

# Package ‘spatialDE’

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**Title** R wrapper for SpatialDE

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**Description** SpatialDE is a method to find spatially variable genes (SVG) from spatial transcriptomics data. This package provides wrappers to use the Python SpatialDE library in R, using reticulate and basilisk.

**License** MIT + file LICENSE

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|                              |                         |
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| <code>.importPyModule</code> | <i>Import SpatialDE</i> |
|------------------------------|-------------------------|

---

## Description

This function loads the SpatialDE Python module and optionally monkey-patches it to remove tqdm calls.

## Usage

```
.importPyModule(proc, patch_tqdm)
```

## Arguments

|                         |  |
|-------------------------|--|
| <code>proc</code>       | A process object generated by <code>basilisk::basiliskStart()</code> |
| <code>patch_tqdm</code> | If TRUE patch calls to tqdm.   |

## Value

An R wrapper for the SpatialDE Python module.

---

`FSV_sig`*Plot Fraction Spatial Variance vs Q-value*

---

## Description

Plot Fraction Spatial Variance vs Q-value

## Usage

```
FSV_sig(  
  results,  
  ms_results = NULL,  
  certain_only = FALSE,  
  log_x = FALSE,  
  do_label = TRUE,  
  covariate_names = NULL  
)
```

## Arguments

|                              |   |
|------------------------------|---|
| <code>results</code>         | results from SpatialDE.   |
| <code>ms_results</code>      | model selection results, should be a data frame with columns <code>g</code> for gene names and <code>model</code> for the model selected. |
| <code>certain_only</code>    | only plot results with narrow 95% confidence interval.  |
| <code>log_x</code>           | Whether to display x axis in log scale.   |
| <code>do_label</code>        | display gene names for statistically significant genes, default TRUE.   |
| <code>covariate_names</code> | names of covariates as a reference, default to NULL.  |

## Value

A `ggplot2` object.

## Author(s)

Davide Corso, Milan Malfait, Lambda Moses

## References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. *Nat Methods* 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**SpatialDE 1.1.3**: the version of the Python package used under the hood.

## Examples

```
## Mock up a SpatialExperiment object with 400 cells and 3 genes
set.seed(42)
spe <- mockSVG(size = 20, tot_genes = 3, de_genes = 1, return_SPE = TRUE)

## Run spatialDE with S4 integration
results <- spatialDE(spe)

## Run model search
msearch <- modelSearch(spe, de_results = results, qual_thresh = NULL,
  verbose = FALSE)

plot <- FSV_sig(results, msearch)
```

---

MOB\_sample\_info

*Mouse Olfactory Bulb sample metadata*

---

## Description

Coordinates and total counts for the samples from the Mouse Olfactory Bulb data generated by Stahl et al. (2016). This data was originally downloaded from [https://github.com/Teichlab/SpatialDE/blob/master/Analysis/MouseOB/MOB\\_sample\\_info.csv](https://github.com/Teichlab/SpatialDE/blob/master/Analysis/MouseOB/MOB_sample_info.csv).

## Usage

```
data(MOB_sample_info)
```

## Format

A data.frame with 262 rows and 3 variables as columns: the x and y coordinates and total\_counts corresponding to each spot.

## References

Stahl, P. L. et al. (2016) 'Visualization and analysis of gene expression in tissue sections by spatial transcriptomics', *Science*, 353(6294), p. 78. doi: 10.1126/science.aaf2403.

---

mockSVG                      *Generate count matrix for spatially variable genes.*

---

### Description

Generate count matrix for spatially variable genes.

### Usage

```
mockSVG(size, tot_genes, de_genes, return_SPE = FALSE)
```

### Arguments

|            |   |
|------------|---|
| size       | An integer scalar. Cells will be spatially arranged on a size x size grid. Default: 10, corresponding to 100 cells. |
| tot_genes  | An integer scalar. Total number of genes. Default: 1000.  |
| de_genes   | An integer scalar. The number of spatially variable genes. Default: 100.  |
| return_SPE | A logical, whether to return result as a <a href="#">SpatialExperiment</a> . Default: FALSE.                        |

### Value

If return\_SPE = TRUE, returns a [SpatialExperiment](#) object.

If not, a list containing:

- coordinates: data.frame with x and y columns;
- counts: matrix with generated gene counts.

### Examples

```
spe <- mockSVG(size = 20, tot_genes = 3, de_genes = 1, return_SPE = TRUE)
spe
```

---

modelSearch                      *Classify Spatially Variable Genes to interpretable fitting classes*

---

### Description

Compare model fits with different models, using the [SpatialDE](#) Python package.

**Usage**

```

modelSearch(x, de_results, ...)

## S4 method for signature 'matrix'
modelSearch(x, de_results, coordinates, qval_thresh = 0.05, verbose = FALSE)

## S4 method for signature 'SpatialExperiment'
modelSearch(
  x,
  de_results,
  assay_type = "counts",
  qval_thresh = 0.05,
  verbose = FALSE
)

```

**Arguments**

|             |  |
|-------------|--|
| x           | A numeric matrix of counts where genes are rows and cells are columns. Alternatively, a <code>SpatialExperiment</code> object.   |
| de_results  | data.frame resulting from <code>run()</code> or <code>spatialDE()</code> .   |
| ...         | For the generic, arguments to pass to specific methods.  |
| coordinates | A data.frame with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'.<br>For the <i>SpatialExperiment</i> method, coordinates are taken from <code>spatialCoords(x)</code> . |
| qval_thresh | numeric scalar, specifying the q-value significance threshold to filter de_results. Only rows in de_results with <code>qval &lt; qval_thresh</code> will be kept. To disable, set <code>qval_thresh = NULL</code> .          |
| verbose     | A logical controlling the display of a progress bar from the Python package.   |
| assay_type  | A character string specifying the assay from x to use as input. Defaults to "counts".  |

**Value**

data.frame of model\_search results.

**Author(s)**

Davide Corso, Milan Malfait, Lambda Moses

**References**

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. *Nat Methods* 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**SpatialDE 1.1.3:** the version of the Python package used under the hood.

## See Also

The individual steps performed by this function: [stabilize\(\)](#), [regress\\_out\(\)](#) and [model\\_search\(\)](#).

## Examples

```
## Mock up a SpatialExperiment object with 400 cells and 3 genes
set.seed(42)
spe <- mockSVG(size = 20, tot_genes = 3, de_genes = 1, return_SPE = TRUE)

## Run spatialDE with S4 integration
de_results <- spatialDE(spe)

## Run model search
model_search <- modelSearch(spe, de_results = de_results,
  qval_thresh = NULL, verbose = FALSE
)
```

---

model\_search

*Compare model fits with different models*

---

## Description

Classify DE genes to interpretable fitting classes.

## Usage

```
model_search(x, coordinates, de_results, qval_thresh = 0.05, verbose = FALSE)
```

## Arguments

|             |   |
|-------------|---|
| x           | matrix-like object of normalized counts. E.g. resulting from <a href="#">regress_out()</a> .  |
| coordinates | data.frame with sample coordinates. Each row is a sample, the columns with coordinates must be named 'x' and 'y'.   |
| de_results  | data.frame resulting from <a href="#">run()</a> .   |
| qval_thresh | numeric scalar, specifying the q-value significance threshold to filter de_results. Only rows in de_results with qval < qval_thresh will be kept. To disable, set qval_thresh = NULL. |
| verbose     | logical controlling the display of the progress bar.  |

## Value

data.frame of model\_search results.

## References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**Examples**

```
## Mock up a SpatialExperiment object with 400 cells and 3 genes
set.seed(42)
mock <- mockSVG(size = 20, tot_genes = 3, de_genes = 1)

stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)

## Run SpatialDE
de_results <- run(regressed, coordinates = mock$coordinates)

## Run model search
ms_results <- model_search(
  x = regressed,
  coordinates = mock$coordinates,
  de_results = de_results,
  qual_thresh = NULL
)
```

---

multiGenePlots

*Plot Spatial Patterns of Multiple Genes*


---

**Description**

Plot Spatial Patterns of Multiple Genes

**Usage**

```
multiGenePlots(x, ...)
```

```
## S4 method for signature 'matrix'
multiGenePlots(
  x,
  coordinates,
  genes_plot,
  viridis_option = "D",
  ncol = 2,
  point_size = 1,
  dark_theme = TRUE
)
```

```
## S4 method for signature 'SpatialExperiment'
multiGenePlots(
  x,
  assay_type = "counts",
```



```

genes_plot,
viridis_option = "D",
ncol = 2,
point_size = 1,
dark_theme = TRUE
)

```

### Arguments

|                |   |
|----------------|---|
| x              | A numeric matrix of stabilized counts (e.g. resulting from <code>stabilize()</code> ) where genes are rows and cells are columns.<br>Alternatively, a <code>SpatialExperiment</code> object.  |
| ...            | For the generic, arguments to pass to specific methods.   |
| coordinates    | A data.frame with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'.<br>For the <code>SpatialExperiment</code> method, coordinates are taken from <code>spatialCoords(x)</code> .          |
| genes_plot     | character vector specifying which genes are to be plotted.  |
| viridis_option | This function uses the <code>viridis</code> palette to color cells for gene expression. Four options are available: "magma" (or "A"), "inferno" (or "B"), "plasma" (or "C"), "viridis" (or "D", the default option) and "cividis" (or "E"). |
| ncol           | Number of columns to arrange the plots.   |
| point_size     | Point size of each plot.  |
| dark_theme     | Whether dark background should be used; this is helpful to highlight cells with high expression when using the <code>viridis</code> palette.  |
| assay_type     | A character string specifying the assay from x to use as input. Defaults to "counts".   |

### Value

This function draws a plot for each specified genes

### Author(s)

Davide Corso, Milan Malfait, Lambda Moses

### References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. *Nat Methods* 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**SpatialDE 1.1.3:** the version of the Python package used under the hood.

### See Also

The individual steps performed by this function: `stabilize()`, `spatialDE()`.

For further analysis of the DE results: `model_search()` and `spatial_patterns()`.

## Examples

```
## Mock up a SpatialExperiment object wit 400 cells and 3 genes
set.seed(42)
spe <- mockSVG(size = 20, tot_genes = 3, de_genes = 1, return_SPE = TRUE)

## Run spatialDE
results <- spatialDE(spe)

ordered_spe_results <- results[order(results$qval), ]
head(ordered_spe_results)

plots <- multiGenePlots(spe,
  assay_type = "counts",
  ordered_spe_results$g,
  point_size = 4,
  viridis_option = "D"
)
```

---

regress\_out

*Regress out library size effect*

---

## Description

Regresses out the effect of library size. This function is a wrapper for `regress_out` from the [NaiveDE](#) Python package.

## Usage

```
regress_out(counts, sample_info)
```

## Arguments

`counts` matrix of variance stabilized counts, e.g. resulting from [stabilize\(\)](#).  
`sample_info` `data.frame` with samples as rows and at least a column with `total_counts`.

## Value

matrix of normalized counts.

## Examples

```
## Mock up a SpatialExperiment object wit 400 cells and 3 genes
set.seed(42)
mock <- mockSVG(20, 3, 1)

stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
```

```
regressed <- regress_out(counts = stabilized, sample_info = sample_info)
```

---

 Rep11\_MOB\_0

*Mouse Olfactory Bulb spatial gene expression data*


---

### Description

Replicate 11 from the spatially dependent gene expression data from the mouse olfactory bulb generated by Stahl et al. (2016). This data was originally downloaded from [https://github.com/Teichlab/SpatialDE/blob/master/Analysis/MouseOB/data/Rep11\\_MOB\\_0.csv](https://github.com/Teichlab/SpatialDE/blob/master/Analysis/MouseOB/data/Rep11_MOB_0.csv).

### Usage

```
data(Rep11_MOB_0)
```

### Format

A matrix with 16218 genes as rows and 262 spots as columns.

### References

Stahl, P. L. et al. (2016) 'Visualization and analysis of gene expression in tissue sections by spatial transcriptomics', *Science*, 353(6294), p. 78. doi: 10.1126/science.aaf2403.

---

 run

*Perform SpatialDE test*


---

### Description

Wraps the run function from the [SpatialDE](#) Python package.

### Usage

```
run(x, coordinates, verbose = FALSE)
```

### Arguments

|             |   |
|-------------|---|
| x           | matrix-like object of normalized counts. E.g. resulting from <a href="#">regress_out()</a> .                      |
| coordinates | data.frame with sample coordinates. Each row is a sample, the columns with coordinates must be named 'x' and 'y'. |
| verbose     | logical controlling the display of the progress bar.  |

**Value**

A data.frame with DE results where each row is a gene and columns contain relevant statistics.

The most important columns are:

- g: the name of the gene
- pval: the p-value for spatial differential expression
- qval: the q-value, indicating significance after correcting for multiple testing
- l: A parameter indicating the distance scale a gene changes expression over

**References**

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**Examples**

```
## Mock up a SpatialExperiment object with 400 cells and 3 genes
set.seed(42)
mock <- mockSVG(size = 20, tot_genes = 3, de_genes = 1)

stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)

## Run SpatialDE
de_results <- run(regressed, coordinates = mock$coordinates)
```

---

spatialDE

*Find spatially variable genes with **SpatialDE***

---

**Description**

Identify genes that significantly depend on spatial coordinates with the **SpatialDE** Python package.

**Usage**

```
spatialDE(x, ...)
```

## S4 method for signature 'matrix'

```
spatialDE(x, coordinates, verbose = FALSE)
```

## S4 method for signature 'SpatialExperiment'

```
spatialDE(x, assay_type = "counts", verbose = FALSE)
```

**Arguments**

|             |  |
|-------------|--|
| x           | A numeric matrix of counts where genes are rows and cells are columns. Alternatively, a <a href="#">SpatialExperiment</a> object.  |
| ...         | For the generic, arguments to pass to specific methods.  |
| coordinates | A data.frame with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'.<br>For the <i>SpatialExperiment</i> method, coordinates are taken from <code>spatialCoords(x)</code> . |
| verbose     | A logical controlling the display of a progress bar from the Python package.   |
| assay_type  | A character string specifying the assay from x to use as input. Defaults to "counts".  |

**Value**

A data.frame with DE results where each row is a gene and columns contain relevant statistics.  
The most important columns are:

- g: the name of the gene
- pval: the p-value for spatial differential expression
- qval: the q-value, indicating significance after correcting for multiple testing
- l: A parameter indicating the distance scale a gene changes expression over

**Author(s)**

Davide Corso, Milan Malfait, Lambda Moses

**References**

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. *Nat Methods* 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**SpatialDE 1.1.3:** the version of the Python package used under the hood.

**See Also**

The individual steps performed by this function: [stabilize\(\)](#), [regress\\_out\(\)](#) and [run\(\)](#).  
For further analysis of the DE results: [model\\_search\(\)](#) and [spatial\\_patterns\(\)](#).

**Examples**

```
## Mock up a SpatialExperiment object wit 400 cells and 3 genes
set.seed(42)
spe <- mockSVG(size = 20, tot_genes = 3, de_genes = 1, return_SPE = TRUE)

## Run spatialDE
de_results <- spatialDE(spe)

head(de_results)
```

---

spatialPatterns      *Automatic expression histology in SpatialDE*

---

## Description

Group spatially variable genes into spatial patterns using Automatic Expression Histology, using the **SpatialDE** Python package.

## Usage

```
spatialPatterns(x, de_results, ...)

## S4 method for signature 'matrix'
spatialPatterns(
  x,
  de_results,
  coordinates,
  qual_thresh = 0.05,
  n_patterns,
  length,
  verbose = FALSE
)

## S4 method for signature 'SpatialExperiment'
spatialPatterns(
  x,
  de_results,
  qual_thresh = 0.05,
  n_patterns,
  length,
  assay_type = "counts",
  verbose = FALSE
)
```

## Arguments

|             |  |
|-------------|--|
| x           | A numeric matrix of counts where genes are rows and cells are columns. Alternatively, a <a href="#">SpatialExperiment</a> object.  |
| de_results  | data.frame resulting from <a href="#">run()</a> or <a href="#">spatialDE()</a> .   |
| ...         | For the generic, arguments to pass to specific methods.  |
| coordinates | A data.frame with sample coordinates. Each row is a sample, the columns with coordinates should be named 'x' and 'y'.<br>For the <i>SpatialExperiment</i> method, coordinates are taken from <a href="#">spatialCoords(x)</a> .                |
| qual_thresh | numeric scalar, specifying the q-value significance threshold to filter <code>de_results</code> . Only rows in <code>de_results</code> with <code>qual &lt; qual_thresh</code> will be kept. To disable, set <code>qual_thresh = NULL</code> . |

|            |         |   |
|------------|---------|---|
| n_patterns | integer | The number of spatial patterns  |
| length     | numeric | The characteristic length scale of the clusters                                       |
| verbose    |         | A logical controlling the display of a progress bar from the Python package.          |
| assay_type |         | A character string specifying the assay from x to use as input. Defaults to "counts". |

**Value**

A list of two data.frames (pattern\_results, patterns):

- pattern\_results: data.frame with pattern membership information for each gene.
- patterns the posterior mean underlying expression from genes in given spatial patterns.

**Author(s)**

Davide Corso, Milan Malfait, Lambda Moses

**References**

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>

**SpatialDE 1.1.3:** the version of the Python package used under the hood.

**See Also**

The individual steps performed by this function: [stabilize\(\)](#), [regress\\_out\(\)](#) and [spatial\\_patterns\(\)](#).

**Examples**

```
## Mock up a SpatialExperiment object with 100 cells and 3 genes
set.seed(42)
spe <- mockSVG(size = 10, tot_genes = 3, de_genes = 1, return_SPE = TRUE)

## Run spatialDE
de_results <- spatialDE(spe)

spatial_patterns <- spatialPatterns(spe, de_results = de_results,
  qual_thresh = NULL, n_patterns = 4L, length = 1.5,
  verbose = FALSE
)

head(spatial_patterns$pattern_results)
head(spatial_patterns$patterns)
```

---

|                  |  |
|------------------|--|
| spatial_patterns | <i>Group spatially variable genes into spatial patterns using automatic expression histology (AEH)</i> |
|------------------|--|

---

### Description

Group spatially variable genes into spatial patterns using automatic expression histology (AEH)

### Usage

```
spatial_patterns(  
  x,  
  coordinates,  
  de_results,  
  qval_thresh = 0.05,  
  n_patterns,  
  length,  
  verbose = FALSE  
)
```

### Arguments

|             |  |
|-------------|--|
| x           | matrix-like object of normalized counts. E.g. resulting from <code>regress_out()</code> .  |
| coordinates | data.frame with sample coordinates. Each row is a sample, the columns with coordinates must be named 'x' and 'y'.  |
| de_results  | data.frame resulting from <code>run()</code> .   |
| qval_thresh | numeric scalar, specifying the q-value significance threshold to filter <code>de_results</code> . Only rows in <code>de_results</code> with <code>qval &lt; qval_thresh</code> will be kept. To disable, set <code>qval_thresh = NULL</code> . |
| n_patterns  | integer The number of spatial patterns   |
| length      | numeric The characteristic length scale of the clusters  |
| verbose     | logical controlling the display of the progress bar.   |

### Value

list of two dataframe (`pattern_results`, `patterns`): `pattern_results` dataframe with pattern membership information for each gene. `patterns` the posterior mean underlying expression fro genes in given spatial patterns.

### References

Svensson, V., Teichmann, S. & Stegle, O. SpatialDE: identification of spatially variable genes. Nat Methods 15, 343–346 (2018). <https://doi.org/10.1038/nmeth.4636>



**Examples**

```

## Mock up a SpatialExperiment object with 400 cells and 3 genes
set.seed(42)
mock <- mockSVG(size = 20, tot_genes = 3, de_genes = 1)

stabilized <- stabilize(mock$counts)
sample_info <- mock$coordinates
sample_info$total_counts <- colSums(mock$counts)
regressed <- regress_out(counts = stabilized, sample_info = sample_info)

## Run SpatialDE
de_results <- run(x = regressed, coordinates = mock$coordinates)

## Run Spatial_patterns
sp <- spatial_patterns(
  x = regressed,
  coordinates = mock$coordinates,
  de_results = de_results,
  qual_thresh = NULL,
  n_patterns = 5, length = 1.5
)

sp$pattern_results
sp$patterns

```

---

|           |                                     |
|-----------|-------------------------------------|
| stabilize | <i>Stabilize variance of counts</i> |
|-----------|-------------------------------------|

---

**Description**

Stabilize variance of negative binomial data using Anscombe's approximation. This function is a wrapper for stabilize from the [NaiveDE](#) Python package.

**Usage**

```
stabilize(counts)
```

**Arguments**

counts            matrix with expression values for samples in columns and genes in rows.

**Value**

matrix of variance stabilized counts.

**Examples**

```
## Mock up a SpatialExperiment object with 400 cells and 3 genes
set.seed(42)
mock <- mockSVG(20, 3, 1)

stabilized <- stabilize(mock$counts)
```

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