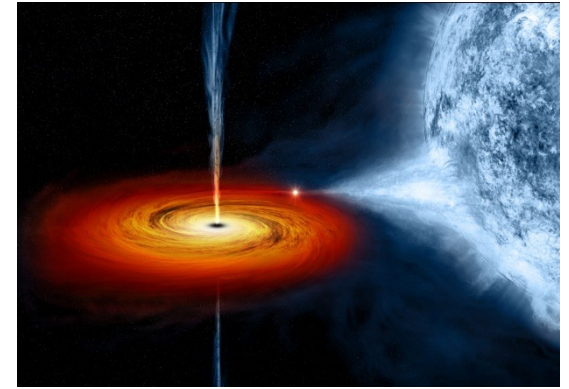
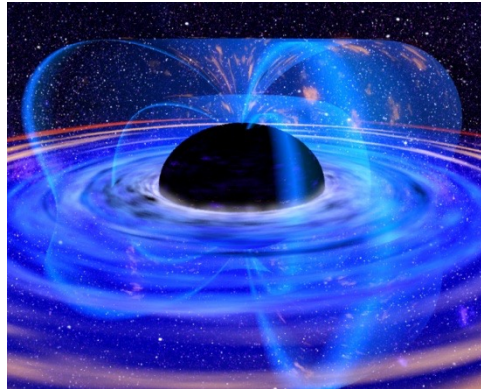


Master in Astrophysics, Particle Physics, and Cosmology
Academic year 2023-2024

High-energy astrophysics



Josep Maria Paredes (jmparedes@ub.edu)

Valentí Bosch (vbosch@ub.edu)

Marc Ribó (mribo@ub.edu)

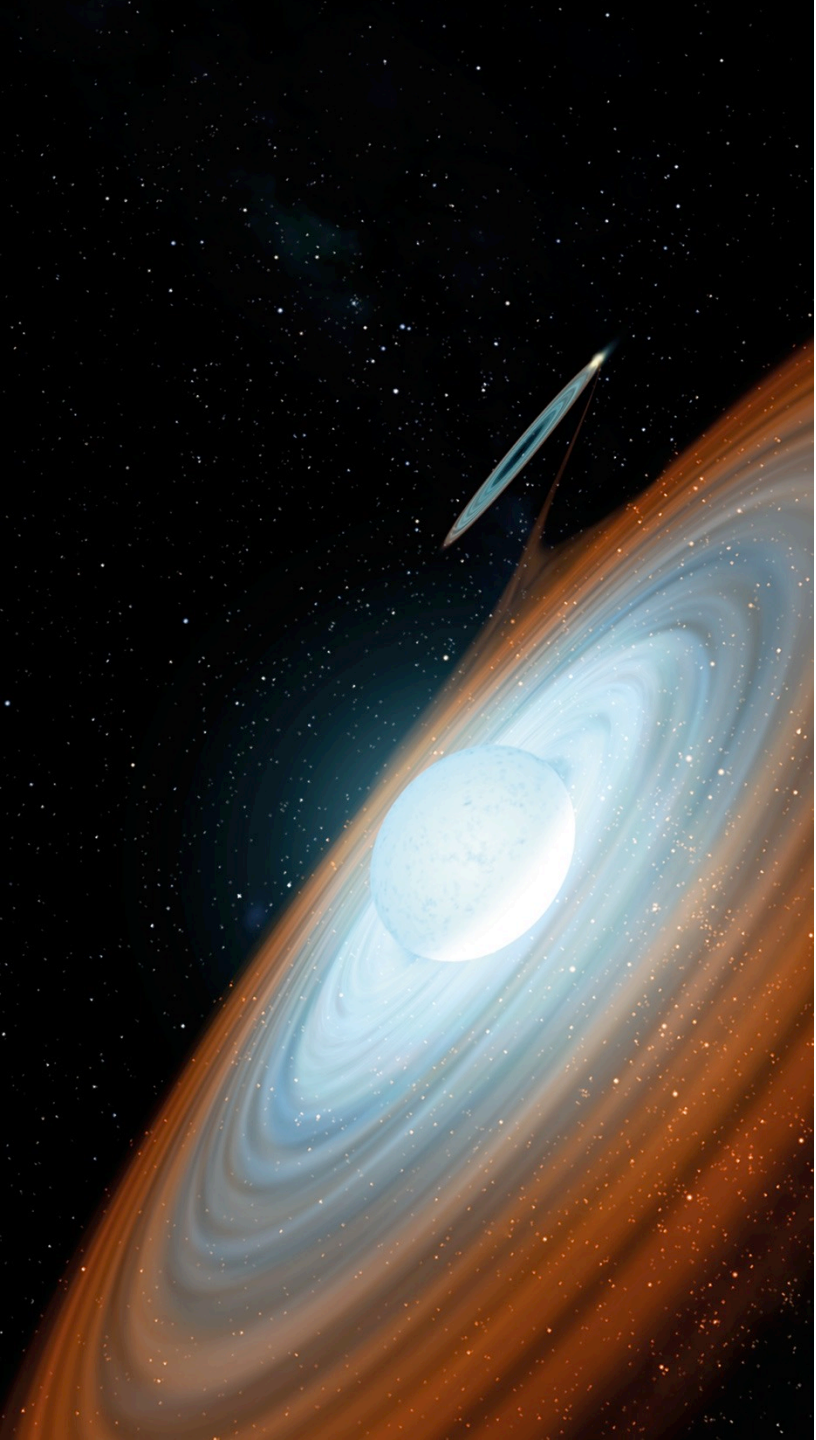
(<https://icc.ub.edu/research/high-energy-astrophysics>)



UNIVERSITAT DE
BARCELONA

 **ICCUB**
Institut de Ciències del Cosmos

 EXCELENCIA
MARÍA
DE MAEZTU



Goals:

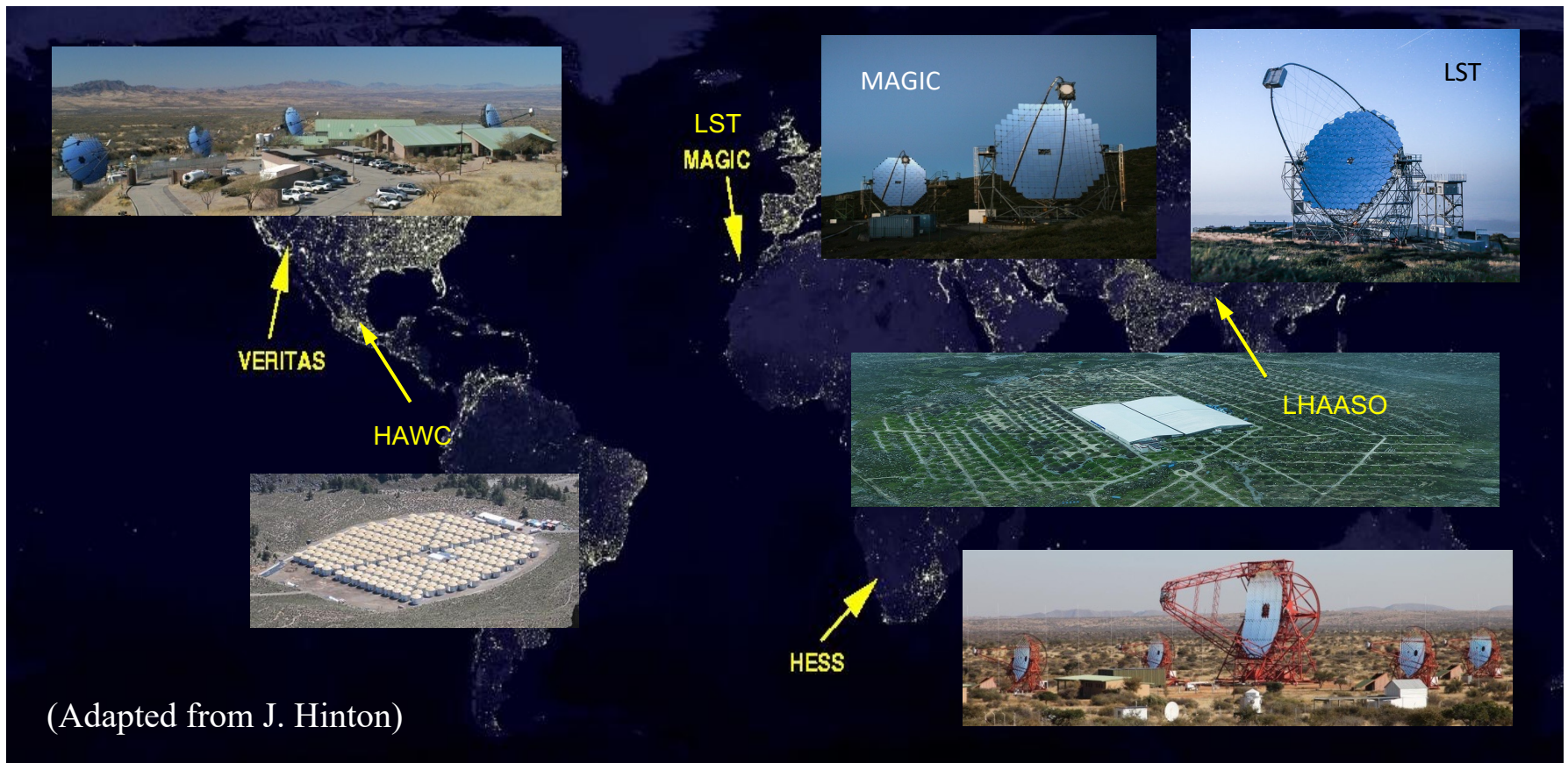
To train, from the observational and theoretical point of view, a group of future researchers in HE astrophysics.

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

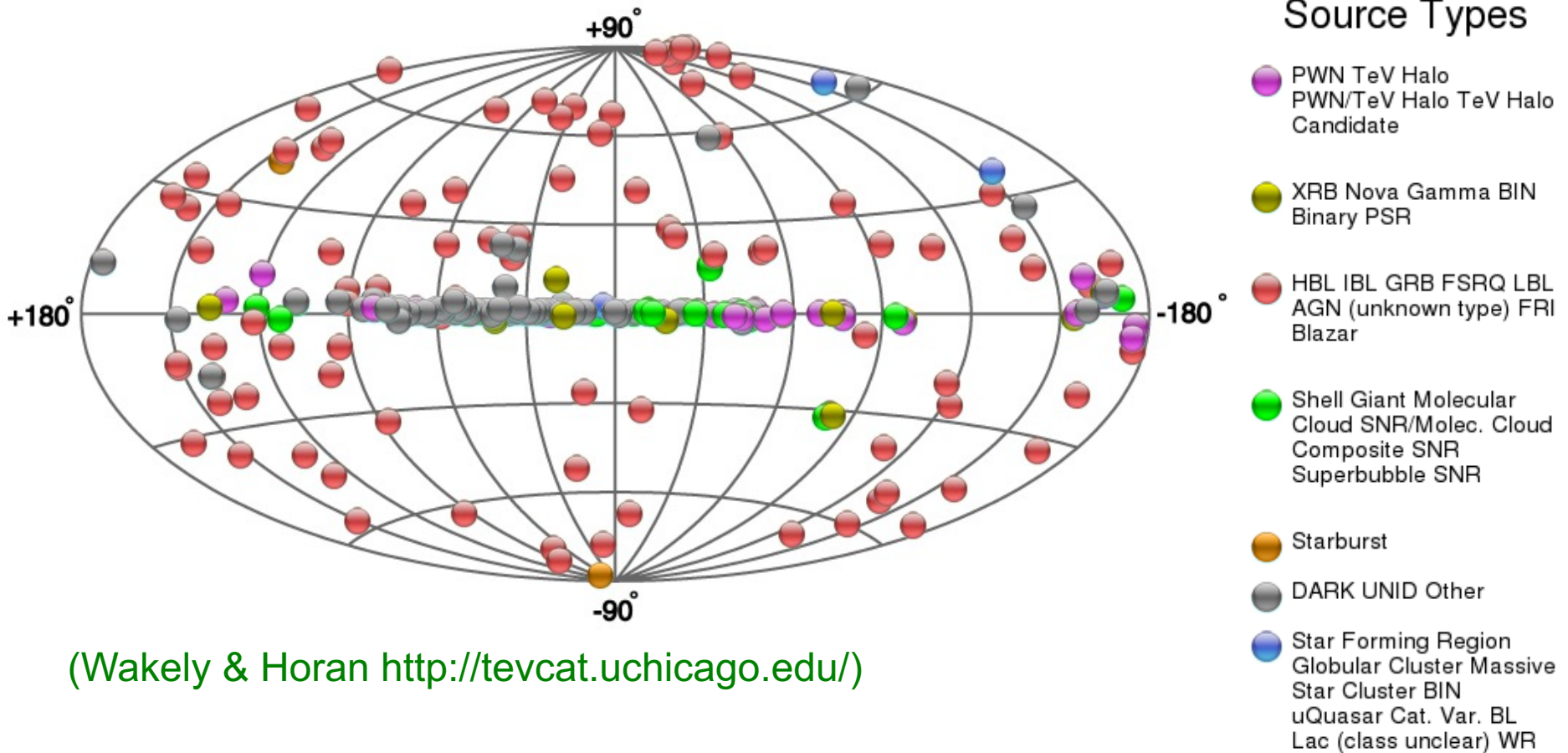
Current generation of TeV facilities:

- ~20 years of data from HESS, MAGIC and VERITAS.
- 6 years of data by HAWC.
- 2 yr of CTA/LST data → Soon much better sensitivity than previous facilities.
- 2 yr of data from LHAASO → PeVatrons everywhere!



TeV sources known

2023 Sep: **272** sources known! **~34%** extragalactic, **~33%** galactic, **~33%** unid

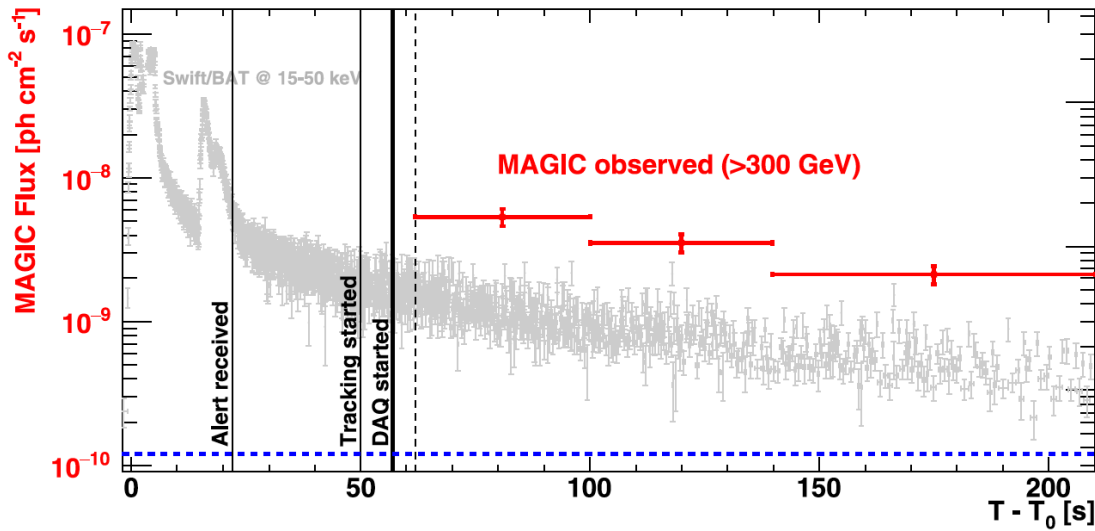


(Wakely & Horan <http://tevcat.uchicago.edu/>)

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.

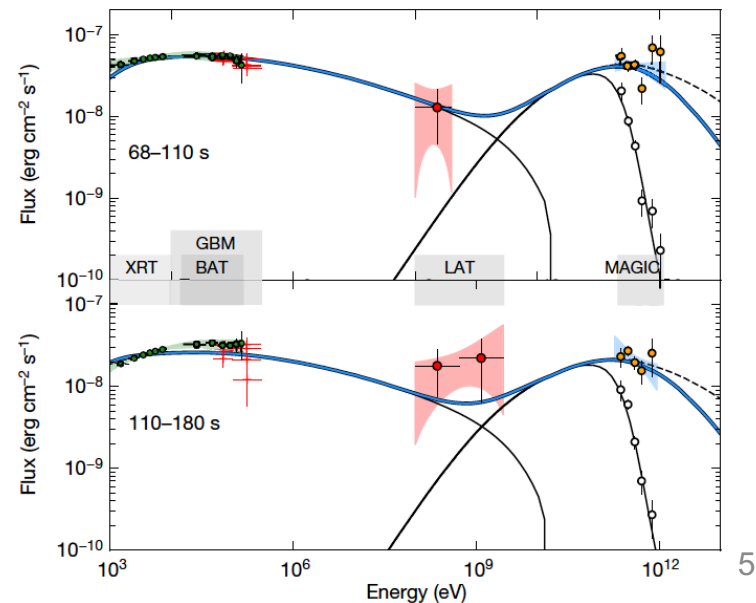
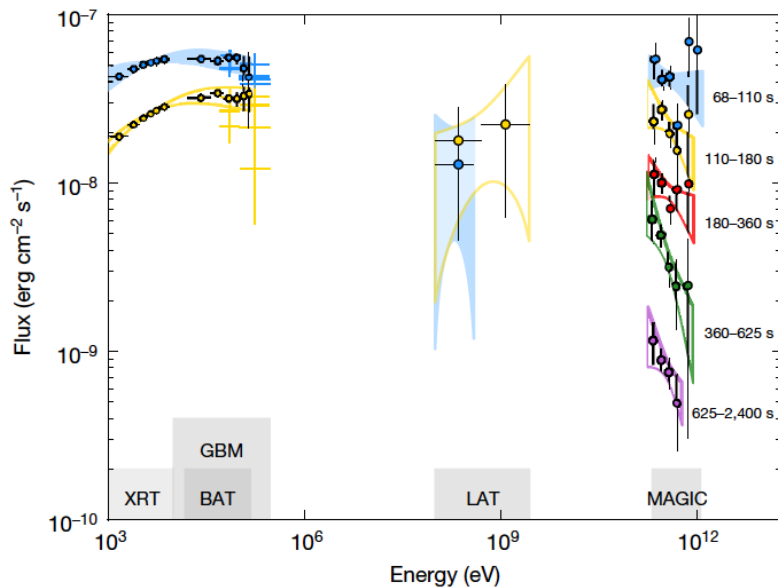
Redshift: $z=0.425$.

Detected **above 300 GeV**.

New IC component.

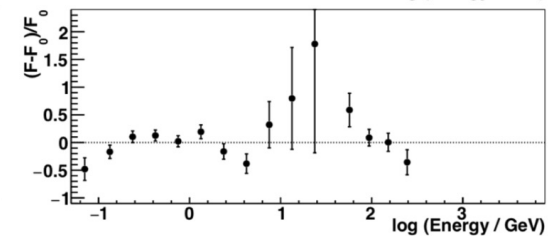
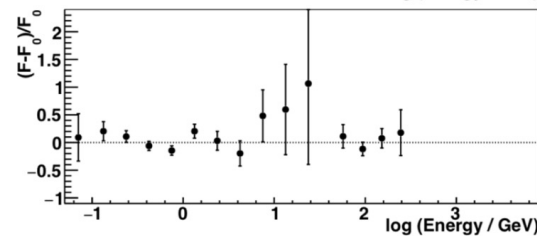
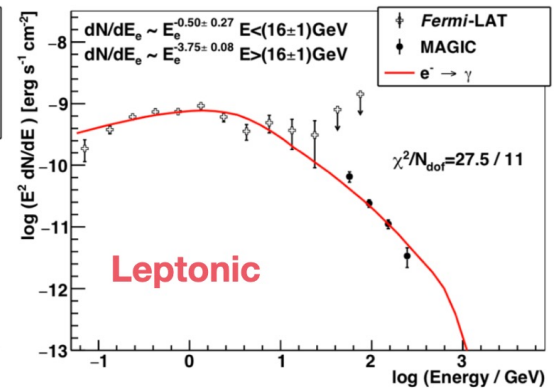
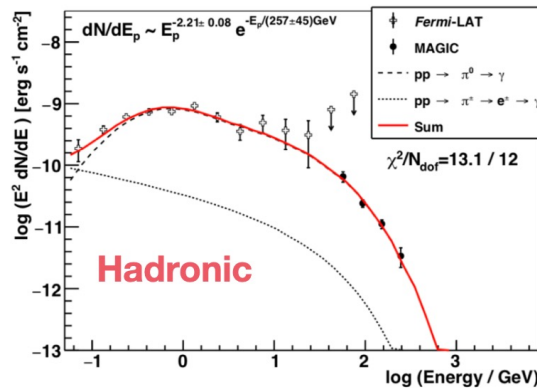
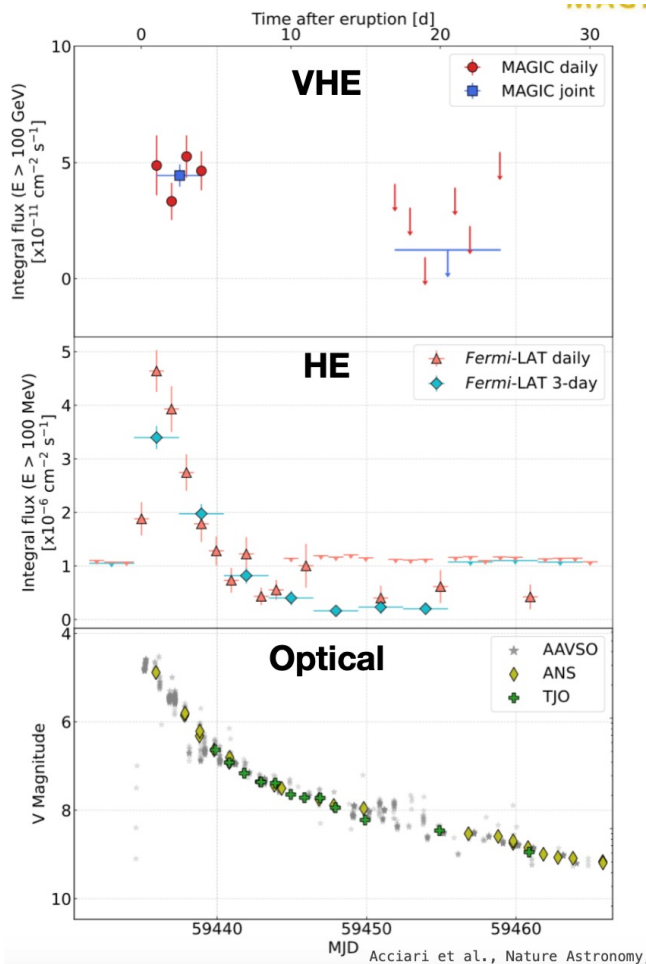
(MAGIC Collaboration 2019a & MAGIC

Collaboration et al. 2019b).



Novae.

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



Acciari et al. Nat. Astronomy, 2022

Different arguments favor **proton acceleration**:

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

Program: 26 h: 24 h lectures, 1 h exam, 1 h presentation

0. Introduction - Messengers from space

JMP, 12 sessions
13 Sep – 4 Oct

- 0.1. Cosmic rays
- 0.2. Neutrinos
- 0.3. Gravitational waves
- 0.4. Electromagnetic waves



1. Particle acceleration and radiation mechanisms in high energy astrophysics

- 1.1. Particle acceleration mechanisms
- 1.2. Diffusion
- 1.3. Energy losses
- 1.4. Radiative processes (thermal, synchrotron, IC scattering, Bremsstrahlung, hadronic, particle annihilation)

2. Accretion and ejection in relativistic sources

VB, 5 sessions
5 – 16 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
23 – 26 Oct

- 4.1. High-energy gamma-ray detectors and satellites
- 4.2. Imaging atmospheric Cherenkov telescopes.
- 4.3. Galactic HE γ -ray sources (pulsars, PWN, SNR, X-ray and γ -ray binaries, etc.)
- 4.4. Extragalactic HE γ -ray sources (AGNs, GRBs, EBL, etc.)
- 4.5. Fundamental physics at HE γ -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 (13/09/2023 – 26/10/2023)
(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 and discussion

Evaluation:

- Participation 20%
- Exam 30%
- Written work 20%
- 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

Master Thesis proposals

Non-thermal emitters in Orion A

Advisors: Valentí Bosch and Gemma Busquet

Can compact accelerators inject PeV cosmic rays in the interstellar medium?

Advisor: Valentí Bosch

On the detectability of isolated black holes in molecular clouds

Advisor: Valentí Bosch

Transient sources with the LST-CTA

Advisor: Pol Bordas and Marc Ribó

Galactic sources with the Cherenkov Telescope Array

Advisor: Pol Bordas

Opportunities

The project PID2022-136828NB-C41 (AYA2022)

PI: Valentí Bosch-Ramon and Josep M. Paredes

Studying the Outflows of High-Energy Sources: observations, analytical modeling, and numerical simulations (SOHES)

is looking for a highly motivated student to apply for a grant to conduct a PhD Thesis on:

- Non-thermal sources in the Orion star forming region (Advisors G. Busquet and V. Bosch).

The project PID2022-138172NB-C43 (FPN2022)

PI: Marc Ribó and Pol Bordas

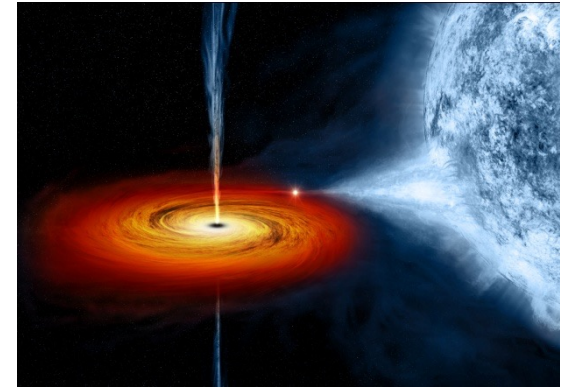
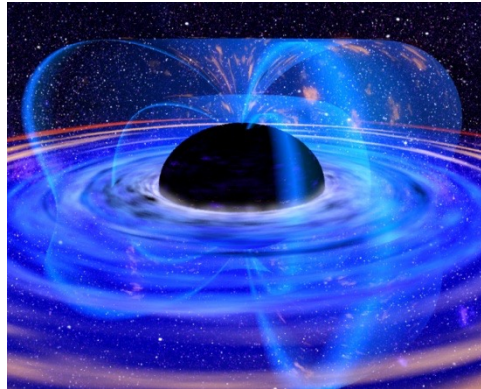
Gamma-Ray Astronomy with CTA-North and MAGIC, Project 1 (CTAMAGIC1)

is looking for a highly motivated student to apply for a grant to conduct a PhD Thesis on:

- VHE astrophysics of transient sources with the LST-CTA (Advisors P. Bordas and M. Ribó).

Master in Astrophysics, Particle Physics, and Cosmology
Academic year 2023-2024

High-energy astrophysics



Josep Maria Paredes (jmparedes@ub.edu)

Valentí Bosch (vbosch@ub.edu)

Marc Ribó (mribo@ub.edu)

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



UNIVERSITAT DE
BARCELONA

 **ICCUB**
Institut de Ciències del Cosmos

 EXCELENCIA
MARÍA
DE MAEZTU