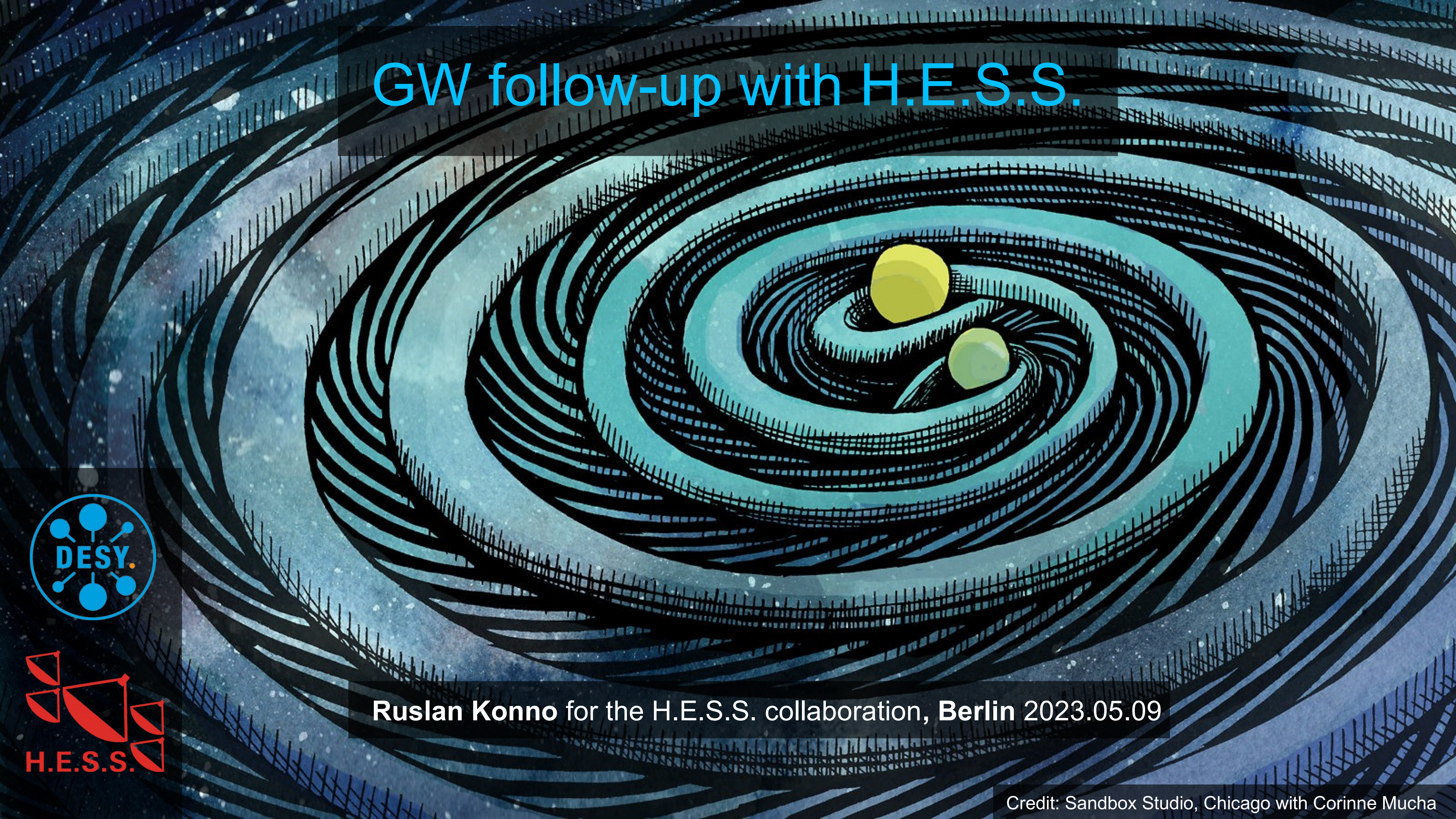
GW follow-up with H.E.S.S.



Ruslan Konno for the H.E.S.S. collaboration, **Berlin** 2023.05.09

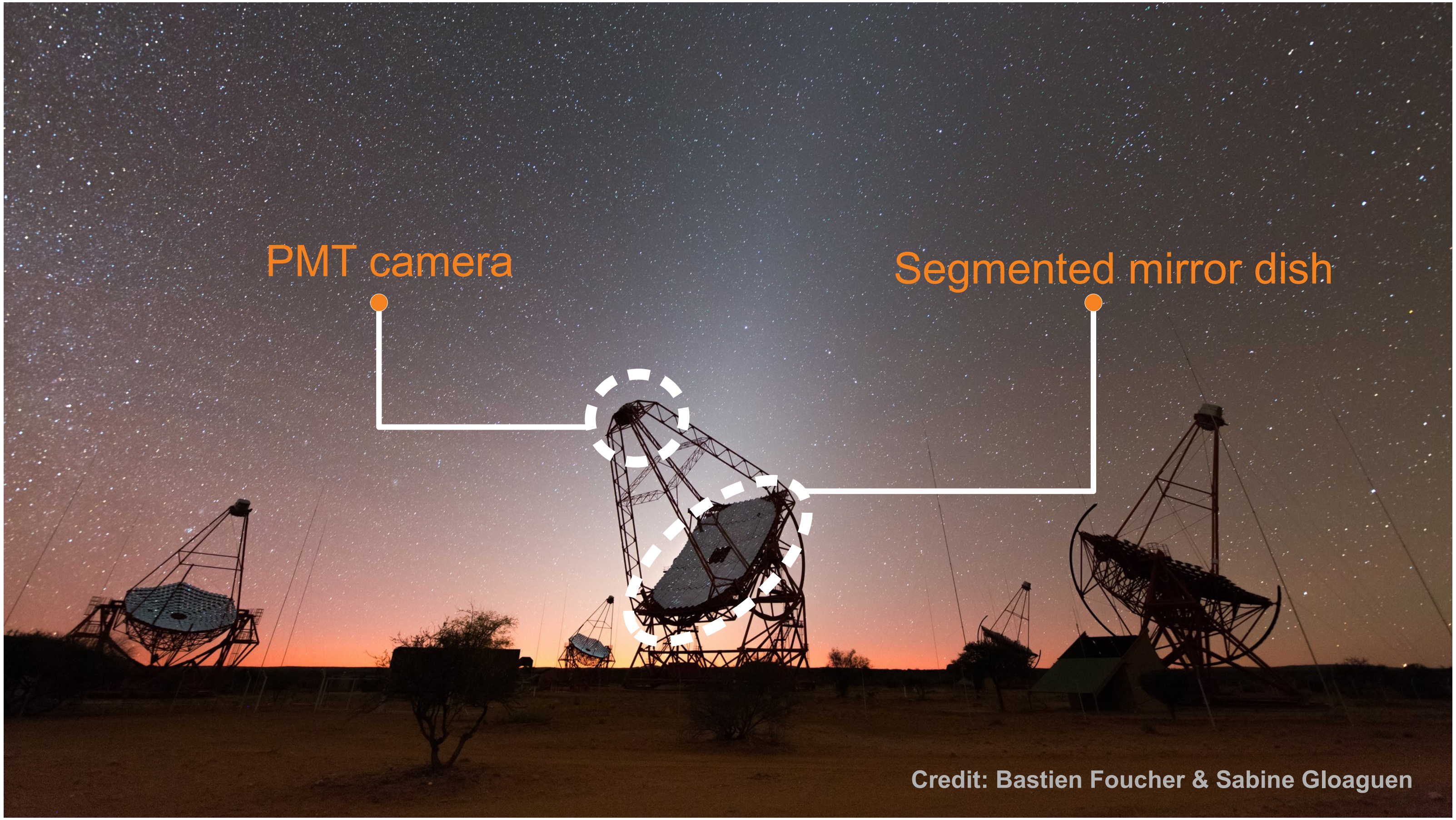
Credit: Sandbox Studio, Chicago with Corinne Mucha

H.E.S.S.

High Energy Stereoscopic System

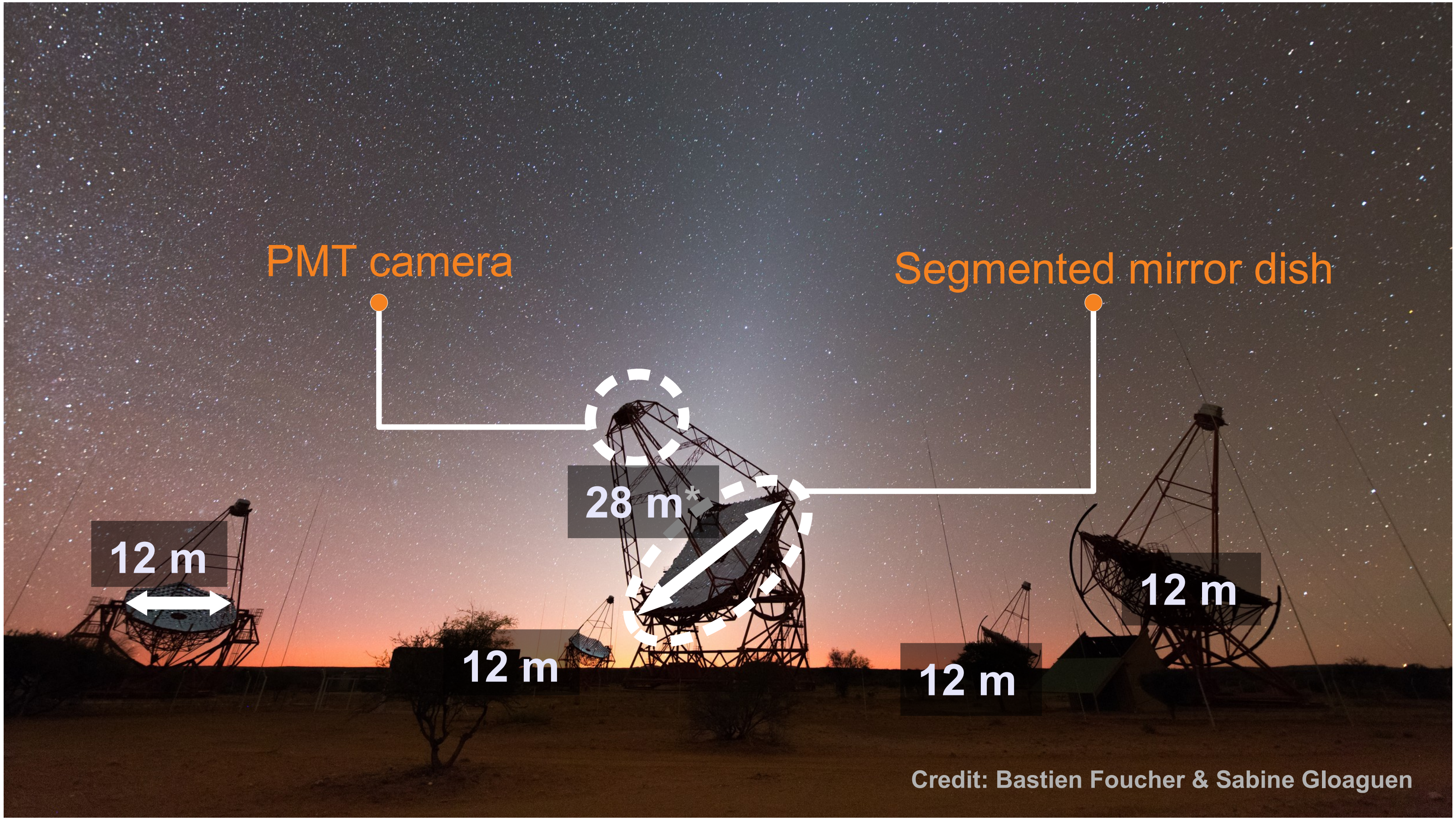
H.E.S.S.

High Energy Stereoscopic System



H.E.S.S.

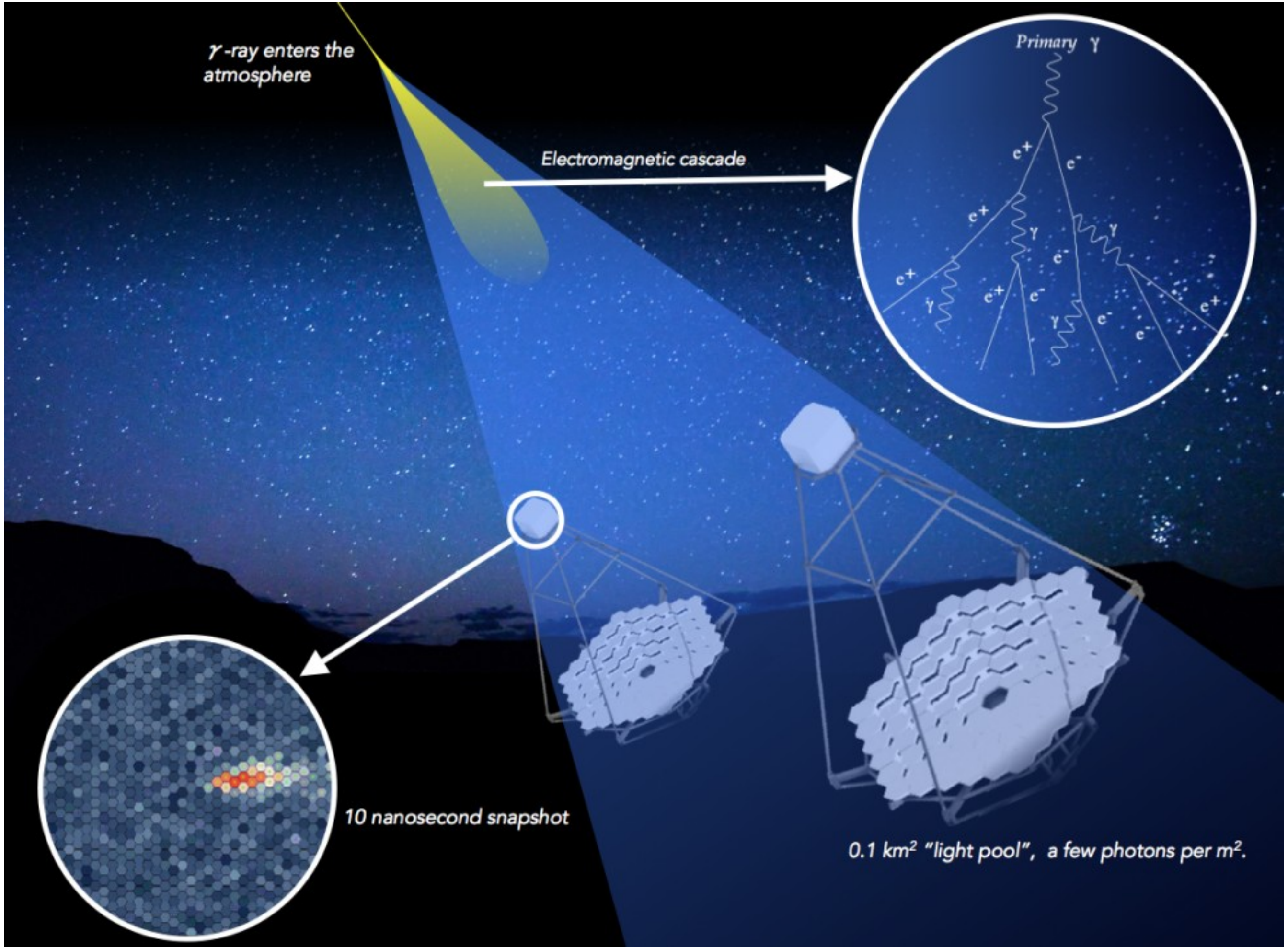
High Energy Stereoscopic System



*Effectively, is actually 32.6 m x 24.3 m.

IACTs

Imaging Atmospheric Cherenkov Telescopes



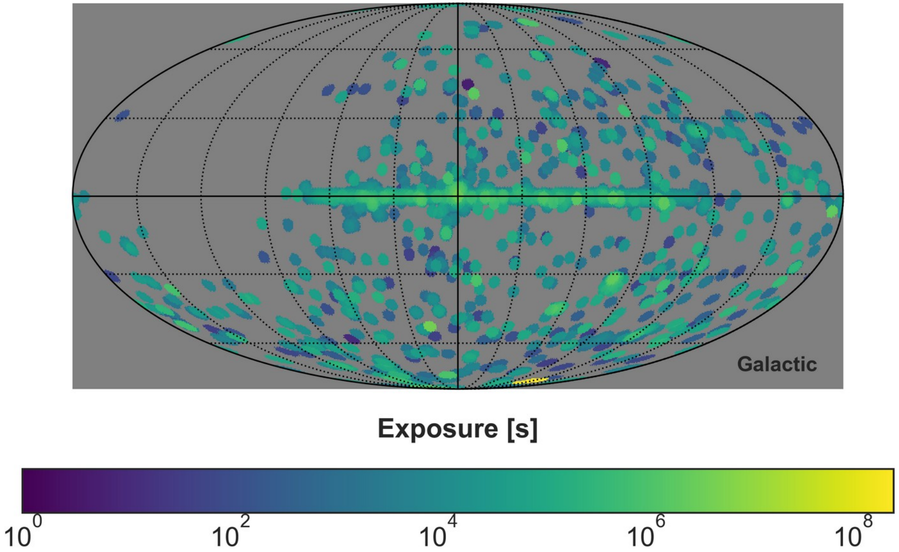
Credit: CTA

H.E.S.S.

Some characteristics

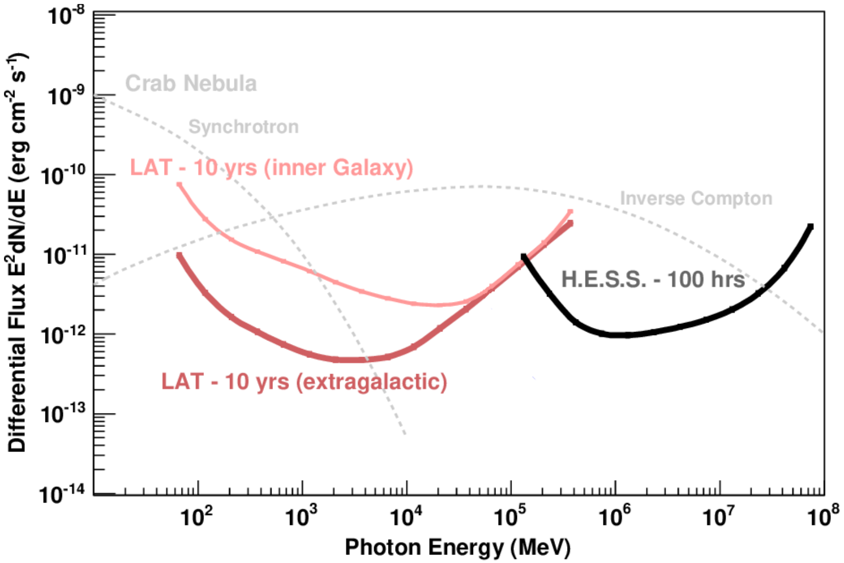
Sky coverage

- Site is in Namibia, Southern Africa
- Open to the Southern sky
- FoV ~ 2.5 x 2.5 Deg^2



Sensitivity

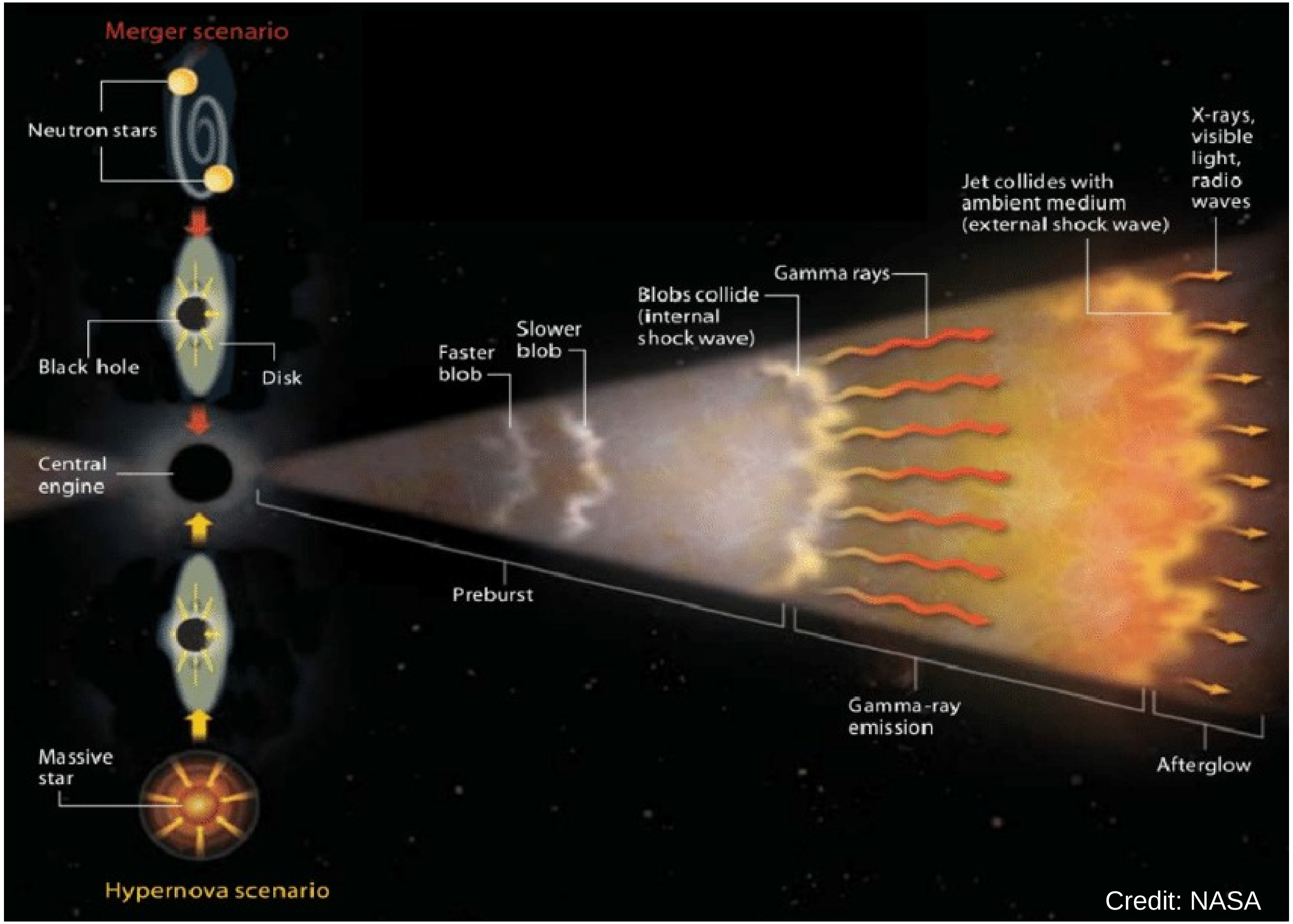
- VHE* range (~50 GeV – ~50 TeV)
- 1 TeV core energy



Funk & Hinton, Astropart Phys 43 (348-355), 2013

* Very-High Energy

GWs in VHE γ-ray astronomy



- Known progenitors of short gamma-ray bursts (sGRBs)
  - e.g. GRB 170817A

  [Abott et al., ApJL, 2017, 848, L13](#)

- sGRBs can be very energetic
  - e.g. >30 GeV for GRB 090510

  [Ackermann, et al. ApJS, 2013, 209, 11](#)

- sGRB Afterglow emission up to TeV is theoretically possible

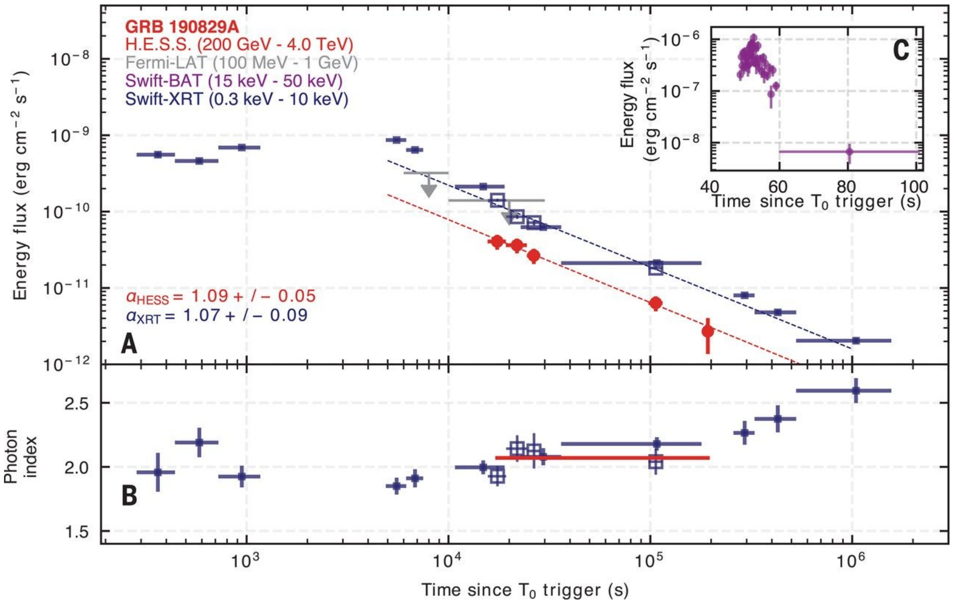
  [Veres & Mészáros, ApJ, 2014, 787, 168](#)

- long GRBs have been detected at TeV energies
  - GRB 180720B
  - GRB 190829A
  - GRB 190114C
  - GRB 201216C
  - GRB 221009A

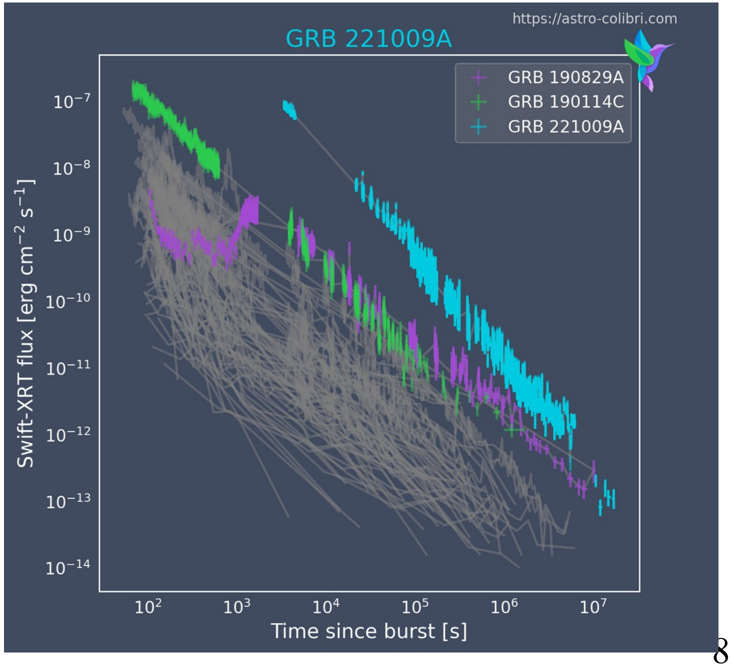
GWs in VHE γ-ray astronomy

- TeV emission of long GRBs seem to correlate with X-rays → X-ray bright GRBs are also VHE bright
- X-Ray emission of sGRBs is fainter but fundamentally similar to lGRBs Nysewander et al, ApJ, 2009, 701, 824

  → Rapid follow-up in the early bright phase necessary

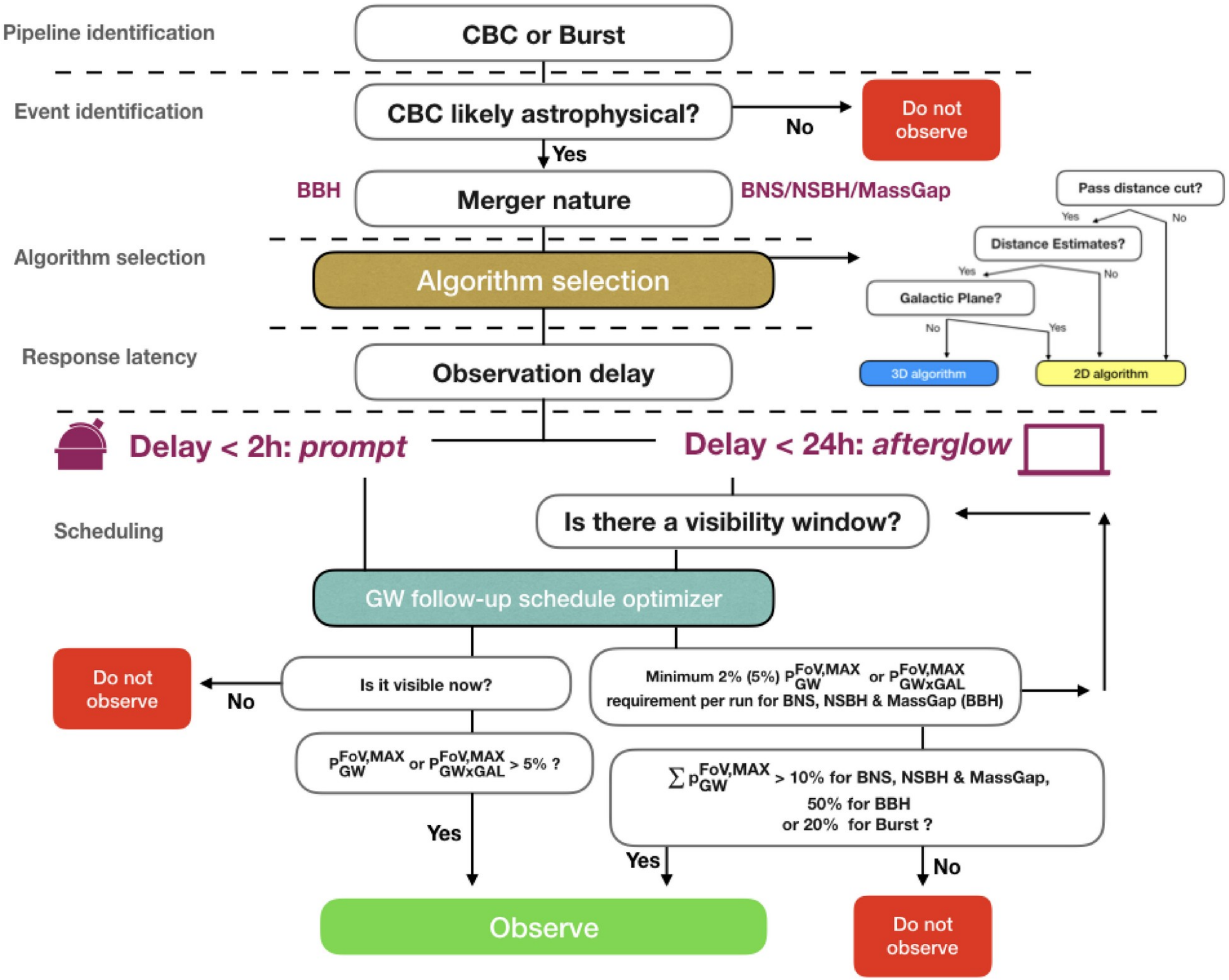


H.E.S.S. collaboration, Science, 2021, 372, 6546

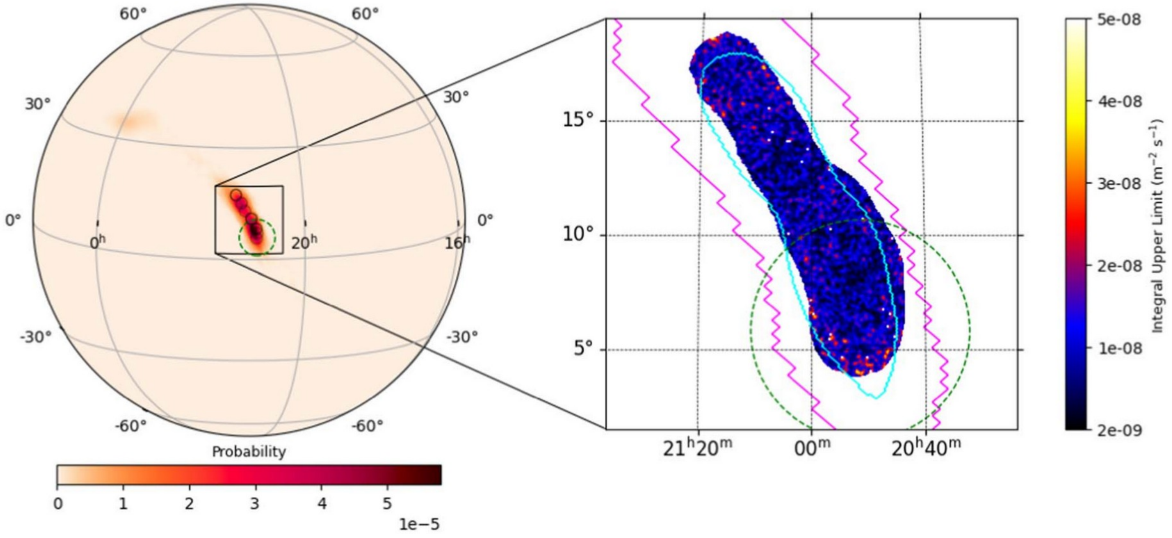


GWs in H.E.S.S.

- GW alerts are received by the automated H.E.S.S. transients system.
- Tiling algorithm based on distance
  - <150 Mpc and outside Galactic plane → Galaxy search (GLADE)
  - Otherwise maximise covered probability
- Tiling considers observational criteria
  - Zenith angle, moon distance, time window
- Minimum 10% possible coverage for BNS/NSBH/MassGap, 50% for BBH.
- If alert during dark time, highest probability pointing is automatically observed as soon as possible.



GWs in H.E.S.S.



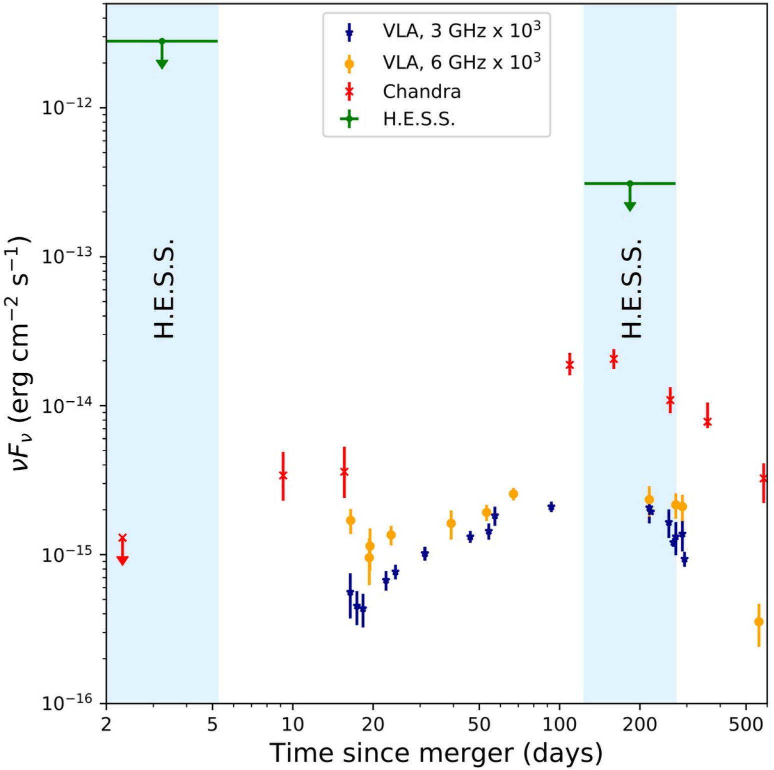
[Abdalla et al, ApJ, 2021, 923, 109](#)

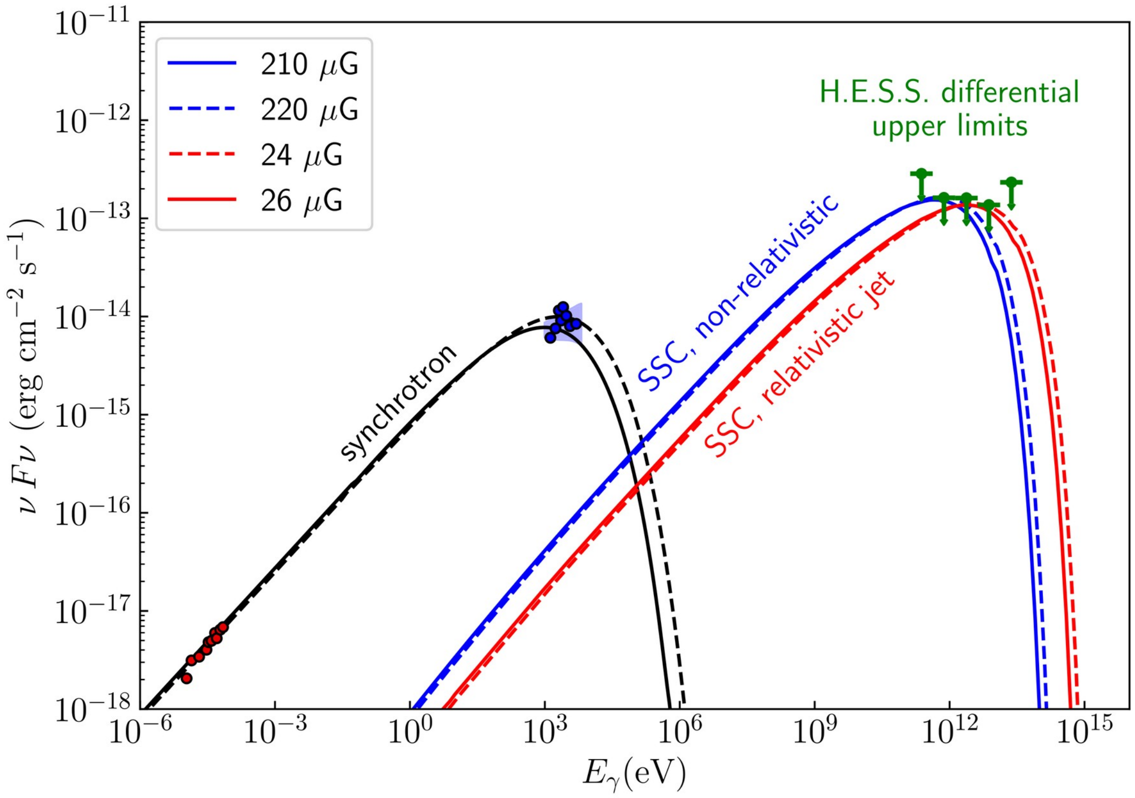
- H.E.S.S. was able to observe...
- O1
  - Too long delays and large uncertainty regions → No triggers
- O2 & O3
  - 1 BNS: GW 170817
  - 1 NS-BH: GW 200115j (bad weather)
  - 4 BBH: GW170814, S190512at, S190728q, S200224ca

GWs in H.E.S.S.

GW170817

- Constrain on the minimum magnetic field strength (>210 μG) during peak of the afterglow.



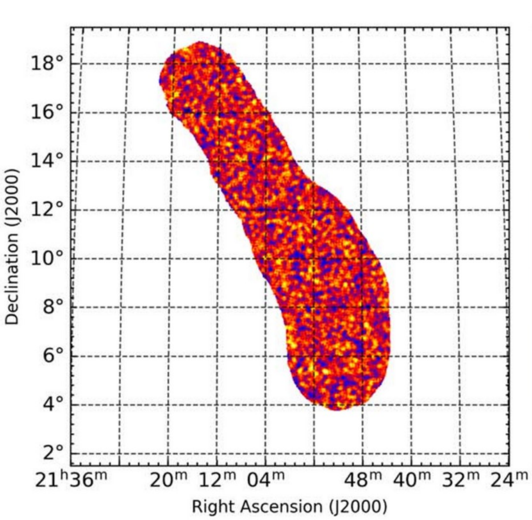


[Abdalla et al, ApJL, 2020, 894, 16](#)

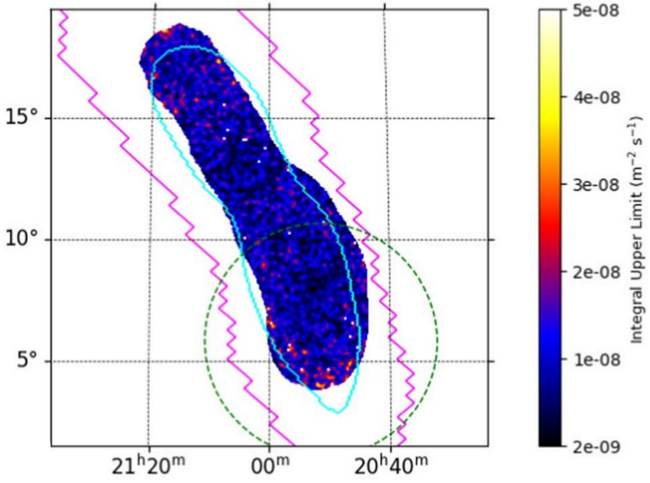
GWs in H.E.S.S.

BBH mergers

- BBH mergers are not expected to produce significant EM radiation, but work as good system tests.
- Constraints in the form of UL maps are produced for each BBH event, available on [H.E.S.S. webpage]

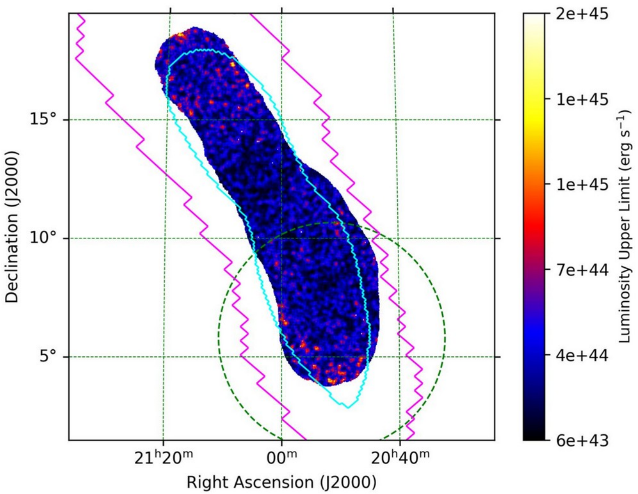


Significance



Integral counts flux UL

(intrinsic E^{-2} spectrum + EBL correction)



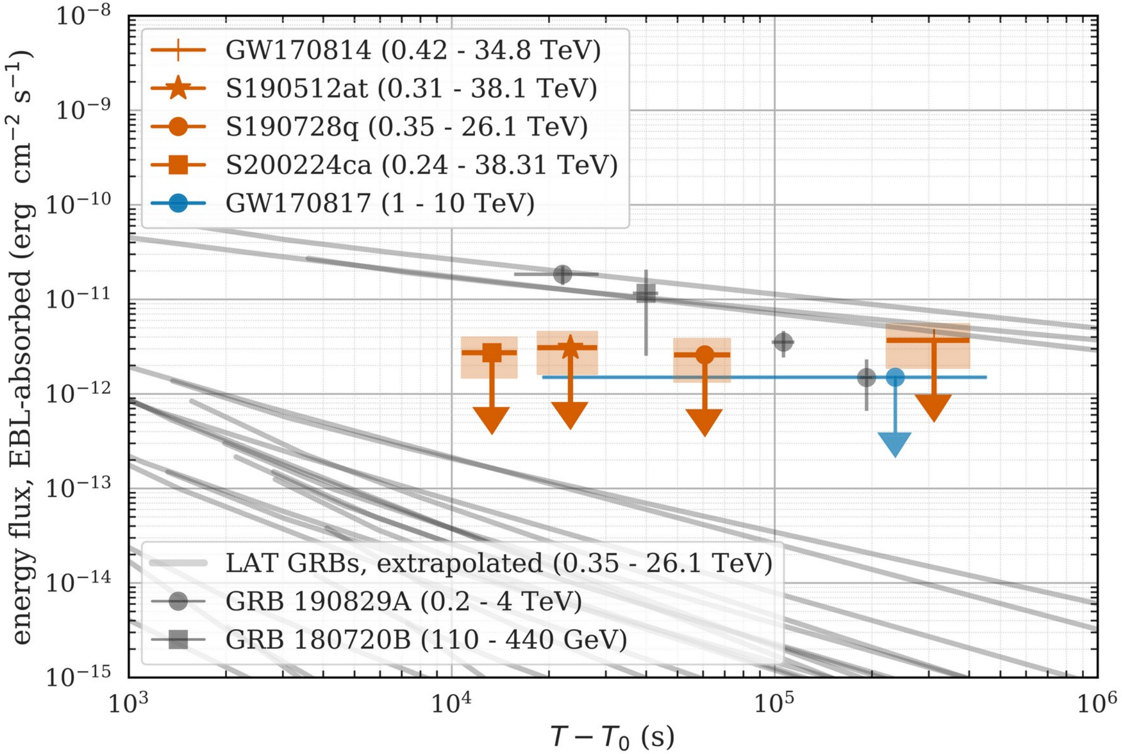
Luminosity UL

Abdalla et al, ApJ, 2021, 923, 109

GWs in H.E.S.S.

- Comparing flux ULs with TeV GRBs and extrapolated Fermi-LAT GRBs
  → A bright signal would have been detected but most GRBs are below ULs.

- Improvement possible with earlier and deeper observations.

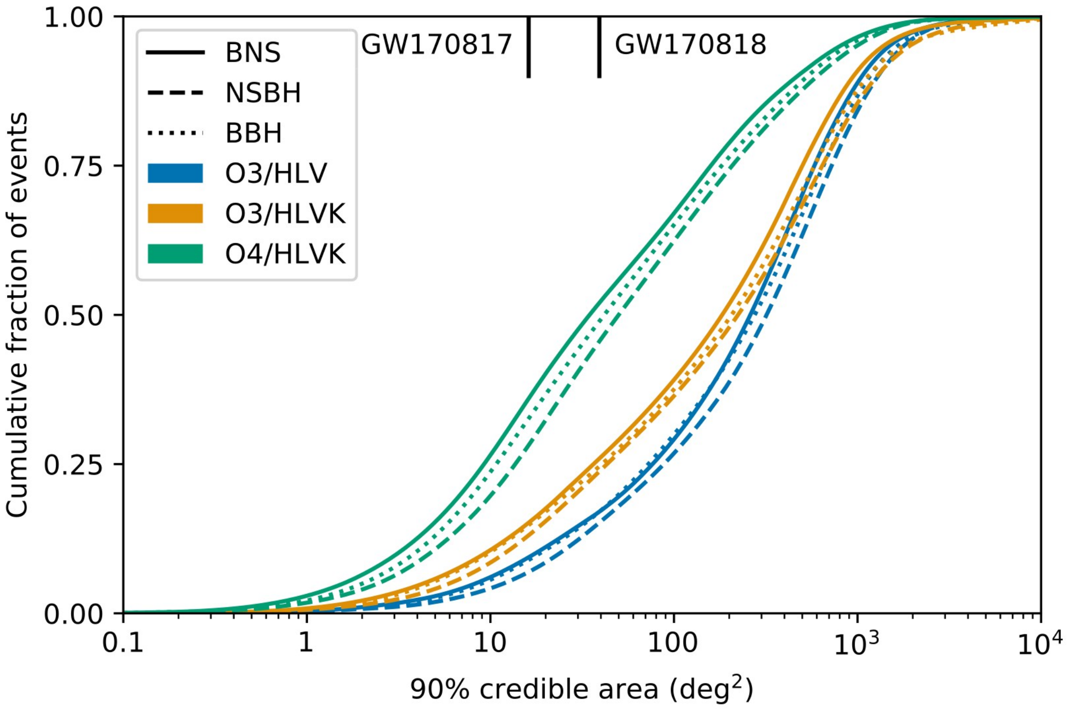


Abdalla et al, ApJ, 2021, 923, 109

Prospects for O4+

- O4 expected to have much better localisations
  → H.E.S.S. can spend more time per pointing (deeper observations)

- Rate of detection will increase
  → Higher chance to observe at early times



Abott et al, LRR, 2020, 23

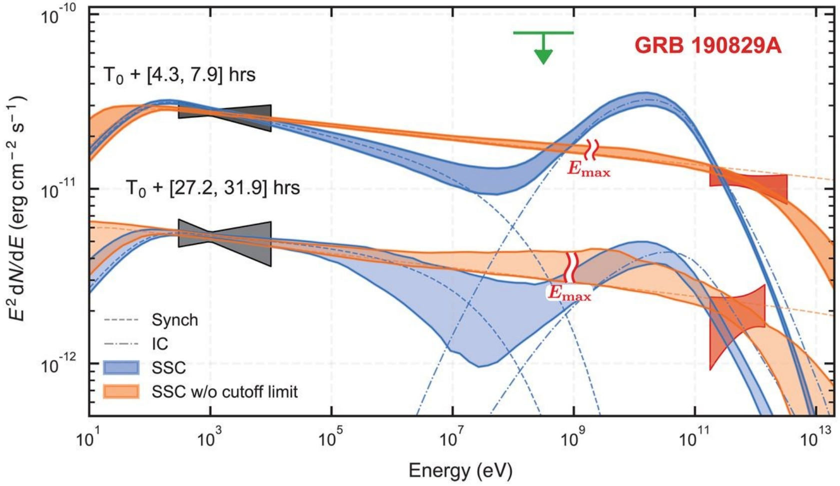
Back-up

VHE emission crisis at long GRBs

- The theoretically well supported origin of VHE γ rays for GRBs is synchrotron self-compton (SSC)
  - Synchrotron in a single zone model cannot produce γ rays above ~GeV energies

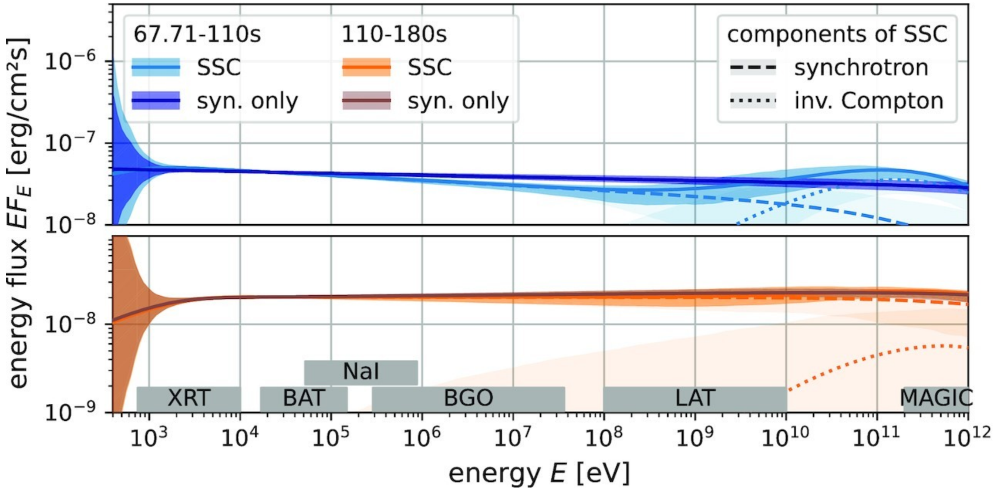
- However, for all detected VHE GRBs, there is no concrete preference between SSC or synchrotron only.

GRB 190829A



H.E.S.S. collaboration, Science, 2021, 372, 6546

GRB 190114C



Klinger et al, MNRAS, 2023, 520, 1