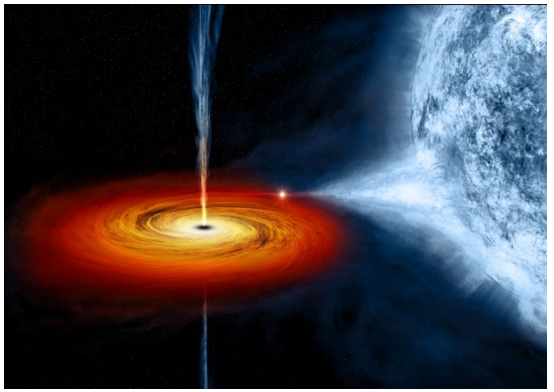
Master in Astrophysics, Particle Physics, and Cosmology
Academic year 2022-2023

High-energy astrophysics





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(https://icc.ub.edu/research/high-energy-astrophysics)

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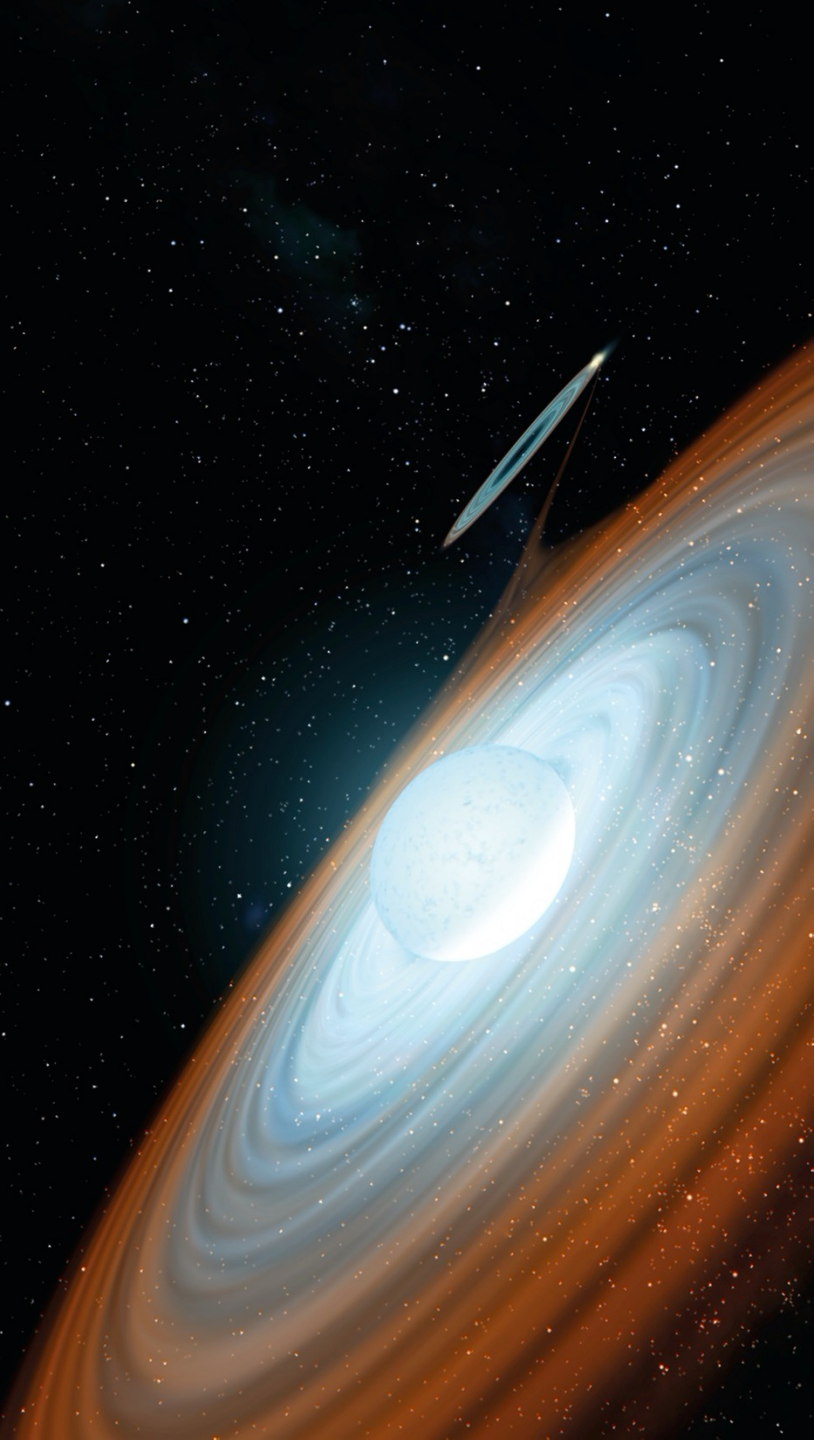
EXCELENCIA MARÍA DE MAEZTU



Goals:

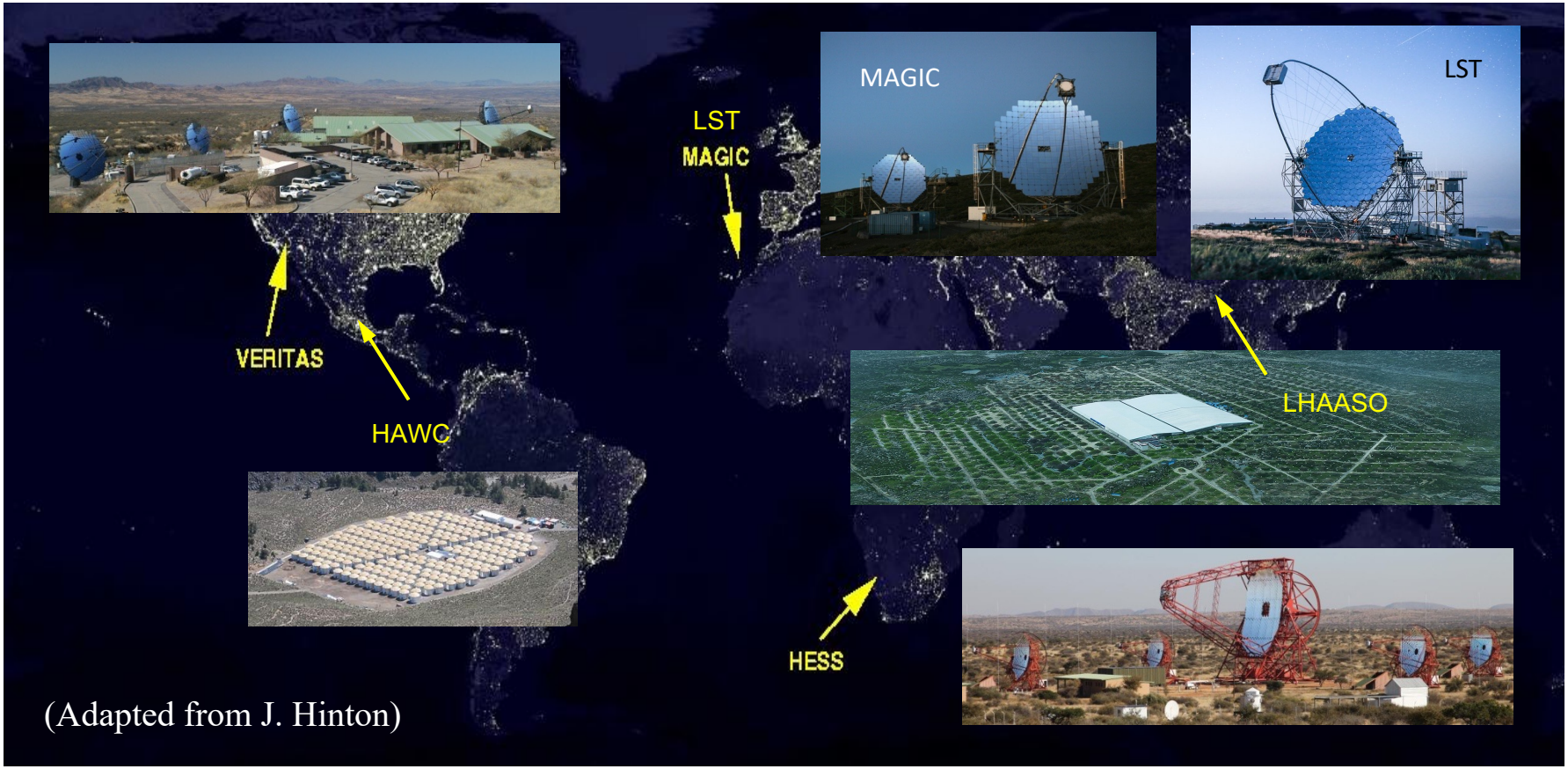
To train, from the observational and theoretical point of view, a group of future researchers in HE astrophysics.

To understand the:

- physical mechanisms capable of **accelerating particles** to high energies and associated **radiative processes**
- **phenomenology** of various kinds of HE astrophysical sources such as supermassive BH in galactic nuclei, XRB stars, pulsars, SNR
- most recent **observational results** and their impact in the models available

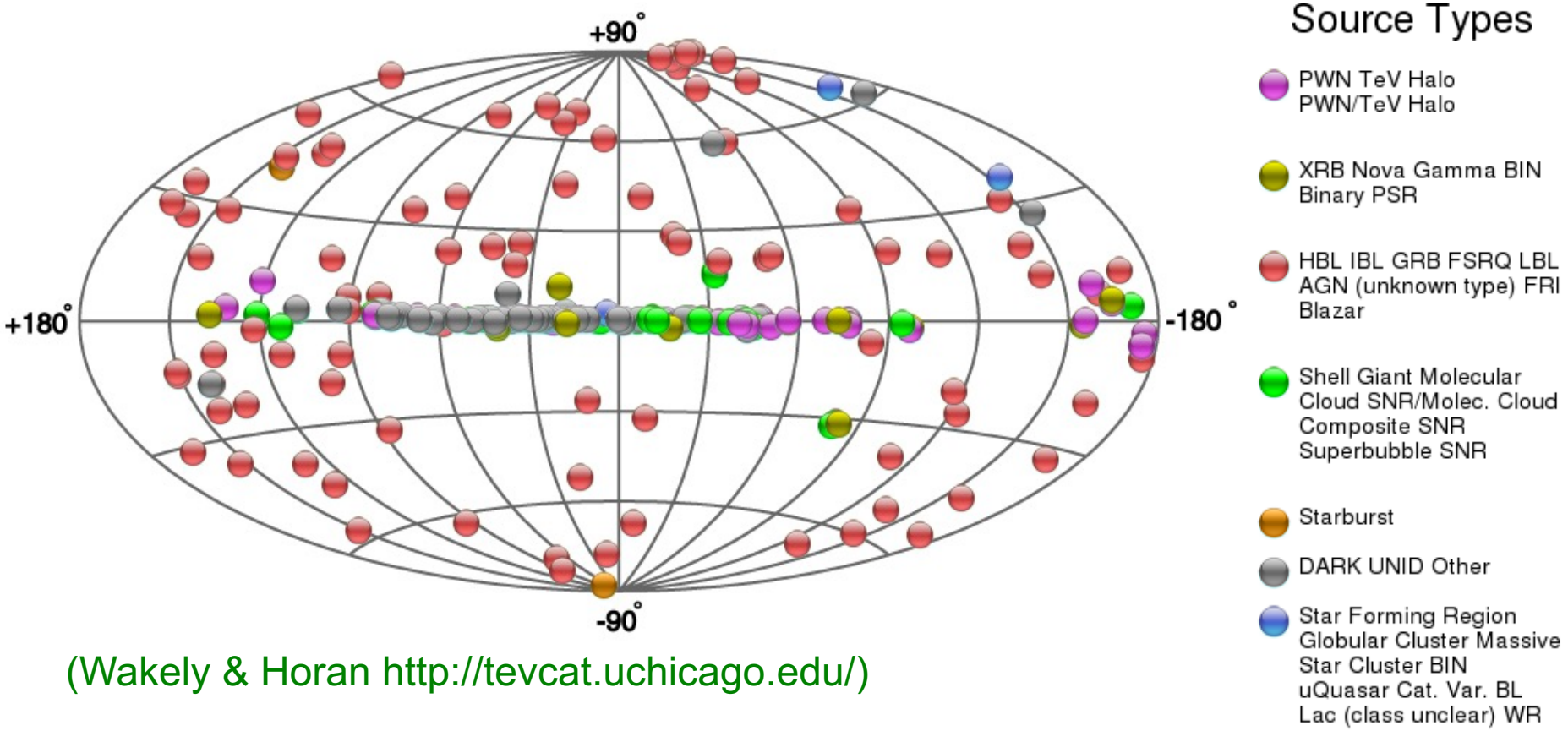
Current generation of TeV facilities:

- 15 years of data from HESS, MAGIC and VERITAS.
- 5 years of data by HAWC.
- 1 yr of CTA/LST data → Soon much better sensitivity than previous facilities.
- 1 yr of data from LHAASO → PeVatrons everywhere!



TeV sources known

2021 Oct: 247 sources known! ~35% extragalactic, ~35% galactic, ~30% unid

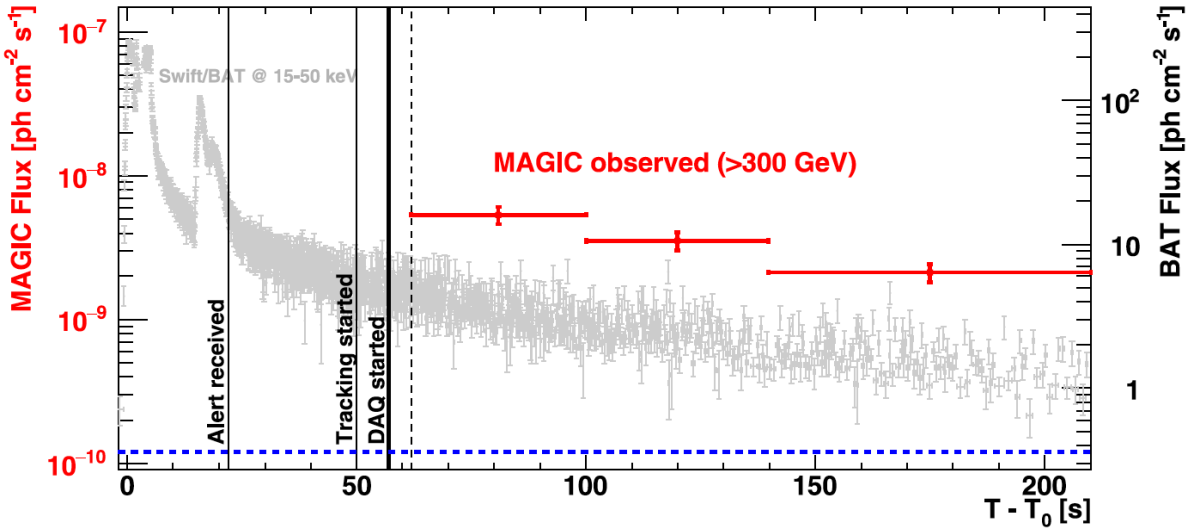


(Wakely & Horan http://tevcat.uchicago.edu/)

We know a similar number of source classes at VHE γ-rays and at HE γ-rays.

Gamma-Ray Bursts (GRBs).

MAGIC discovers GRBs at VHE: GRB 190114C.



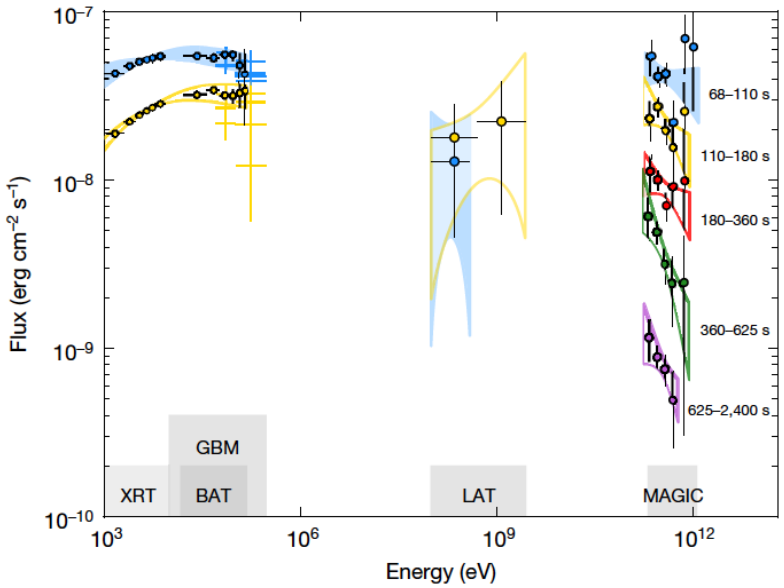
First GRB (long) reported at TeV energies.

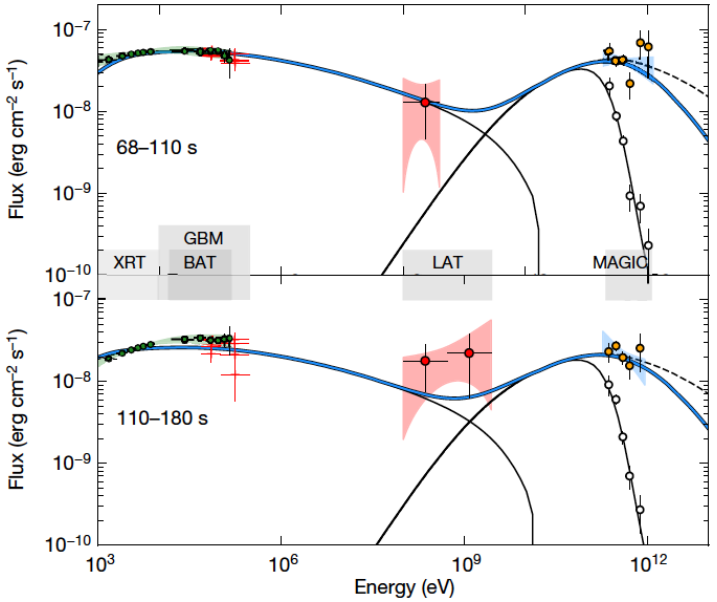
Redshift: z=0.425.

Detected **above 300 GeV**.

New IC component.

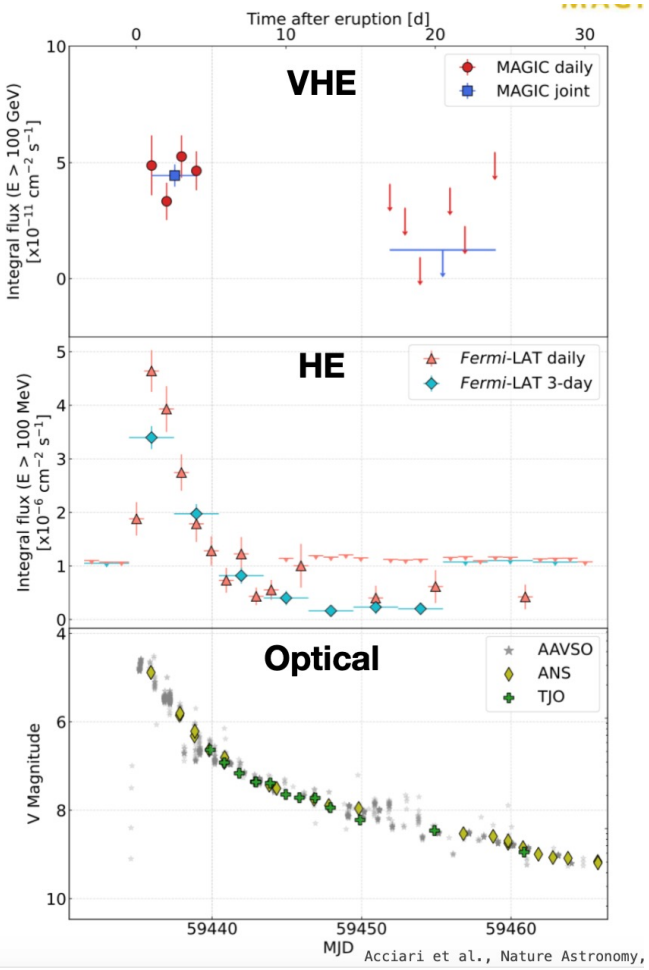
(MAGIC Collaboration 2019a & MAGIC Collaboration et al. 2019b).

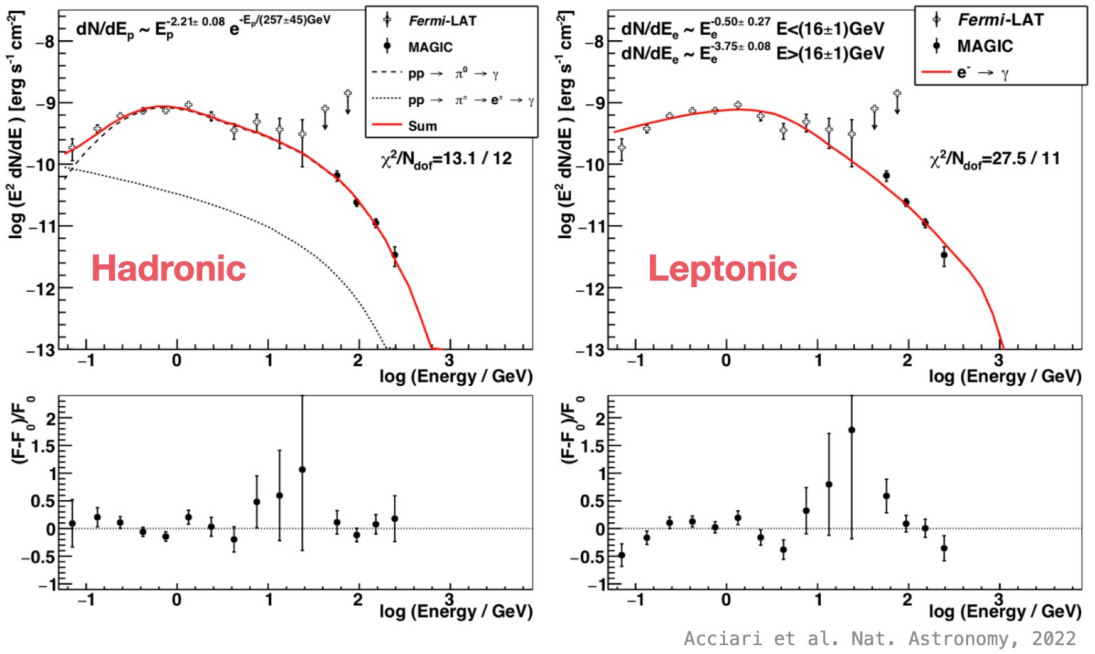




Novae.

MAGIC discovers proton acceleration in the recurrent nova RS Oph. (MAGIC Collaboration 2022).





Different arguments favor **proton acceleration**:

- Flux evolution at different wavelengths.
- Spectral fitting at different epochs.
- Acceleration and cooling timescales.

Program: 30 h: 24 h lectures, 1 h exam, 5 h presentations,

1. **Particle acceleration and radiation mechanisms in high energy astrophysics** — JMP, 12 sessions, 13 Sep – 4 Oct

    1.1. Particle acceleration mechanisms
    1.2. Diffusion
    1.3. Energy losses
    1.4. Radiative processes
        1.4.1. Thermal emission
        1.4.2. Synchrotron radiation
        1.4.3. IC scattering
        1.4.4. Bremsstrahlung
        1.4.5. Hadronic processes
        1.4.6. Particle annihilation

2. **Accretion and ejection in relativistic sources** — VB, 5 sessions, 5 – 13 Oct

    2.1. Accretion onto compact objects
    2.2. Outflows: jets and winds (general physical description)
    2.3. Flow dynamics (production, propagation, content, termination)
    2.4. Emission in relativistic outflows: electron-positron pairs
    2.5. " : protons and nuclei
    2.6. Radiation reprocessing

3. Phenomenology of accreting sources with outflows MR, 3 sessions 17-19 Oct

3.1. Observational tools (analysis and fundamental diagrams)
3.2. X-ray binary accretion modes
3.3. Disks and jets
3.4. Black holes at all scales: from X-ray binaries to AGN

4. High-energy gamma-ray sources in the Universe MR, 4 sessions 20 – 27 Oct

4.1. High-energy gamma-ray detectors and satellites
4.2. Imaging atmospheric Cherenkov telescopes.
4.3. Galactic HE ϒ-ray sources (pulsars, PWN, SNR, X-ray and ϒ-ray binaries, etc.)
4.4. Extragalactic HE ϒ-ray sources (AGNs, GRBs, EBL, etc.)
4.5. Fundamental physics at HE ϒ-rays (dark matter, Lorentz invariance, etc.)

Bibliography

AHARONIAN, F. A. Very high energy cosmic gamma radiation: a crucial window on the extreme universe. Singapore : World Scientific Publishing, cop. 2004.

CHARLES, PHILLIP A. ; SEWARD, FREDERICK D. Exploring the X-ray universe. Cambridge : Cambridge University Press, 1995.

LONGAIR, MALCOLM S. High energy astrophysics. Third ed. Cambridge : Cambridge University Press, 2010.

PACHOLCZYK, A. G. Radioastrofísica : procesos no térmicos en fuentes galácticas y extragalácticas . Barcelona : Reverté, DL 1979.

ROMERO, G.E.; PAREDES, J.M. Introducción a la astrofísica relativista. Textos docents 365. Publicacions i edicions Universitat de Barcelona (eBook: http://www.publicacions.ub.edu/ficha.aspx?cod=11608 or www.unebook.es)

Room V12M	**Monday, Tuesday, Wednesday and Thursday**
17:40-18:40	High Energy Astrophysics (13/09/2021 - 27/10/2021) (J.M. Paredes, V. Bosch, M. Ribó)

Work required to the students:

- Class attendance and active participation
- Exam preparation
- Active preparation/discussion of the assigned work with the supervisor
- Oral presentation of the work

Evaluation:

- Participation 10%
- Exam 30%
- Written work 30%
- Oral presentation 30%

Proposed works and supervisors

Marc Ribó:

- M1. Supernovae at GeV-TeV
- M2. Pulsars or PWN at GeV-TeV
- M3. X-ray binaries (options: NSs vs. BHs, GeV emission, etc.)
- M4. Gamma-ray binaries at GeV-TeV
- M5. Blazars at GeV-TeV (options: EBL, neutrinos)
- M6. EM emission from NS-NS mergers

Valentí Bosch:

- V1. High-Energy Emission from Jet/Medium Interactions in AGN
- V2. High-Energy Emission from Microquasar Jets
- V3. Gamma-rays from Young Stellar Objects
- V4. Disk-Jet connections in Black Hole X-ray Binaries

Another topic of your interest, either observational or theoretical

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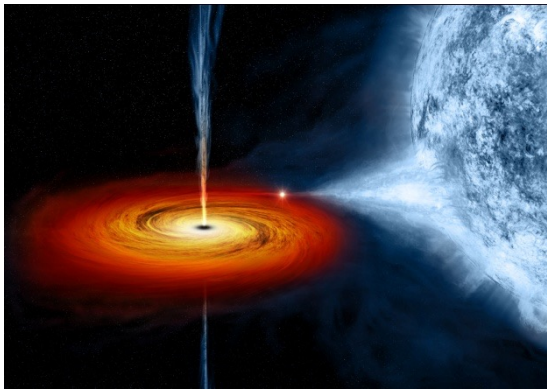

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