

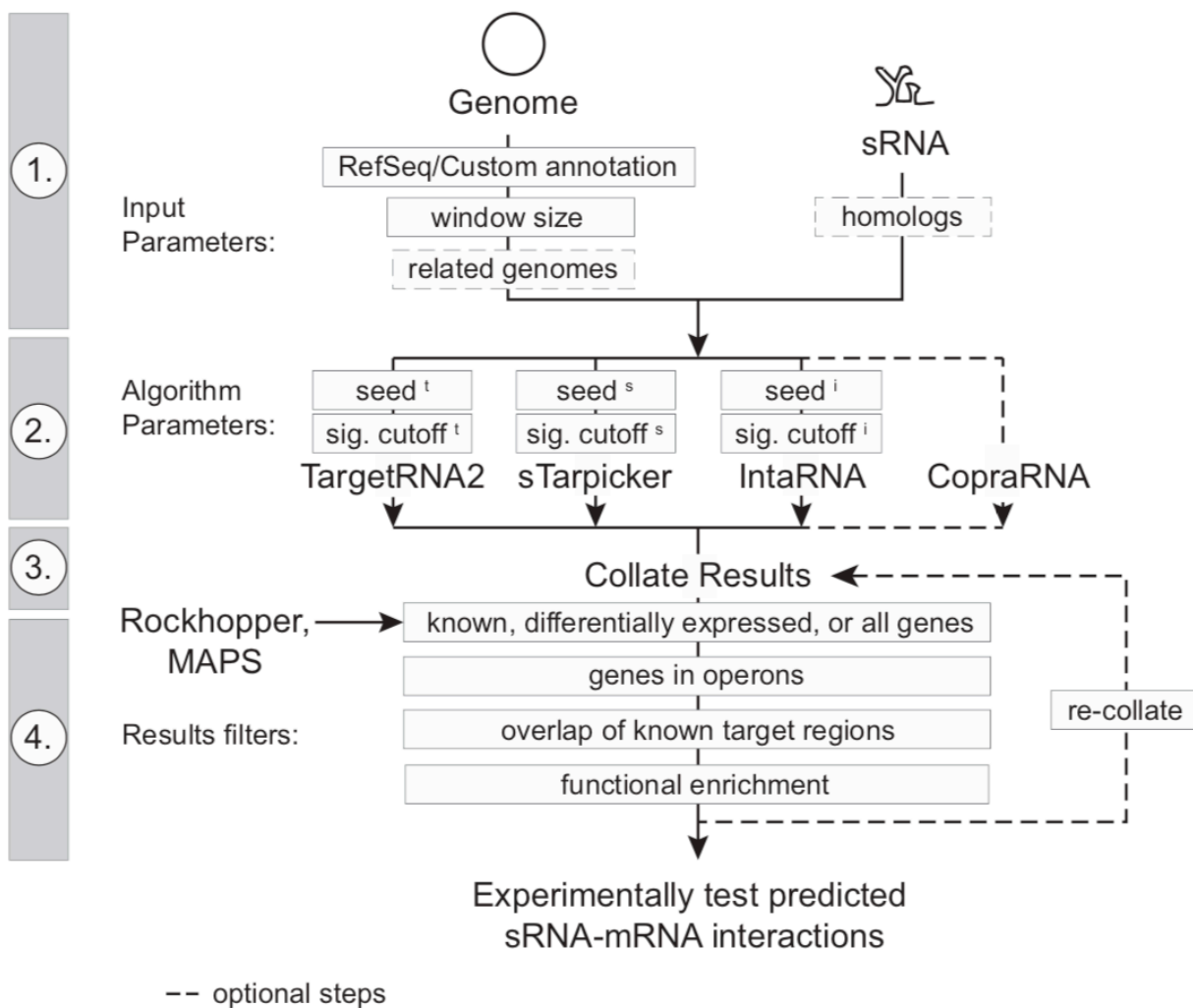


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Cite: A.M. King, C.K. Vanderpool, and P.H. Degnan. sRNA-target Prediction Organizing Tool (SPOT) integrates computational and experimental data to facilitate functional characterization of bacterial small RNAs

1. Rationale

Computational approaches for sRNA target prediction have limitations but are relied upon to generate testable hypotheses for sRNA function. Some algorithms are available online or downloadable (e.g., TargetRNA2, IntaRNA), however these tools frequently yield distinct results, have different data output formats and default search parameters. Therefore, manually compiling results from these disparate tools and integrating the predictions with existing experimental data is not trivial. We have generated an innovative approach to streamline use of multiple existing sRNA target prediction algorithms and integrate predictions with experimental data to generate a unified set of target predictions. To this end, we have developed **SPOT** a flexible software pipeline that searches for sRNA-mRNA binding sites in parallel using separate search tools, collates the predictions, and integrates experimental data using customizable results filters.

Figure 1. Schematic of **SPOT** pipeline analysis (King et al.)

2. Installing SPOT

SPOT is a PERL program that runs TargetRNA2, IntaRNA, StarPicker and CopraRNA in parallel, and collates the results to find consensus sRNA-mRNA targets (Figure 1). Furthermore, additional data types can be utilized to filter the results including expression differences, known binding sites, operon predictions and window size of possible binding sites.

As written the program can run on any Unix/Linux based system, however it has a number of dependencies. To facilitate its use we have set up an [Amazon Web Service \(AWS\)](#) cloud [Amazon Machine Image \(AMI\)](#) with all of the required software installed. Skip to sections 4-7 for setting up your own **SPOT** AMI. However, using the code available [here](#) you can set up and run **SPOT** on a local server.

First, download and install the following software tools and all of their dependencies according the authors' instructions:

- [TargetRNA v2](#)
- [StarPicker](#)
- [IntaRNA v1.0.4](#)
- [CopraRNA v1.2.9](#)

Several modifications were made to the StarPicker and IntaRNA code to accommodate demands of the pipeline.

Replace the following programs with those provided in the GitHub link. Modifications in the code are marked with ## comments and/or initials (PHD). Descriptions of edits made are listed briefly below.

StarPicker:

sTarPicker_global2.pl : changes made to input of command line arguments

IntaRNA v1.0.4:

add_GI_genename_annotation.pl : distinguish GeneIDs vs GI Nos
 get_refseq_from_ftp.pl : Replacement code for get_refseq_from_ftp.sh
 IntaRNA_wrapper.pl : Option added to use local GenBank files, use
 get_refseq_from_ftp.pl
 rerun_enrichment.pl : code snippet re-running enrichment analysis from
 IntaRNA_Wrapper.pl
 termClusterReport.pl : code modified to handle GeneIDs vs GI Nos

CopraRNA v1.2.9:

get_refseq_from_ftp.pl : Replacement code for get_refseq_from_ftp.sh
 termClusterReport.pl : code modified to handle GeneIDs vs GI Nos
 get_CDS_from_gbk.pl : code modified to skip and flag GenBank files not present
 in kegg2refseqnew.csv list

Note: D3 Javascript libraries may or may not be accessible using existing framework to generate functional enrichment heatmaps (<http://d3js.org/d3.v3.min.js>). If problems are encountered, it is possible to edit the master html files in IntaRNA and CopraRNA to use a local version of d3.v3.min.js .

Be sure all programs are added to the user path and all path references in StarPicker, IntaRNA, and CopraRNA match your system installation. The statistics program R is installed as a requirement for IntaRNA and CopraRNA. As such add the following two packages:

- [RColorBrewer](#)
- [gplots](#)

```
$ sudo R
> install.packages(c('RColorBrewer', 'gplots'))
```

Some of the output from the **SPOT** program will be written in an `xlsx` format using the Excel Writer PERL module:

- [Excel-Writer-XLSX-0.98](#)

```
$ sudo cpan Excel::Writer::XLSX
```

Most existing Unix/Linux installations should have `sendmail` installed. If not, install the appropriate package

- [sendmail](#)

```
$ sudo apt install sendmail-bin
```

SPOT can work with local copies of genomes and annotations. However, to access genomes from NCBI install the `efetch` program from the Entrez Direct (`edirect`) toolkit.

- [edirect](#)

Retrieve and decompress the **SPOT** directory from GitHub containing core pipeline script and its additional required support PERL scripts.

- [SPOT](#)

Make sure **SPOT** and all of the programs are in your user path. Modify the core pipeline script with the absolute path locations for TargetRNA2, IntaRNA, StarPicker and CopraRNA, and other support PERL scripts.

3. Running SPOT - Quick Start

SPOT is a pipeline script that when run without arguments will print all of the possible program options:

```
$ spot.pl
Usage ./spot.pl
Input parameters:
-r      Fasta file of sRNA query
-a      RefSeq Accession number (assumes any local files have RefSeq
        number as their prefix)
...
```

The minimum data required for a **SPOT** search are:

1. A fasta file of the small RNA sequence
2. A RefSeq genome accession number

```
$ spot.pl -r sgrS.fasta -a NC_000913
```

This will initiate a job using the SgrS as the sRNA query and the *E. coli* str. K12 (NC_000913) as the reference genome. Progress of the search will be printed to the screen. Run time will depend on the number of processors available as each search tool is distributed to a separate sub process. By default CopraRNA **is not run** unless specifically requested.

4. Running SPOT

SPOT has an array of actions that control the input, algorithm parameters, and results filtering.

```
$ spot.pl
Usage ./spot.pl
Input parameters:
  -r      Fasta file of sRNA query
  -a      RefSeq Accession number (assumes any local files have RefSeq
         number as their prefix)
  -o      output file prefix (default = TEST)
  -g      Use local GenBank or PTT&FNA files for all Programs? (default = N
         use latest from GenBank, CopraRNA cannot use local files)
  -n      Other genome RefSeq ids for CopraRNA listed in quotes ' ',
         current max is 5 genomes (default = '')
  -m      Multisequence sRNA file for each genome in CopraRNA list
         (default = '')
  -x      Email address for job completion notification (default = '')

Algorithm parameters:
  -u      Number of nt upstream of start site to search (default = 60)
  -d      Number of nt downstream of start site to search (default = 60)
  -s      seed sizes for I, T, S e.g., '6 7 6' (defaults TargetRNA = 7,
         IntaRNA & Starpicker = 6)
  -c      P/Threshold value Cutoff for T, S, I e.g., '0.5 .001 un'
         (defaults Target = 0.05, Starpicker = 0.5, IntaRNA = top)

Results Filters:
  -b      Number of nt upstream of start site to filter results
         (default = -20)
  -e      Number of nt downstream of start site to filter results
         (default = 20)
Note: -b and -e ignored if using a list (-l) or Rockhopper
      results (-t)
Note: Set -b and -e to -u and -d to get all possible matches in
      results
  -l      List of up and/or down regulated genes, include binding coord if
         known e.g.,
b1101\tdown\n
b3826\tup\ttsRNA_start\ttsRNA_stop\ttmRNA_start\ttmRNA_stop\n
         OR
  -t      transcriptome expression file from Rockhopper *_transcripts.txt
  -f      Rockhopper fold change cutoff (default = 1.5)
  -q      Rockhopper q value cutoff (default = 0.01)
  -k      Rockhopper Expression cutoff value (default = 100)
  -p      Operon file from DOOR-2 (http://csbl.bmb.uga.edu/DOOR/index.php)
         (optional)
  -w      Report all genes even if List or Rockhopper provided?
         (default = No)
  -y      Exclude target predictions by only 1 method? (default = Yes)
         Note: Does not apply to genes on List or significantly expressed
         from Rockhopper
  -z      Skip sRNA-mRNA detection steps, and just re-analyze data [Yy]es
         (default = No) (Run in the same directory & requires original
         results files from each program)
```

Given the time **SPOT** runs can take it is recommended to use a queueing tool on large distributed servers (`qsub`, `slurm`). Alternatively, on the AWS server, laptop or other smaller computers it is recommended to use `screen` to ensure that jobs are not prematurely aborted if the user account is logged out of.

```
$ screen -L spot.pl -r sgrS.fasta -a NC_000913
```

Four test datasets and precomputed output files are included in the folder `example_files`. The following examples correspond to the four provided test datasets.

test01 - Examine entire *E. coli* str. K12 genome for SgrS sRNA target mRNAs. This folder only has the sRNA sequence in a `fasta` file, uses the individual program default SEED size and significance settings and retrieves the genome sequence for *E. coli* from GenBank. The final option is to have an email sent to the user after the job has completed.

```
$ cd test01
$ ls
sgrS.fasta
$ spot.pl -r sgrS.fasta -o stringent -a NC_000913 -x username@email.edu

=====Prepping RefSeq Files=====
[Thu Aug 23 23:14:27 UTC 2018]
...
```

test02 - Examine *E. coli* str. K12 genome for SgrS sRNA target mRNA matches among a set of defined differentially expressed genes (`sgrS_diff.txt`). In this case the user has a `fasta` file and a traditional GenBank protein translation file (PTT). The user also indicates a larger window size 150 nt upstream of the CDS start position and 100 nt downstream to search for binding sites.

```
$ cd test02
$ ls
sgrS.fasta
sgrS_diff.txt
NC_000913.fna
NC_000913.ptt
$ spot.pl -r sgrS.fasta -l sgrS_diff.txt -u 150 -d 100 -c '0.5 0.001 un' -o
relaxed -a NC_000913 -g Y
```

Note: PTT files can be easily generated in Excel. Allowing for *customization* of gene annotations and subsequent analyses. A script included with **SPOT** is `fnaptt2gbk.pl` which can be used to generate GenBank files using the genome PTT and `fasta` files as inputs. However, always make sure that MAC or DOS line breaks are converted into UNIX line breaks.

test03 - SPOT was designed to allow re-analysis of existing results. This example code block is run in a folder containing the results of **test02**'s search. In this case even though the upstream/downstream region searched was 150nt and 100nt, the reanalysis eliminates any binding sites found outside of 50nt upstream and 30nt downstream. This search also does not use the list of differentially expressed genes.

```
$ cd test03
$ ls
sgrS.fasta
sgrS_diff.txt
NC_000913.fna
NC_000913.ptt
...
$ spot.pl -r sgrS.fasta -u 150 -d 100 -c '0.5 0.001 un' -o changed_50_30 -a
NC_000913 -g Y -b -50 -e 30 -z Y
```

test04 – SPOT can also be run using a **transcript.txt* file generated by the RNAseq analysis program Rockhopper directly (instead of list as in example **test02**). In this example default expression cutoffs are used, however these can be specified by the user. In addition, when provided a set of sRNA homologs and target genomes CopraRNA can be run. In these instances only genomes in RefSeq can be used. Custom genome annotations cannot be utilized.

```
$ cd test04
$ ls
NC_000913_SgrS_transcripts.txt
sgrS.fasta
sgrS_homologs.fasta
$ spot.pl -r sgrS.fasta -t NC_000913_SgrS_transcripts.txt -o express -a
NC_000913 -m sgrS_homologs.fasta -n 'NC_002695 NC_011740' -u 150 -d 100
```

When the jobs have completed compare your results to the files in the corresponding *_results* folder.

5. Data input formats

sRNA fasta file – DNA sequence of sRNA in a standard fasta file. File extension does not matter (*.fasta*, *.fa*, *.fna*, *.frn*, *.ffn*)

RefSeq ID – Standard RefSeq IDs can be used and GenBank files (*.gbff*) will be retrieved using *efetch*. Program will retrieve additional replicons (e.g., plasmids) or scaffolds associated with the provided RefSeq IDs, however, the search will only be

carried out on the file with a name corresponding to the input RefSeq ID. By default the .gbff is renamed to a .gb file, and .fna and .ptt files are generated.

Local Files – Different combinations of local files can be used. They all **must** have the same prefix and end in the following suffixes:

.fna	Genome fasta sequence
.ptt	Protein translation table – gene annotation
.gb or .gbk	Genbank file

Files **without** these suffixes will be ignored. All must have Unix linebreaks and the .ptt file must be tab separated. Allowed input combinations include:

	.fna	.ptt	.gb or .gbk	Status	Action
1.	√	√	√	okay	Start run
2.	√	√		okay	Make .gb file, start run
3.	√		√	okay	Make .ptt file, start run
4.		√	√	okay	Make .fna file, start run
5.			√	okay	Make .fna and .ptt file, start run
6.	√			bad	Abort run
7.		√		bad	Abort run

.ptt Files – This is a legacy GenBank annotation format. However, the StarPicker algorithm used here requires this format. This format is very easy to generate in Excel and can allow users of **SPOT** to customize their annotations. See example:

Escherichia coli str. K-12 substr. MG1655, complete genome - 1..4641652								
4141 proteins								
Location	Strand	Length	PID	Gene	Synonym	Code	COG	Product
190..255	+	21		thrL	b0001	-	-	thr operon leader peptide
337..2799	+	820		thrA	b0002	-	-	Bifunctional aspartokinase
2801..3733	+	310		thrB	b0003	-	-	homoserine kinase
3734..5020	+	428		thrC	b0004	-	-	L-threonine synthase

Note: As indicated above, customization of PTT files allows users to correct or change annotations based on new data. Furthermore, by modifying PTT files **RNAs can be included** in the annotation. First, this allows for sRNA – RNA interactions to be identified. Second, this approach was used in the manuscript to perform a ‘reverse’ search. For a ‘reverse’ search the PTT file is edited to ONLY include the known sRNAs. Then, the user supplies the UTR or putative sRNA binding region to **SPOT** as a fasta file if it were the sRNA. ‘Reverse’ searches cannot use CopraRNA and as sRNAs do not have GI numbers and may not have GenIDs - no functional enrichment plots will be produced. This may result in several warnings when the **SPOT** is run, however it should not influence the final composite predictions.

Differentially expressed genes – Lists of differential genes can be formatted as tab separated files one of two ways. **DO NOT include a header line.**

Simple:

Locus	Expression
b1101	down
b3826	up

With known binding sites:

Locus	Expression	sRNA_start	sRNA_stop	mRNA_start	mRNA_stop
b1101	down	168	187	-30	-9
b3826	up	168	187	-96	-76

Rockhopper *transcript.txt files – **SPOT** can read default output files of Rockhopper from simple pairwise RNAseq experiments. Files generated with the verbose output option in Rockhopper cannot be read. Files should have 12 columns including the normalized expression values for the treatment and control, the *q* Values and the estimated fold-change.

sRNA Multisequence Fasta Files – If running CopraRNA, the sRNA file must conform to expectations of the CopraRNA program:

1. RNA sequences must have Us instead of Ts
2. The sequence names must correspond to the individual genome RefSeq IDs
3. Must include the focal genome sRNA sequence

Operon file from DOOR-2 – sRNAs binding sites may lie within a single gene or its UTR, however, bacterial genomes are organized into operons. Therefore, sRNAs may affect adjacent genes. If a list or *transcript.txt file is provided to identify focal genes in combination with an operon file (*opr), genes in the same transcriptional unit will be included in the final output. For example, in a 4 gene operon A, B, C, D, if only B was significantly differentially expressed, sRNA-mRNA predictions for genes A, C, D will be included in the output files too. Files conforming to those provided by the [DOOR² Database of Prokaryotic Operons](#) must be used. **A header line IS expected.**

OperonID	GI	Synonym	Start	End	Strand	Length	COG_number	Product
2996	16127995	b0001	190	255	+	21	-	thr operon leader peptide
2996	16127996	b0002	337	2799	+	820	COG0527E	Fused aspartokinase I and homoserine dehydrogenase I

Note: Like *ptt files, *opr files can be easily generated from other resources using Excel or with other text tools.

6. Data output formats

Data from each individual algorithm is preserved in the output folder for manual investigation.

TargetRNA2_*.txt = TargetRNA2 Primary report
 *.output = Starpicker Primary report
 intarna_websrv_table_truncated.csv = IntaRNA Primary report
 *_hIntaRNA.csv = CopraRNA Primary report

SPOT generates several output files for further analysis:

XLSX file – Primary file containing consensus table of sRNA-mRNA predictions from the 3 or 4 tools used in the run. File name prefix corresponds to run output prefix that was assigned (-o , default= TEST).

- Sheet 1 (*_complete.txt) shows the aligned predictions, *p* values, and coordinates for the predicted interaction for each gene.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	Locus	Gene	T-Energy	T-Pvalue	T-sRNA_start	T-sRNA_stop	T-mRNA_start	T-mRNA_stop	T-Structure	S-Energy	S-Pvalue	S-sRNA_start	S-sRNA_stop	S-mRNA_start	S-mRNA_stop	S-Structure
2	b1101	ptsG	-10.51	0.018	167	187	-29	-9	<div>Ec_sgrS 187 3' U-GUGGUUAGAGUCAGUGUGU 5' 167</div> <div> : </div> <div>ptsG -29 5' AGACCCCAUCUCAGAGAC- 3' -9</div> <div>gene product:fused glucose-specific PTS enzymes: IIB component/IIC component; PTS system, glucose-specific IIBC component</div>	-20.8	0.004	169	187	-28	-8	<div>sRNA(Ec_sgrS) 169 --uguga</div> <div> </div> <div>Target(ptsG_b1101) -8 ucacgag</div>
3	b0060	polB	-9.86	0.025	151	169	-2	17	<div>Ec_sgrS 169 3' UGUACUACGUCGUCAGU 5' 151</div> <div>: : : </div> <div>polB -2 5' GCGUGGCGCAGGCGUUU 3' 17</div> <div>gene product:DNA polymerase II</div>							

- Sheet 2 (*_summary.txt) has the counts predicted by each gene, and a summary letter and ranking based location and on the number of algorithms that found the same prediction.

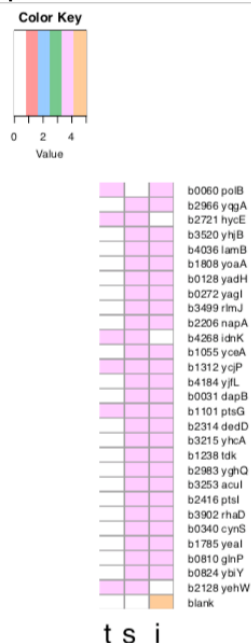
A Prediction overlaps a known binding site

B→E Predictions that are not coincident with a known binding site when one was provided for that gene. Shared letters overlap the same site.

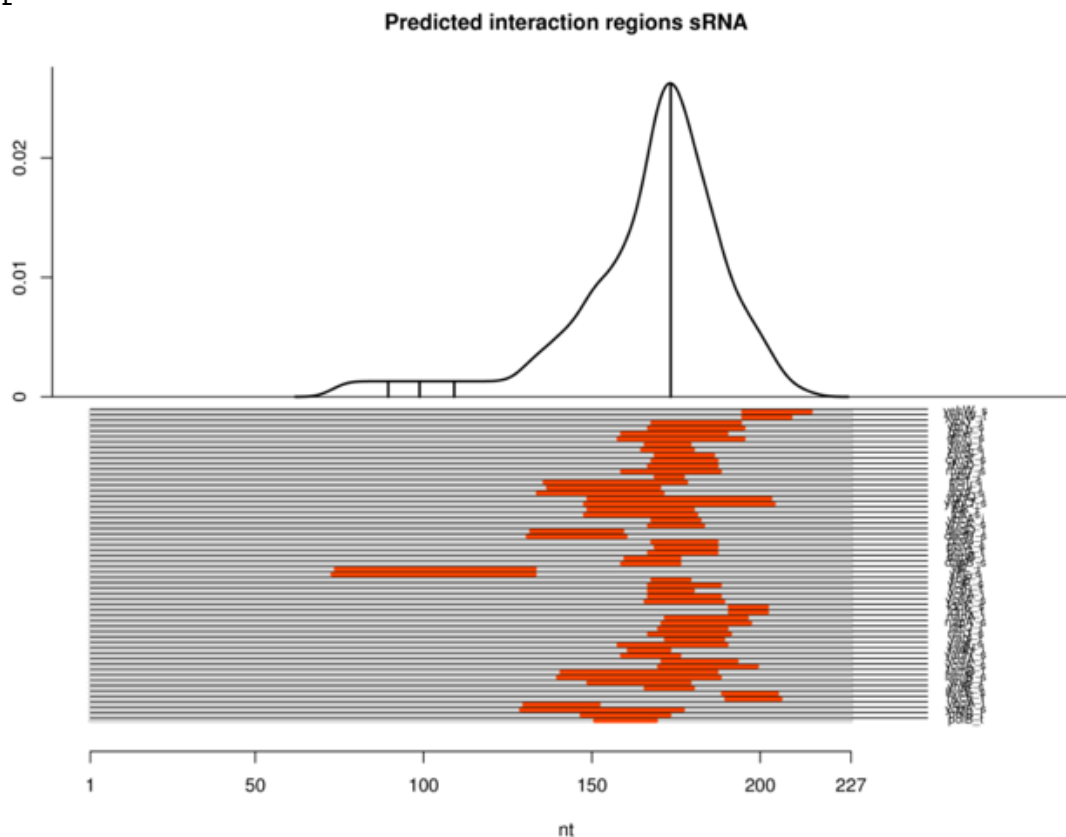
F→I Predictions when no known binding site was provided. Shared letters overlap the same site.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Locus	Gene	Target RNA2	Star	IntaRNA	Count _ALL	TargetRNA2_ 20_20	Star_ 20_20	IntaRNA_ 20_20	Count_ 20_20	TargetRNA 2_M	Star_M	IntaRNA_ M	Rank
2	b1101	ptsG	1	1	1	3	1	1	1	3	F	F	F	4
3	b0060	polB	1		1	2	1		1	2	F		F	4

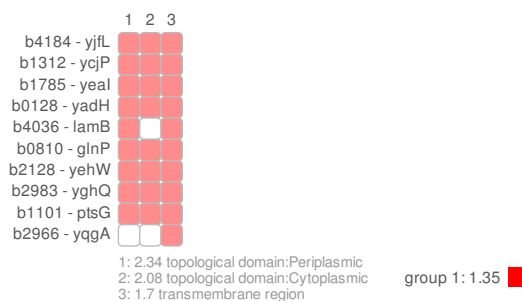
* summary.pdf file – This file has a R generated plot that corresponds to Sheet 2 (*_summary.txt) which can be imported to Illustrator.



COLLATED RESULTS folder – This folder contains plots generated based on IntaRNA tools showing the localization of binding sites of the mRNA and sRNA as *.pdf, *.png and *.ps files.



In addition, a functional enrichment heatmap is included as a *.pdf file similar to those individually provided by IntaRNA and CopraRNA - however it represents the collated results.



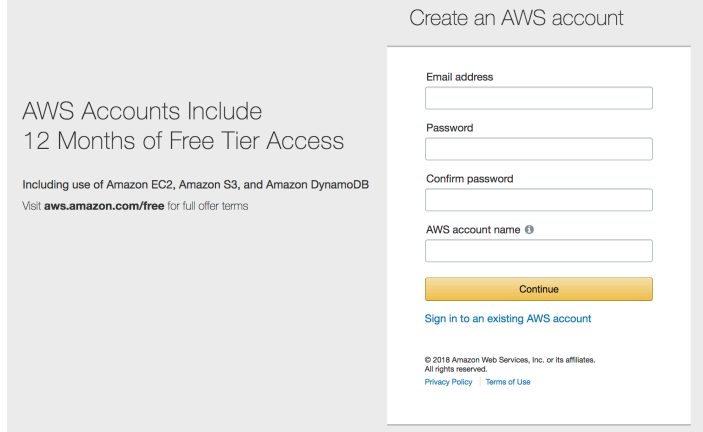
It is possible given the number and type of consensus predictions that are made, that no functional enrichment is produced. See the program file log, for possible comments errors that were noted while running the program.

Example result files for the sRNA SgrS and corresponding test datasets are available with the **SPOT** software distribution.

7. Setup an AWS account

Navigate to the new account setup page:

<https://portal.aws.amazon.com/billing/signup#/start>



For now, set up your home region as “**U.S. East (W. Virginia)**” later you can switch this as necessary.

Unfortunately, when setting up an account you will need a credit card number

Input Education credit - Depending on your application it may be possible to apply for education credits to defray the cost of the AWS server time:

<https://aws.amazon.com/education/awseducate/>



8. Setup personal AWS interface on your laptop

People with MACs:



Terminal will already be installed /Applications/Utilities



Download & Install **XQuartz** if not already installed

<http://xquartz.macosforge.org/landing/>



Download & Install **Cyberduck** <https://cyberduck.io/?l=en>

People with PCs:



Download & Install **PuTTY**

<http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html>



Download & Install **xMing**

http://sourceforge.net/project/downloading.php?group_id=156984&filename=Xming-6-9-0-31-setup.exe

How to setup xMing : http://www.geo.mtu.edu/geoschem/docs/putty_install.html



Download & Install **WinSCP** <http://winscp.net/eng/download.php>

or



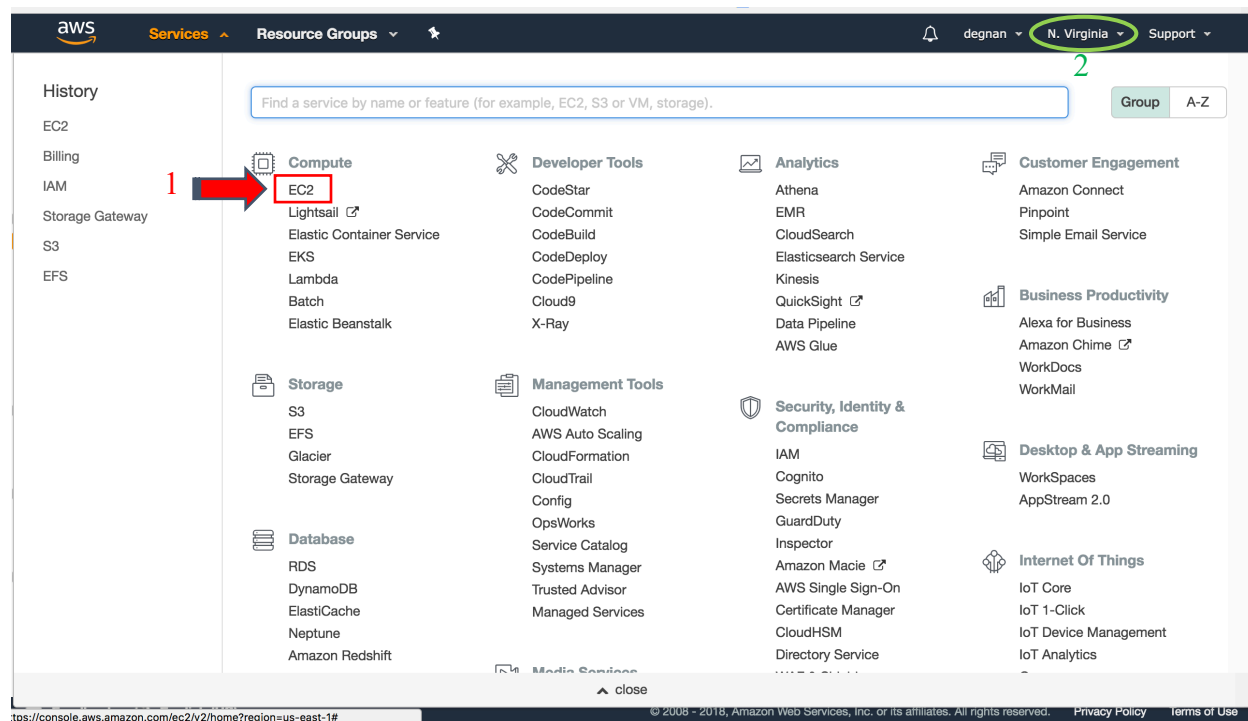
Download & Install **Cyberduck** <https://cyberduck.io/?l=en>

9. Starting an AWS instance

For in-depth instructions regarding starting an AWS instance please see:

<https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/launching-instance.html>

1. After making and logging into your AWS account find your way to the EC2 (Elastic Computing Cloud) page. You can find it under “Services” menu on the upper left-hand corner of the page:



<https://console.aws.amazon.com/ec2/v2/home?region=us-east-1#Home>:

2. Make sure your home region as “**U.S. East (W. Virginia)**”. Your region is indicated in the upper right-hand corner of the page (circled above)

3. On the right-hand side bar under “IMAGES” select “AMIs”

The screenshot shows the AWS Management Console interface. On the left, the navigation menu is expanded to 'IMAGES', and 'AMIs' is highlighted with a red arrow and the number 3. The main area displays 'Resources' for the US East (N. Virginia) region, listing various EC2 resources. Below this is a 'Create Instance' section with a 'Launch Instance' button. The right-hand pane shows 'Account Attributes' and 'Additional Information'.

4. In the search bar switch from “Owned by me” to “Public images” and search for “SPOTv1”

The screenshot shows the AWS Management Console interface. The search bar is set to 'Owned by me' and the search term is 'SPOTv1', indicated by a red arrow and the number 4. The results table shows one entry: 'SPOTv1' with AMI ID 'ami-0ac524786ce503ae1'. The 'Launch' button is highlighted with a blue arrow and the number 5. The details for the selected image are shown below the table.

Name	AMI Name	AMI ID	Source	Owner	Visibility	Status
SPOTv1		ami-0ac524786ce503ae1	243768595940/...	243768595940	Private	available

Image: ami-0ac524786ce503ae1

AMI ID	AMI Name
ami-0ac524786ce503ae1	SPOTv1

Owner	Source
243768595940	243768595940/SPOTv1

Status	State Reason
available	-

Creation date	Platform
September 10, 2018 at 10:31:20	Other Linux

5. Select the blue “Launch” button

6. Now you are on AWS “Step 2: Choose and Instance Type” – Select your computer:

t2.micro is the only free option, however it is maxed out at 1GiB of RAM, 1 processor and 30GiB of storage. *Very slow*
m5.2xlarge 8 virtual processors, 64 GiB of RAM

Step 2: Choose an Instance Type

Currently selected: t2.micro (Variable ECUs, 1 vCPUs, 2.5 GHz, Intel Xeon Family, 1 GiB memory, EBS only)

	Family	Type	vCPUs	Memory (GiB)	Instance Storage (GB)	EBS-Optimized Available	Network Performance	IPv6 Support
<input type="checkbox"/>	General purpose	t2.nano	1	0.5	EBS only	-	Low to Moderate	Yes
<input checked="" type="checkbox"/>	General purpose	t2.micro <small>Free tier eligible</small>	1	1	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.small	1	2	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.medium	2	4	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.large	2	8	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.xlarge	4	16	EBS only	-	Moderate	Yes
<input type="checkbox"/>	General purpose	t2.2xlarge	8	32	EBS only	-	Moderate	Yes
<input type="checkbox"/>	General purpose	m5d.large	2	8	1 x 75 (SSD)	Yes	Up to 10 Gigabit	Yes
<input type="checkbox"/>	General purpose	m5d.xlarge	4	16	1 x 150 (SSD)	Yes	Up to 10 Gigabit	Yes

Cancel Previous **Review and Launch** Next: Configure Instance Details

<input type="checkbox"/>	General purpose	m5.4xlarge	16	64	EBS only	Yes	Up to 10 Gigabit	Yes
--------------------------	-----------------	------------	----	----	----------	-----	------------------	-----

7. Select “Next: Configure Instance Details” button on bottom-right

8. On “Step 3: Configure Instance Details” page – *leave defaults as-is*

Step 3: Configure Instance Details

Configure the instance to suit your requirements. You can launch multiple instances from the same AMI, request Spot instances to take advantage of the lower pricing, assign an access management role to the instance, and more.

Number of instances: 1 [Launch into Auto Scaling Group](#)

Purchasing option: ☐ Request Spot instances

Network: vpc-f517f78f (default) [Create new VPC](#)

Subnet: No preference (default subnet in any Availability Zone) [Create new subnet](#)

Auto-assign Public IP: Use subnet setting (Enable)

Placement group: ☐ Add instance to placement group.

IAM role: None [Create new IAM role](#)

Shutdown behavior: Stop

Enable termination protection: ☐ Protect against accidental termination

Monitoring: ☐ Enable CloudWatch detailed monitoring
[Additional charges apply.](#)

EBS-optimized instance: ☐ Launch as EBS-optimized instance
[Additional charges apply.](#)

Cancel Previous **Review and Launch** Next: Add Storage

9. Select the “Next: Add Storage” button on bottom-right, to move to the next step

10. On the “Step 4: Add Storage” adjust local disk size to 30 GiB

The screenshot shows the AWS Management Console interface for Step 4: Add Storage. The top navigation bar includes the AWS logo, Services, Resource Groups, and user information (degan, N. Virginia, Support). The breadcrumb trail shows: 1. Choose AMI, 2. Choose Instance Type, 3. Configure Instance, 4. Add Storage (active), 5. Add Tags, 6. Configure Security Group, 7. Review.

Step 4: Add Storage
Your instance will be launched with the following storage device settings. You can attach additional EBS volumes and instance store volumes to your instance, or edit the settings of the root volume. You can also attach additional EBS volumes after launching an instance, but not instance store volumes. [Learn more](#) about storage options in Amazon EC2.

Volume Type	Device	Snapshot	Size (GiB)	Volume Type	IOPS	Throughput (MB/s)	Delete on Termination	Encrypted
Root	/dev/sda1	snap-0ea8cfee9142df0b9	25	General Purpose SSD (GP2)	100 / 3000	N/A	<input checked="" type="checkbox"/>	Not Encrypted

[Add New Volume](#)

Free tier eligible customers can get up to 30 GB of EBS General Purpose (SSD) or Magnetic storage. [Learn more](#) about free usage tier eligibility and usage restrictions.

[Cancel](#)
[Previous](#)
[Review and Launch](#)
[Next: Add Tags](#)

11. Select the “Next: Add Tags” button on bottom-right, to move to the next step

12. On the “Step 5: Add Tags” *optionally* hit the “Add Tag” button OR skip to step 14

The screenshot shows the AWS Management Console interface for Step 5: Add Tags. The top navigation bar is identical to the previous screenshot. The breadcrumb trail shows: 1. Choose AMI, 2. Choose Instance Type, 3. Configure Instance, 4. Add Storage, 5. Add Tags (active), 6. Configure Security Group, 7. Review.

Step 5: Add Tags
A tag consists of a case-sensitive key-value pair. For example, you could define a tag with key = Name and value = Webserver.
A copy of a tag can be applied to volumes, instances or both.
Tags will be applied to all instances and volumes. [Learn more](#) about tagging your Amazon EC2 resources.

Key	Value	Instances	Volumes
This resource currently has no tags			

Choose the [Add tag](#) button or [click to add a Name tag](#).
Make sure your [IAM policy](#) includes permissions to create tags.

[Add Tag](#) (Up to 50 tags maximum)

13. For example Add a key = “Name” and value = “my-SPOT” or “SPOT-server”

14. Select the “Next: Configure Security Group” button on bottom-right, to move to the next step

15. On “Step 6: Configure Security Group” page – *leave defaults as-is*

Step 6: Configure Security Group

A security group is a set of firewall rules that control the traffic for your instance. On this page, you can add rules to allow specific traffic to reach your instance. For example, if you want to set up a web server and allow Internet traffic to reach your instance, add rules that allow unrestricted access to the HTTP and HTTPS ports. You can create a new security group or select from an existing one below. [Learn more](#) about Amazon EC2 security groups.

Assign a security group: ☒ Create a new security group ☐ Select an existing security group

Security group name:

Description:

Type	Protocol	Port Range	Source	Description
SSH	TCP	22	Custom 0.0.0.0/0	e.g. SSH for Admin Desktop

[Add Rule](#)

Warning

Rules with source of 0.0.0.0/0 allow all IP addresses to access your instance. We recommend setting security group rules to allow access from known IP addresses only.

[Cancel](#)
[Previous](#)
[Review and Launch](#)

****Note:** For now, we will ignore the *Warning*. In the future consider making your instances harder to access by non-users in your lab/group**

16. Select the “Review and Launch” button on bottom-right, to move to the next step

Step 7: Review Instance Launch

Please review your instance launch details. You can go back to edit changes for each section. Click **Launch** to assign a key pair to your instance and complete the launch process.

Improve your instances' security. Your security group, launch-wizard-6, is open to the world.

Your instances may be accessible from any IP address. We recommend that you update your security group rules to allow access from known IP addresses only. You can also open additional ports in your security group to facilitate access to the application or service you're running, e.g., HTTP (80) for web servers. [Edit security groups](#)

▼ **AMI Details** [Edit AMI](#)

SPOTv1 - ami-0ac524786ce503ae1

sRNA-target Prediction Organizing Tool v1

Root Device Type: ebs Virtualization type: hvm

▼ **Instance Type** [Edit instance type](#)

Instance Type	ECUs	vCPUs	Memory (GiB)	Instance Storage (GB)	EBS-Optimized Available	Network Performance
t2.micro	Variable	1	1	EBS only	-	Low to Moderate

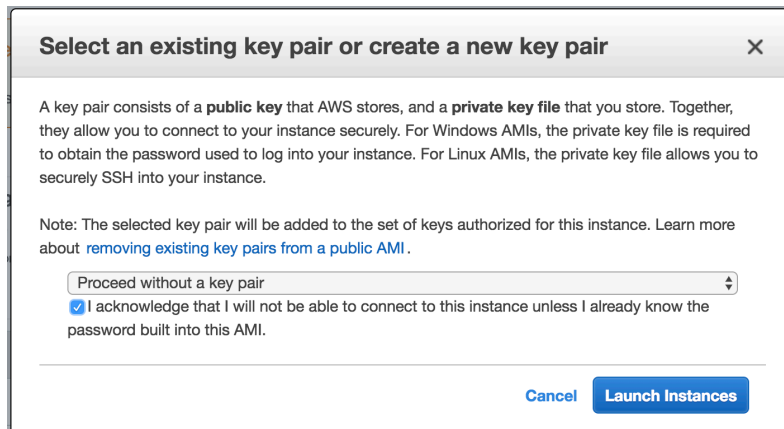
▼ **Security Groups** [Edit security groups](#)

Security Group ID	Name	Description
sg-02ba9bc17710fb86d	launch-wizard-6	launch-wizard-6 created 2018-07-10T11:43:28.048-04:00

[Cancel](#)
[Previous](#)
[Launch](#)

17. You can inspect the settings before hitting the “**Launch**” button. As before ignore warnings.

18. Now it asks you to select or create a key pair.



Select an existing key pair or create a new key pair ✕

A key pair consists of a **public key** that AWS stores, and a **private key file** that you store. Together, they allow you to connect to your instance securely. For Windows AMIs, the private key file is required to obtain the password used to log into your instance. For Linux AMIs, the private key file allows you to securely SSH into your instance.

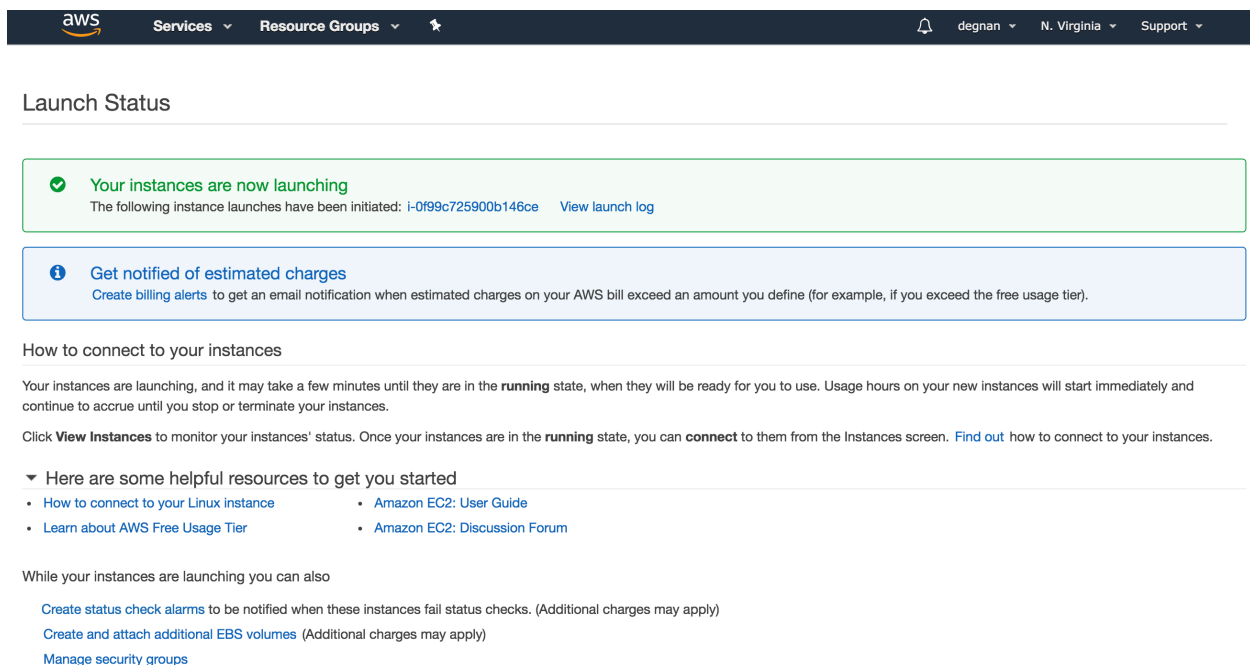
Note: The selected key pair will be added to the set of keys authorized for this instance. Learn more about [removing existing key pairs from a public AMI](#).

Proceed without a key pair

☒ I acknowledge that I will not be able to connect to this instance unless I already know the password built into this AMI.

[Cancel](#) [Launch Instances](#)

19. You will need to download the key and save it to a private location on your computer (e.g., the folder ~/.ssh/).



Launch Status

✓ **Your instances are now launching**
The following instance launches have been initiated: [i-0f99c725900b146ce](#) [View launch log](#)

ℹ **Get notified of estimated charges**
[Create billing alerts](#) to get an email notification when estimated charges on your AWS bill exceed an amount you define (for example, if you exceed the free usage tier).

How to connect to your instances

Your instances are launching, and it may take a few minutes until they are in the **running** state, when they will be ready for you to use. Usage hours on your new instances will start immediately and continue to accrue until you stop or terminate your instances.

Click **View Instances** to monitor your instances' status. Once your instances are in the **running** state, you can **connect** to them from the Instances screen. [Find out](#) how to connect to your instances.

▼ Here are some helpful resources to get you started

- [How to connect to your Linux instance](#)
- [Amazon EC2: User Guide](#)
- [Learn about AWS Free Usage Tier](#)
- [Amazon EC2: Discussion Forum](#)

While your instances are launching you can also

- [Create status check alarms](#) to be notified when these instances fail status checks. (Additional charges may apply)
- [Create and attach additional EBS volumes](#) (Additional charges may apply)
- [Manage security groups](#)

20. From here you can navigate using the left-hand side bar to your “**Instances**”

The screenshot shows the AWS Management Console interface. On the left is a navigation menu with categories like INSTANCES, IMAGES, ELASTIC BLOCK STORE, and NETWORK & SECURITY. The main area displays a table of EC2 instances. The instance 'SPOT-server' (ID: i-0ffb62b4a7db07be) is selected and its details are shown below. The instance is in a 'running' state, located in us-east-1a, and has a public DNS of ec2-18-206-100-156.compute-1.amazonaws.com.

Name	Instance ID	Instance Type	Availability Zone	Instance State	Status Checks	Alarm Status	Public
SPOT-server	i-0ffb62b4a7db07be	t2.micro	us-east-1a	running	2/2 checks ...	None	ec2-18-206-100-156.compute-1.amazonaws.com
md2018	i-0ecfd56d143aa83ac	t2.micro	us-east-1c	stopped		None	

Instance: **i-0ffb62b4a7db07be (SPOT-server)** Public DNS: **ec2-18-206-100-156.compute-1.amazonaws.com**

Description		Status Checks	Monitoring	Tags
Instance ID	i-0ffb62b4a7db07be			
Instance state	running			
Instance type	t2.micro			
Elastic IPs				
Availability zone	us-east-1a			
Security groups	launch-wizard-5. view inbound rules. view outbound rules			
Scheduled events	No scheduled events			
AMI ID	ubuntu/images/hvm-ssd/ubuntu-xenial-16.04-amd64-server-20180814 (ami-04169656fea786776)			
Platform	-			
IAM role	-			
Key pair name	MyKeyPair			
Owner	243768595940			
Public DNS (IPv4)	ec2-18-206-100-156.compute-1.amazonaws.com			
IPv4 Public IP	18.206.100.156			
IPv6 IPs	-			
Private DNS	ip-10-0-10-156.ec2.internal			
Private IPs	10.0.10.156			
Secondary private IPs				
VPC ID	vpc-f517f78f			
Subnet ID	subnet-1bcd1647			
Network interfaces	eth0			
Source/dest. check	True			
T2/T3 Unlimited	Disabled			
EBS-optimized	False			

21. Instance state will be “*Initializing*” until the computer has “booted” up.

22. Once the Instance state switches to “*running*” and you select the instance, details of the instance will be shown below.

23. Find and copy the “IPv4 Public IP” address for your instance. You will use this to login to your server.

IPv4 Public IP:	
-----------------	--

10. Logging into you AWS instance

To log into the server you will need your:

1. Private ssh key [yourid_key.pem](#)
2. [username](#) = first name and last initial as one word (e.g., Jane Doe = janed)
3. [XX-XX-XX-XX](#) = Your specific IPv4 Public IP from above

Login using Terminal on a **MAC or UNIX**.

```
$ ssh -Y -i ~/.ssh/yourid_key.pem username@XX-XX-XX-XX
```

Login from **Windows** using PuTTY

- a. Open PuTTY
- b. Under Category, click on SSH > Auth
- c. Click browse

- d. Find your private key ([yourid_key.pem](#)) and select it
- e. Under Category, click Session and input address of your EC2 instance ([XX-XX-XX-XX](#)) in the "host name" box
- f. Type "SPOT" in the box under saved sessions and click save.
- g. Double-click on the "SPOT" that appears under saved sessions.
- h. Log in with your username. Your key should be used automatically.
- i. For future logins, just double-click the "SPOT" saved session.

Once entered you will find yourself on the command line interface:

```
delta7:Desktop degnan$ ssh -Y -i ~/.ssh/MyKeyPair.pem ubuntu@18.206.100.156
Warning: No xauth data; using fake authentication data for X11 forwarding.
Welcome to Ubuntu 16.04.5 LTS (GNU/Linux 4.4.0-1065-aws x86_64)

* Documentation:  https://help.ubuntu.com
* Management:    https://landscape.canonical.com
* Support:        https://ubuntu.com/advantage

Get cloud support with Ubuntu Advantage Cloud Guest:
http://www.ubuntu.com/business/services/cloud

2 packages can be updated.
0 updates are security updates.

New release '18.04.1 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Thu Aug 23 21:50:22 2018 from 138.23.161.215
ubuntu@ip-172-31-38-185:~$
```

11. References

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