Optical and Gamma-ray Correlations in Scorpius X-1

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X-ray astronomy was born with the discovery of Sco X-1 (Giacconi et al. 1962). Sco X-1 is often considered the prototypical low-mass X-ray binary (LMXB), containing a neutron star accreting from a 0.4 $M_{\odot}$ companion in an 18.9 hour orbit (Steeghs & Casares 2002). It is the best known of the 'Z sources', neutron star LMXBs accreting close to the Eddington limit. These sources trace out a Z-shaped pattern in an X-ray color-color diagram, with quite different behavior in the three branches of the Z. In spite of long-study, the physical interpretation of these branches remains unclear, and so at a basic level we do not understand how neutron stars accrete near the Eddington limit. Indeed, there is even ongoing debate about which point in the Z track corresponds to the highest accretion rates (e.g. Church et al. 2012). To obtain a comprehensive picture of LMXBs requires multiwavelength observations. For example, O'Brien et al. (2004) found in the Z source Cyg X-2, that the optical brightness may be a better tracer of accretion rate than X-rays, so in depth optical observations may be the key to unraveling the mystery.

Sco X-1 is the brightest persistent LMXB, in X-rays and optical, and at a Kepler magnitude of 12.5, ideally suited for the K2 mission. We propose short cadence optical monitoring of Sco X-1 for 88 days. LSU is intimately involved in processing and analysis of Fermi GBM data (Wilson-Hodge et al. 2012). We will correlate Kepler data with individual GBM observations (which uses Earth occultation to obtain source localization twice per 93 min satellite orbit) to obtain ~2700 pairs of optical/gamma-ray measurements to define the optical/gamma-ray relationship in unprecedented detail. Sco X-1 contributes about 20-25% of the net GBM detection, so we may also be able to measure meaningful correlations even between occultations. Our study will be similar in kind to that of McNamara et al. (2003), but will yield an order of magnitude more optical/high-energy data pairs, and dramatic improvements at low frequencies, allowing us, for example, to properly sample the optical power-density spectrum on timescales from hours to days without being compromised by one-day sampling issues. Short cadence observations are essential as Sco X-1 is optically variable on all timescales from seconds upwards, and 30-min cadence would miss much of the frequency sampling (0.2-8 mHz), and critically would not sample typical timescales of motion around the Z diagram (~minutes; White et al. 1976). As a result, 30-min Kepler and Fermi observations might correspond to different branches of the diagram.

88 days of optical coverage span 112 binary orbits, so the data can also be folded to obtain the best ever orbital lightcurve. This will be far superior to lightcurves obtained over a few nights, which are severely compromised by source flickering, or those obtained by sparse sampling (e.g. ASAS; Hynes & Britt 2012), which do not have enough data to completely average flickering. This can be used to precisely update the photometric ephemeris, compare it with the spectroscopic measurements of Galloway et al. (2013), and check for systematic differences for example due to asymmetric irradiation of the donor star. A precise orbital ephemeris is essential for LIGO searches for gravitational waves from non-axisymmetric perturbations of the neutron star surface in order to correct the LIGO signal for the changing distance to the neutron star over the binary orbit.

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