Fermi Gamma-ray Space Telescope

The 5th Fermi Symposium: Summary and Outlook

Eric Charles

SLAC / KIPAC

Nagoya, 2014-10-24

Outline

- Fermi Instrument, Data & Data Products
  - Status & Acknowledgements
  - New developments (Pass 8 & 3FGL Catalog)
- Fermi Science
  - Themes: new data / new models / new questions
  - A (brief) tour of science topics
    - Heavy personal bias toward observations over modeling
- Outlook
- Thank You

Fermi Gamma-ray Space Telescope

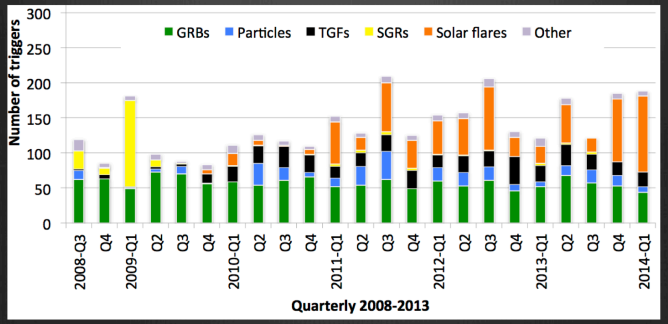
FERMI INSTRUMENT, DATA AND DATA PRODUCTS

Fermi Spacecraft & Instruments are Working Well

McEnery

GBM

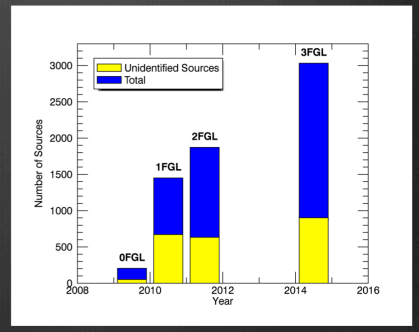
- 2 x10^{12} detector counts resulted in 3469 transient triggers
  - 1491 GRB, 510 TGF, 178 SGR bursts, 829 solar flares
  - >4500 GBM BA shifts by ~40 member team
  - 539 GCN circulars



12

Large Area Telescope

- Triggered on >380 billion (380,000,000,000) events
- Processed 73,859,565,213 events in ISOC pipeline, > 1.0 PB
  - Hundreds of data quality monitor shifts
- 3033 sources in 3rd Fermi LAT source catalog
- 160 Pulsars
- >1500 AGN



8

- **LAT: 3.8e14 Triggers, 73,859,565,213 events processed on ground**
- **GBM: 2e12 detector counts resulted in 3469 transient triggers**
- ***Fermi* responded to 28 ToO requests: Sun, AGN, Crab, Novae, binary systems**
- **In Dec 2013, *Fermi* transitioned to a new observing strategy designed to enhance coverage at the Galactic Center while retaining all-sky coverage**

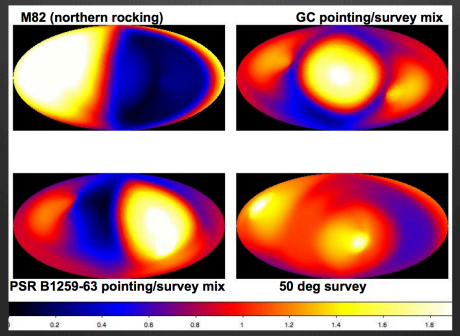
Lots of Dedicated People to Make it Work

Fermi SSC

McEnery

Science Support Center

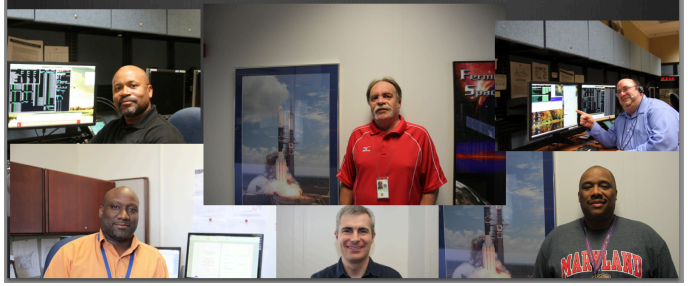
- Planned >330 observatory timelines
- Responded to 28 ToO requests: Sun, AGN, Crab, Novae, binary systems



Operations

Flight Operations Team

- Scheduled 18358 contacts with TDRSS
- Executed 10218 procedures on the observatory
- Respond to an average of ~10 observatory alerts per day
- Perform daily, weekly and quarterly review of spacecraft and instrument health and safety



Instrument Teams

Bruel

What does Pass mean?

- Each pass corresponds to a version of the Fermi LAT data
- It implies a whole package:
  - Intrument simulation
  - Reconstruction code
  - Event selection
  - Instrument Response Functions (IRFs)
  - Systematic uncertainties
  - Isotropic template (which includes the cosmic-ray residual background)
  - And sometimes more (Galactic diffuse model, Earth limb template, Sun+Moon template)
- It's only when we have validated the whole package that we can release it to the public.

& many others

Predictions Two Years Ago at Monterrey

Digel 2012

Highlights from the 5th Fermi Symposium

- Pass 8 in wide use
- 3FGL

LAT Pass 8 Era is Starting

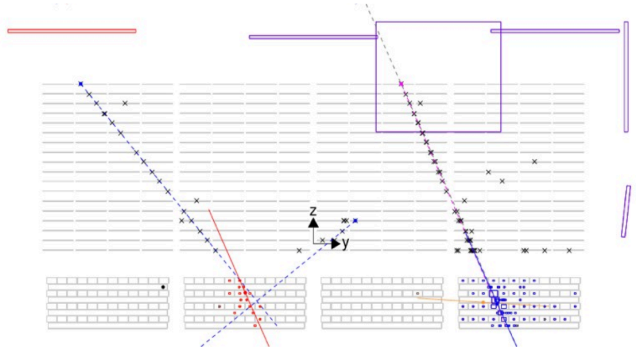
Bruel

De-ghosting

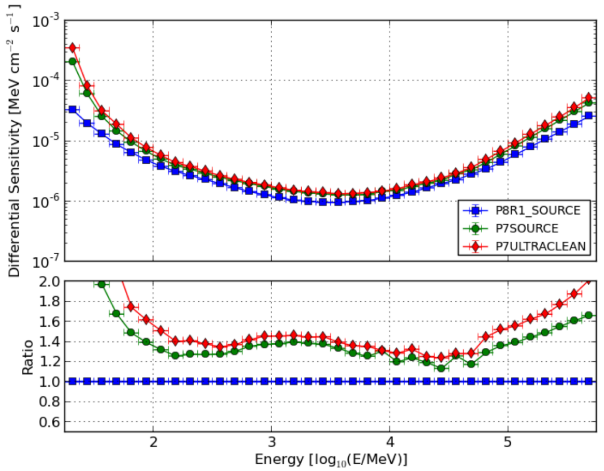
ACD
Remove tiles with no trigger veto but with a signal that should have fired the veto

Tracker
Remove hits from time-over-threshold and tower trigger information

Calorimeter
Perform clustering and cluster classification and keep the most gamma-like



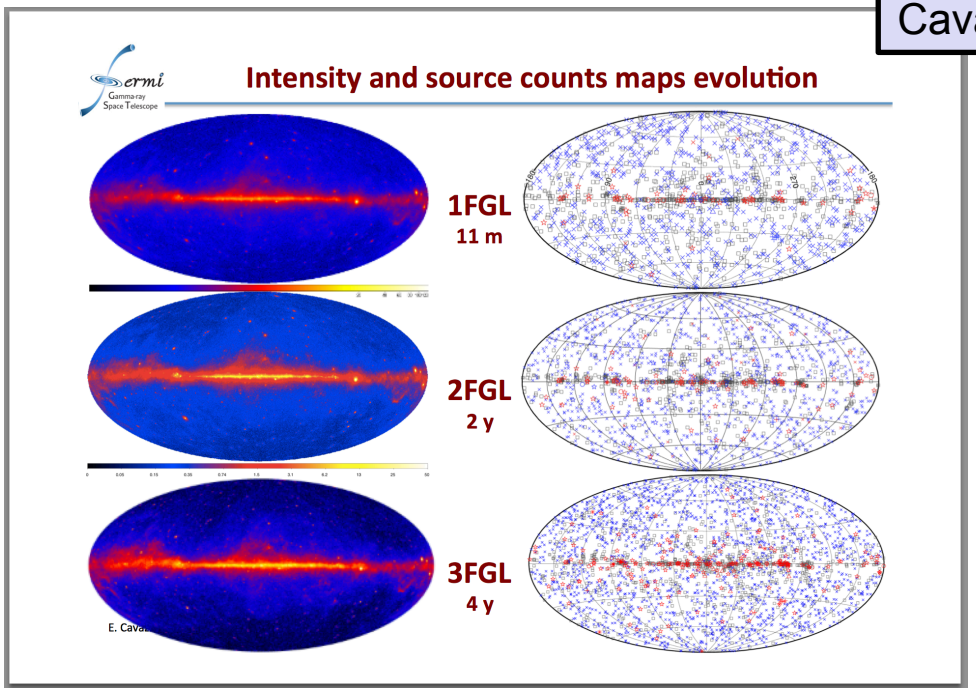
Source sensitivity



- Many results using Pass 8 data, including:
  - 2FHL Catalog (Ajello),
  - PG1553 variablity (Ciprini),
  - Impulsive phase of solar flares (Desainte)
  - Pulsar discoveries (Laffon)
  - Dwarf Spheroidal DM search (Anderson)
  - DM annihilation line search (Albert)
  - GRB Searches (“Vianello”)

The Third Fermi-LAT Source Catalog (3FGL)

Cavazzuti



- The 3FGL catalog uses the Pass 7 reprocessed data set
  - Improved PSF w.r.t. Pass 7
- Deepest catalog from 100MeV to 300GeV
- Significant analysis refinements w.r.t. 2FGL catalog
  - 3033 sources (1873 in 2FGL)

	3FGL
Total	3033
Unassociated	992 (33%)
AGNs	1691 + 66 (ID) (58%)
PSRs	29 + 137 (ID)
PWN	2+9 (ID)
SNR	11+12 (ID)
GLC	15
SBG	4
HMB	3 (ID)
spp	51
Others	11 (gal+Nova+BIN…)
Extended	25
High/Low |b|	2193/841

preliminary

Catalogs are Drivers for Other Studies

Cavazzuti

- Population studies: LogN – LogS, Luminosity Function
- Long term studies
- Reference for works on individual sources (included provides starting source model for any ROI)
- Dichotomy between gamma-ray detected and gamma-ray non-detected blazars at other wavelengths
- Timing correlations between the activity in the gamma-ray bands and other bands
- Correlation between gamma-ray AGNs and the sources of ultra high-energy cosmic rays / high-energy neutrinos
- Sample to probe the Extragalactic Background Light / InterGalactic Magnetic Field
- Contribution of AGNs to the extragalactic diffuse gamma-ray background
- Finding new MSPs
- Triggering dedicated studies of SNRs
- Constrain the population of unresolved Galactic sources
- Build the next generation model for diffuse Galactic emission

Other New / Upcoming "Catalogs"

- GBM Soft-Gamma Repeater (SGR) Catalog Kouveliotou
- LAT Supernova Remnant Catalog(SNRCat) Brandt
- 3rd LAT Active Galactic Nuclei (3LAC) Lott
- 2nd LAT Hard Source List (2FHL) Ajello
- LAT-detected Solar Flare List Omodei
- GBM X-ray Burst (XRB) Catalog Jenke
- GBM GRB Catalog Updates Briggs

Fermi Mission Prospects

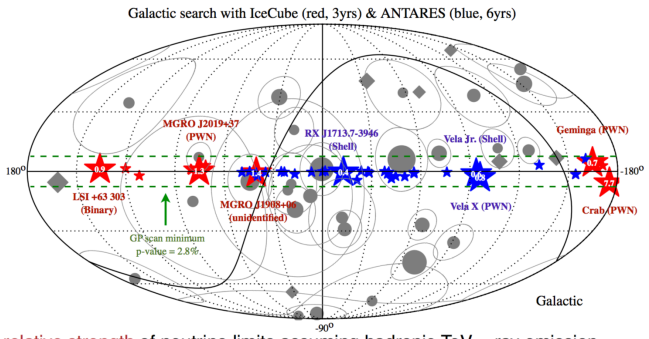
- **Orbit re-entry in the range 2026 - 2044 (depending on solar activity)**
- **No consumables**

"Precedence suggests that NASA does not turn off fully operational missions."
-Julie McEnery

New Synergies other Instruments

Ahlers

Neutrino Point-Source Limits



- relative strength of neutrino limits assuming hadronic TeV γ-ray emission (only shown for selected strong sources):

$$F_\gamma(E_\gamma > E_{\rm th})/F_\nu^{90CL}(E_\nu > E_{\rm th}/2)$$

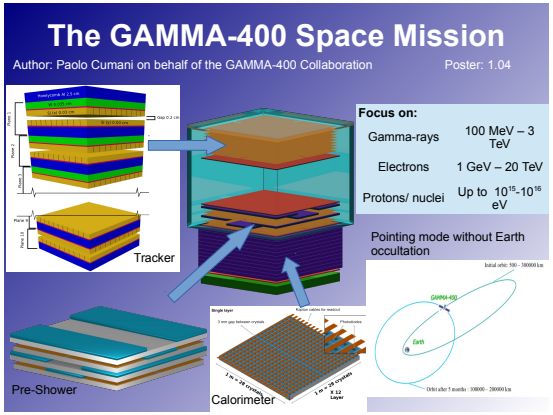
✘ **caveats:** soft spectra, low energy cutoffs and extended emission

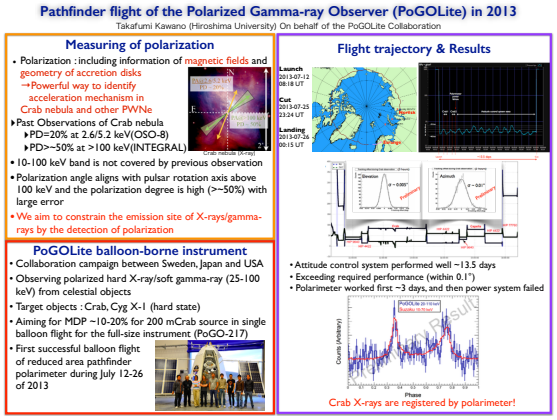
Proposed Source Candidates

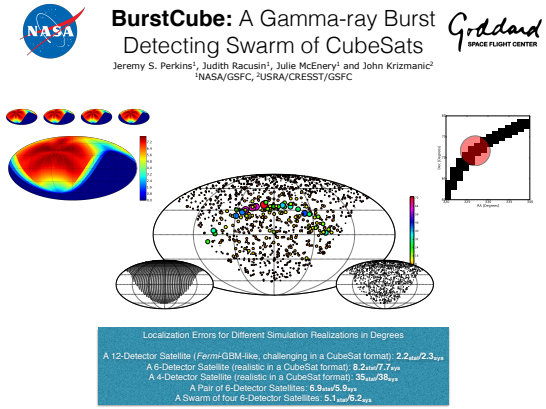
- **Galactic:** (full or partial contribution)
  - heavy dark matter decay [Feldstein *et al.* 1303.7320; Esmaili & Serpico 1308.1105]
  - peculiar hypernovae [Fox, Kashiyama & Meszaros 1305.6606; MA & Murase 1309.4077]
  - diffuse Galactic γ-ray emission [*e.g.* Ingelman & Thunman'96; MA & Murase 1309.4077]
  - unidentified Galactic TeV γ-ray sources [Fox, Kashiyama & Meszaros 1306.6606]
  - sub-TeV diffuse Galactic γ-ray emission [Neronov, Semikoz & Tchernin 1307.2158]
  - "Fermi bubbles" [Su, Slatjer & Finkbeiner'11; Crocker & Aharonian'11; Lunardini & Razzaque'12] [MA & Murase'13; Razzaque'13; Lunardini *et al.*'13]
- **Extragalactic:**
  - association with sources of UHE CRs [Kistler, Stanev & Yuksel 1301.1703] [Katz, Waxman, Thompson & Loeb 1311.0287; Fang, Fujii, Linden & Olinto 1404.6237]
  - GZK from low $E_{\rm max}$ blazars [Kalashev, Kusenko & Essey 1303.0300]
  - cores of active galactic nuclei (AGN) [*e.g.* Stecker *et al.*'91;Stecker 1305.7404]
  - AGN jets [*e.g.* Murase, Inoue & Dermer 1403.4089; 1406.2633]
  - low-power γ-ray bursts (GRB) [Murase & Ioka 1306.2274]
  - starburst galaxies [*e.g.* Loeb & Waxman'06; He *et al.* 1303.1253] [Murase, MA & Lacki 1306.3417; Anchordoqui *et al.* 1405.7648; Chang & Wang 1406.1099]
  - hypernovae in star-forming galaxies [Liu, Wang, Inoue, Crocker & Aharonian 1310.1263]
  - galaxy clusters/groups [Berezinksy, Blasi & Ptuskin'97; Murase, MA & Lacki 1306.3417]

- **Multi-messenger (MM) astronomy**
  - **PeV neutrinos from Ice Cube** Ahlers
  - **Gravity-wave detectors** Allen
- **Multi-wavelength (MW) astronomy**
  - **eRosita (medium-energy X-ray)**
  - **CTA (High-energy gamma-ray)**
  - **SKA (radio)**

Proposed Missions







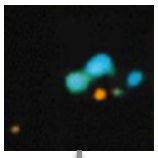
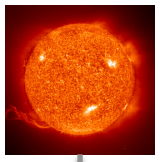
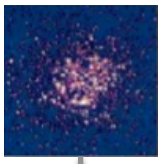
- Wide-Field MAXI (X-ray monitor)
- HARPO (MeV-GeV telescope & polarimeter)
- GAMMA-400 (GeV telescope & calorimeter)
- PoGOLite (Gamma-ray polarimeter)
- PANGU (MeV-GeV telescope & polarimeter)
- GRAINE (Ballon-based emulsion telescope)
- CALET GRB monitor
- TSUBAME (Micro-satellite X-ray polarimeter)
- BurstCube (GRB monitoring CubeSat “swarm”)

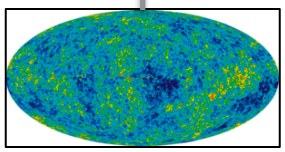
Fermi Gamma-ray Space Telescope

FERMI SCIENCE: THEMES

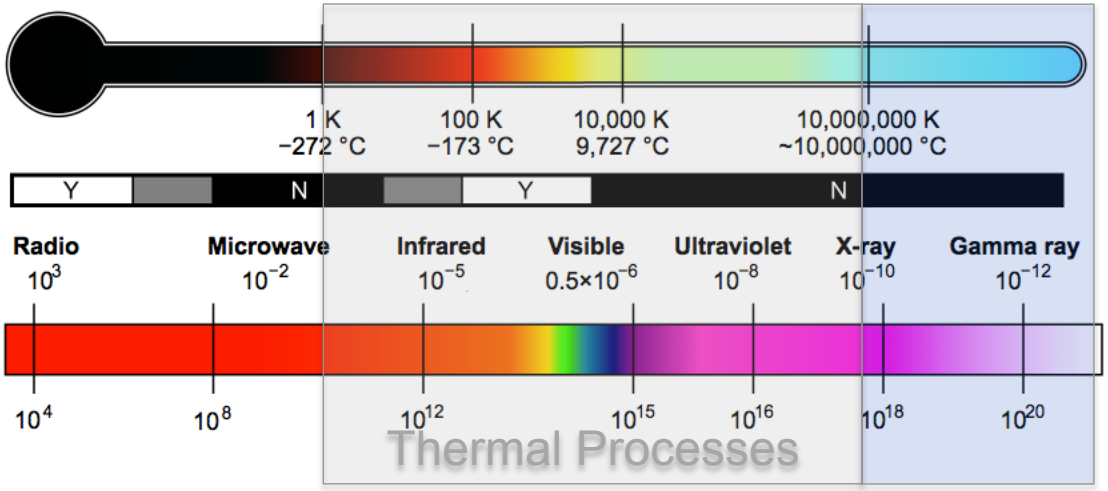
γ-rays Probe the Extreme, Non-Thermal, Universe

Dark Nebula | Dim, young star | Our Sun | Globular Cluster | Accretion Disk

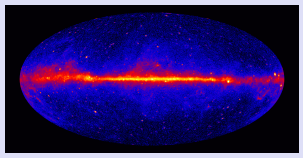





CMB



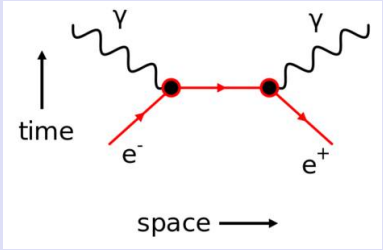
γ-ray sky



Energy & particle source

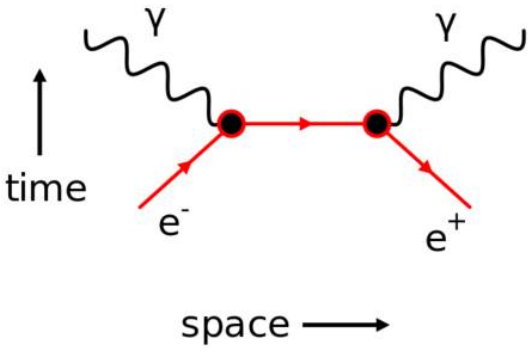
Acceleration mechanism

γ-ray production mechanism



Foreground Effects

Non-thermal γ ray emission



Energy source

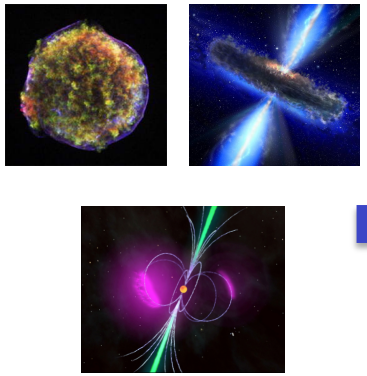
Acceleration mechanism

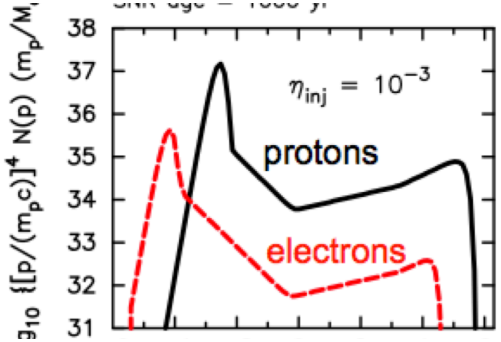
γ-ray production mechanism

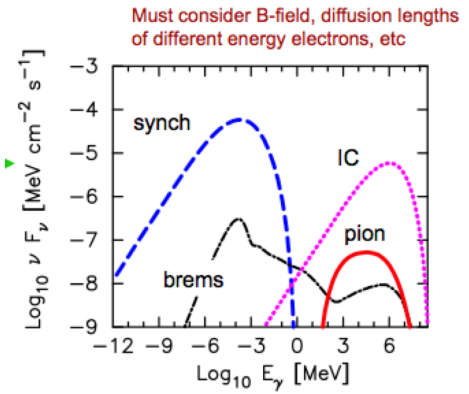
Foreground absorption

γ rays

Non-thermal γ ray emission



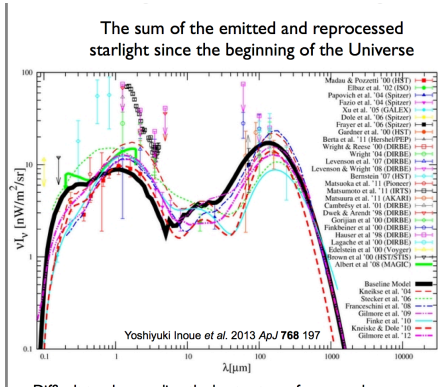


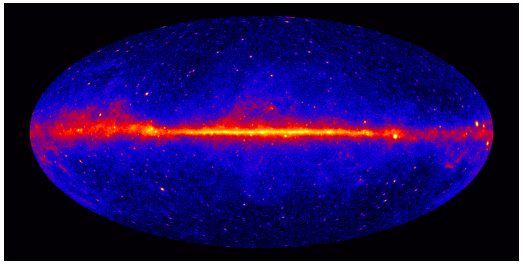


Energy source

Acceleration mechanism

γ-ray production mechanism

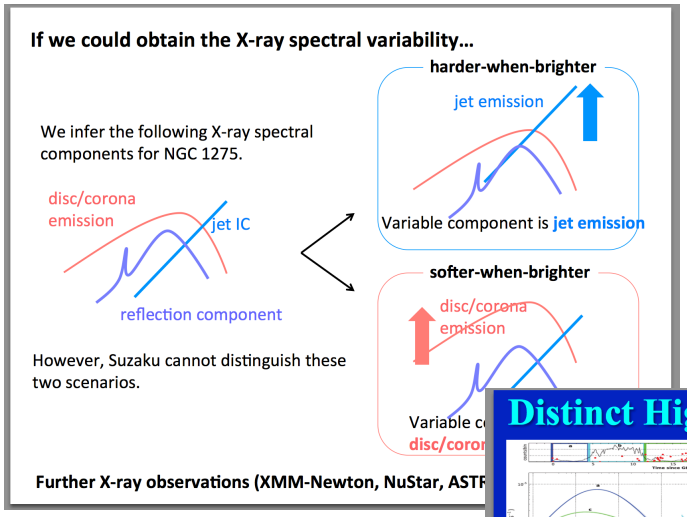


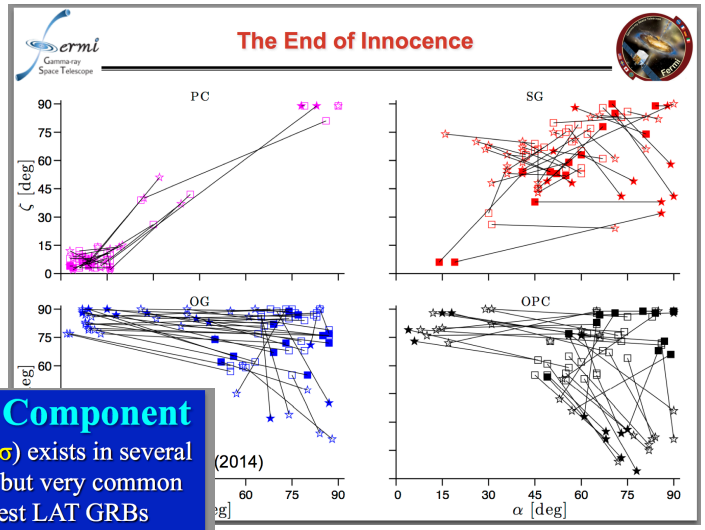


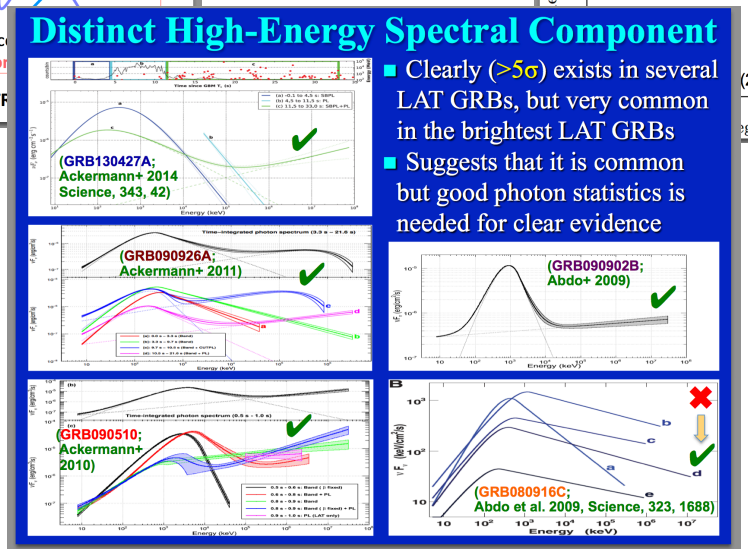
Foreground absorption

γ rays

Theme I: New Data Challenges Old Models





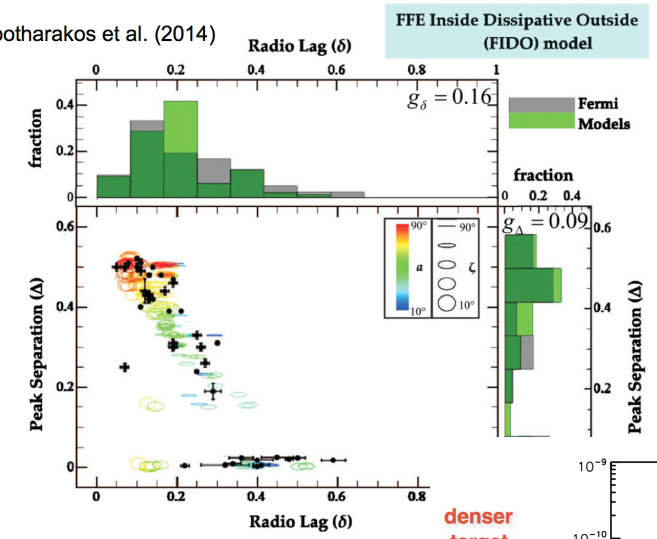


"[The second pulsar catalog was the] end of being able to do science with cartoons."

-Matthew Kerr

Theme II: New Data Allow us to Make New Models

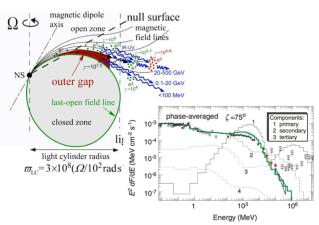
Kalapotharakos et al. (2014)

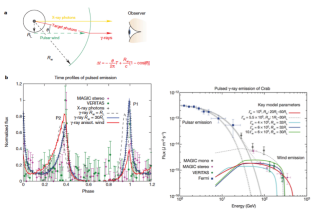


New Models for Crab

1) Magnetospheric Cascade Model (K. Hirotani & MAGIC, Apj 742 43, 2011)

2) Pulsar Wind Scattering Model (F. Aharonian et al. Nature 482, 507, 2012)





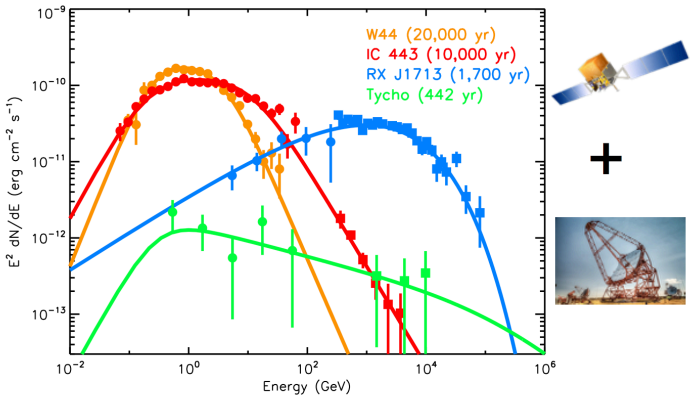
3) Light Cylinder Gap model (Bednarek MNRAS 424, 2012)

In order to test these models:

- Spectral Approach
  -> R. Zanin talk this morning
- **Pulse Shape Approach**
  -> This talk

T. Saito, 5th Fermi Symposium 2014/10/22

denser target



old ← → young

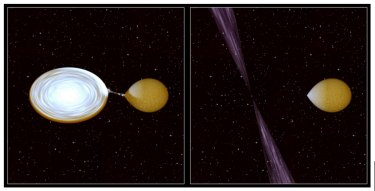
John W. Hewitt — 5th Fermi Symposium - Nagoya, Japan — 17

"When you are modeling you have to take into account all of these things. It can get very complicated"
-Toni Venters

Theme III: Testing New Models raises New Questions

Key puzzles

- Why have these systems stopped being full-fledged LMXBs?
- Do other LMXBs enter such low-luminosity accretion-disc states?
- What is going on in these peculiar accretion-disc states?
- How do these systems produce γ-rays?
- What is the ultimate fate of these systems?



Archibald (ASTRON) MSP γ-ray emission

Proposed Source Candidates

- **Galactic:** (full or partial contribution)
  - heavy dark matter decay [Feldstein *et al.* 1303.7320; Esmaili & Serpi…]
  - peculiar hypernovae [Fox, Kashiyama & Meszaros 1305.6606; MA & Murase 1309.4077]
  - diffuse Galactic γ-ray emission [*e.g.* Ingelman & Thunman'96; MA & Murase 1309.4077]
  - unidentified Galactic TeV γ-ray sources [Fox, Kashiyama & Meszaros 1306.6606]
  - sub-TeV diffuse Galactic γ-ray emission [Neronov, Semikoz & Tchernin 1307.2158]
  - "Fermi bubbles" [Su, Slatjer & Finkbeiner'11; Crocker & Aharonian'11; Lunardini & Razzaque'12] [MA & Murase'13; Razzaque'13; Lunardini *et al.*'13]
- **Extragalactic:**
  - association with sources of UHE CRs [Kistler, Stanev & Yuksel 1301.1703] [Katz, Waxman, Thompson & Loeb 1311.0287; Fang, Fujii, Linden & Olinto 1404.6237]
  - GZK from low $E_{\rm max}$ blazars [Kalashev, Kusenko & Essey 1303.0300]
  - cores of active galactic nuclei (AGN) [*e.g.* Stecker *et al.*'91;Stecker 1305.7404]
  - AGN jets [*e.g.* Murase, Inoue & Dermer 1403.4089; 1406.2633]
  - low-power γ-ray bursts (GRB) [Murase & Ioka 1306.2274]
  - starburst galaxies [*e.g.* Loeb & Waxman'06; He *et al.* 1303.1253] [Murase, MA & Lacki 1306.3417; Anchordoqui *et al.* 1405.7648; Chang & Wang 1406.1099]
  - hypernovae in star-forming galaxies [Liu, Wang, Inoue, Crocker & Aharonian 1310.1263]
  - galaxy clusters/groups [Berezinksy, Blasi & Ptuskin'97; Murase, MA & Lacki 1306.3417]

Markus Ahlers (UW-Madison) High-Energy Neutrinos in Light of Fermi-LAT October 20, 2014 slide 10

Leptonic / Hadronic Summary

	Leptonic	Hadronic
Gamma-ray spectrum	☺	☺
Microwave haze	☺	☹
No spectral changes	☹	☺
Narrow boundary	☺	☹
Absence of a visible shock front	☹	☺

Possible leptonic scenario: (Mertsch, Sarkar, Guo, Mathews etc.):
- Jets from the black hole create shock front
- Shock front dissipates, but leaves plasma turbulences behind
- Electrons are accelerated on the turbulences with a characteristic time less than the cooling time

Possible hadronic scenario: (Crocker, Aharonian):
- Wind from SNRs produces CR during several billions of years
- Magnetic fields confine the CR in the bubble volume
- WMAP haze produced by ~ 30 GeV electrons in the SNR wind which have a characteristic cooling time ~ 10 Myr

A. Franckowiak 15

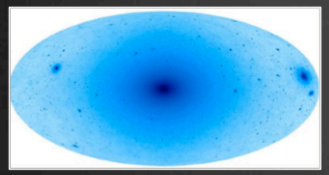
"Lack of imagination is not proof of discovery"
-Dan Hooper

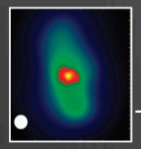
FERMI SCIENCE: A (BRIEF) TOUR OF TOPICS

From Local to Cosmological Sources

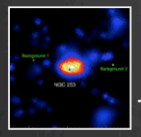
57 NASA press releases, over 15 million youtube/svs hits on Fermi animations

Dark Matter searches

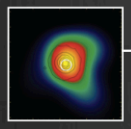




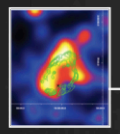
Radio Galaxies



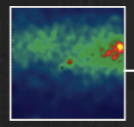
Starburst Galaxies



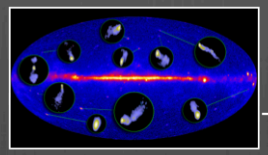
Globular Clusters



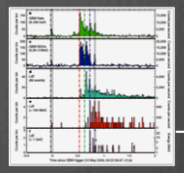
SNRs & PWN



Novae



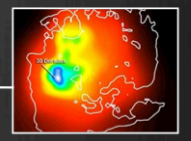
Blazars



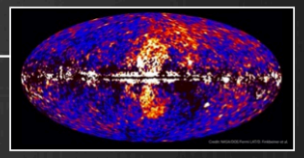
GRBs

Extragalactic

Galactic

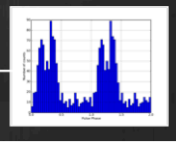


LMC & SMC

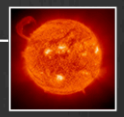


Fermi Bubbles

γ-ray Binaries



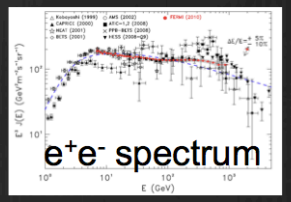
Pulsars: isolated, binaries, & MSPs



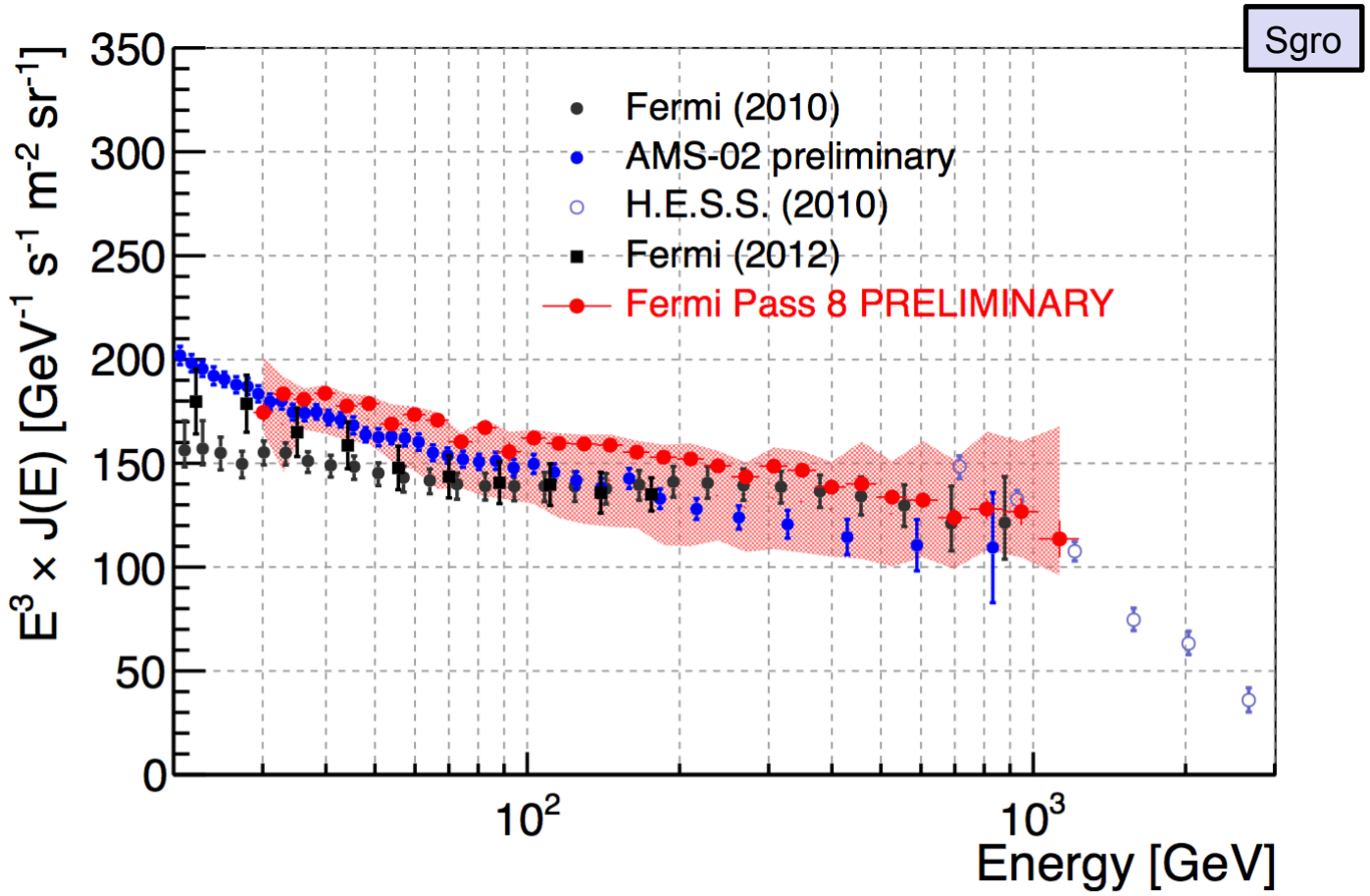
Sun: flares & CR interactions

Terrestrial γ-ray Flashes

Unidentified Sources



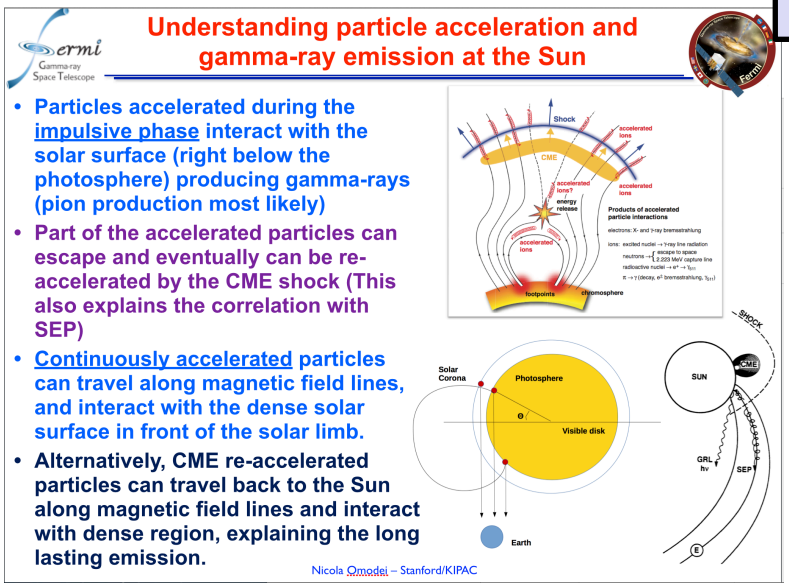
Updated Cosmic-Ray Electron Spectrum

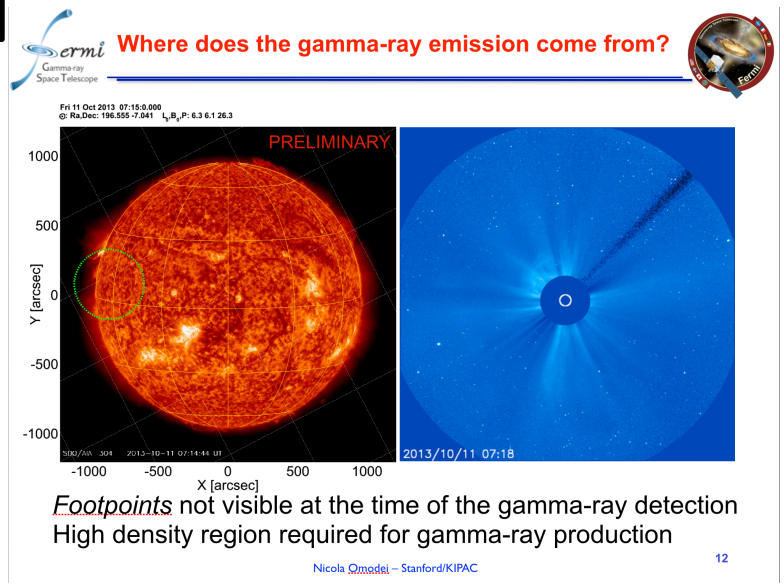


- **Pass 8 update to Fermi-LAT Cosmic-ray electron spectrum**
  - **Up to > 1 TeV (Overlap w/ HESS)**

Gamma Rays from the Solar System

Omodei

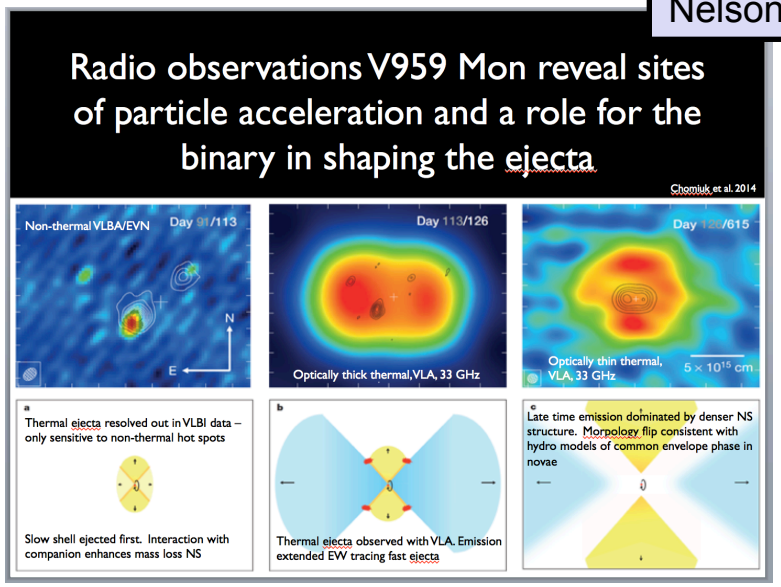




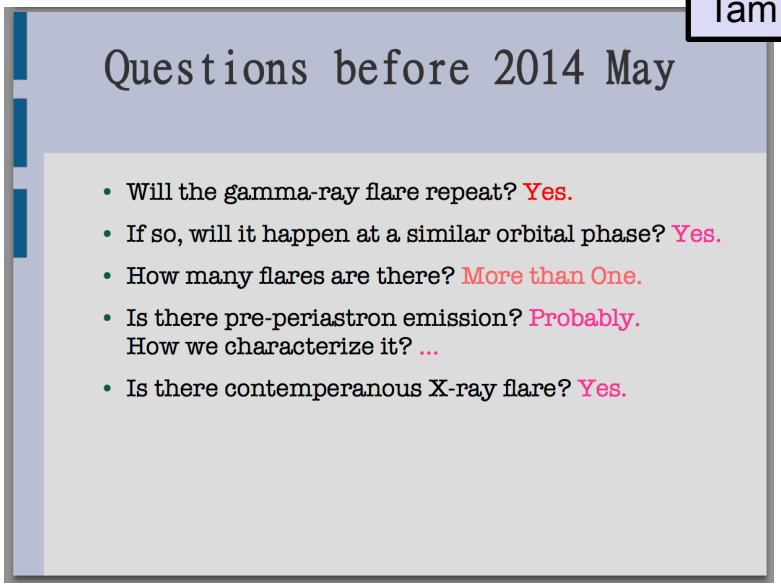
- **GBM + LAT Observation of Solar Flares** Omodei
  - **Gamma rays correlated with coronal mass ejections**
  - **Prompt gamma rays localized to active region**
  - **Observation of gamma rays from flares beyond the Solar Limb**
  - **Pass 8 reconstruction allows for study of impulsive emission** Desainte
- **Sun Monitoring / Quiet Sun observations** Omodei / Giglietto
- **Search for emission along the Ecliptic** Vandenbroucke
- **GBM observations of Terrestrial Gamma-ray Flashes** Briggs

Galactic Transients (Novae / Binaries)

Nelson



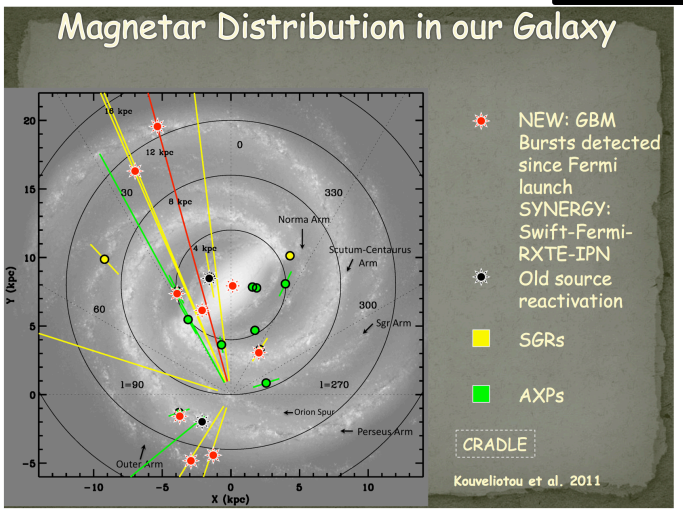
Tam



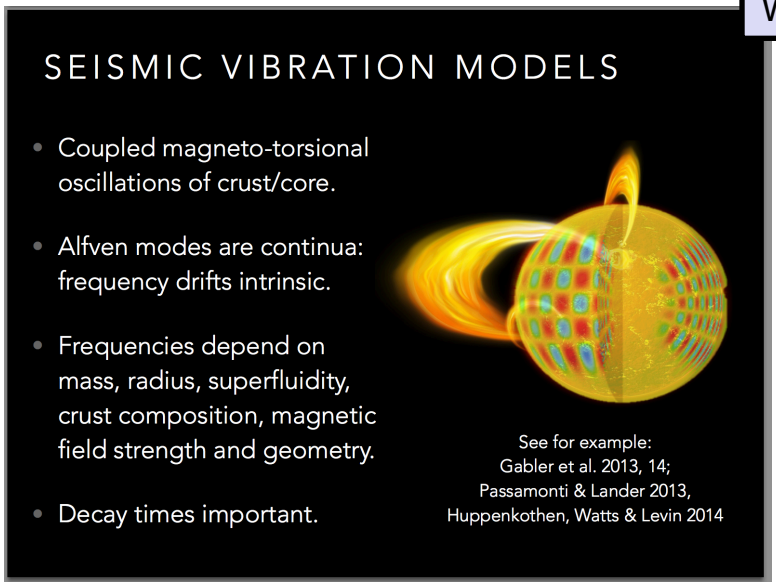
- **MW observations of Galactic Novae demonstrate that binary dynamics affect the particle acceleration** Nelson
- **Superorbital variation in LSI +61° 303** Hadasch
  - **Due to variations in circumstellar disc or mass decretion rate?**
- **Observation of Galactic Binary PSR B1259-63 periastron passage answers several open questions about that system** Tam

Magnetars

Kouveliotou

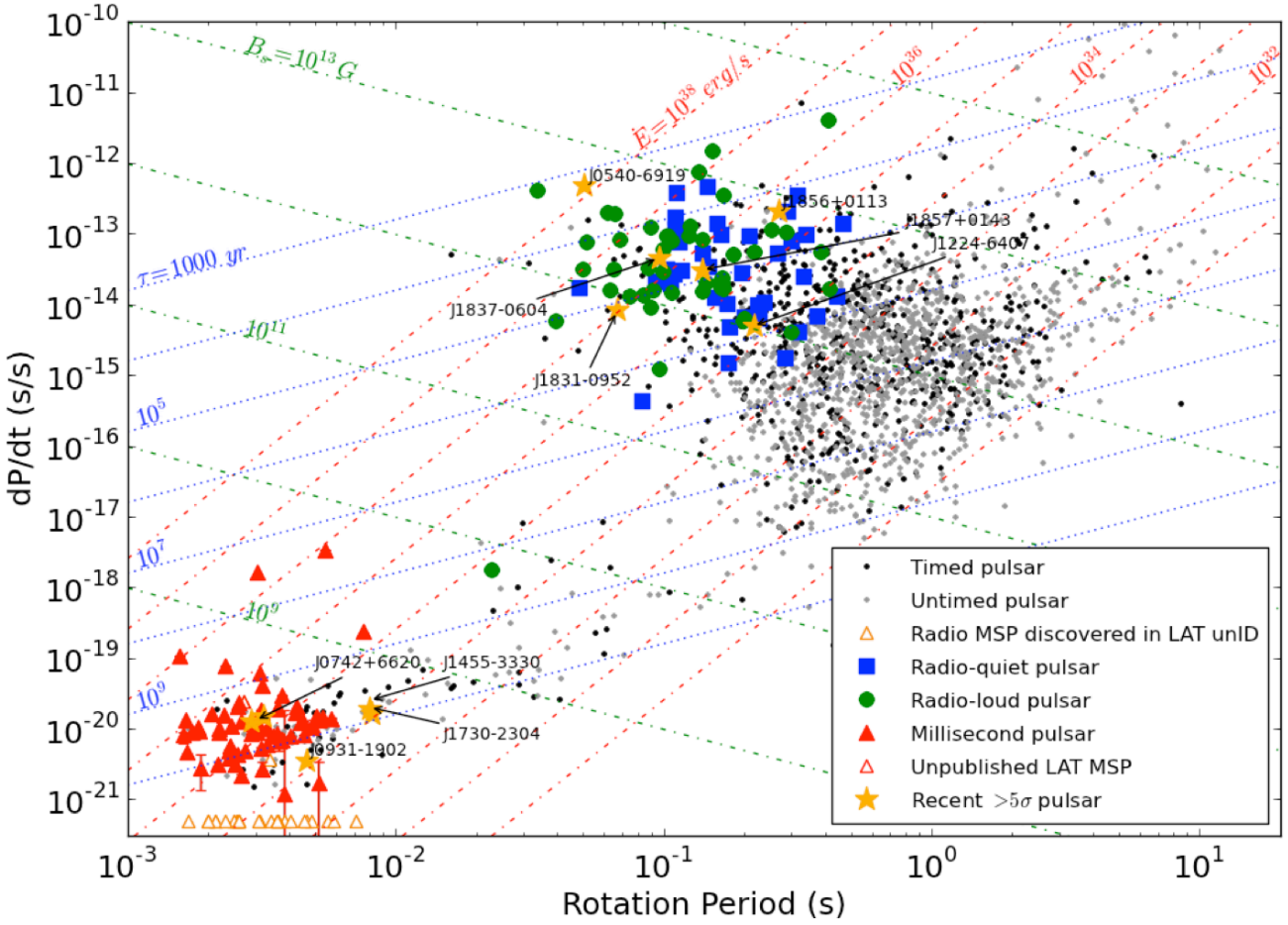


Watts



- **GBM observations of Magnetars**
  - **Soft-gamma repeater (SGR) Catalog**
  - **Correlation between outbursts & state changes**
- **Neutron star astro-siesmology**
  - **Detection of QPOs ~100 Hz by stacking moderate bursts from SGR J1550-5418 burst storm**

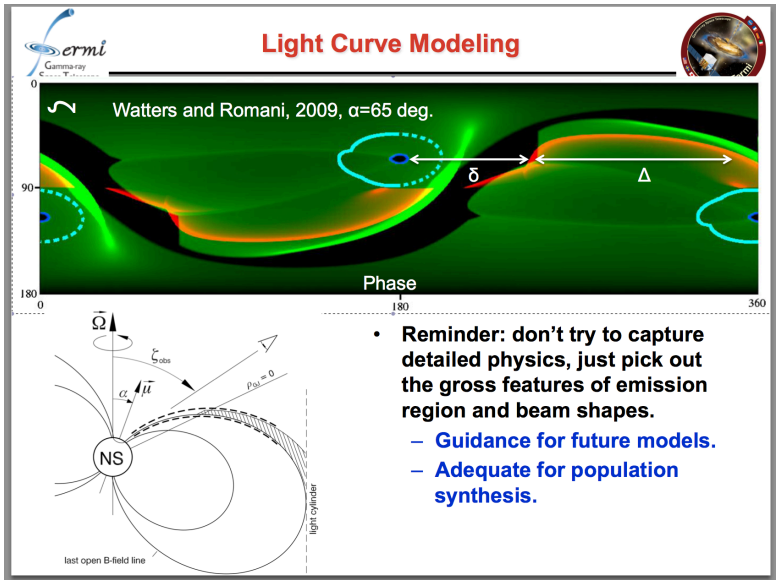
Pulsar Hunting

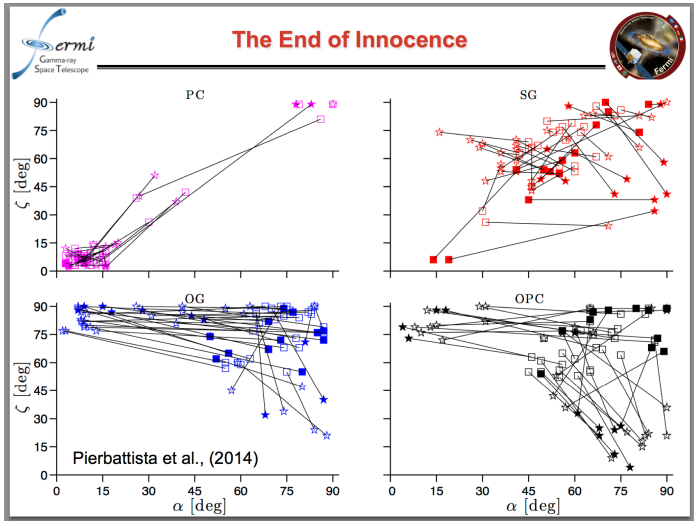


- **10 new pulsation detections w/ Pass 8** Laffon
  - **MSP Fraction is Growing**
- **Observations of Candidate MSP Binaries Variability** Kong / Wang

Pulsar Modeling

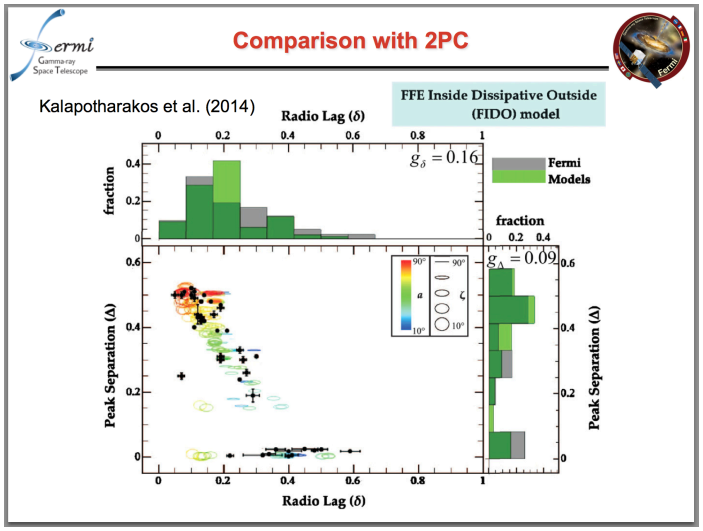
Kerr





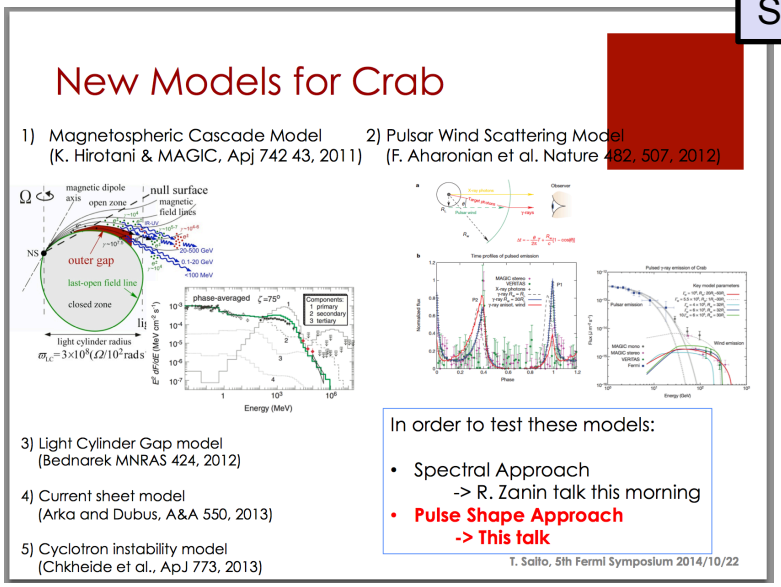
Include Microphysics,
Reconsider Radio Model
Buy Drill & Multimeter

- **Geometry plays key role** Johnston
- **LAT sample allow us to probe viewing / rotation phase space**
- **Initial radio + gamma combined models inconsistent**
- **Updated models fit gamma-ray data well** Timokhin



Pulsars at Very High Energies

Saito

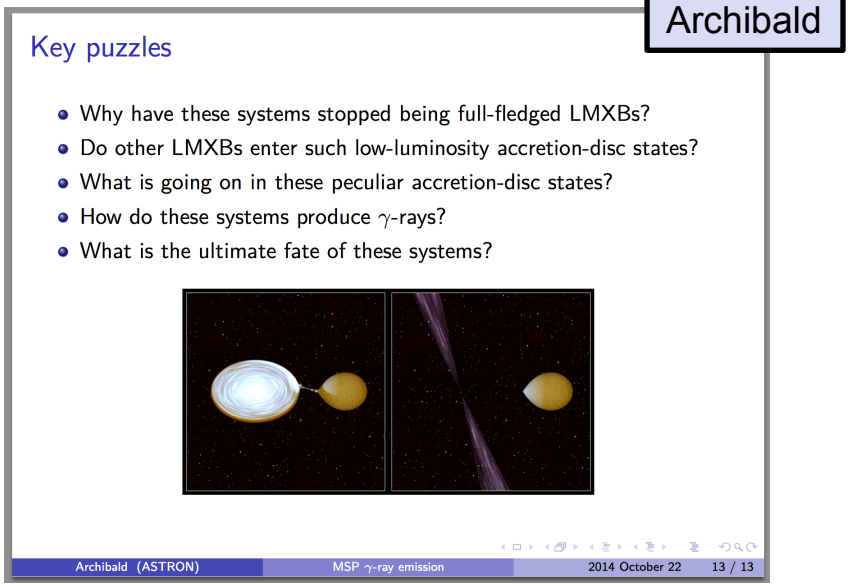


- **Pulsed emission from Crab detected by MAGIC up to ~2TeV**
  - **Inverse Compton emission from electrons w/ Γ > 5e6**
  - **Pulse width still very narrow at these energies**
    - **Tightly constrains IC emission region**
- **Interpulse "Bridge" emission also seen above 50GeV**
- **Pulsations from Vela observed above 50GeV** Takata
- **Phase-gated stacked analysis of *Fermi* pulsars sets upper limits**

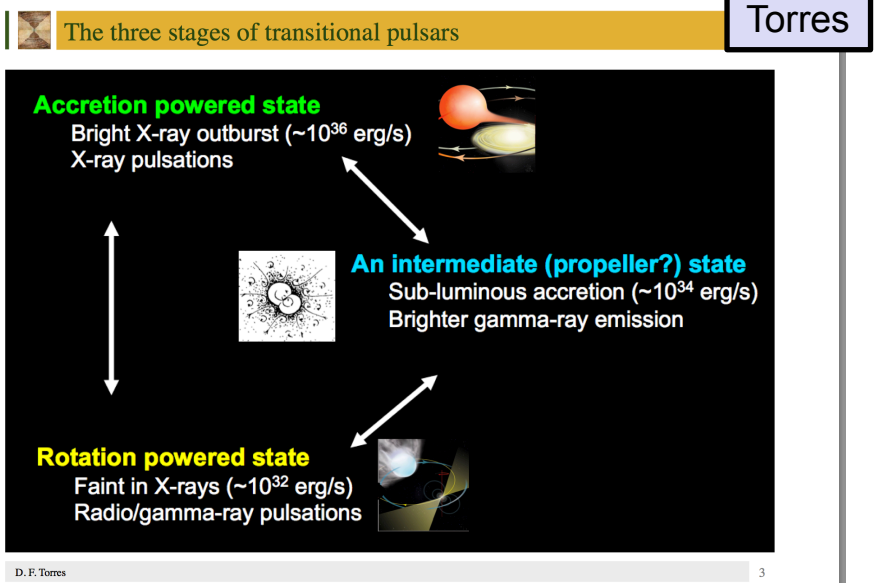
McCann

Pulsars Systems

Archibald



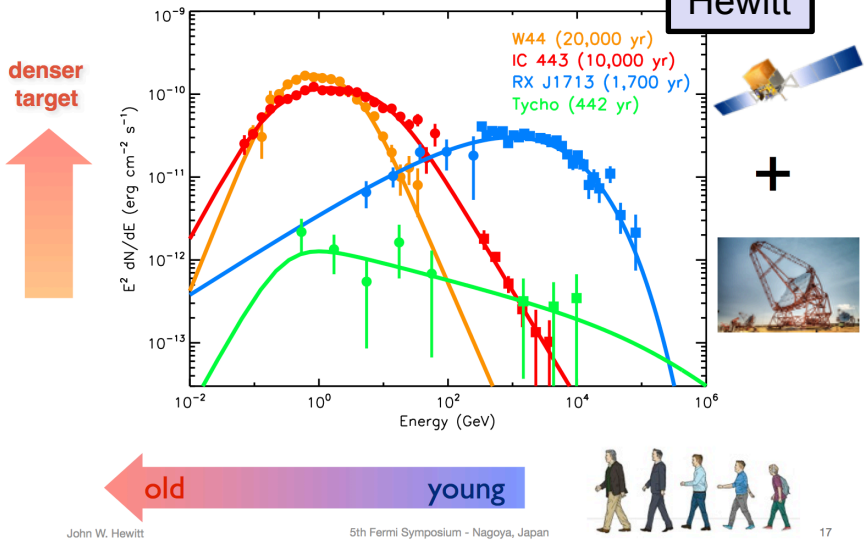
Torres



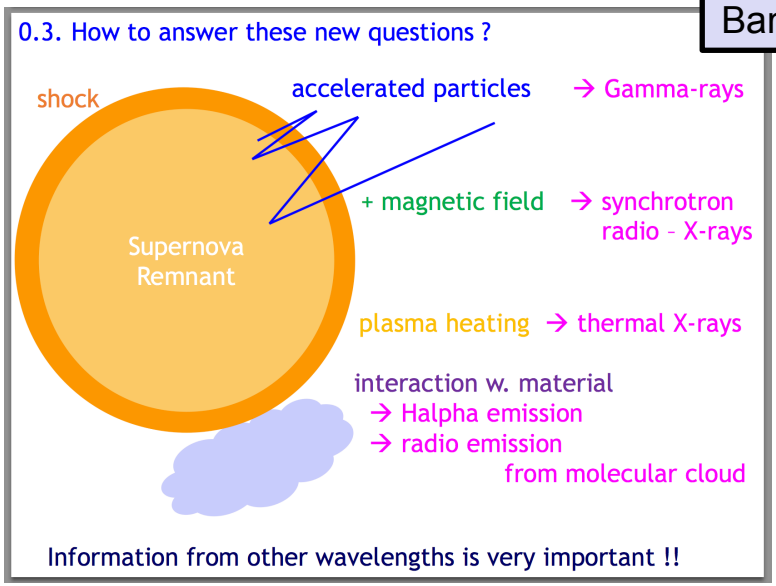
- **Increase in number of eclipsing binary systems (spiders) with Fermi**
  - **Surprising large fraction of new pulsars are spiders**
    - **Selection effects in searching for eclipsing binary systems with radio**
- **Transition objects switch to accreting state with high gamma-ray flux**
  - **Are seeing intra-binary shocks in gamma-rays?** Roberts
  - **Are pulses being shorted out, or simply obscured?**

Particle Acceleration in SNRs

Hewitt



Bamba



- **Excellent overview talks**
  - **Dominant emission mechanism depends on SNR environment**
    - **Nearby target material**
  - **High-energy cutoff decreases with SNR age**
    - **Shock / confinement mechanism evolves**
- **First Pass 8 results**
  - **New SNR CTB 109 detected, RCW 86 is extended source**

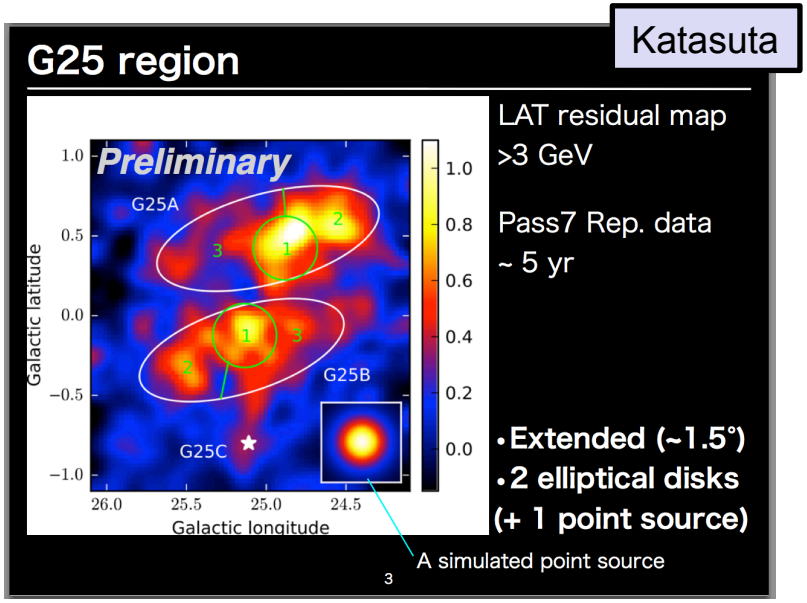
Caragiulo

- **SNR Catalog (32 classified GeV SNRs)**

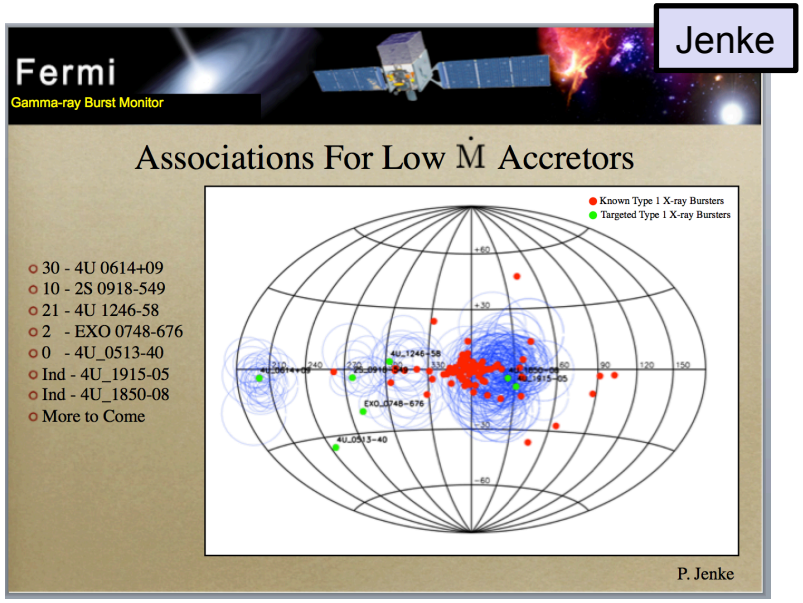
Brandt / Di Palma

Other Galactic Sources

Katasuta



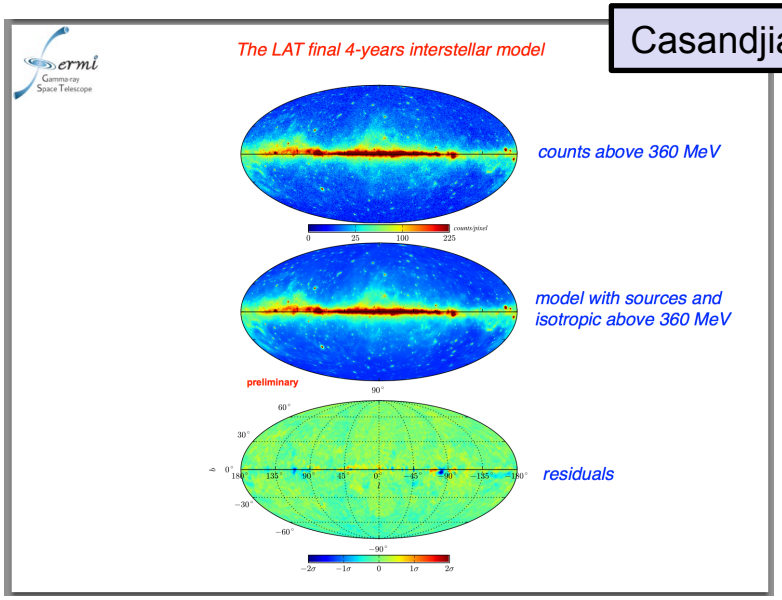
Jenke



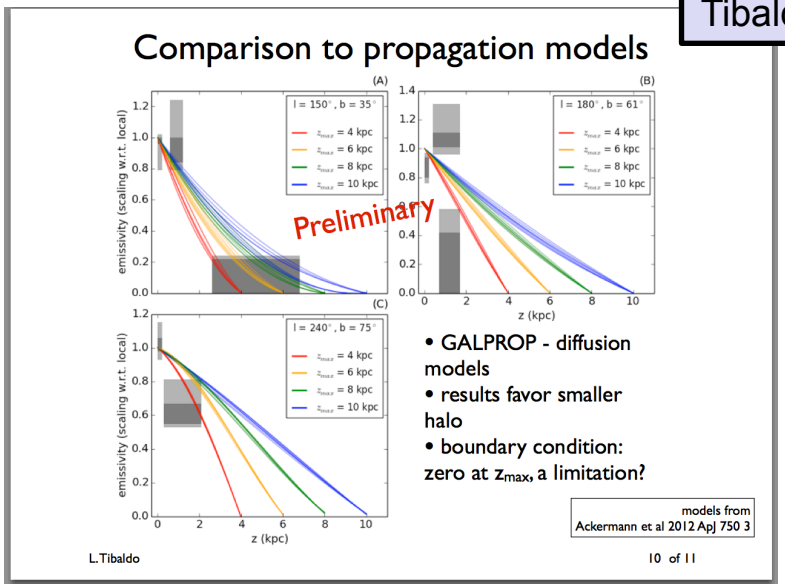
- **Detection of gamma-rays from G25 star-forming region**
- **GBM Catalog of type 1 X-ray Burts**
  - **NS accreting matter from low-mass companion**

Galactic Diffuse Emission

Casandjian

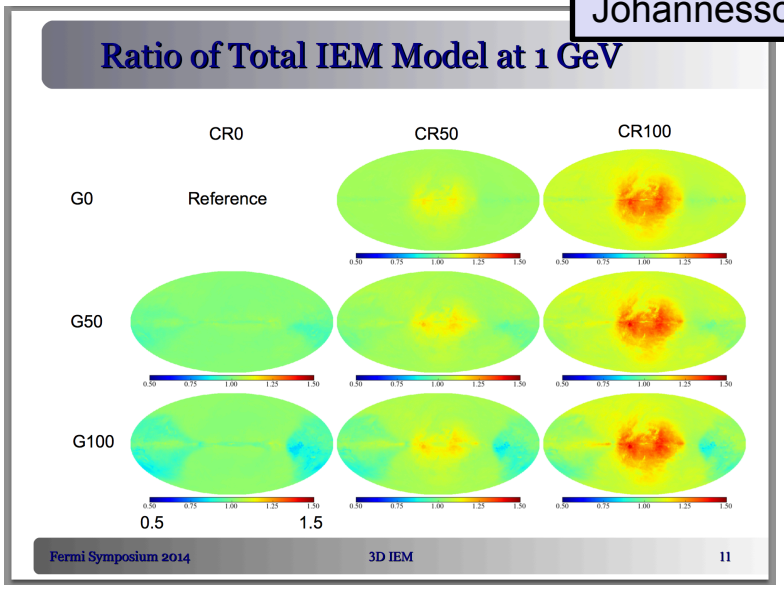


Tibaldo



- **LAT Diffuse emission model**
  - **Extract emissivity variations w/ galactocentric radius**
- **High Velocity Cloud Study**
  - **Extract emissivity variations away from galactic place**
- **Effect of including 3D structure in GALProp modelling**

Johannesson

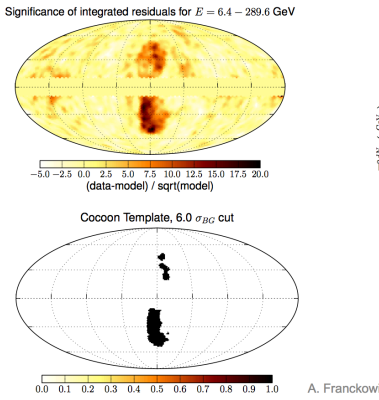


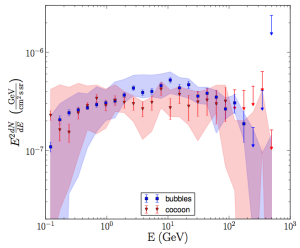
Fermi Bubbles Update

Franckowiak

Substructure – "Cocoon"

- Excess emission in South East of the bubbles
- Variation in spectral shape within systematic errors





No evidence for a pair of jets as claimed in Su and Finkbeiner (ApJ 753, 2012)

A. Franckowiak 10

Leptonic / Hadronic Summary

	Leptonic	Hadronic
Gamma-ray spectrum	☺	☺
Microwave haze	☺	☹
No spectral changes	☹	☺
Narrow boundary	☺	☹
Absence of a visible shock front	☹	☺

Possible leptonic scenario: (Mertsch, Sarkar, Guo, Mathews etc.):
- Jets from the black hole create shock front
- Shock front dissipates, but leaves plasma turbulences behind
- Electrons are accelerated on the turbulences with a characteristic time less than the cooling time

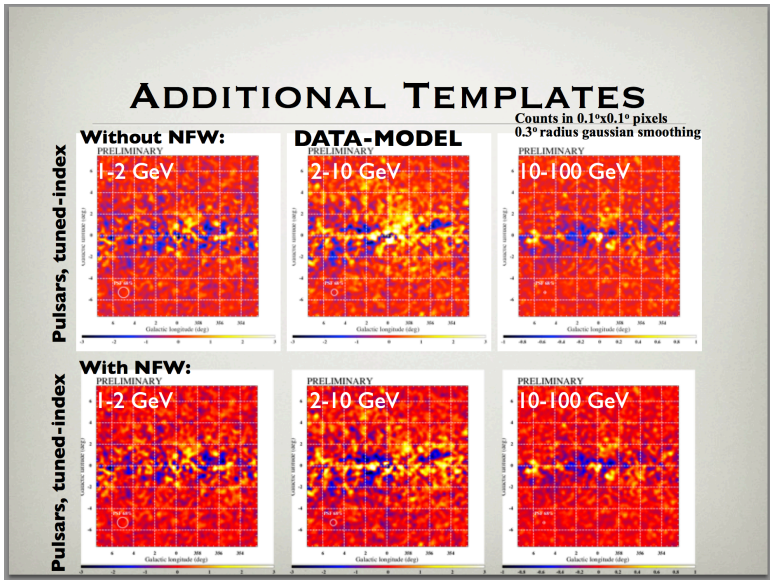
Possible hadronic scenario: (Crocker, Aharonian):
- Wind from SNRs produces CR during several billions of years
- Magnetic fields confine the CR in the bubble volume
- WMAP haze produced by ~ 30 GeV electrons in the SNR wind which have a characteristic cooling time ~ 10 Myr

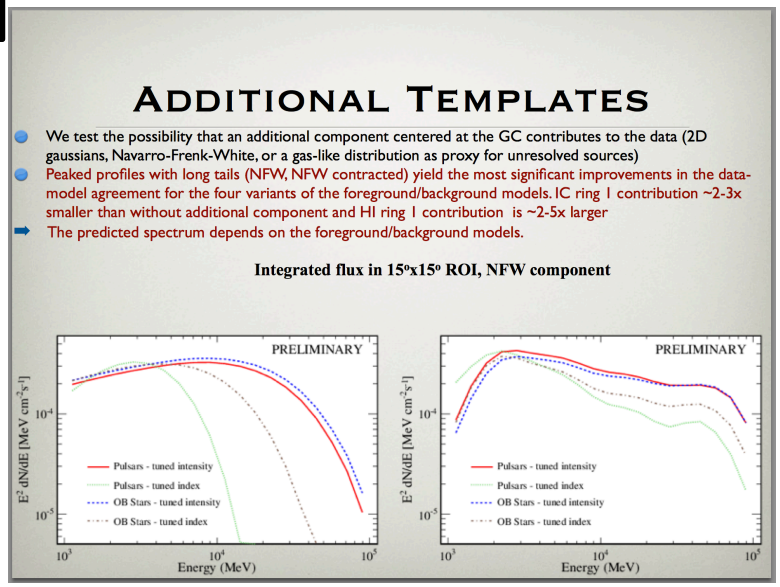
A. Franckowiak 15

- **Updated study of Fermi Bubbles**
  - **Iterative procedure to extract bubble morphology then fit for bubble spectrum**
  - **High-energy cutoff**
  - **North / south bubbles have similar spectrum**
  - **Evidence for cocoon, but not for jet**
- **Leptonic / Hadronic models both have strong / weak features**

Diffuse Emission from the Galactic Center

Murgia

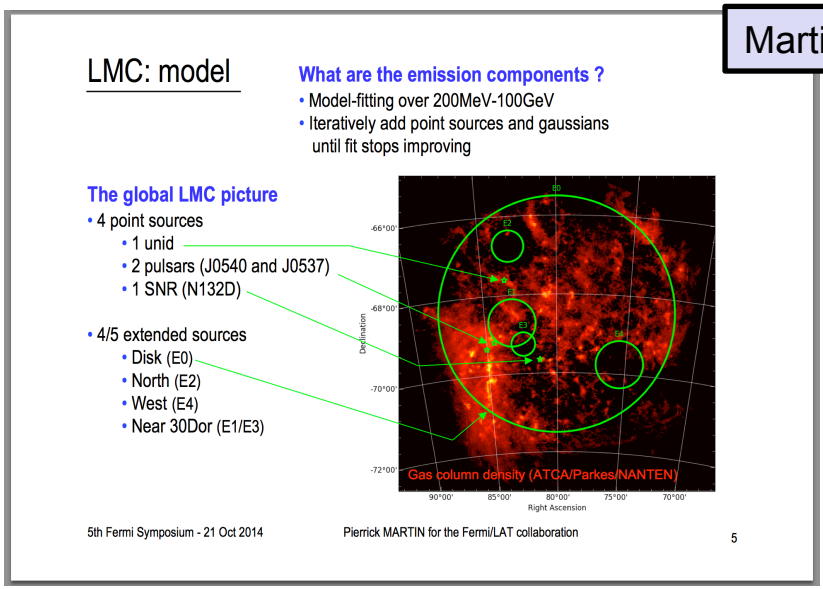




- **Template-based and GALProp-template hybrid analyses both find excess in the 2-10GeV range** Murgia / Casandjian / Linden / Calore
- **The best-fit spectrum and morphology depends somewhat on the modeling of the background / foreground**
- **One plenary & most of 1 parallel session on interpretations**
  - **More on this topic later**

"Galactic" Sources: Magellanic Clouds

Martin



- **Impressive Results from:**
  - **HESS -- TeV discovery of 3 sources in the LMC**
    - **Including 30 Doradus C superbubble**
  - ***Fermi*-LAT– Two pulsars and 1 SNR detected in LMC**
    - **Higher emissivity regions correlate with supergiant cavities / shells**

Active Galactic Nuclei

Reimer

Three corner marks

A. AGN AS A POPULATION AND THE BLAZAR PHENOMENON

Won't address here; see talks by Yoshiyuki Inoue, Markus Ackermann, Marco Ajello, Elisabetta Cavazzuti, Benoit Lott,…

B. THE PHYSICS OF GAMMA-RAY EMITTING AGN

Won't address misaligned AGN (see talks by Y. Fukuzawa, I. Edahiro, E. Meyer, K. Hada, J. Sitarek) or NLSy1 (see posters by F. D'Ammando, H. Shirakawa)

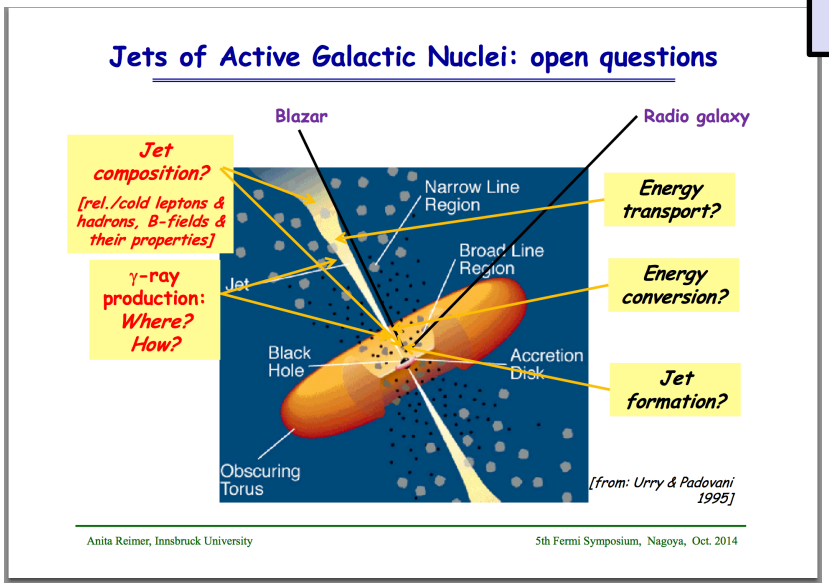
C. AGN AS A TOOL

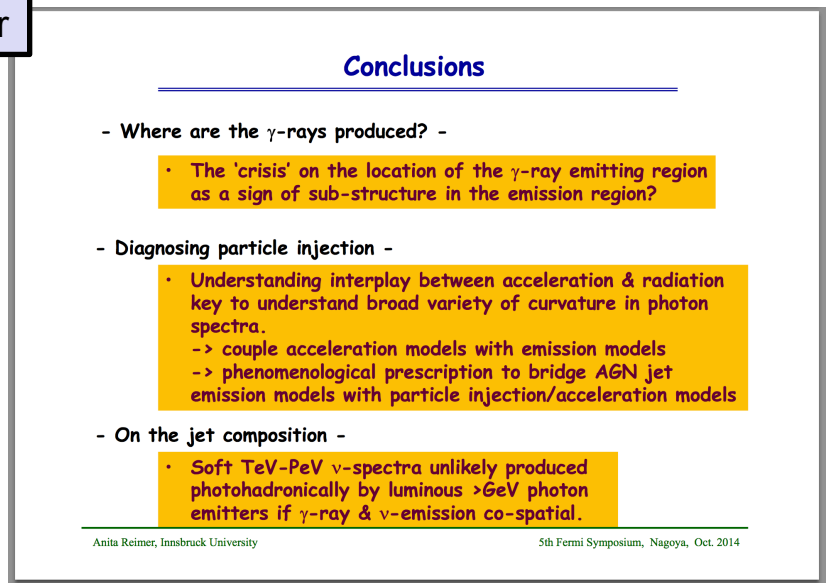
Won't address here; see poster by Alberto Dominguez on EBL

- **AGN are by far the largest source class in LAT catalogs**
  - **Many different ways to pursue science with AGN**

Gamma-Ray Emission from AGN

Reimer





- **Many important questions are still open**
- **Where are the gamma-rays coming from?**
  - **Doesn't always come from near SMBH**
- **Is there a single "Blazar sequence"?**
  - **Maybe, moving towards the "Blazar envelope"**

Tracking down AGN Emission Region w/ MW Data

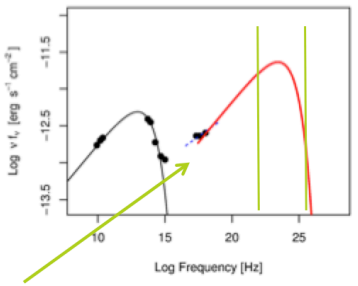
Meyer

The Test: How to Rule out IC/CMB

[Georganopoulos+ 2006]

The IC Component is a copy of the synchrotron, shifted in frequency and luminosity.

That shift is parameterized ONLY by B/δ, no other free parameters.



Getting the X-rays just right means fixing B/δ and consequently implies a high level of gamma-ray emission which should be detectable with Fermi

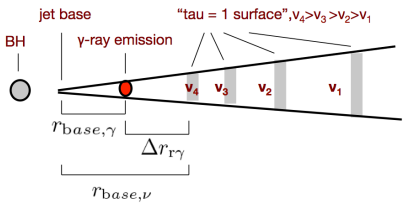
Larsson

Fuhrmann et al. 2013, MNRAS, 44

Locating the γ-ray emission

- radio/radio lags: "time delay core shifts" and VLBI proper motion
- "Königl type", continuous jet
- absolute distance of gamma-ray emission region to the jet base:

$$r_{base,\gamma} = r_{base,\nu} - \Delta r_{\gamma}$$

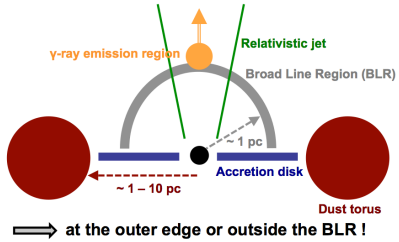


⇨ 3C 454.3 @ 3 mm:

Δr_{γ} = 1.0 +/- 0.5 pc

$r_{base,\nu}$ ~ 1.8 to 2.6 pc

⇨ $r_{base,\gamma}$ ~ 0.8 – 1.6 pc



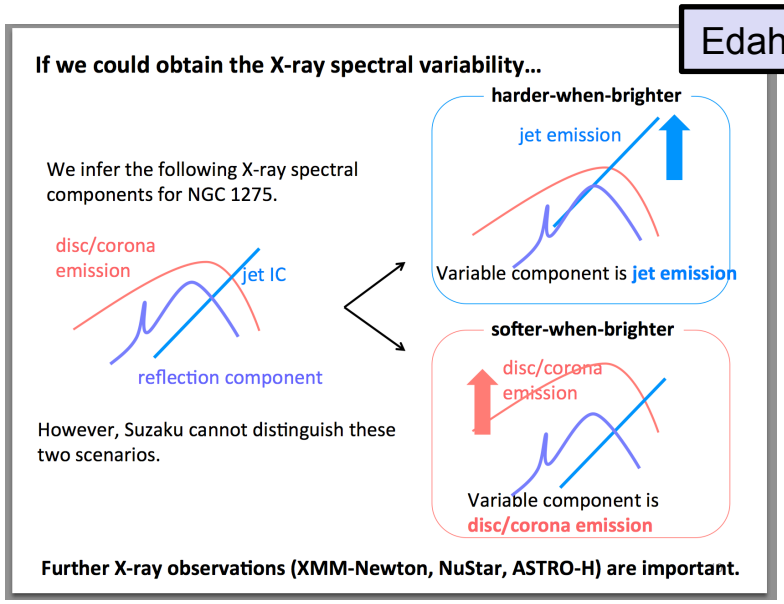
⇨ at the outer edge or outside the BLR !

5th Fermi Symposium– Nagoya, Japan – 20–24 October 2014

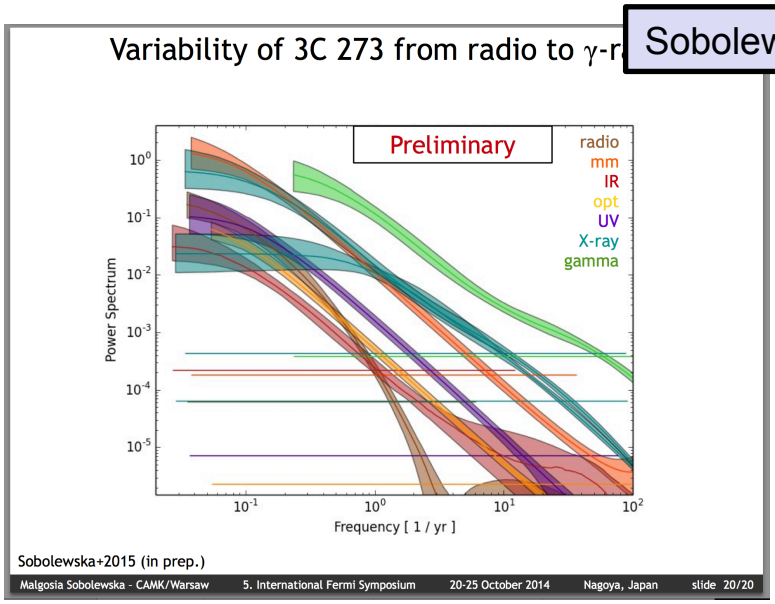
- **AGN jets resolved in Radio & X-ray data (for nearby sources)**
- **Correlated variability with gamma rays can help to establish emission region**
  - **Several cases where gamma rays appear to come from well downstream (~1-10 pc) in the jet**

Understanding AGN Variability

Edahiro



Sobolewska



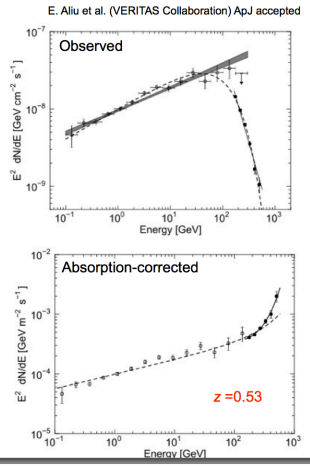
- **MW data help disentangle which spectral components are varying**
- **Stochastic processes at play, broadband study of variability power helps to test models**
- **Surprising observation of ~720 day periodic feature in gamma-ray, optical and radio bands in BL Lac object PG1553+133** Ciprini
  - **Dynamics near the SMBH**

AGN as a tool

Furniss

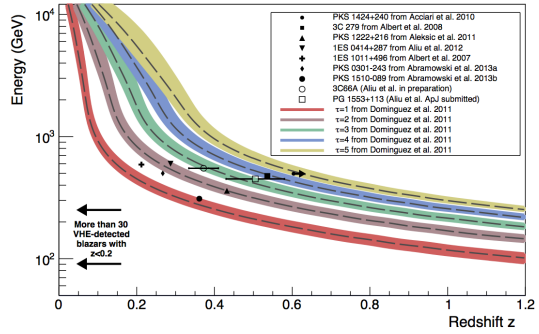
PG 1553+113

- Blazar detected between 160 and 560 GeV
- 0.395 ≤ z < ~0.58 from far UV observations
- 80 Hours of data from May 2010 to June 2012 show steady emission
- 7% Crab
- Place limits on the EBL or z assuming intrinsic emission does not show spectral hardening



The Gamma-ray Horizon

- EBL opacity curves (Dominguez et al. 2011)
- PKS 1424+240 probes an opacity of τ>5
- 3C 66A and PG 1553+113 also pushing up in opacity
- S3 0218+35 @ z=0.944 detected by MAGIC between 100-200 GeV probes < τ~2.5



- **AGN population at cosmological distances**
  - **Blazar are the brightest persistent objects in the universe**
  - **Gamma-rays from AGN probe much of the history of the Universe**
  - **At high-energy pair-production off of optical or infrared light will attenuate gamma-ray flux**

GRBs

Granot

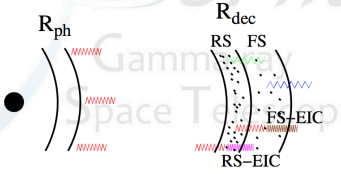
Synergies with other instruments & Conclusions

- Current: Swift, optical/radio telescopes, NuSTAR, Suzaku, TeV (HAWC, IACTs), …
- Multi-messenger: neutrinos (Ice Cube), UHECRs, gravitational waves
- Future: CTA, SVOM, LSST, ZTF, SKA, aLIGO/VIRGO, Astro-H, X/γ-ray polarimetry, ISS-lobster, …
- ***Fermi*** has greatly contributed to GRB science
- We got some answers, but more new questions
- ***Fermi*** GRBs also contributed to non-GRB science
- There is still a lot to look forward to…

Veres

Radiation Sources- Two Zone Model

- Synchrotron peak from photosphere, BB (Mészáros & Rees 2011)
- FS/RS synchrotron
- FS/RS SSC (Sari & Esin 2001)
- Prompt up-scatters on FS/RS electrons (Beloborodov 2005, Murase et al., 2011)
- BB+FS, BB+RS (Ryde 2005; Ando & Mészáros 2008)
- p^+ sync., FS+RS, RS+FS (Razzaque et al., 2009, He et al. 2011)
- Max synch./KN cutoffs (Guetta & Granot 2003)

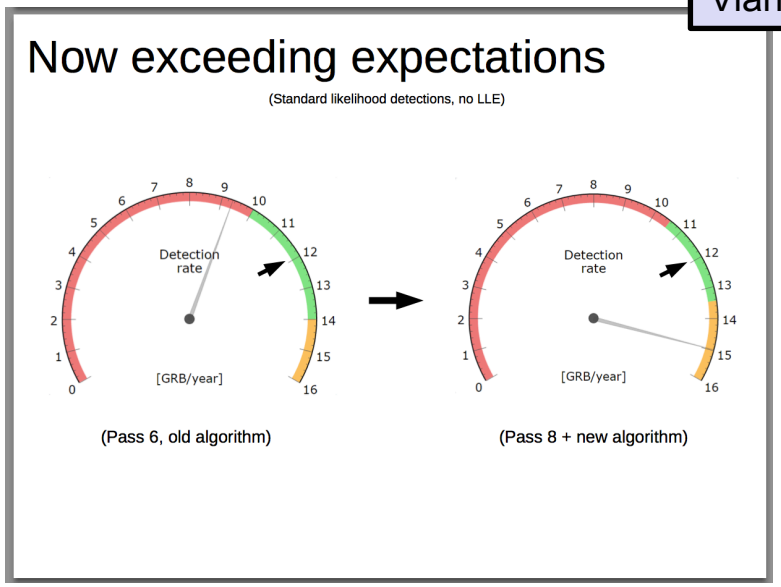


Péter Veres (GWU) 名古屋市 (Nagoya) October 24, 2014 4 / 13

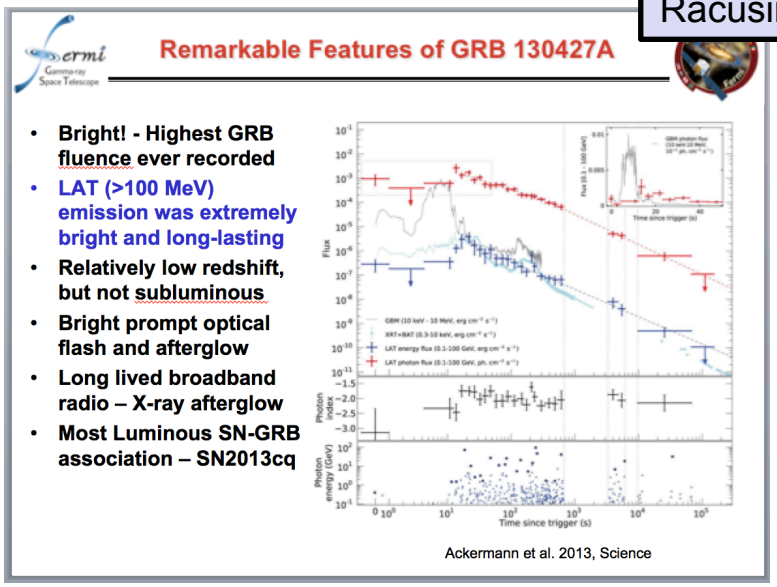
- **Understanding of GRBs has changed with *Fermi* data**
  - **Distinct High-energy components to emission**
  - **Temporal lags between MeV and GeV emission**
- **This has prompted development of new models**
- **Pass 8 model great promise below 100 MeV**
  - **Also much large effective LAT field-of-view**

Many More GRBs, and one very Special GRB

Vianello



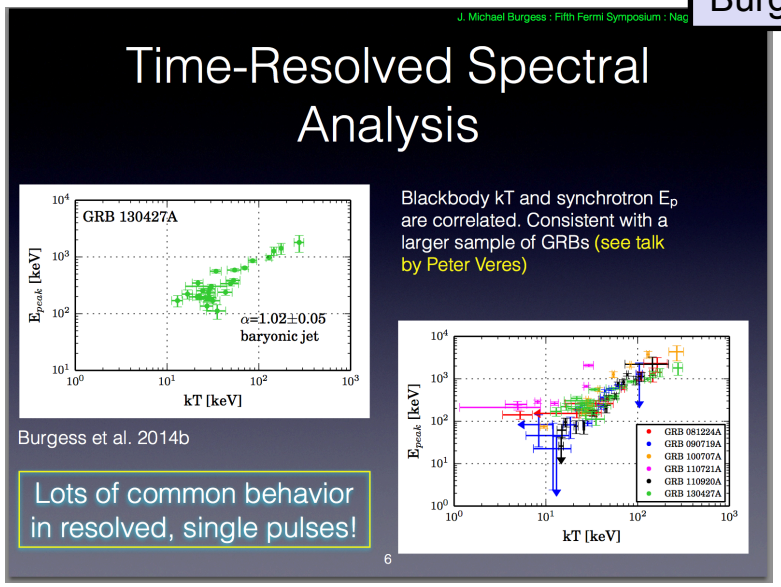
Racusin



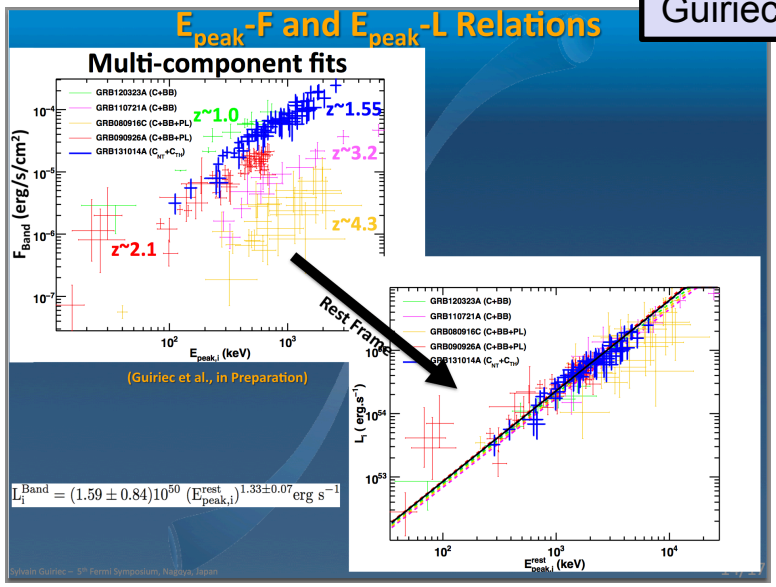
- **Unrelated improvements have significantly increase the number of LAT-detected GRBs (now up to 100)**
  - **Pass 8 reconstruction**
  - **GRB search algorithm**
- **Unprecedented quality data from GRB 130427A give us a new view of GRB physics**

Moving Beyond the "Crisis of the Band Model"

Burgess



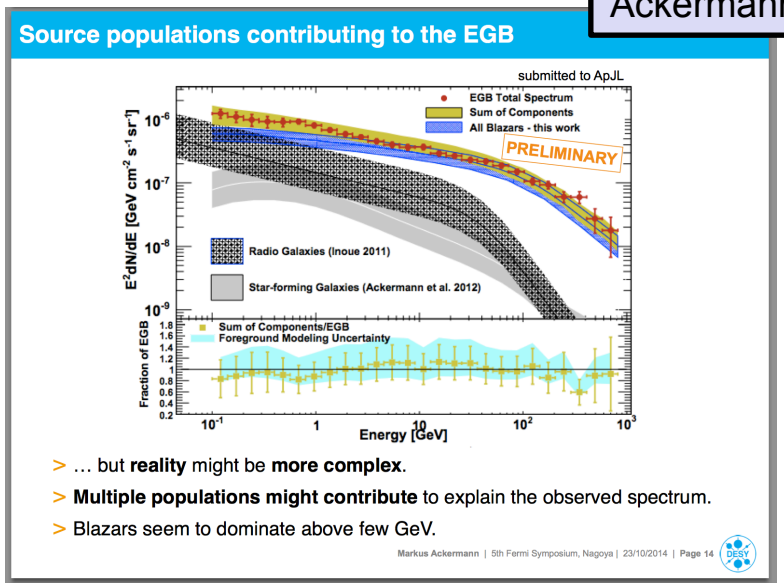
Guiriec



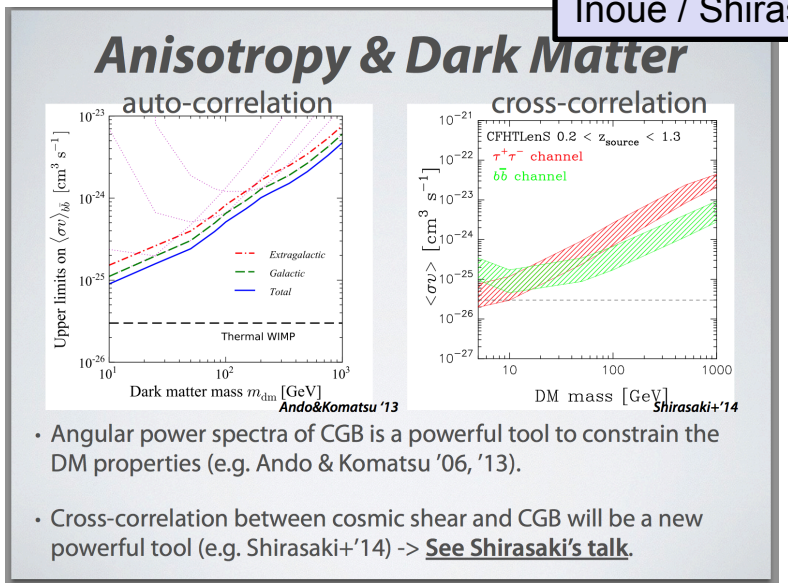
- "Crisis of the Band Model" was a bit topic at 4th Fermi symposium
  - Phenomenological Band model no longer adequate to explain GRB spectra
- New efforts to move beyond the Band Model
  - Physically motivated modeling (e.g. Burgess)
  - Testing consistency of extra components beyond Band model (e.g., Guiriec)
- Much more detailed modeling — Veres

Isotropic Diffuse Emission

Ackermann



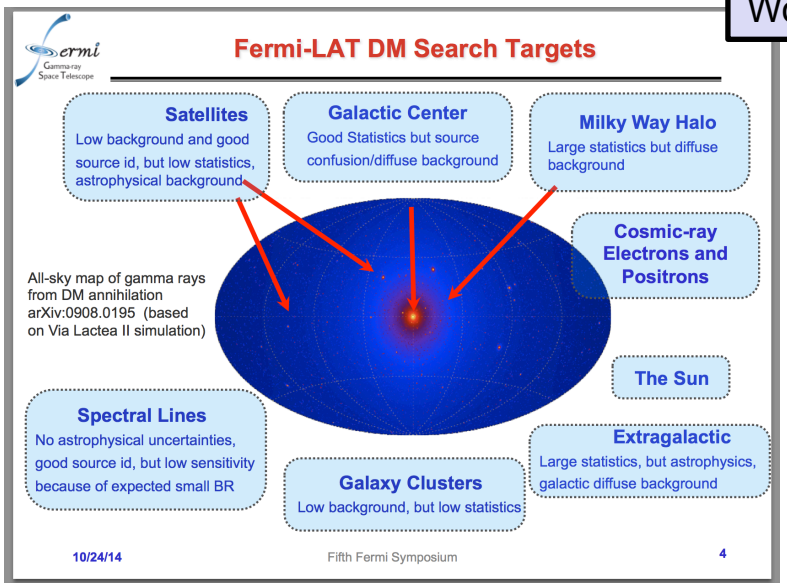
Inoue / Shirasaki



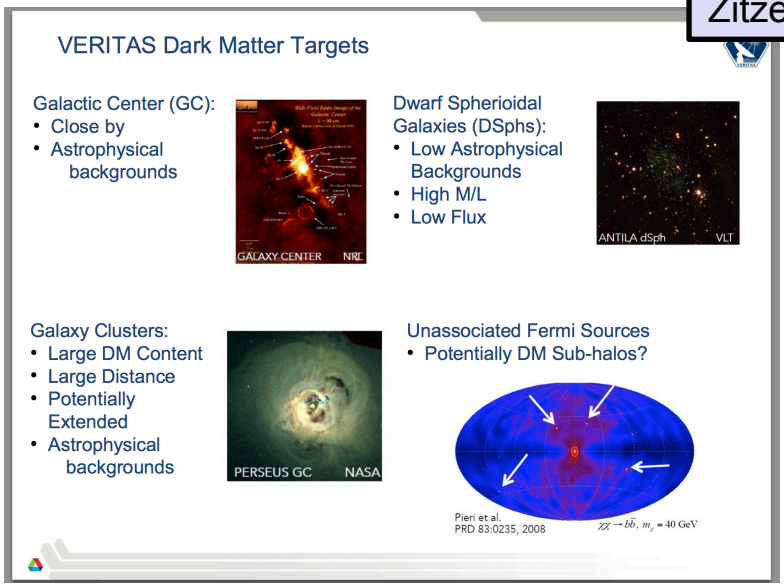
- **Isotropic gamma-ray background (IGRB) from 100MeV to > 500 GeV**
  - **Spectral rollover above 100 GeV**
- **Unresolved blazars, other AGN & starburst galaxies appear to account for most of the IGRB**
- **More information can be obtained from anistropy or cross-correlation analyses**

Dark Matter Searches

Wood



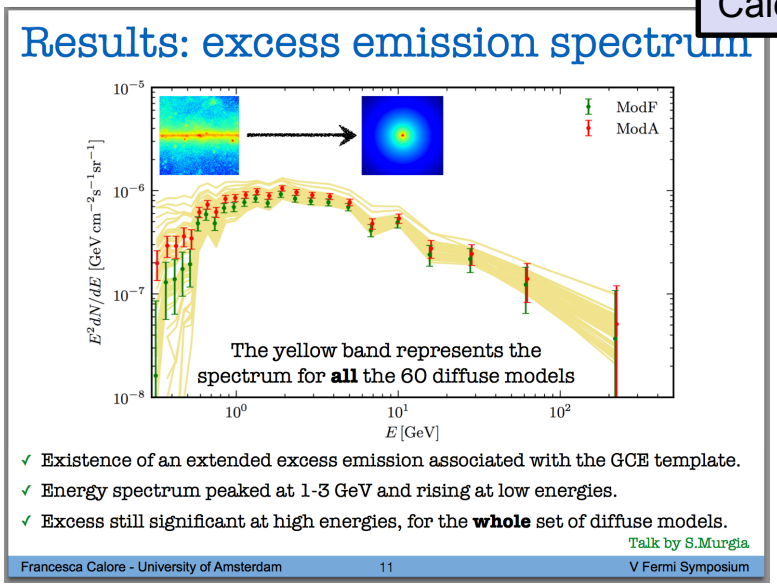
Zitzer



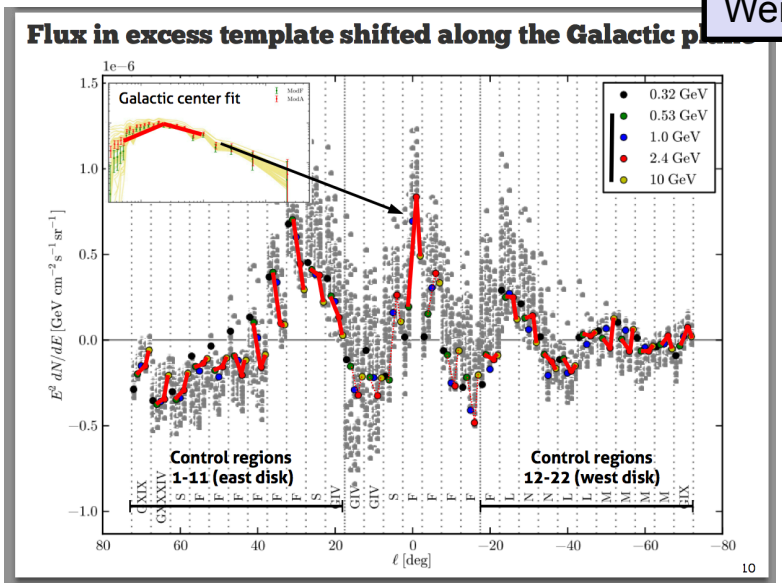
- **Very nice summaries of DM searches from Wood (mainly LAT) and Zitzer (Veritas)**
  - **Wide variety of search targets, most have no observed signal**
  - **GeV Galactic center excess (more later) and positron fraction are main potential signals**
    - **Possible alternative astrophyscial interpretations**
- **Also, a comprehensive talk about primordial black holes** MacGibbon
- **GBM search for spectral lines from sterile neutrinos** Horiuchi

Galactic Center Excess Uncertainties

Calore



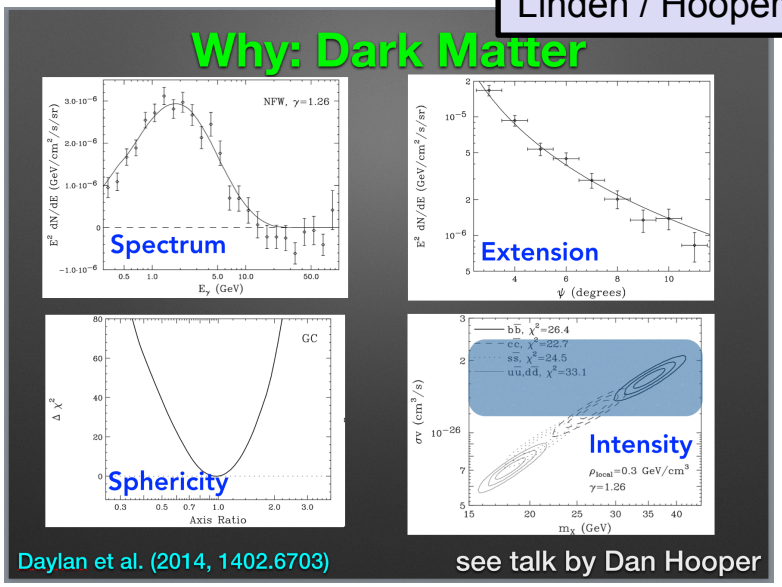
Weniger



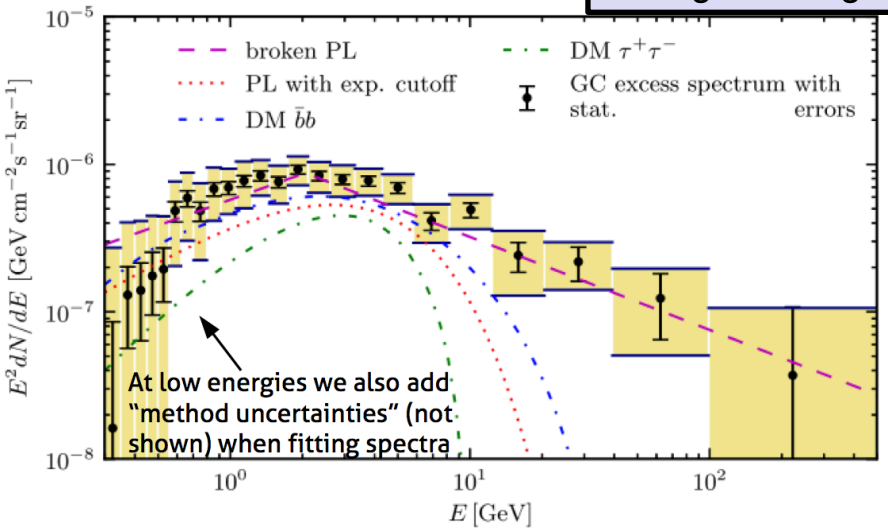
- **Very impressive talks by Calore & Weniger characterizing systematic uncertainties in studying Galactic center excess**
  - **Probing of family of GALProp-based foreground models**
  - **Empirically quantify goodness-of-fit of foreground/background models using control regions along the Galactic plane**
- **GC-excess is robust against systematic uncertainties**
  - **Morphology is also robust. Spectrum less so, broken power law is equally good fit as DM bb spectrum**

Galactic Center Excess Interpretation

Linden / Hooper

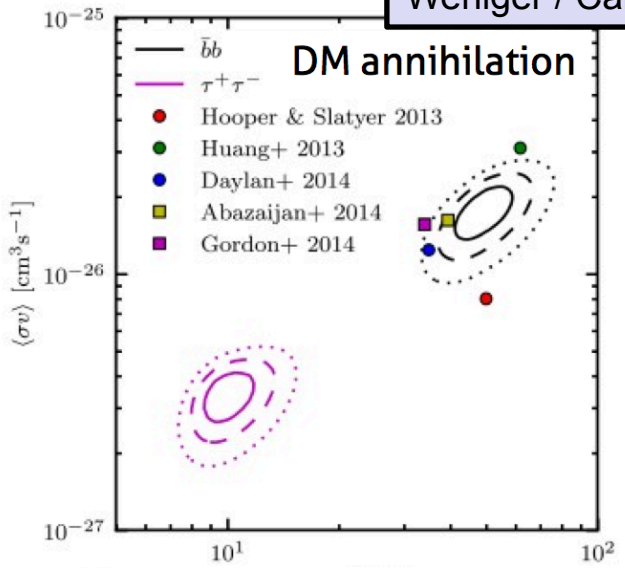


Weniger / Murgia



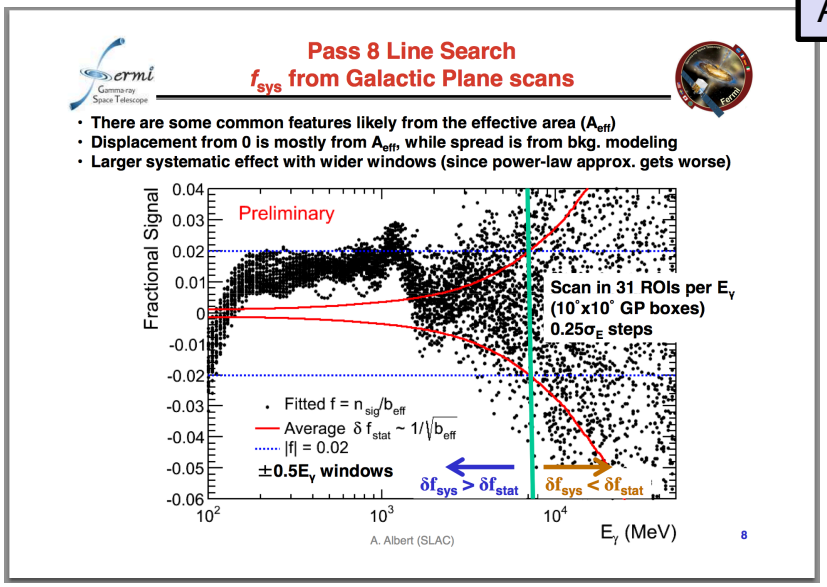
- **GC excess is consistent with DM interpretation in several ways**
  - **Sphericity, extension and intensity disfavor some other proposed interpretations**
- **Most favored DM fits cluster near 3σ contours of Calore et al. DM bb**
  - **<σv> ~ 2e-26 Mχ ~ 50 GeV**

Weniger / Calore

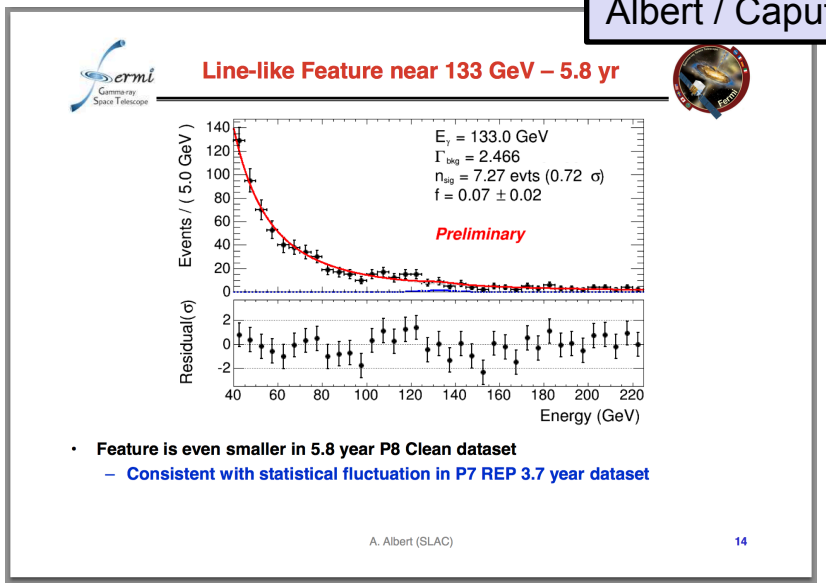


Spectral Line Search / 135 GeV Line Feature Update

Albert



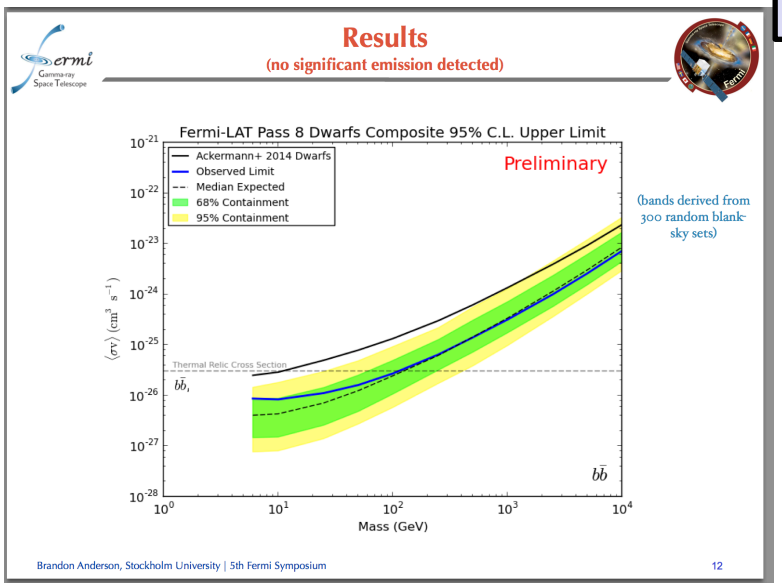
Albert / Caputo

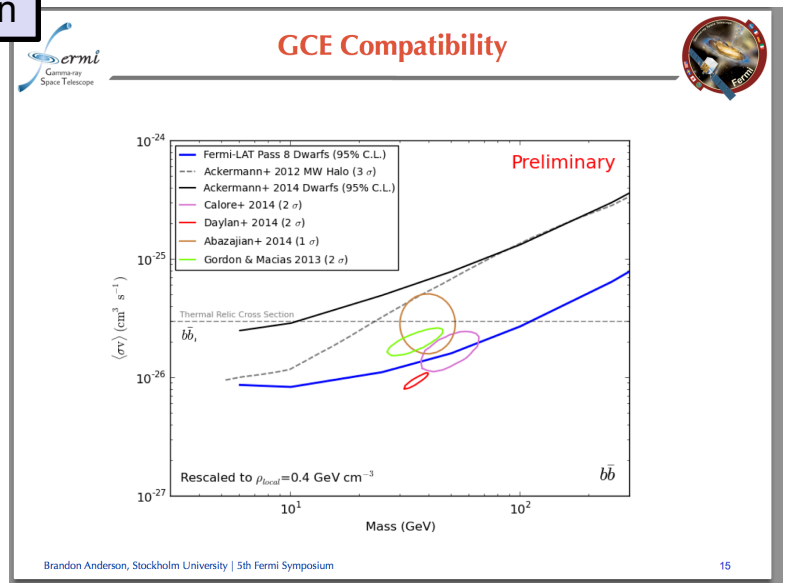


- "Low energy" (< 10 GeV) line search was systematically dominated
  - Empirically quantified systematic uncertainties with scan of control region
- 135 GeV Feature has faded into obscurity (0.7σ pre-trial)

Dwarf Spheroidal DM Search

Anderson



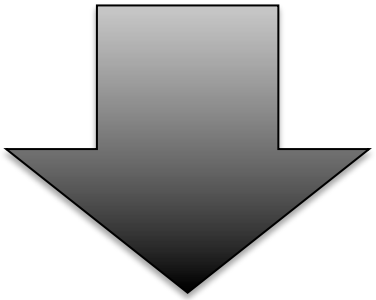


- **Updated stacked Dwarf Spheroidal search to Pass 8**
- **No signal observed, new upper limits fall very close to expected values**
- **Limits are "in tension" with favored regions from GC analysis**
  - **Note however that GC analysis error ellipses don't include scaling uncertainties from DM density**

OUTLOOK

New Data Feeds Discoveries

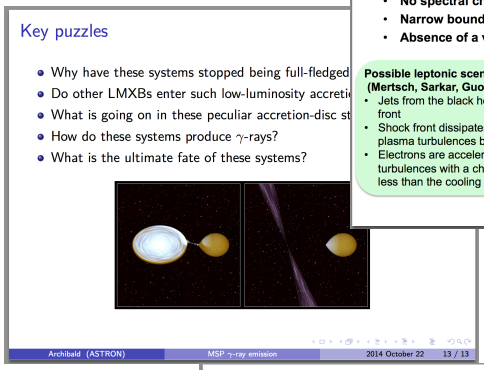
- Pass 8 data opens LAT low-energy range
- 3FGL catalog and various source class specific catalogs will be a key element of many upcoming multi-wavelength studies

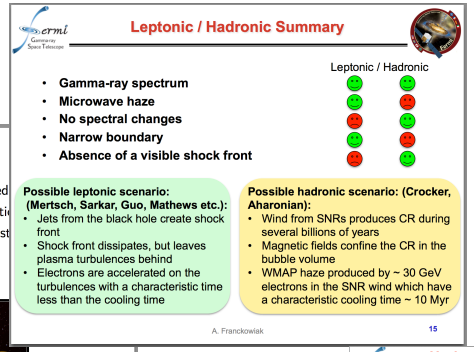


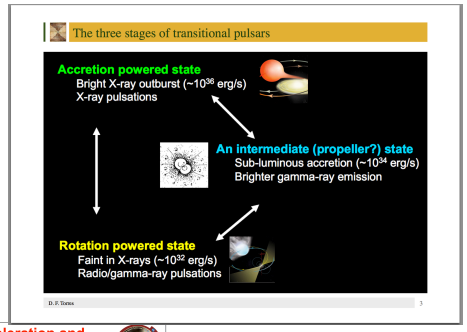
Highlights from the 6th Fermi Symposium

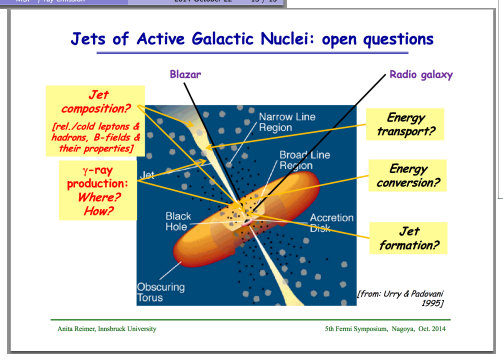
- New discoveries and models facilitated by 3FGL catalog
- 4FGL catalog (Pass 8 based)

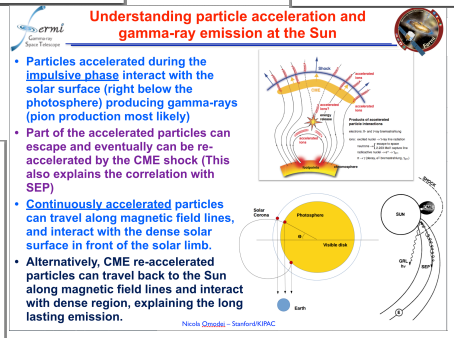
Many New Questions Posed at This Meeting

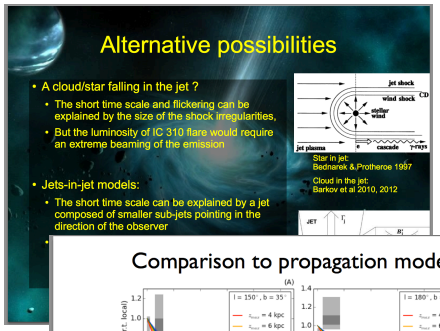


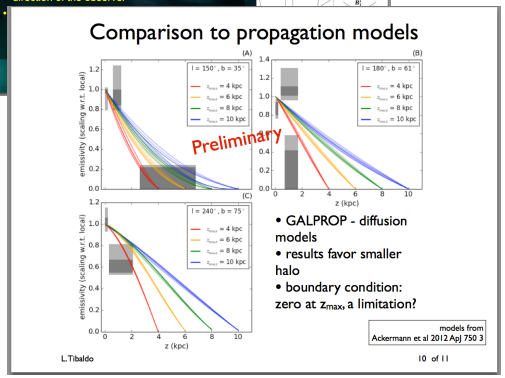












Otsukaresama deshiita!

"I see you have been working very hard!" or maybe "Good job!"

Fermi
Gamma-ray
Space Telescope

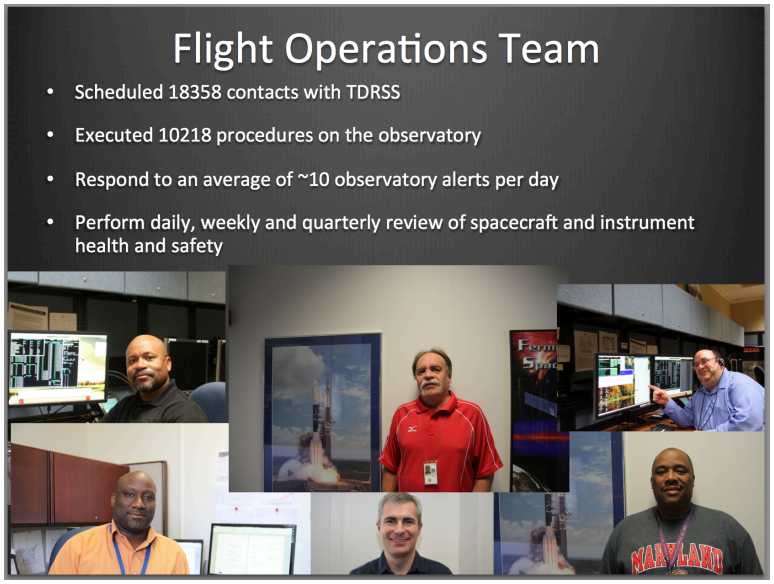
有難う 御座います

Thanks!!!

Local Organizing Committee

Lynn Cominsky
Yasushi Fukazawa
J.D. Myers
Tsunefumi Mizuno
Judy Racusin
Hiromitsu Takahashi
Hiro Tajima
Yasuyuki Tanaka
Toni Venters

Julie McEnery
and the Flight Operations Team



NASA, DOE & international agencies supporting the mission

Science Organizing Committee

Markus Ackermann
Bill Atwood
Ronaldo Bellazzini
Roger Blandford
Elliott Bloom
Philippe Bruel
Fernando Camilo
Patrizia Caraveo
Dan Castro
Elisabetta Cavazzuti
Jan Conrad
Guillaume Dubus
Justin Finke
Yasu Fukazawa
Isabelle Grenier
Jochen Greiner
Nobu Kawai
Julie McEnery
Peter Michelson
Nicola Omodei
Bill Paciesas
Judy Racusin
Steve Ritz
Chris Shrader
Hiro Tajima
Tad Takahashi
Yasunobu Uchiyama
Anna Watts
Colleen Wilson-Hodge

Contributors & Session Chairs

有難う 御座います

Preparation & Organization
Yamoka-san
Fukazawa-san
Tajima-san

SOC Organization
McEnery-sensei
Racusin-san

Running the Symposium
Takahashi-san
Mizuno-san

Graduate students who did the actual work
Edahiro-san (Hiroshima Univ.)
Kawaguchi-san (Hiroshima Univ.)
Kawashima-san (Nagoya Univ.)
Kinoshita-san (Nagoya Univ.)
Shirakawa-san (Hiroshima Univ.)