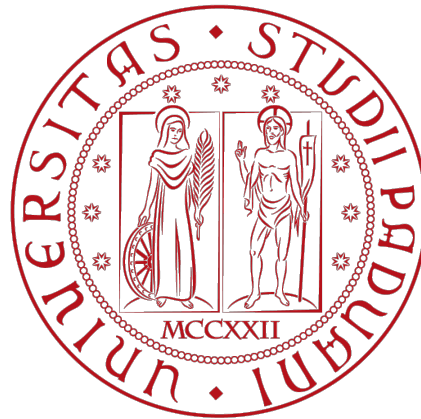


Multiwavelength and multimessenger studies of extragalactic high energy particle sources

Ilaria Viale

Supervisor: Prof. Elisa Bernardini
University and INFN Padova, Italy



MAGIC

Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

Overview

1st year PhD

member of the MAGIC Collaboration

PhD on **multimessenger astrophysics**

- electromagnetic radiation and neutrinos from the same sources
- Focused on the study of Blazar sources as candidate neutrino emitters

Aim

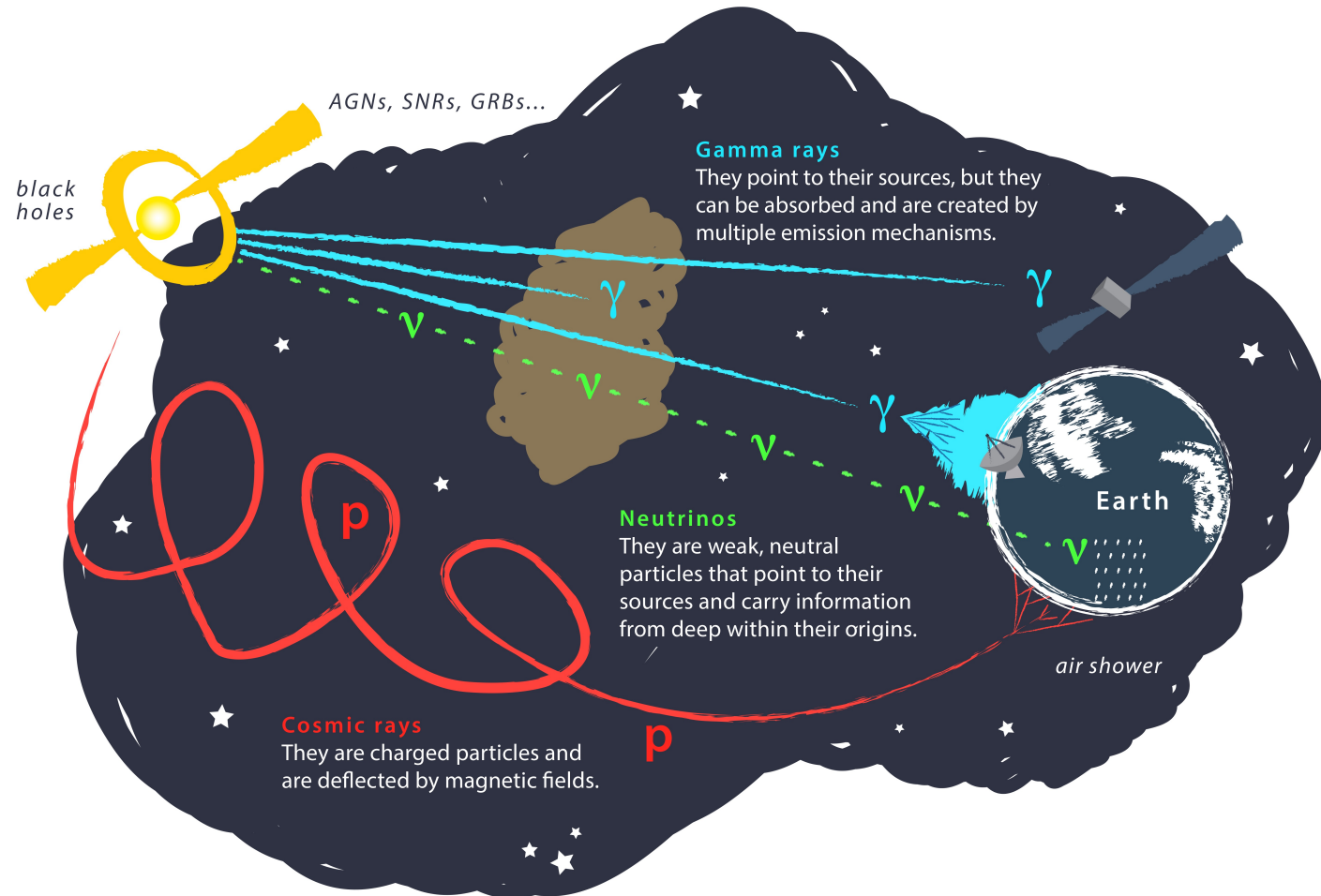
- Characterization and interpretation of the Spectral Energy Distribution of the sources

Multimessenger and neutrino astrophysics

- ❖ Cosmic rays, photons, neutrinos from same sources
- ❖ Neutrinos from pp or $p\gamma$ interactions
- ❖ Important role played by IceCube
 - Extragalactic neutrinos

$pp, p\gamma \rightarrow \dots \rightarrow$

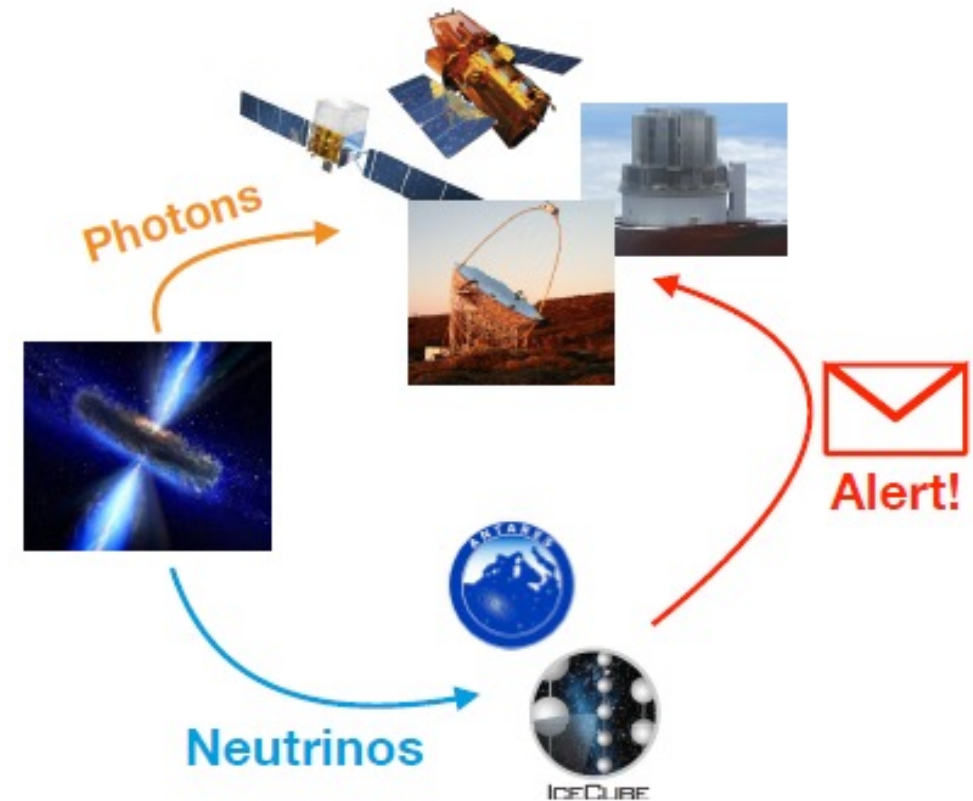
$$\begin{cases} X + \pi^0 \rightarrow X + \gamma\gamma \\ X + \pi^+ \rightarrow X + \mu^+ \nu_\mu \rightarrow X + e^+ \nu_e \bar{\nu}_\mu \nu_\mu \\ X + \pi^- \rightarrow X + \mu^- \bar{\nu}_\mu \rightarrow X + e^- \bar{\nu}_e \nu_\mu \bar{\nu}_\mu \end{cases}$$



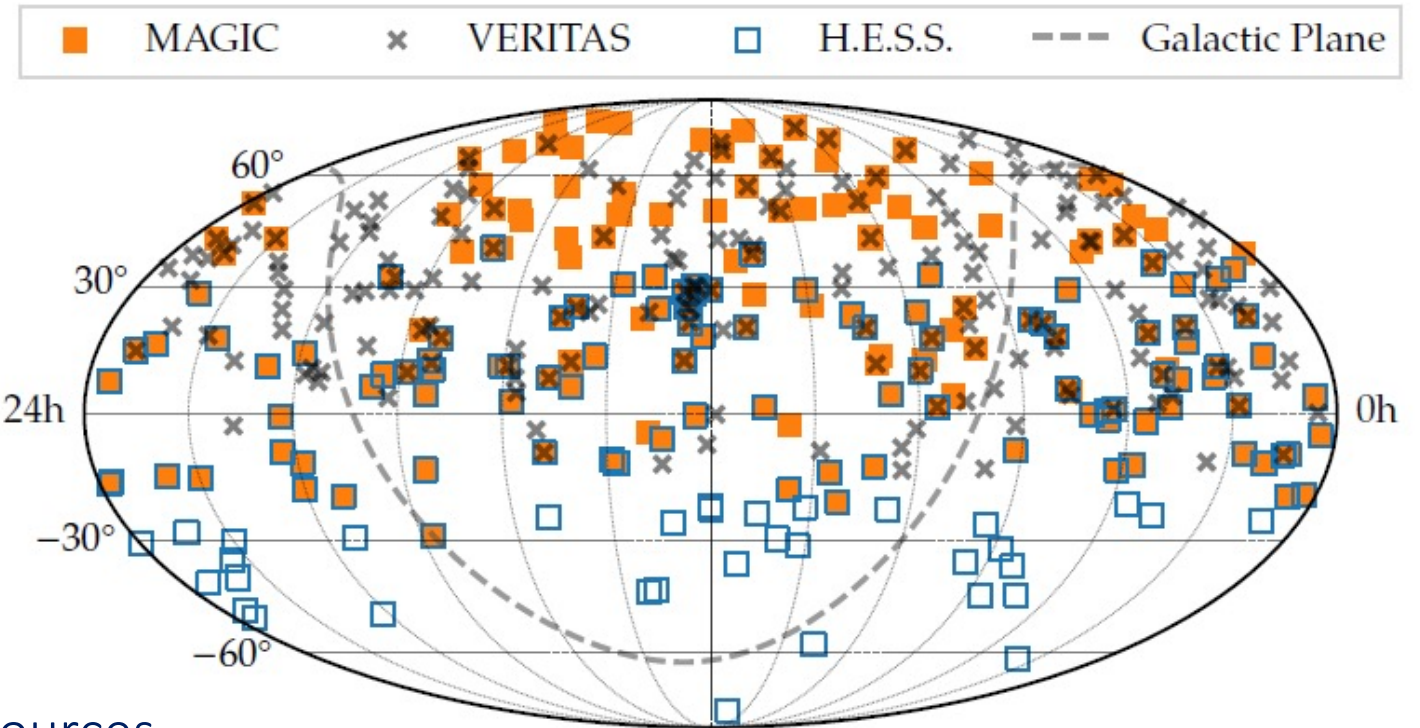
Multimessenger and neutrino astrophysics

❖ Contribution from different instruments is needed:

- Neutrino telescopes
 - Alert emission
- Telescopes for EM radiation
 - Alert response



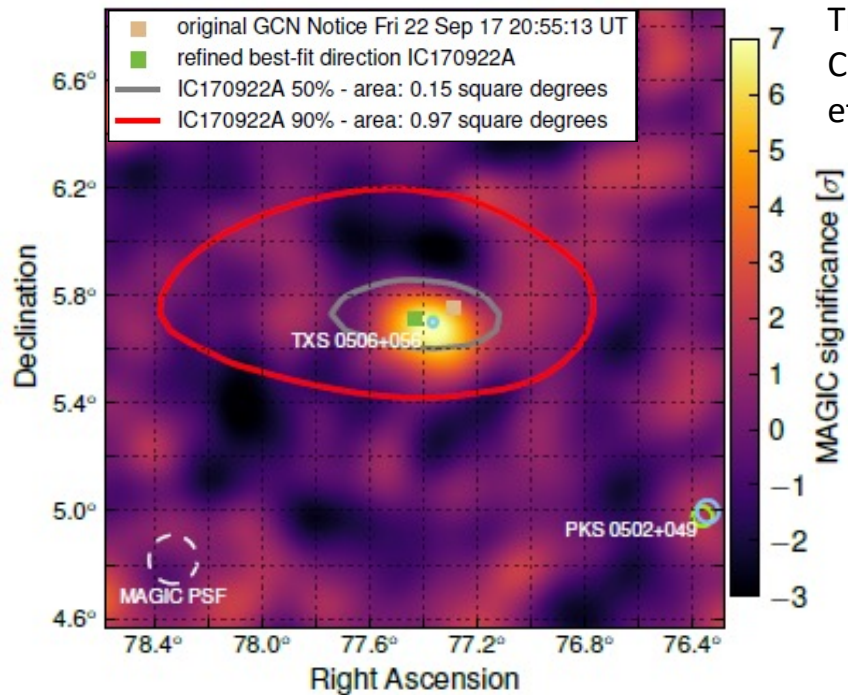
Alerts received by MAGIC



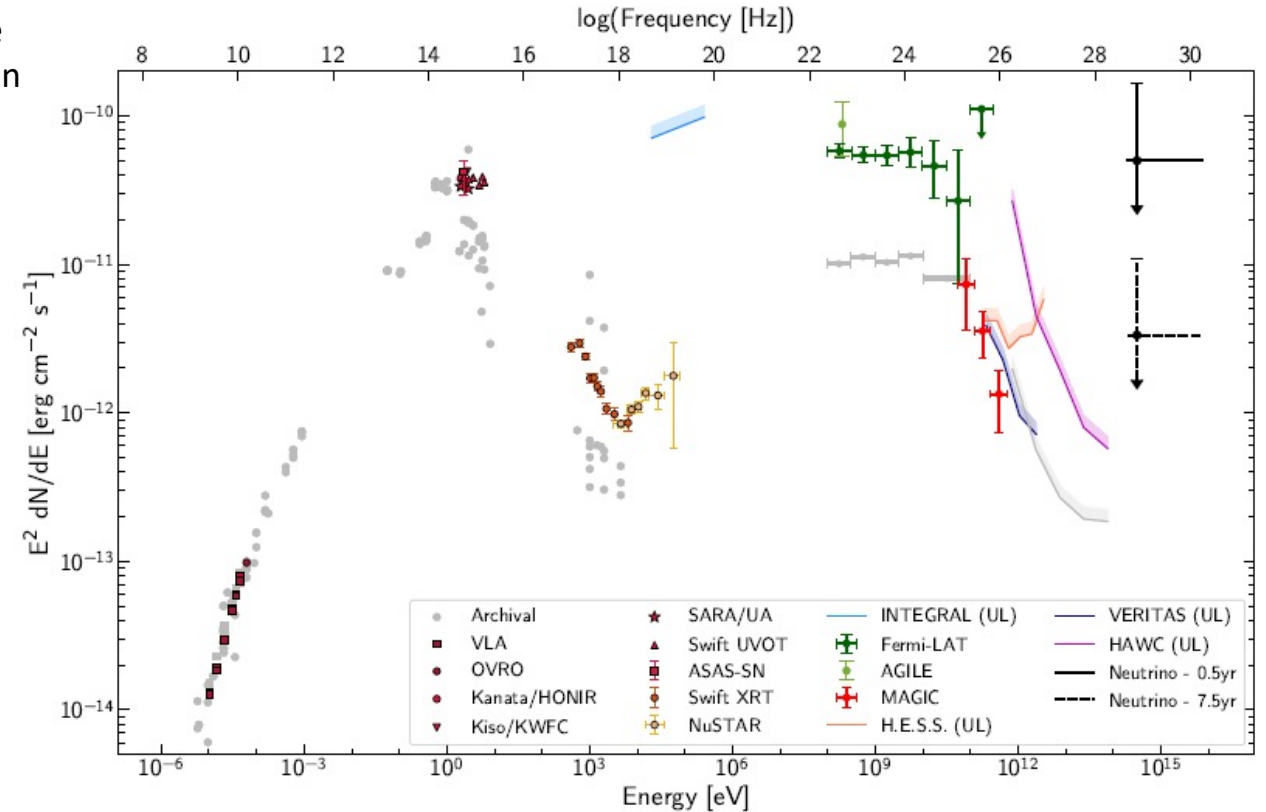
Alerts from IceCube:

- Neutrino clusters, $E > 100$ GeV
 - From set of preselected sources
- Single high energy tracks, $E > 60$ TeV
 - BRONZE and GOLD alerts

A successful follow-up: TXS 0506+056



The IceCube Collaboration
et al. (2018)



IC-170922A: Track-like event with $E \sim 290$ TeV

MAGIC observations: detection in VHE γ -rays
($E > 90$ GeV) with 6.2σ significance

Significance of blazar-neutrino coincidence: 3σ

First multimessenger SED!

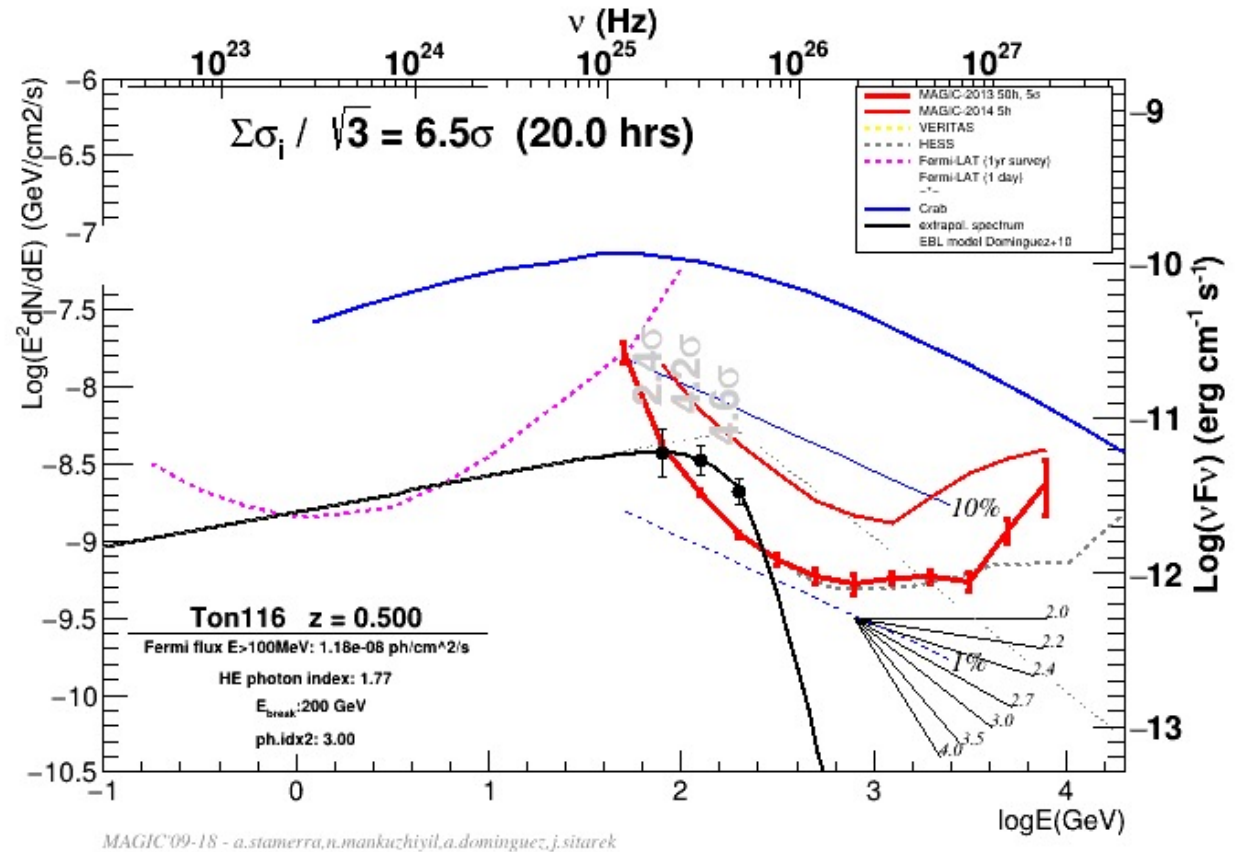
My contribution

Three major works carried out in parallel:

1. Drawing of proposals for multiwavelength observations and alert response
 - MAGIC in particular
2. Multiwavelength data analysis
 - Fermi/LAT, MAGIC, LST-1
3. Development of lepto-hadronic models
 - Can blazars be neutrino emitters and cosmic-ray accelerators?

Proposals

- ❖ Sources of interest and IceCube triggers:
 - Visibility of source
 - Observation time
 - Significance
- ❖ Proposals I contributed to:
 - TXS 0506+056 monitoring
 - Follow-up of potential neutrino sources



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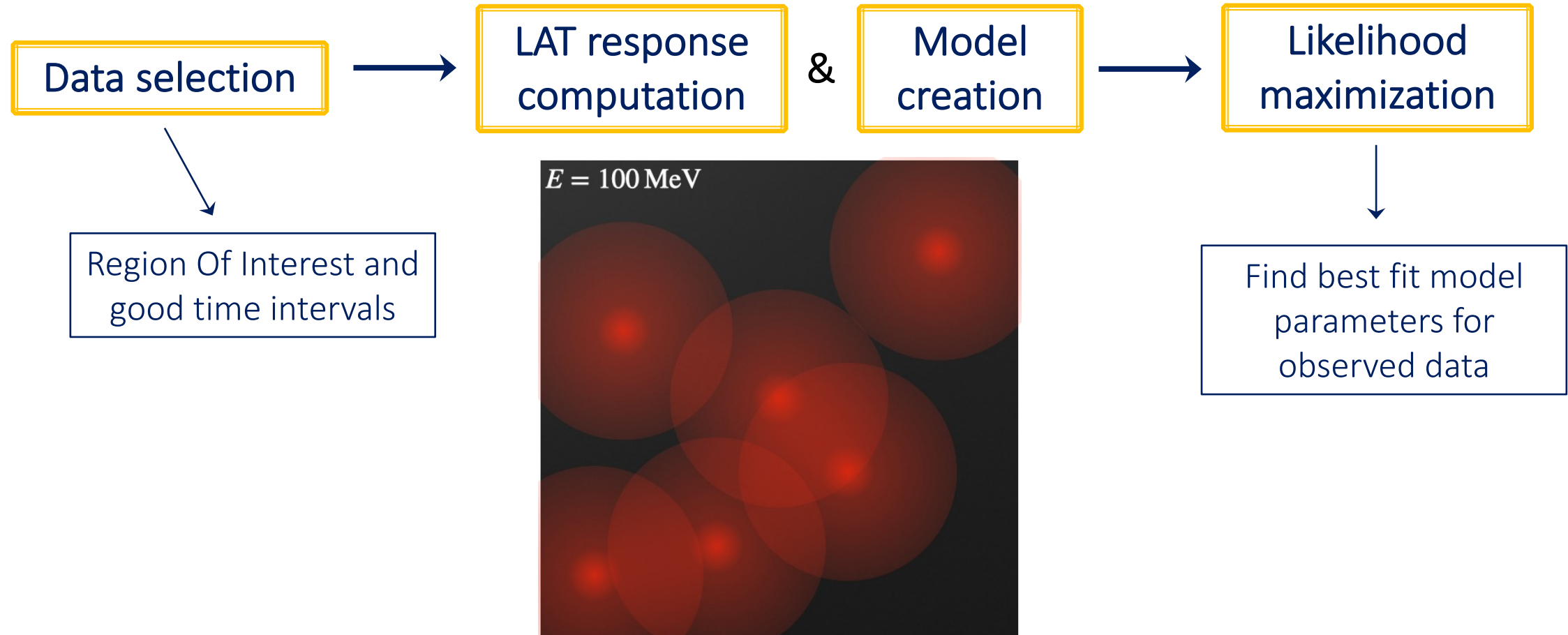
Multi-epoch monitoring of TXS 0506+056 with MAGIC and MWL partners

K. Satalecka,^{a,*} T. Aniello,^b E. Bernardini,^c W. Bhattacharyya,^a M. Cerruti,^c F. D'Ammando,^d E. Prandini,^b C. Righi,^e N. Sahakyan,^f I. Viale,^b P.G. Edwards,^g R. Ojha,^h J. Stevens,^g T. Hovatta,ⁱ S. Kiehlmann,^j A.C.S. Readhead,^k F. Eppel,^l A. Gokus,^l J. Heßdörfer,^l M. Kadler,^l G.F. Paraschos,^m J. Sinapius,^a F. Rösch^l and on behalf of the MAGIC, ATCA, OVRO and TELAMON Collaboration

Searching for VHE gamma-ray emission associated with IceCube neutrino alerts using FACT, H.E.S.S., MAGIC, and VERITAS

Konstancja Satalecka,^{a,*} Elisa Bernardini,^b Daniela Dorner,^c Gašper Kukec Mezek^d and Weidong Jin^e on behalf of the MAGIC, IceCube, FACT, H.E.S.S., VERITAS Collaboration
(a complete list of authors can be found at the end of the proceedings)

Multiwavelength data analysis: Fermi/LAT



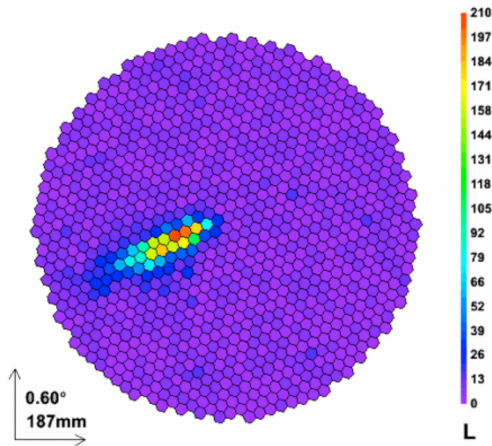
Multiwavelength data analysis: MAGIC

Image
cleaning

Selection of good
quality data

Monte Carlo
simulations

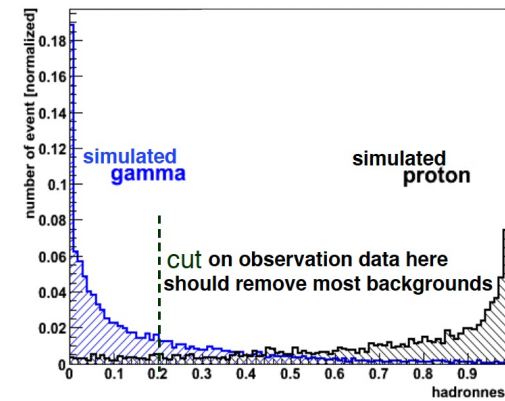
High level
products



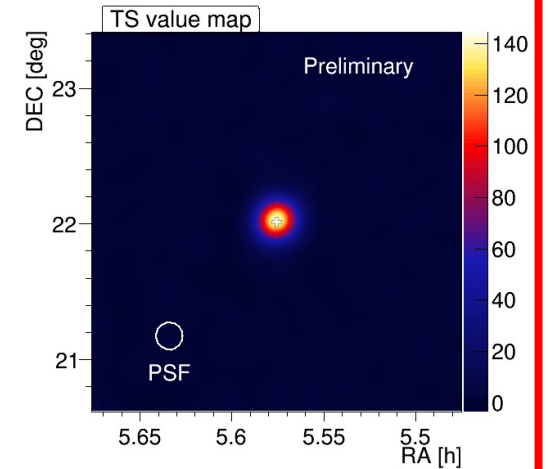
recognition of event



Clear sky, no
hardware problems

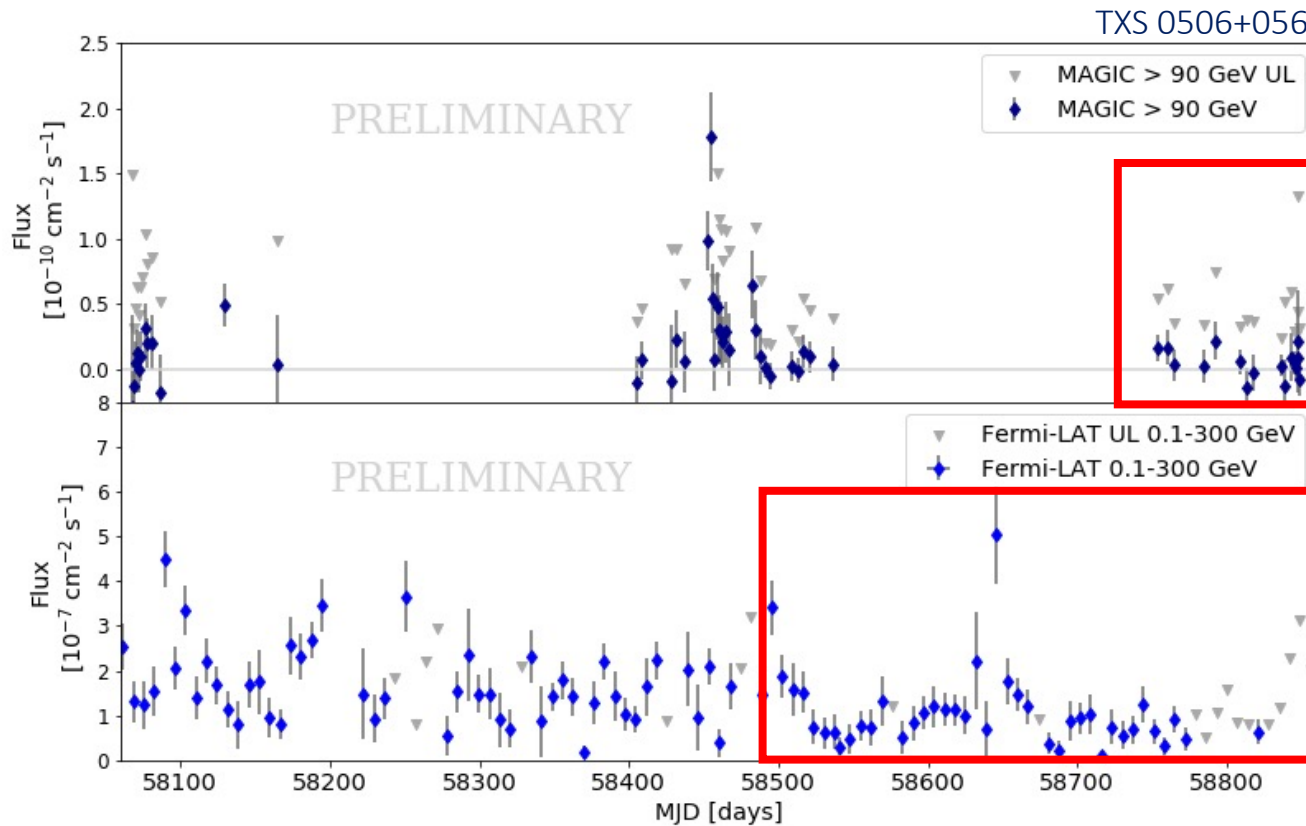


g/h separation, energy and
direction reconstruction



Sky maps, spectrum,
lightcurve, ...

Multiwavelength data analysis: results



This year's works:

- Analysis of TXS 0506+056 in 2019-2021
- Analysis of sources in coincidence with IceCube neutrino alerts
 - OP313: 4 alerts between march and august 2020, all from same neutrino flare

My contribution

Models

Aim: Interpretation of jet emission

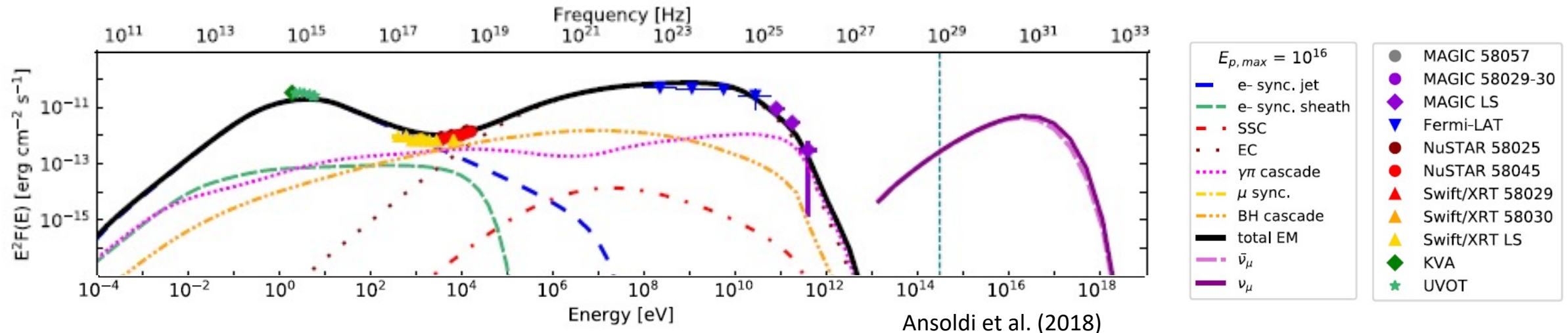
- Particles composing the jet?
- Origin of the second bump?

Leptonic models:

- Synchrotron Self Compton, External Compton

Hadronic models:

- $p\gamma$ interactions



Thank you for your attention!

