Swift's Role in Shaping MAGIC's Multiwavelength High-energy Astrophysics

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Introduction to MAGIC [1]

- First light: 2004
- Location: La Palma, Canary Island
- No. of telescopes: 2
- Mirror: 17 m diameter each
- Field of view: 3.5°
- Trigger area: 4.30 deg^2
- Angular resolution: ~0.1°
- Energy range: ~30 GeV to tens of TeV
- Repositioning speed = 27s /180° for fast follow-up observations
- Automatic repositioning in case of alerts

Fig. 1: MAGIC looking at the Milky Way! *(Image credit: Josue Friedrich)*

Why MAGIC needs Multiwavelength (MWL) support?

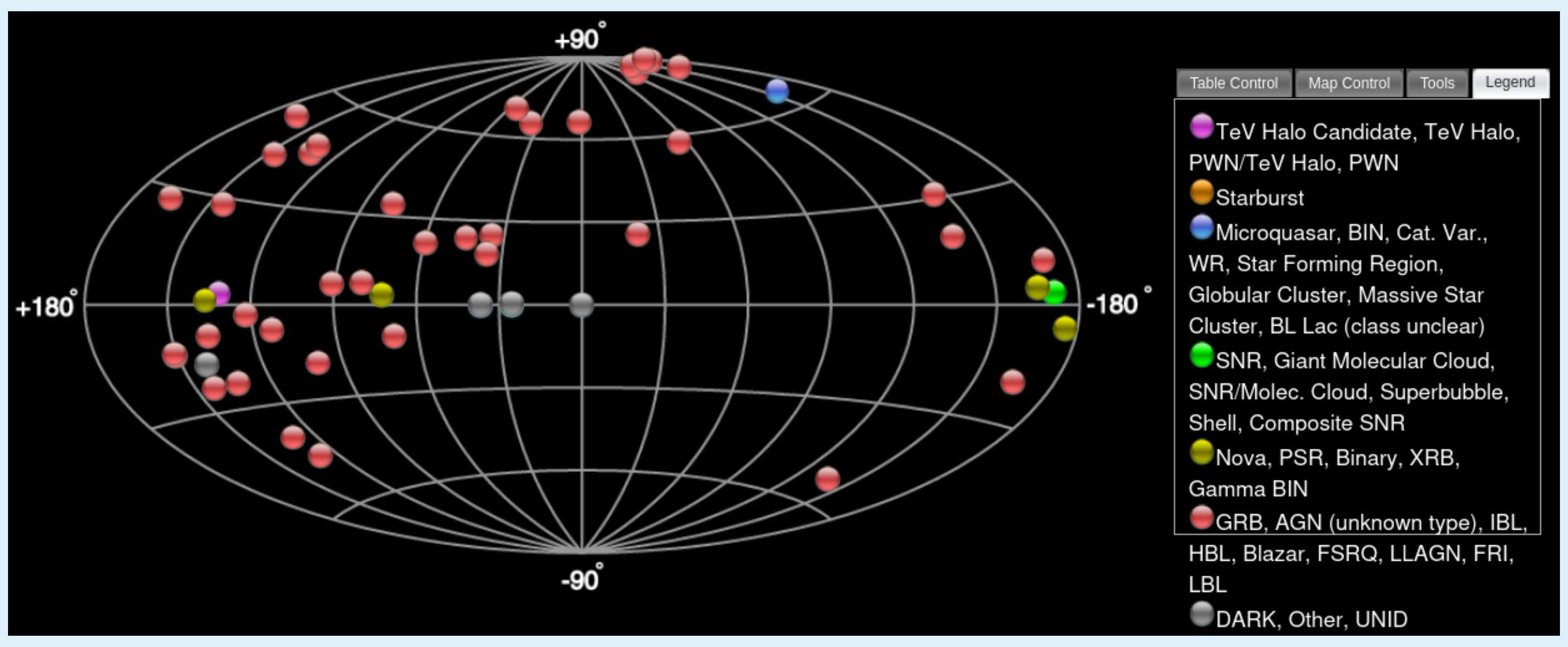
Gamma-ray observations alone provide limited context, so MWL data—from X-rays to optical/UV and radio—is essential. Many gamma-ray sources (e.g., AGNs and GRBs) emit via synchrotron and inverse-Compton processes, with the synchrotron peak often in the X-ray band while inverse-Compton scattering produces VHE gamma-rays. X-ray data are crucial because they offer complementary insights into the source's environment and dynamics, helping to identify sources, reveal spectral properties, track variability, and even probe accretion disk behavior in black hole systems. By combining Swift-XRT data with MAGIC observations, we can constrain electron energy distributions and magnetic fields, pinpoint emission regions and particle acceleration, rapidly localize transients like GRBs, and detect absorption features from intervening material.

Historical Perspective: Evolution of the MAGICal-Swift bond

MAGIC-I entered its commissioning phase in October 2003 with its first 17-m telescope at La Palma. It became stereo when MAGIC-II started taking data in July 2009. In late 2004, the Swift Gamma-Ray Burst Explorer (now the Neil Gehrels Swift Observatory) was launched to rapidly detect GRBs and capture their X-ray and optical/UV afterglows. Swift's fast repointing (≈75s/50°) and broad spectral coverage provided near-simultaneous MWL data, enabling early coordinated observations with MAGIC telescopes.

This synergy is a key for understanding transient phenomena—such as GRBs and AGN flares—by correlating TeV γ-ray data from MAGIC with lower-energy emissions from Swift. Over the past two decades, the collaboration has evolved from rapid, reactive observations to comprehensive, long-term MWL campaigns. Advancements in instrumentation and refined analysis techniques of both MAGIC and Swift have enhanced sensitivity, enabling detailed spectral studies and precise tracking of fast variability.

Some Key Results



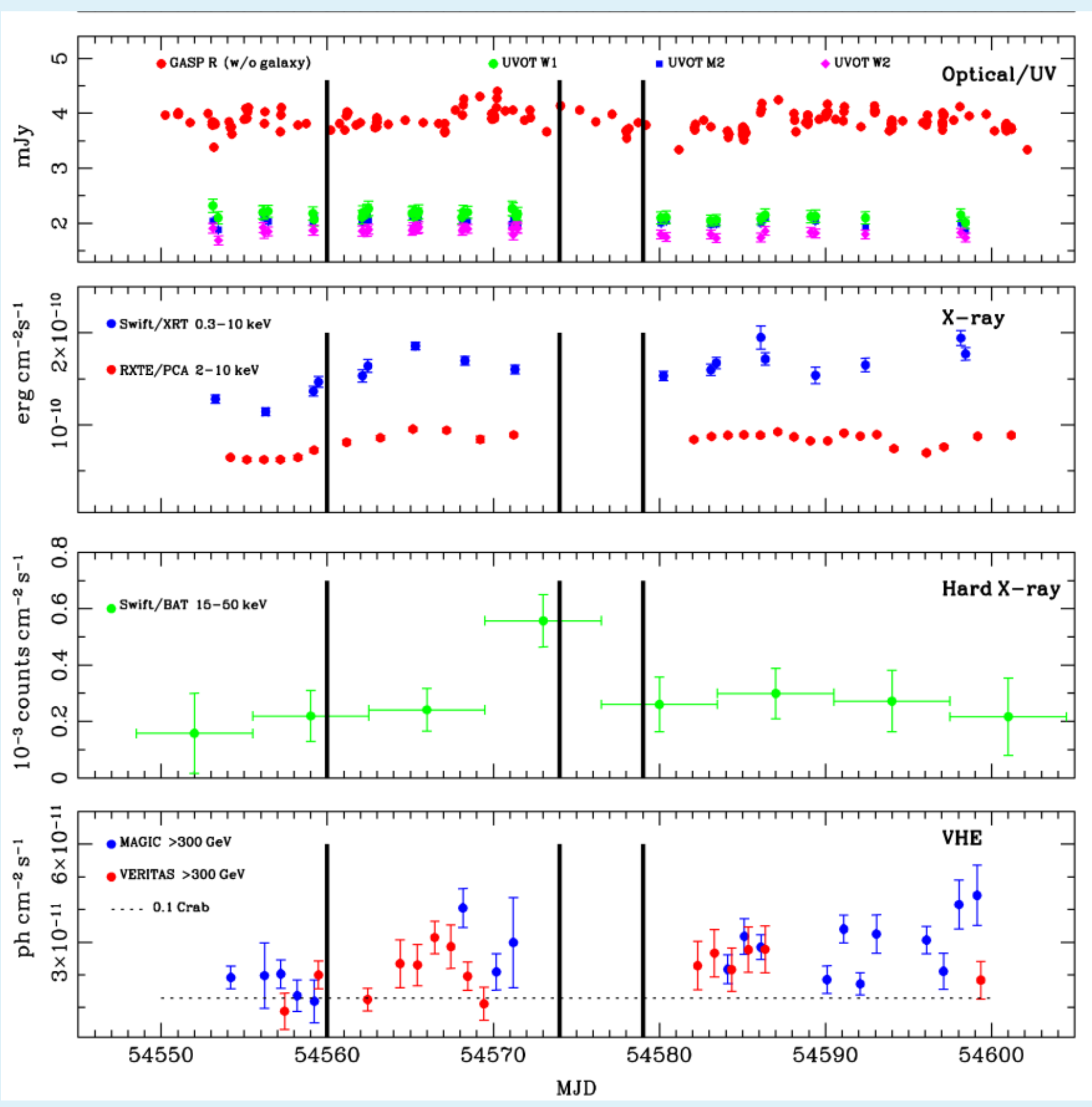
Source type	Numbers
Shell	1
HBL	20
IBL	4
LBL	1
PSR	2
XRB	1
FSRQ	6
GRB	3
PWN	3
Binary	1
Blazar	3
UNID	5
BL Lac (class unclear)	1
AGN (unknown type)	1

Fig. 2: Skymap from TeVCat [2] showing the position of the TeV γ-ray sources discovered by MAGIC.

Table 1: Statistical overview from TeVCat [2] of the TeV γ-ray sources discovered by MAGIC. In total there are 52 sources discovered by MAGIC yet, out of which ~92.3% were followed up by Swift.

1) Mrk 501 (2008): MWL campaign in 2008 found a marginally significant (~3σ) positive correlation with zero time lag. While X-ray to VHE correlation in Mrk 501 has been observed during flaring states, this is the first report for a low X-ray/VHE state, suggesting similar emission mechanisms in both cases. [3]

Fig. 3: MWL light curve for Mrk 501. The thick black vertical lines in all the panels delimit the time intervals corresponding to the three different epochs. The horizontal dashed line in the bottom panel depicts 10% of the flux of the Crab nebula above 300 GeV. [3]



2) GRB190114C (2019): The first GRB detected at TeV energies, showing clear inverse Compton emission. Triggered by instruments including Fermi-GBM, Fermi-LAT, and Swift-BAT, Swift's X-ray/UV data confirmed the synchrotron origin of the lower-energy component, while MAGIC's TeV observations provided direct evidence of inverse Compton scattering. Combined MWL data support a synchrotron self-Compton (SSC) model, advancing our understanding of GRB physics. [4] [5]

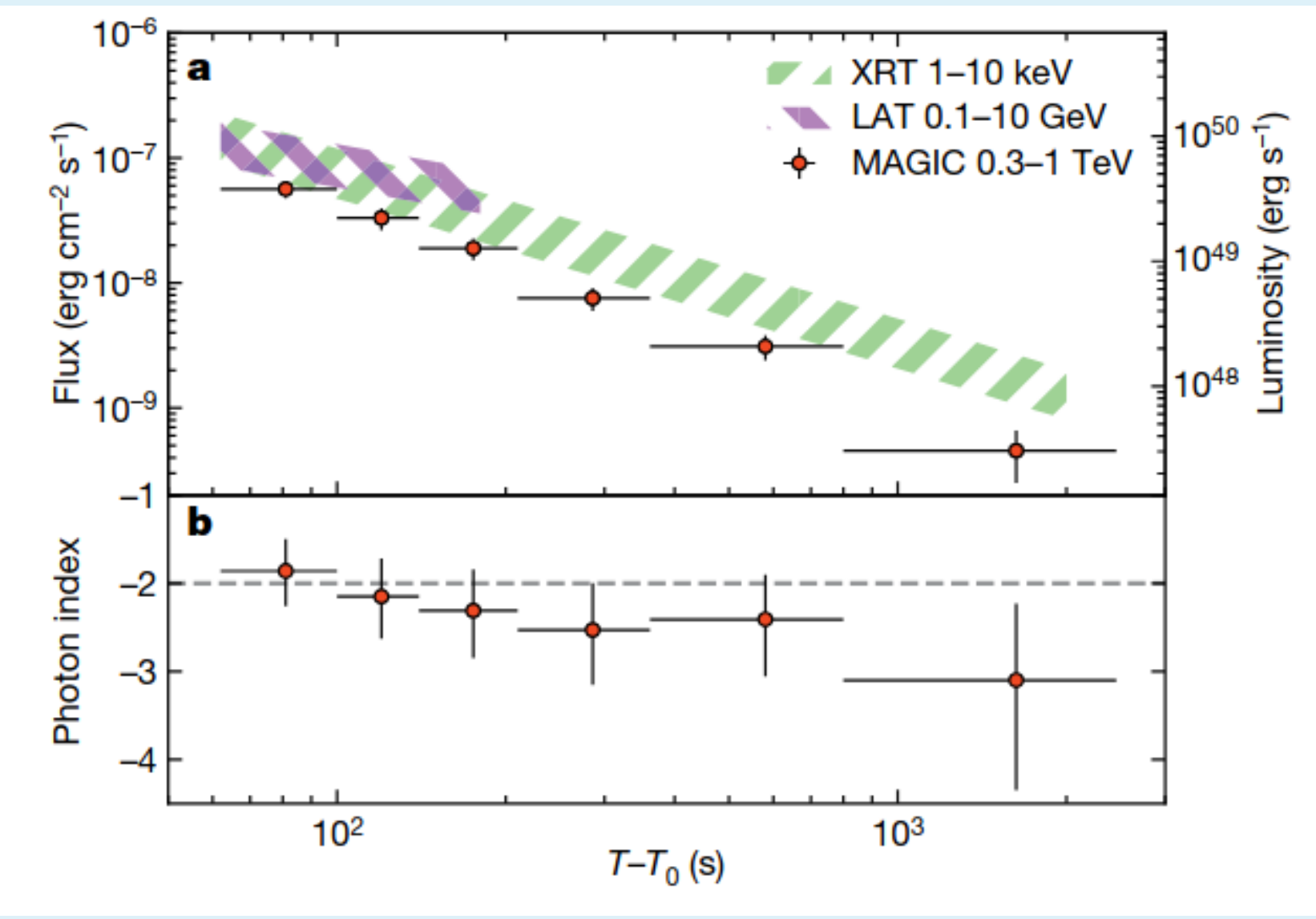


Fig. 4: Light curves in the keV, GeV and TeV bands, and spectral evolution in the TeV band for GRB 190114C. [4]

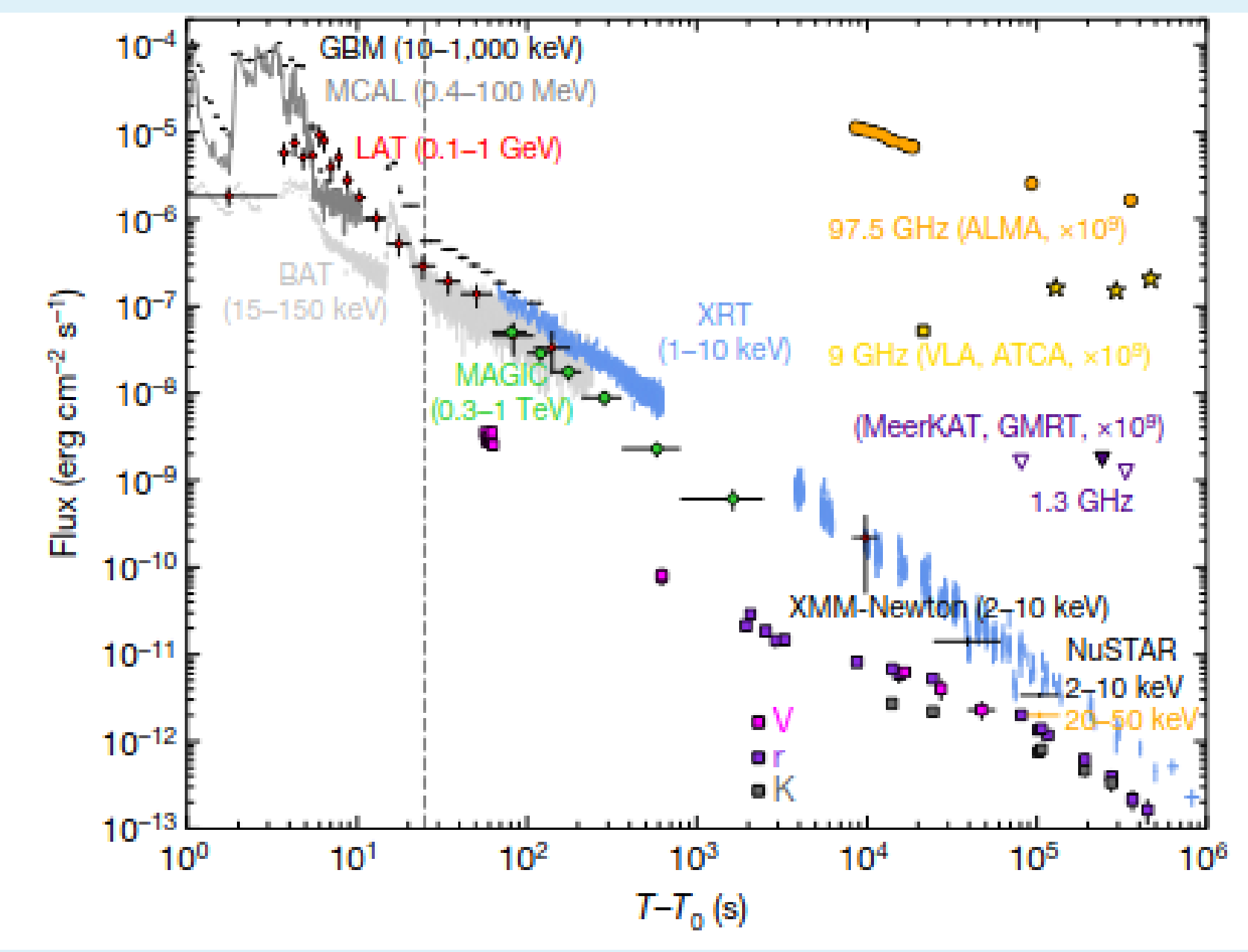


Fig. 5: MWL light curves of GRB 190114C. [5]

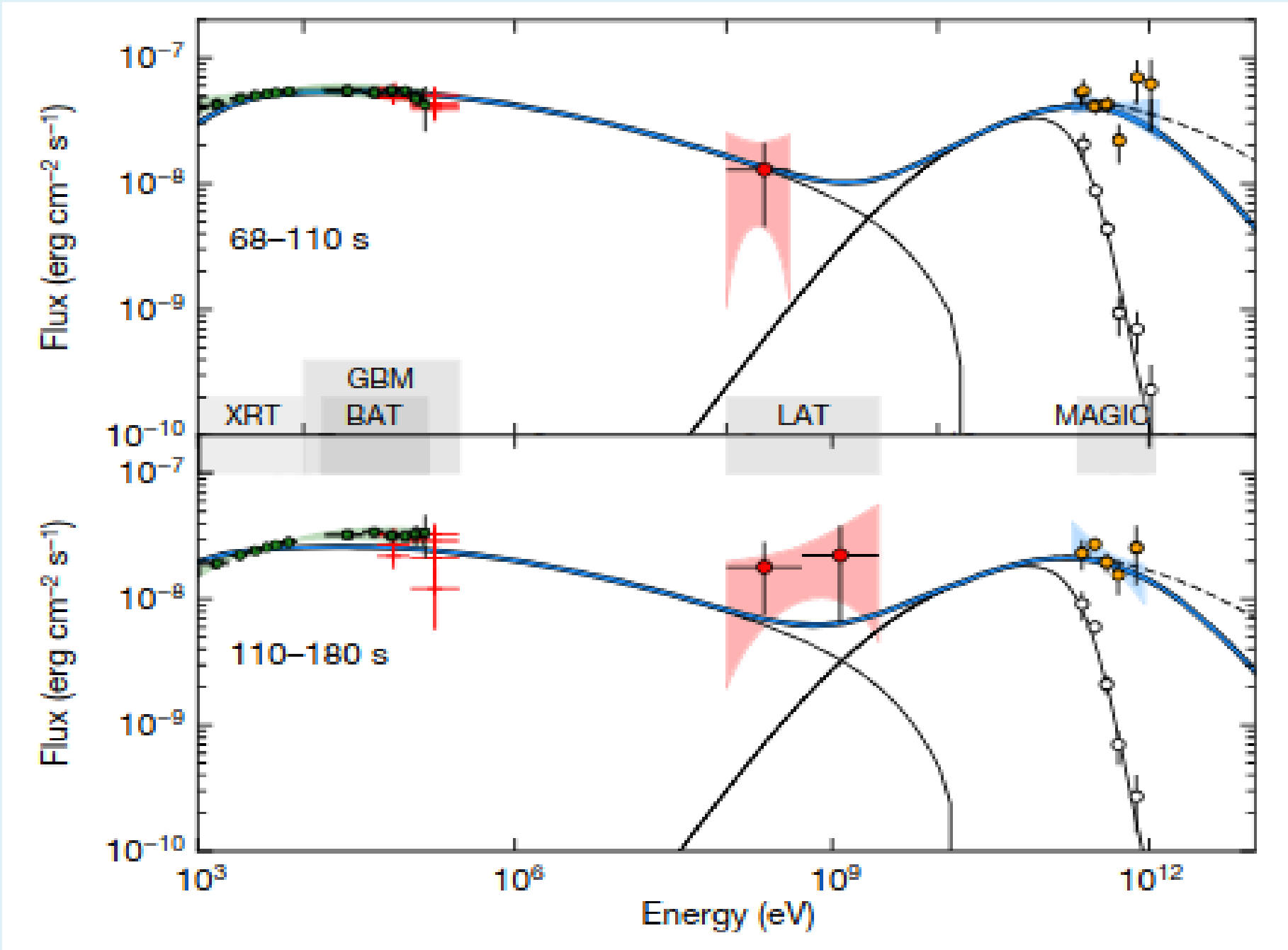


Fig. 6: Broadband spectra modelling for 68–110 s and 110–180 s. Thick blue curve: synchrotron plus SSC afterglow fit, thin solid lines: synchrotron and observed SSC components, dashed lines: SSC without internal γ–γ opacity, and empty circles: observed MAGIC spectrum (uncorrected for EBL attenuation). [5]

3) 3C 279 (2009): The first FSRQ detected in TeV energy γ-rays by MAGIC in 2006 was reobserved during a major optical flare in January 2007 and again from December 2008 to April 2009 after a Fermi alert. In January 2009, a low optical to X-ray state observed in Swift's data coincided with MAGIC's non-detection of VHE γ-rays, confirming reduced high-energy activity. [6]

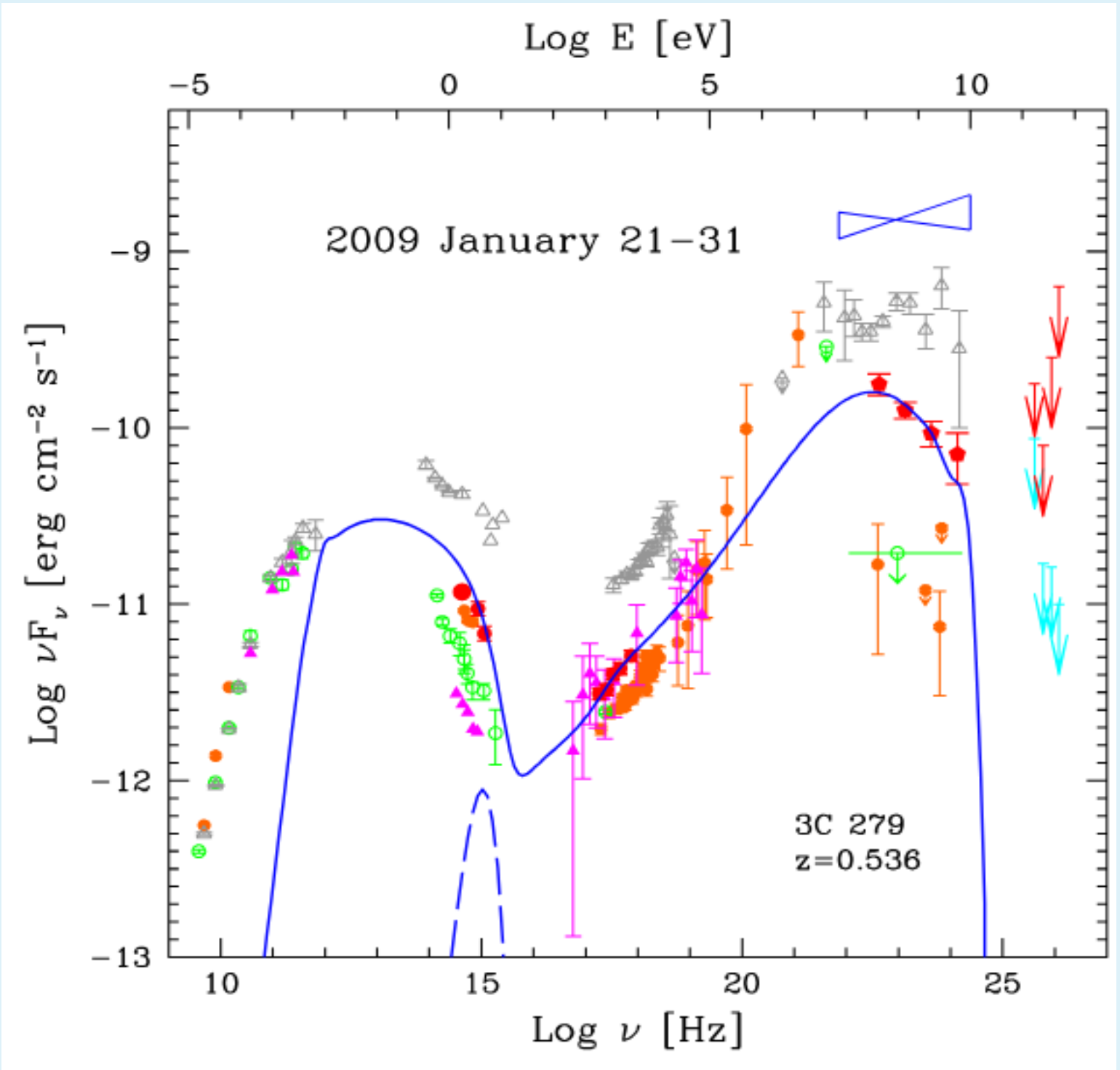


Fig. 7: The SED of 3C 279 on January 2009: MAGIC (taken in the period 21–31 January, red arrows: deabsorbed, cyan arrows: observed), LAT (averaged over the same period, red pentagons), XRT and UVOT (February 1, 2009 red squares) and KVA (January 25, 2009 red filled circle). The SED is modeled assuming the emission region inside the broad line region. The dashed line correspond to blackbody radiation from the IR torus (red). [6]

4) M87 (2018): MAGIC, along with Swift and other observatories, participated in the 2018 M87 campaign, leading to the detection of the first VHE γ-ray flare from M87 since 2010. MAGIC's observations showed that the VHE flux above 350 GeV doubled within ~36 hours. Swift's XRT data revealed a concurrent increase in X-ray flux, confirming the multi-wavelength nature of the event. MAGIC, in coordination with Swift, helped identify the source region of the VHE flare and contributed to constraining emission models. [7]

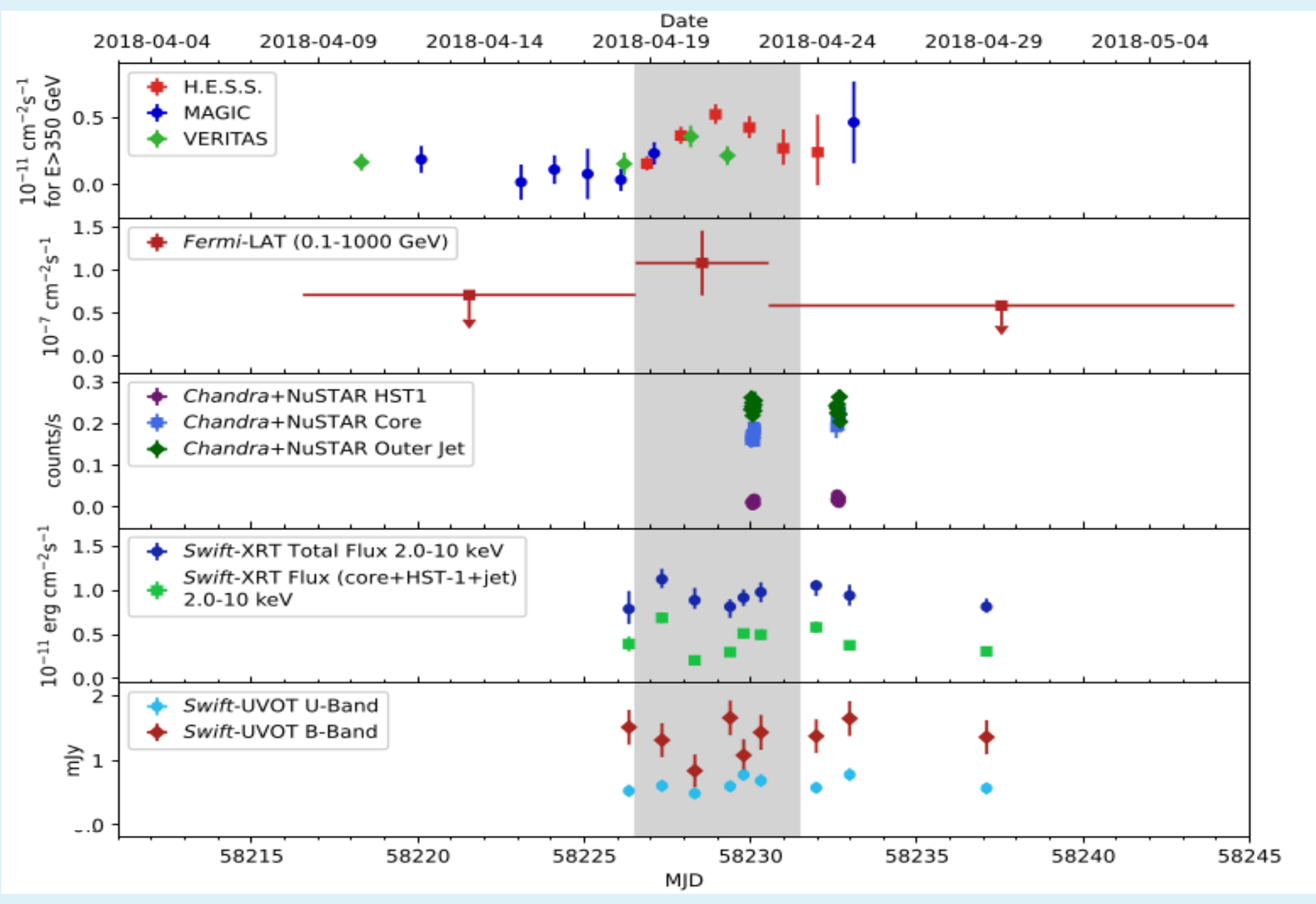


Fig. 8: MWL light curves of M87 taken during the observational campaign covering MJD range 58211–58245. The time period containing the 2008 VHE flare is shaded in grey. [7]

Summary

The long-standing MAGIC–Swift collaboration has paved the way for a robust multi-observatory network across the electromagnetic spectrum, shaping new strategies in high-energy astrophysics. Both instruments are engineered for rapid response: Swift autonomously slews within 20–75 seconds after detecting a GRB with its Burst Alert Telescope, allowing its narrow-field instruments (XRT and UVOT) to quickly capture X-ray and UV/optical afterglows, while MAGIC's lightweight 17-m telescopes can repoint in under 27 seconds for a 180° rotation to capture fleeting VHE gamma-ray emissions. This coordinated approach, where rapid alerts from Swift prompt immediate responses from MAGIC and MAGIC can request ToO from Swift, provides nearly simultaneous MWL data that reveal key details of particle acceleration, cooling, and the interplay between synchrotron and inverse-Compton processes in VHE sources.

References

[1] J. Aleksić et al. 2016, Adtroparticle Physics, Vol. 72, p. 61-75

[2] S. P. Wakely and D. Horan, 2008, ICRC proceedings, Vol. 3, p. 1341–1344.

[3] J. Aleksi´c et al. 2015, A&A 573, A50.

[4] V. A. Acciari et al. 2019, Nature 575, 455–458.

[5] P. Veres, P.N. Bhat et al. 2019, Nature 575, 459–463.

[6] J. Aleksić et al. 2011, A&A 530, A4.

[7] J. C. Algaba et al. 2024, A&A, 692, A140