GWAS: Cbm_Left_VIIIa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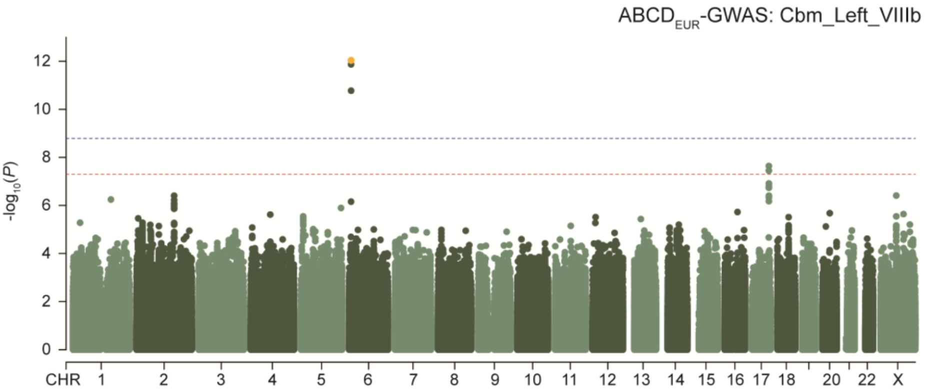
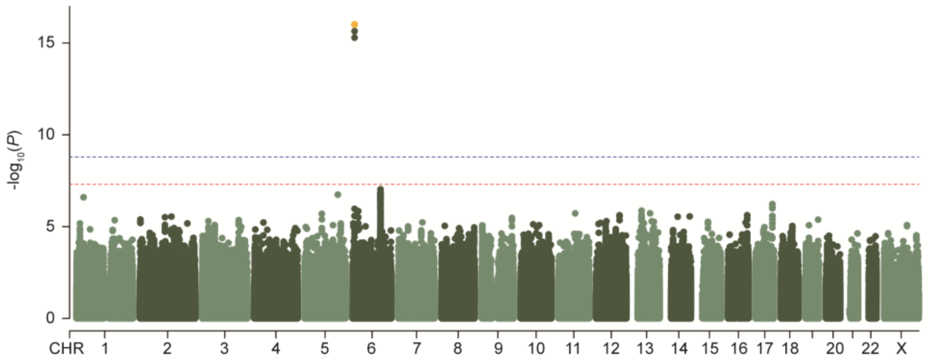
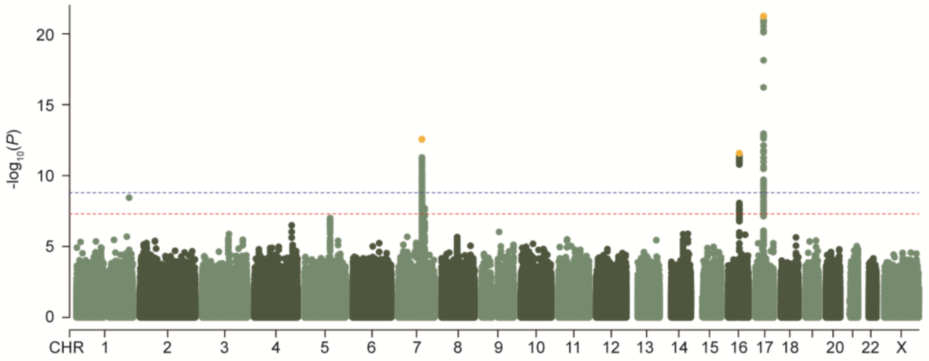

ABCD$_{EUR}$-GWAS: Cbm_Left_VIIIb

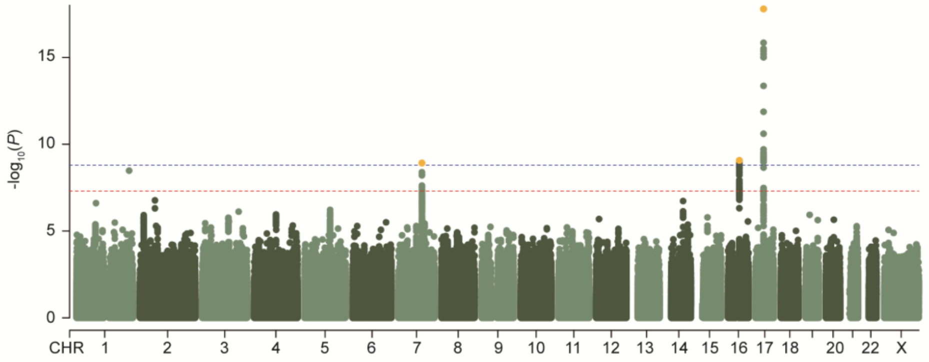
ABCD$_{EUR}$-GWAS: Cbm_Right_VIIIb



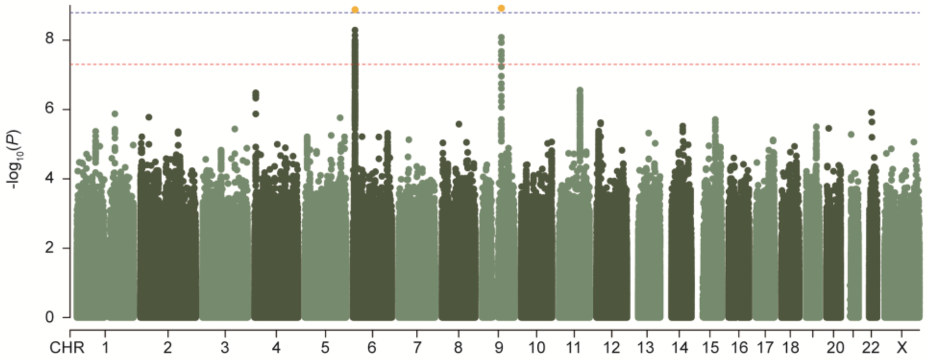
ABCD$_{EUR}$-GWAS: Cbm_Left_IX

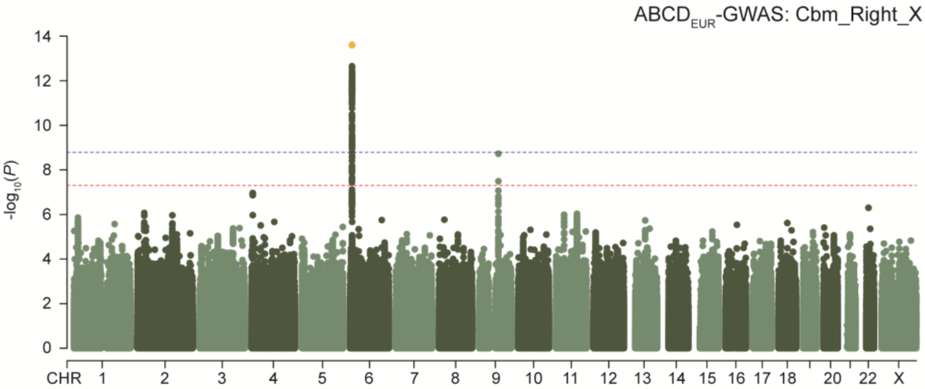


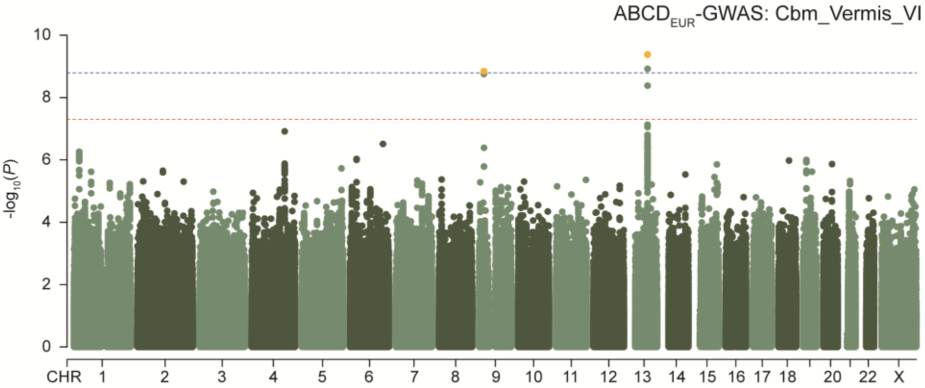
ABCD$_{EUR}$-GWAS: Cbm_Right_IX

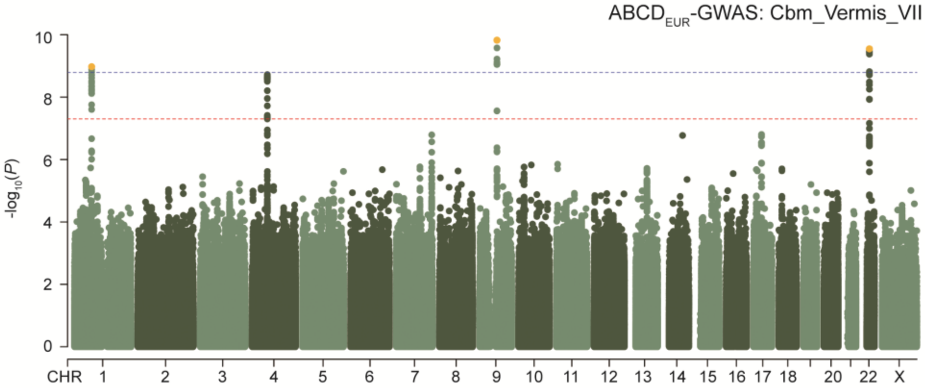


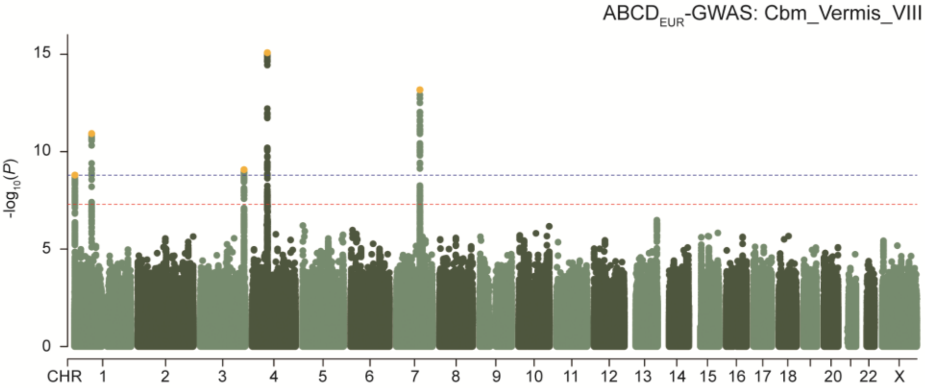
ABCD$_{EUR}$-GWAS: Cbm_Left_X

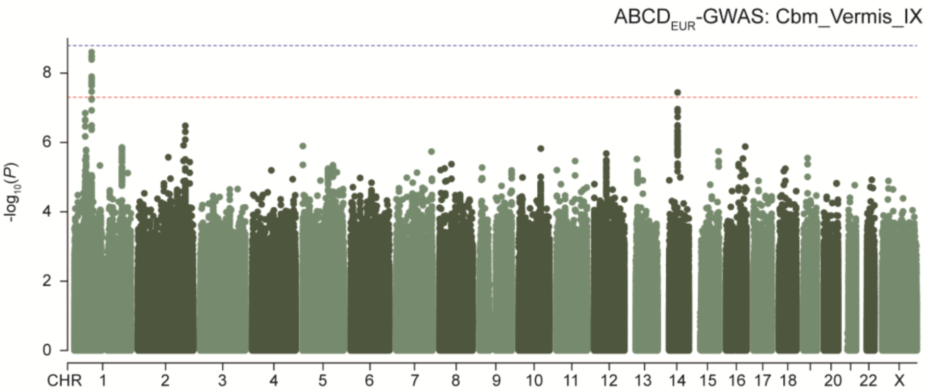


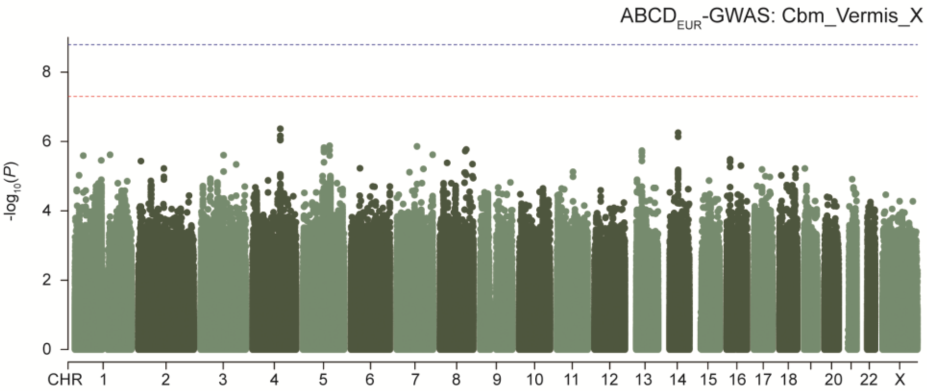

ABCD$_{EUR}$-GWAS: Cbm_Right_X

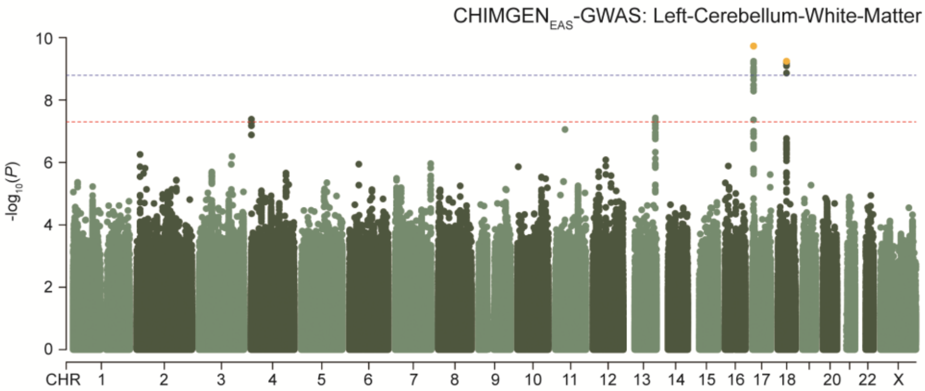

ABCD$_{EUR}$-GWAS: Cbm_Vermis_VI

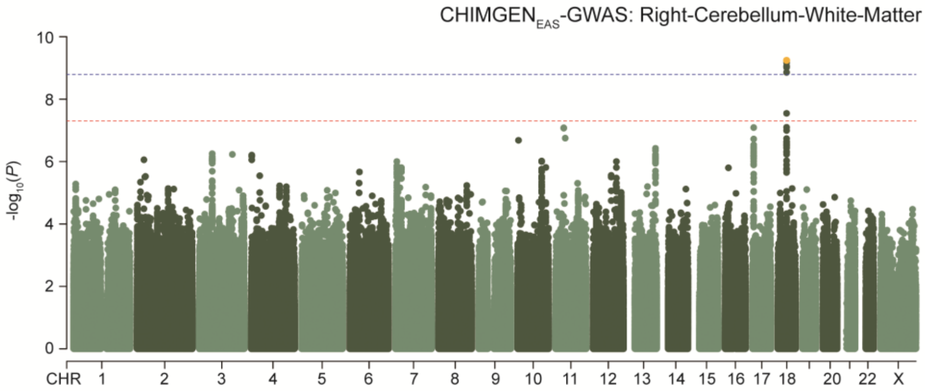

ABCD$_{EUR}$-GWAS: Cbm_Vermis_VII

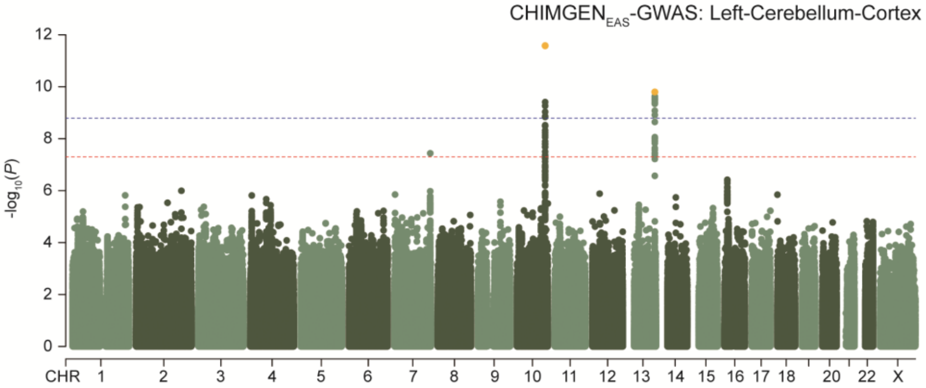

ABCD$_{EUR}$-GWAS: Cbm_Vermis_VIII

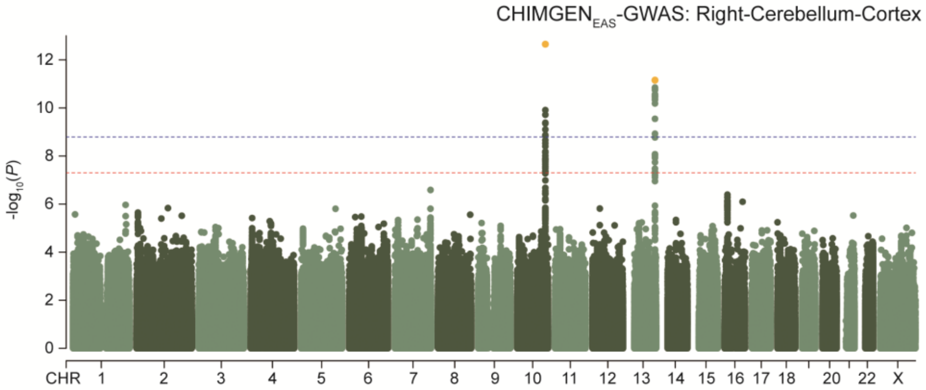

ABCD$_{EUR}$-GWAS: Cbm_Vermis_IX

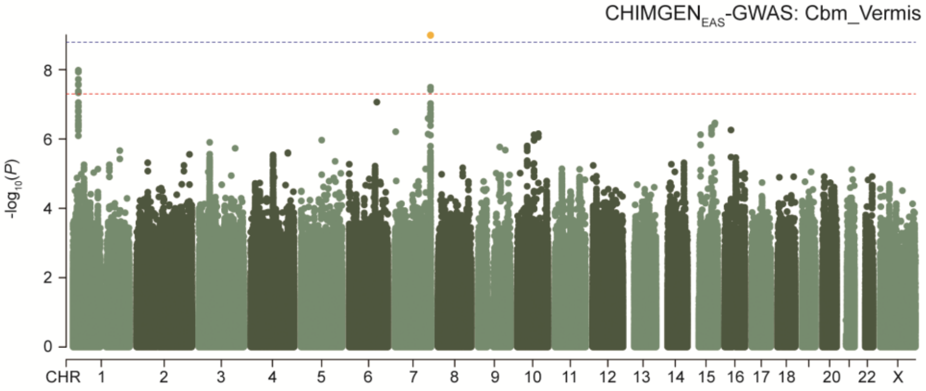

ABCD$_{EUR}$-GWAS: Cbm_Vermis_X

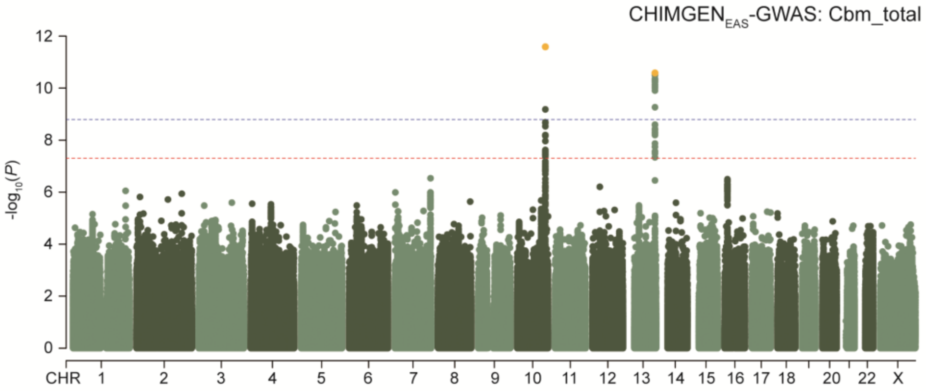

CHIMGEN$_{EAS}$-GWAS: Left-Cerebellum-White-Matter


CHIMGEN$_{EAS}$-GWAS: Right-Cerebellum-White-Matter

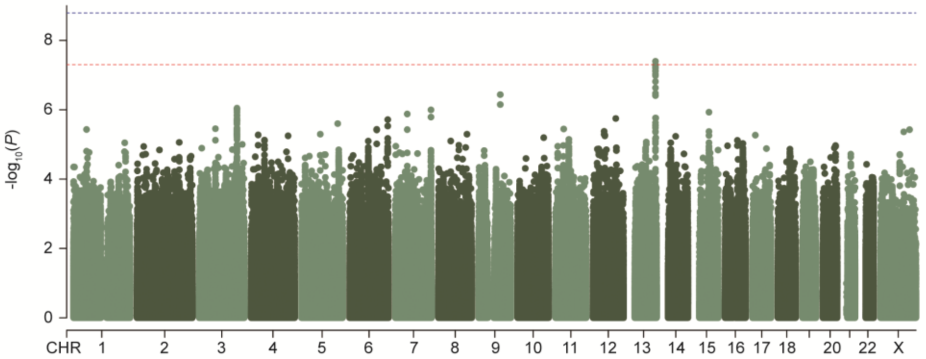

CHIMGEN$_{EAS}$-GWAS: Left-Cerebellum-Cortex


CHIMGEN$_{EAS}$-GWAS: Right-Cerebellum-Cortex

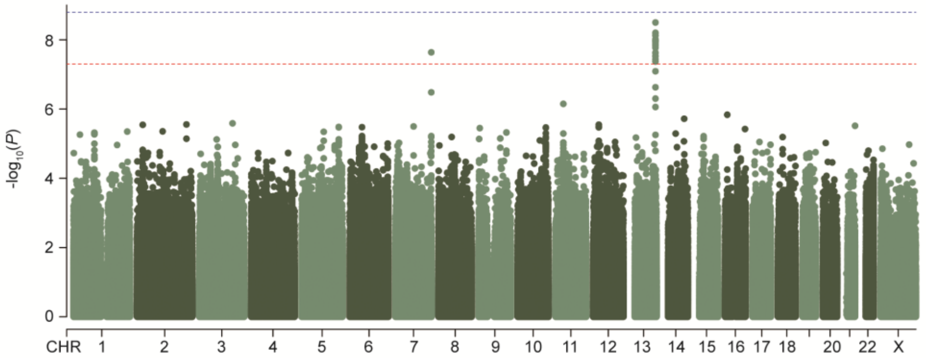

CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis


CHIMGEN$_{EAS}$-GWAS: Cbm_total

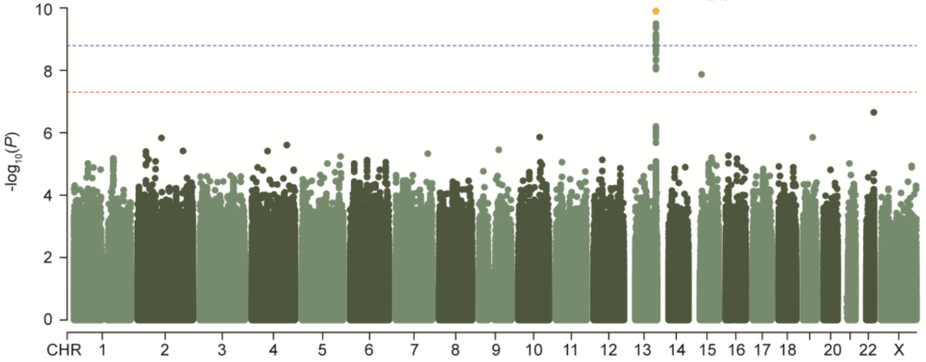
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_I_IV



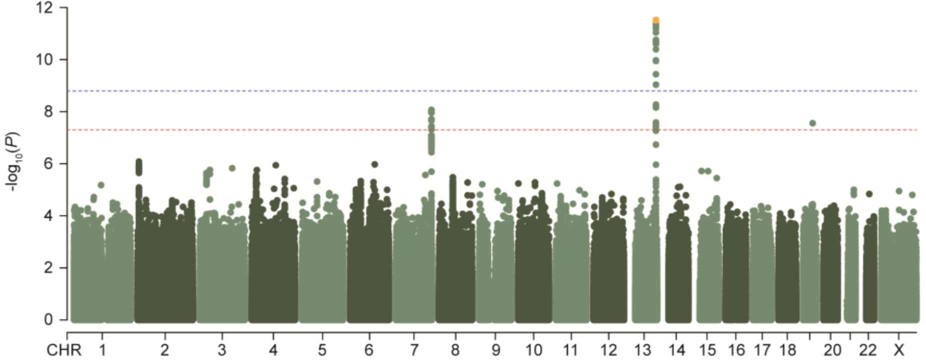
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_I_IV



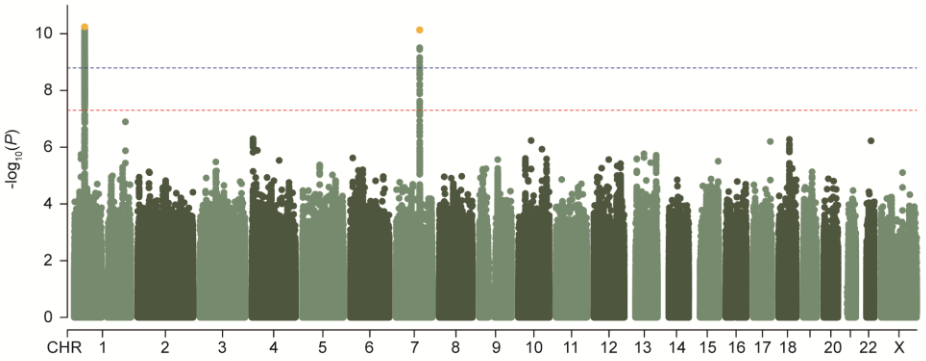
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_V



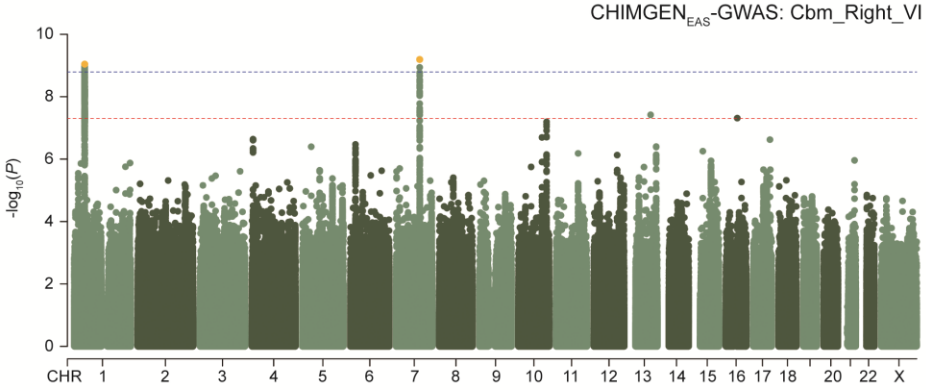
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_V



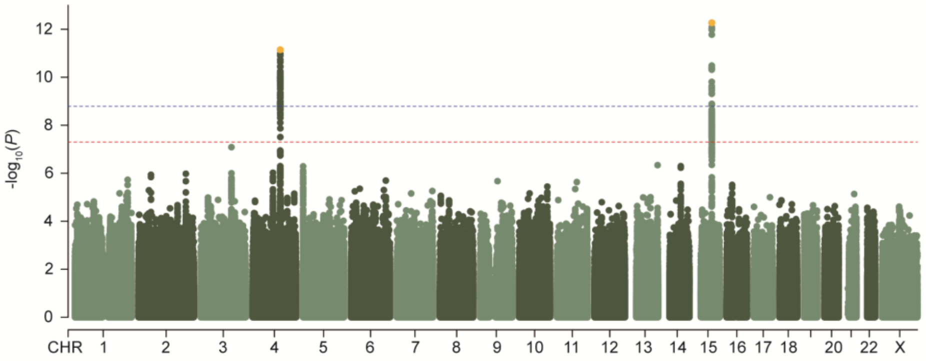
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VI



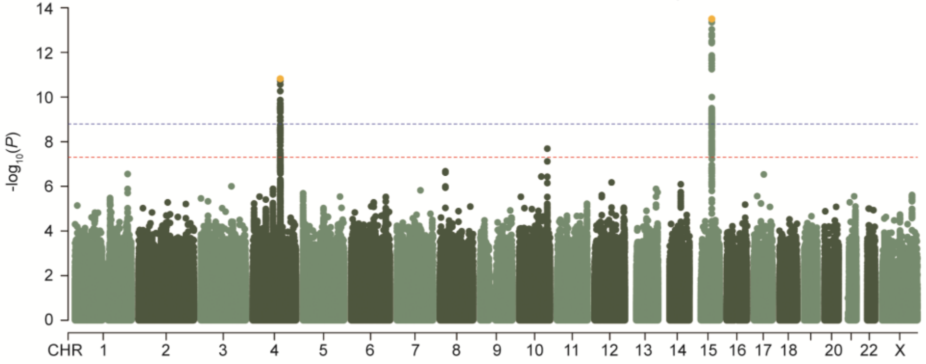
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VI

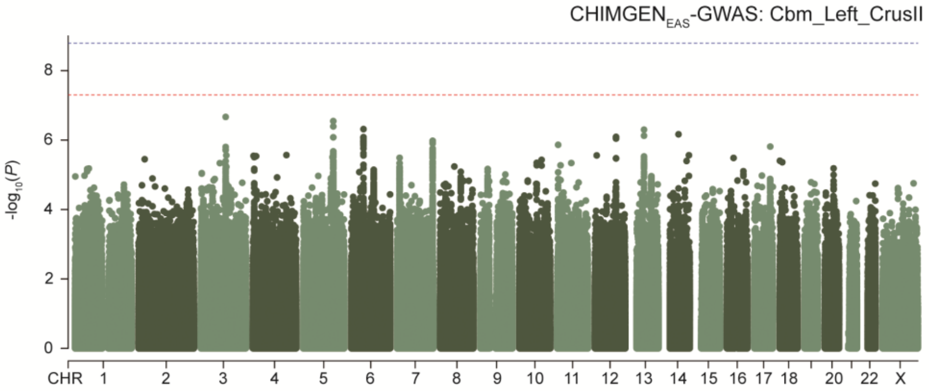


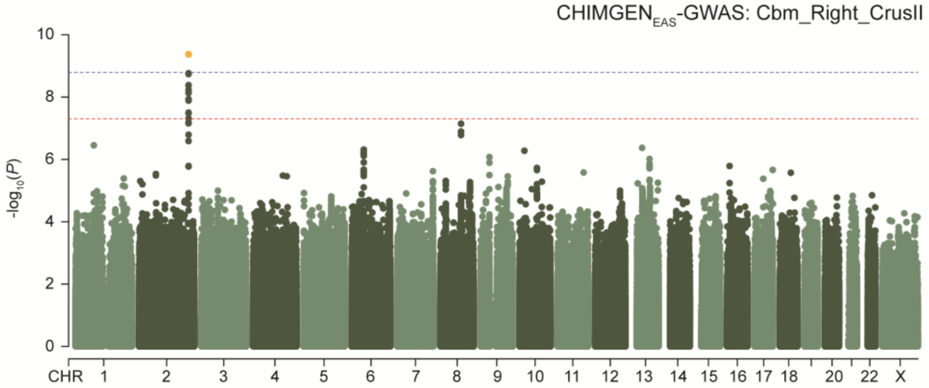
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_CrusI



CHIMGEN$_{EAS}$-GWAS: Cbm_Right_CrusI




CHIMGEN$_{EAS}$-GWAS: Cbm_Left_CrusII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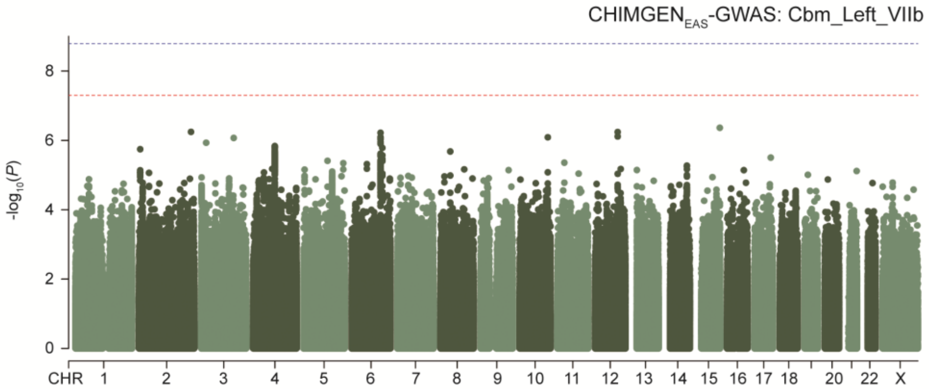
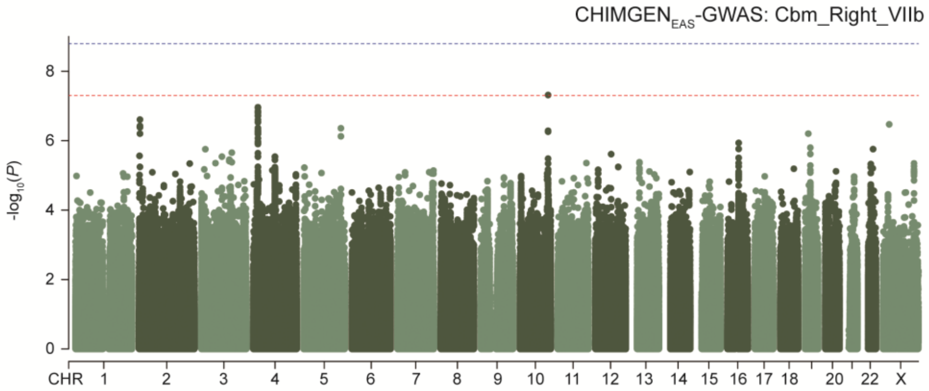
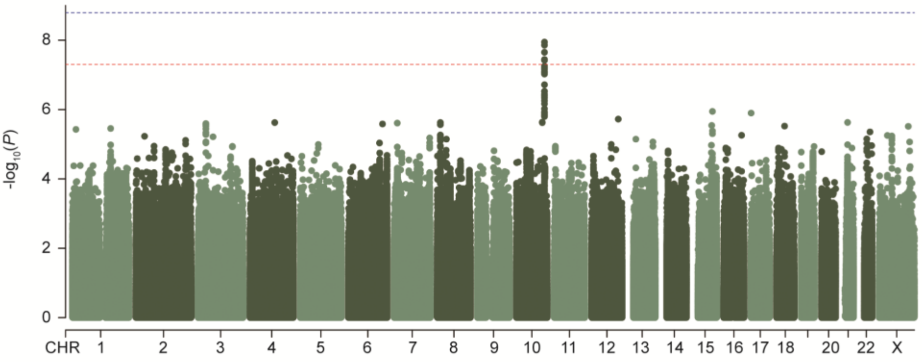
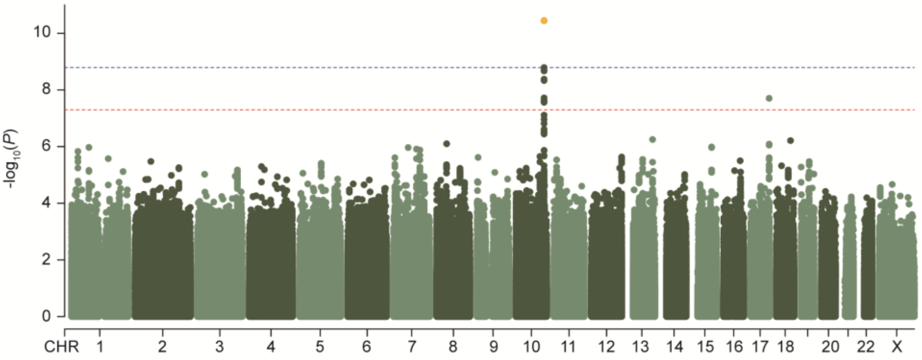
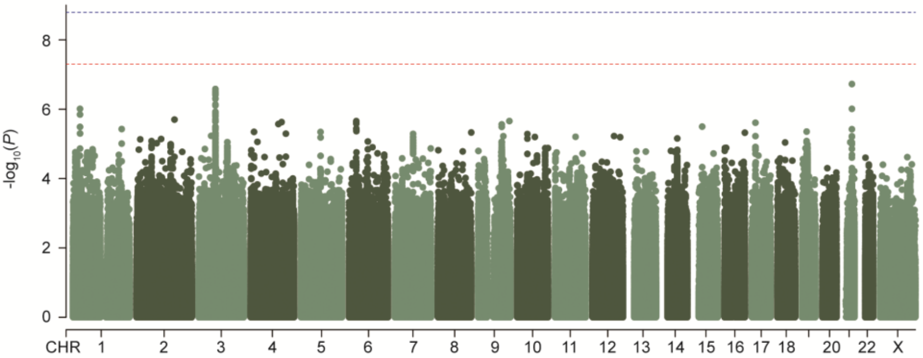
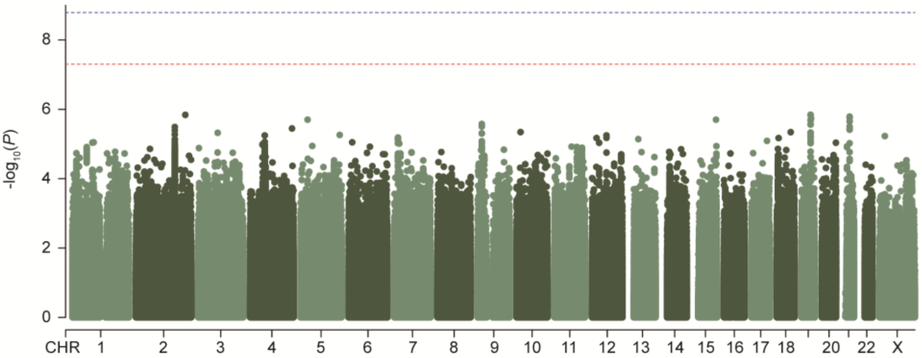

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIb

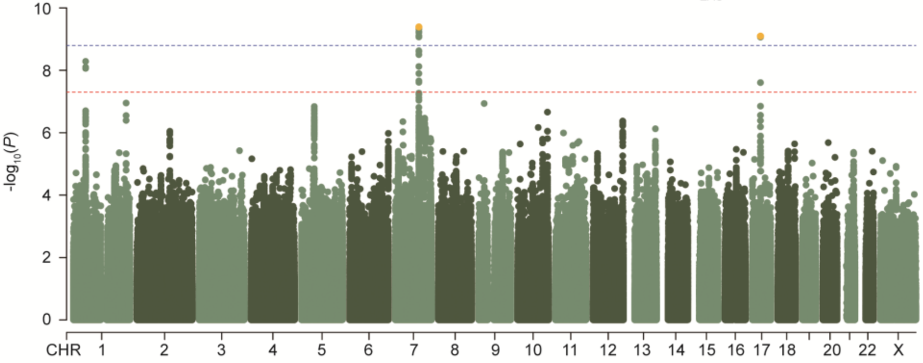

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIb


CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIIa

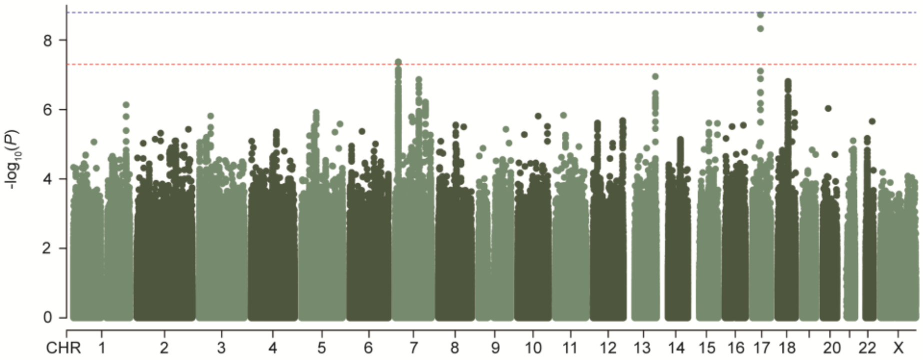

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIIa


CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIIb

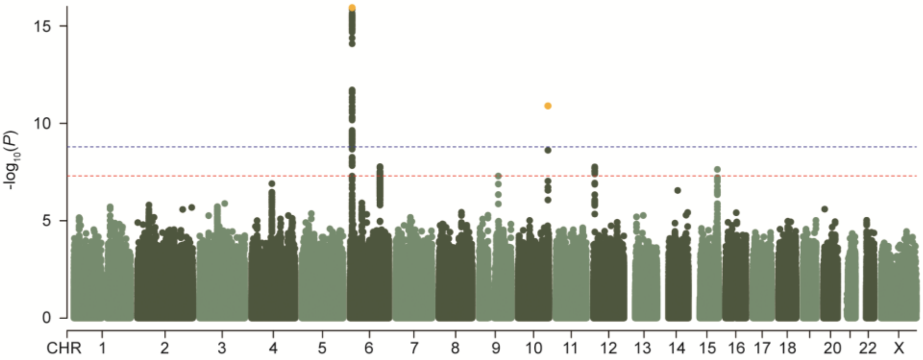

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIIb



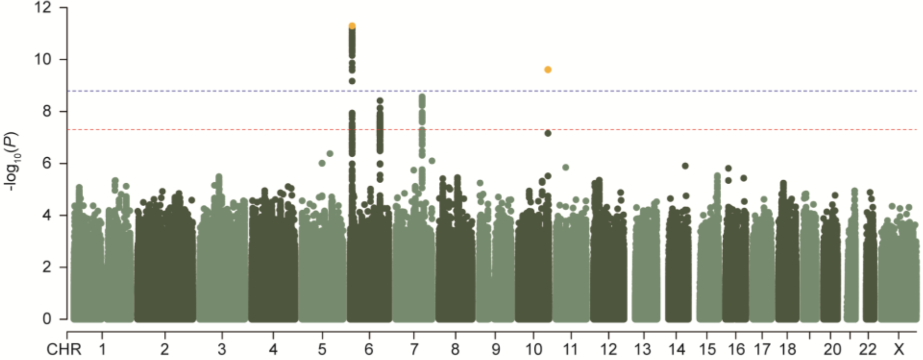
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_IX



CHIMGEN$_{EAS}$-GWAS: Cbm_Right_IX

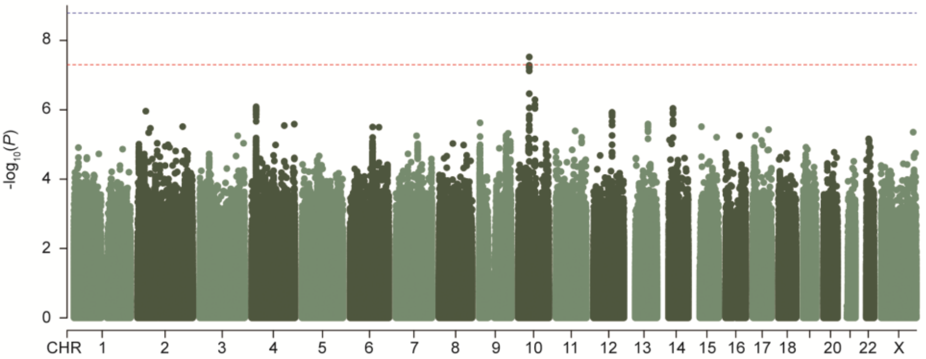


CHIMGEN$_{EAS}$-GWAS: Cbm_Left_X

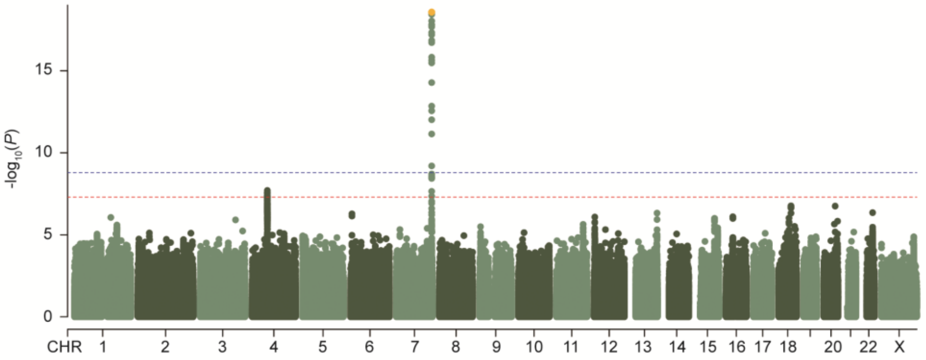


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_X

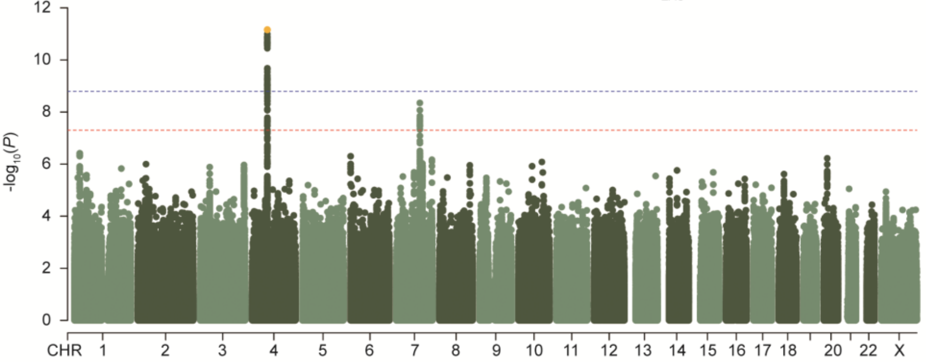
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VI



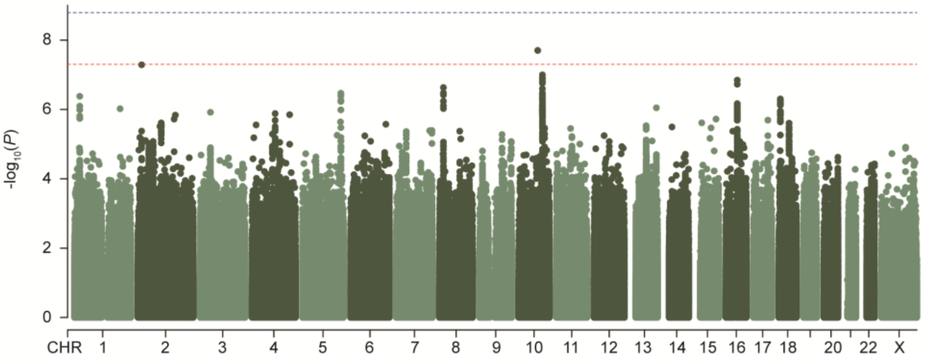
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VII



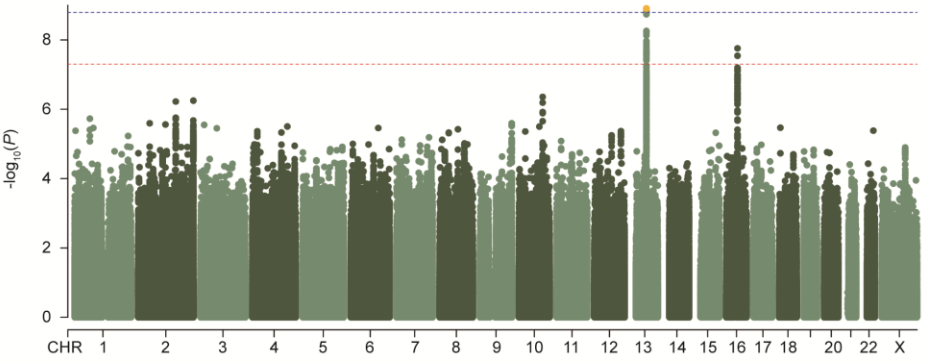
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VIII



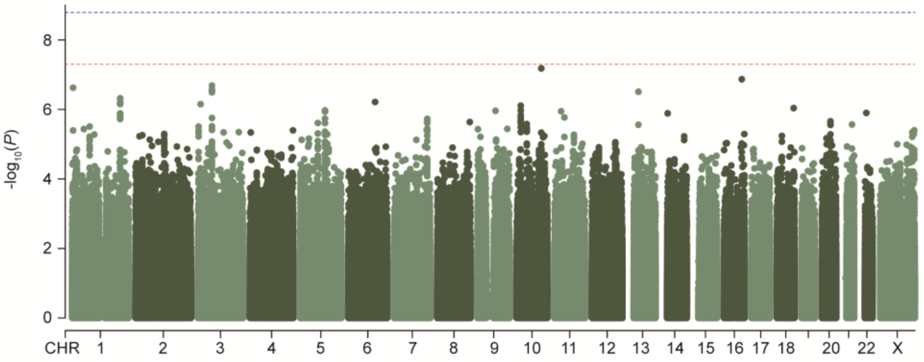
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_IX



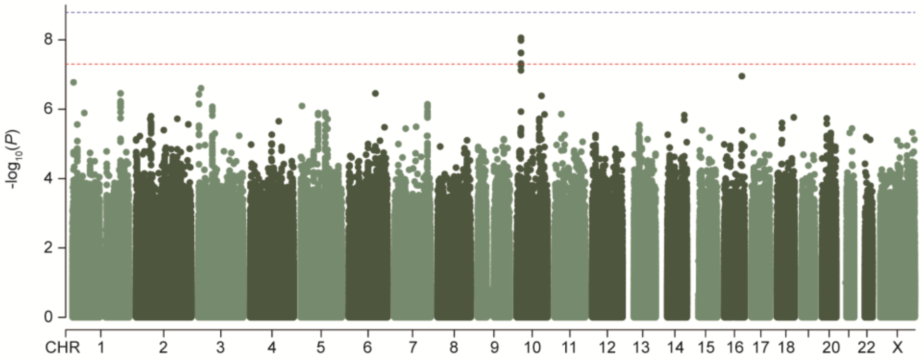
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_X



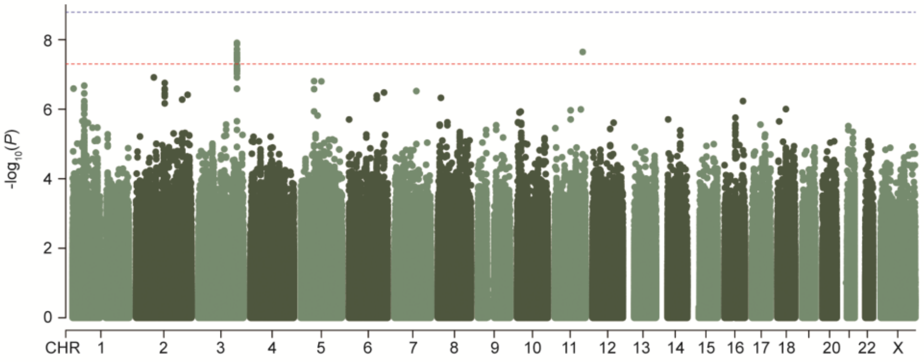
ABCD$_{AFR}$-GWAS: Left-Cerebellum-White-Matter

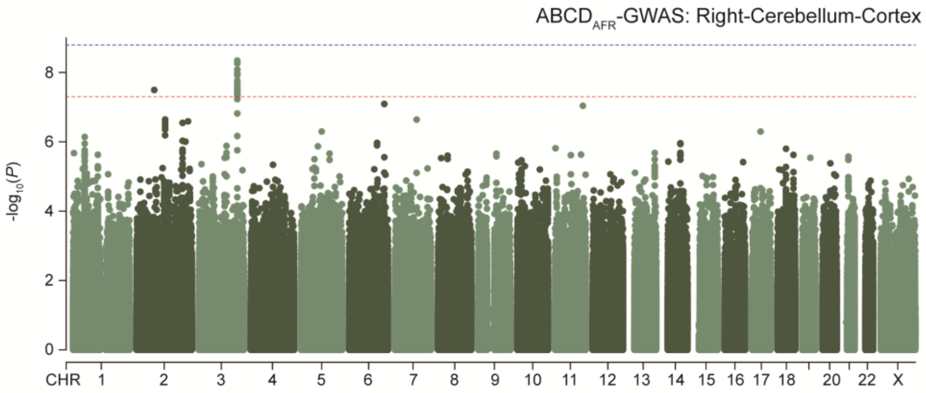


ABCD$_{AFR}$-GWAS: Right-Cerebellum-White-Matter

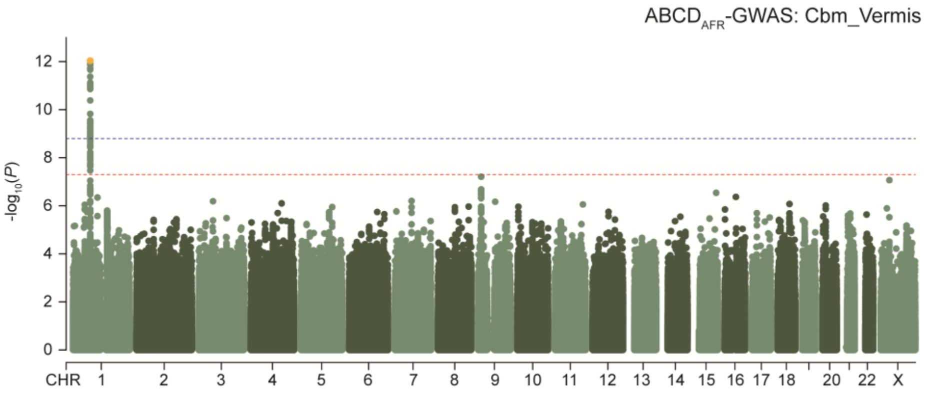


ABCD$_{AFR}$-GWAS: Left-Cerebellum-Cortex

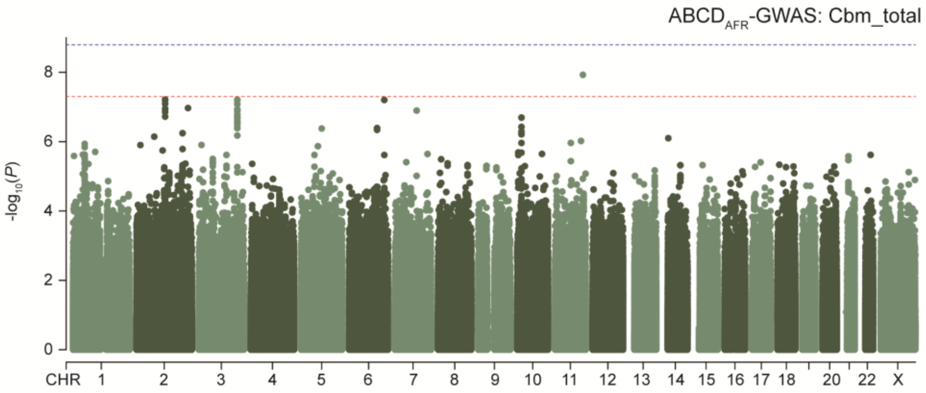




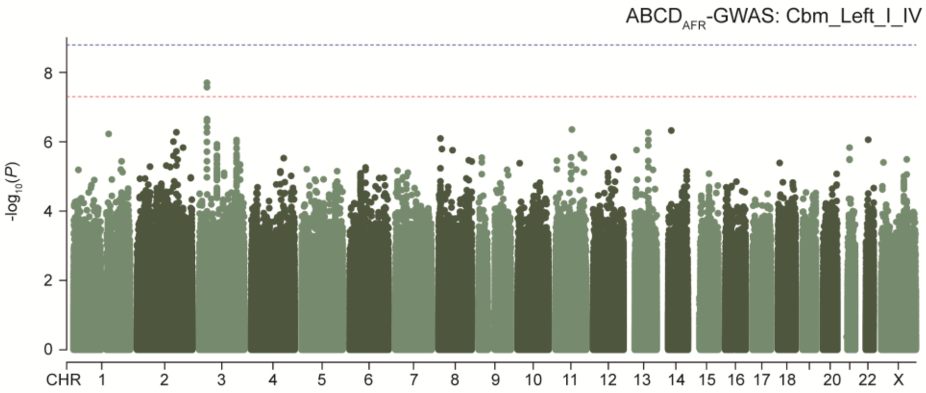
ABCD$_{AFR}$-GWAS: Right-Cerebellum-Cortex



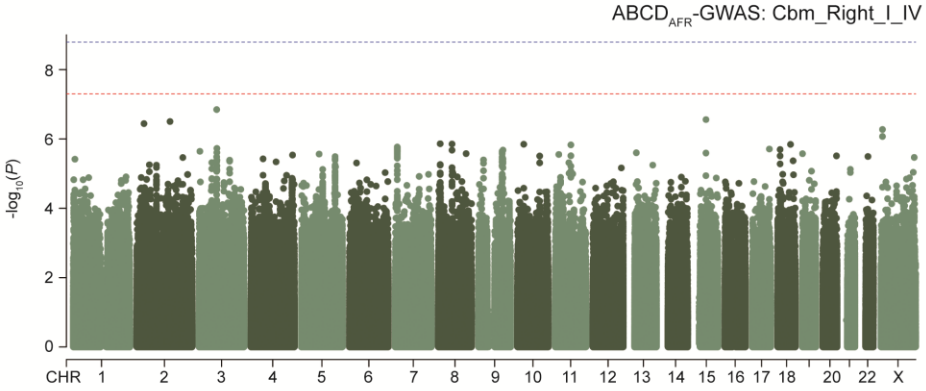
ABCD$_{AFR}$-GWAS: Cbm_Vermis



ABCD$_{AFR}$-GWAS: Cbm_total



ABCD$_{AFR}$-GWAS: Cbm_Left_I_IV


ABCD$_{AFR}$-GWAS: Cbm_Right_I_IV
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4
6
8
CHR
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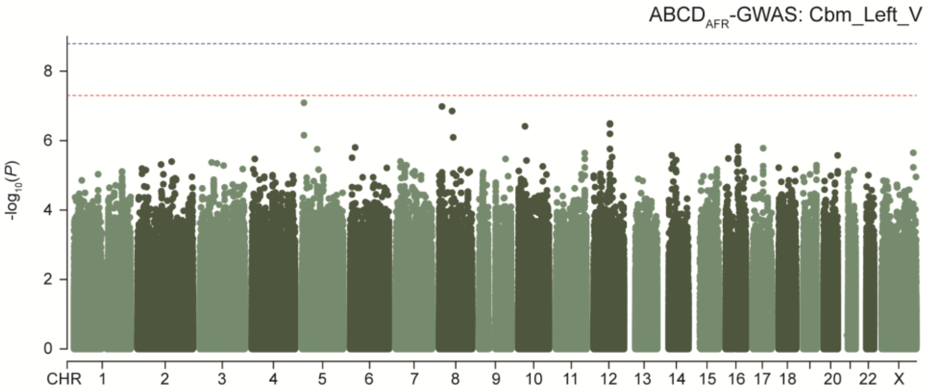
20
22
X


ABCD$_{AFR}$-GWAS: Cbm_Left_V
-log$_{10}$(P)
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6
8
CHR
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7
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11
12
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22
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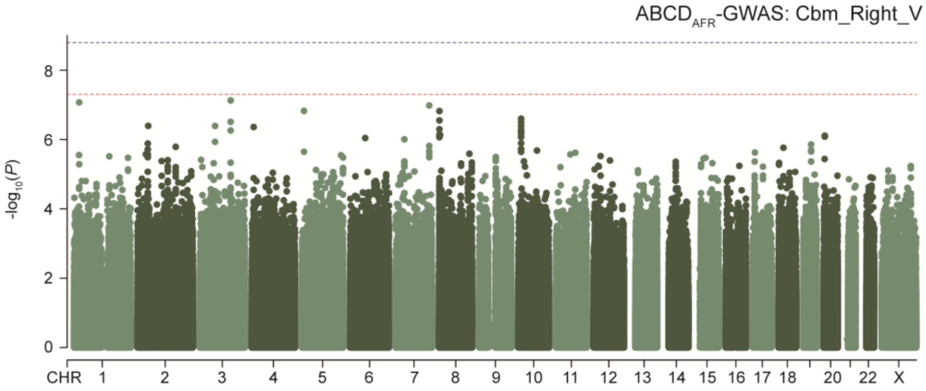
ABCD$_{AFR}$-GWAS: Cbm_Right_V
-log$_{10}$(P)
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8
CHR
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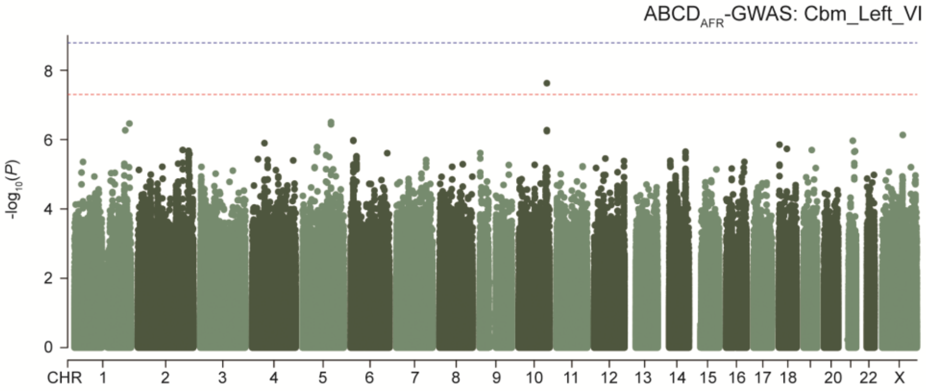
ABCD$_{AFR}$-GWAS: Cbm_Left_VI
-log$_{10}$(P)
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CHR
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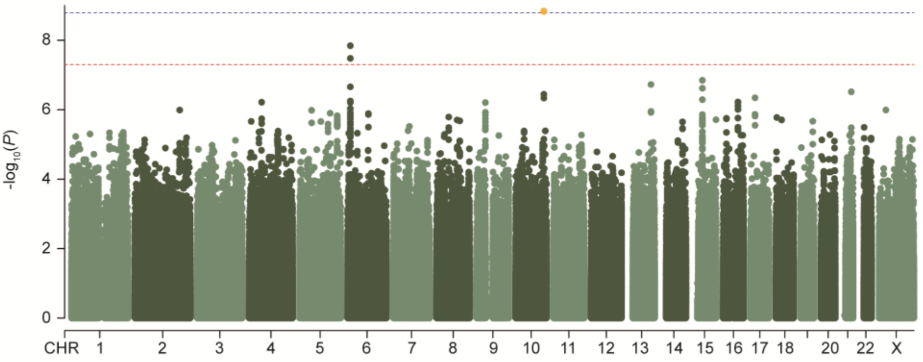
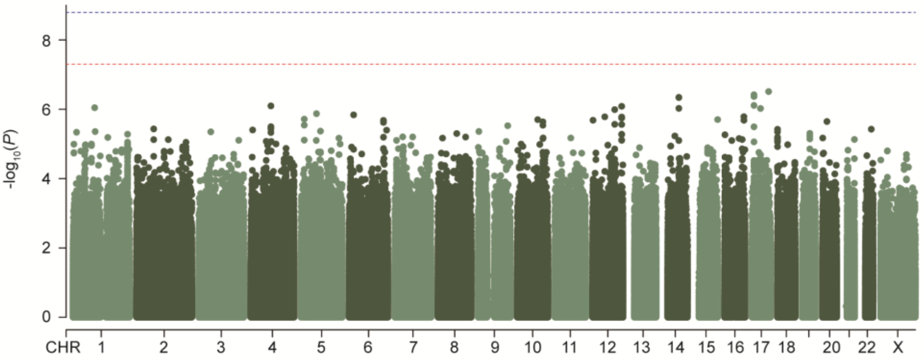
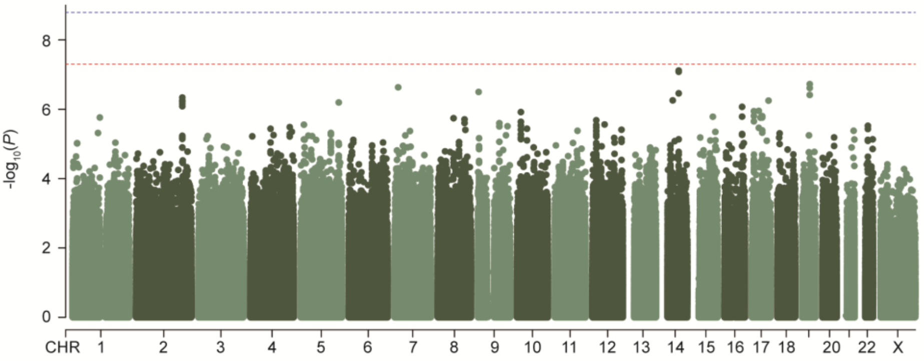


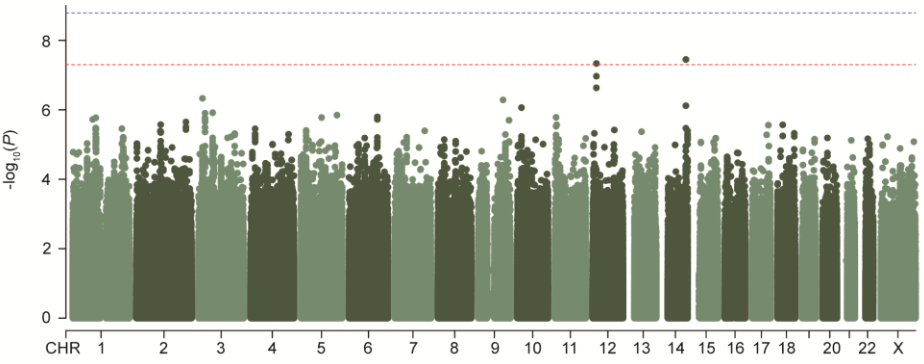
ABCD$_{AFR}$-GWAS: Cbm_Right_VI



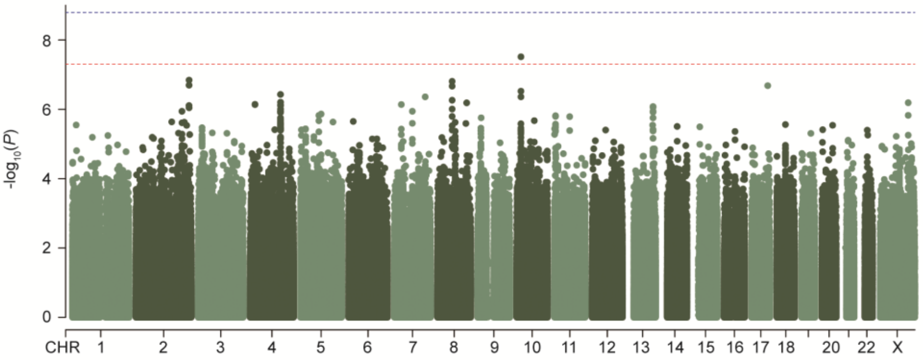
ABCD$_{AFR}$-GWAS: Cbm_Left_CrusI

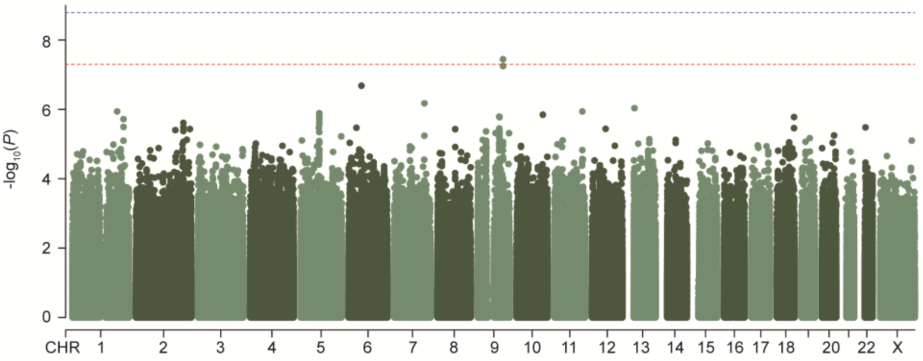


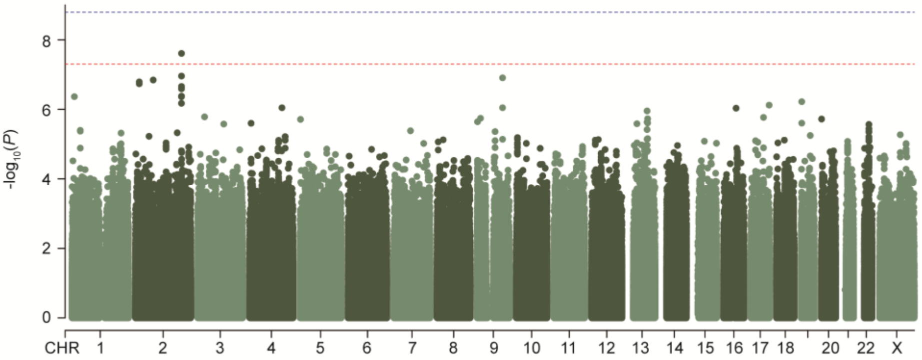
ABCD$_{AFR}$-GWAS: Cbm_Right_CrusI

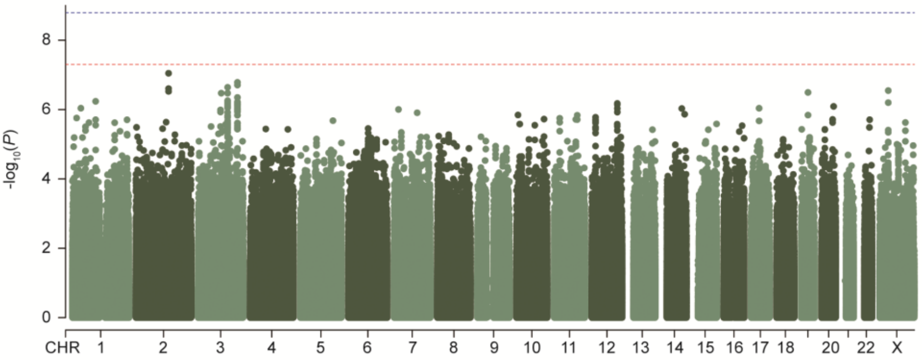


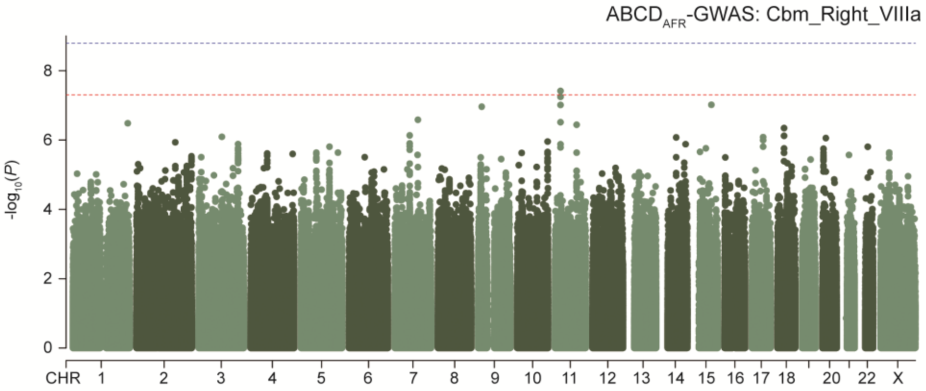
ABCD$_{AFR}$-GWAS: Cbm_Left_CrusII


ABCD$_{AFR}$-GWAS: Cbm_Right_CrusII

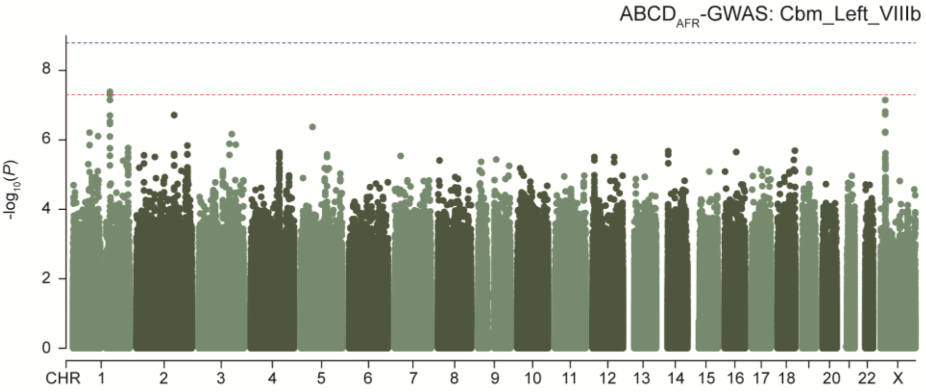

ABCD$_{AFR}$-GWAS: Cbm_Left_VIIb


ABCD$_{AFR}$-GWAS: Cbm_Right_VIIb

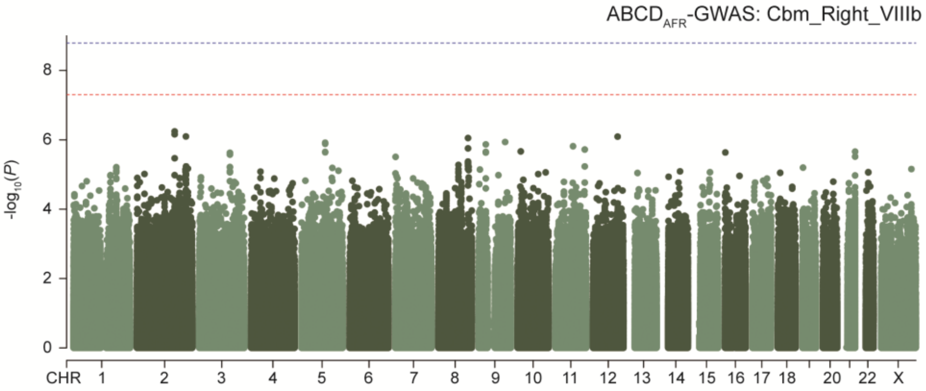

ABCD$_{AFR}$-GWAS: Cbm_Left_VIIIa



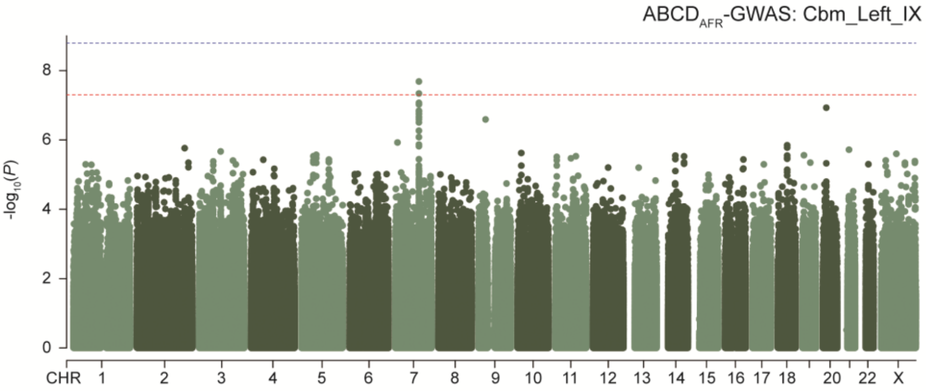
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIIa



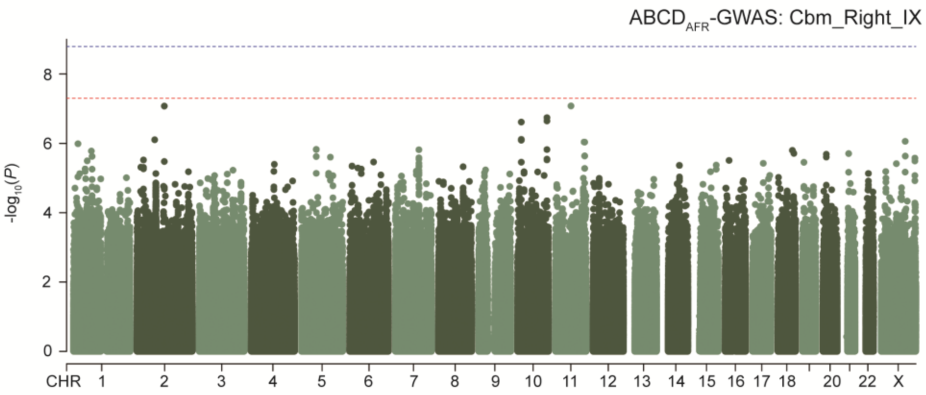
ABCD$_{AFR}$-GWAS: Cbm_Left_VIIIb

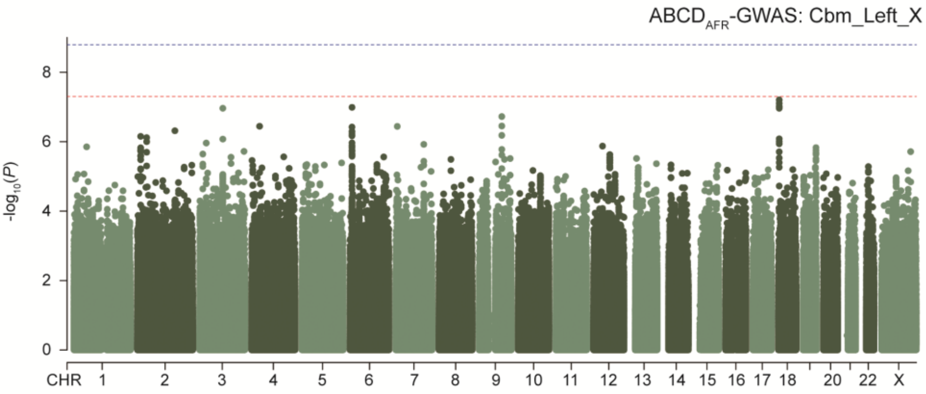


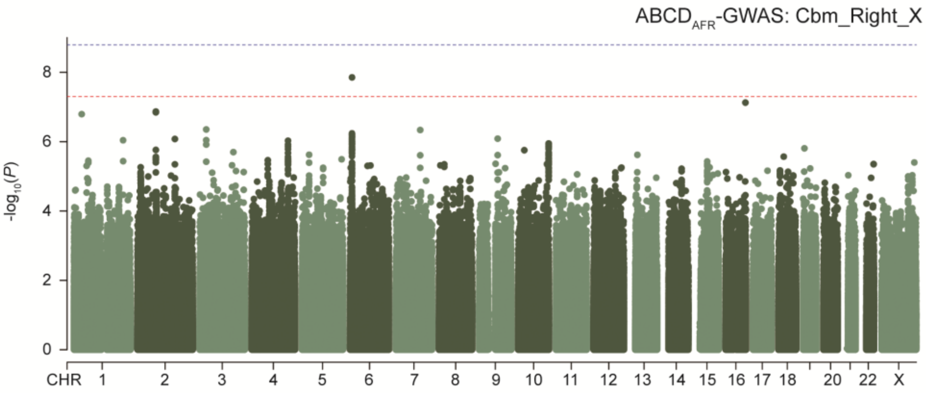
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIIb

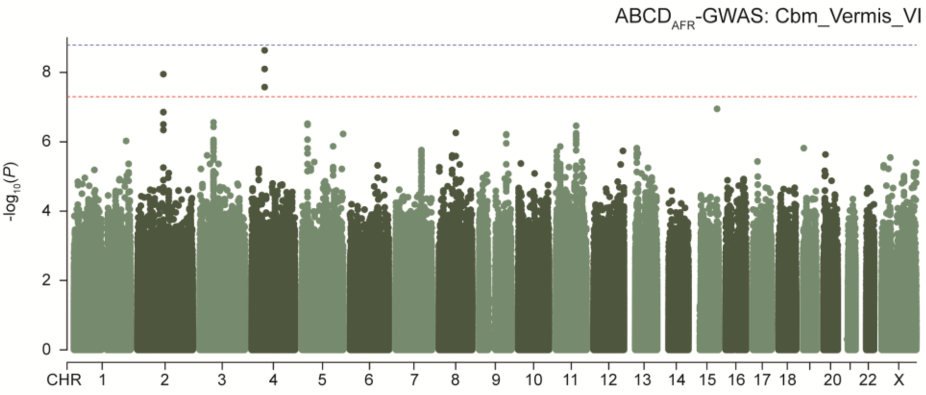


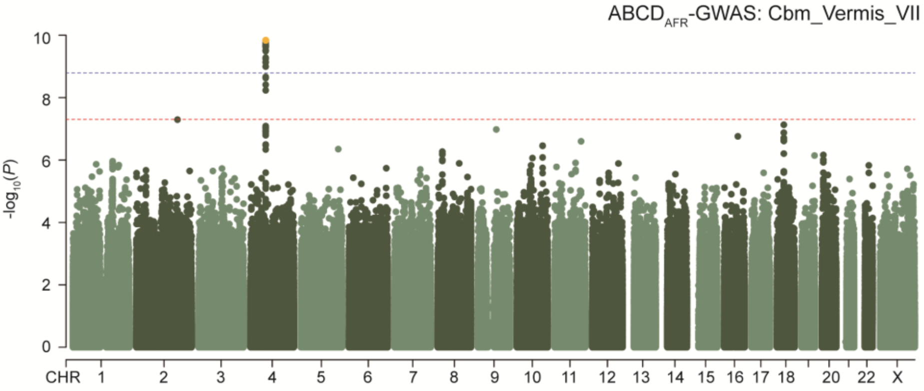
ABCD$_{AFR}$-GWAS: Cbm_Left_IX

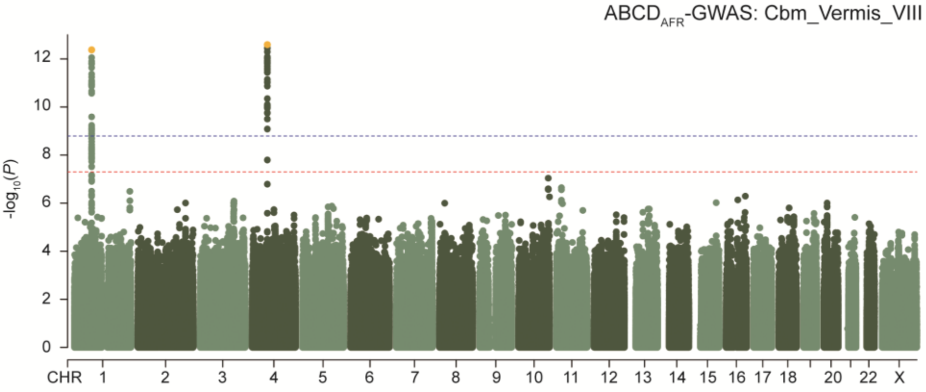

ABCD$_{AFR}$-GWAS: Cbm_Right_IX


ABCD$_{AFR}$-GWAS: Cbm_Left_X


ABCD$_{AFR}$-GWAS: Cbm_Right_X


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VI


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VII
-log$_{10}$(P)
0
2
4
6
8
10
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VIII
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4
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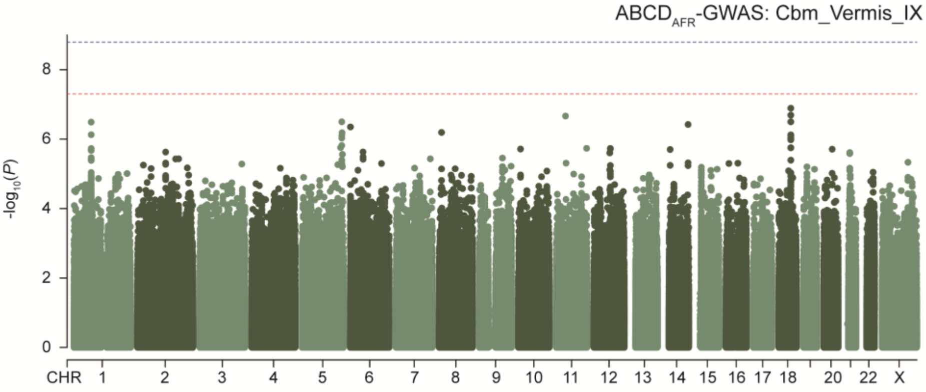
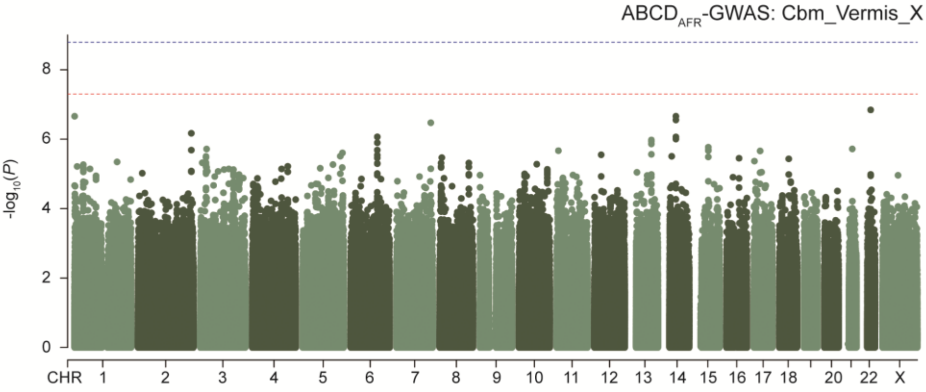
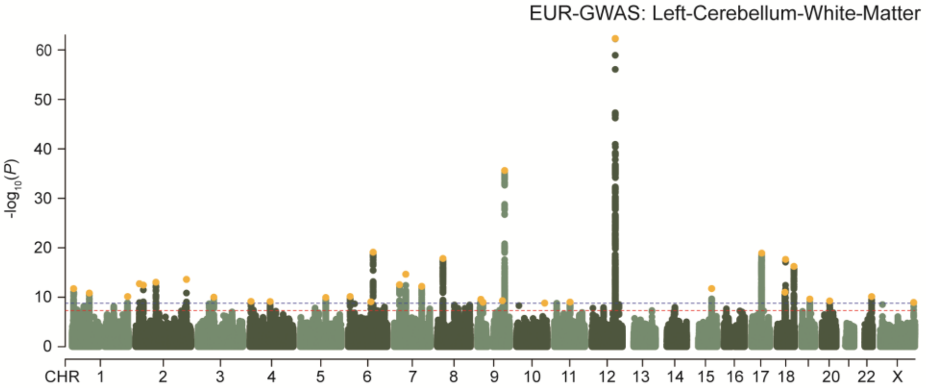
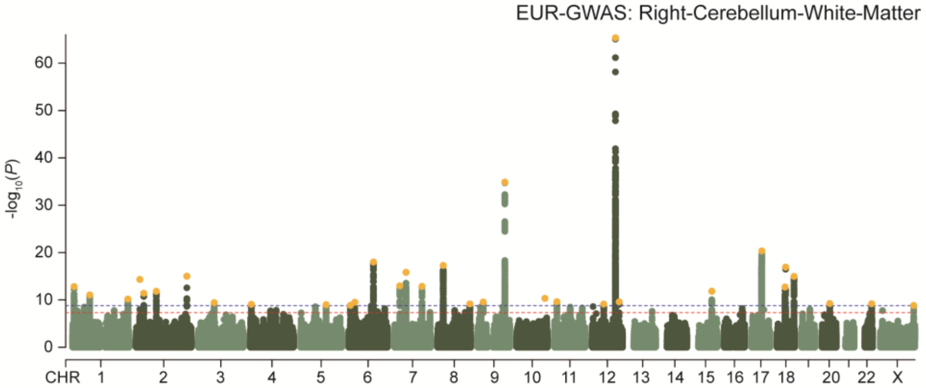
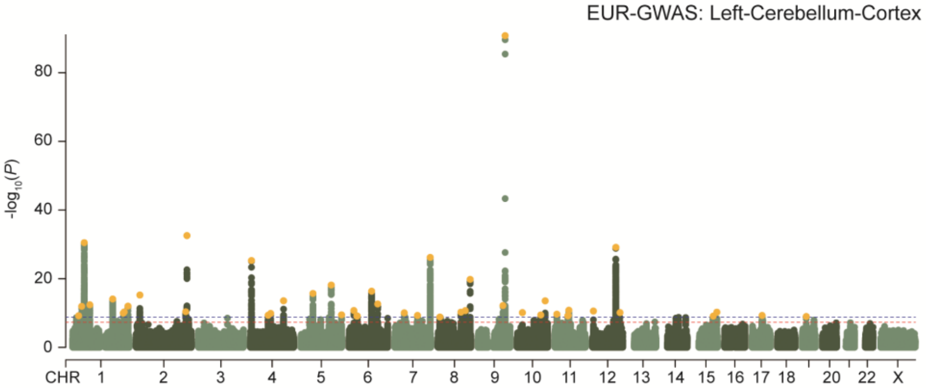
8
10
12
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

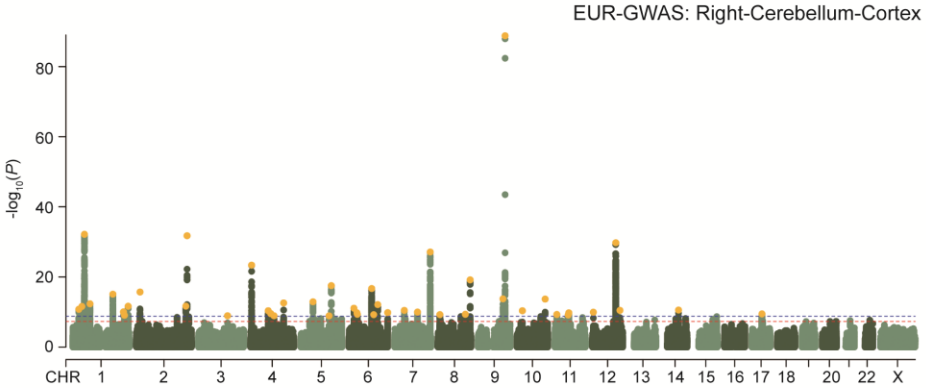

ABCD$_{AFR}$-GWAS: Cbm_Vermis_IX
-log$_{10}$(P)
0
2
4
6
8
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

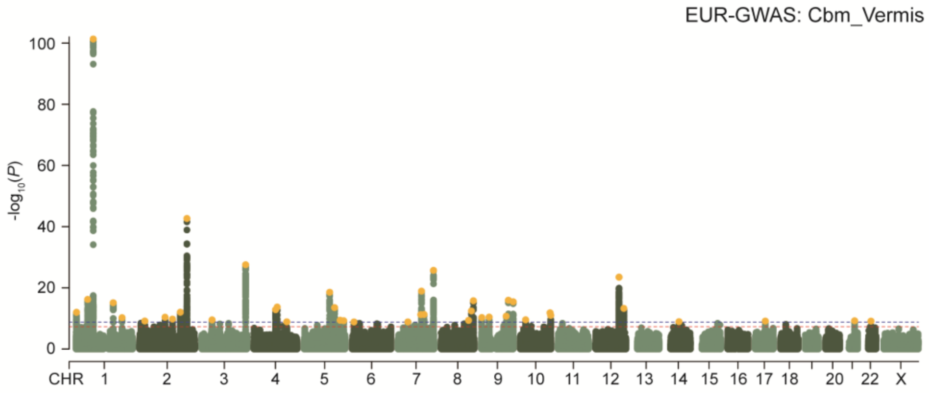

ABCD$_{AFR}$-GWAS: Cbm_Vermis_X
-log$_{10}$(P)
0
2
4
6
8
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

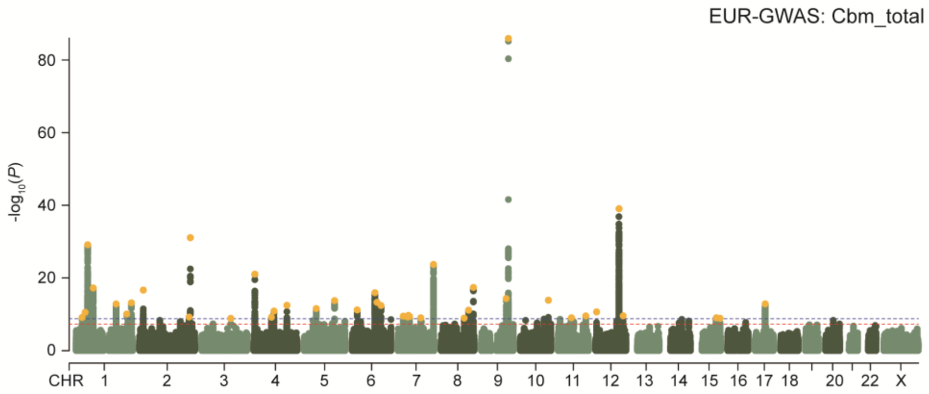

EUR-GWAS: Left-Cerebellum-White-Matter

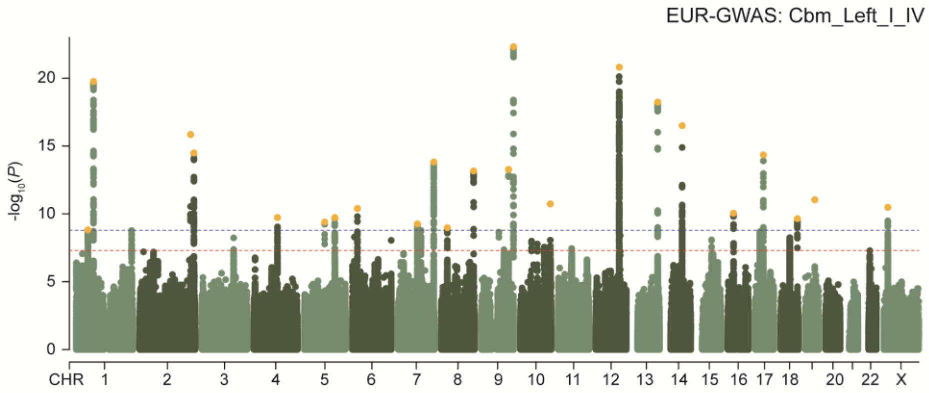

EUR-GWAS: Right-Cerebellum-White-Matter

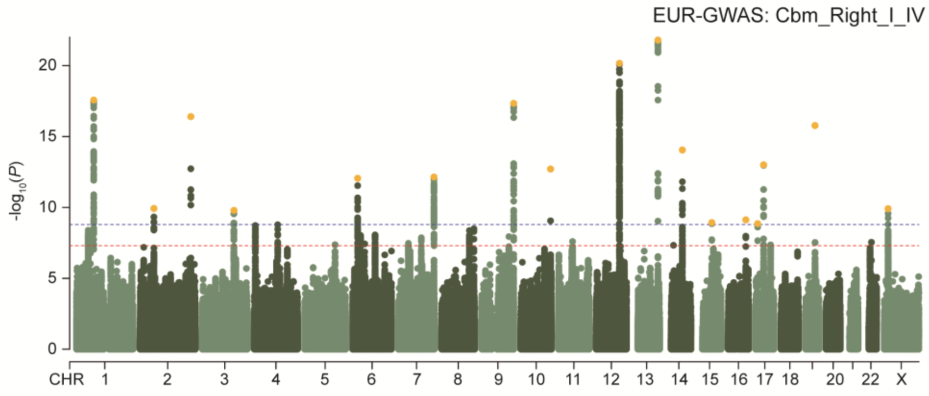

EUR-GWAS: Left-Cerebellum-Cortex

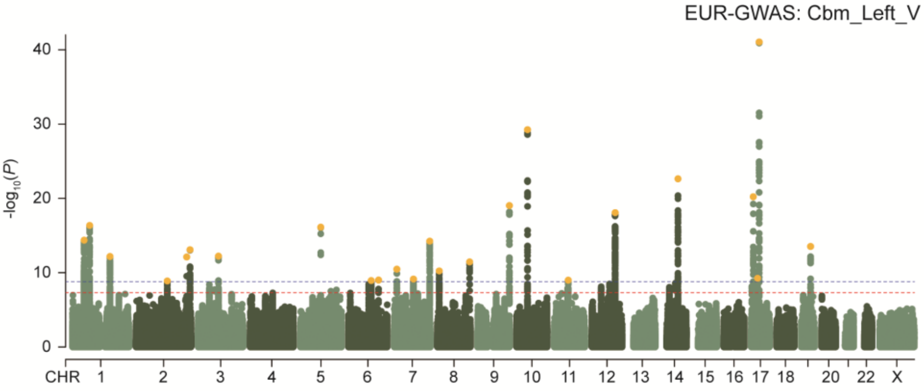

EUR-GWAS: Right-Cerebellum-Cortex

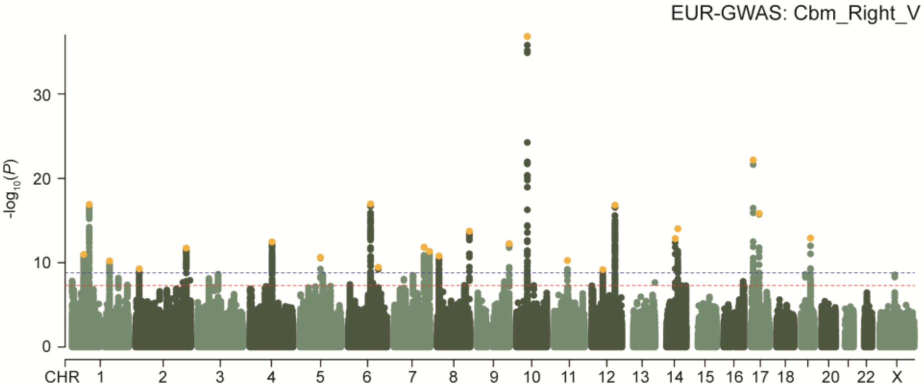

EUR-GWAS: Cbm_Vermis

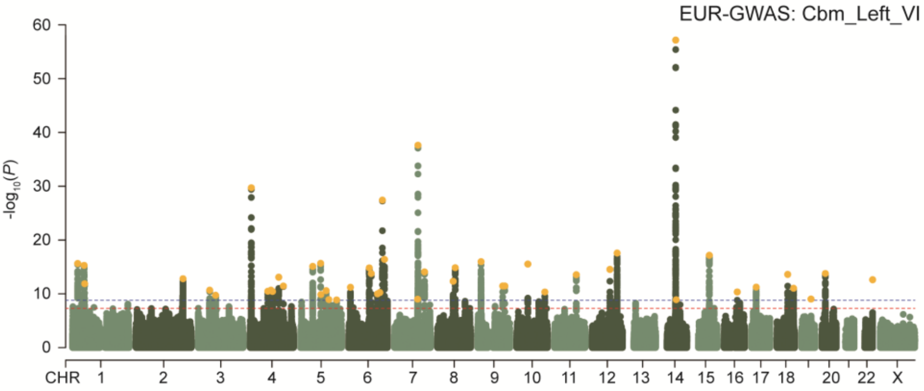

EUR-GWAS: Cbm_total

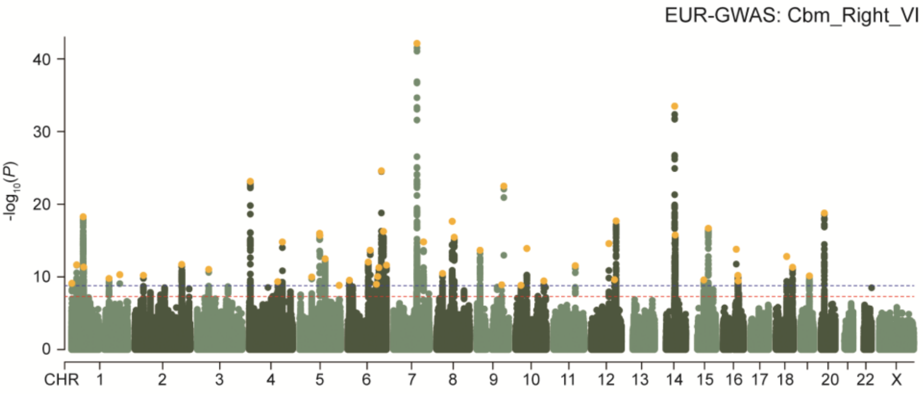

EUR-GWAS: Cbm_Left_I_IV

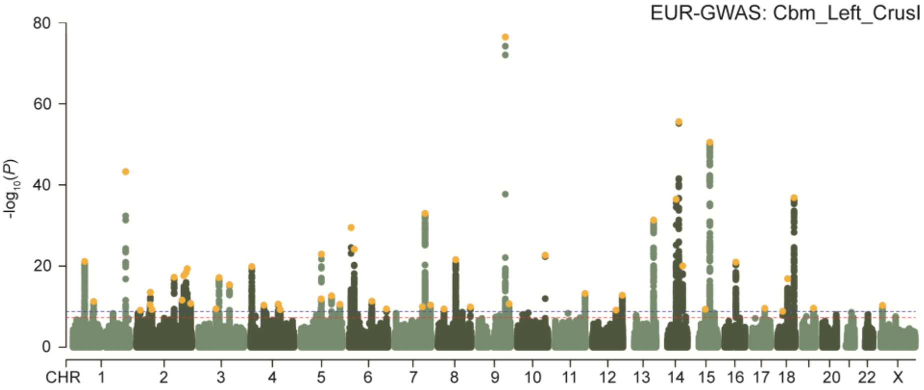

EUR-GWAS: Cbm_Right_I_IV

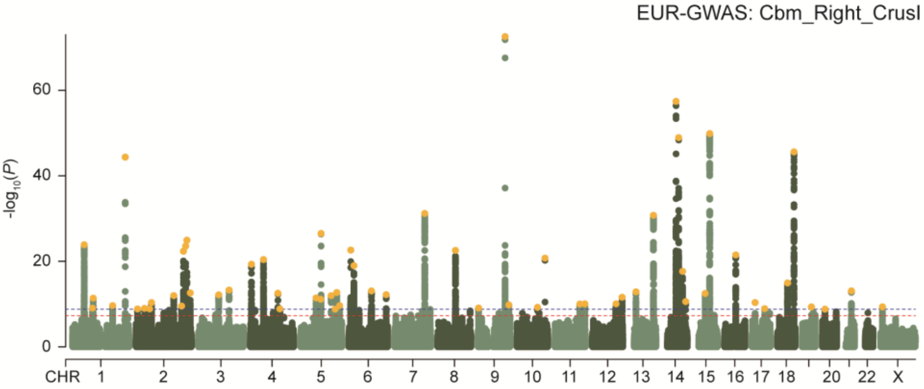

EUR-GWAS: Cbm_Left_V
-log10(P)
0
10
20
30
40
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

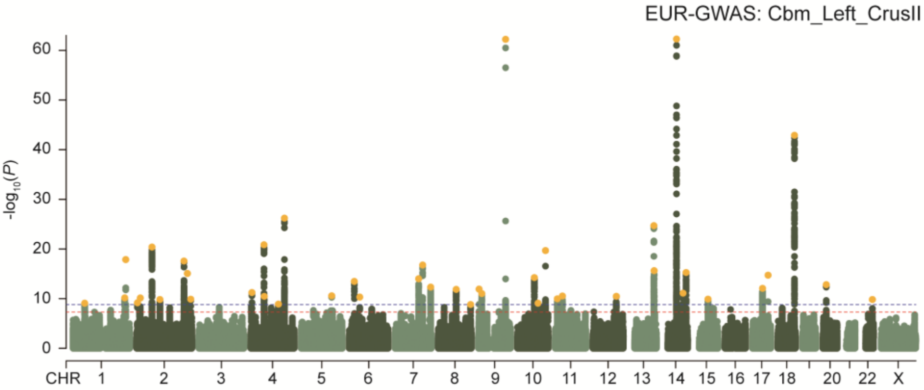

EUR-GWAS: Cbm_Right_V
-log10(P)
0
10
20
30
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

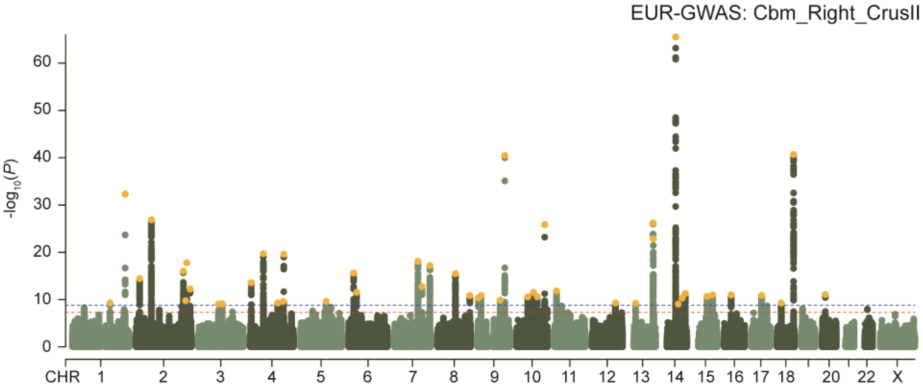

EUR-GWAS: Cbm_Left_VI
-log10(P)
0
10
20
30
40
50
60
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

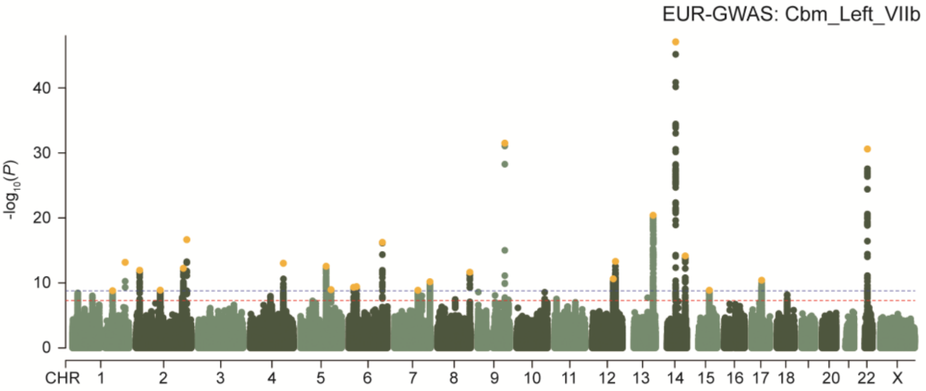

EUR-GWAS: Cbm_Right_VI
-log10(P)
0
10
20
30
40
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

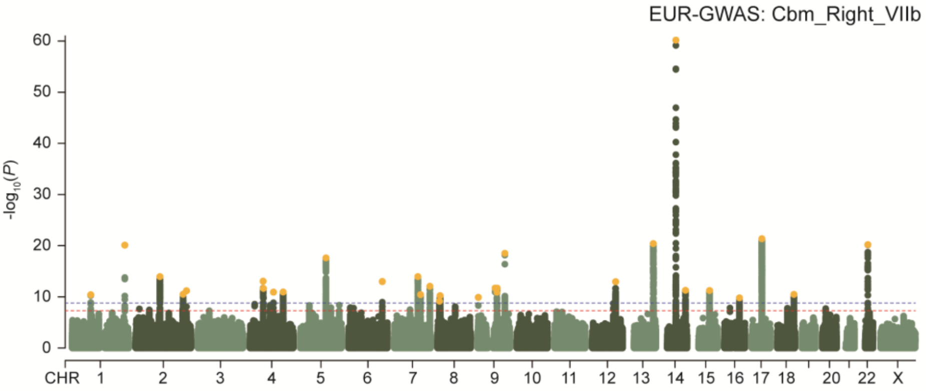

EUR-GWAS: Cbm_Left_CrusI

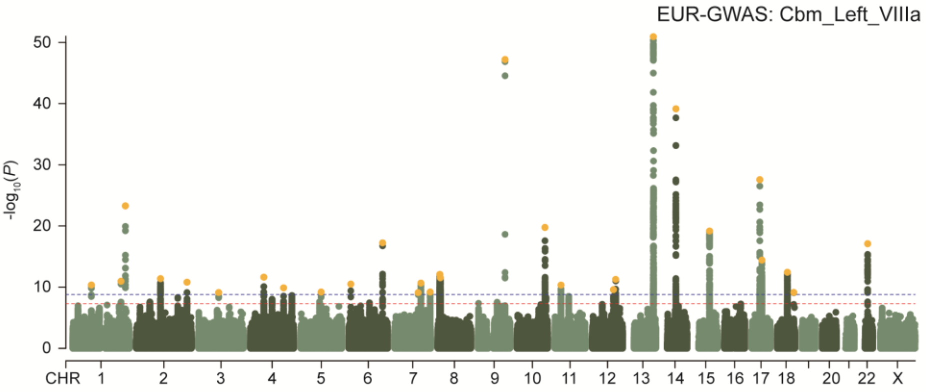

EUR-GWAS: Cbm_Right_CrusI

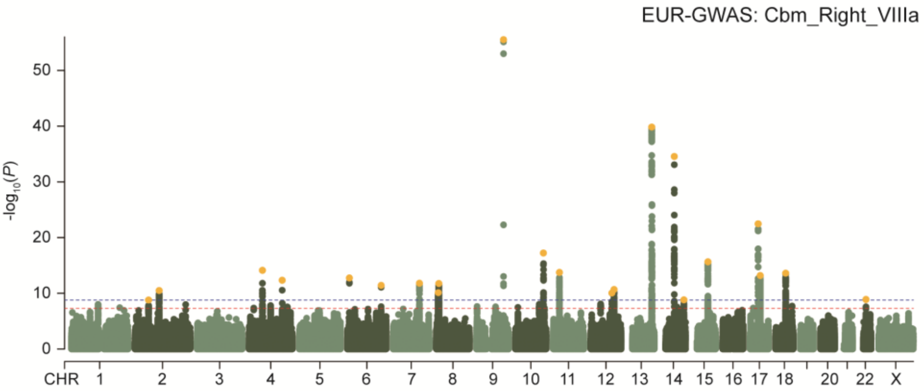

EUR-GWAS: Cbm_Left_CrusII

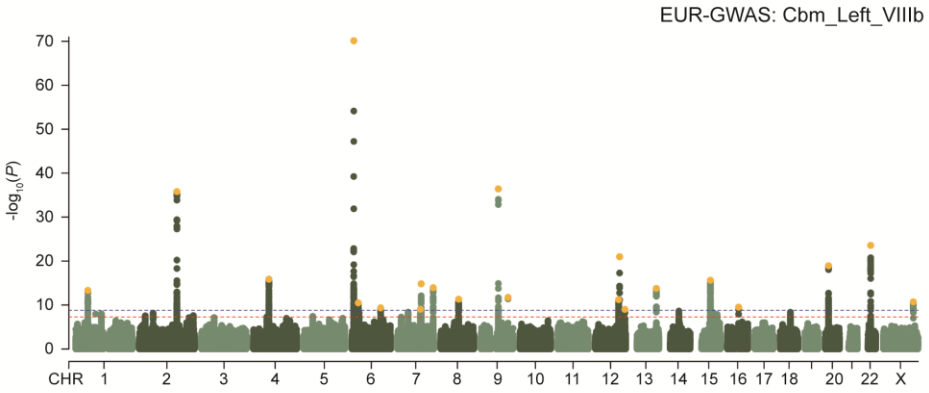

EUR-GWAS: Cbm_Right_CrusII

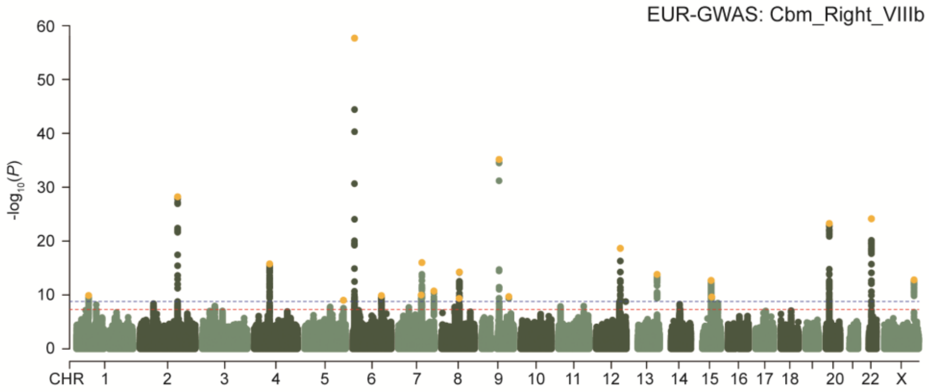

EUR-GWAS: Cbm_Left_VIIb

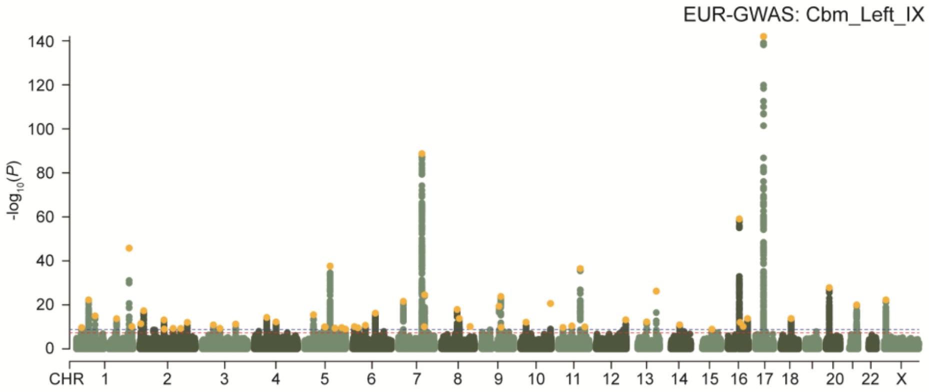

EUR-GWAS: Cbm_Right_VIIb

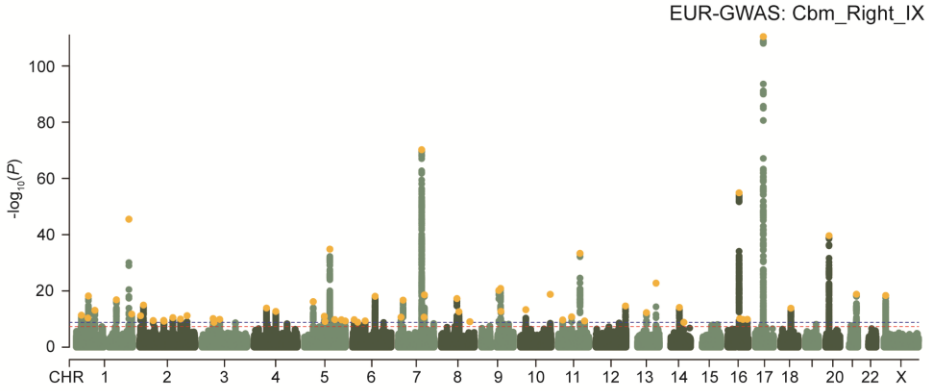

EUR-GWAS: Cbm_Left_VIIIa

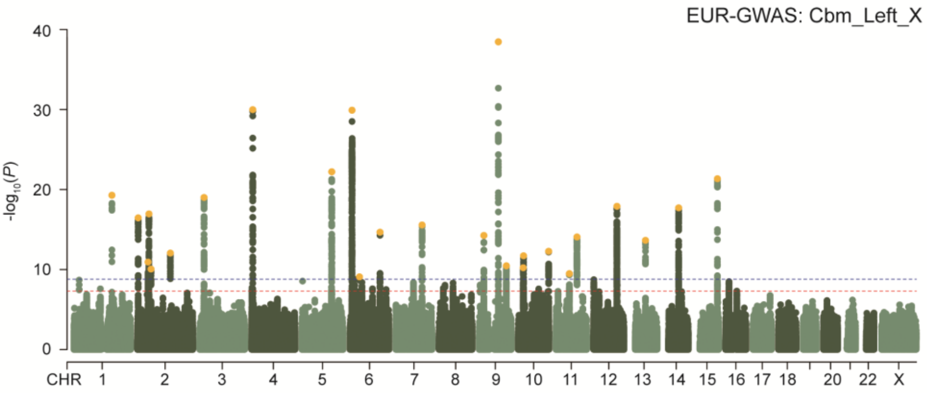

EUR-GWAS: Cbm_Right_VIIIa

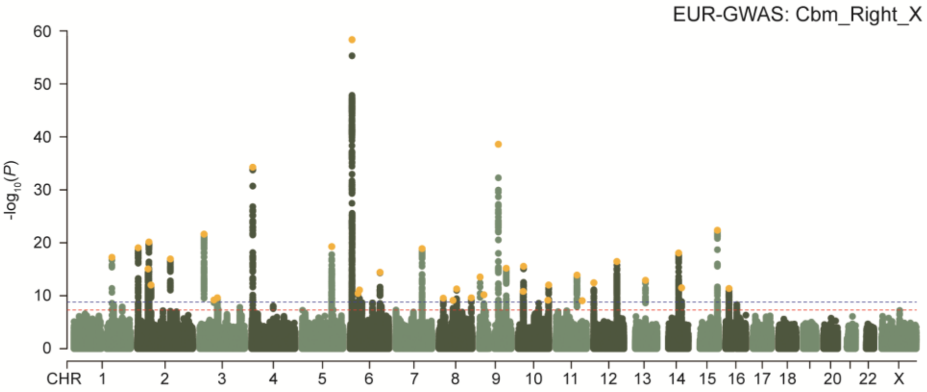

EUR-GWAS: Cbm_Left_VIIIb
-log10(P)
70
60
50
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

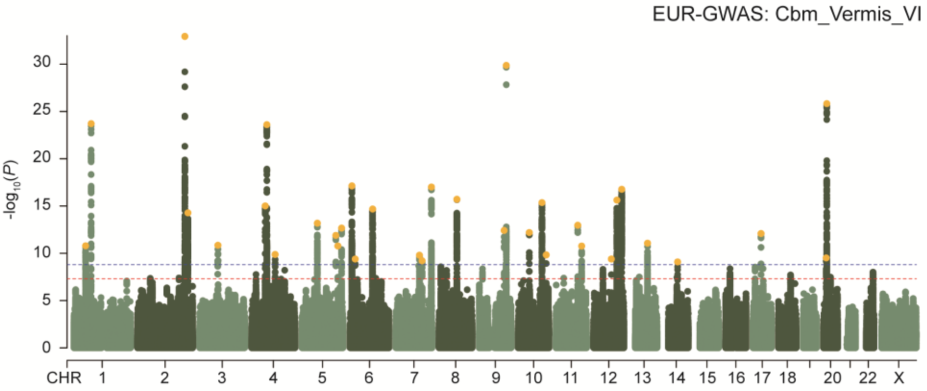

EUR-GWAS: Cbm_Right_VIIIb
-log10(P)
60
50
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

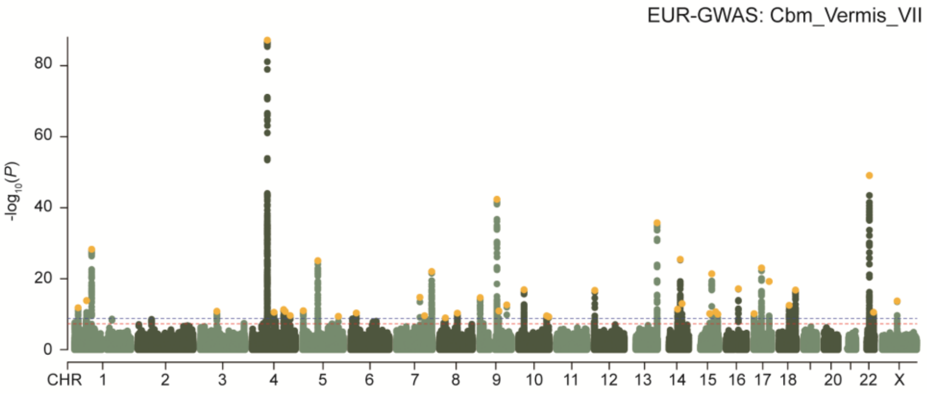

EUR-GWAS: Cbm_Left_IX
-log10(P)
140
120
100
80
60
40
20
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

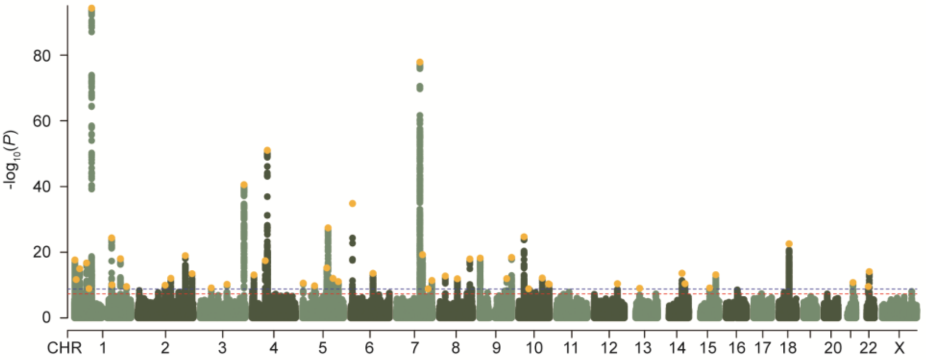

EUR-GWAS: Cbm_Right_IX
-log10(P)
100
80
60
40
20
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

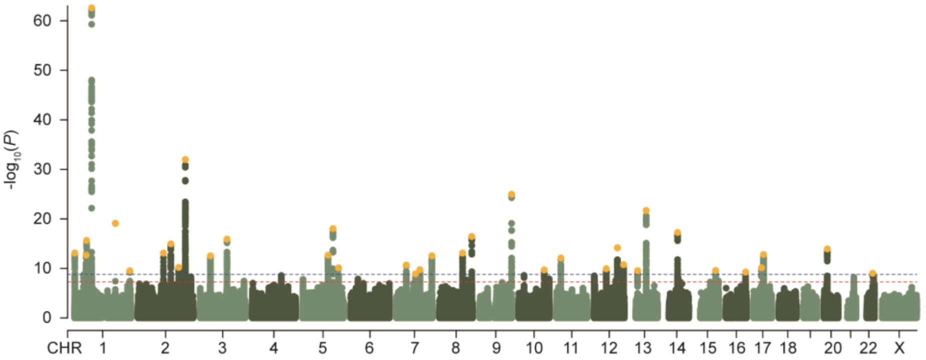

EUR-GWAS: Cbm_Left_X

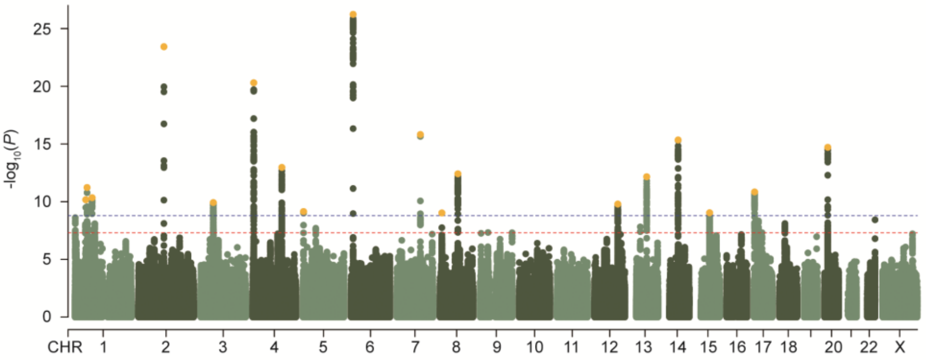

EUR-GWAS: Cbm_Right_X

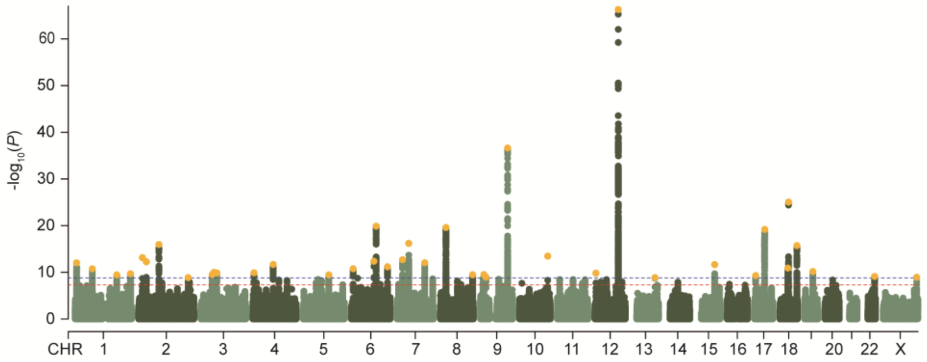

EUR-GWAS: Cbm_Vermis_VI

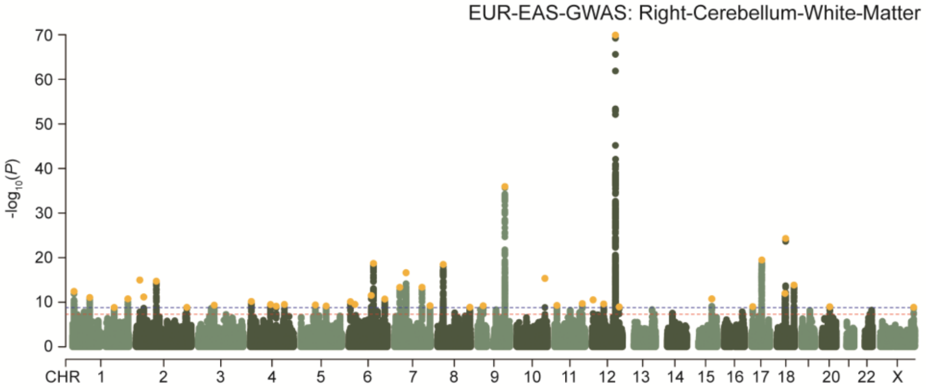

EUR-GWAS: Cbm_Vermis_VII

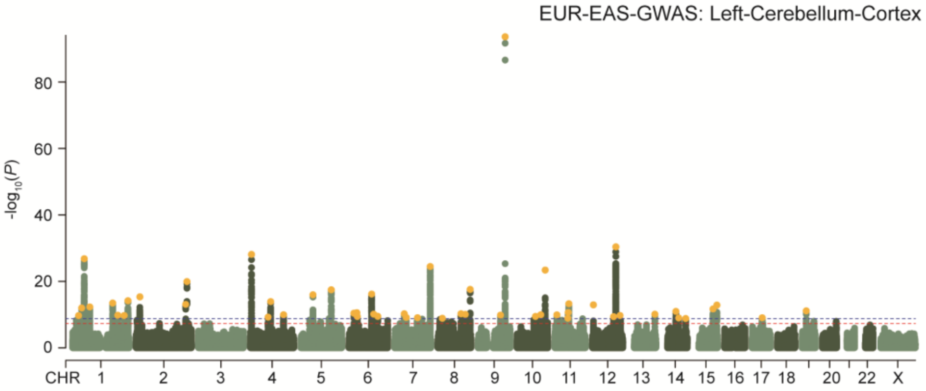

EUR-GWAS: Cbm_Vermis_VIII

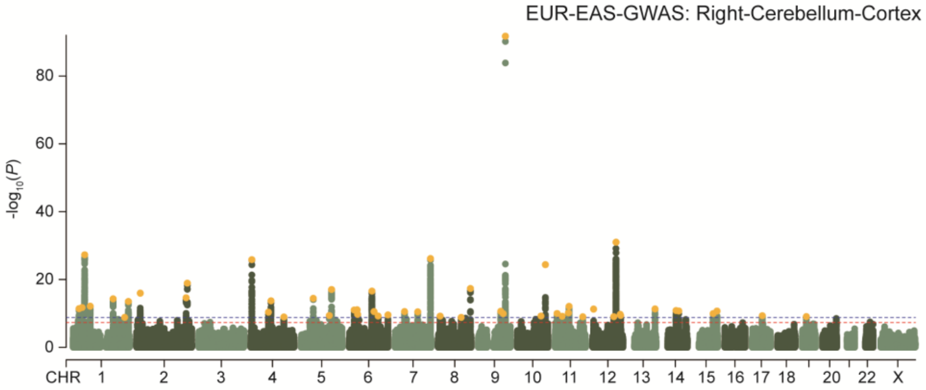

EUR-GWAS: Cbm_Vermis_IX

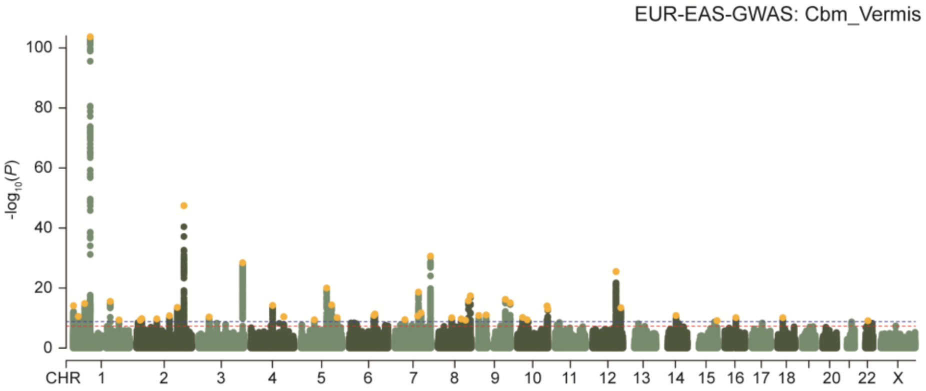

EUR-GWAS: Cbm_Vermis_X

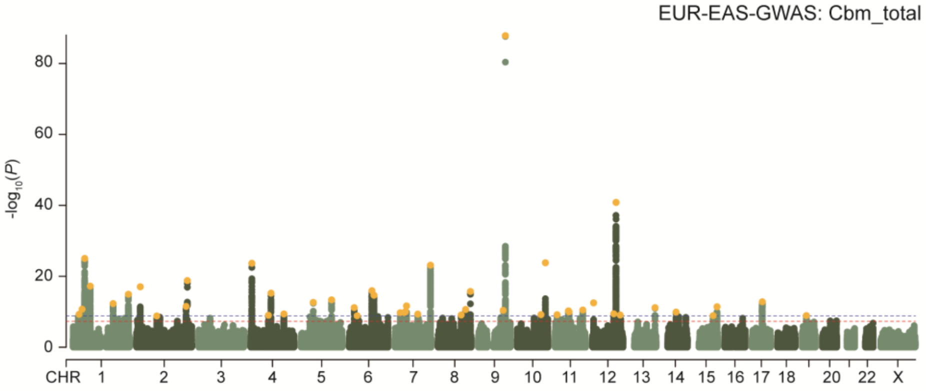

EUR-EAS-GWAS: Left-Cerebellum-White-Matter

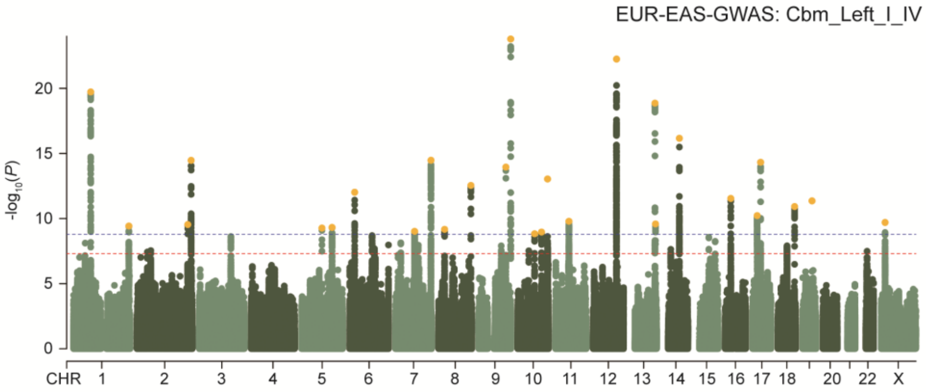

EUR-EAS-GWAS: Right-Cerebellum-White-Matter

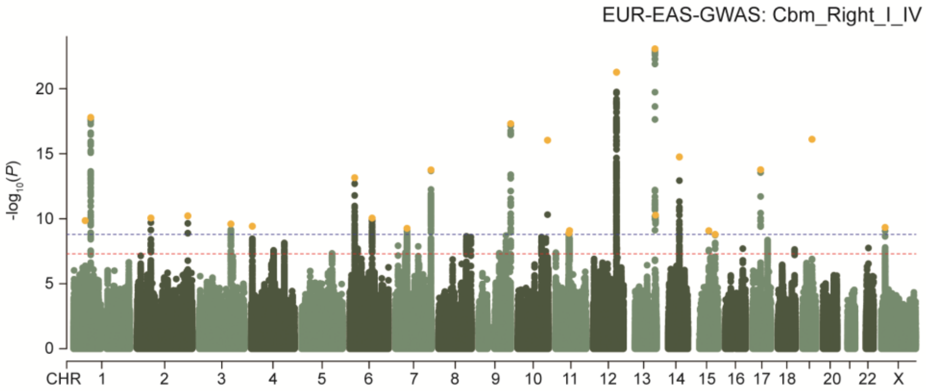

EUR-EAS-GWAS: Left-Cerebellum-Cortex

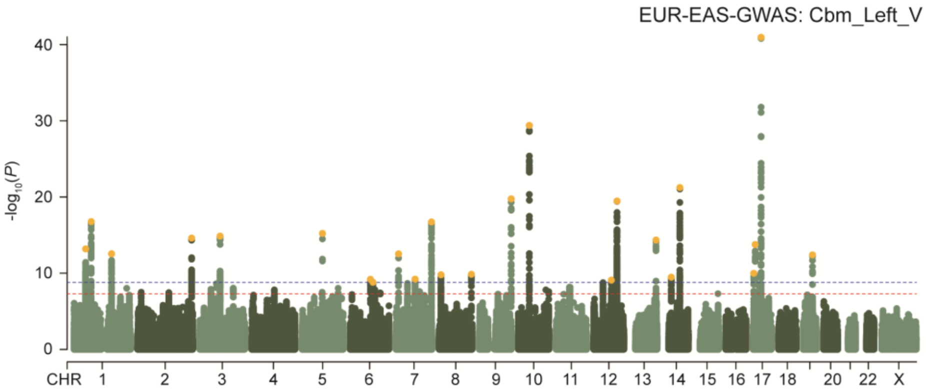

EUR-EAS-GWAS: Right-Cerebellum-Cortex

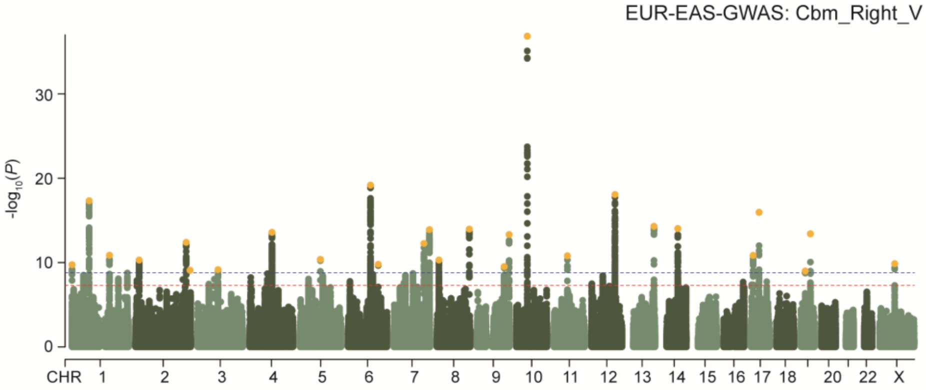

EUR-EAS-GWAS: Cbm_Vermis

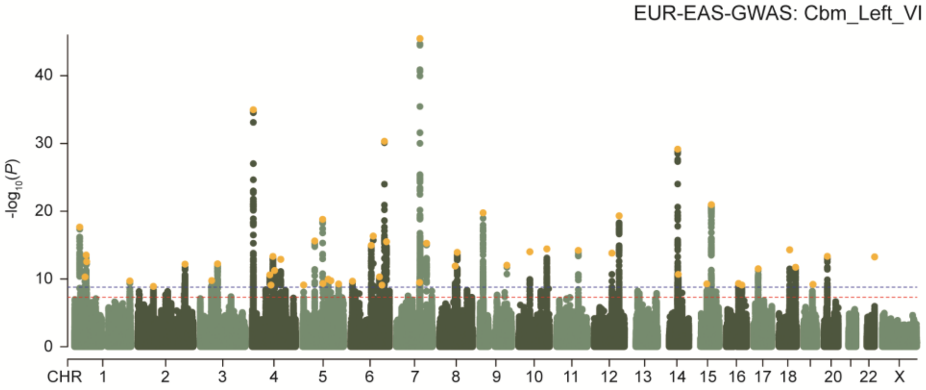

EUR-EAS-GWAS: Cbm_total

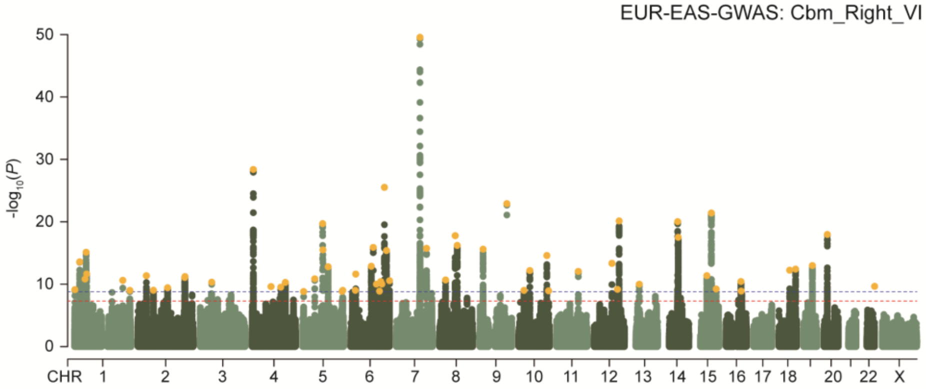

EUR-EAS-GWAS: Cbm_Left_I_IV

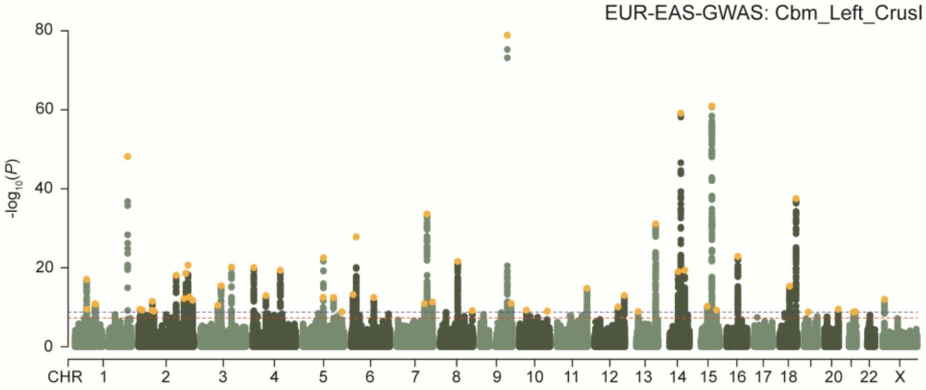

EUR-EAS-GWAS: Cbm_Right_I_IV

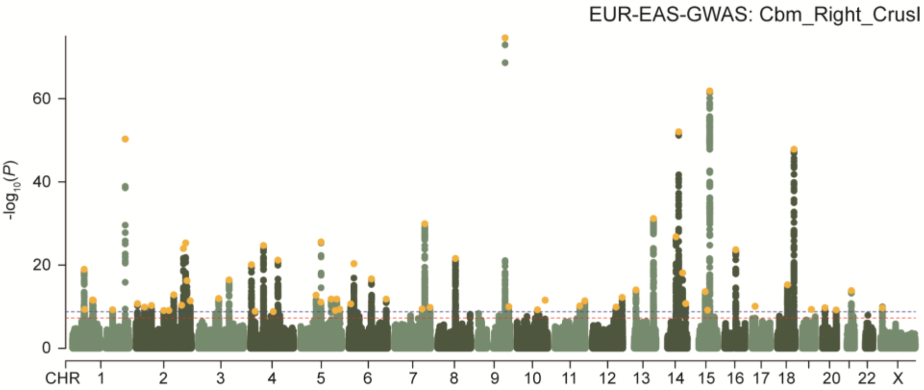

EUR-EAS-GWAS: Cbm_Left_V


EUR-EAS-GWAS: Cbm_Right_V

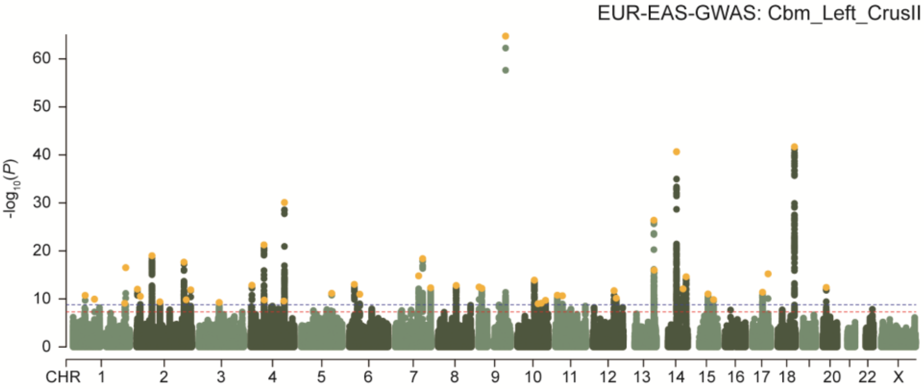

EUR-EAS-GWAS: Cbm_Left_VI


EUR-EAS-GWAS: Cbm_Right_VI


EUR-EAS-GWAS: Cbm_Left_CrusI



EUR-EAS-GWAS: Cbm_Right_CrusI



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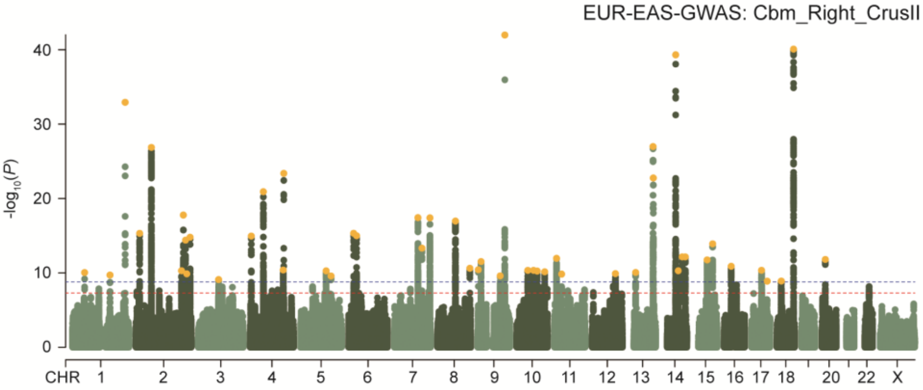
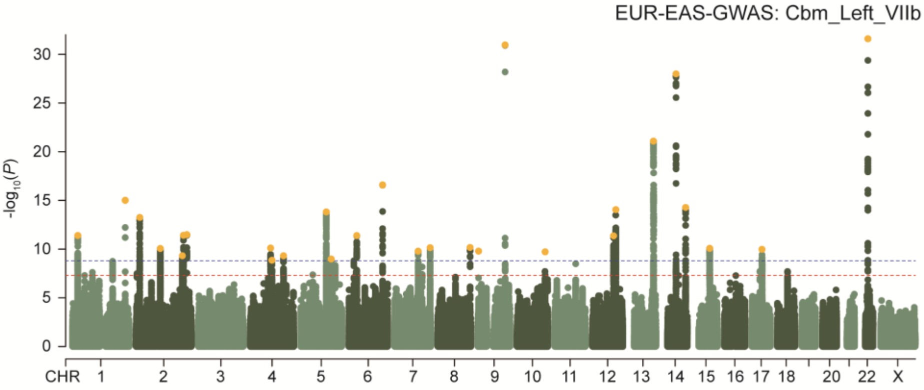
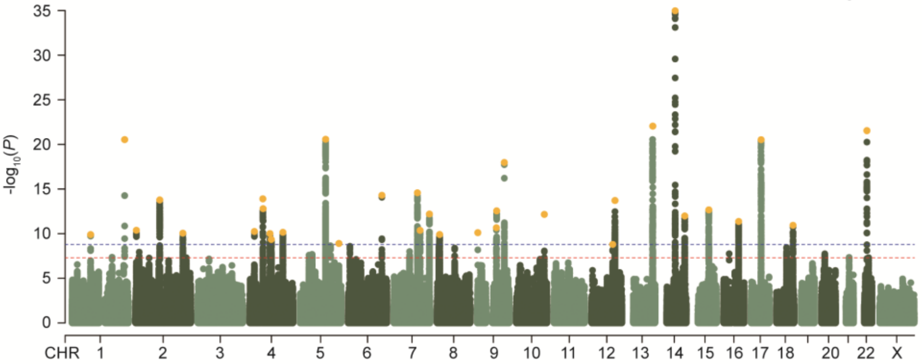


EUR-EAS-GWAS: Cbm_Right_CrusII



EUR-EAS-GWAS: Cbm_Left_VIIb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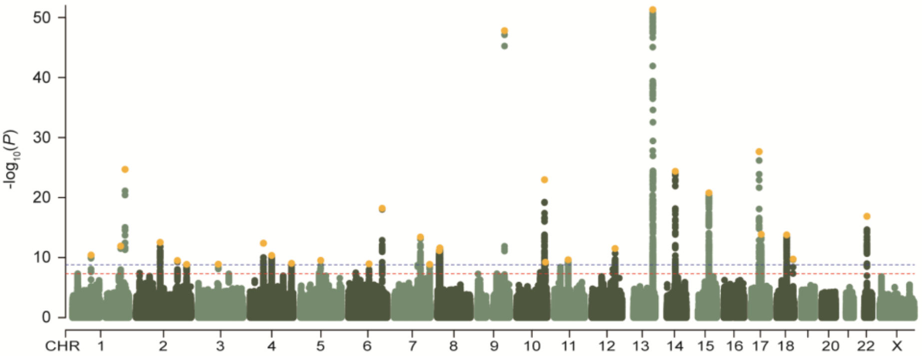
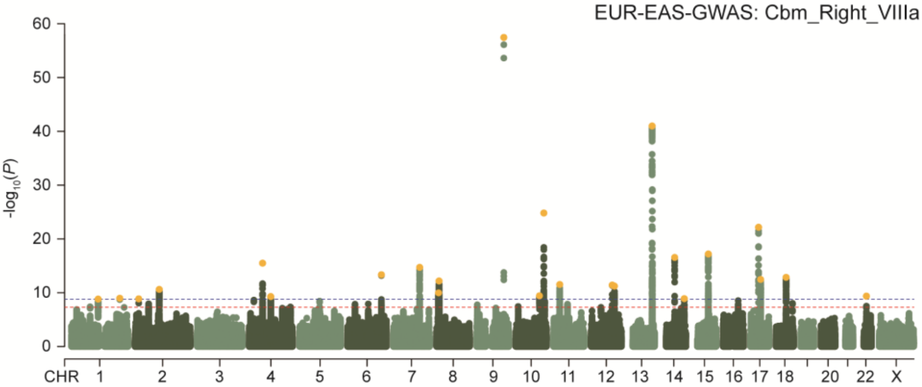
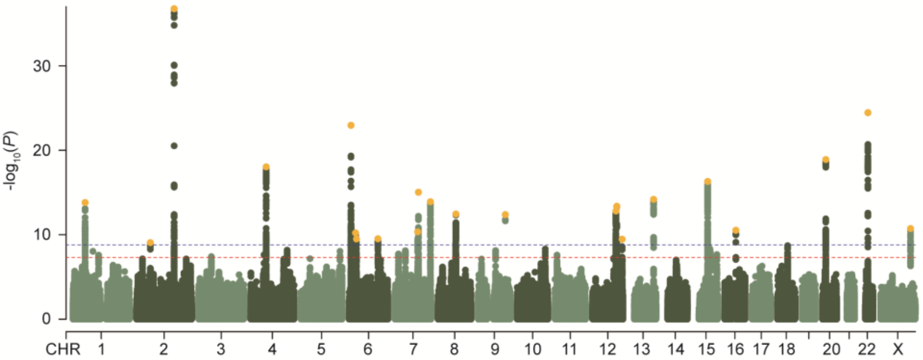

EUR-EAS-GWAS: Cbm_Left_VIIIa


EUR-EAS-GWAS: Cbm_Right_VIIIa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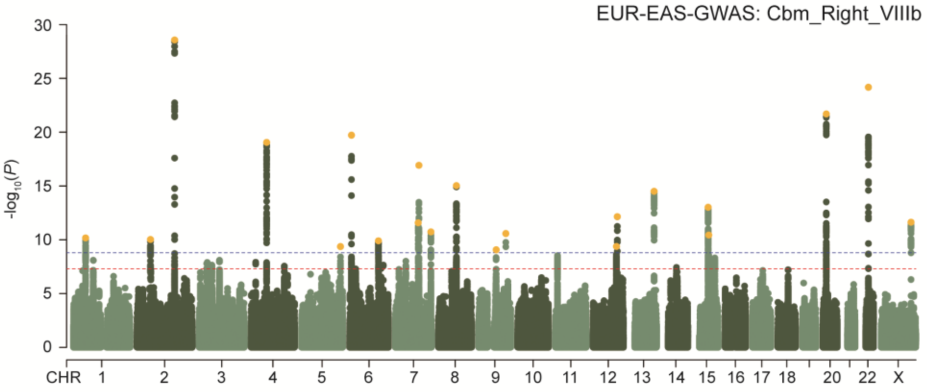
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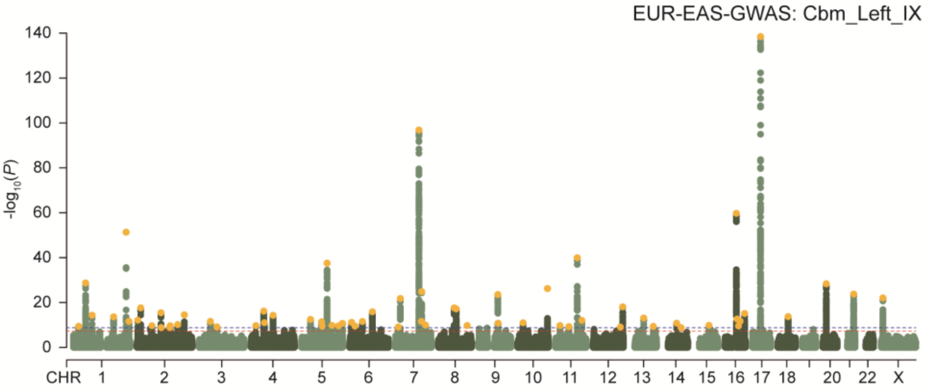
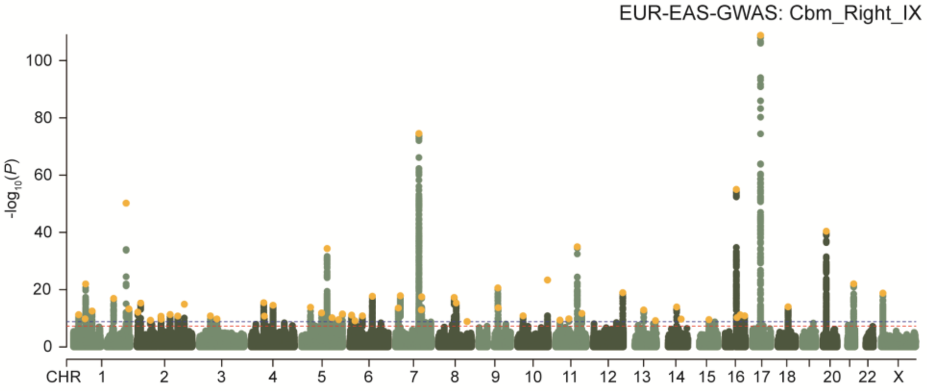
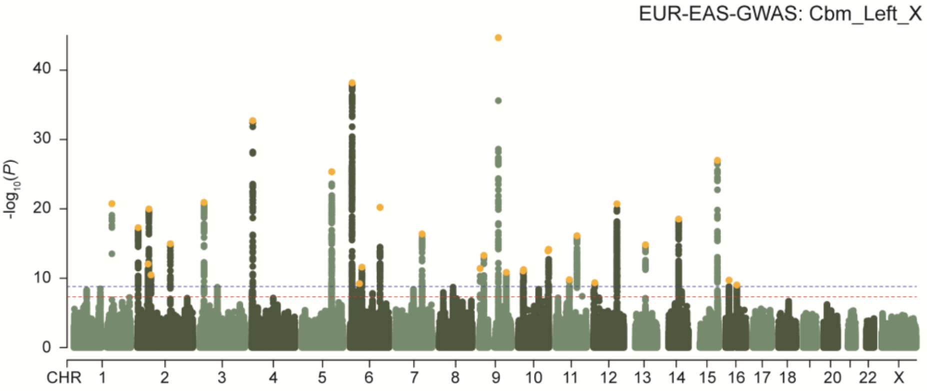
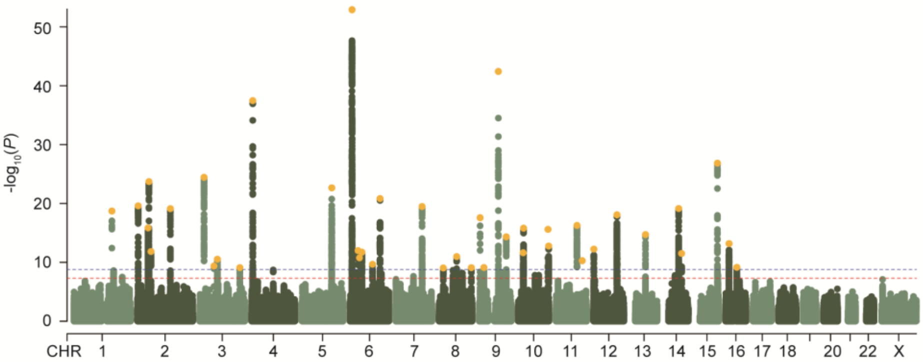
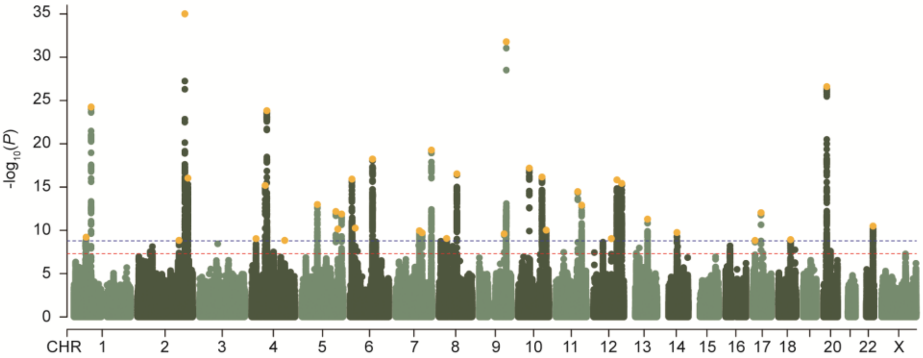

EUR-EAS-GWAS: Cbm_Left_IX


EUR-EAS-GWAS: Cbm_Right_IX

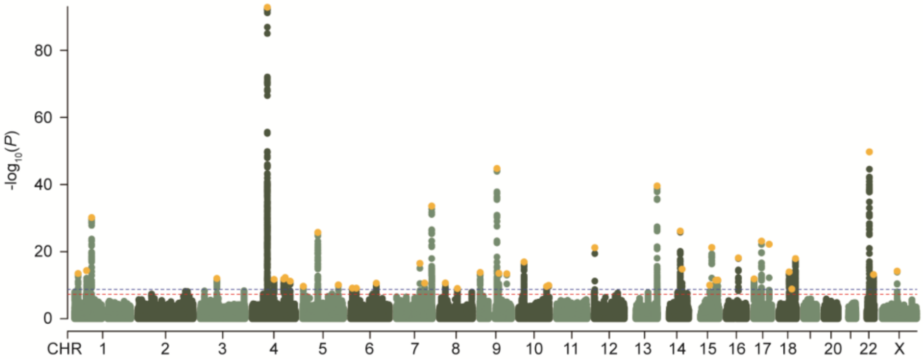

EUR-EAS-GWAS: Cbm_Left_X



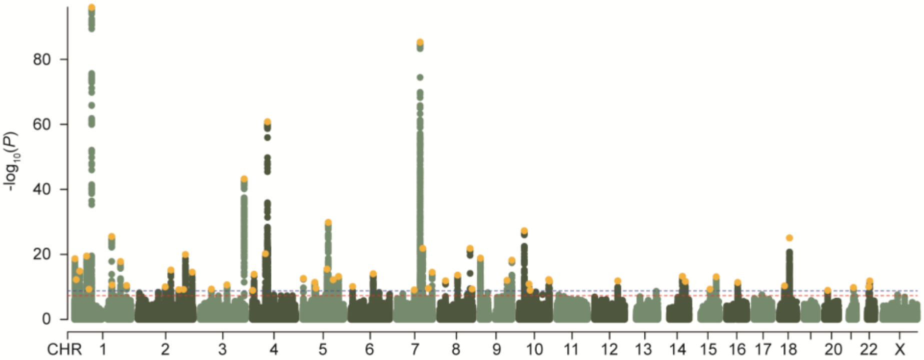
EUR-EAS-GWAS: Cbm_Right_X



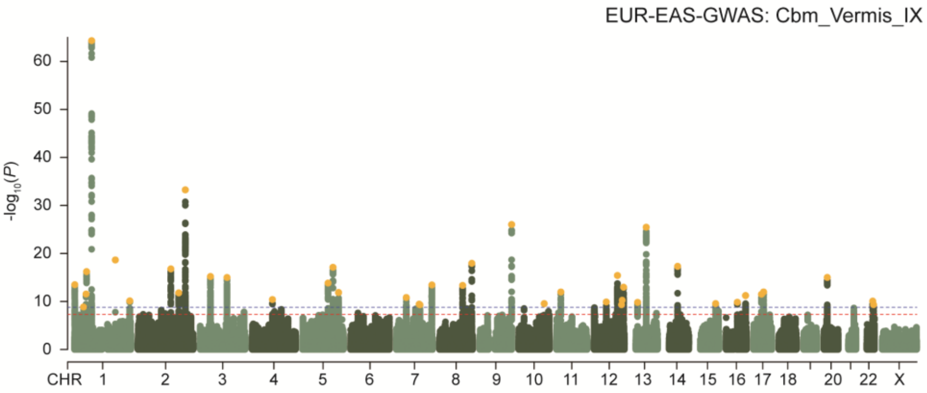
EUR-EAS-GWAS: Cbm_Vermis_VI

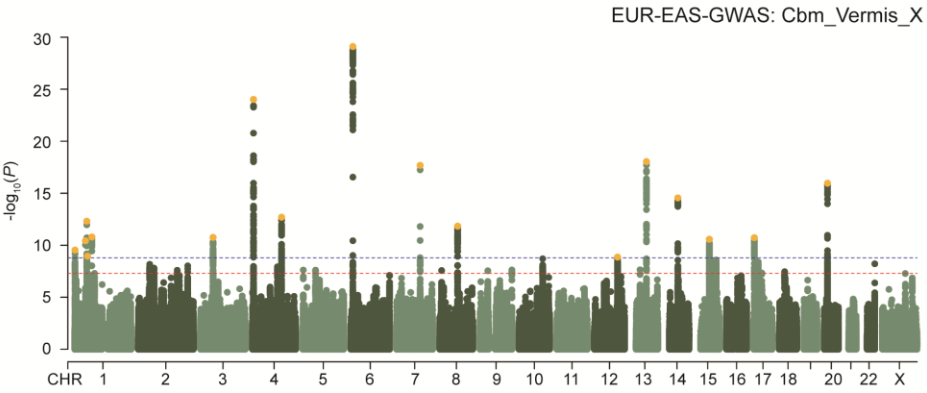


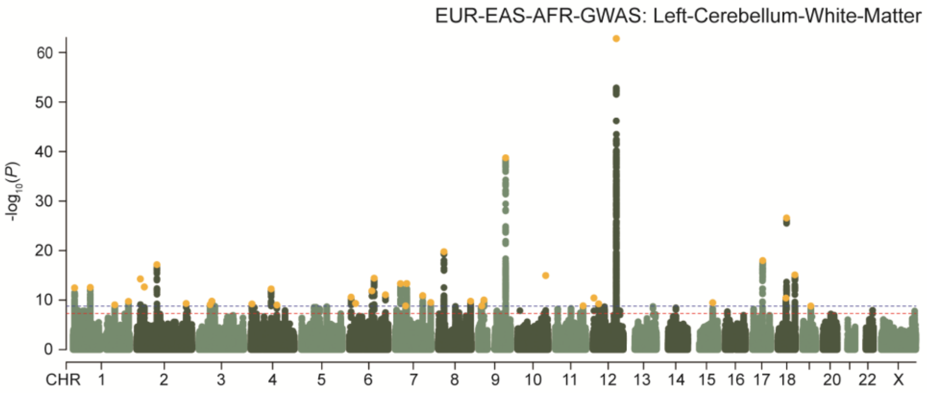
EUR-EAS-GWAS: Cbm_Vermis_VII

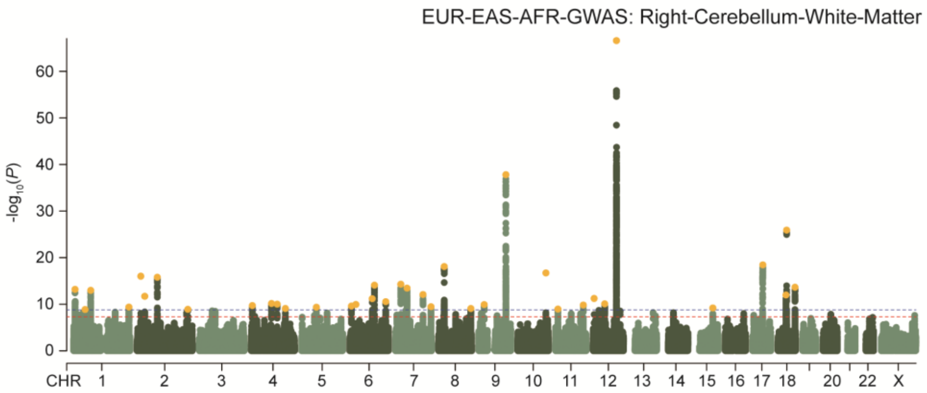


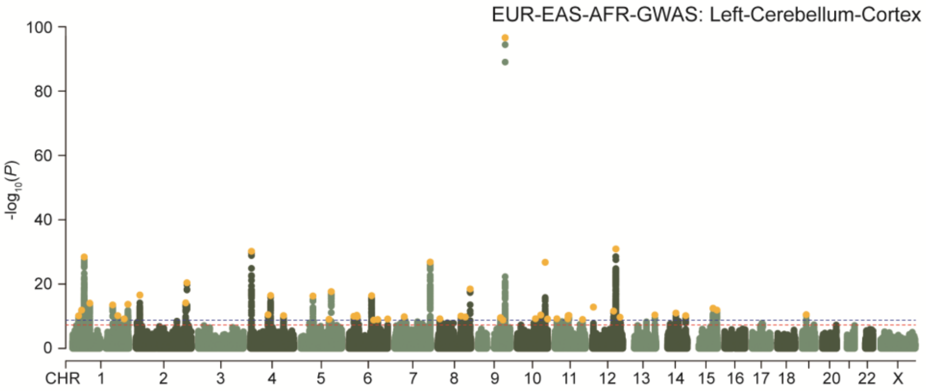
EUR-EAS-GWAS: Cbm_Vermis_VIII

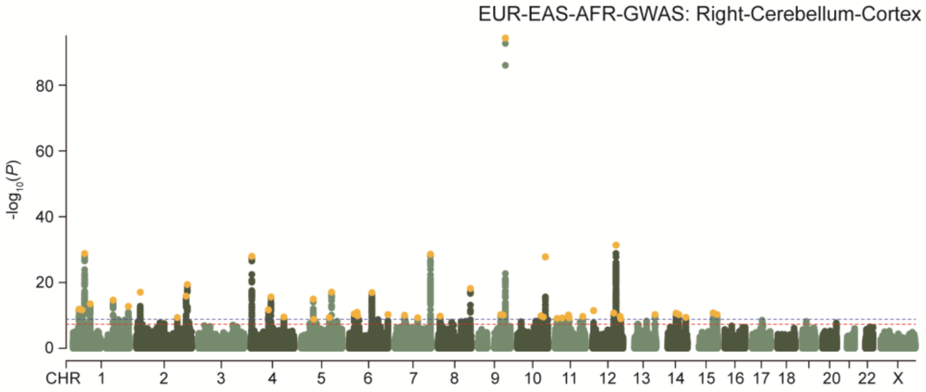

EUR-EAS-GWAS: Cbm_Vermis_IX

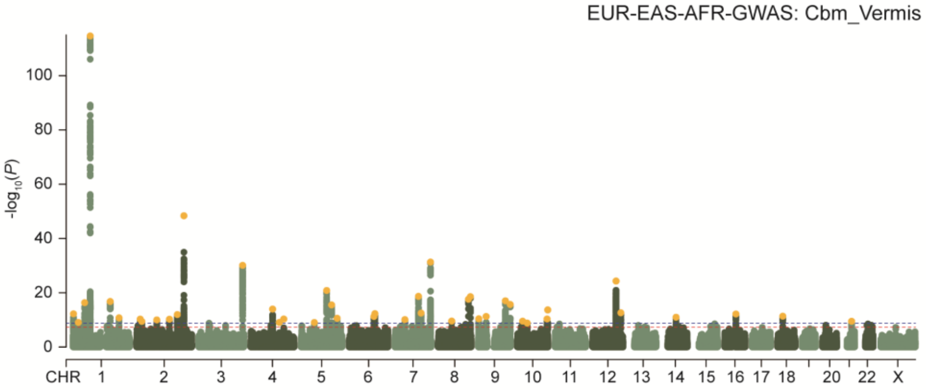

EUR-EAS-GWAS: Cbm_Vermis_X

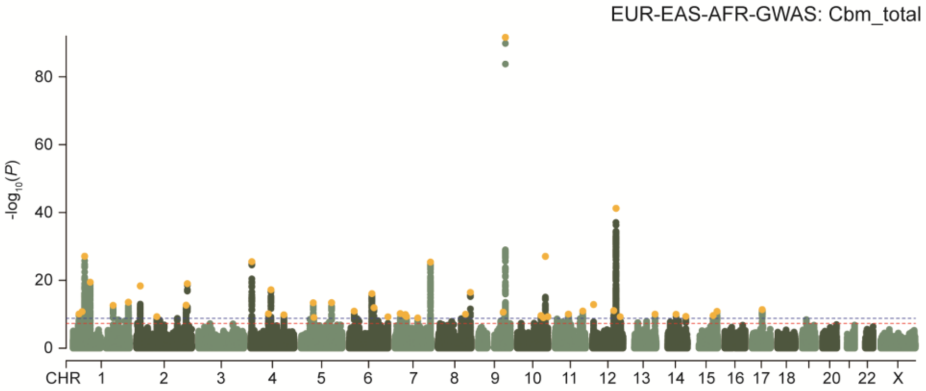

EUR-EAS-AFR-GWAS: Left-Cerebellum-White-Matter

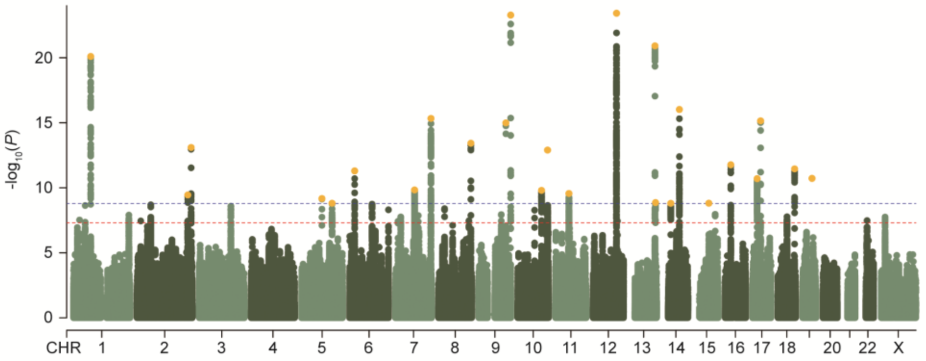

EUR-EAS-AFR-GWAS: Right-Cerebellum-White-Matter

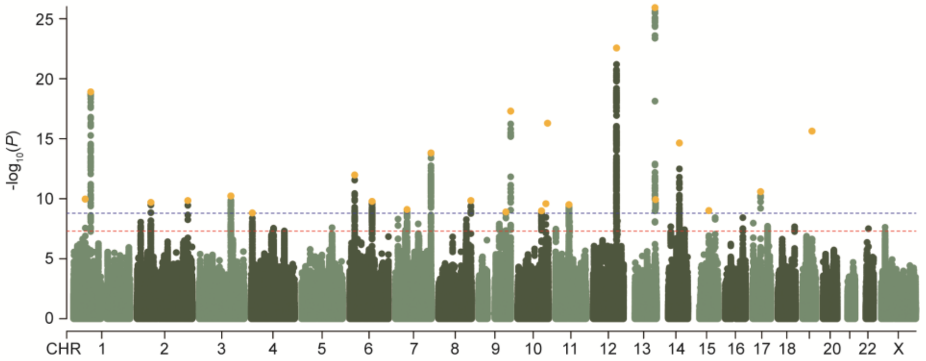

EUR-EAS-AFR-GWAS: Left-Cerebellum-Cortex

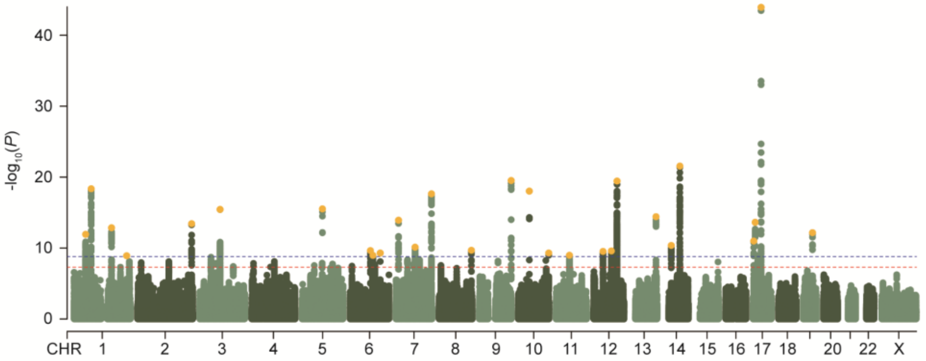

EUR-EAS-AFR-GWAS: Right-Cerebellum-Cortex

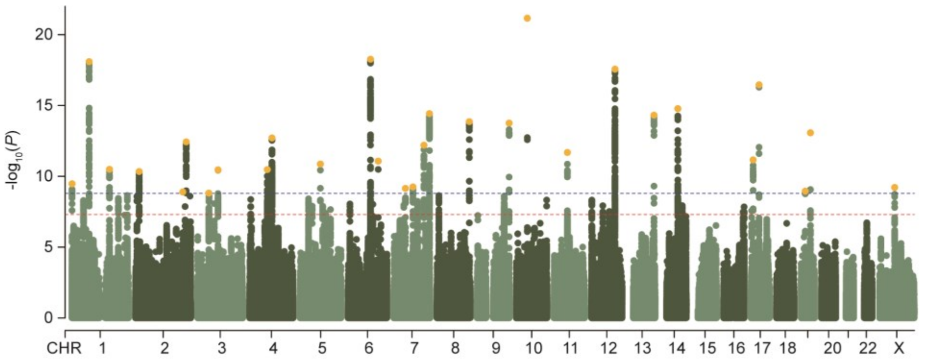

EUR-EAS-AFR-GWAS: Cbm_Vermis

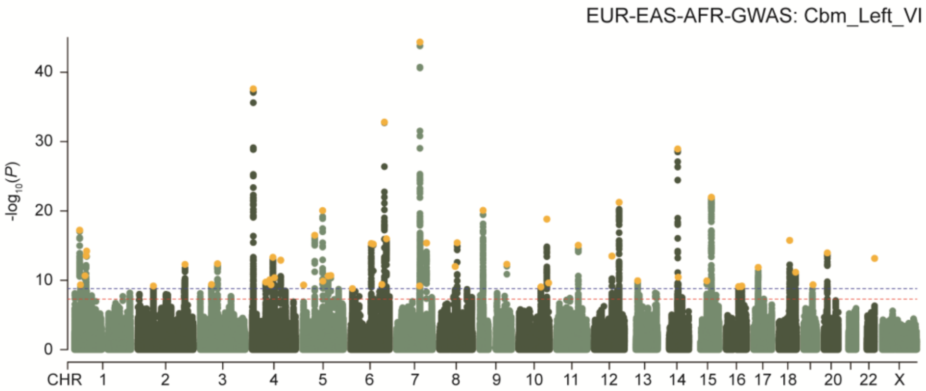

EUR-EAS-AFR-GWAS: Cbm_total


EUR-EAS-AFR-GWAS: Cbm_Left_I_IV

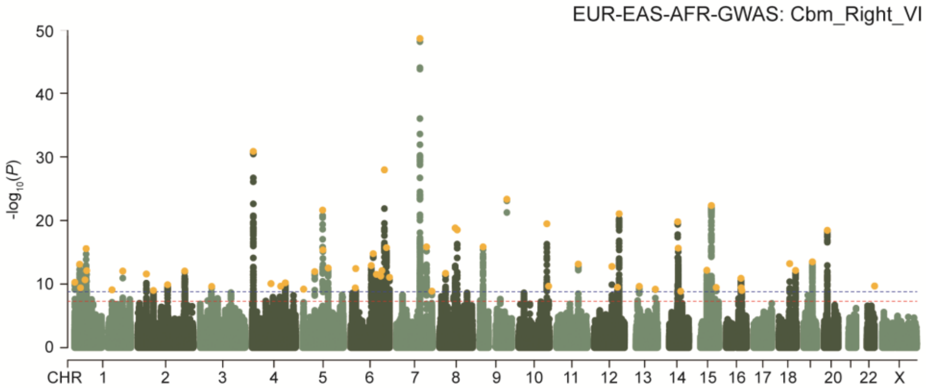

EUR-EAS-AFR-GWAS: Cbm_Right_I_IV


EUR-EAS-AFR-GWAS: Cbm_Left_V

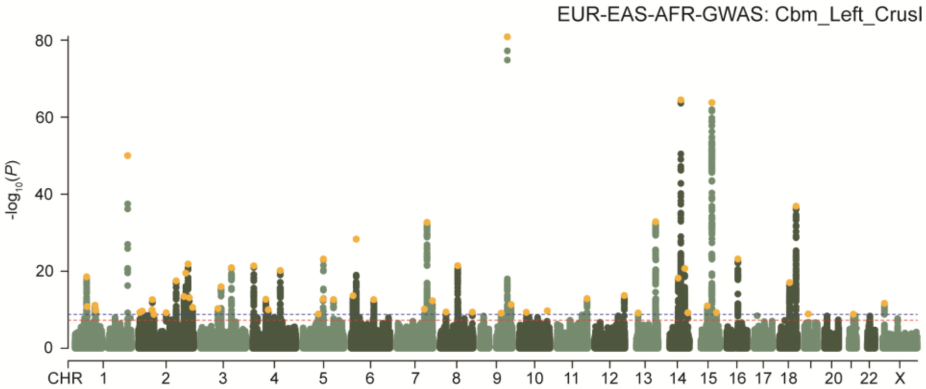

EUR-EAS-AFR-GWAS: Cbm_Right_V



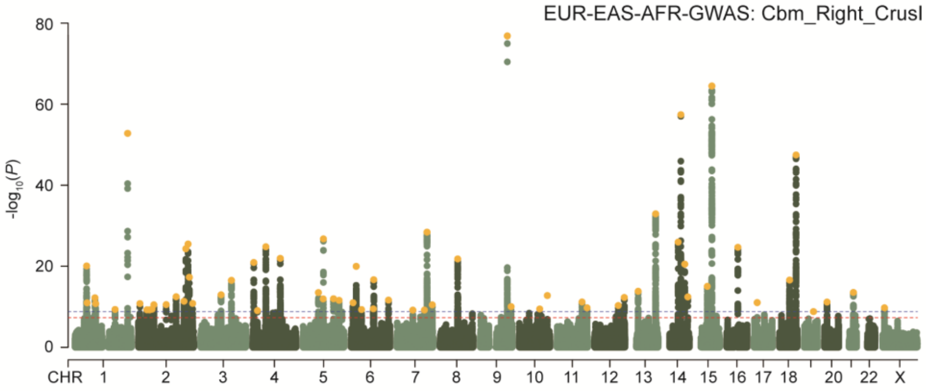
EUR-EAS-AFR-GWAS: Cbm_Left_VI



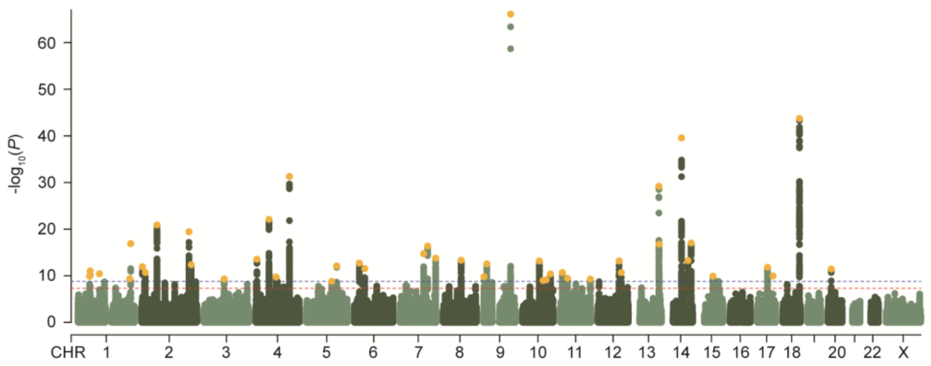
EUR-EAS-AFR-GWAS: Cbm_Right_VI

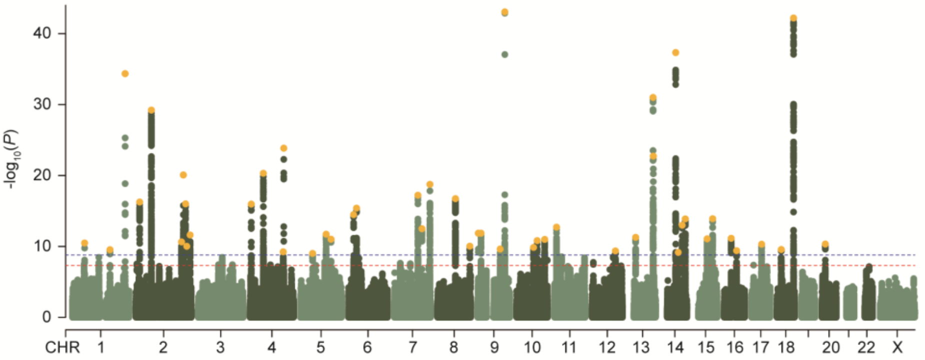


EUR-EAS-AFR-GWAS: Cbm_Left_CrusI



EUR-EAS-AFR-GWAS: Cbm_Right_CrusI


EUR-EAS-AFR-GWAS: Cbm_Left_CrusII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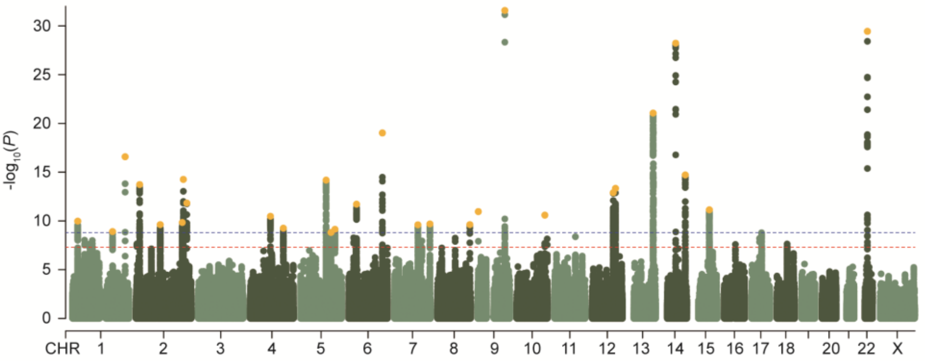
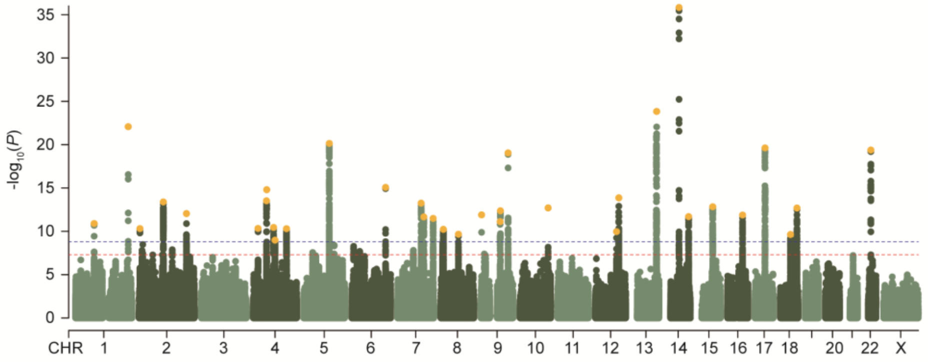
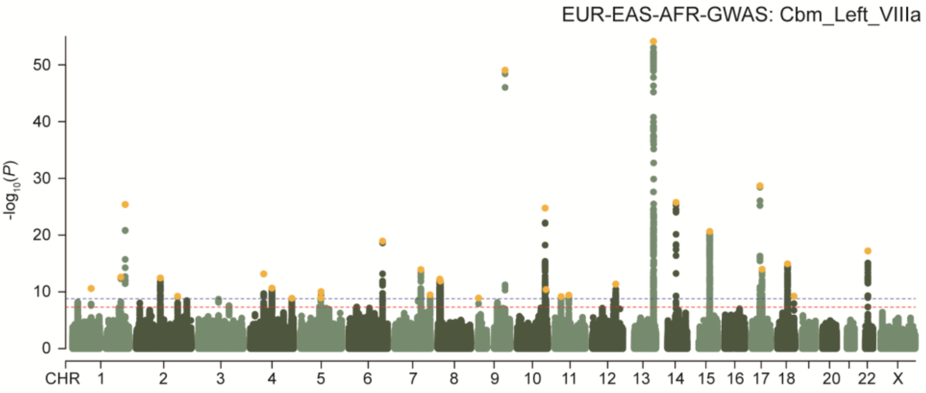
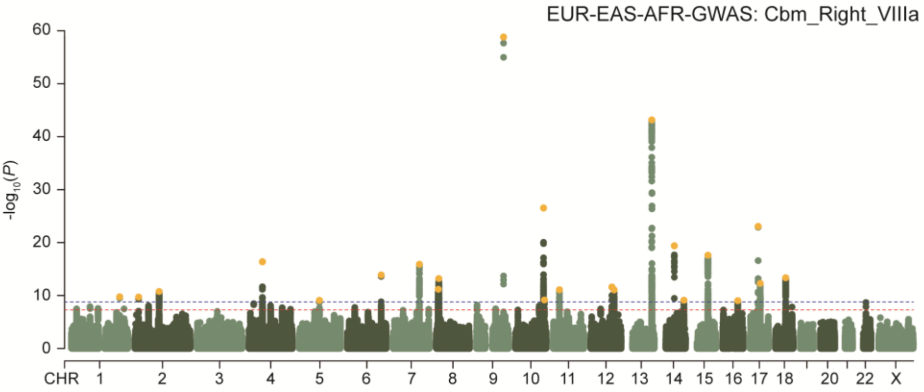

EUR-EAS-AFR-GWAS: Cbm_Left_VIIb


EUR-EAS-AFR-GWAS: Cbm_Right_VIIb


EUR-EAS-AFR-GWAS: Cbm_Left_VIIIa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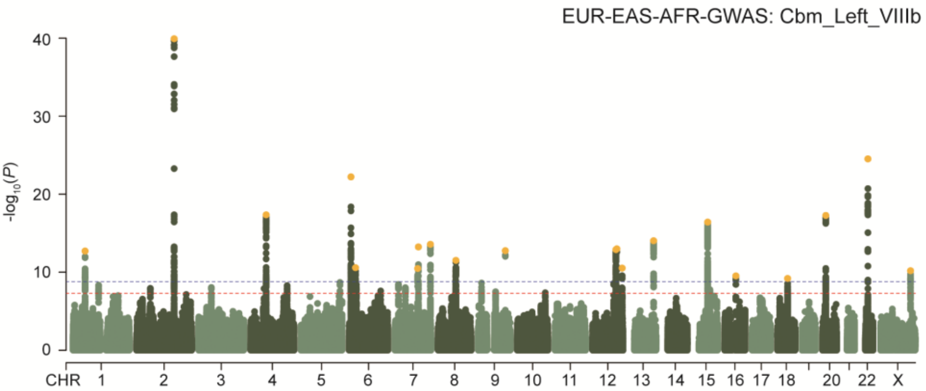
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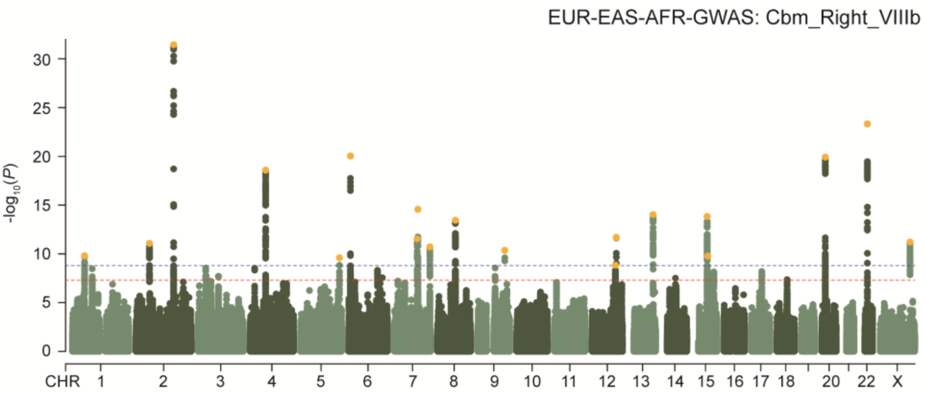
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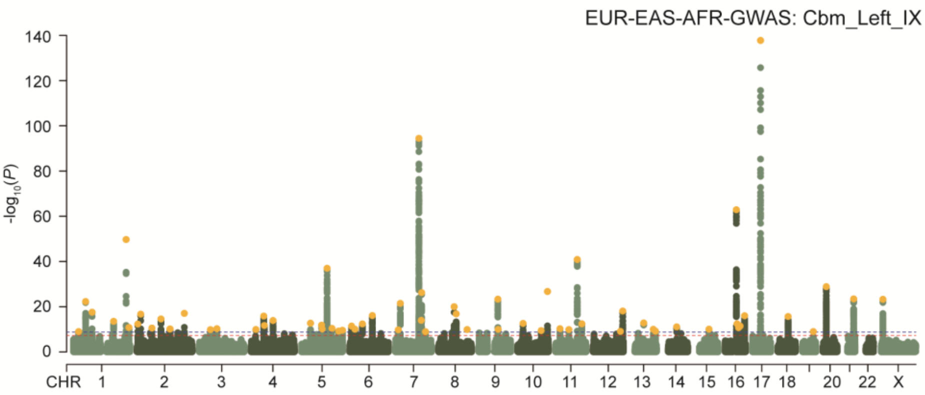
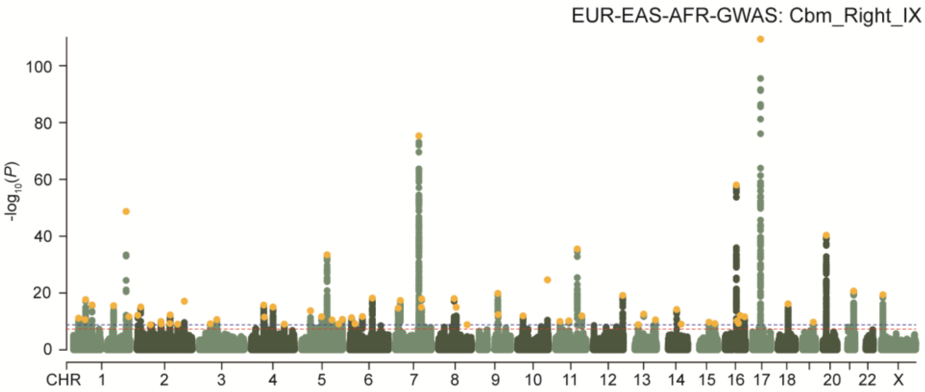
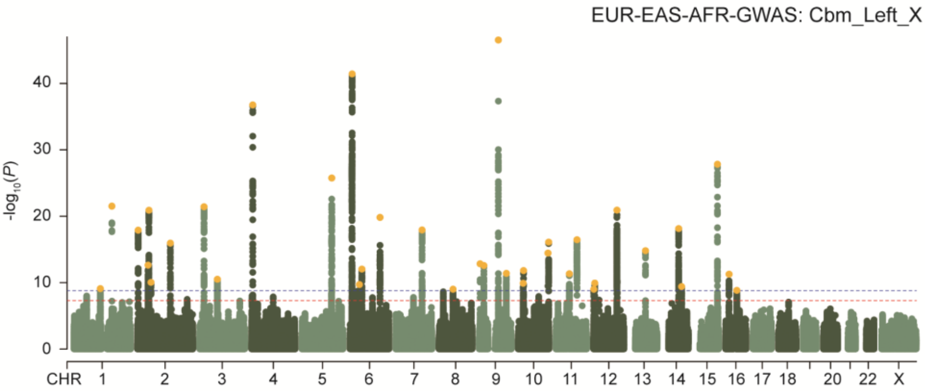
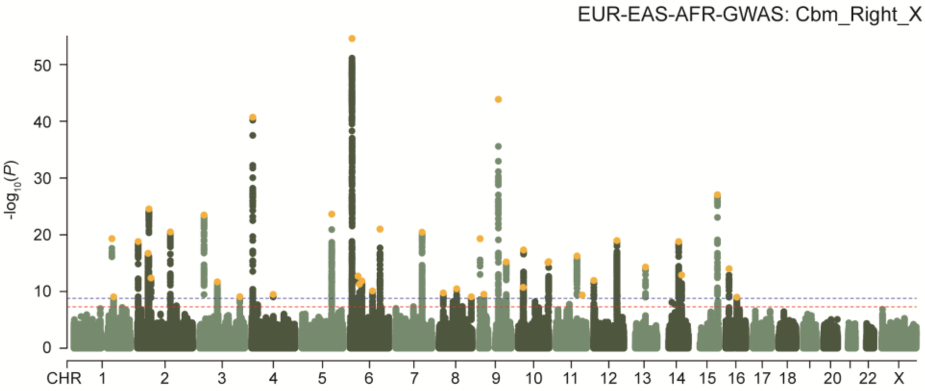
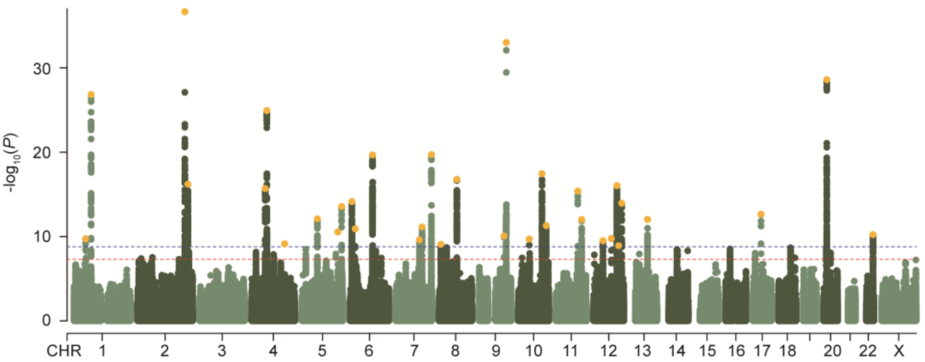

EUR-EAS-AFR-GWAS: Cbm_Left_IX
$-\log_{10}(P)$
140
120
100
80
60
40
20
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Right_IX
$-\log_{10}(P)$
100
80
60
40
20
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

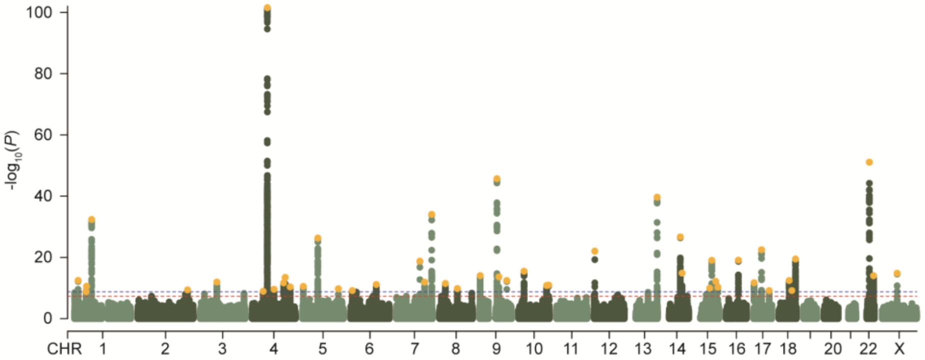

EUR-EAS-AFR-GWAS: Cbm_Left_X
$-\log_{10}(P)$
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Right_X
$-\log_{10}(P)$
50
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

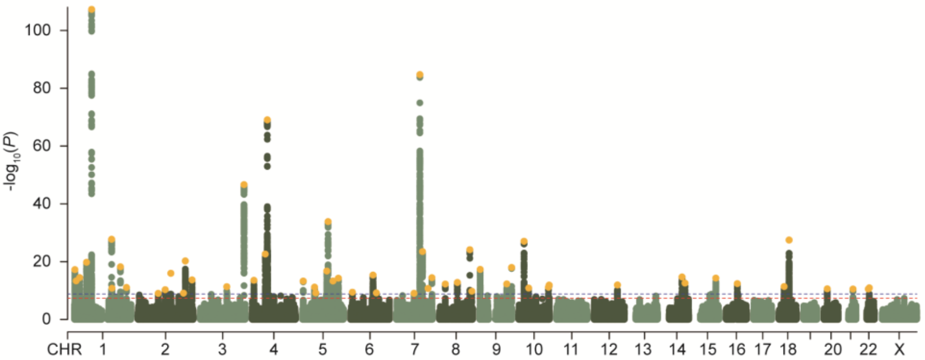
EUR-EAS-AFR-GWAS: Cbm_Vermis_VI



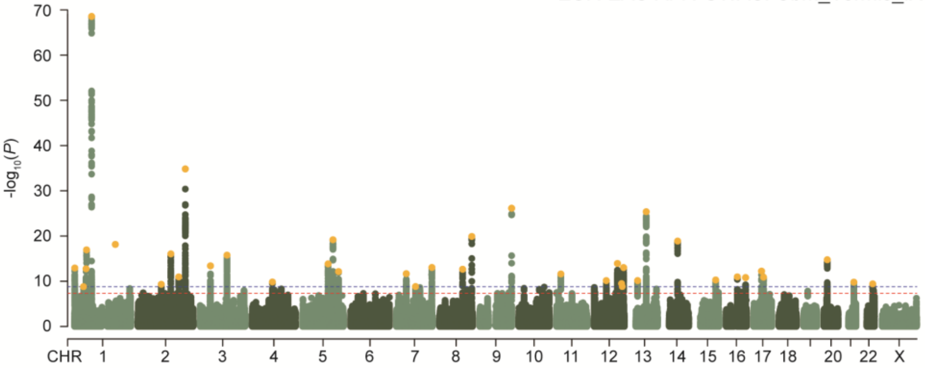
EUR-EAS-AFR-GWAS: Cbm_Vermis_VII



EUR-EAS-AFR-GWAS: Cbm_Vermis_VIII



EUR-EAS-AFR-GWAS: Cbm_Vermis_IX



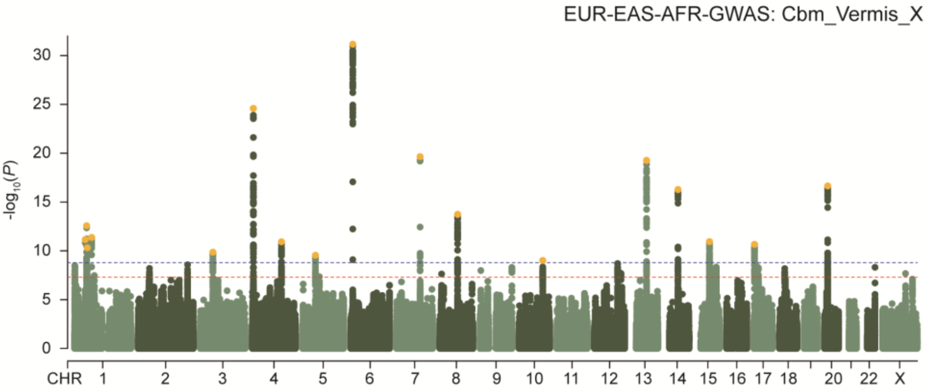
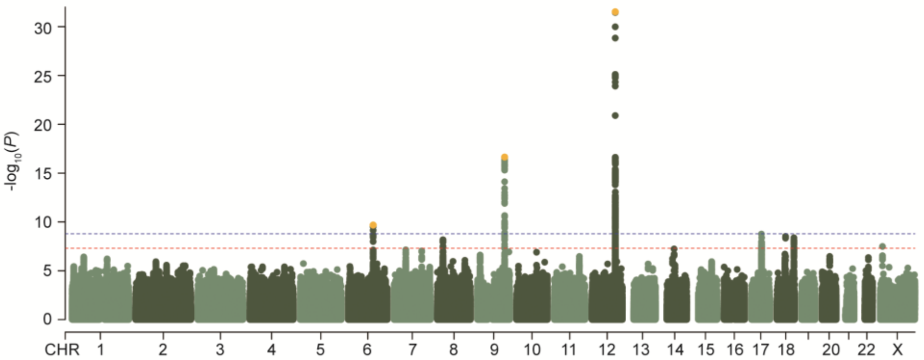
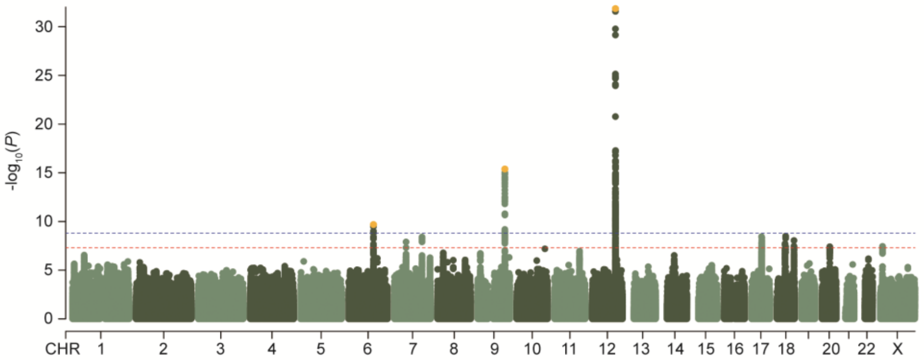


Fig. S3 | Genetic discovery of seven sets of sex-combined univariate GWAS. The Manhattan plots show the results from seven sex-combined univariate GWASs ($\mathrm{UKBB_{EUR}}$-GWAS, $\mathrm{ABCD_{EUR}}$-GWAS, $\mathrm{CHIMGEN_{EAS}}$-GWAS, $\mathrm{ABCD_{AFR}}$-GWAS, EUR-GWAS, EUR-EAS-GWAS, and EUR-EAS-AFR-GWAS) on the 31 cerebellar volumetric traits. Each plot shows genome-wide (red dashed line: $P = 5 \times 10^{-8}$) and study-wide (blue dashed line: $P = 1.61 \times 10^{-9}$) significant associations with 31 cerebellar volumetric traits. Each point represents a single genetic variant plotted according to its genomic position (x axis) and its $-\log_{10}(P)$ value for the association (y axis). Each yellow point represents an independent locus with study-wide significance ($P = 1.61 \times 10^{-9}$). Abbreviations: ABCD, the Adolescent Brain Cognitive Development study; AFR, African ancestry; CHIMGEN, the Chinese Imaging Genetics study; EAS, East Asian ancestry; EUR, European ancestry; GWAS, genome-wide association study; UKBB, the UK Biobank study.

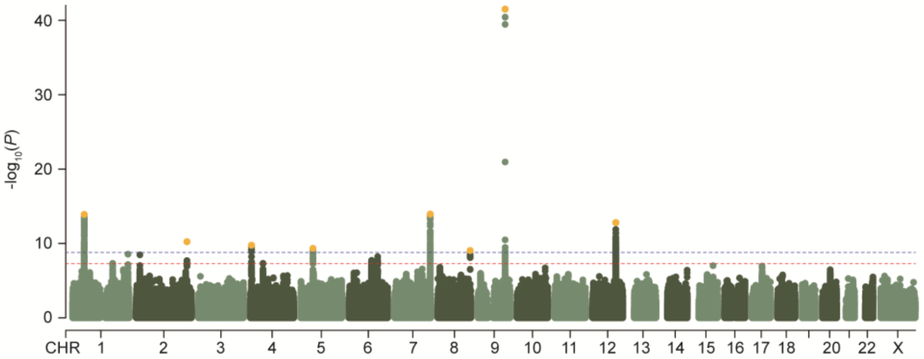
UKBB$_{EUR}$-GWAS: Left-Cerebellum-White-Matter



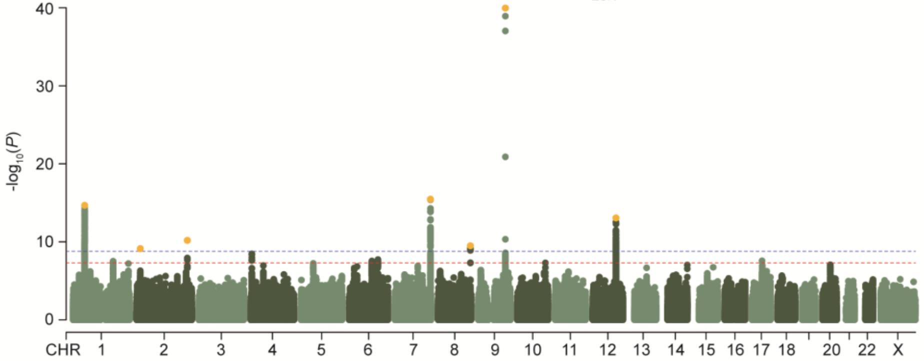
UKBB$_{EUR}$-GWAS: Right-Cerebellum-White-Matter

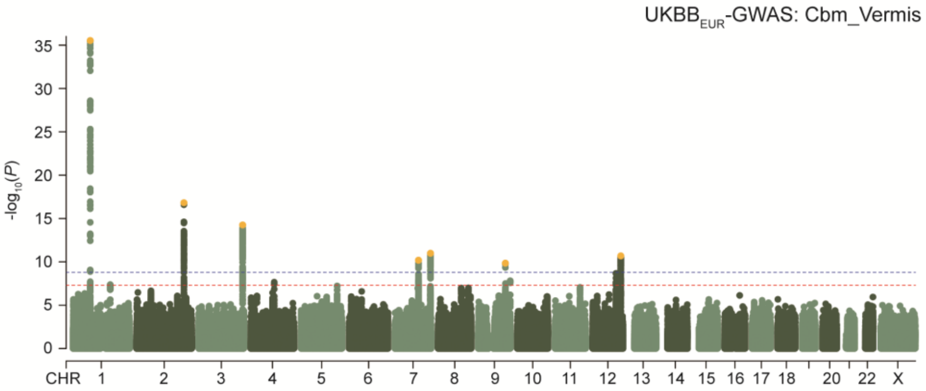


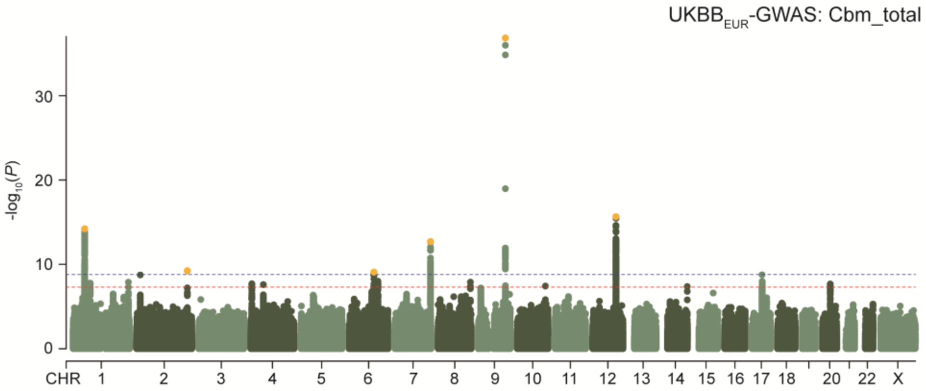
UKBB$_{EUR}$-GWAS: Left-Cerebellum-Cortex

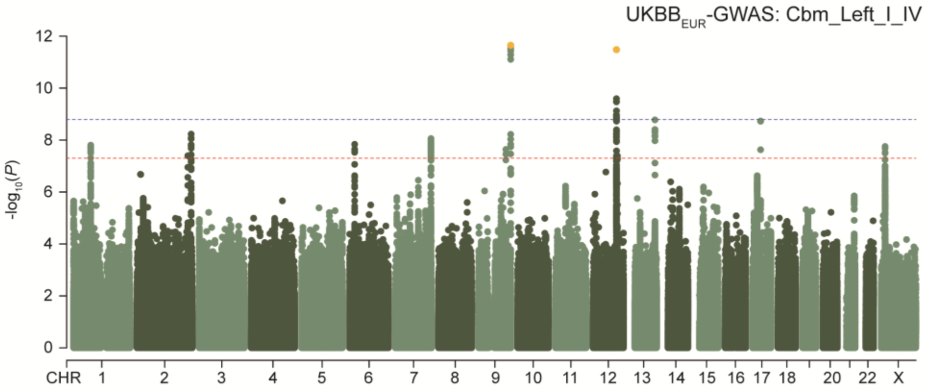


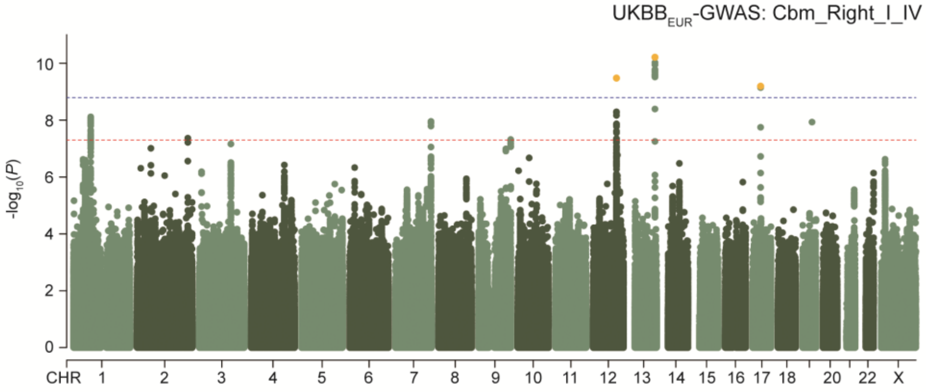
UKBB$_{EUR}$-GWAS: Right-Cerebellum-Cortex

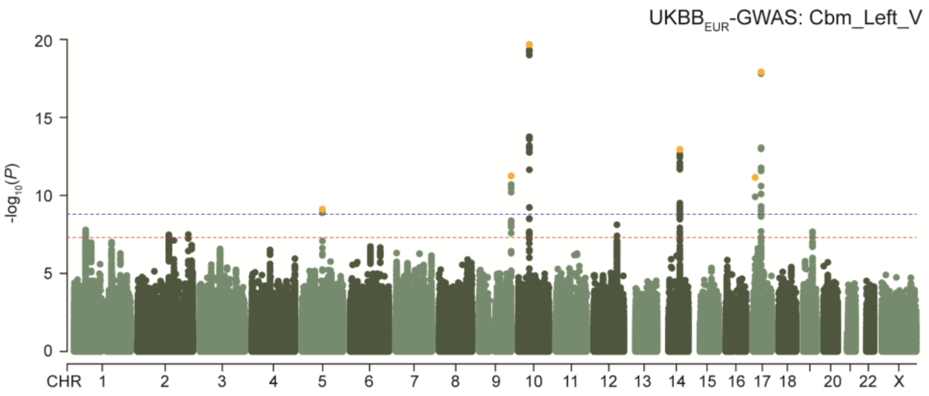


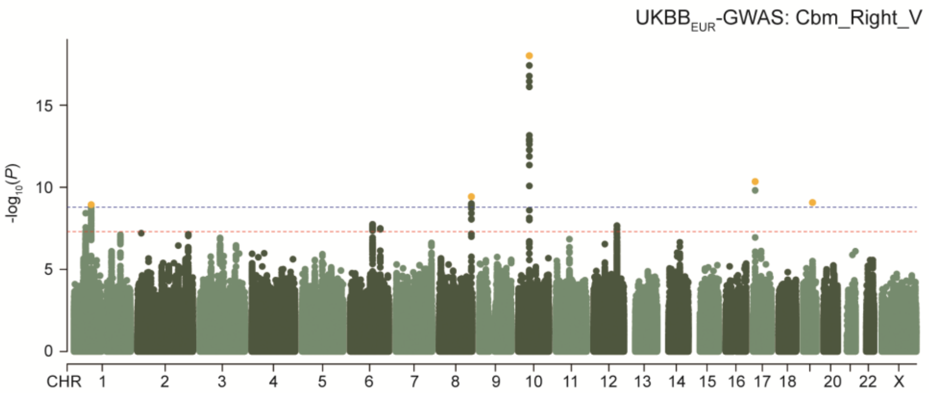

UKBB$_{EUR}$-GWAS: Cbm_Vermis
-log$_{10}$(P)
0
5
10
15
20
25
30
35
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

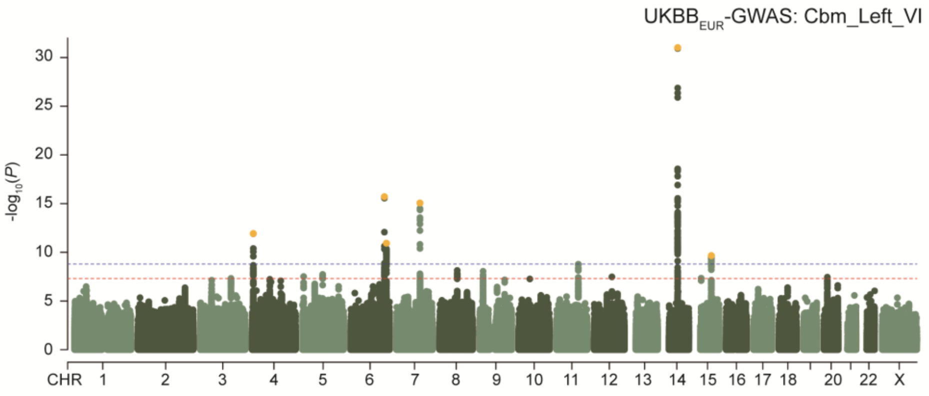

UKBB$_{EUR}$-GWAS: Cbm_total
-log$_{10}$(P)
0
10
20
30
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

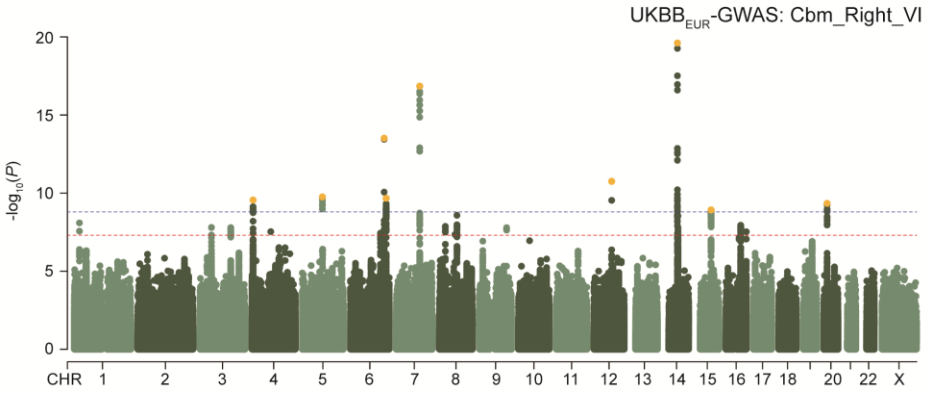

UKBB$_{EUR}$-GWAS: Cbm_Left_I_IV
-log$_{10}$(P)
0
2
4
6
8
10
12
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

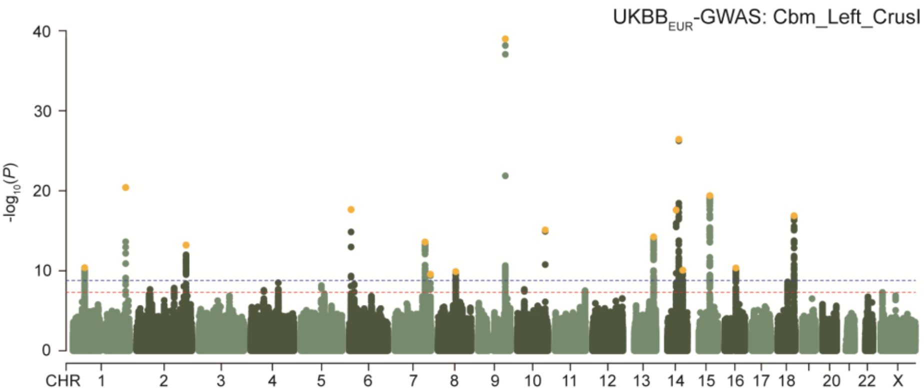

UKBB$_{EUR}$-GWAS: Cbm_Right_I_IV
-log$_{10}$(P)
0
2
4
6
8
10
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


UKBB$_{EUR}$-GWAS: Cbm_Left_V


UKBB$_{EUR}$-GWAS: Cbm_Right_V


UKBB$_{EUR}$-GWAS: Cbm_Left_VI


UKBB$_{EUR}$-GWAS: Cbm_Right_VI


UKBB$_{EUR}$-GWAS: Cbm_Left_CrusI
-log$_{10}$(P)
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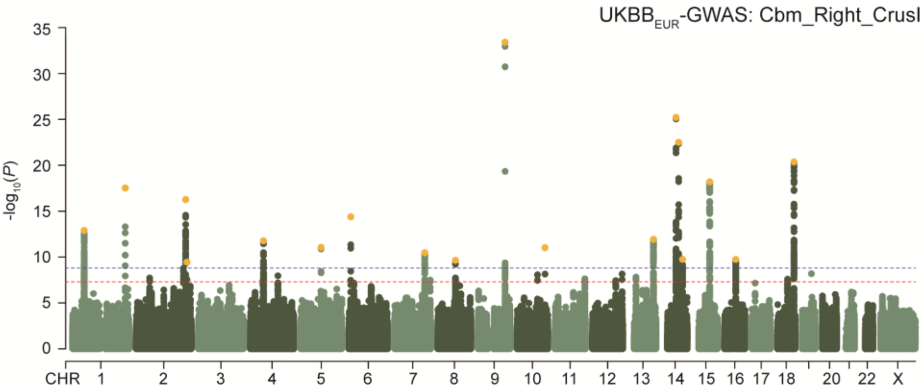
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


UKBB$_{EUR}$-GWAS: Cbm_Right_CrusI
-log$_{10}$(P)
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30
25
20
15
10
5
0
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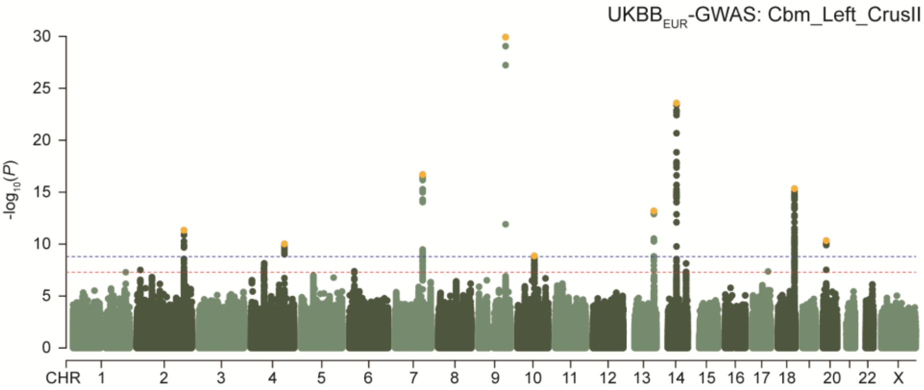
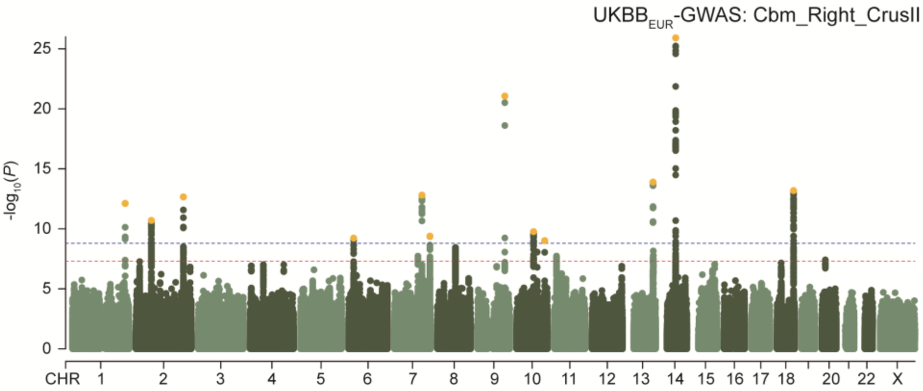

UKBB$_{EUR}$-GWAS: Cbm_Left_CrusII
-log$_{10}$(P)
30
25
20
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


UKBB$_{EUR}$-GWAS: Cbm_Right_CrusII
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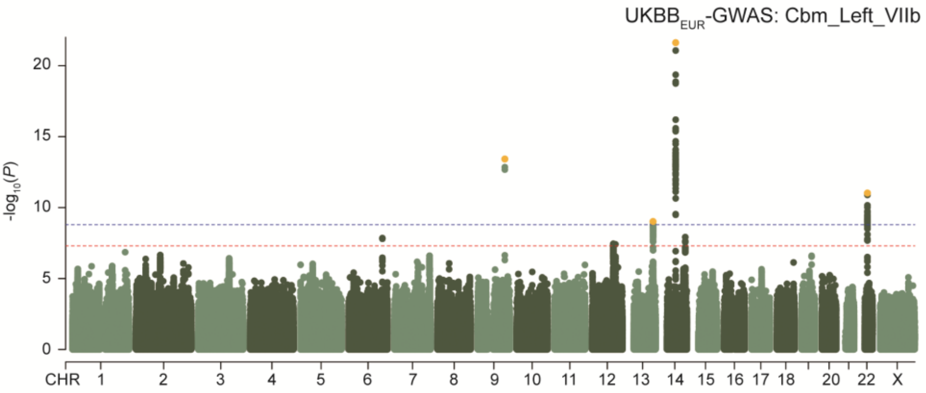
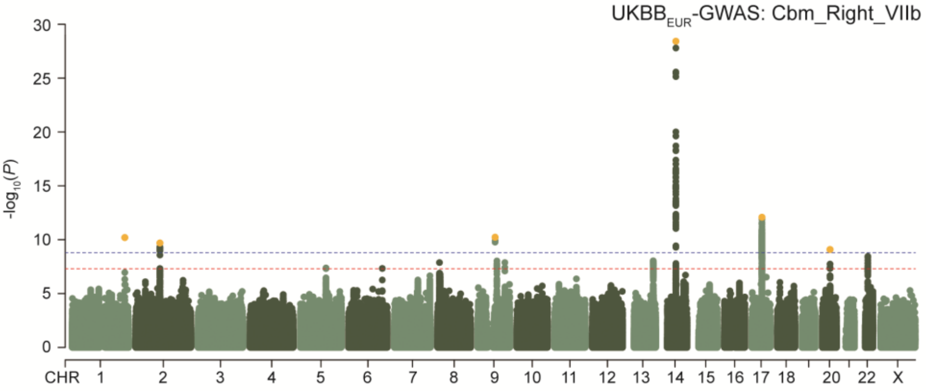
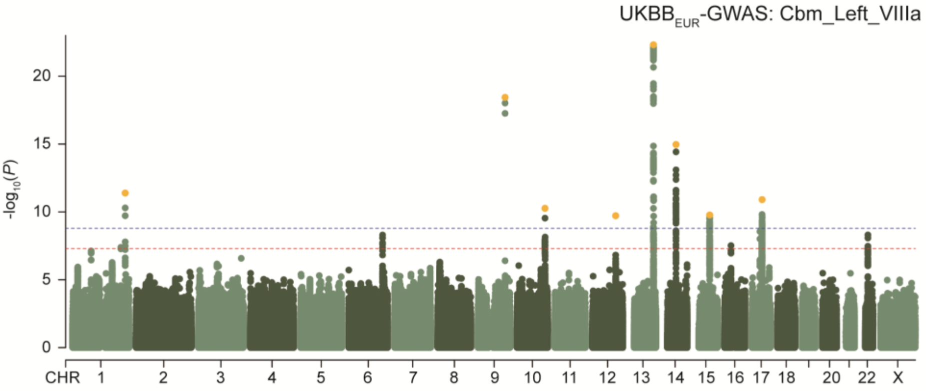
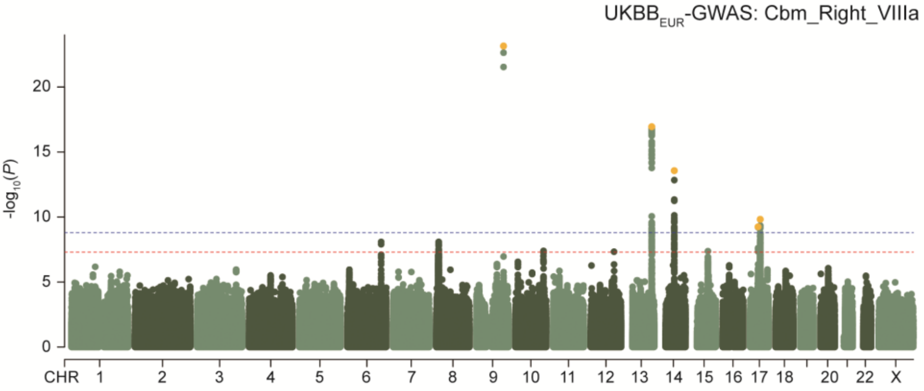
20
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

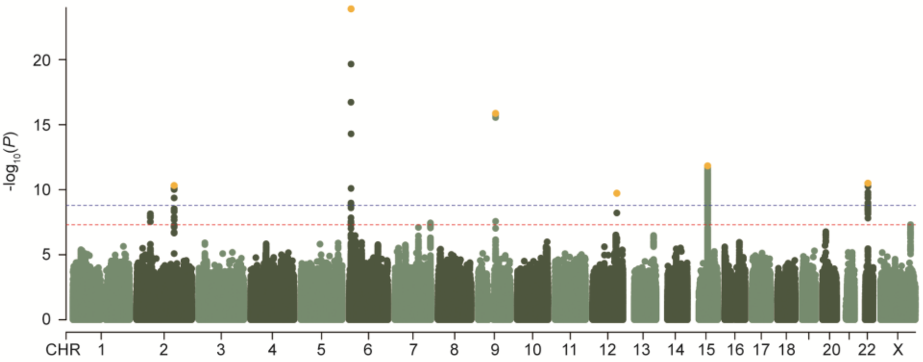

UKBB$_{EUR}$-GWAS: Cbm_Left_VIIb


UKBB$_{EUR}$-GWAS: Cbm_Right_VIIb

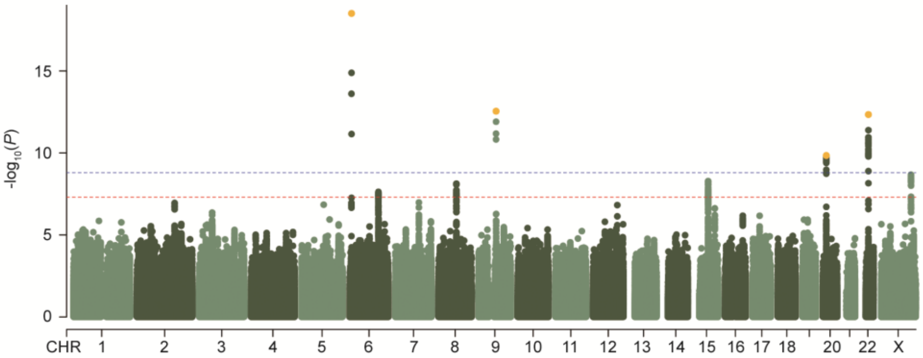

UKBB$_{EUR}$-GWAS: Cbm_Left_VIIIa


UKBB$_{EUR}$-GWAS: Cbm_Right_VIIIa

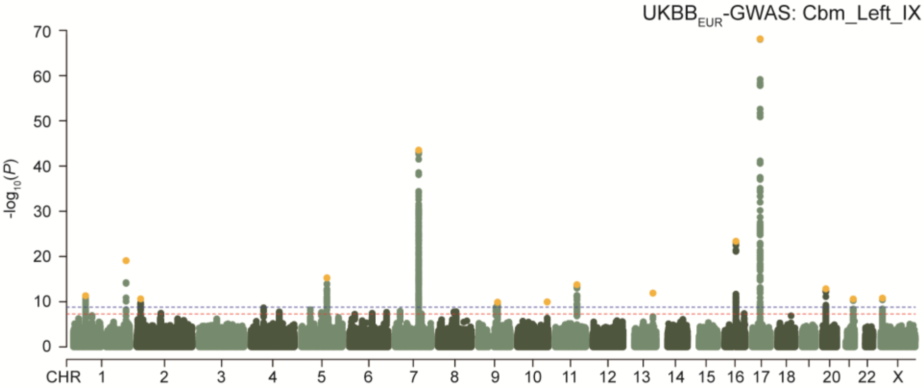
UKBB$_{EUR}$-GWAS: Cbm_Left_VIIIb



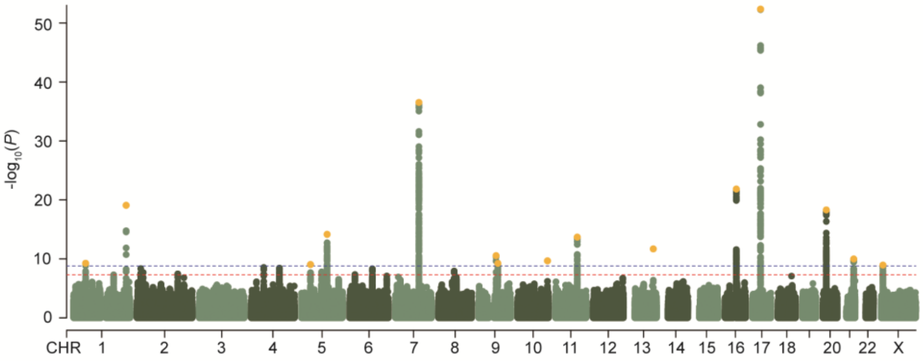
UKBB$_{EUR}$-GWAS: Cbm_Right_VIIIb

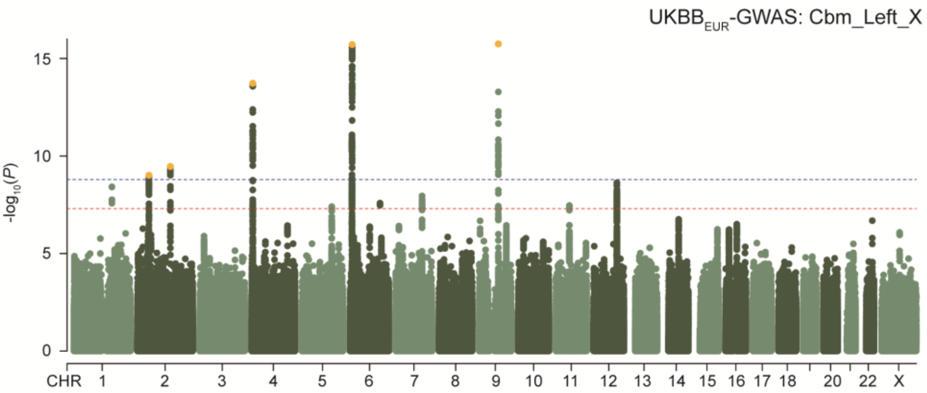


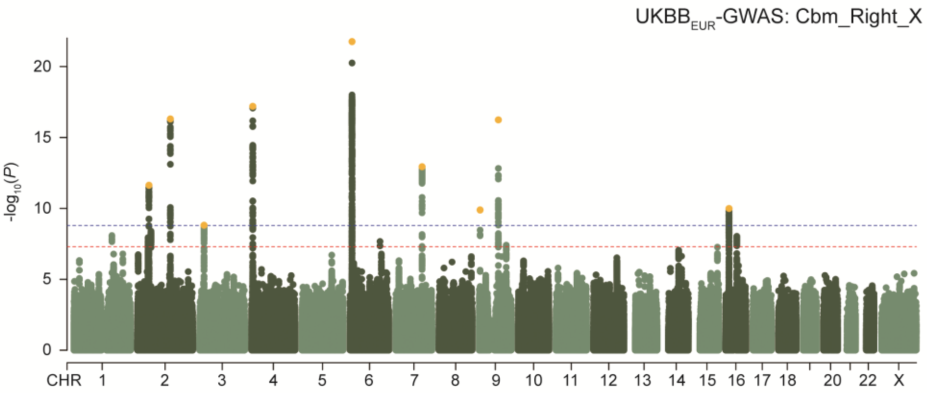
UKBB$_{EUR}$-GWAS: Cbm_Left_IX

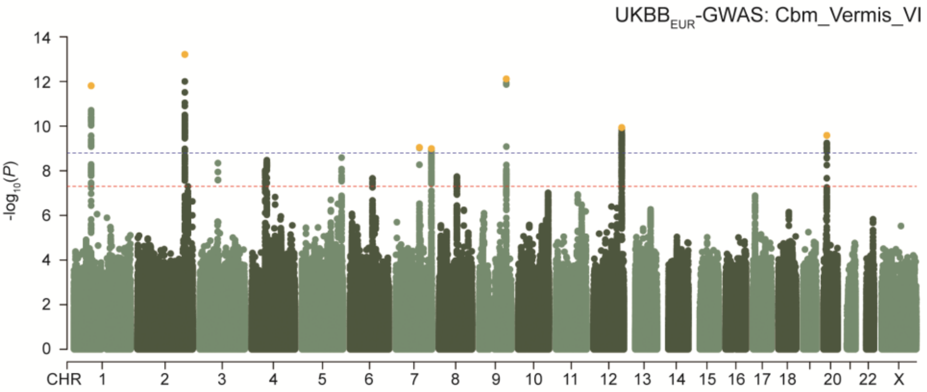


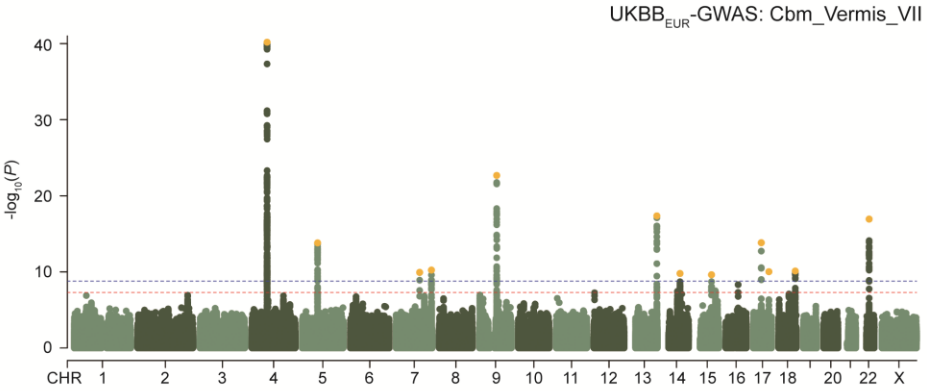
UKBB$_{EUR}$-GWAS: Cbm_Right_IX



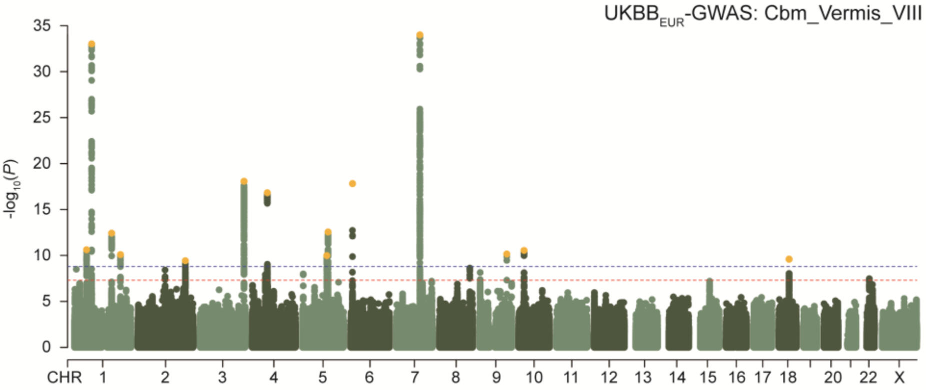

UKBB$_{EUR}$-GWAS: Cbm_Left_X


UKBB$_{EUR}$-GWAS: Cbm_Right_X

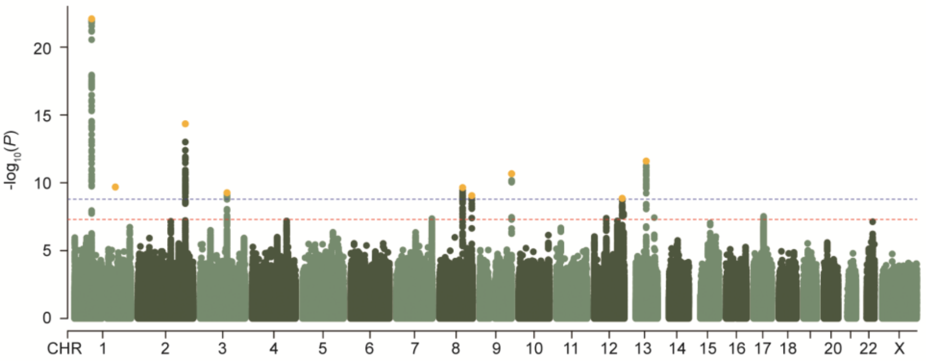

UKBB$_{EUR}$-GWAS: Cbm_Vermis_VI


UKBB$_{EUR}$-GWAS: Cbm_Vermis_VII

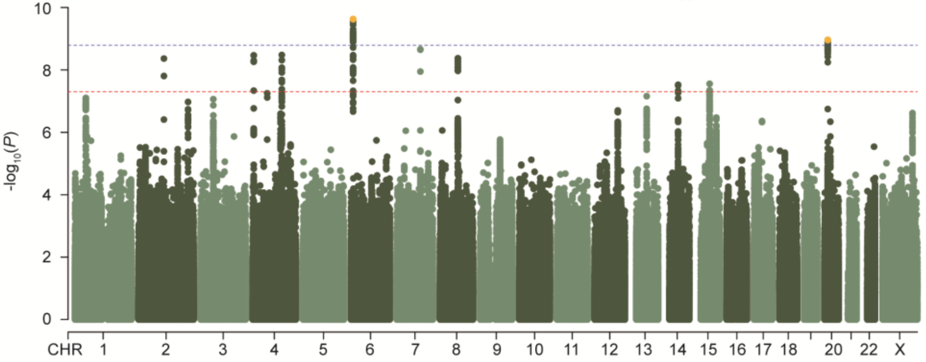
UKBB$_{EUR}$-GWAS: Cbm_Vermis_VIII



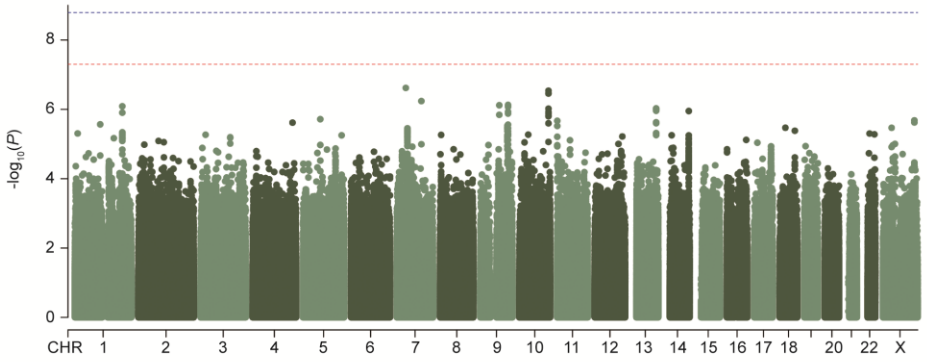
UKBB$_{EUR}$-GWAS: Cbm_Vermis_IX



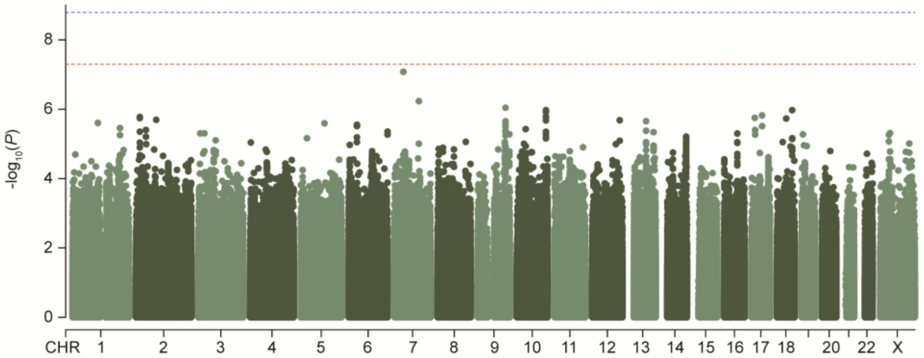
UKBB$_{EUR}$-GWAS: Cbm_Vermis_X



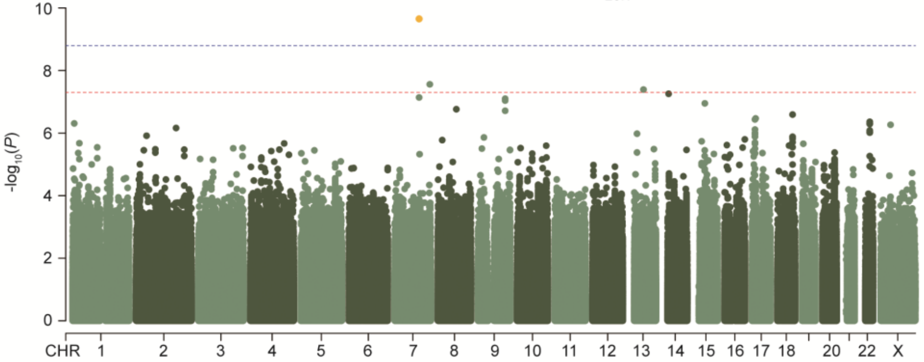
ABCD$_{EUR}$-GWAS: Left-Cerebellum-White-Matter



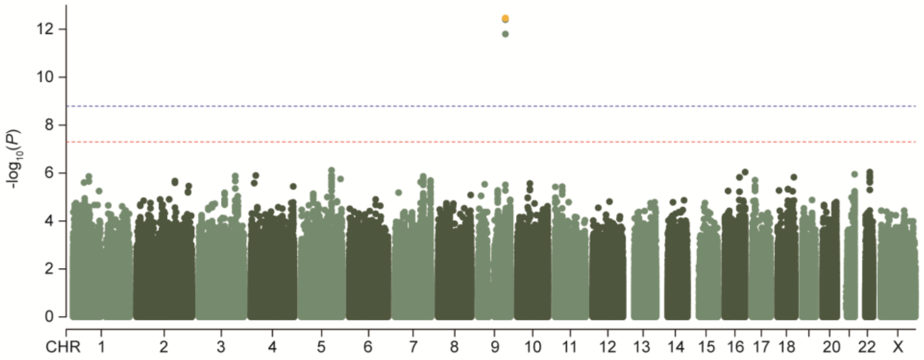
ABCD$_{EUR}$-GWAS: Right-Cerebellum-White-Matter



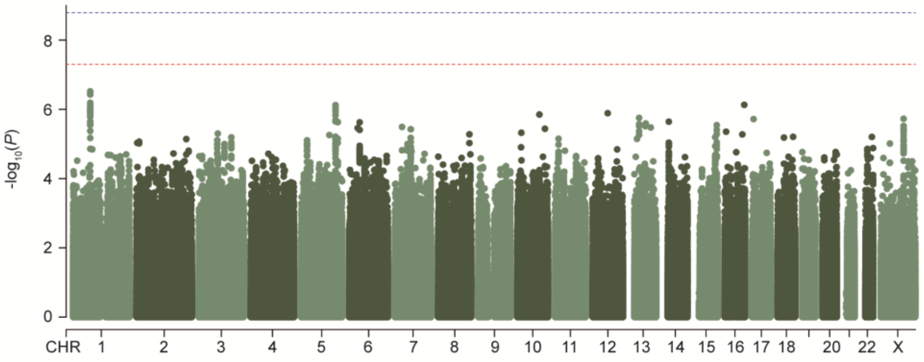
ABCD$_{EUR}$-GWAS: Left-Cerebellum-Cortex

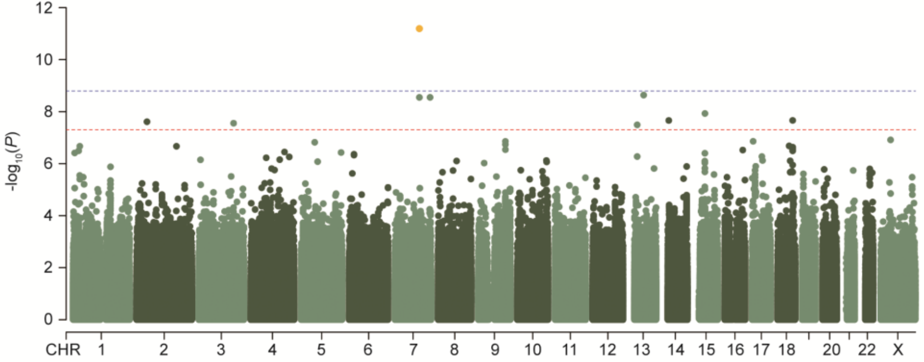


ABCD$_{EUR}$-GWAS: Right-Cerebellum-Cortex

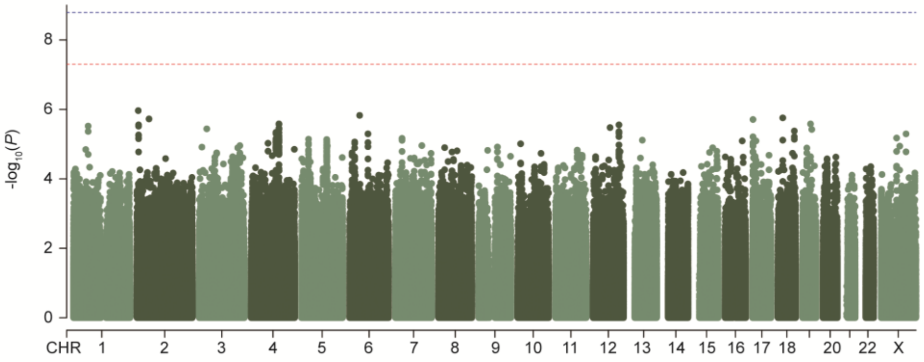


ABCD$_{EUR}$-GWAS: Cbm_Vermis

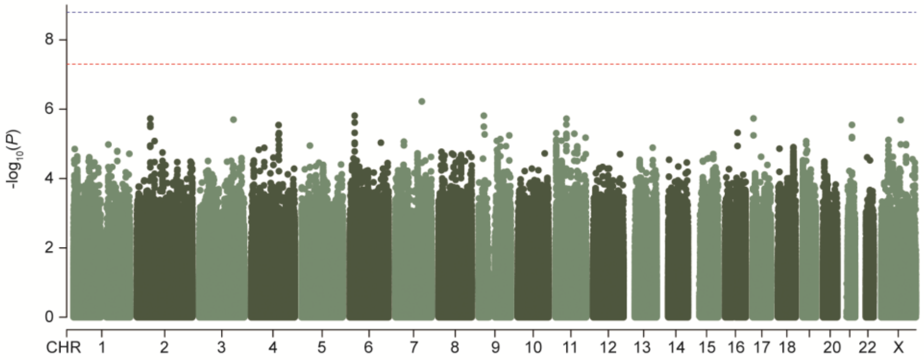




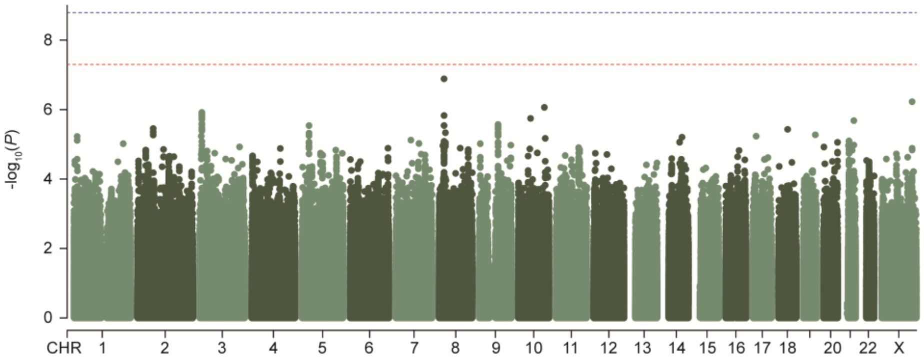
ABCD$_{EUR}$-GWAS: Cbm_total



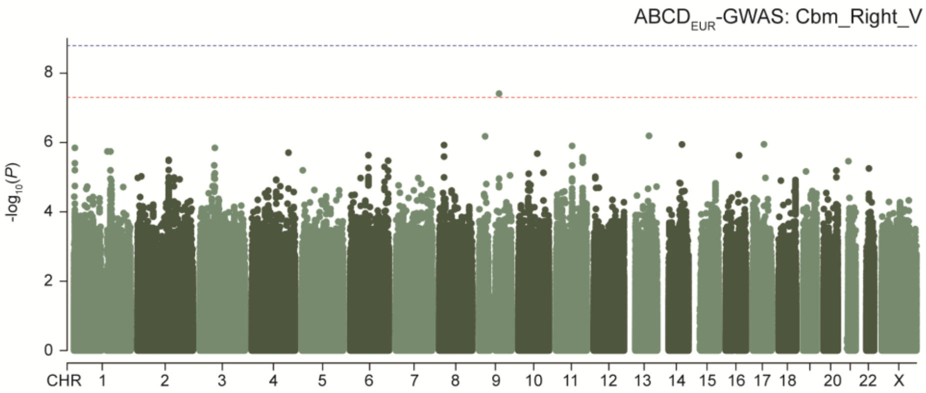
ABCD$_{EUR}$-GWAS: Cbm_Left_I_IV



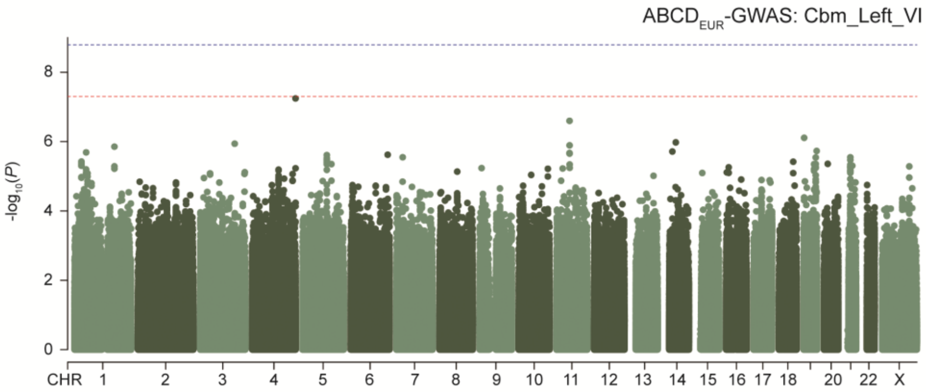
ABCD$_{EUR}$-GWAS: Cbm_Right_I_IV



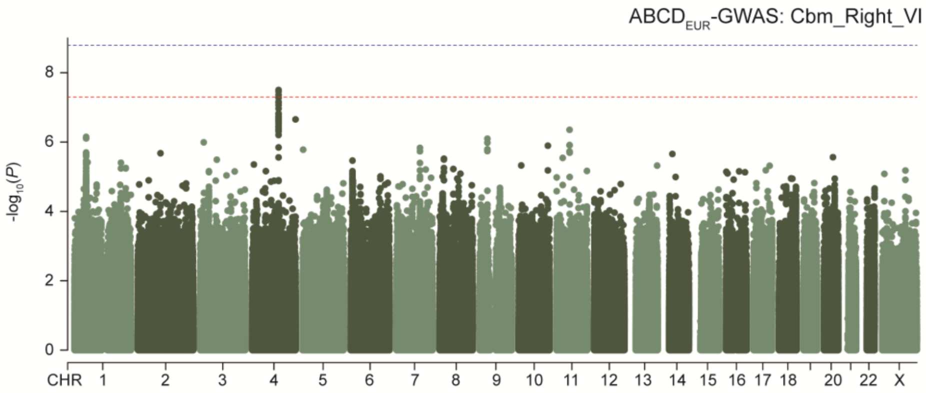
ABCD$_{EUR}$-GWAS: Cbm_Left_V



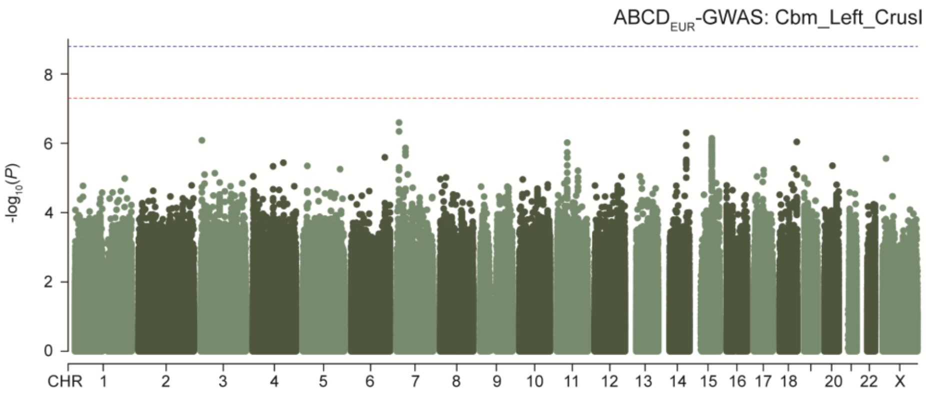
ABCD$_{EUR}$-GWAS: Cbm_Right_V



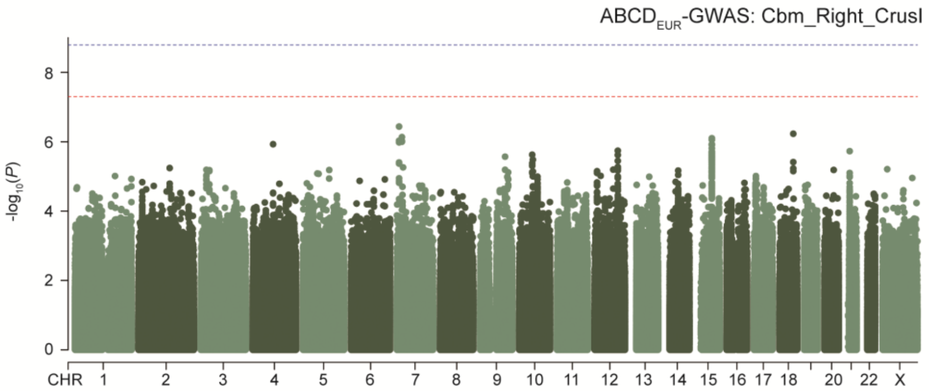
ABCD$_{EUR}$-GWAS: Cbm_Left_VI

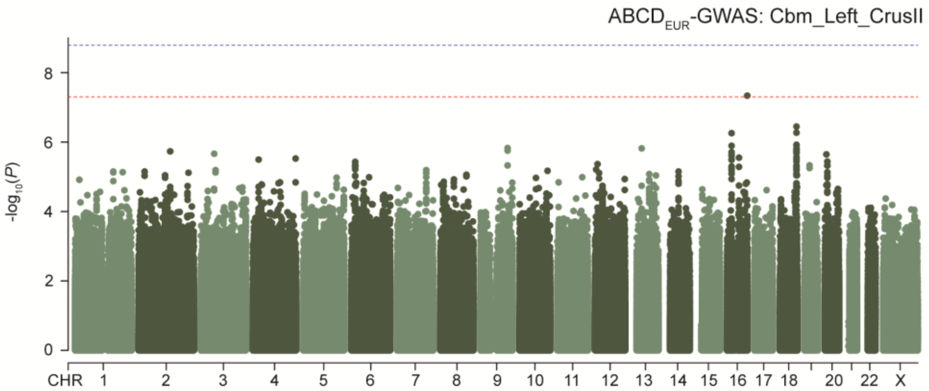


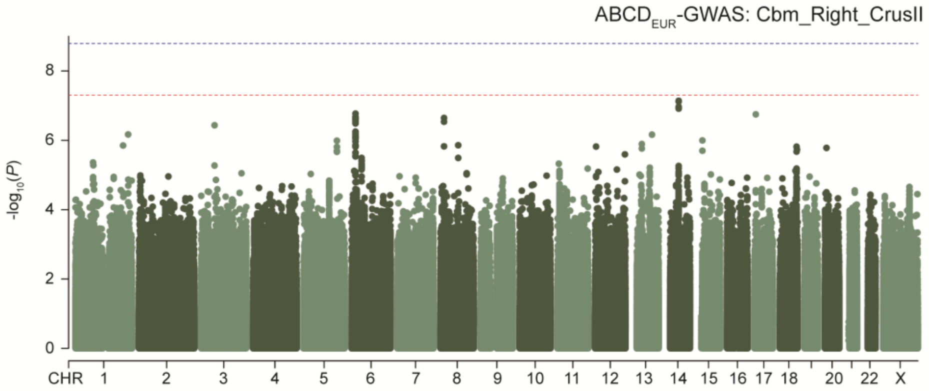
ABCD$_{EUR}$-GWAS: Cbm_Right_VI

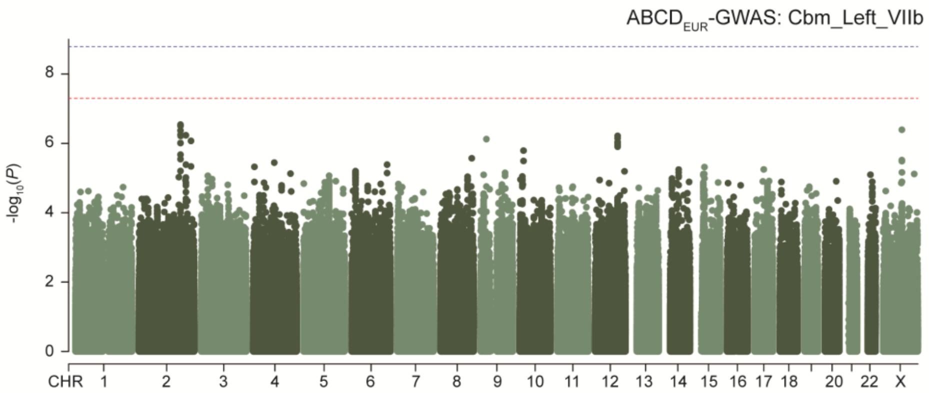


ABCD$_{EUR}$-GWAS: Cbm_Left_CrusI

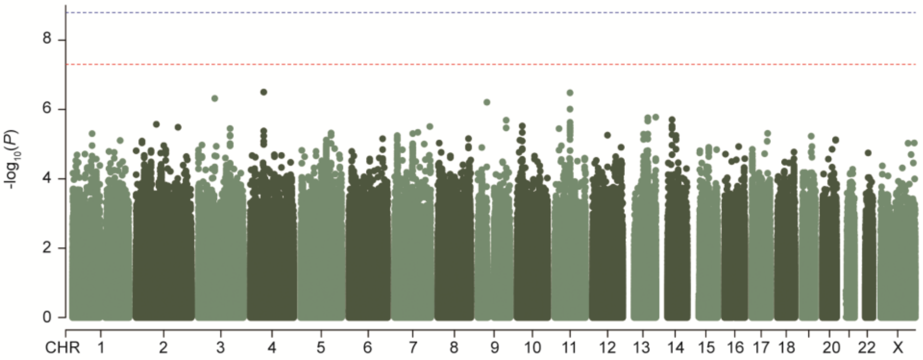

ABCD$_{EUR}$-GWAS: Cbm_Right_CrusI


ABCD$_{EUR}$-GWAS: Cbm_Left_CrusII

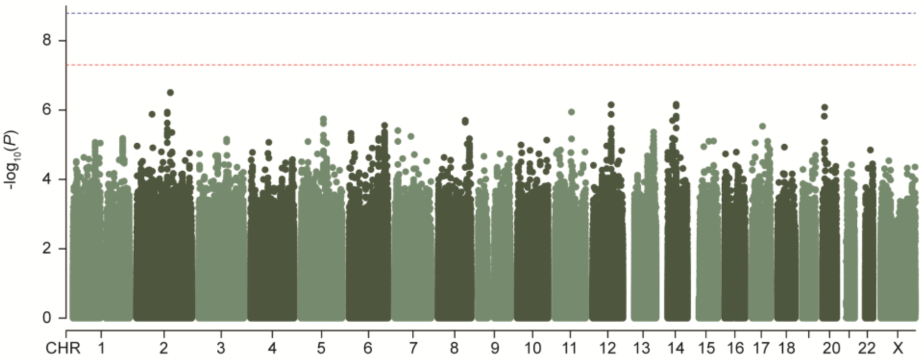

ABCD$_{EUR}$-GWAS: Cbm_Right_CrusII


ABCD$_{EUR}$-GWAS: Cbm_Left_VIIb

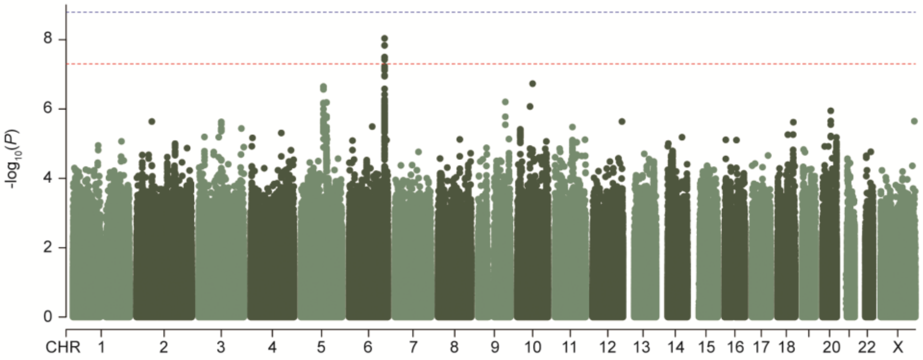
ABCD$_{\text{EUR}}$-GWAS: Cbm_Right_VIIb



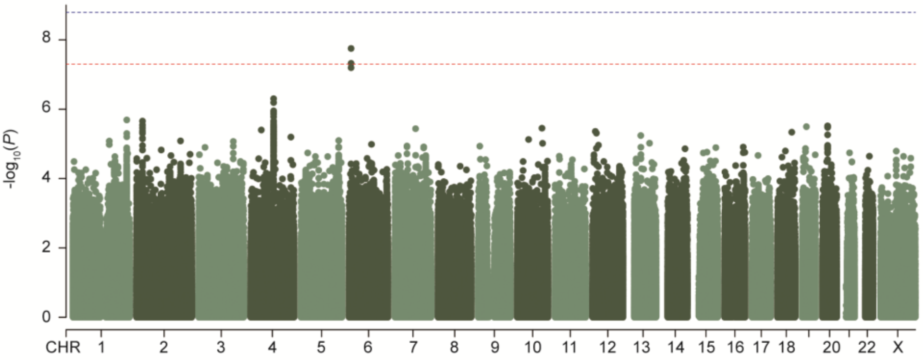
ABCD$_{\text{EUR}}$-GWAS: Cbm_Left_VIIIa

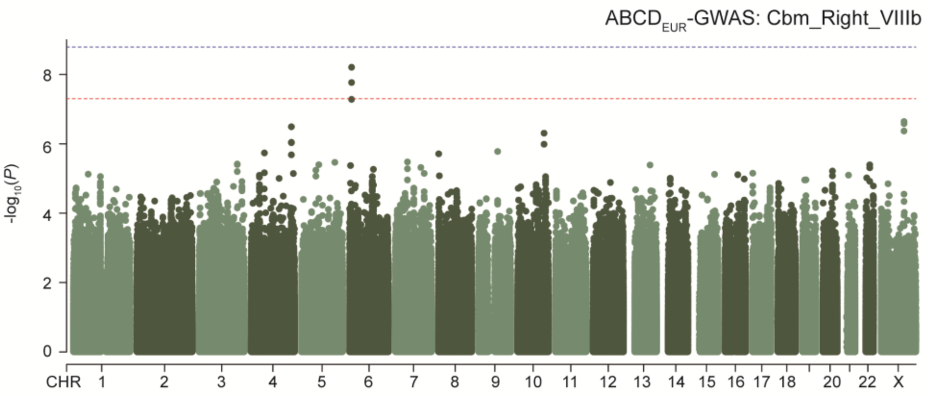


ABCD$_{\text{EUR}}$-GWAS: Cbm_Right_VIIIa



ABCD$_{\text{EUR}}$-GWAS: Cbm_Left_VIIIb




ABCD$_{EUR}$-GWAS: Cbm_Right_VIIIb
-log$_{10}$(P)
0
2
4
6
8
CHR
1
2
3
4
5
6
7
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9
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11
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14
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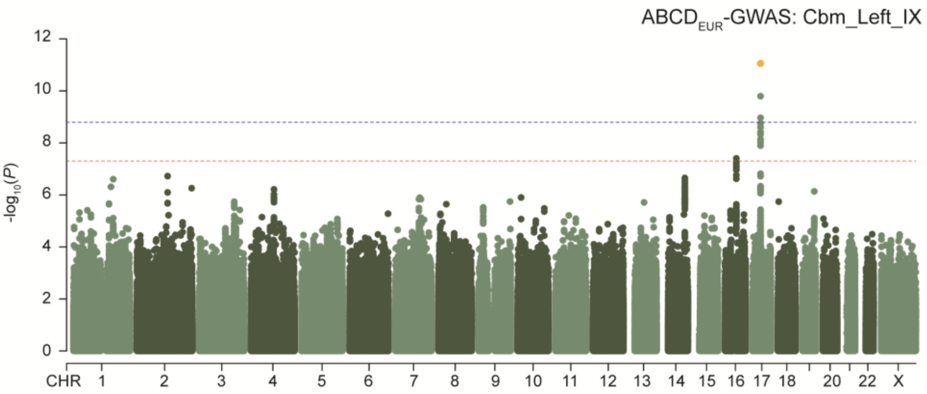
16
17
18
20
22
X


ABCD$_{EUR}$-GWAS: Cbm_Left_IX
-log$_{10}$(P)
0
2
4
6
8
10
12
CHR
1
2
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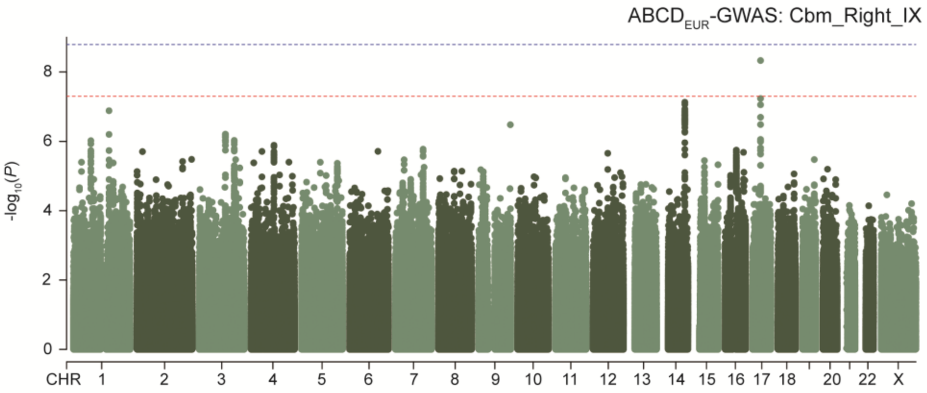
16
17
18
20
22
X


ABCD$_{EUR}$-GWAS: Cbm_Right_IX
-log$_{10}$(P)
0
2
4
6
8
CHR
1
2
3
4
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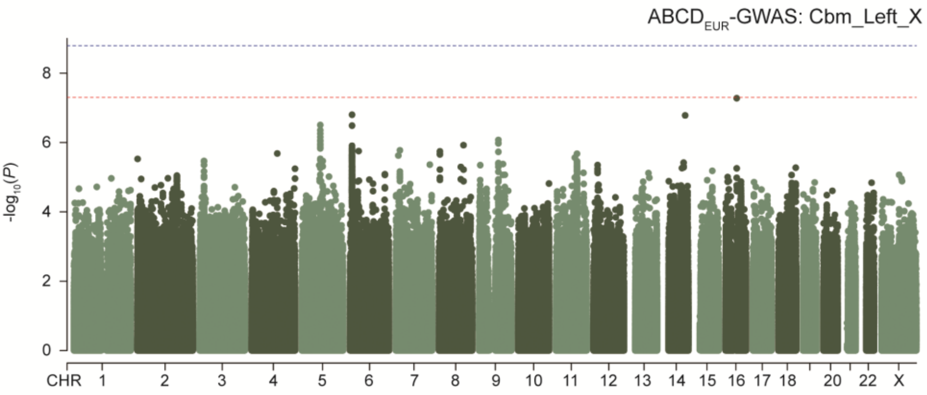
15
16
17
18
20
22
X


ABCD$_{EUR}$-GWAS: Cbm_Left_X
-log$_{10}$(P)
0
2
4
6
8
CHR
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2
3
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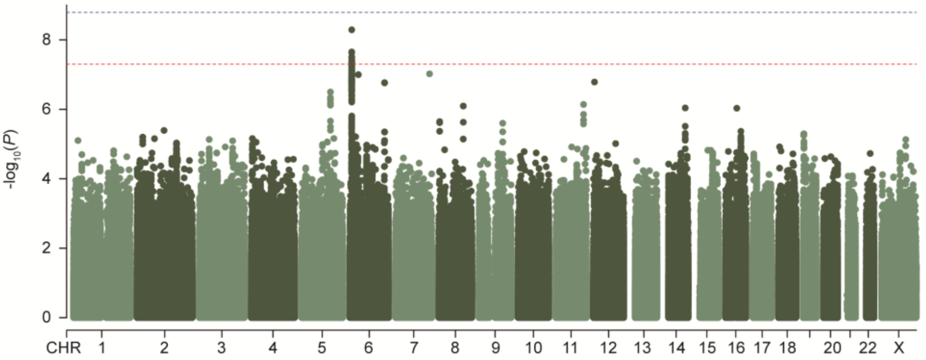
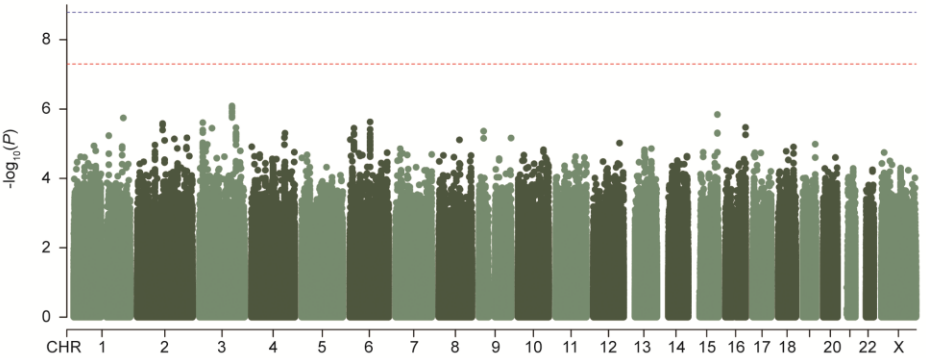
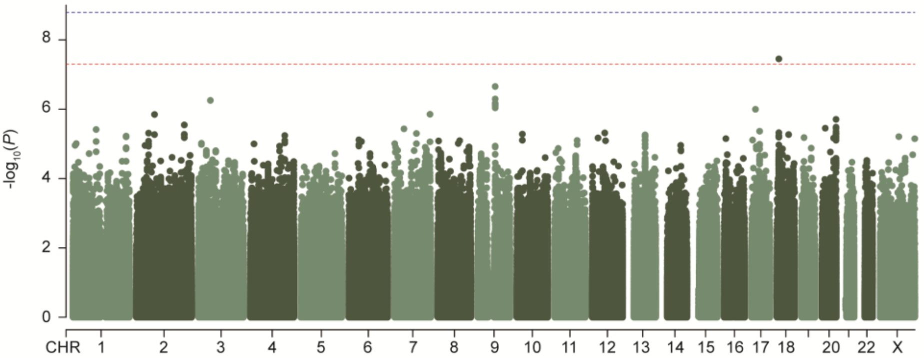
16
17
18
20
22
X



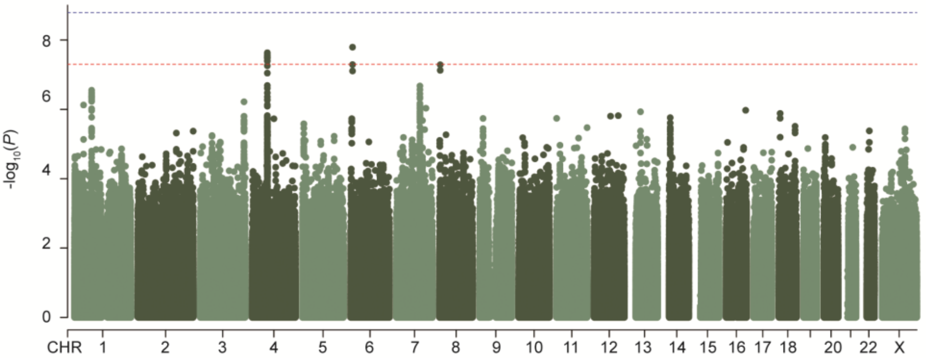
ABCD$_{EUR}$-GWAS: Cbm_Right_X



ABCD$_{EUR}$-GWAS: Cbm_Vermis_VI

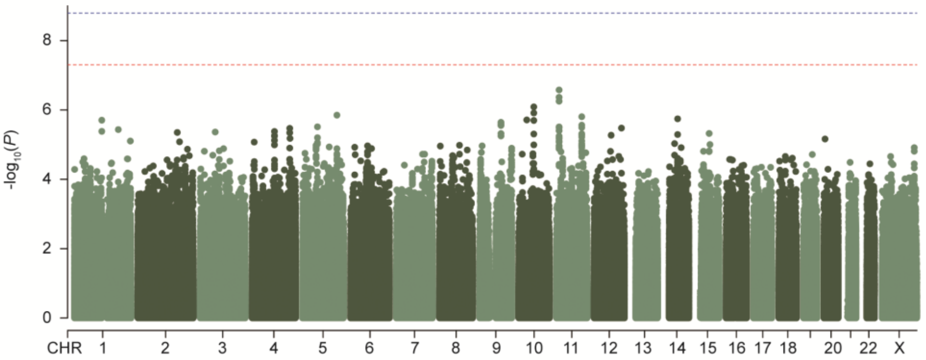


ABCD$_{EUR}$-GWAS: Cbm_Vermis_VII

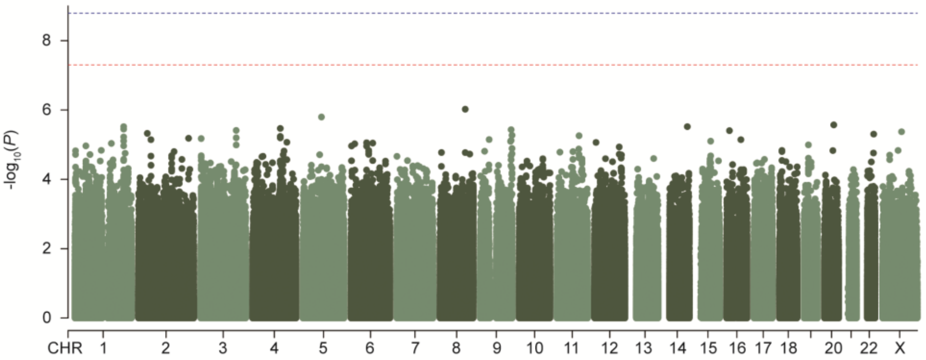


ABCD$_{EUR}$-GWAS: Cbm_Vermis_VIII

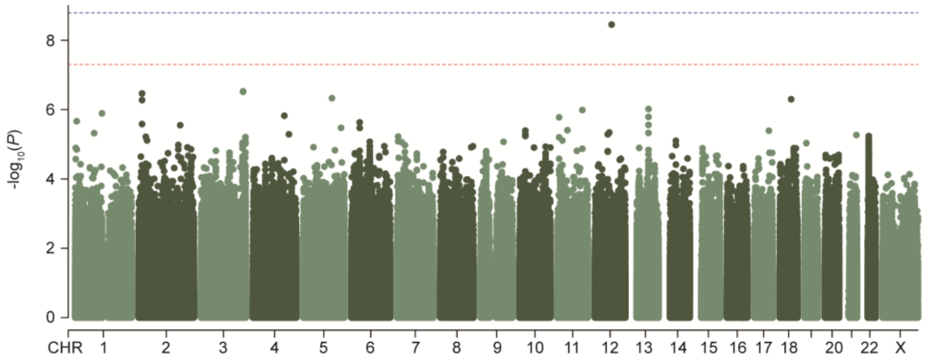
ABCD$_{EUR}$-GWAS: Cbm_Vermis_IX



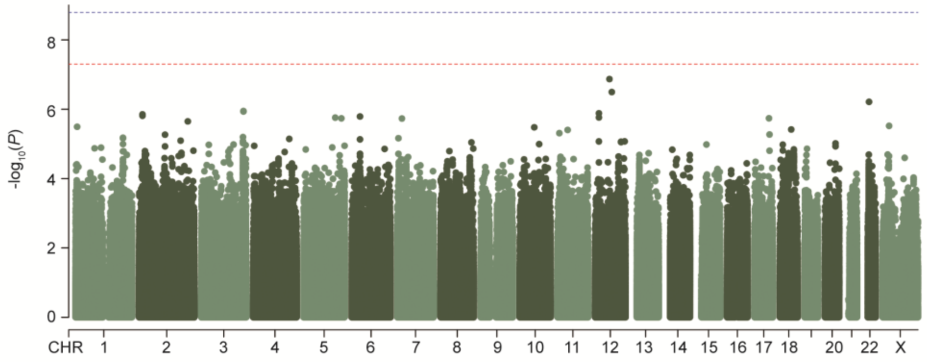
ABCD$_{EUR}$-GWAS: Cbm_Vermis_X

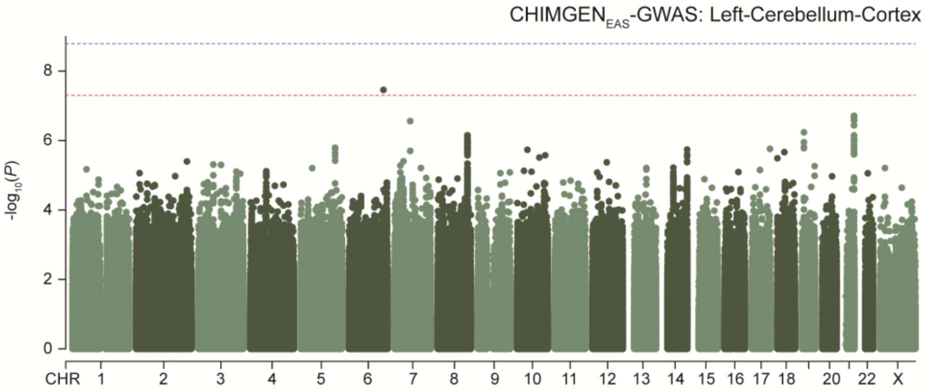


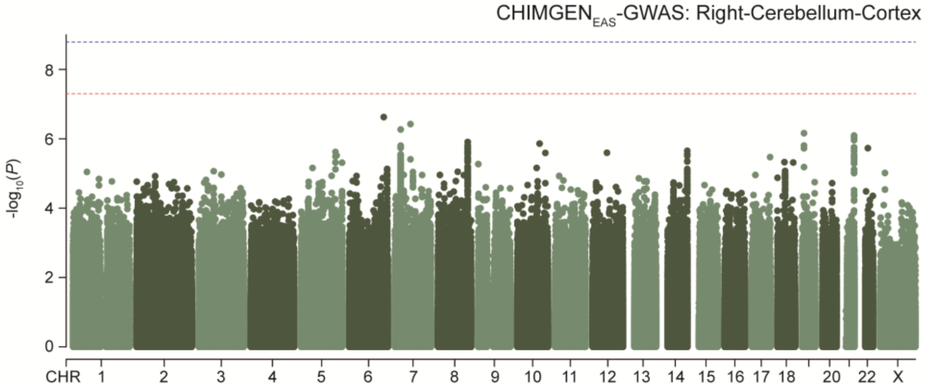
CHIMGEN$_{EAS}$-GWAS: Left-Cerebellum-White-Matter

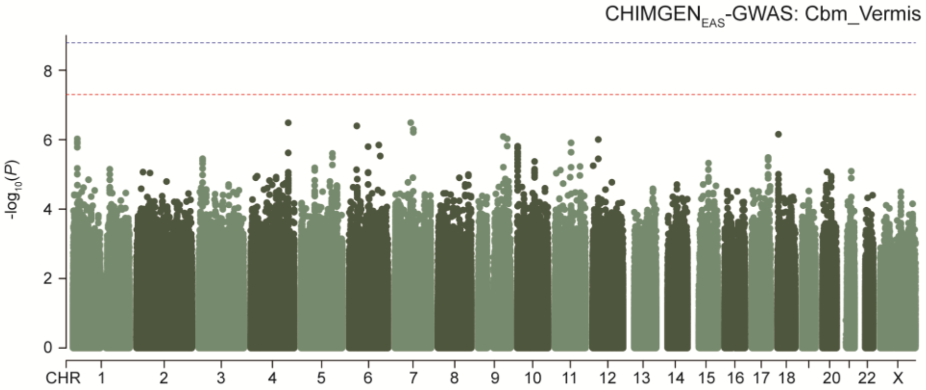


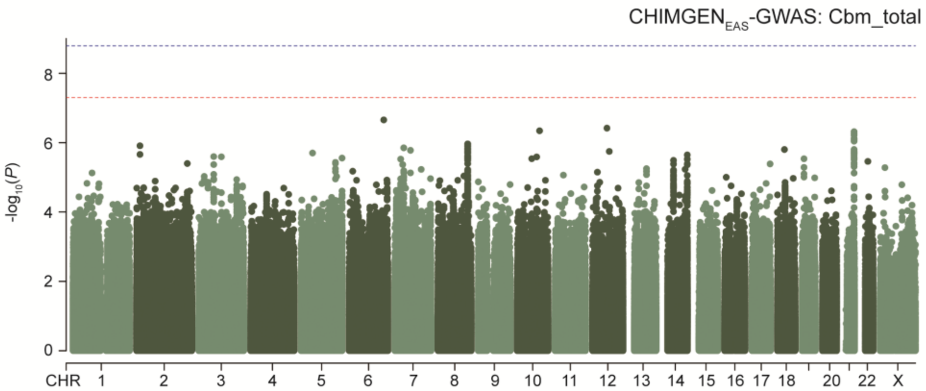
CHIMGEN$_{EAS}$-GWAS: Right-Cerebellum-White-Matter

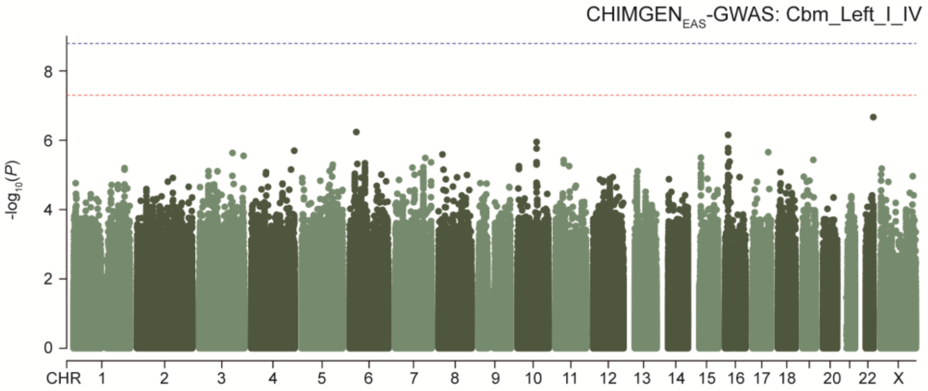


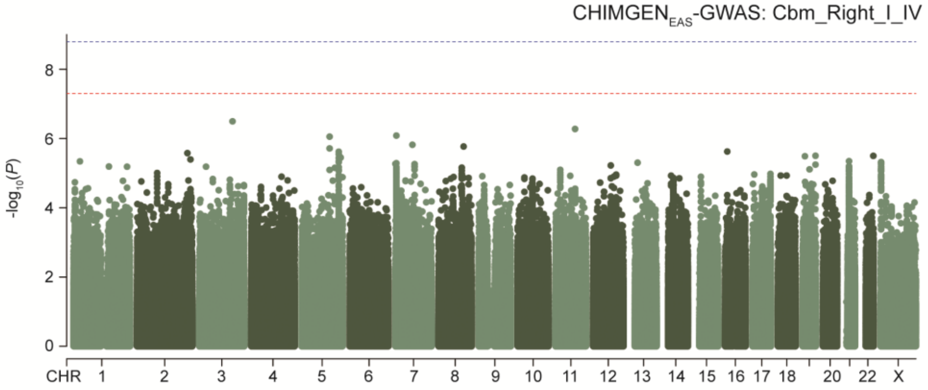

CHIMGEN$_{EAS}$-GWAS: Left-Cerebellum-Cortex

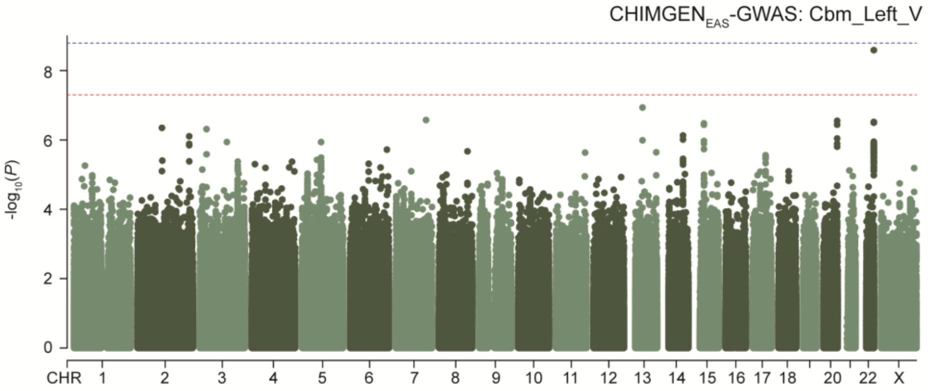

CHIMGEN$_{EAS}$-GWAS: Right-Cerebellum-Cortex


CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis


CHIMGEN$_{EAS}$-GWAS: Cbm_total


CHIMGEN$_{EAS}$-GWAS: Cbm_Left_I_IV


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_I_IV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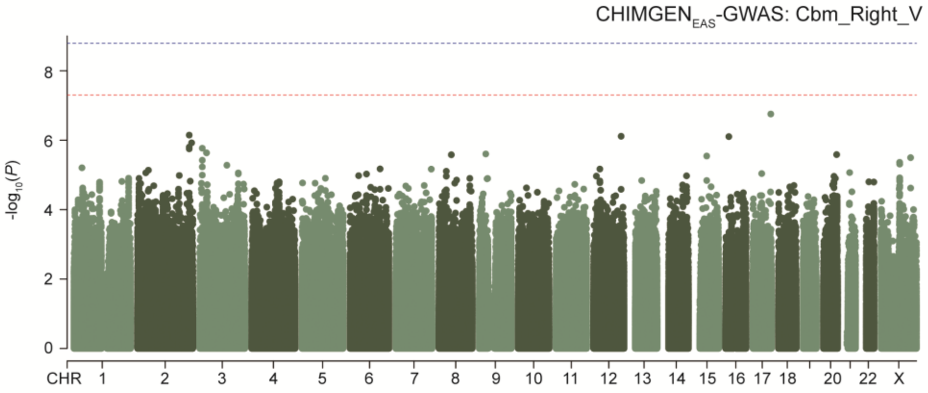
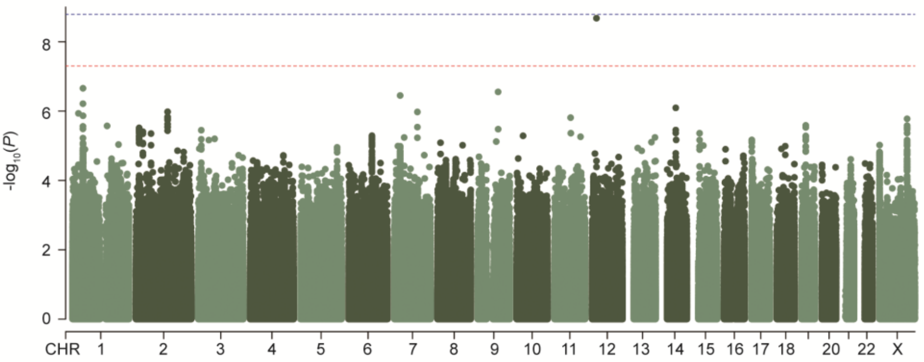
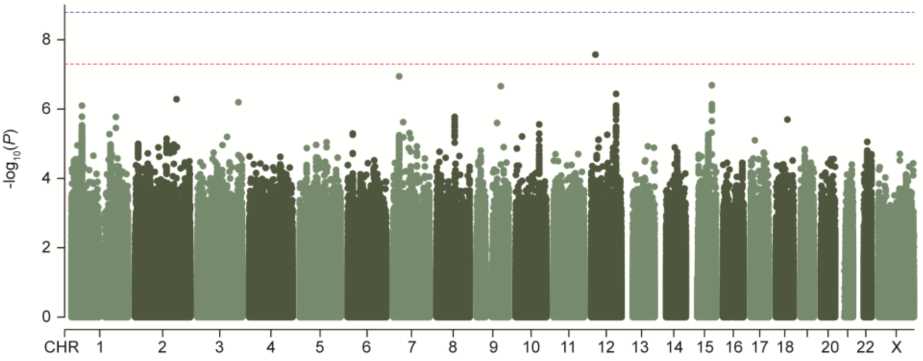

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_V

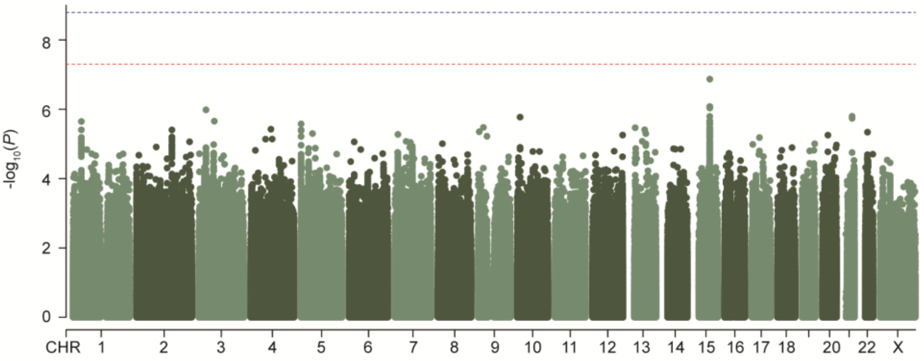
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VI



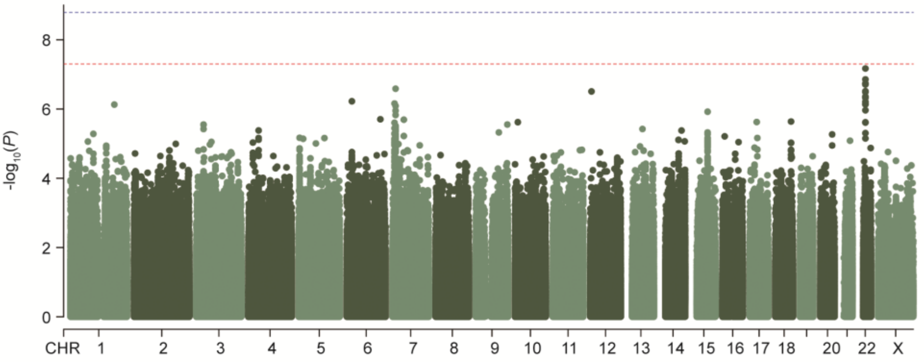
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VI

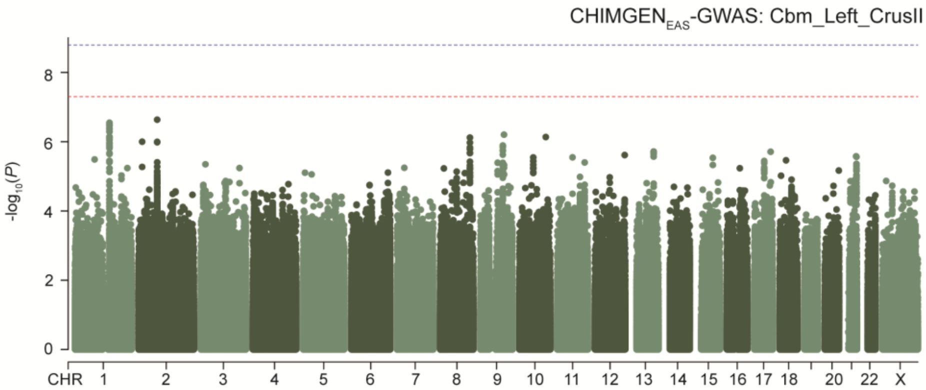


CHIMGEN$_{EAS}$-GWAS: Cbm_Left_CrusI



CHIMGEN$_{EAS}$-GWAS: Cbm_Right_CrusI

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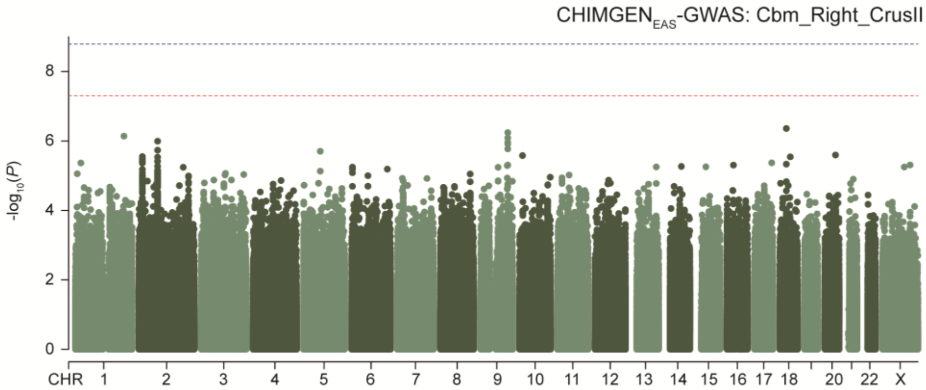
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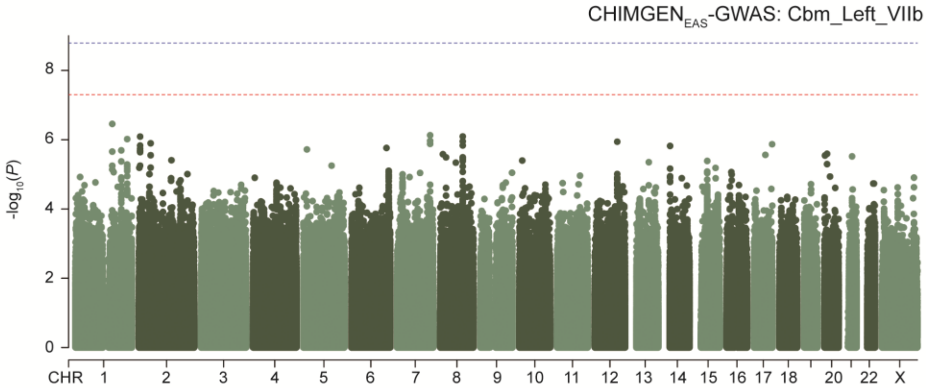
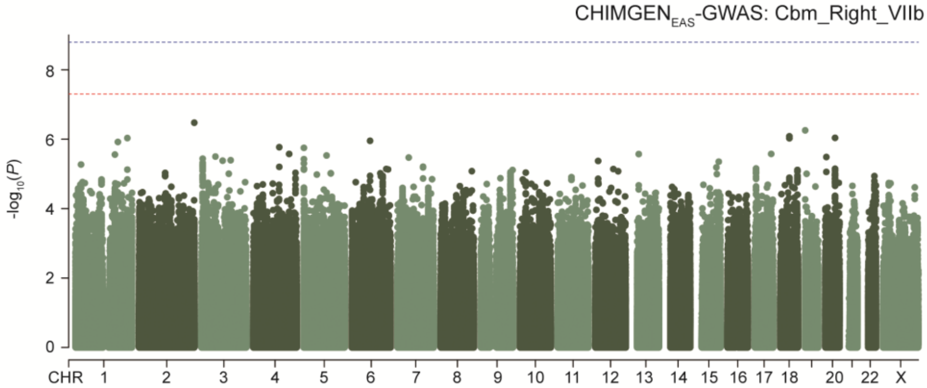
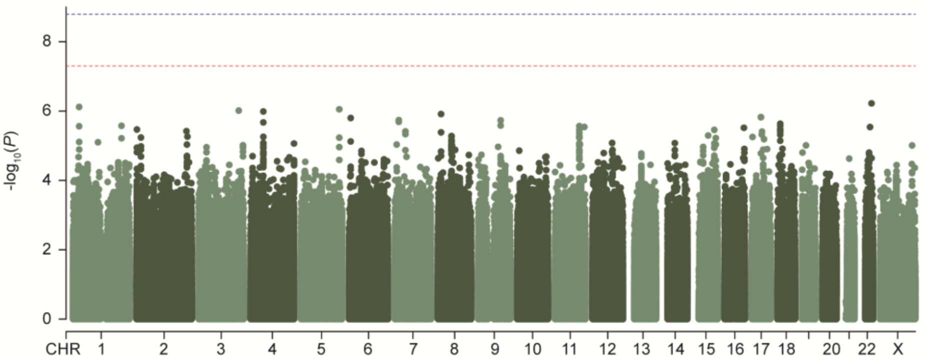
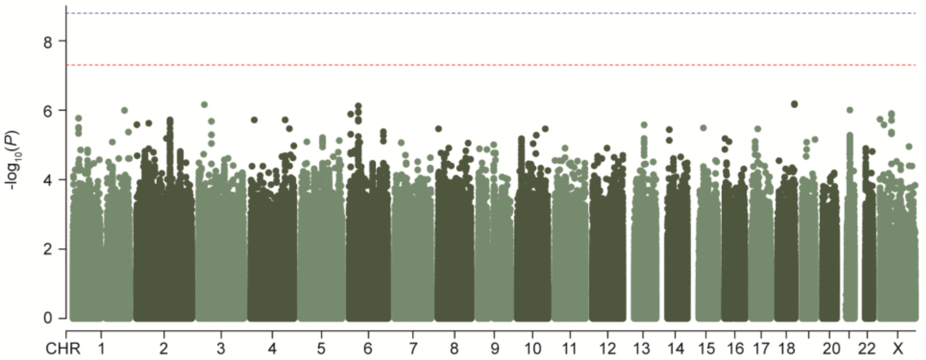

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIb

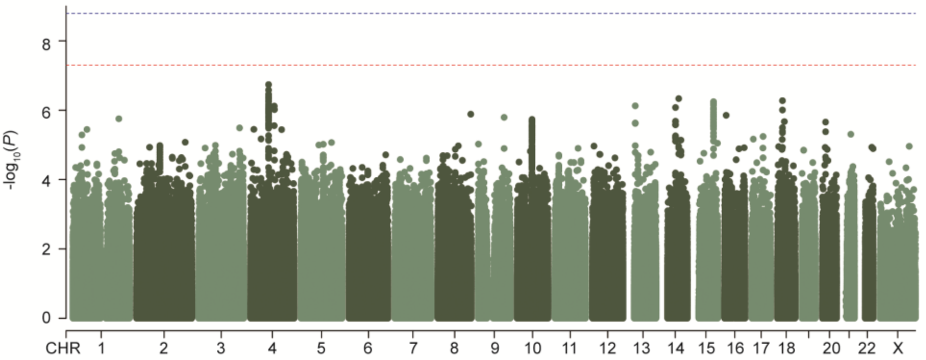

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIb



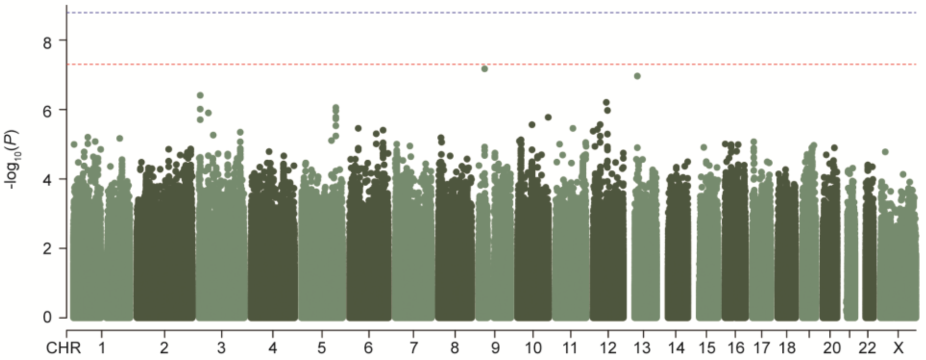
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIIa



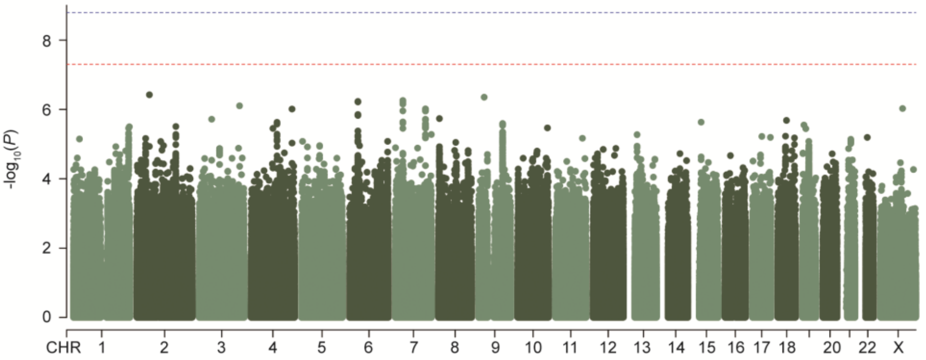
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIIa

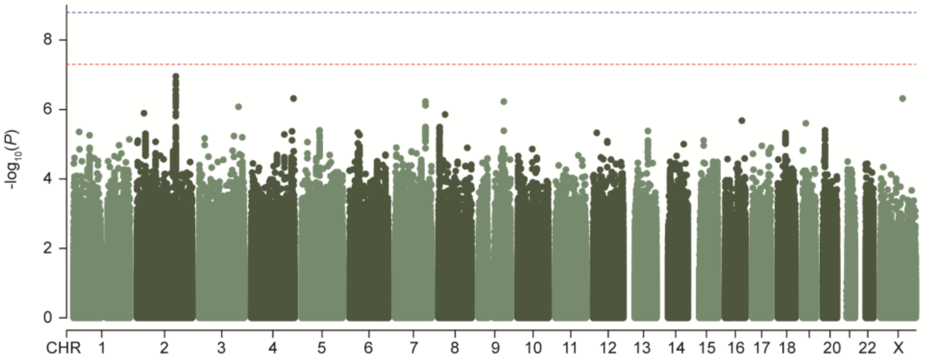


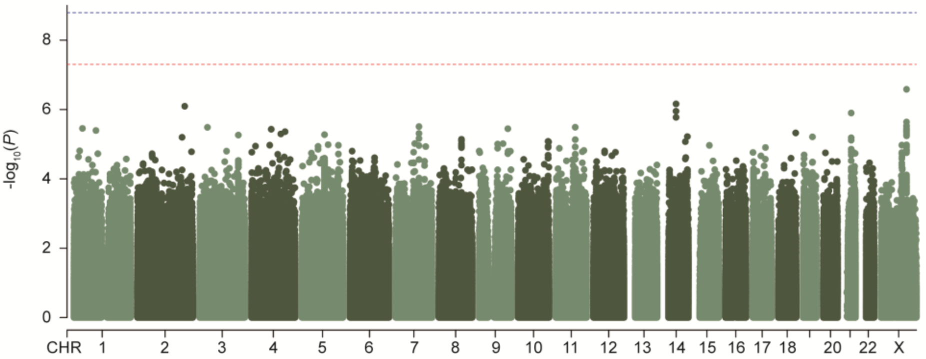
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIIb

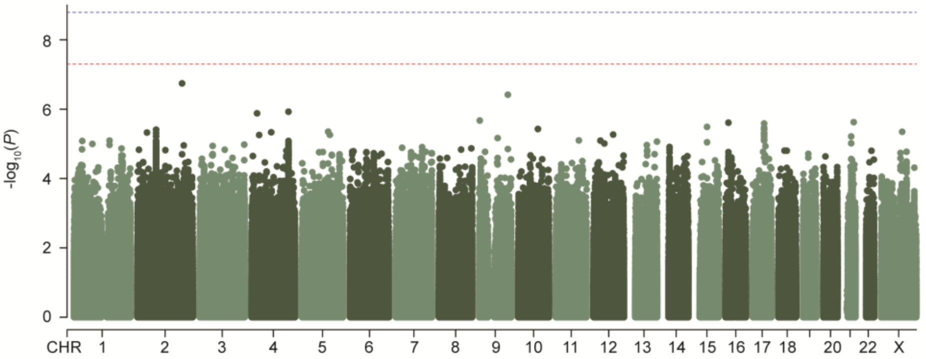


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIIb

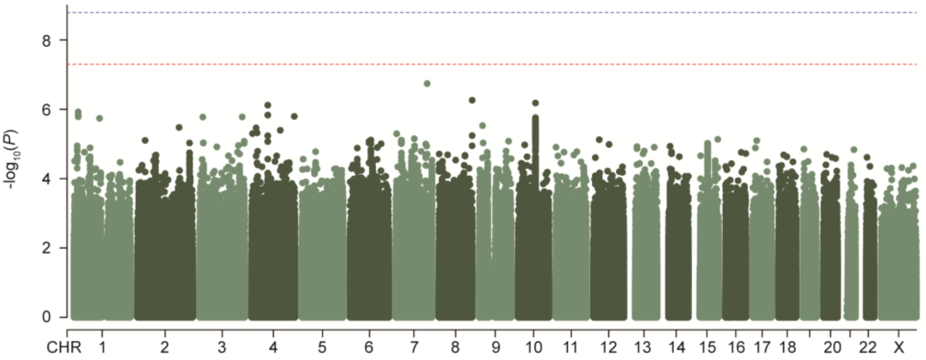

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_IX


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_IX

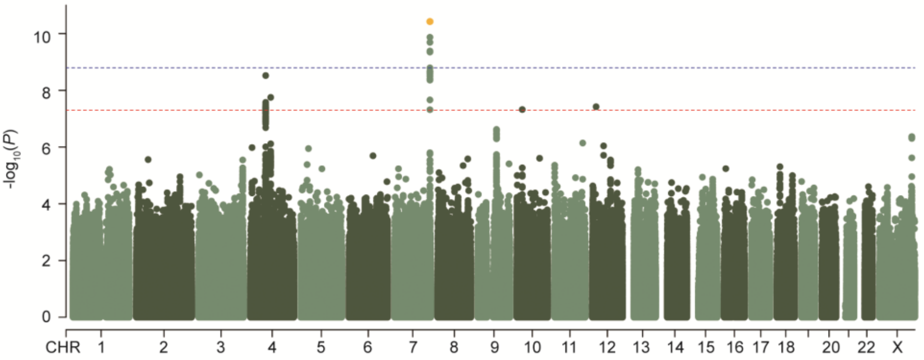

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_X


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_X

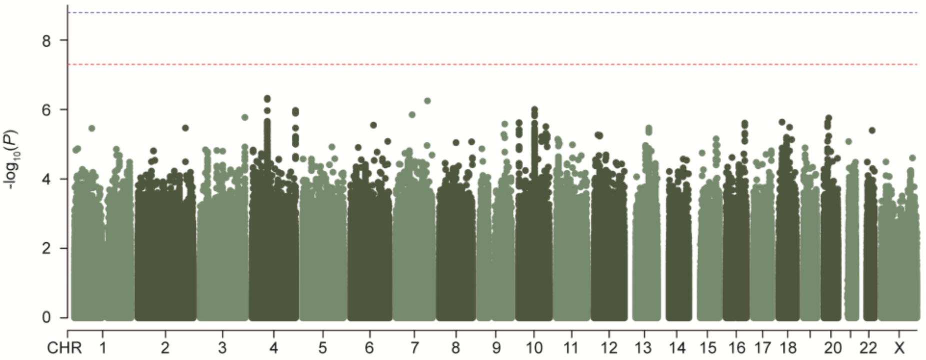
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VI



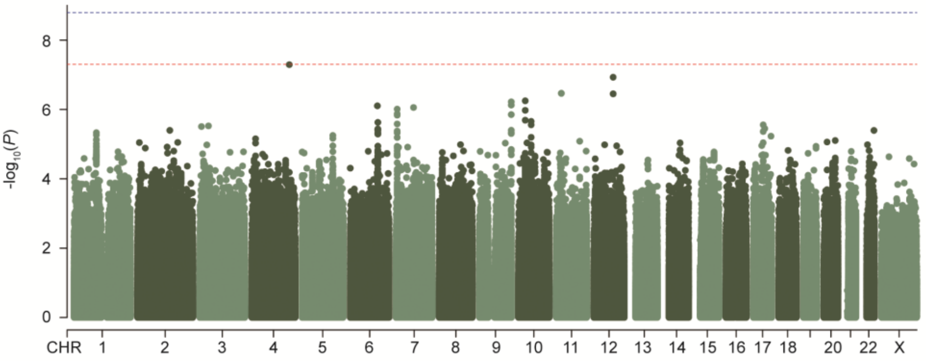
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VII

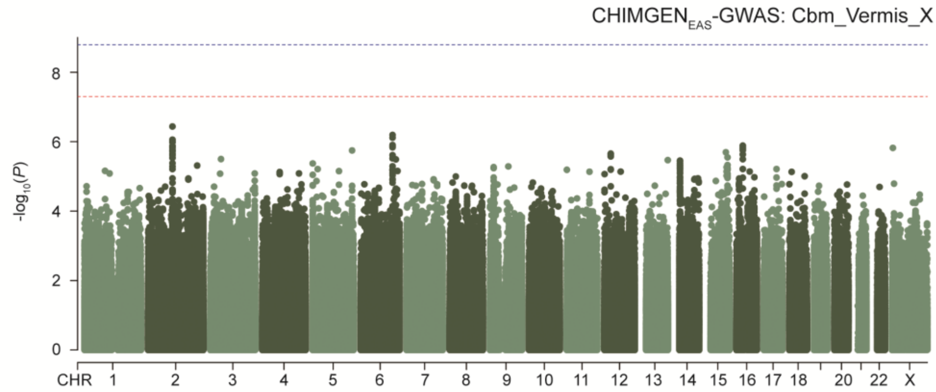


CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VIII

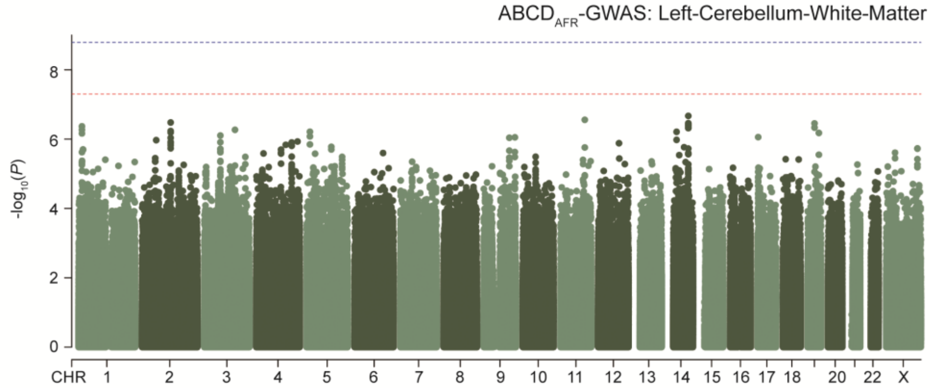


CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_IX

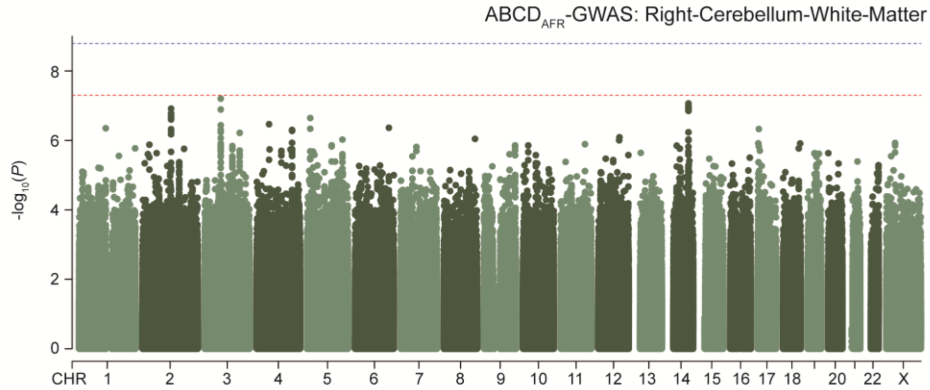




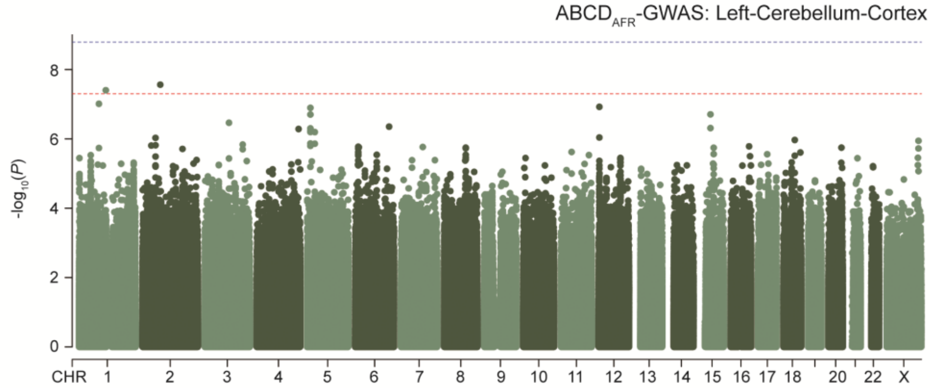
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_X



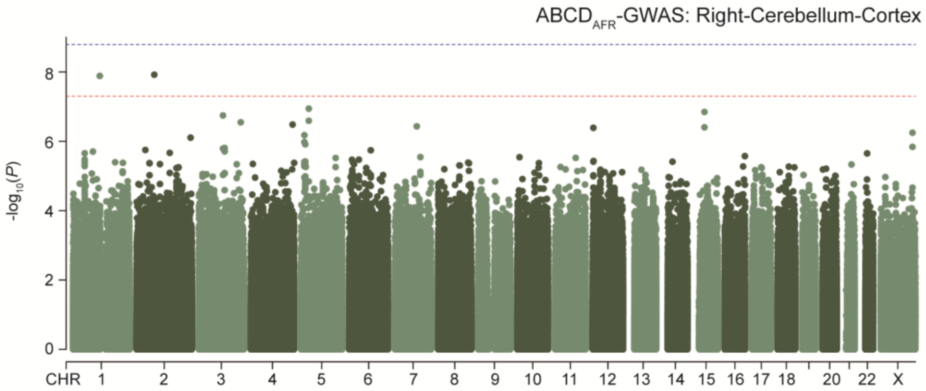
ABCD$_{AFR}$-GWAS: Left-Cerebellum-White-Matter

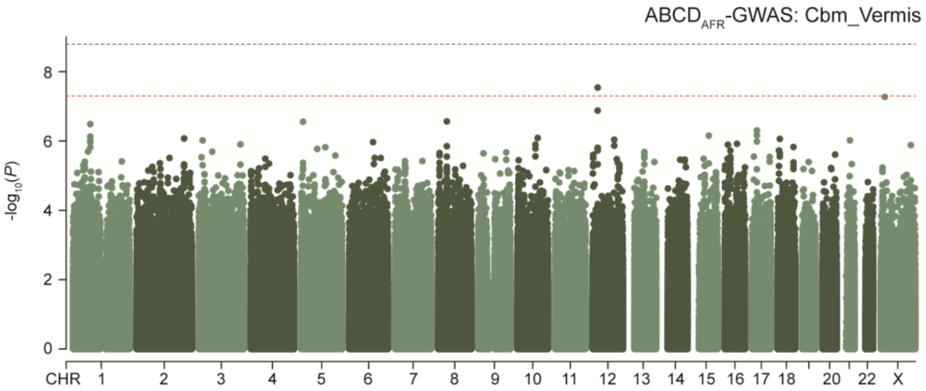


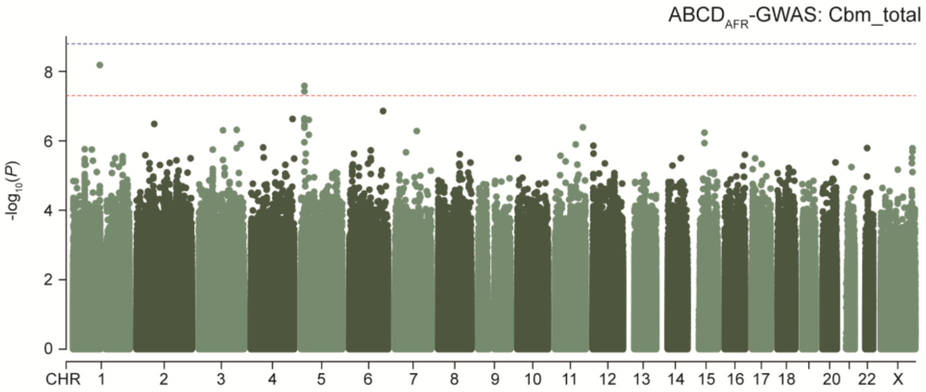
ABCD$_{AFR}$-GWAS: Right-Cerebellum-White-Matter

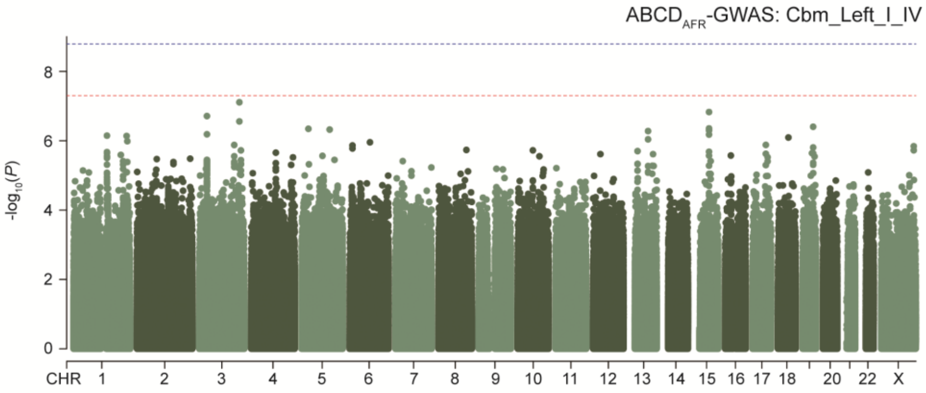


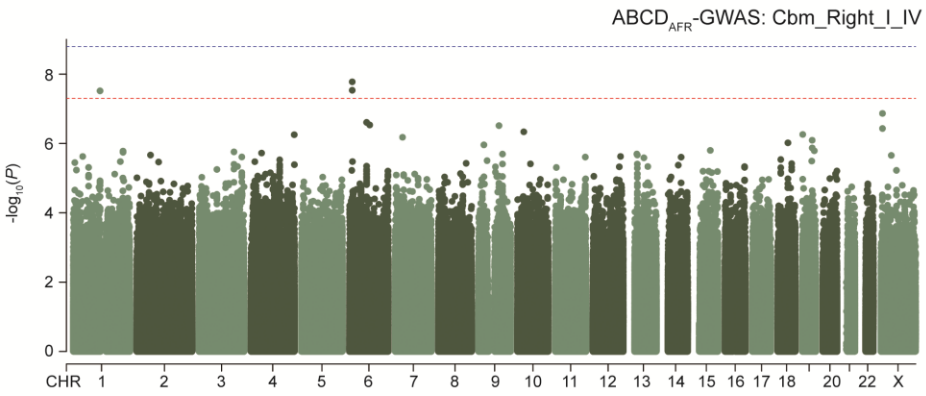
ABCD$_{AFR}$-GWAS: Left-Cerebellum-Cortex


ABCD$_{AFR}$-GWAS: Right-Cerebellum-Cortex

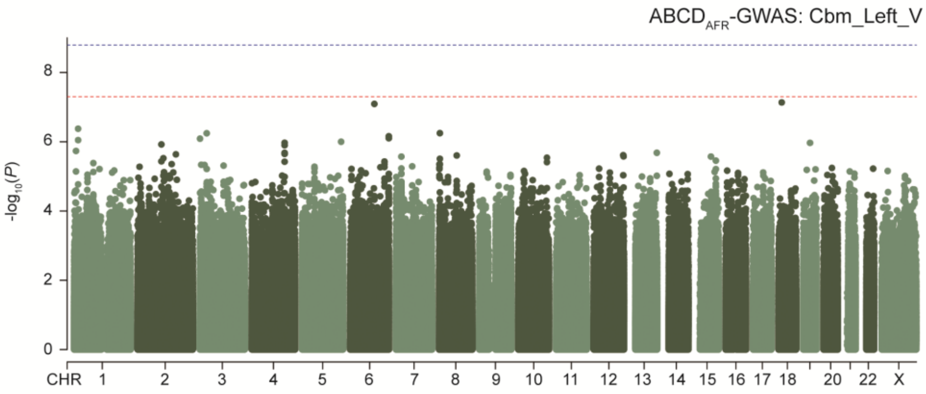

ABCD$_{AFR}$-GWAS: Cbm_Vermis


ABCD$_{AFR}$-GWAS: Cbm_total

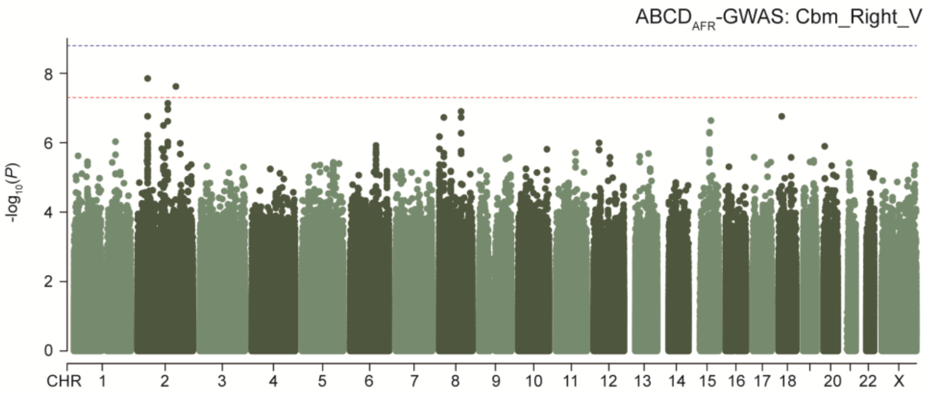

ABCD$_{AFR}$-GWAS: Cbm_Left_I_IV



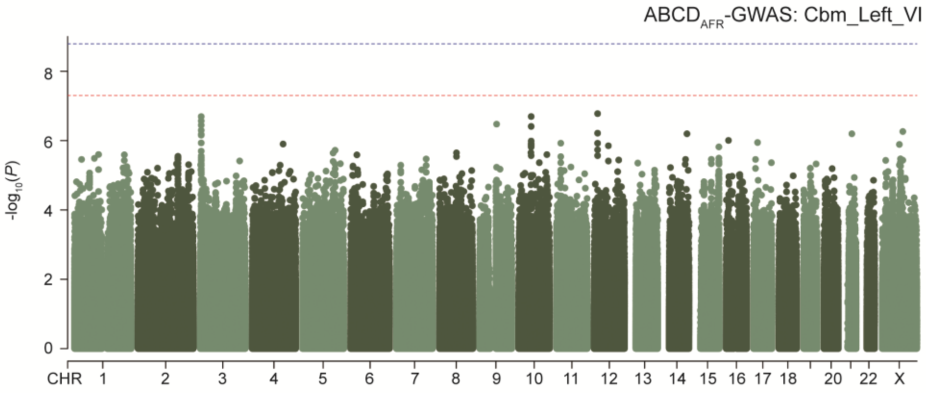
ABCD$_{AFR}$-GWAS: Cbm_Right_I_IV



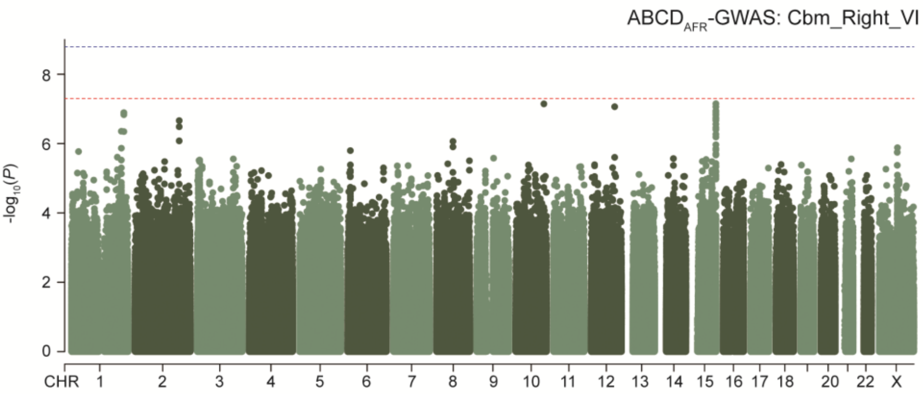
ABCD$_{AFR}$-GWAS: Cbm_Left_V



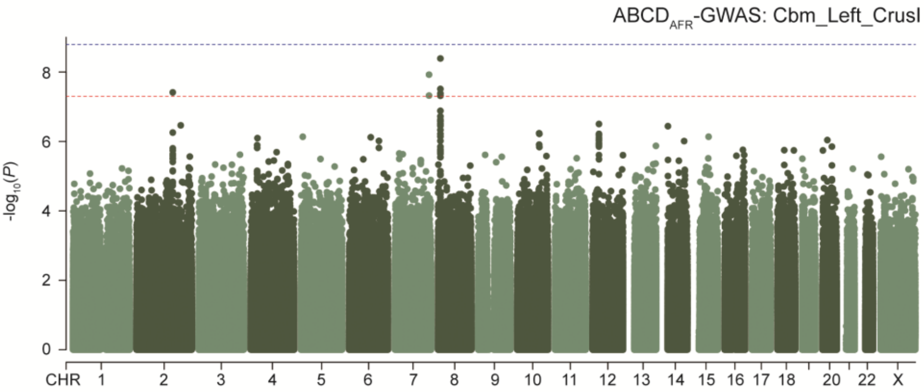
ABCD$_{AFR}$-GWAS: Cbm_Right_V



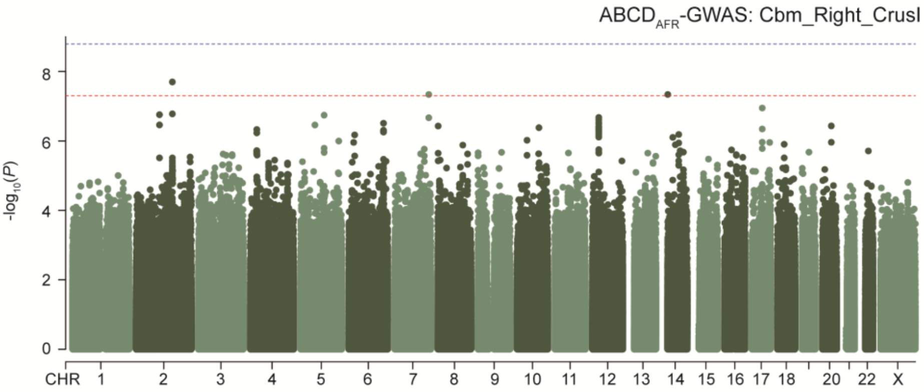
ABCD$_{AFR}$-GWAS: Cbm_Left_VI



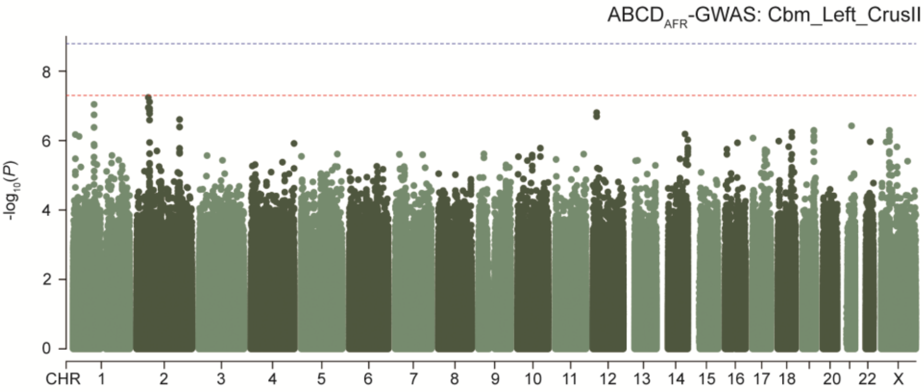
ABCD$_{AFR}$-GWAS: Cbm_Right_VI



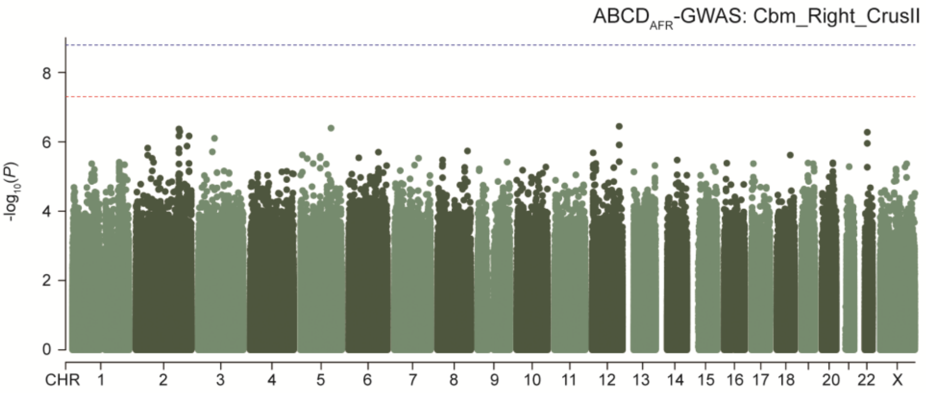
ABCD$_{AFR}$-GWAS: Cbm_Left_CrusI



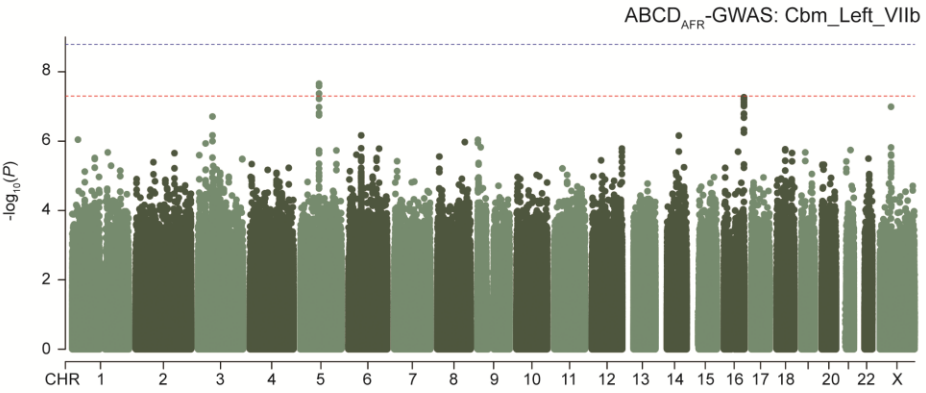
ABCD$_{AFR}$-GWAS: Cbm_Right_CrusI



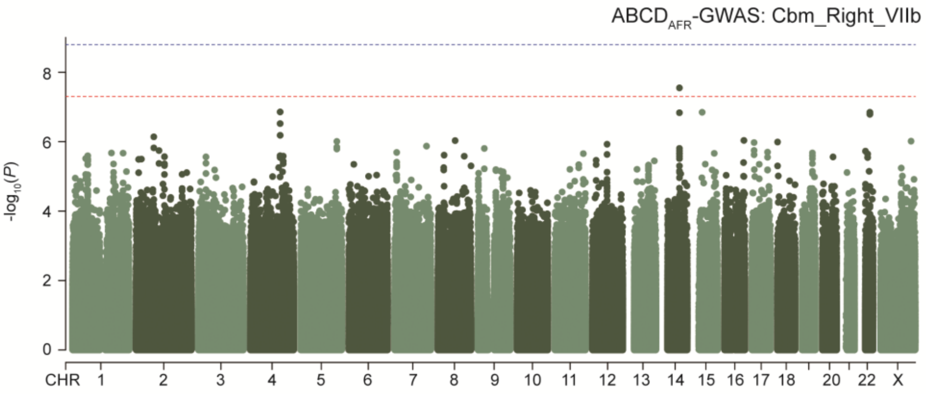
ABCD$_{AFR}$-GWAS: Cbm_Left_CrusII



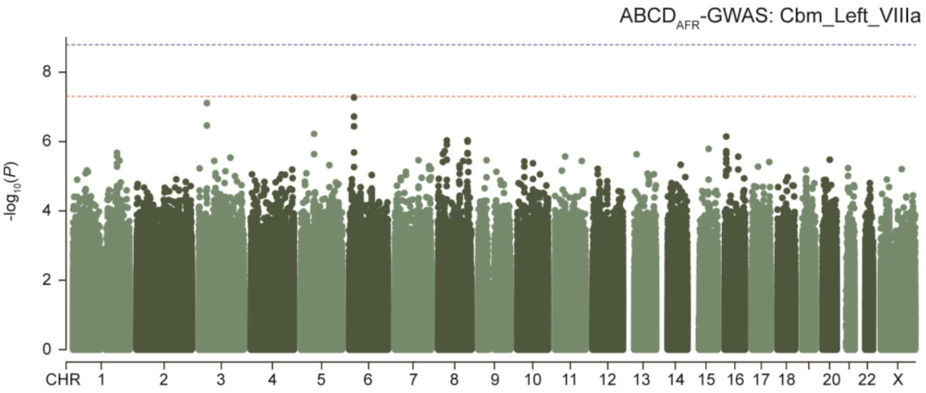
ABCD$_{AFR}$-GWAS: Cbm_Right_CrusII



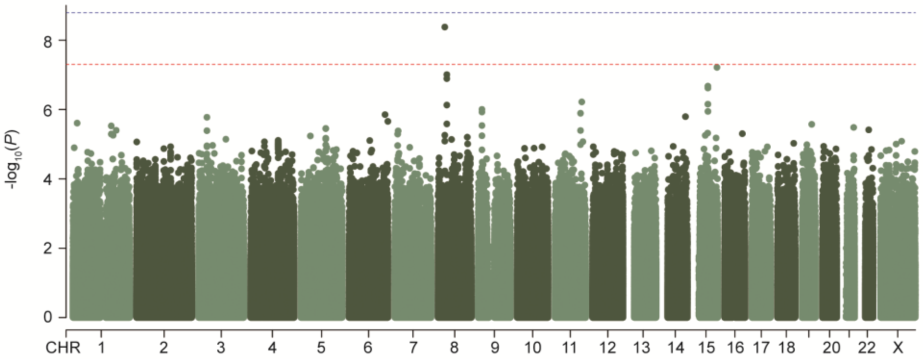
ABCD$_{AFR}$-GWAS: Cbm_Left_VIIb



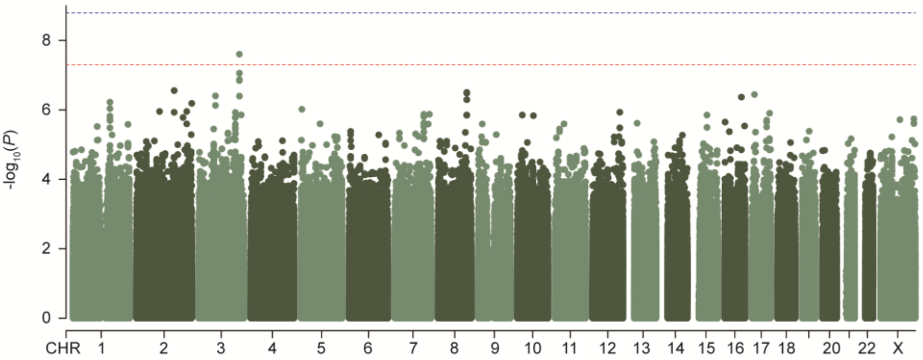
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIb



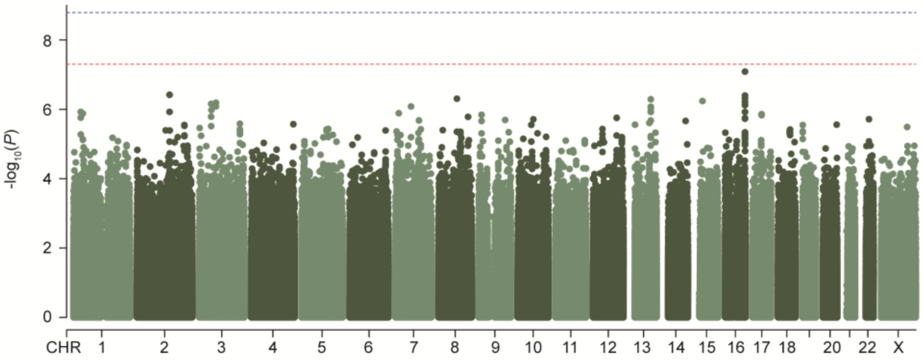
ABCD$_{AFR}$-GWAS: Cbm_Left_VIIIa



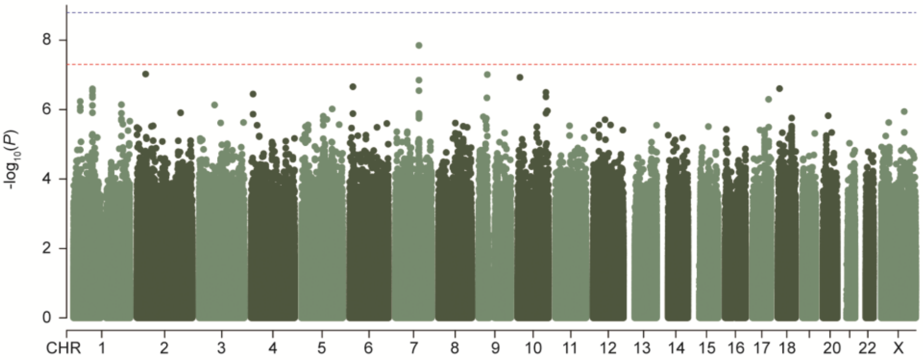
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIIa



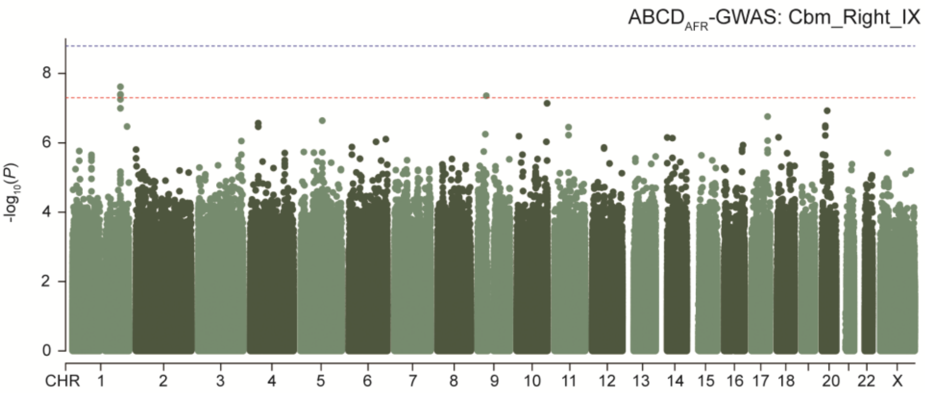
ABCD$_{AFR}$-GWAS: Cbm_Left_VIIIb



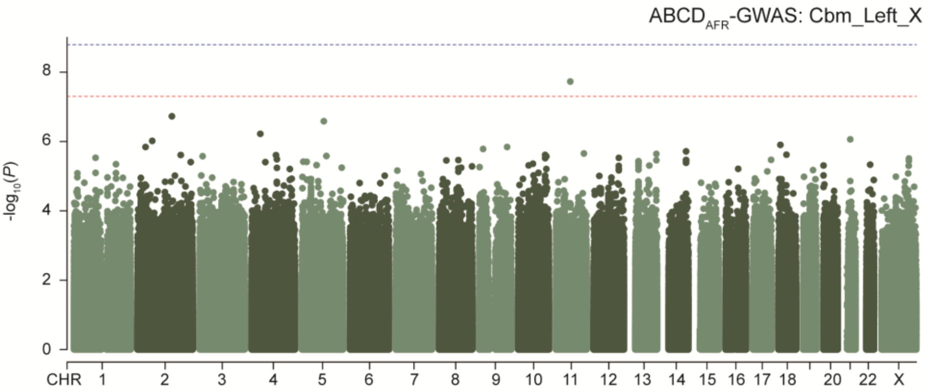
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIIb



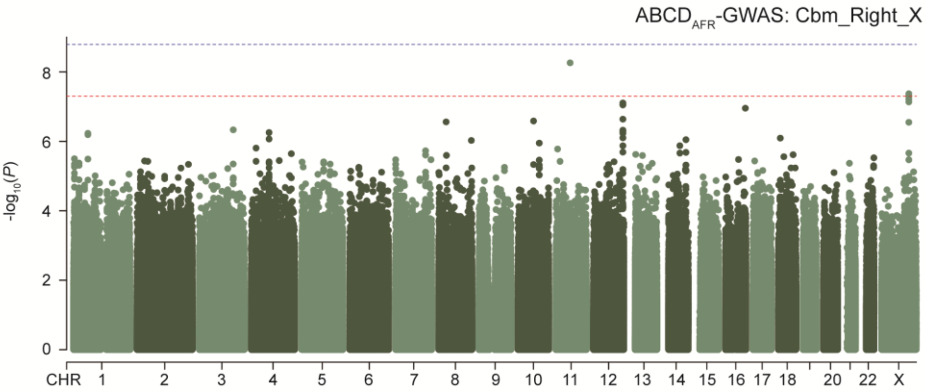
ABCD$_{AFR}$-GWAS: Cbm_Left_IX



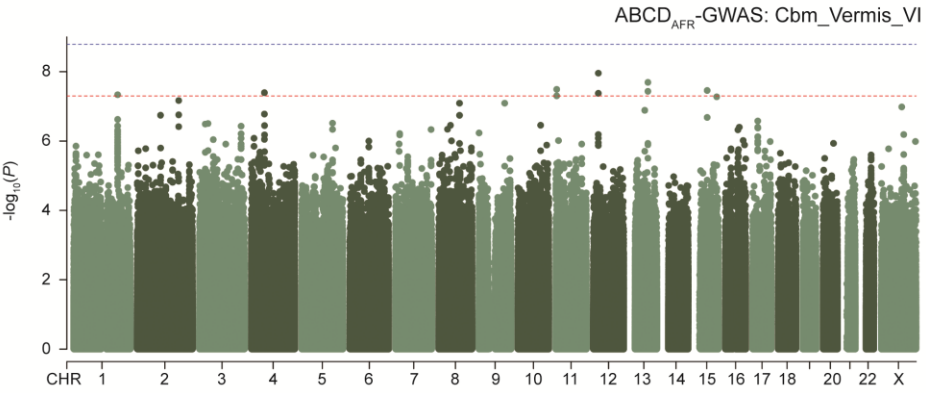
ABCD$_{AFR}$-GWAS: Cbm_Right_IX



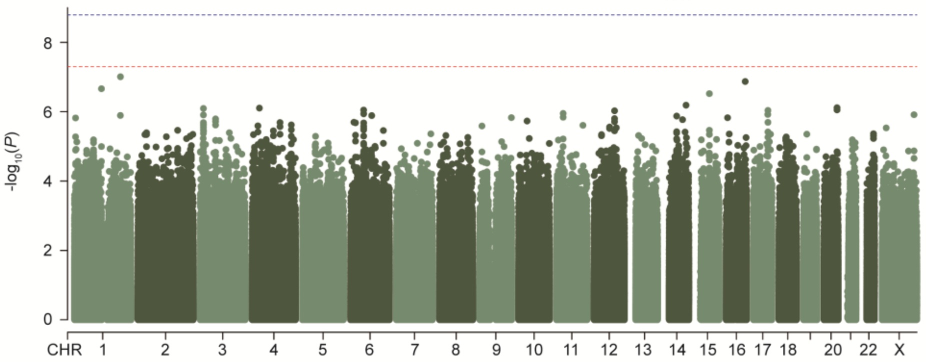
ABCD$_{AFR}$-GWAS: Cbm_Left_X

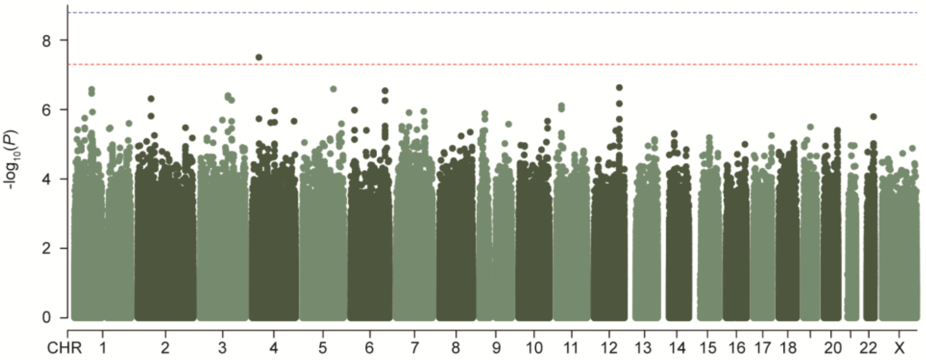


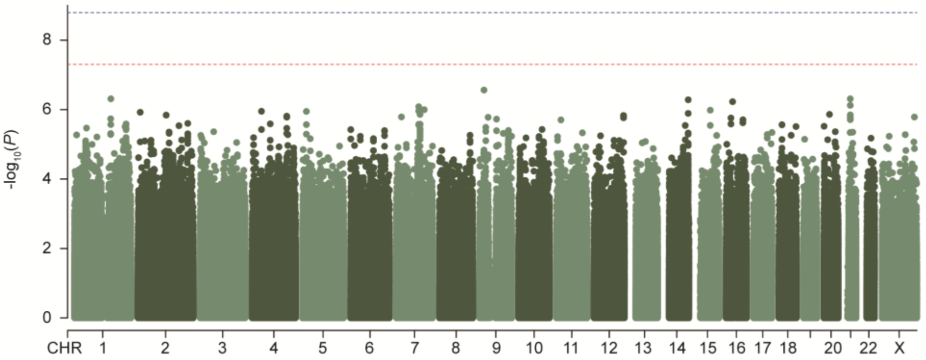
ABCD$_{AFR}$-GWAS: Cbm_Right_X

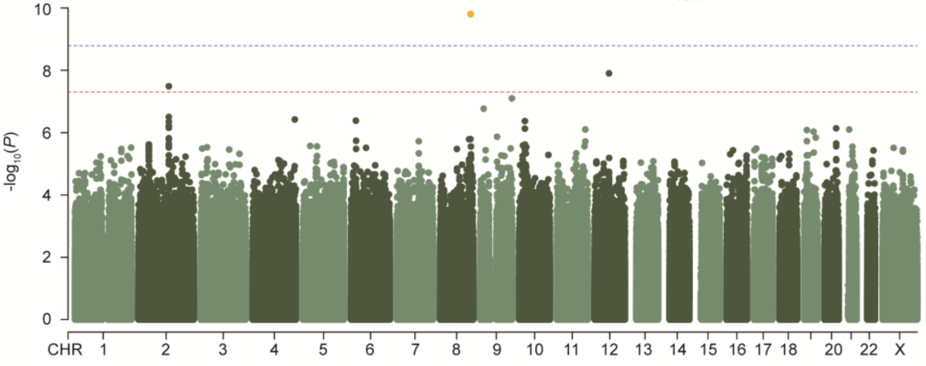


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VI

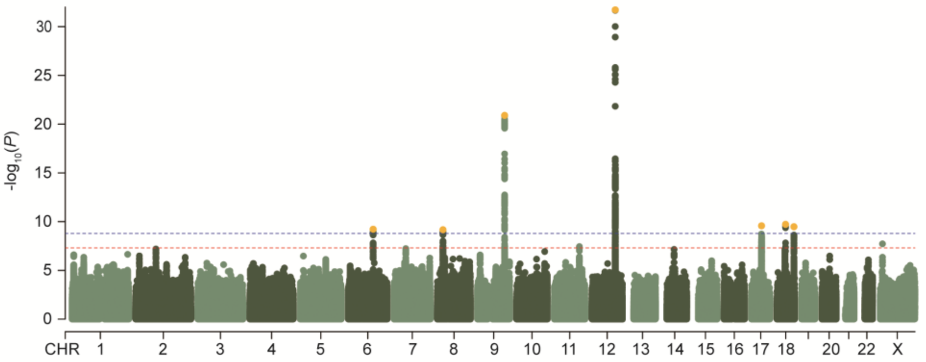

ABCD$_{AFR}$-GWAS: Cbm_Vermis_VII


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VIII

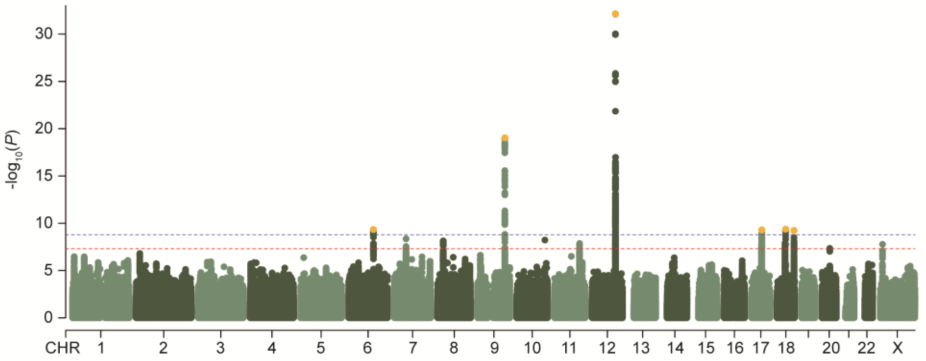

ABCD$_{AFR}$-GWAS: Cbm_Vermis_IX


ABCD$_{AFR}$-GWAS: Cbm_Vermis_X

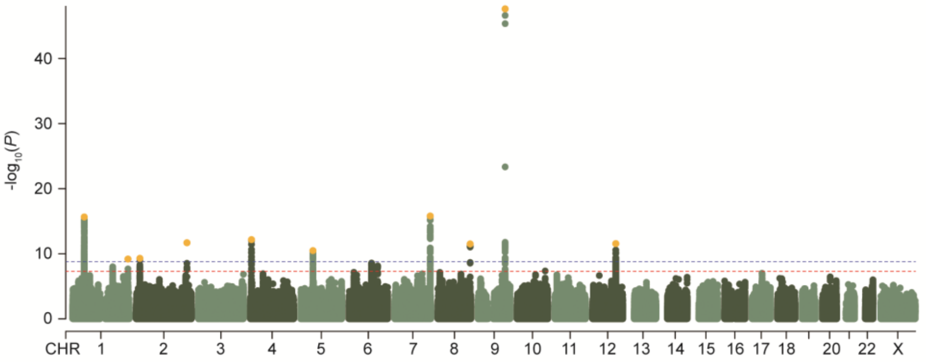
EUR-GWAS: Left-Cerebellum-White-Matter



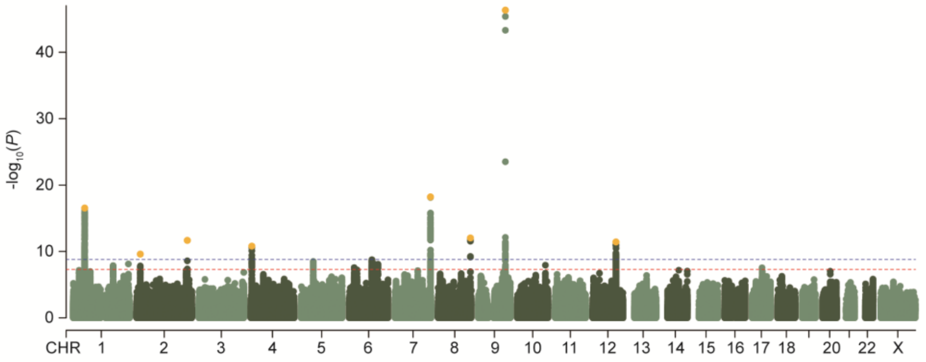
EUR-GWAS: Right-Cerebellum-White-Matter

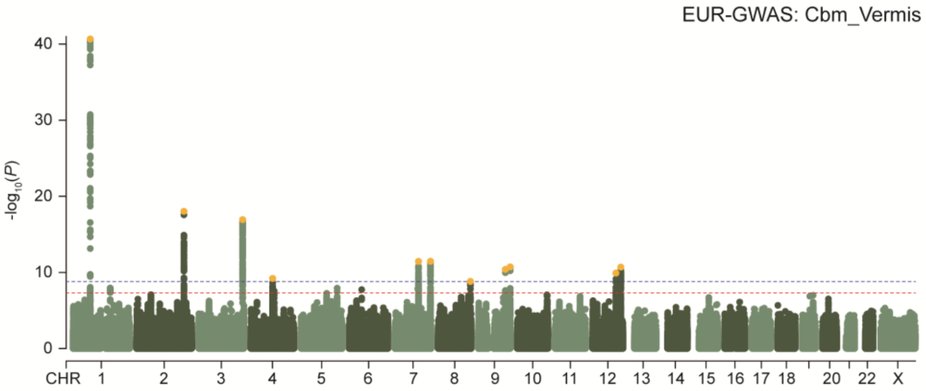


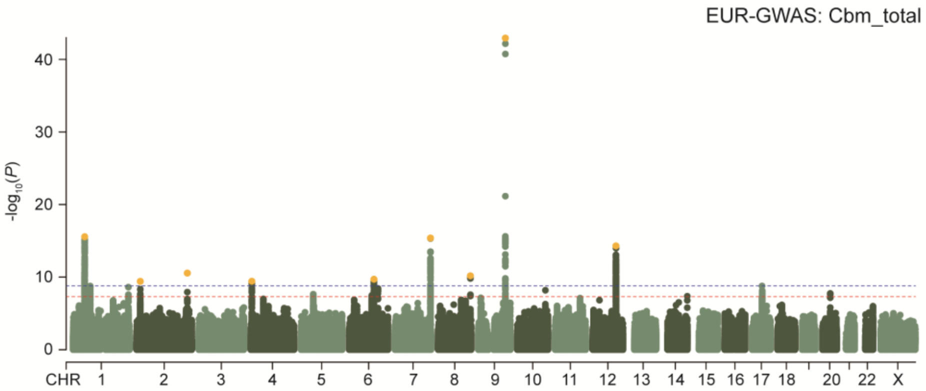
EUR-GWAS: Left-Cerebellum-Cortex

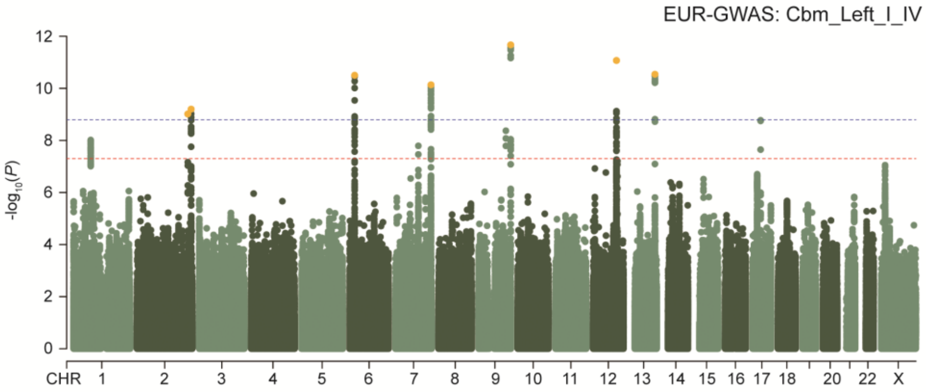


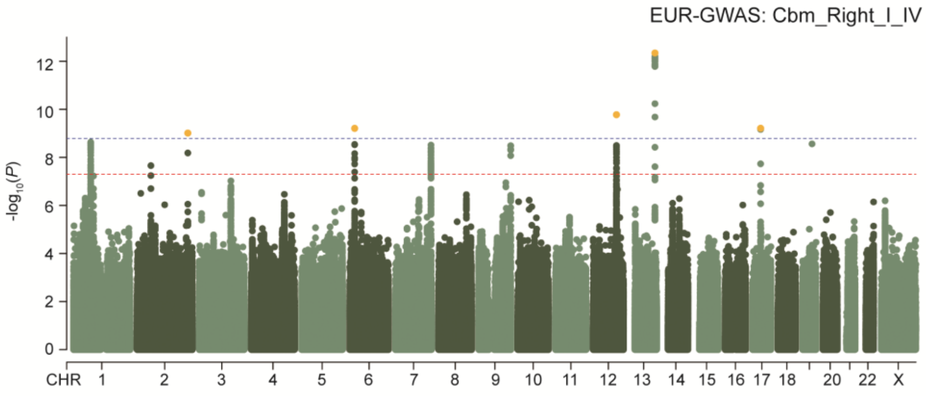
EUR-GWAS: Right-Cerebellum-Cortex




EUR-GWAS: Cbm_Vermis


EUR-GWAS: Cbm_total


EUR-GWAS: Cbm_Left_I_IV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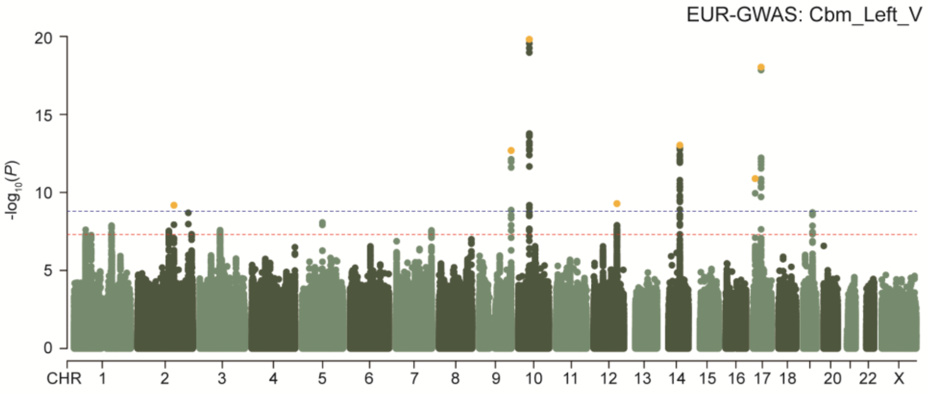
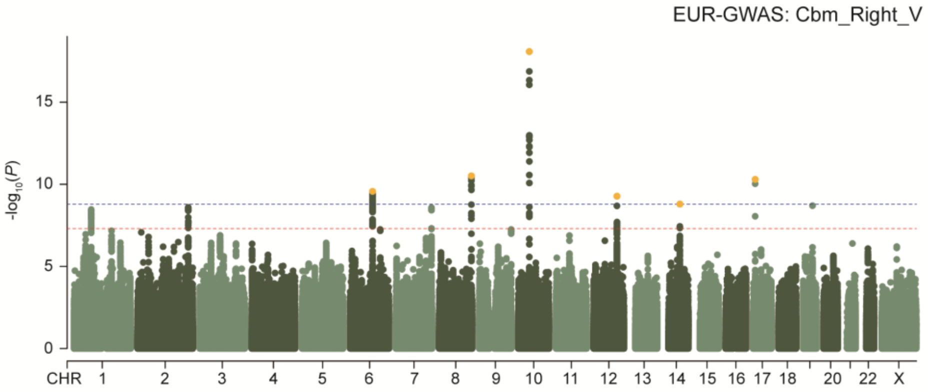

EUR-GWAS: Cbm_Left_V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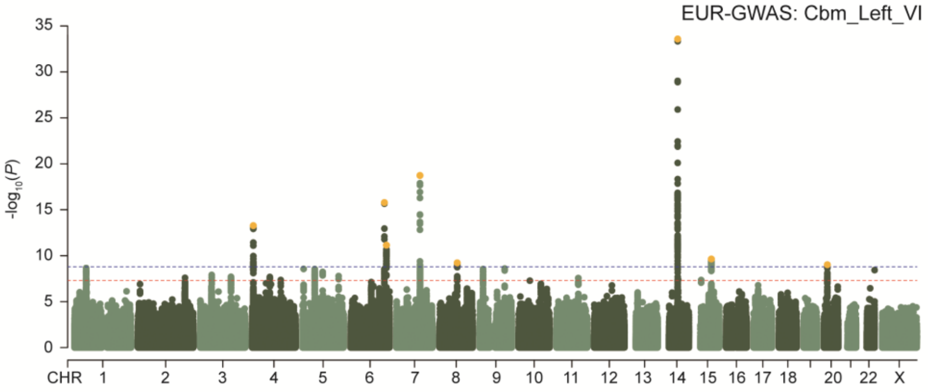
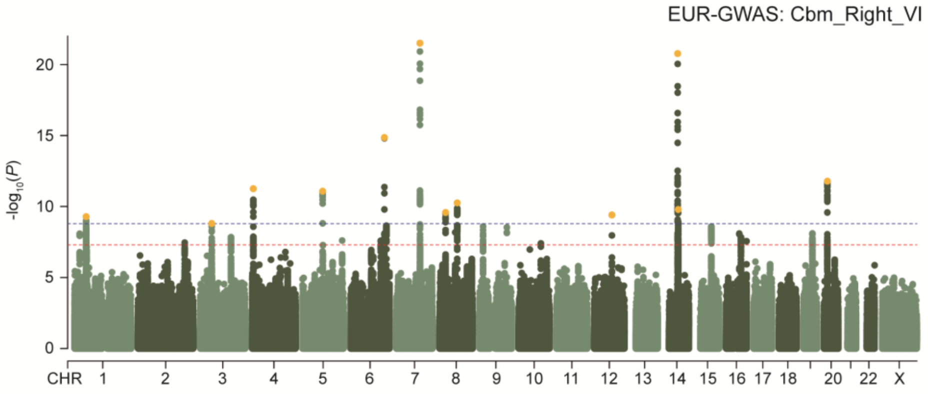
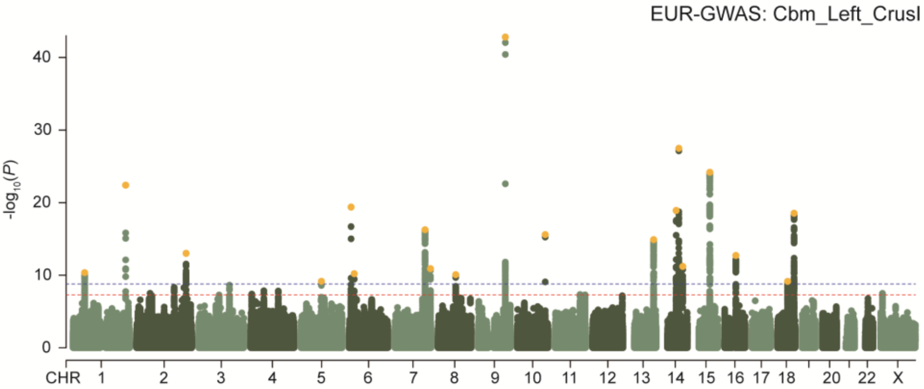
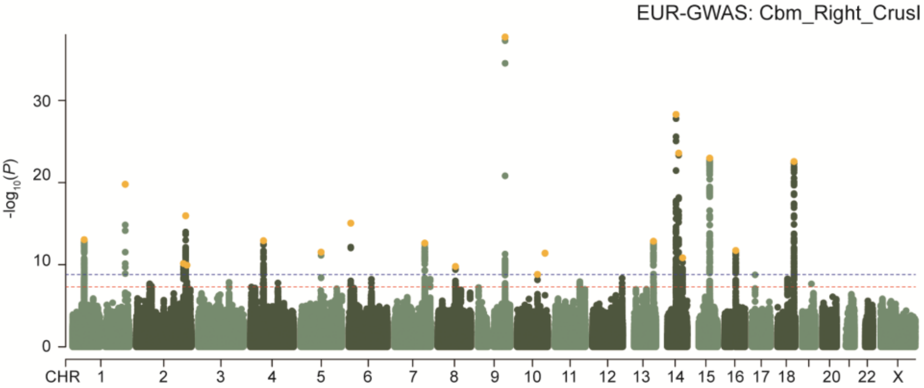
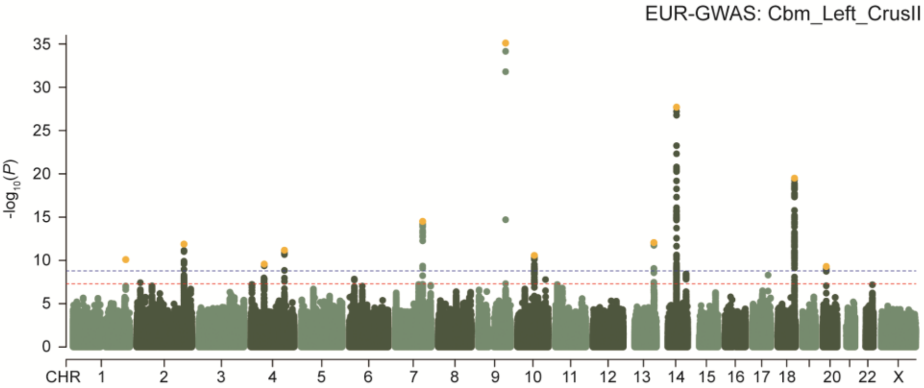
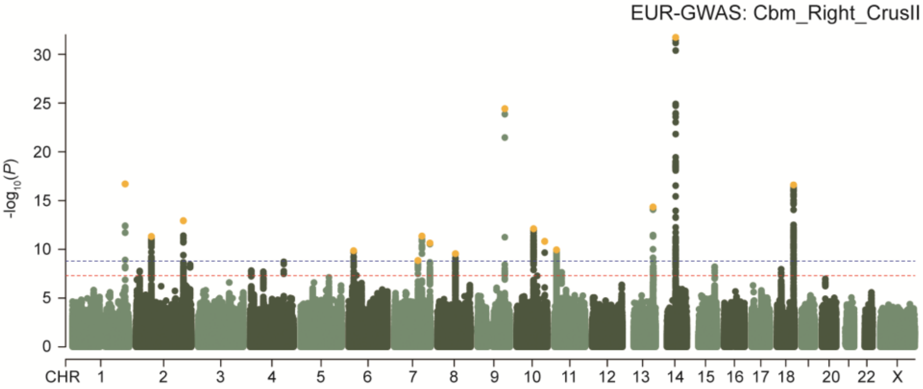

EUR-GWAS: Cbm_Left_VI

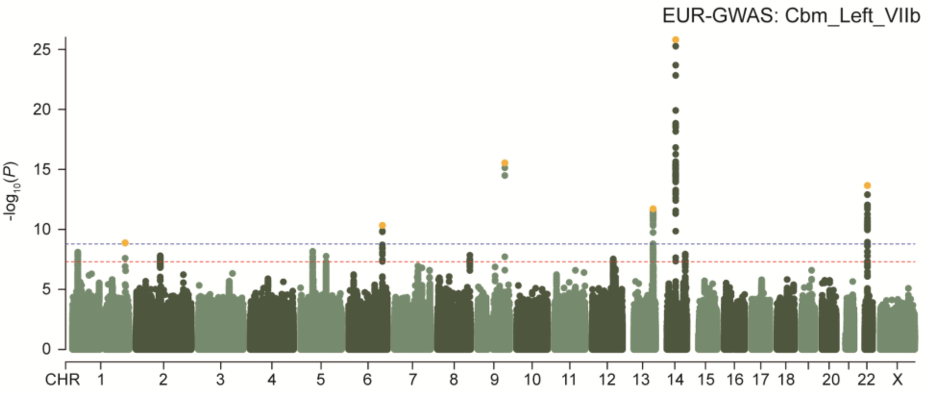

EUR-GWAS: Cbm_Right_VI

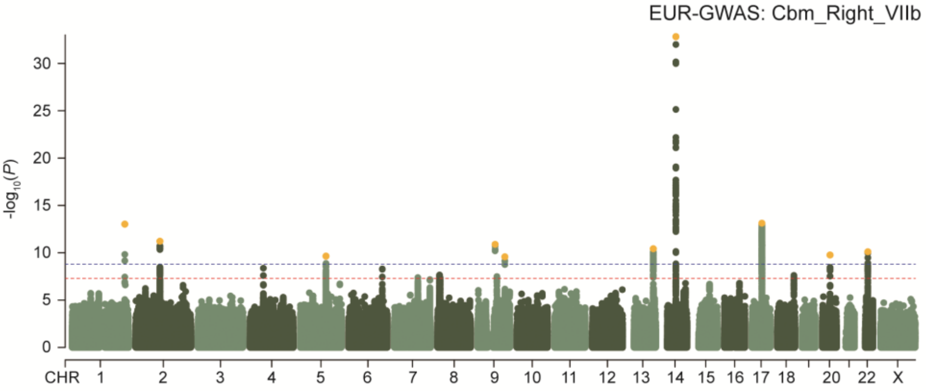

EUR-GWAS: Cbm_Left_CrusI

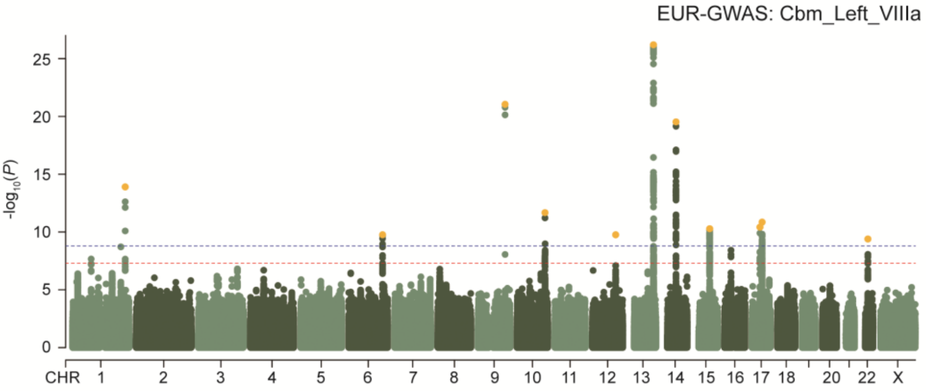

EUR-GWAS: Cbm_Right_CrusI

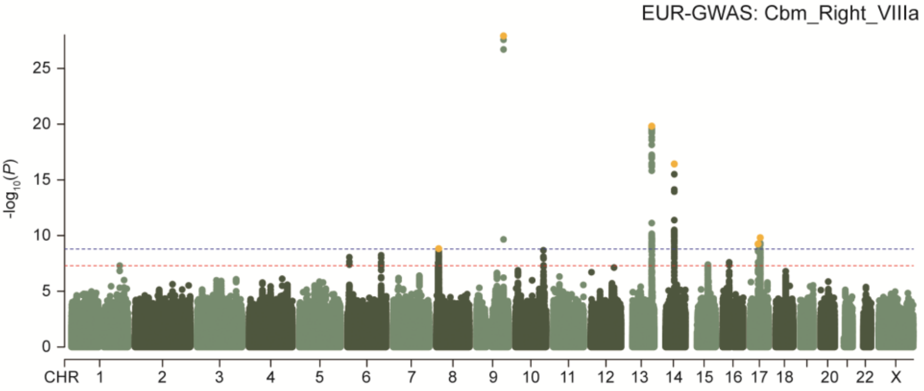

EUR-GWAS: Cbm_Left_CrusII

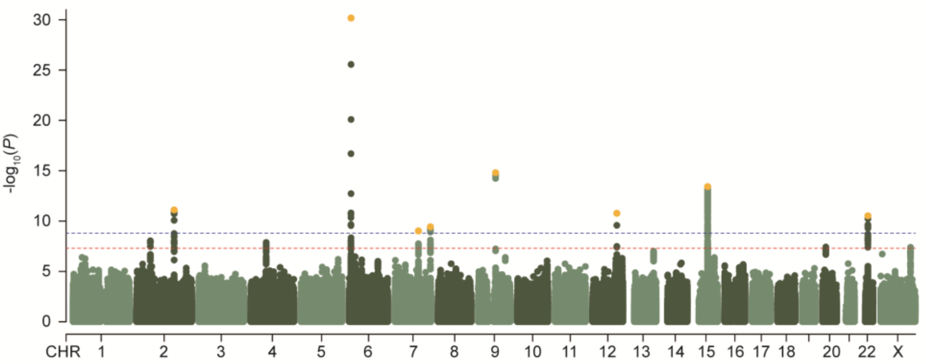

EUR-GWAS: Cbm_Right_CrusII

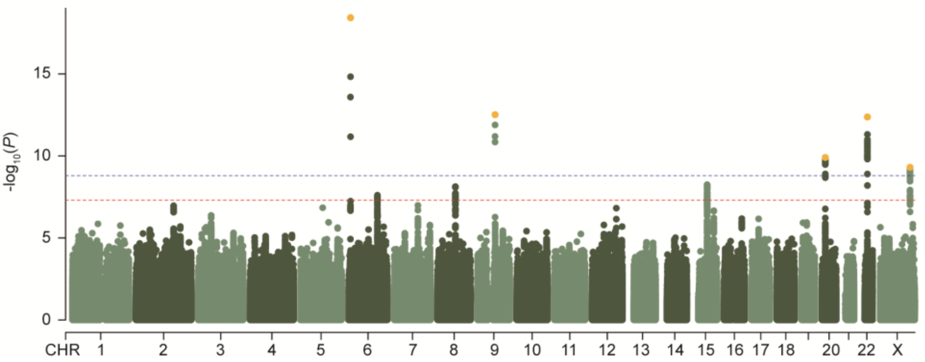

EUR-GWAS: Cbm_Left_VIIb


EUR-GWAS: Cbm_Right_VIIb


EUR-GWAS: Cbm_Left_VIIIa


EUR-GWAS: Cbm_Right_VIIIa


EUR-GWAS: Cbm_Left_VIIIb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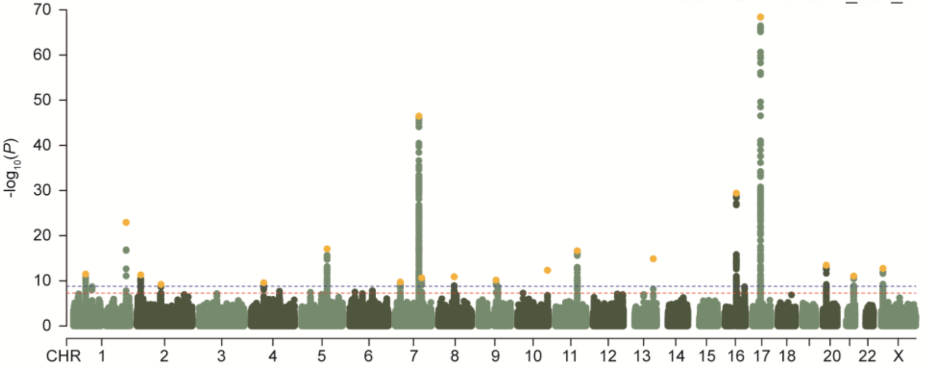
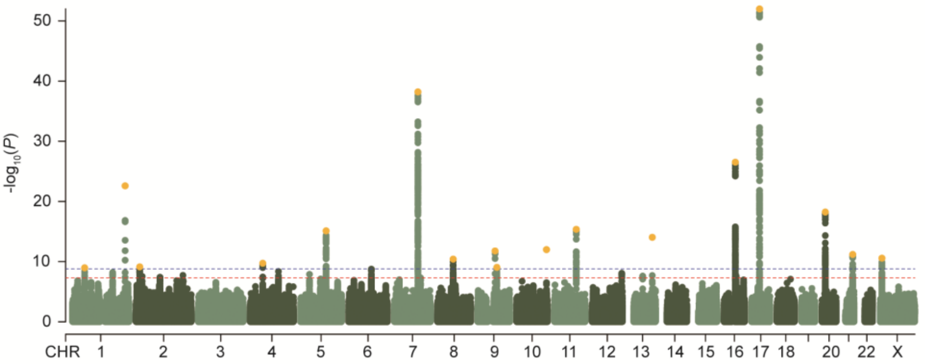
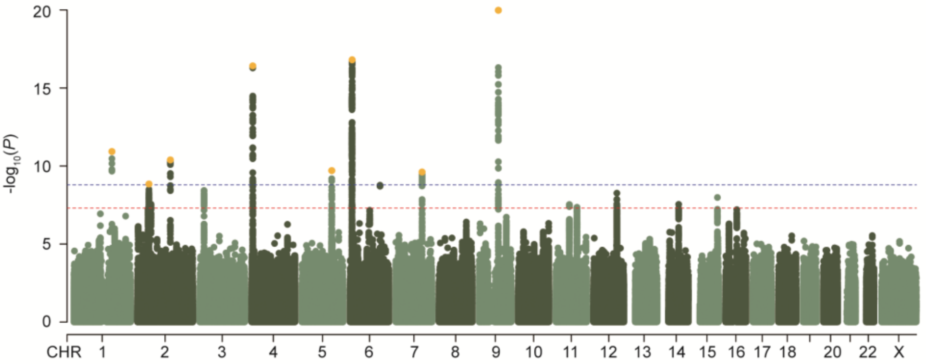
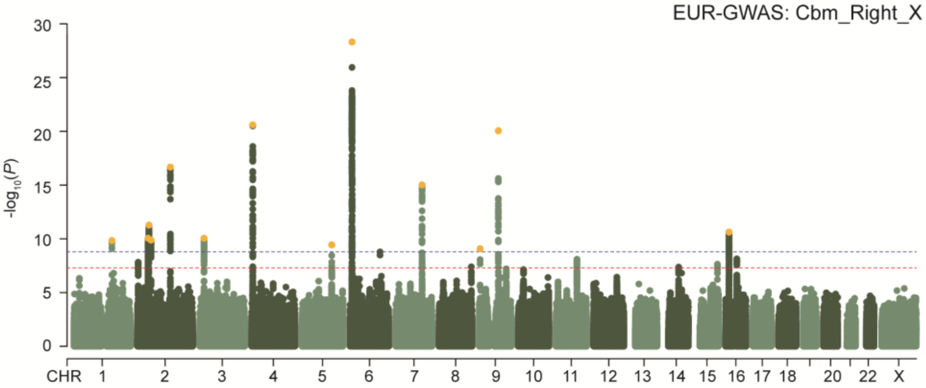

EUR-GWAS: Cbm_Left_IX

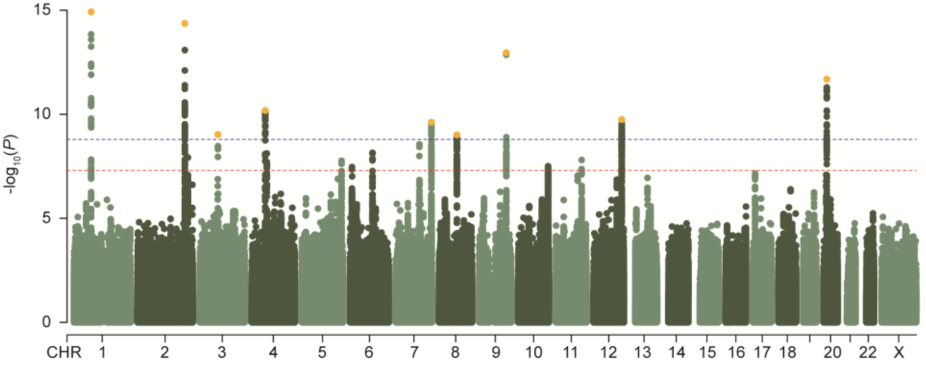

EUR-GWAS: Cbm_Right_IX



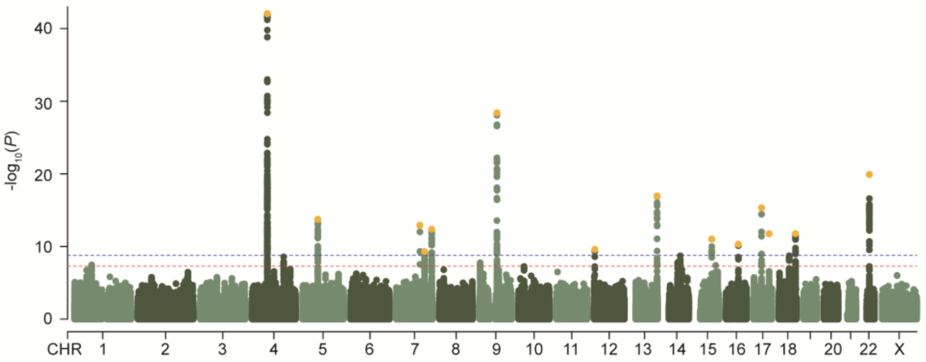
EUR-GWAS: Cbm_Left_X



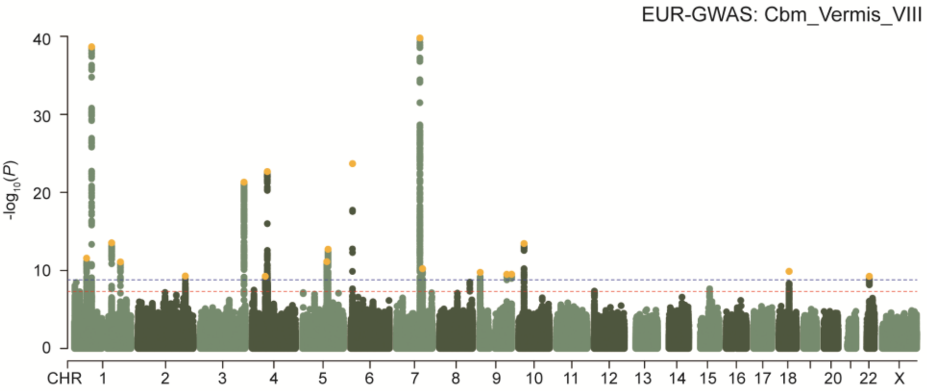
EUR-GWAS: Cbm_Right_X

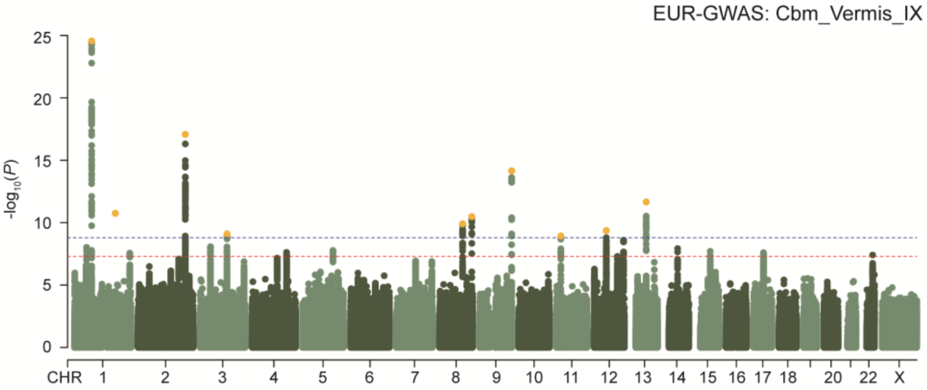


EUR-GWAS: Cbm_Vermis_VI



EUR-GWAS: Cbm_Vermis_VII


EUR-GWAS: Cbm_Vermis_VIII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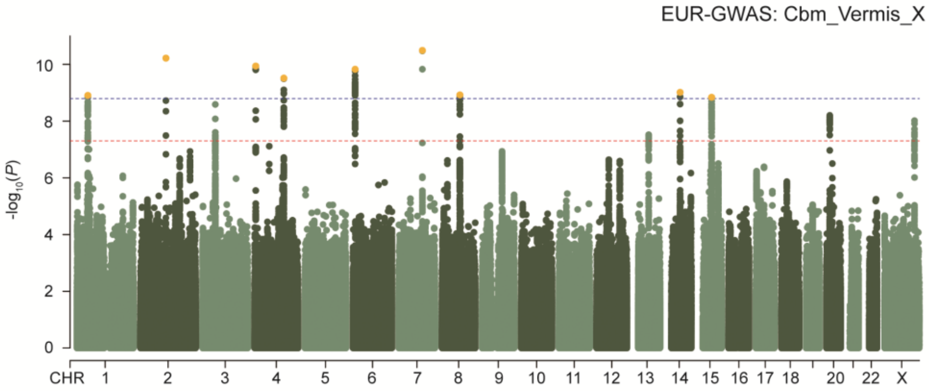
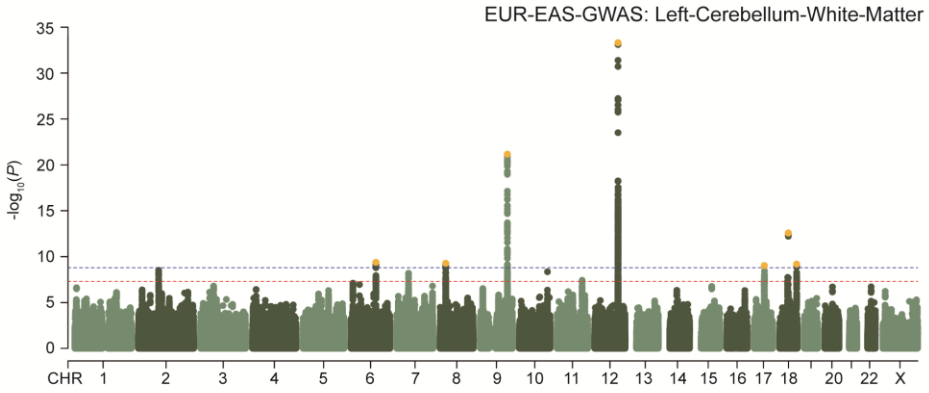
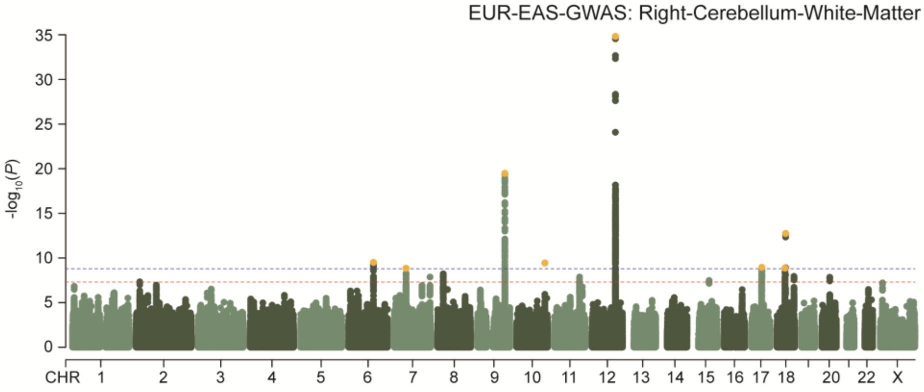
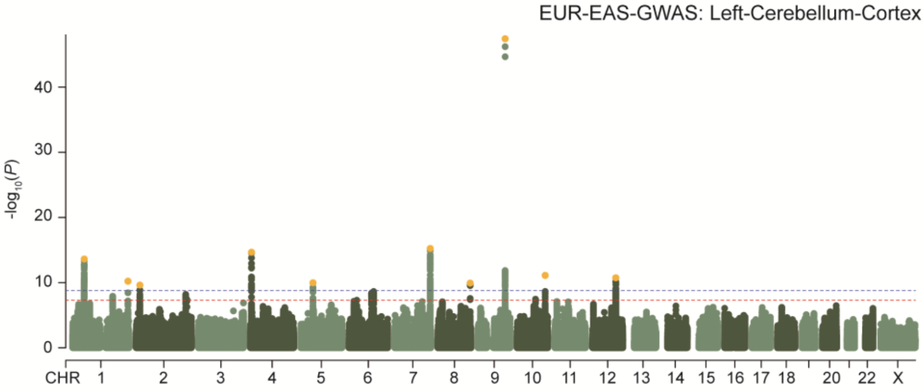
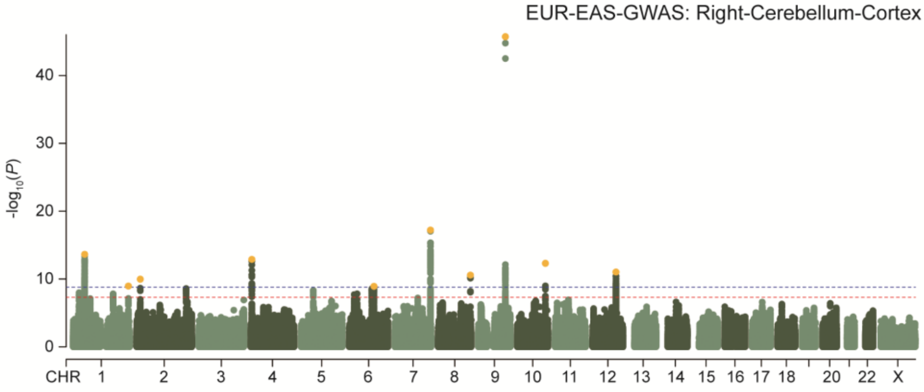

EUR-GWAS: Cbm_Vermis_X


EUR-EAS-GWAS: Left-Cerebellum-White-Matter


EUR-EAS-GWAS: Right-Cerebellum-White-Matter
-log10(P)
35
30
25
20
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-GWAS: Left-Cerebellum-Cortex
-log10(P)
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-GWAS: Right-Cerebellum-Cortex
-log10(P)
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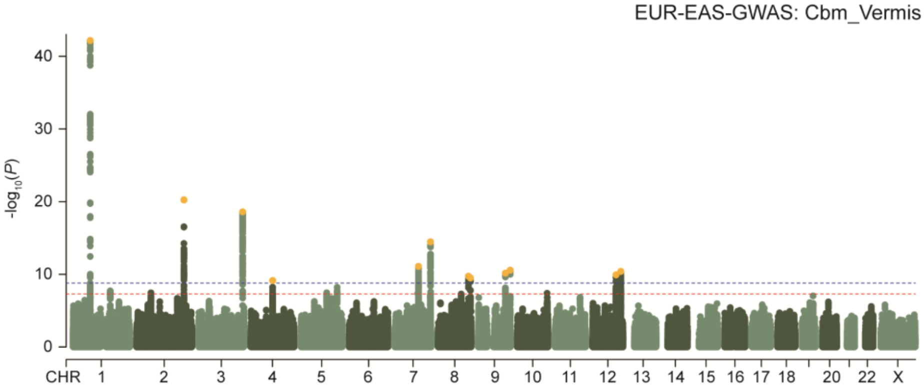
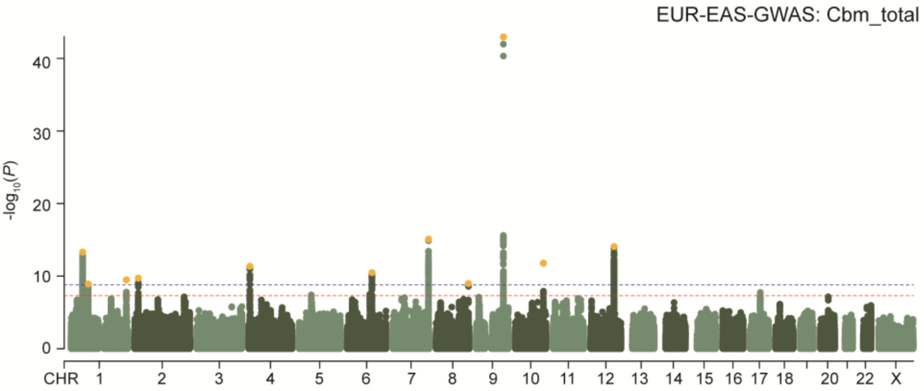
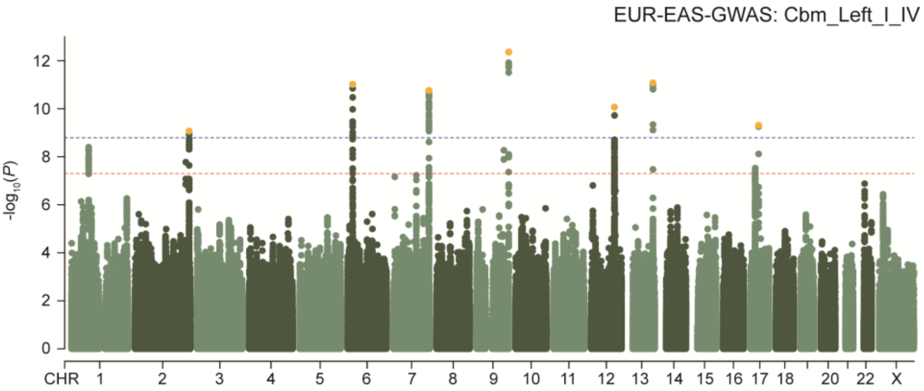
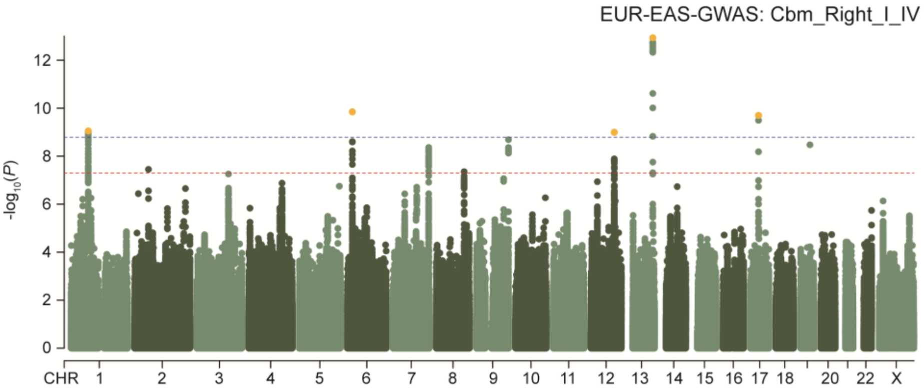
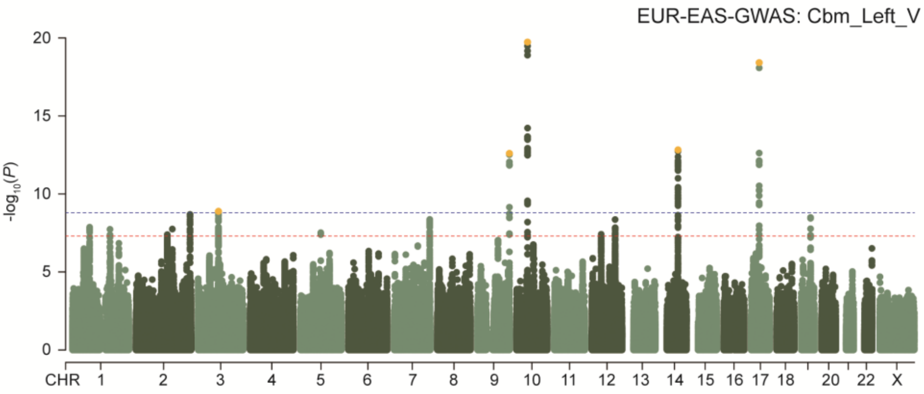
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

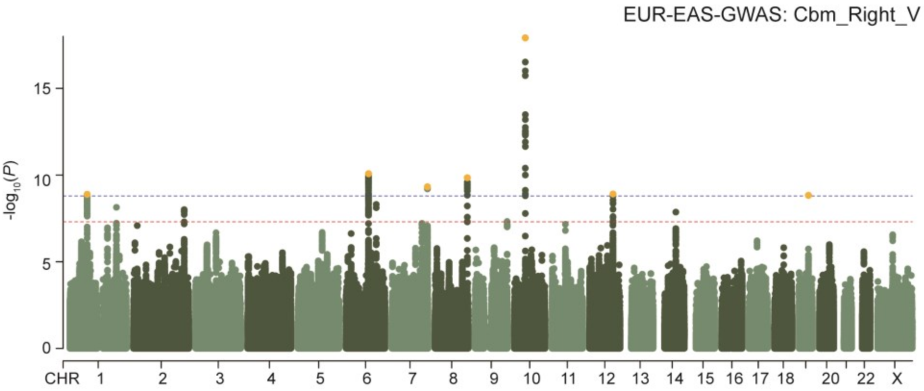

EUR-EAS-GWAS: Cbm_Vermis
-log10(P)
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

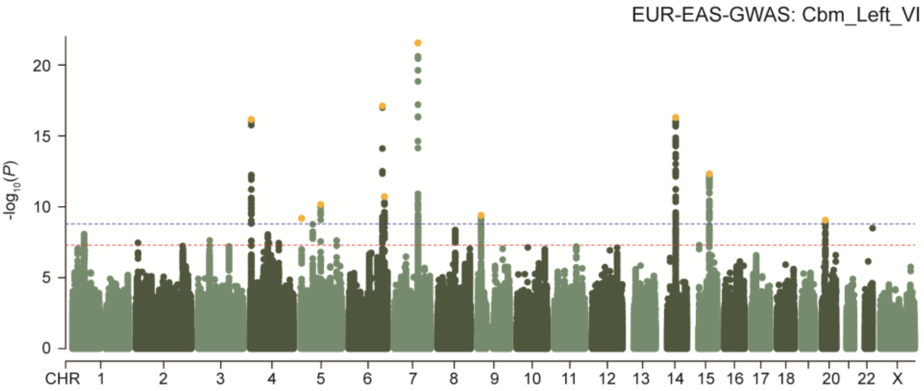

EUR-EAS-GWAS: Cbm_total

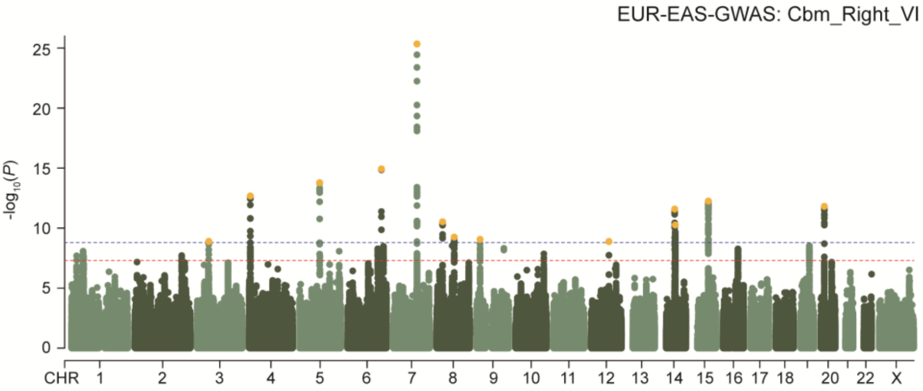

EUR-EAS-GWAS: Cbm_Left_I_IV

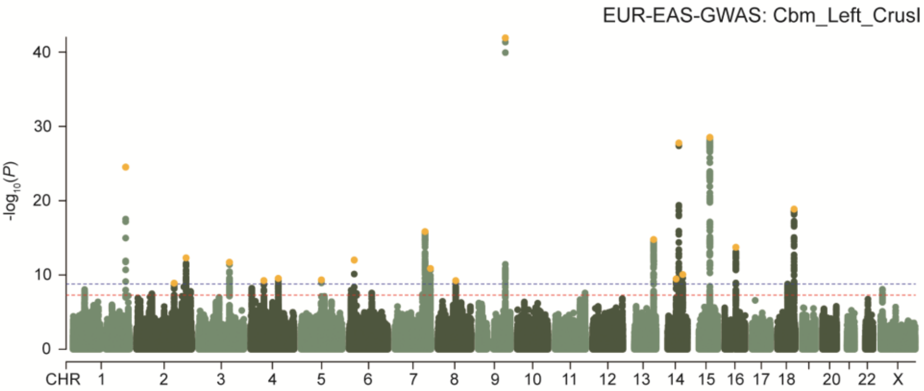

EUR-EAS-GWAS: Cbm_Right_I_IV

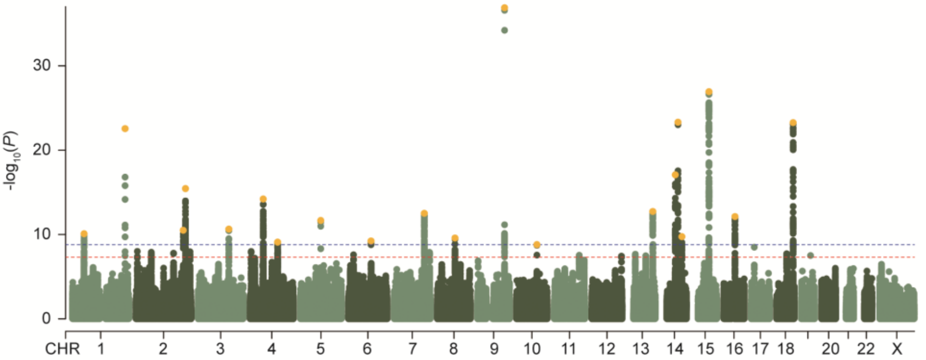

EUR-EAS-GWAS: Cbm_Left_V

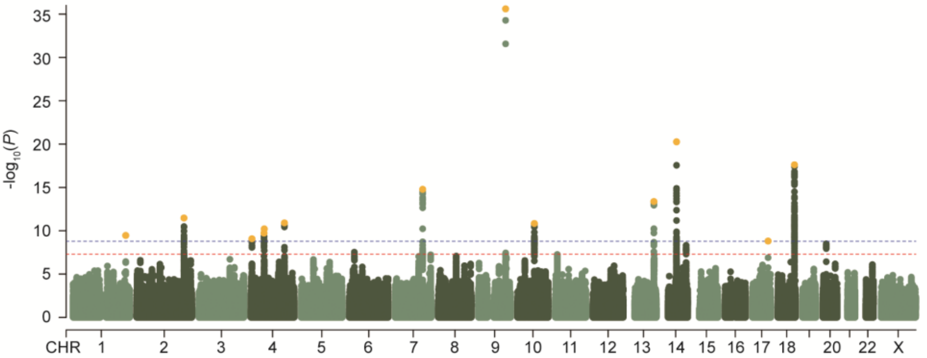

EUR-EAS-GWAS: Cbm_Right_V

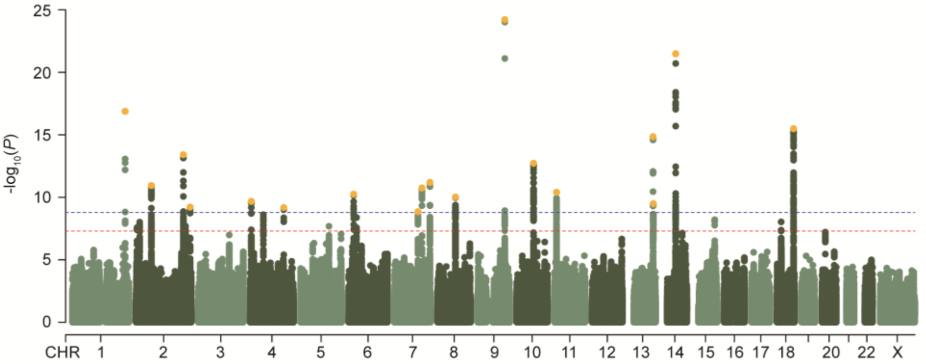

EUR-EAS-GWAS: Cbm_Left_VI

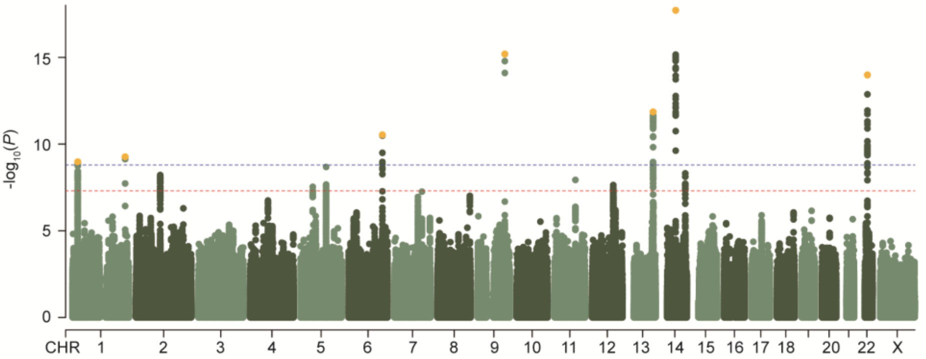

EUR-EAS-GWAS: Cbm_Right_VI

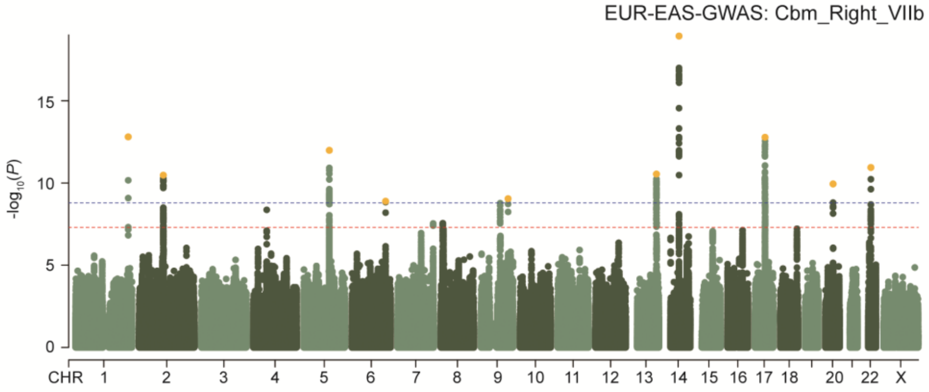

EUR-EAS-GWAS: Cbm_Left_CrusI


EUR-EAS-GWAS: Cbm_Right_CrusI

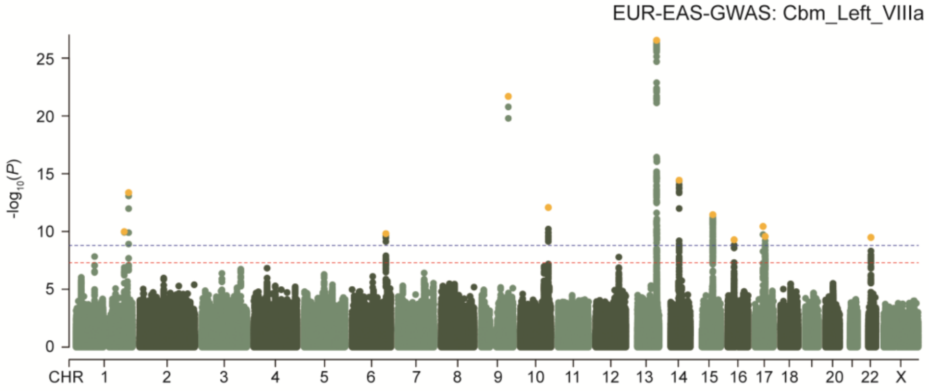

EUR-EAS-GWAS: Cbm_Left_CrusII


EUR-EAS-GWAS: Cbm_Right_CrusII

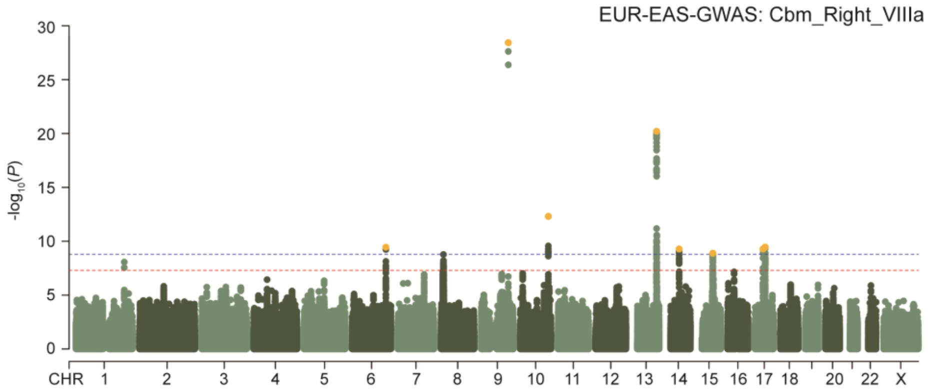

EUR-EAS-GWAS: Cbm_Left_VIIb



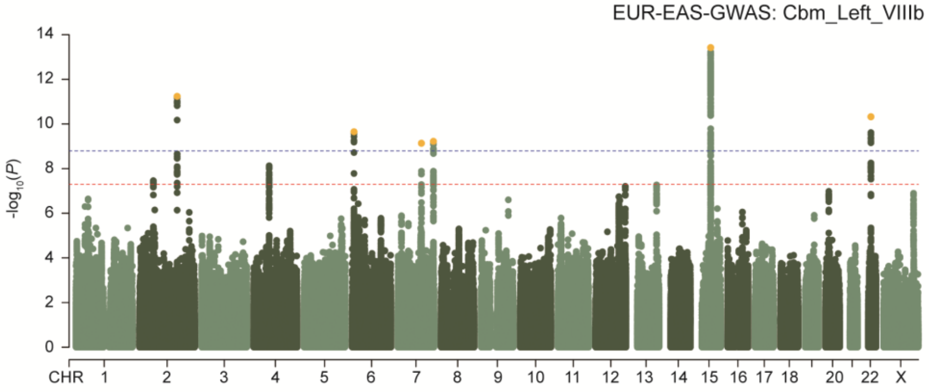
EUR-EAS-GWAS: Cbm_Right_VIIb



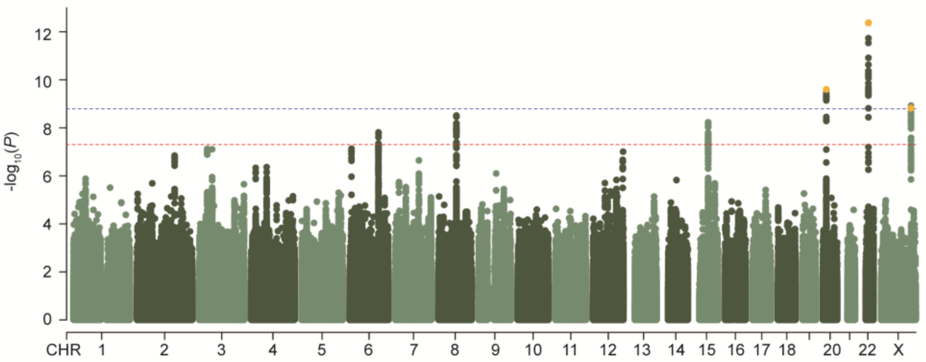
EUR-EAS-GWAS: Cbm_Left_VIIIa



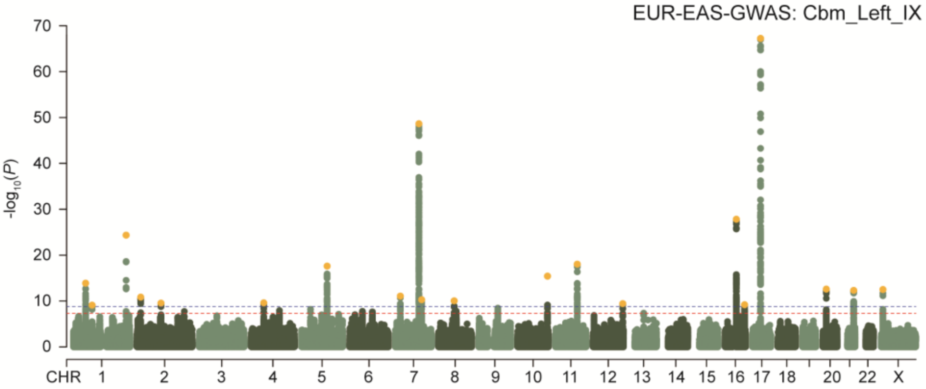
EUR-EAS-GWAS: Cbm_Right_VIIIa



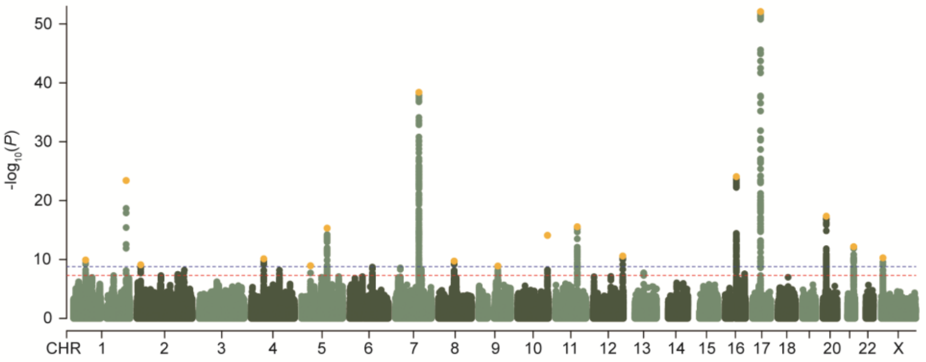
EUR-EAS-GWAS: Cbm_Left_VIIIb



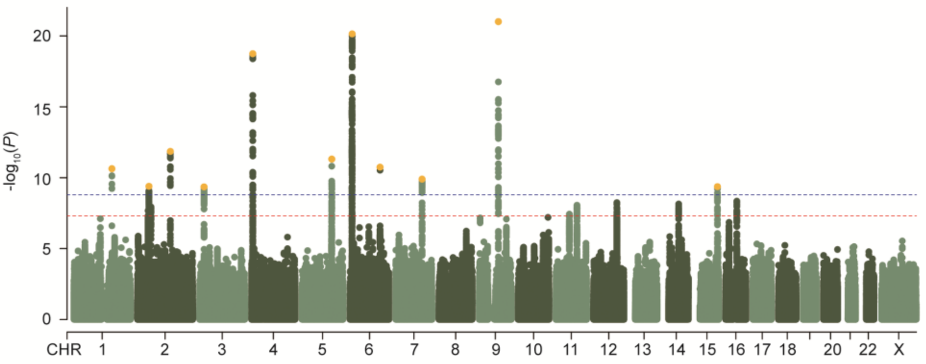
EUR-EAS-GWAS: Cbm_Right_VIIIb



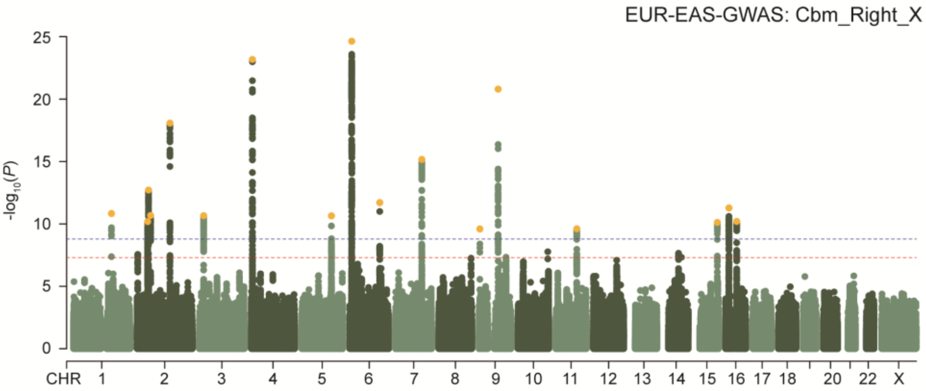
EUR-EAS-GWAS: Cbm_Left_IX

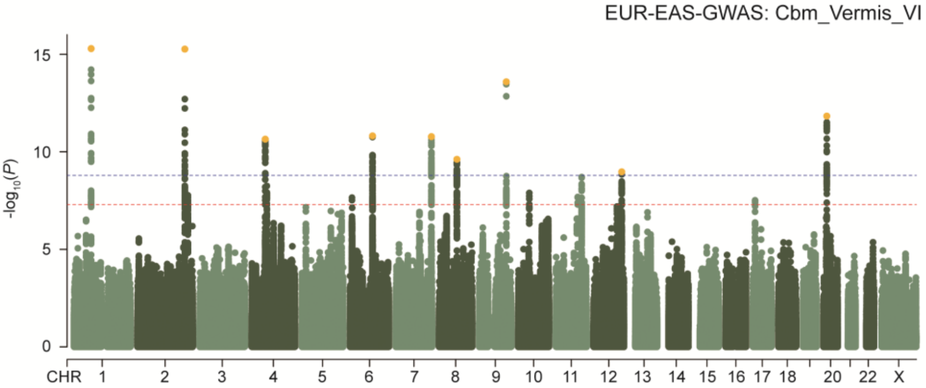


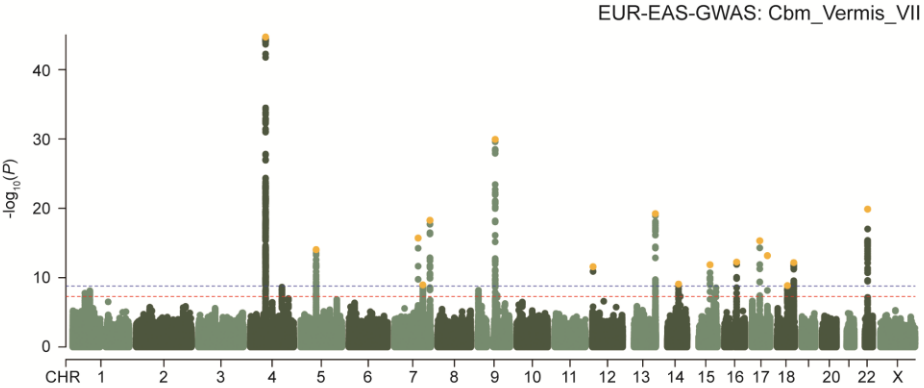
EUR-EAS-GWAS: Cbm_Right_IX

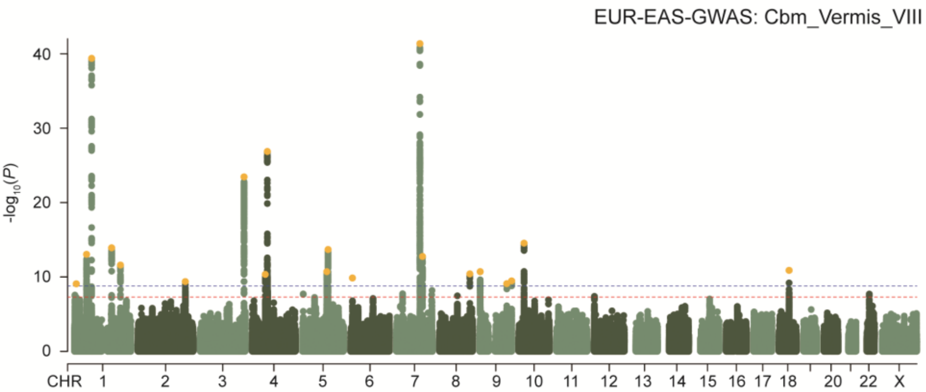


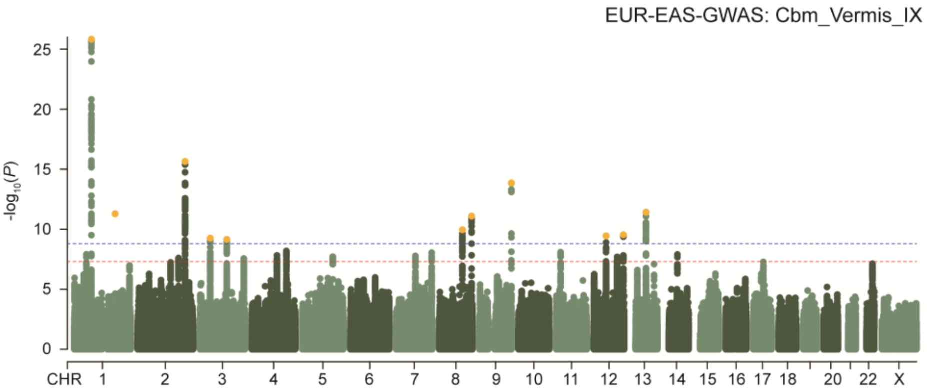
EUR-EAS-GWAS: Cbm_Left_X


EUR-EAS-GWAS: Cbm_Right_X


EUR-EAS-GWAS: Cbm_Vermis_VI


EUR-EAS-GWAS: Cbm_Vermis_VII


EUR-EAS-GWAS: Cbm_Vermis_VIII


EUR-EAS-GWAS: Cbm_Vermis_IX
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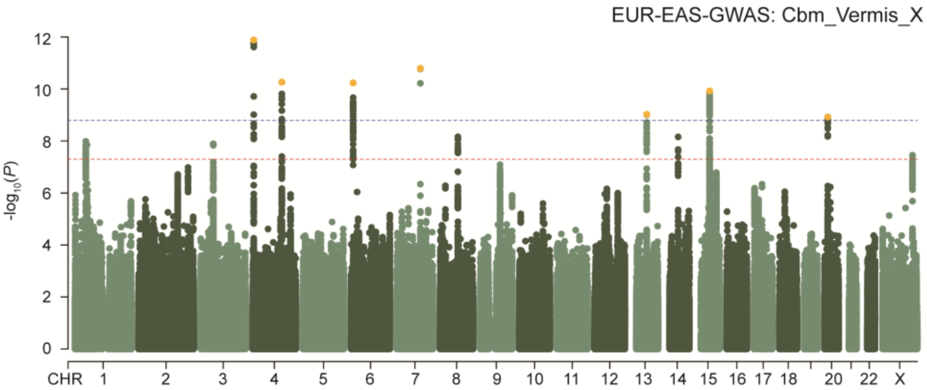
0
5
10
15
20
25
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-GWAS: Cbm_Vermis_X
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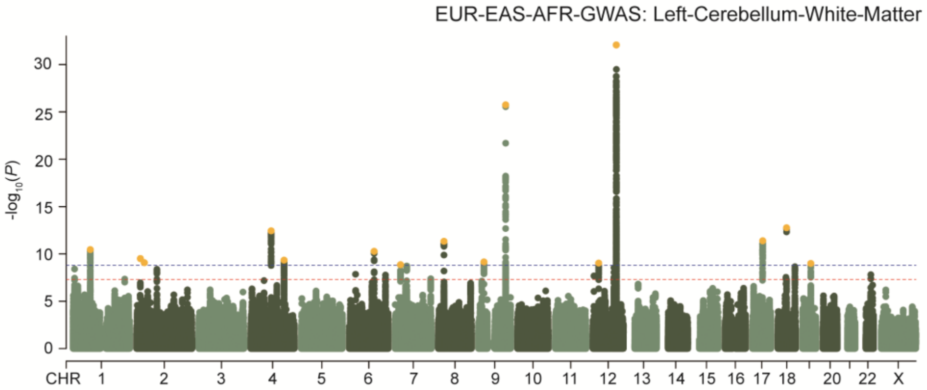
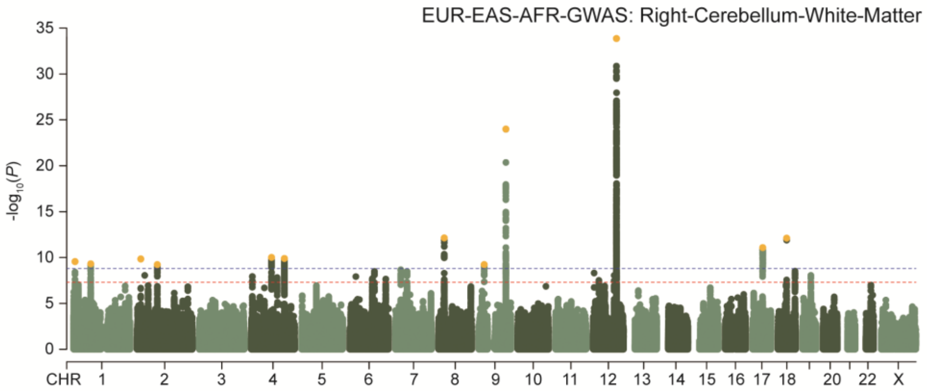
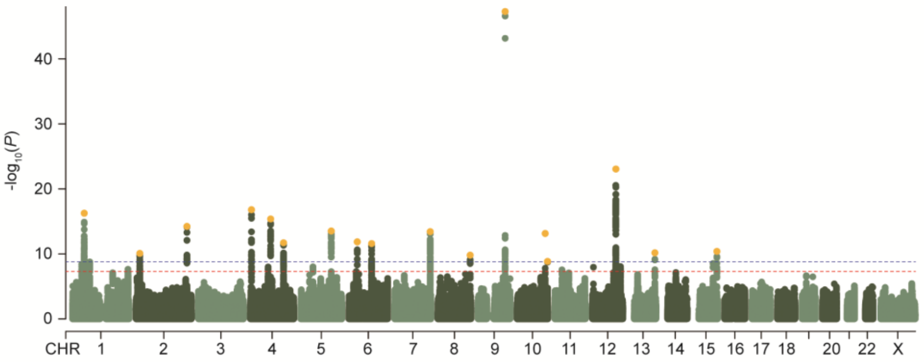
0
2
4
6
8
10
12
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

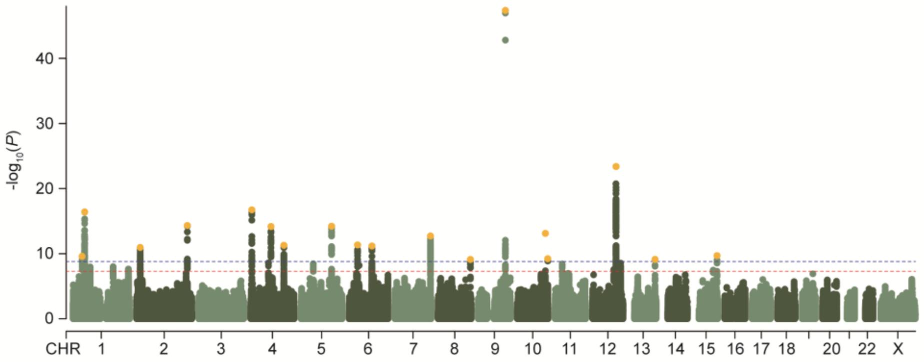

EUR-EAS-AFR-GWAS: Left-Cerebellum-White-Matter
$-\log_{10}(P)$
0
5
10
15
20
25
30
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Right-Cerebellum-White-Matter
$-\log_{10}(P)$
0
5
10
15
20
25
30
35
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

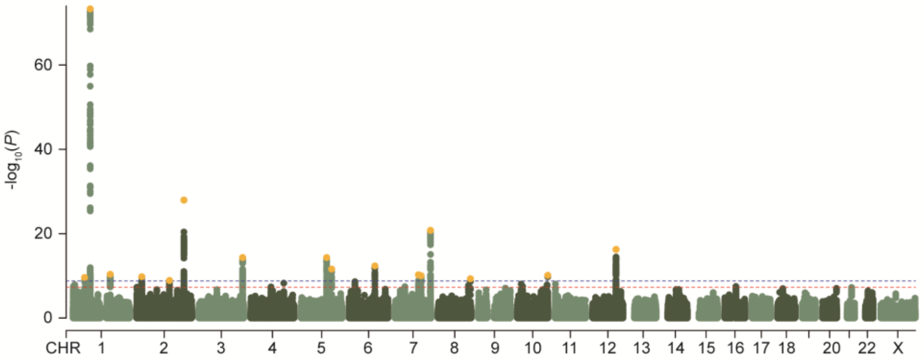
EUR-EAS-AFR-GWAS: Left-Cerebellum-Cortex



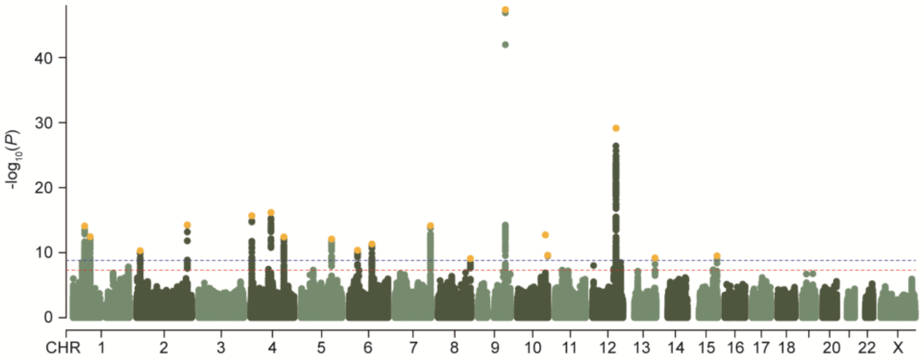
EUR-EAS-AFR-GWAS: Right-Cerebellum-Cortex

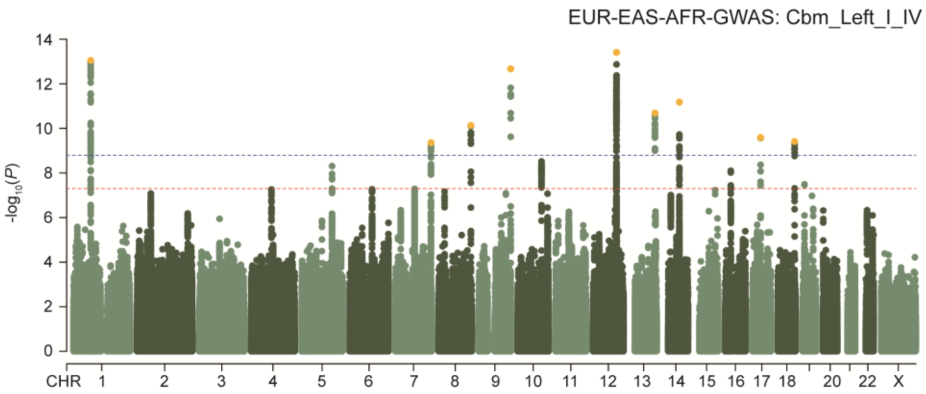


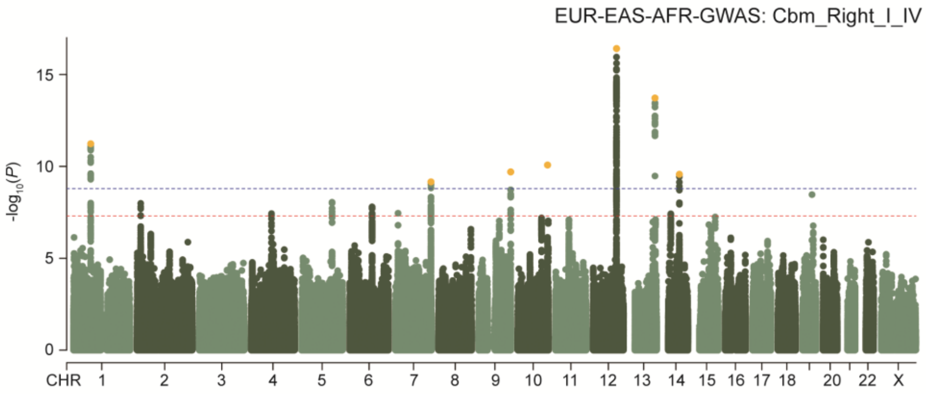
EUR-EAS-AFR-GWAS: Cbm_Vermis

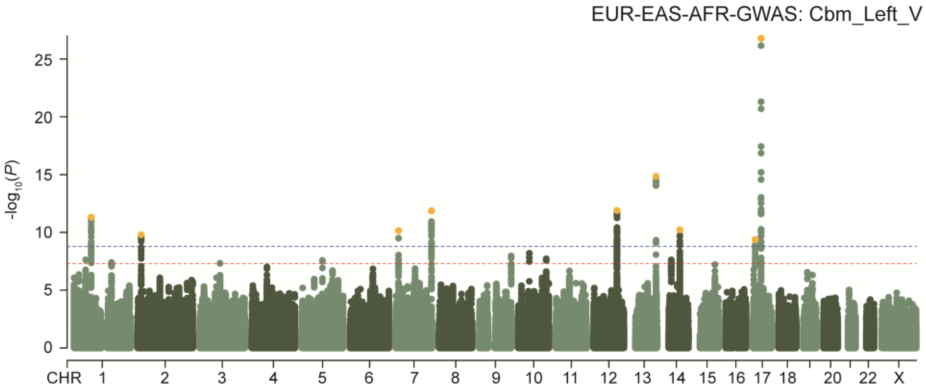


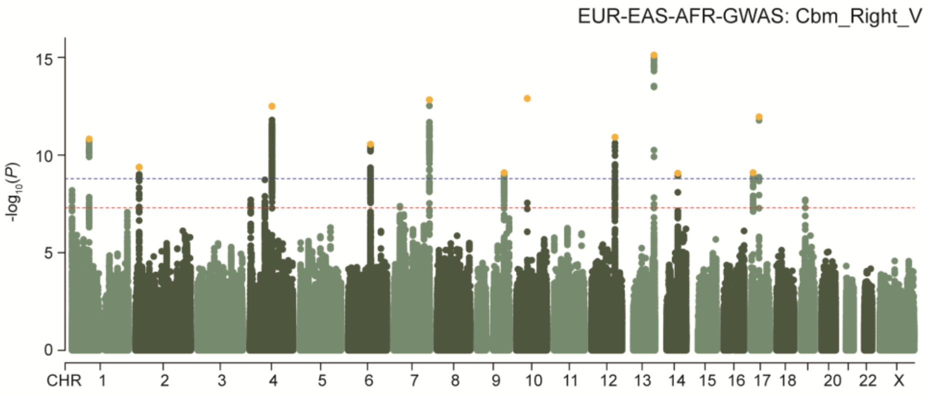
EUR-EAS-AFR-GWAS: Cbm_total



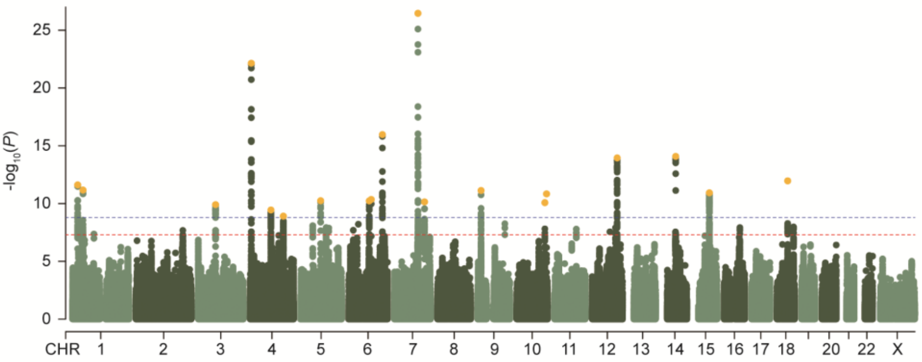

EUR-EAS-AFR-GWAS: Cbm_Left_I_IV
-log$_{10}$(P)
14
12
10
8
6
4
2
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Right_I_IV
-log$_{10}$(P)
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Left_V
-log$_{10}$(P)
25
20
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Right_V
-log$_{10}$(P)
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

EUR-EAS-AFR-GWAS: Cbm_Left_VI



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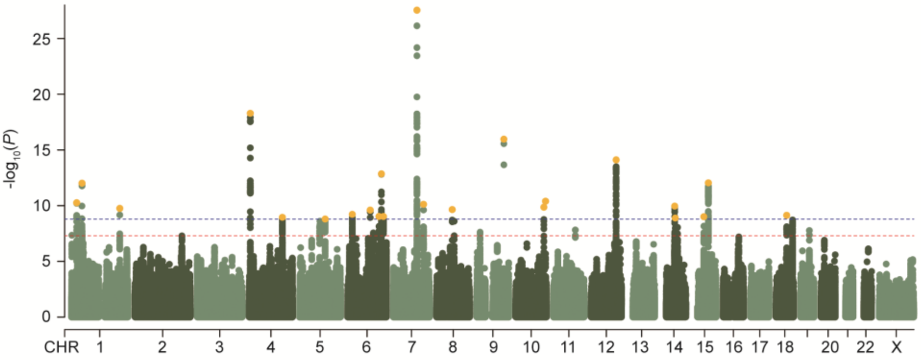
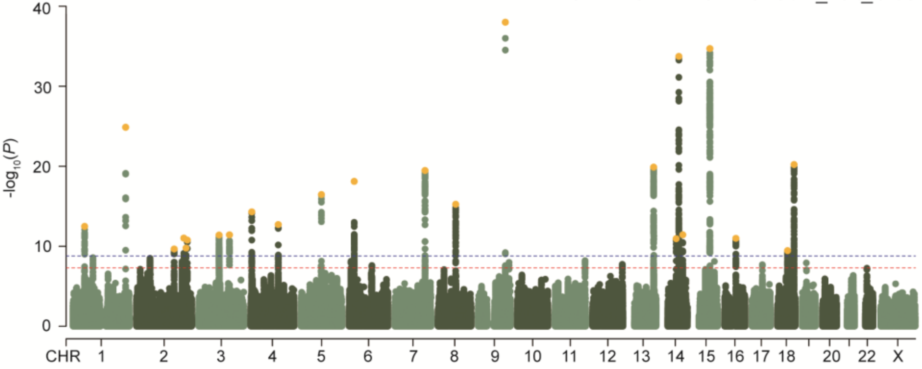


EUR-EAS-AFR-GWAS: Cbm_Left_CrusI



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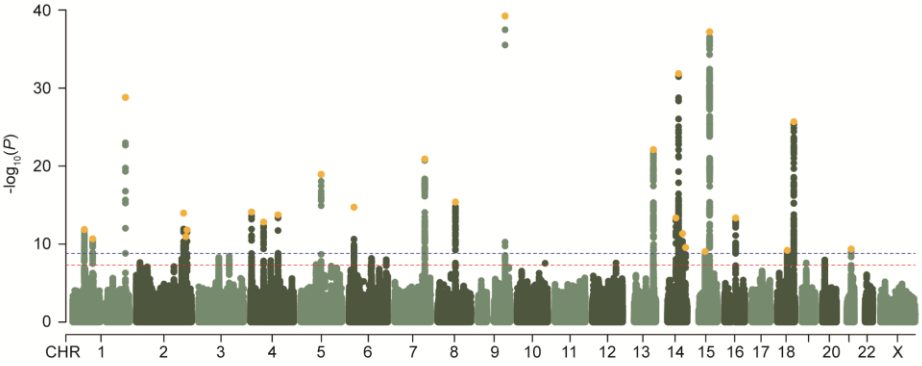

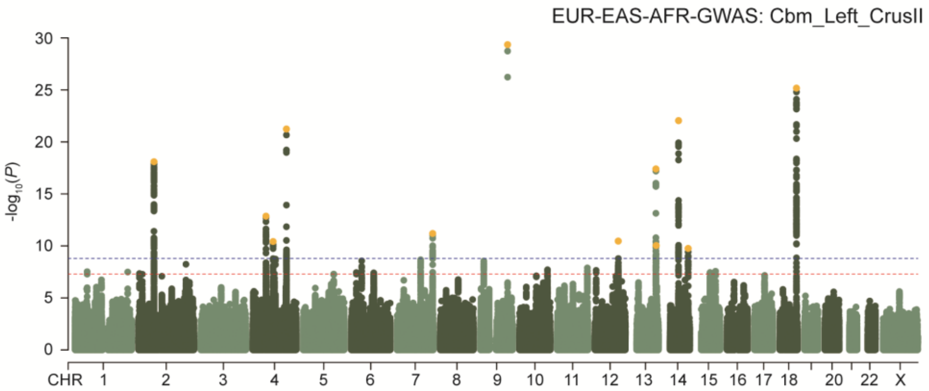
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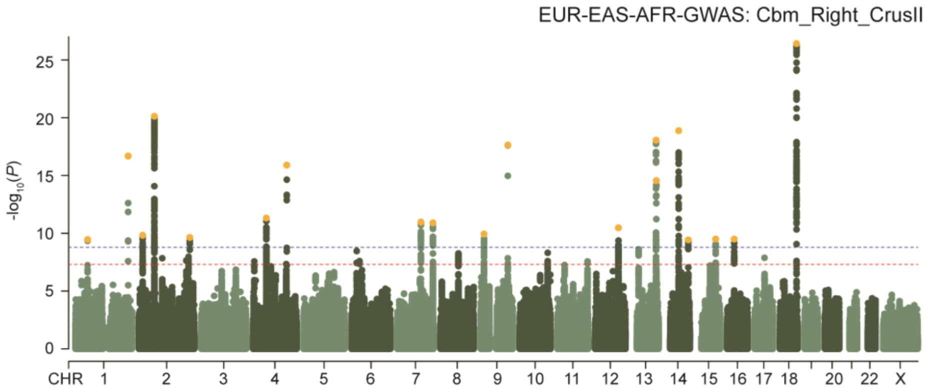
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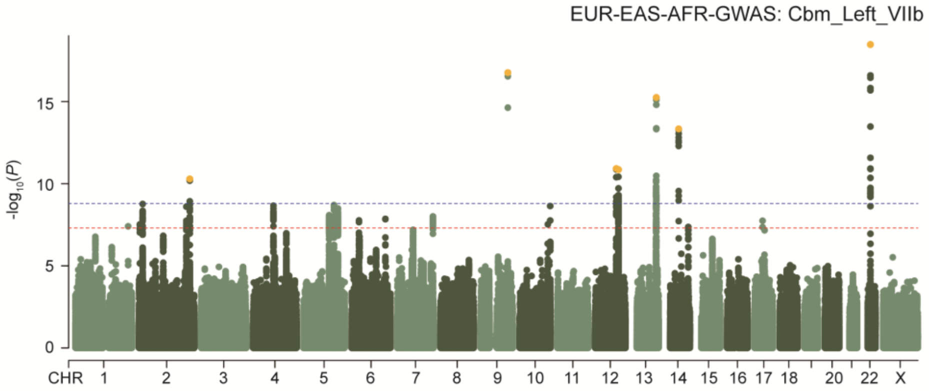
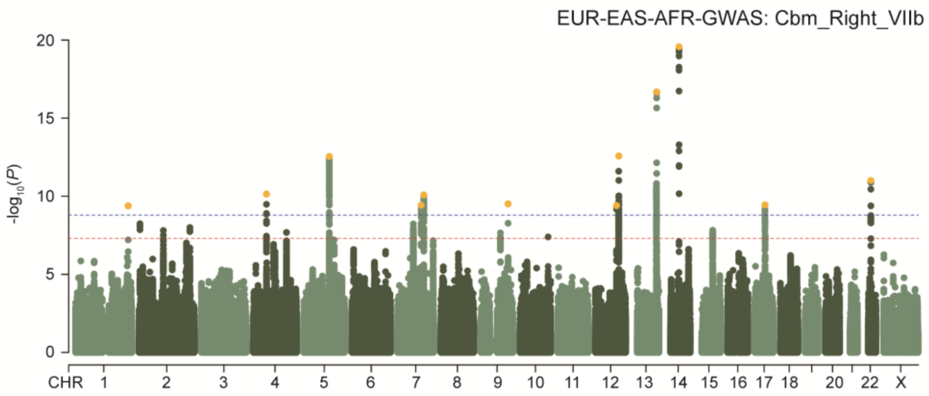

EUR-EAS-AFR-GWAS: Cbm_Left_VIIb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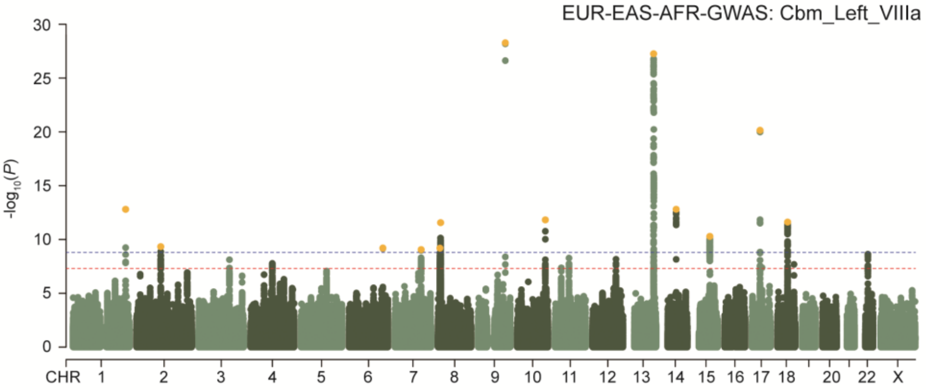
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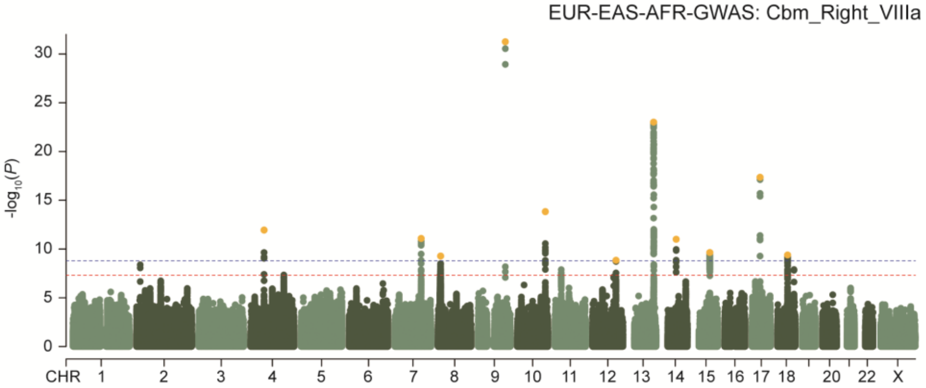
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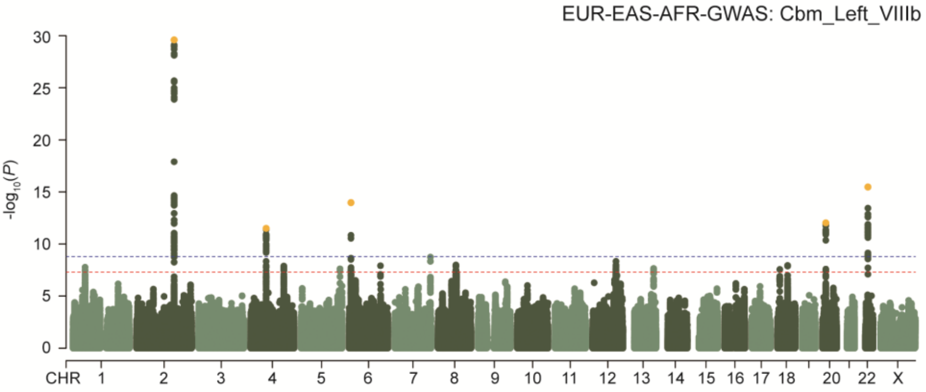
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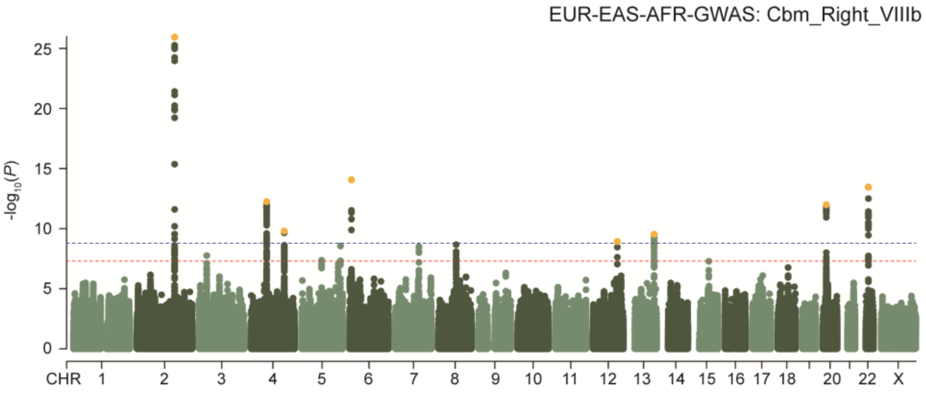
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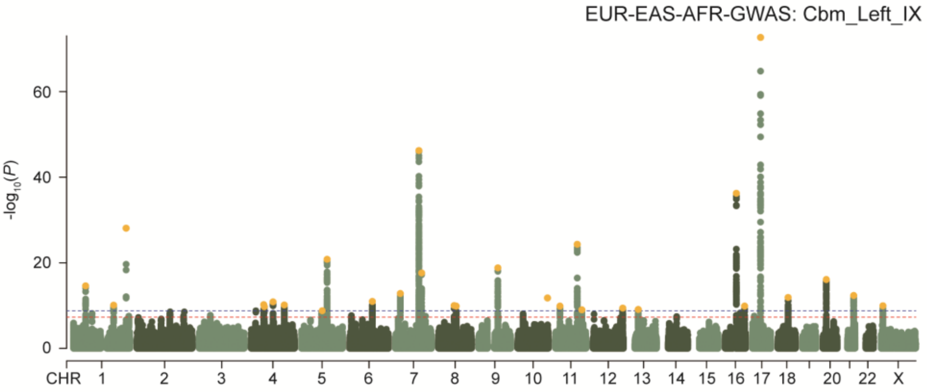
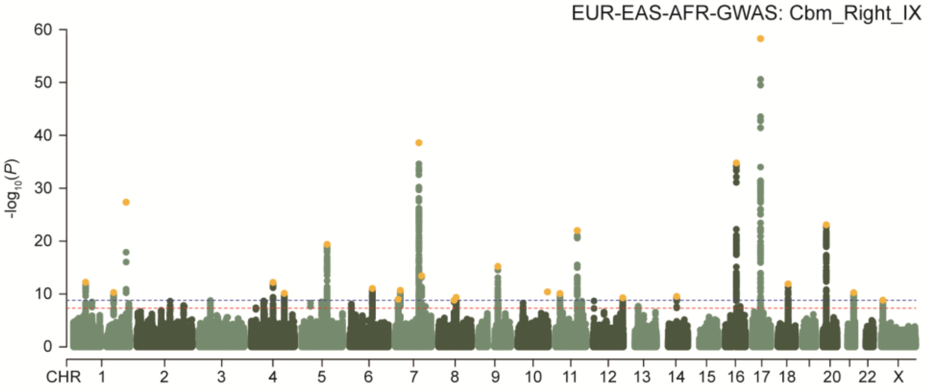
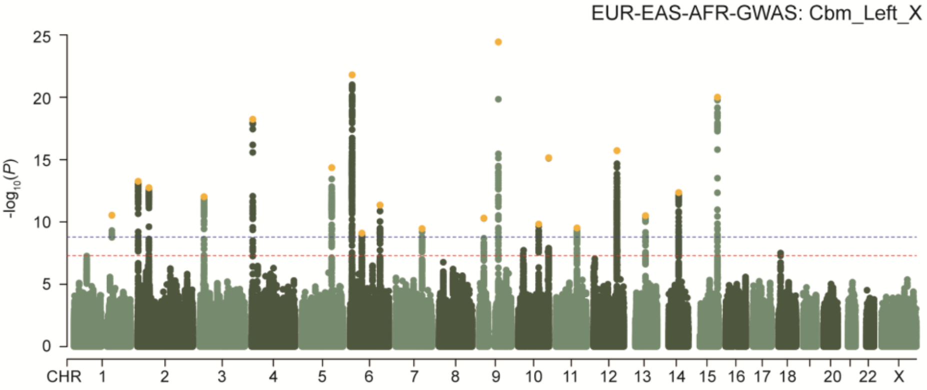
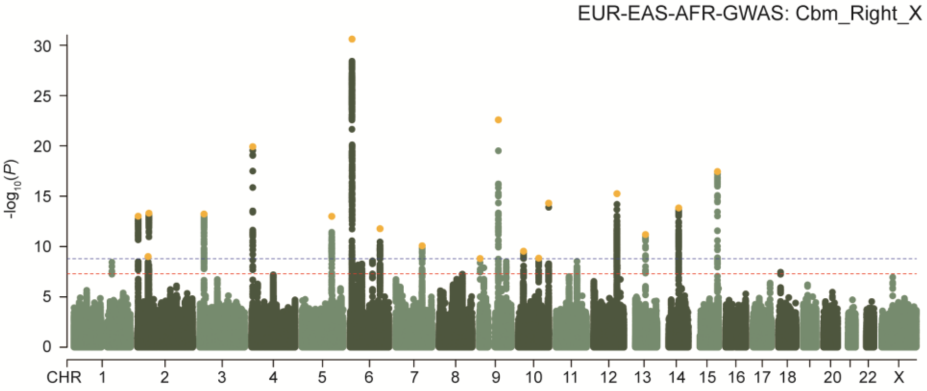
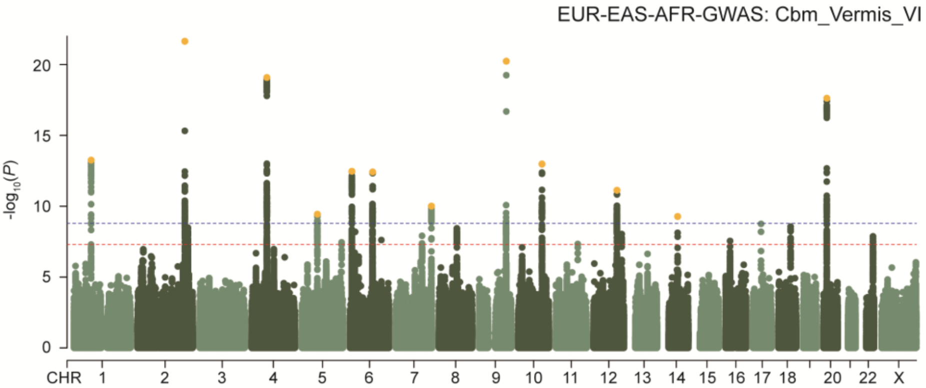
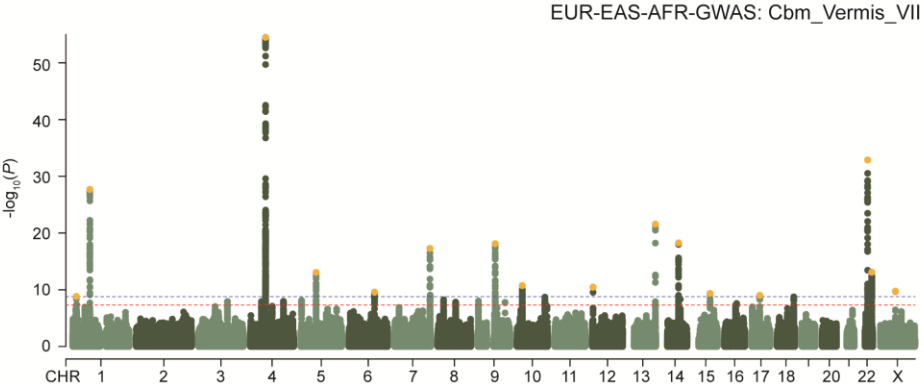

EUR-EAS-AFR-GWAS: Cbm_Left_IX
-log10(P)
60
40
20
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

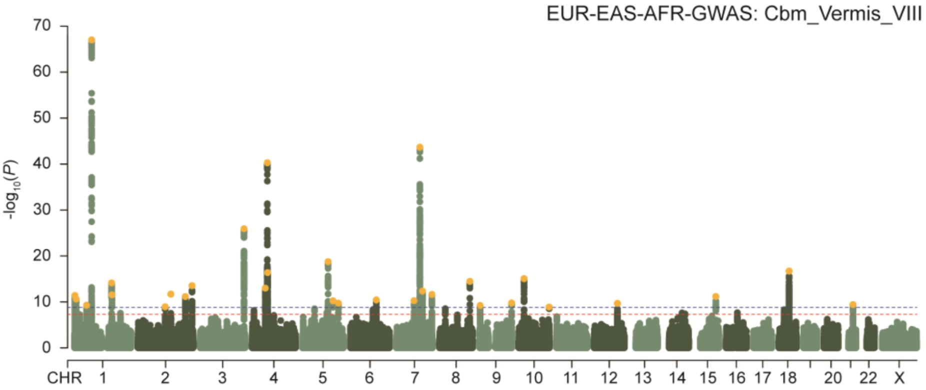

EUR-EAS-AFR-GWAS: Cbm_Right_IX
60
50
40
30
20
10
0
-log10(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

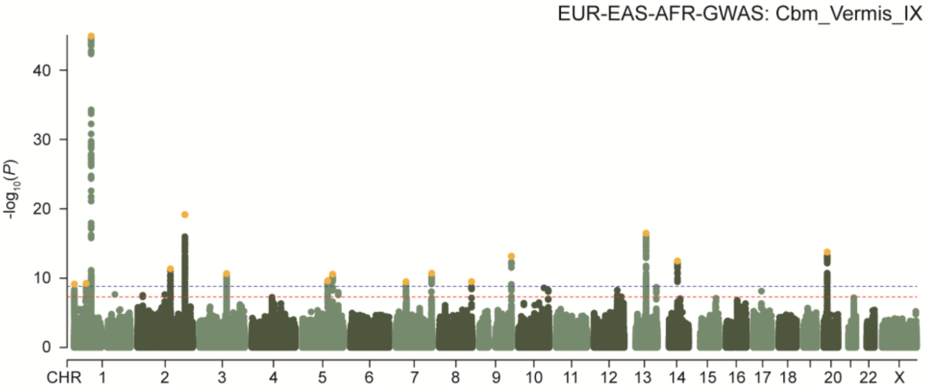

EUR-EAS-AFR-GWAS: Cbm_Left_X
25
20
15
10
5
0
-log10(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Right_X
30
25
20
15
10
5
0
-log10(P)
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Vermis_VI


EUR-EAS-AFR-GWAS: Cbm_Vermis_VII


EUR-EAS-AFR-GWAS: Cbm_Vermis_VIII


EUR-EAS-AFR-GWAS: Cbm_Vermis_IX

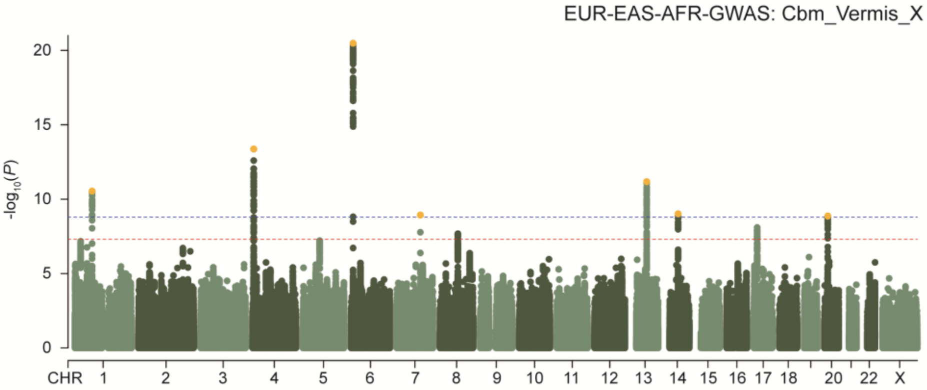
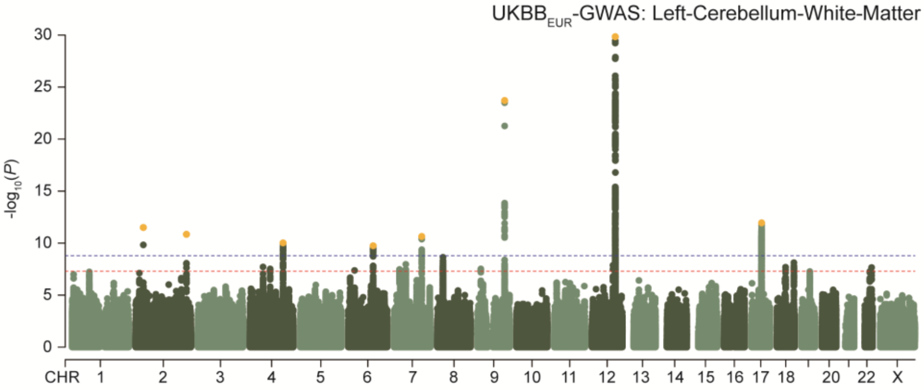
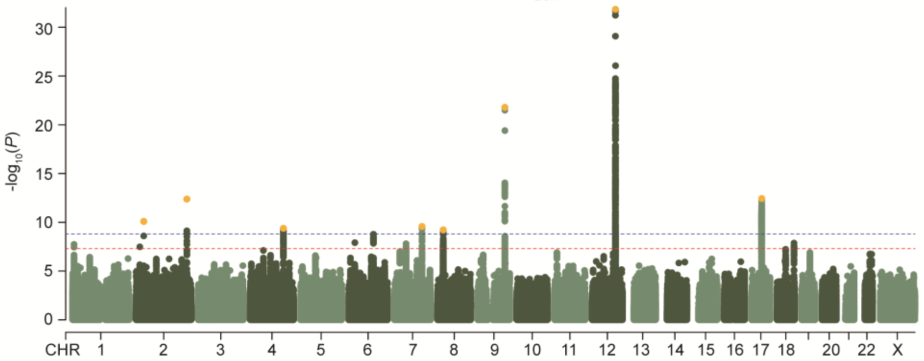
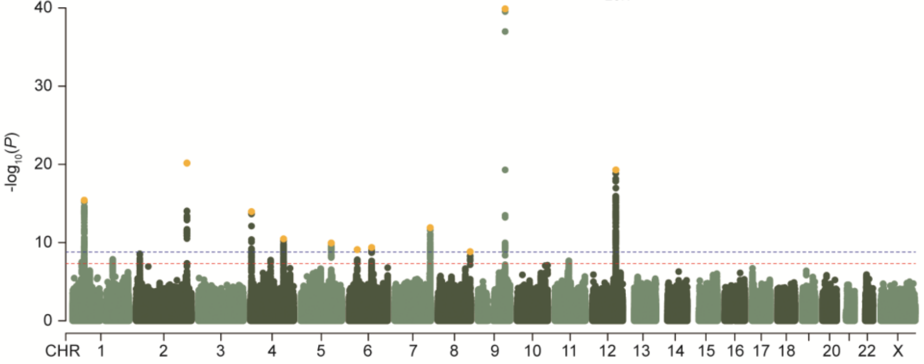
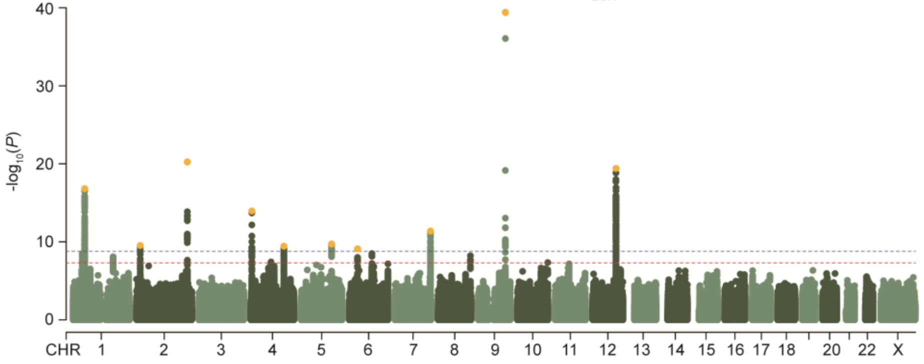


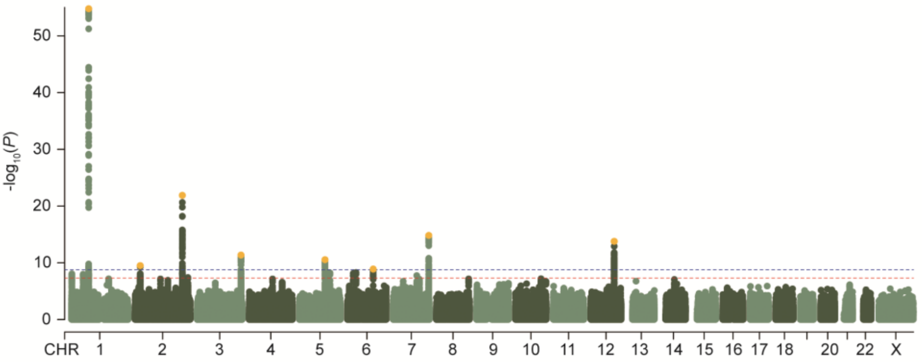
Fig. S4 | Genetic discovery of male-specific univariate GWAS. The Manhattan plots show the results from male-specific univariate GWASs (UKBB$_{\mathrm{EUR}}$-GWAS, ABCD$_{\mathrm{EUR}}$-GWAS, CHIMGEN$_{\mathrm{EAS}}$-GWAS, ABCD$_{\mathrm{AFR}}$-GWAS, EUR-GWAS, EUR-EAS-GWAS, and EUR-EAS-AFR-GWAS) on the 31 cerebellar volumetric traits. Each plot shows genome-wide (red dashed line: $P = 5 \times 10^{-8}$) and study-wide (blue dashed line: $P = 1.61 \times 10^{-9}$) significant associations. Each point represents a single genetic variant plotted according to its genomic position (x axis) and its -log$_{10}$(P) value for the association (y axis). Each yellow point represents an independent locus with study-wide significance ($P = 1.61 \times 10^{-9}$). Abbreviations: ABCD, the Adolescent Brain Cognitive Development study; AFR, African ancestry; CHIMGEN, the Chinese Imaging Genetics study; EAS, East Asian ancestry; EUR, European ancestry; GWAS, genome-wide association study; UKBB, the UK Biobank study.

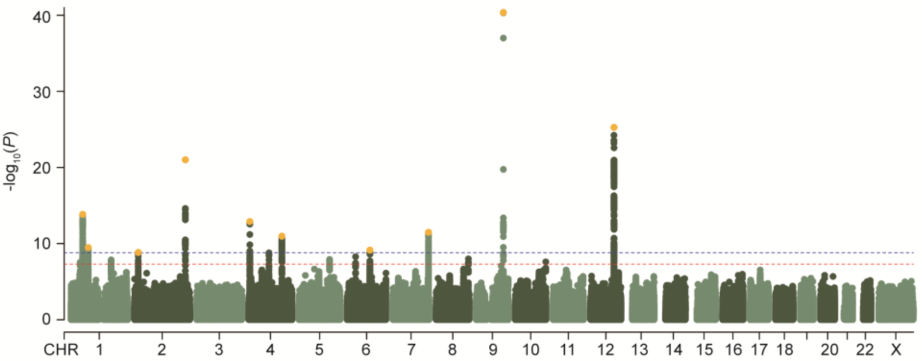

UKBB$_{EUR}$-GWAS: Left-Cerebellum-White-Matter

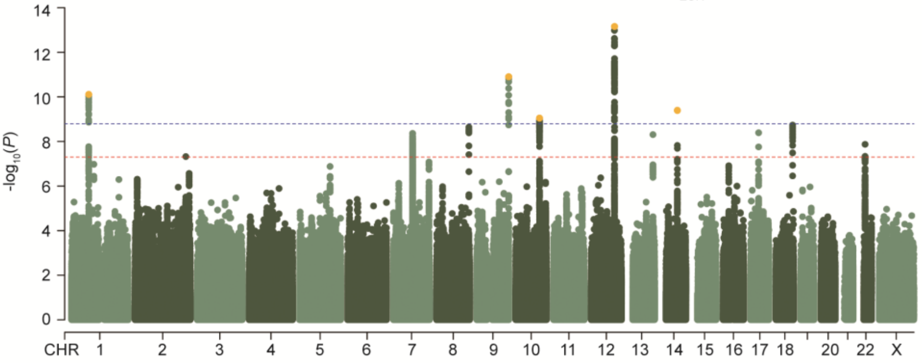

UKBB$_{EUR}$-GWAS: Right-Cerebellum-White-Matter

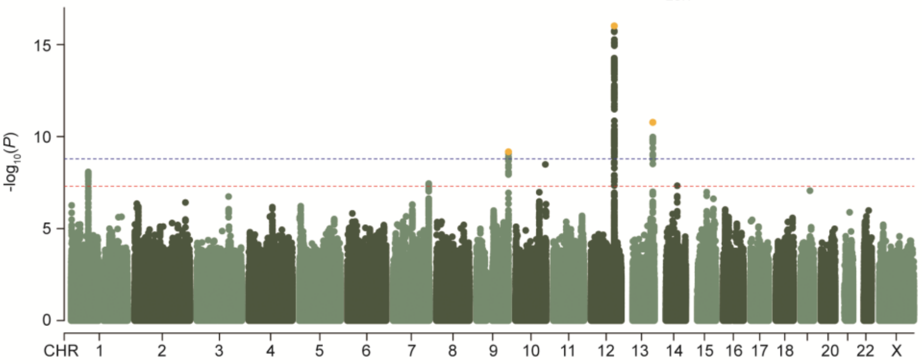

UKBB$_{EUR}$-GWAS: Left-Cerebellum-Cortex

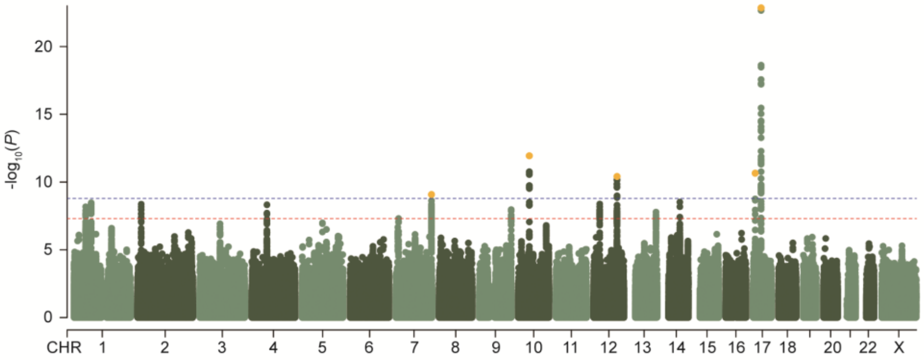

UKBB$_{EUR}$-GWAS: Right-Cerebellum-Cortex


UKBB$_{EUR}$-GWAS: Cbm_Vermis

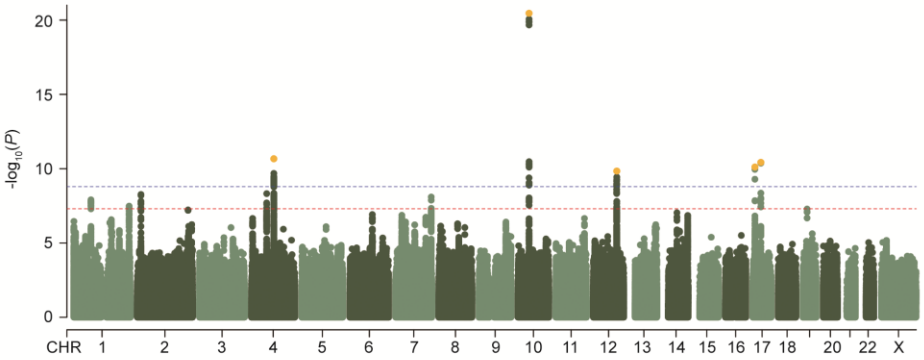

UKBB$_{EUR}$-GWAS: Cbm_total


UKBB$_{EUR}$-GWAS: Cbm_Left_I_IV

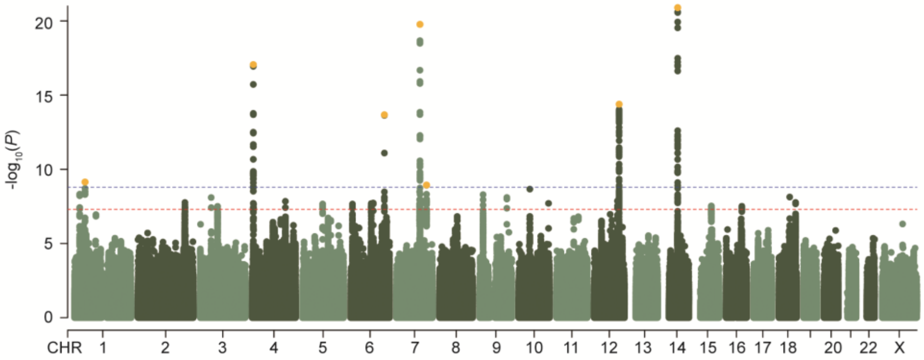

UKBB$_{EUR}$-GWAS: Cbm_Right_I_IV



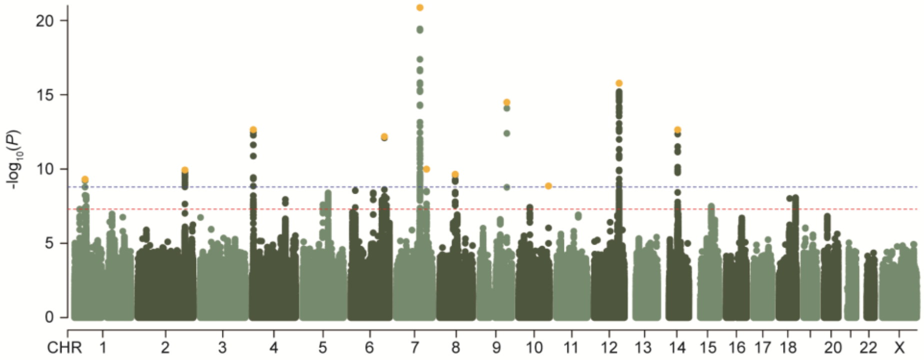
UKBB$_{EUR}$-GWAS: Cbm_Left_V



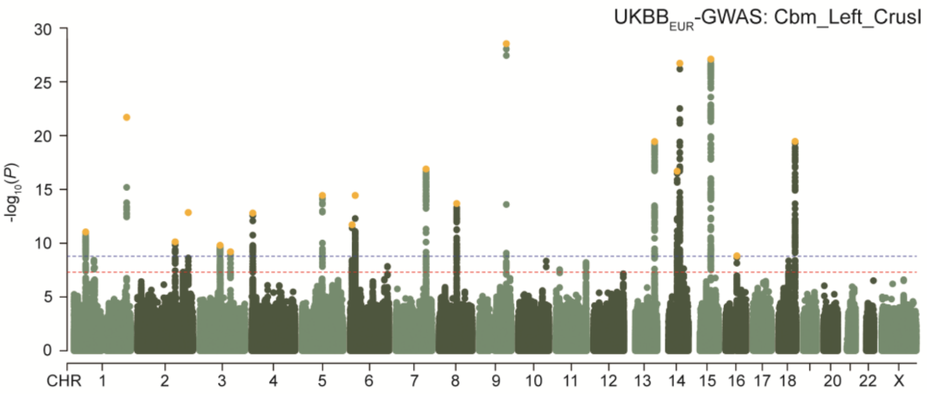
UKBB$_{EUR}$-GWAS: Cbm_Right_V

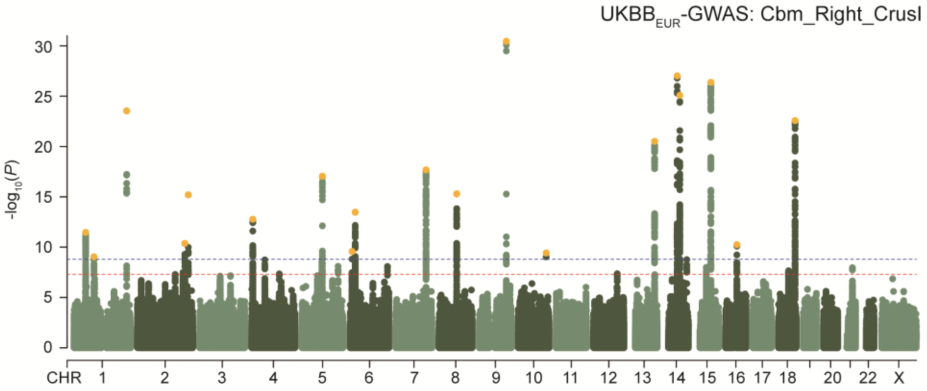


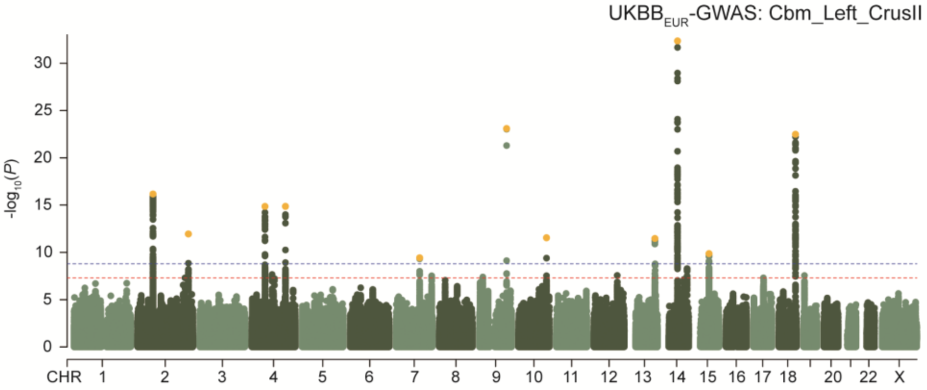
UKBB$_{EUR}$-GWAS: Cbm_Left_VI

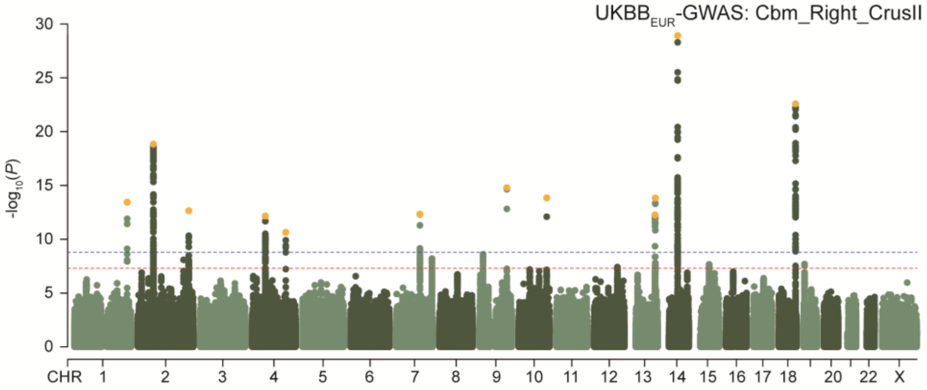


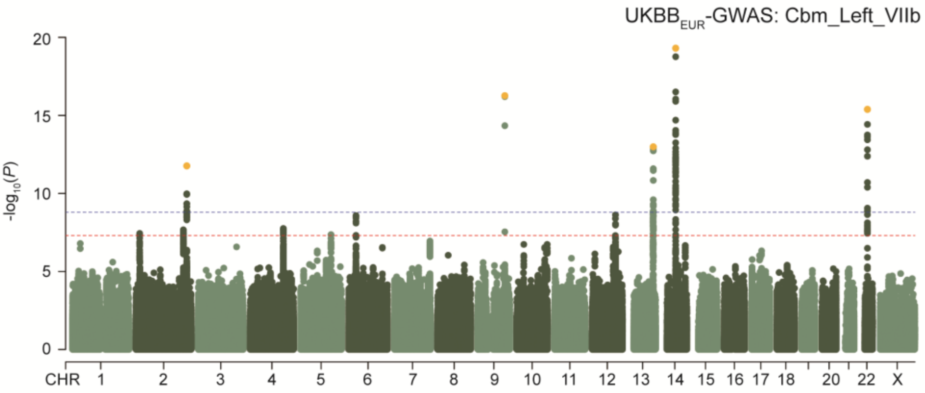
UKBB$_{EUR}$-GWAS: Cbm_Right_VI

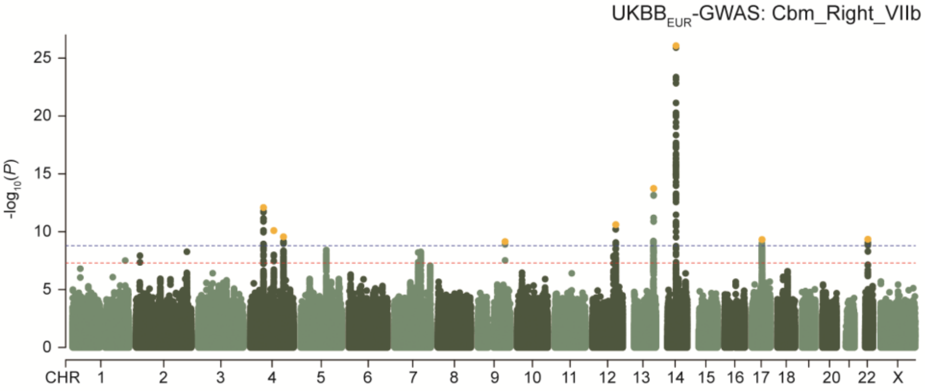

UKBB$_{EUR}$-GWAS: Cbm_Left_CrusI

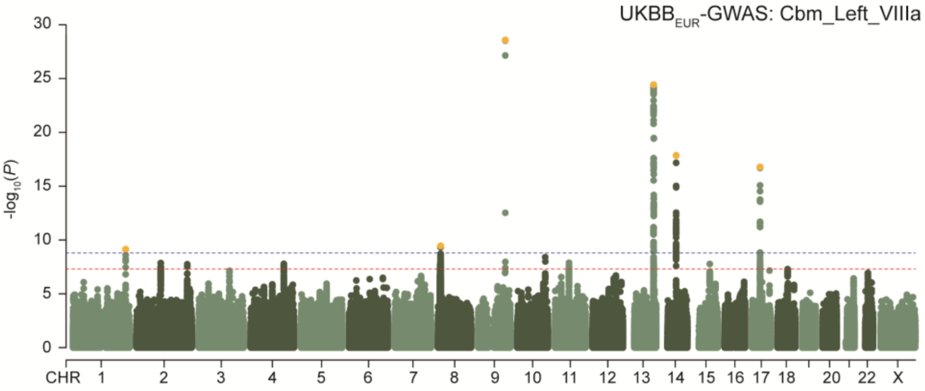

UKBB$_{EUR}$-GWAS: Cbm_Right_CrusI

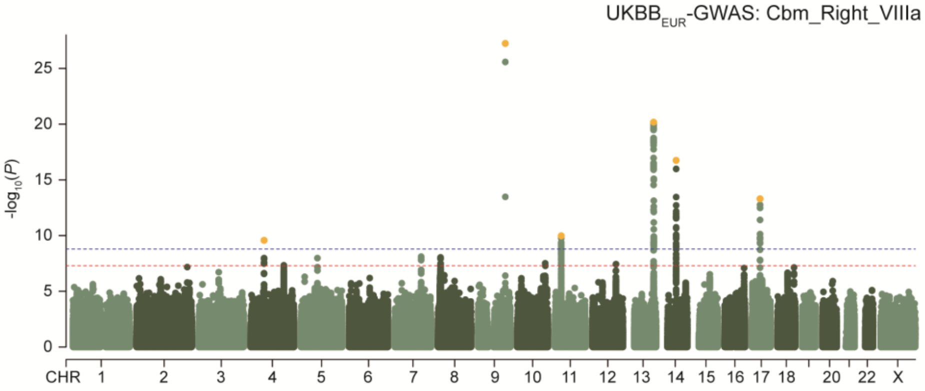

UKBB$_{EUR}$-GWAS: Cbm_Left_CrusII

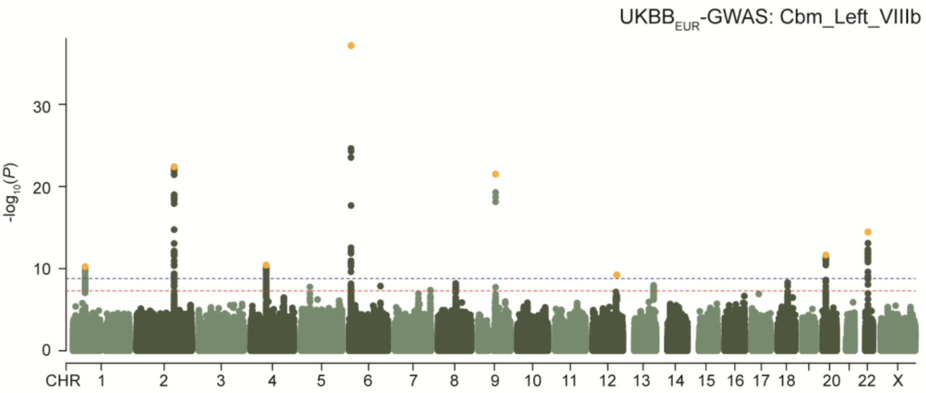

UKBB$_{EUR}$-GWAS: Cbm_Right_CrusII

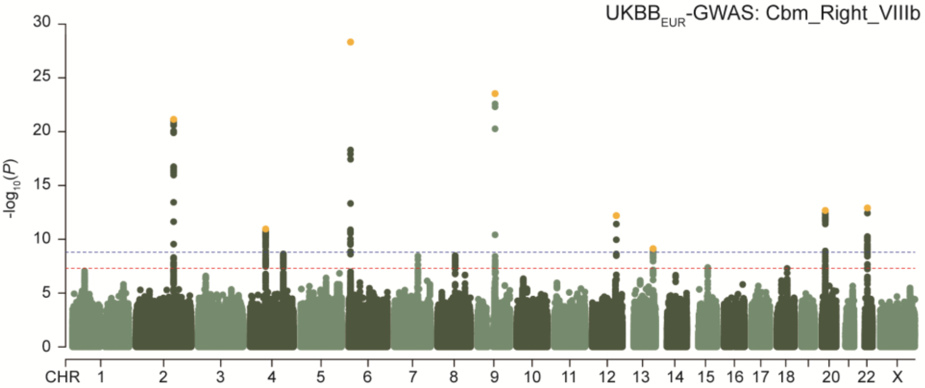

UKBB$_{EUR}$-GWAS: Cbm_Left_VIIb


UKBB$_{EUR}$-GWAS: Cbm_Right_VIIb


UKBB$_{EUR}$-GWAS: Cbm_Left_VIIIa


UKBB$_{EUR}$-GWAS: Cbm_Right_VIIIa


UKBB$_{EUR}$-GWAS: Cbm_Left_VIIIb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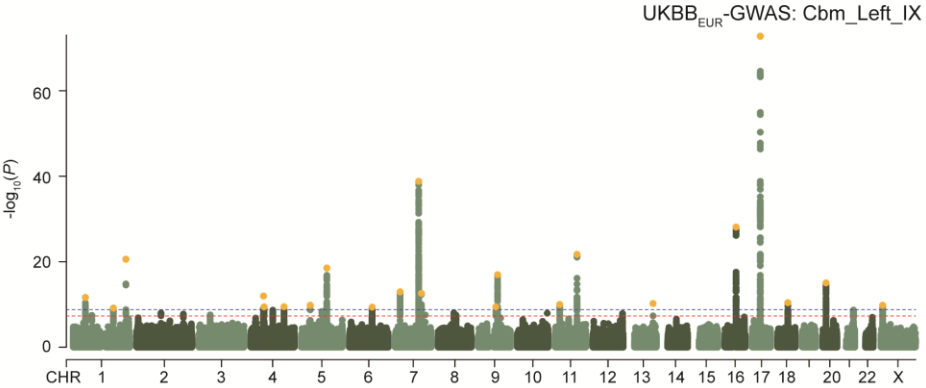
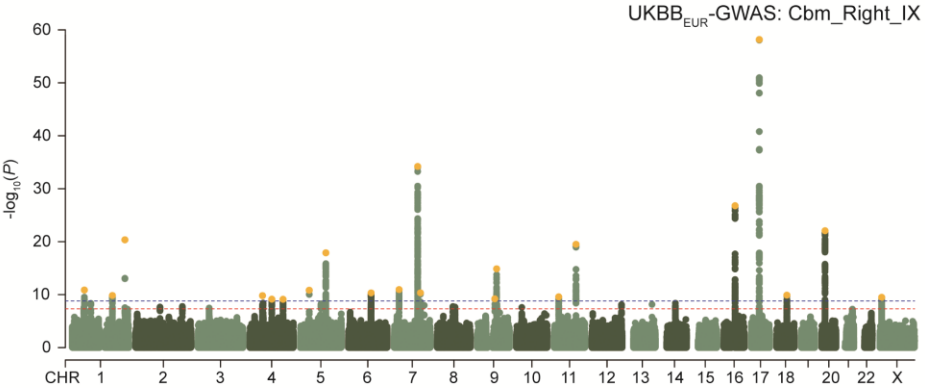

UKBB$_{EUR}$-GWAS: Cbm_Left_IX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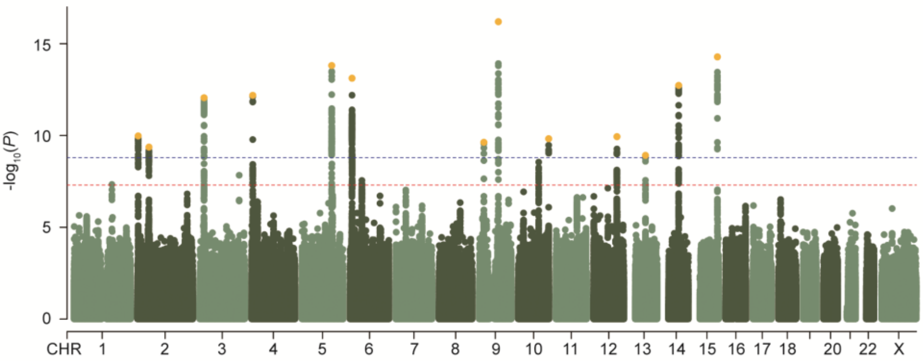
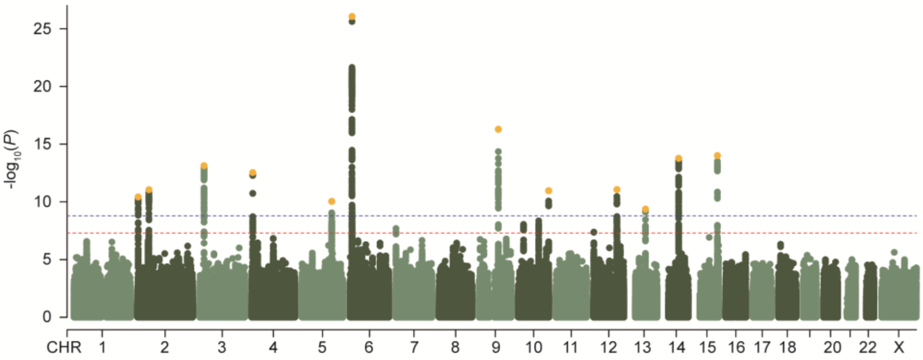
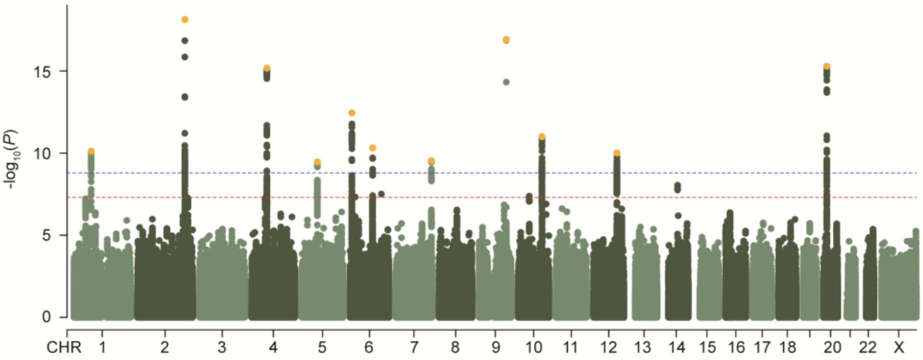


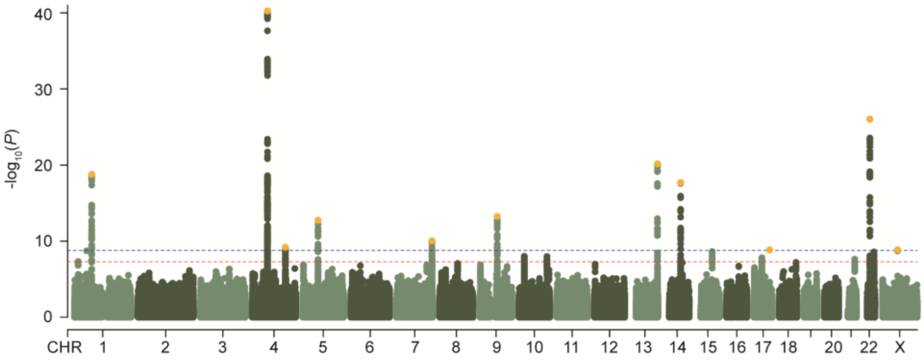
UKBB$_{EUR}$-GWAS: Cbm_Left_X



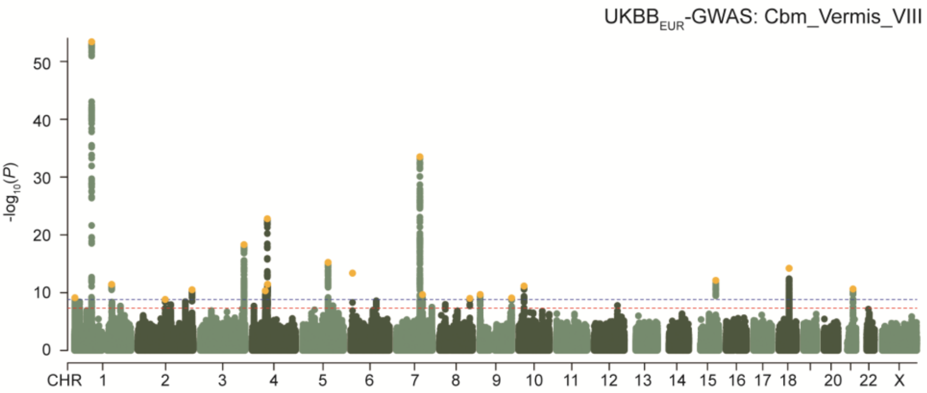
UKBB$_{EUR}$-GWAS: Cbm_Right_X

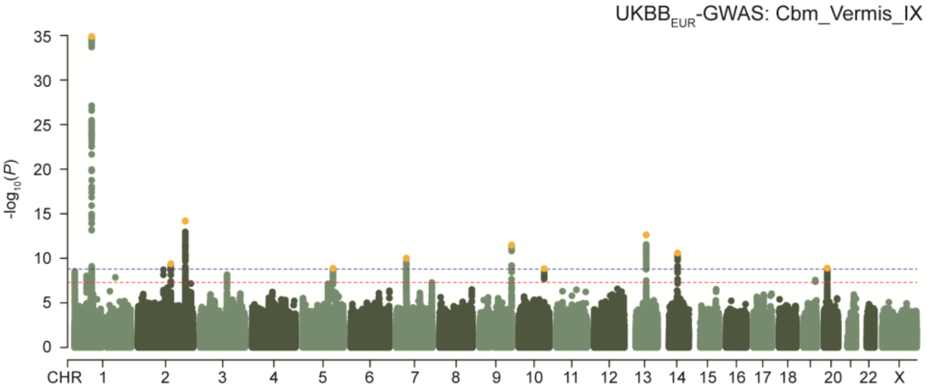


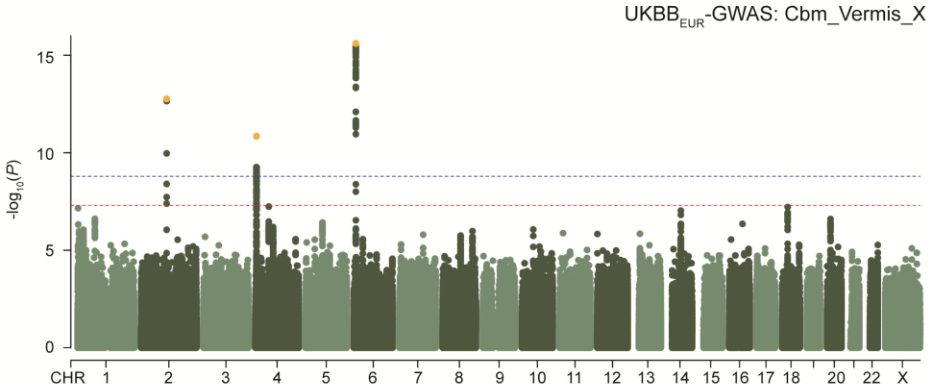
UKBB$_{EUR}$-GWAS: Cbm_Vermis_VI

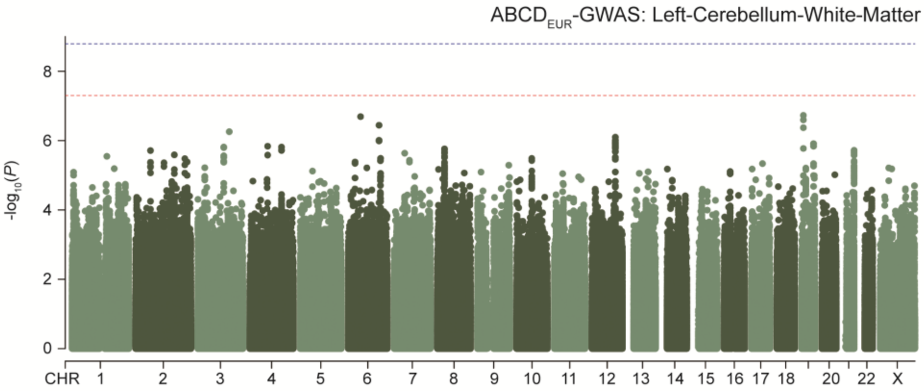


UKBB$_{EUR}$-GWAS: Cbm_Vermis_VII

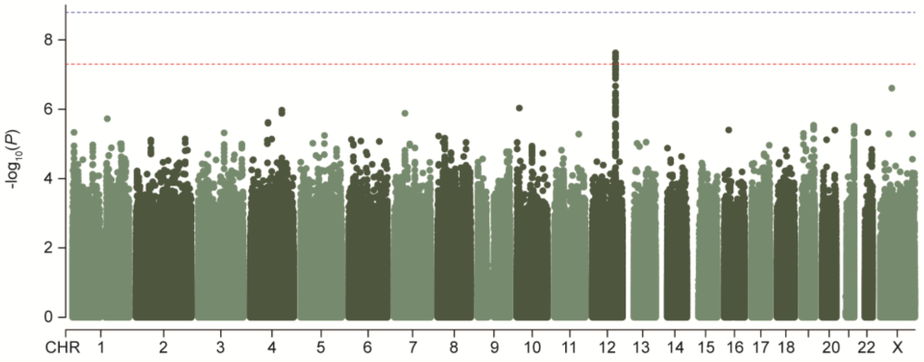

UKBB$_{EUR}$-GWAS: Cbm_Vermis_VIII


UKBB$_{EUR}$-GWAS: Cbm_Vermis_IX

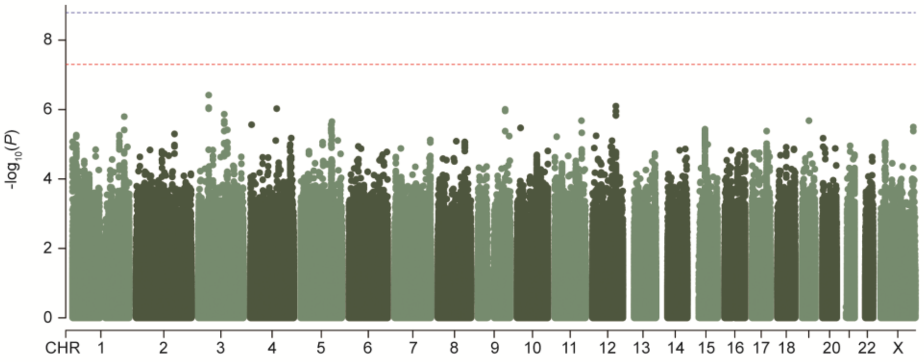

UKBB$_{EUR}$-GWAS: Cbm_Vermis_X


ABCD$_{EUR}$-GWAS: Left-Cerebellum-White-Matter

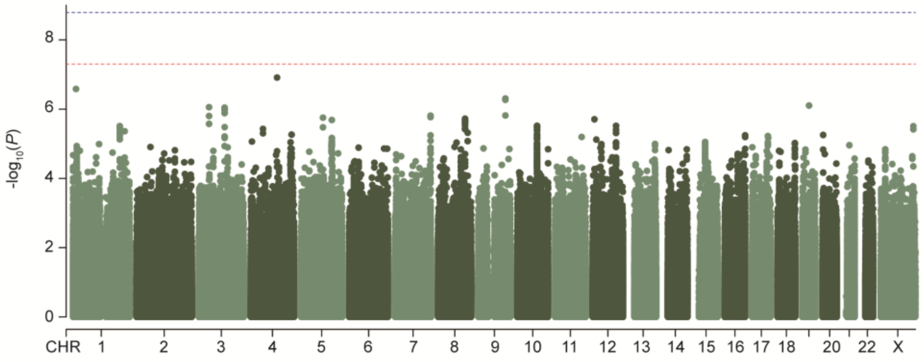
ABCD$_{\text{EUR}}$-GWAS: Right-Cerebellum-White-Matter



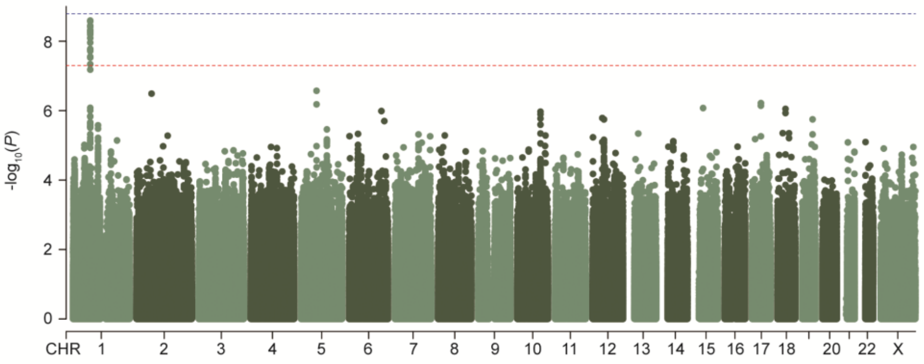
ABCD$_{\text{EUR}}$-GWAS: Left-Cerebellum-Cortex

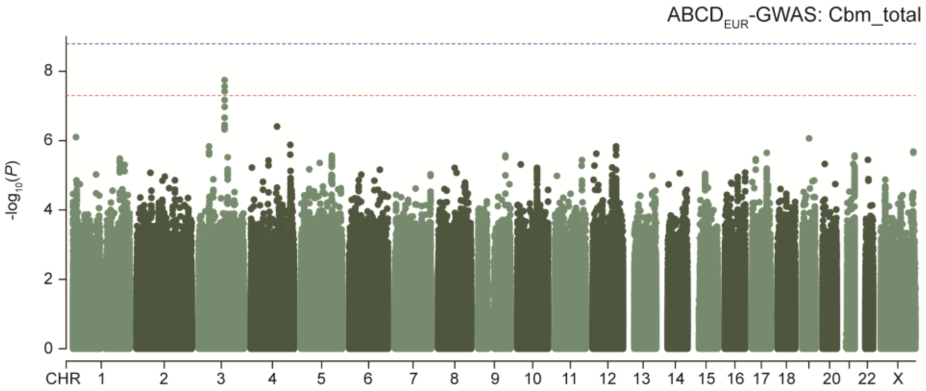


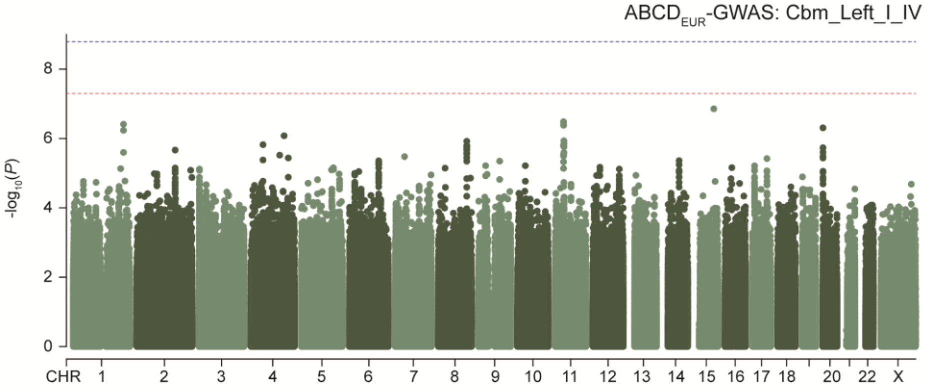
ABCD$_{\text{EUR}}$-GWAS: Right-Cerebellum-Cortex



ABCD$_{\text{EUR}}$-GWAS: Cbm_Vermis




ABCD$_{EUR}$-GWAS: Cbm_total
-log$_{10}$(P)
0
2
4
6
8
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


ABCD$_{EUR}$-GWAS: Cbm_Left_I_IV
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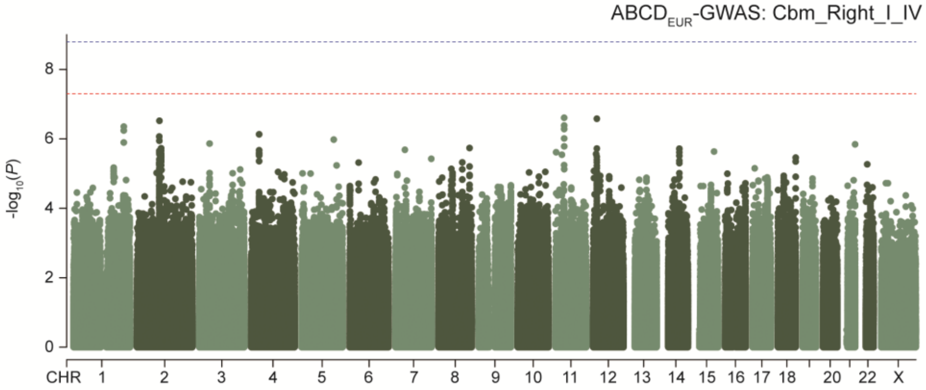
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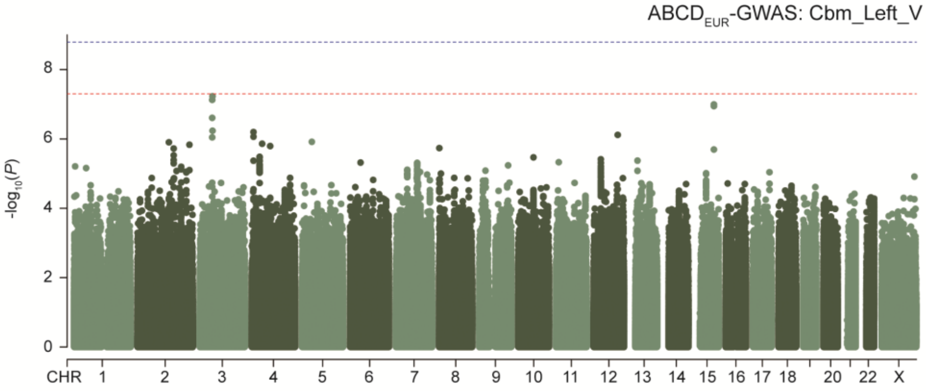
ABCD$_{EUR}$-GWAS: Cbm_Left_V
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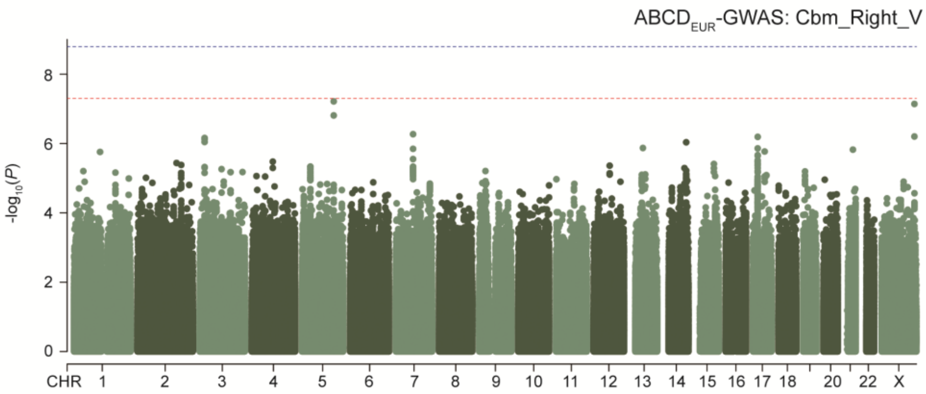
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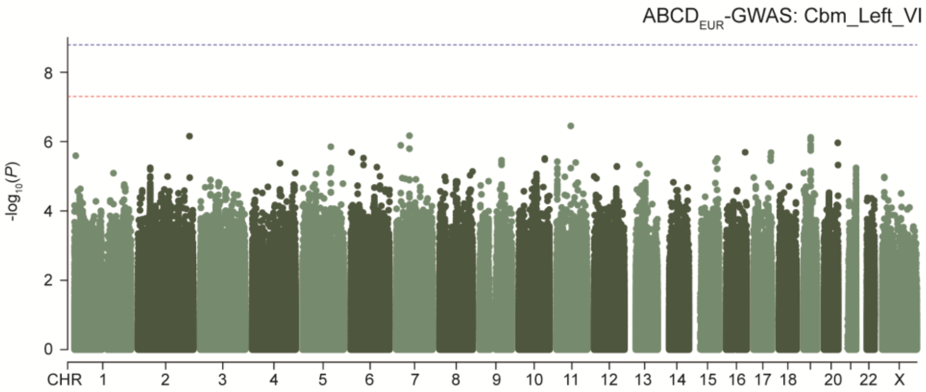
ABCD$_{EUR}$-GWAS: Cbm_Left_VI
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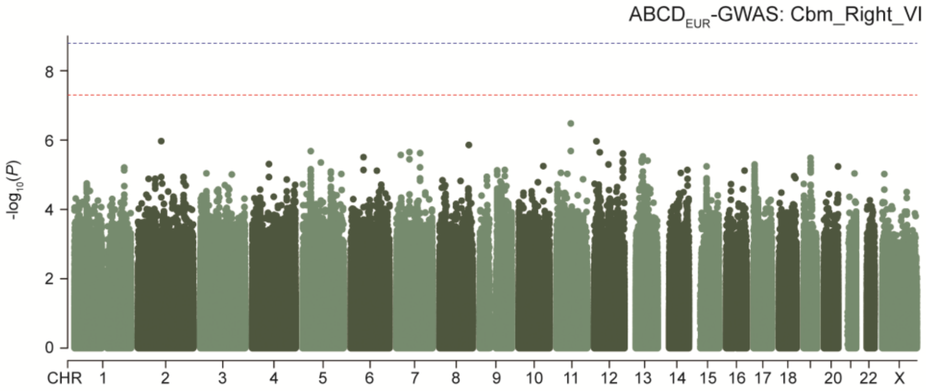
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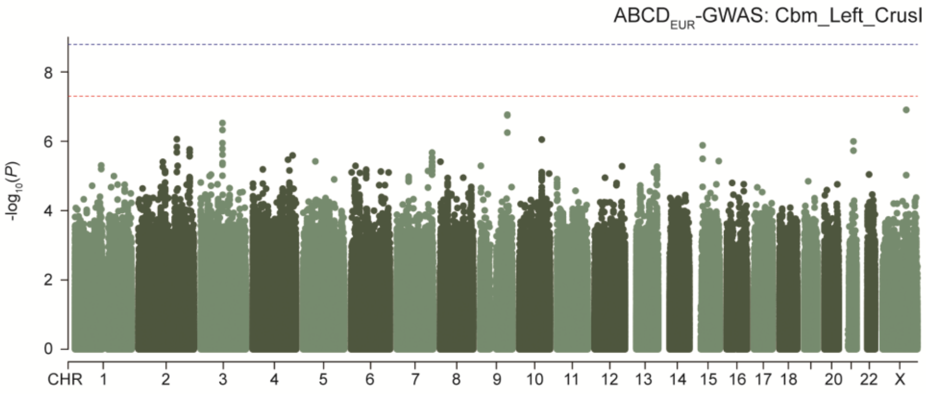
ABCD$_{EUR}$-GWAS: Cbm_Left_CrusI
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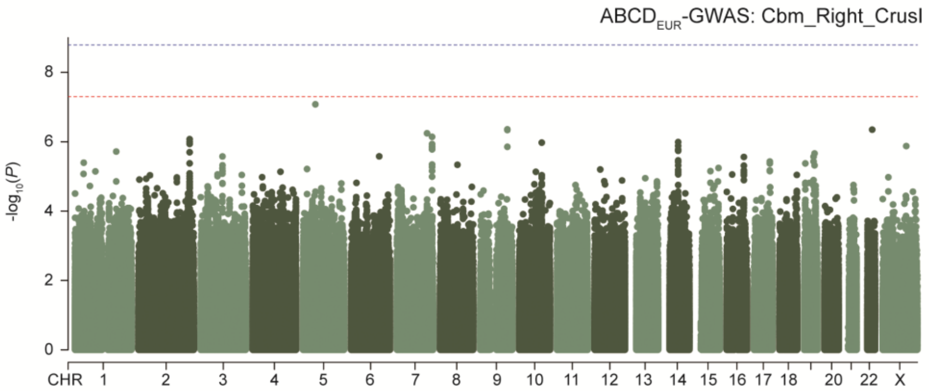
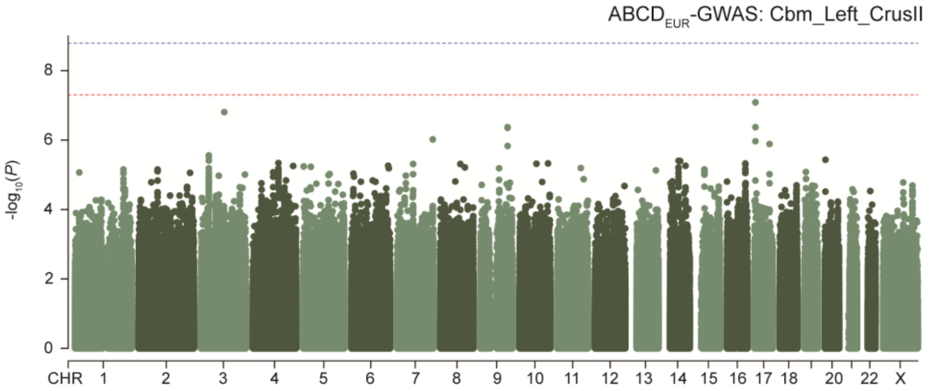

ABCD$_{EUR}$-GWAS: Cbm_Right_CrusI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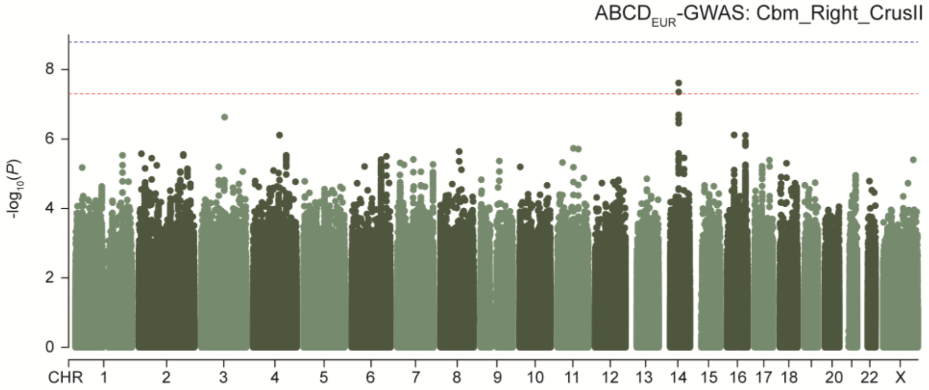
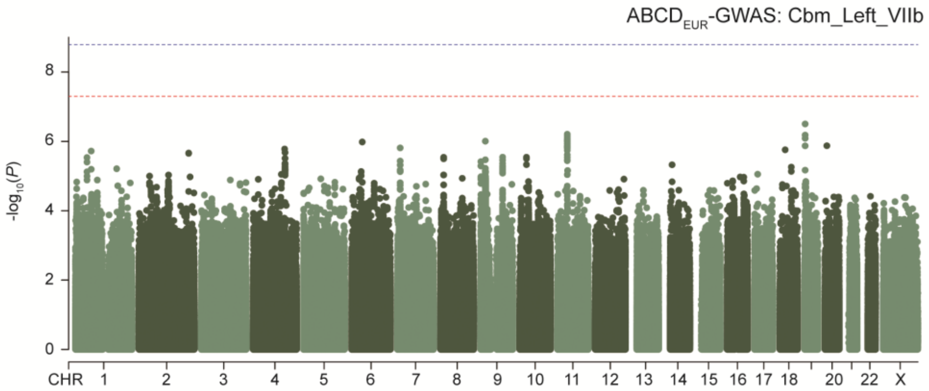
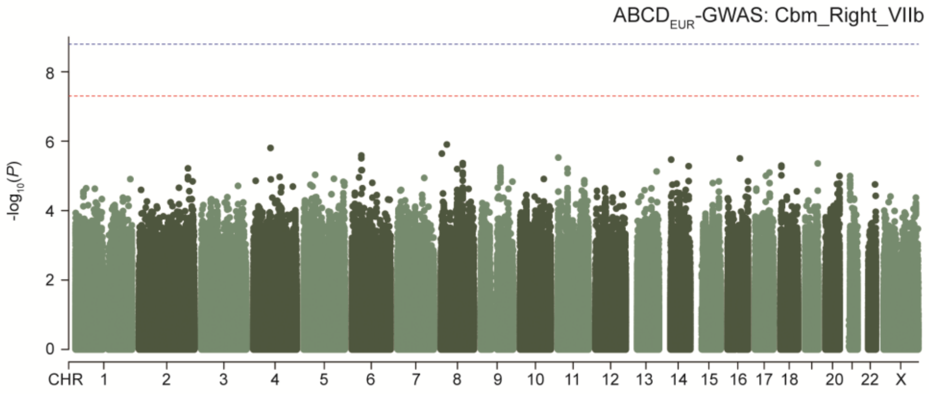
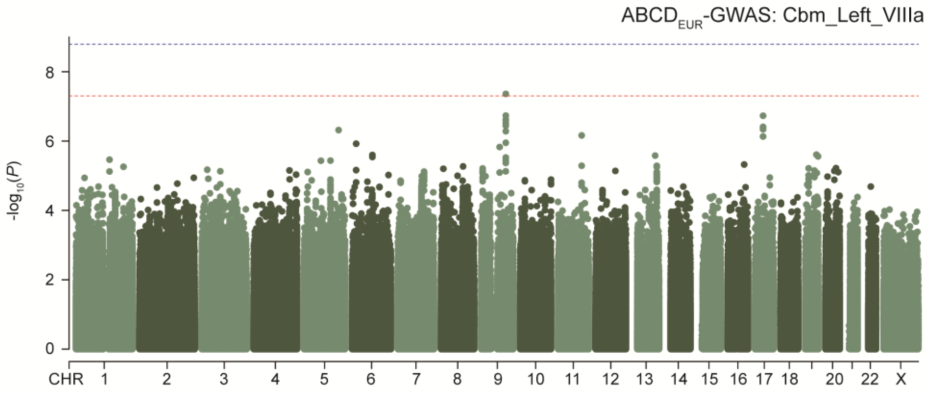
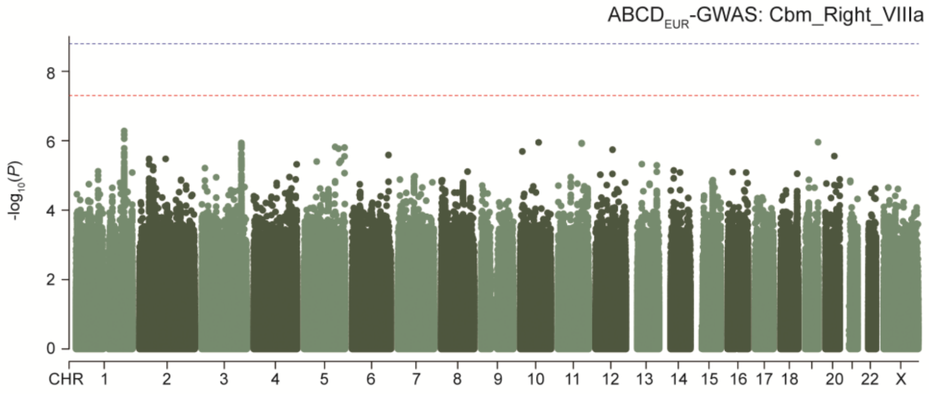
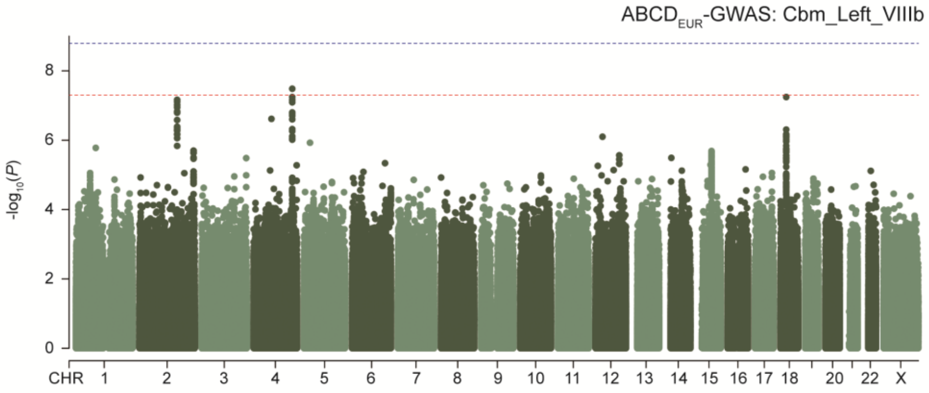

ABCD$_{EUR}$-GWAS: Cbm_Right_CrusII

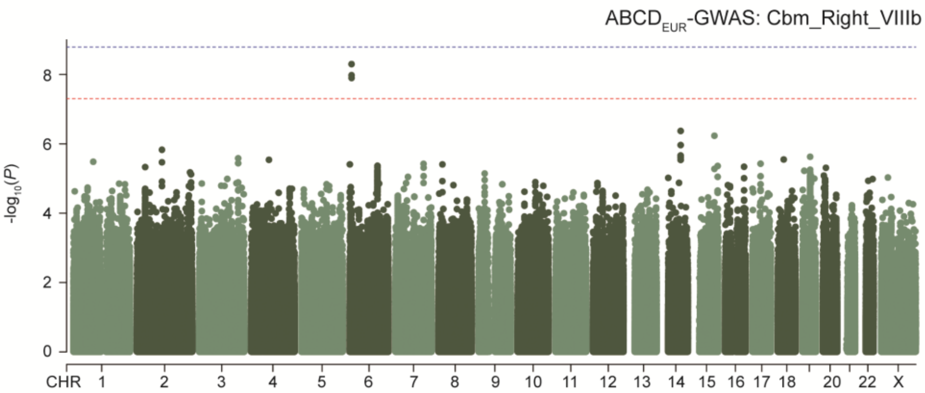

ABCD$_{EUR}$-GWAS: Cbm_Left_VIIb


ABCD$_{EUR}$-GWAS: Cbm_Right_VIIb


ABCD$_{EUR}$-GWAS: Cbm_Left_VIIIa


ABCD$_{EUR}$-GWAS: Cbm_Right_VIIIa


ABCD$_{EUR}$-GWAS: Cbm_Left_VIIIb


ABCD$_{EUR}$-GWAS: Cbm_Right_VIIIb
-log$_{10}$(P)
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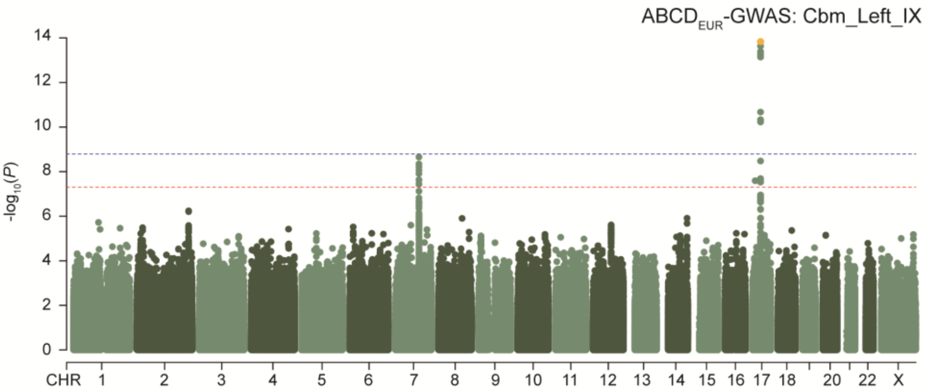
6
8
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


ABCD$_{EUR}$-GWAS: Cbm_Left_IX
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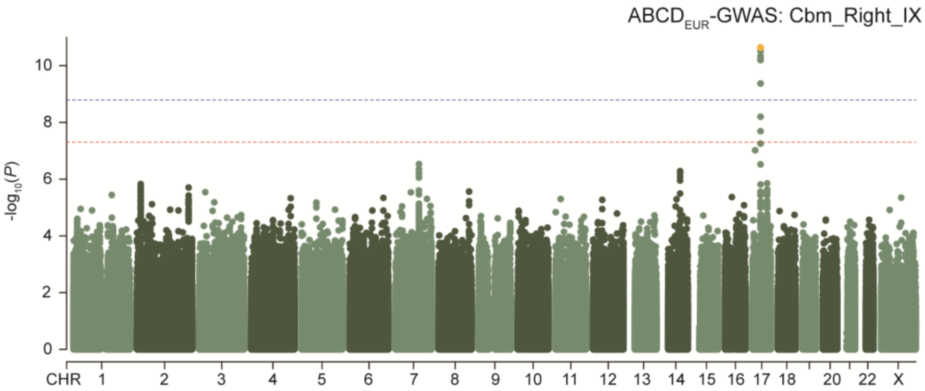
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


ABCD$_{EUR}$-GWAS: Cbm_Right_IX
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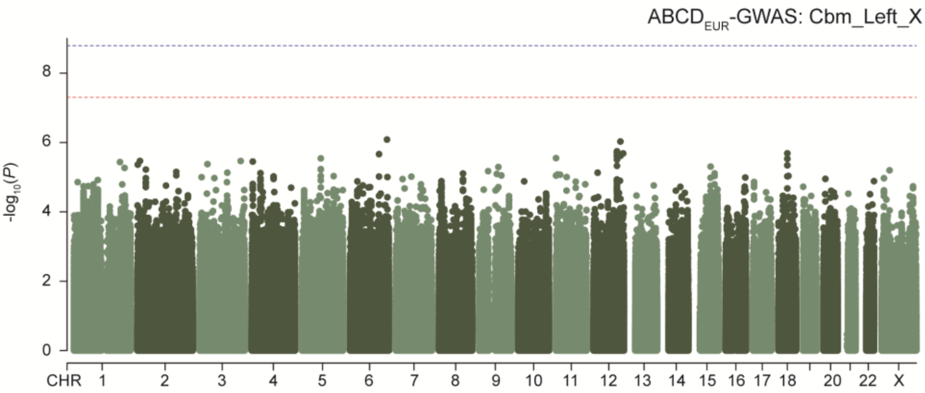
ABCD$_{EUR}$-GWAS: Cbm_Left_X
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6
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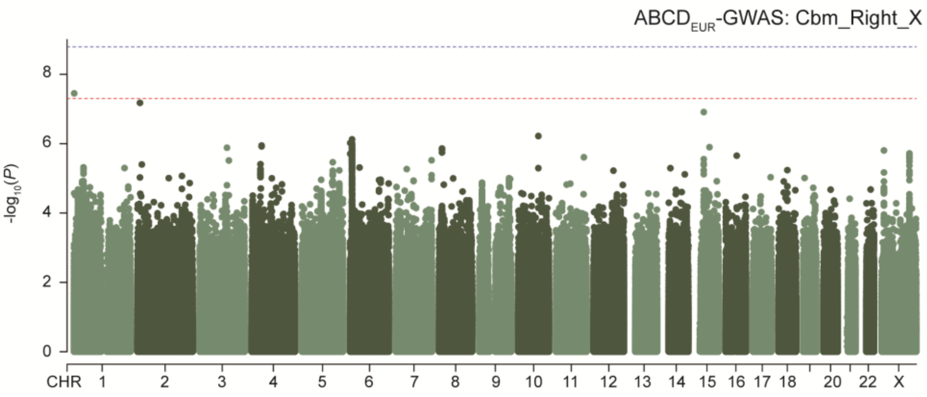
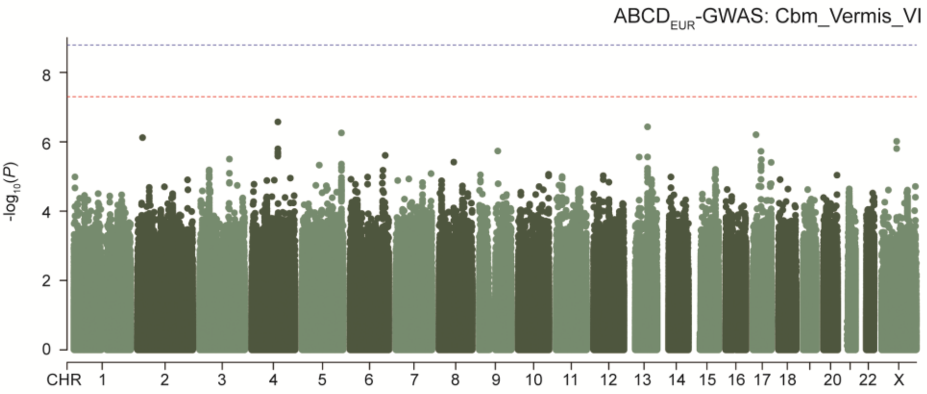
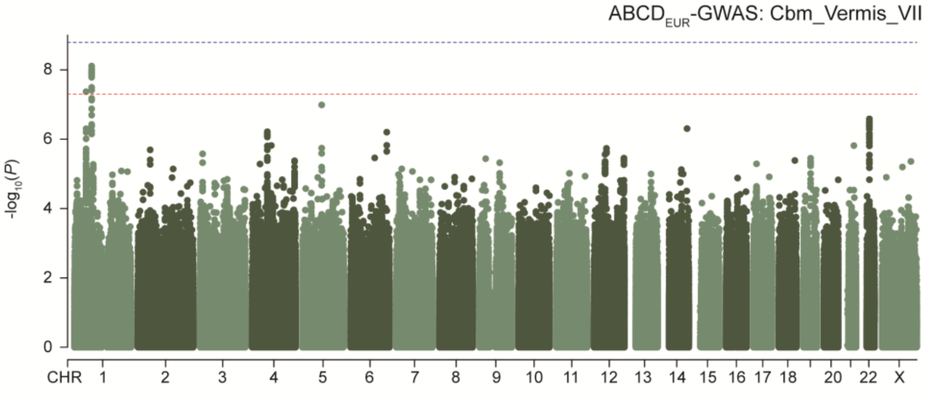
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X



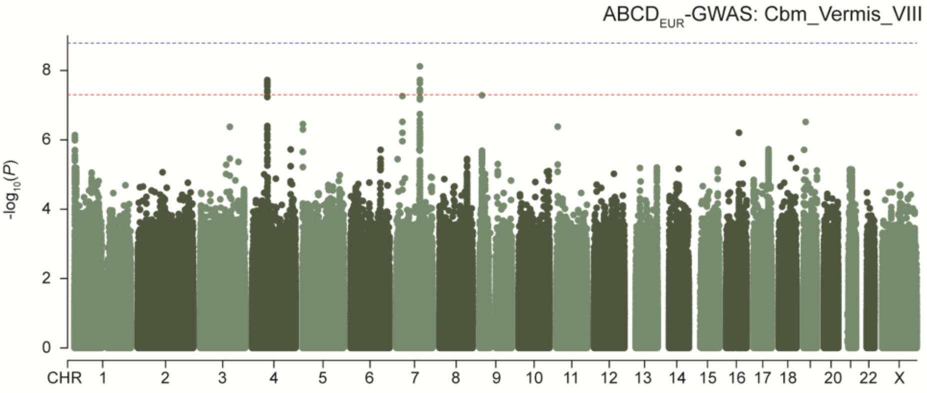
ABCD$_{EUR}$-GWAS: Cbm_Right_X



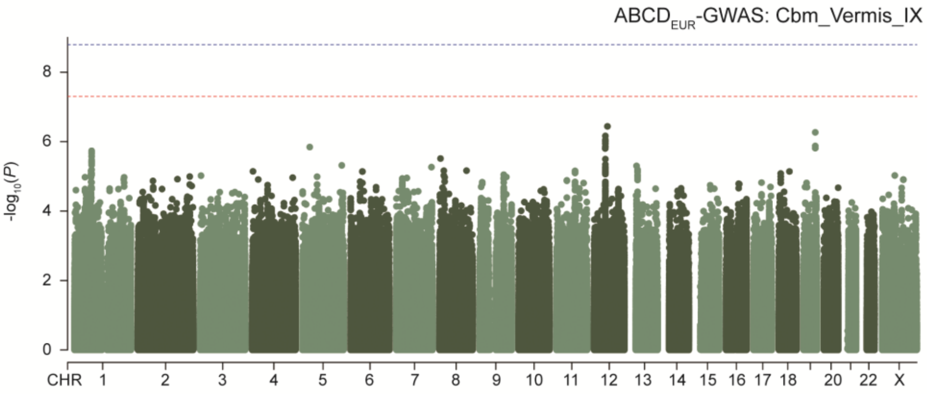
ABCD$_{EUR}$-GWAS: Cbm_Vermis_VI

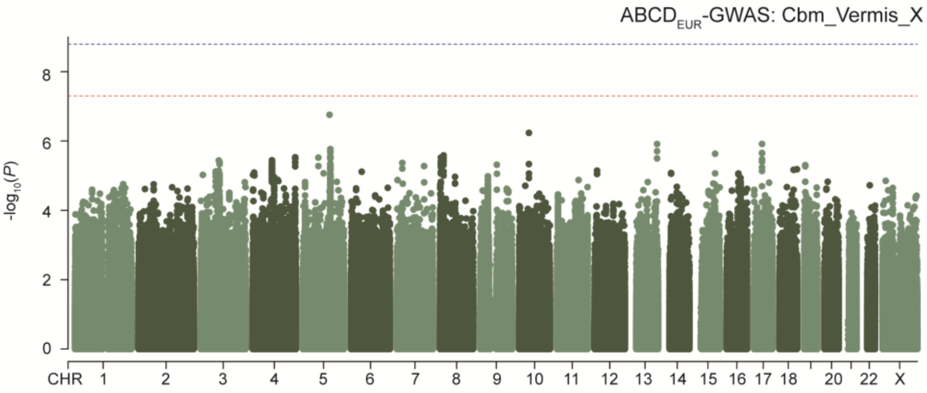


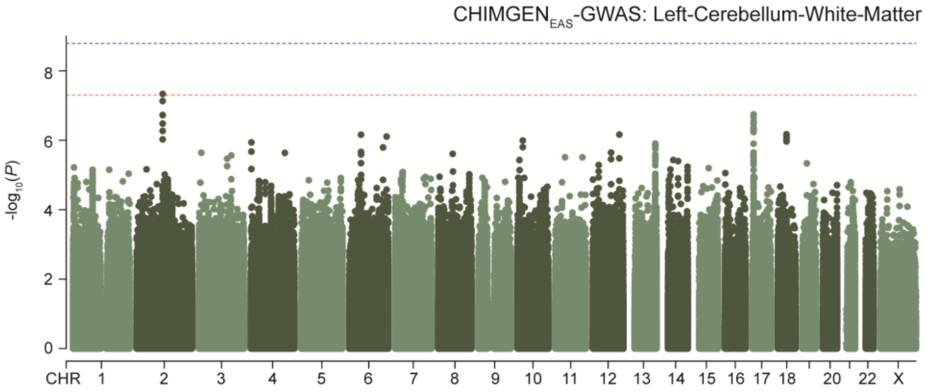
ABCD$_{EUR}$-GWAS: Cbm_Vermis_VII

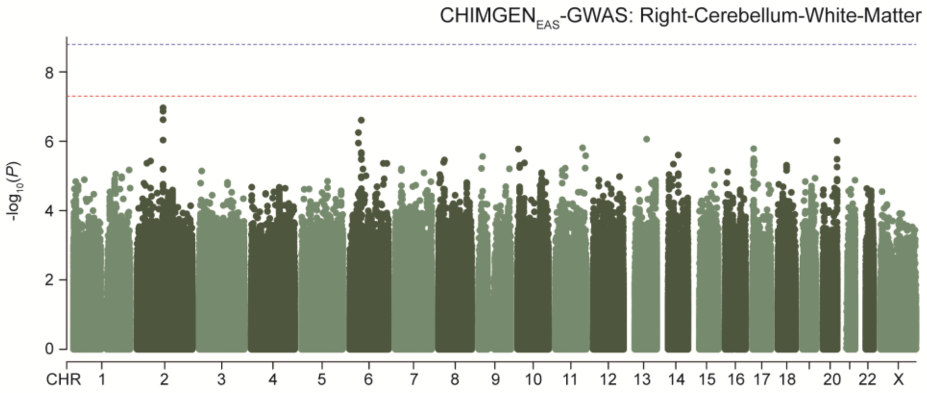


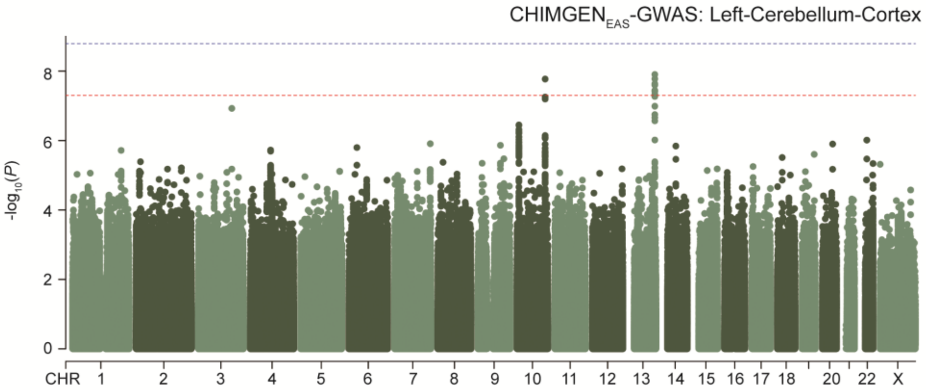
ABCD$_{EUR}$-GWAS: Cbm_Vermis_VIII


ABCD$_{EUR}$-GWAS: Cbm_Vermis_IX


ABCD$_{EUR}$-GWAS: Cbm_Vermis_X


CHIMGEN$_{EAS}$-GWAS: Left-Cerebellum-White-Matter


CHIMGEN$_{EAS}$-GWAS: Right-Cerebellum-White-Matter


CHIMGEN$_{EAS}$-GWAS: Left-Cerebellum-Cortex
-log$_{10}$(P)
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8
CHR
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22
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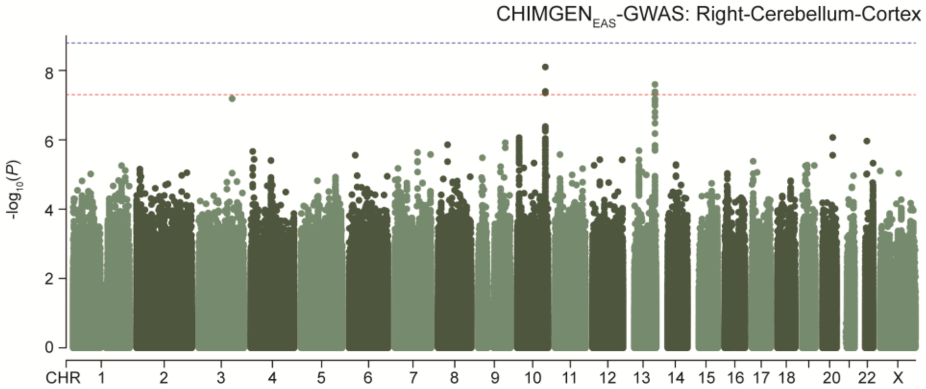
CHIMGEN$_{EAS}$-GWAS: Right-Cerebellum-Cortex
-log$_{10}$(P)
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4
6
8
CHR
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22
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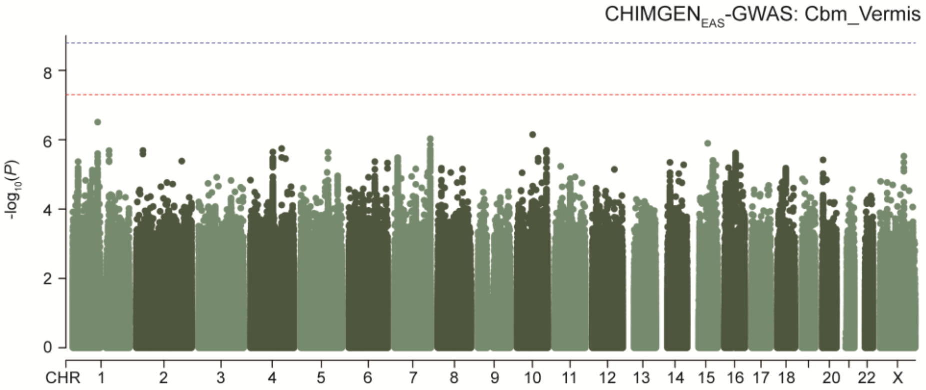
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis
-log$_{10}$(P)
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4
6
8
CHR
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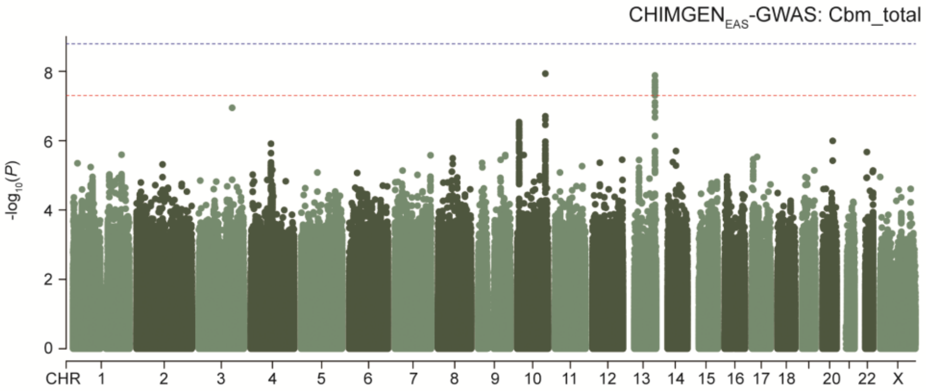
CHIMGEN$_{EAS}$-GWAS: Cbm_total
-log$_{10}$(P)
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6
8
CHR
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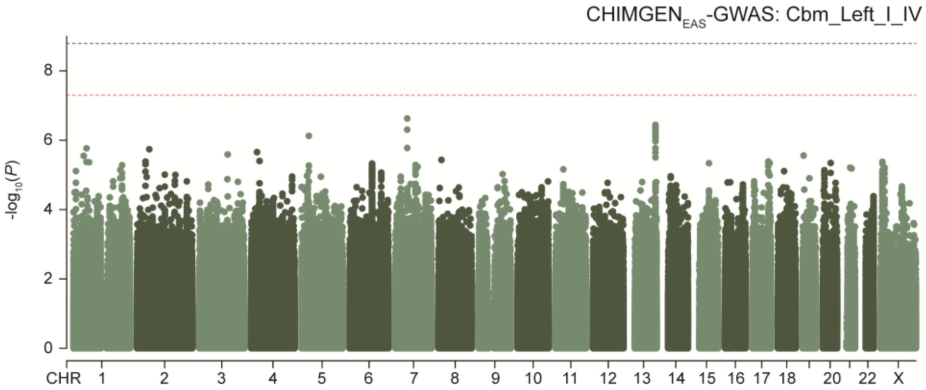
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_I_IV
-log$_{10}$(P)
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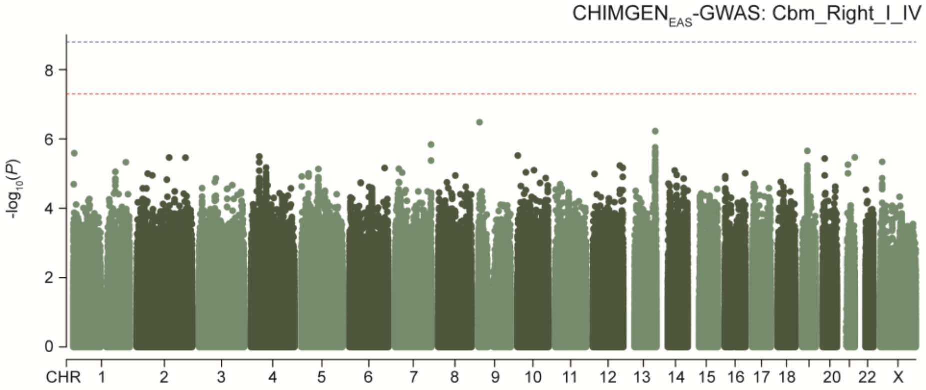
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_I_IV
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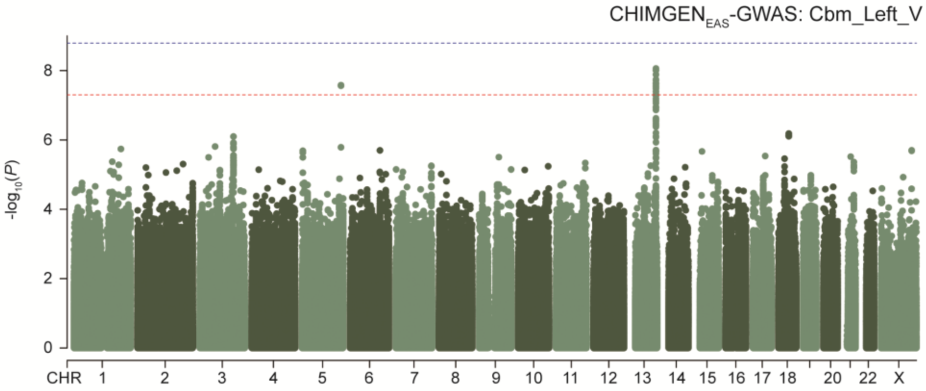
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_V
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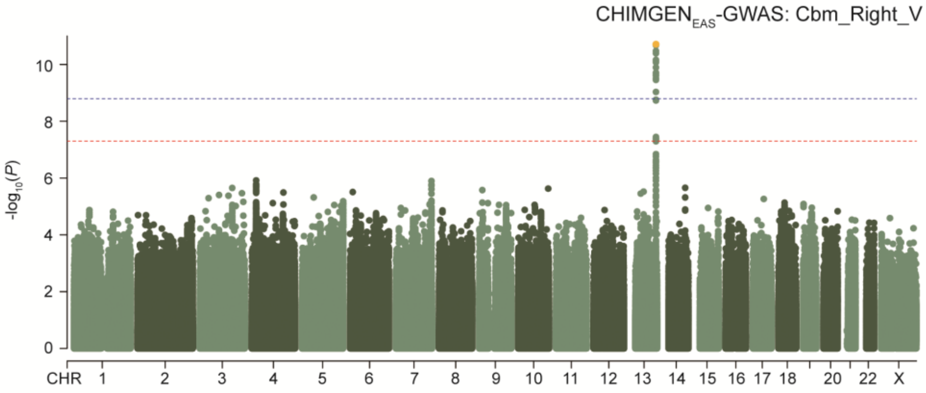
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_V
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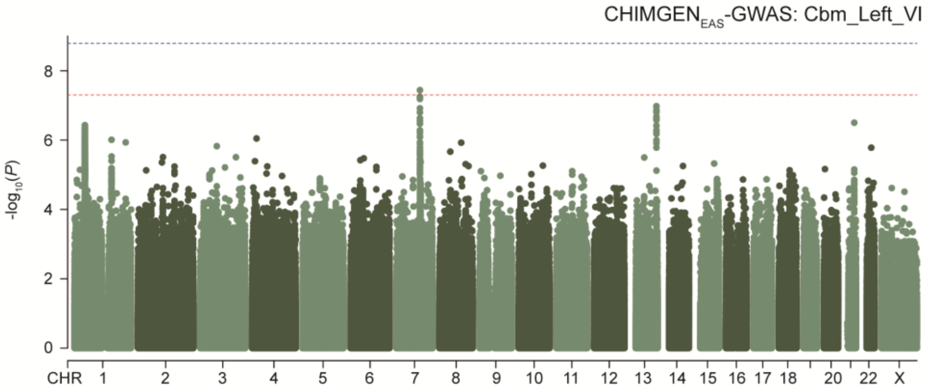
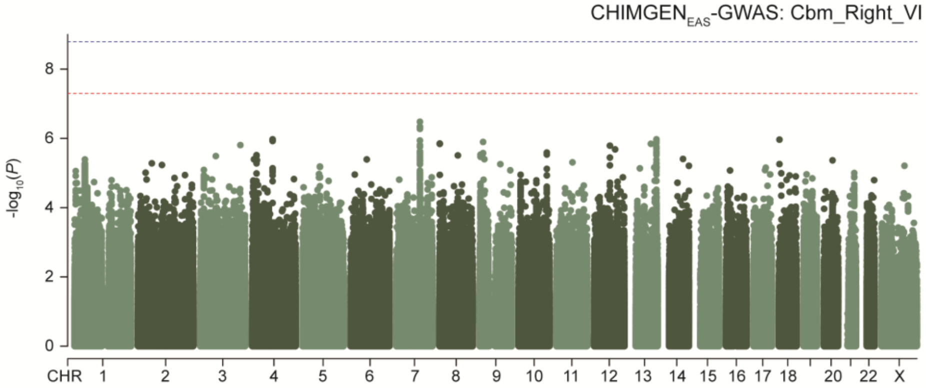
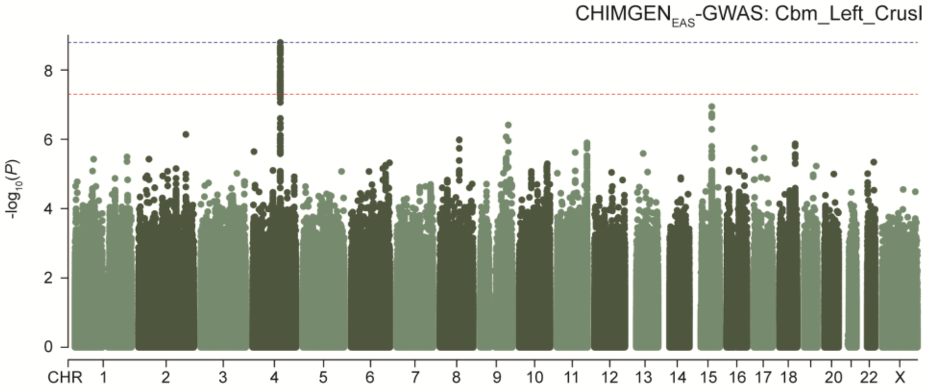
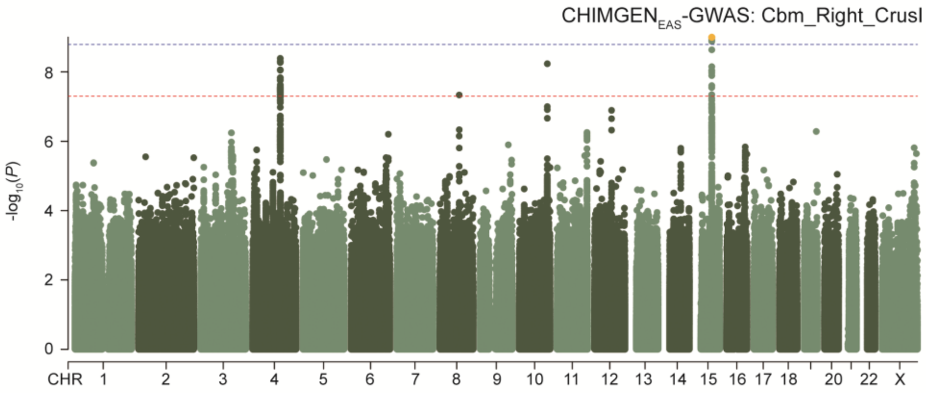
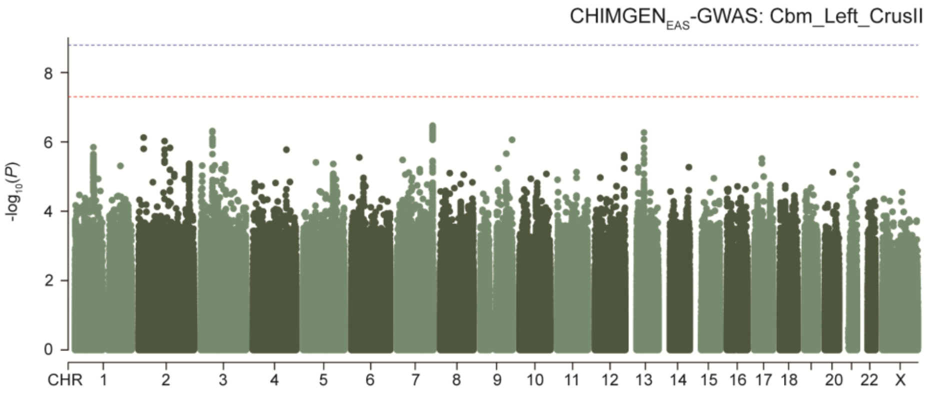

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VI

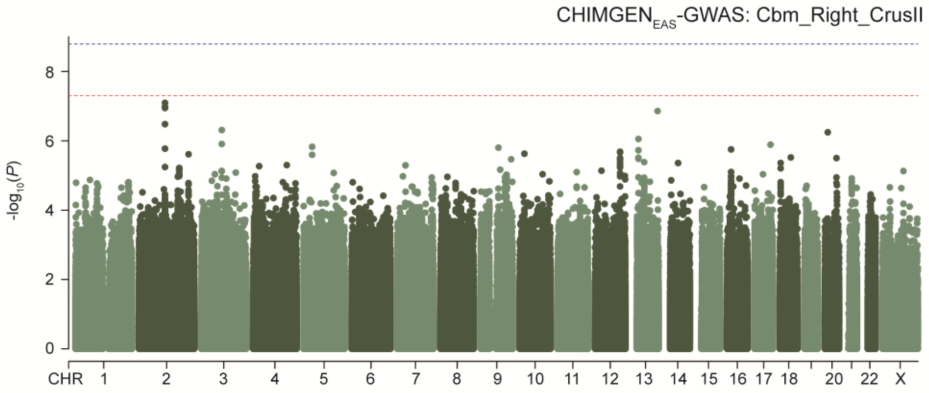

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VI


CHIMGEN$_{EAS}$-GWAS: Cbm_Left_CrusI

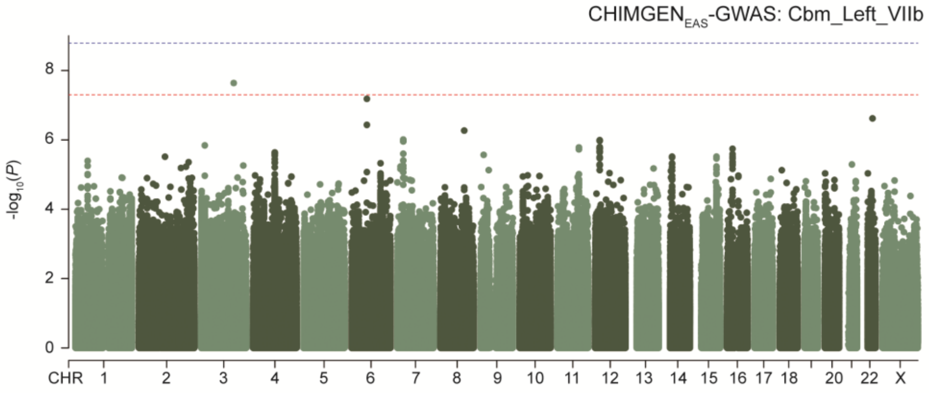

CHIMGEN$_{EAS}$-GWAS: Cbm_Right_CrusI



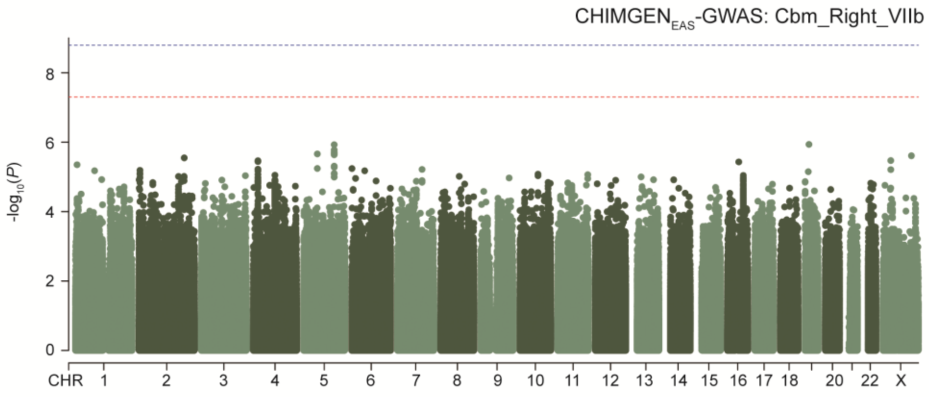
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_CrusII



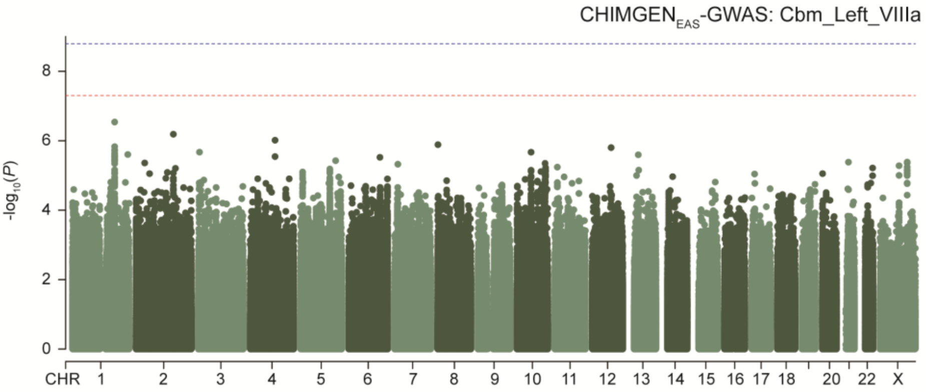
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_CrusII



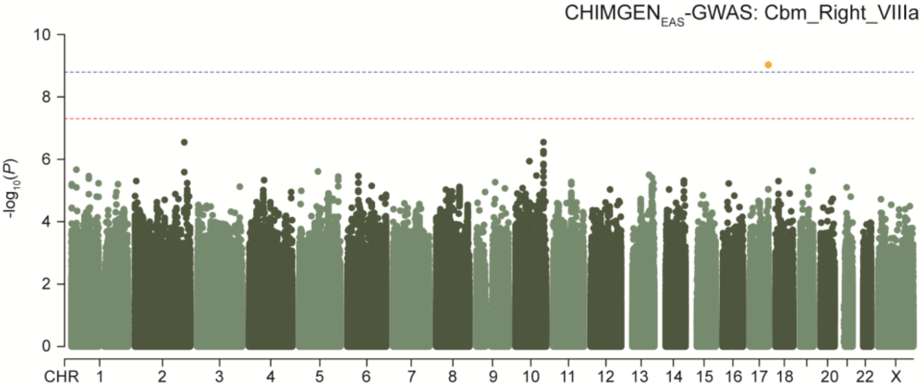
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIb



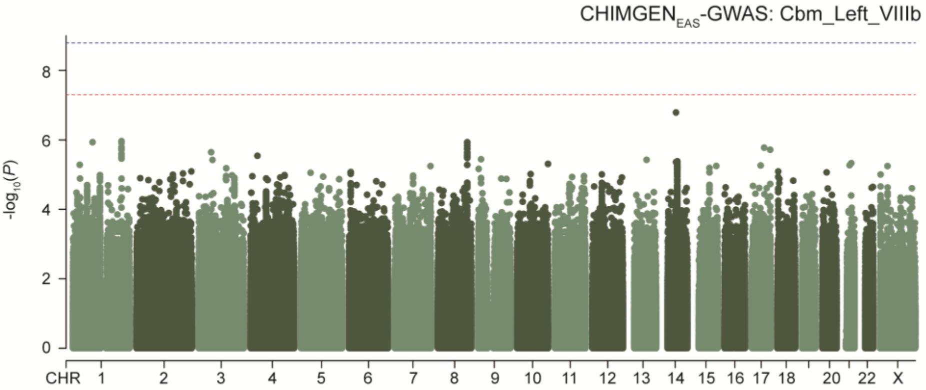
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIb



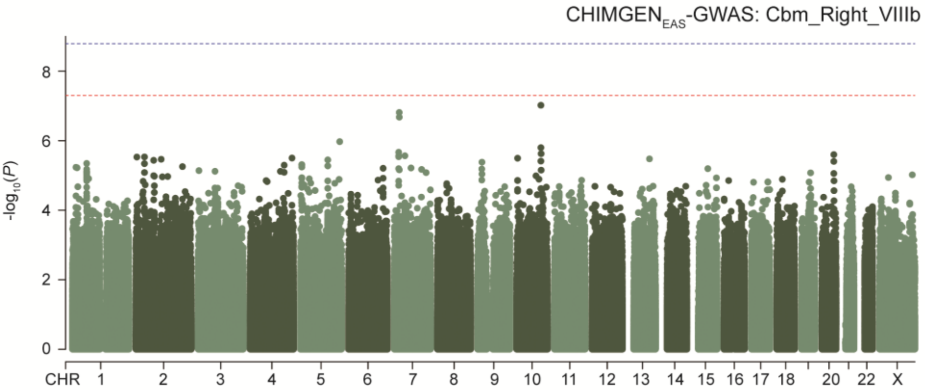
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIIa



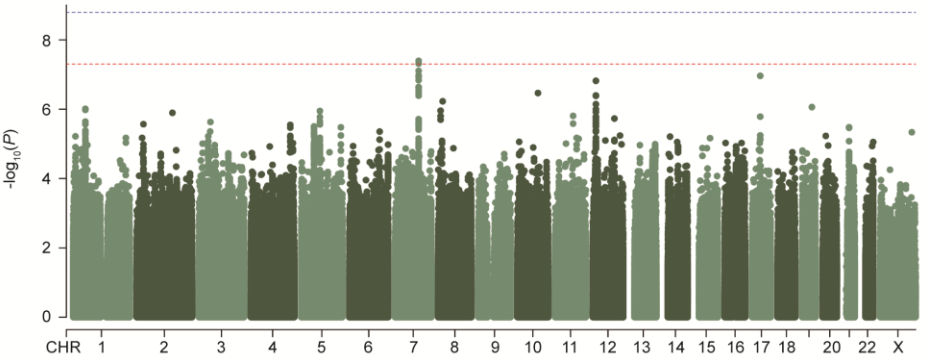
CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIIa

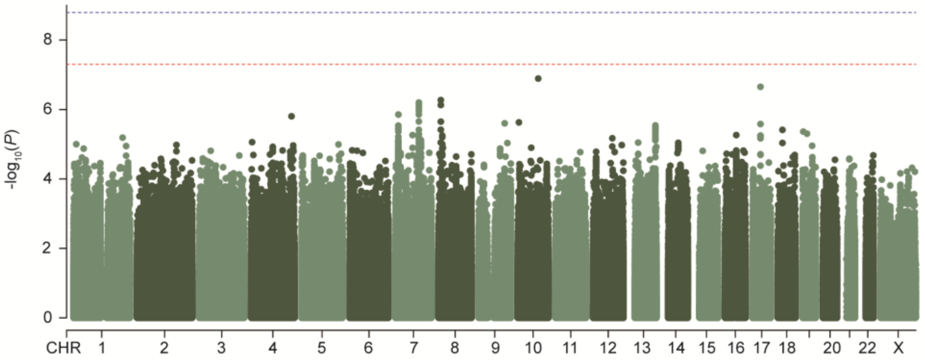


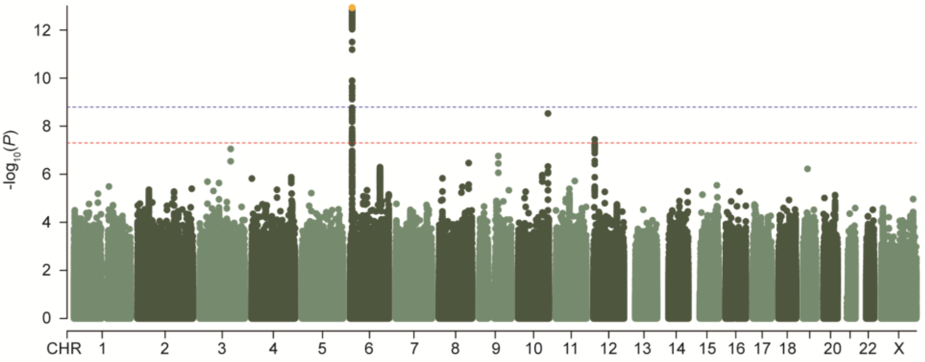
CHIMGEN$_{EAS}$-GWAS: Cbm_Left_VIIIb

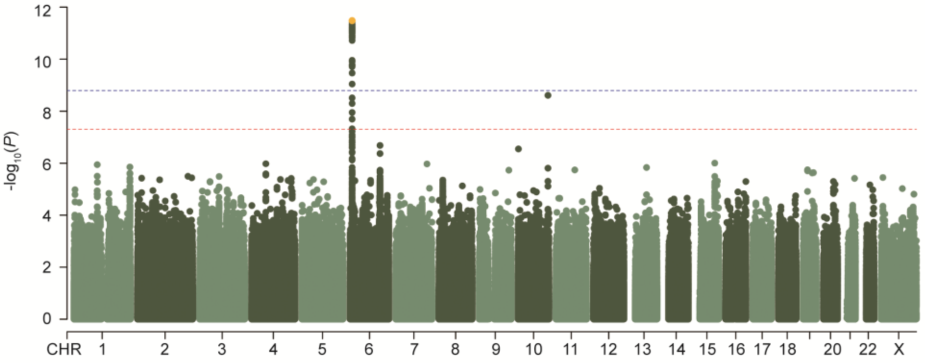


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_VIIIb

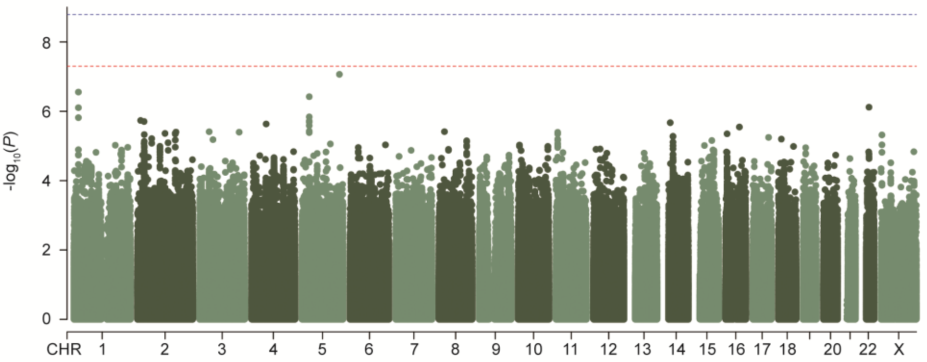

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_IX


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_IX

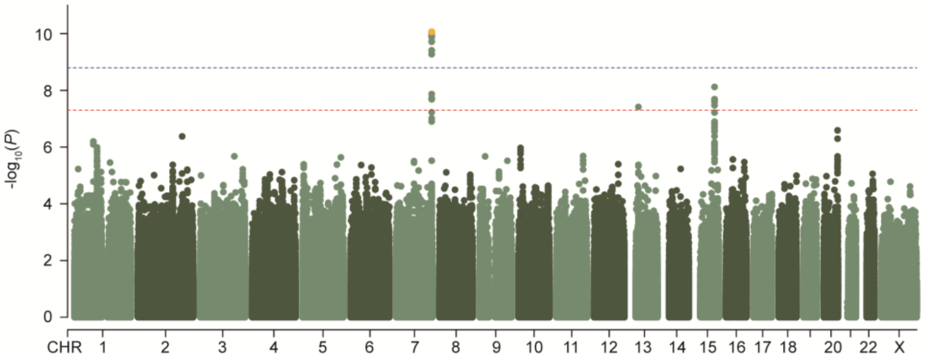

CHIMGEN$_{EAS}$-GWAS: Cbm_Left_X


CHIMGEN$_{EAS}$-GWAS: Cbm_Right_X

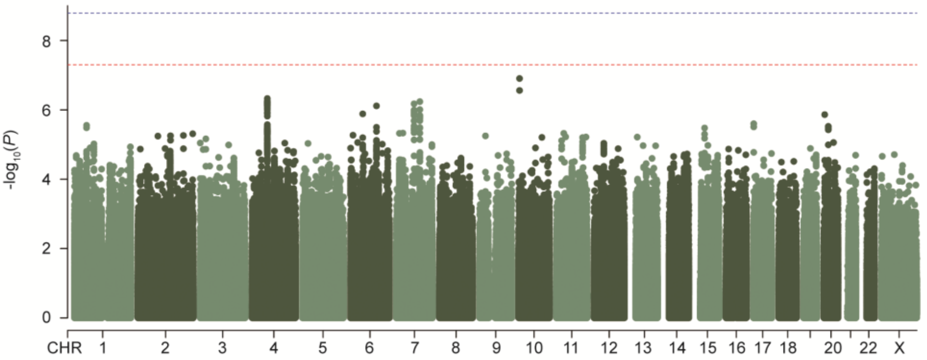
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VI



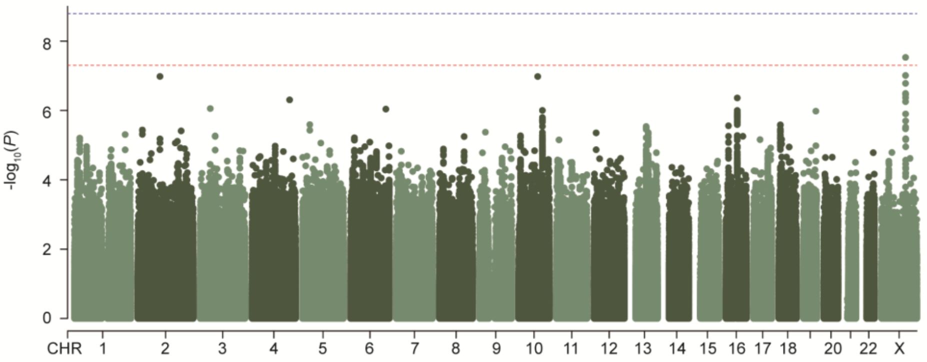
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VII

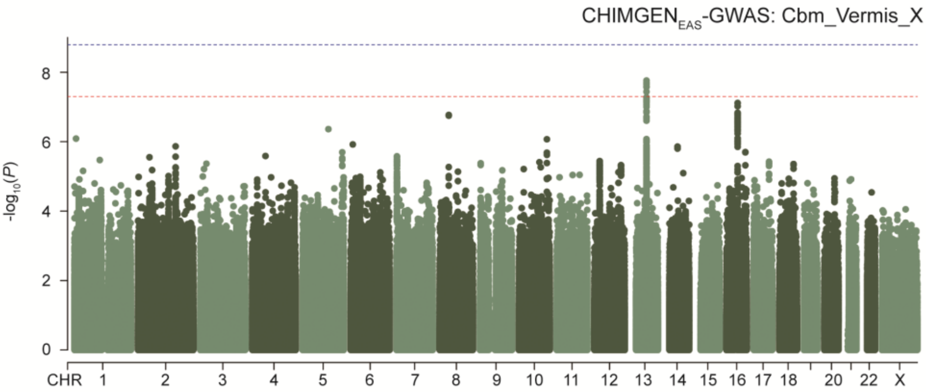


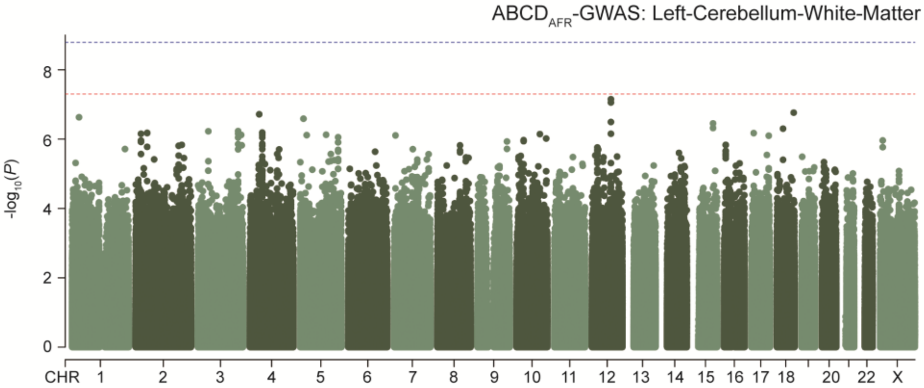
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_VIII

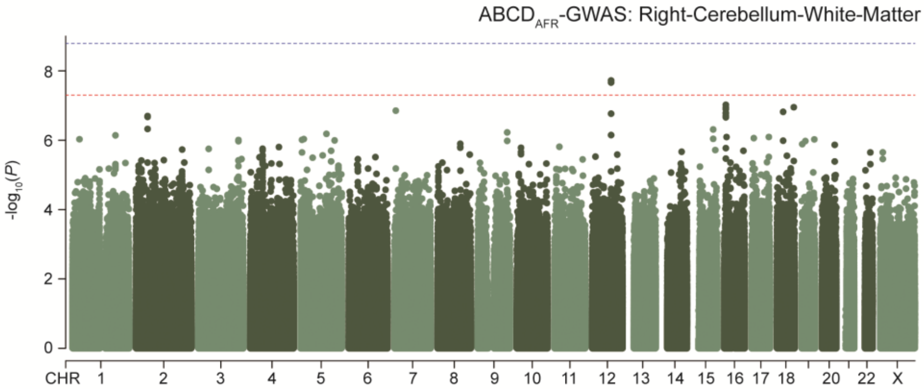


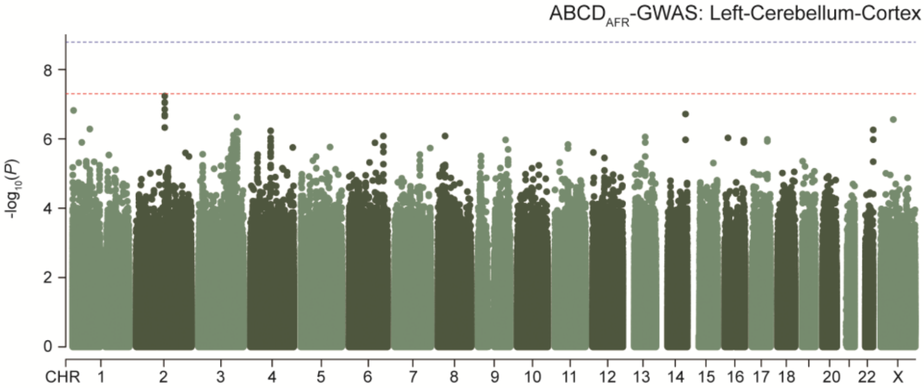
CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_IX

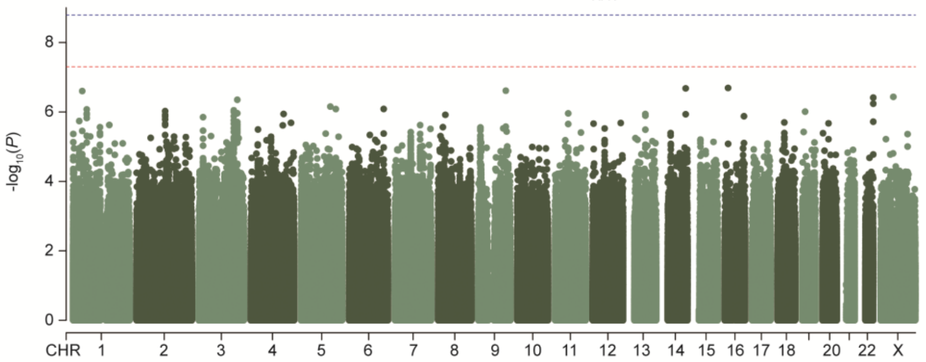



CHIMGEN$_{EAS}$-GWAS: Cbm_Vermis_X

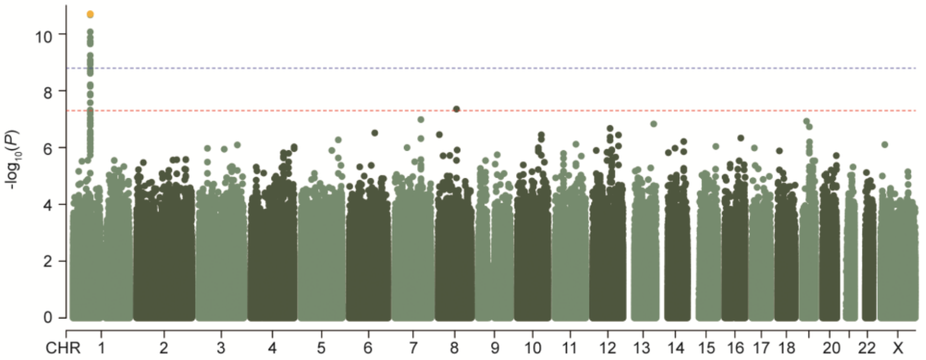

ABCD$_{AFR}$-GWAS: Left-Cerebellum-White-Matter


ABCD$_{AFR}$-GWAS: Right-Cerebellum-White-Matter

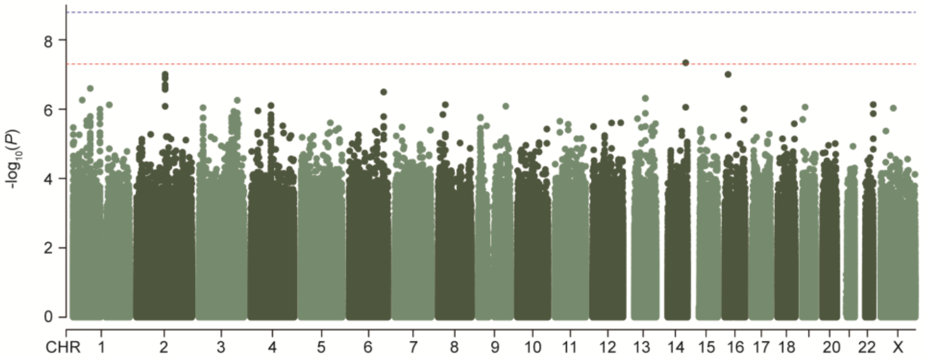

ABCD$_{AFR}$-GWAS: Left-Cerebellum-Cortex



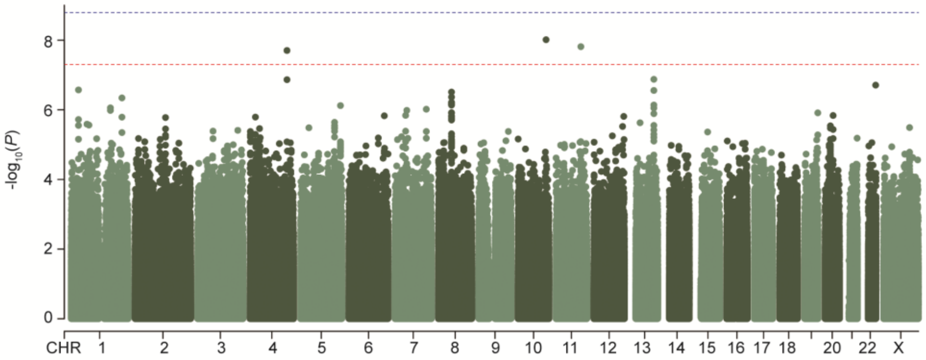
ABCD$_{AFR}$-GWAS: Right-Cerebellum-Cortex



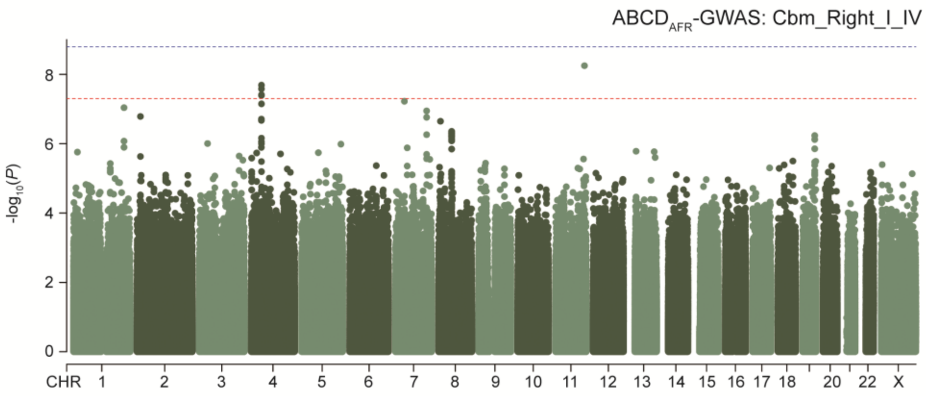
ABCD$_{AFR}$-GWAS: Cbm_Vermis



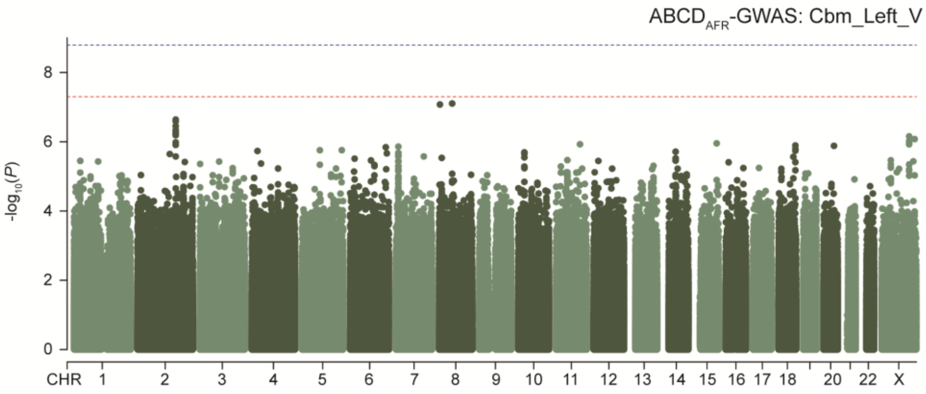
ABCD$_{AFR}$-GWAS: Cbm_total



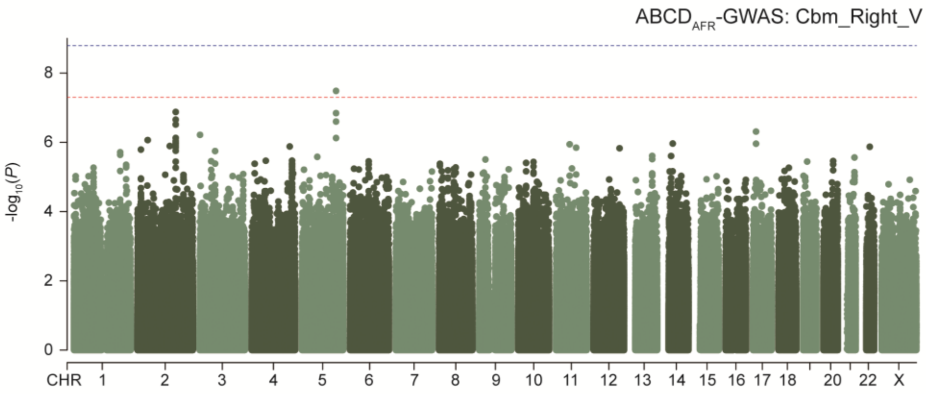
ABCD$_{AFR}$-GWAS: Cbm_Left_I_IV



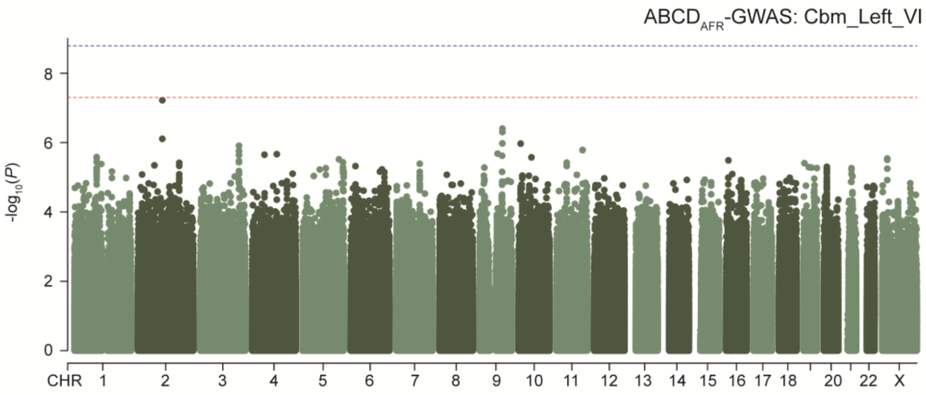
ABCD$_{AFR}$-GWAS: Cbm_Right_I_IV



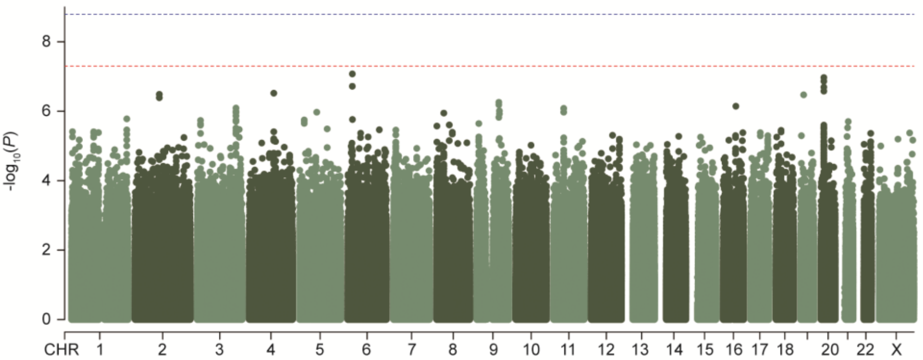
ABCD$_{AFR}$-GWAS: Cbm_Left_V

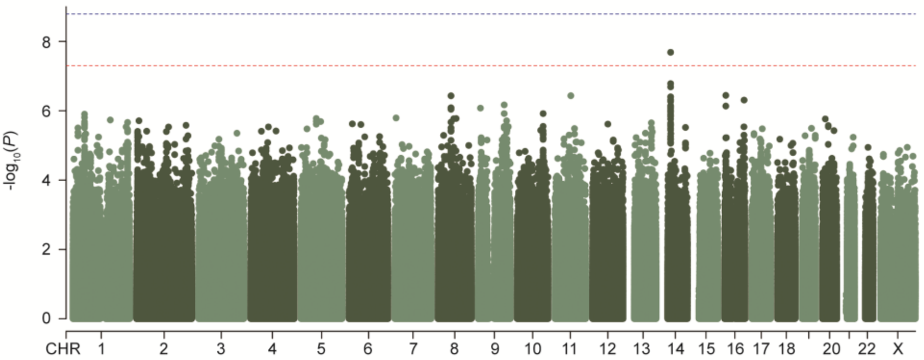


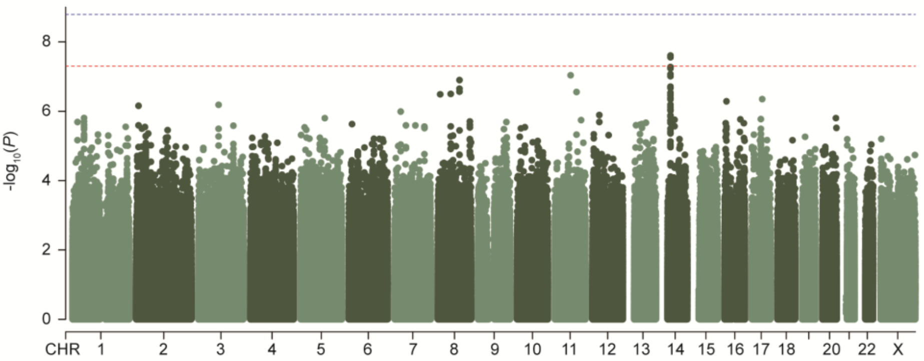
ABCD$_{AFR}$-GWAS: Cbm_Right_V

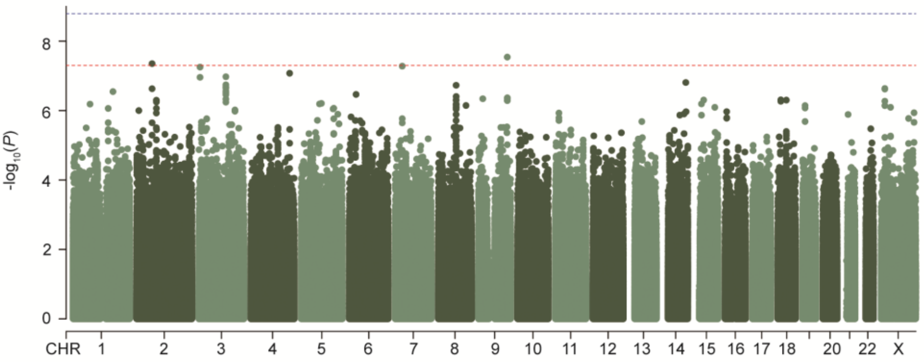


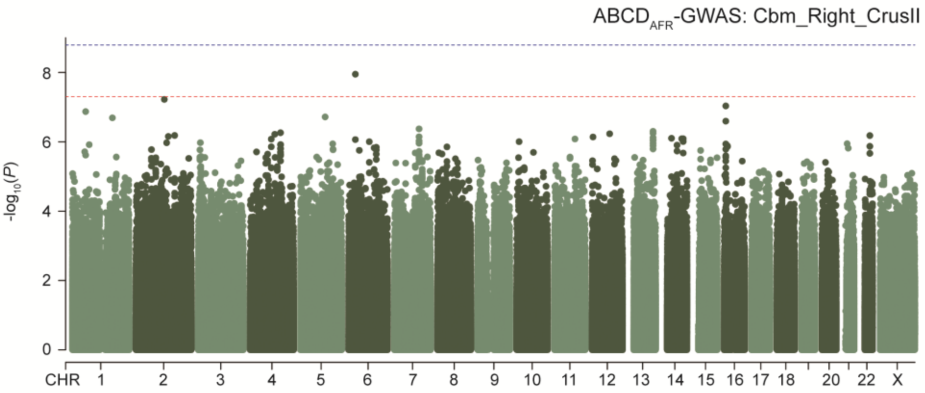
ABCD$_{AFR}$-GWAS: Cbm_Left_VI


ABCD$_{AFR}$-GWAS: Cbm_Right_VI

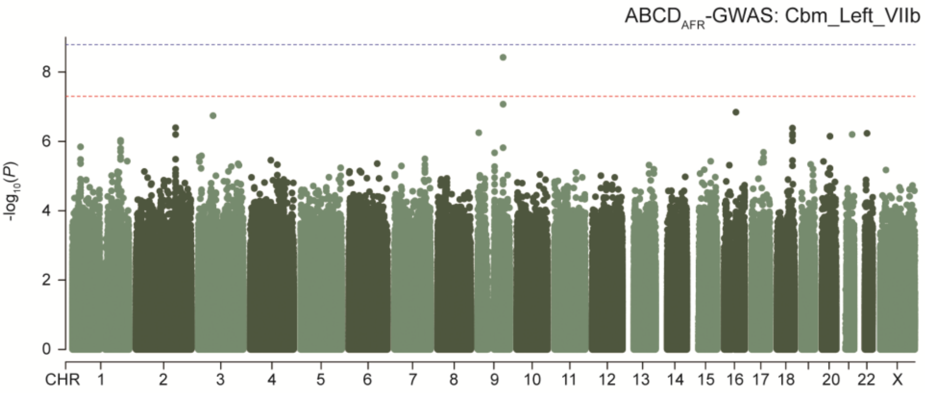

ABCD$_{AFR}$-GWAS: Cbm_Left_CrusI


ABCD$_{AFR}$-GWAS: Cbm_Right_CrusI

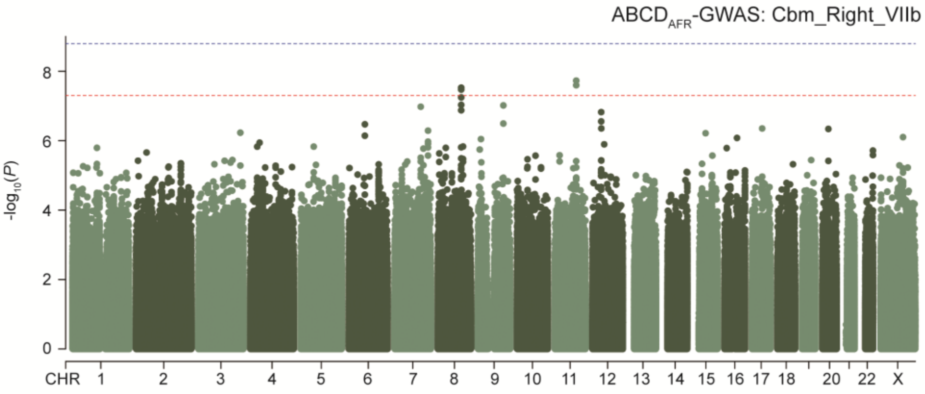

ABCD$_{AFR}$-GWAS: Cbm_Left_CrusII



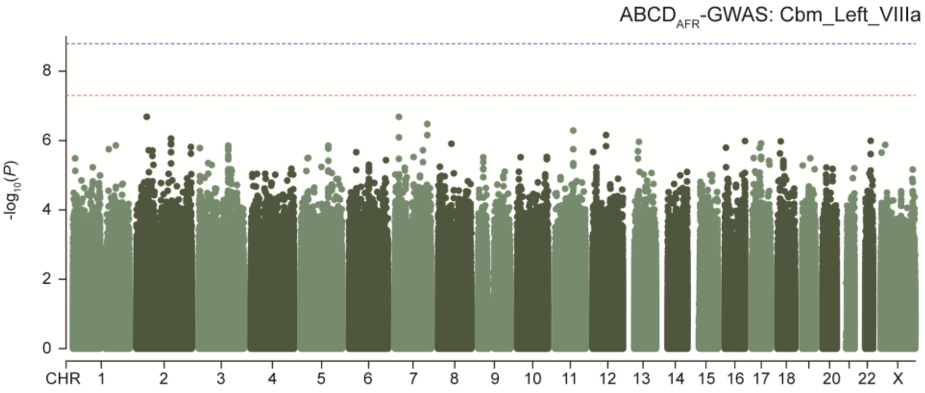
ABCD$_{AFR}$-GWAS: Cbm_Right_CrusII



ABCD$_{AFR}$-GWAS: Cbm_Left_VIIb

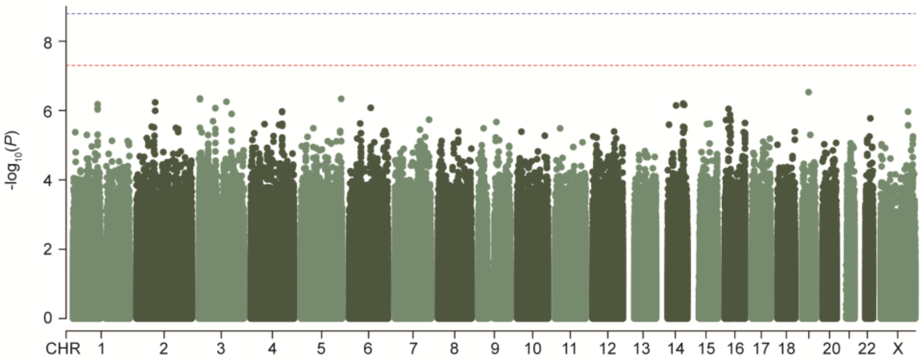


ABCD$_{AFR}$-GWAS: Cbm_Right_VIIb

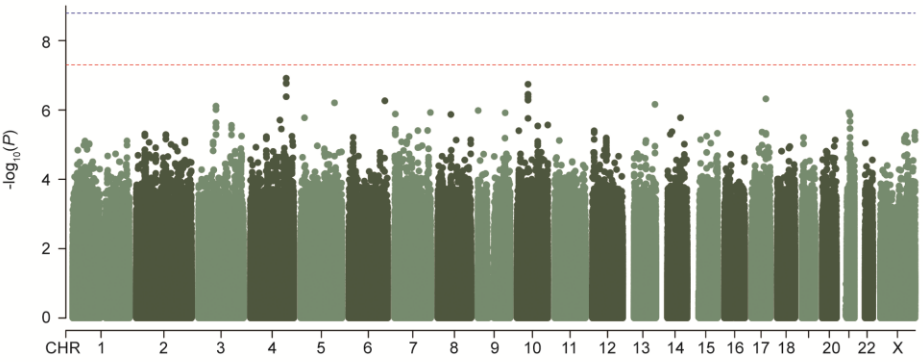


ABCD$_{AFR}$-GWAS: Cbm_Left_VIIIa

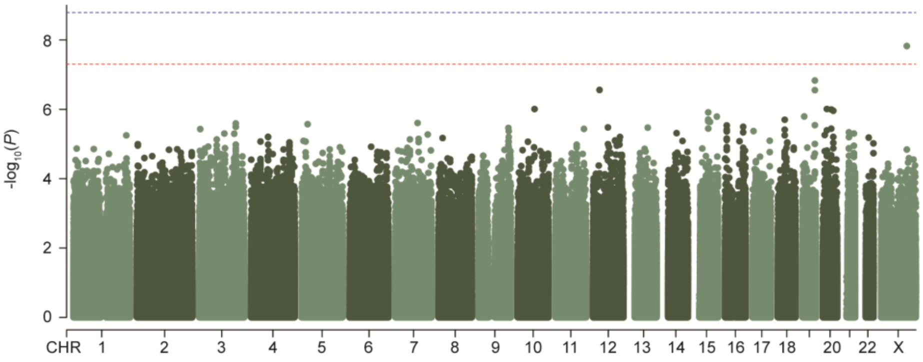
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIIa



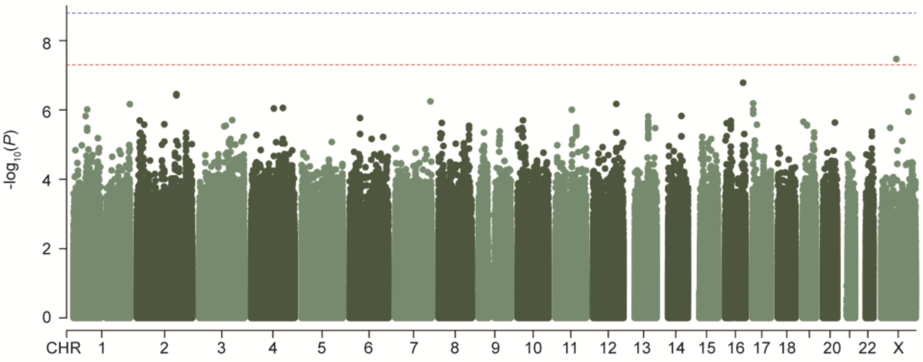
ABCD$_{AFR}$-GWAS: Cbm_Left_VIIIb

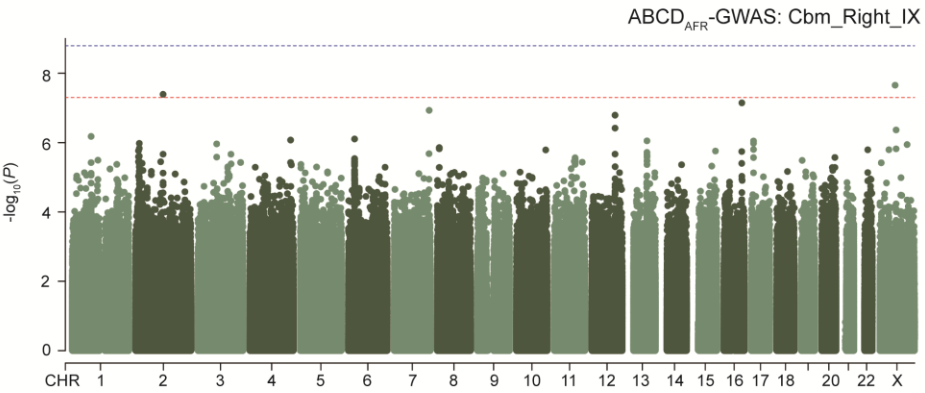


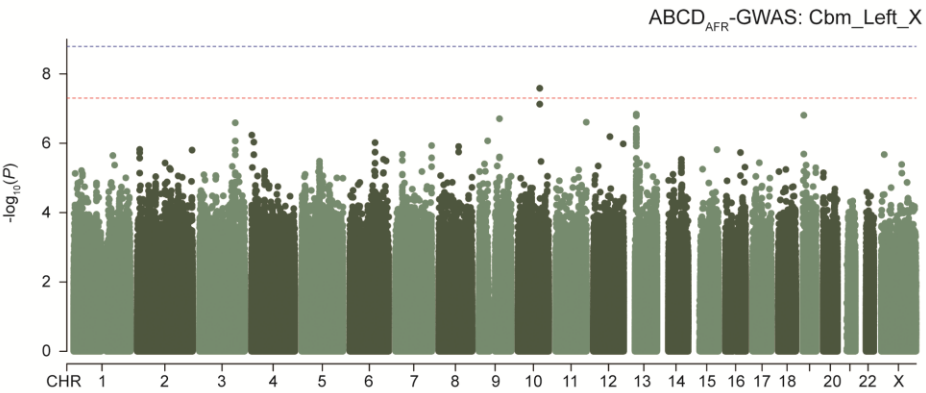
ABCD$_{AFR}$-GWAS: Cbm_Right_VIIIb

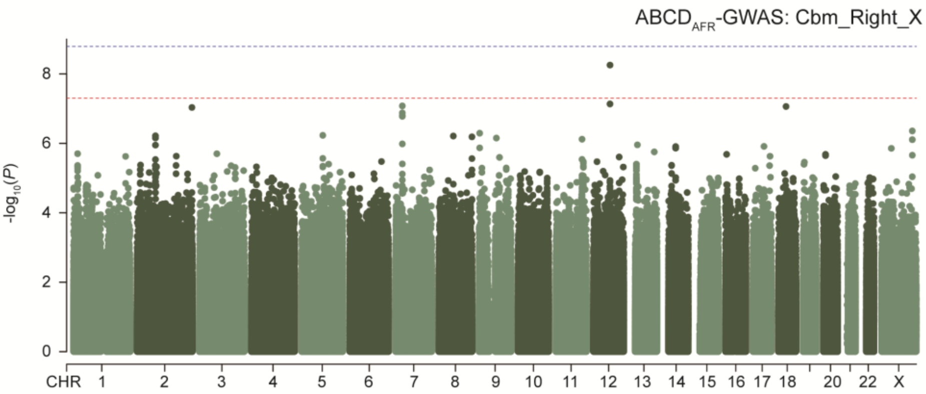


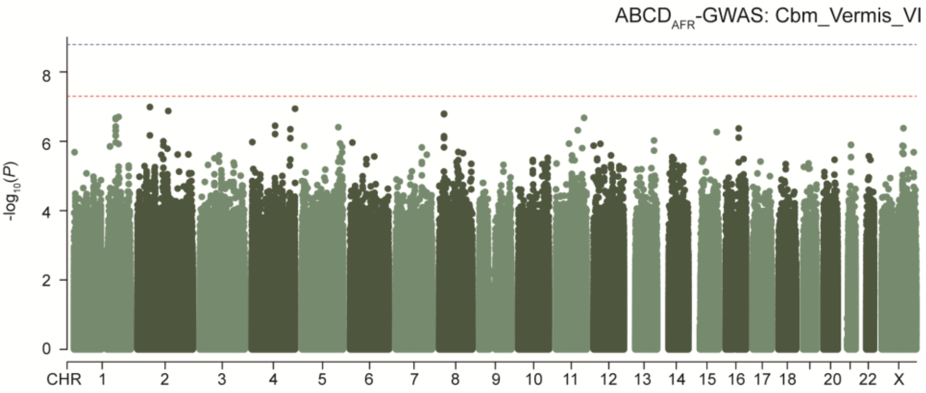
ABCD$_{AFR}$-GWAS: Cbm_Left_IX

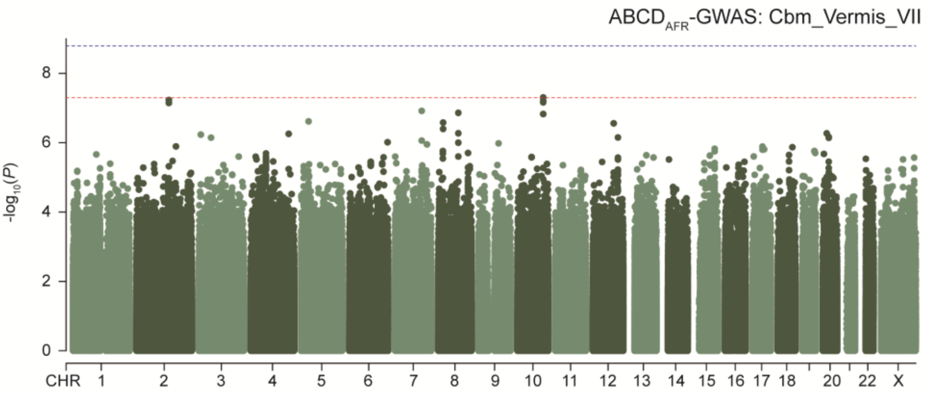


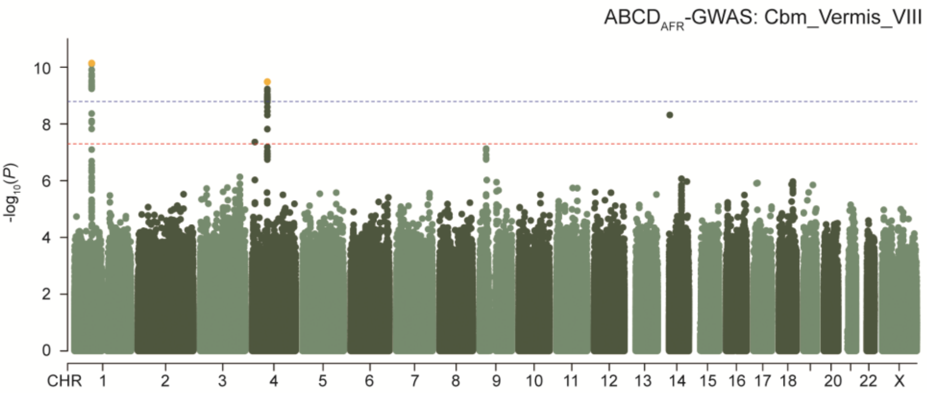

ABCD$_{AFR}$-GWAS: Cbm_Right_IX

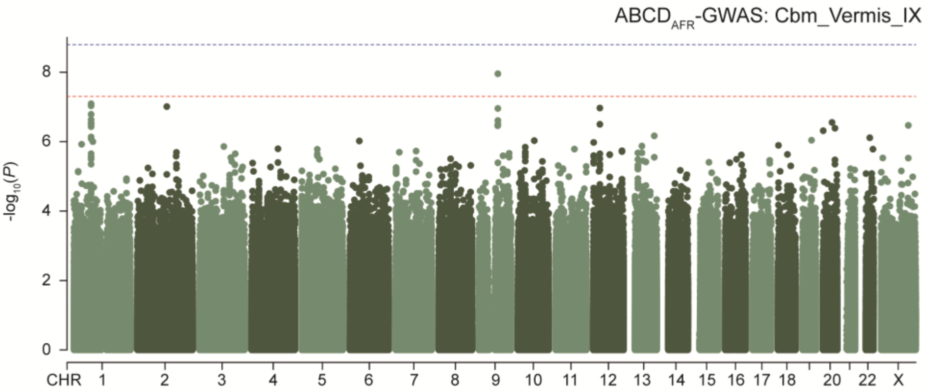

ABCD$_{AFR}$-GWAS: Cbm_Left_X

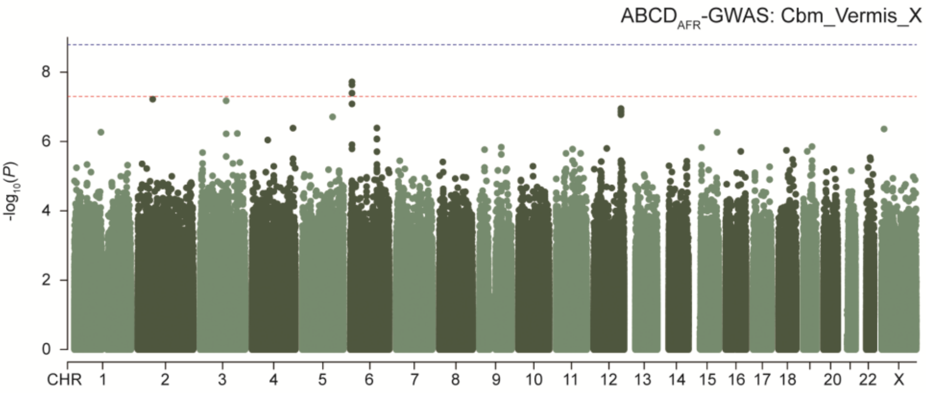

ABCD$_{AFR}$-GWAS: Cbm_Right_X


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VI

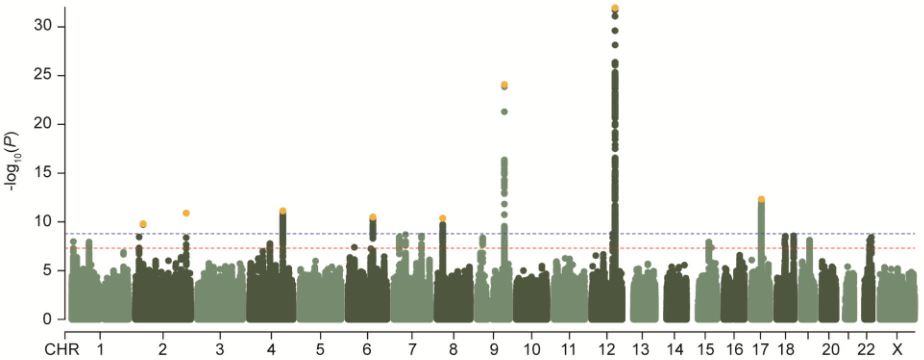

ABCD$_{AFR}$-GWAS: Cbm_Vermis_VII


ABCD$_{AFR}$-GWAS: Cbm_Vermis_VIII

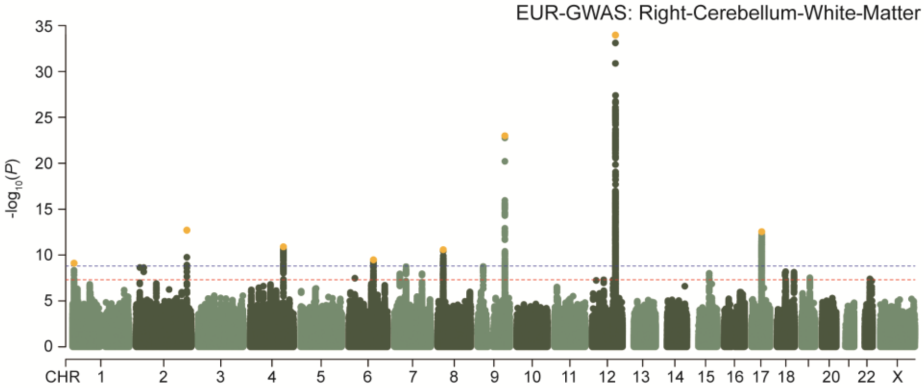

ABCD$_{AFR}$-GWAS: Cbm_Vermis_IX


ABCD$_{AFR}$-GWAS: Cbm_Vermis_X

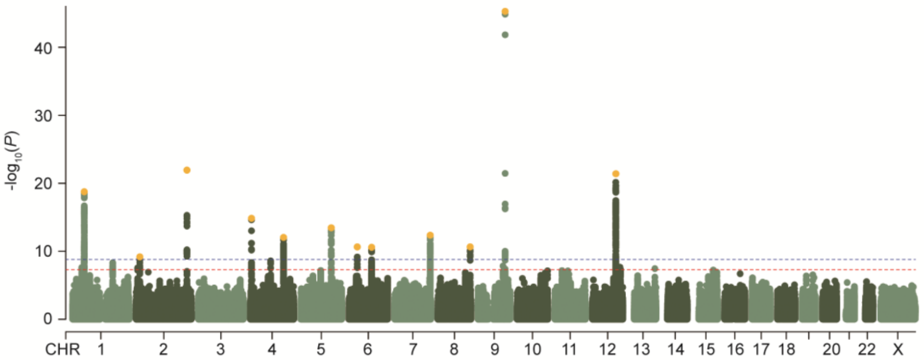
EUR-GWAS: Left-Cerebellum-White-Matter



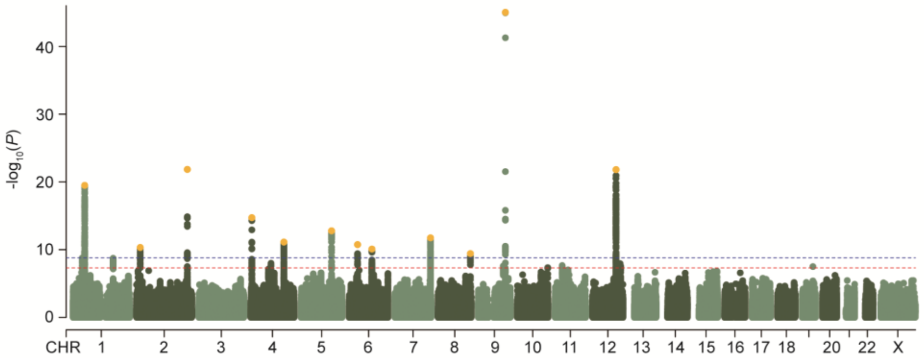
EUR-GWAS: Right-Cerebellum-White-Matter

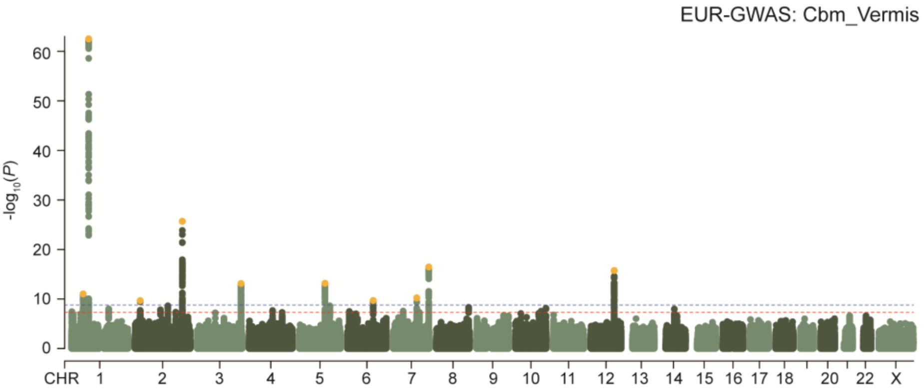


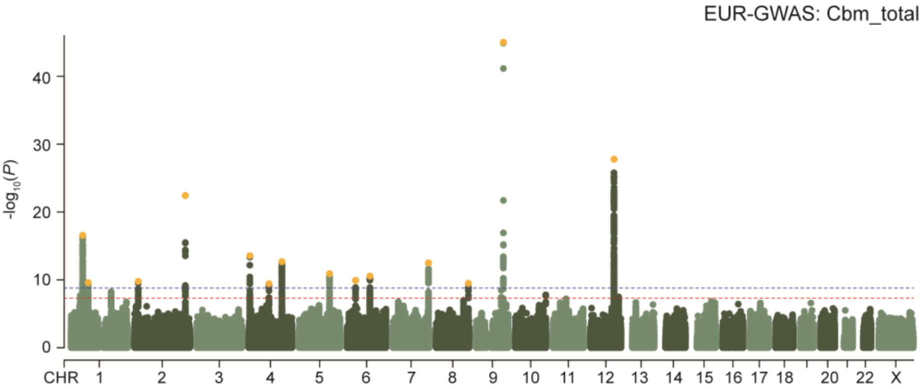
EUR-GWAS: Left-Cerebellum-Cortex

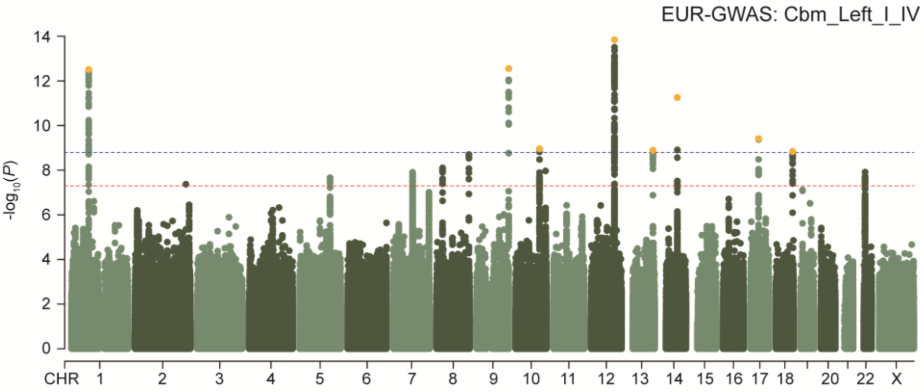


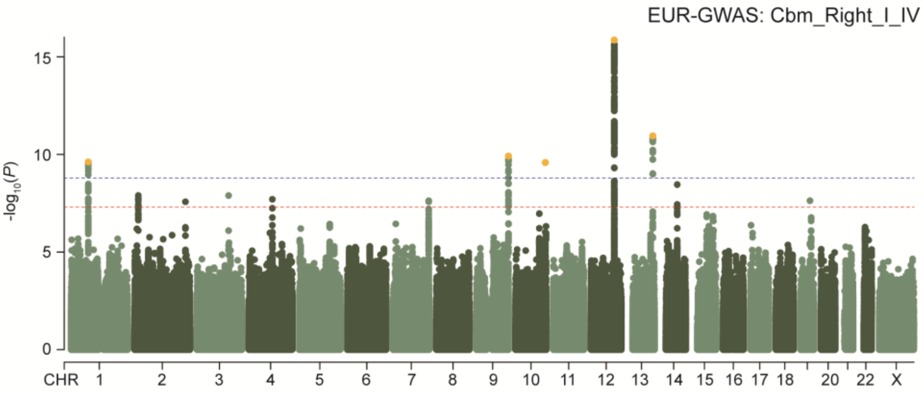
EUR-GWAS: Right-Cerebellum-Cortex



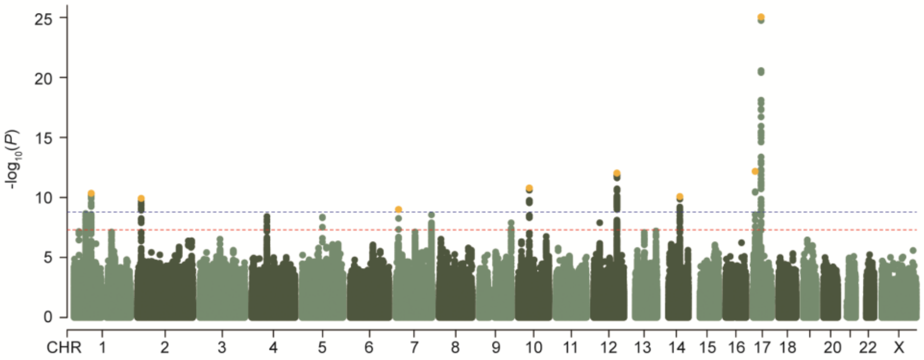

EUR-GWAS: Cbm_Vermis


EUR-GWAS: Cbm_total

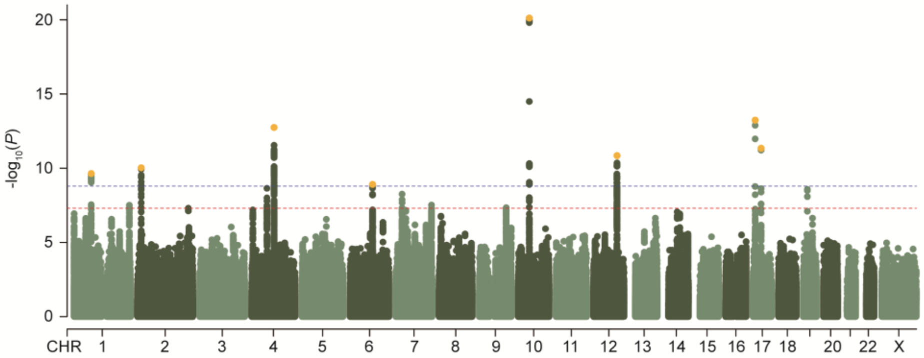

EUR-GWAS: Cbm_Left_I_IV


EUR-GWAS: Cbm_Right_I_IV

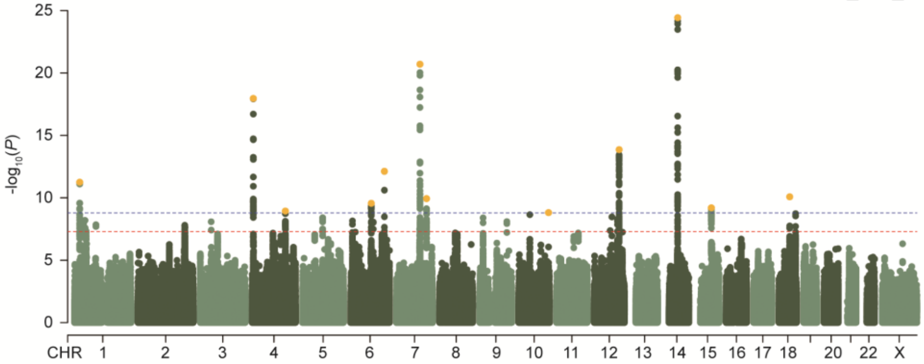
EUR-GWAS: Cbm_Left_V



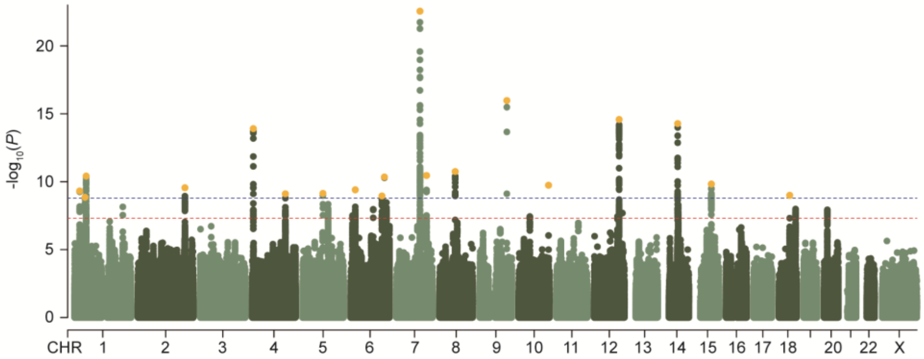
EUR-GWAS: Cbm_Right_V

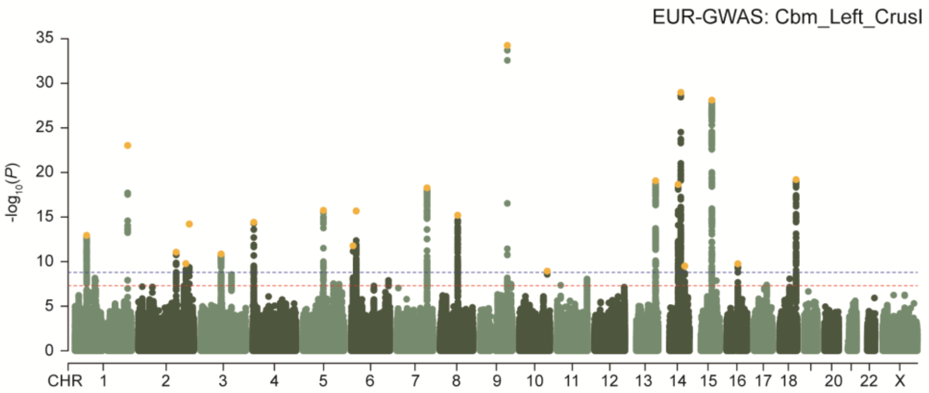


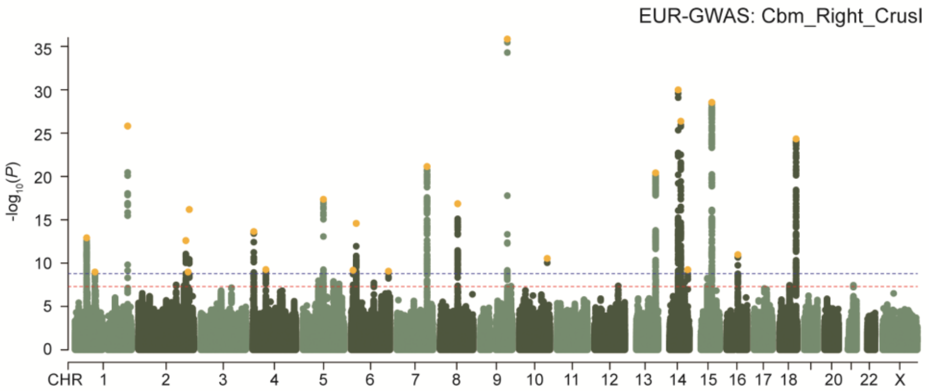
EUR-GWAS: Cbm_Left_VI

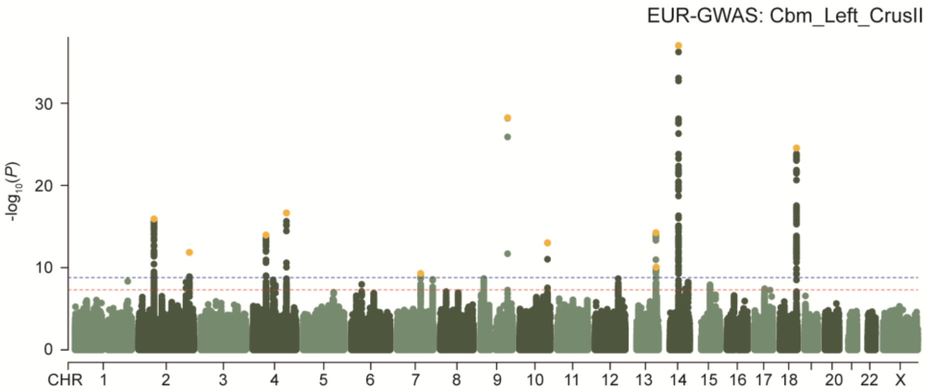


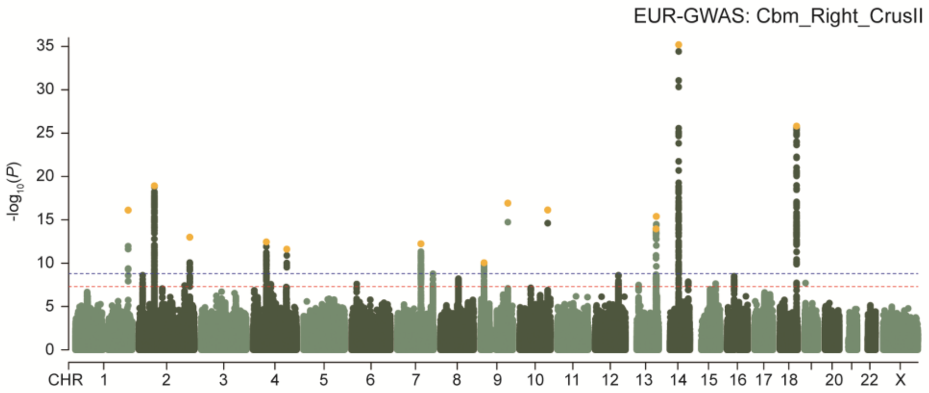
EUR-GWAS: Cbm_Right_VI

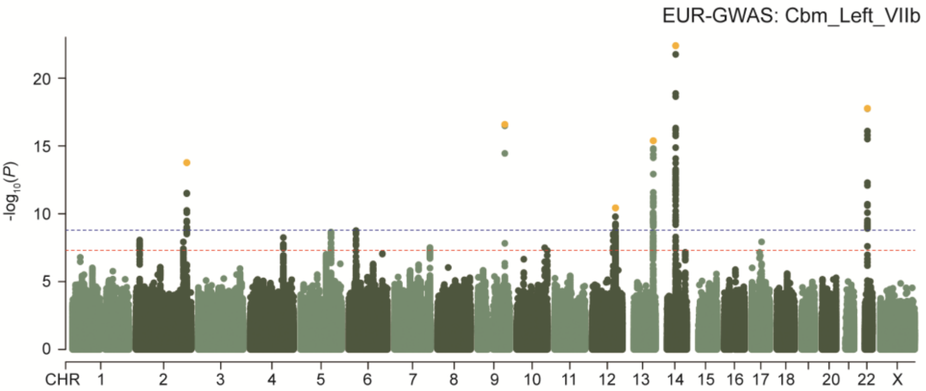



EUR-GWAS: Cbm_Left_CrusI

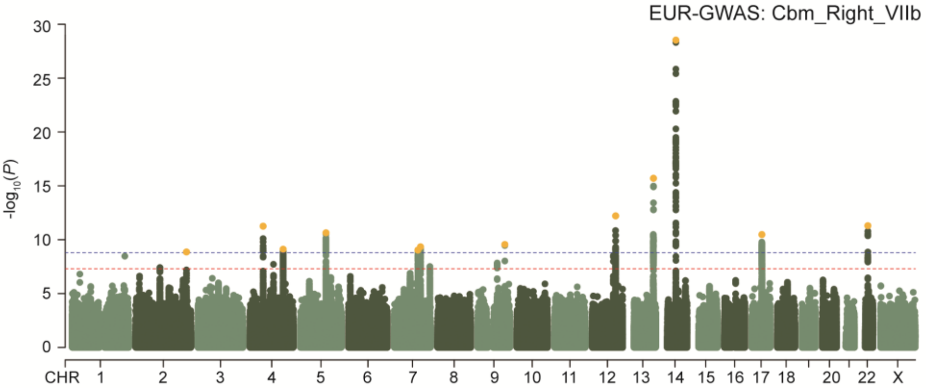

EUR-GWAS: Cbm_Right_CrusI


EUR-GWAS: Cbm_Left_CrusII

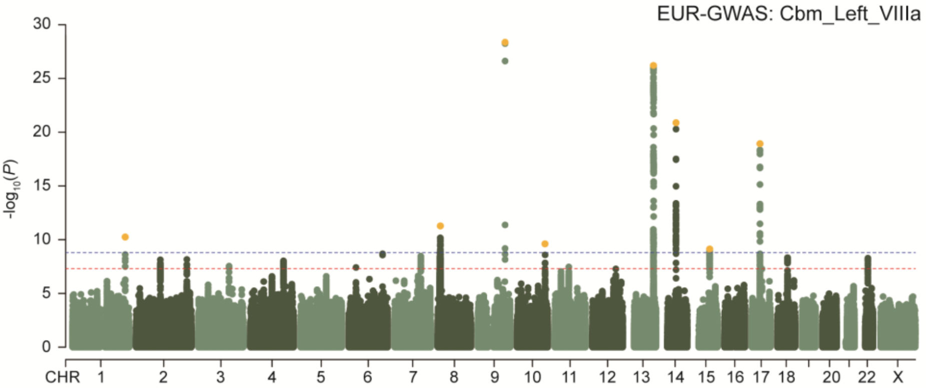

EUR-GWAS: Cbm_Right_CrusII



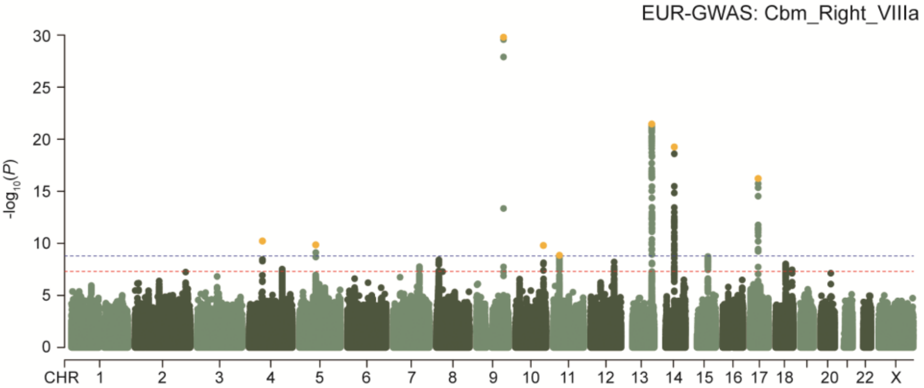
EUR-GWAS: Cbm_Left_VIIb



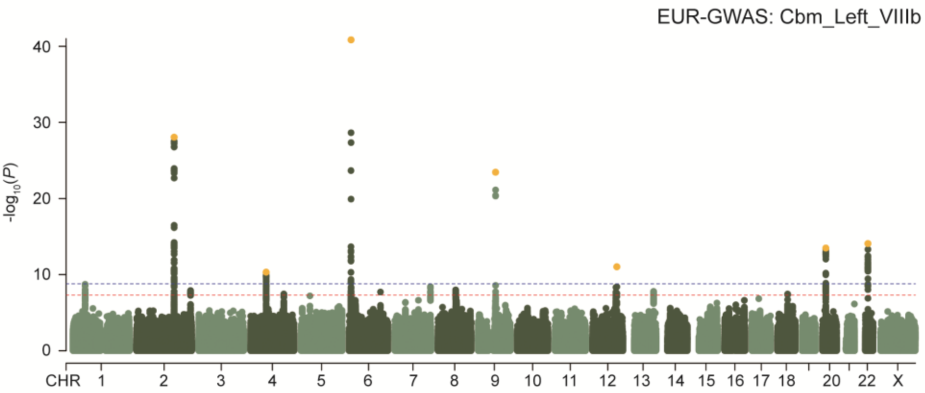
EUR-GWAS: Cbm_Right_VIIb



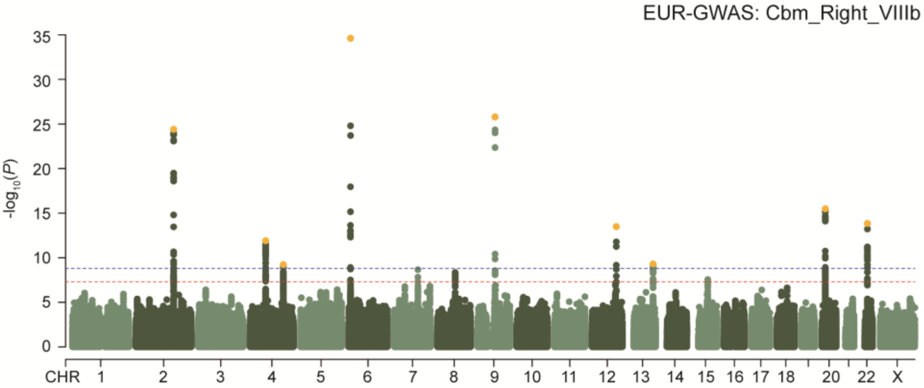
EUR-GWAS: Cbm_Left_VIIIa



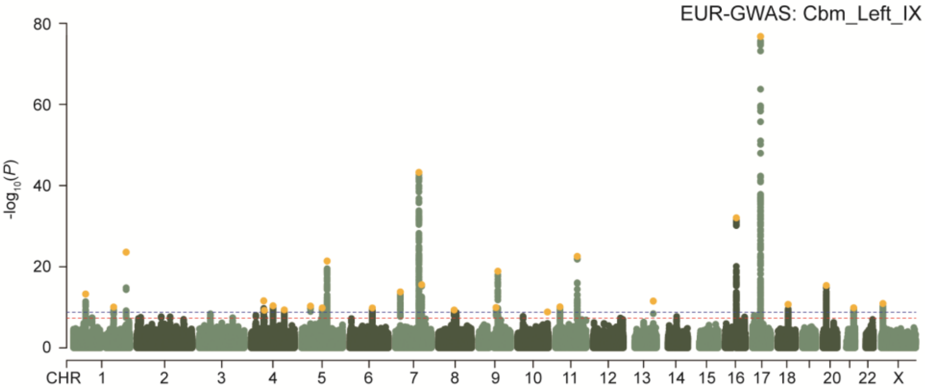
EUR-GWAS: Cbm_Right_VIIIa



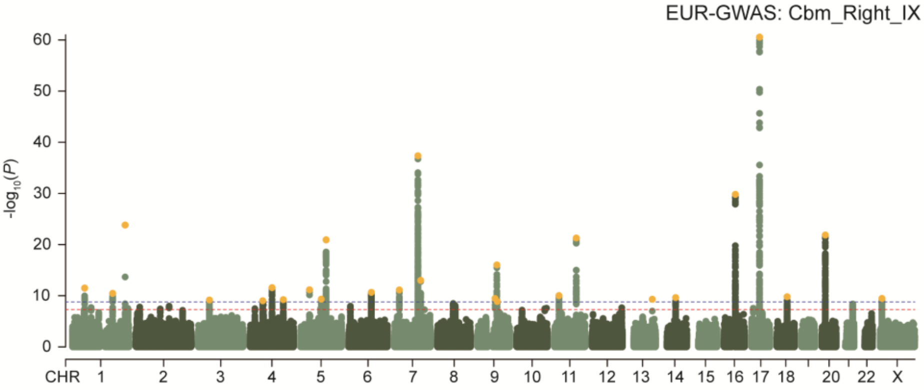
EUR-GWAS: Cbm_Left_VIIIb



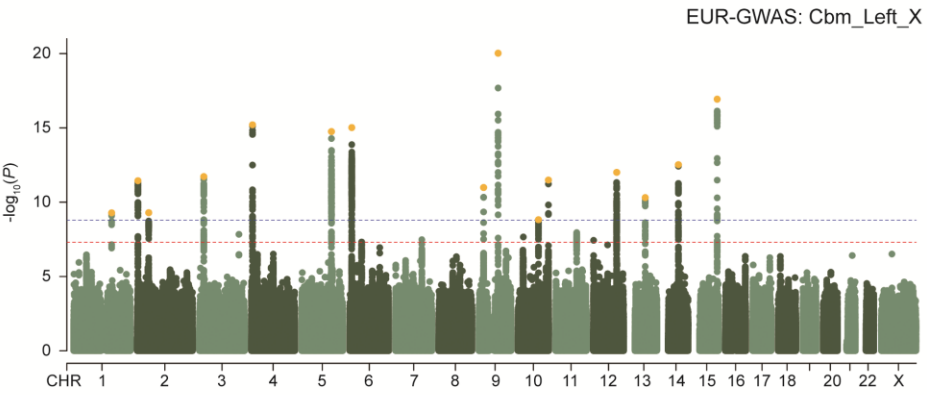
EUR-GWAS: Cbm_Right_VIIIb



EUR-GWAS: Cbm_Left_IX



EUR-GWAS: Cbm_Right_IX


EUR-GWAS: Cbm_Left_X
-log10(P)
0
5
10
15
20
CHR
1
2
3
4
5
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7
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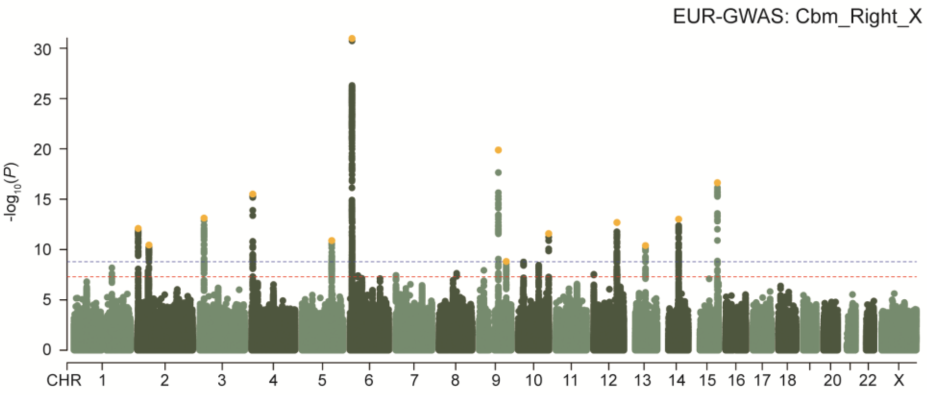
15
16
17
18
20
22
X


EUR-GWAS: Cbm_Right_X
-log10(P)
0
5
10
15
20
25
30
CHR
1
2
3
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11
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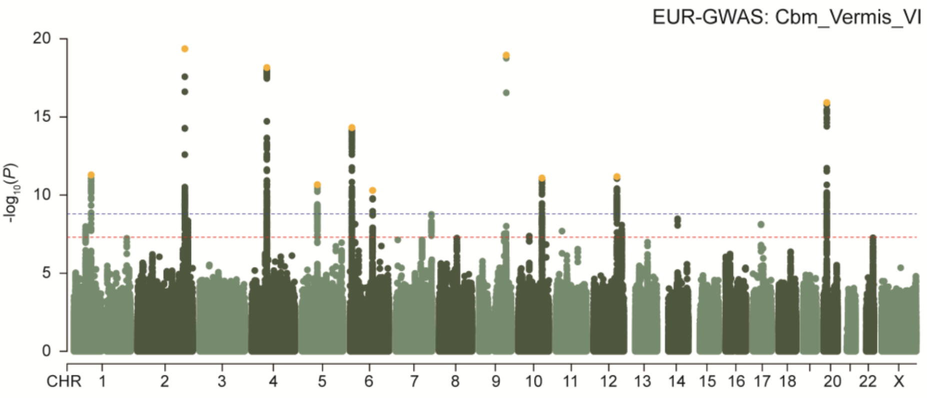
14
15
16
17
18
20
22
X


EUR-GWAS: Cbm_Vermis_VI
-log10(P)
0
5
10
15
20
CHR
1
2
3
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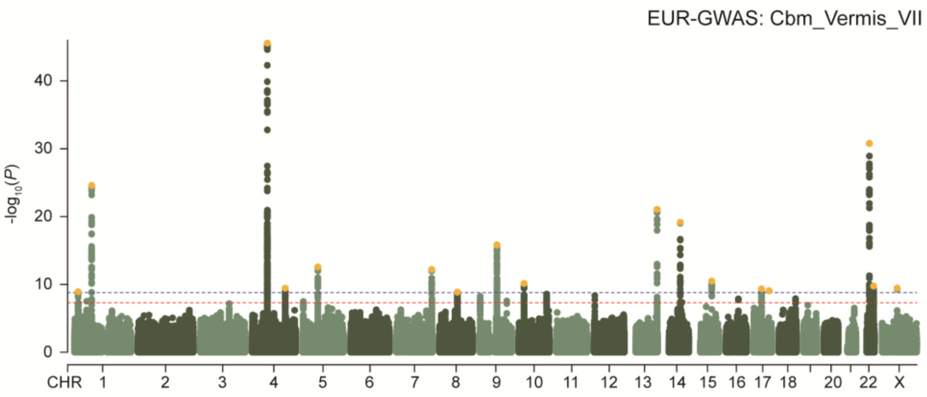
16
17
18
20
22
X


EUR-GWAS: Cbm_Vermis_VII
-log10(P)
0
10
20
30
40
CHR
1
2
3
4
5
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7
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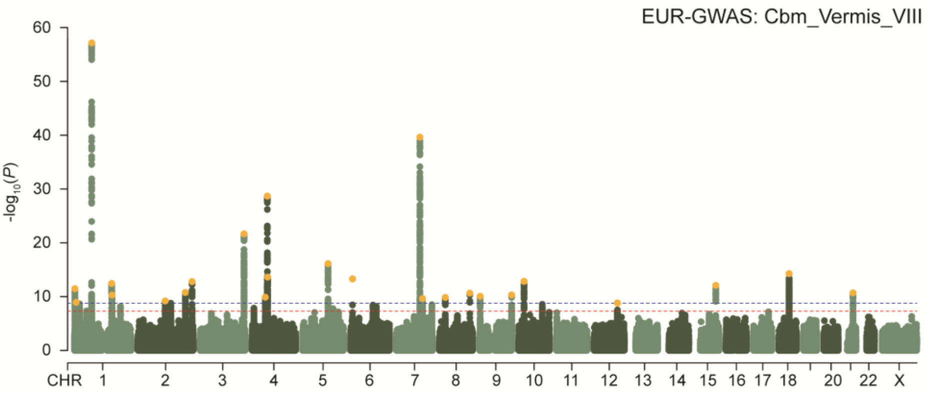
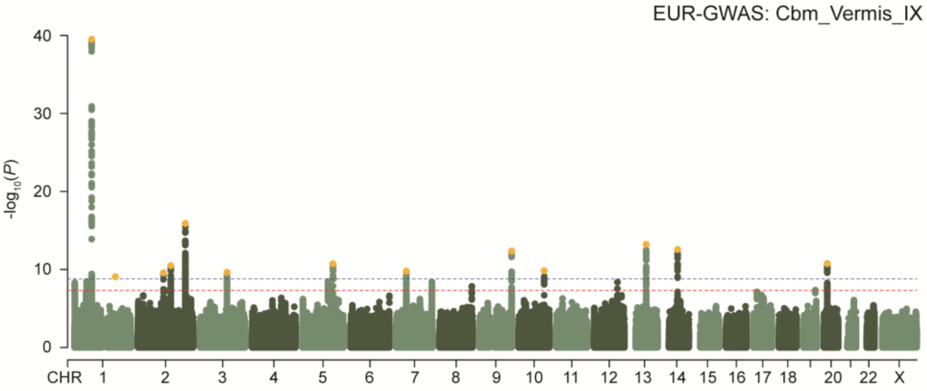
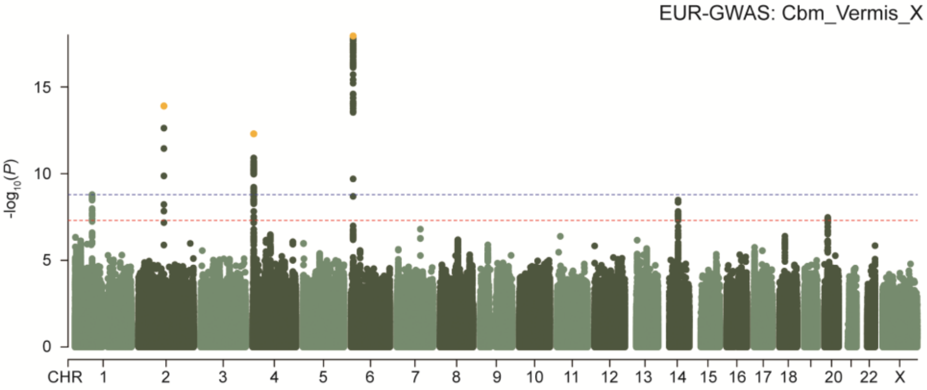
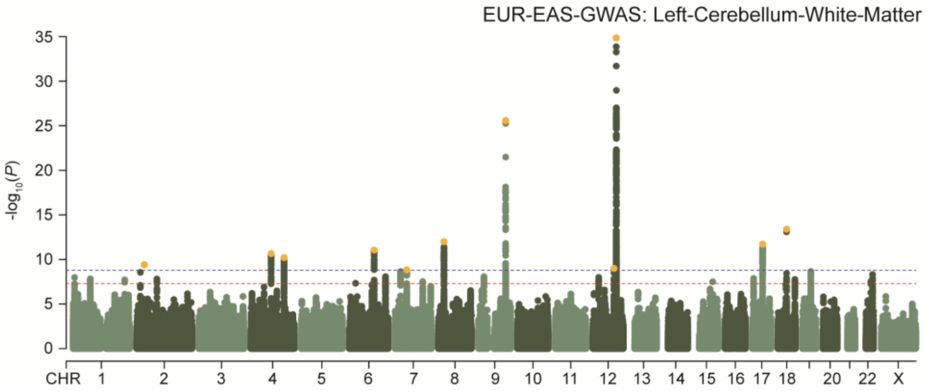
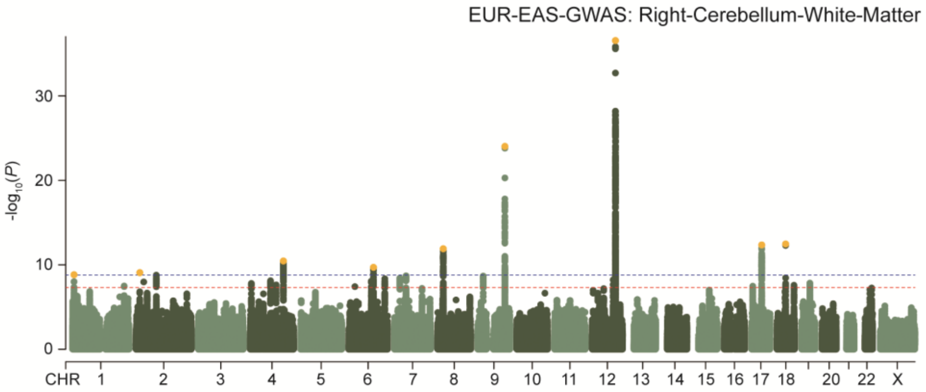
16
17
18
20
22
X

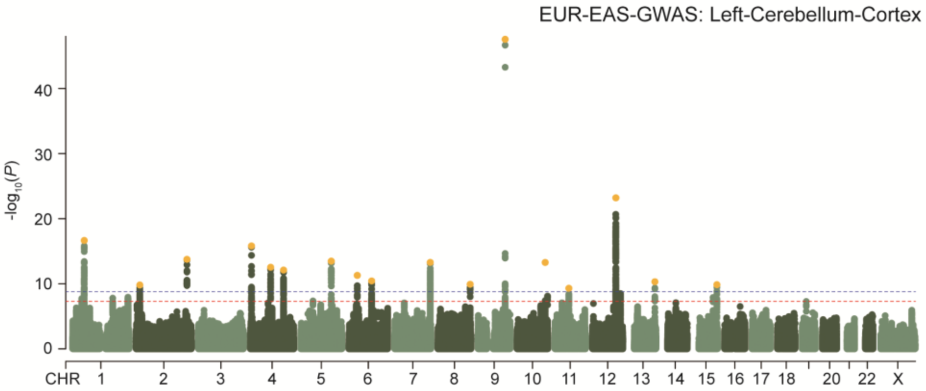

EUR-GWAS: Cbm_Vermis_VIII
-log$_{10}$(P)
60
50
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

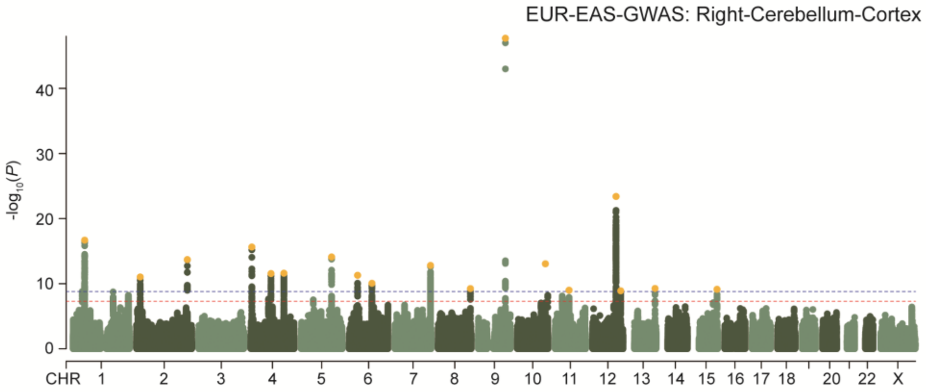

EUR-GWAS: Cbm_Vermis_IX
-log$_{10}$(P)
40
30
20
10
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

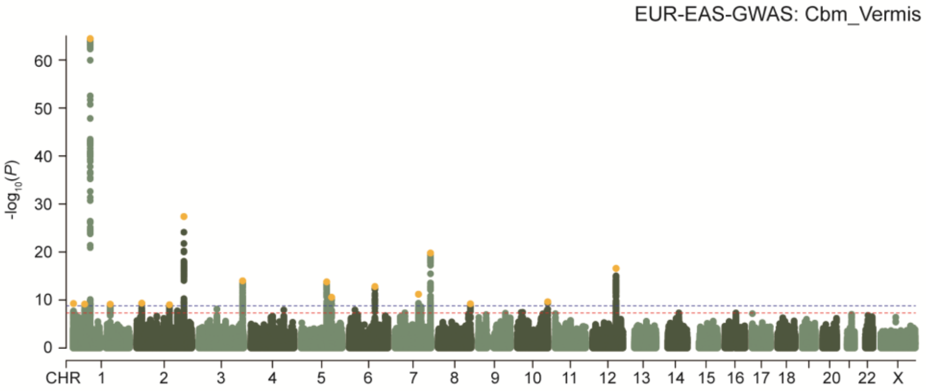

EUR-GWAS: Cbm_Vermis_X
-log$_{10}$(P)
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

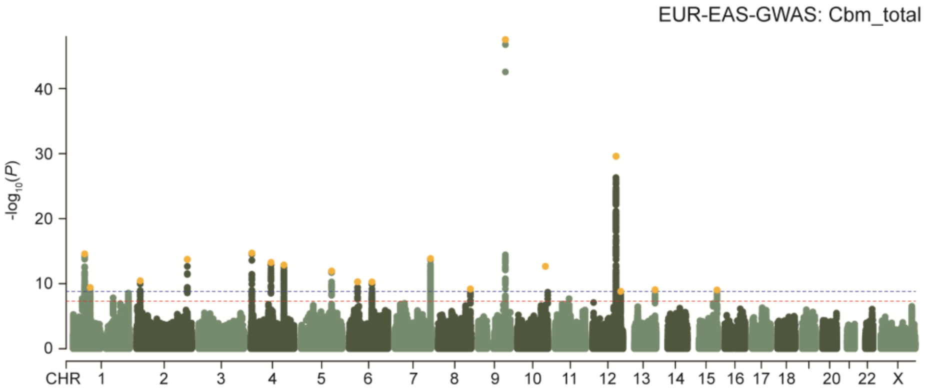

EUR-EAS-GWAS: Left-Cerebellum-White-Matter
-log$_{10}$(P)
35
30
25
20
15
10
5
0
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

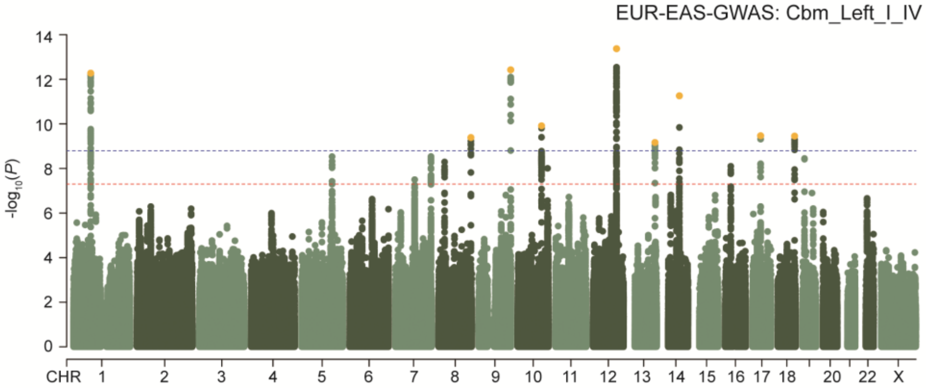

EUR-EAS-GWAS: Right-Cerebellum-White-Matter

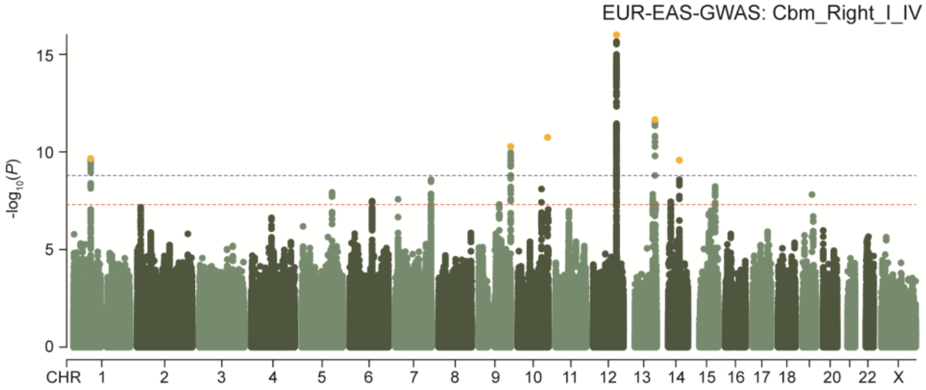

EUR-EAS-GWAS: Left-Cerebellum-Cortex

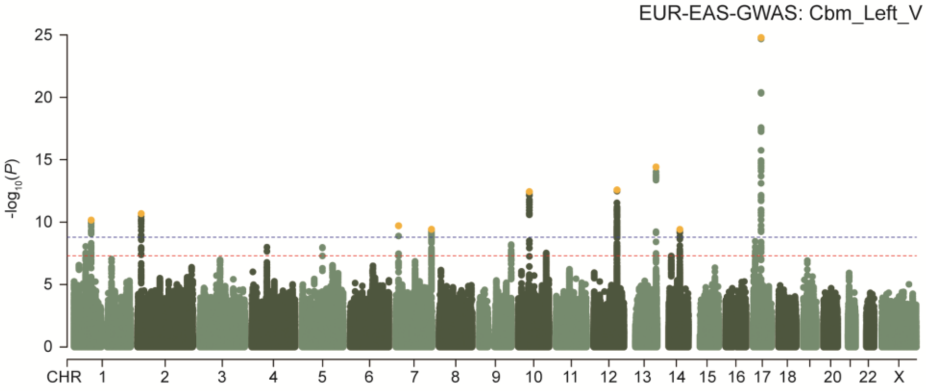

EUR-EAS-GWAS: Right-Cerebellum-Cortex

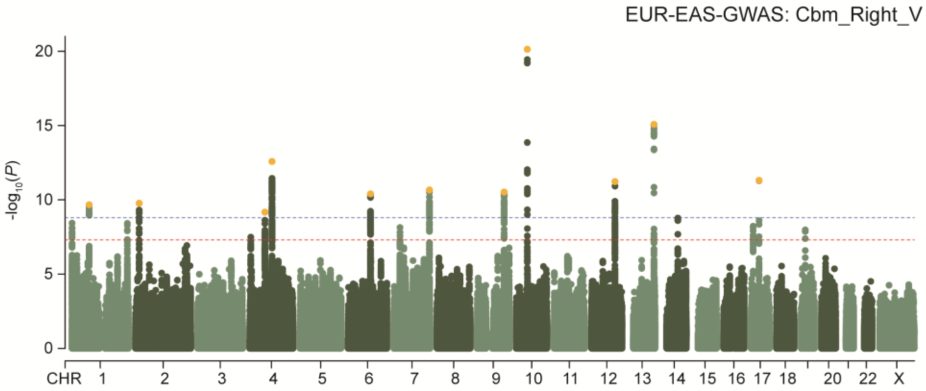

EUR-EAS-GWAS: Cbm_Vermis

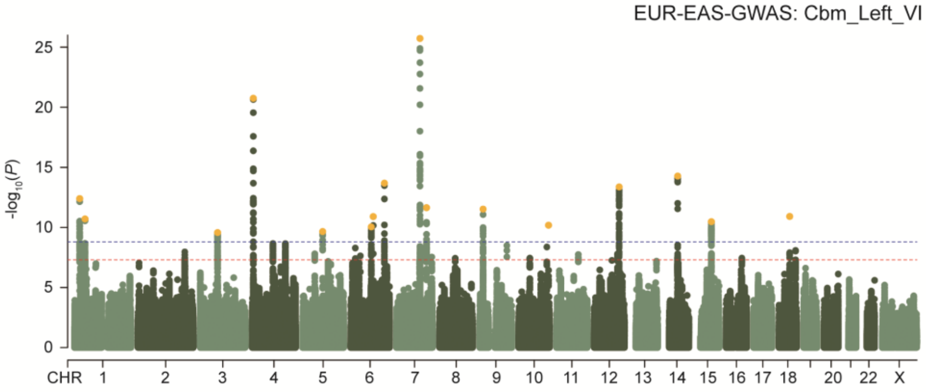

EUR-EAS-GWAS: Cbm_total
-log10(P)
0
10
20
30
40
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

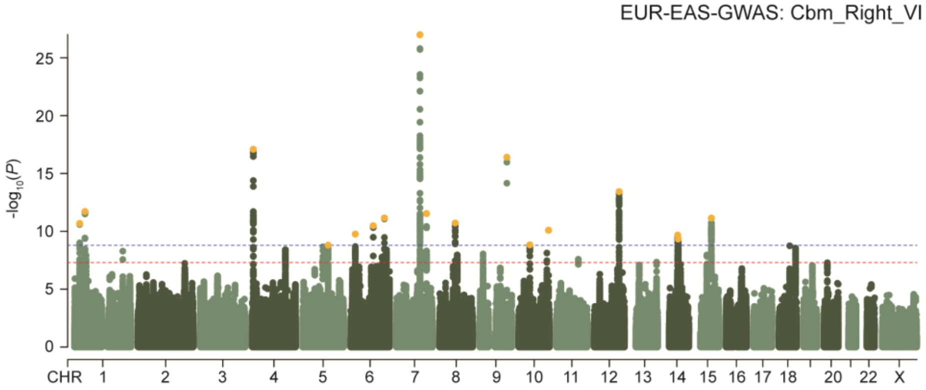

EUR-EAS-GWAS: Cbm_Left_I_IV
-log10(P)
0
2
4
6
8
10
12
14
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

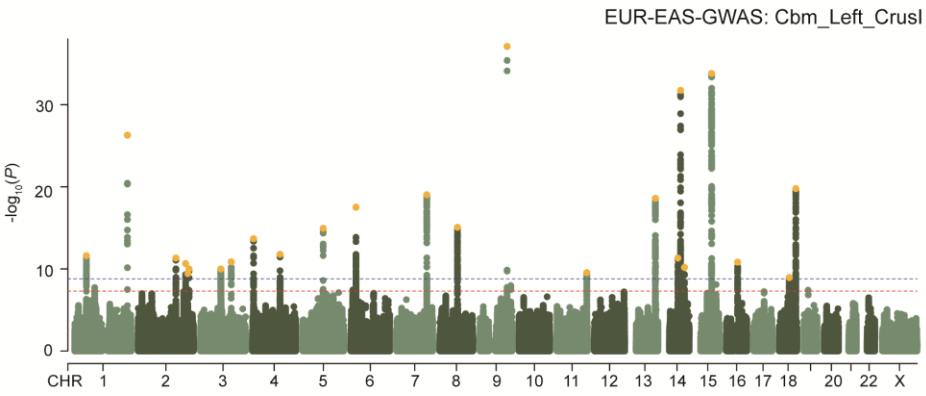

EUR-EAS-GWAS: Cbm_Right_I_IV
-log10(P)
0
5
10
15
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

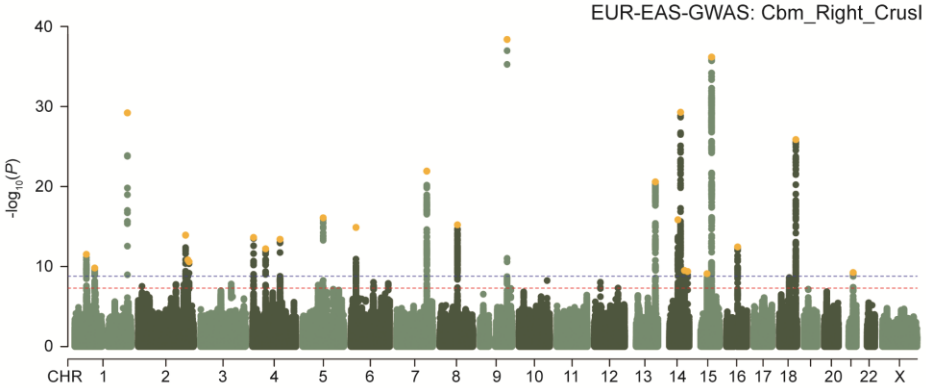

EUR-EAS-GWAS: Cbm_Left_V
-log10(P)
0
5
10
15
20
25
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

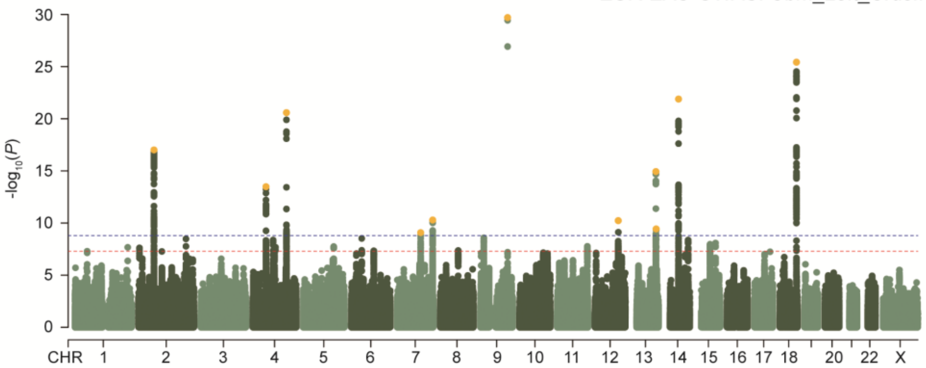

EUR-EAS-GWAS: Cbm_Right_V

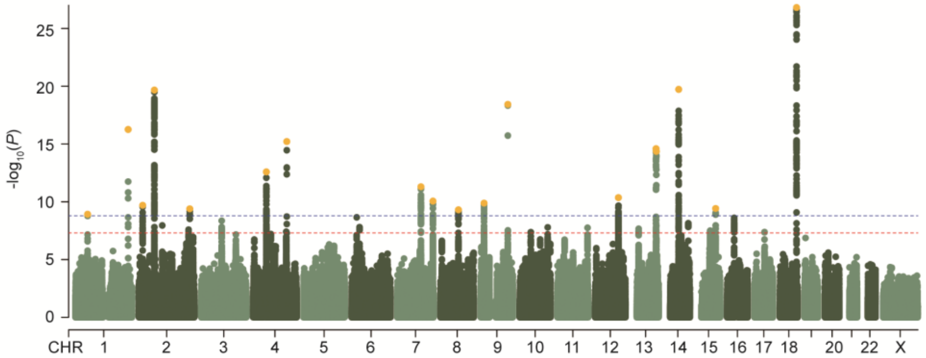

EUR-EAS-GWAS: Cbm_Left_VI

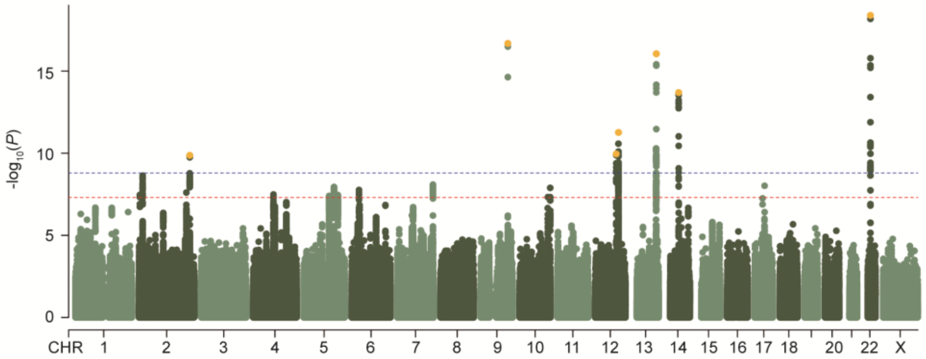

EUR-EAS-GWAS: Cbm_Right_VI

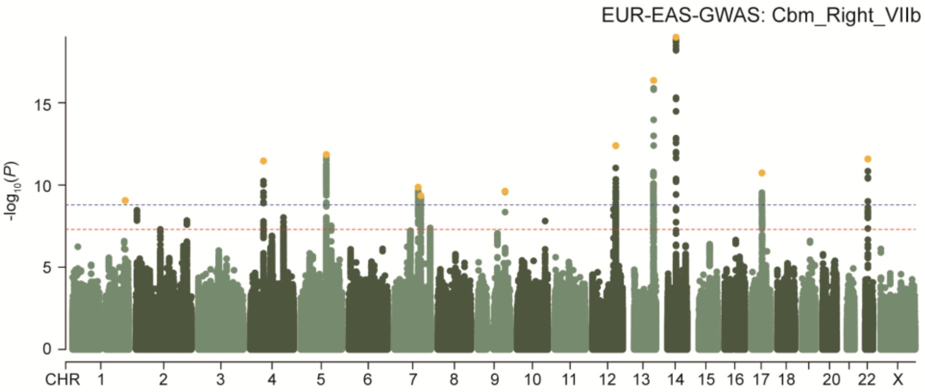

EUR-EAS-GWAS: Cbm_Left_CrusI

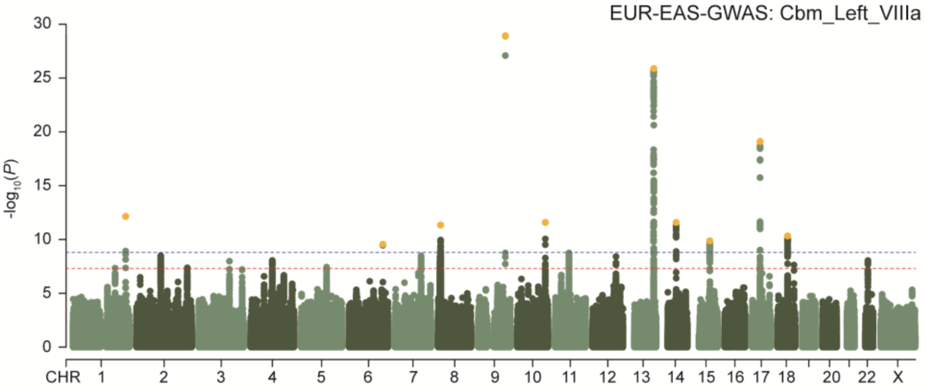

EUR-EAS-GWAS: Cbm_Right_CrusI


EUR-EAS-GWAS: Cbm_Left_CrusII


EUR-EAS-GWAS: Cbm_Right_CrusII


EUR-EAS-GWAS: Cbm_Left_VIIb


EUR-EAS-GWAS: Cbm_Right_VIIb
$-\log_{10}(P)$
0
5
10
15
CHR
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
22
X


EUR-EAS-GWAS: Cbm_Left_VIIIa
$-\log_{10}(P)$
0
5
10
15
20
25
30
CHR
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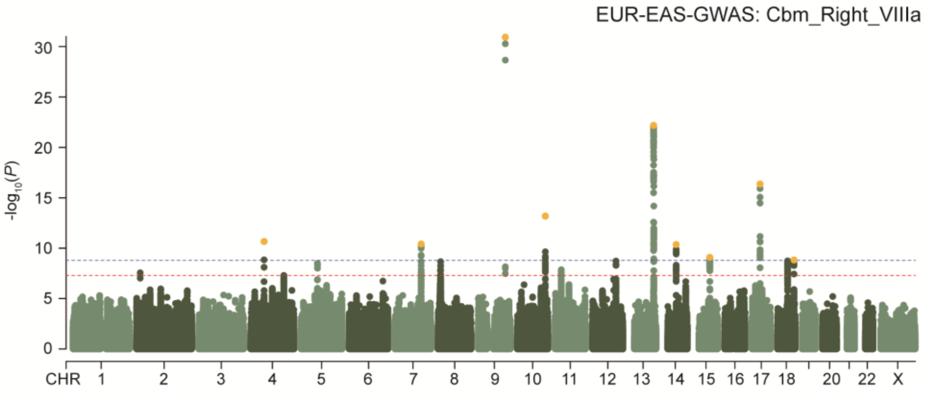
20
22
X


EUR-EAS-GWAS: Cbm_Right_VIIIa
$-\log_{10}(P)$
0
5
10
15
20
25
30
CHR
1
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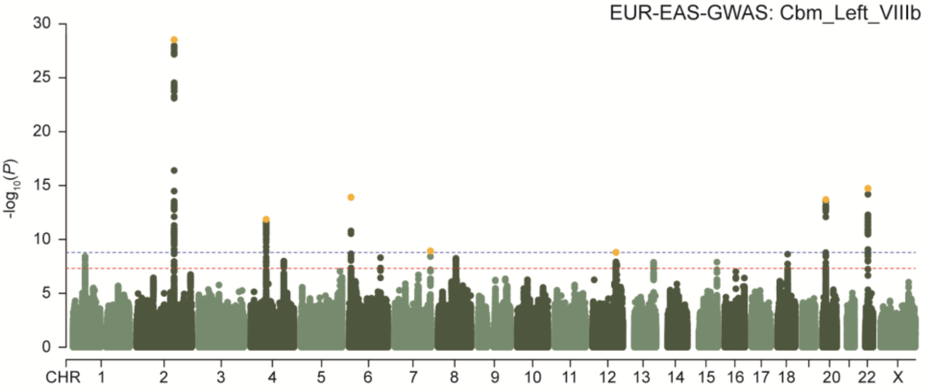
18
20
22
X


EUR-EAS-GWAS: Cbm_Left_VIIIb
$-\log_{10}(P)$
0
5
10
15
20
25
30
CHR
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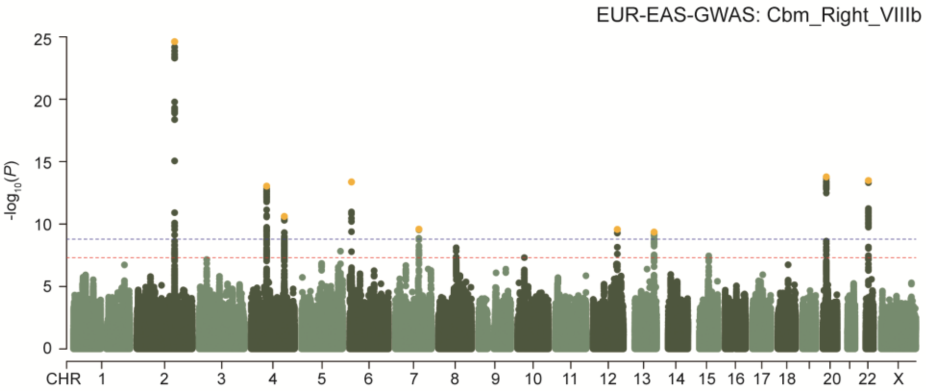
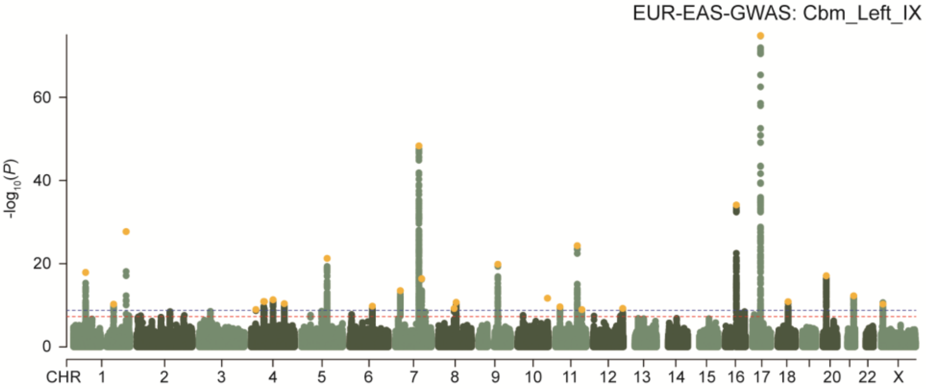
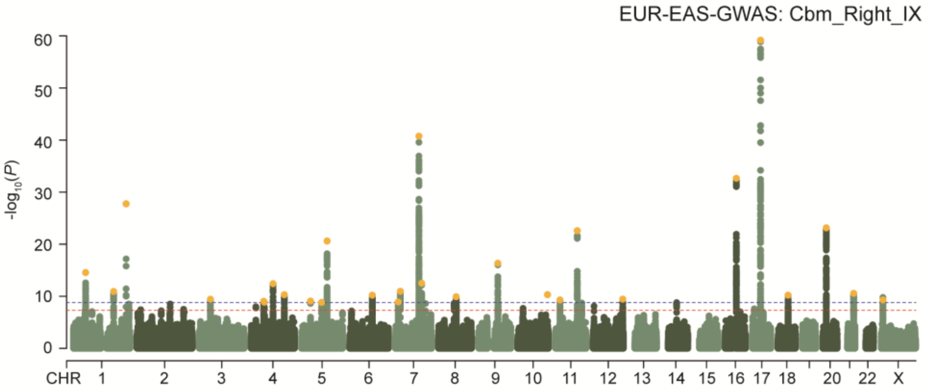
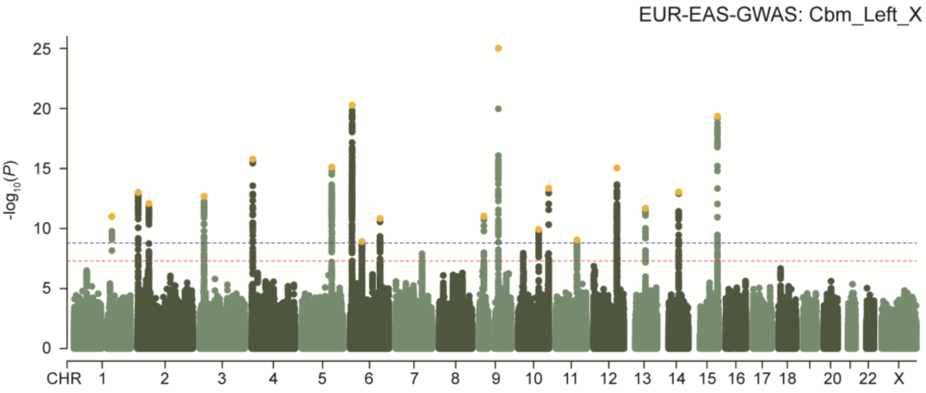
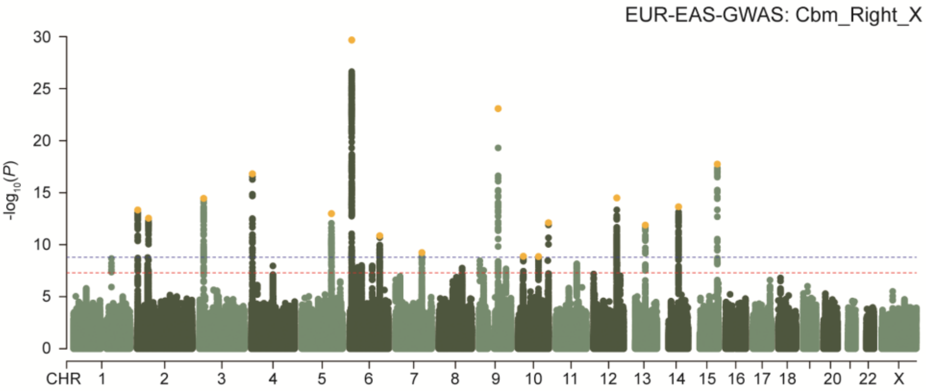
18
20
22
X

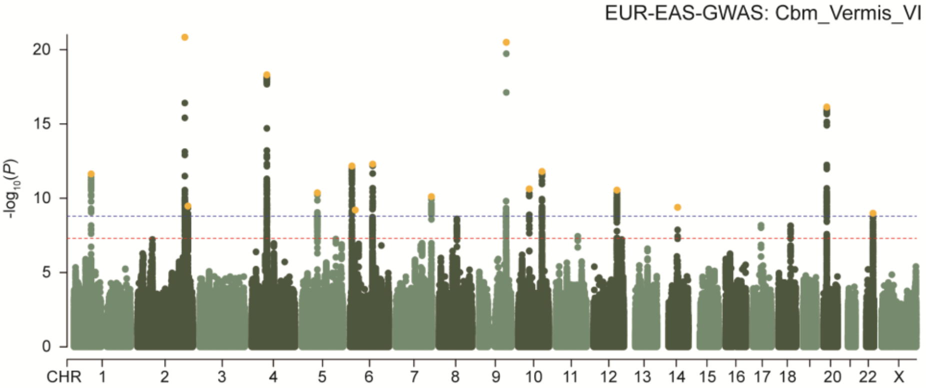

EUR-EAS-GWAS: Cbm_Right_VIIIb

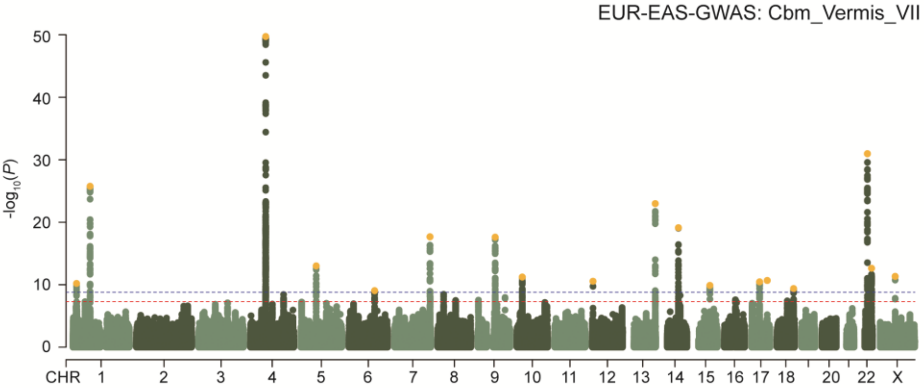

EUR-EAS-GWAS: Cbm_Left_IX

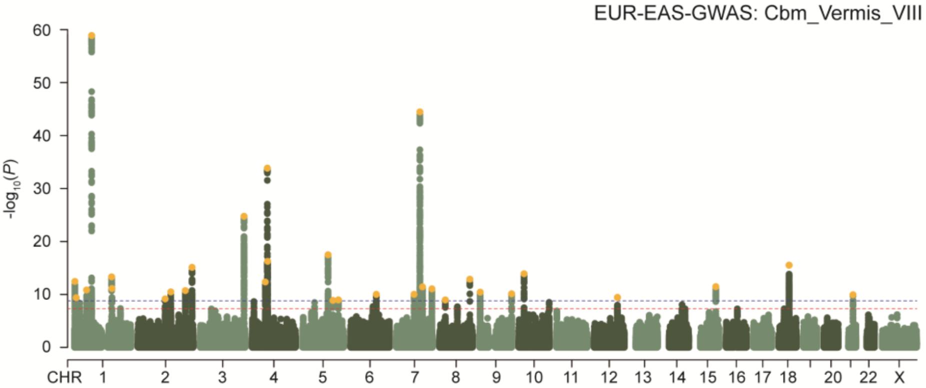

EUR-EAS-GWAS: Cbm_Right_IX

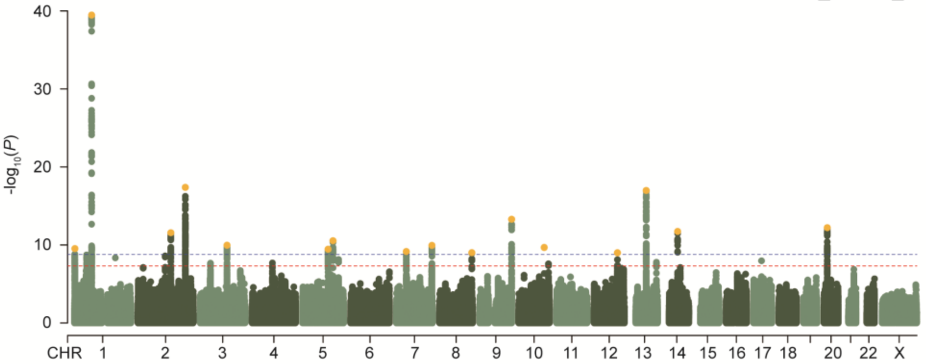

EUR-EAS-GWAS: Cbm_Left_X


EUR-EAS-GWAS: Cbm_Right_X

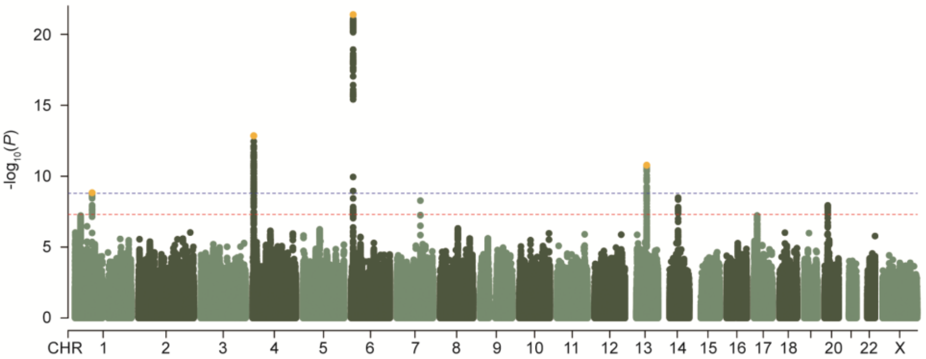

EUR-EAS-GWAS: Cbm_Vermis_VI


EUR-EAS-GWAS: Cbm_Vermis_VII

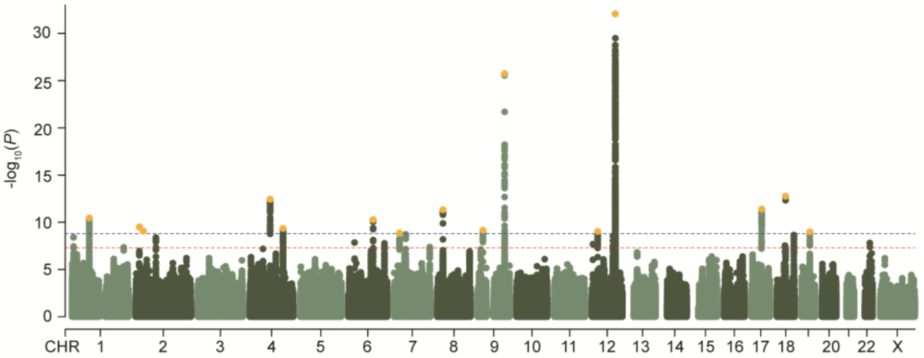

EUR-EAS-GWAS: Cbm_Vermis_VIII



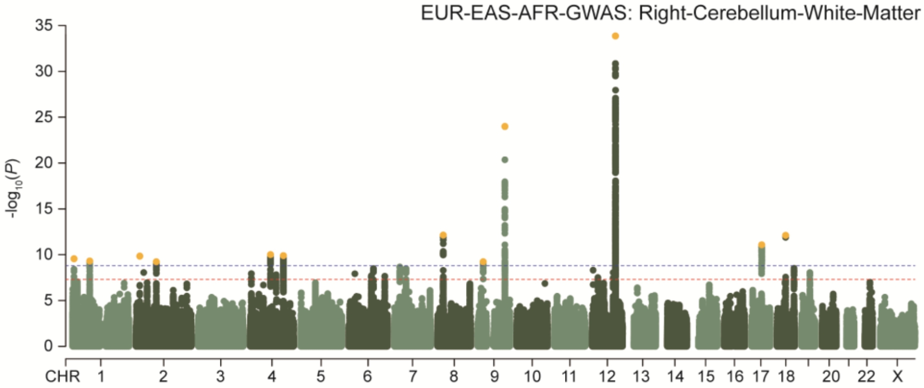
EUR-EAS-GWAS: Cbm_Vermis_IX



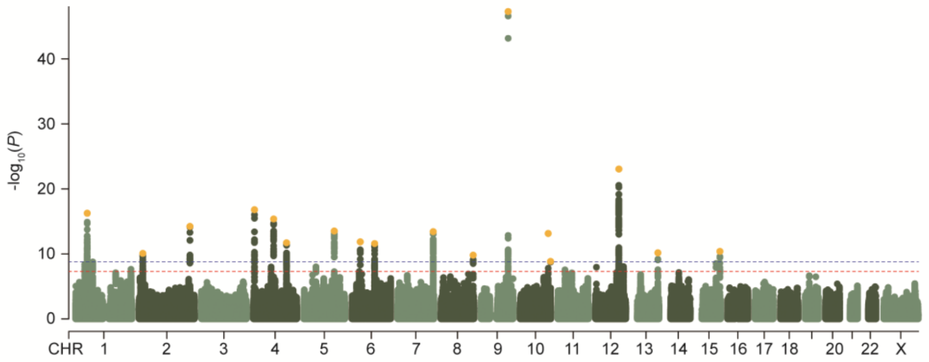
EUR-EAS-GWAS: Cbm_Vermis_X

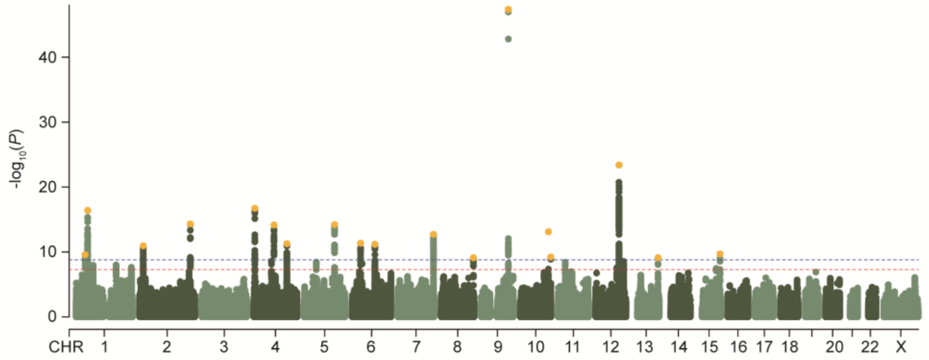


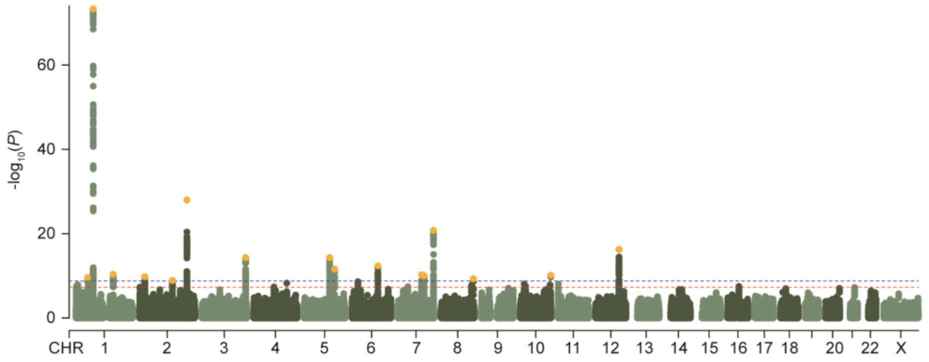
EUR-EAS-AFR-GWAS: Left-Cerebellum-White-Matter

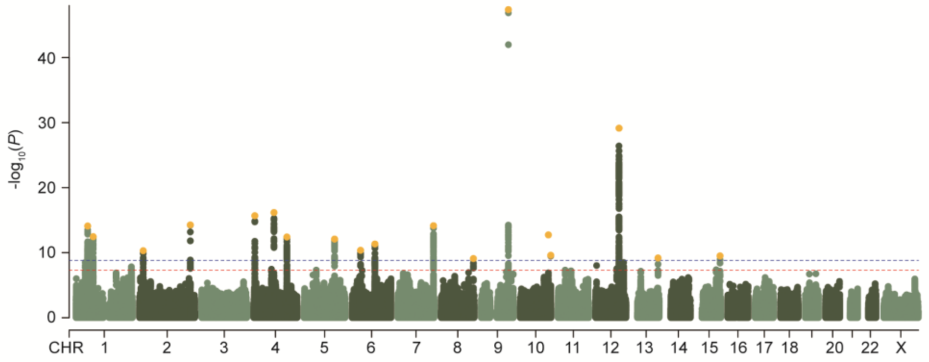


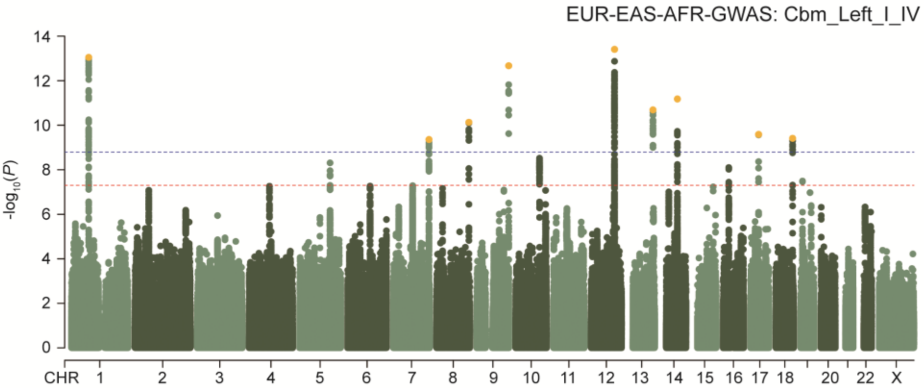
EUR-EAS-AFR-GWAS: Right-Cerebellum-White-Matter

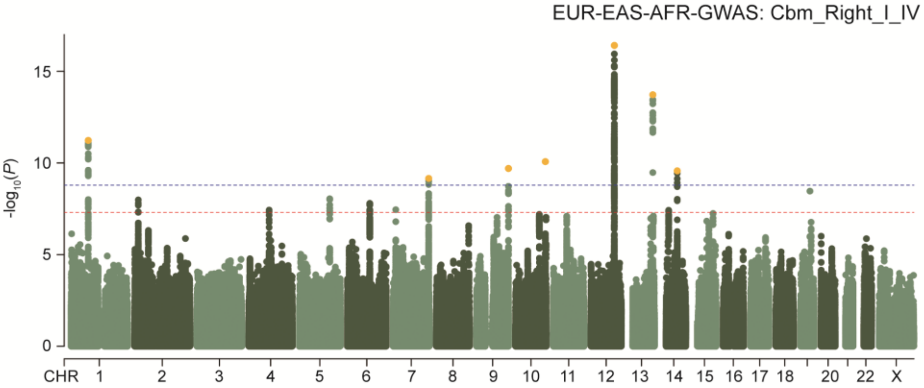

EUR-EAS-AFR-GWAS: Left-Cerebellum-Cortex

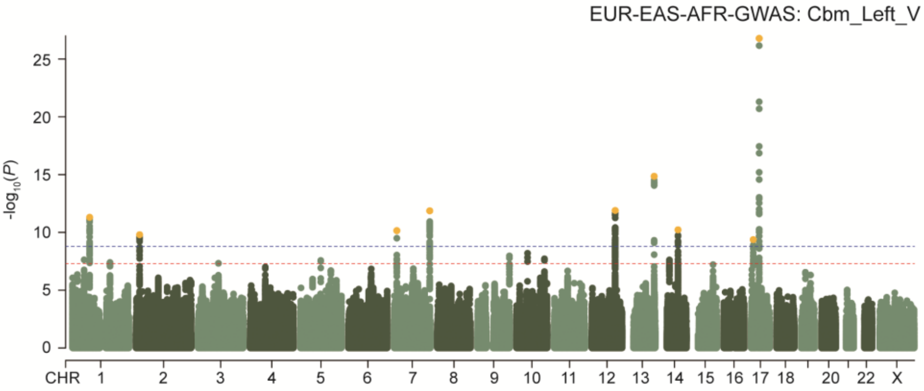

EUR-EAS-AFR-GWAS: Right-Cerebellum-Cortex

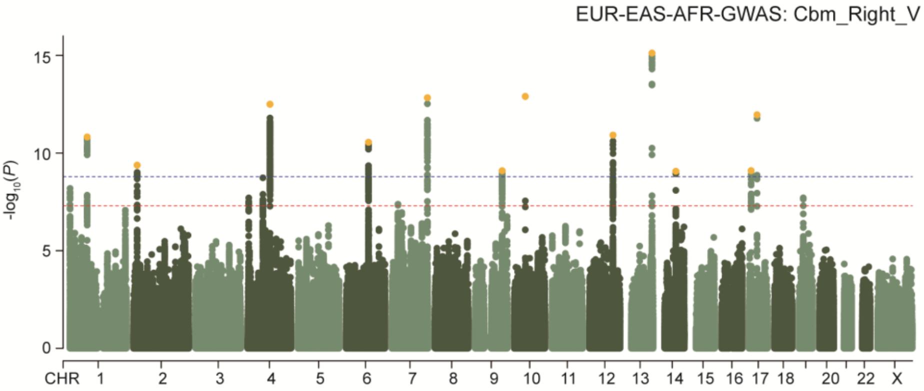

EUR-EAS-AFR-GWAS: Cbm_Vermis

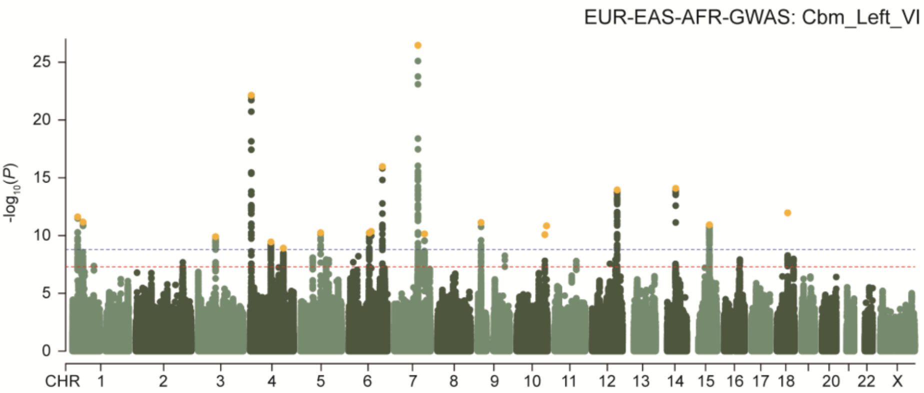

EUR-EAS-AFR-GWAS: Cbm_total


EUR-EAS-AFR-GWAS: Cbm_Left_I_IV

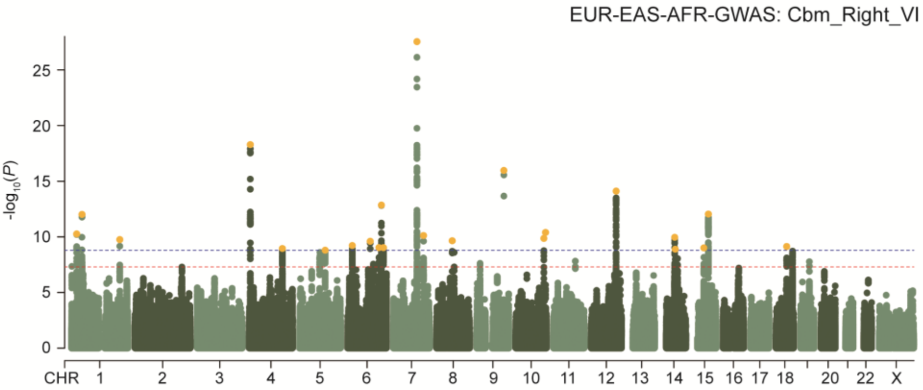

EUR-EAS-AFR-GWAS: Cbm_Right_I_IV


EUR-EAS-AFR-GWAS: Cbm_Left_V

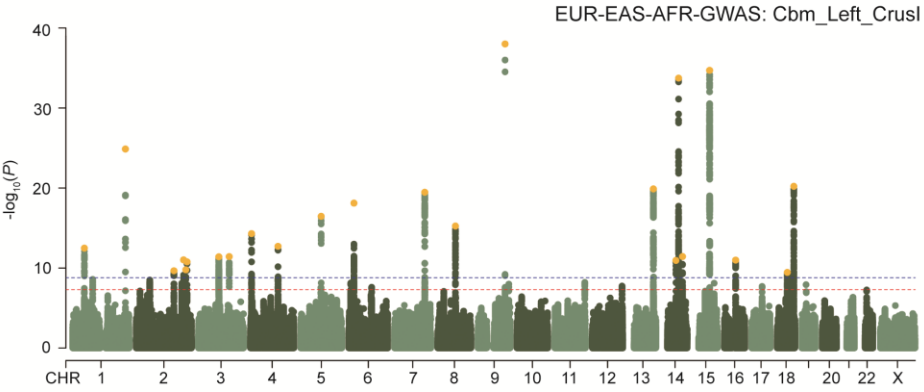

EUR-EAS-AFR-GWAS: Cbm_Right_V



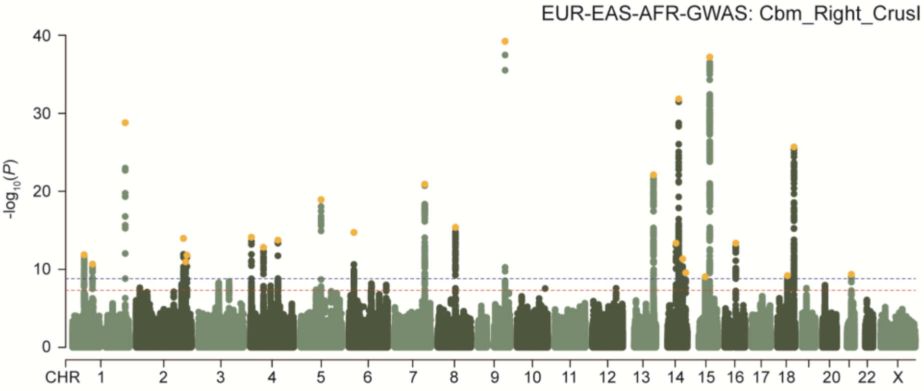
EUR-EAS-AFR-GWAS: Cbm_Left_VI



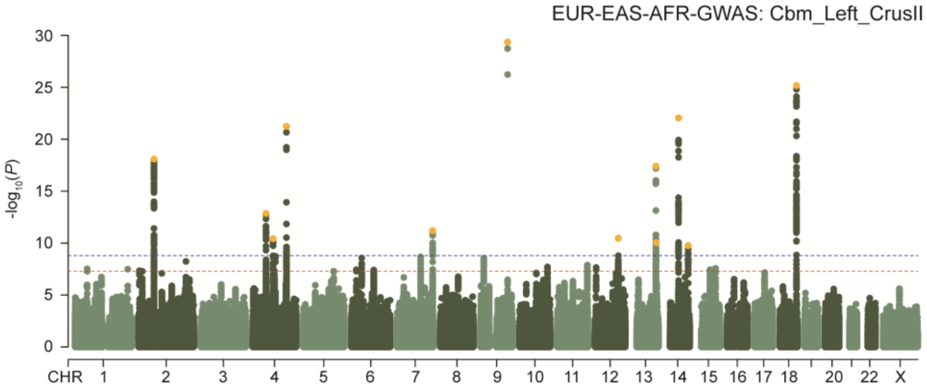
EUR-EAS-AFR-GWAS: Cbm_Right_VI

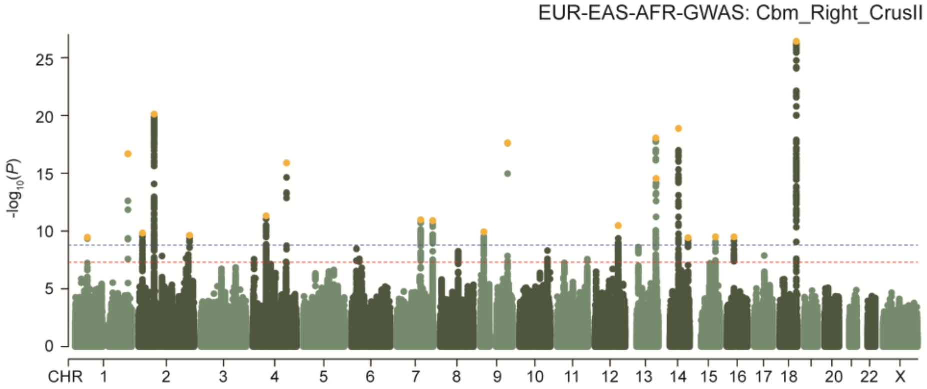


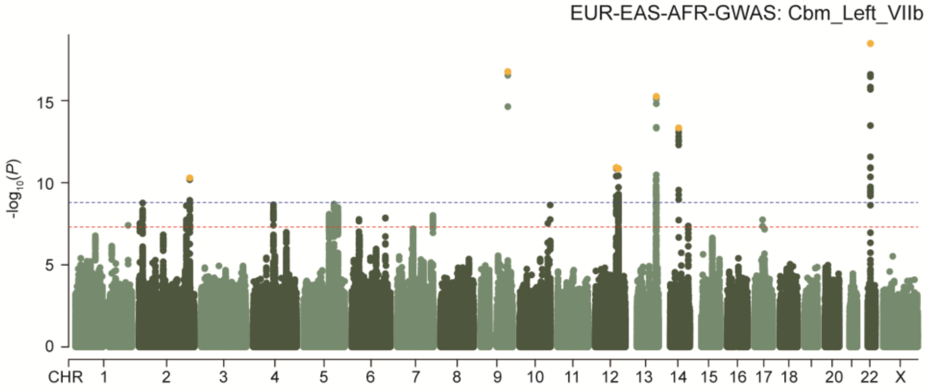
EUR-EAS-AFR-GWAS: Cbm_Left_CrusI

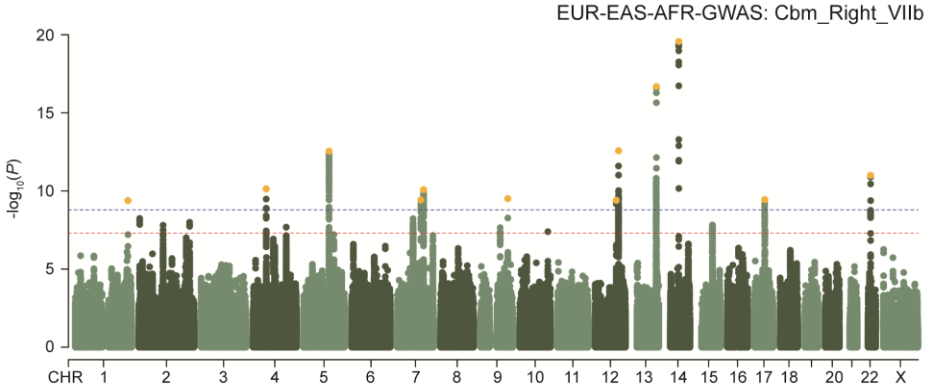


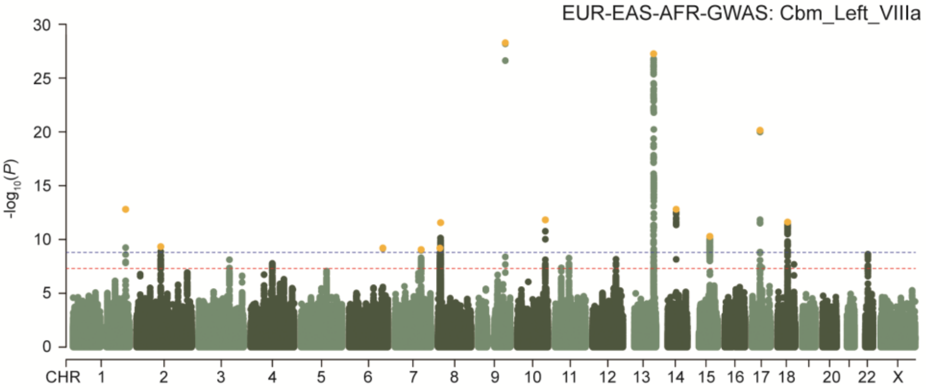
EUR-EAS-AFR-GWAS: Cbm_Right_CrusI

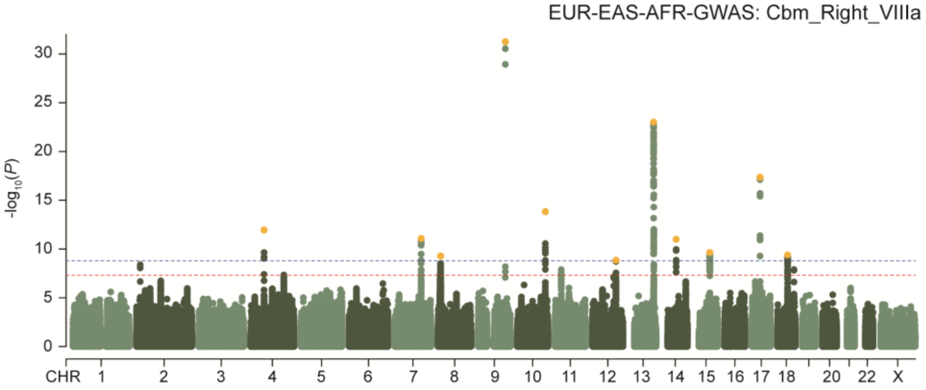

EUR-EAS-AFR-GWAS: Cbm_Left_CrusII
-log$_{10}$(P)
0
5
10
15
20
25
30
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

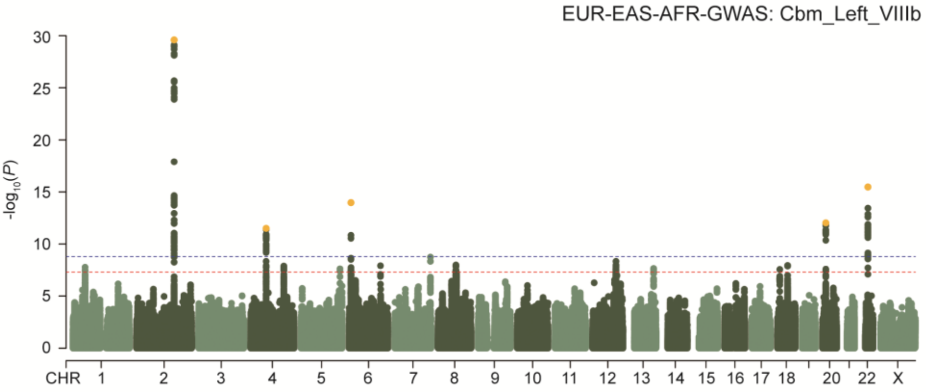

EUR-EAS-AFR-GWAS: Cbm_Right_CrusII
-log$_{10}$(P)
0
5
10
15
20
25
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

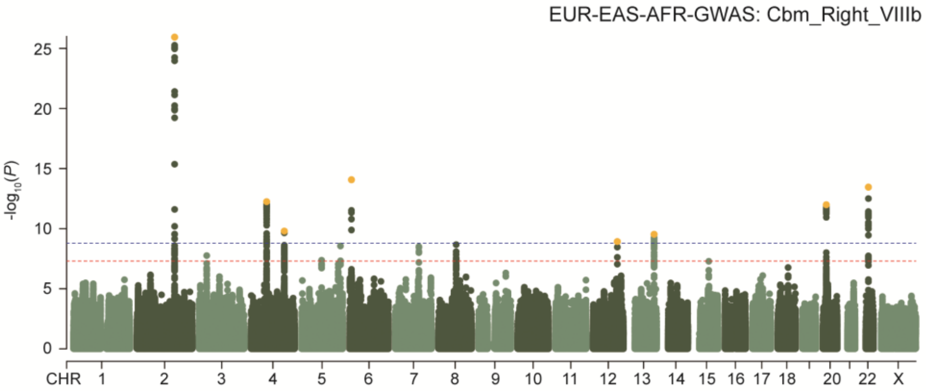

EUR-EAS-AFR-GWAS: Cbm_Left_VIIb
-log$_{10}$(P)
0
5
10
15
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X


EUR-EAS-AFR-GWAS: Cbm_Right_VIIb
-log$_{10}$(P)
0
5
10
15
20
CHR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 X

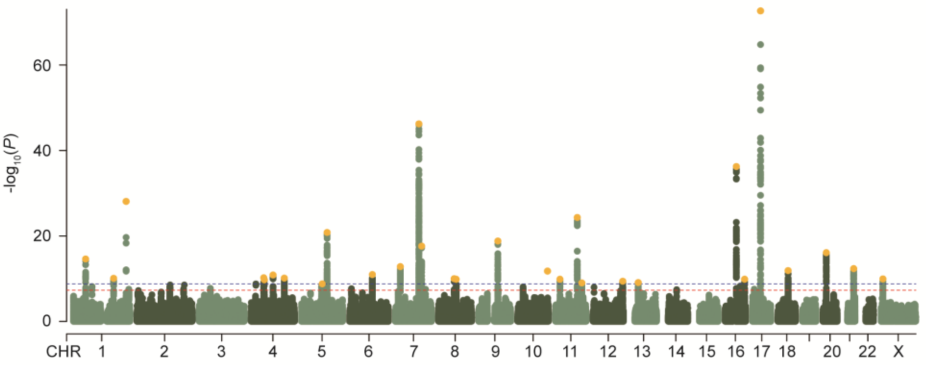

EUR-EAS-AFR-GWAS: Cbm_Left_VIIIa


EUR-EAS-AFR-GWAS: Cbm_Right_VIIIa

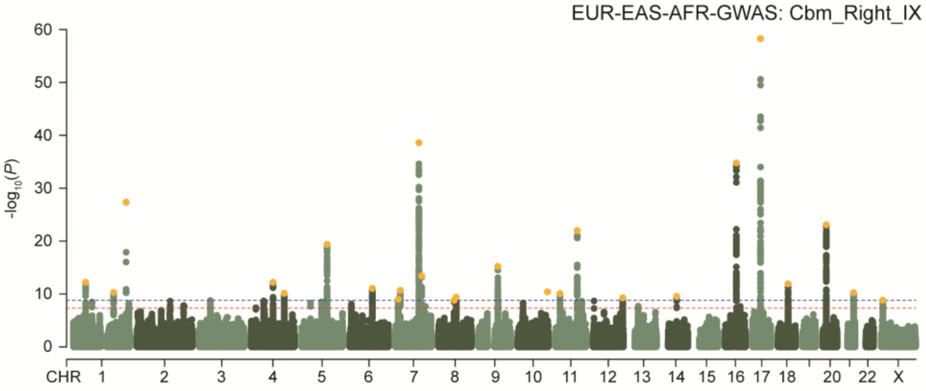

EUR-EAS-AFR-GWAS: Cbm_Left_VIIIb


EUR-EAS-AFR-GWAS: Cbm_Right_VIIIb

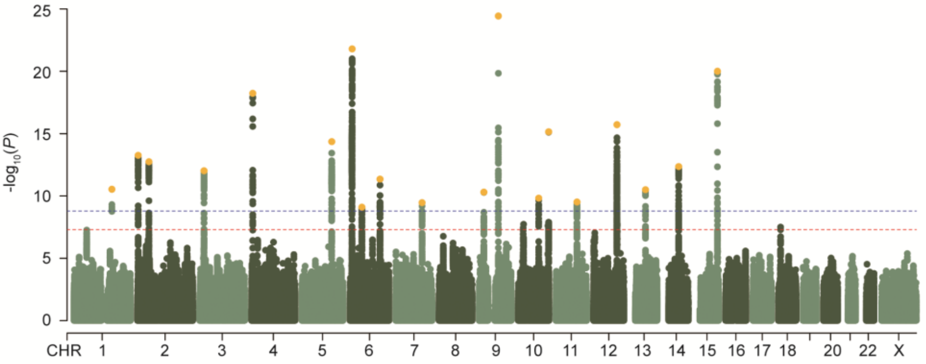
EUR-EAS-AFR-GWAS: Cbm_Left_IX



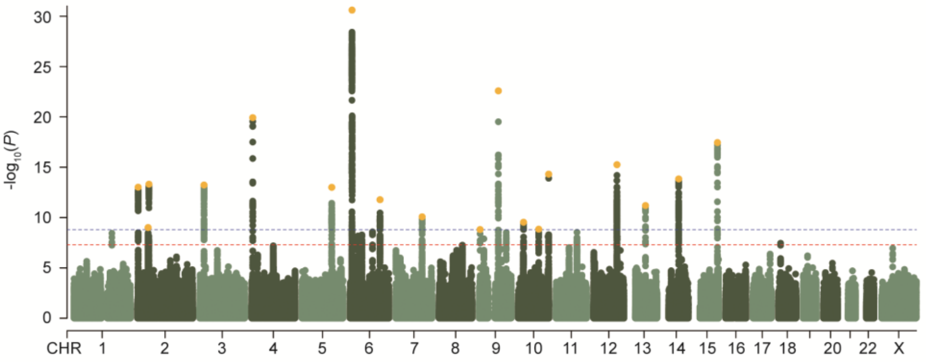
EUR-EAS-AFR-GWAS: Cbm_Right_IX

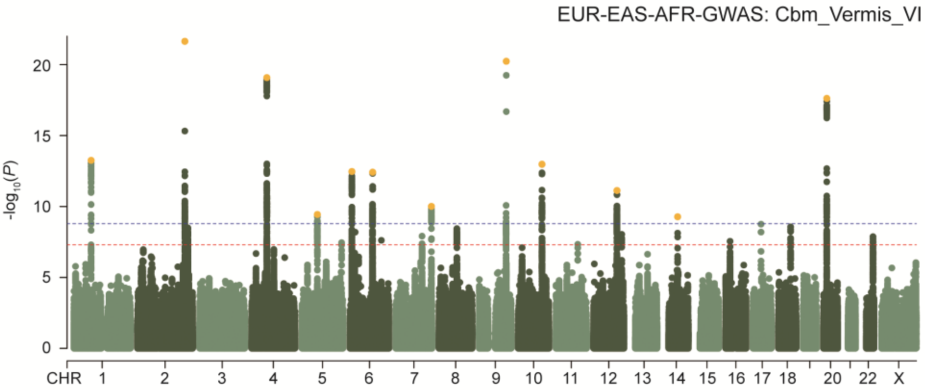


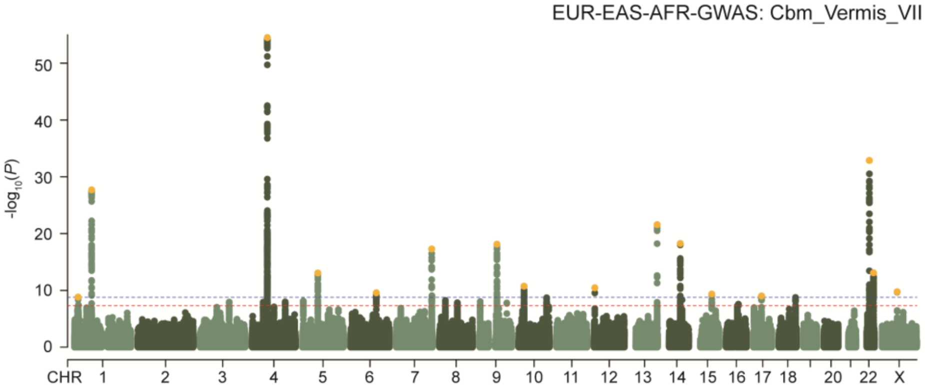
EUR-EAS-AFR-GWAS: Cbm_Left_X

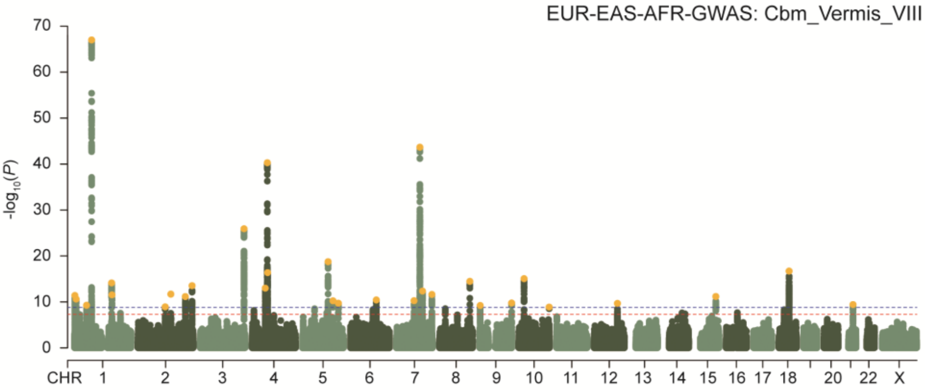


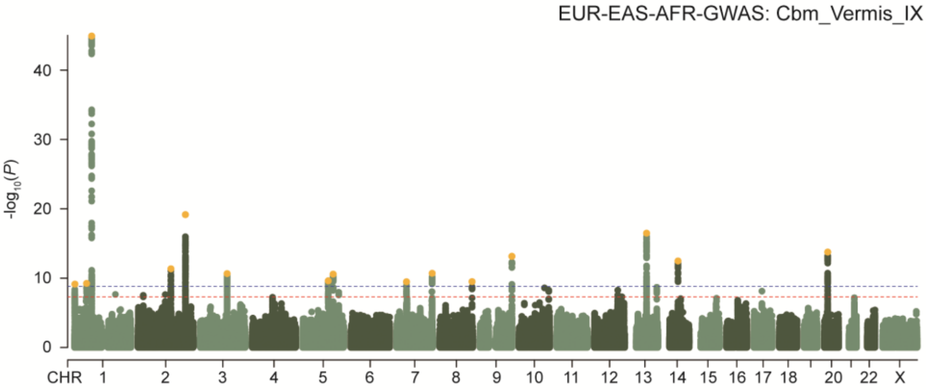
EUR-EAS-AFR-GWAS: Cbm_Right_X




EUR-EAS-AFR-GWAS: Cbm_Vermis_VI


EUR-EAS-AFR-GWAS: Cbm_Vermis_VII


EUR-EAS-AFR-GWAS: Cbm_Vermis_VIII


EUR-EAS-AFR-GWAS: Cbm_Vermis_IX

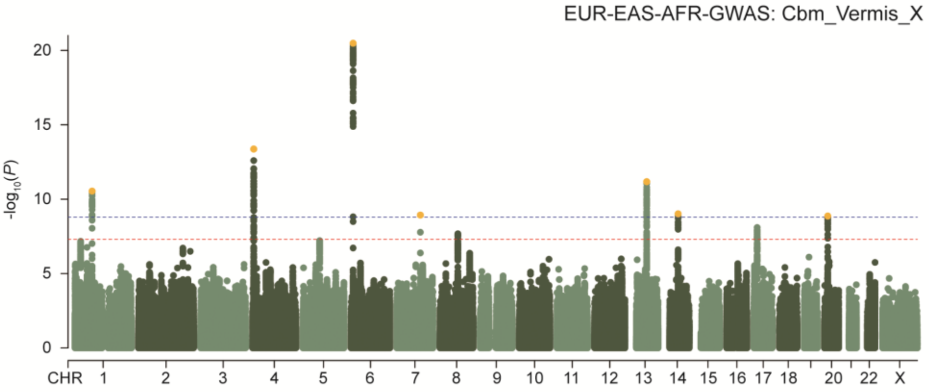
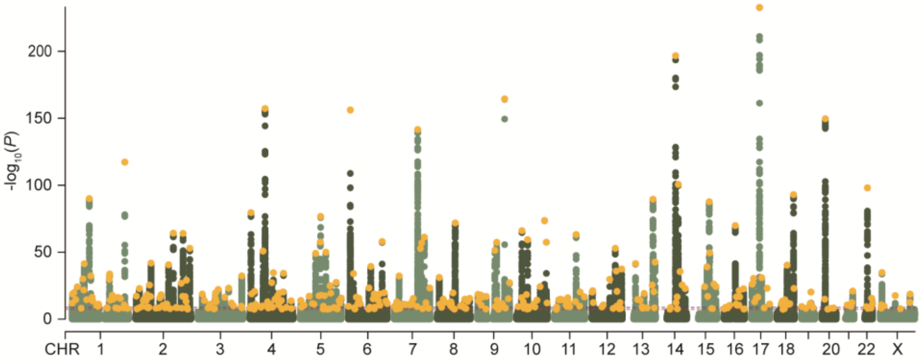
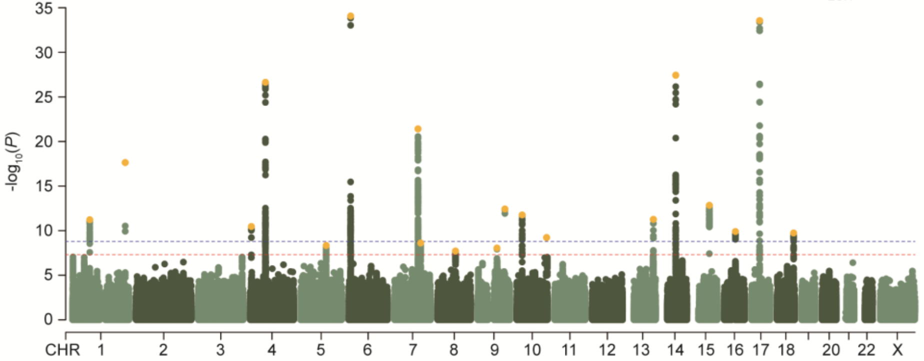


Fig. S5 | Genetic discovery of female-specific univariate GWAS. The Manhattan plots illustrate the results from female-specific univariate GWASs (UKBB$_{EUR}$-GWAS, ABCD$_{EUR}$-GWAS, CHIMGEN$_{EAS}$-GWAS, ABCD$_{AFR}$-GWAS, EUR-GWAS, EUR-EAS-GWAS, and EUR-EAS-AFR-GWAS) on the 31 cerebellar volumetric traits. Each plot shows genome-wide (red dashed line: $P = 5 \times 10^{-8}$) and study-wide (blue dashed line: $P = 1.61 \times 10^{-9}$) significant associations. Each point represents a single genetic variant plotted according to its genomic position (x axis) and its -log$_{10}$(P) value for the association (y axis). Each yellow point represents an independent locus with study-wide significance ($P = 1.61 \times 10^{-9}$). Abbreviations: ABCD, the Adolescent Brain Cognitive Development study; AFR, African ancestry; CHIMGEN, the Chinese Imaging Genetics study; EAS, East Asian ancestry; EUR, European ancestry; GWAS, genome-wide association study; UKBB, the UK Biobank study.

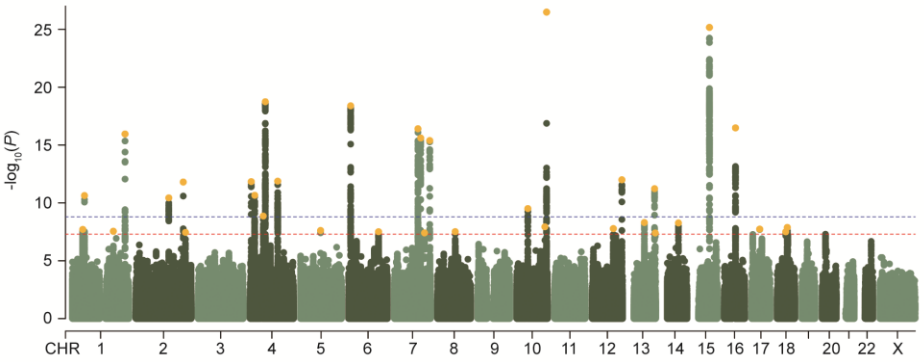
Sex-combined multivariate UKBB$_{EUR}$-GWAS



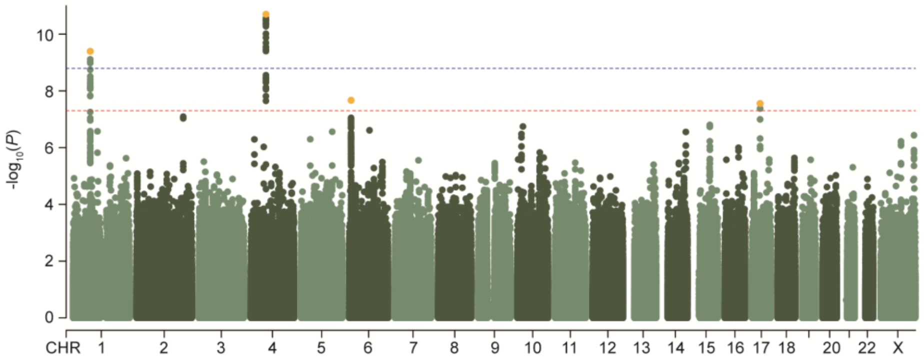
Sex-combined multivariate ABCD$_{EUR}$-GWAS



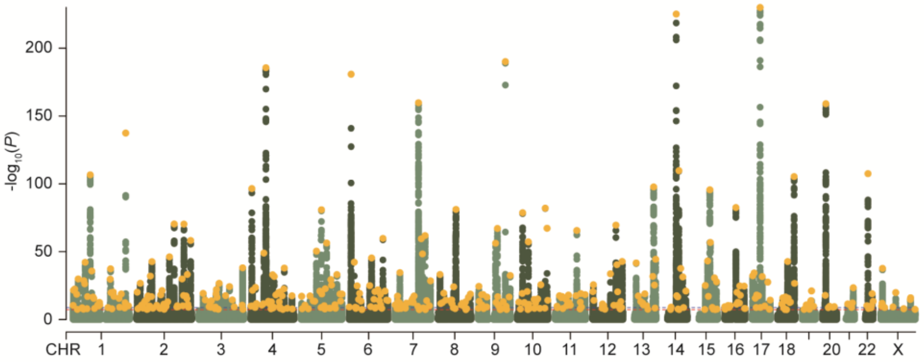
Sex-combined multivariate CHIMGEN$_{EAS}$-GWAS



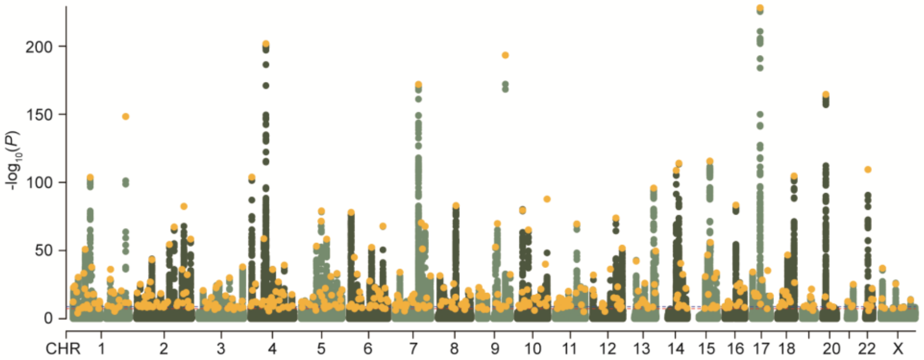
Sex-combined multivariate ABCD$_{AFR}$-GWAS



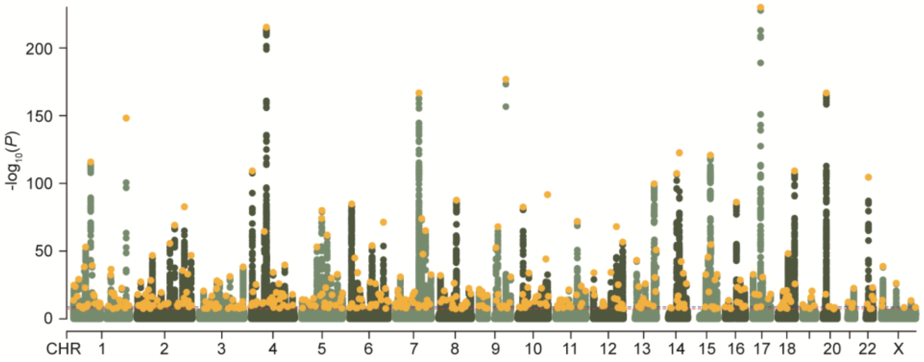
Sex-combined multivariate EUR-GWAS



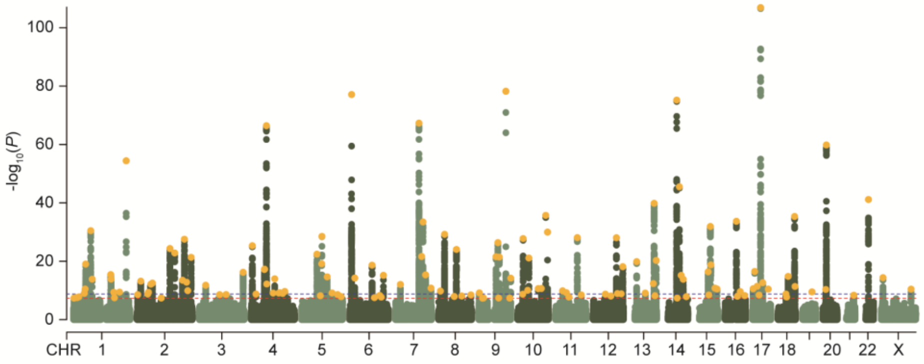
Sex-combined multivariate EUR-EAS-GWAS

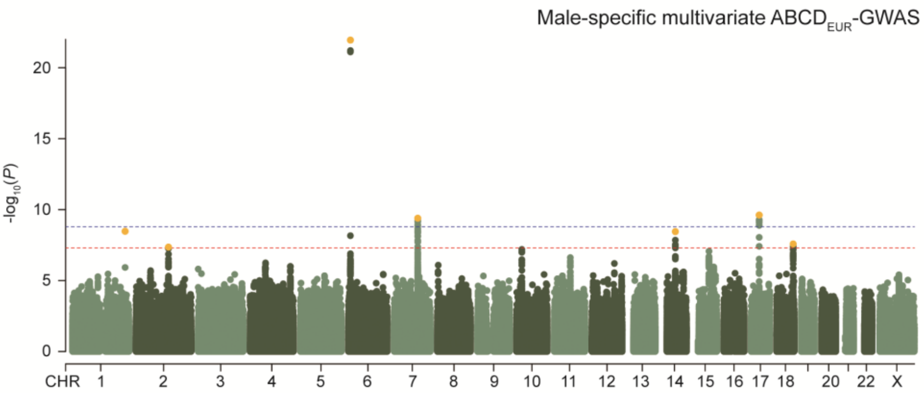


Sex-combined multivariate EUR-EAS-AFR-GWAS

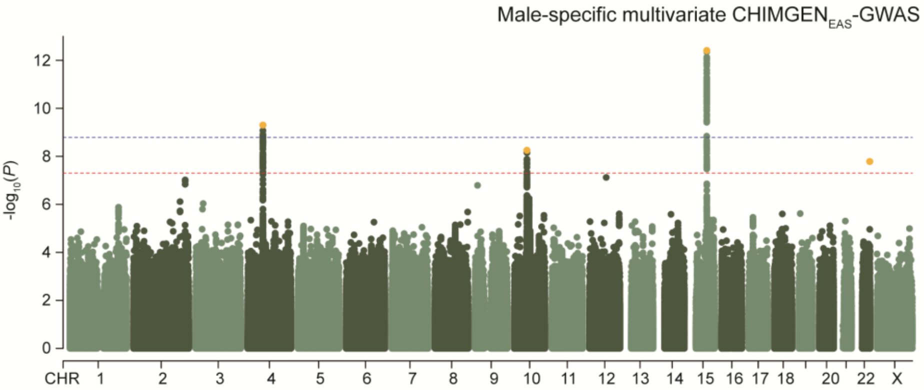


Male-specific multivariate UKBB_{EUR}-GWAS

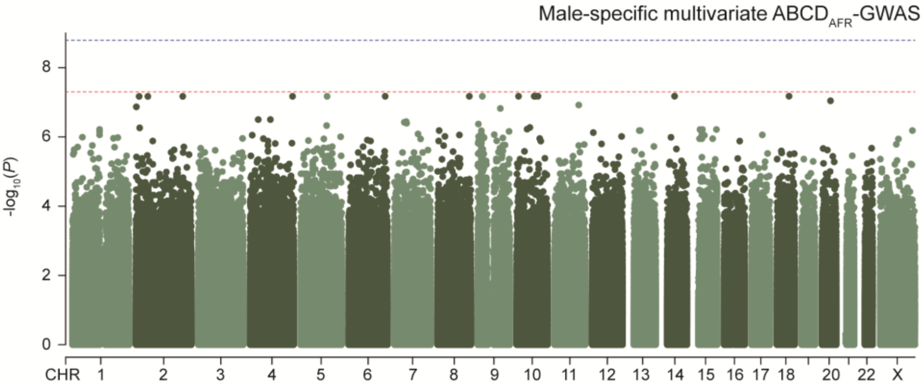




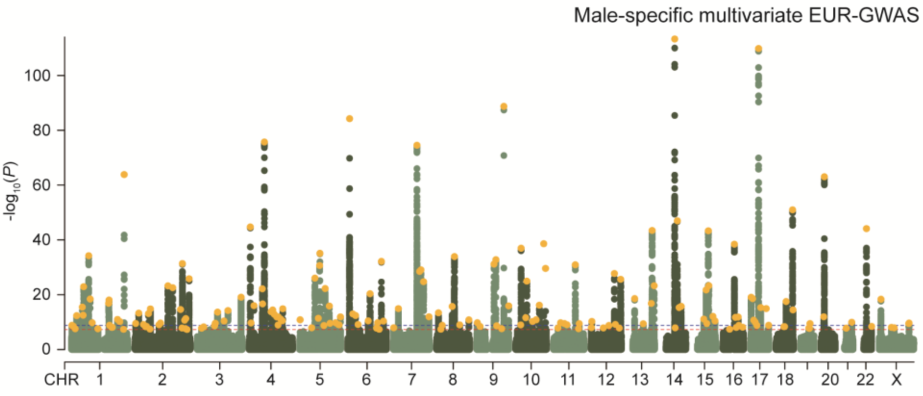
Male-specific multivariate ABCD$_{EUR}$-GWAS



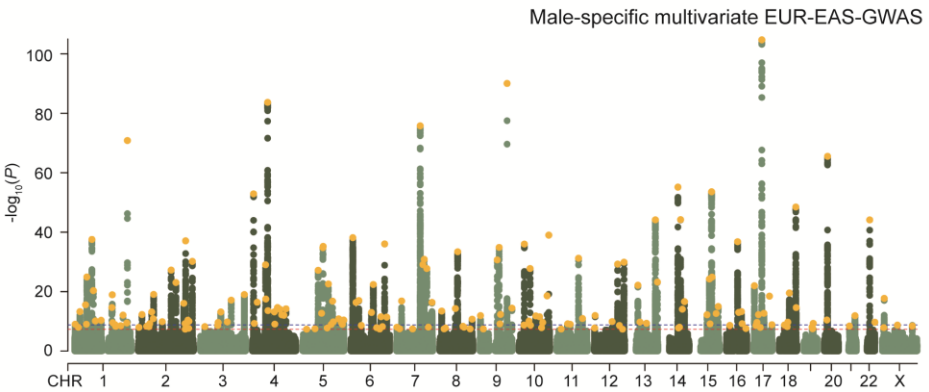
Male-specific multivariate CHIMGEN$_{EAS}$-GWAS

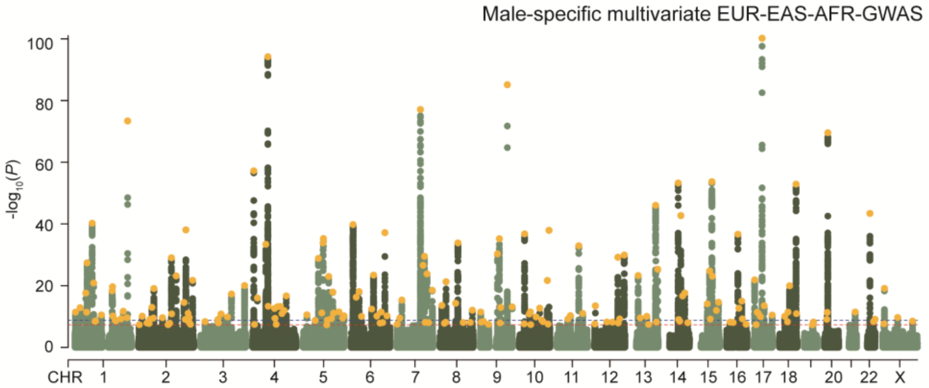


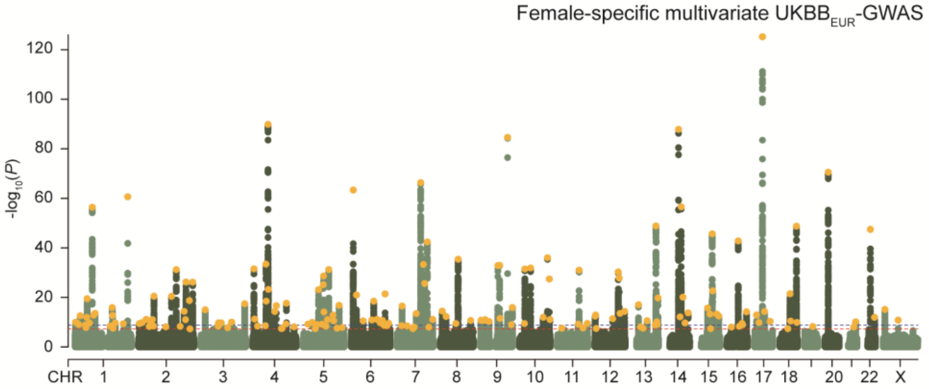
Male-specific multivariate ABCD$_{AFR}$-GWAS

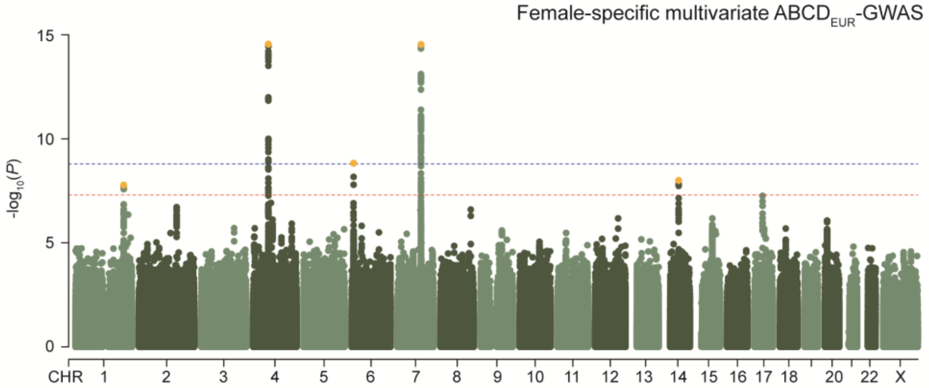


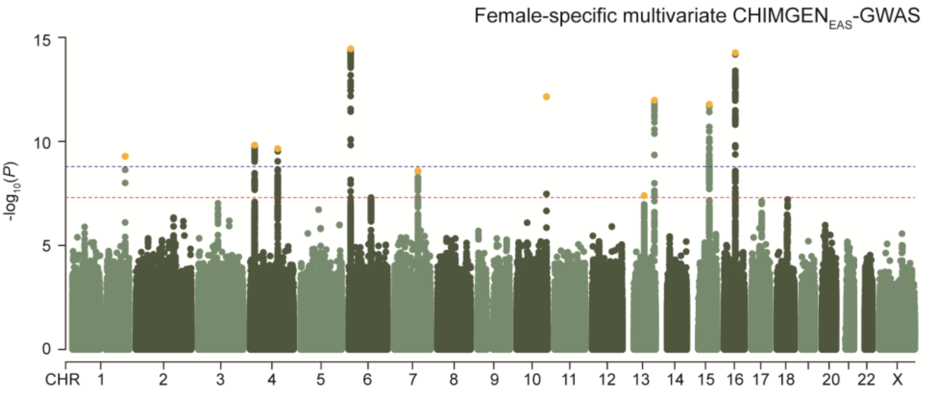
Male-specific multivariate EUR-GWAS

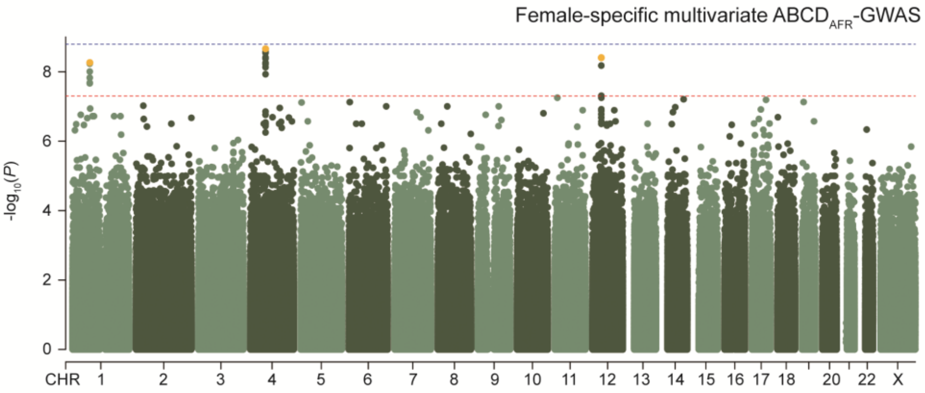

Male-specific multivariate EUR-EAS-GWAS

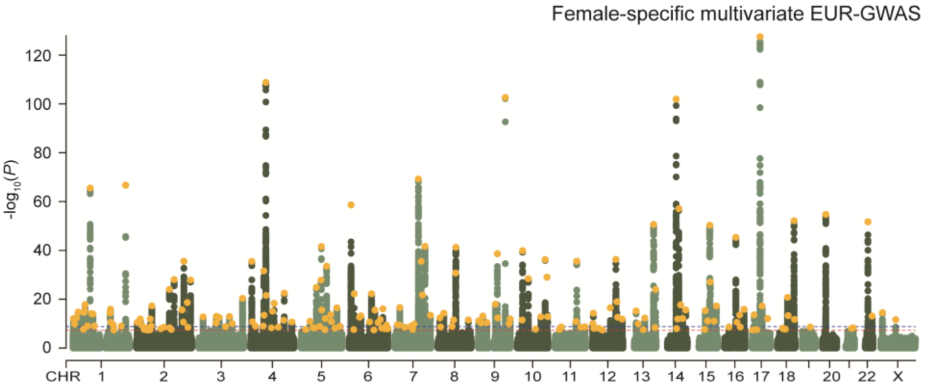

Male-specific multivariate EUR-EAS-AFR-GWAS

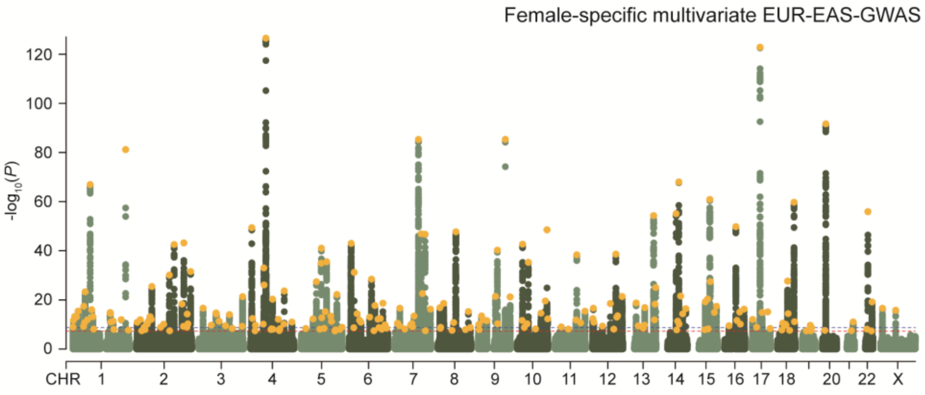

Female-specific multivariate UKBB$_{EUR}$-GWAS


Female-specific multivariate ABCD$_{EUR}$-GWAS


Female-specific multivariate CHIMGEN$_{EAS}$-GWAS


Female-specific multivariate ABCD$_{AFR}$-GWAS


Female-specific multivariate EUR-GWAS


Female-specific multivariate EUR-EAS-GWAS

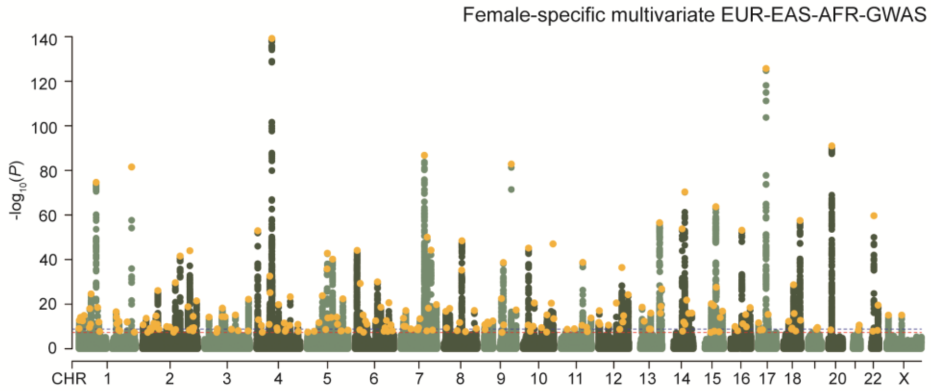


Fig. S6 | Genetic discovery of multivariate GWASs. The Manhattan plots show the results of multivariate GWASs on 27 non-overlapping cerebellar volumetric traits based on sex-combined, male-specific, and female-specific univariate GWASs. Each plot shows both genome-wide (red dashed line: $P = 5 \times 10^{-8}$) and study-wide (blue dashed line: $P = 1.61 \times 10^{-9}$) significance thresholds. Each point represents a single genetic variant plotted according to its genomic position (x axis) and its -log$_{10}$(P) value for the association (y axis). Each yellow point represents an independent locus with genome-wide significant association ($P = 5 \times 10^{-8}$). Abbreviations: ABCD, the Adolescent Brain Cognitive Development study; AFR, African ancestry; CHIMGEN, the Chinese Imaging Genetics study; EAS, East Asian ancestry; EUR, European ancestry; GWAS, genome-wide association study; UKBB, the UK Biobank study.

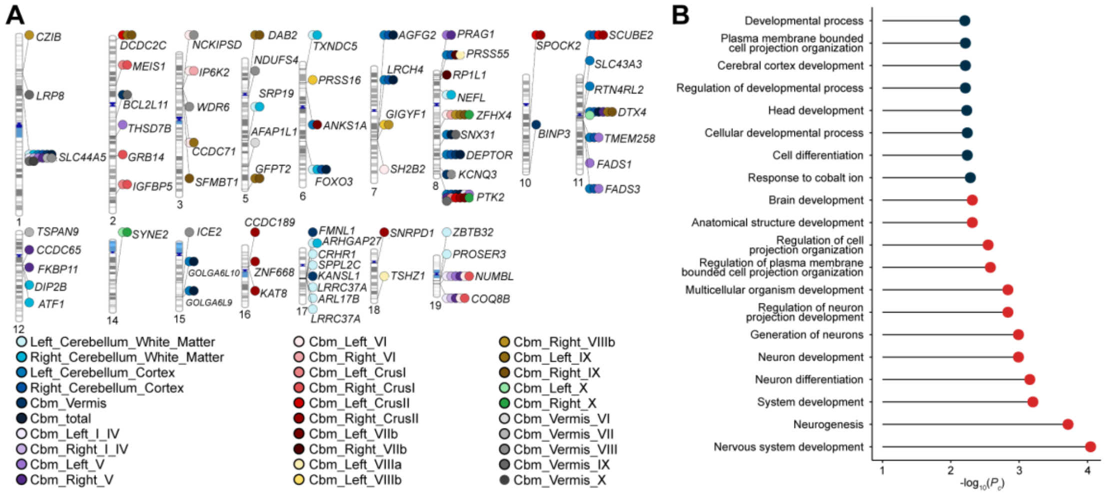


Fig. S7 | Prioritized causal genes and their enriched pathways. (**A**) The ideogram shows the prioritized causal genes identified by the genetic colocalization (PP.H4 > 0.8) analysis between locus-trait associations from EUR-GWASs and eQTLs in cerebellar tissue. (**B**) The Lollipop chart shows the top 20 pathways enriched by the 71 prioritized causal genes. The significant pathways are red colored ($P_c < 0.05$, Benjamini-Hochberg FDR corrected).

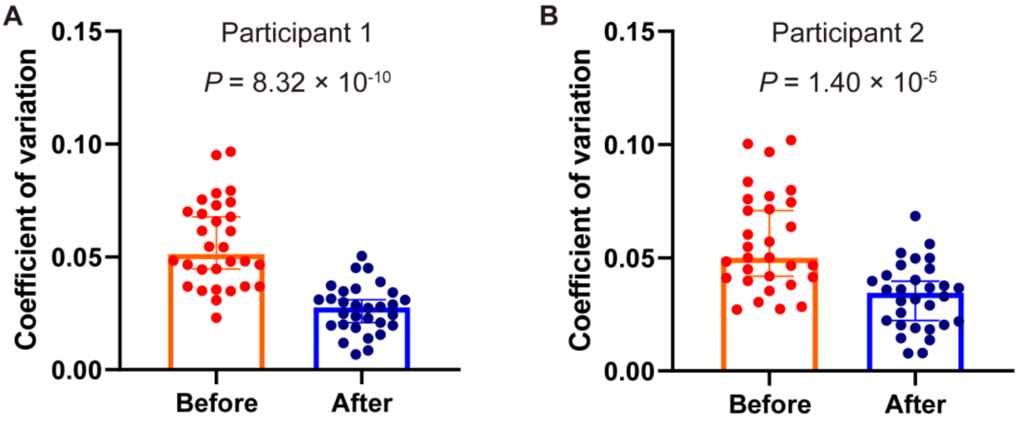


Fig. S8 | Inter-scanner consistency of 30 cerebellar substructure volumes calculated from CerebNet from the same participant before and after Combat harmonization. Two CHIMGEN participants travel to different centers and are scanned with 28 MRI scanners. In each subject, we calculate 30 cerebellar substructure volumes by CerebNet based on the structural MRI data acquired from each scanner and computed CV of each trait across scanners. After applying Combat harmonization to cerebellar substructure volumes, we re-calculate the CV. The Wilcoxon sum rank test is used to investigate the differences in CVs before (red dots) and after (blue dots) harmonization and we found that CVs of all traits before harmonization are reduced after harmonization in both two participants (Wilcoxon rank-sum test, Participant 1: $P = 8.32 \times 10^{-10}$; Participant 2: $P = 1.40 \times 10^{-5}$). The lines indicate the interquartile range of CVs and the box indicate the median of CVs. Abbreviations: CHIMGEN, Chinese imaging genetics; CV, coefficient of variation; MRI, magnetic resonance imaging.