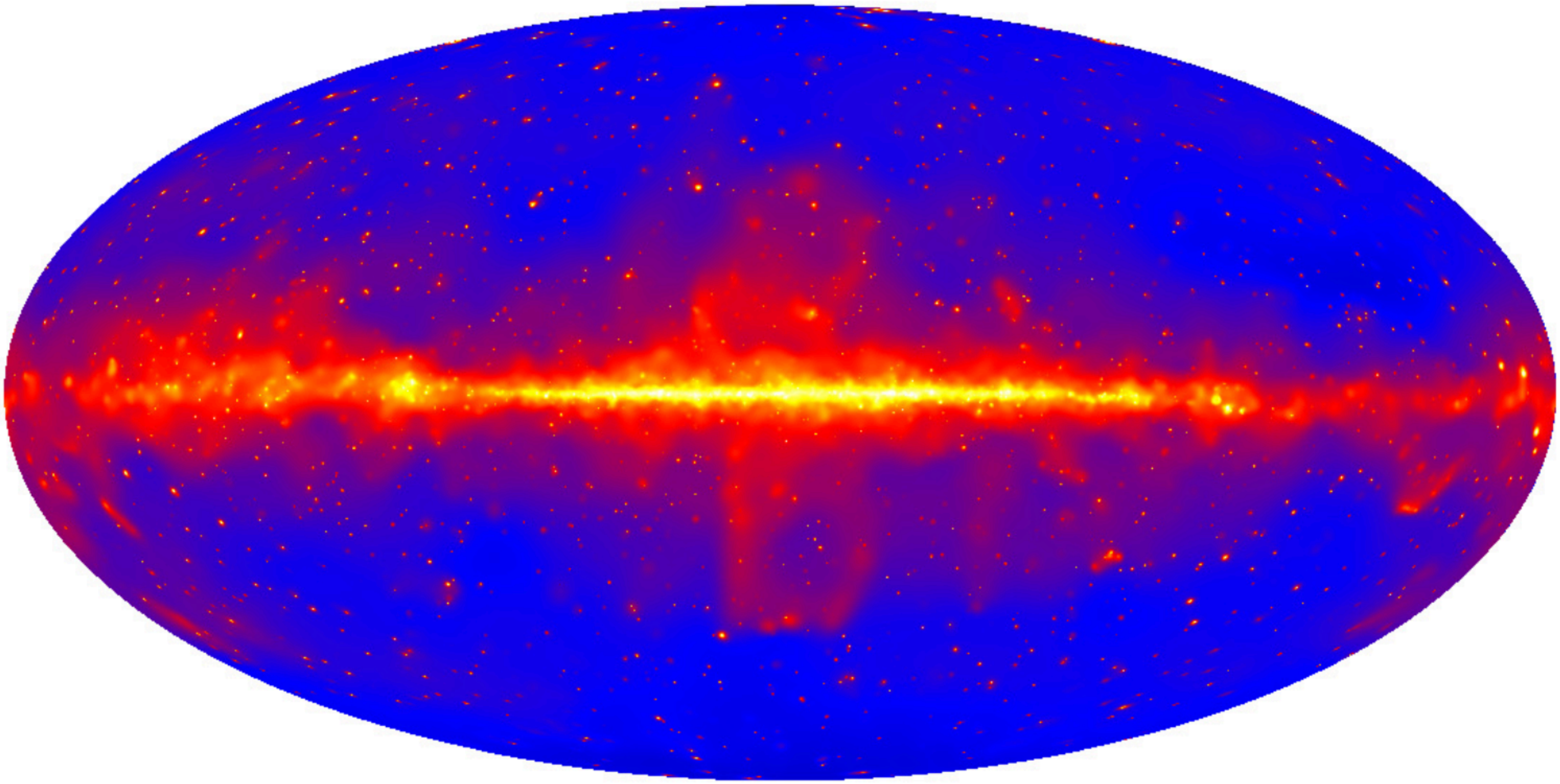
(Some) Results from *Fermi*-LAT



Marco Ajello

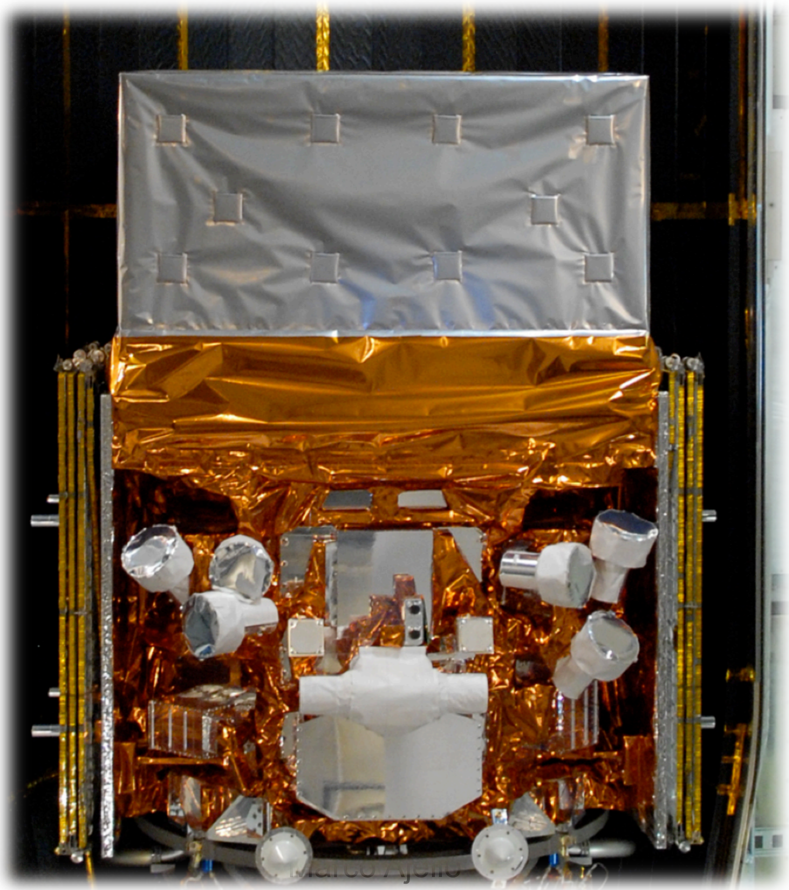
Clemson University

On behalf of the Fermi-LAT collab.

Ackermann+2015, ApJ, 799, 86
Ajello+2015, ApJL, 800,27
Ackermann+2016, PRL, 116, 151105

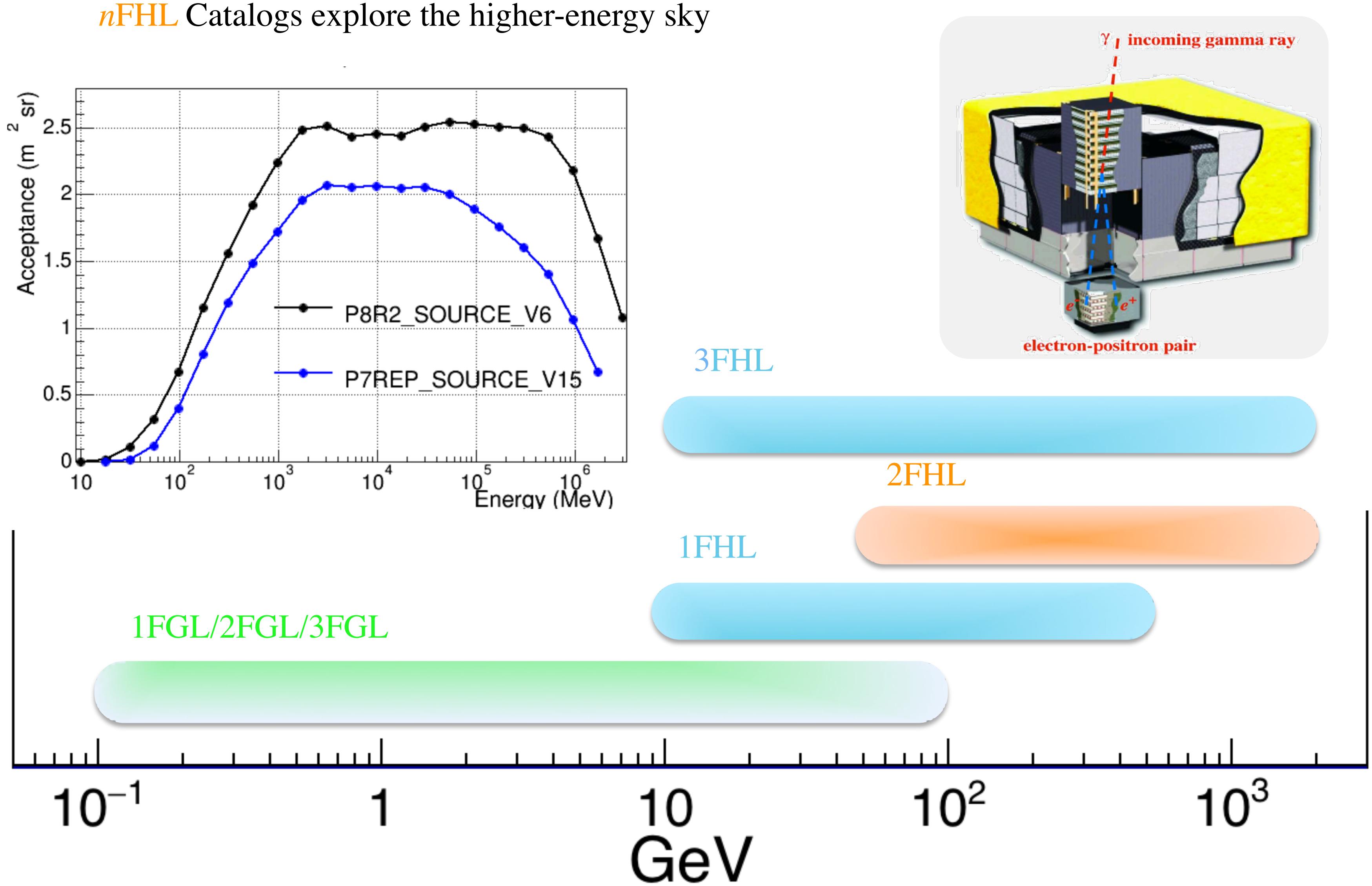
Fermi Large Area Telescope

- *Only instrument able to measure 2 cosmic backgrounds and resolve 1 of them*



Fermi-LAT & Pass 8

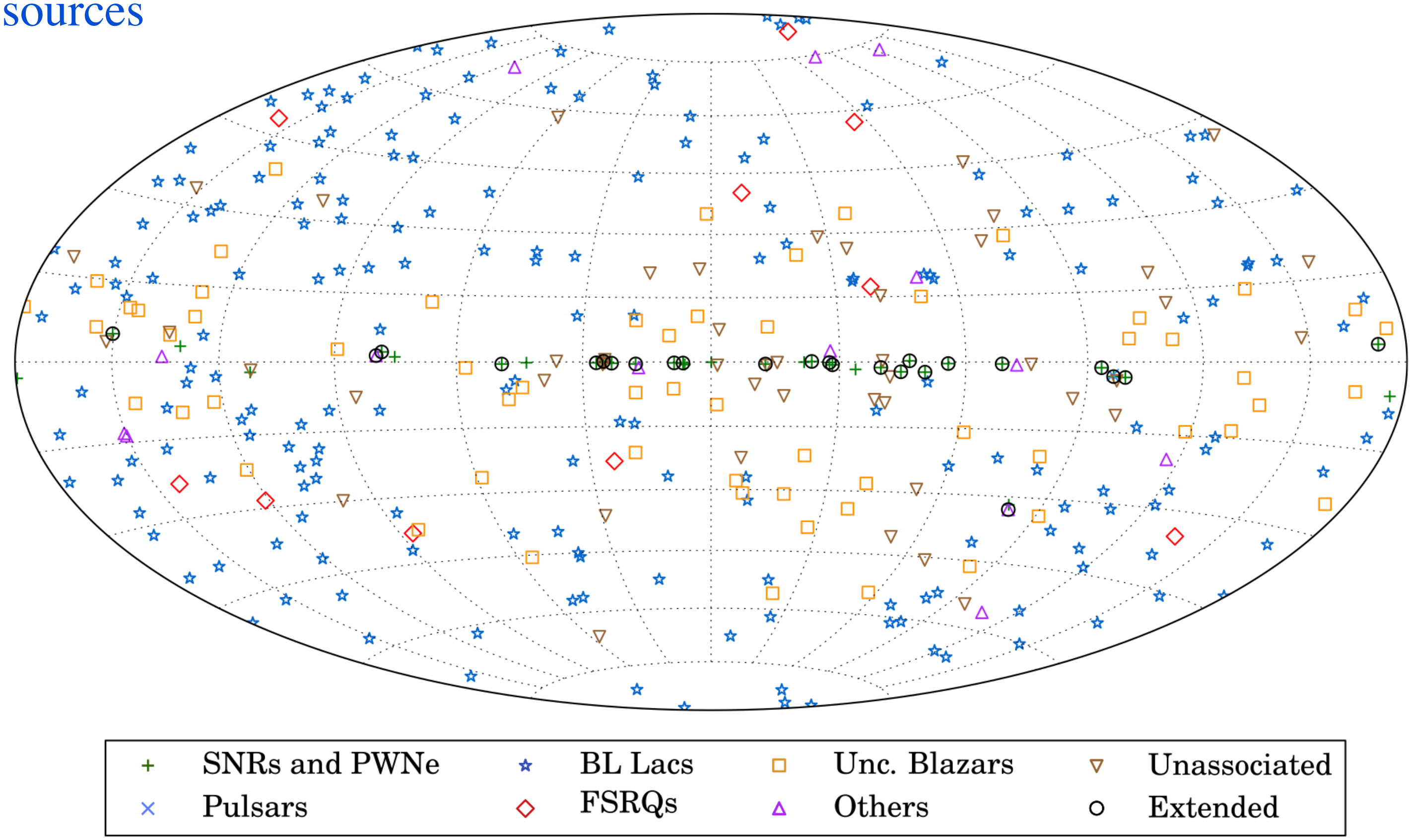
*n*FGL Catalogs detect and characterize sources in the ~0.1-100 GeV energy range
*n*FHL Catalogs explore the higher-energy sky



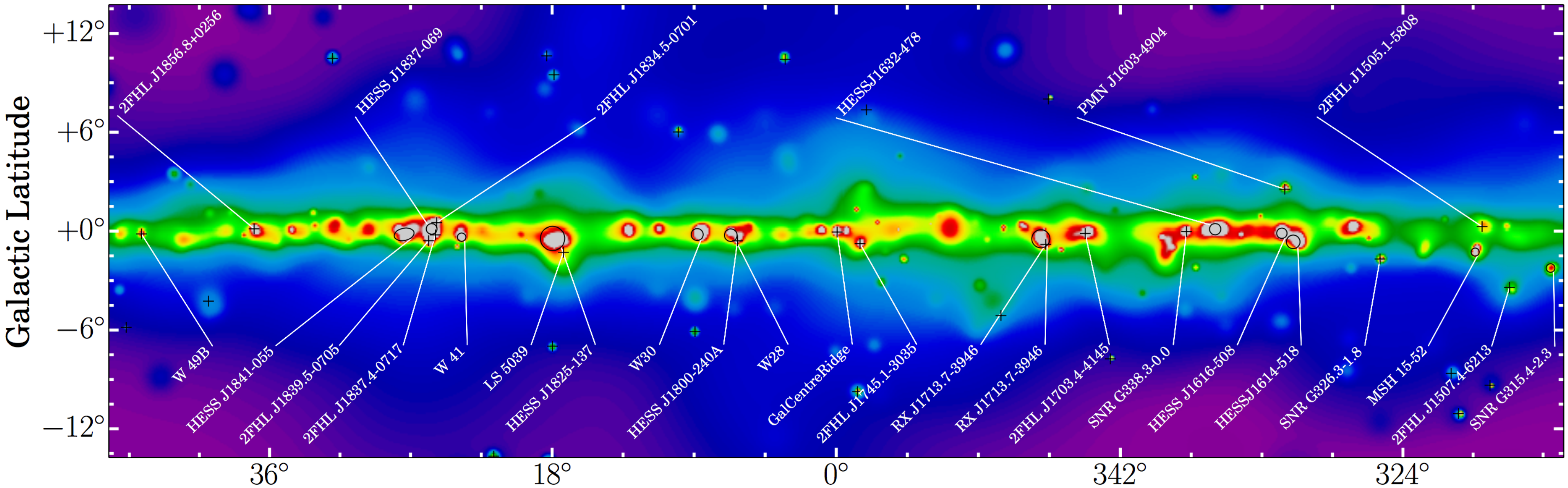
2FHL

- **Some numbers**
  - 360 sources:
    - 75% blazars, 11% Galactic sources, 14% unassociated
  - 25 extended sources
  - 57 new sources

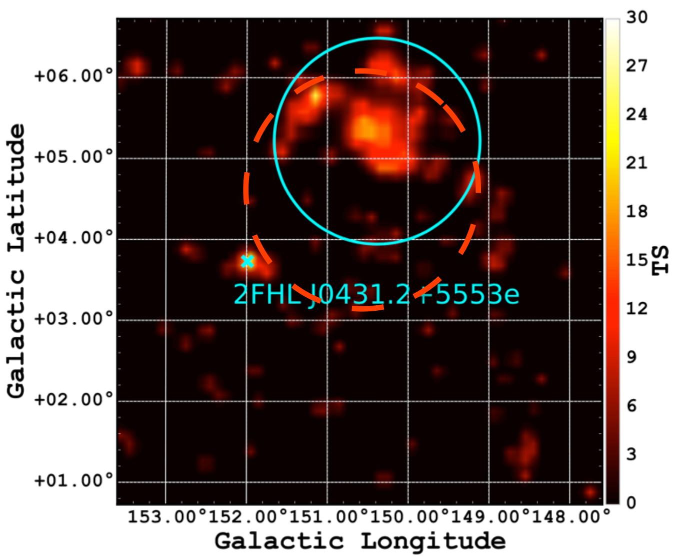
Median localization accuracy is 1.7 arcmin (68%) !



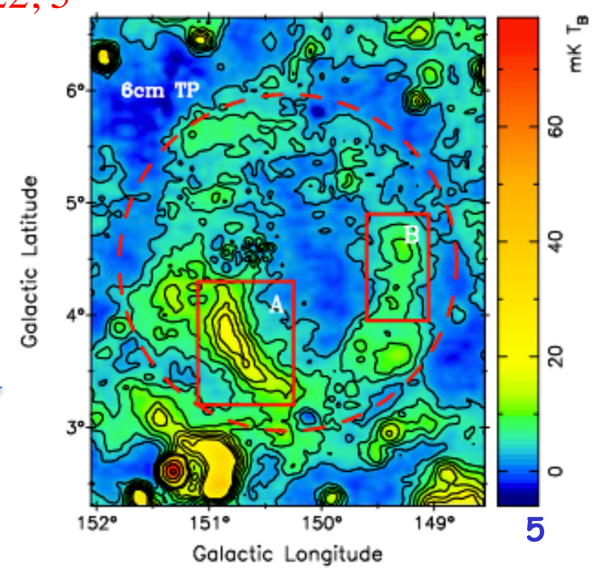
Galactic Accelerators



2FHL, Ackermann+16, ApJS,222, 5



New SNR (G150.3+4.5) discovered by Gao & Han 2014



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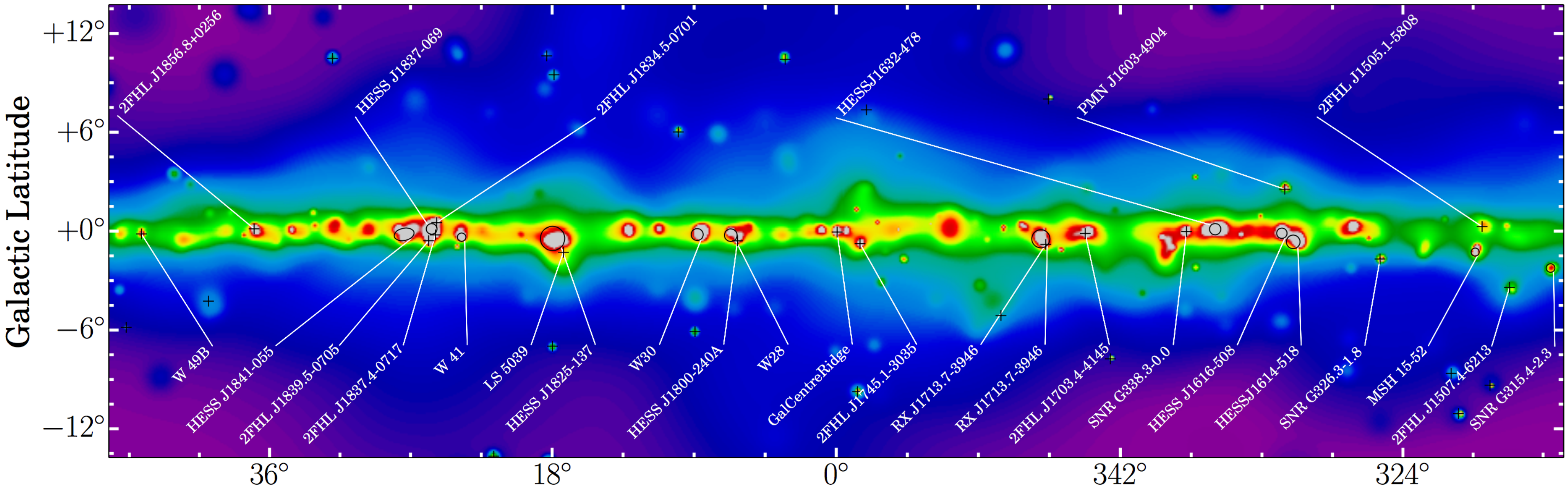

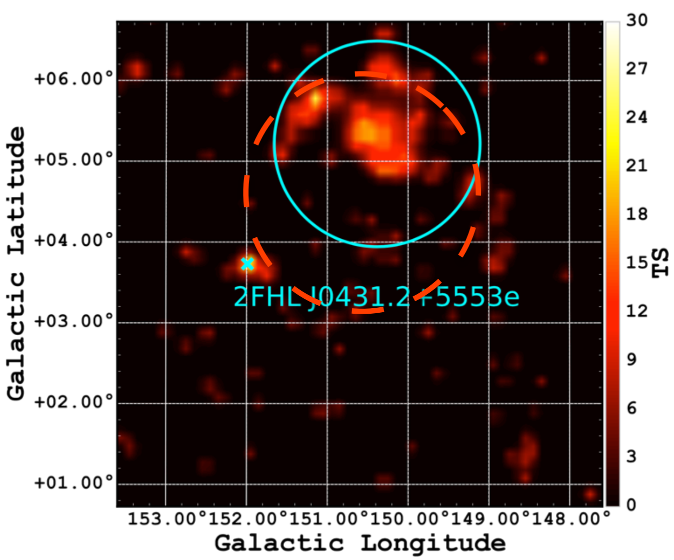

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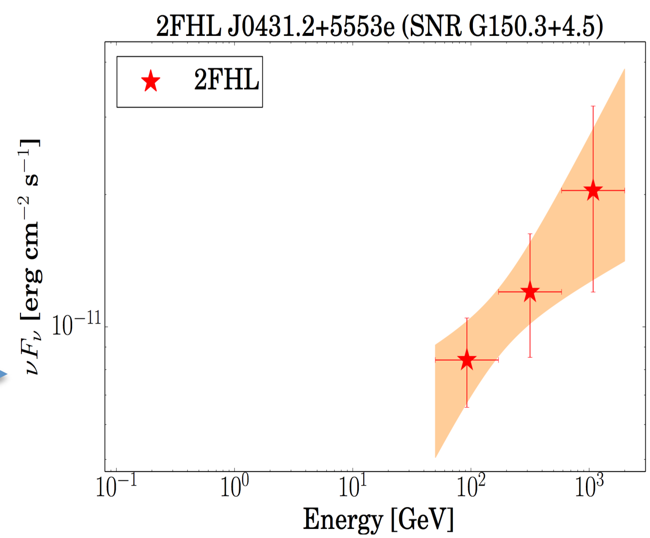
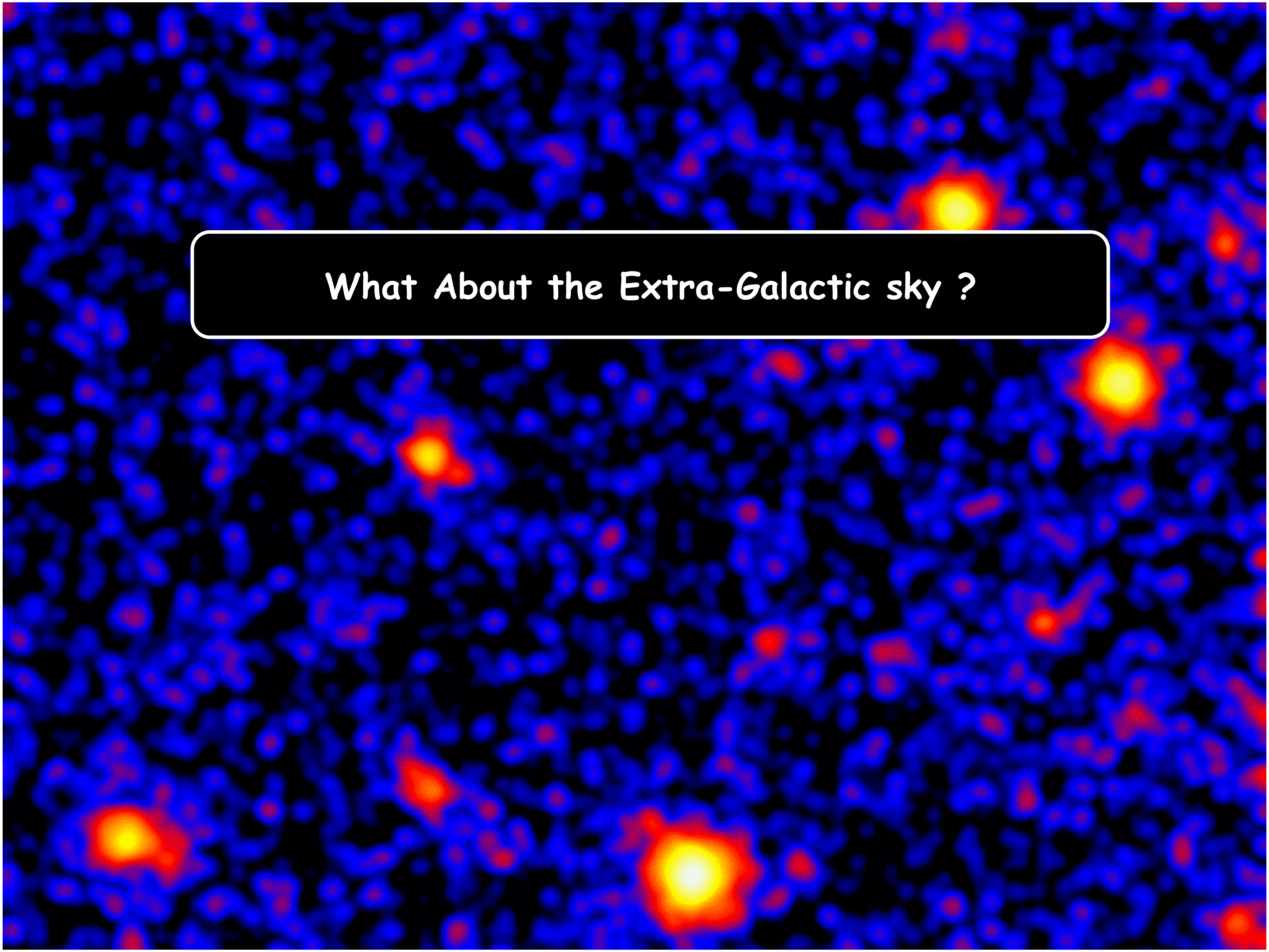
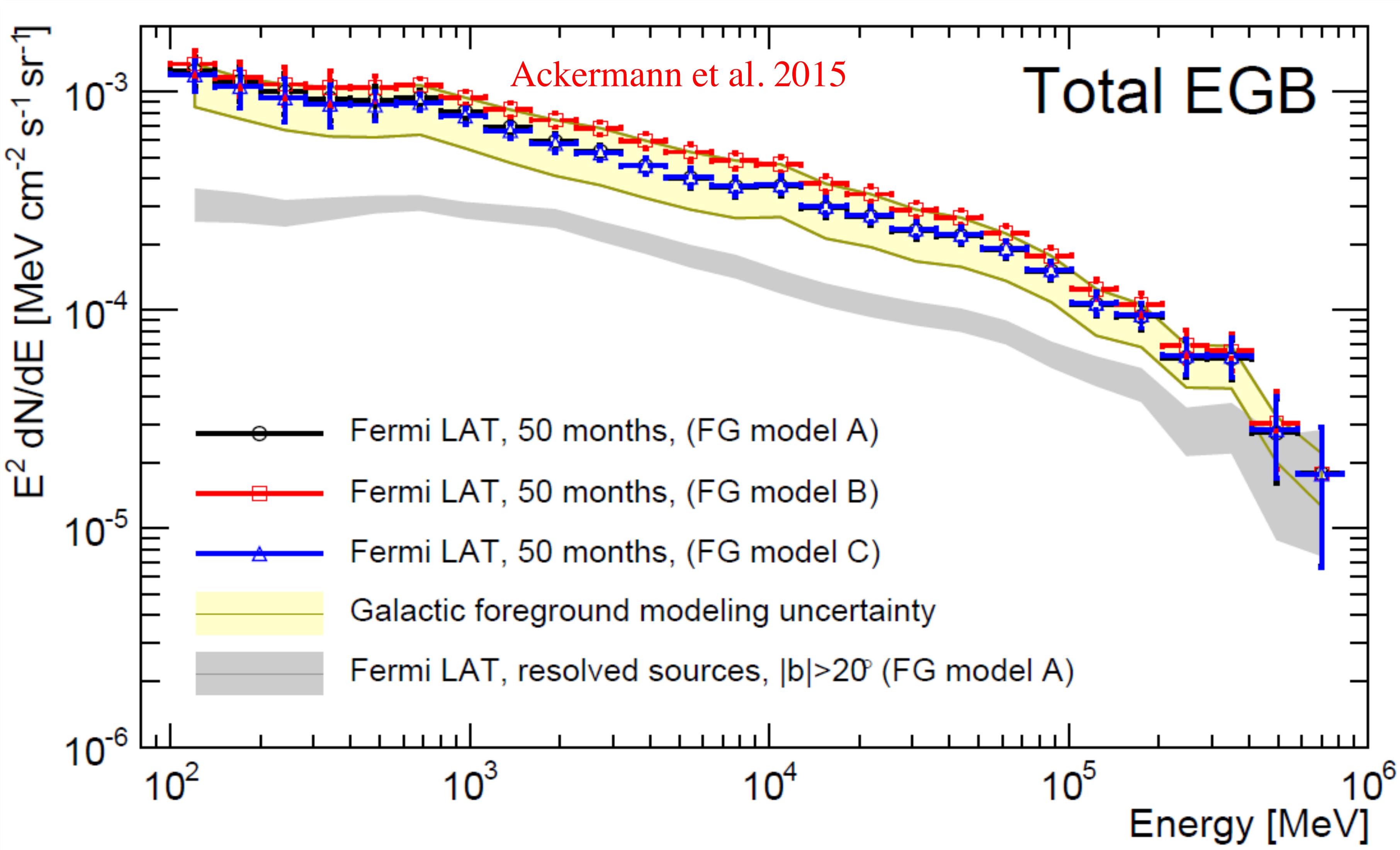


What About the Extra-Galactic sky ?



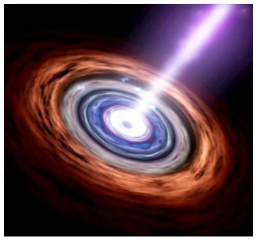
Total Extragalactic Gamma-ray Background

Systematic uncertainty from Galactic foreground represented by yellow band



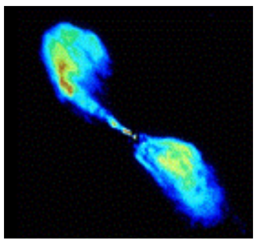
EGB: Why is it important ?

Undetected sources



Blazars

Dominant class of LAT extra-galactic sources. Many estimates in literature. EGB contribution ranging from 20% - 100%.

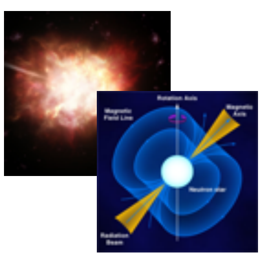


Non-blazar active galaxies

27 sources resolved in 2FGL
~ 25% contribution of radio galaxies to EGB expected. (e.g. Inoue 2011)

Star-forming galaxies

Several galaxies outside the local group resolved by LAT. Significant contribution to EGB expected. (e.g. Pavlidou & Fields, 2002, Ackermann et al. 2012)



GRBs

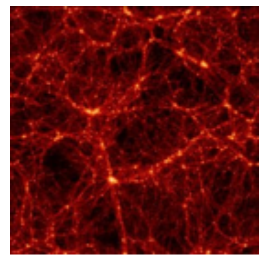
High-latitude pulsars

Small contributions expected. (e.g. Dermer 2007, Siegal-Gaskins et al. 2010)

Diffuse processes

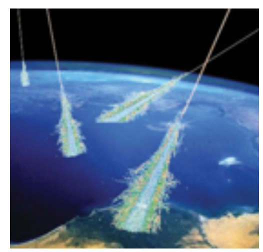
Intergalactic shocks

Widely varying predictions of EGB contribution ranging from 1% to 100% (e.g. Loeb & Waxman 2000, Gabici & Blasi 2003)



Dark matter annihilation

Potential signal dependent on nature of DM, cross-section and structure of DM distribution (e.g. Ullio et al. 2002)



Interactions of UHE cosmic rays with the EBL

Dependent on evolution of CR sources, predictions varying from 1% to 100 % (e.g. Kalashev et al. 2009)

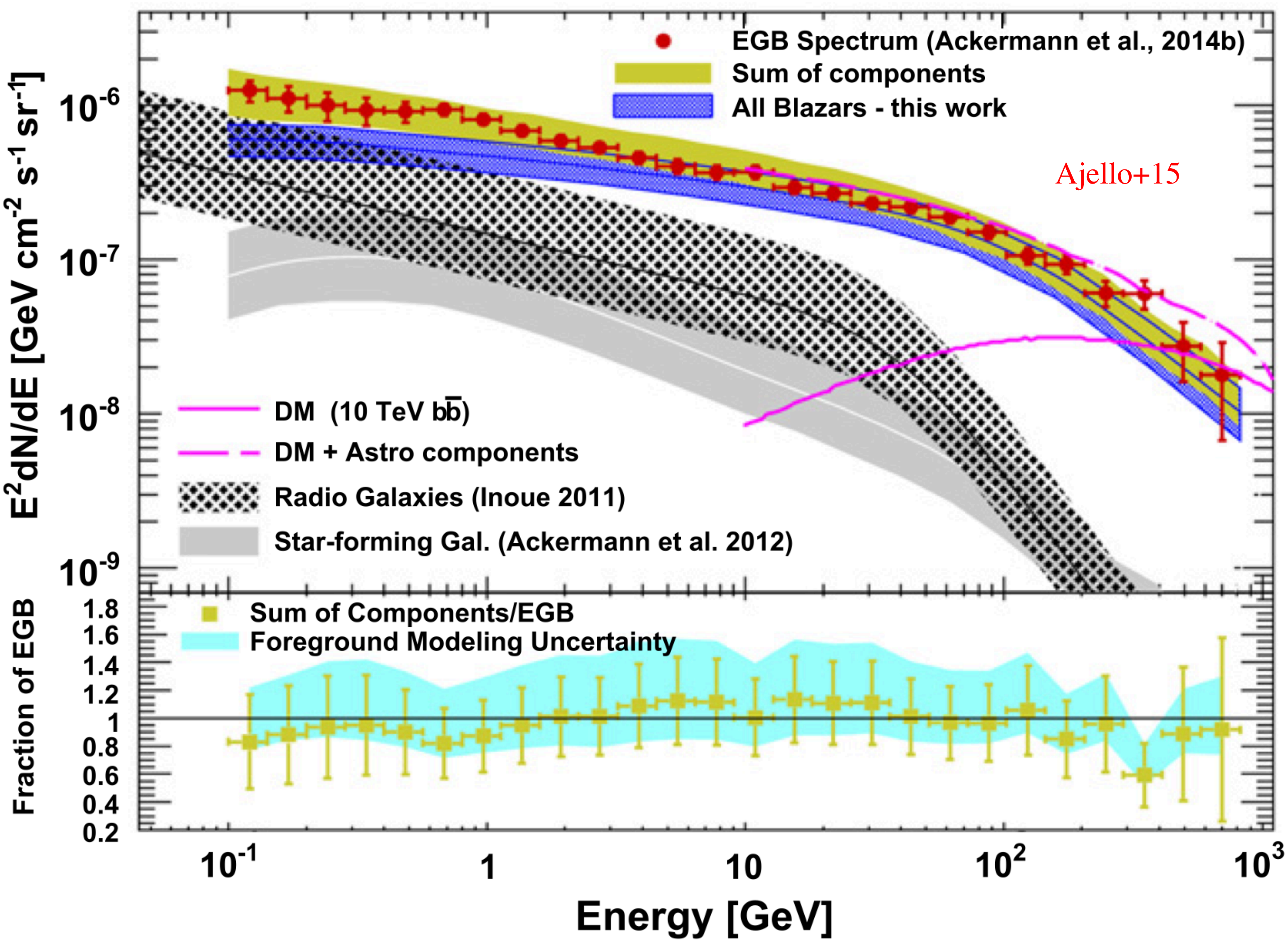
Extremely large Galactic electron halo

(Keshet et al. 2004)

CR interaction in small solar system bodies

(Moskalenko & Porter 2009)

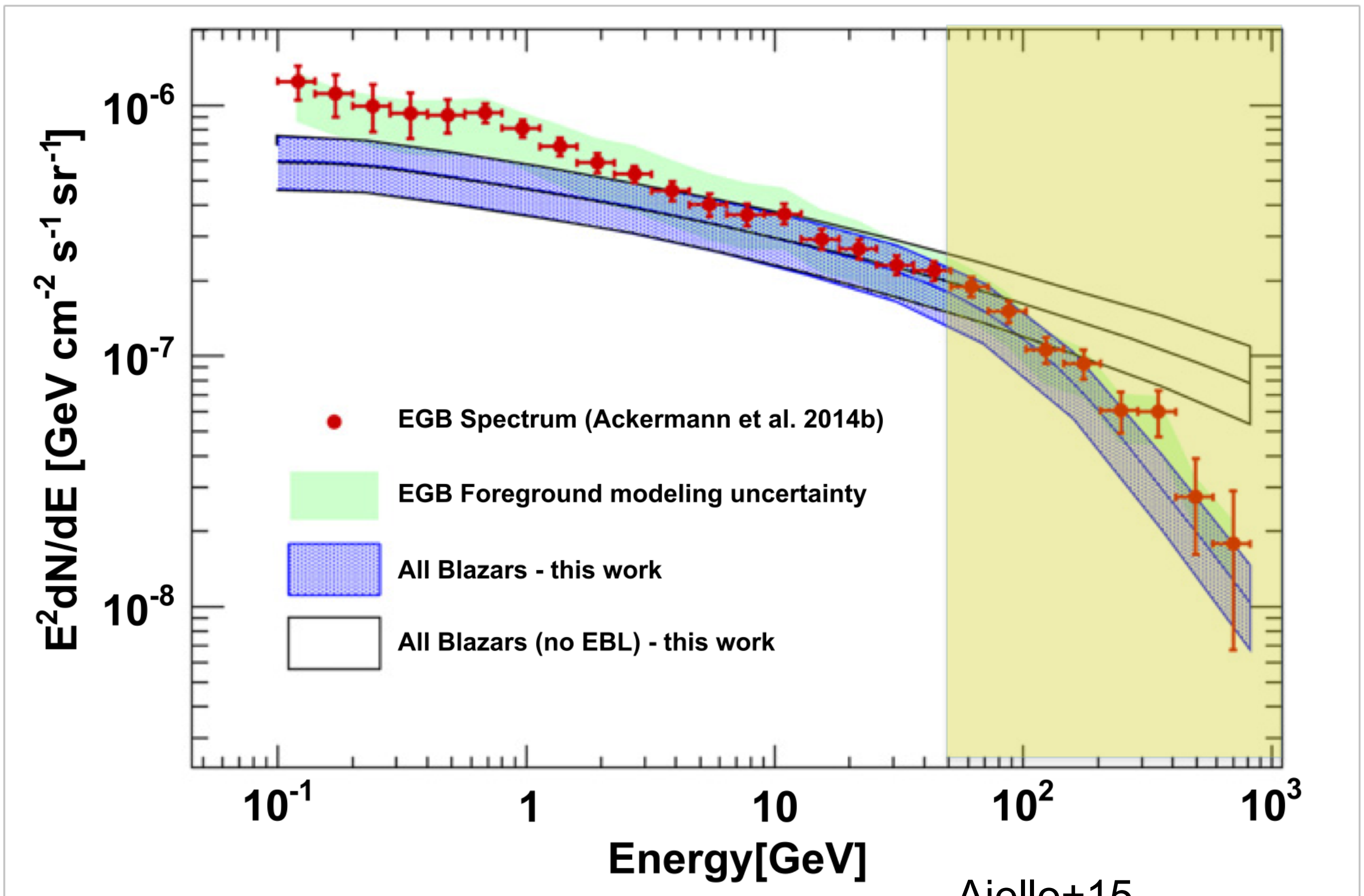
The Origin of the Extragalactic γ-ray Background



Extragalactic Gamma-ray Background

- **Models predict that the >50 GeV EGB is produced by blazars**

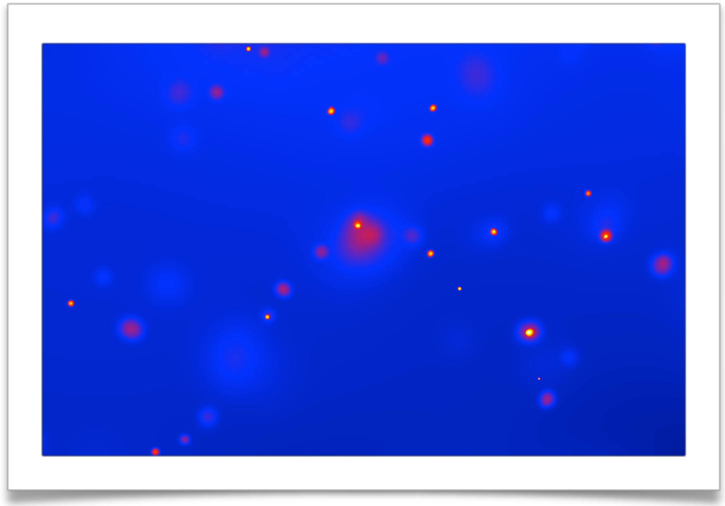
EGB: Ackermann et al. 2015, Models: Ajello+2015, Di Mauro+2015



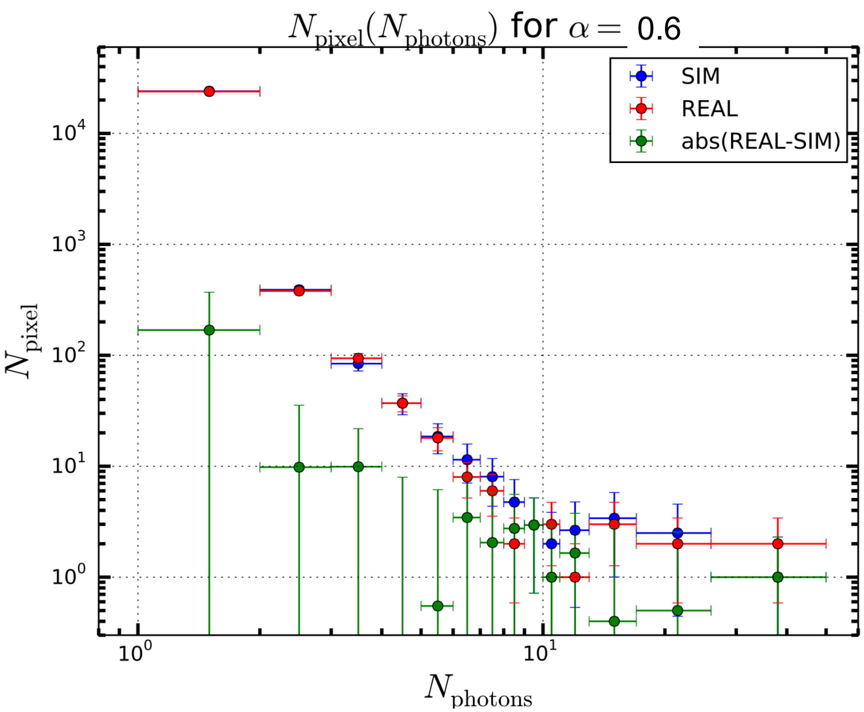
Ajello+15

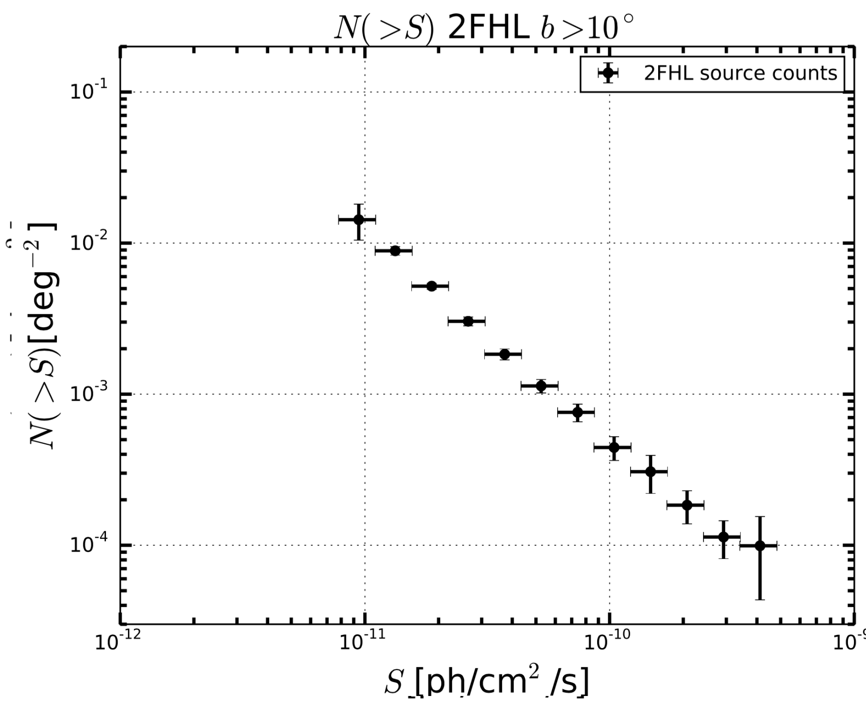
Photon Fluctuation Analysis

Ackermann+, 2016 PRL,116, 151105



- Fluctuations of the background depend also on the properties of the unresolved source population





Photon Fluctuation Analysis

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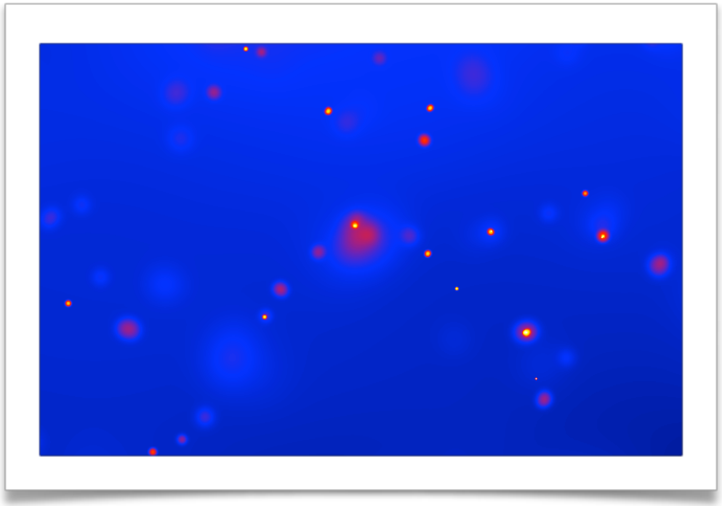
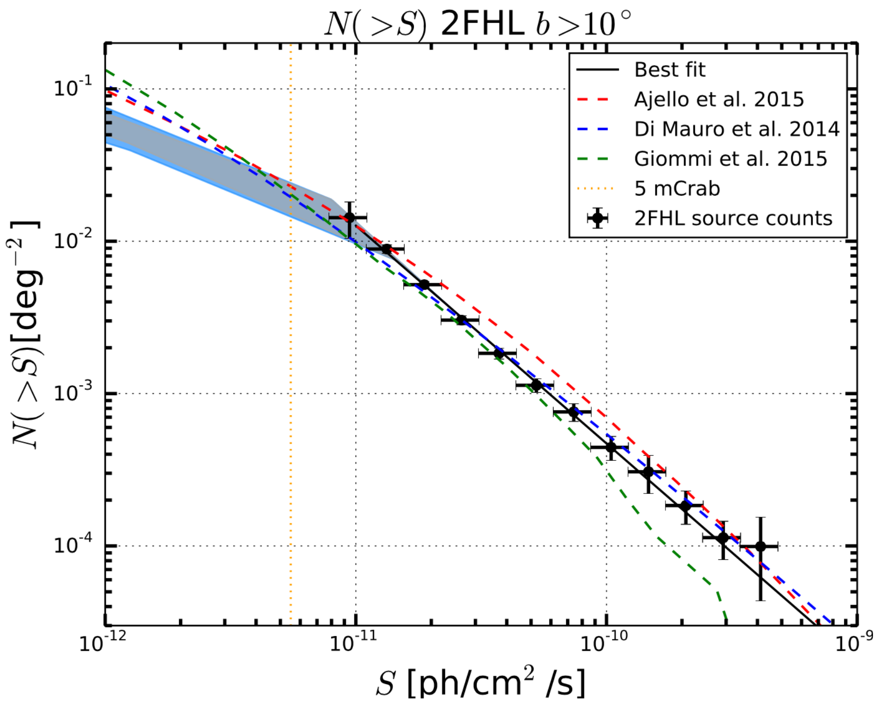


- LAT resolves 86(+15/-18)% of the EGB at >50 GeV

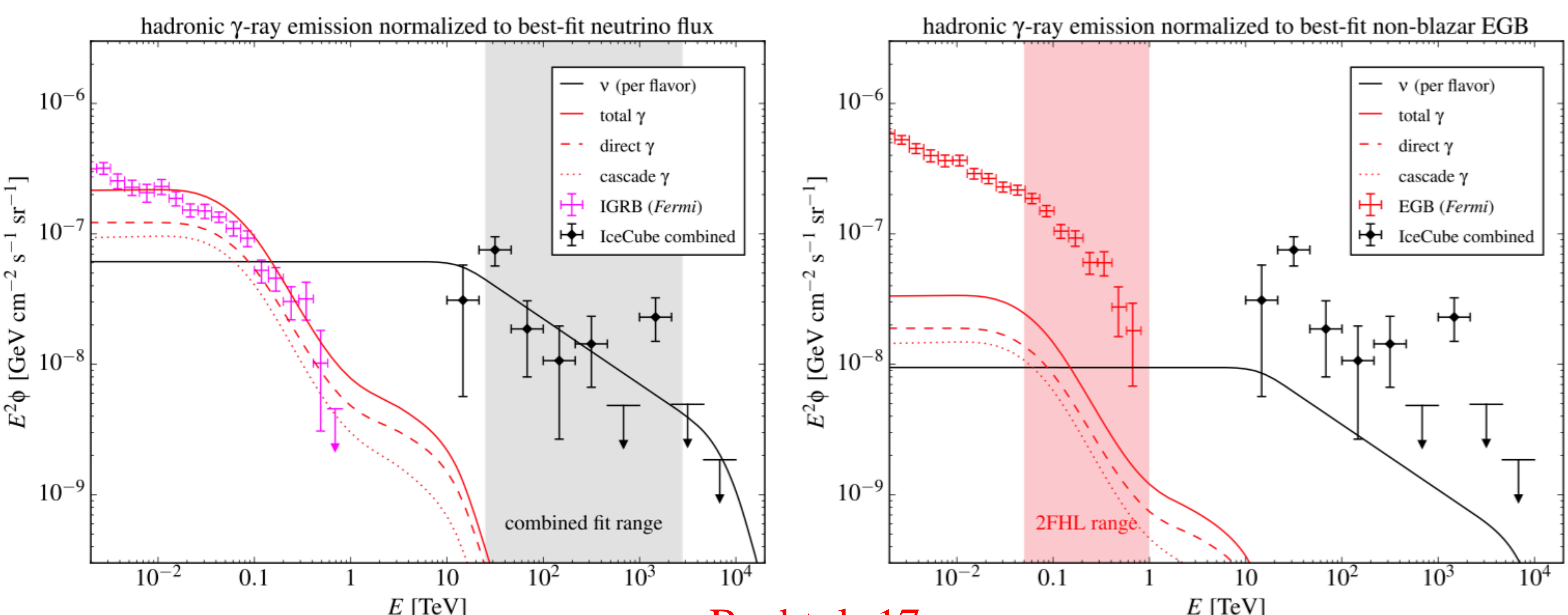


Nearly all the EGB is produced by BL Lacs

Confirmed also by Zechlin+2016, Lisanti+2016

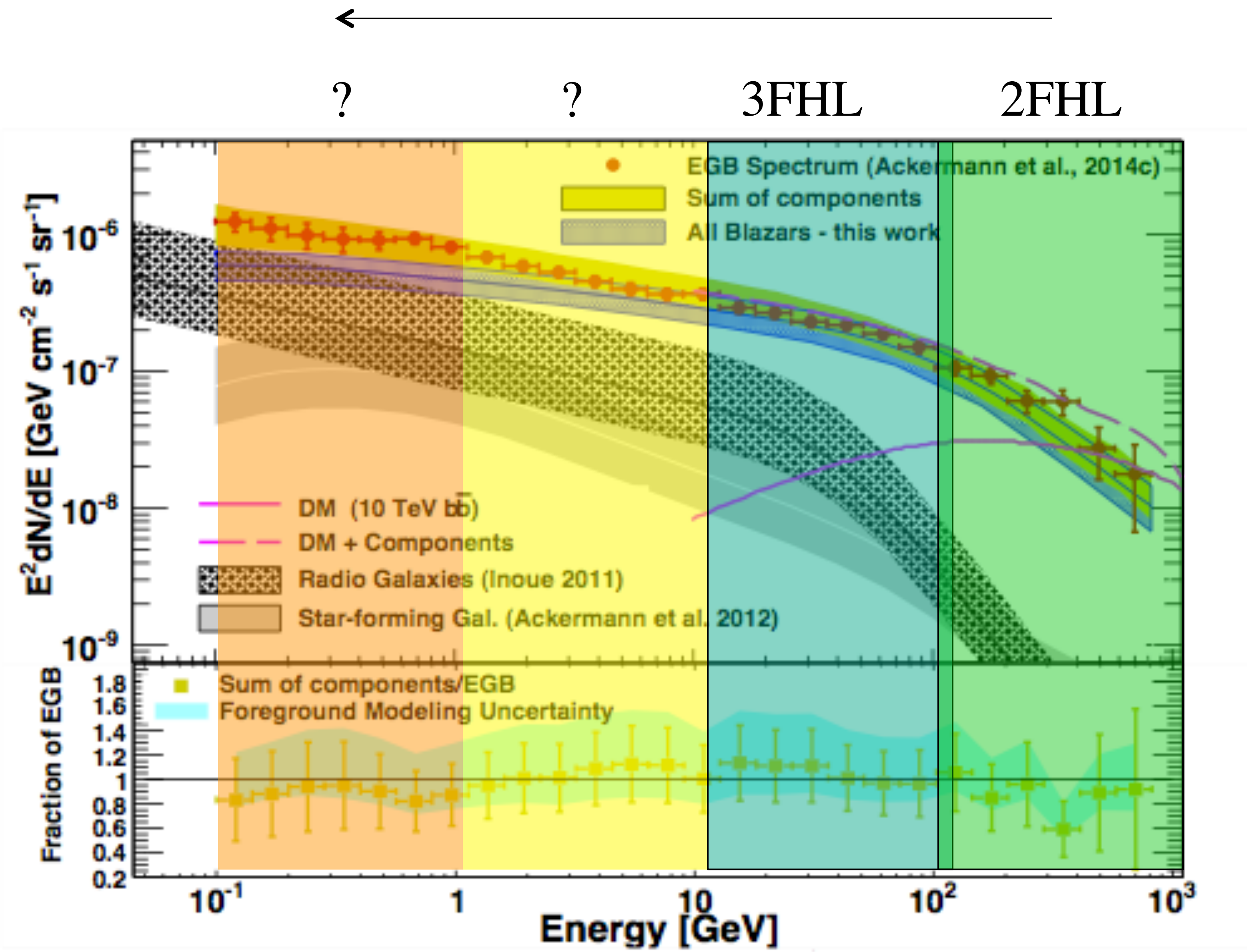
IceCube Neutrinos

- Star-forming galaxies do not seem to be the major contributor to the IceCube (Aartsen 2015, ApJ, 809,98) neutrino flux (Bechtol+17, see also Murase+13, Tamborra+14)



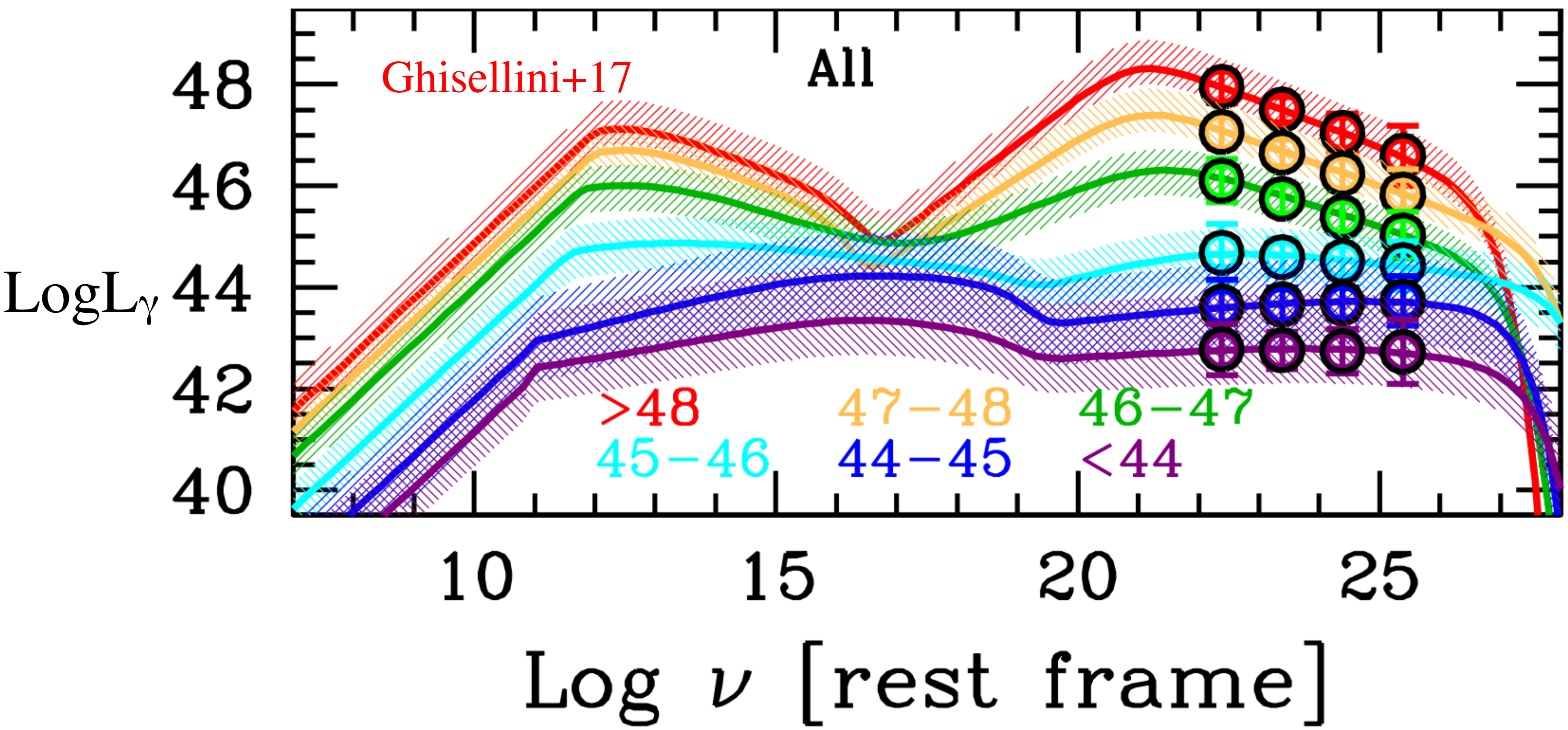
Bechtol+17

Resolving the EGB in all bands



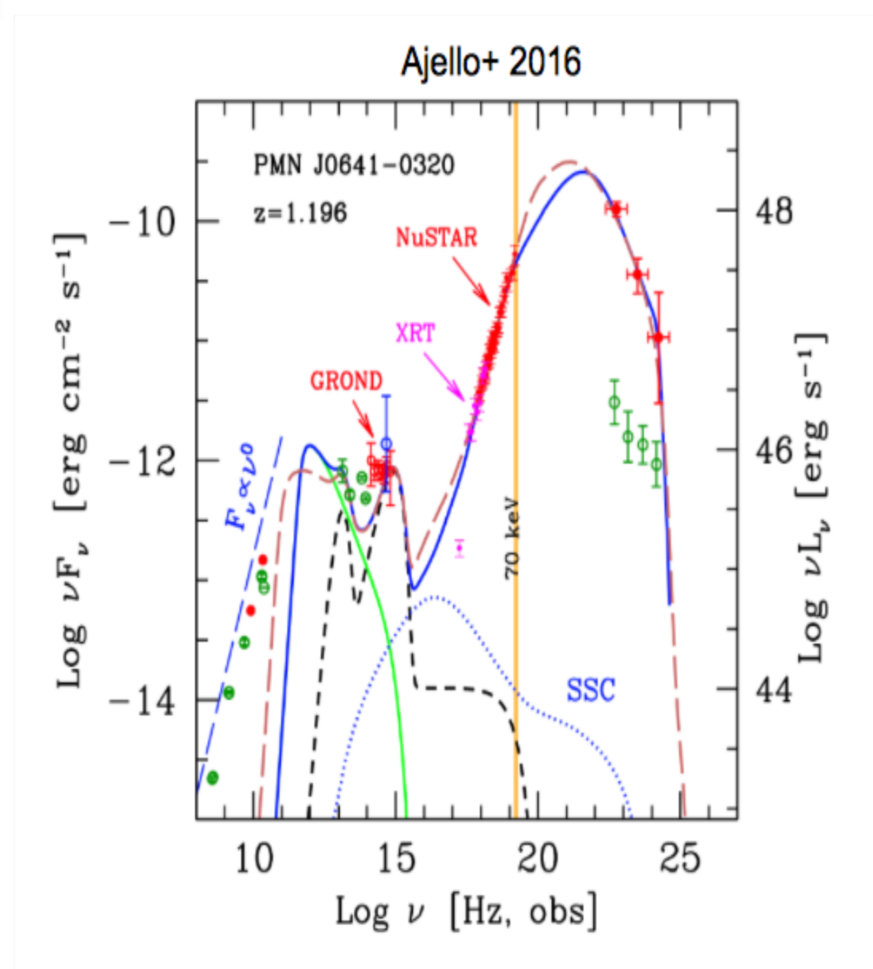
Blazar Population

- The more luminous blazars have a IC peak at <<100 MeV
- We refer to this class as MeV blazars



MeV Blazars

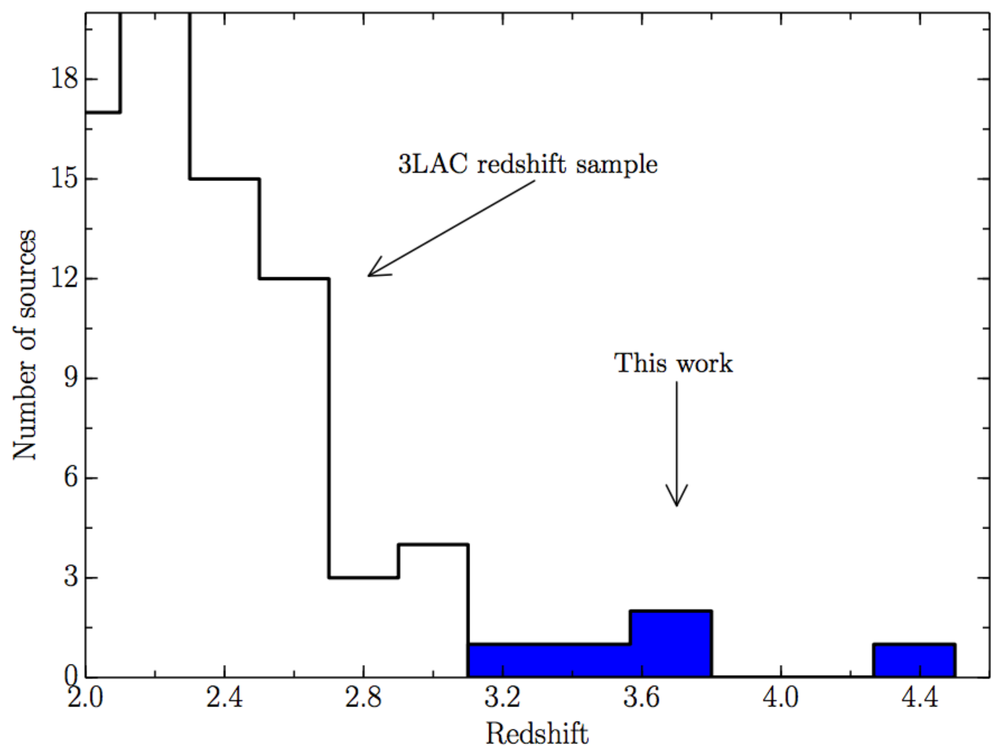
- Among most powerful persistent objects in the Universe
- Large jet power, easily exceeding the total accretion luminosity
  - BH spin may play a role
- Host massive black holes
  - > 1 billion solar masses
- Detected up to very high redshift
- They are also very bright !

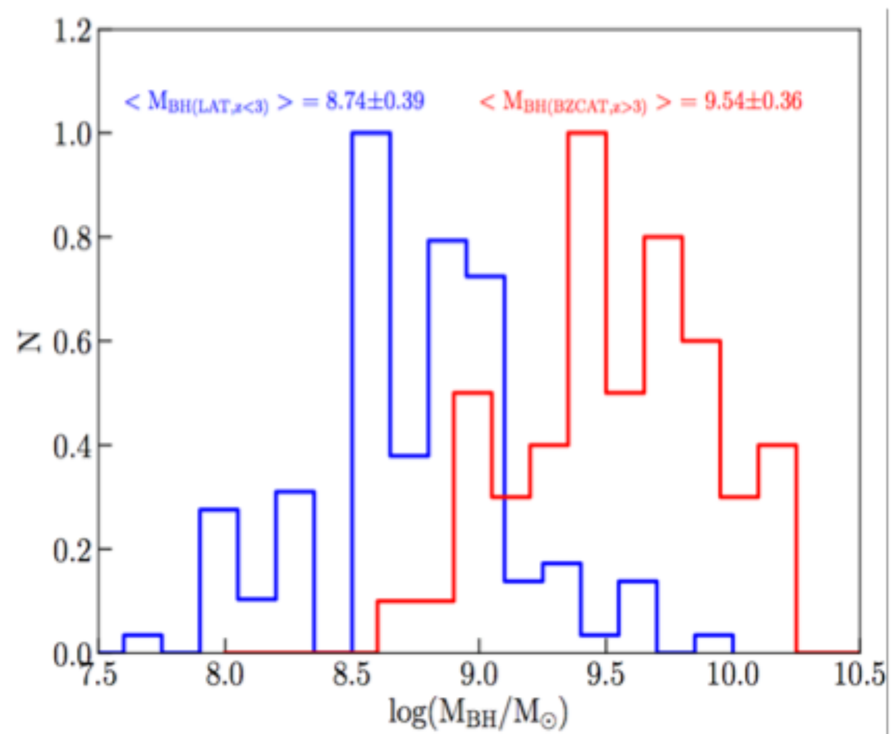


Recent Detections

- Improved low-energy response (with P8) allowed Fermi-LAT to detect 5 z>3.1 blazars (Ackermann+17, ApJL, 837, 5)
- All are objects with $M_{BH}> 10^{8\text{-}9} M_{sun}$
- All have $\Gamma \sim 13\text{-}15$

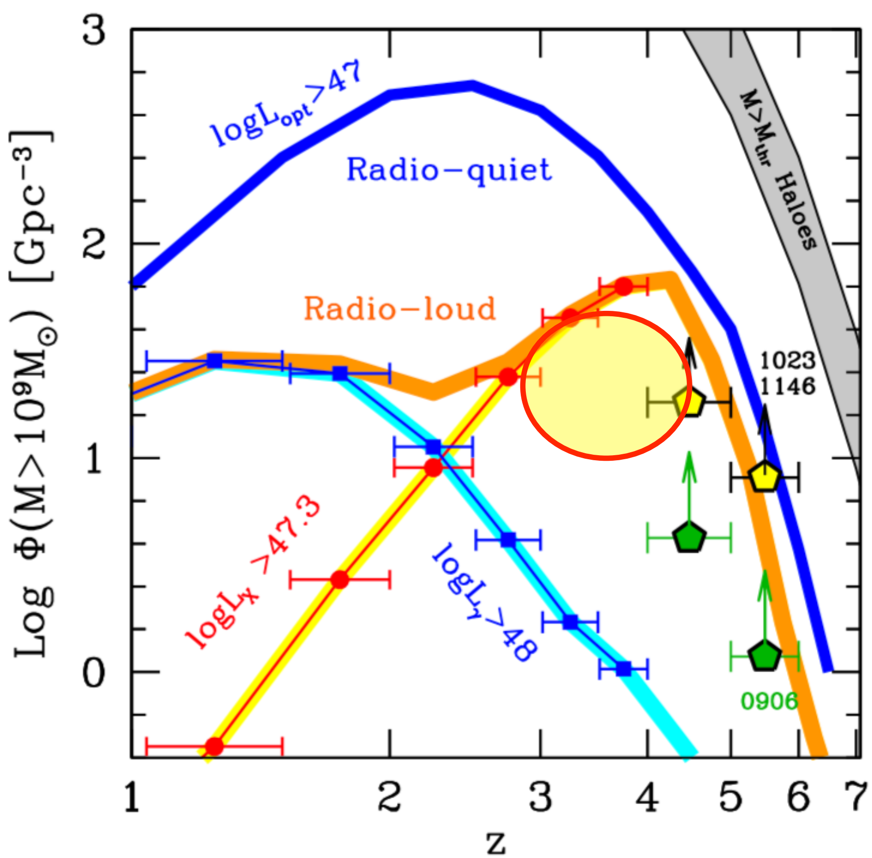
Paliya+17 in prep.





Recent Detections

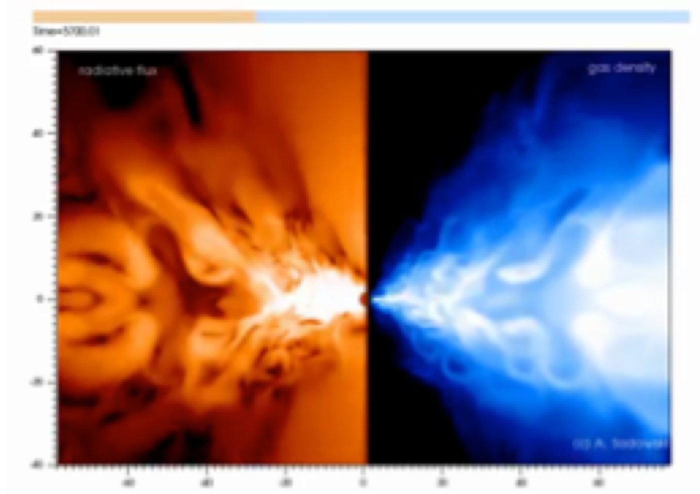
- Between redshift 3 and 4 we have 2 blazars with $M_{BH}>10^9\ M_\odot$
  - They account for ~675 more objects at the same redshift
- Only 5 system were known before
  - Brings up the space density estimate by 40% !



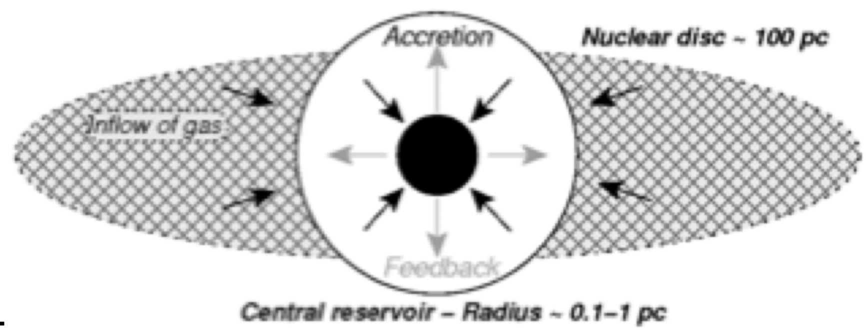
Sbarrato+14

How to grow quickly a black hole

Credit: HST image



Simulation by
A. Sadowski

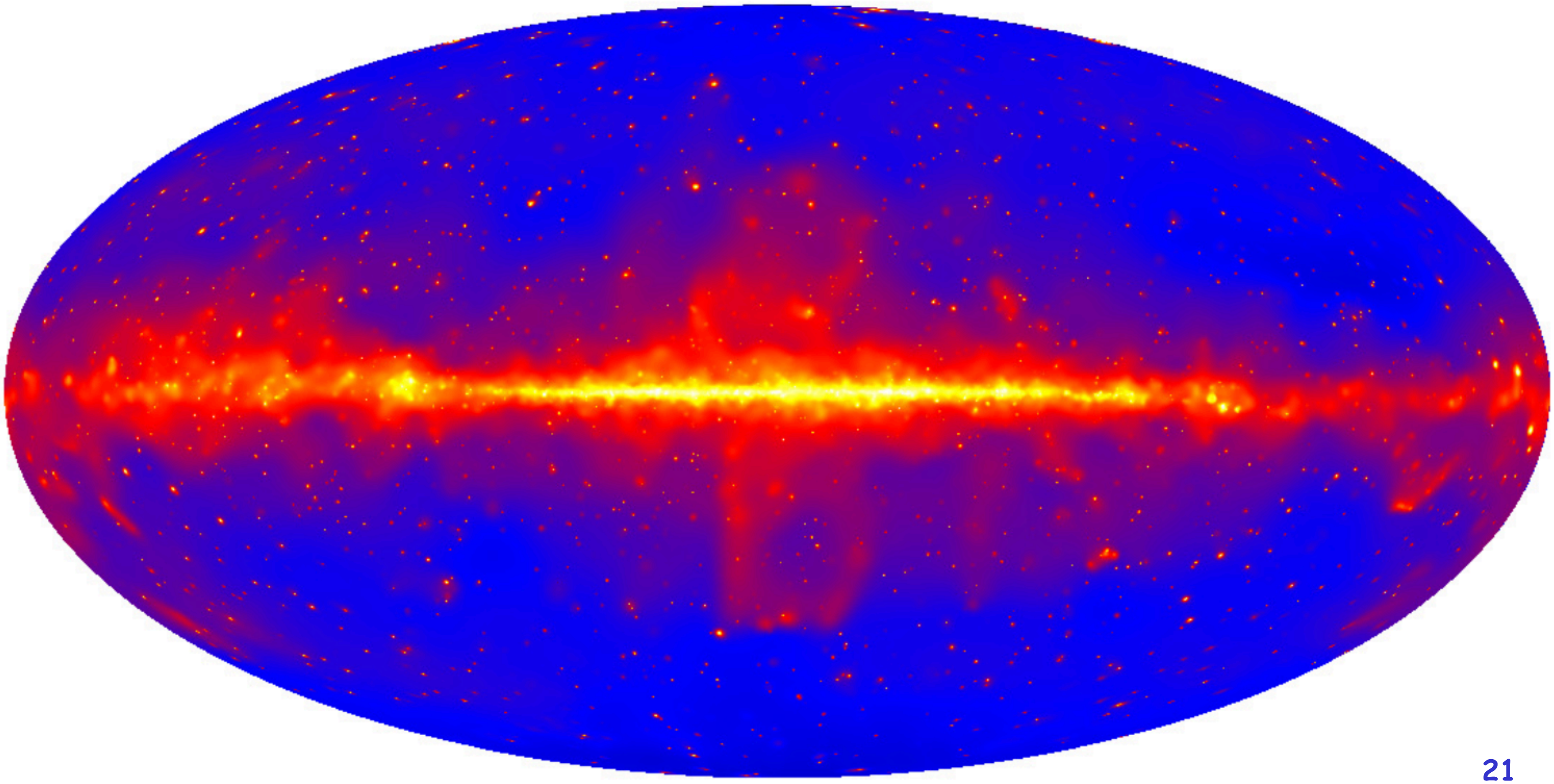


Bonoli+14

3FHL

arXiv:1702.00664

- >1500 objects detected at >10 GeV
  - More than the EGRET >10GeV photons
- 55 extended sources (arXiv: 1702.00476)
- >330 HSP BL Lacs



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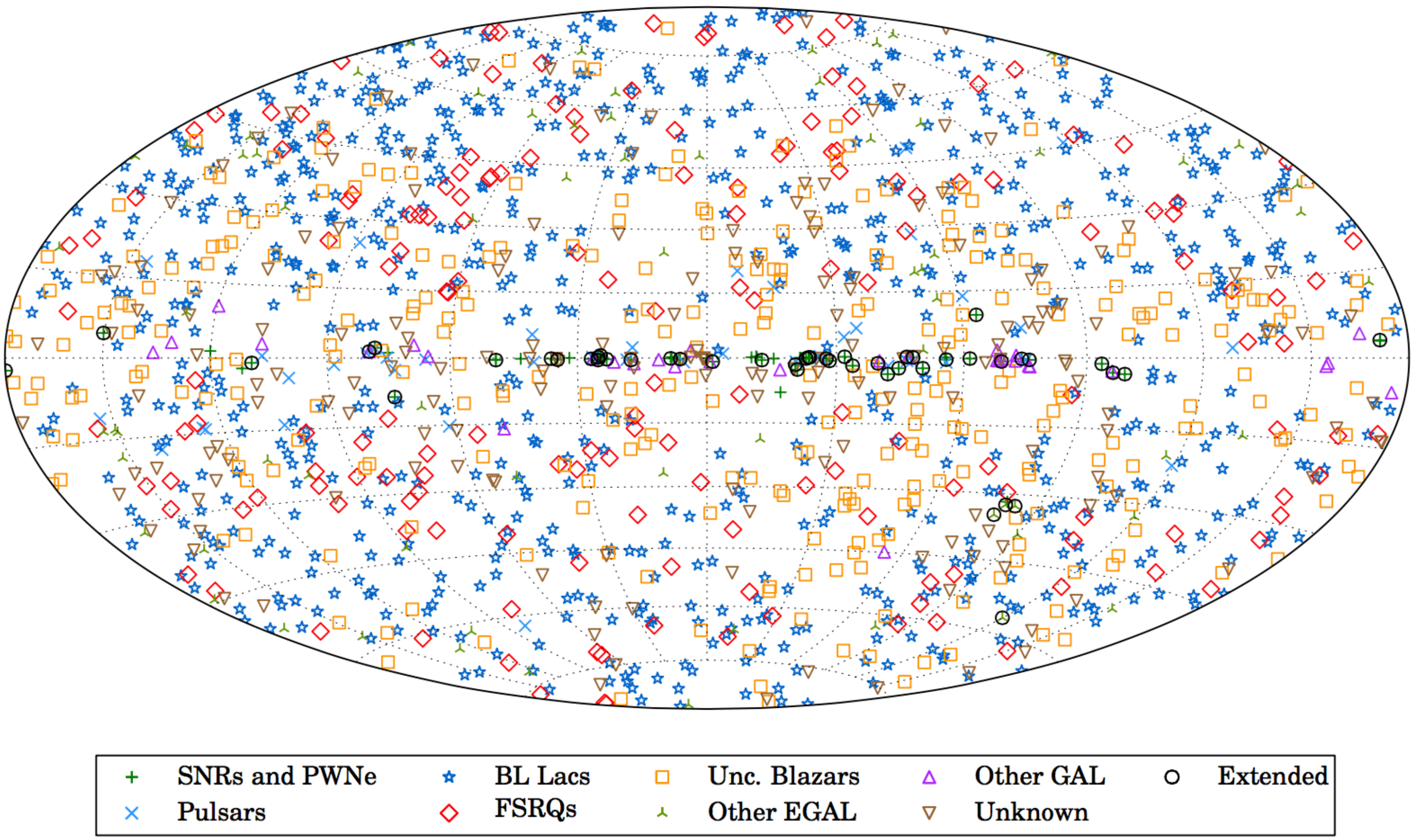


ASTRONOMY

All the Light There Ever Was

Galaxies in every corner of the universe have been sending out photons, or light particles, since nearly the beginning of time. Astronomers are now beginning to read this extragalactic background light

By Alberto Domínguez, Joel R. Primack and Trudy E. Bell

IN BRIEF

The night sky may look dark, but it is actually filled with the accumulated light of all the galaxies that have shone in the universe's history.

This extragalactic background light is difficult to detect because it has spread out throughout the expanding cosmos and because it is outshone by brighter nearby sources of light.

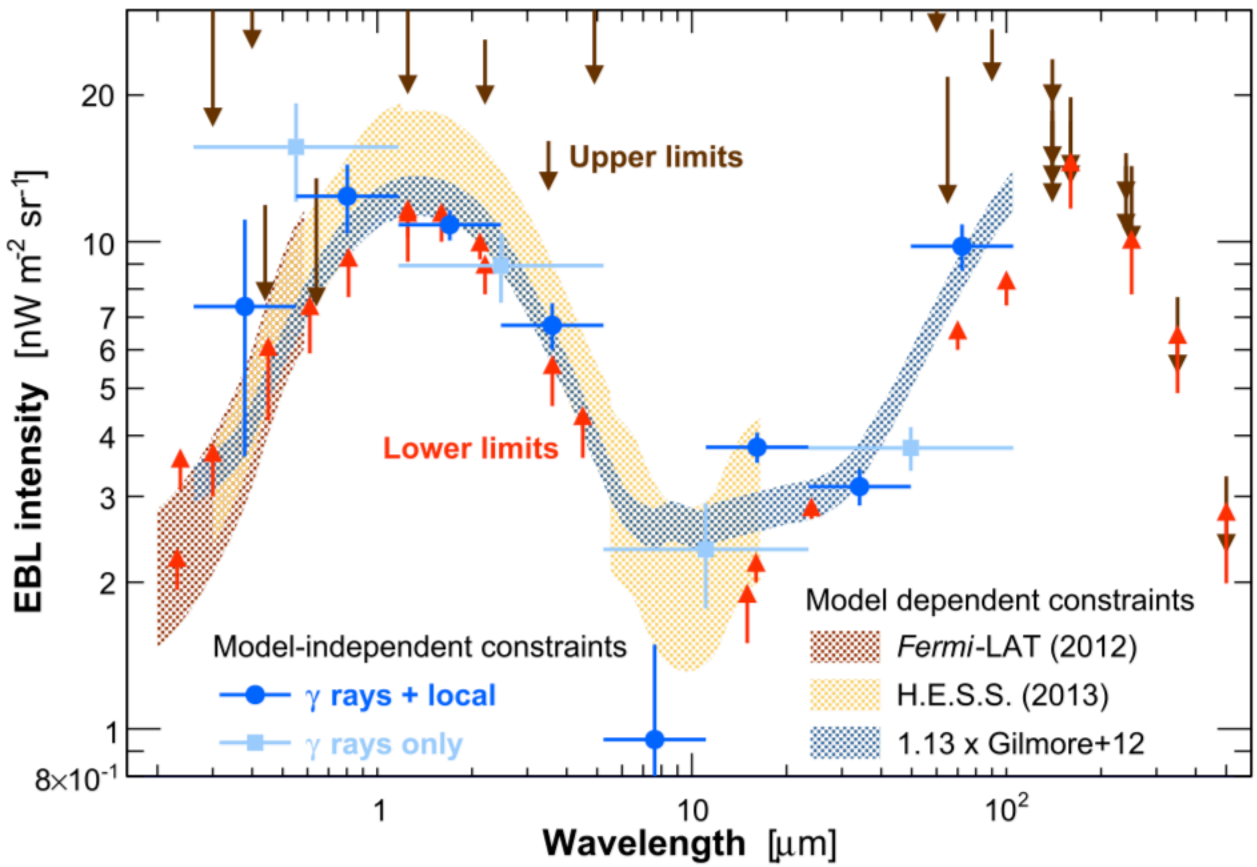
Astronomers have finally been able to measure this light by observing how gamma rays from distant bright galaxies called blazars are dimmed when they collide with photons of the extragalactic background light.

Studying the background in this way allows scientists to examine the record of cosmic history that the light preserves.

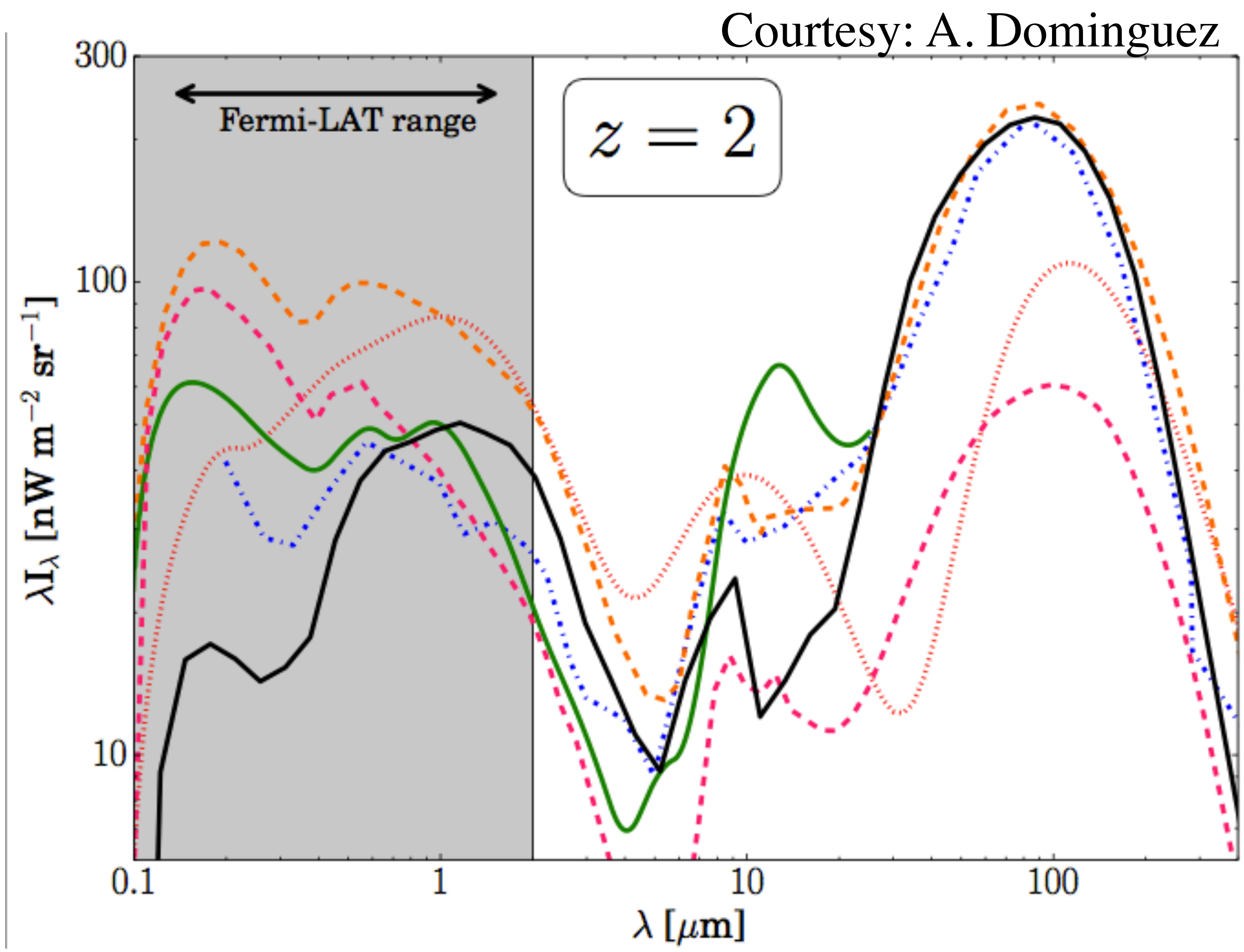
CALEB CHARLAND

Extragalactic Background Light

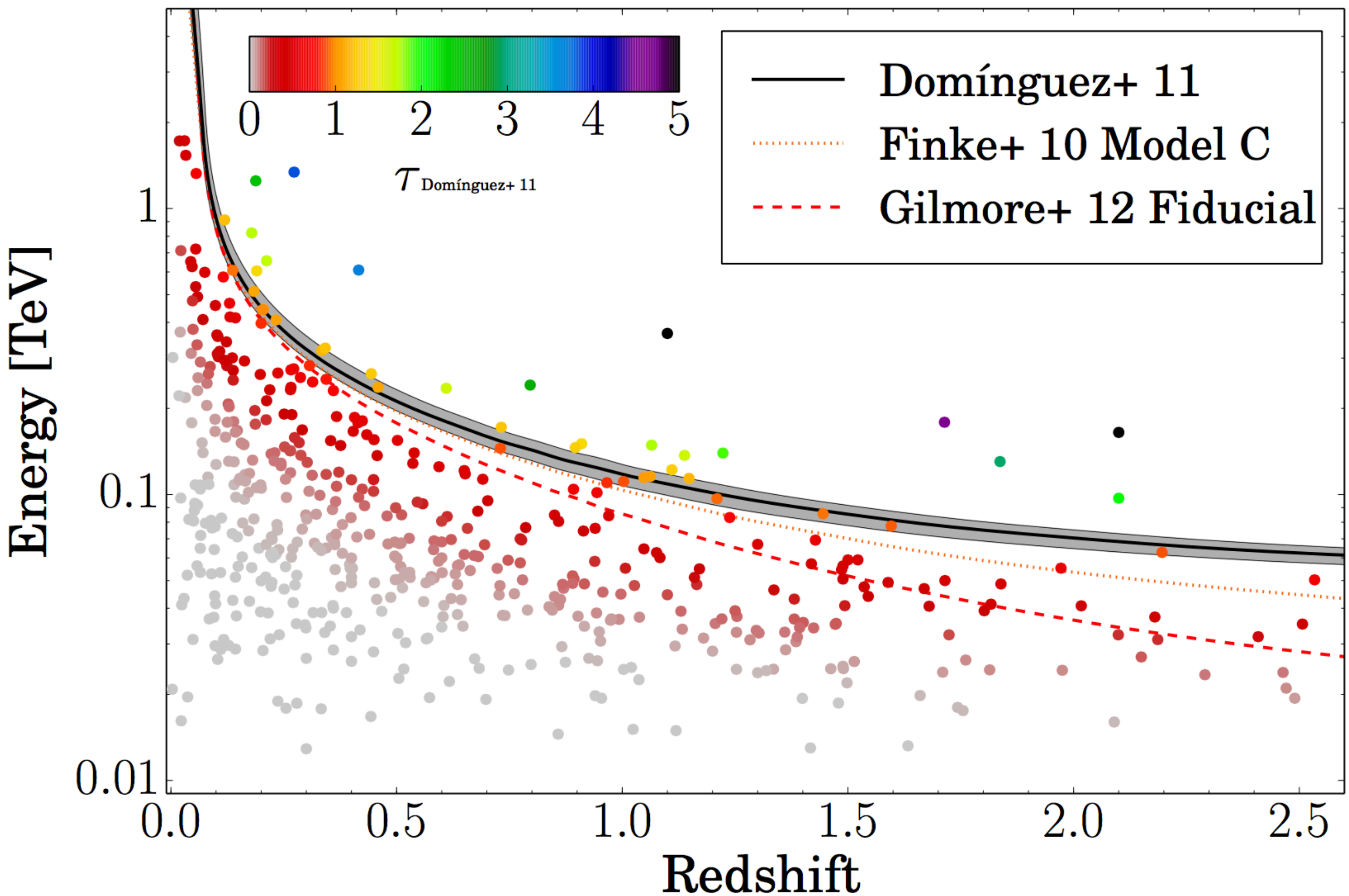
Biteau & Williams 15



Reality Check



High-energy photons in 3FHL



Conclusion

- Fermi-LAT
  - Among the few instruments able to measure and resolve a cosmic background at the same time, and to constrain another one

- EGB:
  - Great resource for multi-messenger astrophysics
  - It can be explained entirely (between 100 MeV and 800 GeV) by known source populations
  - It limits the contribution of SFGs to the neutrino flux

- Sources:
  - Plenty of HSP BL Lacs in the 2/3FHL catalogs
  - MeV blazars are among the brightest sources in the Universe

- EBL: stay tuned