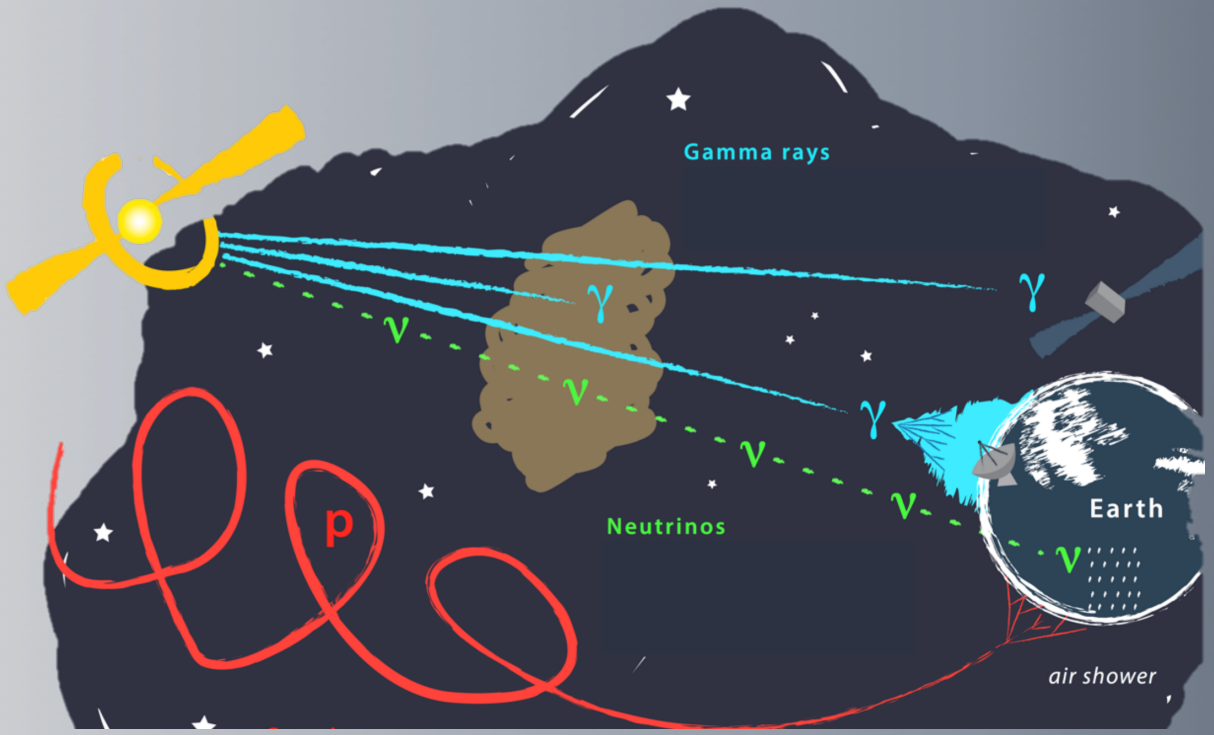
The MAGIC project status and results

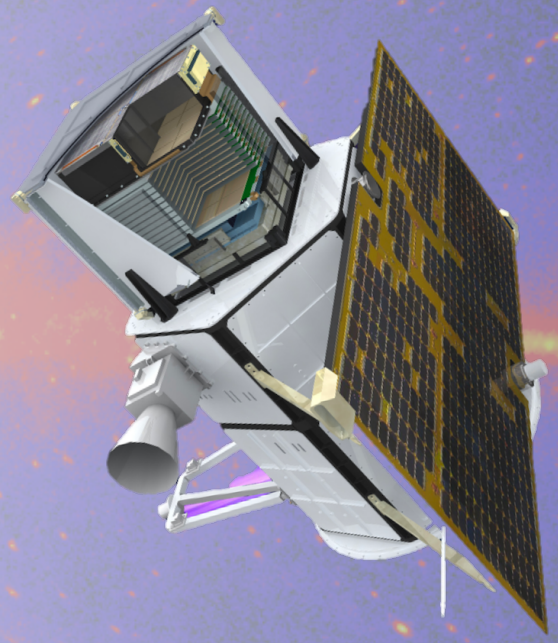
C. Righi on behalf of MAGIC Collaboration

High-energy astrophysics



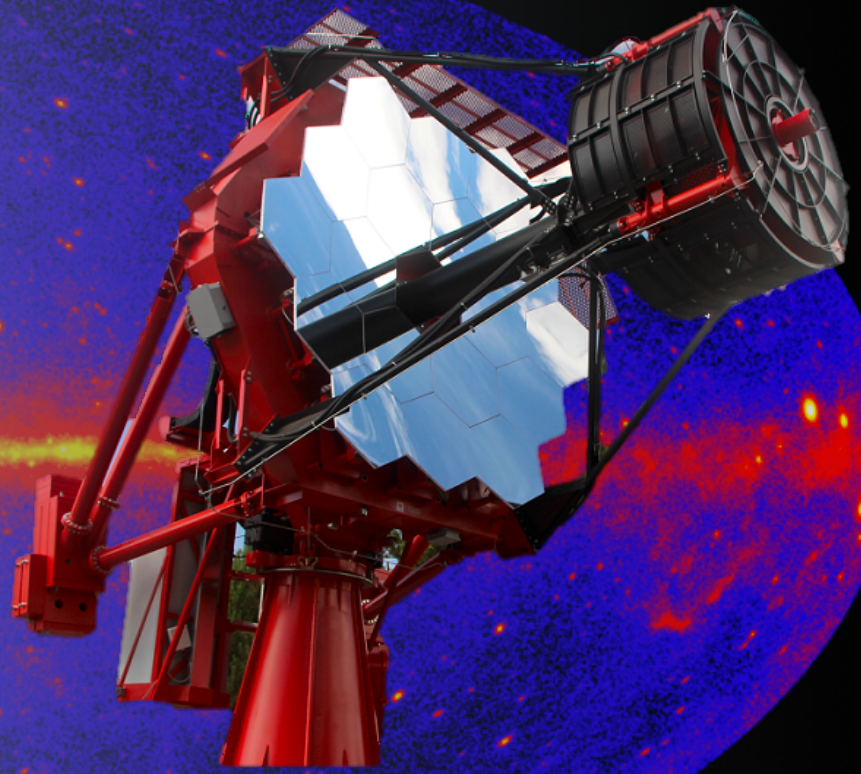
- Information about very energetic events in the Universe
- Better understanding of the acceleration mechanism
- Advanced studies on the fundamental physics (Dark Matter, axion-like particles, Lorentz invariance violation)

Gamma-ray astrophysics



Satellite

Energy range: MeV - GeV



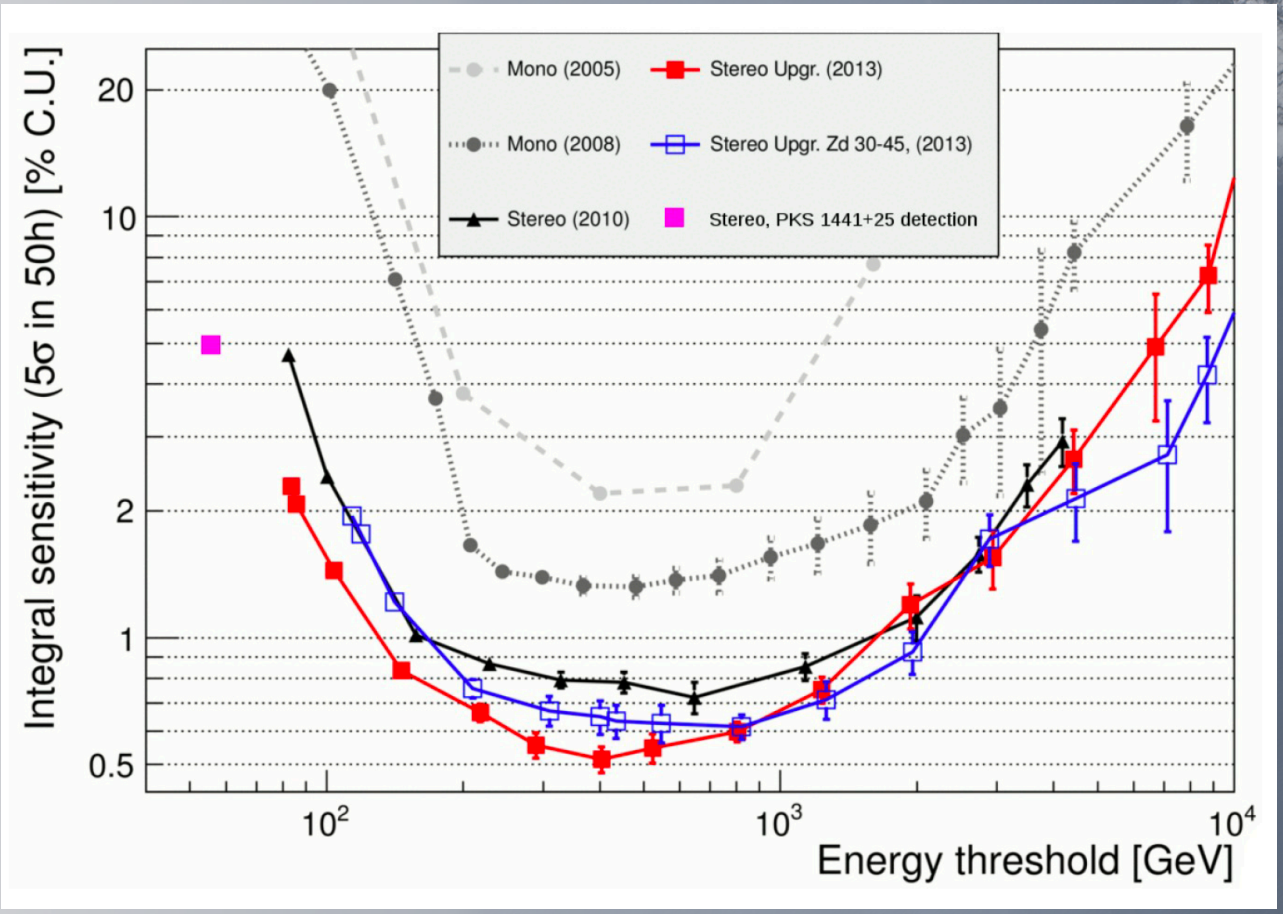
Ground based telescopes

Energy range: GeV - TeV

Where is MAGIC

- Two 17 m diameter Imaging Atmospheric Cherenkov Telescopes
- Canary island of La Palma at 2200 m a.s.l.
- MAGIC-I: since 2004
- MAGIC-II: since 2009
- Energy range ~50 GeV – ~50 TeV (even lower with other triggers, i.e. Geminga pulsar detection)

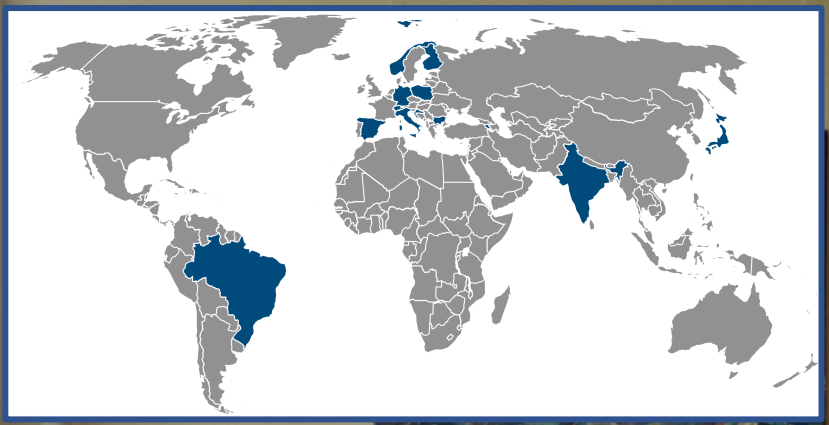
How MAGIC works



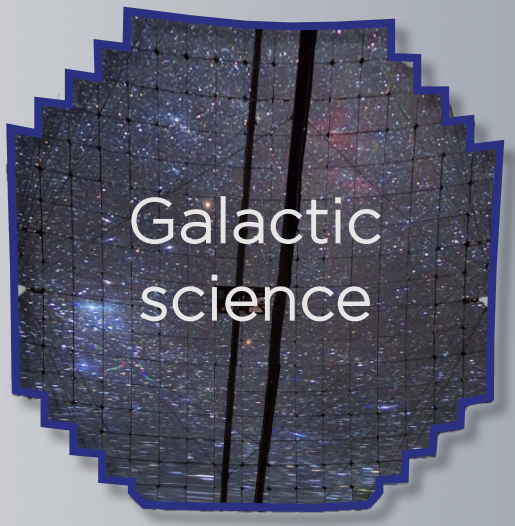
- Stereoscopic system since 2008
- Major upgrade of both cameras/electronics in 2013
- Multiple hardware upgrades pushing the limits of the instrument..
- No major problems due to volcanic eruption or icestorm

The MAGIC Collaboration

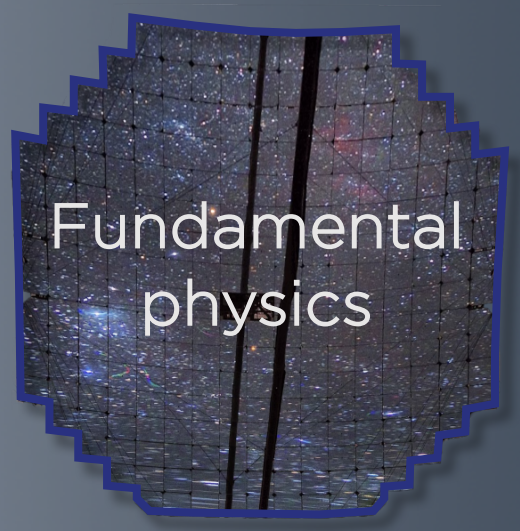
MAGIC Publications



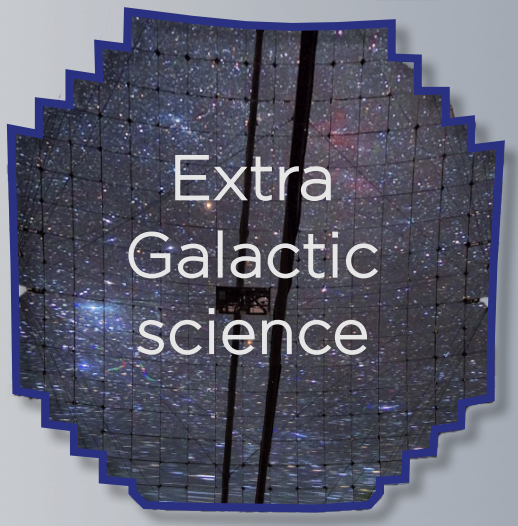
MAGIC scientific highlights



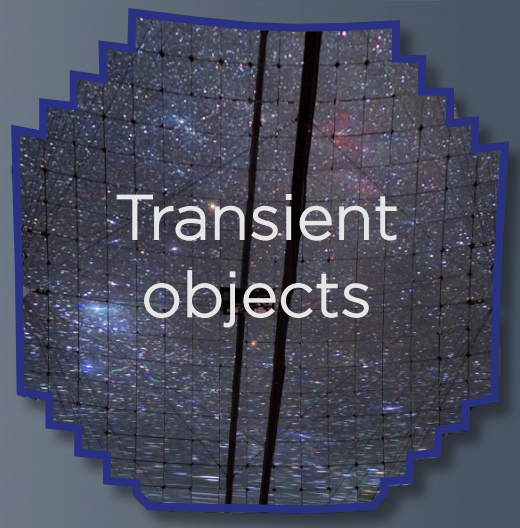
Pulsars, Pulsar wind nebulae, supernovae remnant, binaries



Dark matter, LIV, Cosmic rays, Alps



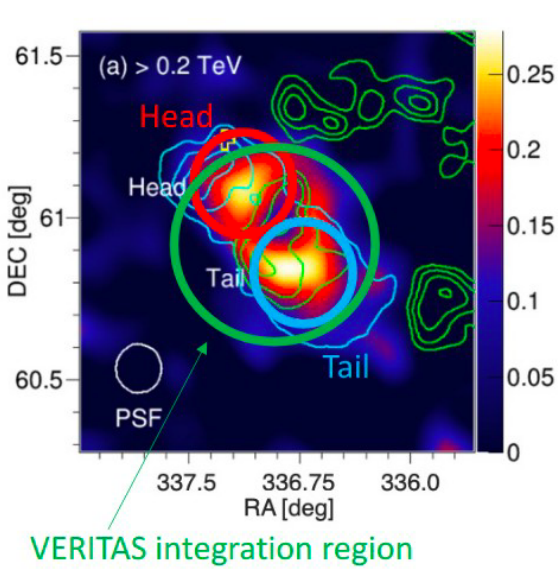
AGNs, Blazars, radiogalaxies, IGMF, EBL

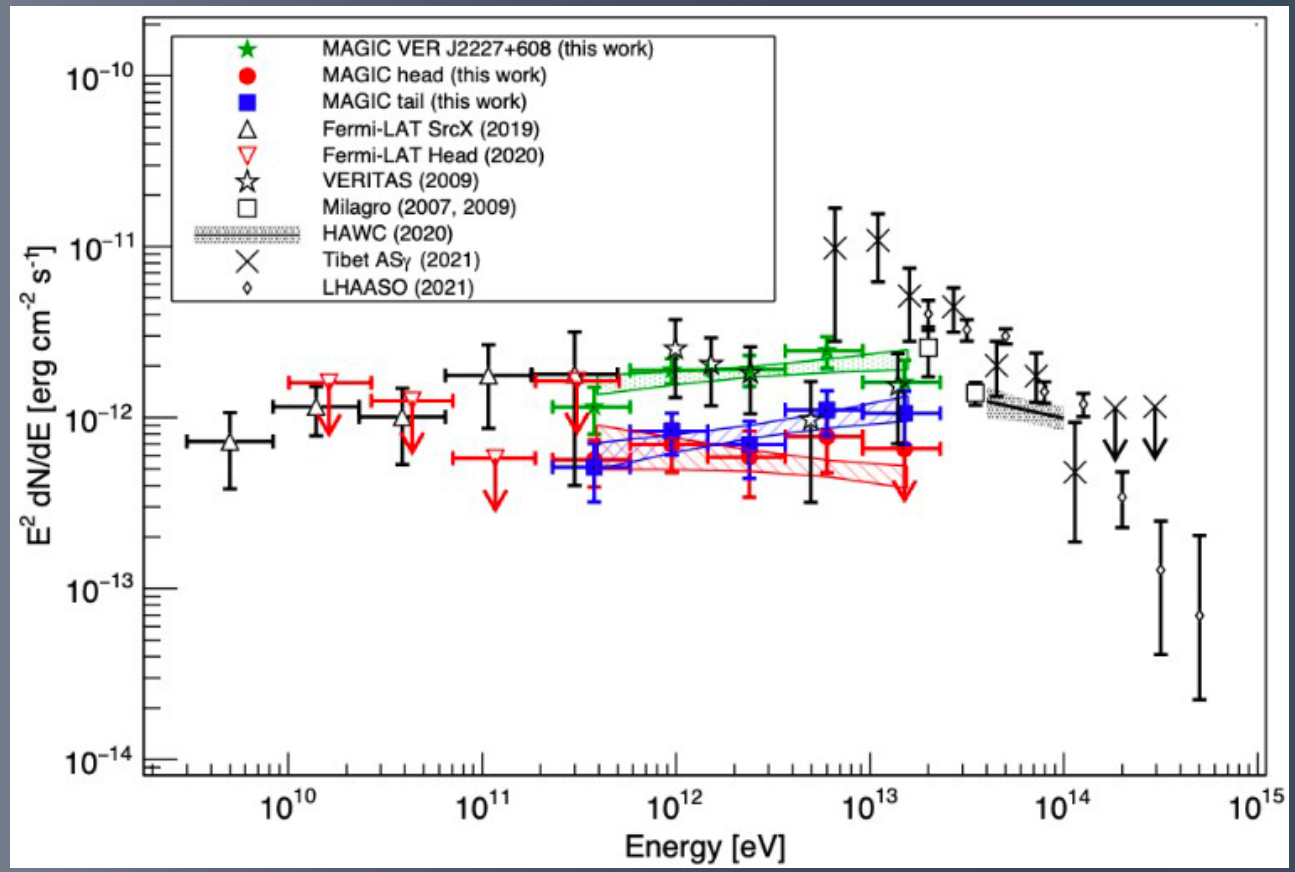


GRBs, neutrinos, FRBs, GWs

MAGIC galactic highlights

LOCALIZING PEVATRON EMISSION



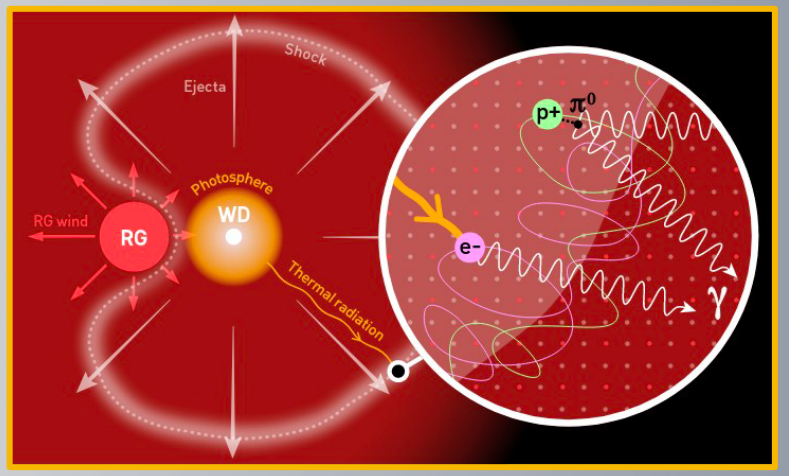


- Energy-dependent morphology detected in SNR G106.3+2.7/Boomerang
- Evidence of UHE localization
- Strengthening of hadronic origin of UHE emission

Presented at Gamma 2022

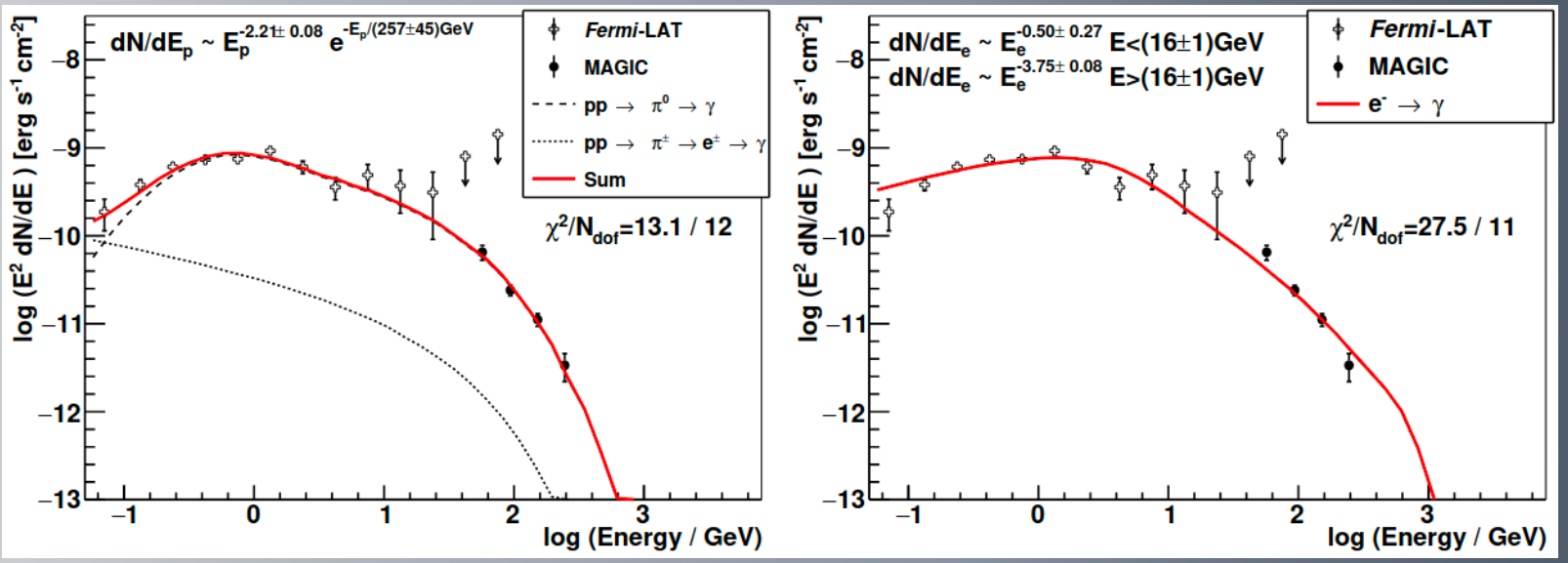
MAGIC galactic highlights

PROTON ACCELERATION IN RS Oph



First VHE nova detection, with 3 strong hints of proton acceleration

1) Hadronic origin requires a natural-2 slope, while leptonic scenario requires a more complex steep acceleration break
2) Best-fit hadronic model preferred over leptonic
3) Hadronic scenario predicts linear raise of E_{Max}, consistent

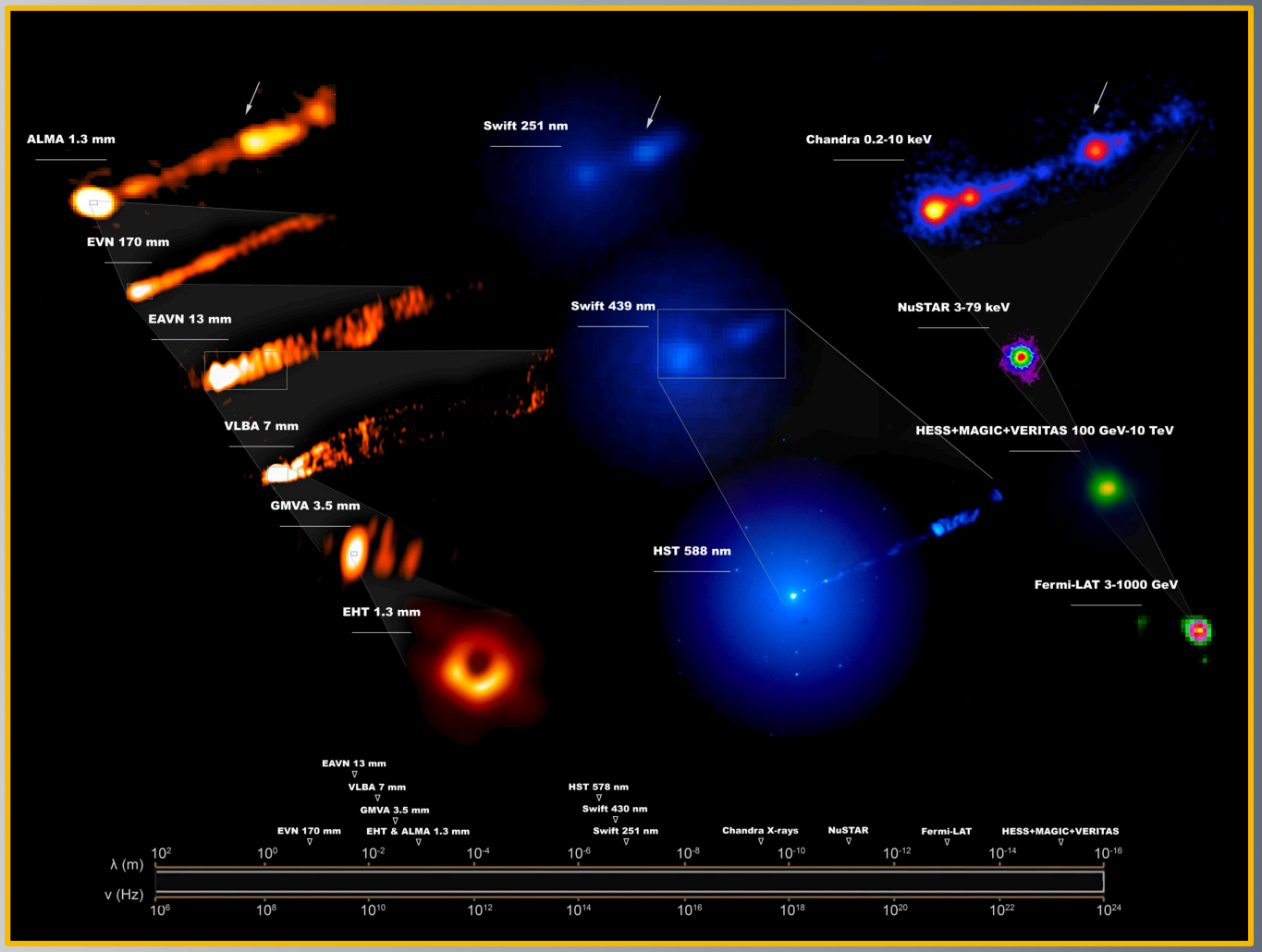


Nature Astronomy vol 6, 2022

See D. Green's talk on Thursday

MAGIC extragalactic highlights

BROADBAND MWL OF M87

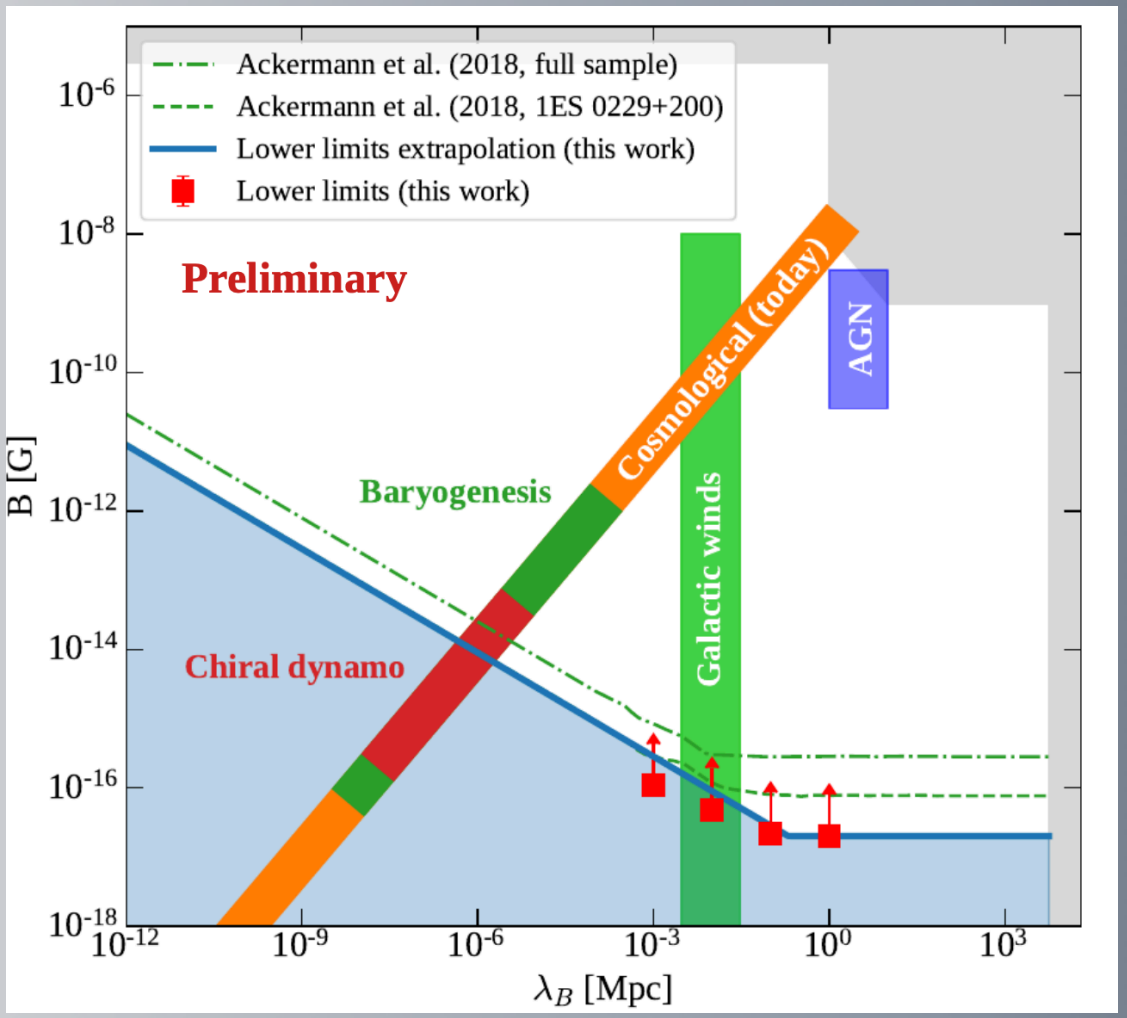


- Broadband coordinated observations in 2017 during quiescent state
- Cannot be modeled by single zone
- Structured jet and time dependence are key
- HE/VHE emission cannot be originated at the same location as mm-band → emission from jet farther from the SMBH (HST-1 knot)

Alagaba et al. 2021

MAGIC extragalactic highlights

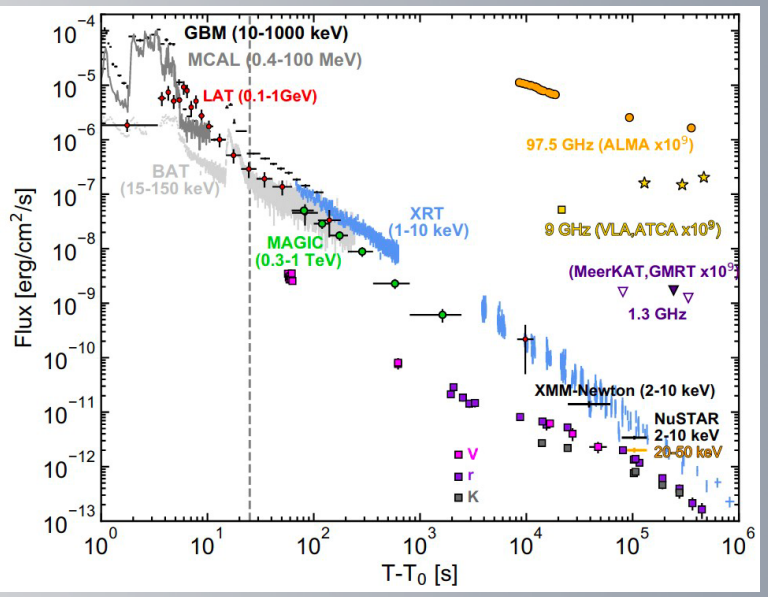
IGMF CONTRAIN FROM 1ES 0229+200

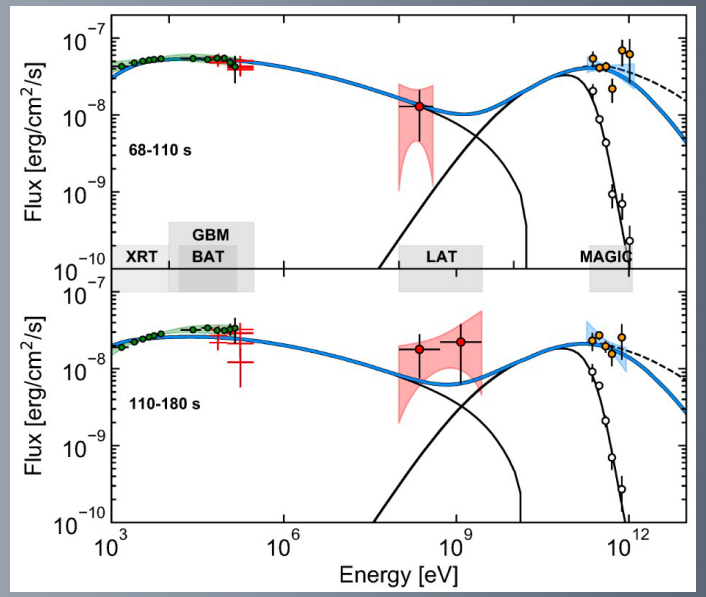


- IGMF – a possible "seed" field for astrophysical dynamos, filling most of the Universe volume
- For the first time we use contemporaneous Fermi, MAGIC, H.E.S.S. and VERITAS data to relax some assumptions of the models
- Strong constraint on models of cosmological magnetogenesis – e.g. IGMF that may have been responsible for baryon asymetry of the Universe.

MAGIC transient highlights

GAMMA RAY BURST



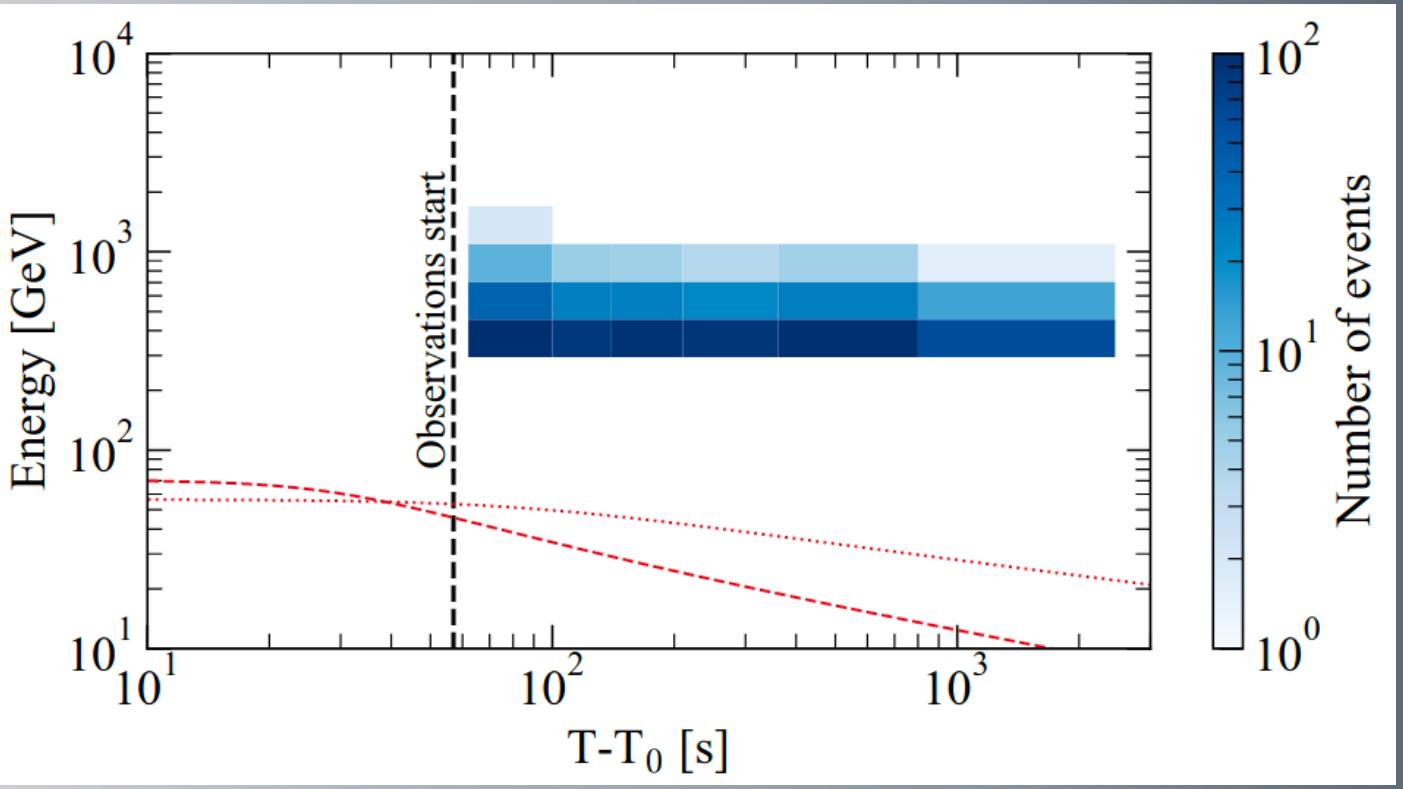


- GRB190114C is the first VHE detection of a GRB with a such high signal
- TeV emission may be explained by a SSC scenario
- Still improving: change of strategy after GRB detections, not limited to 4h after the trigger time → trying to catch also late afterglow emission

MAGIC, Nature 575 (2019) 459-463

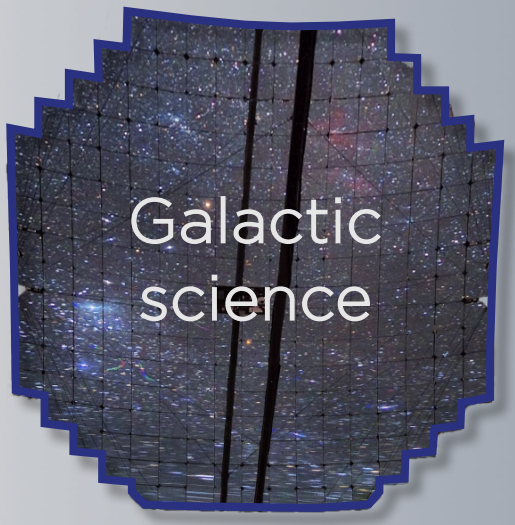
MAGIC APFP highlights

LIV

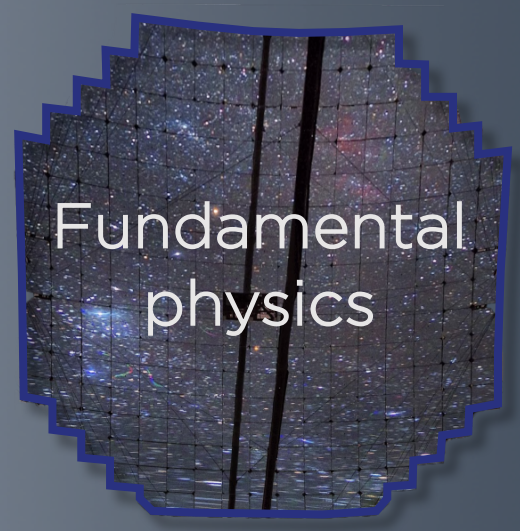


- LIV may be a consequence of Quantum Gravity theory
- GRB detections provide strong signals, of well known time evolution, travelling cosmological distances
- Ideal datasets to test Lorentz Invariance Violation
- Using GRB 190114C we provided competitive limits in the quadratic leading order

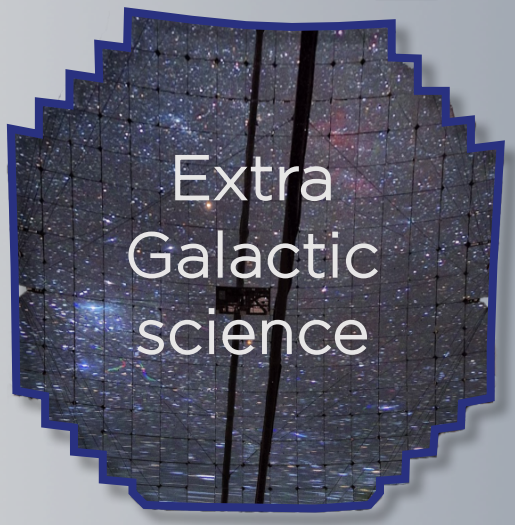
Other MAGIC highlights



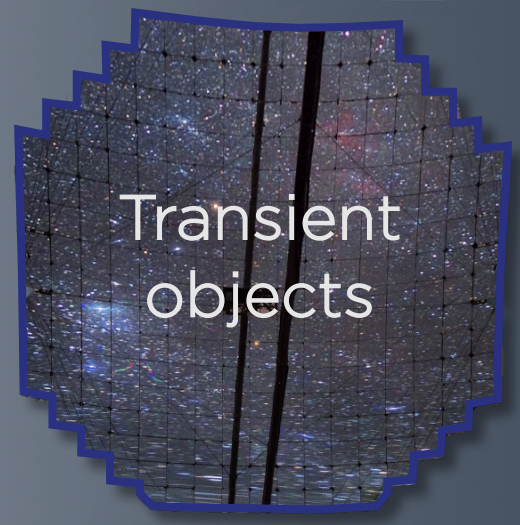
- Lepto-hadronic components
- Optical interferometry



- Dark matter
- CR population

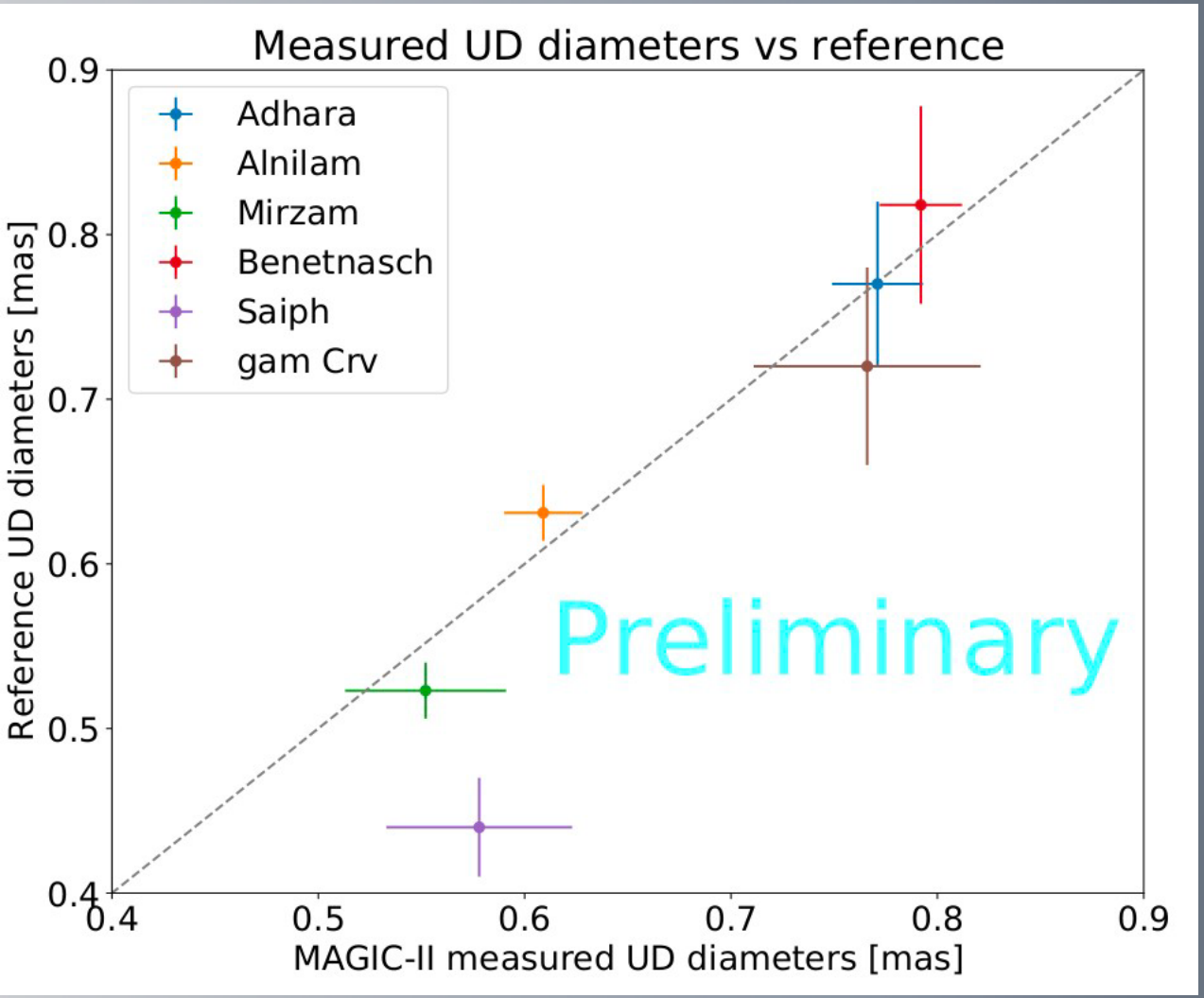


- Intra night variability at VHE
- Long monitoring
- Deep MWL campaigns
- Correlation patterns



- Neutrinos
- FRBs

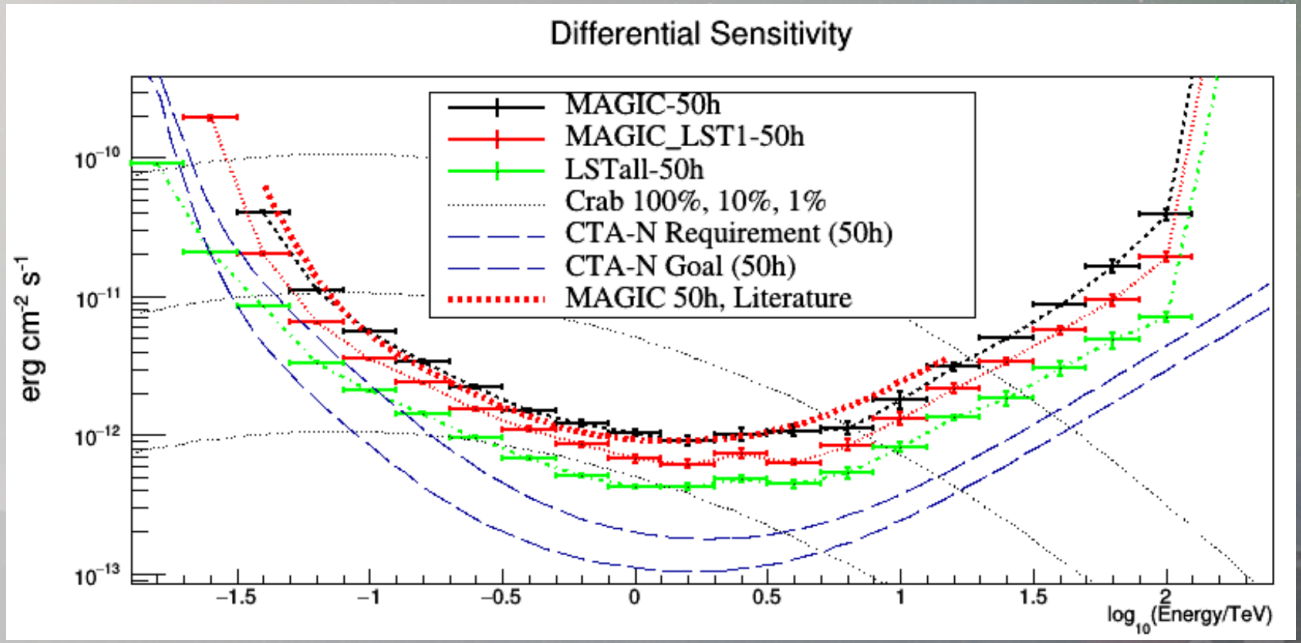
MAGIC as optical telescope



- Routinely operating as optical interferometer during Full Moon
- First results are very promising
- Preliminary studies together with LST Collaboration

SPIE 2022 contribution, review will available soon

MAGIC and LST



From Di Pierro talk at CTA ITA meeting 2019

- Cross-calibration for LST (ICRC 2021)
- Simulations for combined analysis between MAGIC and LST
- MAGIC + LST observations
- Stay tuned for new results!

...for more details on LST see A. Donini's talk

Take home messages

After almost 20 years of operation, the MAGIC telescopes are showing excellent performance

Good scientific harvest, e.g.:

- Discovery of new types of VHE gamma-ray emitters
- Help unveiling the origin of Galactic cosmic rays and Ultra-High-Energy neutrinos
- Understanding particle acceleration in shocks, jets and extreme environments
- Fundamental Physics issues:
  - Lorentz Invariance tests
  - Search for Dark matter

Multi-wavelength/multi-messenger/multi-collaboration projects getting more and more important


Thanks!