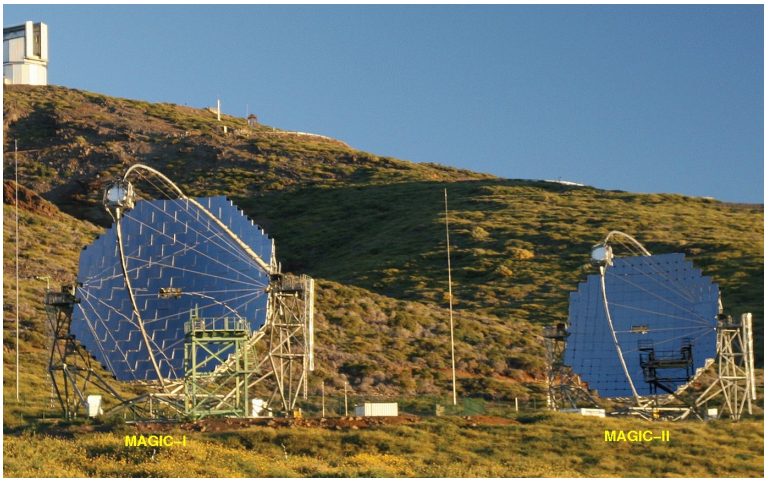
Follow-up of gravitational waves alerts with IACTs using Astro-COLIBRI

Mathieu de Bony
on behalf of the Astro-COLIBRI team (Fabian Schüssler, Patrick Reichherzer, Atilla Alkan, Jayson Mourier)
and on behalf of the tilepy team (Fabian Schüssler, Monica Seglar Arroy, Halim Ashkar, Jayson Mourier)

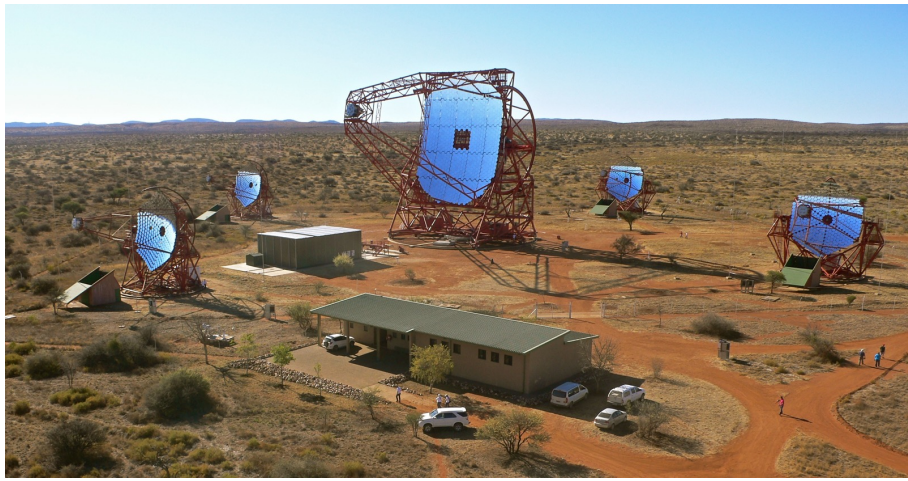
IACTs

Observe Very High Energy gamma-rays (> few tens of GeV)



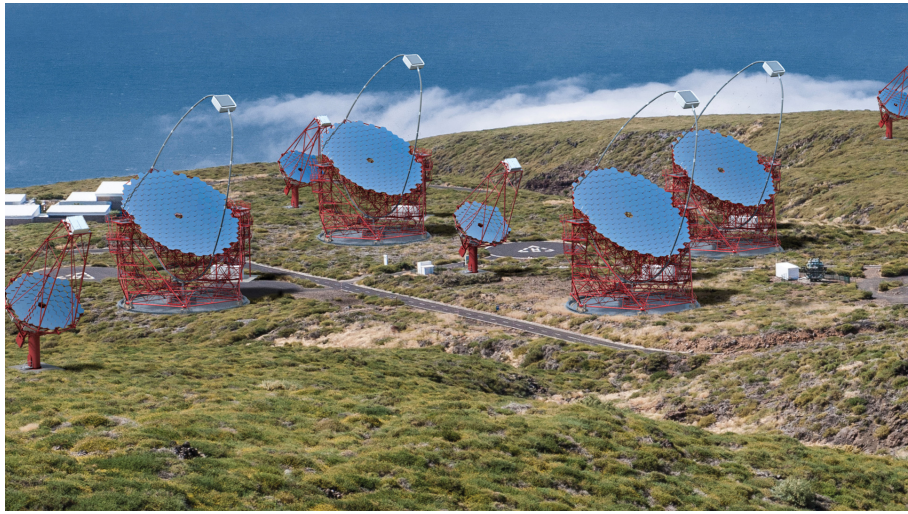
MAGIC
2 x 18m telescopes
FoV ~ 2.5 deg

H.E.S.S.
4 x 12 m telescopes
+ 28 m telescope
FoV ~ 5 deg



VERITAS
4 x 12m telescopes
FoV ~ 3.5 deg

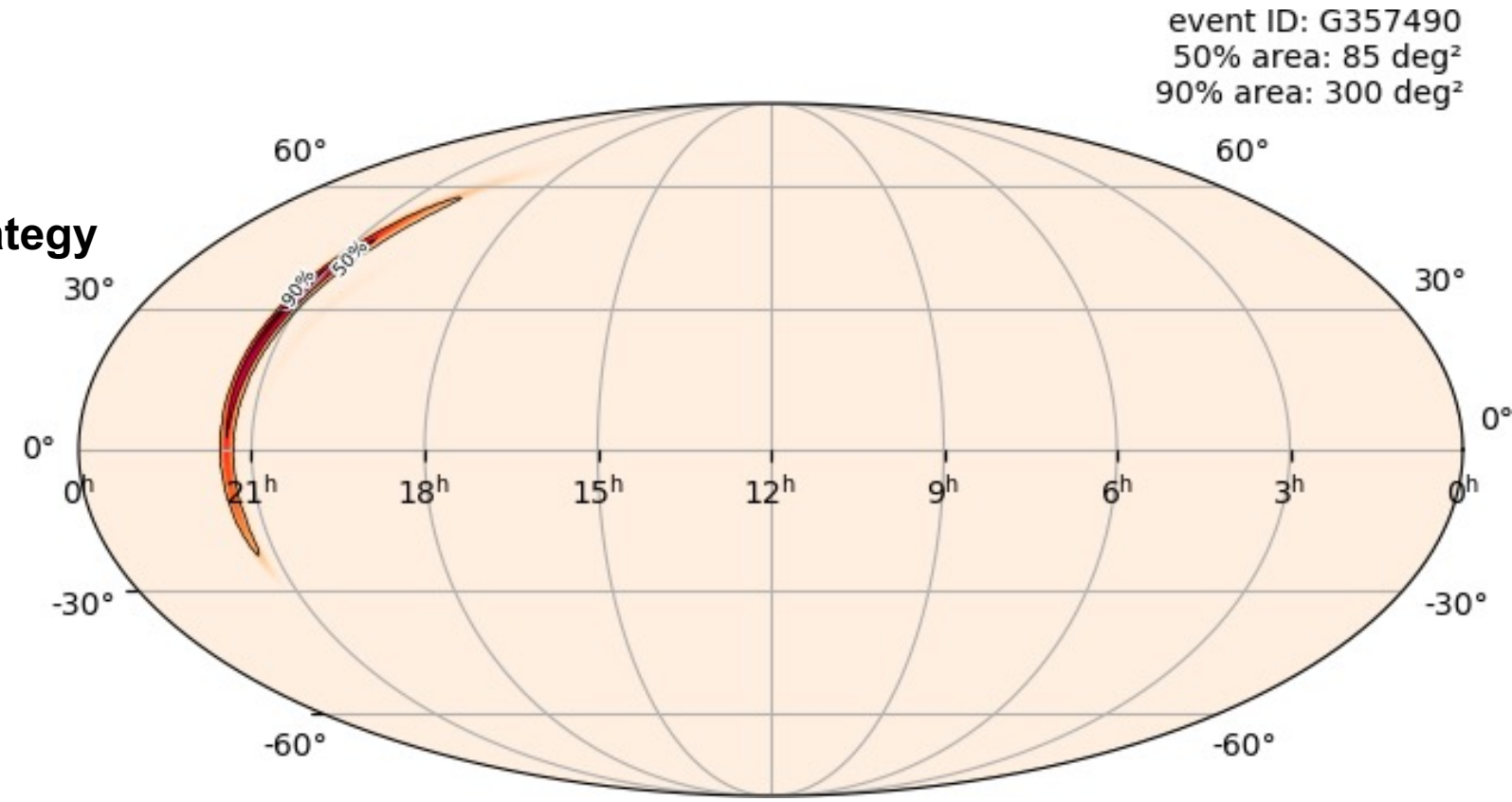
CTA
2 sites
> 64 telescopes
3 size of telescopes
FoV ~ 5 to 10 deg



Challenge of GW follow-up

- **Large localisation uncertainty**
- **Small FoV**

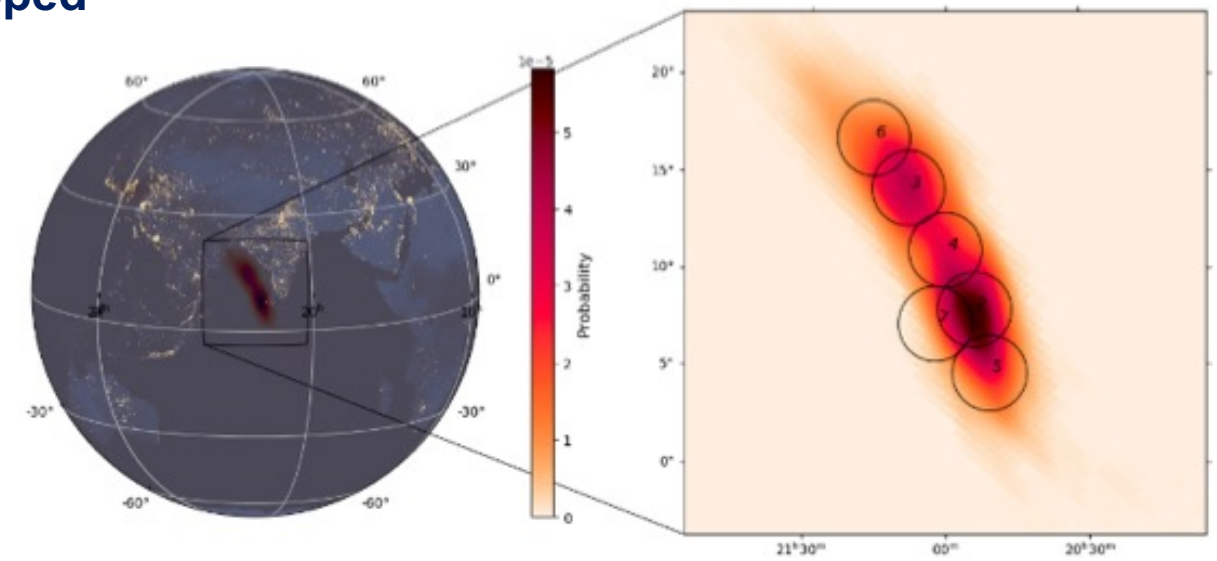
➢ **Covering the uncertainty region requires a smart observation strategy**



Tiling

- **Observation of multiple tiles to cover the uncertainty region**

- **A python software called tilepy has been developed at IRFU / CEA Paris-Saclay since 2016**
  - Currently used by H.E.S.S. and LST-1

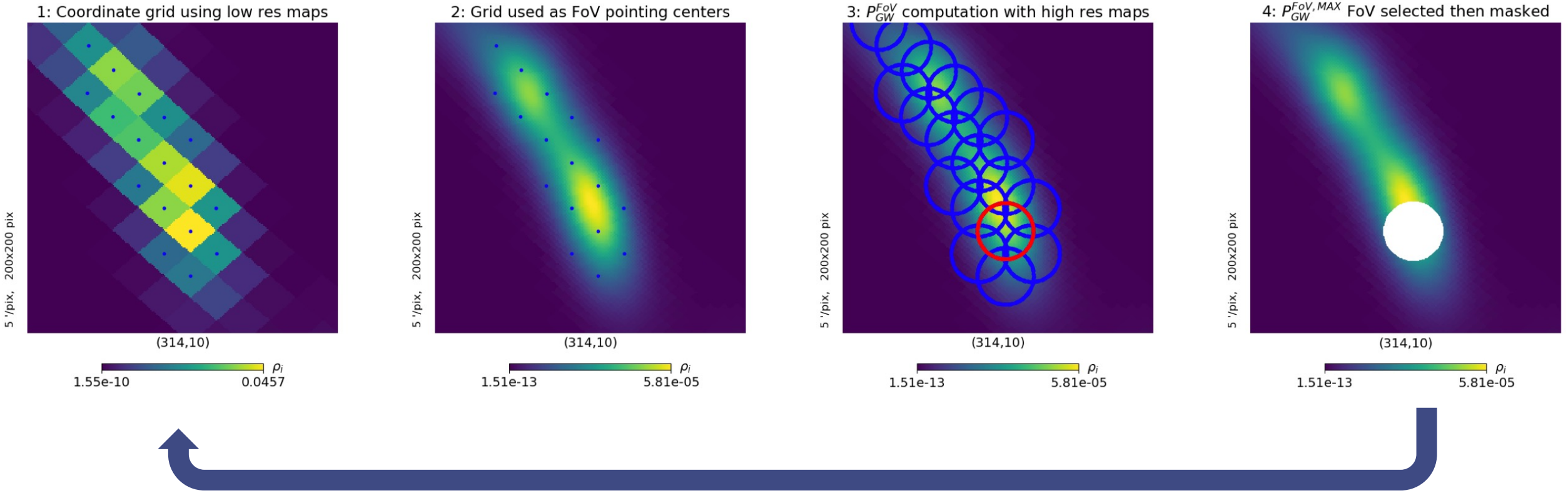


(M. Seglar-Arroyo, 2022)

2D algorithm

- **Iterative algorithm based on spatial information**

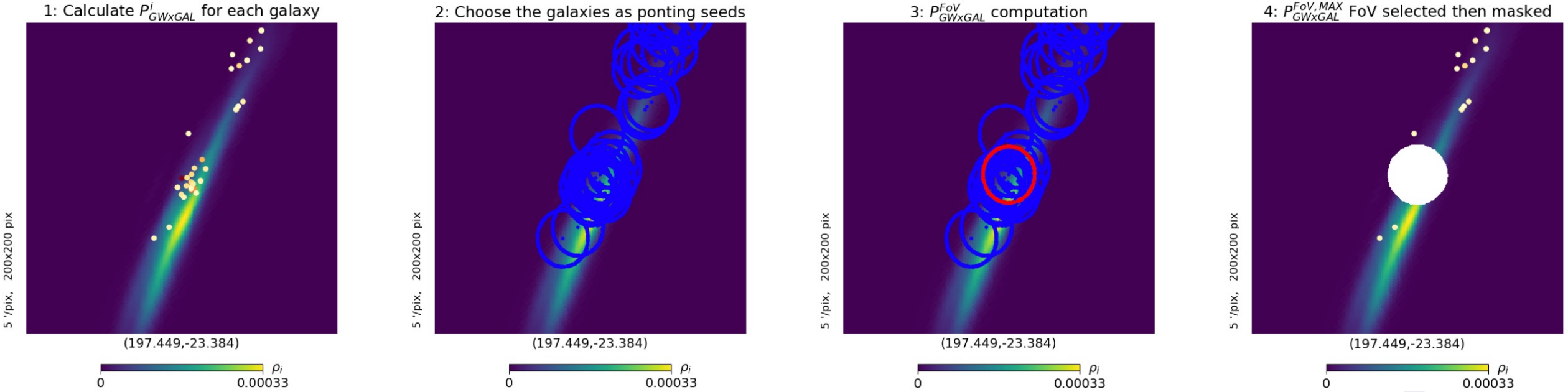
Ashkar et al., ICRC 2021



3D algorithm

- **Correlation of the spatial and distance information with Glade+ galaxy catalog**
  - ➢ **Compute probabilities for each galaxy**
- **Iterative process based on galaxy position**

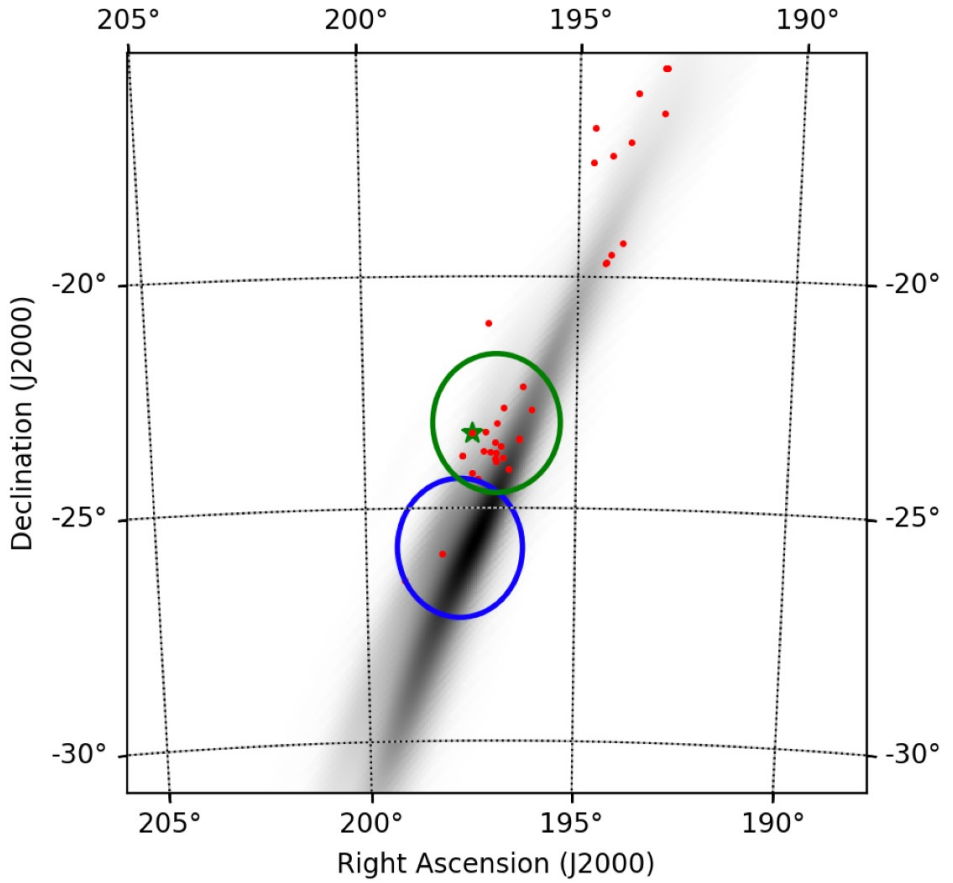
Ashkar et al., ICRC 2021



GW 180817

- **Coincidence EM/GW**
  - BNS merger detected by Ligo/Virgo
  - Short GRB detected by Fermi
- **Poor localisation from both instruments**
- **With the help of tilepy, H.E.S.S. was the first ground based instrument to point in the direction of the event**

Ashkar et al., JCAP 2021



Tilepy

- **Publication in 2021**
  The H.E.S.S. gravitational wave rapid follow-up program, Ashkar et al., JCAP 2021
  DOI : 10.1088/1475-7516/2021/03/045

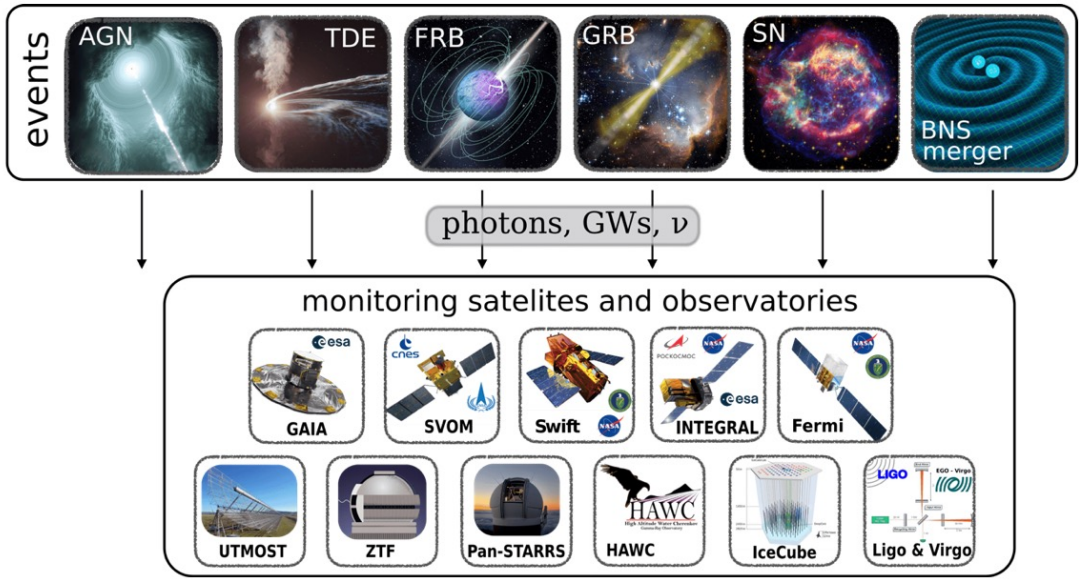
- **Preliminary code release on github : https://github.com/astro-transients/tilepy**
  - **Documentation ongoing**
  - **Refactoring of the code is starting**

Tilepy in the cloud

- Tilepy is now running in the cloud
  - No need for local installation
  - No need to download the map
  - Should work with small connection
  - Stable interface

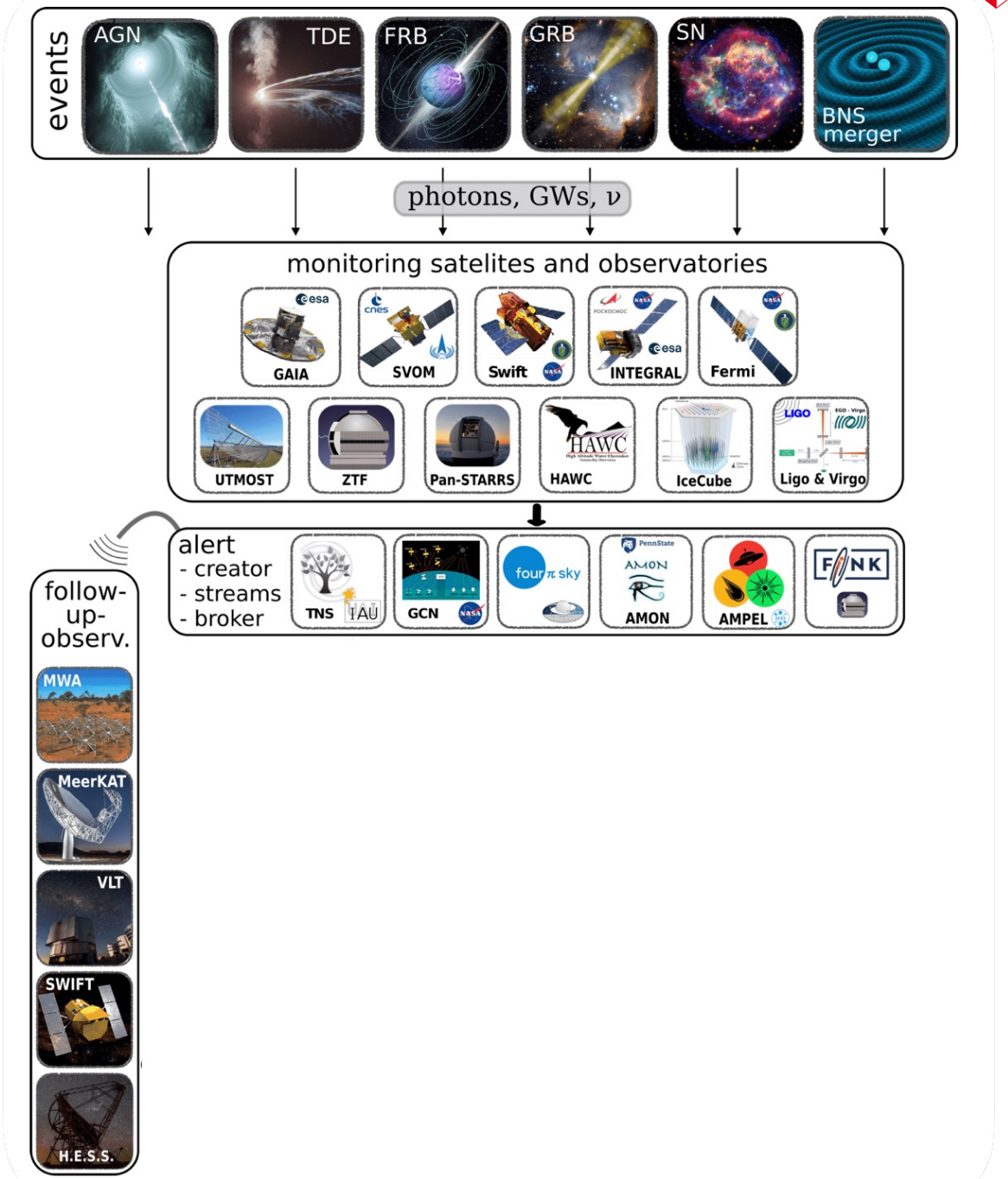
Astro-COLIBRI

A tool for transient astronomy



Astro-COLIBRI

A tool for transient astronomy



Astro-COLIBRI

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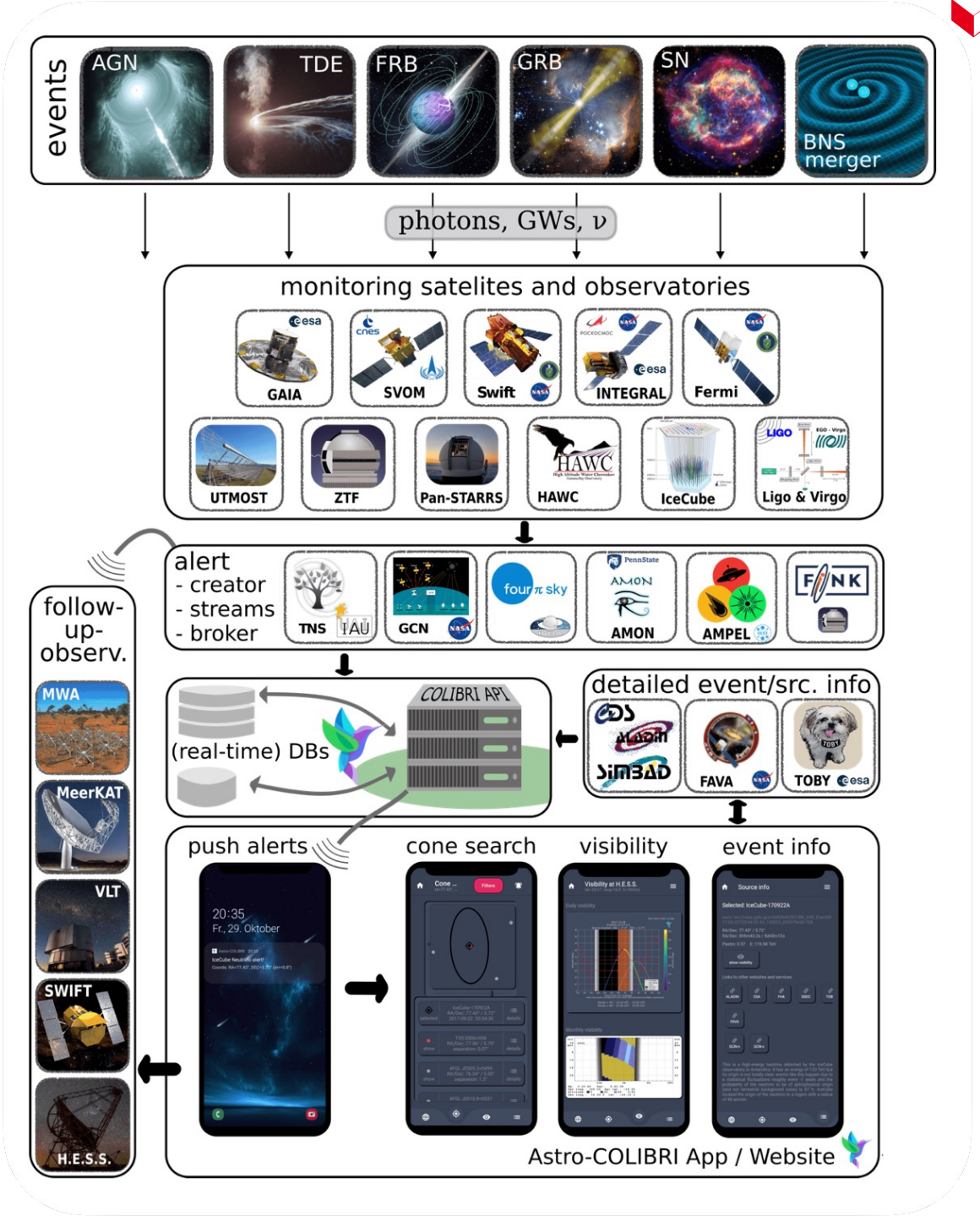

Astro-COLIBRI

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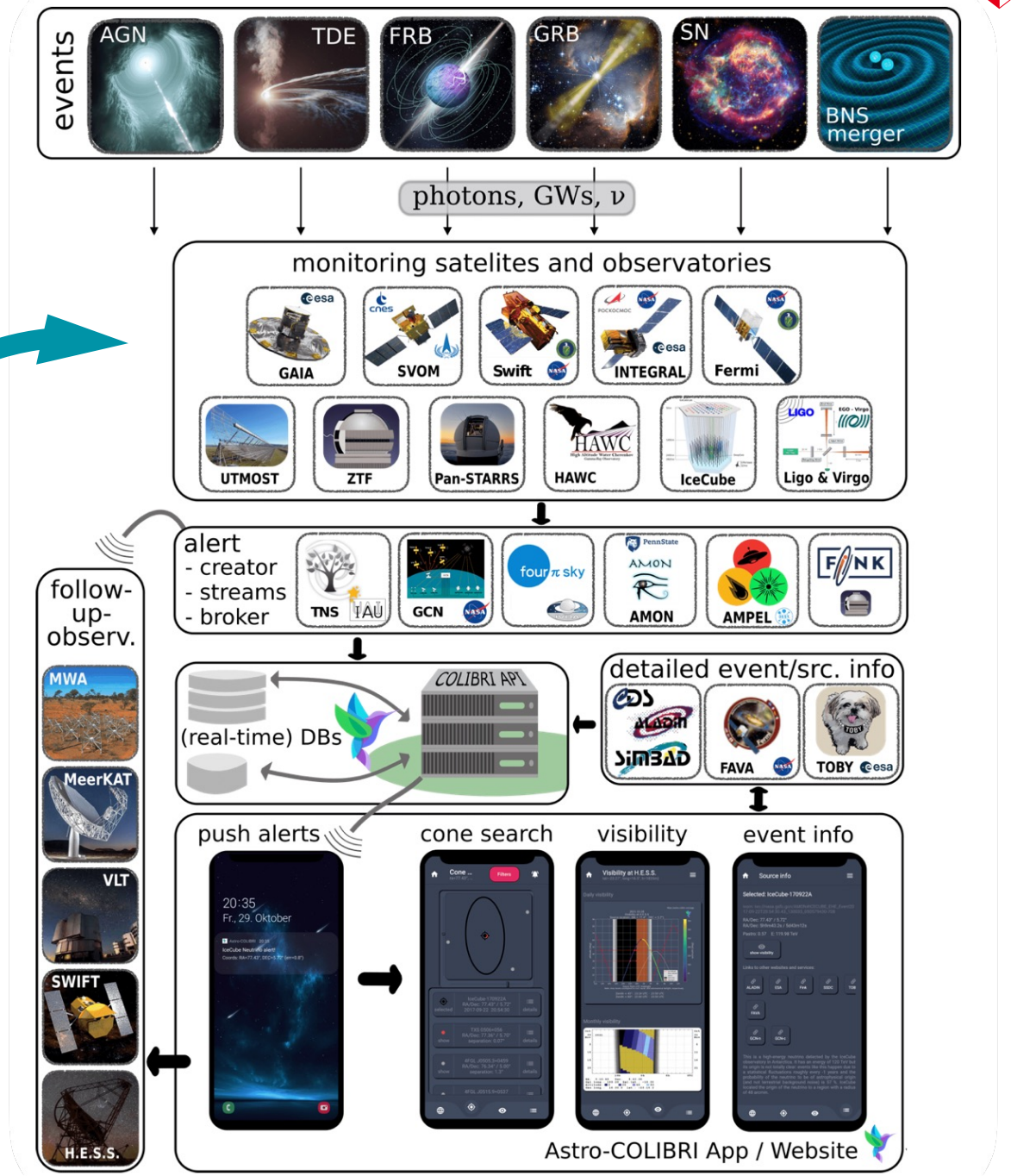
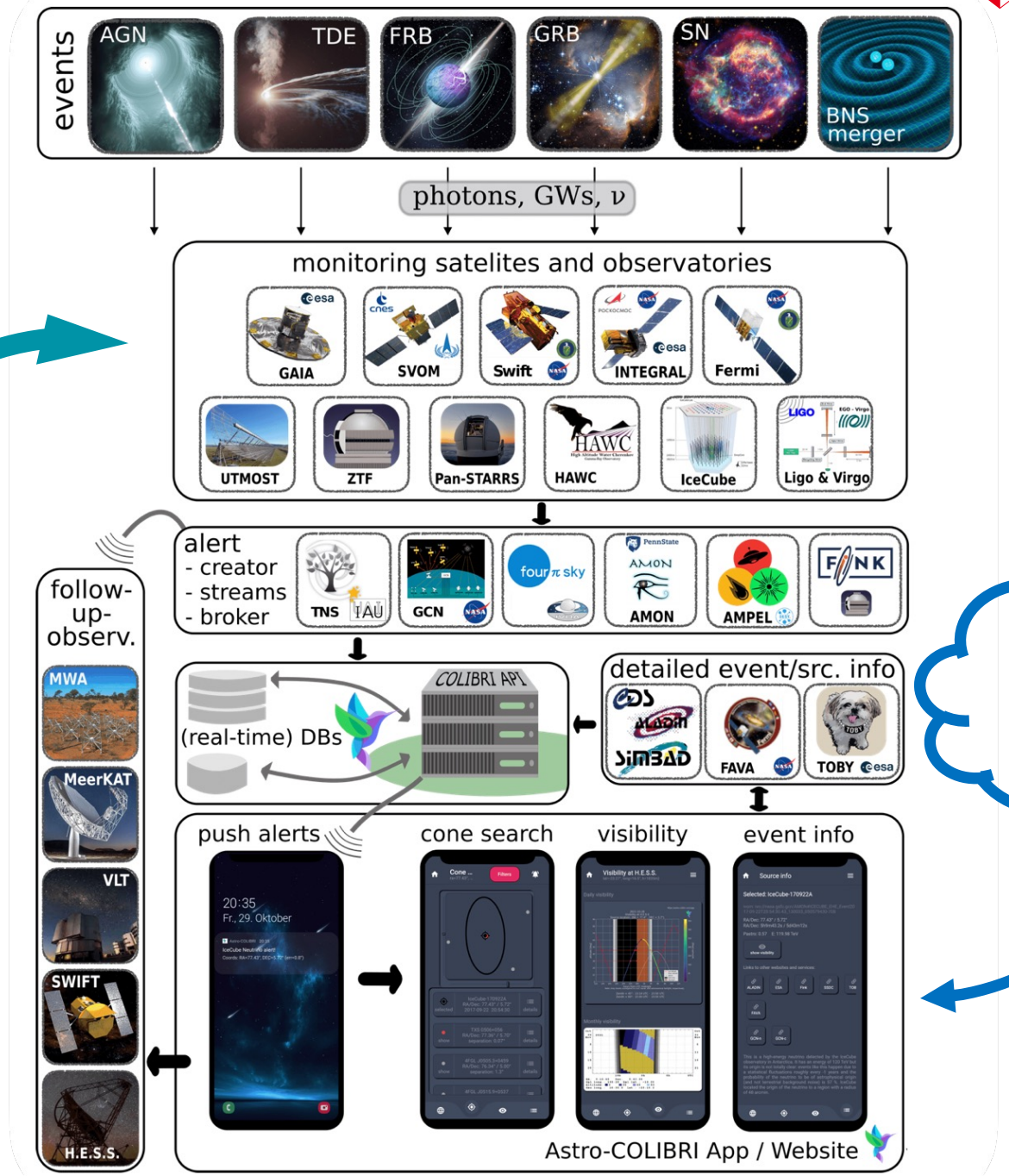


Astro-COLIBRI

A tool for transient astronomy



Tiling with Astro-COLIBRI

The web interface

https://astro-colibri.com

Tiling with Astro-COLIBRI

The web interface

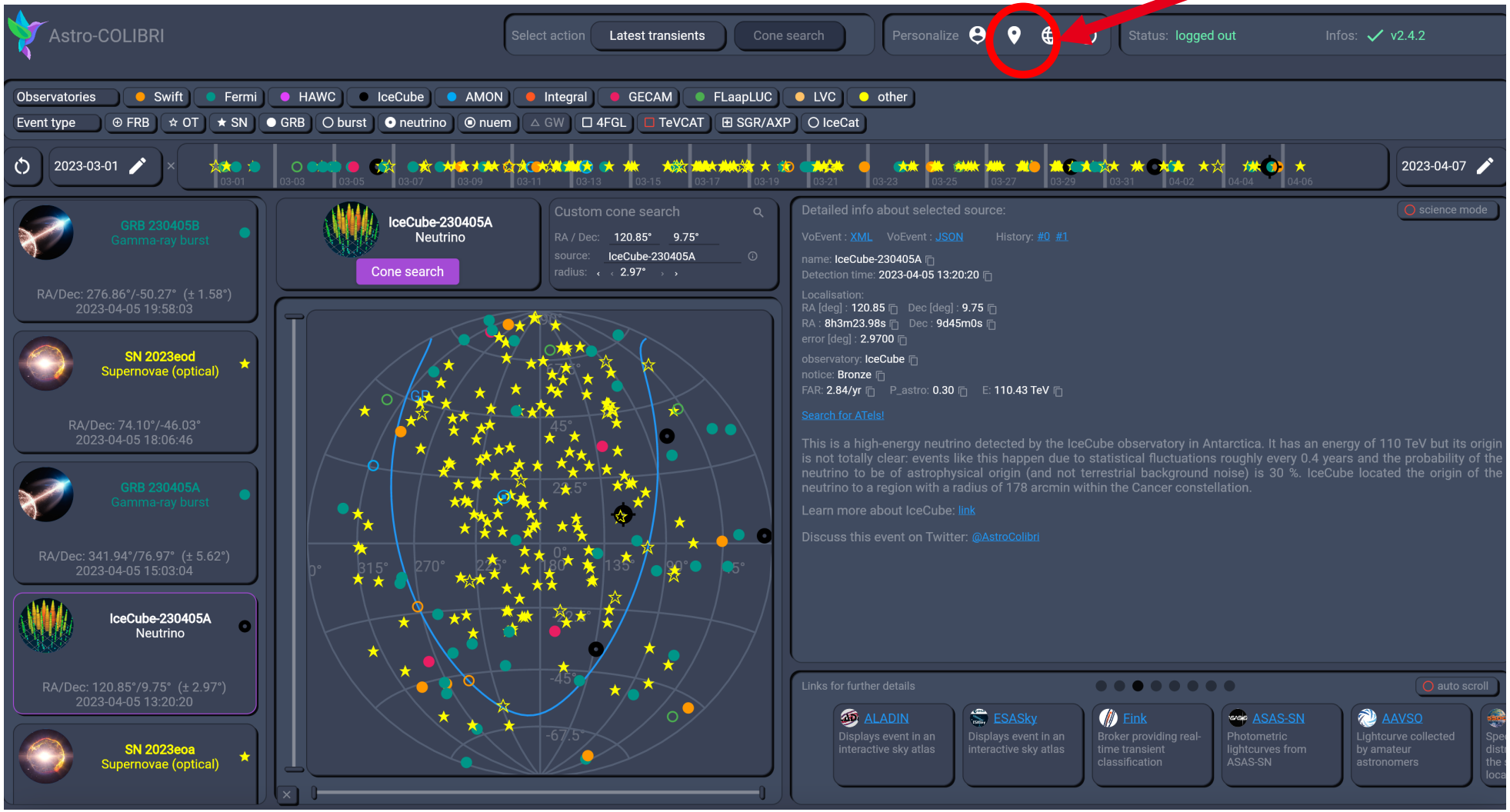
Activate science mode

https://astro-colibri.com

Tiling with Astro-COLIBRI

The web interface

Select your observatory



https://astro-colibri.com

Tiling with Astro-COLIBRI

The web interface

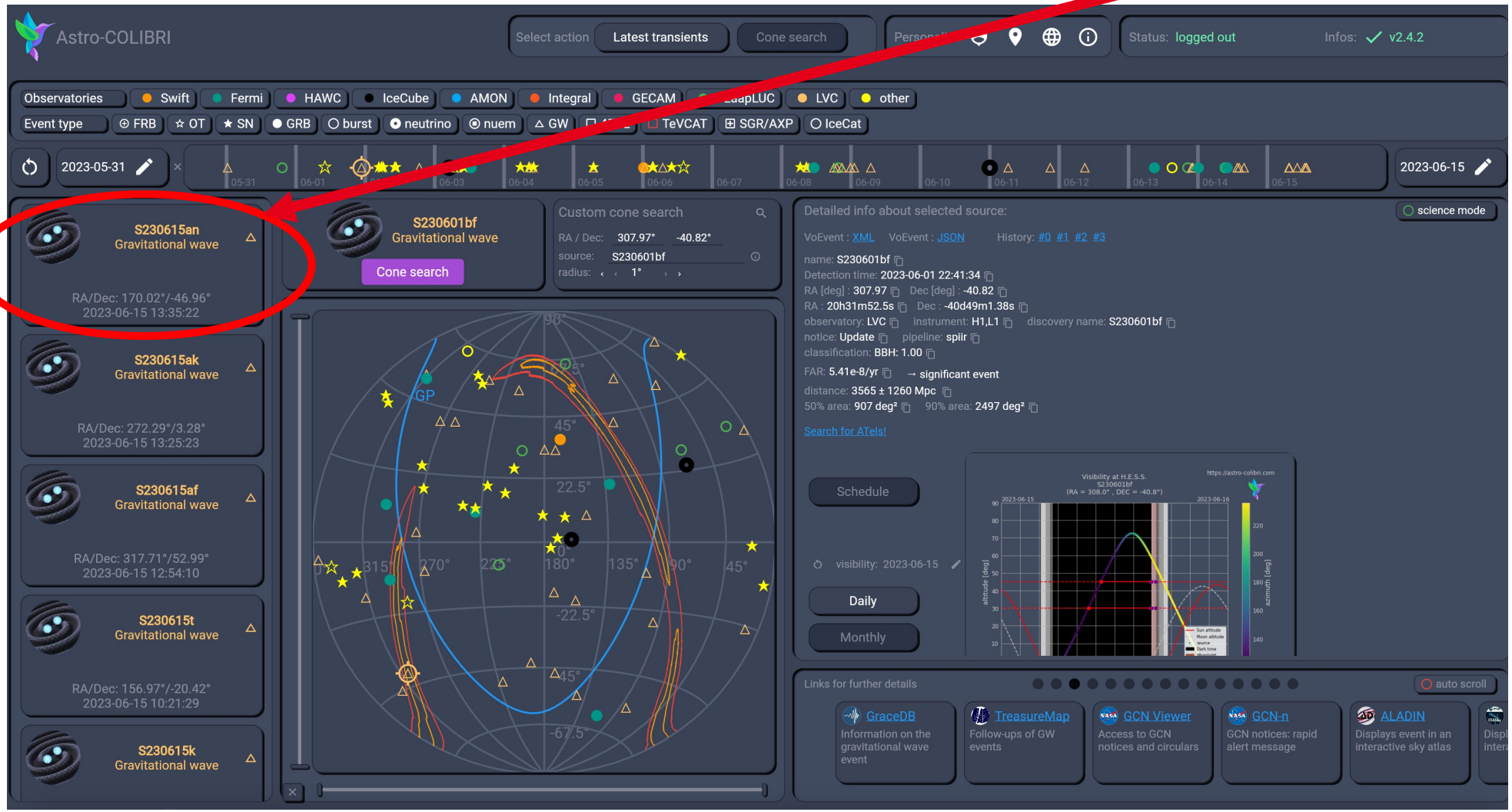
Activate the GW filter

https://astro-colibri.com

Tiling with Astro-COLIBRI

The web interface

Select your event



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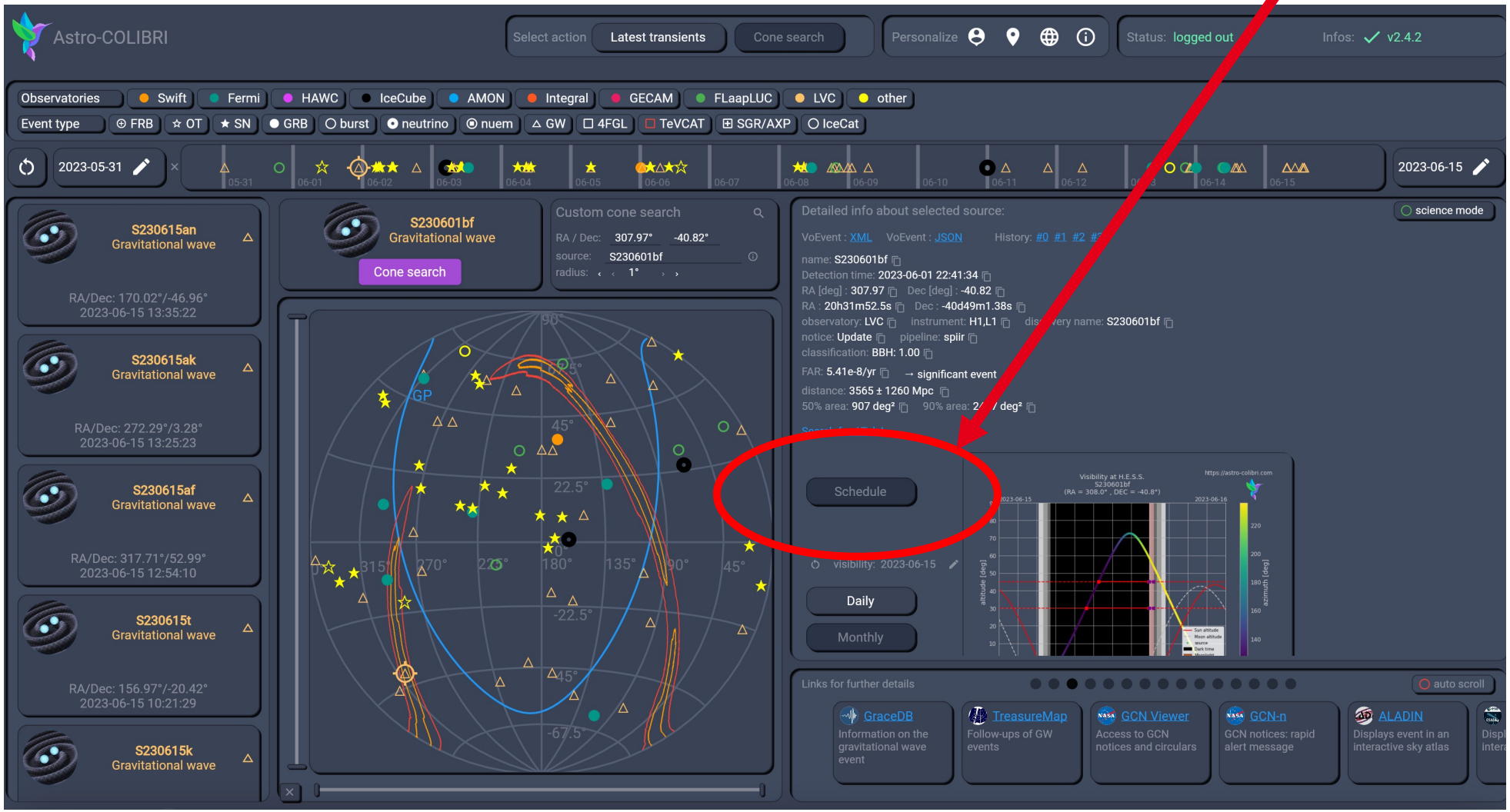
Tiling with Astro-COLIBRI

The web interface



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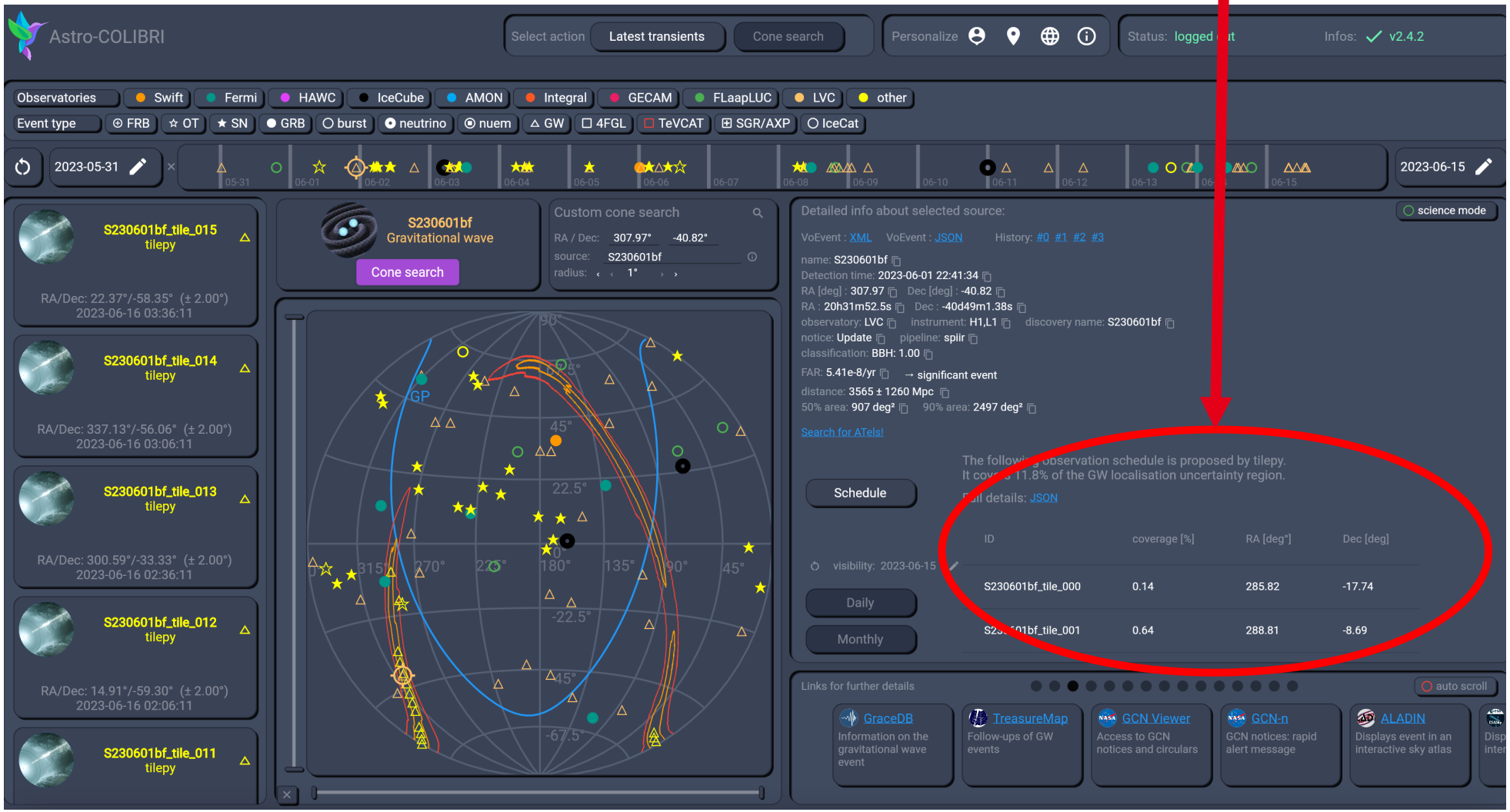
Tiling with Astro-COLIBRI

The web interface

Observation Plan



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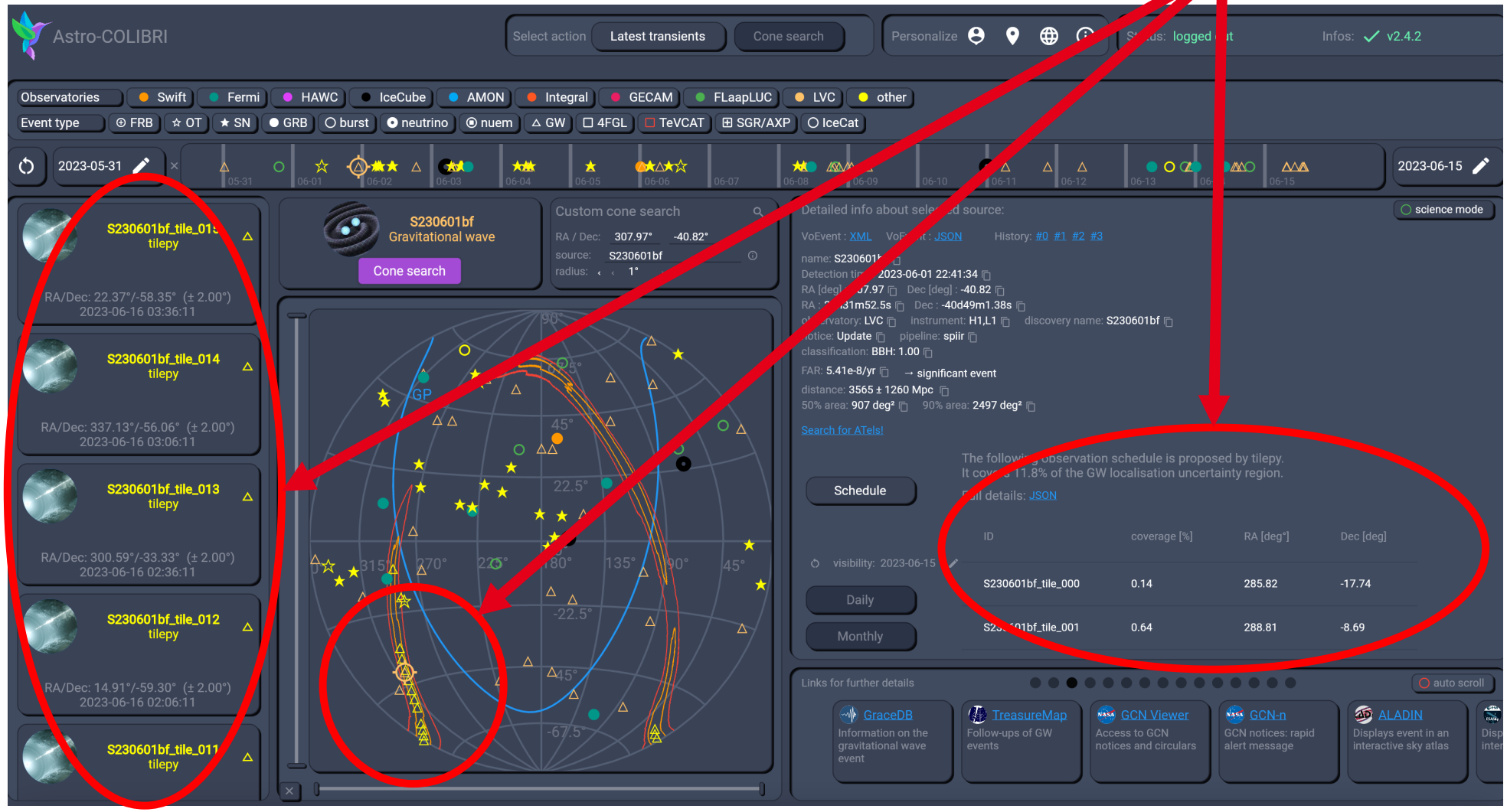
Tiling with Astro-COLIBRI

The web interface

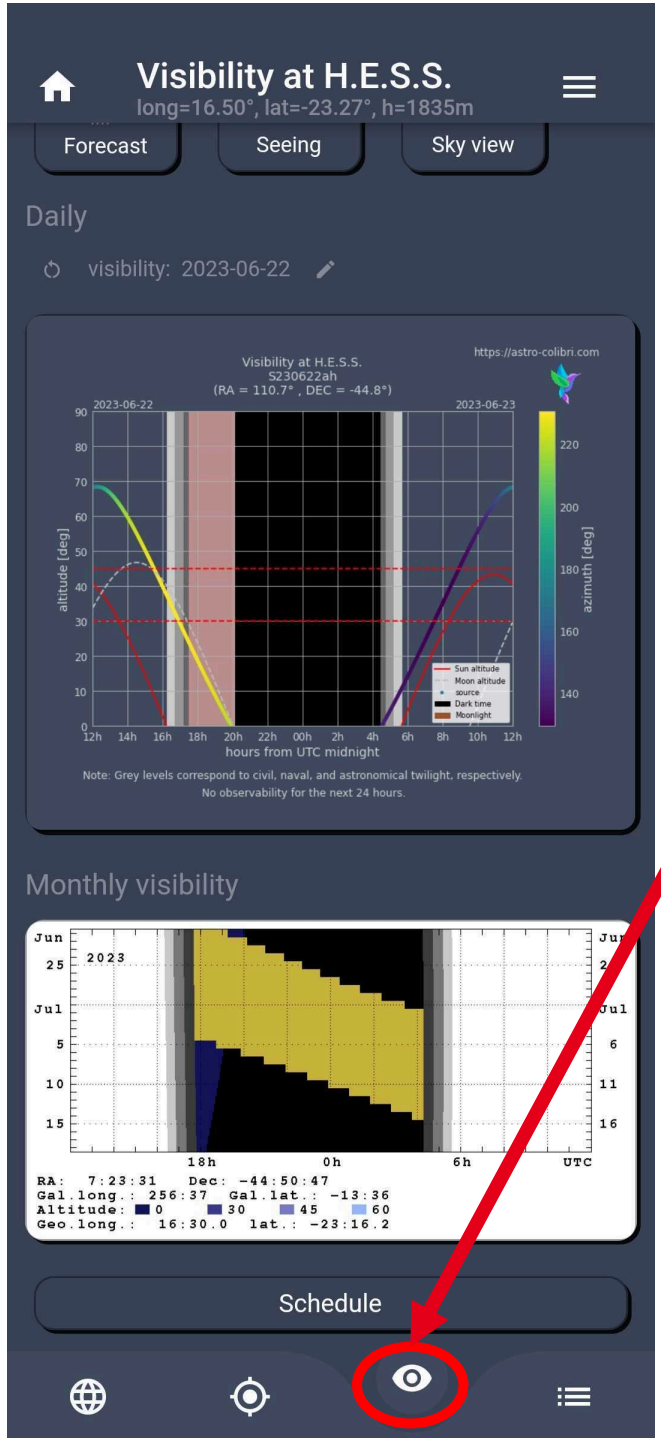


https://astro-colibri.com

Tiling with Astro-COLIBRI
The mobile interface

Android Play Store

Apple iOS App Store

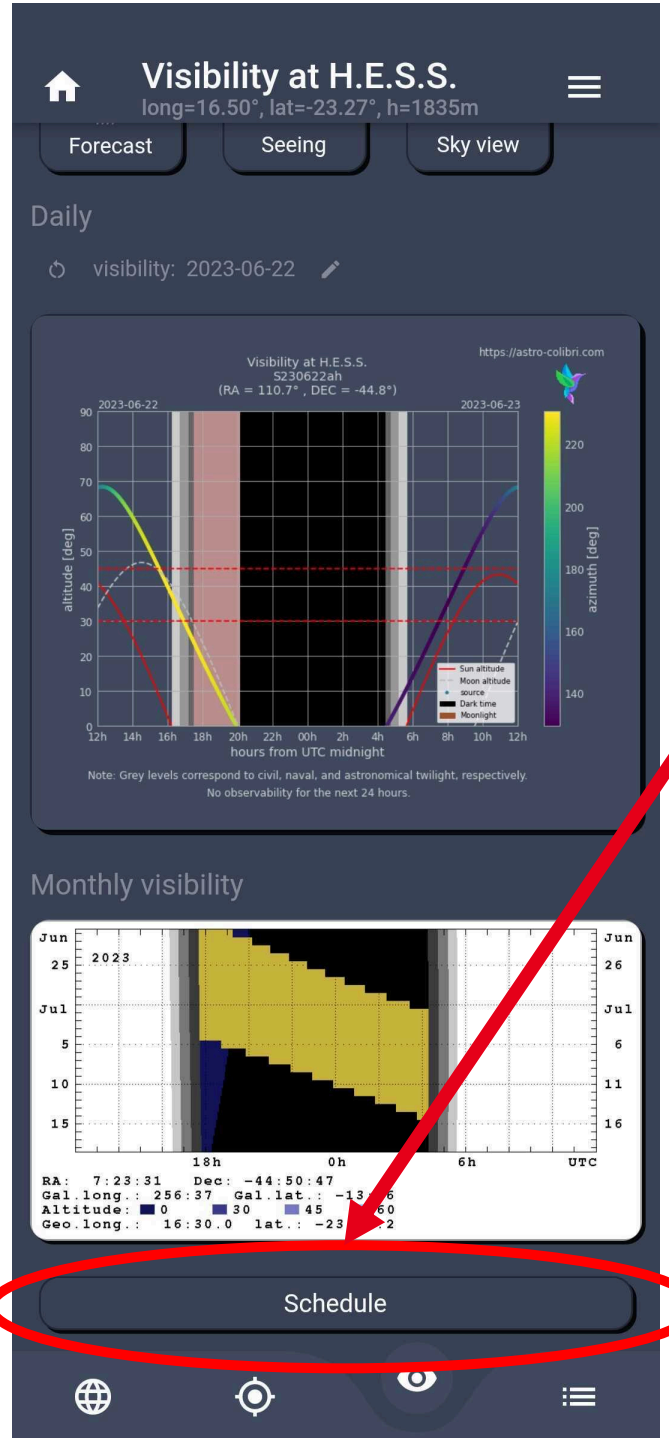


Visibility panel

Tiling with Astro-COLIBRI
The mobile interface

Android Play Store

Apple iOS App Store

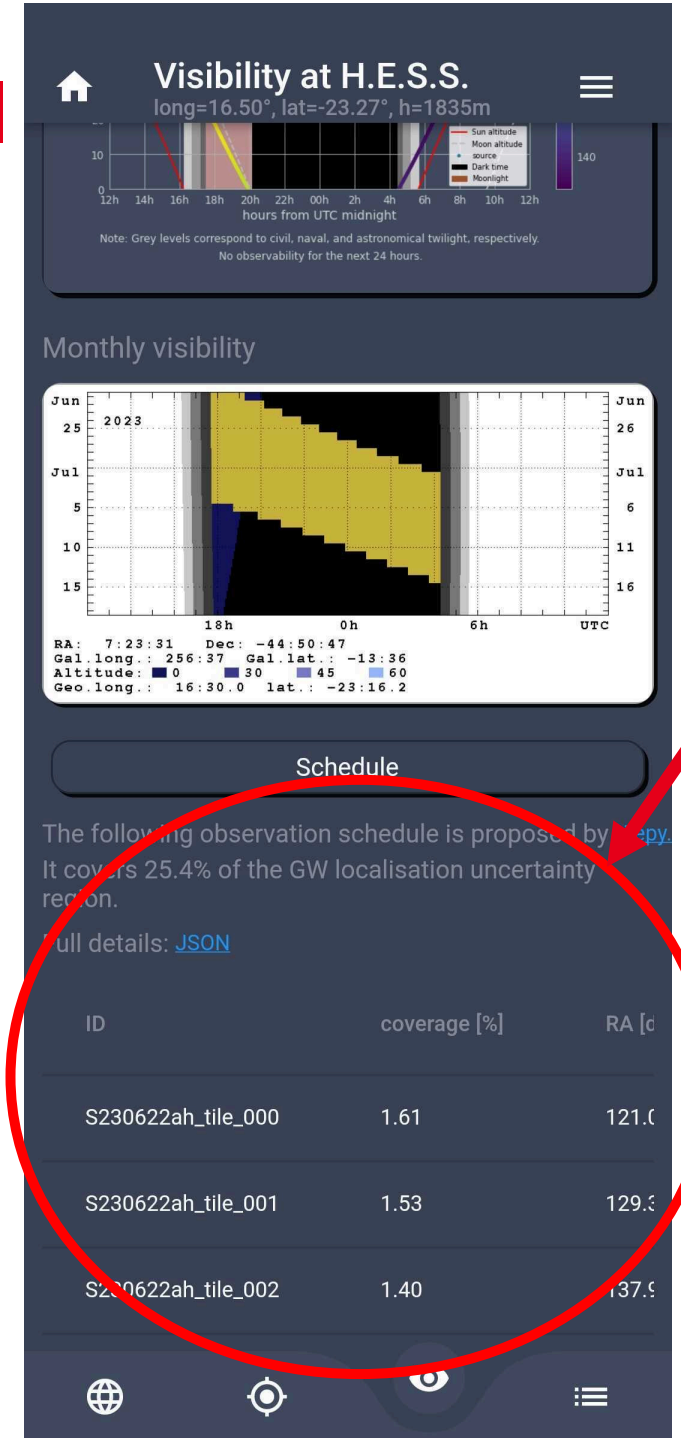


Compute the schedule

Tiling with Astro-COLIBRI
The mobile interface

Android Play Store

Apple iOS App Store



Observation Plan

An API to go further

- **Astro-COLIBRI allows you to set simple observatory parameters**
  (Position, FoV, Zenith limit, Maximum Moon phase)

An API to go further

- **Astro-COLIBRI allows you to set simple observatory parameters**
  (Position, FoV, Zenith limit, Maximum Moon phase)

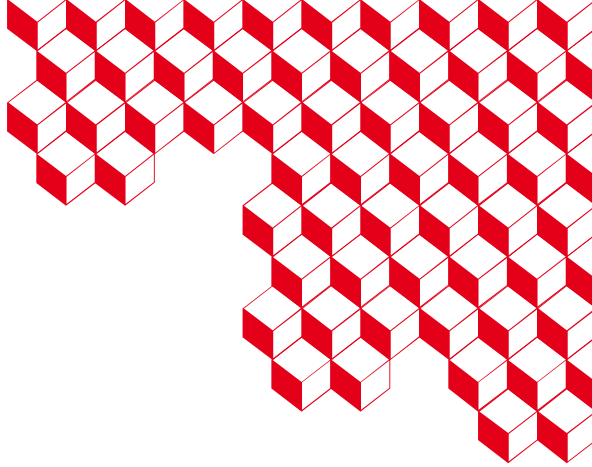
- **The HTTP API allows you to customise much more parameters:**
  - Visibility constraints (Moon, Sun, …)
  - Number of pointings
  - Number of observation nights
  - Start observation time
  - …..

- Website : https://tilepy.com
  API : https://tilepy.com/tiling
  API documentation : https://tilepy.com/apidoc

Conclusion

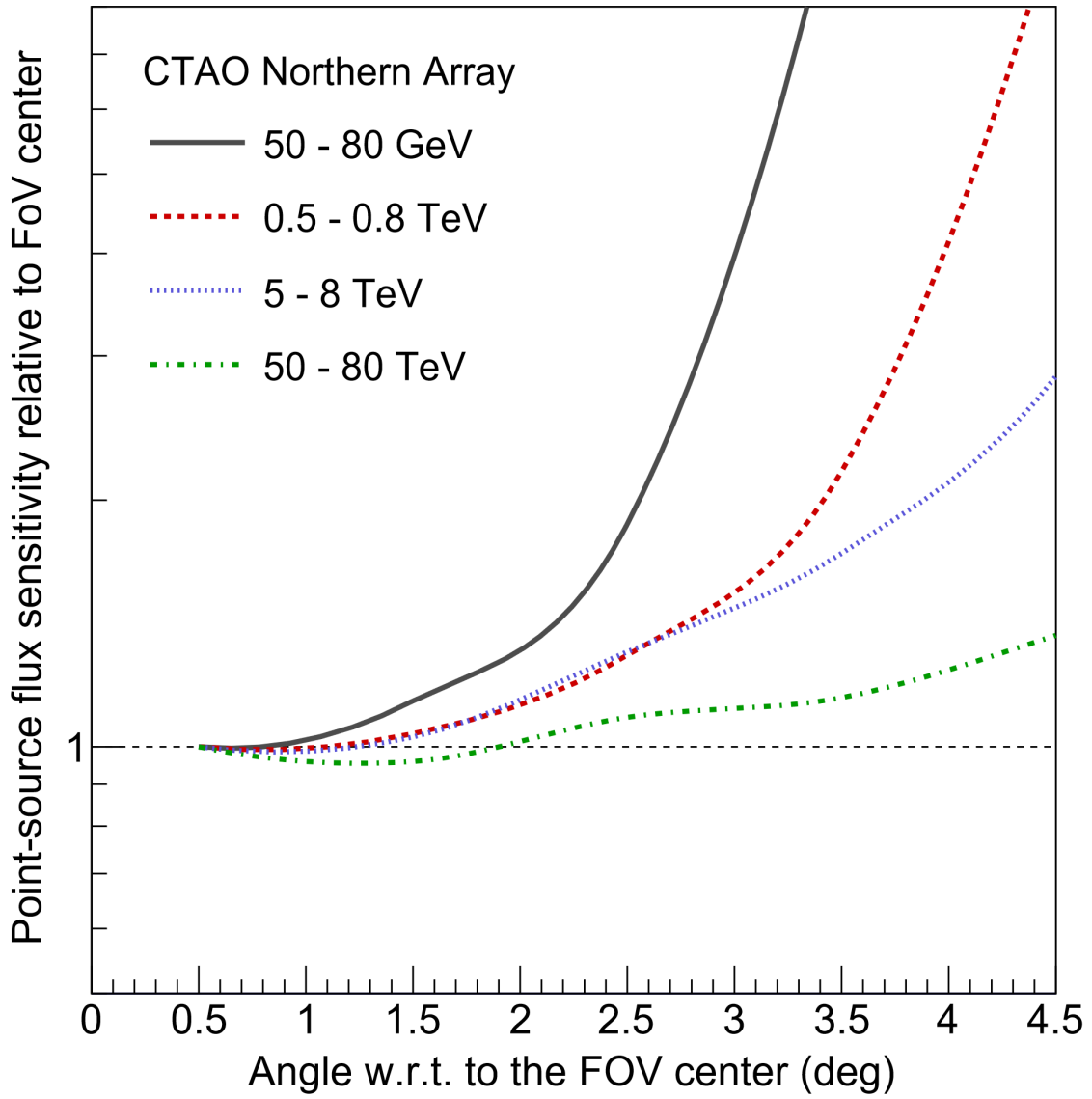
- **IACTs use a tiling observation strategy for GW follow-up**
- **The tilepy python software has been developed to compute an optimal observation schedule**
  - 2D algorithm for distant alerts
  - 3D algorithm for close by alerts
- **tilepy is currently integrated in Astro-COLIBRI**
- **An HTTP API allows also to send requests with more parametrisation possibilities**
- **Feedback is welcome**

tilepy



Thank for your attention

FoV of CTA


CTAO Northern Array
50 - 80 GeV
0.5 - 0.8 TeV
5 - 8 TeV
50 - 80 TeV
Point-source flux sensitivity relative to FoV center
1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Angle w.r.t. to the FOV center (deg)