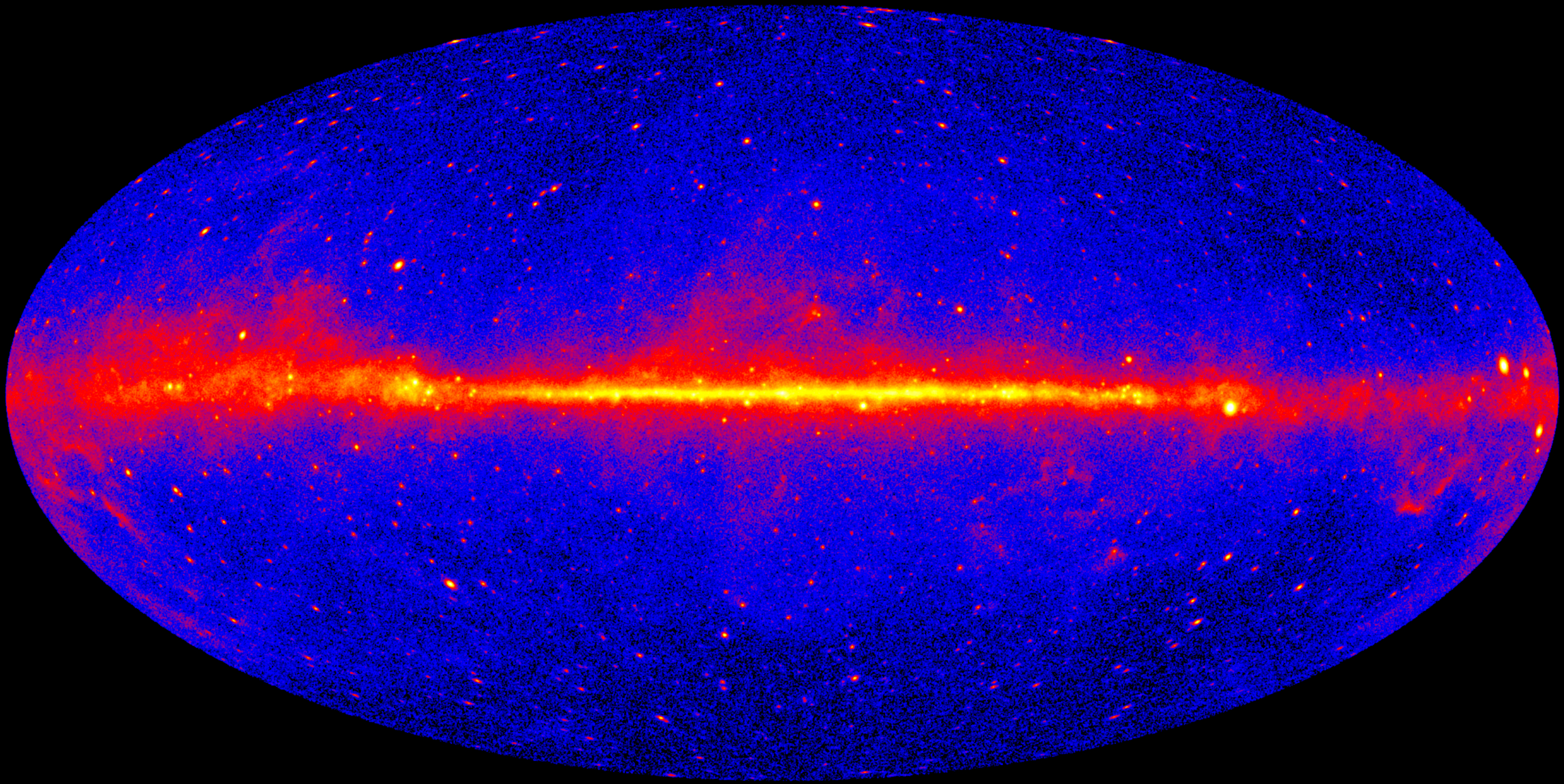
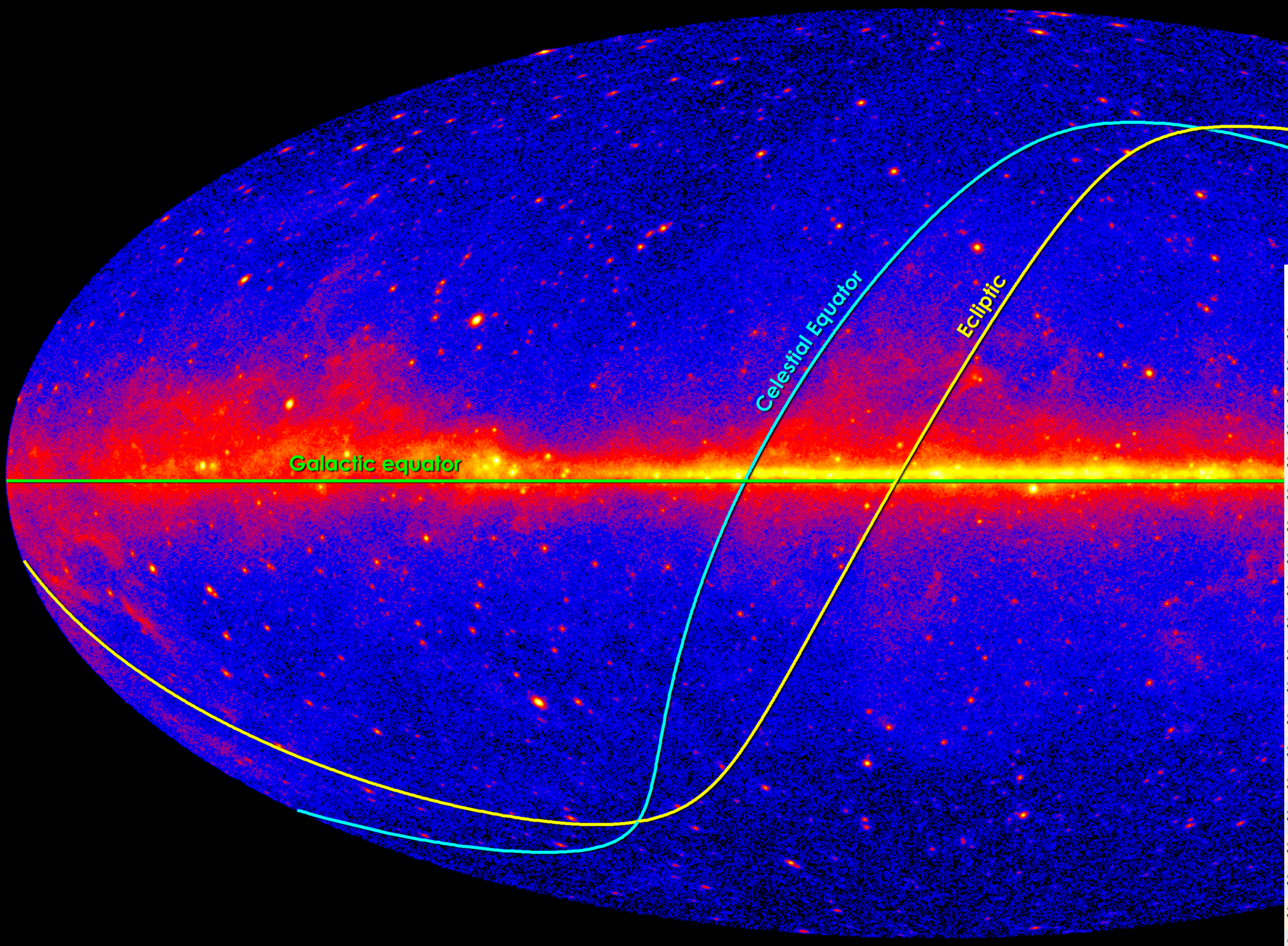
TIM LINDEN

223rd AAS Meeting - Seattle, WA

Evidence for a New Component of Solar Gamma-Ray Emission

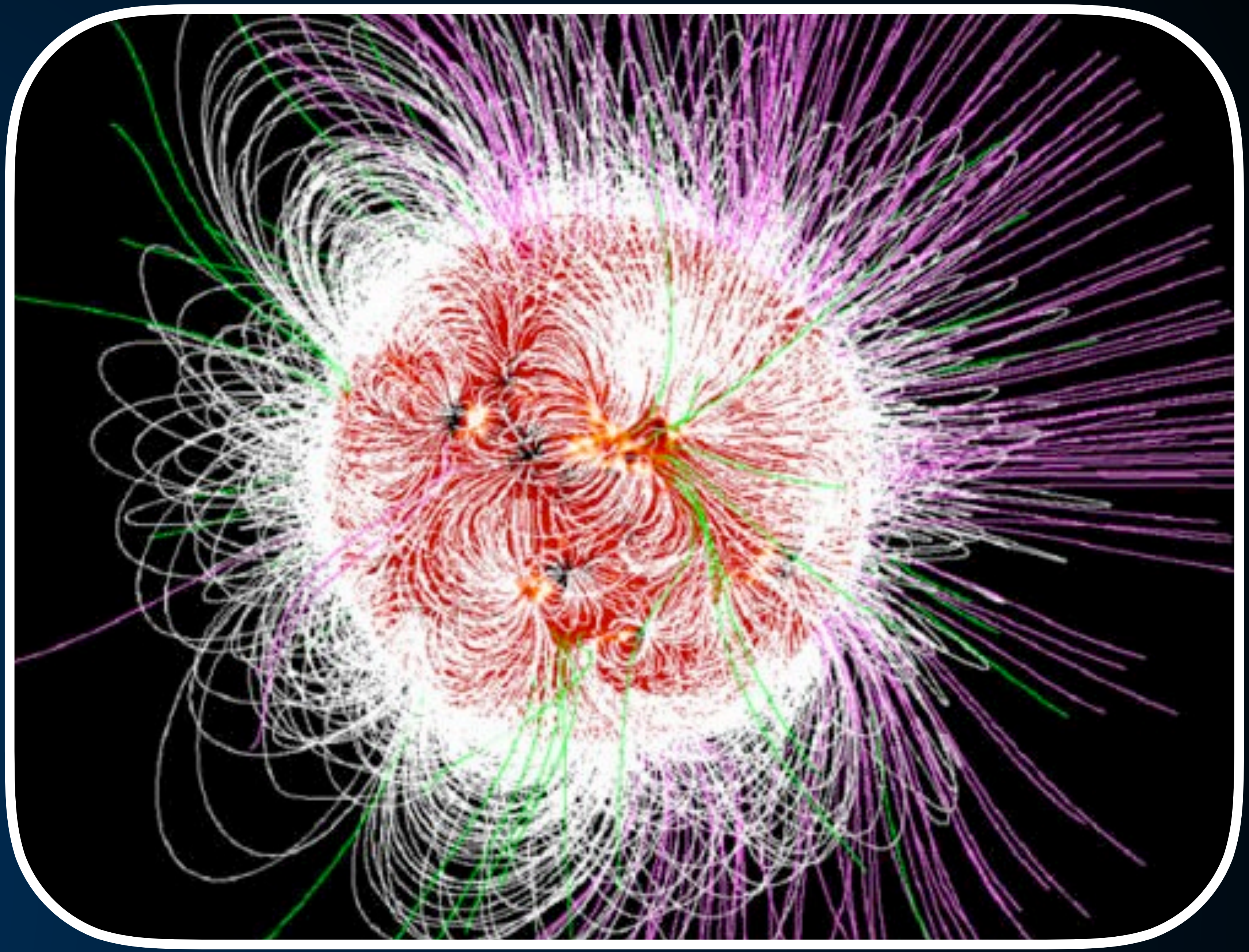
THE OHIO STATE UNIVERSITY
CENTER FOR COSMOLOGY AND ASTROPARTICLE PHYSICS

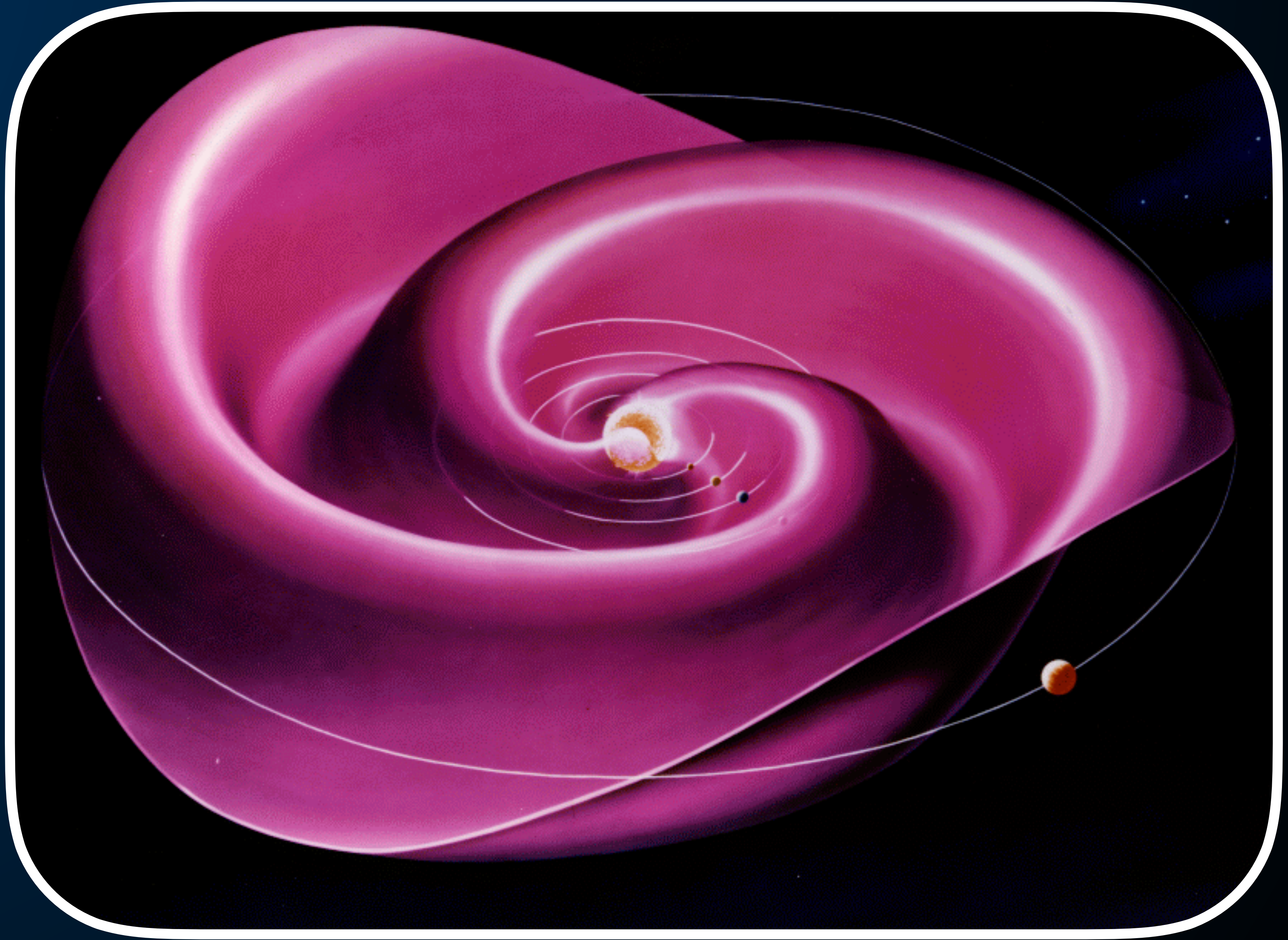




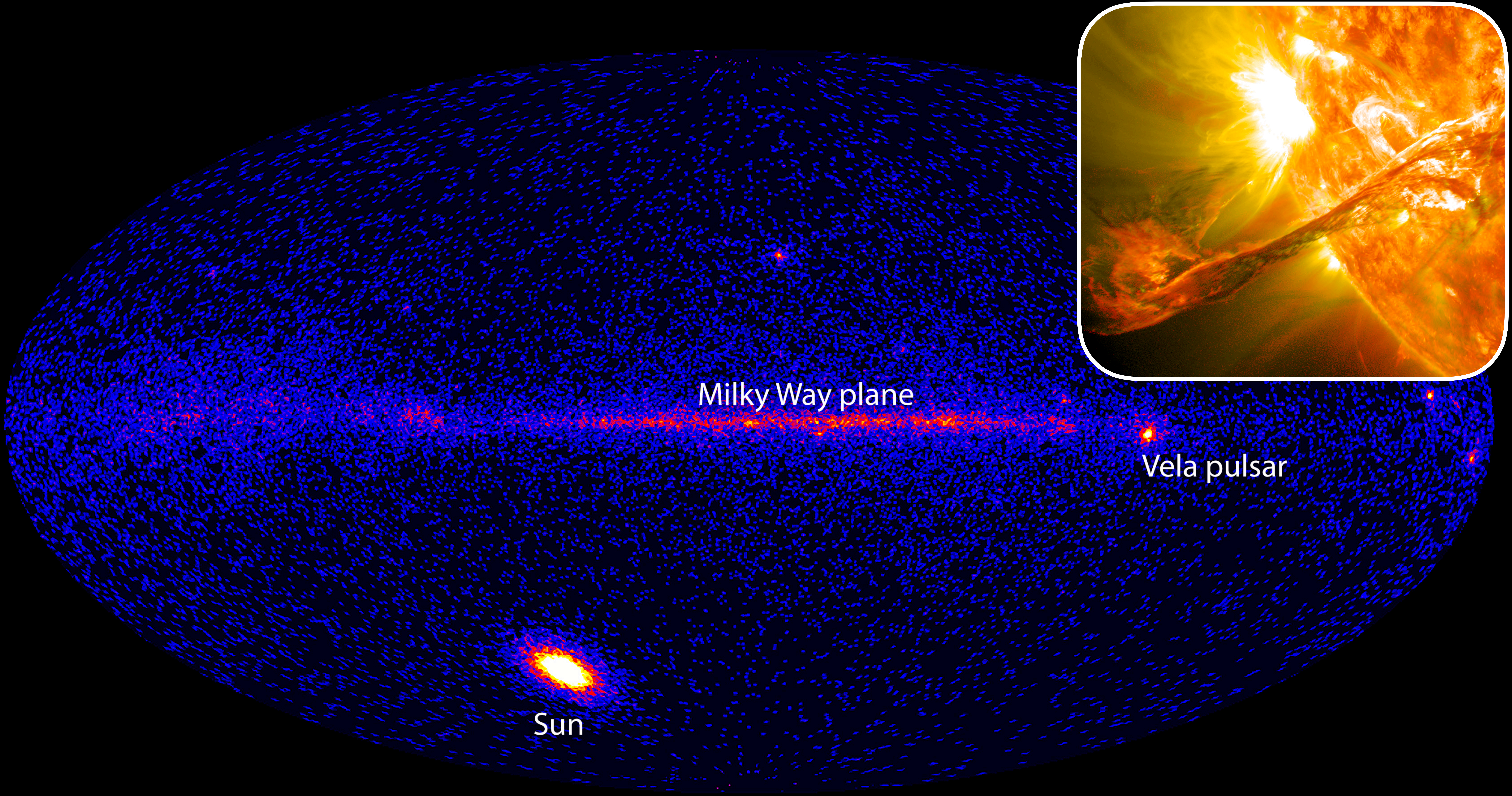
name	assoc name 1	energy flux [erg/cm^2/s]	assoc name 2
3FGL J0835.3-4510	PSR J0835-4510	8.93008e-09	Vela
3FGL J0633.9+1746	PSR J0633+1746	4.15261e-09	Geminga
3FGL J0534.5+2201	PSR J0534+2200	1.47178e-09	Crab
3FGL J1709.7-4429	PSR J1709-4429	1.31463e-09	
3FGL J2254.0+1608	3C 454.3	1.23418e-09	
3FGL J2021.5+4026	LAT PSR J2021+4026	8.83261e-10	
3FGL J2028.6+4110e	Cygnus Cocoon	6.57388e-10	
3FGL J1836.2+5925	LAT PSR J1836+5925	5.98187e-10	
3FGL J1855.9+0121e	W44	5.35680e-10	
3FGL J2021.1+3651	PSR J2021+3651	5.03626e-10	
3FGL J0617.2+2234e	IC 443	5.02055e-10	
3FGL J1512.8-0906	PKS 1510-08	4.92754e-10	
3FGL J0240.5+6113	LS I+61 303	4.72665e-10	
3FGL J1809.8-2332	PSR J1809-2332	4.47994e-10	
3FGL J0007.0+7302	LAT PSR J0007+7303	4.25538e-10	
3FGL J1801.3-2326e	W28	4.15501e-10	
3FGL J1826.1-1256	LAT PSR J1826-1256	4.14665e-10	
3FGL J0534.5+2201i	Crab	3.92571e-10	
3FGL J1104.4+3812	Mkn 421	3.82949e-10	
3FGL J1923.2+1408e	W51C	3.45801e-10	
3FGL J1907.9+0602	LAT PSR J1907+0602	3.19051e-10	
3FGL J1418.6-6058	LAT PSR J1418-6058	3.10352e-10	

Why Gamma-Rays?

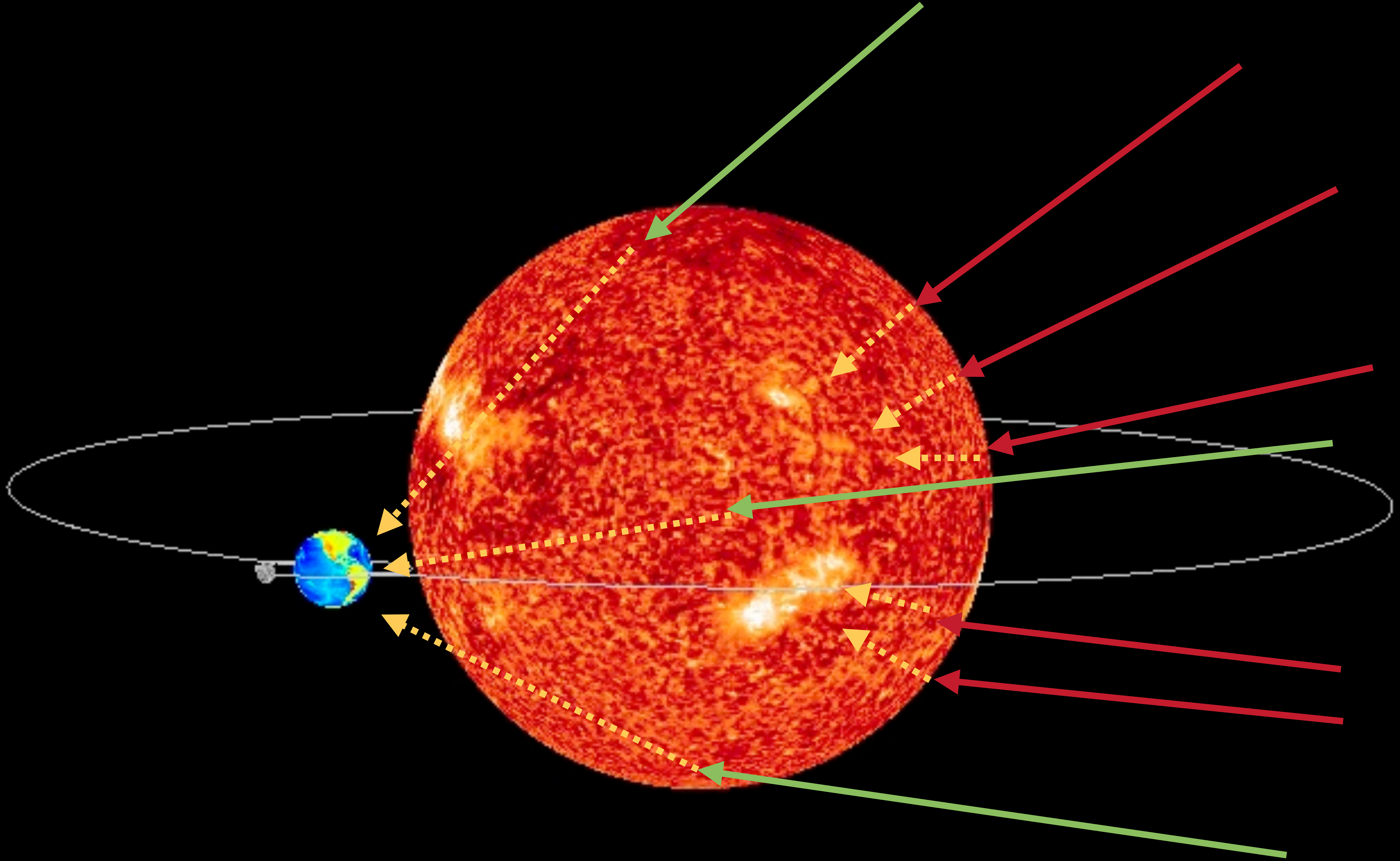


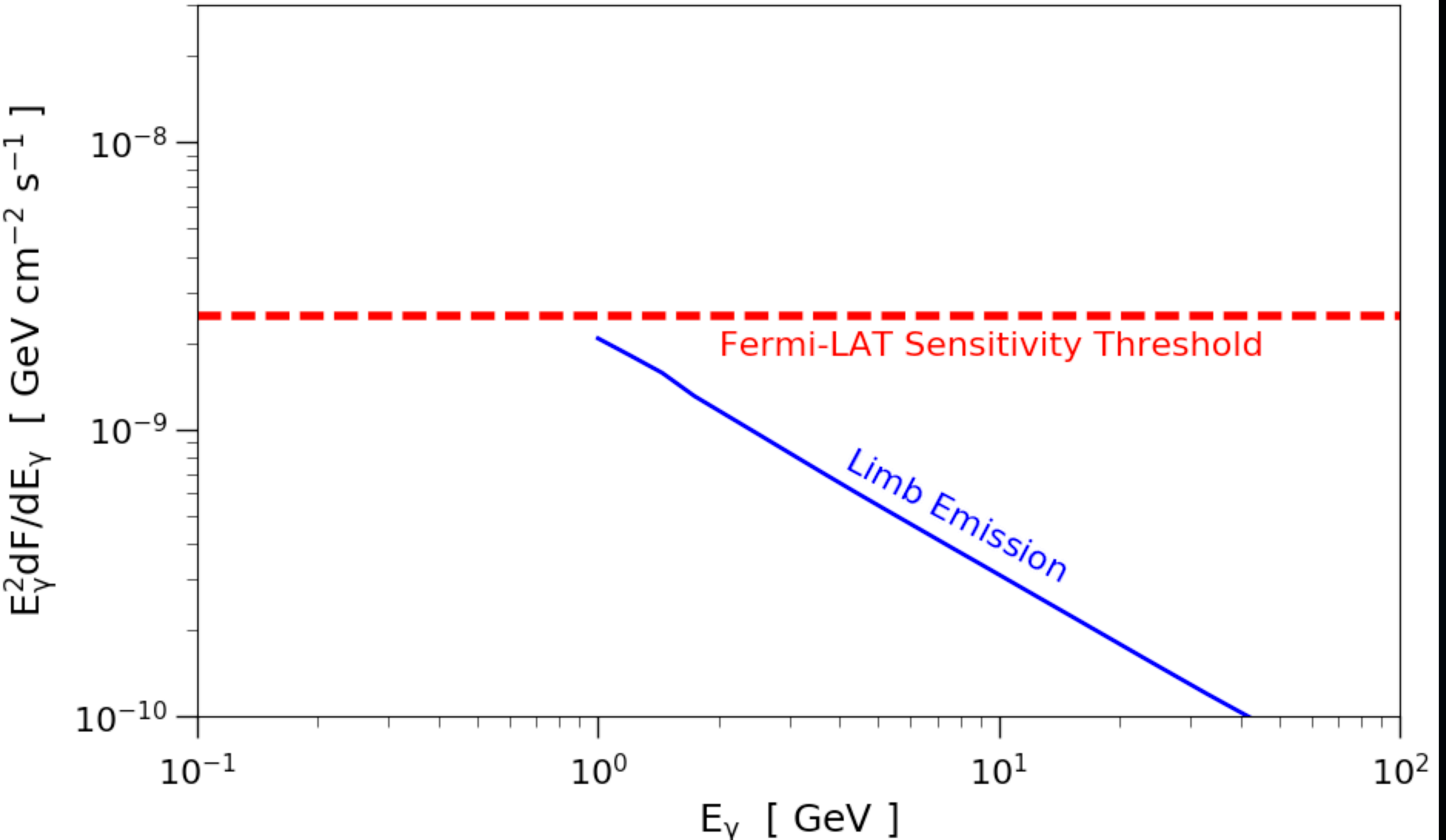


How are solar gamma-rays produced?



Solar Flare gamma-rays are low energy (E_{max} = 4 GeV)





Fermi-LAT Sensitivity Threshold
Limb Emission
10^{-8}
10^{-9}
10^{-10}
10^{-1}
10^{0}
10^{1}
10^{2}
$E_\gamma^2 dF/dE_\gamma$ [GeV cm^{-2} s^{-1}]
E_γ [GeV]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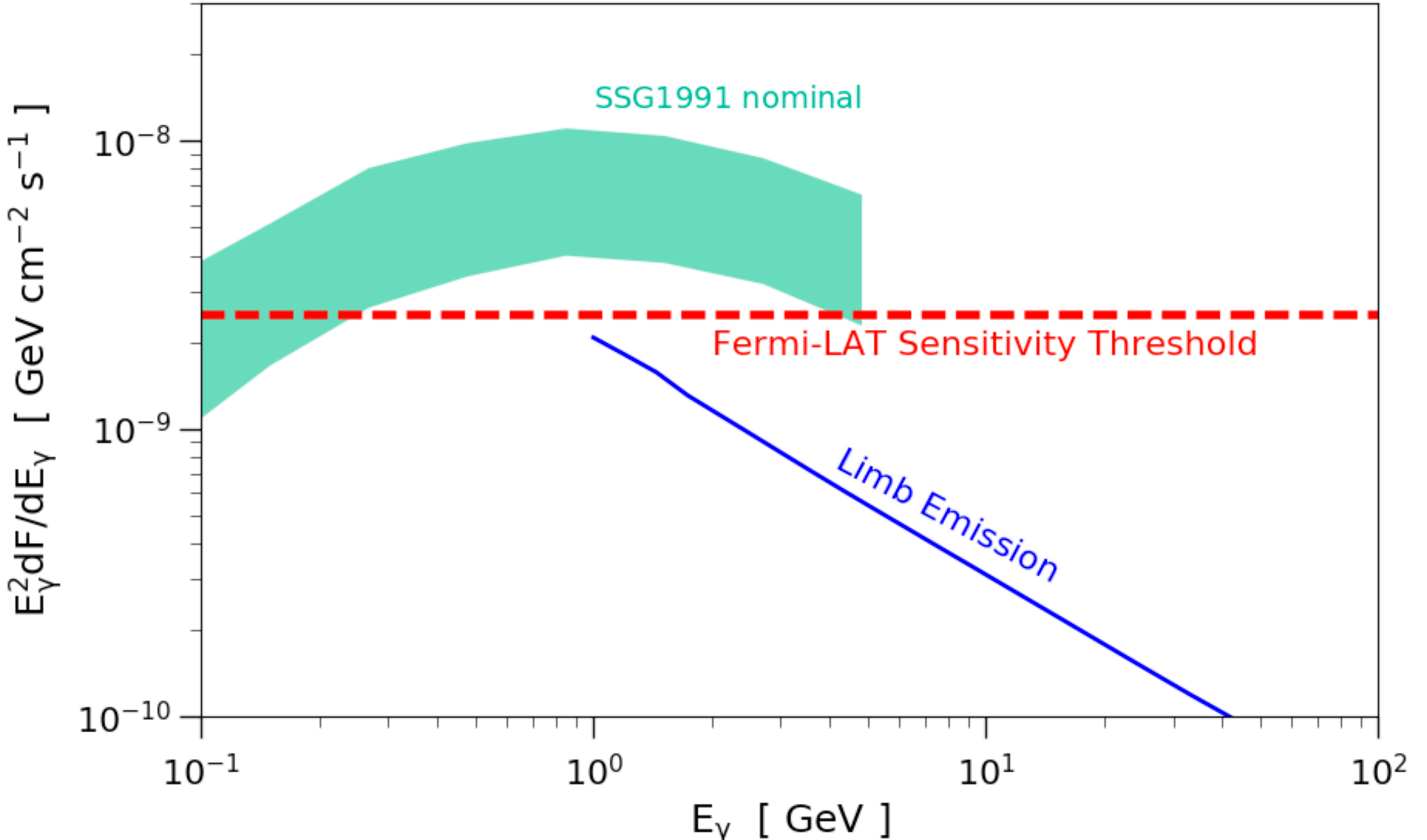
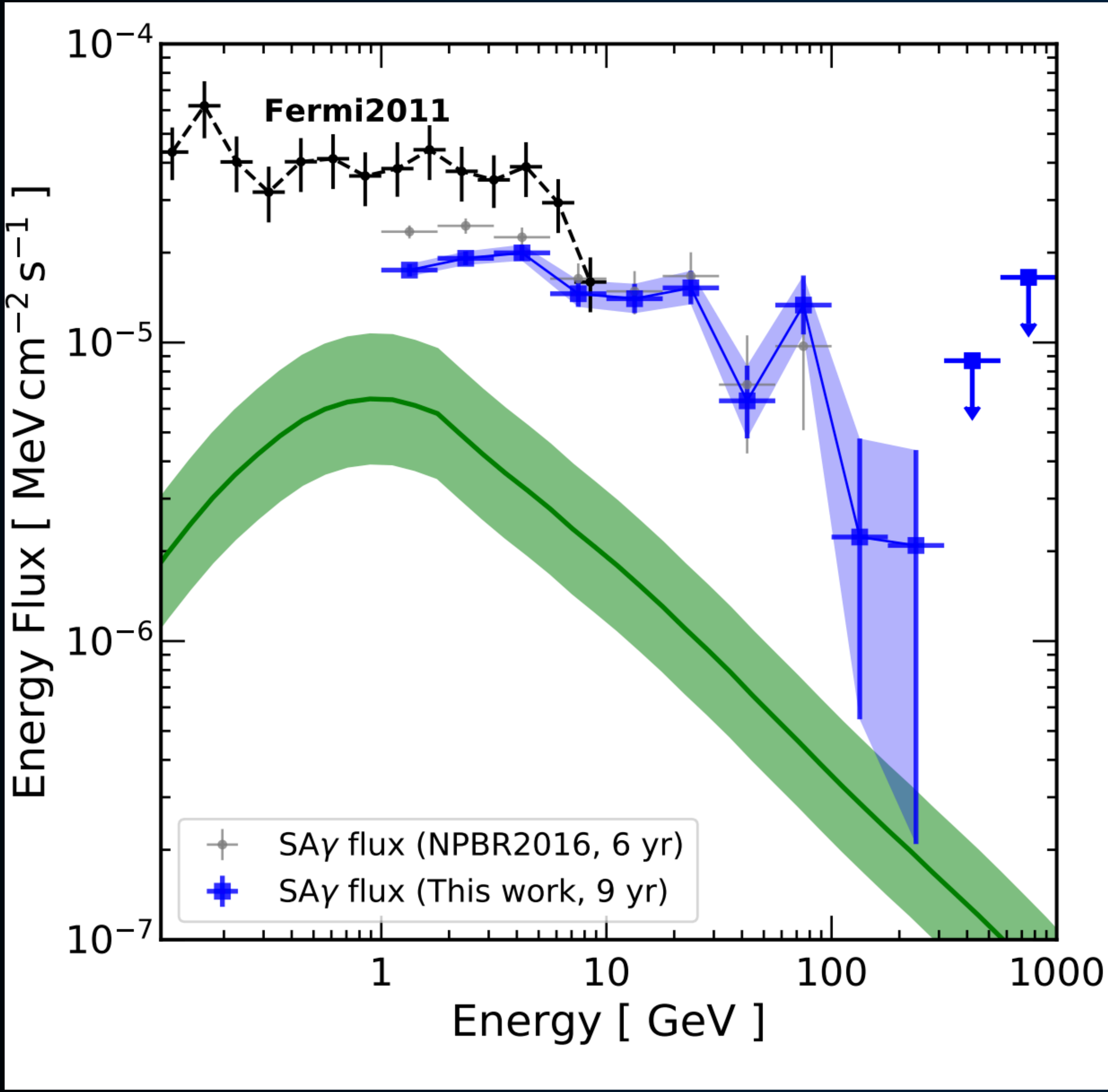
1991ApJ...382..652S
SIGNATURES OF COSMIC-RAY INTERACTIONS ON THE SOLAR SURFACE
D. Seckel, Todor Stanev, and T. K. Gaisser
Bartol Research Institute, University of Delaware, Newark, DE 19716
Received 1991 March 21; accepted 1991 June 5
ABSTRACT
We estimate the fluxes of neutrinos, gamma rays, antiprotons, neutrons, and antineutrons that
of high-energy Galactic cosmic rays with the solar atmosphere. The results are sensitive
cosmic-ray transport in the magnetic fields of the inner solar system. The high-energ
by the Gamma Ray Observatory. The neutrino flux should produce less
generation of neutrino telescopes. The antiproton flux is unobservable a
and antineutron fluxes are detectable only if neutrons prod
discriminated against.
gamma rays: general — neutrinos — Sun: activ
appropriate thickness
without reabsorbing them
would then be suppresse


SSG1991 nominal
Fermi-LAT Sensitivity Threshold
Limb Emission
$E_\gamma^2 dF/dE_\gamma$ [GeV cm^{-2} s^{-1}]
E_γ [GeV]
10^{-8}
10^{-9}
10^{-10}
10^{-1}
10^{0}
10^{1}
10^{2}

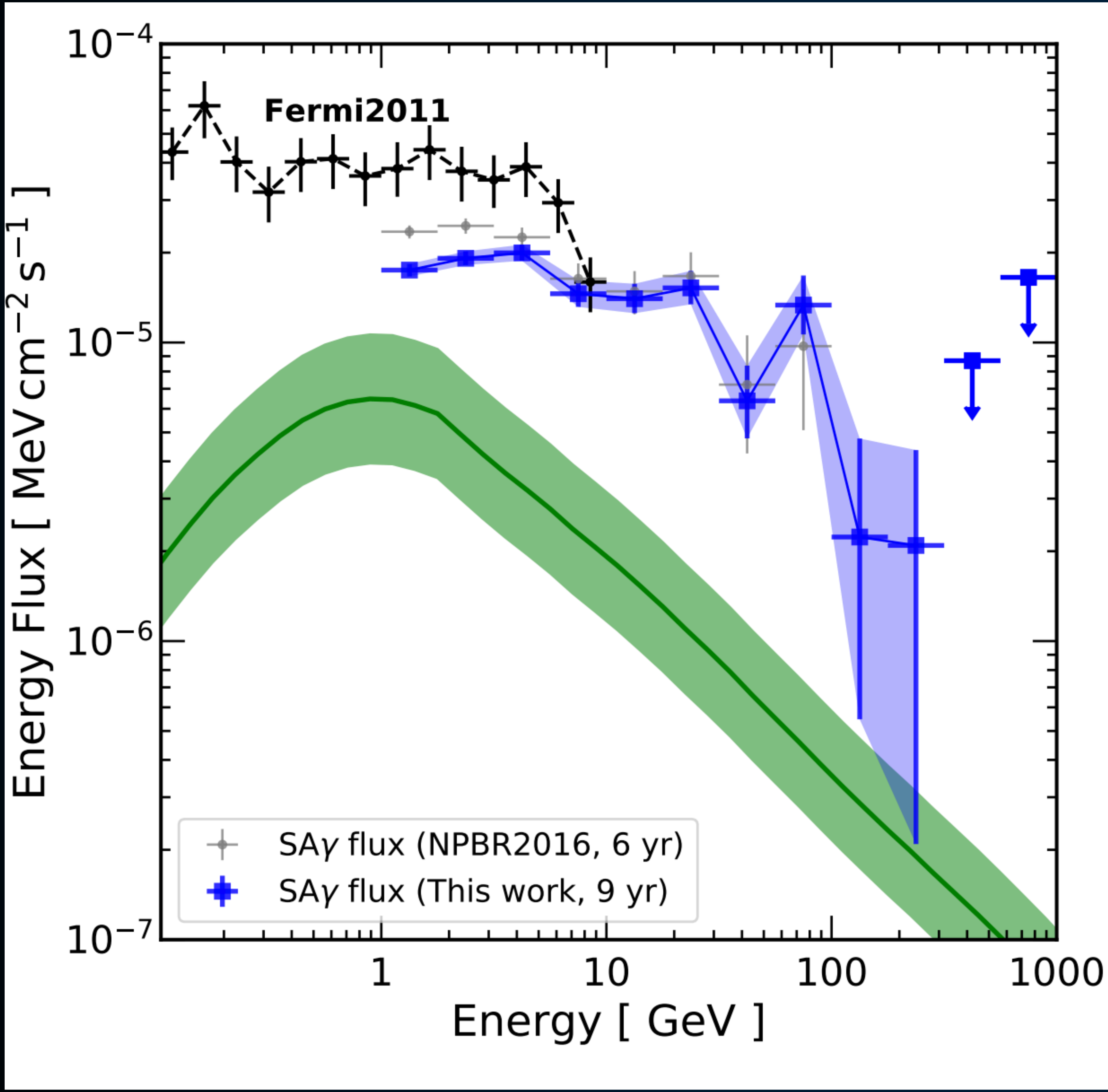
Our Limited Knowledge



Intensity

X

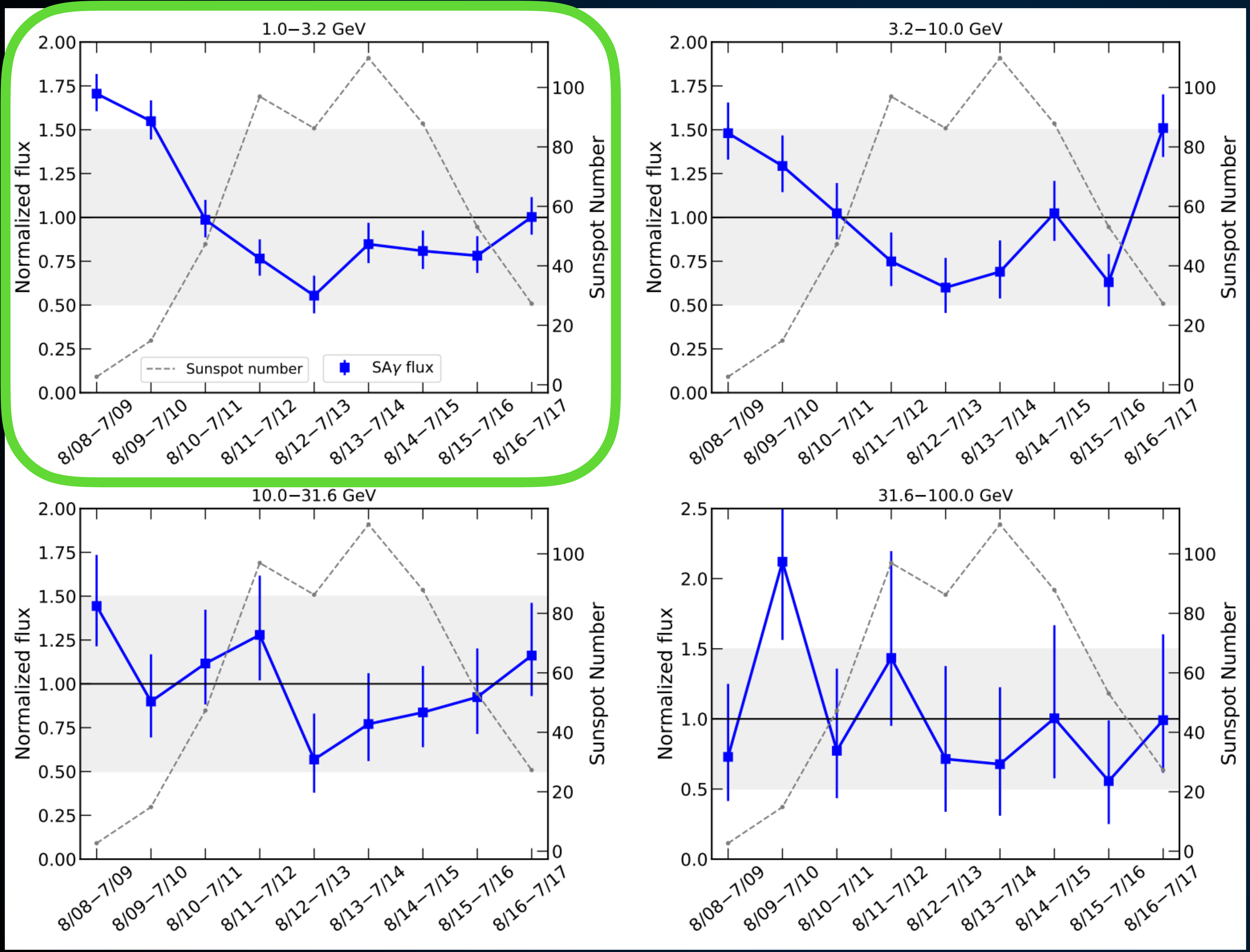
Our Limited Knowledge



Intensity X

Spectrum X

Our Limited Knowledge

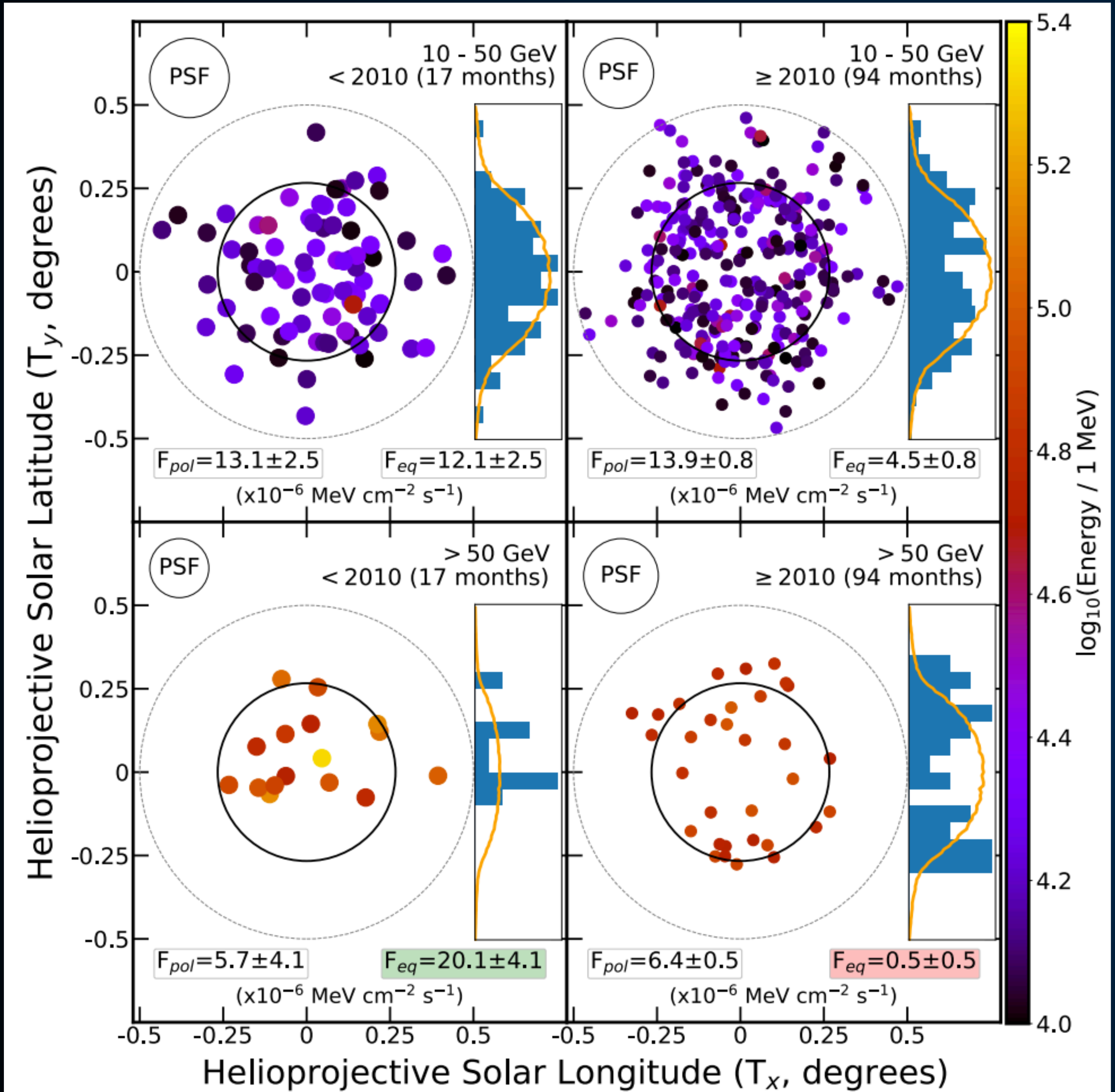


Intensity X

Spectrum X

Time Variability X

Our Limited Knowledge



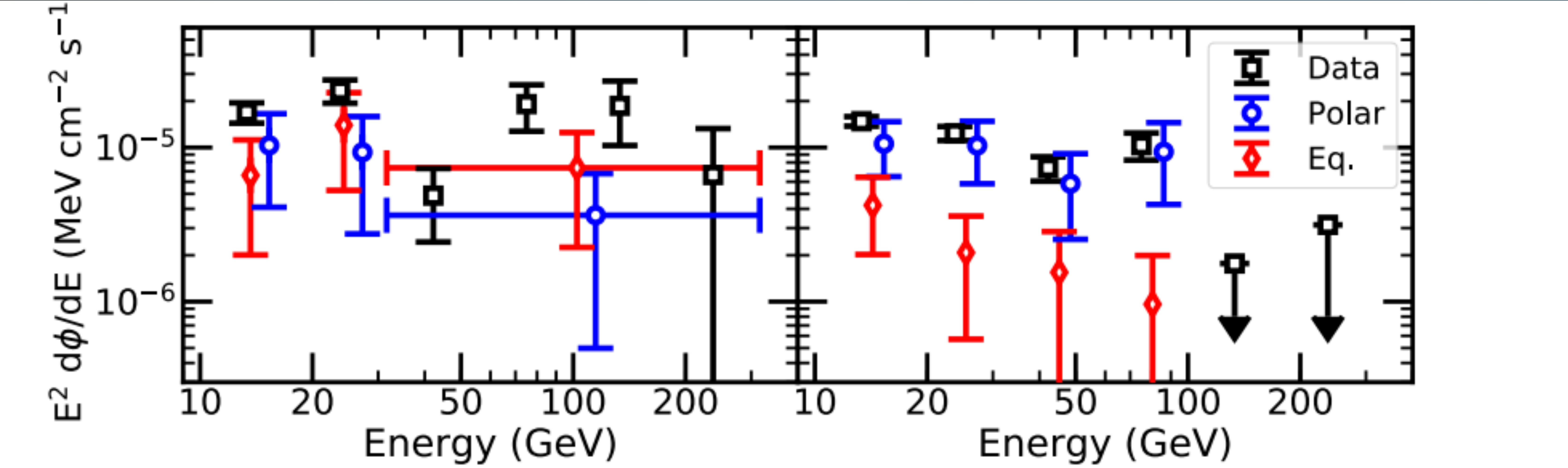
Intensity X

Spectrum X

Time Variability X

Morphology X

Our Limited Knowledge



Time (UTC)	Energy	R.A.	Dec	Solar Distance	Event Class	PSF Class	Edisp Class	P6	P7	BG Contribution
2008-11-09 03:47:51	212.8 GeV	224.497	-16.851	0.068°	UltraCleanVeto	PSF0	EDISP3	✓	✓	0.00050
2008-12-13 03:25:55	139.3 GeV	260.707	-23.243	0.126°	UltraCleanVeto	PSF2	EDISP1	X	X	0.00038
2008-12-13 07:04:07	103.3 GeV	260.346	-23.102	0.399°	UltraCleanVeto	PSF0	EDISP2	X	X	0.00052
2009-03-22 08:43:13	117.2 GeV	1.337	0.703	0.255°	UltraCleanVeto	PSF1	EDISP3	✓	✓	0.00027
2009-08-15 01:14:17	138.5 GeV	144.416	14.300	0.261°	UltraCleanVeto	PSF2	EDISP3	✓	✓	0.00021
2009-11-20 07:55:20	112.6 GeV	235.905	-19.473	0.288°	UltraCleanVeto	PSF1	EDISP1	X	X	0.00020
2008-12-24 05:41:53	226.9 GeV	272.899	-23.343	0.069°	UltraClean	PSF1	EDISP3	X	X	0.00128
2009-12-20 08:06:31	467.7 GeV	268.046	-23.177	0.338°	UltraCleanVeto	PSF1	EDISP0	X	X	0.00208

Intensity X

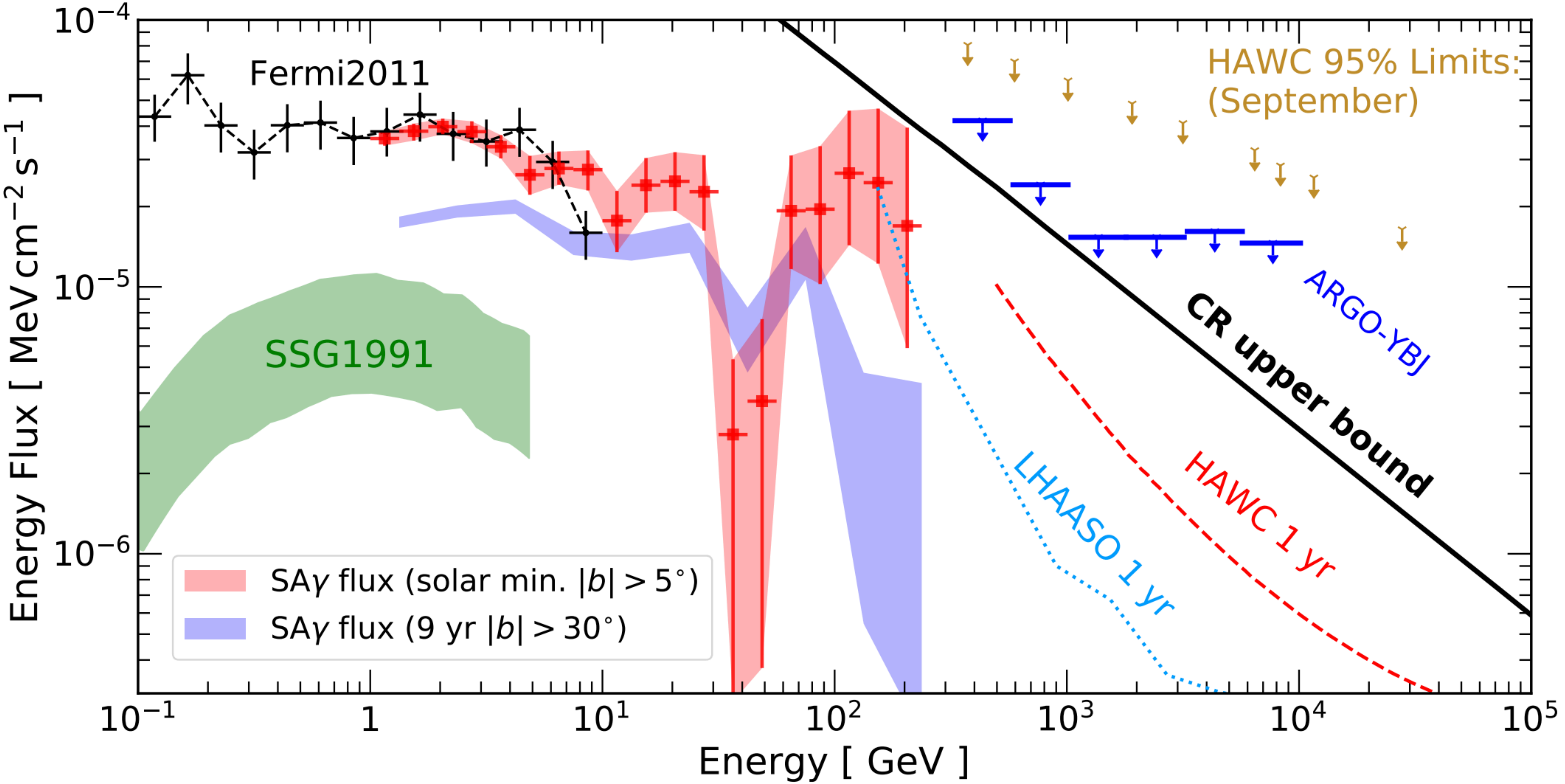
Spectrum X

Time Variability X

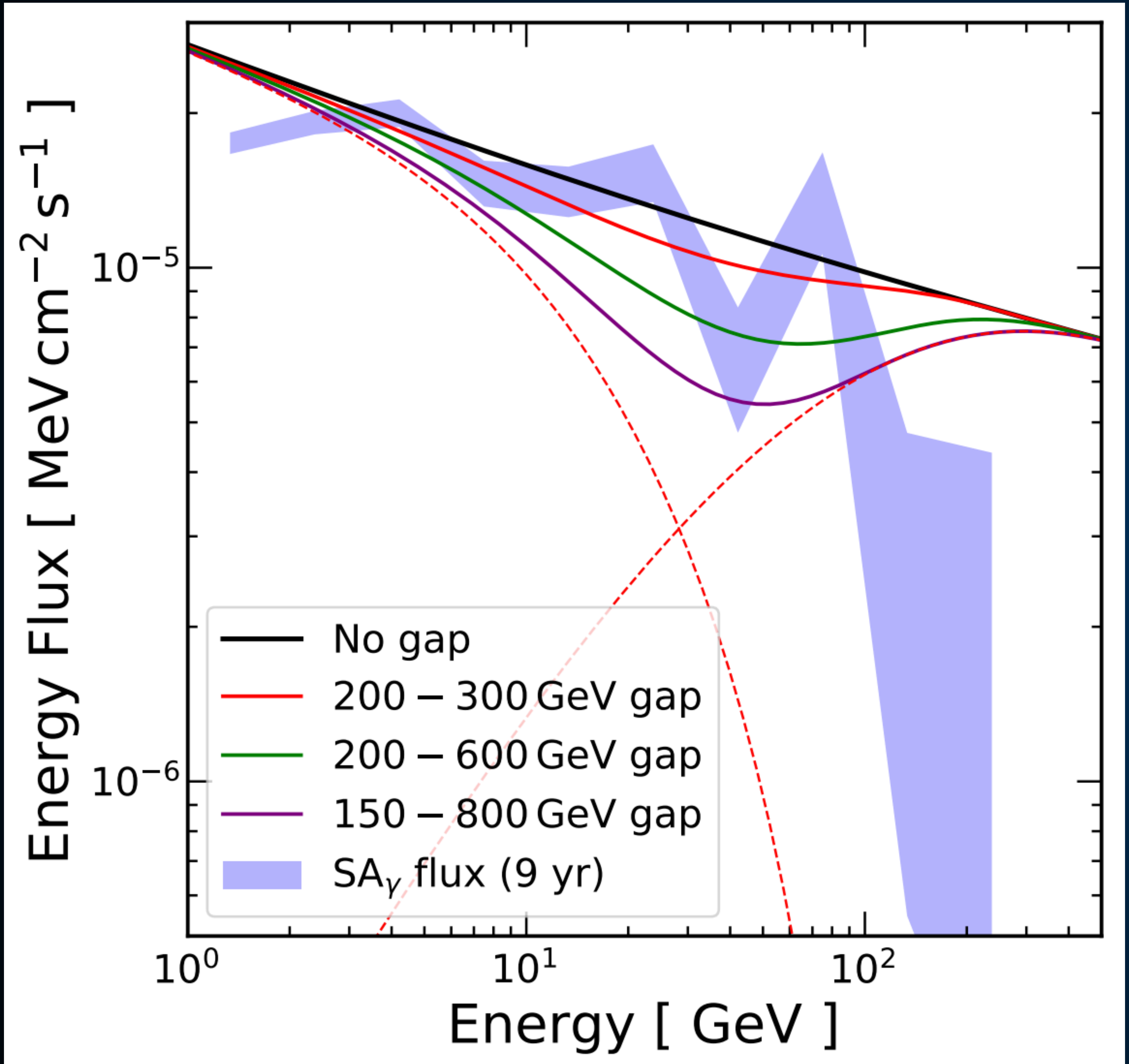
Morphology X

Spectral Variability X

Our Limited Knowledge



Our Limited Knowledge



Intensity X

Spectrum X

Time Variability X

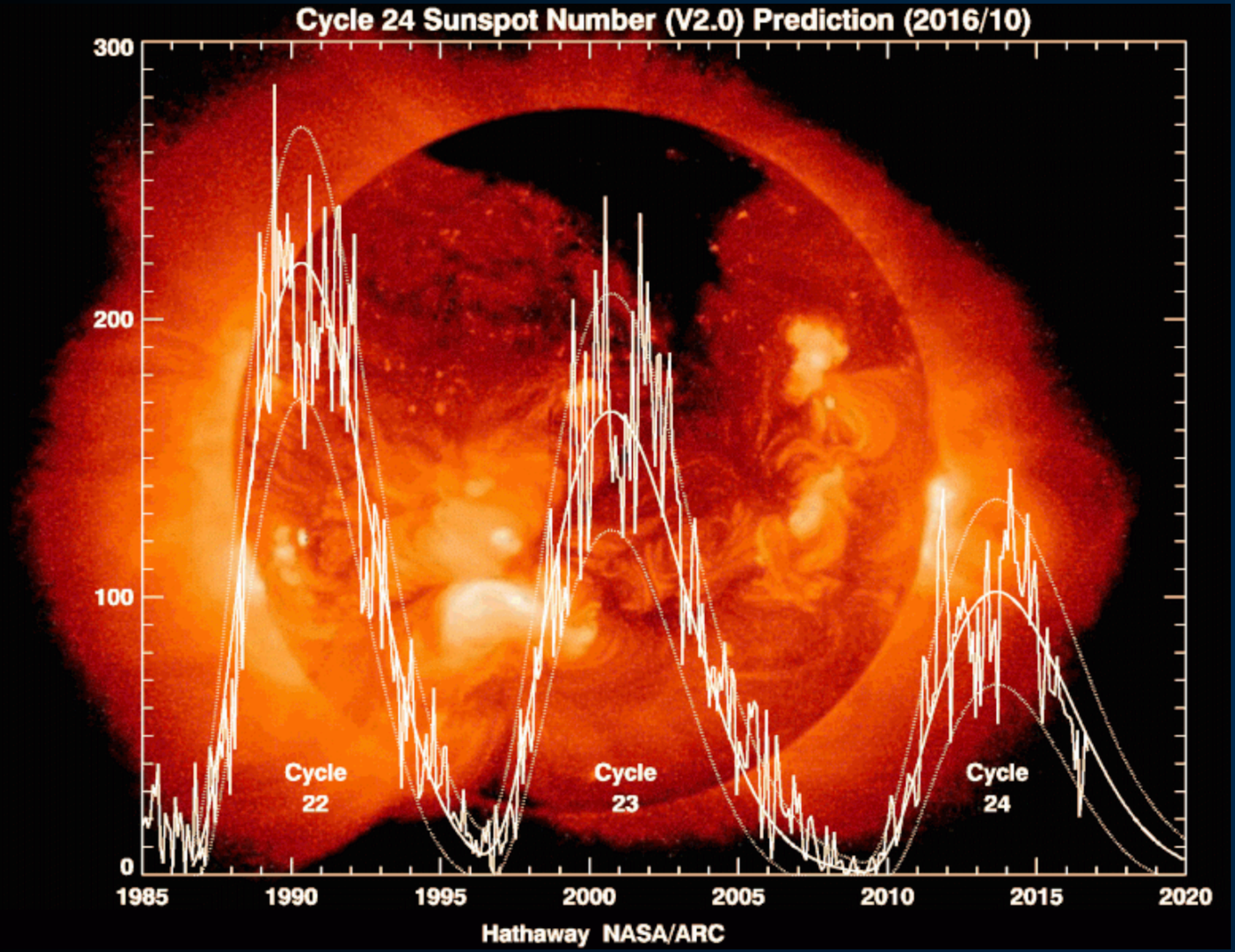
Morphology X

Spectral Variability X

Spectral Dip X

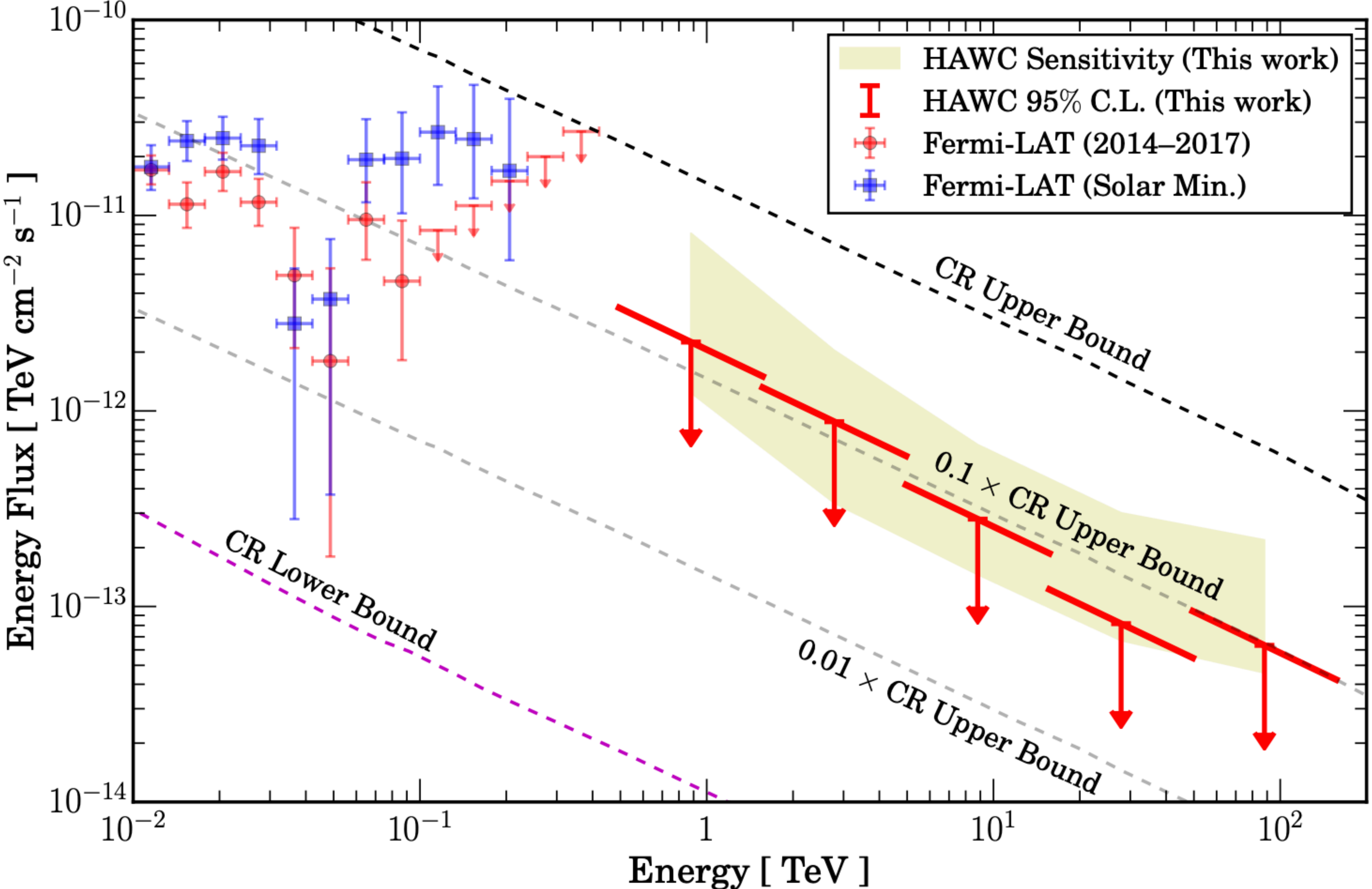
The Whole Picture

Future Prospects



A New Event!—While finalizing this letter, we found a new >100 GeV event. Observed on February 13, 2018 at 17:49:15 UTC, the event has an energy of 162 GeV, is located 0.36° from the solar center, passes the UltraCleanVeto event selection, and belongs to the PSF0 and EDISP3 event classes. As we re-enter solar minimum, this is the first >100 GeV event recorded within 0.5° of the sun since 2009. The event may be connected to a Earth-bound CME observed on February 12, 2018.[1] Preliminary work indicates that this event increases the significance of the >100 GeV time variability above 5σ, and provides evidence that the upcoming solar minimum will provide a substantial flux of high-energy events.


V2
V1



HAWC Sensitivity (This work)
HAWC 95% C.L. (This work)
Fermi-LAT (2014–2017)
Fermi-LAT (Solar Min.)
CR Upper Bound
0.1 × CR Upper Bound
0.01 × CR Upper Bound
CR Lower Bound
Energy Flux [TeV cm^{-2} s^{-1}]
Energy [TeV]
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-2}
10^{-1}
1
10^{1}
10^{2}

Conclusions

We see, but we don’t understand.

Help?

Solar gamma-rays provide a new handle into fundamental questions in solar magnetohydrodynamics.