

National Aeronautics and Space Administration



Fermi
Gamma-ray Space Telescope

www.nasa.gov/fermi

The Fermi Observatory Status and Prospects

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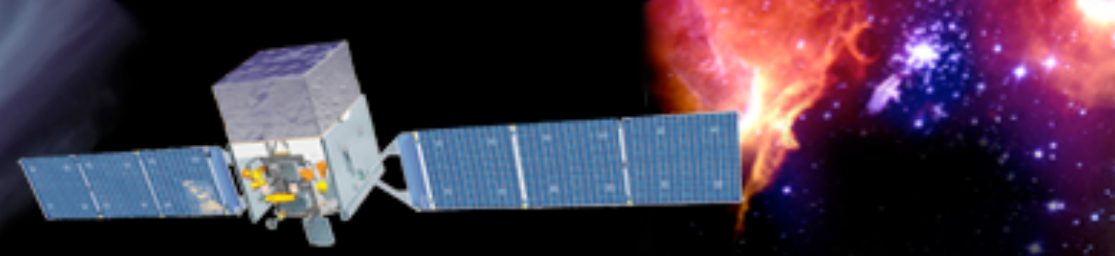
on behalf of the Fermi-LAT collaboration

Vulcano Workshop 2016



Fermi

Gamma-ray Space Telescope



Outline

❖ The Fermi Observatory

- ❖ present and future

❖ Science Highlights

- ❖ themes and techniques

The Fermi Observatory

Large Area Telescope (LAT) - pair conversion telescope

- 20 MeV – > 300 GeV

Huge field of view (2.4sr)

- 20% sky any instant
- All sky for 30' every 3h

Huge energy range

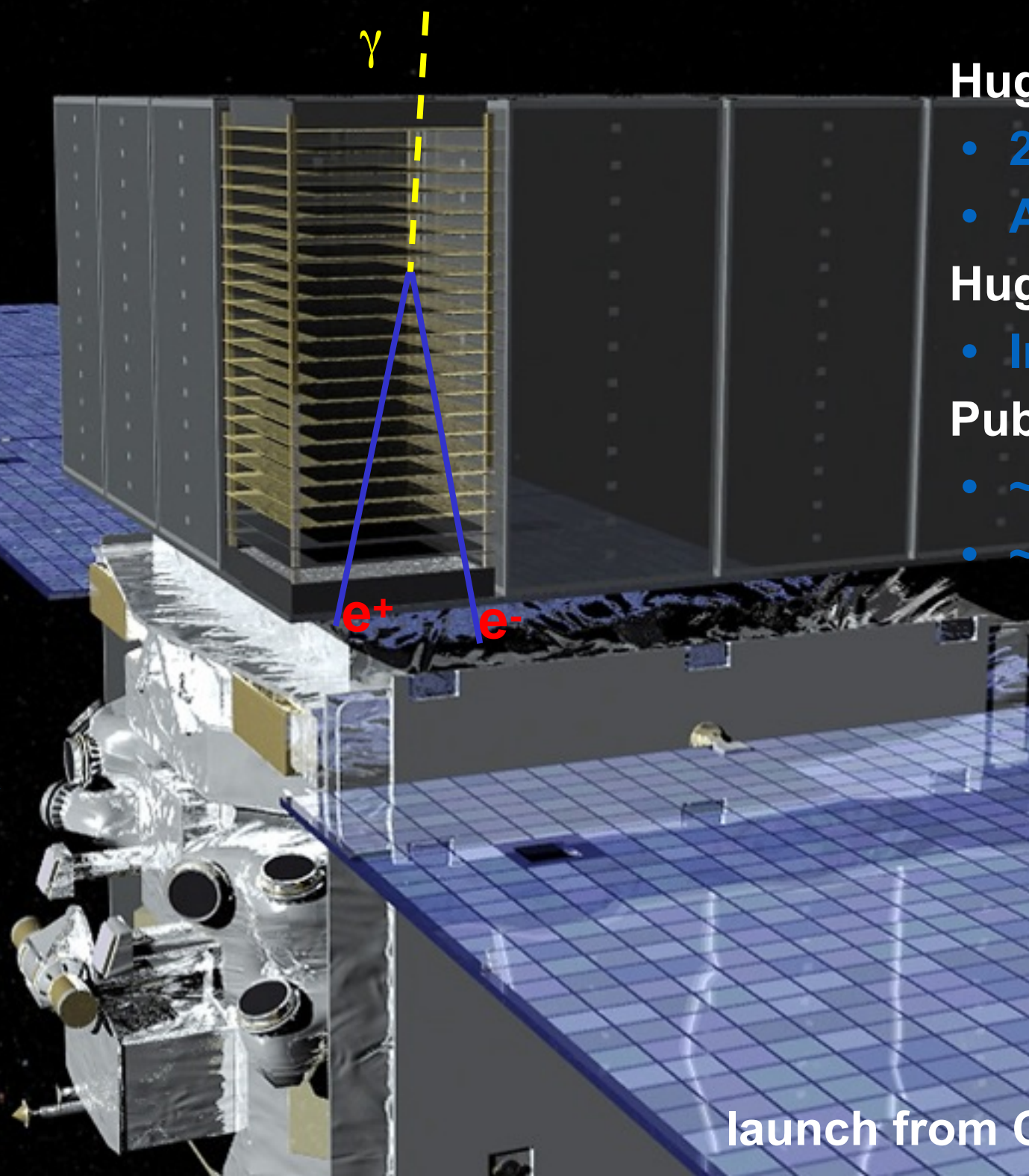
- Including 10-100 GeV

Public data

- ~400 collaboration papers
- ~2400 total nb of papers

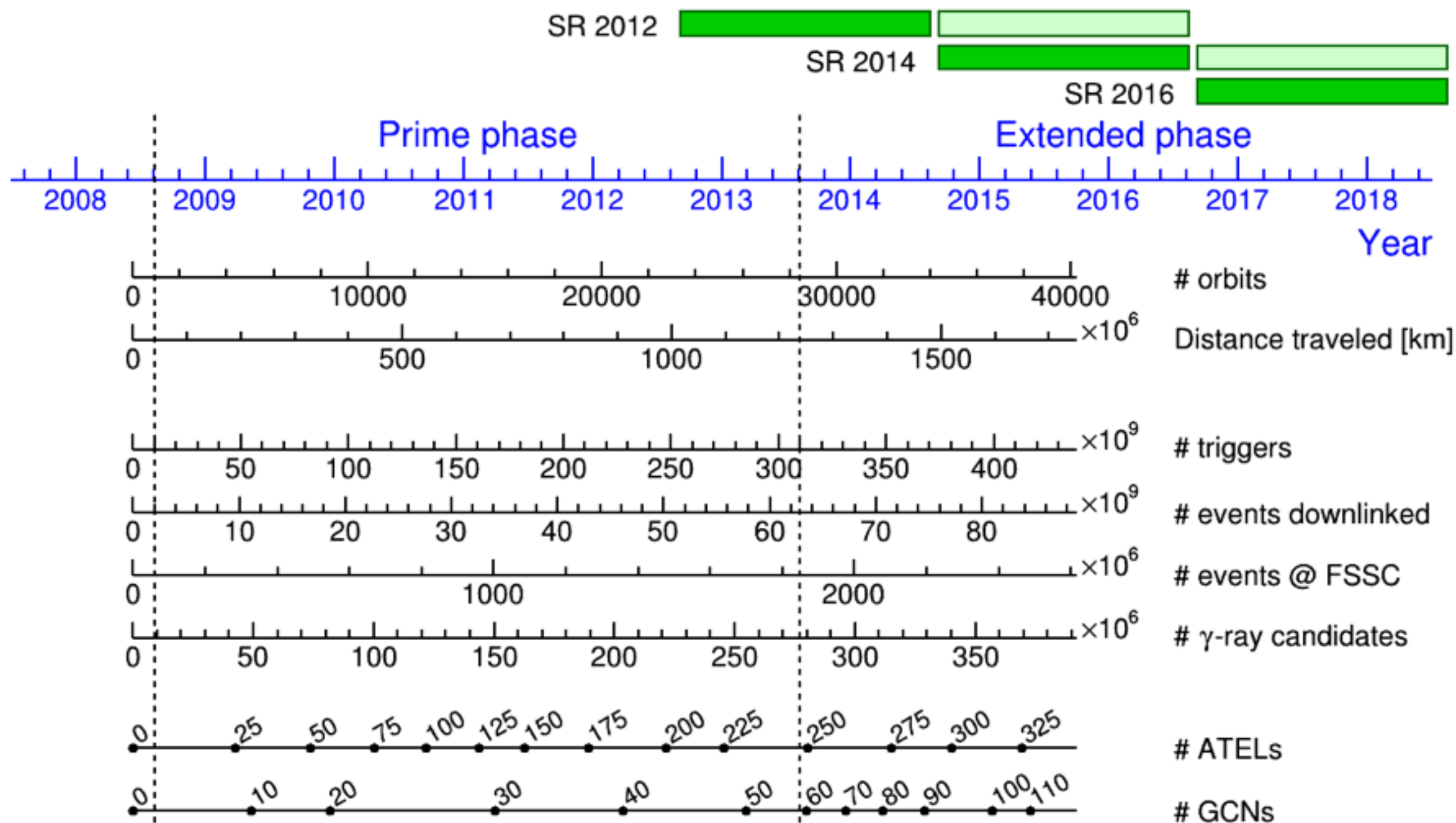
Gamma-ray Burst Monitor (GBM) - counters

- 8 keV – 40 MeV



launch from Cape Canaveral 11-6-2008

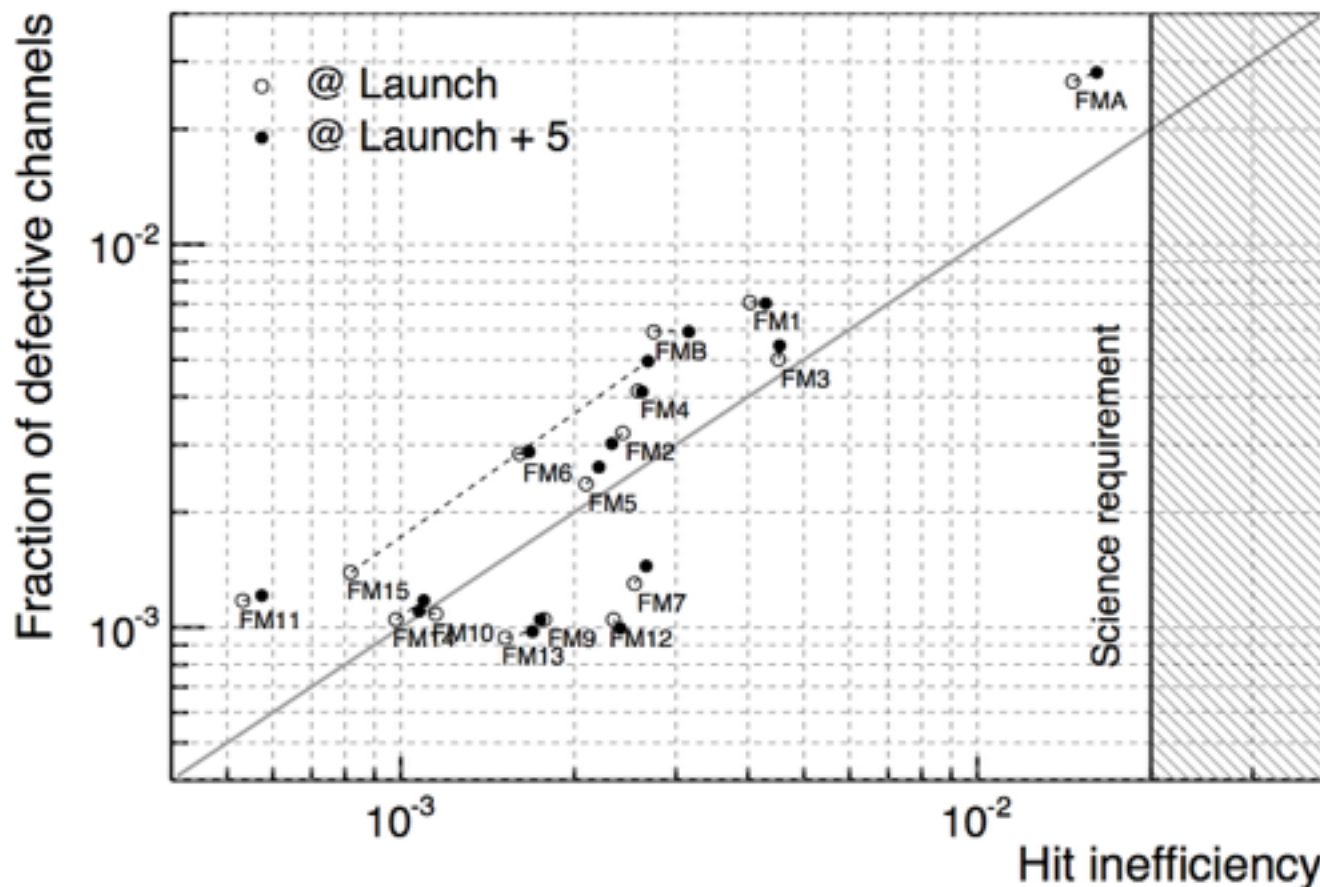
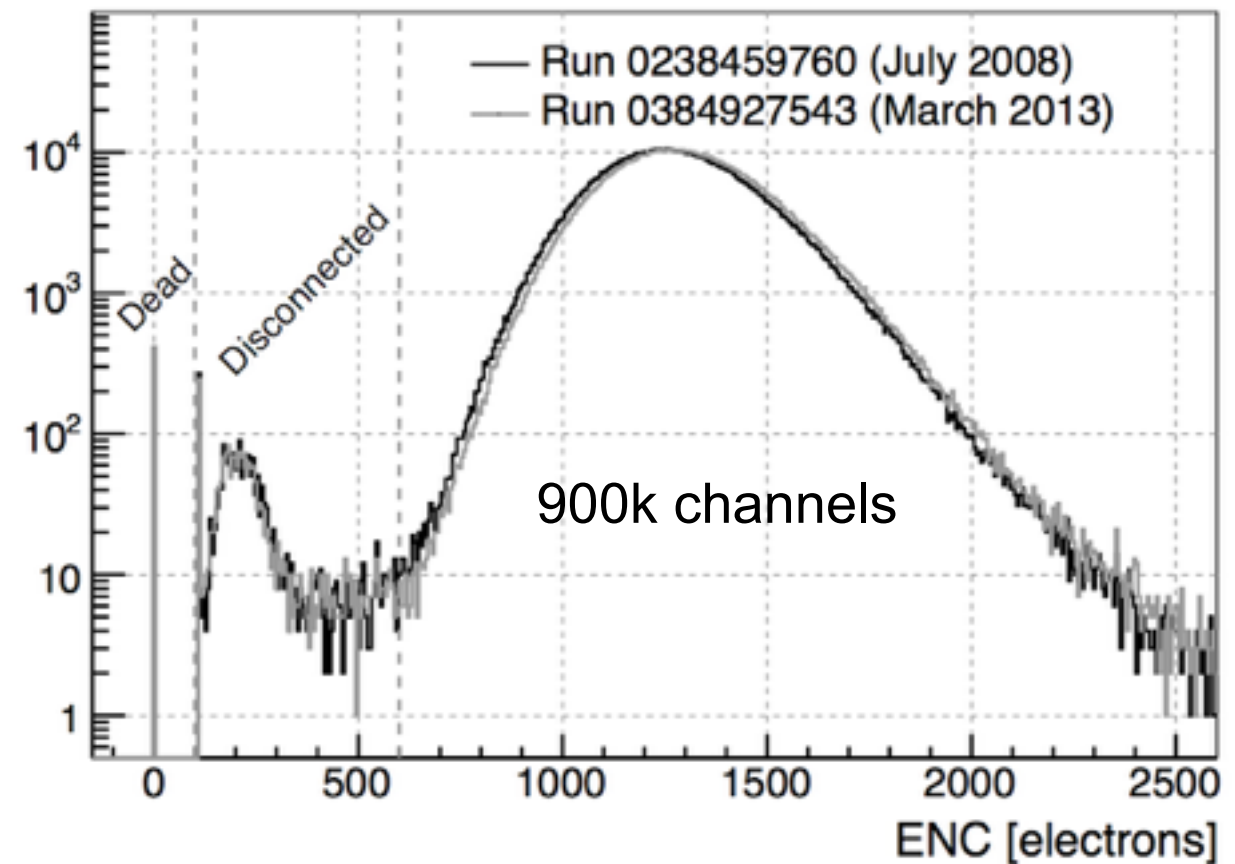
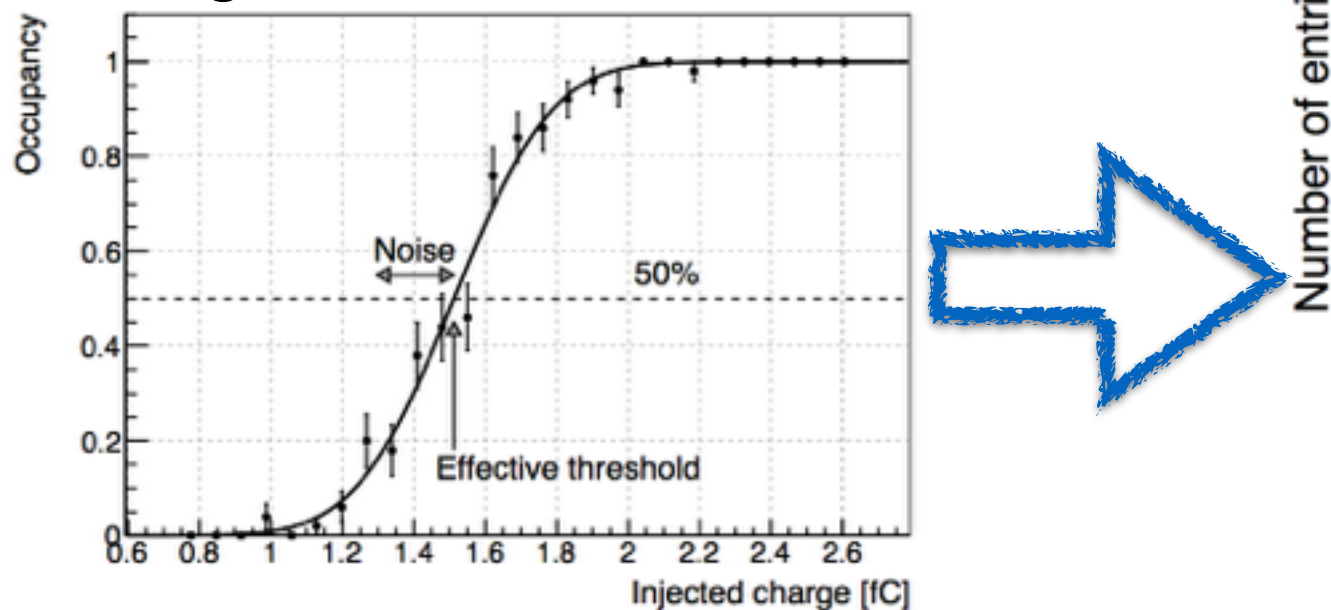
Mission timeline



Extend operations through NASA Senior Reviews (SR)
Spring 2016 SR to confirm operations through 2018 and recommend
through 2020 - <http://science.nasa.gov/astrophysics/documents>

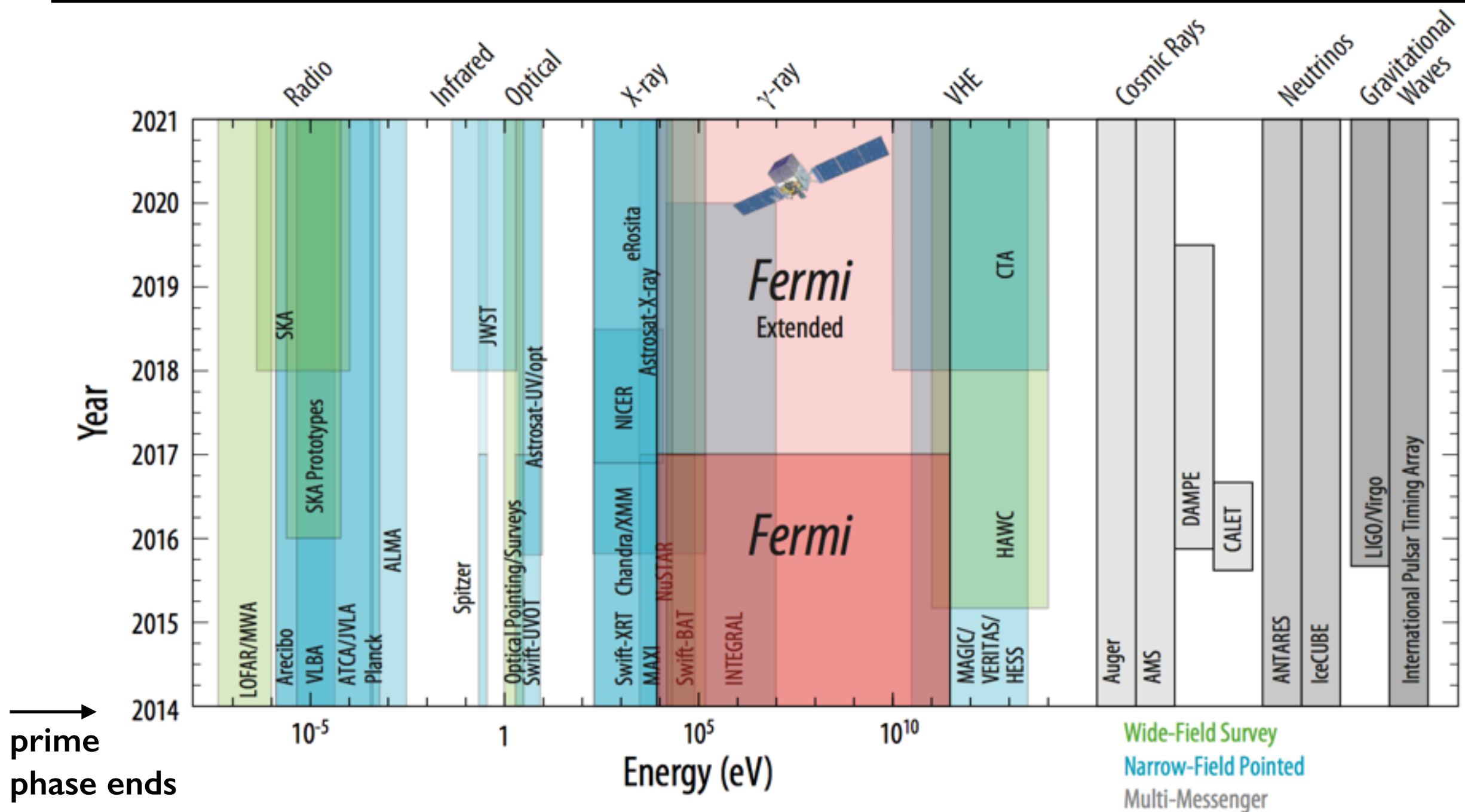
Status of the LAT telescope

single TKR channel noise calibration



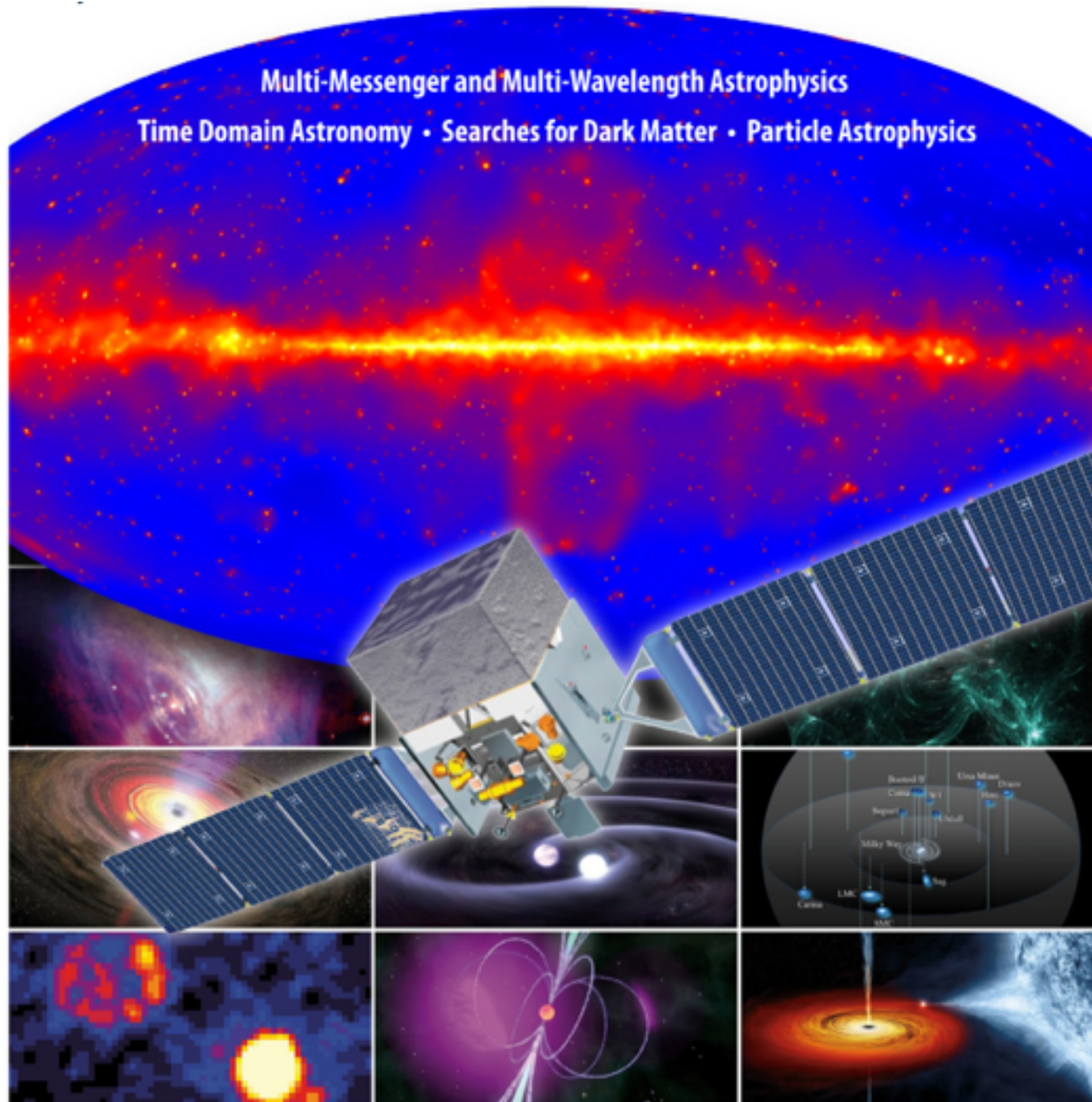
- ❖ 73m² active silicon, 900k chans
 - ▶ ~ATLAS Silicon tracker
- ❖ stable performance
 - ▶ +~2% noisy chans in 5 yrs
- ❖ similar stability in ACD and CAL
 - ▶ ~1% CAL aging in 2 yrs
- ❖ ~hrs/year spent in calibrations

Operating context



- ❖ enhanced multi-messenger/wavelength opportunities
- ❖ Fermi unique all-sky monitor in a broad energy range

Science themes



❖ Messengers

- ▶ gammas, electrons

❖ Time

- ▶ ms transients to multi-year periodicities

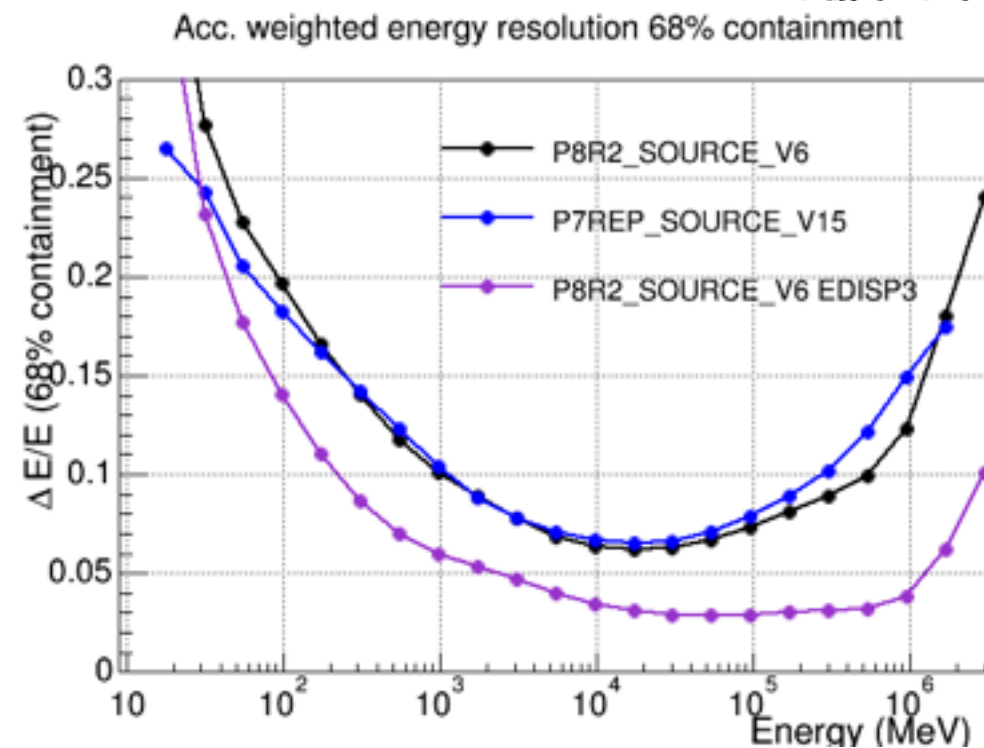
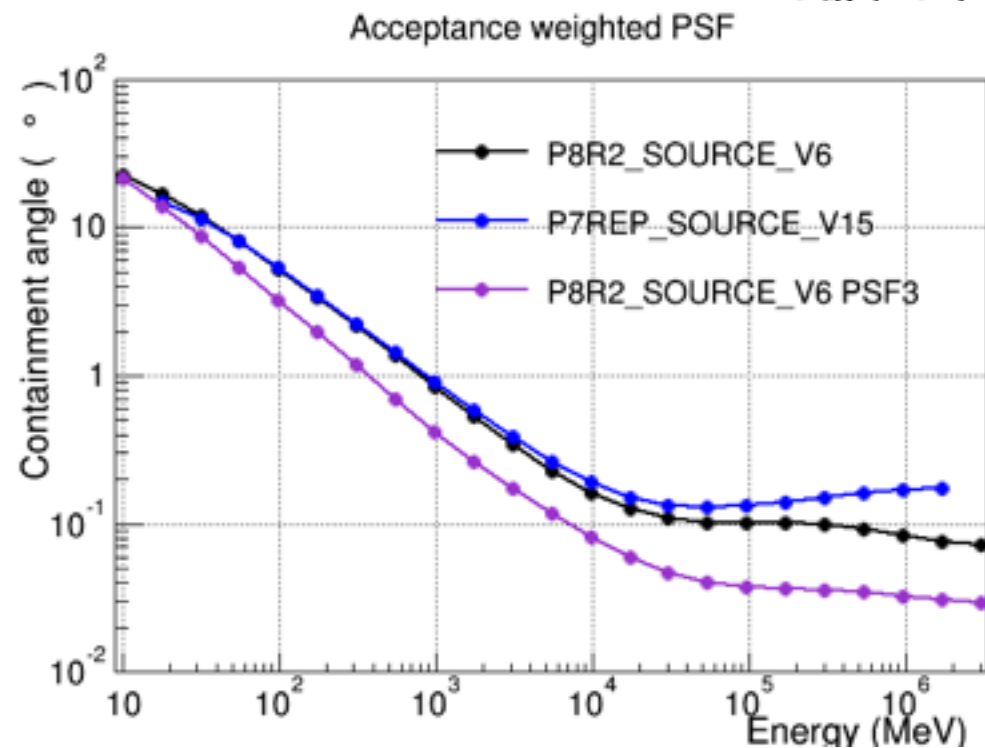
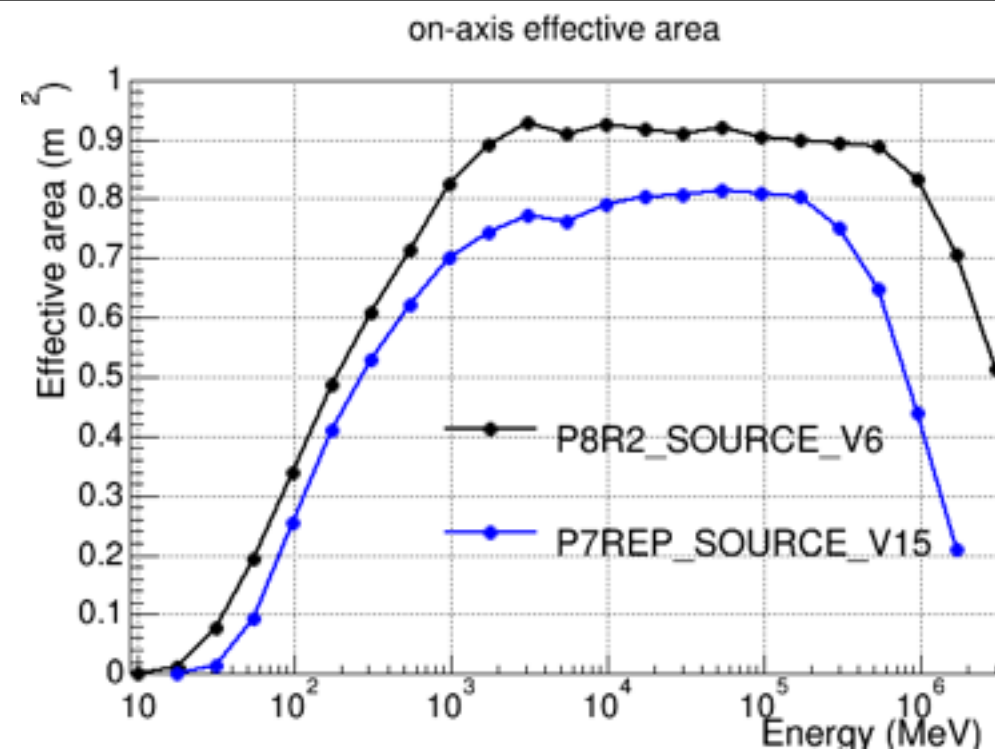
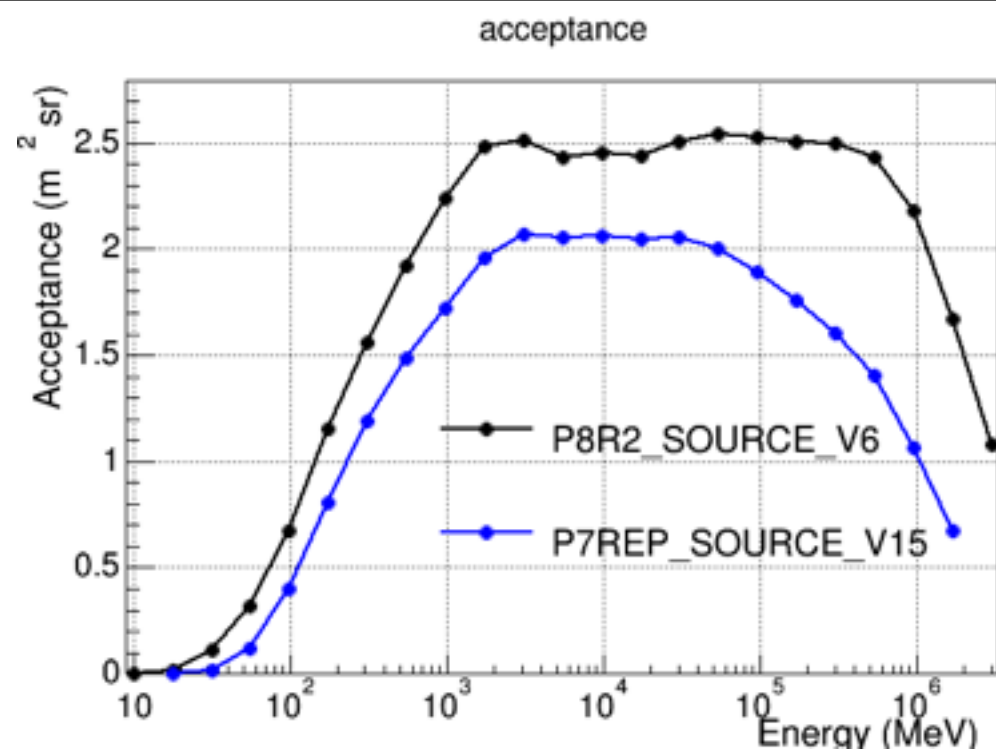
❖ Dark Matter

- ▶ WIMP and axion candidates

❖ Particle Astrophysics

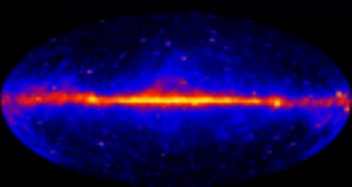
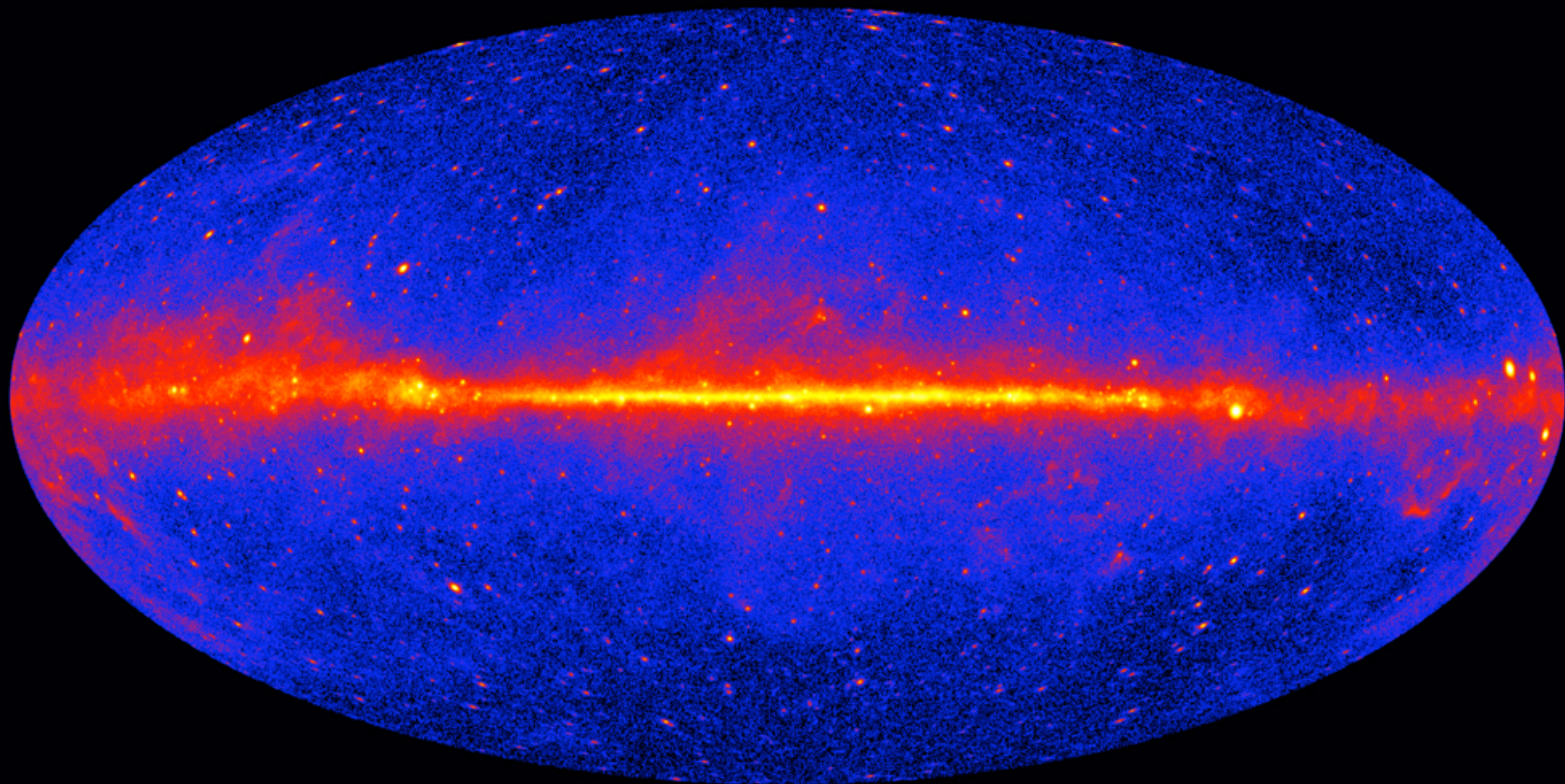
- ▶ CR acceleration sites and mechanisms

LAT performance



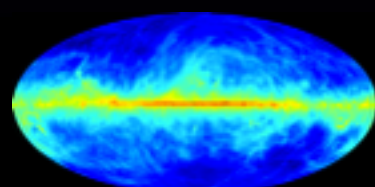
- ❖ larger energy range, higher acceptance, better resolution
- ❖ *Pass 8* performance and data publicly released June 2015

The Fermi γ -ray sky



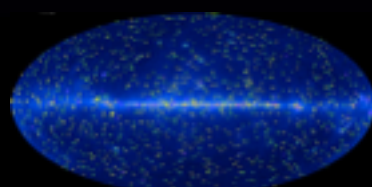
GeV Sky

=



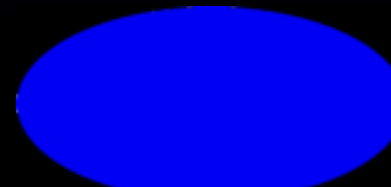
Galactic

+



Point Sources

+



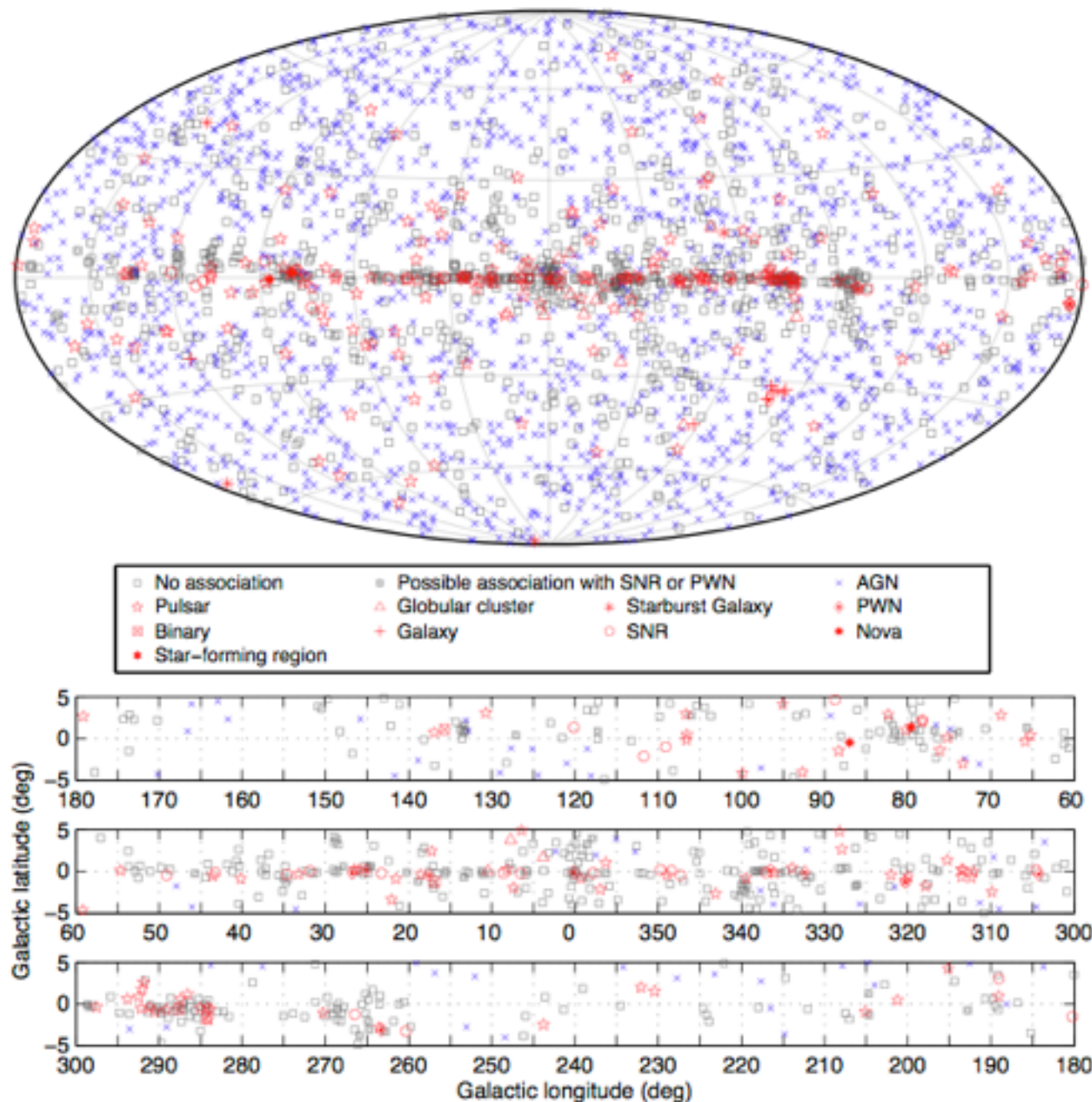
Isotropic

+

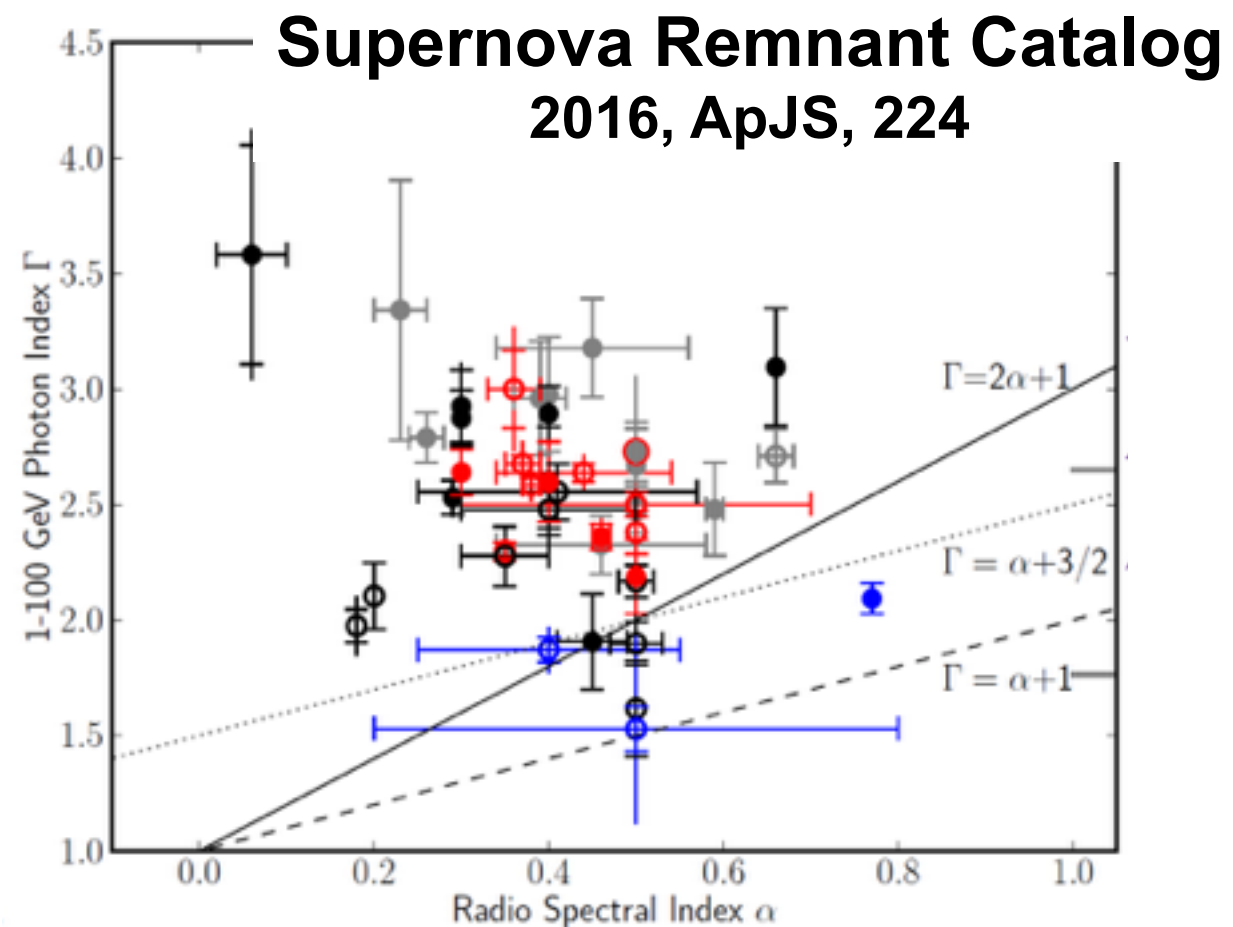
???

next slides show examples of each component

Source catalogs



4 years 3FGL catalog - 3000+ sources
2015, ApJS, 218, 23

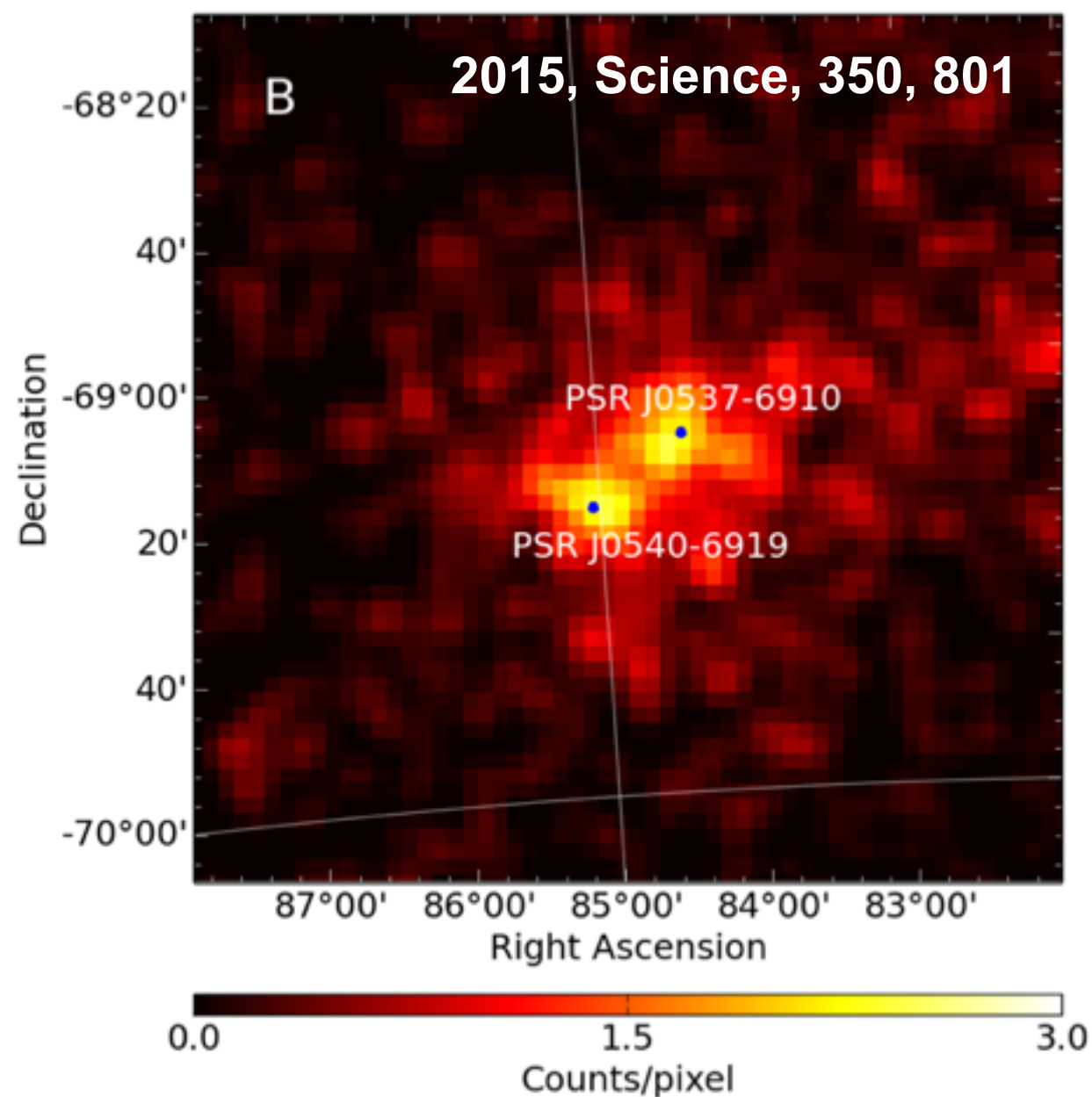
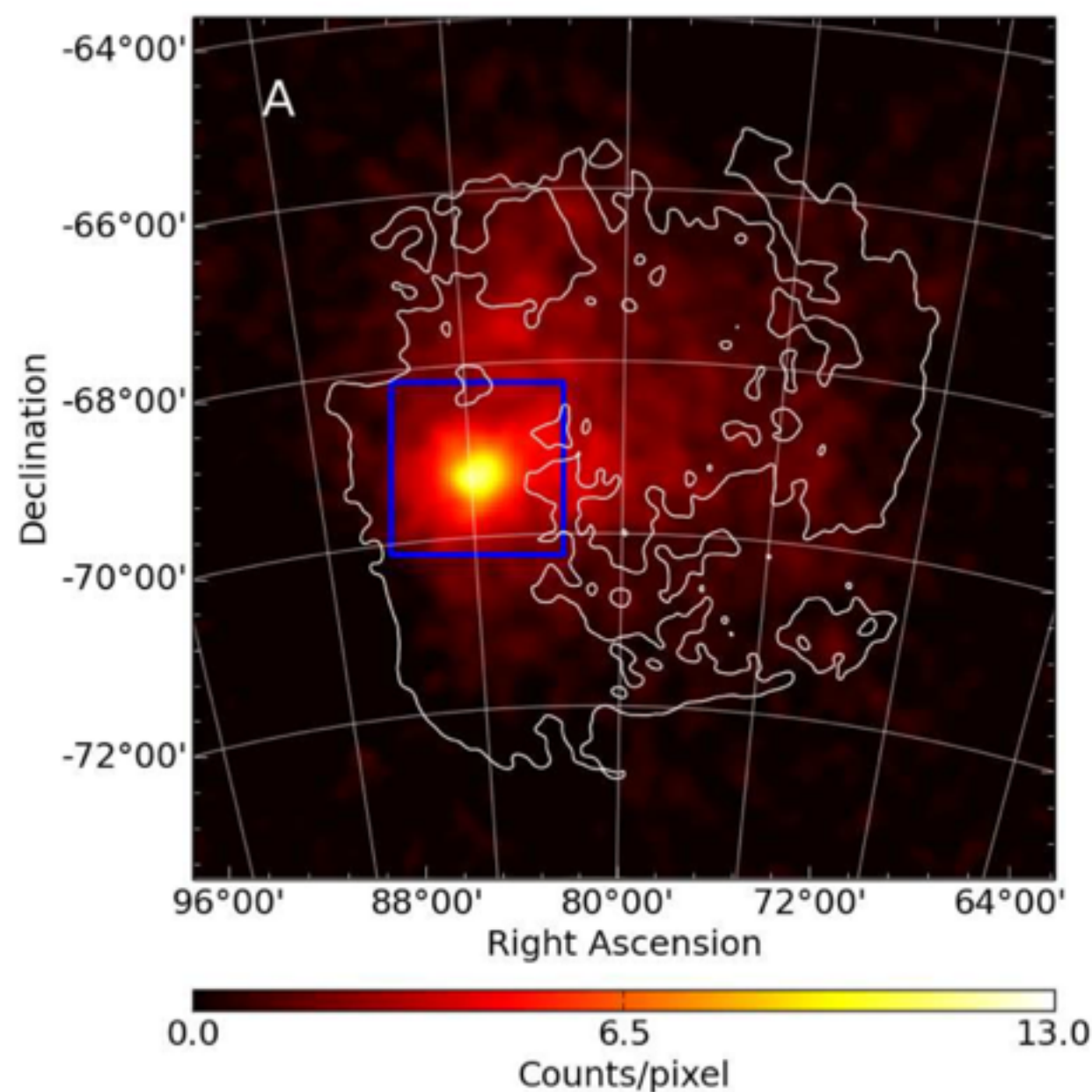


❖ General and source class specific catalogs

▶ AGN, pulsars, SNR, transients (GRB, Solar Flares)

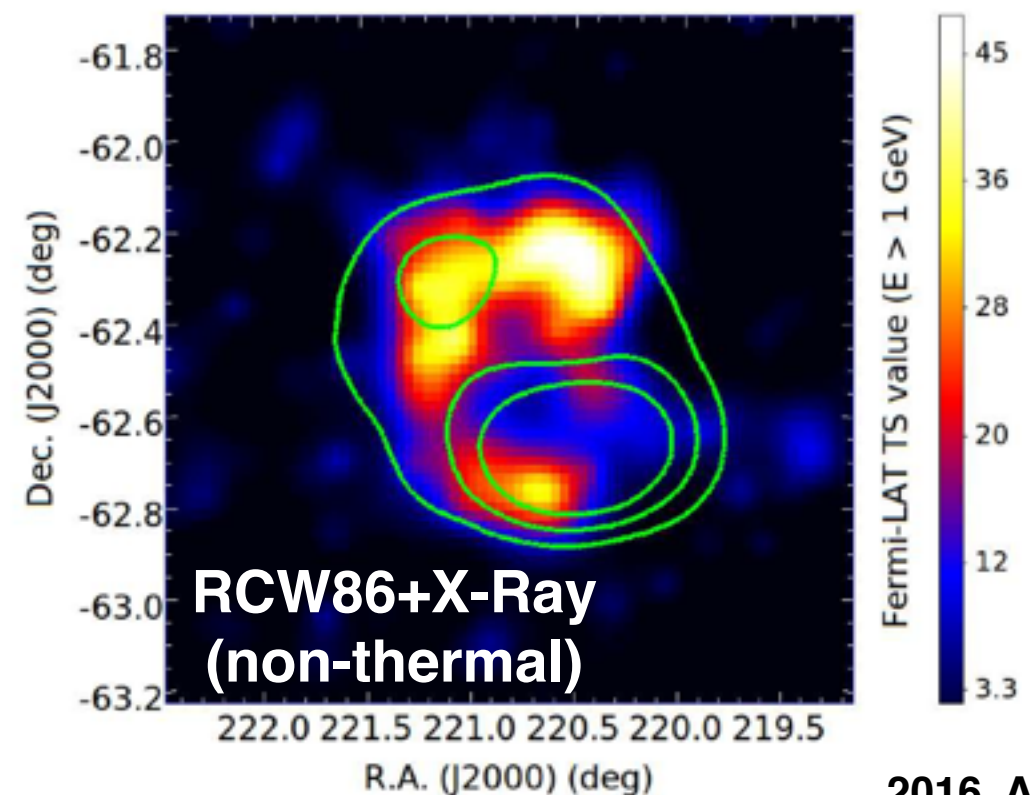
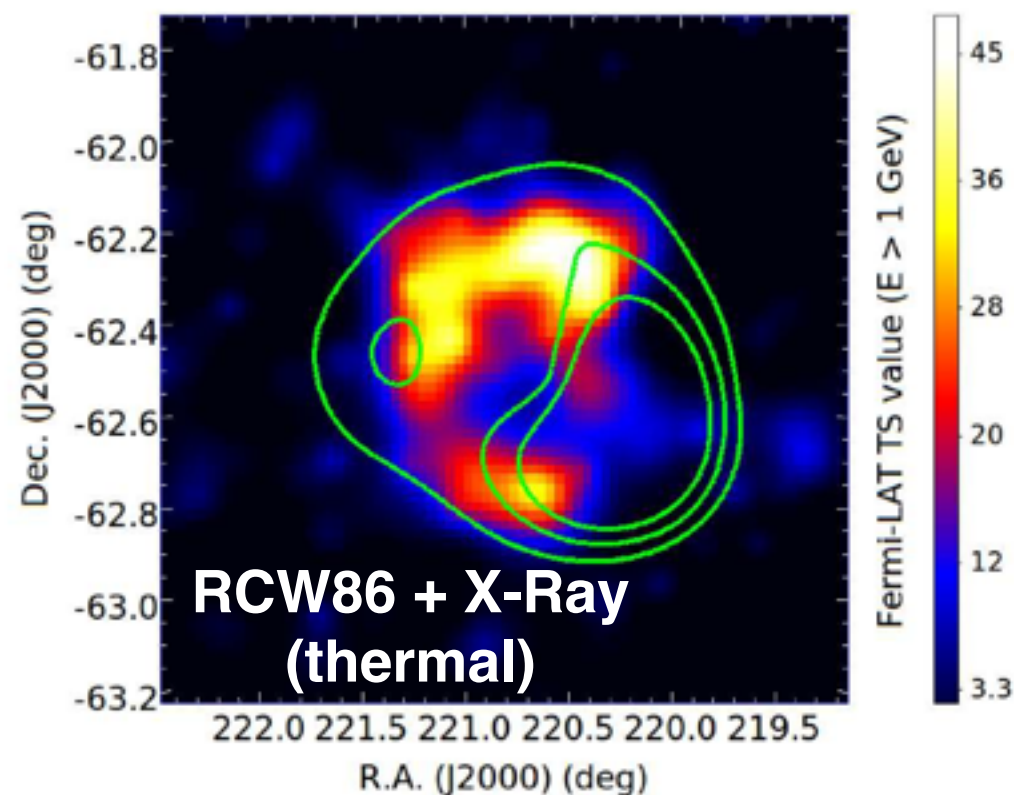
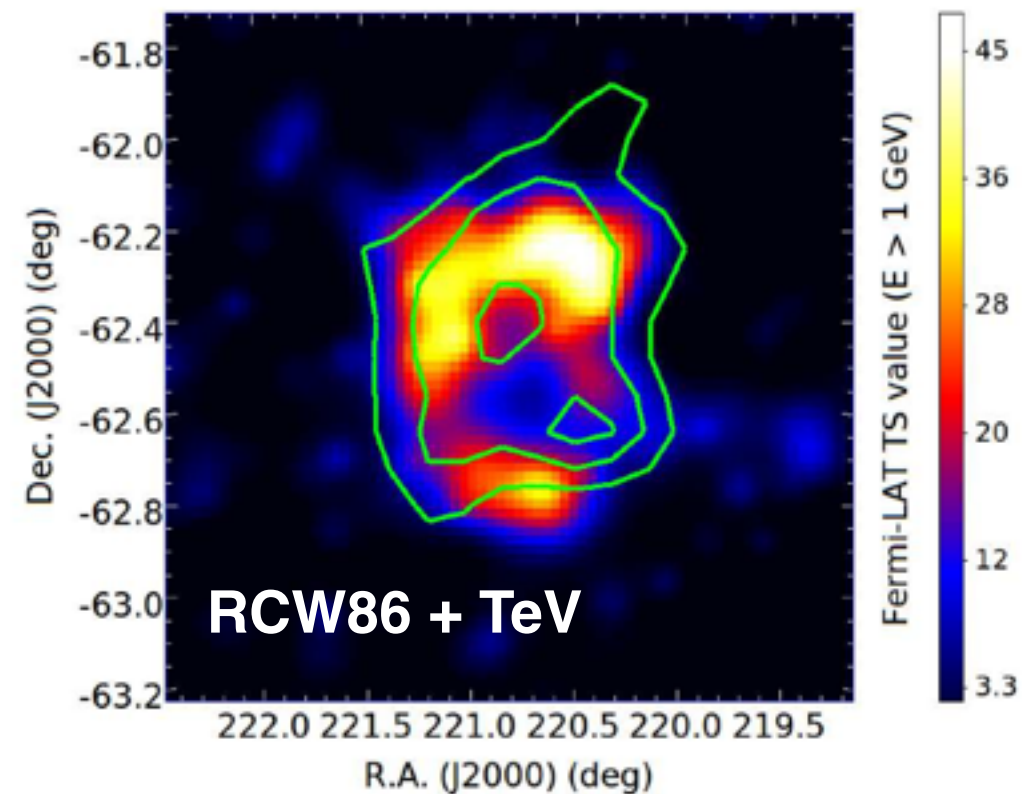
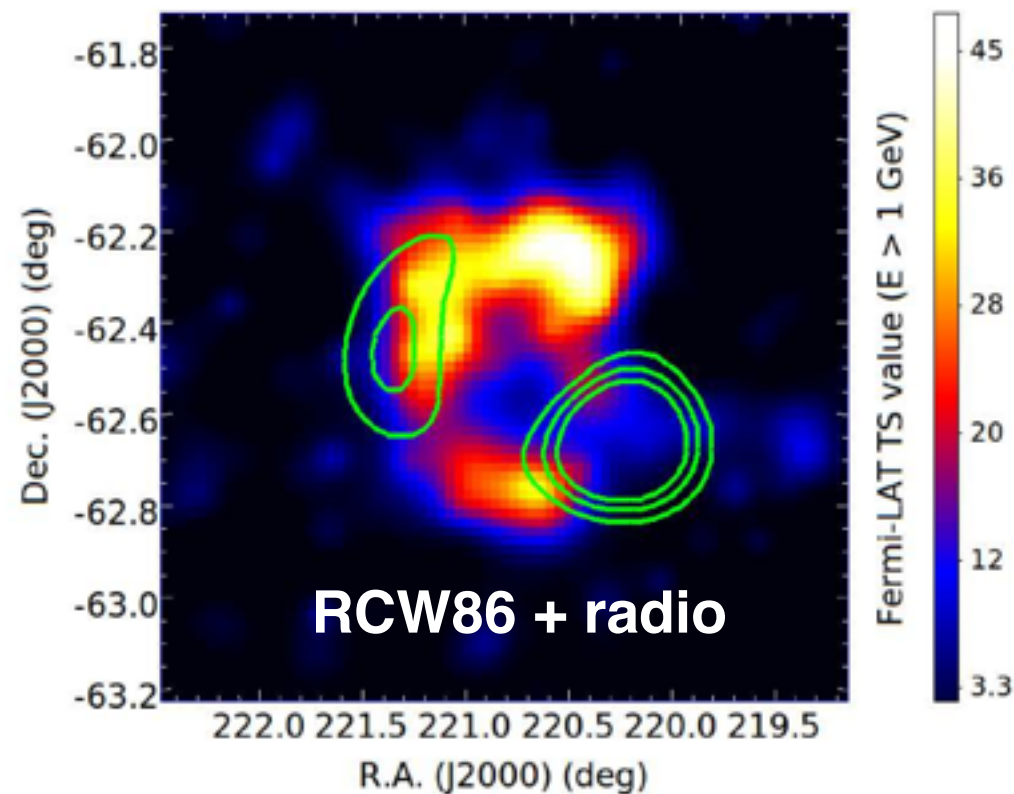
❖ basis for most LAT analyses

Complex regions

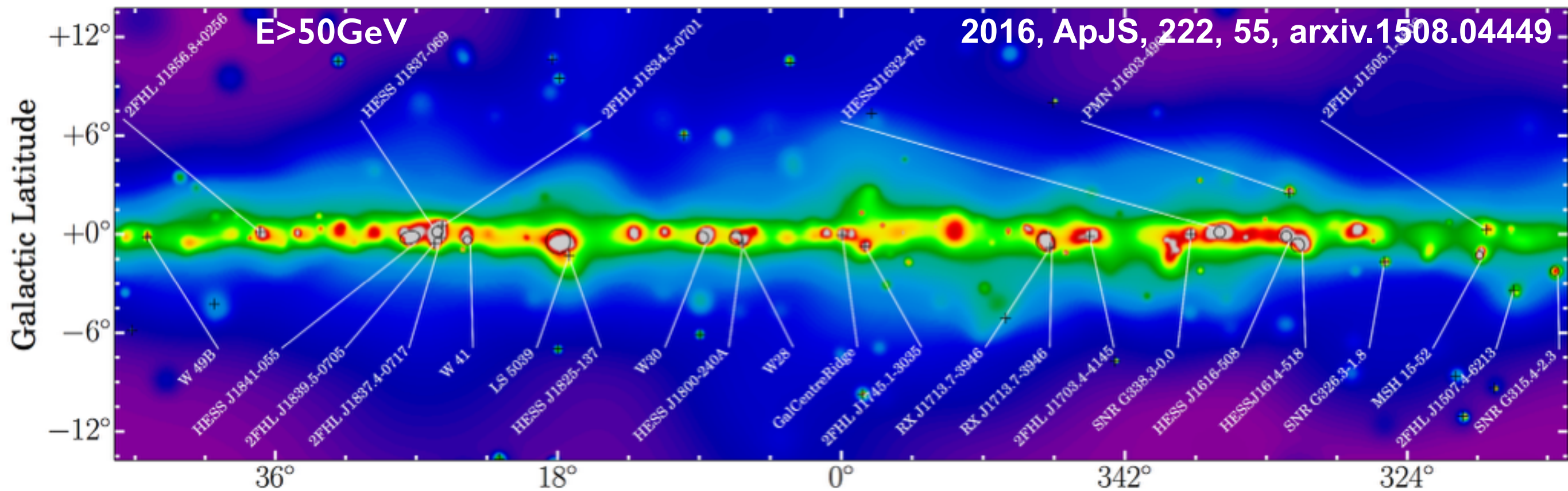


❖ 1st extra-galactic pulsar in the 30Doradus region in the LMC

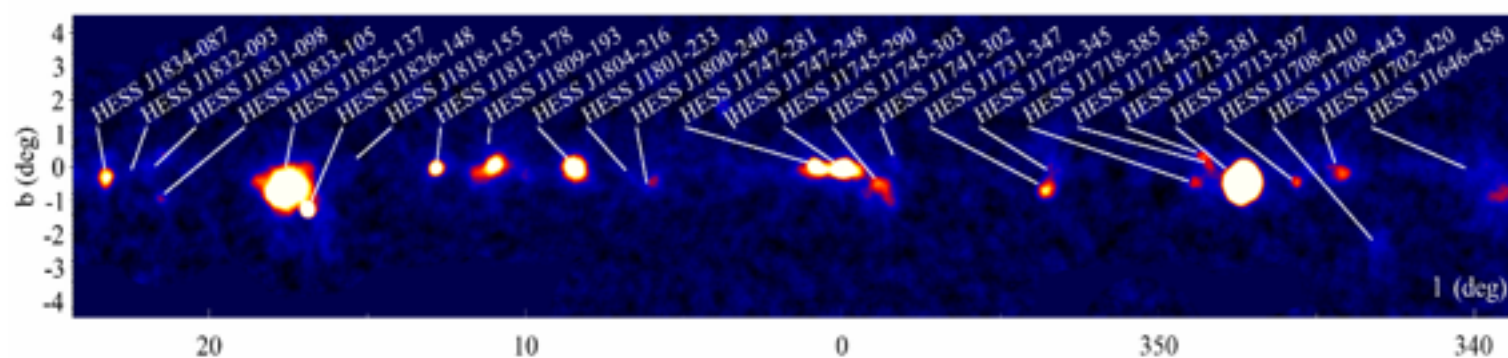
Resolving SNR to track CR



Hard sources



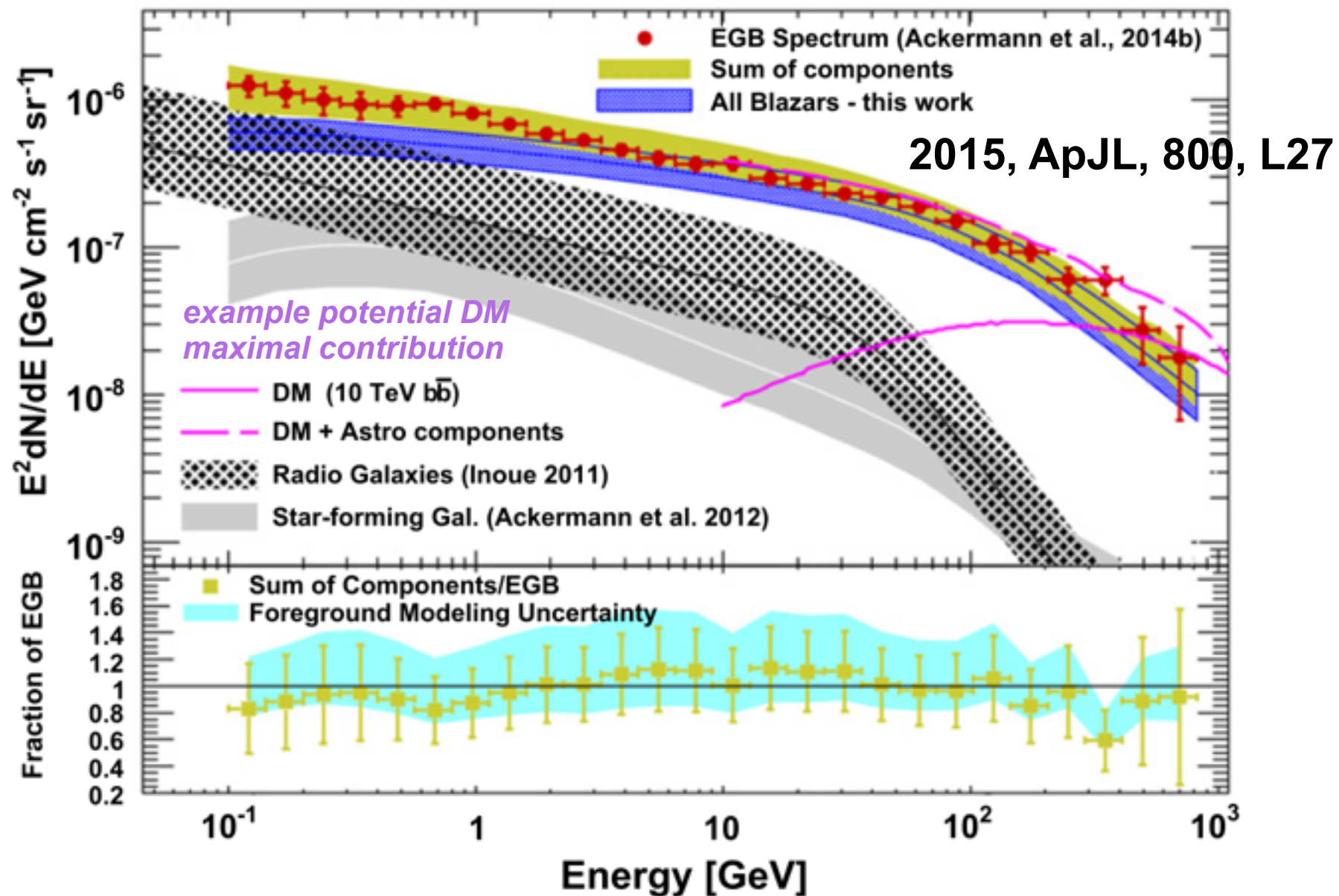
HESS Galactic Plane
Survey arxiv.1307.4690



❖ ~1500 sources above 10 GeV

- ▶ connects GeV and TeV (IACT) observations
- ▶ potential to isolate HE component in SNR, ideal probe for EBL

Isotropic Gamma Rays

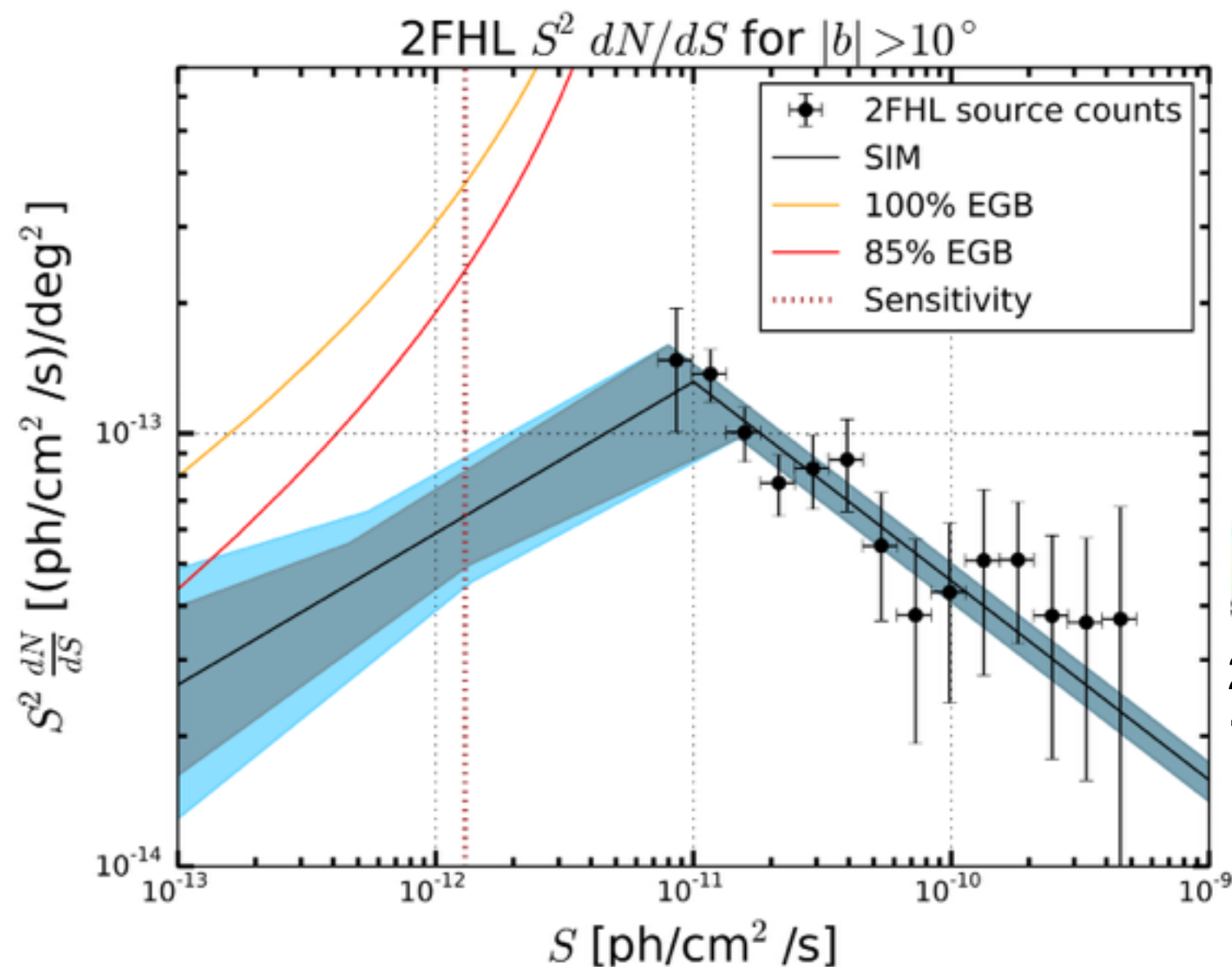


❖ Contributions from unresolved populations

- ▶ low detection threshold crucial for modeling numerous, faint populations
- ▶ high-energy measurements drive critical spectral contribution

❖ Constrains Cosmological Dark Matter

Contributions to isotropic emission



2016, PRL,
116, 151105

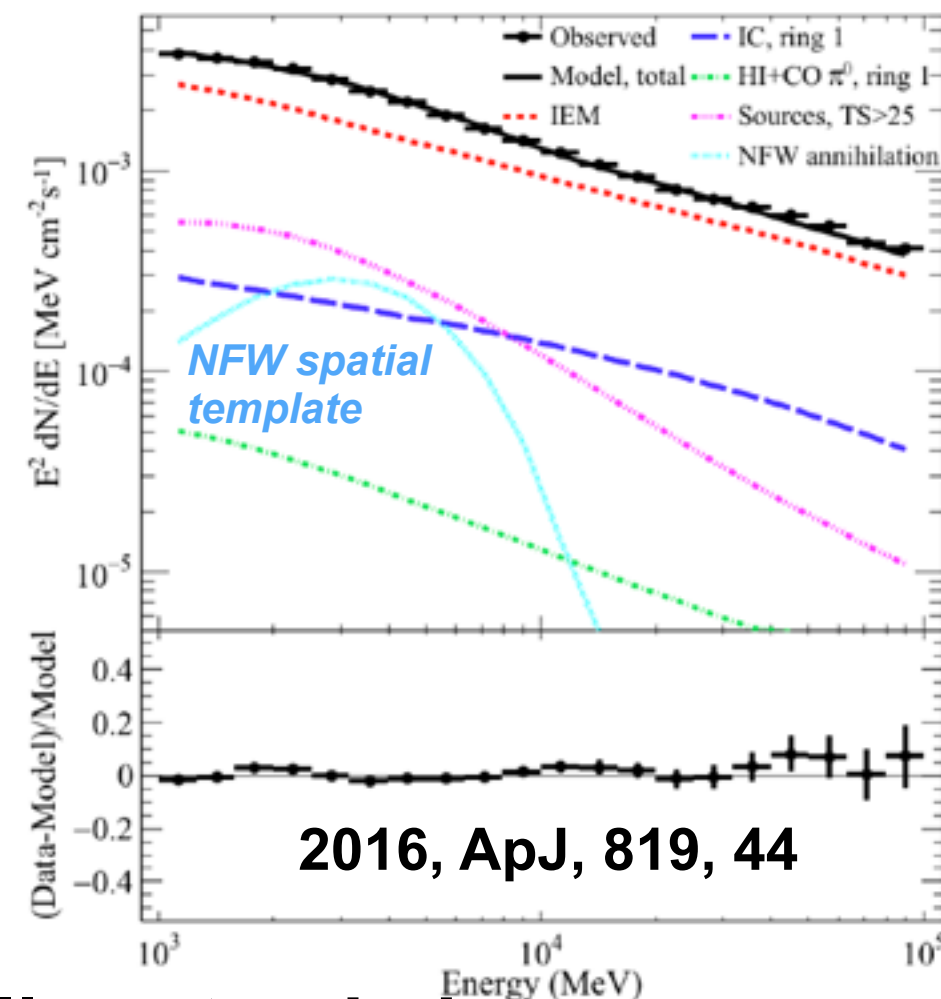
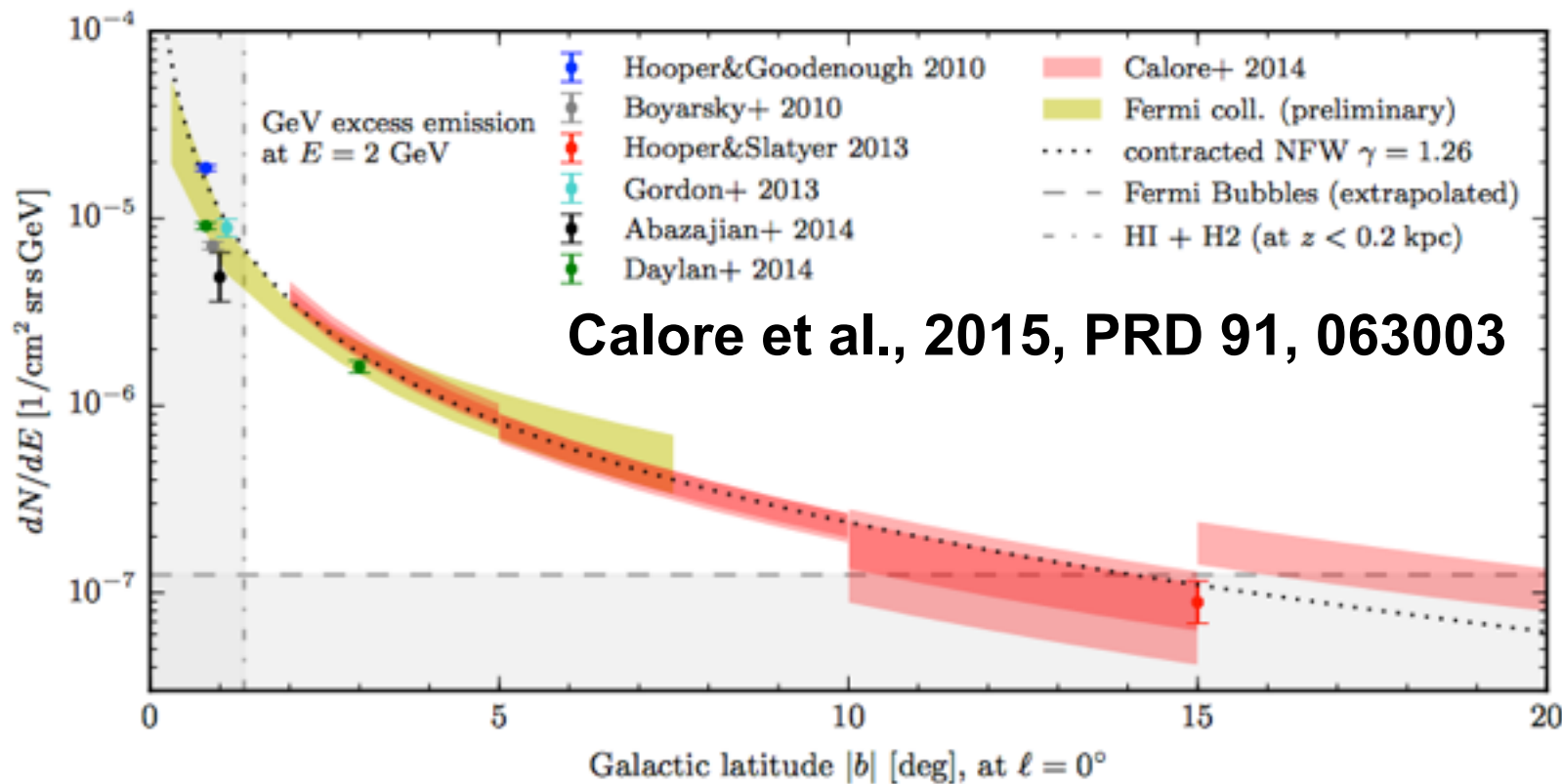
❖ Going below single source detection threshold

▶ 1-point PDF number count (efficiency corrected)

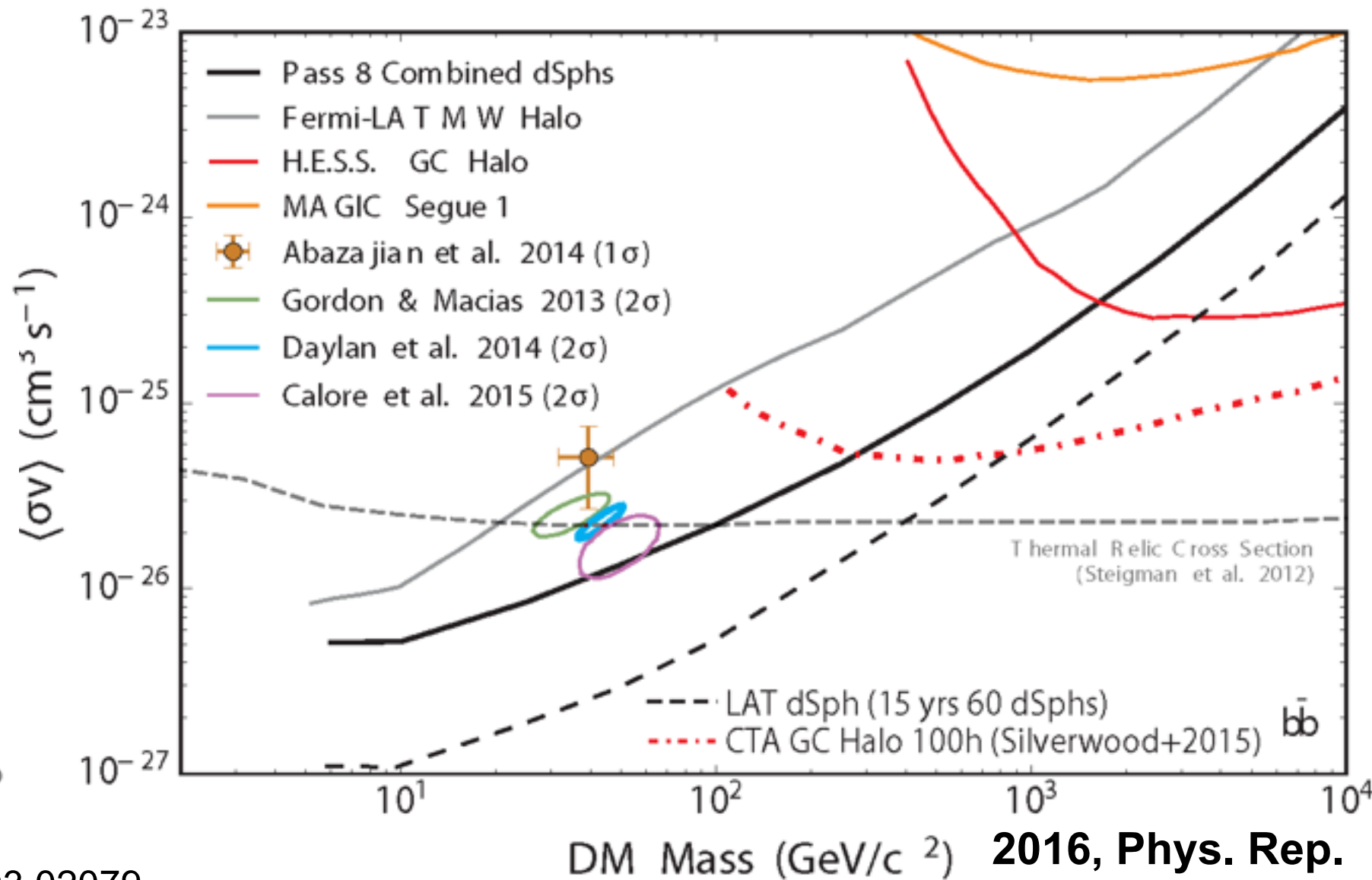
❖ Contributions to isotropic flux from $E > 50$ GeV sources (2FHL)

▶ up to 85% of total EGB

Diffuse emission: the case of the Inner Galaxy



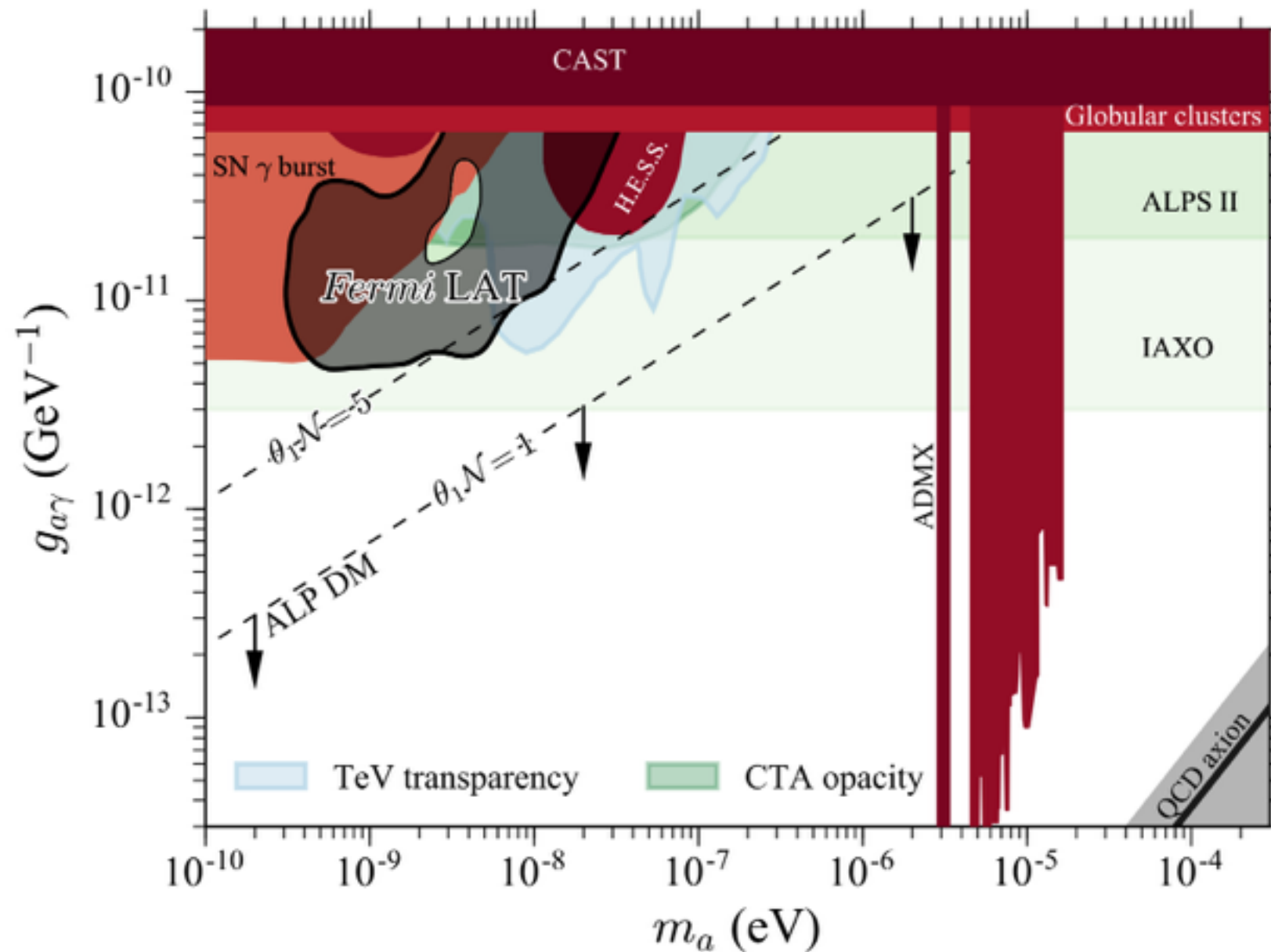
- ❖ Independent analyses report a spatially extended excess
 - ❖ Spherically symmetric, spectrum consistent with DM
 - ❖ Degenerate with potential astrophysical contributions (diffuse from CR inhomogeneities, MSP)
- upcoming study with Pass8 and diffuse templates



2016, Phys. Rep.
arxiv:1605.02016

- ❖ optical surveys are significantly increasing number of dwarfs
- ❖ non observation of gamma-rays from dwarfs in the next 4 years can exclude WIMPs below $\sim 400\text{GeV}$ (thermal relic cross-section into $b\bar{b}$) and DM GC excess

Constraints on axions



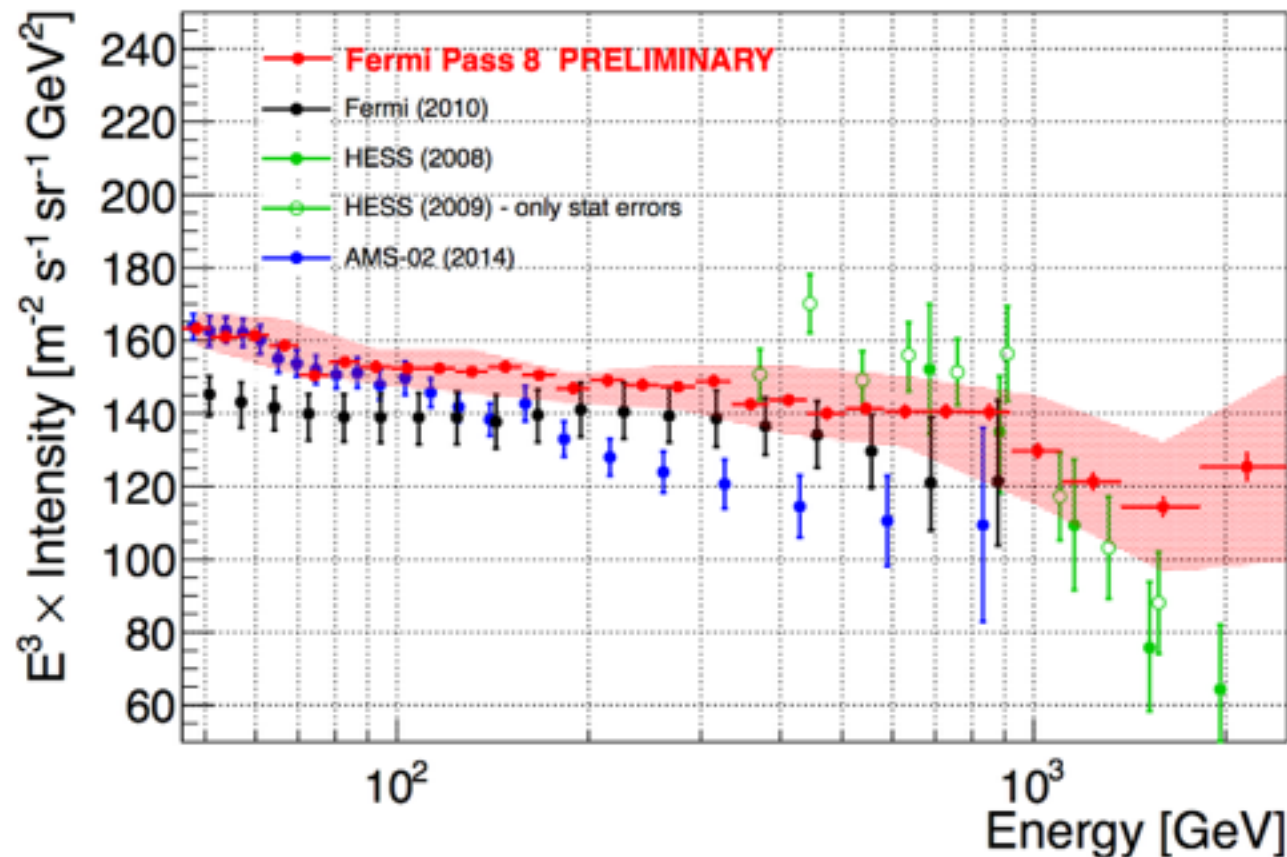
2016, PRL
arxiv:1603.06978

❖ No evidence of ALPs

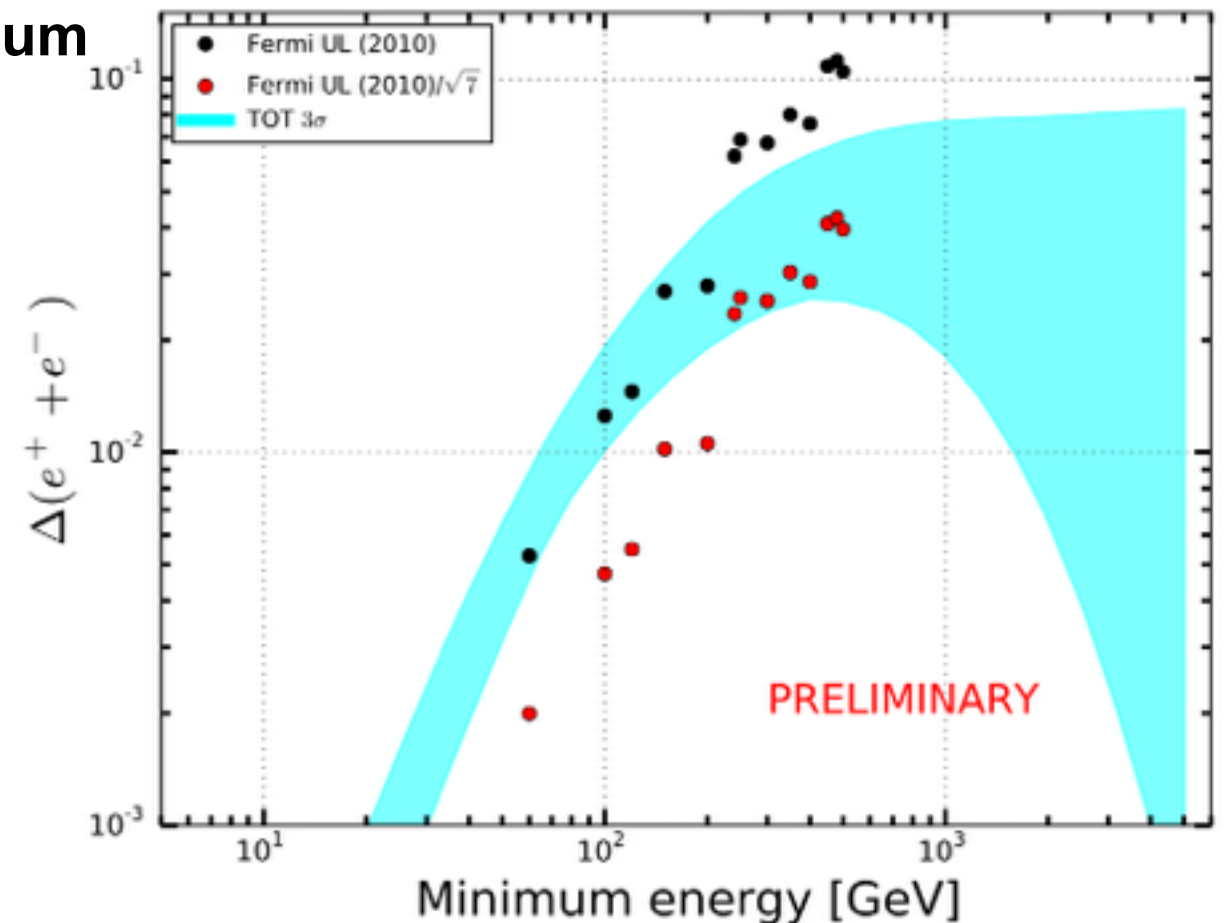
- ▶ searched for oscillations in gamma rays from NGC1275
- ▶ couplings $> 5 \times 10^{-12} \text{ GeV}^{-1}$ for ALP masses $0.5 \lesssim m_a \lesssim 5 \text{ neV}$

CR physics - Electrons

LAT Collaboration, 2015 Fermi Symposium



CRE spectrum



Dipole anisotropy prediction and sensitivity

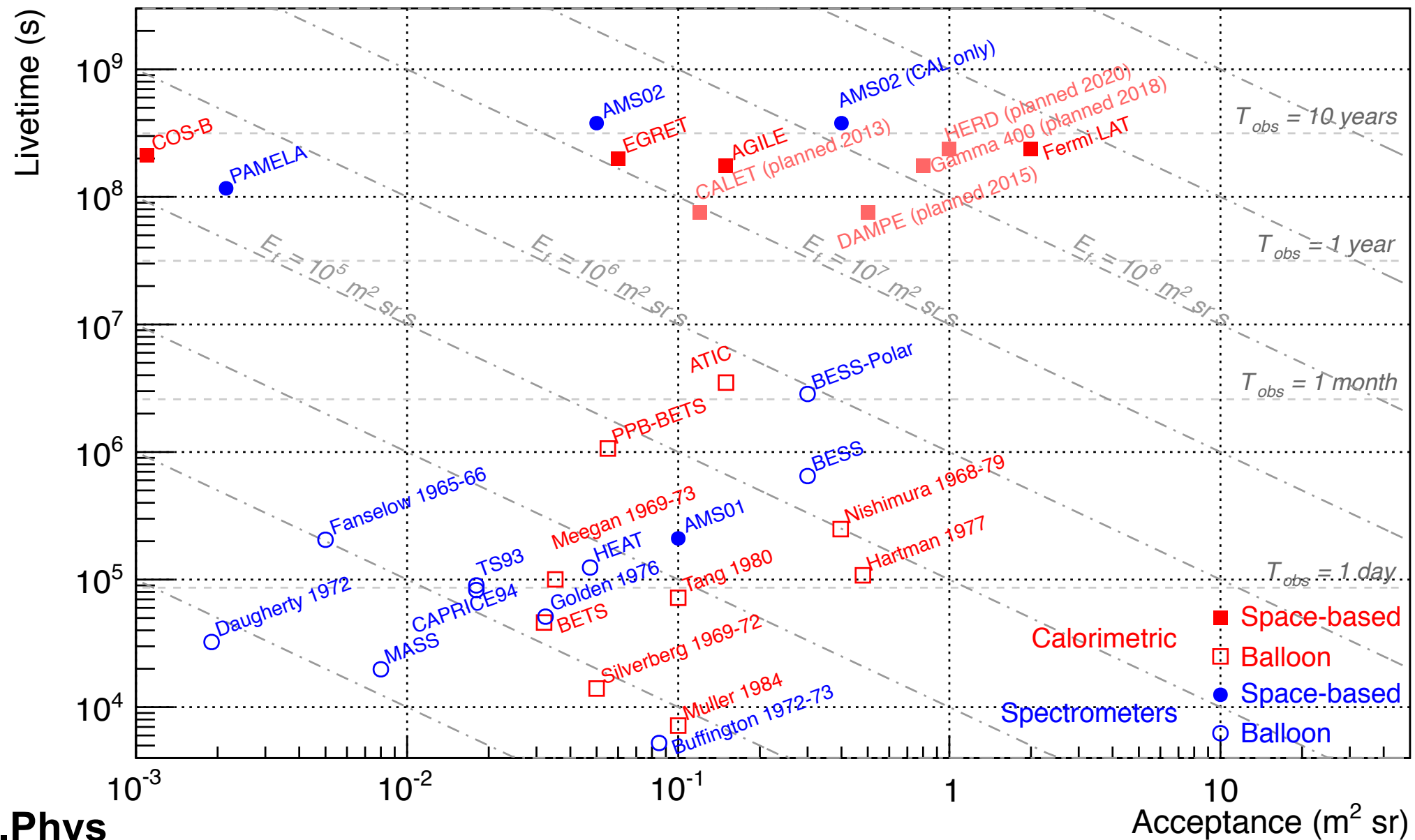
❖ CRE spectrum now probing ~TeV cutoff

▶ compatible but not requiring local component

❖ Potential for CR astronomy through CRE anisotropy

▶ prediction uncertainties get smaller if model fit combines AMS positrons

CRE Context



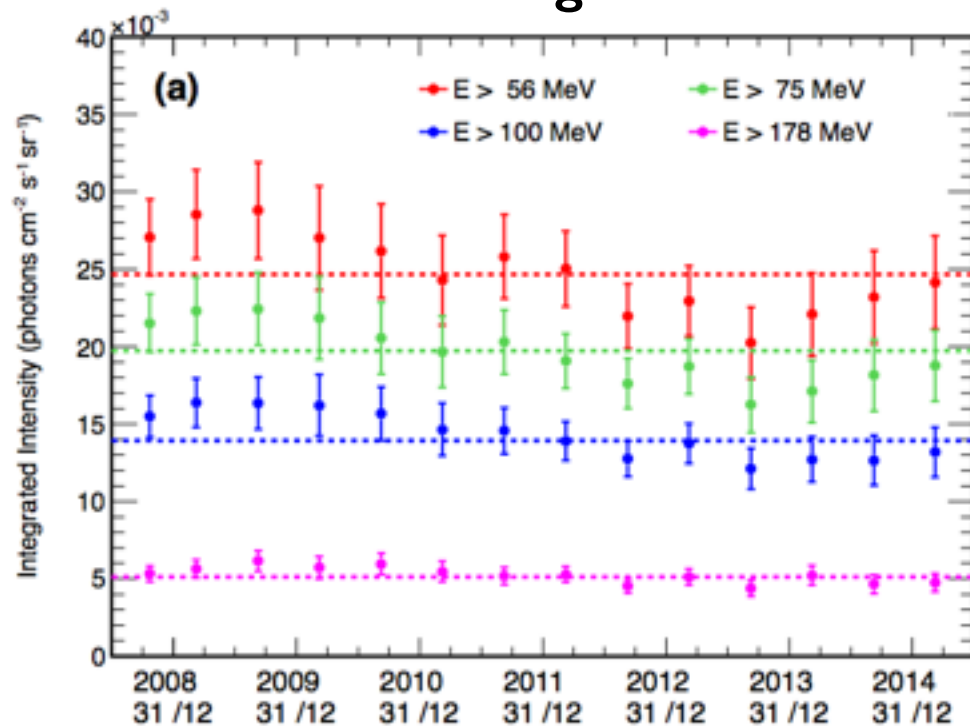
2012,
Astropart.Phys
39-40, 22

❖ Different techniques and challenges

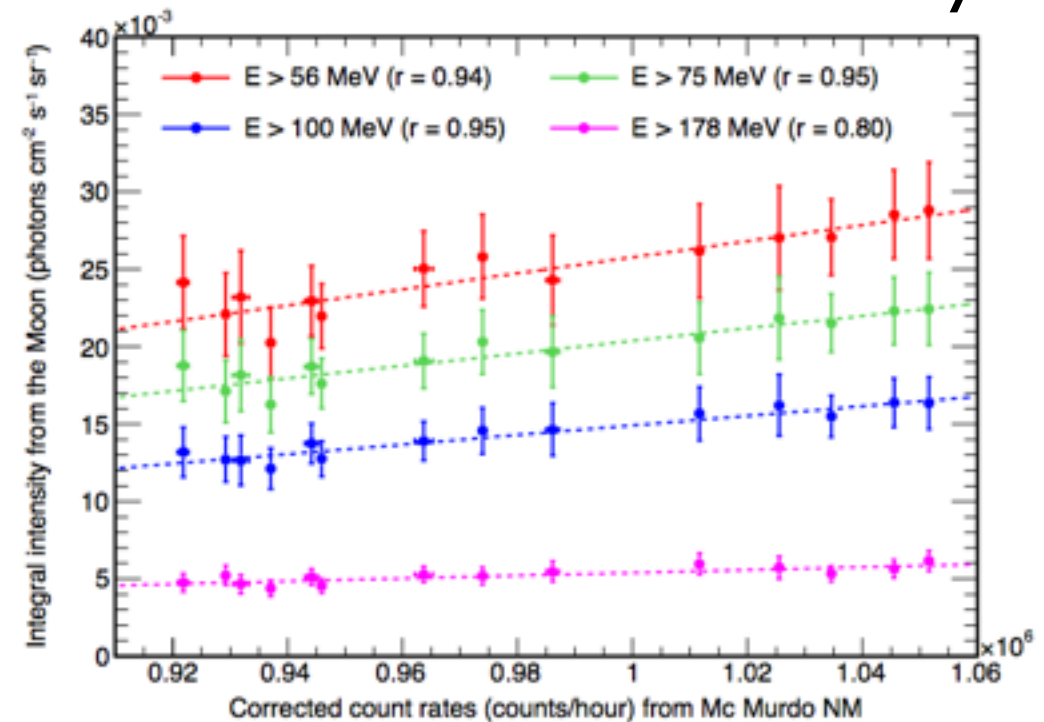
► trade-off between acceptance, resolution, e-p separation

CR physics with the Moon

Broad-band Light Curves of the Moon

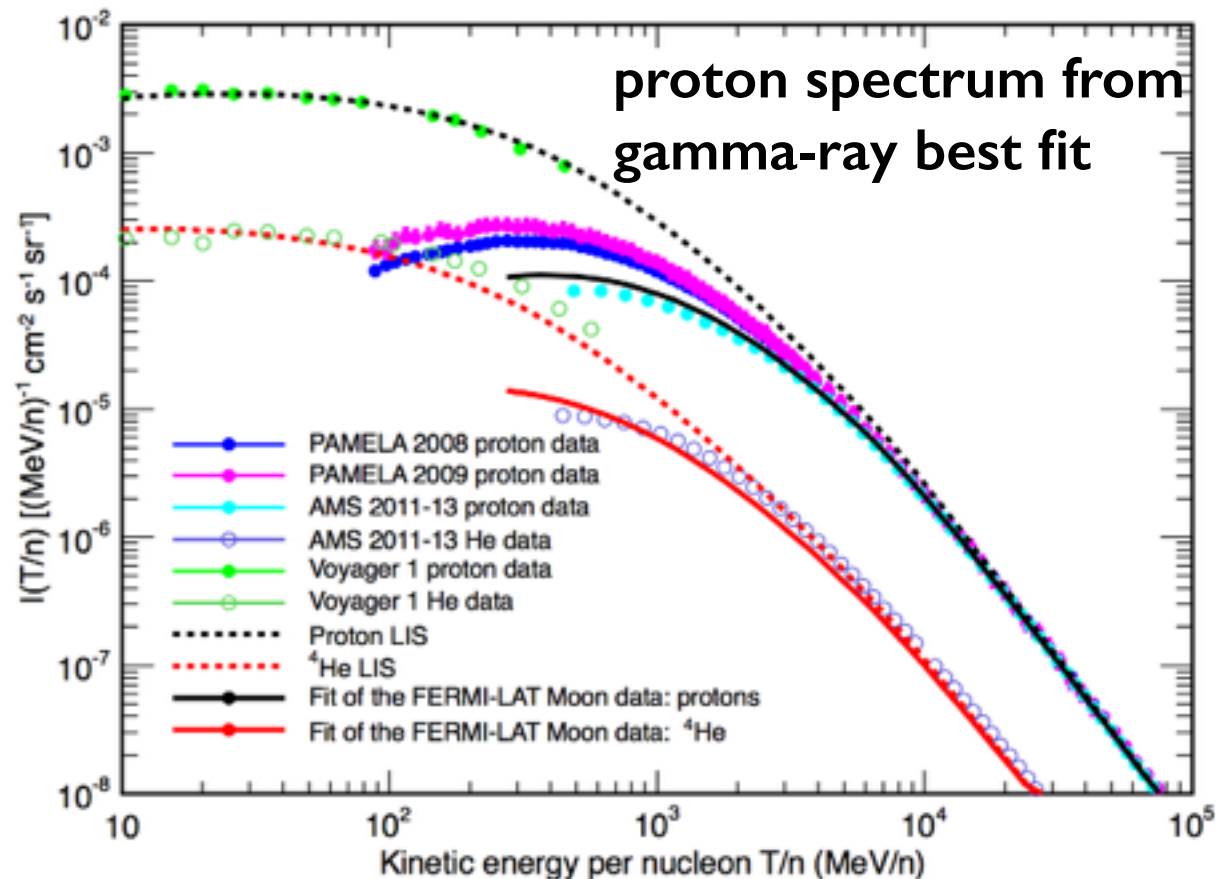


Correlation with solar activity



2016, Phys. Rev. D, 93, 082001

proton spectrum from
gamma-ray best fit



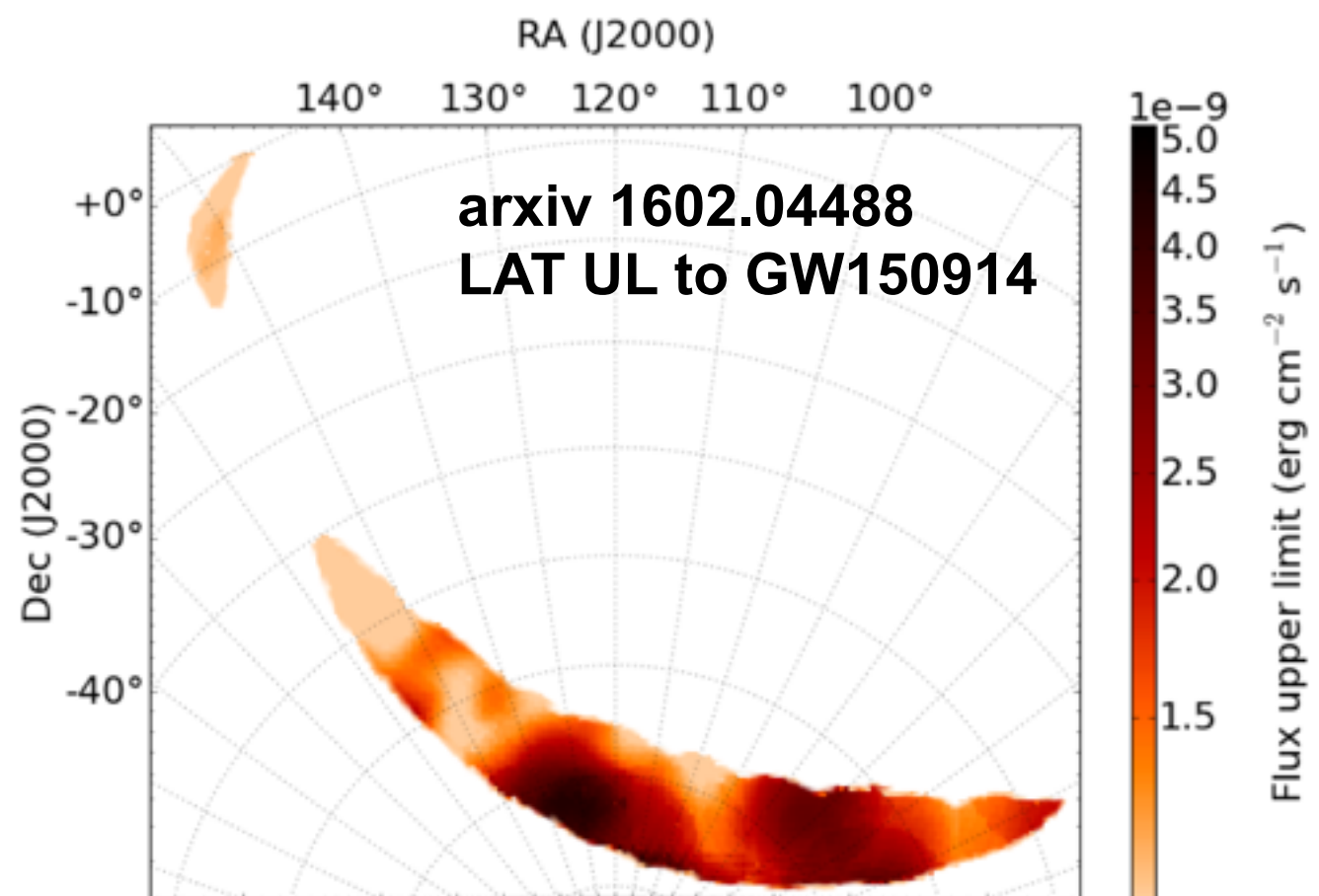
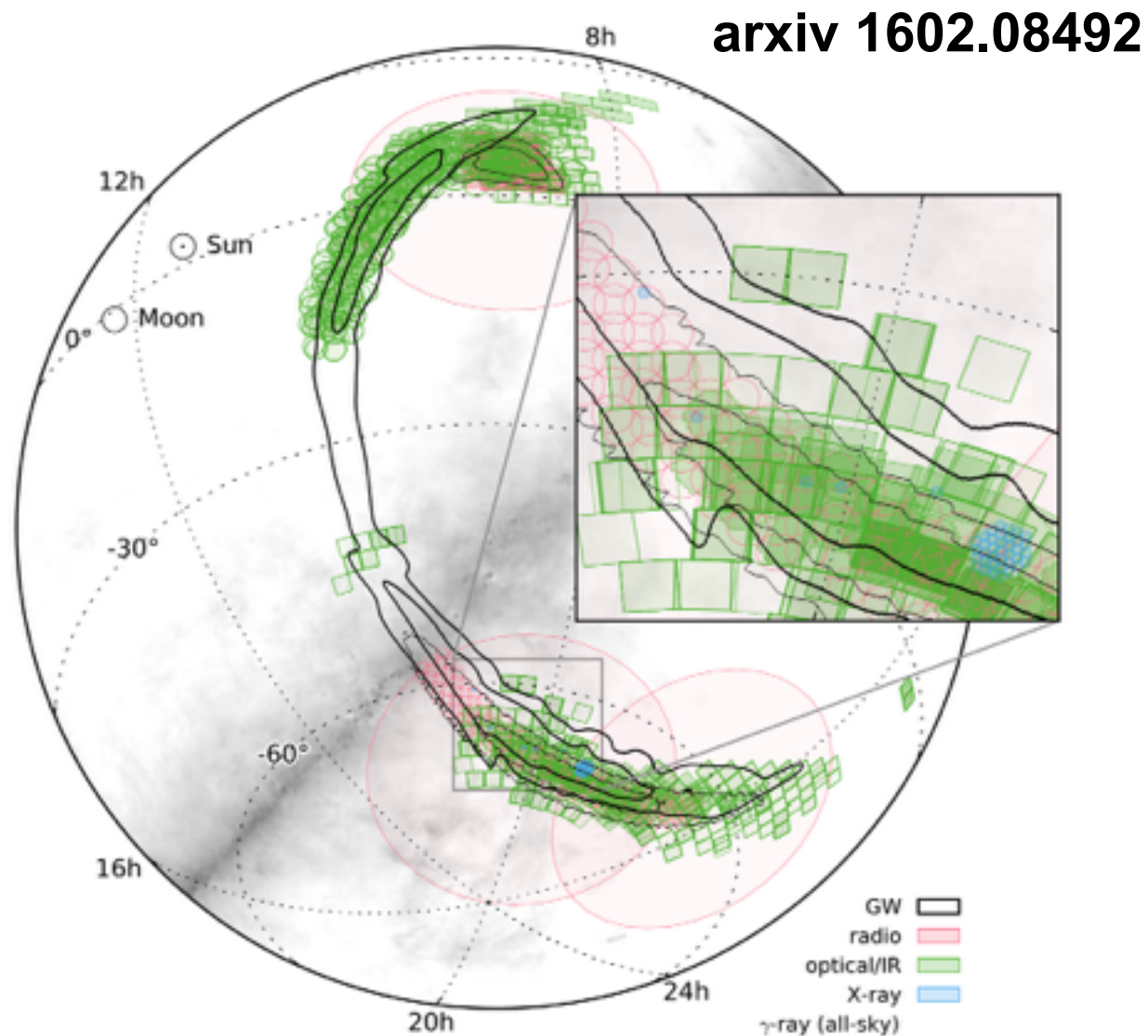
❖ Multi-year flux monitor

► correlates with solar activity

❖ Studies of CR interactions and propagation

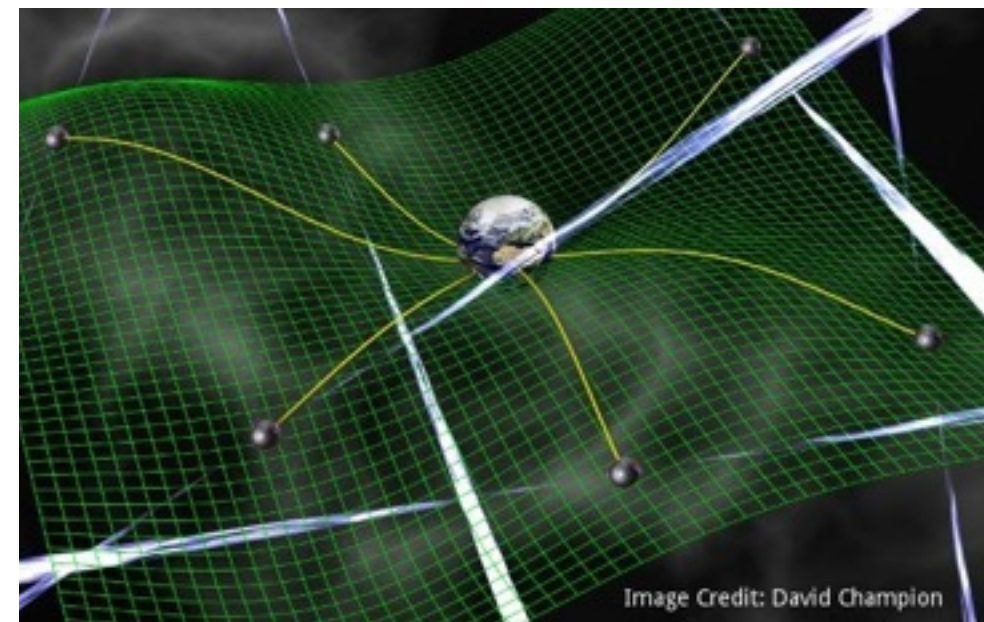
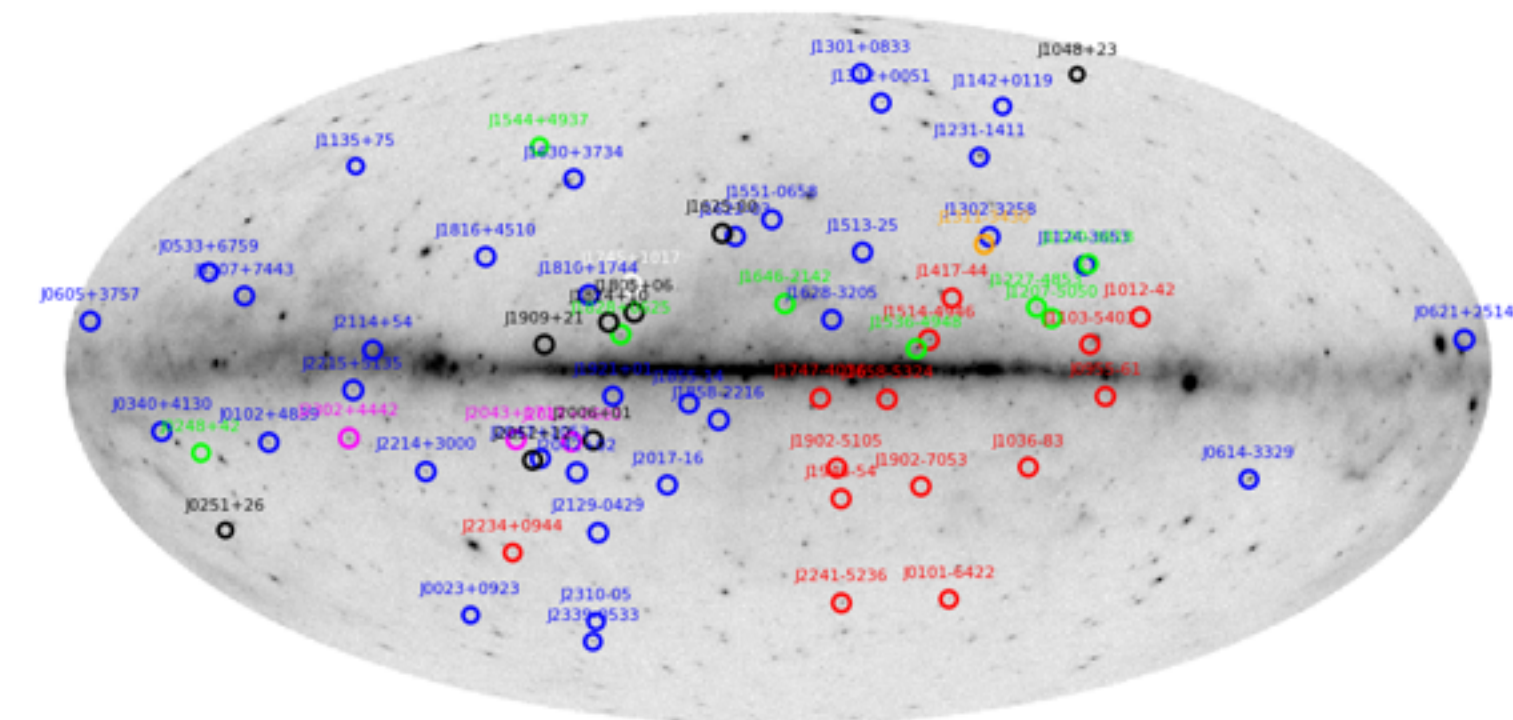
► through comparison of Monte Carlo interaction codes

Special transients - GW followups



- ❖ LAT covers entire sky in 3 hours, with localization $\sim 0.1\text{-}1^\circ$
- ❖ LAT sensitive to transients from ms to years timescales
- ❖ GBM sensitive to impulsive flares
- ❖ Routine searches under MoU with Ligo Virgo Consortium

Pulsar Timing Arrays



- ❖ GW search window at very low frequency (5-500 nHz) through pulsar timing (nanoGRAV)
- ❖ Fermi Pulsar Search Consortium discovered 70 MSPs in LAT unassociated sources (40% of the MSP discoveries since 2008 and about $\frac{1}{3}$ of all known Galactic MSPs)

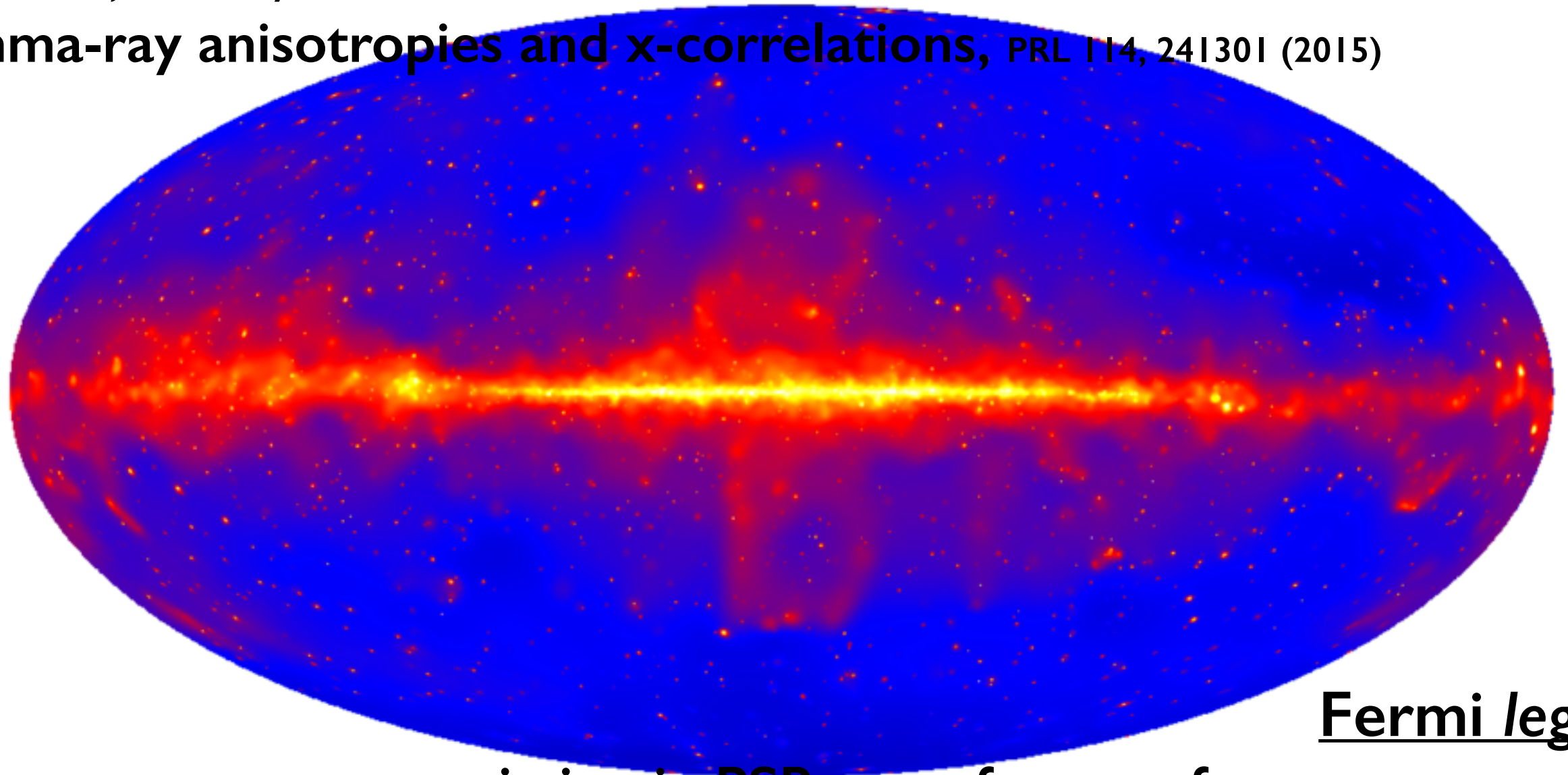
Many more highlights not covered here:

Solar Flares, 2015, ApJL, 805, L15,

Novae, 2014, Science, 345, 554,

DM lines, 2015, Phys. Rev. D, D91, 122002

Gamma-ray anisotropies and x-correlations, PRL 114, 241301 (2015)



Fermi legacy:

gamma-ray emission in PSR away from surface, e.g. 2013, ApJS, 208, 17
rejection of simplest single-zone emission in blazars, e.g. 2015, ApJ, 810, 14

Crab flares, e.g. 2011, Science, 331, 739

challenges to standard GRB afterglow model, e.g. 2014, Science, 343, 42

complete 400+ LAT Collab. publications at <https://www-glast.stanford.edu/cgi-bin/pubpub>



Summary

- ❖ **Fermi is the reference gamma-ray observatory**
 - ❖ ~1G photons, thousands sources, public database
- ❖ **Fermi data probe fundamental questions**
 - ❖ CR origin, particle acceleration and propagation
 - ❖ Dark Matter Identification
 - ❖ EM counterparts to Gravitational Waves