W4995 Applied Machine Learning

Visualization and Matplotlib

01/25/17

Andreas Müller

Principles of data visualization

Why?

Explore

Communicate

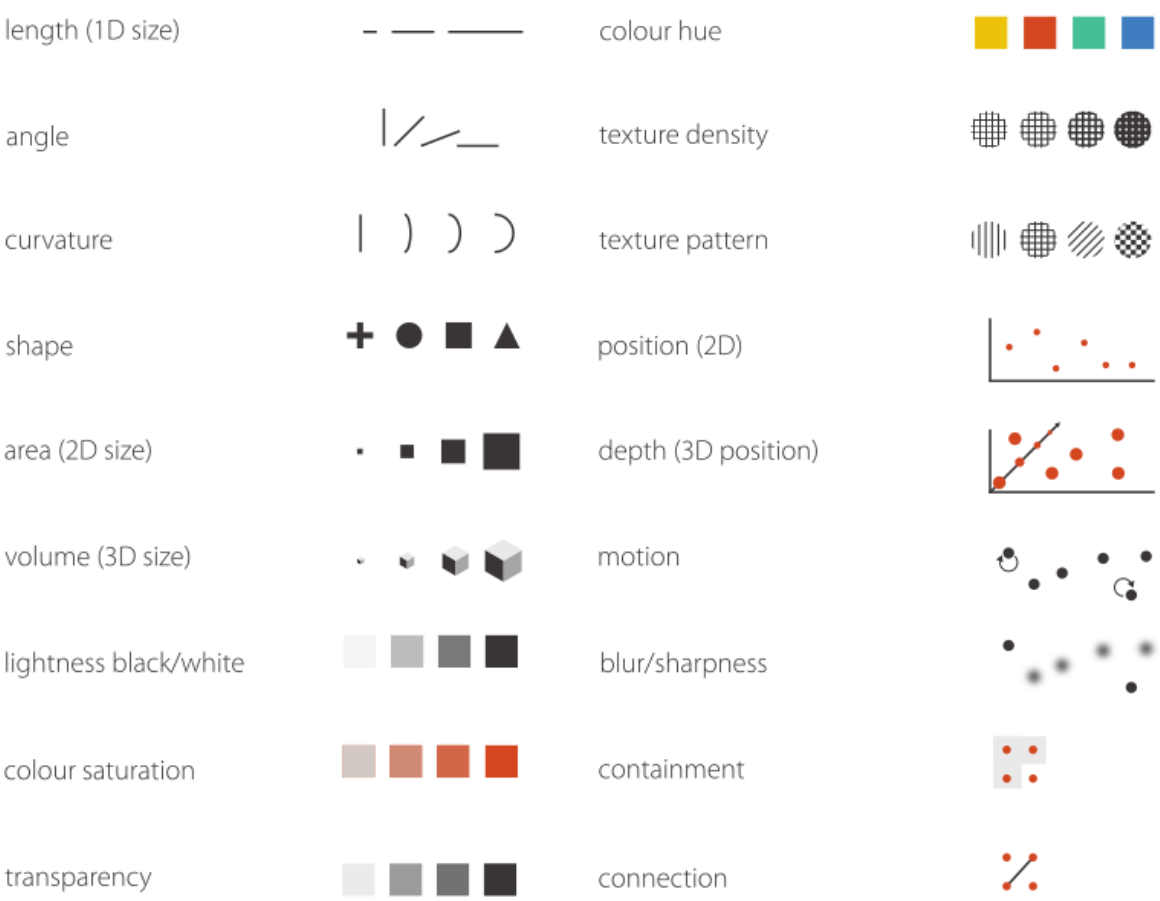
Above else, show the data.
Maximize the data-ink ratio.

- E. Tufte

Tools matter.

- W. S. Cleveland

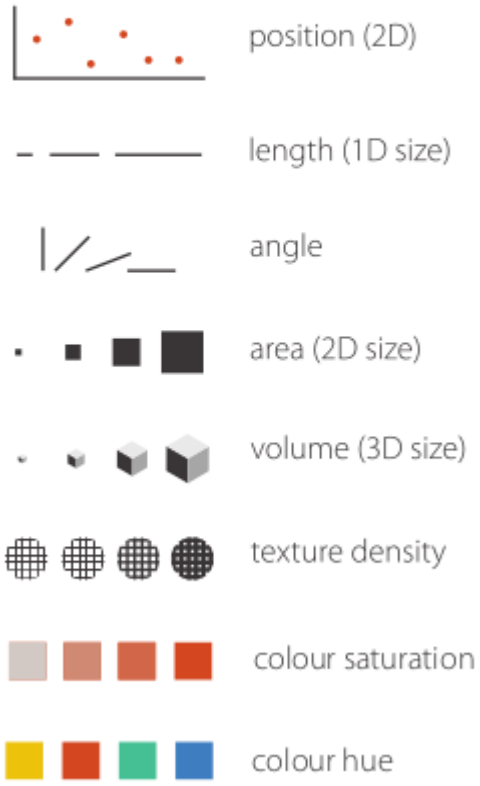
Visual Channels



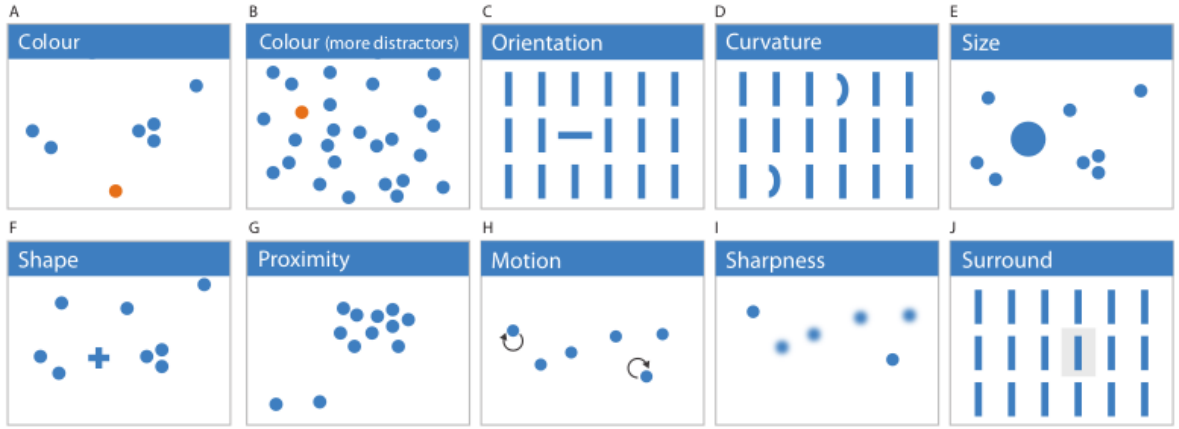
Picking Channels

Quantitative validated

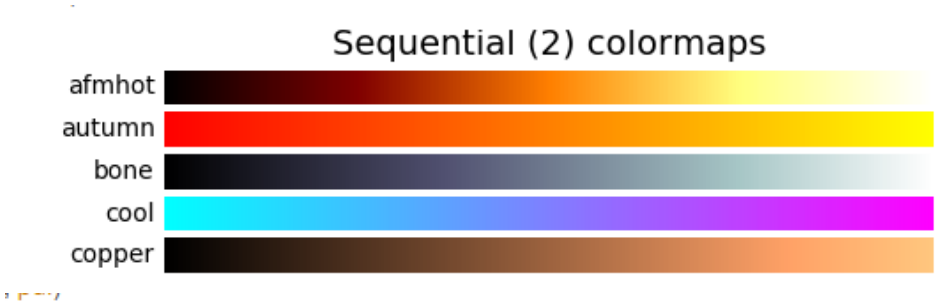
Cleveland and McGill, 1983
Heer and Bostock, 2010
MacKinley, 1986

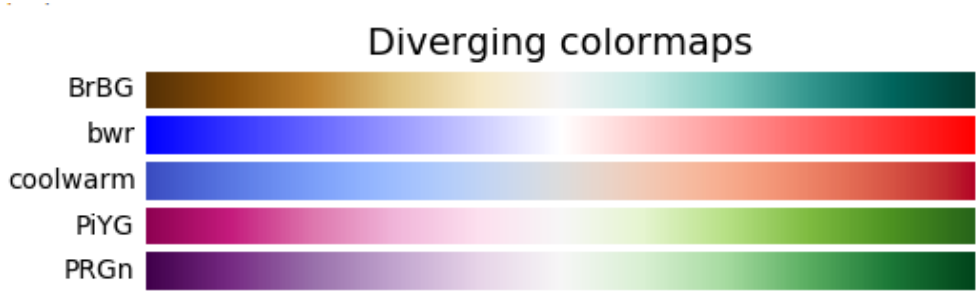


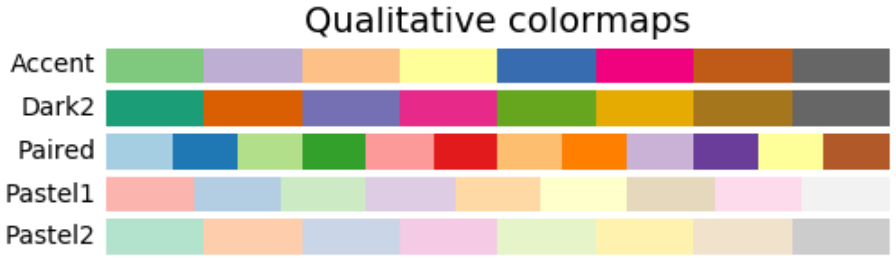
Pop-out Channels

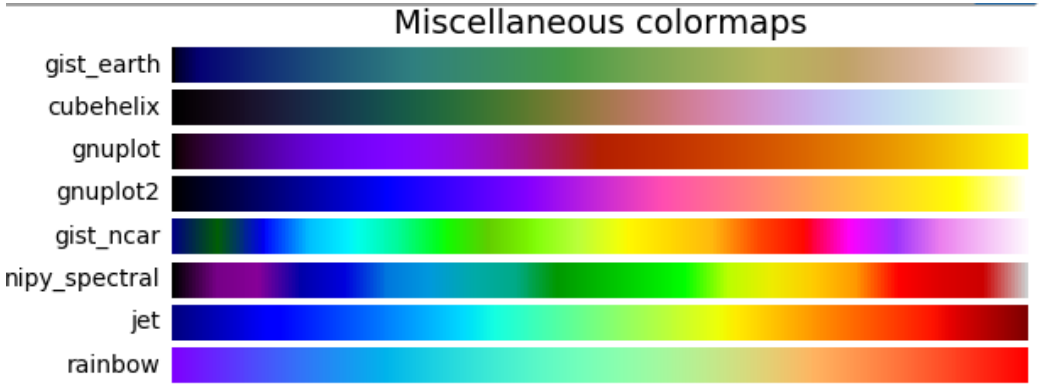


Colormaps


Sequential (2) colormaps
afmhot
autumn
bone
cool
copper

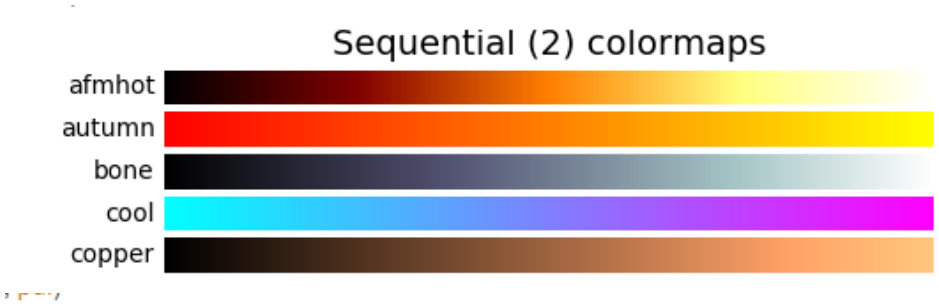

Diverging colormaps
BrBG
bwr
coolwarm
PiYG
PRGn


Qualitative colormaps
Accent
Dark2
Paired
Pastel1
Pastel2


Miscellaneous colormaps
gist_earth
cubehelix
gnuplot
gnuplot2
gist_ncar
nipy_spectral
jet
rainbow


Perceptually Uniform Sequential colormaps
viridis
inferno
plasma
magma

Colormaps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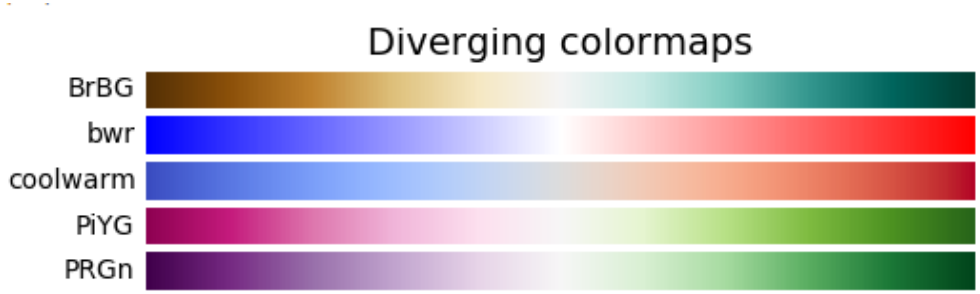
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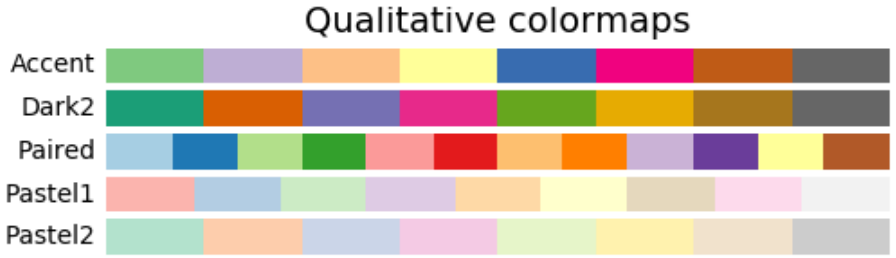
Qualitative colormaps
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Dark2
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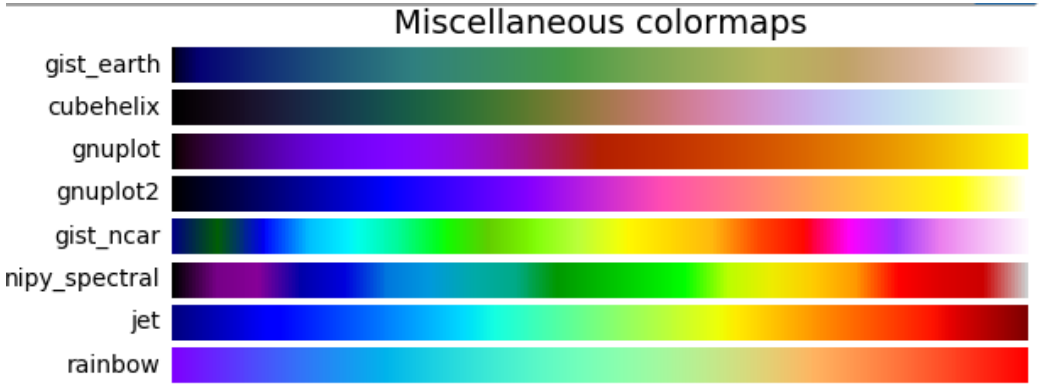
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jet
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Perceptually Uniform Sequential colormaps
viridis
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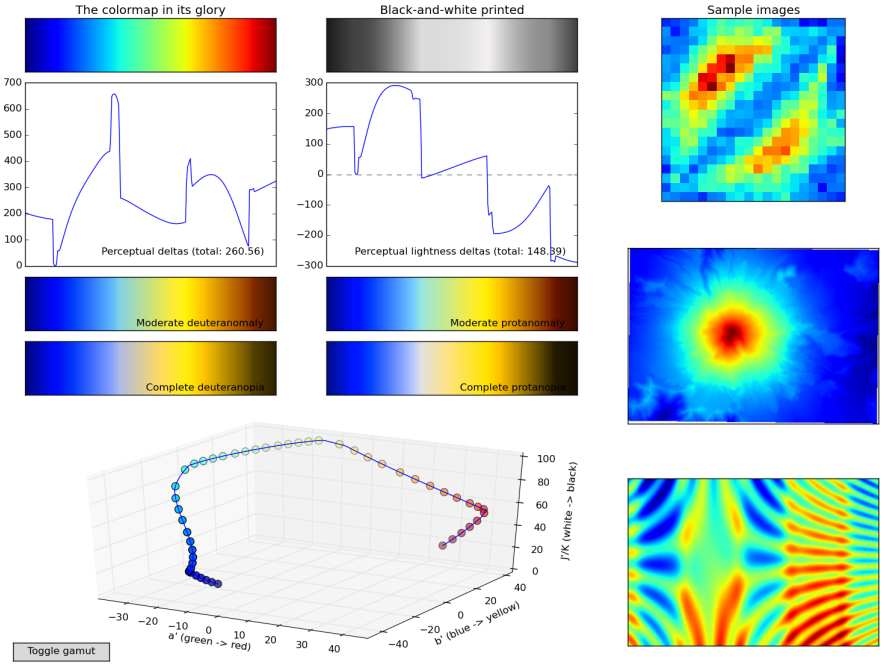
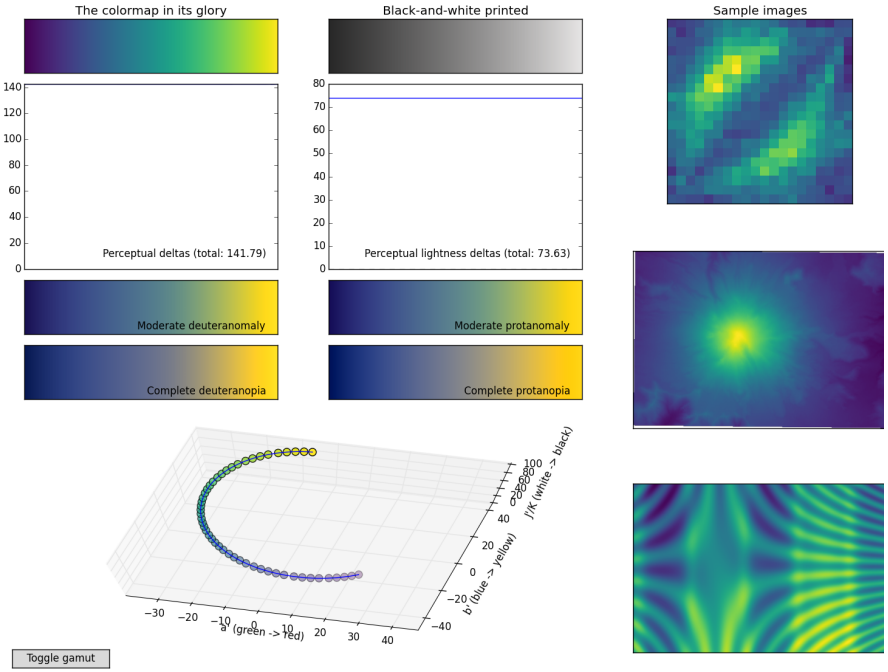
magma

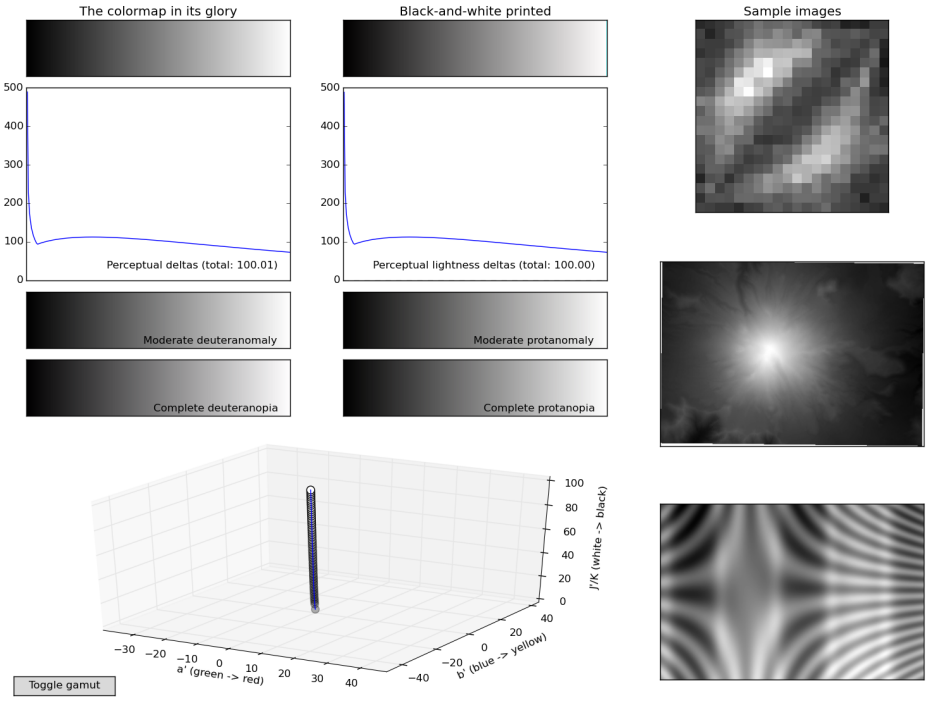
Colormap evaluation: jet



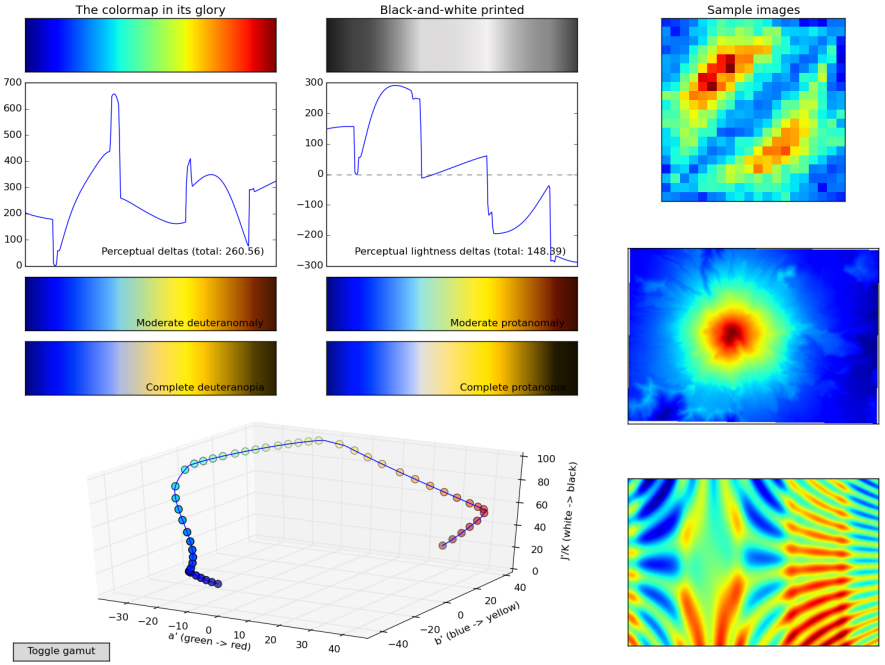
Colormap evaluation: option_d.py



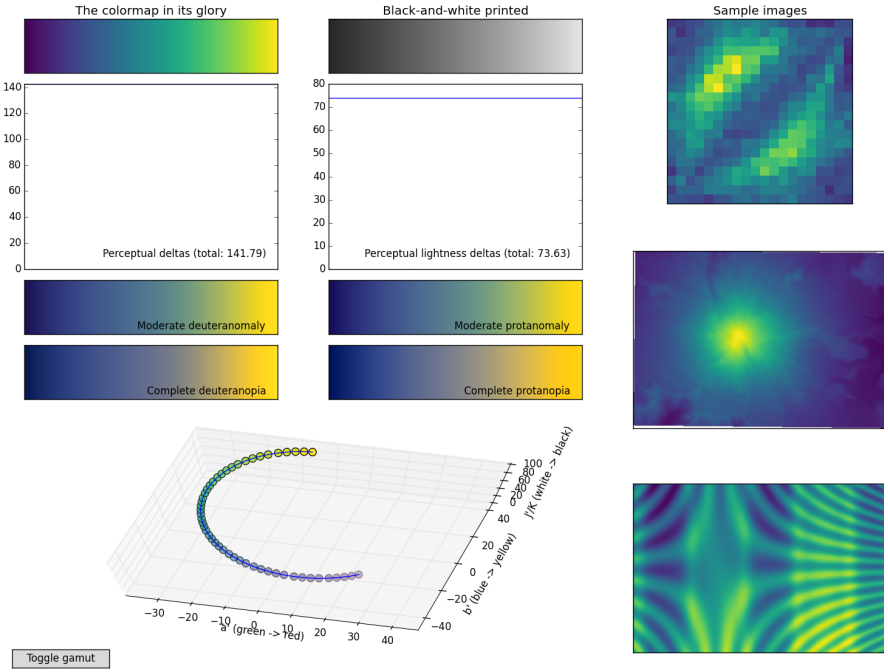
Colormap evaluation: gray



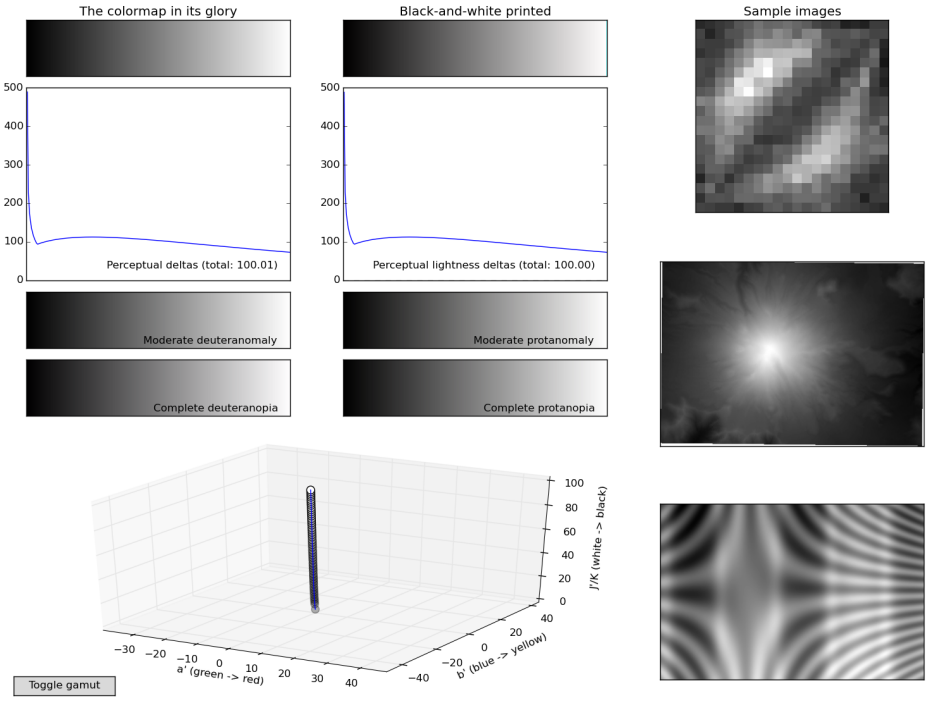
Colormap evaluation: jet



Colormap evaluation: option_d.py



Colormap evaluation: gray



matplotlib

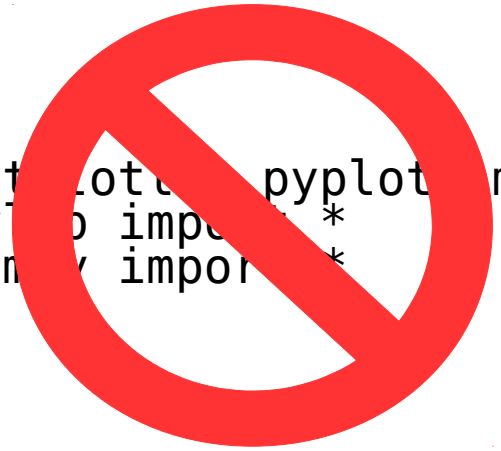
matplotlib v2

update now!
(you can enable classic style if your really want)

Other libs

- pandas plotting - convenience
- seaborn - ready-made stats plots
- bokeh - alternative to matplotlib for in-browser
- several ggplot translations / interfaces

Imports



```
from matplotlib.pyplot import *
from pylab import *
from numpy import *
```

```
import matplotlib.pyplot as plt
import numpy as np
```

matplotlib & Jupyter

`% matplotlib inline`

- sends png to browser
- no panning or zooming
- new figure for each cell
- no changes to previous figures

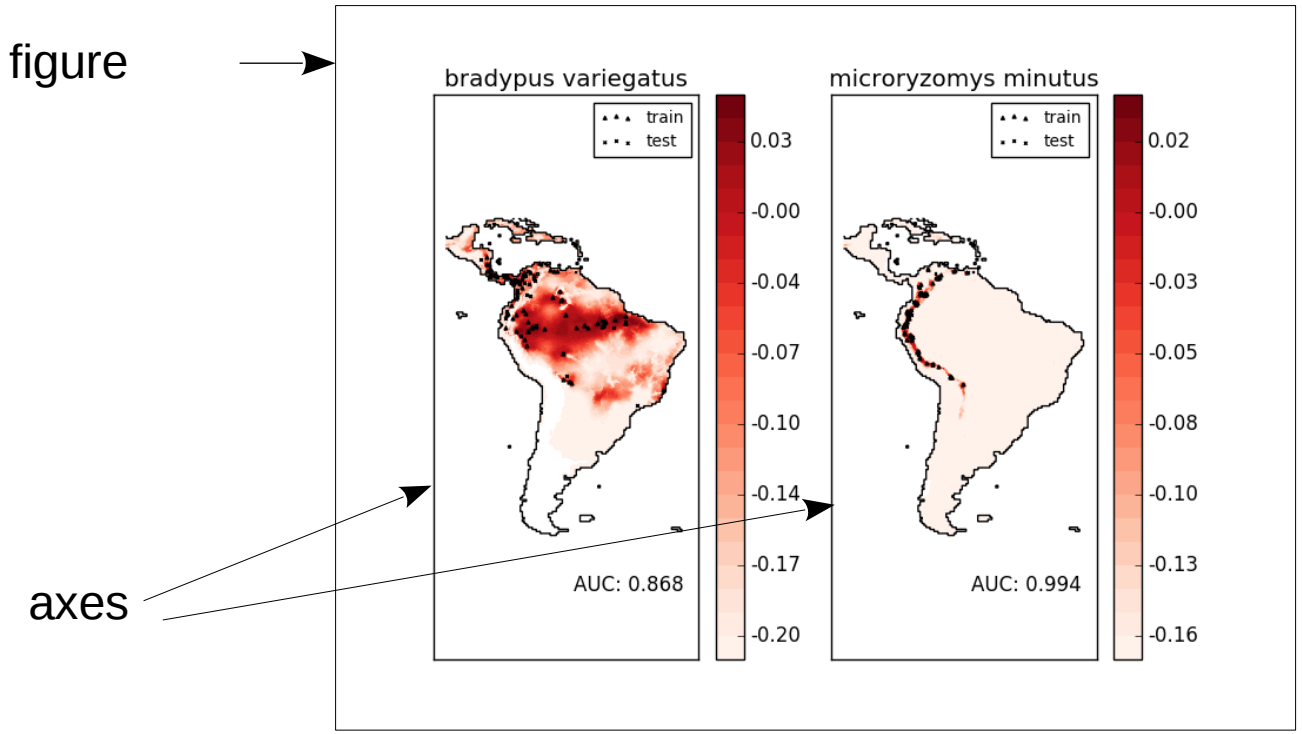
`% matplotlib notebook`

- interactive widget
- all figure features
- need to create figures explicitly
- ability to update figures

Figures and axes

figure = one window or one image file

axes = one drawing area with coordinate system



by default: each figure has one axis

Creating Figures and axes

1st way: don't.

Creates figure with axes on plot command

2nd way: **`fig = plt.figure()`**

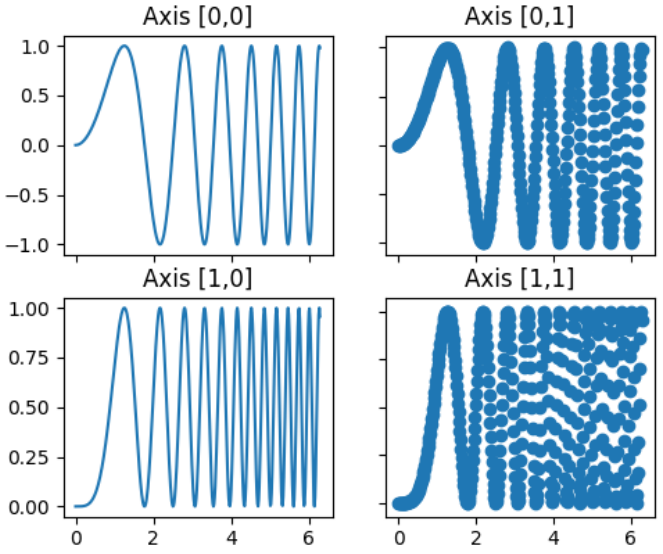
Creates a figure with axes, sets current figure.

Can add more / different axes later.

3rd way: **`fig, ax = plt.subplots(n, m)`**

Creates a figure with a regular grid

of n x m axes.

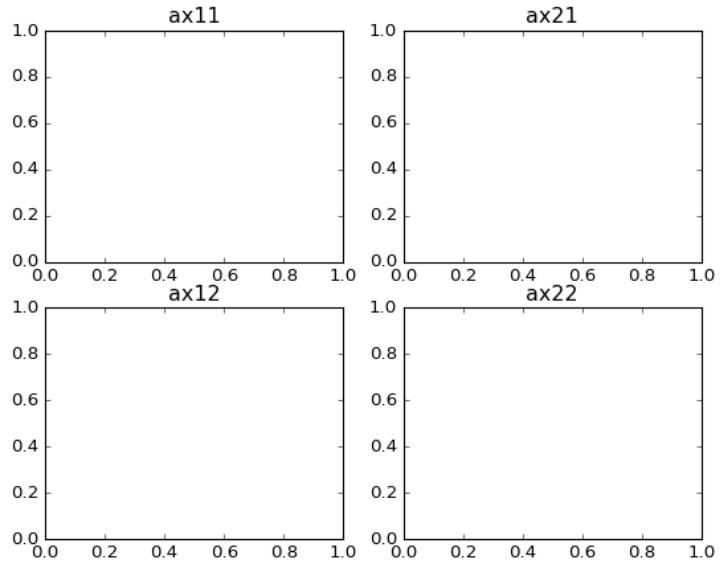


More axes via subplots

`ax = plt.subplot(n, m, i)` `# or plt.subplot(nmi)`

places ax at position “i” in n x m grid (1-based index)

```
ax11 = plt.subplot(2, 2, 1)
ax21 = plt.subplot(2, 2, 2)
ax12 = plt.subplot(2, 2, 3)
ax22 = plt.subplot(2, 2, 4)
```



equivalent:

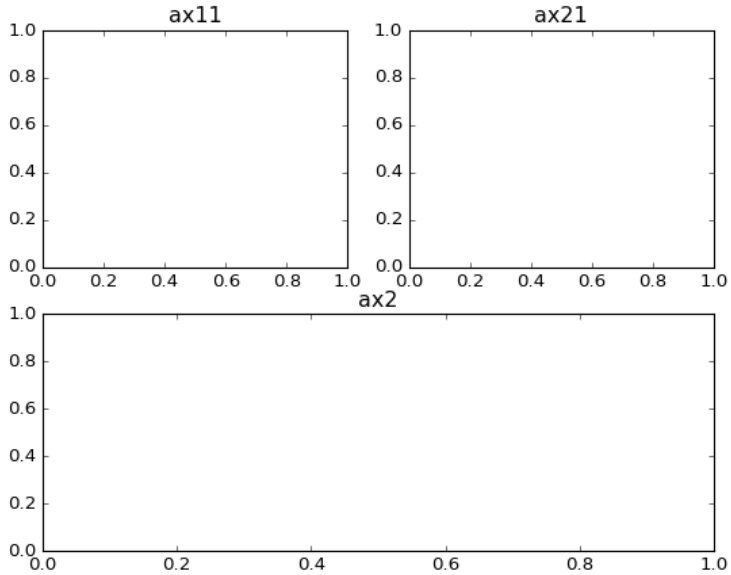
```
fig, axes = plt.subplots(2, 2)
ax11, ax21, ax12, ax22 = axes.ravel()
```

More axes via subplots

`ax = plt.subplot(n, m, i)` `# or plt.subplot(nmi)`

places ax at position “i” in n x m grid (1-based index)

```
ax11 = plt.subplot(2, 2, 1)
ax21 = plt.subplot(2, 2, 2)
ax2 = plt.subplot(2, 1, 2)
```

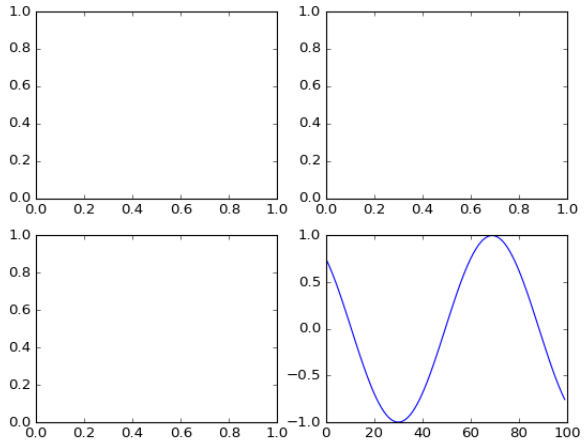


Two interfaces

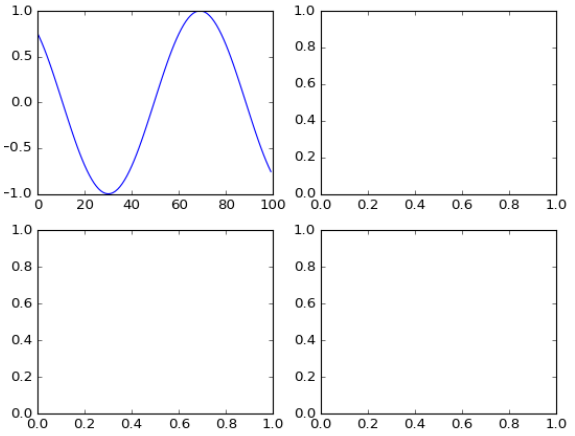
Stateful interface - applies to current figure and axes

object oriented interface - explicitly use object

```
sin = np.sin(np.linspace(-4, 4, 100))
fig, axes = plt.subplots(2, 2)
plt.plot(sin)
```



```
fig, axes = plt.subplots(2, 2)
axes[0, 0].plot(sin)
```



Differences between interfaces

Stateful	Object oriented
`plt.title`	`ax.set_title`
`plt.xlim, plt.ylim`	`ax.set_xlim, ax.set_ylim`
`plt.xlabel, plt.ylabel`	`ax.set_xlabel, ax.set_ylabel`
`plt.xticks, plt.yticks`	`ax.set_xticks, ax.set_yticks` (& `ax.set_xtick_labels`)

```
ax = plt.gca()   # get current axes
fig = plt.gcf()  # get current figure
```

Plotting commands

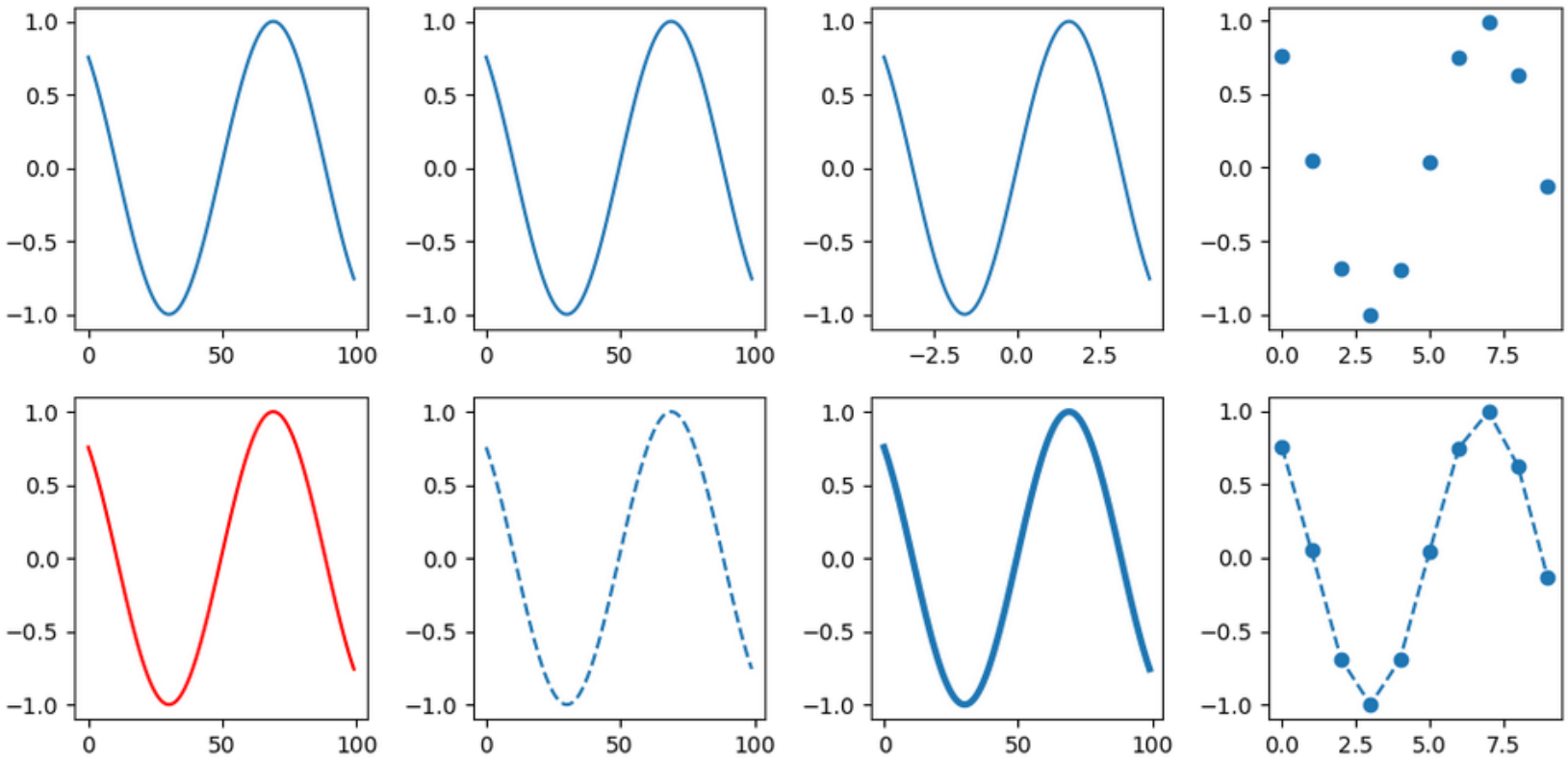
- Gallery:
  http://matplotlib.org/gallery.html

- Plotting commands summary
  http://matplotlib.org/api/pyplot_summary.html

plot

```
fig, ax = plt.subplots(2, 4, figsize=(10, 5))
ax[0, 0].plot(sin)
ax[0, 1].plot(range(100), sin)  # same as above
ax[0, 2].plot(np.linspace(-4, 4, 100), sin)
ax[0, 3].plot(sin[::10], 'o')
ax[1, 0].plot(sin, c='r')
ax[1, 1].plot(sin, '--')
ax[1, 2].plot(sin, lw=3)
ax[1, 3].plot(sin[::10], '--o')
plt.tight_layout() # makes stuff fit - usually works
```

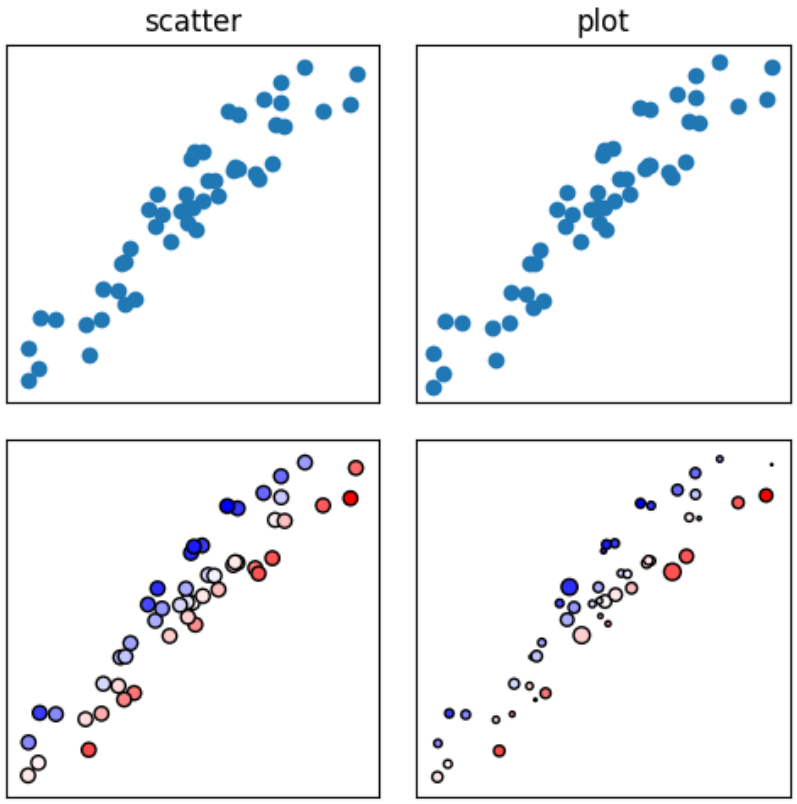
why?



scatter

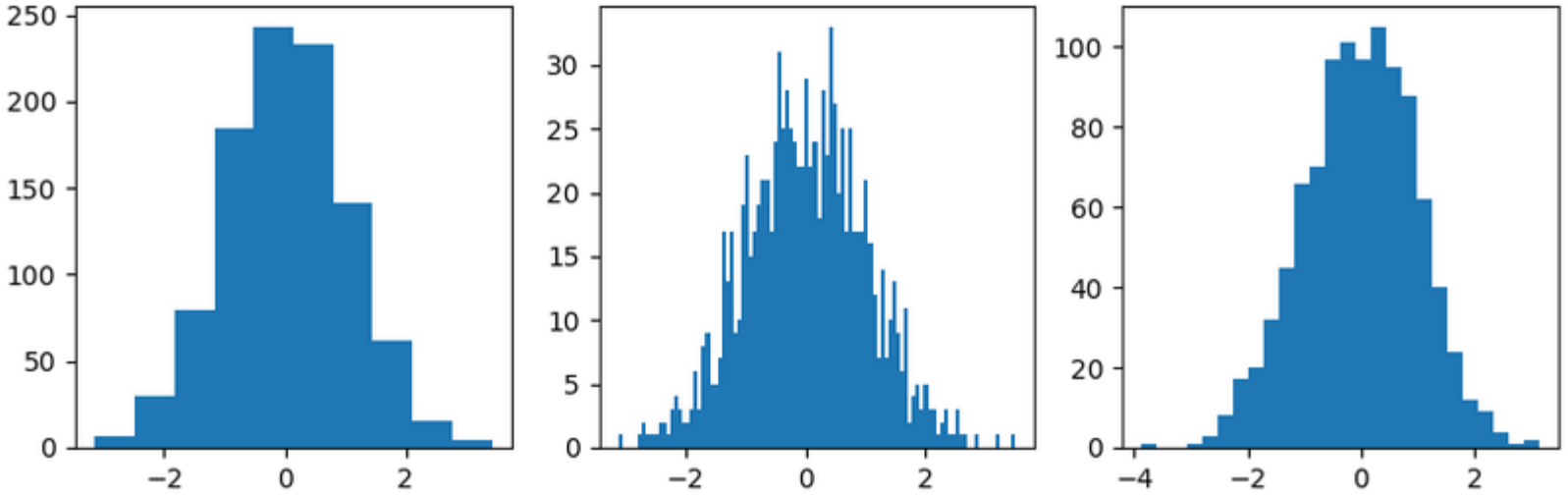
```
x = np.random.uniform(size=50)
y = x + np.random.normal(0, .1, size=50)

fig, ax = plt.subplots(2, 2, figsize=(5, 5),
                       subplot_kw={'xticks': (), 'yticks': ()})
ax[0, 0].scatter(x, y)
ax[0, 0].set_title("scatter")
ax[0, 1].plot(x, y, 'o')
ax[0, 1].set_title("plot")
ax[1, 0].scatter(x, y, c=x-y, cmap='bwr', edgecolor='k')
ax[1, 1].scatter(x, y, c=x-y, s=np.abs(np.random.normal(scale=20, size=50)), cmap='bwr', edgecolor='k')
plt.tight_layout()
```



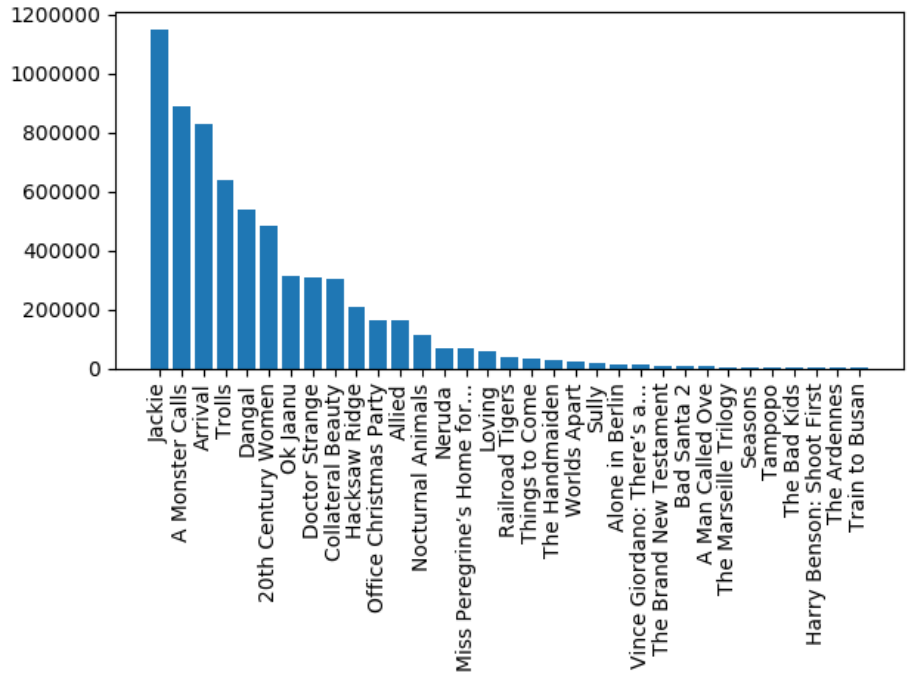
histogram

```
fig, ax = plt.subplots(1, 3, figsize=(10, 3))
ax[0].hist(np.random.normal(size=1000))
ax[1].hist(np.random.normal(size=1000), bins=100)
ax[2].hist(np.random.normal(size=1000), bins="auto")
```

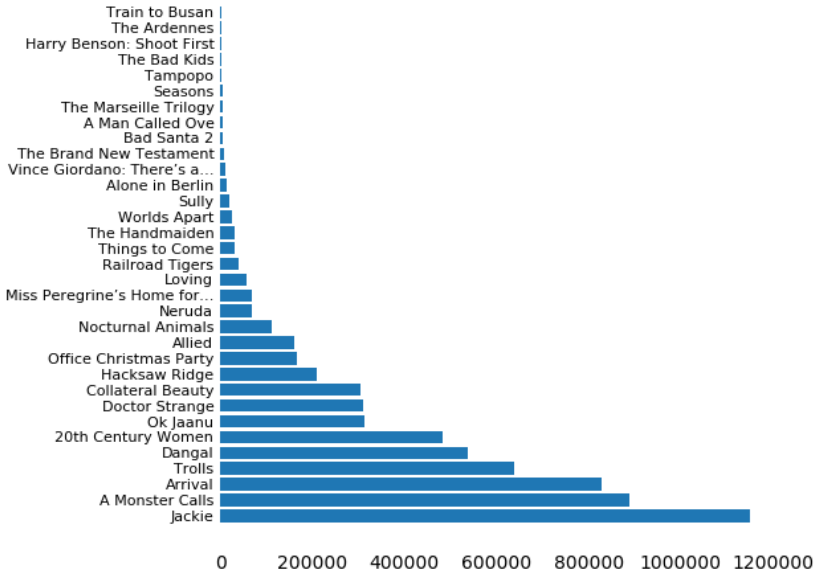


bars

```
plt.figure()
plt.bar(range(len(gross)), gross)
plt.xticks(range(len(gross)), movie, rotation=90)
plt.tight_layout()
```

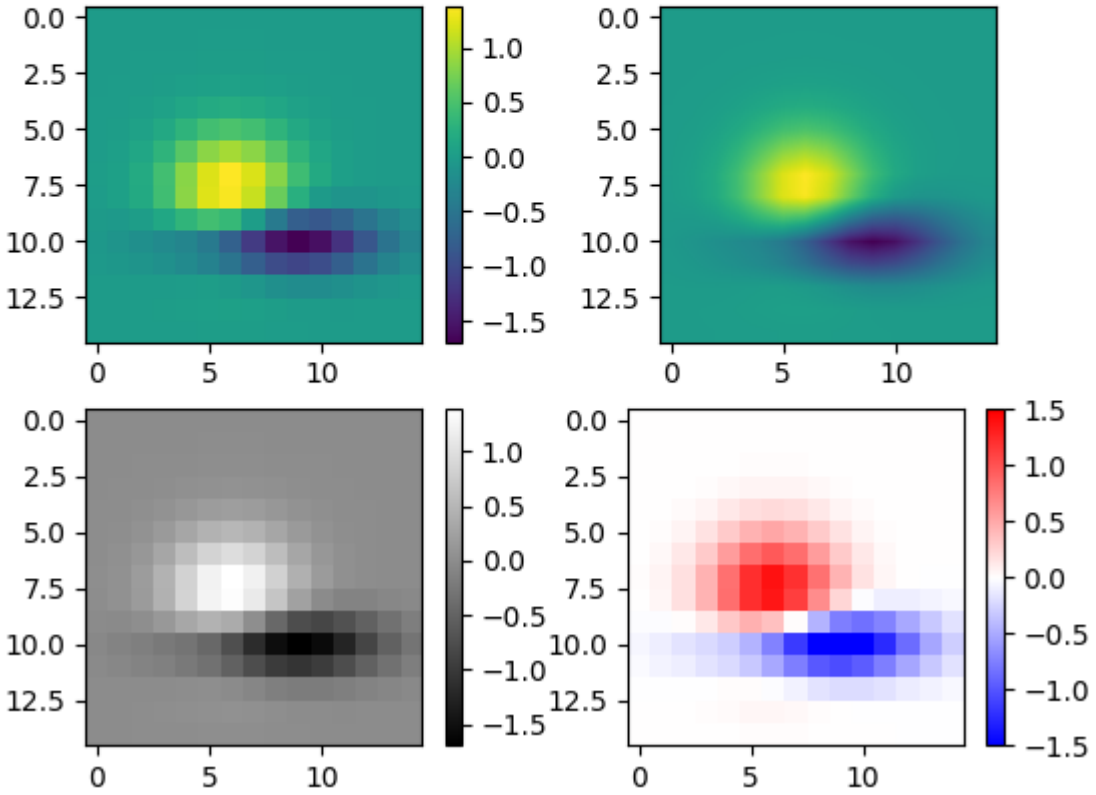



```
plt.figure()
plt.barh(range(len(gross)), gross)
plt.yticks(range(len(gross)), movie, fontsize=8)
ax = plt.gca()
ax.set_frame_on(False)
ax.tick_params(length=0)
plt.tight_layout()
```



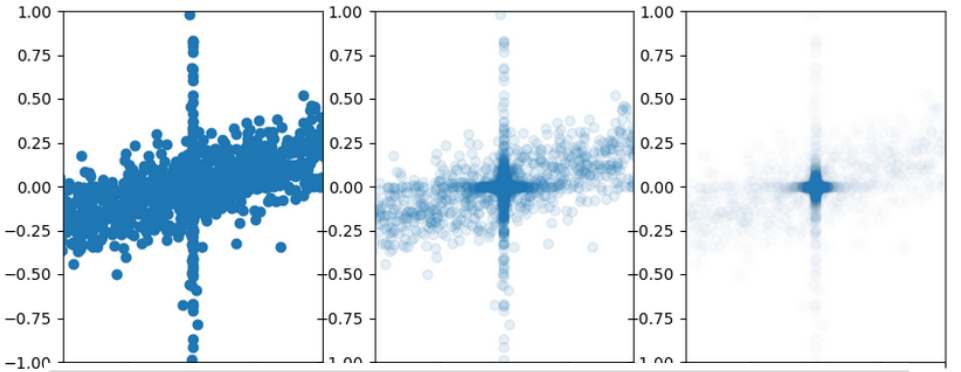
heatmaps

```
fig, ax = plt.subplots(2, 2)
im1 = ax[0, 0].imshow(arr)
ax[0, 1].imshow(arr, interpolation='bilinear')
im3 = ax[1, 0].imshow(arr, cmap='gray')
im4 = ax[1, 1].imshow(arr, cmap='bwr', vmin=-1.5, vmax=1.5)
plt.colorbar(im1, ax=ax[0, 0])
plt.colorbar(im3, ax=ax[1, 0])
plt.colorbar(im4, ax=ax[1, 1])
```

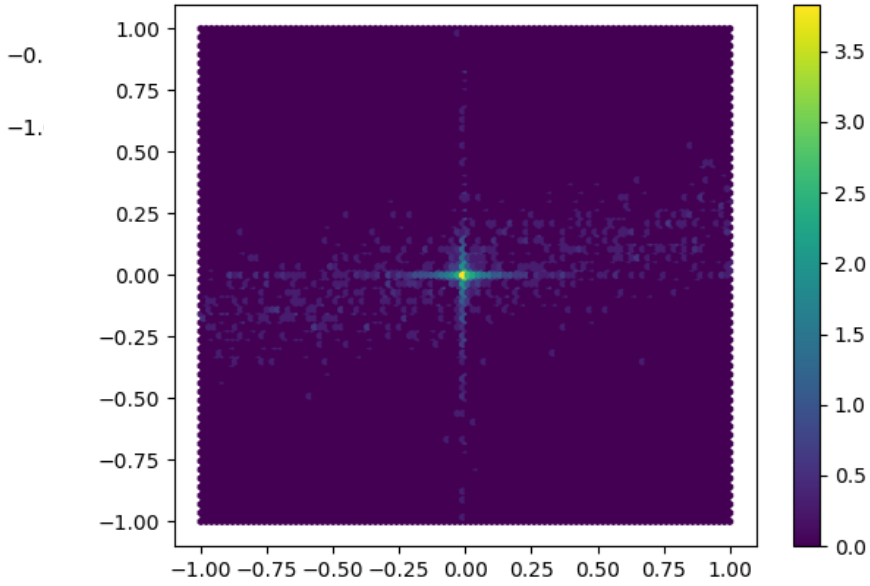


hexgrids

```
fig, ax = plt.subplots(1, 3, figsize=(10, 4),
                       subplot_kw={'xlim': (-1, 1),
                                   'ylim': (-1, 1)})
ax[0].scatter(x, y)
ax[1].scatter(x, y, alpha=.1)
ax[2].scatter(x, y, alpha=.01)
```




```
plt.figure()
plt.hexbin(x, y, bins='log', extent=(-1, 1, -1, 1))
plt.colorbar()
```



Twin x / twiny

```
plt.figure()
ax1 = plt.gca()
line1, = ax1.plot(years, phds)
ax2 = ax1.twinx()
line2, = ax2.plot(years, revenue, c='r')
plt.legend((line1, line2), ("math PhDs awarded", "revenue by arcades"))
ax1.set_ylabel("Math PhDs awarded")
ax2.set_ylabel("revenue by arcades")
```