

Brain cell type proportion analysis using BRETIGEA

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1 Background for BRETIGEA

Several comprehensive RNA-seq experiments in different brain cell types have now been published in humans and mice. Some of these experiments have profiled gene expression of cell populations isolated through immunopanning procedures. Immunopanning involves immunoprecipitation of particular cell types in cell culture plates, based on selection for an antibody adsorbed to the plate surface. Others studies have performed RNA profiling of single cells with microfluidics devices and used clustering methods to identify cell types from the resulting RNA expression profiles. The devices used for single cell RNA sequencing (scRNA-seq) often select cells based on size or via encapsulation in a droplet and involve the creation of a cDNA library from the transcriptome from a theoretical maximum of one cell.

Existing studies have been mainly based on individual datasets, and are therefore subject to systematic noise, including sampling bias due to sample collection or preparation technique, as well as stochasticity in gene expression. As an increasing number of RNA-seq cell type-specific transcriptomic experiments have become available for both human and mouse, we set out to conduct a comprehensive meta-analysis of brain cell type gene signatures, which is now published in McKenzie et al (2018), doi:10.1038/s41598-018-27293-5. We created cell type-specific (i.e. marker) gene signatures for six cell types: astrocytes (ast), endothelial cells (end), microglia (mic), neurons (neu), oligodendrocytes (oli), and oligodendrocyte precursor cells (opc). The goal of our cell type specificity measure, which is fully described in our manuscript, is to measure whether a gene is expressed in only one cell type relative to the others.

The five data sets used in the creation of the cell type marker signatures can be found in the manuscript.

2 Introduction to BRETIGEA

A major goal of **BRETIGEA** (BRAIN cELL Type specific Gene Expression Analysis) is to simplify the process of defining your own set of brain cell type marker genes by using a well-validated set of cell type-specific marker genes derived from both immunopanning and single cell microfluidic experiments, as described in McKenzie et al (2018), doi:10.1038/s41598-018-27293-5. There are brain cell type markers available that have been developed from human data, mouse data,, and combinations using data from both species (the default). Notably, if you use your own marker data, the functions in **BRETIGEA** are applicable to bulk gene expression data from any tissue. This vignette shows how you can perform cell type proportion estimation and adjustment on your own bulk gene expression data.

3 Data loading and input format

First, we will load the package and read in example bulk RNA-sequencing data from four brain regions (frontal white matter, temporal cortex, parietal cortex, and hippocampus), which was generated by the Allen Brain Atlas (“Allen Institute for Cell Science. Aging, Dementia and TBI,” n.d.) and filtered to contain primarily brain marker genes. We also will load a data frame with additional immunohistochemistry quantification measurements from each brain sample, to use as a validation of the method.

```
library(BRETIGEA, quietly = TRUE)
library(knitr) #only used for vignette creation
```

Here is the format of the inputs:

```
str(aba_marker_expression, list.len = 5)
```

```
## 'data.frame':   395 obs. of  377 variables:
## $ X488395315: num  0.6557 4.5264 0 0 0.0397 ...
## $ X496100277: num  0.0951 8.8558 0 0 0.0165 ...
## $ X496100278: num  0 4.87 0 0 0 ...
## $ X496100279: num  0 4.85 0 0 0.17 ...
## $ X496100281: num  0 3.6 0 0 0 ...
## [list output truncated]
```

```
str(aba_pheno_data, list.len = 5)
```

```
## 'data.frame':   377 obs. of  4 variables:
## $ structure_acronym.x: chr  "TCx" "FWM" "FWM" "TCx" ...
## $ ihc_iba1_ffpe      : num  0.0371 0.044 0.0465 0.074 0.1124 ...
## $ ihc_gfap_ffpe      : num  0.0218 NA 0.0664 0.0181 0.0756 ...
## $ id                 : chr  "X488395315" "X496100277" "X496100278" "X496100279" ...
```

4 Relative cell type proportion estimation

To run the brain cell type proportion estimation analysis and extract the matrix of surrogate proportion variables for each of the major six brain cell types (astrocytes, endothelial cells, microglia, neurons, oligodendrocytes, and OPCs), run this:

```
ct_res = brainCells(aba_marker_expression, nMarker = 50)
```

```
##      markers cell
## 1      AQP4  ast
## 2      ALDH1L1 ast
```

```

## 3      BMPR1B  ast
## 4      SLC14A1 ast
## 5      MLC1    ast
## 6      FGFR3   ast
## 7      SLC25A18 ast
## 8      GLI3    ast
## 9      GFAP    ast
## 10     ACSBG1  ast
## 11     SLC4A4  ast
## 12     GJA1    ast
## 13     GJB6    ast
## 14     SLC39A12 ast
## 15     AGT     ast
## 16     CHRDL1  ast
## 17     SLC1A2  ast
## 18     CLDN10  ast
## 19     SOX9    ast
## 20     PPP1R3C ast
## [1] "AQP4"      "ALDH1L1"  "BMPR1B"   "SLC14A1"  "MLC1"     "FGFR3"
## [7] "SLC25A18"    "GLI3"     "GFAP"     "ACSBG1"   "SLC4A4"   "GJA1"
## [13] "GJB6"        "SLC39A12" "AGT"      "CHRDL1"   "SLC1A2"   "CLDN10"
## [19] "SOX9"        "PPP1R3C"  "CLU"      "SLC7A10"  "ID4"      "DIO2"
## [25] "SFXN5"       "SLC6A11"  "ATP13A4"  "ACOT11"   "SCARA3"   "ALDOC"
## [31] "PLCD4"       "ATP1B2"   "NTSR2"    "RGS20"    "ELOVL2"   "PAX6"
## [37] "ENTPD2"      "NCAN"     "KIAA1161" "ETNPPL"   "PPAP2B"   "LGR6"
## [43] "GPAM"        "NWD1"     "F3"       "TPPA"     "CBS"      "LIX1"
## [49] "GRIN2C"      "PHKG1"
## [1] "APOLD1"     "EMCN"     "SDPR"     "PTPRB"    "CDH5"     "SLC38A5" "TM4SF1"
## [8] "NOSTRIN"    "CYR1"     "MECOM"    "MYCT1"    "CLDN5"    "ERG"     "ABCB1"
## [15] "ICAM2"      "FN1"      "ESAM"     "ATP10A"   "VWF"      "CD34"    "PODXL"
## [22] "SLC19A3"    "FLT1"     "TBX3"     "HMCN1"    "ITM2A"    "TEK"     "ITGA1"
## [29] "TIE1"       "ADCY4"    "CLIC5"    "ANXA1"    "OCLN"     "PALMD"   "SEMA3G"
## [36] "ABCG2"      "ROB04"    "SLC16A4"  "SLC52A3"  "SOX7"     "SHE"     "CA4"
## [43] "EBF1"       "CD93"     "KDR"      "SLC2A1"   "PTRF"     "LEF1"    "HIGD1B"
## [50] "FOXF2"
## [1] "CCL3"       "CCL4"     "CD14"     "C1QB"     "IL1A"     "TREM2"   "GPR183"
## [8] "CD83"       "SLC2A5"   "C1QC"     "NCKAP1L"  "CSF1R"    "CD300A"  "FCGR2A"
## [15] "LAPTM5"     "HAVCR2"   "C3AR1"    "CX3CR1"   "PTAFR"    "C1QA"    "FCGR1A"
## [22] "SELPLG"     "PLEK"     "CTSS"     "CSF3R"    "TYROBP"   "SLA"     "PTPN6"
## [29] "TLR2"       "CD86"     "GPR84"    "LYZ"      "MPEG1"    "BCL2A1"  "ITGAM"
## [36] "CD53"       "IRF8"     "IL10RA"   "GPR34"    "AIF1"     "CD74"    "PTPRC"
## [43] "RHOH"       "BLNK"     "TLR1"     "C5AR1"    "FCER1G"   "DOCK2"   "RGS1"
## [50] "ALOX5AP"
## [1] "RELN"       "VIP"      "GAD2"     "TAC3"     "DLX1"     "PENK"
## [7] "SYT1"       "TMEM130"  "GAD1"     "SYNPR"    "STMN2"    "GABRG2"
## [13] "GPR83"      "SST"      "ZMAT4"    "SNAP25"   "RAB3C"    "NELL1"
## [19] "SCG2"       "SYT4"     "CNR1"     "CLSTN2"   "SPHKAP"   "KCNQ5"
## [25] "PNOC"       "ROB02"    "KCNC2"    "GALNTL6"  "VSNL1"    "GRIN2A"
## [31] "GABRA1"     "CHGB"     "SRRM4"    "ZNF804A"  "KIAA1324" "BCL11A"
## [37] "SV2B"       "HTR3A"    "NPY"      "PRMT8"    "CNTNAP2"  "GLRA2"
## [43] "SLC12A5"    "SLC17A6"  "CRH"      "GRIA1"    "GDA"      "INA"
## [49] "RGS8"       "CELF4"
## [1] "PLP1"       "CLDN11"   "ERMN"     "UGT8"     "MOG"      "MOBP"
## [7] "MAG"        "MBP"      "OPALIN"   "GJB1"     "MYRF"     "KLK6"

```

```

## [13] "FA2H"      "CNP"      "ENPP6"    "LPAR1"    "ERBB3"    "TMEM125"
## [19] "ANLN"      "ASPA"     "QDPR"     "S1PR5"    "ENPP2"    "NIPAL4"
## [25] "MAL"       "BCAS1"    "CRYAB"    "LGI3"     "SGK2"     "GPR37"
## [31] "HHIP"      "SLAIN1"   "TMEM88B"  "CNTN2"    "NINJ2"    "ST18"
## [37] "MAP6D1"    "PLEKHH1"  "PRR18"    "TF"       "TRIM59"   "PEX5L"
## [43] "HAPLN2"    "GJC2"     "GJC3"     "SEPT4"    "PPP1R14A" "GPR62"
## [49] "SEC14L5"   "GAL3ST1"
## [1] "PDGFRA"    "SHC4"     "MATN4"    "TNR"      "PNLIP"    "PCDH15"
## [7] "FAM180A"   "NEU4"     "LHFPL3"   "CHST6"    "MEGF11"   "OLIG1"
## [13] "GPR17"     "RNF43"    "RBPJL"    "UGT8"     "PMEL"     "SOX10"
## [19] "GAL3ST1"   "SULF2"    "CCNB1"    "MYT1"     "ACAN"     "XYLT1"
## [25] "CSPG4"     "C1QL1"    "CKAP2"    "GJC3"     "TOP2A"    "PRKG2"
## [31] "BCAS1"     "SAPCD2"   "ZNF488"   "LRRN1"    "TMEM255B" "S100A3"
## [37] "PBK"       "SUSD5"    "STK32A"   "SULF1"    "PRKCQ"    "DPYD"
## [43] "GPSM2"     "LAD1"     "UGDH"     "CKAP2L"   "GJB1"     "EMID1"
## [49] "TGFA"      "ADAM12"
##          AQP4      ALDH1L1    BMPR1B     SLC14A1     MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##          SLC25A18    GLI3      GFAP      ACSBG1     SLC4A4     GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##          SLC39A12    AGT      CHRDL1    SLC1A2     CLDN10     SOX9      PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##          CLU      SLC7A10    ID4      DIO2      SFXN5     SLC6A11    ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11     SCARA3    ALDOC     PLCD4     ATP1B2     NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2     PAX6      ENTPD2     NCAN     KIAA1161    ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B     LGR6      GPAM      NWD1      F3         TTPA       CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##          LIX1      GRIN2C    PHKG1
## [1,] -0.8404202 -0.2054718 -0.7618352
##          APOLD1     EMCN      SDPR      PTPRB     CDH5      SLC38A5
## [1,] -0.6397974 -0.5150059 -0.5503207 -0.4286219 -0.7509274 -0.2792929
##          TM4SF1     NOSTRIN   CYR1      MECOM     MYCT1     CLDN5
## [1,] -0.5732277 -0.5492278 -0.5233367 -0.6553751 -0.4798552 -0.6769395
##          ERG      ABCB1     ICAM2     FN1      ESAM      ATP10A
## [1,] -0.5483382 -0.5187547 -0.6892712 -0.6866703 -0.5985029 -0.386112
##          VWF      CD34      PODXL     SLC19A3    FLT1      TBX3
## [1,] -0.6532856 -0.4892499 -0.6865958 -0.3100597 -0.682325 -0.4185505
##          HMCN1     ITM2A     TEK      ITGA1     TIE1      ADCY4
## [1,] -0.4729641 -0.404837 -0.4247323 -0.6994108 -0.4460777 -0.5100022
##          CLIC5     ANXA1     OCLN     PALMD     SEMA3G     ABCG2
## [1,] -0.2212121 -0.4021003 -0.1725926 -0.4391917 -0.5039709 -0.4910518
##          ROBO4     SLC16A4    SLC52A3    SOX7      SHE       CA4
## [1,] -0.4063845 -0.2065062 -0.4868766 -0.3217972 -0.6208689 0.1057804
##          EBF1      CD93      KDR      SLC2A1     PTRF      LEF1
## [1,] -0.4929378 -0.4586119 -0.4572021 -0.6991769 -0.4608555 -0.1165776
##          HIGD1B     FOXF2
## [1,] -0.1667598 -0.1962837
##          CCL3      CCL4      CD14      C1QB     IL1A      TREM2      GPR183
## [1,] -0.009014479 0.02049567 0.6772439 0.9027497 0.147061 0.8121957 0.6689415
##          CD83      SLC2A5     C1QC     NCKAP1L    CSF1R     CD300A     FCGR2A
## [1,] -0.3230165 0.882668 0.9215579 0.924154 0.7685014 0.8795061 0.8366178

```

```

##          LAPTM5      HAVCR2      C3AR1      CX3CR1      PTAFR      C1QA      FCGR1A
## [1,] 0.9474317 0.8554602 0.8224433 0.3634809 0.7619302 0.8550013 0.6713506
##          SELPLG      PLEK      CTSS      CSF3R      TYROBP      SLA      PTPN6
## [1,] 0.5294624 0.6737376 0.8570066 0.7479062 0.9002925 0.8394877 0.8757021
##          TLR2      CD86      GPR84      LYZ      MPEG1      BCL2A1      ITGAM
## [1,] 0.8563525 0.8670868 0.3866831 0.5769851 0.3112844 0.5858728 0.8377073
##          CD53      IRF8      IL10RA      GPR34      AIF1      CD74      PTPRC
## [1,] 0.8110169 0.7524594 0.8152008 0.6202537 0.8964808 0.9569894 0.9488961
##          RHOH      BLNK      TLR1      C5AR1      FCER1G      DOCK2      RGS1
## [1,] 0.3987691 0.6580784 0.8748194 0.5982698 0.8581698 0.8865086 0.6465002
##          ALOX5AP
## [1,] 0.8643056
##          RELN      VIP      GAD2      TAC3      DLX1      PENK      SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##          TMEM130      GAD1      SYNPR      STMN2      GABRG2      GPR83      SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748
##          ZMAT4      SNAP25      RAB3C      NELL1      SCG2      SYT4      CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##          CLSTN2      SPHKAP      KCNQ5      PNOG      ROBO2      KCNC2      GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1      GRIN2A      GABRA1      CHGB      SRRM4      ZNF804A      KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##          BCL11A      SV2B      HTR3A      NPY      PRMT8      CNTNAP2      GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##          SLC12A5      SLC17A6      CRH      GRIA1      GDA      INA      RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##          PLP1      CLDN11      ERMN      UGT8      MOG      MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##          MAG      MBP      OPALIN      GJB1      MYRF      KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##          FA2H      CNP      ENPP6      LPAR1      ERBB3      TMEM125      ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##          ASPA      QDPR      S1PR5      ENPP2      NIPAL4      MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
##          BCAS1      CRYAB      LGI3      SGK2      GPR37      HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1      TMEM88B      CNTN2      NINJ2      ST18      MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##          PLEKHH1      PRR18      TF      TRIM59      PEX5L      HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##          GJC2      GJC3      SEPT4      PPP1R14A      GPR62      SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##          GAL3ST1
## [1,] -0.8845151
##          PDGFRA      SHC4      MATN4      TNF      PNLIP      PCDH15
## [1,] -0.6594077 -0.8876408 -0.009790091 -0.2148693 -0.04108205 -0.1075733
##          FAM180A      NEU4      LHFPL3      CHST6      MEGF11      OLIG1
## [1,] -0.2698467 -0.2856533 -0.5938882 -0.6238268 -0.1090868 -0.8296958
##          GPR17      RNF43      RBPJL      UGT8      PMEL      SOX10      GAL3ST1
## [1,] -0.5917444 0.435638 0.1101175 -0.8814859 0.05653651 -0.8517942 -0.8665949
##          SULF2      CCNB1      MYT1      ACAN      XYLT1      CSPG4      C1QL1
## [1,] 0.1274339 0.4931099 -0.6166283 -0.1083521 0.1532883 -0.7196438 -0.336823

```

```
##          CKAP2      GJC3      TOP2A      PRKG2      BCAS1      SAPCD2      ZNF488
## [1,] 0.6525218 0.1210485 0.0195238 0.4824663 -0.9974827 -0.6061126 -0.4965659
##          LRRN1      TMEM255B      S100A3      PBK      SUSP5      STK32A      SULF1
## [1,] 0.426307 -0.07905286 -0.09222221 0.01888503 0.3814492 -0.3316909 -0.291499
##          PRKCQ      DPYD      GPSM2      LAD1      UGDH      CKAP2L
## [1,] -0.8390872 -0.8863703 -0.9110727 -0.07256941 -0.06724674 -0.05768831
##          GJB1      EMID1      TGFA      ADAM12
## [1,] -0.83458 -0.1593035 -0.8341445 -0.4069115
```

```
kable(head(ct_res))
```

| | ast | end | mic | neu | oli | opc |
|------------|------------|------------|------------|------------|------------|------------|
| X488395315 | -0.0409765 | -0.0468875 | -0.0249076 | 0.0226400 | -0.0194737 | -0.0287028 |
| X496100277 | 0.0391782 | 0.0090563 | -0.0012271 | -0.1361360 | 0.1323645 | 0.1322346 |
| X496100278 | 0.0742051 | 0.0864415 | 0.1158266 | -0.1360790 | 0.1534334 | 0.1555192 |
| X496100279 | -0.0091306 | -0.0055174 | 0.0103811 | 0.0680277 | -0.0194953 | -0.0216833 |
| X496100281 | 0.1136897 | -0.0070804 | 0.0825388 | 0.0116946 | -0.0243035 | -0.0278465 |
| X496100283 | -0.0440731 | -0.0263346 | -0.0356047 | 0.0449777 | -0.0220543 | -0.0188682 |

4.1 Selecting the *nMarker* parameter

Note that the above analysis uses $nMarker = 50$ marker genes. A notable trade-off in the selection of the number of marker genes to include in the analysis is that the more marker genes you use, the more likely you are to average out any cell type-specific expression changes that may occur across groups in your sample. On the other hand, the fewer marker genes you use, the higher-quality these marker genes will tend to be in terms of strength of cell type specificity. We have chose $nMarker = 50$ because it has been a reasonable number in our experince, but the goals of your analysis may differ and you may want to choose a different number of marker genes for each cell type.

Note that only marker genes which have been measured in your data set will be used by the cell type proportion estimates, so if your data set has fewer gene measurements (e.g., in a proteomics data set), that may be a reason to use fewer marker genes.

Comparing these cell type proportion estimates to the independent immunohistochemistry quantifications of two marker genes (IBA1 and GFAP), you can see that the correlation is strong.

```
cor_mic = cor.test(ct_res[, "mic"], as.numeric(aba_pheno_data$ihc_iba1_ffpe),
  method = "spearman")
print(cor_mic)
```

```
##
## Spearman's rank correlation rho
##
## data: ct_res[, "mic"] and as.numeric(aba_pheno_data$ihc_iba1_ffpe)
## S = 5350838, p-value = 1.729e-10
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
## rho
## 0.328793
```

```
cor_ast = cor.test(ct_res[, "ast"], as.numeric(aba_pheno_data$ihc_gfap_ffpe),
  method = "spearman")
print(cor_ast)
```

```
##
```

```
## Spearman's rank correlation rho
##
## data: ct_res[, "ast"] and as.numeric(aba_pheno_data$ihc_gfap_ffpe)
## S = 3591868, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## 0.4751708
```

The default cell type proportion estimation method is singular value decomposition, but if you want to use PCA, that is an option as well.

```
ct_res = brainCells(aba_marker_expression, nMarker = 50, species = "combined",
  method = "PCA")
```

```
##      markers cell
## 1      AQP4  ast
## 2    ALDH1L1  ast
## 3     BMPR1B  ast
## 4    SLC14A1  ast
## 5      MLC1  ast
## 6     FGFR3  ast
## 7  SLC25A18  ast
## 8      GLI3  ast
## 9      GFAP  ast
## 10   ACSBG1  ast
## 11   SLC4A4  ast
## 12     GJA1  ast
## 13     GJB6  ast
## 14 SLC39A12  ast
## 15      AGT  ast
## 16   CHRDL1  ast
## 17   SLC1A2  ast
## 18   CLDN10  ast
## 19     SOX9  ast
## 20  PPP1R3C  ast
## [1] "AQP4"      "ALDH1L1"    "BMPR1B"     "SLC14A1"    "MLC1"       "FGFR3"
## [7] "SLC25A18"    "GLI3"       "GFAP"       "ACSBG1"     "SLC4A4"     "GJA1"
## [13] "GJB6"        "SLC39A12"   "AGT"        "CHRDL1"     "SLC1A2"     "CLDN10"
## [19] "SOX9"        "PPP1R3C"    "CLU"        "SLC7A10"    "ID4"        "DIO2"
## [25] "SFXN5"       "SLC6A11"    "ATP13A4"    "ACOT11"     "SCARA3"     "ALDOC"
## [31] "PLCD4"       "ATP1B2"     "NTSR2"      "RGS20"      "ELOVL2"     "PAX6"
## [37] "ENTPD2"      "NCAN"       "KIAA1161"   "ETNPPL"     "PPAP2B"     "LGR6"
## [43] "GPAM"        "NWD1"       "F3"         "TPPA"       "CBS"        "LIX1"
## [49] "GRIN2C"      "PHKG1"
## [1] "APOLD1"     "EMCN"       "SDPR"       "PTPRB"      "CDH5"       "SLC38A5"  "TM4SF1"
## [8] "NOSTRIN"    "CYR1"       "MECOM"      "MYCT1"      "CLDN5"      "ERG"       "ABCB1"
## [15] "ICAM2"      "FN1"        "ESAM"       "ATP10A"     "VWF"        "CD34"      "PODXL"
## [22] "SLC19A3"    "FLT1"       "TBX3"       "HMCN1"      "ITM2A"      "TEK"       "ITGA1"
## [29] "TIE1"       "ADCY4"      "CLIC5"      "ANXA1"      "OCLN"       "PALMD"     "SEMA3G"
## [36] "ABCG2"      "ROB04"      "SLC16A4"    "SLC52A3"    "SOX7"       "SHE"       "CA4"
## [43] "EBF1"       "CD93"       "KDR"        "SLC2A1"     "PTRF"       "LEF1"      "HIGD1B"
## [50] "FOXF2"
## [1] "CCL3"       "CCL4"       "CD14"       "C1QB"       "IL1A"       "TREM2"     "GPR183"
## [8] "CD83"       "SLC2A5"     "C1QC"       "NCKAP1L"    "CSF1R"      "CD300A"    "FCGR2A"
```

```

## [15] "LAPTM5" "HAVCR2" "C3AR1" "CX3CR1" "PTAFR" "C1QA" "FCGR1A"
## [22] "SELPLG" "PLEK" "CTSS" "CSF3R" "TYROBP" "SLA" "PTPN6"
## [29] "TLR2" "CD86" "GPR84" "LYZ" "MPEG1" "BCL2A1" "ITGAM"
## [36] "CD53" "IRF8" "IL10RA" "GPR34" "AIF1" "CD74" "PTPRC"
## [43] "RHOH" "BLNK" "TLR1" "C5AR1" "FCER1G" "DOCK2" "RGS1"
## [50] "ALOX5AP"
## [1] "RELN" "VIP" "GAD2" "TAC3" "DLX1" "PENK"
## [7] "SYT1" "TMEM130" "GAD1" "SYNPR" "STMN2" "GABRG2"
## [13] "GPR83" "SST" "ZMAT4" "SNAP25" "RAB3C" "NELL1"
## [19] "SCG2" "SYT4" "CNR1" "CLSTN2" "SPHKAP" "KCNQ5"
## [25] "PNOC" "ROBO2" "KCNC2" "GALNTL6" "VSNL1" "GRIN2A"
## [31] "GABRA1" "CHGB" "SRRM4" "ZNF804A" "KIAA1324" "BCL11A"
## [37] "SV2B" "HTR3A" "NPY" "PRMT8" "CNTNAP2" "GLRA2"
## [43] "SLC12A5" "SLC17A6" "CRH" "GRIA1" "GDA" "INA"
## [49] "RGS8" "CELF4"
## [1] "PLP1" "CLDN11" "ERMN" "UGT8" "MOG" "MOBP"
## [7] "MAG" "MBP" "OPALIN" "GJB1" "MYRF" "KLK6"
## [13] "FA2H" "CNP" "ENPP6" "LPAR1" "ERBB3" "TMEM125"
## [19] "ANLN" "ASPA" "QDPR" "S1PR5" "ENPP2" "NIPAL4"
## [25] "MAL" "BCAS1" "CRYAB" "LGI3" "SGK2" "GPR37"
## [31] "HHIP" "SLAIN1" "TMEM88B" "CNTN2" "NINJ2" "ST18"
## [37] "MAP6D1" "PLEKHH1" "PRR18" "TF" "TRIM59" "PEX5L"
## [43] "HAPLN2" "GJC2" "GJC3" "SEPT4" "PPP1R14A" "GPR62"
## [49] "SEC14L5" "GAL3ST1"
## [1] "PDGFRA" "SHC4" "MATN4" "TNR" "PNLIP" "PCDH15"
## [7] "FAM180A" "NEU4" "LHFPL3" "CHST6" "MEGF11" "OLIG1"
## [13] "GPR17" "RNF43" "RBPJL" "UGT8" "PMEL" "SOX10"
## [19] "GAL3ST1" "SULF2" "CCNB1" "MYT1" "ACAN" "XYLT1"
## [25] "CSPG4" "C1QL1" "CKAP2" "GJC3" "TOP2A" "PRKG2"
## [31] "BCAS1" "SAPCD2" "ZNF488" "LRRN1" "TMEM255B" "S100A3"
## [37] "PBK" "SUSD5" "STK32A" "SULF1" "PRKCQ" "DPYD"
## [43] "GPSM2" "LAD1" "UGDH" "CKAP2L" "GJB1" "EMID1"
## [49] "TGFA" "ADAM12"
## AQP4 ALDH1L1 BMPR1B SLC14A1 MLC1 FGFR3 SLC25A18
## [1,] 0.7958953 0.07419527 0.4061147 0.6875915 0.7476287 0.2868527 0.302239
## GLI3 GFAP ACSBG1 SLC4A4 GJA1 GJB6 SLC39A12
## [1,] 0.4204516 0.9999001 0.2077684 -0.09074864 0.5208035 -0.5028409 0.1784168
## AGT CHRDL1 SLC1A2 CLDN10 SOX9 PPP1R3C CLU
## [1,] 0.7350907 -0.6087144 -0.3359356 -0.3455259 0.5681326 0.1791119 0.5938866
## SLC7A10 ID4 DIO2 SFXN5 SLC6A11 ATP13A4 ACOT11
## [1,] -0.110352 0.6952727 -0.2188643 -0.1894126 -0.5592311 0.3663146 0.1992575
## SCARA3 ALDOC PLCD4 ATP1B2 NTSR2 RGS20 ELOVL2
## [1,] 0.2338075 -0.1107247 -0.5112359 0.1778165 0.4740656 0.1526715 0.1147339
## PAX6 ENTPD2 NCAN KIAA1161 ETNPPL PPAP2B LGR6
## [1,] 0.5797094 0.7823284 0.05518203 -0.1721708 0.3264465 0.5024131 0.0444335
## GPAM NWD1 F3 TTPA CBS LIX1 GRIN2C
## [1,] -0.159156 0.430843 0.1665845 0.3924951 0.2509145 0.8404202 0.2054718
## PHKG1
## [1,] 0.7618352
## APOLD1 EMCN SDPR PTPRB CDH5 SLC38A5 TM4SF1
## [1,] 0.6397974 0.5150059 0.5503207 0.4286219 0.7509274 0.2792929 0.5732277
## NOSTRIN CYR1 MECOM MYCT1 CLDN5 ERG ABCB1
## [1,] 0.5492278 0.5233367 0.6553751 0.4798552 0.6769395 0.5483382 0.5187547
## ICAM2 FN1 ESAM ATP10A VWF CD34 PODXL

```



```

## [1,] 0.6892712 0.6866703 0.5985029 0.386112 0.6532856 0.4892499 0.6865958
##          SLC19A3      FLT1      TBX3      HMCN1      ITM2A      TEK      ITGA1
## [1,] 0.3100597 0.682325 0.4185505 0.4729641 0.404837 0.4247323 0.6994108
##          TIE1      ADCY4      CLIC5      ANXA1      OCLN      PALMD      SEMA3G
## [1,] 0.4460777 0.5100022 0.2212121 0.4021003 0.1725926 0.4391917 0.5039709
##          ABCG2      ROB04      SLC16A4      SLC52A3      SOX7      SHE      CA4
## [1,] 0.4910518 0.4063845 0.2065062 0.4868766 0.3217972 0.6208689 -0.1057804
##          EBF1      CD93      KDR      SLC2A1      PTRF      LEF1      HIGD1B
## [1,] 0.4929378 0.4586119 0.4572021 0.6991769 0.4608555 0.1165776 0.1667598
##          FOXF2
## [1,] 0.1962837
##          CCL3      CCL4      CD14      C1QB      IL1A      TREM2
## [1,] 0.009014479 -0.02049567 -0.6772439 -0.9027497 -0.147061 -0.8121957
##          GPR183      CD83      SLC2A5      C1QC      NCKAP1L      CSF1R      CD300A
## [1,] -0.6689415 0.3230165 -0.882668 -0.9215579 -0.924154 -0.7685014 -0.8795061
##          FCGR2A      LAPTM5      HAVCR2      C3AR1      CX3CR1      PTAFR
## [1,] -0.8366178 -0.9474317 -0.8554602 -0.8224433 -0.3634809 -0.7619302
##          C1QA      FCGR1A      SELPLG      PLEK      CTSS      CSF3R
## [1,] -0.8550013 -0.6713506 -0.5294624 -0.6737376 -0.8570066 -0.7479062
##          TYROBP      SLA      PTPN6      TLR2      CD86      GPR84
## [1,] -0.9002925 -0.8394877 -0.8757021 -0.8563525 -0.8670868 -0.3866831
##          LYZ      MPEG1      BCL2A1      ITGAM      CD53      IRF8
## [1,] -0.5769851 -0.3112844 -0.5858728 -0.8377073 -0.8110169 -0.7524594
##          IL10RA      GPR34      AIF1      CD74      PTPRC      RHOH
## [1,] -0.8152008 -0.6202537 -0.8964808 -0.9569894 -0.9488961 -0.3987691
##          BLNK      TLR1      C5AR1      FCER1G      DOCK2      RGS1
## [1,] -0.6580784 -0.8748194 -0.5982698 -0.8581698 -0.8865086 -0.6465002
##          ALOX5AP
## [1,] -0.8643056
##          RELN      VIP      GAD2      TAC3      DLX1      PENK
## [1,] 0.1166803 -0.6135118 -0.8276635 -0.7295642 -0.7836934 -0.4386146
##          SYT1      TMEM130      GAD1      SYNPR      STMN2      GABRG2
## [1,] -0.9587805 -0.6442915 -0.8571033 -0.5407849 -0.954468 -0.9428849
##          GPR83      SST      ZMAT4      SNAP25      RAB3C      NELL1
## [1,] -0.4040754 -0.1924748 -0.8855612 -0.9937954 -0.7968844 -0.8839205
##          SCG2      SYT4      CNR1      CLSTN2      SPHKAP      KCNQ5      PNOG
## [1,] -0.579349 -0.9400202 -0.4062468 -0.3223093 0.1236097 -0.9203101 -0.4488496
##          ROB02      KCNC2      GALNTL6      VSNL1      GRIN2A      GABRA1
## [1,] -0.8036322 -0.8932601 -0.7152115 -0.8592326 -0.8891878 -0.9103732
##          CHGB      SRRM4      ZNF804A      KIAA1324      BCL11A      SV2B      HTR3A
## [1,] -0.141477 -0.8110747 -0.3509051 -0.6024863 -0.742308 -0.9386318 -0.1299354
##          NPY      PRMT8      CNTNAP2      GLRA2      SLC12A5      SLC17A6      CRH
## [1,] 0.2984589 -0.80817 -0.9295066 -0.6637972 -0.9034275 -0.7684521 -0.4350317
##          GRIA1      GDA      INA      RGS8      CELF4
## [1,] -0.05161995 -0.7713854 -0.8972024 -0.1695003 -0.8067627
##          PLP1      CLDN11      ERMN      UGT8      MOG      MOBP      MAG
## [1,] 0.9305459 0.8798909 0.9359872 0.8949407 0.9124765 0.9624925 0.9200603
##          MBP      OPALIN      GJB1      MYRF      KLK6      FA2H      CNP
## [1,] 0.9924521 0.7476423 0.8302352 0.9282941 0.9099573 0.9222307 0.9139697
##          ENPP6      LPAR1      ERBB3      TMEM125      ANLN      ASPA      QDPR
## [1,] 0.8174142 0.9629297 0.920759 0.8009576 0.884949 0.9246854 0.8106579
##          S1PR5      ENPP2      NIPAL4      MAL      BCAS1      CRYAB      LGI3
## [1,] 0.9338734 0.931507 0.8928996 0.9135844 0.9744962 0.7663222 0.5304539
##          SGK2      GPR37      HHIP      SLAIN1      TMEM88B      CNTN2      NINJ2

```

```
## [1,] 0.8293518 0.8947933 0.8194185 0.8955728 0.6271867 0.932188 0.8435802
##          ST18      MAP6D1      PLEKHH1      PRR18          TF      TRIM59      PEX5L
## [1,] 0.9443919 0.8858248 0.9312008 0.8960713 0.9043357 0.875323 0.7511829
##          HAPLN2      GJC2          GJC3      SEPT4      PPP1R14A      GPR62      SEC14L5
## [1,] 0.8260379 0.8721555 -0.1293849 0.9596247 0.8221449 0.8587124 0.8569685
##          GAL3ST1
## [1,] 0.8845151
##          PDGFRA      SHC4          MATN4          TNFR          PNLIP      PCDH15      FAM180A
## [1,] 0.6594077 0.8876408 0.009790091 0.2148693 0.04108205 0.1075733 0.2698467
##          NEU4      LHFPL3      CHST6      MEGF11      OLIG1      GPR17      RNF43
## [1,] 0.2856533 0.5938882 0.6238268 0.1090868 0.8296958 0.5917444 -0.435638
##          RBPJL      UGT8          PMEL      SOX10      GAL3ST1      SULF2      CCNB1
## [1,] -0.1101175 0.8814859 -0.05653651 0.8517942 0.8665949 -0.1274339 -0.4931099
##          MYT1      ACAN      XYLT1      CSPG4      C1QL1      CKAP2      GJC3
## [1,] 0.6166283 0.1083521 -0.1532883 0.7196438 0.336823 -0.6525218 -0.1210485
##          TOP2A      PRKG2      BCAS1      SAPCD2      ZNF488      LRRN1      TMEM255B
## [1,] -0.0195238 -0.4824663 0.9974827 0.6061126 0.4965659 -0.426307 0.07905286
##          S100A3      PBK      SUSDS      STK32A      SULF1      PRKCQ      DPYD
## [1,] 0.09222221 -0.01888503 -0.3814492 0.3316909 0.291499 0.8390872 0.8863703
##          GPSM2      LAD1      UGDH      CKAP2L      GJB1      EMID1      TGFA
## [1,] 0.9110727 0.07256941 0.06724674 0.05768831 0.83458 0.1593035 0.8341445
##          ADAM12
## [1,] 0.4069115
```

```
kable(head(ct_res))
```

| | ast | end | mic | neu | oli | opc |
|------------|-----------|------------|------------|------------|-----------|-----------|
| X488395315 | -772.2007 | -11.216558 | -27.520538 | 117.72323 | -652.7520 | -52.75793 |
| X496100277 | 738.3115 | 2.166464 | -1.355803 | -707.87803 | 4436.8175 | 243.05687 |
| X496100278 | 1398.3931 | 20.678778 | 127.977252 | -707.58137 | 5143.0376 | 285.85561 |
| X496100279 | -172.0668 | -1.319885 | 11.470150 | 353.72941 | -653.4776 | -39.85540 |
| X496100281 | 2142.4780 | -1.693788 | 91.197438 | 60.80918 | -814.6443 | -51.18396 |
| X496100283 | -830.5568 | -6.299840 | -39.339784 | 233.87439 | -739.2522 | -34.68110 |

The *species* argument controls which species the marker genes are derived from, and can be set to “human” and “mouse” for data specific to those species.

If you want to only estimate the proportion of particular cell types, you can do so by setting the *celltypes* argument. Here, we only estimate the proportions of astrocytes, neurons, and oligodendrocytes. Note that the estimates of each cell type is done independently, so choosing to estimate the proportions of one cell type or not will not affect the estimates of the other cell types.

```
ct_res = brainCells(aba_marker_expression, nMarker = 50, species = "combined",
  celltypes = c("ast", "neu", "oli"))
```

```
##      markers cell
## 1      AQP4  ast
## 2    ALDH1L1  ast
## 3    BMPR1B  ast
## 4    SLC14A1  ast
## 5      MLC1  ast
## 6     FGFR3  ast
## 7    SLC25A18  ast
## 8      GLI3  ast
```

```

## 9      GFAP  ast
## 10     ACSBG1 ast
## 11     SLC4A4 ast
## 12      GJA1 ast
## 13      GJB6 ast
## 14 SLC39A12 ast
## 15      AGT  ast
## 16     CHRDL1 ast
## 17     SLC1A2 ast
## 18     CLDN10 ast
## 19      SOX9 ast
## 20 PPP1R3C ast
## [1] "AQP4"      "ALDH1L1"    "BMPR1B"     "SLC14A1"    "MLC1"       "FGFR3"
## [7] "SLC25A18"    "GLI3"       "GFAP"       "ACSBG1"     "SLC4A4"     "GJA1"
## [13] "GJB6"        "SLC39A12"   "AGT"        "CHRDL1"     "SLC1A2"     "CLDN10"
## [19] "SOX9"        "PPP1R3C"    "CLU"        "SLC7A10"    "ID4"        "DIO2"
## [25] "SFXN5"       "SLC6A11"    "ATP13A4"    "ACOT11"     "SCARA3"     "ALDOC"
## [31] "PLCD4"       "ATP1B2"     "NTSR2"      "RGS20"      "ELOVL2"     "PAX6"
## [37] "ENTPD2"      "NCAN"       "KIAA1161"   "ETNPPL"     "PPAP2B"     "LGR6"
## [43] "GPAM"        "NWD1"       "F3"         "TTPA"       "CBS"        "LIX1"
## [49] "GRIN2C"      "PHKG1"
## [1] "RELN"        "VIP"        "GAD2"       "TAC3"       "DLX1"       "PENK"
## [7] "SYT1"        "TMEM130"    "GAD1"       "SYNPR"      "STMN2"      "GABRG2"
## [13] "GPR83"       "SST"        "ZMAT4"      "SNAP25"     "RAB3C"      "NELL1"
## [19] "SCG2"        "SYT4"       "CNR1"       "CLSTN2"     "SPHKAP"     "KCNQ5"
## [25] "PNOC"        "ROBO2"      "KCNC2"      "GALNTL6"    "VSNL1"      "GRIN2A"
## [31] "GABRA1"      "CHGB"       "SRRM4"      "ZNF804A"    "KIAA1324"   "BCL11A"
## [37] "SV2B"        "HTR3A"      "NPY"        "PRMT8"      "CNTNAP2"    "GLRA2"
## [43] "SLC12A5"     "SLC17A6"    "CRH"        "GRIA1"      "GDA"        "INA"
## [49] "RGS8"        "CELF4"
## [1] "PLP1"        "CLDN11"     "ERMN"       "UGT8"       "MOG"        "MOBP"
## [7] "MAG"         "MBP"        "OPALIN"     "GJB1"       "MYRF"       "KLK6"
## [13] "FA2H"        "CNP"        "ENPP6"      "LPAR1"      "ERBB3"      "TMEM125"
## [19] "ANLN"        "ASPA"       "QDPR"       "S1PR5"      "ENPP2"      "NIPAL4"
## [25] "MAL"         "BCAS1"      "CRYAB"      "LGI3"       "SGK2"       "GPR37"
## [31] "HHIP"        "SLAIN1"     "TMEM88B"    "CNTN2"      "NINJ2"      "ST18"
## [37] "MAP6D1"      "PLEKHH1"    "PRR18"      "TF"         "TRIM59"     "PEX5L"
## [43] "HAPLN2"      "GJC2"       "GJC3"       "SEPT4"      "PPP1R14A"   "GPR62"
## [49] "SEC14L5"     "GAL3ST1"
##      AQP4      ALDH1L1      BMPR1B      SLC14A1      MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##      SLC25A18      GLI3      GFAP      ACSBG1      SLC4A4      GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##      SLC39A12      AGT      CHRDL1      SLC1A2      CLDN10      SOX9      PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##      CLU      SLC7A10      ID4      DIO2      SFXN5      SLC6A11      ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##      ACOT11      SCARA3      ALDOC      PLCD4      ATP1B2      NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##      ELOVL2      PAX6      ENTPD2      NCAN      KIAA1161      ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##      PPAP2B      LGR6      GPAM      NWD1      F3      TTPA      CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##      LIX1      GRIN2C      PHKG1

```

```
## [1,] -0.8404202 -0.2054718 -0.7618352
##          RELN          VIP          GAD2          TAC3          DLX1          PENK          SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##          TMEM130          GAD1          SYNPR          STMN2          GABRG2          GPR83          SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748
##          ZMAT4          SNAP25          RAB3C          NELL1          SCG2          SYT4          CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##          CLSTN2          SPHKAP          KCNQ5          PNOC          ROBO2          KCNC2          GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1          GRIN2A          GABRA1          CHGB          SRRM4          ZNF804A          KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##          BCL11A          SV2B          HTR3A          NPY          PRMT8          CNTNAP2          GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##          SLC12A5          SLC17A6          CRH          GRIA1          GDA          INA          RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##          PLP1          CLDN11          ERMN          UGT8          MOG          MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##          MAG          MBP          OPALIN          GJB1          MYRF          KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##          FA2H          CNP          ENPP6          LPAR1          ERBB3          TMEM125          ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##          ASPA          QDPR          S1PR5          ENPP2          NIPAL4          MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
##          BCAS1          CRYAB          LGI3          SGK2          GPR37          HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1          TMEM88B          CNTN2          NINJ2          ST18          MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##          PLEKHH1          PRR18          TF          TRIM59          PEX5L          HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##          GJC2          GJC3          SEPT4          PPP1R14A          GPR62          SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##          GAL3ST1
## [1,] -0.8845151
```

```
kable(head(ct_res))
```

| | ast | neu | oli |
|------------|------------|------------|------------|
| X488395315 | -0.0409765 | 0.0226400 | -0.0194737 |
| X496100277 | 0.0391782 | -0.1361360 | 0.1323645 |
| X496100278 | 0.0742051 | -0.1360790 | 0.1534334 |
| X496100279 | -0.0091306 | 0.0680277 | -0.0194953 |
| X496100281 | 0.1136897 | 0.0116946 | -0.0243035 |
| X496100283 | -0.0440731 | 0.0449777 | -0.0220543 |

5 Using alternative cell type marker genes from Kelley *et al.*

In addition to the default data set built from a meta-analysis across cell type-specific gene expression data, BRETIGEA also offers access to cell type markers based on leveraging variation across intact tissue samples. The cell types for which markers are available based on this data set are astrocytes, neurons, microglia, and oligodendrocytes.

To use this, change the `data_set` parameter to “kelley” (referring to Kelley *et al.*, 2018, PMID: 30154505) when you call `brainCells()`. Note that the `species` argument will be ignored if `data_set` is set to “kelley”.

```
ct_res = brainCells(aba_marker_expression, nMarker = 50, data_set = "kelley")
```

```
##      markers cell
## 1      NTRK2  ast
## 2      NOTCH2 ast
## 3      SLC1A3 ast
## 4      ATP1A2 ast
## 5       PON2  ast
## 6      PDLIM5 ast
## 7      TP53BP2 ast
## 8       HEPH  ast
## 9      PPAP2B ast
## 10     MLC1   ast
## 11     RAB31  ast
## 12     GPR125 ast
## 13     METTL7A ast
## 14     SLC4A4 ast
## 15     BBOX1  ast
## 16     BMPR1B ast
## 17     ETNPPL ast
## 18 ARHGEF26 ast
## 19      GJA1  ast
## 20     SLC1A2 ast
## [1] "PPAP2B" "MLC1" "SLC4A4" "BMPR1B" "ETNPPL" "GJA1"
## [7] "SLC1A2" "GPAM" "AQP4" "FGFR3" "AGT" "SLC25A18"
## [13] "ATP13A4" "CLDN10" "SOX9" "GJB6" "PPP1R3C" "NTSR2"
## [19] "ACSBG1" "SLC39A12" "LIX1" "SLC7A10" "GLI3" "ALDH1L1"
## [25] "ATP1B2" "F3" "ID4" "ELOVL2" "SFXN5" "RGS20"
## [31] "NCAN" "SLC14A1" "DIO2" "TPPA" "ACOT11" "NWD1"
## [37] "PAX6" "PDGFRA" "GRIN2C" "SCARA3" "KIAA1161" "CHRD1"
## [43] "CBS" "EMID1" "CLU" "GFAP" "GPM2" "RNF43"
## [49] "MXRA8" "MECOM"
## [1] "MOG" "FA2H" "CNP" "ERBB3" "GPR37" "CNTN2"
## [7] "MAG" "ENPP2" "UGT8" "TMEM125" "PLP1" "TF"
## [13] "GJB1" "ASPA" "SLAIN1" "KLK6" "ANLN" "MYRF"
## [19] "MAL" "ERMN" "SGK2" "ST18" "HHIP" "OPALIN"
## [25] "CLDN11" "NIPAL4" "MOBP" "SHC4" "CRYAB" "PPP1R14A"
## [31] "MAP6D1" "SOX10" "GAL3ST1" "NINJ2" "PRR18" "TRIM59"
## [37] "GJC2" "QDPR" "ENPP6" "SEPT4" "HAPLN2" "S1PR5"
## [43] "PLEKHH1" "ZNF488" "GPR62" "SEC14L5" "LPAR1" "OLIG1"
## [49] "PRKCQ" "CHST6"
## [1] "AIF1" "TYROBP" "CD74" "C1QB" "LAPTM5" "ALOX5AP" "CSF1R"
## [8] "C1QA" "HAVCR2" "CX3CR1" "SLC2A5" "SELPLG" "TREM2" "GPR34"
## [15] "ITGAM" "CD53" "CD86" "PTAFR" "FCGR1A" "C1QC" "PTPRC"
## [22] "BLNK" "CTSS" "FCER1G" "TLR1" "NCKAP1L" "PTPN6" "MPEG1"
## [29] "IL10RA" "CD14" "IRF8" "CD300A" "FCGR2A" "TLR2" "PLEK"
## [36] "C3AR1" "SLA" "DOCK2" "GPR183" "CNTN2" "CNP" "MAG"
## [43] "CCL3" "NINJ2" "MAL" "CLDN11" "QDPR" "CSF3R" "KLK6"
## [50] "TF"
## [1] "SNAP25" "CNR1" "GABRA1" "GABRG2" "SV2B" "SLC12A5"
## [7] "RAB3C" "GAD1" "CNTNAP2" "GAD2" "SYT1" "PRMT8"
## [13] "KCNQ5" "GRIN2A" "ZMAT4" "SYT4" "GRIA1" "INA"
```

```

## [19] "BCL11A" "SLC17A6" "CELF4" "KIAA1324" "RGS8" "ROBO2"
## PPAP2B MLC1 SLC4A4 BMPR1B ETNPPL GJA1 SLC1A2
## [1,] -0.5025541 -0.7477438 0.09048259 -0.4063123 -0.326647 -0.5208349 0.3356524
## GPAM AQP4 FGFR3 AGT SLC25A18 ATP13A4 CLDN10
## [1,] 0.1590143 -0.7959551 -0.2870478 -0.7351957 -0.3024247 -0.3664846 0.3453167
## SOX9 GJB6 PPP1R3C NTSR2 ACSBG1 SLC39A12
## [1,] -0.5681646 0.5026505 -0.1792838 -0.4742672 -0.2080146 -0.1785399
## LIX1 SLC7A10 GLI3 ALDH1L1 ATP1B2 F3
## [1,] -0.8404701 0.1101243 -0.420511 -0.07441655 -0.1779509 -0.1667923
## ID4 ELOVL2 SFXN5 RGS20 NCAN SLC14A1 DIO2
## [1,] -0.6953497 -0.1149166 0.1891457 -0.1528931 -0.05527618 -0.6875852 0.218628
## TTPA ACOT11 NWD1 PAX6 PDGFRA GRIN2C
## [1,] -0.3925443 -0.1993598 -0.4308381 -0.5797566 -0.427459 -0.2055993
## SCARA3 KIAA1161 CHRDL1 CBS EMID1 CLU GFAP
## [1,] -0.2339306 0.1721085 0.6085179 -0.2509234 -0.3614802 -0.5940632 -0.9998986
## GPSM2 RNF43 MXRA8 MECOM
## [1,] -0.33791 0.2061761 -0.6480445 -0.09320791
## MOG FA2H CNP ERBB3 GPR37 CNTN2
## [1,] -0.9553868 -0.9374078 -0.9570886 -0.9470527 -0.9563399 -0.936811
## MAG ENPP2 UGT8 TMEM125 PLP1 TF GJB1
## [1,] -0.9337397 -0.9917416 -0.9661407 -0.8633007 -0.99921 -0.9465401 -0.8960731
## ASPA SLAIN1 KLK6 ANLN MYRF MAL
## [1,] -0.9527922 -0.9339612 -0.9648252 -0.9343073 -0.9200252 -0.9465757
## ERMN SGK2 ST18 HHIP OPALIN CLDN11
## [1,] -0.9774926 -0.8833653 -0.9669427 -0.8792891 -0.7946807 -0.9485021
## NIPAL4 MOBP SHC4 CRYAB PPP1R14A MAP6D1
## [1,] -0.9355339 -0.9262692 -0.9307934 -0.7704165 -0.8341845 -0.9422173
## SOX10 GAL3ST1 NINJ2 PRR18 TRIM59 GJC2
## [1,] -0.889713 -0.8625225 -0.9005809 -0.9079648 -0.9344645 -0.8996056
## QDPR ENPP6 SEPT4 HAPLN2 S1PR5 PLEKHH1
## [1,] -0.8591096 -0.8742807 -0.9309558 -0.8274583 -0.9459345 -0.9366046
## ZNF488 GPR62 SEC14L5 LPAR1 OLIG1 PRKCQ
## [1,] -0.5983907 -0.9024721 -0.8754486 -0.9132296 -0.8161764 -0.8763089
## CHST6
## [1,] -0.684862
## AIF1 TYROBP CD74 C1QB LAPTM5 ALOX5AP
## [1,] -0.3667772 -0.4549482 -0.4369198 -0.2800804 -0.4879601 -0.4901835
## CSF1R C1QA HAVCR2 CX3CR1 SLC2A5 SELPLG
## [1,] -0.3691395 -0.1929456 -0.644708 -0.3615215 -0.3424207 -0.4273749
## TREM2 GPR34 ITGAM CD53 CD86 PTAFR
## [1,] -0.5285649 -0.3000078 -0.4559793 -0.2683018 -0.4235582 -0.5261217
## FCGR1A C1QC PTPRC BLNK CTSS FCER1G
## [1,] -0.2301161 -0.3175702 -0.4665704 -0.3460233 -0.4004204 -0.3696705
## TLR1 NCKAP1L PTPN6 MPEG1 IL10RA CD14
## [1,] -0.3978289 -0.4454142 -0.4332804 -0.2814146 -0.3509839 -0.1336975
## IRF8 CD300A FCGR2A TLR2 PLEK C3AR1
## [1,] -0.3603299 -0.3983796 -0.3730523 -0.331365 -0.3125135 -0.3919277
## SLA DOCK2 GPR183 CNTN2 CNP MAG
## [1,] -0.1708626 -0.5143557 -0.3278701 -0.9397309 -0.9768923 -0.9562714
## CCL3 NINJ2 MAL CLDN11 QDPR CSF3R
## [1,] 0.0009828922 -0.9443308 -0.9428705 -0.927282 -0.8680864 -0.5755449
## KLK6 TF
## [1,] -0.9416907 -0.9922734
## SNAP25 CNR1 GABRA1 GABRG2 SV2B SLC12A5

```

```
## [1,] -0.9994439 -0.4711826 -0.8826786 -0.929699 -0.9306014 -0.8922213
##      RAB3C      GAD1      CNTNAP2      GAD2      SYT1      PRMT8
## [1,] -0.8324769 -0.8455382 -0.9100061 -0.8047595 -0.9539956 -0.7734852
##      KCNQ5      GRIN2A      ZMAT4      SYT4      GRIA1      INA
## [1,] -0.9077714 -0.9091246 -0.8637406 -0.9389565 -0.1366514 -0.8630253
##      BCL11A      SLC17A6      CELF4      KIAA1324      RGS8      ROB02
## [1,] -0.7639501 -0.7188173 -0.8249301 -0.6574843 -0.2404888 -0.8230147
```

```
kable(head(ct_res))
```

| | ast | oli | mic | neu |
|------------|------------|------------|------------|------------|
| X488395315 | -0.0409743 | -0.0166393 | -0.0291033 | 0.0218630 |
| X496100277 | 0.0391691 | 0.1090432 | 0.1821966 | -0.1393577 |
| X496100278 | 0.0741579 | 0.1770217 | 0.1403979 | -0.1393649 |
| X496100279 | -0.0091355 | -0.0206609 | -0.0237831 | 0.0673423 |
| X496100281 | 0.1137161 | -0.0139311 | -0.0160118 | 0.0245435 |
| X496100283 | -0.0440718 | -0.0203663 | -0.0219785 | 0.0430816 |

In the Allen Brain Atlas RNA-seq data, the estimated proportions are overall very similar between the “mckenzie” and “kelley” data sets.

```
ct_res_mckenzie = brainCells(aba_marker_expression, nMarker = 50, data_set = "mckenzie", species = "humans")
```

```
##      markers cell
## 1      GPR98 ast
## 2      AQP4 ast
## 3      BMPR1B ast
## 4      ETNPPL ast
## 5      GJB6 ast
## 6      GJA1 ast
## 7      FGFR3 ast
## 8      SLC25A18 ast
## 9      SLC1A2 ast
## 10     SDC4 ast
## 11     GFAP ast
## 12     EDNRB ast
## 13 RNF219-AS1 ast
## 14 LINC00499 ast
## 15     ALDH1L1 ast
## 16     CHI3L1 ast
## 17     CLDN10 ast
## 18     AGT ast
## 19     SLC01C1 ast
## 20     SLC4A4 ast
## [1] "AQP4"      "BMPR1B"      "ETNPPL"      "GJB6"      "GJA1"      "FGFR3"
## [7] "SLC25A18"    "SLC1A2"      "GFAP"      "ALDH1L1"    "CLDN10"    "AGT"
## [13] "SLC4A4"      "GPAM"      "SLC14A1"    "ID4"      "ACSBG1"    "MLC1"
## [19] "SLC39A12"    "NCAN"      "ATP1B2"      "CLU"      "RGS20"      "GLI3"
## [25] "SOX9"      "ACOT11"      "SFXN5"      "ELOVL2"      "SLC7A10"    "SCARA3"
## [31] "PAX6"      "SLC6A11"      "F3"      "DIO2"      "ALDOC"      "ATP13A4"
## [37] "PPAP2B"      "LIX1"      "PPP1R3C"      "CHRD1"      "GRIN2C"      "RNF43"
## [43] "NTSR2"      "NWD1"      "KIAA1161"      "TTPA"      "LGR6"      "EMID1"
## [49] "ENTPD2"      "PLCD4"
## [1] "APOLD1"      "SDPR"      "CD34"      "TM4SF1"      "MECOM"      "VWF"      "ITGA1"
```

```

## [8] "ABCB1" "ABCG2" "ATP10A" "ERG" "HIGD1B" "PODXL" "MYCT1"
## [15] "EBF1" "EMCN" "CLDN5" "NOSTRIN" "ESAM" "PTPRB" "TBX3"
## [22] "PALMD" "LEF1" "CDH5" "SEMA3G" "FN1" "CYR1" "ADCY4"
## [29] "ANXA1" "SLC38A5" "SLC2A1" "TIE1" "ROBO4" "CLIC5" "SOX7"
## [36] "CA4" "ICAM2" "PTRF" "HMCN1" "SLC52A3" "FOXF2" "SLC16A4"
## [43] "ITM2A" "SLC19A3" "OCLN" "SHE" "KDR" "ISG15" "FLT1"
## [50] "AGRN"
## [1] "CCL3" "CCL4" "CD74" "C1QB" "TLR1" "SLA" "IL1A"
## [8] "HAVCR2" "PLEK" "C3AR1" "TREM2" "CD14" "CD300A" "PTPRC"
## [15] "PTAFR" "TLR2" "CD83" "PTPN6" "SLC2A5" "BCL2A1" "GPR183"
## [22] "MPEG1" "IL10RA" "RHOH" "GPR34" "CD53" "BLNK" "TYROBP"
## [29] "CX3CR1" "C5AR1" "C1QA" "SELPLG" "LAPTM5" "CSF3R" "FCER1G"
## [36] "C1QC" "CSF1R" "NCKAP1L" "AIF1" "ALOX5AP" "DOCK2" "ITGAM"
## [43] "LYZ" "FCGR1A" "CD86" "CTSS" "IRF8" "FCGR2A" "RGS1"
## [50] "GPR84"
## [1] "SYNPR" "RELN" "CNR1" "GAD2" "RAB3C" "SYT1"
## [7] "KCNC2" "ZMAT4" "CHGB" "GABRA1" "GAD1" "TAC3"
## [13] "SCG2" "GALNTL6" "STMN2" "SNAP25" "INA" "SRRM4"
## [19] "DLX1" "GDA" "SYT4" "GPR83" "KCNQ5" "GABRG2"
## [25] "ZNF804A" "SPHKAP" "VSNL1" "VIP" "ROBO2" "GRIA1"
## [31] "CLSTN2" "PRMT8" "GRIN2A" "SLC12A5" "TMEM130" "GLRA2"
## [37] "BCL11A" "SV2B" "CNTNAP2" "KIAA1324" "CELF4" "PNOC"
## [43] "RGS8" "NELL1" "PENK" "CRH" "SST" "SULF1"
## [49] "SLC17A6"
## [1] "UGT8" "PLP1" "ERMN" "CLDN11" "MAG" "TF"
## [7] "KLK6" "CNTN2" "MOBP" "ST18" "ERBB3" "MYRF"
## [13] "MOG" "SLAIN1" "OPALIN" "CNP" "ENPP2" "HHIP"
## [19] "QDPR" "ANLN" "GJB1" "LPAR1" "BCAS1" "MBP"
## [25] "ZNF488" "SEPT4" "NINJ2" "FA2H" "TRIM59" "PLEKHH1"
## [31] "GPR37" "MAP6D1" "SGK2" "PEX5L" "TGFA" "LHFPL3"
## [37] "ASPA" "S1PR5" "CRYAB" "HAPLN2" "OLIG1" "PPP1R14A"
## [43] "MAL" "LGI3" "TMEM125" "SEC14L5" "SHC4" "PRR18"
## [49] "GPR62" "XYLT1"
## [1] "TGFA" "XYLT1" "TNR" "MEGF11" "PDGFRA" "GSPM2" "LRRN1" "PCDH15"
## [9] "SHC4" "LHFPL3" "STK32A"
## AQP4 BMPR1B ETNPPL GJB6 GJA1 FGFR3
## [1,] -0.7958953 -0.4061145 -0.3264466 0.5028413 -0.5208029 -0.2868519
## SLC25A18 SLC1A2 GFAP ALDH1L1 CLDN10 AGT
## [1,] -0.3022388 0.3359357 -0.9999002 -0.07419478 0.3455264 -0.7350902
## SLC4A4 GPAM SLC14A1 ID4 ACSBG1 MLC1
## [1,] 0.09074835 0.1591568 -0.6875913 -0.6952725 -0.2077688 -0.7476283
## SLC39A12 NCAN ATP1B2 CLU RGS20 GLI3
## [1,] -0.1784169 -0.05518123 -0.1778163 -0.5938856 -0.152671 -0.4204512
## SOX9 ACOT11 SFXN5 ELOVL2 SLC7A10 SCARA3 PAX6
## [1,] -0.5681311 -0.1992568 0.1894125 -0.1147346 0.110352 -0.2338064 -0.579708
## SLC6A11 F3 DIO2 ALDOC ATP13A4 PPAP2B LIX1
## [1,] 0.5592315 -0.1665847 0.2188641 0.110725 -0.3663146 -0.5024126 -0.8404205
## PPP1R3C CHRDL1 GRIN2C RNF43 NTSR2 NWD1 KIAA1161
## [1,] -0.1791112 0.6087142 -0.2054701 0.2063764 -0.4740655 -0.4308429 0.1721714
## TTPA LGR6 EMID1 ENTPD2 PLCD4
## [1,] -0.3924953 -0.04443324 -0.361383 -0.7823283 0.5112364
## APOLD1 SDPR CD34 TM4SF1 MECOM VWF
## [1,] -0.6399815 -0.5520798 -0.4907274 -0.5695515 -0.6550512 -0.6524641
## ITGA1 ABCB1 ABCG2 ATP10A ERG HIGD1B

```



```

## [1,] -0.6972485 -0.5203408 -0.4937788 -0.3887715 -0.5470173 -0.1689564
##          PODXL      MYCT1      EBF1      EMCN      CLDN5      NOSTRIN
## [1,] -0.686035 -0.4810083 -0.4940037 -0.5164972 -0.6762312 -0.5489817
##          ESAM      PTRPB      TBX3      PALMD      LEF1      CDH5
## [1,] -0.5982823 -0.4305522 -0.4197295 -0.4402406 -0.1165449 -0.7478238
##          SEMA3G      FN1      CYR1      ADCY4      ANXA1      SLC38A5
## [1,] -0.504194 -0.6877241 -0.5232659 -0.5090985 -0.4017235 -0.2817508
##          SLC2A1      TIE1      ROBO4      CLIC5      SOX7      CA4
## [1,] -0.6995822 -0.4477667 -0.4056899 -0.2223977 -0.3214358 0.1048609
##          ICAM2      PTRF      HMCN1      SLC52A3      FOXF2      SLC16A4
## [1,] -0.6872572 -0.4610223 -0.4746686 -0.4871699 -0.1964257 -0.2073382
##          ITM2A      SLC19A3      OCLN      SHE      KDR      ISG15
## [1,] -0.4047572 -0.309978 -0.1732357 -0.619215 -0.4551206 -0.09500632
##          FLT1      AGRN
## [1,] -0.6822437 0.05437876
##          CCL3      CCL4      CD74      C1QB      TLR1      SLA      IL1A
## [1,] -0.009014479 0.02049567 0.9569894 0.9027497 0.8748194 0.8394877 0.147061
##          HAVCR2      PLEK      C3AR1      TREM2      CD14      CD300A      PTPRC
## [1,] 0.8554602 0.6737376 0.8224433 0.8121957 0.6772439 0.8795061 0.9488961
##          PTAFR      TLR2      CD83      PTPN6      SLC2A5      BCL2A1      GPR183
## [1,] 0.7619302 0.8563525 -0.3230165 0.8757021 0.882668 0.5858728 0.6689415
##          MPEGL      IL10RA      RHOH      GPR34      CD53      BLNK      TYROBP
## [1,] 0.3112844 0.8152008 0.3987691 0.6202537 0.8110169 0.6580784 0.9002925
##          CX3CR1      C5AR1      C1QA      SELPLG      LAPTM5      CSF3R      FCER1G
## [1,] 0.3634809 0.5982698 0.8550013 0.5294624 0.9474317 0.7479062 0.8581698
##          C1QC      CSF1R      NCKAP1L      AIF1      ALOX5AP      DOCK2      ITGAM
## [1,] 0.9215579 0.7685014 0.924154 0.8964808 0.8643056 0.8865086 0.8377073
##          LYZ      FCGR1A      CD86      CTSS      IRF8      FCGR2A      RGS1
## [1,] 0.5769851 0.6713506 0.8670868 0.8570066 0.7524594 0.8366178 0.6465002
##          GPR84
## [1,] 0.3866831
##          SYNPR      RELN      CNR1      GAD2      RAB3C      SYT1      KCNC2
## [1,] -0.5407689 0.11676 -0.4061398 -0.8276954 -0.7968191 -0.9588116 -0.8932509
##          ZMAT4      CHGB      GABRA1      GAD1      TAC3      SCG2
## [1,] -0.8855258 -0.1413789 -0.9103821 -0.8571014 -0.729535 -0.5793877
##          GALNTL6      STMN2      SNAP25      INA      SRRM4      DLX1      GDA
## [1,] -0.7152189 -0.95448 -0.9937844 -0.8971981 -0.811072 -0.7836811 -0.7714656
##          SYT4      GPR83      KCNQ5      GABRG2      ZNF804A      SPHKAP      VSNL1
## [1,] -0.9400441 -0.4039511 -0.9202798 -0.9428785 -0.3507682 0.1237171 -0.859272
##          VIP      ROBO2      GRIA1      CLSTN2      PRMT8      GRIN2A
## [1,] -0.6134488 -0.8036823 -0.05150754 -0.3222614 -0.8081944 -0.8891158
##          SLC12A5      TMEM130      GLRA2      BCL11A      SV2B      CNTNAP2      KIAA1324
## [1,] -0.903364 -0.6441962 -0.6638931 -0.742246 -0.9386706 -0.9294711 -0.6023963
##          CELF4      PNOG      RGS8      NELL1      PENK      CRH
## [1,] -0.8067308 -0.4488567 -0.1693912 -0.8839522 -0.4386024 -0.4350206
##          SST      SULF1      SLC17A6
## [1,] -0.1926701 0.08911178 -0.7684385
##          UGT8      PLP1      ERMN      CLDN11      MAG      TF      KLK6
## [1,] -0.8949423 -0.930547 -0.9359886 -0.8798922 -0.9200623 -0.904338 -0.9099586
##          CNTN2      MOBP      ST18      ERBB3      MYRF      MOG
## [1,] -0.9321899 -0.9624937 -0.9443937 -0.9207618 -0.9282964 -0.9124786
##          SLAIN1      OPALIN      CNP      ENPP2      HHIP      QDPR      ANLN
## [1,] -0.8955747 -0.7476443 -0.913972 -0.9315086 -0.819422 -0.8106599 -0.884951
##          GJB1      LPAR1      BCAS1      MBP      ZNF488      SEPT4

```

```
## [1,] -0.8302383 -0.962931 -0.9744962 -0.9924517 -0.5290359 -0.9596253
##          NINJ2      FA2H      TRIM59      PLEKHH1      GPR37      MAP6D1
## [1,] -0.8435832 -0.9222321 -0.8753261 -0.9312029 -0.8947963 -0.8858273
##          SGK2      PEX5L      TGFA      LHFPL3      ASPA      S1PR5
## [1,] -0.8293538 -0.7511845 -0.8519515 -0.5616319 -0.9246865 -0.9338739
##          CRYAB      HAPLN2      OLIG1      PPP1R14A      MAL      LGI3
## [1,] -0.7663217 -0.8260412 -0.8329667 -0.8221472 -0.9135859 -0.5304531
##          TMEM125      SEC14L5      SHC4      PRR18      GPR62      XYLT1
## [1,] -0.8009608 -0.8569698 -0.9115929 -0.8960737 -0.8587162 0.1569451
##          TGFA      XYLT1      TNR      MEGF11      PDGFRA      GPSM2
## [1,] -0.7243984 -0.506883 -0.8940025 -0.7164912 -0.8635213 -0.5814406
##          LRRN1      PCDH15      SHC4      LHFPL3      STK32A
## [1,] -0.2153496 -0.7722088 -0.5199548 -0.6963018 -0.7288558
```

```
ct_res_kelley = brainCells(aba_marker_expression, nMarker = 50, data_set = "kelley")
```

```
##          markers cell
## 1      NTRK2  ast
## 2      NOTCH2 ast
## 3      SLC1A3 ast
## 4      ATP1A2 ast
## 5      PON2   ast
## 6      PDLIM5 ast
## 7      TP53BP2 ast
## 8      HEPH   ast
## 9      PPAP2B ast
## 10     MLC1   ast
## 11     RAB31  ast
## 12     GPR125 ast
## 13     METTL7A ast
## 14     SLC4A4 ast
## 15     BBOX1  ast
## 16     BMPR1B ast
## 17     ETNPPL ast
## 18     ARHGEF26 ast
## 19     GJA1   ast
## 20     SLC1A2 ast
## [1] "PPAP2B" "MLC1" "SLC4A4" "BMPR1B" "ETNPPL" "GJA1"
## [7] "SLC1A2" "GPAM" "AQP4" "FGFR3" "AGT" "SLC25A18"
## [13] "ATP13A4" "CLDN10" "SOX9" "GJB6" "PPP1R3C" "NTSR2"
## [19] "ACSBG1" "SLC39A12" "LIX1" "SLC7A10" "GLI3" "ALDH1L1"
## [25] "ATP1B2" "F3" "ID4" "ELOVL2" "SFXN5" "RGS20"
## [31] "NCAN" "SLC14A1" "DIO2" "TTPA" "ACOT11" "NWD1"
## [37] "PAX6" "PDGFRA" "GRIN2C" "SCARA3" "KIAA1161" "CHRD1"
## [43] "CBS" "EMID1" "CLU" "GFAP" "GPSM2" "RNF43"
## [49] "MXRA8" "MECOM"
## [1] "MOG" "FA2H" "CNP" "ERBB3" "GPR37" "CNTN2"
## [7] "MAG" "ENPP2" "UGT8" "TMEM125" "PLP1" "TF"
## [13] "GJB1" "ASPA" "SLAIN1" "KLK6" "ANLN" "MYRF"
## [19] "MAL" "ERMN" "SGK2" "ST18" "HHIP" "OPALIN"
## [25] "CLDN11" "NIPAL4" "MOBP" "SHC4" "CRYAB" "PPP1R14A"
## [31] "MAP6D1" "SOX10" "GAL3ST1" "NINJ2" "PRR18" "TRIM59"
## [37] "GJC2" "QDPR" "ENPP6" "SEPT4" "HAPLN2" "S1PR5"
## [43] "PLEKHH1" "ZNF488" "GPR62" "SEC14L5" "LPAR1" "OLIG1"
## [49] "PRKCQ" "CHST6"
```

```

## [1] "AIF1"      "TYROBP"    "CD74"      "C1QB"      "LAPTM5"    "ALOX5AP"   "CSF1R"
## [8] "C1QA"      "HAVCR2"    "CX3CR1"    "SLC2A5"    "SELPLG"    "TREM2"     "GPR34"
## [15] "ITGAM"     "CD53"      "CD86"      "PTAFR"     "FCGR1A"    "C1QC"      "PTPRC"
## [22] "BLNK"      "CTSS"      "FCER1G"    "TLR1"      "NCKAP1L"   "PTPN6"     "MPEG1"
## [29] "IL10RA"    "CD14"      "IRF8"      "CD300A"    "FCGR2A"    "TLR2"      "PLEK"
## [36] "C3AR1"     "SLA"       "DOCK2"     "GPR183"    "CNTN2"     "CNP"       "MAG"
## [43] "CCL3"      "NINJ2"     "MAL"       "CLDN11"    "QDPR"      "CSF3R"     "KLK6"
## [50] "TF"
## [1] "SNAP25"    "CNR1"      "GABRA1"    "GABRG2"    "SV2B"      "SLC12A5"
## [7] "RAB3C"     "GAD1"      "CNTNAP2"    "GAD2"      "SYT1"      "PRMT8"
## [13] "KCNQ5"     "GRIN2A"    "ZMAT4"     "SYT4"      "GRIA1"     "INA"
## [19] "BCL11A"    "SLC17A6"   "CELF4"     "KIAA1324"  "RGS8"      "ROBO2"
##      PPAP2B      MLC1      SLC4A4      BMPR1B      ETNPPL      GJA1      SLC1A2
## [1,] -0.5025541 -0.7477438 0.09048259 -0.4063123 -0.326647 -0.5208349 0.3356524
##      GPAM      AQP4      FGFR3      AGT      SLC25A18      ATP13A4      CLDN10
## [1,] 0.1590143 -0.7959551 -0.2870478 -0.7351957 -0.3024247 -0.3664846 0.3453167
##      SOX9      GJB6      PPP1R3C      NTSR2      ACSBG1      SLC39A12
## [1,] -0.5681646 0.5026505 -0.1792838 -0.4742672 -0.2080146 -0.1785399
##      LIX1      SLC7A10      GLI3      ALDH1L1      ATP1B2      F3
## [1,] -0.8404701 0.1101243 -0.420511 -0.07441655 -0.1779509 -0.1667923
##      ID4      ELOVL2      SFXN5      RGS20      NCAN      SLC14A1      DIO2
## [1,] -0.6953497 -0.1149166 0.1891457 -0.1528931 -0.05527618 -0.6875852 0.218628
##      TTPA      ACOT11      NWD1      PAX6      PDGFRA      GRIN2C
## [1,] -0.3925443 -0.1993598 -0.4308381 -0.5797566 -0.427459 -0.2055993
##      SCARA3      KIAA1161      CHRDL1      CBS      EMID1      CLU      GFAP
## [1,] -0.2339306 0.1721085 0.6085179 -0.2509234 -0.3614802 -0.5940632 -0.9998986
##      GPSM2      RNF43      MXRA8      MECOM
## [1,] -0.33791 0.2061761 -0.6480445 -0.09320791
##      MOG      FA2H      CNP      ERBB3      GPR37      CNTN2
## [1,] -0.9553868 -0.9374078 -0.9570886 -0.9470527 -0.9563399 -0.936811
##      MAG      ENPP2      UGT8      TMEM125      PLP1      TF      GJB1
## [1,] -0.9337397 -0.9917416 -0.9661407 -0.8633007 -0.99921 -0.9465401 -0.8960731
##      ASPA      SLAIN1      KLK6      ANLN      MYRF      MAL
## [1,] -0.9527922 -0.9339612 -0.9648252 -0.9343073 -0.9200252 -0.9465757
##      ERMN      SGK2      ST18      HHIP      OPALIN      CLDN11
## [1,] -0.9774926 -0.8833653 -0.9669427 -0.8792891 -0.7946807 -0.9485021
##      NIPAL4      MOBP      SHC4      CRYAB      PPP1R14A      MAP6D1
## [1,] -0.9355339 -0.9262692 -0.9307934 -0.7704165 -0.8341845 -0.9422173
##      SOX10      GAL3ST1      NINJ2      PRR18      TRIM59      GJC2
## [1,] -0.889713 -0.8625225 -0.9005809 -0.9079648 -0.9344645 -0.8996056
##      QDPR      ENPP6      SEPT4      HAPLN2      S1PR5      PLEKHH1
## [1,] -0.8591096 -0.8742807 -0.9309558 -0.8274583 -0.9459345 -0.9366046
##      ZNF488      GPR62      SEC14L5      LPAR1      OLIG1      PRKCQ
## [1,] -0.5983907 -0.9024721 -0.8754486 -0.9132296 -0.8161764 -0.8763089
##      CHST6
## [1,] -0.684862
##      AIF1      TYROBP      CD74      C1QB      LAPTM5      ALOX5AP
## [1,] -0.3667772 -0.4549482 -0.4369198 -0.2800804 -0.4879601 -0.4901835
##      CSF1R      C1QA      HAVCR2      CX3CR1      SLC2A5      SELPLG
## [1,] -0.3691395 -0.1929456 -0.644708 -0.3615215 -0.3424207 -0.4273749
##      TREM2      GPR34      ITGAM      CD53      CD86      PTAFR
## [1,] -0.5285649 -0.3000078 -0.4559793 -0.2683018 -0.4235582 -0.5261217
##      FCGR1A      C1QC      PTPRC      BLNK      CTSS      FCER1G
## [1,] -0.2301161 -0.3175702 -0.4665704 -0.3460233 -0.4004204 -0.3696705

```

```
##          TLR1      NCKAP1L      PTPN6      MPEG1      IL10RA      CD14
## [1,] -0.3978289 -0.4454142 -0.4332804 -0.2814146 -0.3509839 -0.1336975
##          IRF8      CD300A      FCGR2A      TLR2      PLEK      C3AR1
## [1,] -0.3603299 -0.3983796 -0.3730523 -0.331365 -0.3125135 -0.3919277
##          SLA      DOCK2      GPR183      CNTN2      CNP      MAG
## [1,] -0.1708626 -0.5143557 -0.3278701 -0.9397309 -0.9768923 -0.9562714
##          CCL3      NINJ2      MAL      CLDN11      QDPR      CSF3R
## [1,] 0.0009828922 -0.9443308 -0.9428705 -0.927282 -0.8680864 -0.5755449
##          KLK6      TF
## [1,] -0.9416907 -0.9922734
##          SNAP25      CNR1      GABRA1      GABRG2      SV2B      SLC12A5
## [1,] -0.9994439 -0.4711826 -0.8826786 -0.929699 -0.9306014 -0.8922213
##          RAB3C      GAD1      CNTNAP2      GAD2      SYT1      PRMT8
## [1,] -0.8324769 -0.8455382 -0.9100061 -0.8047595 -0.9539956 -0.7734852
##          KCNQ5      GRIN2A      ZMAT4      SYT4      GRIA1      INA
## [1,] -0.9077714 -0.9091246 -0.8637406 -0.9389565 -0.1366514 -0.8630253
##          BCL11A      SLC17A6      CELF4      KIAA1324      RGS8      ROBO2
## [1,] -0.7639501 -0.7188173 -0.8249301 -0.6574843 -0.2404888 -0.8230147
```

```
cell_types_compare = colnames(ct_res_kelley)
for(i in 1:length(cell_types_compare)){
  cor_res = cor.test(ct_res_mckenzie[, cell_types_compare[i]], ct_res_kelley[, cell_types_compare[i]])
  df_compare_cor = data.frame(Cell = cell_types_compare[i], Rho = cor_res$estimate, PVal = cor_res$p.value)
  if(i == 1) df_compare_cor_tot = df_compare_cor
  if(i > 1) df_compare_cor_tot = rbind(df_compare_cor_tot, df_compare_cor)}
kable(df_compare_cor_tot)
```

| | Cell | Rho | PVal |
|------|------|-----------|------|
| rho | ast | 0.9999982 | 0 |
| rho1 | oli | 0.9256712 | 0 |
| rho2 | mic | 0.4774784 | 0 |
| rho3 | neu | 0.9927047 | 0 |

This alternative data set also offers marker genes derived from several specific brain regions:

```
## [1] "CTX" "AMY" "BF" "CB" "CLA" "DI" "FCX" "GP" "HIP" "IN" "LIM" "MED"
## [13] "MID" "OCX" "PCX" "PON" "SC" "STR" "TCX" "WM"
```

6 Using your own cell type marker genes

If you have access to your own marker genes, you can use the *findCells* function instead. This has the same functionality otherwise; *brainCells* is simply a wrapper function for users who want to use the brain cell type marker genes that are provided by **BRETIGEA**. Note the format of the *markers* data frame: you must have one column with the gene symbol, named *markers*, and one column with the corresponding cell type, named *cell*.

```
str(markers_df_brain)
```

```
## 'data.frame': 6000 obs. of 2 variables:
## $ markers: chr "AQP4" "ALDH1L1" "BMPRI1B" "SLC14A1" ...
## $ cell : chr "ast" "ast" "ast" "ast" ...
```

```
ct_res = findCells(aba_marker_expression, markers = markers_df_brain, nMarker = 50)
```

```
## [1] "AQP4"      "ALDH1L1"   "BMPR1B"    "SLC14A1"   "MLC1"      "FGFR3"
## [7] "SLC25A18"  "GLI3"      "GFAP"      "ACSBG1"    "SLC4A4"    "GJA1"
## [13] "GJB6"      "SLC39A12"  "AGT"       "CHRD1"     "SLC1A2"    "CLDN10"
## [19] "SOX9"      "PPP1R3C"   "CLU"       "SLC7A10"   "ID4"       "DIO2"
## [25] "SFXN5"     "SLC6A11"   "ATP13A4"   "ACOT11"    "SCARA3"    "ALDOC"
## [31] "PLCD4"     "ATP1B2"    "NTSR2"     "RGS20"     "ELOVL2"    "PAX6"
## [37] "ENTPD2"    "NCAN"      "KIAA1161"  "ETNPPL"    "PPAP2B"    "LGR6"
## [43] "GPAM"      "NWD1"      "F3"        "TPA"       "CBS"       "LIX1"
## [49] "GRIN2C"    "PHKG1"
## [1] "APOLD1"    "EMCN"      "SDPR"      "PTPRB"     "CDH5"      "SLC38A5" "TM4SF1"
## [8] "NOSTRIN"   "CYR1"      "MECOM"     "MYCT1"     "CLDN5"     "ERG"      "ABCB1"
## [15] "ICAM2"     "FN1"       "ESAM"      "ATP10A"    "VWF"       "CD34"     "PODXL"
## [22] "SLC19A3"   "FLT1"      "TBX3"      "HMCN1"     "ITM2A"     "TEK"      "ITGA1"
## [29] "TIE1"      "ADCY4"     "CLIC5"     "ANXA1"     "OCLN"      "PALMD"    "SEMA3G"
## [36] "ABCG2"     "ROBO4"     "SLC16A4"   "SLC52A3"   "SOX7"      "SHE"      "CA4"
## [43] "EBF1"      "CD93"      "KDR"       "SLC2A1"    "PTRF"      "LEF1"     "HIGD1B"
## [50] "FOXF2"
## [1] "CCL3"      "CCL4"      "CD14"      "C1QB"      "IL1A"      "TREM2"    "GPR183"
## [8] "CD83"      "SLC2A5"    "C1QC"      "NCKAP1L"   "CSF1R"     "CD300A"   "FCGR2A"
## [15] "LAPTM5"    "HAVCR2"    "C3AR1"     "CX3CR1"    "PTAFR"     "C1QA"     "FCGR1A"
## [22] "SELPLG"    "PLEK"      "CTSS"      "CSF3R"     "TYROBP"    "SLA"      "PTPN6"
## [29] "TLR2"      "CD86"      "GPR84"     "LYZ"       "MPEG1"     "BCL2A1"   "ITGAM"
## [36] "CD53"      "IRF8"      "IL10RA"    "GPR34"     "AIF1"      "CD74"     "PTPRC"
## [43] "RHOH"      "BLNK"      "TLR1"      "C5AR1"     "FCER1G"    "DOCK2"    "RGS1"
## [50] "ALOX5AP"
## [1] "RELN"      "VIP"       "GAD2"      "TAC3"      "DLX1"      "PENK"
## [7] "SYT1"      "TMEM130"   "GAD1"      "SYNPR"     "STMN2"     "GABRG2"
## [13] "GPR83"     "SST"       "ZMAT4"     "SNAP25"    "RAB3C"     "NELL1"
## [19] "SCG2"      "SYT4"      "CNR1"      "CLSTN2"    "SPHKAP"    "KCNQ5"
## [25] "PNOC"      "ROBO2"     "KCNC2"     "GALNTL6"   "VSNL1"     "GRIN2A"
## [31] "GABRA1"    "CHGB"      "SRRM4"     "ZNF804A"   "KIAA1324"  "BCL11A"
## [37] "SV2B"      "HTR3A"     "NPY"       "PRMT8"     "CNTNAP2"   "GLRA2"
## [43] "SLC12A5"   "SLC17A6"   "CRH"       "GRIA1"     "GDA"       "INA"
## [49] "RGS8"      "CELF4"
## [1] "PLP1"      "CLDN11"    "ERMN"      "UGT8"      "MOG"       "MOBP"
## [7] "MAG"       "MBP"       "OPALIN"    "GJB1"      "MYRF"      "KLK6"
## [13] "FA2H"      "CNP"       "ENPP6"     "LPAR1"     "ERBB3"     "TMEM125"
## [19] "ANLN"      "ASPA"      "QDPR"      "S1PR5"     "ENPP2"     "NIPAL4"
## [25] "MAL"       "BCAS1"     "CRYAB"     "LGI3"      "SGK2"      "GPR37"
## [31] "HHIP"      "SLAIN1"    "TMEM88B"   "CNTN2"     "NINJ2"     "ST18"
## [37] "MAP6D1"    "PLEKHH1"   "PRR18"     "TF"        "TRIM59"    "PEX5L"
## [43] "HAPLN2"    "GJC2"      "GJC3"      "SEPT4"     "PPP1R14A"  "GPR62"
## [49] "SEC14L5"   "GAL3ST1"
## [1] "PDGFRA"    "SHC4"      "MATN4"     "TNR"       "PNLIP"     "PCDH15"
## [7] "FAM180A"   "NEU4"      "LHFPL3"    "CHST6"     "MEGF11"    "OLIG1"
## [13] "GPR17"     "RNF43"     "RBPJL"     "UGT8"      "PMEL"      "SOX10"
## [19] "GAL3ST1"   "SULF2"     "CCNB1"     "MYT1"      "ACAN"      "XYLT1"
## [25] "CSPG4"     "C1QL1"     "CKAP2"     "GJC3"      "TOP2A"     "PRKG2"
## [31] "BCAS1"     "SAPCD2"    "ZNF488"    "LRRN1"     "TMEM255B"  "S100A3"
## [37] "PBK"       "SUSD5"     "STK32A"    "SULF1"     "PRKCQ"     "DPYD"
## [43] "GPSM2"     "LAD1"      "UGDH"      "CKAP2L"    "GJB1"      "EMID1"
## [49] "TGFA"      "ADAM12"
```

```

##          AQP4          ALDH1L1          BMPR1B          SLC14A1          MLC1          FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##          SLC25A18          GLI3          GFAP          ACSBG1          SLC4A4          GJA1          GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##          SLC39A12          AGT          CHRDL1          SLC1A2          CLDN10          SOX9          PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##          CLU          SLC7A10          ID4          DIO2          SFXN5          SLC6A11          ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11          SCARA3          ALDOC          PLCD4          ATP1B2          NTSR2          RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2          PAX6          ENTPD2          NCAN          KIAA1161          ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B          LGR6          GPAM          NWD1          F3          TTPA          CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##          LIX1          GRIN2C          PHKG1
## [1,] -0.8404202 -0.2054718 -0.7618352
##          APOLD1          EMCN          SDPR          PTPRB          CDH5          SLC38A5
## [1,] -0.6397974 -0.5150059 -0.5503207 -0.4286219 -0.7509274 -0.2792929
##          TM4SF1          NOSTRIN          CYR1          MECOM          MYCT1          CLDN5
## [1,] -0.5732277 -0.5492278 -0.5233367 -0.6553751 -0.4798552 -0.6769395
##          ERG          ABCB1          ICAM2          FN1          ESAM          ATP10A
## [1,] -0.5483382 -0.5187547 -0.6892712 -0.6866703 -0.5985029 -0.386112
##          VWF          CD34          PODXL          SLC19A3          FLT1          TBX3
## [1,] -0.6532856 -0.4892499 -0.6865958 -0.3100597 -0.682325 -0.4185505
##          HMCN1          ITM2A          TEK          ITGA1          TIE1          ADCY4
## [1,] -0.4729641 -0.404837 -0.4247323 -0.6994108 -0.4460777 -0.5100022
##          CLIC5          ANXA1          OCLN          PALMD          SEMA3G          ABCG2
## [1,] -0.2212121 -0.4021003 -0.1725926 -0.4391917 -0.5039709 -0.4910518
##          ROBO4          SLC16A4          SLC52A3          SOX7          SHE          CA4
## [1,] -0.4063845 -0.2065062 -0.4868766 -0.3217972 -0.6208689 0.1057804
##          EBF1          CD93          KDR          SLC2A1          PTRF          LEF1
## [1,] -0.4929378 -0.4586119 -0.4572021 -0.6991769 -0.4608555 -0.1165776
##          HIGD1B          FOXF2
## [1,] -0.1667598 -0.1962837
##          CCL3          CCL4          CD14          C1QB          IL1A          TREM2          GPR183
## [1,] -0.009014479 0.02049567 0.6772439 0.9027497 0.147061 0.8121957 0.6689415
##          CD83          SLC2A5          C1QC          NCKAP1L          CSF1R          CD300A          FCGR2A
## [1,] -0.3230165 0.882668 0.9215579 0.924154 0.7685014 0.8795061 0.8366178
##          LAPTM5          HAVCR2          C3AR1          CX3CR1          PTAFR          C1QA          FCGR1A
## [1,] 0.9474317 0.8554602 0.8224433 0.3634809 0.7619302 0.8550013 0.6713506
##          SELPLG          PLEK          CTSS          CSF3R          TYROBP          SLA          PTPN6
## [1,] 0.5294624 0.6737376 0.8570066 0.7479062 0.9002925 0.8394877 0.8757021
##          TLR2          CD86          GPR84          LYZ          MPEG1          BCL2A1          ITGAM
## [1,] 0.8563525 0.8670868 0.3866831 0.5769851 0.3112844 0.5858728 0.8377073
##          CD53          IRF8          IL10RA          GPR34          AIF1          CD74          PTPRC
## [1,] 0.8110169 0.7524594 0.8152008 0.6202537 0.8964808 0.9569894 0.9488961
##          RHOH          BLNK          TLR1          C5AR1          FCER1G          DOCK2          RGS1
## [1,] 0.3987691 0.6580784 0.8748194 0.5982698 0.8581698 0.8865086 0.6465002
##          ALOX5AP
## [1,] 0.8643056
##          RELN          VIP          GAD2          TAC3          DLX1          PENK          SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##          TMEM130          GAD1          SYNPR          STMN2          GABRG2          GPR83          SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748

```

```
##          ZMAT4      SNAP25      RAB3C      NELL1      SCG2      SYT4      CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##          CLSTN2      SPHKAP      KCNQ5      PNOG      ROBO2      KCNC2      GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1      GRIN2A      GABRA1      CHGB      SRRM4      ZNF804A      KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##          BCL11A      SV2B      HTR3A      NPY      PRMT8      CNTNAP2      GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##          SLC12A5      SLC17A6      CRH      GRIA1      GDA      INA      RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##          PLP1      CLDN11      ERMN      UGT8      MOG      MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##          MAG      MBP      OPALIN      GJB1      MYRF      KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##          FA2H      CNP      ENPP6      LPAR1      ERBB3      TMEM125      ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##          ASPA      QDPR      S1PR5      ENPP2      NIPAL4      MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
##          BCAS1      CRYAB      LGI3      SGK2      GPR37      HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1      TMEM88B      CNTN2      NINJ2      ST18      MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##          PLEKHH1      PRR18      TF      TRIM59      PEX5L      HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##          GJC2      GJC3      SEPT4      PPP1R14A      GPR62      SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##          GAL3ST1
## [1,] -0.8845151
##          PDGFRA      SHC4      MATN4      TNF      PNLIP      PCDH15
## [1,] -0.6594077 -0.8876408 -0.009790091 -0.2148693 -0.04108205 -0.1075733
##          FAM180A      NEU4      LHFPL3      CHST6      MEGF11      OLIG1
## [1,] -0.2698467 -0.2856533 -0.5938882 -0.6238268 -0.1090868 -0.8296958
##          GPR17      RNF43      RBPJL      UGT8      PMEL      SOX10      GAL3ST1
## [1,] -0.5917444 0.435638 0.1101175 -0.8814859 0.05653651 -0.8517942 -0.8665949
##          SULF2      CCNB1      MYT1      ACAN      XYLT1      CSPG4      C1QL1
## [1,] 0.1274339 0.4931099 -0.6166283 -0.1083521 0.1532883 -0.7196438 -0.336823
##          CKAP2      GJC3      TOP2A      PRKG2      BCAS1      SAPCD2      ZNF488
## [1,] 0.6525218 0.1210485 0.0195238 0.4824663 -0.9974827 -0.6061126 -0.4965659
##          LRRN1      TMEM255B      S100A3      PBK      SUSP5      STK32A      SULF1
## [1,] 0.426307 -0.07905286 -0.09222221 0.01888503 0.3814492 -0.3316909 -0.291499
##          PRKCQ      DPYD      GPSM2      LAD1      UGDH      CKAP2L
## [1,] -0.8390872 -0.8863703 -0.9110727 -0.07256941 -0.06724674 -0.05768831
##          GJB1      EMID1      TGFA      ADAM12
## [1,] -0.83458 -0.1593035 -0.8341445 -0.4069115
```

```
kable(head(ct_res))
```

| | ast | end | mic | neu | oli | opc |
|------------|------------|------------|------------|------------|------------|------------|
| X488395315 | -0.0409765 | -0.0468875 | -0.0249076 | 0.0226400 | -0.0194737 | -0.0287028 |
| X496100277 | 0.0391782 | 0.0090563 | -0.0012271 | -0.1361360 | 0.1323645 | 0.1322346 |
| X496100278 | 0.0742051 | 0.0864415 | 0.1158266 | -0.1360790 | 0.1534334 | 0.1555192 |
| X496100279 | -0.0091306 | -0.0055174 | 0.0103811 | 0.0680277 | -0.0194953 | -0.0216833 |

| | ast | end | mic | neu | oli | opc |
|------------|------------|------------|------------|-----------|------------|------------|
| X496100281 | 0.1136897 | -0.0070804 | 0.0825388 | 0.0116946 | -0.0243035 | -0.0278465 |
| X496100283 | -0.0440731 | -0.0263346 | -0.0356047 | 0.0449777 | -0.0220543 | -0.0188682 |

7 Adjusting bulk gene expression data for estimated cell type proportions

BRETIGEA also offers users the ability to adjust their original gene expression matrices for the estimated cell type proportion estimates, in order to deconvolute the signal.

```
brain_cells_adjusted = adjustBrainCells(aba_marker_expression,
    nMarker = 50, species = "combined")
```

```
##      markers cell
## 1      AQP4  ast
## 2    ALDH1L1 ast
## 3    BMPR1B ast
## 4    SLC14A1 ast
## 5      MLC1 ast
## 6     FGFR3 ast
## 7  SLC25A18 ast
## 8      GLI3 ast
## 9      GFAP ast
## 10   ACSBG1 ast
## 11   SLC4A4 ast
## 12     GJA1 ast
## 13     GJB6 ast
## 14  SLC39A12 ast
## 15      AGT ast
## 16   CHRDL1 ast
## 17   SLC1A2 ast
## 18   CLDN10 ast
## 19     SOX9 ast
## 20  PPP1R3C ast
## [1] "AQP4"      "ALDH1L1"    "BMPR1B"     "SLC14A1"    "MLC1"       "FGFR3"
## [7] "SLC25A18"    "GLI3"       "GFAP"       "ACSBG1"     "SLC4A4"     "GJA1"
## [13] "GJB6"       "SLC39A12"   "AGT"        "CHRDL1"     "SLC1A2"     "CLDN10"
## [19] "SOX9"       "PPP1R3C"    "CLU"        "SLC7A10"    "ID4"        "DIO2"
## [25] "SFXN5"      "SLC6A11"    "ATP13A4"    "ACOT11"     "SCARA3"     "ALDOC"
## [31] "PLCD4"      "ATP1B2"     "NTSR2"      "RGS20"      "ELOVL2"     "PAX6"
## [37] "ENTPD2"     "NCAN"       "KIAA1161"   "ETNPPL"     "PPAP2B"     "LGR6"
## [43] "GPAM"       "NWD1"       "F3"         "TTPA"       "CBS"        "LIX1"
## [49] "GRIN2C"     "PHKG1"
## [1] "APOLD1"     "EMCN"       "SDPR"       "PTPRB"      "CDH5"       "SLC38A5"   "TM4SF1"
## [8] "NOSTRIN"    "CYR1"       "MECOM"      "MYCT1"      "CLDN5"      "ERG"       "ABCB1"
## [15] "ICAM2"      "FN1"        "ESAM"       "ATP10A"     "VWF"        "CD34"      "PODXL"
## [22] "SLC19A3"    "FLT1"       "TBX3"       "HMCN1"      "ITM2A"      "TEK"       "ITGA1"
## [29] "TIE1"       "ADCY4"      "CLIC5"      "ANXA1"      "OCLN"       "PALMD"     "SEMA3G"
## [36] "ABCG2"      "ROB04"      "SLC16A4"    "SLC52A3"    "SOX7"       "SHE"       "CA4"
## [43] "EBF1"       "CD93"       "KDR"        "SLC2A1"     "PTRF"       "LEF1"      "HIGD1B"
## [50] "FOXF2"
## [1] "CCL3"       "CCL4"       "CD14"       "C1QB"       "IL1A"       "TREM2"     "GPR183"
```



```

## [8] "CD83"      "SLC2A5"    "C1QC"      "NCKAP1L"   "CSF1R"     "CD300A"    "FCGR2A"
## [15] "LAPTM5"    "HAVCR2"    "C3AR1"     "CX3CR1"    "PTAFR"     "C1QA"      "FCGR1A"
## [22] "SELPLG"    "PLEK"      "CTSS"      "CSF3R"     "TYROBP"    "SLA"       "PTPN6"
## [29] "TLR2"      "CD86"      "GPR84"     "LYZ"       "MPEG1"     "BCL2A1"    "ITGAM"
## [36] "CD53"      "IRF8"      "IL10RA"    "GPR34"     "AIF1"      "CD74"      "PTPRC"
## [43] "RHOH"      "BLNK"      "TLR1"      "C5AR1"     "FCER1G"    "DOCK2"     "RGS1"
## [50] "ALOX5AP"
## [1] "RELN"      "VIP"       "GAD2"      "TAC3"      "DLX1"      "PENK"
## [7] "SYT1"      "TMEM130"   "GAD1"      "SYNPR"     "STMN2"     "GABRG2"
## [13] "GPR83"     "SST"       "ZMAT4"     "SNAP25"    "RAB3C"     "NELL1"
## [19] "SCG2"      "SYT4"      "CNR1"      "CLSTN2"    "SPHKAP"    "KCNQ5"
## [25] "PNOC"      "ROBO2"     "KCNC2"     "GALNTL6"   "VSNL1"     "GRIN2A"
## [31] "GABRA1"    "CHGB"      "SRRM4"     "ZNF804A"   "KIAA1324"  "BCL11A"
## [37] "SV2B"      "HTR3A"     "NPY"       "PRMT8"     "CNTNAP2"   "GLRA2"
## [43] "SLC12A5"   "SLC17A6"   "CRH"       "GRIA1"     "GDA"       "INA"
## [49] "RGS8"      "CELF4"
## [1] "PLP1"      "CLDN11"    "ERMN"      "UGT8"      "MOG"       "MOBP"
## [7] "MAG"       "MBP"       "OPALIN"    "GJB1"      "MYRF"      "KLK6"
## [13] "FA2H"      "CNP"       "ENPP6"     "LPAR1"     "ERBB3"     "TMEM125"
## [19] "ANLN"      "ASPA"      "QDPR"      "S1PR5"     "ENPP2"     "NIPAL4"
## [25] "MAL"       "BCAS1"     "CRYAB"     "LGI3"      "SGK2"      "GPR37"
## [31] "HHIP"      "SLAIN1"    "TMEM88B"   "CNTN2"     "NINJ2"     "ST18"
## [37] "MAP6D1"    "PLEKHH1"   "PRR18"     "TF"        "TRIM59"    "PEX5L"
## [43] "HAPLN2"    "GJC2"      "GJC3"      "SEPT4"     "PPP1R14A"  "GPR62"
## [49] "SEC14L5"   "GAL3ST1"
## [1] "PDGFRA"    "SHC4"      "MATN4"     "TNR"       "PNLIP"     "PCDH15"
## [7] "FAM180A"   "NEU4"      "LHFPL3"    "CHST6"     "MEGF11"    "OLIG1"
## [13] "GPR17"     "RNF43"     "RBPJL"     "UGT8"      "PMEL"      "SOX10"
## [19] "GAL3ST1"   "SULF2"     "CCNB1"     "MYT1"      "ACAN"      "XYLT1"
## [25] "CSPG4"     "C1QL1"     "CKAP2"     "GJC3"      "TOP2A"     "PRKG2"
## [31] "BCAS1"     "SAPCD2"    "ZNF488"    "LRRN1"     "TMEM255B"  "S100A3"
## [37] "PBK"       "SUSD5"     "STK32A"    "SULF1"     "PRKCQ"     "DPYD"
## [43] "GPSM2"     "LAD1"      "UGDH"      "CKAP2L"    "GJB1"      "EMID1"
## [49] "TGFA"      "ADAM12"
##          AQP4      ALDH1L1      BMPR1B      SLC14A1      MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##          SLC25A18      GLI3      GFAP      ACSBG1      SLC4A4      GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##          SLC39A12      AGT      CHRDL1      SLC1A2      CLDN10      SOX9      PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##          CLU      SLC7A10      ID4      DI02      SFXN5      SLC6A11      ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11      SCARA3      ALDOC      PLCD4      ATP1B2      NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2      PAX6      ENTPD2      NCAN      KIAA1161      ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B      LGR6      GPAM      NWD1      F3      TTPA      CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##          LIX1      GRIN2C      PHKG1
## [1,] -0.8404202 -0.2054718 -0.7618352
##          APOLD1      EMCN      SDPR      PTPRB      CDH5      SLC38A5
## [1,] -0.6397974 -0.5150059 -0.5503207 -0.4286219 -0.7509274 -0.2792929
##          TM4SF1      NOSTRIN      CYR1      MECOM      MYCT1      CLDN5
## [1,] -0.5732277 -0.5492278 -0.5233367 -0.6553751 -0.4798552 -0.6769395

```

| | | | | | | |
|----|---------|--------------|------------|------------|------------|--------------------------------|
| ## | ERG | ABCB1 | ICAM2 | FN1 | ESAM | ATP10A |
| ## | [1,] | -0.5483382 | -0.5187547 | -0.6892712 | -0.6866703 | -0.5985029 -0.386112 |
| ## | VWF | CD34 | PODXL | SLC19A3 | FLT1 | TBX3 |
| ## | [1,] | -0.6532856 | -0.4892499 | -0.6865958 | -0.3100597 | -0.682325 -0.4185505 |
| ## | HMCN1 | ITM2A | TEK | ITGA1 | TIE1 | ADCY4 |
| ## | [1,] | -0.4729641 | -0.404837 | -0.4247323 | -0.6994108 | -0.4460777 -0.5100022 |
| ## | CLIC5 | ANXA1 | OCLN | PALMD | SEMA3G | ABCG2 |
| ## | [1,] | -0.2212121 | -0.4021003 | -0.1725926 | -0.4391917 | -0.5039709 -0.4910518 |
| ## | ROBO4 | SLC16A4 | SLC52A3 | SOX7 | SHE | CA4 |
| ## | [1,] | -0.4063845 | -0.2065062 | -0.4868766 | -0.3217972 | -0.6208689 0.1057804 |
| ## | EBF1 | CD93 | KDR | SLC2A1 | PTRF | LEF1 |
| ## | [1,] | -0.4929378 | -0.4586119 | -0.4572021 | -0.6991769 | -0.4608555 -0.1165776 |
| ## | HIGD1B | FOXF2 | | | | |
| ## | [1,] | -0.1667598 | -0.1962837 | | | |
| ## | CCL3 | CCL4 | CD14 | C1QB | IL1A | TREM2 GPR183 |
| ## | [1,] | -0.009014479 | 0.02049567 | 0.6772439 | 0.9027497 | 0.147061 0.8121957 0.6689415 |
| ## | CD83 | SLC2A5 | C1QC | NCKAP1L | CSF1R | CD300A FCGR2A |
| ## | [1,] | -0.3230165 | 0.882668 | 0.9215579 | 0.924154 | 0.7685014 0.8795061 0.8366178 |
| ## | LAPTM5 | HAVCR2 | C3AR1 | CX3CR1 | PTAFR | C1QA FCGR1A |
| ## | [1,] | 0.9474317 | 0.8554602 | 0.8224433 | 0.3634809 | 0.7619302 0.8550013 0.6713506 |
| ## | SELPLG | PLEK | CTSS | CSF3R | TYROBP | SLA PTPN6 |
| ## | [1,] | 0.5294624 | 0.6737376 | 0.8570066 | 0.7479062 | 0.9002925 0.8394877 0.8757021 |
| ## | TLR2 | CD86 | GPR84 | LYZ | MPEG1 | BCL2A1 ITGAM |
| ## | [1,] | 0.8563525 | 0.8670868 | 0.3866831 | 0.5769851 | 0.3112844 0.5858728 0.8377073 |
| ## | CD53 | IRF8 | IL10RA | GPR34 | AIF1 | CD74 PTPRC |
| ## | [1,] | 0.8110169 | 0.7524594 | 0.8152008 | 0.6202537 | 0.8964808 0.9569894 0.9488961 |
| ## | RHOH | BLNK | TLR1 | C5AR1 | FCER1G | DOCK2 RGS1 |
| ## | [1,] | 0.3987691 | 0.6580784 | 0.8748194 | 0.5982698 | 0.8581698 0.8865086 0.6465002 |
| ## | ALOX5AP | | | | | |
| ## | [1,] | 0.8643056 | | | | |
| ## | RELN | VIP | GAD2 | TAC3 | DLX1 | PENK SYT1 |
| ## | [1,] | -0.1166803 | 0.6135118 | 0.8276635 | 0.7295642 | 0.7836934 0.4386146 0.9587805 |
| ## | TMEM130 | GAD1 | SYNPR | STMN2 | GABRG2 | GPR83 SST |
| ## | [1,] | 0.6442915 | 0.8571033 | 0.5407849 | 0.954468 | 0.9428849 0.4040754 0.1924748 |
| ## | ZMAT4 | SNAP25 | RAB3C | NELL1 | SCG2 | SYT4 CNR1 |
| ## | [1,] | 0.8855612 | 0.9937954 | 0.7968844 | 0.8839205 | 0.579349 0.9400202 0.4062468 |
| ## | CLSTN2 | SPHKAP | KCNQ5 | PNOC | ROBO2 | KCNC2 GALNTL6 |
| ## | [1,] | 0.3223093 | -0.1236097 | 0.9203101 | 0.4488496 | 0.8036322 0.8932601 0.7152115 |
| ## | VSNL1 | GRIN2A | GABRA1 | CHGB | SRRM4 | ZNF804A KIAA1324 |
| ## | [1,] | 0.8592326 | 0.8891878 | 0.9103732 | 0.141477 | 0.8110747 0.3509051 0.6024863 |
| ## | BCL11A | SV2B | HTR3A | NPY | PRMT8 | CNTNAP2 GLRA2 |
| ## | [1,] | 0.742308 | 0.9386318 | 0.1299354 | -0.2984589 | 0.80817 0.9295066 0.6637972 |
| ## | SLC12A5 | SLC17A6 | CRH | GRIA1 | GDA | INA RGS8 |
| ## | [1,] | 0.9034275 | 0.7684521 | 0.4350317 | 0.05161995 | 0.7713854 0.8972024 0.1695003 |
| ## | CELF4 | | | | | |
| ## | [1,] | 0.8067627 | | | | |
| ## | PLP1 | CLDN11 | ERMN | UGT8 | MOG | MOBP |
| ## | [1,] | -0.9305459 | -0.8798909 | -0.9359872 | -0.8949407 | -0.9124765 -0.9624925 |
| ## | MAG | MBP | OPALIN | GJB1 | MYRF | KLK6 |
| ## | [1,] | -0.9200603 | -0.9924521 | -0.7476423 | -0.8302352 | -0.9282941 -0.9099573 |
| ## | FA2H | CNP | ENPP6 | LPAR1 | ERBB3 | TMEM125 ANLN |
| ## | [1,] | -0.9222307 | -0.9139697 | -0.8174142 | -0.9629297 | -0.920759 -0.8009576 -0.884949 |
| ## | ASPA | QDPR | S1PR5 | ENPP2 | NIPAL4 | MAL |
| ## | [1,] | -0.9246854 | -0.8106579 | -0.9338734 | -0.931507 | -0.8928996 -0.9135844 |

```
##          BCAS1      CRYAB      LGI3      SGK2      GPR37      HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1      TMEM88B      CNTN2      NINJ2      ST18      MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##          PLEKHH1      PRR18      TF      TRIM59      PEX5L      HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##          GJC2      GJC3      SEPT4      PPP1R14A      GPR62      SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##          GAL3ST1
## [1,] -0.8845151
##          PDGFRA      SHC4      MATN4      TNF      PNLIP      PCDH15
## [1,] -0.6594077 -0.8876408 -0.009790091 -0.2148693 -0.04108205 -0.1075733
##          FAM180A      NEU4      LHFPL3      CHST6      MEGF11      OLIG1
## [1,] -0.2698467 -0.2856533 -0.5938882 -0.6238268 -0.1090868 -0.8296958
##          GPR17      RNF43      RBPJL      UGT8      PMEL      SOX10      GAL3ST1
## [1,] -0.5917444 0.435638 0.1101175 -0.8814859 0.05653651 -0.8517942 -0.8665949
##          SULF2      CCNB1      MYT1      ACAN      XYLT1      CSPG4      C1QL1
## [1,] 0.1274339 0.4931099 -0.6166283 -0.1083521 0.1532883 -0.7196438 -0.336823
##          CKAP2      GJC3      TOP2A      PRKG2      BCAS1      SAPCD2      ZNF488
## [1,] 0.6525218 0.1210485 0.0195238 0.4824663 -0.9974827 -0.6061126 -0.4965659
##          LRRN1      TMEM255B      S100A3      PBK      SUSD5      STK32A      SULF1
## [1,] 0.426307 -0.07905286 -0.09222221 0.01888503 0.3814492 -0.3316909 -0.291499
##          PRKCQ      DPYD      GPSM2      LAD1      UGDH      CKAP2L
## [1,] -0.8390872 -0.8863703 -0.9110727 -0.07256941 -0.06724674 -0.05768831
##          GJB1      EMID1      TGFA      ADAM12
## [1,] -0.83458 -0.1593035 -0.8341445 -0.4069115
```

```
expression_data_adj = brain_cells_adjusted$expression
```

Note that *adjustBrainCells* is a wrapper function to *adjustCells* and if you have your own markers (e.g., for a non-brain data set), then you can use that interface instead for deconvolution of more general cell types.

As you can see, following adjustment, there is no longer a correlation between the RNA expression of the microglia marker gene AIF1 and its encoded protein IHC quantification (IBA1), nor between the RNA and protein expression of the astrocyte marker gene GFAP. (Note there *is* a non-significant trend towards a residual correlation here, which may be because GFAP is not a perfect marker of astrocyte proportion in this data set, but instead varies across samples based on disease state, region, and other factors).

```
cor.test(as.numeric(aba_marker_expression["AIF1", ]),
  as.numeric(aba_pheno_data$ihc_iba1_ffpe), method = "spearman")

##
## Spearman's rank correlation rho
##
## data: as.numeric(aba_marker_expression["AIF1", ]) and as.numeric(aba_pheno_data$ihc_iba1_ffpe)
## S = 5566784, p-value = 5.348e-09
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## 0.3017048

cor.test(expression_data_adj["AIF1", ], as.numeric(aba_pheno_data$ihc_iba1_ffpe),
  method = "spearman")

##
## Spearman's rank correlation rho
##
```

```
## data: expression_data_adj["AIF1", ] and as.numeric(aba_pheno_data$ihc_iba1_ffpe)
## S = 7975568, p-value = 0.9931
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## -0.0004520843

cor.test(as.numeric(aba_marker_expression["GFAP", ]), as.numeric(aba_pheno_data$ihc_gfap_ffpe),
  method = "spearman")

##
## Spearman's rank correlation rho
##
## data: as.numeric(aba_marker_expression["GFAP", ]) and as.numeric(aba_pheno_data$ihc_gfap_ffpe)
## S = 3582778, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## 0.476499

cor.test(expression_data_adj["GFAP", ], as.numeric(aba_pheno_data$ihc_gfap_ffpe),
  method = "spearman")

##
## Spearman's rank correlation rho
##
## data: expression_data_adj["GFAP", ] and as.numeric(aba_pheno_data$ihc_gfap_ffpe)
## S = 6458042, p-value = 0.2962
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## 0.05637708
```

8 Help and other resources

If you have any problems with or questions about using this package, please open an issue on Github or contact the package maintainer.

References

“Allen Institute for Cell Science. Aging, Dementia and TBI.” n.d. <http://aging.brain-map.org/>.