Scheduling follow-up observations of energetic transients with the neutrino target scheduler (NuTS)

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For the EUSO-SPB2 ToO team
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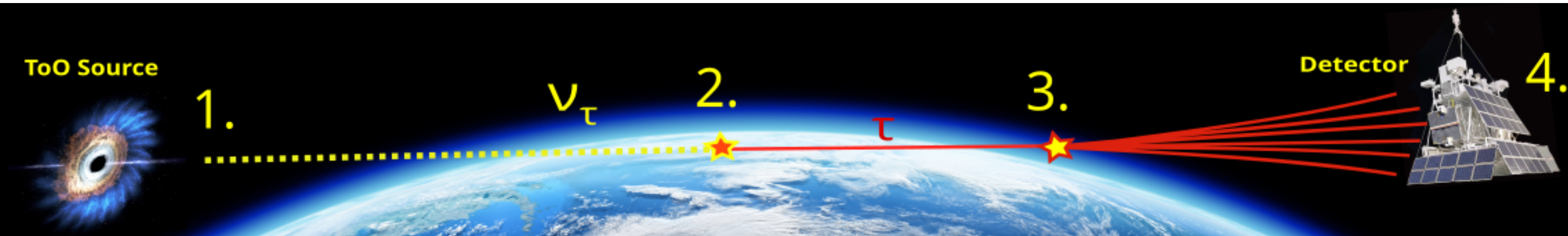
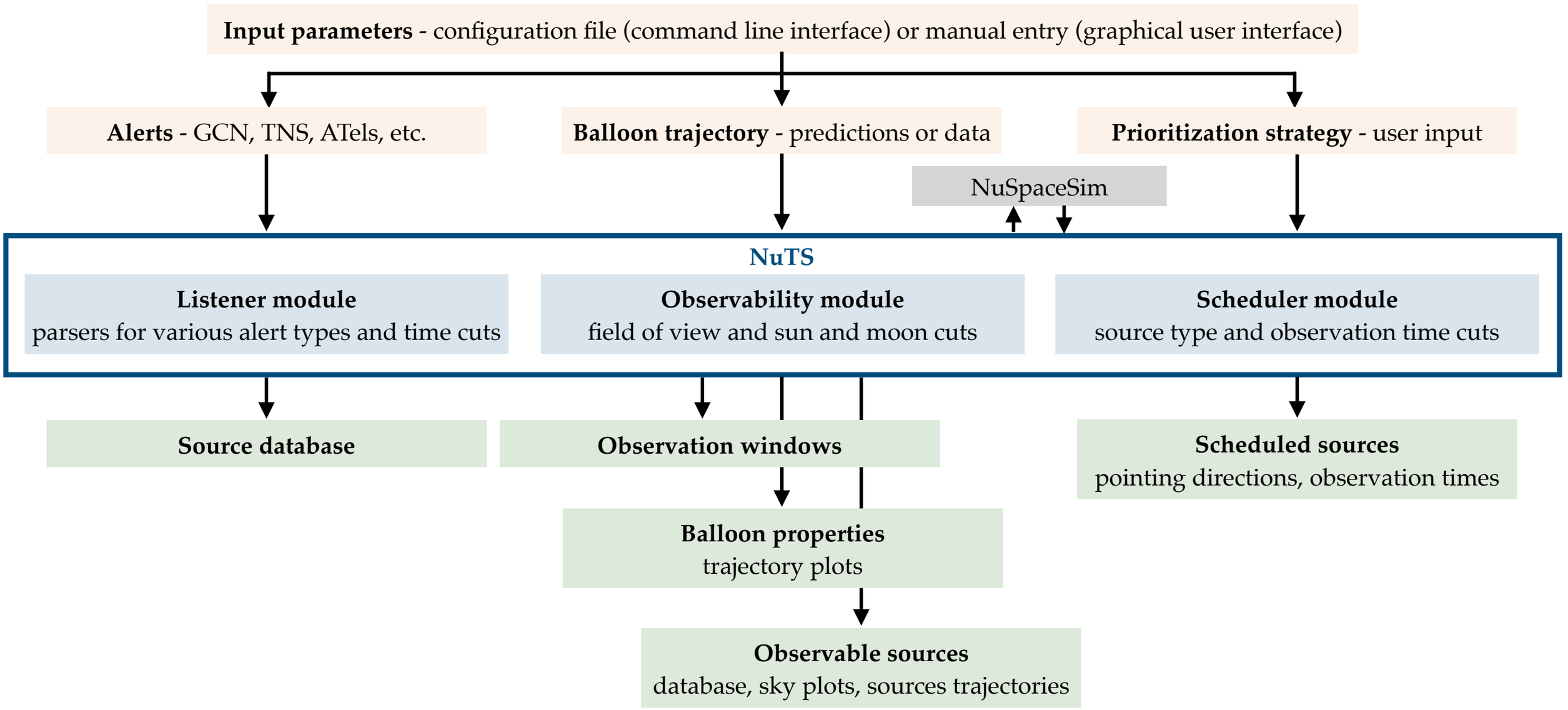


Structure of the software



Contents of the paper

9 pages + 5 pages of appendix
8 figures + 3 figures in appendix

Summary

- paper almost ready for submission (after internal review):
  - one short section left to write (2.3.5)
  - a couple of comments
- code almost ready for release of version 1: some documentation missing

Computation and figures to illustrate the functionalities of NuTS

Parameters:

- trajectory using SuperBit flight
- source database built from GCN, TNS, ATels, steady sources
- other parameters defined in the configuration file:
  - time_increment of 5.0 min
  - fov of EUSO-SPB2, pointing below the limb
  - several scheduling strategies tested (8 parameters) →

```
[settings.scheduler]
strategy_priority_sort = true
strategy_obstime = true
strategy_obsprev = true
strategy_priority_max = "3"
rotation_time = "10.0 min"
min_obs_time = "15.0 min"
max_num_sources = 5
exclusive = true
```

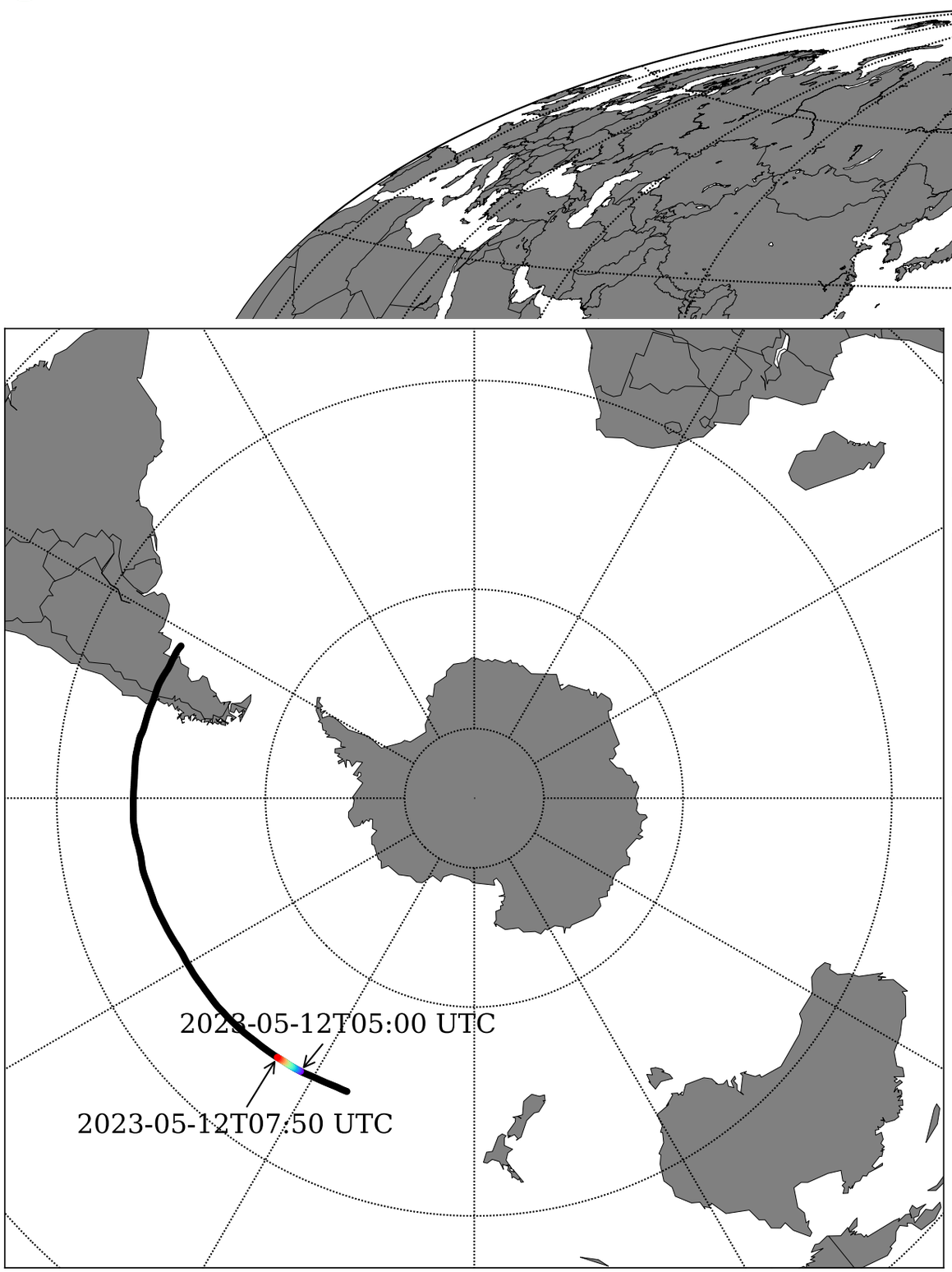
Figures:

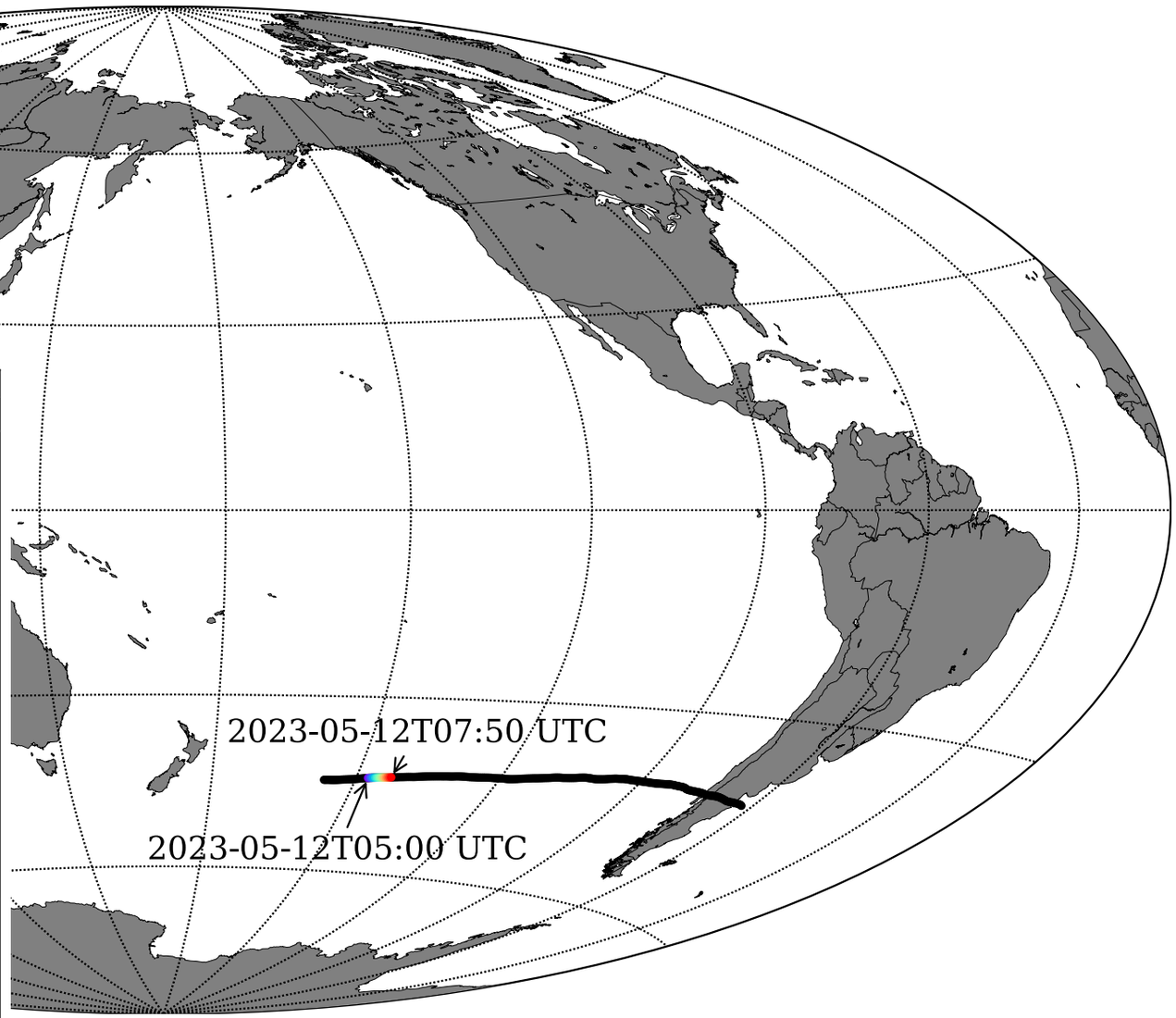
- detector location
- sky maps for geometrical acceptance with observable and scheduled point sources
- sky maps and optimal pointing direction for poorly localized sources
- trajectories of point sources crossing the field of view
- observation windows
- cumulated observation times per priority tier and per source
- examples of schedules
- tests, measurements of position of stars vs predictions of software

⚠ Change of the default priority ranking

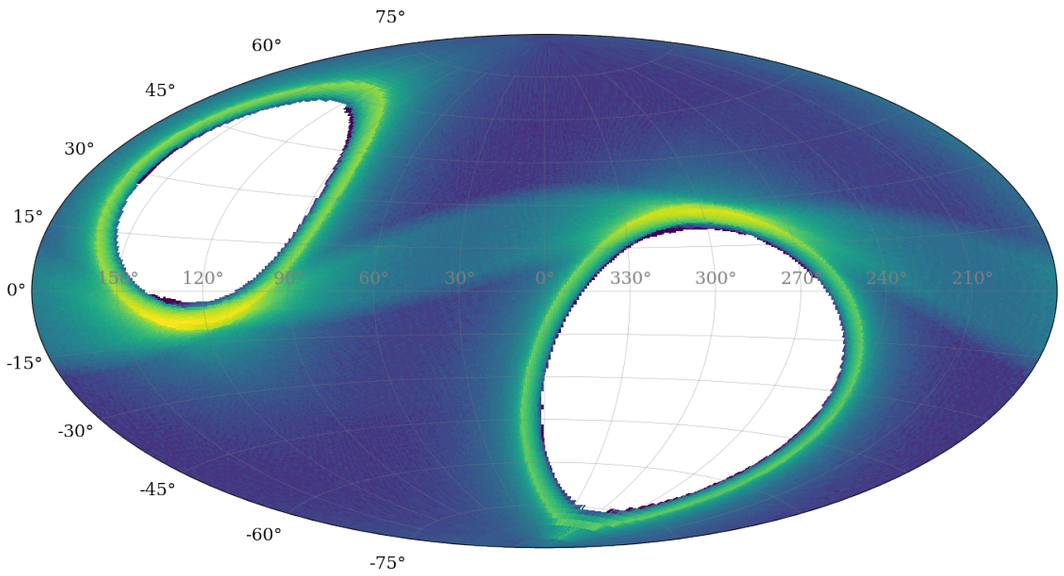
Alert name	Priority value	Follow up time in days
ICECUBE	2	30
ICECUBE BRONZE	2	30
ICECUBE GOLD	2	30
ICECUBE Astrotrack Bronze	2	30
ICECUBE Astrotrack Gold	2	30
IC-HAWC	2	30
LVC Preliminary	2	30
LVC Initial Skymap	2	30
LVC Update Skymap	2	30
LVC Retraction	0	30
ATels	3	365
Blazar	3	365
Flaring Blazar	3	365
Flaring AGN	3	365
TDE	4	365
TDE-H-He	4	365
TDE-He	4	365
GRB	5	30
MAXI	5	30
MAXI Position	5	30
SuperAGILE GRB Position	5	30
SuperAGILE GRB Ground Position	5	30
HAWC	5	30
HAWC Burst Monitor	5	30
Fermi-LAT Position	5	30
Fermi LAT Offline Position	5	30
Fermi-GBM Position	5	30
Fermi GBM Flight Position	5	30
Fermi GBM Final Position	5	30
Fermi-GBM Flight Position	5	30
INTEGRAL	5	30
INTEGRAL Refined	5	30
INTEGRAL Offline	5	30
INTEGRAL Wakeup	0	30
Swift-BAT GRB Position	5	30
AGN	6	365
Galaxy	6	365
SLSN	7	30
SLSN-I	7	30
SLSN-II	7	30
FBOT	7	15
SN	7	15
SN I	7	15
SN II	7	15
SN IIn	7	15
SN IIn-pec	7	15
SN IIp	7	15
SN IIb	7	15
SN II-pec	7	15
SN Ib	7	15
SN Ib-pec	7	15
SN Ib-Ca-rich	7	15
SN Ibn	7	15
SN Ibn/Icn	7	15
SN Ib/c	7	15
SN Ic	7	15
SN Ic-pec	7	15
SN Ic-BL	7	15
SN Icn	7	15
SN Ien	7	15
FRB	8	365
STEADY	8	1000
TEST LVC Preliminary	0	30
TEST LVC Initial Skymap	0	30
TEST LVC Update Skymap	0	30
MAXI Test Position	0	30
SuperAGILE GRB Test Position	0	30
Fermi-GBM Test Position	0	30
TEST INTEGRAL Refined	0	30
TEST INTEGRAL Offline	0	30
TEST INTEGRAL Wakeup	0	30
Fermi-LAT Test Position	0	30
Swift-BAT GRB Test Position	0	30

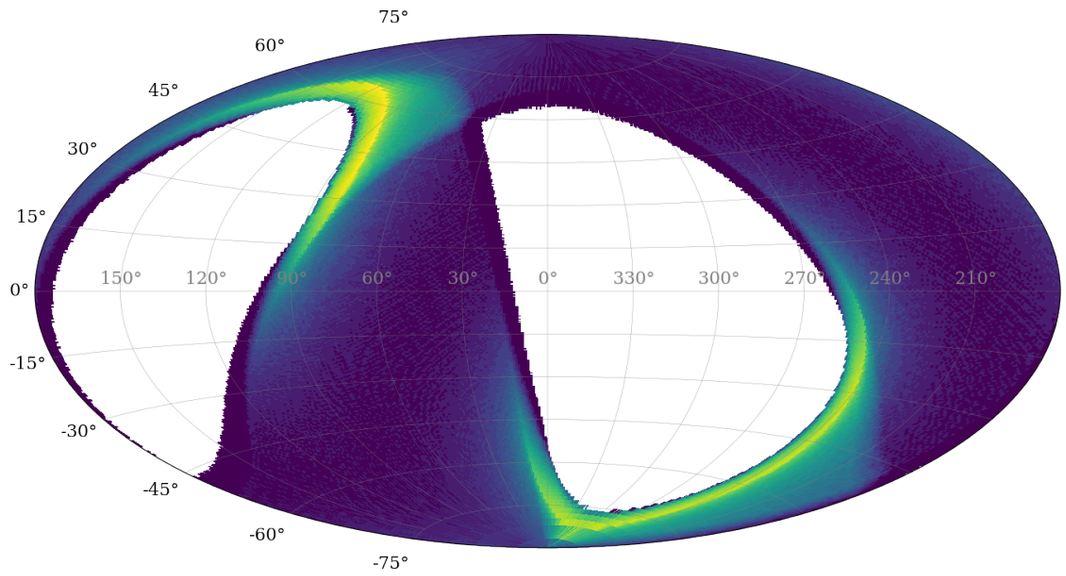
Figures: detector location

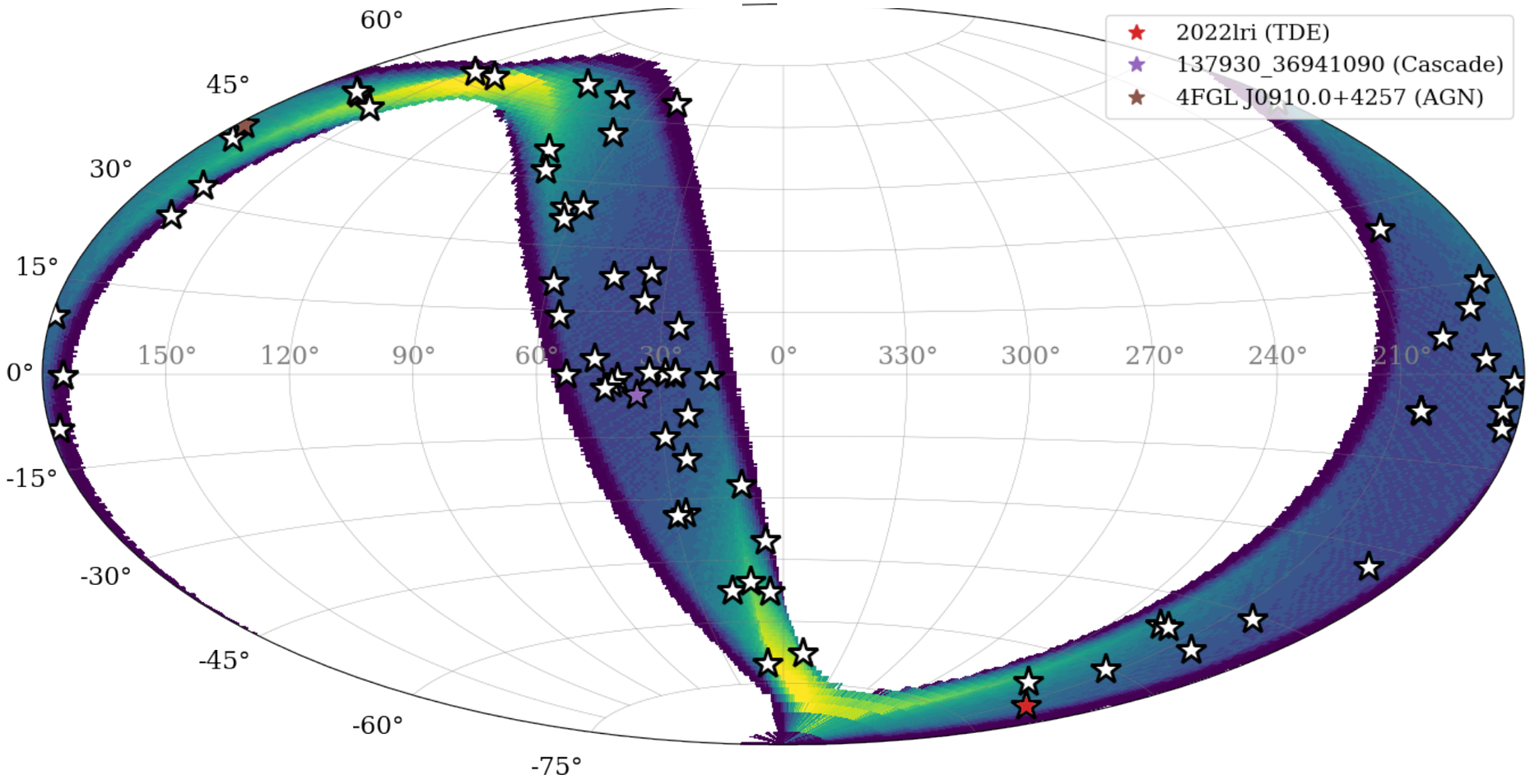




Figures: observable portions of the sky, observable and scheduled sources

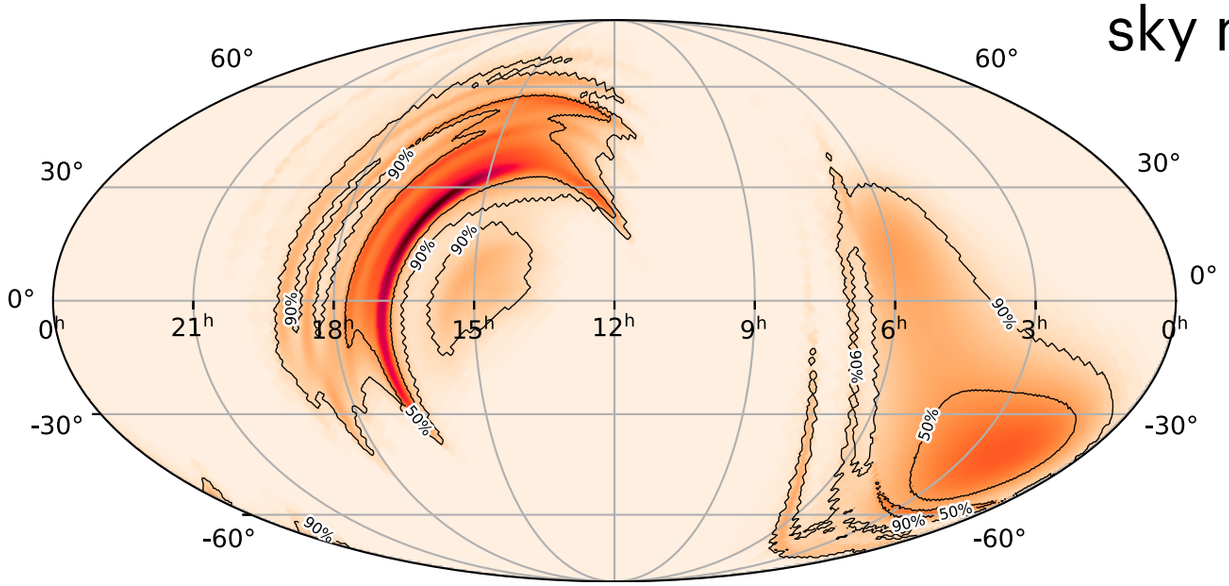


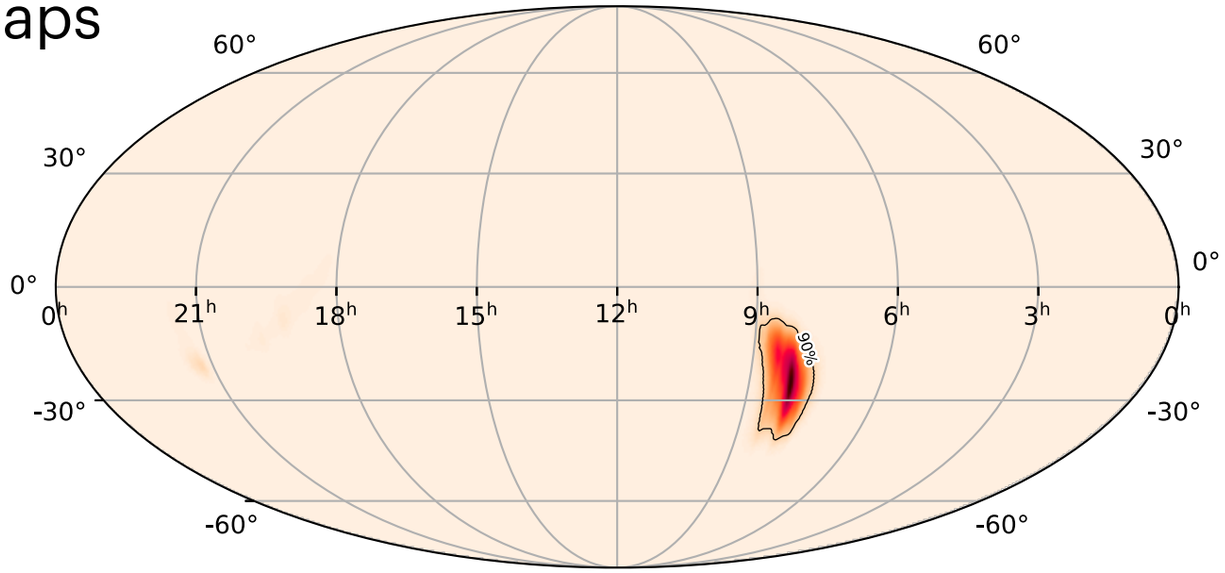




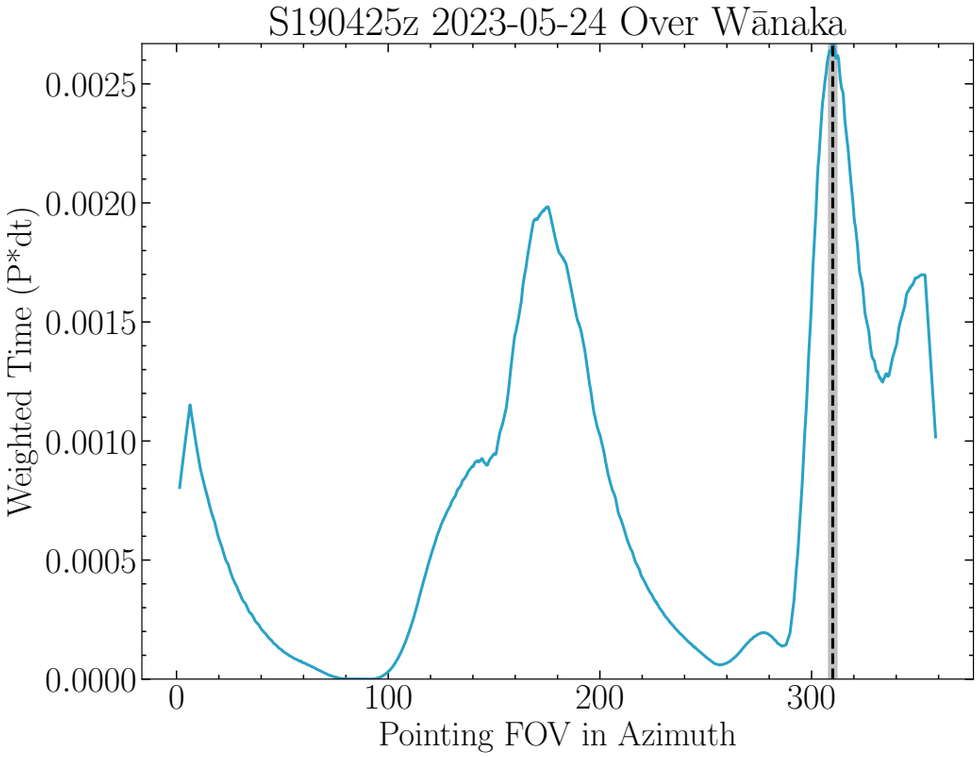
Figures: poorly localized sources, gravitational wave events

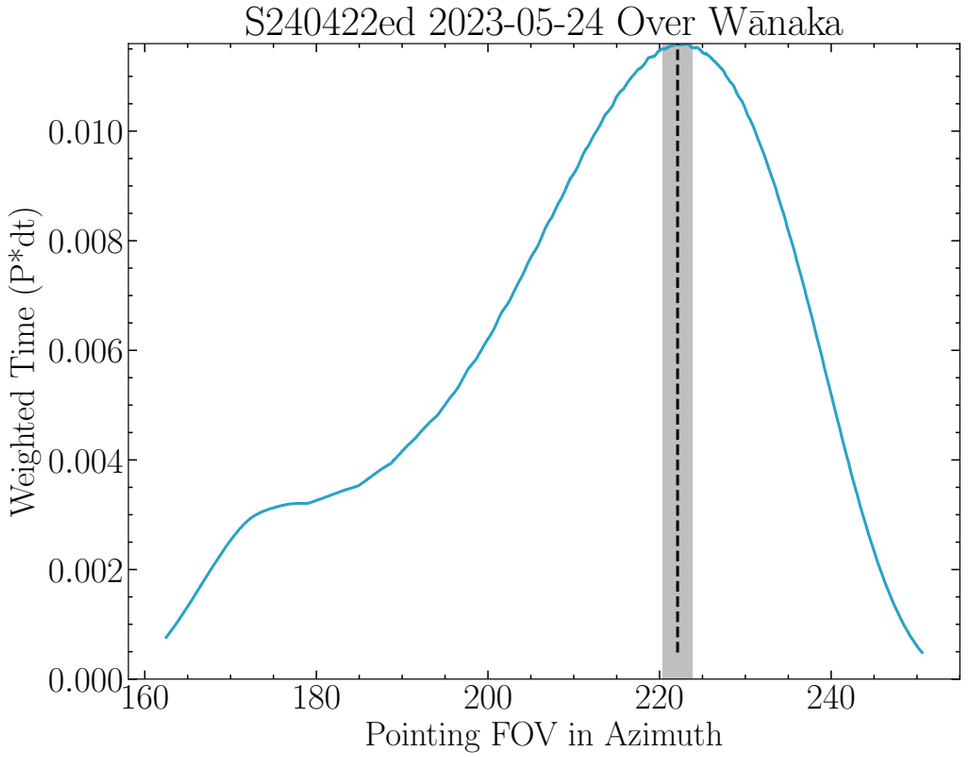
sky maps



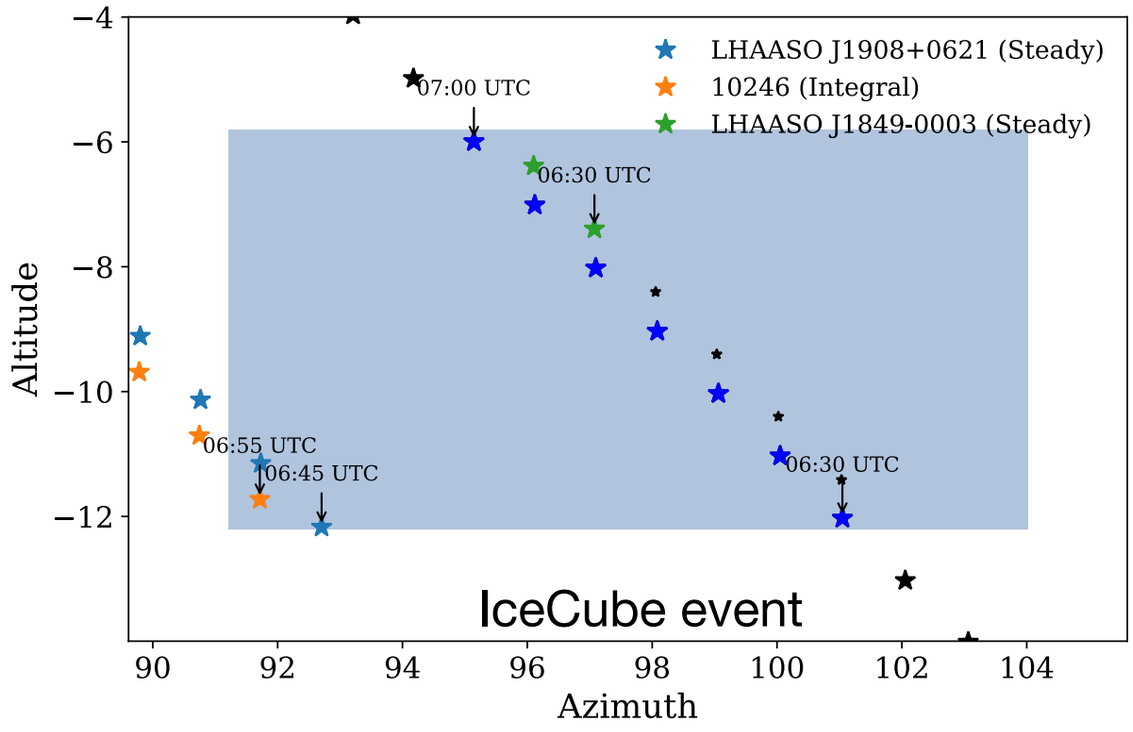


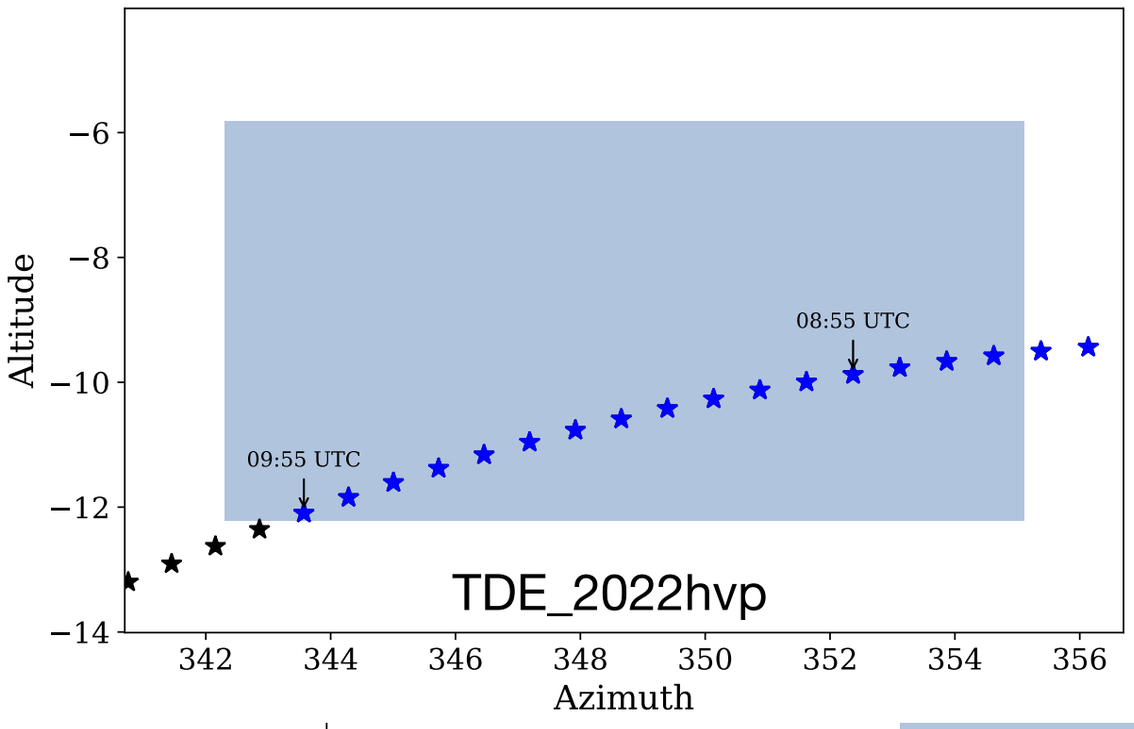
algorithm output

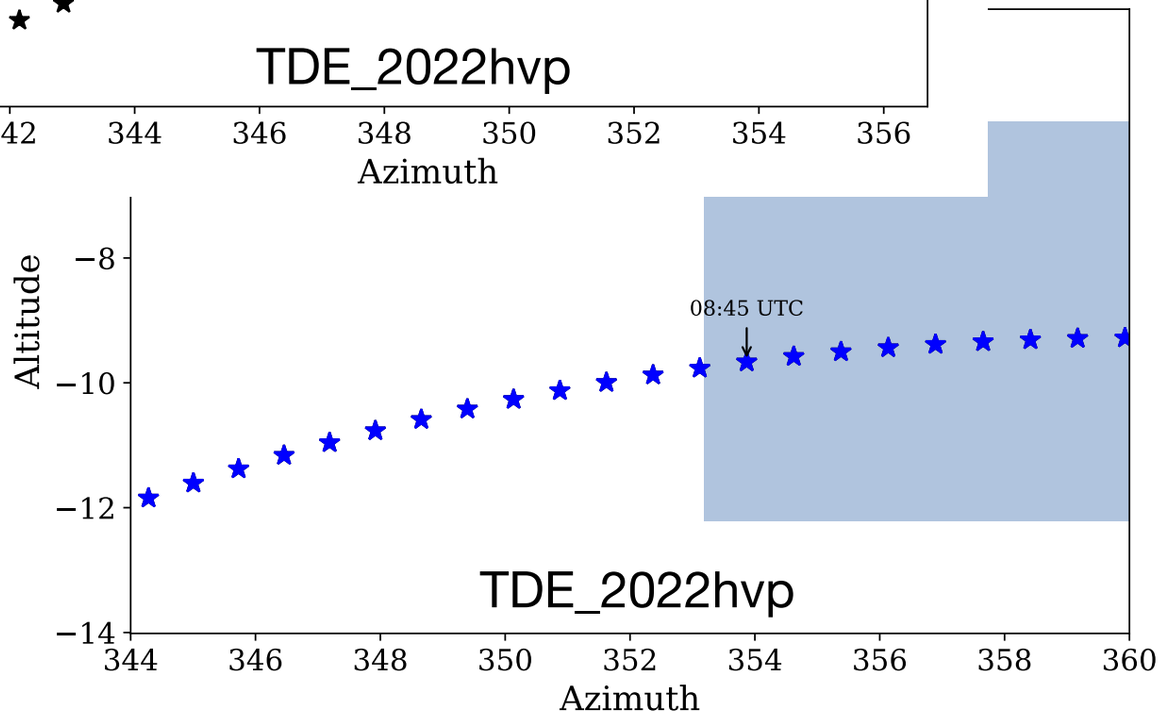


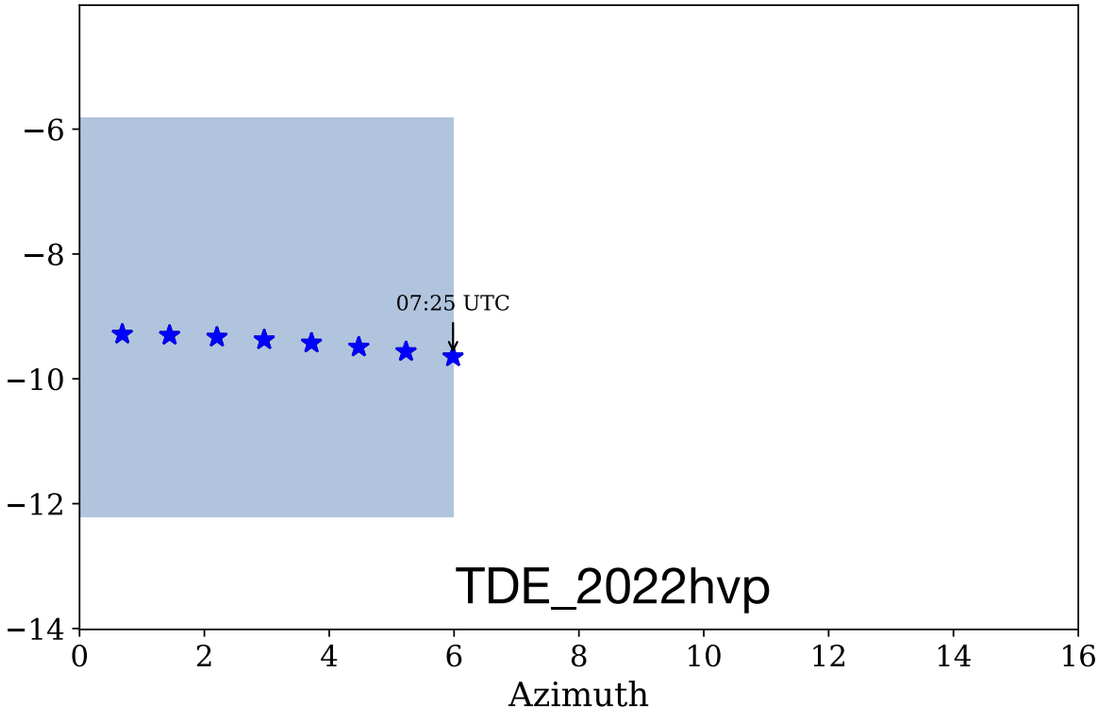


Figures: trajectories of point sources crossing the field of view

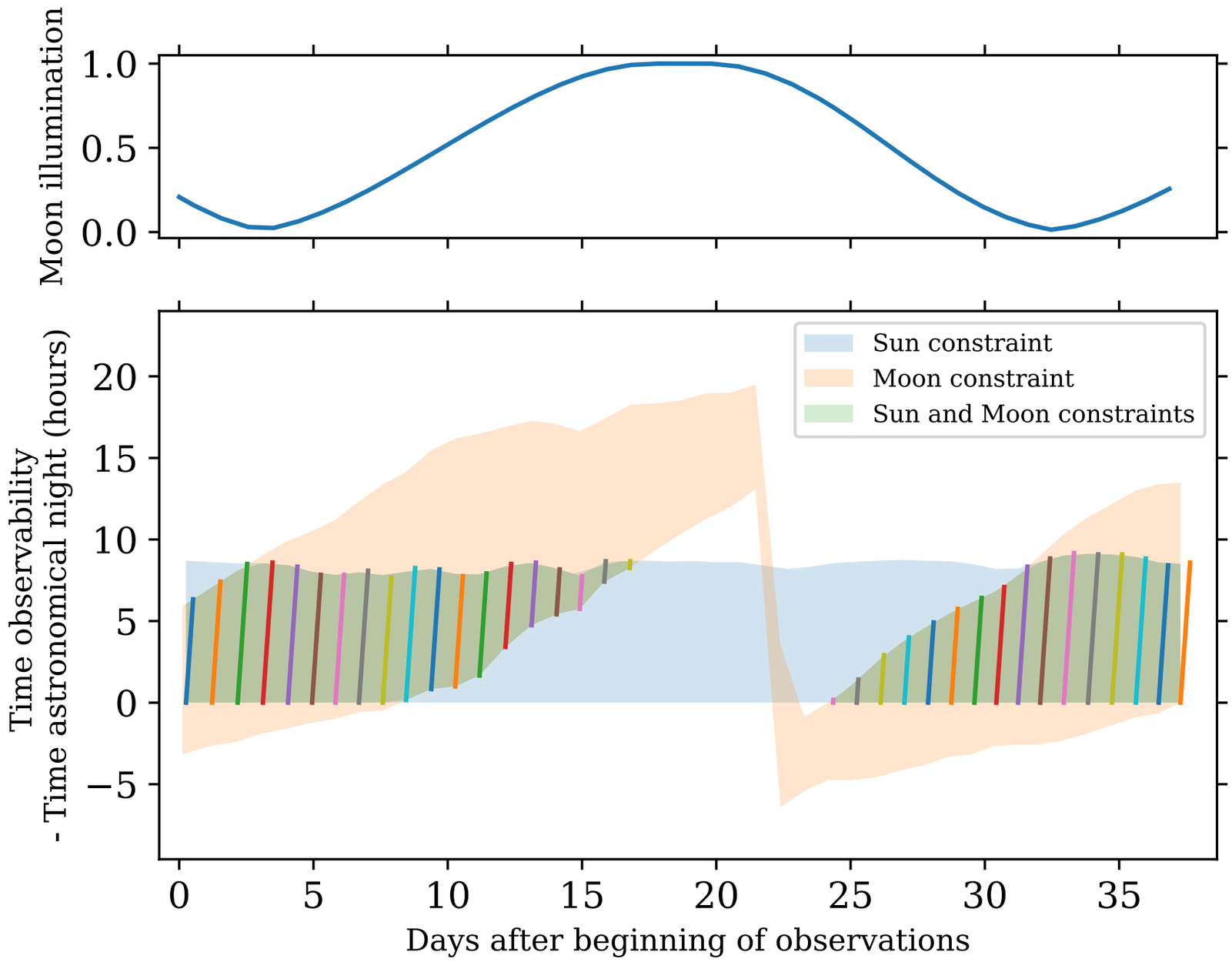




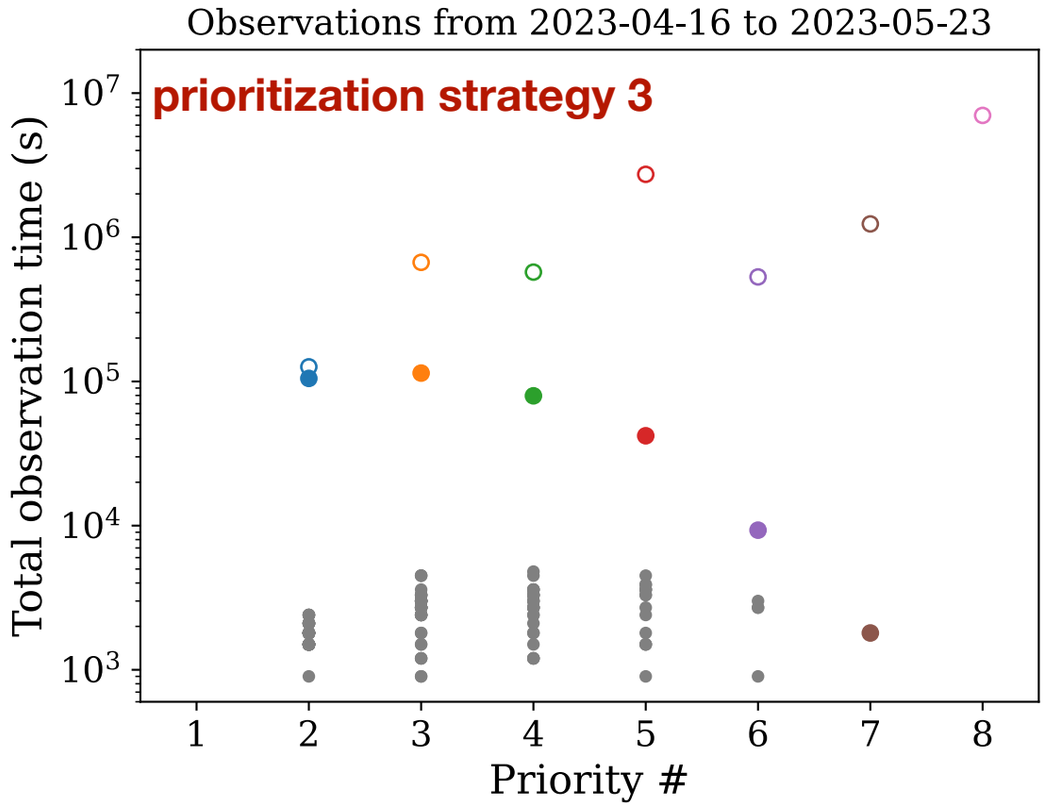


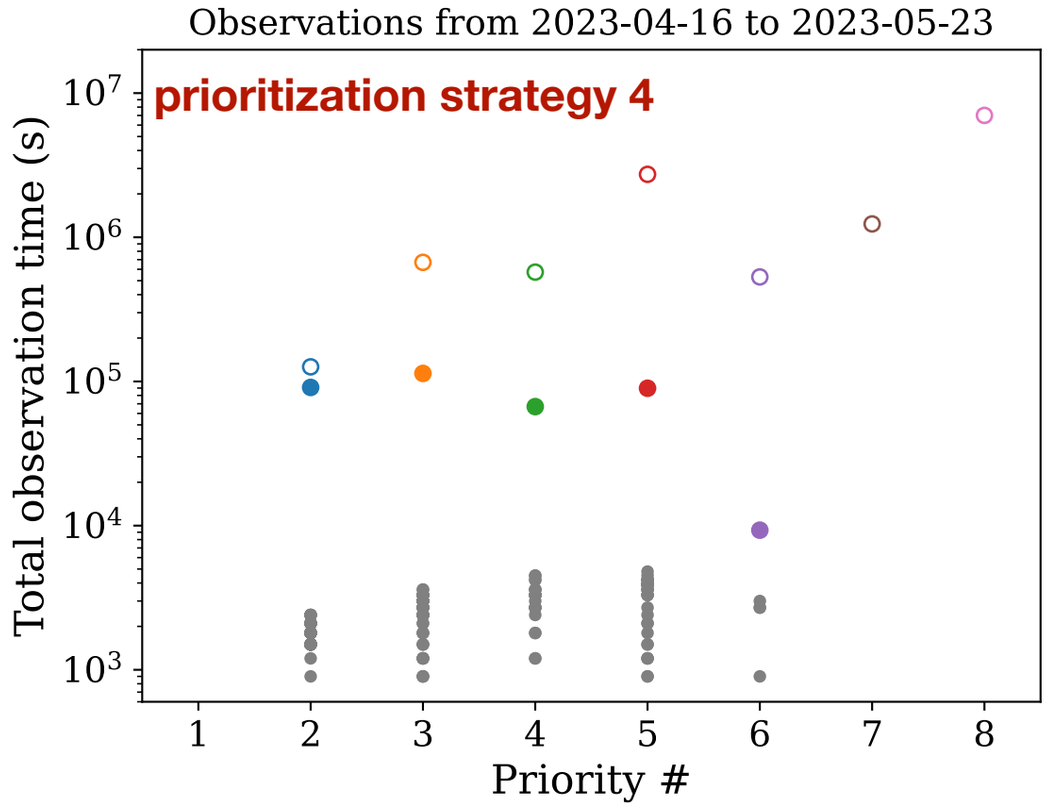


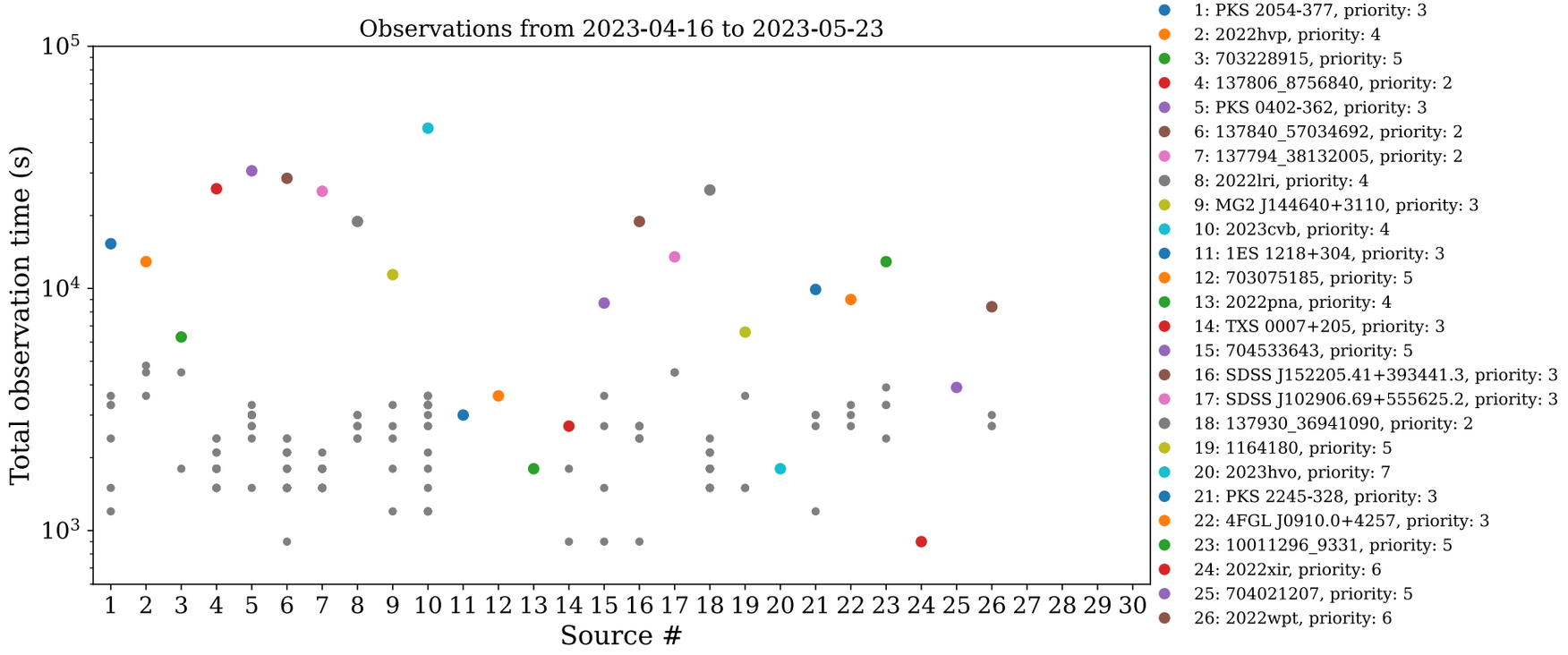
Figures: full flight, observation windows



Figures: full flight, cumulated observation times







Figures: full flight, schedule examples

2023-04-16 - Schedule of observations

Source observed	Pointing and observation times (UTC)	Pointing direction (altitude, azimuth)
PKS 2054-377 (FSRQ)	07:55, [08:05 - 09:05]	(-9.01°, 171.40°)
PKS 2054-377 (FSRQ)	09:05, [09:15 - 09:35]	(-9.01°, 162.01°)
2022hvp (TDE)	09:35, [09:45 - 11:00]	(-9.00°, 347.46°)
703228915 (GRB)	11:05, [11:15 - 12:30]	(-9.01°, 23.69°)
137806_8756840 (IceCube BRONZE)	12:30, [12:40 - 13:10]	(-9.01°, 276.25°)

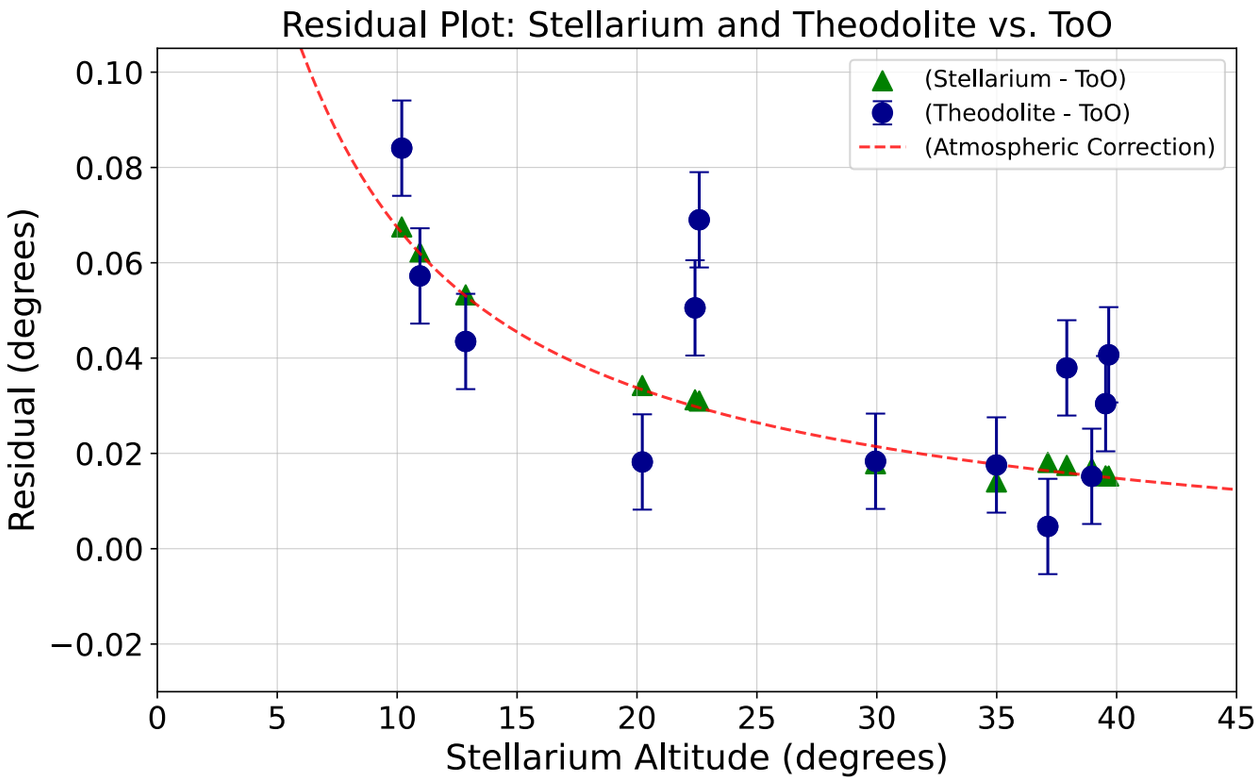
2023-04-17 - Schedule of observations - strategy 3

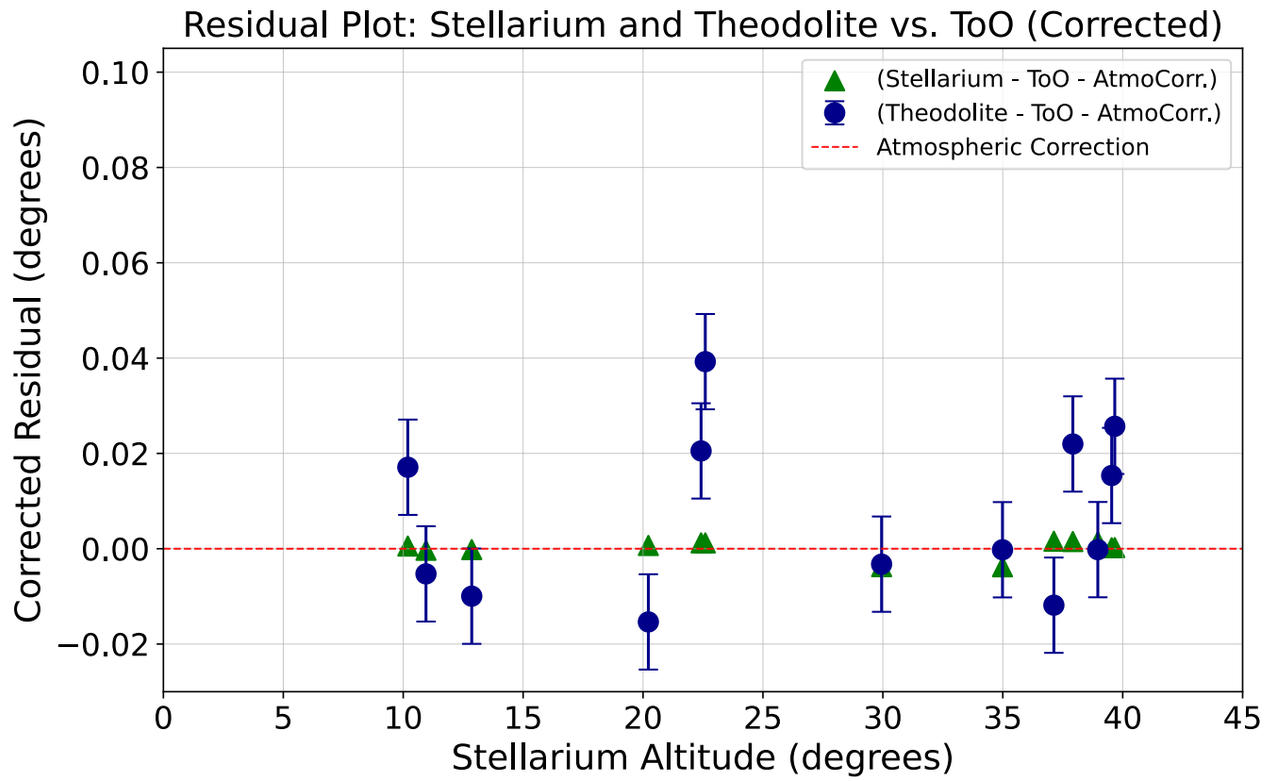
Source observed	Pointing and observation times (UTC)	Pointing direction (altitude, azimuth)
2022hvp (TDE)	07:15, [07:25 - 08:45]	(-9.01°, 359.58°)
2022hvp (TDE)	08:45, [08:55 - 09:55]	(-9.01°, 348.70°)
137806_8756840 (IceCube BRONZE)	11:40, [11:50 - 12:20]	(-9.01°, 275.91°)
PKS 0402-362 (blazar)	12:20, [12:30 - 13:15]	(-9.00°, 194.92°)
PKS 0402-362 (blazar)	13:15, [13:25 - 14:15]	(-9.01°, 182.31°)

2023-04-17 - Schedule of observations - strategy 4

Source observed	Pointing and observation times (UTC)	Pointing direction (altitude, azimuth)
PKS 2054-377 (FSRQ)	07:15, [07:25 - 08:20]	(-9.01°, 171.66°)
2022hvp (TDE)	08:20, [08:30 - 09:40]	(-9.01°, 352.06°)
703228915 (GRB)	10:25, [10:35 - 11:55]	(-9.00°, 21.86°)
PKS 0402-362 (blazar)	11:55, [12:05 - 13:00]	(-9.01°, 198.51°)
PKS 0402-362 (blazar)	13:00, [13:10 - 14:00]	(-9.01°, 185.49°)

Figures: tests, positions of stars





Summary

- paper almost ready for submission (after internal review):
  - one short section left to write (2.3.5)
  - a couple of comments
- code almost ready for release of version 1: some documentation missing

Medium term (v2) — PBR

- Listener: evolution of alert systems
  - New observations ex. VRO, SVOM, next LVK runs
  - Collaboration with AstroColibri?
- Scheduler: validate priority ranking and scheduling strategy
- GUI: plan usage for PBR
- NuTS + NuSpaceSim, sensitivity predictions full flight + update scheduling strategy

Link to the full task list:
https://docs.google.com/spreadsheets/d/1yHvu-pbETx_OYxiW2LqZWGxRL8Gq97VhhtWUs9RZtbc/edit?usp=sharing

- Suggestions welcome for paper submission and code release
- Suggestions and contributions welcome to adapt NuTS to future missions

Thank you!