Title: The Einstein Toolkit

Speakers: Steven Brandt
Date: October 15, 2019 - 1:00 PM

URL: http://pirsa.org/19100074

Abstract: One of the best known open-source tools for studying numerical relativity is the Einstein Toolkit. With it, you can simulate collisions of black holes and neutron stars, and study their horizons and gravitational waves. In this talk we learn more about what the Einstein Toolkit can do, how it works. An introductory, hands-on tutorial will follow.

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Introduction to the Einstein Toolkit

Steven R. Brandt, Frank Löffler, Roland Haas, Peter Diener, others

Center for Computation and Technology
Louisiana State University, Baton Rouge, LA

Oct 13, 2019

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In the beginning...

1.3 Billion Years Ago, two black holes, each with about 30 solar masses, collided. They released three solar masses worth of mass energy as gravitational waves. Earth is in the Proterozoic Eon. Life consists of eukaryotes, including multicellular life forms.

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In the beginning...

541 Million Years Ago, Phanerozoic Eon begins, complex life, including vertebrates, appears.

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In the beginning...

1 Million Years Ago, Neanderthals appear.

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In the beginning...

200 Thousand Years Ago, "Anatomically Modern Humans" apper.

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In the beginning...

In 1687, Newton publishes "Philosophiæ Naturalis Principia Mathematica"

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In the beginning...

In 1905, Einstein publishes his paper on special relativity.

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In the beginning...

In 1914, Einstein publishes his paper on relativity.

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In the beginning...

In 1916, Schwarzchild publishes the Schwarzchild black hole solution

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In the beginning...

In 1936, Einstein correctly describes gravitational waves

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In the beginning...

In 1956, Felix Pirani eliminates coordinate confusion and describes gravitational waves using curvature

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In the beginning...

In 1963, Kerr publishes the Kerr black hole solution

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In the beginning...

In 1994, The head-on collision of two black holes was simulated, as well as distorted single black holes

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In the beginning...

In 1995, Distorted Kerr solutions were simulated by me. :)

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In the beginning...

In 1997, Cactus was created by Paul Walker and Joan Masso. It remains as one of the best, completely open source, collaborative frameworks for studying numerical relativity.

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In the beginning...

In 2005, Praetorius published his results on evolving binary black hole spacetimes.

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In the beginning...

In 2007-2009: LSU/RIT/PennState/Caltech/GeorgiaTech/AEI collaborations

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In the beginning...

In 2012: The Einstein Toolkit

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In the beginning...

In 2015, LIGO detected gravitational waves. The event was called GW150914.

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In the beginning...

Oh man, look at those cavemen go...
— David Bowie

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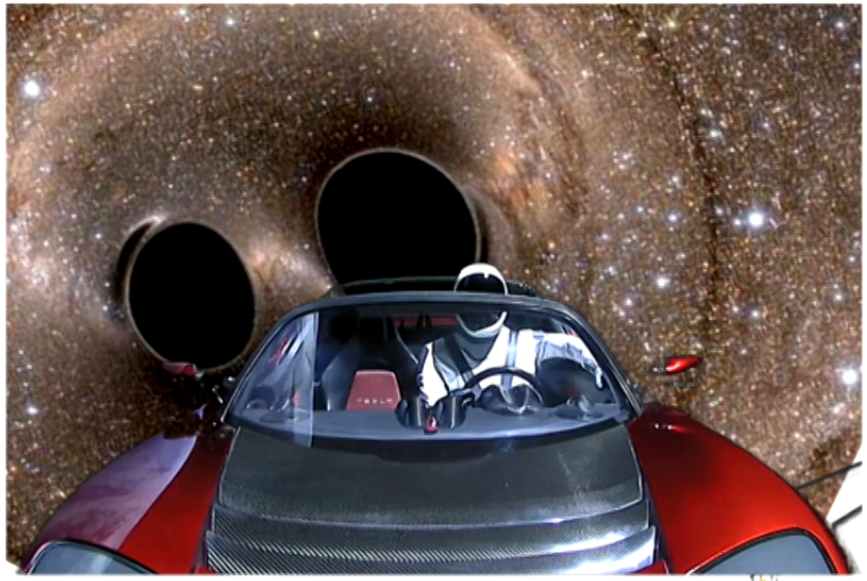
In the beginning...



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Einstein Toolkit

- Collection of scientific software components and tools to simulate and analyze general relativistic astrophysical systems
- Freely available as open source at http://einsteintoolkit.org
- Supported by NSF 1550551/1550461/1550436/1550514, NSF 1212401/1212426/1212433/1212460, NSF 0903973/0903782/0904015 (CIGR), 0701566/0855892 (XiRel), 0721915 (Alpaca), 0905046/0941653(PetaCactus/PRAC)
- State-of-the-art set of tools for numerical relativity, open source
- Currently 259 members from 172 sites and 39 countries
- $>$ 200 publications, $>$ 30 theses building on these components (as of 2013)
- Regular, tested releases
- User support through various channels

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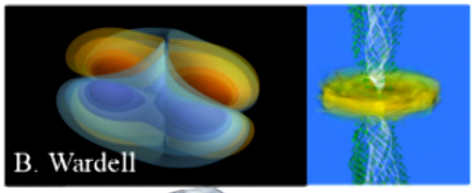
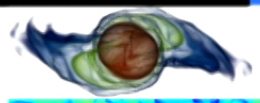
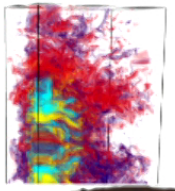
Einstein Toolkit

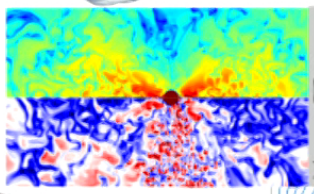
Science

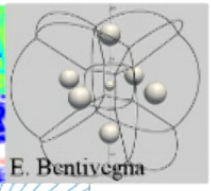
- Binary Black Hole Mergers
- Neutron Star Mergers
- Supernovae
- Accretion Disks
- Boson Stars
- Hairy Black Holes
- Cosmic Censorship

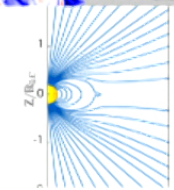












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Community Effort!

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Computational Challenges

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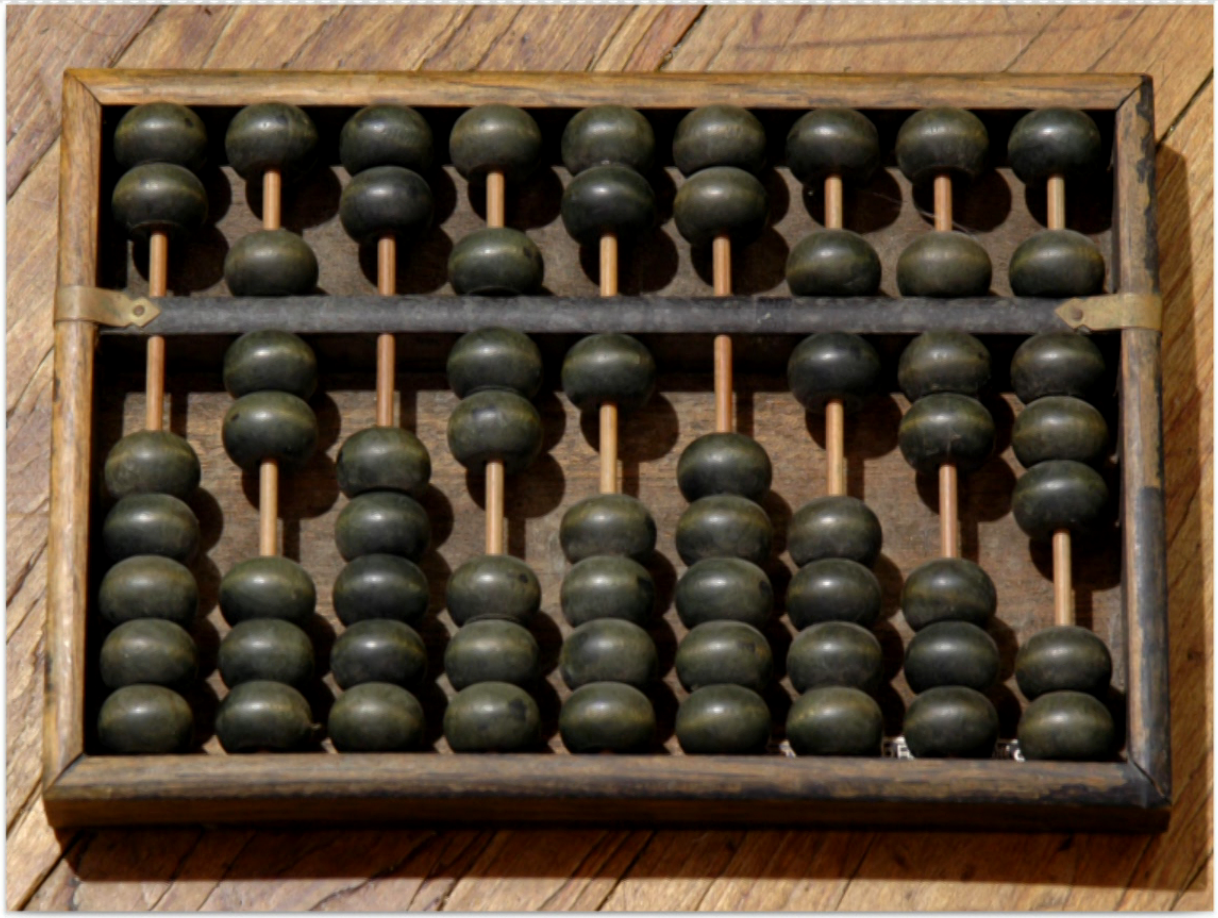

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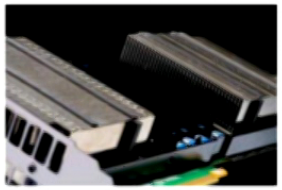
More and more diverse hardware



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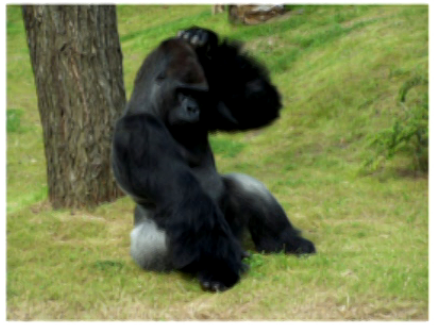
Computational Challenges

- Simulate cutting edge science
- Use latest numerical methods
- Make use of latest hardware
  - Vector
  - SMP parallelism
  - Scale to many nodes
  - AMR



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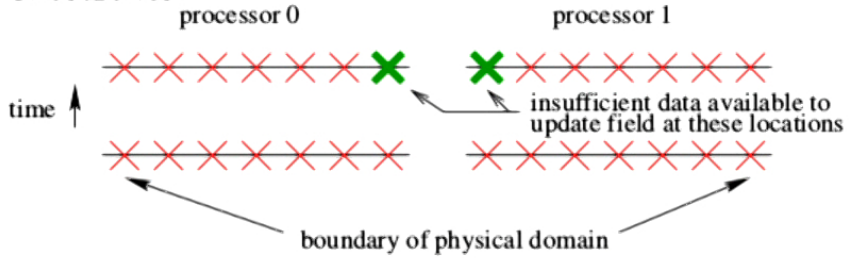
MPI Programming

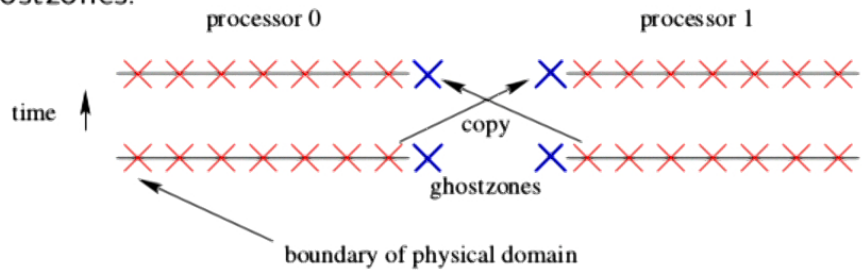
- Efficient use of all hardware is complex and tedious.
- Requires experts from different disciplines
- Requires good data layouts and APIs
- To ensure correctness, need good modularization on a number of levels and understanding of advanced programming concepts.
- Design and implementation needs to be carefully thought out in order to ensure extensibility and portability.

Domain Decomposition

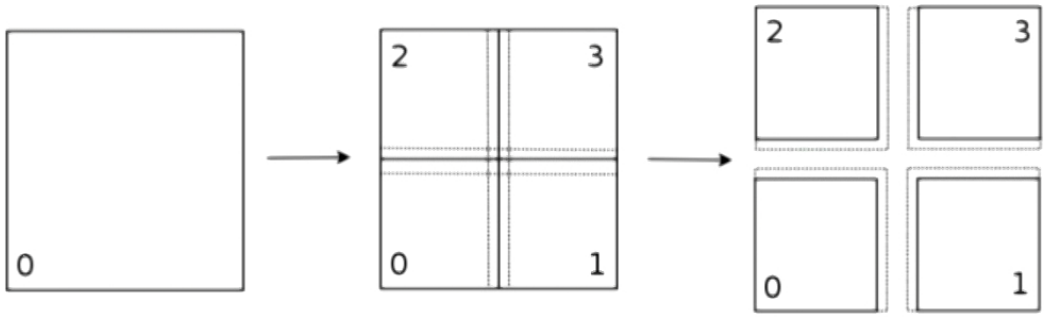
Without Ghostzones:



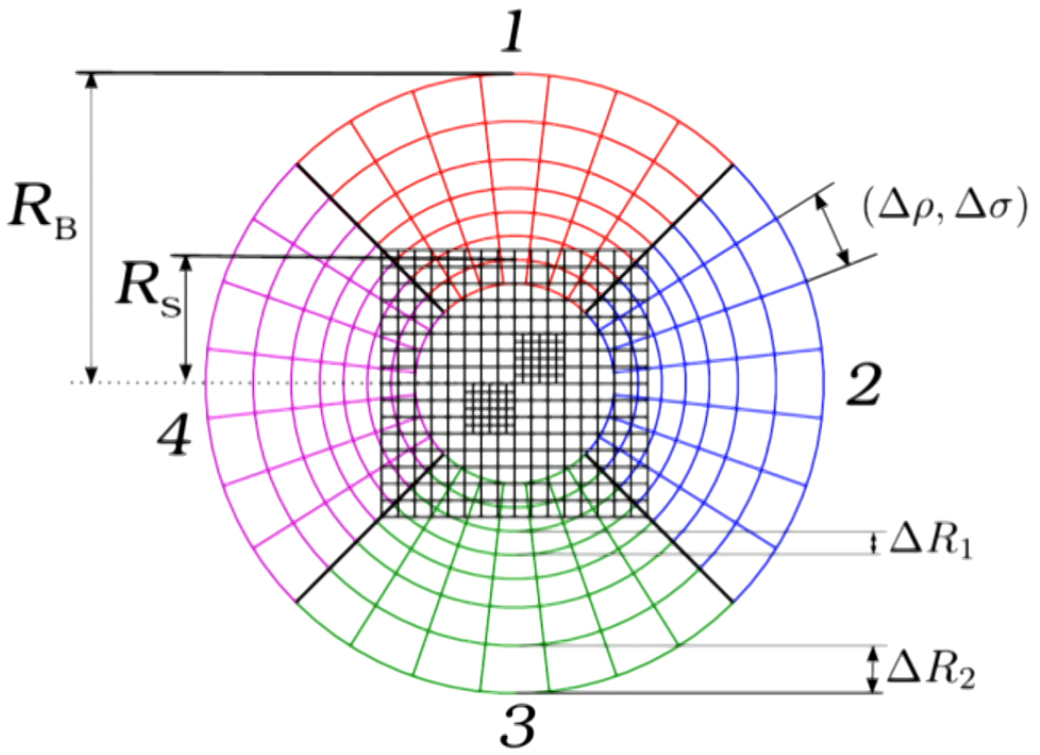
With Ghostzones:



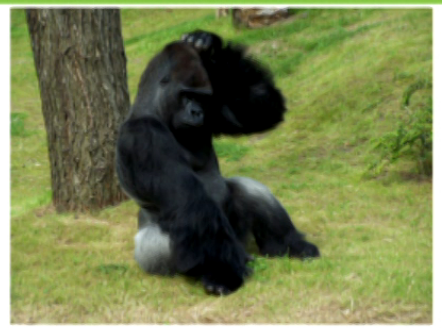
Domain decomposition



Multiblock and refinement



Computational Challenges



- Simulate cutting edge science
- Use latest numerical methods
- Make use of latest hardware
  - Vector (Kranc, NRPy+)
  - SMP parallelism (openmp)
  - Scale to many nodes (MPI, Carpet)
  - AMR (Adaptive Mesh Refinement, Carpet)
  - GPU? (AMReX?)
  - FPGA?
  - ASIC?
  - Neuromorphic processor?
  - Q-bits?

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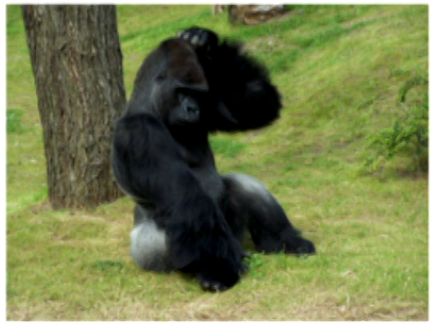
Computational Challenges

More Mundane Challenges

- Efficient I/O
- HDF5
- Checkpoint/Restart
- Parameter Parsing
- Visualization
- Steering



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Collaborative Challenges

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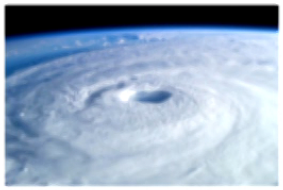

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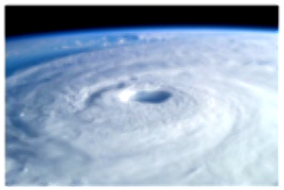

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Workshop




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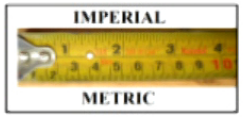

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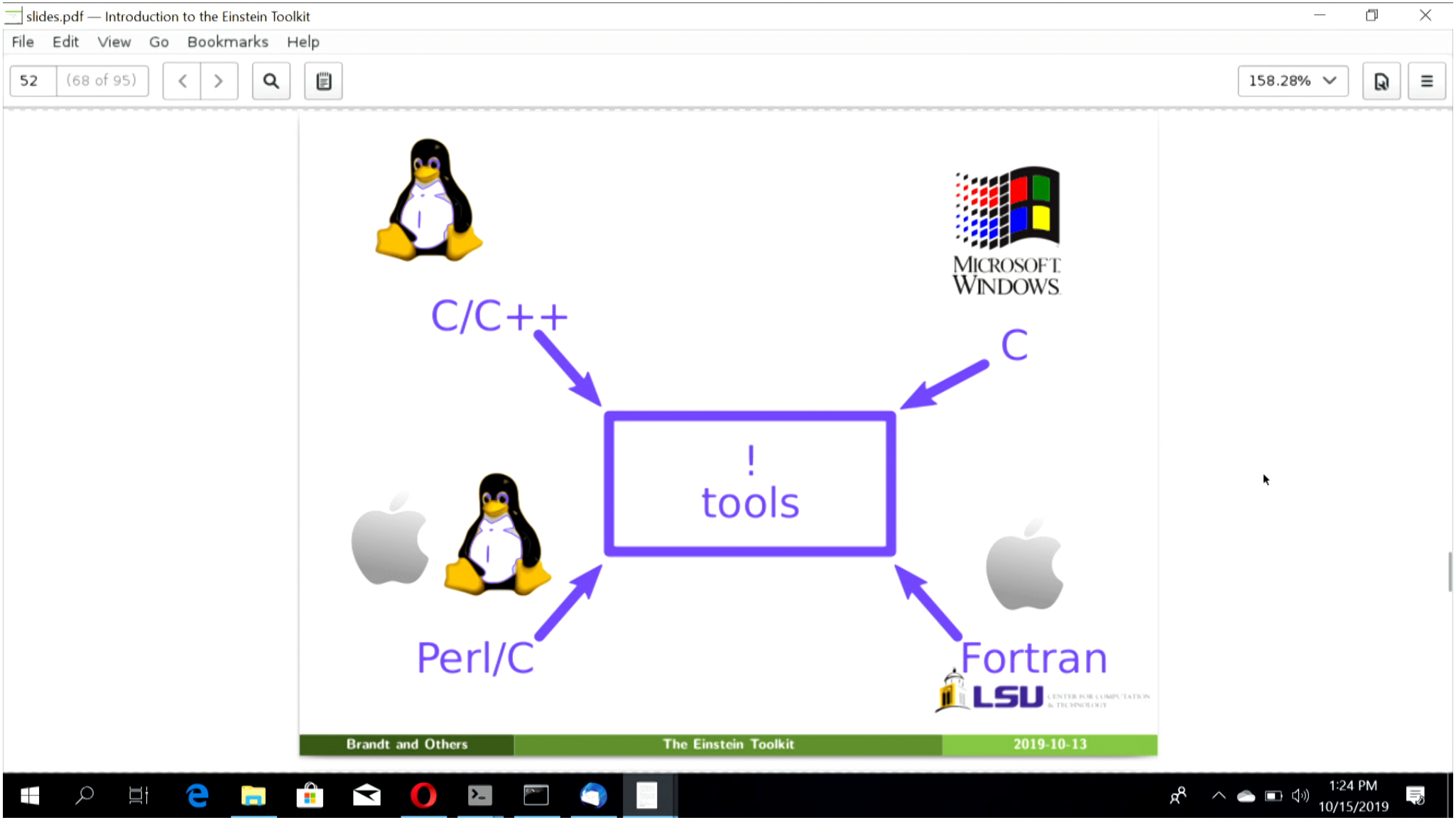
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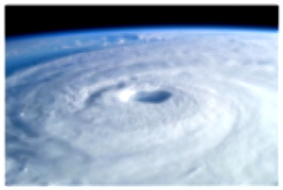

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Collaborative Challenges

How can we work together?

- Researchers in the USA
  - Louisiana
  - Illinois
  - Virginia
  - Pennsylvania
  - Georgia
  - California
- Researchers in Other countries
  - Italy
  - Spain
  - Portugal
  - Canada
  - Germany

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Einstein Toolkit

Goals:

- Community Driven
- Core computational tool for GR
- General purpose tool!

Components:

- Cactus
- Simulation Factory

- Kranc
- NRPy+
- Science Modules

Guiding Principles

- Open
- Community Driven
- Good interfaces
- Separation of physics from computational infrastructure
- Code reviews

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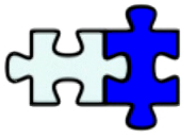
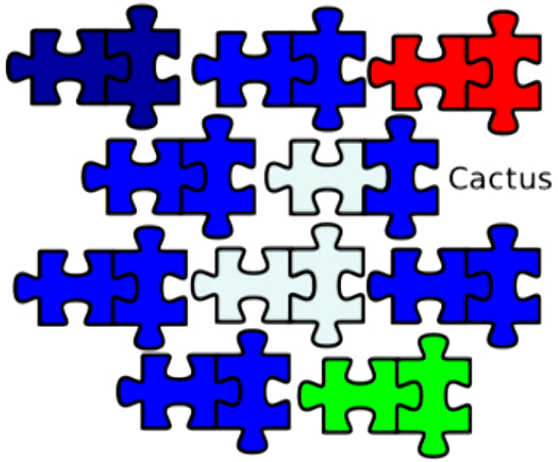
Einstein Toolkit as growing project

- Initially: some infrastructure, some application code



Einstein Toolkit as growing project

- Users from more fields of science



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Base Modules

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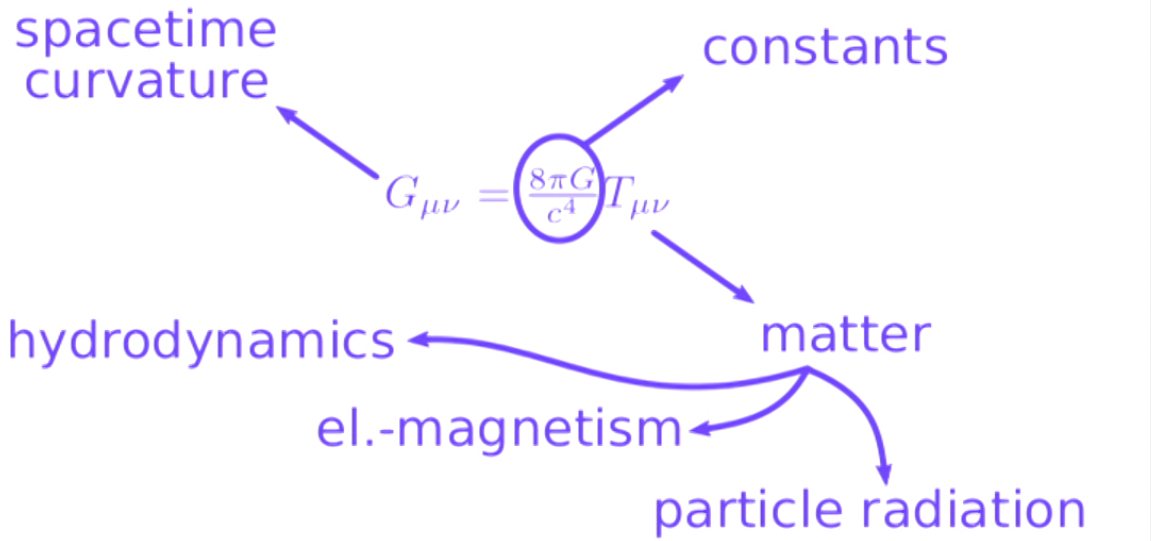
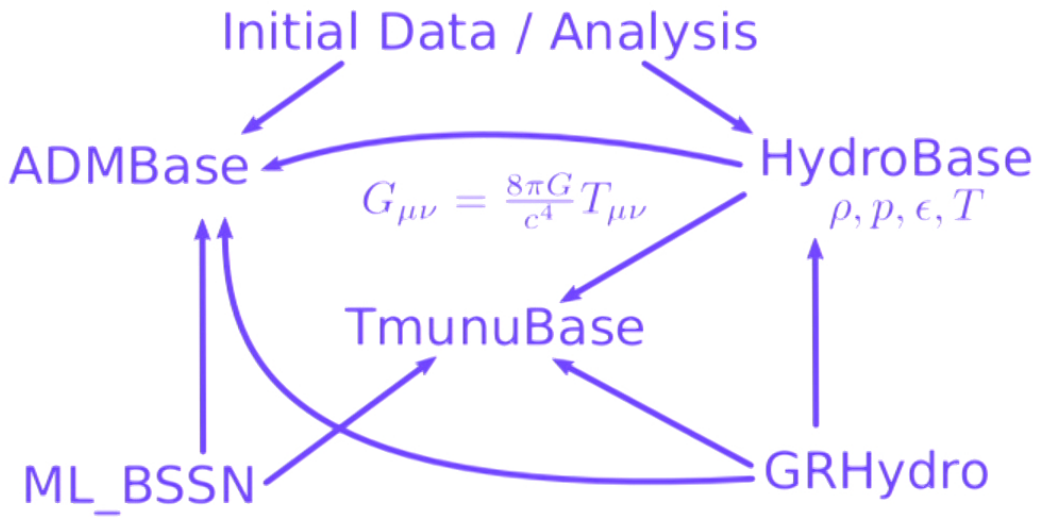
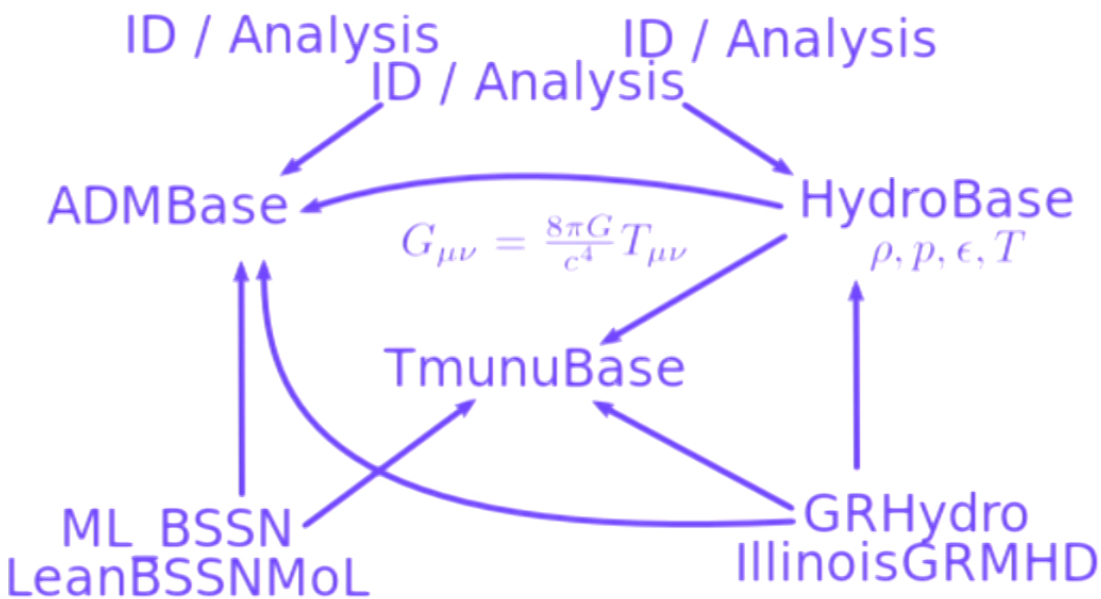
The Einstein Equations

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$







Guiding Principles

- Open, community-driven software development
- Separation of **physics** software and **computational** infrastructure
- Stable interfaces, allowing extensions
- Simplify usage where possible:
  - Doing science >> Running a simulation
  - Students need to know a lot about physics (meaningful initial conditions, numerical stability, accuracy/resolution, have patience, have curiosity, develop a "gut feeling" for what is right ...)
  - Einstein Toolkit **cannot** give that, **however**:
  - Open codes that are easy to use allow to concentrate on these things!

Credits, Citations

In academics: citations, citations, citations!
For Einstein Toolkit:

- Open and free source
- No **requirement** to cite anything
- However: **requested** to cite a few publications
- Which publications:
  - One, maybe two for the Toolkit itself
  - Some components list a few as well
  - List published on website and manage through publication database
  - In the future DOI's to cite the software

Vision

Future

- New Driver Thorn: AMReX
- New Declarative Synchronization: Presync
- New Spherical Coordinates Thorn (RIT)
- New Python Code Generator: NRPy+

Recent

- Proca Thorns
- LEAN Thorns
- GiRaFFE thorns

Summary

open source

Einstein Toolkit

- http://einsteintoolkit.org/
- Tools for high-performance computing in numerical relativity
- Open Source
- World-wide, open Community
- Used in high-end research

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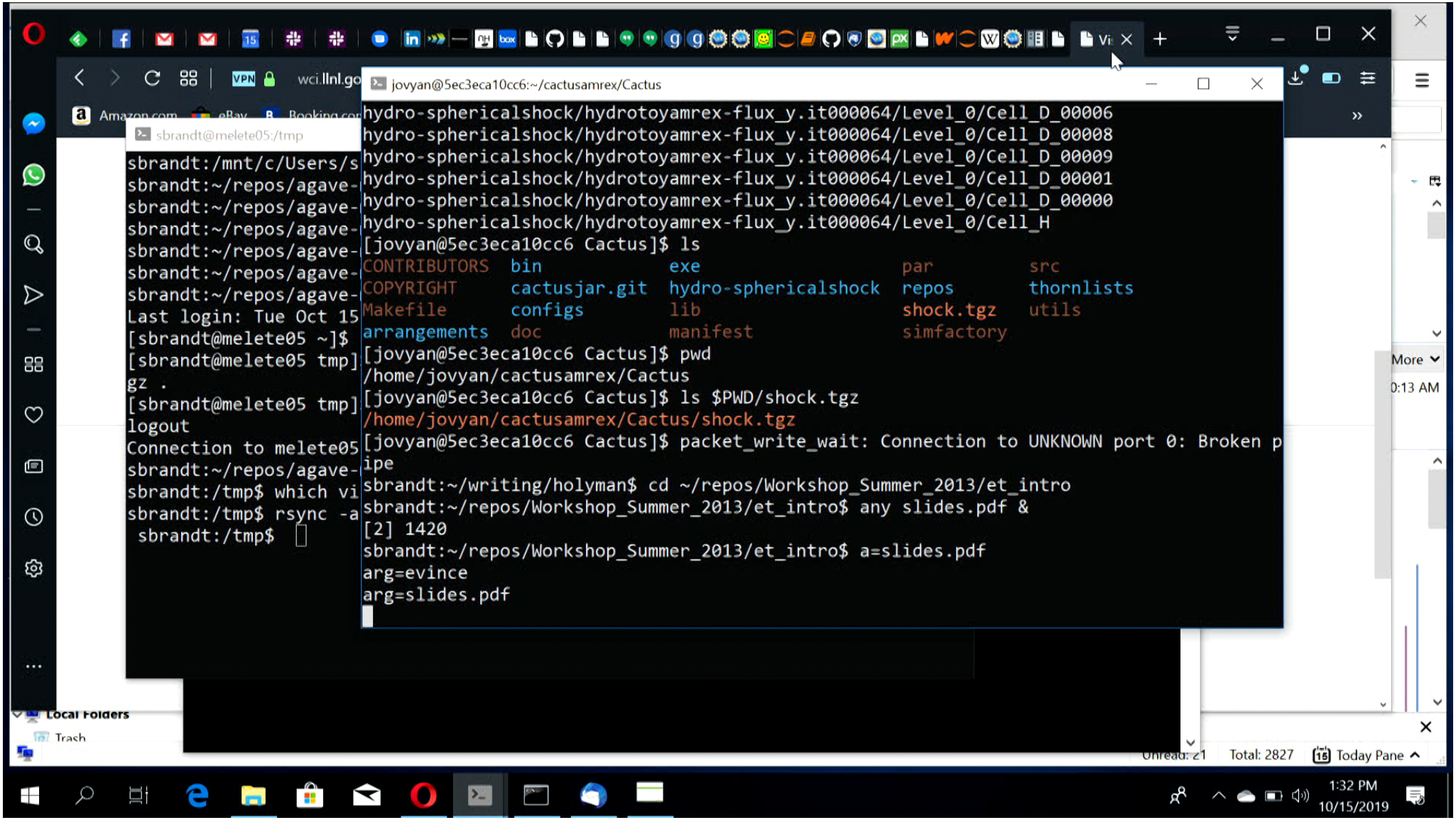
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hydro-sphericalshock/hydrotoyamrex-flux_y.it000064/Level_0/Cell_H
[jovyan@5ec3eca10cc6 Cactus]$ ls
CONTRIBUTORS bin exe par src
COPYRIGHT cactusjar.git hydro-sphericalshock repos thornlists
Makefile configs lib shock.tgz utils
arrangements doc manifest simfactory
[jovyan@5ec3eca10cc6 Cactus]$ pwd
/home/jovyan/cactusamrex/Cactus
[jovyan@5ec3eca10cc6 Cactus]$ ls $PWD/shock.tgz
/home/jovyan/cactusamrex/Cactus/shock.tgz
[jovyan@5ec3eca10cc6 Cactus]$ packet_write_wait: Connection to UNKNOWN port 0: Broken pipe
sbrandt:~/writing/holyman$ cd ~/repos/Workshop_Summer_2013/et_intro
sbrandt:~/repos/Workshop_Summer_2013/et_intro$ any slides.pdf &
[2] 1420
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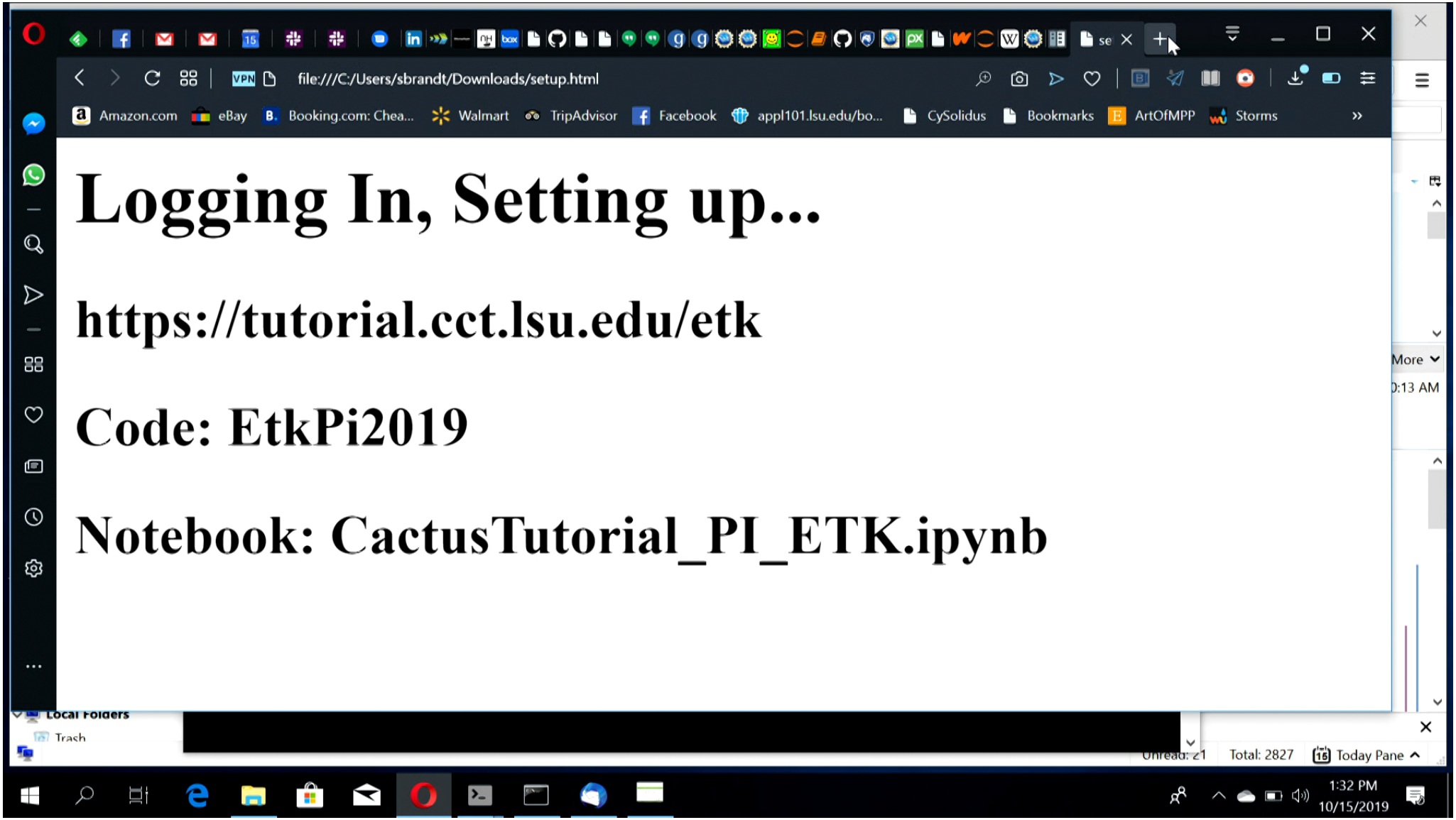
sbrandt:~/repos/agave-
sbrandt:~/repos/agave-
sbrandt:~/repos/agave-
sbrandt:~/repos/agave-
sbrandt:~/repos/agave-
sbrandt:~/repos/agave-
Last login: Tue Oct 15
[sbrandt@melete05 ~]$
[sbrandt@melete05 tmp]
gz .
[sbrandt@melete05 tmp]
logout
Connection to melete05
sbrandt:~/repos/agave-
sbrandt:/tmp$ which vi
sbrandt:/tmp$ rsync -a
sbrandt:/tmp$
Local Folders
Trash
More
0:13 AM
Total: 2827
Today Pane
1:32 PM
10/15/2019


file:///C:/Users/sbrandt/Downloads/setup.html
Amazon.com
eBay
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Walmart
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CySolidus
Bookmarks
ArtOfMPP
Storms
Logging In, Setting up...
https://tutorial.cct.lsu.edu/etk
Code: EtkPi2019
Notebook: CactusTutorial_PI_ETK.ipynb
Local Folders
Trash
Total: 2827
Today Pane
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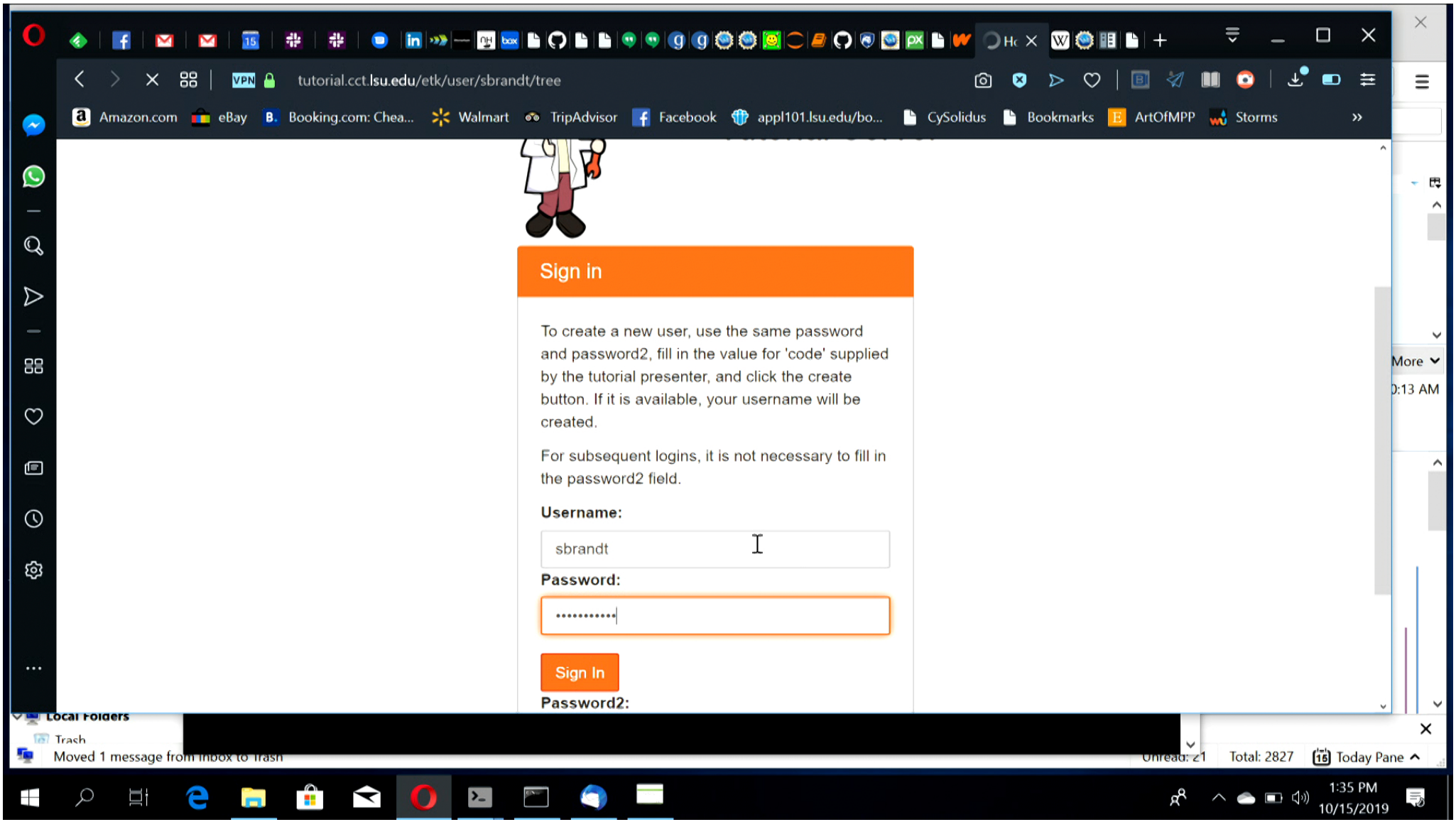
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/tree
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Walmart
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CySolidus
Bookmarks
ArtOfMPP
Storms
Sign in
To create a new user, use the same password and password2, fill in the value for 'code' supplied by the tutorial presenter, and click the create button. If it is available, your username will be created.
For subsequent logins, it is not necessary to fill in the password2 field.
Username:
sbrandt
Password:
Sign In
Password2:
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
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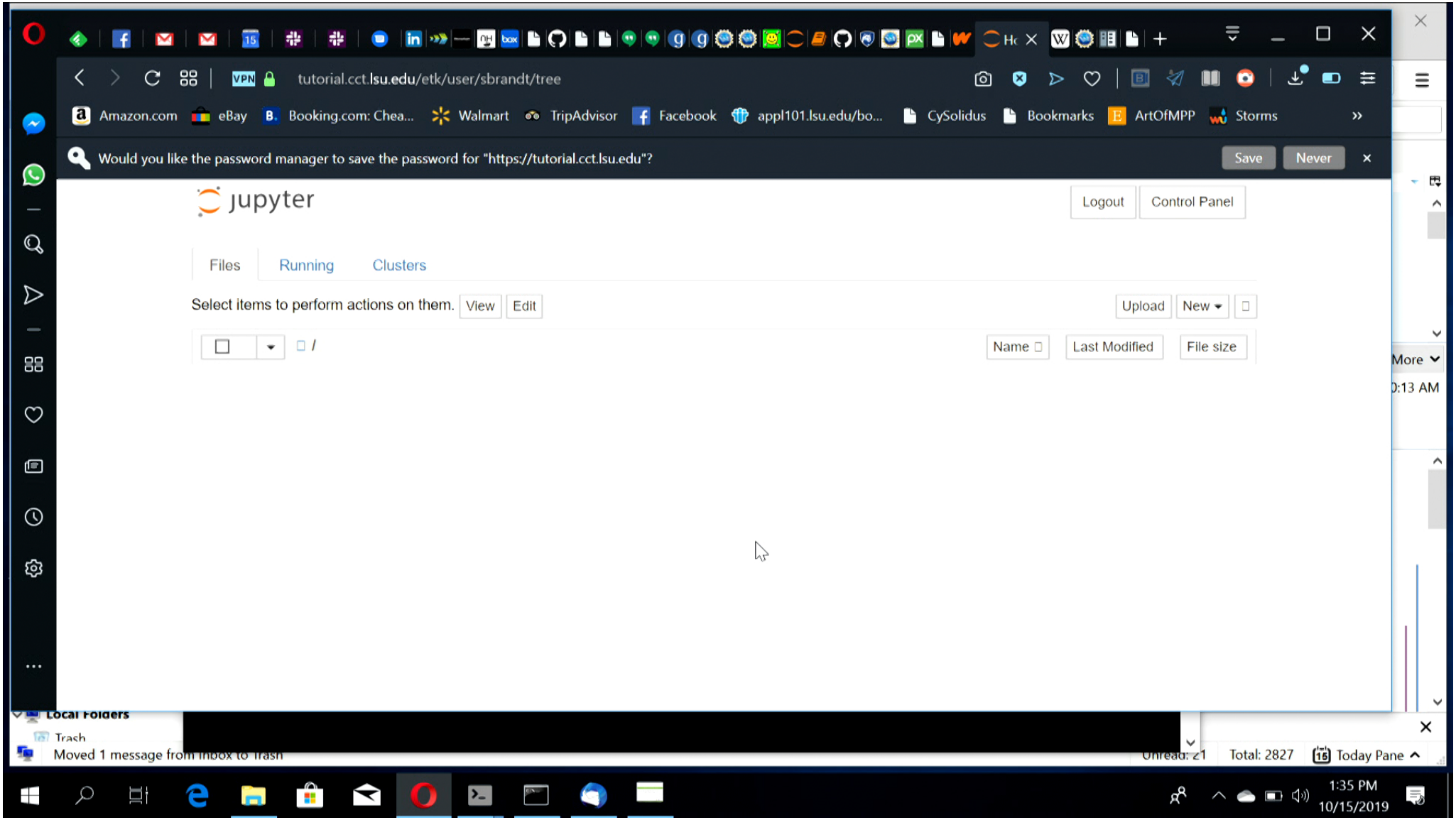
10/15/2019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CySolidus
Bookmarks
ArtOfMPP
Storms
Would you like the password manager to save the password for "https://tutorial.cct.lsu.edu"?
Save
Never
jupyter
Logout
Control Panel
Files
Running
Clusters
Select items to perform actions on them.
View
Edit
Upload
New
Name
Last Modified
File size
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
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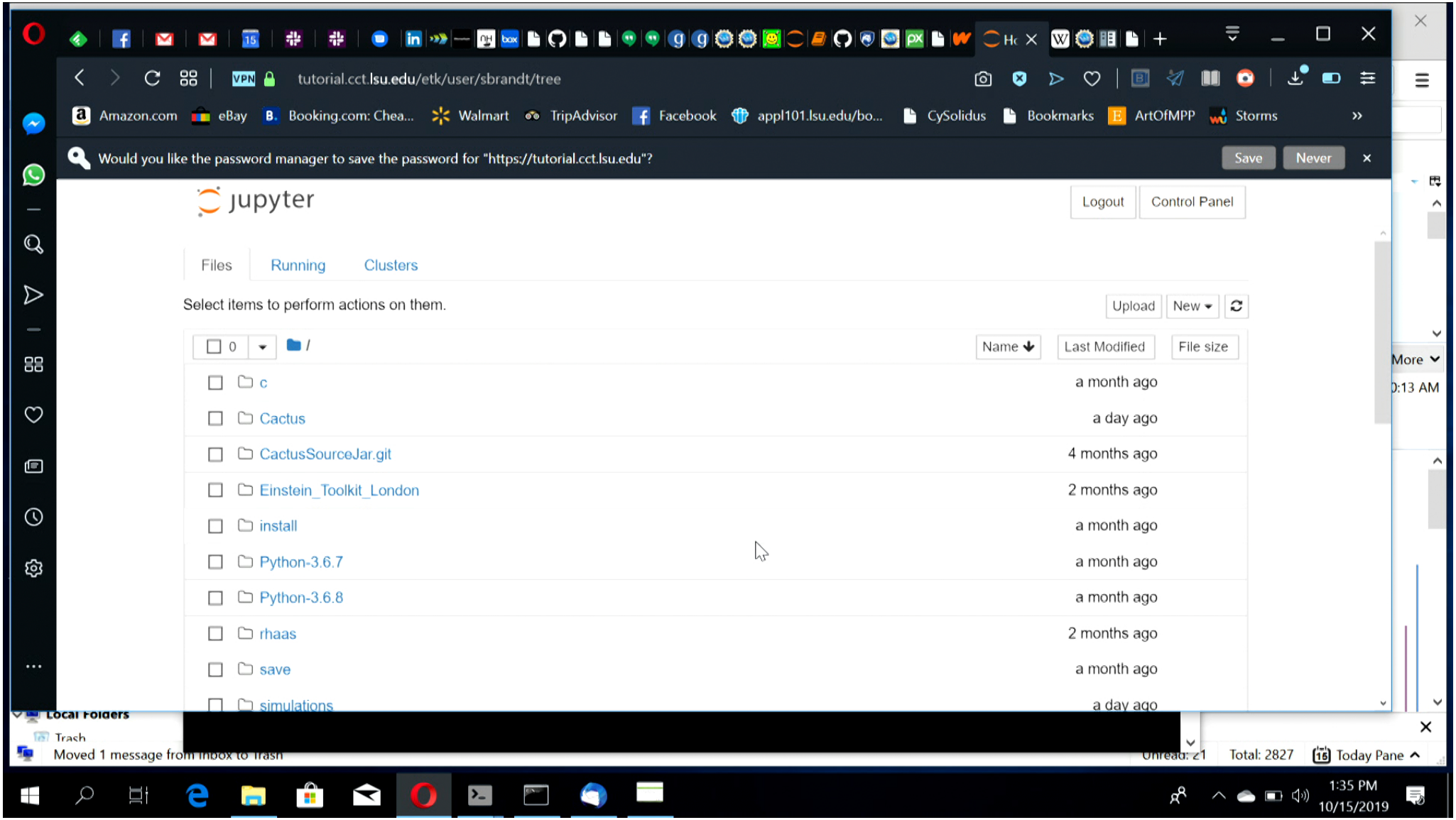
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/tree
Would you like the password manager to save the password for "https://tutorial.cct.lsu.edu"?
Save
Never
jupyter
Logout
Control Panel
Files
Running
Clusters
Select items to perform actions on them.
Upload
New
Name
Last Modified
File size
c a month ago
Cactus a day ago
CactusSourceJar.git 4 months ago
Einstein_Toolkit_London 2 months ago
install a month ago
Python-3.6.7 a month ago
Python-3.6.8 a month ago
rhaas 2 months ago
save a month ago
simulations a day ago
Moved 1 message from Inbox to Trash
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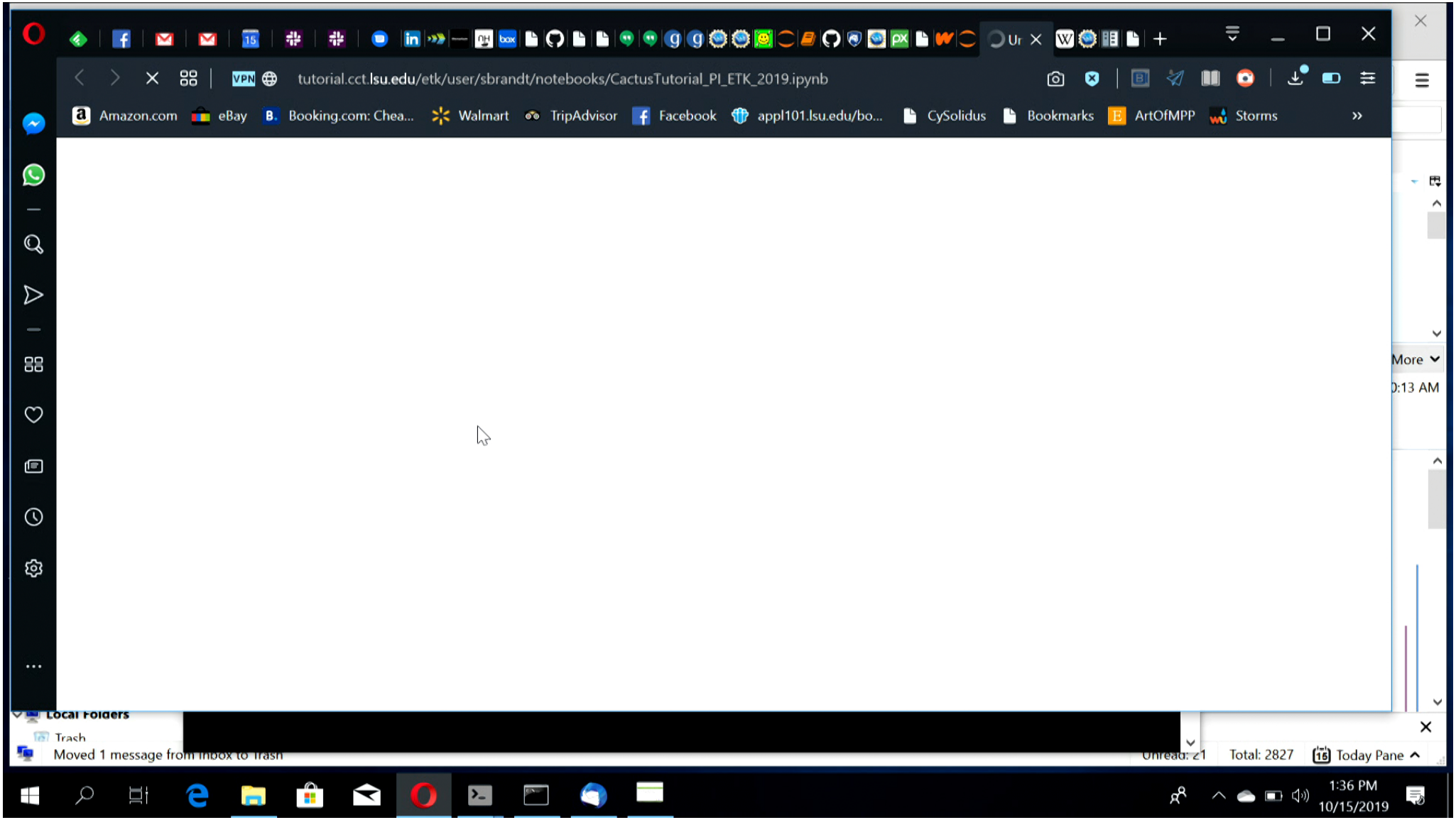
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CySolidus
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ArtOfMPP
Storms
More
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
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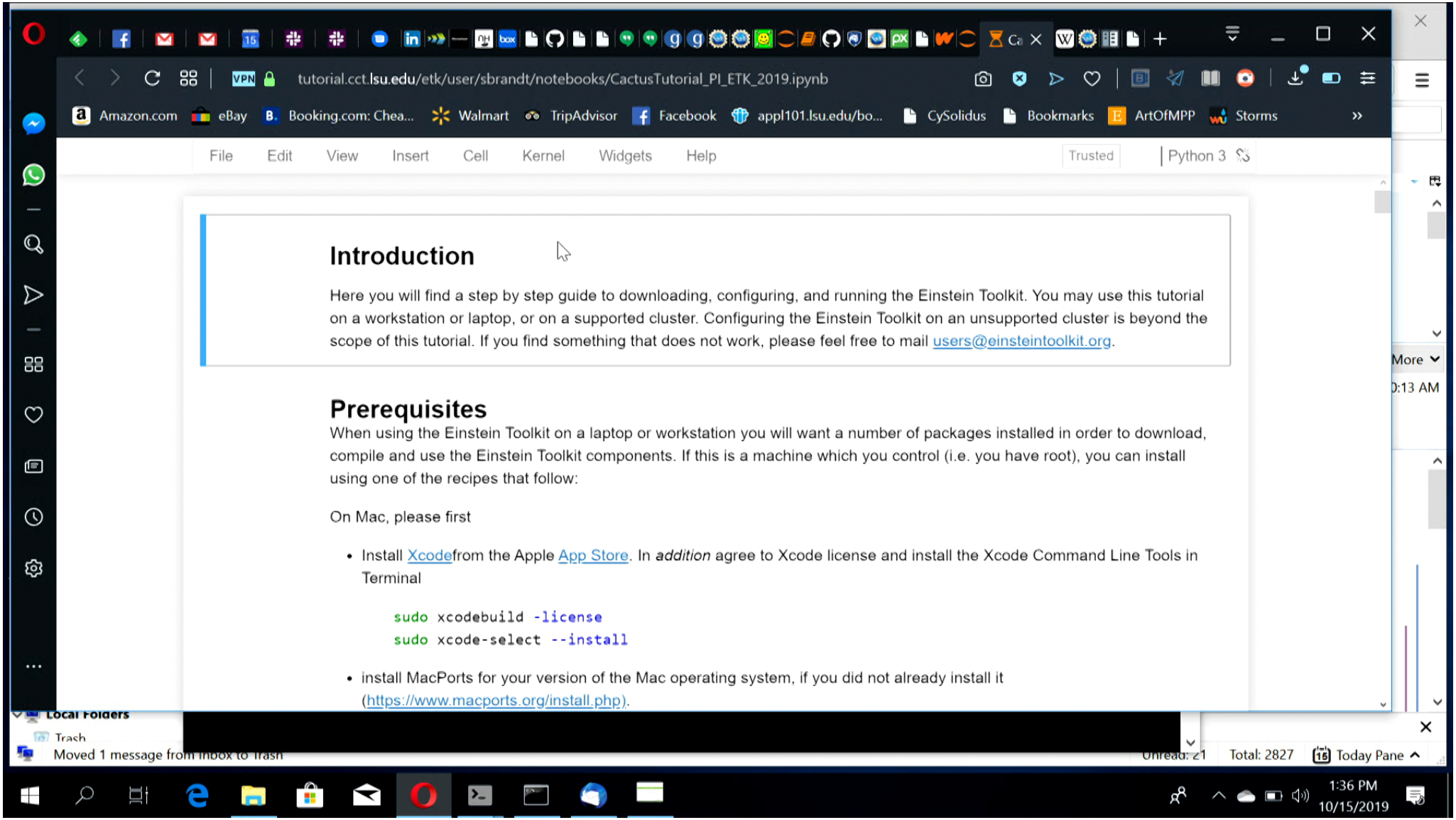
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
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TripAdvisor
Facebook
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ArtOfMPP
Storms
File
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Insert
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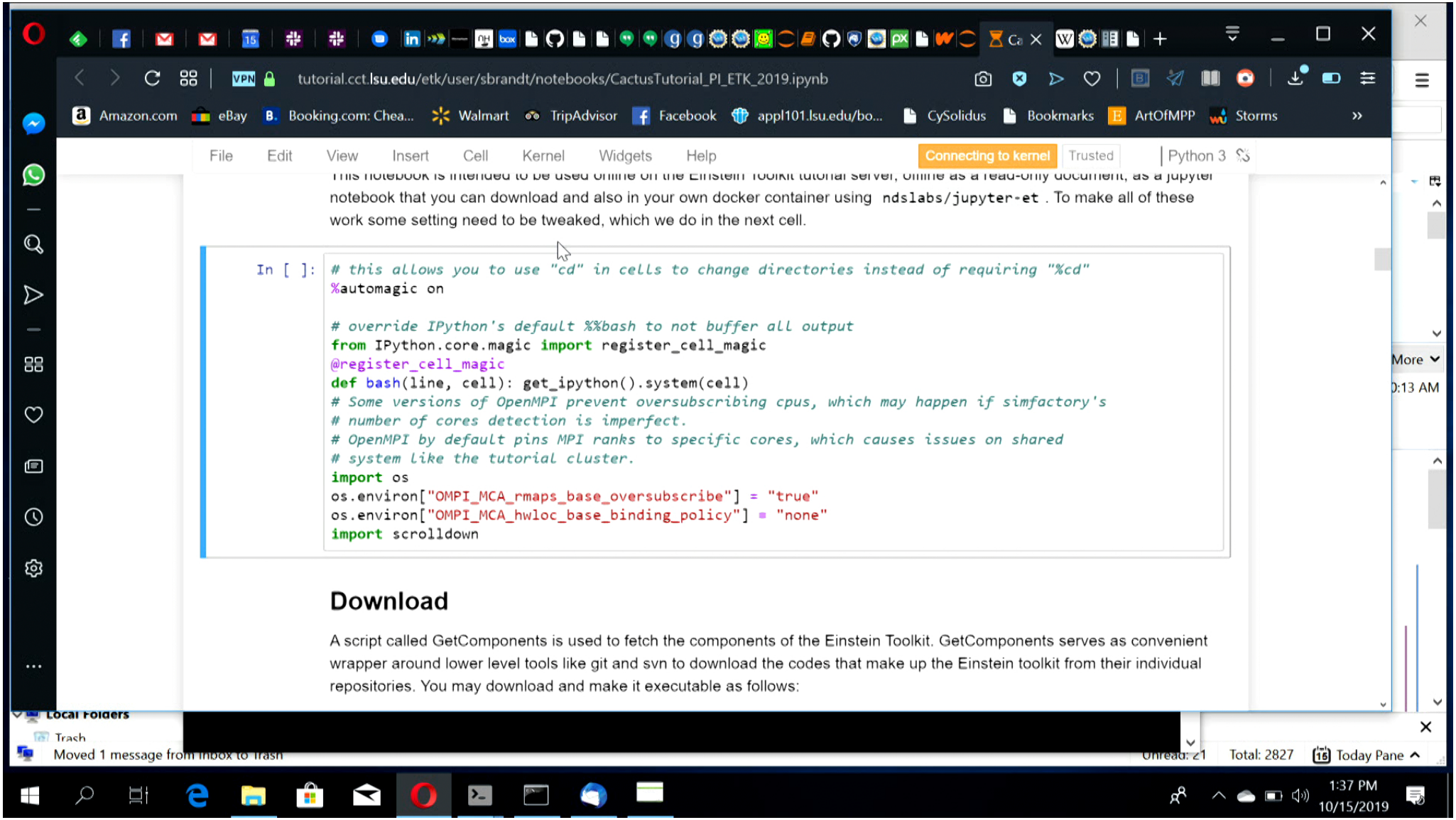
Kernel
Widgets
Help
Trusted
Python 3
Introduction
Here you will find a step by step guide to downloading, configuring, and running the Einstein Toolkit. You may use this tutorial on a workstation or laptop, or on a supported cluster. Configuring the Einstein Toolkit on an unsupported cluster is beyond the scope of this tutorial. If you find something that does not work, please feel free to mail users@einsteintoolkit.org.
Prerequisites
When using the Einstein Toolkit on a laptop or workstation you will want a number of packages installed in order to download, compile and use the Einstein Toolkit components. If this is a machine which you control (i.e. you have root), you can install using one of the recipes that follow:
On Mac, please first
Install Xcodefrom the Apple App Store. In addition agree to Xcode license and install the Xcode Command Line Tools in Terminal
sudo xcodebuild -license
sudo xcode-select --install
install MacPorts for your version of the Mac operating system, if you did not already install it (https://www.macports.org/install.php).
More
0:13 AM
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:36 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Connecting to kernel
Trusted
Python 3
notebook that you can download and also in your own docker container using ndslabs/jupyter-et . To make all of these work some setting need to be tweaked, which we do in the next cell.
In [ ]:
this allows you to use "cd" in cells to change directories instead of requiring "%cd"
%automagic on
# override IPython's default %%bash to not buffer all output
from IPython.core.magic import register_cell_magic
@register_cell_magic
def bash(line, cell): get_ipython().system(cell)
# Some versions of OpenMPI prevent oversubscribing cpus, which may happen if simfactory's
# number of cores detection is imperfect.
# OpenMPI by default pins MPI ranks to specific cores, which causes issues on shared
# system like the tutorial cluster.
import os
os.environ["OMPI_MCA_rmaps_base_oversubscribe"] = "true"
os.environ["OMPI_MCA_hwloc_base_binding_policy"] = "none"
import scrolldown
Download
A script called GetComponents is used to fetch the components of the Einstein Toolkit. GetComponents serves as convenient wrapper around lower level tools like git and svn to download the codes that make up the Einstein toolkit from their individual repositories. You may download and make it executable as follows:
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
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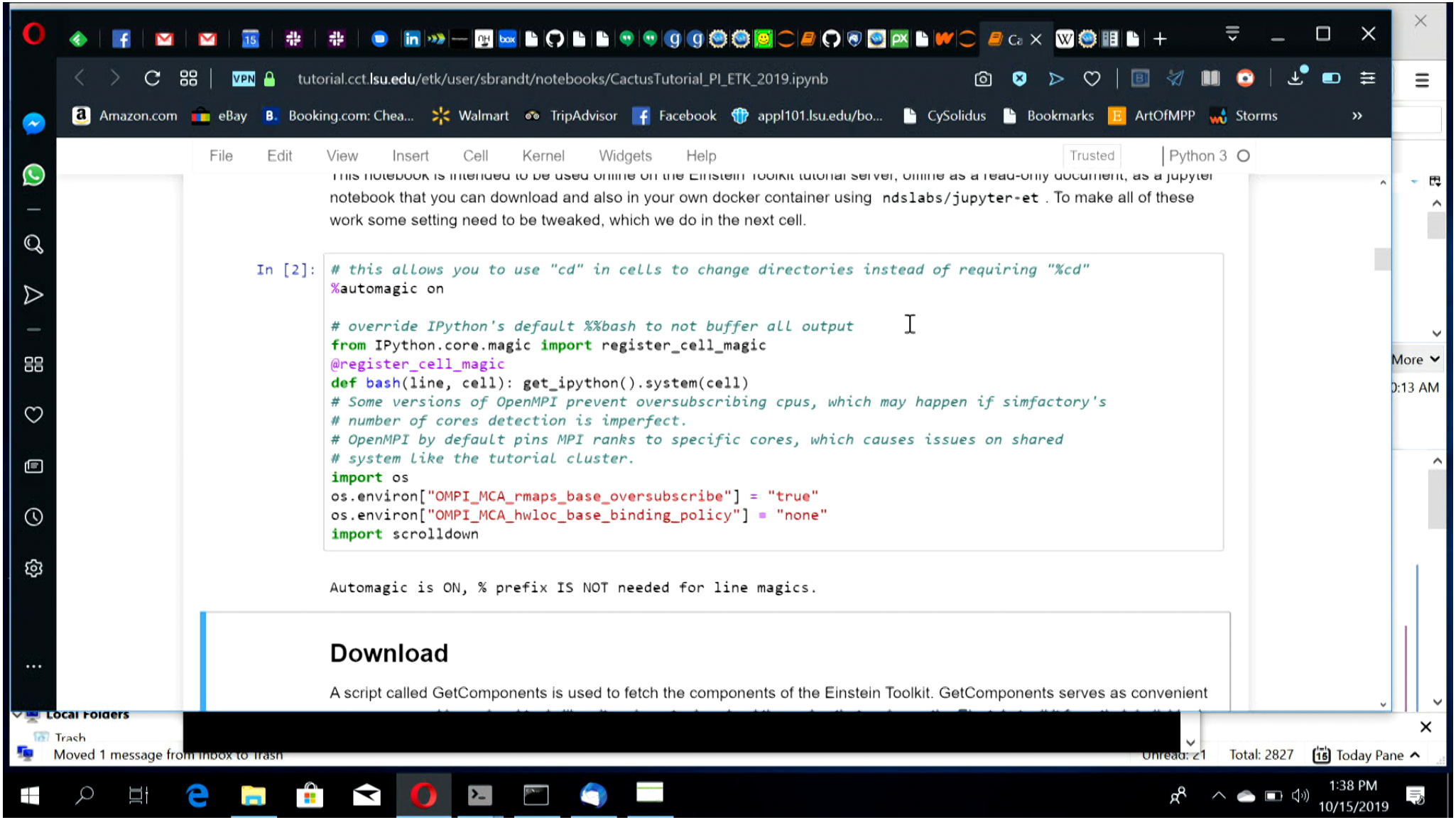
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
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Python 3
notebook that you can download and also in your own docker container using ndslabs/jupyter-et . To make all of these work some setting need to be tweaked, which we do in the next cell.
In [2]:
this allows you to use "cd" in cells to change directories instead of requiring "%cd"
%automagic on
# override IPython's default %%bash to not buffer all output
from IPython.core.magic import register_cell_magic
@register_cell_magic
def bash(line, cell): get_ipython().system(cell)
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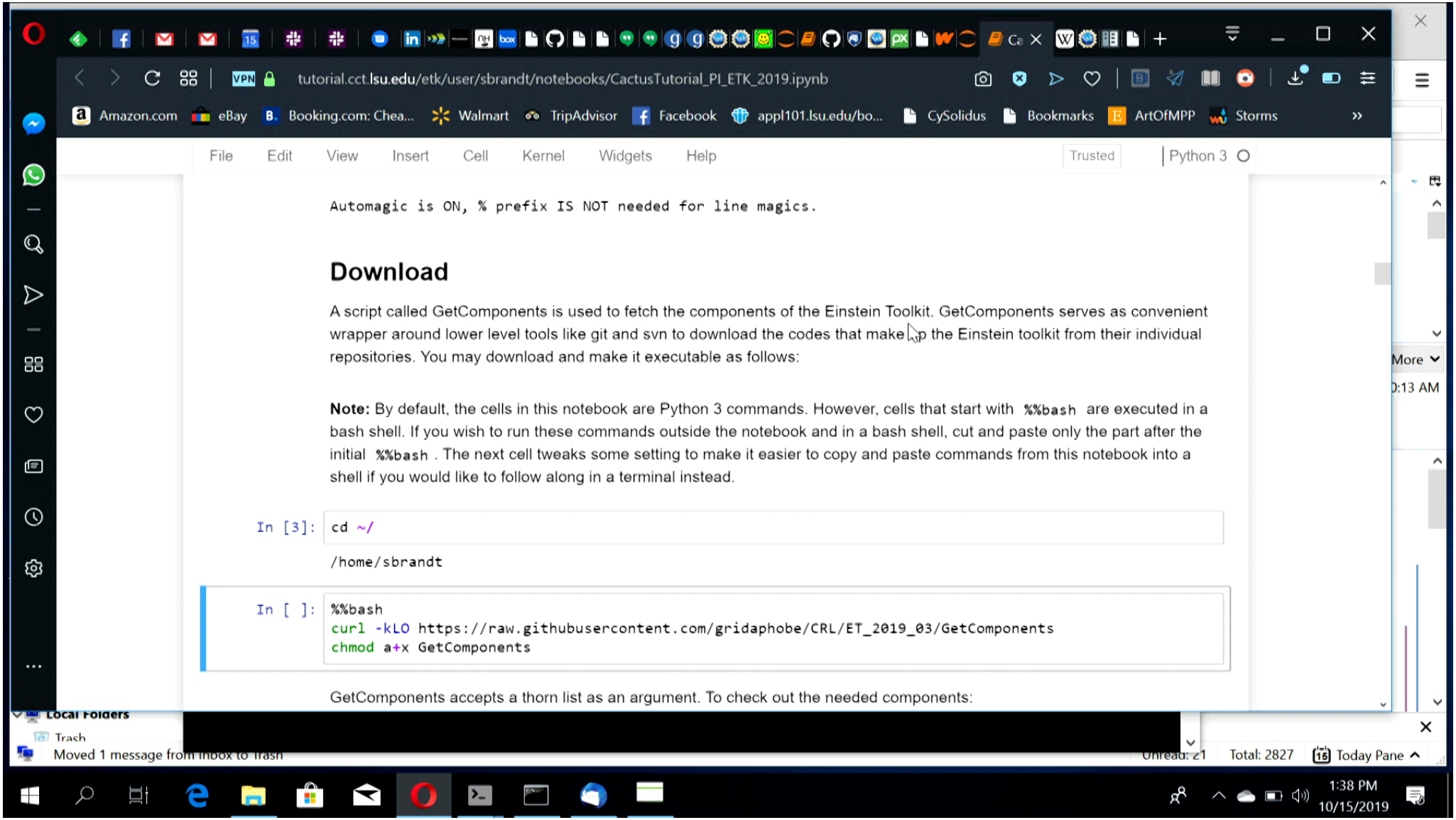
# number of cores detection is imperfect.
# OpenMPI by default pins MPI ranks to specific cores, which causes issues on shared
# system like the tutorial cluster.
import os
os.environ["OMPI_MCA_rmaps_base_oversubscribe"] = "true"
os.environ["OMPI_MCA_hwloc_base_binding_policy"] = "none"
import scrolldown
Automagic is ON, % prefix IS NOT needed for line magics.
Download
A script called GetComponents is used to fetch the components of the Einstein Toolkit. GetComponents serves as convenient
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:38 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
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CySolidus
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ArtOfMPP
Storms
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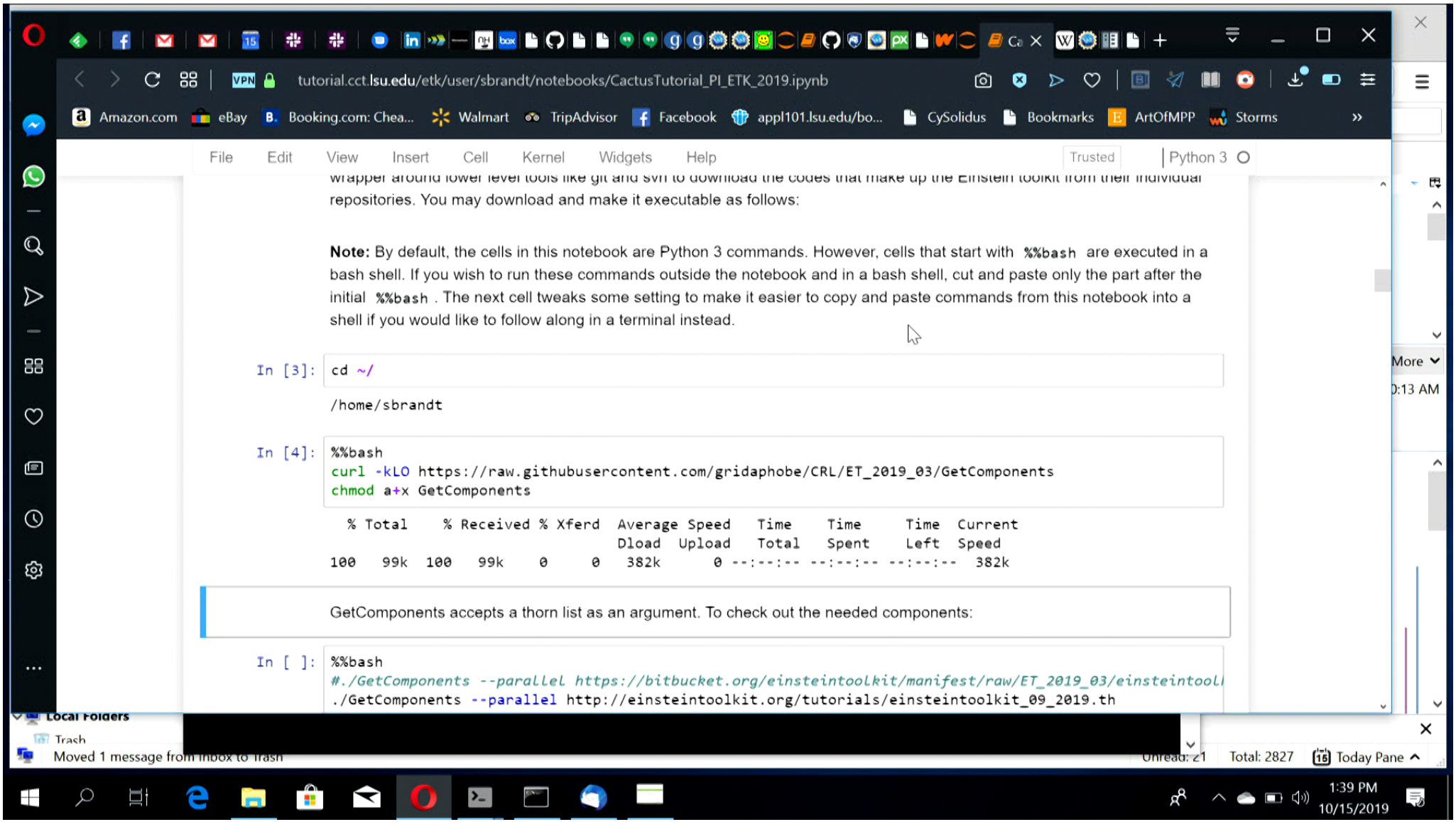
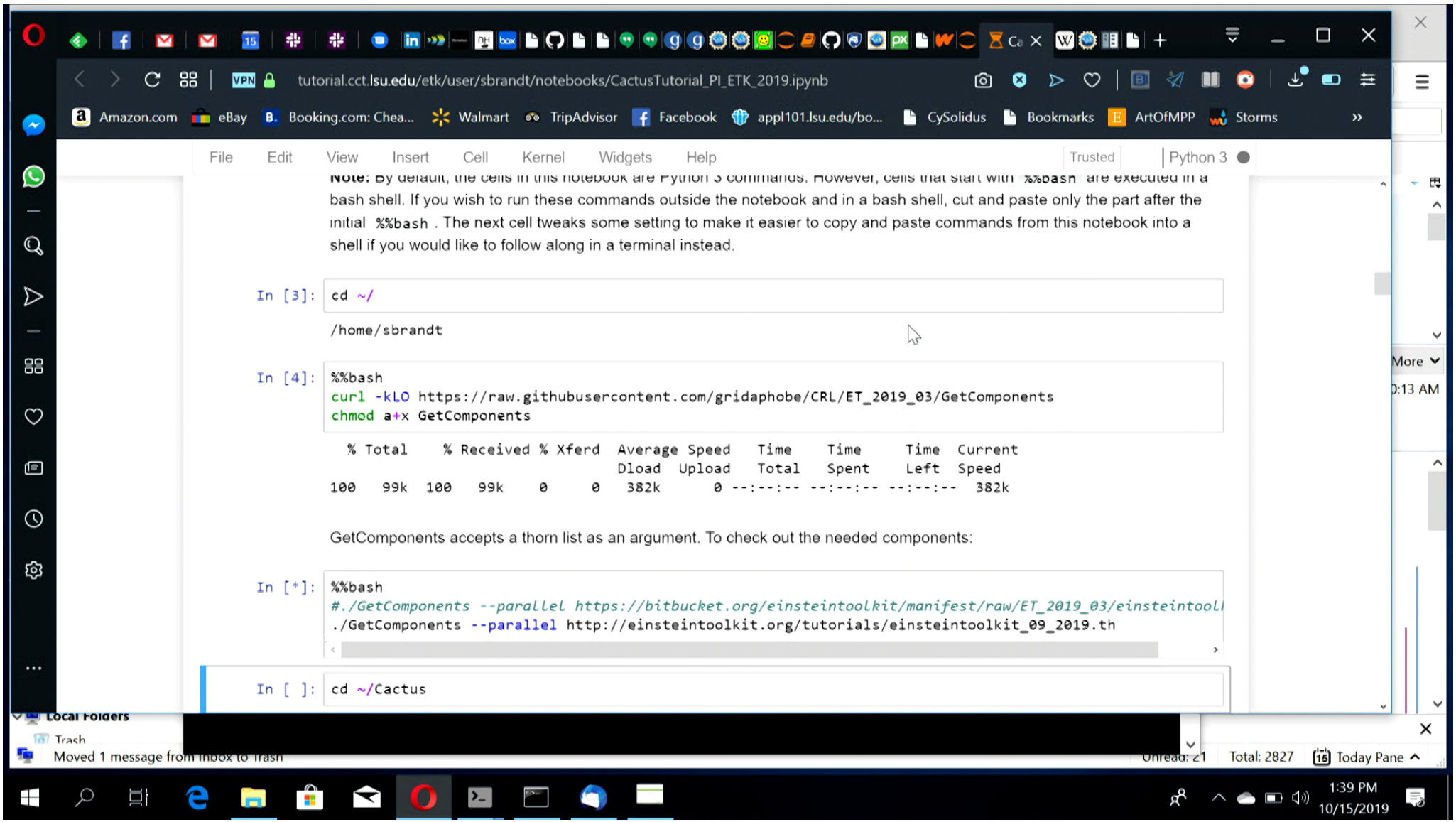
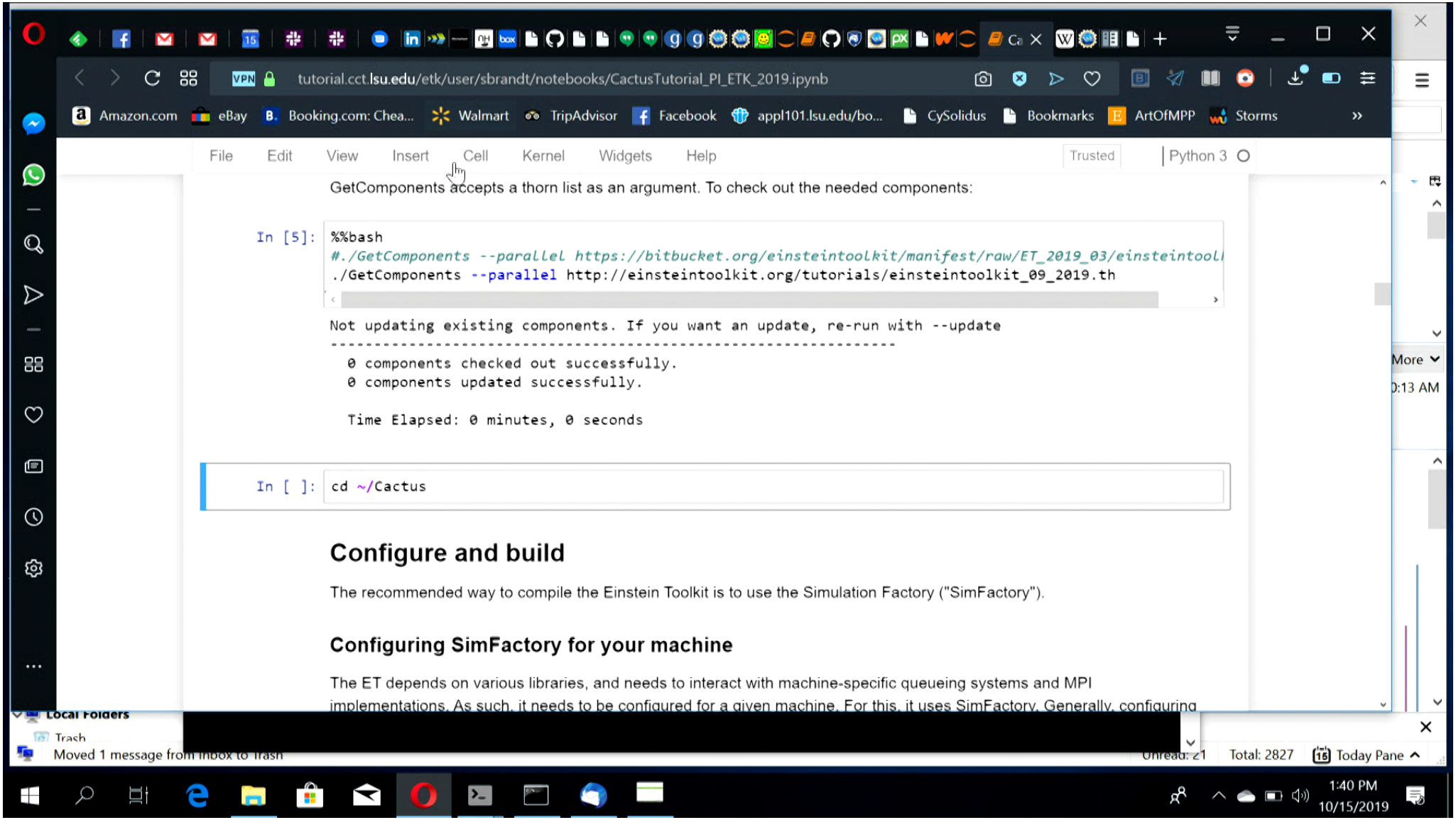
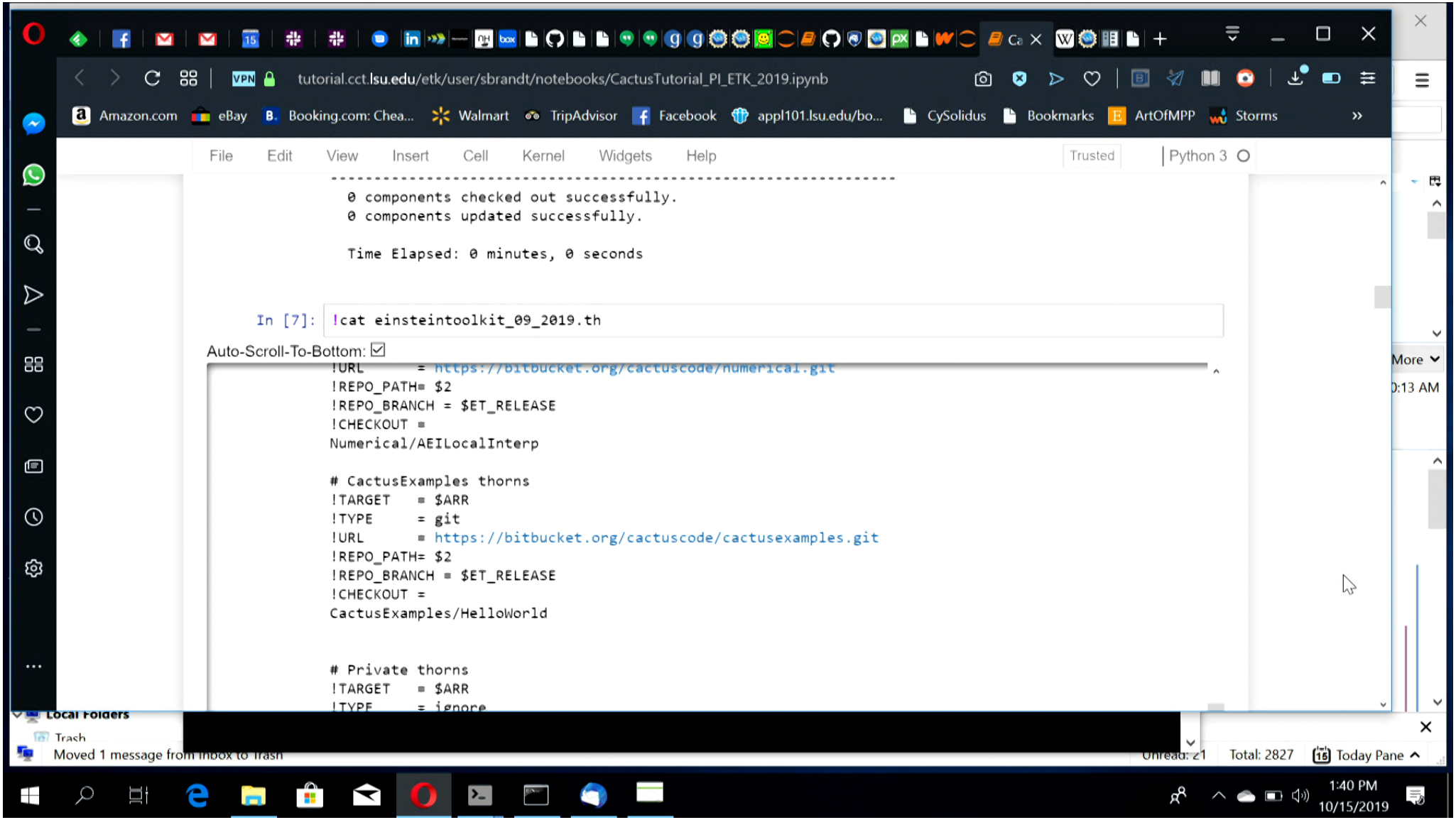
Kernel
Widgets
Help
Trusted
Python 3
Automagic is ON, % prefix IS NOT needed for line magics.
Download
A script called GetComponents is used to fetch the components of the Einstein Toolkit. GetComponents serves as convenient wrapper around lower level tools like git and svn to download the codes that make up the Einstein toolkit from their individual repositories. You may download and make it executable as follows:
Note: By default, the cells in this notebook are Python 3 commands. However, cells that start with %%bash are executed in a bash shell. If you wish to run these commands outside the notebook and in a bash shell, cut and paste only the part after the initial %%bash . The next cell tweaks some setting to make it easier to copy and paste commands from this notebook into a shell if you would like to follow along in a terminal instead.
In [3]:
cd ~/
/home/sbrandt
In [ ]:
%%bash
curl -kLO https://raw.githubusercontent.com/gridaphobe/CRL/ET_2019_03/GetComponents
chmod a+x GetComponents
GetComponents accepts a thorn list as an argument. To check out the needed components:
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:38 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
repositories. You may download and make it executable as follows:
Note: By default, the cells in this notebook are Python 3 commands. However, cells that start with %%bash are executed in a bash shell. If you wish to run these commands outside the notebook and in a bash shell, cut and paste only the part after the initial %%bash . The next cell tweaks some setting to make it easier to copy and paste commands from this notebook into a shell if you would like to follow along in a terminal instead.
In [3]:
cd ~/
/home/sbrandt
In [4]:
%%bash
curl -kLO https://raw.githubusercontent.com/gridaphobe/CRL/ET_2019_03/GetComponents
chmod a+x GetComponents
% Total % Received % Xferd Average Speed Time Time Time Current
Dload Upload Total Spent Left Speed
100 99k 100 99k 0 0 382k 0 --:--:-- --:--:-- --:--:-- 382k
GetComponents accepts a thorn list as an argument. To check out the needed components:
In [ ]:
%%bash
#./GetComponents --parallel https://bitbucket.org/einsteintoolkit/manifest/raw/ET_2019_03/einsteintool
./GetComponents --parallel http://einsteintoolkit.org/tutorials/einsteintoolkit_09_2019.th
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:39 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
bash shell. If you wish to run these commands outside the notebook and in a bash shell, cut and paste only the part after the initial %%bash . The next cell tweaks some setting to make it easier to copy and paste commands from this notebook into a shell if you would like to follow along in a terminal instead.
In [3]:
cd ~/
/home/sbrandt
In [4]:
%%bash
curl -kLO https://raw.githubusercontent.com/gridaphobe/CRL/ET_2019_03/GetComponents
chmod a+x GetComponents
% Total % Received % Xferd Average Speed Time Time Time Current
Dload Upload Total Spent Left Speed
100 99k 100 99k 0 0 382k 0 --:--:-- --:--:-- --:--:-- 382k
GetComponents accepts a thorn list as an argument. To check out the needed components:
In [*]:
%%bash
#./GetComponents --parallel https://bitbucket.org/einsteintoolkit/manifest/raw/ET_2019_03/einsteintool
./GetComponents --parallel http://einsteintoolkit.org/tutorials/einsteintoolkit_09_2019.th
In [ ]:
cd ~/Cactus
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:39 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
GetComponents accepts a thorn list as an argument. To check out the needed components:
In [5]:
%%bash
#./GetComponents --parallel https://bitbucket.org/einsteintoolkit/manifest/raw/ET_2019_03/einsteintool
./GetComponents --parallel http://einsteintoolkit.org/tutorials/einsteintoolkit_09_2019.th
Not updating existing components. If you want an update, re-run with --update
0 components checked out successfully.
0 components updated successfully.
Time Elapsed: 0 minutes, 0 seconds
In [ ]:
cd ~/Cactus
Configure and build
The recommended way to compile the Einstein Toolkit is to use the Simulation Factory ("SimFactory").
Configuring SimFactory for your machine
The ET depends on various libraries, and needs to interact with machine-specific queueing systems and MPI
implementations. As such, it needs to be configured for a given machine. For this, it uses SimFactory. Generally, configuring


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
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appl101.lsu.edu/bo...
CySolidus
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Storms
File
Edit
View
Insert
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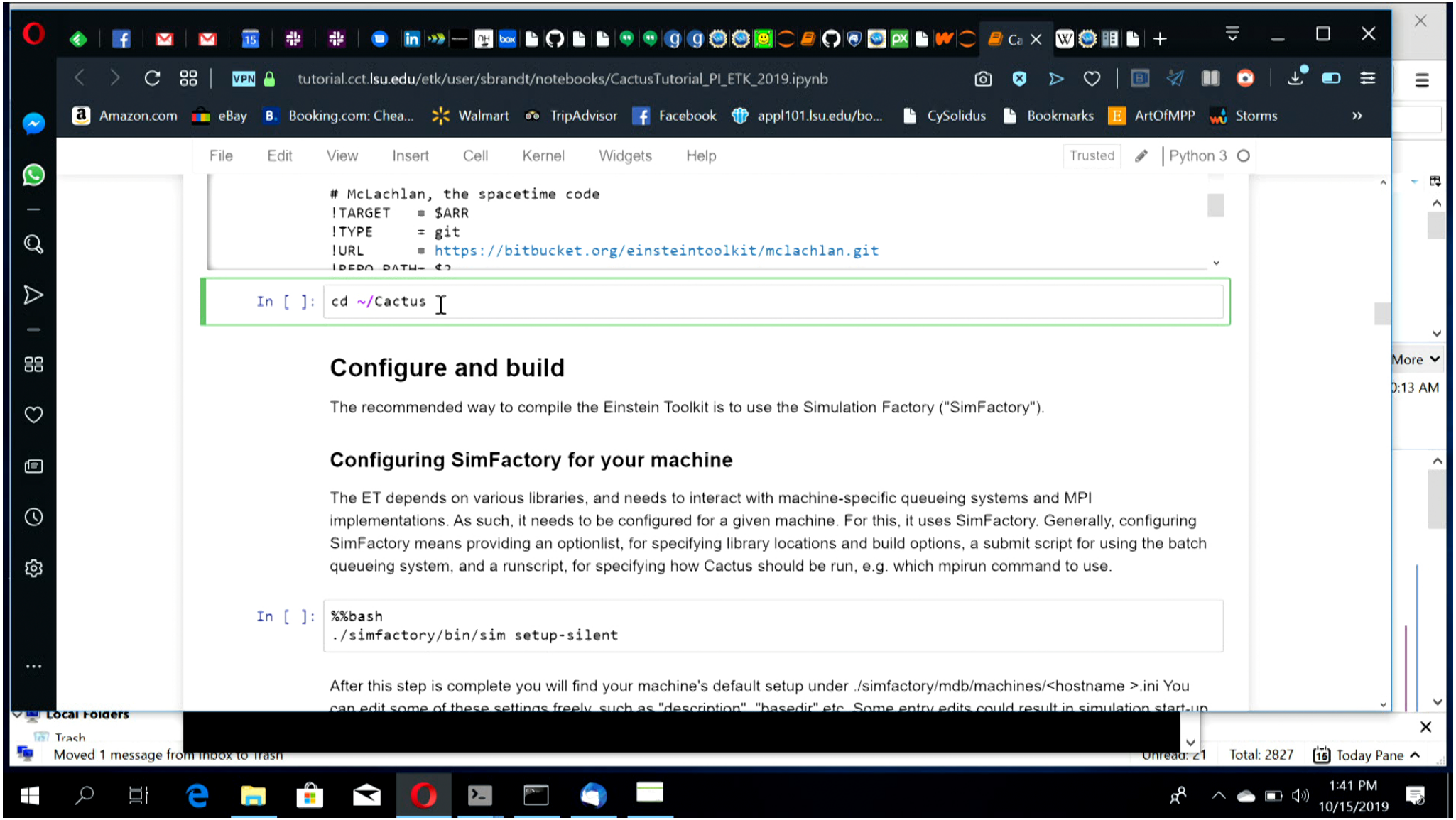
Kernel
Widgets
Help
Trusted
Python 3
0 components checked out successfully.
0 components updated successfully.
Time Elapsed: 0 minutes, 0 seconds
In [7]:
!cat einsteintoolkit_09_2019.th
Auto-Scroll-To-Bottom:
!URL = https://bitbucket.org/cactuscode/numerical.git
!REPO_PATH= $2
!REPO_BRANCH = $ET_RELEASE
!CHECKOUT =
Numerical/AEILocalInterp
CactusExamples thorns
!TARGET = $ARR
!TYPE = git
!URL = https://bitbucket.org/cactuscode/cactusexamples.git
!REPO_PATH= $2
!REPO_BRANCH = $ET_RELEASE
!CHECKOUT =
CactusExamples/HelloWorld
Private thorns
!TARGET = $ARR
!TYPE = ignore
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:40 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
McLachlan, the spacetime code
!TARGET = $ARR
!TYPE = git
!URL = https://bitbucket.org/einsteintoolkit/mclachlan.git
In [ ]:
cd ~/Cactus
Configure and build
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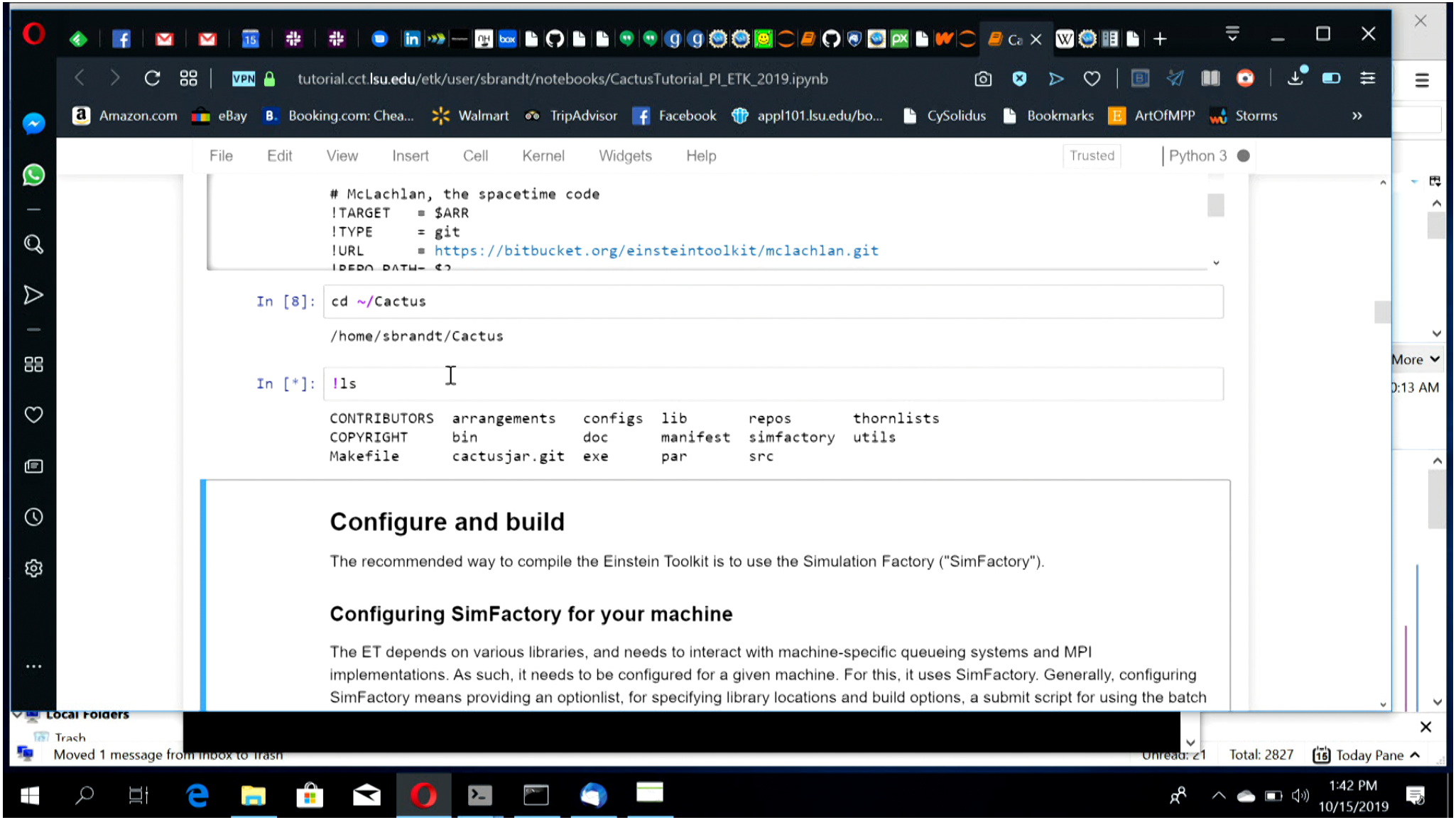
In [ ]:
%%bash
./simfactory/bin/sim setup-silent
After this step is complete you will find your machine's default setup under ./simfactory/mdb/machines/<hostname >.ini You
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:41 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
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TripAdvisor
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appl101.lsu.edu/bo...
CySolidus
Bookmarks
ArtOfMPP
Storms
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
McLachlan, the spacetime code
!TARGET = $ARR
!TYPE = git
!URL = https://bitbucket.org/einsteintoolkit/mclachlan.git
In [8]:
cd ~/Cactus
/home/sbrandt/Cactus
In [*]:
!ls
CONTRIBUTORS arrangements configs lib repos thornlists
COPYRIGHT bin doc manifest simfactory utils
Makefile cactusjar.git exe par src
Configure and build
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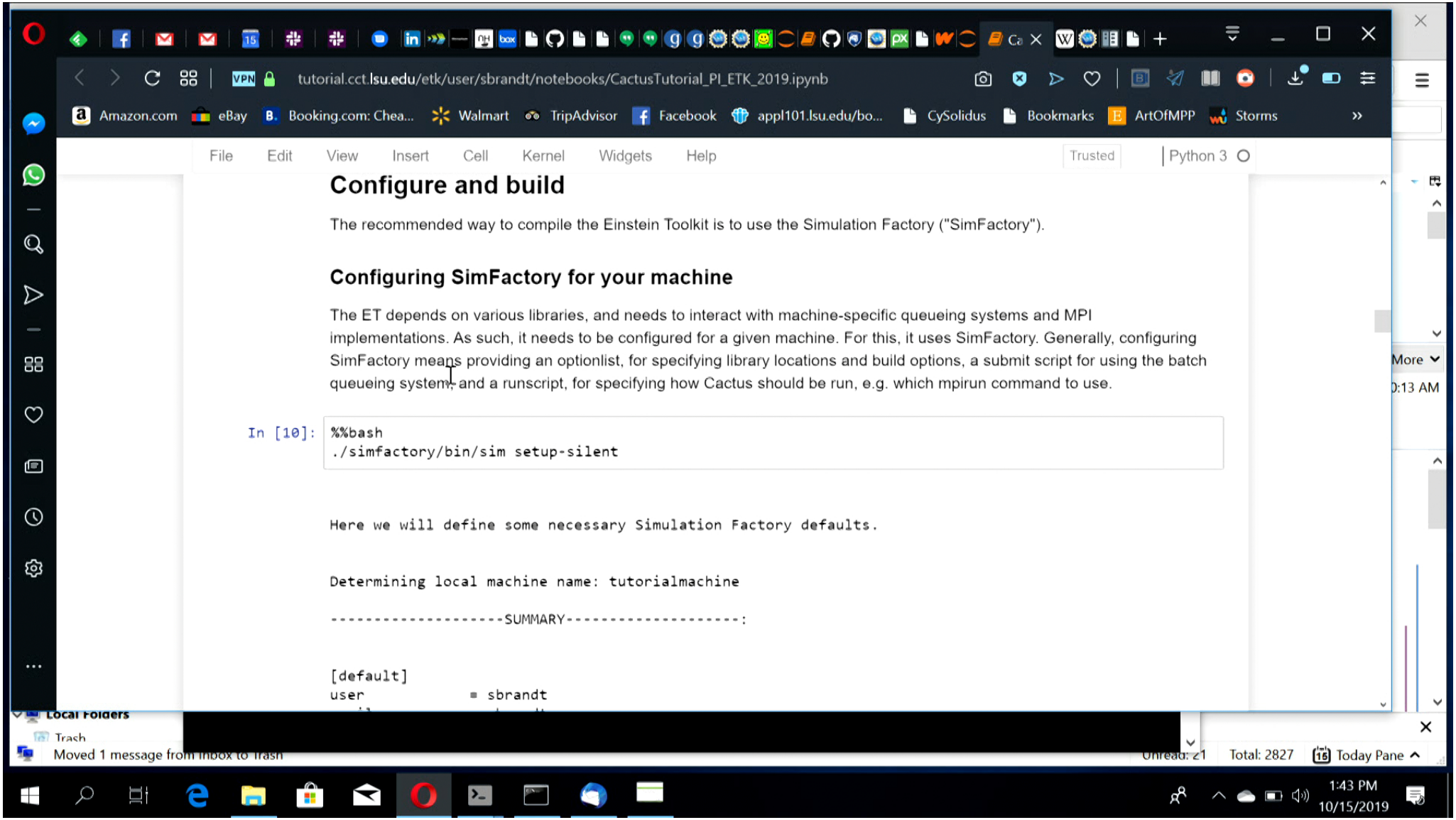
Local Folders
Trash
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:42 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
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Booking.com: Chea...
Walmart
TripAdvisor
Facebook
appl101.lsu.edu/bo...
CySolidus
Bookmarks
ArtOfMPP
Storms
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
Configure and build
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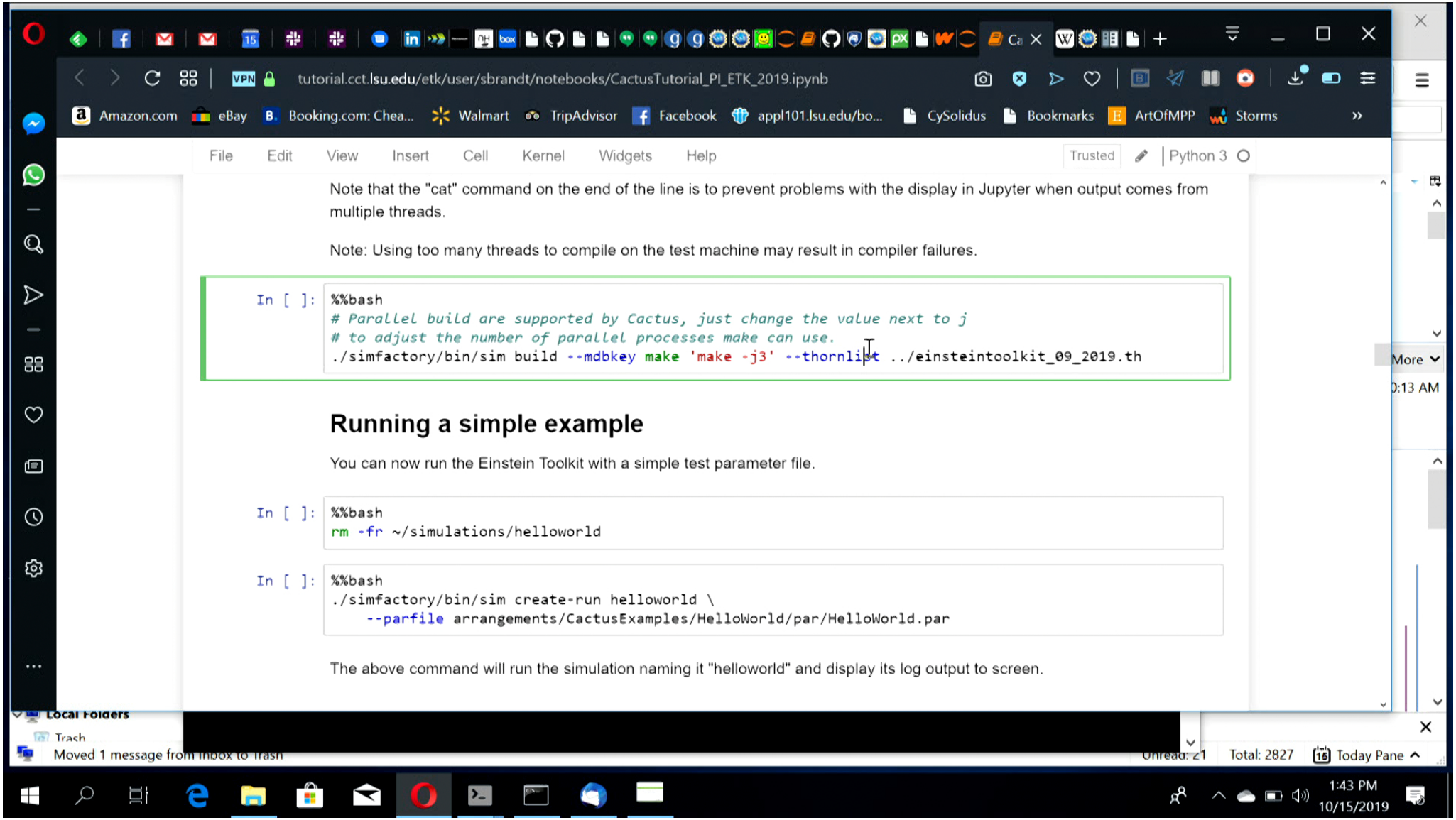
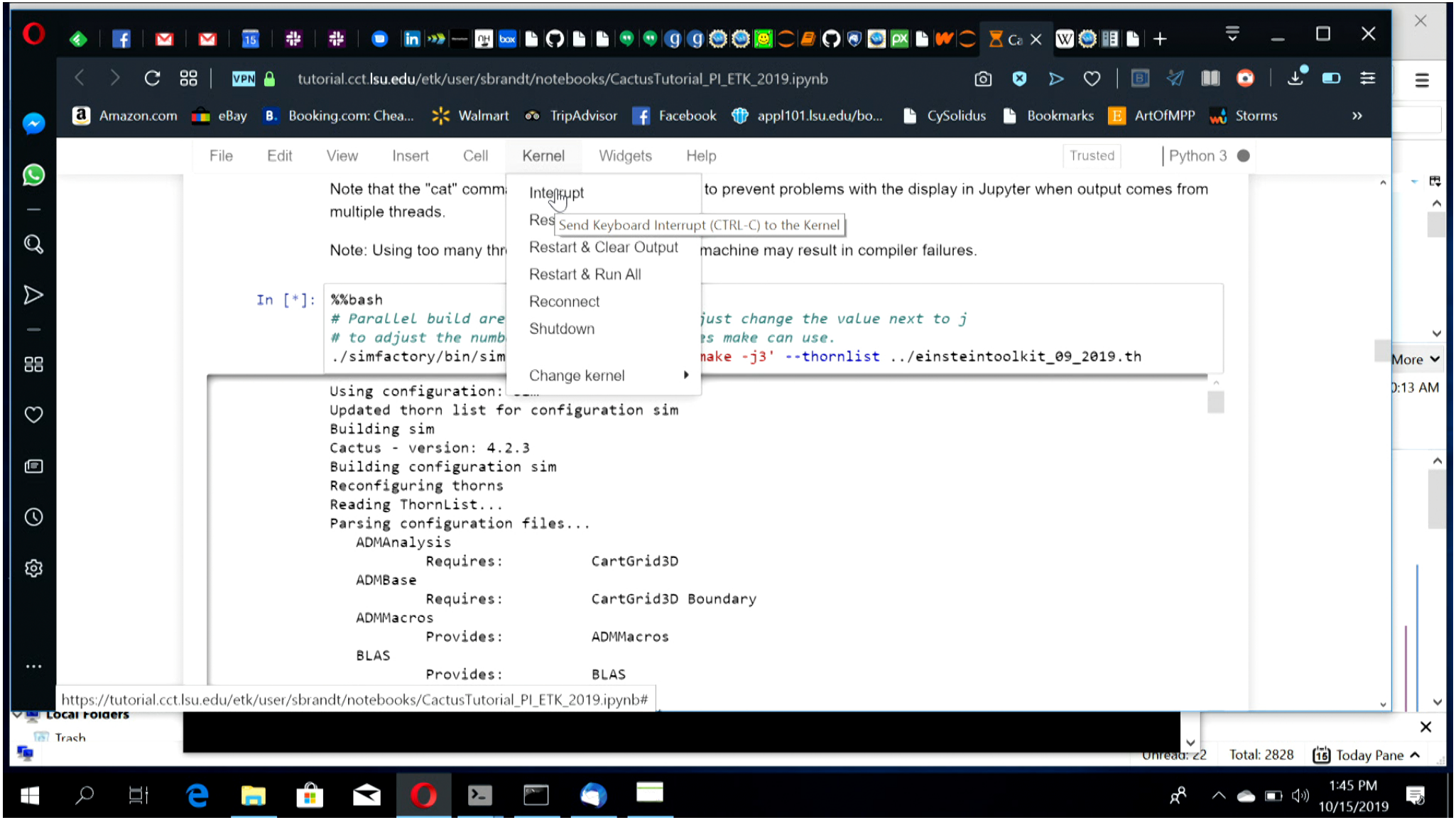
In [10]:
%%bash
./simfactory/bin/sim setup-silent
Here we will define some necessary Simulation Factory defaults.
Determining local machine name: tutorialmachine
--------------------SUMMARY--------------------:
[default]
user = sbrandt
Local Folders
Trash
Moved 1 message from Inbox to Trash
Unread: 21
Total: 2827
Today Pane
1:43 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
Note that the "cat" command on the end of the line is to prevent problems with the display in Jupyter when output comes from multiple threads.
Note: Using too many threads to compile on the test machine may result in compiler failures.
In [ ]:
%%bash
Parallel build are supported by Cactus, just change the value next to j
to adjust the number of parallel processes make can use.
./simfactory/bin/sim build --mdbkey make 'make -j3' --thornlist ../einsteintoolkit_09_2019.th
Running a simple example
You can now run the Einstein Toolkit with a simple test parameter file.
In [ ]:
%%bash
rm -fr ~/simulations/helloworld
In [ ]:
%%bash
./simfactory/bin/sim create-run helloworld \
--parfile arrangements/CactusExamples/HelloWorld/par/HelloWorld.par
The above command will run the simulation naming it "helloworld" and display its log output to screen.
Moved 1 message from Inbox to Trash
Total: 2827
Today Pane
1:43 PM
10/15/2019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File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
Interrupt
Send Keyboard Interrupt (CTRL-C) to the Kernel
Restart & Clear Output
Restart & Run All
Reconnect
Shutdown
Change kernel
to prevent problems with the display in Jupyter when output comes from multiple threads.
machine may result in compiler failures.
In [*]:
%%bash
just change the value next to j
es make can use.
make -j3' --thornlist ../einsteintoolkit_09_2019.th
Using configuration:
Updated thorn list for configuration sim
Building sim
Cactus - version: 4.2.3
Building configuration sim
Reconfiguring thorns
Reading ThornList...
Parsing configuration files...
ADMAnalysis
Requires: CartGrid3D
ADMBase
Requires: CartGrid3D Boundary
ADMMacros
Provides: ADMMacros
BLAS
Provides: BLAS
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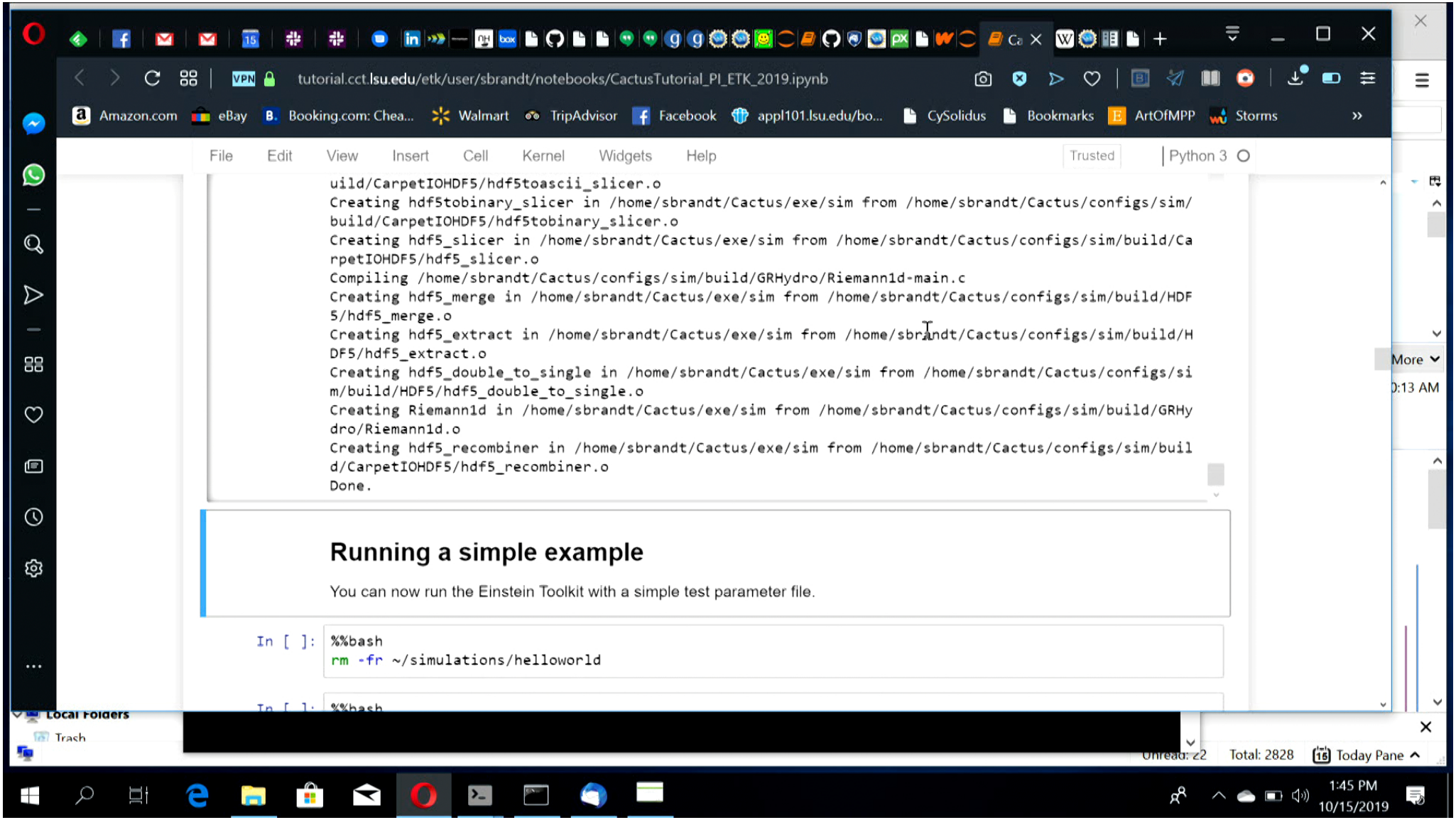
10/15/2019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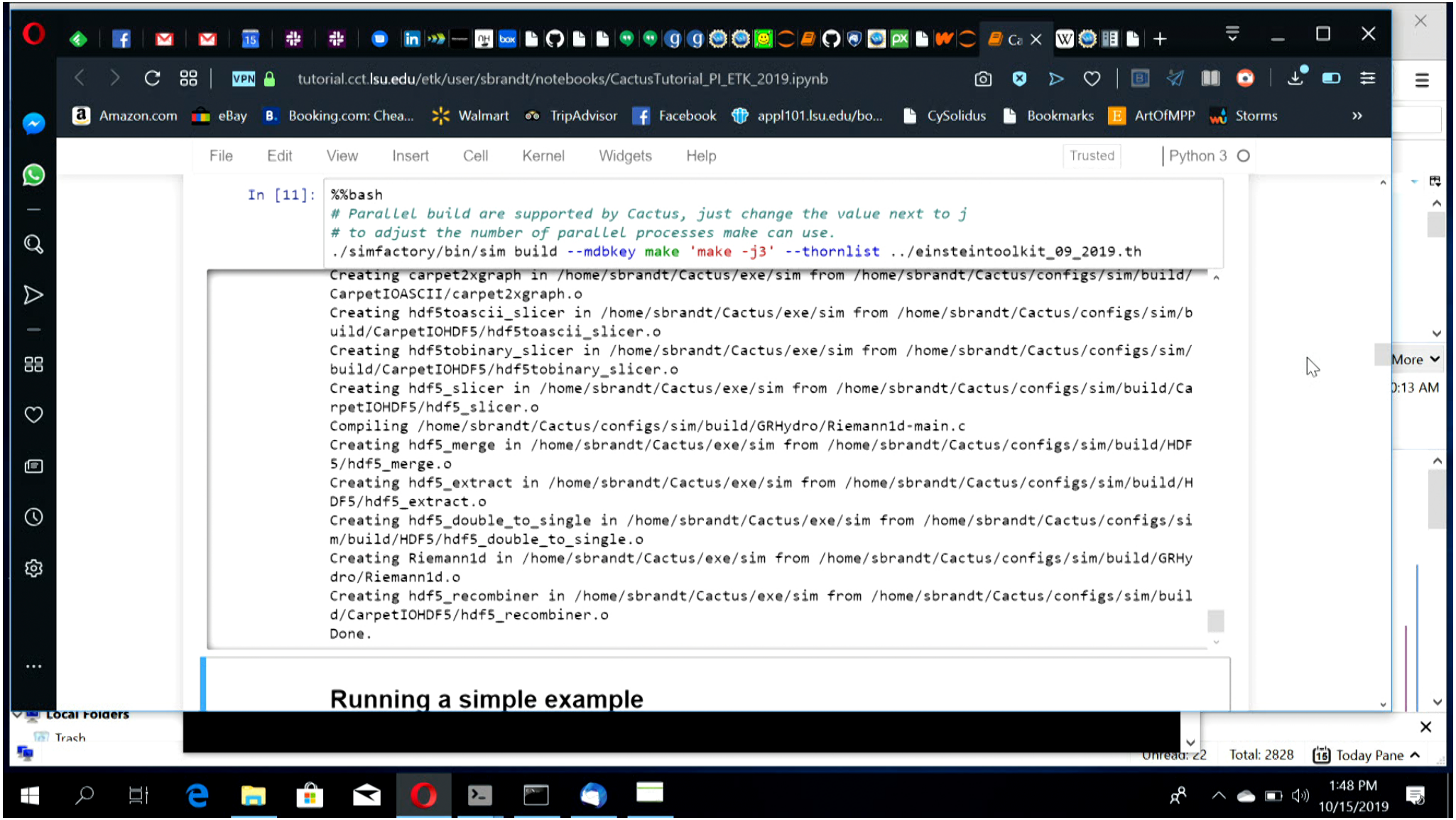
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
uild/CarpetIOHDF5/hdf5toascii_slicer.o
Creating hdf5tobinary_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5tobinary_slicer.o
Creating hdf5_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5_slicer.o
Compiling /home/sbrandt/Cactus/configs/sim/build/GRHydro/Riemann1d-main.c
Creating hdf5_merge in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_merge.o
Creating hdf5_extract in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_extract.o
Creating hdf5_double_to_single in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_double_to_single.o
Creating Riemann1d in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/GRHydro/Riemann1d.o
Creating hdf5_recombiner in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5_recombiner.o
Done.
Running a simple example
You can now run the Einstein Toolkit with a simple test parameter file.
In [ ]:
%%bash
rm -fr ~/simulations/helloworld
In [ ]:
%%bash
Local Folders
Trash
Total: 2828
Today Pane
1:45 PM
10/15/2019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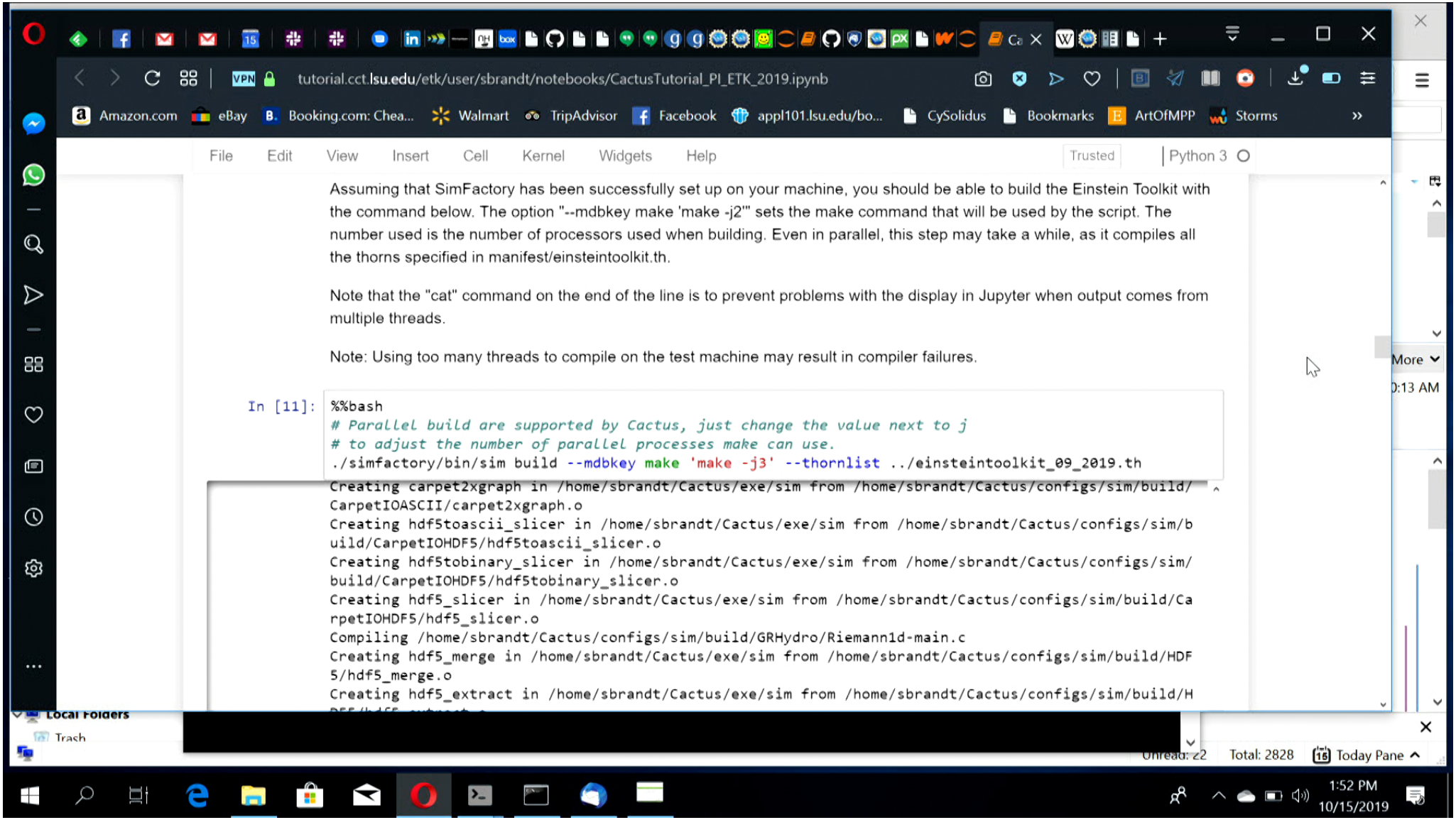
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
In [11]:
%%bash
Parallel build are supported by Cactus, just change the value next to j
to adjust the number of parallel processes make can use.
./simfactory/bin/sim build --mdbkey make 'make -j3' --thornlist ../einsteintoolkit_09_2019.th
Creating carpet2xgraph in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOASCII/carpet2xgraph.o
Creating hdf5toascii_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5toascii_slicer.o
Creating hdf5tobinary_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5tobinary_slicer.o
Creating hdf5_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5_slicer.o
Compiling /home/sbrandt/Cactus/configs/sim/build/GRHydro/Riemann1d-main.c
Creating hdf5_merge in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_merge.o
Creating hdf5_extract in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_extract.o
Creating hdf5_double_to_single in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_double_to_single.o
Creating Riemann1d in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/GRHydro/Riemann1d.o
Creating hdf5_recombiner in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5_recombiner.o
Done.
Running a simple example
Total: 2828
Today Pane
1:48 PM
10/15/2019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Trusted
Python 3
Assuming that SimFactory has been successfully set up on your machine, you should be able to build the Einstein Toolkit with the command below. The option "--mdbkey make 'make -j2'" sets the make command that will be used by the script. The number used is the number of processors used when building. Even in parallel, this step may take a while, as it compiles all the thorns specified in manifest/einsteintoolkit.th.
Note that the "cat" command on the end of the line is to prevent problems with the display in Jupyter when output comes from multiple threads.
Note: Using too many threads to compile on the test machine may result in compiler failures.
In [11]:
%%bash
Parallel build are supported by Cactus, just change the value next to j
to adjust the number of parallel processes make can use.
./simfactory/bin/sim build --mdbkey make 'make -j3' --thornlist ../einsteintoolkit_09_2019.th
Creating carpet2xgraph in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOASCII/carpet2xgraph.o
Creating hdf5toascii_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5toascii_slicer.o
Creating hdf5tobinary_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5tobinary_slicer.o
Creating hdf5_slicer in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/CarpetIOHDF5/hdf5_slicer.o
Compiling /home/sbrandt/Cactus/configs/sim/build/GRHydro/Riemann1d-main.c
Creating hdf5_merge in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/HDF5/hdf5_merge.o
Creating hdf5_extract in /home/sbrandt/Cactus/exe/sim from /home/sbrandt/Cactus/configs/sim/build/H
Local Folders
Trash
More
0:13 AM
Total: 2828
Today Pane
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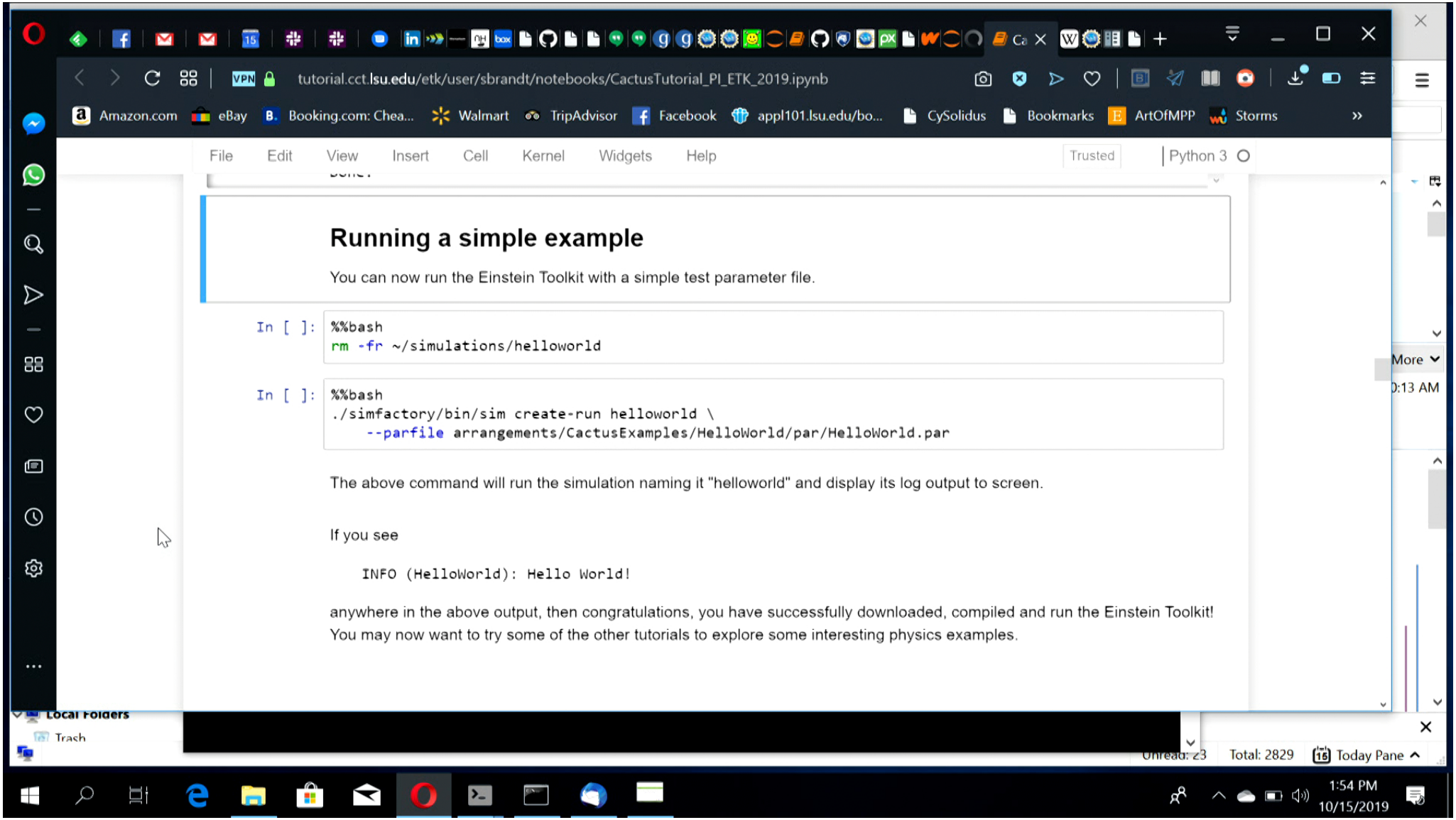
10/15/2019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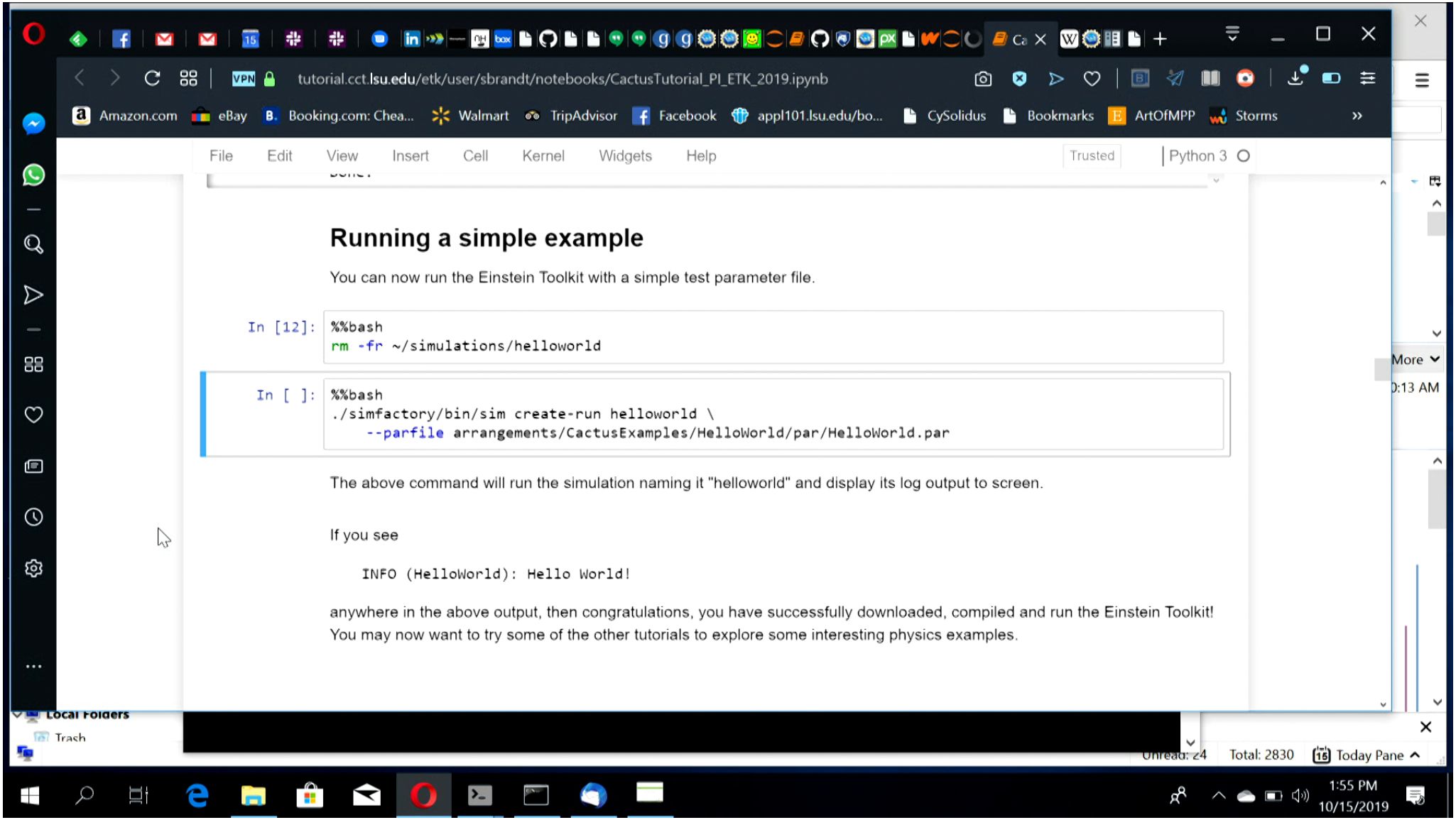
Trusted
Python 3
Running a simple example
You can now run the Einstein Toolkit with a simple test parameter file.
In [ ]:
%%bash
rm -fr ~/simulations/helloworld
In [ ]:
%%bash
./simfactory/bin/sim create-run helloworld \
--parfile arrangements/CactusExamples/HelloWorld/par/HelloWorld.par
The above command will run the simulation naming it "helloworld" and display its log output to screen.
If you see
INFO (HelloWorld): Hello World!
anywhere in the above output, then congratulations, you have successfully downloaded, compiled and run the Einstein Toolkit!
You may now want to try some of the other tutorials to explore some interesting physics examples.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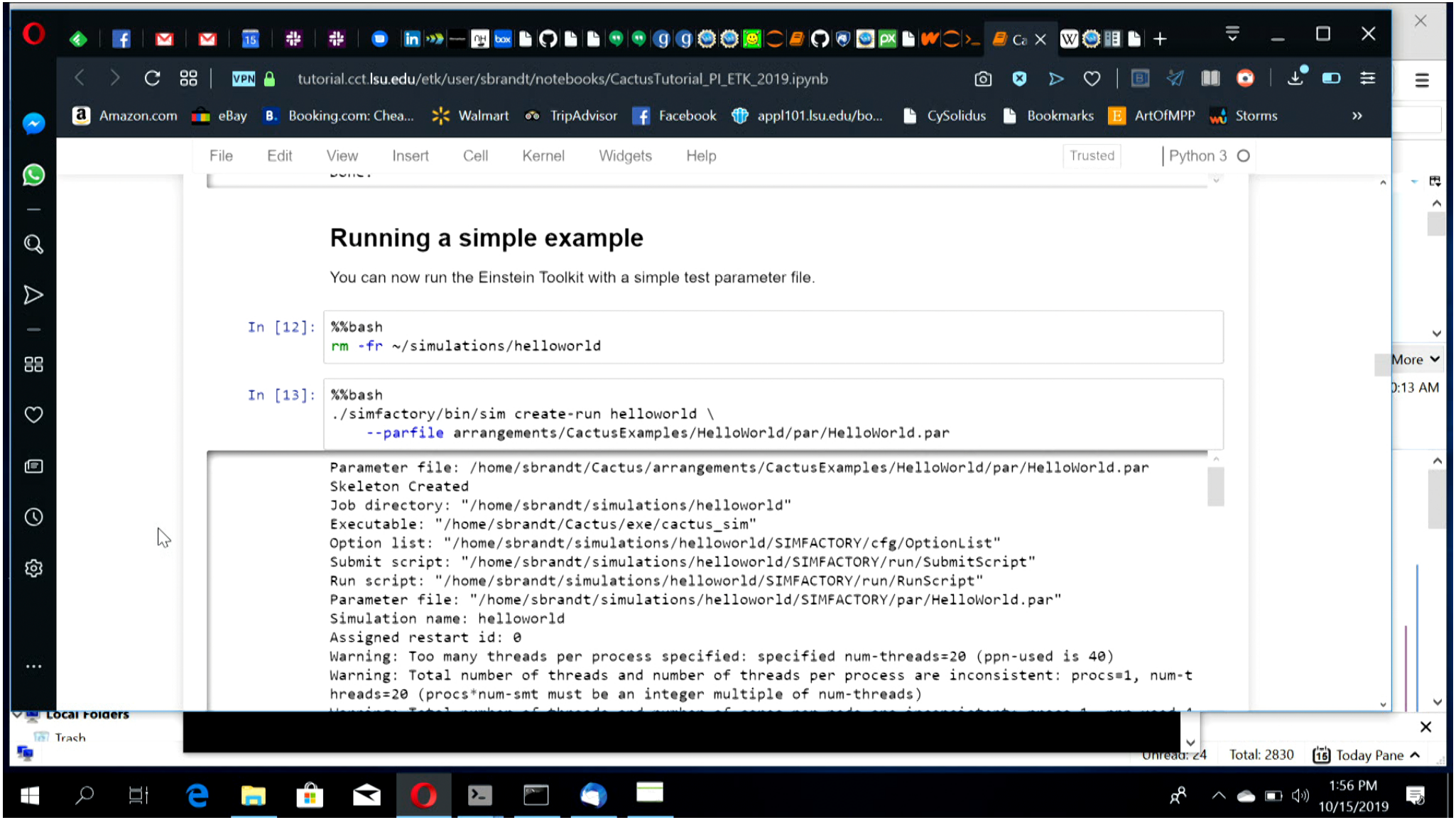
Python 3
Running a simple example
You can now run the Einstein Toolkit with a simple test parameter file.
In [12]:
%%bash
rm -fr ~/simulations/helloworld
In [ ]:
%%bash
./simfactory/bin/sim create-run helloworld \
--parfile arrangements/CactusExamples/HelloWorld/par/HelloWorld.par
The above command will run the simulation naming it "helloworld" and display its log output to screen.
If you see
INFO (HelloWorld): Hello World!
anywhere in the above output, then congratulations, you have successfully downloaded, compiled and run the Einstein Toolkit!
You may now want to try some of the other tutorials to explore some interesting physics examples.
More
0:13 AM
Local Folders
Trash
Total: 2830
Today Pane
1:55 PM
10/15/2019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Widgets
Help
Trusted
Python 3
Running a simple example
You can now run the Einstein Toolkit with a simple test parameter file.
In [12]:
%%bash
rm -fr ~/simulations/helloworld
In [13]:
%%bash
./simfactory/bin/sim create-run helloworld \
--parfile arrangements/CactusExamples/HelloWorld/par/HelloWorld.par
Parameter file: /home/sbrandt/Cactus/arrangements/CactusExamples/HelloWorld/par/HelloWorld.par
Skeleton Created
Job directory: "/home/sbrandt/simulations/helloworld"
Executable: "/home/sbrandt/Cactus/exe/cactus_sim"
Option list: "/home/sbrandt/simulations/helloworld/SIMFACTORY/cfg/OptionList"
Submit script: "/home/sbrandt/simulations/helloworld/SIMFACTORY/run/SubmitScript"
Run script: "/home/sbrandt/simulations/helloworld/SIMFACTORY/run/RunScript"
Parameter file: "/home/sbrandt/simulations/helloworld/SIMFACTORY/par/HelloWorld.par"
Simulation name: helloworld
Assigned restart id: 0
Warning: Too many threads per process specified: specified num-threads=20 (ppn-used is 40)
Warning: Total number of threads and number of threads per process are inconsistent: procs=1, num-t
hreads=20 (procs*num-smt must be an integer multiple of num-threads)
Local Folders
Trash
Total: 2830
Today Pane
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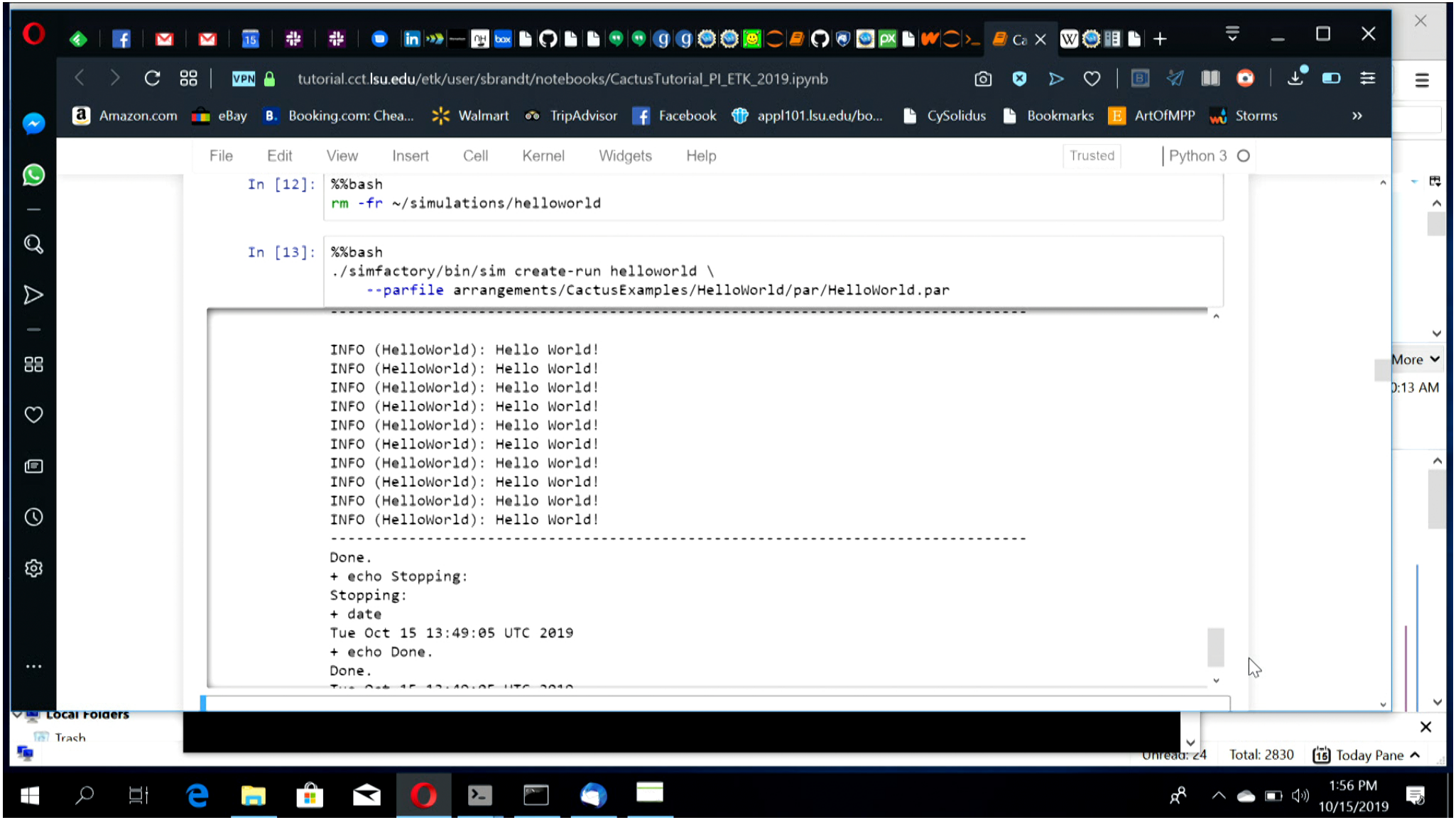
10/15/2019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CySolidus
Bookmarks
ArtOfMPP
Storms
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
In [12]:
%%bash
rm -fr ~/simulations/helloworld
In [13]:
%%bash
./simfactory/bin/sim create-run helloworld \
--parfile arrangements/CactusExamples/HelloWorld/par/HelloWorld.par
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
Done.
+ echo Stopping:
Stopping:
+ date
Tue Oct 15 13:49:05 UTC 2019
+ echo Done.
Done.
Local Folders
Trash
Total: 2830
Today Pane
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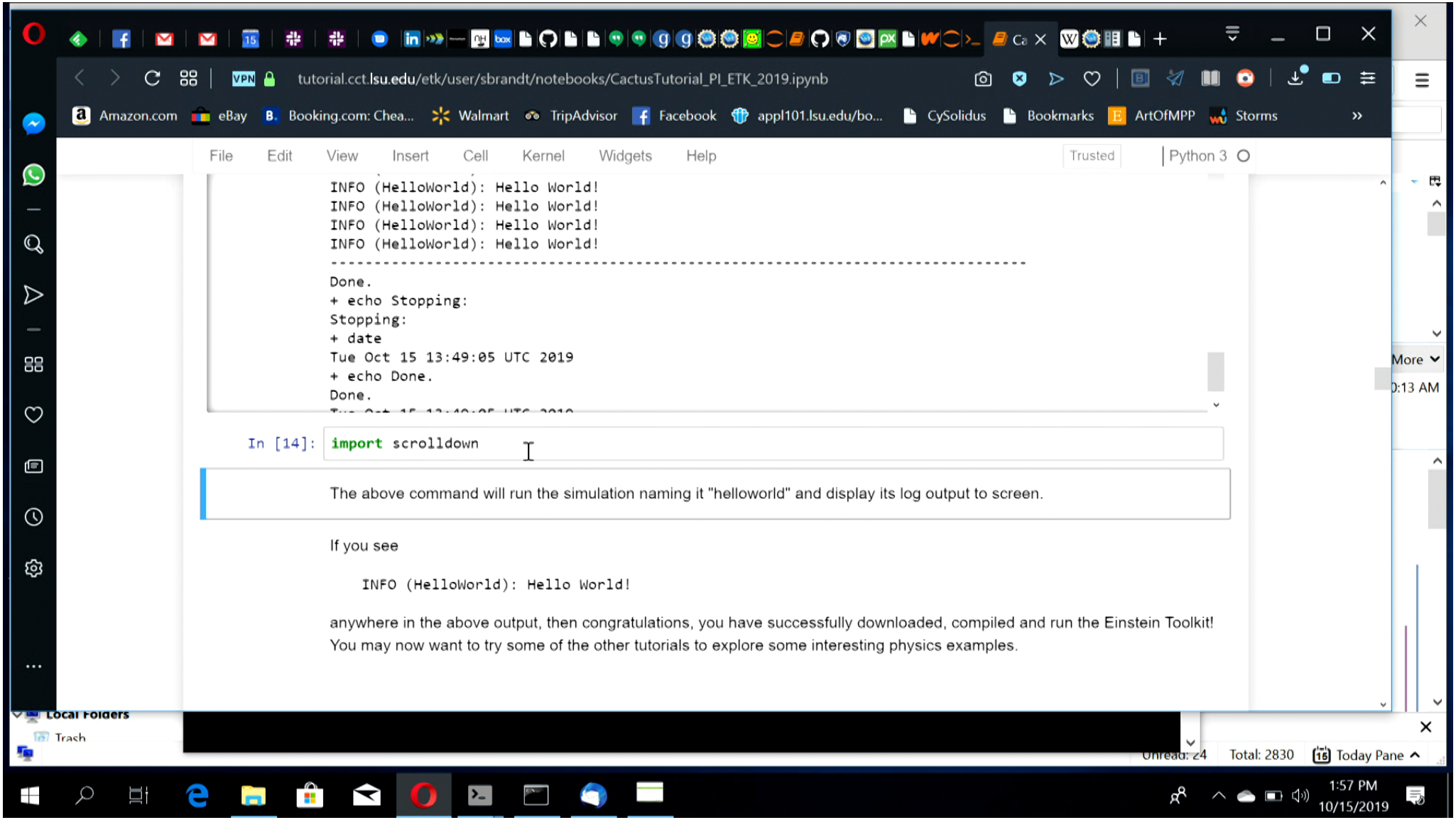
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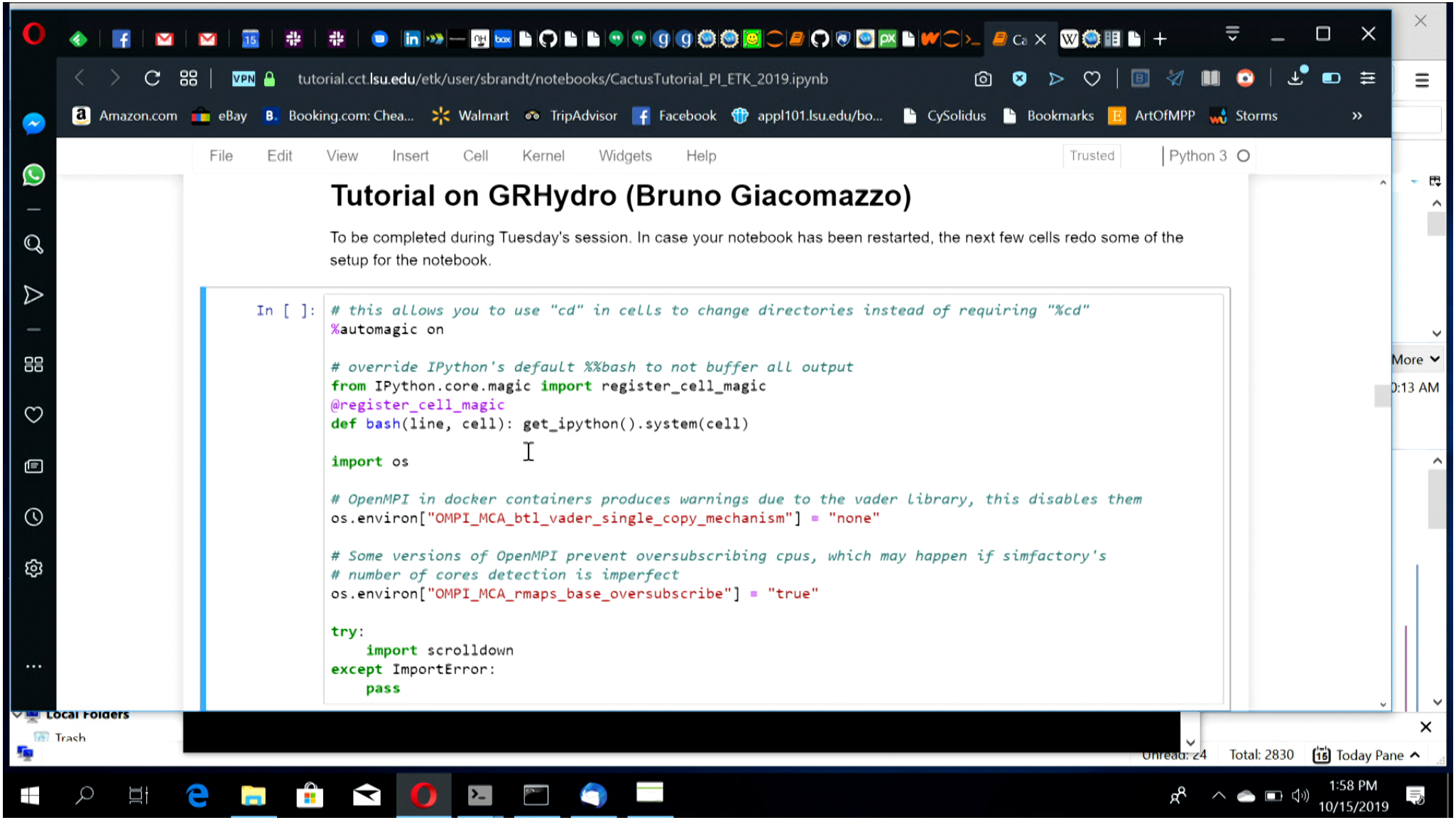
Help
Trusted
Python 3
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
INFO (HelloWorld): Hello World!
Done.
+ echo Stopping:
Stopping:
+ date
Tue Oct 15 13:49:05 UTC 2019
+ echo Done.
Done.
In [14]:
import scrolldown
The above command will run the simulation naming it "helloworld" and display its log output to screen.
If you see
INFO (HelloWorld): Hello World!
anywhere in the above output, then congratulations, you have successfully downloaded, compiled and run the Einstein Toolkit!
You may now want to try some of the other tutorials to explore some interesting physics examples.
Local Folders
Trash
Total: 2830
Today Pane
1:57 PM
10/15/2019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View
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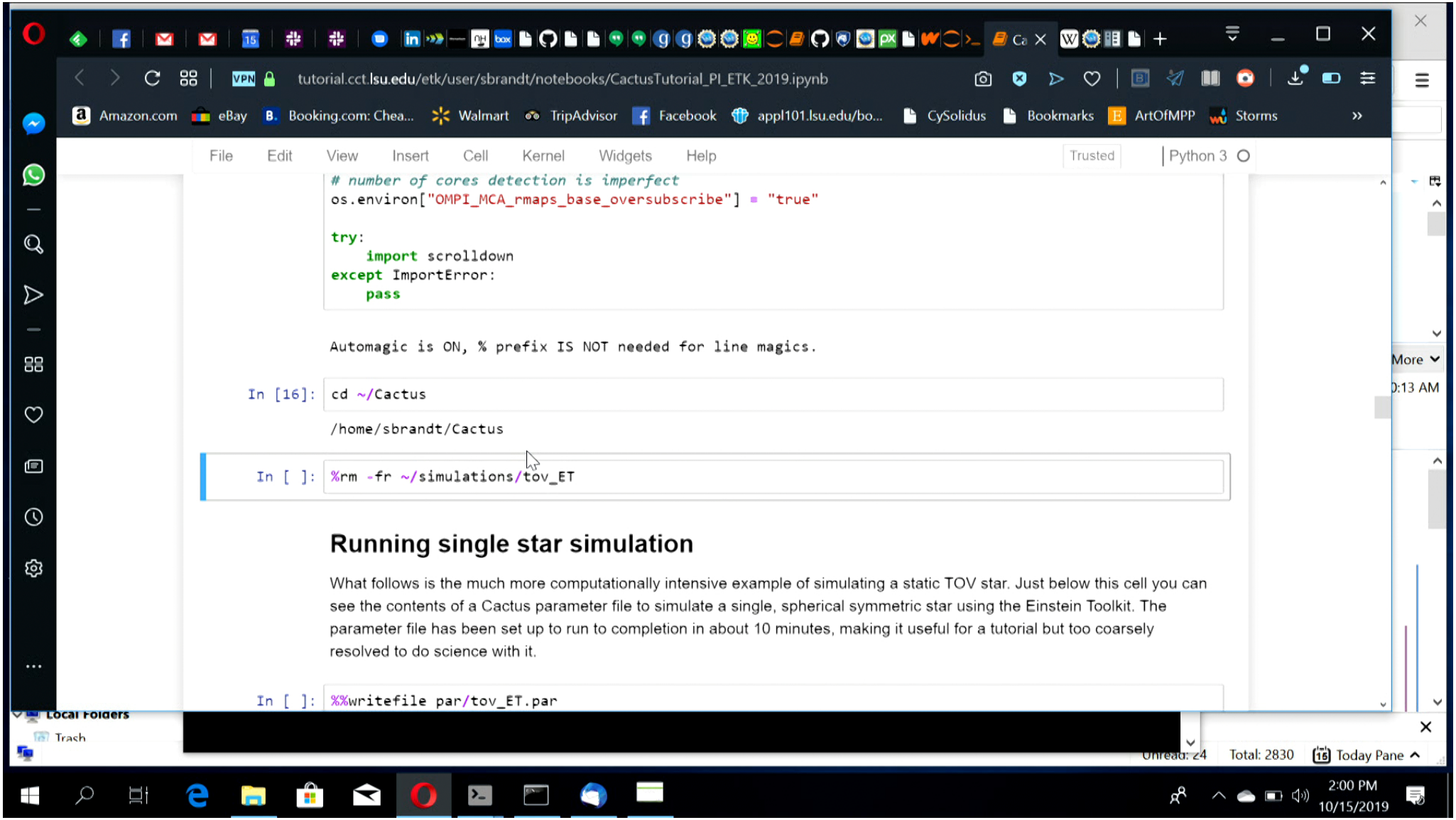
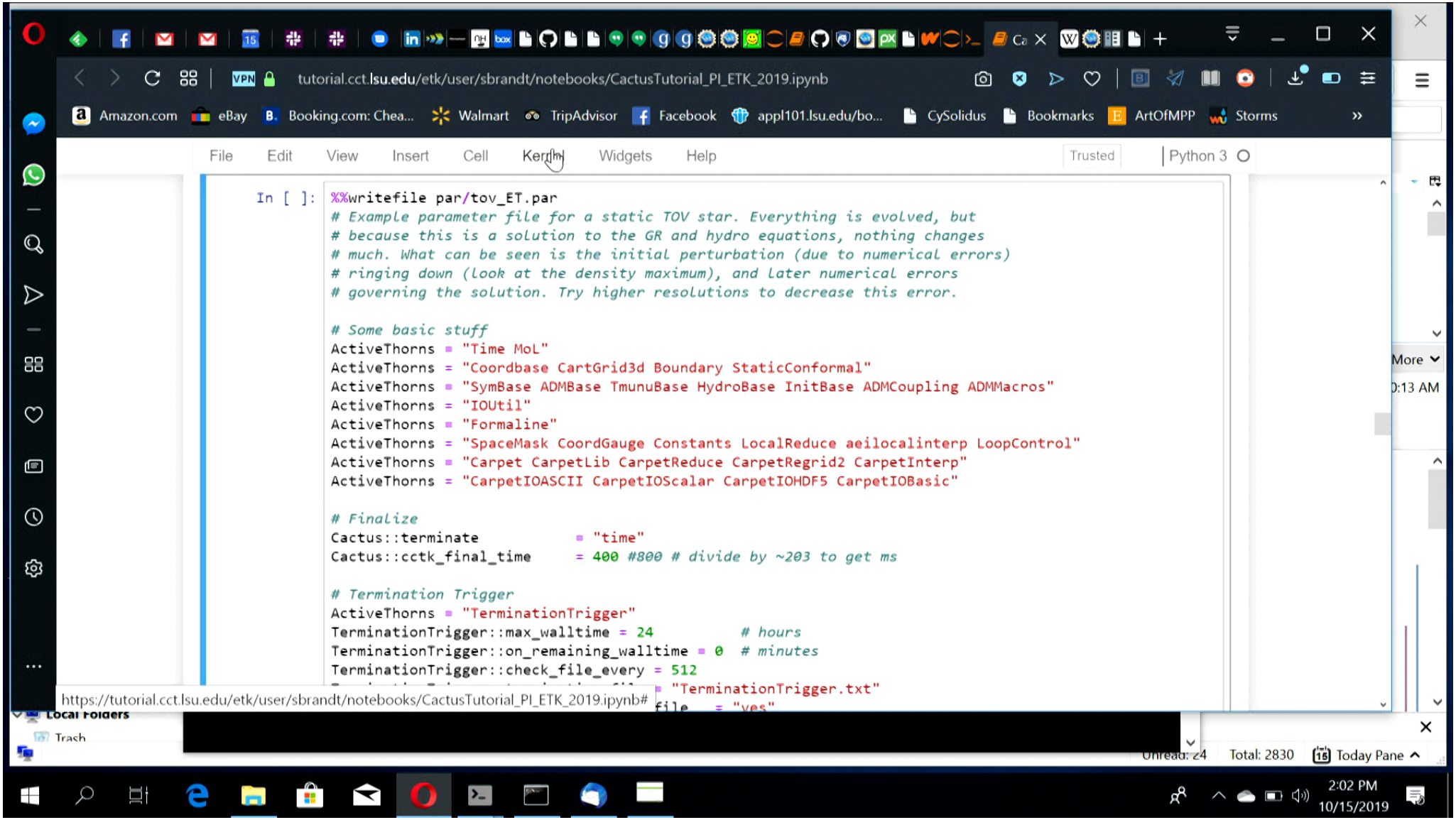
Cell
Kernel
Widgets
Help
Trusted
Python 3
Tutorial on GRHydro (Bruno Giacomazzo)
To be completed during Tuesday's session. In case your notebook has been restarted, the next few cells redo some of the setup for the notebook.
In [ ]:
this allows you to use "cd" in cells to change directories instead of requiring "%cd"
%automagic on
# override IPython's default %%bash to not buffer all output
from IPython.core.magic import register_cell_magic
@register_cell_magic
def bash(line, cell): get_ipython().system(cell)
import os
# OpenMPI in docker containers produces warnings due to the vader library, this disables them
os.environ["OMPI_MCA_btl_vader_single_copy_mechanism"] = "none"
Some versions of OpenMPI prevent oversubscribing cpus, which may happen if simfactory's
number of cores detection is imperfect
os.environ["OMPI_MCA_rmaps_base_oversubscribe"] = "true"
try:
import scrolldown
except ImportError:
pass
Local Folders
Trash
Total: 2830
Today Pane
1:58 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
number of cores detection is imperfect
os.environ["OMPI_MCA_rmaps_base_oversubscribe"] = "true"
try:
import scrolldown
except ImportError:
pass
Automagic is ON, % prefix IS NOT needed for line magics.
In [16]: cd ~/Cactus
/home/sbrandt/Cactus
In [ ]: %rm -fr ~/simulations/tov_ET
Running single star simulation
What follows is the much more computationally intensive example of simulating a static TOV star. Just below this cell you can see the contents of a Cactus parameter file to simulate a single, spherical symmetric star using the Einstein Toolkit. The parameter file has been set up to run to completion in about 10 minutes, making it useful for a tutorial but too coarsely resolved to do science with it.
In [ ]: %%writefile par/tov_ET.par
Local Folders
Trash
Total: 2830
Today Pane
2:00 PM
10/15/2019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Trusted
Python 3
In [ ]:
%%writefile par/tov_ET.par
# Example parameter file for a static TOV star. Everything is evolved, but
# because this is a solution to the GR and hydro equations, nothing changes
# much. What can be seen is the initial perturbation (due to numerical errors)
# ringing down (look at the density maximum), and later numerical errors
# governing the solution. Try higher resolutions to decrease this error.
# Some basic stuff
ActiveThorns = "Time MoL"
ActiveThorns = "Coordbase CartGrid3d Boundary StaticConformal"
ActiveThorns = "SymBase ADMBase TmunuBase HydroBase InitBase ADMCoupling ADMMacros"
ActiveThorns = "IOUtil"
ActiveThorns = "Formaline"
ActiveThorns = "SpaceMask CoordGauge Constants LocalReduce aeilocalinterp LoopControl"
ActiveThorns = "Carpet CarpetLib CarpetReduce CarpetRegrid2 CarpetInterp"
ActiveThorns = "CarpetIOASCII CarpetIOScalar CarpetIOHDF5 CarpetIOBasic"
# Finalize
Cactus::terminate = "time"
Cactus::cctk_final_time = 400 #800 # divide by ~203 to get ms
# Termination Trigger
ActiveThorns = "TerminationTrigger"
TerminationTrigger::max_walltime = 24 # hours
TerminationTrigger::on_remaining_walltime = 0 # minutes
TerminationTrigger::check_file_every = 512
"TerminationTrigger.txt"
file = "yes"
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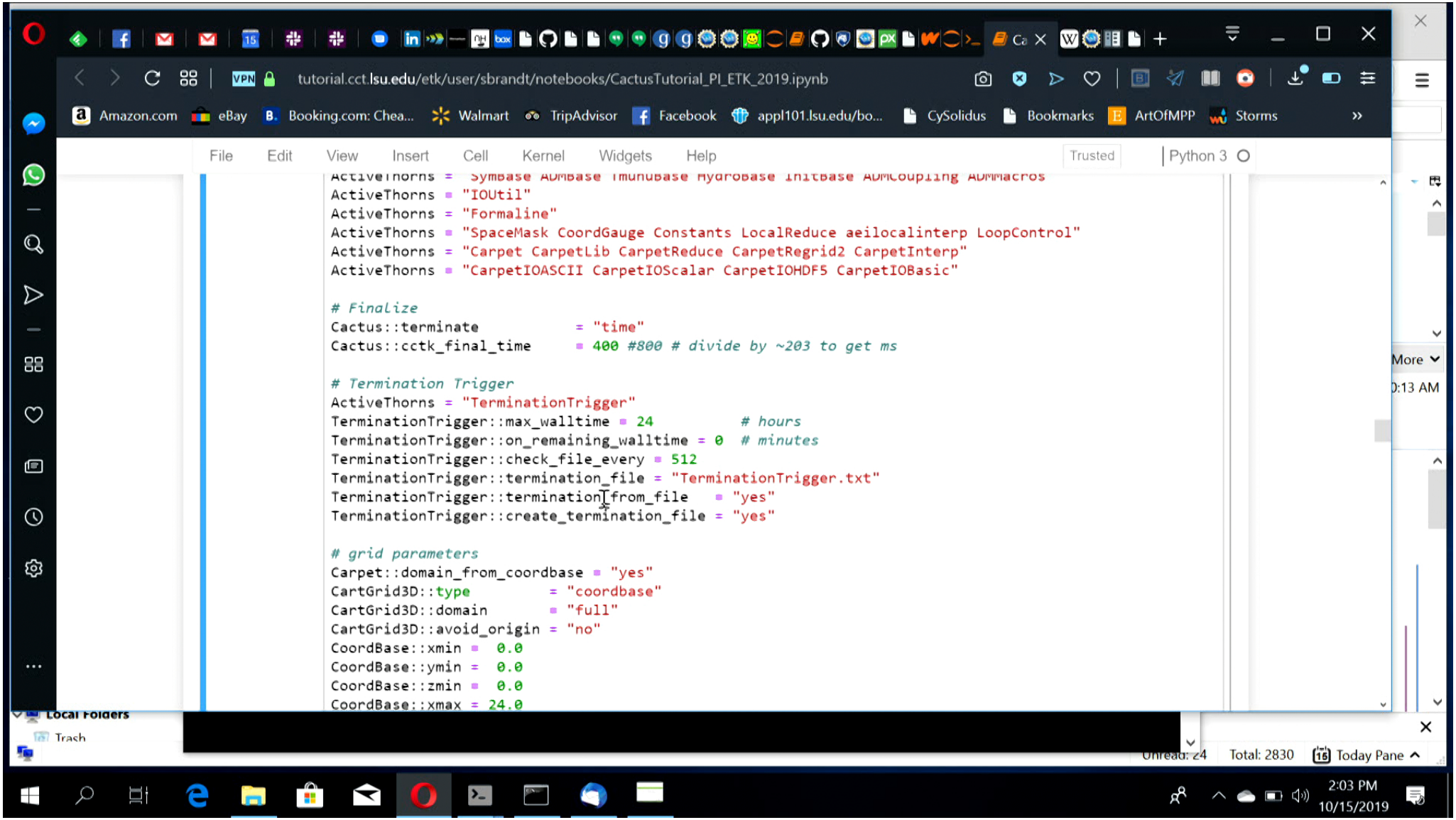
Local Folders
Trash
More
0:13 AM
Total: 2830
Today Pane
2:02 PM
10/15/2019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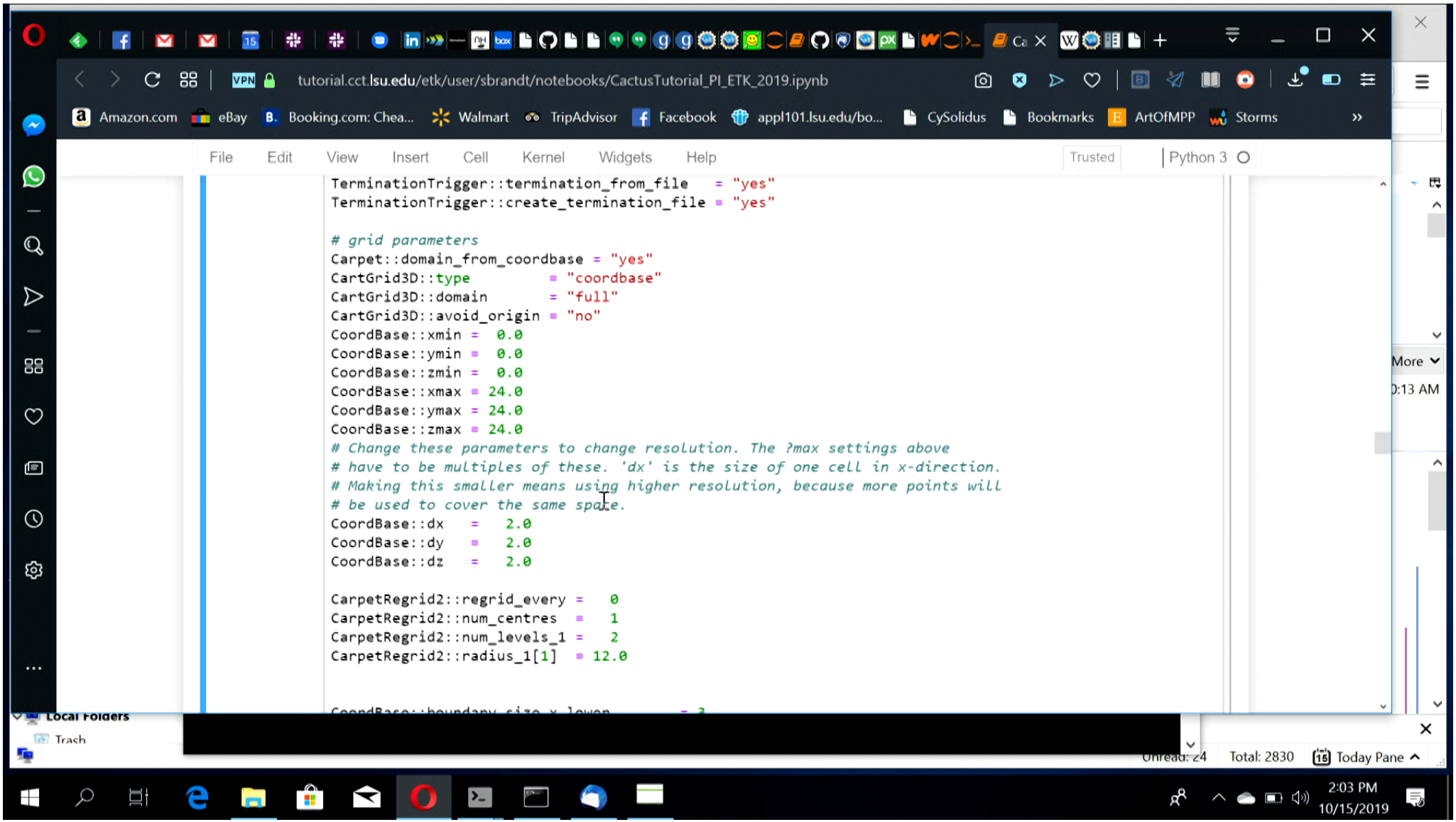
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
ActiveThorns = "IOUtil"
ActiveThorns = "Formaline"
ActiveThorns = "SpaceMask CoordGauge Constants LocalReduce aeilocalinterp LoopControl"
ActiveThorns = "Carpet CarpetLib CarpetReduce CarpetRegrid2 CarpetInterp"
ActiveThorns = "CarpetIOASCII CarpetIOScalar CarpetIOHDF5 CarpetIOBasic"
# Finalize
Cactus::terminate = "time"
Cactus::cctk_final_time = 400 #800 # divide by ~203 to get ms
# Termination Trigger
ActiveThorns = "TerminationTrigger"
TerminationTrigger::max_walltime = 24 # hours
TerminationTrigger::on_remaining_walltime = 0 # minutes
TerminationTrigger::check_file_every = 512
TerminationTrigger::termination_file = "TerminationTrigger.txt"
TerminationTrigger::termination_from_file = "yes"
TerminationTrigger::create_termination_file = "yes"
grid parameters
Carpet::domain_from_coordbase = "yes"
CartGrid3D::type = "coordbase"
CartGrid3D::domain = "full"
CartGrid3D::avoid_origin = "no"
CoordBase::xmin = 0.0
CoordBase::ymin = 0.0
CoordBase::zmin = 0.0
CoordBase::xmax = 24.0
Total: 2830
Today Pane
2:03 PM
10/15/2019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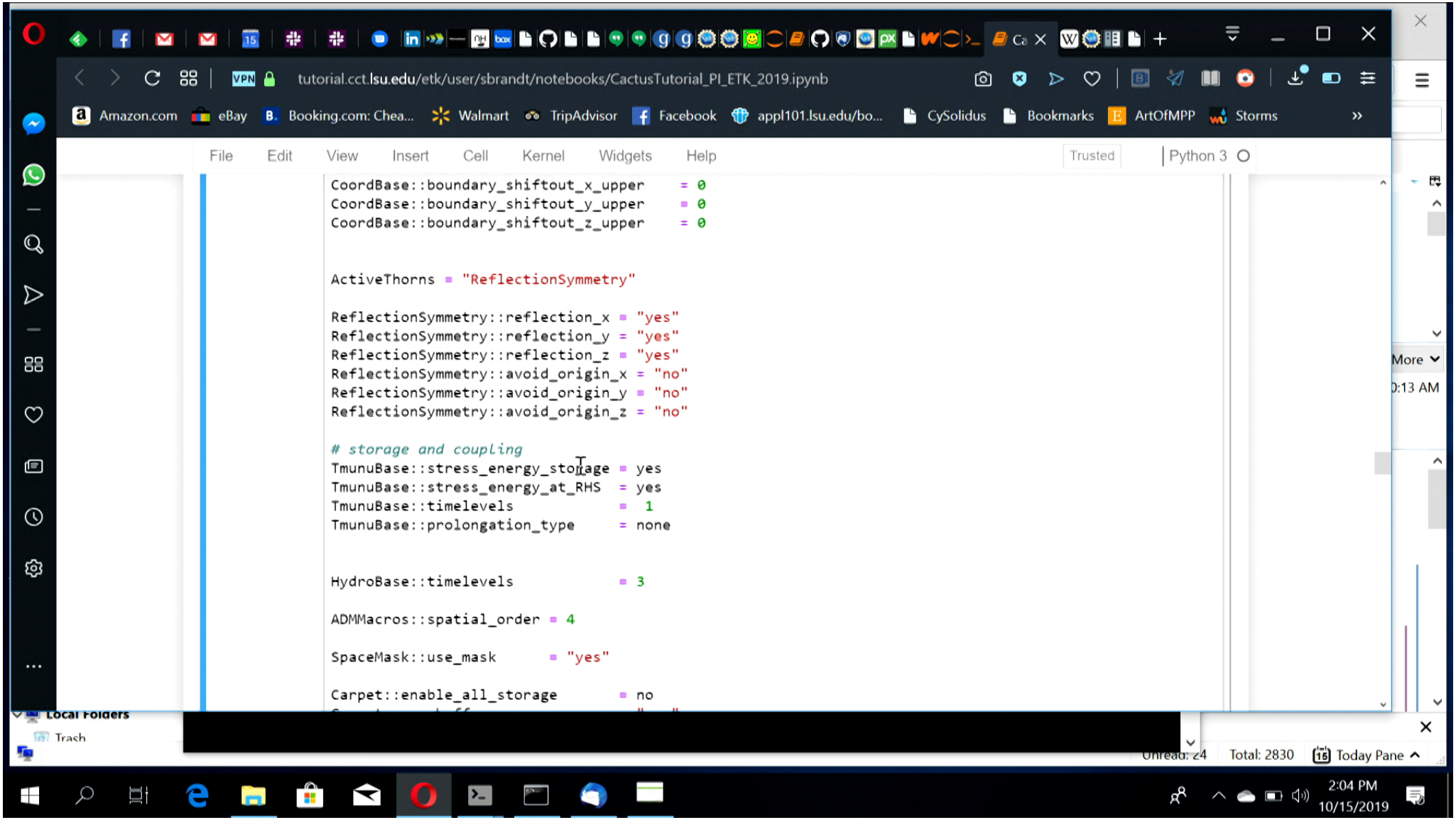
Trusted
Python 3
TerminationTrigger::termination_from_file = "yes"
TerminationTrigger::create_termination_file = "yes"
grid parameters
Carpet::domain_from_coordbase = "yes"
CartGrid3D::type = "coordbase"
CartGrid3D::domain = "full"
CartGrid3D::avoid_origin = "no"
CoordBase::xmin = 0.0
CoordBase::ymin = 0.0
CoordBase::zmin = 0.0
CoordBase::xmax = 24.0
CoordBase::ymax = 24.0
CoordBase::zmax = 24.0
Change these parameters to change resolution. The ?max settings above
have to be multiples of these. 'dx' is the size of one cell in x-direction.
Making this smaller means using higher resolution, because more points will
be used to cover the same space.
CoordBase::dx = 2.0
CoordBase::dy = 2.0
CoordBase::dz = 2.0
CarpetRegrid2::regrid_every = 0
CarpetRegrid2::num_centres = 1
CarpetRegrid2::num_levels_1 = 2
CarpetRegrid2::radius_1[1] = 12.0
Local Folders
Trash
Total: 2830
Today Pane
2:03 PM
10/15/2019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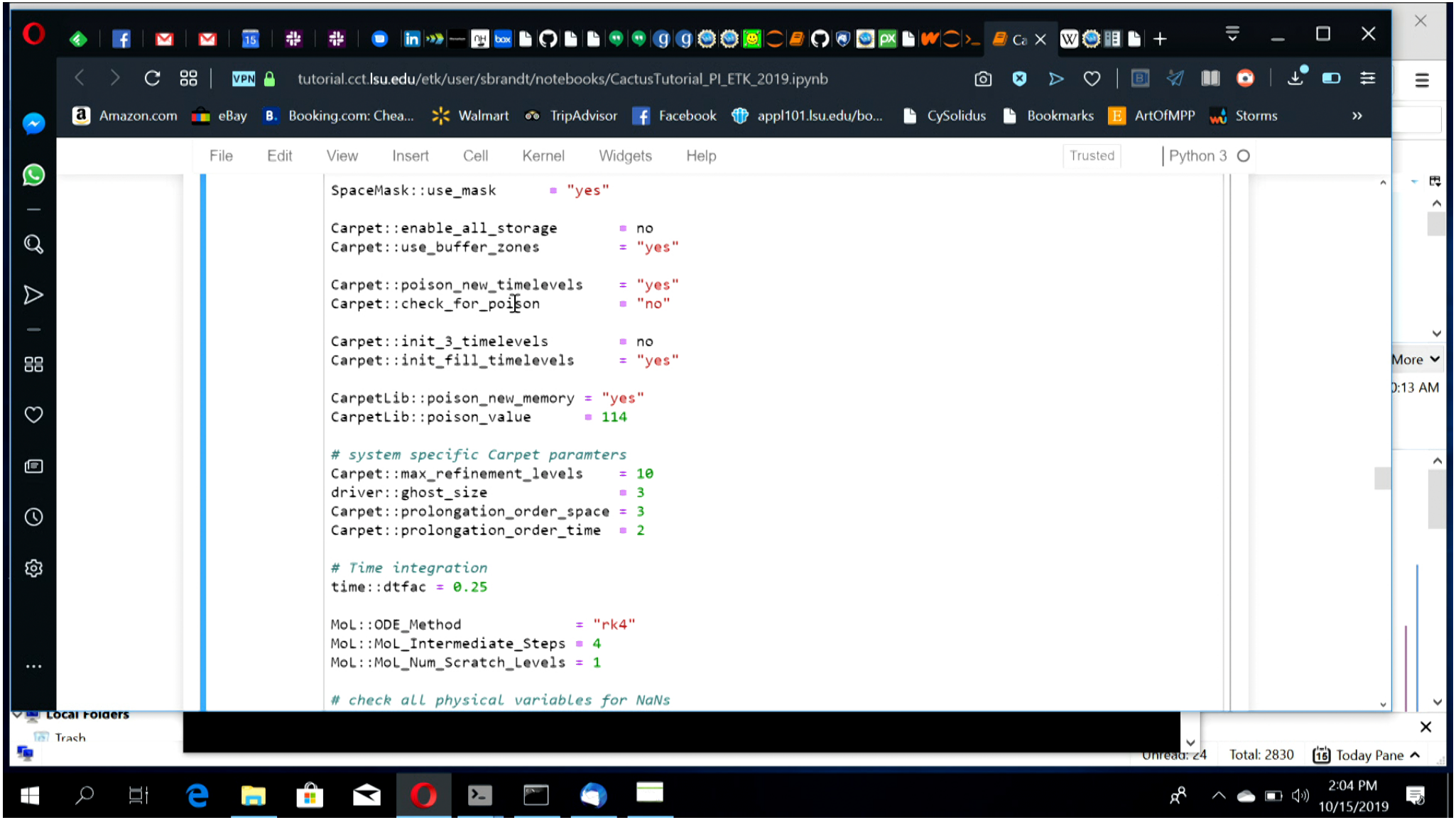
Widgets
Help
Trusted
Python 3
CoordBase::boundary_shiftout_x_upper = 0
CoordBase::boundary_shiftout_y_upper = 0
CoordBase::boundary_shiftout_z_upper = 0
ActiveThorns = "ReflectionSymmetry"
ReflectionSymmetry::reflection_x = "yes"
ReflectionSymmetry::reflection_y = "yes"
ReflectionSymmetry::reflection_z = "yes"
ReflectionSymmetry::avoid_origin_x = "no"
ReflectionSymmetry::avoid_origin_y = "no"
ReflectionSymmetry::avoid_origin_z = "no"
storage and coupling
TmunuBase::stress_energy_storage = yes
TmunuBase::stress_energy_at_RHS = yes
TmunuBase::timelevels = 1
TmunuBase::prolongation_type = none
HydroBase::timelevels = 3
ADMMacros::spatial_order = 4
SpaceMask::use_mask = "yes"
Carpet::enable_all_storage = no
Local Folders
Trash
Total: 2830
Today Pane
2:04 PM
10/15/2019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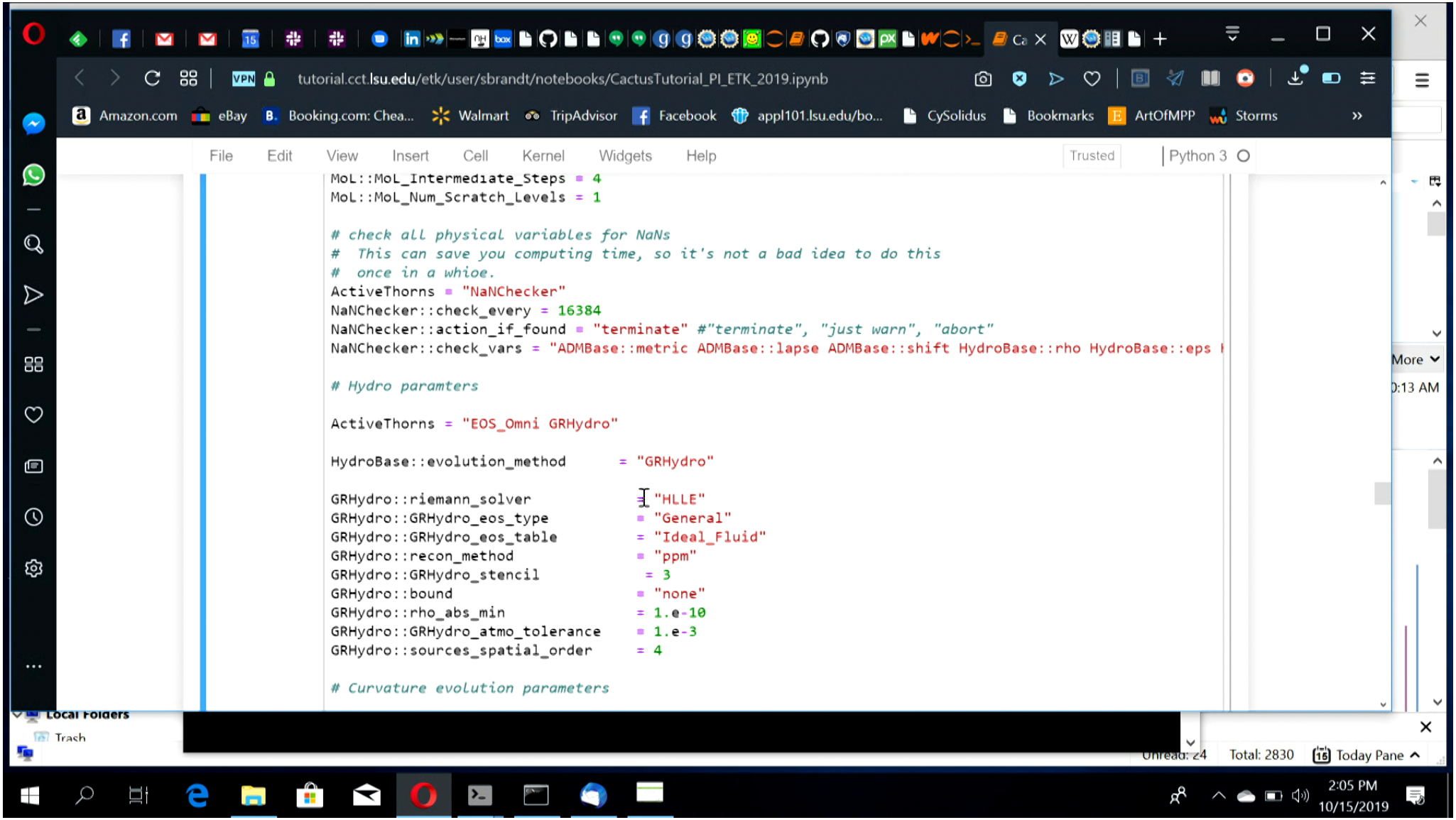
Trusted
Python 3
SpaceMask::use_mask = "yes"
Carpet::enable_all_storage = no
Carpet::use_buffer_zones = "yes"
Carpet::poison_new_timelevels = "yes"
Carpet::check_for_poison = "no"
Carpet::init_3_timelevels = no
Carpet::init_fill_timelevels = "yes"
CarpetLib::poison_new_memory = "yes"
CarpetLib::poison_value = 114
system specific Carpet paramters
Carpet::max_refinement_levels = 10
driver::ghost_size = 3
Carpet::prolongation_order_space = 3
Carpet::prolongation_order_time = 2
Time integration
time::dtfac = 0.25
MoL::ODE_Method = "rk4"
MoL::MoL_Intermediate_Steps = 4
MoL::MoL_Num_Scratch_Levels = 1
check all physical variables for NaNs
Local Folders
Trash
Total: 2830
Today Pane
2:04 PM
10/15/2019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Kernel
Widgets
Help
Trusted
Python 3
MoL::MoL_Intermediate_Steps = 4
MoL::MoL_Num_Scratch_Levels = 1
# check all physical variables for NaNs
# This can save you computing time, so it's not a bad idea to do this
# once in a whioe.
ActiveThorns = "NaNChecker"
NaNChecker::check_every = 16384
NaNChecker::action_if_found = "terminate" #"terminate", "just warn", "abort"
NaNChecker::check_vars = "ADMBase::metric ADMBase::lapse ADMBase::shift HydroBase::rho HydroBase::eps
# Hydro paramters
ActiveThorns = "EOS_Omni GRHydro"
HydroBase::evolution_method = "GRHydro"
GRHydro::riemann_solver = "HLLE"
GRHydro::GRHydro_eos_type = "General"
GRHydro::GRHydro_eos_table = "Ideal_Fluid"
GRHydro::recon_method = "ppm"
GRHydro::GRHydro_stencil = 3
GRHydro::bound = "none"
GRHydro::rho_abs_min = 1.e-10
GRHydro::GRHydro_atmo_tolerance = 1.e-3
GRHydro::sources_spatial_order = 4
Curvature evolution parameters
Local Folders
Trash
More
0:13 AM
Total: 2830
Today Pane
2:05 PM
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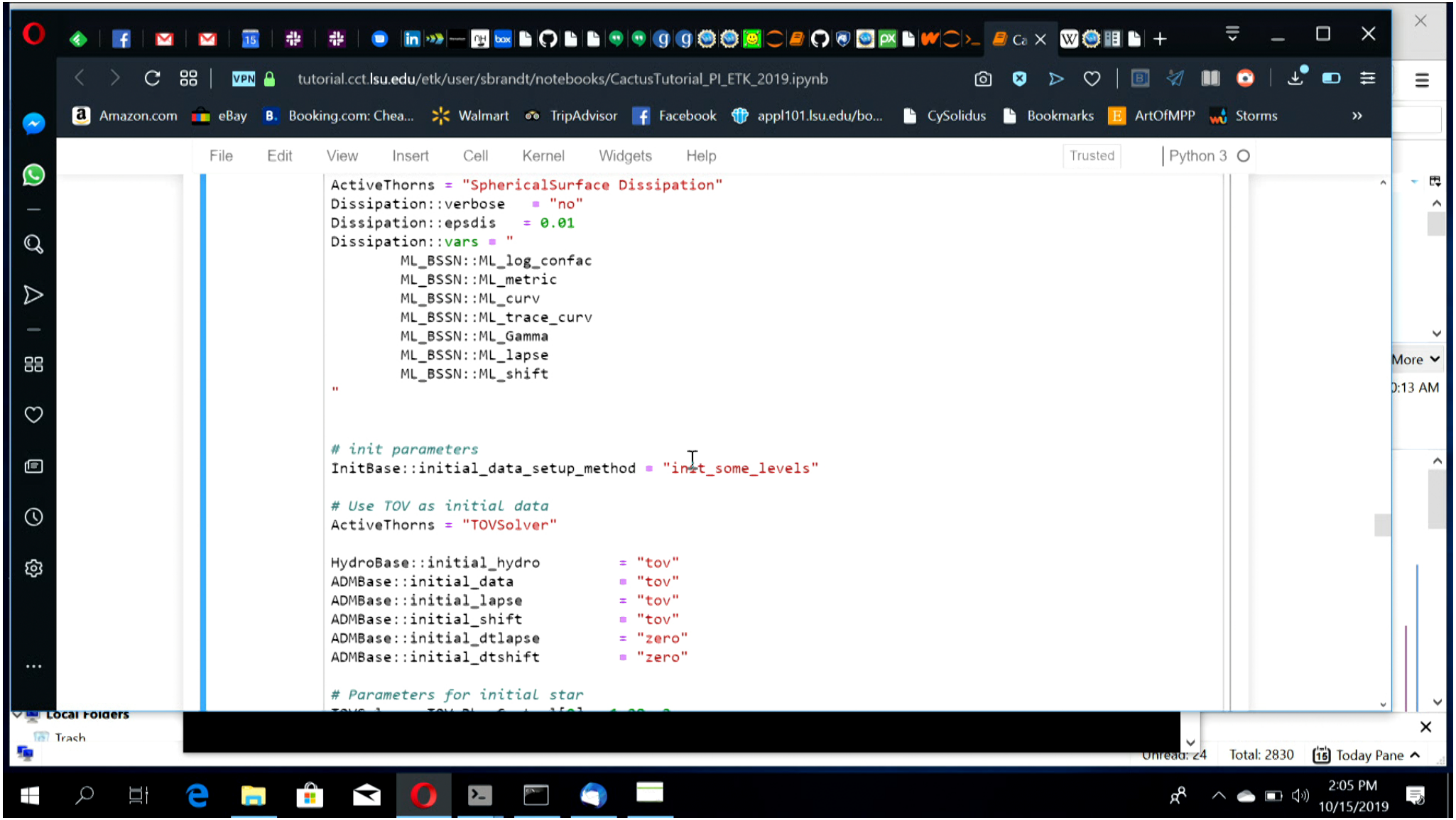
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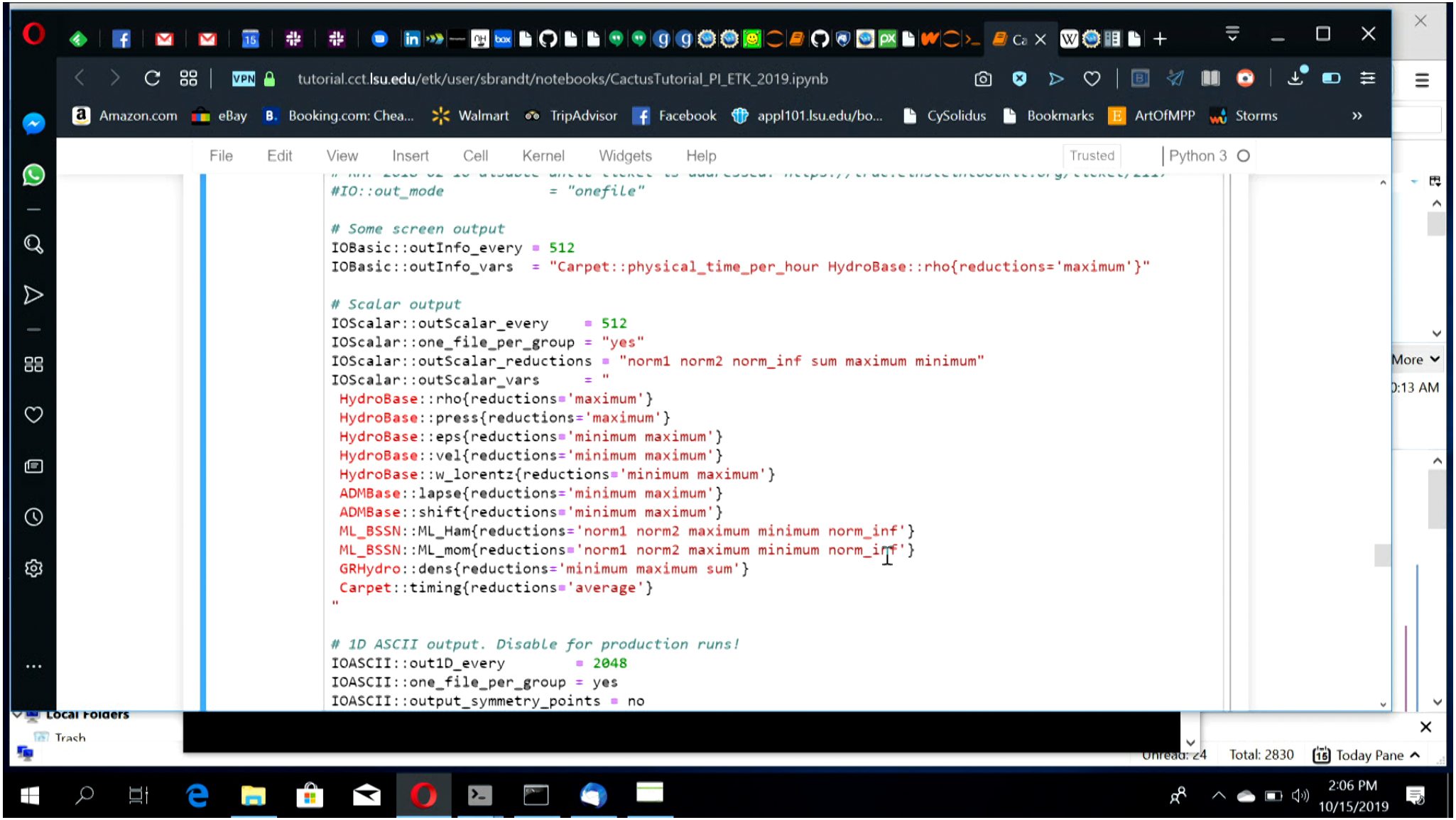
Trusted
Python 3
ActiveThorns = "SphericalSurface Dissipation"
Dissipation::verbose = "no"
Dissipation::epsdis = 0.01
Dissipation::vars = "
ML_BSSN::ML_log_confac
ML_BSSN::ML_metric
ML_BSSN::ML_curv
ML_BSSN::ML_trace_curv
ML_BSSN::ML_Gamma
ML_BSSN::ML_lapse
ML_BSSN::ML_shift
"
init parameters
InitBase::initial_data_setup_method = "init_some_levels"
# Use TOV as initial data
ActiveThorns = "TOVSolver"
HydroBase::initial_hydro = "tov"
ADMBase::initial_data = "tov"
ADMBase::initial_lapse = "tov"
ADMBase::initial_shift = "tov"
ADMBase::initial_dtlapse = "zero"
ADMBase::initial_dtshift = "zero"
Parameters for initial star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Trusted
Python 3
#IO::out_mode = "onefile"
Some screen output
IOBasic::outInfo_every = 512
IOBasic::outInfo_vars = "Carpet::physical_time_per_hour HydroBase::rho{reductions='maximum'}"
Scalar output
IOScalar::outScalar_every = 512
IOScalar::one_file_per_group = "yes"
IOScalar::outScalar_reductions = "norm1 norm2 norm_inf sum maximum minimum"
IOScalar::outScalar_vars = "
HydroBase::rho{reductions='maximum'}
HydroBase::press{reductions='maximum'}
HydroBase::eps{reductions='minimum maximum'}
HydroBase::vel{reductions='minimum maximum'}
HydroBase::w_lorentz{reductions='minimum maximum'}
ADMBase::lapse{reductions='minimum maximum'}
ADMBase::shift{reductions='minimum maximum'}
ML_BSSN::ML_Ham{reductions='norm1 norm2 maximum minimum norm_inf'}
ML_BSSN::ML_mom{reductions='norm1 norm2 maximum minimum norm_inf'}
GRHydro::dens{reductions='minimum maximum sum'}
Carpet::timing{reductions='average'}
"
1D ASCII output. Disable for production runs!
IOASCII::out1D_every = 2048
IOASCII::one_file_per_group = yes
IOASCII::output_symmetry_points = no
Local Folders
Trash
Total: 2830
Today Pane
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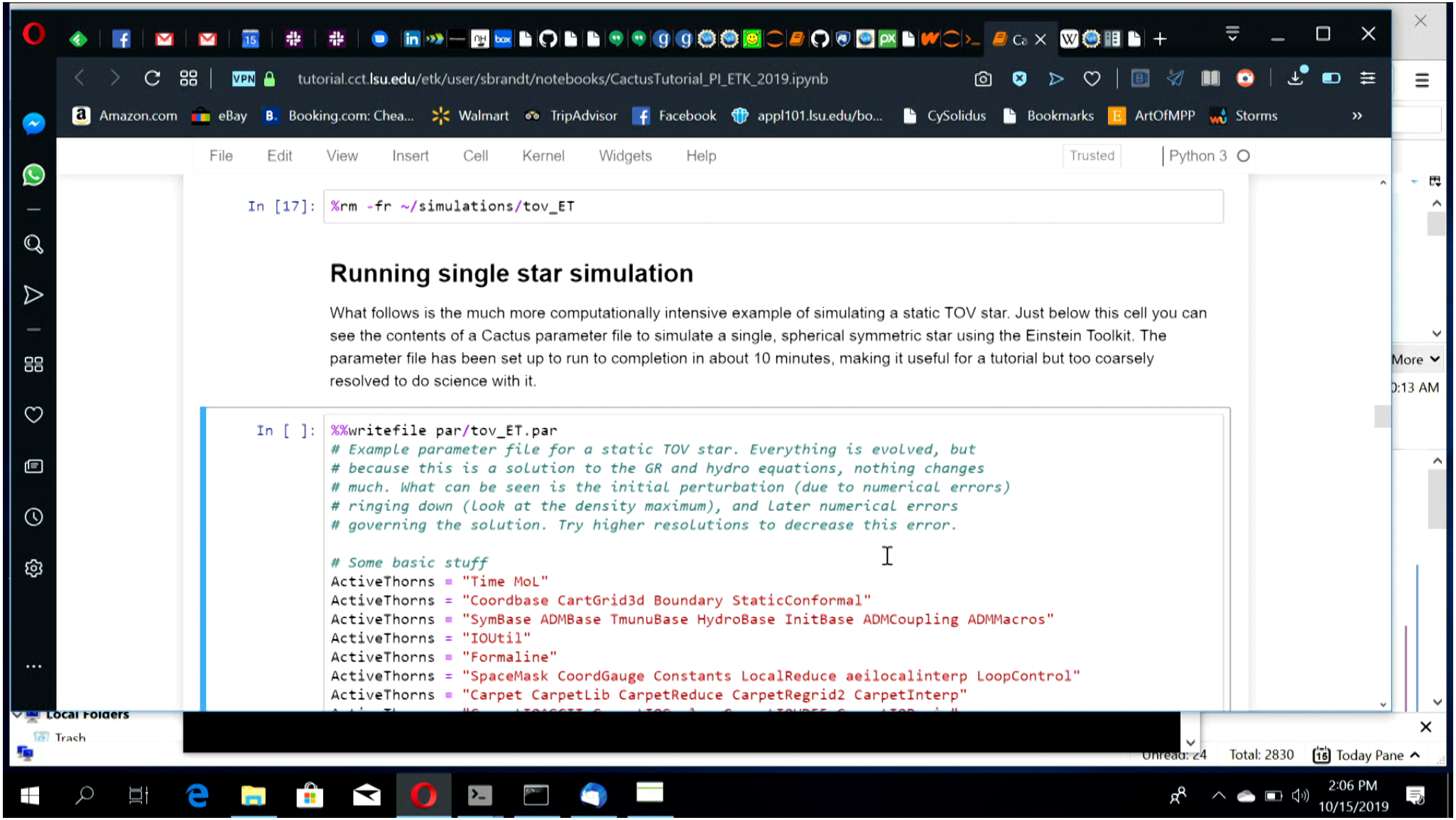
10/15/2019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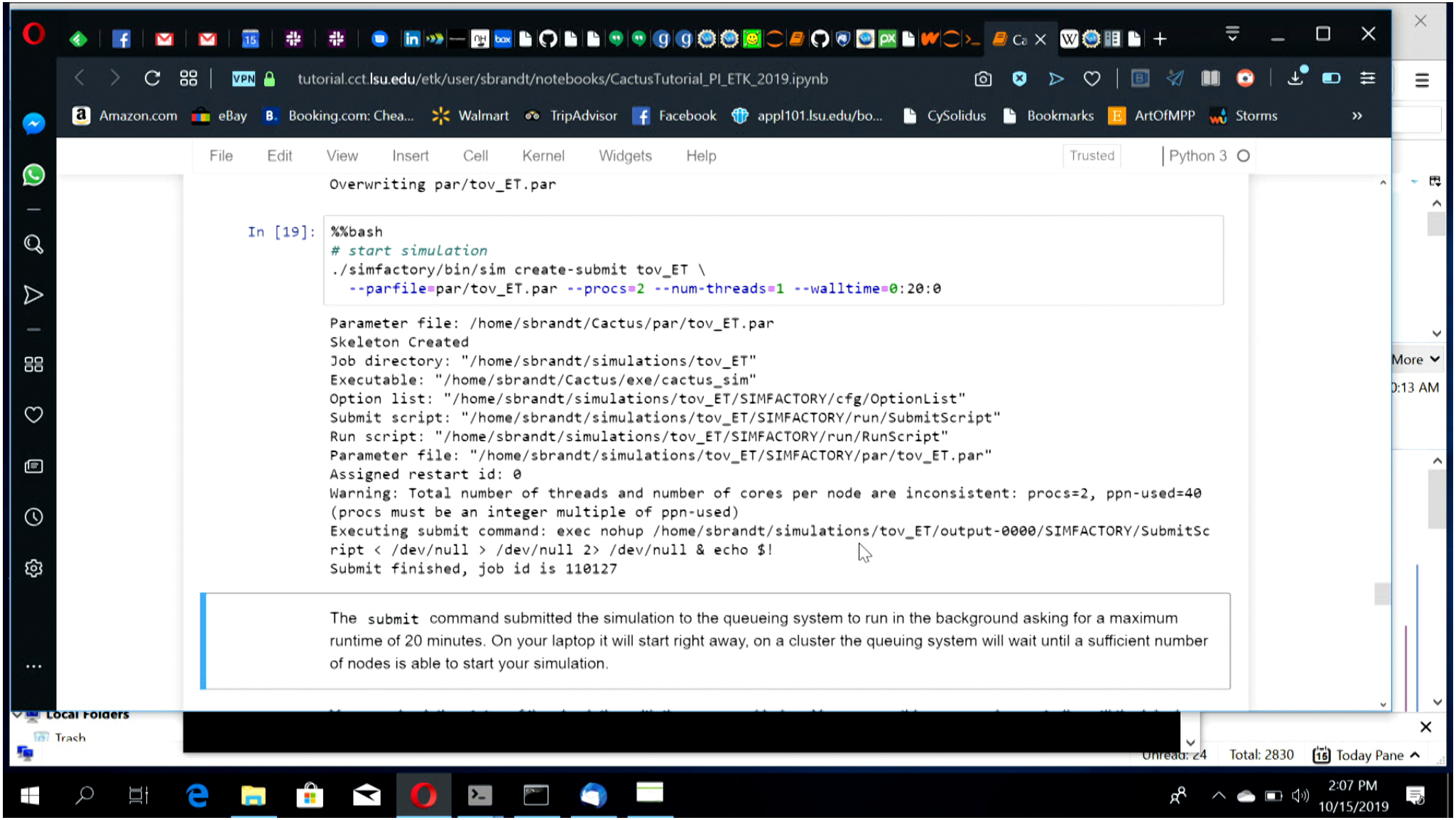
Trusted
Python 3
In [17]: %rm -fr ~/simulations/tov_ET
Running single star simulation
What follows is the much more computationally intensive example of simulating a static TOV star. Just below this cell you can see the contents of a Cactus parameter file to simulate a single, spherical symmetric star using the Einstein Toolkit. The parameter file has been set up to run to completion in about 10 minutes, making it useful for a tutorial but too coarsely resolved to do science with it.
In [ ]: %%writefile par/tov_ET.par
# Example parameter file for a static TOV star. Everything is evolved, but
# because this is a solution to the GR and hydro equations, nothing changes
# much. What can be seen is the initial perturbation (due to numerical errors)
# ringing down (look at the density maximum), and later numerical errors
# governing the solution. Try higher resolutions to decrease this error.
# Some basic stuff
ActiveThorns = "Time MoL"
ActiveThorns = "Coordbase CartGrid3d Boundary StaticConformal"
ActiveThorns = "SymBase ADMBase TmunuBase HydroBase InitBase ADMCoupling ADMMacros"
ActiveThorns = "IOUtil"
ActiveThorns = "Formaline"
ActiveThorns = "SpaceMask CoordGauge Constants LocalReduce aeilocalinterp LoopControl"
ActiveThorns = "Carpet CarpetLib CarpetReduce CarpetRegrid2 CarpetInterp"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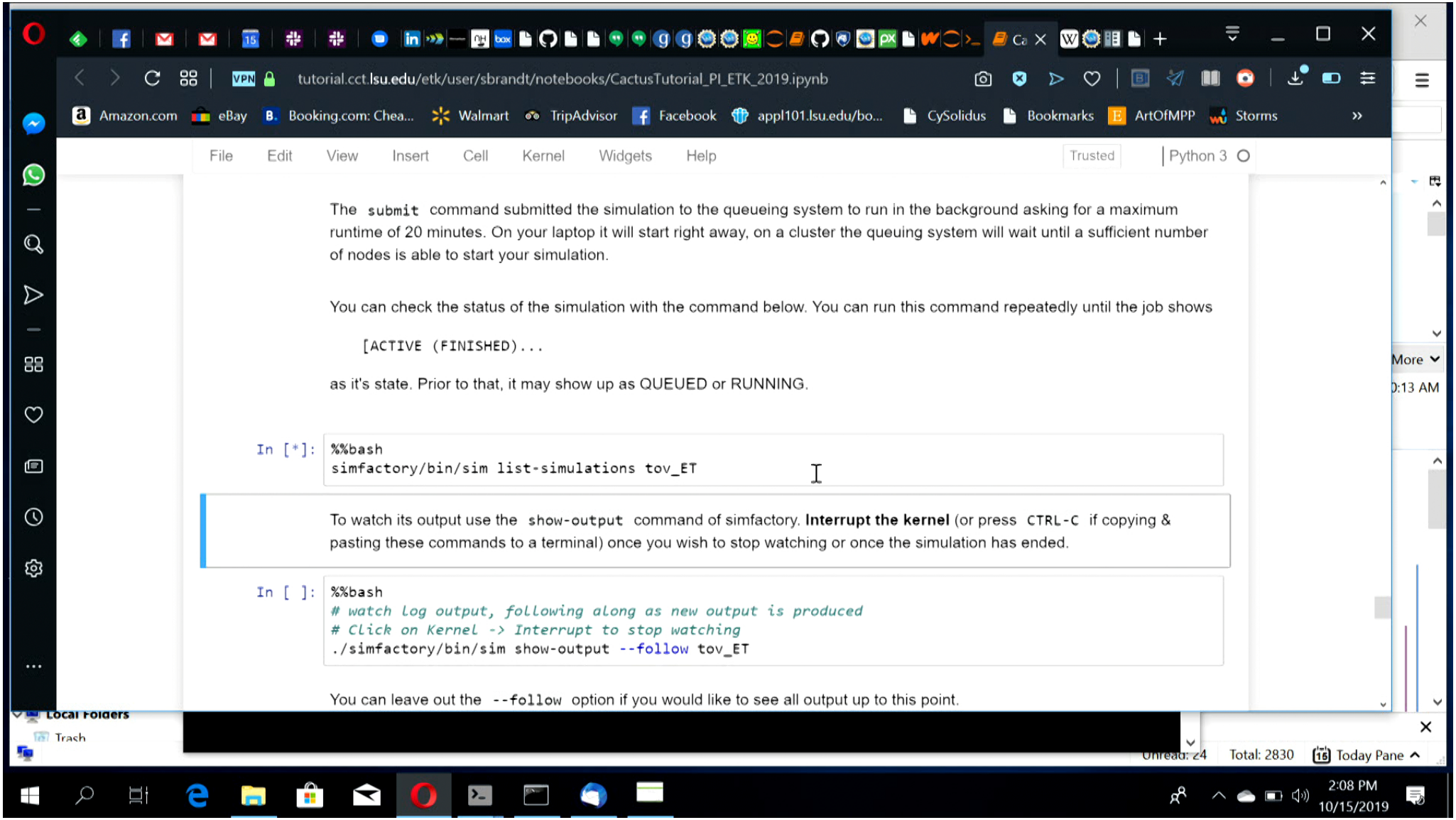
Python 3
Overwriting par/tov_ET.par
In [19]:
%%bash
start simulation
./simfactory/bin/sim create-submit tov_ET \
--parfile=par/tov_ET.par --procs=2 --num-threads=1 --walltime=0:20:0
Parameter file: /home/sbrandt/Cactus/par/tov_ET.par
Skeleton Created
Job directory: "/home/sbrandt/simulations/tov_ET"
Executable: "/home/sbrandt/Cactus/exe/cactus_sim"
Option list: "/home/sbrandt/simulations/tov_ET/SIMFACTORY/cfg/OptionList"
Submit script: "/home/sbrandt/simulations/tov_ET/SIMFACTORY/run/SubmitScript"
Run script: "/home/sbrandt/simulations/tov_ET/SIMFACTORY/run/RunScript"
Parameter file: "/home/sbrandt/simulations/tov_ET/SIMFACTORY/par/tov_ET.par"
Assigned restart id: 0
Warning: Total number of threads and number of cores per node are inconsistent: procs=2, ppn-used=40
(procs must be an integer multiple of ppn-used)
Executing submit command: exec nohup /home/sbrandt/simulations/tov_ET/output-0000/SIMFACTORY/SubmitSc
ript < /dev/null > /dev/null 2> /dev/null & echo $!
Submit finished, job id is 110127
The submit command submitted the simulation to the queueing system to run in the background asking for a maximum runtime of 20 minutes. On your laptop it will start right away, on a cluster the queuing system will wait until a sufficient number of nodes is able to start your simulation.
Local Folders
Trash
Total: 2830
Today Pane
2:07 PM
10/15/2019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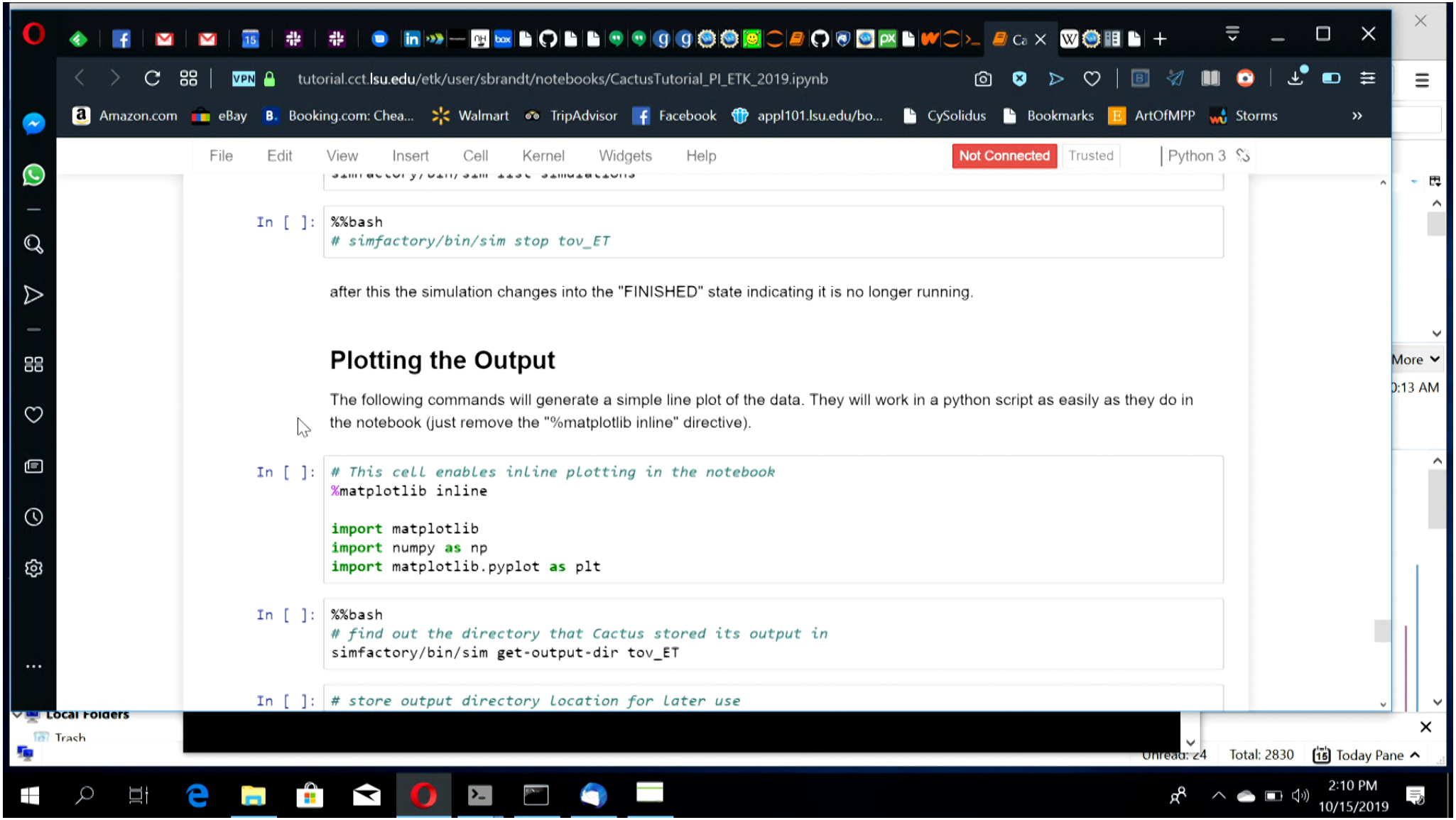
Trusted
Python 3
The submit command submitted the simulation to the queueing system to run in the background asking for a maximum runtime of 20 minutes. On your laptop it will start right away, on a cluster the queuing system will wait until a sufficient number of nodes is able to start your simulation.
You can check the status of the simulation with the command below. You can run this command repeatedly until the job shows
[ACTIVE (FINISHED)...
as it's state. Prior to that, it may show up as QUEUED or RUNNING.
In [*]:
%%bash
simfactory/bin/sim list-simulations tov_ET
To watch its output use the show-output command of simfactory. Interrupt the kernel (or press CTRL-C if copying & pasting these commands to a terminal) once you wish to stop watching or once the simulation has ended.
In [ ]:
%%bash
watch log output, following along as new output is produced
Click on Kernel -> Interrupt to stop watching
./simfactory/bin/sim show-output --follow tov_ET
You can leave out the --follow option if you would like to see all output up to this point.
2:08 PM
10/15/2019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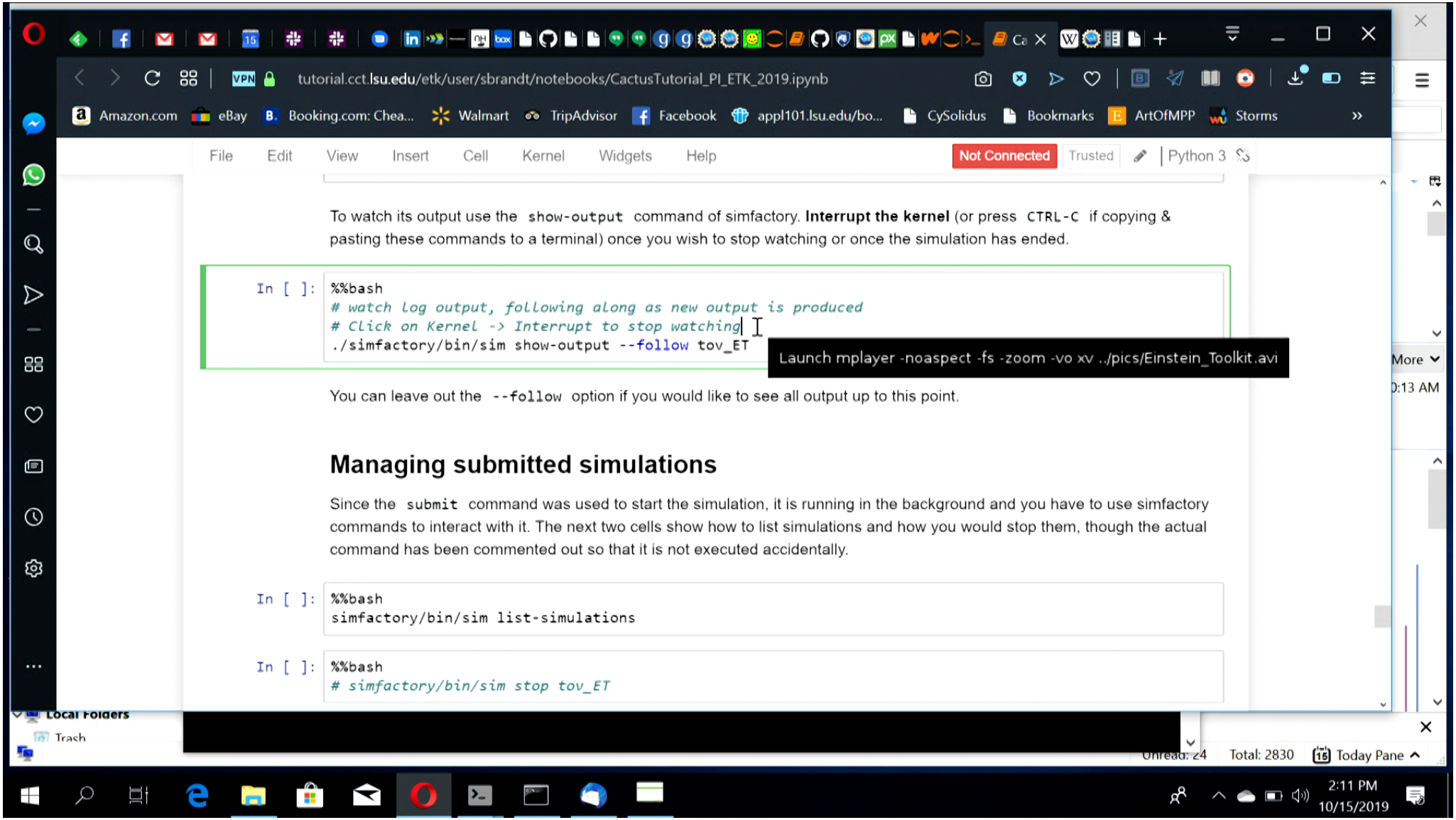
Not Connected
Trusted
Python 3
In [ ]:
%%bash
simfactory/bin/sim stop tov_ET
after this the simulation changes into the "FINISHED" state indicating it is no longer running.
Plotting the Output
The following commands will generate a simple line plot of the data. They will work in a python script as easily as they do in the notebook (just remove the "%matplotlib inline" directive).
In [ ]:
This cell enables inline plotting in the notebook
%matplotlib inline
import matplotlib
import numpy as np
import matplotlib.pyplot as plt
In [ ]:
%%bash
find out the directory that Cactus stored its output in
simfactory/bin/sim get-output-dir tov_ET
In [ ]:
store output directory location for later use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Python 3
To watch its output use the show-output command of simfactory. Interrupt the kernel (or press CTRL-C if copying & pasting these commands to a terminal) once you wish to stop watching or once the simulation has ended.
In [ ]:
%%bash
watch log output, following along as new output is produced
Click on Kernel -> Interrupt to stop watching
./simfactory/bin/sim show-output --follow tov_ET
Launch mplayer -noaspect -fs -zoom -vo xv ../pics/Einstein_Toolkit.avi
You can leave out the --follow option if you would like to see all output up to this point.
Managing submitted simulations
Since the submit command was used to start the simulation, it is running in the background and you have to use simfactory commands to interact with it. The next two cells show how to list simulations and how you would stop them, though the actual command has been commented out so that it is not executed accidentally.
In [ ]:
%%bash
simfactory/bin/sim list-simulations
In [ ]:
%%bash
simfactory/bin/sim stop tov_ET
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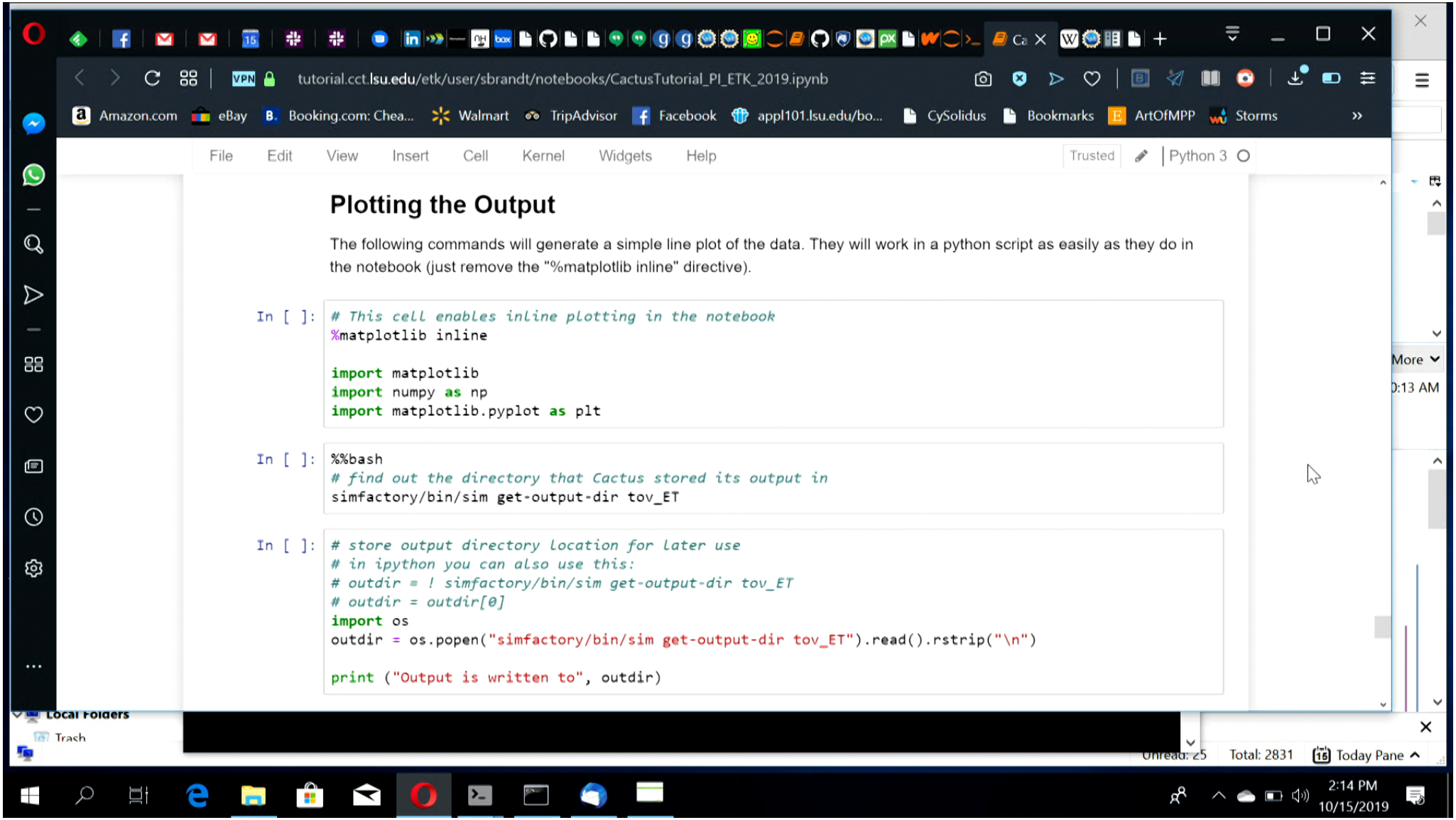
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Python 3
Plotting the Output
The following commands will generate a simple line plot of the data. They will work in a python script as easily as they do in the notebook (just remove the "%matplotlib inline" directive).
In [ ]:
This cell enables inline plotting in the notebook
%matplotlib inline
import matplotlib
import numpy as np
import matplotlib.pyplot as plt
In [ ]:
%%bash
find out the directory that Cactus stored its output in
simfactory/bin/sim get-output-dir tov_ET
In [ ]:
# store output directory location for later use
# in ipython you can also use this:
# outdir = ! simfactory/bin/sim get-output-dir tov_ET
# outdir = outdir[0]
import os
outdir = os.popen("simfactory/bin/sim get-output-dir tov_ET").read().rstrip("\n")
print ("Output is written to", outdir)
Local Folders
Trash
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2:14 PM
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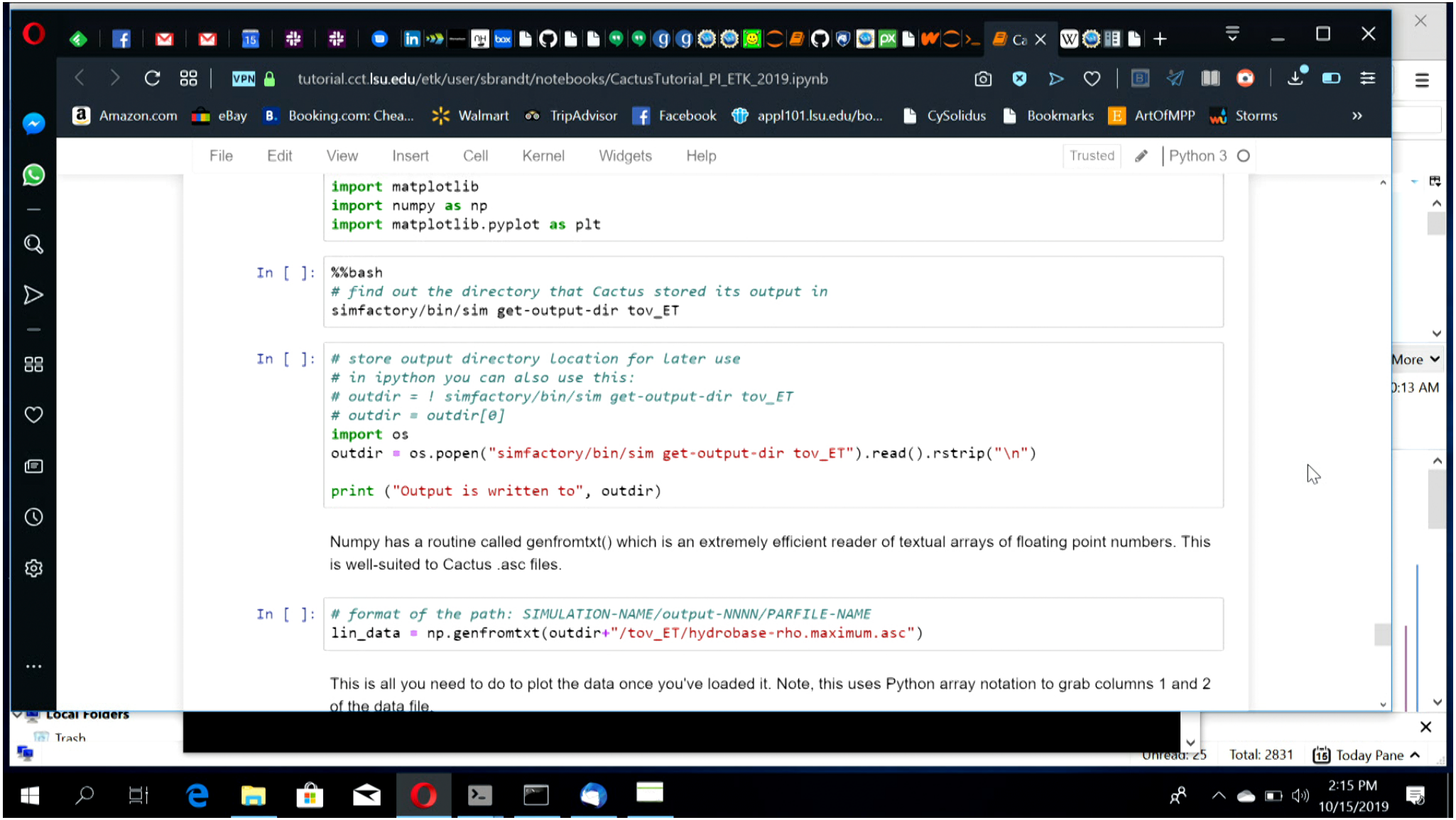
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Python 3
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import numpy as np
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In [ ]:
# store output directory location for later use
# in ipython you can also use this:
# outdir = ! simfactory/bin/sim get-output-dir tov_ET
# outdir = outdir[0]
import os
outdir = os.popen("simfactory/bin/sim get-output-dir tov_ET").read().rstrip("\n")
print ("Output is written to", outdir)
Numpy has a routine called genfromtxt() which is an extremely efficient reader of textual arrays of floating point numbers. This is well-suited to Cactus .asc files.
In [ ]:
# format of the path: SIMULATION-NAME/output-NNNN/PARFILE-NAME
lin_data = np.genfromtxt(outdir+"/tov_ET/hydrobase-rho.maximum.asc")
This is all you need to do to plot the data once you've loaded it. Note, this uses Python array notation to grab columns 1 and 2 of the data file.
Local Folders
Trash
Total: 2831
Today Pane
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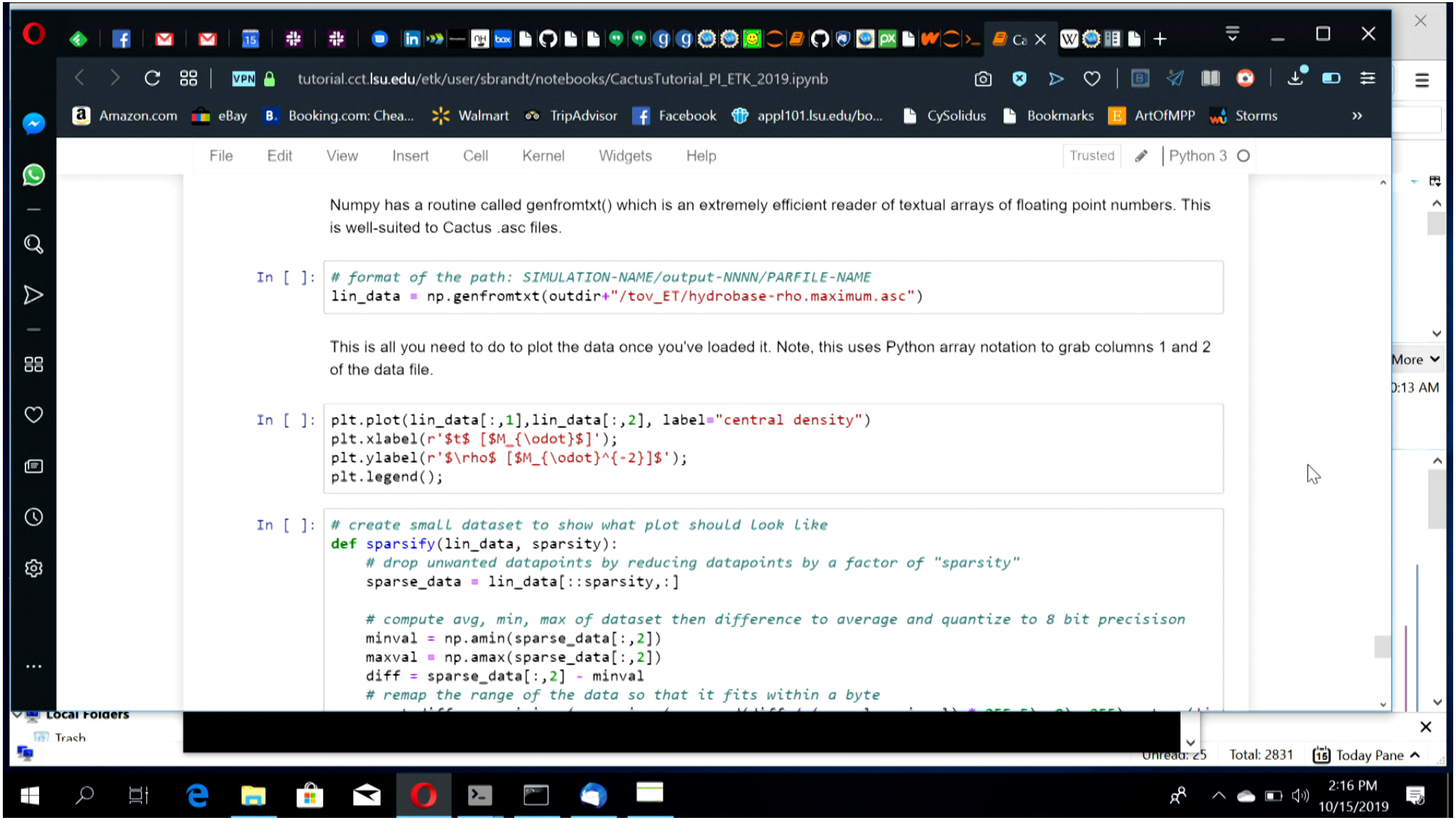
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Python 3
Numpy has a routine called genfromtxt() which is an extremely efficient reader of textual arrays of floating point numbers. This is well-suited to Cactus .asc files.
In [ ]:
# format of the path: SIMULATION-NAME/output-NNNN/PARFILE-NAME
lin_data = np.genfromtxt(outdir+"/tov_ET/hydrobase-rho.maximum.asc")
This is all you need to do to plot the data once you've loaded it. Note, this uses Python array notation to grab columns 1 and 2 of the data file.
In [ ]:
plt.plot(lin_data[:,1],lin_data[:,2], label="central density")
plt.xlabel(r't [$M_{\odot}$]');
plt.ylabel(r'ρ [$M_{\odot}^{-2}]$');
plt.legend();
In [ ]:
# create small dataset to show what plot should look like
def sparsify(lin_data, sparsity):
# drop unwanted datapoints by reducing datapoints by a factor of "sparsity"
sparse_data = lin_data[::sparsity,:]
# compute avg, min, max of dataset then difference to average and quantize to 8 bit precisison
minval = np.amin(sparse_data[:,2])
maxval = np.amax(sparse_data[:,2])
diff = sparse_data[:,2] - minval
# remap the range of the data so that it fits within a byte
Local Folders
Trash
Total: 2831
Today Pane
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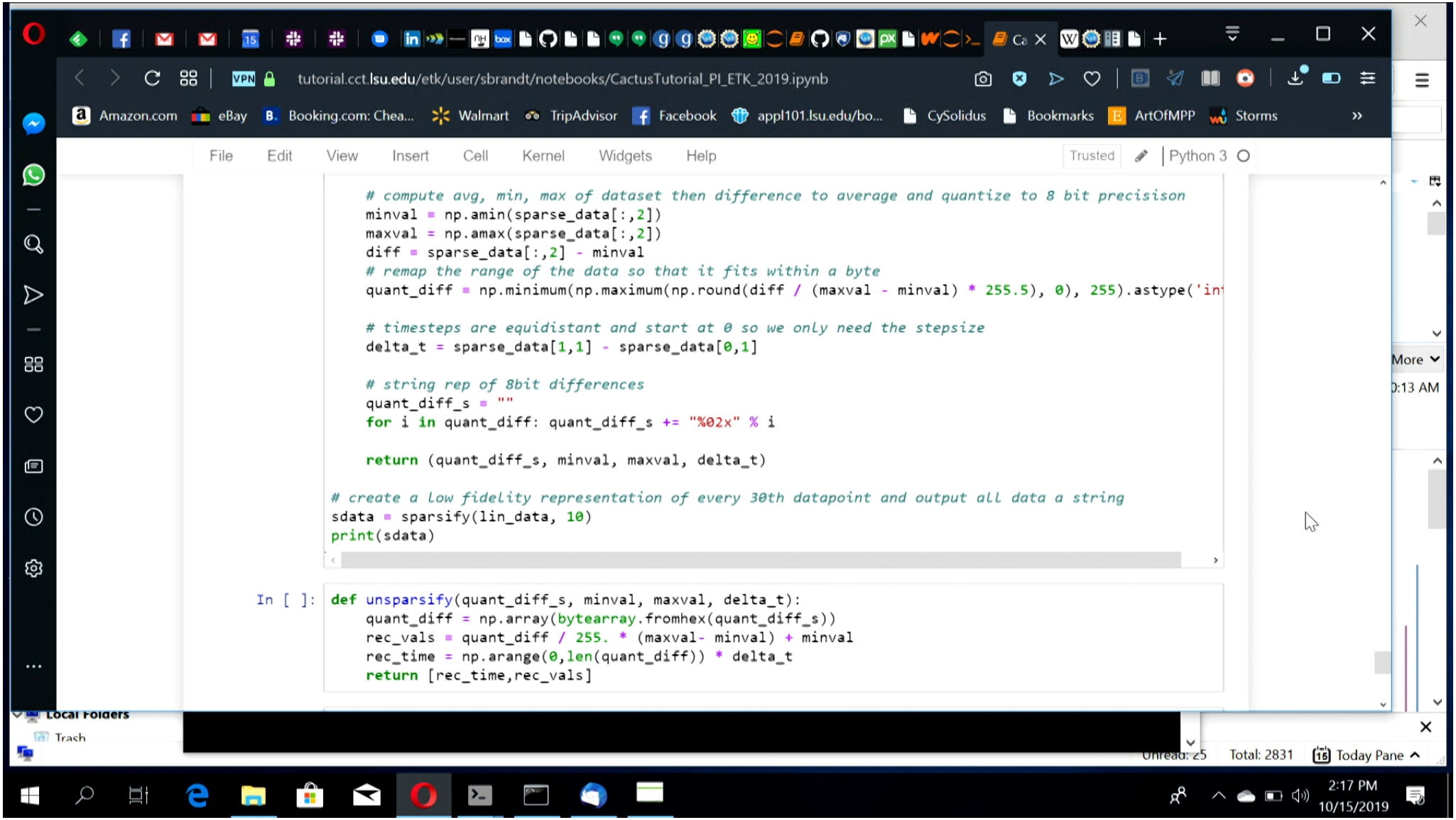
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Trusted
Python 3
# compute avg, min, max of dataset then difference to average and quantize to 8 bit precisison
minval = np.amin(sparse_data[:,2])
maxval = np.amax(sparse_data[:,2])
diff = sparse_data[:,2] - minval
# remap the range of the data so that it fits within a byte
quant_diff = np.minimum(np.maximum(np.round(diff / (maxval - minval) * 255.5), 0), 255).astype('in
# timesteps are equidistant and start at 0 so we only need the stepsize
delta_t = sparse_data[1,1] - sparse_data[0,1]
# string rep of 8bit differences
quant_diff_s = ""
for i in quant_diff: quant_diff_s += "%02x" % i
return (quant_diff_s, minval, maxval, delta_t)
# create a low fidelity representation of every 30th datapoint and output all data a string
sdata = sparsify(lin_data, 10)
print(sdata)
In [ ]:
def unsparsify(quant_diff_s, minval, maxval, delta_t):
quant_diff = np.array(bytearray.fromhex(quant_diff_s))
rec_vals = quant_diff / 255. * (maxval- minval) + minval
rec_time = np.arange(0,len(quant_diff)) * delta_t
return [rec_time,rec_vals]
Local Folders
Trash
Total: 2831
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2:17 PM
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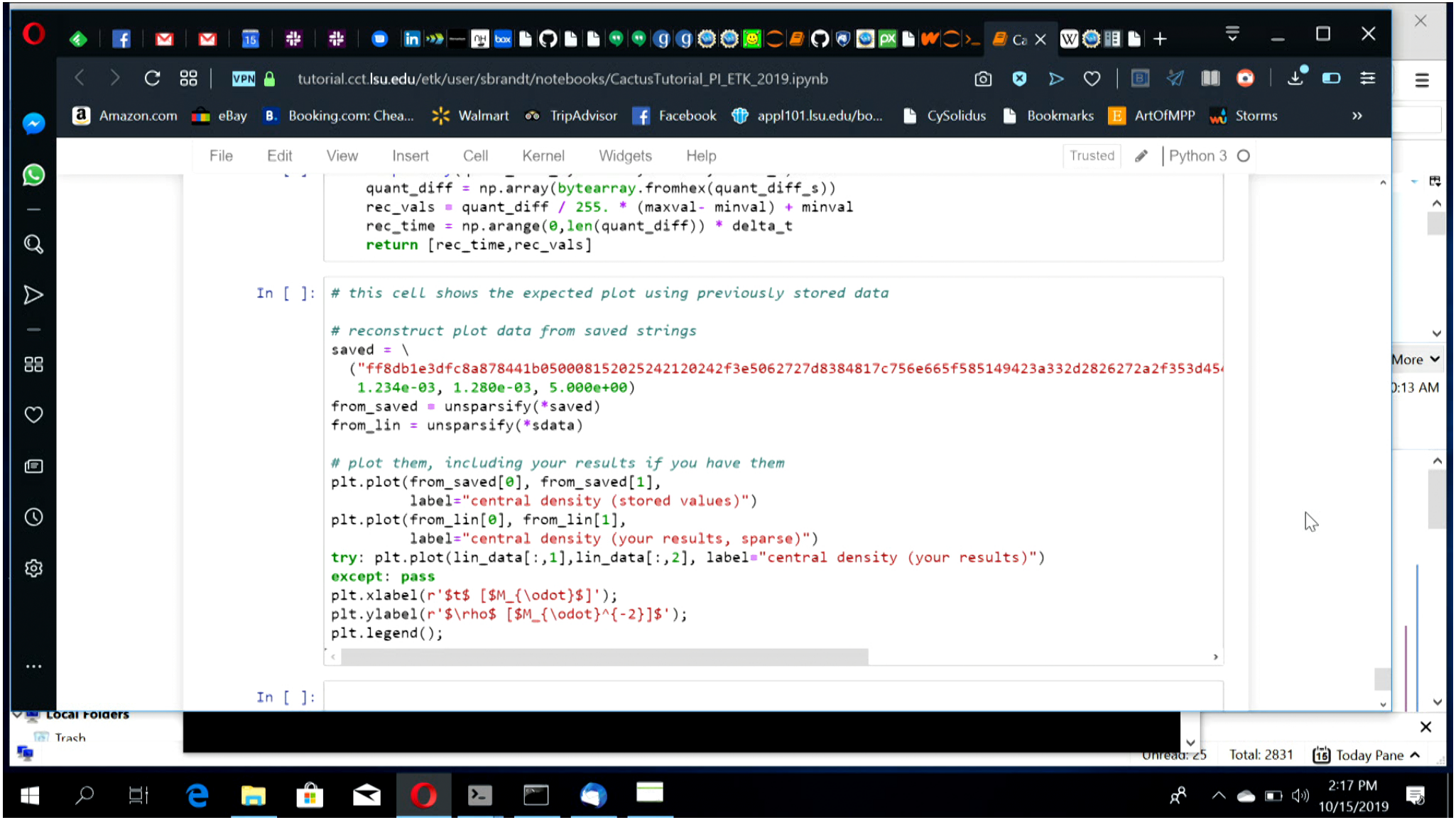
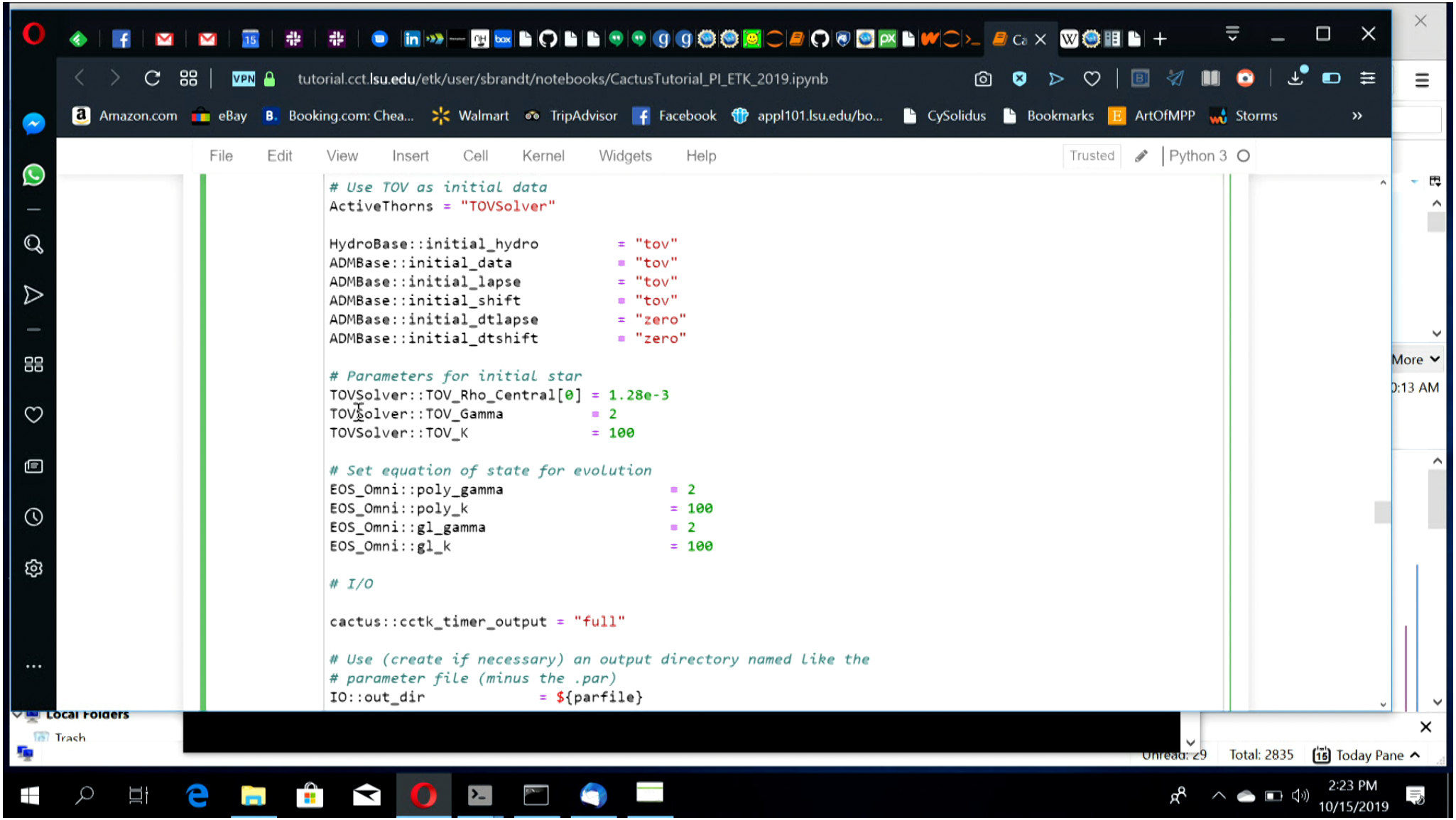

tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
quant_diff = np.array(bytearray.fromhex(quant_diff_s))
rec_vals = quant_diff / 255. * (maxval- minval) + minval
rec_time = np.arange(0,len(quant_diff)) * delta_t
return [rec_time,rec_vals]
In [ ]:
# this cell shows the expected plot using previously stored data
# reconstruct plot data from saved strings
saved = \
("ff8db1e3dfc8a878441b0500081520252421202 42f3e5062727d8384817c756e665f585149423a332d2826272a2f353d45
1.234e-03, 1.280e-03, 5.000e+00)
from_saved = unsparsify(*saved)
from_lin = unsparsify(*sdata)
# plot them, including your results if you have them
plt.plot(from_saved[0], from_saved[1],
label="central density (stored values)")
plt.plot(from_lin[0], from_lin[1],
label="central density (your results, sparse)")
try: plt.plot(lin_data[:,1],lin_data[:,2], label="central density (your results)")
except: pass
plt.xlabel(r't [$M_{\odot}$]');
plt.ylabel(r'ρ [$M_{\odot}^{-2}]$');
plt.legend();
In [ ]:
Local Folders
Trash
Total: 2831
Today Pane
2:17 PM
10/15/2019


tutorial.cct.lsu.edu/etk/user/sbrandt/notebooks/CactusTutorial_PI_ETK_2019.ipynb
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
# Use TOV as initial data
ActiveThorns = "TOVSolver"
HydroBase::initial_hydro = "tov"
ADMBase::initial_data = "tov"
ADMBase::initial_lapse = "tov"
ADMBase::initial_shift = "tov"
ADMBase::initial_dtlapse = "zero"
ADMBase::initial_dtshift = "zero"
Parameters for initial star
TOVSolver::TOV_Rho_Central[0] = 1.28e-3
TOVSolver::TOV_Gamma = 2
TOVSolver::TOV_K = 100
Set equation of state for evolution
EOS_Omni::poly_gamma = 2
EOS_Omni::poly_k = 100
EOS_Omni::gl_gamma = 2
EOS_Omni::gl_k = 100
I/O
cactus::cctk_timer_output = "full"
Use (create if necessary) an output directory named like the
parameter file (minus the .par)
IO::out_dir = ${parfile}
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