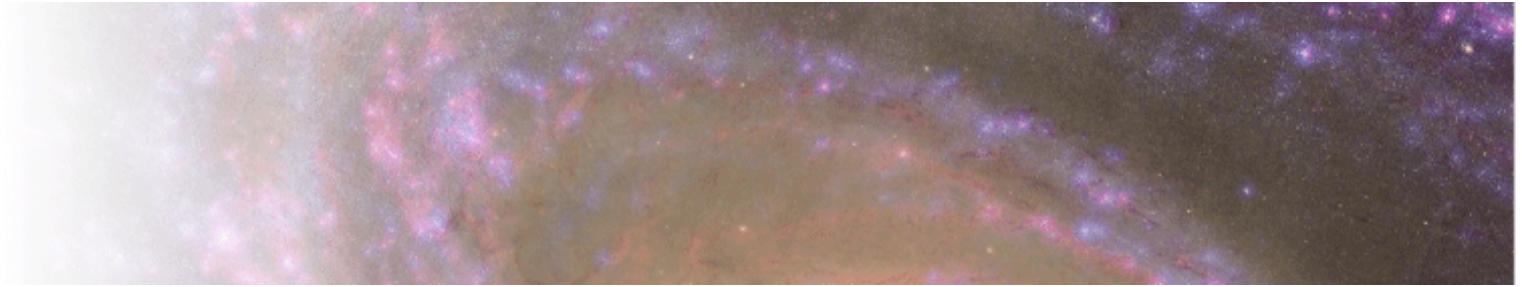


Hands-on the Extreme Universe with High Energy Gamma-ray data

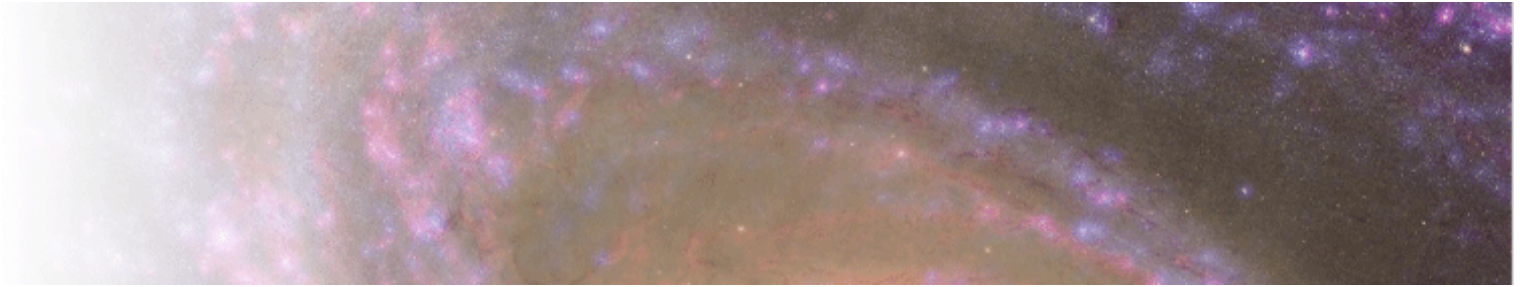
18.07.2022 - 22.07.2022

Sexten – Dolomites Italy



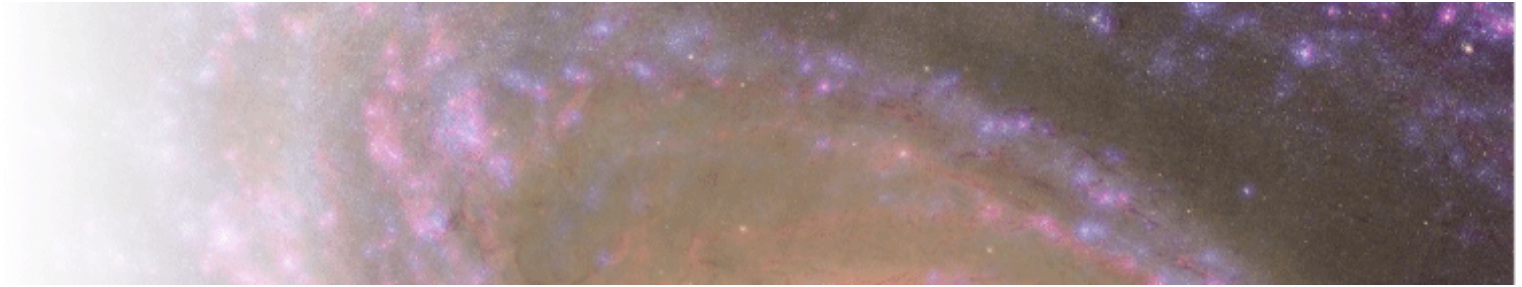
- A beautiful location !





- Thanks to the Organising Committee (Giacomo, Chiara, Giacomo, Patrizia, Nico and Gino)
- Thanks to the HandsOn tutors (Fabio, Giacomo, Gonzalo, Andrea and Martina)
- Thanks to Gabriella Deconi and the Sexten Center soon dedicated to Riccardo Giacconi
- Thanks to our ‘supporters’





- Overview of the program!
 - The Extreme Universe
 - Fermi, current IACTs, LHAASO
 - Next Generation IACT telescopes
 - LST, MST, SCT, ASTRI-SST
 - Theory of VHE sources
 - CR sources, AGN, GRB, PSR-PWN, ALPs
 - Science with Cherenkov Telescopes
 - Transients, Galactic, Extragalactic, DarkMatter, CR
 - Multiwavelength and MultiMessenger connections
 - eROSITA, IXPE, SKA, Neutrinos, GW
 - Special talk – 25 years of GRB afterglows

The Extreme Universe

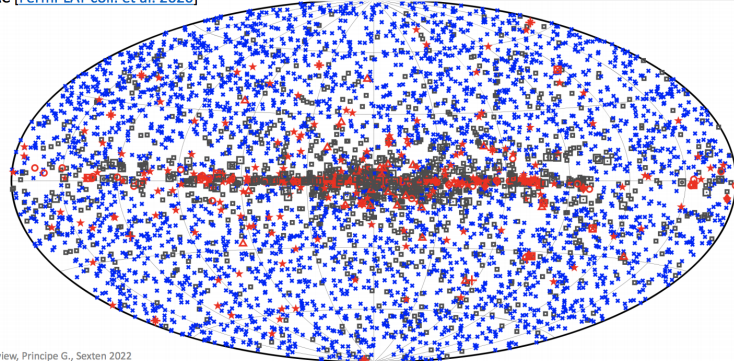


More than 6500 sources detected in first 12 years



4FGL-DR3 catalog [Abdollahi et al. 2022]
12 years of LAT, 50 MeV < E < 1 TeV
4LAC [Fermi-LAT coll. et al. 2020]

- No association
- Pulsar
- Binary
- Star-forming region
- Possible association with SNR or PWN
- Globular cluster
- Galaxy
- Unclassified source
- AGN
- Starburst Galaxy
- SNR
- PWN
- Nova



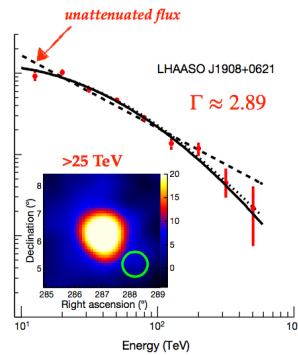
Fermi-LAT review, Principe G., Sexten 2022

9

Fermi: G.Principe

The first SNR as PeVatron?

LHAASO J1908+0621 = SNR G40.5-0.5 + GMC ?

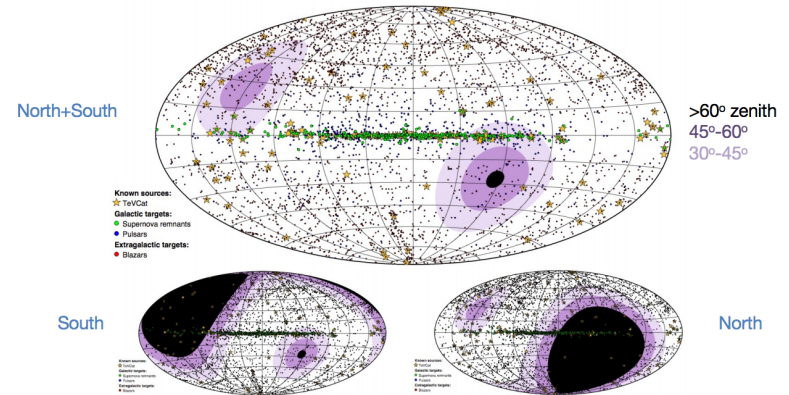


One of the most intriguing sources in the Galactic plane. MGRO J1908+06 spatially associates with an *IceCube hotspot of neutrino emission*. Although the hotspot is not significant yet, this suggests a *possible hadronic origin of the observed gamma-ray radiation*.

Highest energy photon 0.45 PeV => E_p > 2 PeV
confirmation of association with G40.5-0.5 would be *the first evidence of a SNR operating as PeVatron*

soon LHAASO will announce detection of UHE γ -rays from W51 and γ Cygni
=> new developments are anticipated with exciting implications

DESIGN DRIVER:
FULL-SKY COVERAGE



CTA: W.Hofmann

LHAASO: G.Di Sciascio

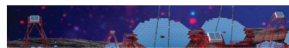
The Extreme Universe

Science with CTA



CTA: F.Longo

CTA will have important synergies with many of the new generation of major astronomical particle observatories. Multi-wavelength and multi-messenger approaches combining CTA data from other instruments will lead to a deeper understanding of the broad-band non-thermal target sources, elucidating the nature, environment, and distance of gamma-ray emitters synergies in each waveband are presented.



<https://arxiv.org/abs/1709.07997>

ASTRI: A.Giuliani

ASTRI Science : overview



Origin of Cosmic Rays

- PeVatrons
- CRs Acceleration and Propagation
- Pulsar Wind Nebulae and TeV Halos

Fundamental Physics

- Intergalactic fields
- Blazars
- LIV and ALP

Transient Follow-Up

The ASTRI Mini-Array of Cherenkov Telescopes at the Observatorio del Teide

S. Scuderi^{1*}, A. Giuliani^{2*}, G. Pareschi³, G. Tosti⁴, O. Catalano⁵, E. Amato⁶, L.A. Antonelli⁷, J. Becerra González⁸, G. Bellasini⁹, C. Bigongiari¹⁰, B. Biondo¹¹, M. Boëtcher¹², G. Bonanno¹³, P. Bruno¹⁴, A. Bulgarelli¹⁵, B. Canestrari¹⁶, M. Capalbi¹⁷, M. Cardillo¹⁸, V. Conforti¹⁹, G. Conino²⁰, M. Corpora²¹, A. Costa²², G. Cusumano²³, A. D'Alò²⁴, E. de Gouveia Dal Pino²⁵, R. Della Ceca²⁶, E. Escribano Rodríguez²⁷, D. Falcaes-Gonçalves²⁸, C. Fermino²⁹, M. Fiori³⁰, V. Fioretti³¹, M. Fiorini³², S. Galassi³³, R. Giacomini³⁴, S. Inverso³⁵, L. Leschke³⁶, S. Lombardi³⁷, L. Nava³⁸, F. Pintore³⁹, A. Stamerra⁴⁰, F. Tavecchio⁴¹, L. Zampieri⁴², R. Alves Batista⁴³, M.C. B. de Amorim⁴⁴, E. Amato⁴⁵, L.A. Antonelli⁴⁶, C. Arcaro⁴⁷, J. Becerra González⁴⁸, G. Bonoli⁴⁹, F. P. B. Brunetti⁵⁰, A.A. Compagnino⁵¹, S. Crestani⁵², A. D'Alò⁵³, M. Fiori⁵⁴, G. Gabiani⁵⁵, G. Rossi⁵⁶, E.M. de Gouveia Dal Pino⁵⁷, J.G. Green⁵⁸, A. Lamastra⁵⁹, M. Landoni⁶⁰, F. Lucarelli⁶¹, G. Morlino⁶², B. Olmi⁶³, E. Peretti⁶⁴, G. Piano⁶⁵, G. Ponti⁶⁶, E. Poretti⁶⁷, P. Romano⁶⁸, F.G. Saturni⁶⁹, S. Scuderi⁷⁰, G. Soffici⁷¹, L. Zappacosta⁷²

JHEAP, 2022, 35, 52

ASTRI Mini-Array Core Science at the Observatorio del Teide

S. Vercellone^{1*}, C. Bigongiari², A. Burtovoi³, M. Cardillo⁴, O. Catalano⁵, A. Franceschini⁶, S. Lombardi⁷, L. Nava⁸, F. Pintore⁹, A. Stamerra¹⁰, F. Tavecchio¹¹, L. Zampieri¹², R. Alves Batista¹³, M.C. B. de Amorim¹⁴, E. Amato¹⁵, L.A. Antonelli¹⁶, C. Arcaro¹⁷, J. Becerra González¹⁸, G. Bonoli¹⁹, F. P. B. Brunetti²⁰, A.A. Compagnino²¹, S. Crestani²², A. D'Alò²³, M. Fiori²⁴, G. Gabiani²⁵, G. Rossi²⁶, E.M. de Gouveia Dal Pino²⁷, J.G. Green²⁸, A. Lamastra²⁹, M. Landoni³⁰, F. Lucarelli³¹, G. Morlino³², B. Olmi³³, E. Peretti³⁴, G. Piano³⁵, G. Ponti³⁶, E. Poretti³⁷, P. Romano³⁸, F.G. Saturni³⁹, S. Scuderi⁴⁰, A. Tutone⁴¹, G. Umana⁴², I. A. Alvarez-Dolado⁴³, D. Rauscher⁴⁴, A. Bonanno⁴⁵, G. Bonanno⁴⁶, D. Basso⁴⁷, A. Bulgarelli⁴⁸, D. Cecarini⁴⁹, D. V. Giordano⁵⁰, V. Giordano⁵¹, G. Naletti⁵², P. Santoro⁵³, N. Zywucki⁵⁴

JHEAP, 2022, 35, 1

Galactic Observatory Science with the ASTRI Mini-Array at the Observatorio del Teide

A. D'Alò^{1*}, E. Amato², A. Burtovoi³, A.A. Compagnino⁴, M. Fiori⁵, A. Giuliani⁶, N. Leung⁷, Palombaro⁸, A. Paizis⁹, G. Piano¹⁰, F.G. Saturni¹¹, A. Tutone¹², A. Uchiyama¹³, S. Crestani¹⁴, G. Cusumano¹⁵, M. Della Valle¹⁶, M. Del Santo¹⁷, A. La Barbera¹⁸, S. Lombardi¹⁹, S. Mereghetti²⁰, G. Morlino²¹, F. Pintore²², P. Romano²³, S. Vercellone²⁴, A. Antonelli²⁵, C. Arcaro²⁶, C. Bigongiari²⁷, M. Boëtcher²⁸, P. Bruno²⁹, A. Bulgarelli³⁰, V. Conforti³¹, A. Costa³², E. de Gouveia Dal Pino³³, J.G. Green³⁴, A. Lamastra³⁵, M. Landoni³⁶, F. Lucarelli³⁷, G. Morlino³⁸, B. Olmi³⁹, E. Peretti⁴⁰, G. Piano⁴¹, G. Ponti⁴², E. Poretti⁴³, P. Romano⁴⁴, F.G. Saturni⁴⁵, S. Scuderi⁴⁶, A. Tutone⁴⁷, G. Umana⁴⁸, I. A. Alvarez-Dolado⁴⁹, D. Rauscher⁵⁰, A. Bonanno⁵¹, G. Bonanno⁵², D. Basso⁵³, A. Bulgarelli⁵⁴, D. Cecarini⁵⁵, D. V. Giordano⁵⁶, V. Giordano⁵⁷, G. Naletti⁵⁸, P. Santoro⁵⁹, N. Zywucki⁶⁰

JHEAP, 2022, 35, 39

Extragalactic Observatory Science with the ASTRI Mini-Array at the Observatorio del Teide

F.G. Saturni^{1*}, C. H. E. Arcaro^{2,4,5,6}, B. Balmaverde⁷, J. Becerra González^{8,9}, A. Caccianiga¹⁰, M. Capalbi¹¹, A. Lamastra¹², S. Lombardi¹³, F. Lucarelli¹⁴, R. Alves Batista¹⁵, I. A. Antonelli¹⁶, E. B. de Gouveia Dal Pino¹⁷, R. Della Ceca¹⁸, J. G. Green¹⁹, G. Gabiani²⁰, S. Vercellone²¹, A. Wolter²², E. Amato²³, C. Bigongiari²⁴, A. Bulgarelli²⁵, M. Cardillo²⁶, V. Conforti²⁷, A. Costa²⁸, G. Cusumano²⁹, V. Fioretti³⁰, S. Germani³¹, A. Ghedina³², V. Giordano³³, A. Giuliani³⁴, F. Incardona³⁵, A. La Barbera³⁶, G. Leto³⁷, F. Longo³⁸, G. Morlino³⁹, B. Olmi⁴⁰, N. Parmiggiani⁴¹, P. Romano⁴², G. Romeo⁴³, A. Stamerra⁴⁴, G. Tagliaferri⁴⁵, V. Testa⁴⁶, G. Tosti⁴⁷, P. A. Caraveo⁴⁸ and G. Pareschi⁴⁹

JHEAP, 2022, 35, 91

Next Generation IACT

MST: J-F. Glicenstein

Summary LST: M.Teshima

- There have always been some problems in the society and world, Pandemic, Volcano eruptions, Price increases, and Shortage of materials.
 - Nevertheless, I appreciate our young colleagues' continuous development of Software and Hardware.
 - We should also continue to work to achieve our goal of a high-performance all-sky observatory with LSTs. PNRR program will make it a reality.
 - LSTs are telescopes for observations of GRBs, transient sources, multi-messenger astronomy, Gravitational-wave sources, High-Energy neutrino sources, and Search for Dark Matters.
 - Surely the CTA consortium should start to work to establish a scientific network with observatories' working in other wavelengths and messengers.
- **Great Scientific results are waiting for you!!**

Conclusion and « take home messages »

- The instrumental requirements on MST structures and cameras follow from the physics requirements of CTA.
- The MST telescopes use a common mechanical Davies-Cotton and 2 cameras designs: NectarCAM (CTAN) and FlashCam (CTAS).
- A prototype of Davies-Cotton structure has been implemented near Berlin in 2012 and extensively tested.
- NectarCAM and FlashCam fulfill all CTA requirements and have comparable performances.
- The FlashCam camera uses off-the-shelf component with a photon detection plane and electronics racks. It had its first light in 2017. A FlashCam is successfully operated since October 2019 on the CT5 telescope of H.E.S.S.
- The NectarCAM camera has a modular structure based on the Nectar ASIC. It has its first light in 2019.
- The installation will follow the « pathfinder » strategy before acceptance of telescopes by CTA.
- The first telescopes should be installed on CTAN and CTAS in 2023-2024.

MST-Sexten 07/22

33

SCT Summary and Outlook

Recent results

- Improved optics alignment
- First measurement of inclination-dependent PSF measurement
- Further work on current camera to improve data analysis
- Full-chain (FPM+SMART+FEE) measurements for camera upgrades
 - Production for full camera started

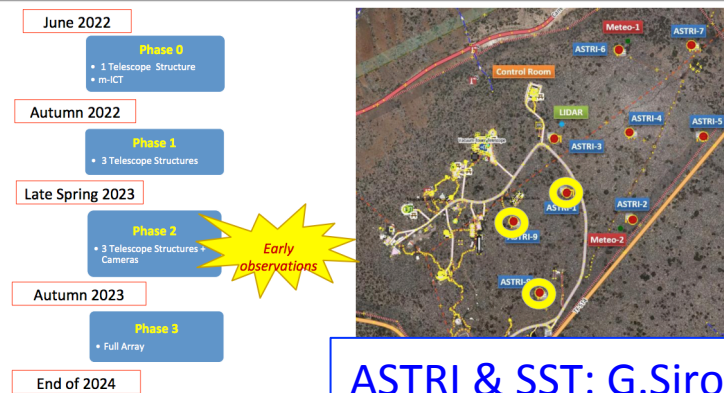
Next steps

- Continued commissioning, engineering, and operations
- Improvements in Optical System (alignments and off-axis PSF)
- Camera upgrade
 - Production and installation of upgraded sensors and electronics
- Discussions with CTAO Project Office
 - Infrastructure planning and budgeting for SCT addition in CTA-S



SCT: E.Bissaldi

The ASTRI Mini-Array Project

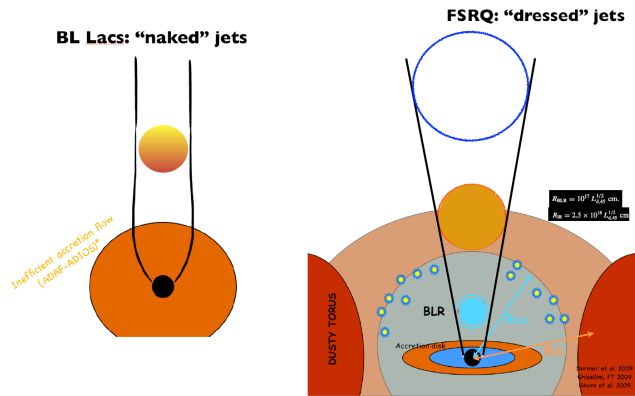


ASTRI & SST: G.Sironi

Theory of VHE sources

Blazars: F.Tavecchio/G.Bonnoli

Blazars in a nutshell



PSR and PWN: G.Morlino

THE STRUCTURE OF THE MAGNETOSPHERE

$$B_* = \frac{2\mu_0}{R_*^3} \quad \vec{B} = B_* \left(\frac{R_*}{R} \right)^3 \left[\cos\theta \mathbf{e}_R - \frac{\sin\theta}{2} \mathbf{e}_\theta \right]$$

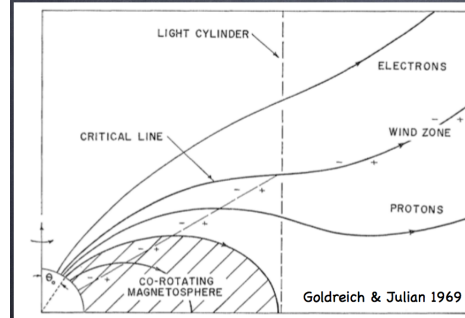
FOR DIPOLE TANGENT LINE: $\sin^2\theta/R = \text{const}$

LAST CLOSED FIELD LINE
DEFINES POLAR CAP $\sin\theta_{pc} = \sqrt{\frac{R_*}{R_L}}$

$$\vec{E} = -\frac{\Omega R \sin\theta}{c} \mathbf{e}_\phi \wedge \vec{B}$$

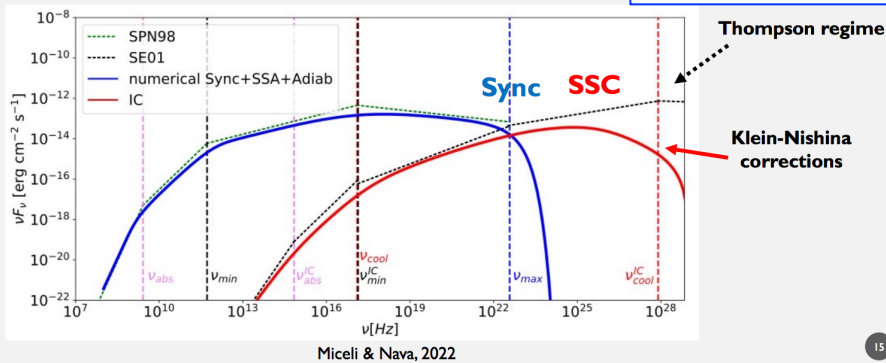
CHARGE DENSITY $\rho_{CJ} = -\frac{\vec{\Omega} \cdot \vec{B}}{2\pi c} \frac{1}{\left[1 - \left(\frac{R}{R_L} \right)^2 \sin^2\theta \right]}$

CRITICAL LINE: WHERE $\vec{\Omega} \cdot \vec{B}$ CHANGES SIGN $\theta_c = \arccos\sqrt{\frac{1}{3}}$



VHE emission: KN corrections

Shaping the VHE spectrum



GRB: D.Miceli

γ : photon

α : ALP

absorption: $\gamma + \gamma_{soft} \rightarrow e^+ + e^-$

γ_{soft} : EBL, BLR

$g_{\alpha\gamma\gamma}$: $\gamma\gamma\alpha$ coupling

E : γ electric field

B : external magnetic field

$\mathcal{L}_{\alpha\gamma} = g_{\alpha\gamma\gamma} \mathbf{E} \cdot \mathbf{B} \dot{\alpha}$

$B_{clu} = O(10) \mu G$

Galaxy cluster:

M. Meyer, D. Montanino, J. Conrad, JCAP 09, 003 (2014) [arXiv: 1406.5972].

G. Galanti, M. Roncadelli, F. Tavecchio, arXiv: 2202.12286.

$B_{jet} = O(1) G$

$B_{ext} = O(1) nG$

Blazar:

F. Tavecchio, M. Roncadelli, G. Galanti, Phys. Lett. B 744, 375 (2015) [arXiv: 1406.2303].

Milky Way:

G. Galanti, F. Tavecchio, M. Roncadelli, C. Evoli, MNRAS 487, 123 (2019) [arXiv: 1811.03548].

$B_{MW} = O(1) \mu G$

Extragalactic space:

G. Galanti and M. Roncadelli, Phys. Rev. D 98, 043018 (2018) [arXiv: 1804.09443].

G. Galanti and M. Roncadelli, JHEAp, 20 1-17

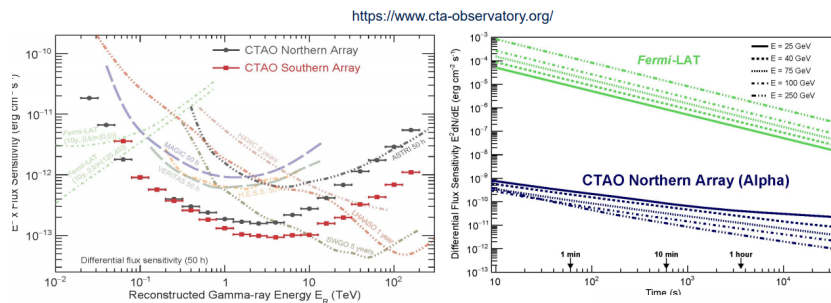
ALPs: G.Galanti

Science with Cherenkov Telescopes

Transients: A.Berti

Studying transients with IACTs: why?

- They are very sensitive instrument on a broad energy range --> good characterization of spectra from ~20 GeV to several TeV for CTA
- They are fast instruments, sensitive to short duration events, detecting enough photons thanks to large collection area --> possibility to perform time analysis, searching for variability, change in spectrum, evolution of system



2022-07-20

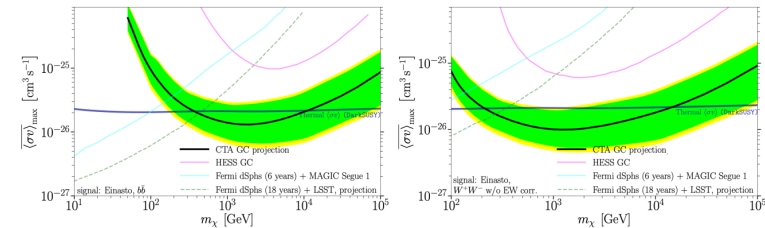
Sexten Workshop 2022

Object-oriented strategies

- If PeVatrons are SNRs (at age \lesssim tens of ys as suggested by theory)
 - Look for emission from close-by clouds illuminated by escaping PeV particles
 - Look for young SNe in close-by galaxies to check for TeV-PeV emission
- Stellar Clusters
 - Very extended sources: require deep observations
- PWNe
 - High spatial resolution + high energy resolution
 - Hadronic contribution: combined analysis with ASTRI, LHAASO (or SWGO) only for powerful pulsars
- Giant magnetic islands
 - the most difficult case to detect: probably only diffuse emission will be detected
- Super-PeVatrons
 - Search of synchrotron emission due to secondaries with LSTs (in possible synergy with Fermi-LAT) [F. Aharonian suggestion]
- For PeVatron candidates High Night sky background deep observations can be done: they do not subtract observation time from other KSPs)
- Overlap with other KSPs: GC and Star-forming regions

Pevatrons: G.Morlino

Galactic center CTA Sensitivity



- Einasto profile

520 h

$$\rho_{\text{DM}} = \rho_s \exp \left[-\frac{\alpha}{2} \left(\frac{r}{r_s} \right)^\alpha - 1 \right], J \sim 7.1 \times 10^{22} \text{ GeV}^2 / \text{cm}^5$$

- Main source of background : sources, Fermi Bubble, interstellar γ , residual CR



The CTA Consortium JCAP01(2021) 057 January 27, 2021 [arXiv:2007.16129]

Aldo Morselli

INFN Roma Tor Vergata

Hands-on the Extreme Universe, Sexten

20 July 2022

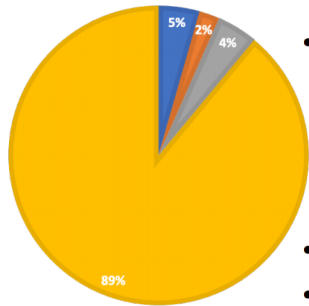
28

Dark Matter: A.Morselli

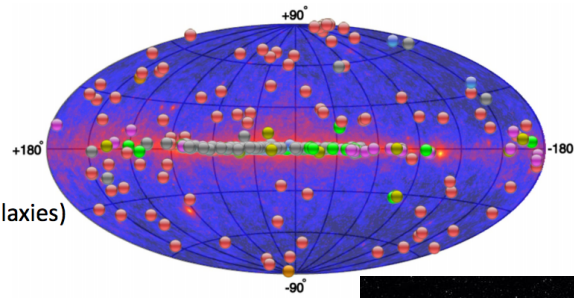
Science with Cherenkov Telescopes

Type of sources

■ GRB ■ Starburst ■ Radiogalaxies ■ Blazars

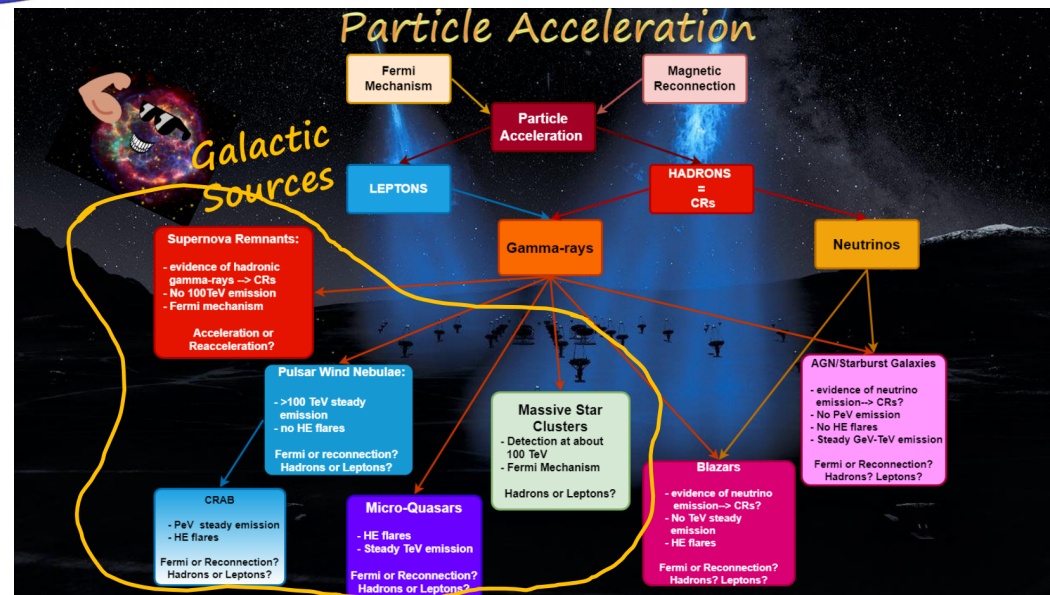


- AGN
 - Blazars
 - FSRQ
 - BL Lac
 - FRI (Radiogalaxies)
- GRB
- Starburst galaxies



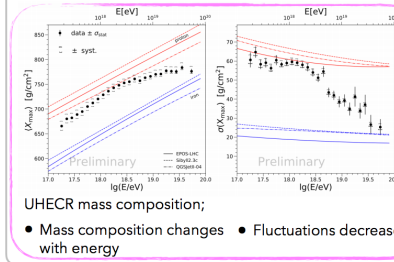
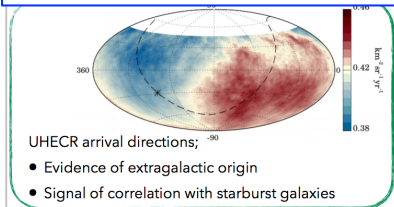
Galactic: M.Cardillo

EGAL: E.Prandini

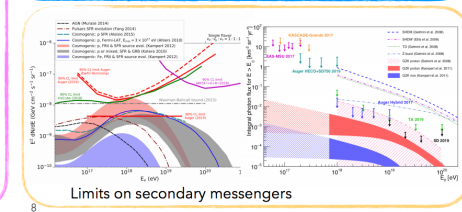
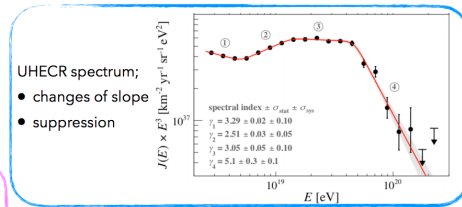


MultiMessenger Connections

UHECR: D.Boncioli



UHECRs at the Pierre Auger Observatory Collection of results from ICRC 2021



Some conclusions

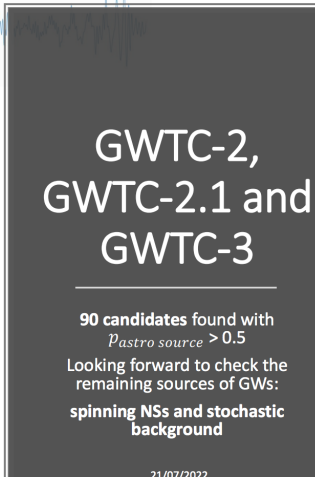
- Diffuse neutrino flux is measured by several detectors and in several event selections (sensitive to different flavours and energy ranges).
 - This is not the cosmogenic CR flux.
 - This is (probably) not the "partner" of the EBL gamma flux (from p-p interactions).
- Several sources identification (TXS 0506+056, NGC 1068, M87, TXS GB6 J1542+6129, PKS 1424+240). They are of different types: blazar (BL Lac/FSRQ ?), Starburst galaxy...
- No dominant single sources and, probably, no dominant source type is responsible for this flux.
 - Current detector sensitivities are \lesssim order of magnitude below expected emissions from single (steady) sources.
 - We need stacking/catalogues search, transient searches. Collaboration with MM partners is essential.
 - Neutrino detectors are excellent for understanding source acceleration mechanisms.
 - The major part of the expected neutrino sources should be reachable with the next generation detectors.
 - EeV sensitive detectors have access to the guaranteed cosmogenic flux.

This work has been supported by European Union's Horizon 2020 Programme under the AHEAD2020 project (grant agreement n. 871158).

V. Kulikovskiy "Astrophysical Neutrinos" @ Sexten 2022

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GW: N.Sorrentino



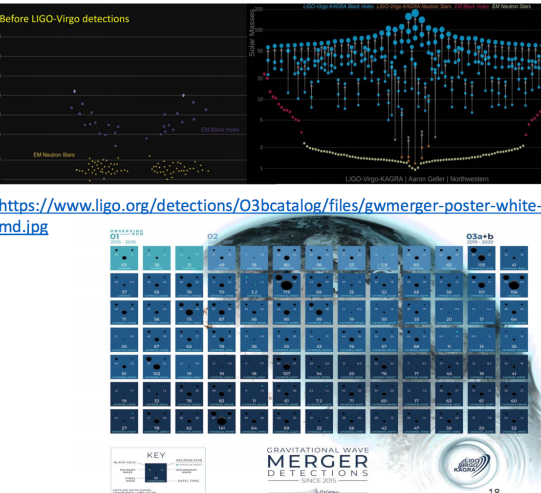
**GWTC-2,
GWTC-2.1 and
GWTC-3**

90 candidates found with $p_{\text{astro source}} > 0.5$

Looking forward to check the remaining sources of GWs:
spinning NSs and stochastic background

21/07/2022

N. Sorrentino on behalf of the LVK collaborations



Before LIGO-Virgo detections

<https://www.ligo.org/detections/O3bcatalog/files/gwmerger-poster-white-md.jpg>

KEY

GRAVITATIONAL WAVE
MERCER
D.E.T.E.C.T.I.O.N.S.
SINCE 2015

18

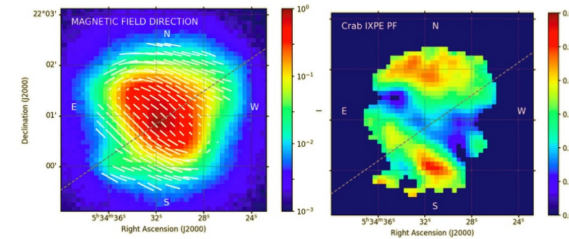
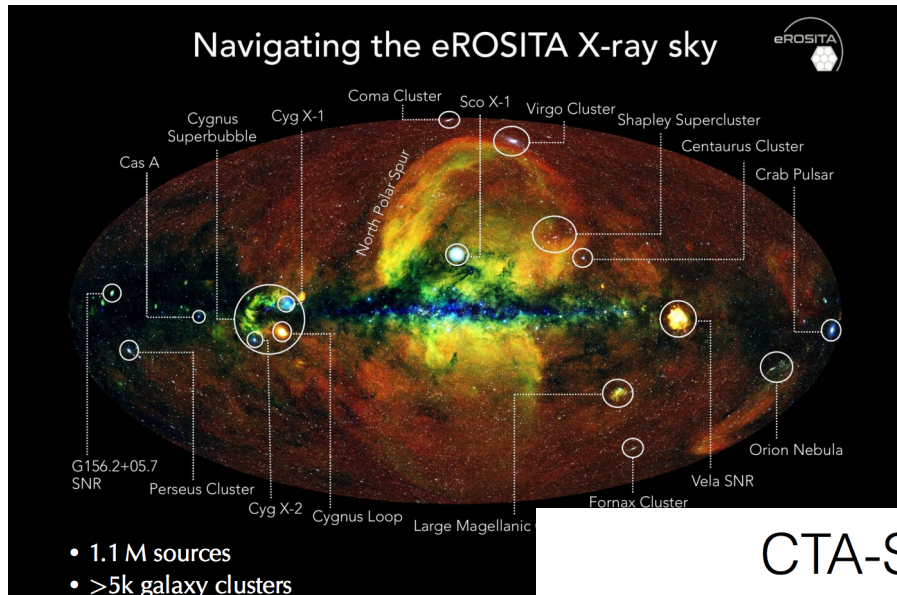
Neutrino: V.Kulikovskij

MultiWavelength Connections

IXPE is not Chandra but, in combination with Chandra data

The X-Ray Image from Chandra gives the best description of the site of particle acceleration. Polarimetry, even with a poorer angular resolution (25" vs 1") can give a measurement of the order of the magnetic field.

IXPE has observed the Crab PWN and PSR in February and March for a total live time of the order of 92 ks. (≈ 1 day).



CTA-SKA synergies

- Main areas of synergy with CTA:
 - cosmic rays - eg in supernova remnants
 - astroparticle physics - neutrinos from blazars, dark matter from gamma rays, dark energy and cosmology from matter dipole etc.
 - star formation history - continuum emission in radio and EBL absorption in VHE gamma rays
 - particle acceleration, primarily in blazars but also other extragalactic and galactic jets (GRBs, radio galaxies, binaries, etc.), galaxy clusters, etc.

eROSITA: J.Wilms

IXPE: E.Costa

SKA: M.Giroletti



Galactic topics

Project motivations

- Supernova Remnants (SNRs) considered as strong candidates for birthplaces of Cosmic Rays in Galactic environments
- One of the strongest HE γ -rays emitters in the Milky Way is the extended SNR W 44
- GeV emission in the remnant close-by region reported in previous works (Uchiyama et al. 2012, Peron et al. 2020)
 - Probably due to escaped CRs
- Joint Fermi-MAGIC project:
 - Detailed morphological and spectral analysis of W 44 region with Fermi-LAT
 - W 44 surroundings observed with MAGIC telescopes
 - Hadronic-based model

Expected hadronic γ -ray emission and comparison with data

Comparison with published data
 The γ -ray flux depends on f_{CR} which in turns is a function of a large number of parameters
 ($\rho_H=20/cm^3$, $t_{age}=3Myr$, $M=10^4 M_\odot/yr$, $\eta_B=0.1$, L_w , s , ϵ_{CR})

↓

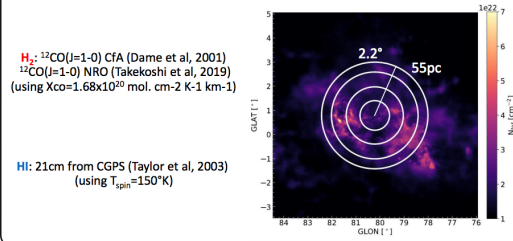
We fix all parameters except L_w , s , ϵ_{CR} that are varied in order to fit (χ^2 minimization) the observed γ -ray spectrum

↓

A posteriori we check if the best fit parameters are compatible with "reasonable" values

For the spectrum comparison, we extract the γ -ray flux from a $2.2''$ region centered on OB2.
 Flux data points from experiments are scaled to account only the flux coming from a region of this size.

We model the ISM around Cyg OB2 as a combination of **molecular** (H_2) and **neutral** (HI) hydrogen. Kinematic cuts: $-20km/s < v < 20km/s$
 HI and H_2 uniformly distributed along the line of sight in $\pm 400pc$

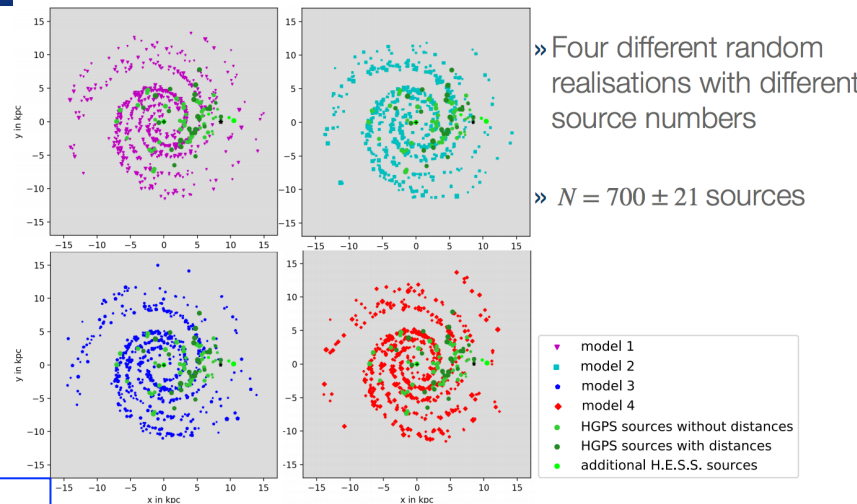


Observation used:

- | | |
|----------------------------------|------------------------------------|
| Spectral data points: | Radial profile: |
| • Fermi-LAT (4FGL J2028.6+4110e) | • Aharonian et al 2019 (Fermi-LAT) |
| • HAWC (HAWC J2030+409) | • Abeysekara et al 2021 (HAWC) |
| • Argo (ARGO J2031+4157) | |

Source model construction - Results

W44: R. Di Tria



- » Four different random realisations with different source numbers
- » $N = 700 \pm 21$ sources

Cygnus OB2: S.Menchiari

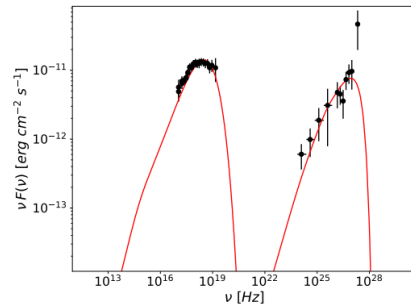
CR propagation: J.Thaler

Extragalactic topics

1ES 0229+20

We apply our model to the prototypical extreme TeV blazar, i.e. 1ES 0229+20

- Downstream region radius
 $R = 1.2 \times 10^{16}$ cm
- Alfvén velocity
 $v_a = 2 \times 10^9$ cm/s
- Mean magnetic field
 $B = 15.9$ mG
- Non-thermal particles power
 $P'_n = 7 \times 10^{39}$ erg/s
- Turbulence power
 $P'_W = 7 \times 10^{39}$ erg/s



Extreme TeV blazars: A.Sciacaluga

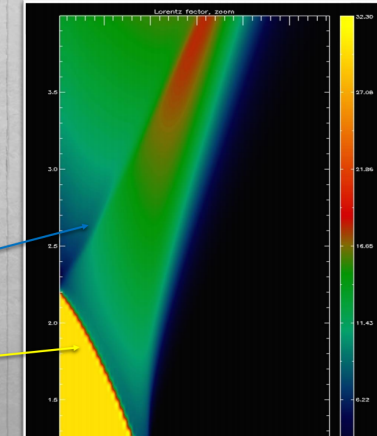
2D simulations with particles for TeV blazars

Setup compatible with TeV blazars

- Relativistic
- Low magnetized and $B = 10^{-3} G$
- $p_e = p_{0e} \left(\frac{z}{z_0}\right)^{-1.8}$ and $p_{0j} \ll p_{0e}$ (underpressured)

reflection shock: re-shocked jet

recollimation shock

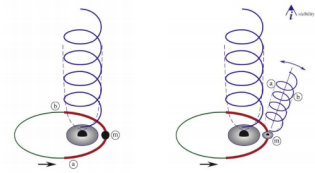


Relativistic jets and recollimation: A.Costa

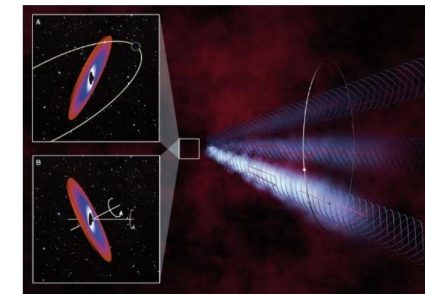
Blazar periodicity

Long-term periodicity could be related to binary black holes [1]:

- Intensity modulation by Doppler factor.
- Precession, deflection or curvature of the jet changing the viewing angle.

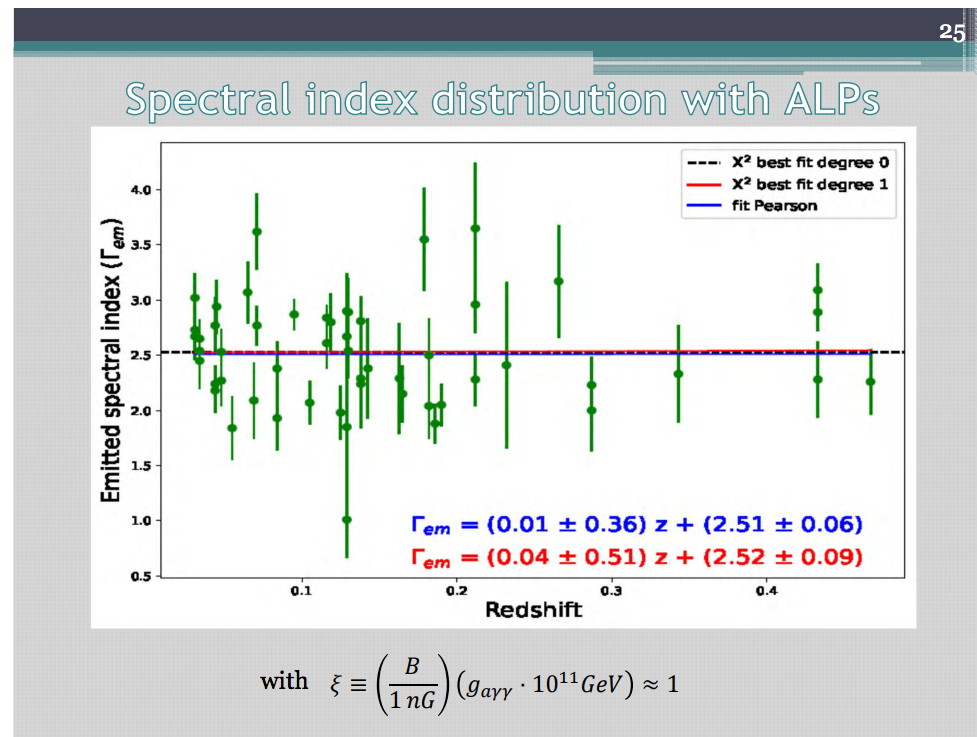


From Tavani et al., 2018 [2]



Blazar periodicity: P. Cristarella Orestano

Fundamental Physics topics

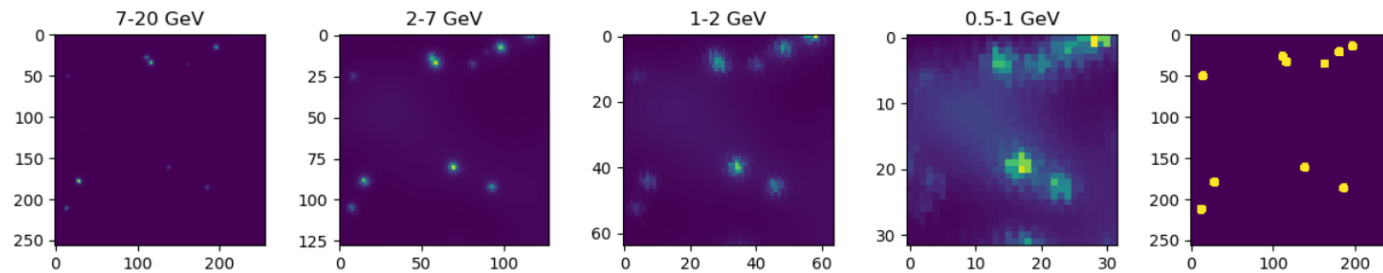


EBL and ALPs: A. Franceschini

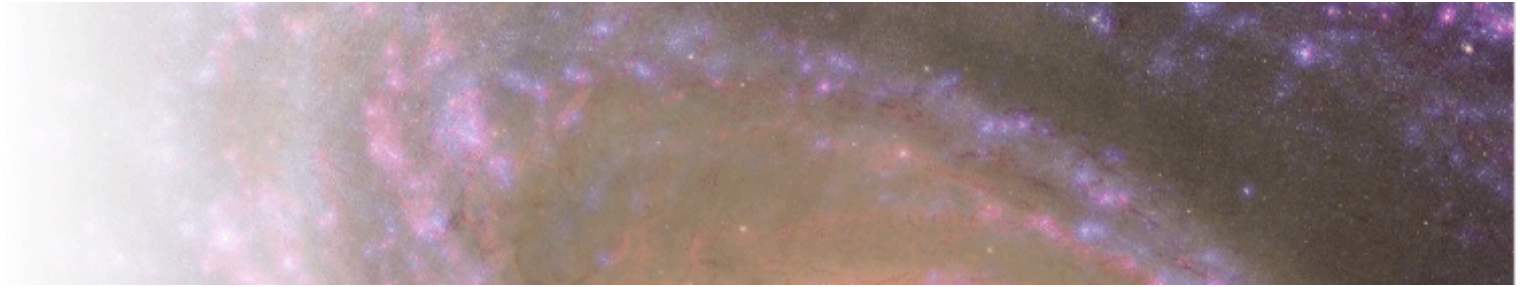
Advanced Analysis topics

Training Data & Localization Network

- Images of full sky data in 6 energy bins [0.3 GeV - 1 TeV].



- Step1: Implement U-Net like algorithm. Segmentation task.
 - Each pixel is assigned with a label score (≈ 1 , pixel belongs to region around sources, ≈ 0 , otherwise).
- Step2: Apply K-Means algorithm
 - Group the pixels in a cluster and center of cluster is source location. (Lon, Lat)

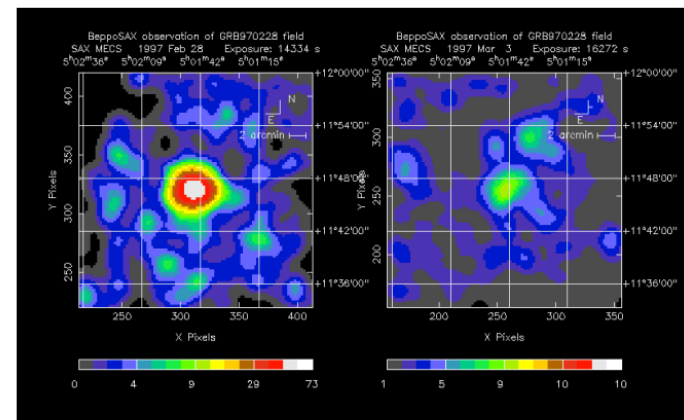
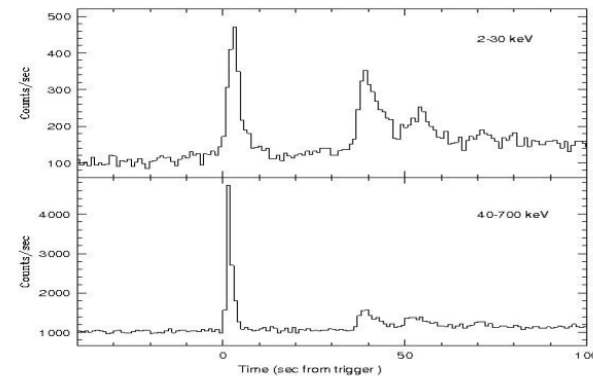


- Overview of the program!
 - The Extreme Universe
 - Fermi, current IACTs, LHAASO
 - Next Generation IACT telescopes
 - LST, MST, SCT, ASTRI-SST
 - Theory of VHE sources
 - CR sources, AGN, GRB, PSR-PWN, ALPs
 - Science with Cherenkov Telescopes
 - Transients, Galactic, Extragalactic, DarkMatter, CR
 - Multiwavelength and MultiMessenger connections
 - eROSITA, IXPE, SKA, Neutrinos, GW
 - Special talk – 25 years of GRB afterglows

Special talk on GRB

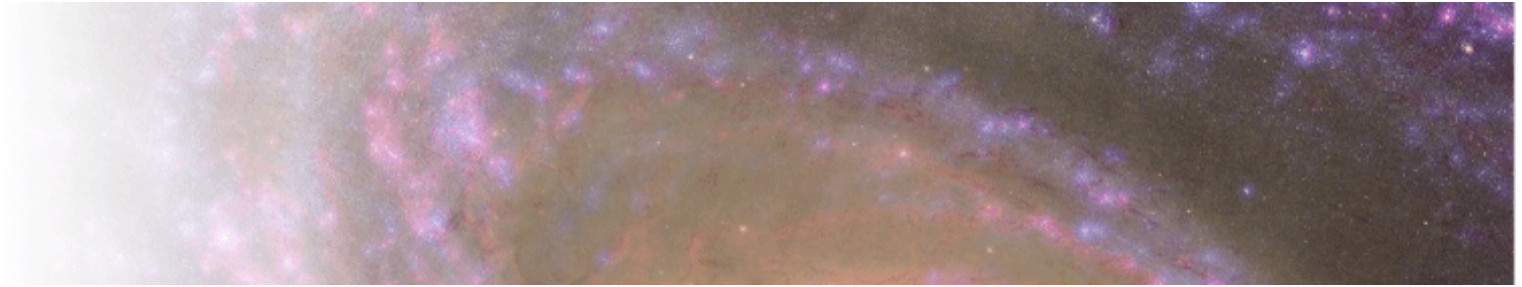
GRB afterglow discovery

- **Unsuccessful search with the first localized GRB GRB970111.**
- **Second GRB promptly identified and well localized: GRB970228**
- **Follow up after 8 hrs: afterglow emission discovered.**



Costa, Frontera et al. 1997

GRB afterglows: E.Costa



- Your overview of the program!
- Build your own ...

Polarisation

γ : photon
 α : ALP
 absorption: $\gamma + \gamma_{\text{soft}} \rightarrow e^+ + e^-$
 γ_{soft} : EBL, BLR

Milky Way:
 G. Galanti, F. Tavecchio, M. Roncadelli, C. Evoli,
 MNRAS 487, 123 (2019) [arXiv: 1811.03548].

$g_{\alpha\gamma\gamma}$: $\gamma\gamma\alpha$ coupling
 E : γ electric field
 B : external magnetic field
 $\mathcal{L}_{\alpha\gamma} = g_{\alpha\gamma\gamma} E \cdot B \vec{a}$

$B_{\text{MW}} = O(1) \mu\text{G}$

$B_{\text{clu}} = O(10) \mu\text{G}$

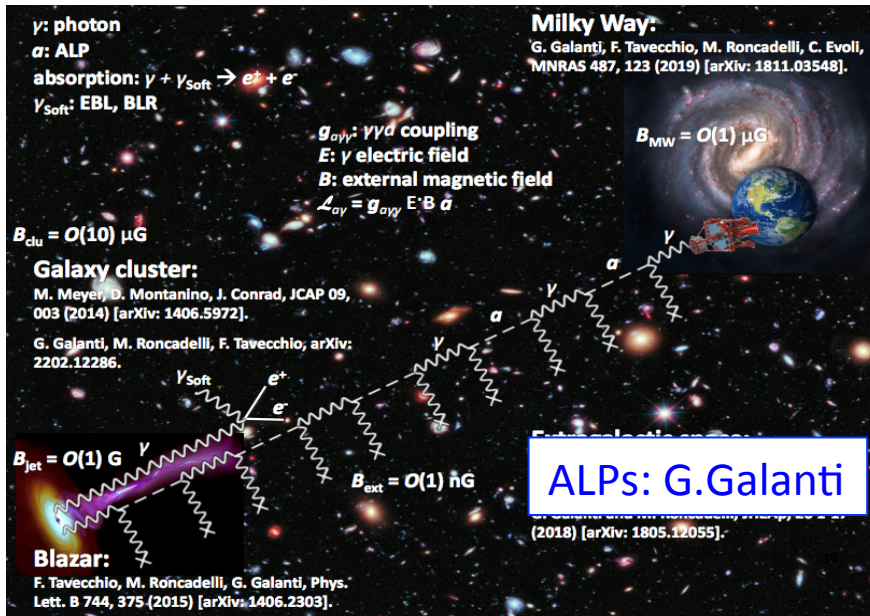
Galaxy cluster:
 M. Meyer, D. Montanino, J. Conrad, JCAP 09,
 003 (2014) [arXiv: 1406.5972].
 G. Galanti, M. Roncadelli, F. Tavecchio, arXiv:
 2202.12286.

$B_{\text{jet}} = O(1) \text{G}$

$B_{\text{ext}} = O(1) \text{nG}$

Blazar:
 F. Tavecchio, M. Roncadelli, G. Galanti, Phys.
 Lett. B 744, 375 (2015) [arXiv: 1406.2303].

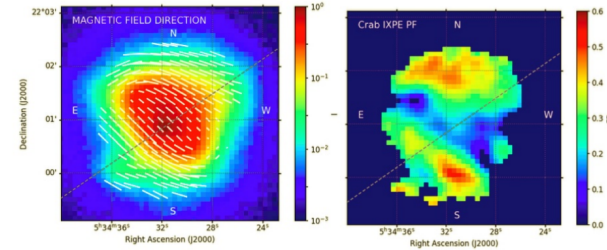
ALPs: G.Galanti
 (2018) [arXiv: 1805.12055].



IXPE is not Chandra but, in combination with Chandra data

The X-Ray Image from Chandra gives the best description of the site of particle acceleration. Polarimetry, even with a poorer angular resolution (25" vs 1") can give a measurement of the order of the magnetic field.

IXPE has observed the Crab PWN and PSR in February and March for a total live time of the order of 92 ks. (≈ 1 day).



IXPE: E.Costa

GRBs

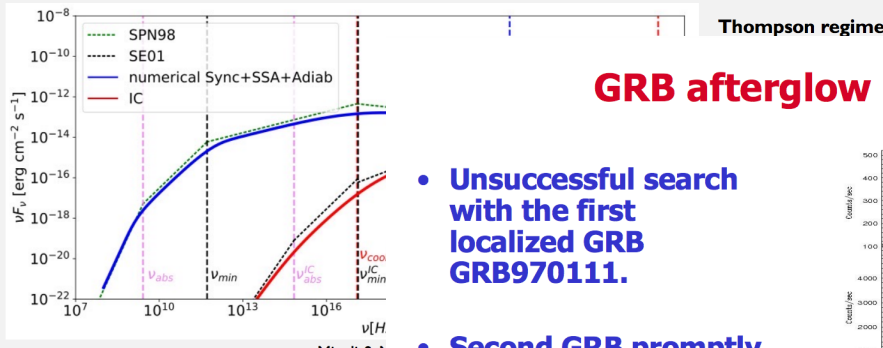
GRB: D.Miceli

Studying transients with IACTs: why?

Transients: A.Berti

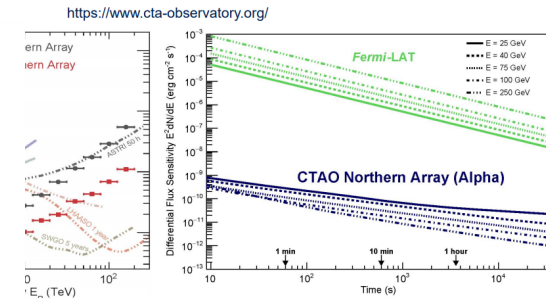
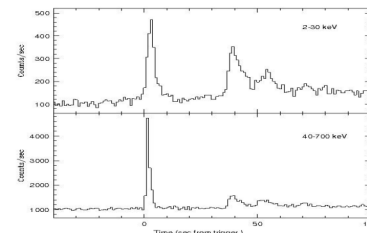
VHE emission: KN corrections

Shaping the VHE spectrum



GRB afterglow discovery

- Unsuccessful search with the first localized GRB GRB970111.
- Second GRB promptly identified and well localized: GRB970228
- Follow up after 8 hrs: afterglow emission discovered.



Sexten Workshop 2022

6



- There have always been some eruptions, Price increases, and hardware.
- Nevertheless, I appreciate our software and hardware.
- We should also continue to work on our observatory with LSTs, PNRR projects.
- LSTs are telescopes for observing astronomy, Gravitational-wave sources, High-Energy neutrino sources, and Search for Dark Matters.
- Surely the CTA consortium should start to work to establish a scientific network of observatories' working in other wavelengths and messengers.

Costa, Frontera et al. 1997

• Great Scientific results are waiting for you!!

LST: M.Teshima

GRB afterglows: E.Costa

Looking forward to check the remaining sources of GWs: spinning NSs and stochastic background

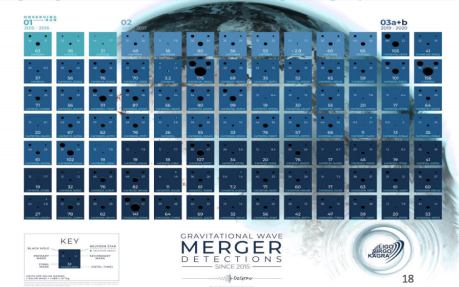
21/07/2022

N. Sorrentino on behalf of the LVK collaborations



GW: N.Sorrentino

www.ligo.org/detections/O3/catalog/files/gwmerger-poster-white



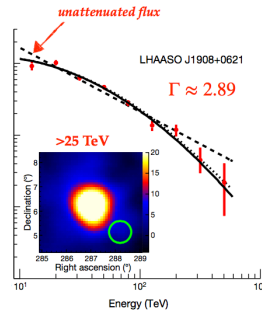
18

Pevatrons

The first SNR as PeVatron?

LHAASO J1908+0621 = SNR G40.5-0.5 + GMC

LHAASO: G.Di Sciascio



One of the most intriguing sources in the Galactic plane. MGRO J1908+06 spatially associates with an *IceCube* hotspot of neutrino emission. Although the hotspot is not significant yet, this suggests a possible hadronic origin of the observed gamma-ray radiation.

Highest energy photon 0.45 PeV $\Rightarrow E_p > 200$ GeV
confirmation of association with G40.5-0.5
the first evidence of a SNR operating as Pevatron

soon LHAASO will announce detection of UHE γ -rays from W51 and γ -Cygni
 \Rightarrow new developments are anticipated with exciting implications

G. Di Sciascio - INFN Roma Tor Vergata

Sesto-Sexten, July 18, 2022

34

Object-oriented strategy Pevatrons: G.Morlino

- If PeVatrons are SNRs (at age \lesssim tens of ys as suggested by theory)
 - ◆ Look for emission from close-by clouds illuminated by escaping PeV particles
 - ◆ Look for young SNe in close-by galaxies to check for TeV-PeV emission
- Stellar Clusters
 - ◆ Very extended sources: require deep observations
- PWNe
 - ◆ High spatial resolution + high energy resolution
 - ◆ Hadronic contribution: combined analysis with ASTRI, LHAASO (or SWGO) only for powerful pulsars
- Giant magnetic islands
 - ◆ the most difficult case to detect: probably only diffuse emission will be detected
- Super-PeVatrons
 - ◆ Search of synchrotron emission due to secondaries with LSTs (in possible synergy with Fermi-LAT) [F. Aharonian suggestion]
- For PeVatron candidates High Night sky background deep observations can be done: they do not subtract observation time from other KSPs)
- Overlap with other KSPs: GC and Star-forming regions

ASTRI Science : overview

ASTRI: A.Giuliani

Origin of Cosmic Rays

- PeVatrons
- CRs Acceleration and Propagation
- Pulsar Wind Nebulae and TeV Halos

The ASTRI Mini-Array of Cherenkov Telescopes at the Observatorio del Teide

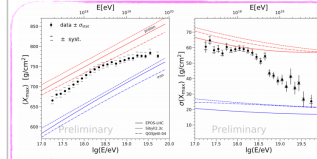
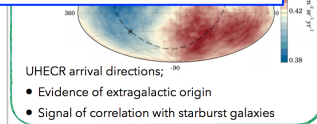
S. Scuderi¹, A. Giuliani¹, G. Pareschi¹, G. Tosti¹, G. Catalano¹, E. Amaro¹, L.A. Antonelli¹, J. Becerra Gonzalez¹, G. Bellandi¹, C. Bigongiari¹, B. Bondi¹, B. Bontecchi¹, G. Brunetti¹, P. Bruno¹, A. Bulgarelli¹, D. Canestrari¹, M. Capelli¹, M. Cardillo¹, V. Costantini¹, G. Costantini¹, M. Corradi¹, A. Costa¹, G. Cusumano¹, A. D'Al¹, F. de Gouveia Dal Pino¹, F. Della Croce¹, E. Escribano Rodriguez¹, D. Falanga-Gonzalez¹, G. Ferrero¹, M. Fiori¹, M. Fiorani¹, M. Fiorani¹, S. Gil¹, B. Gil¹, ASTRI Mini-Array Core Science at the Observatorio del Teide

JHEAP, 2022, 35, 52

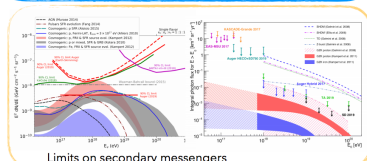
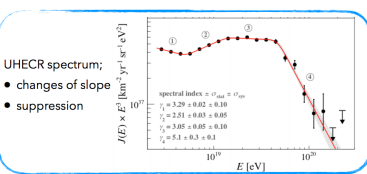
ASTRI Mini-Array Core Science at the Observatorio del Teide

S. Verellone¹, C. Bigongiari¹, A. Burrows¹, M. Cardillo¹, G. Catalano¹, A. Franceschini¹, M. C. Lombardi¹, L. Nava¹, F. Pintore¹, A. Stamerra¹, F. Tavecchio¹, I. Zampieri¹, R. Alves Batista¹, G. M. E. Amaral¹, L. A. Antonelli¹, C. Arcaro¹, J. Becerra Gonzalez¹, G. Bondi¹, F. P. P. Phil¹, G. Brunetti¹, A. A. Compagnino¹, S. Crestaro¹, A. D'Al¹, M. Fiori¹, G. Galati¹, JHEAP, 2022, 35, 1

UHECR: D.Boncioli



UHECRs at the Pierre Auger Observatory



Collection of results from ICRC 2021

A. A. Compagnino¹, M. Fiori¹, G. Catalano¹, S. L. V. A. Valle¹, M. Del Sordo¹, A. La Torre¹, F. Pintore¹, P. Romano¹, S. Verellone¹, A. Antonelli¹, P. Bruno¹, A. Bulgarelli¹, V. Costantini¹, A. Costa¹, F. de Gouveia Dal Pino¹, F. Della Croce¹, E. Escribano Rodriguez¹, D. Falanga-Gonzalez¹, G. Ferrero¹, M. Fiori¹, M. Fiorani¹, M. Fiorani¹, S. Gil¹, B. Gil¹, ASTRI Mini-Array at the Observatorio del Teide

JHEAP, 2022, 35, 39

A. A. Compagnino¹, M. Fiori¹, G. Catalano¹, S. L. V. A. Valle¹, M. Del Sordo¹, A. La Torre¹, F. Pintore¹, P. Romano¹, S. Verellone¹, A. Antonelli¹, P. Bruno¹, A. Bulgarelli¹, V. Costantini¹, A. Costa¹, F. de Gouveia Dal Pino¹, F. Della Croce¹, E. Escribano Rodriguez¹, D. Falanga-Gonzalez¹, G. Ferrero¹, M. Fiori¹, M. Fiorani¹, M. Fiorani¹, S. Gil¹, B. Gil¹, ASTRI Mini-Array at the Observatorio del Teide

JHEAP, 2022, 35, 91

A. A. Compagnino¹, M. Fiori¹, G. Catalano¹, S. L. V. A. Valle¹, M. Del Sordo¹, A. La Torre¹, F. Pintore¹, P. Romano¹, S. Verellone¹, A. Antonelli¹, P. Bruno¹, A. Bulgarelli¹, V. Costantini¹, A. Costa¹, F. de Gouveia Dal Pino¹, F. Della Croce¹, E. Escribano Rodriguez¹, D. Falanga-Gonzalez¹, G. Ferrero¹, M. Fiori¹, M. Fiorani¹, M. Fiorani¹, S. Gil¹, B. Gil¹, ASTRI Mini-Array at the Observatorio del Teide

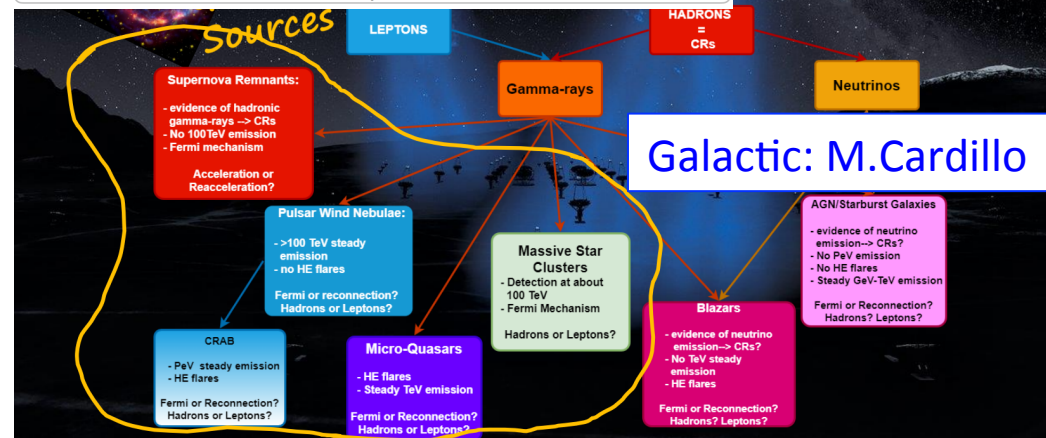
JHEAP, 2022, 35, 91

A. A. Compagnino¹, M. Fiori¹, G. Catalano¹, S. L. V. A. Valle¹, M. Del Sordo¹, A. La Torre¹, F. Pintore¹, P. Romano¹, S. Verellone¹, A. Antonelli¹, P. Bruno¹, A. Bulgarelli¹, V. Costantini¹, A. Costa¹, F. de Gouveia Dal Pino¹, F. Della Croce¹, E. Escribano Rodriguez¹, D. Falanga-Gonzalez¹, G. Ferrero¹, M. Fiori¹, M. Fiorani¹, M. Fiorani¹, S. Gil¹, B. Gil¹, ASTRI Mini-Array at the Observatorio del Teide

JHEAP, 2022, 35, 91

A. A. Compagnino¹, M. Fiori¹, G. Catalano¹, S. L. V. A. Valle¹, M. Del Sordo¹, A. La Torre¹, F. Pintore¹, P. Romano¹, S. Verellone¹, A. Antonelli¹, P. Bruno¹, A. Bulgarelli¹, V. Costantini¹, A. Costa¹, F. de Gouveia Dal Pino¹, F. Della Croce¹, E. Escribano Rodriguez¹, D. Falanga-Gonzalez¹, G. Ferrero¹, M. Fiori¹, M. Fiorani¹, M. Fiorani¹, S. Gil¹, B. Gil¹, ASTRI Mini-Array at the Observatorio del Teide

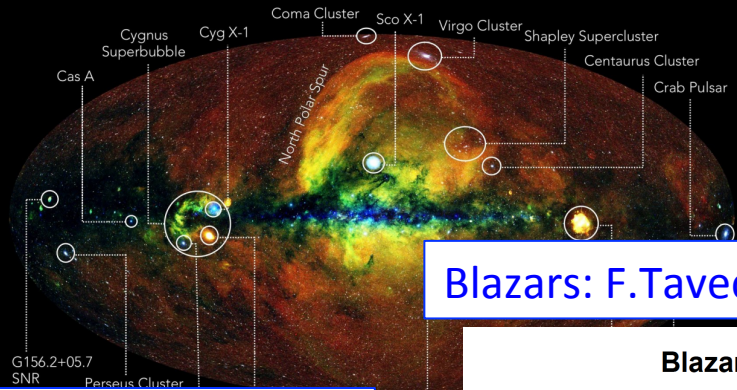
JHEAP, 2022, 35, 91



Galactic: M.Cardillo

Extragalactic topics

Navigating the eROSITA X-ray sky

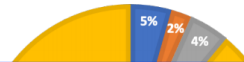


eROSITA: J.Wilms

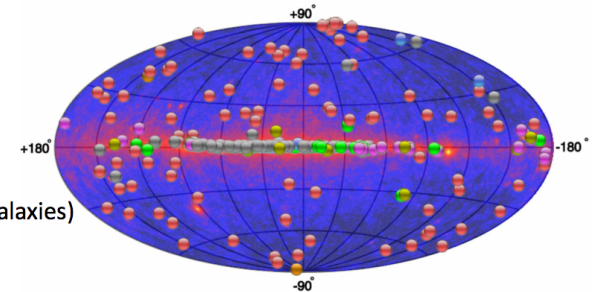
- >5k galaxy clusters

Type of sources

GRB Starburst Radiogalaxies Blazars



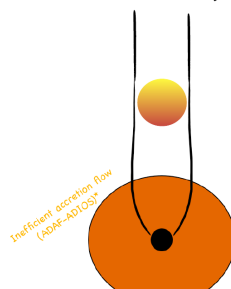
- AGN
- Blazars
 - FSRQ
 - BL Lac
 - I (Radiogalaxies)



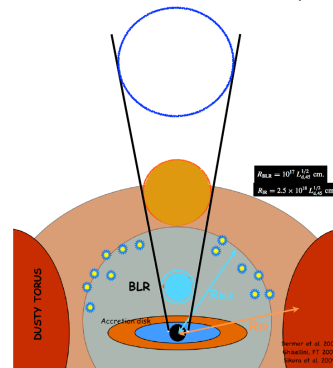
Blazars: F.Tavecchio/G.Bonnoli

Blazars in a nutshell

BL Lacs: "naked" jets



FSRQ: "dressed" jets



Some conclusions

- Diffuse neutrino flux is measured by several detectors at different selections (sensitive to different flavours and energy ranges)
 - This is not the cosmogenic CR flux.
 - This is (probably) not the "partner" of the EBL gamma flux (from dark matter annihilation).
- Several sources identification (TXS 0506+056, NGC 1068, J1542+6129, PKS 1424+240). They are of different types (BL Lac/FSRQ?), Starburst galaxy...
- No dominant single sources and, probably, no dominant responsible for this flux.
 - Current detector sensitivities are an order of magnitude below the expected flux from single (steady) sources.
 - We need stacking/catalogues search, transient searches. Collaboration with other neutrino detectors is essential.
 - Neutrino detectors are excellent for understanding source acceleration mechanisms.
 - The major part of the expected neutrino sources should be reachable with the next generation detectors.
 - EeV sensitive detectors have access to the guaranteed cosmogenic flux.

Neutrino: V.Kulikovskij

Starburst galaxies

EGAL: E.Prandini

eROSITA-SKA synergies

Synergy with CTA:

- eg in supernova remnants

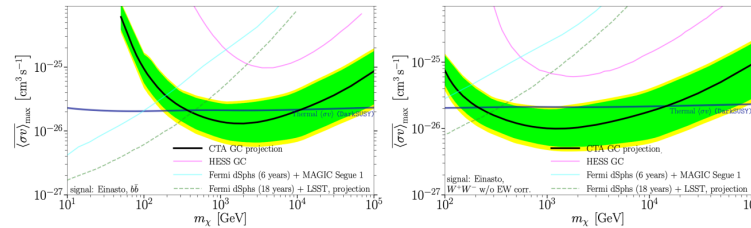
physics - neutrinos from blazars, dark matter from annihilation, dark energy and cosmology from matter dipole etc.

- star formation history - continuum emission in radio and EBL absorption in VHE gamma rays
- particle acceleration, primarily in blazars but also other extragalactic and galactic jets (GRBs, radio galaxies, binaries, etc.), galaxy clusters, etc.

SKA: M.Giroletti

Fundamental Physics

Galactic center CTA Sensitivity



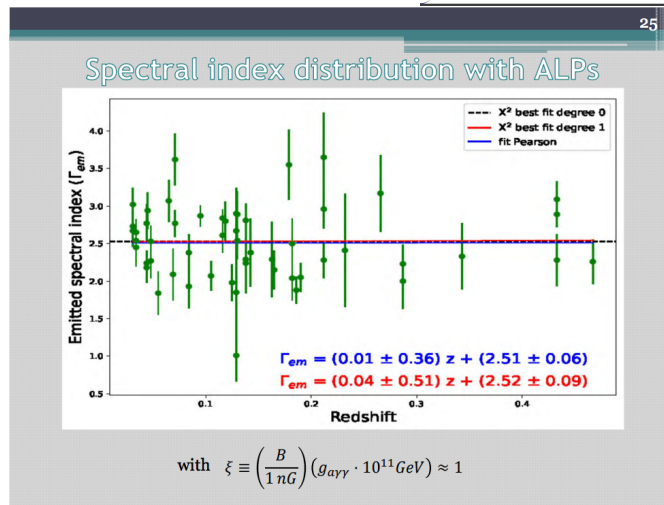
- Einasto profile

520 h

$$\rho_{\text{DM}} = \rho_s \exp \left[-\frac{\alpha}{2} \left(\frac{r}{r_s} \right)^\alpha - 1 \right], \quad J \sim 7.1 \times 10^{22} \text{ GeV}^2 / \text{cm}^5$$

- Main source of background : sources, Fermi Bubble, interstellar γ , residual CR

The CTA Consortium JCAP01(2021) 057 January 27, 2021 [arXiv:2007.16129]



EBL and ALPs: A. Franceschini

Dark Matter: A.Morselli

Milky Way:
G. Galanti, F. Tavecchio, M. Roncadelli, C. Evoli, MNRAS 487, 123 (2019) [arXiv: 1811.03548].

$B_{\text{MW}} = O(1) \mu\text{G}$

$\gamma_{\text{Soft}}: \text{EBL, BLR}$

$g_{\alpha\gamma\gamma}: \gamma\gamma\alpha$ coupling
 $E: \gamma$ electric field
 $B: \text{external magnetic field}$
 $\mathcal{L}_{\alpha\gamma\gamma} = g_{\alpha\gamma\gamma} \mathbf{E} \cdot \mathbf{B} \hat{\alpha}$

$B_{\text{clu}} = O(10) \mu\text{G}$

Galaxy cluster:
M. Meyer, D. Montanino, J. Conrad, JCAP 09, 003 (2014) [arXiv: 1406.5972].
G. Galanti, M. Roncadelli, F. Tavecchio, arXiv: 2202.12286.

$B_{\text{jet}} = O(1) \text{ G}$

$B_{\text{ext}} = O(1) \text{ nG}$

Blazar:
F. Tavecchio, M. Roncadelli, G. Galanti, Phys. Lett. B 744, 375 (2015) [arXiv:1406.2303].

Extragalactic space:
G. Galanti and M. Roncadelli, Phys. Rev. D 98, 043018 (2018) [arXiv: 1804.09443].
G. Galanti and M. Roncadelli, JHEAp, 20 1-17

ALPs: G.Galanti

VHE and Optics

Conclusion and « take home messages »



- The instrumental requirements on MST structures and cameras follow from the physics requirements of CTA.
- The MST telescopes use a common mechanical Davies-Cotton and 2 camera designs: NectarCAM (CTAN) and FlashCam (CTAS).
- A prototype of Davies-Cotton structure has been implemented near Berlin in 2012 and extensively tested.
- NectarCAM and FlashCam fulfill all CTA requirements and have comparable performances.
- The FlashCam camera uses off-the-shelf component with a photon detection plane and electronics racks. It had its first light in 2017. A FlashCam is successfully operated since October 2019 on the CT5 telescope of H.E.S.S.
- The NectarCAM camera has a modular structure based on the Nectar ASIC. It has its first light in 2019.
- The installation will follow the « pathfinder » strategy before acceptance of telescopes by CTA.
- The first telescopes should be installed on CTAN and CTAS in 2023-2024.

MST-Sexten 07/22

MST: J-F. Glicenstein

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SCT Summary and Outlook



Recent results

- Improved optics alignment
- First measurement of inclination-dependent PSF measurement
- Further work on current camera to improve data analysis
- Full-chain (FPM+SMART+FEE) measurements for camera upgrades
 - Production for full camera started

Next steps

- Continued commissioning, engineering, and operations
- Improvements in Optical System (alignments and off-axis PSF)
- Camera upgrade
 - Production and installation of upgraded sensors and electronics
- Discussions with CTAO Project Office
 - Infrastructure planning and budgeting for SCT addition in CTA-S



SCT: E.Bissaldi

The ASTRI Mini-Array Project



June 2022

Phase 0

- 1 Telescope Structure
- m-ICT

Autumn 2022

Phase 1

- 3 Telescope Structures

Late Spring 2023

Phase 2

- 3 Telescope Structures
- Cameras



Autumn 2023

Phase 3

- Full Array

End of 2024



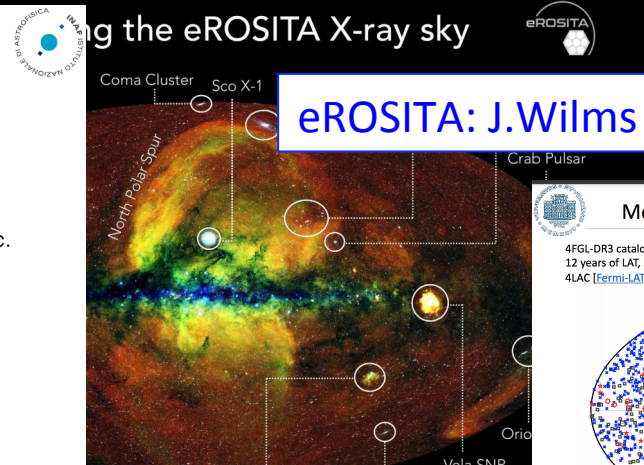
ASTRI & SST: G.Sironi

Multiwavelength

CTA-SKA synergies

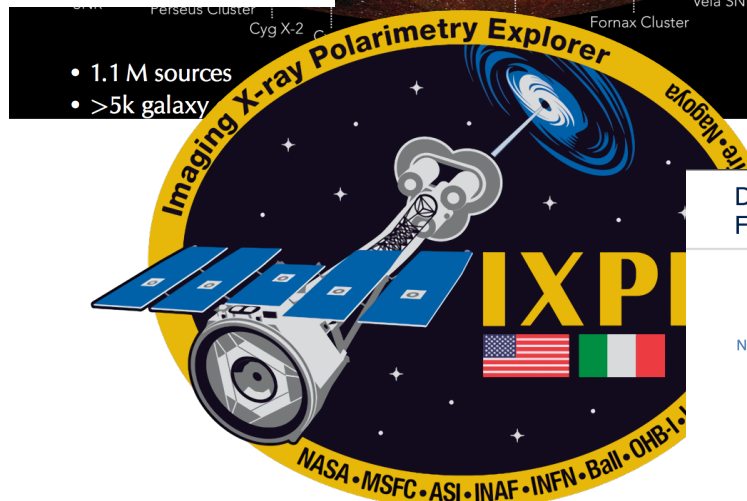
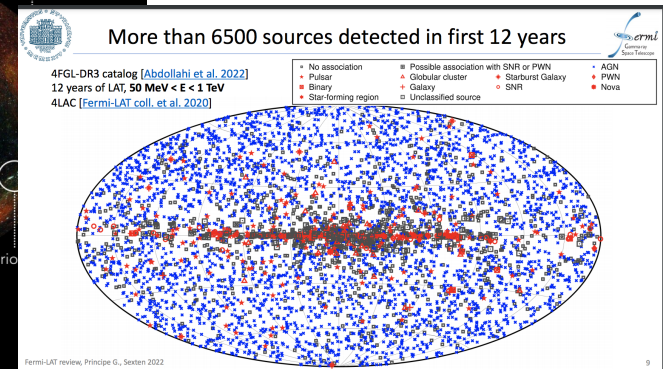
- Main areas of synergy with CTA:
 - cosmic rays - eg in supernova remnants
 - astroparticle physics - neutrinos from blazars, dark matter from gamma rays, dark energy and cosmology from matter dipole etc.
 - star formation history - continuum emission in radio and EBL absorption in VHE gamma rays
 - particle acceleration, primarily in blazars but also other extragalactic and galactic jets (GRBs, radio galaxies, binaries, etc.), galaxy clusters, etc.

SKA: M.Giroletti



eROSITA: J.Wilms

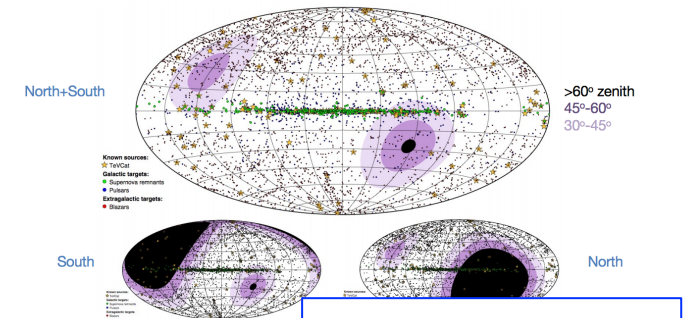
Fermi: G.Principe



IXPE: E.Costa

Optical:?

DESIGN DRIVER:
FULL-SKY COVERAGE

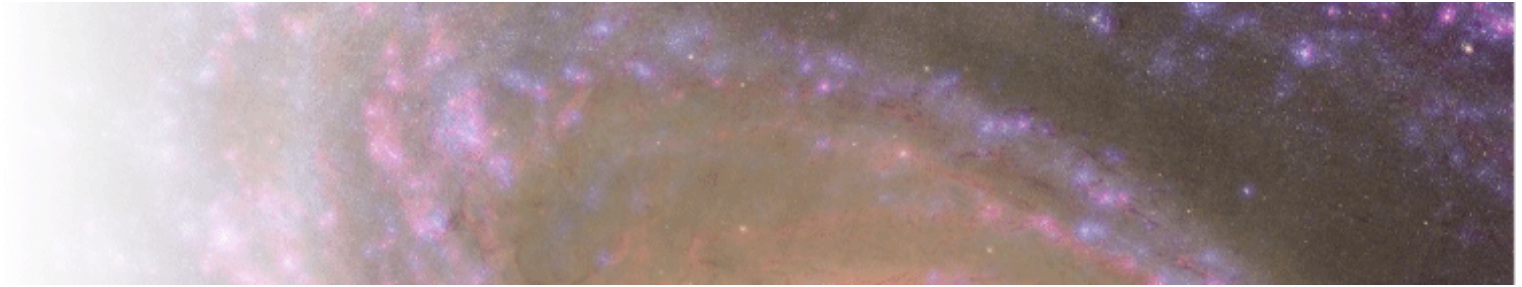


CTA: W.Hofmann

Multiwavelength



Optical: C.Righi, G.Bonnoli, I.Burelli, D.Miceli et al.

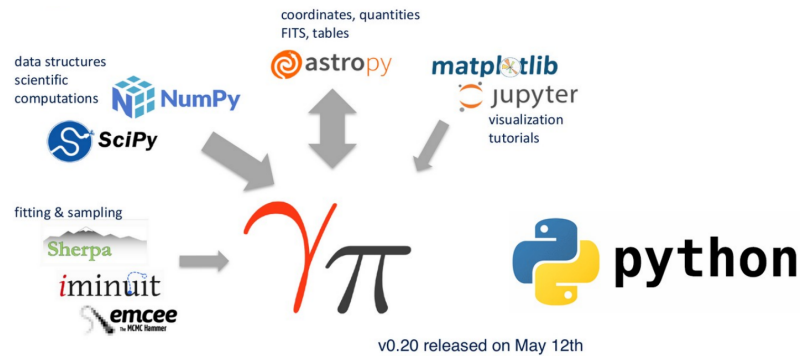


- Hands On
 - High Level Analysis for CTAO and ASTRI
 - Gammapy
 - Participants reports on HandsOn – Friday
- Tutorials
 - The Communication as a bridge between Science and Society
 - From Science to Society: a fruitful path

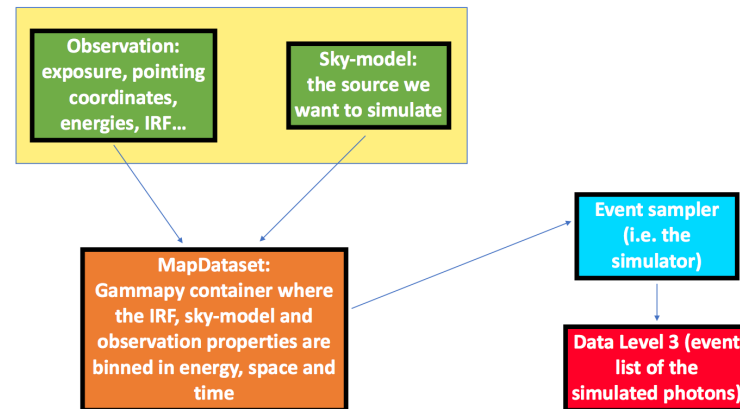
Gammapy: F.Pintore, G.Rodriguez, G.Principe, A.Giuliani, M.Cardillo



Introduction to Gammapy



Simulations with Gammapy



Outlook



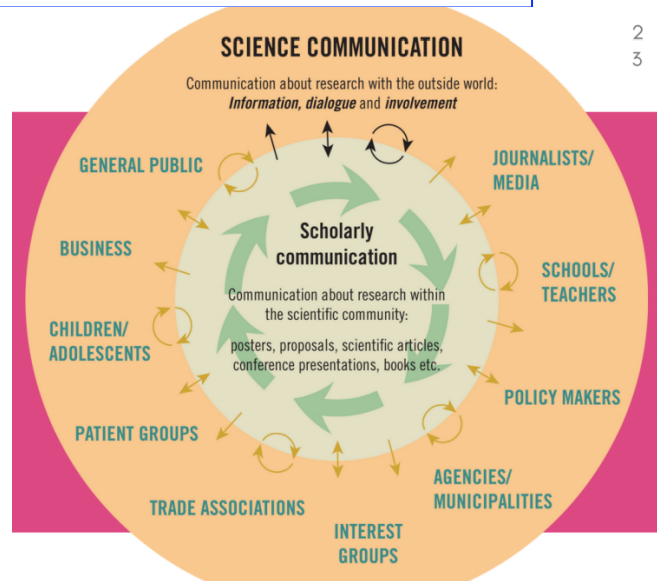
All the people involved (CTAC and CTAO) are actively working on the preparation of the first CTAO SDC!

- Start of the execution of the SDC expected in **mid 2023**.
- The idea is to deliver the SDC simulations in bunches (most likely of 1 year each) with a given cadence (e.g. every month)
- **Winners' nominations: Jan 2024!!**

CTAO Data Challenge: F. Pintore

Thank you very much for your attention!

Science Communication: R.Spiga



2
3

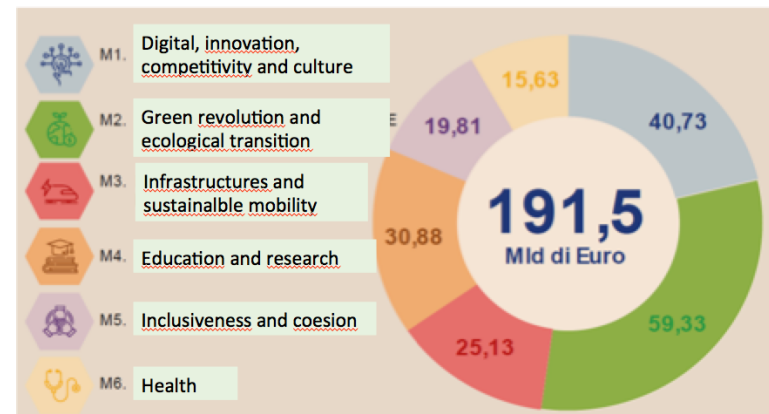
Gli STRUMENTI

Instruments

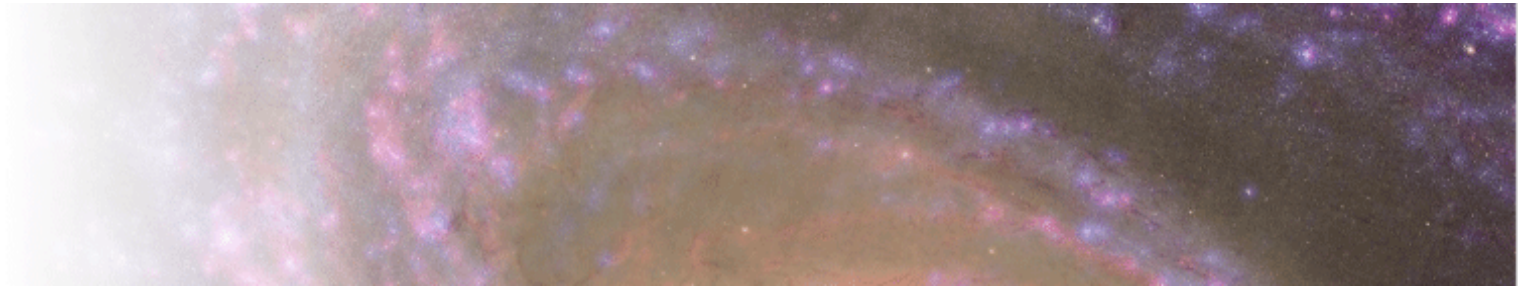
PNRR

16 components,
6 Missions

Received from and
reflect to
the Italian strategic
pillar



Interaction with private sector F.Giordano



- A wonderful conference !

Hands-on the Extreme Universe with High Energy Gamma-ray data



18 Jul 2022, 10:00 → 22 Jul 2022, 14:00 Europe/Rome

Sexten



ABSTRACT_BOOKL...

Zoom Link

Zoom SextenWorks...

MONDAY, 18 JULY



10:00 → 13:00 The Extreme Universe



10:00

The Fermi view of the High Energy sky

30m



Speaker: Giacomo Principe (Istituto Nazionale di Fisica Nucleare)

Review_Fermi_LAT_...

10:30

From the current IACT to CTA

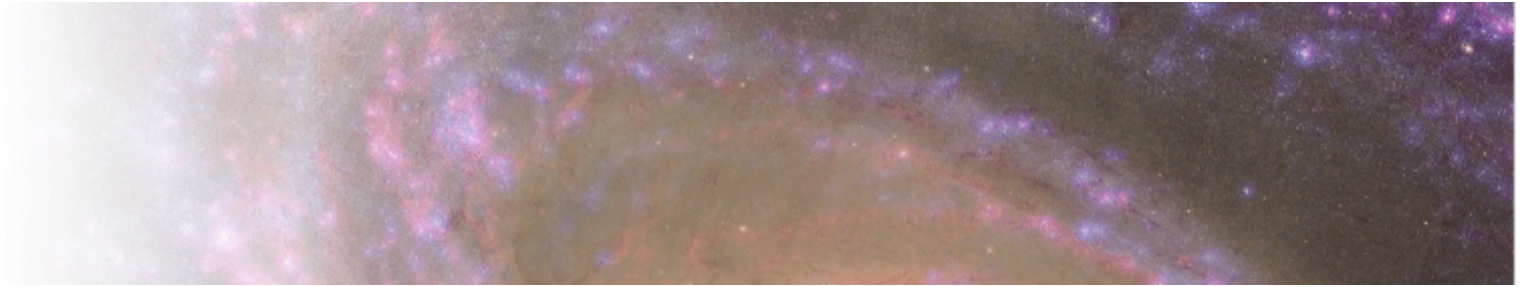
30m



Speaker: Werner Hofmann

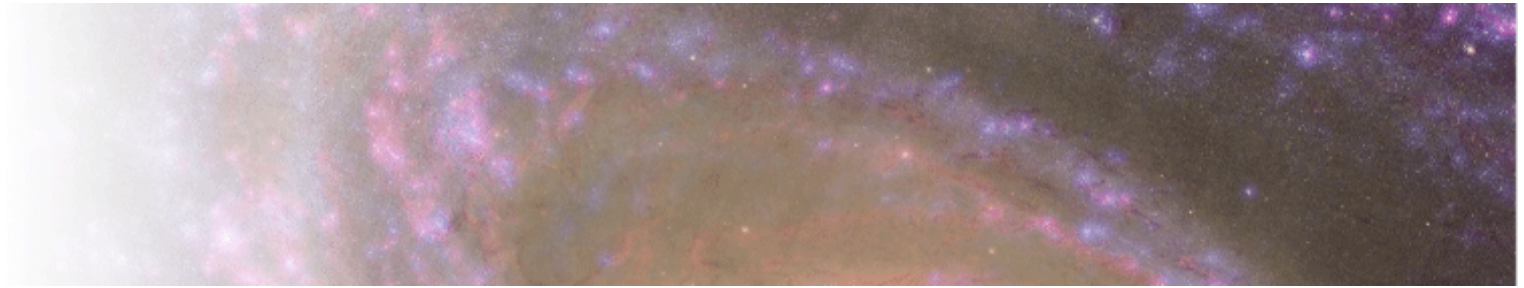
2022_07_Sexten_CT...

The indico page will be sent you soon



- A wonderful group !





- See you at Sexten 2024!

