Introduction to Galaxy

Johns Hopkins University
February 4, 2013

Dave Clements, Emory University
http://galaxyproject.org/

Mo Heydarian, Johns Hopkins University
http://jhu.edu/
Agenda

9:00  Welcome
9:20  Basic Analysis with Galaxy
10:20 Basic Analysis into Reusable Workflows
10:40 Break
11:00 RNA-Seq Example Part I
12:00 Galaxy Project Overview
12:20 Lunch
1:05  RNA-Seq Example Part II
       Cufflinks, Visualization and Visual Analytics
1:55  Sharing, Publishing and Reproducibility
2:15  Break
2:35  Setting up your own Galaxy Cluster on AWS
4:30  Done
Introductions

In 35 seconds or less tell us
• your name
• your affiliation(s)
• something about your research
• something about what you want to learn
Goals

1. Introduce Galaxy
2. Introduce bioinformatics concepts and formats
3. Hands-on experience
   • Load and integrate data
   • Perform bioinformatic analysis with Galaxy
   • Save, share describe and publish your analyses
   • Visualize your results
   • Set up your own Galaxy server in the cloud

This workshop will not cover details of how tools are implemented, or new algorithm designs, or which assembler or mapper or ... is best for you.
Welcome

Basic Analysis with Galaxy

Basic Analysis into Reusable Workflows

Break

RNA-Seq Example Part I

Galaxy Project Overview

Lunch

RNA-Seq Example Part II

Cufflinks, Visualization and Visual Analytics

Sharing, Publishing and Reproducibility

Break

Setting up your own Galaxy Cluster on AWS

Done
Basic Analysis

On human chromosome 22, which coding exons have the most repeats in them?

http://cloud1.galaxyproject.org (gold)
http://cloud2.galaxyproject.org (sable)
http://cloud3.galaxyproject.org (black)

(~ http://usegalaxy.org/galaxy101)
Exons & Repeats: A General Plan

- Get some data
  - Coding exons on chromosome 22
  - Repeats on chromosome 22
- Mess with it
  - Identify which exons have repeats
  - Count repeats per exon
  - Save, download, ... exons with most repeats

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(~ http://usegalaxy.org/galaxy101 )
Exons, from UCSC

Repeats, from UCSC
Exons, from UCSC

Repeats, from UCSC

Overlap pairings
### Exon overlap counts

<table>
<thead>
<tr>
<th>Exon</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

### Exons, from UCSC
### Exon overlap counts

<table>
<thead>
<tr>
<th>Exon 1</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<table>
<thead>
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<th>Count</th>
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<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

### Join on exon name

<table>
<thead>
<tr>
<th>Exon 1</th>
<th>Exon 2</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>1</td>
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Exons, from UCSC

<table>
<thead>
<tr>
<th>Exon</th>
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<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Join on exon name

Rearrange columns w/ cut

<table>
<thead>
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Some Galaxy Terminology

**Dataset:**
Any input, output or intermediate set of data + metadata

**History:**
A series of inputs, analysis steps, intermediate datasets, and outputs

**Workflow:**
A series of analysis steps
Can be repeated with different data
The analysis we just finished was about

- Human chromosome 22
- Overlap between exons and repeats

But, ...

- there is nothing inherently in the analysis about humans, chromosomes, exons or repeats

- It is a series of steps that sets the score of one set of features to the number of overlaps from another set of features.
Create a generic *Overlap* Workflow

**Extract Workflow from history**
Create a workflow from this history. Edit it to make some things clearer.

**Run / test it**
- Guided: rerun with same inputs
- On your own: Count # CpG islands in each exon
  Did that work?

**On your own:**
- Count # of exons in each repeat
  Did that work? *Why not?*
- Edit workflow: doc assumptions
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RNA-seq Exercise

http://usegalaxy.org/u/jeremy/p/galaxy-rna-seq-analysis-exercise


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http://cloud3.galaxyproject.org (black)
RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality
- Trim as we see fit.
- Map the reads to the human reference using Tophat
- Run Cufflinks on Tophat output to assemble reads into transcripts
- Visualize it

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- All datasets are FASTQ and from the Body Map 2.0 project

What is **FASTQ**?

- Specifies sequence (FASTA) and quality scores (PHRED)
- Text format, 4 lines per entry

```plaintext
@SEQ_ID
GATTTGGGGTTCAAGCAGTATCGATCAAATAGTAAATCCATTTGTTCAACTCACAGTTT
+
!'**((**++)***+++)(++**).1***='**55CCF>>CCC65
```

- **FASTQ** is such a cool standard, there are 3 (or 5) of them!

```plaintext
S - Sanger       Phred+33,  93 values  (0, 93) (0 to 60 expected in raw reads)
I - Illumina 1.3 Phred+64,  62 values  (0, 62) (0 to 40 expected in raw reads)
X - Solexa       Solexa+64,  67 values (-5, 62) (-5 to 40 expected in raw reads)
```

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality: Option 1
  - NGS QC and Manipulation → **Compute Quality Statistics**
  - NGS QC and Manipulation → **Draw quality score boxplot**
- Gives you no control over how it is calculated or presented.

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality: Option 2
  - NGS QC and Manipulation → FastQ Summary Statistics
  - Graph / Display Data → Boxplot of quality statistics
- Gives you a lot of control over what the box plot looks like, but no additional information

RNA-seq Exercise: A Plan

• Get input datasets; hg19, will mostly map to chr19

• Look at quality: Option 3

  • NGS QC and Manipulation → Fastqc

  • Gives you a lot a lot more information but little control over how it is calculated or presented.

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality
- Trim as we see fit: Option 1
  - NGS QC and Manipulation → FASTQ Trimmer by column
    - Trim same number of columns from every record
    - Can specify different trim for 5’ and 3’ ends

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality
- Trim Filter as we see fit: Option 2
  - NGS QC and Manipulation → **Filter FASTQ reads by quality score and length**
  - Keep or discard whole reads at a time
  - Can have different thresholds for different regions of the reads.
  - Keeps original read length.

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality
- Trim as we see fit: Option 3

- NGS QC and Manipulation → FASTQ Quality Trimmer by sliding window
- Trim from both ends, using sliding windows, until you hit a high-quality section.
- Produces variable length reads

RNA-seq Exercise: A Plan

- Get input datasets; hg19, will mostly map to chr19
- Look at quality
- Trim as we see fit.
- Map the reads to the human reference using Tophat

- Imagine pages and pages of discussion on the intricacies and pitfalls of RNA-seq mapping here.

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What is Galaxy?

• **A free (for everyone) web service** integrating a wealth of tools, compute resources, terabytes of reference data and permanent storage

• **Open source software** that makes integrating your own tools and data and customizing for your own site simple

• These options result in several **ways to use Galaxy**

http://galaxyproject.org
Galaxy is available ...

• As a free (for everyone) web service

  http://usegalaxy.org

However, a centralized solution cannot scale to meet the analysis needs of the entire world.
Galaxy is available ...

- As a free (for everyone) web service
  http://usegalaxy.org

- As open source software
  http://getgalaxy.org
As Open Source Software: Local Galaxy Instances

- Galaxy is designed for local installation and customization
- Easily integrate new tools
- Easy to deploy and manage on nearly any (unix) system
- Run jobs on existing compute clusters
- Requires a computational resource on which to be deployed

http://getgalaxy.org
Encourage **Local** Galaxy Instances

- Encourage and support Local Galaxy Instances
- Support increasingly decentralized model and improve access to existing resources
- Focus on building infrastructure to enable the community to integrate and share tools, workflows, and best practices

**Galaxy Tool Shed**
http://toolshed.g2.bx.psu.edu
Encourage Public Galaxy Instances

http://wiki.galaxyproject.org/PublicGalaxyServers

Interested in:

- ChIP-chip and ChIP-seq?
  - ✓ Cistrome
- Statistical Analysis?
  - ✓ Genomic Hyperbrowser
- Protein synthesis?
  - ✓ GWIPS-viz
- de novo assembly?
  - ✓ CBIIT Galaxy
- Reasoning with ontologies?
  - ✓ OPPL Galaxy
- Repeats!
  - ✓ RepeatExplorer
- Everything?
  - ✓ Andromeda

Plus many more
As Open Source Software: Local Galaxy Instances

- Galaxy is designed for local installation and customization
- Easily integrate new tools
- Easy to deploy and manage on nearly any (unix) system
- Run jobs on existing compute clusters
- Requires a computational resource on which to be deployed

http://getgalaxy.org
Got your own cluster?

- Control *where* tool execution happens

- Galaxy *works with any DRMAA* compliant cluster job scheduler (which is most of them).

- Galaxy is *just another client* to your scheduler.
Galaxy is available ...

- As a free (for everyone) web service
  http://usegalaxy.org
- As open source software
  http://getgalaxy.org
- *On the Cloud*
  http://usegalaxy.org/cloud
Galaxy CloudMan

http://usegalaxy.org/cloud

- Start with a **fully configured and populated** (tools and data) Galaxy instance.
- Allows you to scale up and down your compute assets as needed.
- Someone else manages the data center.
- **We are using this today.**

![Amazon Web Services](https://aws.amazon.com)

- You will set up an instance today

http://aws.amazon.com/education
Or, step by step
Galaxy Resources and Community

Unified Search
Mailing Lists (very active)
Issues Board
Events Calendar, News Feed
Community Wiki
GalaxyAdmins
Screencasts
Tool Shed
Public Installs
CiteULike group, Mendeley mirror
Annual Community Meeting

http://wiki.galaxyproject.org
Unified Search: [http://galaxyproject.org/search](http://galaxyproject.org/search)

**Galaxy Web Search**

Search the entire set of Galaxy web sites and mailing lists using Google.

Run this search at Google.com (useful for bookmarking)

Want a different search?

Project home

---

**Find**

- Everything on …
- Tools for …
- Email about …
- Source code for …
- Published Histories, Pages, Workflows, about …
- Related feature requests
- Papers using Galaxy for …
- Documentation on …
Mailing Lists
http://wiki.galaxyproject.org/MailingLists

Galaxy-Announce
Project announcements, low volume, moderated
Low volume (42 posts, 1600 members in 2012)

Galaxy-User
Questions about using Galaxy and usegalaxy.org
High volume (2900 posts, 2700 members in 2012)

Galaxy-Dev
Questions about developing for and deploying Galaxy
High volume (4500 posts, 850 members in 2012)
Community can create, vote and comment on issues

## Galaxy Event Horizon

Events with Galaxy-related content are listed here. Also see the Galaxy Events Google Calendar for a listing of events and deadlines that are relevant to the Galaxy Community. This is also available as an RSS feed.

If you know of any event that should be added to this page and/or to the Galaxy Event Calendar, please add it here or send it to outreach@galaxypilot.org.

### Upcoming Events

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Venue/Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 4</td>
<td>Introduction to Galaxy Boot Camp</td>
<td>UC Davis Biinformatics Core, Davis, California, United States</td>
</tr>
<tr>
<td>March 2-5</td>
<td>Accessible, Transparent and Reproducible Analysis With Galaxy, part of ABRF 2013</td>
<td>ABRF 2013, Palm Springs, California, United States</td>
</tr>
<tr>
<td>March 26-28</td>
<td>RNA Technologies and Analysis Workshop</td>
<td>DOE JGI User Meeting</td>
</tr>
<tr>
<td>April 5-6</td>
<td>2013 GMOD Meeting</td>
<td>Cambridge, United Kingdom</td>
</tr>
<tr>
<td>April 7-10</td>
<td>GO Galaxy Workshop</td>
<td>Bocuration 2013, Cambridge, United Kingdom</td>
</tr>
<tr>
<td>April 9-11</td>
<td>Workshop: Integrated Research Data Management for Next Gen Sequencing Using Galaxy and Cloud Services</td>
<td>BioIT World, Boston, Massachusetts, United States</td>
</tr>
<tr>
<td>May 14-16</td>
<td>Tutorial: Exploring and Enabling Biomedical Data Analysis with Galaxy</td>
<td>Great Lakes Bioinformatics Conference (GLBIO) 2013, Pittsburgh, Pennsylvania, United States</td>
</tr>
<tr>
<td>May 21</td>
<td>Initiation à l'utilisation de Galaxy</td>
<td>Les deux ateliers sont maintenant complets.</td>
</tr>
<tr>
<td>May 29</td>
<td>Analyse de données issues de séquencier nouvelle génération sous Galaxy</td>
<td>Les deux ateliers sont maintenant complets.</td>
</tr>
<tr>
<td>June 5-7</td>
<td>Informatics on High Throughput Sequencing Data Workshop</td>
<td>Toronto, Ontario, Canada</td>
</tr>
</tbody>
</table>

## News Items

Announcements of interest to the Galaxy Community. These can include items from the Galaxy Team or the Galaxy community and can address anything that is of wide interest to the community.

The Galaxy News is also available as an RSS feed.

See **Add a News Item** below for how to get an item on this page, and the RSS feed. Older news items are available in the Galaxy News Archive.

### News

**February 2013 Galaxy Update**

The February 2013 Galaxy Update is now available.

**Highlights:**

- Three new public Galaxy servers
- New papers
- Open Positions at five different institutions
- GCC2013 Training Day Tool voting, Registration, and Sponsorships
- January GalaxyAdmins Web Meetup slides and screencast
- Other Events and Deadlines
- Galaxy Distributions
- Toolshed Contributions
- Other News

If you have anything you would like to see in the March Galaxy Update, please let us know.

Dave Clements and the Galaxy Team

*Posted to the Galaxy News on 2013-02-01*

**GCC2013 Training Day Topics: Vote!**

A list of possible topics for the GCC2013 Training Day is now available. Please take a few minutes to review these possibilities and then vote for your favorite three topics.

Your vote will determine not only the topics that are offered, but also which topics should be offered more than once, assigned to which rooms, and which ones should not be scheduled at the same time. Your vote matters.
http://wiki.galaxyproject.org

**Galaxy Wiki**

**Galaxy** is an open, web-based platform for accessible, reproducible, and transparent computational biomedical research.

- **Accessible:** Users without programming experience can easily specify parameters and run tools and workflows.
- **Reproducible:** Galaxy captures information so that any user can repeat and understand a complete computational analysis.
- **Transparent:** Users share and publish analyses via the web and create Pages, interactive, web-based documents that describe a complete analysis.

This is the Galaxy Community Wiki. It describes all things Galaxy.

**Use Galaxy**

Galaxy’s [public service website](http://usegalaxy.org) makes analysis tools, genomic data, tutorial demonstrations, persistent workspaces, and publication services available to any scientist. Extensive [user documentation](http://usegalaxy.org) (applicable to any public or local Galaxy instance) is available on this wiki and elsewhere.

**Deploy Galaxy**

Galaxy is open source for all organizations. Local Galaxy servers can be set up by downloading and customizing the Galaxy application.

- Admin
- Cloud

**Community & Project**

Galaxy has a large and active user community and many ways to [Get Involved](http://usegalaxy.org).

- Community
- News
- Events
- Support
- Galaxy Project

**Contribute**

- **Users:** Share your histories, workflows, visualizations, data libraries, and [Galaxy Pages](http://usegalaxy.org), enabling others to use and learn from them.
- **Deployers and Developers:** Contribute tool definitions to the Galaxy [Tool Shed](http://toolshed.g2.bx.psu.edu/) (making it easy for others to use those tools on their installations), and code to the core release.
- **Everyone:** [Get Involved](http://usegalaxy.org)!
Registration & abstract submission opens February 22

http://galaxyproject.org/GCC2013
The Galaxy Team

http://wiki.galaxyproject.org/GalaxyTeam
Galaxy is hiring post-docs and software engineers at both Emory and Penn State.

Please help.

http://wiki.galaxyproject.org/GalaxyIsHiring
Welcome

Basic Analysis with Galaxy

Basic Analysis into Reusable Workflows

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Galaxy Project Overview

Lunch

RNA-Seq Example Part II

Cufflinks, Visualization and Visual Analytics

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RNA-seq Exercise: A Plan

- ...
- Trim as we see fit.
- Map the reads to the human reference using Tophat
- Run Cufflinks on Tophat output to assemble reads into transcripts
  
  *Imagine pages and pages of discussion on the intricacies and pitfalls of RNA-seq transcript prediction here.*

RNA-seq Exercise: A Plan

- ... 
- Map the reads to the human reference using Tophat
- Run Cufflinks on Tophat output to assemble reads into transcripts
  - Imagine pages and pages of discussion on the intricacies and pitfalls of RNA-seq transcript prediction here.
- Visualize it

Visualizing Genomics

Supported external browsers

- UCSC
- Ensembl
- GBrowse
- IGB
- IGV

Traditional browser strengths:

- Showing what is nearby
- what else is happening here
- highlighting correlations
- integrating many datasets
But, wouldn’t it be nice to

- Use visualization to evaluate and refine analyses?
- Expose some basic analyses in visualization to make it more informative?
- Make that analyze-visualize-refine loop seamless and fast? That is, integrate the two?
- Use visualization to learn tools and explore their parameter space?
- Not be tied to a predefined reference genome?
Trackster: Galaxy’s embedded track browser
Create a visualization in Galaxy

or
Isn’t it nice to

• To do all those things we talked about?
  • Use visualization to evaluate and refine analyses?
  • Expose some basic analyses in visualization to make it more informative?
  • Make that analyze-visualize-refine loop seamless and fast? That is, integrate the two?
  • Use visualization to learn tools and explore their parameter space?
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More Galaxy Terminology

**Share:**
Make something available to someone else

**Publish:**
Make something available to everyone

**Galaxy Page:**
Analysis documentation within Galaxy; easy to embed any Galaxy object

Let’s all share...
Reproducibility: Everybody talks about it, but ...

Galaxy aims to push the goal of reproducibility from the bench to the bioinformatics realm

All analysis in Galaxy is recorded without any extra effort from the user.

Histories, workflows, visualizations and pages can be shared with others or published to the world.
Windshield splatter analysis with the Galaxy metagenomic pipeline

Sergei Kosakovskiy Pond1,2,6,9, Samir Wadhawan3,6,7,
Francesca Chiromonte4, Guruprasad Ananda1,3, Wen-Yu Chung1,3,8,
James Thiessen9

Supplemental material is available online at http://www.genome.org. All data
and tools described in this manuscript can be downloaded or used directly at
http://galaxyproject.org. Exact analyses and workflows used in this paper are
Sharing for Galaxy Administrators Too

Data Libraries
Make data easy to find

Genome Builds
Care about a particular subset of life?

Galaxy Tool Shed
Wrapping tools and datatypes
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2:15 Break, but first ...
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Acknowledgements

Mo Heyderian
Karen Reddy
Barbara Sollner-Webb

Steven Salzberg
The Galaxy Team
You!

Johns Hopkins University
Biological Chemistry
Center for Computational Biology

AWS Education Grant

NIH  NSF  Huck Institute
Penn State University    Emory University
Feedback Please!

Thanks

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clements@galaxyproject.org
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AWS Credentials