# Technology Needs for MeV Gamma-Ray Astronomy

*M. McConnell, M. Baring, D. Bhattacharya, P. Bloser, S. Boggs, G. Case, M. Cherry, C. C. Cheung, V. Connaughton, G. Denolfo, C. Dermer, M. Finger, J. Fishman, N,. Gehrels, E. Grove, A. Harding, S. Hunter, K. Hurley, T.J. Johnson, W.N. Johnson, R. M. Kippen, H. Krawczynski, M. Leising, R. Murphy, T. O'Neill, W. Paciesas, B. Phlips, R. Preece, R. Rothschild, D. Lazzati, H. Marshall, J. Ryan, G. Share, D. Smith, S. Sturner, J. Tomsick, W.T. Vestrand, C. Wilson-Hodge, E. Wulf, A. Zoglauer, A. Zych*

There are tremendous scientific opportunities for MeV gamma-ray astronomy in the coming decades. Some of these are discussed in an accompanying abstract. Here we describe the technology needs. Detection methods in the ~0.1–100 MeV range are as diverse as the physical processes that produce those gamma rays. Two methods that are inescapable in this range are Compton scattering and pair production. At the low end of the scale, 400 keV is close to the effective useful upper end of the photoelectric effect. The photoelectric effect has been used effectively at 500 keV and below with collimated/shielded spectrometers and also with coded aperture imagers. Above ~400 keV (up to ~10 MeV), Compton telescopes are the instrument of choice in the nuclear range where the instrumental background can be very high. The coincidence requirement of a Compton telescope greatly reduces the effect of the internal nuclear background in the detecting elements. Coincidence windows (0.1–1 $\mu$s) and time-of-flight measurements (1–10 ns) allow few interloper events, either from accidental coincidences or from neutrons or photons outside the field of view. Detecting materials where the physical motion of charge takes place, e.g., Si, Ge, CZT, gas, have relatively poor time-of-flight resolution as compared to scintillators. Energy resolution is an important parameter as well, one where solid state detectors are generally superior.

Designs based on photoelectric absorption or Compton scattering would both benefit from the development of new detection technologies, such as new scintillator materials (coupled with new solid-state readout devices), finer spatial resolution, and improved signal timing. The angular resolution of Compton imaging is still rather limited (~1-2° at best), so there is still much to be gained in both angular resolution and FOV. Polarization information is also intrinsic to Compton scattering, so that a carefully designed Compton telescope can also provide polarization measurements.

Above ~10 MeV, pair telescopes, either using gas or layered solid state detectors take over from Compton telescopes. All instruments in this range rely on the pair production process and the tracking of the electron-positron pair. The incident direction, energy, and polarization of individual gamma rays are reconstructed through kinematic analysis of measured positions and energies of electron-positron pair. The technique enables simultaneous imaging, spectroscopy, and polarimetry of medium-energy gamma rays over a broad (several steradian) field of view. New designs under development push the energy range down to below 10 MeV such that it overlaps with that of Compton telescopes and may provide significant polarization sensitivity. The angular resolution at these low energies is limited by the momentum transfer to the nucleus. At these low energies, it is difficult to make solid state detectors thin enough to avoid significant electron scattering which destroys polarization sensitivity. High spatial resolution gas-based time projection chambers show promise at these energies.

The development of other useful technologies for this energy regime should also be encouraged. For example, grazing incidence imaging technology is advancing to the point where focusing at energies above 100 keV may become possible. In addition, the focusing of gamma-rays using Laue lenses has been pursued now for several years. It offers the ability to focus photons with energies of several hundred keV, but is currently limited to a relatively narrow bandpass.