Status of the H.E.S.S. experiment

Operating Cherenkov telescopes 20 years after their installation

H.E.S.S.

S. Ohm (DESY) & S.J. Wagner (LSW) for the H.E.S.S. collaboration, RICH2022, Edinburgh September 2022

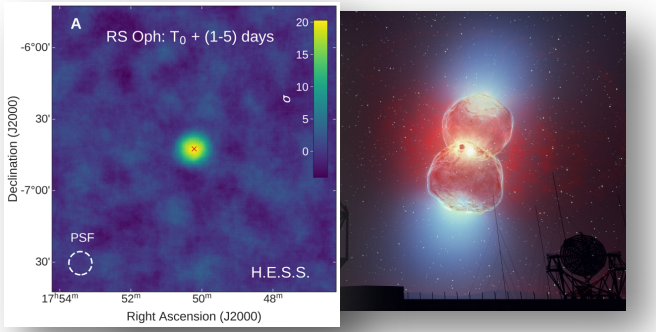
The H.E.S.S. telescope array

- 5 telescopes with 960 / 1764 pixel cameras
- 3.5° – 5.0° field-of-view, ~0.1° angular resolution
- 30 GeV – 100 TeV, ~15% energy resolution

H.E.S.S. Collaboration: ~250 members, at 38 institutes, in 13 countries

Shift of science focus over the years

1st Galactic transient: Nova RS Oph



H.E.S.S. Collaboration: Science, 376, 6588 (2022)

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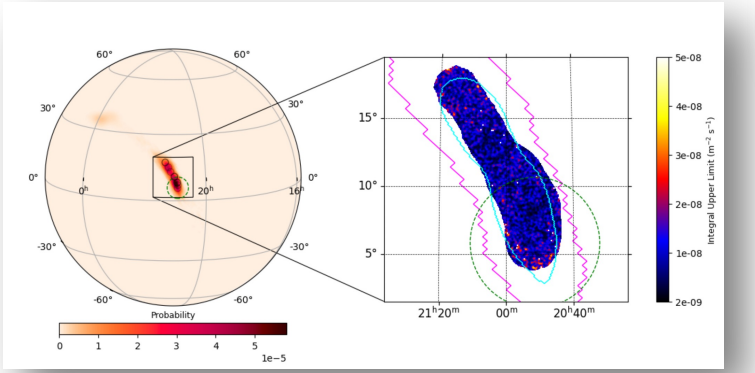
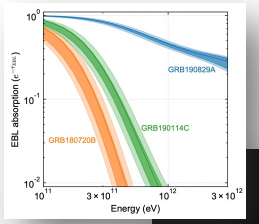
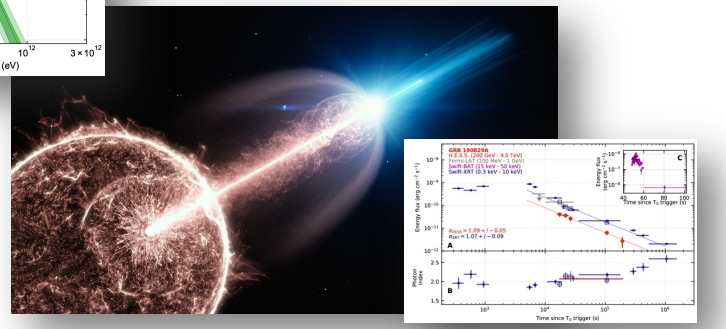
Multi-messenger: GW follow-up



H.E.S.S. Collaboration: ApJ, 923, 109 (2021)

Time-domain & multi-wavelength: e.g. GRBs





H.E.S.S. Collaboration: Science, 372, 1081 (2021)

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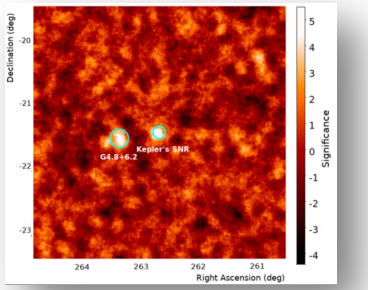
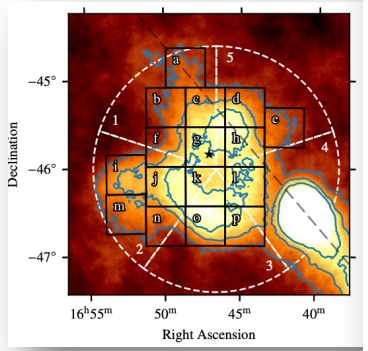
Deep exposures: Kepler SNR

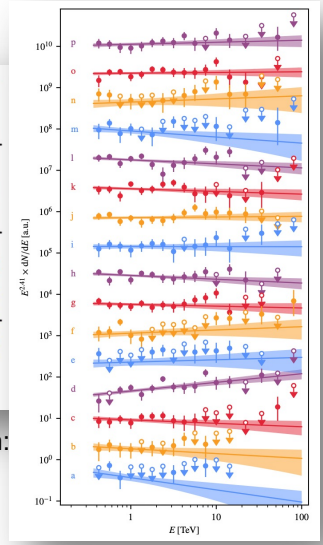


H.E.S.S. Collaboration: A&A, 662, A65 (2022)

Availability & Stability are key

Precision measurements: Westerlund 1

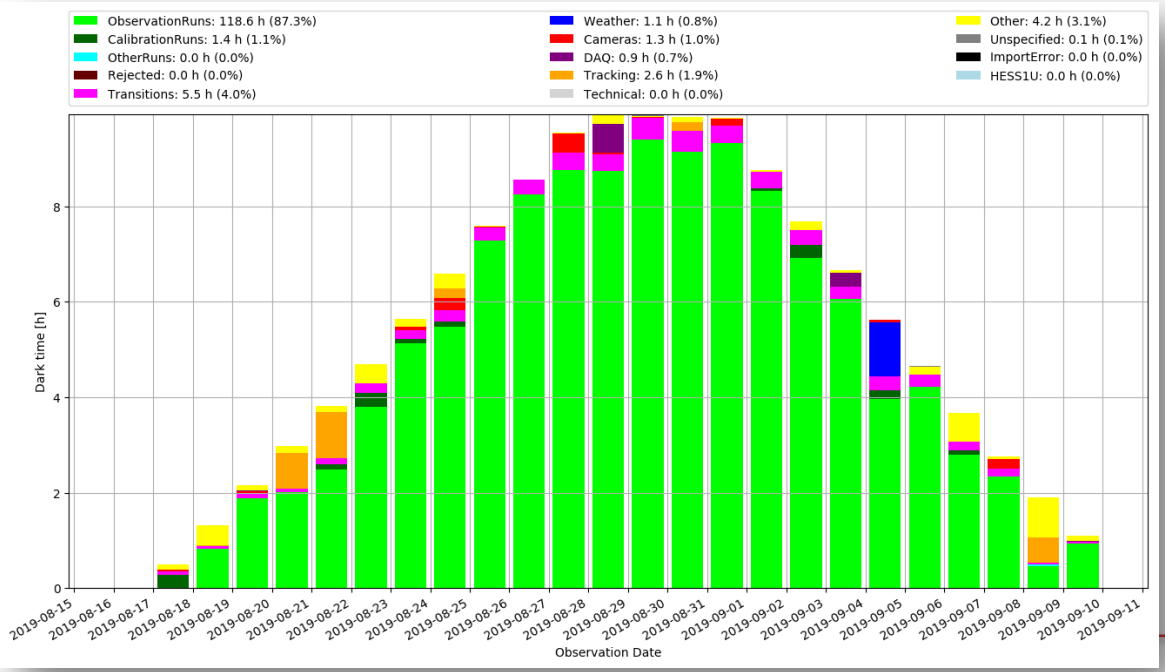




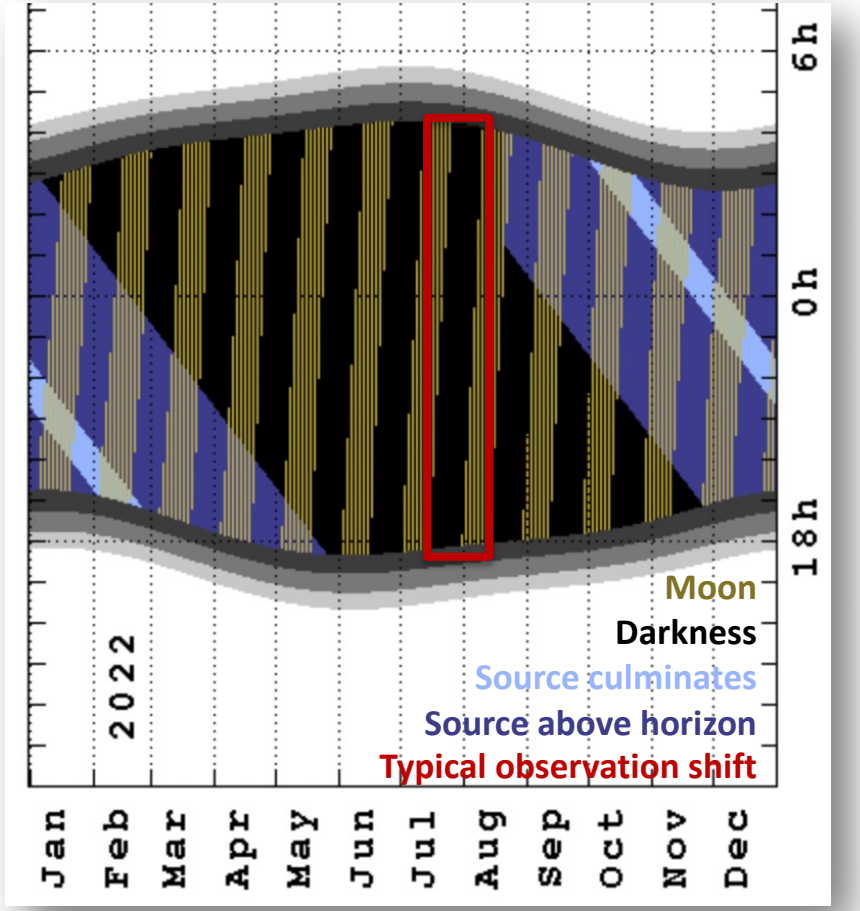
H.E.S.S. Collaboration: A&A in press (2022)

How H.E.S.S. operates

- Observations in dark nights (~1000 hrs / 10% duty cycle)
- Typically spent on
  - Scientific observations
  - Calibration & technical observations
  - Transitions between sky objects
  - Downtime due to technical problems & maintenance, or
  - Downtime due to bad weather



Visibility of objects throughout the year



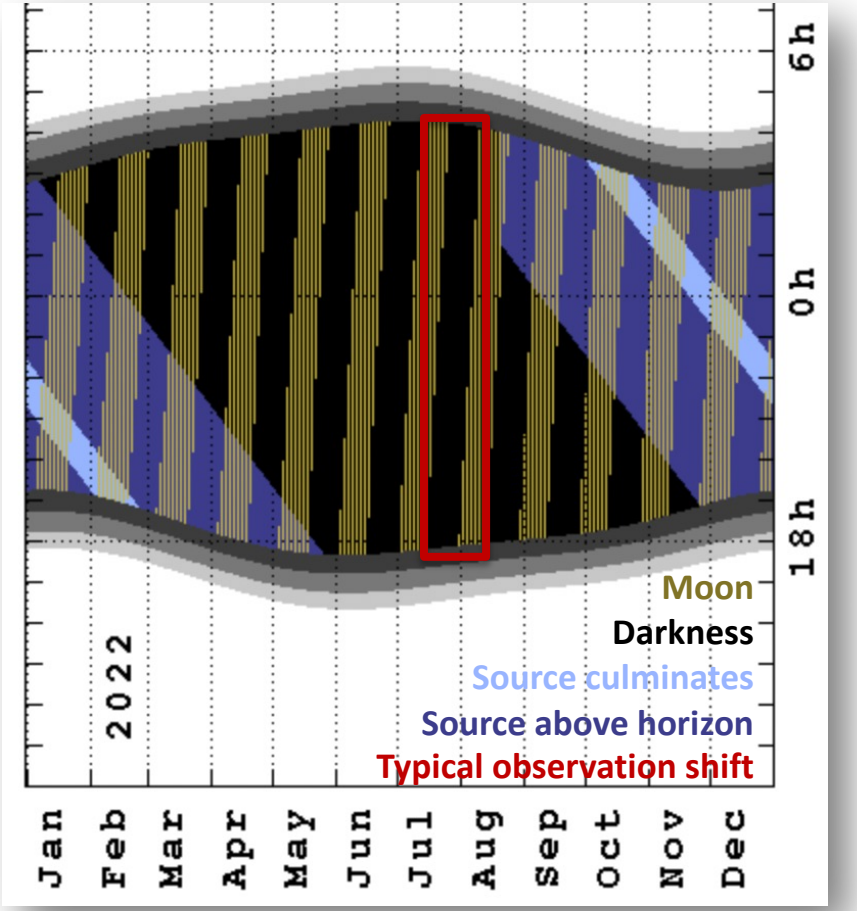
How H.E.S.S. operates, and where one can improve

- Observations in dark nights (~1000 hrs / 10% duty cycle)
- Typically spent on
  - Scientific observations
  - Calibration & technical observations
  - Transitions between sky objects
  - Downtime due to technical problems & maintenance, or
  - Downtime due to bad weather

- Potential to increase observation time
  - Observe under moderate moonlight
  - Observe under “twilight”
  - Reduce downtime due to technical problems & maintenance
  - Optimise calibration & technical observations

- Regular hardware maintenance and upgrades to maintain e.g. optical throughput of the system

Visibility of objects throughout the year

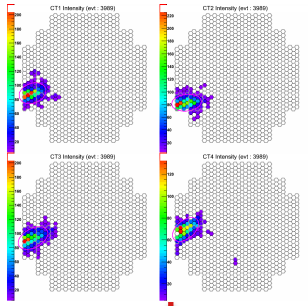


Upgrades maintain & improve performance and stability

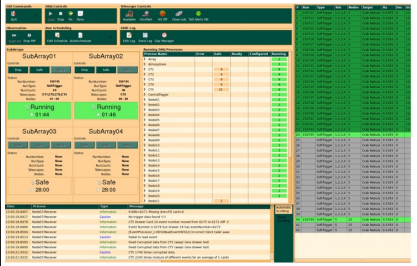
CT1-4 operational

CT5 1st light

CT2-4 camera upgrade



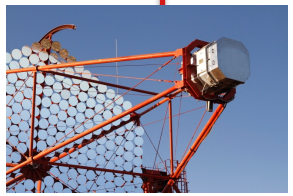
DAQ & cluster upgrade



2002 2004 2008 2010 2012 2014 2016 2018 2020 2022

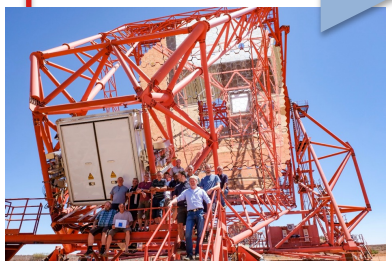
H.E.S.S. 1st light

CT1-4 mirror refurbishment



CT1 camera upgrade

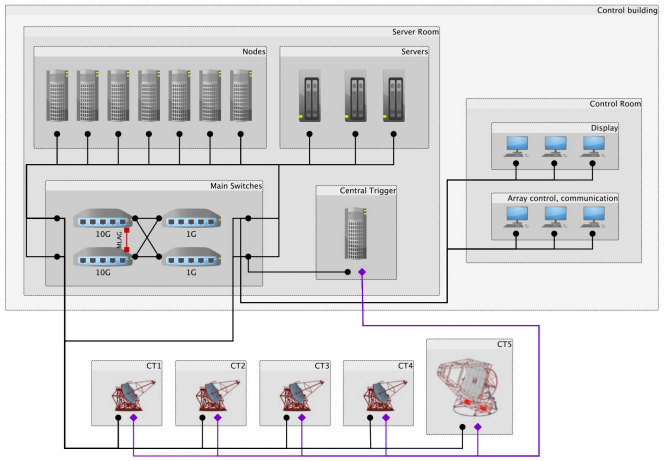
CT3 mirror refurbishment



CT5 camera upgrade

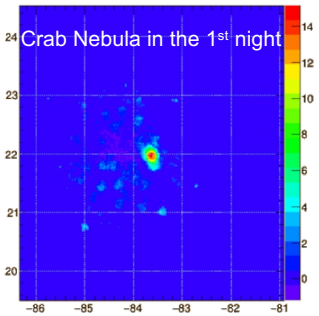
Hardware changes in the first HESS extension

- Data Acquisition System (DAQ) upgrade
  - Upgrade of main DAQ hard- and software on- and off-site in 2019
  - Preparations for new CT5 camera and increased computing needs
  - Preparation for continued HESS operations
  - Enhanced functionality for cluster setup and monitoring, ++

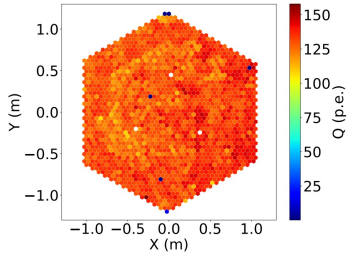


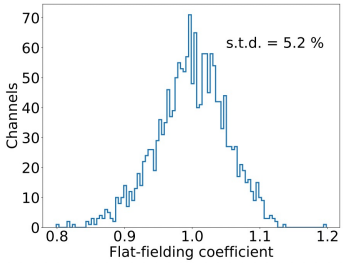
S.J. Zhu, et al., ICRC 2021

- CT5 camera upgrade
  - Installation of CTA MST prototype camera in CT5 in October 2019
  - Very stable operation since ~3 years (>99% uptime)
  - Performance meeting CTA requirements

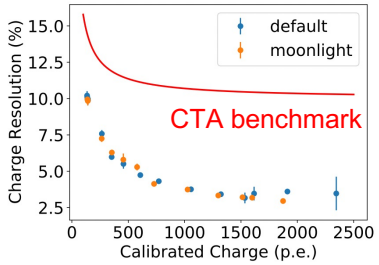


Relative pixel response





Charge resolution



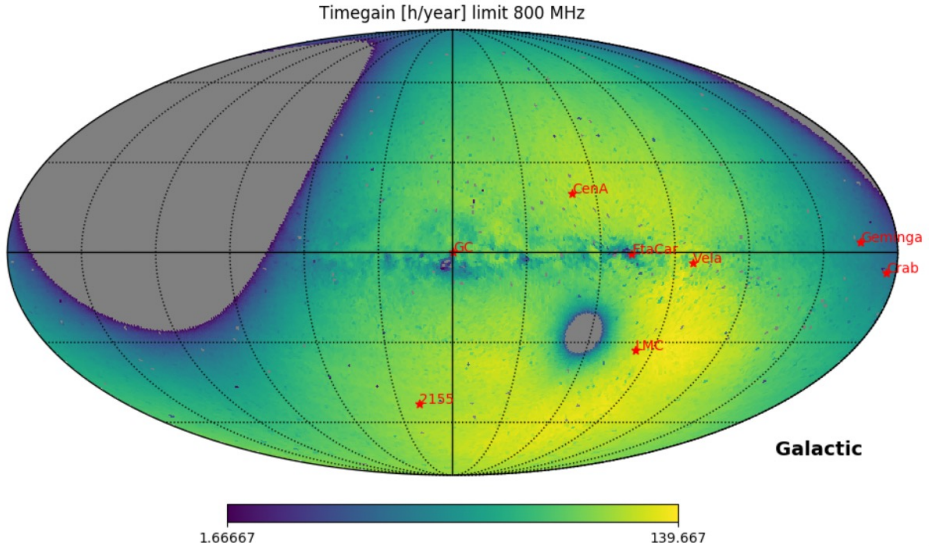
B. Bi, et al., ICRC 2021

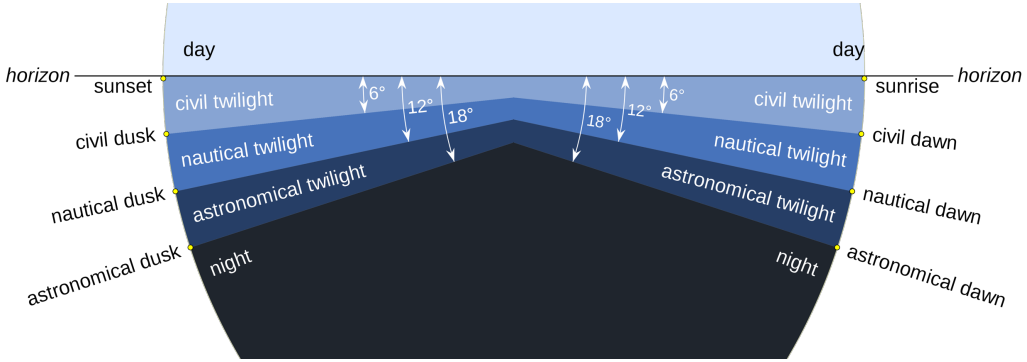
Extending observation time through moonlight and twilight observations

- Moonlight observations
  - Initial tests of moon observations in 2019
  - Hardware settings fixed since 03/2020
  - Full implementation since 01/2021 including scheduling, transient follow-up system, etc.

- Current moon settings
  - Max. illuminated moon fraction: 40%
  - Target-moon separation: 45° – 145°
  - Max. Night-sky background (NSB): 3.5 x NSB_{dark}

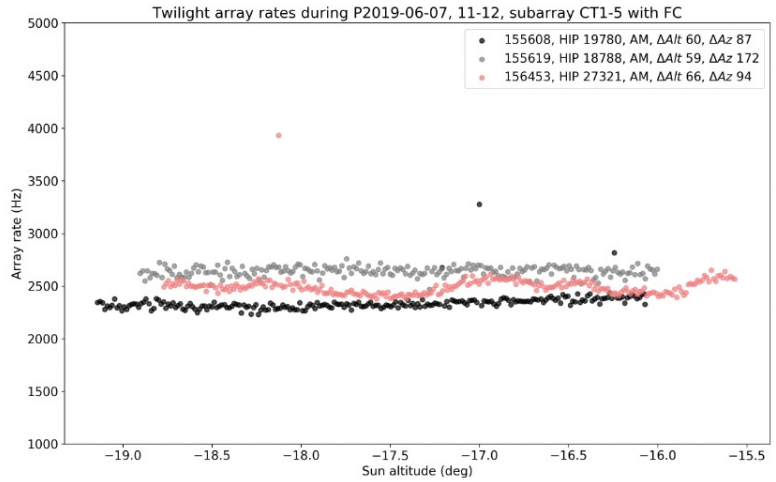
⇒ >250 hours/yr extra





- "Darkness" definition
  - Historically, observations conducted in astronomical darkness (sun elevation: -18°)
  - Extensive tests to start/end observations in astronomical twilight
  - Darkness definition changed to sun el. of -16°

⇒ ~70 hours/yr extra

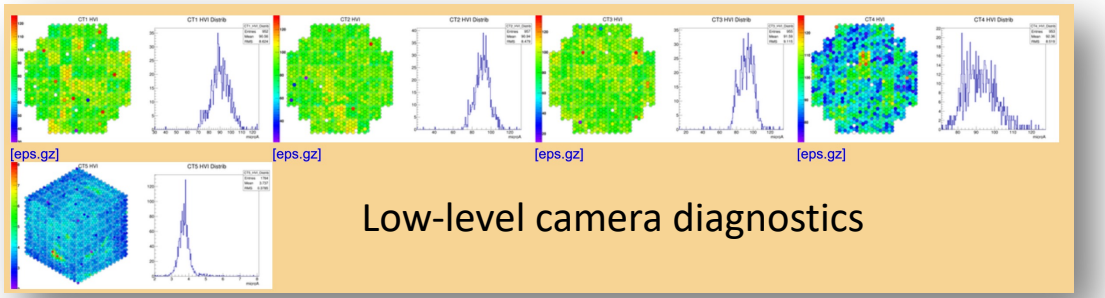


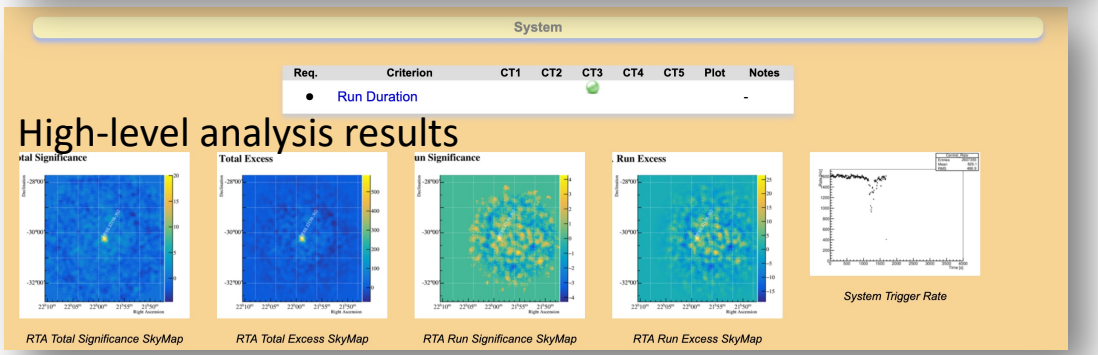
Extending observation time through changes in procedures

- Established professional operators during Corona
- Supported by shifters from partner institutes
- Established remote control room at DESY Zeuthen; more locations coming

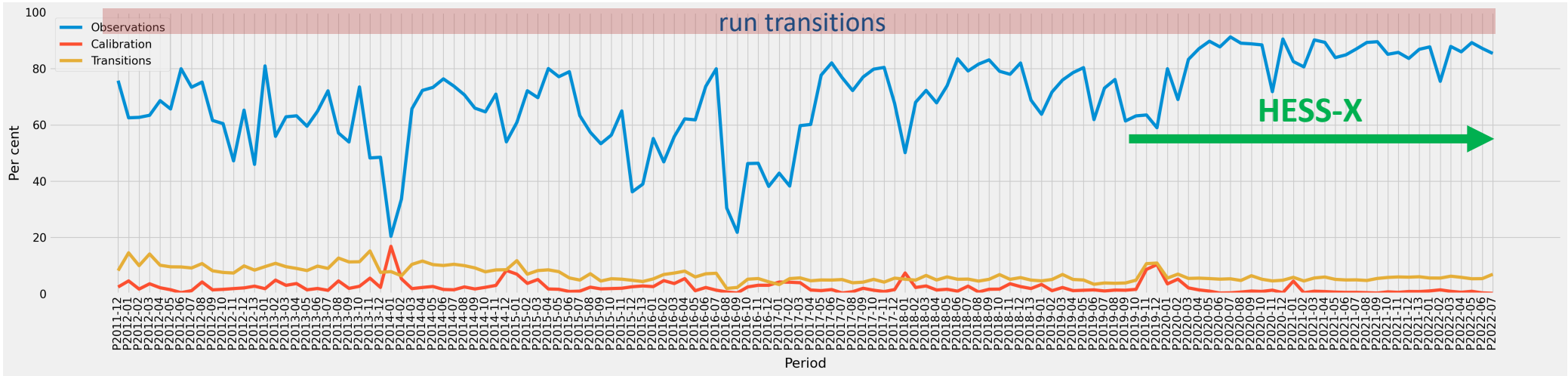
- Documentation, error policy, guidelines
- Consolidated calibration strategy
- Day shifters at partner institutes monitor data quality and long-term instrument behaviour

=> Training, fast problem identification



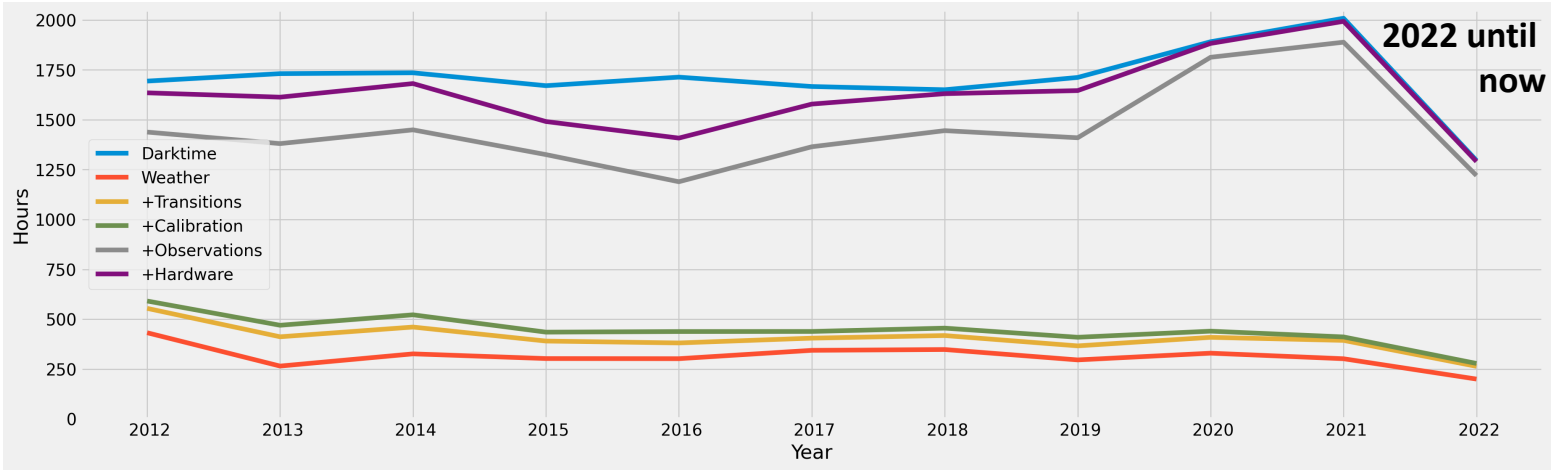


Data taking efficiency: long-term and in 1st H.E.S.S. extension



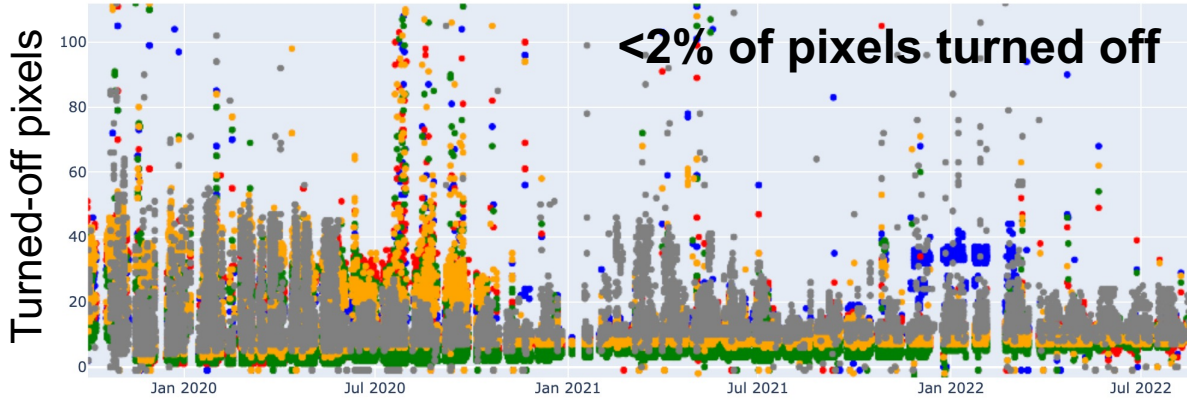
Weather corrected,
Weighted per telescope

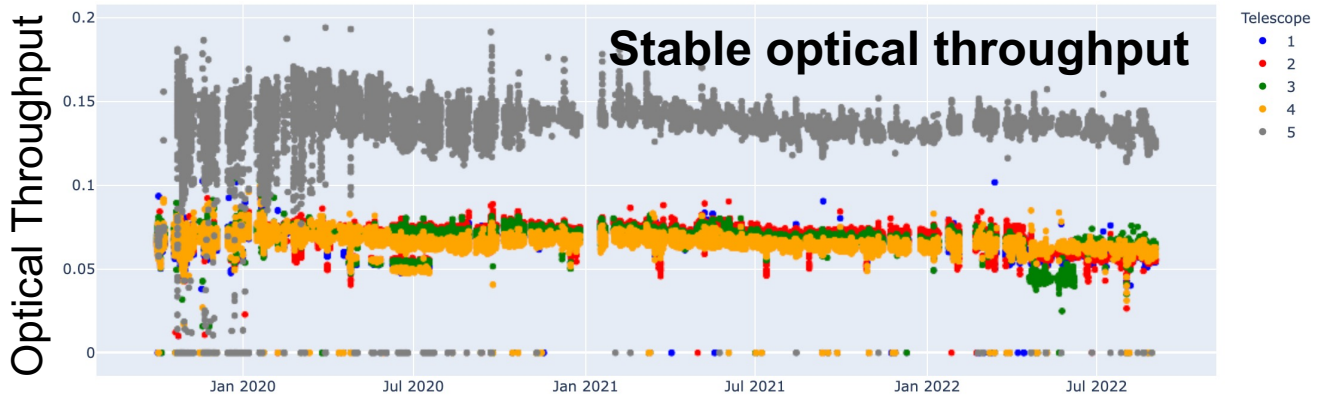
- Data taking efficiency during 1st H.E.S.S. extension at very high level (~90%, close to optimal)
- 5-telescope availability
  - 2020: 92%; 2021: 88%; 2022: 87%
- From 2012 – 2019: ~900 – 1000 hrs/yr
- In 1st H.E.S.S. extension
  - Moonlight observations: +250 hours
  - Hardware availability: +100 – 150 hours
  - Darkness definition: +70 hours
  - Procedures: +50 hours
  - Calibration optimization: +15 hours

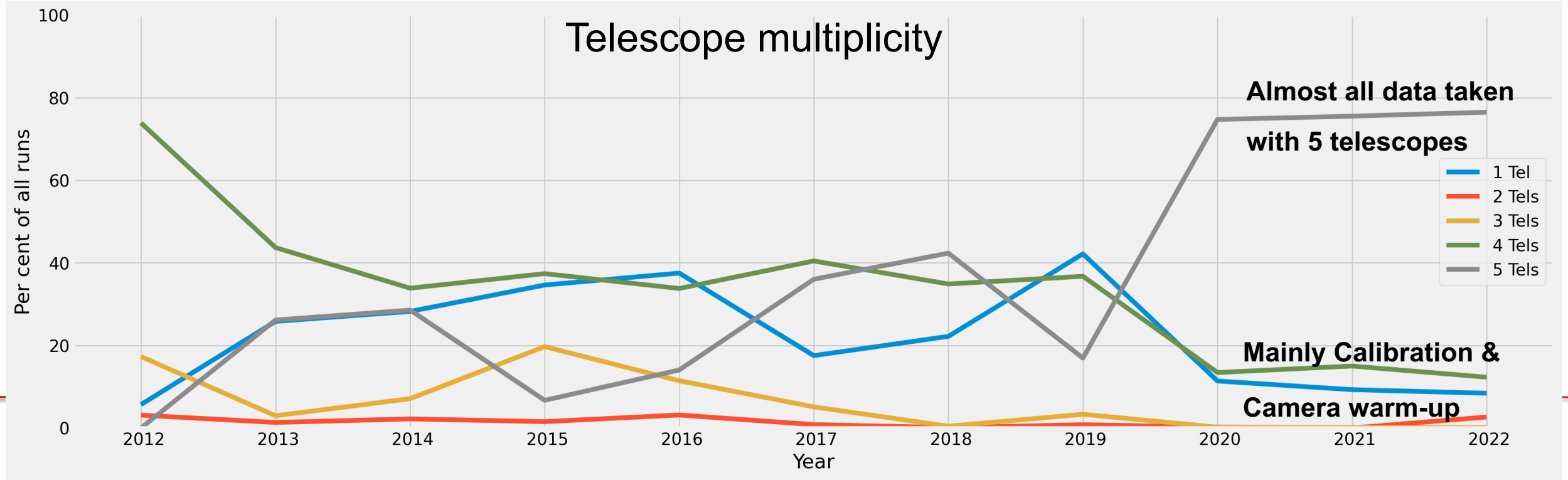


H.E.S.S.

Long-term data quality and stability in 1st H.E.S.S. extension







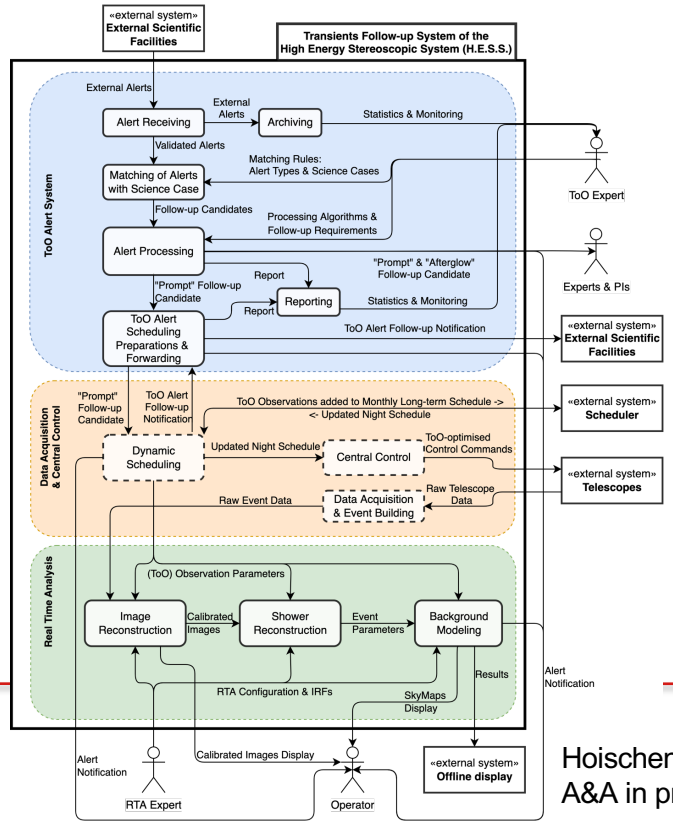
H.E.S.S. in the context of time-domain astrophysics

- Time-domain and multi-messenger astronomy needs
  - End-to-end strategy for follow-up
  - Real-time analysis (RTA) to guide follow-ups
  - Fast data transfer for final analysis
  - Next-day analysis to alert astrophysics community

- H.E.S.S. on-site analysis capabilities
  - RTA tailored to different source types (latency ~2 min)
  - Fast and performant on-site calibration and next-day analysis (latency ~8 hours)
- Data transfer
  - Internet connection supports additional moonlight data + 2 modes of charge integration data for CT1-4
  - Implemented data transfer via internet in 2019 (latency ~12 hours)

⇒ Final analysis results available in ~24 hours

H.E.S.S. Transients System



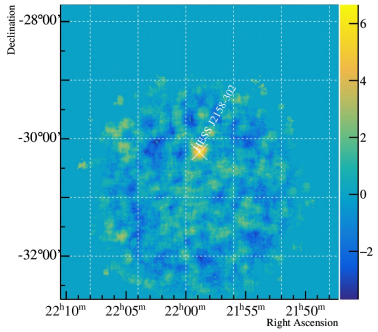
Hoischen et al.
A&A in press (2022)

RTA night view

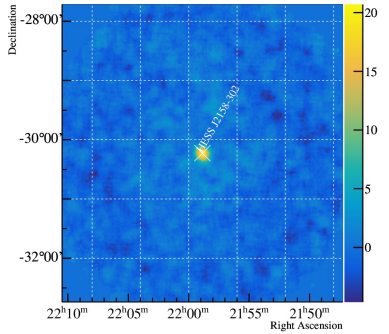
Preliminary Nightly Analysis Results (for runs that finished processing)
see Results View for longer-term monitoring of sources

Target	Analysis	config	Runs	LiveTime	Signif (σ)	σ/√t	Excess	<zen>	<offs>
	RTA	RingBg std_zeta_hybrid	3	01:26	2.69	2.25	25.65	31°	0.06°
	RTA	RingBg std_zeta_hybrid	2	00:57	-0.64	-0.65	-5.91	13°	0.05°
6	RTA	RingBg std_zeta_hybrid	1	00:28	2.27	3.30	15.83	5°	0.03°
8	RTA	RingBg std_zeta_hybrid	1	00:22	0.98	1.62	5.52	7°	0.03°
	RTA	RingBg std_zeta_hybrid	2	00:30	1.10	1.56	5.70	21°	0.05°
	RTA	RingBg std_zeta_hybrid	2	00:57	1.04	1.06	4.61	34°	0.53°
	RTA	RingBg std_zeta_hybrid	1	00:29	**4.40**	6.32	27.11	4°	0.35°
	RTA	RingBg std_zeta_hybrid	4	01:55	2.08	1.50	10.42	34°	0.66°
	RTA	RingBg std_zeta_mono	6	02:45	-1.45	-0.87	-9.60	44°	0.49°

RTA run significance



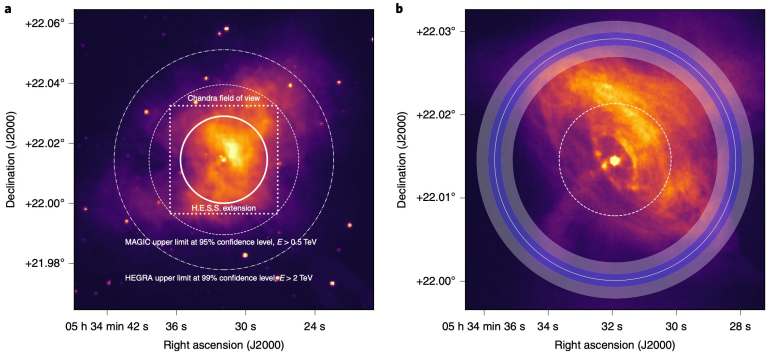
RTA integrated significance



Instrument stability and further improvements

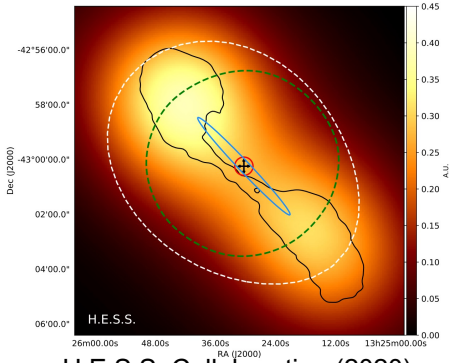
- Continuous developments to further improve data and analysis products
- Data/MC validation chain (Leuschner et al., Gamma 2022)
- Run-wise simulations (Holler et al., APh, 123, 102491, 2020)
  - Provide instrument response functions tailored to observation and hardware
  - Application to extension measurement of e.g. Crab Nebula and Centaurus A

Crab Nebula



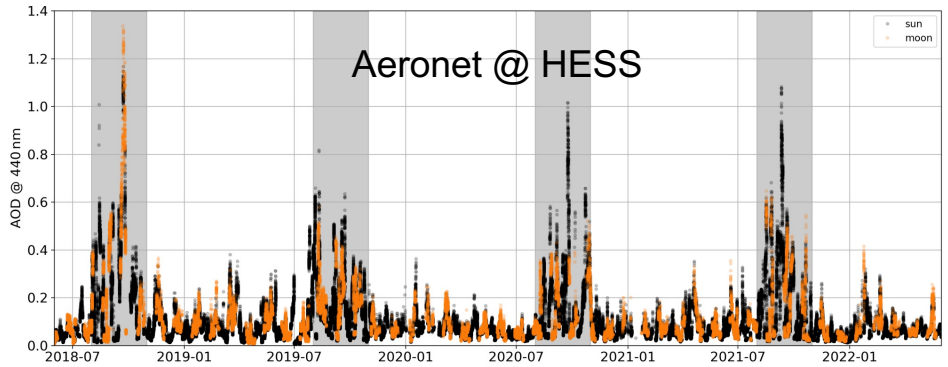
H.E.S.S. Collaboration (2020), Nature Astronomy, 4, 167

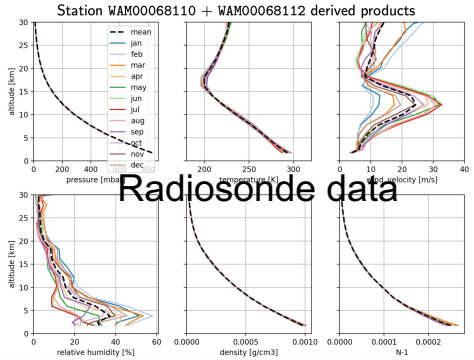
Cen A

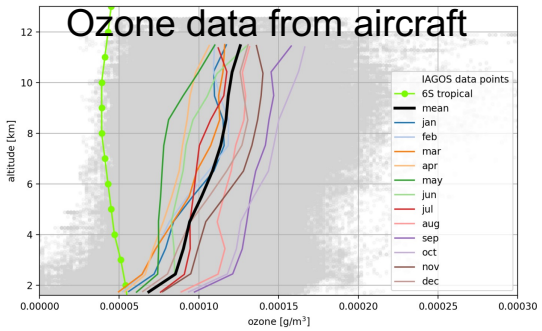


H.E.S.S. Collaboration (2020), Nature, 582, 7812

- Atmosphere monitoring and correction scheme
  - AERONET, radiosonde & aircraft data provide measure of aerosol content and atmosphere transparency
  - Correction reduces systematic errors and makes archival data available that was not considered before







Holch et al., AtmoHEAD conference (2022)

Summary

- H.E.S.S. observed throughout the pandemic thanks to dedicated personnel on- and off-site
- More data (from 10% – 15% duty cycle)
- Better data (more homogenous data)
- Exciting new discoveries

- 2nd extension phase starting in October 2022
  - Aim at maintaining high uptime & efficiency
  - Operate CTA hardware for extended periods of time (e.g. Cherenkov cameras)
  - Further engage people in instrument and data quality => train future CTA personnel
  - Knowledge transfer to CTA via e.g. public technical notes
  - Increase recognition of individuals for technical work (cf. JENAS survey)

⇒ H.E.S.S. is operating better than ever and is prepared for continued observations!