Overseeing Researchers: Professor Charles J. Hailey, Dr. Kaya Mori

Research Focus: High-resolution X-ray tomography of compact cloud clumps illuminated by an evolved supernova remnant, extended versus point source analysis on potential compact cloud clusters.

Abstract:

Since their discovery, surveys revealed over 1,000 giant molecular clouds (MCs) ($M \gtrsim 10^4 M_\odot$) in our galaxy and resolved some of them to have rich sub-structures such as clumps and cores. Their masses and physical sizes typically range in $M \sim 0.5 - 500\ M_\odot$ and $r \sim 0.03 - 3$ pc. Giant MCs are often described by the clump mass function (CMF) of a single power-law model $dN/d \ln M \propto M^{-\alpha}$ below $M \sim 100\ M_\odot$. Larger mass clumps show $\alpha \sim 1.4$–1.8, while smaller clumps at $M \lesssim 2\ M_\odot$ show a flatter slope of $\alpha \lesssim 0.3$. The break in the CMF, which corresponds to $r \sim 0.1$pc, suggests change in the formation physics of MCs and it should impact the star formation in MCs. However, the CMF shape differs between nearby giant MCs – it indicates that the internal dynamics of MCs is subject to complex formation processes. In fact, $r \sim 0.1$ pc is considered as the critical length scale for cloud formation/fragmentation both theoretically and observationally. Thus, compact cloud clumps (CCCs) with size $r \sim 0.1$ pc offer a unique testbed for exploring gas dynamics and star formation with MHD simulations. Based on MARX simulation and subsequent PSF fitting, it was estimated that Chandra will be able to resolve the size of each source to $\Delta\theta \approx 2''$ or $r \approx 0.04$ pc. This resolving capability is comparable to the Jeans length ($r \sim 0.1$ pc) where we expect the smallest-scale CCCs can be formed.

30 ksec Chandra observations were made of the southern boundary of the G22.7-0.2 supernova remnant shell including the known X-ray binary XMMU 183245-0921539 and 3 potential Molecular Clouds N1, N2, and N3. To determine whether N1, N2, and N3 were MC's or not extended versus point source analysis had to be done. Due to the Chandra Point Spread Function (PSF) the light from dim point sources such as x-ray binaries is spread by Chandra's optics making them appear like extended sources. Fortunately the Chandra PSF can be accurately simulated using Chandra Ray Trace (ChaRT) a tool that simulates light rays refracting through the Chandra's optics to create a PSF. The rayfiles produced by ChaRT can be processed through a MARX simulation to produce an event file of the PSF. The radial profiles of each source and its PSF can then be plotted against each other as normalized histograms using SHERPA with their comparative regressions being characteristic of a point such as an X-ray binary or an extended source such as an MC.

To test the effectiveness of this process it was first used on verifying XMMU 183245-0921539 as a point source. As the PSF is dependent on pointing information and spectral information which cannot be derived from merged observations the PSF had to be created for each individual observation of the source and then merged. Once the radial profiles for the merged initial observations and merged PSF were plotted it showed an almost identical trend with each point having overlapping uncertainties. It follows from this that XMMU 183245-0921539 is a point source.

From here the MC candidates N1, N2, and N3 were analysed. Because these points are very dim there was not enough data to create accurate spectral models from the Chandra observations so the Hydrogen column density, photon index, and energy flux of the sources from previous XMM and Nustar observations. To convert this information into a format suitable for ChaRT energy flux was converted to photon flux for Chandra and along with the exposure time, telescope offset and energy range the spectral data as would be observed by Chandra was simulated. From here the produced ray files were processed just as they had been for XMMU 183245-0921539 with SHERPA analysis currently ongoing.