matplotlib
Cheat sheet
Version 3.7.4

Quick start API

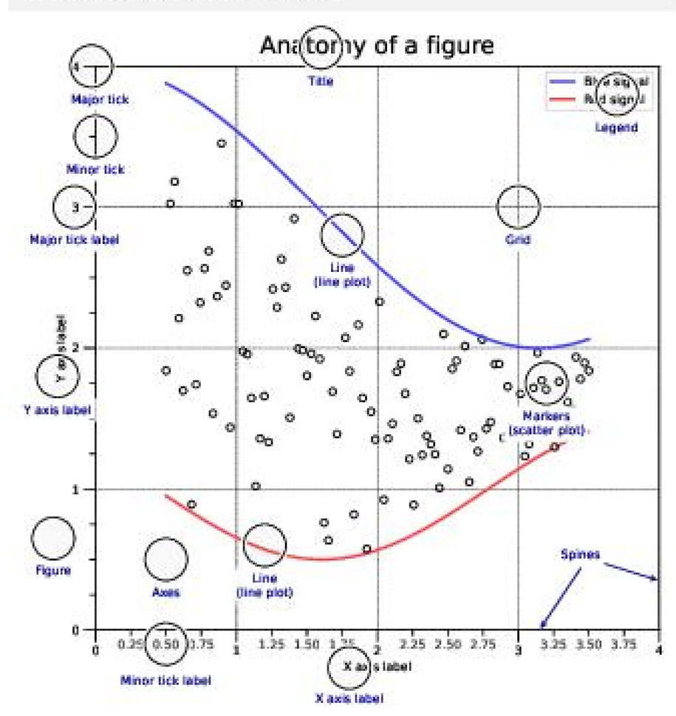
```
import numpy as np
import matplotlib as mpl
import matplotlib.pyplot as plt

X = np.linspace(0, 2*np.pi, 100)
Y = np.cos(X)

fig, ax = plt.subplots()
ax.plot(X, Y, color='green')

fig.savefig("figure.pdf")
plt.show()
```

Anatomy of a figure



Subplots layout API

subplot[s](rows, cols, …)
fig, axs = plt.subplots(3, 3)

G = gridspec(rows,cols, …)
ax = G[0, :]

ax.inset_axes(extent)

d=make_axes_locatable(ax)
ax = d.new_horizontal('10%')

Getting help

- matplotlib.org
- github.com/matplotlib/matplotlib/issues
- discourse.matplotlib.org
- stackoverflow.com/questions/tagged/matplotlib
- https://gitter.im/matplotlib/matplotlib
- twitter.com/matplotlib
- Matplotlib users mailing list

Basic plots

plot([X], Y, [fmt], …) API
X, Y, fmt, color, marker, linestyle

scatter(X, Y, …) API
X, Y, [s]izes, [c]olors, marker, cmap

bar[h](x, height, …) API
x, height, width, bottom, align, color

imshow(Z, …) API
Z, cmap, interpolation, extent, origin

contour[f]([X], [Y], Z, …) API
X, Y, Z, levels, colors, extent, origin

pcolormesh([X], [Y], Z, …) API
X, Y, Z, vmin, vmax, cmap

quiver([X], [Y], U, V, …) API
X, Y, U, V, C, units, angles

pie(X, …) API
Z, explode, labels, colors, radius

text(x, y, text, …) API
x, y, text, va, ha, size, weight, transform

fill[_between][x](…) API
X, Y1, Y2, color, where

Advanced plots

step(X, Y, [fmt], …) API
X, Y, fmt, color, marker, where

boxplot(X, …) API
X, notch, sym, bootstrap, widths

errorbar(X,Y,xerr,yerr, …) API
X, Y, xerr, yerr, fmt

hist(X, bins, …) API
X, bins, range, density, weights

violinplot(D, …) API
D, positions, widths, vert

barbs([X], [Y], U, V, …) API
X, Y, U, V, C, length, pivot, sizes

eventplot(positions, …) API
positions, orientation, lineoffsets

hexbin(X, Y, C, …) API
X, Y, C, gridsize, bins

Scales API

ax.set_[xy]scale(scale, …)
- linear: any values
- log: values > 0
- symlog: any values
- logit: 0 < values < 1

Projections API

subplot(…, projection=p)
p='polar'
p='3d' API
p=ccrs.Orthographic() API
import cartopy.crs as ccrs

Lines API

linestyle or ls
"-" ":" "--" "-." (0,(0.01,2))

capstyle or dash_capstyle
"butt" "round" "projecting"

Markers API

'.' 'o' 's' 'P' 'X' '*' 'p' 'D' '<' '>' '^' 'v'
'1' '2' '3' '4' '+' 'x' '|' '_' 4 5 6 7
'$♠$' '$♣$' '$♥$' '$♦$' '$→$' '$←$' '$↑$' '$↓$' '$◐$' '$◑$' '$◒$' '$◓$'

markevery
10 [0, -1] (25, 5) [0, 25, -1]

Colors API

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	'Cn'
b	g	r	c	m	y	k	w			'x'
DarkRed	Firebrick	Crimson	IndianRed	Salmon						'name'
(1,0,0)	(1,0,0,0.75)	(1,0,0,0.5)	(1,0,0,0.25)							(R,G,B[,A])
#FF0000	#FF0000BB	#FF000088	#FF000044							'#RRGGBB[AA]'
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0 'x.y'

Colormaps API

plt.get_cmap(name)

Uniform: viridis, magma, plasma
Sequential: Greys, YlOrBr, Wistia
Diverging: Spectral, coolwarm, RdGy
Qualitative: tab10, tab20
Cyclic: twilight

Tick locators API

```
from matplotlib import ticker
ax.[xy]axis.set_[minor|major]_locator(locator)
```

ticker.NullLocator()
ticker.MultipleLocator(0.5)
ticker.FixedLocator([0, 1, 5])
ticker.LinearLocator(numticks=3)
ticker.IndexLocator(base=0.5, offset=0.25)
ticker.AutoLocator()
ticker.MaxNLocator(n=4)
ticker.LogLocator(base=10, numticks=15)

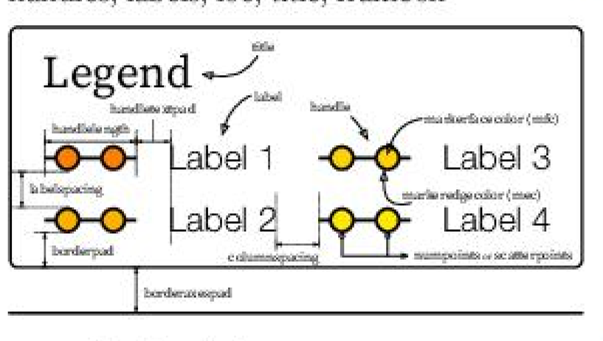
Tick formatters API

```
from matplotlib import ticker
ax.[xy]axis.set_[minor|major]_formatter(formatter)
```

ticker.NullFormatter()
ticker.FixedFormatter(['zero', 'one', 'two', …])
ticker.FuncFormatter(lambda x, pos: "[%.2f]" % x)
ticker.FormatStrFormatter('>%d<')
ticker.ScalarFormatter()
ticker.StrMethodFormatter('{x}')
ticker.PercentFormatter(xmax=5)

Ornaments

ax.legend(…) API
handles, labels, loc, title, frameon



ax.colorbar(…) API
mappable, ax, cax, orientation

ax.annotate(…) API
text, xy, xytext, xycoords, textcoords, arrowprops

text → xy
xytext textcoords xycoords

Event handling API

```
fig, ax = plt.subplots()
def on_click(event):
  print(event)
fig.canvas.mpl_connect(
  'button_press_event', on_click)
```

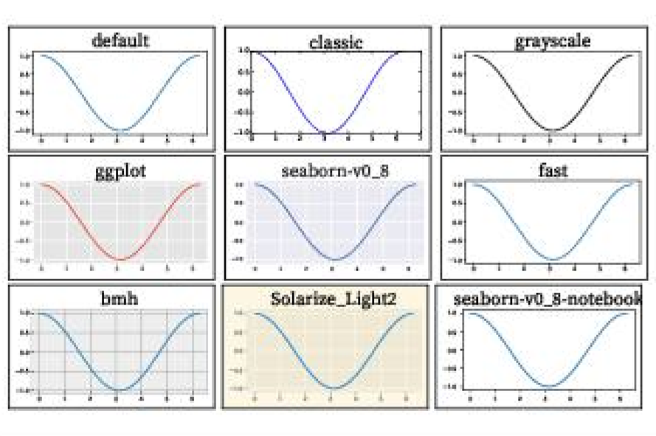
Animation API

```
import matplotlib.animation as mpla

T = np.linspace(0, 2*np.pi, 100)
S = np.sin(T)
line, = plt.plot(T, S)
def animate(i):
    line.set_ydata(np.sin(T+i/50))
anim = mpla.FuncAnimation(
    plt.gcf(), animate, interval=5)
plt.show()
```

Styles API

plt.style.use(style)



Quick reminder

```
ax.grid()
ax.set_[xy]lim(vmin, vmax)
ax.set_[xy]label(label)
ax.set_[xy]ticks(ticks, [labels])
ax.set_[xy]ticklabels(labels)
ax.set_title(title)
ax.tick_params(width=10, …)
ax.set_axis_[on|off]()

fig.suptitle(title)
fig.tight_layout()
plt.gcf(), plt.gca()
mpl.rc('axes', linewidth=1, …)
[fig|ax].patch.set_alpha(0)
text=r'$\frac{-e^{i\pi}}{2^n}$'
```

Keyboard shortcuts API

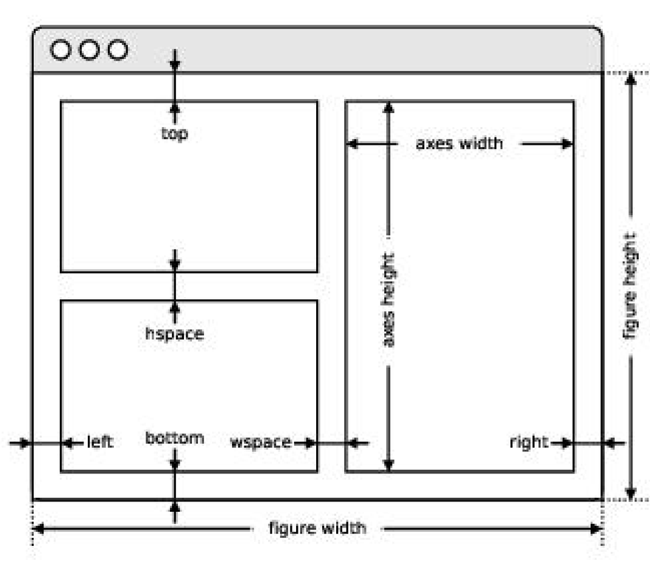
ctrl + s Save	ctrl + w Close plot
r Reset view	f Fullscreen 0/1
f View forward	b View back
p Pan view	o Zoom to rect
x X pan/zoom	y Y pan/zoom
g Minor grid 0/1	G Major grid 0/1
l X axis log/linear	L Y axis log/linear

Ten simple rules READ

1. Know your audience
2. Identify your message
3. Adapt the figure
4. Captions are not optional
5. Do not trust the defaults
6. Use color effectively
7. Do not mislead the reader
8. Avoid "chartjunk"
9. Message trumps beauty
10. Get the right tool

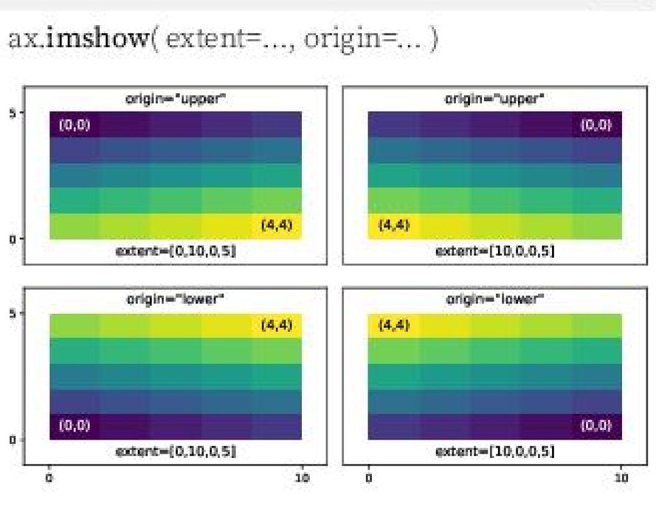
Axes adjustments API

plt.subplots_adjust(…)



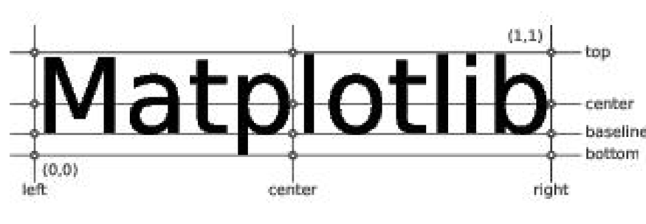
Extent & origin API

ax.imshow(extent=…, origin=…)



Text alignments API

ax.text(…, ha=… , va=…, …)



Text parameters API

ax.text(…, family=…, size=…, weight=…)
ax.text(…, fontproperties=…)

The quick brown fox	xx-large (1.73)
The quick brown fox	x-large (1.44)
The quick brown fox	large (1.20)
The quick brown fox	medium (1.00)
The quick brown fox	small (0.83)
The quick brown fox	x-small (0.69)
The quick brown fox	xx-small (0.58)
The quick brown fox jumps over the lazy dog	black (900)
The quick brown fox jumps over the lazy dog	bold (700)
The quick brown fox jumps over the lazy dog	semibold (600)
The quick brown fox jumps over the lazy dog	normal (400)
The quick brown fox jumps over the lazy dog	ultralight (100)
The quick brown fox jumps over the lazy dog	monospace
The quick brown fox jumps over the lazy dog	serif
The quick brown fox jumps over the lazy dog	sans
The quick brown fox jumps over the lazy dog	cursive
The quick brown fox jumps over the lazy dog	italic
The quick brown fox jumps over the lazy dog	normal
The quick brown fox jumps over the lazy dog	small-caps
The quick brown fox jumps over the lazy dog	normal

Uniform colormaps

viridis, plasma, inferno, magma, cividis

Sequential colormaps

Greys, Purples, Blues, Greens, Oranges, Reds, YlOrBr, YlOrRd, OrRd, PuRd, RdPu, BuPu, GnBu, PuBu, YlGnBu, PuBuGn, BuGn, YlGn

Diverging colormaps

PiYG, PRGn, BrBG, PuOr, RdGy, RdBu, RdYlBu, RdYlGn, Spectral, coolwarm, bwr, seismic

Qualitative colormaps

Pastel1, Pastel2, Paired, Accent, Dark2, Set1, Set2, Set3, tab10, tab20, tab20b, tab20c

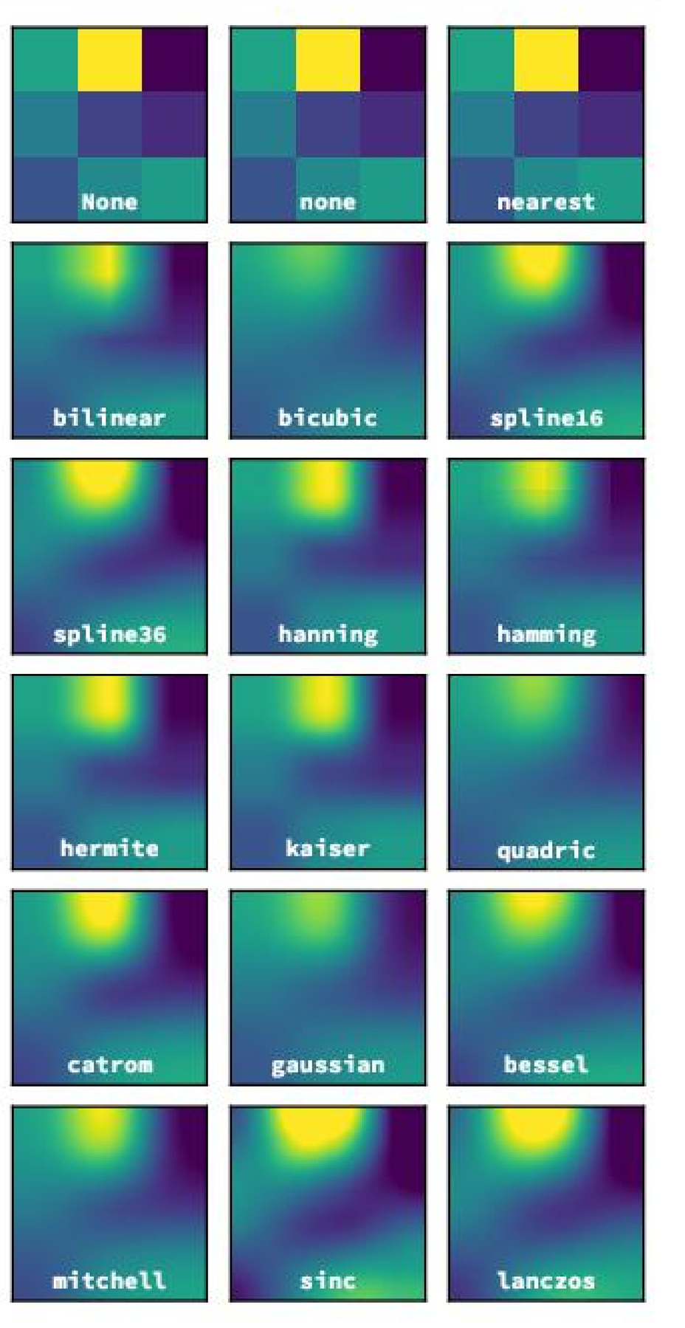
Miscellaneous colormaps

terrain, ocean, cubehelix, rainbow, twilight

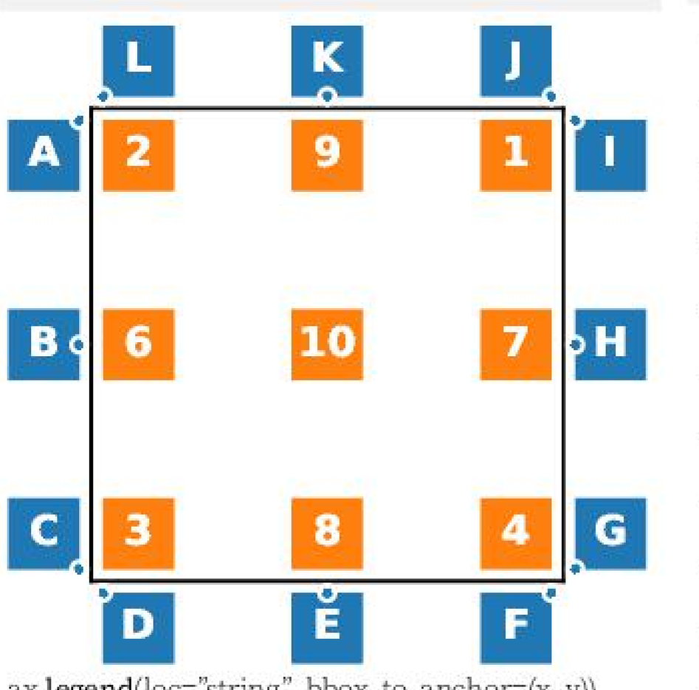
Color names API

black, k, dimgray, dimgrey, gray, grey, darkgray, darkgrey, silver, lightgray, lightgrey, gainsboro, whitesmoke, w, white, snow, rosybrown, lightcoral, indianred, brown, firebrick, maroon, darkred, r, red, mistyrose, salmon, tomato, darksalmon, coral, orangered, lightsalmon, sienna, seashell, chocolate, saddlebrown, sandybrown, peachpuff, peru, linen, bisque, darkorange, burlywood, antiquewhite, tan, navajowhite, blanchedalmond, papayawhip, moccasin, orange, wheat, oldlace, floralwhite, darkgoldenrod, goldenrod, cornsilk, gold, lemonchiffon, khaki, palegoldenrod, darkkhaki, ivory, beige, lightyellow, lightgoldenrodyellow, olive, y, yellow, olivedrab, yellowgreen, darkolivegreen, greenyellow, chartreuse, lawngreen, honeydew, darkseagreen, palegreen, lightgreen, forestgreen, limegreen, darkgreen, g, green, lime, seagreen, mediumseagreen, springgreen, mintcream, mediumspringgreen, mediumaquamarine, aquamarine, turquoise, lightseagreen, mediumturquoise, azure, lightcyan, paleturquoise, darkslategray, darkslategrey, teal, darkcyan, c, aqua, cyan, darkturquoise, cadetblue, powderblue, lightblue, deepskyblue, skyblue, lightskyblue, steelblue, aliceblue, dodgerblue, lightslategray, lightslategrey, slategray, slategrey, lightsteelblue, cornflowerblue, royalblue, ghostwhite, lavender, midnightblue, navy, darkblue, mediumblue, b, blue, slateblue, darkslateblue, mediumslateblue, mediumpurple, rebeccapurple, blueviolet, indigo, darkorchid, darkviolet, mediumorchid, thistle, plum, violet, purple, darkmagenta, m, fuchsia, magenta, orchid, mediumvioletred, deeppink, hotpink, lavenderblush, palevioletred, crimson, pink, lightpink

Image interpolation API



Legend placement

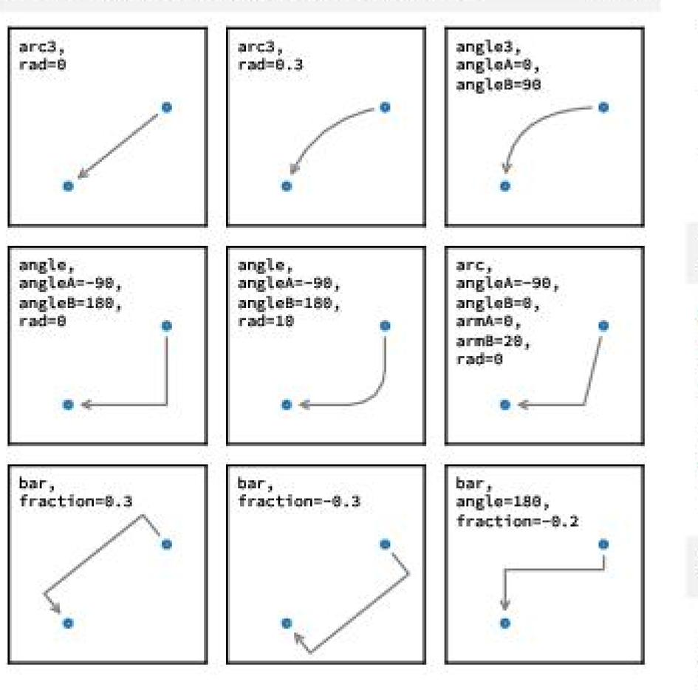


ax.legend(loc="string", bbox_to_anchor=(x, y))

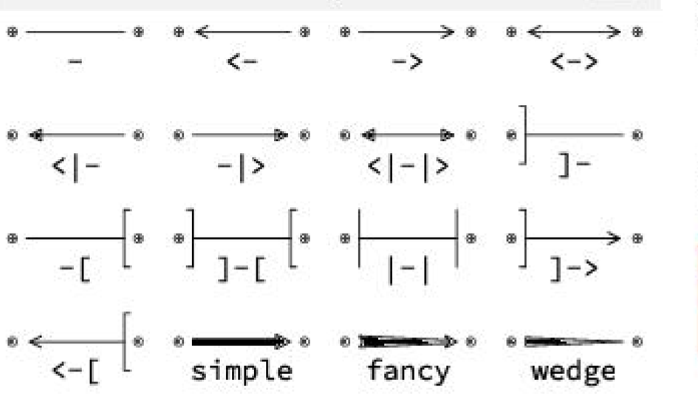
2: upper left	9: upper center	1: upper right
6: center left	10: center	7: center right
3: lower left	8: lower center	4: lower right

A: upper right / (-0.1, 0.9)	B: center right / (-0.1, 0.5)
C: lower right / (-0.1, 0.1)	D: upper left / (0.1, -0.1)
E: upper center / (0.5, -0.1)	F: upper right / (0.9, -0.1)
G: lower left / (1.1, 0.1)	H: center left / (1.1, 0.5)
I: upper left / (1.1, 0.9)	J: lower right / (0.9, 1.1)
K: lower center / (0.5, 1.1)	L: lower left / (0.1, 1.1)

Annotation connection styles API



Annotation arrow styles API



How do I …

… resize a figure?
→ fig.set_size_inches(w, h)
… save a figure?
→ fig.savefig("figure.pdf")
… save a transparent figure?
→ fig.savefig("figure.pdf", transparent=True)
… clear a figure/an axes?
→ fig.clear() → ax.clear()
… close all figures?
→ plt.close("all")
… remove ticks?
→ ax.set_[xy]ticks([])
… remove tick labels ?
→ ax.set_[xy]ticklabels([])
… rotate tick labels ?
→ ax.tick_params(axis="x", rotation=90)
… hide top spine?
→ ax.spines['top'].set_visible(False)
… hide legend border?
→ ax.legend(frameon=False)
… show error as shaded region?
→ ax.fill_between(X, Y+error, Y-error)
… draw a rectangle?
→ ax.add_patch(plt.Rectangle((0, 0), 1, 1)
… draw a vertical line?
→ ax.axvline(x=0.5)
… draw outside frame?
→ ax.plot(…, clip_on=False)
… use transparency?
→ ax.plot(…, alpha=0.25)
… convert an RGB image into a gray image?
→ gray = 0.2989*R + 0.5870*G + 0.1140*B
… set figure background color?
→ fig.patch.set_facecolor("grey")
… get a reversed colormap?
→ plt.get_cmap("viridis_r")
… get a discrete colormap?
→ plt.get_cmap("viridis", 10)
… show a figure for one second?
→ fig.show(block=False), time.sleep(1)

Performance tips

scatter(X, Y)	slow
plot(X, Y, marker="o", ls="")	fast
for i in range(n): plot(i, X[i], "o")	slow
plot(X, marker="o", ls="")	fast
cla(); imshow(…); canvas.draw()	slow
im.set_data(…); canvas.draw()	fast

Beyond Matplotlib

Seaborn: Statistical data visualization
Cartopy: Geospatial data processing
yt: Volumetric data visualization
mpld3: Bringing Matplotlib to the browser
Datashader: Large data processing pipeline
plotnine: A grammar of graphics for Python

NUMFOCUS
OPEN CODE = BETTER SCIENCE

Matplotlib for beginners

Matplotlib is a library for making 2D plots in Python. It is designed with the philosophy that you should be able to create simple plots with just a few commands:

1 Initialize

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

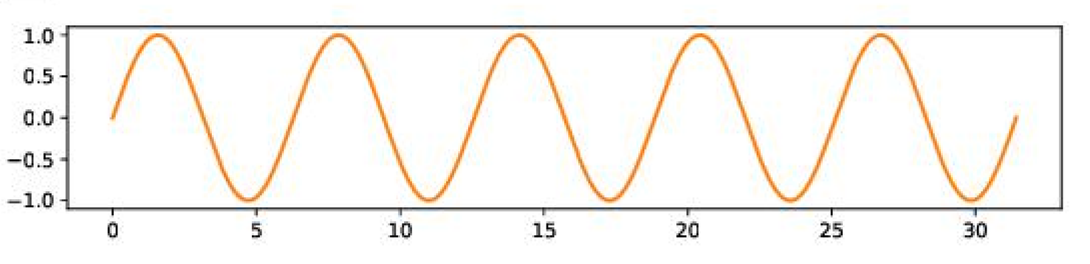
2 Prepare

```
X = np.linspace(0, 10*np.pi, 1000)
Y = np.sin(X)
```

3 Render

```
fig, ax = plt.subplots()
ax.plot(X, Y)
plt.show()
```

4 Observe



Choose

Matplotlib offers several kind of plots (see Gallery):

```
X = np.random.uniform(0, 1, 100)
Y = np.random.uniform(0, 1, 100)
ax.scatter(X, Y)
```

```
X = np.arange(10)
Y = np.random.uniform(1, 10, 10)
ax.bar(X, Y)
```

```
Z = np.random.uniform(0, 1, (8, 8))

ax.imshow(Z)
```

```
Z = np.random.uniform(0, 1, (8, 8))

ax.contourf(Z)
```

```
Z = np.random.uniform(0, 1, 4)

ax.pie(Z)
```

```
Z = np.random.normal(0, 1, 100)

ax.hist(Z)
```

```
X = np.arange(5)
Y = np.random.uniform(0, 1, 5)
ax.errorbar(X, Y, Y/4)
```

```
Z = np.random.normal(0, 1, (100, 3))

ax.boxplot(Z)
```

Tweak

You can modify pretty much anything in a plot, including limits, colors, markers, line width and styles, ticks and ticks labels, titles, etc.

```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, color="black")
```

```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, linestyle="--")
```

```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, linewidth=5)
```

```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, marker="o")
```

Organize

You can plot several data on the same figure, but you can also split a figure in several subplots (named *Axes*):

```
X = np.linspace(0, 10, 100)
Y1, Y2 = np.sin(X), np.cos(X)
ax.plot(X, Y1, X, Y2)
```

```
fig, (ax1, ax2) = plt.subplots(2, 1)
ax1.plot(X, Y1, color="C1")
ax2.plot(X, Y2, color="C0")
```

```
fig, (ax1, ax2) = plt.subplots(1, 2)
ax1.plot(Y1, X, color="C1")
ax2.plot(Y2, X, color="C0")
```

Label (everything)

```
ax.plot(X, Y)
fig.suptitle(None)
ax.set_title("A Sine wave")
```

```
ax.plot(X, Y)
ax.set_ylabel(None)
ax.set_xlabel("Time")
```

Explore

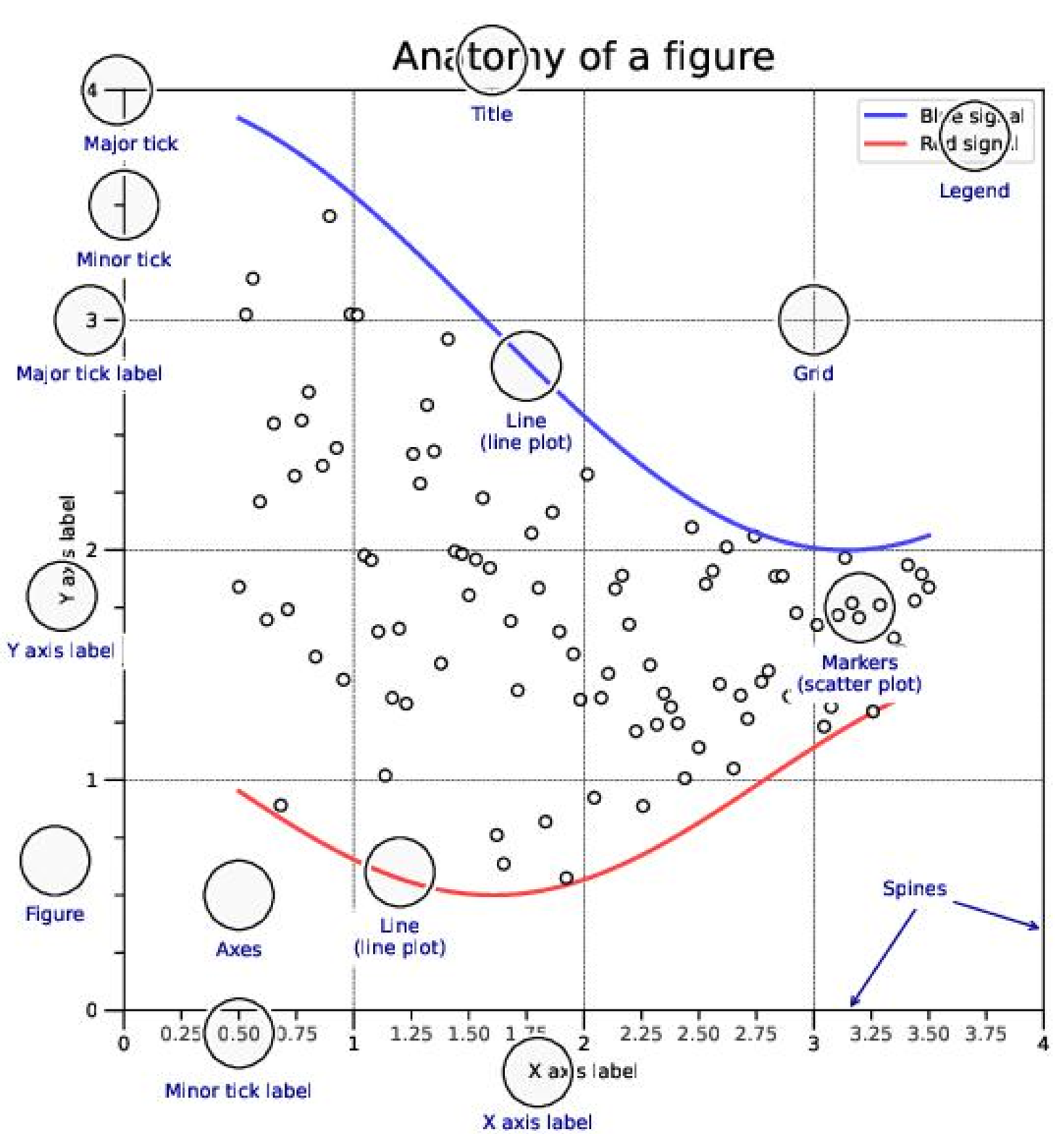
Figures are shown with a graphical user interface that allows to zoom and pan the figure, to navigate between the different views and to show the value under the mouse.

Save (bitmap or vector format)

```
fig.savefig("my-first-figure.png", dpi=300)
fig.savefig("my-first-figure.pdf")
```


Matplotlib for intermediate users

A matplotlib figure is composed of a hierarchy of elements that forms the actual figure. Each element can be modified.



Figure, axes & spines

```
fig, axs = plt.subplots(3, 3)
axs[0, 0].set_facecolor("#ddddff")
axs[2, 2].set_facecolor("#ffffdd")
```

```
gs = fig.add_gridspec(3, 3)
ax = fig.add_subplot(gs[0, :])
ax.set_facecolor("#ddddff")
```

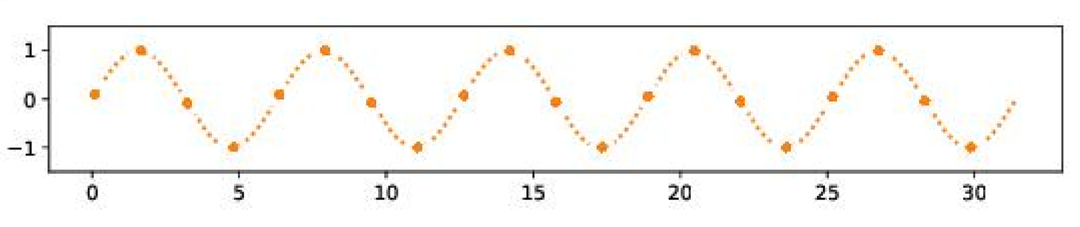
```
fig, ax = plt.subplots()
ax.spines["top"].set_color("None")
ax.spines["right"].set_color("None")
```

Ticks & labels

```
from mpl.ticker import MultipleLocator as ML
from mpl.ticker import ScalarFormatter as SF
ax.xaxis.set_minor_locator(ML(0.2))
ax.xaxis.set_minor_formatter(SF())
ax.tick_params(axis='x',which='minor',rotation=90)
```

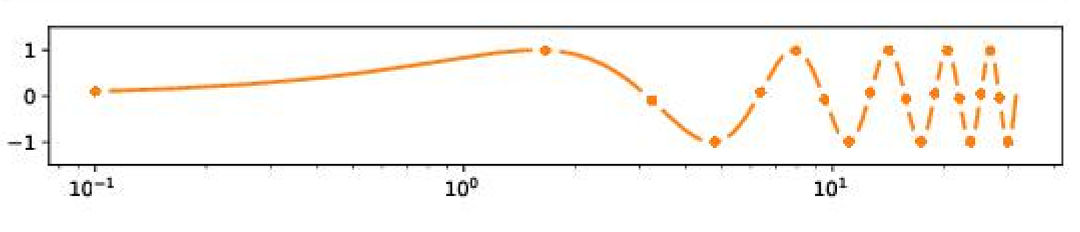
Lines & markers

```
X = np.linspace(0.1, 10*np.pi, 1000)
Y = np.sin(X)
ax.plot(X, Y, "C1o:", markevery=50, mec="1.0")
```



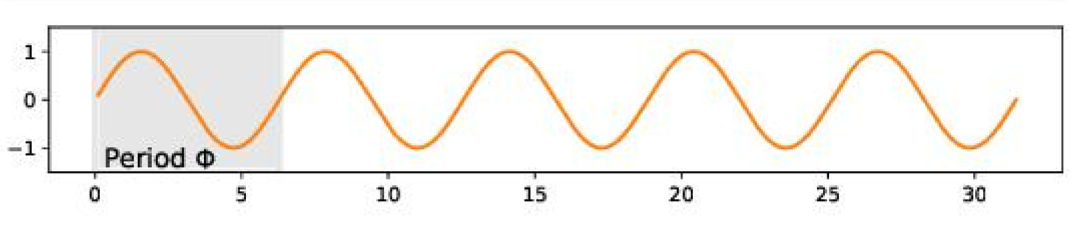
Scales & projections

```
fig, ax = plt.subplots()
ax.set_xscale("log")
ax.plot(X, Y, "C1o-", markevery=50, mec="1.0")
```



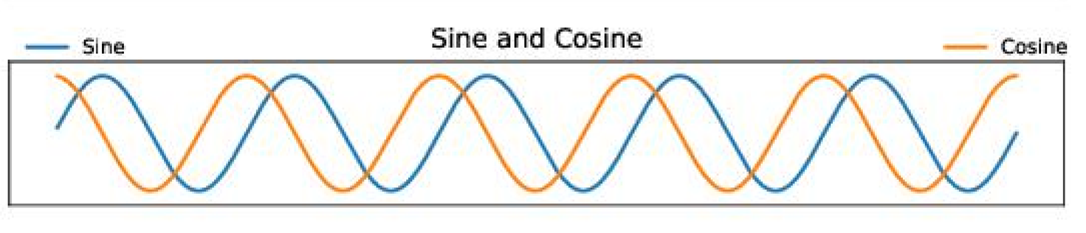
Text & ornaments

```
ax.fill_betweenx([-1, 1], [0], [2*np.pi])
ax.text(0, -1, r" Period $\Phi$")
```



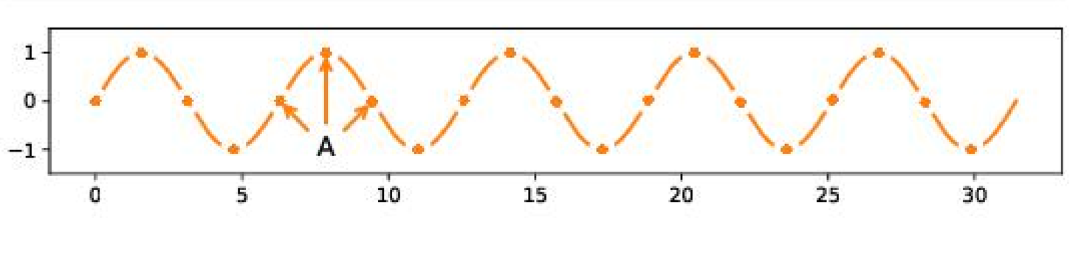
Legend

```
ax.plot(X, np.sin(X), "C0", label="Sine")
ax.plot(X, np.cos(X), "C1", label="Cosine")
ax.legend(bbox_to_anchor=(0,1,1,.1), ncol=2,
          mode="expand", loc="lower left")
```



Annotation

```
ax.annotate("A", (X[250],Y[250]), (X[250],-1),
  ha="center", va="center", arrowprops={
    "arrowstyle": "->", "color": "C1"})
```



Colors

Any color can be used, but Matplotlib offers sets of colors:

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Size & DPI

Consider a square figure to be included in a two-column A4 paper with 2 cm margins on each side and a column separation of 1 cm. The width of a figure is (21 - 2*2 - 1)/2 = 8 cm. One inch being 2.54 cm, figure size should be 3.15×3.15 in.

```
fig = plt.figure(figsize=(3.15, 3.15), dpi=50)
plt.savefig("figure.pdf", dpi=600)
```


Matplotlib tips & tricks

Transparency

Scatter plots can be enhanced by using transparency (alpha) in order to show area with higher density. Multiple scatter plots can be used to delineate a frontier.

```
X = np.random.normal(-1, 1, 500)
Y = np.random.normal(-1, 1, 500)
ax.scatter(X, Y, 50, "0.0", lw=2) # optional
ax.scatter(X, Y, 50, "1.0", lw=0) # optional
ax.scatter(X, Y, 40, "C1", lw=0, alpha=0.1)
```

Rasterization

If your figure has many graphical elements, such as a huge scatter, you can rasterize them to save memory and keep other elements in vector format.

```
X = np.random.normal(-1, 1, 10_000)
Y = np.random.normal(-1, 1, 10_000)
ax.scatter(X, Y, rasterized=True)
fig.savefig("rasterized-figure.pdf", dpi=600)
```

Offline rendering

Use the Agg backend to render a figure directly in an array.

```
from matplotlib.backends.backend_agg import FigureCanvas
canvas = FigureCanvas(Figure()))
... # draw some stuff
canvas.draw()
Z = np.array(canvas.renderer.buffer_rgba())
```

Range of continuous colors

You can use colormap to pick from a range of continuous colors.

```
X = np.random.randn(1000, 4)
cmap = plt.get_cmap("Oranges")
colors = cmap([0.2, 0.4, 0.6, 0.8])

ax.hist(X, 2, histtype='bar', color=colors)
```

Text outline

Use text outline to make text more visible.

```
import matplotlib.patheffects as fx
text = ax.text(0.5, 0.1, "Label")
text.set_path_effects([
  fx.Stroke(linewidth=3, foreground='1.0'),
  fx.Normal()])
```

Multiline plot

You can plot several lines at once using *None* as separator.

```
X,Y = [], []
for x in np.linspace(0, 10*np.pi, 100):
  X.extend([x, x, None]), Y.extend([0, sin(x), None])
ax.plot(X, Y, "black")
```

Dotted lines

To have rounded dotted lines, use a custom `linestyle` and modify `dash_capstyle`.

```
ax.plot([0, 1], [0, 0], "C1",
        linestyle=(0, (0.01, 1)), dash_capstyle="round")
ax.plot([0, 1], [1, 1], "C1",
        linestyle=(0, (0.01, 2)), dash_capstyle="round")
```

Combining axes

You can use overlaid axes with different projections.

```
ax1 = fig.add_axes([0, 0, 1, 1],
                   label="cartesian")
ax2 = fig.add_axes([0, 0, 1, 1],
                   label="polar",
                   projection="polar")
```

Colorbar adjustment

You can adjust a colorbar's size when adding it.

```
im = ax.imshow(Z)

cb = plt.colorbar(im,
        fraction=0.046, pad=0.04)
cb.set_ticks([])
```

Taking advantage of typography

You can use a condensed font such as Roboto Condensed to save space on tick labels.

```
for tick in ax.get_xticklabels(which='both'):
    tick.set_fontname("Roboto Condensed")
```

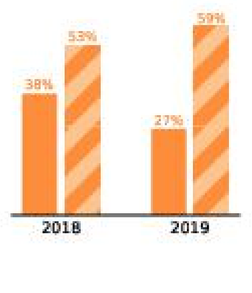
Getting rid of margins

Once your figure is finished, you can call `tight_layout()` to remove white margins. If there are remaining margins, you can use the `pdfcrop` utility (comes with TeX live).

Hatching

You can achieve a nice visual effect with thick hatch patterns.

```
cmap = plt.get_cmap("Oranges")
plt.rcParams['hatch.color'] = cmap(0.2)
plt.rcParams['hatch.linewidth'] = 8
ax.bar(X, Y, color=cmap(0.6), hatch="/")
```



Read the documentation

Matplotlib comes with an extensive documentation explaining the details of each command and is generally accompanied by examples. Together with the huge online gallery, this documentation is a gold-mine.