Alternative Observing Strategies for the Fermi Mission

– A Recommendation

Vers. 8/04/2013

Background:

August 2013 marks the 5th anniversary of the science phase of the *Fermi* mission. For most of this time the mission has operated in a survey mode, imaging the sky every three hours and providing fairly uniform coverage of the whole sky on the 53-day orbit precession cycle. This survey approach has yielded a rich science return from *Fermi* across a wide range of astrophysical topics. However, *Fermi* is a versatile observatory with several other observing modes (e.g. autonomous repoint, pointed mode), which can be enabled to accommodate specific science programs (e.g. GRBs, flaring AGN, etc.). In light of the continued evolution of *Fermi* science and with an eye to the future extended *Fermi* mission phase, it was thought that due consideration should be given to alternative observing strategies.

Process:

The *Fermi* Mission, with the support of the Fermi User Group (FUG), solicited white papers from the community to examine alternate observing strategies. The initial solicitation for white papers began 17 January 2013 and ended on 27 March 2013. Five contributions were received, including one each from the Fermi GBM and LAT teams. The web page with the details of the solicitation, all five white papers and the details of four alternate pointing strategies can be found here:
http://fermi.gsfc.nasa.gov/ssc/proposals/alt_obs/obs_modes.html

The Mission formed a committee to evaluate the white papers and to recommend whether to adopt a new pointing strategy or keep to the current survey mode. The membership of the committee is in the Appendix. A brief organizing telecon was held in early July. After briefly discussing all five white papers, it was decided that two of the white papers were proposing observing strategies that could more properly be accommodated in the annual GI program. The discussion during the face-to-face meeting at the University of Maryland on 25 July 2013 therefore focused on the remaining three white papers.

The face-to-face meeting began with brief presentations from each of those groups proposing an alternate observing strategy. Most of the subsequent discussion focused on the science case and the impact that any new scheme would have on the current science program. The instrument teams and the FSSC also spoke on the operations impact of alternate observing strategies along with the appropriate timescale to make any changes. The results of the discussion lead to a consensus recommendation to change *Fermi's* observing mode. This recommendation is given below, followed by brief summaries of the science case and the impact. The white papers, available on the web, provide much more detailed discussions on each of these points.

Committee Recommendation

We recommend that the Fermi mission undertake a new observing strategy that emphasizes coverage of the Galactic center region (i.e. "Option 4" or similar). This recommendation should be adopted with the following conditions:

- Implementation should occur by December 2013. The time between now and then is needed to solicit community comment on the recommendation and to run some observatory thermal models to better understand the impact of this new observing strategy.
- The modified observing strategy should run for one year.
- After one year is up, the *Fermi* Project Scientist will organize a review to decide whether to maintain the modified observing strategy or return to survey mode.

Motivation for Revised Science Program

There are three key science programs that motivate a modified survey mode emphasizing the Galactic center for one year.

- Over the next year, the passage of the G2 cloud around SgrA* represents a rare opportunity to study our nearest massive black hole. Although predictions of the expected high-energy emission are uncertain, an armada of telescopes has been deployed to monitor this passage (https://wiki.mpe.mpg.de/gascloud/ProposalList), including NASAs NuSTAR, Swift and Chandra. Regular monitoring has already resulted in the discovery of new source populations including a hitherto unknown magnetar within 3 arcsec of SgrA* and new activity from previously known but long dormant compact objects.

- Young, energetic gamma-ray pulsars are typically found near the Galactic plane, and given the density of stars in the Galaxy, the surface density of such pulsars on the sky is peaked towards the Galactic center. It is likely that the majority of the many LAT unassociated sources in the plane are such pulsars that have not yet been detected in radio, x-rays or gamma-rays. For blind gamma-ray pulsation searches, maximizing a source's count rate over a period (T) of months to a year is crucial for success as the power in a detection is a strong function of the source count rate. This is because the number of trials and amount of computing required is a strong function of T, and young pulsars often don't spin stably for durations more than a year or two. A galactic center-weighted survey mode should yield several new energetic pulsars from such searches. In addition, the extra coverage will likely provide new gamma-ray detections of known radio pulsars towards the region. Gamma-ray timing of millisecond pulsars, which are much more isotropically distributed on the sky, will be only slightly impacted given the stable spin nature of those systems which typically allows all of the events detected over the full *Fermi* mission to be used in timing studies.

- A clear observation of a gamma-ray line from the Galactic center would be an unequivocal signal for the annihilation of dark matter particles. A candidate for such a signal, at energies around 130 GeV, was found in the LAT data in early 2012, and caused great interest in the community. Over the last 1.5 years it became clear that it is challenging to explain the feature by an instrumental effect, since it is absent in many test regions. However, a similar feature was found in the low incidence angle data from the Earth limb, suggesting important contributions from systematics, which need to be clarified. Interestingly, the Galactic center feature was found to become somewhat less significant in the P7REP reprocessed data, as well as when incorporating the quality of the energy reconstruction into the statistical analysis on an event-by-event basis. In addition, the significance of the 130 GeV feature has declined when data since the line was reported are folded in. These findings might indicate a statistical fluke, but are still not conclusive.

  Adopting the modified survey mode `Option 4' would help to answer the main open questions: First, it would increase the average exposure per orbit on the Galactic center by a factor 2.2, which would benefit checks of the statistical robustness of the feature. Second, it would increase the rate at which low-incidence angle Earth limb data are recorded by a factor >2, which is good for systematic checks. The initial claims of a dark matter signal at 130 GeV were based on data until early February 2012. Data taken from February 2012 on can be used to statistically confirm or reject the signal without trials. Changing to `Option 4' from December 2013 for one year would increase the exposure of the Galactic center within the time interval February 2012 to December 2014 by a factor of 1.42, and significantly help to discriminate the signal from the null-hypothesis. Detailed projections for the expected time evolution of the signal significance can be found in the LAT Collaboration and Weniger et al. white papers.

<u>Impact on Current Science Program and Observatory Operations</u>

The individual white papers have each evaluated the impact that a modified survey mode has on other science programs currently being carried out under the standard survey mode. For full details about this impact we urge those interested to read these contributions on the web page. The LAT Collaboration, for example, has specifically looked at exposure maps of the Option 4 compared to standard survey mode. The committee and the other attendees discussed the science impact in some detail. The overarching conclusion is that the Observing Strategy known as Option 4 has good exposure and uniformity of sky coverage needed for other science programs.

The modified observing strategy will require some work on the part of the instrument teams to ensure the best possible scientific output. In particular:

1. Automated instrument monitoring suites have been adapted to the current observing strategy and will need to be re-tuned.

2. Analysis of short-term transients requires accurate predictions about the background rates, which depend on the position and orientation of the spacecraft. It is likely that the instrument teams will need to refine the techniques they use to obtain these predictions.

3. Changing the observing strategy will change the mapping of each direction in the sky into instrument reference frames. Any systematic biases that vary in the instrument frame could induce apparent variability in Celestial sources. Dedicated studies will be required to quantify the magnitude of any such effects.

4. The proposed observing strategy will increase the gradient of the exposure near the Galactic center. This increases the possibility that systematic biases in the instrument response could appear as large scale diffuse structure and will also require dedicated studies to quantify the magnitude of any such effects.

At this point in the mission, the instrument teams have developed very detailed knowledge of their instruments, as well as effective algorithms to extract that knowledge. Therefore, we expect that the work involved in addressing these issues will not be burdensome, and that any systematic effects of the types described in points 3 and 4 will be relatively minor and correctable.

Appendix – Committee Membership

- Eric Charles (KIPAC/SLAC)
- Seth Digel (KIPAC/SLAC)
- Douglas Finkbeiner (Harvard University)
- Dale Frail (NRAO)
- Gino Tosti (Universita di Perugia)
- Scott Ransom (NRAO)
- Christoph Weniger (University of Amsterdam)

Also attending the face-to-face meeting were Julie McEnery (Fermi Project Scientist), Elizabeth Hays (Deputy Project Scientist), William Paciesas (GBM PI), Robin Corbet (GSFC/FSSC), Elizabeth Ferrara (GSFC/FSSC), Jeremy Perkins (GSFC/FSSC), Keith McGregor (NASA HQ), Louis Kaluzienski (NASA HQ).