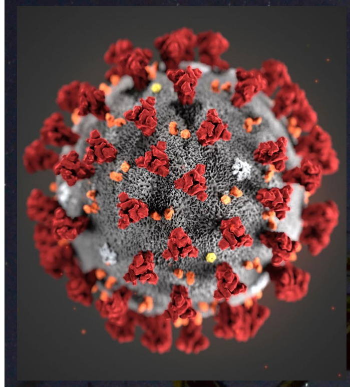
The MAGIC telescopes: status report

David Paneque

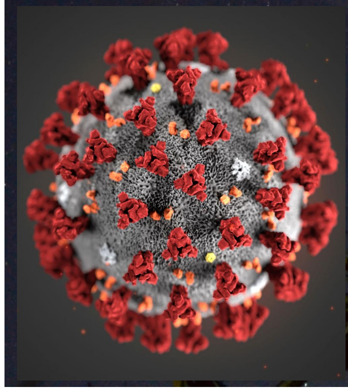
On behalf of the MPP gamma-ray group



The MAGIC telescopes: status report

David Paneque

On behalf of the MPP gamma-ray group



The MAGIC telescopes: status report

David Paneque
On behalf of the MPP gamma-ray group
MPP Project Review 2021

Outline

1 – The MAGIC telescopes
2 – MPP gamma-ray group and contributions to MAGIC
3 – Operation challenges: Covid-19 + Volcano activity
4 – Technical activities in 2021 *(super-brief summary)*
5 – Scientific results in 2021 *(super-brief summary)*
6 – Conclusions

1 – The MAGIC telescopes (and collaboration)

The MAGIC Stereoscopic system

- **MAGIC: Two Imaging Atmospheric Cherenkov Telescopes (IACTs) of 17 meter diameter mirror dish to perform Very High Energy (VHE) gamma-ray astronomy**
  - **Operational energy range: from 50 (20) GeV to >100 TeV**
  - Sensitivity: 0.7% the Crab Nebula flux (above 220 GeV) after 50 hours observation
    - → About 5% of the Crab Nebula flux in 1 hour of observation
- **The strategy** : *operate until (at least) CTA is in scientific operation (**> 2026**)*
  - 2004 : Crab Nebula detected. Start scientific operation of MAGIC 1 (Single telescope)
  - 2006 : MAGIC upgraded with the MUX-DAQ system (More stable and better pulse-information)
  - 2009 : MAGIC upgraded with a second telescope (stereo observations)
  - 2012 : Large upgrade of the hardware system (*improved sensitivity and reliability*)

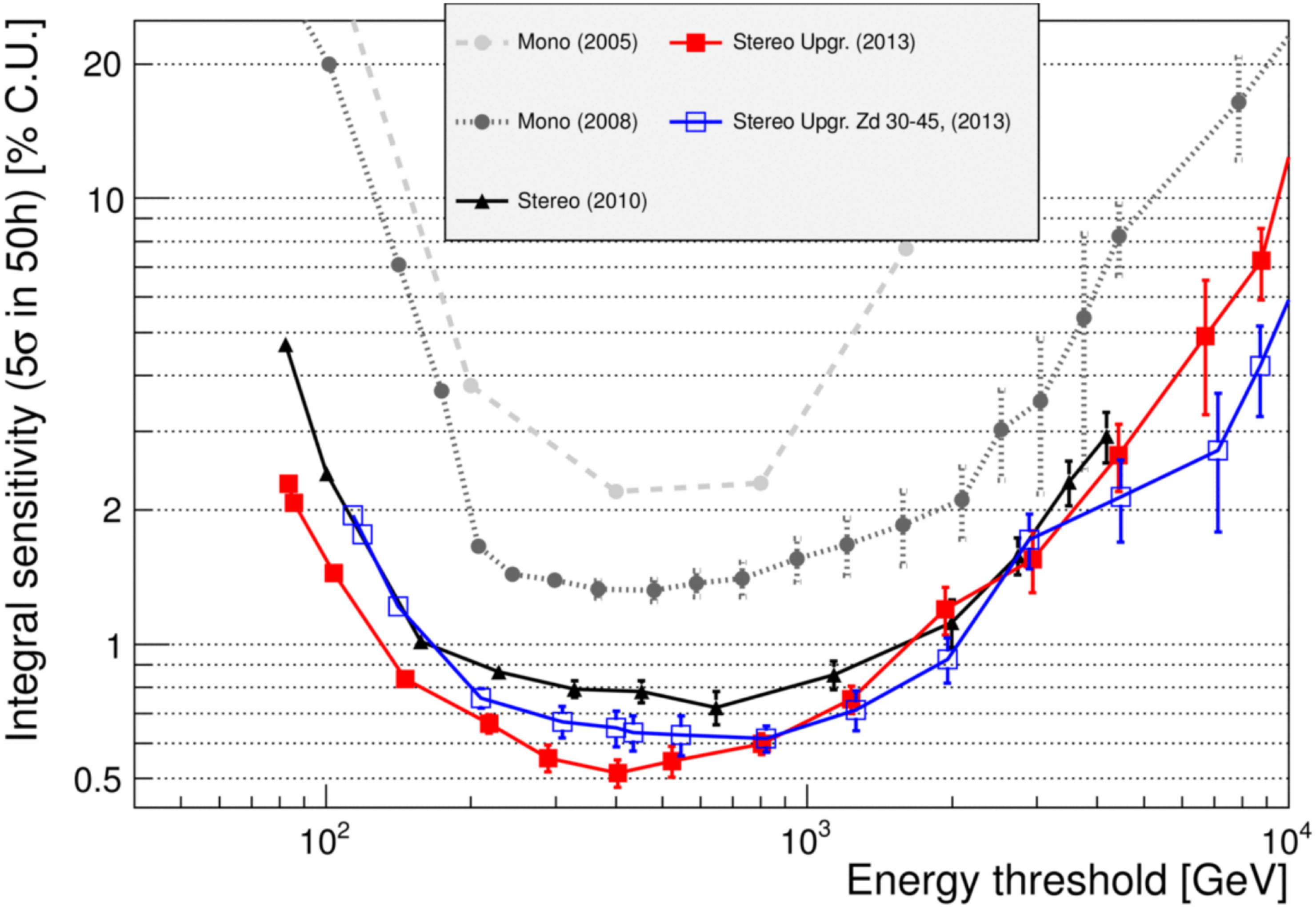
The MAGIC collaboration (*December 2021*)

About **270 scientists** (including affiliated scientists) from **13 countries**

→ **Number of members continues to increase over time…**

Evolution of the MAGIC Performance

4-fold improvement in sensitivity over the last 18 years



Aleksic et al., (MAGIC collab.) Astroparticle Physics 72, 76-92, 2016

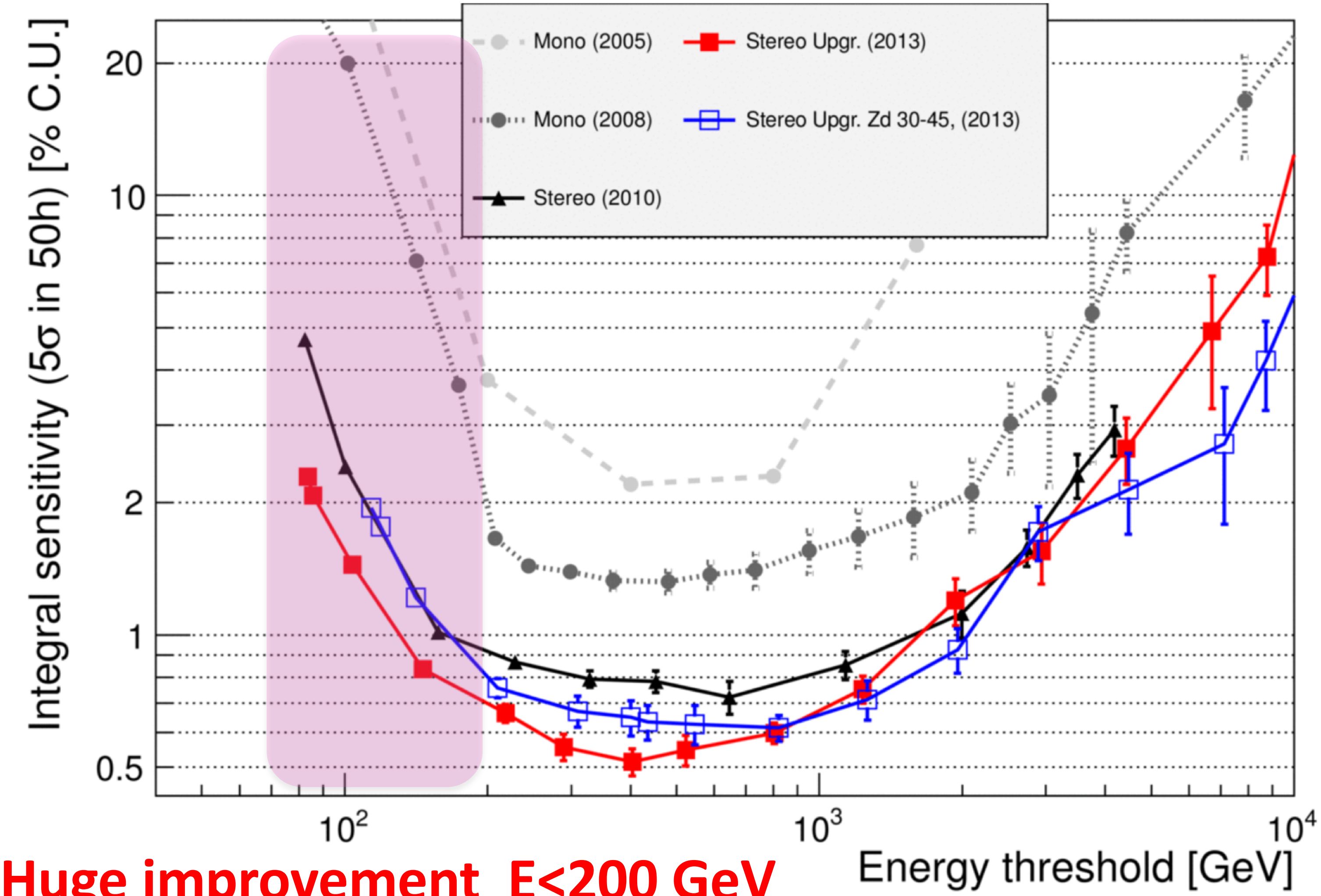
Better sensitivity + Lower energy threshold = More science !!

Evolution of the MAGIC Performance

4-fold improvement in sensitivity over the last 18 years

→ More than 10-fold improvement below 200 GeV

→ Obs. time for detection reduced 100 times below 200 GeV



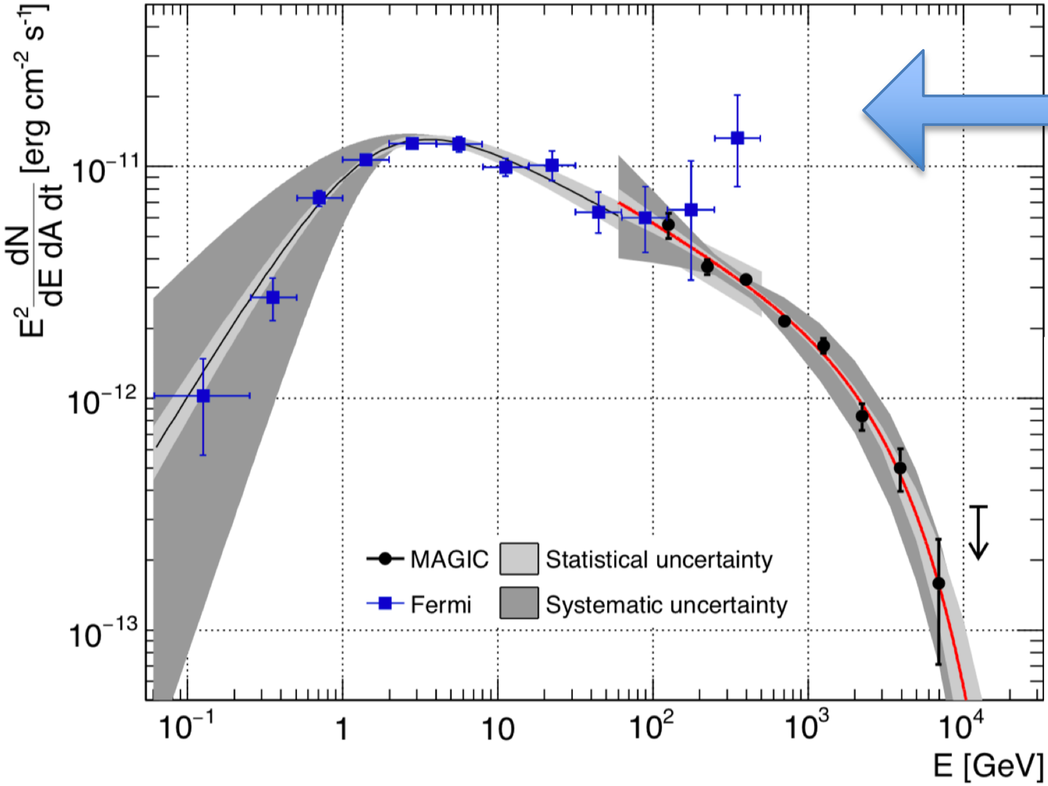
Aleksic et al., (MAGIC collab.) Astroparticle Physics 72, 76-92, 2016

Huge improvement E<200 GeV

Better sensitivity + Lower energy threshold = More science !!

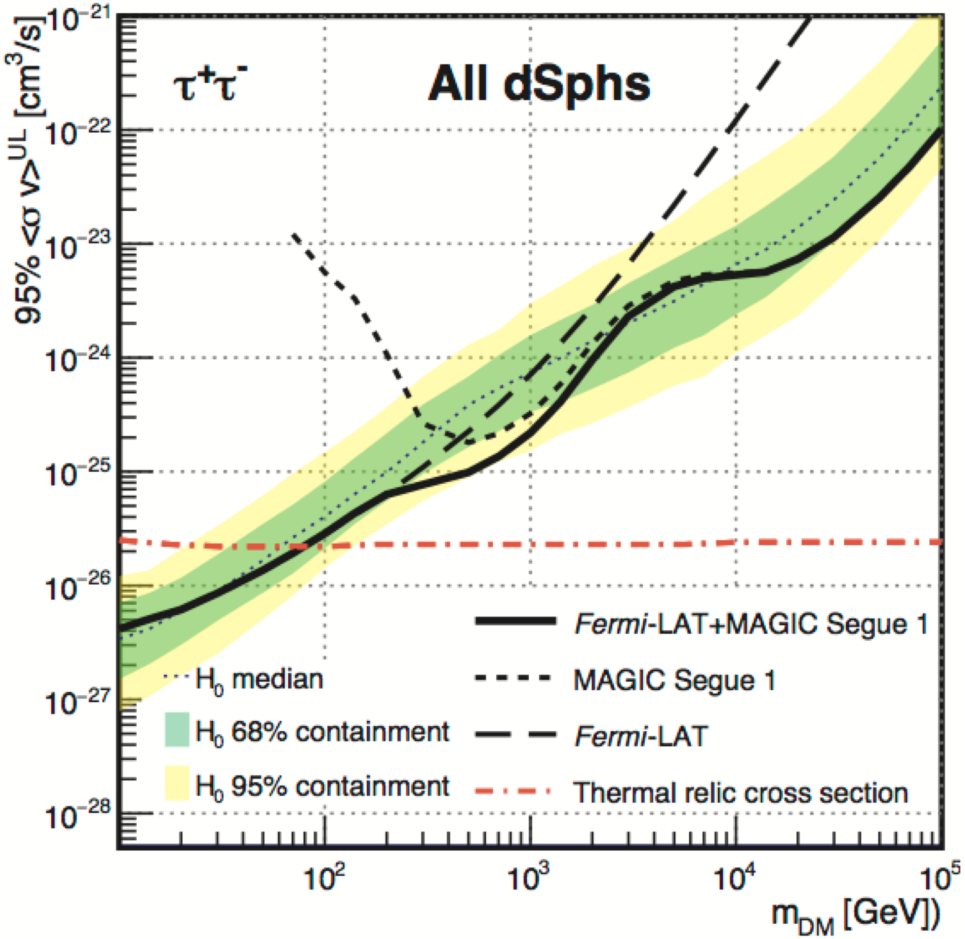
Synergy between *Fermi*-LAT and MAGIC

The GeV and TeV bands are complementary (wealth of behaviours)



Cosmic Ray studies with SNRs (Cassiopea A):
Ahnen et al 2017,
MNRAS 472, 2956

Dark Matter searches (searches with dSphs):
Ahnen et al.,
2016, JCAP 02, 039



2 – The MAGIC MPP group
(and overall contributions)

The MPP experimental gamma-ray group

About 16 Scientists (@2021)

Director: Masahiro Teshima

Senior (3):

Razmik Mirzoyan, Thomas Schweizer, David Paneque

Postdoc (5-3+2+1):

David Green, Martin Will, Moritz Huetten (now @Tokyo),
Yusuke Suda (now @ Hiroshima), Kazuma Ishio (now @Lodz),
Alessio Berti, Axel Arbet-Engels, Seiya Nozaki (sometime in 2022 ?)

ORIGINS Excellence Cluster

The MPP experimental gamma-ray group

About 16 Scientists (@2021)

Director: Masahiro Teshima

Senior (3):
Razmik Mirzoyan, Thomas Schweizer, David Paneque

Postdoc (5-3+2+1):
David Green, Martin Will, Moritz Huetten (now @Tokyo),
Yusuke Suda (now @ Hiroshima), Kazuma Ishio (now @Lodz),
Alessio Berti, Axel Arbet-Engels, ***Seiya Nozaki (sometime in 2022 ?)***

ORIGINS Excellence Cluster

PhD Students (5-1+1+2): Lea Heckmann, Yating Chai, Alexander Hahn,
Juliane van Schenperberg, Giovanni Ceribella (now @Tokyo),
Giorgio Pirola, **Jarred Green (Jan2022), Felix Schmuckermaier (Jan2022)**

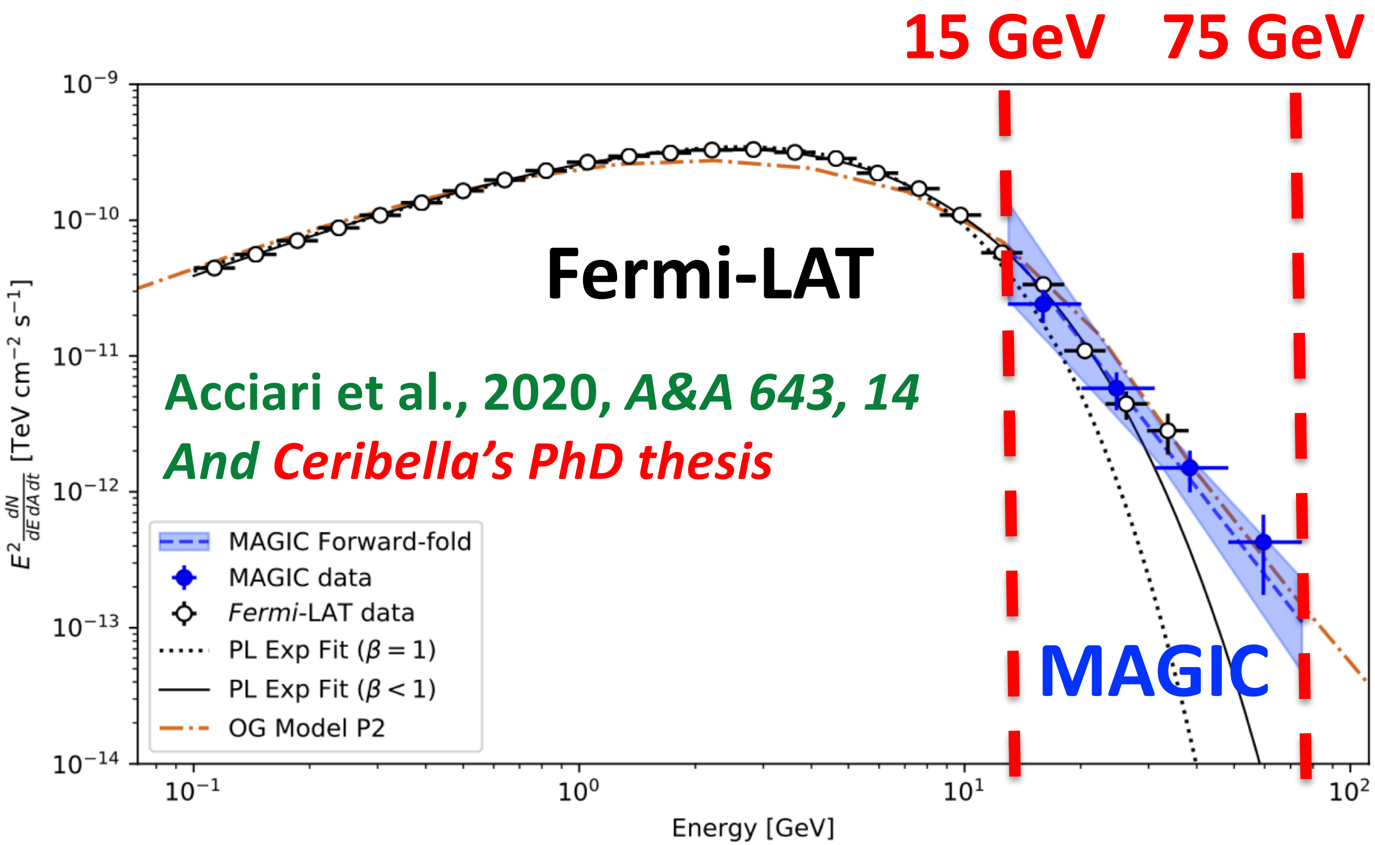
Undergraduate (3-1):
Marine Pihet, Elli Jobst, Susanne Weber, Felix Schmuckermaier (@MPP)

The MPP experimental gamma-ray group

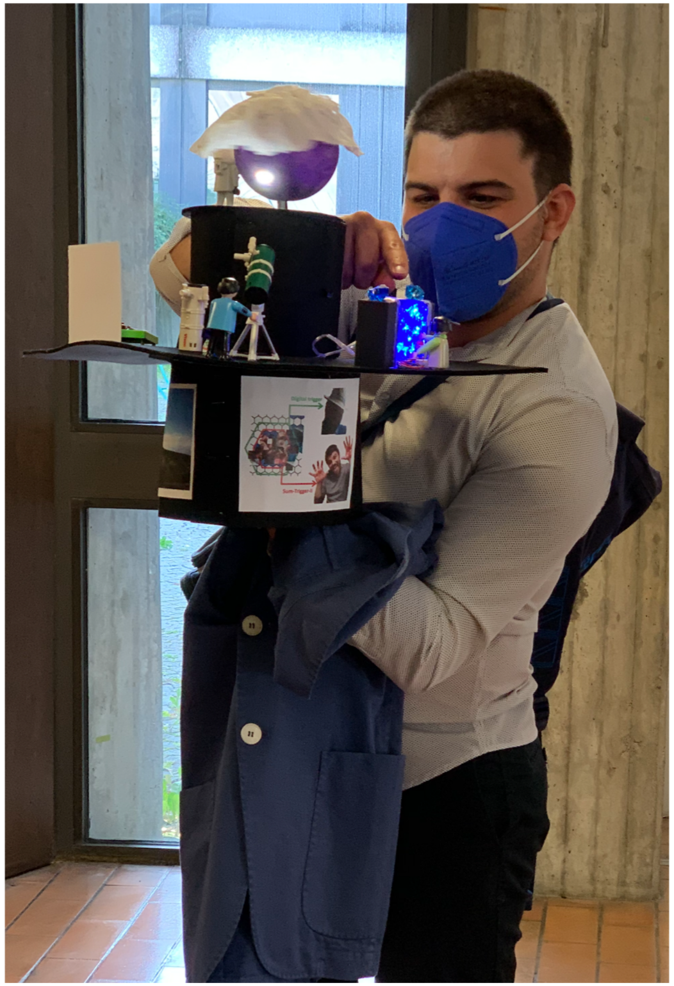
Sum-Trigger performance paper

F. Dazzi, T. Schweizer, **G. Ceribella**, *et al,*
IEEE Transactions on Nuclear Science, vol. 68, no. 7, pp. 1473-1486, July 2021, doi: 10.1109/TNS.2021.3079262
And Ceribella's PhD thesis

Discovery of Geminga pulsar at VHE



Giovanni Ceribella
PhD thesis defense (Sep14, 2021)



On October 1st, he was already working in Tokyo

Giovanni Ceribella

For the invaluable work on the Sum-Trigger and the outstanding contributions to the publication of the first detection of the Geminga pulsar at very-high-energy gamma rays

Florian **2021** Goebel
Prize

The MPP experimental gamma-ray group

About 16 Scientists (@2021)

Director: Masahiro Teshima

Senior (3):
Razmik Mirzoyan, Thomas Schweizer, David Paneque

Group Secretary (also official MAGIC collaboration secretary):
Diana Werner *(helps keeping low entropy in the system)*

Mechanical + Engineering departments:

The gamma-ray group has a strong support from the mechanical and electrical engineer departments from MPP, which is absolutely needed for the construction and operation/maintenance of the telescopes
O. Reimann, T. Haubold (→Alfons Eiterer), D. Fink, M. Fras, S. Horn, D. Strom, H. Wetteskind, S. Tran, J. Besenrieder, C. Jablonksi, R. Stadler, W. Haberer, S. Schmidl, T. Dettlaf…

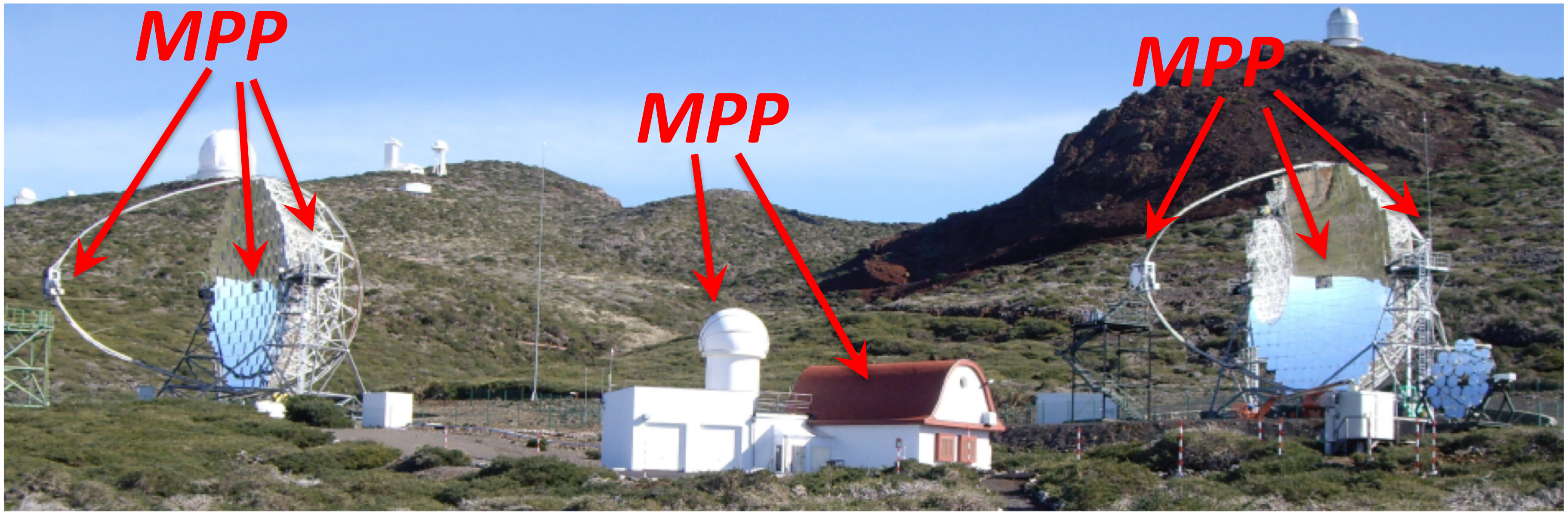
MPP activities with/within MAGIC

MPP is the group with most resources within the MAGIC collaboration

→ ***MAGIC was born at MPP (E. Lorenz & R. Mirzoyan in mid 90s)***

→ ***Most hardware was designed, built and now maintained by MPP***

2 Telescope structures (cooperation with company MERO)
2 Telescope cameras + 2 Calibration systems
LIDAR + MAM (for monitoring atmospheric conditions)
Sum-Trigger-II (for lowering energy threshold)
Support instrumentation for Very Large Zenith Angle observations
Mirror production with novel technology (for durability and easy clean)



MPP activities with/within MAGIC

MPP is the group with most resources within the MAGIC collaboration

→ ***MAGIC was born at MPP (E. Lorenz & R. Mirzoyan in mid 90s)***

→ ***Most hardware was designed, built and now maintained by MPP***

Involvement at all levels: Organizational, hardware, software, science

In year 2021

Masahiro Teshima
MAGIC-LST contact
Chair of the Time Allocation Committee

Razmik Mirzoyan
Deputy chair of Collaboration Board

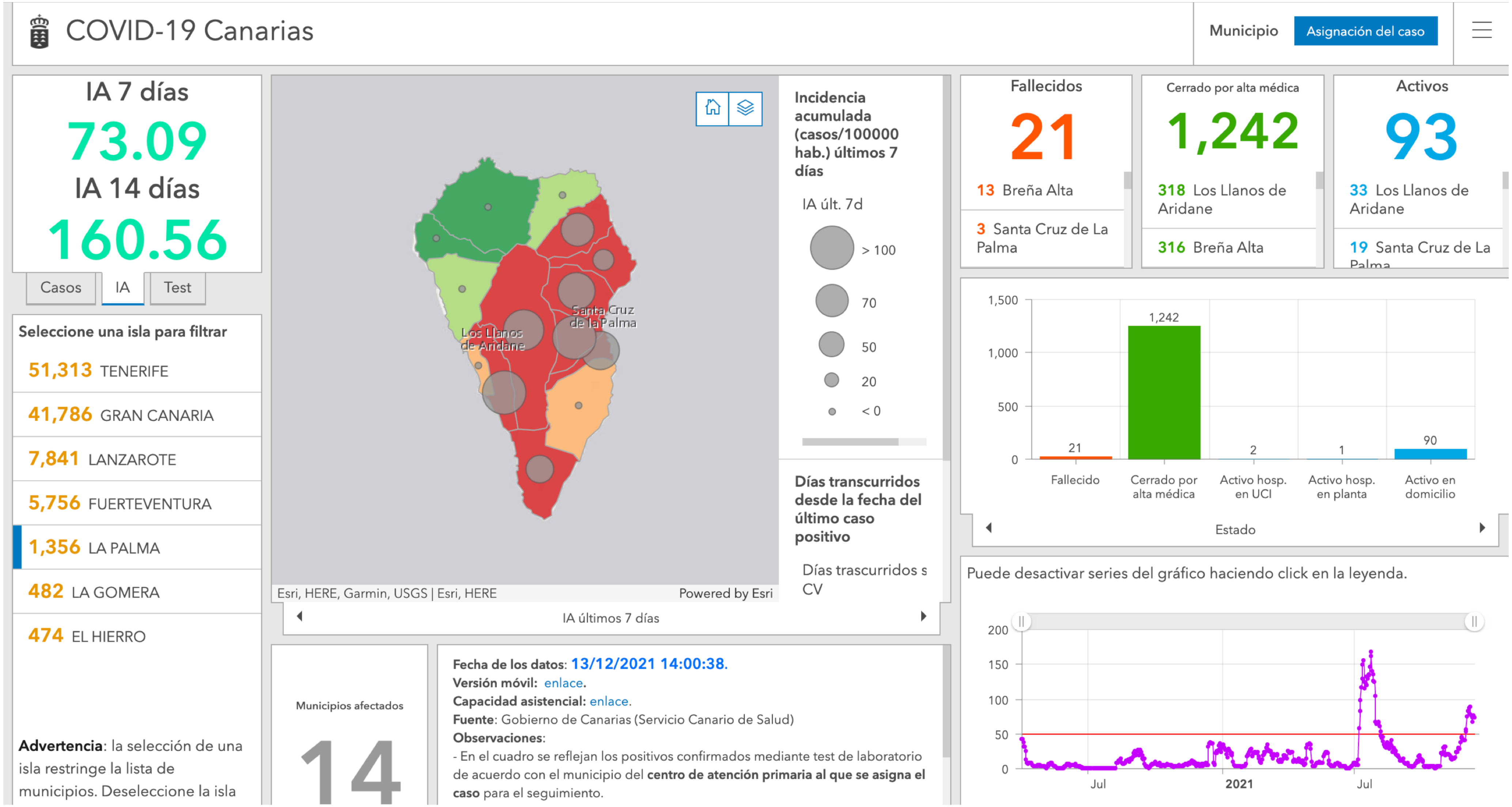
David Paneque
Deputy Spokesperson

MPP members are always playing key roles in the leadership of the MAGIC collaboration

David Green Galactic group coordinator
Alessio Berti Transient group coordinator
Moritz Huetten (now @Tokyo) Astroparticle and fundamental physics

3 - Operation challenges:
Covid-19 + Volcano activity

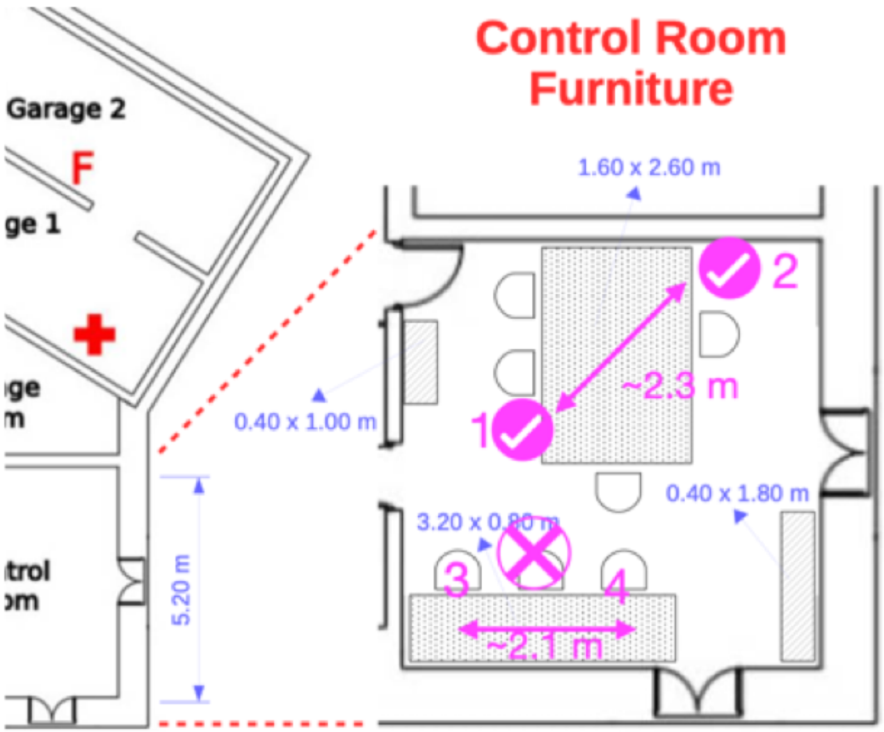
Covid-19 in La Palma getting worse, but situation is much better than in most of Europe: **7-day index is 73**



Reminder — Safety Rules

- A new Appendix — all new rules related to Covid-19
- Read the document before arriving
- Read the Appendix before planning your shift in C17

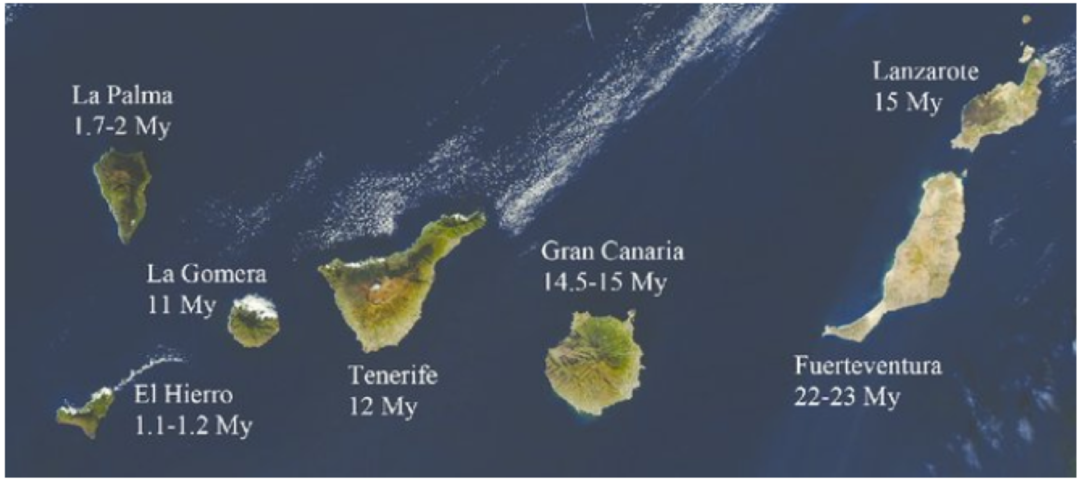
Contents

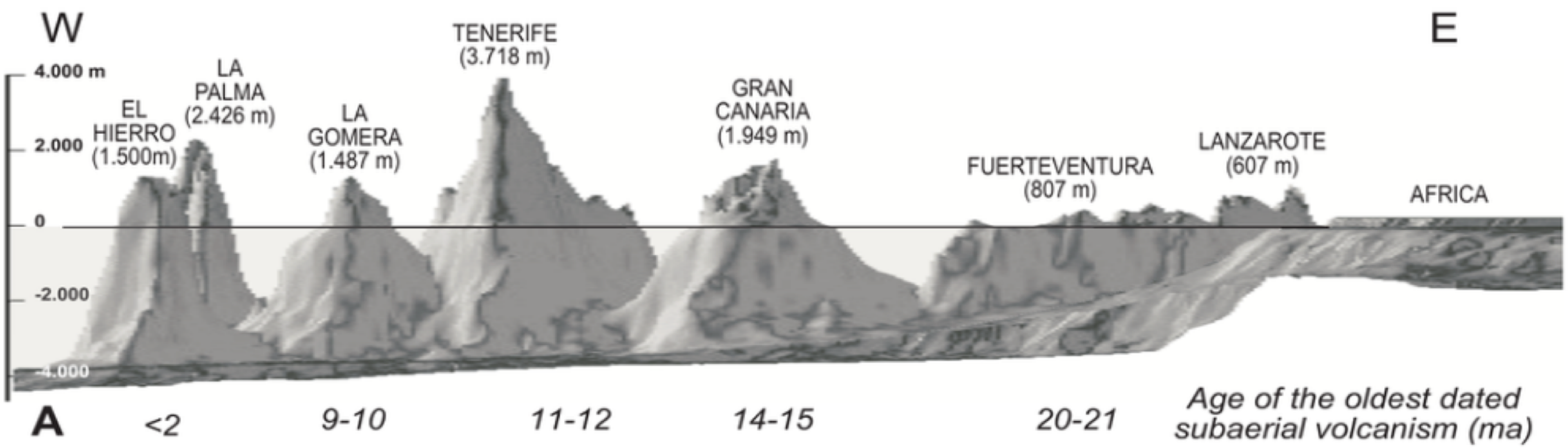


We established protocols to operate during Covid-19, and they have been working well during these last ~2 years. **In principle, Covid-19 is no longer a "major problem" for operations**

And when operations were becoming more and more normal… Volcano eruption on September 19th… **really ???**

We often forget that we put the telescopes in a relatively young volcanic island…

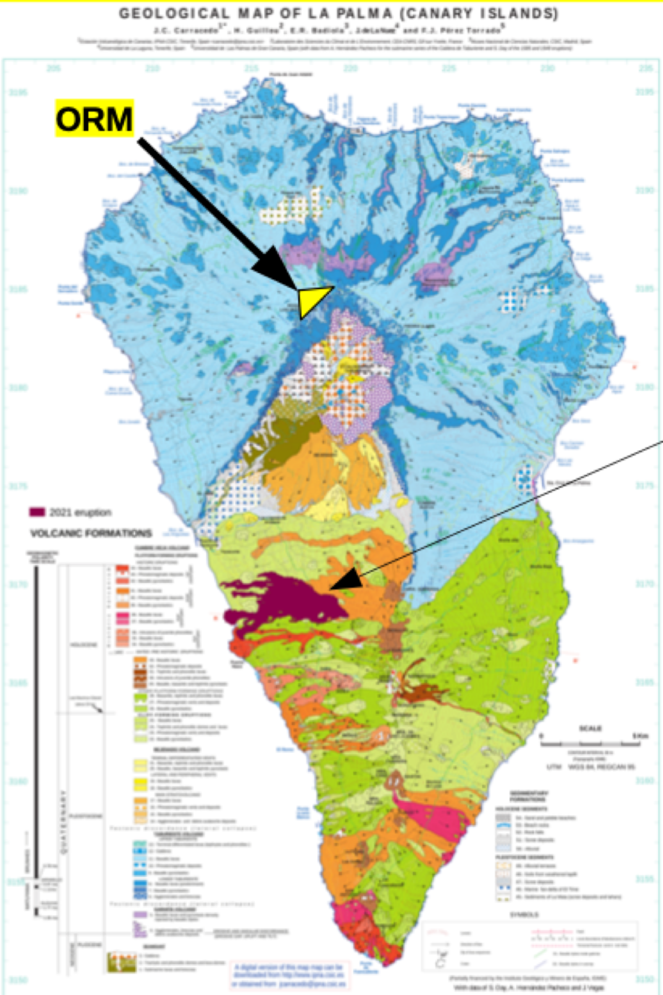




Carracedo et al, 2001

Longest historical volcano eruption in La Palma (>87d)

Support for telescope operations
during Cumbre Vieja 2021 eruption



Carracedo et al, 2001

Rift (*dorsal*) volcano:
Cumbre Vieja
123 ka-present

La Palma-South

Historical eruptions (≥ s XVI)

- 1585 – 84d – Tajuya
- 1646 – 82d – Martín
- 1676 – 66d – San Antonio
- 1712 – 56d – El Charco
- 1949 – 37d – San Juan/Nambroque
- 1971 – 24d – Teneguía
- **2021 - >87d – Cumbre Vieja**

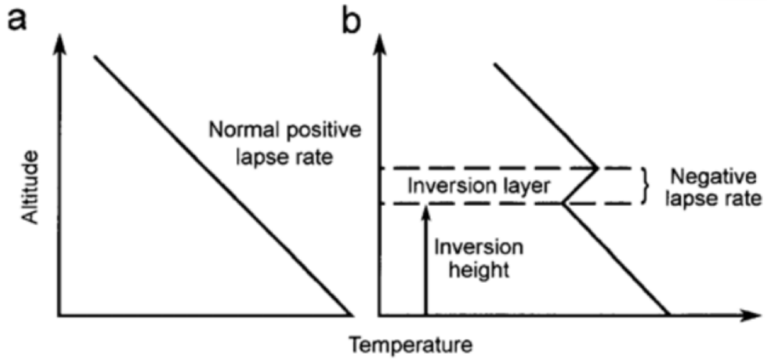
AVERAGE = 53±26 D

From Julio A. Castro (IAC), Nov. 2021

Quite protected for the same reason the observatory is good for astronomy: the inversion layer keeps clouds and volcanic ashes/gas down.

~16 km distance from Volcano to the observatory

~1500m height difference



But the ashes and smoke (pushed by volcano) can sometimes go through inversion layer, and if wind blows in direction of the observatory …

Photo from the observatory taken by Marine Pihet (2021/12/13)

Longest historical volcano eruption in La Palma (>87d)

Earthquakes are in principle not a problem (>16 km away, and max M=5.1)

but ashfall is a big problem:

→ mechanical: ash particles particles getting into filters and motors or grease.

→ chemical: may age mirrors faster

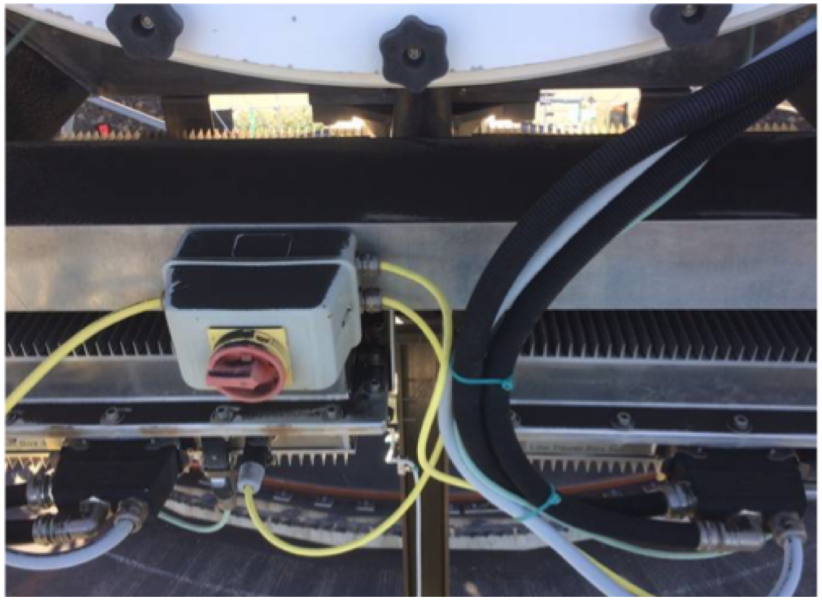
And toxic gases (e.g. SO2) can also reach the observatory *(peaks of 3000 micrograms/m3)*

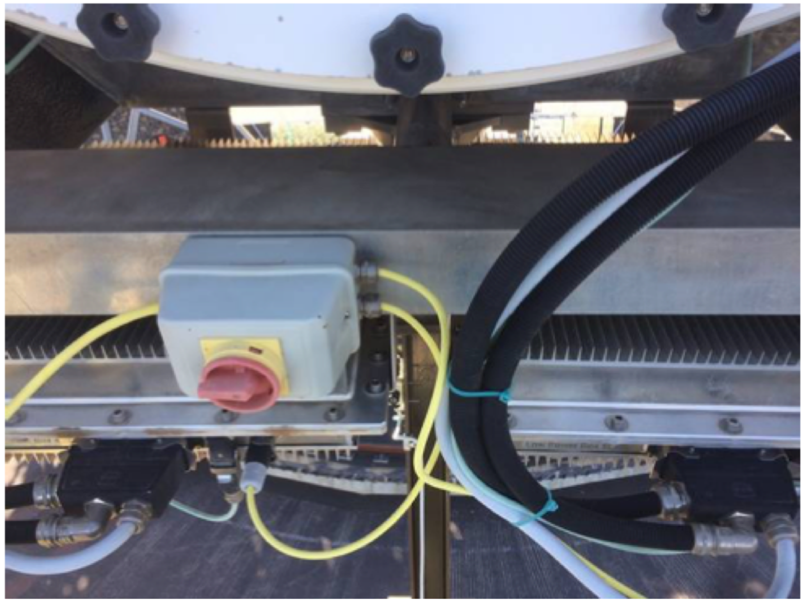
Operations have stopped until volcano activity stops. Sensitve parts in the telescope have been protected, and operators are asked to stay indoors during ashfall and periods of toxic gases

Longest historical volcano eruption in La Palma (>87d)

Regular inspections and cleaning by our local crew at La Palma

Camara LV boxes (M2) before/after cleaning with can of compressed air

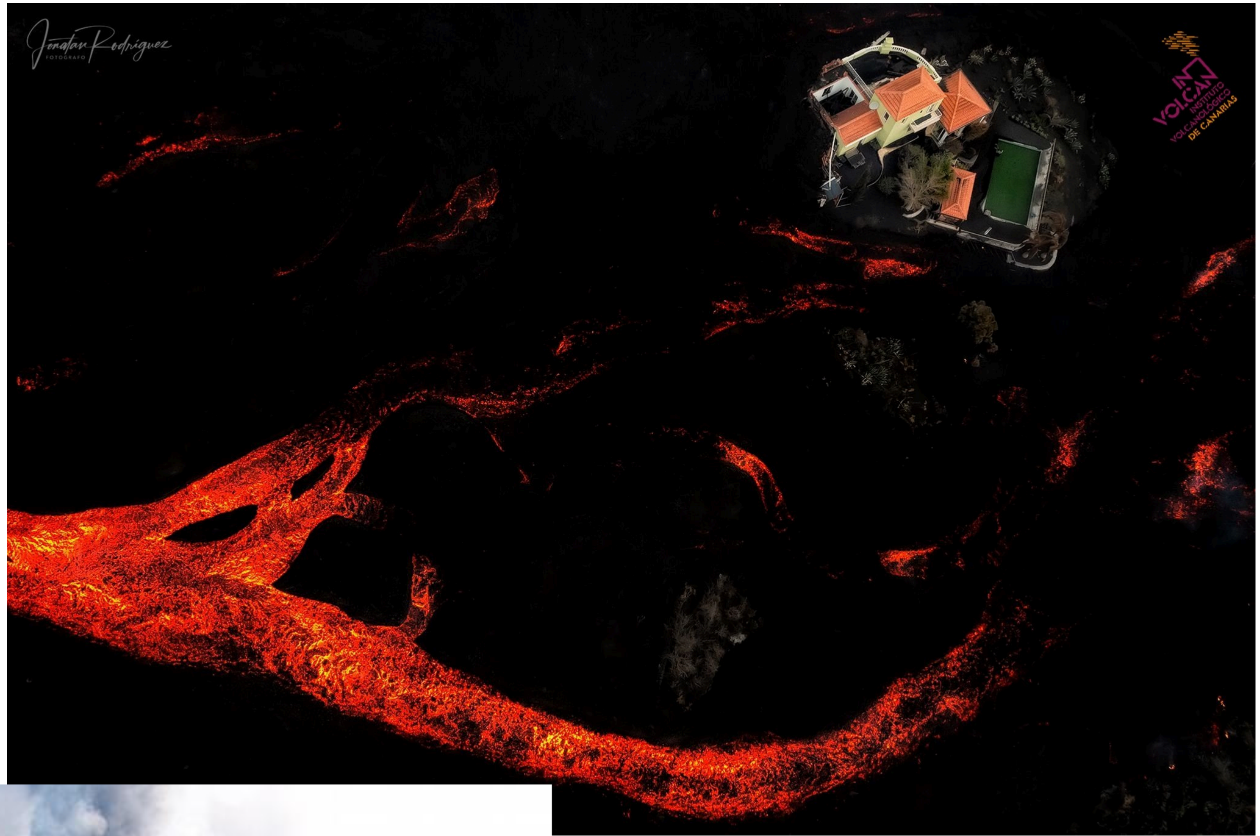




Dramatic situation for the people living in la Palma

→ About 10% of people have been relocated

→ Large economic losses (business, tourism, banana fields…)



We all are looking forward to the end. Some experts say towards the end of the year (based on SO_2 ejection)… **but big uncertainty**

4 – Technical activities in 2021

Remark:

Because of limited time for this talk, I will not report about the regular (yearly) activities related to the maintenance of the telescope structure, camera, calibration system, LIDAR …

All these activities are CRUCIAL for the standard operation of the MAGIC telescopes, and are done, mostly, by MPP mechanical&electronic engineers and technicians
(*H. Wetteskind, D. Fink, M. Fras, T. Dettlaf, J. Schlammer …)*

Critical review to ensure reliable long-term hardware operation:
Technical coordinators + Razmik Mirzoyan, among others

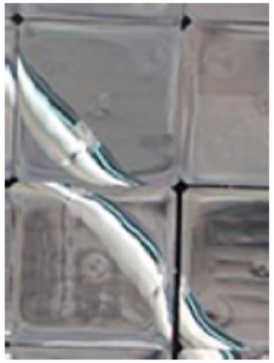
→ **Global effort among all sub-system experts**

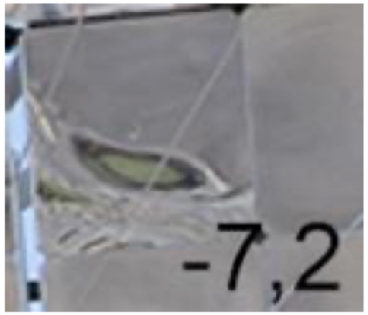
→ **Evaluate aging of several parts and make sure we have spares (or we can fix)**

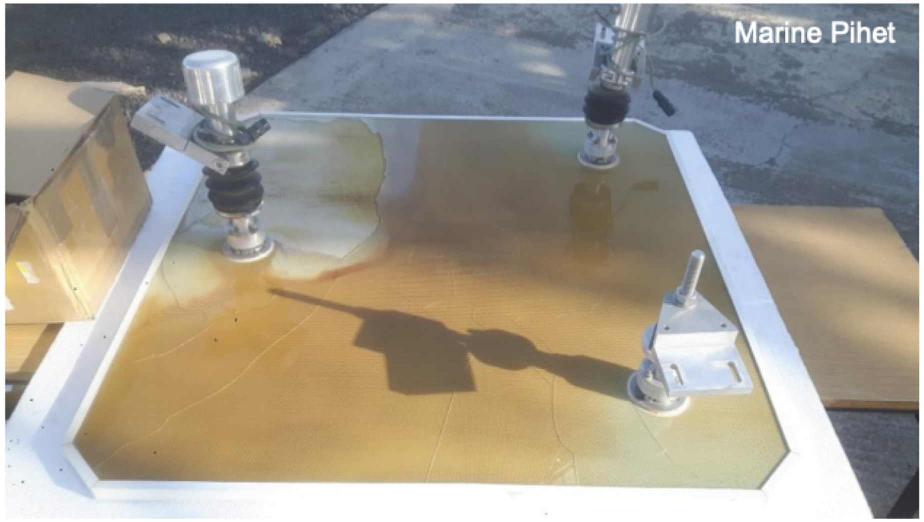
Replacement of aged/damaged mirrors with better (more durable ones)

R. Mirzoyan, M. Will, J. van Schenperberg, M. Pihet

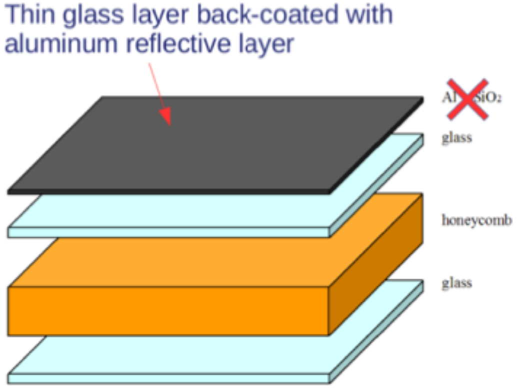
- Reason for Maintenance
  - Restore reflectivity
  - Bring PSF back to best possible size
  - Removal of non-specular reflection
  - Counter-weight reduction
  - Minor safety concerns (detached, damaged mirrors)
  - Install new 1x1 m² back-coated glass mirrors from MLT





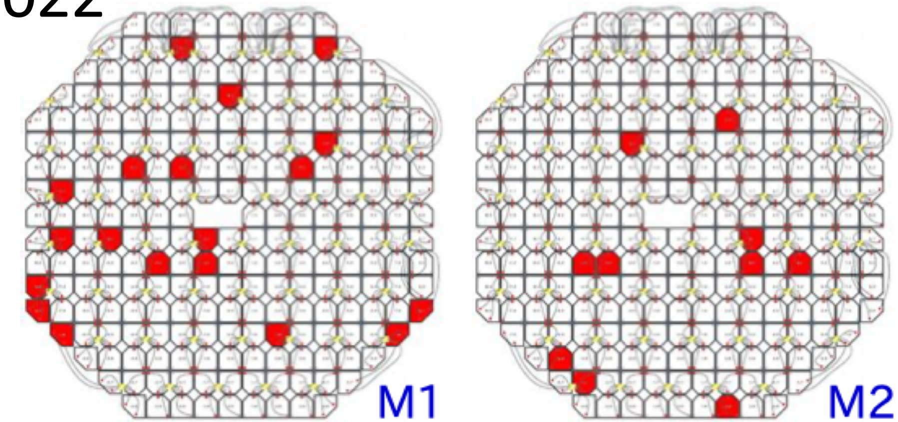


Novel development of our MPP group with Media Lario



Replacement of aged/damaged mirrors with better (more durable ones)

- **29 novel back-coated mirrors installed in September 2021**
- 46 (@MAGIC site) will be installed in 2022
- Negotiations with mirror maker (Media Lario) for a mold for mirrors with 35.5 m focal distance
- Ordered additional 53 mirrors

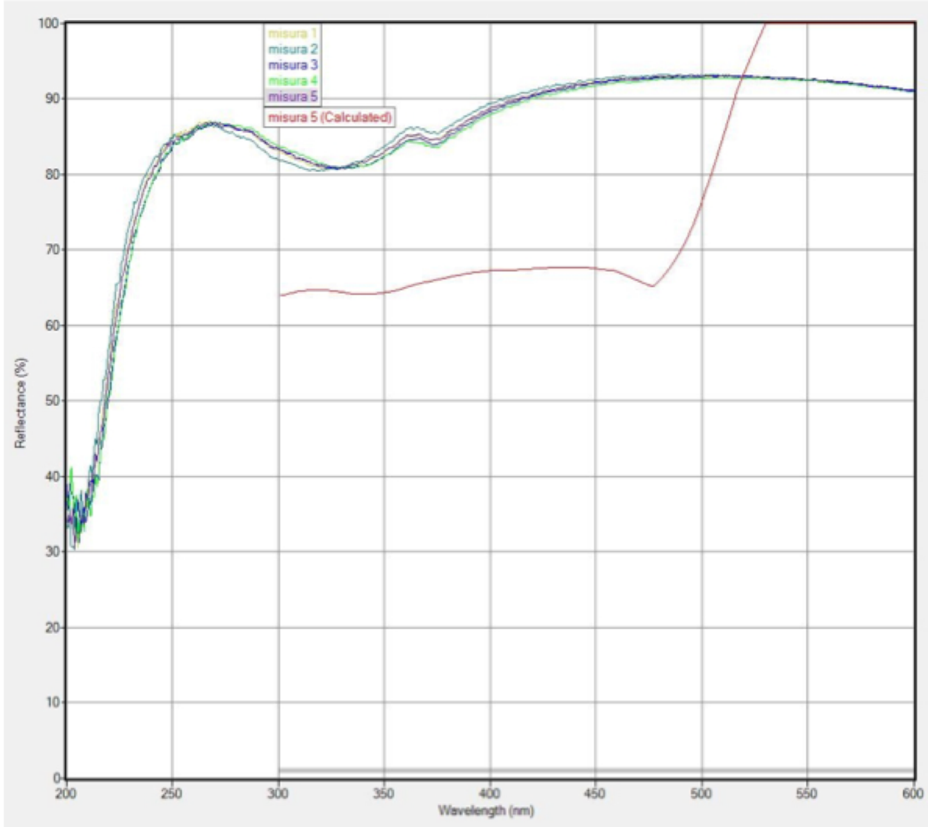


V. Acciari (Tech. coordinator)

Parameters of the new mirror for the MAGIC LIDAR

R. Mirzoyan and F. Schmuckermaier

- Material: Schott Supremax blank – a borosilicate glass - extracted from a plate, with a low coefficient of thermal expansion of 3.25x10-6/°C.
- Diameter: 610 mm
- Thickness: ~ 38 mm
- Shape: concave sphere
- Radius of curvature: ~ 3 m
- Surface roughness: ~ 2-3 nm Rq
- Shape accuracy: < 2 µm PV
- Coating: standard aluminum with a SiO_2 protective layer, with R>90% @532 nm.



Reflectivity

Upgrade of the cooling system of the MAGIC telescope cameras (as part of critical review)

R. Mirzoyan

The company HEKRA made an offer to upgrade the electronic modules in the cooling system

That will alllow them to maintain operation of the system in the coming years

We ordered this item in year 2021 (which was not initially budgeted by MPP group)

hekra

Angebot-Nr.	1210355
Vorgang-Nr.	30210537
Kunden-Nr.	20125
Datum	22.09.2021
Seite	6 / 8

Zusammenstellung

Pos.	Anzahl	Einh.	Bezeichnung	Einzelpreis	Gesamtpreis
*Titelsumme	1		Reise/Arbeitszeit/Transferkosten		20.633,30 €
*Titelsumme	2		Materialeinsatz Neuteile		13.447,56 €
*Titelsumme	3		Fernwartungszugang - Mobilfunknetz		2.988,82 €

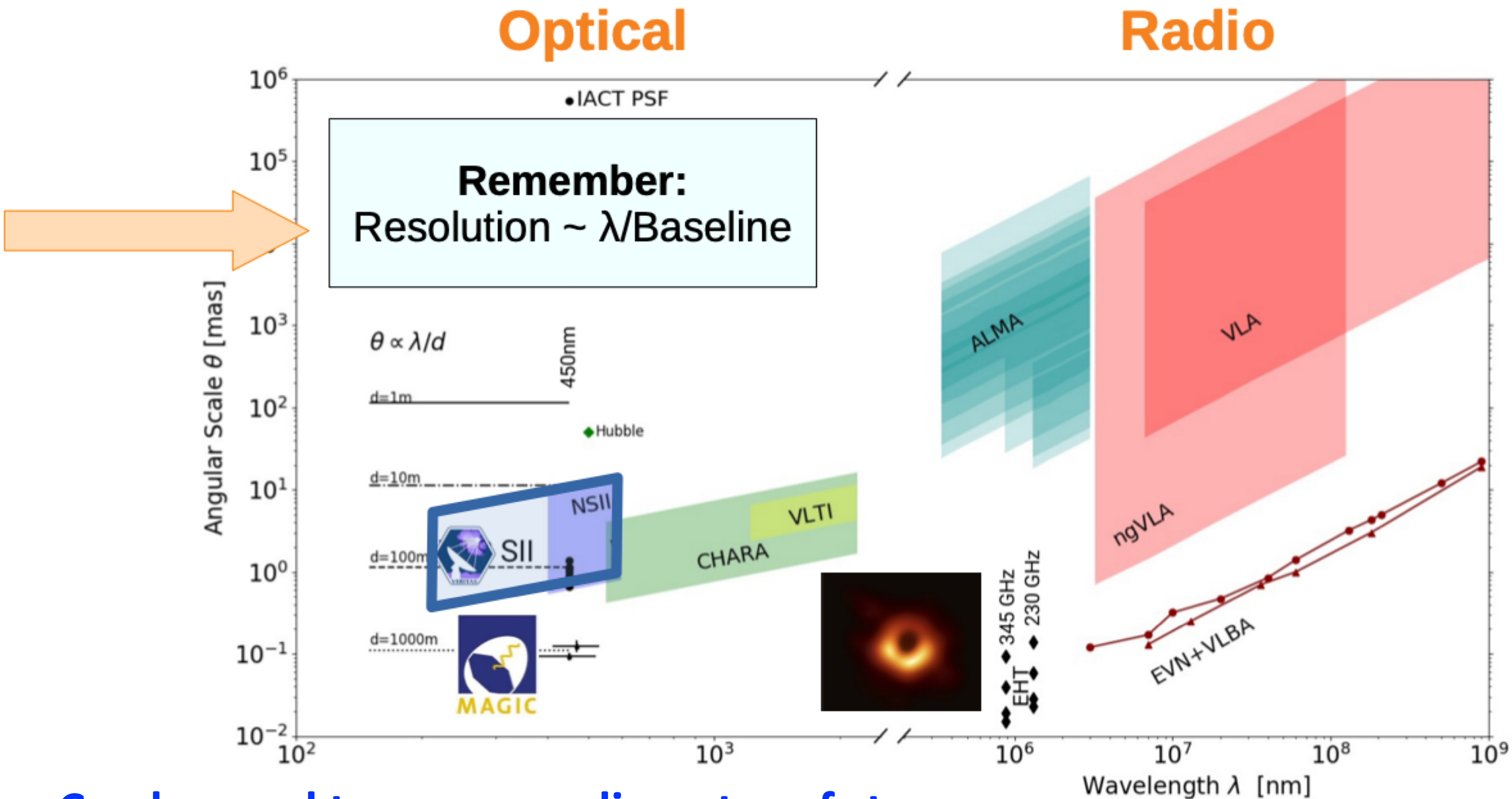
Gesamtsumme netto	37.069,68 €
zzgl. UST 19%	7.043,24 €
Gesamtsumme brutto	44.112,92 €

Summary page of the offer from the company HEKRA for the upgrade of the coolong system of the MAGIC telescopes

Intensitity interferometry with the MAGIC telescopes

T. Schweizer, D. Fink, R. Mirzoyan + CIEMAT group (Madrid) + Geneva University group

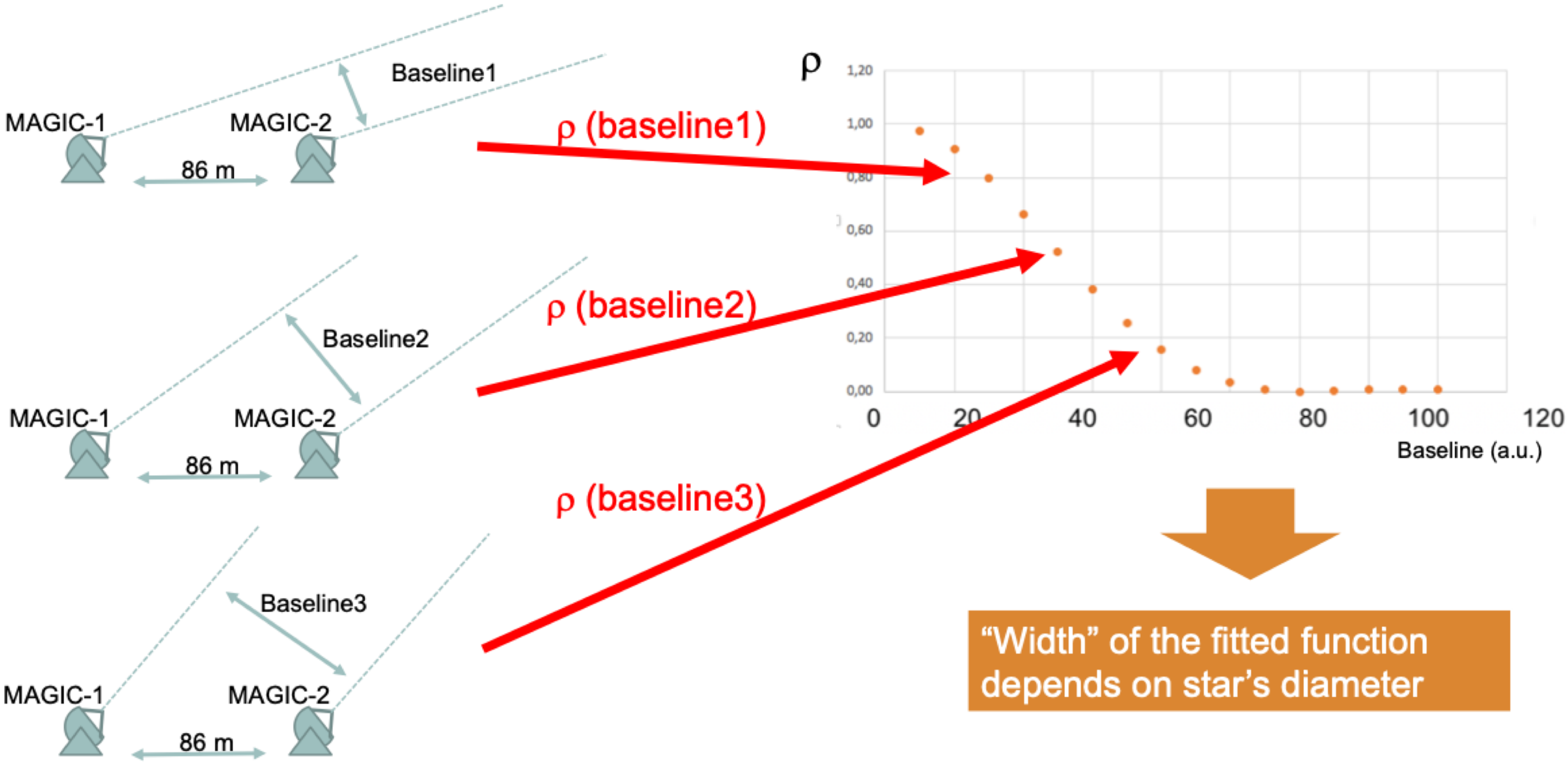
Hardware upgrade to expand physics portfolio of MAGIC telescopes



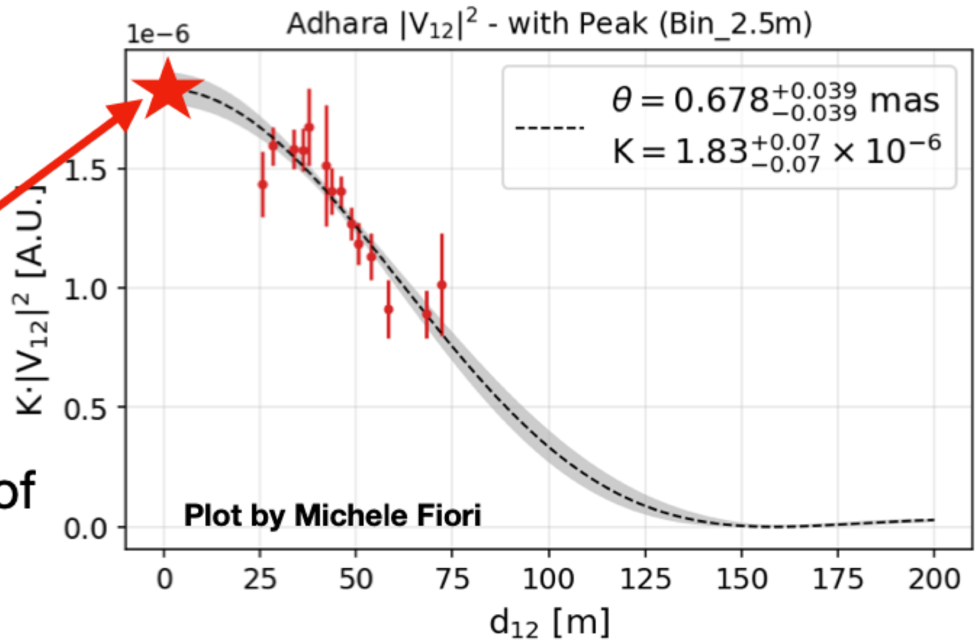
Can be used to measure diameter of stars or binary systems or Nova explosions

Intensitity interferometry with the MAGIC telescopes

T. Schweizer, D. Fink, R. Mirzoyan + CIEMAT group (Madrid) + Geneva University group

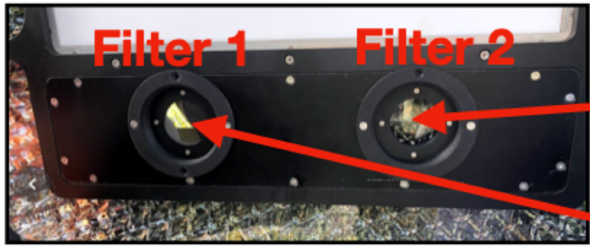


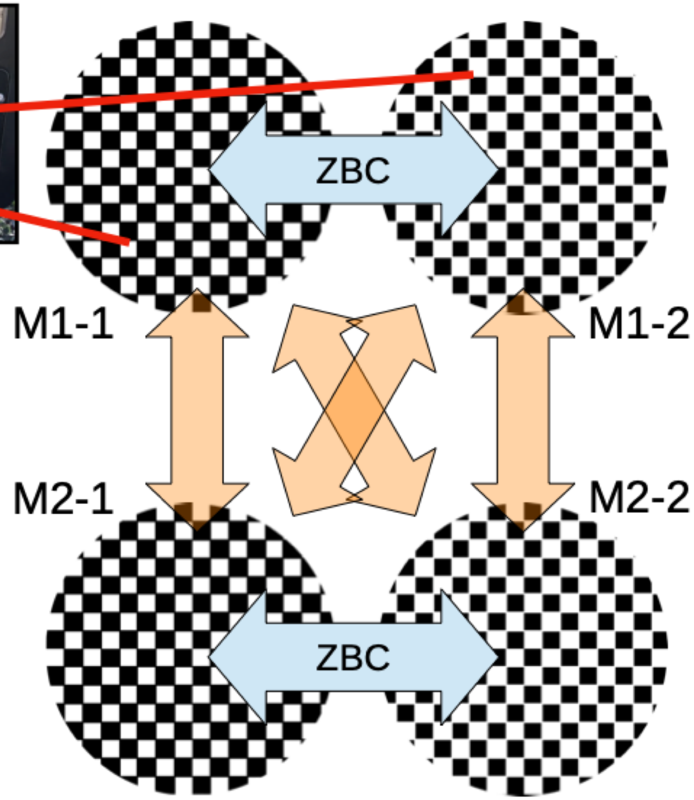
Unique to MAGIC: Precision calibration of zero baseline correlation

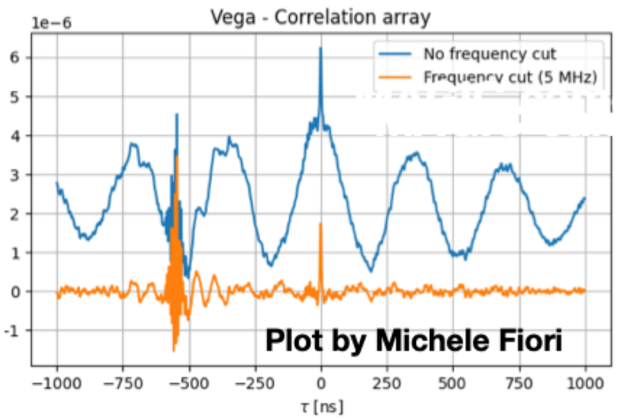


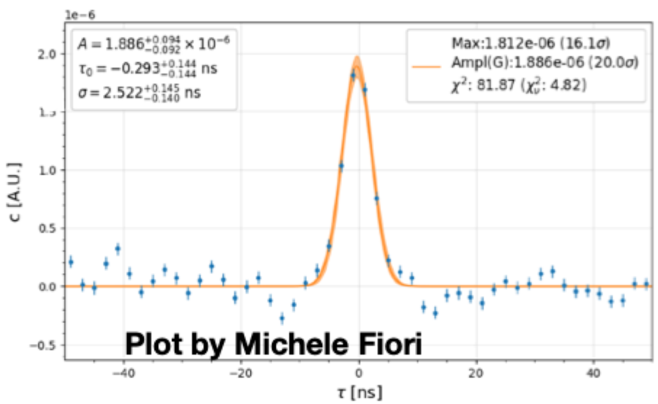
- The largest uncertainty of the measurement of the diameter of stars stems from the knowledge of the zero-baseline-visibility

- Only MAGIC can focus a mirror checkerboard pattern into two camera pixels simultaneously.

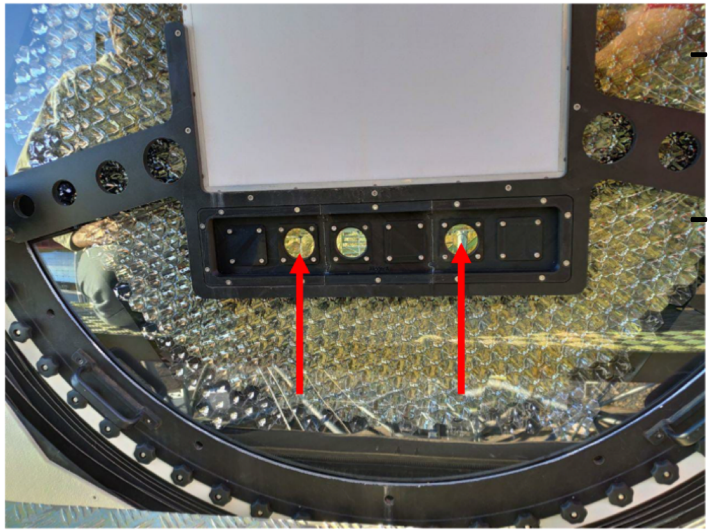








Intensity interferometry with the MAGIC telescopes



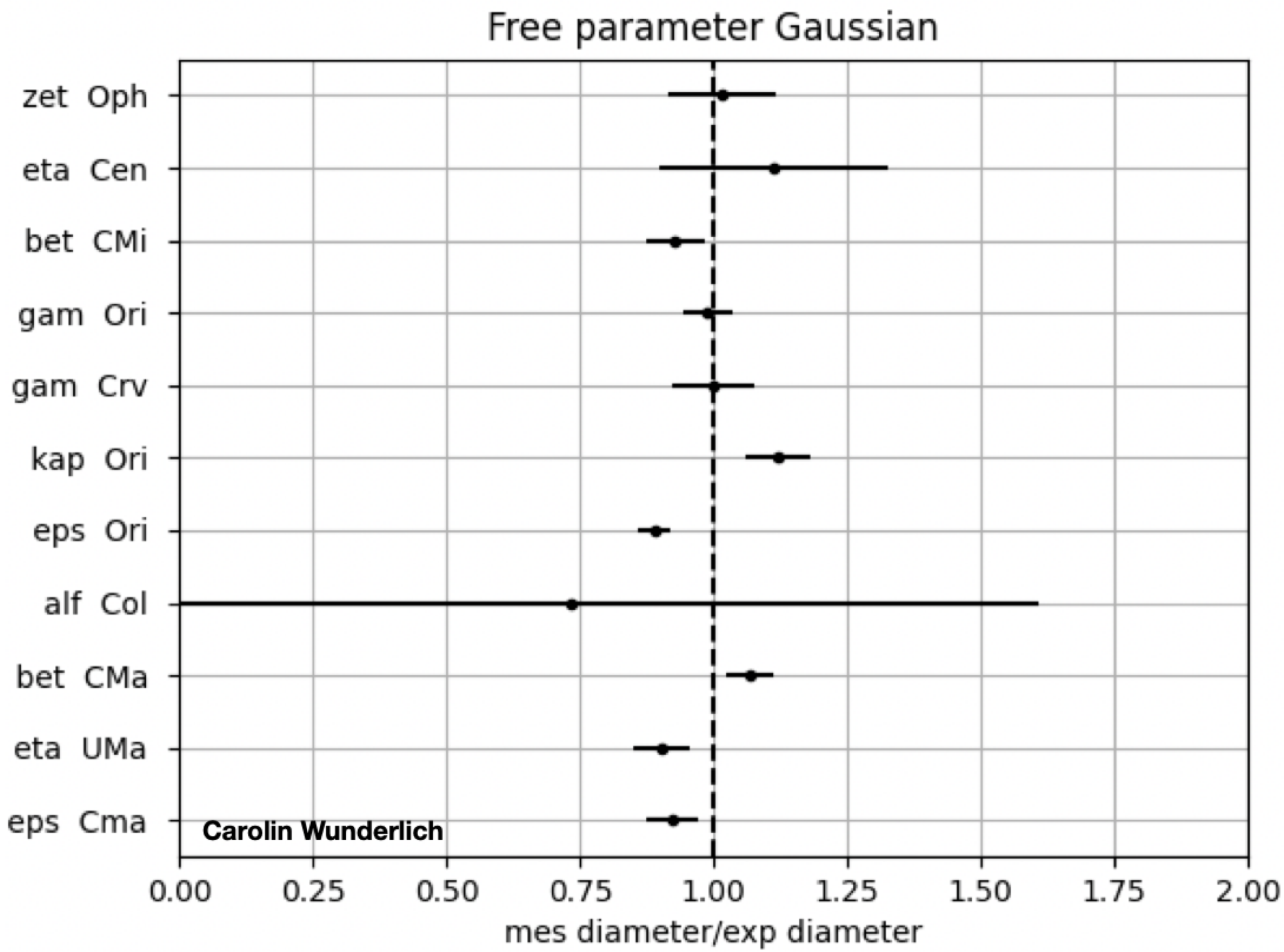
- CIEMAT produced new filter holder with room for 6 filters
- → Installed and tested on July 2021. Two filters on each camera (pixels 250 and 251)

D. Fink (MPP) produced 4 new sets of fiber+delay+photodiode+Optical receiver+amplifer

→ Installed and tested in July 2021. Allows to connect pixels 251 and 260 of both telescope cameras permanently to readout

Intensity interferometry with the MAGIC telescopes

Measured value compared to literature value for the size of several (well known) stars

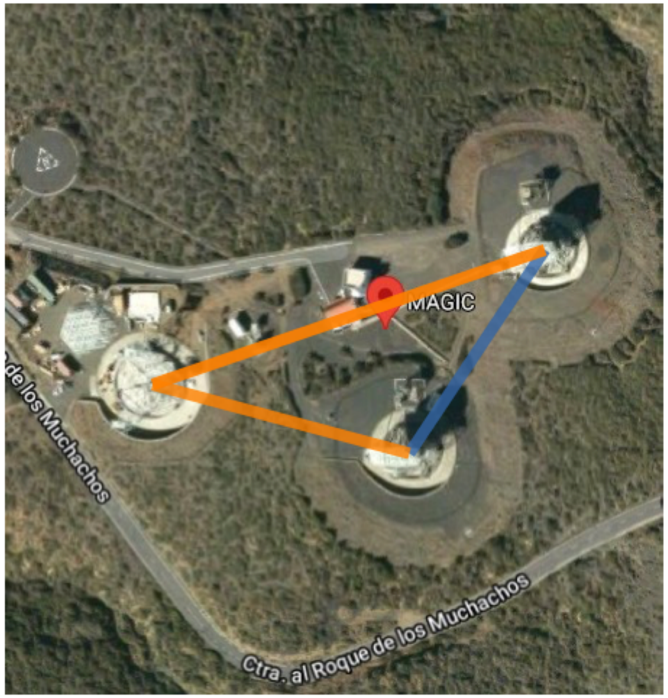


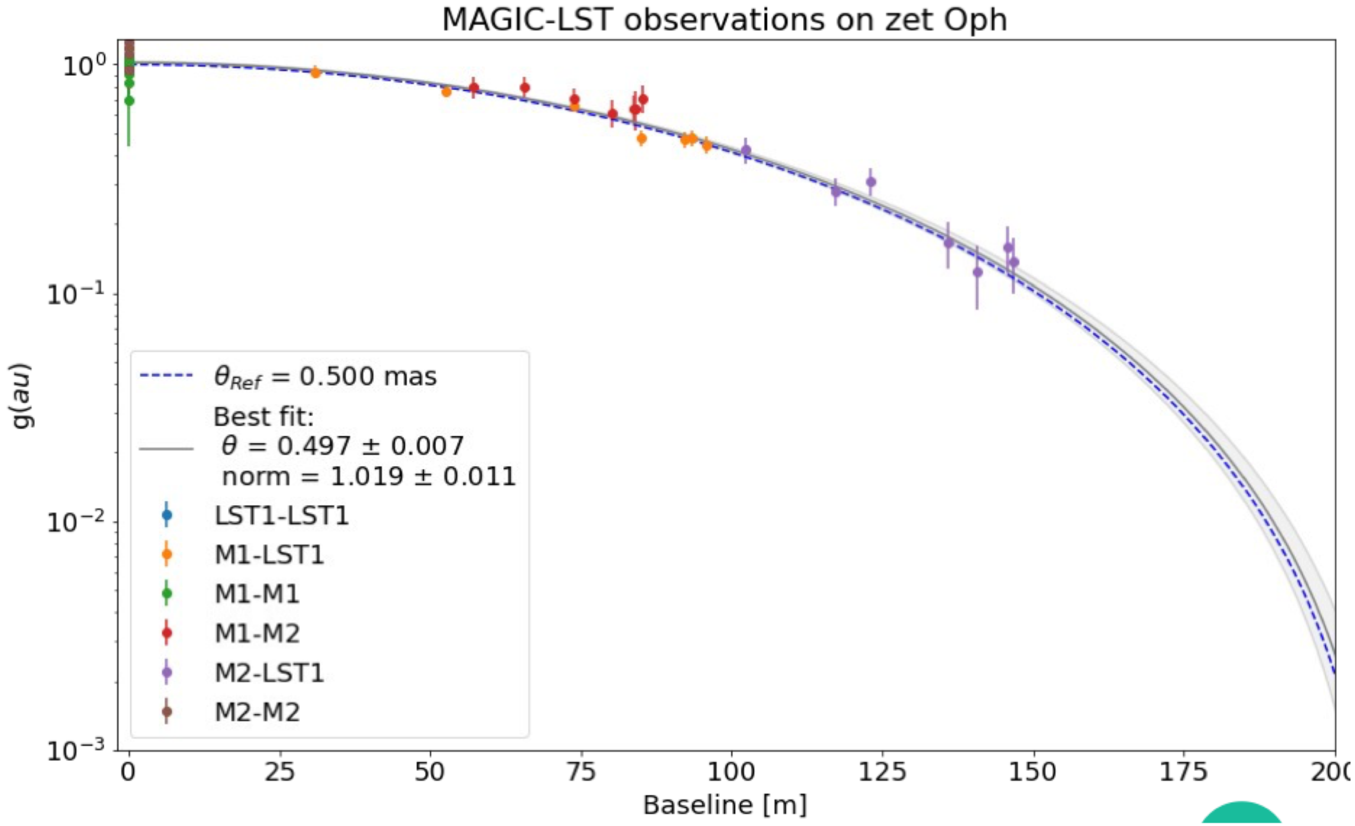
Intensity interferometry with the MAGIC telescopes

Adding LST telescope would be a game-changer

→ Many more possible baselines and more sensitivity

→ *See also report from M. Will (CTA-LST)*





For relatively "low investment" (cost and people) we can expand the physics portfolio of the MAGIC (+LST) gamma-ray telescopes

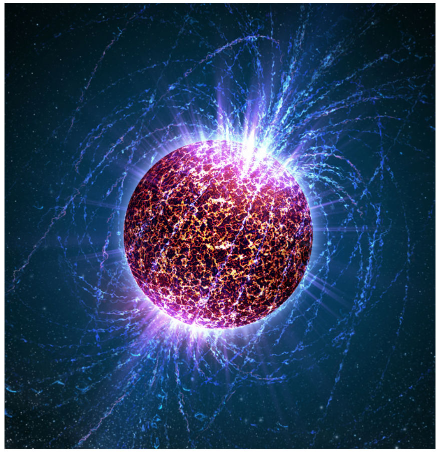
5 – Scientific results in 2021

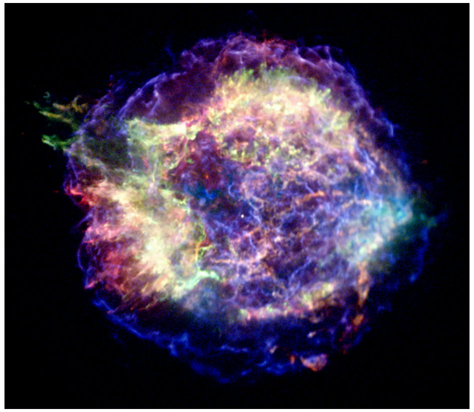
Science with the MAGIC telescopes

Find & characterize the extreme particle accelerators in the Universe

→ Gamma rays will be produced, and can be used to probe them

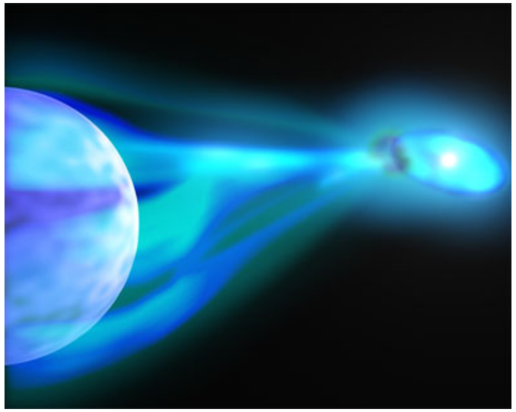
Pulsars

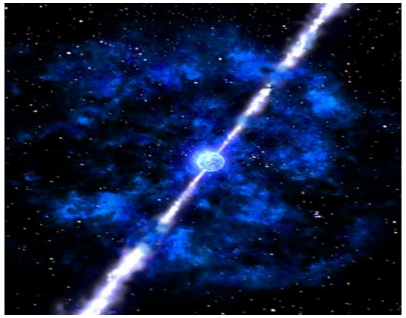




SNR+PWN

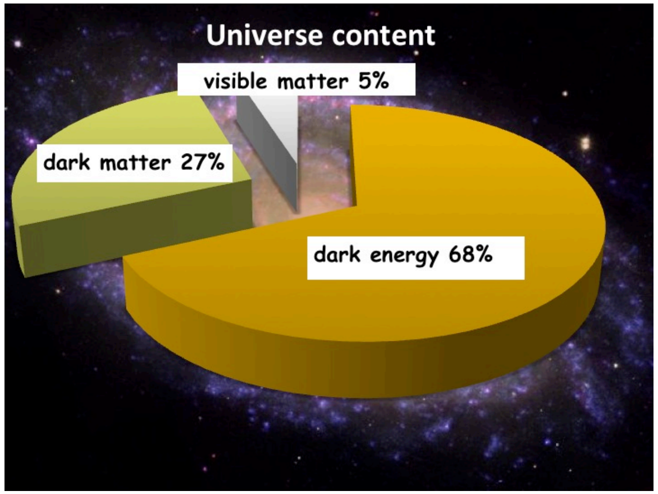
Binary systems & Novae

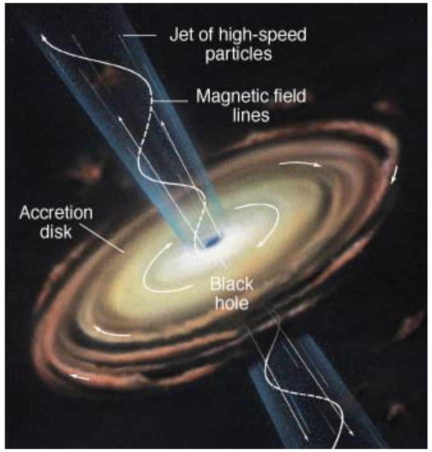




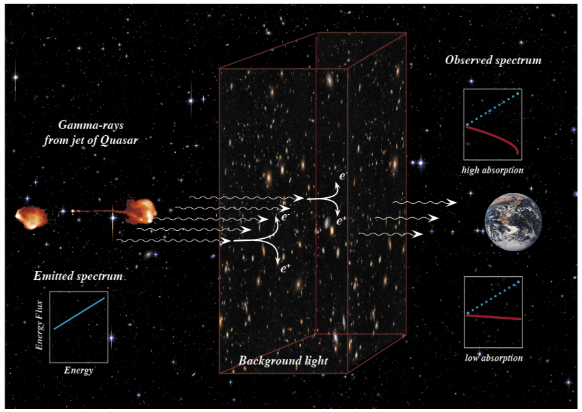
GRBs

Dark Matter searches





AGNs



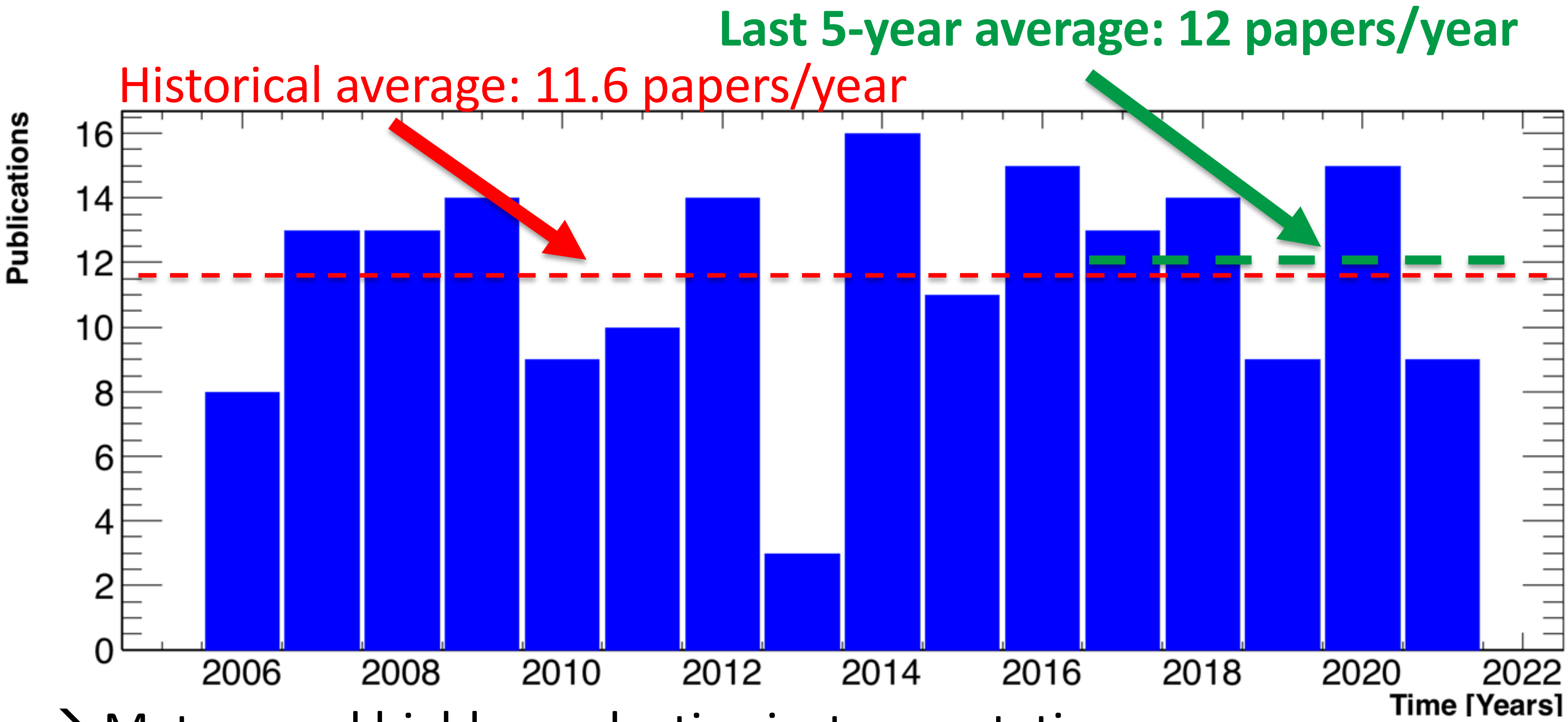
EBL
IGMF
ALPs
LIV

Science with the MAGIC telescopes

MAGIC refereed papers (published): 186

Broad range of topics: from conventional to exotic (astro)physics

Number of publications vs Year (*until 2020/12/14*)



→ Mature and highly productive instrumentation

→ **Many publications benefit from *Fermi*-MAGIC synergy**

→ Most scientifically productive IACT in last 5 years

Science with the MAGIC telescopes

<u>There are exciting publications submitted</u>, as well as others being prepared and will be submitted in the next months.

Unfortunately, due to various reasons, I cannot talk about them in this talk, but you will here about them in the next few months.

I will briefly mention a few MAGIC publicaitons with <u>strong contribution from MPP members</u> on two topics:

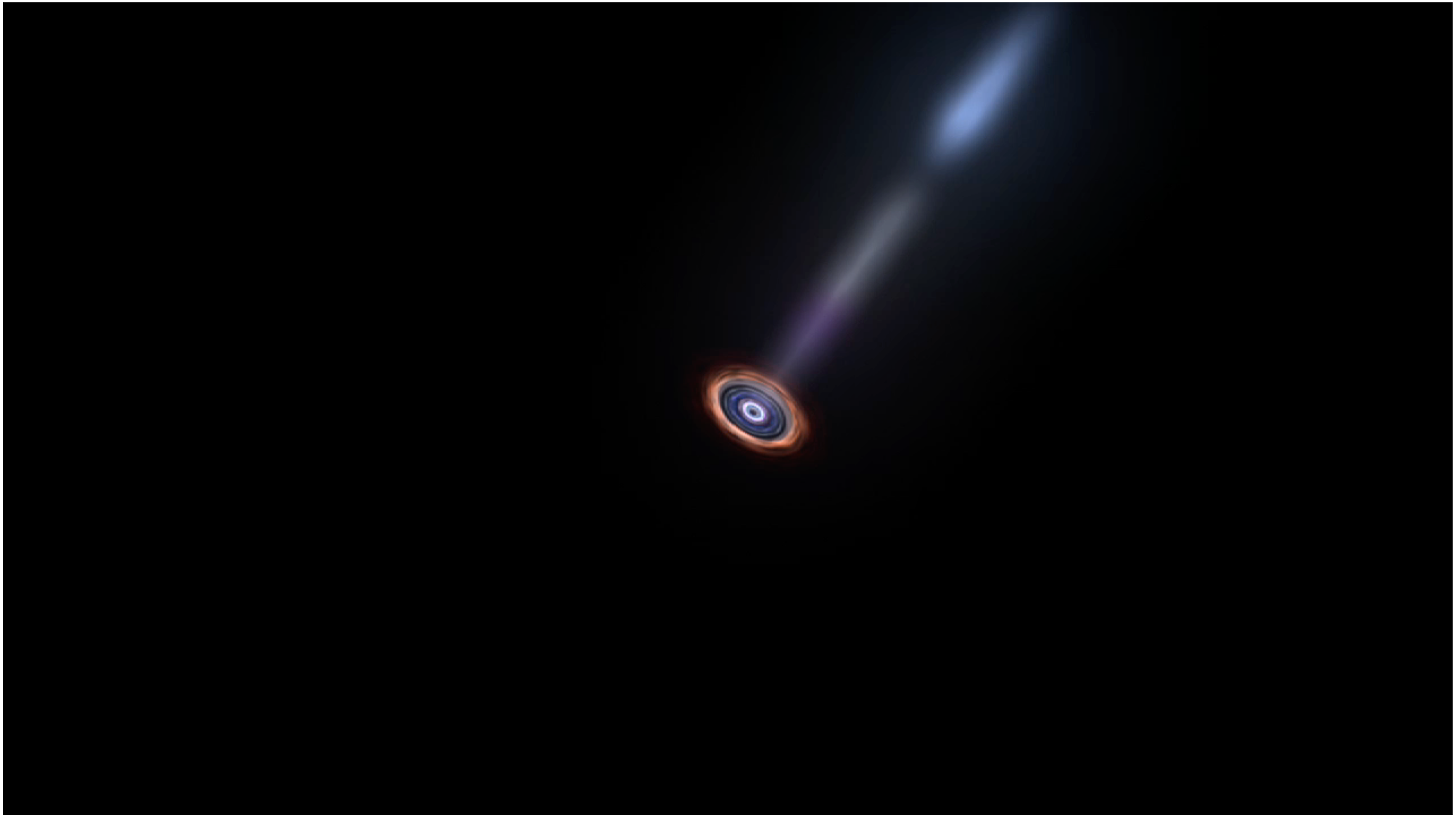
- Active Galactic Nuclei (AGNs)
- Gamma-Ray Bursts (GRBs)

AGNs as possible sources of the most energetic CRs

AGNs are the most powerful persistent gamma ray objects

→ powered by supermassive black holes (10^6 – 10^9 Suns)

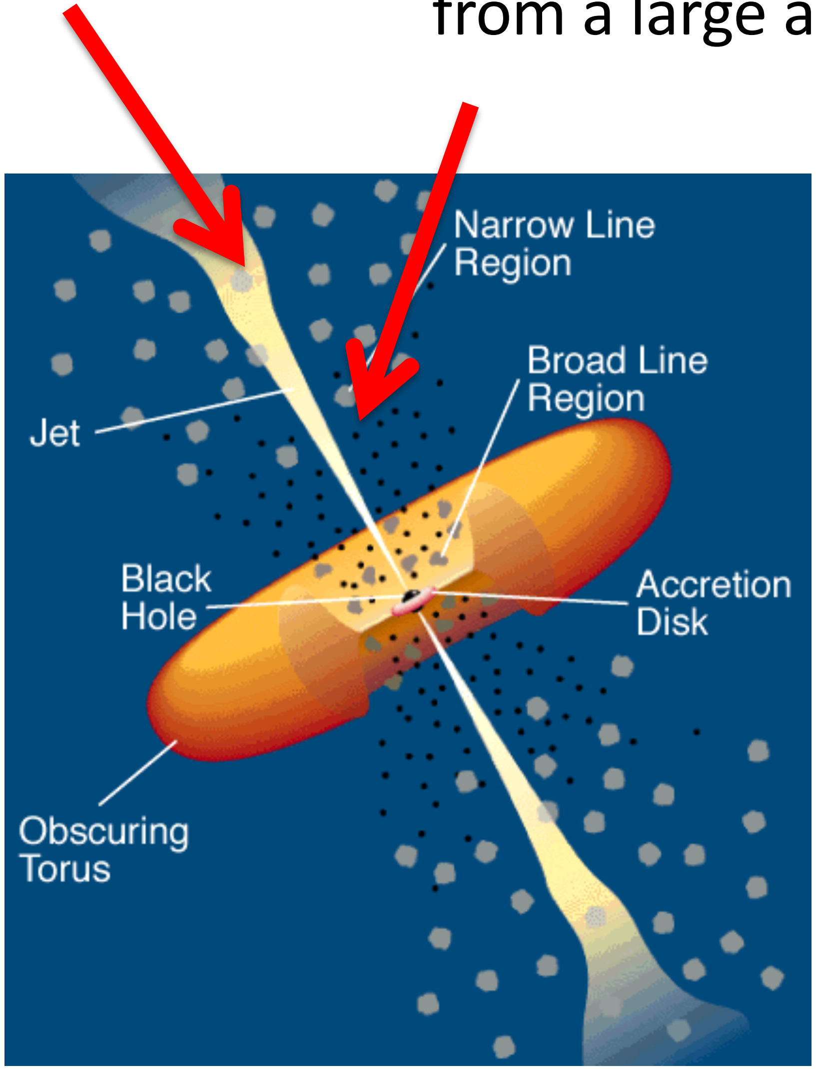
→ Can produce jets of collimated & relativistically moving plasma



Active Galactic Nuclei (AGNs)

Blazars are radio loud AGNs with the jet pointing towards the Earth

Radio galaxies are radio loud AGNs where the jet is observed from a large angle (Theta>10 deg)



Pictorial description of an AGN

Image Credit: C.M.Urry & P. Padovani

Active Galactic Nuclei (AGNs)

Blazars are radio loud AGNs with the jet pointing towards the Earth

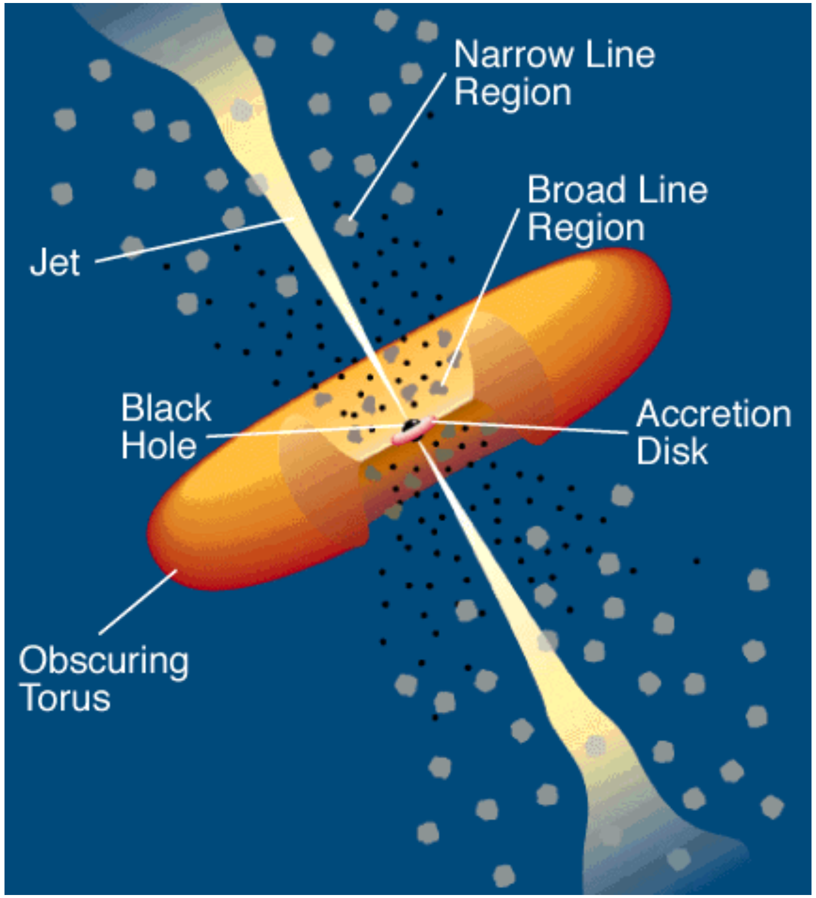
Radio galaxies are radio loud AGNs where the jet is observed from a large angle (Theta>10 deg)

Emission is Doppler boosted, and hence it appears more extreme

Energy
→increased by Doppler

Energy flux
→increased by Doppler^4

Time variations
→shortened by Doppler



No large Doppler boosting implies less brightness (at all wavelenghts) in comparison to blazars

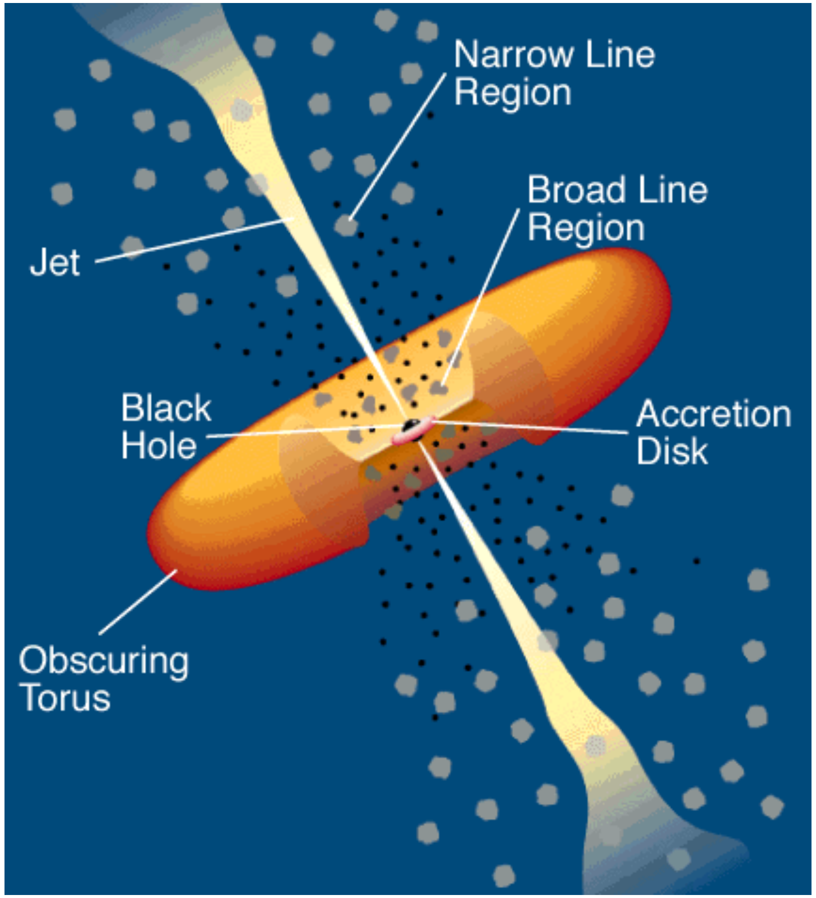
Pictorial description of an AGN

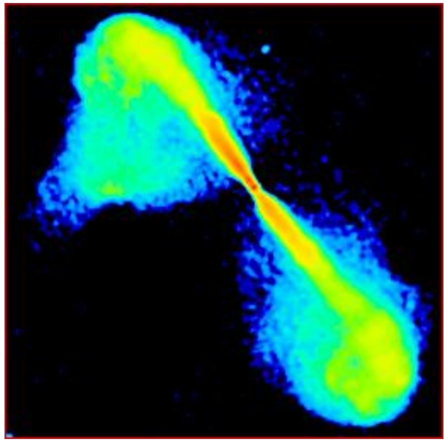
Image Credit:
C.M.Urry & P. Padovani

AGNs are powerful particle accelerators

Pictorial description of an AGN

Image Credit: C.M.Urry & P. Padovani





AGN jets are collimated streams of plasma forming **<u>the largest structures in the Universe</u>**, reaching even Mpc scales.

Jets are produced by rapidly rotating supermassive (~ 10^6-10^9 $M_\odot$) black holes surrounded by magnetized accretion disks. Thus, jets **<u>are direct probes of black hole physics</u>**.

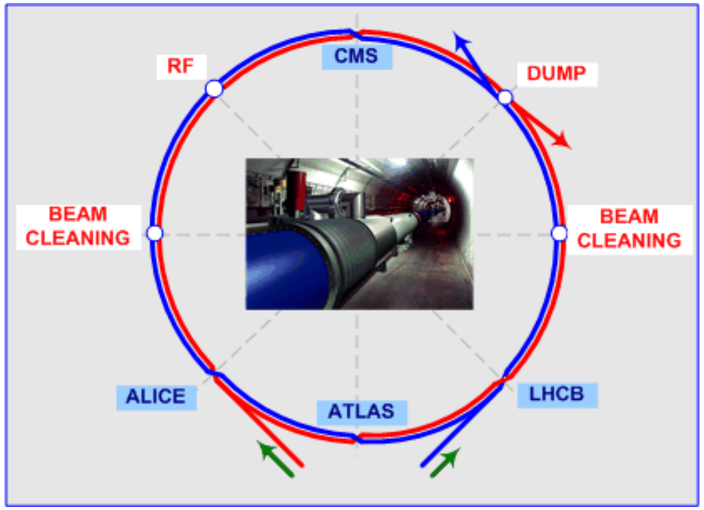
Jets are **<u>extremely efficient accelerators of particles</u>** to ultrarelativistic energies. Known to produce electrons with 10^{14} eV energies, and claimed to accelerate protons up to the highest observed energies $\geq 10^{20}$ eV

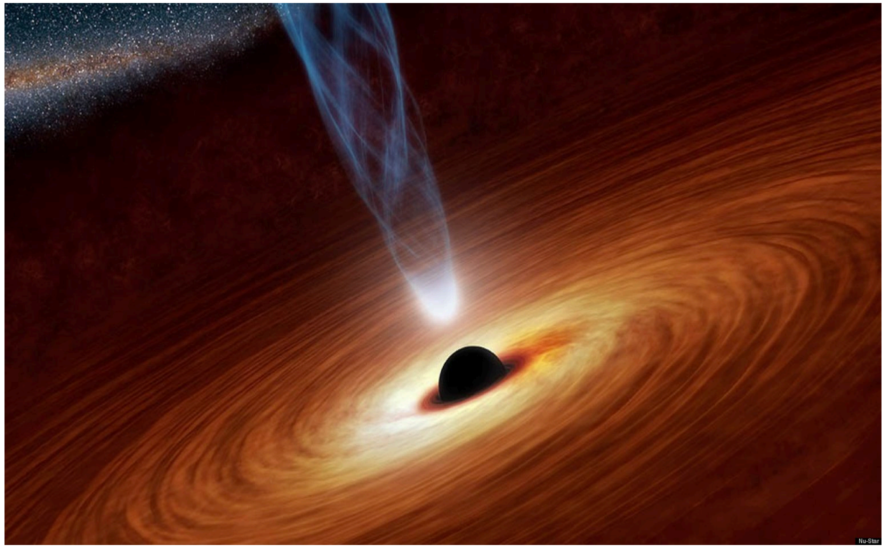
AGNs as our Extreme Particle Accelerators

LHC **vs** **bright AGN**

ATLAS/CMS
LHCb + Alice

MAGIC/VERITAS/HESS/Fermi,++
X-ray , Optical/radio, IceCube…





Physics studies with cosmic particle accelerators

Disadvantage: Cannot play with knobs in controlled environment

Advantage: Study extreme processes and environments

Much cheaper (*no need to build the accelerator…)*

The project requires "observing" over many years in order to integrate over sufficient data/effects → **long-term multi-instrument observations.**

Observational challenge when studying AGNs:

Apparent morphology of AGNs “differs with energy”

For the science fiction freaks:
This is a supermassive black hole (BH), *according to Christopher Nolan (Interestellar, 2014)*

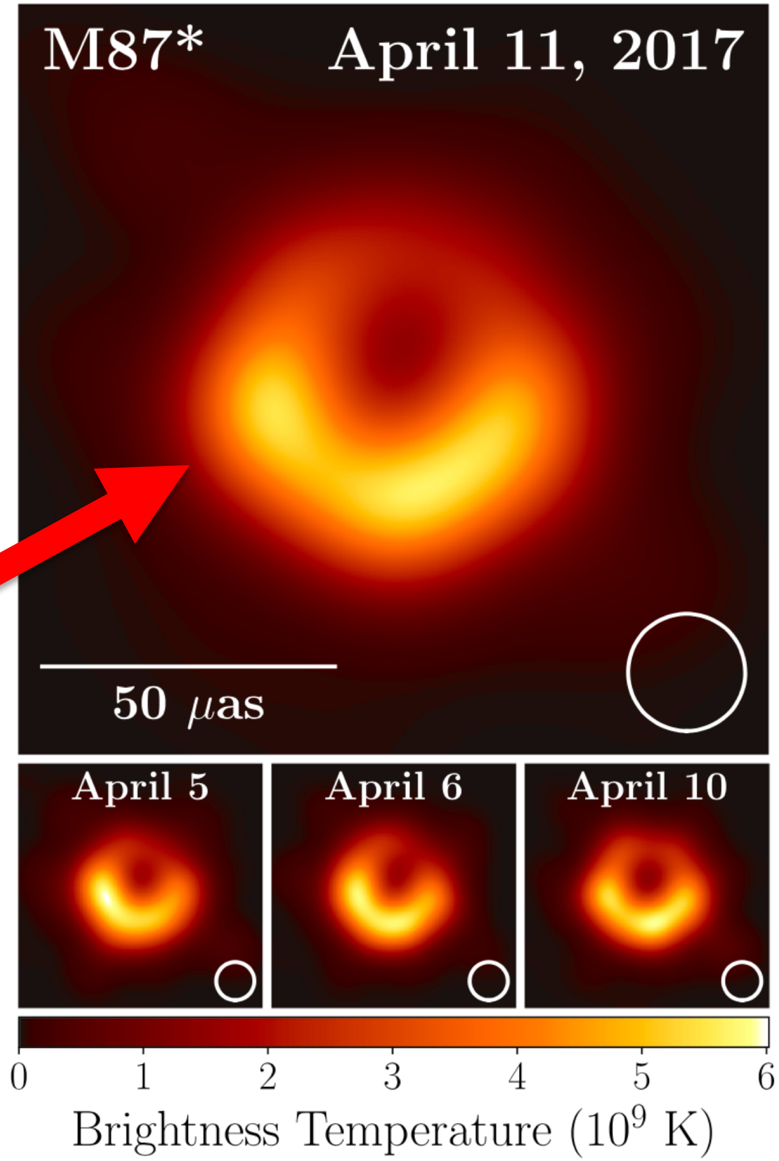
They call it *Gargantua* …

Observational challenge when studying AGNs:

Apparent morphology of AGNs “differs with energy”

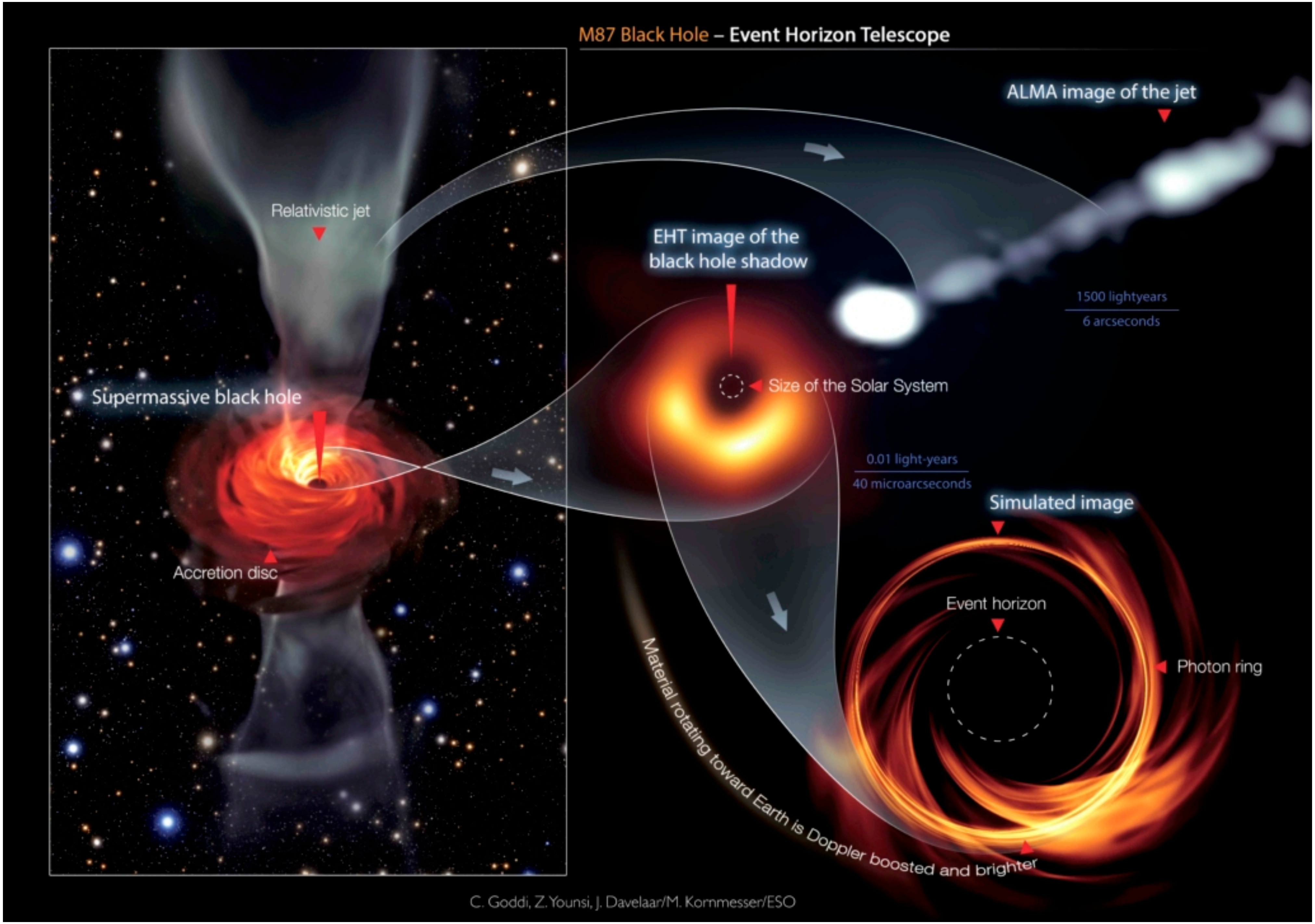
The Event Horizon Telescope collab. ApJ Letters. 875, L1, 2019

For the science fiction freaks:
This is a supermassive black hole (BH), *according to Christopher Nolan (Interestellar, 2014)*

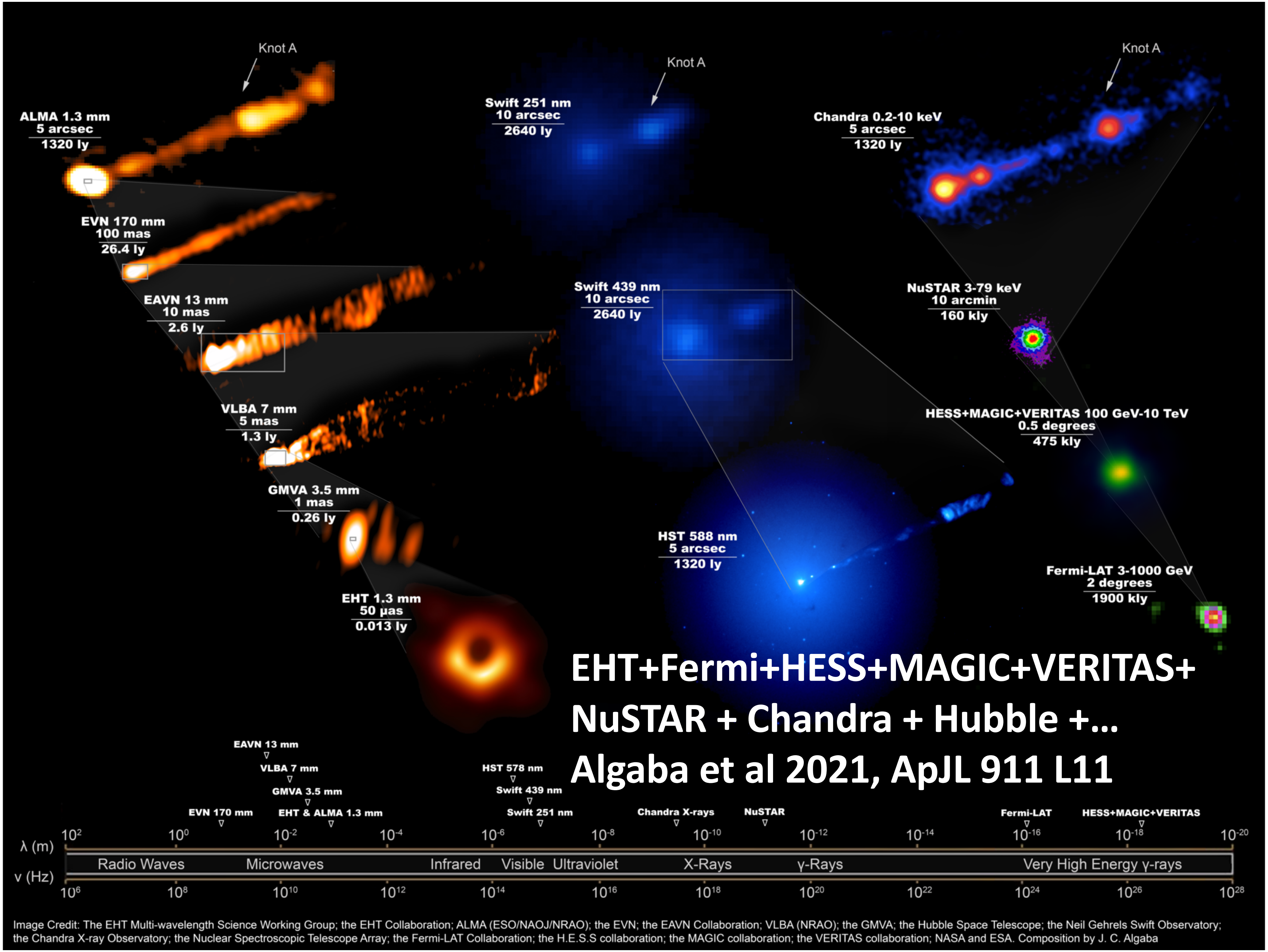


And this is a real supermassive BH, at the center of the radio galaxy M87

→ They got it almost right !!



M87 Black Hole – Event Horizon Telescope
ALMA image of the jet
Relativistic jet
EHT image of the black hole shadow
1500 lightyears
6 arcseconds
Supermassive black hole
Size of the Solar System
0.01 light-years
40 microarcseconds
Simulated image
Accretion disc
Event horizon
Photon ring
Material rotating toward Earth is Doppler boosted and brighter
C. Goddi, Z. Younsi, J. Davelaar/M. Kornmesser/ESO

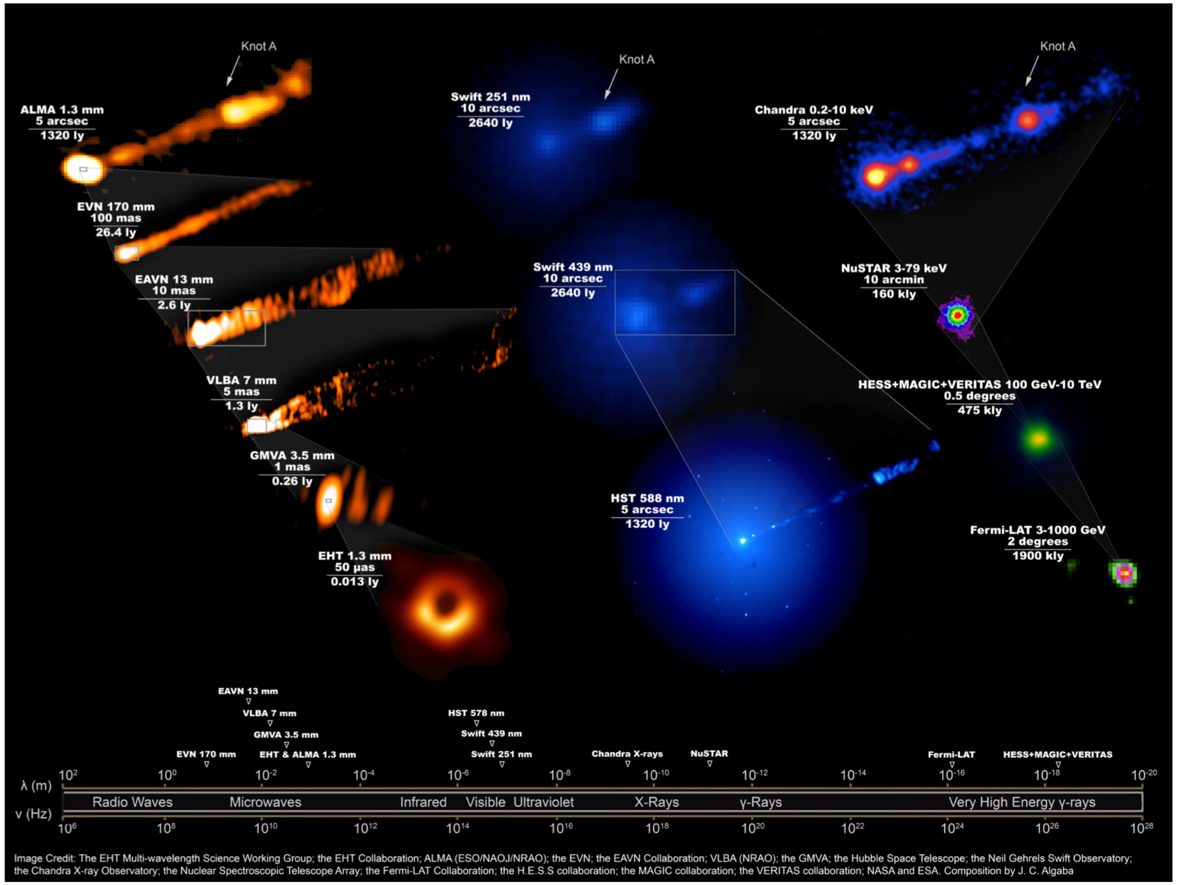

Knot A
ALMA 1.3 mm
5 arcsec
1320 ly
EVN 170 mm
100 mas
26.4 ly
EAVN 13 mm
10 mas
2.6 ly
VLBA 7 mm
5 mas
1.3 ly
GMVA 3.5 mm
1 mas
0.26 ly
EHT 1.3 mm
50 µas
0.013 ly
Knot A
Swift 251 nm
10 arcsec
2640 ly
Swift 439 nm
10 arcsec
2640 ly
HST 588 nm
5 arcsec
1320 ly
Knot A
Chandra 0.2-10 keV
5 arcsec
1320 ly
NuSTAR 3-79 keV
10 arcmin
160 kly
HESS+MAGIC+VERITAS 100 GeV-10 TeV
0.5 degrees
475 kly
Fermi-LAT 3-1000 GeV
2 degrees
1900 kly
EHT+Fermi+HESS+MAGIC+VERITAS+
NuSTAR + Chandra + Hubble +…
Algaba et al 2021, ApJL 911 L11
EAVN 13 mm
VLBA 7 mm
GMVA 3.5 mm
EVN 170 mm
EHT & ALMA 1.3 mm
HST 578 nm
Swift 439 nm
Swift 251 nm
Chandra X-rays
NuSTAR
Fermi-LAT
HESS+MAGIC+VERITAS
λ (m)
10^2 10^0 10^-2 10^-4 10^-6 10^-8 10^-10 10^-12 10^-14 10^-16 10^-18 10^-20
Radio Waves
Microwaves
Infrared
Visible
Ultraviolet
X-Rays
γ-Rays
Very High Energy γ-rays
ν (Hz)
10^6 10^8 10^10 10^12 10^14 10^16 10^18 10^20 10^22 10^24 10^26 10^28
Image Credit: The EHT Multi-wavelength Science Working Group; the EHT Collaboration; ALMA (ESO/NAOJ/NRAO); the EVN; the EAVN Collaboration; VLBA (NRAO); the GMVA; the Hubble Space Telescope; the Neil Gehrels Swift Observatory; the Chandra X-ray Observatory; the Nuclear Spectroscopic Telescope Array; the Fermi-LAT Collaboration; the H.E.S.S collaboration; the MAGIC collaboration; the VERITAS collaboration; NASA and ESA. Composition by J. C. Algaba

Apparent **morphology** of AGNs **“differs with energy”**

Shape of AGNs depend on the energy band used to characterize it. Moreover, the angular resolution of available instruments goes from **~10^{-4} arcsec at radio (10^{-5} arcsec with EHT) to ~0.1 deg at gamma rays**

→ *This complicates the comparison of the images at different energies*

Shown nicely in this video → **https://www.youtube.com/watch?v=q2u4eK-ph40**



EHT+Fermi+HESS+MAGIC +VERITAS+ NuSTAR + Chandra + Hubble + …

Algaba et al 2021, ApJL 911, L11

Alexander Hahn
(PhD student at MPP) is one of the corresponding authors of this paper

A structured jet is necessary to explain M87's spectrum

→ not possible to use the „one-zone“ theoretical scenarios to explain the full broadband data

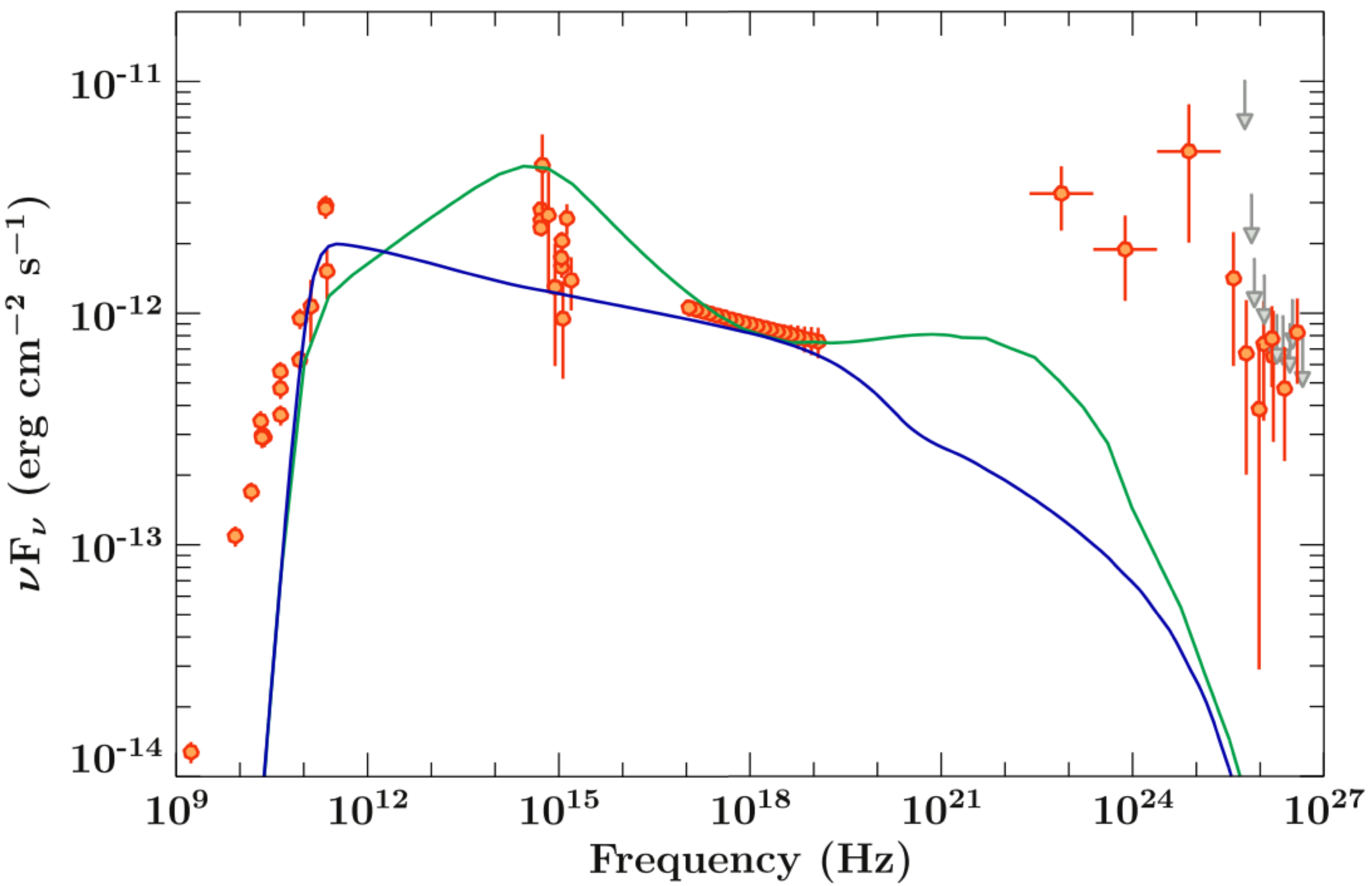
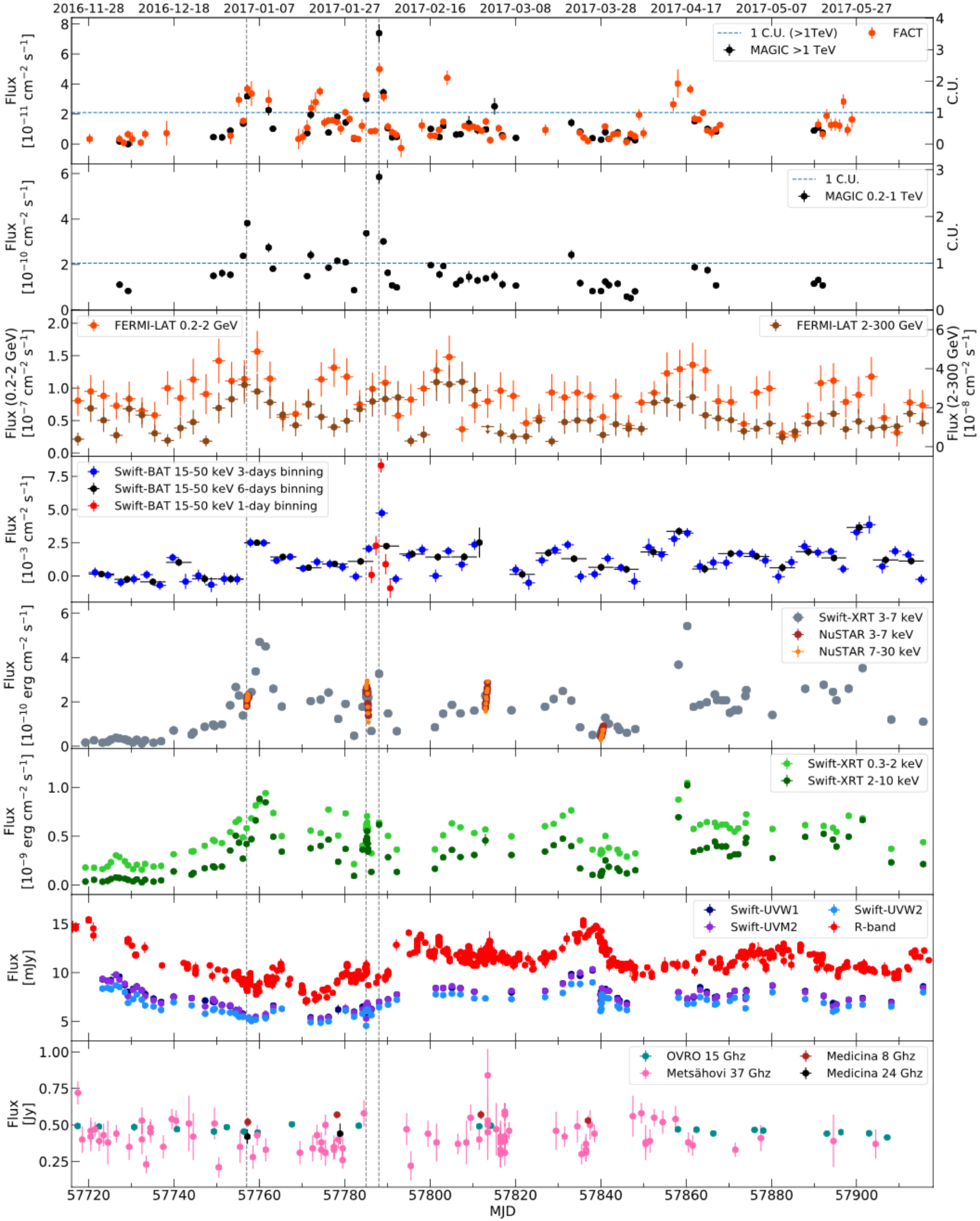


Figure 17. SED fit focusing on the EHT data. Blue and green lines display the resulting SEDs for models 1a and 1b, respectively. At γ-ray energy bands, one can see the SSC emission components although they underestimate the observed γ-ray flux density.

EHT+Fermi+HESS+. MAGIC+VERITAS+ NuSTAR + Chandra + Hubble + …

Algaba et al 2021, ApJL 911, L11

Alexander Hahn
(PhD student at MPP) is one of the corresponding authors of this paper



Multi-Instrument study of the nearby TeV blazar Mrk421

Multi-instrument Light Curves

MAGIC collaboration Acciari et al 2021, A&A 655, 89

Corresponding authors:
Axel Arbet-Engels + D.P.

Multi-Instrument study of theTeV blazar Mrk421

MAGIC collaboration

Acciari et al 2021, A&A 655, 89

Axel Arbet-Engels + D.P.

Fractional variability vs energy

→ Clear increase of flux variations with energy with double-bump structure

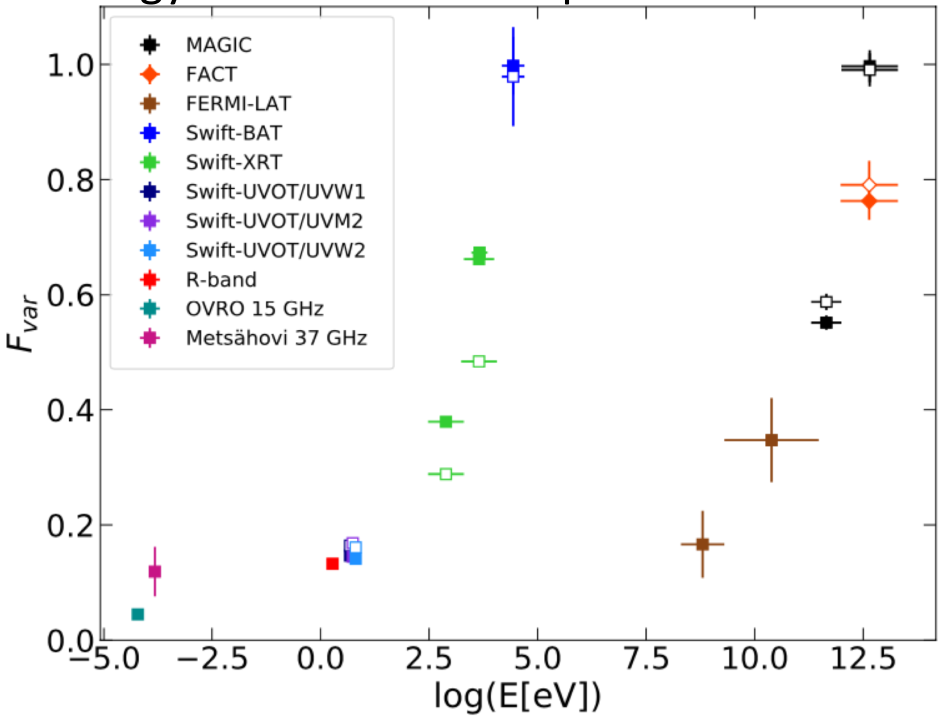


Fig. 6. Fractional variability $F_{\rm var}$ obtained from the light curves shown in Fig. 1. MAGIC, FACT, *Swift*-XRT, *Swift*-UVOT, *R*-band and radio fluxes are nightly binned. *Fermi*-LAT and *Swift*-BAT fluxes have a 3-day binning. Results from each instrument are plotted in different colours. The filled markers include all data. The hollow markers include VHE and *Swift* data lying within a time window of 4 h from each other.

Broadband SED during strong flare

→ Need for scenario with, at least, two distinct emitting regions

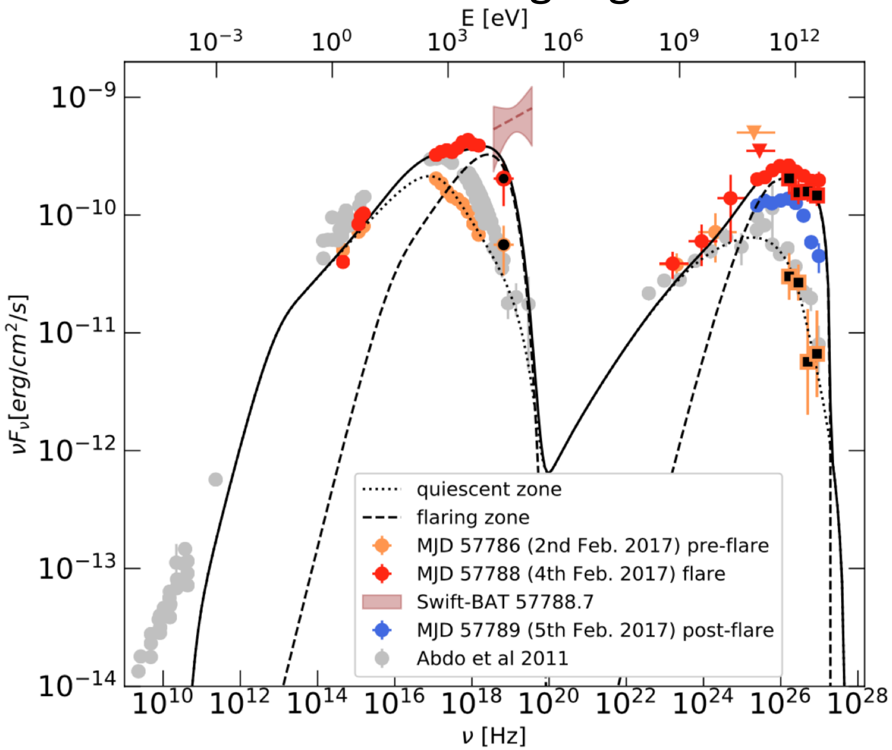


Fig. 16. Simultaneous broadband SEDs of MJD 57786 (pre-flare state), MJD 57788 (flare), and MJD 57789 (post-flare). *Fermi*-LAT spectral points are integrated over 3 days around the VHE measurements. VHE data with square black-filled markers are obtained from FACT observations, while X-ray data in black-filled markers are from *Swift*-BAT. The FACT SED for the pre-flare state was averaged from MJD 57786 to MJD 57787. The full black line is the two-zone model for the MJD 57788 flare state. The black dotted line represents the emission from the quiescent zone while the dashed line is the one from the flaring zone. The model parameters are listed in Table 6. Archival data representing the typical Mrk 421 state from Abdo et al. (2011) are shown in grey.

GeV-radio correlation in Mrk421 (2007-2016)

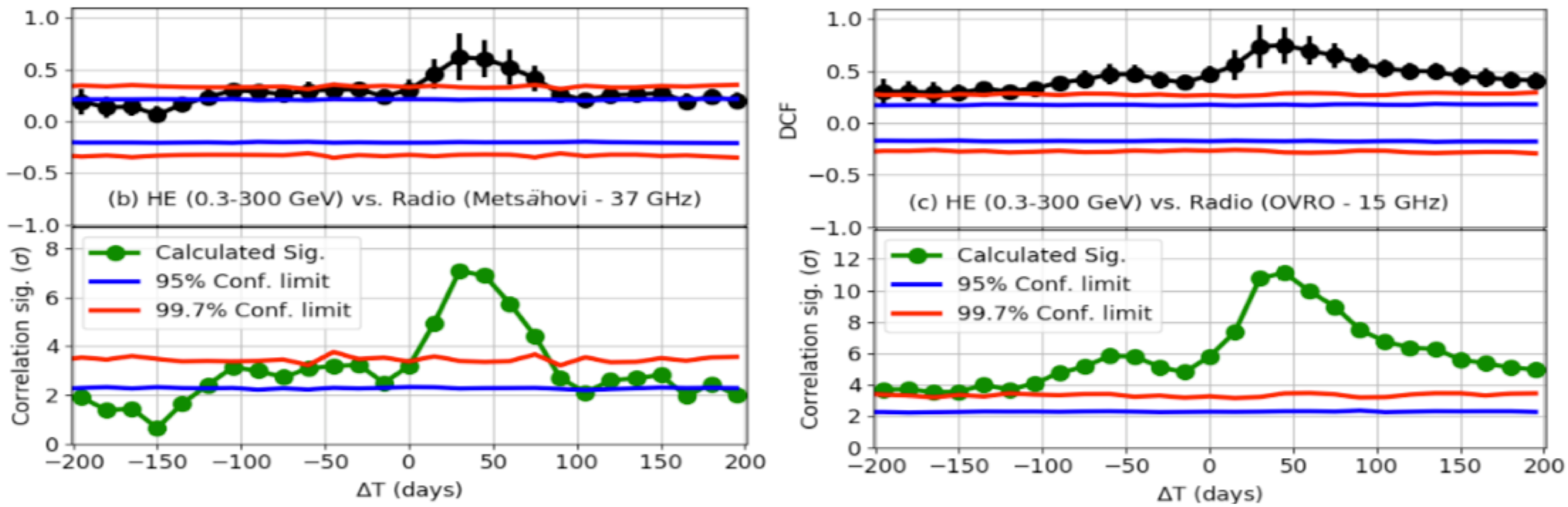
MAGIC collab.

Acciari et al 2021, MNRAS 504, 1427

Corr. Authors: Banerjee, Terzic, Majumdar, Paneque

37 GHz (Metsahovi) **15 GHz (OVRO)**

> 0.3 GeV (Fermi-LAT)



Correlation in the flux variations is particularly important with radio because the radio instruments have the best angular resolution, and hence they can help locating the regions responsible for the electromagnetic emission that we measure.

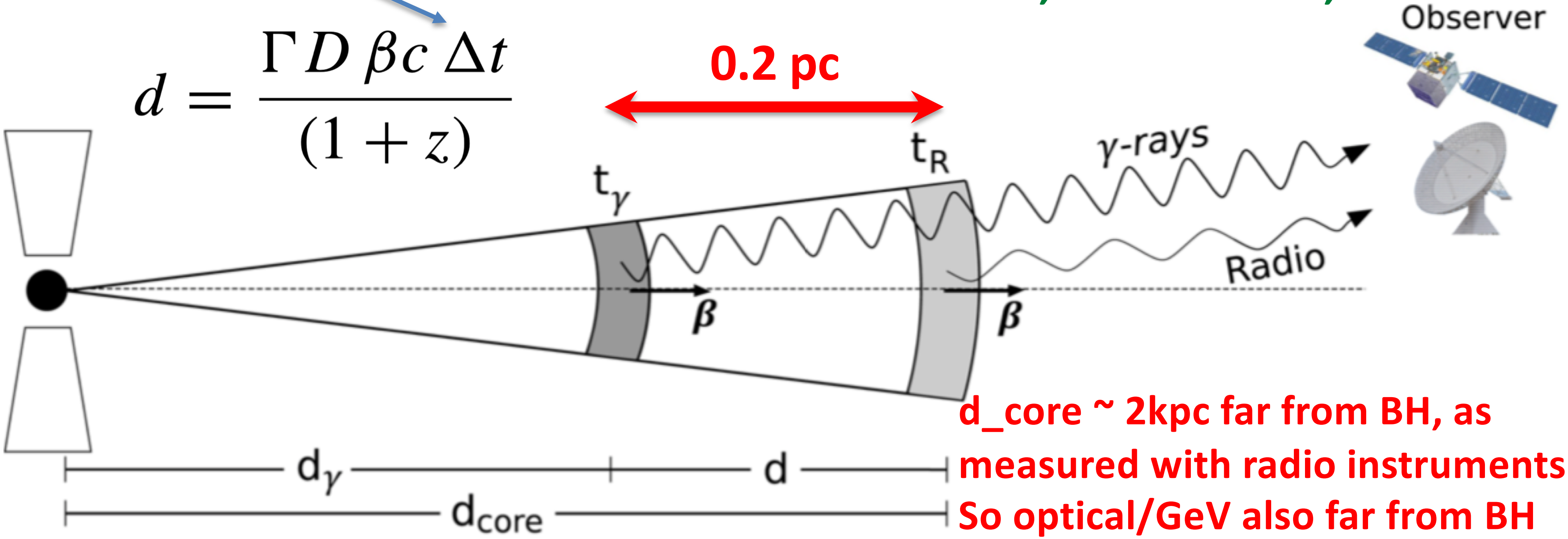
→ If correlation exists, the two emission bands must be connected

Radio-GeV correlation in Mrk421 (2007-2016)

The correlation GeV-radio and Optical-radio, with a time lag of ~45 days is an intrinsic characteristic in the multi-year emission of Mrk421, and not a particularity of a rare flaring activity.

Acciari et al 2021, MNRAS 504, 1427

$$d = \frac{\Gamma D \, \beta c \, \Delta t}{(1+z)}$$



d_core ~ 2kpc far from BH, as measured with radio instruments
So optical/GeV also far from BH

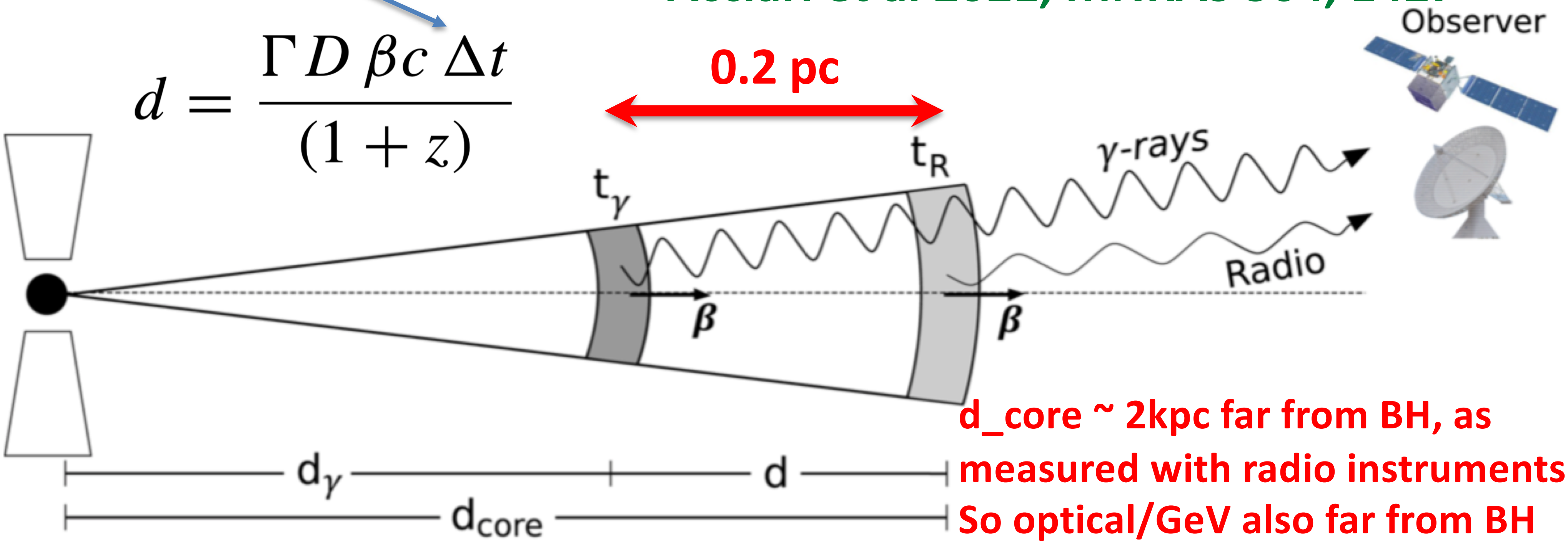
Emission may be produced by plasma (or jet disturbance) moving along the jet of Mrk421, first crossing the surface of unit gamma-ray opacity and then, **about 0.2 pc down the jet**, crossing the surface of unit radio opacity

Radio-GeV correlation in Mrk421 (2007-2016)

The correlation GeV-radio and Optical-radio, with a time lag of ~45 days is an intrinsic characteristic in the multi-year emission of Mrk421, and not a particularity of a rare flaring activity.

Acciari et al 2021, MNRAS 504, 1427

$$d = \frac{\Gamma D \beta c \Delta t}{(1+z)}$$



d_core ~ 2kpc far from BH, as measured with radio instruments
So optical/GeV also far from BH

VHE/X-ray may be produced in a small region with very high energy particles close to the central engine, very far away from the radio/optical/GeV emission. This would explain naturally the (typical) lack of correlation between VHE/X-ray and optical/GeV

GRBs, most powerful (transient) gamma-ray sources

- **GRB were serendipitously discovered at MeV in the late 60s**, becoming the brightest objects in the sky during minute timescales
- **GRBs @ Cosmological distances**, most luminous sources in Universe

Observationally, <u>two kinds of GRBs:</u>

Short (T_{90} < 2s): Binary neutron star mergers (*produce GWs*)

Long (T_{90} > 2s): Collapse of dying massive stars

GRBs, most powerful (transient) gamma-ray sources

- **GRB were serendipitously discovered at MeV in the late 60s**, becoming the brightest objects in the sky during minute timescales
- **GRBs @ Cosmological distances**, most luminous sources in Universe

Observationally, <u>two kinds of GRBs:</u>

Short (T_{90} < 2s): Binary neutron star mergers (*produce GWs*)

Long (T_{90} > 2s): Collapse of dying massive stars

<u>Two emission components, both produced in collimated jets:</u>

Prompt: primarily at MeV, lasts less than a few hundred seconds

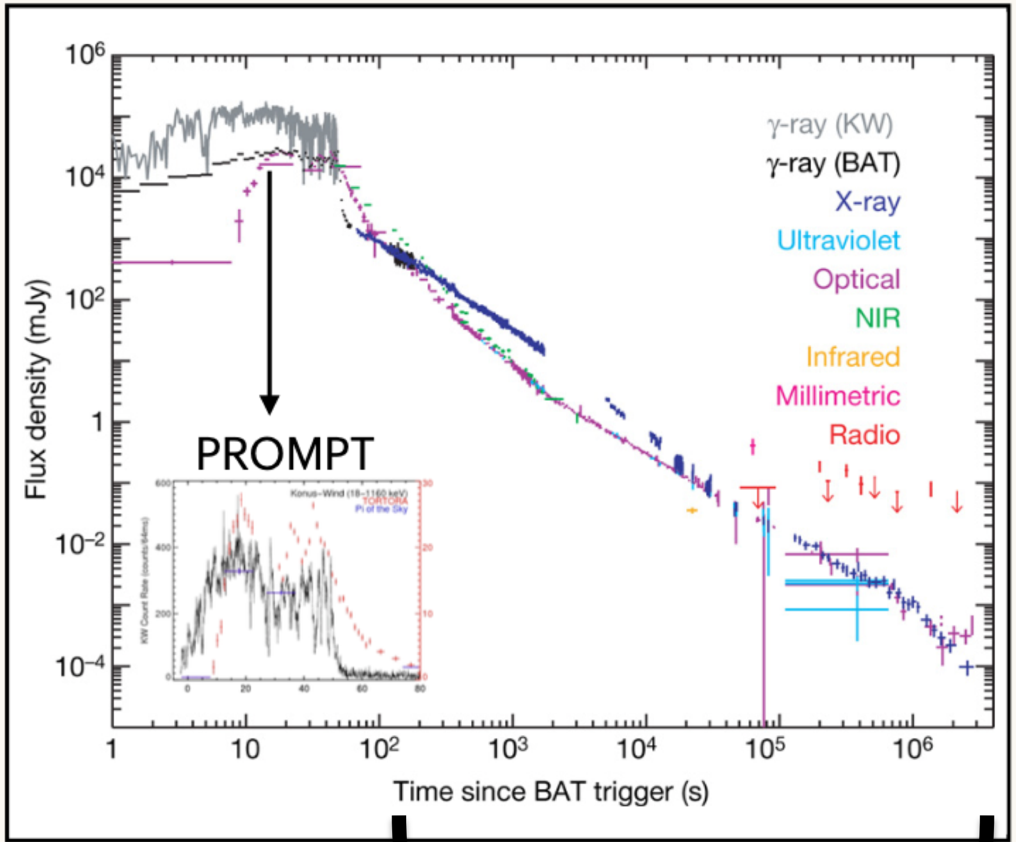
Afterglow: from GeV down to radio, decays gradually, longer times

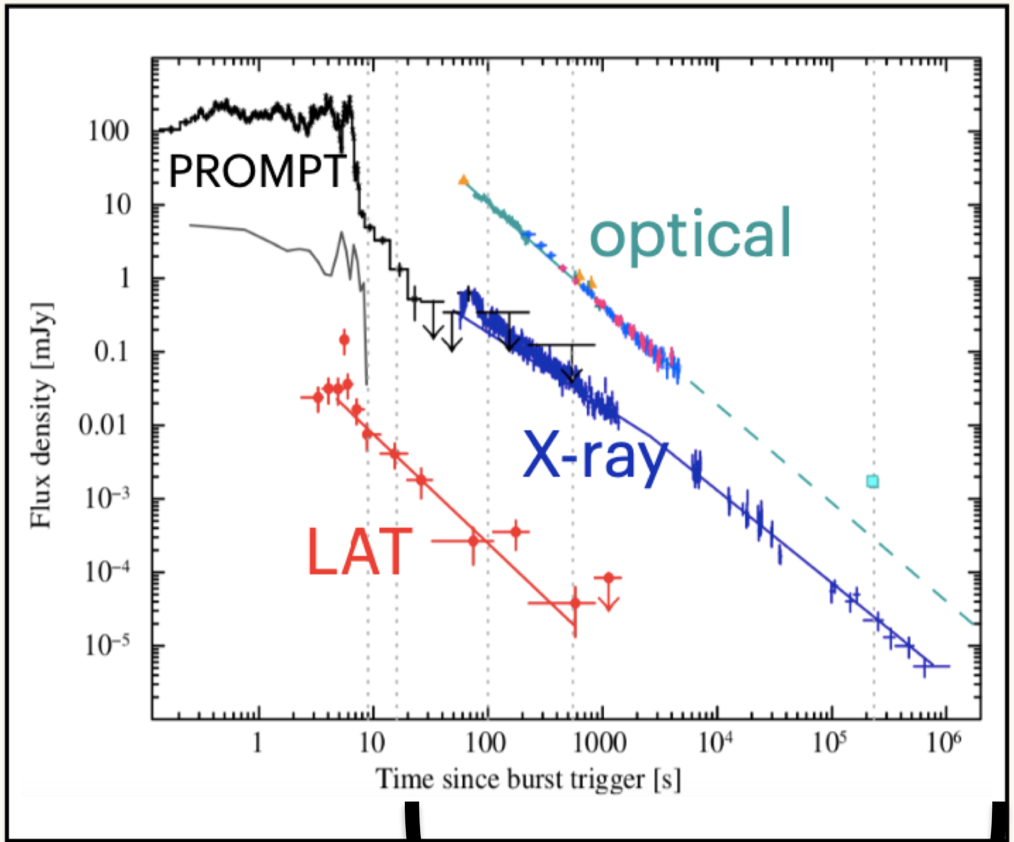
Energy released in prompt is x10 energy released in afterglow

GRBs, most powerful (transient) gamma-ray sources

GRB 080319B
Racusin et al., 2008

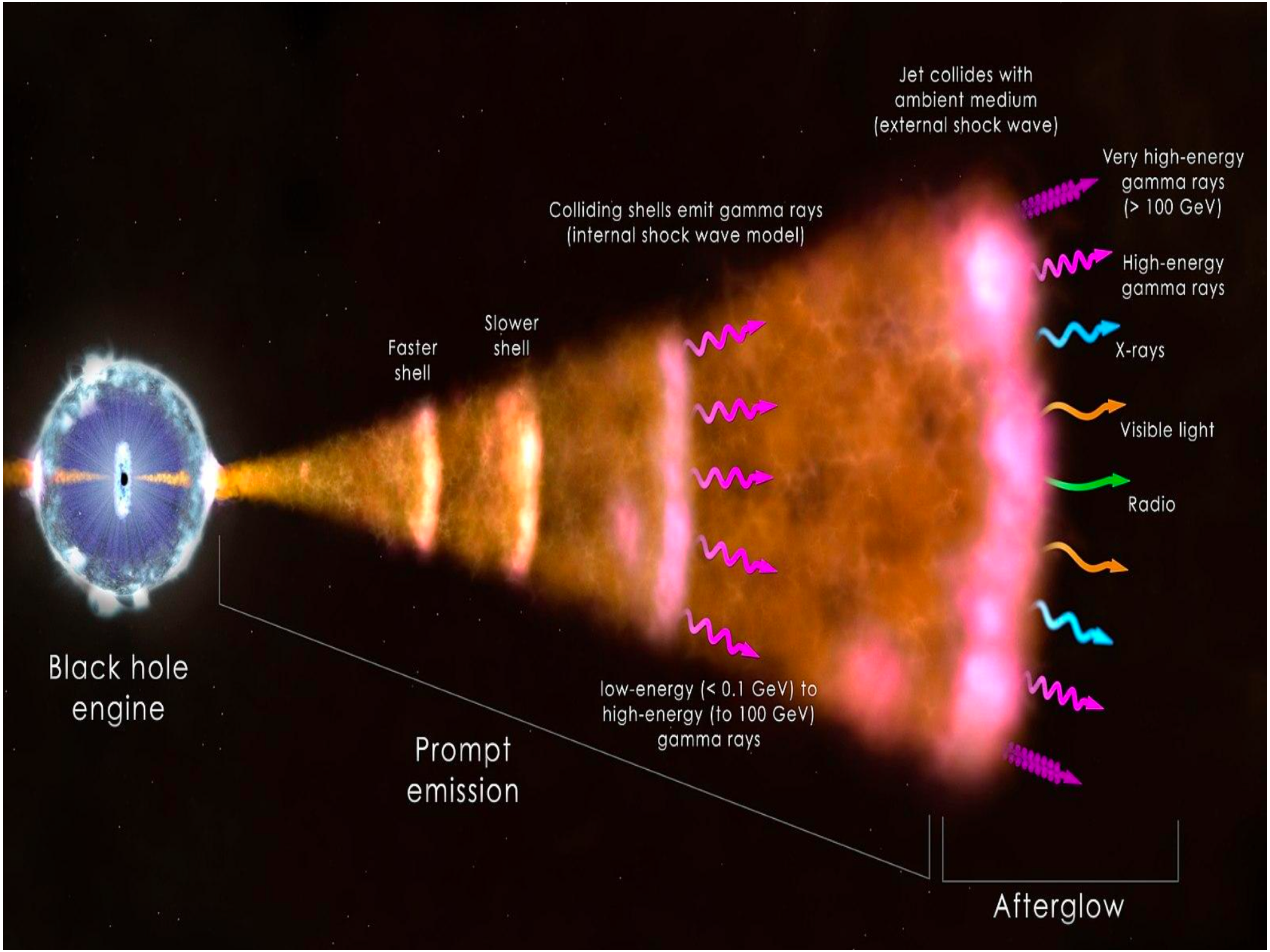
GRB 110731A
Ackermann et al., 2013





Afterglow

Afterglow



Jet collides with
ambient medium
(external shock wave)
Very high-energy
gamma rays
(> 100 GeV)
Colliding shells emit gamma rays
(internal shock wave model)
High-energy
gamma rays
Slower
shell
Faster
shell
X-rays
Visible light
Radio
Black hole
engine
low-energy (< 0.1 GeV) to
high-energy (to 100 GeV)
gamma rays
Prompt
emission
Afterglow

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

ATel #12390; *Razmik Mirzoyan on behalf of the MAGIC Collaboration*
on 15 Jan 2019; 01:03 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst

Referred to by ATel #: 12395, 12475

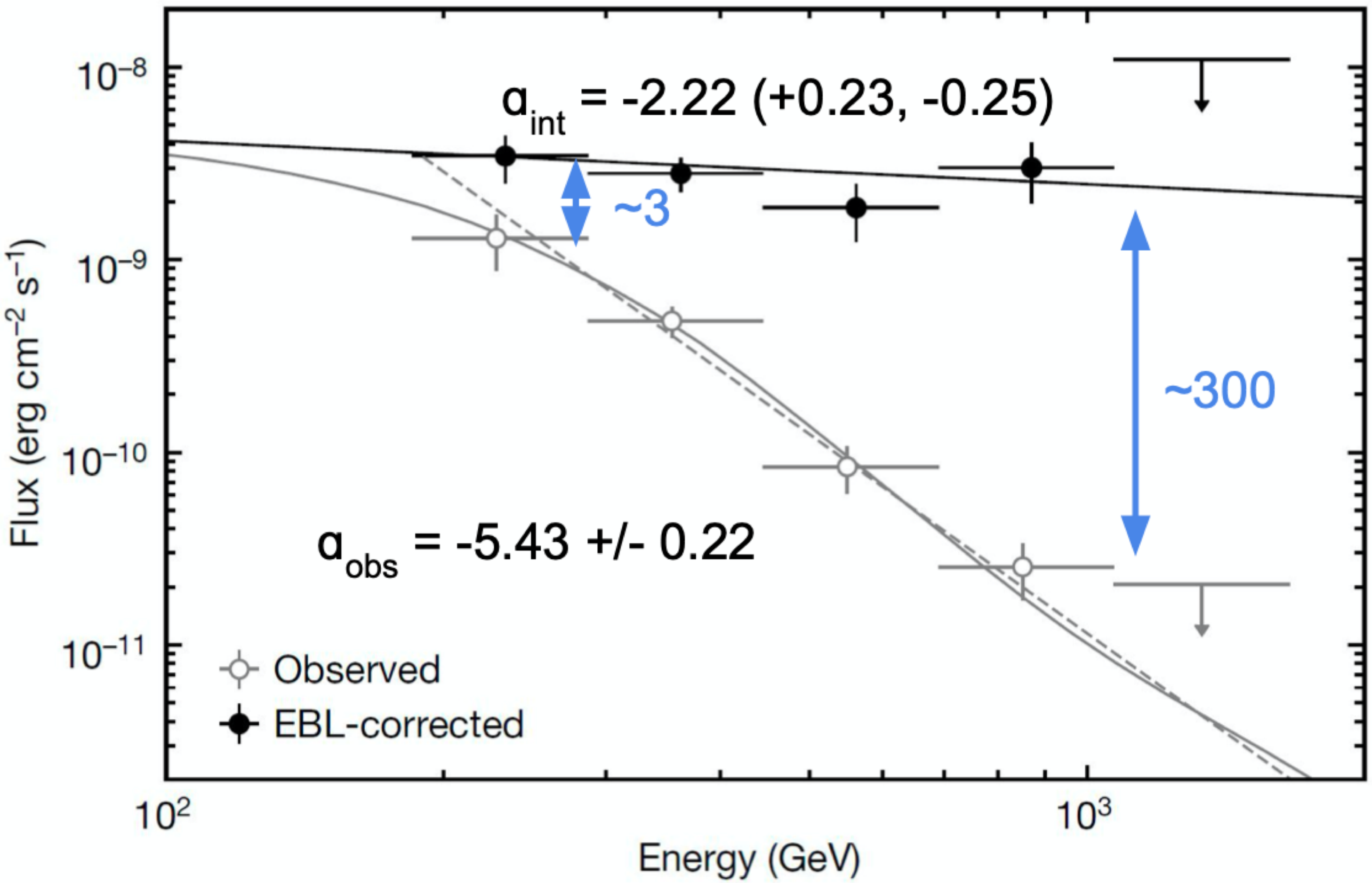
Final analysis yielded > 50 sigma

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started observing at about 50s after Swift T0: 20:57:03.19. The MAGIC real-time analysis shows a significance >20 sigma in the first 20 min of observations (starting at T0+50s) for energies >300GeV. The relatively high detection threshold is due to the large zenith angle of observations (>60 degrees) and the presence of partial Moon. Given the brightness of the event, MAGIC will continue the observation of GRB 190114C until it is observable tonight and also in the next days. We strongly encourage follow-up observations by other instruments. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) and K. Noda (nodak@icrr.u-tokyo.ac.jp). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

First VHE gamma-ray spectrum of a GRB

GRB190114C
(z=0.42, ~2 Gpc)

Alessio Berti and Razmik Mirzoyan among the corresponding authors



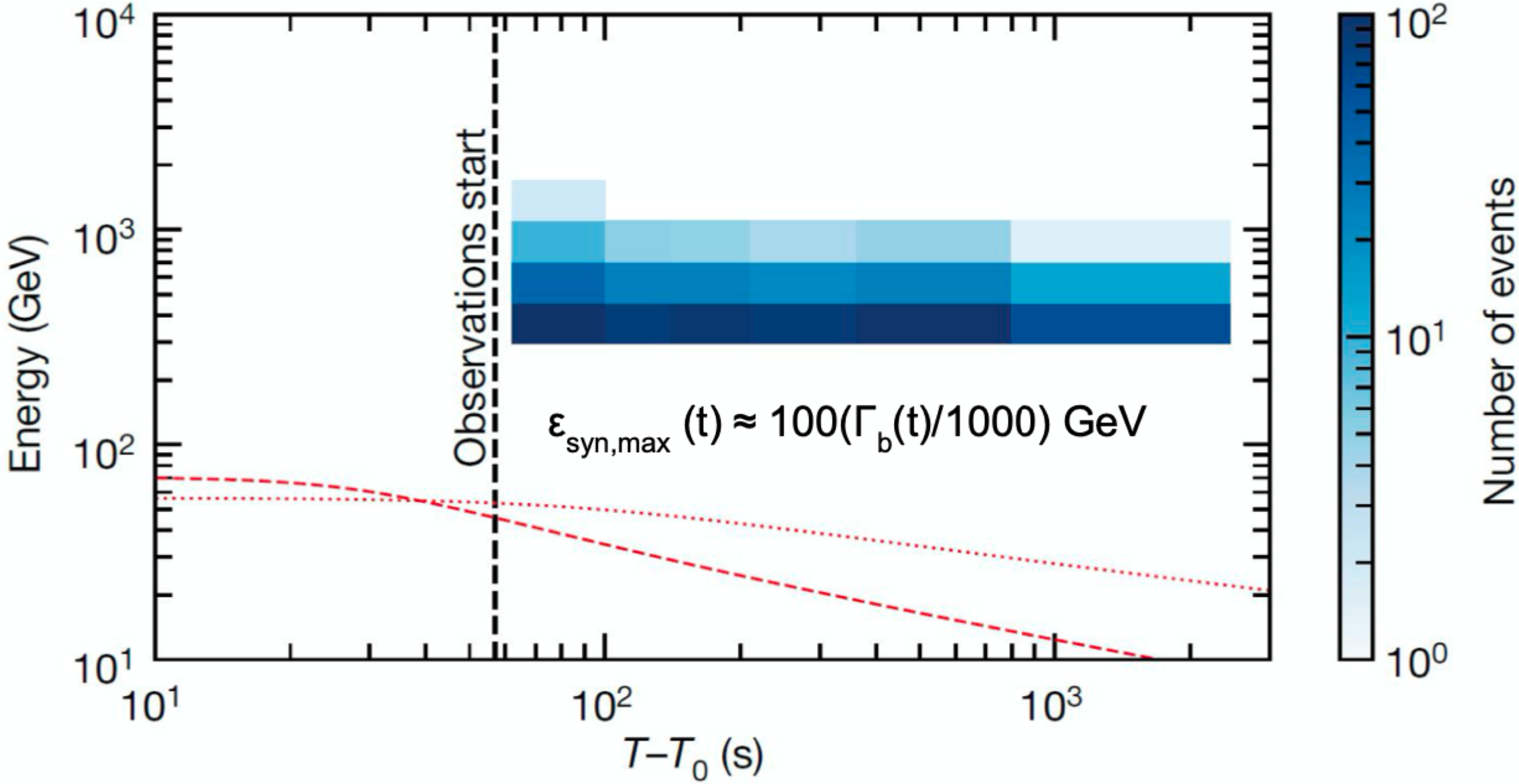
MAGIC Coll., Nature 575, 455 (aka: discovery paper)

Time integrated spectrum (T_0+62s to T_0+2454s) → huge absorption by EBL, emission extending up to 1 TeV, intrinsic spectrum compatible with α=-2

First detection of a gamma-ray burst at TeV energies

Distribution of VHE g-rays in energy versus time for GRB 190114C

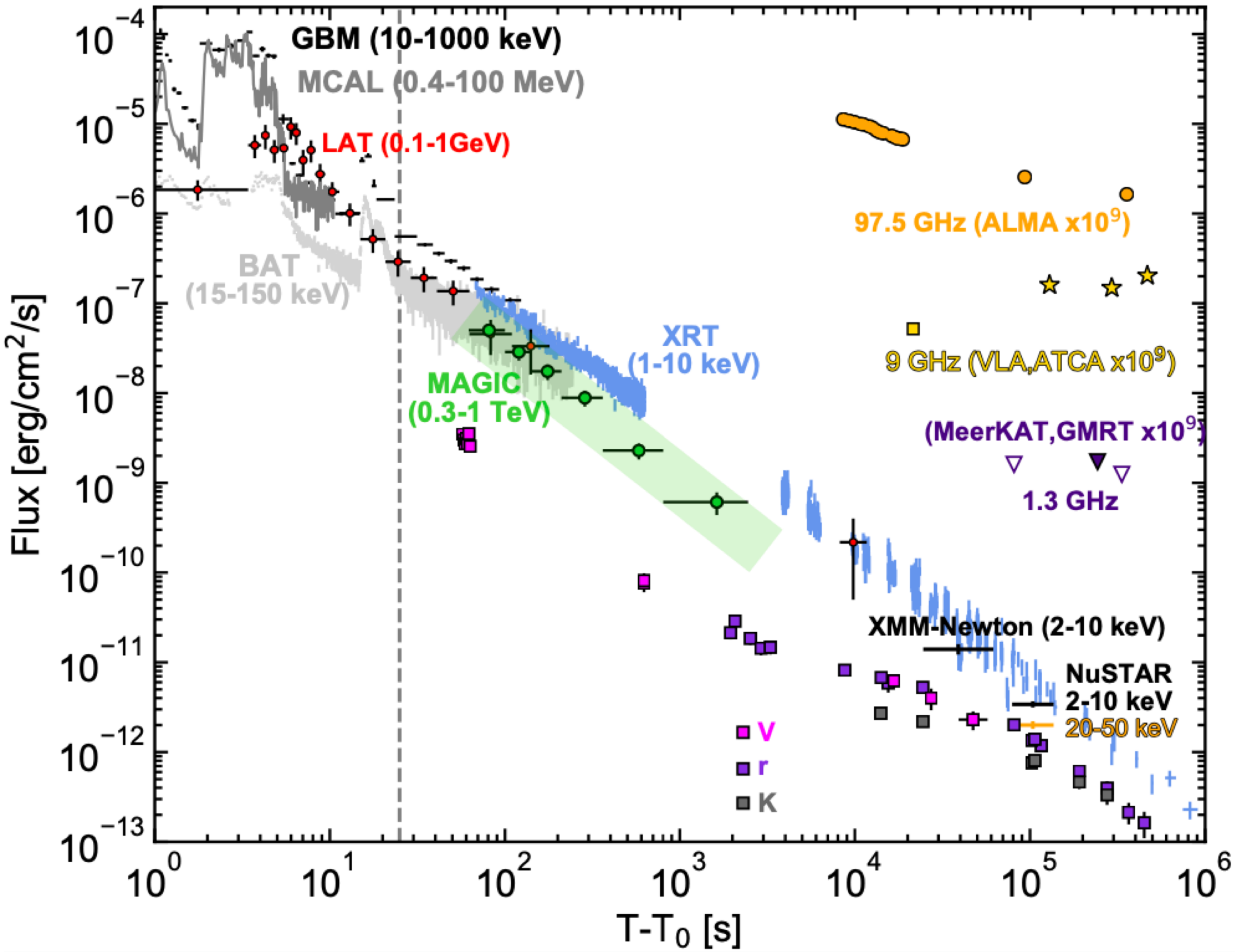
MAGIC Coll. et al., Nature 575, 455 (aka: discovery paper)



Energy of photons detected by MAGIC is well above the synchrotron "burnoff limit", hence the emission process responsible for VHE gamma rays cannot be the one producing the X-rays (synchrotron)

First detection of a gamma-ray burst at TeV energies

MAGIC Coll. et al., Nature 575, 459 (aka: MWL paper)



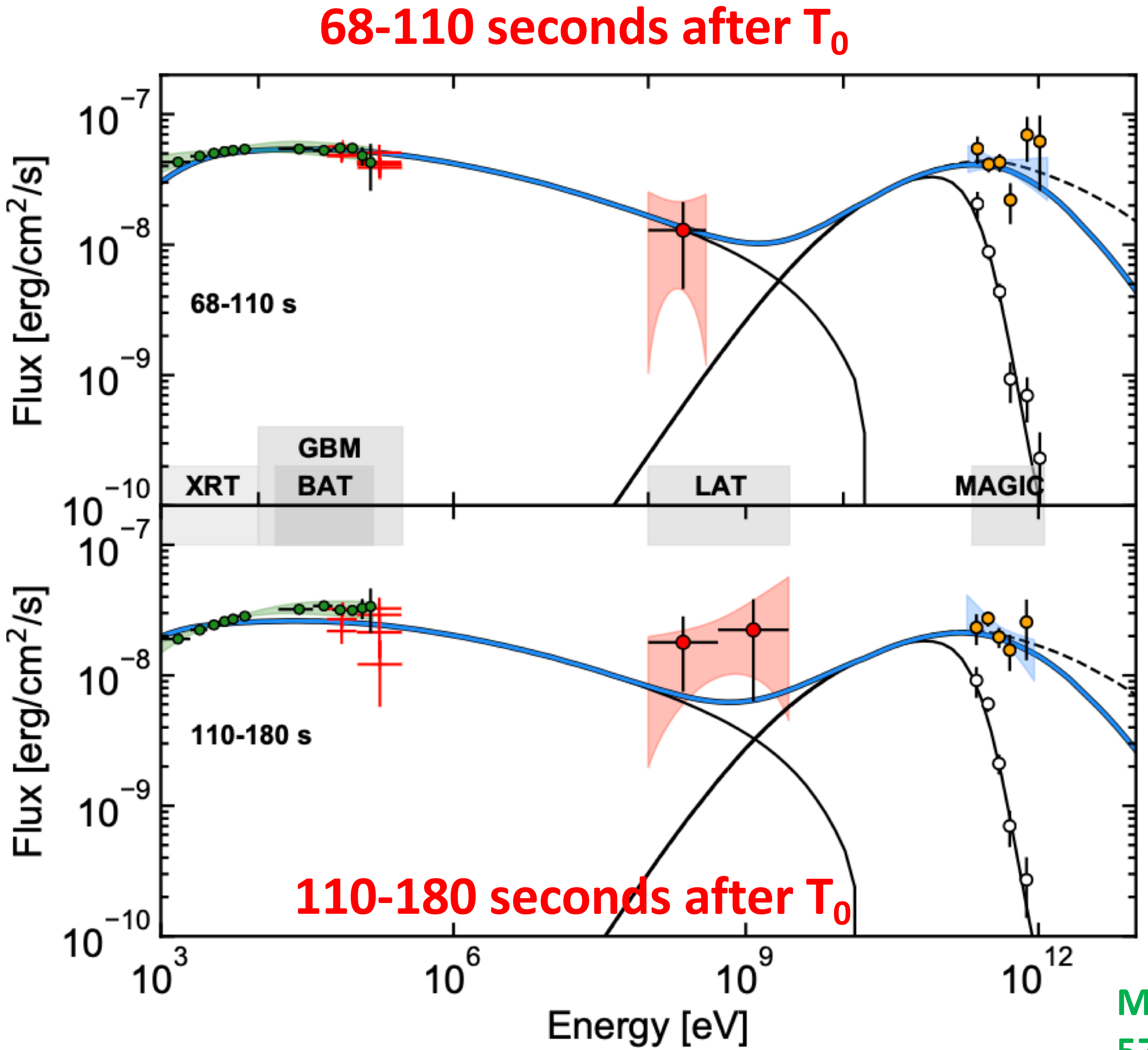
Multi-instrument lightcurves for GRB190114C

TeV g-rays show similar energy budget as GeV and keV photons, and evolve in time similarly

→ **AFTERGLOW**

Reasonable to attempt **description with a Synchrotron self-Compton (SSC)** theoretical scenario. <u>Hadronic scenarios disfavored by the data.</u>

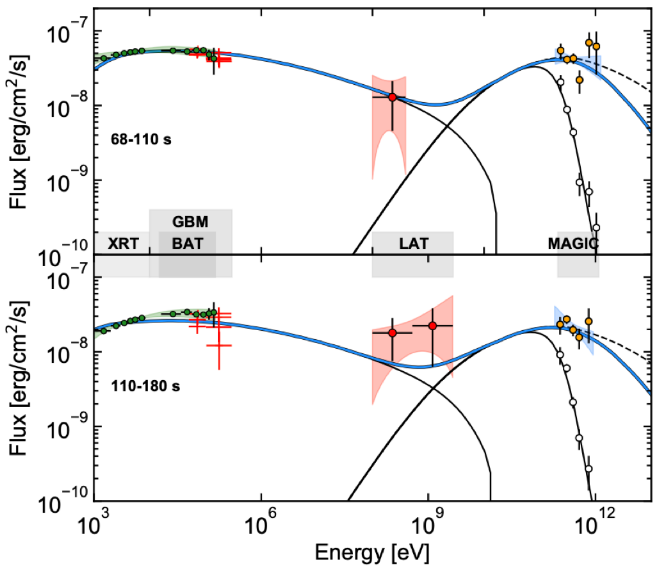
First detection of a gamma-ray burst at TeV energies

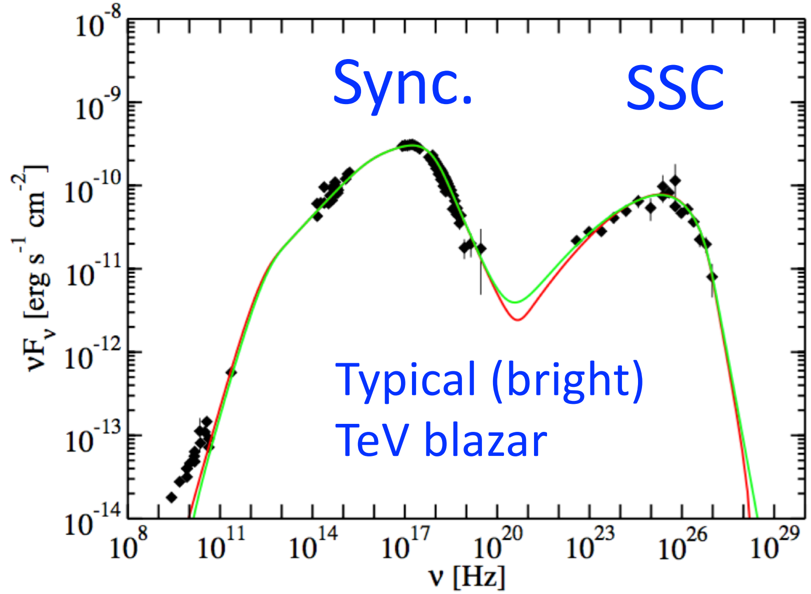


SSC scenario could describe well the broadband data, using relatively „standard" model parameters

MAGIC Coll. et al., Nature 575, 459 (aka: MWL paper)

First detection of a gamma-ray burst at TeV energies





TeV emission is associated with afterglow, explained with SSC model,

→ The TeV emission affected by strong Klein-Nishina effect, gamma-gamma opacity in the source, and gamma-gamma absorption in the EBL (sort of "obscured", or "hidden" to us)

→ energy in SSC is comparable to that in the Synchrotron

→ Decreased difference of afterglow with prompt by x2

→ Model parameters similar to that of typical GRBs

→ SSC component may be common in GRBs

→ beginning of new era to study GRBs ?

Similar to blazars and pulsar wind nebulae 30 years ago ?

First detection of a gamma-ray burst at TeV energies

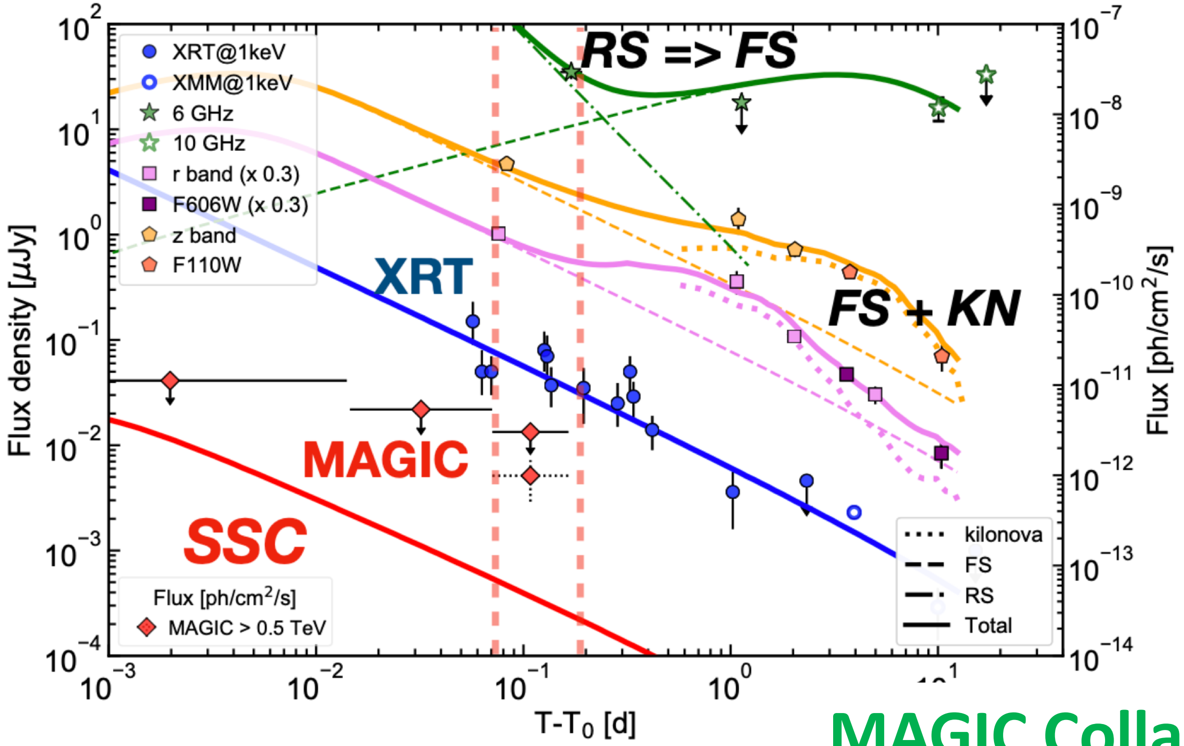
Since January 14th 2019, the detection of 3 additional long GRBs have been announced at VHE energies

GRB 180720B (z=0.65), detected by **HESS** at 5 sigma
→ announced at the *CTA symposium*, **May 2019**

GRB 190829A (z=0.08), detected with **HESS** at 22 sigma
→ announced with *Astronomer's Telegram* on **Aug30th, 2019**

GRB201216C (z=1.1), detected with **MAGIC** at 6 sigma
→ announced with *Astronomer's Telegram* on **Dec17th, 2020**
→ **Most distant VHE gamma-ray source to date**

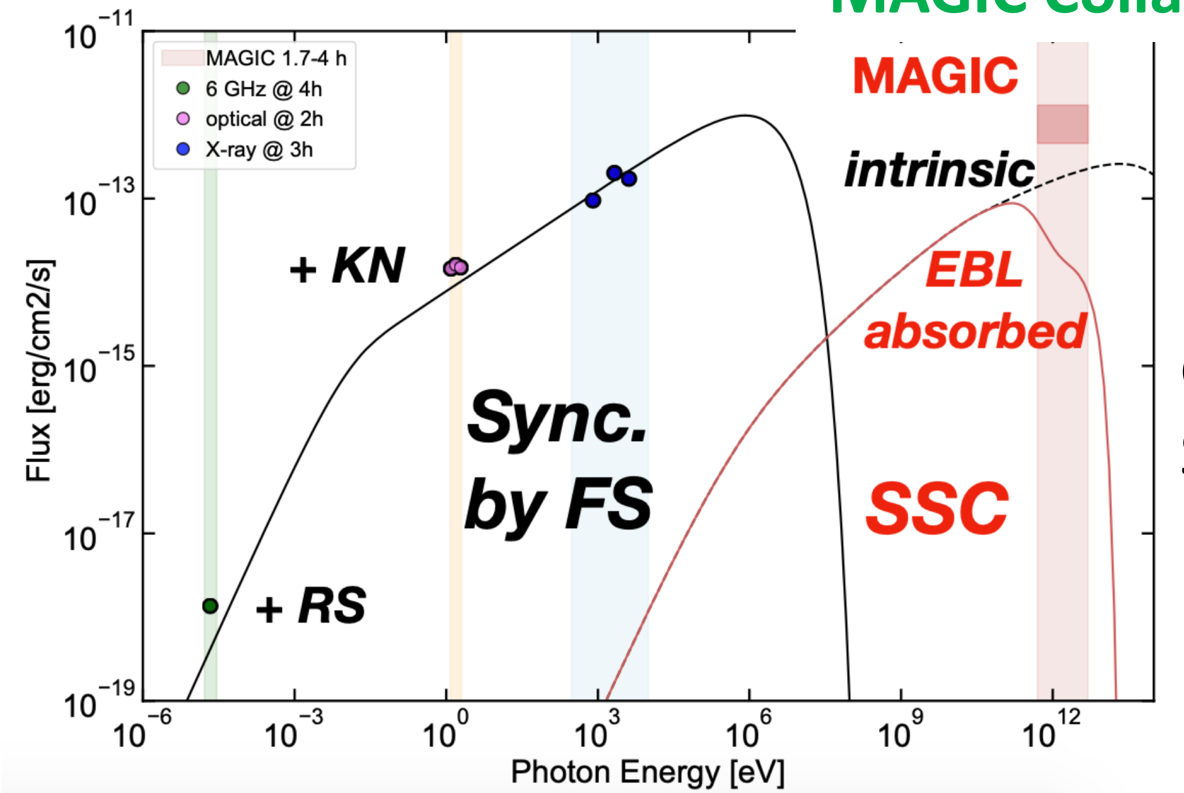
Took many years… and now all GRBs come „at the same time" !!
All can be explained within the Synchrotron self-Compton scenario
It seems SSC component is indeed common among long GRBs
→ **Time will confirm or reject this testable hypothesis**



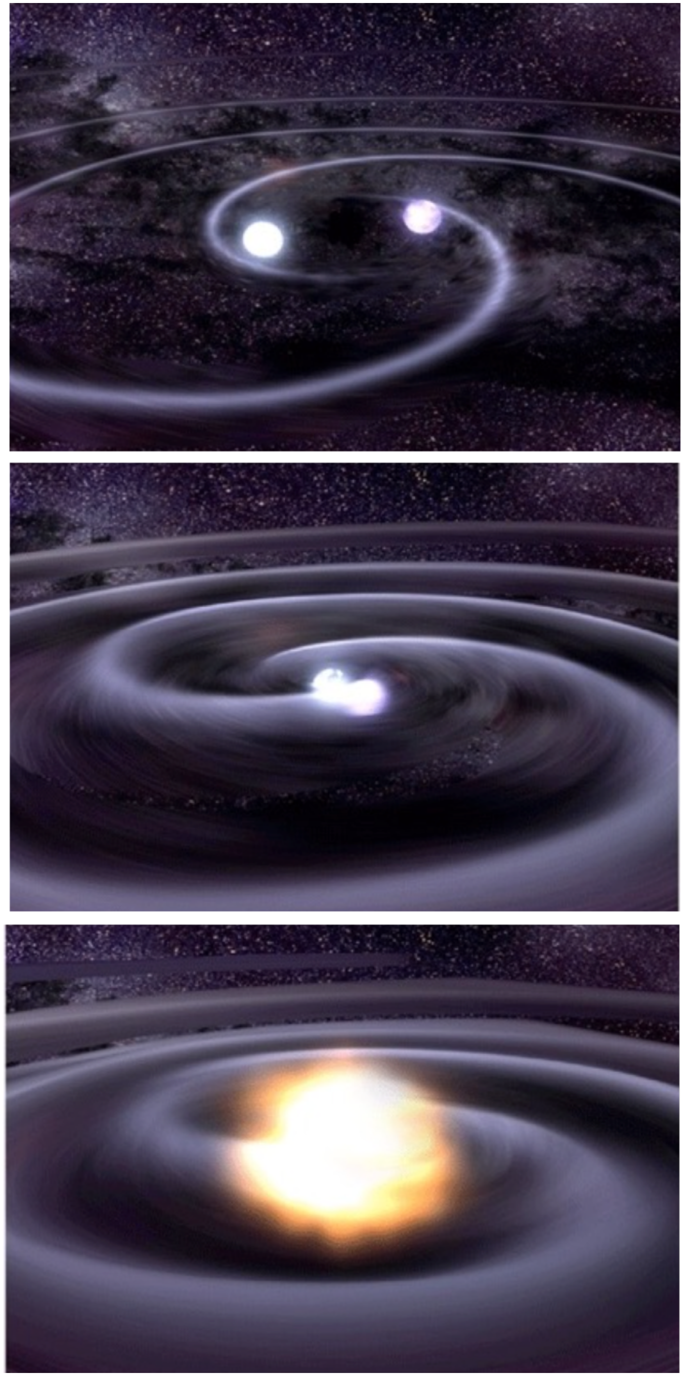
MAGIC detects the first hint (~3σ) of a VHE emission in a short GRB

GRB160821B (z=0.16)

MAGIC Collaboration, ApJ, 908 (2021) 90



In this case (contrary to long GRBs) the explanation with SSC model does not work well (neither the LC nor the SED)



Short GRBs are expected to be produced by NS-NS mergers.

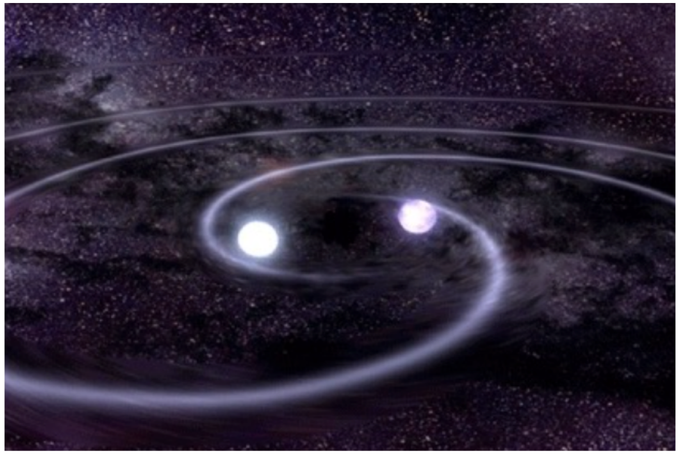
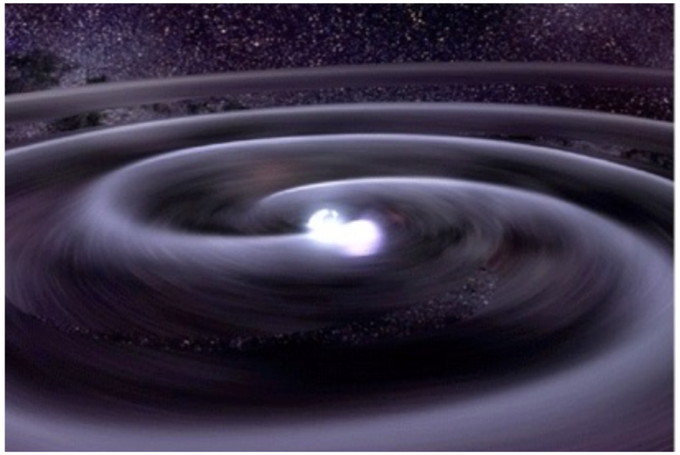
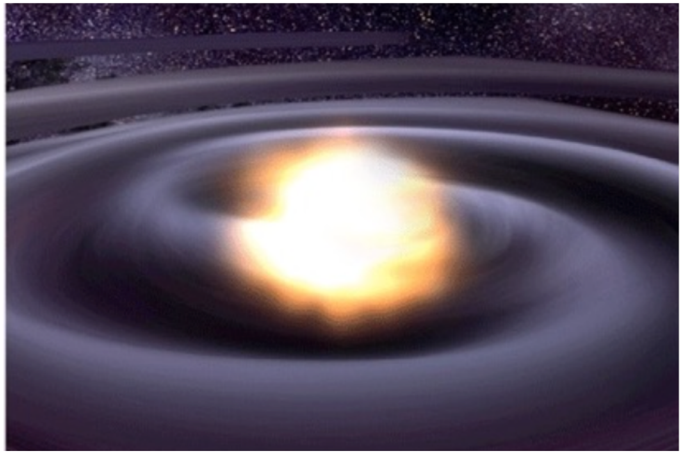
They are particularly interesting because

1) they are rare at gamma rays
10 times less abundant than long GRBs in LAT

2) They are expected to produce gravitational waves that could be detected

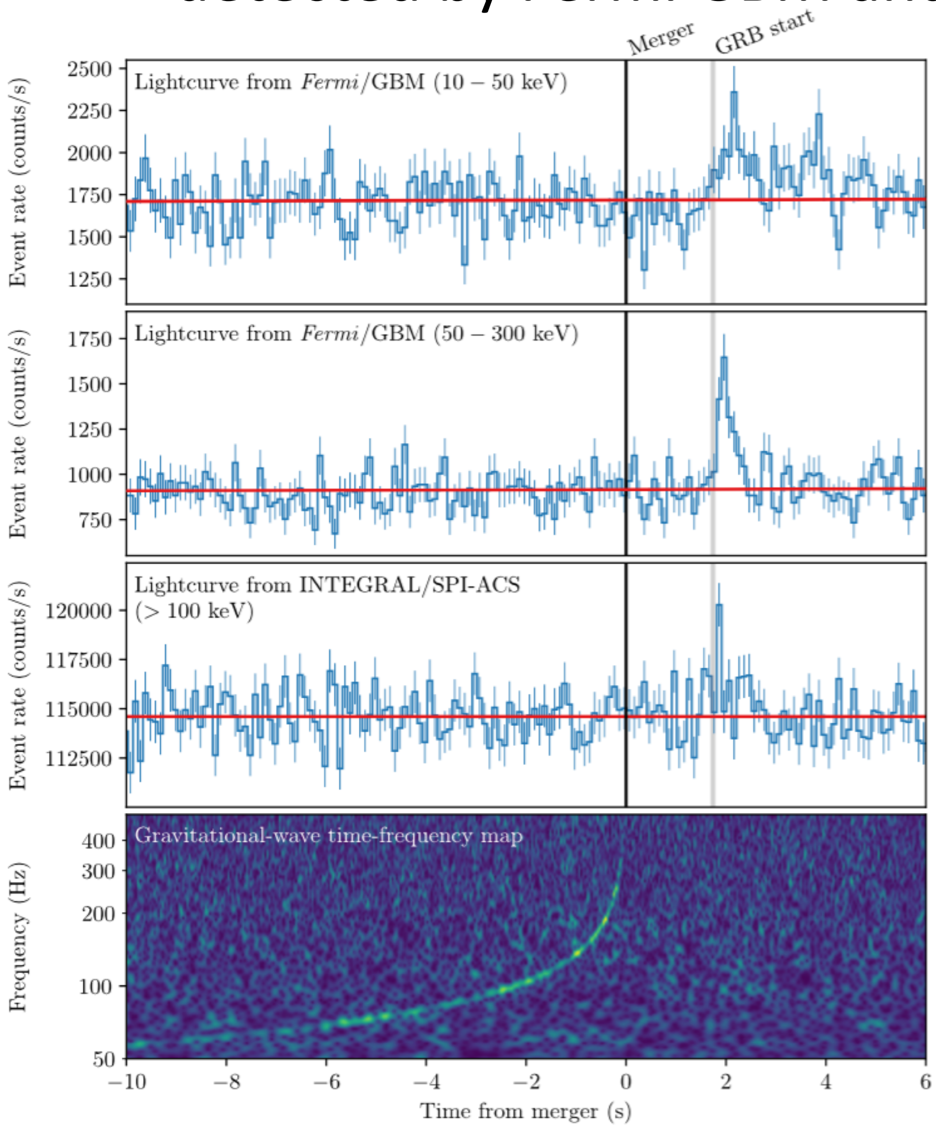
First and only EM-GW event to date is a short GRB

17th, August 2017

First Neutron Star – Neutron Star merger

→ GW170817 correlated with short GRB detected by Fermi GBM and INTEGRAL



Fermi-GBM 10-50 keV

Fermi-GBM 50-300 keV

INTEGRAL >100 keV

Abbot et al (LIGO) ApJ, 848, 13A 2017

MAGIC observation Cycle-17 starts in February 2022

We opened the program to proposals from scientists external to MAGIC collaboration

The MAGIC Telescopes

Gamma-ray astronomy at low energies with high sensitivity

HOME | GENERAL INFORMATION | SCIENCE WITH MAGIC | MAGIC MEMBERS | MAINTENANCE

MAGIC > MAGIC observation proposals

MAGIC observation proposals (Cycle 17)

MAGIC OBSERVATIONS PROPOSED BY EXTERNAL SCIENTISTS

The MAGIC collaboration encourages individual external scientists to propose observations to be performed with the MAGIC telescopes. Observation time will be granted by the Time Allocation Committee based on scientific merit.

The observation cycle 17 spans from 2022 February 18th to 2023 February 2nd. **The deadline to submit the MAGIC proposals is 2021 October 29th at 23:00 CET.**

MAGIC is not an open observatory, and the analysis of the data requires specific expertise and tools. Some members from the MAGIC team will be supporting the external projects throughout the entire procedure of proposal submission, and (if the observation time is granted) data reduction and publication. The details on the authorship of the publications will be discussed and agreed before the submission of the observation proposal. The MAGIC collaboration shall be included in the authors' list of the publications reporting these data results for the first time.

Overall over-subscription by fator ~2

MAGIC Proposal Submission System

Hello, David, you are logged in as dpaneque9. logout — evaluation: open, 1d 16h 02m left

User's tasks: proposals management — help/tips for proposers

Coordinator's tasks: browse submitted proposals

Evaluator's tasks: MAGIC evaluation — XMM evaluation — final reports — help/tips for evaluators (including technical reports)

main page — Please, click here to change your password.

MAGIC Cycle-17 proposals evaluation system

— TAC evaluation reports for the Cycle 17 proposals —

This page will be constantly updated with information, as this becomes available

Cycle 17 scientific evaluation (*Excel format*) (44 kB)

Time Allocation Committee (TAC) meeting Dec10-14

Intense discussions about proposals… hard time to decide what gets observed and what will not

Conclusions

MAGIC is 18 years old, but keeps operating wonderfully, under leadership of MPP at all levels (organization, science & technical)

- Factor of 4 improvement in sensitivity since beginning of science operation
  → *More than one order of magnitude better sensitivity below 200 GeV*
- And telescopes keep improving over time (starting intensity interferometry)
- Activities related to overall critical review started this year

The telescopes survived a global pandemic, and now holding against a volcano. Will resume the ~week after the volcano activity stops

The collaboration is big (~270, including affiliated scientists) and diverse (13 countries), and keeps growing

→ New groups joined in year 2021: Granada (Spain) and Beren (Norway)

Instrument+collaboration are matured and very productive, regularly publishing on a broad range of scientific topics

→ **9 publications in 2021, despite covid-19+Volcano**

→ ***Most scientifically productive Cherenkov telescope in the last 5 years***