The moon-coverage

A python tool for mission and instrument planning

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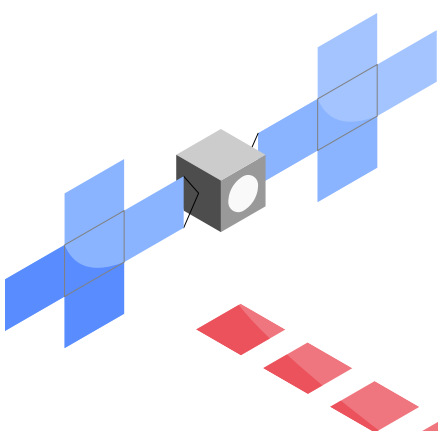

PSIDA 2022

This presentation

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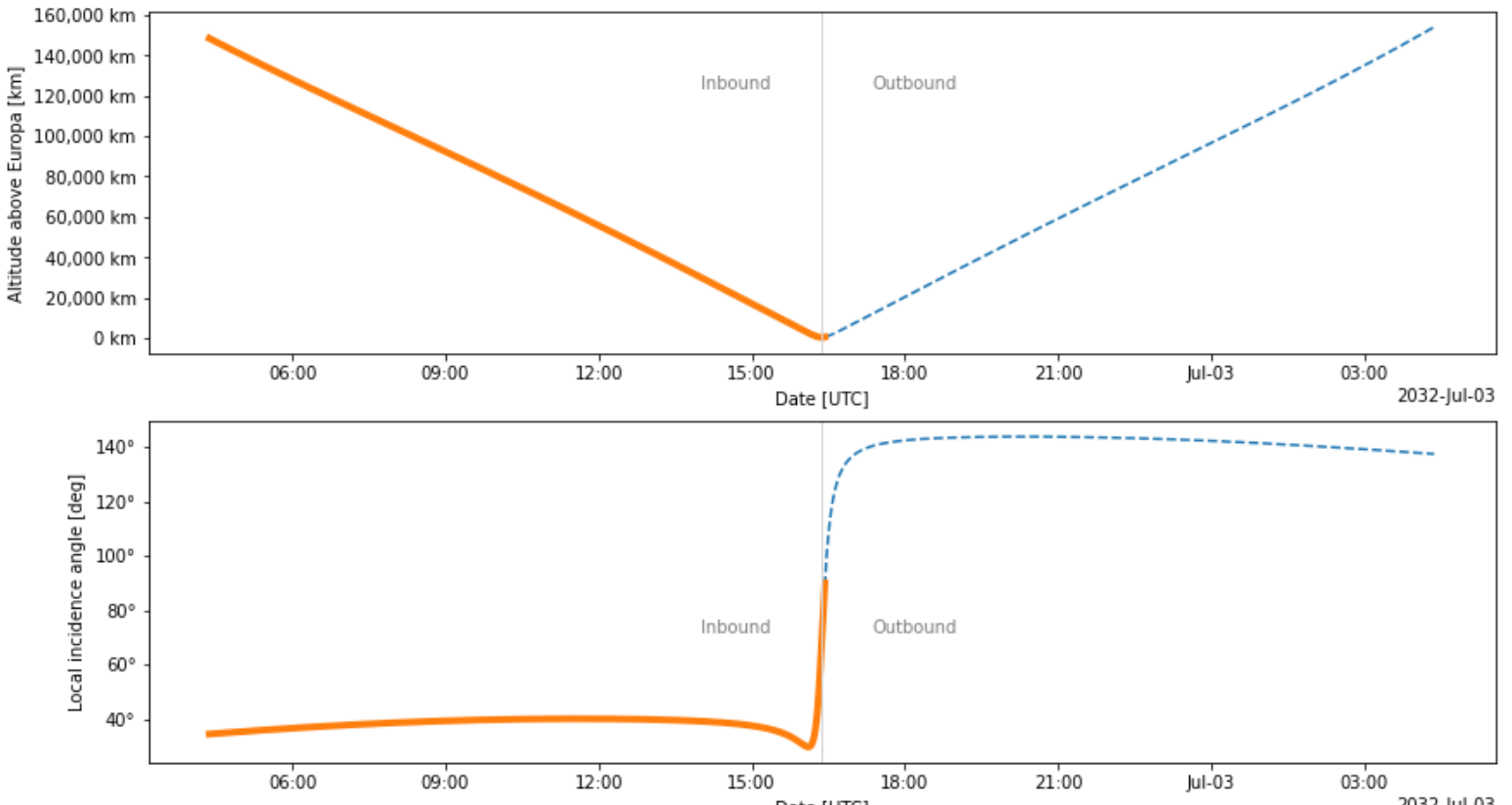
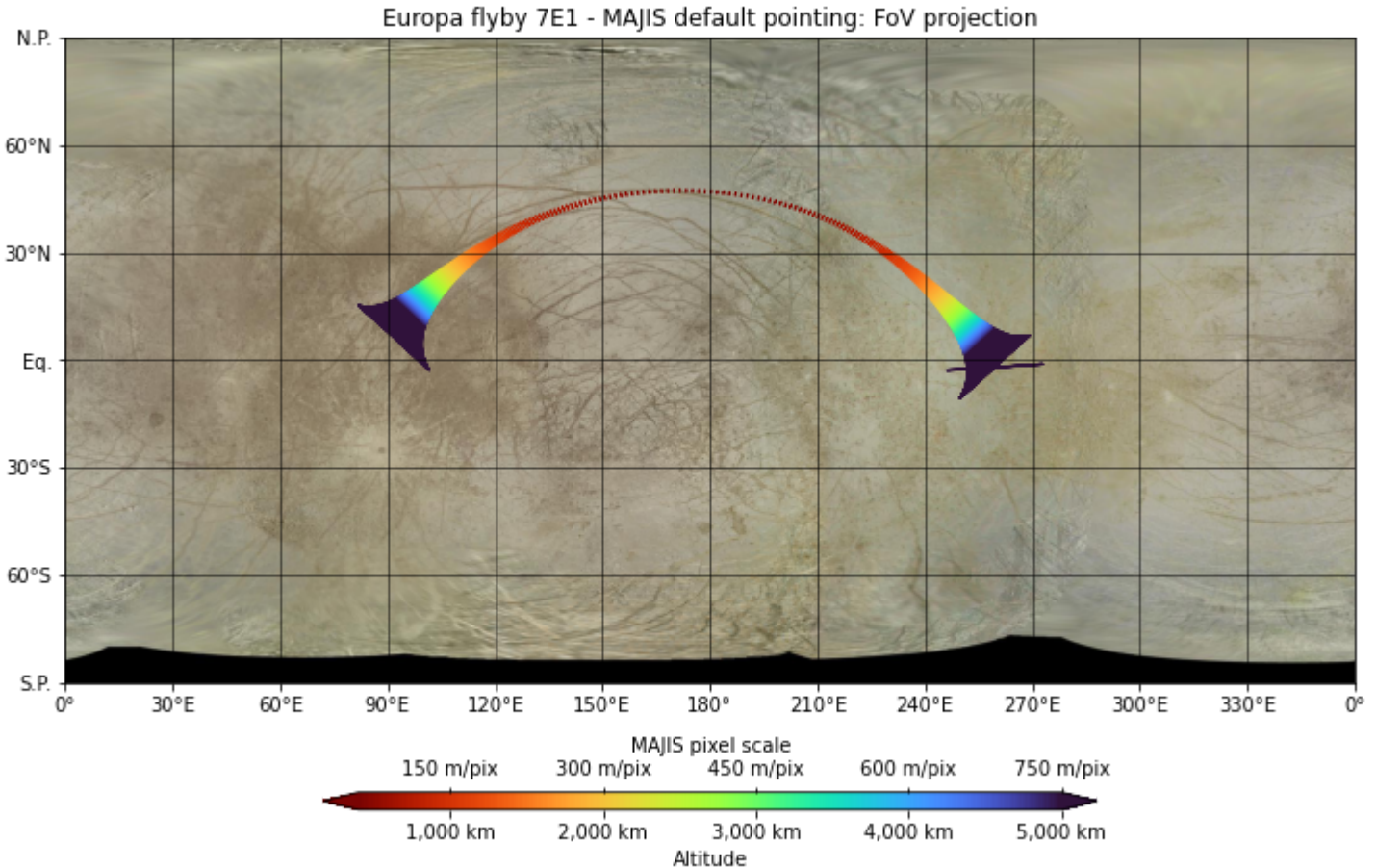
Mission planning

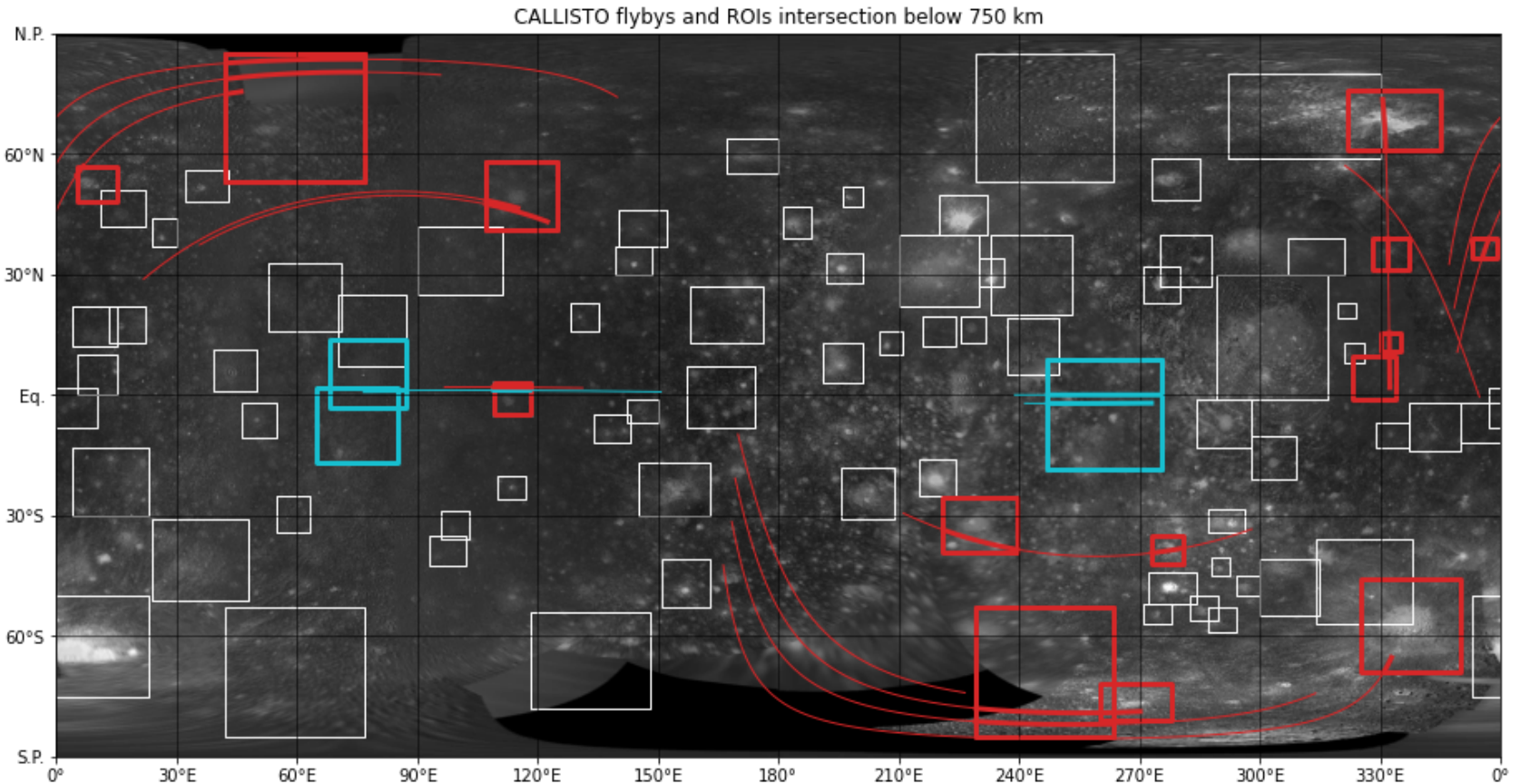
1) Timelines and filtering



2) Tracks and footprints

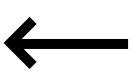


3) ROI intersections



SPICE, SPICE, SPICE !!!

- NAIF toolkit / spiceypy
- MAPPS / ckviewer / ...
- Cosmographia



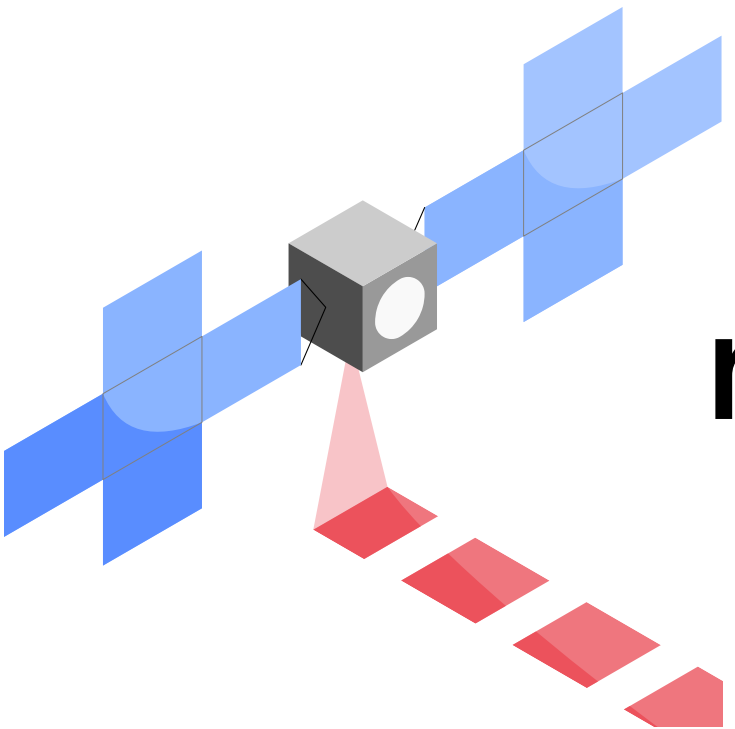
- Expert users
- Mission / instrument specific
- Complex setup

Can we make simpler?

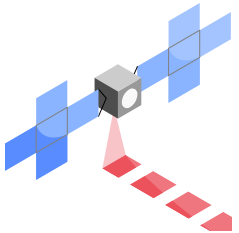
Customizable SPICE visualizations for non-expert users

moon-coverage

planetary-coverage



moon-coverage



moon-coverage

- Python `3.8`+ object oriented library
- Open-source `BSD` licence
- Use only `numpy`, `matplotlib` and `spiceypy`

- Founded by ***ESA SOC***
- Developed at the ***LPG/Nantes Université***

- Fully tested and documented package
- Available on PyPI (`0.11.0`)
- Deployed on ESA Datlabs in April 2021

moon-coverage.univ-nantes.fr

How to install it?

jupyter

ESA DataLabs

```
%pip install moon-coverage
```

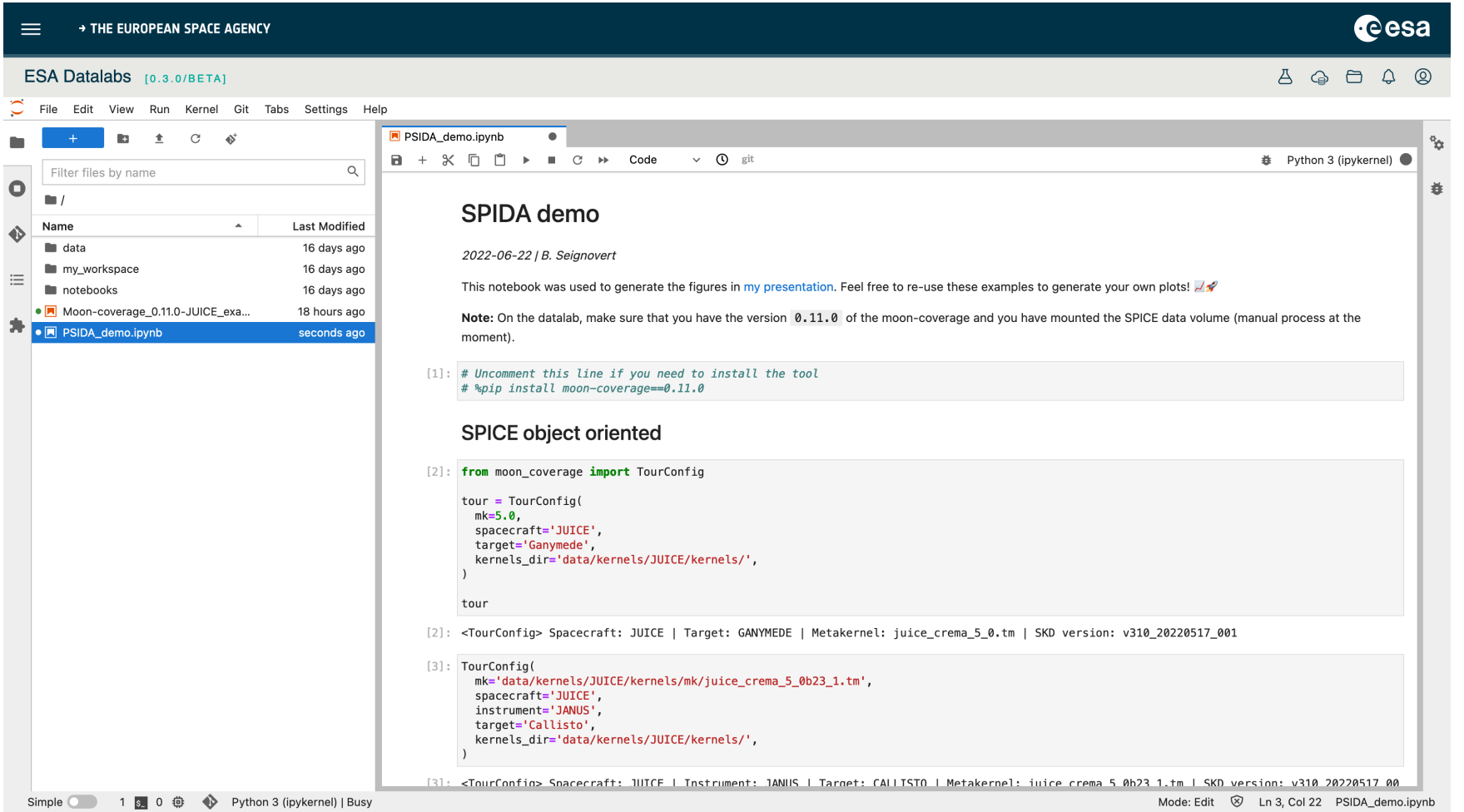
recommanded

Python

```
pip install moon-coverage
```

Demo time ! 

Disclaimer: I hope you like coding!



All the figures were generated with this notebook on ESA DataLabs.

SPICE object oriented

```python
from moon_coverage import TourConfig

tour = TourConfig(
    mk=5.0,
    spacecraft='JUICE',
    target='Ganymede',
    kernels_dir='kernels/',
)
```

```
<TourConfig>
    Spacecraft: JUICE
    Target: GANYMEDE
    Metakernel: juice_crema_5_0.tm
    SKD version: v310_20220517_001
```

```python
from moon_coverage import TourConfig

TourConfig(
    mk='juice_crema_5_0b23_1.tm',
    spacecraft='JUICE',
    instrument='JANUS',
    target='Callisto',
    kernels_dir='kernels/',
)
```

```
<TourConfig>
    Spacecraft: JUICE
    Instrument: JANUS
    Target: CALLISTO
    Metakernel: juice_crema_5_0b23_1.tm
    SKD version: v310_20220517_001
```

Trajectory properties

```
1  traj = tour['2035-06-01']
2
3  traj.dist  # [km]
```

```
3098
```

Trajectory properties

```
1  traj = tour['2035-06-01T01:00:00']
2
3  traj.dist  # [km]
```

```
3145
```

Trajectory properties

```
1 traj = tour['2035-06-01T01:00:00']
2
3 traj.dist, traj.inc, traj.emi, traj.phase
```

```
3145, 77, 0, 77
```

Trajectory properties

```
1 traj = tour[
2    '2035-06-01T01:00:00',
3    '2035-06-01T01:30:00',
4    '2035-06-01T02:00:00',
5 ]
6
7 traj.dist
```

```
[3145, 3144, 3120]
```

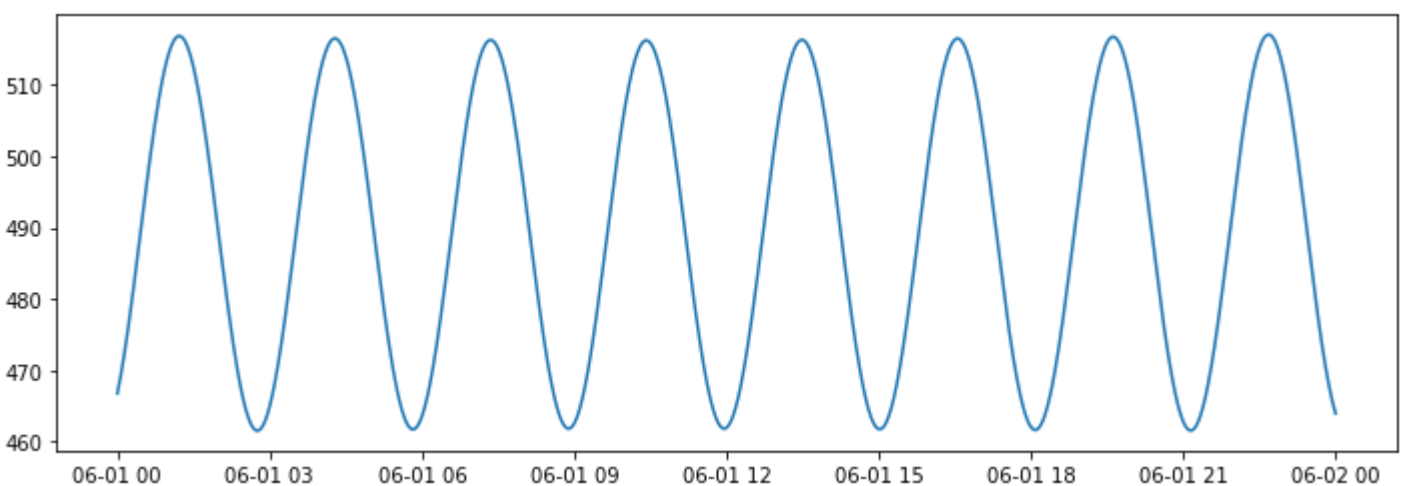
Trajectory properties

```
1  traj = tour['2035-06-01':'2035-06-02':'1 min']
2
3  traj.dist
```

```
[3098, 3098, 3099, ..., 3096, 3095, 3095]
```

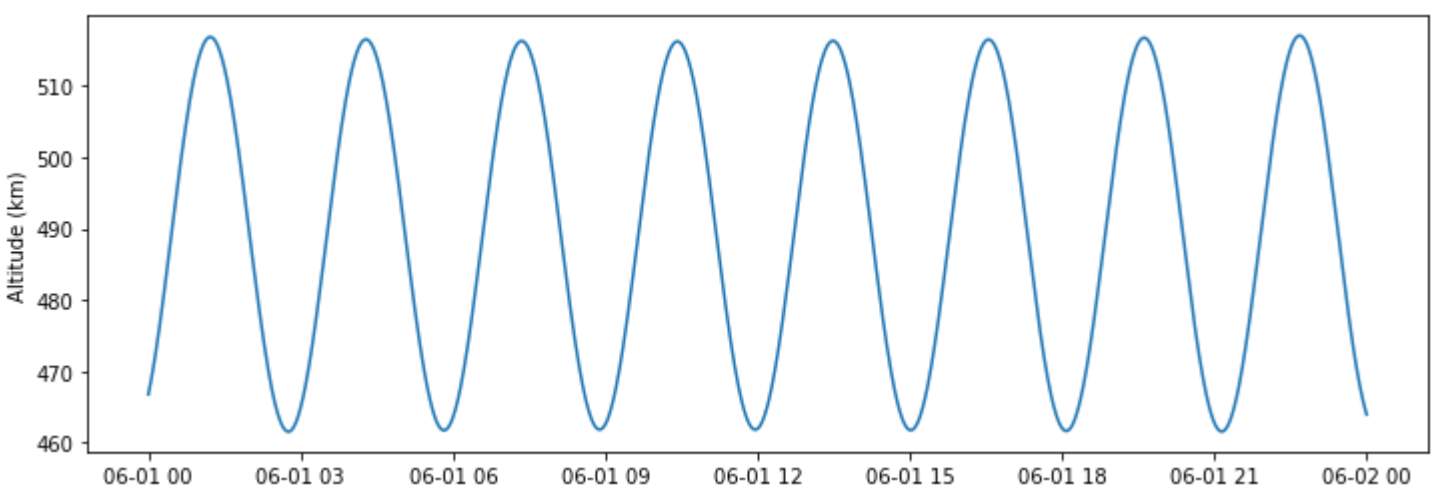
Trajectory property timeline

```
1 import matplotlib.pyplot as plt
2
3 plt.figure()
4
5 plt.plot(traj.utc, traj.alt)
```



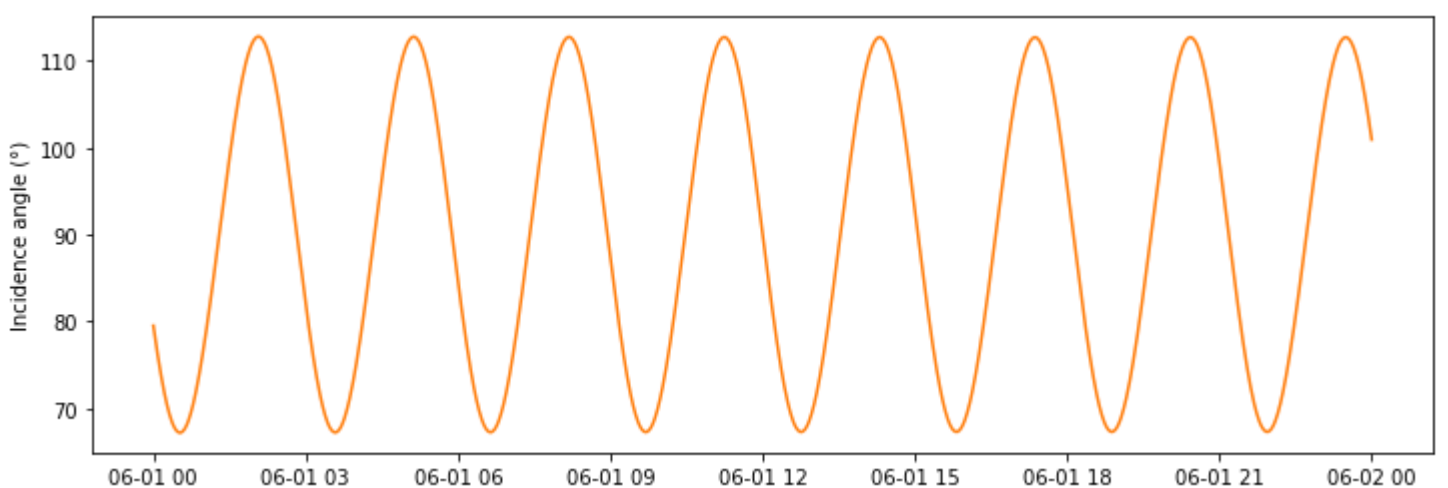
Trajectory property timeline

```
1 plt.figure()
2
3 plt.plot(traj.utc, traj.alt)
4
5 plt.ylabel('Altitude (km)')
```



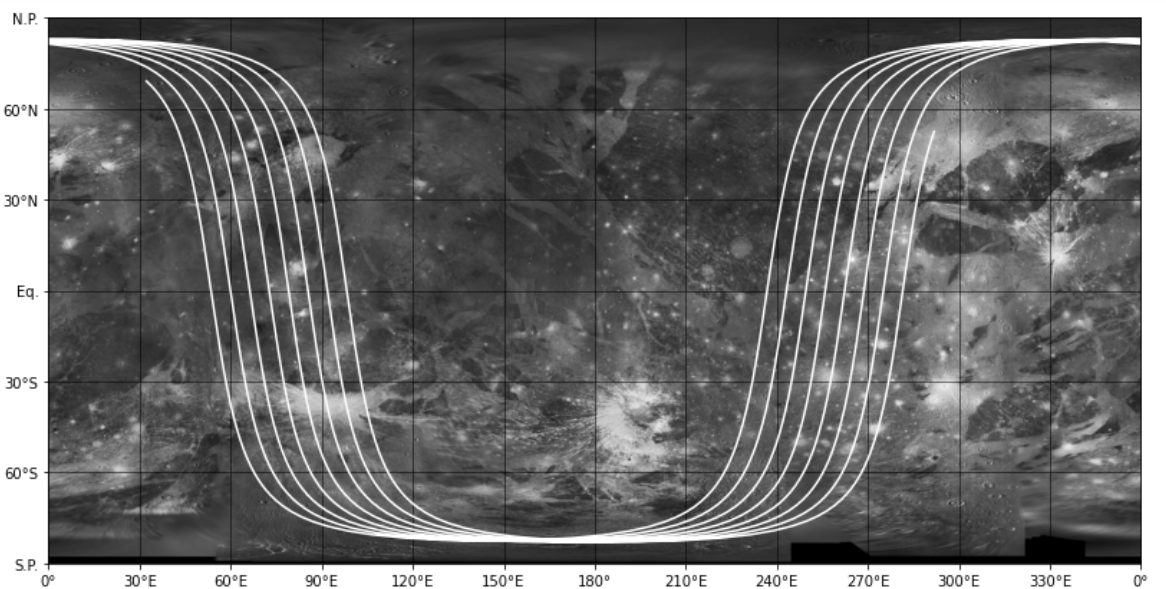
Trajectory property timeline

```
1 plt.figure()
2
3 plt.plot(traj.utc, traj.inc, color='tab:orange')
4
5 plt.ylabel('Incidence angle (°)')
```

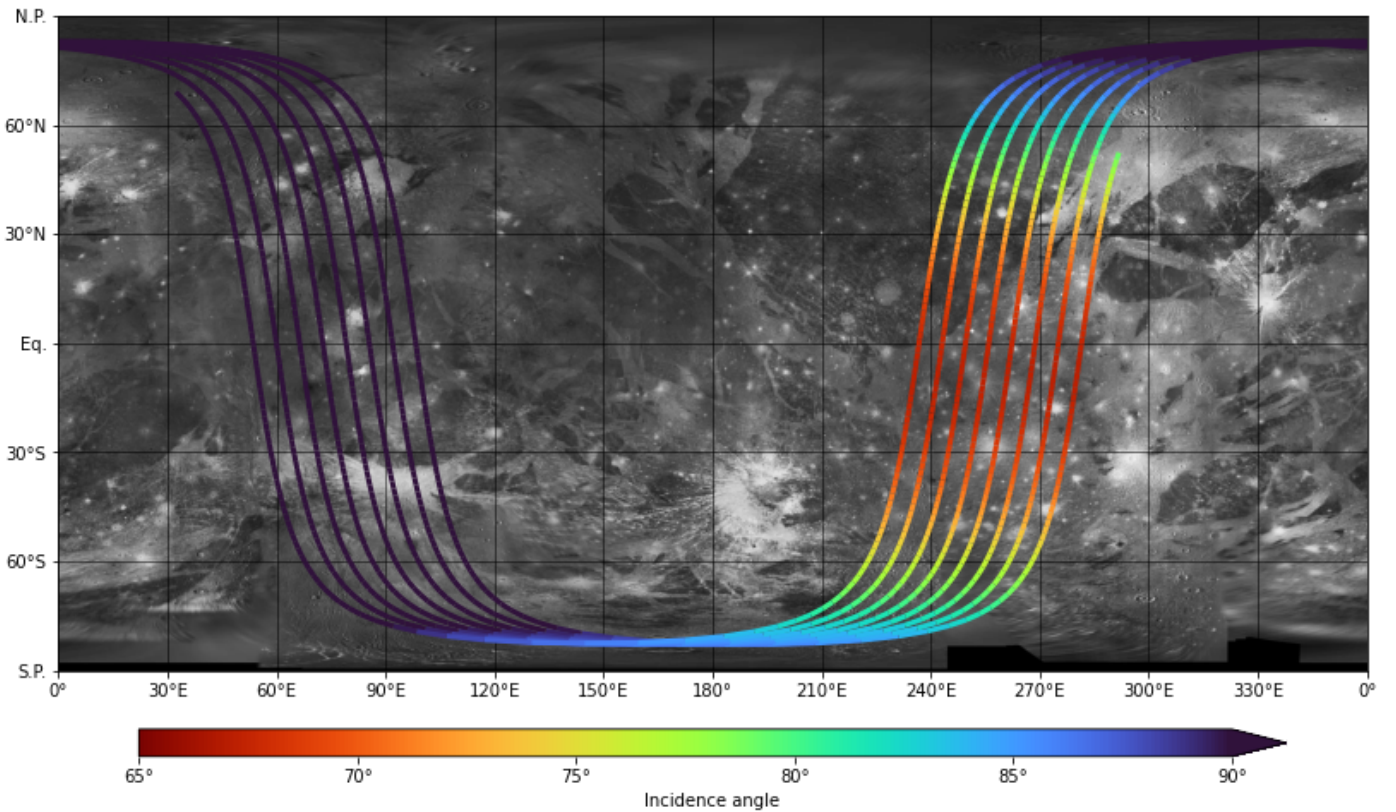


Groundtrack map

```python
from moon_coverage import GANYMEDE

fig = plt.figure()
ax = fig.add_subplot(projection=GANYMEDE)

ax.plot(traj, color='white')
```



```python
fig = plt.figure()
ax = fig.add_subplot(projection=GANYMEDE)

ax.plot(traj, 'inc')
```



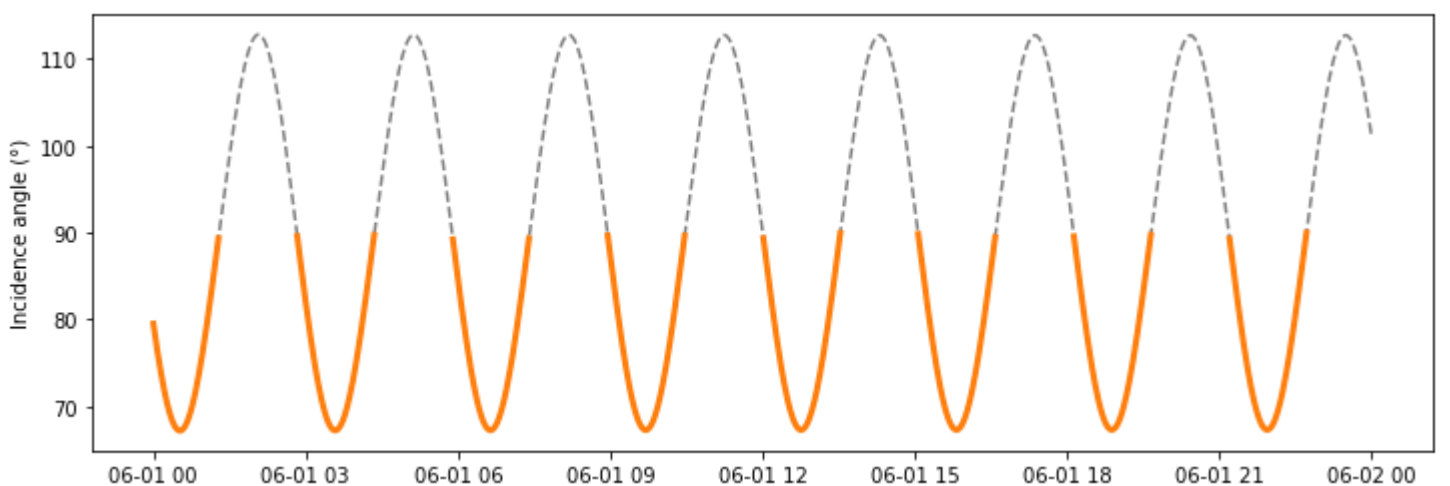
Trajectory filtering

```
1  traj_day = traj.where(traj.inc < 90)
2
3  traj_day.dist
```

```
[3098, 3098, 3099, ..., NaN, NaN, NaN]
```

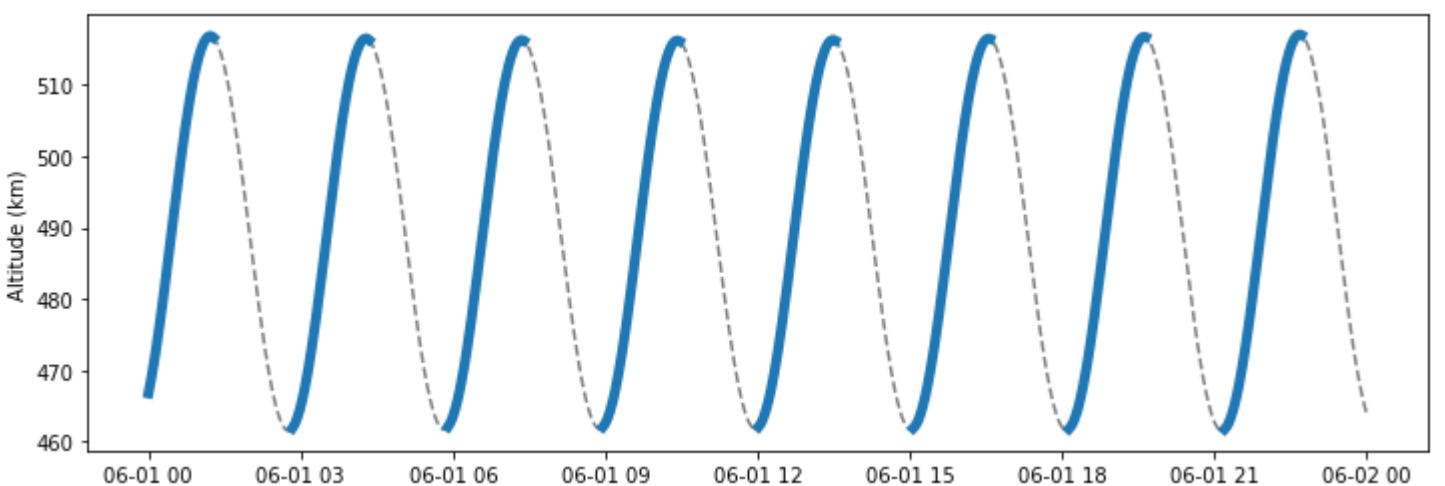
Trajectory filtering

```
plt.figure()

plt.plot(traj.utc, traj.inc, color='gray', linestyle='--')
plt.plot(traj_day.utc, traj_day.inc, color='orange', linewidth=5)

plt.ylabel('Incidence angle (°)')
```

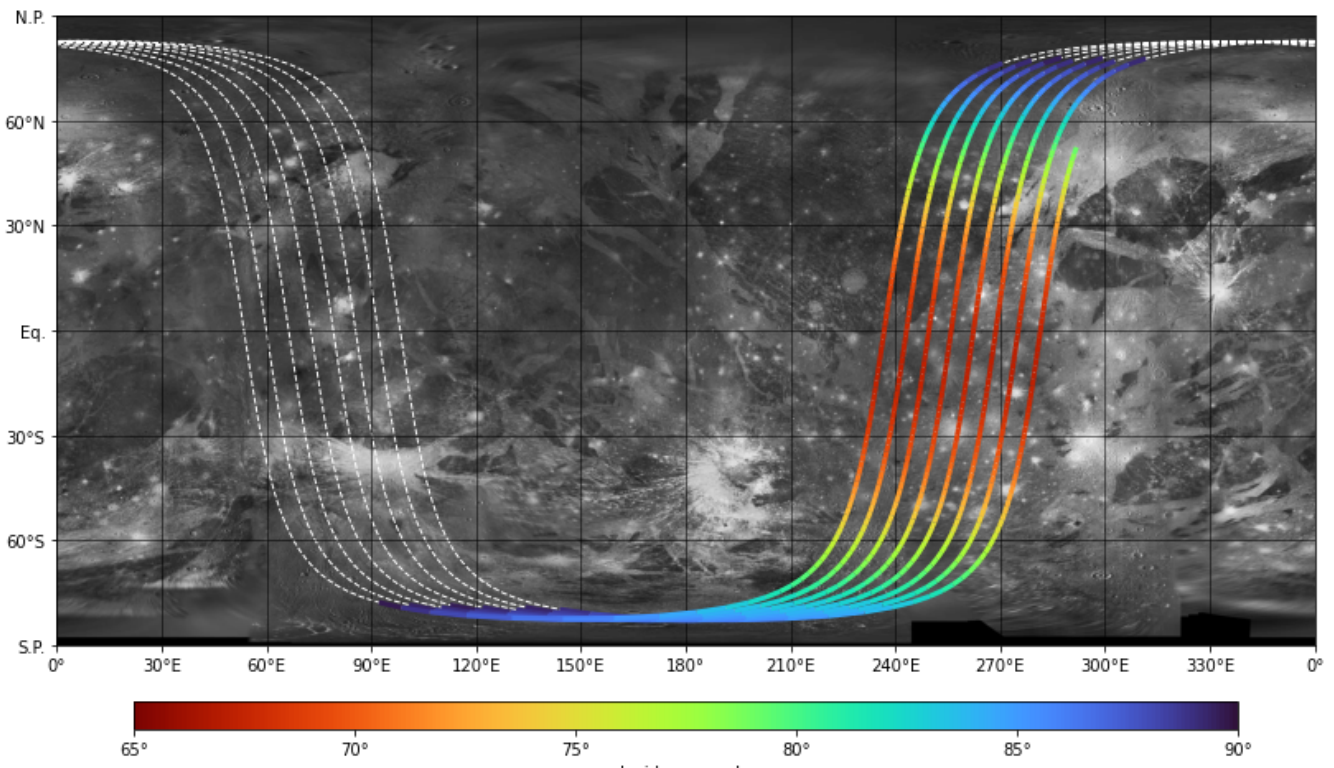


Trajectory filtering

```
1 plt.figure()
2
3 plt.plot(traj.utc, traj.inc, color='gray', linestyle='--')
4 plt.plot(traj_day.utc, traj_day.alt, color='blue', linewidth=5)
5
6 plt.ylabel('Altitude (km)')
```



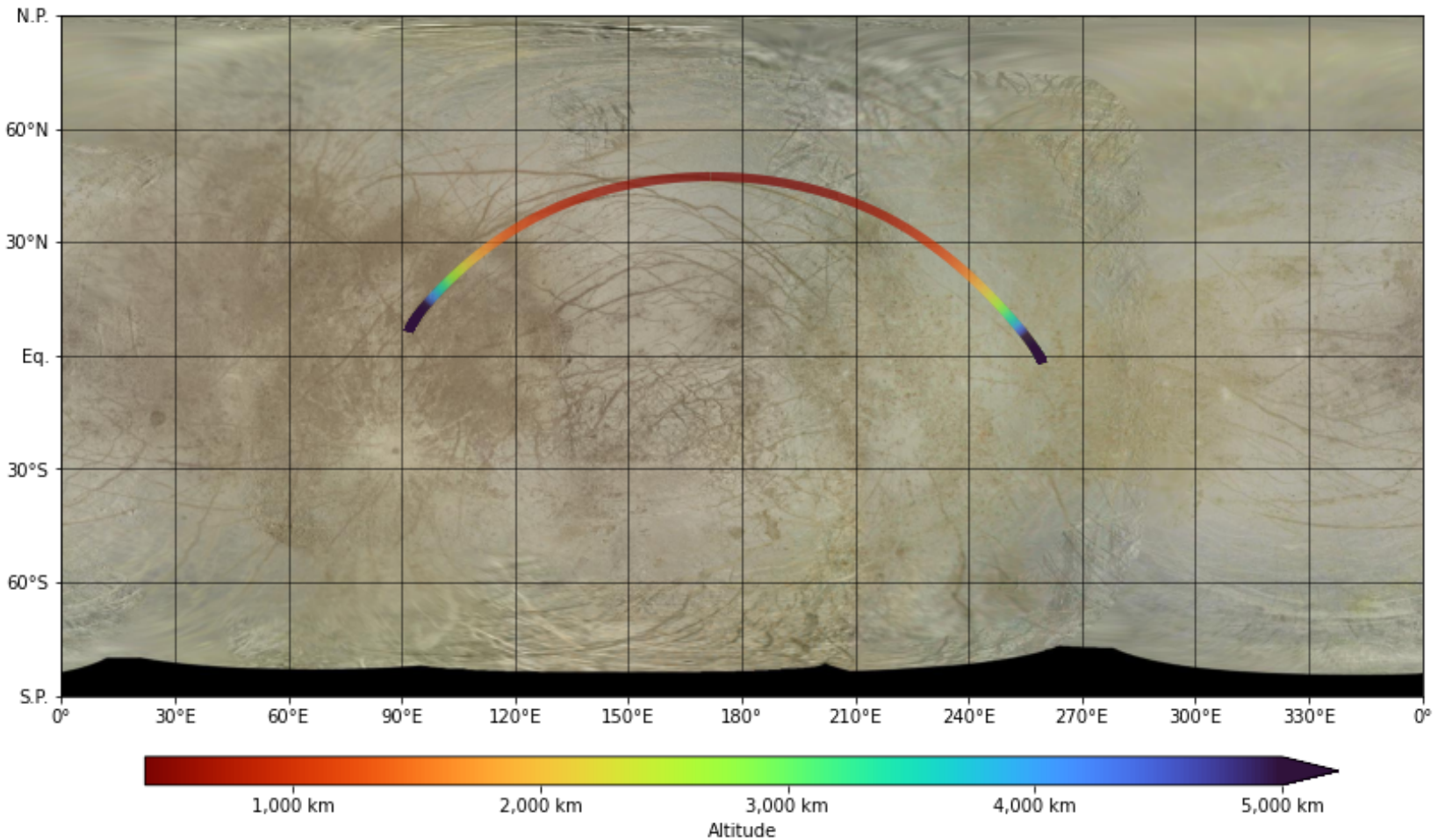
```
fig = plt.figure()
ax = fig.add_subplot(projection=GANYMEDE)

ax.plot(traj, color='white', linestyle='--', linewidth=1)
ax.plot(traj_day, 'inc')
```



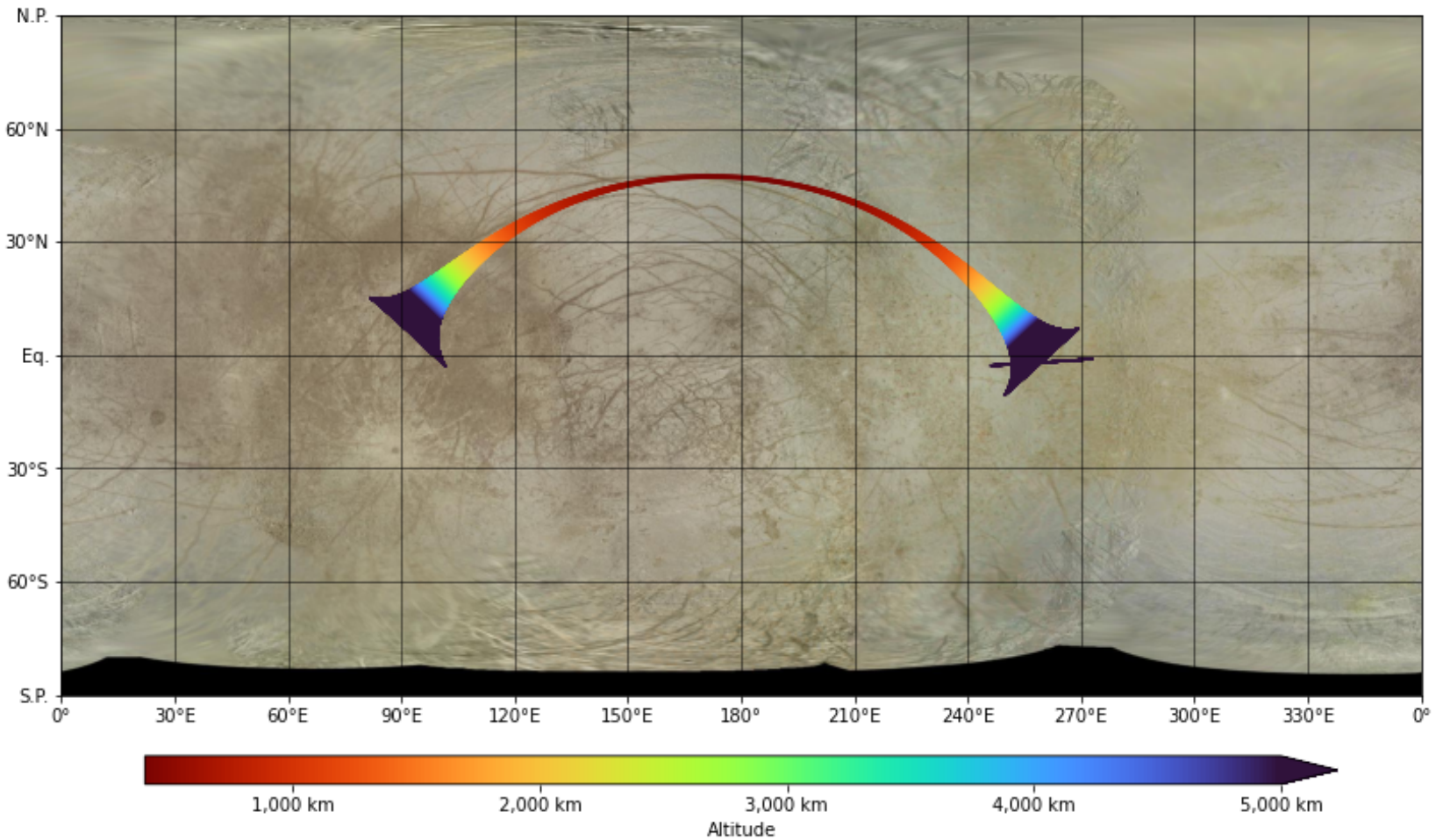
15 lines from stratch to plot! 🙌

```python
from moon_coverage import TourConfig, EUROPA

tour = TourConfig(
  mk=5.0,
  spacecraft='JUICE',
  instrument='MAJIS_IR',
  target='EUROPA',
)

traj = tour['2032-07-02T15:22:25':'2032-07-02T17:22:25':'1 sec']

fig = plt.figure()
ax = fig.add_subplot(projection=EUROPA)

ax.plot(traj, 'alt', vmin=400, vmax=5000)
```

15 lines from stratch to plot! 🙌



add MAJIS instrument footprint?

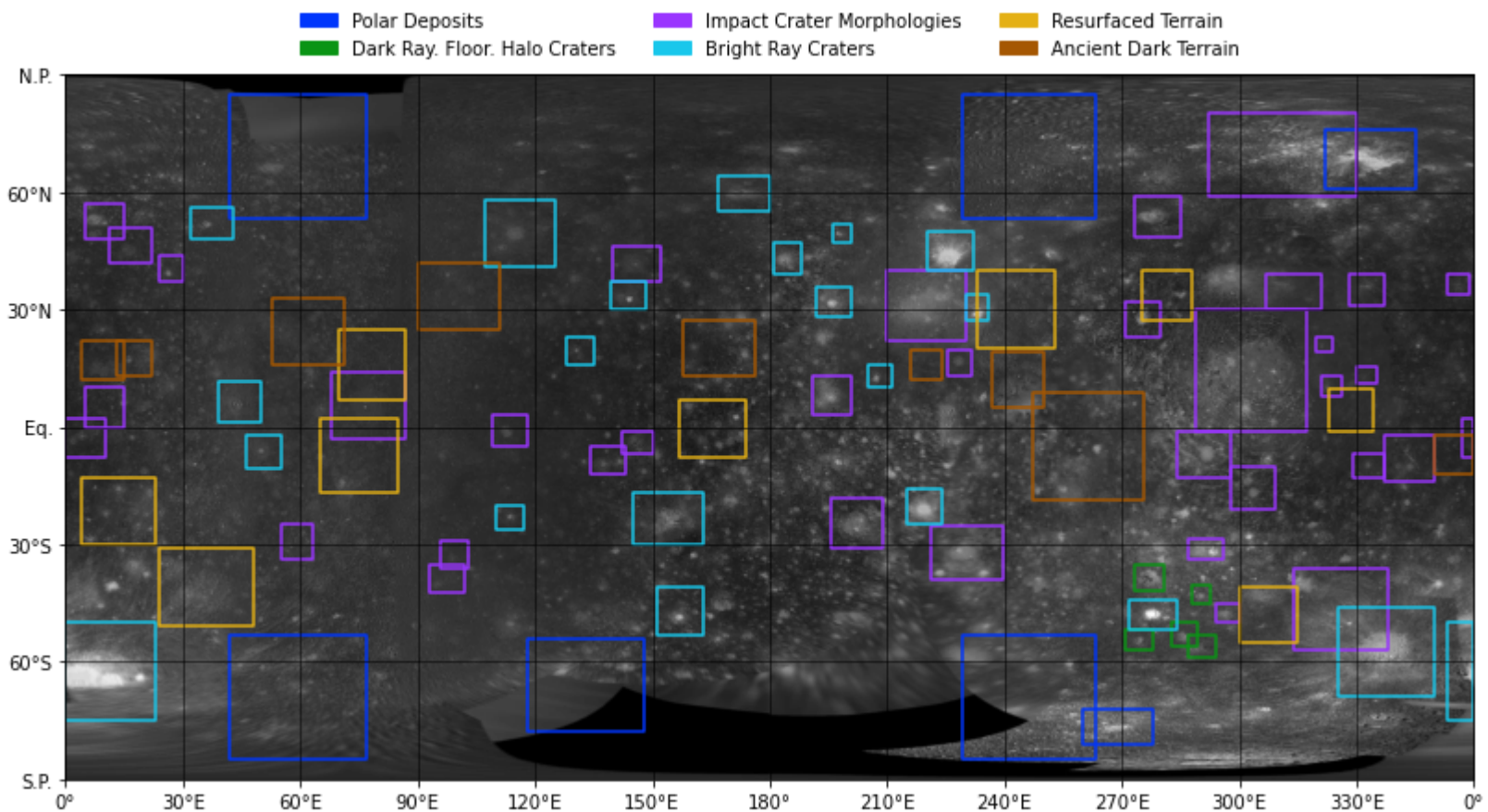


add MAJIS instrument footprint?

```
from moon_coverage import TourConfig, EUROPA

tour = TourConfig(
  mk=5.0,
  spacecraft='JUICE',
  instrument='MAJIS_IR',
  target='EUROPA',
)

traj = tour['2032-07-02T15:22:25':'2032-07-02T17:22:25':'1 sec']

fig = plt.figure(figsize=(20, 9))
ax = fig.add_subplot(projection=EUROPA)

ax.add_collection(traj.fovs('alt', vmin=400, vmax=5000))
```

Regions of Interest (ROI)

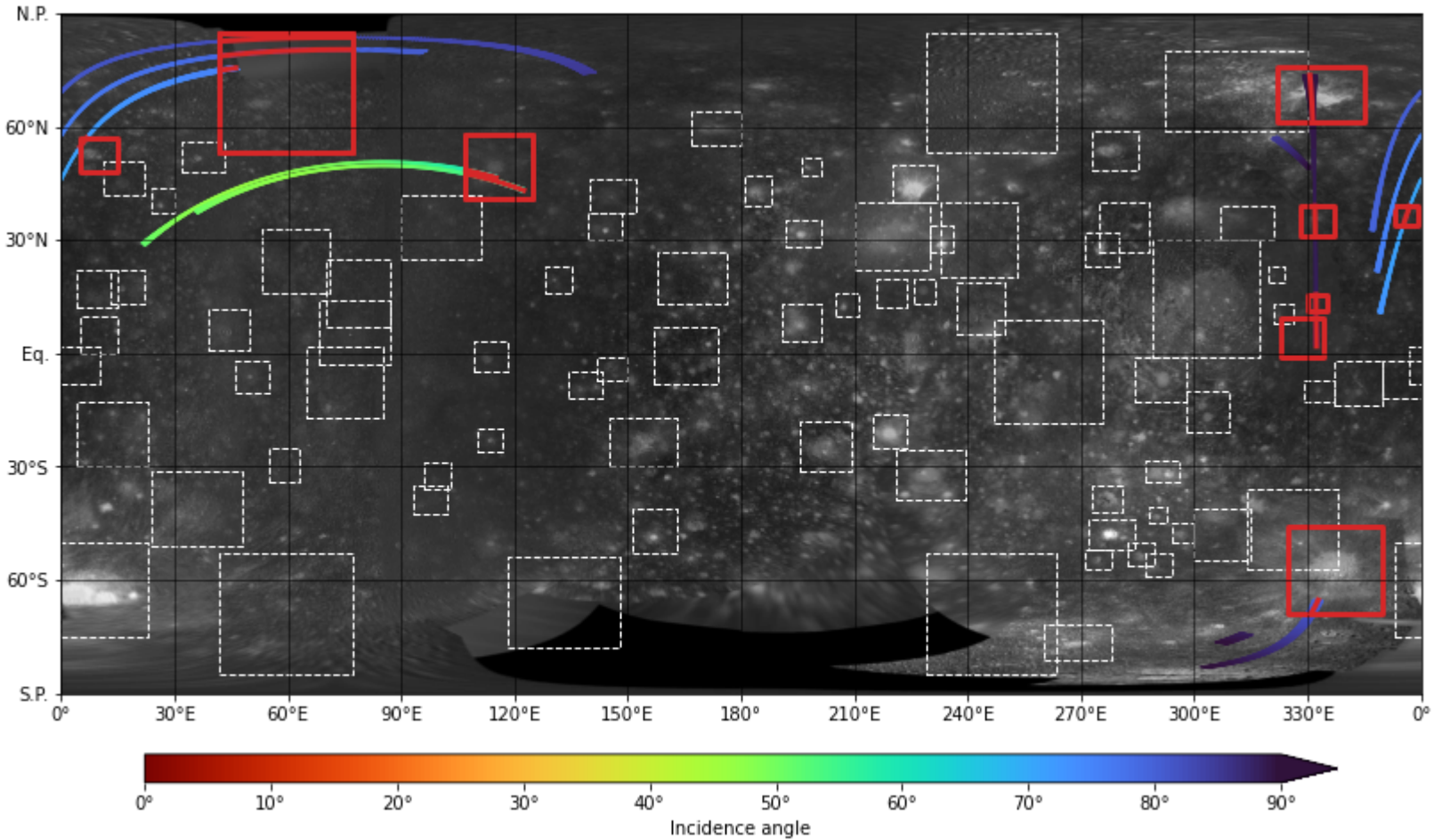
```
from moon_coverage import CallistoROIs, CALLISTO

fig = plt.figure()
ax = fig.add_subplot(projection=CALLISTO)

ax.add_collection(CallistoROIs)

ax.legend(handles=CallistoROIs.handles, loc='lower center',
          bbox_to_anchor=(.5, 1), ncol=3, frameon=False);
```


Polar Deposits
Dark Ray. Floor. Halo Craters
Impact Crater Morphologies
Bright Ray Craters
Resurfaced Terrain
Ancient Dark Terrain
N.P.
60°N
30°N
Eq.
30°S
60°S
S.P.
0°
30°E
60°E
90°E
120°E
150°E
180°
210°E
240°E
270°E
300°E
330°E
0°

Complexe ROI intersections

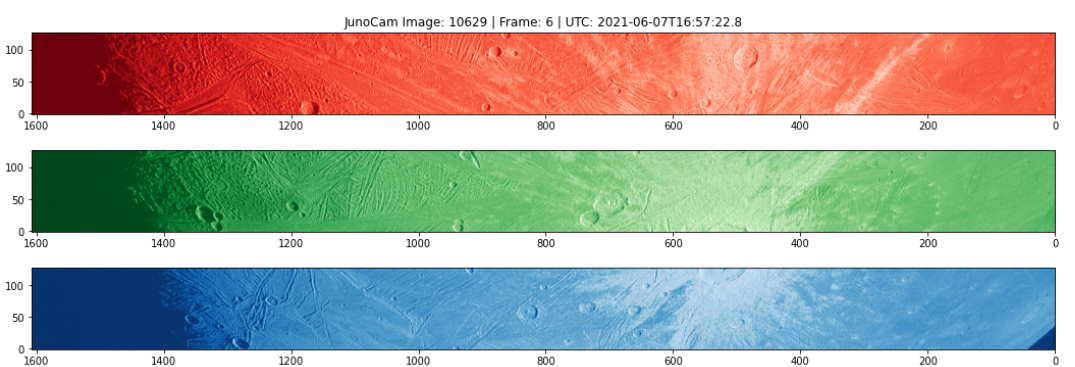
```
tour = TourConfig(
    mk=5.0, spacecraft='JUICE', instrument='MAJIS_IR', target='Callisto',
)

fig = plt.figure()
ax = fig.add_subplot(projection=CALLISTO)

ax.add_collection(CallistoROIs(edgecolor='white', linestyle='--'))

for flyby in tour.flybys:
    traj = flyby.where((flyby.alt < 750) & (flyby.inc < 90))

    ax.add_collection(traj.fovs('inc', vmin=0, vmax=90))

    if traj in CallistoROIs:
        ax.plot(traj & CallistoROIs, color='red')
        ax.add_collection((CallistoROIs & traj)(edgecolor='red'))

ax.colorbar(vmin=0, vmax=90, label='inc', extend='max')
```

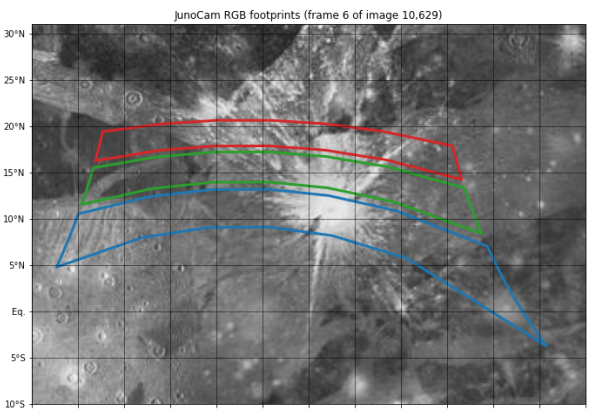
JUICE Callisto flybys planning



Summary

- **moon-coverage** is python generic mission planning tool library based on **SPICE** for **non expert-user**.
- Generate custom *timelines*, *groundtrack* and *ROI intersections*.
- *Open-source*, fully *tested* and *documented*, with many **examples**.





This presentation:

slid.es/seignovert/psida-2022

The tool:

moon-coverage.univ-nantes.fr

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