

Analyzing Single Cell ATAC-Seq data

Your browser does not support the HTML5 video element

For your convenience, here is a video showing the below steps.

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This guide illustrates how to process FASTQ files produced using the 10x Genomics Chromium Single Cell ATAC assay to obtain a Single cell counts data node, which is the starting point for analysis of single-cell ATAC experiments.

If you are new to Partek Flow, please see [Getting Started with Your Partek Flow Hosted Trial](#) for information about data transfer and import and [Creating and Analyzing a Project](#) for information about the Partek Flow user interface.

This tutorial uses a [10X 5k PBMC dataset](#) if you would like to follow along exactly.

Transfer files and create a new project

We recommend uploading your FASTQ files (fastq.gz) to a folder on your Partek Flow server before importing them into a project. Data files can be transferred into Flow from the *Home* page by clicking the **Transfer file** button (Figure 1). Following the instruction in Figure 1 to complete the data transfer. Users have the option to change the **Upload directory** by clicking the **Browse** button and either select another existing directory or create a new directory.

To create a new project, from the *Home* page click the **New Project** button; enter a project name and then click **Create project**. Once a new project has been created, click the **Add data** button in the *Analyses* tab.

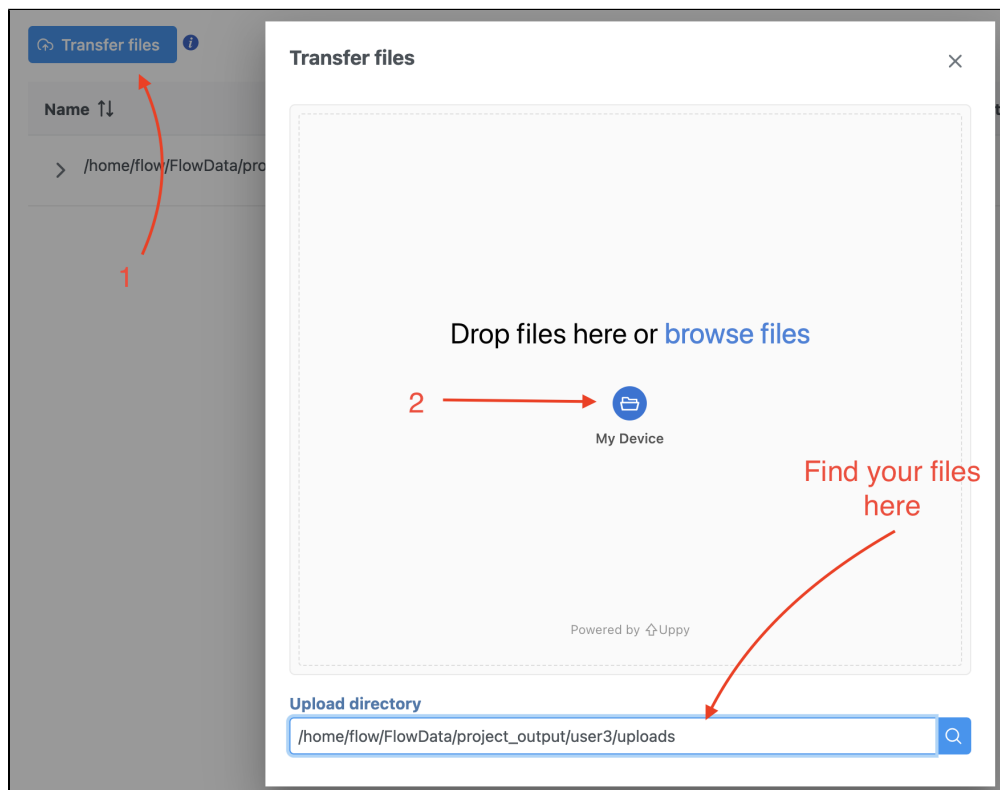


Figure 23. Transfer file in Partek Flow.

Import the FASTQ files

To proceed, click the **Add data** button in the *Analyses* tab. In the *Single cell* > *scATAC-Seq* section select **fastq** and click **Next**. The file browser interface will open (Figure 3). Select the FASTQ files using the file browser interface and push the **Finish** button to complete the task. Paired end reads will be automatically detected and multiple lanes for the same sample will be automatically combined into a single sample. We encourage users to include all the FASTQ files including the index files although they are optional.

When the FASTQ files have finished importing, the *Unaligned reads* data node will appear in the *Analyses* tab.

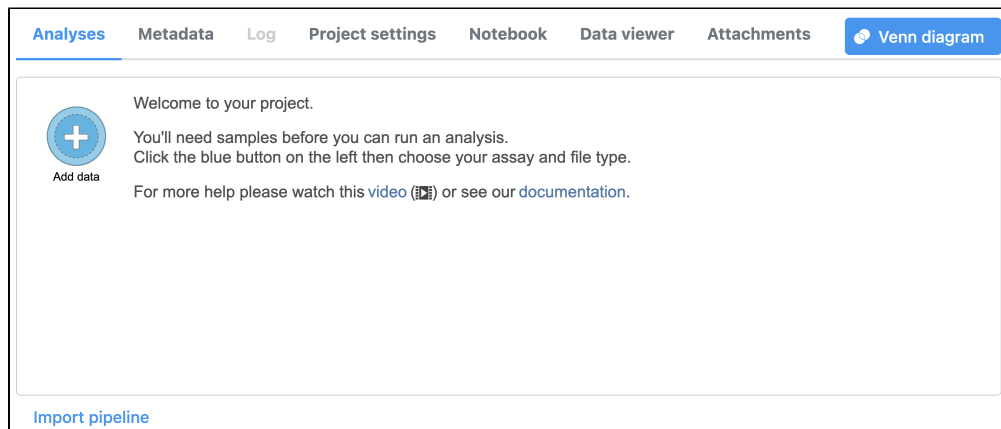


Figure 24. Data tab in Partek Flow.

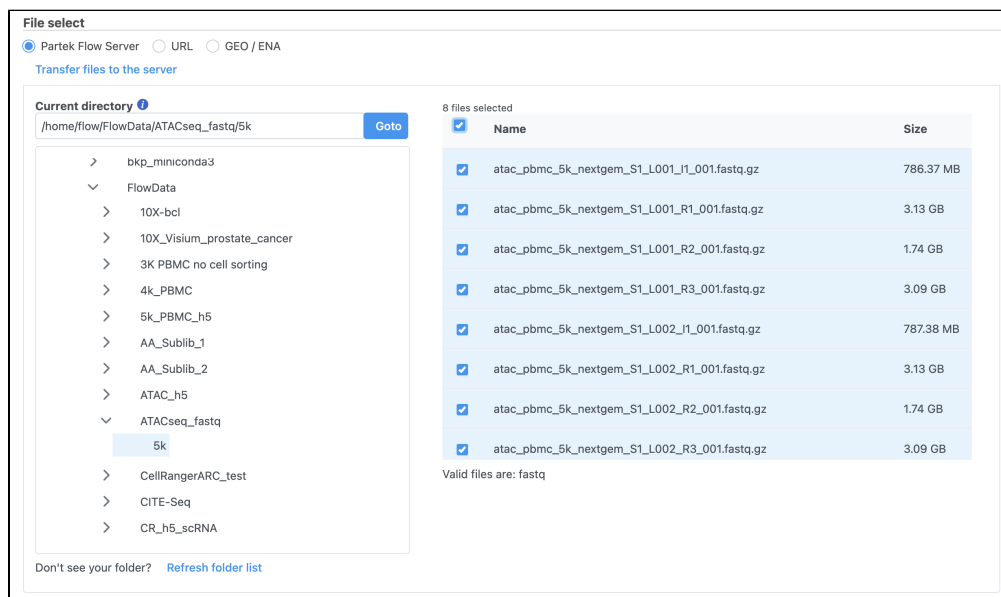


Figure 25. Input FASTQ files for scATAC-Seq data in Flow.

Convert FASTQ to count

To deal with the single cell ATAC-seq FASTQ data, Flow® has wrapped the 'cellranger-atac count' pipeline from Cell Ranger ATAC v2.0[1]. It takes FASTQ files and performs multiple analysis simultaneously including reads filtering and alignment, barcode counting, identification of transposase cut sites, peak and cell calling, and generates the count matrix.

To run Cell Ranger - ATAC task:

- Click the *Unaligned reads* data node
- Select **Cell Ranger - ATAC** in the **10x Genomics** section in the task menu on the right
- Select **Single cell ATAC** in *Assay type* for ATAC-Seq data only
- Choose the proper *Reference assembly* for the data (you may have to create the reference)
- Press the **Finish** button to run the task with default settings (Figure 4)

Assay type

10X assay type

☒ Single cell ATAC
 ☐ Single cell Multiome ATAC + Gene Expression

Reference assembly

Assembly

Select assembly or add a custom library.

Homo sapiens (human) - hg38 ▾

Index

Ensembl Transcripts release 109 (Matt Luberti) ▾

Subsample

☐ **Subsample percentile**
 Downsample to preserve this fraction of reads.

1

^
 v

Advanced options

Option set

-- Default -- ▾

Configure

Back

Finish

Figure 26. Convert FASTQ by Cell Ranger - ATAC task in Flow.

To learn more about how to run [Cell Ranger - ATAC](#) task in Flow, please refer to our online [documentation](#).

The output of the count matrix then becomes the starting point for downstream analysis for scATAC-seq data in Flow (Figure 5).

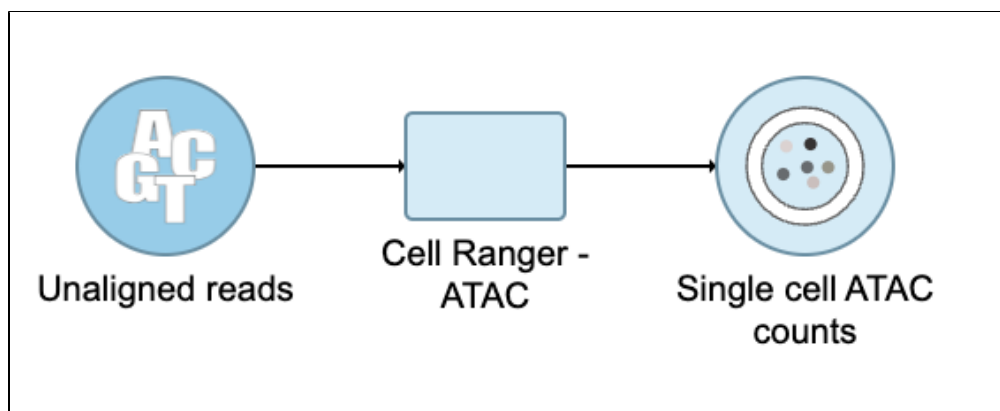


Figure 27. Single cell QA/QC task for scATAC-Seq data in Flow.

QA/QC

An important step in analyzing single cell ATAC data is to filter out low quality cells. A few examples of low-quality cells are doublets, cells with a low TSS enrichment score, cells with a high proportion of reads mapping to the genomic blacklist regions, or cells with too few reads to be analyzed. Users are able to do this in Partek Flow using the Single cell QA/QC task.

- Click on the *Single cell counts* node
- Click on the **QA/QC** section in the task menu
- Click on **Single cell QA/QC**

A task node, *Single cell QA/QC*, is produced. Initially, the node will be semi-transparent to indicate that it has been queued, but not completed. A progress bar will appear on the *Single cell QA/QC* task node to indicate that the task is running (Figure 5).

- Click the *Single cell QA/QC* node once it finishes running
- Click **Task report** in the task menu

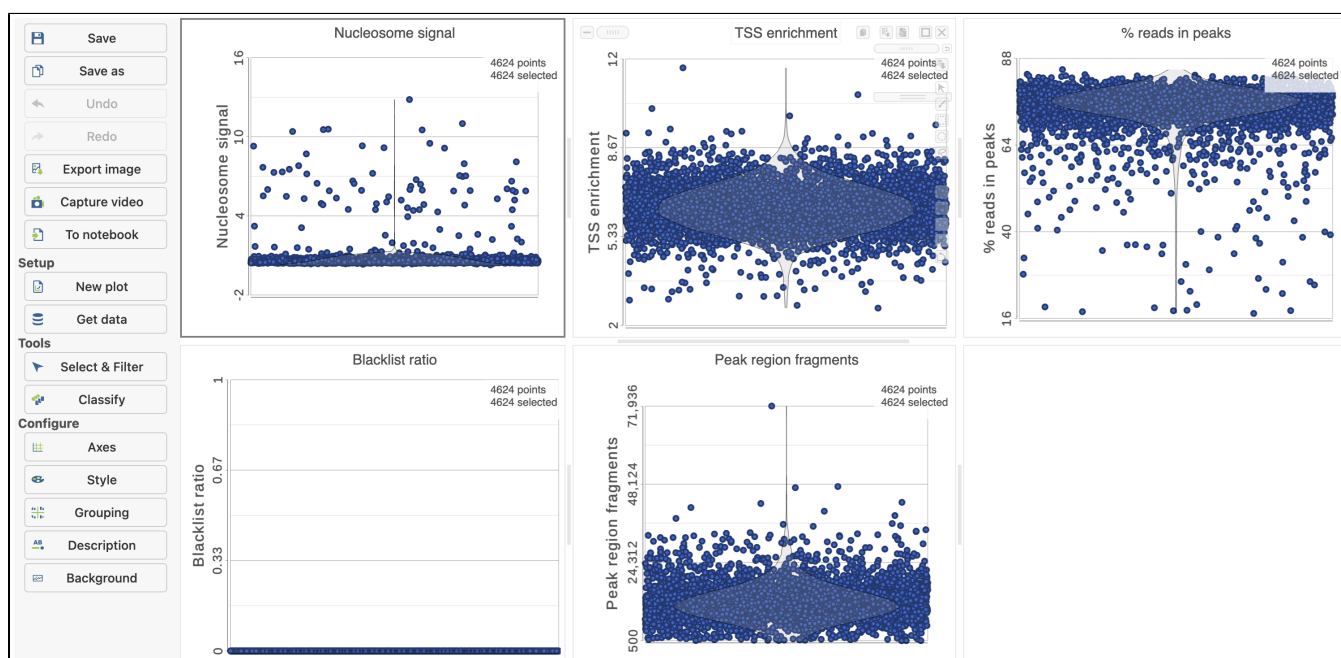


Figure 28. QA/QC task report for scATAC - Seq data in Flow.

The *Single cell QA/QC* report includes interactive violin plots showing the value of every cell in the project on several quality measures (Figure 6).

There are five plots: Nucleosome signal, TSS enrichment, % reads in peaks, Blacklist ratio, and Peak region fragments. Each point on the plots is a cell and the violins illustrate the distribution of values for the y-axis metric. Cells can be filtered either by clicking and dragging to select a region on one of the plots or by setting thresholds using the filters below the plots. Here, we will apply a filter for the number of read counts. The plot will be shaded to reflect the filter. Cells that are excluded will be shown as black dots on both plots.

Descriptions of QC metrics:

Nucleosome signal: calculated per single cell, which quantifies the approximate ratio of mononucleosomal to nucleosome-free fragments. The histogram of DNA fragment sizes (determined from the paired-end sequencing reads) should exhibit a strong nucleosome banding pattern which corresponds to the length of DNA wrapped around a single nucleosome.

TSS enrichment: Transcriptional start site (TSS) enrichment score. The ENCODE project has defined an ATAC-seq targeting score based on the ratio of fragments centered at the TSS to fragments in TSS-flanking regions (see <https://www.encodeproject.org/data-standards/terms/>). Poor ATAC-seq experiments typically will have a low TSS enrichment score.

Peak region fragments: total number of fragments in peaks which is a measure of cellular sequencing depth/complexity. Cells with very few reads may need to be excluded due to low sequencing depth. Cells with extremely high levels may represent doublets, nuclei clumps, or other artifacts.

% reads in peaks: Represents the fraction of all fragments that fall within ATAC-seq peaks. Cells with low values (i.e. <15-20%) often represent low-quality cells or technical artifacts that should be removed. Note that this value can be sensitive to the set of peaks used.

Blacklist ratio: The ENCODE project has provided a list of blacklist regions, representing reads which are often associated with artifactual signals. Cells with a high proportion of reads mapping to these areas (compared to reads mapping to peaks) often represent technical artifacts and should be removed.

Filter cells

To filter out low quality cells (Figure 7),

- Open the **Select & Filter** menu
- Set the filters on nucleosome signal < 4; Peak region fragment 500-30000; leave the rest as they are
- Click the filter icon  and **Apply observation filter** to run the Filter cells task on the first *Single cell ATAC counts* data node, it generates a *Filtered cells* node



Figure 29. Filter low quality cells in Partek Flow.

Filter features

Another common task is to filter the data to include only informative features. Partek Flow has a wide variety of flexible filtering options.

Filter features task can be invoked from any counts or single cell data node. Noise Reduction and Statistics Based filters take each feature and perform the specified calculation across all the cells. The filter is applied to the values in the selected data node and the output is a filtered version of the input data node.

In the task dialog, click the check box to activate one or more of the filter types, configure the filter(s), and click **Finish** to run (Figure 8).

☒ Noise reduction filter i

Exclude features where

value <= 1.0 in at least 99.00 % of the cells

☐ Statistics based filter i

Filter features by

☒ Counts ☐ Percentiles

Keep the top 100.0 features with highest variance

Figure 30. Filter features in Partek Flow.

Annotate regions

To understand the importance of enriched regions in regulating gene expression, Flow uses **Annotate regions** task to add information about overlapping or nearby genomic features. That gives regulatory context for enriched regions.

The input for *Annotate peaks* is a Peaks type data node.

- Click the **Filtered features** data node
- Click the **Peak analysis** section in the toolbox
- Click **Annotate regions**
- Set the *Genomic overlaps* parameter

The *Genomics overlaps* parameter lets you choose one of two options (Figure 9).

- *Report one gene region per peak (precedence applies)* chooses one gene section for each peak using the precedence order to settle cases where more than one gene section overlaps a peak. The order of precedence is TSS, TTS, CDS Exon, 5' UTR Exon, 3' UTR Exon, Intron, Intergenic.
- *Report all gene regions per peak* creates a row for each gene section that overlaps a peak in the task report.

Select Annotation file

Assembly

Homo sapiens (human) - hg38

Annotation model

Ensembl Transcripts release 109 (Matt Luberti)

Output options

Genomic overlaps

If a peak overlaps more than one genomic features, precedence rules apply (in case of ties it's random): 1. TSS 2. TTS 3. CDS Exons 4. 5' UTR Exons 5. 3' UTR Exons 6. Introns 7. Intergenic

☒ Report one gene region per peak (precedence applies)

☐ Report all gene regions per peak

TSS upstream limit

The number of bases upstream from the transcription start site (TSS) to consider within the promoter region. (--upstream-tss)

1,000

TSS downstream limit

The number of bases downstream from the transcription start site (TSS) to consider within the promoter region. (--downstream-tss)

1,000

TTS upstream limit

The number of bases upstream from the transcription termination site (TTS) to consider within the promoter region. (--upstream-tts)

1,000

TTS downstream limit

The number of bases downstream from the transcription termination site (TTS) to consider within the promoter region. (--downstream-tts)

1,000

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[Finish](#)

Figure 31. Annotate regions in Partek Flow.

Users are able to define the transcription start site (TSS) and transcription termination site (TTS) limit in the unit of bp.

- Choose a gene/feature annotation from the drop-down menu
- Click **Finish** to run

TF-IDF (frequency-inverse document frequency) normalization

Latent semantic indexing (LSI) was first introduced for the analysis of scATAC-seq data by Cusanovich *et al.* 2018[2]. LSI combines steps of frequency-inverse document frequency (TF-IDF) normalization followed by singular value decomposition (SVD). Partek Flow wrapped Signac's TF-IDF normalization for single cell ATAC-seq dataset. It is a two-step normalization procedure that both normalizes across cells to correct for differences in cellular sequencing depth, and across peaks to give higher values to more rare peaks[3].

TF-IDF normalization in Flow can be invoked in *Normalization and scaling* section by clicking any *single cell counts* data node (Figure 10).

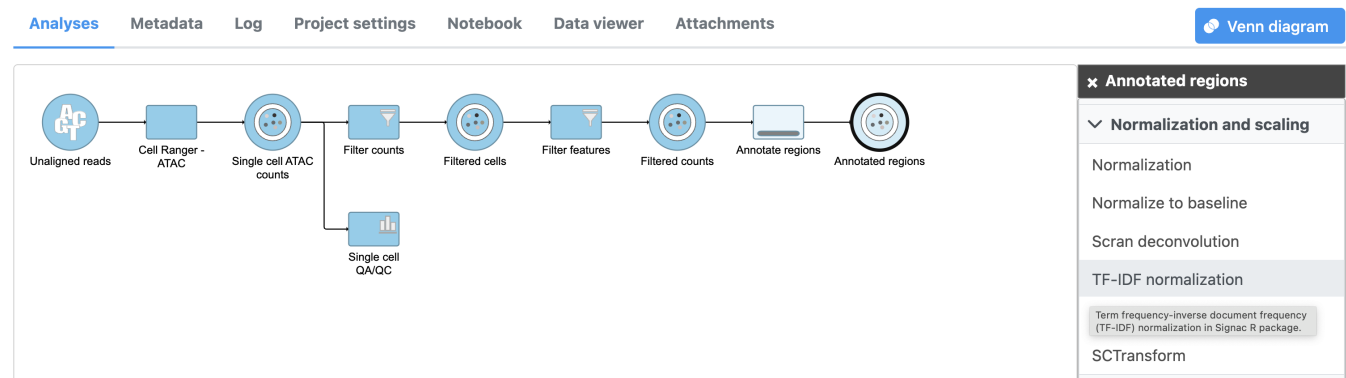


Figure 32. TF-IDF normalization for scATAC-Seq in Flow.

To run **TF-IDF normalization**,

- Click a **Single cell counts** data node, in this case the **Annotated regions** node
- Click the **Normalization and scaling** section in the toolbox
- Click **TF-IDF normalization**

The output of **TF-IDF normalization** is a new data node that has been normalized by $\log(TF \times IDF)$.

SVD (singular value decomposition)

Singular value decomposition (SVD) will be applied to *TF-IDF* output in scATAC-Seq data. It returns a reduced dimension representation of a matrix. Although SVD and Principal components analysis (PCA) are two different techniques, the SVD has a close connection to PCA. Because PCA is simply an application of the SVD. For users who are more familiar with scRNA-Seq, you can think of SVD as analogous to the output of PCA. And similarly, the statistical interpretation of singular values is in the form of variance in the data explained by the various components.

To run **SVD** task,

- Click a **Normalized counts** data node
- Click the **Exploratory analysis** section in the toolbox
- Click **SVD**

The GUI is simple and easy to understand. The **SVD** dialog is only asking to select the number of singular values to compute (Figure 11). By default 100 singular values will be computed if users don't want to compute all of them. However, the number could be adjusted manually or typed in directly. Simply click the **Finish** button if you want to run the task as default.

The task report for **SVD** is similar to PCA. Its output will be used for downstream analysis and visualization, including Harmony and WNN.

Singular values count

Number of singular values to compute

☐ All

☒ 

Figure 33. SVD task configuration dialog in Partek Flow.

Graph-based clustering

Graph-based clustering (Figure 12) identifies groups of similar cells using SVD values as the input. By including the informative SVDs, noise in the data set is excluded, improving the results of clustering.

- Click the **SVD** output
- Click **Exploratory analysis** in the task menu
- Click **Graph-based clustering**
- Check **Compute biomarkers**
- Click **Finish** to run as default

Clustering

Clustering algorithm

Three modifications of Louvain clustering algorithm are available (Waltman & Van Eck, 2013). The most recent version is Smart Local Moving approach (SLM).

☒ Louvain ☐ Louvain with refinement ☐ SLM

☒ Compute biomarkers

Queue a "Compute biomarkers" task for the resulting attribute, which will compute the features that are expressed highly when comparing each cluster.

Advanced options

Option set

-- Default --



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[Finish](#)

Figure 34. Configure Graph-based clustering in Flow.

A new *Graph-based clusters* data and a *Biomarkers* data node will be generated.

- Double-click the **Graph-based clusters** node to see the cluster results and statistics (Figure 13)
- Double-click the **Biomarkers** node to see the computed biomarkers if you have selected this option (Figure 14)

The *Graph-based clustering result* (Figure 13) lists the *Total number of clusters* and what proportion of cells fall into each cluster as well as *Maximum modularity* which is a measurement of the quality of the clustering result where optimal modularity is 1. The *Biomarkers* report (Figure 14) includes the top features for each graph-based cluster. It displays the top-10 genes that distinguish each cluster from the others. **Download** at the bottom right of the table can be used to view and save more features. These are calculated using an ANOVA test comparing the cells in each group to all the other cells, filtering to genes that are 1.5 fold upregulated, and sorting by ascending *p-value*. This ensures that the top-10 genes of each cluster are highly and disproportionately expressed in that cluster.

Cluster results

Maximum modularity: 0.519794

Cluster statistics

Total number of clusters 4

Cluster 	Size 	Size % 
1	3632	80.55%
2	611	13.55%
3	243	5.39%
4	23	0.51%

Task details

Figure 35. Graph-based clustering results in Flow.

Biomarkers for Graph-based

Top features 	Cluster 1 	Cluster 2 	Cluster 3 	Cluster 4 
1	chr19:50328852-50329789 (NR1H2)	chr12:52566619-52567518 (KRT74)	chr13:86757061-86757920	chr6:4281578-4282483
2	chr15:97960021-97960935 (ARRDC4)	chr12:121557436-121558356 (KDM2B)	chr17:82909216-82910126 (TBCD)	chr6:22062684-22063619 (CASC15)
3	chr3:72100450-72101314 (LINC00877)	chr2:231425765-231426666	chr11:114065779-114066711 (ZBTB16)	chr3:194396909-194397620 (GP5)
4	chr10:71888455-71889366 (---)	chr14:24633910-24634826 (GZMB)	chr5:133467003-133467901 (FSTL4)	chr22:17257804-17258726 (ADA2)
5	chr2:47072520-47073340 (TTC7A)	chr1:10524933-10525845 (PEX14)	chr8:144262121-144263019 (MIR7112)	chr3:183115834-183116736 (MCCC1)
6	chr20:50274663-50275572 (PELATON)	chr1:202197386-202198289 (LGR6)	chr15:90856427-90857324 (RN7SL363P)	chr2:216015680-216016587 (MREG)
7	chr15:92803664-92804551 (FAM174B)	chr12:68159376-68160284 (IFNG)	chr8:37870835-37871732 (RAB11FIP1)	chr4:51423-52297 (ZNF595)
8	chr6:44058486-44059251 (---)	chr1:100028503-100029416 (SLC35A3)	chr1:57307141-57308057 (DAB1)	chr8:125601923-125602490
9	chr2:26008664-26009543	chr20:57604857-57605745 (ZBP1)	chr20:3665641-3666555	chr14:102948865-102949791 (CDC42BPB)
10	chr1:183590286-183591143 (NCF2)	chr22:23263698-23264612 (FBXW4P1)	chr16:81524087-81524996 (CMIP)	chr6:6588266-6589130 (LY86)

 Download

Figure 36. Computer biomarkers results in Flow.

UMAP

Similar to t-SNE, Uniform Manifold Approximation and Projection (UMAP) is a dimensional reduction technique. UMAP aims to preserve the essential high-dimensional structure and present it in a low-dimensional representation. UMAP is particularly useful for visually identifying groups of similar samples or cells in large high-dimensional data sets.

To run UMAP (Figure 15):

- Click the **SVD** data node
- Click the **Exploratory analysis** section of the toolbox
- Click **UMAP**
- Click **Finish** to run with default settings

UMAP produces a *UMAP* task node. Opening the task report launches a scatter plot showing the *UMAP* results. Each point on the plot is a cell for single cell data. The plot will open in 2D or 3D depending on the user preference.

Initialize output values

Initialize the low dimensional embedding either at random or using a spectral embedding of the fuzzy 1-skeleton.

Random ▼

Advanced options

Option set

-- Default -- ▼

[Configure](#)

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[Finish](#)

Figure 37. UMAP configuration in Partek Flow.

Promoter sum matrix

The Annotate regions task in Flow labels individual peaks as promoters for a particular gene if the peak falls 1000 bases upstream from a gene's transcription start site, or 100 bases downstream from a gene's transcription start site by default (Figure 9). A promoter sum for a given gene is the number of cut sites per cell that fall within all the peaks labeled as promoters (-1000bp ~ 100bp by default or user defined through Annotate regions) for that gene. Higher promoter sum values indicate higher chromatin accessibility in the promoter region [4].

Flow task **Promoter sum matrix** summarizes each promoter sum and outputs a cell x gene matrix. In the matrix, only genes that have peaks within its promoter region have been included. In Flow **Promoter sum matrix** can be invoked in the Peak analysis section by clicking the Annotated regions data node (Figure 16).

To run **Promoter sum matrix** in Flow,

- Click the **Annotated regions** data node
- Click the **Peak analysis** section in the toolbox
- Click **Promoter sum matrix**

Once the task has been finished, a new data node will be produced where the promoter sum value for each feature can be used to color UMAP/t-SNE and to determine cell type with raw data. We recommend users normalize its output prior to color the UMAP just like the scRNA-seq data.

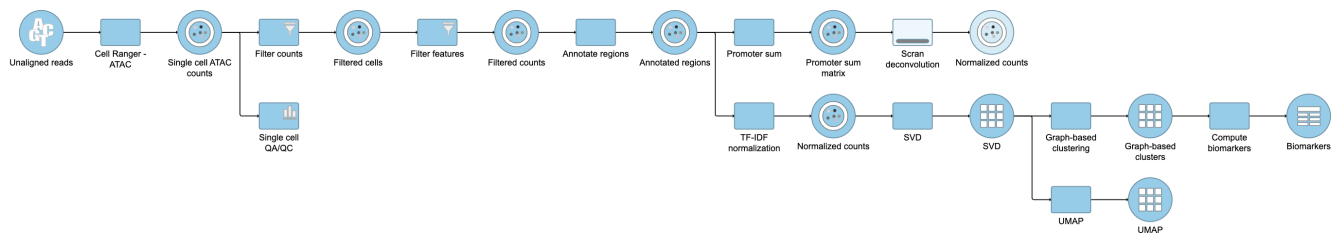


Figure 38. Promoter sum matrix in Flow.

Classifying cells

Double-clicking the *UMAP* task node will open the task report in the Data Viewer.

To classify a cell, just select it then click **Classify selection** in the **Classify** tool.

For example, we can classify a cluster of cells expressing high levels of *MS4A1* as B cells.

- Make sure the right data source has been selected. For scATAC-seq data, it shall be the normalized counts of promoter sum values in most cases (Figure 17)
- Set *Color by* in the **Style** configuration to the normalized counts node
- Type *MS4A1* in the search box and select it. Rotate the 3D plot if you need to see this cluster more clearly.
- Click  to activate Lasso mode
- Draw a lasso around the cluster of *MS4A1*-expressing cells
- Click **Classify selection** under *Tools* in the left panel
- Type **B cells** for the Name
- Click **Save** (Figure 18)

Repeat the above steps to finish the other cell type classifications. To be able to use the classifications in downstream tasks and visualizations, you must first apply them.

- Click **Apply classifications**
- **Name** the classification (e.g. Cell type)
- Check the **Compute biomarkers** if needed
- Click **Run** to complete the task

Once the classifications have been added to the project, one can color the UMAP/t-SNE plot by the Classification or compare the differentially expressed genes between different cell types.

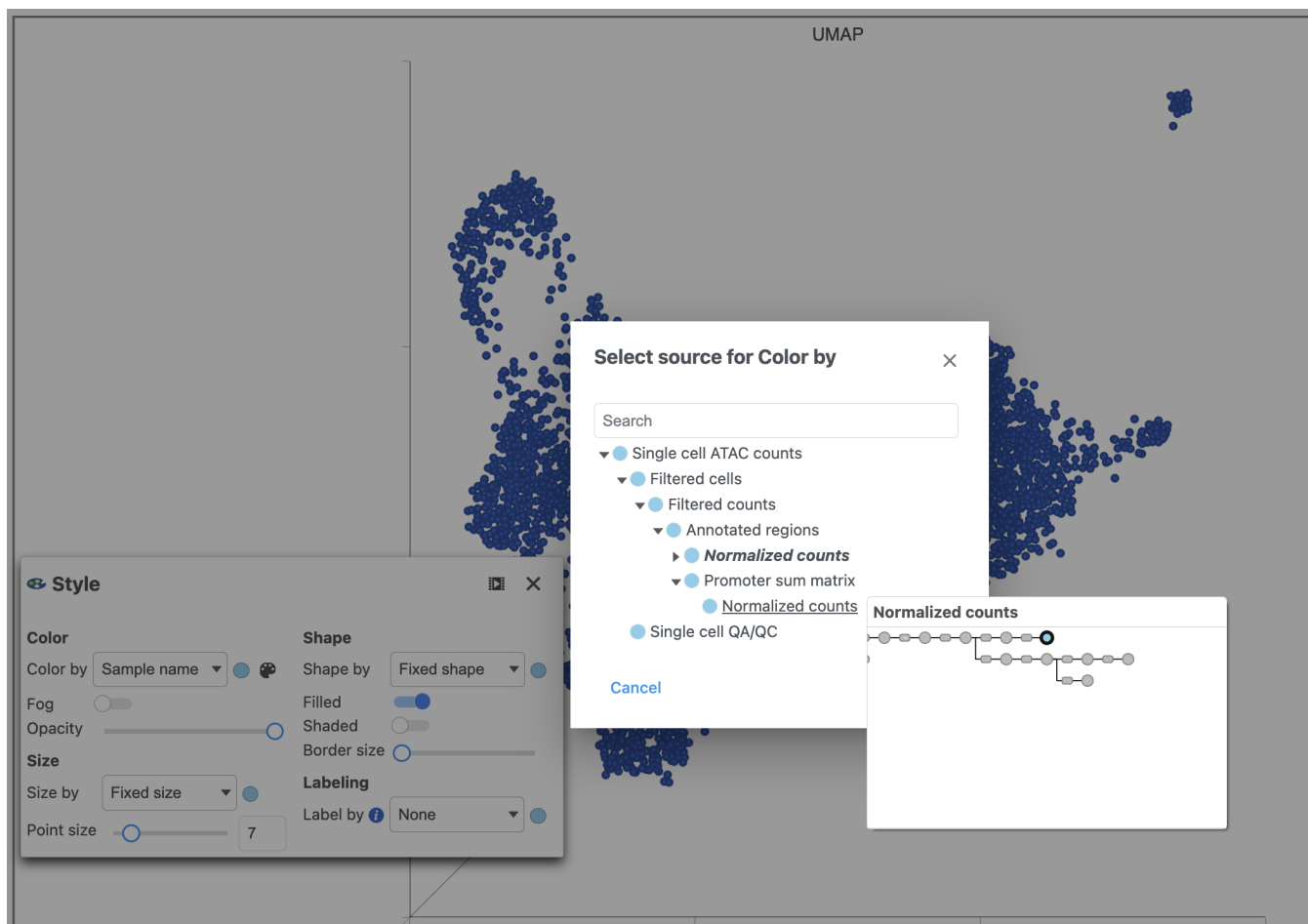


Figure 39. Select the data source in Data Viewer.

Define comparisons i

Factor Cell type

B cells

T cells

N/A

>

<

>

<

Numerator

B cells

VS

Denominator

T cells

☒ Combine i ☐ Pairwise i

Add comparison

Comparisons

Comparison	Delete
B cells vs. T cells	

Figure 42. Define comparisons in Hurdle model.

Hurdle model produces a Feature list task node. The results table and options are the same as the GSA task report except the last two columns. The percentage of cells where the feature is detected (value is above the background threshold) in different groups (Pct(group1), Pct(group2)) are calculated and included in the Hurdle model report.

A filtered Feature list data node can be produced by running the Differential analysis filter in the Hurdle model task report (Figure 21) .

Results: 438

Filter

Clear all

☐ Region ID

☐ Gene name

☐ Transcript name

☐ Gene IDs

☐ Transcript IDs

☐ Gene section

☐ P-value

☒ FDR step up

Less than or...

0.01

0

1

☐ Ratio

☒ Fold change

From

-2

to

2

☒ Exclude range

☐ LSMean

☐ Low expressed

☐ Pct(B cells)

☐ Pct(T cells)

Save filter

Saved filters

⚙️

▼

(No saved filters available)

🔍

Generate filtered node

💾

Save as managed list

Figure 43. Generate filtered node for differential analysis results in Flow.

Once we have filtered a list of differentially expressed genes, we can visualize these genes by generating a [heatmap](#), or perform the Gene set enrichment analysis and [motif detection](#).

Pipeline

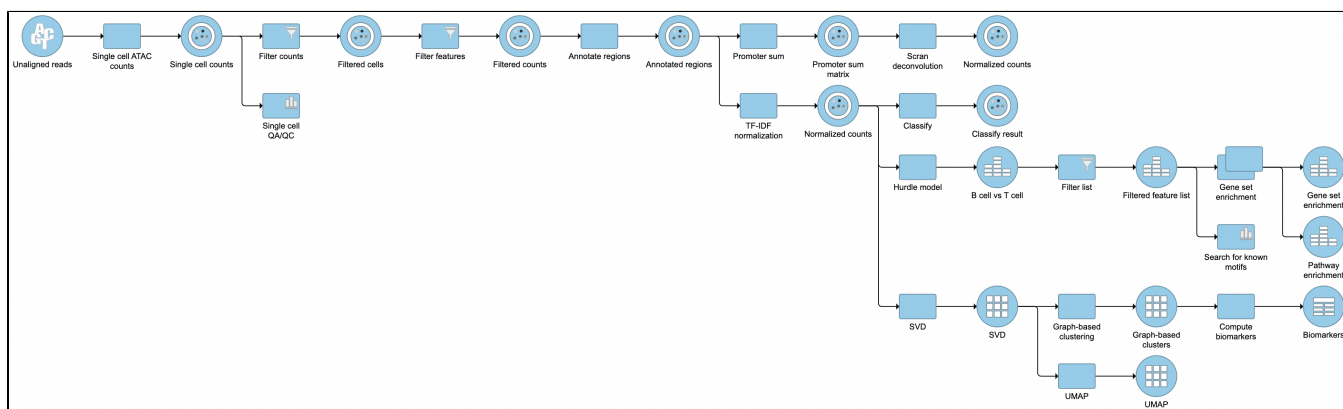


Figure 44. Described pipeline shown in the Analyses tab

For information about automating steps in this analysis workflow, please see our documentation page on [Making a Pipeline](#).

References

1. <https://support.10xgenomics.com/single-cell-atac/software/pipelines/latest/what-is-cell-ranger-atac>
2. Cusanovich, D., Reddington, J., Garfield, D. *et al.* The *cis*-regulatory dynamics of embryonic development at single-cell resolution. *Nature* **555**, 53–542 (2018). <https://doi.org/10.1038/nature25981>
3. <https://satijalab.org/signac/index.html>
4. <https://support.10xgenomics.com/single-cell-atac/software/visualization/latest/tutorial-celltypes>

Additional Assistance

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Your Rating: ☆☆☆☆☆ Results: ★★★★★ 4 rates