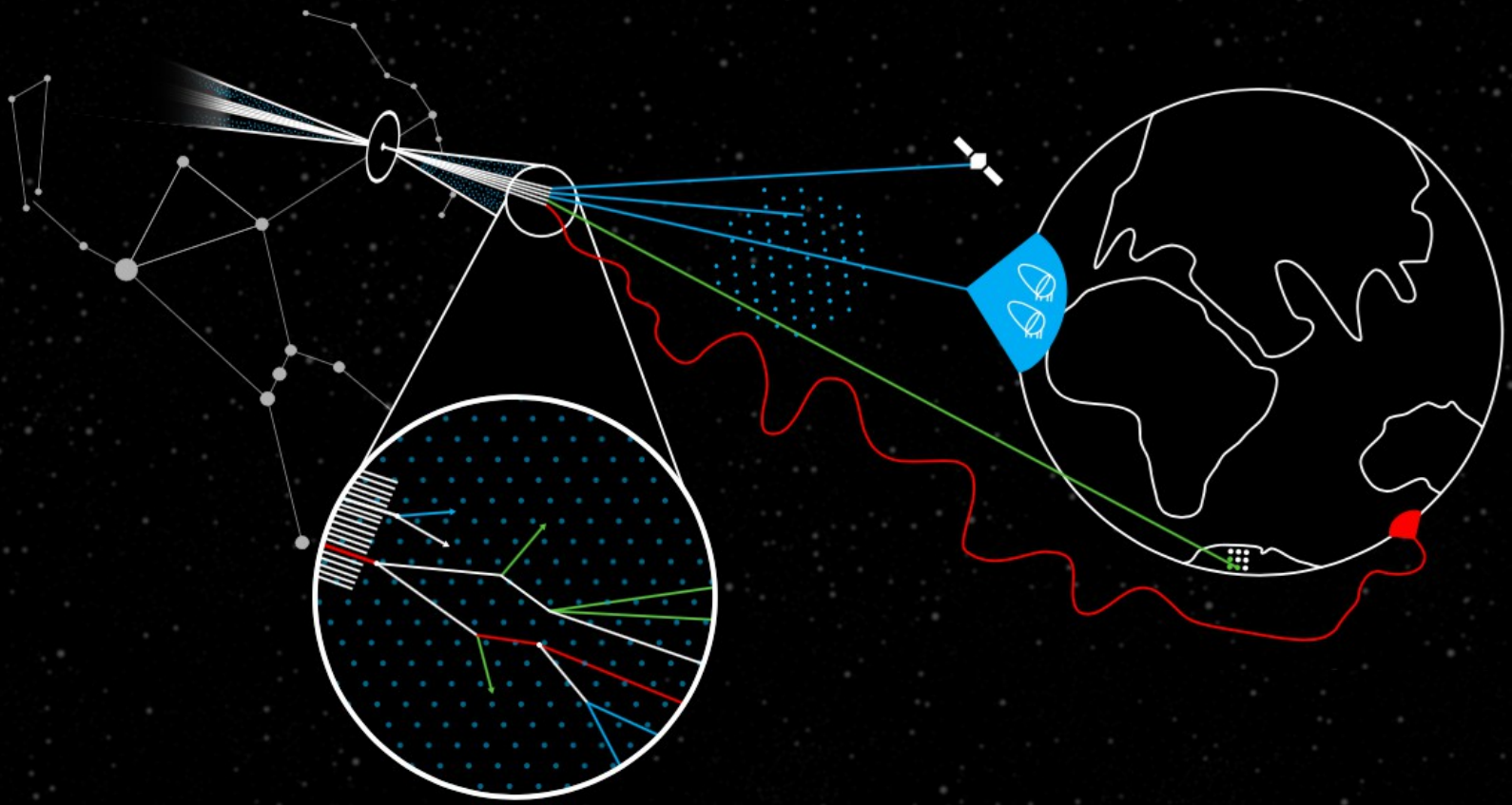
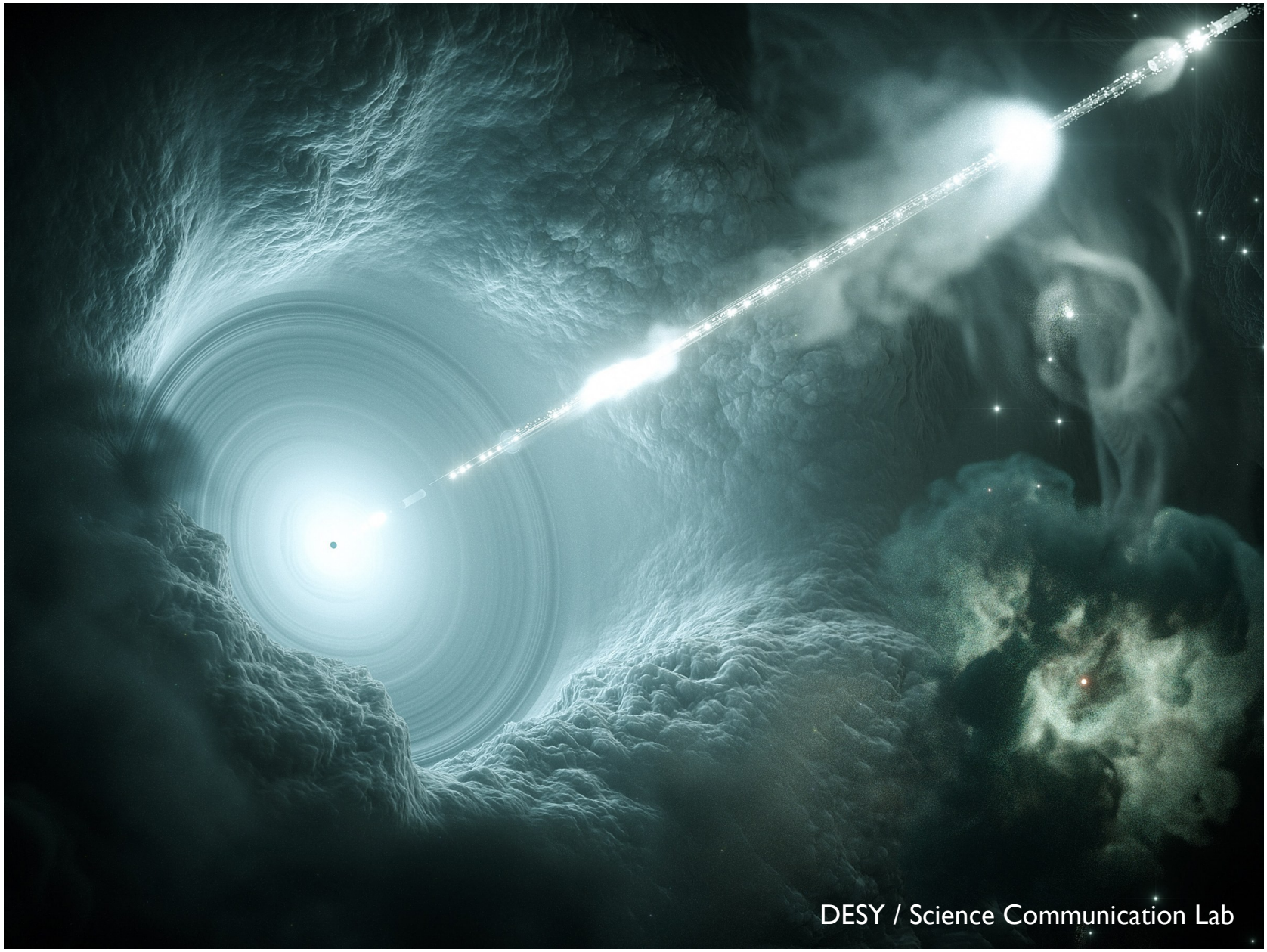


VHE gamma-ray observations of TXS 0506+056

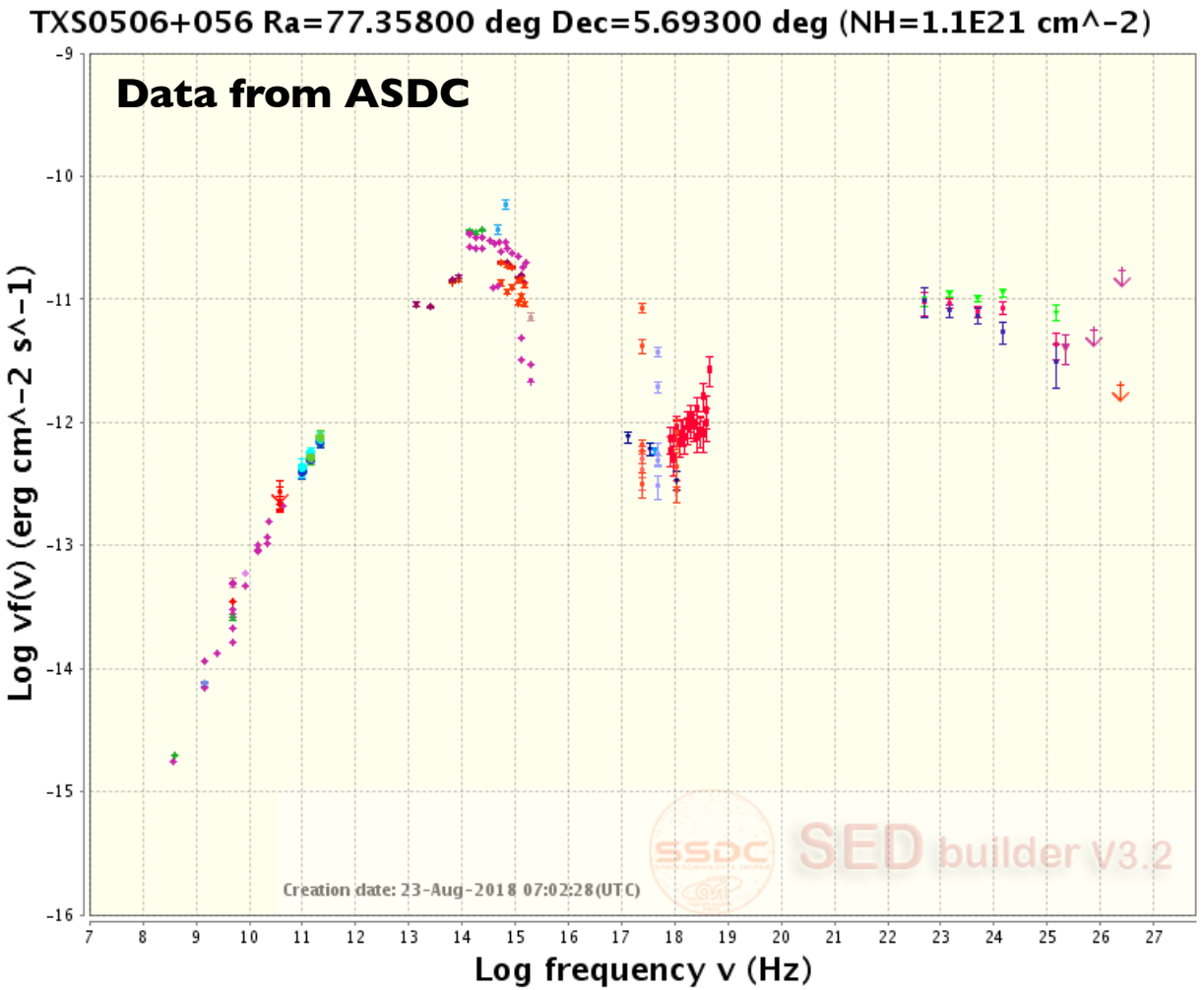
Konstancja Satalecka (DESY), TeVPA 2018

TXS 0506+056 – an ordinary blazar?

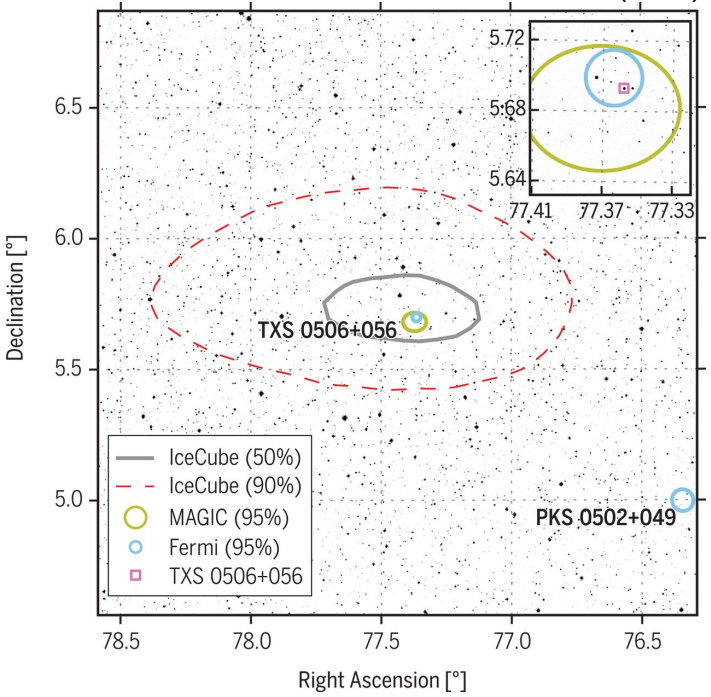


TXS 0506+056 – an ordinary blazar?

Typical blazar of BL Lac type, z= 0.34 (Paiano et al., 2018)



IC+Fermi+MAGIC++., Science 361, 146 (2018)

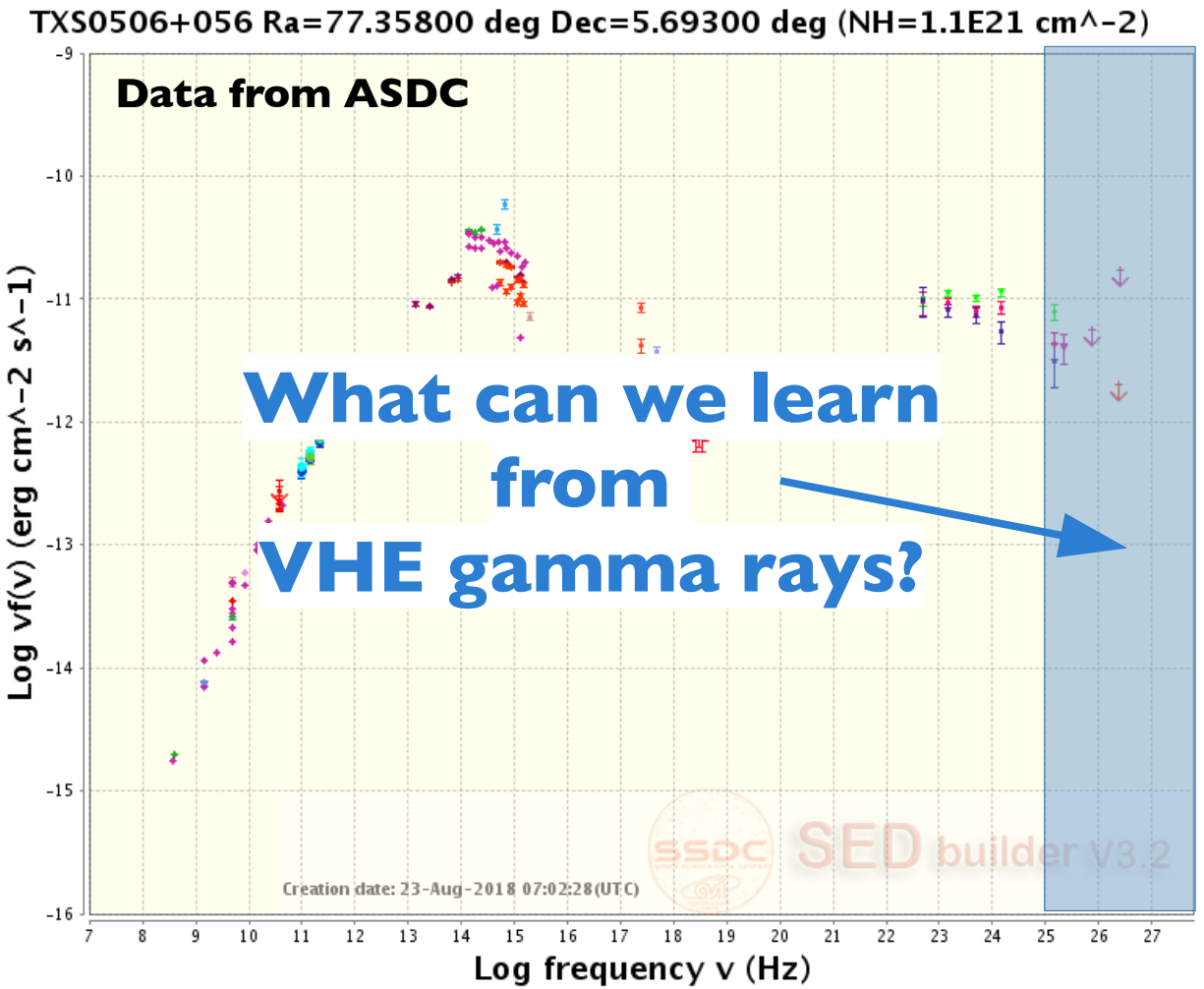


Chance coincidence: ~3 sigma (space + flux enhancement)

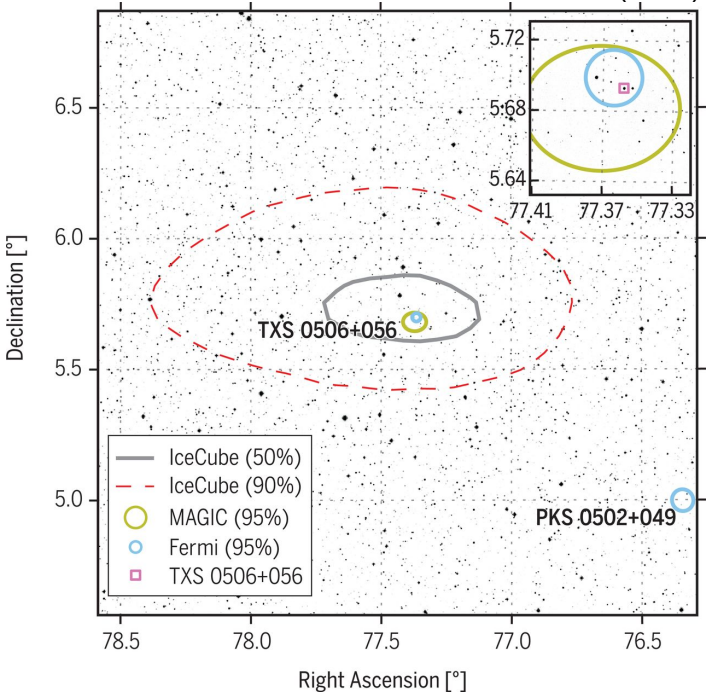
Can neutrinos be produced efficiently by BL Lac objects?

TXS 0506+056 – an ordinary blazar?

Typical blazar of BL Lac type, z= 0.34 (Paiano et al., 2018)



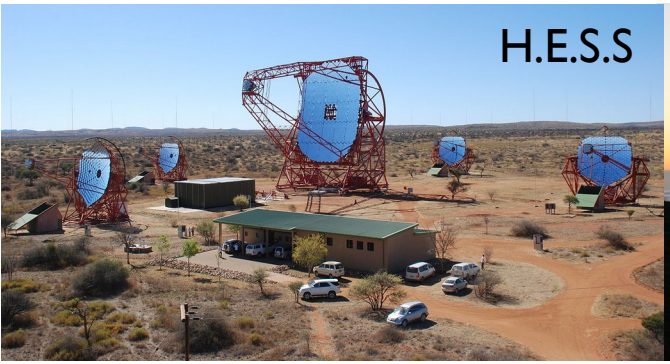
IC+Fermi+MAGIC++., Science 361, 146 (2018)



Chance coincidence: ~3 sigma (space + flux enhancement)

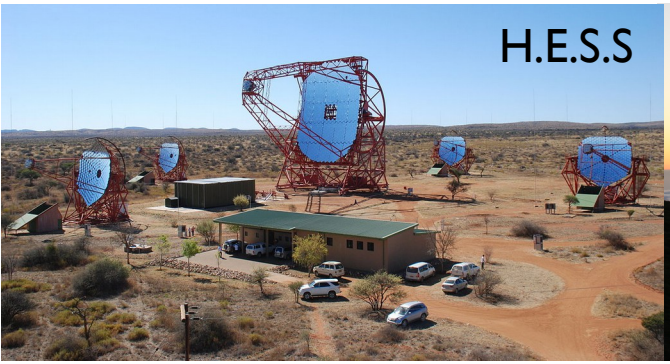
Can neutrinos be produced efficiently by BL Lac objects?

Imaging Atmospheric Cherenkov Telescopes



- Use Cherenkov radiation emitted in extended atmospheric showers to identify the initial particle: gamma ray or cosmic ray
- Sensitive to gamma rays 50 GeV-50 TeV
- Collection area $O(10^5)m^2$, angular resolution ~0.1 deg, FoV ~3.5-5 deg (pointing)
- > 200 sources discovered in VHE gamma rays: SNR, PWN, pulsars, binaries, AGN, starburst galaxies….
- Others science topics: GRBs, FRBs, dark matter, LIV, CR spectrum….

Imaging Atmospheric Cherenkov Telescopes

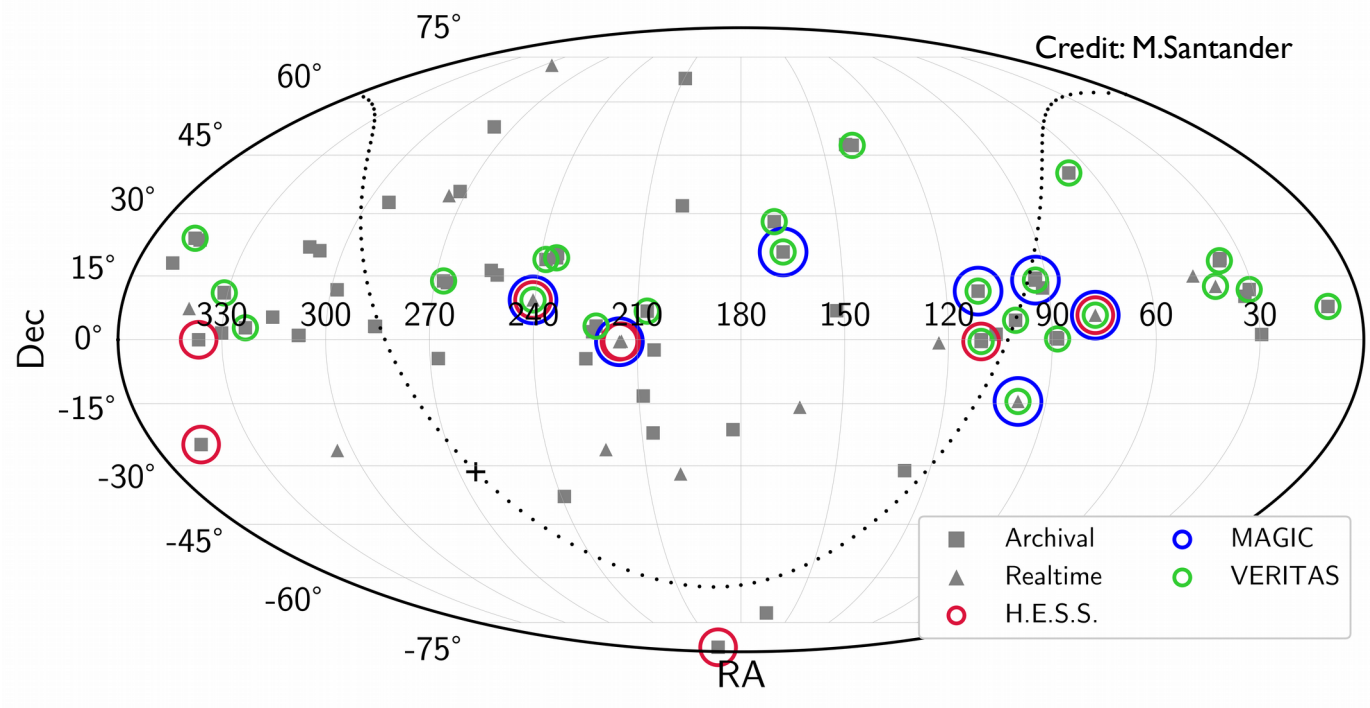


- Use Cherenkov radiation emitted in extended atmospheric showers to identify the initial particle: gamma ray or cosmic ray

Gamma-ray highlights - plenary talks on Wednesday + dedicated parallel sessions + many, many posters!

- > 200 sources discovered in VHE gamma rays: SNR, PWN, pulsars, binaries, AGN, starburst galaxies….
- Others science topics: GRBs, FRBs, dark matter, LIV, CR spectrum….

IACT neutrino events follow-up

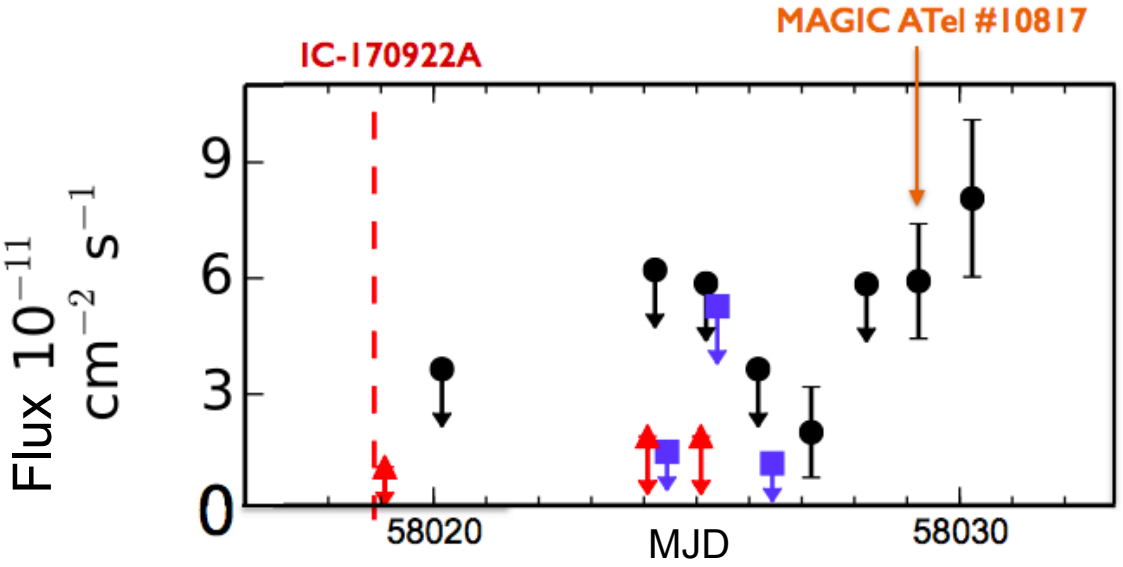


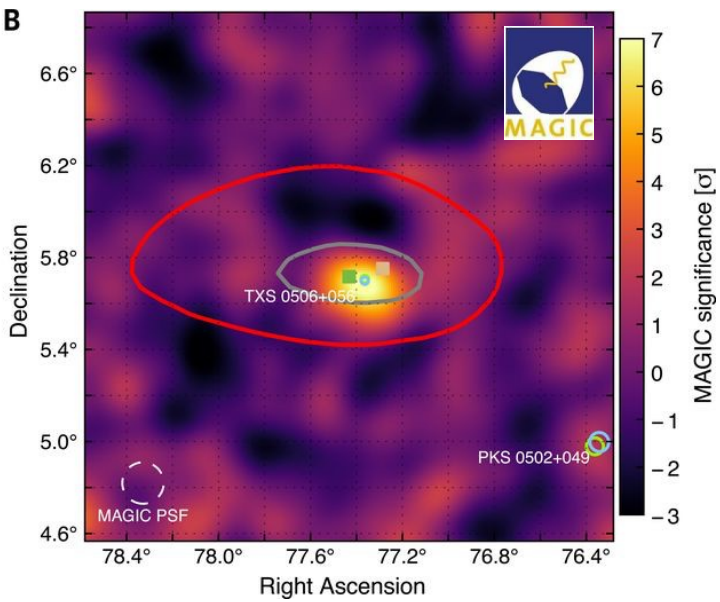
- NToO program developed since 2007 → Gamma-ray follow-up (GFU) since 2012, IC+MAGIC+VERITAS, focus: ν multiplets from AGN (M.G. Aartsen et al., JINST, 11, P11009,2016)
- Archival HESE/EHE directions (M. Santander et al., ICRC 2017)
- Real-time HESE/EHE follow-up since 2016

  > 100 h IACT time invested in nu follow-up!

IC-170922A follow-up

IC+Fermi+MAGIC++., Science 361, 146 (2018)



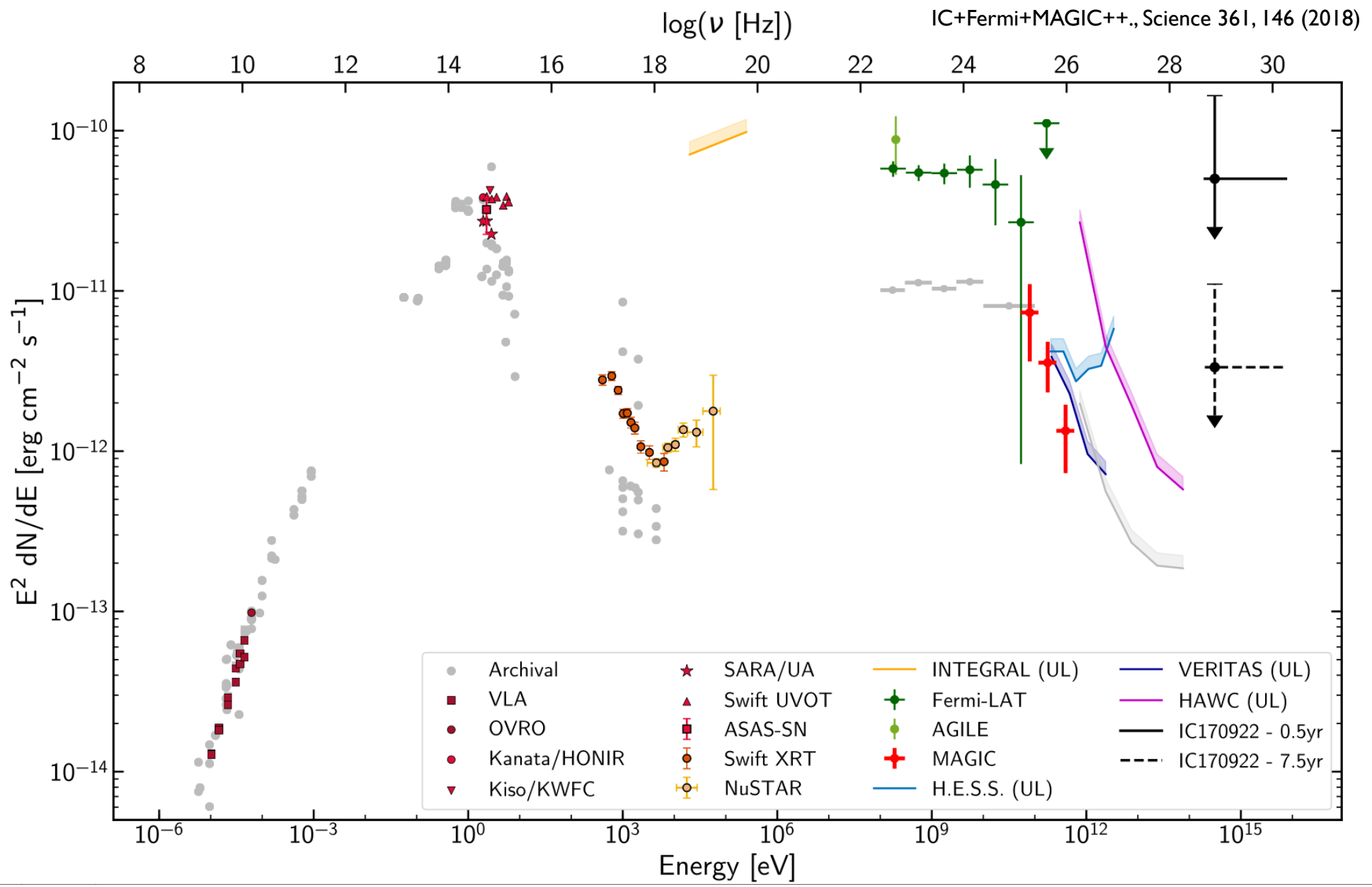


- **H.E.S.S**: fastest follow-up (~4 h delay), total 3.25 h/ 3 nights → no detection> 175 GeV
- **VERITAS**: first obs. ~12 h delay, total 5.5 h/ 3 nights → no detection > 175 GeV
- **MAGIC**: first obs. ~32 h delay (Sep 24th), 3.5h, weather non-optimal

  → 1h used for UL

  Sep 28th - Oct 4th: 13h collected/1 week → **detection > 90 GeV!** (Oct 3rd: ATel#10817)

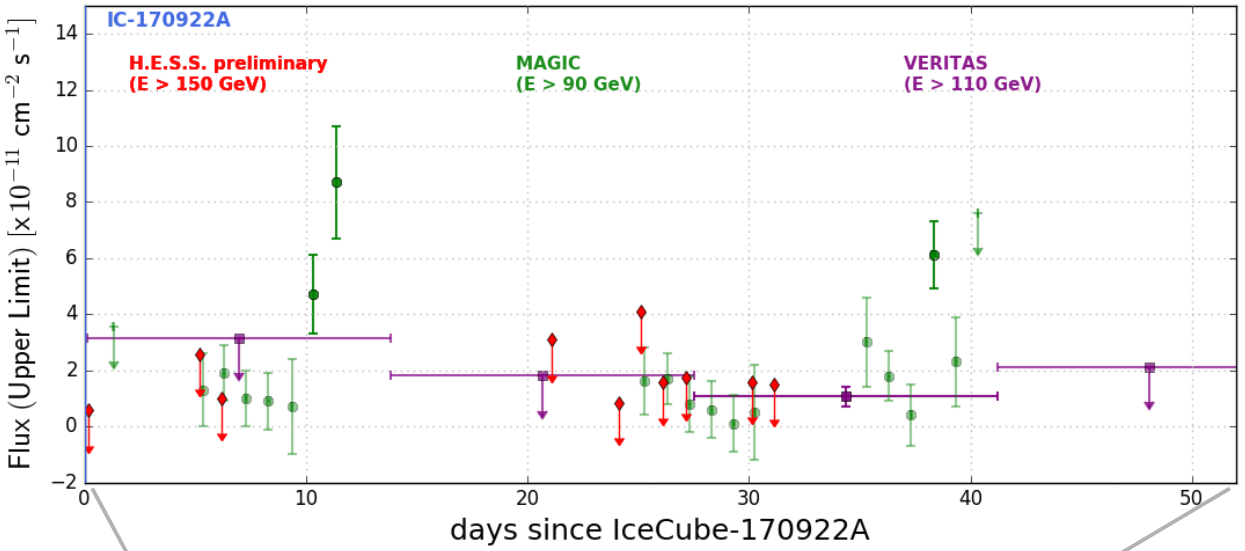
First MultiMessenger spectrum!



Further observations

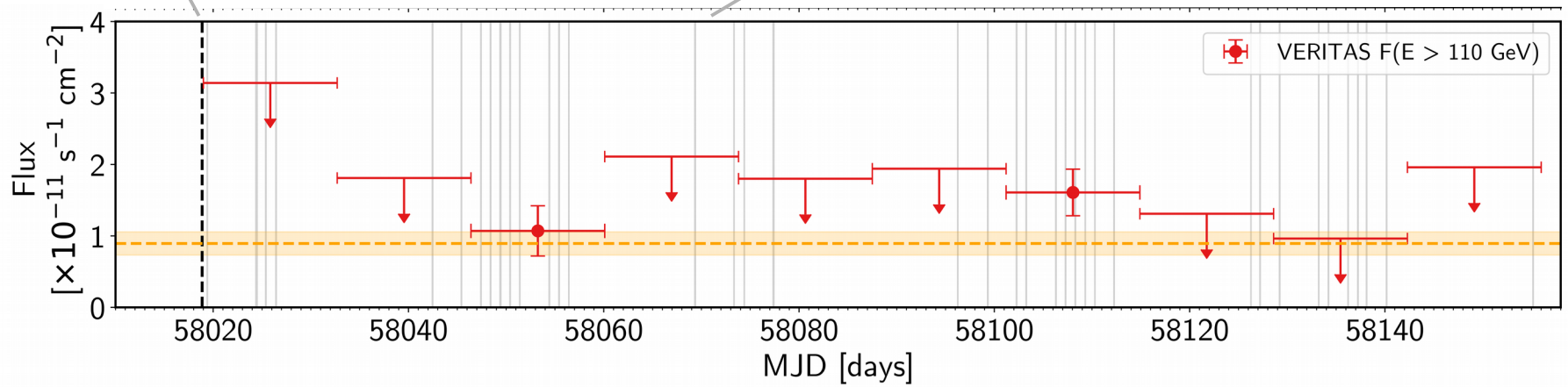
The MAGIC Collaboration, ApJL 863, 1, arXiv:1807.04300
The VERITAS Collaboration, accepted by ApJL, arXiv:1807.04607

Credit: F. Schüssler



MAGIC: 41 h collected between Sep 24th - Nov 2nd
Day-scale variability
Probability of constant flux < 0.3%
2 flares (Oct 3rd-4th + Oct 31st) +
Lower state detected > 90 GeV
(see talk by L. Foffano, Wed@14:45)

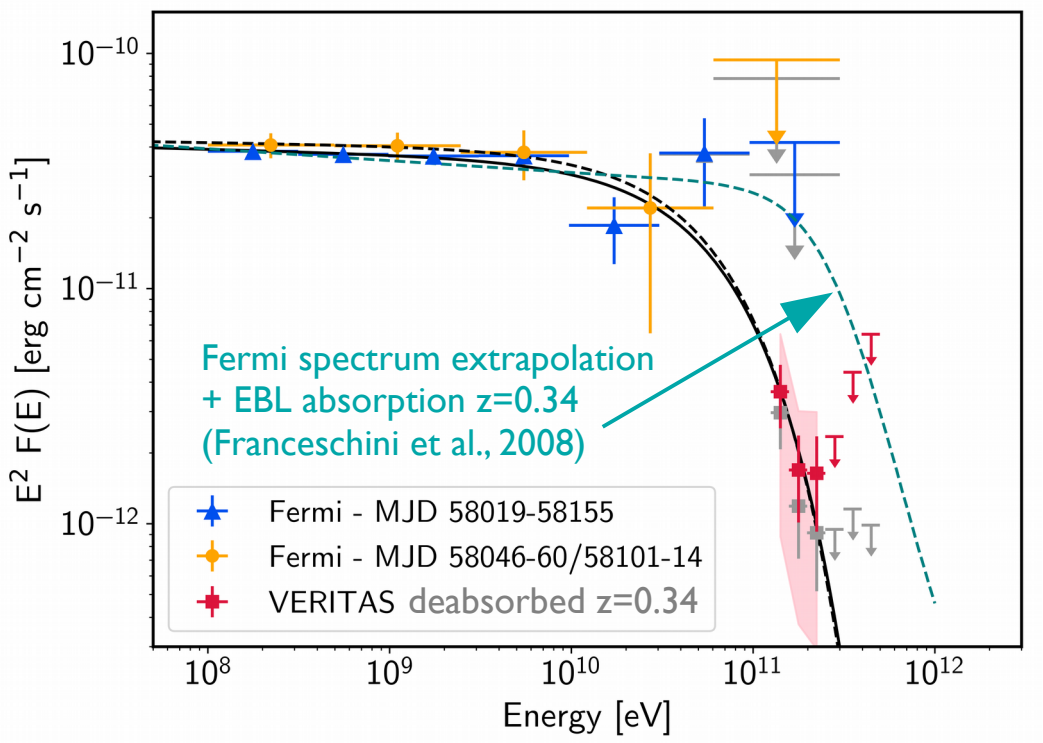
H.E.S.S: 13 h collected between Sep 22nd – Oct 24th
(see poster by F. Schüssler)



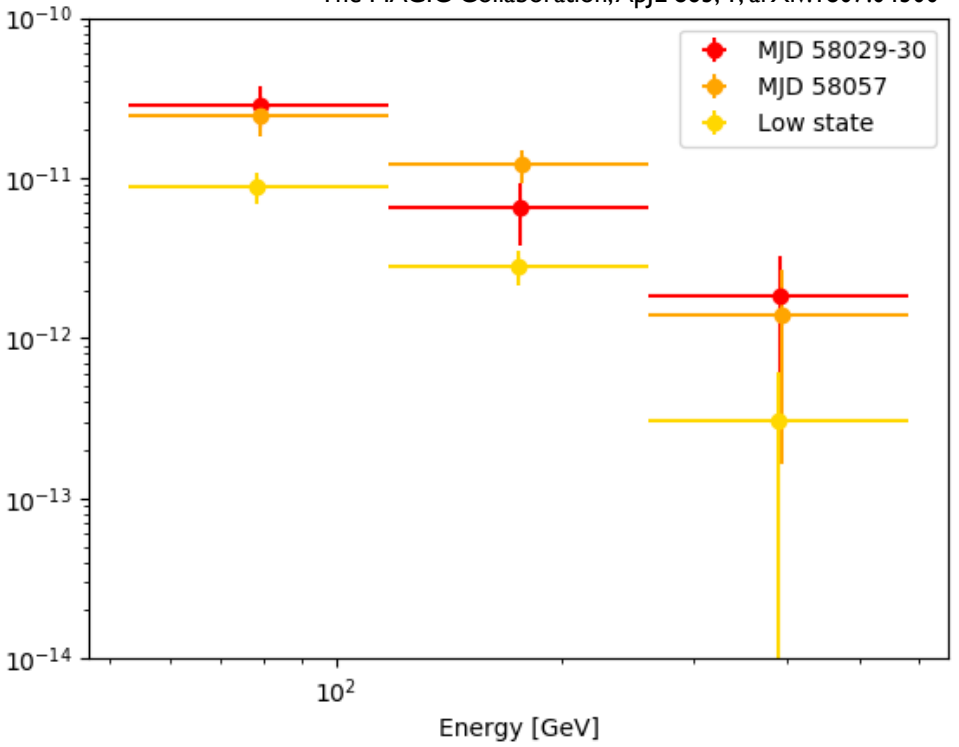
VERITAS: 35 h collected between Sep 23rd – Feb 6th → **detection > 100 GeV**

Further observations: spectrum

The VERITAS Collaboration, accepted by ApJL, arXiv:1807.04607



The MAGIC Collaboration, ApJL 863, 1, arXiv:1807.04300



- **MAGIC**: 2 flares + lower state, but no spectral index variability measured
- **MAGIC+VERITAS:** simple PL, index much softer than Fermi-LAT (~ 4.0)

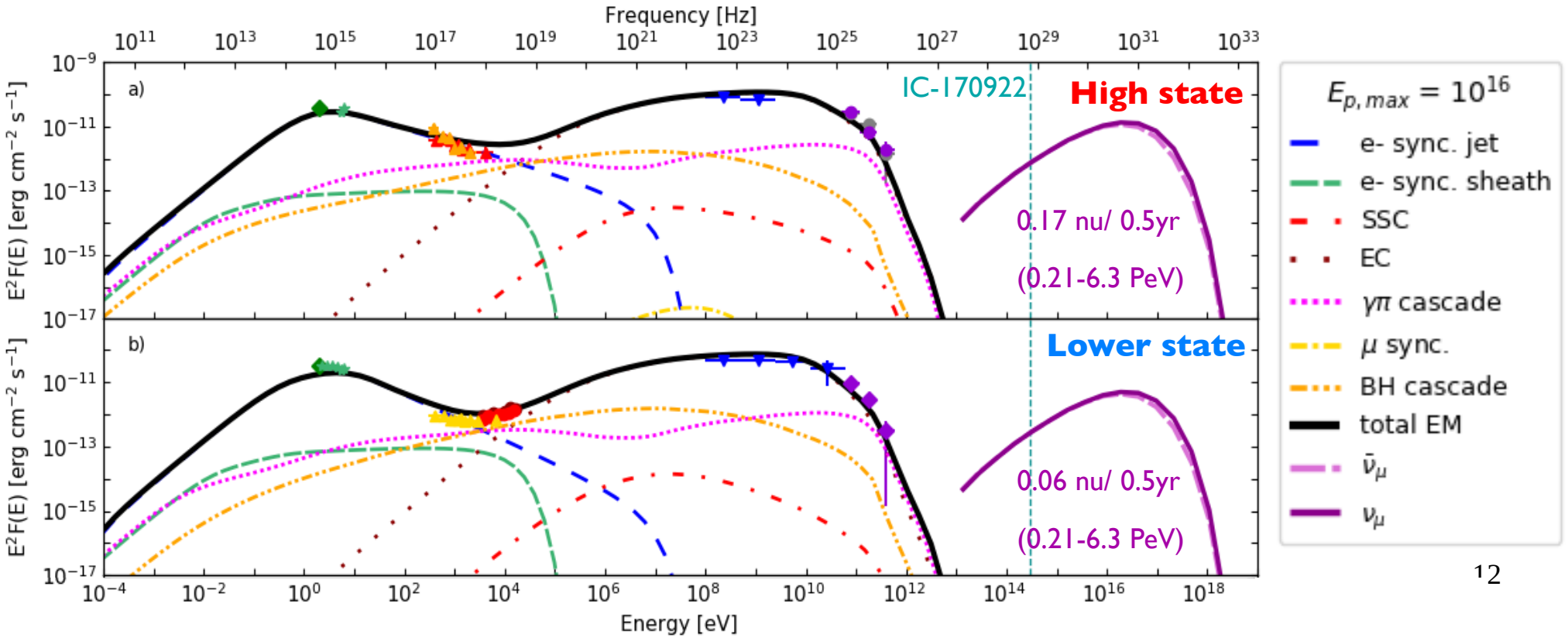
  → clear spectral curvature, apart from EBL effect: internal absorption, primary particle spectral break, production inefficiency…?

Interpretation: jet-sheath model

The MAGIC Collaboration, ApJL 863, 1, arXiv:1807.04300

See talk by: E.Bernardini Mon@17:05

- Jet-sheath model (Ghisellini G., Tavecchio F., Chiaberge M., 2005, A&A, 432, 401)
- Components: leptonic (synchrotron, SSC, EC) + hadronic (photo-meson cascade, BH cascade, synch. rad. from pions and muons)
- Day-scale variability → Size of emitting region ~10^{16} cm
- Internal absorption: $\tau_{\gamma\gamma}(E_\gamma \sim 100\ \mathrm{GeV}) \sim 1$ consistent with the observed spectral break



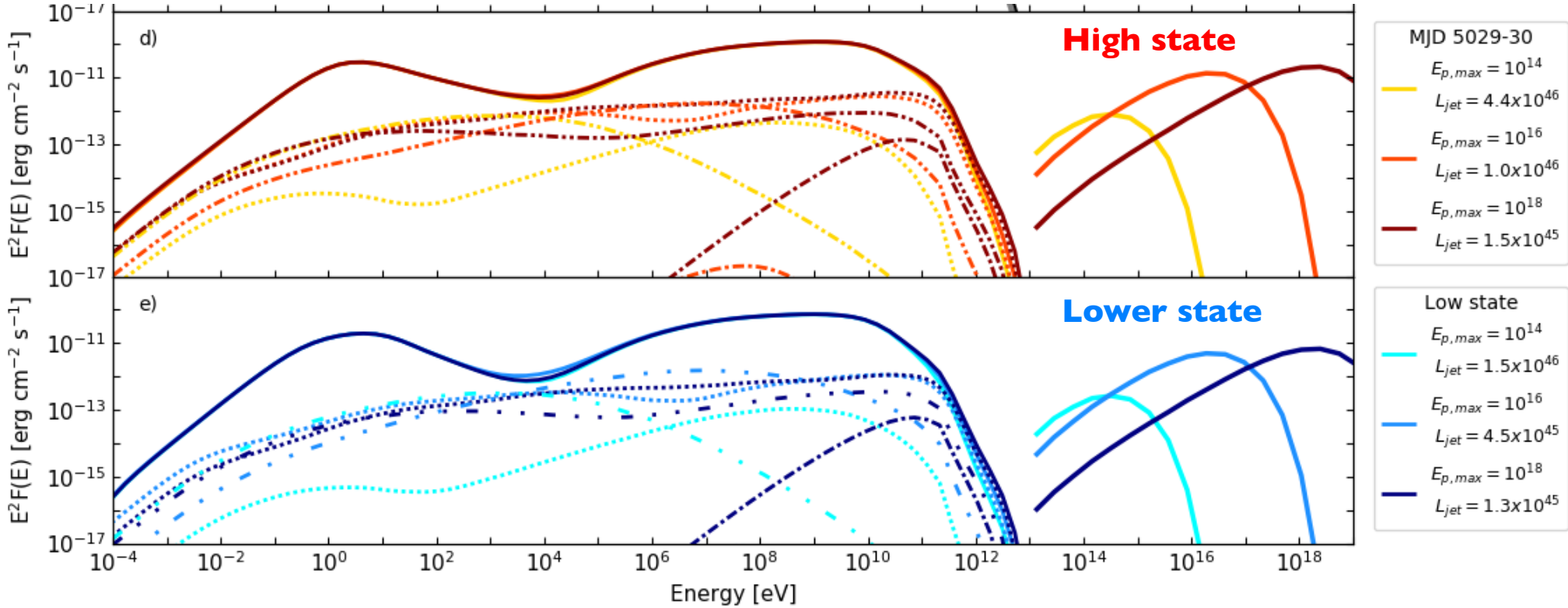
Interpretation: CR accelerator

The MAGIC Collaboration, ApJL 863, 1, arXiv:1807.04300

See talk by: E.Bernardini Mon@17:05

- X-ray and VHE gamma-ray data set tight constraints on max. proton energy $E_{p,max}$
- Scan of $E_{p,max}$: 10^{14}-10^{18} eV (co-moving frame)

  → TXS 0506+056 able to accelerate CR to UHE!



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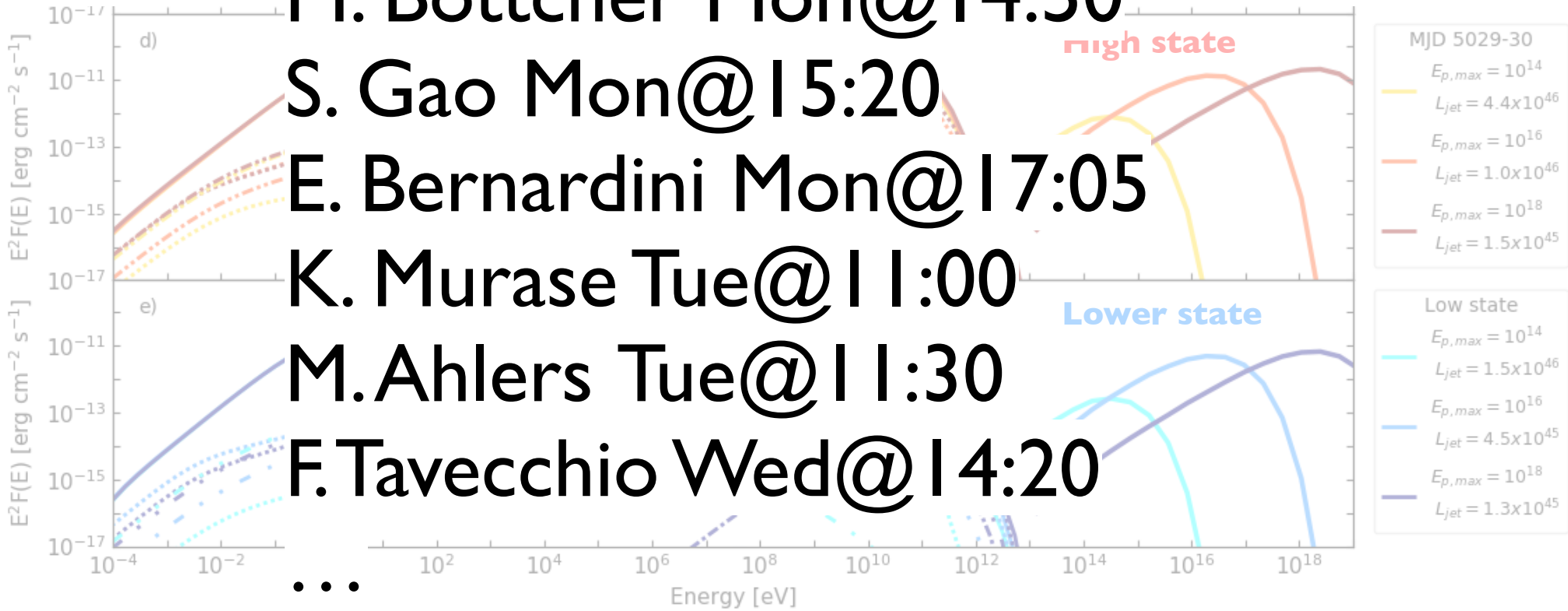
- X-ray and VHE gamma-ray data set tight constraints on max. proton energy $E_{p,max}$
- Scan of $E_{p,max}$

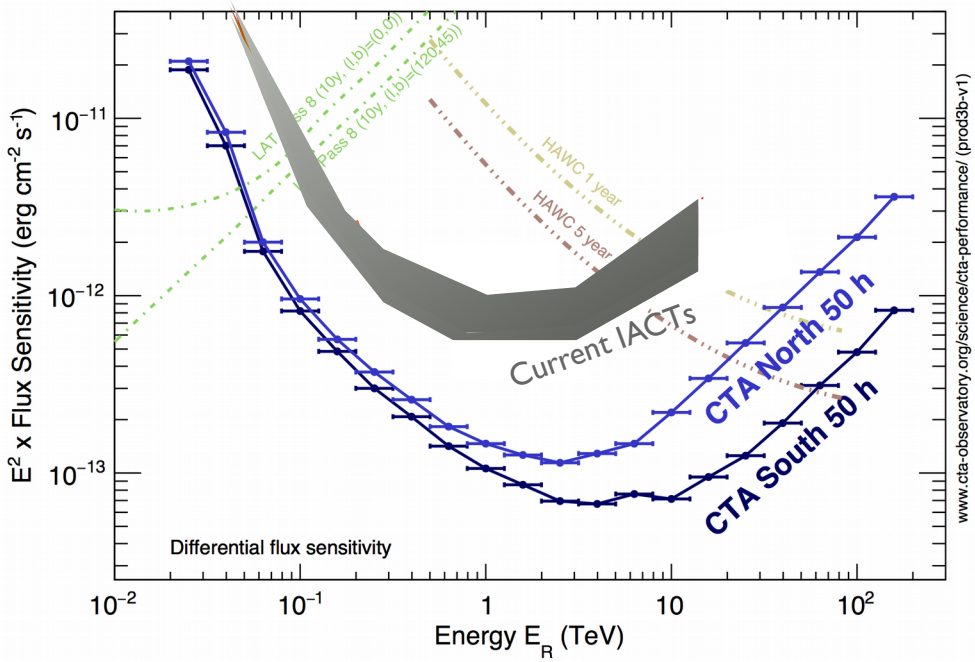
More on interpretation:

→ TXS 0506+056 able to accelerate CR to UHE!

M. Böttcher Mon@14:50
S. Gao Mon@15:20
E. Bernardini Mon@17:05
K. Murase Tue@11:00
M. Ahlers Tue@11:30
F. Tavecchio Wed@14:20
…

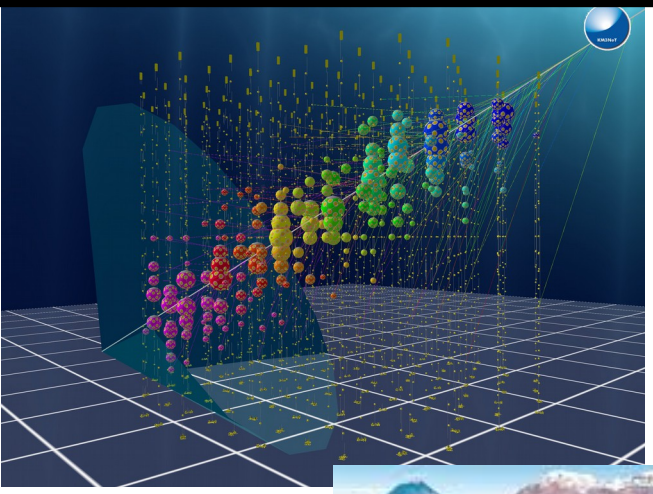


Future: CTA



- Next IACT generation: Cherenkov Telescope Array
- North + South arrays with ~few10s IACTs each
- Larger energy range, sensitivity x 10 current instruments, fast reaction to alerts:
  - New source populations, also potential nu emitters (e.g. GRBs, distant AGN, etc)
  - Precise spectral measurements: distinction between leptonic/hadronic features
  - Precise time evolution of flux and spectrum → invaluable input for models
- Neutrino event follow up - Key Science Program! *(see talk by F. Schussler Mon @17:40)*
- First telescopes on site ~2020

Future: CTA + IC-Gen2 + KM3Net



KM3Net: Multi-km3 size ν telescope in Mediterranean Sea

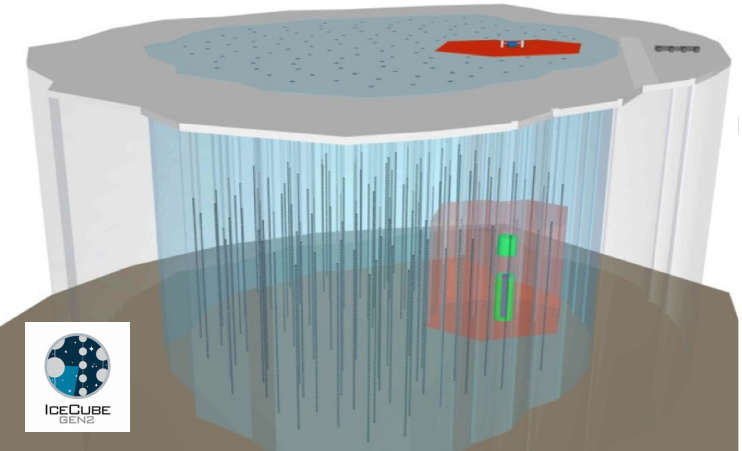
- ORCA: neutrino oscillations
- ARCA: TeV - PeV astrophysical neutrinos (Galactic Center!)
  - First strings deployed successfully in 2017
  - Completion ~2022

(see talk by P. Migliozzi Wed@14:00)

CTA: new generation IACT array

- Neutrino follow-up – Key Science Program
- First telescopes on site ~2020

(see talk by F. Schussler Mon @17:40)

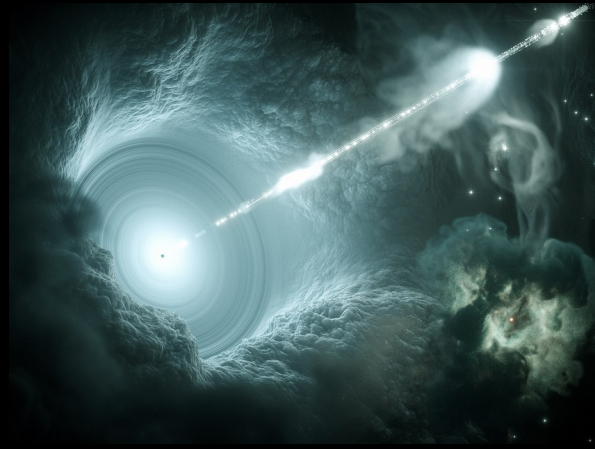


IC-Gen2: wide-band (MeV-EeV) neutrino observatory

- Mixed technique: radio, Cherenkov radiation, surface detectors
- Deployment start ~2025

(see talk by S. Blot, Mon@16:15)

Summary



- First time observation of VHE γ-rays in coincidence with a high energy neutrino
- Further monitoring of TXS 0506+056 with the MAGIC & VERITAS telescopes
  - VHE gamma-ray flux variable at timescale ~1 day, MAGIC reveals two flares and a lower state
  - Soft spectrum with index ~4.0 + Fermi/LAT data → break due to internal absorption
- First time full MultiMessenger spectral energy distribution available for interpretation:
  - Jet-sheath model reproduces the MWL SED & neutrino rates
  - X-ray & γ-ray data constrain the maximum CR energies to 10^{14} - 10^{18} eV

    → first CR emitter?!

CTA, KM3Net and IC-Gen2 promise exciting results starting from mid-2020