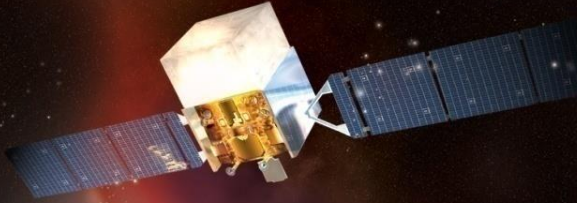




Fermi

Gamma-ray Space Telescope



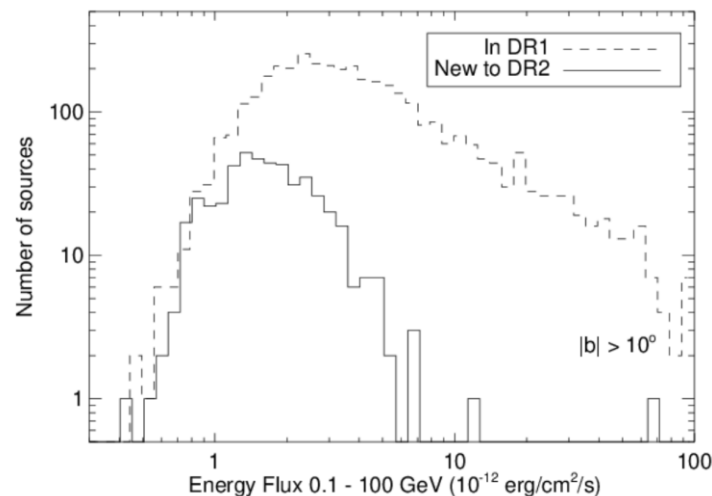
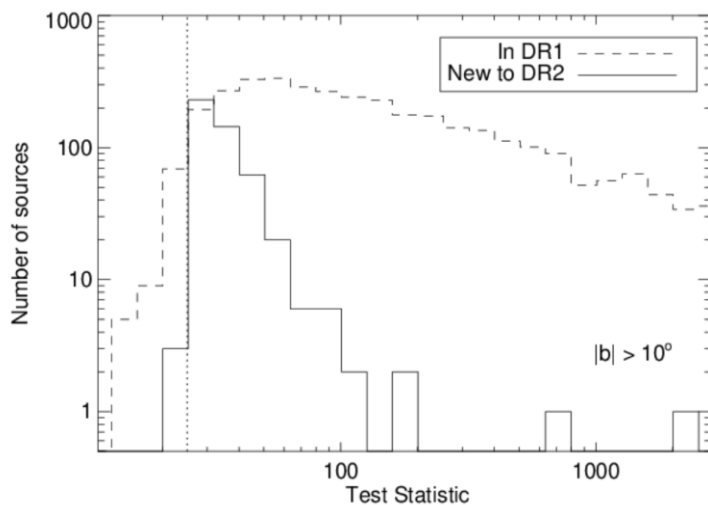
LAT Update

Peter Michelson

4FGL-DR2 and Future FGL Catalogs

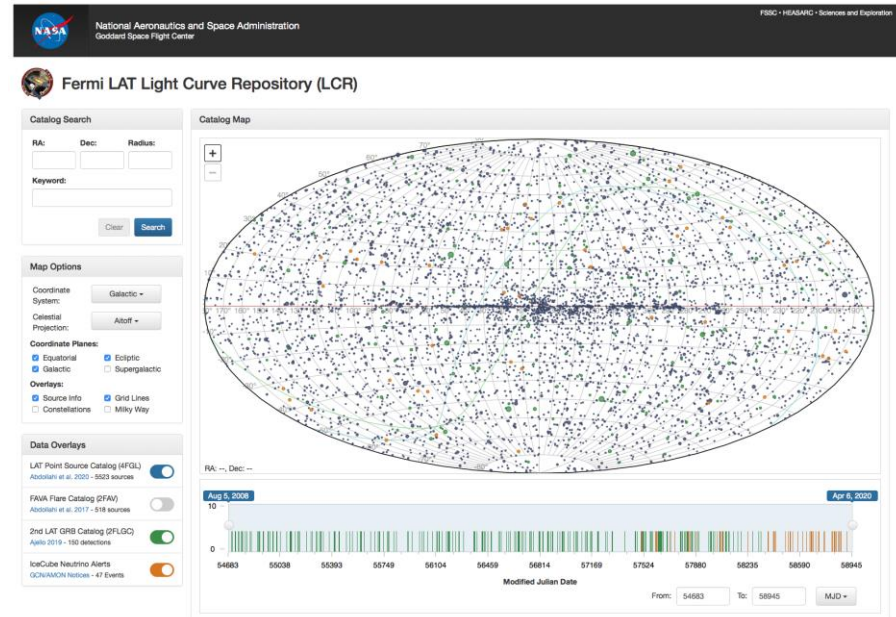


- Updated 4FGL-DR1 (8 years) to 4FGL-DR2 (10 years)
- Energy Range: 50 MeV – 1 TeV
- Same methodology and diffuse model as 4FGL (DR1), but with more data
 - Plan on future incremental updates (DR3 – 12 years already in works)
- 5788 sources
 - 723 new sources just above detection threshold
 - 120 dropped below detection threshold, but kept for comparison
 - 40 newly associated
- Catalog: https://fermi.gsfc.nasa.gov/ssc/data/access/lat/10yr_catalog/
- ArXiv description: <https://arxiv.org/abs/2005.11208>

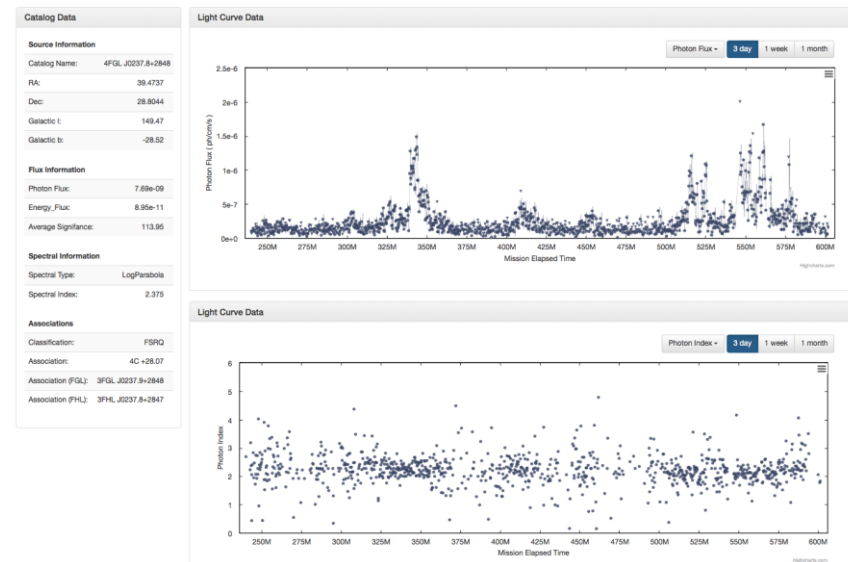




- **Related Senior Review PMOs:**
 - Establish and maintain a library of γ -ray source light curves on timescales of days, weeks, and months, updated as new data become available.
 - Resolve emission mechanisms in blazars by finding γ -ray flares in coincidence with ultra-high-energy neutrinos detected by IceCube.
- Demo this afternoon by Dan Kocevski
- Aiming to release by early 2021

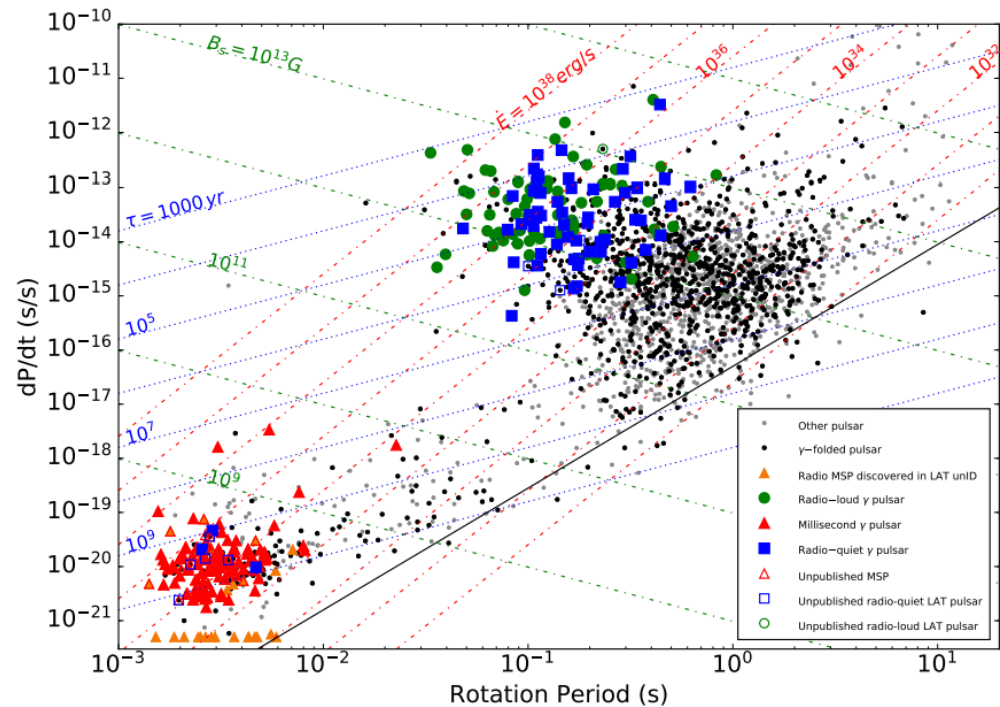
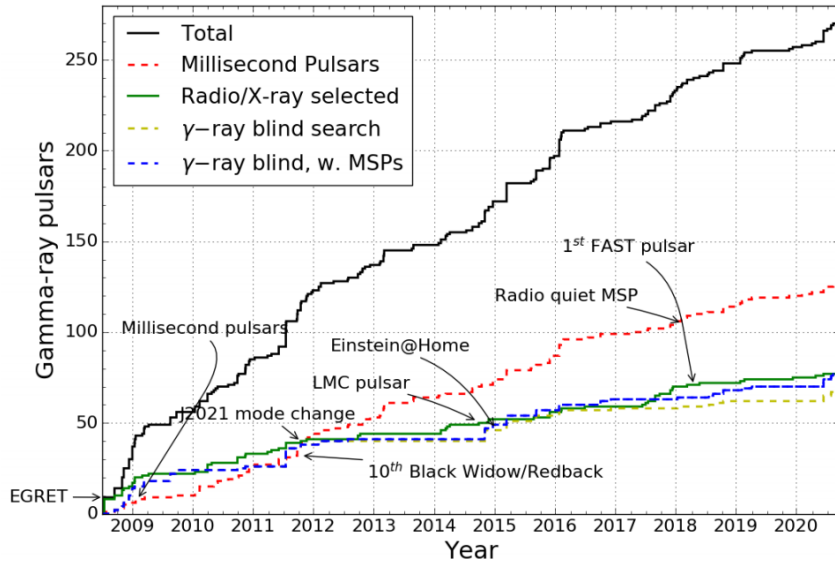


Fermi LAT Light Curve Repository - Source Report

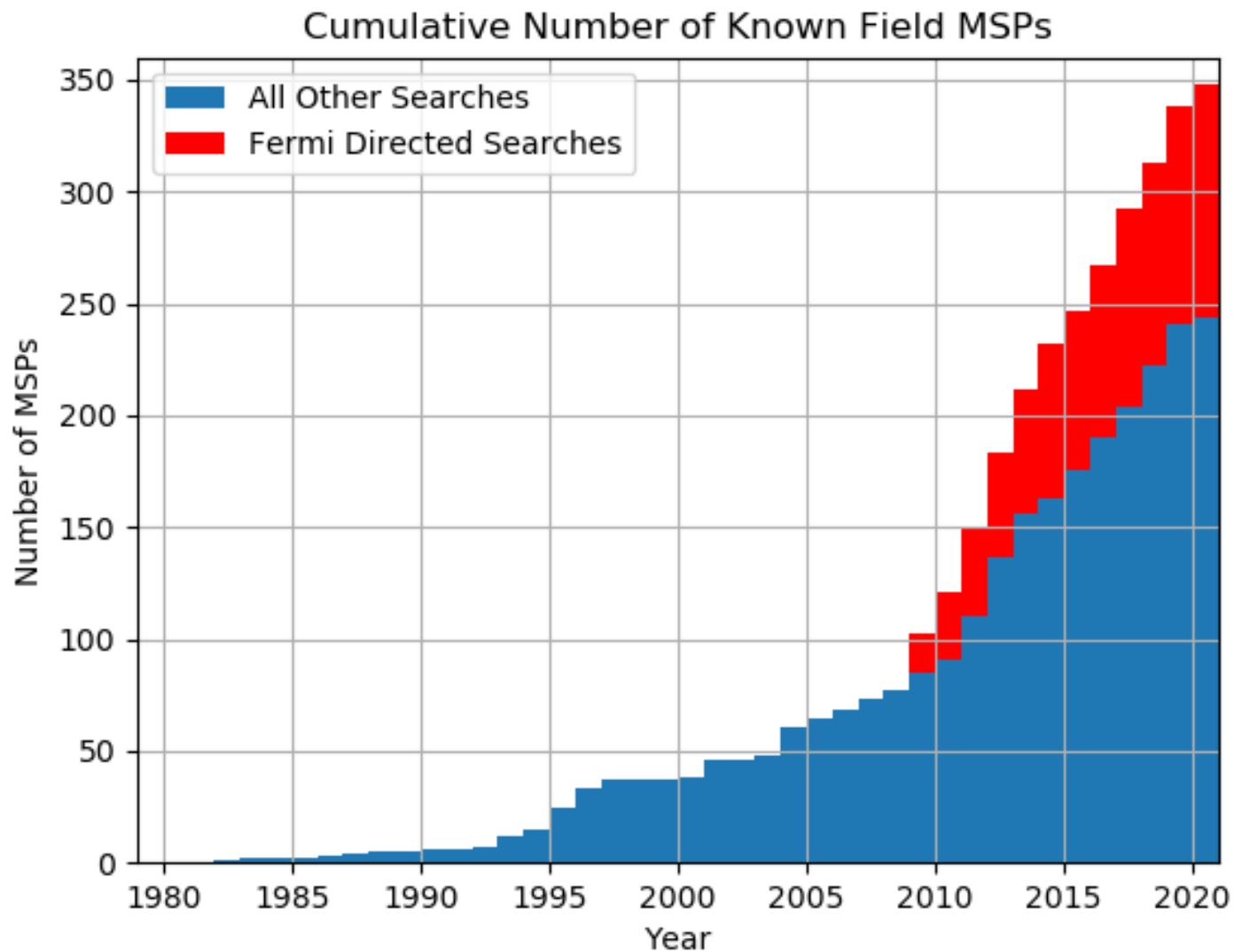




- As of last week, sample frozen at 270 pulsars (144 young + 126 MSPs), c.f. 2PC (117)
- Included in catalog:
 - Ephemerides (up to MJD 58,000, longer as possible)
 - Use 4FGL-DR2 spectra
 - Updated distances
 - Pulsar light curves with classifications
 - Updated radio fluxes / upper limits
- Current main activities: drafting paper, finishing light curve analysis, collating distances
- Expect to wrap up this year!



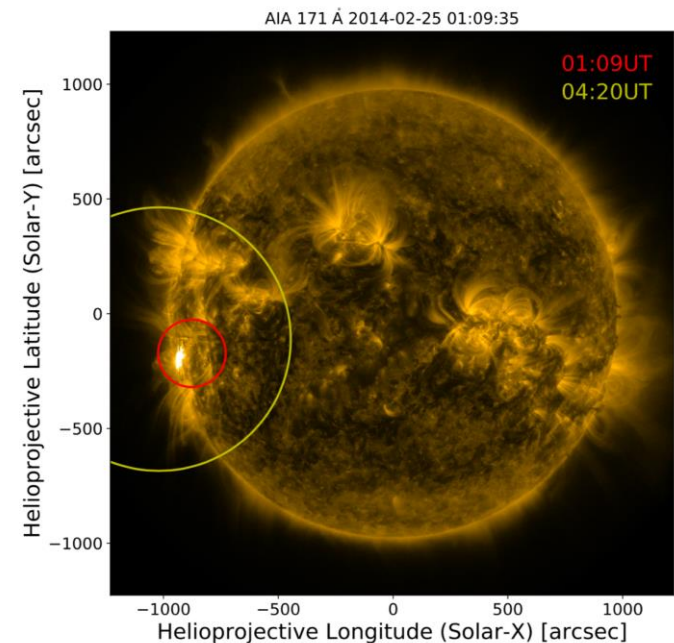
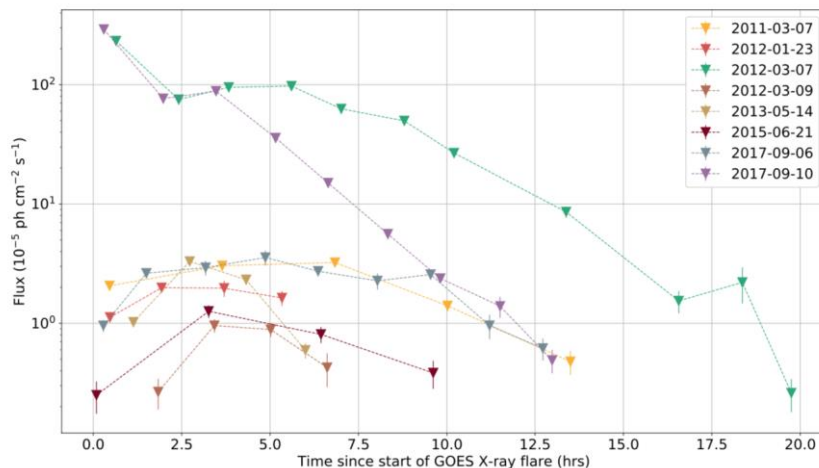
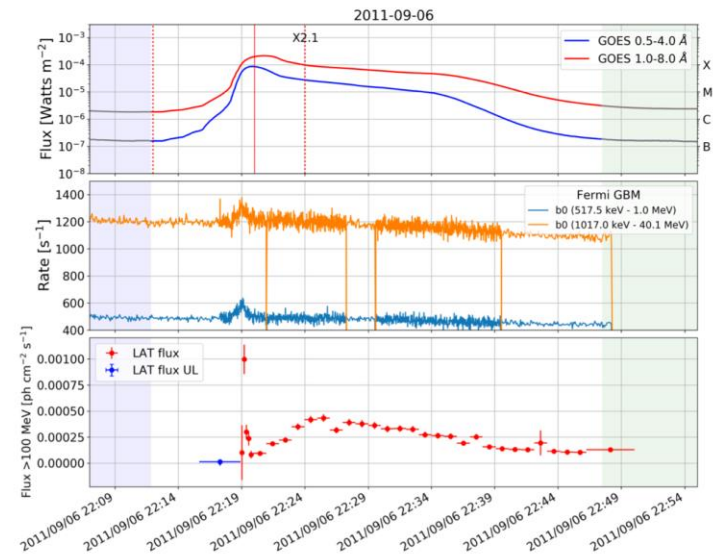
Radio pulsar discoveries and Fermi



1st LAT Solar Flare Catalog



- LAT Collaboration et al., ApJ, about to be submitted
- 45 solar flare from 2010-2018
 - 37 show prompt impulsive emission – acceleration at flare site
 - 21 show delayed emission (>2 hours) - coronal mass ejection (CME)
 - 3 flares from behind the limb – associated with CME
- γ -ray spectra consistent with the decay of pions produced by >300 MeV protons
- Largest sample of high-energy gamma-ray flares provides a unique opportunity to perform population/correlation studies on the different phases of the flare opening a new window into solar physics





- **ICECUBE/AMON issues Gold/Bronze alerts at a rate of ~25/year**
- **LAT Flare Advocates perform searches around neutrino positions on timescales**
 - 1 day
 - 1 month
 - full mission
- **Search for both known sources in a flaring state and new sources**
- **Issue GCN Circulars on all events, both GCN/ATels on candidate counterparts**

Fermi-LAT Gamma-ray Observations of IceCube-200614A and detection of a new gamma-ray source, Fermi J0202.8+3132

ATel #13811; *S. Garrappa (DESY-Zeuthen) and S. Buson (Univ. of Wuerzburg) on behalf of the Fermi-LAT collaboration*
on 16 Jun 2020; 14:44 UT
Credential Certification: Sara Buson (sara.buson@gmail.com)

Subjects: Gamma Ray, >GeV, Neutrinos, Request for Observations, AGN, Blazar



We report an analysis of observations of the vicinity of the high-energy IC200614A neutrino event (GCN 27941) with all-sky survey data from the Large Area Telescope (LAT), on board the Fermi Gamma-ray Space Telescope. The IceCube event was detected on 2020-06-14 at 12:41:21.41 UT (T0) with J2000 position RA =33.84 (+4.77 -6.39) deg, Decl. =31.61(+2.75 -2.28) deg 90% PSF containment. Five cataloged >100 MeV gamma-ray sources (The Fermi-LAT Collaboration 2019, arXiv:1902.10045) are located within the 90% IC200614A localization error. These are 4FGL J0159.0+3313, 4FGL J0202.4+2943, 4FGL J0203.7+3042, 4FGL J0205.2+3212 and 4FGL J0220.2+3246. Based on a preliminary analysis of the LAT data over the timescales of 1-day and 1-month prior to T0, these objects are not significantly detected ($> 5 \sigma$).

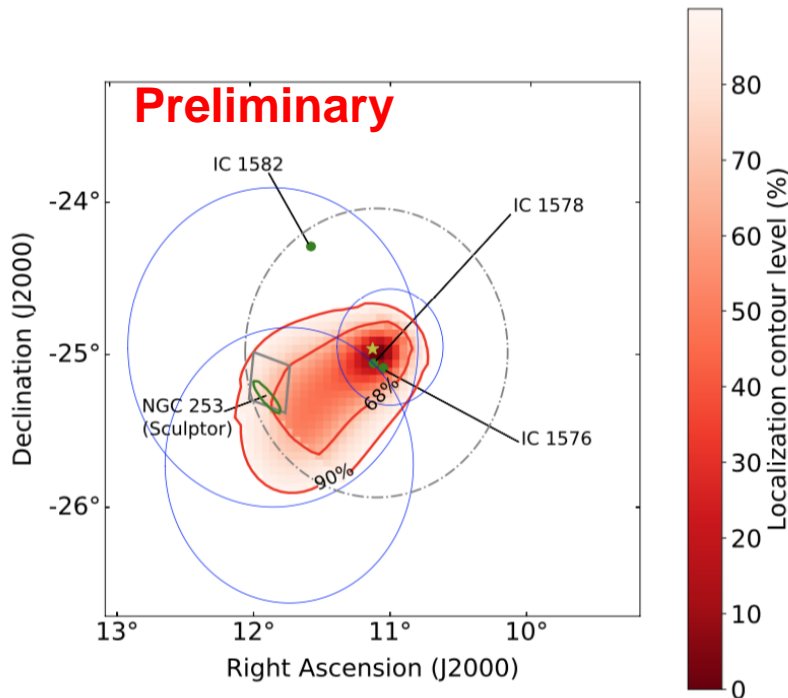
We searched for intermediate (days to years) timescale emission from a new gamma-ray transient source. Preliminary analysis indicates no significant ($> 5 \sigma$) new excess emission (> 100 MeV), at the IC200614A best-fit position. Assuming a power-law spectrum (photon index = 2.0 fixed) for a point source at the IceCube best-fit position, the >100 MeV flux upper limit (95% confidence) is $< 8e-10$ ph $cm^{-2} s^{-1}$ for ~ 11 -years (2008-08-04 / 2020-06-14 UTC), $< 9e-9$ ($< 8e-8$) ph $cm^{-2} s^{-1}$ for a 1-month (1-day) integration time before T0.

Within the 90% confidence localization of the neutrino, ~ 2.7 deg offset from the best-fit IC200614A position, a $>5 \sigma$ excess of gamma rays, Fermi J0202.8+3132 was detected in an analysis of the integrated LAT data (> 100 MeV) between 2008-08-04 and 2020-06-14. Assuming a power-law spectrum, the best-fit localization is (J2000) RA: 30.71, Dec: 31.55 (0.16 deg 99% containment, 0.08 deg 68% containment), with best-fit spectral parameters flux = $(5 \pm 3)e-10$ ph $cm^{-2} s^{-1}$ and index = 1.8 ± 0.2 . In a preliminary analysis of the LAT data over one day and one month prior T0, Fermi J0202.8+3132 is not significantly detected in the LAT data. A possible counterpart for Fermi J0202.8+3132 is the BL Lac candidate object NVSSJ020242+313212 (D'Abrusco et al. 2019, ApJS 242, 1), located 0.03 deg from the best-fit LAT localization.

Two additional $\sim 4 \sigma$ excess of gamma rays are detected within the 90% confidence localization of IC200614A in an analysis of the LAT data (> 100 MeV) between 2008-08-04 and 2020-06-14. One is found at the best-fit localisation RA= 32.69, Dec= 30.97 (0.15 deg 99% containment), and has best-fit spectral parameters flux = $(4 \pm 3)e-10$ ph $cm^{-2} s^{-1}$ and index = (1.8 ± 0.2) . The second one, at best-fit localisation RA= 35.91, Dec= 32.01 (0.2 deg 99% containment), has best-fit spectral parameters flux = $(1.3 \pm 0.7)e-9$ ph $cm^{-2} s^{-1}$ and index = (2.2 ± 0.2) . These excesses are located ~ 1.2 deg and ~ 1.8 deg away from the best-fit IC200614A position, respectively. In a preliminary analysis of the LAT data over one day and one month prior to T0, they are not significantly detected in the LAT data.



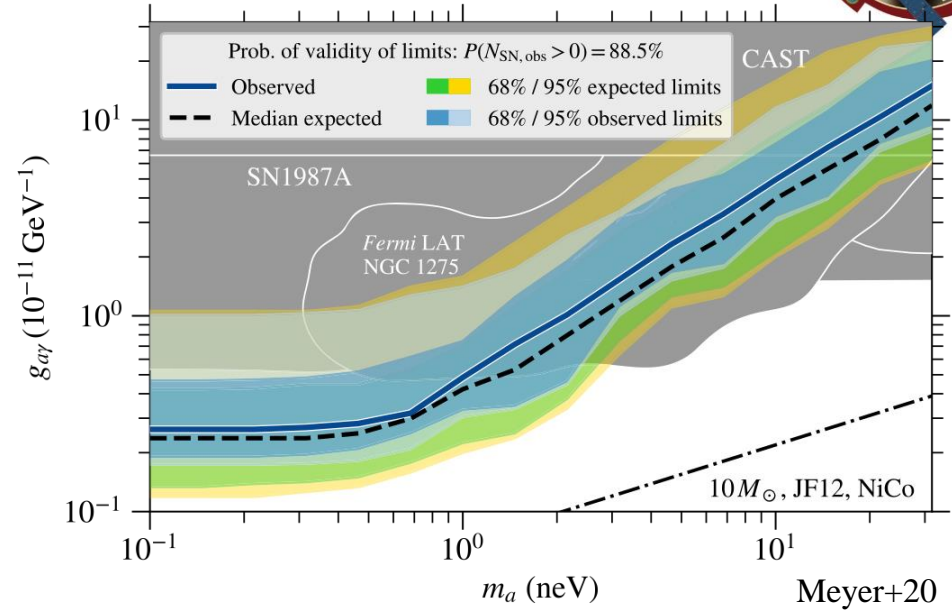
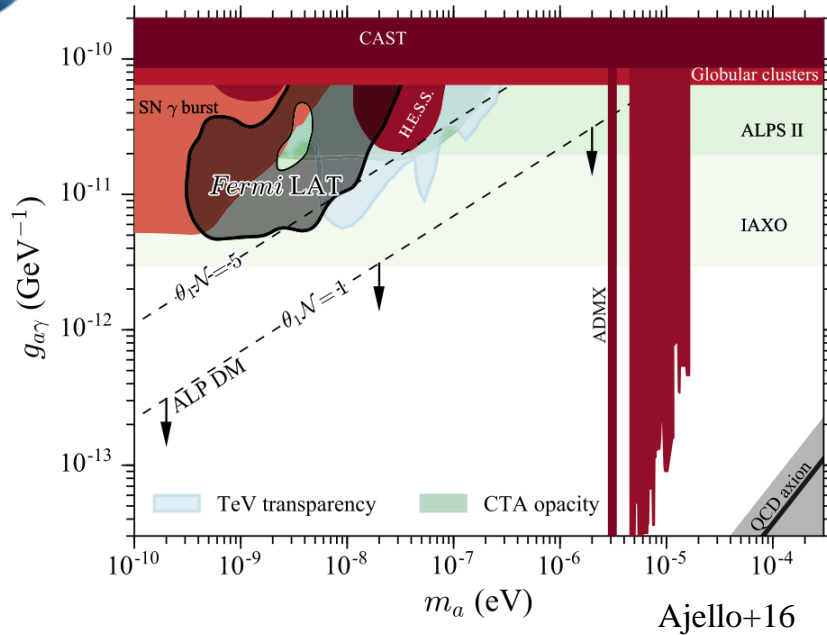
On April 15, 2020, the LAT detected and localized high-energy gamma rays up to 1.7 GeV from the short GBM GRB 200415A.



LAT Collaboration, in-prep

- Most credible counterpart is NGC 253 (Sculptor Galaxy) at only 3.5 Mpc away (ruling out cosmological origin)
- Inter Planetary Network (IPN) also localized the sub-MeV emission within the Sculptor galaxy and GBM, Swift/BAT and ISS/ASIM observations strongly suggest that the source is a Magnetar Giant Flare (MGF), the second outside our Galaxy.
- LAT signal appears delayed by 20 seconds and temporally extended (300 s) with respect the GBM signal:
 - This is quite peculiar with respect to other short GRBs detected by the LAT.
- This maybe the first detection of a Magnetar in GeV
- The LAT observation suggests that MGF are followed by a relativistic outflow: particles are accelerated in the shock between the outflow and the existing Magnetar bow shock.

Constraining Axion-like-Particles (ALPs)



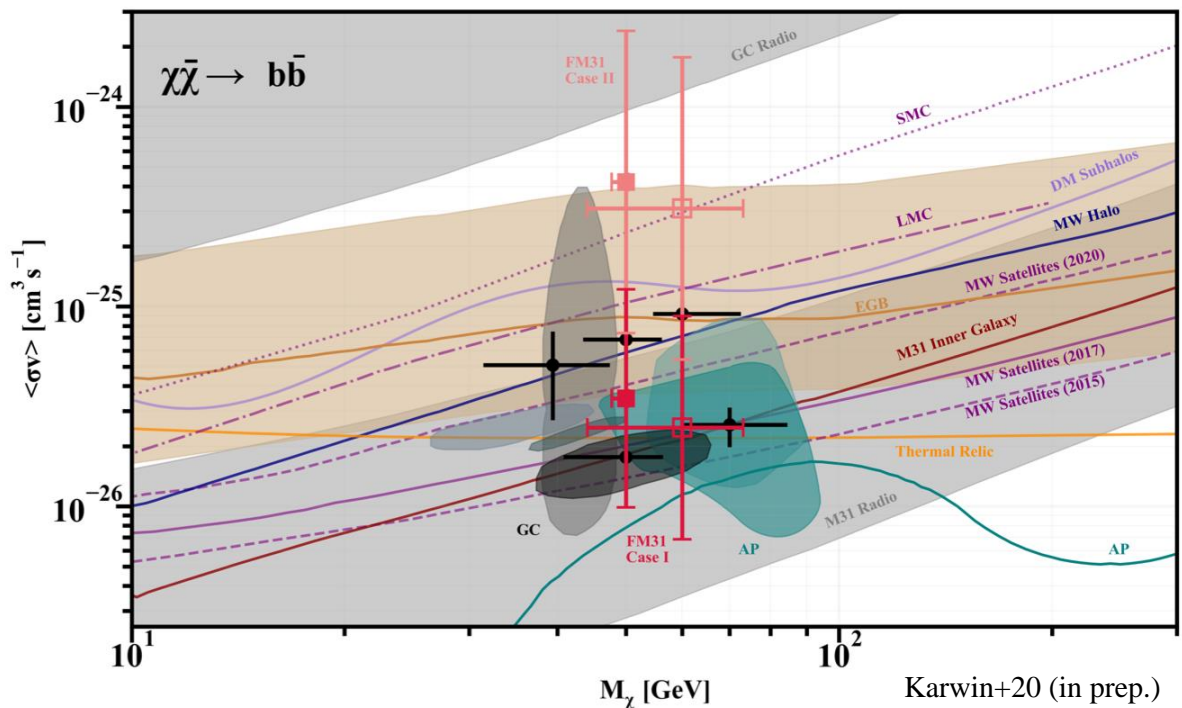
- **ALPs are a particle Dark Matter candidate predicted by many extensions of the standard model. They could be detected by coupling to photons.**
- Left: Search for spectral features from photon-to-ALP oscillations in the gamma-ray spectrum of NGC 1275 (the central galaxy of the Perseus cluster), with black shaded region showing excluded parameter space. **Analysis could be easily extended to other cluster galaxies (e.g., M87 in the Virgo cluster).**
- Right: ALPs produced in core-collapse supernovae through the Primakoff mechanism could subsequently convert to gamma rays in magnetic field of Milky Way. From sample of 20 extragalactic core-collapse SNe, Meyer+20 improved previous constraints from SN1987A by a factor of 2. **This is a very promising avenue as new optical surveys like ASAS-SN and ZTF greatly expand the SN sample.**

Constraining WIMP Dark Matter



Search for evidence of WIMP hypothesis: look for annihilation signature anywhere there's a matter cusp or concentration

DM Indirect Detection



- Many different places have been examined:
 - Galactic center
 - halos; e.g. M31
 - dwarf spheroidals, etc.
- Observations toward M31's outer halo has shown a tentative excess (shown in red) that has a large overlap with DM interpretations of the GC excess.
- Uncertainties in all the results clearly far too high to make any robust conclusions, either positive or negative, as each system has it's own unique challenges.
- **There are still many interesting systems that could provide additional clues about the nature of the GC excess and dark matter.**



- **Within Fermi-LAT collaboration science working groups, we have noticed inconsistent analyses making it into mature paper drafts. A few examples:**
 - (Less common now) **incorrect mapping of diffuse models to point source models**
 - (Somewhat common) **incorrect energy dispersion settings on diffuse models**
 - (Common) **inconsistent point source analysis when using 4FGL (weighted vs. unweighted likelihood)**
 - (Sporadic) **incorrect sun/moon template, incorrect global settings (choice of ROI, point sources, ...)**
- **This is largely due to an increased reliance on documentation and “default” software settings. Fewer active members of the LAT team with extensive institutional knowledge built up during earlier phases of the mission.**
- **Approach: Capture such knowledge in a set of “Best Practices” applicable to a broad set of analyses, and use that knowledge to**
 - 1. Update and expand existing documentation.**
 - 2. Tweak analysis software such that defaults / warnings / errors help prevent inadvertent errors.**

“Best Practices” for LAT Analysis



- Effort led within C&A Group, will ultimately coordinate with FSSC as needed
- Initial steps:
 - Reach out to Science groups for contributions of analysis scripts. Try to get a good set of representative analyses to handle a wide range of science cases, e.g. blazar light curves vs. point source analysis in the Galactic plane.
 - Collect experiences/anecdotes from junior researchers who are encountering Fermi science software for the first time.
- So far:
 - Input from Catalog group: attempt to make the analysis scripts used in the 4FGL pipeline available for ad hoc analysis. (Will solve lots of problems!)
 - Input from Galactic group junior researchers on snags.
- Will have broad discussion in plenary session at upcoming Collaboration Meeting on this approach as well as complementary efforts for checking analyses:
 - Residuals analysis
 - “Sanity checker” script