

ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany

**Gamma-ray Astronomy
Directly from Space
Rapporteur Report**

37th International
Cosmic Ray Conference
12–23 July 2021

**ICRC 2021, Berlin/my office
July 23, 2021**

Regina Caputo, NASA/GSFC

Gamma-ray Astronomy from Space

Overview and Statistics

- Numbers of submissions: 103 abstracts
- Numbers of recordings: 121
 - + review/highlight talks
- New this year! Number of discussion sessions: 12
 - Shared Sessions: **10 GAI**, 3 MM, 2 CRD, 1 DM (1 unique)
 - A summary of summaries
- Somewhat artificial between GAI/GAD/MM/DM/CRD...etc
 - Science vs. instrument split?
- Number of time zones: >8

Gamma-ray Astronomy from Space

Mea Culpa

- Focus on contributed work and discussion sessions
 - Challenges of virtual conferences
- This is a best effort to cover a lot of things
 - I have my science biases, those will come through
- *Thank you* to the Discussion Session conveners and the Conference organizers
- *Thank you* to the Zoom/Conference Support

Feedback for the Organizers

My perspective

Discussion sessions

- Very positive feedback generally
- Conveners had the freedom to design their session
- Varying levels of success
 - Conveners who compiled 1 slide summaries had the most discussion ← huge effort
- Conveners wanted more time to organize the sessions
- More time for the session (getting through talks and discussion was tough)

Feedback for the Organizers

My perspective

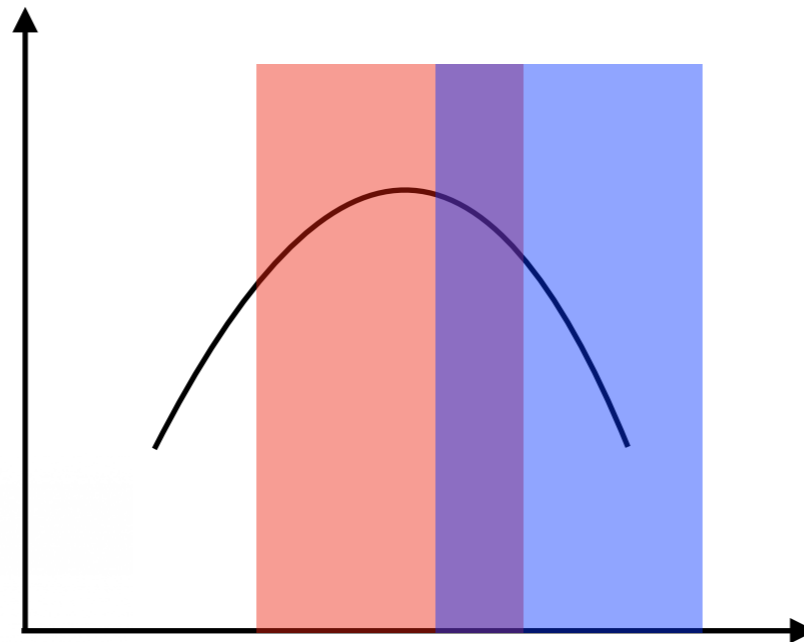
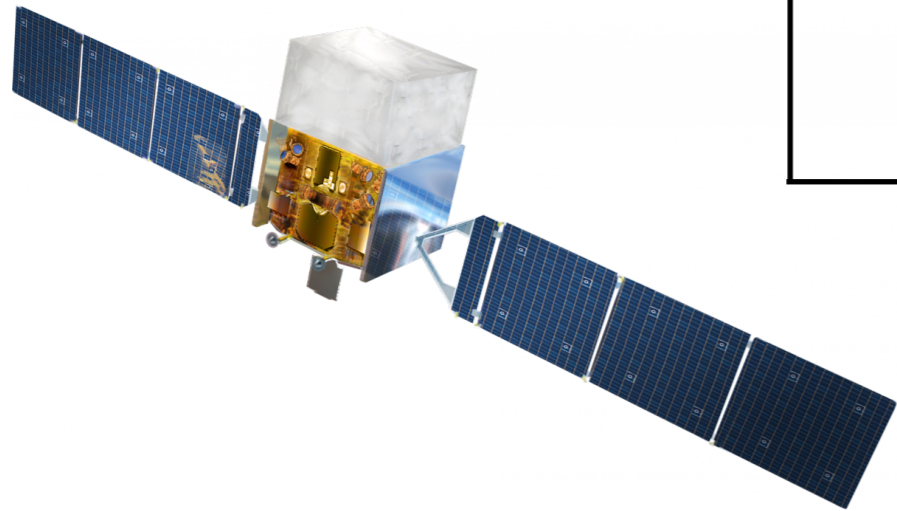
Virtual event

- Online event is more accessible, pre-uploaded material made this especially true
- My biases and privileges: (extrovert, able bodied, sufficient travel funds...etc)
- Hard to recreate the conference experience
- Slack!

A challenge for attendees to watch all the videos in advance of the session (>30h of watching time per session)

GAD/GAI split

A Gentle-person's agreement



10 overlapping discussion sessions

GAD/GAI split

A Gentle-person's agreement

GAD extragalactic sources and space-based gamma-ray instrumentation (except when uniquely GAD)



GAI galactic sources and ground-based gamma-ray instrumentation (except when uniquely GAI)

Gamma-Ray Astronomy from Space

The Landscape



Overview: A Summary

Gamma-ray Astronomy from Space

- The landscape has matured over the years
 - Many gamma-ray telescopes in space
 - Many tools available to analyze the data (and combine the data among instruments)
 - More telescopes... more data... more questions...
- Looking through the future
 - Many concepts being developed
 - Opportunities in for the future of space-based gamma-ray astronomy

Discussion Sessions

All related to Space Gamma-Ray Astronomy

43	(GAD) New and Upcoming Instruments for Space-Based Gamma-Ray Astronomy
44	(GAD-GAI-CRD) The origins of Galactic Cosmic Rays
45	(GAD-GAI-CRD) Probing the Distribution of Cosmic Rays in Galaxies
46	(GAD-GAI-CRD) Supernova Remnants
47	(GAD-GAI-MM) The central engines of fast transients: Gamma-Ray Bursts and Fast Radio Bursts
48	(GAD-GAI-MM) AGN and Jets: Theory and Observations I
49	(GAD-GAI-MM) AGN and Jets: Theory and Observations II
50	(GAD-GAI) Galactic Compact objects: Pulsars Binary Systems, Microquasars
51	(GAD-GAI) Census of Gamma-Ray Sources (catalogs, source populations, unassociated sources)
52	(GAD-GAI) Analysis, Methods, Catalogs, Community Tools, Machine Learning...
53	(GAD-GAI) PWN and Halos
16	(CRD, DM, GAD, MM) Cosmic Ray Antiparticles and Electrons

Discussion Sessions

All related to Space Gamma-Ray Astronomy

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Extragalactic Science: Transients

Discussion

47: Central Engines of Fast Transients: GRBs and FRBs

Andrew Taylor and Francesco Longo

- One slide summary, session divided GRBs and FRBs/Magnetars
- 5 Big questions:
 - Observational frontier, Observational bottlenecks, Future observations, Planned instruments sufficient, Strategies and lessons learned

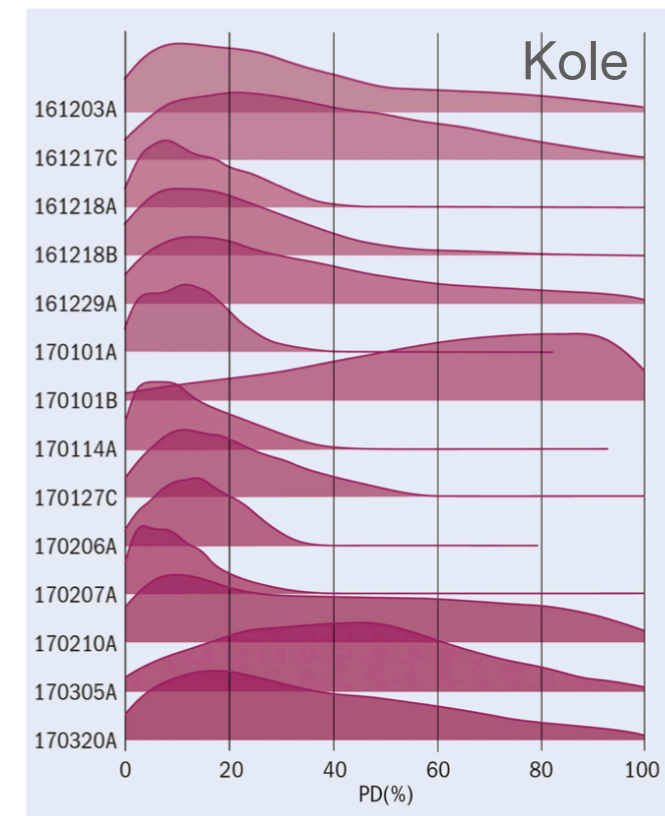
Discussion

47: Central Engines of Fast Transients: GRBs and FRBs

Andrew Taylor and Francesco Longo

- Outstanding questions: early GRB emission and polarization fraction of prompt emission
- Observatories with improved GRB localization
- Alternative models for prompt emission phase still being developed
- Off-axis GRB detection

GRB Polarization measurements from POLAR



- Discrepancies in polarization measurements with POLAR and ASTROSAT-I are being investigated. POLAR-2 scheduled to fly in mid-2020s

Transients

Gamma-ray Bursts

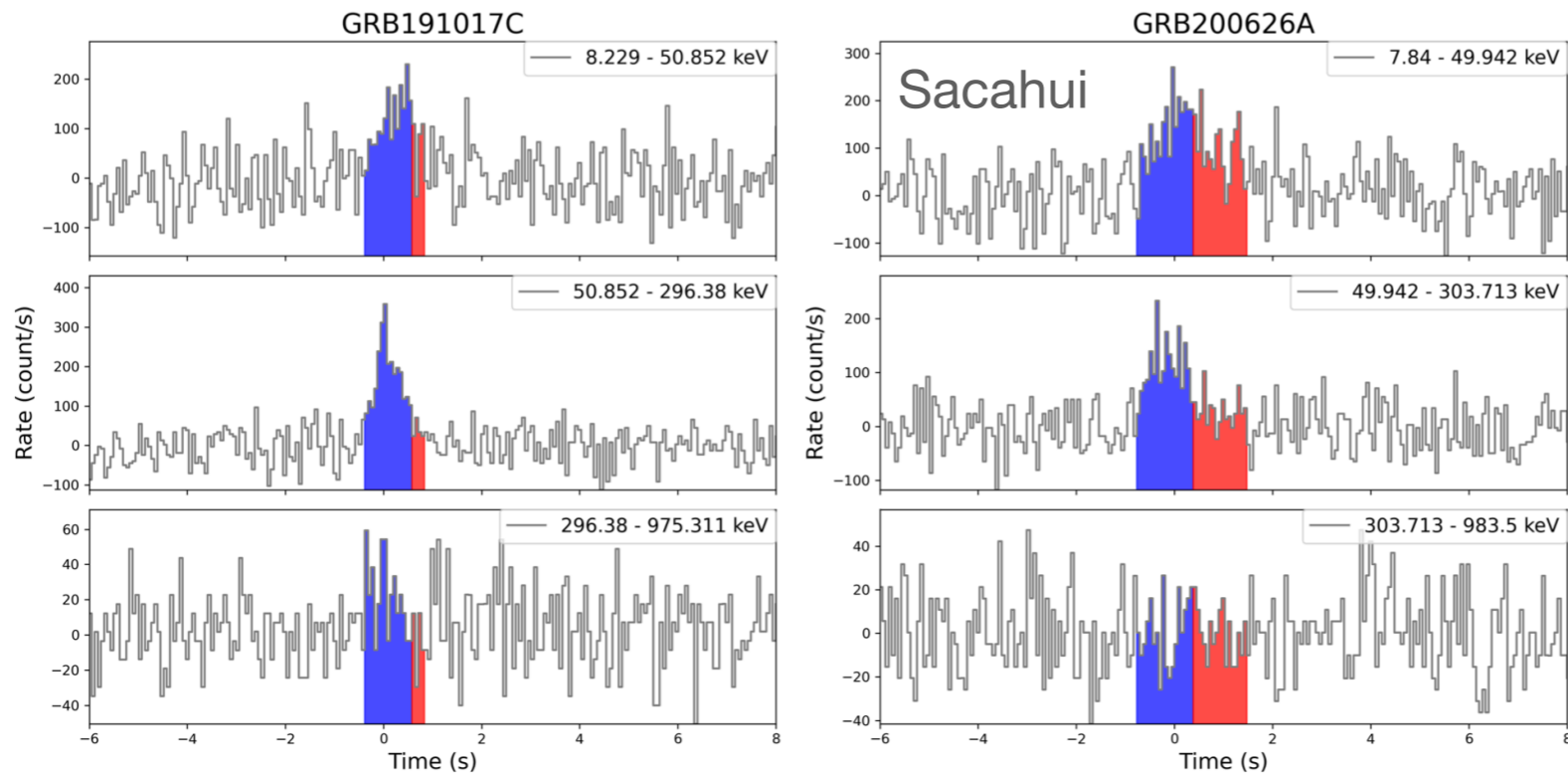


Figure 2: Composed light curves for GRB 191017C and GRB 200626A are shown. The nonthermal pulse is indicated in blue and the thermal soft component in red.

GRB 170817A analogs:
Short non-thermal pulse at early times
Soft thermal component at late times

Fermi-GBM bursts: 10% IGRBs,
1% sGRBs have precursors

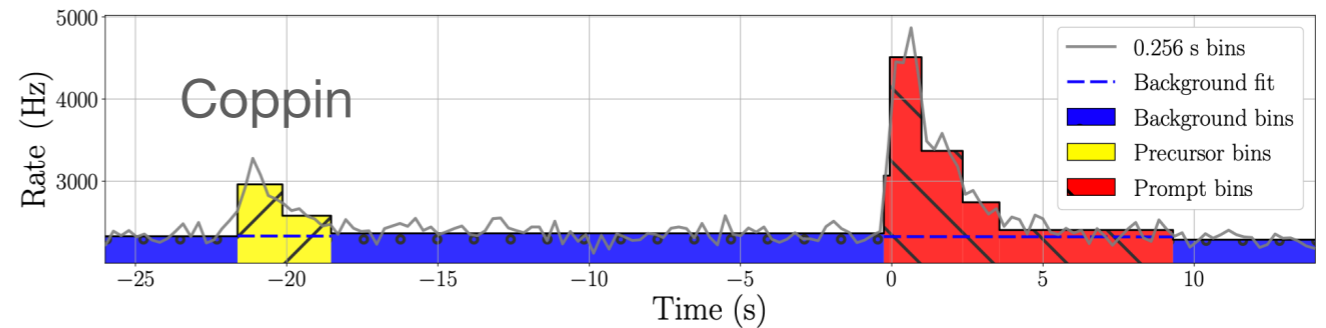
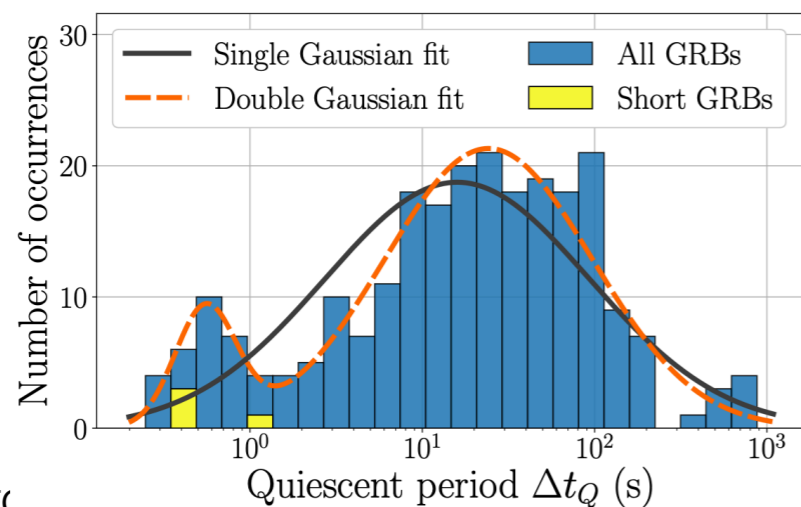


Figure 3: Light curve for GRB 120308588, illustrating the Bayesian block procedure.

Discussion

47: Central Engines of Fast Transients: GRBs and FRBs

Andrew Taylor and Francesco Longo

- Magnetars are of particular interest
- GRB200415A: ultra-short GRB
 - Distinguishing Magnetar Giant Flares from a genuine short GRB (Polarization a potential answer)
- SGR 1900+14
 - Source of UHECR? Hypernova that left a magnetar
- FRBs: HE, VHE and fast optical contemporaneous observations
 - Constrain emission mechanisms
- FRBs from Giant Magnetar Flares? (Something to explore)

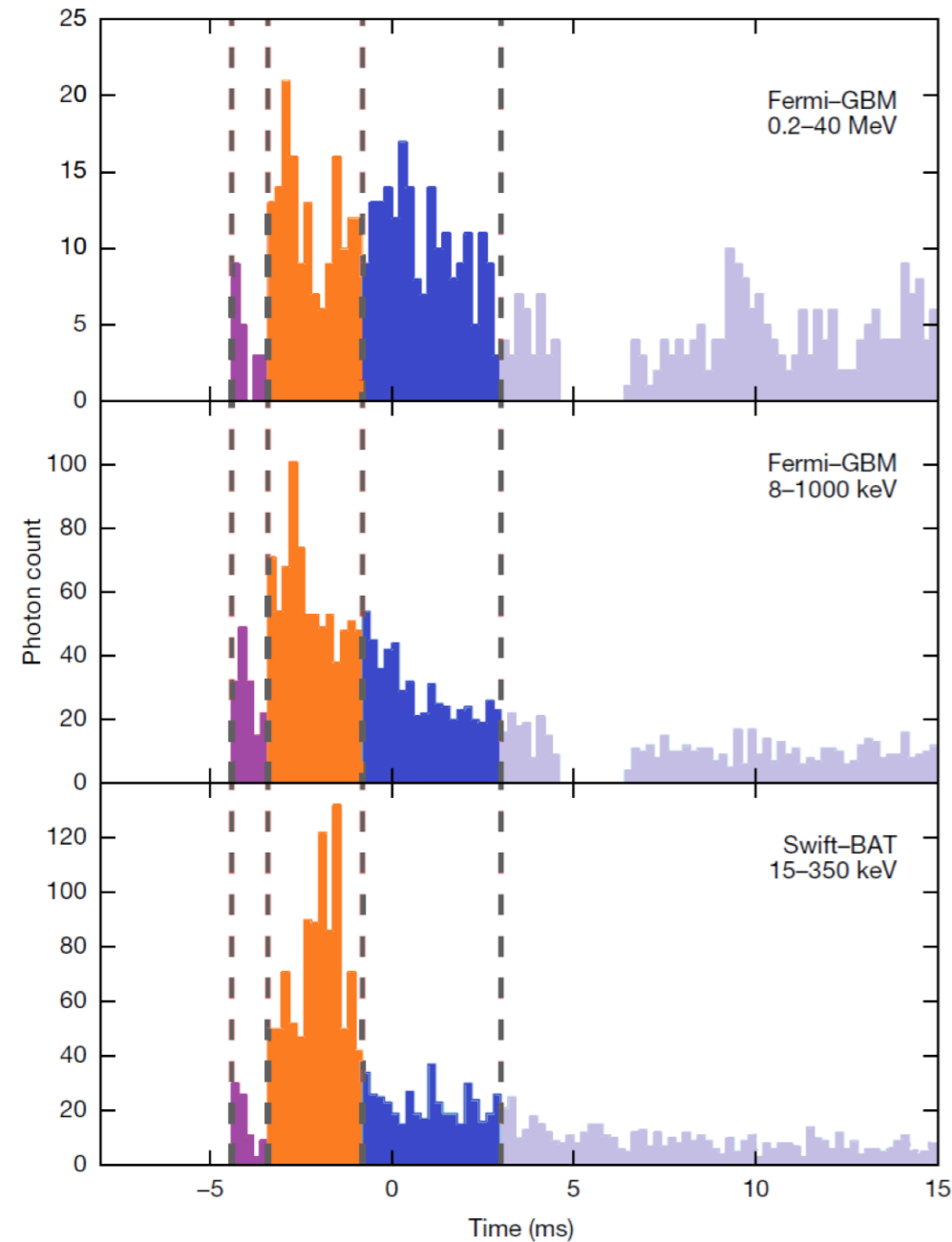
Transients

Magnetar Flares/Fast Radio Bursts

GRB 200415A: very short and very bright

3rd Class of GRBs?

Other GRBs like 200415A



Bissaldi

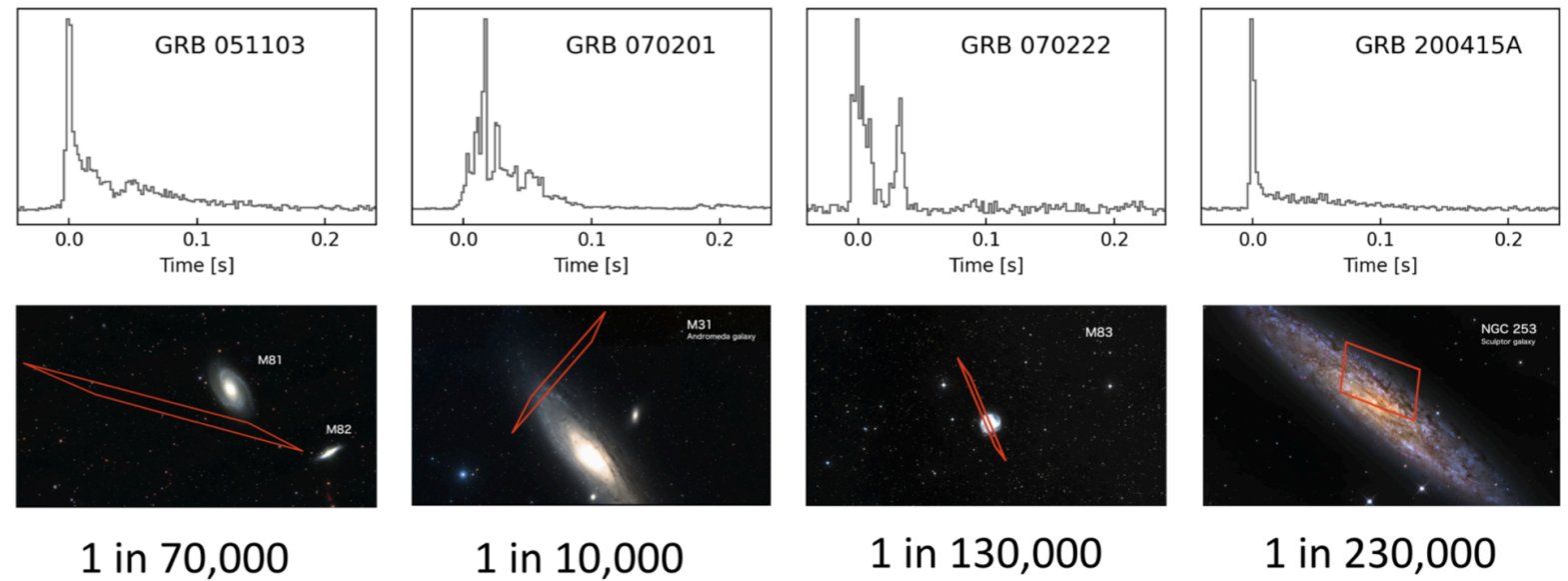
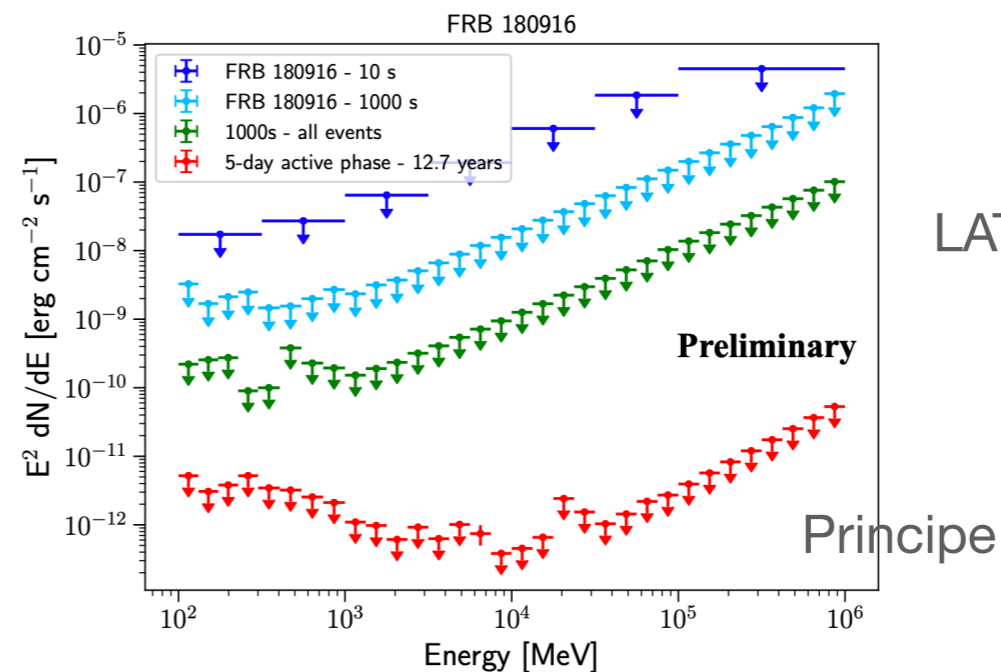


Figure 2: Light curves and localizations for the four identified short GRB that show incompatible with a cosmological origin. The numbers below each event is the chance alignment.

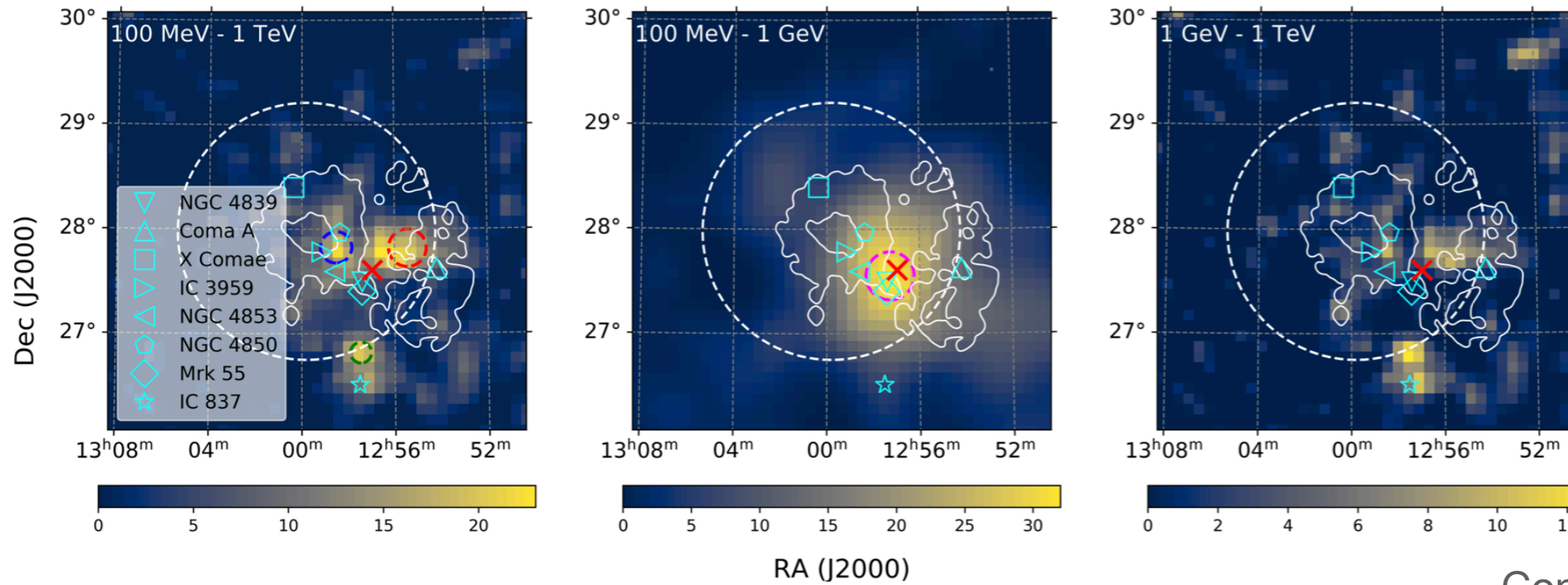
Negro



Upper limits on
LAT energies of FRBs

Extragalactic Science: Galaxy Clusters, Magnetic Fields, Active Galaxies

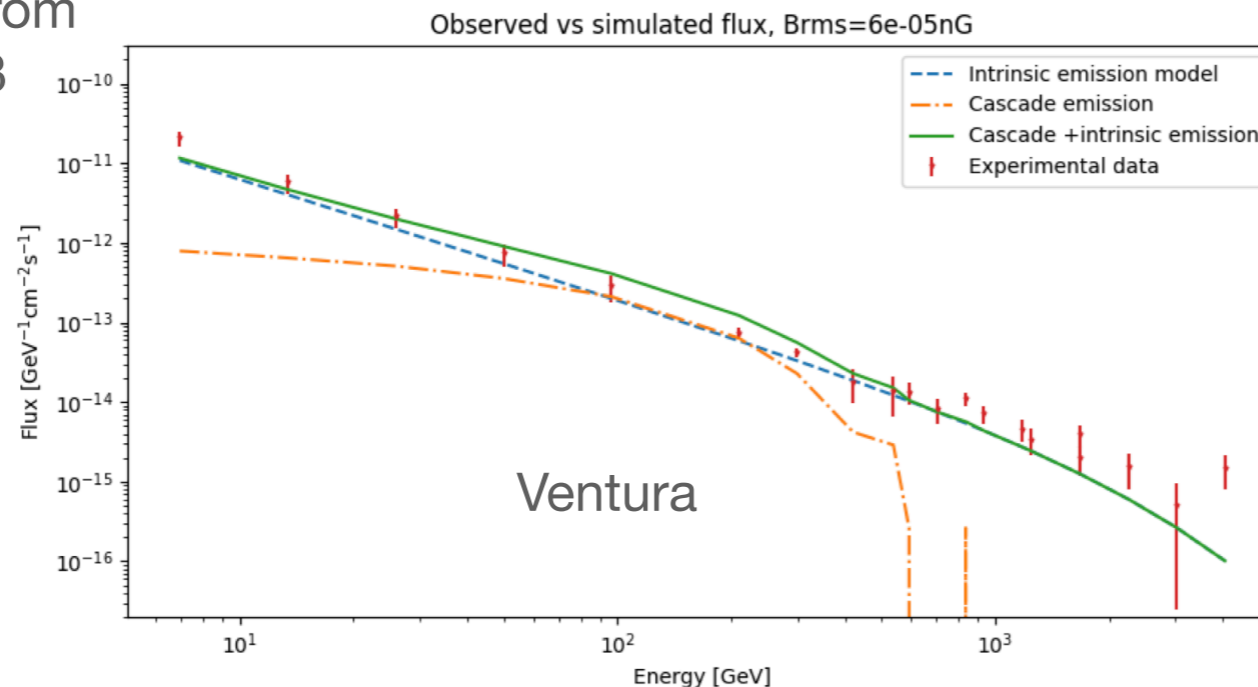
Galaxy Clusters and Magnetic Fields



Zargaryan

Coma Cluster Morphology
3 point-like sources +
extended emission (disk) $R \sim 0.82$ deg

IGMF constraints from
HESS 1943+213



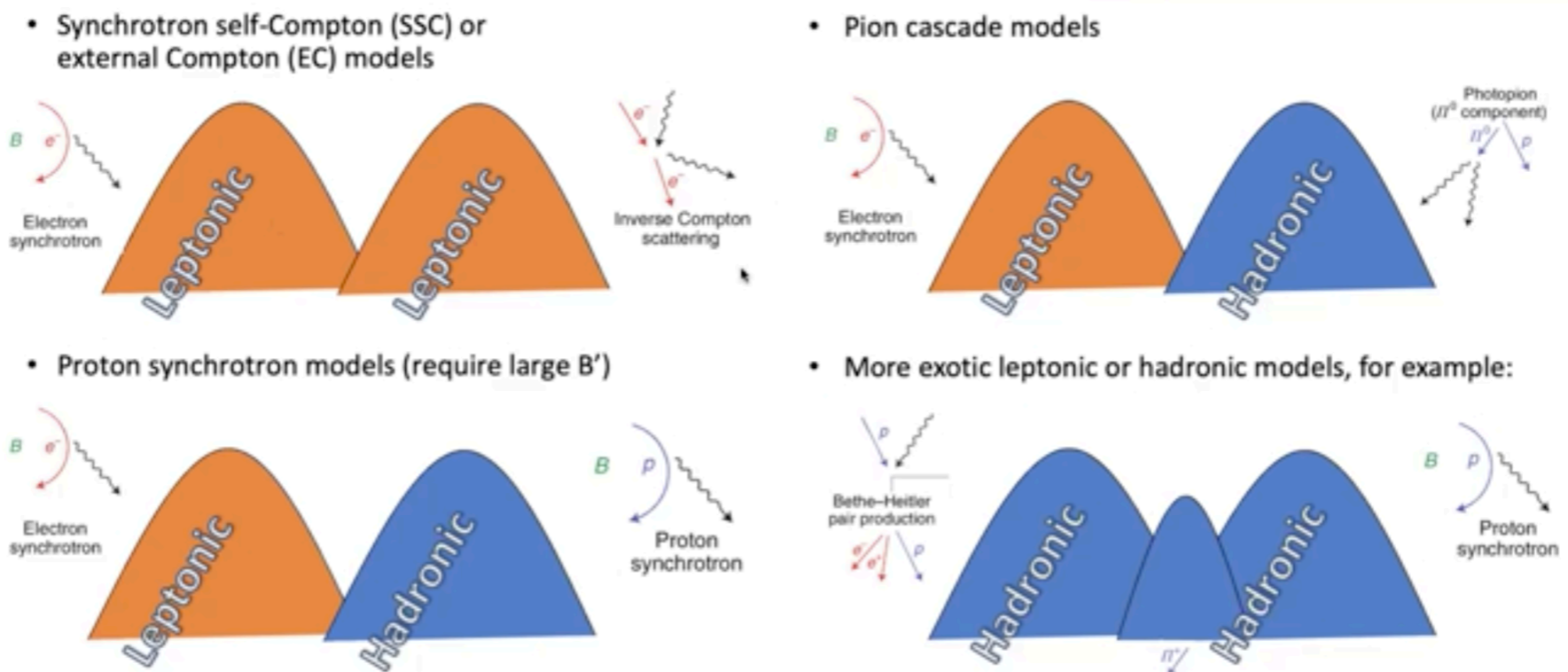
Discussion

48: Modeling AGN's Spectral Energy Distribution

Sara Buson and Walter Winter

- Summary slides and 2 min from each speaker + overall discussion
 - Electromagnetic picture of AGN blazars:
 - Double humps, EBL attenuation, neutrinos

Typical model



Discussion

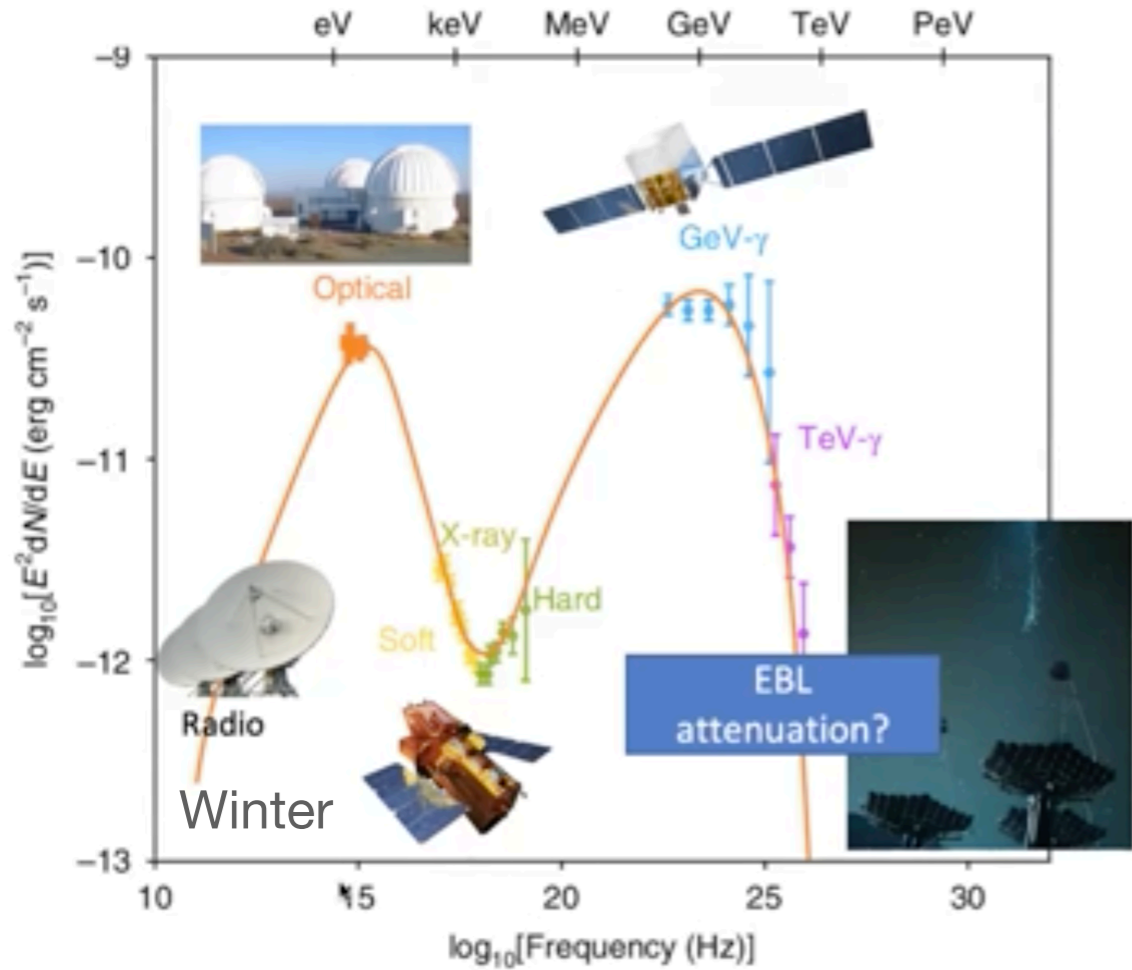
48: Modeling AGN's Spectral Energy Distribution

Sara Buson and Walter Winter

- Time-dependent SED observations may distinguish models
 - Need better/continuous monitoring across wavelengths
 - What drives flares?
- Does the “blazar sequence” exist? What creates it?
- X-rays are important! (Indicative of hadronic signatures)
- Models may draw a strong connection between jet/disk
- Selection criteria of objects needs to be clear (MM perspective)

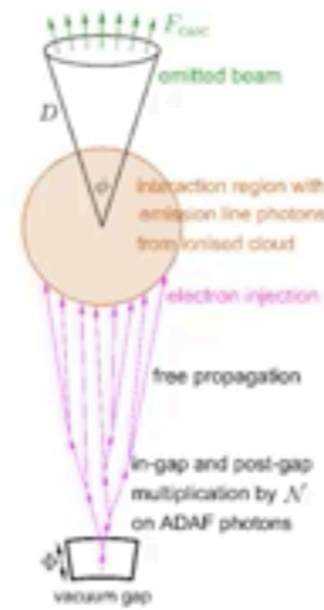
Active Galactic Nuclei

TXS 0506+056



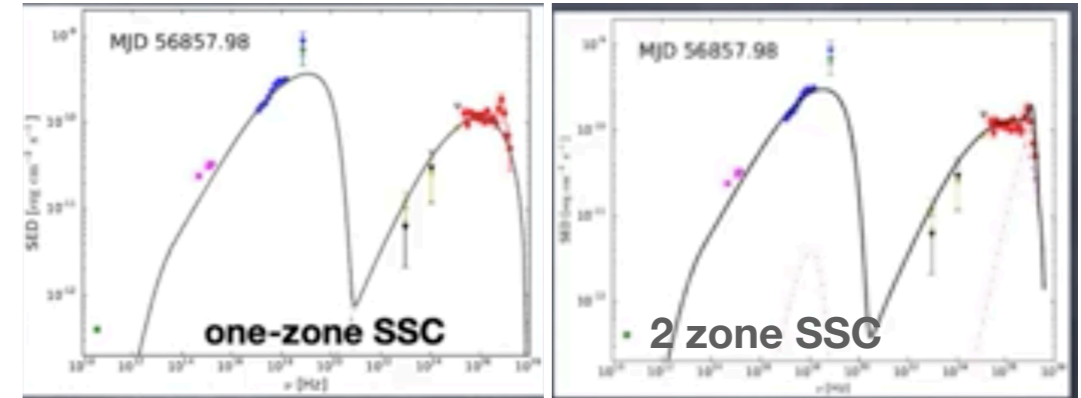
Principe

Gamma-ray emission from radio galaxies/quasars:
Significant emission from 11 young radio sources
Upper limits from stacking of below-threshold young radio sources



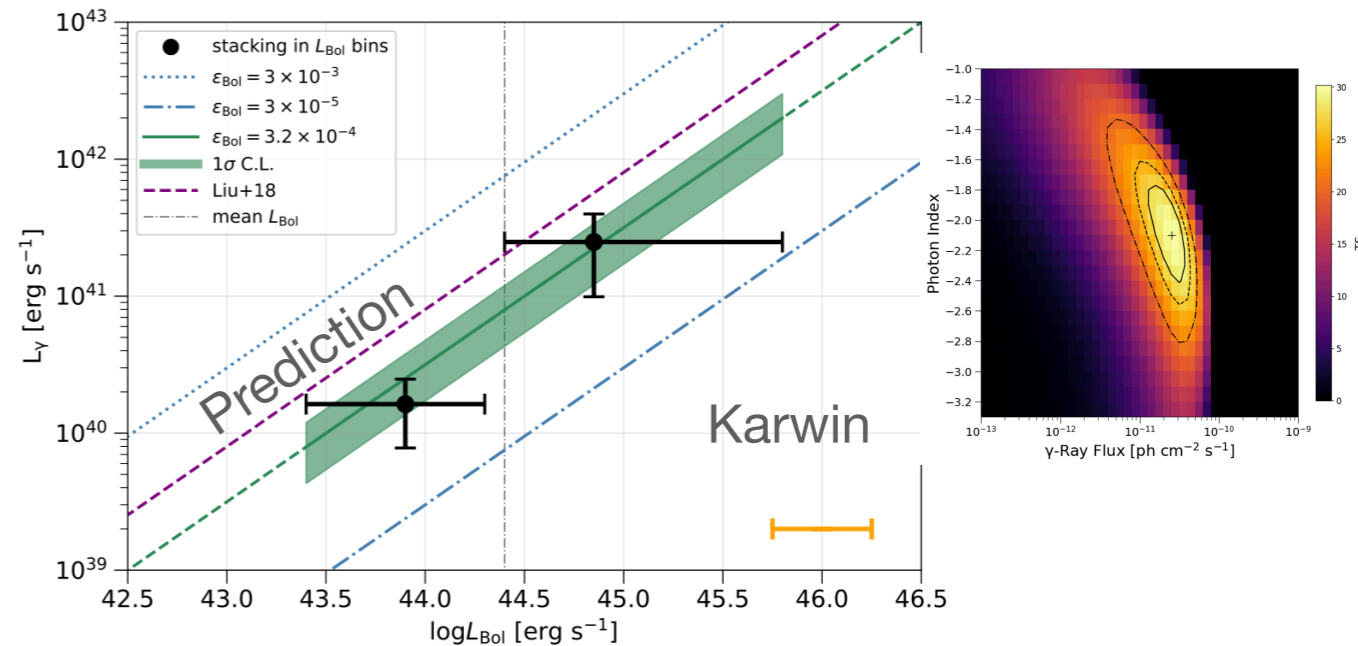
Wendel

2-Zone emitting region of Mik 501



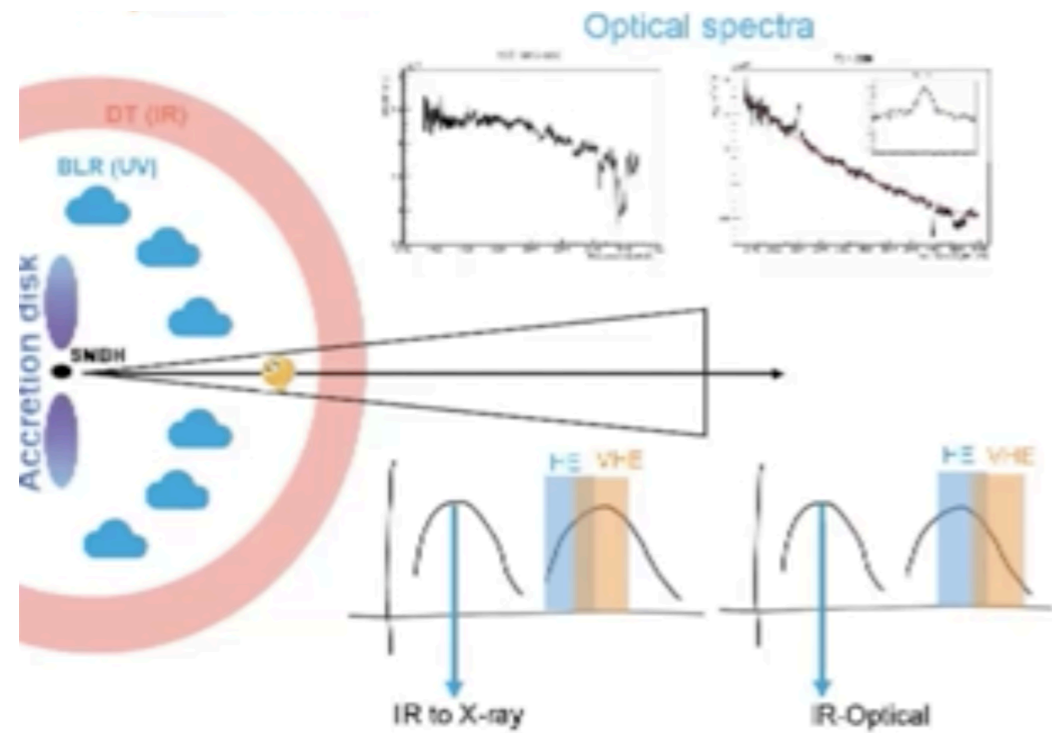
Becerra González

Gamma-ray Emission from Ultrafast Outflows

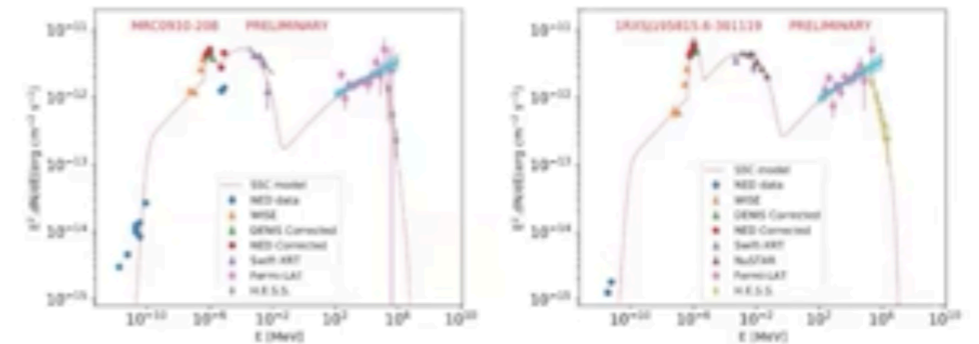


Potential source of IceCube Neutrino flux and UHCRs

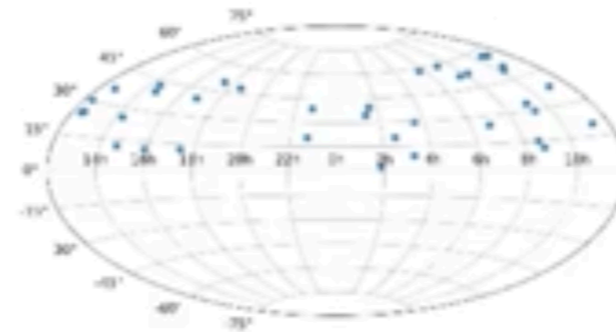
Active Galactic Nuclei



New BL Lacs: HSPs
Understanding radiation mechanisms



Priyana Noel



The VERITAS HBL sample

Luminosity function of
TeV emitting HBLs

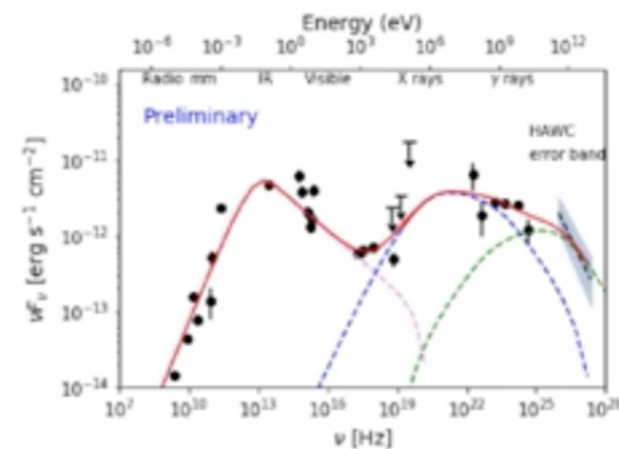
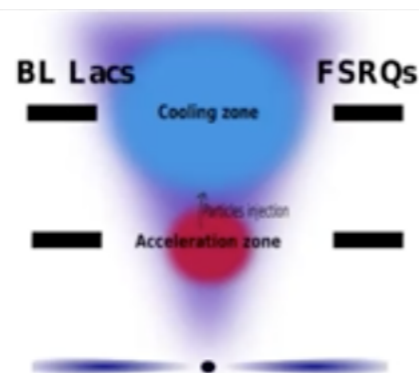
Errando

Sources of EeV-scale neutrinos: TeV FSRQs (8 known)

Understanding the blazar sequence
Observing OT081 in different states

Manganaro

MHD winds
Boula



Lepto-hadronic model fitted to a M87 SED

VHE non-flaring emission
from M87

Ureña-Mena

Discussion

49: Studying the variable emission from AGN in a MWL context

Elisabete M de Gouveia Dal Pino and Manuel Meyer

- Brief overview, 4 parts (3 min/speaker), discussion
- Temporal MWL obs.: particle acceleration + location of emission
- Time variable AGN emission:
 - Individual bright AGN flares,
 - long-term monitoring and source surveys,
 - modeling: SED, variability, particle acceleration

Discussion

49: Studying the variable emission from AGN in a MWL context

Elisabete M de Gouveia Dal Pino and Manuel Meyer

- Open questions:
 - Connections between UHECR, gamma-rays, MWL, neutrinos
 - One zone/multi-zone? Photon/particle production in jet?
 - The particle jet: Leptonic or lepto-hadronic? magnetically dominated? Particle acceleration by reconnection plasmoid-like?
 - What can polarization teach us?
 - Time-variability as a test of fundamental theories of space-time

Active Galactic Nuclei

“Relentless multiwavelength variability”

Multi-epoch monitoring of TXS 0506+056
Satalecka

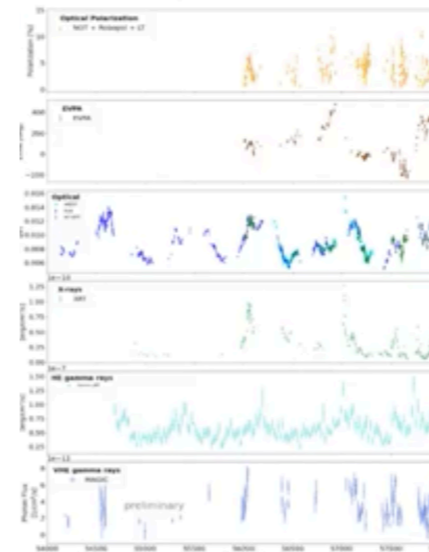
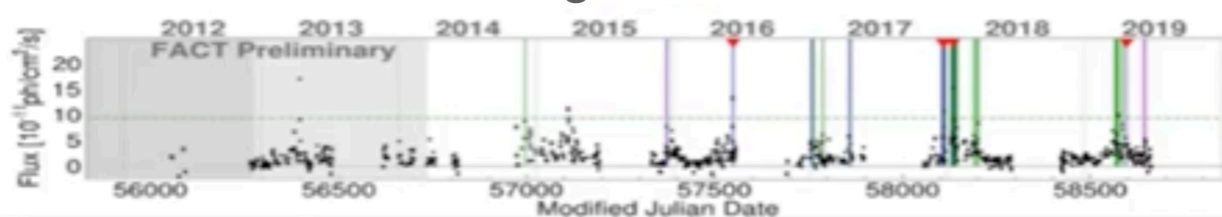
Mrk 421 Mrk 501
Gokus Sliusar Heckmann

What causes flares
magnetic reconnection?
Petropoulou

Jormanainen

Gravitationally lensed blazar: QSO B0218+3577
Combination of emission mechanisms:
Synchrotron, SSC, external Compton

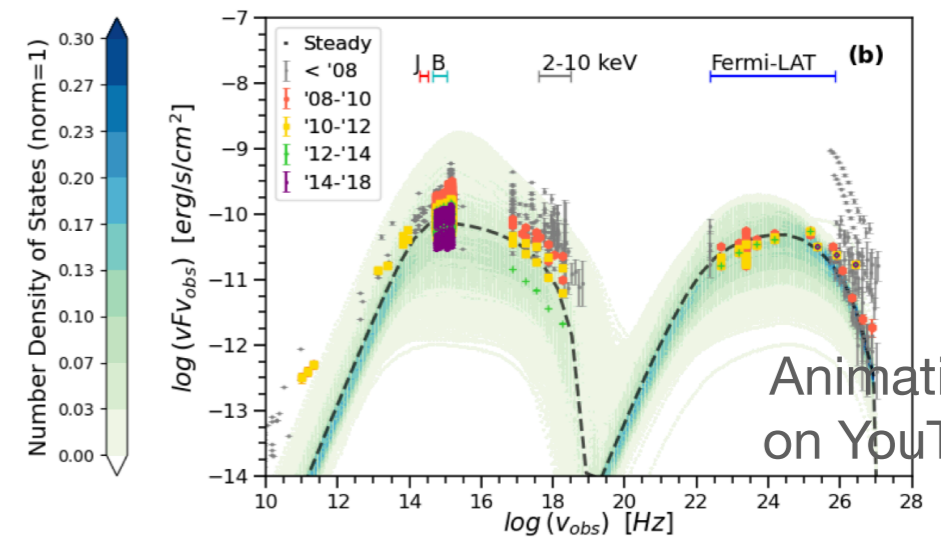
FACT Monitoring



Variability of PG 1553+133:
Evidence of binary BH?

Prandini

Long-term Blazar variability: BlaVar



Polkas

Animations
on YouTube

Changing parameter of 1 zone model
doesn't describe all variability properties

VERITAS: Operate fully remotely,
Continuing AGN monitoring program

Discussion

49: Studying the variable emission from AGN in a MWL context

Elisabete M de Gouveia Dal Pino and Manuel Meyer

- Importance of monitoring across wavelengths (X-rays)
- Radio galaxies as test beds for particle acceleration (EHT)
- Polarization: signatures of acceleration mechanisms
- Look at full light curves, snap shots don't tell full picture
 - Time variability in one zone models vs multi zone models
- Theoretical issues
 - Disentangle particle acceleration mechanisms in the jet
 - Reconnection acceleration (2D vs. 3D) and how they impact emission

Science: Our Galaxy

Discussion

44: Origin of Galactic Cosmic Rays

Luigi Tibaldo and Giovanni Morlino

- One slide overview of talks (~4 sections), discussion after
- The path of a CR is complicated :)
 - Acceleration inside source, Escape Source, and Propagate across galaxy (and none of the spectra of the same)
- Blind search for low energy cutoffs (“pion bump”) in Fermi sources shows that ~50 objects may be hadronic accelerators: SNRs and binaries
 - Superbubbles/Stellar clusters: the news of the ICRC
- Many advances in theory of particle acceleration in SFRs and modeling of gamma-ray emission.

Covered in more detail by GAI and CRD

Discussion

45: Distribution of Galactic Cosmic Rays

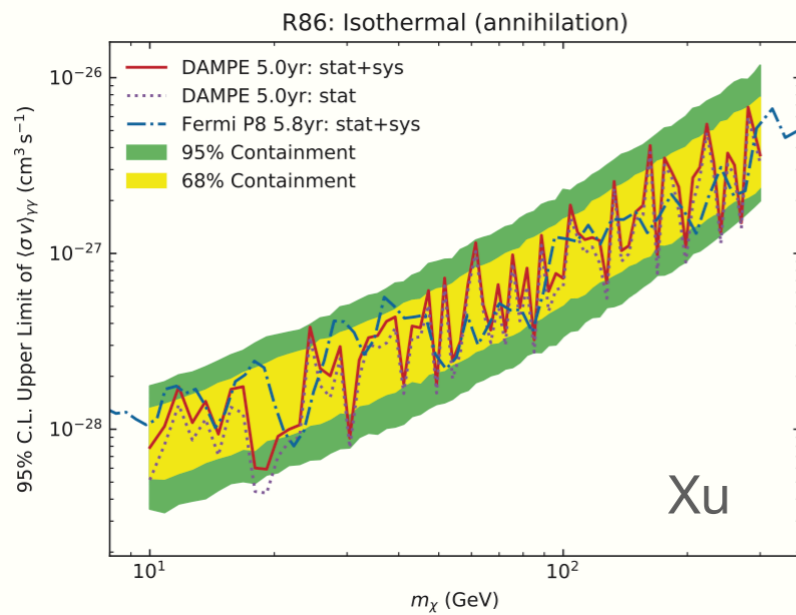
Sabrina Casanova, Elena Orlando, Daniele Gaggero

- Overview and option questions, rapid 1-slide, additional material from conveners with discussion following
- Observations and Open questions
 - Acceleration and transport shape CR spectra close to sources
 - Escape power of energetic leptons from sources
- Different scales
 - Near Earth \rightarrow 10-100 pc \rightarrow *Large Scale Galactic (diffuse gamma ray) \rightarrow Beyond (Fermi bubbles, CR Halos around MW and M31)*

Covered in more detail by GAI and CRD

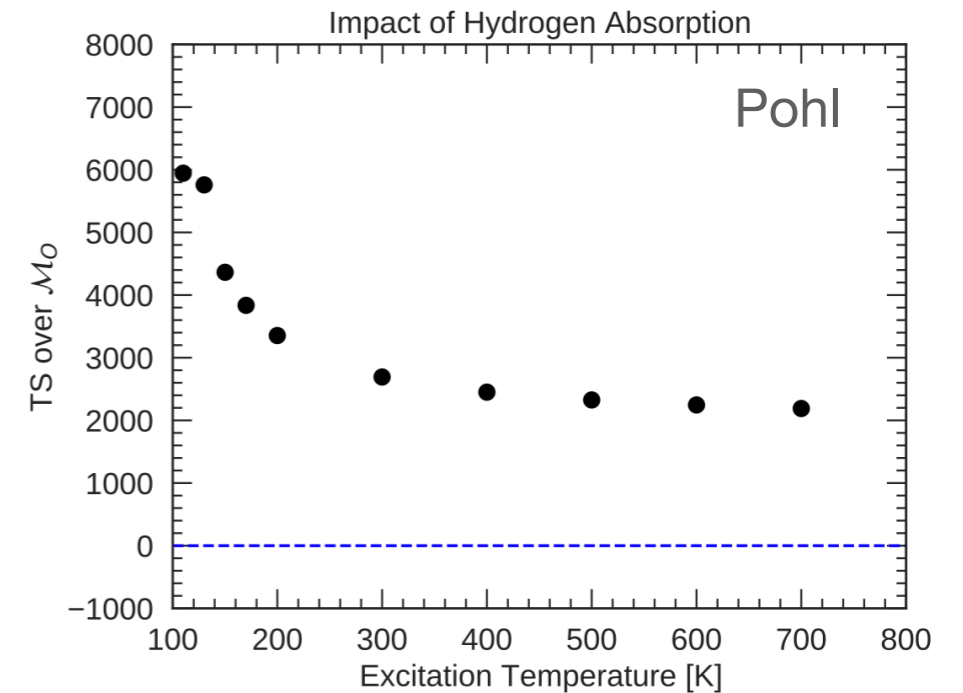
Galactic Center

Excess, Lines



No lines from DAMPE

Modeling Neutral Atomic Hydrogen (HI) improves GC fit

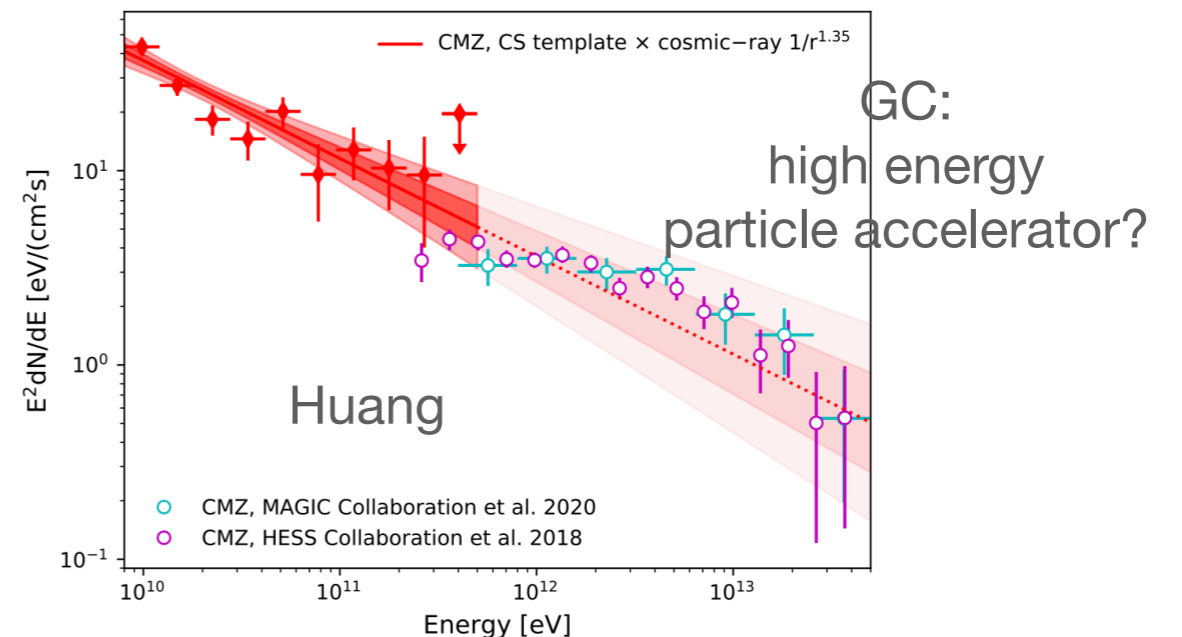


Source of hardening of CR spectra: CR transport/PeVatron?
Origin of the Fermi bubbles



Chandra data doesn't exclude MSP hypothesis for GCE
need Radio followup

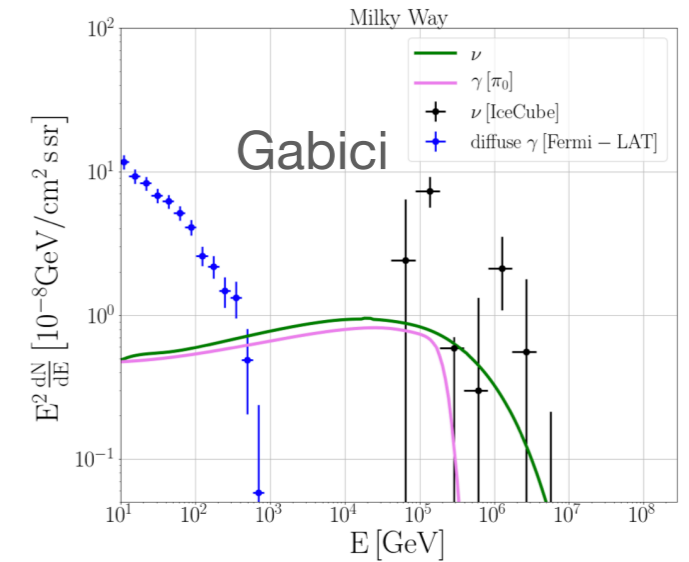
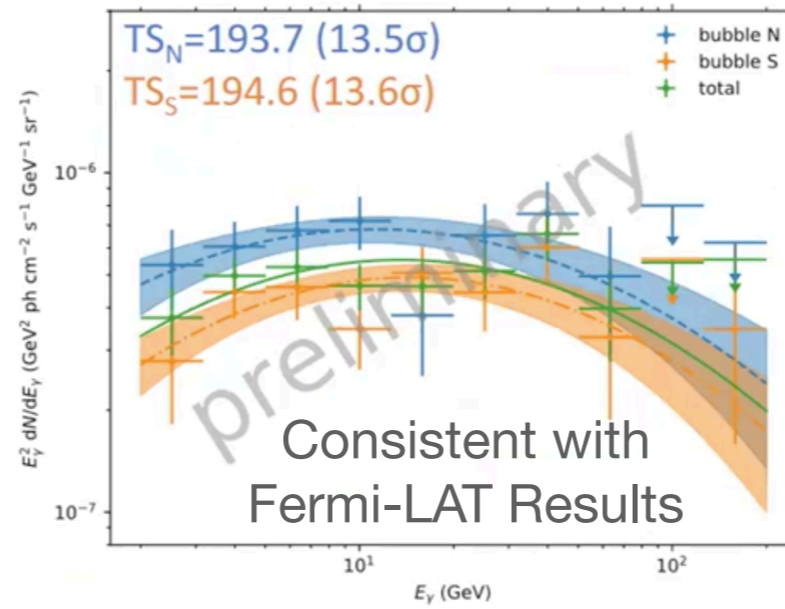
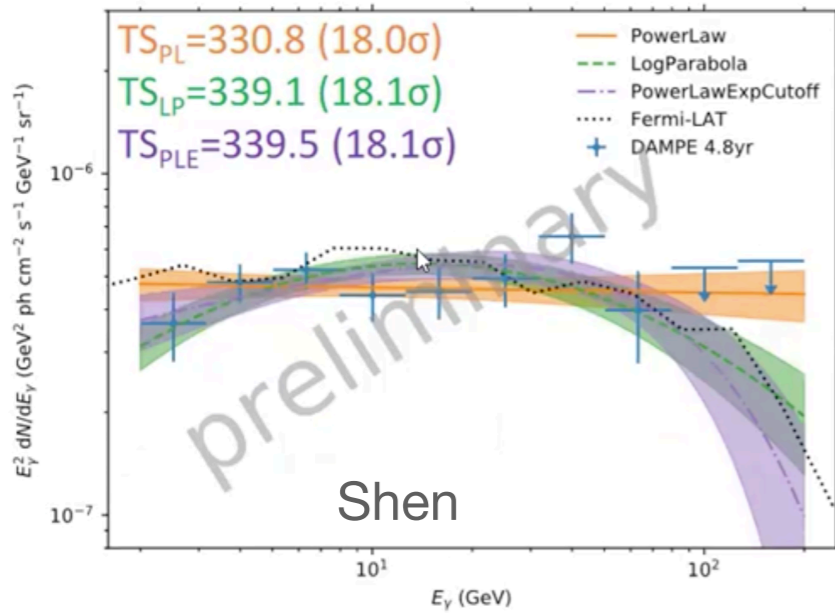
Berteaud



Galactic Center

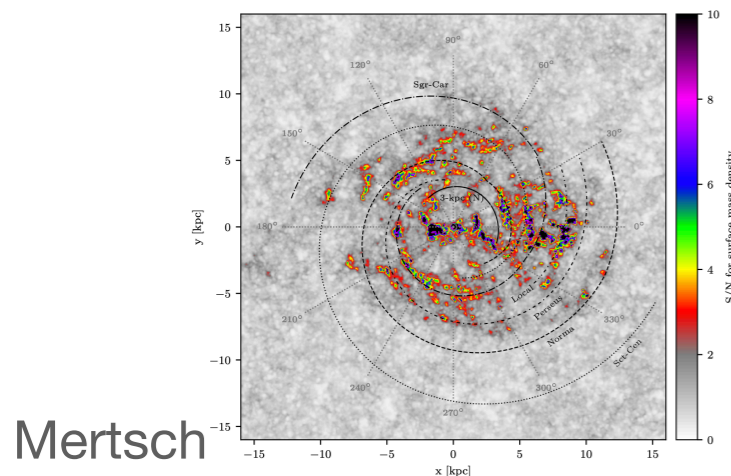
Gas Maps, Bubbles, Halos

First DAMPE results of Fermi bubbles



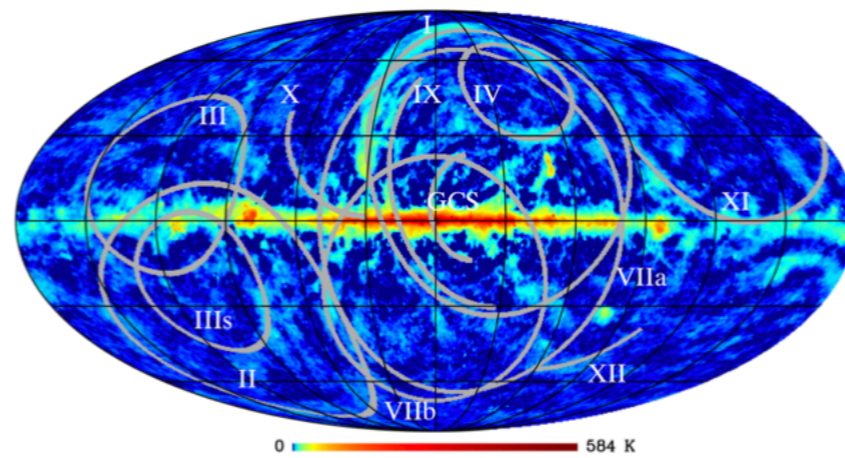
CR halos around M31/MW,
Source of IceCube neutrinos?

Galactic CO maps:
Surface Map density
for BEG03 model



Mertsch

Counterparts of radio loops
In gamma-rays:
distance, composition, origin?

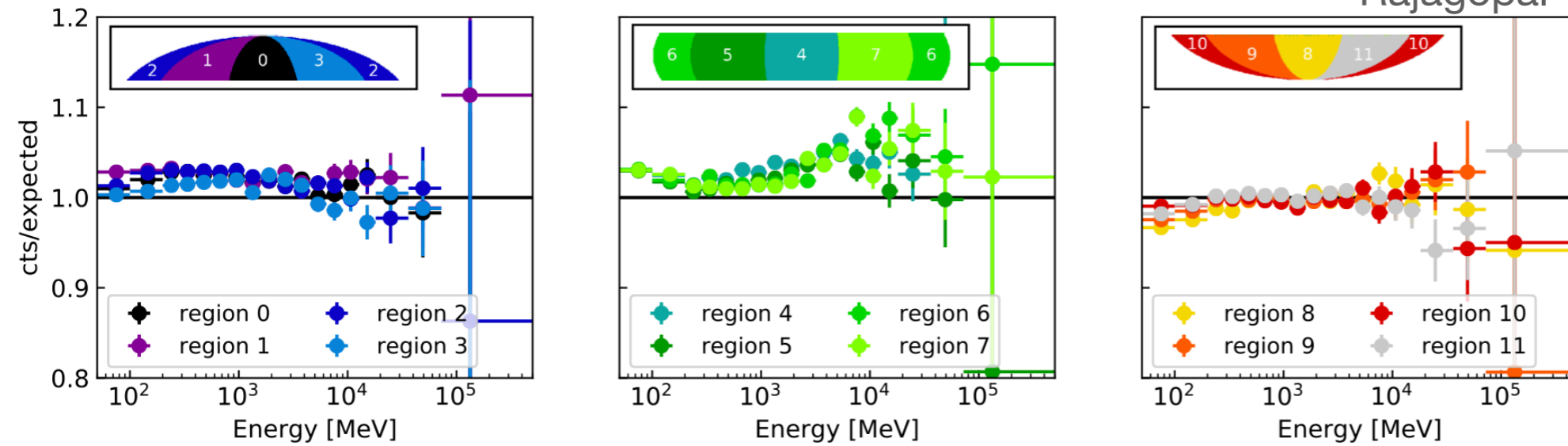


Johannesson

Observations of radiation
produced by CRs
interacting with ISM gas
and radiation fields —>
CR distribution,
confinement and
transport

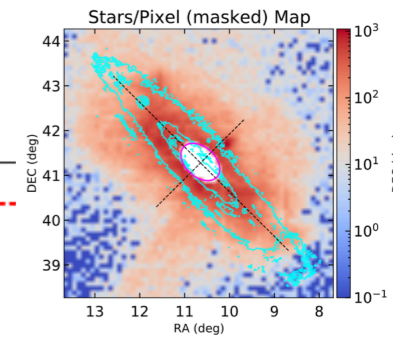
Diffuse Emission and Galaxies

New modeling to measure Isotropic diffuse emission

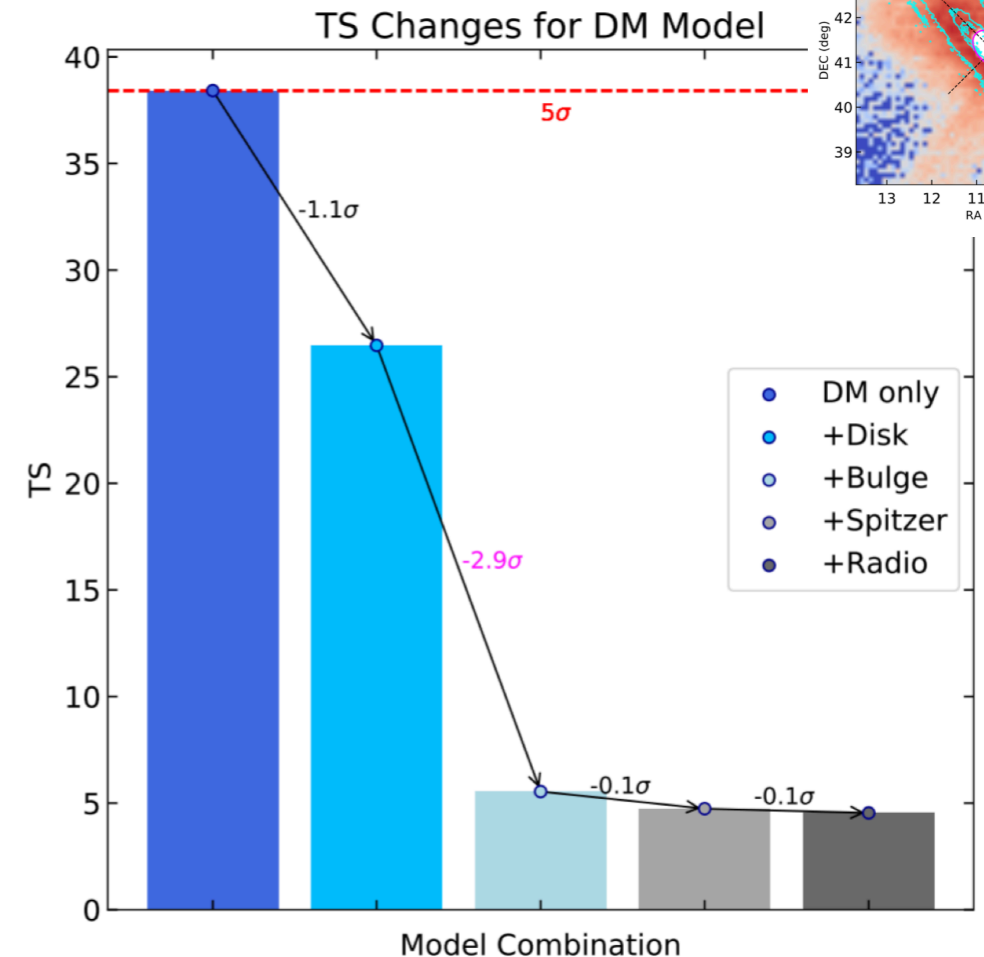
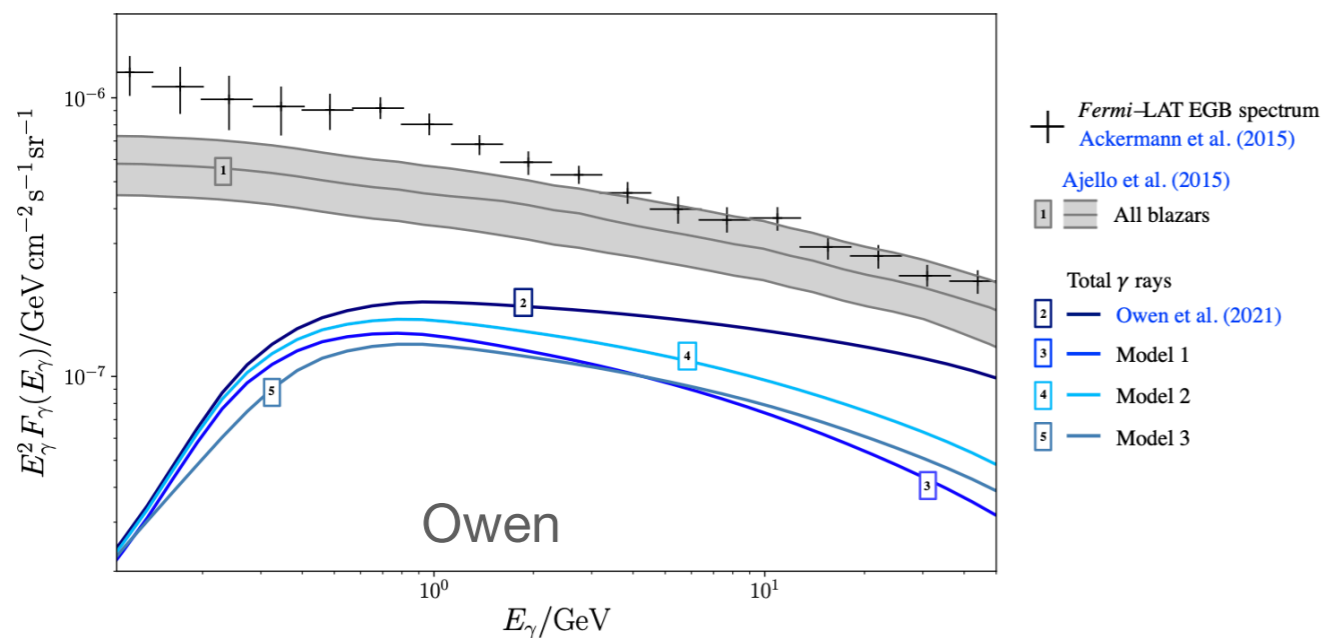


Rajagopal

Andromeda



Signatures of Star-forming Galaxies in EGB



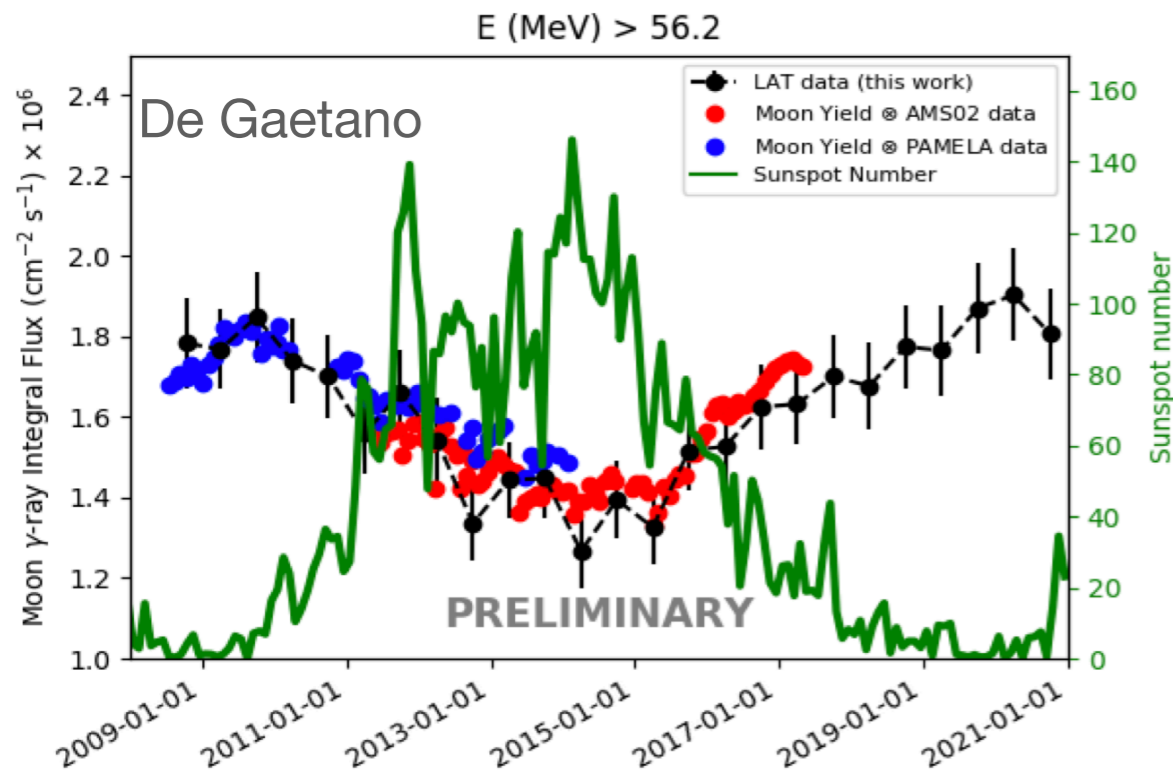
Zimmer

Science: The Solar System

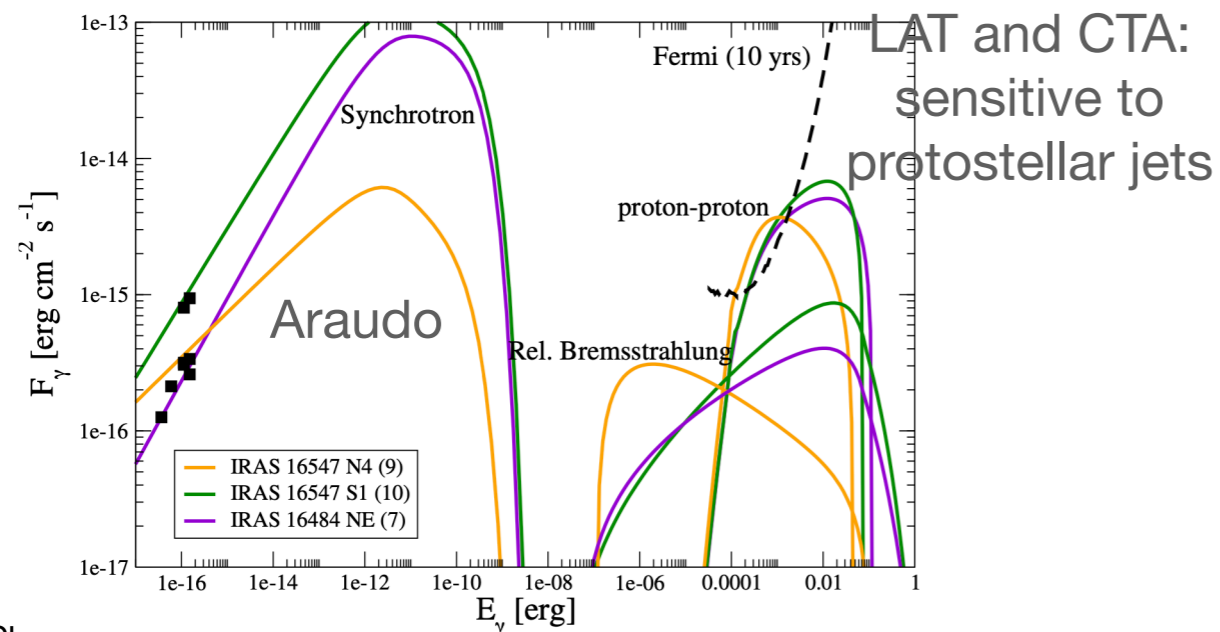
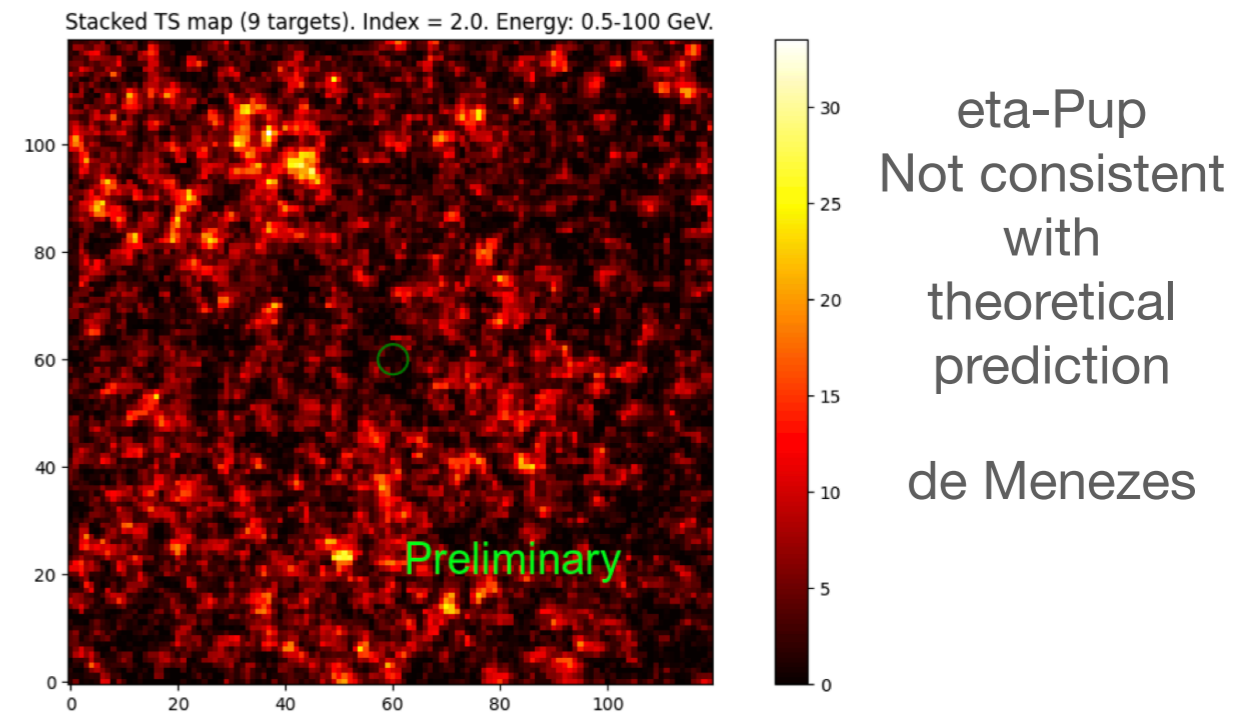
The Solar System

The Moon, Stars, Protostars, Antistars

Time Evolution of the Moon over a solar cycle

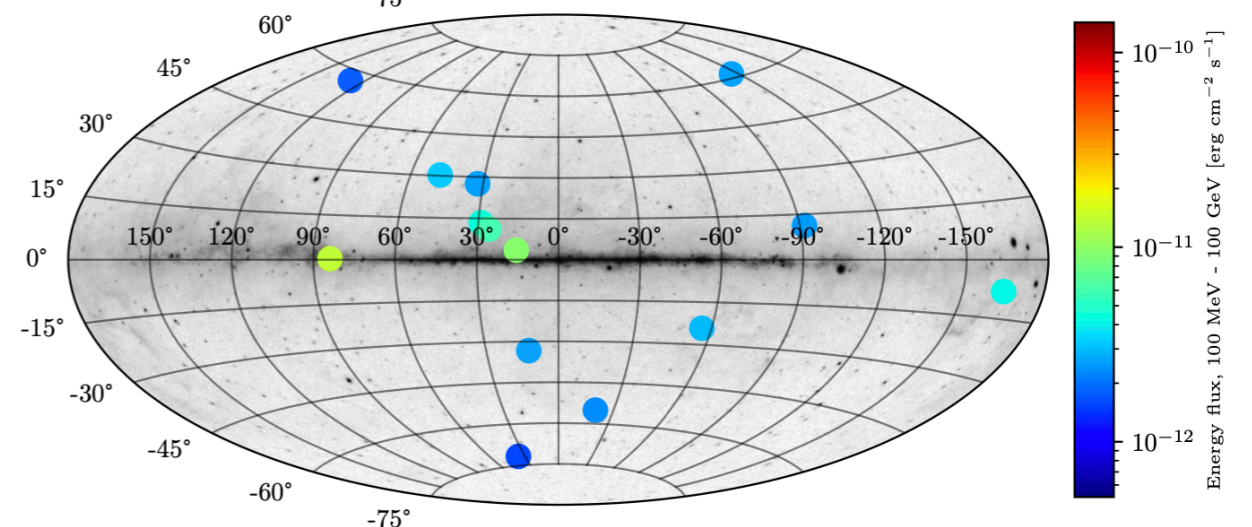


Nine super luminous stars in LAT



LAT and CTA:
sensitive to
protostellar jets

Antistar candidates



Dupourqué

Catalogs, Tools and Analysis Packages

Discussion

51: The Census of Gamma-ray Sources

Reshmi Mukherjee and Stefan Ohm

- Two sets of two min flash talks then discussion
 - Catalogs: Fermi-LAT 4th source catalog, Fermi-LAT 10 year monthly-transient catalog, Low Energy Fermi-LAT catalog. Studies: Population studies, SFRs in the cosmic gamma-ray background
 - Analysis Methods: Neural networks, pixel count statistics, Ties with Future telescopes
- Recent topics? Upcoming missions/prospects for population studies? What resources are needed? Identifying new source classes in catalogs? (Spectral/spatial/timing) MWL needed? Connecting MeV-PeV? Sharing tools? And Cross checking results?

The Census of Gamma-ray Sources

New release of 4FGL

Lott

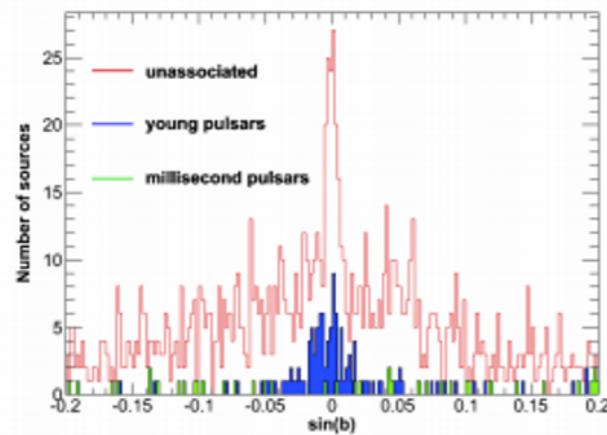


Figure 3: Galactic-latitude distribution of unassociated sources around the Galactic plane compared to that of pulsars.

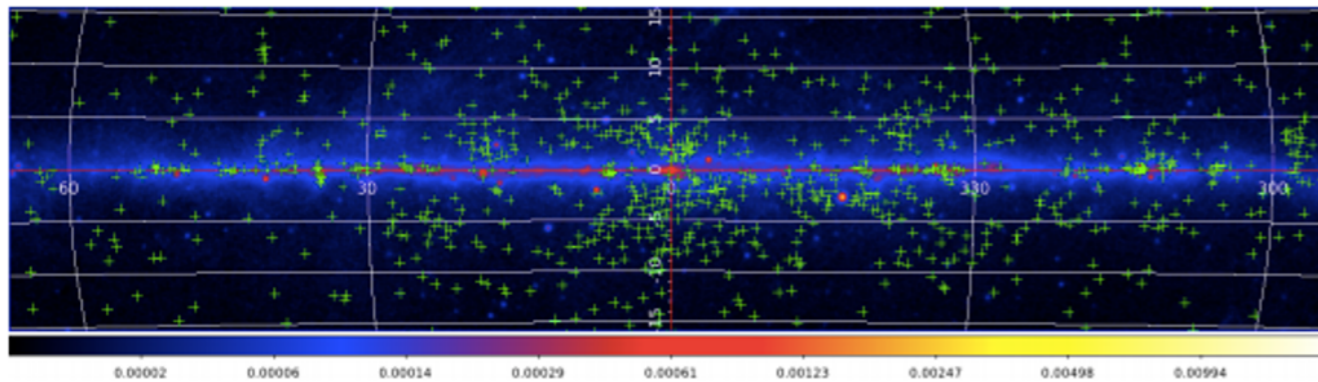


Figure 4: Positions of unassociated sources (green crosses) around the Galactic Center. The background is the Fermi-LAT intensity map above 1 GeV in Galactic coordinates and Hammer-Aitoff projection in units of $\text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$

Population Studies of Fermi LAT Galactic sources

PROBLEMS:

- 1) ~1/3 unidentified sources;
- 2) many unresolved sources producing diffuse emission

OUR METHOD & PRELIMINARY RESULTS:

Detected sources

Unresolved sources

Model Parameter Scan

Density (pulsars/kpc ³)	Min. Luminosity (photons/s)	Index of Luminosity	Log-likelihood
4	1×10^{36}	-2.4	6
10	1×10^{35}	-1.8	66
20	1×10^{34}	-1.6	129
50	1×10^{34}	-1.8	152
100	1×10^{33}	-1.6	154
200	1×10^{33}	-1.8	141

Undetected Source Template

ICRC2021 – July 2021

Elena Orlando, M. Rasmussen, A. Strong

Acero et al. 2015 ApJS 218
Ackermann et al 2013 ApJS, 209, 34
Strong, A.W. 2007 Ap&SS, 309, 35

Estimating number of Galactic sources below LAT flux sensitivity

43% new sources are associated
Show distinct features → sets them apart from classes of gamma-ray emitters

Discussion

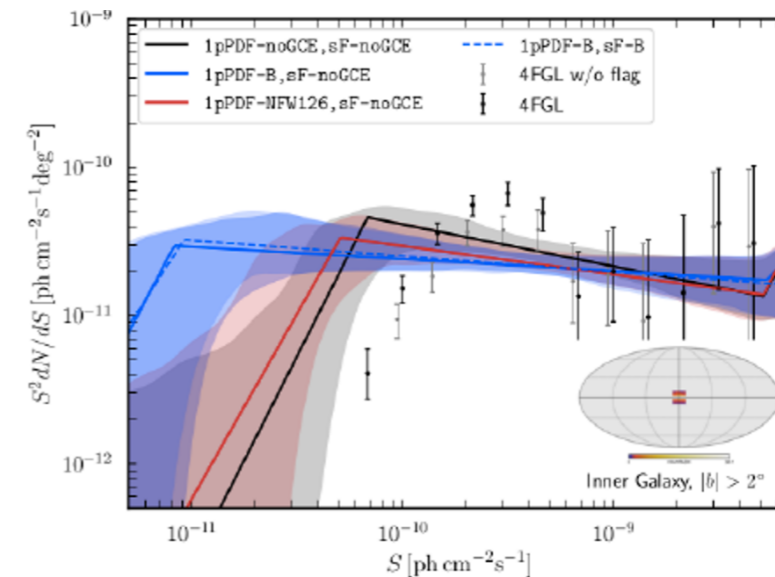
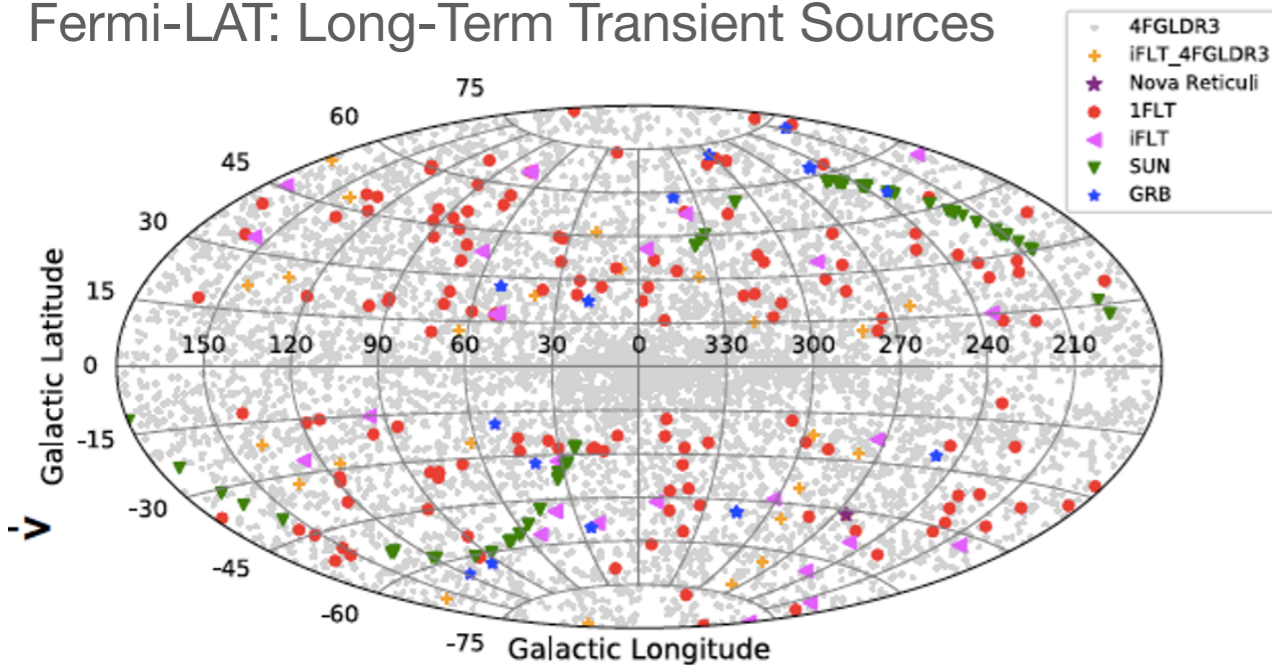
51: The Census of Gamma-ray Sources

Reshmi Mukherjee and Stefan Ohm

- Localization and Classification of gamma-ray sources using neural nets applied to simulations → Fermi Catalogs
 - Challenges with faint sources
- Analysis of Fermi LAT inner galaxy from 2-5 GeV
 - Goal: understand GCE, expand to broader energy range
 - Unresolved point sources to $dN/dS \sim 5E-11$ ph/cm²/s

The Census of Gamma-ray Sources

Fermi-LAT: Long-Term Transient Sources



Manconi

Meru
 Populated by softer sources
 Comparatively large fraction of FSRQs
 Only when actively flaring

Sub-threshold point source
 contributions to GCE

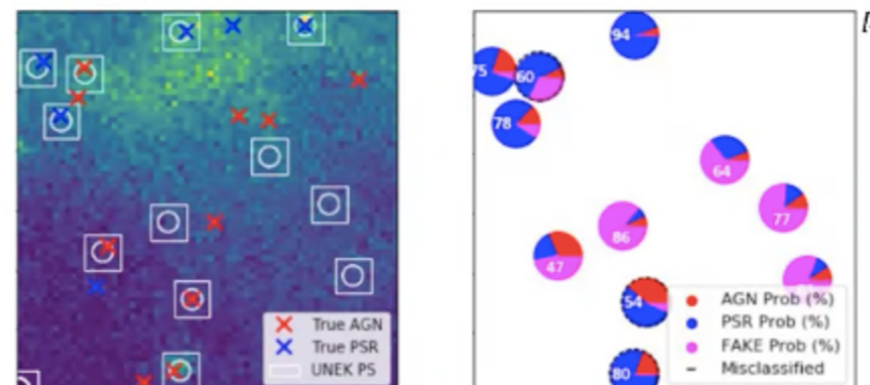
Adaptive template fitting (skyFACT)
 and photon count statistics
 Corroborating partial stellar
 origin of LAT GCE

Localization and classification of gamma-ray
 sources using Neural networks

Van den Oetelaar

Combined

With the localisation and classification methods combined, a catalogue can now be automatically processed, even without the need to consult other catalogues. The false positives from localisation can be filtered out through the background labels (FAKE) in classification. Moreover, the classification network shows how confident it is in each classification, indicating which sources should be investigated further.



Discussion

51: The Census of Gamma-ray Sources

Reshmi Mukherjee and Stefan Ohm

- Photon index distributions for unassociated sources
 - high-lat dominated by blazers;
low-lat dominated by soft spectrum not seen in other classes
- Source population synthesis studies
 - Focus on unidentified and unresolved sources (contribution to diffuse emission)
- High-latitude monthly variability (15 new sources/year): AGN mostly
- Low-energy band of LAT (20-200 MeV) is particularly interesting
 - Building on 1FLE, Potential for many new sources, Motivation for new MeV missions. Source confusing is the main challenge
- Gamma-ray emission modeling in star-forming galaxies

Discussion

52: Analysis Methods, Catalogues, Community Tools, Machine learning

Dan Parsons and Dominik Elsaesser

- Analysis tools are important and should be recognized!
- No flash talks (# contributions), directed questions then general discussion
- Four different contributions grouped
 - Open source tools, Source detection classification, Analysis techniques, Deep learning for gamma-ray shower analysis

Contributions in more detail by GAI

Current, Future and Proposed Missions

Discussion

43: New and Upcoming Instruments for Space-Based Gamma-ray Astronomy

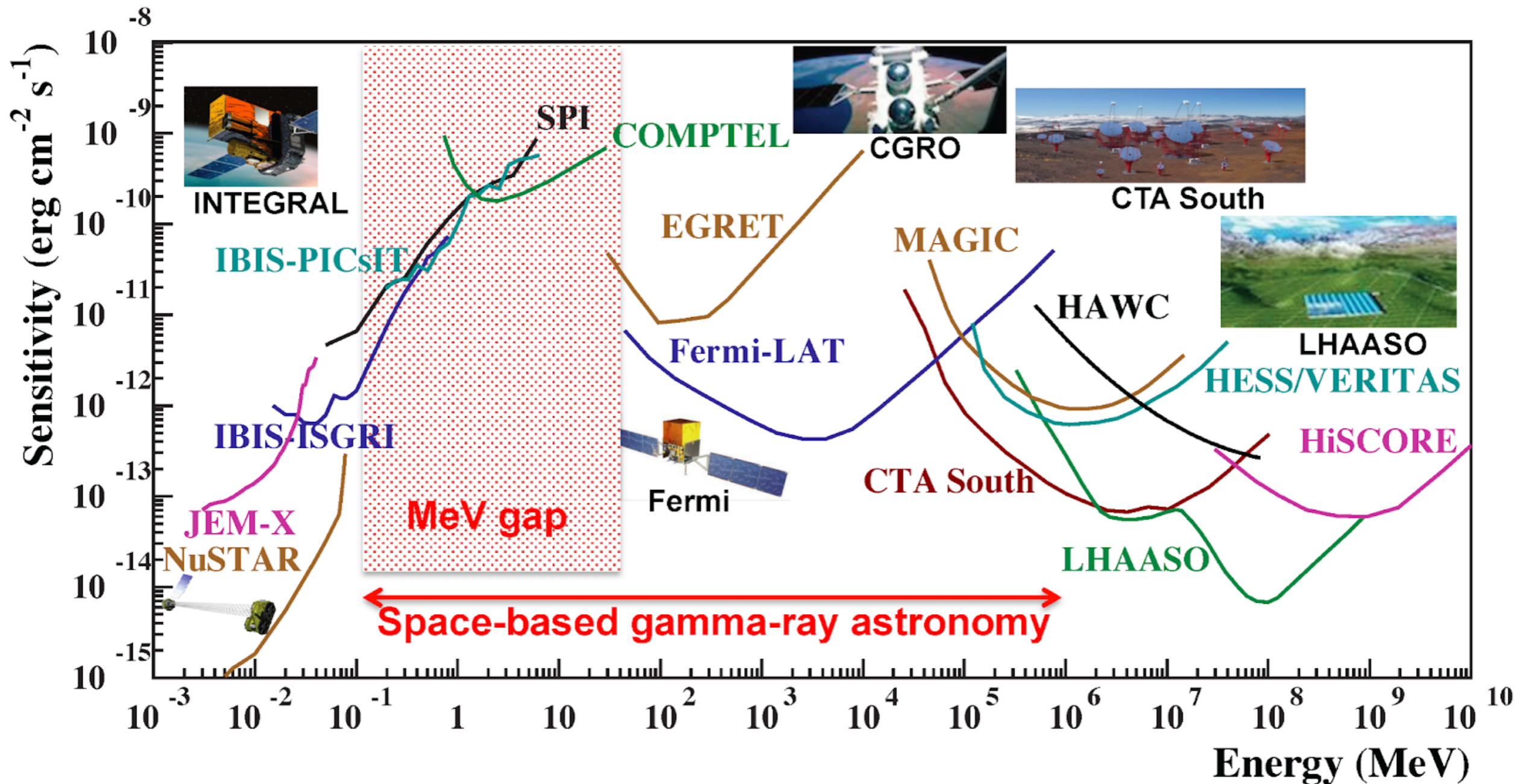
Vincent Tatischeff and Jeremy Perkins

- Overview from conveners, one slide rapid talks, Discussion
 - Small(ish) missions
 - BurstCube, Crystal Eye, HEPD-02, MeVCube, POLAR-2, 12U CubeSat, GRAINE
 - Large(r) missions
 - AMEGO-X, COSI SMEX, GECCO, GRAMS, APT, HERD

Discussion

43: New and Upcoming Instruments for Space-Based Gamma-ray Astronomy

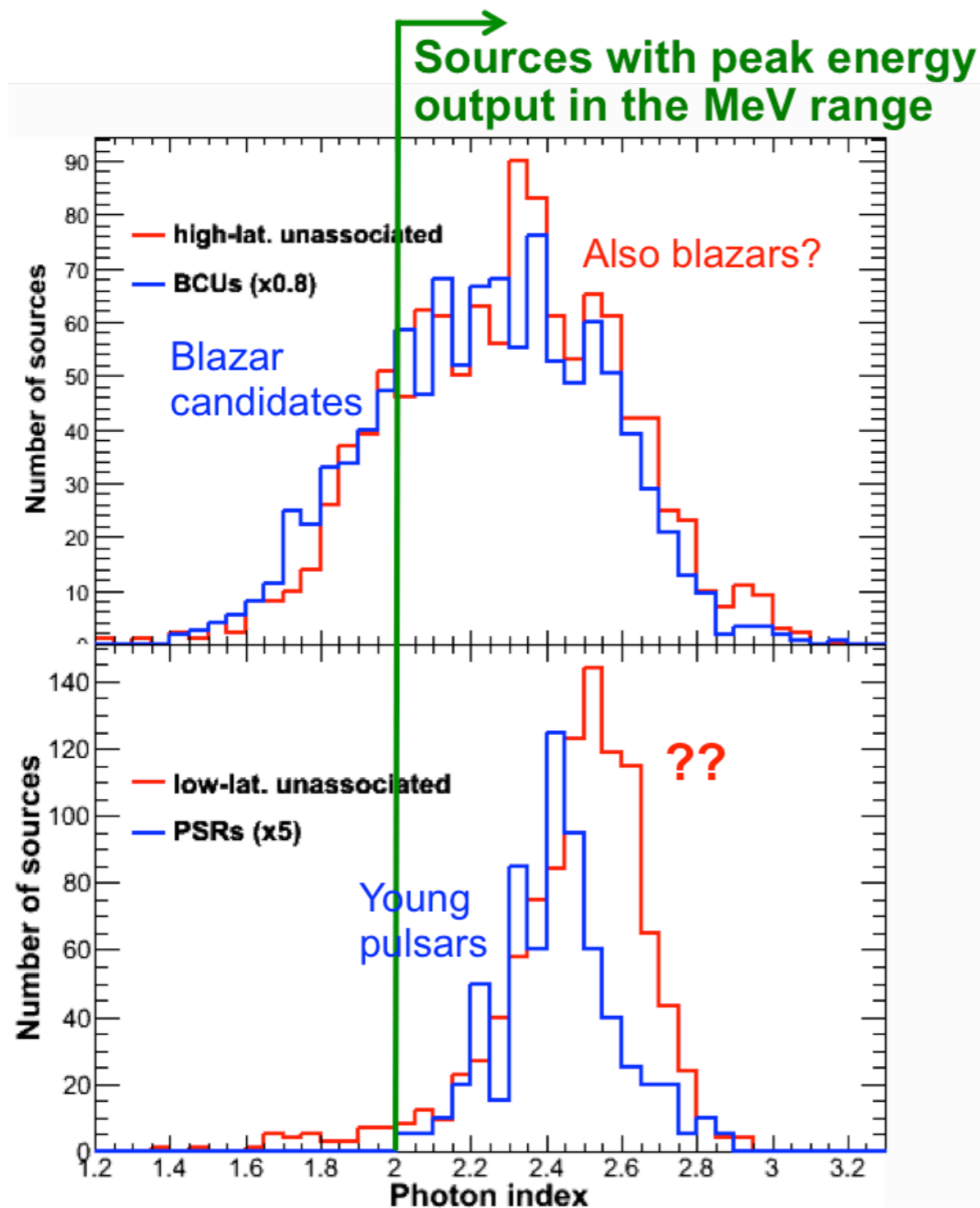
Vincent Tatischeff and Jeremy Perkins



Discussion

43: New and Upcoming Instruments for Space-Based Gamma-ray Astronomy

Vincent Tatischeff and Jeremy Perkins



Fermi-LAT 4FGL 3rd release

More than 1000 unassociated sources at low Galactic lat with spectra not typical with known sources

Discussion

43: New and Upcoming Instruments for Space-Based Gamma-ray Astronomy

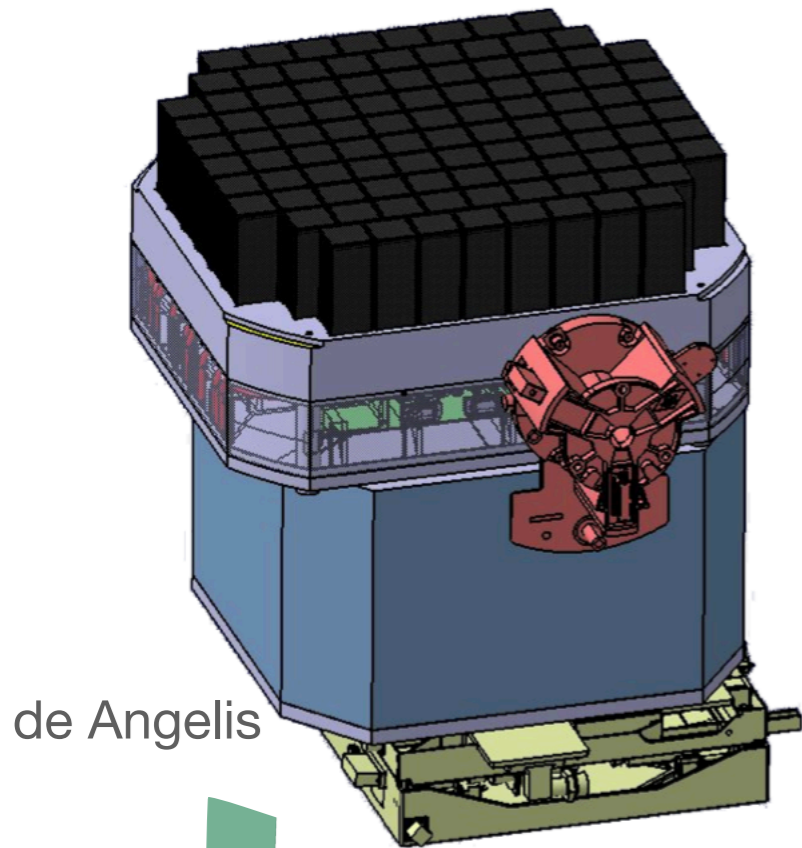
Vincent Tschiff and Jeremy Perkins

- Discussion points:
 - Project status of your mission?
 - Several larger mission proposal or a single one?
 - How do CubeSats fit into the landscape?
 - What's next in the HE regime?
 - How do we consistently compare performance?
- Lots of outstanding questions in MeV gamma-ray astronomy
 - Proposed missions reflect this interest

Future Instruments/Missions

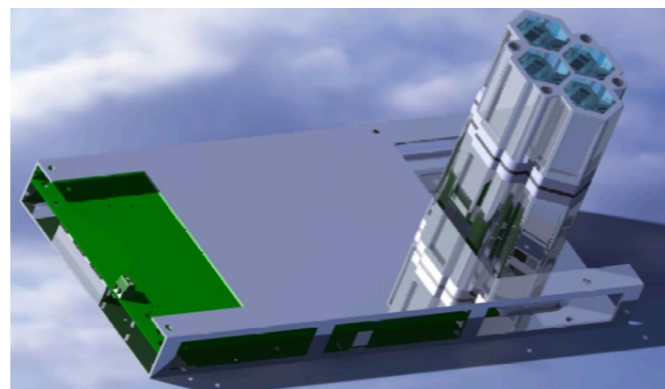
keV to TeV

GRB Polarization: POLAR-2 (2024)

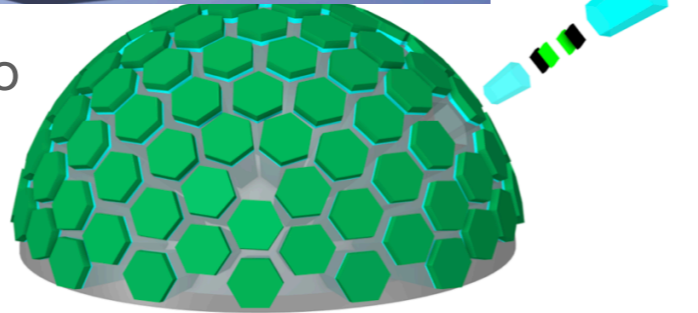


de Angelis

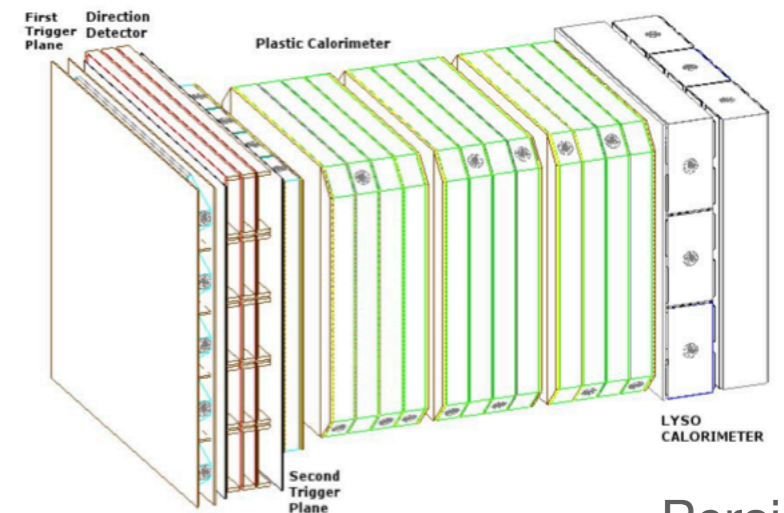
Crystal Eye and Pathfinder (2023)



Barbato

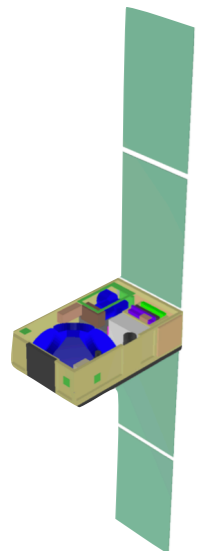


HEPD-02 (Advanced Implementation Stage)

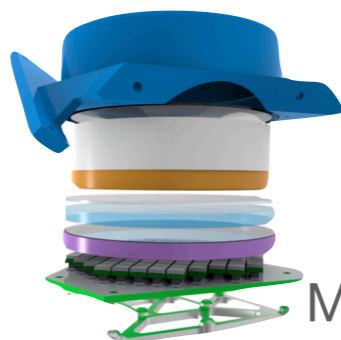


Perciballi

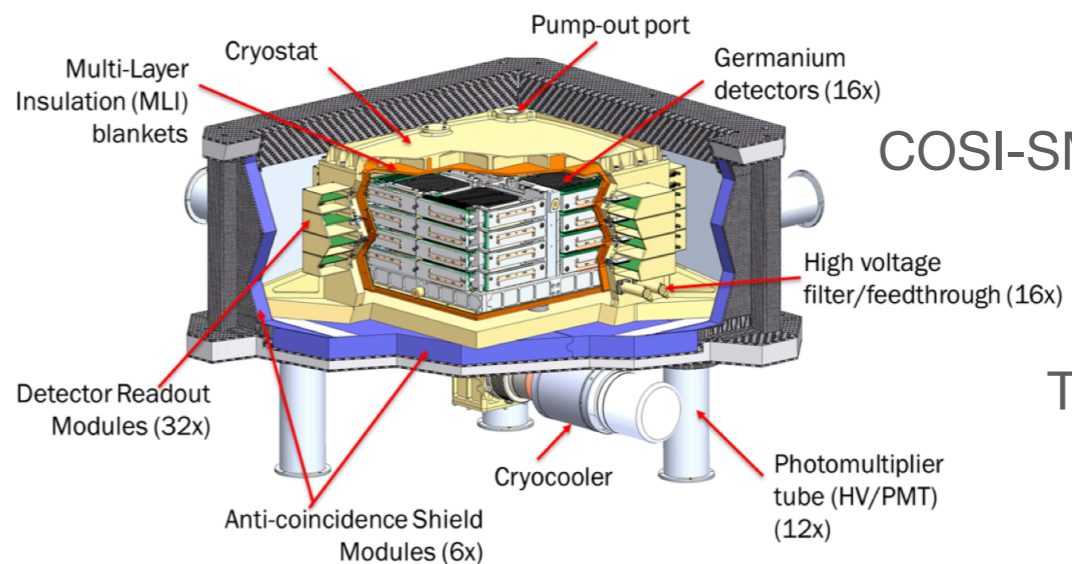
BurstCube (2022)



INSITU
COSI scintillator
SiPMs array
DAQ board



Martinez

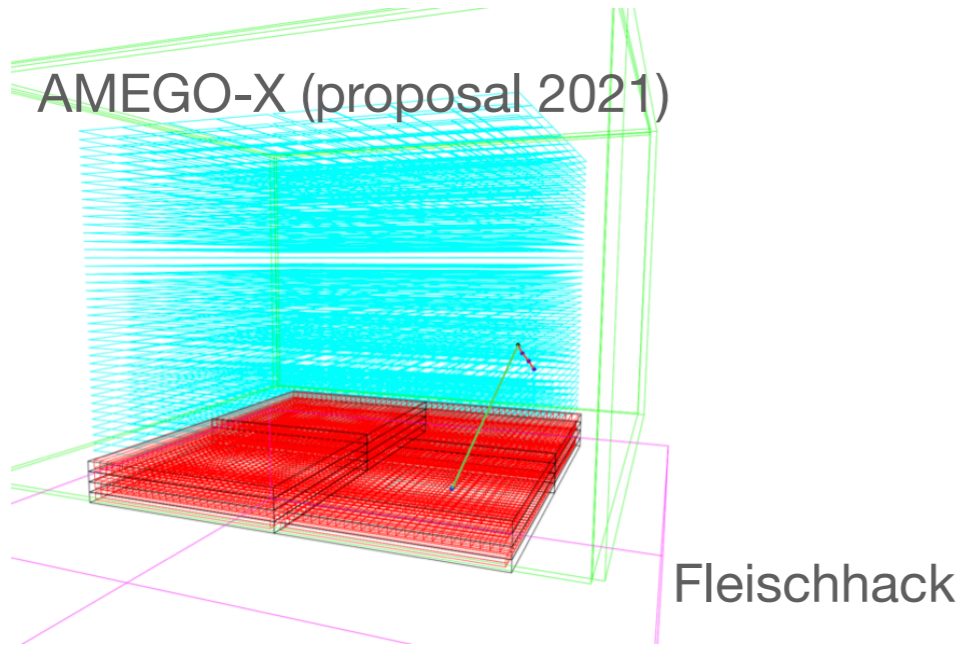


COSI-SMEX (Phase A)

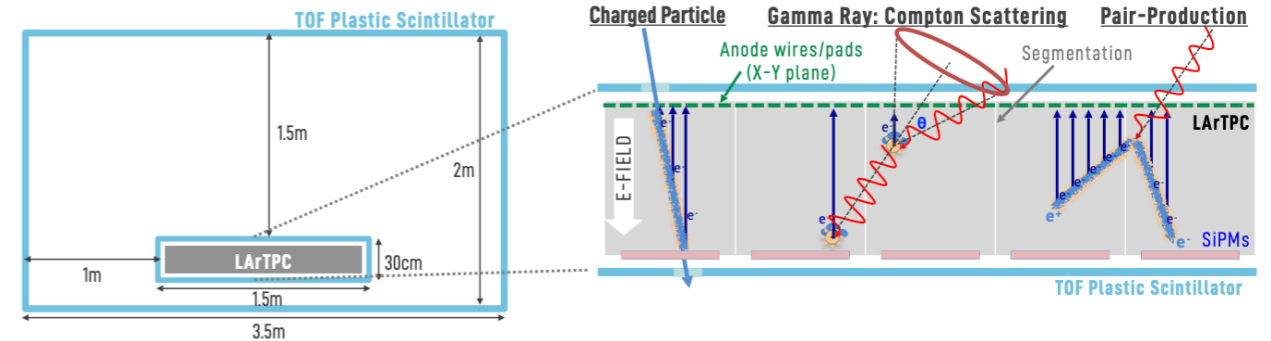
Tomsick

Future Instruments/Missions

keV to TeV



GRAMS



Aramaki

GRAINE



Takahashi

APT, APTlite (2019), ADAPT (2025)

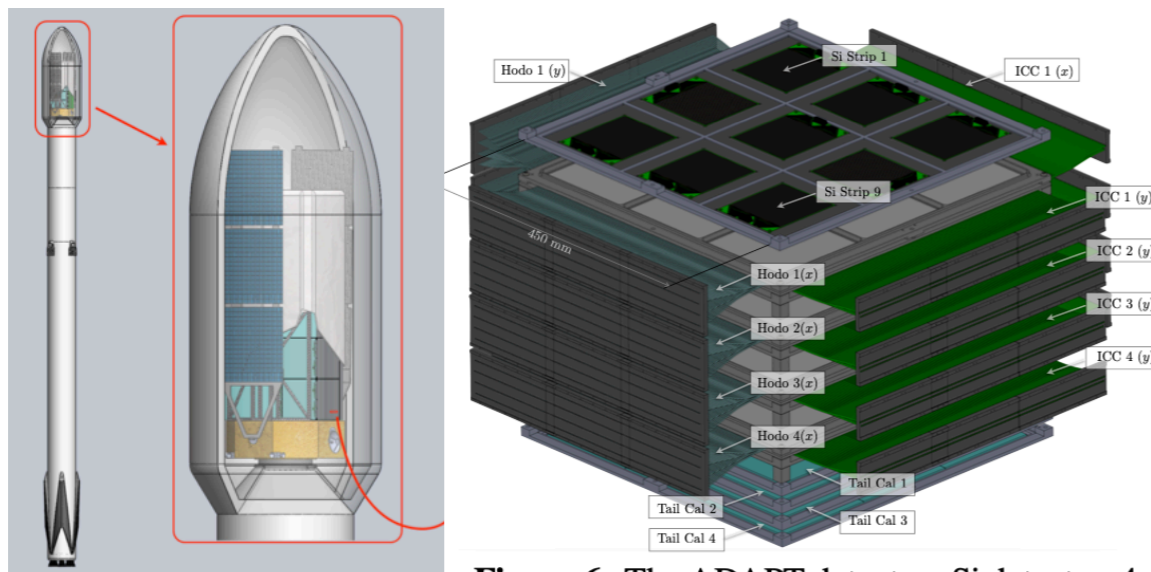


Figure 6: The ADAPT detector: Si detector, 4 layers of the scifi tracker and ICC, followed by the 4 tail counters.

Sudvarg,
Chen, Buckley

Summary

Of Summaries of Gamma-ray Astronomy from Space

Thank you for listening!

- The landscape has matured over the years
 - Many gamma-ray telescopes in space
 - Jets are complicated! The same questions across communities
 - Many tools available to analyze the data (and combine the data among instruments)
 - More telescopes... more data... more questions...
- Looking through the future
 - Many concepts being developed
 - Opportunities in for the future of space-based gamma-ray astronomy

