PROCEEDINGS OF SCIENCE

ICRC Rapporteur: Space Based Gamma-ray Astronomy

Jeremy S. Perkins*
NASA/GSFC
E-mail: jeremy.s.perkins@nasa.gov

Approximately 74 presentations at the 35th International Cosmic Ray Conference in Busan, Korea pertained to space-based gamma-ray astronomy. These proceedings are a summary of those contributions and span a wide range of scientific topics. Four themes continued to appear: there is unprecedented coverage of the gamma-ray sky, the gamma-ray detecting missions and instruments are mature and well understood, new missions and instruments are coming online, and our current understanding of the sky is leading us to develop new experiments.

35th International Cosmic Ray Conference — ICRC2017
10–20 July, 2017
Bexco, Busan, Korea

*Speaker.

PoS(ICRC2017)1117

1. Introduction

Presenting a rapporteur talk at an International Cosmic Ray Conference (ICRC) is an honor. However, it is also a large and sweeping task. There is no way that a single contribution can represent all of the space based gamma-ray results that were presented in Busan at the 35th ICRC[1] without passing over a key detail or misinterpreting a result. This contribution will, of course, be presented through the eyes of the author and it is a best effort representation of the state of the field as seen at the ICRC. The goal of this contribution is to report on these presentations which will of course be a limited view of the state of the field. There are many many more results in the larger scientific literature cannot be covered.

It is important to not take for granted that the scientific community can currently take advantage of many, stable, well characterized instruments (Figure 1). This situation has benefited from the work of thousands of dedicated people. Almost every presentation used data from multiple telescopes and missions; at this time it is unusual not to see a spectral energy distribution (SED) spanning several orders of magnitude using optical, radio, X-ray, and gamma-rays (spanning the GeV to TeV energy ranges). Most of these instruments are very mature and so we also benefit from a detailed understanding of their response and can leverage advanced analysis methods. Since the *Fermi* Large Area Telescope (LAT) has been in operation for nine years at this point, we have deep exposure on any part of the sky in the high energy (HE; 100 MeV - 100's GeV) range. The very high energy (VHE; $>$ 100's GeV) sky has been studied in detail by the modern air Cerenkov experiments and we are beginning to see a survey of the sky from the always on, large field of view High-Altitude Water Cherenkov Observatory (HAWC) experiment. This is truly a golden age for gamma-ray studies of the sky which is standing on the back of the discovery period of the 80's and 80's. However, there is always another golden age coming.

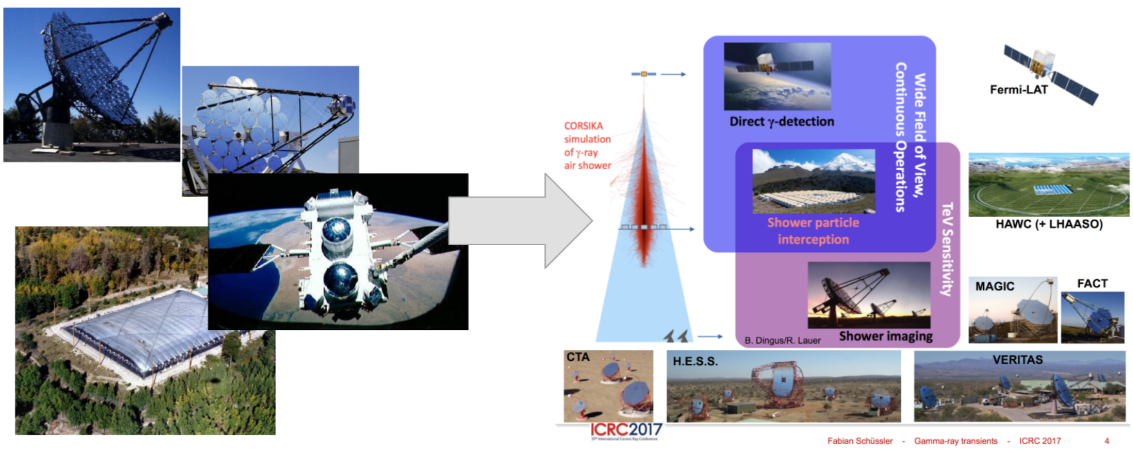


Figure 1: The first generation instruments of the 80's and 90's such as Whipple, HEGRA, CAT, CGRO, Milagro, and others has led to the current, modern era. It is normal at this point that any study of the gamma-ray sky includes data spanning the full electromagnetic spectrum (and sometimes beyond into neutrinos or gravitational waves). These modern instruments are mature; they are well characterized and have advanced analysis tools resulting in our ability to dig deep into the data.

[1]https://pos.sissa.it/301/

Four overarching themes continued to appear in the spaced based gamma-ray astronomy presentations whether the authors intended to include them or not.

- As mentioned above, there is an unprecedented coverage of the gamma-ray sky currently. The space based missions, including *Fermi* LAT, are providing the multiwavelength context.
- The current generation of telescopes and missions have been in operation for about a decade. This has resulted in mature analysis tools, large data sets, and well-characterized responses. Many presentations were about pushing the boundaries in terms of deep observations and/or new analysis techniques.
- Several new instruments are coming on line and starting to produce results such as DAMPE, POLAR and COSI.
- Many presentations mentioned the need for a new mission in space. Not necessarily something to replace *Fermi* but recognition that not all of the answers are in the HE range.

These proceedings are organized in broad science topics but these four themes will guide the discussion.

2. Galaxies and Active Galactic Nuclei

While there are many examples in the following sections detailing the significance of the current broad energy coverage, several presentations on Galaxies and Active Galactic Nuclei (AGN) relied heavily on the combination of data from multiple instruments. The spaced based instruments allow for a measurement of AGN SED over many orders of magnitudes. Without this context, our understanding of the emission mechanisms of AGN would be limited.

[1] presented an analysis of a refined and deeper, observation of NGC 253 (one of the few starburst galaxies detected in gamma-rays) with H.E.S.S. and *Fermi* LAT. At VHE the measurement is more accurate and, due to the doubling of the data set and Pass 8, the LAT measurements are improved and the energy threshold lowered. The SED is still best fit with a power law over five energy decades but a hint of a deviation is seen below 1 GeV which could be interpreted as a pion-decay feature.

[2] cleverly combined the coded mask data from *Swift*-BAT and INTEGRAL to produce an improved hard X-ray spectrum of 3C 279. They then added to this optical (UVOT and SMARTS), soft X-ray data (*Swift*-XRT), and HE gamma-rays (*Fermi* LAT). This allowed them to do detailed modeling of the full multiwavelength SED (Figure 2). It should be emphasized that this is something that is normal to do now - use measurements from the optical through gamma-ray and deduce what is going on in a source. The power of this technique should not be minimized. It is not a failure that we are still trying to understand AGN; our data sets are richer and our understanding has increased but more questions remain. After the modeling was done, VHE measurements were released by H.E.S.S. which seem to indicate that there is a hadronic component in the jet (as predicted by [2]).

Significant effort has been made over the last decade to catch blazars in flaring states. [3] presented an example: the organization of a multiwavelength campaign allowed them to measure

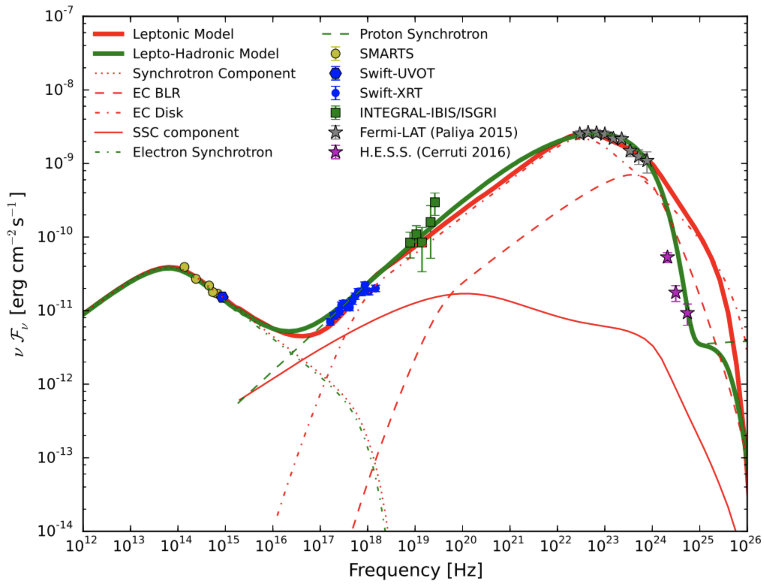


Figure 2: Broad band SED of 3C 279 as presented by [2]. The current generation of instruments allows us to produce SED over a large energy range and, very important for variable AGN, short periods of time (semi-simultaneous). An interesting point about this SED is that the models (red and green lines) were produced prior to the release of the H.E.S.S. results at VHE. These observations indicated that the emission might contain a hadronic component.

the SED of BL Lacertae in a high and low state with *Fermi* LAT, *Swift* and VERITAS providing an interpretation of the particle acceleration in the jet. Other examples of using multiwavelength information were presented including monitoring of NGC 1275 [4], looking for correlations [5], and modeling efforts such as [6, 7, 8]. None of these could be successful without understanding the full context of the SED provided by multiple instruments.

The large time baselines of the LAT (which just passed 9 years on orbit) allow researchers like [9] to construct very detailed light curves of blazars. Since the LAT is an all-sky monitor, they were able to look at variability on yearly, monthly, and daily timescales. Other authors dug deeper into LAT data in different ways. [10] leverage the long exposure of the LAT and improved sensitivity gained by Pass 8 to search for high redshift blazars and found 5 with $3.3 < z < 4.31$. These high redshift blazars are outliers; they have large black hole masses ($8.5 < \mathrm{LogM_{BH}} < 9.8$) and are very luminous. Their peak power is in the MeV range holding promise for future MeV missions (the detection of these few implies that many more exist, see Section 9).

Continuing the theme of looking deeper into the gamma-ray data, the *Fermi*-LAT collaboration [11] presented the deepest all-sky survey at E > 10 GeV using 7 years of Pass 8 data (Figure 3). This survey found 1556 sources (3 times more than the previous catalog covering the same energy range; 1FHL). The majority of the sources are extragalactic (79%) and probably AGN. An exciting prospect for future study (and future telescopes such as CTA) is that there are 211 brand new sources not found in other catalogs (LAT or TeVCat).

A constant in spaced-based gamma-ray astronomy is large angular resolution (as compared to other telescopes). [12] presented a method using gravitational lensing and the excellent temporal

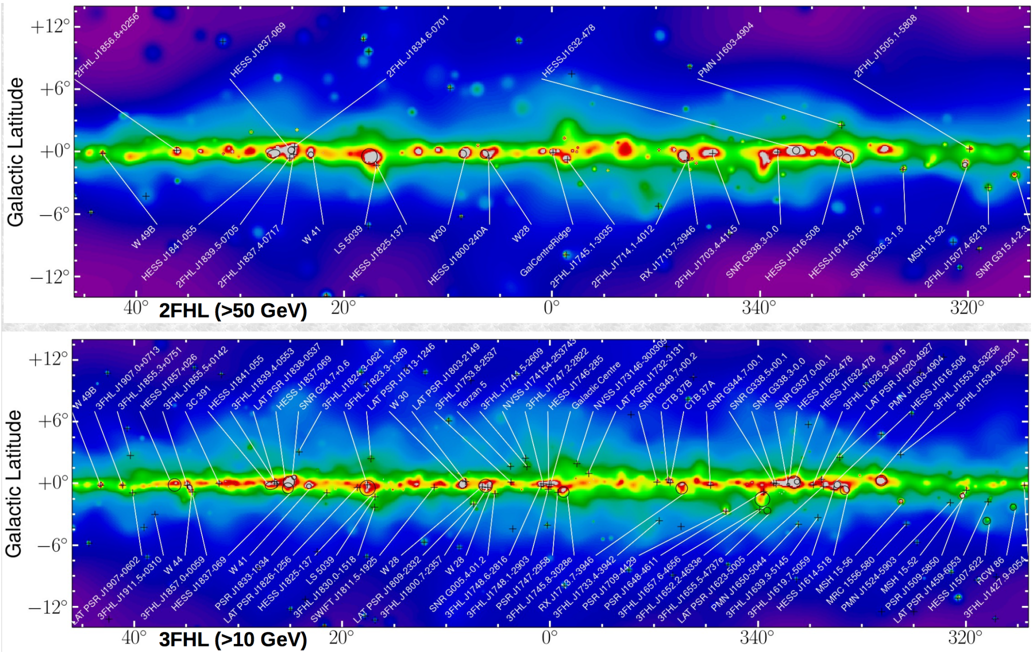


Figure 3: A comparison of the galactic plane seen in the 2FHL (above 50 GeV) and the 3FHL (above 10 GeV) seen with the *Fermi* LAT (from [11]). The improvement in statistics is due to the greater exposure (about 8 years) and the greater sensitivity due to Pass 8. A number of new sources have been found (211) that are not sen in other catalogs and hold promise for searches with future observatories like CTA.

resolution of the LAT to achieve milliarcsecond resolution spatial measurements of astrophysical jets (specifically B2 0218+35). They determined that the gamma-ray flares are not always from the radio core and the radio core is not at the central engine.

There are many unidentified and uncertain sources and regions in the LAT data (this continues with the recent catalogs; the 3FHL mentioned above includes 11% unassociated and 2% unknown). There were several contributions documenting unique methods to identify sources and understand the gamma-ray sky. [13] used boosted decision trees to find infrared counterparts, [14] applied machine learning techniques and [15] used an energy dependent 1pt PDF method.

3. Gamma-ray Bursts and Time Domain Astrophysics

The most prolific gamma-ray burst (GRB) detector in operation, the *Fermi* Gamma-ray Burst Monitor (GBM) is operating superbly. [16] presented an overview of the state of the GBM which includes the detection of over 2000 GRBs. 266 of them are joint detections with *Swift* and 121 are also detected by the LAT. GBM is currently detecting about 200 long GRBs per year thought to be associated with massive star collapse and 40 short GRBs per year thought to be associated with compact merger events. GBM is also detecting terrestrial gamma flashes (TGFs; associated with thunderstorms), pulsars, X-ray bursts and other objects such as the Crab. Many people are digging deep into the data of specific bursts (like GRB 160709A [17]) or trying to understand relativistic jets from the perspective of GRBs [18].

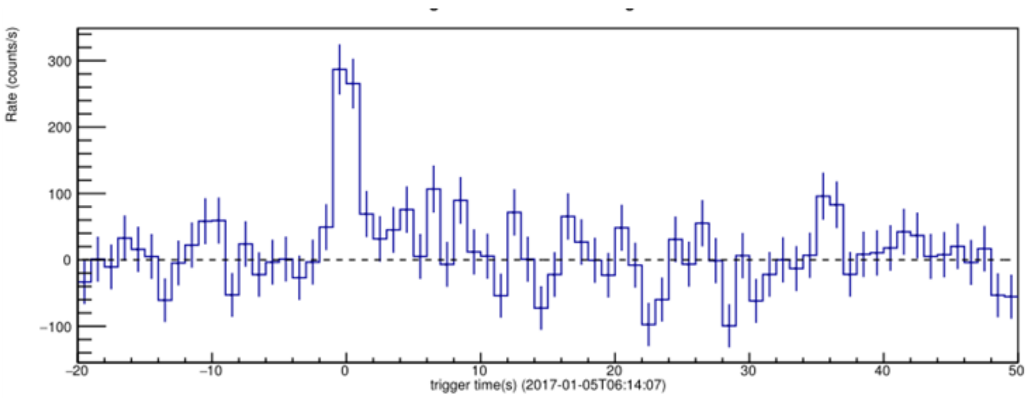
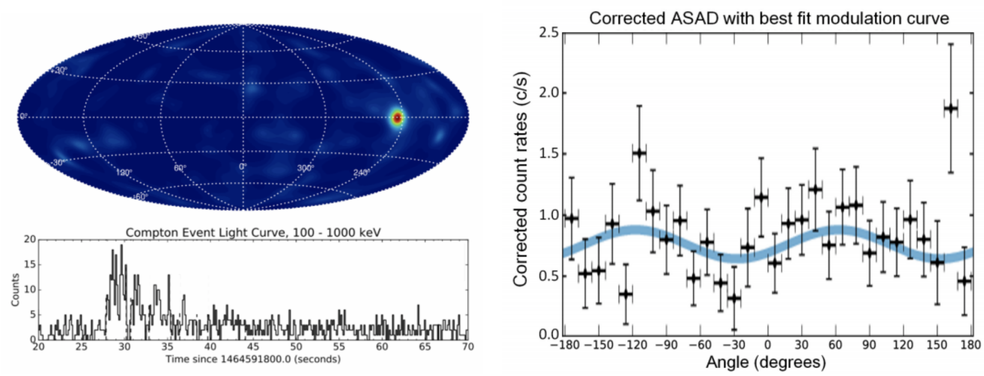


Figure 4: POLAR light curve (background-subtracted) of GRB 170105A. POLAR is a Compton scattering polarimeter designed to detect GRBs. While no polarization measurements were presented at the ICRC, they presented calibration data showing their sensitivity to polarimetry. POLAR is on-board the Chinese space laboratory Tiangong-2 (TG2).

Many new instruments are online and are producing results. The Lomonosov space mission was launched in 2016 and includes both a GRB detector as well as wide field of view optical cameras [19]. A table of GRB light curves were presented from the GBM on board the CALET mission [20]. Several presentations on the POLAR measurements of GRBs detailed their 55 GRB detections (Figure 4). POLAR is a Compton telescope designed to measure GRB polarization; the polarization measurements are coming soon [21, 22]. Exciting results are coming out of COSI[23], including an observation of a GRB (Figure 5). See Section 9 for more details.



(a) Image and light curve

(b) Polarization modulation (ASAD)

Figure 5: COSI observation of GRB 160530A as presented by [23]: (a) image showing the GRB localization in Galactic coordinates (top) and the light curve (bottom) of the burst; (b) the corrected azimuthal scattering angle distribution (ASAD) showing the polarization modulation of GRB 160530A.

The ICRC is, by definition, a multimessenger conference (it is one of the few places where the astrophysical and astroparticle communities come together). As such, these topics were very well covered in the plenary sessions by [24] and [25]. A few points about the space based searches are in order. Right now there is coverage from 10 keV to 100's of GeV (for example, LAT covers the full sky from ~ 20 MeV to 100's of GeV and GBM[26], CALET-GBM[27], POLAR[21], and DAMPE[28] cover the hard X-ray/low energy gamma-ray). As mentioned before, we are in an unique position that if an event occurs whether it be a gravitational wave, neutrino, or something else, these instruments will have eyes on the event and the data are there. This is a difficult task and only by looking throughout the electromagnetic spectrum and over the full sky will we be able to catch something when it happens and understand what happened (see Figure 6).

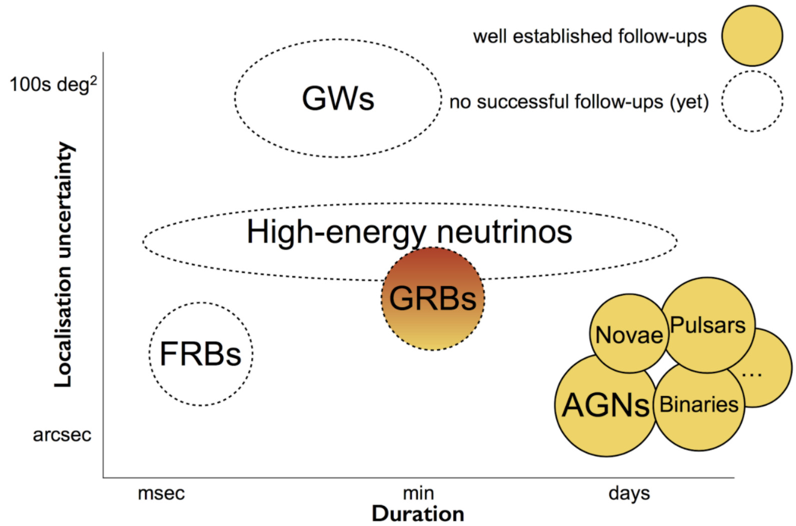


Figure 6: The difficulty in looking for the gamma-ray signal from multimessenger events is detailed in this slide by [25]. The combination of large error regions (which means telescopes with small fields of view have to tile) and short durations adds to the complexity of follow-up. Wide field-of-view instruments have the best chance of catching photons during an astrophysical event.

4. Our Galaxy

One of the largest sources of gamma-rays for space-based missions (and thus one of the largest backgrounds) is our own galaxy (Figure 7). It is very important to understand this emission not only to understand the processes that produce it but, as [29] said, 'better models for the structure of the Galaxy are needed to fully utilize the precision measurements currently available.' To dig deeper in the gamma-ray data, we must fully understand the gamma-ray emission of our own Galaxy. To this end, the GALPROP[2] team have been working on updates to the *Fermi* diffuse model using the most recent data available (electrons, 408 MHz, Planck, and *Fermi*-LAT [30]). They have also developed new 3D models for the interstellar medium[31] and the Galactic Gas[29]. While several people are working on a global picture of the galaxy, [32] presented a detailed study of the MBM 53-55 and Pegasus loop regions using Planck and LAT data (Figure 7). They creatively used the gamma-rays to compensate for the dust temperature and are trying to understand the contribution of 'dark gas' to the total gas column density.

One of the most exciting results to come out of the LAT during the past 9 years of operations was the detection of the *Fermi* Bubbles. [33] gave a very detailed plenary talk providing an

[2]https://galprop.stanford.edu/

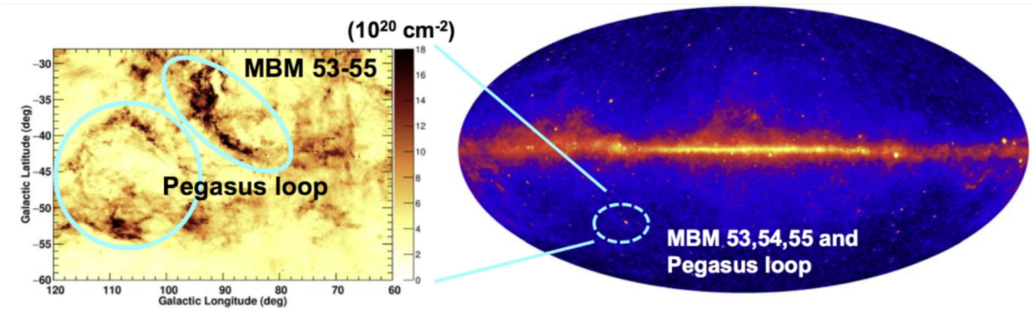


Figure 7: (right) The full gamma-ray sky as seen by the *Fermi*-LAT . You can clearly see the bright emission from the galactic plane (a source in its own right) which much be adequately modeled as a background if we are to understand the rest of the sky. (left) The corrected N(Htot) map in unit of 10^{20} cm^2 as shown by [32].

overview. We know that the bubbles have a hard spectrum, sharp edges, and no spectral variation. There are many models used to describe their origin but they fall in three broad categories: AGN activity, star formation/star burst in the plane, or in situ production. [33] also presented a kinetic model that involves 1st and 2nd order electron acceleration and inhomogeneous radiation fields along with anisotropic diffusion. [34] presented another model that involved an outflow of gas interacting with pre-accelerated cosmic rays.

5. Supernova Remnants

In some ways the tie between the cosmic ray and gamma-ray sky is strongest when studying Supernova Remnants (SNR). (Also, SNR make some of the best images in gamma-rays so apologies for the number of figures in this section). [35] explained that cosmic ray measurements provide insight into the sources best investigated in gamma rays while the gamma rays provide a unique perspective on cosmic ray astrophysics. One can use gamma rays to address cosmic ray origins, acceleration and propagation. SNR are another source where multiwavelength observations are key since the combining of spatial and spectral information allows you to infer the underlying particle populations, acceleration mechanisms, and emission processes. You also need multiwavelength information to adequately find and identify new sources.

[36] and colleagues have prepared a new extended source catalog with the LAT (Figure 8). This grew out of looking for pair-halo emission (see Section 7) and is thus focused on results outside of the Galactic plane. Even then, this catalog contains 8 new sources of 'Galactic Origin' which are probably SNR but could also be from star forming regions (for more studies of this type of region see [37]). An example of the results of the extended source catalog is FHES J1741.5-390 (Figure 9) which is an unassociated source that is a possible shell-type SNR. It has a large angular extent and a hard spectral index. It matches the position and morphology of the gamma-ray source in [38] and encompasses SNR G351.0-5.4. As they dig into the FHES catalog we can expect more details on this and the other objects they found.

An exiting new development presented at this meeting is the second HAWC catalog[39] covering 507 days of observations and contains 39 gamma-ray sources (Figure 10). 16 of these sources are 1 degree away from known TeV gamma-ray sources and follow-up using VERITAS and *Fermi*-LAT data is critical to understanding what these objects might be. The combination of HAWC and

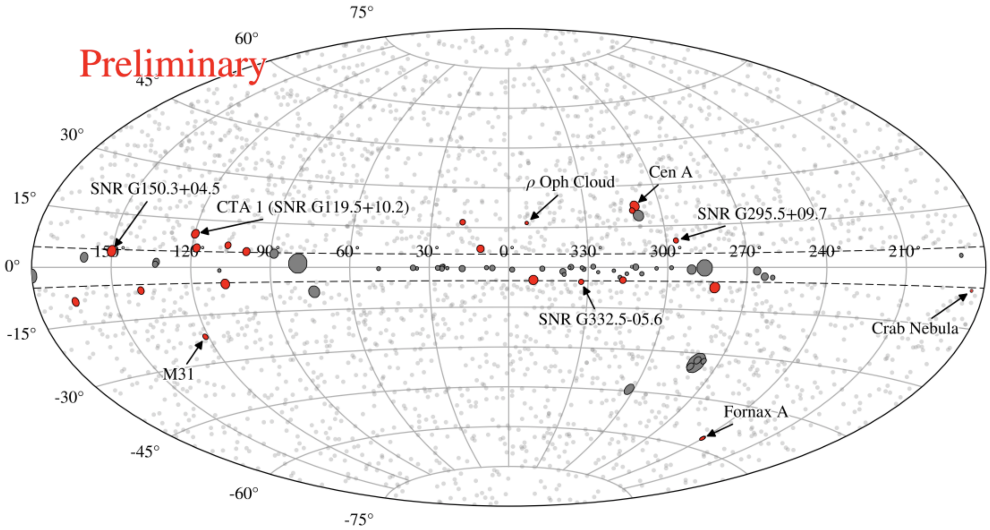


Figure 8: Distribution of FHES sources in Galactic coordinates from [36]. See the text for more details. An example of digging deeper into the *Fermi*-LAT data, this work found several new extended sources which are probably SNR including a new shell type SNR, FHES J1741.5-390 (see Figure 9

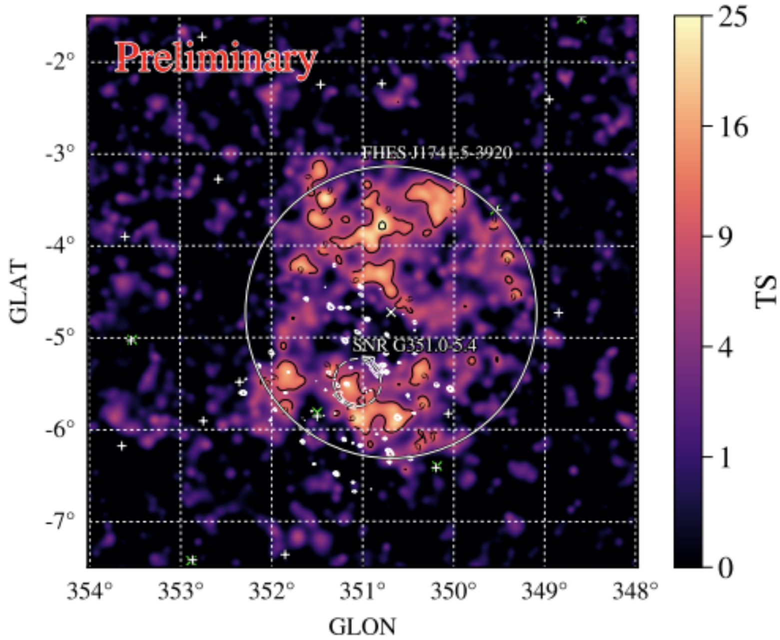


Figure 9: Residual test statistic map for the FHES extended source candidate FHES J1741.5âĹŠ3920 from [36]. See the text for more details. This source seems to be the same one seen by [38] and encompasses SNR G351.0-5.4. Even though the LAT has been in operation for several years, new sources continue to be found and as the galactic diffuse model is improved, we can expect even more.

Fermi-LAT is of particular interest because both experiments have very wide fields of view and survey all (or most) of the sky. As an example [40] presented a detailed study of the complicated Cygnus region trying to tease out what is going on by looking at the SED from the LAT, VERITAS and HAWC. This is similar to the efforts of [41] on CTB 37A. These are just the first studies and we can expect many more results as HAWC continues to operate.

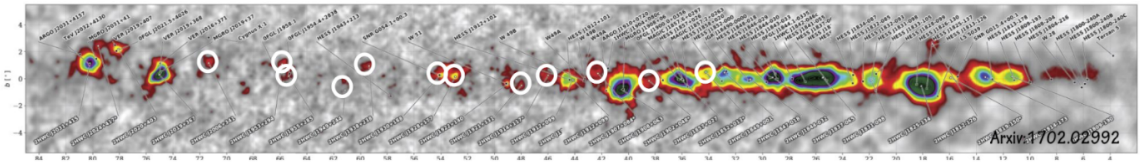


Figure 10: An image of the galactic plane by HAWC from [42] above 10's of GeV. This catalog covered 507 days of observations and contains 39 gamma-ray sources. As the experiment continues to operate, they will look deeper into the gamma-ray sky.

A beautiful analysis of the Gamma-Cygni region was presented by [43] showing how the morphology of the region changes with energy starting at 15 GeV in the LAT all the way through 450 GeV with MAGIC. There are similarities between the energies but also striking differences (Figure 11).

6. Pulsars and Binaries

We received a wonderful overview of pulsars from [44] which cannot be replicated here. In brief, our standard, pre-*Fermi* , paradigm is being replaced. Prior to the launch of *Fermi* , it was postulated that particles were accelerated in 'gaps' where there are unscreened fields (places such as the polar cap, the slot gap or the outer gap). Since then, *Fermi*-LAT has detected over 200 gamma-ray pulsars including a large number of millisecond pulsars (MSPs, the gamma-ray MSPs now make up 50% of all known MSPs) which differ from young pulsars (Figure 12). The MSPs are older and have probably been spun up by a binary companion. Much of what we see from young pulsars (such as their radio loudness) are mainly a function of the viewing angle. We have also learned that MSPs have lower magnetic fields than the young pulsars. From a detailed analysis of all of the new light curves, most of the double peaked emission that is seen is better fit by high-altitude emission models. As always, there are exceptions.

[44] coherently summarized: the soft gamma-ray emission comes from low altitudes (for high $\dot{E}$) while the high energy emission comes from high altitudes. Older pulsars are more efficient. However, no single model works for the variety of observables that exist (there is probably still polar cap emission in some MSPs). We have also seen some strange things like the TeV component in the Crab and the glitches seen pulsars like J2021+4026[45].

There were a few presentations on individual pulsars and binaries. [47] provided an update of pulsar observations with DAMPE. They report on three pulsars (PSR J0007+7303, Vela, and Geminga)[47]. In all three they can identify multiple peaks in the phase-folded light curve. [48] provided an updated analysis of joint *Fermi* -MAGIC observations of Cyg X-1 and X-3 detailing again the need for multiwavelength observations to understand the inner workings of these sources.

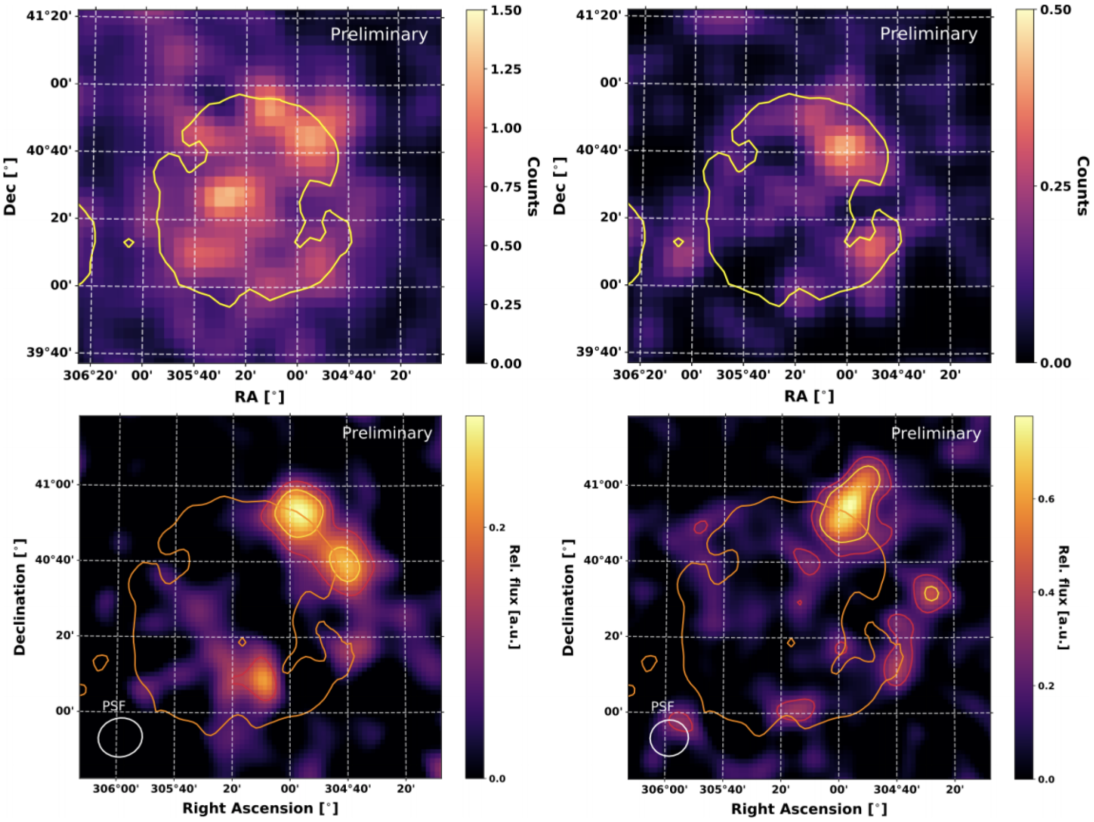


Figure 11: Morphology of the gamma-ray emission of Gamma-Cygni region at different energy bands from [43]. Starting in the upper left and going clockwise: 15 - 50 GEV with the *Fermi*-LAT , 50 - 200 GeV with the *Fermi*-LAT , > 450 GeV with MAGIC, and 200 - 450 GeV with MAGIC. The yellow line is a radio contour. The various energy ranges display different morphologies.

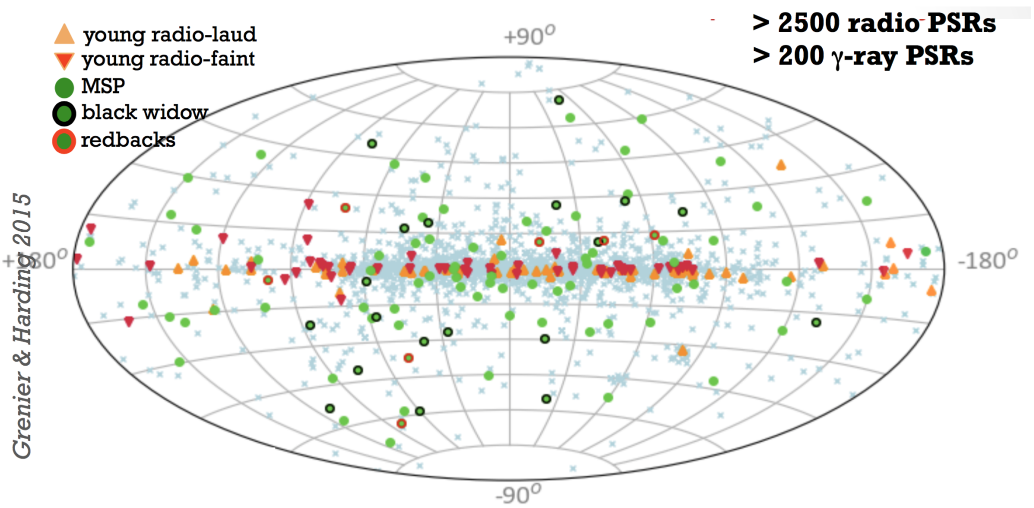


Figure 12: The distribution of pulsars on the sky as presented by [44] and from [46]. The *Fermi*-LAT has detected over 200 gamma-ray pulsars and the MSPs that have been detected by *Fermi* make up 50% of the known MSPs. The other distinct population, young pulsars, is also indicated.

7. Extragalactic Fields

The study of the extragalactic sky with an instrument like the LAT allows for the study of extragalactic fields such as the extragalactic background light (EBL) and the inter galactic magnetic field (IGMF)[49]. Significant work has been done using observations of TeV (and GeV) blazars to measure and put limits on these phenomenon (Figure 13). Constraining the EBL is important; it is the light that pervades our Universe and carries information about reionization, star formation, galaxy evolution and active galaxy emission. There also might be details on dark matter decay and other more exotic phenomenon encoded within it. Multiple approaches to calculating the EBL exist and there are multiple approaches to measuring it. The reason that indirectly measuring it via gamma-rays is so appealing is that it is very hard to directly measure the infrared and optical parts of the EBL due to contamination by foreground sources.

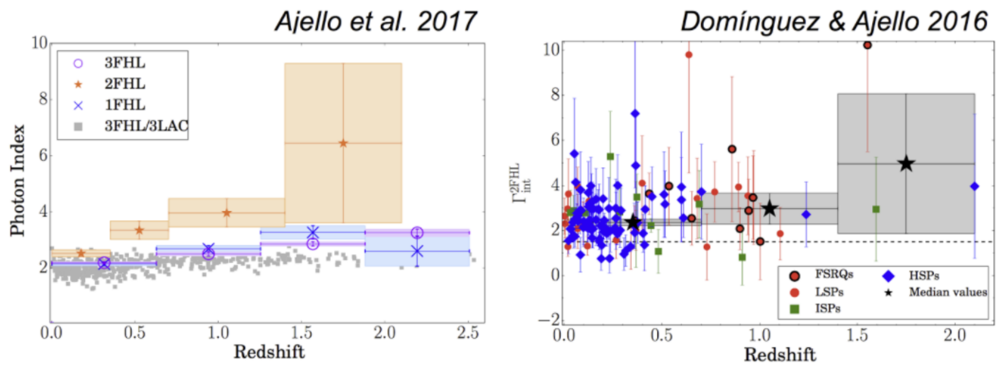


Figure 13: Figure as presented by [49]. On the left shows the photon index of blazars in various LAT catalogs versus redshift[50]. The photon index increases (softens) with redshift; an indication of EBL attenuation. The plot on the right is also showing photon index versus redshift but in this case, the authors have assumed an EBL model and corrected the spectra for it. In this case, no softening is seen with redshift[51].

A unique method of indirectly measuring the EBL via LAT only data was presented (most techniques involve TeV data or joint TeV and GeV data)[49]. The EBL interacts with gamma-rays as they propagate through the universe via pair production causing a softening of the spectra with redshift. This is directly seen in the newest high energy LAT catalog (the spectra of blazars in the 3FHL[50] increases with redshift). If you use some of the recent EBL models to correct the spectra of these blazars, the effect goes away. See Figure 13 and the references included in the caption for more details.

The IGMF is more difficult to measure. Similarly to the EBL, the measurement involves looking for features due to the interactions of gamma-rays via pair production. In this case, the pairs produced by TeV photons are deflected in the IGMF and then these produce GeV gamma-rays that are detected at the Earth. The result could be a time delay in flares or the existence of 'pair-halos' around extragalactic point sources. [36] looked for these pair halos around a sample of TeV blazars and put a bound on the IGMF ($B_{IGMF} > 3 \times 10^{-13}$ G if active for $\sim$ 10Myr or $B_{IGMF} > 10^{-16}$ G if active for $\sim$ 10 yr). An interesting side effect of this effort is the production of an extragalactic extended source catalog based on 8 years of LAT data (Figures 14, 8, and 9; and Section 5).

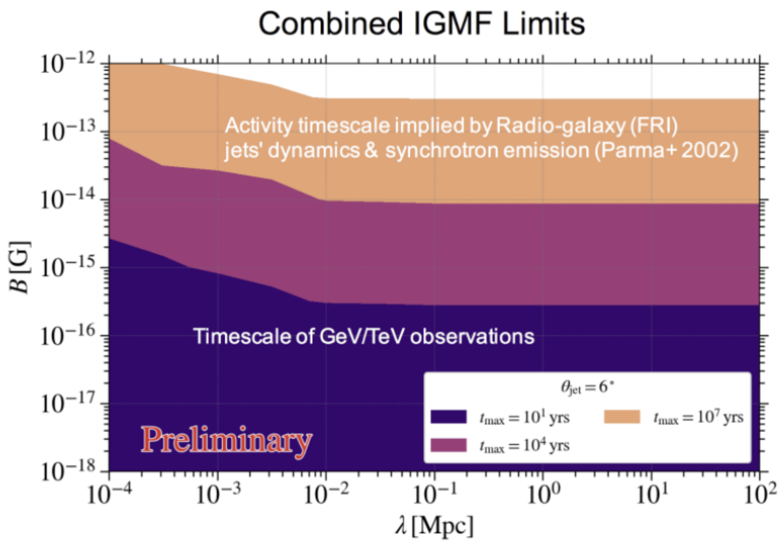


Figure 14: [36] presented 95% lower limits on the field strength of the IGMF. Shown here are combined exclusion limits for different blazar activity times. See the proceedings for more details.

These efforts depend upon detailed calculations of the EBL and of gamma-ray propagation through the inter galactic medium. [52] presented an analytical framework for calculating pair halos which is must faster than Monte Carlo (ELMAG[3] is the benchmark) and is designed for *Fermi*-LAT data. [53] also presented work on a code adapted from CRPropa[4](it takes about 4 hours on 12 cores to propagate 10^5 initial photons). [54] also presented work on gamma-ray propagation with an emphasis on the "electromagnetic cascade model".

8. Updates

There were several updates on simulations, software, and analysis packages. This is an often neglected but vitally important part of the scientific process. At times it is on par with building the instruments; software upgrades can significantly improve the results from a mission or telescope. It at least should receive a part of our resources and our praise. There is tremendous momentum behind open source science and open source tools and our community should embrace this and encourage it. [55] presented EDGE[5], a diffusion and emission simulations package. [56] detailed an analysis package designed to aid in the analysis of *Fermi*-LAT data called fermipy[6]. [57] showed two posters: one on a Baysian Kalman filter [57] and one on an event generator for telescopes like e-ASTROGRAM[7] [58]. Finally, [59] has been using GEANT 4[8] to understand gamma-rays from the Sun.

[3] http://elmag.sourceforge.net/
[4] https://crpropa.desy.de/
[5] https://github.com/rlopezcoto/EDGE
[6] http://fermipy.readthedocs.io/
[7] http://eastrogam.iaps.inaf.it/
[8] https://www.geant.org/

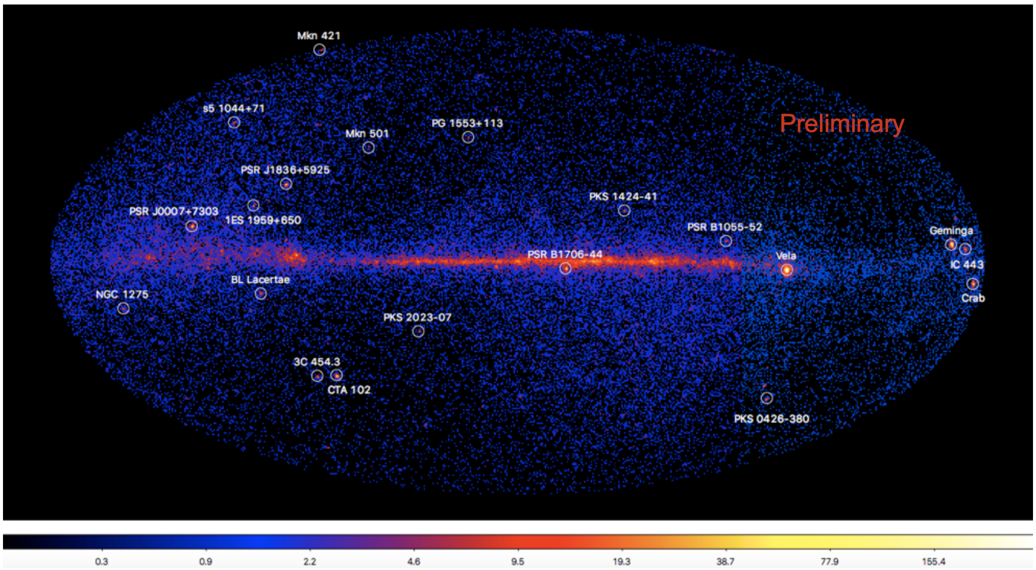


Figure 15: >2 GeV Gamma-ray skymap from 17 month's of DAMPE observations as shown by Liang [60]. The bright Galactic Plane is clear as well as the 20 selected bright DAMPE gamma-ray point sources (Note that the sky map is not exposure corrected).

A series of presentations on DAMPE (Figure 15) informed us about the state of that mission (launched in December of 2015) including an overview in the plenary session[61]. There were specific presentations on the gamma-ray sources detected by DAMPE[60] (90,000 gamma-rays have been detected in 510 days) and the variable sky[28] (including light curves of CTA 102 and 3C 454.3). Several technical posters are included: machine learning[62], gamma-ray selection[63], and gamma-ray performance[64].

We received updates on missions just beginning to operate and some in development. POLAR, a mission designed to look for GRB polarization, let us know about their optimization[65], data center[66], and calibration (their results were already mentioned Section 3). GRAINE[67], a large aperture emulsion telescope, has had several flights and is planning to fly a 5m^2 aperture telescope in the 2020s. We heard about their GRB measurements and (computer automated) track identification. The ultra-Fast Flash Observatory (UFFO) was launched in 2016 April and is designed to detect the prompt optical emission from GRBs[68]. UFFO uses a novel slewing mirror telescope with a 1.4 second response time (Figure 16). CALET, designed to look at electrons, presented an update on their gamma-ray measurements[69]. You can clearly see the bright gamma-ray sources in their sky map (CTA 102, Vela, Geminga, and the Crab) as well as the galactic plane.

9. Future Missions

One of the themes of the ICRC with respect to space-based gamma-ray astrophysics was the use of multiwavelength data to understand objects and put the gamma-ray data in context. The gamma-ray data (GeV and TeV) alone provide a wealth of information about the underlying non-thermal particle populations, the emission mechanisms, and the structure of the objects of interest.

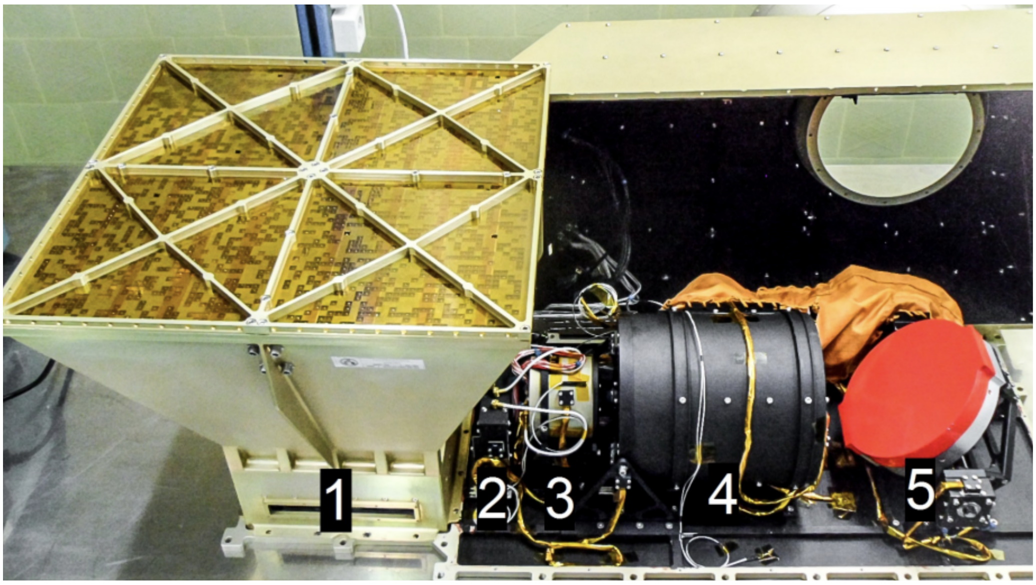


Figure 16: The UFFO pathfinder as presented by [68]. It contains a Burst Alert and Trigger Telescope (1), and a fast slewing mirror system (5). See the text for more details.

There is a key piece missing, the MeV portion, and several attendees highlighted this lack of information in their talks (Figure 17).

The MeV domain is one of the most under-explored windows in the universe. Currently, the germanium detector (SPI) onboard INTEGRAL covers the 18 keV to 8 MeV with a field of view of tens of degrees and good continuum sensitivity[9]. COMPTEL on board CGRO was the last all-sky survey instrument in this energy band. This energy range is difficult to explore. Both Compton and Pair production cross-sections reach a minimum in this energy range so detecting photons requires care. The backgrounds (both external and internal to the instruments) are high and must be accounted for.

The rewards are great, however. Many objects have their peak power output in the MeV band and to understand these objects it is critical to understand them where they are brightest. There are many interesting lines in this energy range such as the 511 keV positron annihilation line, and lines from stellar and supernova nucleosynthesis (^{26}Al, ^{60}Fe, and ^{44}Ti). Since most instruments developed to work in this band will utilize the Compton detection technique, gamma-ray polarization can be measured. Polarization is a key parameter in disentangling emission models in a wide variety of objects (we have already seen preliminary results from COSI and POLAR at this meeting).

Several missions are beginning to explore this range. COSI[23] is a balloon born GeD Compton detector that flew in 2016 and is now producing exciting results on GRBs, the 511-keV annihilation line (they confirm the detection of the positron annihilation signal from the inner 16 degree region of the Galactic center), and several other objects (their balloon flight went far enough north to see the Crab, Cyg X-1, and Centaurus A). An upgrade to COSI, COSI-X, was recently approved for a phase-A study. See Section 3 for a sample of their results.

[9]https://www.cosmos.esa.int/web/integral/instruments-spi

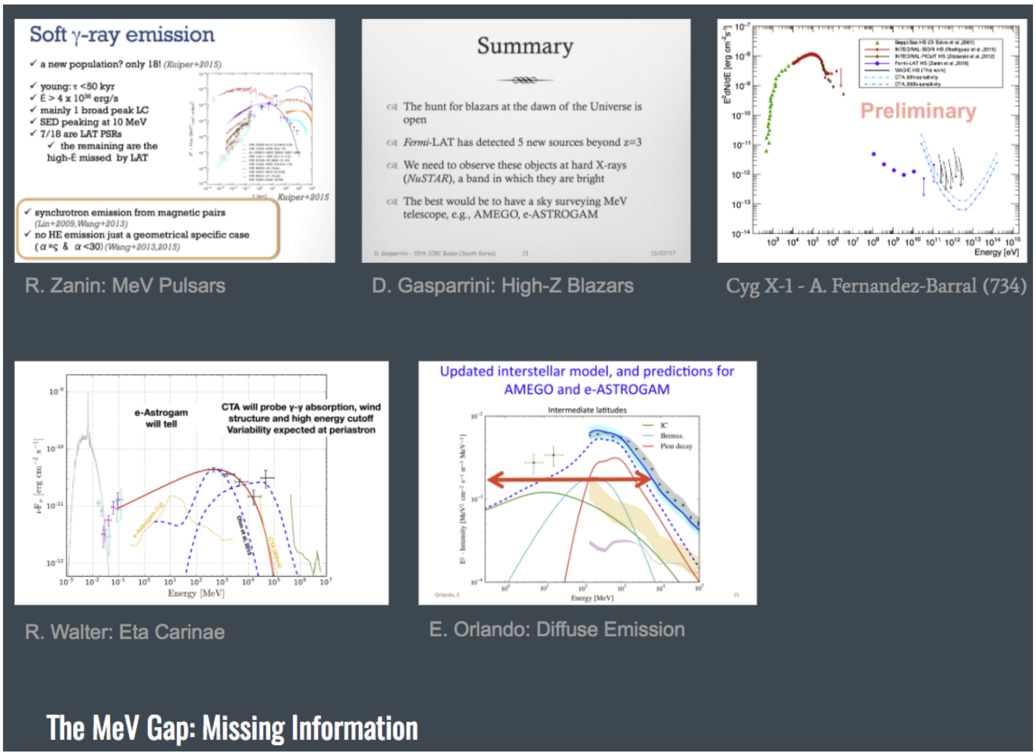


Figure 17: An array of presenters highlighted the lack of information in the MeV band. [44] mentioned a possible new population of MeV pulsars, [10] talked about distant and powerful MeV AGN, [48] and [70] presented SEDs of Cyg X-1 and Eta Carinae respectively with an obvious gap in the MeV range, and [30] detailed the importance of looking at diffuse emission in the MeV.

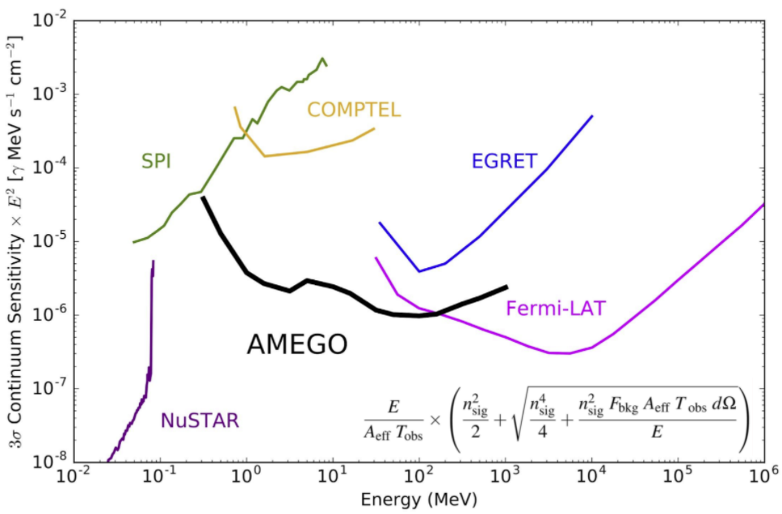


Figure 18: AMEGO is a proposed instrument for the MeV domain and this figure shows its preliminary sensitivity as presented by [71]. AMEGO is designed to achieve at least an order of magnitude increase in sensitivity over COMPTEL.

Several presenters are looking forward to a day where there is an all-sky MeV survey mission like *Fermi*-LAT in the GeV. This comes back to the point that we are very fortunate to have a suite of well-understood, high performing instruments in the sky. When working on a project, you can take it for granted that there will be LAT observations of the object of interest in the LAT database. [44] mentioned the discovery of a new population of soft gamma-ray pulsars (Figure 17, 18 have been detected). These pulsars peak at 10 MeV and do not have high energy emission. We have already seen that a mission like *Fermi* can change our understanding of Pulsars and we can expect similar things with a mission in the MeV. [10] postulates that the 5 new LAT blazars detected above a redshift of 3 with the LAT are just the tip of the iceberg. These types of blazars peak in the MeV band and an all-sky surveying mission will find hundreds of these types of objects at high redshifts. It is clear from looking at the SEDs of sources like Cyg X-1 [48] and Eta Carinae[70] that there is missing information in the MeV band and sensitive measurements there will inform us about what is going on. Without this knowledge we will not be able to understand what is happening. A very obvious measurement will be of gamma-ray diffuse emission and [30] presented work on predictions for an all-sky observatory.

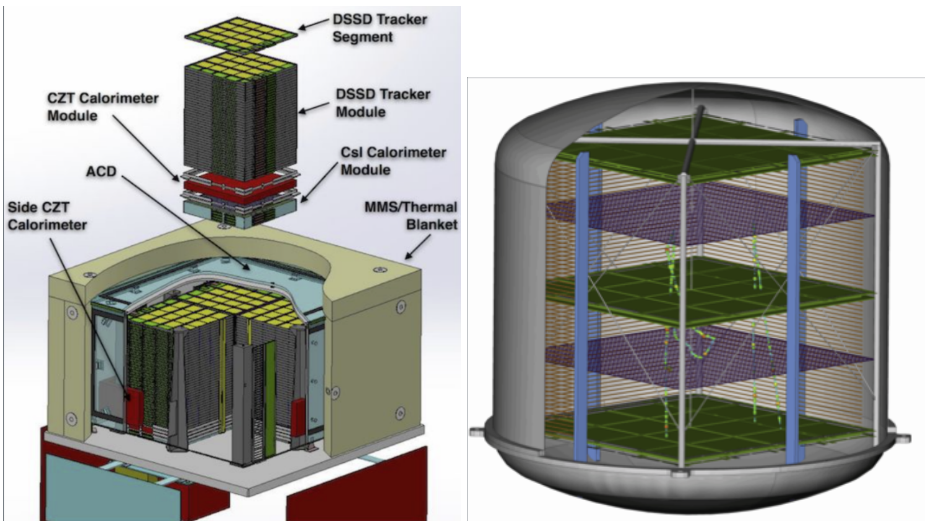


Figure 19: Several collaborations are pushing instruments to search the MeV sky; a relatively unexplored region of the electromagnetic spectrum. On the left is the AMEGO instrument as presented by [72]. AMEGO is a proposed MeV telescope making use of solid state detectors. STG3 is on the right [73] which is a large TPC instrument also optimized for the MeV range.

Several missions are trying to fit this bill and two of them are using similar technology to *Fermi*-LAT (silicon based tracker and a calorimeter): e-ASTROGAM[10] and AMEGO[11]. AMEGO (Figures 18 and 19) was well represented at the ICRC so most of this section will be describing the science behind AMEGO and the techniques employed (similar techniques and science cases exist for e-ASTROGAM). [72] presented the concept of the mission. It is a probe class mission for consideration in NASA's 2020 decadal review (e-ASTROGAM is being proposed to ESA's M5 Call). AMEGO will provide three new capabilities in MeV astrophysics: sensitive continuum

[10] http://eastrogam.iaps.inaf.it/
[11] https://asd.gsfc.nasa.gov/amego/

spectral studies, polarization, and nuclear line spectroscopy. It has a wide aperture (the field of view is 2.5 sr), sensitivity at least 20 times better than COMPTEL, a broad energy range (0.2 MeV to 10 GeV) and good angular resolution and polarization sensitivity. Basically, AMEGO will do for the MeV sky what *Fermi*-LAT did for the GeV sky. Going from EGRET to *Fermi*-LAT meant an order of magnitude increase in the number of gamma-ray sources (200 to more than 3000). We can expect to see the same improvement going from the tens of sources detected with COMPTEL to AMEGO. The AMEGO instrument looks remarkably similar to the LAT (not a coincidence; heritage is very important when developing a space instrument). It is made up a silicon tracker (double sided strip detectors) where an incoming photon Compton scatters or pair produces depending on its energy and two calorimeters: Cadmium Zinc Telluride (CZT) and CsI. The CZT calorimeter[74] measures the location and energy of Compton scattered photons and the CsI calorimeter extends the upper energy range. For more details on the instrument and its performance see [71] and [75].

The AMEGO (and e-ASTROGAM) teams are large and growing and the AMEGO team presented the case for an MeV instrument. [76] highlighted the need for an MeV mission for AGN studies; a highlight of which are MeV blazars [10] which harbor some of the most massive black holes in the universe and seem to exist at high redshift (which leaves open the question of how these massive black holes formed so early). AMEGO will be a GRB detecting machine due to its sensitivity and energy coverage, seeing about 400 long GRBs per year [77]. In the age of multi-messenger astrophysics, AMEGO will be a large player in looking for counterparts to gravitational wave signals and neutrino detections. [78] stated that AMEGO will explore new areas of dark matter parameter space and provide unprecedented access to its particle nature.

The MeV window can be explored with non-silicon instruments as well. [73] presented on HARPO and ST3G (Figure 19), a high pressure time projection chamber (TPC) which would have excellent polarization sensitivity and almost 4π acceptance. They have demonstrated a prototype in a gamma-ray beam (1.74 - 74 MeV) and proved the ability to measure polarization modulation. Currently a balloon flight design is in progress which can self-trigger.

Other avenues exist for future gamma-ray missions in space than looking in the MeV regime. Gamma-400[79] is an approved mission scheduled to launch in the mid 2020s which will extend the high energy sky of *Fermi*-LAT by improving angular and energy resolution at the high energies ($>$ 1 GeV). These improvements would allow Gamma-400 to identify many of the unidentified source detected by the LAT, continue the high energy dark matter search, and look for gamma-ray lines resulting from the annihilation of Dark matter. This would be a very interesting mission to be in operation when CTA is at design sensitivity. Especially interesting would be its ability to resolve the origin of the galactic center emission. On the opposite end of the size scale is BurstCube[80]. A '6U' CubeSat 10 cm x 20 cm x 30 cm in size which is designed to look for the astrophysical counterparts of gravitational wave signals (and detect many other gamma-ray transients along the way). BurstCube has 4 CsI scintillators read out by silicon photomultipliers on board and will increase the sky coverage for detecting GRBs and other transients.

References

[1] C. Hoischen, S. Ohm, A. Taylor, H. J. Völk, R. Yang and The H.E.S.S. Collaboration, *Revisiting the starburst galaxy NGC 253 with H.E.S.S. and Fermi-LAT*, in *35th International Cosmic Ray*

Conference, vol. 301 of *Proceedings of Science*, July, 2017.

[2] E. Bottacini, M. Böttcher, E. Pian, W. Collmar and D. Gasparrini, *Challenges in Reconciling Observations and Theory of the Brightest HE Flare ever of 3C 279*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 642, July, 2017.

[3] Q. Feng for the VERITAS Collaboration, S. G. Jorstad, A. P. Marscher, M. L. Lister, Y. Y. Kovalev, A. B. Pushkarev et al., *Multiwavelength observations of the blazar BL Lacertae: a new fast TeV gamma-ray flare*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 648, July, 2017.

[4] Y. Fukazawa, K. Shiki, Y. Tanaka, H. Takahashi, F. Imazato, R. Itoh et al., *GeV gamma-ray, X-ray, and optical monitoring of a radio galaxy NGC 1275*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, July, 2017.

[5] A. Garcia-Gonzalez, M. Gonzalez, N. Fraija and the HAWC Collaboration, *X-ray/gamma-ray flux correlations in the BL Lacs Mrk 421 and Mrk 501 using HAWC data*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 624, July, 2017.

[6] T. Vuillaume, G. Henri and P. Petrucci, *An Inhomogeneous Jet Model for the Broad-Band Emission of Radio Loud AGNs*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 864, July, 2017.

[7] C. Perennses, H. Sol and J. Bolmont, *Intrinsic time lags in blazar flares and the search of Lorentz Invariance Violation signatures*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 611, July, 2017.

[8] P. Banasiński, W. Bednarek and J. Sitarek, *Gamma-ray flares from AGN jets colliding with luminous stars*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 651, July, 2017.

[9] F. Zefi, *Characterizing the long-term gamma-ray variability of the BL Lac object 1ES 1215+303 with Fermi-LAT*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 628, July, 2017.

[10] D. Gasparrini, V. S. Paliya, M. Ajello, R. Ojha and the Fermi-LAT Collaboration, *Gamma-ray Beacons at the Dawn of the Universe*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 659, July, 2017.

[11] A. Domínguez, B. Lott, S. Cutini, M. Ajello, P. Fortin and The Fermi-LAT Collaboration, *The Gamma-ray Sky Above 10 GeV (The 3FHL Catalog)*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1103, July, 2017.

[12] A. Barnacka, *Resolving High energy Universe using strong gravitational lensing*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 661, July, 2017.

[13] J. Lefaucheur, C. Boisson, P. Goldoni and S. Pita, *Looking for infrared counterparts of Fermi/LAT blazar candidates*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 600, July, 2017.

[14] S. Einecke, D. Elsässer, W. Rhode and K. Morik, *Towards Refined Population Studies: High-Confidence Blazar Candidates and their Multiwavelength Counterparts using Machine Learning*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 626, July, 2017.

[15] H.-S. Zechlin, *The gamma-ray source-count distribution as a function of energy*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 644, July, 2017.

PoS(ICRC2017)1117

[16] C. M. Hui and The Fermi GBM Team, *Time-domain astronomy with Fermi GBM*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 593, July, 2017.

[17] D. Tak, S. Guiriec, Z. L. Uhm, N. Omodei and J. McEnery, *Thermal and Non-thermal Emission Study in GRB160709A*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 643, July, 2017.

[18] Z. L. Uhm, *On the nature of relativistic jets in gamma-ray bursts*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, July, 2017.

[19] V. Bogomolov and The Lomonosov Collaboration, *Results of the Multimessenger GRB Observations in the Lomonosov Mission*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 669, July, 2017.

[20] K. Yamaoka and The CALET collaboration, *CALET GBM Observations of Gamma-ray Bursts and Gravitational Wave Sources*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 614, July, 2017.

[21] M. Kole and The POLAR Collaboration, *First Results of POLAR: A dedicated Gamma-ray Burst Polarimeter*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 852, July, 2017.

[22] S. Xiong, Y. Wang, Z. Li, J. Sun, H. Li, Y. Huang et al., *Overview of the GRB observation by POLAR*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 640, July, 2017.

[23] L. Chiu, S. E. Boggs, C. A. Kierans, A. Lowell, C. Sleator, J. A. Tomsick et al., *The Compton Spectrometer and Imager (COSI)*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 796, July, 2017.

[24] E. Resconi, *High Energy Multi-messenger Astronomy*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1083, July, 2017.

[25] F. Schüssler, *High-energy gamma-ray transients and multi-messenger links*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1106, July, 2017.

[26] C. M. Hui and The Fermi GBM Team, *Search for gravitational wave counterparts with Fermi GBM*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, July, 2017.

[27] M. Mori, Y. Asaoka and The CALET collaboration, *Search for gamma-ray emission from electromagnetic couterparts of gravitational wave sources with the CALET calorimeter*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 637, July, 2017.

[28] Q. Yuan, S.-J. Lei, Y.-F. Liang and The DAMPE collaboration, *The variable sky of DAMPE*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 617, July, 2017.

[29] G. Jóhannesson, *Interstellar gas in 3D, implications for CR propagation and gamma-ray emission*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 871, July, 2017.

[30] E. Orlando, G. Jóhannesson, I. V. Moskalenko, T. A. Porter and A. W. Strong, *Multi-wavelength Signatures of Cosmic Rays in the Milky Way*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 692, July, 2017.

[31] T. A. Porter, G. Jóhannesson and I. V. Moskalenko, *High-Energy Gamma-Rays from the Milky Way: 3D Spatial Models for the CR and Radiation Field Densities*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 737, July, 2017.

PoS(ICRC2017)1117

[32] T. Mizuno and The Fermi-LAT collaboration, *Study of the ISM and CRs in the MBM 53-55 Clouds and the Pegasus Loop*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 688, July, 2017.

[33] P. Mertsch and V. Petrosian, *The Fermi Bubbles from Stochastic Acceleration by Turbulence in a Galactic Outflow*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1108, July, 2017.

[34] G. Giancinti and A. M. Taylor, *A Hadronic Model of the Fermi Bubbles: Cosmic-rays in a Galactic Breeze*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, July, 2017.

[35] T. J. Brandt, *Connecting γ-ray emission from SNRs to Galactic CRs*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1105, July, 2017.

[36] M. Wood, R. Caputo, M. Di Mauro, M. Meyer, The Fermi-LAT Collaboration and J. Biteau, *Preliminary Results of the Fermi High-Latitude Extended Source Catalog*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 647, July, 2017.

[37] R.-Z. Yang, F. Aharonian and C. Evoli, *Diffuse γ-ray emission near the young massive cluster NGC 3603*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, July, 2017.

[38] M. Araya, *Discovery of an Extended Source of Gamma-ray Emission in the Southern Hemisphere*, *ArXiv e-prints* (Sept., 2016) , [1609.06225].

[39] N. Park, The VERITAS Collaboration, The LAT Collaboration and The HAWC Collaboration, *VERITAS and Fermi-LAT observations of TeV gamma-ray sources from the second HAWC catalog*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 696, July, 2017.

[40] B. Hona and The HAWC Collaboration, *Correlated GeVâĂŞTeV Gamma-Ray Emission from Extended Sources in the Cygnus Region*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 710, July, 2017.

[41] S. Abdollahi, T. Mizuno, Y. Fukazawa, H. Katagiri, B. Condon and The Fermi LAT Collaboration, *ON THE ORIGIN OF GAMMA-RAY EMISSION FROM SNR CTB 37A WITH FERMI LAT*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 743, July, 2017.

[42] A. U. Abeysekara, A. Albert, R. Alfaro, C. Alvarez, J. D. Álvarez, R. Arceo et al., *The 2HWC HAWC Observatory Gamma-Ray Catalog*, ApJ **843** (July, 2017) 40, [1702.02992].

[43] M. Strzys, I. Vovk, C. Fruck, S. Masuda, T. Saito and The MAGIC Collaboration, *γ-Cygni the GeV to TeV Morphology with MAGIC and Fermi-LAT*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 685, July, 2017.

[44] R. Zanin, *γ ray emission from puslars and their nebulae*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1104, July, 2017.

[45] A. Allafort, L. Baldini, J. Ballet, G. Barbiellini, M. G. Baring, D. Bastieri et al., *PSR J2021+4026 in the Gamma Cygni Region: The First Variable γ-Ray Pulsar Seen by the Fermi LAT*, ApJ **777** (Nov., 2013) L2, [1308.0358].

[46] I. A. Grenier and A. K. Harding, *Gamma-ray pulsars: A gold mine*, *Comptes Rendus Physique* **16** (Aug., 2015) 641–660, [1509.08823].

[47] M. M. Salinas, X. Wu, S. Zimmer, F. Gargano, Z. Shen and The DAMPE Collaboration, *First Observations of Pulsars with DAMPE*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 709, July, 2017.

PoS(ICRC2017)1117

[48] A. Fernández-Barral, The MAGIC Collaboration, F. Aharonian, V. Bosch-Ramon and R. Zanin, *Gamma-rays from microquasars Cygnus X-1 and Cygnus X-3*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 734, July, 2017.

[49] E. Pueschel, *The Extragalactic Background Light*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 1107, July, 2017.

[50] M. Ajello, W. B. Atwood, L. Baldini, J. Ballet, G. Barbiellini, D. Bastieri et al., *3FHL: The Third Catalog of Hard Fermi-LAT Sources*, ApJS **232** (Oct., 2017) 18.

[51] A. Domínguez and M. Ajello, *Spectral Analysis of Fermi-LAT Blazars above 50 GeV*, ApJ **813** (Nov., 2015) L34, [1510.07913].

[52] F. Oikonomou, *Time dependence of AGN pair echo, and halo emission as a probe of extragalactic magnetic fields*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 869, July, 2017.

[53] R. A. Batista and A. Saveliev, *Morphological properties of blazar-induced gamma-ray haloes*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 602, July, 2017.

[54] T. Dzhatdoev, E. Khalikov and B. Kircheva, *Extragalactic γ-ray propagation: beyond the absorption-only model*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 866, July, 2017.

[55] R. López-Coto, J. Hahn, J. Hinton, R. D. Parsons, F. Salesa Greus, S. BenZvi et al., *EDGE: A code to calculate diffusion of cosmic-ray electrons and their gamma-ray emission*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 735, July, 2017.

[56] M. Wood, R. Caputo, E. Charles, M. Di Mauro, J. Magill and J. Perkins, *Fermipy: An open-source Python package for analysis of Fermi-LAT Data*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 824, July, 2017.

[57] D. Bernard and M. Frosini, *Optimal measurement of charged particle momentum from multiple scattering: Bayesian analysis of filtering innovations*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 830, July, 2017.

[58] D. Bernard, *A Bethe-Heitler 5D polarized $\gamma \to$ e+e- pair conversion event generator*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 859, July, 2017.

[59] B. Gao, S. Chen, C. Yu, K. Liu, H. He and Z. Li, *Study of Solar Gamma Rays basing on Geant4 code*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 878, July, 2017.

[60] Y.-F. Liang, K.-K. Duan, Z.-Q. Shen, X.-L. Xu, S. Garrappa and The DAMPE Collaboration, *Bright gamma-ray sources observed by DAMPE*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 603, July, 2017.

[61] S. Lei, Q. Yuan, Z. Xu, K. Duan, M. Su and The DAMPE Collaboration, *Gamma-ray Astronomy with DAMPE*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 616, July, 2017.

[62] S. Garrappa, P. Fusco, F. Gargano, F. Loparco, M. N. Mazziotta and The DAMPE Collaboration, *A Machine Learning classifier for photon selection with the DAMPE detector*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 764, July, 2017.

[63] Z. Xu, X. Li, J. Zang, W. Jiang, Y. Li and The DAMPE collaboration, *Gamma-ray selection of DAMPE*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 794, July, 2017.

PoS(ICRC2017)1117

[64] K.-K. Duan, Y.-F. Liang, Z.-Q. Shen, Z.-L. Xu, C. Yue and The DAMPE Collaboration, *The performance of DAMPE γ-ray detection*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 775, July, 2017.

[65] H. L. Xiao, W. Hajdas, R. Marcinkoski and The POLAR Collaboration, *Optimization of the final settings for the space-borne Hard X-ray Polarimeter POLAR*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 668, July, 2017.

[66] H. L. Xiao, W. Hajdas, R. Marcinkoski and The POLAR Collaboration, *PSI Data Center for Space-borne Hard X-ray Polarimeter: POLAR*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 858, July, 2017.

[67] S. Takahashi and The GRAINE Collaboration, *GRAINE: γ-ray observations with a high angular resolving and polarization sensitive large-aperture emulsion telescope*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 835, July, 2017.

[68] G. Gaikov, S. Jeong, V. G. Agaradahalli, I. H. Park, A. M. Amelushkin, V. O. Barinova et al., *The Slewing Mirror Telescope of UFFO-pathfinder: first performance report in space*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 774, July, 2017.

[69] N. Cannady and The CALET Collaboration, *High Energy Gamma-ray Observations with CALET*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 720, July, 2017.

[70] R. Walter, M. Balbo and C. Panagiotou, *Fermi acceleration under control: eta Carinae*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 746, July, 2017.

[71] R. Caputo, F. Kislat, J. L. Racusin and The AMEGO Team, *AMEGO: Simulations of the Instrument Performance*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 783, July, 2017.

[72] A. Moiseev and The AMEGO Team, *AMEGO: All-sky Medium Energy Gamma-ray Observatory*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 798, July, 2017.

[73] D. Attié, S. Amano, P. Baron, D. Baudin, D. Bernard, P. Bruel et al., *HARPO, prototype of a gamma-ray polarimeter: Results of a polarised photon beam test between 1.7 and 74 MeV*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 818, July, 2017.

[74] A. Moiseev, *High-Energy 3D position Resolution Calorimeter for the Use in Space Gamma-ray Astronomy based on position-sensitive virtual F* , in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 799, July, 2017.

[75] J. S. Perkins and The AMEGO Team, *AMEGO: Instrument and Technology Development*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, July, 2017.

[76] J. S. Perkins, M. Ajello, L. Marcotulli, E. Meyer, V. S. Paliya, T. Venters et al., *AMEGO: Active Galactic Nuclei*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 598, July, 2017.

[77] J. L. Racusin, A. Lien and The AMEGO Team, *AMEGO: Transients and Multi-Messenger Sources*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 792, July, 2017.

[78] R. Caputo, M. Meyer, M. Sánchez-Conde and The AMEGO Team, *AMEGO: Dark Matter Prospects*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 792, July, 2017.

[79] N. Topchiev and The GAMMA-400 Collaboration, *High-energy gamma-ray studying with GAMMA-400*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 802, July, 2017.

[80] J. L. Racusin, J. S. Perkins, M. Briggs, G. de Nolfo, J. Krizmanic, R. Caputo et al., *BurstCube: A CubeSat for Gravitational Wave Counterparts*, in *35th International Cosmic Ray Conference*, vol. 301 of *Proceedings of Science*, p. 760, July, 2017.