Observing Strategy for the Astri MA

Andrea Giuliani
for the ASTRI Project

"Pillar" Sources

from Vercellone et al.

Pillar 1
Origin of CRs

- **PeVatrons**
- **CRs Propagation**
- **Pulsar Wind Nebulae**

Pillar 2
Cosmology and Fund. Physics

Name	Type	Exposure (Hrs)
Tycho Snr	SNR	400
Gal. Center	Diffuse	260
VER J1907	SNR+PWN	500
G106.3+2.7	SNR	200
γ-Cygni	SNR	500
W28	SNR/MC	500
M82	Starburst	400
Crab	PWN	300
Geminga	PWN	500
IC 310	Radio gal	10-500
M87	Radio gal	10-500
Mkn 501	Blazar	5-500
1ES 0229+200	Blazar	200-250

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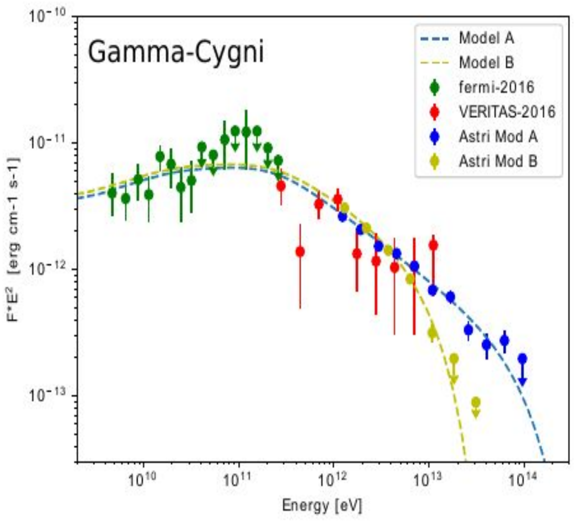
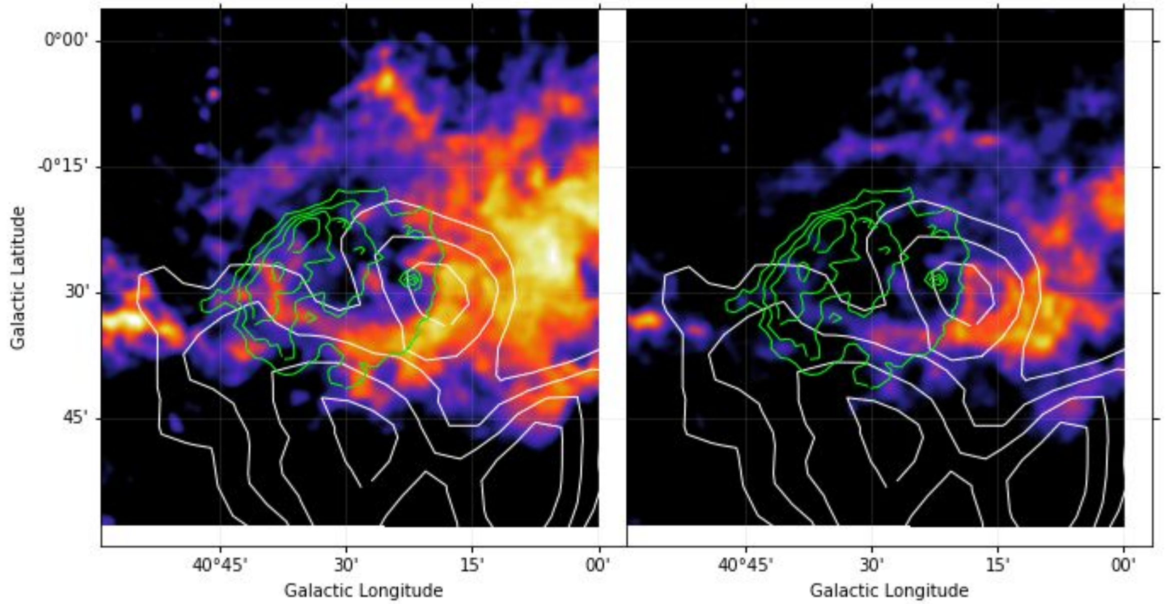


Figure 15: γ-ray spectrum of γ-Cygni. Data are from Fermi-LAT and VERITAS while theoretical models A and B (described in the text) are showed with dashed curves. Blue and yellow dots show the ASTRI Mini-Array simulations for model A and B, respectively, for 500 hr of exposure.

HAWC J1908+063



Maps of 12 CO (left) and 13 CO (right) emission in the MGRO J1908+06 region integrated between 58-62 km s −1 . The white solid lines are the same as in Fig. 1, while the green contours are the continuum emission from SNR G40.5-0.5 at 1.4 GHz.

Crestan et al. , MNRAS, 2021

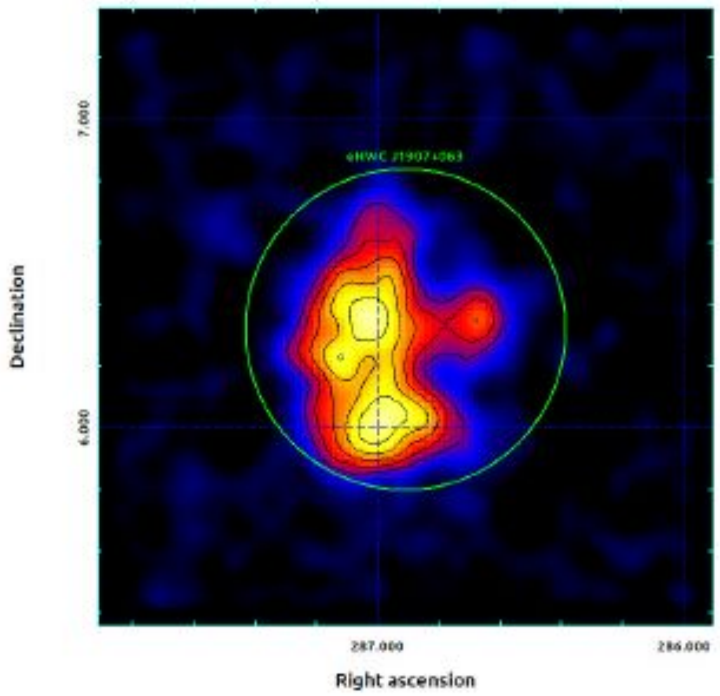


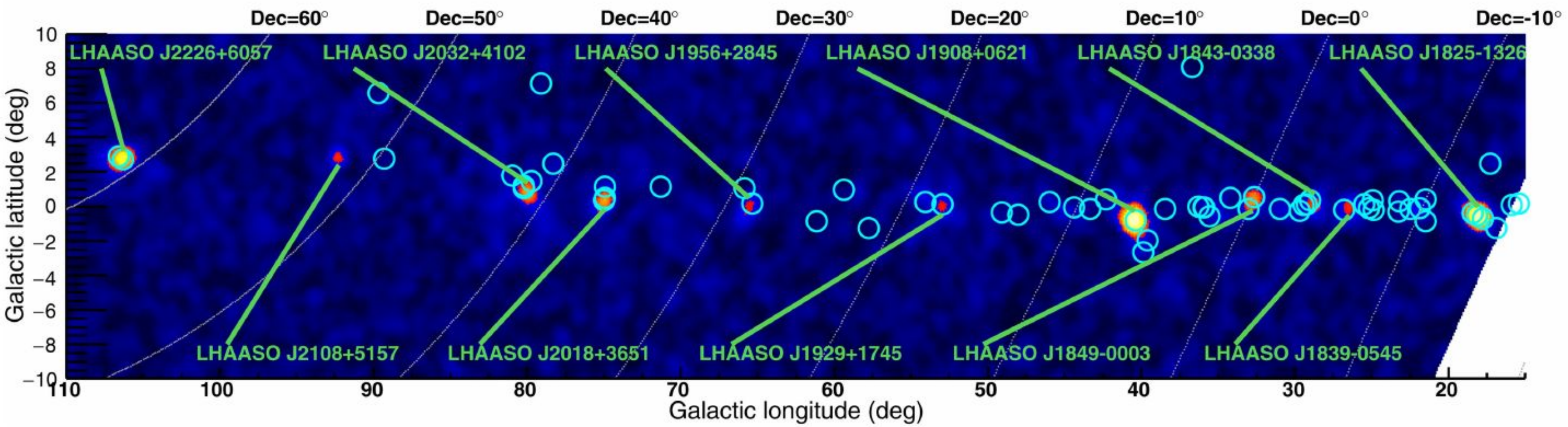
Figure 12: ASTRI Mini-Array 200 hr simulation of the region of the Galactic source 2HWC J1908+063. The light green circle marks the $\sim 0.52^\circ$ HAWC error-box for $E > 56$ TeV (see text for details).

Vercellone et al. . - In preparation

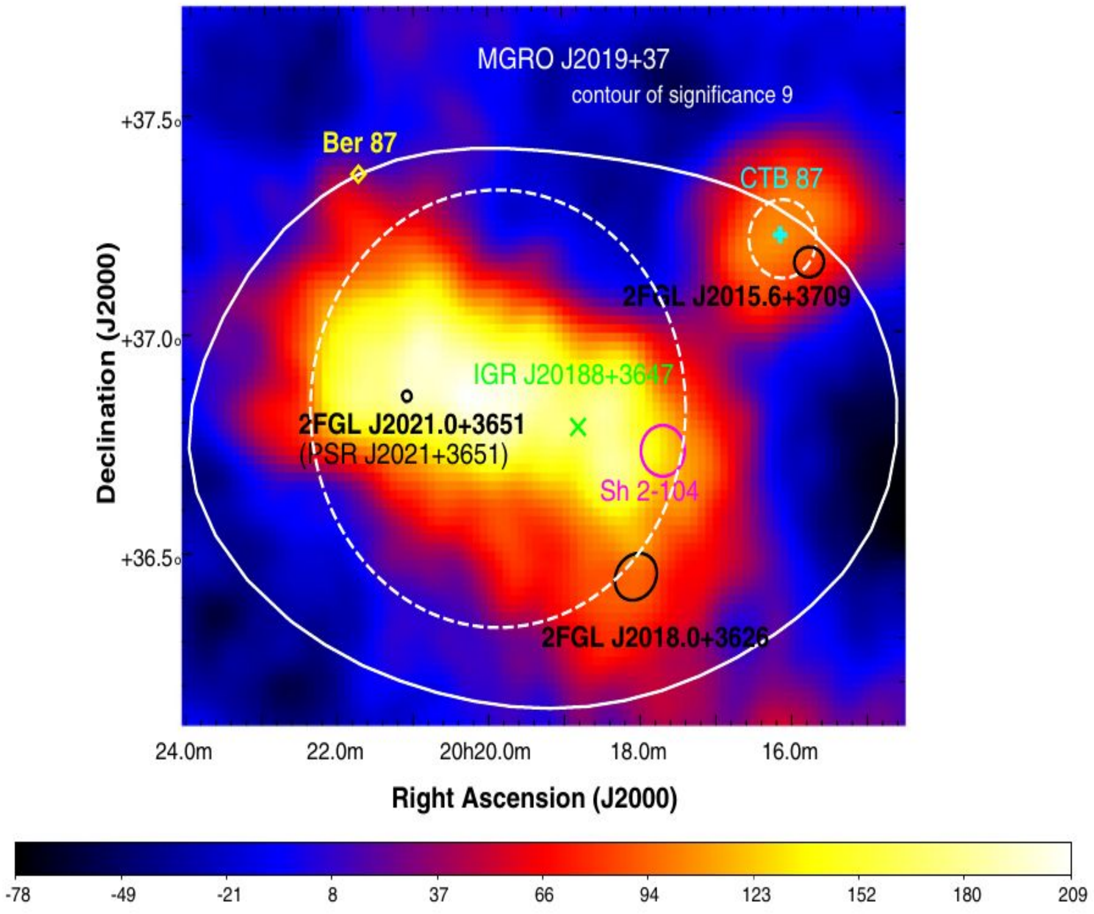
LHAASO Sources

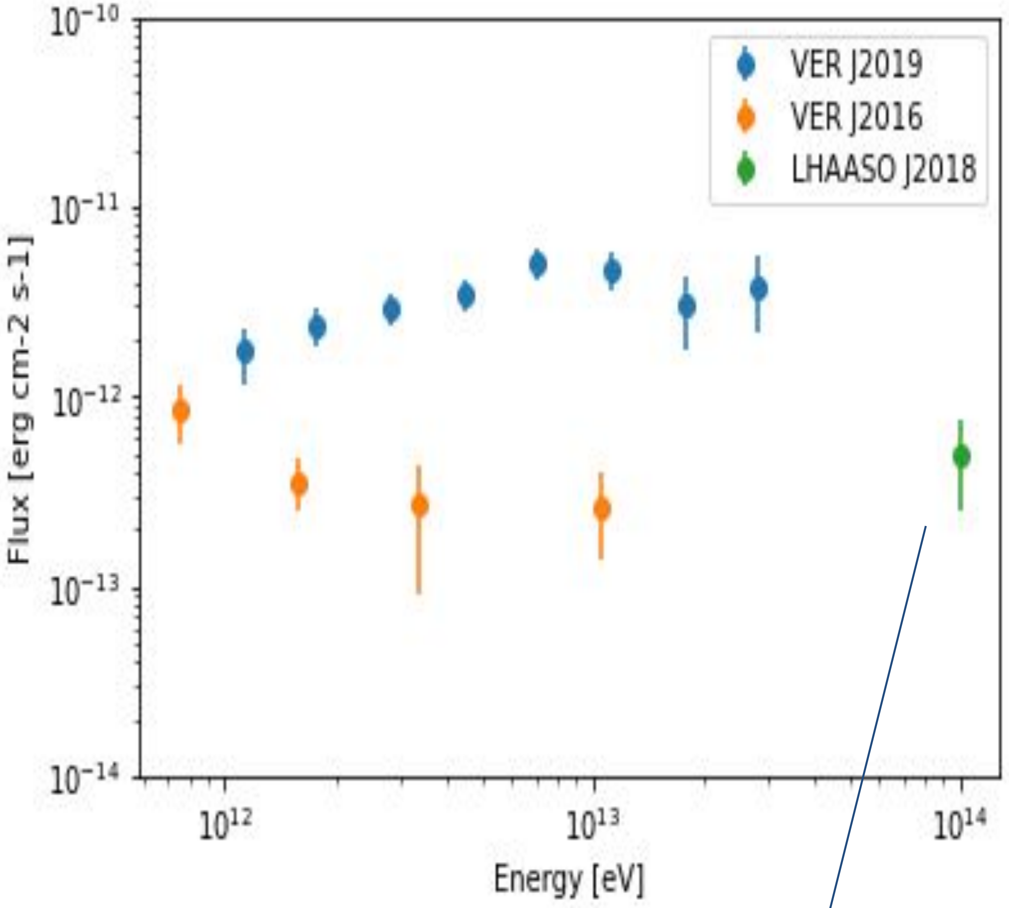
Source name	RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326	276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545	279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338	280.75	−3.65	8.5	$0.26 - 0.10^{+0.16}$	0.73(0.17)
LHAASO J1849-0003	282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745	292.25	17.75	7.4	$0.71 - 0.07^{+0.16}$	0.38(0.09)
LHAASO J1956+2845	299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102	308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157	317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

Celestial coordinates (RA, dec.); statistical significance of detection above 100 TeV (calculated using a point-like template for the Crab Nebula and LHAASO J2108+5157 and 0.3° extension templates for the other sources); the corresponding differential photon fluxes at 100 TeV; and detected highest photon energies. Errors are estimated as the boundary values of the area that contains ±34.14% of events with respect to the most probable value of the event distribution. In most cases, the distribution is a Gaussian and the error is 1σ.



LHAASO J2018+3651



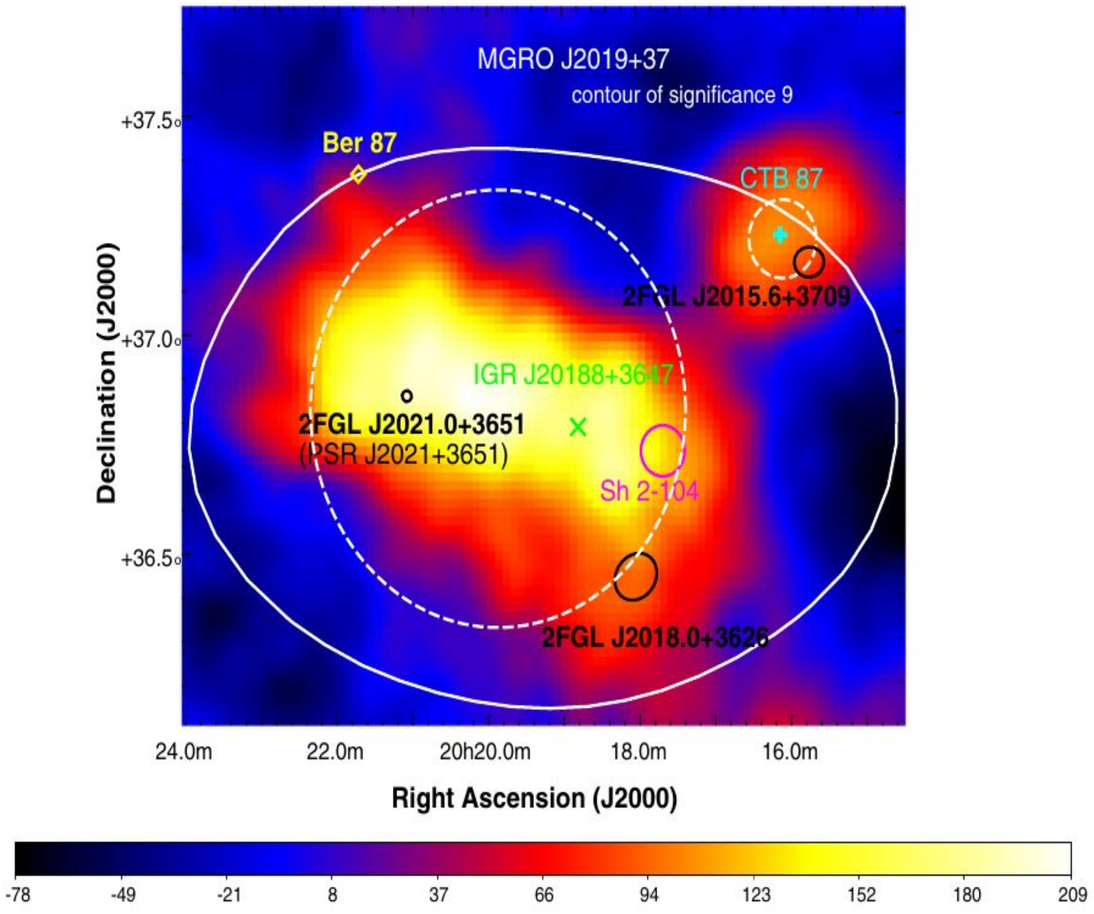


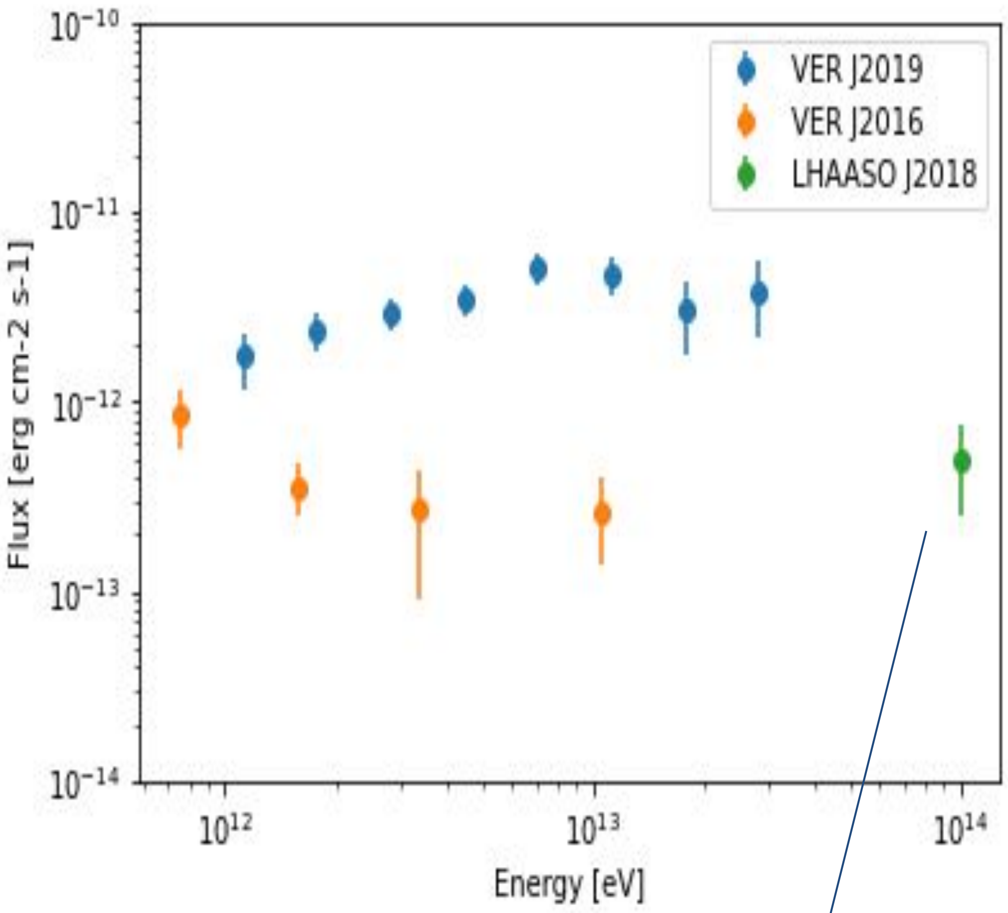
From : The Astrophysical Journal, 788:78 (10pp), 2014

LHAASO source !

~ 1 ph every 2 hrs (E > 50 TeV) in the MA

LHAASO J2018+3651





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LHAASO source !

~ 1 ph every 2 hrs (E > 50 TeV) in the MA

Observing Plan

Issue : we need a lot of exposure

Strategy :

Focus on few sky fields → Long exposures

3 aces up the sleeve :

- Large FoV → Several sources in the FOV
- Observations with moonlight → Increases avail. time ~50%
- Large Z.A. → Increase Aeff @ high energies

Observing Plan : an example

Per year :

Moonless Night Hours	1565
Fraction of clear nights (<20% cloud)	0,79
Loss due to bad weather	0,04
Loss due to “Calima”	0,07
Average Annual Observation Time	1100

Availability: 91%
Uptime: 1000 h
Downtime 100 h
Mean Dead Time: 20 h
5 Failures at system level per year

Duty Cycle: 13% defined as AAOT/Hours yr

on 3 years : 3300 -3000 hours (moonless)

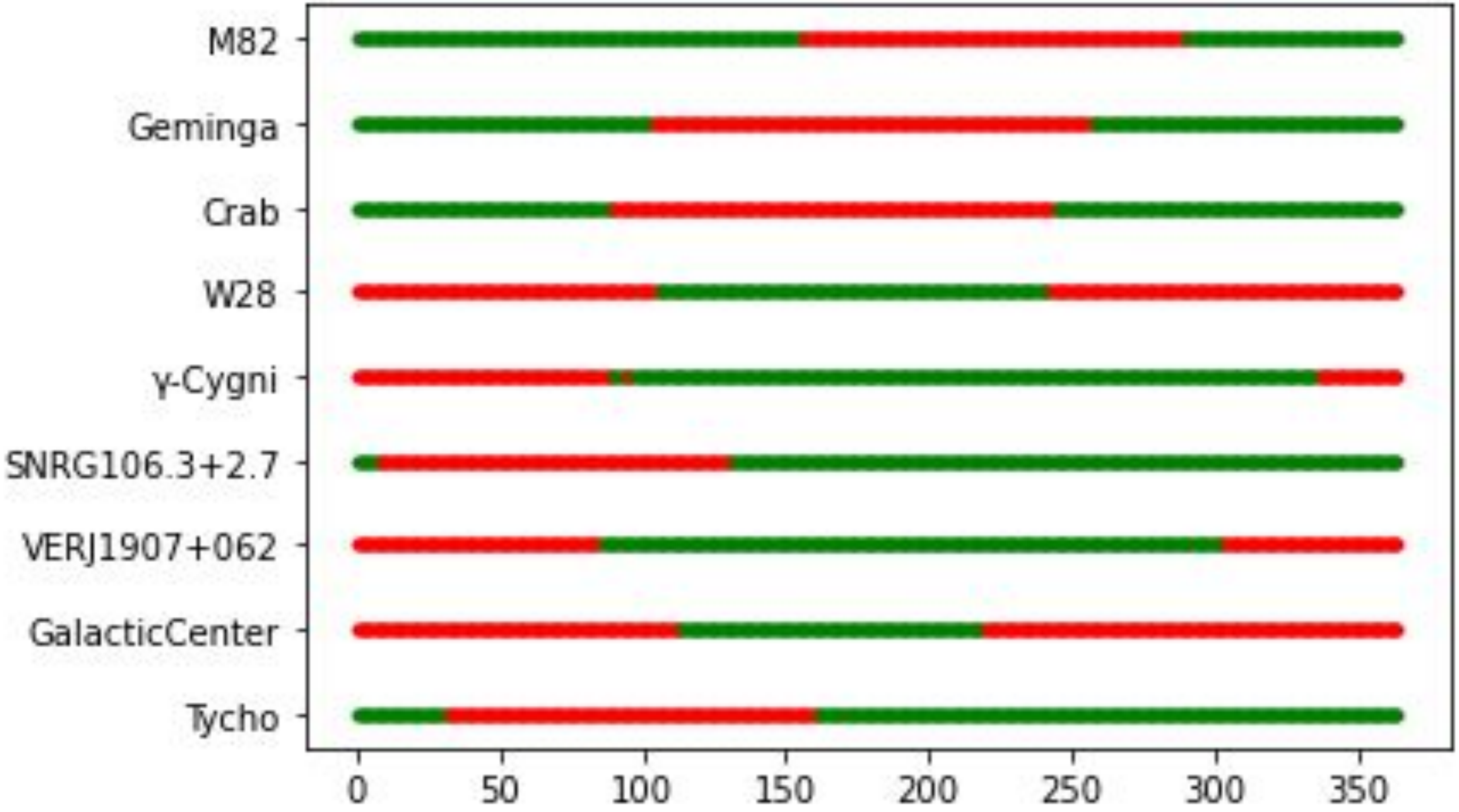
Time budget (Hrs):

Pillar 1 2000

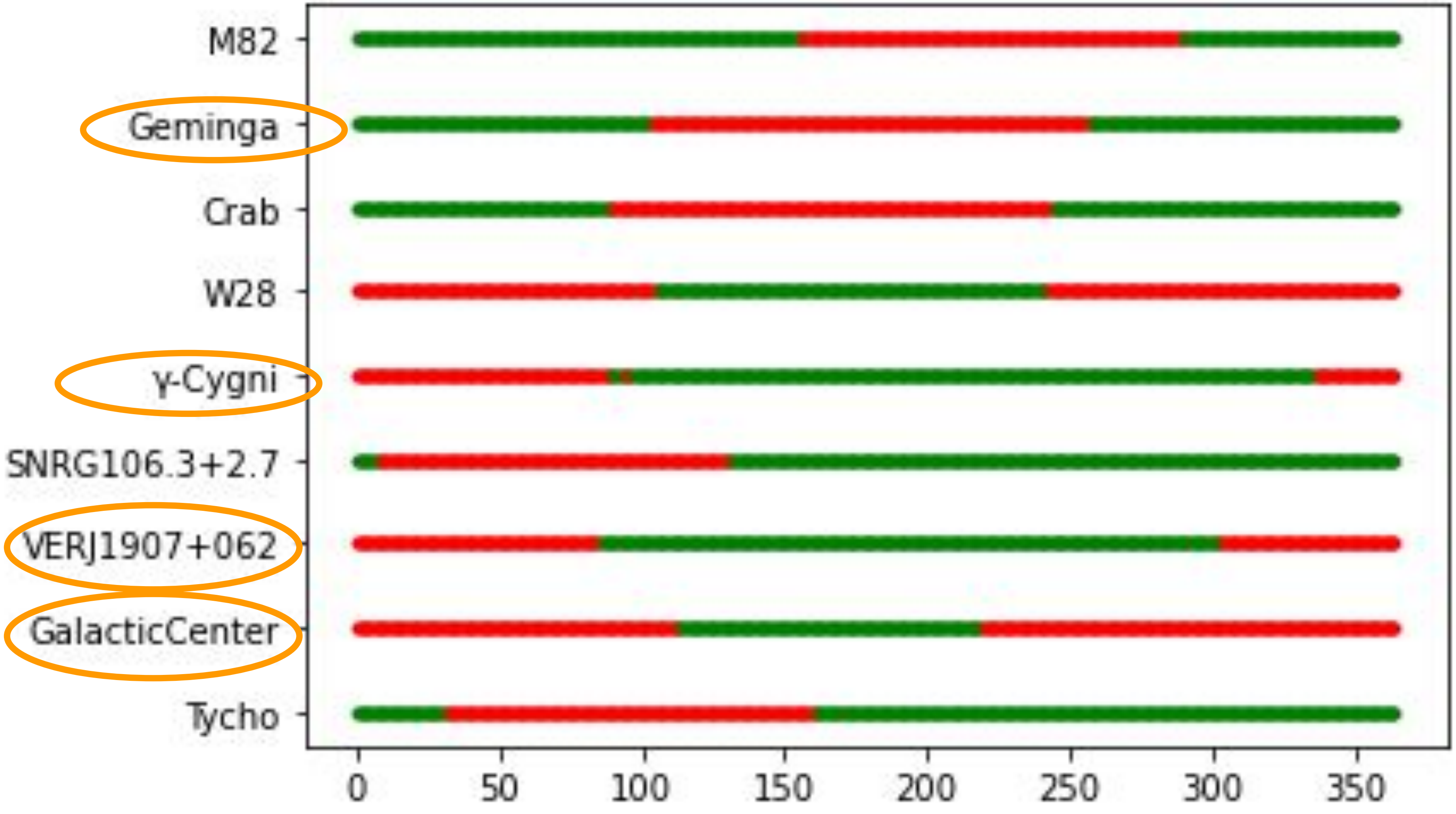
- Pevatrons 1000
- CRs diffusion 500
- PWNe 500

Pillar 2 1300

Observing Plan



Observing Plan : an example

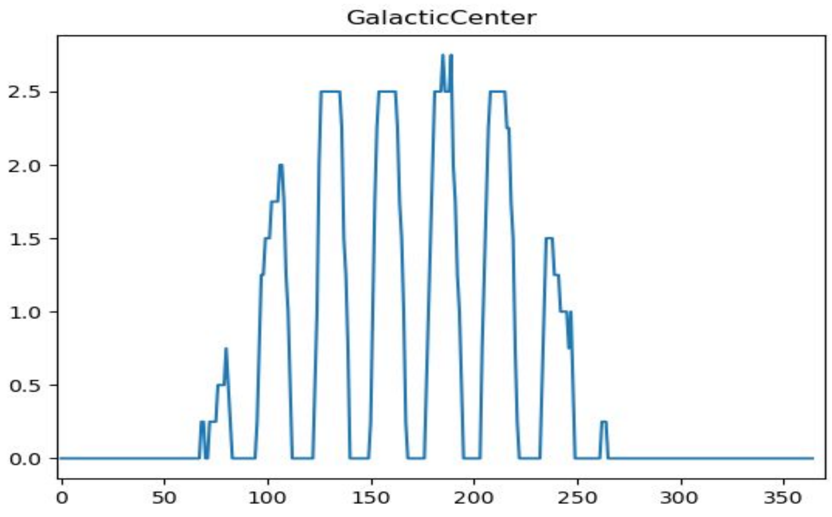


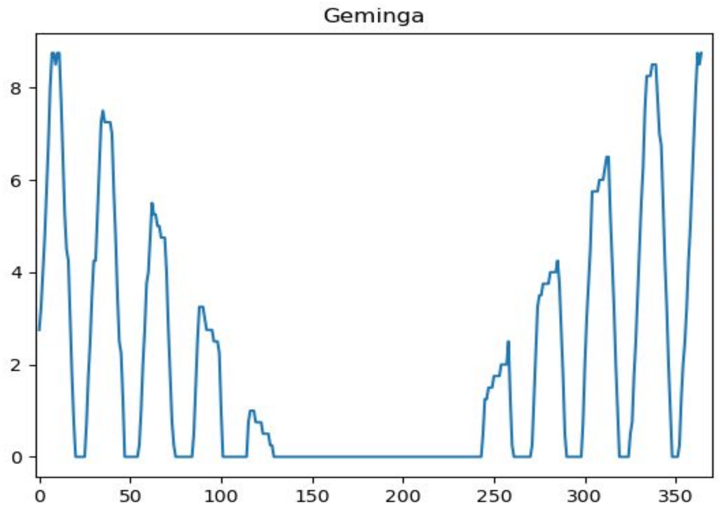
plus :

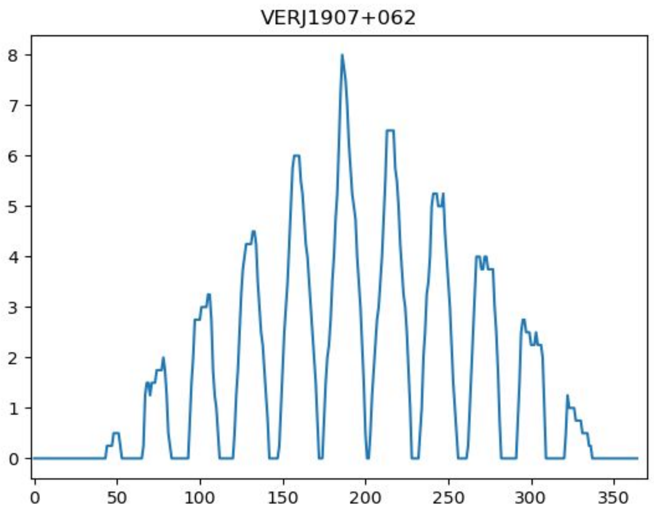
IC 310

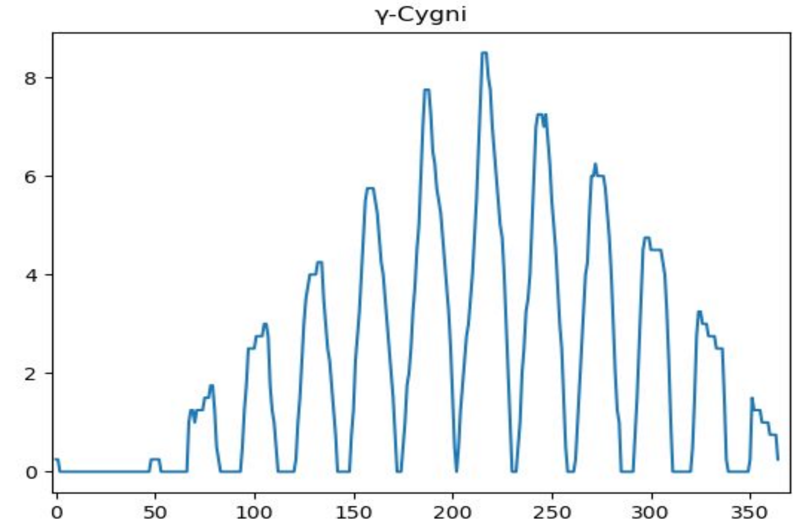
Mrk 501

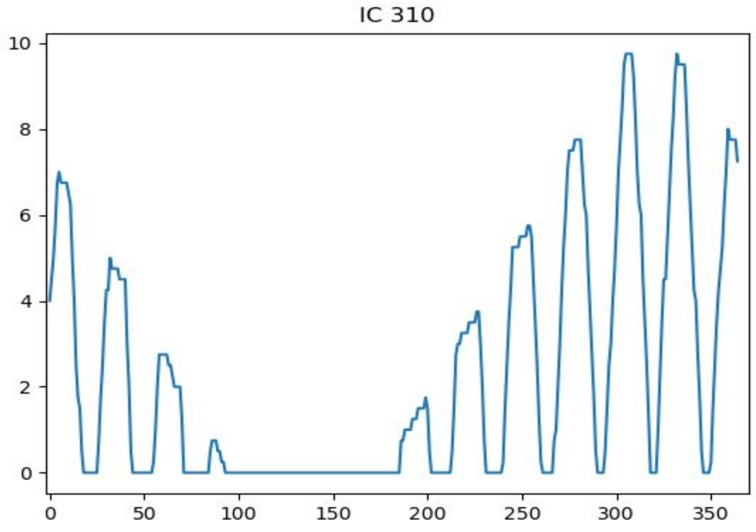
Observing Plan . Visibility in 2024

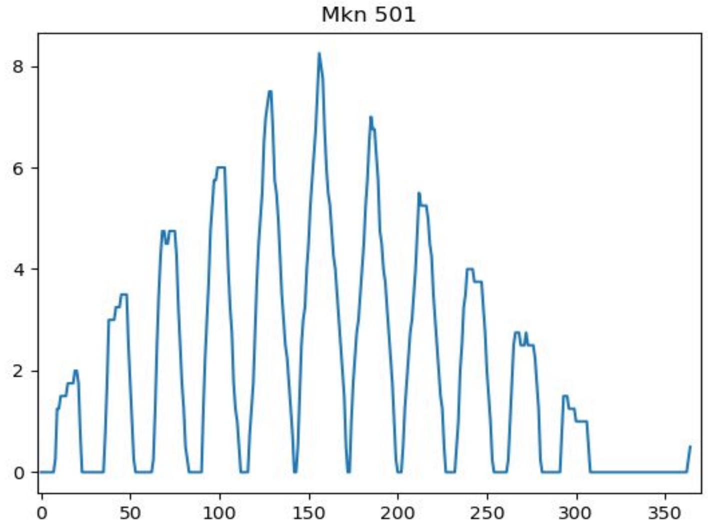












Observing Plan

Hours per year (2024) :

Geminga :	*148.25*
Mkn 501 :	*144.5*
g-Cygni (1) :	*26.75*
Gal Center :	*138.0*
VER J1907+062 :	*142.5*
g-Cygni (2) :	*91.75*
IC 310 :	*180.0*

Over 3 years :

P1 :	**1641.75**
Pevatrons :	841.5
CRs diffusion :	355.5
PWNe :	444.75
P2 :	**973.5**

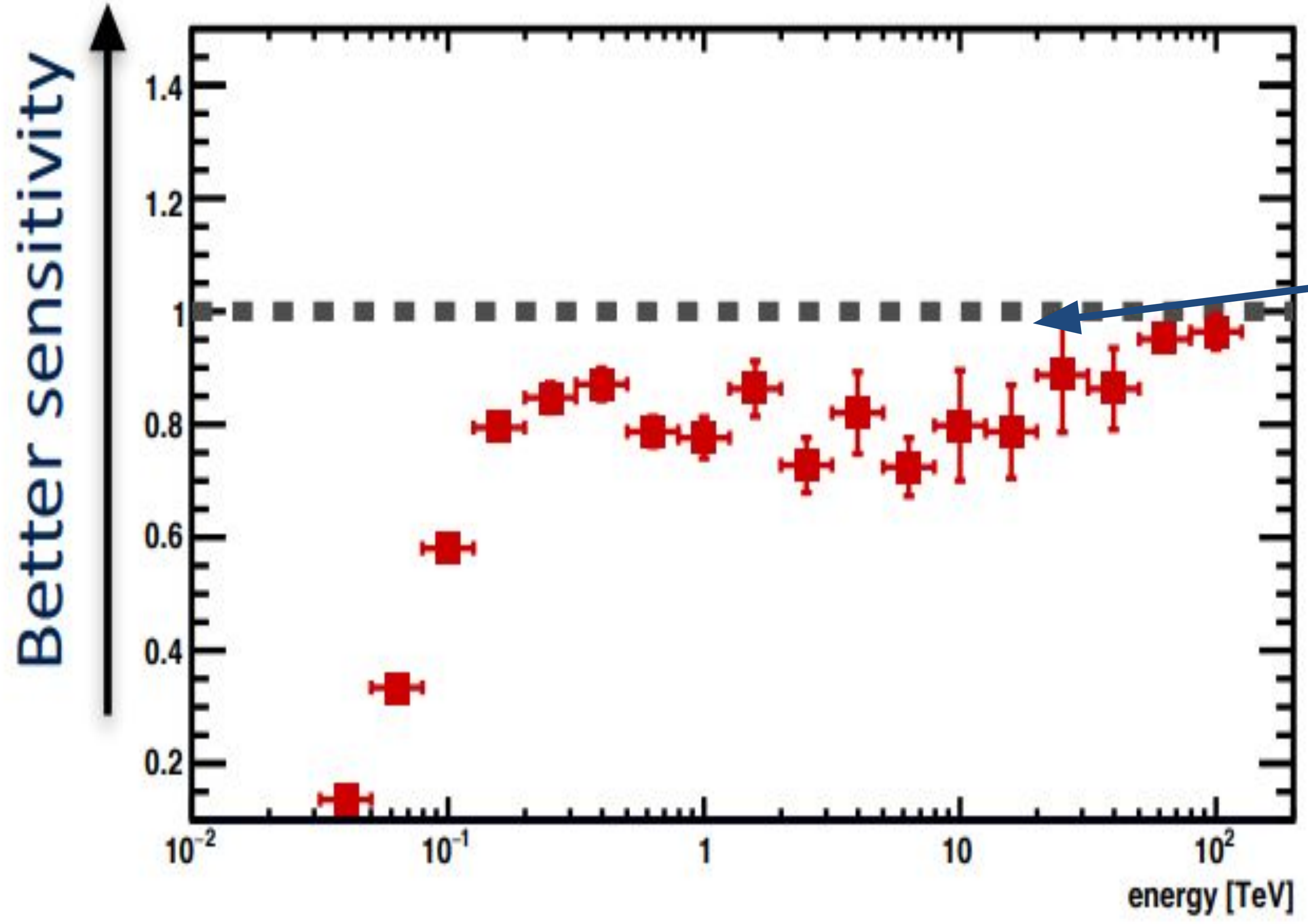
Time budget :

Pillar 1 2000

- Pevatroni 1000
- CRs diffusion 500
- PWNe 500

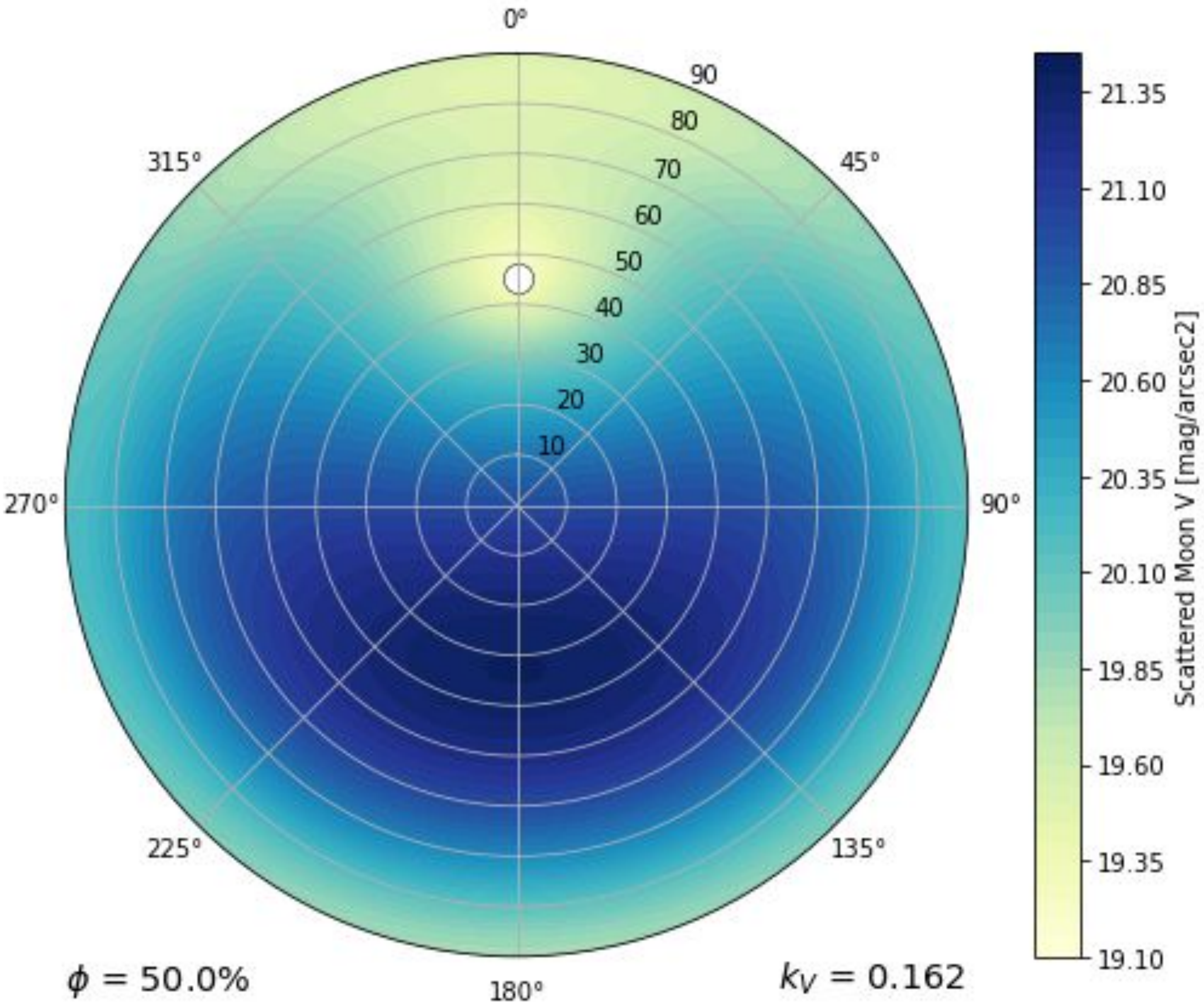
Pillar 2 1300

Observing Plan - MoonLight (CTA)



Little degradation above ~ 10 TeV

MoonLight

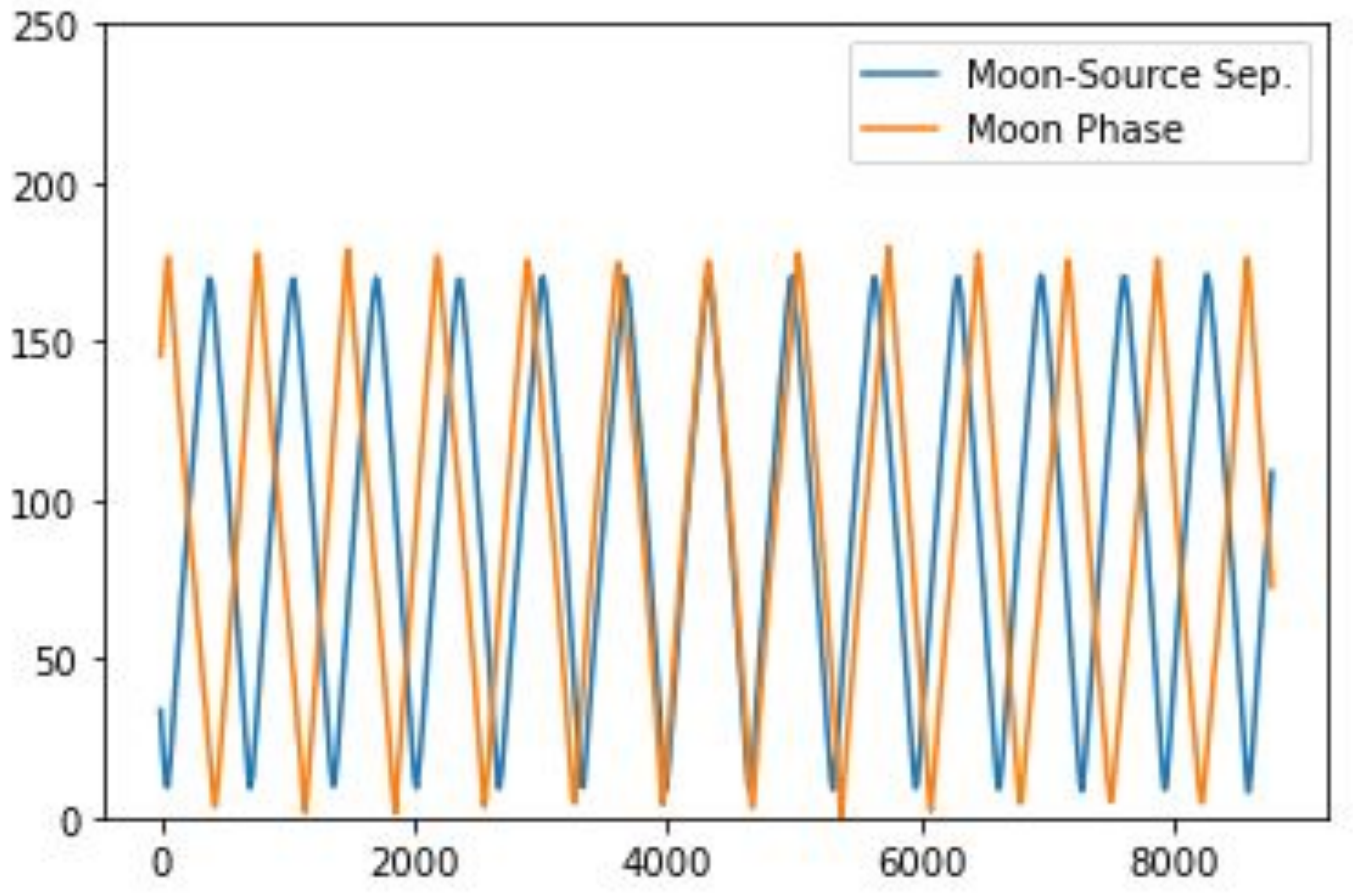


- SpecSim
  (https://specsim.readthedocs.io)
- Based on the model by ***Krisciunas&Schaefer***

Brightness in V [mag/arcsec^2]

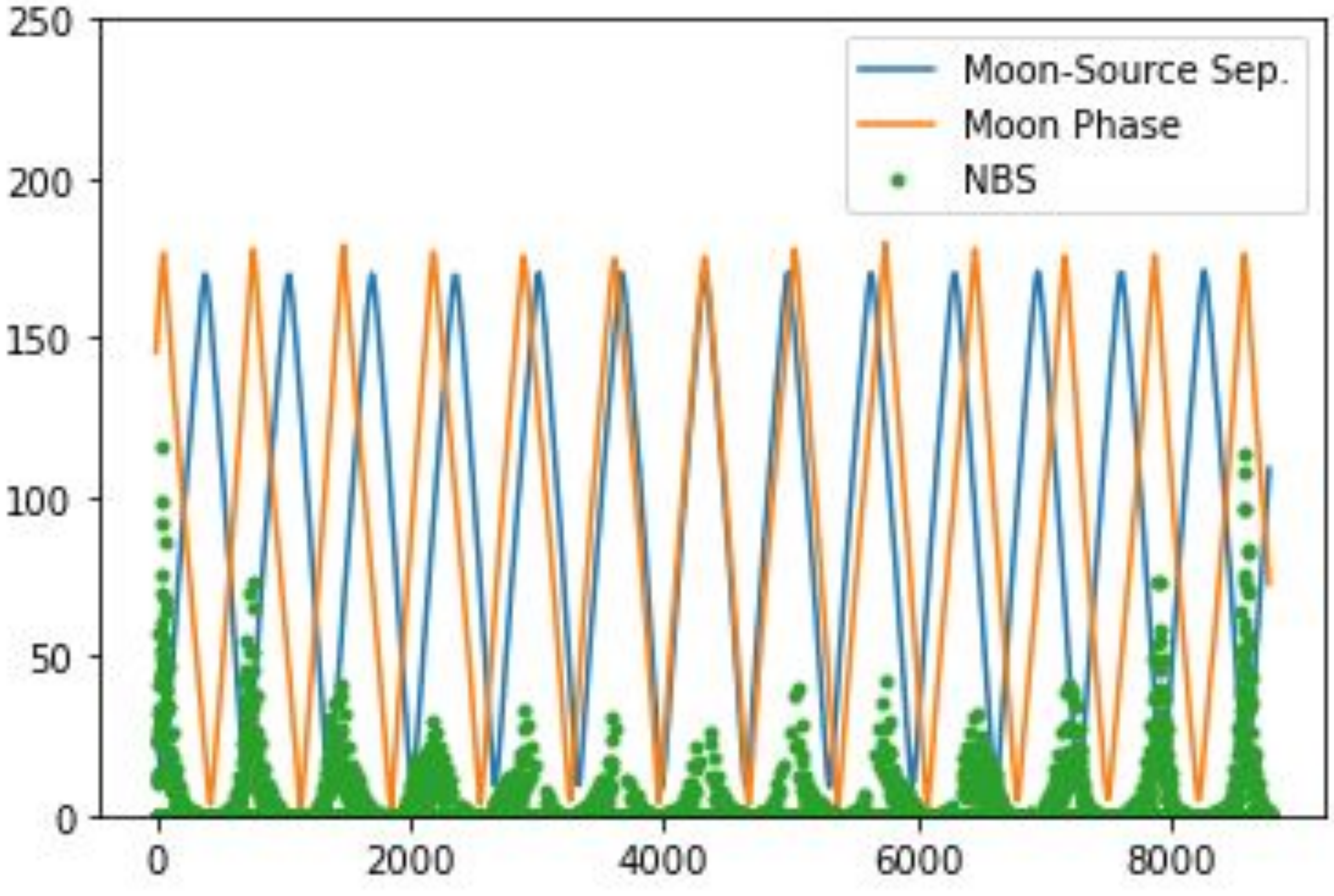
	SkyCalc	**SpecSim**	**diff Fluxes**
halfmoon_sep20	*20.04*	*20.03*	*0.9 %*
halfmoon_sep40	*20.47*	*20.52*	*4.7 %*
halfmoon_sep60	*20.68*	*20.75*	*6.7 %*
fullmoon_sep40	*18.33*	*18.30*	*2.8 %*

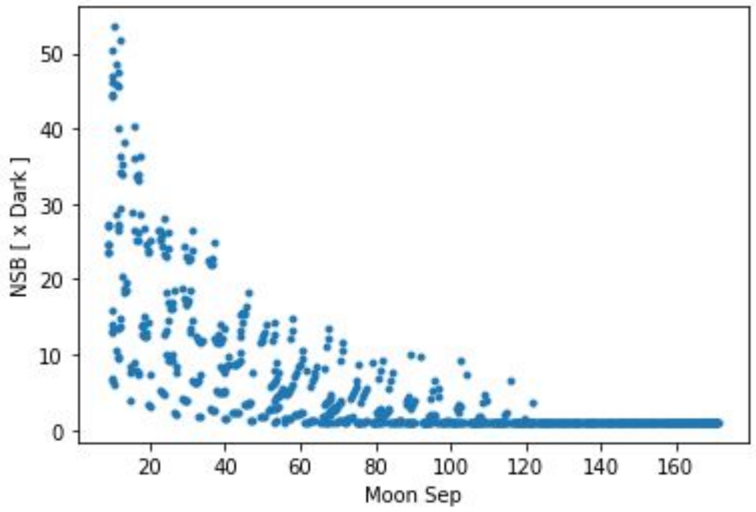
Observing Plan - MoonLight - Geminga Halo

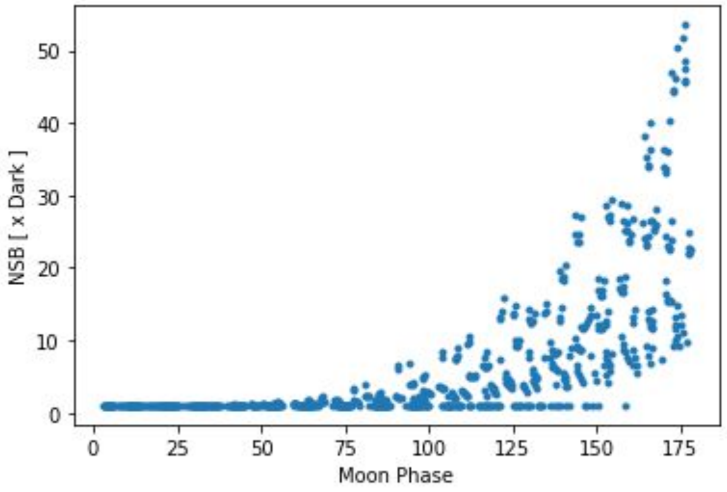


- For year 2026

Observing Plan - MoonLight - Geminga Halo

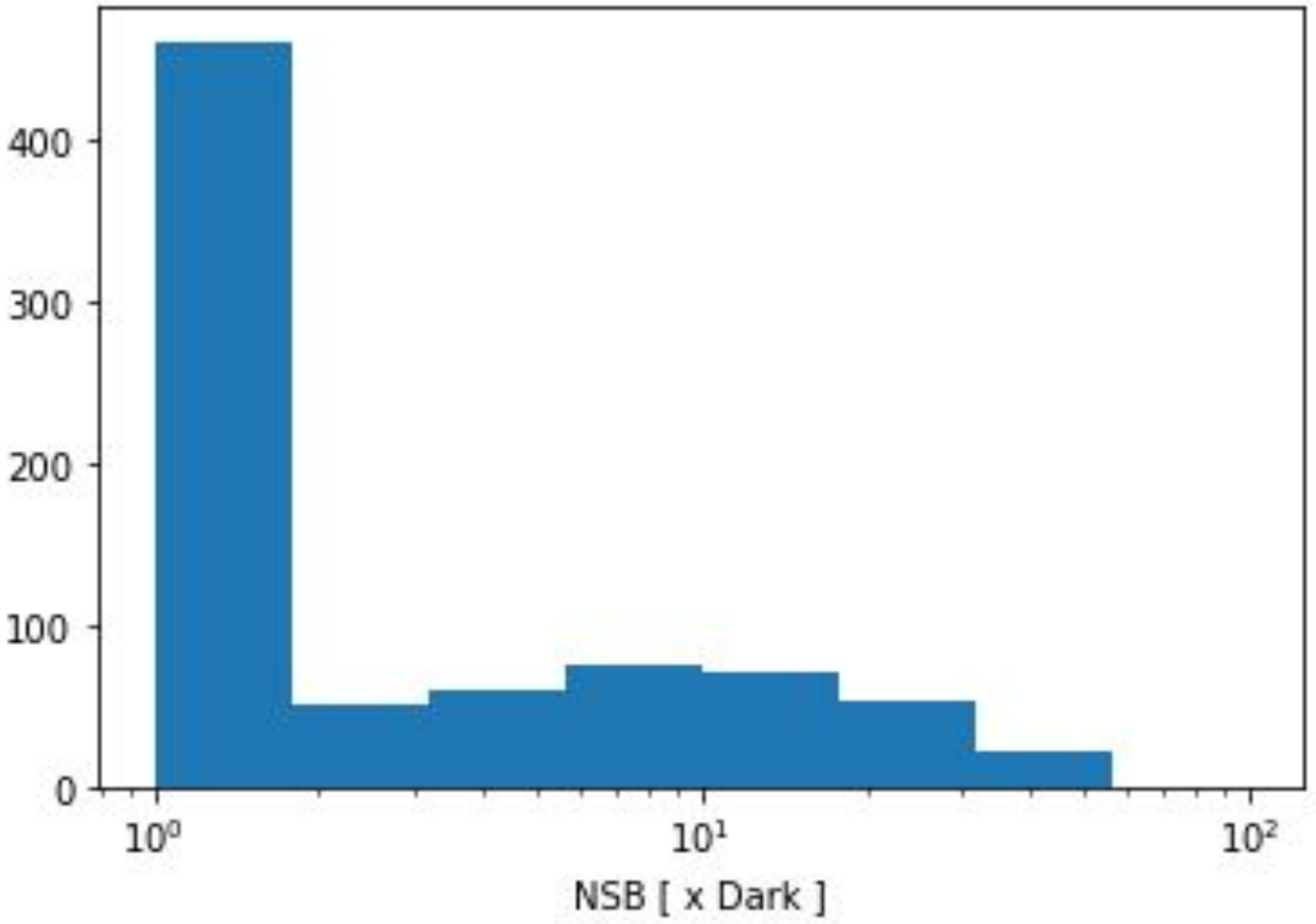


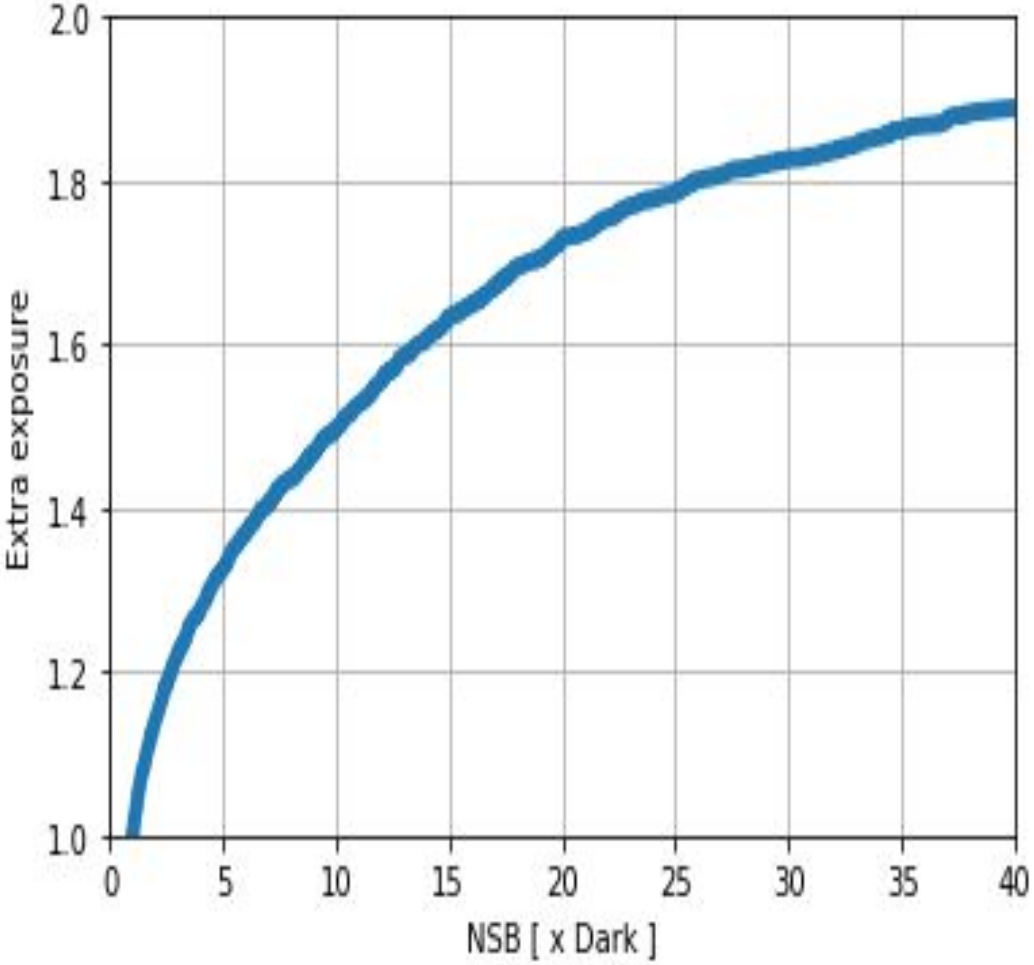




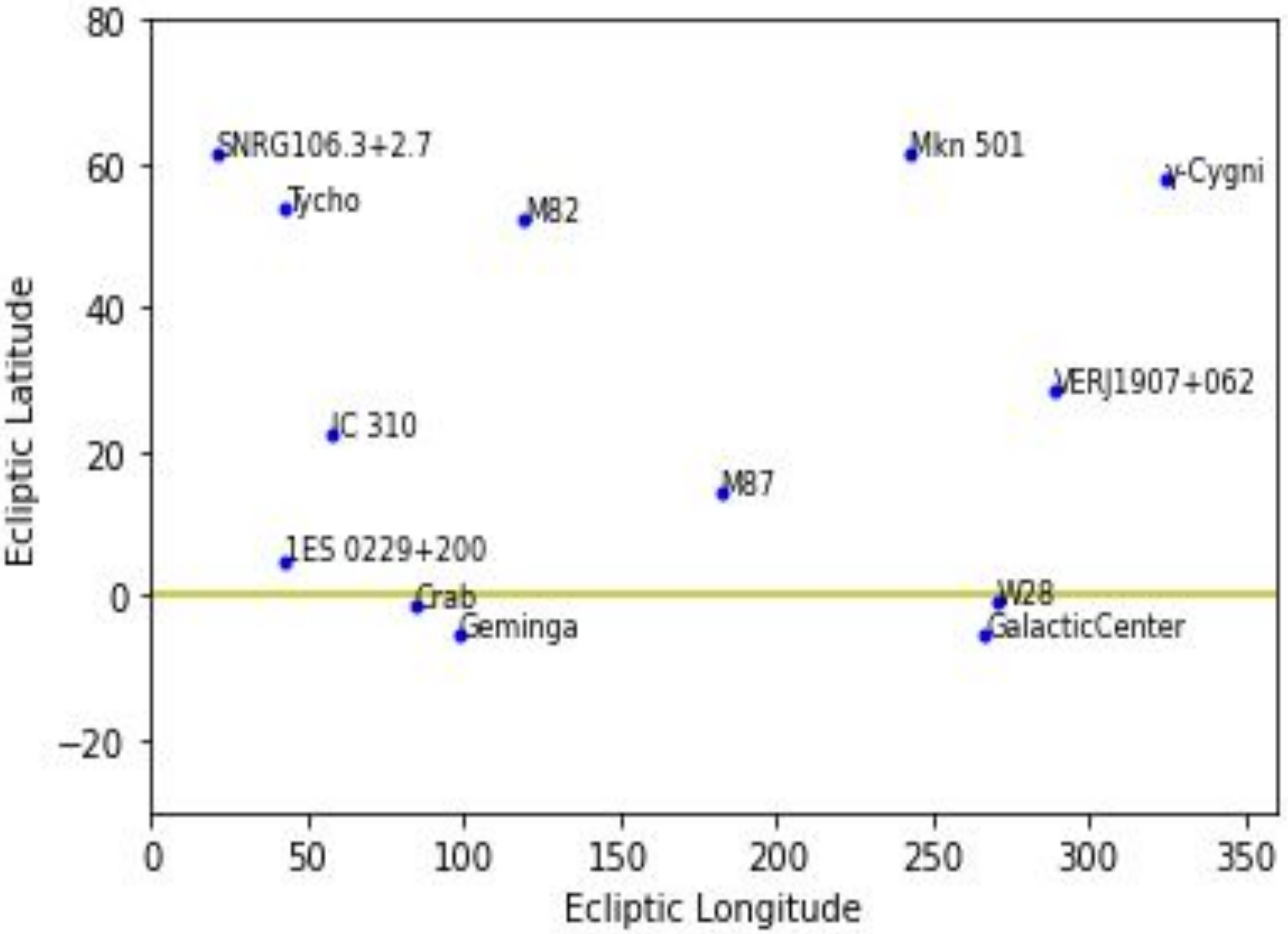
- For year 2026
- Dark : m_V= 21.55

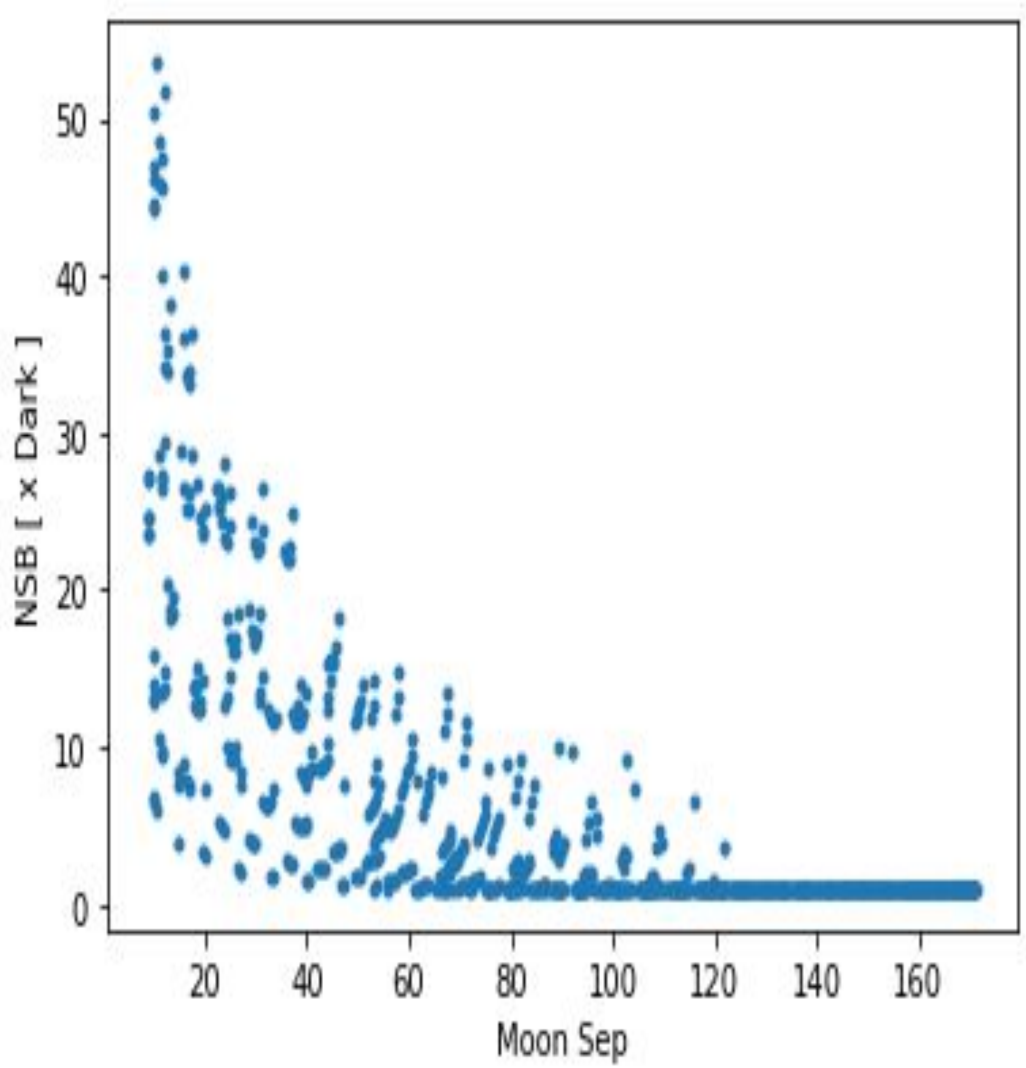
Observing Plan - MoonLight - Geminga Halo



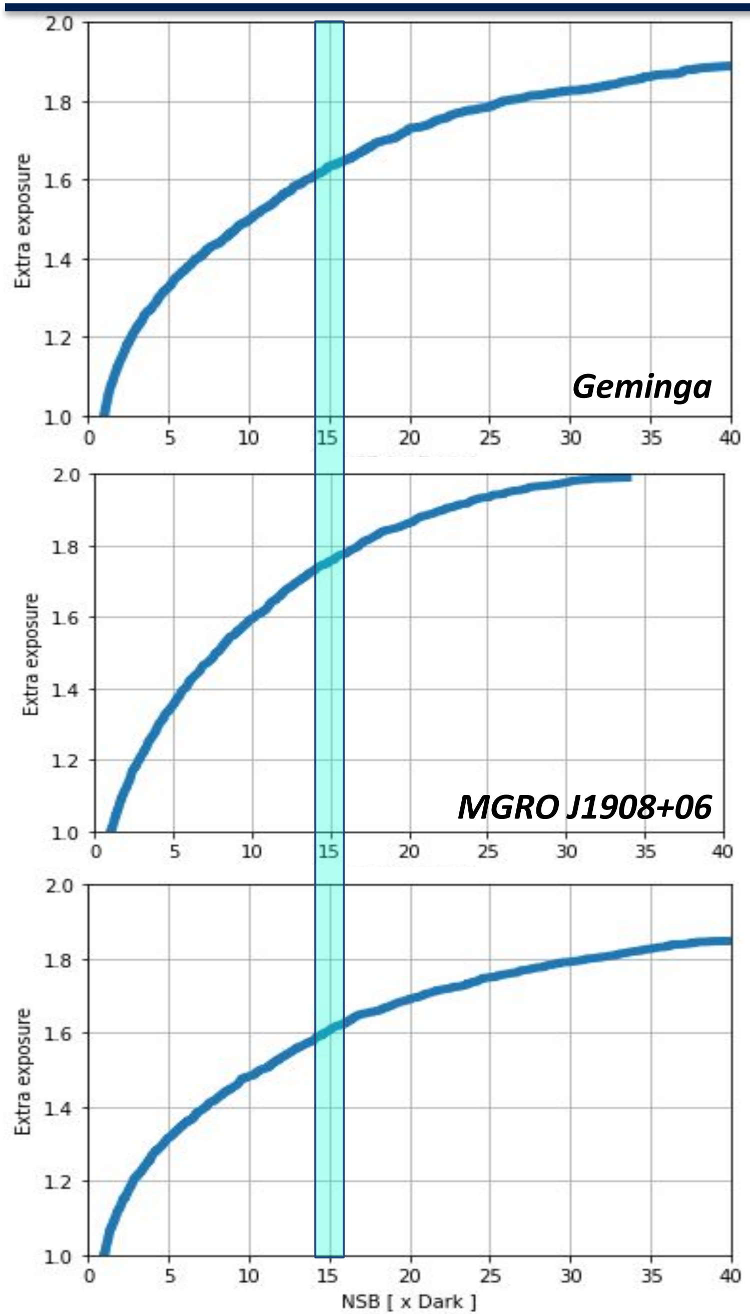


Observing under MoonLight





Observing under MoonLight



Dark NSB : ***0.24 ph / cm^2 ns sr***

in the band 300-650 nm

15 x Dark NSB : ***3.6 ph / cm^2 ns sr***

corresponding to : ***~ 1 GHz*** *on one camera pixel*

~ 50-70 %

Observing Plan - Large FOV → sec. targets

Lot of TeV sources in the Observing-Plan fields, for example :

GC ……………………….. SNR G0.9+0.

VERJ1907 ……………... W 49B,

SS 433,

2HWC J1902+048

gamma-Cygni ……... 2HWC J2024+417

Geminga ………………… IC 443

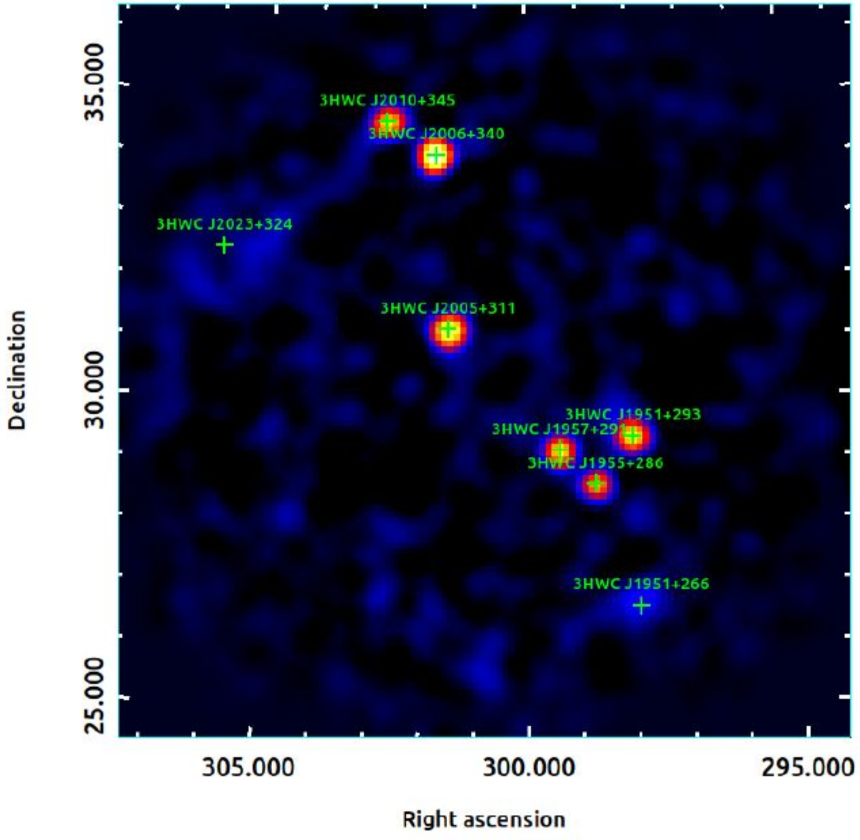


Figure 13: ASTRI Mini-Array 200 hr simulation of the Cygnus Region. Green crosses mark the positions of the 3HWC sources in a 10° × 10° field of view (see text for details).

Astri MA data-challenge

- Focused on analysis issues :
  - ***Simulation of DL3 data*** (gammapy simulator)
  - Realistic sky model
    - Extended Sources and source confusion
    - Lhaaso spectra
    - “Crowded” sky regions
    - diffuse emission
  - Observing strategy
    - Wobble / fullAperture ? (maximising the scientific output)
    - Realistic pointing plan
  - Variability
  - Systematics
- First and “Mini”
  - Only two sky regions : Galactic /extraGalactic
  - First of a serie of DCs

Sky regions

ASTRI Mini-Array

IC 310

- **Astri Science-UC 1**
  (Observing a point like source)
- Isolated pointlike source
- Wobble strategy
  - wobble optim.
  - reflected regions analysis
- Variability

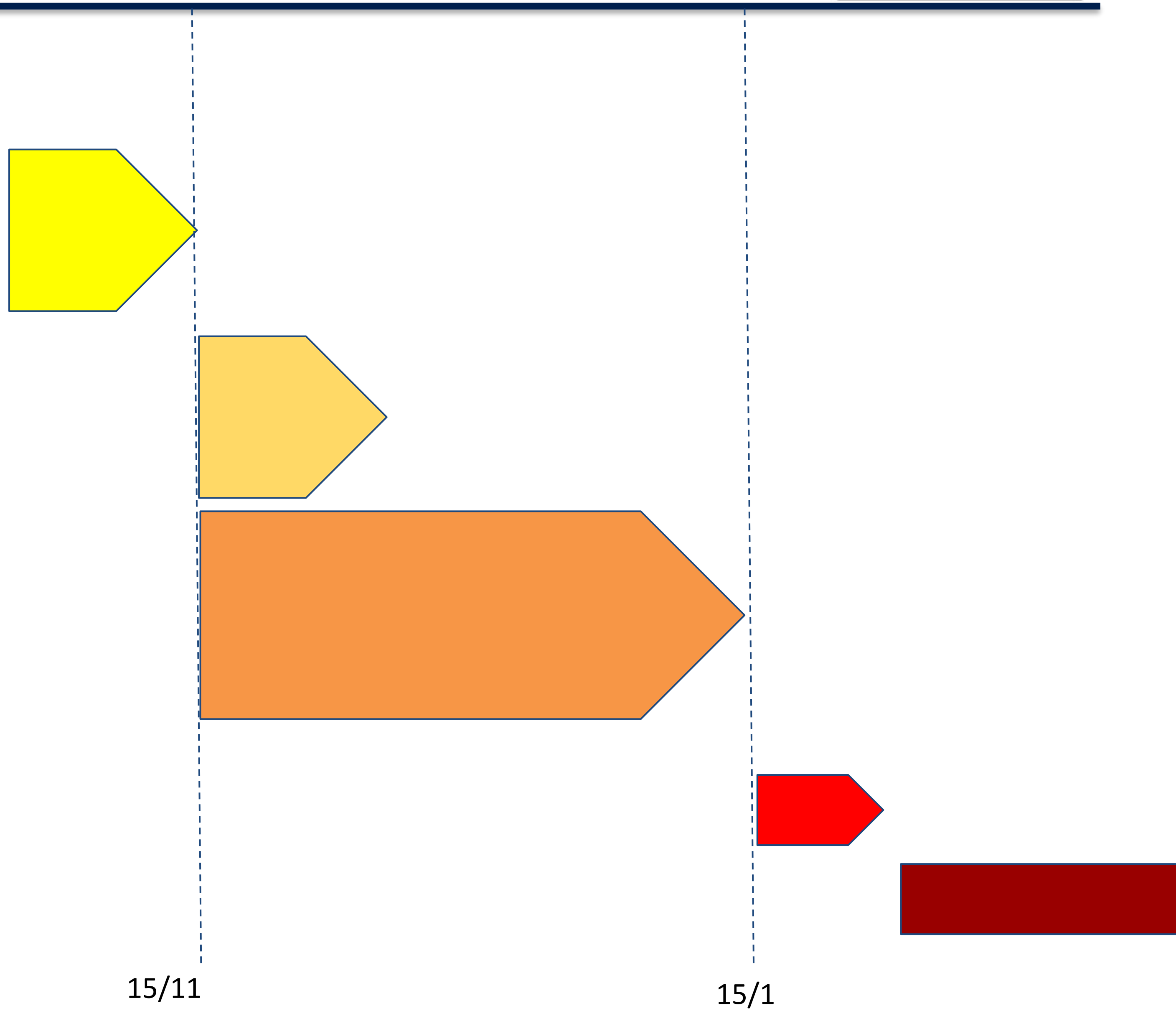
Cygnus region

- **Astri Science-UC 3**
  (Tiling of a region)
- Complex region
  - crowded
  - extended sources
  - diffuse emission
  - multi-TeV sources
- Detailed sky-model required for the analysis

Timeline

How should we proceed ?

- Define regions
- Source list
- Pointing Strategy
- IRFs validation/production
- Sky model
  - Diffuse emission
  - Sources
  - Transients ?
- run Simulations
- Data analysis



Conclusions

The observing plan will be focused on few (8-12) sky fields :

➔ *Large exposures (hundreds of hrs) on the selected sources*

Large FOV :

➔ *On the Galactic plane we expect many filed sources*

Observations with moonlight :

➔ *observing with half-moon is possible (!) increasing the available time by a factor 1.5*