Simulated observations

To determine whether the variability of 1AGL J2022+4032 for E ≥ 100 MeV would have been detectable if the source were half as bright (Case 1) or at higher energies (Case 2), we produced simulated observations of hypothetical sources with the same intrinsic variability, where "intrinsic" includes the effects of systematic errors. We assume that the intrinsic flux in each observation is drawn from a Gaussian distribution whose mean is equal to the mean flux of the source in order to find the variance which reproduces the observed value of V=3.88 for 1AGL J2022+4032. We determined that, given the exposures of each of the 42 time intervals, an intrinsic variability of 26% (square root of variance 33.8 × 10^{-8} photons cm^{-2} s^{-1} for 131 × 10^{-8} photons cm^{-2} s^{-1} , the mean flux of 1AGL J2022+4032 for E ≥ 100 MeV) produces a distribution in V with a median equal to the observed value, 3.88. For Case 1, we simulated 10000 series of 42 observations for a source with intrinsic fluxes taken from a Gaussian distribution with mean equal to 60 × 10^{-8} photons cm^{-2} s^{-1} and square root of variance of 15.5 × 10^{-8} photons cm^{-2} s^{-1} using the same exposures as 1AGL J2022+4032 for E ≥ 100 MeV. The median value of V is 0.50. V ≤ 0.48 is produced in 49% of trials, while V ≥ 1.0 in 28% of trials. The same level of intrinsic variability would be likely to produce a variability index similar to that of 1AGL J2021+3652, but would not be likely to be classified as variable, if the source were half as bright. For Case 2, we simulated 10000 series of 42 observations for a source with intrinsic fluxes taken from a Gaussian distribution with mean equal to 33 × 10^{-8} photons cm^{-2} s^{-1} and square root of variance 8.4 × 10^{-8} photons cm^{-2} s^{-1}, using the exposures of 1AGL J2022+4032 for E ≥ 400 MeV. The median value of V is 1.75. V ≤ 1.11 is produced in 31% of trials, while V ≥ 1.0 in 74% of trials. The same level of flux variability at high energies would be detected more often than not. Equivalent intrinsic variability at the flux level of 1AGL~J2021+3652 for E ≥ 400 MeV would be completely undetectable.

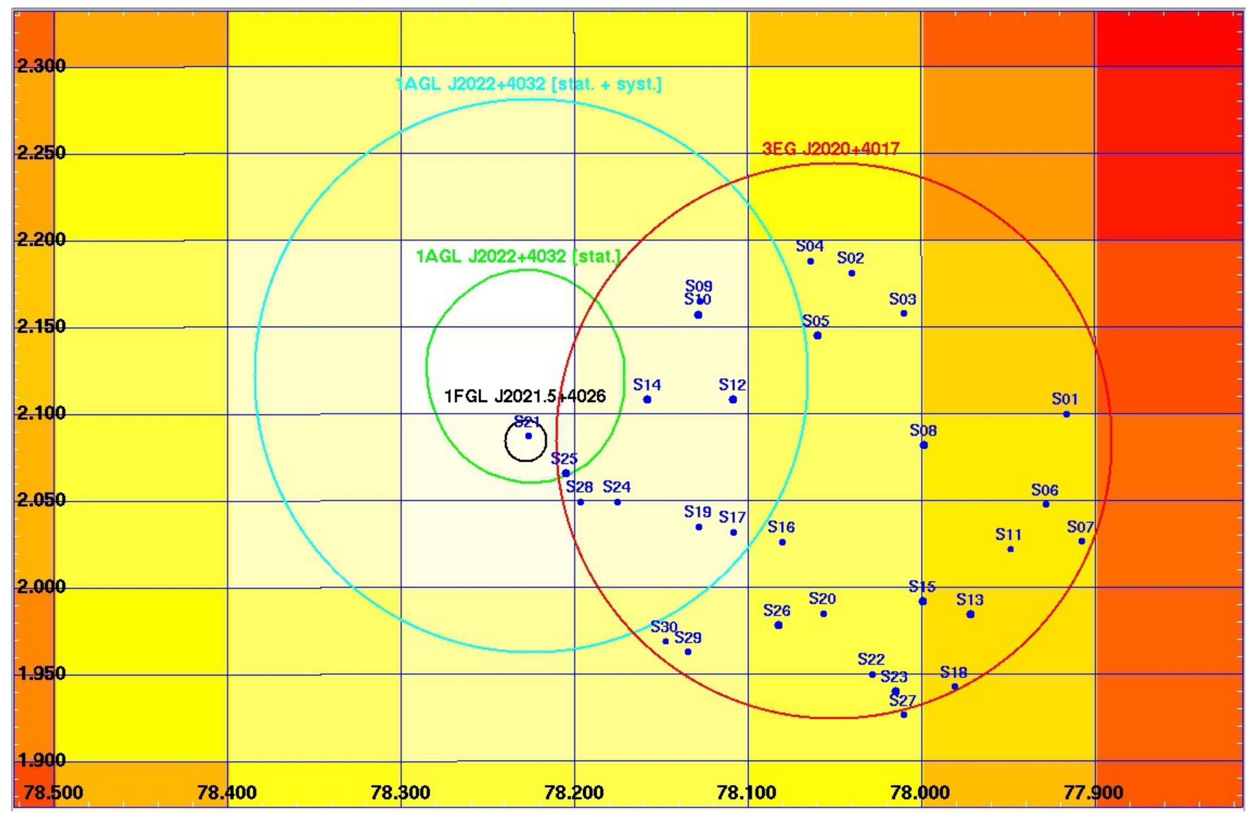
Discussion of possible counterparts

In the figure at right, we show the X-ray sources listed in Weisskopf et al. (2006) as possible counterparts for 3EG J2020+4017. The AGILE contour of the persistent source is consistent with the position of the X-ray source S21, which has been associated with the LAT PSR J2021+4026 whose pulsations were discovered by Fermi. Trepl et al. (2010) searched the XMM-Newton archival data and found 2XMM J202131.0+402645, a point source coincident with S21. However, re-analyzing the Chandra data, they found that S25, a strong point source within the Fermi 0FGL error box although outside the Fermi 1FGL error box, showed evidence of variability during the Chandra observation. In addition, S25 is not visible in the XMM data, indicating long-term X-ray variability. If S25 is also a variable γ-ray source, it would be within the AGILE source location accuracy of ~ 1° for the 1-2 week observation durations, and could be responsible for the variability apparently observed by AGILE below 400 MeV. However, S25 has an infrared counterpart and could be a normal star. The Fermi 11-month source catalog (Abdo et al. 2010a) detected a nearby source, 1FGL J2020.0+4049, associated with TeV source VER J2019+407, that is within the one-week error circle of AGILE. It was not detected by AGILE, probably because of its hard spectrum with index -2.12 ± 0.08. Its Fermi light curve is consistent with no variability at a level of 33%; however, its measured flux for E > 100 MeV decreased from (22 ± 6)× 10^{-8} photons cm^{-2} s^{-1} in the first month to below 4.3× 10^{-8} photons cm^{-2} s^{-1} by the seventh month. An intrinsic flux variability of 34 × 10^{-8} photons cm^{-2} s^{-1} over the longer AGILE observation period would explain the apparent flux variability of 1AGL J2022+4032. Detection of simultaneous flaring in γ-ray and, e.g., X-rays would provide a definitive identification. However, soft X-ray instruments have fields of view too narrow to make triggered observations practical. We note that a special class of microquasars may not necessarily produce simultaneous hard X-ray emission (RV09).

Variable pulsar/PWN - It is possible that the pulsar LAT PSR J2021+4026 itself has variable γ-ray emission for the energy range below 400 MeV. This scenario, if confirmed, would open a new field of investigation of γ-ray pulsars. However, in the absence of other information supporting this hypothesis pulsar, γ-ray variability of LAT PSR J2021+4026 is unlikely. This conclusion is based on both previous observational evidence from EGRET and from general theoretical considerations. In particular, the spin period and time derivative (Abdo et al. 2009b) of LAT PSR J2021+4026 (P = 265 ms, Pdot = 54.8 × 10^{-15}) assign a unremarkable position to this pulsar in both the P-Pdot diagram and in the pulsar γ-ray luminosity vs. period (or Goldreich-Julian current) diagram. Instabilities in the γ-ray pulsed emission of LAT PSR J2021+4026 might be associated with radio and/or X-ray signal changes during the period of the detected γ-ray variability. Future monitoring of LAT PSR J2021+4026 can contribute to test this fascinating hypothesis.

Background blazar - Another possibility is that a blazar behind the Galactic plane is contributing variable γ-ray emission to the measured flux of 1AGL J2022+4032. There are a number of known blazars in the Cygnus region, but they are well outside the typical AGILE one-week error circle. Most optical and radio AGN catalogs avoid the Galactic plane because of the high concentration of Galactic sources, heavy extinction, and/or diffuse radio emission (1LAC). Each of these difficulties is especially acute at the position of 1AGL J2022+4032, which is located within the Gamma-Cygni supernova remnant shell. Trepl et al. (2010) found multiple areas of concentrated radio emission within the Fermi error box of 1FGL J2021.5+4026 as well as evidence of variable X-ray emission from nearby source S25. In addition, the γ-ray flux could be well below the detection threshold of AGILE (which, in the presence of a known, bright γ-ray source is quite high) and still contribute to the overall γ-ray variability within the one-week AGILE error box. Knowing that the intrinsic distribution of blazars should be isotropic, we can use the AGN associations above |b|>10° in the First AGN Catalog (1LAC) to estimate the probability of finding at least one blazar within the ~ 1° error box of a one-week observation with AGILE. The probability of finding a blazar similar to the 599 1LAC associations is ~ 0.05. A more conservative estimate using only the 281 1LAC associated FSRQs, yielding a probability of ~ 0.02 of finding at least one FSRQ, would better represent the need for γ-ray variability and the non-detection by Fermi. In either case, the probability of chance coincidence is quite low.

X-ray quiet microquasar - Taking into account both the AGILE-GRID emission above 100 MeV and the Super-AGILE upper limit in the 15-60 keV range (~ mCrab), we consider the possibility that the detected γ-ray variability is caused by transient activity of an X-ray quiet microquasar. RV09 analyzed several Galactic sources with variable emission in the γ-ray energy range and showing a ratio $L_\gamma/L_X >> 1$. They proposed that this kind of emission (shortly variable, X-ray quiet, ...) can be produced by proton-dominated jets in a special class of Galactic microquasars. The bulk of the emission at γ-ray energies is produced by hadronic jets emitted from an accreting source. The model of RV09 predicts a γ-ray luminosity for this process on the order of ~ 10^{34} erg/s. Assuming the presence of a γ-ray source (an X-ray quiet microquasar) within the error box of LAT PSR J2021+4026, we find that that it is required to be at a distance of ~ 300 pc from the Earth, i.e., closer than the pulsar (1-2 kpc). The probability of finding this particular type of microquasar within the error box of 1AGL J2022+4032 is difficult to quantify. Nevertheless, because X-ray binaries are concentrated in the star-forming regions in the Galactic plane, and high-mass X-ray binaries particularly along tangents of spiral arms such as the Cygnus region (Liu et al. 2007, 2006) the likelihood that there is an appropriate microquasar within the error box is much higher than that of blazars, which are isotropically distributed. Similar reasoning applies to such possible source types such as massive stellar winds (Tavani et al. 2009b) and novae (Abdo et al. 2010d).



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