The H.E.S.S. Transients Follow-up System

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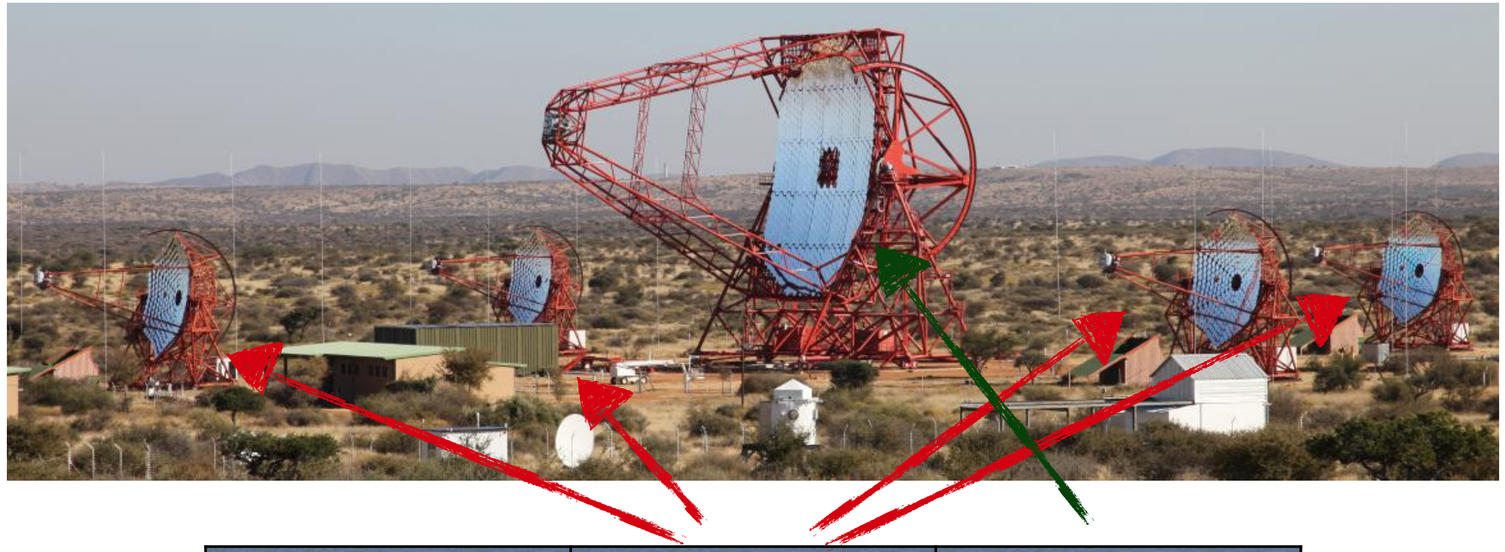
Universität Potsdam

Bundesministerium
für Bildung
und Forschung

High Energy Stereoscopic System
- an Array of Imaging Air Cherenkov Telescopes



	CT1-4	CT5
# Telescopes	4	1
Mirror Area	107 m^2	614 m^2
PMTs	960	2048
Field of View	5 deg	3.2 deg
Rotation speed	100 deg/min	200 (100) deg/min
Energy threshold	~ 150 GeV	~ 50 GeV
Year of construction	2003	2012

Transients and IACTs

- Obvious advantages:
  - Probe extreme time-scales to challenge theory and models
  - Accumulate signal faster than ~ square-root of time
  - Common benefit for all branches of astronomy

→ **Multi-Wavelength and Multi-Messenger approach comes naturally**

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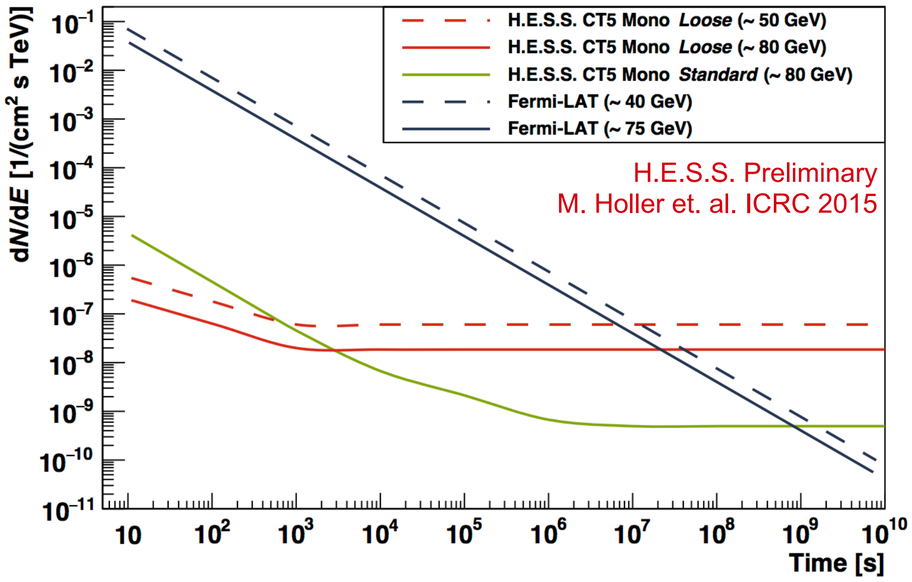
Challenges:

- Not that many known transient phenomena in the IACT energy range:
  - AGN flares & GRBs (since this year!)
  - Main objective → **Discoveries!**



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- Follow-up constraints (not unique for IACTs)
  - operated only in (moonless) nights
  - Only a fraction of the sky accessible at a given time
  - Field of view ~ few deg in diameter
  - Cover many different timescales:
    - seconds
    - days
    - weeks

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- Hence: Largely dependent on external triggers
  - React as fast as possible
  - Solid decision making needed
  - Clear reaction schemes needed
  - Need to know about results as soon as possible

→ **Transients follow-up system**

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Main Objectives of the System

- Receive and process high-level astrophysical alerts
  - standardised format (VoEvent)
  - matching to H.E.S.S. science cases
  - decision making (can include complex algorithms and scanning patterns)
- Initiation of the follow-up observations
  - controls array of telescopes as fast as possible
  - reaction details dependant on the science case and it’s time-scale
  - changing the nominal observation schedule
- Provide Feedback
  - analysis results in real-time
  - decide between prolongation or abortion of the observations
  - alert experts, PIs and the community

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ToO Alert System

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Central Control & Data Acquisition

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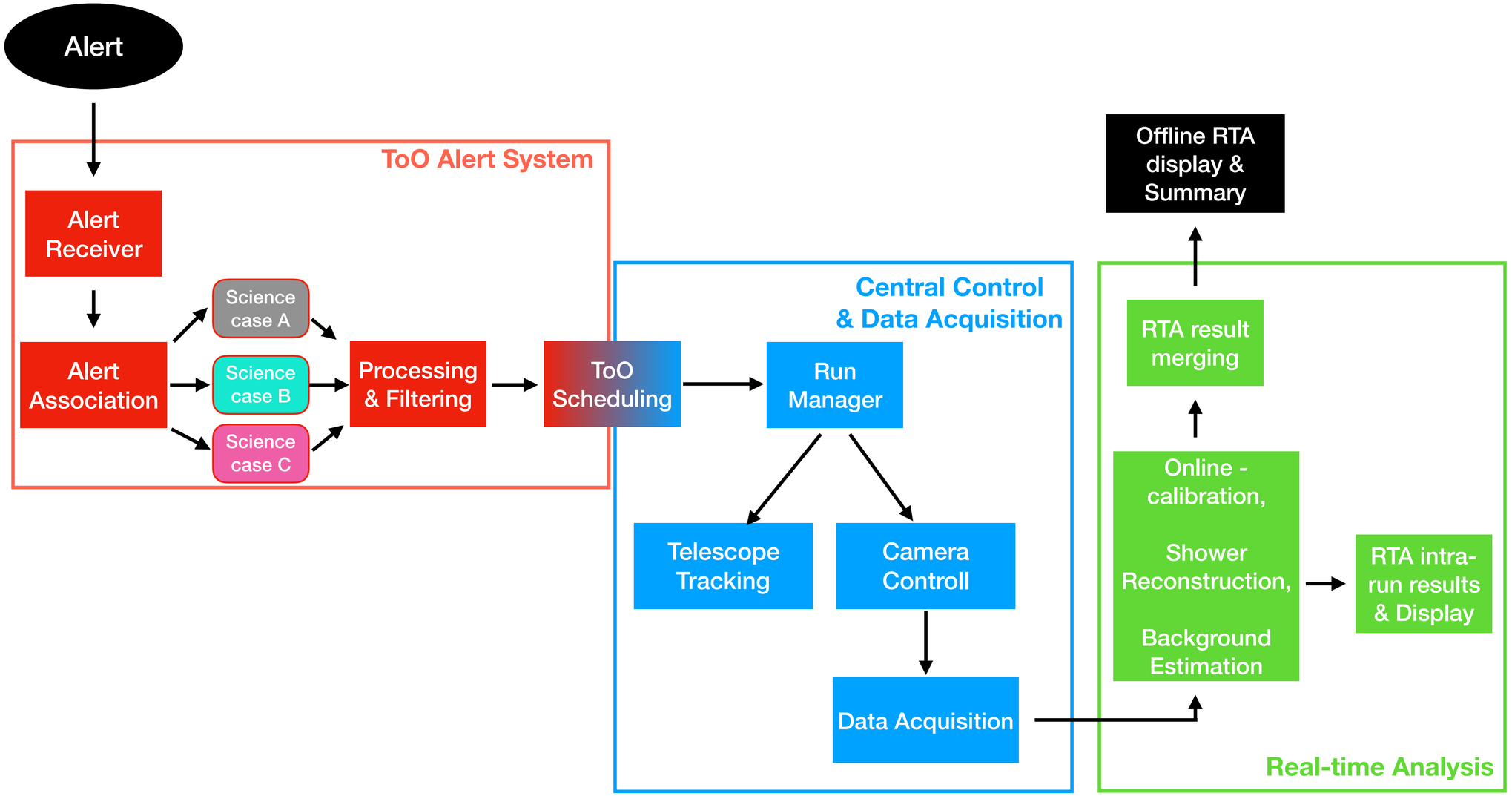
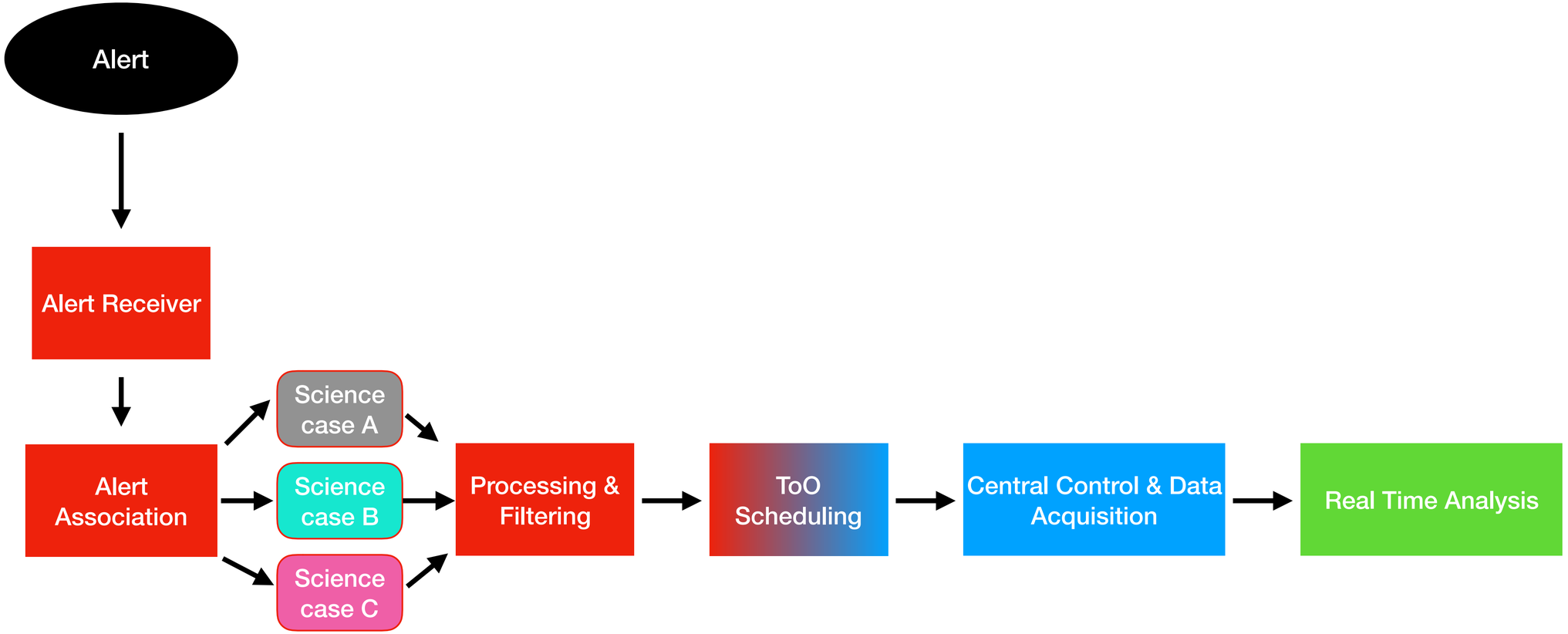
Real-time Analysis

The H.E.S.S. Transients Follow-up System - Overview

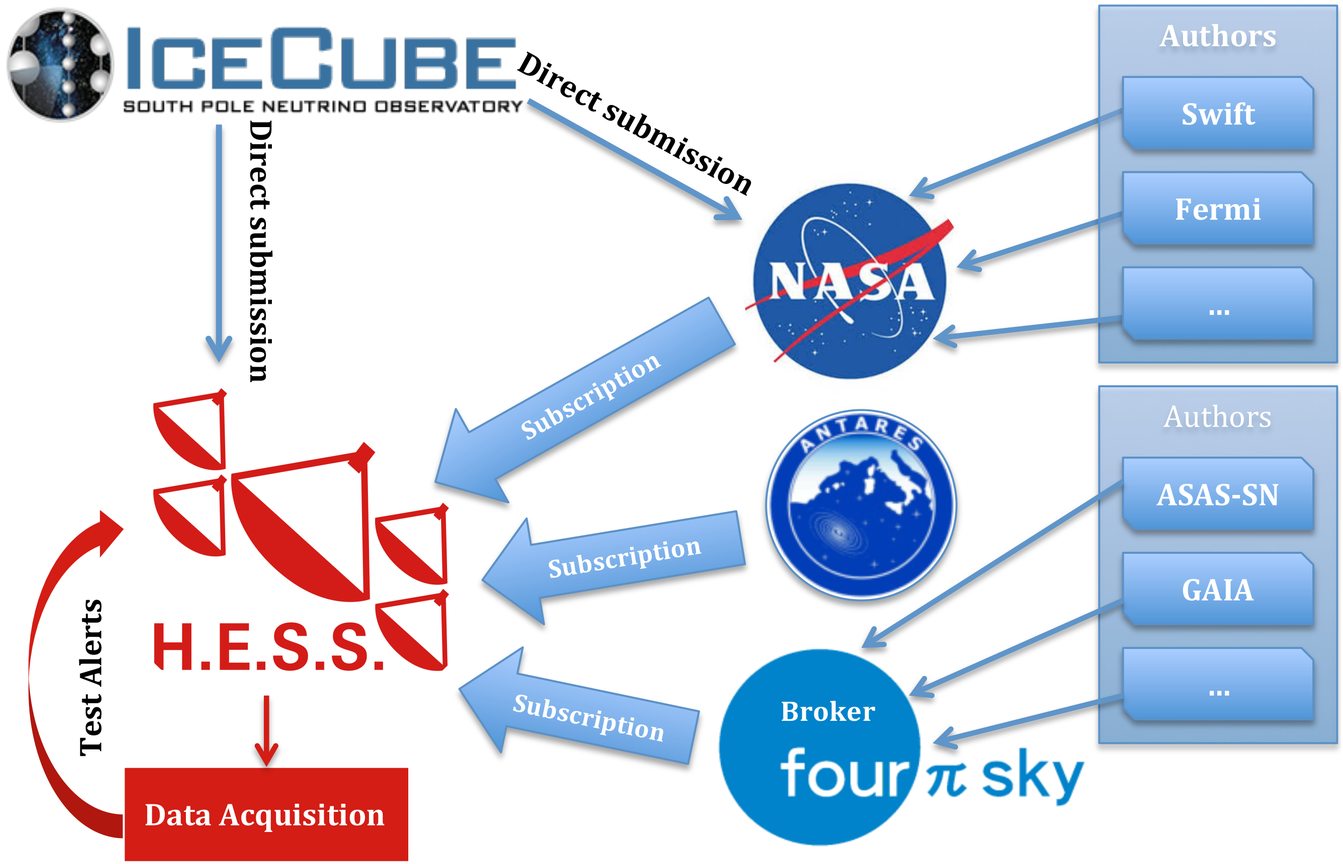


The H.E.S.S. Transients Follow-up System - Simplified view, focused on Transients Alert handling



Receiving Alerts

- Based on *comet*[1] broker - implementation of VoEvent Transport Protocol with many helpful features
- Subscribed to GCN, 4piSky, Antares and whitelisted IceCube IPs for direct submission of alerts
- Broker is monitored with *monit*[2] to guarantee uptime of the receiver.



Alert statistics per month

- Receives ~ 50k alerts
- Stores ~18k
- 1.5 k non-test alerts
- ~ 50 alerts of interest for H.E.S.S.

[1] see comet.readthedocs.io/
[2] monit is a watchdog which automatically restarts a process if it crashes.

Matching Alerts to Science Cases

- Initial parsing of alerts
  - identifying the experiment, alert type, …
    done with voevent-parse[1].
  - identification of the alert type is driven by the IVORN (unique alert identifier)

- A single incoming alert will be matched with all science case configurations which are related to this alert.
  - Processed in prioritised order
    (proposal grade & urgency of timely follow-up)
  - Each science case has its own configuration file
  - Easy to register additional science cases with a new configuration

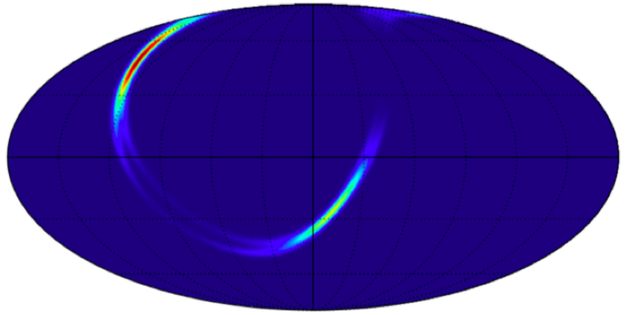
Alert Type	Matched Science Cases
LAT_Updated_Pos	GRB_prompt, GRB_afterglow
LAT_Pos_Gnd	GRB_prompt
LAT_Offline_Pos	GRB_afterglow
BAT_GRB_Pos	GRB_prompt, SGRAXP_prompt, GRB_afterglow, GRB...
gwnet_LVC_#S_Preliminary	GravitationalWave
gwnet_LVC_#S_Initial	GravitationalWave
gwnet_LVC_#S_Update	GravitationalWave, GravitationalWave
GBM_Gnd_Pos	GRB_prompt, GRB_afterglow_long, GRB_afterglow
GBM_Fin_Pos	GRB_prompt, GRB_afterglow
IceCube_HESE#	Neutrino_prompt, Neutrino_afterglow
ICECUBE_EHE_AMON	Neutrino_prompt, Neutrino_afterglow
IceCube_GFU	Neutrino_GFU_Prompt, Neutrino_GFU_Afterglow,
gwnet_LVC_#MS_Preliminary	GravitationalWave_Test, GravitationalWave_Test
gwnet_LVC_#MS_Initial	GravitationalWave_Test, GravitationalWave_Test
MAXI_Unknown	Flaring_Star_All, Flaring_Star_Prompt, Flarin...
MAXI_Known	Flaring_Star_Afterglow, Flaring_Star_Prompt, ...
HESS_FireDrill	FireDrill

[1] see https://voevent-parse.readthedocs.io/en/stable/#

Alert Processing and Filtering

- Science case configurations are defined by proposals:
  - states selection criteria (variables in the VoEvent)
  - states visibility criteria (zenith angle, observation window)
  - **more complex algorithms**:
    - script based, provided by the program PIs
    - e.g. coordinates compared with target catalog,
    - e.g. correlate Gw localisation map with galaxy catalog
  - options for the observations
    - reverse mode allowed
    - automatic reaction wanted

Localisation Uncertainty



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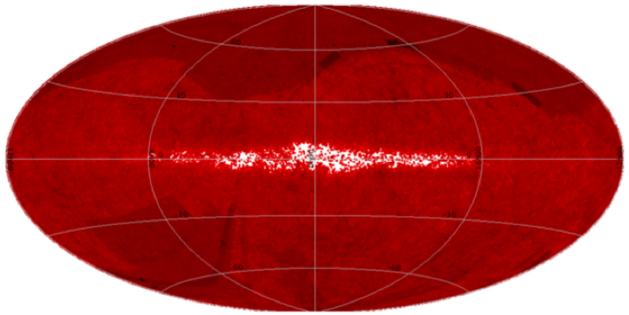
Galaxy Catalog



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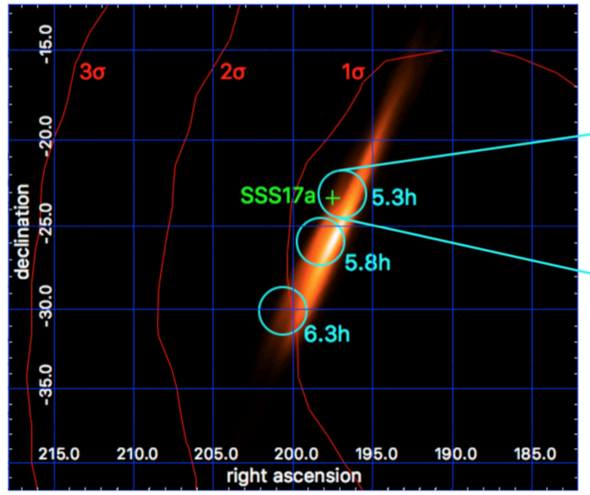
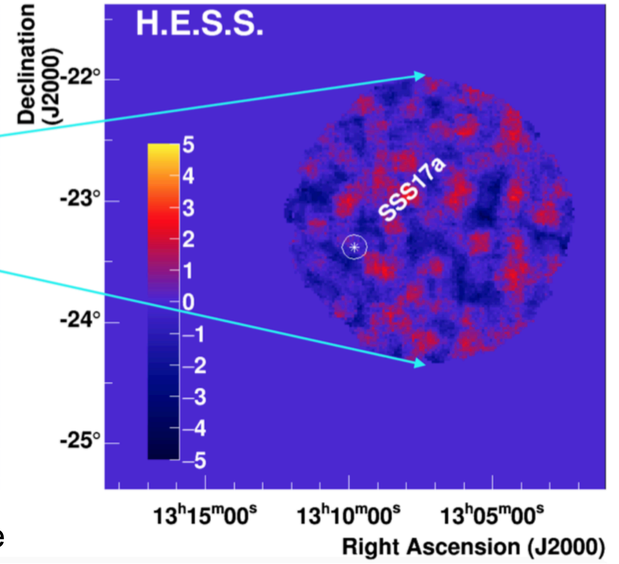
from TEV GAMMA-RAY OBSERVATIONS OF THE BINARY NEUTRON STAR MERGER GW170817 WITH H.E.S.S.





Observation Schedule with % coverage of galaxies within the uncertainty region

See Seglar-Arroyo et.al. (arXiv:1705.10138) for details

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All cuts and criteria specified in configuration files

- allows for quick and easy adaptation of strategy without modifications to the code

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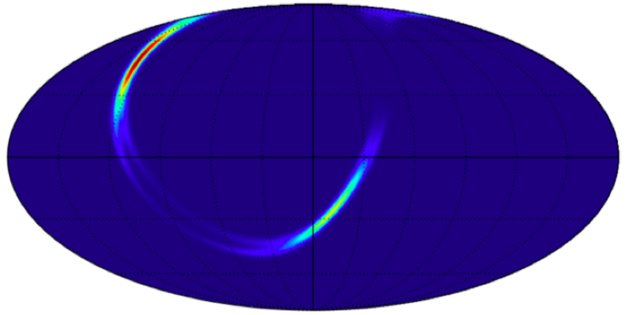

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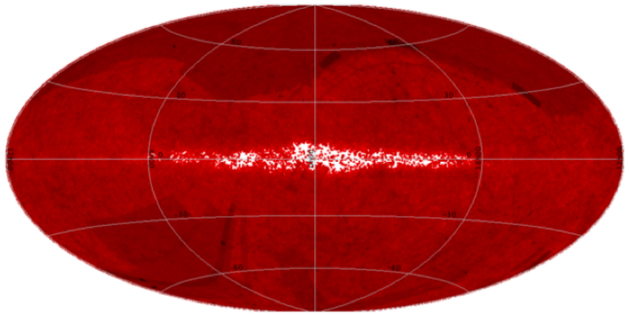

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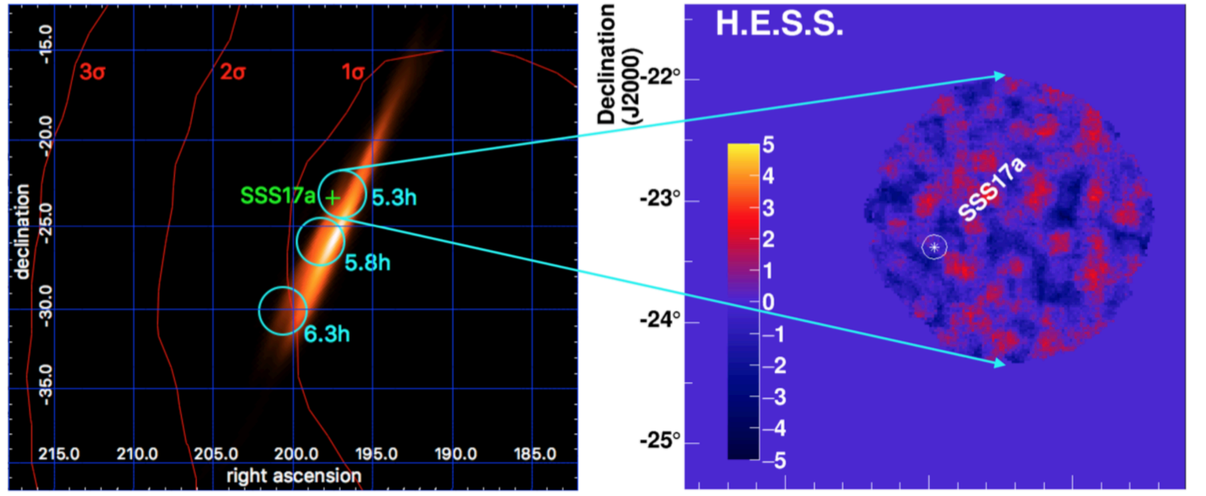

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Scheduling ToO Observations

- Two main modes:
  - **Prompt:** if the position of the ToO is visible within the next 10 minutes.
    - Fully automatic reaction
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    - transition between observations with a **special ToO mode**
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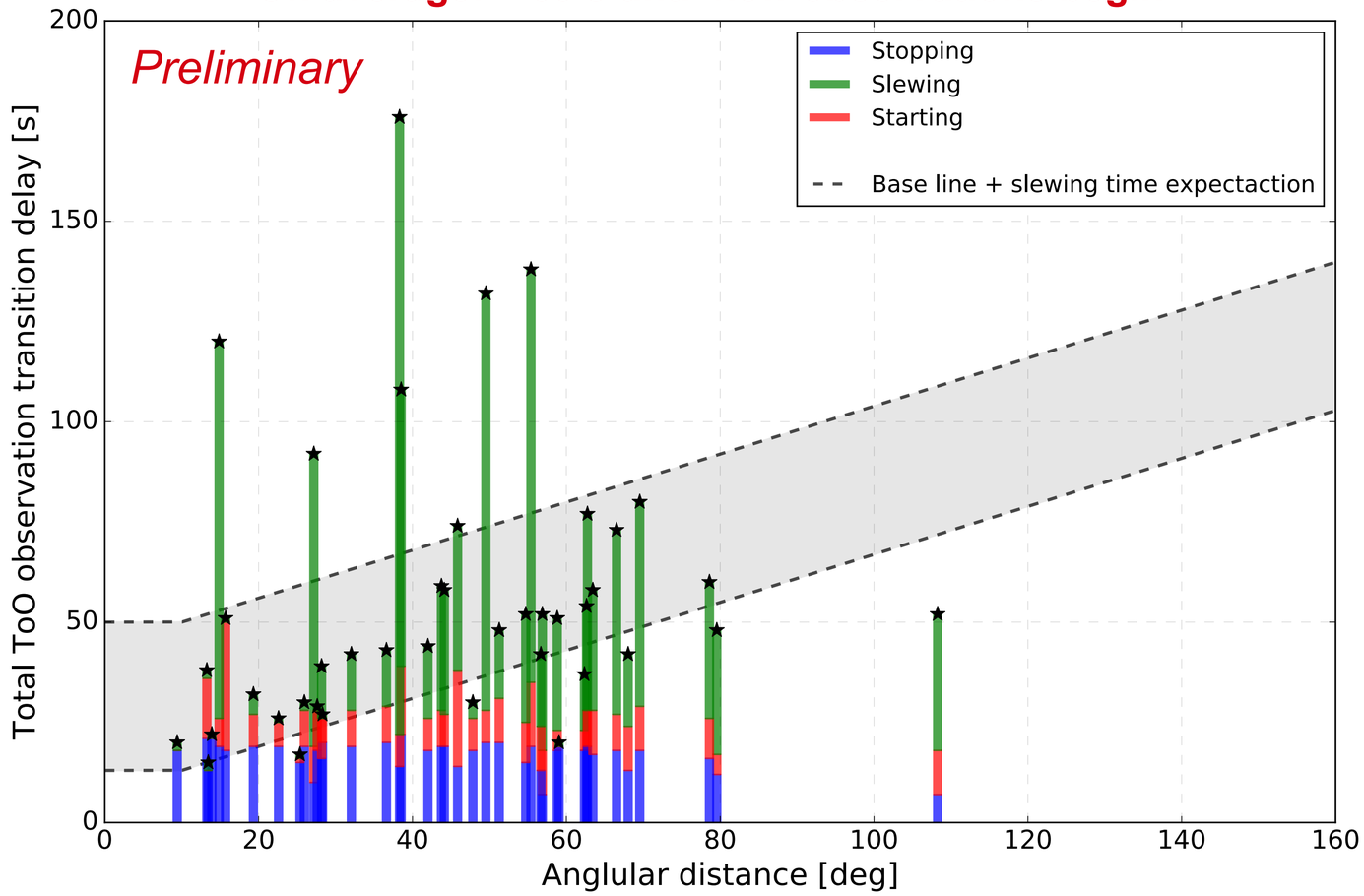

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Also handle corner cases:
- Coordinate updates
- new alerts with higher priority
- alert position is within the current FoV

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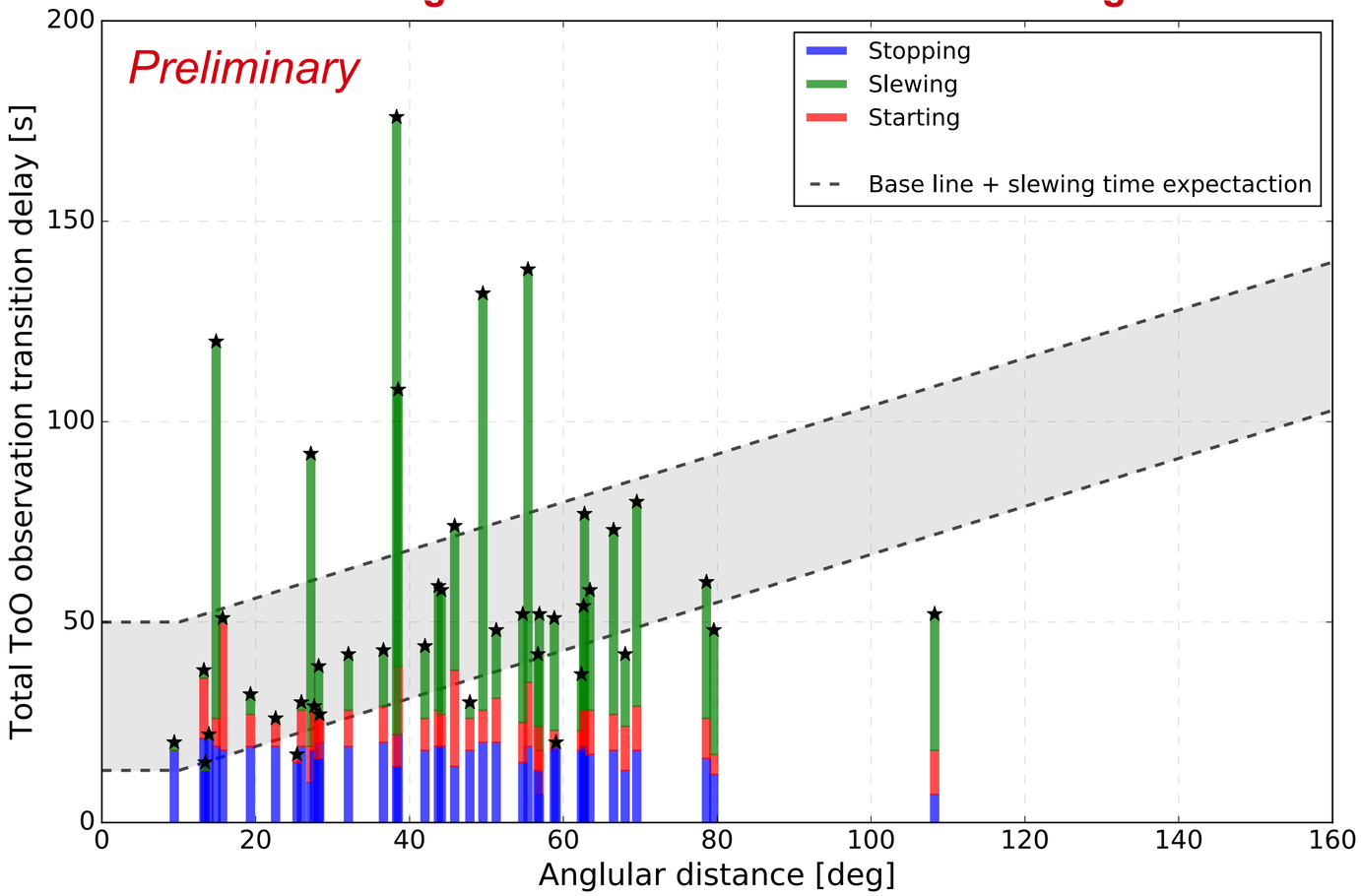

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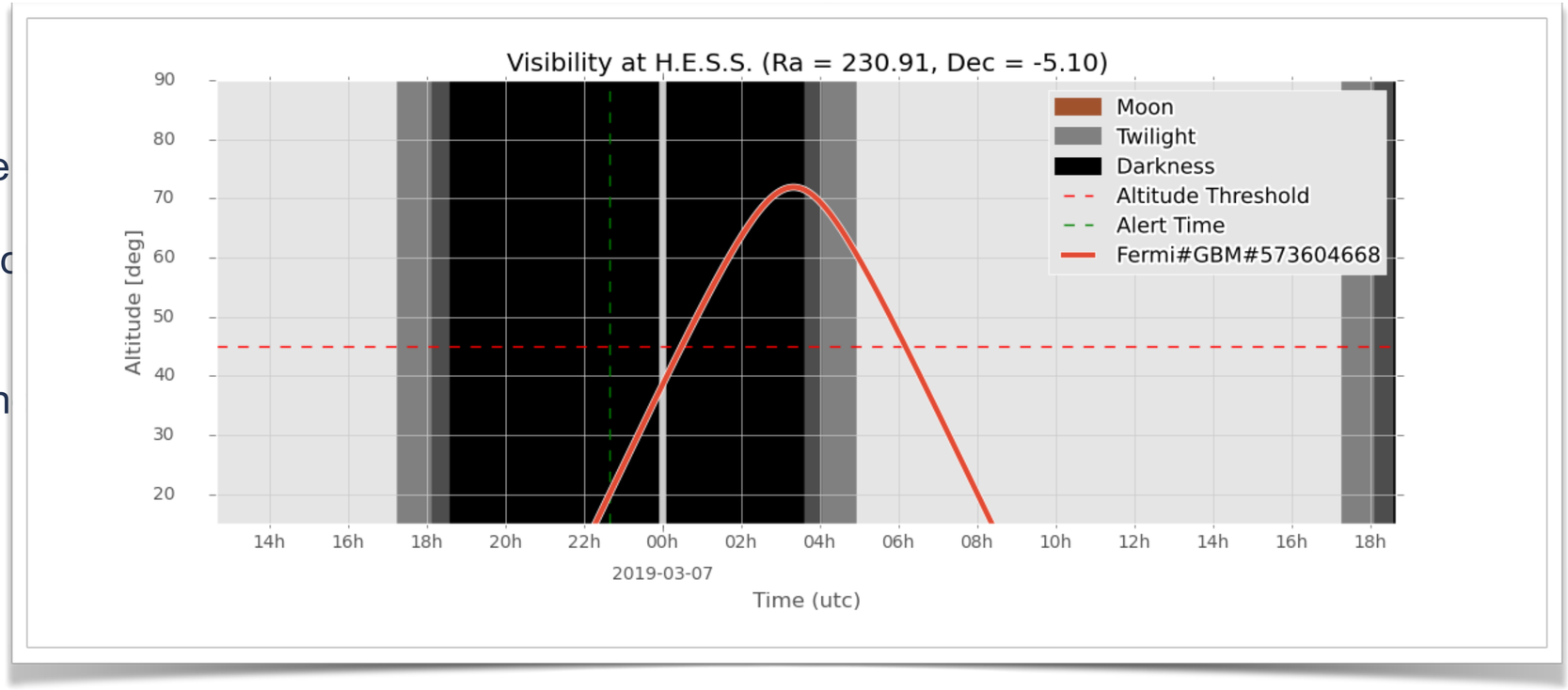
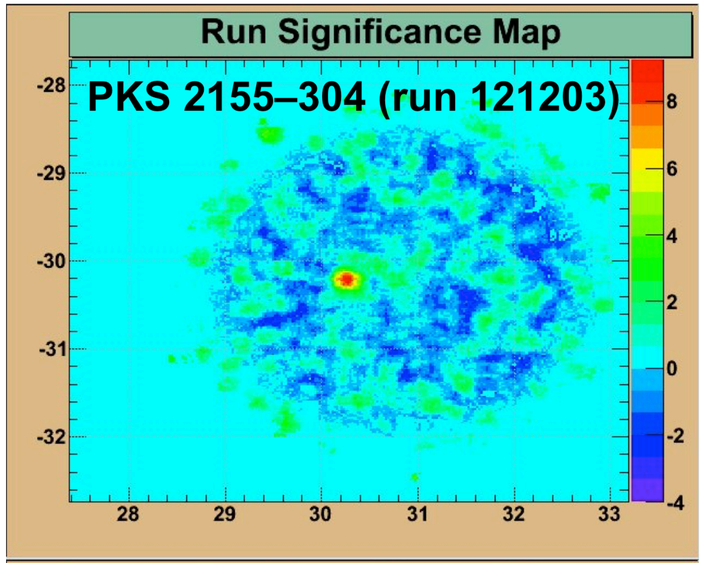
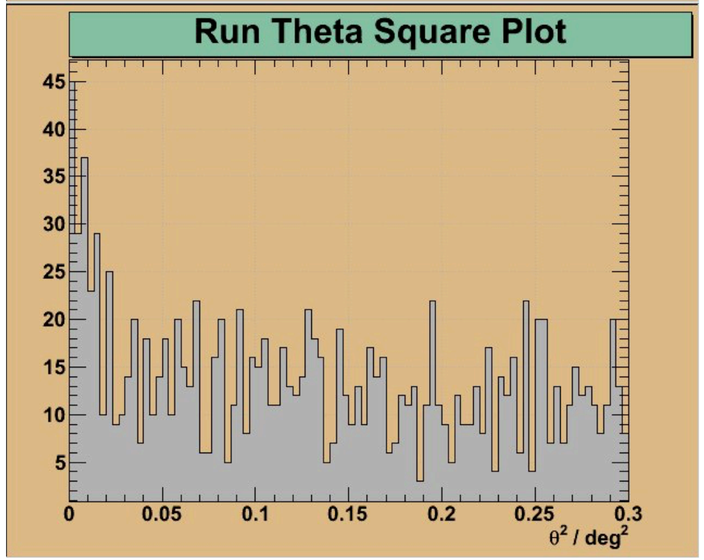


  - **Afterglow:** observation starts later than 10 minutes after the event
    - Shifters are alerted by pop-ups, sound and emails (including instructions)
    - Experts and PIs are alerted by email.
    - Observations are initiated with the help of scripts (given in the instructions) by the shifters.
    - Allows to Consult PIs and Experts on-call by phone.
    - Also applies to alerts during the day.

Real Time Analysis

- Simplified live-calibration scheme
- Different operation modes (mono and stereo)
- Shows live:
  - Theta^2 histograms
  - Sky maps
- Merging of consecutive observations
- Entered in a database
  - allows to review results from the last night(s)
- Used to decide if observations should be prolonged
  - during the same night (e.g. AGN monitoring)
  - for the next night(s)





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  - for the next night(s)
- Used to inform the community quickly (currently via ATels)

H.E.S.S. detection of a strong VHE activity from the blazar 3C 279

ATel #11239; ***Mathieu de Naurois for the H. E.S. S. collaboration***
*on **28 Jan 2018; 15:00 UT***
Credential Certification: Jean-Philippe Lenain (jlenain@in2p3.fr)

Subjects: Gamma Ray, VHE, Request for Observations, AGN, Blazar, Quasar

Referred to by ATel #: 11246, 11464, 11680

H.E.S.S. and ATOM detection of renewed activity of the FSRQ 3C 279

ATel #11680; ***Mathieu de Naurois for the H. E.S. S. Collaboration***
*on **4 Jun 2018; 14:05 UT***
Credential Certification: Michael Zacharias (m.zacharias@lsw.uni-heidelberg.de)

Subjects: Optical, Gamma Ray, >GeV, VHE, Request for Observations, AGN, Black Hole, Blazar, Quasar

Referred to by ATel #: 11687

H.E.S.S. follow-up of IceCube-170922A

ATel #10787; ***Mathieu de Naurois for the H. E.S. S. collaboration***
*on **27 Sep 2017; 14:33 UT***
Credential Certification: Fabian SchÃÂ¼ssler (fabian.schussler@cea.fr)

Subjects: VHE, Neutrinos

Referred to by ATel #: 10799, 10817, 10830, 10833, 10844, 11419

Transients Follow-up System - Summary, Conclusions, lessons learnt and outlook

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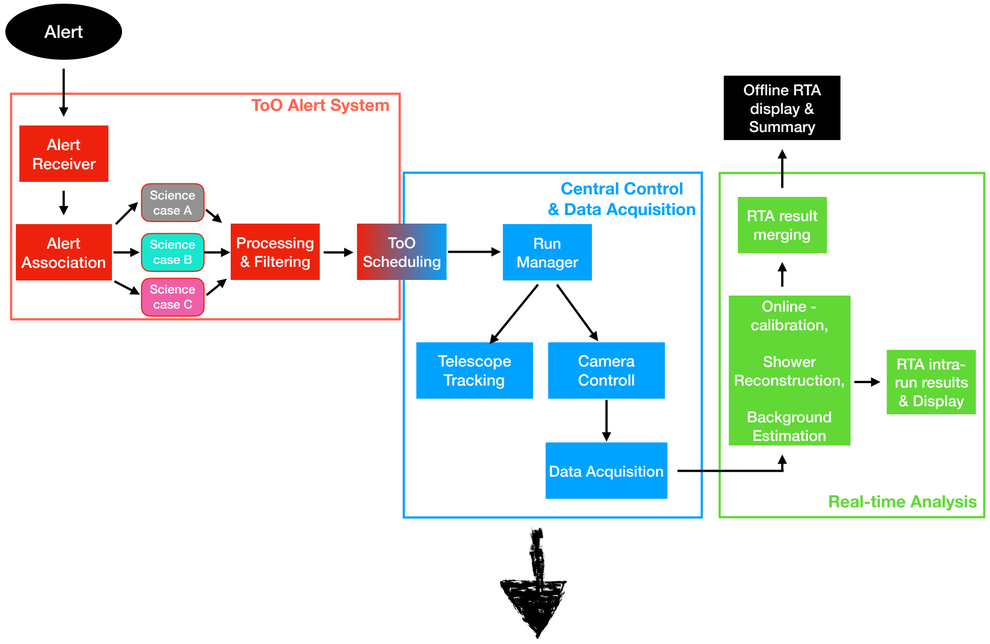
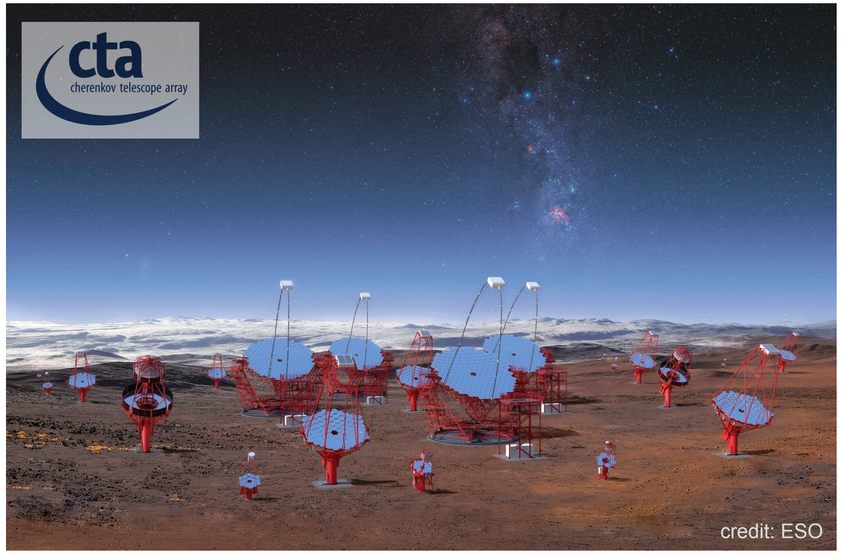
H.E.S.S. is > 15 years old → successfully upgraded with modern capabilities

Can now handle transients alerts end-to-end





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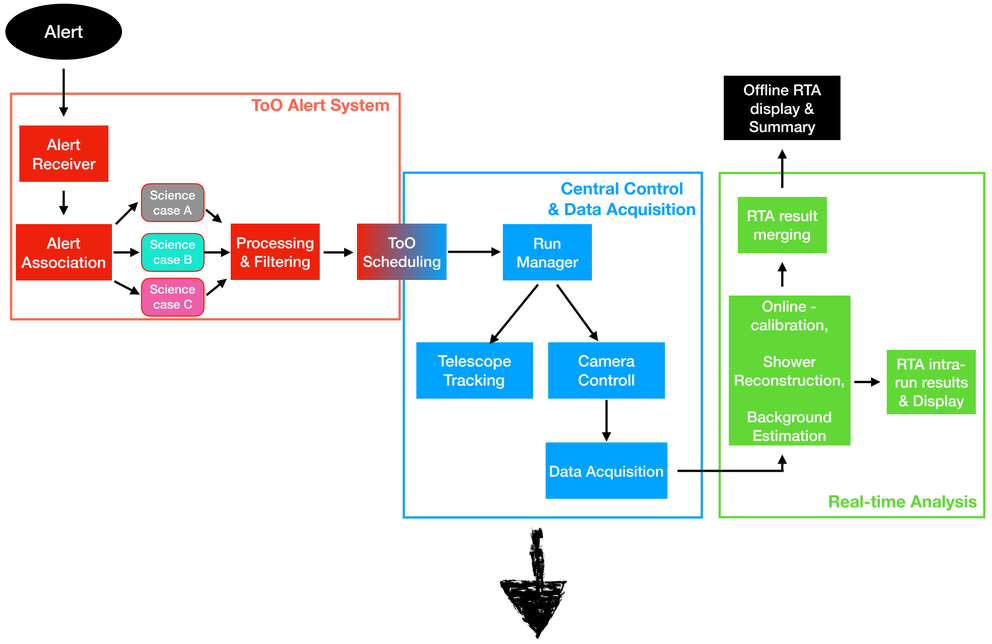

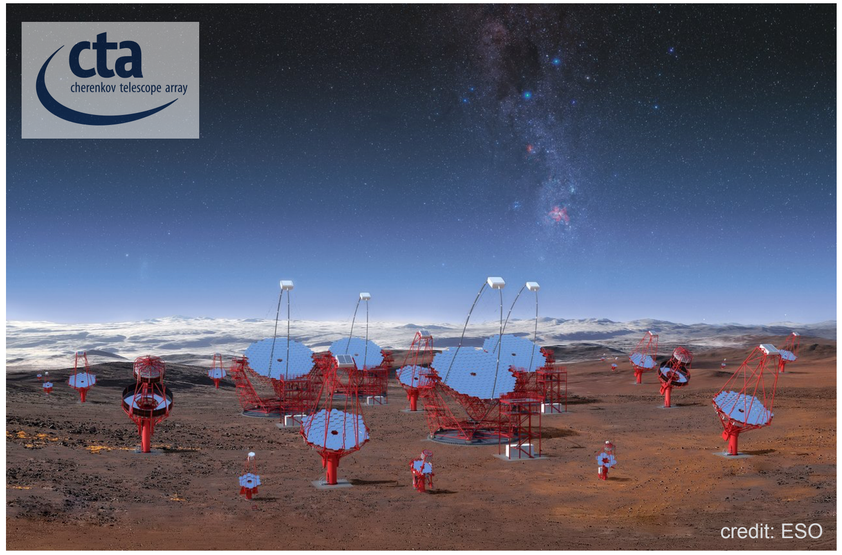

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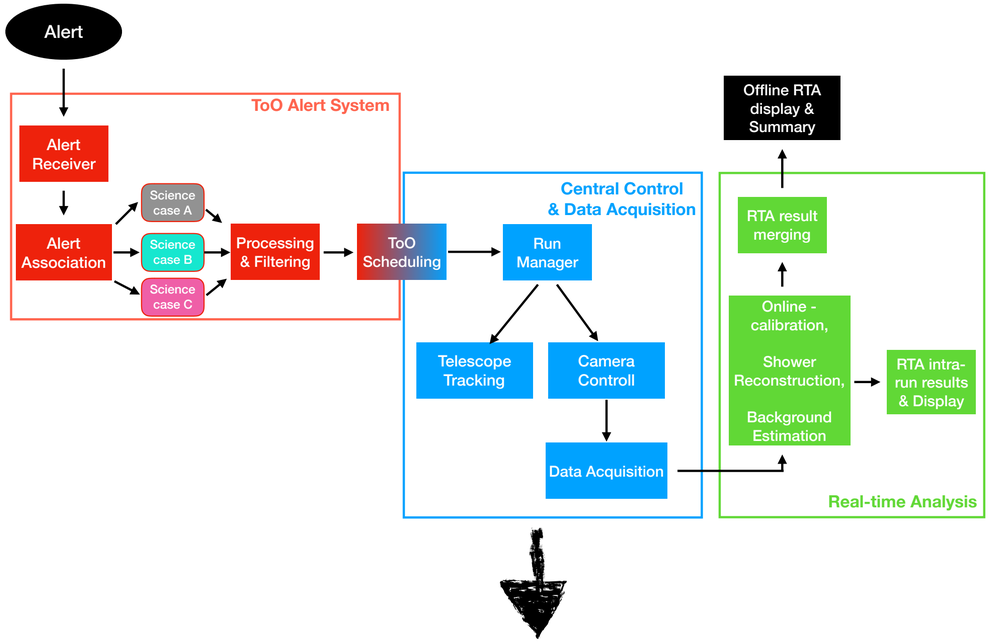

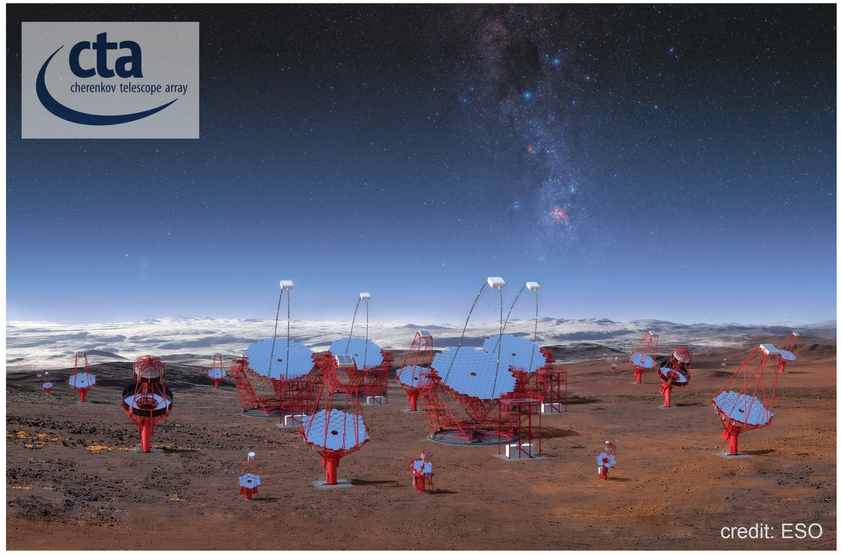

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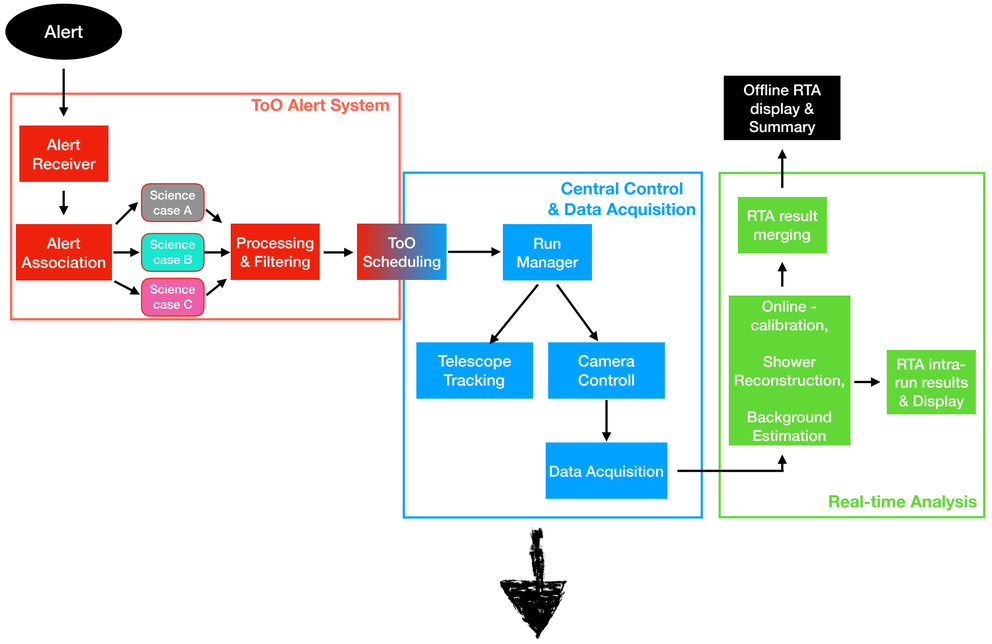
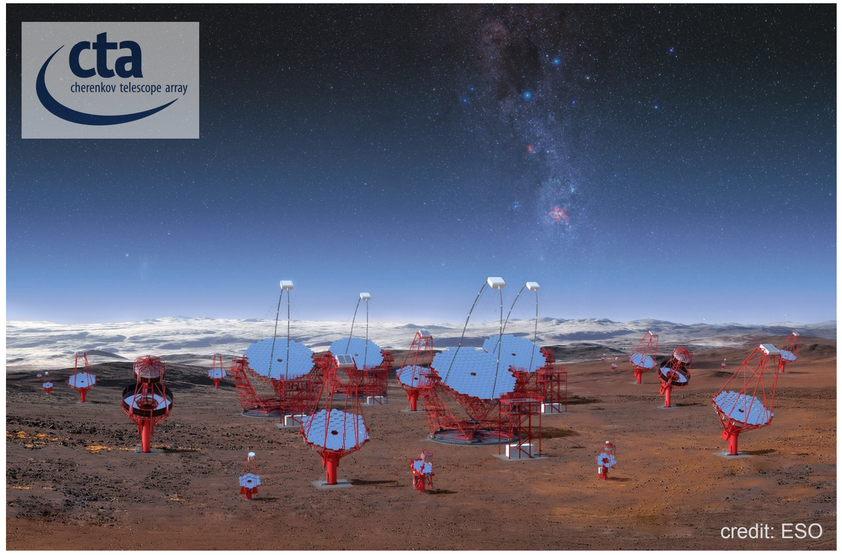
Link GW alerts and GRB alerts automatically, link Neutrino alerts + X
Many more applications





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Additional complexity for CTA
Potentially many different sub-arrays at the same time
Coordination between two sites